28TH SESSION
OF THE WORKING GROUP
ON NUMERICAL EXPERIMENTATION (WGNE-28)

Toulouse, France, 5-9 November 2012

Prepared by

Andy Brown[1], Christian Jakob[1] and Jean-Noël Thépaut[2]
[1]Co-Chairs and [2]In-coming Co-Chair of WGNE

WGNE is a Joint Working Group of the Commission for Atmospheric Sciences
and the
World Climate Research Programme

1. INTRODUCTION

The meeting was opened at 09:05 on 5 November 2012 by Christian Jakob on behalf of the Co-chairs of WGNE (Christian Jakob and Andy Brown). They welcomed the members of WGNE to the 28th session and thanked all for attending and contributing. He also acknowledged the support from CAS and WCRP as well as Météo-France for hosting the event. He also thanked the invited experts for their attendance. This was followed by the participants briefly introducing themselves and providing short background to their fields of expertise.

Christian introduced the agenda indicating the rescheduling of the discussion on aerosols from Wednesday afternoon to Thursday late morning. It was also indicated that in developing the programme for this meeting it was apparent that future WGNE meetings could be scheduled over 4 days with resulting savings. The agenda was adopted.

Florence Rabier, representing the local host, welcomed all on behalf of Météo-France and provided an overview of logistical arrangements for the week.

Philippe Bougeault extended this welcome and commented on the scope and quality and of the work of WGNE on model development and its relevance for improved services to society on both weather and climate time scales.

Philippe presented the research at Météo-France and its focus on improved understanding of processes related to weather; sea state (waves, coastal submersion); climate and climate change; air quality (impacts on health and visibility); accidental pollution in the atmosphere and the ocean; volcanic ash alerts; hydrology (floods and droughts) and the snow mantel (specifically avalanche risks). He explained that the Météo-France research themes cover the upper ocean, the land surface and the cryosphere.

He then described the airborne facility of Météo-France and its capability of aerosol / microphysical studies. An overview of the use of Unmanned Arial Vehicles by Météo-France was given highlighting its use to study fog and the heat flux over water surfaces.

Philippe also described Météo-France' involvement in the focussed observational studies of ConcordIASI and its benefits to improved understanding of the atmosphere over Antarctica. He also touched on the extensive observational systems deployed over land and the Mediterranean to support Hymex.

The presentation was concluded by an overview of the Météo-France capabilities to study the snow mantle at the Météo-France research facilities in Grenoble with specific reference to avalanche potential and thermal conductivity.

2. MEETING GOALS AND ACTIONS FROM LAST MEETING

The Co-chairs stated that the goal of WGNE-28 was to review of progress (e.g. through centre reports) and to discuss current and future specific initiatives (e.g. Polar Prediction Sub-seasonal to Seasonal Prediction Projects; session on aerosols in NWP and Climate models).

The importance of WGNE was highlighted in its role of bridging the weather and climate modelling and research communities and to continuously promote model development as a fundamental building block to improved understanding and predicting of both weather and climate.

Christian Jakob gave an overview of action items, indicating that all were acted upon since the previous meeting.

3. CAS AND WWRP MATTERS

3.1 Commission for Atmospheric Science

Deon Terblanche conveyed the best wishes from the President of CAS, Michel Beland, who could unfortunately not attend, to the participants for WGNE-28 and expressed his appreciation for the contributions to, and progress within WGNE.

He urged WGNE to continue to debate and identify those modeling priorities that can best be solved by joint work between the weather and climate research communities.

Deon reviewed the future environmental and socio economic stressors identified by CAS that highlight priorities that should also be considered by WGNE as it evolves. These priorities are:

- The development of a Global Greenhouse gas Information System through optimal integration of in-situ observations, satellite observations and enhanced by data assimilation and modeling,

- Enhanced Sub-seasonal to seasonal predictions through a joint research effort by weather and climate scientists,

- Tackling the grey zone, and related precipitation processes,

- Geo-engineering and critical assessment of these methods,

- Integrated environmental predictions for megacities and large urban complexes,

- Polar prediction services which require models to be fine-tuned and/or adapted to high latitudes.

3.2 WWRP including THORPEX

Deon Terblanche provided background to the WWRP, including THORPEX, highlighting the recent review of THORPEX and its achievements.

Reference was made to the planned World Weather Open Science Conference planned in August 2014 as well as the summer school on earth system science for weather prediction planned in NH summers of either 2013 or 2014, depending on funding support.

The post-THORPEX legacy was discussed and the process to ensure a smooth transition to these new arrangements. This process will culminate in the CAS-16 Session to be held from 18-26 November 2013 in Turkey. He indicated that the THORPEX legacy will be taken forward by time limited projects such as the Polar Prediction Project and the Sub-seasonal to Seasonal Prediction Project and a new project for which an implementation plan still needs to be developed re-focusing on high impact weather in a changing climate.

In addition, the current recommendation is for the WWRP to include, with some realignment, two of the THORPEX working groups in its structures: The working group on *Data Assimilation and Observing Systems* (DAOS) and the working group on *Predictability and Dynamical Processes (PDP)*. Projects will therefore use the expertise within all the working groups of WWRP to focus research on specific topics or regional issues. To facilitate closer cooperation between Nowcasting Research and Mesoscale Meteorological Research, the plan is to merge these two groups into one group.

In the discussion that followed the presentation, CAS was invited to provide additional input and guidance to WGNE to ensure that its activities are aligned to the emerging needs as identified by CAS. WGNE is also ready to contribute towards the 2014 World Weather Open Science Conference and the planned summer school and expectations by CAS in this regard should be communicated to the Co-chairs.

4. UPDATE ON THE FUTURE OF THORPEX DATA ASSIMILATION ACTIVITIES

Tom Hamill presented the Data Assimilation and Observing Systems Committee Report.

The THORPEX DAOS committee met in September 2012 in Madison Wisconsin. Major subjects for the committee at this meeting were to review the efficacy of mid-latitude targeted observations, to consider new and existing observation platforms, and new data assimilation methods. The committee reviewed results from an observing systems experiment (OSE), whereby targeted dropsonde data in the Pacific was either assimilated or not along with the operational data stream in the ECMWF system. No impact from the assimilation of the extra data was found, suggesting that assimilation systems have improved dramatically and that the observation network is relatively dense compared to 10 years ago, when previous OSEs were conducted. DAOS is also concerned about the loss of scatterometer surface wind data from QuickSCAT, though assimilation of scatterometer data from the Indian Oceansat may mitigate this loss. DAOS is also concerned about the potential loss of polar orbiting satellite data, especially AMSU satellite data, in a few years when the existing US polar orbiters are at the end of their life span. Concerning assimilation methods, Tom Auligne of NCAR presented an intriguing new assimilation method which permits ensemble data assimilation using the classic variational machinery, potentially eliminating the need for more complex hybrids of ensemble Kalman filters and variational schemes.

In the discussion that followed, the importance of data assimilation systems to forecasting system performance was reiterated. The recommendation to include the existing THORPEX DAOS working group in the future structure of the WWRP was welcomed. Data assimilation and analyses and how best to share these between WGNE and the DAOS working group were identified as topics for further discussion during the meeting.

ACTION ITEM: WGNE should add a DAOS ex-officio member to ensure effective links between the working groups.

5. WCRP MATTERS

Michel Rixen provided an update on WCRP matters, noting that 3 major processes and events have started shaping the future of the program: the ICSU visioning process leading to the new Future Earth Initiative, the Open Science Conference leading to the 6 Grand Challenges (GC) led by various WCRP entities, and the UN Global Framework for Climate Services (GFCS) the Implementation Plan for which has now been approved by the WMO Executive Council. He observed that the cross cutting capabilities to be developed under Future Earth might provide collaborative and funding opportunities for groups active at the weather-climate interface such as WGNE. A new Working Group on Regional Climate is currently being established to respond to this new landscape.

The GC on *Clouds and climate sensitivity*, led by WGCM with inputs from the WGNE and GEWEX communities, will focus on current barriers pertaining to the inability to constrain the effects of clouds on climate sensitivity estimates, the lack of understanding of regional circulation and precipitation changes (especially over land) and unreliable representation of the coupling between cloud processes and large-scale dynamics. Rapid progress could be achieved by the critical mass of MIPs efforts, emerging new models (e.g. LES, CRMs over large domains and super-parameterization) and leveraging of the golden age of Earth

Observations. Other GCs such as the one on extremes and the one on regional climate could also offer opportunities for WGNE.

The WCRP 4th International Conference on Reanalysis confirmed the need for a family of reanalyses to address their uncertainties, the need for qualitative information on reanalysis products for end-users, the need for coupling between earth domains and interdisciplinary approaches, and the need for a stewardship of reanalyses and observations. The CMIP5 workshop has featured a number of WGNE contributions on the assessment of climate models, including the transpose-AMIP experiment. The International Conference on Regional Climate 4 -7 Nov 2013 in Brussels will cover key findings from the IPCC Working Group I contribution to the Fifth Assessment Report and major results from the CORDEX experiment.

The growing emphasis to integrate WCRP model and data into a seamless archive following the Earth System Grid (ESG) standards and protocols was highlighted. These further developments will be taken on by the WCRP Data Advisory Council and the WCRP Modelling Advisory Council.

Michel warmly thanked Christian Jakob for his strong leadership in bringing weather and climate communities together during his term as WGNE co-chair.

In the discussion that followed, WGNE endorsed again Obs4MIPS, the observational part of the ESG, as a key component to support climate and weather research. The need for WGNE to position itself on the various Grand Challenges was highlighted. The WGNE community also raised the importance of model development issues for WGRC, which should be adequately addressed at the regional scale as well, and suggested a possible representation of WGNE on that community.

5.1 A short update on the WCRP Modelling Advisory Council

Christian Jakob, as Co-chair of the newly formed WCRP Modelling Advisory Council (WMAC), explained how this body will be an advisory council for discussion and communication between groups involved in modelling, to identify priority areas, to act as forum for discussion and to promote model development in general. WMAC will build on the previous effort of the WCRP Modelling Panel and will consider the lessons learned from that initiative. As WCRP JSC does not have sufficient time or expertise to discuss modelling issues in detail, WMAC is viewed as an extension of JSC to allow the modelling community to come together and identify gaps and duplication, and to advise on how these can be best addressed.

In the discussion that followed it was recalled that although climate change will manifest itself primarily through changes in the circulation of the atmosphere at shorter timescale, tropospheric dynamics have no designated “home” in any of the WCRP projects. The possible representation of WWRP on WMAC was also discussed briefly and it was strongly felt that the addition of a WWRP representative to WMAC would provide an important link between WWRP and WCRP to *bring weather into WMAC*, in addition to WGNE’s involvement. The members of WGNE view WMAC as an ideal body to champion issues related to model development, especially if the above matters could be addressed. Some near term initiatives could include summer schools, prizes and tropospheric circulation studies.

6. CLIMATE MODEL METRICS PANEL

Peter Gleckler provided an update on the WGNE/WGCM Climate Model Metrics Panel. This effort was initiated by WGNE and since 2010 has become a joint WGNE/WGCM activity. There are currently 8 members of this panel (4 members identified by both working groups)

with a diverse expertise in developing objective measures of model performance. He reported on the panel's efforts to foster a limited set of frequently used performance metrics in an attempt to establish community benchmarks for climate models. These routine metrics are based on well-established performance measures in the peer reviewed literature and often represent the first quantitative step in model evaluation beyond looking at a difference map. The presentation included examples of incremental improvements in the CMIP5 simulations (versus CMIP3) as well as comparisons of relative model performance. Efforts to extend beyond the large scale mean climate include some basic characteristics of ENSO, monsoons and the MJO.

During the coming year the panel intends to make publicly available a set of routine metrics including well-documented codes, observations and a database of metrics results for all CMIP5 and earlier generation simulations. These performance summaries will enable interested modelling groups to easily incorporate multi-model evaluation into their model development process. A community-based metrics/diagnostic code repository is also under consideration. This concept was further discussed after the presentation, and was raised as a possible discussion item for the WGNE systematic errors workshop (April 2013). A wiki (http://www-metrics-panel.llnl.gov/wiki) has been launched which further describes the panel's activities.

7. WWRP AND WCRP POLAR PREDICTION PROJECTS

Thomas Jung presented the WWRP Polar Prediction Project (PPP) and gave a short overview of the WCRP Polar Climate Predictability Initiative, highlighting the mechanisms for coordination between the two initiatives.

Thomas pointed out that the WWRP PPP constitutes the hourly to seasonal research component of the WMO Global Integrated Polar Prediction System (GIPPS). The research areas will focus on underpinning research (e.g. predictability and dynamics; teleconnections), forecast system development (e.g. observations, modelling, data assimilation, ensemble forecasting) and services (e.g. Societal and Economic Research Applications (SERA), verification). He also highlighted the differences in temperature tendencies between polar areas and the tropics, new TIGGE products focusing on polar areas, the role of sea ice in medium range forecasting and progress w.r.t. stochastic sea ice parameterization.

