FRAMS and the new WMO Polar Regional Climate Centre

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Canadian Centre for Climate Modelling and Analysis (CCCma)

WGSIP 19, 9-12 October 2017

WMO Regional Climate Centres

WMO EC-69 (May 2017) endorsed a Polar Regional Climate Centre PRCC hybrid network structure involving three nodes:

http://www.wmo.int/pages/prog/wcp/wcasp/rcc/rcc.php

Legend

- designated RCC
- RCC in demonstration phase
- RCC proposed
- designated RCC-Network
- RCC-Network in demonstation phase
- RCC-Network proposed

Polar Regional Climate Centre nodes

Role by geographical areas of responsibility:

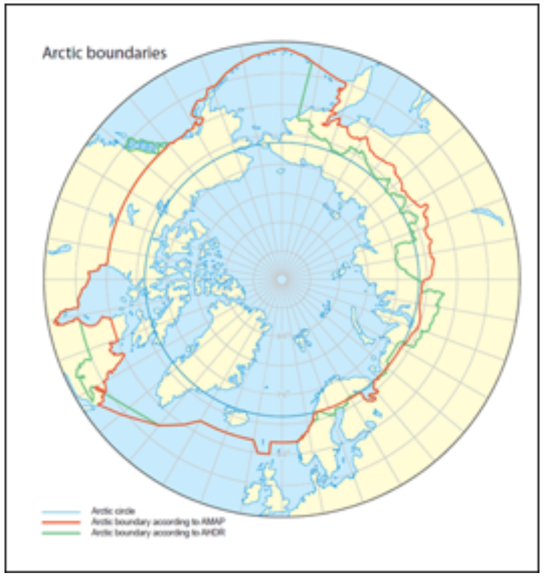
- **Canada** will lead the **North American Node** (with Canada and the USA as members of the consortium)
- **Norway** will lead the **Northern Europe and Greenland Node** (with Denmark, Finland, Iceland, Norway, Sweden and possibly other interested European countries as members of the consortium)
- **Russian Federation** will lead the **Eurasian Node**

Role by functional cross-node responsibility:

- **Canada** will lead development of **Long-Range Forecasts (LRF)**
- **Norway** will lead **Operational Data Services**
- **Russian Federation** will lead the **Climate Monitoring**

Multi-Model LRF products will include sea ice

- Arctic domain defined as 60°N to North Pole (90°N), with important exceptions
- First **Pan-Arctic Regional Climate Outlook Forum (PARCOF)** will be held Spring 2018 in Canada
- **Arctic sea ice** a *highly recommended* seasonal forecast product



Forecasting Regional Arctic Sea Ice from a Month to Seasons (FRAMS)

- Funded by Canadian “Marine Environmental Observation, Prediction and Response” (MEOPAR) research network
- A YOPP-endorsed project
- **Overall objective**: develop improved, multi-model *user-relevant* forecasts of Arctic Sea ice on time scales from a month to seasons
- Capabilities will be developed in association with establishing of WMO Polar Regional Climate Centre (PRCC) node at GPC Montreal
- **Three components** described on following slides

MEOPAR

YOPP
YEAR OF POLAR PREDICTION

Forecasting component

- Forecast models:

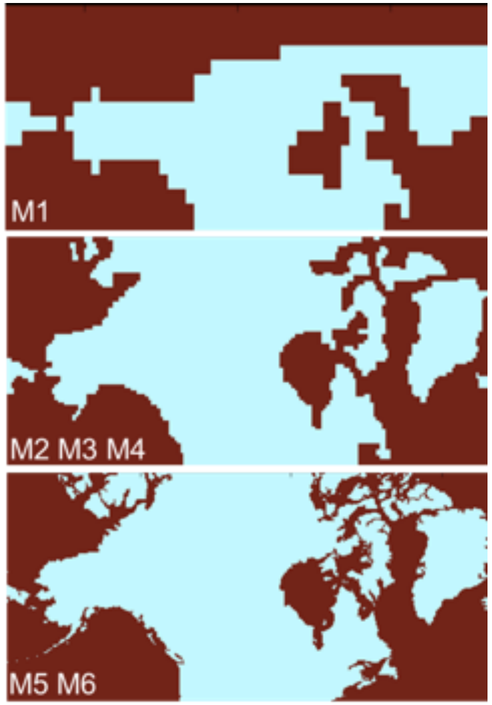
label	name	centre	sea ice component, properties, rheology	max resolution/range
M1	CanCM3/4	MSC	concentration/thickness, cavitating fluid	≈200 km / 12mon
M2	GEM-NEMO	MSC	CICE, 5 ice categories, EVP	≈ 40 km / 12mon
M3	CFSv2	NOAA (US)	GFDL SIS, 5 ice categories, EVP	≈ 40 km / 9 mon
M4	System 5	Météo France	GELATO, 4 ice categories, EVP	≈ 40 km / 6 mon
M5	GloSea5	Met Office (UK)	CICE, 5 ice categories, EVP	≈ 10 km / 6 mon
M6	En-GIOPS	MSC	CICE, 10 ice categories, EVP	≈ 10 km / 1 mon

- Forecast products:

Forecast Product	Purpose
pan-Arctic ice extent/area	benchmark for comparison with previous studies
spatial SIC[1], SIT[2]	"best estimate" forecasts of local SIC and SIT
spatial probabilistic SIC	probabilities of local SIC exceeding user-defined thresholds
ice retreat/advance dates	timing of local SIC seasonal advance and retreat
Canadian Ice Service Outlook Dates	improve existing CIS Seasonal Outlook by incorporating model forecasts and providing event timing probabilities
specialized shipping-relevant products	innovative products tailored for shipping sector (e.g. navigability) and incorporating feedback from end users

