ABSTRACT BOOK FOR POSTER PRESENTATIONS

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Albers, John	Isolating stratospheric versus tropical diabatic heating based sources of subseasonal predictive skill	**P-A1-03**	Monday 17 Sept.	Center Green
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Attard, Hannah	The Relationship Between Tropospheric Synoptic-Scale Events and Vertical Wave Activity Flux Near the Tropopause	**P-A8-01**	Wednesday 19 Sept.	Center Green
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Spangehl, Thomas	Probabilistic evaluation of decadal predictions using a satellite simulator for SSM/I and SSMIS	**P-B5-08**	Wednesday 19 Sept.	Foothills Lab
Spring, Aaron	Variability and predictability of land and ocean carbon sinks assessed in MPI-ESM CO2 emission-driven simulations	**P-B6-06**	Wednesday 19 Sept.	Foothills Lab
Spring, Aaron	Impact of initial conditions perturbations on potential decadal predictability of ocean carbon fluxes assessed in MPI-ESM	**P-B6-07**	Wednesday 19 Sept.	Foothills Lab
Strazzo, Sarah	Harnessing skill from statistical and dynamical models to improve subseasonal forecasts: A Bayesian approach	**P-A3-27**	Tuesday 18 Sept.	Center Green
Sukumarapillai, Abhilash	Role of Enhanced Synoptic Activity and its Interaction with Intra-seasonal oscillations on the lower extended range prediction skill	**P-A1-25**	Monday 17 Sept.	Center Green
Sukumarapillai, Abhilash	Cyclogenesis Prediction in the Extended Range in a Multi-Model Framework : Application of a New Signal Amplification Technique to Improve Track Prediction.	**P-A3-28**	Tuesday 18 Sept.	Center Green
Sukumarapillai, Abhilash	Towards the Development of the CFS based Grand Multi Model Ensemble prediction System and its Improved Skill Realized through Better Spread-Error Relationship	**P-A3-29**	Tuesday 18 Sept.	Center Green
Sun, Lantao	Contribution of stratospheric processes to tropospheric predictive skill on subseasonal time scale in NCAR's CESM1	**P-A1-26**	Monday 17 Sept.	Center Green
Sun, Shan	Subseasonal Prediction Skill with an Icosahedral, Vertically Quasi-Lagrangian Coupled Model	**P-A2-12**	Tuesday 18 Sept.	Center Green
Sun, Shan	Aerosol Impact on Subseasonal Prediction using FIM-Chem-iHYCOM Coupled Model	**P-A7-01**	Wednesday 19 Sept.	Center Green
Sun, Yongqiang	Potential Sources for Extended Weather Predictability during NH Winter Season	**P-A1-27**	Monday 17 Sept.	Center Green
Takaya, Yuhei	Seasonal to multi-annual predictions of Asian summer monsoons using an atmosphere-ocean-sea ice-land coupled model	**P-B3-12**	Tuesday 18 Sept.	Foothills Lab
Tietsche, Steffen	Atmospheric and oceanic sinks of Arctic predictability	**P-B1-29**	Monday 17 Sept.	Foothills Lab
Tiwari, Pushp Raj	On the predictability of precipitation over North India in S2S framework	**P-A4-11**	Wednesday 19 Sept.	Center Green

Tjiputra, Jerry	Improved seasonal projection of regional ocean biogeochemical states through Ensemble data assimilation	**P-B6-08**	Wednesday 19 Sept.	Foothills Lab
Tolstykh, Mikhail	New version of the long-range forecast system at the Hydrometcentre of Russia	**P-B5-09**	Wednesday 19 Sept.	Foothills Lab
Tolstykh, Mikhail	Some results of studying initialization shock and drift in S2S database coupled models	**P-C1-09**	Thursday 20 Sept.	Center Green
Tozer, Carly	Diagnosing the atmospheric mechanisms that influence forecast skill of rainfall extremes	**P-A1-28**	Monday 17 Sept.	Center Green
Tseng, Kai-Chih	Explaining the consistency of MJO teleconnection patterns with linear Rossby wave theory	**P-A1-29**	Monday 17 Sept.	Center Green
Tuinenburg, Obbe	Optimizing N:P:K ratios in agricultural fertilizers based on seasonal predictions	**P-A4-12**	Wednesday 19 Sept.	Center Green
Turkington, Thea	Use of Subseasonal-to-Seasonal Predictions for Extreme Temperature Forecasts over Singapore and the Surrounding Region	**P-A3-30**	Tuesday 18 Sept.	Center Green
Turkington, Thea	S2S-SEA Workshop Series – lessons learnt and moving forward	**P-A4-13**	Wednesday 19 Sept.	Center Green
VIGAUD, Nicolas	Wintertime weather regimes over North America and their predictability from submonthly reforecasts	**P-A3-31**	Tuesday 18 Sept.	Center Green
Vigaud, Nicolas	North American summer heat waves and modulations from the North Atlantic simulated by an AGCM	**P-B3-13**	Tuesday 18 Sept.	Foothills Lab
Villarini, Gabriele	On the decadal predictions of flood events across the central United States	**P-B3-14**	Tuesday 18 Sept.	Foothills Lab
Villarini, Gabriele	Extending the seasonal predictability of statistical dynamical streamflow forecasts	**P-B3-15**	Tuesday 18 Sept.	Foothills Lab
Vitart, Frederic	Extended-range forecasting at ECMWF	**P-A3-32**	Tuesday 18 Sept.	Center Green
Vitart, Frederic	The ECMWF land surface scheme and its initialisation in S2S reforecast applications	**P-A5-03**	Thursday 20 Sept.	Center Green
Vitart, Frederic	Sub-seasonal prediction of aerosols fields and impact on meteorology using the ECMWF's coupled Ensemble Prediction System	**P-A7-02**	Wednesday 19 Sept.	Center Green
Wang, Shuguang	Seasonal Noise Versus Subseasonal Signal: Forecasts of California Precipitation During the Unusual Winters of 2015–2016 and 2016–2017	**P-A3-33**	Tuesday 18 Sept.	Center Green
Wang, Shuguang	Prediction of MJO convection in the S2S hindcast dataset	**P-A3-34**	Tuesday 18 Sept.	Center Green
Wang, Xiaochun	Evaluating Northwestern Pacific Tropical Storm Density Forecast in the Subseasonal to Seasonal Prediction Project Database	**P-A3-35**	Tuesday 18 Sept.	Center Green
Wang, Zhuo	Extratropical Impacts on Atlantic Tropical Cyclone Activity and the Implications for S2S Prediction and Predictability	**P-A1-30**	Monday 17 Sept.	Center Green
Wayand, Nicholas	A new Sea Ice Prediction Portal: year-round S2S sea ice forecasting	**P-B6-09**	Wednesday 19 Sept.	Foothills Lab
Weisheimer, Antje	Systematic errors in ECMWF's monthly and seasonal forecasts: The impact of stochastic perturbations in the atmosphere	**P-A2-13**	Tuesday 18 Sept.	Center Green
Weisheimer, Antje	How confident are predictability estimates of the winter NAO?	**P-B5-10**	Wednesday 19 Sept.	Foothills Lab
Widlansky, Matthew	How predictable are seasonal sea level anomalies?	**P-B4-10**	Wednesday 19 Sept.	Foothills Lab
Wu, Bo	EnOI-IAU initialization scheme designed for decadal climate prediction system IAP-DecPreS	**P-B2-13**	Tuesday 18 Sept.	Foothills Lab
Wu, Tongwen	Parameters optimization to improve MJO prediction using CMA S2S model	**P-A2-14**	Tuesday 18 Sept.	Center Green
Wulff, Ole	Subseasonal prediction of heat waves	**P-A3-36**	Tuesday 18 Sept.	Center Green
Xin, Xiaoge	Decadal Prediction Skill of BCC-CSM1.1 Climate Model in East Asia	**P-B2-14**	Tuesday 18 Sept.	Foothills Lab
Xue, Yan	Operational Ocean Reanalysis for S2S at NCEP: Upgrading from 1 degree MOM3 GODAS to ¼ degree MOM6 Hybrid-GODAS	**P-A6-05**	Thursday 20 Sept.	Center Green
Yadav, Ramesh Kumar	Relationship between Indian summer monsoon and Atlantic Nino	**P-C3-11**	Thursday 20 Sept.	Center Green
Yang, Jing	Sub-seasonal prediction of extreme temperature over East China: a mid-to-late July prediction barrier	**P-A3-37**	Tuesday 18 Sept.	Center Green
Yang, Rongqian	Warm Season Forecast Experiments with Different Treatments on Ground Water and Evaporative Parameterizations in the NCEP Coupled Forecast System	**P-B2-15**	Tuesday 18 Sept.	Foothills Lab
Yang, Xiaosong	Roles of atmospheric initial state in improving the short-term seasonal climate prediction	**P-A1-31**	Monday 17 Sept.	Center Green

Yoon, Jin-Ho	How much surface soil moisture influence precipitation predictability?	**P-B1-30**	Monday 17 Sept.	Foothills Lab
Zamora, Ryan	Evaluation of downscaled GEOS-5 seasonal forecasts used to improve hydrologic forecasting in the United States	**P-B4-11**	Wednesday 19 Sept.	Foothills Lab
Zhang, Chidong	Connection between two S2S Predictability Sources: QBO and MJO	**P-A1-32**	Monday 17 Sept.	Center Green
Zhang, Wei	Precipitation from Tropical Cyclones: High-resolution Simulations and Seasonal Forecast	**P-B2-16**	Tuesday 18 Sept.	Foothills Lab
Zhang, Yaocun	Sub-seasonal forecast of precipitation over Eastern China in summer monsoon season: Results from BCC_CSM hindcast experiments	**P-A3-38**	Tuesday 18 Sept.	Center Green

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-01)

Enhancement of the late boreal winter Lead Time Predictability over the Extratropical Region

Abid, Muhammad Adnan (1), Kucharski, Fred(1,2), Kang, In-Sik(2,3), Tompkins, Adrian (1), Molteni, Franco (4)

ESP, ICTP (1), CECCR, KAU, Jeddah, Saudi Arabia (2), SNU, South Korea (3), ECMWF, UK (4)

Seasonal to monthly predictability over the extratropical regions during the boreal winter season is a challenging issue. Generally, the predictability decreases with the lead-time and this is because it losses memory based on the initialization. However, the internal atmospheric dynamics such as the coupling of the lower stratosphere with troposphere may provide some signal, which may affect the predictability. To understand this perspective of lead time over the boreal winter, we analyzed the newly simulated dataset available from the European Centre for Medium-Range Weather forecasts (ECMWF) namely as SYSTEM 5(SYS5), which has a high pressure top and is able to resolve the stratosphere. We analyzed the monthly predictability in the hindcast dataset based on November initial condition every year and forecast the next 7 months. Total 25 ensemble members are available for each forecast on the resolution of 1 x 1 degree. The Era Interim reanalysis dataset is used as an observation to analyze the performance of the model.

We find that the prediction skill of the extratropical region in particular over the Pacific and North American (PNA) region increases with a lead-time. After a drop in the first lead month the prediction skill increases to 0.4-0.5 in the month of February (lead-3) based on the November initial conditions, which is statistically significant at 95% level. The increase in the prediction skill is also noted over the North Atlantic region at lead-3, where almost no prediction skill is noted at lead-1. The increase in predictability of the extratropical region is contradictory to the tropics, which is considered a source of atmospheric predictability, where prediction skill degrades with lead-time. It shows that the extra-tropical internal atmospheric memory including lower stratosphere plays an important role in the enhancement of this prediction skill over the PNA and the adjoining region. We also analyzed the predictability in the extreme ENSO years and found that the predictability over the PNA and Atlantic region is higher in the El Niño compared to that of La Niña years at lead-3. We hope that this study may help in understanding the enhancement of the late wintertime prediction skill over the extratropics in particular in the month of February over the PNA and the Atlantic sector.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-02)

Mechanisms and predictability of the MJO teleconnection signals in the NASA GEOS-5 subseasonal reforecasts

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Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD (1), Universities Space Research Association, Columbia, MD (2), Science Systems and Applications, Lanham, MD (3)

Tropical-extratropical teleconnections are considered key to advancing subseasonal prediction. The Madden Julian oscillation (MJO), characterized by large scale convective envelopes propagating along the tropical Indo-Pacific sector, is known to modulate midlatitude circulation and associated weather patterns. Although there is a general consensus on the MJO's influence on the midlatitude circulation, which is thought to be due to modulations of the North Atlantic Oscillation (NAO) and the Pacific North America (PNA) pattern, relatively less is known about the predictability of these teleconnection signals in dynamical forecast models. The composite evolution of the midlatitude circulation anomalies and associated wave train structure as the delayed response to tropical heating are reported in many studies that have examined reanalyses and long model simulations. However, it is yet to be determined whether they lend any beneficial subseasonal forecast skill, especially to weekly mean surface temperature and precipitation over North America. Investigating useful predictable signals from the MJO teleconnections is also complicated by the fact that the MJO is a moving heat source with an approximate periodicity of 30-60 days, and that the structure and amplitude of the midlatitude response can be sensitive to the longitudinal positioning of the heating anomaly as well as the propagation speed of the MJO.

The objective of this study is to investigate the impact of MJO teleconnections on forecast accuracy at 2-3 week lead over North America, with an emphasis on the above-mentioned lesser known aspects of these teleconnections. To this end, we utilize a suite of subseasonal reforecasts performed with the latest NASA GEOS-5 seasonal-to-subseasonal (S2S) system. These reforecasts were performed as part of the NOAA SubX project, wherein the NASA GEOS-5 atmosphere-ocean coupled model was run at _ degree horizontal resolution, initialized every 5 days for the period 1999-2016. The GEOS-5 model shows skillful predictions of the MJO, with the correlation coefficient based on the real-time multivariate MJO (RMM) index staying at or above 0.5 up to forecast lead 26-36 days. The system is thus a useful tool for investigating MJO teleconnection processes.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-03)

Isolating stratospheric versus tropical diabatic heating based sources of subseasonal predictive skill

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CIRES - University of Colorado Boulder

The roles of stratospheric circulation and tropical diabatic heating anomalies in modulating subseasonal (weeks 2-6) tropospheric forecast skill for extended winter (December-March) is investigated using a linear inverse model (LIM). The LIM is constructed from 5-day lag covariances of 7-day running mean anomalies, determined as departures from climatology of the 55-year Japanese Reanalysis for the 1958-2016 period. The model's linear dynamical operator includes explicit representations of tropospheric and stratospheric dynamical variables and tropical diabatic heating and is able produce forecasts that compare well with observations on the subseasonal timescales of interest.

Previous LIM analysis found the stratosphere's influence on tropospheric variability was restricted to fluctuations in high latitude surface pressure. However, due to its choice of state vector, that LIM may have misrepresented some stratospheric effects as tropospheric effects. Our new LIM, which is based on a longer data record and explicitly includes a deep vertical layer spanning the lower to mid-stratosphere, allows investigation of the role of vertically deep stratospheric variability in initiating strong stratosphere-troposphere coupling.

The extended stratospheric LIM is able to demonstrate the important role that vertically deep stratospheric variability plays in modulating the linear predictability of tropospheric dynamical variables for lags of 15 days and greater. To separate the contributions of stratospheric versus tropical variability, we construct modified LIM operators that individually restrict tropical heating effects or stratosphere-troposphere coupling in order to isolate the timescales and geographic regions that are modulated most strongly by the respective forms of variability. We find that in addition to providing forecast skill in terms of high latitude surface pressure (as was found in previous work), our model has an improved representation of stratospheric sources of skill for subseasonal forecasts of upper tropospheric circulation anomalies, and interactions between tropical diabatic and extratropical stratospheric anomalies. Finally, both the LIM and ECMWF (taken from the S2S database) hindcast skill for the years 1995-2016 is evaluated in the context of LIM estimates of potential predictability, which may be simply derived from the LIM forecast signal-to-noise ratio, with a particular focus on the region spanning from North America to the North Atlantic.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-04)

Air-sea interaction in the impact of the MJO on South American climate

Barreiro, Marcelo (1), Sitz, Lina (2), de Mello, Santiago (1), Fuentes Franco, Ramon (3), Renom, Madeleine(1), Farneti, Riccardo (2)

Universidad de la Republica, Uruguay (1), The Abdus Salam International Centre for Theoretical Physics, Italy (2), Swedish Meteorological and Hydrological Institute, Sweden (3)

Simulations with a regional climate model show that Phase 5 of the MJO influences South American rainfall through a teleconnection that involves the development of a cyclonic anomaly located between 30-60S, which promotes weakening and southward shift of the SACZ. A dipolar SST anomaly forced by heat flux anomalies during Phase 3 is instrumental to these MJO-induced anomalies through the forcing of an anticyclonic circulation that generates wind convergence in the southern section of the SACZ.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-05)

MJO-atmospheric river connections and their sensitivity to air-sea coupling across a CESM2 hierarchy

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University of Miami, USA (1), NCAR, USA (2)

Organized tropical convective disturbances and their linkages to extratropical weather are mediated in part through air-sea interactions and upper-ocean processes. However, the sensitivity of intraseasonal tropical disturbances to ocean model sophistication has not been sufficiently explored, and this may limit our understanding and model S2S predictive skill of cross-latitudinal, multi-scale interactions. In this study, we examine tropical intraseasonal disturbances (the Madden-Julian oscillation) and their influence on midlatitude extreme weather events (atmospheric rivers) using a newly developed hierarchical framework that leverages version 2 of the Community Earth System Model (CESM2). Within the hierarchical framework CESM2 is coupled to a fully prognostic ocean model (POP); a multi-column, one-dimensional version of POP at each ocean grid point; a simple thermodynamic (slab) ocean model; and a prescribed-SST ocean. Through the hierarchical framework, dominant mechanisms driving the tropical-extratropical interactions are revealed. We also discuss the precursor dynamic and thermodynamic signals involved in MJO-atmospheric river teleconnections and atmospheric river formation across the suite of simulations. The identification and advanced mechanistic understanding of the processes contributing to MJO-atmospheric river interactions holds significant potential to improve model predictive skill on S2S scales.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-06)

Clustered and Quasi-Simultaneous Extreme Weather Events on Subseasonal Time Scales

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University at Albany/SUNY

Extreme weather events (EWEs) can contribute disproportionally subseasonal temperature and rainfall anomalies and can represent an important intraseasonal forecast challenge. Quasi-simultaneous and clustered EWEs may occur in different parts of the world absent the realization that the EWEs may be dynamically linked with one another (Bosart et al. 2017; https://journals.ametsoc.org/doi/abs/10.1175/MWR-D-16-0230.1) . Examples of quasi-simultaneous and clustered EWEs will be shown.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-07)

Predictability of Heat Waves Over South Asia in the participated models of Subseasonal Experiment

Arunchandra Chandra (1), Benjamin Kirtman (2)

University of Miami, USA (1), University of Miami, USA (2)

With the increasing severity of the high-impact weather events such as heat waves, there is a growing demand of skillful predictions beyond the 10-day forecast. The effects are more severe in South-Asia-some of the hottest zones by across Asia. For example, more than 1030 people were killed in the 2002 heatwave in south India. This study focused on assessing the predictability of heatwaves over this region in different global models participated in the Subseasonal experiment. Heat waves are identified from the daily-mean surface air temperature exceeding a grid and day-varying threshold corresponds to the 97.5 percentile of the historical daily temperatures from the ERA-Interim reanalysis data. The occurrence of heat waves is classified based on its intensity and duration. The differences between observed and simulated heat wave events are documented for different lead times and ensemble members. The predictability of the heatwaves is assessed in terms of potential predictors such as Madden-Julian Oscillation and fluctuations of Asian Monsoon precipitation with the measures such as Real-time Multivariate MJO Index for defining the strength and phase of MJO, convection conditions over the surrounding Ocean and changes in the circulation associated with the advection of air-masses.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-08)

Cloud Resolving Modeling for Improved S2S Predictability of Arabian Peninsula Winter Rainfall

Raju Attada(1), Hari Prasad Dasari(1), Ravi Kumar Kunchala(1), Sabique Langodan(1), Aneesh Subramanian(2), Omar Knio(1), and Ibrahim Hoteit(1)

"King Abdullah University of Science and Technology (KAUST), Physical Sciences and Engineering Division, Thuwal, Saudi Arabia (1), Climate, Atmospheric Science and Physical Oceanography Department, Scripps Institution of Oceanography, USA (2)"

The predictability of rainfall over the water-scarce Arabian Peninsula (AP) at sub-seasonal to seasonal (S2S) scales is of critical importance for various socio-economic sectors. A Cloud-System Resolving Model (CRM) is implemented in this study to provide a better representation of the clouds formation and associated precipitation at S2S time scales over this desert areas. The CRM brings down the grid resolution to few kilometers, which reduces parameterizations uncertainties and increases the role of the different microphysical properties. We configured the Weather Research Forecasting (WRF) model at 2km resolution over the MENA region driven by ERA-Interim reanalysis to simulate the cloud formation and precipitation characteristics in the winter seasons. Several CRM simulations are performed over a decade period between 2006 to 2016 at S2S time scales. The boundary forcings of sea surface temperature and soil moisture are updated at 6-hour intervals. Validation results suggest that the simulated rainfall with the WRF-CRM at S2S scales is in better agreement with the observed rainfall compared to a non-cloud resolving model, adequately representing the precipitation patterns over the AP. The CRM predictability of rainfall at sub-seasonal scales is about 30-40% higher than that at seasonal scales. We will present the main results of this study and discuss the dominant mechanisms that are behind the improved simulations of precipitation at S2S time scales over the AP with a cloud-resolving model.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-09)

Accuracy and skill of subseasonal prediction of heat waves over southern Africa and associated atmospheric circulation characteristics

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The subseasonal predictability of heat waves over southern Africa are explored by making use of daily 2m maximum temperature ensemble forecast data available from the S2S database (at http://apps.ecmwf.int/datasets/data/s2s). Heat waves are in this study defined as when the daily maximum temperature exceeds the climatological 90th percentile of the maximum temperature for the month of interest for at least 3 consecutive days. The hindcast ensemble forecasts of 2m maximum temperatures produced by the Met Office's UKMO model over the period 1996 to 2009 are used to assess the accuracy and skill of heat wave day forecasts for the southern African region. The UKMO forecasts are integrated for 60 days, allowing 8 individual weekly forecast periods with lead-times of 0, 7, 14, 21, 28, 35, 42 and 49 days respectively. The week 3 and beyond forecasts are of interest in this study. In a preliminary exploration on the accuracy and skill of the prediction of heat wave days (for a specific 60 day period during the exceptionally hot austral summer season of 2015-16 over South Africa), it was shown that forecasts on this time scale is poor. However, the observed transitions between week 2 and 3 and again between week 4 and 5 were to some extent suggested by the forecasts. Also, the highest Brier Skill Score occurred on the days that were also heat wave days. Both these transitions coincided with large scale atmospheric circulation patterns that can in turn be linked to certain long-wave characteristics, providing thus hope for useful predictions on this time scale or at least to identify times of higher predictability. In this study, the accuracy and skill of heat wave day forecasts on the subseasonal time scale over multiple seasons will be presented, whilst highlighting atmospheric circulation characteristics during times of relatively higher skill.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-10)

Linking Northern Hemisphere temperature extremes to Rossby wave packets

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Temperature extremes are projected to become more severe due to global warming, with events like the 2003 (Europe) and 2010 (Russia) heat waves occurring more frequently. Assessing the intrinsic predictability of these events requires a better understanding on the evolution and spatial characteristics of upper-tropospheric Rossby wave packets (RWPs). Diagnosing RWPs and spatio-temporal properties of their embedded eddies (e. g. phase velocity) provides information about the local waviness in the upper troposphere. Using reanalysis data, we first investigate the statistical connection between RWP amplitude and lower-tropospheric temperature extremes. Areas of large RWP amplitude are found to be associated with an increased probability of lower-tropospheric temperature extremes in many regions of the Northern Hemisphere midlatitudes. Although a seasonal and inter-regional variability is apparent, this link is always stronger than in an analysis using a circumglobal waviness metric based on Fourier wavenumber amplitudes. Furthermore, the advantage of identifying and following the evolution of RWPs is also revealed by investigating their role during the aforementioned heat waves, as well as the one that affected western Europe in 2016. Elaborating on these findings, we also explore established ideas from linear wave theory, such as the Rossby wave propagation on zonally asymmetric basic state waveguides. We conclude that in order to investigate the physical mechanisms behind any source of subseasonal predictability of temperature extremes, we first need to better understand the response of the upper-tropospheric circulation to their forcing.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-11)

Are Peak Summer Sultry Heat Wave Days over the Yangtze–Huaihe River Basin Predictable?

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The Yangtze–Huaihe River basin (YHRB) is the core region of sultry heat wave occurrence over China during peak summer [July and August (JA)]. The extremely hot and muggy weather is locally controlled by a descending high pressure anomaly connected to the western Pacific subtropical high. During 1961–2015, the heat wave days (HWDs) in JA over the YHRB exhibit large year-to-year and decadal variations. Prediction of the total number of HWDs in JA is of great societal and scientific importance. The summer HWDs are preceded by a zonal dipole SST tendency pattern in the tropical Pacific and a meridional tripole SST anomaly pattern over the North Atlantic. The former signifies a rapid transition from a decaying central Pacific El Niño in early spring to a developing eastern Pacific La Niña in summer, which enhances the western Pacific subtropical high and increases pressure over the YHRB by altering the Walker circulation. The North Atlantic tripole SST anomalies persist from the preceding winter to JA and excite a circumglobal teleconnection pattern placing a high pressure anomaly over the YHRB. To predict the JA HWDs, a 1-month lead prediction model is established with the above two predictors. The forward-rolling hindcast achieves a significant correlation skill of 0.66 for 1981–2015, and the independent forecast skill made for 1996–2015 reaches 0.73. These results indicate the source of predictability of summer HWDs and provide an estimate for the potential predictability, suggesting about 55% of the total variance may be potentially predictable. This study also reveals greater possibilities for dynamical models to improve their prediction skills.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-12)

The Modulation of Equatorial Wave Activity by the Boreal Summer Intraseasonal Oscillation: Assessing S2S Model Prediction Skill

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The boreal summer monsoon over southeastern Asia is strongly modulated by the boreal summer intraseasonal oscillation (BSISO). The BSISO is a large-scale organized system of convection and circulation that initiates in the tropical Indian Ocean and propagates mainly northeastward toward the Maritime Continent and Asia producing wide-ranging impacts on the atmosphere and ocean locally and through global teleconnections. The BSISO and its impacts span multiple temporal and spatial scales and thus represents a bridge between weather, including equatorial wave activity and tropical cyclones, and seasonal monsoon prediction.

In this study, we investigate the predictability of equatorial wave activity (e.g. Kelvin, equatorial Rossby waves) in relation to the BSISO using recently developed BSISO indices (BSISO1 and BSISO2). We show that during boreal summer, anomalous precipitation and surface wind variance is strongly modulated by the BSISO, equatorial Rossby waves, Kelvin waves, and tropical depression (TD-type) disturbances. In addition, a strong relationship between the BSISO1 index and equatorial wave activity exists in that when the larger-scale BSISO1 convective activity is enhanced during phases 5 and 6 (suppressed during phases 1 and 2), equatorial wave activity is enhanced (suppressed). The relationship between BSISO2 and equatorial wave activity is more complicated and warrants further investigation. Given this relationship between the lower-frequency BSISO and higher frequency precipitation-bearing variability suggests the possibility that the BSISO might provide subseasonal predictability of variability in this region during BSISO events.

We also devise a method to quantify the predictability and prediction skill of equatorial wave activity in relation to the BSISO using the WCRP/WWRP Subseasonal to Seasonal (S2S) Project's hindcast database and discuss our initial assessment of hindcast skill of these features from the S2S database.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-13)

Atmospheric Circulation Response to Episodic Arctic Warming in an Idealized Model

Hell, Momme (1), Schneider, Tapio (2), Li, Camille (3)

SIO/UCSD, USA (1), Caltech, USA (2), GFI Bergen, Norway (3)

Recent Arctic sea ice loss has drawn attention as a potential driver of fall/winter circulation changes. Past work has shown that sea ice loss can be related to a stratospheric polar vortex breakdown, with the result of long-delayed surface weather phenomena in late winter/early spring. In this study, we separate the atmospheric dynamic components and mean timescales to episodic polar surface heat fluxes using large ensembles of an idealized GCM in absence of continents and seasons. The atmospheric ensemble-mean response is linear related to the surface forcing strength and insensitive to the forcing symmetry. Analyses in the Transformed Eulerian Mean show that the responses can be separated into 1) an in-phase thermal adjustment, and 2) a lagged, eddy-driven component invoking long-standing anomalies in the lower stratosphere. The mid-latitude adjustment to the episodically reduced baroclinity leads to a northward eulerian flow in the stratosphere as a response to less wave breaking that perturbs zonal mean momentum budget. A northward flow in the stratosphere leads to downward motion in high latitudes by mass continuity. The downward flow in the polar stratosphere advects the vertical background temperature gradient and leads to an local warming and weakening of the stratospheric vortex. In addition, we discuss the dependence on the background state via correlation in ensemble member space. Thus, we range the role of arctic perturbations in the transient large-scale circulation.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-14)

Simulations of the Asian summer monsoon in the subseasonal to seasonal scale

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Subseasonal prediction of the Asian summer monsoons (ASM) is controlled by both initial conditions and boundary forcing, and is thus an especially challenging task. The subseasonal predictability of tropical monsoon rests largely on the existence of low-frequency tropical intraseasonal oscillations. Several sources of subseasonal predictability have not yet been identified/tapped for improving the skill of the predictions. The main objective of the present study is to examine global model simulated ASM predictability at subseasonal timescales when the model is forced with interannually varying observed SSTs. The NCEP GFS model has been run for the monsoon seasons over the 1982-2010 period using 15 member ensemble. The model simulated sub-seasonal to seasonal predictions have been evaluated against available observations using several skill metrics. It is found that while the mean monsoon characteristics in terms of seasonal rainfall and circulation pattern at lower and upper troposphere are well simulated by the model, the same cannot be said about sub-seasonal scale as far as the phase and magnitude of subseasonal variability is concerned. Temporal correlation between observed SST and simulated rainfall (the Indian region) at the sub-seasonal scale is examined to quantify the model's ability to correctly respond to imposed surface forcing. Role of generation and propagation of convectively coupled equatorial waves especially over the equatorial Indian Ocean and west Pacific on the subseasonal predictability has been examined. While looking for additional sources of subseasonal predictability in the ASM region, it is found that inability of the physical parameterization schemes in the model to adequately represent the clouds and convection in this region could be one of the possible reasons for the rapid deterioration of subseasonal to seasonal scale predictions.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-15)

Predictability of winter Pacific weather regimes and its connections with MJO on medium-range timescales

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A weather regime is a persistent and/or recurrent large-scale atmospheric circulation pattern which is associated with specific weather conditions on a regional scale. Accurate simulations of weather regimes are important in weather and climate.

The predictability of weather regimes over the North Pacific (20-80N, 120E-60W) at medium-range timescales (up to 384hr) are investigated for extended winters (November-March) in 2006/07-2013/14 and 1985/86-2013/14 using the The Interactive Grand Global Ensemble (TIGGE) and NOAA's second-generation global medium-range ensemble reforecast datasets, respectively. The TIGGE portals quasi-operationally provide 9 medium-range ensemble forecasts routinely operated at Numerical Weather Prediction (NWP) centres. We focus on five of the leading operational NWP centres: CMC (Canada), ECMWF (EU), JMA (Japan), NCEP (USA), and UKMO (UK).

Pacific trough (PATR), the positive and negative phases of PNA (PNA+ and PNA-), Pacific blocking (PABL), and Alaskan blocking (ALBL) are detected as wintertime weather regimes over the Pacific region from the ERA-Interim data. The frequency of PATR (PNA-, PABL and ALBL) is significantly increased (decreased) during El Nino months. The NWP models have common biases in the frequency of regime transitions, and therefore the models prefer PATR and PNA- to the other regimes with lead time. Verification of probabilistic Pacific regime forecasts reveals that the forecasts made by state-of-the-art models are useful up to a lead time of 15-16 days on average and that their skills are higher than those of probabilistic Euro-Atlantic regime forecasts. Probabilistic PATR and PABL forecasts show higher skills than the other probabilistic regime forecasts. Probabilistic regime forecasts initialised from PNA- show higher skills than those from the other regimes. ECMWF generally shows the best probabilistic skills, followed by UKMO. In addition, tropical-midlatitude teleconnections during the Madden-Julian Oscillation (MJO) phases can be seen to act as forcing for these regimes. We show that the probabilistic skills for these mid-latitude regimes also depend on the MJO phase at the initial time of the forecast.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-16)

Additional Prediction Skill Provided by the MJO to Midlatitude Circulations on S2S Timescales

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The Madden Julian Oscillation (MJO) is a tropical intraseasonal oscillation with subsequent impact in the mid-latitudes on subseasonal-to-seasonal (S2S) timescales. Specifically, Rossby waves, initiated by this tropical convective heating, are known to modulate the mid-latitude circulation days-to-weeks after MJO activity, possibly providing additional forecast skill at S2S lead times. In this study, we examine these MJO teleconnection patterns (via the 500 hPa geopotential height field) by quantifying the propagation of the skill added by the MJO across the mid-latitudes. This analysis is performed for the suite of models within the S2S Database. Increased prediction skill is found at lead times of up to 2-4 weeks following active MJO periods compared to non-active MJO periods, however, the location of the improved skill is dependent on the model examined. An additional analysis specifically focuses on forecast skill for blocking patterns over the North Atlantic based on recent results by Henderson et al. (2016). This analysis of model skill between active MJO events and non-active MJO events provides insight on the additional information the MJO supplies in increasing S2S timescale predictability within the mid-latitudes.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-17)

Understanding the Role of the Indian Ocean in Recent Australian Heat Extremes

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Australia has observed a run of record extreme heat during austral spring in recent years. Previous work using the Bureau of Meteorology's seasonal forecasting system has suggested these events were attributable to the warming of the climate as well as internal atmospheric variability, hypothesising a link to warming in the central-western tropical Indian Ocean. They proposed that deep convection results in a Rossby wave pattern at the 200hPa geopotential height level that propagates towards Australia, resulting in a high geopotential height anomaly that produces conditions favourable to above average maximum temperatures across Australia. The aim of this study is to explore this relationship and improve understanding that could lead to more skilful prediction of future monthly and seasonal heat extremes across Australia.

Reanalysis data and data from the Bureau of Meteorology's seasonal prediction model, POAMA, are examined. An attempt to understand the hottest springs is made by searching for common dynamical patterns amongst the 10% hottest and coldest of the POAMA's 33-ensemble member forecasts of Australia's maximum temperature, and by comparing to the reanalysis data. Partial regression techniques are used to assess the influence of the tropical Indian Ocean sea surface temperature. Rossby wave analysis and different model initialisation dates are also examined.

The regression analysis shows a statistically significant positive anomaly in the 200hPa geopotential height over Australia, with an apparent Rossby wave leading backwards to the Indian Ocean, in both reanalysis and model data. The warmest members capture the 200hPa Australian height anomaly, with some evidence of the Rossby wave pattern. The coldest members had weaker anomalies offset from Australia by approximately half a wavelength westward. This suggests that the circulation pattern is an important condition for a hot spring to occur in Australia. The sea surface temperature and precipitation anomalies in the reanalysis and warm ensemble members are warmer and wetter in the western and central tropical Indian Ocean (the region of the suspected Rossby wave source) in anomalously warm spring years.

Preliminary Rossby wave analysis supports the theory that Rossby waves are being emitted from this region and are propagating towards Australia, and is consistent with other studies. Predictability of these patterns will also be discussed.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-18)

Ocean-coupled NICAM (NICOCO) and its application on MJO - El Niño interacting events.

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The termination of the intense 1997/1998 El Niño was extraordinarily abrupt. The May 1998 Madden-Julian Oscillation (MJO) is among possible contributors to the abrupt termination, but its role remained controversial and speculative because of the difficulty of sufficiently simulating the El Niño and MJO simultaneously. An ensemble simulation series using a newly developed, fully ocean-coupled version of a global cloud system resolving numerical model NICAM replicated the specific atmosphere and ocean conditions of May 1998 in unprecedented detail. Despite the model bias due to the drift of the dynamical ocean, the new ocean-coupled version maintained the good reproducibility of MJO signals of the atmospheric NICAM. Ensemble members with stronger MJO activities over the Maritime Continent experienced quicker sea surface temperature drop in the eastern Pacific, confirming that the easterly winds associated with the remote MJO accelerated ocean upwelling to abruptly terminate the El Niño. We intend to introduce more NICOCO simulations of MJO - El Niño interacting events if possible.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-19)

Genesis of Super Cyclone Pam (2015): Modulation of Low-frequency Large-Scale Circulations and the Madden–Julian Oscillation by Sea Surface Temperature Anomalies

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Super cyclone Pam (2015) was formed in the central tropical Pacific under conditions that included El Niño modoki as well as the passage of a convectively-enhanced phase of the Madden–Julian Oscillation (MJO) in the western Pacific. This study examines the influence that sea surface temperature anomalies (SSTAs) have on the MJO and low-frequency large-scale circulation, and establishing how they modulated the genesis of Pam.

Two series of numerical experiments were conducted by using a nonhydrostatic global atmospheric model with observed (OBSSST) and climatological (CLMSST) SSTs. The results suggested that low-frequency westerly winds at 850 hPa (U850) were intensified in the central tropical Pacific due to the observed SSTA. The amplitude of the MJO simulated in OBSSST was larger than that in CLMSST. In addition, the experiments initialized during 26 February–2 March exhibited a phase of the MJO in OBSSST was ahead of that in CLMSST, and the genesis location in OBSSST was ~10° to the east of that in CLMSST. An analysis of large-scale fields indicated that a positive U850 maintained by SSTAs and intensification of U850 by the MJO modified distribution of large-scale cyclonic vorticity and precipitable water. These changes in large-scale fields modified the location and timing of intensification of pre-Pam and resulted in the Pam's genesis location 10° farther east with slight impact on its genesis probability. Additional experiments in which SSTA in the central tropical Pacifc only was retained showed that SSTAs in the central tropical Pacific were the dominant cause of modifications to largescale fields, the MJO and Pam's genesis location.

The results using an atmosphere-ocean coupled version of NICAM (NICOCO) will be also presented.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-20)

Impact of air-sea interactions on subseasonal prediction in the 2016 Indian summer monsoon

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The Indian summer monsoon affects the livelihood of over 1 billion people, yet forecasting of the subseasonal active-break cycle of convection remains a challenge. One component of the monsoon system in which there is a significant lack of understanding is the role of air-sea interactions, especially in the Bay of Bengal. During the summer of 2016 the Bay of Bengal Boundary Layer Experiment (BoBBLE) field campaign performed intensive observations of the atmosphere and ocean, with instruments including radiosondes, seagliders, Argo floats, acoustic Doppler current profilers (ADCPs) and an automatic weather station measuring surface fluxes.

MetUM-GOML2.0 is a general circulation model which couples the UK Met Office Unified Model to a K-profile parametrization (KPP) Global Ocean Mixed Layer, which represents vertical mixing but has no horizontal or vertical advection. This is significantly computationally cheaper to run than a full dynamical ocean. Global 15-day reforecasts are performed, initialized every day during the 2016 summer monsoon season, with MetUM-GOML2.0. These are verified against reanalyses and, where possible, observations from the BoBBLE field campaign. The subseasonal convection (boreal summer intraseasonal oscillation; BSISO) and the evolution of model biases are investigated.

Reforecasts are also performed using the MetUM with the atmosphere only (persisting the initial sea surface temperature anomaly). Hence, the impact of air-sea interactions on the Indian summer monsoon is investigated, including the effect on the BSISO and other weather systems such as monsoon depressions. Similarly, reforecasts are performed with the MetUM coupled to a full dynamical ocean model (Nucleus for European Modelling of the Ocean; NEMO) to investigate the impact of ocean dynamics, such as the summer monsoon current which advects warm, saline water round the tip of India from the Arabian Sea into the Bay of Bengal.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-21)

Performance-based MJO Hindcast Evaluation in SubX

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The Subseasonal eXperiment (SubX) is a NOAA/Climate Testbed project focused on subseasonal predictability and predictions. Seven global models have produced seventeen years of ensemble retrospective forecasts initialized weekly to investigate subseasonal prediction and predictability. There is a coordinated effort to evaluate the Madden-Julian Oscillation in the SubX re-forecasts for the purpose of demonstrating the potential usefulness of these predictions.

This presentation will focus on the performance of the individual models and the multi-model ensemble in predicting the phase, amplitude, eastward propagation, and initiation of the MJO. Additionally, we will evaluate the link between MJO performance and the ability of the models to simulate convectively coupled equatorial waves.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-22)

On the role of midlatitude warm conveyor belts in shaping MJO-midlatitude teleconnections

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The adequate representation of the midlatitude response to the Madden-Julian Oscillation (MJO) in numerical weather prediction models is essential for the forecast accuracy on sub-seasonal time scales. This is due to the effect that MJO-related teleconnections have on weather regimes in the Atlantic/European sector and on the frequency of northern hemispheric midlatitude blocking. This study analyses the role of extratropical cyclones and their associated warm conveyor belts (WCBs) in shaping the midlatitude response to the MJO, with a particular focus on atmospheric blocking. WCBs are coherent ascending airstreams in the warm sector of extratropical cyclones that transport air into the upper troposphere driven by latent heat release due to condensation.