Thomas described the Year of Polar Prediction which is planned for 2017-2018 and aimed at an intensive observational and modelling period to advance polar prediction capabilities. This will be augmented by research into forecast-stakeholder interaction, verification and a strong educational component and be preceded by a planning phase leading up to 2017-2018 and a consolidation phase thereafter during 2018-2022. He indicated that the Steering Group's next meeting will be from 12-13 December at ECMWF.

An overview of the WCRP Polar Climate Predictability Initiative (PCPI), using input from Ted Shepherd, was presented. This initiative will focus on:

- Why are the climates at the two poles changing so differently to each other (with the Arctic changing rapidly, and the Antarctic unevenly), and to global climate?
- Why are climate models generally unable to capture the observed behaviour in Polar Regions?
- What does high latitude climate change mean for lower latitudes?
- Do the ongoing amplified changes in the Arctic have an influence on extremes in the Arctic?
- How predictable is Arctic climate?
- Is the stability of ice sheets changing? What is the probability of catastrophic ice sheet breakdown in the next few decades?

It was further pointed out that the PCPI will be a sub-initiative within the 'Cryosphere in a Changing Climate' WCRP Grand Challenge with overall responsibility within CliC and SPARC responsibility for the development of the stratospheric component. It was pointed out that there would be benefits for close cooperation on issues of mutual interest.
In the discussion that followed, WGNE expressed its strong encouragement for the polar prediction initiatives by WCRP and WWRP/THORPEX to be merged into one project and offered WGNE support to especially the YOPP. In this regard WGNE could consider a special model development sub-project which could further assist in bridging the current two initiatives.

ACTION ITEM: Thomas Jung was requested to provide more information to the members of WGNE on the polar workshop scheduled for June 2013 at ECMWF.

8. CENTRE REPORTS

8.1 Brazil

Saolo Freitas presented on recent developments at CPTEC, Brazil. CPTEC has made some advances on NWP on several scales:

- On regional scale, a locally adaptive emergency system is running with the BRAMS model at 1 km resolution to provide guidance on severe weather occurrence. Also a new product using BRAMS at 5 km resolution covering the entire South America is running and is under evaluation. Rainfall forecast presents good improvement. Very soon, a set of new physical parameterizations will be tested in this configuration.

- On global scale, preliminary results using a new set of physical parameterizations indicate better scores. More robust evaluation will appear soon.

- The GSI 3d-VAR data assimilation approach has been adopted by CPTEC and this system was implemented with the AGCM. The new analysis presents huge improvements in comparison with the old GPSAS system. Next January, the same methodology will be applied for regional modelling with BRAMS.

- The ensemble forecast has been improved with new methodology for the application of random perturbations developed at CPTEC.

8.2 Canada

Ayrton Zadra presented recent developments at Environment Canada.

The 2011/2012 period was marked by the arrival of the IBM Power-7 supercomputer, and three major upgrades in the operational NWP suites: a major increase (2x) in the amount of satellite data assimilated, a new seasonal-to inter-annual prediction system, and new 10-km 4DVar regional prediction system. Various upgrades are planned for 2013, when existing systems will go to higher resolution and new systems will become operational. The NWP suites are being re-organized and the role of ensembles is expected to become increasingly important.

8.3 NCEP

Bill Lapenta provided a report on recent modelling activities at the National Centers for Environmental Prediction (NCEP). Major accomplishments in the past year include the implementation of the 3D EnVAR data assimilation methodology in the Global Data Assimilation System (GDAS) used to initialize the Global Forecast System (GFS). The

upgrade incorporated the assimilation of the NPP ATMS data and GPSRO bending angle and the package has resulted in improved global forecast skill metrics consistent with pre-implementation testing.

Other major system upgrades included increasing the horizontal and vertical resolutions of the Global Ensemble Forecast System (GEFS) from T190L28 to T254L42 from 0 - 192 hours and T190L28 to T190L42 from 192 - 384 hours. The Short Range Ensemble System was also upgraded from 32km to 16km and is solely composed of the NMM and ARW non-hydrostatic cores while the ETA and Regional Spectral Models were removed from the membership. The Rapid Update Cycle was replaced with the Rapid Refresh maintaining a 12km CONUS mesh but moved to the GSI for the data assimilation system. NCEP also implemented the first instance of a coupled GFS/GOCART dust numerical guidance system at T126L64.

NOAA has recently acquired the next operational and backup supercomputer system expected to become operational no later than 31 August 2013. Each cluster is an IBM iDataPlex system composed of 10,048 processors delivering a peak performance of 208 Trillion calculations per second. The machine is currently undergoing acceptance and the production suite is being ported. Major upgrades under development for 2014 include increasing the GDAS/GFS resolution to T878 (Eulerian) or T1148 (Semi-Lagrangian) and the assimilation of NPP CrIS and METOP-B data. Assimilation of SSMI/S is also under consideration. Other major systems expected to be upgraded in 2014 include the CONUS based systems (North American Mesoscale) and Rapid Refresh with emphasis on enhanced data assimilation and physics to improve precipitation forecasts and the representation of severe weather parameters. Additional upgrades are planned for the GEFS, North American Ensemble Systems, regional hurricane, waves and ocean systems.

8.4 JMA

Chiashi Muroi presented a report on current status and recent developments at JMA.

JMA replaced its supercomputer system for operational NWP in June 2012 and the theoretical performance of the new supercomputer is 847TFlops and 30 times faster than the previous one. Operation of the Local Forecast Model (LFM) with 2 km horizontal resolution has started in August to provide severe weather events information. Rapidly updated cycle with 3D-Var is applied as data assimilation system for LFM. Developments and plans regarding to global and regional forecasting systems were presented.

8.5 DWD

Michael Baldauf presented recent developments at DWD, Germany.

DWD currently runs operationally the global hydrostatic model GME at about 20 km resolution, and the non-hydrostatic model COSMO in the two setups COSMO-EU (7 km) and the convection-permitting setup COSMO-DE (2.8 km). Several changes of the GME-3DVar during the last year concerned the use of atmospheric motion vector, winds over land, of wind profiler networks and of Oceansat-2 scatterometer data. Additionally an increase in resolution from 30 km to 20 km slightly improved skill over Europe and the both hemispheres (but not in the tropics). The GME will be replaced by the newly developed non-hydrostatic model ICON probably at the end of 2013. In contrast to GME, ICON conserves total mass and tracer masses and delivers consistent mass transport. It has a grid nesting optionto replace COMO-EU later on (probably at the end of 2014). It uses a horizontal-explicit vertical-implicit time integration scheme, but no time-splitting. A special treatment of the horizontal pressure gradients allows the simulation of rather steep slopes.

In the convection permitting model COSMO-DE, a Smagorinsky diffusion was introduced and the lake model Flake was switched on. Since May 2012 DWD runs a convection-permitting COSMO-DE ensemble with 20 members. Perturbations concern initial and boundary conditions by a multi-member approach, the physics parameterizations are perturbed in a non-stochastic approach. A main advantage in comparison to the deterministic COSMO-DE run is an earlier signal for severe convective events during summer.

9. RECENT DEVELOPMENTS

9.1 Numerical Methods

Mikhail Tolstykh presented recent developments in numerical methods.

The presentation covered two topics: the review of the `Weather and Climate Prediction on Next Generation Supercomputers: Numerical and Computational Aspects' conference held in Exeter (22-25/10/2012) and the WGNE survey on global models dynamical core development. The review of the conference discussed, among other subjects, the time integration schemes and the use of accelerators such as GPUs. The survey on dynamical core development has shown that most centers work on either improving their existing dynamical cores or developing new ones. Four centers work on both. Statistics on the type of horizontal approximation, time integration scheme and grid were given.

The WGNE survey on dynamical cores as compiled by MT is attached as Annex A.

9.2 Data Assimilation

Florence Rabier and Jean-Noël Thépaut presented recent developments in data assimilation.

A short summary of the WCRP 4th International Conference on Reanalysis was provided, focusing on data assimilation aspects. Critical elements reported were the importance of the assimilating models and the assimilation methods, with the need to have dedicated techniques to address reanalysis issues (long window, coupling of the earth system, cycling of background and model error covariances). A report was also provided on the conclusions of the Fifth WMO Workshop on the Impact of Various Observing Systems on NWP held in Sedona, Arizona, 22 - 25 May 2012. For global models, the highest ranked contributors for the forecast error reductions are AMSU-A, AIRS/IASI, radiosonde, aircraft, and AMVs. GPS-RO also has substantial impact, but the data volume is declining approaching the end of COSMIC lifetime. Several satellite sensors contribute to forecast skill, and more complementarities is seen, compared to previous years. Good progress was noted from all-sky radiance assimilation and radiances over land due to a better emissivity modelling. At the meso-scale, substantial progress on data assimilation was reported for satellite radiances, radar reflectivity and Doppler winds.

There is a general recognition that additional metrics are needed beyond the traditional objective scores such as ACC, RMS error and total energy in the case of FSO. Metrics that are more closely related to high-impact weather and service delivery should be developed and explored. Studies of observation impact on the forecasting of tropical cyclone and other severe weather events deserve particular attention. There is a need to invest in enhanced wind observations in the tropics and over the oceans especially. A relatively cost-effective enhancement would be to increase the collection of aircraft observations. A brief status report on ongoing data assimilation developments among major NWP centres was given. If variational analysis remains the most widely used technique operationally, ensemble techniques have much improved in maturity and most centres invest in ensemble data assimilations via various algorithms (ensemble of 4D-Vars, 4D ensemble Var, hybrid

techniques, pure EnKF). One major concern shared by most Centres is the issue of scalability, which ensemble techniques are agreed to be better at tackling than traditional variational techniques. Most centres invest in improving their use of satellite observations from advanced infrared sounders, in all sky conditions, and at increasingly high resolution. Last but not least, a short status report on PILDAS was given and centres were encouraged by WGNE to consider participation.

9.3 Ensemble Prediction

The report was presented by Tom Hamill and Chiashi Muroi and summarized the current status of global and regional ensemble prediction systems.

It was noted that most centers have moved / are moving toward methods that initialize their ensembles to be representative of analysis errors rather than methods that pre-select perturbations that are expected to grow rapidly (e.g, singular vectors, breeding). In 2012, operational centers and research laboratories are actively involved in developing methods for improving the representation of forecast uncertainty in ensembles, uncertainty that results from model imperfections or the inappropriate use of deterministic parameterizations. This aspect of ensemble forecasting is both novel and comparatively immature. Several methods for estimating this uncertainty were tested in the NCEP global ensemble forecast system and reviewed at WGNE. A combination of several (ECMWF's stochastic perturbed physical tendencies, UK Met Office stochastic vorticity confinement, and NOAA's stochastically perturbed boundary layer humidity) were found together to add significant spread and improve the calibration of the NCEP ensemble. The ensemble prediction report also provided a brief review of NOAA's new reforecast data set for its global ensemble prediction system, which was shown to be useful for statistical post-processing, which can reduce forecast bias and improve reliability.
The increased development of cloud-permitting regional ensemble model was pointed out.

In the discussion that followed, WGNE noted the large variety in implementation of regional EPS systems and expressed concern over how well this community is organized. Reference was made to the International Conference on Ensemble Methods in Geophysical Sciences scheduled for the week following WGNE at Météo-France.

ACTION ITEM: WGNE request a summary from TIGGE-LAM on the status of various regional Ensemble Prediction Systems and current efforts (projects, workshops etc) to co-ordinate their development.

10. SPARC REPORT AND DISCUSSION

A summary of Stratospheric Processes and their role in Climate (SPARC) activities over the past year was presented by David Jackson, with a focus on activities of most relevance to WGNE.

Two new SPARC activities have recently been approved by the SPARC Scientific Steering Group:

- The SPARC Reanalysis / analysis Intercomparison Project (S-RIP) aims to perform a comprehensive assessment and intercomparison of reanalyses in the tropopause region and the middle atmosphere. The assessment will be useful for research scientists aiming to use reanalyses to perform scientific investigations, as it will indicate the strengths and weaknesses of each reanalysis (*e.g.* to represent stratospheric sudden warmings). S-RIP shall also engender a strong interaction between researchers and producers of reanalyses, with the aim of producing better reanalyses in the future.

- In the Stratospheric Network for the Assessment of Predictability (SNAP) multi model multi case ensemble forecasts shall be run to investigate whether the impact of the stratosphere on tropospheric forecasts are generic or model dependent, and how much they depend on initial conditions or on the evolution of the stratospheric forecast state.

Initial ideas for two new SPARC activities were presented. The first is an assessment of model vertical resolution. It is important that any such activities is focused rather than too broad-ranging, and two possible areas where this study could be focused are a) the representation of the tropopause and associated impacts (on *e.g.* the QBO); b) the resolution and propagation of gravity waves. The second one focuses on the representation of parameterized and resolved gravity wave forcing in models, with scope to extend it to examine gravity wave sources in parameterization schemes. A linkage to the vertical resolution study is possible too.