[1]SIC = sea ice concentration [2]SIT = sea ice thickness

Sea ice resolution



- Apply recent R&D for probabilistic, advance/retreat date forecasts

Table 2: Eastern Arctic - Outlook Dates

Arctic Events	Earliest Date (1968-2012)	Latest Date (1968-2012)	Median (1981-2010)	Outlook
Baffin Bay Northern Route - Open drift or less - Bergy water	10 Jun 13 Jun	18 Aug 15 Sep	13 Jul 27 Jul	26-28 Jun 6-8 Jul
Baffin Bay Area - Bergy water	10 Aug	7 Oct	6 Sep	26-28 Aug
Frobisher Bay to Home Bay Route - Open drift or less	22 Jul	19 Sep	5 Aug	5-7 Aug
Frobisher Bay to Cape Dyer Route - Open drift or less	24 Jun	15 Sep	25 Jul	22-24 Jul
Pond Inlet Area - Fracture - Bergy water	10 Jul 25 Jul	19 Aug 12 Sep	23 Jul 8 Aug	19-21 Jul 6-8 Aug

Current format for deterministic CIS outlook (sample)

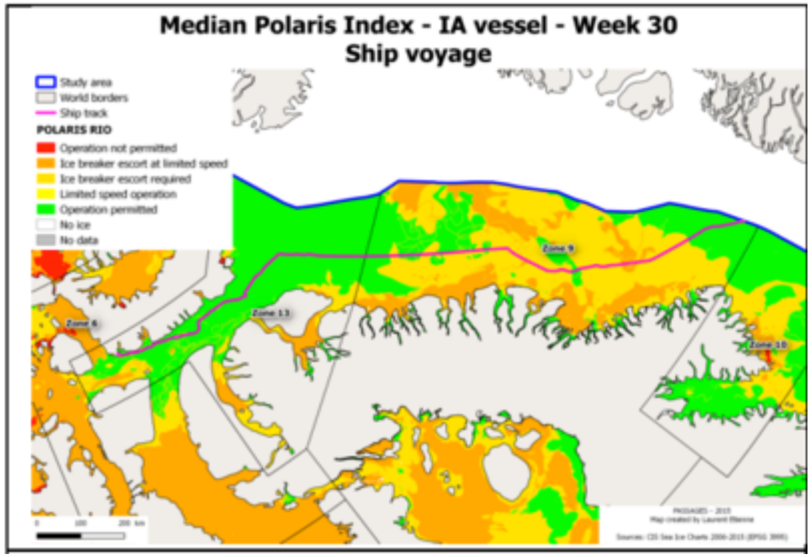
Analysis component

- **Analyze forecasts and observations** to better understand
  - ➢ Sources of sea ice predictability
  - ➢ Sources of bias and error in forecasts, informing improvements
- Apply existing **Lagrangian Ice Tracking System (LITS),** which tracks sea ice trajectories using daily ice motion vectors, to
  - ➢ Assess predictability of multi-year ice based on initial locations from CIS charts, observed & forecast ice motion
  - ➢ Assess ability of forecasts to represent dynamical processes known to contribute to melt-season predictability, such as late-winter sea ice divergence along the Eurasian coastline
  - ➢ Use LITS-based and other statistical forecasts to benchmark dynamical forecast skill
- **Observational datasets** used for verification and analysis include:

verification product	description, temporal coverage, resolution
NASA, HadISST2, Had2CIS	monthly SIC, whole Arctic, 1979-present, ≈50-100 km
historical CIS charts	weekly ice conditions, Canadian Arctic, 1979-present, ≈25 km
real time CIS charts	weekly ice conditions (daily where known marine activity)
RIOPS, GIOPS analyses	daily SIC, whole Arctic, 2011-present, 2-4 km and 10-15 km
PIOMAS, CryoSat2/SMOS	monthly/weekly SIT, whole Arctic, 1978/2010-present, ≈50 km
Polar Pathfinder	daily sea ice motion vectors, whole Arctic, 1978-present, 25km

End-user component

- **Consultations with forecast end users**, mainly in the Arctic shipping sector, will inform
  - ➢ development of user-relevant products
  - ➢ communication/visualization of probabilistic forecast information
- Initial discussions have identified **sector interest in forecasting**
  - ➢ sea ice strength
  - ➢ sea ice pressure
  - ➢ multi-year ice concentration
  - ➢ level (first-year) ice concentration and thickness
- Will also explore forecasting of navigability measures such as AIRSS and POLARIS along ship tracks →
- End-user panel leadership established, workshops to be held in spring 2018 & 2020



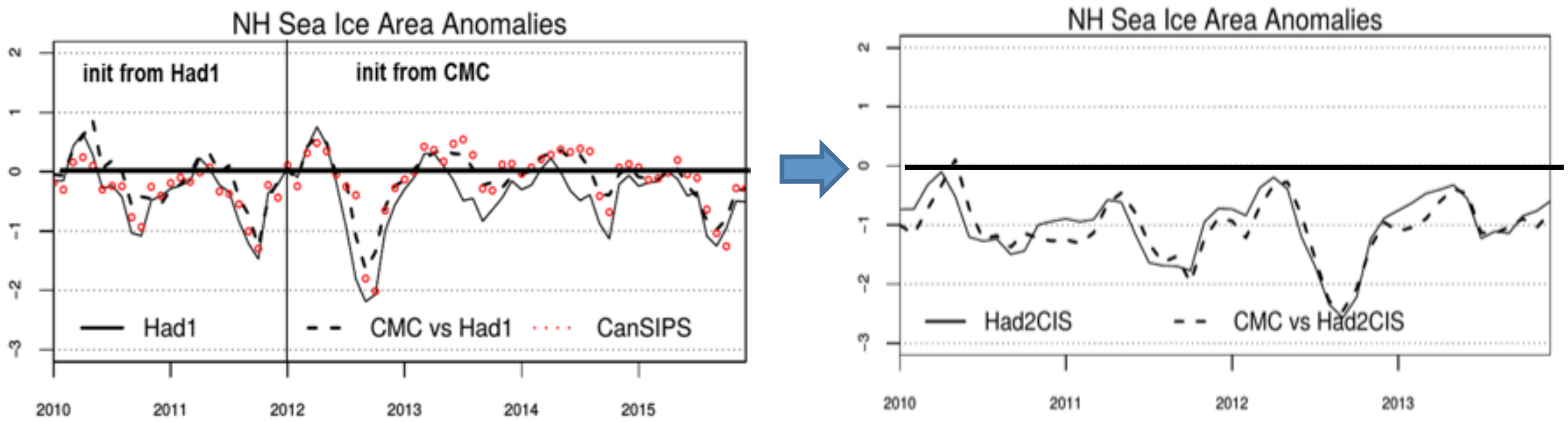
Stoddard et al. (2016)