The aforementioned weather systems (cyclones, blocks, WCBs) are objectively identified in ERA-Interim reanalyses in November to March 1979-2016. Time-lagged composites reveal that the frequency of extratropical cyclones over the North Pacific varies greatly with the state of the MJO. During the active phase of the MJO over the Indian ocean, the frequency of extratropical cyclones is significantly enhanced over the western North Pacific. Correspondingly, the frequency of WCBs is anomalously high in the same region. The diabatically processed air masses of the WCBs are fed into the upper troposphere where they contribute to the maintenance of a blocking high over the central North Pacific. At later stages of the MJO, the synoptic activity ceases over the western North Pacific but increases over the eastern North Pacific. The collocation of enhanced WCB activity and blocking frequency over the Gulf of Alaska indicates a contribution of these cross-isentropically ascending air streams to the maintenance of the blocking high. Thus, the results of this study suggest that in addition to the representation of the MJO and of the background state, the adequate representation of midlatitude diabatic processes is of great importance when forecasting the midlatitude blocking response to the MJO.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-23)

Evaluation of the Madden-Julian Oscillation on rainfall over the Northwest of South America

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The Madden-Julian Oscillation (MJO) is the leading driver of intraseasonal rainfall variability in the tropics. It is a convective signal that usually develops in the Indian Ocean, propagates through the western Pacific and, when it reaches the eastern Pacific, becomes nondescript. However, many studies have demonstrated that MJO can influence rainfall in regions well beyond the Eastern Hemisphere tropics, such as South America. This paper presents a diagnostic analysis of the relationships between the activity and the phases of the MJO by using the operational Real-Time Multivariate MJO index (RMM) and a regional index (EOF1) developed in this study. The regional index is based on an empirical orthogonal function (EOF) based on observed outgoing longwave radiation (OLR). In addition, the OLR data applies a bandpass filter of a 20 to 100 day cycle to the EOF analysis in order to capture MJO intraseasonal variability. Both indices yield consistent results with respect to MJO influence on precipitation, OLR, and tropospheric circulation anomalies in the Northwest of South America (NWSA).

Results show positive precipitation anomalies in phases 1, 2, and 8 to the west of the Andes; meanwhile, in phase 7 positive anomalies concentrate themselves in Colombian territory. In contrast, negative anomalies are evident in the region for phases 3, 4, 5, and 6. Overall, the magnitude of both positive and negative response in the rainy season is strongest over Ecuador. Moreover, composites of OLR based on the EOF1 index show positive values of EOF1 corresponding to phase 1 (enhance convection on NWSA) of the MJO and large negative values of EOF1 corresponding to phase 5 (suppressed convection on NWSA) of the MJO. The composites of OLR based on EOF1 also show stronger signals over the area of study and weaker values over the Maritime Continent in comparison to other MJO indices. Finally, anomalies in pressure velocity are consistent with phases of more precipitation. This presentation will address the mechanisms that underlie this MJO influence on the region.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-24)

Subseasonal predictability of precipitation and temperature over North America and relationships with teleconnection patterns

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The subseasonal predictability of surface temperature and precipitation is examined for two global ensemble prediction systems (ECMWF VarEPS and NCEP CFSv2), with an emphasis on the week 3–4 (i.e. 15–28 days ahead) fortnight-average anomaly correlation skill over North America, in each calendar season. Although the ECMWF system exhibits slightly higher skill for both temperature and precipitation in general, these two systems show similar geographical variations in the week 3–4 skill in all seasons, and encouraging skill in certain regions. The regions of skill are then interpreted in terms of large scale teleconnection patterns. During winter in particular, week 3–4 predictability is found to be higher during extreme phases of the El Niño–Southern Oscillation, Pacific-North American (PNA) / Tropical-Northern Hemisphere mode, and Arctic Oscillation (AO)/ North Atlantic Oscillation (NAO). Both forecast systems are found to predict these teleconnection indices quite skillfully, with the anomaly correlation of the wintertime NAO and PNA exceeding 0.5 for both models. In both models, the subseasonal contribution to the PNA skill is found to be larger than for the NAO, where the seasonal component is large. The monsoon system leads to higher skill in the summer precipitation and surface temperature in the southwest US, while high skill over northern California in spring is found to be associated with the seasonal variability of the AO.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-25)

Role of Enhanced Synoptic Activity and its Interaction with Intra-seasonal oscillations on the lower extended range prediction skill

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IITM, Pune (1), IMD, Pune(2), MOES, Govt. of India (3), Cochin University (4)

Indian summer monsoon of 2015 was deficient with prominence of short-lived (long-lived) active (break) spells. The real-time extended range forecasts disseminated by Indian Institute of Tropical Meteorology (IITM) using an indigenous Ensemble Prediction System (EPS) based on National Center for Environmental Predictions (NCEP's) Climate Forecast System (CFS) could broadly predict these intraseasonal fluctuations at shorter time leads (i.e. up to 10 days), but failed to predict at longer leads (15-20 days). This particular study aims to examine the rationale behind the inability of the EPS in predicting the active/break episodes at longer leads. It is found that the 2015 monsoon season was dominated by synoptic scale disturbances and the model failed to capture them at longer forecast leads. The scale dependant energy exchange analysis suggest that the interaction between synoptic scale disturbances and low frequency mode was prominent during 2015 monsoon season. This might have also contributed to the lower ERP skill at longer leads.

The prediction and monitoring of Monsoon Intraseasonal Oscillation on extended range time scale have been carried out using the newly implemented MME based on CFS called CGEPS. The performance of the CGEPS is analyzed for pentad lead predictions over different homogeneous regions of India. Over most of the homogeneous regions, the CGEPS shows useful skill only up to P2 lead except for SPI. The predicted and observed large-scale low frequency component of the MISO is compared for different initial conditions. The CGEPS is able to predict the large scale enhanced and suppressed phases of convection associated with MISO reasonably well. The bivariate correlations and RMSE between the observed and predicted MISO shows that the useful skill is reduced by 3 days compared to the hindcast skill. Further analysis suggests that synoptic scale variance during 2015 monsoon season was considerably higher than that of ISO variance. This reduced skill and role of ISO advocates the challenges of ERP in the absence of strong ISO signal. The scale interactive energy exchange between different modes of variability suggests that the modulation of synoptic scale variability is enhanced during 2015 monsoon season. This irregularity in the 30-60 day northward propagating and 10-20 day westward propagating monsoon ISO and its modulation and enhanced interaction with synoptic disturbances might have limited the predictability in the extended range time scale during 2015 monsoon season. Hence the dominance of the synoptic scale variability and its unpredictable nature considerably limited the skill of ERP during 2015. This event-to-event and year-to-year variability of the ISO's and its interaction with synoptic scale basically controls the variability in the prediction skill of ERP.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-26)

Contribution of stratospheric processes to tropospheric predictive skill on subseasonal time scale in NCAR's CESM1

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There is increasing evidence that stratospheric processes and variability provide a source of predictive skill on subseasonal time scale. Specifically, the knowledge of extreme stratospheric polar vortex conditions has been shown to exhibit enhanced predictive skill of tropospheric circulation related to the North Atlantic Oscillation (NAO)/Northern Annular Mode (NAM). In this study, the role of stratospheric processes in subseasonal prediction is explored utilizing two parallel sets of 45-day reforecasts (10 ensemble members each) over the period 1999-2015, with NCAR's CESM1. The reforecasts were conducted with the default 30-level, as well as the 46-level version of CESM. The detailed comparison of reforecasts performed with two models with the same tropospheric physics and model resolution but a poorly and well-resolved stratosphere, allows for the examination of the processes responsible for potentially enhanced predictive skill. We found that for both model configurations the week 2 to week 6 NAO predictive skill is generally higher following anomalously week and strong vortex events than following a stratospheric neutral state. We will discuss the contribution of a well resolved stratosphere to the subseasonal predictive skill of stratospheric circulation including the quasi-biennial oscillation (QBO) and extreme stratospheric events, and implications for NAO forecasts.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-27)

Potential Sources for Extended Weather Predictability during NH Winter Season

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Princeton/GFDL (1), GFDL (2), GFDL (3)

The study here tries to identify periods and regions of increased weather predictability beyond the classic 2-week limits in the mid-latitudes. The subseasonal to seasonal prediction (S2S) project database (Vitart et al 2017) is explored in order to separate periods of extended predictability ("forecasts of opportunity") for different regions from periods of relative low predictability. Composites of these periods are then compared to understand the physical mechanisms behind different weather predictability behaviors. We will focus on the teleconnections (interactions) between midlatitudes and tropics, especially the linkage between mid-latitude weather predictability and the MJO (both its phase and amplitude). The robustness of this linkage and the interaction pathways will also be investigated using datasets from different operational centers. The performance of Geophysical Fluid Dynamics Laboratory (GFDL) High-resolution Atmospheric Model (HiRAM) in capturing these pathways will be evaluated and examined in detail to maximize its potential for subseasonal prediction.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-28)

Diagnosing the atmospheric mechanisms that influence forecast skill of rainfall extremes

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Extreme rainfall events typically have a large impact on society, from high rainfall leading to flooding, to low rainfall resulting in drought. It follows that skilful prediction of rainfall extremes may assist in mitigating and preparing for the potential impacts of these events. The skill of rainfall forecasts lies in the ability of forecast models to simulate the climate processes that influence the rainfall variability in the region of interest at relevant timescales. Here our region of interest is Tasmania, Australia's largest producer of renewable energy from hydropower, an industry that is particularly sensitive to rainfall extremes. The water catchments are primarily located in the western part of the State, which is unique from both eastern Tasmania and the rest of Australia due to local topographical influences and its location in the path of the prevailing mid-latitude westerly winds. Beyond this knowledge there is an incomplete understanding of the synoptic and dynamic processes influencing rainfall variability and extremes in the region. This study addresses this gap through the characterisation of rainfall extremes in Tasmania and the construction of atmospheric flow composites around these extreme events. We consider the onset and decay of the event and find a link between large scale planetary waveguide modes, including the Pacific South American pattern, and both wet and extreme events across Tasmania. We show that there is a coherent structure in the troposphere prior, during and following the event, which provides both a basis and bound (in regards to the lead time at which a coherent structure is evident) for predictability of these events. Data from both the JRA reanalysis product and the Climate Analysis Forecast Ensemble (CAFE) coupled climate model are used in this analysis, which will ultimately help to evaluate and interpret forecast models in their ability to forecast atmospheric modes relevant to rainfall extremes in Tasmania and indeed, other locations in the southern hemisphere.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-29)

Explaining the consistency of MJO teleconnection patterns with linear Rossby wave theory

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The Madden Julian Oscillation (MJO) creates strong variations in extratropical atmospheric circulations that have important implications for subseasonal-to-seasonal (S2S) prediction. In particular, previous study shows that certain MJO phases are characterized by a consistent modulation of geopotential height in the North Pacific and adjacent regions across different MJO events, which is beneficial for the extended numerical weather forecasts (2 weeks-1 months).

In this study, we examine the MJO phase dependency of teleconnection robustness by using a Linear Baroclinic Model (LBM). The results show that MJO phases 2, 3, 6 and 7 can consistently generate Pacific-North America like patterns on S2S timescales while others phases are more sensitive to variations in the basic state as well as the MJO heating locations. These results also provide a possible explanation why specific MJO phases are characterized by improved prediction skill of geopotential height on S2S timescales with a reduced ensemble spread over different ensemble members while other phases lose predictions skill at lead times around the traditional prediction limit of 10-13 days.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-30)

Extratropical Impacts on Atlantic Tropical Cyclone Activity and the Implications for S2S Prediction and Predictability

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Our recent studies revealed the impacts of extratropical Rossby wave breaking (RWB) on Atlantic tropical cyclones (TCs). When RWB occurs more frequently over the North Atlantic, the enhanced mixing between the warm, moist air from the tropics and the cold, dry air from the extratropics results in strong vertical wind shear and reduced tropospheric humidity in the Atlantic main development region (MDR); the basin-wide TC counts are reduced, and TCs are generally less intense, have a shorter lifetime, and are less likely to make landfalls.

Further analyses show that the variability of RWB occurrence in the western Atlantic is largely independent of that in the eastern Atlantic. The former is more closely tied to the environmental variability of the tropical North Atlantic and is more likely to hinder TC intensification or reduce the TC lifetime because of its proximity to the central portion of TC tracks. Consequently, the basin-wide TC counts and the accumulated cyclone energy have a strong correlation with western-basin RWB occurrence but a much weaker correlation with eastern-basin RWB occurrence.

The link between RWB and extratropical variability is examined through weather regime analysis. RWB occurrence in the West Atlantic is closely related to two recurrent weather patterns over the North Pacific-North America sector. In contrast, the weather regimes over the North Atlantic are all associated with weak or uncoherent anomalies of RWB occurrence in the West Atlantic. This explains the weak link between the NAO and Atlantic tropical cyclone activity, and suggests the possible impacts of upstream processes from the North Pacific-North America sector on Atlantic tropical cyclones.

The S2S prediction and predictability of Atlantic tropical cyclones is also examined. The analysis of the GEFS reforecasts suggests that the predictability of tropical cyclogenesis is reduced during episodes of active RWB, and the numerical experiments using the WRF model suggest that the processes outside of the tropical Atlantic strongly modulate Atlantic tropical cyclone activity.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-31)

Roles of atmospheric initial state in improving the short-term seasonal climate prediction

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Beyond the primary roles of ocean state (e.g., ENSO) in seasonal climate prediction, we find that the atmosphere initial state plays significant roles in improving the short-term seasonal climate prediction. The physical processes translating the observed atmosphere initialization into predictive skill, such as stratosphere-troposphere interaction and air-sea coupling, will be discussed. As a case study, we will discuss the roles of atmospheric initial state in predicting the winter precipitation anomalies over the western United States during the major 2015/16 El Niño event.

SESSION: (A1) Mechanisms of S2S predictability

(P-A1-32)

Connection between two S2S Predictability Sources: QBO and MJO

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This presentation takes the observed connection between QBO and MJO as an example to illustrate how fundamental understanding of S2S predictability should benefit the S2S prediction pipeline that includes observations, data assimilation, numerical prediction, postprocessing, prediction verification, information dissemination, and user engagement.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-01)

Skillful five week forecasts of tornado and hail activity

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Every year in the United States, convective severe weather poses a grave threat to society, producing tornadoes and hail that often result in casualties and property loss. Fortunately, skillful predictions of severe weather activity for short lead times of 0–8 days and longer lead times of more than one month have been realized. However, this leaves a “forecast gap” in the critical subseasonal time scale of 2–5 weeks, when early-action decision making by stakeholders is typically made. Here we develop an empirical prediction model that fills this gap, demonstrating skillful “forecasts of opportunity” of environmental parameters favorable to severe weather, and actual tornado and hail events themselves, with lead times of 2–5 weeks. To attain this skill, we use as a predictor the current state of the Madden-Julian Oscillation, one of the atmosphere’s prominent sources of subseasonal predictability that is known to have physical teleconnections with weather over the United States. We show that the model has skill in regions prone to severe weather, such as the Plains and the Southeast, where improvement in the subseasonal prediction of severe weather has great value for supporting early-action decision making by stakeholders.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-02)

Fully Coupled Sub–Seasonal to Seasonal Forecasts in CESM

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Atmospheric Modeling and Predictability

We have been actively producing fully coupled, near real-time sub-seasonal to seasonal forecasts in collaboration with the North American Multi-Model Ensemble (NMME) project. We are now updating our hindcasts and forecasts to improve initialization, and assess the impact of such improvements.

We are initializing with ocean and ice simulations which are forced with NCEP state and JRA55 winds in the tropics. The Atmosphere is initialized with NCEP state. The land is initialized using the following method: The Community Land Model version 4 (CLM4; Lawrence et al 2011) was used to produce restart files for every month from 1979 to the end of 2016 that reflect the observed surface state anomalies. This was done by first performing two 30 year cycles from 1950-1979 to ensure that soil moisture and temperature stabilized with respect to the modern climate state. After completing the second cycle the simulation was continued from 1979-2016 and restart files were output every month. All the simulations discussed above were forced with 6-hourly precipitation, temperature, specific humidity, wind speed, lowest atmospheric level pressure, and incoming longwave and shortwave radiation from the Climate Research Unit-National Centers for Environmental Prediction joint dataset (CRU-NCEP downloaded from http://dods.ipsl.jussieu.fr/igcmg/IGCM/BC/OOL/OL/CRU-NCEP). Note that this 60-year spin-up cycle is more than sufficient for stabilizing state variables of CLM when performing simulations using Satellite Phenology (commonly referred to as SP mode). This procedure would require a much longer spin-up period on the order of a few hundred years if interactive vegetation was activated, commonly known as active Biogeochemical Cycle or BGC). The current simulations use CLM4 in SP mode. [Technique by Ahmed Tawfik].

The ensemble spread for previous forecasts was done using a small perturbation to initial conditions of order 1.e-14. Work by Yaga Richter et al has shown that this technique does not have adequate ensemble spread in the 2-4 week prediction range, and therefore is not well-suited for sub-seasonal to seasonal predictions. Instead, we use a Random Field (RF) method.

The RF perturbation initialization method for generating adequate ensemble spread is described by Magnussen et. Al. 2009. RF initialization involves taking a difference between two random initial conditions, from the same season as the starting month of the simulation, scaling it by a perturbation scaling factor (PSF), and adding and subtracting it from the initial state of the model. Because the perturbations are taken between two prior model states, they are in approximate flow balance. Each random difference therefore generates two ensembles, and the method can be applied to generate as many ensembles as are needed. Magnussen et. al. 2009 demonstrated that RF initialization is as effective in generating model spread as several other, more sophisticated methods, such as the ensemble transform (ET) and singular vectors (SV).

With these developments we expect more skillful precipitation prediction over continental regions in the warm seasons and improved predictions of forecast reliability.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-03)

Assimilation of sea ice in an Earth system model and its impacts for climate prediction

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We aim at testing the added value of assimilating sea ice concentration (SIC) within the Norwegian Climate prediction Model (NorCPM) that combines the Norwegian Earth system model with the ensemble Kalman filter data assimilation method. We first employ an idealised twin experiment to identify the optimal implementation in a fully coupled Earth system model that is using the multi-category CICE model. It is found that: 1) updating the ice concentration of each individual category yields large improvements of ice concentration and ice thickness without introducing a drift 2) joint coupled update of ocean and sea ice enhances the performance of the ocean and sea ice components. Second, this setting is applied in a real framework in combination with assimilating SST and sub-surface hydrographic data for the period 1980-2010 and compared to the version of the system without SIC assimilation. SIC assimilation greatly reduces the error of sea ice thickness compared to independent data set. The seasonal prediction of sea ice extent is enhanced for all sub-regions of the Arctic and predominantly beats persistence. There is a large seasonality in the performance with best skill for boreal winter in the Barents, Bering and Okhotsk Sea and for boreal summer in the Central, Greenland, Baffin, Chucky, Laptev, Kara, Hudson and Beaufort Seas. The benefit of sea ice assimilation is largest for boreal summer as a consequence of the improved initial sea ice state but there is no improvement in in boreal winter as variability is mostly driven by the ocean already successfully constrained by ocean assimilation.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-04)

The predictability of malaria: Case of Senegal, West Africa

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This study is a contribution to the Climate and Health Project in development at the CPC/NOAA. Diagnostics are being performed on subseasonal and seasonal timescales, based on malaria simulations, monitoring and forecast of malaria climate drivers. Experimental risk maps and time series of malaria parameters for West Africa and Senegal in particular are generated and validated with observational clinical data recorded by the National Program for Malaria Control (NPMC) of Senegal.

The main meteorological variables known to influence malaria include precipitations, temperature but also relative humidity. In Senegal and over the Sahelian band in general, our previous study showed that while the rainfall season is at its peak in July-August-September (JAS), the peak of the malaria outbreak season occurs in September-October-November (SON). Furthermore, some studies have shown that Atlantic and Pacific SST modulate West Africa rainfall and indirectly malaria incidence.

This work is being conducted in several stages. Firstly, we employ the Liverpool Malaria Model (LMM) and the VECTRI model (VECtor borne disease community model of ICTP, TRIeste). With these 2 malaria models, we simulate hindcasts of malaria incidence, using as inputs: daily rainfall, daily 2m maximum and minimum temperature of available datasets at the CPC/NOAA. Secondly, we employ the Canonical Correlation Analysis (CCA) and the Sea Surface based Statistical Seasonal Forecast (S4CAST), where the predictand is rainfall or temperature extracted from meteorological stations, satellite, and reanalysis, or the malaria models' outputs; and the predictor is the observed SST (ERSSTv4) and NMME predicted SST including separately NMME model members and their ensemble mean. Results from these experiments are presented

Keywords: Malaria, Climate, Forecast, Predictability, Senegal, West Africa

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-05)

FIM-iHYCOM in SubX: Evaluation of Model Errors and MJO Index Skill

Green, Benjamin W. (1,2); Sun, Shan (1,2); Bleck, Rainer (1,2,3);
Benjamin, Stanley G. (2); Grell, Georg A. (2)

CIRES/CU, USA (1); NOAA/OAR/ESRL/GSD, USA (2); NASA/GISS, USA (3)

The FIM-iHYCOM model has produced both real-time and retrospective forecasts at subseasonal timescales for NOAA's Subseasonal Experiment (SubX). FIM-iHYCOM couples the atmospheric Flow-following finite volume Icosahedral Model (FIM) to an icosahedral-grid version of the Hybrid Coordinate Ocean Model (HYCOM). This coupled model is unique in terms of its grid structure: in the horizontal, the icosahedral meshes are perfectly matched for FIM and iHYCOM, eliminating the need for a flux interpolator; in the vertical, both models use an adaptive ALE (Arbitrary Lagrangian-Eulerian) coordinate. For SubX, FIM-iHYCOM initializes four time-lagged ensemble members around each Wednesday, which are integrated forward to provide 32-day forecasts.

Because FIM-iHYCOM is a fairly new modeling system, it is important to evaluate the model in terms of systematic biases. Here, FIM-iHYCOM biases are evaluated against NOAA's operational CFSv2; overall, the performance is comparable. FIM-iHYCOM has a smaller global precipitation bias than CFSv2 (verifying against GPCP), which is partially attributable to FIM-iHYCOM's use of a modified version of the Grell-Freitas scale aware convective parameterization.

In addition to investigating systematic model errors, the performance of FIM-iHYCOM in terms of forecasting MJO bivariate indices (RMM and VPM) is examined. The coupled FIM-iHYCOM performs comparably to CFSv2. Moreover, tests in which FIM was forced by observed sea-surface temperatures - i.e., uncoupled atmosphere-only FIM runs - showed a substantial reduction in RMM skill. This strongly suggests that some level of ocean coupling is necessary for improved forecasting at subseasonal timescales.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-06)

Skill of the BCC S2S Forecast System in Predicting the Subseasonal Rainfall over China in Summer and Model Bias Correction

Anning Huang

Nanjing Univeristy

The skill of BCC S2S forecast system in predicting the sub-seasonal rainfall over China in summer has been systematically evaluated and the model bias correction method has been developed in this study. Results indicate that the skill of BCC S2S system in predicting the sub-seasonal rainfall over China in summer varies regionally and interannually.The BCC S2S system tends to display a relatively higher ability in predicting the sub-seasonal rainfall over China in summer at the forecast lead time of around 5~10 days, the forecast skill decreases with the forecast lead time increased.The application of model systematic error correction can significantly improve the ability of the BCC S2S system in predicting the sub-seasonal rainall over China in summer.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-07)

Using Seasonal Forecasts to Drive a Great Lakes Hydrodynamic/Ice Model

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Ice cover in the Great Lakes region shows high year--to-year variability and has significant economic, environmental and societal impacts. The presence of ice cover caps moisture fluxes from lake to atmosphere, impacting lake levels and regional weather through lake--effect snow. Ice cover severely hinders commercial shipping and fishing which are multi-billion dollar industries in this region. Additionally, fatalities on the Great Lakes during winter are not uncommon and in many cases this may be attributed to a poor understanding of when and where ice will form. The Finite Volume Community Ocean Model (FVCOM) coupled with the Los Alamos Community Ice CodE (CICE) will soon be transitioned from testing and development to the new Great Lakes Operational Forecast System. This coupled model framework was used to make a seasonal projection of the 2017 Great Lakes ice season by applying the Climate Forecast System's seasonal forecast as boundary conditions. Despite having high skill in regards to lake state variables and ice cover during a 23 year hindcast period (Kessler et al. 2017), the seasonal forecast showed very little skill, and the causes are investigated. Alternative methodology (e.g. ensemble forecasts) and sources for prescribing boundary conditions (e.g. North American Multi-Model Ensemble) are considered and tested as a means to improve the seasonal ice forecast.

Kessler, J.A., J. Wang, A. Manome, P. Chu. Modeling Great Lakes Ice Cover using FVCOM and UG-CICE (oral). 60th annual Conference on Great Lakes Research, Detroit, MI, May 15-19, 2017.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-08)

A mechanism of mixed-layer formation in the Indo-western Pacific Southern Ocean: preconditioning by an eddy-driven jet-scale overturning circulation

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The formation of a narrow band of the deep winter mixed layer (hereafter "mixed layer wedge") in the Indo-western Pacific Southern Ocean is examined using an eddy-resolving POP model simulation. The mixed layer wedge starts to deepen in June, centered at 47.5°S, with a meridional scale of only ~2° latitude. Its center is located ~1° north of the model's Subantarctic Front (SAF). The Argo-based observed mixed layer is similarly narrow and occurs adjacent to the observed SAF.

In the small sector of 130°E-142°E, where the SAF is persistent and the mixed layer is deepest, the formation of the narrow mixed layer wedge coincides with destratification underneath the mixed layer. This destratification can be attributed primarily to the downwelling branch of a jet-scale overturning circulation (JSOC). The JSOC, which was reported in an earlier study by the authors, is driven by eddy momentum flux convergence and is therefore thermally indirect: its descending branch occurs on the warmer equatorward flank of the SAF, promoting destratification during the warm season. The model-generated net air-sea heat flux reveals a similar wedge-like feature, indicating that the flux contributes to the MLD wedge, but again this feature is preconditioned by the JSOC. Ekman advection contributes to the formation of the mixed layer, but it occurs farther north of the region where the mixed layer initially deepens.

These findings suggest that the eddy-driven JSOC associated with the SAF play an important role in initiating the narrow, deep mixed layer wedge that forms north of the SAF.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-09)

GEOS S2S-2_1: The GMAO High Resolution Seasonal Prediction System

Molod, Andrea

NASA/GMAO

A new version of the coupled modeling and analysis system used to produce near real time subseasonal to seasonal forecasts was recently released by the NASA/Goddard Global Modeling and Assimilation Office. The new version runs at higher atmospheric resolution than the previous, (approximately 1/2 degree globally), contains a substantially improved model description of the cryosphere, and includes additional interactive earth system model components (aerosol model). In addition, the Ocean data assimilation system has been replaced with a Local Ensemble Transform Kalman Filter.

Here will describe the new system, along with the plans for the future (GEOS S2S-3_0) which will include a higher resolution ocean model and more interactive earth system model components (interactive vegetation, biomass burning from fires). We will also present results from a series of retrospective seasonal forecasts. Results show significant improvements in surface temperatures over much of the northern hemisphere and a much improved prediction of sea ice extent in both hemispheres. The precipitation forecast skill is comparable to previous S2S systems, and the only tradeoff is an increased "double ITCZ", which is expected as we go to higher atmospheric resolution.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-10)

Hindcast Simulations of the Madden Julian Oscillation (MJO) in CESM: Assessing the role of regional resolution variations and parameterized physics

Neale, Richard (1), Olson, Jerry (1), Hannay, Cecile (1),
Rothstein, Mathew (1)

NCAR, USA (1)

Various studies have linked the accurate simulation of the Madden Julian Oscillation (MJO) in climate models, to having either an adequate horizontal resolution to resolve large-scale/convection interactions, or the correct physical process parameterizations to enable the correct dynamics-physics coupling, sufficient to grow and propagate MJO-like disturbances.

The extent to which resolution and physical parameterizations matter in climate models will be presented in this talk. We use the NCAR Community Earth System Model (CESM) in HIndcast/CAPT-type configurations covering the 2009/10 period of the YOTC campaign. The period covers three active MJO events. Each simulation set constitutes a series of 20-day hindcasts, performed, in the control case, with a global, 1 degree resolution. Our default configuration uses version 5 of the Community Atmosphere Model (CAM5). This version has demonstrated significant skill in hindcasts out to 20-days for certain measures of the MJO (Klingaman et al., 2015). Paradoxically, the MJO performance of CAM5 AMIP-type and fully coupled simulations is poor in comparison.

With this model version we assess the role of resolution both globally and regionally. A global high-resolution (0.25 deg) set of simulations is compared to the 1 degree set for local MJO skill and more remote extra-tropical impacts in the Northern hemisphere. Additionally, we assess the potential role of resolution by isolating its importance in different regions. Using a regionally refined version of CESM we provide higher resolution (0.25 deg) within the 1 degree global simulations over a number of key tropical regions. These include over the Indian Ocean, where the MJO initiates; over the Maritime Continent, where barrier effects can damp the MJO; and over the West Pacific, where MJOs grow to maturity.

Finally, we investigate the role of modified and improved parameterized physics in the hindcast of MJO activity. This employs the current development version of the CESM atmosphere model (CAM6), which uses a radically different set of parameterized physics including a high-order turbulence scheme (CLUBB), and is used to generate an additional set of simulations for the YOTC period. With this full experiment set we demonstrate the relative merits of resolution and parameterized physics on the simulation of the MJO in CESM, with some surprises!

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-11)

Representation of synoptic-scale Rossby wave packets in the S2S prediction project database

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Coherent Rossby wave packets (RWPs) are one of the dominating large-scale atmospheric phenomena which shape the weather and climate in midlatitudes. Hence, a realistic representation of the initiation, propagation and decay of RWPs is essential for skillful numerical weather prediction (NWP) forecasts. Using an objective RWP identification and tracking technique, this study is the first to verify the representation of northern hemispheric RWPs in reforecast of the S2S prediction project database against climatology derived from reanalysis data. Consistent with the climatology, the NWP models in the S2S database show on average one RWP every four days. These RWPs tend to have a shorter mean lifetime but cover longer distances than those identified from reanalysis data. This is particularly noticeable for the models in the S2S prediction project database with a rather coarse horizontal grid spacing. The longer propagation distance is related to a positive bias in the RWP envelope over the eastern North Atlantic and over Europe leading to an underestimation of the number of RWPs decaying in this region. A subsequent analysis of atmospheric blocking suggests that the underestimation of RWP decay over the eastern North Atlantic/Europe is due to the inability of the models to adequately represent the frequency of atmospheric blocking. The representation of atmospheric blocking and therefore the representation of RWP decay improve greatly in models with finer grid spacing.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-12)

Subseasonal Prediction Skill with an Icosahedral, Vertically Quasi-Lagrangian Coupled Model

Shan Sun (1), Rainer Bleck (2), Benjamin W. Green (3) and Stanley G. Benjamin (4)

CU/CIRES and NOAA/ESRL (1,2,3), NOAA/ESRL (4)

A coupled atmosphere (FIM) and ocean (iHYCOM) modeling system FIM-iHYCOM has been developed for subseasonal to seasonal prediction, where both component models operate on a common icosahedral horizontal grid to avoid surface flux interpolation and use adaptive near-isentropic vertical coordinates. Once-per-week subseasonal hindcasts with 4 time-lagged ensemble members over an 18-year period have been carried out with this model at 60km horizontal resolution for NOAA's Subseasonal Experiment (SubX). Results from these multi-year hindcasts indicate that both deterministic and probabilistic forecast skill at weeks 3-4 from FIM-HYCOM is comparable to that of the operational model CFSv2. Predictions of blocking simulations and sudden stratospheric warming events will be discussed in some detail.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-13)

Systematic errors in ECMWF's monthly and seasonal forecasts: The impact of stochastic perturbations in the atmosphere

Antje Weisheimer (1,2)

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ECMWF's ensemble prediction system from days to weeks and months contains an explicit representation of model uncertainties due to sub-grid scale physical processes. Currently two model uncertainty schemes are active: the stochastically perturbed physical tendency (SPPT) scheme and the stochastic kinetic energy backscatter (SKEB) scheme. SPPT introduces multiplicative noise to the total physics tendency of wind, temperature and humidity. It is SPPT that has the largest effect of the two schemes on the ensemble in the extended and seasonal forecast range.

Here we show, using experiments with ECMWF's monthly and seasonal ensemble forecasting systems, how systematic errors grow during the forecasts and what impact model uncertainty representation has on these systematic errors. Some of the errors in the seasonal forecasts can be traced back to as early as the first week of the forecasts. In particular, we will discuss how slowly evolving errors like SST biases evolve during the course of the first and subsequent months. It will be shown that stochastic physics results in a reduction of excessive tropical rainfall near the ITCZ and an increase in rainfall over the Western tropical Pacific, leading to a reduction of these overall biases. The impact of stochastic physics on Indian Ocean precipitation bias is not consistent across seasons with mostly a negative impact during the summer monsoon season.

In terms of probabilistic forecast quality it has been found that one of the most remarkable impacts of SPPT is to increases the under-dispersive spread of MJO predictions by a significant amount which results in improved skill scores. Tropical temperature and precipitation forecasts are also improved during the first month due to the stochastic physics schemes.

SESSION: (A2) Modelling issues in S2S prediction

(P-A2-14)

Parameters optimization to improve MJO prediction using CMA S2S model

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Using the Beijing Climate Center sub-seasonal to seasonal forecast (S2S) model of China Meteorological Administration (CMA), several key physical parameters are perturbed by the Latin hypercube sampling method to find a better configuration for representation of Madden-Julian oscillation (MJO) in the simulation. By parameter optimization, MJO's spectrum, spatial structure and propagation, as well as the mean state and variance, can be improved to some extent. Further, several sets of initialized hindcasts using the optimized parameters are conducted. Their results are compared with the CMA S2S hindcasts and show that with an optimized model, the forecast skill of MJO can reach to beyond 3-week lead time. The evident improvement occurs in the period of 2 to 3 weeks lead time, especially for MJO propagation from the Indian Ocean to the western Pacific.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-01)

Validation of the leading pattern of intraseasonal variability in South America in CFSv2 and its predictability in subseasonal predictions

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The Seasonal-Intraseasonal (SIS) pattern is defined as the leading EOF of the 10-90-day filtered OLR anomalies in a region over South America (40S-5N, 70W-32.5W). Previous studies have shown that IS variability of rainfall and circulation in the region can be studied and monitored through the SIS pattern activity, indicated by the time series of the first principal component (named SIS index). Therefore, the representation of the SIS patterns by the NCEP Climate Forecast System version 2 (CFSv2) during austral summer (DJF) and winter (JJA) was assessed using the 123-day reforecasts as simulation runs. The reforecasts were initialized during 12 years between January 1999 and December 2010. For the DJF (JJA) season, the runs selected were those initialized at 00Z from the first of November (May) until the 10th of the month. Thereby, as there are 12 years of reforecasts available, 120 runs were obtained for each target season, and their variability analyzed. The lead-dependent anomalies were filtering using a recursive Murakami band-pass filter with cut-off periods 10 and 90 days.

The main features associated with the SIS pattern like the well-known dipole between the southeastern South America (SESA) and the South Atlantic Convergence Zone regions during summer and the monopole centered over Paraguay and SESA during winter are represented by the model despite some slight differences in location and tilting of the centers. During summer, eastward-moving OLR anomalies in tropical latitudes are observed along the Indian Ocean and the Maritime Continent, and it was found that they are simulated by the reforecasts but displaced to the east. On the other hand, during winter, only weak tropical convective activity in the Pacific Ocean is observed in relation to the evolution of the IS mode in South America. However, a distinct feature observed for the season are alternating centers of OLR anomalies in the southeast Pacific Ocean, which are in part represented by the model.

The OLR reforecasts of the CFSv2 provided in the S2S database were used to assess the predictability of the OLR in South America and of the SIS index during the warm season, from weeks 1 to 4. Scores as the mean error, mean squared error and anomaly correlation were computed. Details will be presented at the conference.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-02)

Global precipitation hindcast quality assessment of the Subseasonal to Seasonal (S2S) prediction project models

Andrade, Felipe (1), Coelho, Caio (1), Cavalcanti, Iracema (1)

CPTEC/INPE, BRAZIL (1)

This study assesses the quality of subseasonal (weekly aggregated) global precipitation hindcasts from all models participating in the Subseasonal to Seasonal (S2S) prediction project. Different deterministic forecast quality metrics are employed for verifying accumulated precipitation hindcasts considering lead times up to 4 weeks using the Global Precipitation Climatology Project (GPCP) dataset as observational reference. The correlation scores are found to be higher during the first week and drop as lead time increases, concentrating meaningful signals in the tropical region mostly due to El Niño-Southern Oscillation (ENSO) and Madden-Julian Oscillation (MJO)-related effects. The model's rank shows ECMWF, UKMO, and KMA as the top scoring models even when using a single (unperturbed) control member instead of the all members ensemble mean. Models with a larger number of perturbed members (BoM and CNRM) display great sensitivity to the single (unperturbed) control member, evidencing the value of ensemble prediction. The lowest correlation scores are shared by ISAC, CMA, and HMCR during almost all weeks. These models show large systematic errors measured through bias and variance ratio computed for further elucidating shortcomings in S2S models not revealed by the correlation assessment. The subseasonal atmospheric circulation hindcast quality is also examined revealing the importance of using a relatively finer spatial resolution and a coupled model for resolving the essential tropical atmospheric circulation dynamics, particularly for simulating tropical precipitation variability. In the extratropical region, circulation hindcast quality is found to be low after the second week likely due to errors associated with model deficiencies in representing atmospheric teleconnections and the inherent inability to predict the extratropical variability.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-03)

A process-oriented evaluation of the model errors associated with atmospheric river activity along the West Coast of North America

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Atmospheric rivers are elongated plumes of intense moisture transport that are capable of producing extreme and impactful weather. Along the west coast of North America, they occasionally cause considerable mayhem – delivering flooding rains during periods of heightened activity and desiccating droughts during periods of reduced activity. The intrinsic chaos of the atmosphere makes the prediction of atmospheric rivers at subseasonal lead times (3–5 weeks) an inherently difficult task. In prior work we have demonstrated that state-of-the-art numerical weather prediction models lack skill in forecasting AR activity at subseasonal lead times. In this study, we provide insight into the models' deficiencies by performing a process-oriented evaluation of the key dynamical processes that impact the location and frequency of atmospheric river activity along the west coast of North America. Model errors in atmospheric river activity are directly related to errors in their depiction of the 500-hPa geopotential heights and blocking over the North Pacific. In turn, these errors are linked to the models' ability to accurately simulate the Madden-Julian oscillation, the subtropical jet, their interaction as a Rossby wave source, and the subsequent development of downstream teleconnections and blocking. In light of the wide-ranging impacts associated with landfalling atmospheric rivers, even modest gains in the ability of numerical models to predict them at subseasonal lead times have great worth in supporting early action decision making and thereby benefit numerous sectors of society.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-04)

Assessment of the forecast skill of precipitation over New Caledonia (SW Pacific) at the subseasonal time scale

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Located in the tropical Southwest Pacific 1,500 km east of Queensland, Australia, the archipelago of New Caledonia is prone to heavy rainfall events that may be related either to tropical (including cyclones) or to mid-latitude perturbations, and that are likely to be triggered or enhanced by the mountainous profile of the main island. Precipitation over New Caledonia should therefore exhibit some subseasonal predictability owing to the influence of large-scale drivers, such as ENSO and the Madden-Julian oscillation.

This study aims to assess the skill in predicting precipitation over New Caledonia at the subseasonal range in GCM forecasts. Verification was first carried out on the daily gridded rainfall output in the Météo-France contribution to the WWRP/WCRP S2S project by evaluating the 15-member ensemble hindcasts over the years 1993-2014. It was then adapted over longer periods (e.g one week) so as to consider time spans for which predictability should be more relevant at larger intraseasonal lead times (week 1, week 2, fortnight 1…). The observation dataset used for verification is the Multi-Source Weighted-Ensemble Precipitation (MSWEP) version 2.1 global historic daily precipitation dataset, that covers the period 1979-2016 on a 0.25° grid. Additional verification was also carried out on rain gauge data.

Given the usually poor ability of GCMs to accurately simulate daily rain rates after a few days lead, as shown by direct verification metrics such as RMSE, the gist of this study is to highlight what kind of relevant information on precipitation over New Caledonia can be extracted in a S2S forecast, and up to which lead time, using climatology as a benchmark. The most promising approaches selected rely on grouping rain rates into several discrete categories (e.g rain vs no rain, quantiles) before applying categorical scores based on contingency tables, for instance ROC Skill Score, Pierce Skill Score and Gerrity Score. Another aspect to consider with these approaches is the usefulness of such categories for potential end-users at a subseasonal scale, for instance with respect to extreme event anticipation.

Further improvement to the rainfall forecasts will be sought through both dynamical and statistical downscaling.