A comparison of the representation of the stratosphere in global NWP systems, and its impact, is underway and initial findings were presented. Volunteers from NMSs were sought to help complete the study, which currently suffers from a lack of available resources.

In the discussions that followed WGNE encourage the modelling centres to follow the activities of the SPARC DynVar which will hold its 3rd workshop, 22-24 April 2013, jointly with the 1st SPARC SNAP workshop, 24-26 April 2013, in Reading.

ACTION ITEM: Modelling centres to provide David Jackson (SPARC) with the names of focal points on stratospheric issues.

11. CENTRE REPORTS

11.1 Météo-France

Florence Rabier presented on recent developments at Météo-France.

In 2012, there were modifications in the global NWP system, including optimizing the use of observations (observation error tuning, inclusion of more IASI channels, enhanced use of scatterometer data and of GPS-ZTD observations), tuning of the convection scheme, and introducing a model error inflation term in the ensemble data assimilation system which provides the errors of the day to the deterministic 4D-Var. The scores with respect to radiosonde observations over the Northern Hemisphere and Europe have continued to be very competitive in the last year.

At the mesoscale, there have been some improvements in the model physics in the convective-scale Arome model together with introduction of finer orography and climatologies. Arome usually performs forecasts 4 times a day. An additional forecast is being added from the 03UTC analysis, to complement the information available to the forecaster in the early morning. A focus was given on the HyMeX field experiment currently in its first SOP phase. Some precipitating events over the Mediterranean area have been observed and predicted by a range of local models. The exchange of data (in particular Synops and radar data from Spain) has helped for assimilation and verification. Some research work on fine-scale ensemble assimilation was also presented. In 2013, work will be mainly devoted to inserting new observations (Suomi-NPP, Metop-B...) and preparing for the migration to a new super-computer.

11.2 China Meteorological Agency

Xueshen Shen presented on recent developments at the China Meteorological Agency.

The current NWP system in CMA includes two parallel systems; one is the spectral model system; another is the grid point model system which is developed by CMA. The global medium-range, ensemble as well as typhoon forecast are produced by the spectral model system, with resolution TL639L60 for the deterministic version, and T213L31 for the ensemble (M15) and typhoon forecasts. The meso-scale products come from the gridpoint model GRAPES_MESO with 15km horizontal resolution and 33 vertical levels. Additionally, a 3-hourly rapid update cycle and a regional typhoon intensity forecast system are running based on the GRAPES_MESO. The above constitutes the NWP production system in CMA.
In 2012, 3 upgrade activities are conducted, including addition of the NOAA-18 radiance into TL639L60, new implementation of regional typhoon intensity forecast based on GRAPES_MESO (GRAPES_TYM), and several revisions of GRAPES_MESO. Also, two high resolution windows began to run with 3km resolution, and cover the Beijing city and Guangzhou city areas, respectively.

The new GRAPES_GFS parallel global medium range forecast system is running, but not yet officially operational. In 2012, main upgrades to GRAPES_GFS are the revised cumulus convection, shallow convection, PBL and microphysics. These revised physical processes greatly improve the stratocumulus and cloud cover simulations, and improve the forecast skill significantly as expected.

CMA also reported the future launch plan of the Chinese satellites, and the supercomputer upgrade plan.

11.3 Russian Federation

Mikhail Tolstykh presented recent developments in NWP and climate modelling in the Russian Federation.

The progress in global and regional numerical weather prediction, data assimilation was presented. Main achievements are the preparation of the new version of the global SLAV model with the horizontal resolution of 20-25 km for parallel runs and the establishment of the specialized limited area ensemble prediction system based on the COSMO-RU model with 2.2 km resolution. This ensemble prediction system is the product of international collaboration inside COSMO consortium and is targeted to Sochi, the city of 2014 Winter Olympics. Also, the progress in numerical climate modeling at the Institute of Numerical Mathematics/Russian Academy of Sciences was reviewed.

11.4 ECMWF

Jean-Noël Thépaut presented on recent developments at the European Centre for Medium Range Weather Forecasts (ECMWF).

Over the last year, ECMWF implemented two major upgrades of the forecasting system. The first one, implemented in November 2011, includes a revision of the cloud scheme addressing a better representation of the super-cooled liquid water and cirrus ice, the implementation of variational bias correction for aircraft temperature data and the assimilation of the US NEXRAD radar data. In June 2012, a second major cycle was introduced, comprising a complete revision of the background error covariances in the assimilation system, an improved filter of the variances in the Ensemble of Data Assimilation, improvements in the convection/cloud parameterizations, and enhancements to the wave model. These two new model/DA versions improved significantly the scores. In addition, the seasonal forecasting system was upgraded with the introduction of System-4 (better ocean model, updated version of the atmospheric model, higher resolution, etc.). The EUROSIP multi-model system was also improved with the inclusion of the NCEP system. The main areas of development for the forthcoming year include the increased vertical resolution (137 levels for the high resolution system and 92 levels to be introduced at a later

stage for the EPS), further development of the long window 4D-VAR systems, improved configuration of the EDA (flow-dependent variances for unbalanced variables, error correlation specifications, etc.) and general improvements of the model performance, including its scalability. ECMWF plans to produce a reanalysis covering the 20th century until real time, in a coupled and ensemble mode (ERA-CLIM2 project). ERA-interim will also be replaced by a newer reanalysis for the satellite era, post 1979.

ECMWF also hosts the MACC (-II) project which is a precursor to the GMES atmospheric services.

11.5 National Center for Atmospheric Research

Julio Bacmeister presented on recent developments at the National Centre for Atmospheric Research (NCAR).

This presentation concentrated on a comparison of high resolution climate simulations (0.25 degree) with simulations at conventional resolution (1 degree). CAM clouds exhibit strong sensitivity to increased resolution with large decreases in LWCF seen as resolution increases from 1 degree to 0.25 degree. Simulated precipitation does not change dramatically with resolution. Some features such as wintertime precipitation over the southeastern US show clear improvements at high-resolution. By contrast summertime precipitation over the US is unaffected by resolution. In particular, both low and high resolution simulations miss the observed, nocturnal maximum over the Midwest, suggesting that organized mesoscale systems are still not present at 0.25 degree resolution.

Plans for future development were discussed including the November 2012 model release that officially adopts the spectral element dynamical core as the default for future model versions.

11.6 Republic of Korea

Hoon Park presented recent progress at KMA.

The NWP system of KMA was introduced in terms of resolution, target forecast length, and mid-term plan. For the global deterministic system, enhancement in the data assimilation inner loop (90km to 60km) improves performance by more than 5% in terms of 500hpa height RMSE in NH. In May 2012, KMA started to operate a 1.5km resolution local area numerical model based on UM, and initial conditions are produced by the MetOffice 3DVar system. KMA plans to use more local observations such as radar reflectivity, ground GPS, and wind profiler.

Some results from assimilation of KMA geostationary satellite (COMS) data in global model were shown. The AMV data shows some improvement on the global model while Clear Sky Radiance (CSR) is neutral. The use of CSR could be continued for 1.5km local model to improve initial condition of early morning, 03LST.

A KMA new global model development project (KIAPS) was shown in terms of dynamic core and physics development plan. A survey on 3 potential dynamic cores was conducted for KIPAS. Among them, some results from a shallow water model using spectral element CG/DG over cubed sphere grid system was shown.

11.7 Bureau of Meteorology, Australia

Gary Dietachmayer provided a report on recent modeling activities at the Centre for Australian Weather and Climate Research (CAWCR). Work continues on rationalization of the NWP suite, in which it is planned to reduce the number of component systems from nine

to seven. First step in this process was the introduction to operations of a substantially improved global system. Updates on the development progress of the limited-area systems were also provided.

In the climate space, a significant milestone was reached when CAWCR published data from both versions of its "ACCESS" climate model to the Earth-System-Grid as part of the CMIP5 project. Initial evaluation suggests that both versions represent a solid advance on previous Australian climate models, and with the CMIP timeline met, more detailed evaluation studies are now underway, with particular focus on cloud distribution and microphysical properties.

Finally, a new project, supported across a number of research organizations and including significant university involvement, has begun to build a "virtual laboratory" for Australian Climate and Weather science. The aim here is to enhance collaborative development of the ACCESS model, by reducing technical hurdles to new users, and facilitating the sharing of experiments, data and results.

11.8 United Kingdom MetOffice

Andy Brown presented the latest modelling developments at the UK MetOffice.

An overview of the primary models in the MetOffice NWP suite was presented. Models are run in both deterministic and ensemble mode, all with 70 vertical levels on global, regional and local domains. An overview of the IBM P7 computer system size, performance and utilization was given highlighting that about 40% use is for weather forecasting and the remainder for climate applications.

Examples highlighting the London-2012 Summer Olympic NWP demonstrators for Nowcasting support and in providing wind and wave as well as air quality forecasts were presented. The 12 member, 2.2 km ensemble system that is run 4 times per day nested in the regional ensemble system will be switched to run directly from the higher resolution (33 km) global ensemble system before the end of 2012.

Systematic investigation of the impacts of resolution on seasonal and climate predictions showed higher resolution leading to reduced SST bias over the North Atlantic, improved winter blocking frequency and winter NAO skill.

In the discussion that followed a debate was stimulated on momentum budgets in models and a possible project on this. The importance of momentum flux measurements in Antarctica was highlighted and more potential benefits of more thorough attention tendencies were supported. Mention was made of encouraging SPARC/GASS to become involved in a bigger project.

ACTION ITEM: Ayrton Zadra, Andy Brown and Julia Bacmeister were requested to propose next steps for a study on model momentum budgets

ACTION ITEM: Michael Baldauf was requested to extend the tables with specifications of model characteristics at the various centres to include CPU and run-time information.

13. SCIENCE TALKS

13.1 Climate activities at Météo-France Including Seasonal Forecasting

Dr Planton presented climate activities at Météo-France.

The climate research pursued at CNRM relies mainly on modelling. The coupled climate system model CNRM-CM is developed in collaboration with CERFACS and IPSL. Its atmospheric component ARPEGE-Climat, is derived from the weather forecasting model in a "seamless" approach. This is also the case for ALADIN-Climat, a limited area model completing the variable resolution version of ARPEGE-Climat for regional climate studies. An overview of some scientific topics are illustrated in the field of climate variability studies, climate change scenarios at the global scale (CMIP5, analysis of multi-model ensemble, development of CNRM-CM6), climate change scenarios at the regional scale (sources of uncertainties, CORDEX, coupled regional scenarios), detection and attribution studies (application of new methodologies) and climate prediction (Eurosip, stochastic methodology).
For more information: ftp://cnrm-ftp.meteo.fr/pub-ext/planton

12.2 Successes and challenges of a seamless development of physical parameterizations

Dr Francois Bouyssel presented on the successes and challenges of a seamless development of physical parameterizations. Two physical packages are being developed at Météo-France for large scale (Arpege/Aladin NWP and Climat) and convective scale (Arome/Meso-Nh) models. Most of physical parameterizations are validated on a wide range of temporal and spatial scales. Same radiation and similar surface schemes are used in all models. There is an on-going effort to converge on PBL schemes. An important step forward has been reached with the use of a prognostic TKE scheme and a mass-flux shallow convection scheme in Arpege/Aladin NWP models, with significant benefits on stability, PBL scores and low level cloudiness. The Arome thermal scheme is currently being tested in Arpege, leading to some modifications in the algorithms and in the parameterization of entrainment/detrainment. A new convection scheme has been developed for the large scale models, with prognostic equations for the updraft vertical velocity and convective hydrometeors, same microphysics for resolved and convective precipitations and a CAPE closure. This new scheme is validated in a multi-scales framework ranging from 1D, 3D NWP, 3D Climat forced and 3D Climat coupled.

The seamless approach is nevertheless challenging for some parameterizations, which may need different level of complexity at various scales. For instance, Arome's microphysical scheme is much more sophisticated than in Arpege and designed for short time steps. The development of convective schemes suitable for grey zones of deep convection and turbulence is another difficulty with this approach.

12.3 Radar Data Assimilation

Jean-François Mahfouf presented on the developments related to radar data assimilation at Météo-France.

Since December 2008, Météo-France is operating a convective scale mesoscale model AROME at 2.5 km over a limited area domain covering a large part of Western Europe. This model has a dedicated assimilation system based on 3D-Var with a rapid update cycle of 3 hours. Radar observations are assimilated operationally since December 2008 for Doppler winds and April 2010 for reflectivity (through a 1D Bayesian inversion of relative humidity profiles). These data have proved to be beneficial to the analysis both in terms of information content and on quality of the subsequent forecasts (short-range precipitation and atmospheric winds). The importance of "no rain" information from radars has been found useful for improving the humidity analysis. Ongoing developments concern the use of X-band radars and radars from other countries than France (EUMETNET OPERA programme), and diagnostics on correlation of observation errors (in order to increase the spatial sampling of radar data).