Improved sea ice initialization in Canadian models

- Though some skill documented in hindcasts, real time predictions ~useless due to deficiencies in initialization of sea ice concentration (SIC) and thickness (SIT):
  1) hindcast SIC initialized with HadISST1.1 (Had1)
     - poor temporal consistency → erroneous trends
     - passive microwave-based, whereas CMC analysis used in ops that uses SAR etc. "sees" more ice, especially in melt season

     → **huge high bias** in forecast area/extent, with even positive anomalies predicted in some months

Solution: initialize hindcast SIC with "Had2CIS" = blend of HadISST2 and Canadian Ice Service charts

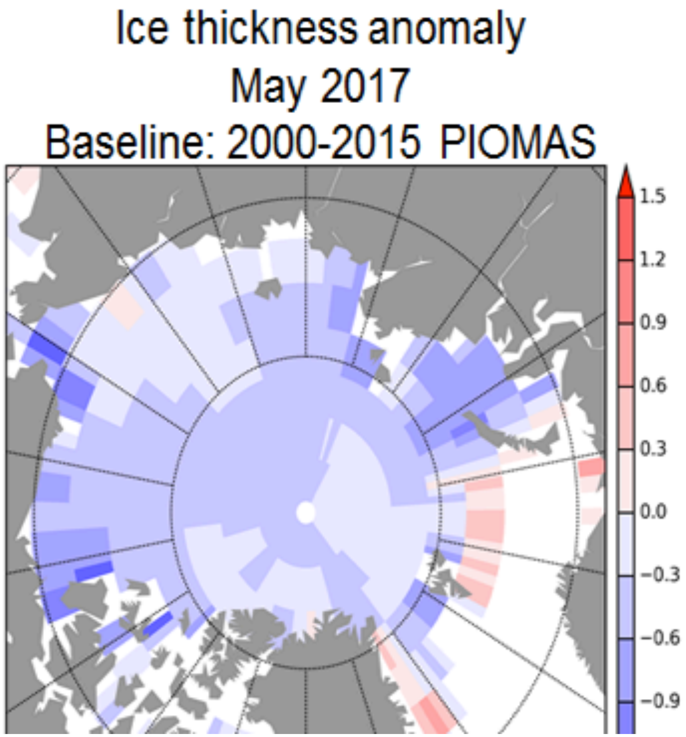


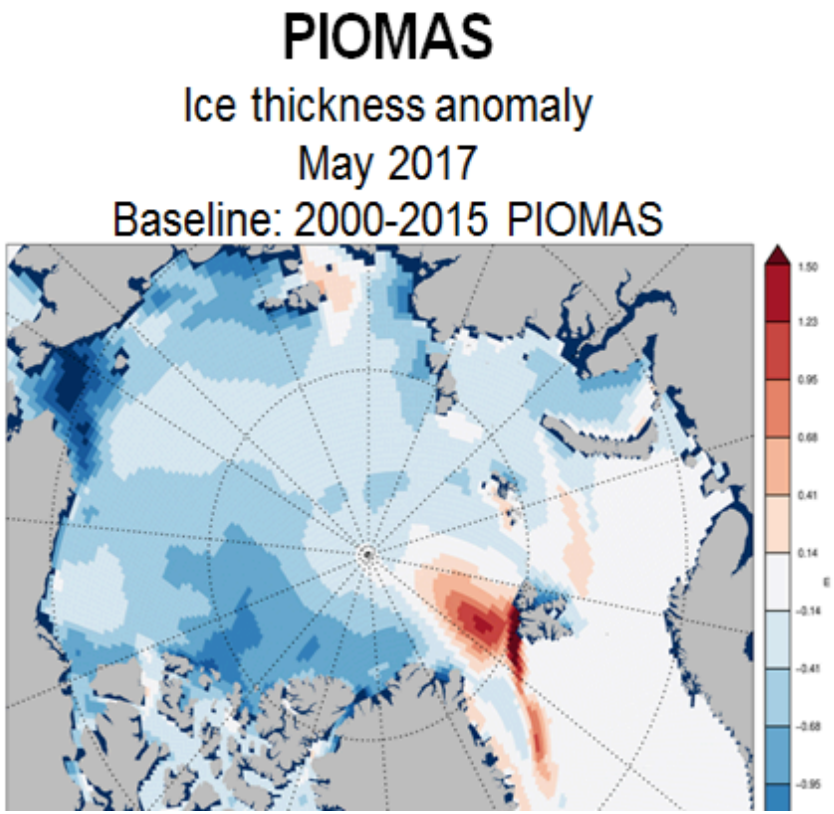
Improved sea ice initialization in Canadian models

2) Hindcasts and real time forecasts were initialized with stationary climatological SIT