1

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-05)

Global multi-model evaluation of atmospheric river subseasonal prediction skill

DeFlorio, Michael (1), Waliser, Duane (2), Goodman, Alexander (3), Guan, Bin (4),
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NASA JPL/California Institute of Technology (1,2,3,4), University of California-Los Angeles (2,4),
University of California-San Diego, Scripps Institution of Oceanography (5), ECMWF (6)

We use the Subseasonal-to-Seasonal (S2S) Project database, which includes extensive hindcast records of eleven operational weather models, to assess global prediction skill of atmospheric rivers (ARs) on S2S timescales. We develop a metric to assess AR skill that is suitable for S2S timescales by counting the total number of AR days which occur over each model and observational grid cell during a week-long lead window. This one-week AR occurrence metric (AR1wk) is suitable for S2S prediction skill assessment because it does not consider discrete hourly or daily AR objects, but rather an aggregate representation of AR occurrence over a longer period of time. AR1wk average forecast skill in the ECMWF hindcast system outperforms a reference forecast based on monthly climatology of AR1wk at week-2 (14 day to 20 day) lead over a number of subtropical to midlatitude regions, with slightly better skill evident during wintertime. ECMWF outperforms the reference forecast at week-3 (21 day to 27 day) lead over the North Atlantic/U.K., South Pacific/Australia, and South Pacific/Chile regions during wintertim. AR1wk is modulated during certain phases of the El Niño-Southern Oscillation (ENSO), Arctic Oscillation (AO), Pacific-North America (PNA) teleconnection pattern, and Madden-Julian Oscillation (MJO), and statistically significant differences in AR1wk forecast skill are shown for various mode/lead/region combinations, including during El Niño relative to La Niña conditions at week-0 (0 day to 6 day) lead over the South Pacific/Australia region; during -AO relative to +AO conditions at week-2 lead over the North Pacific/West U.S. region; and during particular phases of MJO over each region.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-06)

Seamless transition from weather to climate – A method for forecast definition and validation

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COLA/George Mason University (1); Southern Illinois University (2)

The necessary accuracy and representative timescales of weather and climate predictions vary with forecast lead time. This is one of the tenets of so-called “seamless prediction.” Today numerical forecast models, particularly global models, are used for all time scales from days to seasons or longer, and all operational long-term forecasts necessarily predict short-term weather on their way to the longer lead times. Weather forecasts are generally deterministic and are validated instantaneously or as averages or totals over short time intervals such as one day or the duration of a storm. As the lead time of forecasts increase, focus shifts to longer time averages; monthly and eventually seasonal means. We have recently published results applying a Poisson weighting in time of forecasts that transition, as the Poisson function does, from highly skewed to very short time scales at the beginning of a forecast to ever-widening Gaussian-weighted averages beyond a week or two. This provides a seamless transition to classical monthly and seasonal climate forecasts. However, it also means that the validation state for any particular observed date also varies with forecast lead time, potentially complicating calculation of climatologies for the purpose of determining anomalies (which also vary with lead time in this approach). We examine in greater depth the applications of this approach to S2S forecasts, including how the ensemble dimension can be exploited for additional information in seamless prediction. We also look beyond the simple Poisson weighting to more sophisticated distributions that allow greater control over the shape and transformation of the weighting distribution as a function of forecast lead.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-07)

Merits of one hundred parallel simulations in seasonal prediction

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JAMSTEC,Japan(1)

This work explores merits of one hundred ensemble simulations from a single dynamical seasonal prediction system by evaluating differences in skill scores between ensembles predictions with few (12) and many (~100) ensemble members. A 100-ensemble retrospective seasonal forecast experiment for 1983-2015 is beyond current operational capability. Prediction of extremely strong ENSO and the Indian Ocean Dipole events is significantly improved in the larger ensemble. It indicates that the ensemble size of 10-members, used in some operational systems, is not adequate for the occurrence of 15% tails extreme climate events, because only about 1 or 2 members (approximately 15% of 12) will agree with the observations. Even if running a 100-ensemble prediction system is quite costly, improved prediction of disastrous extreme events may be useful for minimizing risks of possible human and economic losses.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-08)

Improving S2S forecast skill of precipitation and surface air temperature using multi-model strategy

Guo, Zhichang(1), Dirmeyer, Paul A.(2)

GMU, USA(1)

Seasonal (S2S) Prediction Project. To develop a reliable and timely climate product from these datasets, we propose a new methodology to assess an individual model's forecast skill, generate statistical weights based on the skill of member model forecasts, and use aforementioned weights to produce an optimized single forecast. The results show that the new methodology outperforms individual models and the simple multi-model averaging method, and effectively reduces real forecast error and predictability error.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-09)

NOAA's Reanalysis and Reforecast Project for Subseasonal Forecasting

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ESRL/PSD (1,2), CIRES (3)

The next version of NOAA's Global Ensemble Forecast System (GEFS) will produce forecasts to +35 days lead time. Since statistical postprocessing with a long time series is necessary, the real-time GEFS forecasts will be accompanied by a 20-year global reanalysis and ensemble reforecast. We will describe the real-time GEFS system, the reanalysis, the reforecast, data access, and preliminary results.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-10)

An alternative estimate of potential predictability on the Madden-Julian Oscillation phase space using S2S models

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Hokkaido University (1), Japan Meteorological Agency (2)

This study proposes an alternative method to estimate the potential predictability without assuming the perfect model. A theoretical consideration relates a maximum possible value of the initial-value error to the covariance between analysis and ensemble-mean forecast. The prediction limit of the MJO was evaluated, based on reanalysis and forecast datasets by ECMWF, JMA and the NCEP in the S2S project. The results showed that the predictability was higher when MJO amplitude exceeded unity.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-11)

Influence of Arctic Predictability on Mid-latitudes Seasonal Forecasts

Euihyun jung, Jee-hoon Jeong

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Recent Arctic Amplification and cold surges in the east side of the continent have issued especially in boreal winter. The mid-latitude and Arctic regions are adjacent and affect to each other in climate system.

Using dynamical models, to assess the effect of Arctic predictability on the mid-latitudes, 20 dynamical models are used. Some models simulate the surface air temperature(SAT) relationship between the Artic and the mid-latitudes called “Warm Arctic Cold Continents” and these models also simulate SAT well in the northern hemisphere.

And using statistical method, dynamical model forecast can be improved. That method uses ART1 index which area-averaged SAT in the Arctic and project it in northern hemisphere. This can estimate effect on improved Arctic predictability on mid-latitude forecast accuracy. In this experiment, improvement of forecast skill in the mid-latitudes coming from accurate Arctic prediction is shown.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-12)

The Regional Arctic System Model (RASM): A tool to produce improved S2S to S2D Arctic sea ice forecasts

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Naval Postgraduate School, USA (1), Institute of Oceanology Polish Academy of Sciences, Poland (2), University of Colorado, USA (3)

The Arctic Ocean has experienced an accelerated retreat of its sea ice cover, due to an amplified warming relative to the rest of Earth. In fact, it is predicted to become near ice-free in summer within a couple to several decades. Such environmental changes allow increased commercial and other activities in the Arctic Ocean. Hence, improved understanding and advanced modeling capability for simulation and prediction of the evolving Arctic System are necessary to address increasing demands for environmental intelligence from national stakeholders, including energy, shipping and tourism industries, native communities, national defense and policy makers. In this talk, we summarize our approach involving the use of the Regional Arctic System Model (RASM) and present results of S2S sea ice forecasts for 2017-2018.

RASM is a fully coupled regional climate system model with separate atmospheric, ocean, sea ice, and land-hydrology models and a flux coupler to connect them. It utilizes the Weather Research and Forecasting (WRF) Model, the Los Alamos National Laboratory Parallel Ocean Program (POP) and Sea Ice Model (CICE), the Variable Infiltration Capacity (VIC) land surface model, and the stream flow routing scheme (RVIC). RASM is used to dynamically downscale the Climate Forecasting System Reanalysis (CFSR) for 1979-present and to create internally consistent physical initial conditions for all RASM components for S2S ensemble forecasts. Our initial effort has started with S2S prediction of the September minimum sea ice extent. Here we present results of S2S ensemble forecasts of sea ice extent, concentration and thickness for each month of 2017 as well as for September 2018 minimum. The 2017 forecast consists of 4 different 28-member ensembles with lead times of 2 weeks, 1, 2, and 3 months. Similarly, we produce September 2018 forecast from the RASM initial conditions at the start of June, July, and August, in contribution to the Sea Ice Prediction Network (SIPN) 2018 Sea Ice Outlook (SIO) effort.

The sea ice minima of 2018 and 2017 are additionally forecasted by 2 sets of ensembles with lead times of 5 and 6 months. All forecast ensembles are forced after the initialization with the NCEP Climate Forecast System Version 2 (CFSv2). Forecast skill of each ensemble member will be evaluated using available satellite observations of sea ice extent, concentration and thickness (for winter target months). We will investigate the effects of initial conditions, sea ice rheology, target month, and lead time on the forecast skill.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-13)

Subseasonal and seasonal predictions of West Pacific tropical cyclones

Klingaman, Nicholas (1), Hodges, Kevin (1), Peatman, Simon (1), Novakova, Lenka (1), Feng, Xiangbo (1), Vidale, Pier Luigi (1)

NCAS-Climate and Department of Meteorology, University of Reading (1)

Tropical cyclones are a substantial threat to lives and livelihoods in West Pacific nations, including the Philippines, China and Japan. Reliable predictions of tropical cyclone activity on sub-seasonal to seasonal timescales are therefore critical for providing advance warning to safeguard lives and protect infrastructure. While many previous studies have assessed seasonal prediction skill for basin-wide cyclone activity in terms of the number of storms or their aggregated intensity (e.g., ACE metrics), fewer studies have considered whether models can predict variables more closely to related to cyclone impacts, such as the amount of cyclone-related precipitation.

This presentation will review the skill of UK Met Office ensemble forecasts for tropical cyclones in the West Pacific, at lead times from the medium range (7-15 days) to seasonal (6 months). In addition to overall skill for cyclone frequency and intensity, we also assess the fidelity of teleconnections from major modes of variability, such as the Madden-Julian Oscillation (MJO) and the El Nino-Southern Oscillation (ENSO) to cyclone activity. For example, we find that medium-range forecasts of West Pacific cyclone intensity are more accurate during active MJO phases in the West Pacific. This provides actionable information to forecasters who use Met Office forecast data in real time. Further, we assess model performance for cyclone-related precipitation, near-surface winds and ocean-to-land moisture transports, using a technique that composites these fields within a certain radius from the cyclone centre. We relate biases in mean cyclone activity, its variability and teleconnections to the evolution of mean-state biases in S2S forecasts in fields related to cyclone formation and intensification, including sea-surface temperatures, mid-tropospheric relative humidity and vertical wind shear.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-14)

Tropical cyclone prediction skills - MJO dependence in S2S dataset

Chia-Ying Lee (1), Suzana J. Camargo (2), Fréderic Vitart (3), Adam H. Sobel(2,4), and Michael K. Tippett(4)

IRI/Columbia University, USA (1), Lamont/Columbia University, USA (2), ECMWF, UK (3), APAM/Columbia University, USA (4)

The Madden-Julian Oscillation (MJO) is one of important climate controls of tropical cyclone (TC) activity, in particular, on the intraseasonal time scale. Given the ongoing effort to develop dynamical seasonal-to-subseasonal (S2S) TC predictions, it is important to examine whether global models are able to reproduce the MJO-TC relationship, and how this ability affects their forecast skill. Results from the S2S project (by F. Vitart) suggest that global models have skill in predicting the MJO phase with up to two weeks of lead time (four weeks for the ECMWF model). Meanwhile, our results show that the MJO-TC modulation of storm genesis is reasonably captured, with some models (e.g., ECMWF, BoM, NCEP, MetFr) performing better than others. However, we also find that the models' skill in predicting basin-wide genesis and accumulated convective energy (ACE) are mainly due to the models' ability in simulating the climatological TC seasonality. Removing the seasonality significantly reduces the models' skill. Even the best model (ECMWF) in the most reliable basins (western north Pacific and Atlantic) has very little skill in predicting TC anomalies (close to 0.1 in Brier skill score for genesis and close to 0 in rank probability skill score for ACE). This brings up the questions: do other factors contribute to the intraseasonal TC prediction skill besides seasonality? Is the low skill, after removing the seasonality, due to poor MJO simulations, or to poor representation of some aspect of the MJO-TC relationship? Can the model skill be improved through using derived parameters, such as using a genesis potential index, rather than the direct output from TC detection, or through bias-correction in the post-process? In this presentation, we will quantitatively discuss the dependence of the TC prediction skill on MJO, focusing on Western North Pacific and Atlantic, where the S2S TC predictions are relatively more skillful. We will analyze the models' skill in predicting TC genesis, ACE, and the spatial distribution of daily TC occurrence. We will use both the direct output from TC detection and a genesis potential index for genesis prediction. For track prediction, we will use cluster analysis and consider the models' skill for different track types. We will also discuss the dependence of models' skill on MJO phase, intensity and models' characteristics.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-15)

Skill assessment of Seasonal forecast for temperature and precipitation extremes based on APCC Multimodel Ensemble

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Korea

The reliable information of climate extreme forecast on a seasonal time scale is necessary to cope with severe events. In this study, we examines the observed spatial and temporal variation of extreme temperature and precipitation over the globe for the period 1982~2016 and evaluate the skill of forecasts for climate extremes, defined by upper and lower 15th percentile from climatological distribution, from individual models and MME in a both deterministic and probabilistic sense.

Over the last 35 years (1982-2016), the frequency of occurrence for upper 15th percentile (lower 15 the percentile) extreme seasonal temperatures has increased (decreased). During the recent 11 years, probability of occurrence for upper 15th percentile extreme temperature is also significantly enhanced over the globe. In deterministic sense, the individual models well capture the variation of extreme temperature and the MME shows better skill than individual models when considering overall performance across all seasons. However, in precipitation, it is failed to capture climate extreme even though MME using state of the art models.

And we assess the skill of probabilistic forecast of seasonal extreme temperature and precipitation using APCC individual models by comparing the different probabilistic MME approaches in terms of ROC score recommended by WMO SVS-LRF. The results indicate that a parametric Gaussian fitting method and pooling approach is the most appropriate way to estimate forecast probability and to combine individual models' prediction for global climate extremes. And the current prediction systems are capable to predict extreme temperature but the predictability of extreme precipitation on seasonal scale is still limited. Additionally, sensitivity experiments on different percentiles (10/15/20%) are discussed.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-16)

Seasonal prediction of the Asian summer Monsoon

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BCC_CSM1.1 (m) is a coupled climate system model with a moderate resolution developed at the Beijing Climate Center (BCC), China Meteorological Administration (CMA). The atmospheric component in BCC_CSM1.1m is the BCC_AGCM2.2 at T106 horizontal resolution and 26 vertical layers, and the land model is BCC_AVIM1.0 with a same horizontal resolution as the atmospheric model. The ocean component and sea ice component are MOM4-L40 and SIS, respectively. Both the ocean and sea ice model use a tripolar grid, in which the latitudinal resolution is 1° longitude and the meridional resolution ranges from 1/3° latitude between 10°S and 10°N to 1° latitude at 30°S/30°N polarward. The different components are fully coupled with an inclusion of global carbon cycle.

BCC_CSM1.1 (m) was applied in seasonal climate prediction. The ensemble system includes 24 ensemble members, of which 9 are from an empirical singular vector scheme (SV) and 15 are generated from the lagged average forecasting scheme (LAF). The hindcasts are initiated from the first day of each calendar month from 1991 to 2013 and ended with a 9-month forecast integration. Based on the retrospective forecasts of the operational forecast systems, a comprehensive assessment of the prediction skill on Asian summer climate is discussed, especially on the Asian summer monsoon, ENSO, and some other important atmospheric teleconnection indices. The differences between the ensemble means by LAF members and SV members are compared. The real-time predictions in recent years are also shown.

BCC_CSM1.1(m) presents a high skill for ENSO prediction. The temporal correlation coefficients between observations and 0-, 1- and 2-month lead predictions are 0.92, 0.91, and 0.83 for the Nino3.4 index. However, the predictions show varying skill for different dynamical monsoon indices. For the South and Southeast Asian summer monsoon, reasonable skill is found in the model's forecasting of certain aspects of monsoon climatology and spatiotemporal variability. Nevertheless, deficiencies such as significant forecast errors over the eastern equatorial Indian Ocean are also found. In particular, overestimation of the connections of some dynamical monsoon indices with large-scale circulation and precipitation patterns exists in most ensemble mean forecasts, even for short lead-time forecasts.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-17)

Verification of 2 years of CNR-ISAC subseasonal forecasts

Mastrangelo, Daniele (1), Malguzzi, Piero (2)

CNR-ISAC

The CNR-ISAC subseasonal forecasting system is operationally run on a weekly basis to produce 41-member ensemble forecasts in the framework of the S2S project. In this work, two years of probabilistic forecasts, 106 weeks collected from April 2015, are evaluated against ECMWF ERA-Interim reanalyses to obtain indication on the performance of the forecasting system. The evaluation is based on week averages starting from the first forecast day.

The non-probabilistic scores of 500-hPa geopotential height and 850-hPa temperature anomalies are used to get an overview of the model performance. The anomaly correlation coefficient (ACC) shows enhanced predictive skill during the cold months on both the extratropical hemispheres. In the same period, favorable ACC values are occasionally recorded beyond week 2, especially over some areas. The root mean squared forecast error saturates towards the climatological one between week 2 and 3.

Attribute diagrams are used to evaluate the probabilistic forecast skill of 2-m temperature over land-points in terms of warm/cold (above/below normal) events, a relevant information in operational activities. Despite the expected loss of resolution along the forecast range, for both the events the forecasting system reproduces, up to the 4th week, the average frequency observed in the two examined years. Beyond week 2, residual reliability is detected for the forecast probabilities ranging around the average observed frequency, especially in warm events. The reliability of the forecasting system is also systematically better than the reliability obtained persisting the probabilities from the previous week of the same forecast.

The same evaluation is provided for total accumulated precipitation.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-18)

The S2S Museum – a website of ensemble forecast products –

Mio Matsueda and Akio Yamagami

University of Tsukuba

We introduce a website displaying a variety of ensemble forecast products: the S2S (Subseasonal to Seasonal) Museum (http:// gpvjma.ccs.hpcc.jp/S2S/ or google “S2S Museum”).

The S2S Museum displays various products of 11 global S2S ensemble forecasts and reforecasts, provided by the WWRP/THORPEX/WCRP joint S2S project to improve forecast skill and understanding on the S2S timescale, and promote its uptake by operational centres and exploitation by the applications community. The S2S Museum contains forecasts of the Arctic/Antarctic Oscillation (AO/AAO) indices, the North Atlantic Oscillation (NAO) index, teleconnection pattern indices (e.g. the Pacific/North American (PNA) & the Western Pacific (WP) indices), stream function and velocity potential, wave activity flux, Madden-Julian Oscillation (MJO), rainfall, the Sudden Stratospheric Warming (SSW), sea surface temperature, and sea-ice cover.

The forecast products available at the S2S Museum are regularly updated every day, with a 21-day delay, and are available only for research and education purposes.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-19)

Sub-seasonal Climate Forecast Rodeo

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Bureau of Reclamation, USA (1), NOAA, USA (2)

The Bureau of Reclamation, as the largest water wholesaler and the second largest producer of hydropower in the United States, benefits from skillful forecasts of future water availability. During the past eight years, every state in the Western United States has experienced drought that have affected the economy both locally and throughout the United States through agricultural production, water supply, and energy. Researchers, water managers from local, regional, and federal agencies, and groups such as the Western States Water Council agree that improved precipitation and temperature forecast information at the sub-seasonal to seasonal (S2S) timescale is an area with significant potential benefit to water management, particularly with respect to drought. In response, and recognizing NOAA's leadership in forecasting, Reclamation partnered with NOAA to develop and implement a real-time sub-seasonal forecasting competition. For a year, solvers submitted forecasts of temperature and precipitation for weeks 3&4 and 5&6 every two weeks on a 1x1 degree grid for the 17 western state domain where Reclamation operates. The competition began on April 18, 2017 and winners are anticipated to be announced in early fall 2018. Forecasts were verified as observational data became available using spatial anomaly correlation and scores were posted on a competition leaderboard hosted by the National Integrated Drought Information System (NIDIS). The leaderboard can be accessed at: https://www.drought.gov/drought/sub-seasonal-climate-forecast-rodeo. To be eligible for cash prizes – which total $800,000 – solvers must outperform two benchmark forecasts during the real-time competition as well as in a required 11-year hind-cast.

At the conclusion of the real-time portion of the competition, there are teams outperforming the benchmarks in all four competition categories. With prestige and monetary incentives on the line, it is hoped that the competition will spur innovation of improved S2S forecasts through novel approaches, enhancements to established models, or otherwise. Additionally, the competition aims to raise awareness on the S2S forecast need and the potential benefits- which extend beyond water management – to drought preparedness, public health, and other sectors.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-20)

Assessing multi-model subseasonal prediction of winter blocking in East Asia

Ji-Hyun Oh, Ja-Yeon Moon, Sun-Hee Shin, Young-Mi Min, and Soon-Jo Yoon

APEC Climate Center, Korea

"Three cold days and four warm days" refers to a 7-day cycle with 3 consecutive cold days followed by 4 consecutive warm days. It is commonly accepted as a dominant winter pattern affecting Korea. Recently, however, Korea has experienced extreme cold surges last more than 10 days during boreal winters. Ural-Siberian blocking centered over 30°–100°E was the major contributor to the severe cold surges in East Asia. The blocking reinforced the Siberian High near the surface through the advection of cold polar air leading to cold air outbreaks in East Asia.

Because of its socioeconomic impact in highly populated East Asia regions, predicting the blocking is vital. Nevertheless, prediction of blocking events is among the most challenging problems in weather prediction and climate prediction. Previous studies demonstrated that general circulation models tend to underestimate the blocking frequency. Moreover, time scale ranging from 2 weeks to a season was thought to be a "predictability desert", less effort was devoted to predict the blocking events in subseasonal time scale. To shed light on producing reliable subseasonal forecast, WMO World Weather Research Programme (WWRP) and World Climate Research Program (WCRP) launched a project, subseasonal-to-seasonal (S2S) Project. Capitalizing on the multi-model hindcasts data archive established by S2S Project, this study investigates blocking prediction skill of three models from European Centre for Medium-range Weather Forecasts (ECMWF), Environment and Climate Change Canada (ECCC), and National Centers for Environmental Prediction (NCEP), which produce forecasts every Thursday in common.

The blocking index based on the meridional gradient of the geopotential height at 500 hPa is used to identify Ural-Siberian blocking events. Various aspects of the blocking as well as systematic biases of the models are examined to derive substantial benefit from the subseasonal prediction. In addition, multi-model ensemble (MME) prediction will be compared to individual model performance.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-21)

On the Skewed Nature of Ensemble Forecasts

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It is often not appreciated that an ensemble-mean forecast is generally not the most likely forecast, because the forecast distribution is generally skewed. This skew arises from the state-dependence of the unpredictable system dynamics responsible for the spread of the forecast ensemble. Its existence can be demonstrated in even the simplest system with state-dependent noise, even when the initial forecast distribution and asymptotic (that is, climatological) forecast distribution are both symmetric. In general, the forecast distributions of systems with state-dependent noise must therefore be both skewed and heavy-tailed. This remarkable property not only implies that an ensemble mean forecast is generally biased, but also that the tails of the forecast distribution are strongly asymmetric for positive and negative forecast anomalies. Standard forecast metrics based on second-order moments of the forecast distribution are blind to this important forecast information.

Although forecast distributions may not be Gaussian, the standard deviation has been shown to be a useful indicator of forecast ensemble spread. In the same spirit, we propose the stochastically generated skew (SGS) as a useful metric of both the difference between the ensemble mean forecast and the most likely forecast and the asymmetry of the forecast tails, i.e. of extreme value risks. This is motivated by the facts that 1) the distributions of many geophysical quantities are approximately SGS distributions, 2) Gaussian distributions are a subclass of SGS distributions, and 3) simple analytic expressions exist for the difference between the ensemble-mean and most likely forecast, as well as for the tail asymmetry.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-22)

Downscaling Subseasonal Predictions of Ocean Extremes

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Extreme events in the marine environment can have multiple negative impacts including loss of life, damage to infrastructure and ecosystems, and disruption of transportation. Early information about the likelihood of future extreme events is clearly critical for decision makers in order to issue effective warnings and develop strategies to mitigate potential negative impacts. The atmosphere-ocean system is characterized by modes of variability which vary on time scales of order seconds to centuries and space scales from meters to global. Due to the inherent nonlinearities in the system, these modes interact and modulate each other such that large-scale circulation patterns can enhance or suppress processes on smaller scales and vice versa. Such interactions can create "windows of opportunity" for more accurate subseasonal-to-seasonal (S2S) predictions.

To take advantage of coupling across scales, realistic high-resolution models with a good representation of the important nonlinear interactions are needed. This is particularly important for ocean extremes in coastal environments where tides, with timescales on the order of hours, play an important role. Tides are an important source of high-frequency variability and generator of mean (residual) circulation. Tides can also enhance vertical mixing locally and this has the potential to influence predictability on S2S time scales (e.g., by increasing the thermal inertia of the water column). Clearly tides can be a major contributor to ocean extremes of physical variables such as water temperature, current and sea level. We will present case studies of downscaled S2S predictions of ocean extremes in the Gulf of Maine and Scotian Shelf region using a regional high-resolution ocean model forced by global seasonal hindcasts provided by Environment and Climate Change Canada. These case studies will be selected based on high predictability "windows of opportunity" in the atmosphere identified through statistical analysis of atmospheric reanalysis data and observations. The efficiency of the transmission of atmospheric predictability to the ocean will be discussed.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-23)

Subseasonal prediction of the Indian monsoon: Case study over Bihar

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IRI, Columbia University, USA (1), IMD, Pune, India (2)

Subseasonal forecast precipitation skill over India during the southwest monsoon is quantified in models from the S2S database, with a focus over Bihar in NE India and on the ECMWF and CFSv2 models. Canonical correlation analysis (CCA) based on biweekly averages for gridded hindcast and observed precipitation data is used to calibrate the forecasts, using both deterministic and probabilistic skill measures to assess the model hindcasts under cross-validation. The results demonstrate CCA as a means to calibrate and downscale S2S monsoon forecasts, while the CCA modes provide a useful means to attribute forecast skill to the boreal summer intraseasonal oscillation and ENSO "sources" of S2S predictability.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-24)

Demonstration of method of seasonally varying regression slope coefficients to prediction of Corn Belt Region Rainfall

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University at Albany, Atmospheric and Environmental Sciences

A statistical algorithm for subseasonal, monthly timescale prediction of rainfall in the United States Corn Belt region is presented. A 30-day backward-summed precipitation index is subtracted from a 30-day forward-summed index to trace transition events toward more moist or more dry conditions. A prediction of this index at zero lead-time constitutes an assessment of change from the previous to the subsequent 30 day period. The method of seasonally varying regression slope coefficients is applied to diagnose the seasonally evolving 500 hPa geopotential height anomaly patterns serving as precursors to changes in this index. Forecast index values are made by projecting the recent 30-days of height anomalies onto this seasonally evolving pattern. A cross-validated reforecast time series is generated, which is correlated at 0.47 with the verification series. Results suggest that relationships that vary continuously across seasons limit predictability by most statistical methods, but that accounting for these seasonal variations can yield statistical methods for prediction of subseasonal variability with better skill than numerical models. Results suggest predictability derives from signals of internal atmospheric variability and from waves coupled to convection.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-25)

Study of Sub-Seasonal Predictability using the Unified Forecast System at NCEP

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I.M.Systems Group,USA(1), NCEP, USA (2,3)

NOAA's National Centers for Environmental Prediction (NCEP) is accelerating its efforts to improve its numerical guidance and prediction capability covering the weeks 3 and 4 period. The NCEP Unified Forecast System (UFS) is designed to improve forecast capability in the weather, sub seasonal and seasonal time scales. UFS is a multi-component global coupled system in the NEMS framework and will comprise of the GFDL FV3 dynamic core for the atmospheric component, GFDL Modular Ocean Model 6.0 (MOM6) and Los Alamos CICE v5 sea ice model coupled through the NEMS mediator. This study uses a set of validation procedures that include process oriented metrics to examine the impact on coupling to changes in model parameterization schemes (such as shallow and deep convection, radiation, microphysics, gravity wave drag due to orographic and non-orographic processes, etc.). Evaluation of skill changes due to model parameterization modifications will be made against the skill of existing benchmark model forecasts that are initialized at 0000 UTC from the Climate Forecasting System Reanalysis (CFSR) on the 1st and 15th of the each month covering a 7 year period between April 2011 to March 2018 and integrated for 35 days. Conventional radiosonde observations, along with various novel satellite observations and field experiment data set will be used to validate key model variables and the simulation of important phenomenon like ENSO, MJO in the tropics that are an important source of the sub seasonal predictability

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-26)

Progress towards fully-calibrated daily forecasts of rainfall and temperature from GCMs

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Nowadays it is common to calibrate seasonal forecasts from GCMs using statistical methods to reduce biases and make forecast probabilities reliable. Much progress has been made on the calibration of forecasts of monthly and seasonal totals where climate signals are strong. Indeed, most seasonal climate forecasts or outlooks are communicated and evaluated at monthly or seasonal resolutions. However, for many sectorial modelling applications, daily weather sequences are required. The successful generation of properly calibrated daily time-series is tremendously challenging because it requires getting spatial, temporal and inter-variable correlation structures right, especially if forecasts are to be used in wide-scale decision support systems, e.g. for natural water resources management and agriculture.

Existing, commonly-used methods like quantile-mapping have known weaknesses for applications in seasonal forecast calibration. Therefore, in this study we aim to develop more robust but efficient post-processing methods. Because we are targeting seasonal forecasts, an important question is raised: is it better to post-process the forecasts at daily or monthly time steps? We therefore develop methods using two approaches: (1) monthly-to-daily post-processing whereby forecasts are calibrated at the monthly time step and disaggregated to daily; and (2) daily-to-daily post-processing whereby forecasts are calibrated at the daily time step directly. The calibration techniques combine elements of the Bayesian joint probability (BJP) modelling approach, the Schaake Shuffle and analogue methods.

The two new methods are applied to post-process ECMWF System4 outputs and produce daily forecasts of rainfall and temperature for Australia across sub-seasonal to seasonal timescales. BJP calibration achieves reliable forecasts at both daily and monthly time steps. The Schaake Shuffle and disaggregation methods are able to ensure that the forecasts have the correct inter-variable relationships and temporal correlation structure. Examples are provided that elicit the strengths and weakness of the two post-processing approaches. The new forecasts are being used in follow up studies to force hydrological models for streamflow forecasting and crop models for yield forecasting

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-27)

Harnessing skill from statistical and dynamical models to improve subseasonal forecasts: A Bayesian approach

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Predicting climate at lead times of two to four weeks remains a challenging task. While dynamical models and multi-model ensembles in particular represent the state-of-the-art tools for subseasonal climate prediction, these models do not always optimally identify predictable signals such as those associated with the Madden-Julian Oscillation (MJO), Arctic Oscillation (AO), or El Niño/Southern Oscillation (ENSO). For example, operational subseasonal (Week 3–4) forecasters at the NOAA Climate Prediction Center draw both from calibrated dynamical model forecasts (CFS and ECMWF) and from statistical forecasts based on observed ENSO, MJO, and trend information. Both the dynamical and statistical models yield skillful forecasts for some regions and seasons, but not always for the same regions and seasons. Given this mismatch in dynamical versus statistical model skill, we seek to create a merged statistical-dynamical forecast that exploits the strengths of both types of model. To accomplish this, we employ Bayesian joint probability modeling to produce (1) calibrated dynamical model forecasts, and (2) statistical forecasts that use the observed MJO, ENSO, and AO as predictors of week 3–4 temperature and precipitation. Dynamical model data from the SubX hindcast dataset, covering the period 1999–2015, are used to develop the calibration models. To ensure that we adequately capture interannual variability associated with ENSO, statistical models are developed using longer historical observational datasets covering the 1981–2015 period. Finally, for the common period 1999–2015, we merge the dynamical and statistical forecasts using Bayesian model averaging to yield an optimal forecast. We compare the skill and statistical reliability of cross-validated dynamical, statistical, and merged probabilistic (re)forecasts of temperature and precipitation through continuous ranked probability skill scores, Heidke skill scores, and reliability diagrams. The merged statistical-dynamical forecasts tend to improve the spatial coverage of positive skill relative to individual dynamical or statistical model forecasts.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-28)

Cyclogenesis Prediction in the Extended Range in a Multi-Model Framework : Application of a New Signal Amplification Technique to Improve Track Prediction.

Abhilash. S(1,2), Saranya. S. Ganesh(1), A. K. Sahai(1), S. Joseph(1), A. Dey(1), R. Mandal(1), R. Chattopadhyay(1) and R. Phani(1)

IITM, Pune(1), Cochin Unuversity (2)

An attempt has been made in this study to assess the skill of real-time extended range prediction of genesis location, track and intensity of Tropical Cyclones (TC) over North Indian Ocean (NIO) using an in-house Multi-Model Ensemble (MME) Prediction System (MMEPS) incorporating state of the art climate models. The MMEPS known as Climate Forecast System (CFS) based Grand Ensemble Prediction System (CGEPS) is prepared using different combinations of the National Environmental Prediction Center's (NCEP's) CFSv2 and bias corrected Global Forecast System Version 2 (GFSv2) at two different resolutions. A Genesis Potential Parameter (GPP) has been used to analyze different stages of development of the cyclones and its propagation characteristics. The individual contributing parameters such as vorticity, shear, thermal instability and humidity to the GPP is then evaluated during its life cycle. A modified version of GFDL vortex tracker scheme is used to generate the track positions from model forecasts. The model derived GPP is compared with that computed using the ERA-Interim daily fields and the track forecast skill is calculated against the Indian Meteorological Department (IMD) best track data sets. The MMEPS was able to capture the cyclogenesis over NIO region well in advance at a lead time of more than one week.

Further, implementation of a Bias-Correction and Signal Amplification (BCSA) Technique is applied to the raw model output for improving track predictions Cyclonic Storms (CS) over North Indian Ocean (NIO). Bias-Correction method involves the removal of lead-dependent climatological-bias from MME forecasts by using European Centre for Medium-Range Weather Forecasts Re-analysis (ERA-Interim) daily-averaged datasets as observations. The corrected data is then subjected to Signal Amplification procedure involving a two-point space and time correction of ensembles based on the leading signal (ensemble mean), whereby large uncertainties and disagreements between different model outputs are reduced. Results show that BCSA Technique is, indeed, improving the track forecasts of selected CS cases with significant reduction in track errors even at longer lead times. The pre-genesis track and intensity predictions were promising and the MME system is capable of capturing almost all desirable features of the cyclone forecasting system such as cyclogenesis, pre-genesis track and intensity even at longer lead times of more than one week.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-29)

Towards the Development of the CFS based Grand Multi Model Ensemble prediction System and its Improved Skill Realized through Better Spread-Error Relationship.

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IITM, Pune (1), University of MIami, USA (2), NCEP, USA (3), Cochin University (4)

Ensemble forecasts using a single model, with initial conditions as diverse as is plausible given observation errors, are notoriously under-dispersive. That is, nature (or verification) falls outside the ensemble range more often than it should by chance. As an INDO-US collaboration towards improving Indian monsoon region prediction capabilities, a multi-model ensemble (MME) prediction system has been created. To increase model diversity within a manageable code base, this MME uses a suite of different variants of the US NOAA NCEP Climate Forecast System (NCEP-CFSv2) and its atmosphere component, the Global Forecast System (GFS), with different resolutions, parameters, and coupling configurations (to address coupled SST biases), motivated by the different physical mechanisms thought to influence monsoon forecast errors in the extended range (10-20 day lead times). Based on performance experience, and aiming to maximize the operational skill for our available computer resource, we choose to pool 3 variants based on CFS: 11 members of CFST126 (~100km), 11 members of CFST382 (~38km), and 21 members of GFS forced with bias corrected forecasted SST from CFS. Evaluation of various skill measures suggests that this CFS based MME system known as CGMME is better than any participating single model ensembles (SMEs) in terms of pentad lead deterministic and probabilistic skill scores as well as it's improved skill in predicting the large scale monsoon intraseasonal oscillations (MISOs).

It is found that the CGMME provides multiple benefits: by encompassing the errors in both ICs and forecast model physics, it provides better probability forecasts from the users' perspective (measured by increased reliability). Part of the overconfidence penalty involved in SMEs is overcome in the MME, improving the spread-error relationship, so that the MME approach adds value to both the deterministic and probabilistic forecast. This CFS-based grand multi model ensemble prediction system is shown to be better, both in deterministic measures of the ensemble mean forecast, and in probabilistic skill measures like spread-error relationships (which penalize overconfidence, the forecast face of model under-dispersion). For clarity, users are presented with a single consensus forecast (the CGMME ensemble mean) and associated uncertainties and reliability estimates. These extended-range forecasts address the prime goal of the National Monsoon Mission, initiated by the Government of India in 2012: "To Improve Prediction Skill of Monsoon Weather and Climate", and specifically the monsoon prediction capabilities of the CFS. Based on the results above, further diversification efforts such as physics-parameter sweep ensembles would likely also enhance CGMME's skill (so long as the members do not become inherently inferior), opening a fruitful path for future research computations that will ultimately inform and improve operations.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-30)

Use of Subseasonal-to-Seasonal Predictions for Extreme Temperature Forecasts over Singapore and the Surrounding Region

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Situated in the tropics, Singapore experiences a fairly uniform temperature range all year. However, extended periods of anomalous warm temperatures can cause disruption to agriculture, impose societal distress, and increase energy consumption. These episodes usually happen during drier periods of the year, although other factors such as El Niño aggravated the warm conditions. Subseasonal processes are equally important as the ability to explain the variability of warm conditions on a week-to-week basis will have important implications in public's preparedness against heat exhaustion. A recent example of the March-April 2016 heatwave across the Malay Peninsula demonstrated that while the El Niño of 2016 had played a significant role, the week-to-week variability was also critical. This study presents the 2016 case study and assesses the skill of S2S predictions for temperature around Singapore in general, with a focus on extremes. The skill is relatively high for the region: the mean squared skill score for ECMWF compared to ERA Interim weekly average temperature is between 0.3 and 0.7 for a lead time of 4 weeks, compared to persistence (MSSS between -1 and 0.5). Although, differences of up to 2°C between ERA-Interim data used for verification and weather station data highlights the limitation in using reanalysis datasets for extremes. Even so, the 2016 heat wave case study shows the ability of the models to forecast the week-to-week variations in temperature, including the peak and cessation of the warmest temperatures, and therefore demonstrates the potential benefit of S2S predictions for Singapore and the surrounding region.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-31)

Wintertime weather regimes over North America and their predictability from submonthly reforecasts

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Large-scale weather regimes refer to geographically fixed modes of low-frequency variability persisting beyond the lifetime of individual weather disturbances (i.e., beyond about a week). While these large-scale circulation or weather regimes are often used as a reference to express forecasts over the Euro-North Atlantic sector, the low-dimensional weather regime view has been less commonly used over North America. Consistent with earlier studies based on upper-tropospheric circulation patterns, a 4-regime wintertime classification is identified for the Pacific-North America sector by means of a k-means cluster analysis of daily 500hPa geopotential height reanalyses fields. The regimes resemble Rossby wavetrain patterns, except one regime related to a NAO-like meridional pressure gradient, and are all associated with distinct rainfall anomalies over the United States. This study examines the extent to which the observed 4-cluster partition is reproduced by submonthly reforecasts from the subseasonal-to-seasonal (S2S) database in terms of spatial structures, daily regime occurrences and seasonal regime counts. The skill in forecasting observed daily regime sequences and weekly regime counts is investigated from week-1 to -4 leads, alongside skill relationships with ENSO and the MJO to provide further insights into potential opportunities for skillful winter rainfall predictions based on large-scale weather regimes.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-32)

Extended-range forecasting at ECMWF

Frederic Vitart

ECMWF

ECMWF has produced ensemble-based sub-seasonal forecasts since 2004. This presentation will discuss its skill in predicting several sources of predictability, such as the MJO, sudden stratospheric warmings (SSWs) as well as a general assessment of tropical and extratropical skill scores and their evolution since 2004. Possible improvements will be discussed: increased atmospheric resolution, SST bias correction, interactive aerosols and ozone, benefit of a lag ensemble generation.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-33)

Seasonal Noise Versus Subseasonal Signal: Forecasts of California Precipitation During the Unusual Winters of 2015–2016 and 2016–2017

Shuguang Wang, Alek Anichowski, Michael K. Tippett, Adam H. Sobel

Columbia University

Subseasonal forecasts of California precipitation during the unusual winters of 2015–2016 and 2016–2017 are examined in this study. It is shown that two different ensemble forecast systems were able to predict monthly precipitation anomalies in California during these periods with some skill in forecasts initialized near or at the start of the month. The unexpected anomalies in February 2016, as well as in January and February 2017, were associated with shifts in the position of the jet stream over the northeast Pacific in a manner broadly consistent with associations found in larger ensembles of forecasts. These results support the broader notion that what is unpredictable atmospheric noise at the seasonal time scale can become predictable signal at the subseasonal time scale, despite that the lead times and verification averaging times associated with these forecasts are outside the predictability horizons of canonical midrange weather forecasting.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-34)

Prediction of MJO convection in the S2S hindcast dataset

Shuguang Wang (1), Adam H. Sobel (1), Michael K. Tippett (1), Frederic Vitart (2)

Columbia University, USA (1); ECMWF, UK (2)

Prediction of tropical intraseasonal convection in the WMO Subseasonal to Seasonal (S2S) forecast database is evaluated using the OLR-based MJO (OMI) index. Using a lag correlation test, it is first shown that the OMI index can represent both northward and eastward propagation in summer, and eastward propagation in winter. Hence, OMI is suitable to use OMI to track the MJO in all seasons. The OMI prediction skills measured by anomaly correlation coefficient exceeding 0.5 range from 20 to more than 35 days in winter in the S2S models, but systematically lower in summer by 5 to 10 days. This suggests that intraseasonal convection is inherent less predictive in summer than in winter, and this is not due to difference in the amplitude. Many S2S models significant underestimate OMI amplitudes at longer forecast leads. A majority of S2S models have relatively lower skill at or downstream of the Maritime Continent. Probabilistic evaluation of the S2S model skills in forecasting OMI amplitude indicates that ranked probability skill scores are significantly degraded in many models.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-35)

Evaluating Northwestern Pacific Tropical Storm Density Forecast in the S2S Prediction Project Hindcast Database

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Tropical storm activity is modulated by intraseasonal variability in the northwestern Pacific region. This modulation could provide predictability of tropical storms on subseasonal to seasonal (S2S) timescales. To assess the potential for tropical storm forecasting on S2S timescales, the forecast skill of tropical storm density is evaluated using S2S Prediction Project Database. The evaluation period is from May 1 to Oct. 31, 1999 to 2010. Tropical storm density is computed from the ensemble forecasts from six operational centers: BoM. CMA, ECMWF, JMA, METFR and NCEP. In both observation and these six forecast systems, the tropical storm density is modulated by Boreal Summer Intraseaosonal Oscillation (BSISO), which can be depicted by the BSISO indices, BSISO1 and BSISO2. During BSISO1 phases 1, 5, 6, 7, and 8, the northwestern Pacific region is dominated by an anomalous cyclonic circulation and positive precipitation anomaly, and tropical storm density tends to be enhanced. Similarly, during phases 1, 2, 3, 4, and 8 of BSISO2, the tropical storm density also tends to be enhanced. Six models can reproduce the modulation of tropical storm density by BSISO with some skill. The de-biased Brier Skill Score is also used to compare the tropical storm density forecast skill of these models. The ECWMF forecast system shows positive Brier Skill Score when forecast lead time is from 11 to 30 days, indicating better tropical storm forecast than reference forecast based on climatology

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-36)

Subseasonal prediction of heat waves

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The past decades have seen an increasing number of extreme heat events. In Europe the heat waves of 2003, 2006, 2010 and 2015 had severe impacts on agriculture and caused elevated mortality rates. Forecasting these events beyond the weather forecasting range is thus of major importance to a multitude of stakeholders. In our study, we assess the relative importance of a range of predictors of heat waves in Europe that provide predictability for all seasons, for instance soil moisture, surface heat fluxes, geopotential height and SST at a range of subseasonal lead times. The resulting patterns are evaluated in terms of their possible physical connection to the occurrence of heat waves. A case study for the 2003 heat wave shows that although the subseasonal forecasting systems fail at predicting the atmospheric circulation anomalies during the heat wave more than 2 weeks ahead, the forecast of the weekly averaged surface temperature anomalies has skill at lead times up to 3 weeks for some forecasting systems. In addition to the influence of the dry soils in spring that is suggested to cause extended predictability, we see that those ensemble members that reproduce the large scale circulation anomalies better also have higher temperature skill.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-37)

Sub-seasonal prediction of extreme temperature over East China: a mid-to-late July prediction barrier

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Dynamical sub-seasonal forecast skill of hot days over East China is evaluated by using the ECMWF Sub-seasonal to Seasonal (S2S) reforecast dataset. Yangtze River Basin (YRB) region exhibits the highest forecast skill. A mid-to-late July barrier of sub-seasonal forecast skill is identified over the YRB, which is well demonstrated in the multi-year and case studies. The mid-to-July barrier has been found to be associated with the reduction of 500hPa geopotential height (GHT500) forecast skill, because this period is a climatological sub-seasonal transitional phase when WNPSH experiences an abrupt northward migration. The uncertainty in the forecasted WNPSH sub-seasonal march in the mid-to-late July is responsible for the occurrence of the sub-seasonal forecast barrier. This warrants further study of other meteorological fields to verify the mid-to-late summer barrier in sub-seasonal forecast over East Asia. The results also suggest that improvement of the climatological intraseasonal oscillation (CISO) forecast may hold key to overcome the prediction barrier.