13. WGCM ACTIVITIES

Sandrine Bony presented the activities of WGCM. WGCM objectives are to review and foster the development of coupled climate models (AOGCMs) (connected with WGNE); coordinate model experiments and inter-comparisons and promote and facilitate model validation and diagnosis of shortcomings; and understanding processes and feedbacks in the climate system (connected with WGNE).

An overview of the CMIP5 progress and lessons learned to date in terms of data and infrastructure as well as the science was given. From a science perspective the spread of projections in CMIP5 AOGCMs are comparable to CMIP3. However, CMIP5 offers many additional capabilities (carbon and chemistry, short-term climate change, comparison paleo/future, forcings and feedbacks diagnostics, high-resolution, high-frequency outputs, etc) and this will facilitate a better understanding of the spread and better assess the robustness of model results. The great value of idealized CMIP5 experiments was also pointed out.

In terms of model biases some quantities show considerable improvement (*e.g.* rate of sea ice loss in Arctic) or a decrease in model spread (*e.g.* AMOC, Nino3 standard deviation). However, many others have not significantly improved (*e.g.* double ITCZ, Arctic clouds and circulation, Antarctic sea ice loss, southern ocean too warm, SPCZ too zonal).

Included in the next steps CMIP5 analysts will be requested feedback about model shortcomings (and interpretation) and in encouraging the writing of a synthesis papers about CMIP5 results. WGNE was invited to engage on these issues.

Regarding joint WGNE-WGCM activities, the presentation focused on Transpose-AMIP which is basically running climate models in NWP mode, and its proposed sub-projects. An invitation was extended to global modeling centers (NWP and climate) to submit data.

The leading role of WGCM in the WCRP Grand Challenge on "Clouds, Circulation and Climate Sensitivity" and the potential opportunities for rapid progress were discussed in light of:

- Clouds are largely responsible for the uncertainty in climate and precipitation sensitivity (how much warming and precipitation increase will come for a given increase in CO2),
- Estimates of regional precipitation change vary widely between climate models because of poor representation of clouds in models,
- Changes in Climate Extremes (tropical cyclones, heat waves) are sensitive to the representation of clouds in models,
- The modeled response of climate to changes of aerosols is highly dependent on the representation of clouds.

The presentation was concluded with a summary of five targeted research topics and the strategy for integration and coordination with WCRP structures and WGNE.

14. WCRP GRAND CHALLENGES AND WGNE's ROLE

The WCRP Grand Challenge concept, as discussed at the WCRP JSC in October 2011 focuses on identifying critical areas of climate science where specific barriers are preventing progress and where targeted research efforts are likely to demonstrate significant progress over the next 5-10 years.

The WCRP Grand Challenges and their links to the WCRP Projects and Working Groups in terms on primary responsibilities are:

- Regional Climate Information (CLIVAR, WGRC, SPARC)
- Regional Sea-Level Rise (CLIVAR)
- Cryosphere in a Changing Climate (CLIC)
- Clouds, Circulation and Climate Sensitivity (WGCM)
- Changes in Water Availability (GEWEX)
- Prediction and Attribution of Extreme Events (GEWEX)

The WCRP Grand Challenges offer a number of key topics to be addressed in the next 5 to 10 years, several of those offering opportunities for the WGNE community at the climate-weather interface. This is also highlighted by the requests from WCRP (and WGCM) to engage in the Grand Challenges.

In the discussion that followed the question on how well weather is handled in climate models was identified as an issue that should be led by WGNE, including the write-up of a synthesis paper on the topic. The Grand Challenges related to clouds and extreme events are of particular relevance to WGNE. It was suggested that a session on the WCRP Grand Challenges could be included at the workshop on systematic errors.

In the context of WGNE, a critical question is how coupled models reproduce the weather and how to best diagnose this.

It was noted that biases in CMIP5 are still a major source of concern and short-term runs can help identifying systematic/persistent errors such as in the case of the double ITCZ or Southern Ocean bias issues and their origin. This will require innovative diagnostics.

Similarly, the impact of convective schemes on large scale circulation, dynamical interaction questions regarding diabatic heating, momentum, differences between tropics and high latitudes and more generally speaking the coupling between clouds and circulation is still poorly understood. These issues offer great potential on the Sub-seasonal to Seasonal time scale.

It was also indicated that WGNE links to other Grand Challenges, including Cryosphere in a changing climate, Prediction and Attribution of Extreme events and Changes in Water availability.

15. WGSIP ACTIVITIES

Hervé Douville presented on the WGSIP activities.

WGSIP aims at developing a program of numerical experimentation for seasonal-to-interannual variability and predictability, paying special attention to assessing and improving predictions. The main objective of the presentation was to provide a brief overview of recent WGSIP activities and of the status of seasonal to decadal forecasting based on both WCRP and PCMDI initiatives. At the seasonal timescale, the Climate system Historical Forecast Project (CHFP) was presented as well as three related subprojects (GLACE, Ice-HFP and Strat-HFP) exploring the contribution of the land surface, sea ice and the stratosphere to climate predictability. At the decadal timescale, preliminary results of the multi-model CMIP5 decadal hindcasts were presented as well as some results of the 2012-2016 forecasts based on the Met Office Decadal Forecast Exchange initiative. Finally, potential linkages with the Subseasonal to Seasonal (S2S) initiative, the FP7 SPECS European project and the CMIP project were also discussed.

In the discussion that followed it was pointed out that, on the seasonal timescale, limited skill was derived from the land initialization and that problems were observed in snow cover and the non-stationarity of the snow-AO relationship. Sudden stratospheric warming events occurred with better frequency in the high-top GCMs evaluated as part of the WGSIP-SPARC initiative but with no big gains in overall skill. WGNE felt that a better understanding of these experiments should be encouraged.

In the CMIP5 decadal experiments, 10 year hindcasts initialized in 1960, 1965 etc. showed that temperature predictions benefitted from initialization but that this is not the case for precipitation.

The possible synergy between WWRP-WCRP S2S and CHFP as a systematic repository of seasonal hindcasts was discussed and how this could benefit from FP7 SPECS as the next European contribution to HFP.

In terms of the CMIP6 experiment design for decadal predictions it was pointed out that model biases represent a major stumbling block to progress. However, it was recommended that the scope of the envisaged workshop on model tuning should be widened to include model development more generally (as well as parameter estimation techniques).

16. SUB-SEASONAL PREDICTION PROJECT

Frederic Vitart presented the Sub-seasonal to Seasonal project (S2S) which is a joint WWRP/THORPEX-WCRP research project with the primary objective to improve the forecast skill and understanding on the timescale beyond 2 weeks, but less than a season. This project will link weather and climate forecast activities. Demonstrating and promoting the use of sub-seasonal forecasts for applications will be an important component of this project. The research priorities of the S2S project will be to evaluate the potential predictability of sub-seasonal events, with a special emphasis on high-impact weather events, to understand systematic errors and biases in the sub-seasonal to seasonal time range, to compare, verify and test multi-model combinations of sub-seasonal forecasts and to set up demonstration projects. It is proposed to set up a sub-seasonal database which will include operational sub-seasonal forecasts from Global Producing Centres a few weeks behind real-time. A list of possible topics where S2S and WGNE could interact was presented: model errors (e.g. monsoon, MJO Maritime Continent Barrier), ocean-atmosphere coupling, representation of extratropical teleconnections in GCMS, stratosphere-troposphere coupling, aerosols and extreme events.

In the discussion following this presentation, WGNE agreed to review the list of variables that will be archived in the S2S database before the next S2S meeting in February 2013, with a special attention to land-surface parameters. It was also recommended that the S2S steering group should include a person working on land-surface processes. It was agreed to consider the extension of the two current WGNE projects on tropical storm and precipitation verification to the sub-seasonal time scale. It was also found that S2S could play a role in helping to rationalize the study of systematic errors between the various medium-range, sub-seasonal and seasonal databases (TIGGE, S2S, CHFP etc.).

ACTION ITEM: WGNE members to feedback to S2S steering group on any key variables missing from the list proposed for S2S database.

17. YOTC/MJO-TF AND obs4MIPS

Duane Waliser presented on the Year of Tropical Convection (YOTC), the MJO Task Force and the YOTC Science Planning Group Accomplishments and Near-Term Activities.

The presentation included an overview of YOTC and its linkages to other programs and activities as well as evidence of the visibility of YOTC in the peer-reviewed literature. Duane also provided a summary of the YOTC progress and timeline since inception, including planned activities over the next few years. Results of Transpose-AMIP studies involving eight CMIP5 modeling groups and focusing on the YOTC data period were presented.

The use of the UK Met Office Unified Model at cloud-system-resolving resolutions over large, limited-area tropical domains to study organized convection and scale interactions in the tropical atmosphere (CASCADE) related to the analysis of scale interactions was discussed. Insights into physical processes, comparisons of climate / NWP resolution and conclusions for parameterization were presented.

Duane then described in some detail the Vertical Structure and Diabatic Processes of the MJO: *Global Model Evaluation Project*, a joint initiative between MJO Task Force/YOTC and GASS. This project focuses on 20-year climate simulations, 2-day MJO hindcasts and 20 day MJO hindcasts which is conducted with the commitments of over 40 modeling groups using AGCM and/or CGCM.

The MJO Task Force was established in January 2010, initially for three years, to facilitate improvements of the MJO in weather and climate models in order to increase the predictive skill of the MJO and related weather and climate phenomena. It is organized into four sub-projects:

- MJO metric(s) for WGNE/WGCM Climate Metrics Panel,
- Process-oriented diagnostics/metrics for MJO simulation,
- Boreal summer monsoon ISV monitoring and forecast metrics,
- MJO TF + GASS Multi-Model Diabatic Processes Experiment.

It was also indicated that a request was made to WWRP/THORPEX and WCRP for continuation.

The presentation concluded on work being done to use satellite observations for CMIP5/IPCC Model Evaluation.

In the discussion that followed the importance of more input from the modelling community to influence satellite plans, including current capabilities such as CloudSat, were highlighted in order to develop a coherent voice from modelling community to that effect. The role that, among others, the WCRP Data Advisory Council and RRR process to review requirements could play was highlighted. RRR is however primarily focussing on operational requirements, so additional mechanisms should be sought to address more fundamental research in model developments.

ACTION ITEM: Christian Jakob to provide Duane Waliser a mailing list for use in a call for data/metric tailored for on Interseasonal Variability (ISV) for the boreal summer from modelling centres.

ACTION ITEM: Michel Rixen to send background to the WMO RRR process to Co-Chairs.

18. MONSOON PREDICTION – HOW WELL ARE CENTRES DOING AT VARIOUS RANGES?

Andy Brown presented on the Met Office and ECMWF skill in predicting the Asian Monsoon, providing an overview of the challenges that span all time scales and modelling systems

regarding rainfall amounts, spatial distribution and how this relates to errors in the predicted low-level wind fields. It was also pointed out that other models have problems.

Within a few forecast days the Met Office models develop a “dry” monsoon contrasting with the ECMWF spinning up the monsoon resulting in a “wet” monsoon. At ECMWF the boundary layer over Arabian Sea is implicated in monsoon problem although several outstanding questions remain. Separately it has been discovered that there are significant differences between the analyses of the two centers. It was noted that it would be relatively easy for someone to extend the comparisons to include multiple centers through use of data in the TIGGE archive.

ECMWF and the Met Office are now working to further understand the causes of the differences between their systems through comparing physical tendencies from short-range forecasts (with each other and with those from kilometre-scale limited area model simulations carried out as part of the EMBRACE project) and analysis increments from the data assimilation. Potentially a more ambitious project could be worked up involving other centers (e.g. as with current GASS MJO work), and, if there is sufficient interest, this should be considered in conjunction with thinking on the WCRP Grand Challenges.

In the discussion that followed other monsoon regions (including Africa) were covered and the reasons given why, with the available resources, current investigations are focused on the Asian Monsoon. Reference was made to possible links to the WCRP Grand Challenges and the India Monsoon Mission, a 5-10 year project which will include high resolution modelling. It was suggested that someone from India could be invited to assist with diagnosis in a WGNE led/co-led initiative. The relevance to the S2S project and the Monsoon Panel was also highlighted.

19. VERIFICATION

19.1 TC Verification

Chiashi Muroi provided an update of Tropical Cyclone (TC) verification for 2011. 11 NWP centers participate in verification for global models. KMA's improvements from its installation of Unified Model in 2011 and ECMWF's steady advancements were presented. Common slow model biases are also pointed out for TC's in Western Northern Pacific region. In addition to the global model verification, four regional models were also verified, and the advantage against their global model were presented.

In the discussion that followed Christian, on behalf of WGNE, thanked Chiashi and his colleagues at JMA for this work.