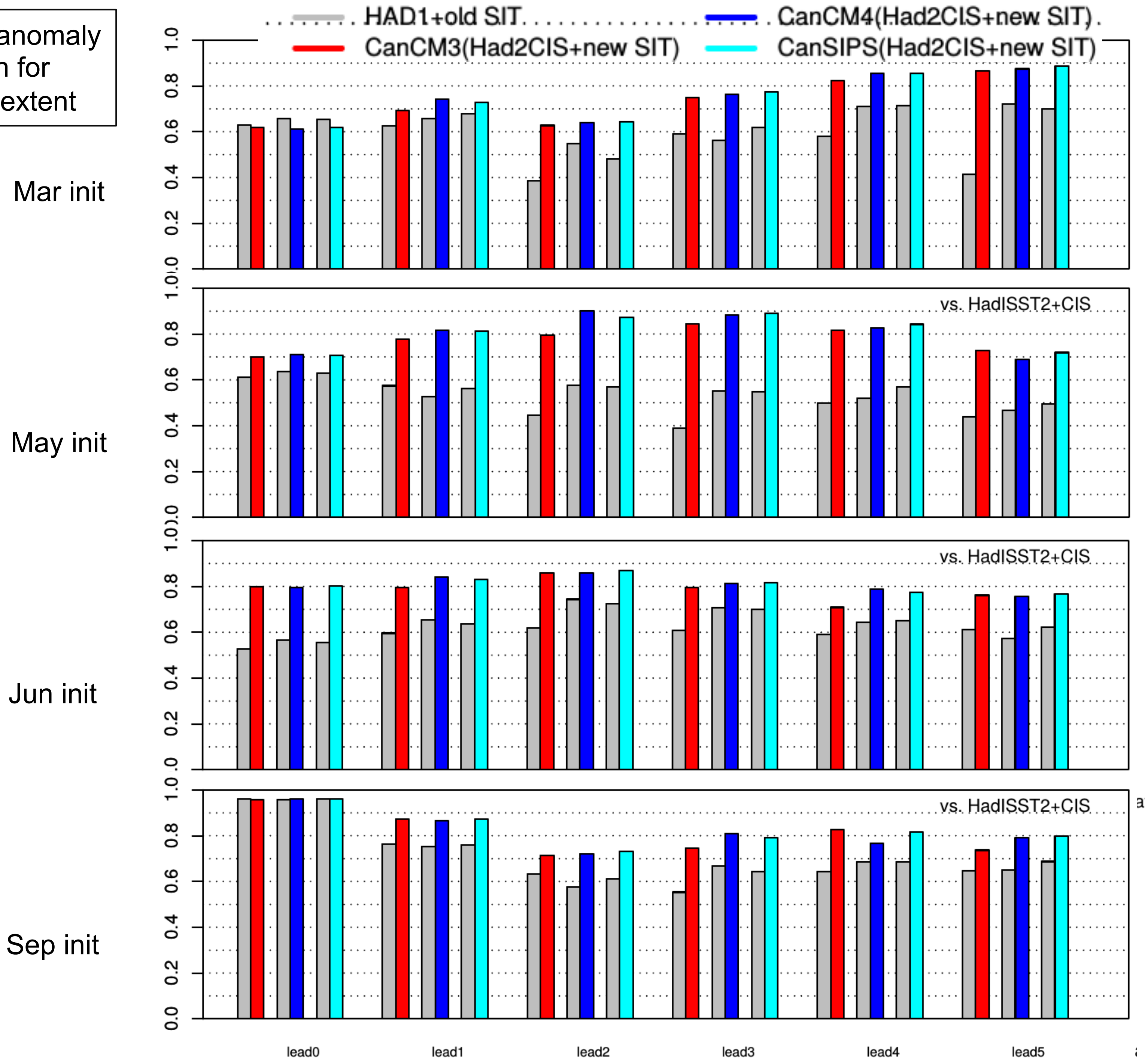
Solution: initialize with SIT estimated by statistical model of Dirkson et al. (J. Clim 2017)