SESSION: (A3) S2S ensemble predictions and forecast information

(P-A3-38)

Sub-seasonal forecast of precipitation over Eastern China in summer monsoon season: Results from BCC_CSM hindcast experiments

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This study presents a comprehensive evaluation of sub-seasonal precipitation prediction using BCC_CSM over Eastern China in summer monsoon season. Multiple metrics are used to assess the hindcast predication results from 1994 to 2014. It is found that the BCC_CSM has reasonable performance in predicting the precipitation spatial patterns at sub-seasonal time scales over Eastern China in summer monsoon season, especially moderate intensity precipitation. However, there are significant interannual differences in the model predicted results. The possible reasons for these differences are examined in detail. We selected better and worse predicted cases by using multiple metrics. For the better predicted results, there exist strong intraseasonal signals during the seasonal evolution periods of the East Asian monsoon precipitation, and the model can capture the subseasonal signals in amplitude and phase. Subseasonal and low frequency signals are important for extending the predictive skill of monsoon precipitation. For the worse predicted cases, the intraseasonal signals in the East Asian monsoon region are weak.

SESSION: (A4) S2S forecasts for decision making

(P-A4-01)

The Skill of Statistically Forecasting the Early Monsoon Onset in the Southwestern United States at a Subseasonal to Seasonal Time Scale

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University of Arizona (1)

Forecasts at the subseasonal to seasonal timescales have been recognized by the scientific community as having significant socioeconomic value. However, although these forecasts are skillful at forecasting warm season atmospheric teleconnection patterns, they are less skillful at forecasting warm season precipitation, which puts in question their practicality. In this study, the observed 500-hPa atmospheric circulation anomalies in the Northern Hemisphere are related to the dominant patterns of the observed two-month standard precipitation index (SPI) in the continental United States during the early warm season (June and July) from 1979-2011. An empirical orthogonal function analysis and canonical correlation analysis are then applied to determine the dominant coupled modes between the observed teleconnection patterns and SPI with a focus on the southwestern United States. Next, the same procedure is performed on five ensemble members of the CFSv2 reforecast data at a week four to five forecast period from 1999-2010 to determine the dominant coupled modes between the modeled geopotential height anomalies and SPI. These modeled coupled modes are then correlated with the observed coupled modes to determine the statistically significant pattern correlations and whether the CFSv2 reforecast data has any skill in forecasting the early monsoon onset four to five weeks out.

SESSION: (A4) S2S forecasts for decision making

(P-A4-02)

Analysing the uncertainty of reanalyses to assess the predictability at S2S time-scales of key climate and energy variables for the energy sector.

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ENEA,Italy (1)

Variability of meteorological variables at sub-seasonal to seasonal timescales (from 3-4 weeks 3-4 months) can have enormous impacts on the renewable energy sector by modifying energy outputs and needs. A decision support tool based on S2S climate predictions co-designed and co-developed with relevant users (energy companies) can make energy sector more resilient to climate variability and high-impact events. This is the main goal of the S2S4E project funded by the European Horizon 2020 programme and to achieve this goal is necessary to explore the scientific frontiers of S2S predictions. The advancement of the understanding of observational climate data sets, such as meteorological reanalysis, can largely contribute to the development of decision support tool by maximizing the utility of S2S forecasts for the key climate and energy metrics of value to the energy sector.

With the aim to provide an assessment of uncertainty of observational products, a comparison among the observational datasets has been carried out. Several different global reanalyses (ERA-Interim, ERA-5, MERRA-2, JRA-55, NCEP-R2) are analyzed and compared with satellite and in situ observations. Essential climate variables needed for the generation and analysis of energy indicators (such as temperature, solar irradiation, wind speed, precipitation) are assessed. To this end, a set of diagnostics (called “namelist”) for climatologies, trends and inter- and intra-annual variability and co-variability of essential climate variables are developed and implemented into the Earth System Model evaluation Tool (ESMValTool). The ESMVAlTool (Eyring et al., 2016) is a community tool that has so far been mainly used for the evaluation of Earth System Models with observations. However, ESMValTool can more generally be used to compare any pair of datasets against one another, ensuring reproducibility and transparency. Performance metrics are introduced in order to evaluate the quality of datasets according to their ability to reproduce simultaneous, compounds phenomena that can impact the energy sector.

SESSION: (A4) S2S forecasts for decision making

(P-A4-03)

Balancing Europe's wind power output through spatial deployment informed by weather regimes

Grams, Christian M. (1,2), Beerli, Remo (1,3), Pfenninger, Stefan (4), Staffell, Iain (5), and Wernli, Heini (1)

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As wind and solar power provide a growing share of Europe's electricity, understanding and accommodating their variability on multiple timescales remains a critical problem. On weekly timescales, variability is related to long-lasting weather conditions, called weather regimes, which can cause lulls with a loss of wind power across neighbouring countries. Here we show that weather regimes provide a meteorological explanation for multi-day fluctuations in Europe's wind power and can help guide new deployment pathways which minimise this variability. Mean generation during different regimes currently ranges from 22 GW to 44 GW and is expected to triple by 2030 with current planning strategies. However, balancing future wind capacity across regions with contrasting inter-regime behaviour – specifically deploying in the Balkans instead of the North Sea – would almost eliminate these output variations, maintain mean generation, and increase fleet-wide minimum output. Solar photovoltaics could balance low-wind regimes locally, but only by expanding current capacity tenfold. New deployment strategies based on an understanding of continent-scale wind patterns and pan-European collaboration could enable a high share of wind energy whilst minimising the negative impacts of output variability.

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SESSION: (A4) S2S forecasts for decision making

(P-A4-04)

Differences in timescales of rainfall predictability for six countries, within agricultural context

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Every region and country is unique with respect to its overall vulnerability to climate variability, and agrarian societies are often particularly impacted. Recent research has shown that differences in predictive skill from place to place depend not only on the ability of models, such as those from the North American Multimodel Ensemble (NMME), to demonstrate skill, but also on the Subseasonal to Seasonal (S2S) timescales which have the most predictive capacity. Tools such as dynamic cropping calendars, which can provide valuable information for farmers and other decision-makers, take into account the S2S information that is most relevant for each particular country considering the associated seasonality of its agricultural profile. Here we examine rainfall in six countries that currently represent the ACToday project, a Columbia World Project. We use best available observed daily data for each country and output from a suite of NMME models, in conjunction with the Climate Predictability Tool to evaluate the timescales which demonstrate the most skill. We examine subseasonal statistics at seasonal timescales, such as monsoon onset date and number of dry spells and extreme wet days, as well as total seasonal rainfall. We analyze these results within the seasonal agricultural context for each case in order to optimize the effectiveness of the information that can be provided.

SESSION: (A4) S2S forecasts for decision making

(P-A4-05)

Assessing User Needs and Model Accuracy of Seasonal Climate Forecasts for Winter Wheat Producers in the South-Central United States

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Successful agriculture is essential to global food security, but productivity can be severely impacted by drought, flood, or heat. Seasonal climate forecasts can provide critical decision-support for farmers to adapt to and mitigate these threats. However, past research has shown shortcoming of these forecasts in providing decision support. For example, agricultural producers and farm businesses frequently criticize for lacking relevant information for specific farm decisions and for generally lacking accuracy as well as the spatial and temporal resolution needed for concrete decision making. We present findings from a multi-disciplinary, user-driven research project that address these criticisms. In collaboration with the agricultural community, we assessed seasonal forecast needs of winter wheat producers in the south-central U.S. and tested the capability of a high-resolution seasonal climate forecast model with regard to its capability to provide decision-relevant information with sufficient accuracy.

At the conference, we present results from two studies that (1) improve our understanding of the forecast needs of winter wheat producers in the Southern Great Plains (Texas, Oklahoma, Kansas, Colorado), and (2) quantify the error of a high-resolution seasonal forecast model for the most important forecast elements for winter wheat producers in our study region. Winter wheat is one of the largest crops in the U.S. and globally. Through an online survey of 109 agricultural advisors in Colorado, Kansas, Oklahoma, and Texas we learned that forecast lead-time only needs to be up to 2.5 months, and we found that forecast needs include both averages and extremes, such as average precipitation and the number of dry days per month. The relevance of weather and climate threats, such as extreme rainfall, drought, or heat, depended on the time of year and the growth stage of the crop. For example, drought was a particular threat during planting, whereas extreme rainfall was a greater threat during harvest. Subsequent to analyzing the survey, we conducted an error comparison between high-resolution (50 x 50 km) retrospective seasonal forecasts and a persistence forecast, which we considered an alternative decision support tool for farmers. Although both model and persistence forecasts were lacking accuracy in our study region, the model forecasted extremes more accurately than persistence in summer, whereas model forecasts for averages were generally more accurate in winter.

Our research illustrates, broadly speaking, the value and benefits of co-produced, user-driven research in the field of agriculture and mitigation of climate variability. More specifically, the results of our study give an understanding of real-world farm decision making, show how current seasonal forecast data can be translated into more meaningful forecast products, highlight shortcomings in current seasonal forecast models in the south-central U.S., and give recommendations for future improvements in seasonal climate model development.

SESSION: (A4) S2S forecasts for decision making

(P-A4-06)

Evaluation of ECMWF S2S models in Predicting Rainfall Onset over West Africa

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The study examines the performance of CMA S2S models in predicting rainfall onset dates (RODs) in West Africa. The ability of 60 day precipitation reforecast dataset to replicate the characteristics of RODs was evaluated using two observed datasets. The reforecasts datasets were analyzed from 10 to 60 days, and the results were compared separately to examine which of the forecast days capture the observed. Two definitions were used to compute RODs over the study area and their results are analysed and compared. The evaluation considers how well the S2S model reproduce the observed mean and inter-annual variability of RODs over the sub-continent. It also investigates how well the model links RODs with the northward movement of the monsoon system over the sub-region. The observation shows that the mean RODs follow a latitudinal progression, and the dates increases northward from the south. The performance of the S2S model in reproducing RODs largely depends on the definition used. The capability of the model to replicate the observed RODs over the three zones in West Africa drops as the number of forecast days increased. For instance, the 10 and 20 days forecasts perform better than 60 days forecasts. The study shows that the ability of the S2S model to simulate RODs over the sub-region is strongly linked to how well the model capture the northward movement of the monsoon system and the associated sea surface temperature. The study also show some differences between RODs in the observed datasets and the model data, which depend on the ROD definitions. The results of this study have application in managerial decision making over West Africa.

SESSION: (A4) S2S forecasts for decision making

(P-A4-07)

Experimenting a sub-seasonal prediction bulletin as part of the CREWS-Burkina Faso project

Lefort Thierry, Lafore Jean-Philippe, Peyrillé Philippe

METEO-FRANCE

CREWS (Climate Related Early Warning System) is supporting the improvement of operational capabilities in Burkina Faso to produce and deliver hydro-meteorological services for early warning, contributing to risk reduction for relevant national sectors with an emphasis on flood-related risks and improved early warning and risk information for agriculture and food security. https://www.crews-initiative.org/en/projects/burkina-faso-strengthening-national-capacities-early-warning-system-service-delivery

Météo-France is accompanying the National Meteorological Service of Burkina Faso in the elaboration of a sub-seasonal forecasting methodology in order to address needs such as the prediction of the start of the rainy season, or dry spells during the monsoon.

In 2018, a heuristic strategy has been adopted by using indicators based on well known modes of variability in western Africa, as well as relevant parameters for which numerical models have a better skill than precipitation (column water vapor, velocity potential). Examples will be given of decisions and benefits that arose from these experimental bulletins. Within the CREWS-Burkina project, operational bulletins will be issued in 2019, taking advantage of feedbacks from Burkina Faso's Weather Service and experience from ongoing monitoring of the African monsoon (MISVA: http://misva.sedoo.fr)

SESSION: (A4) S2S forecasts for decision making

(P-A4-08)

A multi-model approach for cold spell sub-seasonal prediction in Northern Turkey

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Producing sub-seasonal forecasts with two-to-six months target, aimed at assessing the probability of occurrence of extreme events, is crucial for many economic sectors, in particular agriculture and agribusiness. This time-scale is in fact critical to put into action mitigation strategies that could save farms from predicted weather hazards. In this study we present a multi-model ensemble that includes four of the climate prediction systems involved in the Subseasonal-to-Seasonal (S2S) Prediction project, in an effort to improve the quality of forecasts in the beginning of spring, identified as the most sensitive time of the year by agribusiness end-users. In fact, early spring frosts are particularly damaging for the ovary development of many fruit trees, resulting in dramatic losses at the harvest time.

Sub-seasonal forecasts aimed at predicting climate anomalies and extreme, as well as the hazard associated with the occurrence of intense events, start in March and run for the following six weeks. The multi-model provides a probabilistic forecast, which expresses the likelihood of occurrence of cold spells together with an hazard coefficient, that companies may use for risk analysis. Here we analyze the case of the Turkish region facing the Black Sea, which is global leader in the production of many varieties of fruit and nuts.

SESSION: (A4) S2S forecasts for decision making

(P-A4-09)

S2S precipitation forecast for Ethiopia's Water Management

Rezaul Haider, Malaquias Peña, Xinyi Shen, Rehenuma Lazin, Emmanouil Anagnostou and Zoi Dokou

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S2S forecast datasets are being used to support an NSF's PIRE project for Ethiopia. The region is characterized by high inter-annual precipitation variability that results in droughts and floods, stressing its local communities. Better predictions of water availability can supply farmers and water management authorities with critical guidance, enabling informed water resource allocation and management decisions that will in turn ensure food and water security in the region. Prediction of water availability is tied to the ability to predict precipitation amounts one month to several seasons in advance. The objective of this study is to quantify the skill of available S2S dynamical prediction systems for the region of interest and whether post-processing (bias correction and downscaling) techniques can enhance the usefulness of the products for model hydrologists collaborating in the project. We have organized gridded forecast outputs from NCEP S2S, and time series of global analysis data to diagnose the main climate controls that determine monthly precipitation anomalies over Ethiopia, particularly the area surrounding lake Tana. Pattern correlations have been determined in both the analysis and the historical forecast datasets. This talk will present the results found and how the data is being used for water management.

SESSION: (A4) S2S forecasts for decision making

(P-A4-10)

Harnessing dynamical seasonal climate forecasts for agricultural applications in Australia

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In Australia, seasonal forecasts for agriculture remain predominantly bound to statistical seasonal climate forecasts. This is despite GCM forecasts forming the basis for the official climate outlooks produced by the Bureau of Meteorology for several years now. Furthermore, on-farm decision support tools typically do not integrate any climate forecast information at all. The disconnection is partly due to a lack of post-processing methods sophisticated enough to produce all of the meteorological inputs required for crop models, for example: rainfall, temperature, solar radiation and potential evapotranspiration.

We have previously developed methods to calibrate GCM forecasts and produce daily meteorological inputs for crop models for lead times of up to 12 months ahead. The forecasts are skilful when the GCMs allow and transition to climatological scenarios when no further skill is extractable. The daily sequences have realistic temporal and inter-variable correlations; essential features for producing realistic crop growth simulations.

In this study, we apply GCM calibrated forecasts to produce sugarcane yield forecasts for the Tully region in north-eastern Australia. Sugarcane farming is the second largest agricultural industry in the region with production worth about $244 million annually. We show that the GCM-based forecasts are able to produce significantly skilful forecasts of sugarcane yield by running the ensemble forecasts through the APSIM sugarcane crop model.

In parallel to the sugarcane study, we apply calibrated GCM forecasts to predict wheat and sorghum yields across Australia. In this case, the calibrated meteorological forecasts are input into an agro-climatic wheat/sorghum stress index model. Successful integration of the GCM forecasts will enable the operational wheat and sorghum outlooks for Australia to be transitioned away from the legacy statistical system.

In addition to agricultural applications, the new GCM post-processing methods are being tested by the Bureau of Meteorology to downscale GCM rainfall forecasts to hydrological catchments for use in seasonal streamflow forecasting.

SESSION: (A4) S2S forecasts for decision making

(P-A4-11)

On the predictability of precipitation over North India in S2S framework

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CACP, UK (1), NCMRWF, INDIA (2)

India gets more than 80% of its wheat production from North India (NI) region. Precipitation during winter season (December-February; DJF) is very important for Rabi crops, particularly for wheat. Sub-seasonal to Seasonal (S2S) prediction has long been considered a predictability desert and forecasting across this scale has received very less attention than medium and seasonal scale. Therefore, after a problem on this scale and its associated implications in various sectors (for e.g. agriculture and food security, water and health), the question arises whether strategies of S2S prediction that have proved useful elsewhere can they be adapted to the North Indian plains and complex terrain of Himalayas as well? The aim of the present study is in three-folds. Firstly, it attempts to assess the sub seasonal to seasonal predictive skill of six general circulation models (GCMs) for a period of 31 years (1982-2012) and identify forecast windows of opportunity. Secondly, an attempt has been made to reproduce the information of the GCMs at higher resolution using both dynamical and statistical downscaling approaches along with bias correction. Thirdly, an attempt has been also made to use the S2S prediction for water cycle studies as lives of millions of people in North Indian plains depends on water availability from rivers of western Himalayan origin. Finally, the plausible reasons of model failure, potential sources of predictability across this scale and how S2S framework has played a key role in addressing such issues is highlighted.

SESSION: (A4) S2S forecasts for decision making

(P-A4-12)

Optimizing N:P:K ratios in agricultural fertilizers based on seasonal predictions

Tuinenburg, Obbe (1), Supit, Iwan (2), Hutjes, Ronald (3)

Utrecht University (1), Wageningen University (2)

The use of seasonal atmospheric predictions for agricultural purposes usually focuses on determining planting and harvesting dates. For West-Africa, previous work demonstrated the utility of seasonal atmospheric predictions in narrowing t he window of planting and harvesting Sorghum and Maize in Burkina Faso.

Apart from the decisions of the moments of planting and harvesting, crop management can benefit from seasonal predictions. An important part of this management is the application of fertilizers. Decisions have to be made about the moment and amount of fertilizers to be applied.

Crop development depends on the availability of nutrients (NPK), and sensitivity to adverse meteorological conditions varies during different phenological stages. As an example, fertilizer that is applied half way between anthesis and flowering will not be absorbed, and fertilizer applications early in the season will lead to strong crop development, however, this may result in more severe water stress effects later in the season.

Because of this link between fertilizer application and crop development and crop sensitivity to adverse conditions, we determine the potential use of sub-seasonal to seasonal (S2S) predictions in optimizing the of fertilizer applications. We will do this for Maize and Sorghum in West-Africa.

In our approach, we use the WOFOST crop model, that is modified to model the fertilizer application and uptake. This crop model is forced with sub-seasonal to seasonal atmospheric predictions of precipitation, radiation, temperature, humidity and wind from the S2S-prediction project (S2Sprediction.net).

Initial results show that the optimization of N:P:K ratios based on subseasonal predictions can substantially increase crop yields. The relative merit of optimizating planting dates, harvesting dates and fertilizing strategies will be presented for Maize and Sorghum in West-Africa.

SESSION: (A4) S2S forecasts for decision making

(P-A4-13)

S2S-SEA Workshop Series – lessons learnt and moving forward

Turkington, Thea and Rahmat, Raizan

Centre for Climate Research Singapore

In 2016, a survey of all National Meteorological and Hydrological Services in the Association of Southeast Asian Nations (ASEAN) region highlighted that the development of a regional capability in the use of sub-seasonal to seasonal (S2S) forecasts was a high priority for the region. Due to the relatively high skill over Southeast Asia, particularly for the Maritime Continent, the region has the potential to benefit substantially from subseasonal forecasts. The S2S-Southeast Asia (S2S-SEA) capability building project was therefore set up to familiarise ASEAN National Meteorological and Hydrological Services (NMHSs) with S2S products, improve their understanding on the mechanisms of S2S predictability, and equip the participants with the knowledge to investigate the skill and usefulness of the subseasonal forecast in various applications. A series of four week long workshops were planned over four years 2017-2020. The first S2S-SEA workshop was held in early 2017, covering of introduction to S2S prediction and the S2S database, using python and the IRI data library. In the second workshop planned for August 2018, the proposed topic is probabilistic thresholds for rainfall, allowing for the ASEAN region to discuss important rainfall thresholds for the region (such as dry periods, or multiple days of heavy rain), as well as assess the model skill for the region.

The first two workshops (Phase 1) were aimed at developing the capability of ASEAN NMHSs to understand the S2S modelling system as well as to evaluate models for their performance on various parameters of temperature and rainfall. Various lessons learnt from Phase 1 will be shared. For the next 2 workshops (Phase 2), the activities will focus on developing products that are useable and useful for end users. From the very first workshop, many of the NMHSs representatives expressed a strong desire for developing products for end users in the agriculture, disaster risk reduction, water resources, and other sectors. Looking forward, it is hoped that the results from the previous workshops will provide the foundation for two future workshops and contribute to the development of regional NMHS' climate services to end-users.

SESSION: (A5) Land initialization and processes

(P-A5-01)

Reduction of model precipitation bias and impact on summer prediction skill

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Soil moisture is a well-known source of summer potential predictability, in particular over regions of intense land-atmosphere coupling. However, improving soil moisture initialization in dynamical forecast systems leads to increased temperature and precipitation prediction skill over fewer regions than one could expect. This limitation could originate from model precipitation biases, prone to rapidly spoil the soil moisture anomalies present in the land surface initial conditions.

In order to make the most out of soil moisture as a source of prediction skill, we implemented a method to reduce the precipitation bias throughout the model integration. Both the frequency and intensity of precipitation intercepted by the land surface are corrected at each time step. The impact of such a method in terms of model mean climate and boreal summer forecast skill is assessed for several key atmospheric variables.

SESSION: (A5) Land initialization and processes

(P-A5-02)

Subseasonal-to-Seasonal Forecasts with the Norwegian Climate Prediction Model

Fei, Li (1), Yvan, Orsolini (1), Francois, Counillon (2), Yongqi, Gao (2), Noel, Keenlyside (3), Mao-Lin, Shen (3)

NILU, Norway (1), NERSC, Norway (2), UiB, Norway (3)

There is now a renewed concerted international effort to tackle the time scales that fall between weather and climate, i.e. between 10 days and one season, the so-called subseasonal-to-seasonal (S2S) time scale. We present first results of S2S forecasts with the Norwegian Climate Prediction model (NorCPM), with a focus on mid and high northern latitudes. As an initialized prediction system for seasonal-to-decacal prediction, NorCPM developed from the Norwegian Earth System Model (NorESM), a state-of-the-art climate model, and advanced data assimilation techniques based on the Ensemble Kalman Filter approach. The initialisation of land is carried out by using the Community Land Model (CLM), in which the initial and boundary data is taken from the NCEP (National Centers for Environmental Prediction) reanalysis. The initialisation of ocean is carried out by an ocean analysis using the Miami Isopycnic Coordinate Ocean Model (MICOM), in which sea surface temperature anomaly and temperature and salinity profiles are monthly assimilated into the ocean component. The atmospheric component of the model is the Whole Atmosphere Community Climate Model (WACCM), a “high-top” chemistry–climate model that extends from the Earth's surface to the lower thermosphere, and is run with interactive stratospheric chemistry. The initialisation of atmosphere is via nudging WACCM for a 2-week period. One of the focus is the role of land initialisation, and snow cover and depth in particular. Pairs of 3-month ensemble forecasts were started on every 1st November in the years 1980–2010, with either realistic initialization of snow variables based on CLM/NCEP, or else with “scrambled” snow initial conditions from an alternate year. We analyze skill increment resulting from more realistic snow initialisation.

SESSION: (A5) Land initialization and processes

(P-A5-03)

The ECMWF land surface scheme and its initialisation in S2S reforecast applications

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ECMWF

Over the last ten years, several changes have been implemented within the ECMWF land-surface model comparing to the one used in the ECMWF Interim Reanalysis (ERA-Interim), covering 1979-2018 period and widely used in climate studies. The surface scheme labeled CHTESSEL (Carbon and Hydrology Tiled ECMWF scheme for surface exchanges over Land) is currently used operationally for medium-range forecasting and in the seasonal outlook up to one year ahead. This is also included in the new ERA5 reanalyses, for which a first 7-year dataset has been released covering the 2010-2017 period. In addition, a stand-alone version of CHTESSEL forced with the meteorology provided by atmospheric reanalysis is generating the land surface initial conditions for the ECMWF S2S reforecast system as operational in 2018. An overview of CHTESSEL components and the impact to land initialization on S2S forecasting performance will be presented.

SESSION: (A6) Ocean initialization and processes

(P-A6-01)

The impact of reduced sea ice in the Barents/Kara seas on midlatitude wintertime atmospheric circulation and predictability in a seasonal prediction system.

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2) Ca' Foscari University of Venice, Venice, Italy.
(3) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Bologna, Italy.

While in the last decades the sea ice cover in the Arctic ocean has experienced an ongoing loss in volume and extent with significant consequences for the northern hemisphere atmospheric circulation, climate model projections indicate that this loss will be exacerbated in the future. Sea ice is an important component of the global climate system as its presence strongly affects the air–sea interaction and, thus, both the atmosphere and ocean. The Barents/Kara (B/K) seas is the part of the Arctic ocean experiencing the largest interannual variability and the largest loss in sea ice concentration since the start of the observational period. In response to negative anomalies in sea ice in the B/K seas, observational and model results point to increased local surface heat fluxes from the ocean to the atmosphere, increased surface temperatures and a reduced meridional surface temperature gradient, with far-reaching effects in the Euro-Atlantic domain, including changes in the NAO and the eddy-driven jet stream a few months later. This implies a dual character of the response, from immediate local changes in surface fluxes (e.g. affecting atmospheric stability) to a delayed remote response in the atmospheric circulation. On a seasonal time scale, the Arctic sea ice concentration anomalies in autumn may strongly influence the winter Euro-Atlantic climate and its predictability. In this study such influences are robustly investigated using a fully-coupled seasonal prediction system (CMCC Seasonal Prediction System version 3) by implementing an extensive negative sea ice concentration anomaly in the B/K seas lasting the whole month of November and making use of an ensemble of multi-year reforecasts. Preliminary results reveal significant differences in the midlatitude atmospheric circulation

SESSION: (A6) Ocean initialization and processes

(P-A6-02)

The Copernicus Marine Service Global Reanalysis Ensemble Product GREPV1: Validation of the ocean variability over the 1993-2016 period

Dubois, Clotilde (1,2), Drévillon, Marie (1), von Schuckmann, Karina (1), Garric, Gilles (1), Masina, Simona (3), Storto, Andrea (3), Jackson, Laura (4), Peterson, Andrew (4), Zuo, Hao (5), Balsaseda, Magdalena (5)

Mercator Ocean, France (1), Meteo France (2), CMCC, Italy (3), Met Office Hadley Centre, UK (4), ECMWF, UK (5)

The Copernicus Marine Environment Monitoring Service CMEMS – http://marine.copernicus.eu- now delivers a multi-reanalyses ensemble products based on GLORYS2V4 from Mercator Ocean (France), ORAS5 from ECMWF (UK), FOAM/GloSea5 from Met Office (UK), and C-GLORS from CMCC (Italy). They are based on the high resolution - 1/4° horizontal grid - ocean reanalyses based on the NEMO ocean model and constrained by altimetry, SST observations and in situ T and S profiles, were produced with different tunings, and were evaluated jointly using common validation guidelines (Masina et al, 2015, DOI: 10.1007/s00382-015-2728-5). They cover the period 1993-2016.

Most of them are used for initialization of the seasonal or decadal forecast within their respective host institute. Here, we explored a large ensemble of ocean indicators such as heat content, surface currents, heat and mass transports, and western boundary currents, AMOC, sea ice extent. Those indicators are developed and compared with difference set of observations. The different indicators are thus complied in the CMEMS Ocean State Report which monitor sthe ocean on yearly basis. The first one, for the year 2016 as been published as Ocean State Report #1, 2016,DOI:10.1080/1755876X.2016.1273446.

SESSION: (A6) Ocean initialization and processes

(P-A6-03)

Development of a global ocean and coupled data assimilation system for subseasonal to seasonal forecasts in Japan Meteorological Agency.

Yosuke Fujii (1), Takahiro Toyoda (1), Shogo Urakawa (1), Hiroyuki Sugimoto (2), Ichiro Ishikawa (2), Yuhei Takaya (1), Chiaki Kobayashi (1), Toshiyuki Ishibashi (1), and Takeshi Iriguchi (1)

JMA/MRI, Japan (1), JAM, Japan (2)

A global ocean data assimilation system based on a 4-Dimensional Variational (4DVAR) method is currently being developed mainly for improving subseasonal to seasonal forecasts in Japan Meteorological Agency (JMA). The system consists of an analysis model with a coarse horizontal resolution (1º zonal and 0.3-0.5º meridional) and a forecast model with a higher eddy-permitting resolution (0.25º zonal and meridional). In the analysis model, temperature and salinity observation data are assimilated through a 4DVAR method with 10-day assimilation terms in which analysis increments for Incremental Analysis Updates (IAU) are optimized. Sea Ice Concentration (SIC) fields are separately analyzed by a 3-Dimensional Variational (3DVAR) method and inserted into the model through IAU. Temperature and salinity fields of the forecast model are using those fields in the analysis model through IAU with 5-day assimilation terms. The 3DVAR method of SIC with insertion of the result through IAU is also applied to the forecast model. The analysis model with the 4DVAR scheme outperforms the same model with a 3DVAR scheme in terms of the analysis accuracy of near-surface temperature. It also reproduces a fine structure of tropical instability waves which is physically consistent, and the forecast model represents the structure more clearly. They also improve the representation of SIC fields in polar regions over the current operational system to which sea ice data assimilation is not applied.

JMA Meteorological Research Institute (MRI) has also developed an experimental weakly-coupled atmosphere ocean Data Assimilation (DA) system, MRI-CDA1, based on JMA’s systems currently used in operations. MRI-CDA1 is composed of the global atmosphere 4DVAR system for numerical weather predictions and the global ocean 3DVAR system and the coupled atmosphere-ocean model for seasonal forecasts. The coupled DA system improves representation of lagged correlation between SST and precipitation in the western equatorial Pacific over the uncoupled version of the DA system. The precipitation fields are also slightly improved by the coupled DA.

SESSION: (A6) Ocean initialization and processes

(P-A6-04)

Impact of Satellite Sea Surface Salinity Observations on ENSO Predictions from the GMAO S2S Forecast System

Hackert, Eric (1), Kovach, Robin (2), Marshak, Jelena (1), Borovikov, Anna (2), Molod, Andrea (1), Vernieres, Guillaume (3)

NASA, USA (1), SSAI, USA (2), NOAA, USA (3)

El Niño/Southern Oscillation (ENSO) has far reaching climatic impacts over the globe and so extending useful ENSO forecasts would be of great benefit for society. However, one key variable that has yet to be fully exploited within coupled forecast systems is accurate estimation of near-surface ocean density. Sea surface salinity (SSS), combined with temperature, help to identify ocean density changes and associated mixing near the ocean surface. In order to better understand the global hydrological cycle, NASA has developed satellite technology to observe SSS from space. From September 2011 until June 2015 Aquarius has been providing near weekly global coverage of satellite SSS. More recently, the Soil Moisture Active/Passive (SMAP) satellite has been re-tasked to also observe SSS starting in March 2015 extending until present.

In this presentation, we assess the impact of satellite SSS observations for improving near-surface dynamics within ocean analyses and how these impact dynamical ENSO forecasts using the S2S system from GMAO. We highlight the impact of satellite SSS on ocean reanalyses by comparing validation statistics of experiments that assimilate SSS versus those that withhold SSS. We find that near-surface validation versus observed statistics for salinity are slightly degraded when assimilating SSS. This is an expected result due to known biases between SSS (measured by the satellite at ~1cm) and in situ measurements (typically measured by Argo floats at 5m). On the other hand, a very encouraging result is that both temperature and absolute dynamic topography statistics (i.e. independent observations) are improved with SSS assimilation.

Previous work has shown that correcting near-surface density structure via SSS assimilation can improve coupled forecasts. For example, Hackert et al., 2014 showed that long-lead ENSO forecasts were significantly improved when assimilating Aquarius SSS. Here we present an ensemble of coupled hindcasts that are initialized from the GMAO S2S reanalyses to test the impact that salinity has on ENSO predictions. In particular, we show forecast examples from May 2015 (i.e. an example of El Niño). This example is especially advantageous since SSS data are available from both Aquarius and SMAP and so the impact of each can be deciphered/compared by initializing with separate Aquarius and SMAP reanalysis experiments. We also show results from May 2016 (SMAP only) to demonstrate the impacts of SSS assimilation for a La Niña forecast scenario. Finally, we assess the impact of SSS assimilation on a longer-term basis by evaluating ENSO validation statistics from April until September 2018. During this period, the SSS assimilation experiment serves as a new ensemble to the production S2S system and so can be evaluated in near-real time.

The coupled model that is used in this project is the new S2S_v2.1 that has recently become the seasonal coupled forecast production model for NASA GMAO. This version couples the 0.5o resolution, 72 levels atmosphere (model version - Heracles-5_4_p3) with the Modular Ocean Model Version 5 (Griffies, 2012) with 0.5o resolution and 40 vertical levels. For all the initialization experiments, all available along-track absolute dynamic topography (AVISO, 2013) and in situ observations (Argo, 2000) are assimilated using the LETKF scheme of Penny et al., 2013. In order to minimize the transition from the previous production coupled model to this current version, SST is relaxed to MERRA-2 values (Gelaro et al., 2017). In addition to the data routinely assimilated in the production experiment, separate experiments are performed assimilating Aquarius V5 and SMAP V4 data.

SESSION: (A6) Ocean initialization and processes

(P-A6-05)

Operational Ocean Reanalysis for S2S at NCEP: Upgrading from 1 degree MOM3 GODAS to _ degree MOM6 Hybrid-GODAS

Yan Xue(1), Travis Sluka(1),(2),(4), Steve Penny(2), James Carton(2),
Hyun-Chul Lee(3), Rahul Mahajan(3)

CPC/NCEP, USA(1), University of Maryland, USA(2), EMC/NCEP, USA(3), Innovim, LLC, USA(4)

A number of troubling weaknesses have been found in the operational global ocean data assimilation system (GODAS) and the ocean component of Climate Forecast System Reanalysis (CFSR) that are used to provide ocean initialization for the S2S system at NCEP. We identified large systematic errors in salinity and velocity fields in GODAS and CFSR, as well as a serious issue in fitting to observations too strongly in both GODAS and CFSR during the international Ocean Reanalysis Intercomparison Project (ORA-IP) and the Observing System Experiments for evaluating the TAO array. A Hybrid 3DVar/EnKF Global Ocean Data Assimilation System (Hybrid-GODAS) has been developed and evaluated using real data for a 21-year reanalysis (Penny et al. 2015). The Hybrid-GODAS shows significant advantage over the 3DVar GODAS, and produced significant improvements in the analysis of temperature, salinity, sea surface height and velocity compared to GODAS.

NCEP is developing the Hybrid-GODAS as a replacement for GODAS. We use the recently released GFDL Modular Ocean Model version 6 (MOM6) at _ºx_º horizontal resolution and Sea-Ice Simulator (SIS2), which is the ocean component of the next generation S2S system at NCEP and the CM4 earth system model at GFDL for the Coupled Model Intercomparison Project (CMIP6). This upgrade includes a drastic increase of zonal resolution from 1o to _o, an increase of vertical resolution from 10m to 2m near the surface with vertical levels increased from 40 to 75, and use of the Arbitrary Lagrangian Eulearian (ALE) algorithm in the vertical. The upgrade also includes expanded observation data sets from assimilating in situ temperature and synthetic salinity profiles to assimilating all in situ temperature and salinity profiles, satellite altimetry and satellite SST. The upgrade, without a relaxation to the OI SST, allows the model SST to interact with surface fluxes through the bulk formula and reanalysis surface variables from the CFSR that have been corrected in climatology based on observation products. The proposed upgrades will significantly improve our capability in monitoring and understanding not only temperature but also salinity and velocity variability that play a critical role in the evolution of El Niño / Southern Oscillation (ENSO), and other climate modes such as Atlantic Multidecadal Variability (AMV) and Pacific Decadal Variability (PDO) and therefore improving the S2S and S2D forecast skill.

SESSION: (A7) Aerosols

(P-A7-01)

Aerosol Impact on Subseasonal Prediction using FIM-Chem-iHYCOM Coupled Model

Shan Sun (1), Georg A. Grell (2) and Li Zhang (3)
CU/CIRES & NOAA/ESRL (1,3), NOAA/ESRL (2)

The aerosol impact on subseasonal forecast is investigated using a global coupled atmosphere, ocean and chemistry system of FIM-Chem-iHYCOM. The online chemistry includes a simple suite with bulk aerosols only. The sources and sinks for aerosols, fire and anthropogenic emissions are prescribed during the model integration. We compared the model sensitivity with biomass burning (wildfire emissions) at different seasons in a multiyear study, and found the bias in the surface shortwave radiation is reduced when fire emissions are included. Additional emphasis of this work is on the effect of aerosols on cloudiness and precipitation, to demonstrate the importance of using the correct aerosol optical properties at the subseasonal time scale.

SESSION: (A7) Aerosols

(P-A7-02)

Sub-seasonal prediction of aerosols fields and impact on meteorology using the ECMWF's coupled Ensemble Prediction System

Angela Benedetti and Fréderic Vitart

ECMWF

Recent years have seen the rise of global operational atmospheric composition models for several applications including climate monitoring, provision of boundary conditions for regional air quality forecasting, and energy sector applications, to mention a few. Typically global forecasts are provided in the medium-range up to five days ahead. In this work we investigate the feasibility of sub-seasonal to seasonal prediction of aerosols using the ECMWF's coupled Ensemble Prediction System. The motivation of this study is to understand the impact of the aerosol direct effect on meteorological variables such as winds, temperature and precipitation. A comparison between simulations with fully prognostic and interactive aerosols and a control run using an up-to-date aerosol climatology currently used operationally at ECMWF will be presented.

Aerosol forecast fields at the weekly/monthly scales will also be presented and compared with corresponding analysis to assess their quality. Moreover, a brief analysis of the anomalous wild fires season of 2015 in Indonesia will also be presented from the point of view of the radiative impacts of the biomass burning aerosols on the regional meteorology.

SESSION: (A8) Stratosphere

(P-A8-01)

The Relationship Between Tropospheric Synoptic-Scale Events and Vertical Wave Activity Flux Near the Tropopause

Attard, Hannah (1), Lang, Andrea (2)

University at Albany, SUNY, USA (1), University at Albany, SUNY, USA (2)

Rossby waves excited within the extratropical waveguide can disperse and propagate horizontally, potentially impacting the downstream weather, and vertically, potentially inducing extreme stratospheric conditions (e.g., sudden stratospheric warming events). Previous work has shown that several categories of synoptic events can excite tropopause waveguide perturbations that are associated with horizontal Rossby wave dispersion and propagation. This research expands upon our understanding of horizontal Rossby wave processes by utilizing NASA's MERRA-2 dataset to examine the role of synoptic events in producing vertically propagating Rossby waves.

The analysis is based on case lists of two types of synoptic events: tropospheric blocking ridges, hereinafter blocks, and rapidly deepening extratropical cyclones, hereinafter bombs, in the cool seasons of 1980-2015. To quantify the impact of these synoptic events in producing vertically propagating Rossby waves, the tropopause-level zonal-mean meridional eddy heat flux anomaly was calculated with respect to the climatological mean for the 11-day period following and including each synoptic event. The zonal-mean meridional eddy heat flux is directly proportional to the vertical component of Rossby wave propagation.

The results show that both blocks and bombs can be associated with upward Rossby wave propagation but that the magnitude of the heat flux anomaly following each event is variable. In a composite sense, blocks that occurred in Europe (West Pacific) were followed by statistically significant positive (negative) 100-hPa zonal-mean meridional eddy heat flux anomaly. Bombs that occurred in the West Pacific (Atlantic) were followed, on average, by statistically significant positive (negative) 100-hPa zonal-mean meridional eddy heat flux anomaly. The presented results will also diagnose the temporal and spatial variability of blocks and bombs that were associated with the top quartile (T25) and bottom quartile (B25) of heat flux anomaly in each region. The results showed that all T25 (B25) events had similar planetary-scale 100-hPa momentum and thermal perturbations that constructively phased to create distinctive regions of positive (negative) heat flux that, when summed, produced an anomalously positive (negative) zonal-mean value.