ACTION ITEM: WGNE encourages Chiashe Muroi and his team to publish the results on verification of TC forecast in global models.

19.2 Precipitation

Chiashi Muroi provided a result of precipitation forecast verification over Japan. A strong diurnal cycle of bias scores in summer season is observed in some global models. Improvements of DWD in summer ETS were indicated, which may be due to their global model resolution.

Florence Rabier reported that over France model QPF and precipitation data, based on 4000 gauges, are averaged and compared over at 0.5 X 0.5 degrees blocks. It was indicated that NCEP showed a higher positive bias in the recent past at low rain rates while ECMWF in general is doing well over France.

Bill Lapenta reported on the results over CONUS, USA focusing on the 2011-12 cold, 2012 warm seasonal and annual rainfall. On the annual timescale ECMWF was doing well, as well as UKMO and Météo-France. In general wet bias is still evident at low rain rates and dry bias at high rain rates. For the cold and warm seasons similar results were found, but with a positive bias at all rain rates for UKMO in the cold season. It was pointed out that DWD did not show the bias at low rain rate and questions were asked to the possible reasons for this.

Michael Baldauf presented the results over Germany for the year, winter, summer and spring seasons and pointed to some observed frequency biases.

ACTION ITEM: Modelling Centres are encouraged to continue to investigate and report reasons for precipitation verification behaviour.

20. RECENT DEVELOPMENTS IN HIGH-RESOLUTION NWP

Dr Bill Lapenta reported that the operational centres continue to implement sub 5km horizontal resolution convective resolving systems to satisfy unique customer requirements. Examples form the centre include the importance of severe weather (i.e., strong convection and hurricanes), aviation parameters such as ceiling and visibility, fog, flooding, coastal phenomena and urban environments. A common theme observed across the centres is the desire to remove intermediate grids required for nesting limited area domains without compromising skill within the high resolution nests. Some centres are also moving towards a rapidly updating cycle structure with data assimilation systems creating analyses on an hourly frequency with subsequent 18+ hour forecast.

Challenges associated with high resolution data assimilation were noted and include complex control variables (i.e., microphysics) and variational-ensemble approaches. The models will continue to require advancement of detailed physical parameterizations to provide skilful guidance of sensible weather elements required by customers. The development of global non-hydrostatic systems continues to be a major thrust with ECMWF exploring the possibility of running for an non-hydrostatic global system at 5km in 2020 and 2.5km in the 2025 time frame. In the meantime some centres continue to optimize nesting formulations for computational efficiency. It was also noted that there is a need to reformulate verification metrics for high resolution models required to make informed development decisions. It was noted that most of the centres have only just begun to consider the need for high resolution ensemble systems to provide estimates of uncertainty to the end user.

The second part of the presentation, by Gary Dietachmayer, covered more speculative work, examining several examples of very high resolution systems that are not computationally tractable now, but may become so in the future. ECMWF demonstrated that recent computational efficiency improvements to its spectral model had enabled successful experimentation with a 2.5km resolution (and hence convection-permitting) global system. Météo France and the UKMO provided examples of the importance of high *vertical* resolution for particular applications: fog-forecasting for the former and cold air pooling for the latter.

Finally, Météo France, UKMO, and CAWCR provided examples of simulations in the 400 to 100 meter resolution range which demonstrated the ability of these systems to capture very fine scale structures such as trapped lee waves, boundary-layer rolls and cells, and undular bores.

21. PHYSICS OF WEATHER AND CLIMATE MODELS WORKSHOP REPORT

Christian Jakob gave a summary of the WGNE co-sponsored Workshop on the Physics of Weather and Climate Models which took place from 20-23 March 2012 at Caltech,

Pasadena, California. It was attended by about 120 participants of which 40 were students, and the lecture topics focused on the tropics, high latitudes and clouds. The workshop also included break-out sessions, evening panel discussions and a final session which derived the following recommendations:

- The need to improve funding for model physics development,
- Focus on the long-standing issues in NWP and Climate models (biases, precipitation, extremes etc.),
- How to grow the model developer community through various incentives,
- Coordinating effort in model evaluation in support of model physics development,
- Communication related to model development and its role in improving predictive skill.

In the discussion that followed it was suggested to pursue a BAMS paper to promote model development (and tuning), possibly in cooperation with WMAC and GASS.

22. GOVST WORKSHOP UPDATE

Bill Lapenta presented plans and progress towards organising of the joint GOV/WGNE workshop Short- to medium-range coupled prediction for the atmosphere-wave-sea-ice-ocean which is planned for 19-22 March 2013 at NOAA-NCEP, Washington DC. The results of a survey to gauge interest in the workshop were also presented. The workshop objectives are to conduct a workshop and invite members of the WGNE and GODAE OceanView community with interests in developing coupled high resolution earth systems for short- to medium- range prediction, focusing on:

- Present the latest evidence of the impact of coupled modeling on the earth system analysis and forecasts,
- Present the latest progress in the development and identify gaps in knowledge and leading scientific questions to be addressed for coupled earth system:
    - observations
    - physical parameterization
    - dynamical modeling
    - data assimilation,
- Discuss the requirements and opportunities for collaboration between each area,
- Discuss the formation of a joint group (Why/How/Who/When/Where),
- Report on progress, gaps and challenges in the field and specific, actions/recommendations for further progress.

23. SYSTEMATIC ERROR WORKSHOP UPDATE

Christian Jakob and Any Brown gave an overview on the planning towards the 4th WGNE workshop on systematic errors in weather and climate models planned for 15-19 April 2013 at the Met Office in Exeter, UK. To date 151 abstracts were submitted, covering a wide range of topics led by keynote speakers.

24. Global Atmospheric System Studies (GASS)/ GEWEX Cloud System Study (GCSS)/ GEWEX Atmospheric Boundary Layer Study (GABLS)

Jon Petch summarized the most recent activities of the Global Atmospheric System Studies (GASS) group, highlighting some accomplishments of the 40+ projects over the last 20 years. The main outcomes of the Pan-GASS meeting held in Boulder which brought together 220 scientists working on parameterization development, process studies and observations and evaluations related to the atmosphere and atmospheric models were presented. It was further indicated that there are 10 active projects crossing clouds, radiation and dynamical processes such as the MJO.

Jon indicated that reorganising some of the projects' archives could be beneficial to the community but resourcing to do this was unclear.

25. THE GREY ZONE PROJECT

Jon Petch summarised the current status and plans for the Grey Zone project. The project is led by Paul Field and Pier Siebesma and is a GASS and WGNE joint activity focusing on the behaviour of atmospheric models with horizontal grid-lengths close to the scale of the key processes of interest. In the first stages of this project the key process is convection in a cold air outbreak and there are Limited Area Models and Large Eddy Simulation models involved.

Jon presented the plans and progress with regards to the "Constrain" cold-air outbreak experiment of 31 January 2010 using Global models at high resolution, mesoscale/Limited Area Models (LES) and Large-Eddy Simulation (LES) models. The sensitivity to microphysics was highlighted and the complexity of this case due to ice-phase processes. It was indicated that the deadline for submission of results on the case is April 2013 with a meeting to discuss the results in the second half of 2013. Other cases should also be considered for Grey Zone investigation.

In the discussion that followed the importance to advertise the use of ultra-high resolution simulations more widely was encouraged. The additional steps that can be taken after this cold outbreak case were also debated.

ACTION ITEM: The Grey-zone project is encouraged to develop a Transpose-AMIP component and to see how best to include a climate component in their work.

26. GLOBAL LAND ATMOSPHERE SYSTEM STUDY (GLASS)

Martin Best presented a report from the GEWEX GLASS panel. The new structure of GLASS promotes activities in three areas: benchmarking, model data fusion and land-atmosphere coupling. There are a number of current projects that are active within GLASS, but three projects were presented, one in each of these areas. The first is a benchmarking project using the PALS system for the analysis, the second is a joint experiment with GABLS looking at land-atmosphere feedbacks and sensitivities and the third is a land data assimilation model comparison. WGNE is requested to promote these projects to get the most involvement from the operational and climate modeling centres.

ACTION ITEM: Jon Petch to ensure that information on the GASS and GLASS key projects are provided to WGNE Co-Chairs for distribution to WGNE members.

ACTION ITEM: WGNE members to indicate their interest to participate in GASS and GLASS key projects.

27. GFDL REPORT

The GFDL status report, presented by V. Balaji Princeton University and NOAA/GFDL, included an overview of recent developments at GFDL. Informed by their 2012-2016 Strategic Science Plan, it covers current and proposed developments in the representation of climate processes, and the construction of comprehensive models for studies of detection and attribution of climate change; climate predictability and prediction; the statistics of extreme events like tropical storms; and developments in the atmospheric dynamical core. Highlights include recent research results on aerosol-cloud feedbacks in the decline on the Indian monsoon; the relative role of land use change and anthropogenic CO2 emissions in driving global warming; reduced biases in high-resolution coupled models; the use of an

advanced data assimilation system for parameter estimation; and a prototype global non-hydrostatic cloud-resolving model.

28. AEROSOLS

This session focused on the following two questions:

- How important are aerosols for predicting the physical system (NWP, seasonal, climate) as distinct from predicting the aerosols themselves?

- How important is atmospheric model quality for air quality forecasting?

28.1 Centre activities

Saulo Freitas presented an overview on how the different centres treat aerosols.

At JMA climatological aerosol information is used in calculation of aerosol direct effect. The seasonal variation of horizontal distribution is considered in the horizontal distribution but not in the vertical. JMA also plans to update the aerosol optical depth climatology, to use new satellite data and to extend the period for climatology calculation. It was noted that the new optical depth tends to be smaller over land (especially over the Antarctica and over desert) than current optical depth. The development of a global aerosol chemical transport model for climate change at MRI was also discussed.

At NCAR work has been done with CAM5 which includes multiple-moment aerosols with cloud microphysics/aerosol interaction and the comparisons with CAM4 with its bulk aerosols and no indirect effect. It was shown that the CAM5 results correspond more closely to observed global temperatures with the overestimation being offset.

ECMWF is focusing on the “most promising” areas where improved representation of atmospheric composition can benefit NWP, long-range predictions and reanalysis. In addition the use of atmospheric composition observations as an additional monitoring and diagnostic capability for winds/transport and physical processes, and new forecast capabilities (visibility, comprehensive land surface, surface albedo including aerosol deposition on snow…) are being investigated. Given the present configuration of the MACC/ECMWF aerosol analysis, preliminary findings conclude that having the full interactions between aerosols and radiation/cloud processes within the analysis does not bring much to the subsequent forecasts, and that the increased complexity and cost (~x2) does not justify its operational implementation. However, it was shown that locally, it can have a significant beneficial impact, for example on the 10 meter-winds off the west coast of Africa and the Somali jet.

At the Met Office a range of NWP experiments of increasing complex aerosol representation (and cost) were conducted, focusing on the June – July 2009 period. Better diurnal variability of AOD was found as a result of prognostic aerosols. Large sensitivities in remote clean air regions to more “realistic” cloud droplet number concentration were also found while the indirect effect also led to an improvement in NH cold bias. The impacts on precipitation were small, but the errors generally improved.

At Météo-France considerable effort is directed towards tropospheric ozone and dust forecasting over Europe and France. Studies have also been conducted related to the impact of desert dust on high resolution numerical modeling using AROME coupled to a desert dust module with beneficial impact on monsoon and convective storm prediction over West Africa.

At Environment Canada the emphasis is primarily on multi-scale chemical weather forecast model composed of dynamics and physics (GEM) and *on-line* chemistry modules. The GEM-MACH currently used is not a fully interactive model. For phase 2 of the Air Quality Modelling Evaluation International Initiative, a new version of GEM-MACH allowing full interaction among the various atmospheric and chemical (gas and aerosol) processes such as clouds, radiation, boundary layer, etc. will be developed in 2013.

At DWD, work is being done with COSMO – ART (Aerosol and Reactive Tracers), showing the statistically significant positive impact on 2m temperatures.

An overview of the NCEP NEMS GFS Aerosol Component (NGAC), NCEP's global interactive atmosphere-aerosol forecast system was presented. The verification against analyses and observations indicates a neutral-to-positive impact in temperature forecasts due to realistic time-varying treatment of aerosols.

Saulo then provided a comprehensive overview of related work at CPTEC in Brazil, focusing primarily on biomass burning, its aerosol loading of the atmosphere and comparisons with AERONET and MODIS. The impact on the modeled atmospheric temperature profiles through the direct effect was shown as well as on precipitation and near-surface wind. Tuning the surface scheme LEAF to work better for tropical/sub-tropical biomes was described.

28.2 GURME and MACC Activities

Liisa Jalkanen presented the GAW Urban Research Meteorology and Environment (GURME) activities and highlighted the relevant task as set out in the GAW 2008-2015 Strategic Plan. Urban population growth is now creating new challenges and opportunities for weather, climate and related environmental services that are specific to the unique and complex urban environment and in which negative health impacts due to compromised air quality is a major concern.