Modified CanSIPS initial SIT

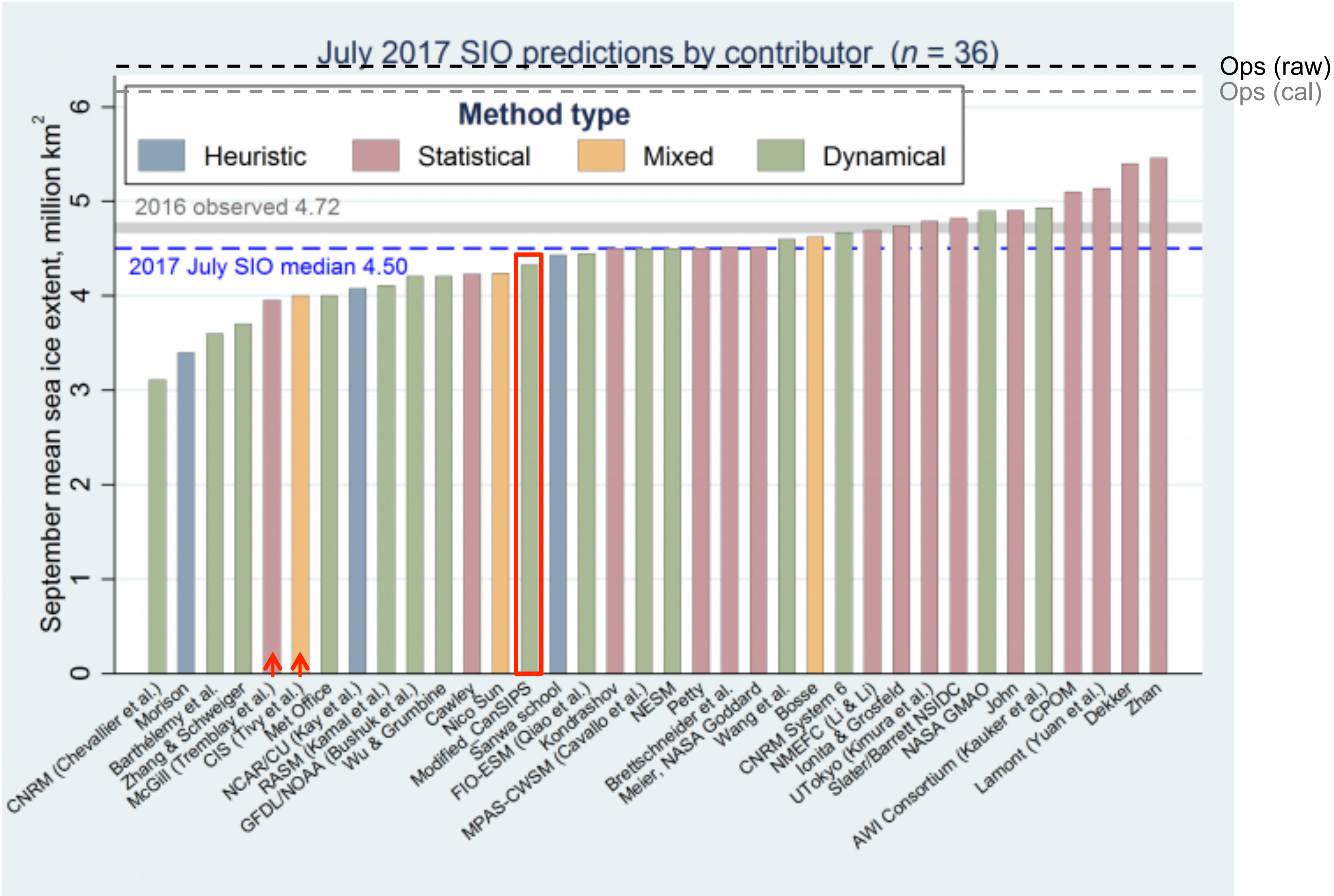




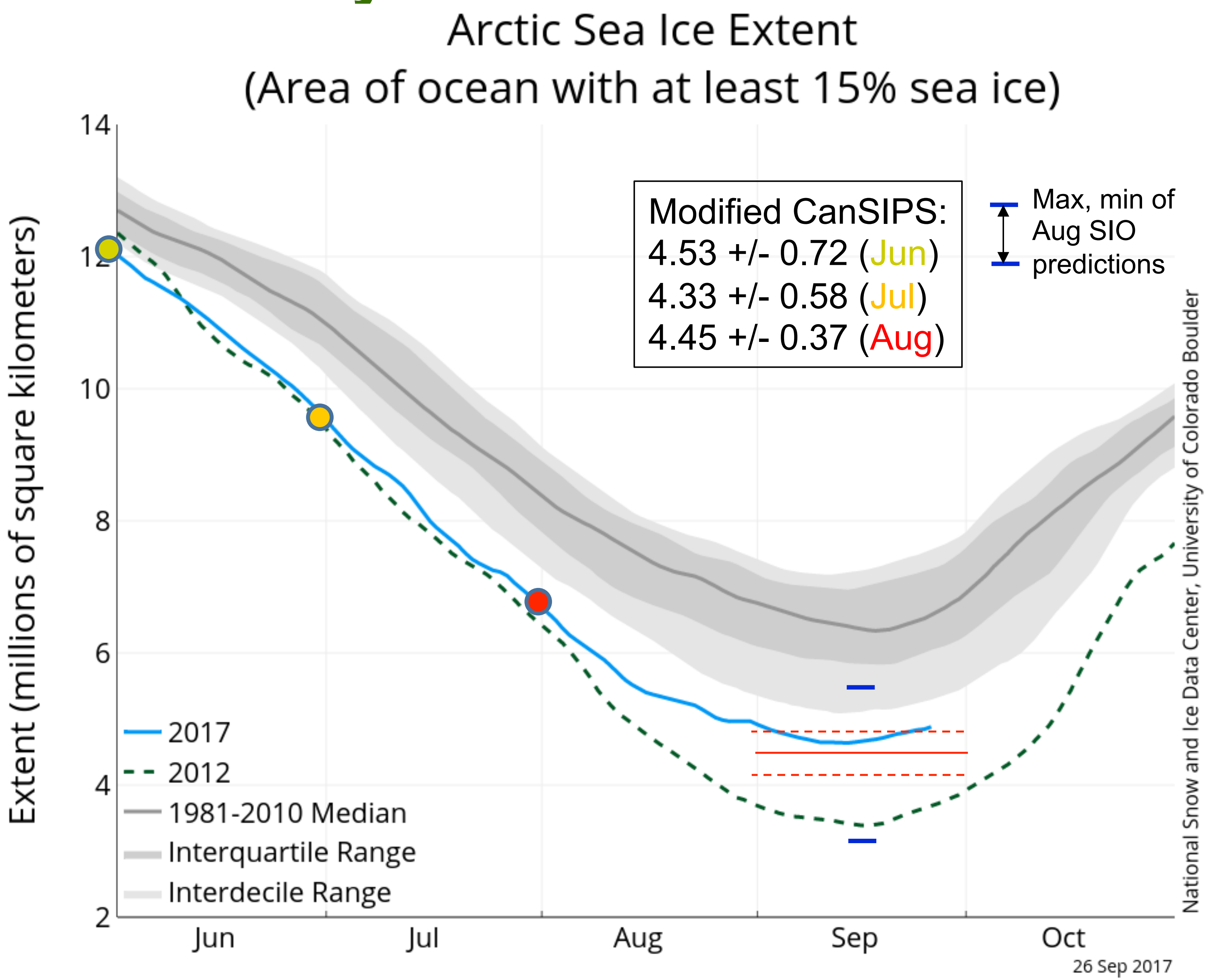
Hindcast anomaly correlation for Arctic ice extent