SESSION: (A8) Stratosphere

(P-A8-02)

Seasonal persistence of circulation anomalies in the Southern Hemisphere stratosphere, and its implications for the troposphere

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University of Reading, UK (1), ECMWF, UK (2)

Previous studies have highlighted an important organising influence of the seasonal Southern Hemisphere stratospheric vortex breakdown on the large-scale stratospheric and tropospheric circulation, which should provide a source of seasonal predictability for the troposphere. In this study we show, using reanalysis data, that perturbations to the winter SH stratospheric vortex persist into austral spring, and lead to a shift in the statistics of the breakdown event during austral summer. There is dynamical coupling to the troposphere throughout this period. The statistical relationships associated with the anomaly persistence provide illuminating diagnostics for model evaluation, and are used to understand the performance of the recent and latest ECMWF seasonal forecast systems in their prediction of the Southern Annular Mode during this time of year.

SESSION: (A8) Stratosphere

(P-A8-03)

The Combined Influence of the MJO and the Stratospheric Polar Vortex on Northern Hemisphere Winter Weather Patterns

Jason C. Furtado (1), Matthew R. Green (1), Elizabeth A. Barnes (2), Michelle L'Heureux (3), Laura Ciasto (3,4), Kirstin Harnos (3,4), Adam Allgood (3)

University of Oklahoma, USA (1), Colorado State University, USA (2) NOAA Climate Prediction Center, USA (3), Innovim, LLC, USA (4)

Skillful subseasonal weather predictions for the Northern Hemisphere (NH) extratropics remain a major challenge for the forecast community Two intraseasonal modes of variability that modulate the strength and position of the polar jet stream are: (1) the Madden-Julian Oscillation (MJO) and (2) NH polar vortex variability. This talk presents emerging evidence that these two modes, while oftentimes considered separately, may actually interact and modulate the expected teleconnections from either mode in isolation. Through composite analysis using reanalysis data, we show that MJO-induced wavetrains are altered across the NH whether or not the state of the stratospheric polar vortex is considered in the composite. Likewise, these changes alter the temperature patterns and storm tracks across the Northern Hemisphere. Results indicate that subseasonal weather variability for the Atlantic and Europe is dominated by polar vortex variability more so than the MJO and vice versa for the Pacific and western North America. However, "MJO + polar vortex" composite results over much of North America and especially the United States differ more from the single-mode composites, suggesting higher forecast skill there when considering the joint influence of the MJO and the polar vortex. Relations of this joint influence of the MJO and polar vortex to extreme weather frequency, blocking regimes, and wave propagation diagnostics are also discussed.

SESSION: (A8) Stratosphere

(P-A8-04)

Predictability of wintertime stratospheric circulation examined by non-stationary fluctuation dissipation relation.

Masaru Inatsu (1), Naoto Nakano (2), Seiichiro Kusuoka (3), Hitoshi Mukougawa (2)

Hokkaido University (1), Kyoto University (2), Okayama University (3)

The dynamics and predictability of stratospheric LFV in boreal winter are examined using a phase space spanned by two EOFs of the 10-hPa height. A linearized nonstationary FDR is developed based on drift vector and diffusion tensor. The authors found that the solution well represented the forecast spread of the JMA. The linearized NFDR captures the local maximum of the forecast spread during the onset period of the major SSWs.

SESSION: (A8) Stratosphere

(P-A8-05)

Using causal discovery algorithms to evaluate Troposphere-Stratosphere linkages in the ECMWF forecast model

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Extremely strong and weak phases of the stratospheric polar vortex are known to affect the North Atlantic Oscillation and therefore mid-latitude weather. Troposphere–Stratosphere coupling thus provides an important source of predictability winter forecast on subseasonal to seasonal timescales. However, the exact mechanisms are still unclear and their representations in climate models vary.

Extracting the physically relevant teleconnection pathways from large model ensembles remains challenging. One major issue is to separate the signal from the noise given large internal atmospheric variability. This is compounded by varying dimensions in space and time and competing effects of different processes.

Here, to overcome these current limitations, we apply a novel type of time-series analysis, called causal effect networks (Kretschmer et al. 2016), to compare the representation of troposphere-stratosphere coupling in observations and ECMWF system 5 forecast data. This allows evaluating these processes with more confidence than using solely correlation analysis. We focus on winter circulation in the North Atlantic/European region and particularly assess the role of stratospheric polar vortex variability to predict the North Atlantic Oscillation.

SESSION: (A8) Stratosphere

(P-A8-06)

Winter 2017/18 Sudden Stratospheric Warming Hits and False Alarms in S2S Forecasts

Andrea L. Lang and Hannah E. Attard

University at Albany, SUNY

The Northern Hemisphere experienced stratospheric variability during the winter of 2017/18 that culminated in a mid-February major sudden stratospheric warming (SSW) event. A shift in the Atlantic storm track prior to the SSW was associated with a series of Arctic cyclones that maintained high-latitude ridging in the North Atlantic. Following the SSW event, persistent blocking in the North Atlantic led to a transition to extreme negative Arctic Oscillation conditions and a record breaking cold air outbreak in Europe. Using data from the Subseasonal–to–Seasonal (S2S) Prediction Project database and ERA-Interim data as verification, this presentation will highlight the S2S forecast successes on a variety of scales associated with this event.

In addition, to highlighting the S2S forecast successes during the period of the SSW, this presentation will also analyze two periods during the winter (early December 2017 and early January 2018) in which multiple models in the S2S database produced SSW false alarms. This portion of the presentation will examine the role of the stratospheric forecast errors on surface temperature forecast skill. By considering SSW from both a hit and false alarm perspective, the analysis will evaluate the role of the atmospheric initial state, model configuration and set up, and categorical synoptic-scale forecast error in SSW forecast skill for the winter of 2017/18

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-01)

A multi-system evaluation of predictive capacity over the Arctic and mid-latitudes at the seasonal time scale

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CNRM UMR 3589 (Météo-France / CNRS), France (1), Barcelona Supercomputing Center (BSC), Spain (2), Met Office Hadley Centre, UK (3)

In the framework of the H2020-APPLICATE project, we evaluate the ability of three different seasonal forecast systems (CNRM-CM-6, EC-Earth3, GloSea5) to capture the variability of the Arctic state as well as impacts on the mid-latitudes on seasonal time scales. We analyze a common re-forecast period from 1993 to 2014 for November and May initializations, up to 6 months lead time. Results are shown in terms of deterministic and probabilistic skill scores for atmospheric variables over the Arctic and northern hemisphere midlatitudes, for both individual systems and the multi-model ensemble. An assessment of bias and variability of Arctic sea ice extent in the three forecasting systems and the multi-model is included in the analysis. User-relevant metrics as well as indices describing the Arctic-midlatitudes linkages (ice-free area, blocking frequency) are explored. Results will be discussed in the light of other available re-forecast datasets based on state-of-the-art GCMs (e.g. Copernicus C3S seasonal forecasts).

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-02)

A minimalistic damped harmonic oscillator framework for assessing decadal climate predictability in the Subpolar North Atlantic

Bethke, Ingo (1,2), Counillon, Francois (3,2), Wang, Yiguo (3,2), Kimmritz, Madlen (3,2), Keenlyside, Noel (4,2)

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The Subpolar North Atlantic (SPNA) stands out for its high decadal predictability of heat content variability. At the same time, climate models exhibit oscillatory behaviour on time scales of approximately 20 years in that region. We show that a damped harmonic oscillator model driven by North Atlantic Oscillation (NAO) variability successfully mimics the behaviour of more complex climate prediction models and exhibits similar hindcast performance during the period 1980 to present. In line with previous studies that emphasise the role of ocean dynamics, the performance of the damped oscillator model drops if the ocean heat transport – represented as SPNA heat content tendency – is kept unitialised. The model's resonance characteristic further suggests that the amount of predictable internal variability is conditional and critically depends on the most recent frequency history of the atmospheric forcing. It is therefore likely that the pre-1995 extended period of predominantly positive NAO led to enhanced SPNA predictability in subsequent years and decades. The simulated variability during the period of interest is not very sensitive to the spin-up length as the variability synchronises rather quickly (within few decades) once the NAO forcing is applied. This confirms the utility of using atmospheric re-analysis products to synchronise the ocean in prediction models. Amongst other applications, the damped harmonic oscillator framework may help to investigate the limits of SPNA decadal predictability under the assumption that the atmospheric forcing itself is not predictable and to better understand inter-model differences in SPNA predictions that arise from diverging resonance characteristics.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-03)

Forecasting the climate response to volcanic eruptions

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BSC(1), ICREA(2)

The last major volcanic eruptions, the Agung in 1963, El Chichón in 1982 and Pinatubo in 1991, were each associated with a cooling of the troposphere that has been observed over large continental areas and over the western Pacific, the Indian Ocean and the southern Atlantic. Simultaneously, Eastern tropical Pacific temperatures increased due to prevailing El Niño conditions. Here we show that the pattern of these near-surface temperature anomalies is reproduced with decadal simulations of the EC-Earth model initialised with climate observations and forced with an estimate of the observed volcanic aerosol optical thickness. Sensitivity experiments highlight that the post-eruption cooling is mainly due to the volcanic forcing, whereas El Niño events following the eruptions would have occurred even without volcanic eruptions. Focusing on the period 1961-2001, the main source of skill of this decadal forecast system during the first two forecast years is related to the initialisation of the model. The contribution of the initialisation to the skill becomes smaller than the contribution related to the volcanic forcing after two years, the latter being substantial in the Western Pacific, the Indian Ocean and the Western Atlantic. This study investigates two protocols to account for the volcanic forcing in real-time forecasts: applying a two-year exponential decay to the initial stratospheric aerosol load observed at the beginning of the forecast allows to simulate the aerosol forcing in the Tropics after tropical volcanic eruptions, but causes forecast deficiencies at high latitudes. Using the forcing of a past eruption with a similar magnitude to forecast the climate response to a future eruption is appropriate if both have similar spatiotemporal characteristics of the forcing.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-04)

Variable Decadal Temperature Prediction Skill in the North Atlantic: The Role of Ocean Heat Transport

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Universität Hamburg, Germany (1), IMPRS-ESM, Germany (2), Deutscher Wetterdienst (DWD), Germany (3), Max Planck Institute for Meteorology, Germany (4)

Recent studies found a strong time-dependence for skill estimates of seasonal-to-decadal predictions in the North Atlantic region in the 20th century (Weisheimer et al., 2017, QJRMS; Brune et al., 2017, Clim.Dyn.). The time-dependence of prediction skill might be connected to model-specific preferences in representing certain climate states, or to differently long memories of processes in the climate system that prediction skill could arise from. Knowledge of the climate state at the beginning of a prediction and how the climate can be expected to evolve might therefore give an indication of the prediction skill that is to be expected from a seasonal-to-decadal prediction for a particular start year.

In this study, we use the strength of subpolar ocean heat transport (OHT) in the North Atlantic as an indicator of decadal surface temperature prediction skill in the North Atlantic for the period 1901-2010. We evaluate the skill of predictions with the MPI-ESM-LR (Müller et al., 2014, GRL) started in years of strong and weak OHT separately to assess the influence of the initial OHT strength on interannual-to-decadal SST prediction skill. SSTs in the northeast Atlantic show predictive skill higher than the overall average on interannual-to-decadal time scales when OHT is strong at the initialization of a hindcast. On the same time scale, northeast Atlantic SST variability is strongly influenced by OHT strength at 50N. Different northeast Atlantic SST prediction skills for hindcasts started in years of strong and weak OHT at 50N can on the decadal time scale be attributed to a balance of different OHTs and ocean-atmosphere surface heat flux patterns: Wherever the OHT variability dominates surface heat flux variability, the skill of SST predictions at lead years 7-9 is high and vice versa. Strong surface air temperature anomalies we find over Scandinavia after strong phases of OHT at 50N suggest that these findings have an impact on decadal surface air temperature predictions.

OHT variability in the subpolar North Atlantic is correlated with decadal prediction skill variability of northeast Atlantic SSTs. This study therefore suggests that the strength of OHT in the subpolar North Atlantic could be used to describe the rime-dependence of skill, and in a next step be used to extimate the expected skill for surface temperature predictions in the North Atlantic for a given start year. This finding implies that for the assessment of expected prediction skill of a prediction of the future, physical processes need to be taken into account. However, these mechanisms depend on the variable and region that is predicted, and on the prediction time scale.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-05)

Multi-year prediction of climate, drought, and wildfire in southwestern North America using CESM

Chikamoto, Yoshimitsu (1), Timmermann, Axel (2), Widlansky, Matthew (3)
Balmaseda, Magdalena (4) & Stott, Lowell (5)

Utah State University, USA (1), Pusan National University, South Korea (2), University of Hawaii (3), ECMWF (4), University of Southern California (5)

Past severe droughts over North America have led to massive water shortages and increases in wildfire frequency. Triggering sources for multi-year droughts in this region include randomly occurring atmospheric blocking patterns, ocean impacts on atmospheric circulation, and climate's response to anthropogenic radiative forcings. A combination of these sources translates into a difficulty to predict the onset and length of such droughts on multi-year timescales. Here we present results from a new multi-year dynamical prediction system that exhibits a high degree of skill in forecasting wildfire probabilities and drought for 10–23 and 10–45 months lead time, which extends far beyond the current seasonal prediction activities for southwestern North America. In this system, the internal variability of observed 3-dimensional ocean temperature and salinity are assimilated into the earth system model, CESM, with prescribing the external radiative forcings. This system simulates the observed low-frequency variability of precipitation, soil water, and wildfire probabilities in close agreement with observational records and reanalysis data. The underlying source of multi-year predictability can be traced back to variations of the Atlantic/Pacific sea surface temperature gradient, external radiative forcings, and the low-pass filtering characteristics of soils.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-06)

Predictability of phase shifts of the Atlantic Multidecadal Oscillation

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Climate Forecast Applications Network (1), (3), University of Washington (2)

A shift from the current warm phase of the Atlantic Multidecadal Oscillation (AMO) would have substantial impacts for U.S. and European weather, and particularly for Atlantic hurricanes. Previous abrupt shifts in 1926, 1971 and 1995 share common precursors, suggesting predictability of major North Atlantic climate shifts. A new conceptual model of North Atlantic climate change is based on shifts between persistent stable states that are initiated as short-term sea surface temperature perturbations and are maintained by ocean-atmosphere feedbacks for periods of multiple decades. Low-frequency climate changes occur through occasional pulses of upper-ocean heat uptake and release, rather than gradually, implying that interannual processes are intrinsic to low-frequency North Atlantic changes.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-07)

Co-variability between summer southeastern South America rainfall anomalies and tropical sea surface temperatures anomalies in CMIP5 decadal predictions

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The year-to-year variability of summer rainfall anomalies in Southeastern South America (SESA) along the last century exhibits the combination of variability in different time scales (Interannual, Decadal, Multidecadal) and trends. Thus, how the rainfall in the region will evolve in the next years-decades largely depends on the combined influence of the internal natural variability, mostly associated with the tropical ocean evolution, and the external climate forcing, associated with both natural and anthropogenic sources. Therefore, the objective of this work is to describe the influence of the observed large-scale interannual variability of the sea surface temperatures (SST) on austral summer rainfall in SESA, and to assess the ability of decadal hindcast simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme in reproducing it.

In order to better understand the influence of the observed large-scale interannual variability of the SST on austral summer rainfall in SESA in a global warming context, a singular value decomposition analysis was performed over the 1962-2013 period. The leading co-variability mode (SVD1) shows a clear global warming signal, mainly related to warming in the Pacific and Indian Oceans, in association with a rainfall increase in SESA. Also, the mode exhibits significant variability ranging from the interannual scale to long-term trends. In particular, the decadal variability signal is remarkable, with a particular phase shift at around middle 1970s. After detrending the series, the spatial distribution of both SST anomalies and precipitation anomalies in SESA associated with the first mode resembles that typically related with El Niño-Southern Oscillation (ENSO). Moreover, the mode temporal evolution has a remarkable variability on decadal scales, which shows that the relationship between SST anomalies, especially in the Tropical Pacific Ocean, and SESA precipitation is not stationary.

The ability of a set of 5 CMIP5 models decadal hindcasts initialized every year from 1960-onward to reproduce SVD1 activity was assessed. To estimate the importance of the initialization, results were compared with those obtained by historical or “unitialized” simulations. It was found that CMIP5 decadal hindcasts are able to represent SVD1 spatial structures when the trends are either considered or not, improving in both cases results from uninitialized simulations. Also, detrended SVD1 activity shows skill in the first two prediction years. Good skill is a result from the combination of a good representation of the low and high frequency oscillations (associated with periods longer and shorter than 5 years, respectively) in SVD1 activity. When trends are also considered, skill increase in the successive prediction years, indicating additional value from global warming effect over climate variability. SVD1 activity prediction was assessed during extreme positive ENSO events, obtaining good results for the first two prediction years. These facts represent a promising result for the predictions of rainfall in the SESA region on interannual and longer time scales.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-08)

The sub-sampling approach applied to the Summer North Atlantic Oscillation

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Inst. of Oceanography, CEN, Univ. of Hamburg, Germany (1), IAC, ETH Zurich, Switzerland (2), Max Planck Institute for Meteorology, Hamburg, Germany (3), Deutscher Wetterdienst, Hamburg, Germany (4)

The North Atlantic Oscillation (NAO) has been shown to be most influential on European weather in winter, but effects on meteorological parameters have also been shown during summer. Here, we use a subsampling algorithm to demonstrate predictability for the Summer Northern Atlantic Oscillation (SNAO) with the Max Planck Institute Earth System Model (MPI-ESM) seasonal prediction system for 3 - 4 months in advance. While the full hindcast ensemble mean does not have a significant hindcast skill, the sub-sampled prediction with the help of physically based predictors does show it.

For the seasonal hindcasts, we use the global coupled climate model MPI-ESM (MR resolution) with a 30 member hindcast ensemble initialized every May between 1982 - 2015 to predict the July-August SNAO. As predictors for the sub-sampling algorithm we use variables like the Arctic sea-ice volume before the start of the respective prediction. The use of statistical predictors in the sub-sampling approach for the SNAO results in a significant increase in the hindcast skill for precipitation over the British Isles. A moderate increase in hindcast skill for 500 hPa geopotential and minor regional increases in hindcast skill for surface temperature over Europe are also observed.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-09)

The South Pacific Meridional Mode and Its Role in Pacific Seasonal-to-Decadal Variability

Jason C. Furtado (1), Yujia You (1)

University of Oklahoma, USA (1)

Tropical and extratropical Pacific climate variability substantially impact physical and biological systems in the Pacific Ocean on seasonal to decadal timescales. The Pacific Meridional Mode, a thermodynamically-coupled mode of variability, is a major conduit which links the extratropical Pacific oceanic and atmospheric anomalies to the tropical Pacific. Most recent literature on Pacific climate variability and the meridional modes has been almost entirely North Pacific-centric, leaving questions as to what role the South Pacific may play in El Niño-Southern Oscillation (ENSO) variability across multiple timescales. This presentation offers evidence that the South Pacific Meridional Mode (SPMM) indeed plays a significant role in tropical Pacific internannual to decadal climate variability. Akin to the North Pacific Meridional Mode (NPMM), the SPMM exhibits anomalous subtropical South Pacific sea surface temperature (SST) warming in response to a weakened South Pacific High and weakened southeasterly trade winds. However, as opposed to the NPMM, the seasonality of the SPMM SST and wind is out-of-phase, with the oceanic (atmospheric) component of the SPMM peaking during austral summer (winter). Moreover, whether or not the SPMM is in-phase or out-of-phase with the NPMM strongly influences the occurrence, amplitude, and the flavor of a developing ENSO event. Indeed, skillful predictions of ENSO events may be possible with about a 9-month lead, challenging the “Spring Barrier” plaguing ENSO predictability studies. Links between the SPMM / South Pacific climate variability and Pacific-basin decadal climate variability more generally are also explored.1

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-10)

Characterising seasonal climate predictability and uncertainty through expert elicitation

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The development of successful climate services at the seasonal timescale (and other timescales) depends critically on predictability. Sources of predictability vary across different regions. A recent review by Steptoe et al. (2017), shows that rainfall over China has the most connections with global climate drivers (e.g., with the El Niño–Southern Oscillation, the Indian Ocean Dipole, North Atlantic Oscillation and the Southern Annular Mode) and has links to both Northern and Southern Hemisphere modes of variability. This makes the characterisation of seasonal rainfall predictability and uncertainty over China complex and challenging.

Expert elicitations encompass a range of systematic approaches that seek to make explicit subjective expert judgements on highly uncertain subject matter (Slottje et al., 2008). If obtained with care these unpublished scientific insights, based on accumulated experience, have the potential to make a valuable contribution to decision making (Thompson et al. 2016).

This research uses expert elicitation to characterise seasonal rainfall predictability and uncertainty over China. We conducted more than 20 elicitations with the world's leading experts in seasonal forecasting of the East Asian Summer Monsoon (EASM) in the Yangtze region of China. We will present our initial results, showing that there is strong agreement among experts that ENSO is an important source of monsoon predictability in this region. Specifically, a strong El Nino peaking in winter is likely to be followed by heavy rainfall in this region the following summer. However, judgements regarding the relative importance of regional factors such as; the strength and position of the western Pacific subtropical high, snow cover on the Tibetan plateau and blocking in the mid-high latitudes, varied between experts.

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SESSION: (B1) Mechanisms of S2D predictability

(P-B1-11)

Exploring Nonstationarities in East Africa Seasonal Precipitation Predictability

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Tropical sea surface temperature (SST) variations serve as the backbone for precipitation predictions over East Africa for three notable rainy seasons: the 'short' rains during October-December and the 'long' rains during March-May over the Horn of Africa and the 'Kiremt' rains during June-September over Ethiopia. The relationships between SST variations - including the El Nino Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and ENSO-like decadal oscillations - and East Africa seasonal precipitation change through time, potentially providing forecasters with a false sense of predictability for key rainy seasons. A noteworthy recent example of such a transient relationship is between ENSO and Horn of Africa precipitation during March-May, as their correlation since the mid-1990s has increased greatly relative to earlier periods.

Motivated by the transient relationships between East Africa precipitation and its predictors, forced changes and variability in East Africa precipitation predictability during the 20th and 21st centuries are examined in a 40-member ensemble of atmospheric model simulations driven by the observed time-varying boundary conditions. Forced changes and variability are both investigated for each of the three seasons using histograms constructed from the 30-year correlations of areally averaged East Africa precipitation between each member of the ensemble with the average of the remaining ensemble members during 1951-1980 and 1981-2010. A statistically significant shift of the histograms to higher correlations and a narrowing in spread of the correlations from 1951-1980 to 1981-2010 for all three East Africa precipitation seasons suggests that the boundary conditions forced an increase in predictability and reduced the variability in prediction skill. The proximate cause for the increase in predictability is a warming of the global oceans in concert with an increase in SST variance over the Indian Ocean and ENSO regions from 1951-1980 to 1981-2010. However, the still noteworthy spread in prediction skill between the ensemble members for each 30 year period serves as a cautionary tale of the effect of internal variability on predictability. We will consider under what circumstances internal variability is most likely to affect prediction skill.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-12)

Assessing the Impact of a Future Volcanic Eruption on Decadal Predictions

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The likelihood of a large volcanic eruption in the future provides the largest uncertainty concerning the evolution of the climate system on the time scale of a few years; but also an excellent opportunity to learn about the behavior of the climate system, and our models thereof. So the question emerges how predictable is the response of the climate system to future eruptions? By this we mean, to what extent will the volcanic perturbation affect decadal climate predictions and how does the pre-eruption climate state influence the impact of the volcanic signal on the predictions? To address these questions, we performed decadal forecasts with the MiKlip prediction system in the low-resolution configuration for the initialization years 2012 and 2014, which differ in the Pacific Decadal Oscillation (PDO) phase among other things. Each forecast contains an artificial Pinatubo-like eruption starting in June of the first prediction year. For the construction of the aerosol radiative forcing, we used the global aerosol model ECHAM5-HAM in a version adapted for volcanic eruptions. We investigate the response of different climate variables, including near-surface air temperature, precipitation, frost days, and sea ice area fraction. Our results show that the average global cooling response over four years of about 0.2K and the precipitation decrease of about 0.025mm/day, is relatively robust throughout the different experiments and seemingly independent of the initialization state. However, on a regional scale, we find substantial differences between the initializations. The cooling effect in the North Atlantic and Europe lasts longer and the Arctic sea ice increase is stronger than in the simulations initialized in 2014. In contrast, the forecast initialized with a negative PDO shows a prolonged cooling in the North Pacific basin.

More informations about this study in the journal of the European Geosciences Union "Earth System Dynamics" https://doi.org/10.5194/esd-2018-5

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-13)

Multidecadal variability in the Indian summer monsoon and its connection with global sea surface temperature

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More than one-an-a-half billion inhabitants over the south Asian region depend upon the vagaries of monsoonal rainfall. Improvement in the prediction of monsoon rainfall at different spatiotemporal scale depends upon our knowledge about its modes of variability. This is more important especially in a scenario when the contribution from natural variability and anthropogenic forcing to the total change has become difficult to distinguish. Although numerous studies have investigated rainfall variability at different timescale, documentation on multidecadal variability in monsoon rainfall has been limited primarily due to non- availability of long-term data. Here, using long-term (1871–2016) observed dataset based on rain gauge observations, we identify a multidecadal or ultra low-frequency (UL) mode of variability in the Indian summer monsoon rainfall (ISMR) using a non-parametric spectral approach. Well documented decreasing trend in ISMR in the second half of the twentieth century is explained by this mode. Probability of occurrences of seasonal flood and drought significantly depend upon the positive and negative phases of ISMRUL, respectively. Also, consecutive occurrences of excess or below normal rainfall over India are mostly observed if they are favored by the phases of ISMRUL (positive ISMRUL for excess and negative ISMRUL for below normal rainfall).

We performed convectional principal component analysis to decompose June—September averaged global sea surface temperature (SST) into different modes of variability. It is found that ISMRUL is associated with a multidecadal mode of variability in SST, which largely resembles North Pacific Gyre Oscillation (NPGO). A see-saw in horse-shoe like pattern in SST over the northern Pacific region in nearly 67-year timescale is associated with changes in surface pressure and circulation over the north-central Asia. Positive phase of this SST mode induces negative surface pressure anomaly over the Siberian High region. North Pacific SST and surface pressure over Siberia are possibly connected by the North Pacific Oscillation (NPO), the atmospheric component of NPGO. This leads to an anomalous cyclonic circulation over the north-central Asia and strong southerly wind anomalies along the east coast of China.

Decreased surface pressure over north-central Asia is associated with higher meridional tropospheric temperature gradient over the Indian region. This favors strengthening of the tropical easterly jet via thermal wind balance. Stronger jet structure is associated with stronger Hadley cell circulation and increased low-level jet over India and adjacent oceans. Which, in turn, create conducive environment for increased seasonal mean monsoon rainfall over India.

The phase angle of this SST mode was remarkably similar, and leading by 2-3 years, to that of ISMRUL during 1871–1975. However, the relationship between the SST mode and ISMRUL weakened after late-1970s, which could be attributed to the anthropogenic activities. Better understanding of SST-ISMR teleconnections has large implications towards water management, disaster preparedness and agricultural planning. The results presented here bears particular importance towards modeling and forecasts of Indian monsoon rainfall.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-14)

New Ocean-Atmosphere Coupled Feedback in the Tropical Atlantic: Wind-Mixed Layer-SST Modes

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The tropical climate system hosts ocean-atmosphere coupled processes, some of which give rise to large-scale climate fluctuations. Among others, air-sea coupled feedback associated with thermodynamic coupling between wind, evaporation, and sea surface temperature (SST), called wind-evaporation-SST (WES) feedback, is known to force or sustain a cross-equatorial SST gradient over the tropical Atlantic and Pacific Oceans. Although the above WES concept is based on an assumption that an oceanic mixed-layer depth (MLD) is constant, it is known that interannual variations in MLD plays a role in generating SST anomalies.

By constructing simple air-sea coupled models and solving the eigenvalue problem of the systems, it is shown that two additional ocean-atmosphere coupled feedback, which contribute to a cross-equatorial SST anomaly gradient, exist in the tropical Atlantic when oceanic mixed layer depth (MLD) variations are taken into account. It is found that those feedback processes are as strong as the canonical WES feedback in our simple model framework, but they exist as a weakly unstable mode or a least damped mode like the WES feedback in the presence of damping effects and relevant negative feedback. The anti-phase relationship between anomalous SST and MLD seen in the simple coupled model bears some resemblance to those of the Atlantic meridional mode, the dominant climate variability accompanied by cross-equatorial SST gradient, in the observation and the state-of-the-art coupled model (MIROC6). The result indicates that an accurate simulation of oceanic mixed-layer is important for better predicting an anomalous cross-equatorial gradient of SST and thus, associated climate variability.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-15)

Time scales and sources of European temperature variability

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Skillful predictions of continental climate would be of great practical benefit for society and stakeholders. It nevertheless remains fundamentally unresolved to what extent climate is predictable, for what features, at what time scales, and by which mechanisms. Here we identify the dominant time scales and sources of European surface air temperature (SAT) variability during the cold season using a coupled climate reanalysis, and a statistical method that estimates SAT variability due to atmospheric circulation anomalies. We find that eastern Europe is dominated by subdecadal SAT variability associated with the North Atlantic Oscillation, whereas interdecadal and multidecadal SAT variability over northern and southern Europe are thermodynamically driven by ocean temperature anomalies. Our results provide evidence that temperature anomalies in the North Atlantic Ocean are advected over land by the mean westerly winds, and, hence, provide a mechanism through which ocean temperature controls the variability and provides predictability of European SAT.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-16)

Seasonal Prediction of Temperatures in Europe from Arctic Sea Surface Temperatures

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Arctic anomalies of sea ice extent and sea surface temperature (SST) have been shown to be skillful predictors of weather anomalies in the mid-latitudes on the seasonal time scale. In particular, lower-than-normal sea ice extent in the Barents Sea in autumn has sometimes predated cold winters in parts of Eurasia. Here we address three questions pertaining to the potential for predicting seasonal surface air temperature (SAT) in Europe from SSTs in the Nordic Seas. First, we show that autumn SST anomalies not just in the Barents Sea, but also along the warm Norwegian Atlantic Current, can be used to predict wintertime SAT anomalies. This predictability is likely mediated by North Atlantic Oscillation (NAO) anomalies in winter, which again influence European SATs. There is also a non-negligible potential for prediction during other times of the year. Second, we demonstrate that the predictive skill is sometimes sensitive to detrending of the underlying data, depending on the strength of the trends. European SATs in spring and summer appear to be predictable from SSTs one season ahead, but this is largely because of inflated correlations due to warming trends. Third, we show that the potential for prediction is non-stationary in time. The high skill during recent decades appears to be nearly unprecedented in the period after 1900.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-17)

Potential reemergence of seasonal soil moisture anomalies in North America

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Soil moisture is an important predictor of regional climate variations and water resources. Most previous research on soil moisture and associated climate predictability has focused on sub-seasonal to seasonal time scales. We produce a new analysis using long-term in situ soil moisture observations, and we found a rebound in root zone soil moisture predictability on inter-seasonal to inter-annual (ISI) time scales. We call this rebound potential soil moisture “re-emergence” because it is likely related to more persistent soil moisture memory, on time scales of several months to a year or longer, within the sub-surface soil layer. An analogous climate process in which a reservoir of long-term memory is tapped on a seasonally varying basis, sea surface temperature anomaly re-emergence, enhances decadal scale climate variability in the North Pacific, e.g. Pacific Decadal Oscillation (PDO). Soil moisture re-emergence could similarly enhance hydro-climate predictability at ISI time scales, including by reddening remotely forced climate variability signals over land.

Long-term soil moisture observations are limited. Hence, we evaluated soil moisture re-emergence in various land data assimilation products, e.g. North American Data Assimilation System version 2 (NLDAS2) and climate model simulations. We found pronounced spatial and seasonal dependence of soil moisture re-emergence, which was sometimes but not always robust across these datasets despite the fact that in all cases their corresponding land surface/hydrology models were forced with observed climate forcing. An analysis of the CESM-Large Ensemble showed similar re-emergence characteristics, but varying across the 42 ensemble members, suggesting a potential but undetermined role of internal variability. In a separate land surface modeling experiment, we found that soil moisture re-emergence in some regions intensified when we muted inter-annual precipitation variability compared to a corresponding control experiment. Overall, we documented for the first time a soil moisture re-emergence process that can potentially contribute to ISI predictability.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-18)

Response of Southern Ocean Mixed Layer Depth to the Southern Annular Mode on seasonal to interannual timescales from an eddy-resolving ocean model

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The Southern Annular Mode (SAM) is the leading mode of atmospheric variability in the Southern Hemisphere extratropics. The spatial pattern of the positive SAM is characterized by a poleward shift and intensification of the atmospheric jet stream. The SAM has undergone an upward trend in recent decades. Although the ocean responses to the trend of the SAM have been investigated in prior studies, seasonal-to-interannual time-scale impacts of the SAM on air-sea interactions and ocean circulations are not well understood. In this study, using an eddy-resolving ocean model forced by observed atmospheric forcing, we examine the relationship between the SAM and depth of the mixed layer which is a gateway for air-sea exchanges of greenhouse gas and heat. The results show a significant correlation between the austral summer SAM and the mixed layer depth during following austral winter. For instance, following the positive SAM events, the mixed layers north of the Antarctic Circumpolar Currents are anomalously deeper in the eastern Indian and eastern Pacific Southern Ocean. In contrast, the mixed layers are anomalously shallower in the western Pacific Southern Ocean. A previous study showed that net air-sea heat flux and Ekman heat advection contribute to this zonally asymmetric structure. Our analyses suggest that ocean frontal dynamics also makes important contributions to the mixed layer responses particularly for the eastern Indian and eastern Pacific Southern Ocean. The ocean mixed layer is closed tied to the mode water formations and air-sea gas exchanges. Therefore, a better understanding of SAM's impacts on the mixed layer will improve our understanding of its long-term role in ocean biogeochemistry in the Southern Ocean.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-19)

Inter-basin source for two-year predictability of the prolonged La Niña event in 2010-2012

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Multi-year La Niña events often induce persistent cool and wet climate over global lands, altering and in some case mitigating regional climate warming impacts. The recent event lingered from mid-2010 to early 2012 and brought about intensive precipitation over many land regions of the world, particularly Australia. This resulted in a significant drop in global mean sea level despite the background upwards trend. This La Niña event is surprisingly predicted out to two years ahead in a few coupled models, even though the predictability of El Niño-Southern Oscillation during 2002-2014 has declined owing to weakened ocean-atmosphere interactions. However, the underlying mechanism for high predictability of this multi-year La Niña episode is still unclear. Experiments based on a climate model that demonstrates a successful two-year forecast of the La Niña support the hypothesis that warm sea surface temperature (SST) anomalies in the Atlantic and Indian Oceans act to intensify the easterly winds in the central equatorial Pacific and largely contribute to the occurrence and two-year predictability of the 2010-2012 La Niña. The results highlight the importance of increased Atlantic-Indian Ocean SSTs for the multi-year La Niña's predictability under global warming.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-20)

The Role of the Ocean in the 2015 European Summer Heat Wave

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In general, seasonal forecasts of summertime conditions in extra-tropical regions have low skill compared to the winter. During the summer of 2015 central Europe experienced a major heat wave that was preceded by anomalously cold sea surface temperatures in the northern North Atlantic. Recent observation based studies found links between North Atlantic Sea Surface Temperatures in the spring and European summer, suggesting that there is potential for predictability. Through the use of the global coupled climate model HadGEM3, this study aims to investigate whether in some cases seasonal forecasts can be more skilful. Here, we focus on the 2015 European heat wave and its possible link to the North Atlantic cold blob and more remote sea surface temperature anomalies. The coupled model is initialized using anomalous 3D temperature and salinity fields from the ocean model component forced with atmospheric reanalyses. These are coupled to arbitrary atmosphere and sea ice conditions taken from the historical/rcp4.5 simulation of HadGEM3. No data-assimilation is used. The philosophy is that when the ocean anomalies are large, a method that avoids drift and adjustment shocks might be superior, even if the initialised fields are an imperfect representation of the observations. The initialised forecast ensemble is compared to an ensemble initialised with exactly the same atmosphere and sea-ice state, but with climatological temperature and salinity fields. Initial results show for the summer of 2015 a large signal-to-noise ratio with surface air temperature anomalies of 2 degree Celsius over large parts of Europe. This result, however, depends on the initial atmosphere and sea ice conditions. The impact of ocean, atmosphere and sea-ice initial states on the forecast will be discussed using a suite of initialised ensembles in which the impact of each of these fields is isolated.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-21)

Decadal climate predictability in the southern Indian Ocean revealed by using SST-nudging initialization scheme

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Decadal climate predictability in the southern Indian Ocean is demonstrated by performing decadal reforecast experiments using a coupled general circulation model (CGCM) with sea-surface temperature (SST) nudging initialization scheme. Decadal climate variability in the southern Indian Ocean is characterized by basin-wide SST warming and high sea-level pressure (SLP) anomalies during a warm phase of the southern Indian Ocean. The easterly wind anomalies associated with the high SLP anomalies act to bring more moisture from the southern Indian Ocean toward southern Africa and enhance austral summer rainfall there with a frequency of around 20 years. Previous studies reported that local air-sea interaction in the southern Indian Ocean plays a crucial role in generating the decadal climate variability over southern Africa. However, recent studies suggest that eastward-propagating SST and SLP anomalies from the South Atlantic may contribute to excitation of decadal climate variability there. Although efforts have been made to understanding the underlying physical mechanisms, predictability of the decadal climate variability, in particular, the internally generated variability independent from external atmospheric forcing, remains poorly understood.

In this study, different ensemble members of decadal reforecast experiments were generated using a CGCM, called the SINTEX-F2, in which only the model SST is initialized with SST-nudging scheme. The SST-nudging scheme, which is widely adopted for initialization of seasonal climate prediction, restores the model SST to the observed SST by adjusting the model's surface heat flux. The decadal reforecast experiments show high prediction skills of the decadal SST variability, in particular, in the Agulhas Retroflection region. One reforecast experiment initiated from 1994 reasonably captures warm SST and high SLP anomalies propagating from the South Atlantic to the southern Indian Ocean. This leads to successful prediction of the warm state in the Agulhas Retroflection region during early 2000s. Also, the other experiment initiated from 1999 skillfully predicts a phase change from warm to cold states during late 2000s. These results suggest that the SST-nudging initialization scheme may have the essence to capture the predictability of the internally generated decadal climate variability in the southern Indian Ocean.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-22)

Role of subsurface ocean initialization in decadal climate predictability over the South Atlantic

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Decadal climate predictability in the South Atlantic is investigated using a coupled general circulation model, called the SINTEX-F2, with two initialization schemes: one assimilates sea surface temperature (SST) only, and the other is additionally assimilating subsurface ocean temperature and salinity. Decadal climate variability in the South Atlantic is characterized by a meridional dipole pattern of warm and cold SST anomalies associated with the strengthening/weakening of the South Atlantic subtropical high. Recent studies suggest that the decadal SST variability in the South Atlantic slowly propagates eastward as quasi-stationary oceanic Rossby waves along the eastward South Atlantic Current and induces decadal SST variability in the southern Indian Ocean. Since the SST variability is accompanied with the overlying sea-level pressure variability, it has potentials in affecting southern African rainfall through modulation of moisture transport from the southern Indian Ocean. Considering socio-economic impacts over southern Africa, skillful prediction of decadal climate variability in the South Atlantic is greatly important.

Decadal reforecast experiments in which only the model SST is initialized with the observed SST show moderately high skills of decadal SST variability in the southern South Atlantic. On the other hand, the experiments in which the subsurface ocean temperature and salinity in the model are additionally initialized with the observation show an improvement of the prediction skills, in particular, in the Southeast Atlantic where the decadal SST variability is notably large. Comparison of upper-ocean heat balance between the two reforecast experiments reveals that in the case of recent warm state in the Southeast Atlantic after 2006, an improvement of zonal ocean heat transport from the west and east sides of the Southeast Atlantic leads to skillful prediction of the warm SST anomalies there. This is mainly due to the improved zonal advection of mean warm temperature by zonal current anomalies, probably related to assimilation of the upper-ocean density anomalies. These results have much implications for potential roles of subsurface ocean assimilation in the skillful prediction of decadal climate variability over the South Atlantic.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-23)

Seasonal predictions of European summer climate re-assessed

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Current state-of-the-art prediction systems show seasonal predictability in various areas, including large parts of the North Atlantic, but their prediction skill for European climate is still very limited, particularly during the summer season. To improve the seasonal prediction skill of European summers, we incorporate a mechanism that connects areas of high predictability in the tropical Atlantic with the summer climate in Europe. The mechanism has its origin in the tropical North Atlantic in spring, where either warm or cold sea surface temperature (SST) anomalies are connected with the European climate by an upper-level wave-train. This wave-train generates a zonal sea level pressure gradient, that in turn influences the climate over central Europe in the following summer. In addition, this east-west pressure gradient is opposed to the summer North Atlantic Oscillation, which is the leading mode of North-Atlantic-European atmospheric variability in summer, but has a north-south pressure gradient and an impact on northern and southern, rather than on central Europe.