An overview of a number of GURME projects and collaborations was presented, including those related to Latin American cities, Delhi in India and Shanghai, China. Mentioned was also made of initiatives to ensure the near real-time availability of air quality information to support air quality modeling and services. The 4th International Workshop on Air Quality Forecasting (IWAQFR) to be held in Geneva on 12-14 December 2012 was highlighted.

Angela Benedetti presented the work being done by the MACC-II team at ECMWF on aerosol and chemical weather forecasts, in the context of the Global Monitoring for Environment and Security (GMES) - Atmosphere. MACC provides quasi-operational daily forecasts and re-analysis of atmospheric composition on global and regional scales. Data are used as boundary conditions for European air quality models.

The global system is based on the ECMWF Integrated Forecasting System (IFS), coupled to a global chemical transport model (CTM: MOZART, TM5 or MOCAGE) while the regional ensemble comprises seven Chemical Transport Models run on a common European domain. The retrospective and near real time services were described and an overview of the European Air Quality Forecast service provided.

Examples of the forecast products related to recent extreme dust storms, heat waves and fires, and volcanic ash events were shown. Ongoing refinements to the treatment of aerosols and the development of C-IFS - online chemistry in IFS were described as well as the benefits this approach has in terms of computing resources when compared to integrating the aerosol and chemistry in the IFS.

28.3 Interactions of NWP and Air Quality Communities

In the discussion that followed favourable comments were made with regard to the approach being followed by ECMWF - two grids, coarse for chemistry and aerosols and higher resolution for weather. However, no clear answers were given to the question on how atmospheric composition assisted dynamical core improvement. It was suggested that further attention to conservation issues, physics and the assimilation of additional tracers should be considered.

A proposal was also made to focus on common experiments and/or case studies such as the Egypt/Middle East dust storm of 18 April 2012 to be considered as a candidate.

29 Report of JWGFV

Laurie Wilson presented a report on the Joint Working Group on Forecast Verification Research (JWGFVR) and gave a overview of the 5th International Verification Methods Workshop that took place from 1-7 December 2011 in Melbourne, Australia, combined with a verification training workshop which benefitted participants from 44 countries. He also reminded WGNE participants of availability of WMO publications on methods for verification of quantitative precipitation forecasts and clouds, and indicated a similar publication on tropical cyclone verification close to completion.

The success of the first spatial method intercomparison project (ICP1) focusing on precipitation over the US has resulted in ICP2 now being planned for Europe, to include additional parameters, in cooperation with Mesoscale Working Group.

Laurie indicated that there is increased use of diagnostic methods in verification, both spatially and point-wise. New scores that have become available were presented with their definitions:

- EDS–EDI–SEDS–SEDI scores for use in the verification of extreme high impact weather, and based on contingency tables. The SEDS and EDI scores are suggested for use by modeling centers represented at WGNE,
- SEEPS (Stable Equitable Error in Probability Space) a three-category score for precipitation which uses the climatological cumulative distribution function of long-term station data and could likely be proposed for the CBS standard model verification for precipitation,
- 2AFC, a discrimination score which works for categorical, probabilistic, continuous forecasts and observations, and relates directly to trapezoidal area under ROC curve.

Previous recommendation to WGNE of the importance of an emphasis on verification using observations and to evaluate surface variables surface data was again given.

The presentation concluded with a summary of challenges in verification research (verification of seamless forecasts, spatial verification of ensembles, user orientated verification etc.) and some comments on verification against own analyses.

In the discussion that followed it was agreed that the inclusion of more surface variable in verification studies should be included. The use of radar data in verification was promoted as a next step. In addition, the JWGFVR was requested to provide to continue to guide WGNE members and modeling centers with regards to the scores to be used and how to do the bootstrapping.

ACTION ITEM: JWGFVR to provide advice to WGNE members on the most appropriate scores and bootstrapping methods to be used for precipitation verification

ACTION ITEM: The modeling centers were requested to adopt the advised approach for precipitation verification (e.g. for presentation at next WGNE meeting).

30. VERIFICATION AGAINST OWN ANALYSIS

Jean-Noël Thépaut, Tom Hamill, and Michael Baldauf presented evidence on the differences between operational analyses from the various global weather prediction facilities and their impact on numerical weather prediction verification. Jean-Noël and Michael presented evidence that forecasts, especially short-range forecasts, will appear to have more skill when verified against their own analysis than when verified against another centre's analysis. Tom presented evidence quantifying how different the analyses were for different variables. For 2-m temperature, differences over land, even in time averages, of several K were common. For 250 hPa zonal wind, there are large differences in certain locations such as in the equatorial Pacific. Tom also discussed several potential options, such as (a) verifying against an ensemble-mean analysis after masking out locations where differences were especially large, (b) using consistency between analyses as some guide for weighting the various analyses, and (c) using the fit of short-term forecasts to observations to determine weights in a multi-analysis mean. Other options mentioned by participants were (d) to verify against all analyses and then report the mean, and (e) to verify against random analyses. It was decided that further study was needed.

A status was given on major NWP centres scores verification, with emphasis on polar verification. For standard WMO scores, noticeable features over the past year included:

- ECMWF lead in most scores, ranges and areas when verifying against own analysis,
- A much narrower spread when Centres score against observations,
- A noticeable improvement of NCEP performance after their hybrid DA implementation in May 2012,
- A large impact for BoM of adopting the unified model system.

ECMWF has been nominated as the WMO Lead Centre for Deterministic Forecast Verification (WMO-LCDNV) and the associated website (http://apps.ecmwf.int/wmolcdnv/) was presented. This website, still under construction, offers a large variety of ways of intercomparing model score performance, and WGNE members were kindly invited to provide feedback to ECMWF.

Polar scores (poleward of 60 degrees) are now routinely produced and more Centres start to (slowly) contribute. It was shown that ERA-interim (fixed DA system in time) provides an independent way of measuring the improvement of NWP models over the last decades. A new feature that was recently added is the verification of polar scores against observations. Forecast errors are generally substantially larger in Polar Regions compared to the extratropical hemispheric averages, and are seasonal dependent. Last but not least, the Concordiasi dataset as independent verification for short-range forecasts over Antarctica was also presented by Météo-France.

Modelling centres were encouraged to provide information on polar scores and the link to the Polar Prediction Project was pointed out.

31. SUMMARY AND FUTURE WGNE ACTIVITIES

31.1 Data Assimilation, Reanalysis Issues

The discussion centered on what the optimal role of WGNE in terms of data assimilation should be. Considering the substantial data assimilation expertise in the THORPEX DAOS

Working Group and the possibility the this working group will become part of the standing WWRP structures post THORPEX (after 2014), it was suggested that links should be sufficient through some membership overlap, as is being achieved now with Florence Rabier's involvement. The WGNE role to ensure communication between DAOS and operational centers would also be beneficial.

Reanalysis and research on reanalysis techniques is promoted. WDAC could task WGNE and DAOS to work together to assist in modeling of co-variances and coupling issues. WDAC should also oversee the general issue of OSSE infrastructure in support of observational design for climate applications.

31.2 Momentum

Further discussion emphasized the importance of the representation of the momentum budget to model performance, and enthusiasm for a project to look at this. A relatively simple first step was thought desirable in order to ensure broad participation (hopefully from both weather and climate modelers), with the possibility of more ambitious projects to follow. [Action under 11.8]

31.3 Aerosol GAW

The discussion focused on whether there is a message from Saulo's presentation to indicate how well has aerosols got to be treated for NWP. Impressions are that for NWP, on a broad scale it is not so important, but large effects can occur on specific regions and during specific events. It was suggested that modeling centers should focus on a set of simple systematic coordinated experiments, e.g. the Egypt/Middle East dust storm of 18 April 2012. These cases could be identified through interaction between Jean-Noël Thépaut, Saulo Freitas and Angelina Benedetti. Clarity also needs to be sought on how well aerosols are treated at longer time scales and what makes for a good aerosol climatology.

ACTION ITEM: Jean-Noël Thépaut, Saulo Freitas and Angelina Benedetti to discuss next steps re aerosol case studies

ACTION ITEM: Request WGSIP information on how aerosols are treated in models for seasonal predictions.

31.4 WCRP Grand Challenge

The WCRP six grand challenges were reviewed with specific reference to the two of most relevance to WGNE, i.e. those focusing on clouds and extremes. WGNE also needs to articulate how it intends to interact and contribute to the Grand Challenges. The possibility of a project focusing on diagnostics and the analyses of weather and climate models on systematic errors initiated by a breakout session at systematic errors workshop was promoted.

31.5 Next meeting and steps between meetings

The invitation from Australia to host the next meeting was discussed against the background of limited budgets, the need to improve intersession communication and activities. It was decided to accept the proposal to have WGNE meetings roughly every 18 months, supplemented by virtual meetings through teleconference and more regular reporting. The offer from Australia for a March 2014 meeting was welcomed.

ACTION ITEM: Co-Chairs of WGNE and the WMO Secretariat to design a programme for virtual meetings and reporting schedule to complement future WGNE meeting on a 18 month basis.

32. DECISIONS AND ACTIONS

32.1 Summary of action items

ACTION ITEM: WGNE should add a DAOS ex-officio member to ensure effective links between the working groups.

ACTION ITEM: Thomas Jung was requested to provide more information to the members of WGNE on the polar workshop scheduled for June 2013 at ECMWF.

ACTION ITEM: WGNE request a summary from TIGGE-LAM on the status of various regional Ensemble Prediction Systems and current efforts (projects, workshops etc) to co-ordinate their development..

ACTION ITEM: Modelling centres to provide David Jackson (SPARC) with the names of focal points on stratospheric issues.

ACTION ITEM: Ayrton Zadra, Andy Brown and Julia Bacmeister were requested to propose next steps for a study on model momentum budgets

ACTION ITEM: Michael Baldauf was requested to extend the tables with specifications of model characteristics at the various centres to include CPU and run-time information.

ACTION ITEM: WGNE members to feedback to S2S steering group on any key variables missing from list proposed for S2S database.

ACTION ITEM: Christian Jakob to provide Duane Waliser a mailing list for use in a call for data/metric tailored for on Interseasonal Variability (ISV) for the boreal summer from modelling centres.

ACTION ITEM: Michel Rixen to send background to the WMO RRR process to Co-Chairs.

ACTION ITEM: WGNE encourages Chiashe Muroi and his team to publish the results on verification of TC forecast in global models.

ACTION ITEM: Modelling Centres are encouraged to continue to investigate and report reasons for precipitation verification behaviour.

ACTION ITEM: The Grey-zone project is encouraged to develop a Transpose-AMIP component and to see how best to include a climate component in their work.

ACTION ITEM: Jon Petch to ensure that information on the GASS and GLASS key projects are provided to WGNE Co-Chairs for distribution to WGNE members.

ACTION ITEM: WGNE members to indicate their interest to participate in GASS and GLASS key projects.

ACTION ITEM: JWGFVR to provide advice to WGNE members on the most appropriate scores and bootstrapping methods to be used for precipitation verification

ACTION ITEM: The modeling centers were requested to adopt the advised approach for precipitation verification (e.g. for presentation at next WGNE meeting).

ACTION ITEM: Jean-Noël Thépaut, Saulo Freitas and Angelina Benedetti to discuss next steps re aerosol case studies

ACTION ITEM: Request WGSIP information on how aerosols are treated in models for seasonal predictions.

ACTION ITEM: Co-Chairs of WGNE and the WMO Secretariat to design a programme for virtual meetings and reporting schedule to complement future WGNE meeting on a 18 month basis.

32. CLOSURE

The 29th face-to-face meeting of WGNE is planned for March 2014 in Melbourne, Australia. The meeting was closed at 11:00 on 9 November 2012 and the Co-chairs thanked the members and experts for their contributions and wish them all a safe travel back home.

Annexes:

A. WGNE Survey on Dynamical Cores
B. Meeting Agenda
C. List of Participants

Annex A.

WGNE 2012 Survey of centres plans for new dynamical cores

Mikhail Tolstykh,

Institute of Numerical Mathematics/Russian Academy of Sciences,
and Hydrometcentre of Russia,
email: tolstykh@inm.ras.ru, mtolstykh@mail.ru

In September 2012, a questionnaire was sent to centres participating in WGNE asking to describe their current and potential future dynamical cores for global atmospheric model. 11 centres responded.