1) July Sea Ice Outlook



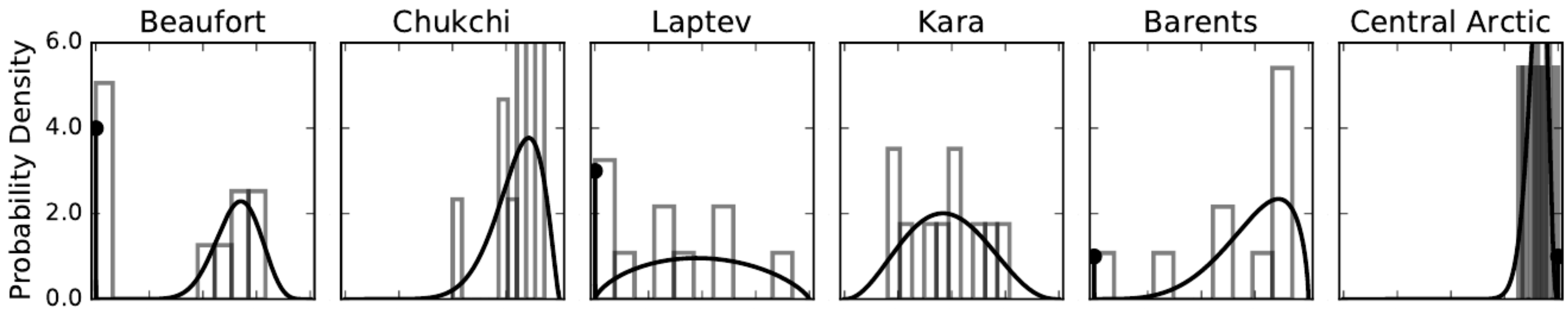
Preliminary Sea Ice Outlook verification



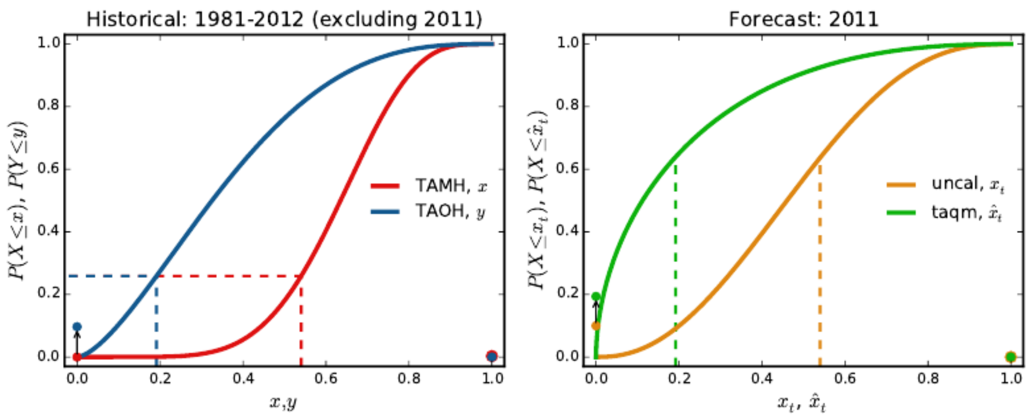
Sea ice probabilistic forecast method

Dirksen et al. in preparation

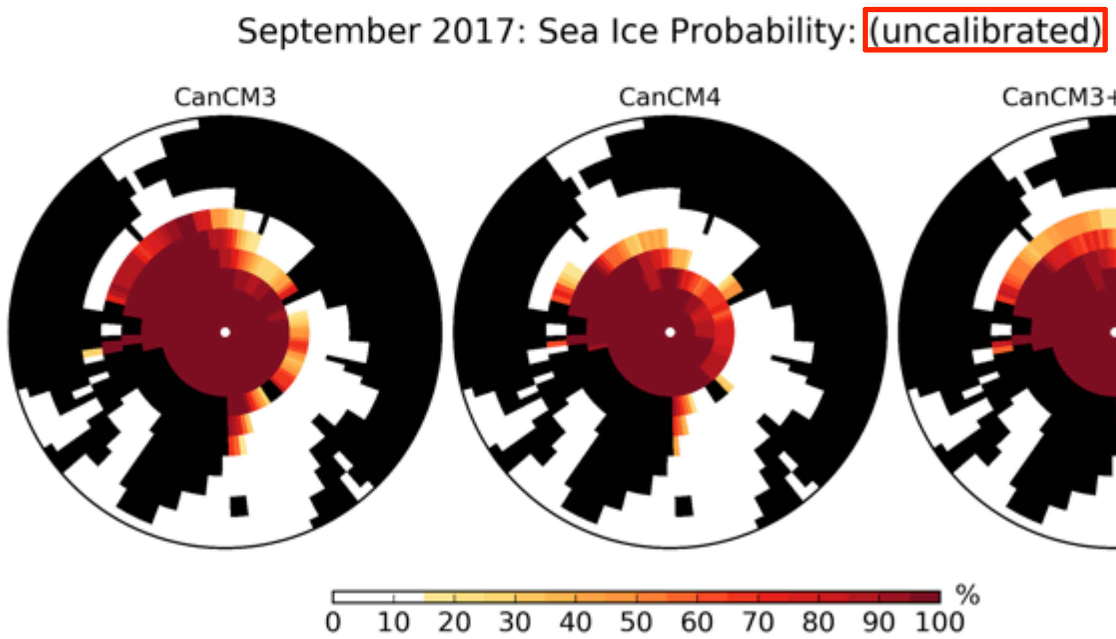
Step 1: Fit "count" concentrations to inflated beta distribution on [0,1]