To verify whether the proposed mechanism can improve seasonal predictions, we analyse the mixed resolution hindcast ensemble simulations generated by MPI-ESM, including a 30 members ensemble starting every year in May. We test every ensemble member for the proposed connection between the wave-train, the zonal sea level pressure gradient and their impact on European summer temperatures, and find that the mechanism is represented in some but not in every ensemble member. To determine whether the mechanism in the considered year is in its positive or negative state, we use the condition of the spring SST anomalies as a predictor. We show that, if an analysis is conducted by predicting the state of the mechanism with spring SSTs, and by using only those selected ensemble members in which the mechanism is the prominent one, the seasonal prediction skill can be improved in the North-Atlantic-European sector, especially in the areas where the mechanism is expected to show a prominent signal.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-24)

An Asymmetric Rainfall Response to ENSO in East Asia

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This study explores the impact of El Niño and La Niña events on precipitation and circulation in East Asia. The results are based on statistical analysis of various observational datasets and Geophysical Fluid Dynamics Laboratory's (GFDL's) global climate model experiments. Multiple observational datasets and certain models show that in the southeastern coast of China, precipitation exhibits a nonlinear response to Central Pacific sea surface temperature anomalies during boreal deep fall/early winter. Higher mean rainfall is observed during both El Niño and La Niña events compared to the ENSO-Neutral phase, by an amount of approximately 0.4-0.5 mm/day on average per oC change. We argue that, in October to December, while the precipitation increases during El Niño are the result of anomalous onshore moisture fluxes, those during La Niña are driven by the persistence of terrestrial moisture anomalies resulting from earlier excess rainfall in this region. This is consistent with the nonlinear extreme rainfall behavior in coastal southeastern China, which increases during both ENSO phases and becomes more severe during El Niño than La Niña events.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-25)

The impact of tropical precipitation on summertime Euro-Atlantic circulation via a circumglobal wave-train

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The influence of summertime tropical precipitation variability on seasonal circulation anomalies in the Euro-Atlantic sector is investigated. The dominant mode of the maximum covariance analysis (MCA) between the Euro-Atlantic circulation and tropical precipitation reveals a cyclonic anomaly over the extratropical North Atlantic, contributing to anomalously wet conditions over western Europe and dry conditions over eastern Europe and Scandinavia (in the positive phase). The related mode of tropical precipitation variability is associated with tropical Pacific SST anomalies and is closely linked to the El Nino/Southern Oscillation (ENSO). The second MCA mode consists of weaker tropical precipitation anomalies but a stronger extratropical signal which reflects internal atmospheric variability. The teleconnection mechanism is tested in barotropic model simulations, which indicate that the observed link between the dominant mode of tropical precipitation and the Euro-Atlantic circulation anomalies is largely consistent with linear Rossby wave dynamics. The barotropic model response consists of a circumglobal wave-train in the extratropics that is primarily forced by divergence anomalies in the eastern tropical Pacific. Both the eastward and westward group propagation of the Rossby waves are found to be important in determining the circulation response over the Euro-Atlantic sector. The mechanism was also analysed in an operational seasonal forecasting system, ECMWF's System 4. Whilst System 4 is well able to reproduce and skillfully forecast the tropical precipitation, the extratropical circulation response is absent over the Euro-Atlantic region, which is likely related to biases in the Asian jetstream.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-26)

Observational evidence of European summer weather patterns predictable from spring

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Forecasts of summer weather p+I2atterns months in advance would be of great value for a wide range of applications. However, seasonal dynamical model forecasts for European summers have very little skill, particularly for rainfall. It has not been clear whether this low skill reflects inherent unpredictability of summer weather or, alternatively, is a consequence of weaknesses in current forecast systems. In Ossó et al. 2017 we analyze atmosphere and ocean observations and identify evidence that a specific pattern of summertime atmospheric circulation––the summer East Atlantic (SEA) pattern––is predictable from the previous spring. An index of North Atlantic sea-surface temperatures in March–April can predict the SEA pattern in July–August with a cross-validated correlation skill above 0.6. Our analyses show that the sea-surface temperatures influence atmospheric circulation and the position of the jet stream over the North Atlantic. The SEA pattern has a particularly strong influence on rainfall in the British Isles, which we find can also be predicted months ahead with a significant skill of 0.56. Our results have immediate application to empirical forecasts of summer rainfall for the United Kingdom, Ireland, and northern France and also suggest that current dynamical model forecast systems have large potential for improvement. We will also report the results of recent work, which has provided more detailed insight into the seasonal evolution of the atmospheric response, and the processes involved.

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SESSION: (B1) Mechanisms of S2D predictability

(P-B1-27)

Wind-Driven Hindcasts with the Kiel Climate Model: Variability and Teleconnections

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Wind stress is an important driver of ocean and sea ice variability, sometimes involving also a feedback to the atmosphere. A prominent example is the El Niño/Southern Oscillation (ENSO). Wind stress anomalies are just one element of the Bjerknes feedback that links anomalies in the atmosphere, the surface and sub-subsurface ocean. ENSO shows how wind stress acts as an important element of recurring climate modes, particularly on the interannual timescale. Similar processes operate on decadal timescales, as, for example, during the recent global warming hiatus, which was shown to be reproduced by a coupled model when forced by observed wind stress in the tropical Pacific. Thus, wind stress forcing of the ocean circulation is important to understand climate predictability on a wide range of timescales, from seasonal to decadal.

We perform hindcast ensembles with the Kiel Climate Model (KCM) driven with daily wind stress anomalies from the ERA-20C reanalysis covering the period 1900-2010. By comparing the variability of the ensemble mean to observations, we identify those components of climate variability that are forced by wind stress. Local and remote effects are considered. The latter can be established through teleconnections either via the ocean circulation or an atmospheric bridge. Most influence of the wind stress on sea surface temperature and sea level pressure is found in the tropics. In the extratropics, the wind stress explains more than half of the monthly variability in the Atlantic Meridional Overturning Circulation (AMOC) index at 26°N.

Ensemble simulations in which the wind stress forcing is restricted to certain ocean basins are also conducted. It is shown, for example, that the wind stress over the tropical Pacific is most important in explaining the observed variability not only over the tropical Pacific but also the tropical Indian Ocean where no wind stress forcing was applied.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-28)

Impacts of the Atlantic Multidecadal Variability on North American Summer Climate and Heat Waves

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The impacts of the Atlantic multidecadal variability (AMV) on summertime North American climate are investigated using three coupled global climate models (CGCMs) in which North Atlantic sea surface temperatures (SSTs) are restored to observed AMV anomalies. Large ensemble simulations are performed to estimate how AMV can modulate the occurrence of extreme weather such as heat waves.

It is shown that, in response to an AMV warming, all models simulate a precipitation deficit and a warming over northern Mexico and the southern United States that lead to an increased number of heat wave days by about 30% compared to an AMV cooling. The physical mechanisms associated with these impacts are discussed. The positive tropical Atlantic SST anomalies associated with the warm AMV drive a Matsuno–Gill-like atmospheric response that favors subsidence over northern Mexico and southern United States. This leads to a warming of the whole tropospheric column, and to a decrease in relative humidity, cloud cover, and precipitation. Soil moisture response to AMV also plays a role in the modulation of heat wave occurrence. An AMV warming favors dry soil conditions over northern Mexico and the southern United States by driving a year-round precipitation deficit through atmospheric teleconnections coming both directly from the North Atlantic SST forcing and indirectly from the Pacific. The indirect AMV teleconnections highlight the importance of using CGCMs to fully assess the AMV impacts on North America.

Given the potential predictability of the AMV, the teleconnections discussed here suggest a source of predictability for the North American climate variability and in particular for the occurrence of heat waves at multiyear time scales .

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-29)

Atmospheric and oceanic sinks of Arctic predictability

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(1) ECMWF, UK, University of Reading, UK (2)

Uncertainty of Arctic seasonal to interannual predictions arising from model errors and initial state un- certainty has been widely discussed in the literature, whereas the irreducible forecast uncertainty (IFU) arising from the chaoticity of the climate system has received less attention. However, IFU provides important insights into the mechanisms through which predictability is lost and hence can inform prioritization of model development and observations deployment. Here, the authors characterize how internal oceanic and surface atmospheric heat fluxes contribute to the IFU of Arctic sea ice and upper-ocean heat content in an Earth system model by analyzing a set of idealized ensemble prediction experiments. It is found that atmospheric and oceanic heat flux are often equally important for driving unpredictable Arctic-wide changes in sea ice and surface water temperatures and hence contribute equally to IFU. Atmospheric surface heat flux tends to dominate Arctic-wide changes for lead times of up to a year, whereas oceanic heat flux tends to dominate regionally and on interannual time scales. There is in general a strong negative covariance between surface heat flux and ocean vertical heat flux at depth, and anomalies of lateral ocean heat transport are wind driven, which suggests that the unpredictable oceanic heat flux variability is mainly forced by the atmosphere. These results are qualitatively robust across different initial states, but substantial variations in the amplitude of IFU exist. It is concluded that both atmospheric variability and the initial state of the upper ocean are key ingredients for predictions of Arctic surface climate on seasonal to interannual time scales.

SESSION: (B1) Mechanisms of S2D predictability

(P-B1-30)

How much surface soil moisture influence precipitation predictability?

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GIST, Korea (1), Cheonnam National University, Korea (2), KOPRI, Korea (3)

In this study, we attempt to assess the relative influence of soil moisture memory and tropical sea surface temperature (SST) in seasonal rainfall over the contiguous United States and other part of the world. Using observed precipitation, the NINO3.4 index and soil moisture and evapotranspiration simulated by a land surface model for 61 years, analysis was performed using partial correlations to evaluate to what extent land surface and SST anomaly of El Niño and Southern Oscillation (ENSO) can affect seasonal precipitation over different regions and seasons. Results show that antecedent soil moisture is as important as concurrent ENSO condition in controlling rainfall anomalies over the U.S., but they generally dominate in different seasons with SST providing more predictability during winter while soil moisture, through its linkages to evapotranspiration and snow water, has larger influence in spring and early summer. The proposed methodology is applicable to climate model outputs to evaluate the intensity of land-atmosphere coupling and its relative importance.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-01)

Toward Improvement in Seasonal Forecasting in the Southwest United States Using Regional Climate Product at Convective-Permitting Scale

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University of Arizona (1), University of Illinois (2)

Accurate regional and local scale information about seasonal climate variability and its impact on water availability is important in many practical applications like agriculture, water resource planning, long term decision making etc. Presently, the primary source for real time seasonal climate forecast comes from the Climate Prediction Center (CPC) within the NOAA National Center for climate Prediction (NCEP) which uses its model forecast component (CFSv2) of North American Multi-Model Ensemble (NMME). However, it has been observed that in comparison to the cool season, the level of skill in warm season seasonal forecasts of precipitation produced by the NMME is much lower due to the poor climatological representation of warm season convective precipitation. To fully realize the potential in improving warm season seasonal forecasts using a dynamical modeling approach requires dynamical downscaling of NMME models to better improve their representation of convective precipitation. Specifically, a convective-permitting (3km) scale is required to explicitly represent thunderstorms in a regional model. Also, for basin scale study, coarse resolution models must be downscaled to create high spatial resolution information for efficient hydrologic forecasting. Driven by these motivations, this study addresses towards a method useful to improve the seasonal forecasting and to get reliable precipitation and streamflow projection for use in practical purposes. Reanalyses of Climate Forecast System (CFSR) is used for purpose of creating initial conditions for creating initial conditions for CFSv2 retrospective forecasts. CFSR is dynamically downscaled to analyze the credibility of Regional Climate Model products when seasonality and interannual variability of mean and extreme precipitation is concerned. A decade long (2000-2010) dynamically downscaled RCM simulation is generated using Weather Research and Forecasting model (WRF) with a 12-km spatial resolution covering the Colorado River basin by dynamically downscaling CFSR data. An additional convective-permitting nested domain (3 km resolution) is included for the WRF simulation for specific sub basins of Southwest U.S region. In this study, we have shown the improvement of convective permitting model product in representing mean climatology as well as climatology of extreme precipitation events in Upper and Lower Colorado basin. It is evident that use of regional model adds value to the reanalyses in terms to better spatial and temporal representation which is also consistent with previous studies. Hence it appears to be an important initial step towards seasonal to subseasonal (S2S) forecasting using downscaled product from global CFS forecast models.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-02)

Developing the next-generation operational seasonal forecast system at JMA

Shoji, Hirahara (1,2), H. Sugimoto (1,2), I. Ishikawa (1,2), T. Komori (1,2), T. Toyoda (2), Y. Adachi (1,2), Y. Kubo (1,2), Y. Fujii (2)

JMA, Japan(1), MRI, Japan(2)

This talk will give an overview of the next generation seasonal forecast system at the Japan Meteorological Agency.

The system will employ a higher resolution atmosphere/land/ocean/sea ice sub-models than the current operational system, JMA/MRI-CPS2.

The ocean initial conditions are generated with 4DVAR and a newly introduced sea-ice assimilation scheme.

An eddy-permitting ocean resolution improves the representation of tropical instability waves and the equatorial Pacific cold tongue bias.

Some preliminary results are presented.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-03)

A comparison of CCSM4 high-resolution and low-resolution predictions for south Florida drought

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Precipitation has implications for hydrological, ecological, and water management activities in the Florida Everglades. Climate data users in south Florida, particularly those involved with Everglades restoration, desire climate information at a higher spatial resolution than is typically available in most climate models, and a more complete representation of the physical processes leading to precipitation. As precipitation can influence many activities in south Florida and the Florida Everglades, it is important to have confidence in seasonal climate predictions of precipitation, particularly related to drought as the implications can be far reaching and costly. However, many of the leading climate prediction models and suites have coarse atmosphere and ocean resolutions. Florida precipitation can vary on resolutions much finer than 1°, and oceanic drivers of Florida precipitation may need to be better represented, including meso-scale variability, to correctly represent precipitation variability that is coupled to local oceanic variability. Here, we examine the influence of increasing the horizontal resolution of global climate models on south Florida drought predictions. Though an 0.5° atmosphere is still too coarse for most climate data users in south Florida, our goal is to determine if the increased resolution results in better skill and representation of drought events over south Florida than 1.0° atmosphere 1.0° ocean predictions. Implicit to this is what we might gain by using a high-resolution global model for climate predictions, and if that gain is worth the resources for south Florida.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-04)

The post-processing chain of GCFS seasonal forecast data for C3S

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Deutscher Wetterdienst, Germany (1)

The Deutscher Wetterdienst (German meteorological service) contributes seasonal forecasts with its German Climate Forecast System (GCFS) to the Copernicus Climate Change Service (C3S). This offers an opportunity to provide standardized data in a comfortable way to users with different scientific backgrounds. Furthermore the data will be easily comparable to those of other centers.

For this purpose the forecast data output needs to be adjusted to the common data specifications which are particularly designed to satisfy the needs of this climate service according to C3S demands. The specifications include a list of requested variables and an extensive standard for the metadata to ensure an overall consistency of the data from all provided models.

The conversion of data into a designated data format needs special care. For instance, for an operational service it is not sufficient to create data fields which are comparable by spatial and temporal resolution. Alongside to the data fields, also metadata must be provided to supply the users with adequate information about the processed data, the producer and the model from which the data originates.

It is also important to precisely describe the parameters in order to avoid misinterpretation of the data fields or errors. Users should be aware of such features when applying these data. For example how snow cover over Greenland is interpreted, which soil layer scheme is used or for which layer depth or height certain parameters are defined.

By presenting the full chain of data post processing we highlight the importance of this work as a bridge between the forecast production and the final product which is made available to the user.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-05)

A skill assessment of the extratropical circulation in the high-res and low-res MiKlip decadal prediction system

Kadow, Christopher (1), Grieger, Jens (1), Illing, Sebastian (1), Schartner, Thomas (1), Schuster, Mareike (1), and Ulbrich, Uwe (1)

Freie Universität Berlin, Germany (1)

The development of skillful decadal forecast systems is ongoing research in different institutions around the globe. In this study we assess the change of decadal forecast skill with respect to the extratropical circulation and synoptic variability. We investigate different model resolutions of the MiKlip (fona-miklip.de) decadal prediction system simulated with MPI-ESM-LR and MPI-ESM-HR, the German contribution to CMIP6 and the Decadal Climate Prediction Project (DCPP). Therefore, a collection of three different metrics, which assess extratropical synoptic weather systems, is applied to the mentioned decadal prediction datasets. Two of the synoptic assessment methodologies are based upon a Lagrangian approach, objectively identifying and tracking extratropical cyclones (Murray & Simmonds, 1991) and windstorms (Leckebusch, 2008) respectively. The third approach is an Eulerian one, and uses the definition of the extratropical stormtrack (Blackmon, 1976). All used synoptic measures as well as the skill metrics are part of the Freie Universität Berlin evaluation system (Freva; www-miklip.dkrz.de). With the refinement in horizontal and vertical resolution, the forecast skill for all three circulation measures in terms of anomaly correlation increases significantly, especially along the North-Atlantic storm track.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-06)

Stochastic subgrid turbulence parameterisation maintaining resolution independent statistics for all spatial scales over decadal timescales

Kitsios, Vassili (1), Frederiksen, Jorgen S. (2)

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In decadal prediction there is the ever-growing need for larger ensembles of general circulation models to properly sample the possible events, whether it be for data assimilation or ensemble prediction applications. This increases the computational expense to make predictions of the system for a given period. However, our stochastic subgrid parameterisation framework alleviates this computational burden by producing lower resolution models that reproduce the statistics of a higher resolution reference case for all spatial scales over decadal timescales and beyond.

The subgrid parameterisation coefficients are calculated from the statistics of higher resolution reference direct numerical simulations (DNS) truncated into resolved and unresolved scales. For each longitudinal and meridional wavenumber pair, the stochastic model consists of a deterministic drain dissipation matrix acting on the resolved transient fields and a stochastic backscatter force, which together represent the transient interactions between the subgrid and resolved eddies (Frederiksen & Kepert, 2006). The drain matrix captures the coupling between the vertical levels. The subgrid interactions also introduce a meanfield shift. This meanfield shift is additionally decomposed into various components. The first component parameterises the interactions between the subgrid eddies and resolved meanfield and is linearly proportional to the latter. The second component is a nonlinearly function of the resolved meanfield and represents the interactions between it and the subgrid meanfield. The final term parameterises the interactions between the subgrid eddies and the resolved topography and is linearly proportional to the topography. This decomposition is achieved by applying an extended version of the regression method of Kitsios et. al. (2014) to a series of model generated climate states.

This stochastic representation of the subgrid interactions is validated by producing large eddy simulations (LES) of the atmosphere that agree with the reference DNS on the basis of time averaged kinetic energy spectra, zonal jet structure, and non-zonal streamfunction fields. As compared to the DNS of truncation wavenumber 63, successful LES are produced with truncation wavenumbers 31 and 15, which represent a reduction in computational expense of 87.5% and 98.4%, respectively. The latter LES is particularly impressive as it not only represents the drain of energy out of the system due to the subgrid interactions, but also the injection of energy associated with the unresolved baroclinic instability. The contribution of each of the subgrid model components (eddy-eddy, eddy-meanfield, meanfield-meanfield, eddy-topographic) to the quality of the LES is identified. Exact agreement is only achieved when all of the components are included.

In addition to producing resolution independent statistics, this stochastic subgrid parameterisation approach has also been previously shown to assist in maintaining ensemble spread. This approach has also been successfully applied to oceanic flows and three-dimensional boundary layers. In fact, it is a general framework applicable to any multi-scale nonlinear system.

References:

Frederiksen, J.S. & S. M. Kepert, 2006, Dynamical subgrid-scale parameterizations from direct numerical simulations. J. Atmos. Sci., 63, 3006-3019.

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SESSION: (B2) Modelling issues in S2D prediction

(P-B2-07)

Representation of NAO/PNA activity reliant on ENSO phase in dynamical seasonal prediction models

Lee, Yun-Young

APEC Climate Center, Rep. of Korea

The North Atlantic Oscillation (NAO) and Pacific-North American (PNA) patterns are major atmospheric modes over North Atlantic and North Pacific basin; the phases and amplitudes of these modes have huge impacts on human life by altering regional to national weather including temperature and rainfall extremes. The activity of two atmospheric modes is strongly dependent on leading oceanic mode that is El Niño Southern Oscillation (ENSO). PNA is mainly forced by tropical Pacific sea surface temperature (SST) and convection changes associated with ENSO. Thus, positive PNA is more frequent during El Niño while negative PNA is more frequent during La Niña. On the contrary, negative NAO tends to coincide with El Niño as other studies have suggested. An assessment of simulated NAO/PNA and their linkage to ENSO is essential for the future success of predicting weather extremes in addition to modes themselves. Main focus of this study is to investigate how well the observed ENSO dependency of NAO/PNA activity is replicated in 9 operational dynamical seasonal prediction models of the APEC Climate Center multi-model ensemble.

The correlation coefficient analysis for the northern-hemisphere winter season (Dec-Jan-Feb) from 1983/84 to 2004/05 reveals that most 9 models have larger coefficients between monthly Niño3.4 and PNA/NAO index compared to the observation. This study also analyzes the density distribution of NAO/PNA index during 8 El Niño and 7 La Niña years. In the observation, one notable feature is that atmospheric mode activity is not symmetric between El Niño and La Niña. The strength of PNA median is much weaker during La Niña compared to during El Niño, although it shows opposite sign between two ENSO phases. Even NAO is not symmetric at all. The sign of NAO median during La Niña is the same with the sign during El Niño. However, regardless of mode, models display clear symmetry of atmospheric activity between two ENSO phases. The results demonstrate that seasonal prediction models tend to not only overestimate the relationship between ENSO and PNA/NAO strength but also intensify the symmetry of PNA/NAO activity between ENSO phases. Oceanic/atmospheric mean field composites of El Niño and La Niña years are also diagnosed for 9 individual models in order to investigate the underlying dynamics responsible for the deficiencies in representing NAO/PNA activity associated with ENSO.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-08)

Assessing Seasonal Predictability Sources in the Climate Forecast System Version 2

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University of Illinois

Seasonal prediction is of considerable socioeconomic value as the products may be utilized across many sectors (e.g. energy, agriculture, public health, etc.). In order to improve our current forecast capabilities, models must be continuously assessed in order to discover where improvements can be made. One particular focus is to identify sources of predictability and evaluate their representations in operational models. Low frequency climate modes are a key source of predictability on the seasonal time scale, and such modes may modulate prediction skill of the extratropical atmosphere. Here, the representation of two low-frequency climate modes, the ENSO and the NAO, are examined in the Climate Forecast System Version 2 (CFSv2) using the reforecasts from 1982-2010.

The predictability of these modes is discussed, and deficiencies in the teleconnections are explored. The ENSO is highly predictable, as expected, however there are some errors in the representation. In particular, an eastward shift in the ENSO warm tongue (convection zone) is evident. This eastward shift leads to an eastward shift in the Pacific North American pattern. Although this may look small on a global scale, it has important implications for regional climate anomalies. We find, as previous studies have found, that the model poorly predicts the NAO. Since statistical and dynamic models have predicted NAO with large skill a season to a year in advance, it led us to question what sources of NAO predictability are not well represented and where a disconnection may be evident within the CFSv2. Here, we analyze the representation of northern hemispheric sea surface temperature and the stratosphere during NAO winters, and large differences between the “truth” and prediction were found in both the sea surface temperature and the stratosphere, leading us to believe that these sources of NAO predictability are broken within the model. We also examine how these two low-frequency climate modes modulate the prediction skill of the northern hemispheric geopotential height fields, as well as a domain over the North Atlantic. Results show statistically significant changes in predictive skill during different phases of ENSO and NAO.

This study aims to analyze a model that is part of several collaborative efforts to improve subseasonal to seasonal prediction, as well as assisting NCEP in making improvements to the CFSv2.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-09)

Building a set of ocean observations for the initialisation and validation of the Climate Analysis Forecast Ensemble (CAFE) system

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CSIRO Oceans and Atmosphere, Australia (1)

A probabilistic dynamical prediction consists of integrating an ensemble of climate models forward in time from a set of initial conditions constrained to the current climatic state by observations. Therefore, skilful multi-year climate prediction relies on both the development of coupled ocean-atmosphere climate models in combination with advanced approaches to forecasting and a comprehensive set of underpinning observations.

The technologies comprising ocean observing systems include a wide array of instruments and platforms. The observation platforms broadly include, moored buoys and drifters, radar stations, satellites, floats, dedicated manned and unmanned vehicles, and platforms and vessels of opportunity. New or improved ocean-observing satellites and in situ sensors and platforms, coupled with advances in telecommunications, are continuously becoming available for improving the ocean observation system. During the last decade, the use of autonomous in situ platforms has revolutionized the ocean observing system, and the fast, technological advance on platforms and sensors (including biogeochemical sensors) will continue to improve the system. Satellites, moored buoys, and floats (e.g. Argo) make up much of the current generation of improvements in ocean observing systems.

The heterogeneous nature of the ocean observing system requires a sophisticated data integration and interpretation activity for all available in situ and satellite observations. In the CSIRO CAFE system, the Observations and Processes team provide integrated satellite and in situ observational ocean data sets for initialising the ocean model of the forecasting system, provide withheld data sets and produce data products for model validation and, provide process resolving observations to inform model physics assessments and dominating ocean dynamics. Here we present a comprehensive review and assessment of the observations used in the CSIRO CAFE system for data assimilation and model validation.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-10)

Prospects for Year 2 climate forecasts with useful skill

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The US recently passed the Weather Research and Forecasting Innovation Act of 2017, which defines S2S forecasts as weather forecasts with leads between two weeks and two years. However, most operational seasonal forecasting has been aimed at leads ranging from 1-12 months, and most experimental decadal forecasting has been aimed at leads going well beyond 2 years, often focusing more on multi-year means (e.g., forecasts for averaged anomalies over years 2-5). Considerably less attention has been paid to the intermediate forecast range of months 13-24, or "Year 2". Yet we might expect forecast skill from Year 2 to be the dominant contributor to multiyear skill of initialized decadal forecasts, and the effects of deeper ocean model errors may also be less impactful for this forecast lead than for decadal forecasts. There are also sources of memory within internal climate variability (e.g., extratropical re-emergence of mixed layer anomalies, land surface memory, multi-year La Niñas) that may provide predictability primarily on year-to-year time scales.

In this talk we assess the current state of "Year 2" forecast skill from hindcast databases generated by both operational and CMIP5/6 coupled general circulation models (CGCMs). We also compare this CGCM skill to two different alternative forecast techniques: (1) a linear inverse model (LIM), a linear empirical dynamical model trained solely on the 1-month lag covariance matrix of observed sea surface temperature (SST) and sea surface height (SSH) global anomalies from 1961-2010; and (2) a "model-analog" technique, which finds analogs to the same observed SST and SSH anomalies, not within observations but rather within long [O(500 yrs)] CGCM uninitialized simulations. We find that both the LIM and model-analogs have Year 2 hindcast skill that is considerably greater than the initialized CGCM hindcasts, suggesting both that improvement in Year 2 skill is possible, even with current models, and that S2D research should include a specific focus aimed at the Year 2 problem.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-11)

Influence of CMIP6 Forcing on Historical and Decadal Hindcast Simulations with MPI-ESM

"Pohlmann, Holger (1), Bittner, Matthias (1), Wieners, Karl-Hermann (1), Modali, Kameswarrao (1), Kadow, Christopher (2), Illing, Sebastian (2), Pankatz, Klaus (3), Müller, Wolfgang A. (1,3), and Marotzke, Jochem (1)"

Max Planck Institute for Meteorology, Germany (1), Freie Universität Berlin, Institute of Meteorology, Germany (2), German Weather Service, Germany (3)

In this study we compare an ensemble of historical simulations using CMIP5 external forcing, performed within the German Medium-term Climate Predictions (MiKlip – fona-miklip.de) project, with another ensemble using CMIP6 forcing performed for the contribution to the CMIP6. Both ensembles are produced using the same high-resolution version of our Max Planck Institute Earth-System Model (MPI-ESM-HR). The analysis of the model performance and uncertainties of different metrics and trends is applied to the complete historical period (1850-2005) as well as sub-periods (e.g., 1960-2005) to account for the increase of observations. Furthermore, we compare two ensembles of decadal hindcast simulations with each other, also produced with the same MPI-ESM-HR model, using either CMIP5 or CMIP6 forcing. The analysis includes different state-of-the-art prediction skill metrics for decadal climate hindcast evaluation. To account for the small ensemble size the significance of the results is an issue. We estimate the impact of the initialization by comparing the prediction skill rising from the external forcing in the historical simulations with the prediction skill in the decadal hindcast simulations. The comparison of the results caused by the different external forcing bears us the unique possibility to systematically evaluate the impact of the change from CMIP5 to CMIP6 forcing on MPI-ESM simulations.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-12)

Tropical SSTs: The Boon and Bane of S2D predictions

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Much of the potential for predictability on S2D scales rests on the accurate representation and predictability of tropical SSTs, whose worldwide impacts occur through the Hadley and Walker circulations and forced planetary Rossby waves. Model misrepresentations of the magnitudes and patterns of tropical SST changes on S2D scales thus have important consequences. The sensitivities of remote teleconnections to SST errors at different tropical locations may be estimated from the global responses to prescribed localized SST anomalies in atmospheric models. Such investigations yield in effect a "Fuzzy Green's Function" of the global atmospheric response to tropical SST forcing, and have been conducted by prescribing 42 regularly spaced localized tropical SST patches as anomalous boundary conditions in the NCAR and ECHAM5 models. The dominant EOF patterns of the 42 responses, and the relative magnitudes with which they are excited by the individual patches, determine the dominant pairs of response and forcing (formally, the left and right singular vectors of the Green's function operator). The dominant SST patterns can be interpreted both as major sources of S2D predictability and as patterns of tropical SST forecast errors to which the errors in remote regions are most sensitive.

The dominant SST sensitivity pattern (which is different for every season) has a very different structure from the dominant ENSO pattern of observed SST variability, and has the largest magnitudes but opposite signs in the western and eastern halves of the Indo-Pacific warm pool. It is therefore particularly important for models to predict SSTs accurately in this region, which they currently do not. Specifically, on the seasonal scale, the NMME models used for seasonal predictions extend the predicted central Pacific SST anomalies during ENSO events too far westward into the warm pool. On decadal and longer scales, the CMIP5 models underestimate the magnitude and misrepresent the spatial variation of tropical SST changes, and hence the magnitude of the atmospheric circulation changes (including changes in weather extremes) in most regions of the globe. By underestimating the changes in SST gradients, the models exaggerate the relatively robust regional thermodynamic aspects of the changes on these time scales over the equally important dynamic circulation aspects that are much less robust and spuriously weak in the models.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-13)

EnOI-IAU initialization scheme designed for decadal climate prediction system IAP-DecPreS

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A decadal climate prediction system named as IAP-DecPreS was constructed, based on a coupled model FGOALS-s2 and a newly developed initialization scheme, referred to as EnOI-IAU. We introduce the design of the EnOI-IAU scheme, assess the accuracies of initialization integrations using the EnOI-IAU and preliminarily evaluate hindcast skill of the IAP-DecPreS. The EnOI-IAU scheme integrates two assimilation approaches, ensemble optimal interpolation (EnOI) and incremental analysis update (IAU).

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-14)

Decadal Prediction Skill of BCC-CSM1.1 Climate Model in East Asia

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Improved decadal prediction skill is found for summer surface air temperature in central China for the forecast years 2-5 by BCC-CSM1.1. This is related to enhanced prediction skill of the western tropical Pacific SST. The mechanism analysis shows that BCC-CSM1.1 could more realistically reproduce the relationship between East Asian circulation and western tropical Pacific SST through the initialization.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-15)

Warm Season Forecast Experiments with Different Treatments on Ground Water and Evaporative Parameterizations in the NCEP Coupled Forecast System

Yang, Rongqian (1), Ek, Michael (2), Chen, Fei (3), Barlage, Michael (4), Yang, Zong-liang (5)

EMC/NCEP, USA (1), NCAR, USA (2), NCAR, USA (3), NCAR, USA (4), UT-Texas, USA (5)

Skillful short-term weather forecasts, which rely heavily on quality atmospheric initial conditions, have a fundamental limit of about two weeks owing to the chaotic nature of the atmosphere. Useful forecasts at subseasonal to seasonal time scales, on the other hand, require well-simulated large-scale atmospheric response to slowly varying lower boundary forcings from both ocean and land surface. The critical importance of ocean has been recognized, the ocean indices have been used in a variety of climate applications. In contrast, impact of land surface anomalies, especially soil moisture and associated evaporation, has been proven notably difficult to demonstrate.

The Noah Land Surface Model (LSM) is the land component of NCEP CFS used for seasonal predictions. The Noah LSM originates from the Oregon State University (OSU) LSM. The evaporation control in the Noah LSM is based on the empirical Penman-Monteith equation, which takes into account the solar radiation, relative humidity, and soil moisture effects. The Noah LSM is configured with four soil layers with a fixed depth of 2 meters and free drainage at the bottom soil layer. This treatment assumes that the soil water table depth is well within the specified range. The treatment also potentially misrepresents the soil moisture memory effects at seasonal time scales.

To overcome ground water treatment limitation, an enhanced version of Noah Multiple Parameterization (Noah MP) LSM was developed. In the Noah MP LSM, an unconfined aquifer is attached to the bottom of the soil to allow the water table move freely up and down. In addition, an alternative Ball-Berry photosynthesis-based evaporation parameterization is available to examine the impact using a different evaporation control methodology.

To examine the impact of the physics treatments in the Noah LSMs on seasonal predictions, warm season ensemble CFS experiments were carried out for selected nine years comprising three ENSO warm, cold, and neutral years, the CFS skills in predicting SST, precipitation and T2m anomalies are compared. In addition, focusing on the 2011 and 2012 intense summer droughts in the central US, seasonal ensemble forecast experiments with early May initial conditions are also carried out for the two years. The differences in predicting precipitation and T2m anomalies with different parameterization treatments will be presented and reasons will be discussed.

SESSION: (B2) Modelling issues in S2D prediction

(P-B2-16)

Precipitation from Tropical Cyclones: High-resolution Simulations and Seasonal Forecast

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This study examines the performance of Geophysical Fluid Dynamics Laboratory (GFDL) Forecast-Oriented Low Ocean Resolution version of CM2.5 (FLOR; ~50-km mesh) and high-resolution FLOR (HiFLOR; ~25-km mesh) in reproducing the climatology and interannual variability in rainfall associated with of tropical cyclones (TCs) in both sea surface temperature (SST)-nudging and seasonal-forecast experiments. Overall, HiFLOR outperforms FLOR in capturing the climatology of TC rainfall, in particular in East Asia, North America and Australia. In general, FLOR and HiFLOR underestimate the observed TC rainfall in the coastal regions along the Bay of Bengal because of their limited capability in simulating the bimodal structure of the TC genesis seasonality. Overall, the good performance of HiFLOR and FLOR in capturing the climatology of TC rainfall may arise from their performance in simulating the climatology of TC density. Overall, while HiFLOR leads to a better characterization of the areas affected by TC-rainfall, the SST-nudging and seasonal-forecast experiments with both models show limited skill in reproducing the year-to-year variation in TC rainfall.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-01)

Grand European and Asian-Pacific Multi-model Seasonal Forecasts: Maximization of Skill and of Potential Economical Value to End-users

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Multi-Model Ensembles (MMEs) are powerful tools in dynamical climate prediction as they account for the overconfidence and the uncertainties related to single-model ensembles. Previous works suggested that the potential benefit that can be expected by using a MME amplifies with the increase of the independence of the contributing Seasonal Prediction Systems. In this work we combine the two MME Seasonal Prediction Systems (SPSs) independently developed by the European (ENSEMBLES) and by the Asian-Pacific (APCC/CliPAS) communities. To this aim, all the possible multi-model combinations obtained by putting together the 5 models from ENSEMBLES and the 11 models from APCC/CliPAS have been evaluated.

The grand ENSEMBLES-APCC/CliPAS MME enhances significantly the skill in predicting 2m temperature and precipitation compared to previous estimates from the contributing MMEs. Our results show that, in general, the better combinations of SPSs are obtained by mixing ENSEMBLES and APCC/CliPAS models and that only a limited number of SPSs is required to obtain the maximum attainable performance. The number and selection of models that perform better is usually different depending on the region/phenomenon under consideration so that all models are useful in some cases. It is shown that the incremental performance contribution tends to be higher when adding one model from ENSEMBLES to APCC/CliPAS MMEs and vice versa, confirming that the benefit of using MMEs amplifies with the increase of the independence the contributing models.

To verify the above results for a real world application, the Grand ENSEMBLES-APCC/CliPAS MME is used to predict retrospective energy demand over Italy as provided by TERNA (Italian Transmission System Operator) for the period 1990-2007. The results demonstrate the useful application of MME seasonal predictions for energy demand forecasting over Italy. It is shown a significant enhancement of the potential economic value of forecasting energy demand when using the better combinations from the Grand MME by comparison to the maximum value obtained from the better combinations of each of the two contributing MMEs.

The above results demonstrate for the first time the potential of the Grand MME to significantly contribute in obtaining useful predictions at the seasonal time-scale and are discussed in a peer-review paper recently published on Climate Dynamics (Alessandri et al., 2017; doi:10.1007/s00382-016-3372-4).

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-02)

The Barcelona Supercomputing Center's contribution to the EUCP project

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The European Climate Prediction system project (EUCP) is a new Horizon 2020 project, which will develop an innovative European regional ensemble climate prediction system based on a new generation of improved and typically higher-resolution climate models, covering timescales from seasons to decades initialized with observations, and designed to support practical and strategic climate adaptation and mitigation decision-taking on local, national and global scales. In this communication, we will present the ongoing contribution of the Barcelona Supercomputing Center to EUCP. The BSC efforts center around two main areas: the aggregation of climate information sources and the generation of multi-model seamless uncertainty quantification for climate predictions at the regional scale. In the first case, we investigate techniques to better characterise the forecast uncertainty in climate predictions and in particular the advantage of the multi-model approach in the representation of that uncertainty in order to turn the large amount of raw simulations and information into actionable information in probabilistic form. We also evaluate the advantages of single-model calibration versus multi-model calibration in terms of forecast quality and investigate combining multiple forecast systems using methodologies based on past performance, with particular attention being paid to the prediction of extreme events. In the second case, we aim to develop methodologies to bring together initialised decadal climate predictions and non-initialised climate projections based on global climate models in order to provide seamless climate information for users over a period of 1 to 40 years into the future, with a focus on the European region. This is done by comparing the predictions based on global initialized and non-initialized simulations for common prediction time horizons and estimating the prediction time until which the initialized predictions show skill compared to non-initiliazed simulations for different large-scale and local variables. Finally, we also estimate the added-value of combining initialized forecast with non-initialized forecasts for certain regions and variables.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-03)

Predictability, information, and probabilistic skill in the CESM Decadal Prediction Large Ensemble

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The CESM decadal prediction large ensemble (DPLE) is a community dataset consisting of decadal hindcasts from 62 start dates with 40 ensemble members. The unprecedented scale of the DPLE allows the use of probabilistic forecast verification techniques from the weather and seasonal forecasting communities to assess the probabilistic decadal prediction skill. We firstly consider the limit of initial value predictability of upper ocean heat content in the DPLE. Potential predictability is assessed by measuring the information content of the DPLE compared to the uninitialized CESM large ensemble dataset. We find that the predictability timescale is dependent on ocean basin, but also on start date, with projections from some start-dates showing significant potential predictability beyond the 10-year forecast horizon.

We decompose the information content into ensemble mean and ensemble spread contributions. The information in the ensemble mean shows a large dependence on start date. The information in the ensemble spread initially varies little with start date, though this dependence on start date increases with increasing lead time. This indicates the DPLE does include information about state-dependent predictability, and particularly motivates improved initialization of decadal predictions, to better account for uncertainty in the initial conditions and short lead-time forecasts. We finally consider the skill of the DPLE at predicting surface temperature and precipitation over land, and find the potential for skill even out to ten-years, dependent on region and start date.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-04)

Initialized decadal predictions of the rapid warming of the North Pacific SSTs around 1990 and the persistent warm period in the 1990s

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Around 1990, the North Pacific Ocean (40°-50°N, 160°-200°E) underwent a rapid warming, with sea surface temperatures (SSTs) increasing by 2⍰ from 1988 to 1991, and then underwent a persistent warm period from 1991 to 1997. Corresponding to the changes in SST patterns, reanalysis data revealed that during the 1990s, there was a “SSW minimum” period. To be specific, no major SSWs were observed during the nine consecutive winters from 1989/1990 to 1997/1998. Moreover, a previous modeling study suggested that the enhanced North Pacific sea surface temperatures (SSTs) are unfavorable for the occurrence of the major sudden stratospheric warmings (SSWs). In particular, enhanced North Pacific SSTs lead to the formation of the negative western Pacific atmospheric teleconnection pattern -- specifically, a positive anomaly of the Aleutian low, which inhibits planetary wave propagation into the stratosphere.

The onset of major sudden stratospheric warmings has significant follow-on effects on surface weather and climate in the northern Hemisphere extratropical regions. As the anomalous circulation of a major sudden stratospheric warming propagate downwards into the troposphere over a period of several weeks, a negative phase of the Arctic Oscillation forms near the surface, which leads to a strong anomalous warm Arctic and cold Eurasia. Thus, successfully predicting North Pacific SSTs is likely important to predict stratospheric climate and surface climate over Arctic and Eurasia.

Here, the extent to which a climate prediction system initialized using observations of the ocean and atmosphere states is able to capture the observed changes in North Pacific sea surface temperatures (SSTs) in 1990s and other atmospheric variables is investigated. The decadal climate prediction system based on the stratosphere resolving atmosphere-ocean coupled Max-Planck-Institute Earth System Model (MPI-ESM) is used in this study, in the LR, MR and HR configurations.

It is demonstrated that, for all of the three versions of the Earth System Model, the ensemble hindcasts initialized at the end of 1987 capture the rapid rise in North Pacific SST around 1990 and the follow-up persistent warm period over 1991-1997, which are not captured by the uninitialized hindcasts. Furthermore, the ensemble-mean hindcasts initialized in 1987 are able to reproduce the observed features in atmospheric circulation related to the North Pacific warming, including the weakening of the Aleutian low in the troposphere (especially in HR configuration), and the strengthening and cooling of the stratospheric polar vortex (especially in LR configuration). These results show that, despite the generally low predictive skill in North Pacific Ocean, the decadal climate prediction system shows considerable skill at least in specific cases.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-05)

Another view on ensemble subsampling: Are more ensemble members always better?

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In seasonal prediction it is common to use the ensemble mean to estimate variables like the North Atlantic Oscillation (NAO). A common view is that in an estimation of the ensemble mean, more ensemble members deliver better results. Here, we challenge this view: By filtering the ensemble members with a statistical post-processing procedure, called ensemble sub-sampling, we can increase the prediction skill for meteorological variables like the NAO and with it connected fields over Europe. The subsampling mechanism chooses ensemble members of a dynamical model by evaluating their closeness to the NAO values gained from statistical predictors, evaluated before the start of the prediction.