Below are the input provided. Following abbreviations are used: FD – finite differences, FV – finite volumes, SP – spectral representation, SI – semi-implicit time integration scheme, HE-VI – horizontally explicit – vertically implicit time integration scheme; SL – semi-Lagrangian advection, Eul – Eulerian advection

CPTEC, Brazil

1. Current dynamical core

- numerics (finite-difference/spectral/…)

Spectral

- grid (lat-lon/cubed sphere/…)

lat-lon

- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)

semi-implicit

- advection type (Eulerian/semi-Lagrangian)

both (user choice)

- mass conservation for tracers (yes/no)

yes

- particular features

full Eulerian, or Eulerian except for specific humidity (which is Lagrangian) or full semi-Lagrangian

2. Plans for significant future upgrades

Is being initiated in parallel operation a new version of the global model (T299L64) that includes the following new features: semi-Lagrangian with reduced grid and transport at grid of specific humidity

3 New dynamical core developments

It started a discussion to remain with the spectral or to use a new finite volume dynamic core

Environment Canada

1. Current dynamical core

- numerics (finite-difference/spectral/…)

FD

- grid (lat-lon/cubed sphere/…)

Two options:
(a) global lat-lon
(b) Yin-Yang
Please note:

- horizontal grid: Arakawa-C
- vertical grid: two options (a) regular or (b) Charney-Phillips
- time integration scheme Iterative implicit (2 iterations)

- advection type (Eulerian/semi-Lagrangian)

SL

- mass conservation for tracers (yes/no)

no

2. Plans for significant future upgrades and/or new dynamical core developments.

- currently implementing a new operational global model:
  (a) increased horizontal resolution: 25km
  (b) horizontal grid: lat-lon
  (c) vertical grid: Charney-Phillips
- preparing implementation of a new global model in 2013:
  (a) increased horizontal resolution: 15km
  (b) horizontal grid: Yin-Yang
  (c) vertical grid: Charney-Phillips
- pursuing research on icosahedral grid

CMA, China

1. Current dynamical core

- numerics: FD
- grid: regular lat-lon
- time integration: semi-implicit (SI)
- advection type: semi-Lagrangian
- mass conservation for tracers: no
- equations : hydrostatic

2. New dynamical core developments

- numerics: multi-moment constrained FV
- grid: Yin-Yang or cubed sphere
- time-integration: explicit TVD RK
- mass conservation, including tracers: yes
- equations: compressible nonhydrostatic

DWD, Germany

1. Current dynamical core

global GME:

- numerics (finite-diffference/spectral/…)

FD

- grid (lat-lon/cubed sphere/…)

icosahedron, A-grid

- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)

Leapfrog, semi-implicit

- advection type (Eulerian/semi-Lagrangian)

SL

- mass conservation for tracers (yes/no)

no

regional COSMO:

- numerics (finite-diffference/spectral/…)

FD
- grid (lat-lon/cubed sphere/…)
rotated lat-lon, C-grid/Lorenz-grid (vertical)
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)
HE-VI
- advection type (Eulerian/semi-Lagrangian)
Eulerian FV (alternatively: SL for higher stability in complex terrain)
- mass conservation for tracers (yes/no)
'almost' yes for FV-scheme
- particular features

2. New dynamical core developments
future global ICON (probably operational at begin of 2014):

- numerics (finite-diffference/spectral/…)
mixed FD / FV (for continuity eq.)
- grid (lat-lon/cubed sphere/…)
icosahedron, C-grid / Lorenz-grid (vertical)
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)
fully explicit (sound timte step!), Predictor-corrector-time integration
- advection type (Eulerian/semi-Lagrangian)
Eul (Miura 2007)
- mass conservation for tracers (yes/no)
yes
- particular features
allows refinement areas (later on will replace the 'european setup' COSMO-EU)

current developments for regional COSMO (as possible alternatives):
use of the EULAG dynamical core -->
- numerics (finite-diffference/spectral/…)
FV
- grid (lat-lon/cubed sphere/…)
rotated lat-lon, A-grid
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)
SI (anelastic equations!)
- advection type (Eulerian/semi-Lagrangian)
Eul
- mass conservation for tracers (yes/no)
yes

ECMWF

1. Current dynamical core
(dynamical core of joint development with Meteo-France)
- numerics: spectral transform method, vertical finite-element (FE)
- grid: reduced Gaussian grid on the sphere
- time integration: semi-implicit (SI)
- advection type: semi-Lagrangian (optional Eulerian)
- mass conservation for tracers: no
- equations : fully compressible (optional hydrostatic/non-hydrostatic (NH))
- particular features: terrain-following hybrid vertical (mass) coordinate (Laprise, 1992) with optionally finite-element or finite differences in the vertical, no staggering of variables except in the NH for vertical velocity in the vertical. Iterative-centered-implicit (ICI) scheme for stability of the NH model.

2. Current plans for significant future upgrades and/or new dynamical core developments.

- code refactoring in the spirit of OOPS to facilitate new developments e.g. make the use of spectral transforms entirely internal to the dynamical core
- mass conservation: explore "intelligent" mass fixers as well as more inherently conservative SL formulations
- Scrutinise the dynamics-physics interaction at non-hydrostatic, convection-resolving/permitting scales
- Scrutinise the future scalability of all aspects of the dynamical core of IFS
- Explore alternative equations and solution procedures to enhance stability, accuracy and scalability while reducing the cost of the NH formulation.
This is sought in the spirit of Arakawa and Konor (2009), satisfying the asymptotic limit solutions, namely hydrostatic at large scales and anelastic at small scales
- Re-assess the suitability of the vertical discretization

Meteo-France

1. Current dynamical core
(dynamical core of joint development with ECMWF)
- numerics: spectral transform method, vertical finite-element (FE)
- grid: reduced Gaussian grid on the sphere
- time integration: semi-implicit (SI)
- advection type: semi-Lagrangian (optional Eulerian)
- mass conservation for tracers: no
- equations : fully compressible (optional hydrostatic/non-hydrostatic (NH))
- particular features: terrain-following hybrid vertical (mass) coordinate (Laprise, 1992) with optionally finite-element or finite differences in the vertical, no staggering of variables except in the NH for vertical velocity in the vertical. Iterative-centered-implicit (ICI) scheme for stability of the NH model.

2. Current plans for significant future upgrades and/or new dynamical core developments.

Some work proceeds jointly with ECMWF, in particular on alternative NH equations and solution procedures. Comparison of SI and HEVI schemes is also under plans.

JMA, Japan

1. Current dynamical core
- numerics (finite-diffference/spectral/…)
Spectral
- grid (lat-lon/cubed sphere/…)
Reduced gaussian grid
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)
SI
- advection type (Eulerian/semi-Lagrangian)
SL
- mass conservation for tracers (yes/no)
no

2. Current plans for significant future upgrades and/or new dynamical core developments.

B-1)
- numerics (finite-diffference/spectral/…)

FV
- grid (lat-lon/cubed sphere/…)

Yin-Yang
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)

HE-VI
- advection type (Eulerian/semi-Lagrangian)

Eul
- mass conservation for tracers (yes/no)

Yes

B-2)
- numerics (finite-diffference/spectral/…)

Spectral
- grid (lat-lon/cubed sphere/…)

Lat-Lon
- time integration scheme (semi-implicit/horizontally explicit-vertically implicit)

SI
- advection type (Eulerian/semi-Lagrangian)

SL
- mass conservation for tracers (yes/no)

no

NCAR

1. Current dynamical core

1) Spectral element (as of 10/2012)
2) FV (Lin Rood maintained for low resolution 2.5x2 Paleo climate)

- numerics:
  DG – discontinuous Galerkin

- grid (lat-lon/cubed sphere/…)
Cubed sphere(spectral elements (SE)), lat-lon(FV)

- time integration scheme (semi-implicit/horizontally explicit-vertically implicit):
  everything explicit

- advection type (Eulerian/semi-Lagrangian)
This is under development. I think at the moment we use SE's "natural" advection in the horizontal, but mass is conserved.

In the vertical, tracer advection is by lagrangian vertical remapping, as in the Lin-Rood FV dycore. For momentum and temperature vertical advection is with an eulerian finite-difference

- mass conservation for tracers (yes/no)
yes

- particular features
Energy is conserved per element.

2. Current plans for significant future upgrades and/or new dynamical core developments

We will perform all vertical advection with the vertical remapping technique.

Horizontal tracer advection will be performed with a semi-lagrangian technique - "CSLAM" developed by Peter Lauritzen

Hydrometcentre of Russia

1. Current dynamical core

- numerics: 4th order FD
- grid: regular lat-lon
- time integration: semi-implicit (SI)
- advection type: semi-Lagrangian
- mass conservation for tracers: no
- equations : hydrostatic
- particular features: vorticity-divergence formulation on the unstaggered grid (Z grid).

2. Current plans for significant future upgrades and/or new dynamical core developments

2.1 Upgrade of the hydrostatic model

- reduced lat-lon grid
- mass-conservative semi-Lagrangian advection on the reduced lat-lon grid following Nair et al, 2002
- improving scalability

2.2 Development of the nonhydrostatic version

- fully compressible equation set
- grid: reduced lat-lon or cubed sphere
- mass conservation
- we will try first to do it with the semi-implicit semi-Lagrangian approach, however, other options could be chosen

UK Met Office

1. Current dynamical core

The current dynamical core of the Met Office's Unified Model is the so-called New Dynamics. See Davies et al. (2005). It has been operational since 2002.

1.1 Numerics (finite-difference/spectral/...)
Standard centred second-order finite-difference on an Arakawa C-grid in the horizontal and a Charney-Phillips grid in the vertical. [It would be good to know what staggering (or not) is used by other centres...]

1.2 Grid (lat-lon/cubed sphere/...)
Standard lat-lon grid with all variables stored at the pole except for the meridional velocity component. This grid can be rotated for LAM applications.

1.3 Time integration scheme (semi-implicit/horizontally explicit-vertically implicit)
Two-time-level semi-implicit semi-Lagrangian scheme with off-centring. A predictor-corrector approach is used to give a linear Helmholtz problem which is solved using a GCR(k) method.

1.4 Advection type (Eulerian/semi-Lagrangian)
A semi-Lagrangian approach is used for all variables except dry density for which a flux-form

Eulerian scheme is used to give inherent dry mass conservation. Cubic-Lagrange interpolation is generally used. However: a non-interpolating-in-the-vertical approach is used for potential temperature; a quasi-cubic scheme is used in the horizontal for moisture with the option for quintic interpolation in the vertical.

1.5 Mass conservation for tracers (yes/no)
No. Where required (e.g. climate runs) mass conservation is enforced using a form of the Priestley (1993) algorithm.

1.6 Particular features
1. Nonhydrostatic, deep-atmosphere equation set (but with gravity independent of height) with the spherical geopotential approximation
2. Terrain-following physical height coordinate
3. Thermodynamic prognostic variables are: potential temperature, dry density, Exner pressure

2. Plans for significant future upgrades
It is planned that the current dynamical core of the Met Offce's Uni_ed Model will be upgraded to the so-called ENDGame dynamics towards the end of 2013/early 2014.

2.1 Numerics (finite-difference/spectral/...)
Standard centred second-order finite-difference on an Arakawa C-grid in the horizontal and a Charney-Phillips grid in the vertical.

2.2 Grid (lat-lon/cubed sphere/...)

Standard lat-lon grid with only the meridional velocity component stored at the pole. This grid can be rotated for LAM applications.

2.3 Time integration scheme (semi-implicit/horizontally explicit-
vertically implicit)
Two-time-level semi-implicit semi-Lagrangian scheme with (reduced compared to the New Dynamics) off-centring. An iterative approach is used to give a linear Helmholtz problem which is solved using a BiCGSTAB method.

2.4 Advection type (Eulerian/semi-Lagrangian)
A semi-Lagrangian approach is used for all variables. Cubic-Lagrange interpolation is generally used. However: there is the option for quintic interpolation in the vertical for moisture. Dry mass conservation is imposed by a simple global mass corrector applied every time step. An inherently mass-conserving SL scheme (SLICE) is optionally available.

2.5 Mass conservation for tracers (yes/no)
No. Where required (e.g. climate runs) mass conservation is enforced using the Zerroukat (2010) algorithm.

2.6 Particular features
1. Nonhydrostatic, deep-atmosphere equation set with the spherical geopotential approximation
2. The discrete equations can be switched to be (quasi-)hydrostatic and/or shallow-atmosphere
3. Terrain-following physical height coordinate
4. Thermodynamic prognostic variables are: a form of virtual potential temperature (appropriate for use with dry density), dry density, Exner pressure

3. New dynamical core developments
A large collaborative project, GungHo, is underway to develop a new dynamical core for the

Unified Model. The principal aim of this project is to make a sea change improvement to the scalability of the UM so that it will run efficiently on the anticipated next-generation exascale computers, whilst retaining the model's accuracy. Therefore a key element of the project is to replace the latitude-longitude grid with a quasi-uniform grid. The project will run from February 2011 to January 2016 and it is envisaged that, if successful, the new dynamical core will become operational by 2020. The following are current likely developments:

- The numerics will retain an Arakawa C-grid aspect to them (perhaps in the form of a mixed element approach if a finite-element scheme is used) plus Charney-Phillips staggering in the vertical. We are investigating extensions of the finite-difference TRiSK method of Thuburn et al. (2009) and also mixed-finite-element methods.
- The grid will likely be one of: icosahedral (hexagon/pentagon); gnomonic cubed-sphere; triangular; or Yin-Yang.
- Our aim is to retain a two-time-level semi-implicit integration scheme using a form of multi-grid solver for the Helmholtz problem, if this proves sufficiently scalable. If it does not then we will use a two-time-level HEVI scheme (not a split-explicit scheme).
- Advection of tracers and dry density will be some form of flux scheme to give inherent conservation. It is likely that the momentum equations will be cast in vector-invariant form.
- The (switchable) nonhydrostatic deep-atmosphere equations with the spherical geopotential approximation will be retained.
- A terrain-following height coordinate (possibly Lagrangian in nature) will be used.
- It seems likely that a form of virtual potential temperature (appropriate for use with dry density), dry density, Exner pressure will continue to be used as the thermodynamic variables.