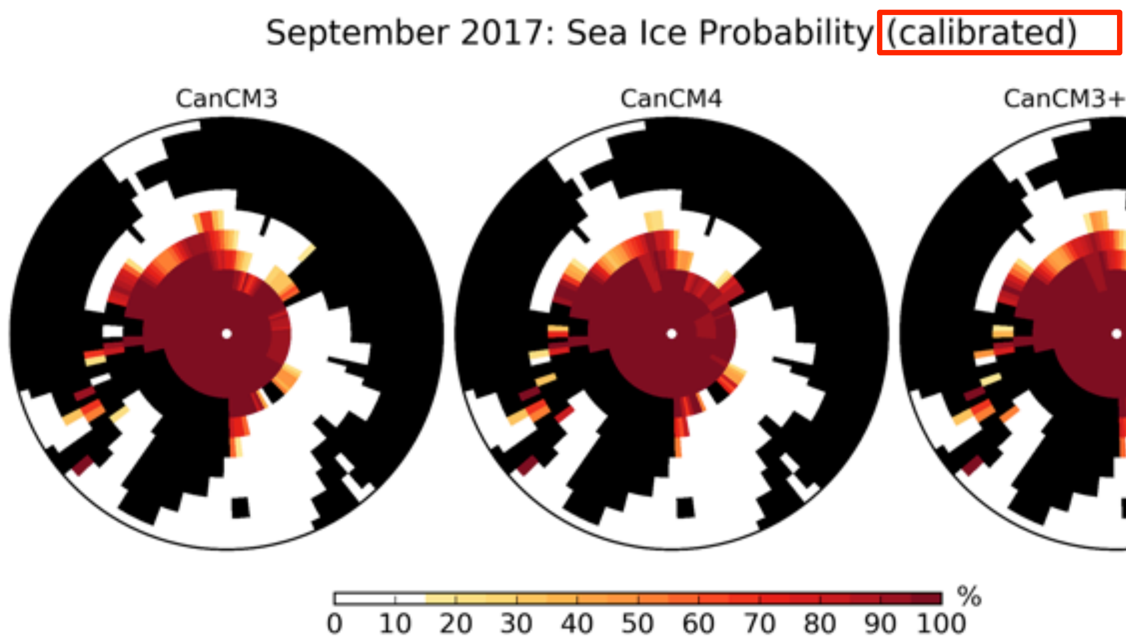


Step 2: Obtain calibrated forecast distribution through *trend adjusted quantile mapping* (taqm) between historical and hindcast distributions



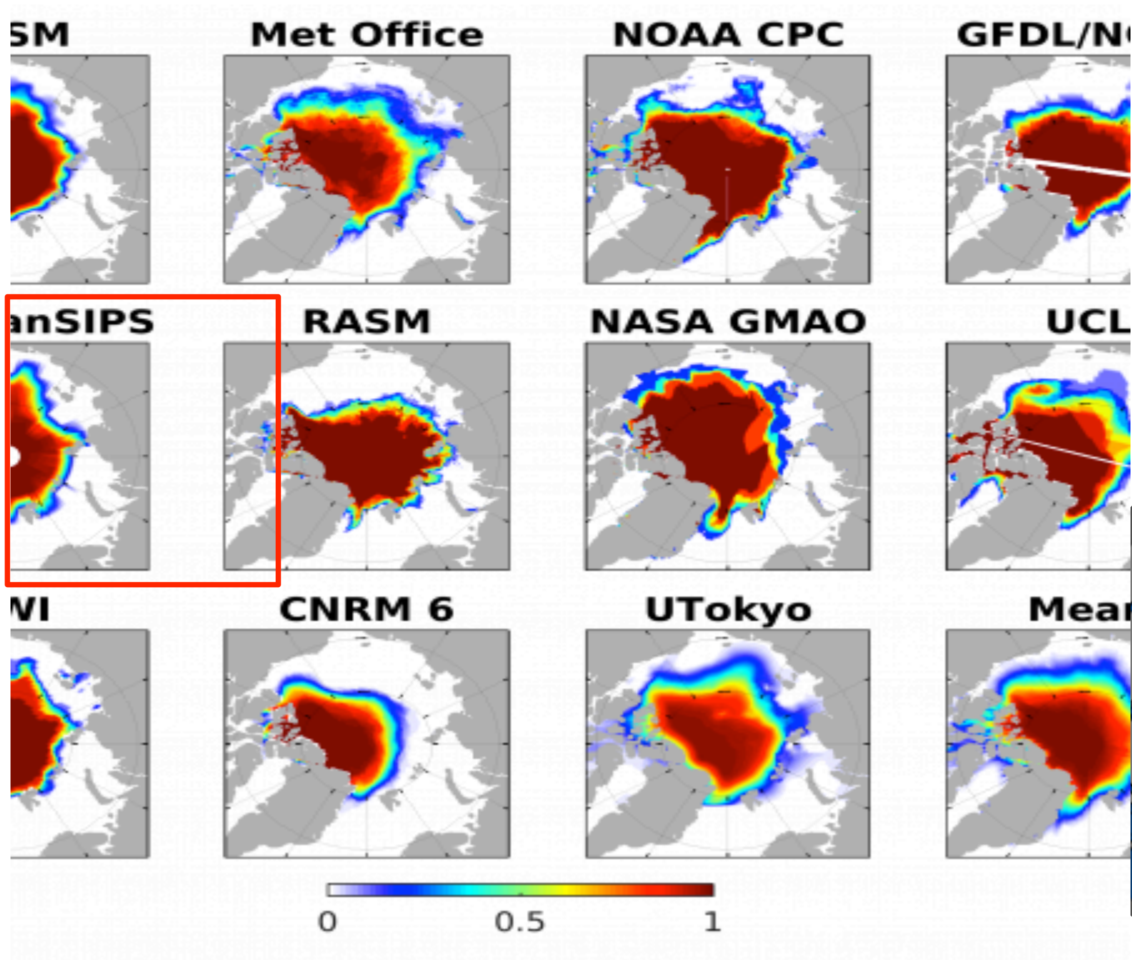
Sea Ice Probability: July initialization