To show the effect of ensemble subsampling, we describe the mechanism as a statistical-dynamical prediction. We merge the distribution given by the dynamical ensemble members with distributions generated from the statistical predictors and demonstrate how the decreased spread of the new statistical-dynamical prediction leads to a sharper prediction and with it in most cases to better prediction skill. Decisive is here apart from the forecast skill of the subcomponents also the balance between the spread of the distribution of the model and the predictors. Filtering the ensemble members by such a statistical post-processing procedure leads consequently to a reduction of noise. As an application we investigate the prediction of the NAO and connected variables over Europe during the last four decades.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-06)

Model selection for DeFoReSt: a strategy for recalibrating decadal predictions.

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Near-term climate predictions such as decadal climate forecasts are increasingly being used to guide adaptation measures. Due to the uncertainties in initial conditions of weather and climate, forecasts are framed probabilistically. One issue frequently observed for probabilistic forecasts is that they tend to be not reliable, i.e. the forecasted probabilities are not consistent with the relative frequency of the associated observed events. Thus, these kind of forecasts need to be re-calibrated. Moreover, decadal prediction models typically exhibit systematic errors like lead-time dependent uncondtional (drift) and conditional biases.

With DeFoReSt, we proposed a "Decadal Climate Forecast Recalibration Strategy", a parametric post-processing approach to tackle these problems. The original approach of DeFoReSt assumes third order polynomials in lead time to capture conditional and unconditional biases, second order for dispersion, first order for start time dependency. Here, we propose not to restrict orders a priori but use a systematic model selection strategy to obtain model orders from the data based on non-homogeneous boosting. We apply DeFoReSt with model selection to the MiKlip system (Germany's initiative for decadal prediction) to identify the relevant predictors for recalibrating this decadal prediction system.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-07)

Towards Dynamical Seasonal Forecasting of Extratropical Transition in the North Atlantic

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Extratropical transition can extend the threat of tropical cyclones into the mid-latitudes and modify it through expansion of rainfall and wind fields. Despite the scientific and socioeconomic interest, seasonal forecasting of extratropical transition has received little attention. The GFDL Forecast-Oriented Low Ocean Resolution (FLOR) model exhibits skill in seasonal forecasts of tropical cyclone frequency in the North Hemisphere. The high-resolution version of FLOR (HiFLOR) yields substantially improved skill in seasonal predictions of major hurricanes. Both models are employed for ensemble retrospective seasonal forecast experiments in the North Atlantic, representing one of the first attempts to predict the extratropical transition activity months in advance. Contrasting model performance sheds light on the influence of model resolution on seasonal prediction skills. A preliminary July-initialized twelve-member ensemble retrospective seasonal forecast experiment with HiFLOR exhibits retrospective skill in seasonal forecasts of basin-wide and regional ET activity relative to best track and reanalysis data. In contrast, the skill of HiFLOR in prediction of non-ET activity is limited. Future work targeted at improved prediction of non-ET storms provides a path for enhanced TC activity forecasting.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-08)

A conceptual prediction model for seasonal drought processes using atmospheric and oceanic standardized anomalies: application to regional drought processes in China

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Reliable drought prediction is fundamental for water resource managers to develop and implement drought mitigation measures. Considering that drought development is closely related to the spatial-temporal evolution of large-scale circulation patterns, we developed a conceptual prediction model of seasonal drought processes based on atmospheric and oceanic Standardized Anomalies (SA). Empirical Orthogonal Function (EOF) analysis is first applied to drought-related SA at 200 hPa and 500 hPa geo-potential height (HGT) and sea surface temperature (SST). Subsequently, SA-based predictors are built based on the spatial pattern of the first EOF modes. This drought prediction model is essentially the synchronous statistical relationship between 90-day-accumulated atmospheric/oceanic SA-based predictors and 3-month SPI (SPI3), calibrated using a simple stepwise regression method. Predictor computation is based on forecast atmospheric/oceanic products retrieved from the NCEP Climate Forecast System Version 2 (CFSv2), indicating the lead time of the model depends on that of CFSv2. The model can make seamless drought predictions for operational use after a year-to-year calibration. Model application to four severe regional drought processes recently in China indicates its good performance in predicting seasonal drought development, despite its weakness in predicting drought severity. Overall, the model can be a worthy reference for seasonal water resource management in China.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-09)

Interdecadal variability in seasonal forecast skill of Northern Hemisphere winters over the 20th century

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Seasonal hindcast experiments, using prescribed sea surface temperatures (SSTs), are analyzed for Northern Hemisphere winters from 1900 to 2010. Ensemble mean Pacific/North American index (PNA) skill varies dramatically, dropping toward zero during the mid-twentieth century, with similar variability in North Atlantic Oscillation (NAO) hindcast skill. The PNA skill closely follows the correlation between the observed PNA index and tropical Pacific SST anomalies. During the mid-century period the PNA and NAO hindcast errors are closely related. The drop in PNA predictability is due to mid-century negative PNA events, which were not forced in a predictable manner by tropical Pacific SST anomalies. Overall, negative PNA events are less predictable and seem likely to arise more from internal atmospheric variability than positive PNA events. Our results suggest that seasonal forecasting systems assessed over the recent 30 year period may be less skillful in periods, such as the mid-twentieth century, with relatively weak forcing from tropical Pacific SST anomalies.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-10)

Improved Seasonal Predictability of Droughts by Conditioning the Prediction on ENSO

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Currently, conventional 3 month standardized precipitation index (SPI) forecasts exhibit useful forecast skill only in lead month 1. By conditioning the seasonal drought prediction on El Niño-Southern Oscillation (ENSO) phases, we present an approach to exploit starting conditions known to increase forecast skill in lead month 1 and thereby produce useful forecasts of 3 month SPI up to lead month 4. SPI forecasts calculated from precipitation hindcasts of the Max Planck Institute Earth System Model are evaluated for winter over the period 1982-2013. We condition the prediction on two different ENSO phases and restrict the prediction to areas exhibiting significant lagged correlations of winter precipitation with Niño3.4 index. With this approach our 3 month SPI forecasts exhibit useful skill in the ENSO conditioned prediction of winter droughts in lead months 2 to 4 in equatorial South America and southern North America. On top, our results hint at possibilities to improve seasonal SPI forecasts in the aforementioned regions independent of an active ENSO by appropriate spatial averaging through the identification of hotspots of seasonal drought predictability.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-11)

Coupled reanalysis for forecast initialisation with an ETKF data assmilation system

Paul Sandery and Terence O'Kane

CSIRO

Coupled asynchronous data assimilation and state estimation is explored using covariances between atmosphere, ocean and sea-ice obtained from a 96 member climate model ETKF system. Assimilated observations include RADS altimetry; SST from NavOceano, AMSR-E, AMSR-2, Pathfinder and VIIRS; Surface salinity from SMOS and OSISAF seaice concentration. In-situ temperature and salinity is included from from Argo, CTD, PIRATA and TAO-Triton. We also explore weak and strongly coupled data assimilation and direct assimilation of JRA55 atmospheric reanalysis data. SST and SLA bias detection and correction schemes are incorporated. Reanalysis experiments are carried out from 2002-2018. Results show that the system has meaningful error-spread relationships and mainly constrains modes of the atmosphere and ocean relavant to climate reanalysis. Forecast innovation errors sampled over many assimilation cycles show the methods used here are appropriate for other coupled modelling systems in generating an ensemble of initial conditions and verification of system performance. The data assimilation framework is suitable for higher resolution coupled applications and provides a platform for nested downscaled coupled ensemble prediction.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-12)

Seasonal to multi-annual predictions of Asian summer monsoons using an atmosphere-ocean-sea ice-land coupled model

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Accurate predictions of Asian monsoons have been a great challenge for dynamical predictions since the Asian monsoons involve complex atmosphere-land-ocean interactions. The Japan Meteorological Agency (JMA) has made a continuous effort to improve predictive performance of its seasonal prediction systems with a focus on East Asia. This paper highlights a progress of JMA seasonal prediction systems and its application for further-long predictions. In the past decade, two versions of atmosphere-ocean coupled models were employed to operational seasonal and ENSO predictions at JMA, and they enhanced capability in predicting seasonal characteristics of Asian summer monsoons, such as the western North Pacific and East Asian monsoons and tropical cyclone activity. Based on the success, we explored the feasibility of further long predictions with the latest system (JMA/MRI-CPS2). Results of a large (52-member) ensemble prediction experiment over 37 years (1980-2016) first demonstrate successful predictions one-year ahead for the western North Pacific monsoon index (correlation of 0.50) and total tropical cyclone days (correlation of 0.39). In addition, we conducted preliminary multi-annual predictions during 30 years (1981-2010) with JMA/MRI-CPS2, and found remarkably high skills (correlation higher than 0.7) for year 2-5 surface temperature over a large part of East Asia. The predictability of the further long predictions originates from model's ability to represent inter-basin interactions to extend the predictability due to ENSO, global warming trend and decadal variability over the Indo-western Pacific. These results show great promise in operational seasonal to multi-annual predictions and imply its wide range of potential applications in the Asia.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-13)

North American summer heat waves and modulations from the North Atlantic simulated by an AGCM

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IRI, USA (1), LDEO, USA (2), LDEO, USA (3), IRI, USA (4), LDEO, USA (5)

Recurrent thermal regimes are identified over continental North America in summer by means of a k-means cluster analysis of daily maximum temperature simulated by ECHAM5 forced by historical SSTs for 1930-2013 and validated with reanalyses fields. Two regimes associated with broad continental warming and above average temperatures in the northeastern United States, respectively, are characterized by ridging anomalies over North America, Europe, and Asia that suggest correlated heat wave occurrences in these regions. Their frequencies are mainly related to both La Niña and warm conditions in the North Atlantic. In this perspective, ECHAM5 multi-member experiments forced by observed SSTs in all oceanic basins except in the North Atlantic, where are prescribed climatological SSTs and anomalous positive or negative SSTs mimicking the Atlantic Multidecadal Variability (AMV) phases, are next used to further examine the influence of seasonal-to-decadal (S2D) variability in the North Atlantic and most particularly the impact of AMV SST patterns on continental warming. The results obtained indicate that regime frequency changes are primarily controlled by Atlantic SST variability on all time scales beyond the seasonal cycle, whereas the intensity of temperature anomalies is impacted by AMV SST forcing through upper-tropospheric warming and enhanced stability suppressing rising motion during the positive phase of the AMV.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-14)

On the decadal predictions of flood events across the central United States

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The frequency of flood events has been increasing notably across large areas of the central United States over the past 50+ years. Analyses of the observational records can provide us with the improved understanding of the physical drivers that are responsible for the observed changes. Here we couple these insights with decadal predictions of temperature and precipitation, and examine the potential decadal predictability of the frequency of flood events at almost 300 U.S. Geological Survey stream gaging stations in the central United States. Analyses will focus on lead times ranging from 1 to 10 years, and compare and contrast the results based on raw and statistically-downscaled model data using different evaluation metrics.

SESSION: (B3) S2D ensemble predictions and forecast information

(P-B3-15)

Extending the seasonal predictability of statistical dynamical streamflow forecasts

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Seasonal streamflow forecasts facilitate water allocation, reservoir operation, flood risk management, and crop forecasting. They are generally obtained by forcing hydrological models with outputs from general circulation models (GCMs), or using large-scale climate indices as predictors in statistical models. In contrast, hybrid statistical-dynamical forecasts are still rare; while computationally efficient, their skill is largely unknown. Here, we conduct a systematic statistical forecasting of seasonal streamflow using eight GCMs from the North-American Multi-Model Ensemble, from 0.5 to 9.5 months ahead, at 290 streamgauges in the U.S. Midwest. Probabilistic forecasts are developed for low to high streamflow using predictors that reflect both climatic and anthropogenic influences. Results indicate that seasonal streamflow predictability can be considerably enhanced in all four seasons by including GCM forecasts of the climate and antecedent conditions. In contrast, streamflow forecast biases can be decreased in summer and fall by including predictors that reflect land use and water consumption.

SESSION: (B4) S2D forecasts for decision making

(P-B4-01)

Seasonal to interannual predictability and prediction of Atlantic hurricane activity

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Climate Forecast Applications Network (1), (2)

The quantification of hurricane risk on seasonal to decadal time scales is of substantial economic relevance to the financial sector. Climate-model based forecasting methods show very limited skill beyond about 4 months. The springtime ENSO 'predictability barrier' limits the skill ENSO and SST-based statistical forecasting methods of late summer hurricane activity to lead times no greater than one season. To assess whether there is any predictability of Atlantic hurricane activity at extended lead times, we undertook a comprehensive climate dynamics analysis to identify extended-range precursors to the seasonal Atlantic hurricane activity. We have identified strong systematic global and hemispheric circulation patterns in the troposphere and stratosphere (including QBO) and in sea level pressure that relate to North Atlantic tropical cyclone activity. Our analysis has identified an intriguing spike in global hurricane precursors at quasi-biennial leads of 24 to 26 months, and other long-lead predictors that complement seasonal forecasts of ACE and US landfalls made in December, March and May for the following Atlantic hurricane season.

SESSION: (B4) S2D forecasts for decision making

(P-B4-02)

Statistical prediction of minimum and maximum air temperature in the Western North America

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This work uses a statistical model based on canonical correlation analysis (CCA) to explore the seasonal predictions of minimum and maximum air temperature in the Western North America. The results indicate that statistical methods can provide modest predictability for seasonal anomalies of air temperature over much of the region, especially for the summer. It was used remote and local predictors to explore the predictability of minimum and maximum air temperature (Tmin and Tmax) over the Western North America. The first predictor variable field is sea surface temperature anomalies (SST) across the tropical and northern Pacific basin, representing the influence of large-scale climate variability patterns, which in turn affect local surface air temperature. The second predictor variable field is soil moisture (SM) anomalies, which is thought to exert a local or regional influence on temperatures near the surface by influencing the surface energy balance. These experiments indicate that both local and remote predictors influence the predictability of air temperature, and that this influence is dependent on the season that is being predicted as well as if the prediction is made for Tmin or Tmax. SST has a strong effect on the summer temperatures, but SM does not play any role in the variability. On the other hand, in the winter, both SM and SST have some ability to predict Tmin and Tmax. However, those two predictands also present some important differences: while SST influence both Tmin and Tmax, the influence is stronger for Tmin for both summer and winter. On the other hand, SM influences Tmax more strongly during winter, especially for lags of two and three months. The results exhibit positive forecast skill, but demonstrate considerable variability across seasons in model predictors and forecast performance of seasonal air temperature for the Western North America region. The results also demonstrate the importance of careful analysis in forming statistical forecast models that will be used depending on the season that is being predicted.

SESSION: (B4) S2D forecasts for decision making

(P-B4-03)

On the use of seasonal climate forecasts in the Chinese energy sector

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Uncertainty in seasonal climate forecasts arises from multiple sources (e.g. initial conditions, model parameters, observations, human judgement). If these uncertainties are not adequately characterised and conveyed to those using this information to inform decision making, then this may result in a false sense of certainty, leading to maladaptive decision making and ultimately a loss of trust in providers. As a result, climate service providers face the challenge of both adequately characterising uncertainty in climate information, and that of tailoring information to meet the needs of users (Otto et al., 2016). However, in trying to convey information about uncertainty to users, providers may encounter a preference amongst decision makers for deterministic information (e.g. Taylor and Dessai, 2014, Taylor; Dessai & Bruine de Bruin, 2015). It is therefore important to develop evidence-based guidance on the treatment of uncertainty for climate service providers. This should be informed by a detailed understanding of the challenges – related to both the institutional factors and individual understanding – that decision makers face in using uncertain climate information.

We interviewed 20 Chinese users from the Yangtze region (including the Three Gorges Dam Corporation) to explore how they currently understand and utilise information about uncertainty in seasonal forecasts. We found that uncertainty is not often made explicit within seasonal forecast documents in China. However, in cases where established relationships exist, decision makers and forecasters are having informal conversations about the reliability of the forecast. Interview findings also highlight that Chinese users have a preference for tailored probabilistic statements relating to climate variables and timescales that directly relate to their decision-making process. This research ultimately aims to improve the treatment of uncertainty by providing uncertainty guidance to seasonal climate service providers.

SESSION: (B4) S2D forecasts for decision making

(P-B4-04)

Wind drought episodes in the US and Europe: the power of case studies.

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Barcelona Supercomputing Center (1)

Variability of wind speeds at monthly and seasonal timescales has a direct impact on wind power generation. Episodes of widespread and prolonged lack of wind pose at risk the business owners: they can be short of revenues to pay their loans and moreover the value of their assets decreases. Such a high-impact event happened during the first months of 2015 in the US. Wind anomalies in the southwest of the North American continent were more than three standard deviations away from the climatology, revealing a very rare event. The situation was totally unprecedented in the records, and there was confusion in the industry on what was causing that anomalous episode. In this presentation we will show the role that Pacific sea surface temperatures played to force the event. The status of ENSO and North Pacific Mode during the episode will be presented and its relationship with US wind speeds in the past records analyzed. A set of experiments using retrospective climate predictions where the role of SSTs can be systematically studied shows that high sea surface temperatures in the western tropical pacific were responsible for that event. Then a similar event of low wind speeds in Europe during winter 2016/2017 will also be briefly discussed using similar techniques. Revealing the forcing mechanisms for those case studies is relevant in many aspects: it facilitates that users understand how and why seasonal predictions are made possible; it makes the forecasts more credible; and it can highlight physical processes that should be improved in the modeling systems.

SESSION: (B4) S2D forecasts for decision making

(P-B4-05)

Toward user-relevant monthly to seasonal forecasts of Arctic sea ice: The FRAMS project

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Forecasting Regional Arctic Sea Ice from a Month to Seasons (FRAMS) is a Canada-funded Year of Polar Prediction (YOPP)-endorsed project. Its objectives are to develop (i) user-relevant forecast products for Arctic sea ice, covering time scales from a month to seasons, in consultation with end users in the Arctic marine transportation sector, and (ii) capacity for multi-model Arctic sea ice forecasting in support of the WMO's developing Arctic Regional Climate Centre (ArcRCC) and Pan-Arctic Regional Climate Outlook Forums (PARCOFs). The project includes a forecasting component that is aimed at developing and assessing multi-model sea ice forecasts based on contributions from WMO Global Producing Centres (GPCs) for Long Range Forecasts (currently GPCs Montreal, Washington, Toulouse, Exeter and ECMWF). This is complemented by an analysis component that will identify physical processes and aspects of initial states that enable sea ice to be skillfully predicted and examine their representation in the forecast models, pointing to sources of error and possible avenues for improvement. Finally, an end-user component of FRAMS will interface with end users in the Arctic shipping sector to ascertain sector needs for seasonal sea ice forecast information.

This presentation will describe the current state of development and delivery of monthly to seasonal Arctic sea ice forecasts under FRAMS, as well as analyses of performance and sources of error in its multi-model forecast suite.

SESSION: (B4) S2D forecasts for decision making

(P-B4-06)

Dominant effect of relative tropical Atlantic warming on major hurricane occurrence in the North Atlantic: 2017 and the future.

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The 2017 hurricane season in the North Atlantic Ocean was highly active, with six major hurricanes (MHs) – including three that made landfall (Hurricanes Harvey, Irma, and Maria) – causing widespread damage over the Gulf Coast and the Caribbean. A number of factors might be linked to this enhanced MH activity in 2017, such as unusually warm sea surface conditions over the tropical Atlantic and off the coast of North America, as well as moderate La Niña conditions in the Pacific and associated remote impacts.

The particularly active MH season in 2017 was predicted well in real-time seasonal predictions starting from initial conditions on 1 July using a high-resolution global coupled model (HiFLOR) developed at the Geophysical Fluid Dynamics Laboratory. HiFLOR also can simulate the observed interannual variation of MH frequency in historical simulations, and offers skill in retrospective seasonal predictions (r=+0.74 for the period 1980–2017)

To elucidate the critical factors responsible for the occurrence of this highly active MH season in 2017, we used HiFLOR to conduct a series of idealized seasonal predictions for the period 1 July through 30 November. We show that the increase in 2017 MHs was not caused by La Niña conditions in the Pacific Ocean, but by pronounced warm sea surface conditions in the tropical North Atlantic. It is further shown that, in the future, a similar pattern of North Atlantic surface warming, superimposed upon long-term increasing SST from increases in greenhouse gas concentrations and decreases in aerosol loading, will likely lead to even higher numbers of MHs. Thus, continued anthropogenic forcing has the potential to further amplify the risk of MHs in the North Atlantic, with corresponding socio-economic implications. The key factor controlling MH activity in the future appears to be relative sea surface warming (how much the tropical Atlantic warms relative to the rest of the global ocean), rather than absolute warming in the North Atlantic alone – consistent with previous studies concerning weaker storms.

SESSION: (B4) S2D forecasts for decision making

(P-B4-07)

User needs and user-oriented products for decadal predictions: the MiKlip forecast webpage and the GPCC-DI drought index

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The German research program MiKlip aims at developing an operational decadal climate prediction and evaluation system. Within this context the research project SUPPORT at the German Meteorological Service (Deutscher Wetterdienst DWD) collects user needs for decadal predictions and develops user-oriented pilot products.

To gather user needs a questionnaire has been distributed to public administration, agriculture, water management and research sectors. Two user workshops in 2016 and 2017 gathered representatives of governmental agencies, international organizations, research institutions and companies to discuss user needs and possible decadal prediction products. As an outcome of this, we concluded that the products should be structured on multiple layers for different user groups: general information, specific predictions, original data. Interested users have been contacted to discuss a potential cooperation. The MiKlip forecast webpage (see below) has been evaluated on the workshop and by a questionnaire. The third workshop in 2018 will present new products and discuss user needs on the seasonal to decadal time scale.

The MiKlip forecast webpage presents decadal predictions as an insight into research for the public (http://www.fona-miklip.de/decadal-forecast/decadal-forecast-for-2018-2027/). They consist of 4- and 1-year mean recalibrated temperature predictions of the global Earth System Model MPI-ESM-LR at 5° resolution and the regional climate model COSMO-CLM at 0.5° resolution over Europe. The prediction skills of ensemble mean and probabilistic predictions are determined via the Mean Squared Error Skill Score (MSESS) and the Ranked Probability Skill Score (RPSS) with respect to the reference predictions observed climatology and uninitialized climate simulations to compare the prediction skill of decadal forecasts in the past with the data users usually apply for decision-making. A traffic light system shows the category green/ yellow/ red if the decadal prediction skill is better than both/ one/ no reference prediction.

Furthermore, decadal prediction skills of the Global Precipitation Climatology Centre Drought Index (GPCC-DI) and its components the Standardized Precipitation Index with adaptations from DWD (SPI-DWD) and the Standardized Precipitation Evapotranspiration Index (SPEI) are analyzed. Drift correction of ensemble mean predictions and recalibration of probabilistic predictions are applied. They are evaluated compared to the reference predictions mentioned above. The evaluation of 4-year mean droughts at 5° resolution shows large skills for the SPEI in the tropics and several skill hot spots for the SPI-DWD. The GPCC-DI gives a global coverage but hardly enhances SPI-DWD and SPEI skills. However, ensemble mean prediction skills are reduced by large conditional biases depending on the magnitude which have not been corrected. To meet user requirements drought predictions at higher resolutions are investigated. 1-year mean droughts reveal smaller skills because of larger small-scale noise, but new skillful regions emerge due to regional processes predictable for 1-year means. Drought predictions at 2° resolution reveal similar patterns with enhanced fine-scale structures mostly without losing skill. An exemplary decadal GPCC-DI prediction for 2008-2011 reproduces observed tendencies in most regions, but intensities frequently differ. Recalibrated probabilistic predictions reveal better results than ensemble mean predictions in many regions. Thus, skillful user-oriented drought predictions can be provided for several future time periods and regions.

SESSION: (B4) S2D forecasts for decision making

(P-B4-08)

Some pitfalls in understanding and interpretation of climate forecasts

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Smart use of climate forecasts relies on users developing a calibrated understanding of the skill of the forecasts, the strengths and limitations of the forecasts, and the broader contexts in which the forecast is used. This process requires a fairly dedicated effort and is subject to a range of pitfalls that hinder user's understanding.

These pitfalls relate to the attributes of ensemble forecasts, the need to cope with generally modest levels of skill, the small population sample of climate forecasts, and to expectations from the users of climate forecasts.

SESSION: (B4) S2D forecasts for decision making

(P-B4-09)

Assessing the added value of near-term decadal climate change information for decision making in agricultural sector

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Near-term decadal climate prediction represents a source of information that has the potential to improve decision-making and strengthen the resilience of a wide range of socio-economic sectors heavily influenced by climate variability and change. However, up to now, very little effort has been put into using near-term decadal climate forecasts for adaptation and mitigation purposes. This is probably linked, at least partially, to knowledge constraints and lack of illustrations on how to use this data by the stakeholders and a lack of applied studies illustrating how the skill can be transformed into value. This work aims to tackle some of these aspects for the agricultural sector in a context of climate services. Starting from the forecast quality assessment of multi-year averages of temperature and precipitation, we also provide the skill assessment of key agroclimatic indices resulted from the co-development with final agricultural users. Some of those indices are the standardised precipitation evapotranspiration Index (SPEI) and the heating degree days (HDD), which are strongly linked to crop yield variability. The added value of near-term decadal climate information will be shown with respect to standard non-initialized climate simulations and will demonstrate the potential applicability of these forecasts at global spatial scales, to enhance the adaptation and mitigation activities in the agricultural sector.

SESSION: (B4) S2D forecasts for decision making

(P-B4-10)

How predictable are seasonal sea level anomalies?

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With higher relative sea levels, minor coastal flooding is occurring more often during periods of large astronomical tides. If combined with above-normal seasonal sea levels, often associated with climate-driven variability in the ocean, coastal flooding becomes more severe. Many coastal communities, ranging from small-island nations to large-urban centers, are experiencing recurrent flooding. Such total high water events expose coastlines to potentially damaging storm-related flooding, yet seasonal prediction of coastal high water is in an early development stage. Advancements in forecasting seasonal climate variability using global coupled ocean-atmosphere models, which have the ability to simulate sea level variability, provides an opportunity to predict future high water events several months in advance. By compiling monthly sea level anomaly predictions from multiple models, which are especially skillful in the tropical Pacific Ocean (out to 6 months) but more challenged along continental coasts, improved future outlooks are perceivable. At the University of Hawaii Sea Level Center, we are exploring the seasonal predictability of U.S. coastal sea level anomalies as part of the Marine Prediction Task Force (NOAA-CPO-MAPP) effort to expand on a real-time forecasting product that is being served online to the Pacific Islands community. The goal is to reduce the residual between predicted tides and observed water levels by forecasting relative sea level changes. Here, an update on the opportunities and challenges in expanding sea level forecasts to the Atlantic, Gulf of Mexico, and Pacific Coasts will be discussed.

SESSION: (B4) S2D forecasts for decision making

(P-B4-11)

Evaluation of downscaled GEOS-5 seasonal forecasts used to improve hydrologic forecasting in the United States

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Drought and flooding are two of the most important and impactful climate feature on regional agriculture, water and ecosystems, and human health. However, the current seasonal prediction (which are few) of the indicators of these phenomena lack accurate information of the terrestrial water storage which is linked closely to changes in local meteorology. We present one such way to improve river flow and drought forecasting using a combination of forecast modeling, spatial downscaling, and land surface modeling. Here we use the NASA Goddard Earth Observing System-5 (GEOS-5) atmospheric general circulation model (AGCM), which has been extensively used in operational and research studies. Higher resolution forecast data of important land surface variables (e.g. groundwater, soil moisture, etc.) would be advantageous in improving hydrologic forecasts. This leaves the improvement of the native GEOS-5 model resolution (~ 1.0°) through downscaling an appealing approach. We utilize the National Center for Atmospheric Research's (NCAR) Generalized Analog Regression Downscaling (GARD) algorithm to downscale GEOS-5 forecasting data using the North American Land Data Assimilation System (NLDAS-2) dataset to enhance the spatial resolution of our data to 0.125°. We then use this new dataset as an input for NASA's Land Information System Version 7 (LIS-7), a land surface model that can generate the necessary hydrologic variables to create improved drought and flooding indicators for seasonal (~3-month) forecasts.

Here we present an evaluation of the GARD algorithm and how its' output compares to previous raw forecasts and observational data, with the hope of improving river flow and drought forecasting. 1

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-01)

Interannual variability and predictability assessment of JJA surface air temperature over the Arabian Peninsula in North American Multimodel Ensemble.

"EHSAN, MUHAMMAD AZHAR (1)", "Kucharski, Fred (2)", "Almazroui, Mansour (3)", "Ismail, Muhammad (4)", "Tippett Michael (5)"

"ICTP, Italy (1)", "ICTP, Italy (2)", "CECCR, Saudi Arabia (3)", "CECCR, Saudi Arabia (4)", "IRI, USA (5)"

Interannual variability and predictability of summer season (June-July-August: JJA) air-temperature over the Arabian Peninsula (AP) is investigated using observations and reforecast data obtained from North American Multimodel Ensemble (NMME) for the period of 1982-2017. The regional-mean air-temperature over AP shows a statistically significant warming trend. The warming over the AP is related to the equatorial Indian and Atlantic Ocean SSTs as well as local SSTs located in Mediterranean Sea, which itself showed significant warming trend in recent time. When trend is removed from the data the equatorial Indian Ocean still stand out as the major source of predictability of the air-temperature over AP. The potential and actual predictability of the air-temperature over the AP is explored in the reforecast data obtained from NMME at different lead times. First, unanimously all models shows positive temperature anomalies in recent decades (after 1998), which is matching with observed trend. Second, the interannual variability of the air-temperature anomalies in all the predictions is synchronized, but the magnitude of the air-temperature anomalies are notably different and underestimate the observed air-temperature anomaly, habitually due to the large error in the predicted temperature climatology. The focus of this study is to find the sensitivity of the potential and actual predictability of the air-temperature over the AP to different coupled model reforecast data and to their initial conditions. In general, all pooled models reforecast show an increase in potential predictability with a decrease in lead-time, however, CFSv2, GFDL-FlorA and GFDL-FlorB show higher JJA air-temperature potential and actual predictability as compared to COLA, GFDL-Aero and NASA.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-02)

Potential predictability of the INMCM4 and INMCM5 climate models on decadal timescales

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In this talk we consider two methods for estimation of potential predictability of climate models with respect to initial conditions and external forcings. Method of «analogues» (Nicholls, 1980; Branstator et al., 2012) evaluates the distance between the set of modeling data (data ensemble) and its "analogue" (the specific selection of points from the same dataset so the distances between the correspondent pairs of points in these sets are minimal). Predictability time could be then defined as the time when the mean distance between the ensemble points becomes close to the mean squared distance estimated for the data ensemble. Second approach is based on the calculation of the information entropy as a measure of the distance between the two ensembles and use of an empirical model approximating dynamics of the system of interest in probabilistic manner (Kleeman, 2002; Penland and Sardeshmukh, 1995).

Both methods were applied to the climate models of the Institute of Numerical Mathematics (Russian Academy of Sciences) INMCM4 and INMCM5 (Volodin et al., 2010; 2017) and produced close estimates for the predictability times. Direct ensemble model runs give close patterns of most predictable structures as well as the time of potential predictability. Predictability times for the INMCM4 and INMCM5 are equal to 2-3 years for Pacific region and 4-5 years for the North Atlantic (for the annual mean temperature of the upper 300m ocean layer). The INMCM5 is more predictable in the Pacific (by about 1 year). Family of INM models shows relatively low predictability with respect to other IPCC models (Branstator et al., 2012).

Acknowledgments. Numerical experiments were performed on MVS1P1 cluster of JSCC RAS. Financial support was provided by Russian Science Foundation (project 14-27-00126).

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-03)

National Earth System Prediction Capability: Metrics, Post-processing, and Products for Seasonal to Subseasonal Workshop

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The National Earth System Prediction Capability (ESPC) is a US interagency partnership to improve the common science and earth system modeling capability, to better support each agency's mission from 0 to 30 years. ESPC conducted a workshop in February for a broad enterprise discussion of S2S user needs, agency capabilities, gaps between needs and capabilities, and products to support decisions. Discussions also centered around verification metrics to better support earth system development.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-04)

Seasonal to Multi-Year Climate Hindcast Experiments by MIROC models

Takahito Kataoka (1), Hiroaki Tatebe (1), Hiroshi Koyama (1), and Takashi Mochizuki (1)

JAMSTEC, Japan (1)

Toward the decision on initialization strategy of the MIROC6 prediction system contributing to the Decadal Climate Prediction Project (DCPP), we conduct sets of hindcast experiments using MIROC5.2, which has an atmospheric model of lower-resolution and simpler-physics but shares the same ocean components with the latest version MIROC6, for the period between 1980 and 2009. The model is initialized by assimilating observed ocean temperature and salinity and we test hindcast experiments based on both full-field and anomaly initializations. In addition, we carry out two other hindcast experiments by replacing some of the atmospheric initial conditions with those from ERA-Interim. All the experiments show predictive skills in the North Pacific and North Atlantic sea surface temperature anomalies (SSTA) despite the fact that the full-field assimilation run simulates a "double-cell Atlantic meridional overturning circulation (AMOC)" due to the underestimation of the ocean heat transport in the model. Regarding the seasonal prediction skill, retrospective forecasts based on the anomaly-field initialization tend to show a higher skill for the Niño3.4 SSTA prediction and the use of the atmospheric reanalysis as the initial condition improves the skills for both full-field and anomaly-filed based experiments.

Results from hindcast by MIROC6 will be introduced as well.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-05)

A framework for decadal prediction assessment

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Decadal predictions, as the climate prediction of one to ten years out, are in high economic and social demand, yet constrained by its current low prediction skills. Therefore, it is a core issue to investigate the margin of improvements and the contributing components from climate prediction systems.

Theoretically, interannual to decadal predictions can outperform the current prediction skill assessment based on hindcast analysis. However, few of the previous studies have compared the hindcast skills with the predictability that indicates the 'skill limit'. In this study, we use mean squared skill score to assess the prediction skill of temperature in CCSM4 decadal hindcast experiment in CMIP5 archive, and compare it with its potentially achievable 'perfect model' predictability based on CESM1.0 simulations. We estimated the margin of potential skill improvement for temperature and its sources. For lead years 1 to 2, initialisation is the major source of prediction skill improvement. On a longer time scale, decadal predictions rely more on a better model performance.

This work is important as to pointing out the limitation of interannual to decadal predictions and the relative importance of prediction system components on different timescales. It is based on only one climate model, and only for near surface temperature, but can perform as a framework to be applied to other variables and state-of-the-art decadal prediction systems.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-06)

Improving seasonal forecasting skill using NMME outputs over the Sahel

Ndiaye, Ousmane

ANACIM

CANCELLED

In west Africa people livelihood depends heavily on seasonal rainfall. This has triggered an early interest of forecasting seasonal climate over the Sahel and an operational outlook seasonal forecast operates since 1998. In this study we try to improve upon existing operational seasonal forecast using high resolution rainfall data from ENACTS which increases decision making for users who ask information at high resolution and we used the North American Multi-Model Ensemble outputs. Amongst NMME parameters, soil moisture from CMC1-CanCM4 offers good predictive skill for early season and the GFDL-CM2p5-FLOR-B01 rainfall captures very well rainfall during June to September period. The transition season when the ITCZ is moving from South (Gulf of Guinea) to the North (Sahel) is the most challenging period to predict (AMJJ).

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-07)

MPI-ESM predictive skill of the PDO on decadal time scales

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Long range forecasts and climate projections are meeting at decadal time scales. As the predictability for variables like temperature and precipitation is quite low at grid point level over decadal time scales, the community is investigating the skill in ocean-atmosphere coupled processes.

The pacific decadal oscillation (PDO) is a recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin. It has been shown that the mode of the PDO is connected to the global mean surface temperature (GMST) trend. The GMST trend over the coming decade is hence an important objective for decadal predictions.

D'Orgeville and Peltier (2007) demonstrated that the PDO consists of two components with characteristic periods of around 20 years and 60 years. Thus the phase of the first component of the PDO should be well defined in initial conditions of decadal forecasts and the models should have in principle the ability to capture the phase of the PDO on decadal time scales.

In this study we evaluate the predictive skill of MPI-ESM (Max Planck Institute Earth-System Model) in forecasting the PDO-Index and also the capability of the model to reproduce the teleconnections associated with the PDO. MPI-ESM is a coupled ocean-atmosphere earth system model developed by the Max Planck Institute for Meteorology in Hamburg. This research is carried out within the Miklip project (Medium-term Climate Predictions) funded by the German Federal Ministry of Education and Research.

We compare re-forecasts of the PDO-Index to the observations for both low (~1.9°) and high (~1°) resolution simulations. Further, we asses the predictive skill of the PDO for different lead times, model resolution and initialization methods. We will discuss the capability of the model to reproduce the associated teleconnection patterns and the processes which are connected to predictive skill the pacific.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-08)

Probabilistic evaluation of decadal predictions using a satellite simulator for SSM/I and SSMIS

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In this study the decadal prediction skill is evaluated focusing on different components of the global hydrological cycle. A satellite simulator for SSM/I (Special Sensor Microwave Imager) and SSMIS (Special Sensor Microwave Imager and Sounder) is developed and applied to decadal hindcasts performed within MiKlip (Decadal Climate Prediction, project funded by the Federal Ministry of Research and Education in Germany, http://fona-miklip.de).

The satellite simulator is used to deduce radiances (brightness temperature) from climate model data for the different spectral channels which are covered by the satellite based instruments. Therefore, the evaluation is performed within the instrument's parameter space. This enables to reduce uncertainties on the side of the observations when compared to classical evaluation approaches.

The Fundamental Climate Data Record (FCDR) for SSM/I and SSMIS which is made available by CM SAF (EUMETSAT Satellite Application Facility on Climate Monitoring) is used as observational reference (dataset publicly available, DOI: 10.5676/EUM_SAF_CM/FCDR_MWI/V003). The FCDR constitutes a quality-controlled, re- and inter-calibrated dataset of brightness temperatures as measured from different satellites for the period 1978 to 2015.

Here we focus on probabilistic evaluation results for 1988 to 2015 (time period covered by SSM/I and SSMIS) for selected channels representing water vapor and precipitation. While the 22 GHz channel is sensitive to the water vapor content, the 85 GHz channel (e.g. vertical minus horizontal polarization) is sensitive to the hydrometeor content.

SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-09)

New version of the long-range forecast system at the Hydrometcentre of Russia

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We are developing a new system for operational long-range forecasts. While the old system was based on the atmosphere-only model, the new system consists of the SL-AV atmospheric model [1], INMIO ocean model [2] and CICE sea-ice model [3]. Some details on this coupled model, including a brief description of the coupler and implementation, are given in [4].

The resolution of the atmosphere model has increased from 1.4x1.1 degrees lon-lat and 28 levels to 0.9x0.72 degrees, 85 levels with the uppermost level at 0.3 hPa. The parameterizations of subgrid-scale processes in the atmosphere model (shortwave- and longwave radiation, planetary boundary layer, cloudiness, shallow convection) have been substantially upgraded [1]. The ocean model has the resolution of 0.25 degrees and 49 horizons.

Each component of the surface heat balance in the coupled model is tuned according to IPCC recommended values. Both mean annual integral values and geographical distribution are in a good agreement with reanalysis data.

While waiting for new computer system able to run this coupled model intensively (expected to be available this year), we have results with the atmosphere-only model using either persistent SST anomalies or prescribed SST and sea-ice evolution.

We have computed seasonal hindcasts with the atmospheric model using persistent SST anomalies approach. The mean RMS errors of hindcasts are smaller in comparison with these of the old system while the anomaly correlations are higher. Reproduction of the North Atlantic oscillation is studied.

We have also carried out AMIP2 experiment with the SL-AV atmosphere model. The results will be shown for reproducing the statistics of important stratosphere features – sudden stratospheric warmings, quasi-biennial oscillation.

The preliminary results in reproducing modern climate with the coupled model will be shown.

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SESSION: (B5) Hindcast and forecast quality assessment

(P-B5-10)

How confident are predictability estimates of the winter NAO?

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The winter North Atlantic Oscillation is the main mode of variability over the Euro-Atlantic region on a range of time scales from days to seasons and longer. Recently, significant ensemble mean correlation skill of approximately r≈0.6 for the NAO and its hemispheric counterpart of the Artic Oscillation were reported for dynamical forecasting systems. However, the predictive skill in these studies comes with a paradox, or conundrum: the level of actual forecast skill appears to be too high compared to the intrinsic predictability one would expect for such forecasting systems, given their low signal-to-noise ratios. The implication of a situation with higher-than-expected skill is that the real world appears more predictable than the forecast model seems to suggest, or under-confident.

Here we analyse the behaviour in the ECMWF seasonal forecasting system using different configurations and conclude that while the real world correlation skill predictability in recent decades is underestimated over Greenland and the Denmark Strait, this is not the case for the Eastern Atlantic and Europe. In contrast, the more traditional diagnostics of RMS error versus ensemble spread give no indication of under-confidence.

Correlation measures suffer from large uncertainties due to small samples taken from specific long-term general circulation regimes. Long seasonal hindcasts covering the full 20th Century allow to put the predictability situation of the recent decades into a longer climate context. It is found that in these 110-year hindcasts the predictable component of the real world matches perfectly the predictable component of the forecast model for the NAO index. Recent decades see high levels of NAO skill and a tendency to underestimate the real skill. Previous climate periods, however, do not show indications for such a behaviour. The flow patterns associated with the most skilful years show strong geopotential height anomalies over Greenland and parts of the Artic. The observed predictability is higher throughout the atmospheric column in these regions but only for the most recent decades.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-01)

Proposal for an international project aimed at quantifying the impact of land Earth system processes and feedbacks on seasonal climate forecasts (GLACE-ESM)

Alessandri, Andrea (1)

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Several works have been showing the importance of the land biosphere (i.e. vegetation/land cover including anthropogenic effects and land-use changes) in forcing interannual climate anomalies and in modulating the forcing from soil moisture and/or snow. In this respect, a recent effort has clearly demonstrated significant effects of the representation of realistic vegetation-cover anomalies in the prediction of temperature and precipitation at multiple time-scales using the EC-Earth/ECMWF system.

Earth System Models (ESMs) development has seen in the last decade an accelerated effort for the land biosphere (including anthropogenic forcing). The aim of this initiative is to evaluate the impact of including Earth System processes over land (from the latest Earth System Model developments in the frame of CMIP6 and beyond) on the performance of seasonal forecasts by state-of-the-art dynamical prediction systems. As a result, this effort is also expected to be a contribution towards new frontiers in the development of Earth system predictions and towards uncertainty reduction by better understanding/constraining the land surface processes.