References

Davies, T., Cullen, M., Malcolm, A., Mawson, M., Staniforth, A., White, A. & Wood, N. 2005, A new dynamical core for the Met Office's global and regional modelling of theatmosphere, Q. J. R. Meteorol. Soc. 131, 1759-1782.

Priestley, A. 1993 , A quasi-conservative version of the semi-Lagrangian advection scheme, Mon. Wea. Rev. 121, 621- 629.

Thuburn, J., Ringler, T. D., Skamarock, W. C. & Klemp, J. B. 2009 , Numerical representation of geostrophic modes on arbitrarily structured C-grids, J. Comput. Phys. 228, 8321-8335.

Zerroukat, M. 2010, A simple mass conserving semi-Lagrangian scheme for transport problems, J. Comput. Phys. 229, 9011-9019.

ANNEX B

MEETING AGENDA

WGNE-28, 05-09 November 2012, Toulouse, France

Monday, 05 November

09h00 – 10h30	**Welcome, Adoption of the Agenda, Local Arrangements** (15 min) *C. Jakob, A. Brown, F. Rabier* **Welcome by METEO-France** (10 min) *P. Bougeault* **Meeting Goals and Actions from last meeting** (20 min) *C. Jakob, A. Brown* **CAS & WWRP matters** (45 min) *D. Terblanche*
10h30 - 11h00	Coffee
11h00 - 13h00	**Update on the Future of THORPEX Data Assimilation Activities** (15+15 min) *T. Hamill* **WCRP matters** (45 min) *M. Rixen* **A short update on the WCRP Modeling Advisory Council** (15 min) *C Jakob* **Climate Model Metrics Panel** (20+10 min) *P. Gleckler*
13h00 – 14h00	Lunch
14h00 – 15h00	**WWRP and WCRP Polar Prediction Projects** (30 + 30 min) *T Jung*
15h00 – 15h30	Coffee
15h30 – 17h30	**Centre Reports** (5, 20 min each) *Brazil, Canada, NCEP, JMA, DWD*
1800-1930	**Ice Breaker hosted by METEO-France**

Tuesday, 06 November

09h00 – 10h30	**Recent developments in Numerical Methods** (30 min) *M. Tolstykh, M. Baldauf* **Recent developments in Data assimilation** (30 min) *F. Rabier, J.N. Thepaut* **Recent developments in Ensemble Prediction** (30 min) *T. Hamill, C. Muroi*
10h30 – 11h00	Coffee break
11h00 – 13h00	**SPARC report and discussion** (20+10 min) *D. Jackson*

Centre Reports (4, 20 min each)
France, China, Russia, ECMWF

13h00 – 14h00 Lunch

14h00 – 16h00 **Centre reports** (4, 20 min each)
NCAR, Korea, BOM, UKMO

16h00 – 16h30 Coffee break

16h30 – 18h00 **Science talks** (3x30 min each)

Serge Planton: Climate activities at Meteo-France including seasonal forecasting

François Bouyssel: Successes and challenges of a seamless development of physical parametrizations

Jean-François Mahfouf: Radar data assimilation

Wednesday, 07 November

09h00 – 10h30 **WGCM activities** (20+10 min)
S. Bony

Discussion of WCRP Grand Challenges and WGNE's role (30 min)
Participants

WGSIP activities (20+10 min)
H. Douville

10h30 – 11h00 Coffee break

11h00 - 13h00 **Sub-seaonal prediction project** (30 + 30 min)
F. Vitart

YOTC/MJO-TF and obs4MIPS (30 min)
D. Waliser

Monsoon prediction – How well are centres doing at various ranges? (30 min)
A. Brown

13h00 – 14h00 Lunch

14h00 – 15h00 **TC verification** (30 min)
C. Muroi

Precipitation Verification (30 min)
Participants

15h00 – 15h30 Coffee break

15h30 – 17h30 **Recent developments in high-resolution NWP** (30 min)
B. Lapenta, G Dietachmayer

Physics of Weather and Climate models workshop report (20 min)
C Jakob

GOVST workshop update (20 min)
B. Lapenta

Systematic Error Workshop update (20 min)

C. Jakob, A. Brown

Thursday, 08 November

09h00 – 10h40 **GASS/GCSS/GABLS report and discussion** (20+10 min)
J. Petch

The grey zone project (20 min)
J. Petch

GLASS report and discussion (20+10 min)
M. Best

GFDL report (20 min)
V. Balaji

10h40 – 11h00 Coffee break

11h00 – 13h00 **Session on Aerosols**

How important are aerosols for predicting the physical system (NWP, seasonal, climate) as distinct from predicting the aerosols themselves?

How important is atmospheric model quality for air quality forecasting?

Centre activities - (45 min)
Participants led by S. Freitas – Focus on Aerosol treatment in NWP system, not air quality modelling

GURME activities – (45 min)
Liisa Jalkanen, Angela Benedetti

Discussion on interactions of NWP and Air Quality communities (30 min)
Participants led by Andy Brown and Liisa Jalkanen

13h00 – 14h00 Lunch

14h00 – 15h00 **Report of JWGV** (30+30 min)
L. Wilson

15h00 – 15h30 Coffee

15h30 – 17h00 **Verification scores including polar verification** (30 min)
J.N. Thepaut

Discussion on verification against own analysis (60 min)
Participants led by T. Hamill

1830 **Museum visit followed by dinner**

Friday, 09 November

09h00 – 10h30 **Meeting summary and discussion of future WGNE activities, including workshops and projects** (90 min)
C. Jakob, A. Brown, Participants

10h30 – 11h00 **Decisions and Actions**
C. Jakob, A. Brown

11h00 **Close**

ANNEX C

WGNE-28, Toulouse, France, 5-9 November 2012
LIST OF PARTICIPANTS

Members

Professor Christian Jakob *(Co-Chair)*
School of Mathematical Sciences, Monash University
Monash, VIC 3800
Australia
christian.jakob@monash.edu

Dr Andy Brown *(Co-Chair)*
UK Met Office, FitzRoy Road
Exeter EX1 3PB
United Kingdom
andy.brown@metoffice.gov.uk

Dr Michael Baldauf
Abteilung Meteorologische Analyse und Modellierung, Deutscher Wetterdienst,
Frankfurter Str. 135
D-63067 Offenbach
Germany
Michael.Baldauf@dwd.de

Dr Gary Dietachmayer
CAWCR, Bureau of Meteorology, GPO Box 1289
Melbourne VIC 3001
Australia
G.Dietachmayer@bom.gov.au

Dr Thomas Hamill
NOAA/ESRL, Physical Sciences Division, R/PSD 1, 325 Broadway
Boulder, CO 80305-3328
USA
tom.hamill@noaa.gov

Dr William Lapenta
Environmental Modelling Center, NOAA National Centers for Environmental Prediction
5200 Auth Road
Suitland, MD 20746-4325
USA
Bill.Lapenta@noaa.gov

Dr Chiashi Muroi
1-3-4 Ote-machi, Chiyoda-ku
Tokyo 100-8122
Japan
cmuroi@met.kishou.go.jp

Dr Florence Rabier
Deputy-Head of NWP, CNRM-GAME, Météo-France et CNRS, Météopole,42 Avenue G. Coriolis
31057 Toulouse
France
florence.rabier@meteo.fr

Dr Mikhail Tolstykh
Institute of Numerical Mathematics, Russian Academy of Sciences
Gubkina Strasse, 8
Moscow 119991
Russian Federation
tolstykh@inm.ras.ru

Dr Xueshen Shen
No.46 South ZhongGuanCun Street, Haidian
Beijing 100081
China
shenxs@cams.cma.gov.cn

Dr Ayrton Zadra
Research Scientist, Numerical Prediction Research, Meteorological Service of Canada, Environment Canada, 2121, route Transcanadienne
Dorval (Québec) H9P 1J3
Canada
ayrton.zadra@ec.gc.ca

Dr Jean-Noël Thépaut
ECMWF, Shinfield Park, Reading, Berks, RG2 9AX
Reading, Berks, RG2 9AX
United Kingdom
jean-noel.thepaut@ecmwf.int

Dr Saulo Freitas
CPTEC/INPE, Av dos Astronautas, 1.758, Jd. Granja - CEP: 12227-010
São José dos Campos - SP
Brazil
saulo.freitas@cptec.inpe.br

Dr Julio Bacmeister
AMP/CGD, National Center for Atmospheric Research
Boulder, CO 80307-3000
USA
juliob@ucar.edu

Ex-officio members

Dr David Jackson
Manager of Stratosphere and Large Scale Dynamics, Met Office FitzRoy Road
Exeter Devon EX1 3PB
United Kingdom
david.jackson@metoffice.gov.uk

Dr Jon Petch
Met Office, Manager of Clouds and Radiation Group, FitzRoy Road
Exeter EX13PB
United Kingdom
jon.petch@metoffice.gov.uk

Dr Martin Best
UK Met Office, FitzRoy Road
Exeter EX1 3PB, United Kingdom
martin.best@metoffice.gov.uk

Invited experts

Dr Sandrine Bony
Laboratoire de Météorologie Dynamique (LMD/IPSL), CNRS/UPMC, Tour 45-55, 3ème étage, 4 place Jussieu, boite 99
75252 Paris cedex 05
France
Sandrine.Bony@lmd.jussieu.fr

Dr Hervé Douville
Météo-France/CNRM
42 avenue Coriolis
31057 Toulouse, France
herve.douville@meteo.fr

Dr Angela Benedetti
ECMWF, Shinfield Park, Reading, Berks, RG2 9AX
Reading, Berks, RG2 9AX
United Kingdom
angela.benedetti@ecmwf.int

Prof. Thomas Jung
Alfred-Wegener-Institute for Polar and Marine Research, Bussestrasse 24
D-27570 Bremerhaven
Germany
Thomas.Jung@awi.de

Dr Frederic Vitard
European Centre for Medium-Range Weather Forecasts, Shinfield Park
Reading, Berks, RG2 9AX
United Kingdom
frederic.vitart@ecmwf.int

Dr Peter Gleckler
Lawrence Livermore National Laboratory
P.O. Box 808, L-103 Livermore,
CA 94550 USA
gleckler1@llnl.gov

Dr François Bouyssel
Météo-France
CNRM/GMAP,
42 avenue Coriolis
31057 Toulouse, France
Francois.Bouyssel@meteo.fr

Dr Duane Waliser
Jet Propulsion Laboratory, MS 180-400
California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA 91109
duane.e.waliser@jpl.nasa.gov

Dr V. Balaji
NOAA/GFDL and Princeton University
201 Forrestal Road
Princeton NJ 08540-6649
USA
v.balaji@noaa.gov

Dr Lawrence Wilson
Environment Canada
2121 Transcanada Highway, 5th Floor
Dorval, Québec
CANADA H9P 1J3
lawrence.wilson@ec.gc.ca

Dr Serge Planton
Météo-France
CNRM/GMGEC
42 avenue G. Coriolis
31057 Toulouse (France)
serge.planton@meteo.fr

Dr Jean-François Mahfouf
MétéoFrance/CNRS
42 avenue G. Coriolis
31057 Toulouse (France)
jean-francois@meteo.fr

Dr Hoon Park – Korea
Numerical Weather Prediction Division
Korea Meteorological Administration
460-18 Shindaebang- 2dong Dongjak-gu Seoul
Korea
hoon@kma.go.kr

Dr Mitch Moncrieff
UCAR
3450 Mitchell Lane
Boulder, CO, 80307-3000
United States of America
moncrief@ucar.edu

WMO
Dr Deon Terblanche
Director, RES/ARE
WMO, 7 bis, Avenue de la Paix, CP 2300
CH-1211 Geneva
Switzerland
dterblanche@wmo.int

Dr Liisa Jalkanen
ARE/RES, Chief, AER Division
WMO, 7 bis, Avenue de la Paix, CP 2300
CH-1211 Geneva
Switzerland
ljalkanen@wmo.int

Dr Michel Rixen
RES/WCRP
WMO, 7 bis, Avenue de la Paix, CP 2300
CH-1211 Geneva
Switzerland
mrixen@wmo.int