The lack of enough observations to constrain the model complexity has led to the development of often diverging representation of surface processes between different land surface models. Therefore, the use of multi-models is also fundamental because of the poorly constrained parameterizations over land. Building from already established multi-model efforts (e.g. SNOWGLACE, LS3MIP) a set of soil-moisture and snow initialized hindcasts (covering some portion of the satellite-era) will be taken as the reference to further quantify the impact of land Earth System processes on seasonal forecasts. Long memory biophysical states will be either persisted (from available satellite observations prior of the onset of the hindcast) or (optionally) initialized/dynamically simulated by the land models. It is expected that a good representation of the groups previously involved in GLACE-2 will participate in this coordinated efforts. Preliminary contact and indication of possible interest has already been expressed by several modelling groups.

In connection with the ongoing experiences in CMIP6, LS3MIP, LUMIP, GSWP-3, SNOWGLACE and PROCEED, the details of experimental protocol will be implemented during 2018. Optionally, decadal (5-years or more) hindcasts may be as well considered. See GLACE-ESM Concept Note at following google doc link: https://tinyurl.com/GLACE-ESM

SESSION: (B6) Frontiers in earth system prediction

(P-B6-02)

Impact of different inizialization procedures on the decadal predictability of ocean carbon uptake.

Bernardello, Raffaele (1), Sicardi Valentina (1), Acosta, Mario (1), Ortega, Pablo (1), Guemas, Virginie (1), Tourigny, Etienne (1), Doblas-Reyes, Francisco (1)

BSC, Spain (1)

Since the beginning of the industrial revolution humans have increased atmospheric CO2 content by almost 50%. Following this CO2 increase, global temperatures have been rising steadily, causing serious concern in the international community. The recent COP21 Paris agreement on climate ties the participating countries to take actions to reduce anthropogenic carbon emissions in order to contain global warming within 2oC by the end of this century. This translates into the necessity to precisely estimate the compatible CO2 emissions well ahead of time to make sure targets are met.

The global ocean carbon uptake is characterized by marked decadal oscillations linked to global-scale climate modes of variability. This characteristic has hampered past attempts to detect trends in carbon uptake but, at the same time, could represent a source of predictability on decadal timescales.

Here, we present results from a suite of simulations carried out with the Earth System Model EC-Earth. These simulations include reconstructions of the ocean biogeochemical state for the period 1960 to present and a set of near-term retrospective predictions initialized every 3 years for the period 1994 to present. The simulations are designed to test the impact of two different initialization techniques in the predictive skill of air-sea CO2 flux. One initialization technique is based on data-assimilation of physical fields only, while the second technique proposed includes also assimilation of climatological 3D nutrient fields. This second solution is meant to improve the prediction of net primary production which can have a significant impact on the natural variability of the ocean carbon uptake. Skill scores are used to validate these retrospective predictions derived from both techniques in order to obtain a complete evaluation of the sources of predictive capability in the modelling system (ESM+initialization technique).

SESSION: (B6) Frontiers in earth system prediction

(P-B6-03)

Mechanisms and predictability of multiyear ecosystem variability in the North Pacific

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Aleutian Low variations provide vorticity, buoyancy, and heat-flux forcing to the North Pacific Ocean, which in turn cause changes in ocean circulation, mixed layer characteristics and sea ice coverage. In this process the white noise atmospheric characteristics are integrated dynamically and thermodynamically to generate red noise ocean spectra. Using the Community Earth System Model we study the resulting biogeochemical and ecosystem responses in the North Pacific. We find that ocean dynamical variables have an impact on the tendencies of key nutrients and biological production, which leads to a further reddening of biogeochemical spectra resulting in potential predictability on time scales of 2–4 years. However, this low-pass filtering does not apply to all biogeochemical variables and is regionally dependent. It is shown that phytoplankton biomass in the Central North Pacific adjusts to the much shorter-term variability associated with changes in mixed layer depth, light availability, and zooplankton grazing, thus limiting the predictability of phytoplankton anomalies to about 1 year. In the eastern North Pacific the slow advection of anomalous nutrient concentrations leads to longer persistence of phytoplankton variability and increased potential predictability of up to 3 years.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-04)

Potential Predictability of the Tropical Pacific Ocean

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CSIRO Ocean and Atmosphere

We use idealised coupled model simulations to investigate the potential predictability of the tropical Pacific. We show that the potential predictability of NINO indices extends out to several years. We then investigate and contrast the predictability of tropical air-sea CO2 fluxes and ocean primary productivity with the NINO indices. We explore the processes that give rise to the predictability of these biogeochemical fields.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-05)

Lorenz and the nature of subseasonal to decadal predictability

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Lorenz originally estimated atmospheric predictability to be limited to about two weeks as the time interval over which the difference between two initially close states grows to become indistinguishable from that between two randomly chosen states. Nonetheless there is evidence of at least some predictability far beyond two weeks, associated with coherent modes of variability such as the MJO on subseasonal scales and ENSO on seasonal and longer scales. The ocean with its longer memory plays a crucial role in longer-range predictability, and coherent coupled atmosphere-land and atmosphere-cryosphere interactions also contribute to it. Improving long-range predictions by exploiting the existence of such coherent low-frequency phenomena and interactions is the primary focus of this conference, and indeed a primary goal of our science. On all this there is general agreement.

What is less obvious is what is the best way to harvest this predictability, and how to quantify its limits. Does one really need high-resolution earth system models to do this? The answer hinges on the basic nature of the predictability. There is mounting evidence that the predictable signals in both the atmosphere and the upper ocean at forecast ranges beyond about two weeks are predominantly linear, and associated with relatively few (a few dozen) patterns of variability. This is consistent with the continuing high competitiveness of low-order stochastically forced linear inverse models (LIMs) with coupled GCMs at making skillful predictions from subseasonal to decadal scales. The vastly simpler LIMs are useful not only for providing skillful predictions (both deterministic and probabilistic) but also for providing reliable estimates of predictability at these scales. The loss of predictability with forecast lead time in such models can be characterized by error growth curves that can be directly related to the model parameters. Remarkably, the form of these curves at longer ranges is identical to Lorenz's general ansatz for such curves in a chaotic nonlinear system. This further supports the idea that the predictable signals at subseasonal to decadal scales are approximately linear, and the nonlinear interactions are sufficiently chaotic as to effectively amount to a stochastic noise forcing.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-06)

Variability and predictability of land and ocean carbon sinks assessed in MPI-ESM CO2 emission-driven simulations

Aaron Spring (1,2), Hongmei Li (1), Tatiana Ilyina (1)

Max Planck Institute for Meteorology, Germany (1), International Max Planck Reseach School on Earth System Modelling (2)

The ocean as a sink for anthropogenic carbon responsible for removing of about 25% of anthropogenic CO2 emissions and thereby playing a vital role in moderating the Earth's climate. Assessing variability and near-term predictability of the ocean carbon sink plays a crucial role in monitoring future emission reductions in the light of the Paris Agreement 2015. Initialized Earth-System-Model (ESM) simulations are a suitable tool for predicting the evolution of the global carbon sink. Yet internally generated variability is superimposed on the externally forced climate signal, challenging our ability to distinguish between anthropogenic trends and natural climate variability.

Previous studies (Li et al. 2016, Séférian et al. 2018) investigated the potential prediction skill of these inter-annual changes of ESMs on the oceanic uptake of CO2 by evaluating the model prediction/hindcast against the model itself, however in these cases atmospheric CO2 concentration boundary condition were set to not vary by season. Here, we build on previous studies using emission-driven simulations, allowing for the seasonal cycle in atmospheric CO2, accounting for an interactive exchange of carbon between ocean, atmosphere and land, and carbon cycle climate feedbacks. With such interactive carbon cycle simulations we address the question whether the prediction skill in carbon fluxes is potentially affected. This study serves as a pre-assessment whether inter-annual variability changes in emission-driven compared to concentration-driven simulations, and hence could improve prediction skill on decadal timescales. As a proof of concept we use the uninitialized Max-Planck-Institute ESM simulations in a low resolution setup to compare inter-annual variability measured as the standard deviation of de-trended annual carbon fluxes in concentration-driven and emission-driven simulations of key regions for carbon uptake between 1950 and 1999.

Results indicate that emission-driven simulations show an increased seasonal amplitude of the difference between pCO2 of the ocean and atmosphere (dpCO2) in the North Hemisphere and hence also increases the inter-annual variability in North Atlantic sea-air CO2 flux by ~25%, whereas the inter-annual variability of terrestrial carbon fluxes reduces by ~10% over North America. Our study highlights the importance of using emission-driven simulations for variability studies and suggest

SESSION: (B6) Frontiers in earth system prediction

(P-B6-07)

Impact of initial conditions perturbations on potential decadal predictability of ocean carbon fluxes assessed in MPI-ESM

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Earth-System-Model (ESM) simulations are a powerful tool to predict the evolution of the global carbon sink. Recent studies found prediction skill in the oceanic carbon uptake, but its origins are poorly understood. Li and co-workers (2016) find predictive skill up to 4-7 years in the North Atlantic CO2 uptake when evaluating against assimilated ocean with uninitialized biogeochemical components. They attribute prediction skill to the improved winter state. Séférian and co-workers (2018) investigated the potential prediction skill of an ESM in a perfect-model approach ensuring that model biases do not affect predictability. They add noise to the initial conditions in the sea-surface temperature to create ensemble members. This study sets a potential upper limit and surveys predictability regionally. However, underlying processes of predictability and time-scale of persistence remain largely unexplored. The physical oceanography community started estimating decadal climate predictability using the perfect-model approach to assess potential climate predictability. As the biogeochemical components rely on the physical ocean fields, we recap the "perfect-model approach" from the biogeochemical point of view. A strong focus lies on processes: those driving and initiating multi-year variability, which may lead to predictability; and those blurring the biogeochemical memory. Here, we use initial conditions the Max Planck Institute ESM in a low resolution configuration (MPI-ESM LR) to create several ensemble members with perturbations in the biogeochemical or physical initial conditions of the ocean: We manipulate biogeochemical initial conditions (e.g. dissolved inorganic carbon, alkalinity) while keeping climate unchanged, and vice versa in a second set of simulations disturb physical initial conditions (i.e. temperature, salinity) while the biogeochemistry remains unchanged. We investigate potential predictability horizon of ocean carbon fluxes and underlying influencing processes. Thereby, we explore the impacts of initializations of ocean physics and biogeochemical fields on the biogeochemical state and evolution of the ESM.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-08)

Improved seasonal projection of regional ocean biogeochemical states through Ensemble data assimilation

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The predictability of regional ocean biogeochemistry critically depends on both accurate initial conditions and process representations. The latter highly relies on the parameterized formulations, which are typically poorly constrained in models. In this study, we developed an efficient data assimilation system that aims to improve projections of various biogeochemical states through optimizing the ecosystem parameters in the model. The scheme, based on a sequential Ensemble Kalman Filter, was applied to a one-dimensional configuration of the ocean biogeochemical general circulation model in three stations in mid and high latitudes. Through the assimilation of monthly climatology profiles of nitrate, silicate, phosphate and oxygen in addition to seasonal surface pCO2 data, our optimized parameters able to yield significantly improved seasonal cycle of key biogeochemical states. The model a posteriori prediction of seasonal net primary production significantly improves in all three sites relative to the free runs. Model performance against non-assimilated observations was improved as well. The optimized parameters are consistent with independent observational-based estimates. Our results highlights the need to improve the process representation in the model to better capture the seasonal cycle prior to long-term predictions.

SESSION: (B6) Frontiers in earth system prediction

(P-B6-09)

A new Sea Ice Prediction Portal: year-round S2S sea ice forecasting

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University of Washington (1)

The recent declining extent and increasing variability of Arctic sea ice poses a unique challenge for S2S prediction. At the same time, there is an increasing demand for skillful regional sea ice forecasts due to the opening of Arctic waters. A significant barrier to understanding current model skill and targeting improvements is a lack of a central database to enable inter-model comparisons and evaluations. This study addresses this issue by extending the work started in 2008 that issues seasonal sea ice outlooks (SIOs) based on a diverse set of forecast techniques. Starting in 2018, and as part of the second generation of the Sea Ice Prediction Network (SIPN2), we have developed a central server and web portal housing multi-model ensemble sea ice reanalysis, reforecasts, and operational forecasts. Automated scripts re-grid and normalize diverse model forecast variables (sea ice concentration, ice thickness, snow depth, ice age, etc.) and evaluate historical reforecasts against available satellite observations. The portal also allows contributors to access formatted forecasts and perform their own analysis without the need to download large datasets. We will present an overview of the SIPN2 portal and provide examples of the type of analysis this database enables. Earlier results from the SIO found that shorter lead times (0-2 months) have the largest room for improvement predicting September minimum sea ice extent. We extend this work by evaluating multi-model ensemble reforecast skill for multiple sea ice variables at pan-Arctic and regional scale across the Arctic.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-01)

Should initial conditions for decadal predictions be as close as possible to observations?

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Seasonal-2-decadal predictions draw their skill partly from the initialization of the atmosphere, but to a large extent also from the slowly varying components of the climate system, such as the ocean. The quality of the initialization is often judged by the "closeness" of the initial conditions and/or perturbations to observations. Here, we argue that we need to keep an eye on the model's native state, that is how much we change the model's “native" state by initialization. To that end, we look at ensemble hindcast simulations in the earth system model MPI-ESM, where we use a weakly coupled assimilation based on nudging to reanalysis in the atmosphere and a localized Ensemble Kalman Filter (enKF) in the ocean. After demonstrating hindcast skill for surface temperature, we focus on the evolution of the variability of the Atlantic Meridional Overturning Circulation (AMOC) and show that for the implementation of the oceanic enKF, a focus on oceanic sub-surface variability is crucial. In turn, we propose to rethink measures of the quality of the initialization: instead of solely aiming to be as close as possible to the observed state, we suggest to include in the assessment the evolution of the variability in the hindcast ensemble, in particular in relation to the variability of a free unconstrained simulation.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-02)

Skillful climate forecasts of the tropical Indo-Pacific Ocean using model-analogs

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Seasonal forecasts made by coupled general circulation models (CGCMs) undergo strong climate drift and initialization shock, driving the model state away from its long-term attractor. Here we explore initializing directly on a model's own attractor, using an analog approach in which model states close to the observed initial state are drawn from a "library" obtained from prior uninitialized CGCM simulations. The subsequent evolution of those "model-analogs" yields a forecast ensemble, without additional model integration. This technique is applied to four of the eight CGCMs comprising the North American Multimodel Ensemble (NMME), by selecting from prior long control runs those model states whose monthly tropical IndoPacific SST and SSH anomalies best resemble the observations at initialization time. Hindcasts are then made for leads of 1-12 months during 1982-2015. Deterministic and probabilistic skill measures of these model-analog hindcast ensembles are comparable to those of the initialized NMME hindcast ensembles, for both the individual models and the multi-model ensemble. In the eastern equatorial Pacific, model-analog hindcast skill exceeds that of the NMME. Despite initializing with a relatively large ensemble spread, model-analogs also reproduce each CGCM's perfect-model skill, consistent with a coarse-grained view of tropical Indo-Pacific predictability. This study suggests that with little additional effort, sufficiently realistic and long CGCM simulations provide the basis for skillful seasonal forecasts of tropical IndoPacific SST anomalies, even without sophisticated data assimilation or additional ensemble forecast integrations. The model-analog method could provide a baseline for forecast skill when developing future models and forecast systems.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-03)

Sensitivity of the oceanic conditions for the seasonal forecast of Météo France

Dubois, Clotilde (1,2), Clavier, Matthieu (1), Garric, Gilles (1), Parent, Laurent (1), Chevallier, Matthieu (2)

Mercator Ocean, Frane (1), Météo France, France (2)

Météo France is one of the EUROSIP and C3S contributors for the seasonal forcasts. In this framework, Mercator Ocean is providing the ocean restart for the initial oceanic condition of their seasonal forecast system both for the hindcast and the forecast. The oceanic restart is created using the NEMO model issue from the seasonal forecast coupled model which is nudged in temperature and salinity towards the Mercator Ocean ocean reanalysis: GLORYS. Here, we explored the performance of those oceanic restarts using different set ups. The performance and the biais of those initial conditions are evaluated when different ocean reanalysis are used: GLORYS2V3 versus GLORYS2V4. Furthermore, the impact of different model version of the ocean model is assess; here: NEMO3.2 versus NEMO3.6, the impact of additional nudging; here the additional nudging of the sea ice is assess. Finally, the impact of the ocean resolution is quantify between ORCA1° and ORCA025.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-04)

Aspect of GCM downscaled Regional Climate Modeling in simulating Spatiotemporal monsoon variability during ENSO and normal conditions and dependencies on boundary conditions

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Spatiotemporal variability of summer monsoon using Regional Climate Model (RegCM) is one of the most vital issue in the subcontinent like South-Asia. A number of research scientists have been showing their interest on monsoon study and a lot of scientists are investing their time to overcome the model uncertainty and trying to simulate the phases of monsoon by considering very advance tools in the model equations. After a group of upgradation in the directive way, RegCM has been advanced to overcome the topographical issues for better projection/simulation over the Indian region and these continuous up gradation in model equation was setted up to make the RegCM more accurate. The aim of regional climate model is to incorporate the regional phenomena in model simulation over a particular region and therefore, RegCM are generally preferred for long/medium range simulation. Current study is shown the difficulty in model simulation to simulate the regional phenomena due to spatiotemporal disturbance during ENSO years. Simulation of different phases of rainfall during summer monsoon is disturbed by the El-Nino and La-nino years. In other words, the NNRP1 forced downscaled RegCM Model is performing very poor during the El-Nino phase. The model performance glowing during the cold phases (in which years SST anomaly showing negative over Nino 3.4 region) in comparison to observational datasets where during warm phases (in which years SST anomaly showing positive over Nino 3.4 region) the RegCM performance is being very sensitive. It will be worthy to study the sensitivity of RegCM's Mix99 performance in either different year cycle or in warm/cold phases rather than continuous long term approach.

Keyword: Indian monsoon, RegCM, ENSO years.

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SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-05)

Full-field initialized decadal predictions with the MPI earth system model: an initial shock in the North Atlantic

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Our decadal climate prediction system, which is based on the Max-Planck-Institute Earth System Model, is initialized from a coupled assimilation run that utilizes nudging to selected state parameters from reanalyses.

We apply full-field nudging in the atmosphere and either full-field or anomaly nudging in the ocean. Full fields from two different ocean reanalyses are considered. This comparison of initialization strategies focuses on the North Atlantic Subpolar Gyre (SPG) region, where the transition from anomaly to full-field nudging reveals large differences in prediction skill for sea surface temperature and ocean heat content (OHC).

We show that nudging of temperature and salinity in the ocean modifies OHC and also induces changes in mass and heat transports associated with the ocean flow In the SPG region, the assimilated OHC signal resembles well OHC from observations, regardless of using full fields or anomalies.

The resulting ocean transport, on the other hand, reveals considerable differences between full-field and anomaly nudging. In all assimilation runs, ocean heat transport together with net heat exchange at the surface does not correspond to OHC tendencies, the SPG heat budget is not closed. Discrepancies in the budget in the cases of full-field nudging exceed those in the case of anomaly nudging by a factor of 2-3. The nudging-induced changes in ocean transport continue to be present in the free running hindcasts for up to 5 years, a clear expression of memory in our coupled system. In hindcast mode, on annual to inter-annual scales, ocean heat transport is the dominant driver of SPG OHC. Thus, we ascribe a significant reduction in OHC prediction skill when using full-field instead of anomaly initialization to an initialization shock resulting from the poor initialization of the ocean flow

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-06)

Initialisation of the ocean carbon cycle in the CAFE system

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Recent studies have reported considerable multi-year changes in the strength of ocean carbon uptake, globally and regionally. Current and the limited observations of the ocean carbon cycle have necessitated some degree of interpolation and/or large-scale spatial and temporal averaging. This has the potential either to bias and/or alias the results toward a dynamically inconsistent ocean state, thereby making understanding the drivers of these changes challenging, and limiting skill in predictions. At present two major approaches exist to estimate the ocean state: 1 better) actively assimilating ocean physical and biogeochemical observations; and 2) actively assimilating ocean physical observations with prognostic ocean biogeochemistry, initialised from ocean biogeochemical observations such as GLODAP (GLobal Ocean Data Analysis Project). This second approach assumes that the ocean biogeochemical variability is primarily driven by the ocean dynamics, conserves carbon while allowing more extended reanalyses products.

Here we use CSIRO's Climate Analysis and Forecast Ensemble System (CAFES) coupled to the WOMBAT (World Ocean Model of Biogeochemistry and Trophic Dynamics) ocean biogeochemical model, to explore the initialisation of ocean biogeochemistry and carbon. This initialisation takes into account the current temporal and spatial observational coverage and the simulated variance from our model ensemble. To assess our approach, we use surface ocean carbon observational datasets such as from the Surface Ocean Carbon Atlas (SOCAT) - that are not utilised our initialisation. Our results further suggest that ocean carbon observations may provide a valuable additional constraint on the recent circulation changes inferred from wind and water properties. Furthermore, initialisation appears to offer a tractable pathway, through constraining the response of the marine biogeochemistry to physical changes, to also improve the representation of the marine biogeochemistry in Earth System Models; identified as a challenge for projecting the role of the ocean, and its feedbacks, in the global carbon cycle.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-07)

WGSIP's Long-Range Forecast Transient Intercomparison Project (LRFTIP)

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The Long-Range Forecast Transient Intercomparison Project (LRFTIP) is an initiative of WCRP's Working Group on Subseasonal to Interdecadal Prediction (WGSIP). Its objective is to develop a multi-model archive of hindcast climatologies and associated diagnostics that represent the evolution of climate prediction models from observation-based initial states, averaged over many ensemble members and forecast years, as a function of lead time. Such model trajectories characterize initialization shocks and drifts, and hence can inform investigations of (i) the transient behavior of initialized subseasonal to decadal climate predictions, (ii) the development of model biases, and (iii) the relative merits of different forecast initialization methods

A focus thus far has been to derive hindcast climatologies from multi-model hindcast datasets assembled for various climate prediction research initiatives, including S2S (subseasonal), the WGSIP CHFP and EU ENSEMBLES projects (seasonal), and CMIP5 (decadal). Currently 4 subseasonal, 19 seasonal, and 15 decadal prediction models are represented. This presentation will describe the structure and current status of the LRFTIP dataset, as well as examples from the suite of multi-model diagnostics being developed, which potentially could serve as a standard set of shock and drift diagnostics for climate prediction models.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-08)

Multiyear climate prediction using 4D-Var coupled data assimilation system

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An initialization relevant to interannual-to-decadal climate prediction has usually used a simple restoring approach for oceanic variables. Here, we demonstrate the potential use of four-dimensional variational (4D-Var) coupled data assimilation on the leading edge of initialization approach particularly in multiyear (5-year-long) climate prediction. We perform full-field initialization rather than anomaly initialization and assimilate the atmosphere states together with the ocean states to an atmosphere-ocean coupled climate model. In particular, it is noteworthy that ensembles of multiyear hindcasts using our assimilation results as initial conditions exhibit an improved skill in hindcasting the multiyear changes of the upper ocean heat content over the central North Pacific. The 4D-Var approach enables us to directly assimilate a time trajectory of slow changes of the Aleutian Low that are compatible with the sea surface height and the ocean heat content. Consequently, we can estimate a coupled climate state suitable for hindcasting dynamical changes over the extratropical North Pacific as observed.

SESSION: (C1) Initialization initialization shock and model error (includes data assimilation)

(P-C1-09)

Some results of studying initialization shock and drift in S2S database coupled models

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Initialization shocks and drifts are important issues in coupled model forecasts [1]. Long Range Forecast Transient Intercomparison Project (LRFTIP) [2] is the project of WCRP Working Group for Subseasonal to Interdecadal Prediction (WGSIP) devoted to their study.

Using the database of subseasonal hindcasts produced by coupled models participating in WMO S2S project [3], we created daily climatology of ECCC, ECMWF, Meteo-France, NCEP, UK MetOffice models for hindcasts starting around 1st of May and 1st of November. The daily climatology means averaging over ensemble members and hindcast years for a particular day field. All the centers run S2S forecasts for at least 31 days.

We compare hindcast climatology with observation (or reanalyses) climatology for some fields, including precipitation, total cloud cover. The focuses of our attention are Tropical Pacific and North Atlantic regions. The results of this comparison will be presented.

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SESSION: (C2) Research to operation (includes seamless prediction)

(P-C2-01)

A seamless verification framework to estimate the predictability of climate means and extremes across timescales

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It is widely recognized that there is utility in quantifying the potential predictability of sub-seasonal to multi-decadal climate variations. Such estimates allow us to identify “hot spot” regions where the potential for making skillful climate forecasts is highest, as well as “cold spot” regions where climate noise dominates any signal. Further, these estimates can help target investigations into the sources and physical processes giving rise to predictability for various regions and at various timescales. Finally, they can help provide guidance as to where and when the issuance of climate forecasts may be most reasonable. In this talk, we outline an observationally-based method for estimating the predictability of climate means and extremes across timescales ranging from weeks to decades. We then apply the method to station-based precipitation data over the United States and quantify the dominant timescales of predictability for different precipitation characteristics (e.g. intensity v. frequency; means v. extremes) and different regions. We also outline how the method can be applied to other societally-relevant metrics—e.g. as being compiled by WCRP/WWRP’s S2S Project—which in turn can inform user communities as to whether the metrics they find most useful also represent feasible targets for prediction efforts at the timescales of interest. We close by describing its application to output from the numerical models used to make climate forecasts, including short-term seasonal forecasting systems and long-term climate simulation systems. Such analyses in turn can: 1) help assess sources of error in these forecasts; 2) help develop observationally-constrained skill masks that can be applied to these forecasts; and 3) ultimately help quantify realizable “room for improvement” between potential and actual predictability of various climate parameters. Overall, the method provides a seamless verification framework for the reliability, limits, and uncertainty of forecasted means and extremes across multiple timescale.

SESSION: (C2) Research to operation (includes seamless prediction)

(P-C2-02)

PRES2iP: Prediction of Rainfall Extremes at Subseasonal-to-Seasonal Periods

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Extreme precipitation events cause several hazards including property and infrastructure damage, agricultural losses, and injuries and fatalities as a result of fast-moving water or waterborne diseases. While prior studies of extreme precipitation events have focused on sub-daily to sub-weekly predictability, decisions for planning and resilience-building require longer predictability timescales, specifically on the subseasonal-to-seasonal (S2S; 14 to 90 days) timescales. This five-year project seeks to enhance our fundamental understanding of the forcing and dynamics behind the evolution of S2S extreme precipitation events in the USA and subsequently improve the modeling and prediction of such extreme events. Our diverse and interdisciplinary research team aims to answer four research questions: (1) What are the synoptic patterns associated with S2S extreme precipitation events in the contiguous US?; (2) What role, if any, do large-scale modes of climate variability play in modulating these events?; (3) How predictable are S2S extreme precipitation events across temporal scales?; and (4) How do we create informative forecast tools of S2S extreme precipitation events for decision makers? This presentation provides an overview of this project and highlights findings from Year 1 of this project. Such findings include results of our Year 1 Workshop with stakeholders (e.g., water resource managers, emergency managers, and tribal environmental professionals). Engaging stakeholders facilitates co-production of knowledge, which yields benefits for the scientists and stakeholders in deciding what products and results are most meaningful for mitigating socioeconomic impacts of extreme precipitation events. From the data analysis side, initial examination of observational and reanalysis precipitation data highlights vulnerable regions to extreme precipitation events historically in the contiguous US and a composite analysis of favorable synoptic-scale patterns associated with these events. Expanding these results and integrating them into a statistical framework to study extreme precipitation events in model output and integrating larger-scale modes of climate variability into S2S predictability of extreme precipitation events will also be discussed.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-01)

Examining the role SH sea-ice forcing on southern Africa rainfall extreme variability: Model sensitivity experiment

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The contribution of various climate forcings and their complex interactions is of key importance in climate predictability studies. The inclusion of all components of the climate system presumably offer superior result. As previous studies noted, sea-ice has not only a noticeable importance in the Earth's energy and water budget but also has a considerable effect on local and remote atmospheric and oceanic circulations. According to these numerical and observational studies, the Antarctic Dipole temperature anomalies, for instance, present the largest El Niño-Southern Oscillation (ENSO) signal outside of the tropical Pacific and represents the largest interannual variability in the Antarctic sea ice field. The changes of the basin-scale meridional circulation in the South Pacific and South Atlantic and stationary Rossby wave propagation associated with the ENSO variability might be the main mechanisms for the tropical/polar teleconnection. In addition, sea-ice extent and drift velocities were reportedly found to be sensitive to the main modes of southern hemisphere variability, including the PSA (Pacific South America), SAM (Southern Annular Mode), SAO (Semi-Annual Oscillation). Nonetheless, the role of sea-ice dynamical coupling in the context of southern African (extreme) rainfall climate variability is not extensively explored. The study therefore attempts to quantify the role of sea-ice forcing by conducting various model sensitivity experiments in a manner that decomposes the signature of sea-ice forcing. In this context, the response of the southern Africa climate system was examined under four different model configurations which all forced by the time-varying CO2 and ozone fields provided through the CMIP5 (Coupled Model Intercompariosn Project Phase Five) archive for the period 1870-2100:

a) Complete system experiment that employs an earth system model (ESM) that interactively couples atmosphere, ocean, biosphere and cryosphere models.

b) AMIP type experiment, using the AMIP sea-surface temperatures (SSTs) and non-varying annual cycle sea-ice concentrations (SICs) provided through CMIP5 lower boundary forcing.

c) As experiment (b) but with non-varying annual cycle SICs forcing.

d) As experiment (b) but with non-varying annual cycle SSTs forcings

The ESM simulation of the observed trends of the SH SST, SIC and eddy fluxes eddy-driven jet stream is realistic. The latter is found to show a significant (95%) association with the southern Africa rainfall extremes as represented by standardized perspiration index (SPI). The response of these extreme behavior under other experiments would be examined and contrasted against this all-forcing numerical experimentation.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-02)

Improved ENSO predictability in CCSM4 simulations with stochastic parameterization

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Once important source of predictability on interannual timescales comes from the El Nino-Southern Oscillation (ENSO). The temporal evolution of ENSO in NCAR's Community Climate System Model is compared to a simulation in which the model's atmospheric diabatic tendencies are perturbed every time step using a Stochastically Perturbed Parameterized Tendencies (SPPT) scheme.

The temporal evolution in the simulation with SPPT compares better with the ERA20C reanalysis in having shorter memory, lower inter-annual sea surface temperature variability, and more irregular transitions between El Nino and La Nina states than the control simulation.

The mechanisms by which short timescale perturbations to atmospheric processes can affect tropical interannual variability are further investigated using a hierarchy of simplified models.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-03)

Decadal variability in weather regimes and teleconnections in reanalysis datasets and century long hindcasts.

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Atmospheric intraseasonal variability, especially in the extratropics during the cold season, is characterized by preferred large-scale quasi-stationary flow patterns that have non-Gaussian characteristics. They are known as weather regimes and can be associated with significant temperature and precipitation anomalies. Several observation- based and model studies have shown that El Nino-Southern Oscillation (ENSO) and Madden and Julian Oscillation (MJO) forcing affects the relative frequency of occurrence of circulation regimes. The ENSO forcing is particularly important for the Pacific North-American (PNA) region, whose intraseasonal variability is directly linked to tropical Pacific SST anomalies. The MJO forcing affects the occurrence (and sub-seasonal predictability) of the North Atlantic Oscillation (NAO) and, to a lesser extent, the Euro-Atlantic Blocking.

On the other hand, several recent studies have shown that wintertime large scale extratropical circulation over both the Pacific North American and the Euro-Atlantic sectors exhibits a non-negligible interdecadal variability, which seems to be related to a decadal modulation of the tropical-extratropical teleconnections and can strongly impact on seasonal predictability (see for example Weisheimer et al. 2016, O'Reilly et al. 2017, O'Reilly 2017).

In this study we use century reanalysis datasets and a range of coupled and atmospheric-only ensemble seasonal hindcasts together with climate simulations to investigate the inter decadal variability of wintertime extratropical weather regimes and their associated tropical and extratropical teleconnections.

The implications of the results of this study for S2D predictability and the evaluation of S2D forecasting systems is discussed.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-04)

Heavy rainfall in Paraguay during the 2015-2016 austral summer: causes and sub-seasonal-to-seasonal predictive skill

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Columbia Water Center (1), Columbia International Research Institute for Climate and Society (2), Dirección de Meteorología e Hidrología, Paraguay (3)

During the austral summer 2015-16, severe flooding displaced over 170000 people on the Paraguay River system in Paraguay, Argentina, and Southern Brazil. These floods were driven by repeated heavy rainfall events in the Lower Paraguay River Basin. Alternating sequences of enhanced moisture inflow from the South American Low-Level Jet and local convergence associated with baroclinic systems were conducive to mesoscale convective activity and enhanced precipitation. These circulation patterns were favored by cross-timescale interactions of a very strong El Niño event, an unusually persistent Madden-Julian Oscillation in phases four and five, and the presence of a dipole SST anomaly in the central southern Atlantic Ocean. The simultaneous use of seasonal and sub-seasonal heavy rainfall predictions could have provided decision makers useful information about the start of these flooding events from at least two-to-four weeks in advance. Probabilistic seasonal forecasts available at the beginning of November successfully indicated heightened probability of heavy rainfall (90th percentile) over southern Paraguay and Brazil for December-February. Raw sub-seasonal forecasts of heavy rainfall exhibited limited skill at lead times beyond the first two predicted weeks, but a Model Output Statistics approach involving principal component regression substantially improved the spatial distribution of skill for Week 3 relative to other methods tested including extended logistic regressions. A continuous monitoring of climate drivers impacting rainfall in the region, and the use of bias-corrected heavy precipitation seasonal and sub-seasonal forecasts, may help improve flood preparedness in this and other regions.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-05)

On the decreasing Arabian Peninsula Winter Precipitation and its teleconnections

"EHSAN, MUHAMMAD AZHAR (1)", "Kucharski, Fred (2)", "Almazroui, Mansour (3)", "Ismail, Muhammad (4)"

"ICTP, Italy (1)", "ICTP, Italy (2)", "CECCR, Saudi Arabia (3)", "CECCR, Saudi Arabia (4)"

The precipitation over Arabian Peninsula (AP) during November-April (NDJFMA) exhibited a marked decreasing trend during the 116 years period from 1901-2016. The NDJFMA precipitation is positively associated with Sea Surface Temperature Anomalies (SSTAs) particularly over El Niño Southern Oscillation (ENSO) region, while they are negatively associated with western Pacific SSTs. The cold ENSO phase tend to reduce, while warm tends to increase precipitation over AP. The idealized AGCM experiments using atmospheric global climate model (AGCM) with SSTs idealized heat and trend imposed during last century provide a plausible explanation of the decreasing precipitation over AP. The role of western Pacific SSTs, which exhibits a strong warming trend, could be a major factor for the decreasing precipitation over AP.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-06)

Remote and Local Influences in Forecasting Pacific SST: a Linear Inverse Model and the NMME Multimodel Ensemble Study

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A suite of statistical linear inverse models (LIMs) are used to investigate the predictability of Pacific Ocean sea surface temperature (SSTs) on seasonal and decadal timescales. Observed monthly SST anomalies in the Pacific sector (between 15oS and 60oN) are used to construct the LIMs for seasonal and decadal prediction. The LIMs were further broken up into three different regions, Tropics plus Extratropics (15oS to 60oN), only Tropics (15oN to 15oS), and only Extratropics (16oN to 60oN). The forecast skills of the LIMs are then compared to that from two current operational forecast systems. The analysis reveals that LIM has a better predictability for the Northeastern Pacific than NMME models. LIM also is found to have comparable predictability for the ENSO region with NMME models. This predictability, however, is highly dependent on the initialization month, with forecasts initialized during the summer having better skill than those initialized during the winter. The predictability with LIM is also influenced by the verification period utilized to make the predictions, likely due to the changing character of El Nino in the 20th century. The North Pacific seems to be a source of predictability for the Tropics on seasonal to interannual time scales, while the Tropics act to worsen the skill for the forecast in the North Pacific. The data were also band passed into seasonal, interannual and decadal time scales to identify the relationships between time scales using the structure of the propagator matrix. For the decadal component, this coupling occurs the other way around: Tropics seems to be a source of predictability for the Extratropics, but the Extratropics don't improve the predictability for the Tropics. These results indicate the importance of temporal scale interactions in improving predictability on decadal timescales. Therefore, LIMs are not only useful as benchmarks for estimates of statistical skill, but also to isolate contributions to the forecast skills from different timescales, spatial scales or even model components.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-07)

Seasonal rainfall Modulated by Topography and Indian Ocean Sea Surface Temperature in Rwanda

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This study was aimed to investigate the influence of topography and Indian Ocean sea surface temperature (SST) on central Africa seasonal rainfall distribution and the atmospheric

Circulation anomaly associated. The analysis covers the years 1979–2011 and is carried out using Climate Research Unit (CRU) and Tropical Applications of Meteorology using SATellite (TAMSAT) rainfall estimates. The results show that positive (negative) SST over western Indian Ocean leads to anomalous moisture convergence (divergence) at low level and strong convective (weak convective) enhancing rising (sinking) air motion over the western Indian ocean which in return increase significantly (suppress) rainfall over the study region. It is found that the impact of Sea Surface Temperature (SST) anomaly over central Africa is stronger during October to December rainfall season compared to March may season with correlation coefficient ranging between 0.7-0.8 and 0.05-0.1 respectively.Pressure analysis demonstrate that the High pressure was located to windward side and low pressure on the leeward side. Topography was found to be the most important factor to regulate the precipitation location, Air lifted up the mountains range along the west branch of the great lakes region releases much of its moisture as precipitation. As a result,the mountainous region thereare prone to heavy precipitation.The results also reveal the considerable influence of wind speed and wind direction, precipitation was found to increase with increasing wind speed. Precipitation amounts were found to be higher for westerly and southerly winds than for easterly and northerly winds. Rainfall distribution overCentral Africa was found to be strongly determined by the presence of elevated African topography.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-08)

Dominant atmospheric circulation patterns associated

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The study investigated the dominant atmospheric circulation patterns associated with abnormal rainfall over Rwanda during the March–May (MAM) rainfall season in 1981–2010. The data sets used in this study include: rainfall, wind, sea surface temperature (SST), and humidity. Correlation and composite analysis and Percent of Normal Index (PNI) were deployed in this study. In the wet years (1987, 1988, and 1998), the country was dominated by moisture convergence, which is in line with wind anomalies that exhibits strong westerly winds from the Atlantic Ocean and southeasterly winds originated from the Indian Ocean. These winds carry moist air mass passing over Congo to the study area, leading to wet events. On the other hand, easterly winds were noted over the study area during the dry years (1984, 2000, 2007, and 2008).

The observed wet years coincided with the El Niño events, while the dry years are noted during the La Niña episodes. The dry years exhibited a wide spread of moisture divergence anomaly at the low level and were characterized by the sinking motion as opposed to the wet years with the rising motion. The anomalies of velocity potential/divergence further showed that the wet (dry) years were characterized by convergence (divergence) at the low level. The results also show that there exists a low positive correlation between mean MAM rainfall and SST over the Indian Ocean, which shows minimum influence of the Ocean. On the other hand, it was noted that rainfall amounts is significantly correlated at 95% confidence level with the elevation (altitude) of a given station. This study improves the understanding of the occurrence of wet and dry events in Rwanda, which is helpful in future monitoring of these events.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-09)

A Seamless Process-based Model Evaluation Framework for Subseasonal-to-Decadal Timescales

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Common approaches to diagnose systematic errors involve the computation of metrics aimed at providing an overall summary of the performance of the model in reproducing the particular variables of interest in the study, normally tied to specific spatial and temporal scales. However, the evaluation of model performance is not always tied to the understanding of the physical processes that are correctly represented, distorted or even absent in the model world. As the physical mechanisms are more often than not related to interactions taking place at multiple time and spatial scales, cross-scale model diagnostic tools are not only desirable but required. Here, a recently proposed circulation-based diagnostic framework is extended to consider systematic errors in both spatial and temporal patterns at multiple timescales. The framework, which uses a weather-typing dynamical approach, quantifies biases in shape, location and tilt of modeled circulation patterns, as well as biases associated with their temporal characteristics, such as frequency of occurrence, duration, persistence and transitions. Relationships between these biases and climate teleconnections (e.g., ENSO and MJO) are explored using different models.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-10)

Impact of air-sea interaction on the NH summertime atmospheric mean state, interannual variability and the monsoon-desert mechanism

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Previous studies have established the existence of a large scale teleconnection between ascent in the South Asian Summer Monsoon and subsidence over the Mediterranean (known as “the monsoon-desert mechanism”). Improving the representation of this mechanism could potentially improve the skill of seasonal forecasts of European summer weather patterns. In this study, the impact of air-sea interactions on the representation of the monsoon-desert mechanism are analysed in two 45-year experiments with the Met-Office Unified Model. In the first coupled experiment, the atmosphere is allowed to freely interact with a high resolution mixed-layer ocean model. The diagnosed daily SSTs from this experiment are then used to force an atmosphere-only uncoupled experiment. The coupled experiment is able to capture the observed westward propagating Rossby-wave trains excited by the Indian Summer Monsoon, while in the uncoupled experiment the Rossby-wave response is more local. It is shown that in the coupling experiment more moisture is transported inland and monsoon precipitation reach further north than in the uncoupled experiment favouring westward Rossby wave propagation.

SESSION: (C3) Time scale interaction (includes teleconnections)

(P-C3-11)

Relationship between Indian summer monsoon and Atlantic Nino

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The ISM is correlated with negative phase of Atlantic Nino. Atlantic Nino intensifies the ITCZ which generates stationary wave meridionally consisting of anomalous negative GPH over NW Europe, which acts as center of action for the propagation of a Rossby wave train to NW India via Europe consisting of anomalous high over NW of India reinforcing the outbreak of monsoon activities.