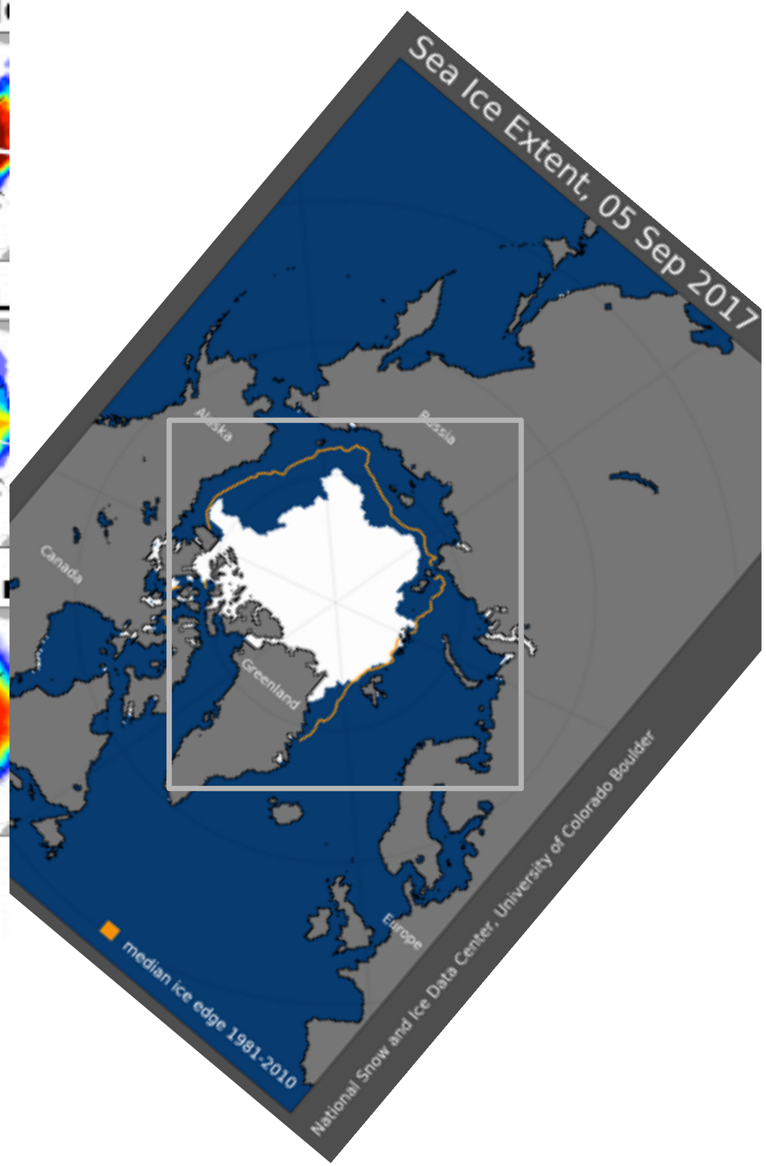


Sea Ice Probability: July initialization

Sea Ice Outlook Sep 2017 SIP forecasts from July

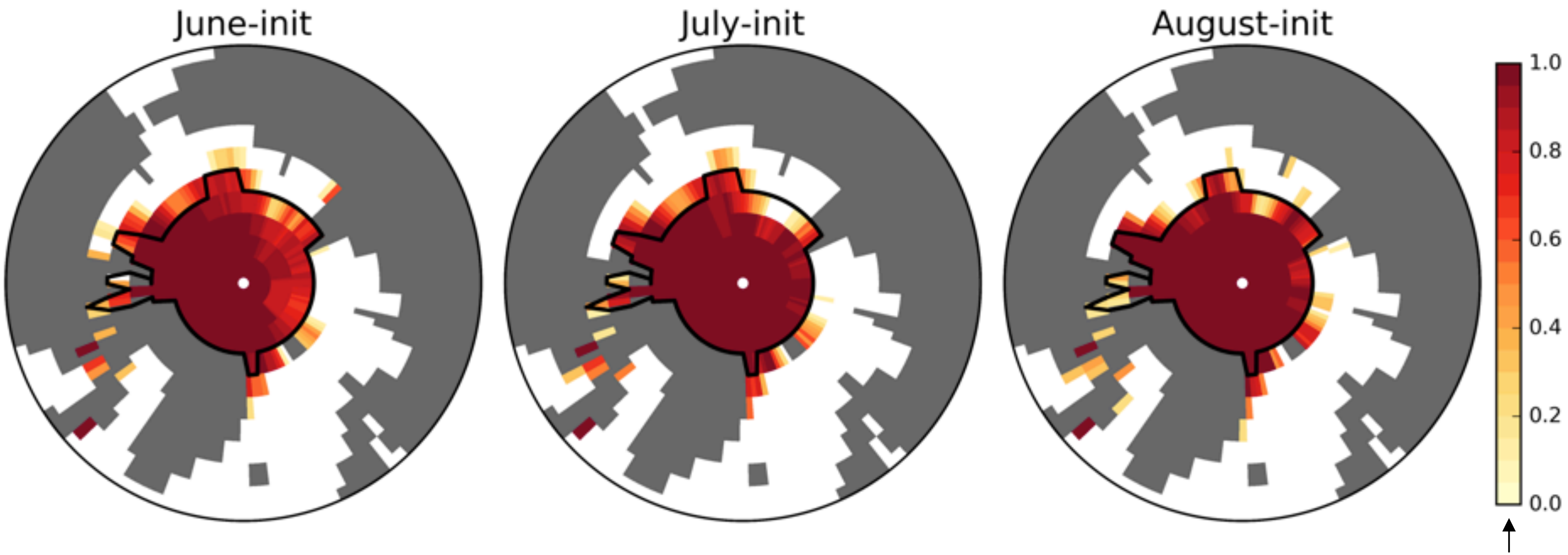


(median ice edge ~ green contour)



Preliminary verification

Black contour = observed Sep 2017 ice edge



Sea ice probability >15%

Summary

- FRAMS will develop multi-model, user-relevant seasonal forecast products for Arctic sea ice in support of WMO's Polar Regional Climate Center
- Sea ice initialization is tricky, especially when mismatches between hindcast and real time data sources
- Hindcast skill increased and real time forecasts debiased by improved initialization of Canadian models
- Calibration technique developed that improves skill and facilitates multi-model probabilistic forecasts → will be applied in PRCC development

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

North American Multi-Model Ensemble (NMME) update

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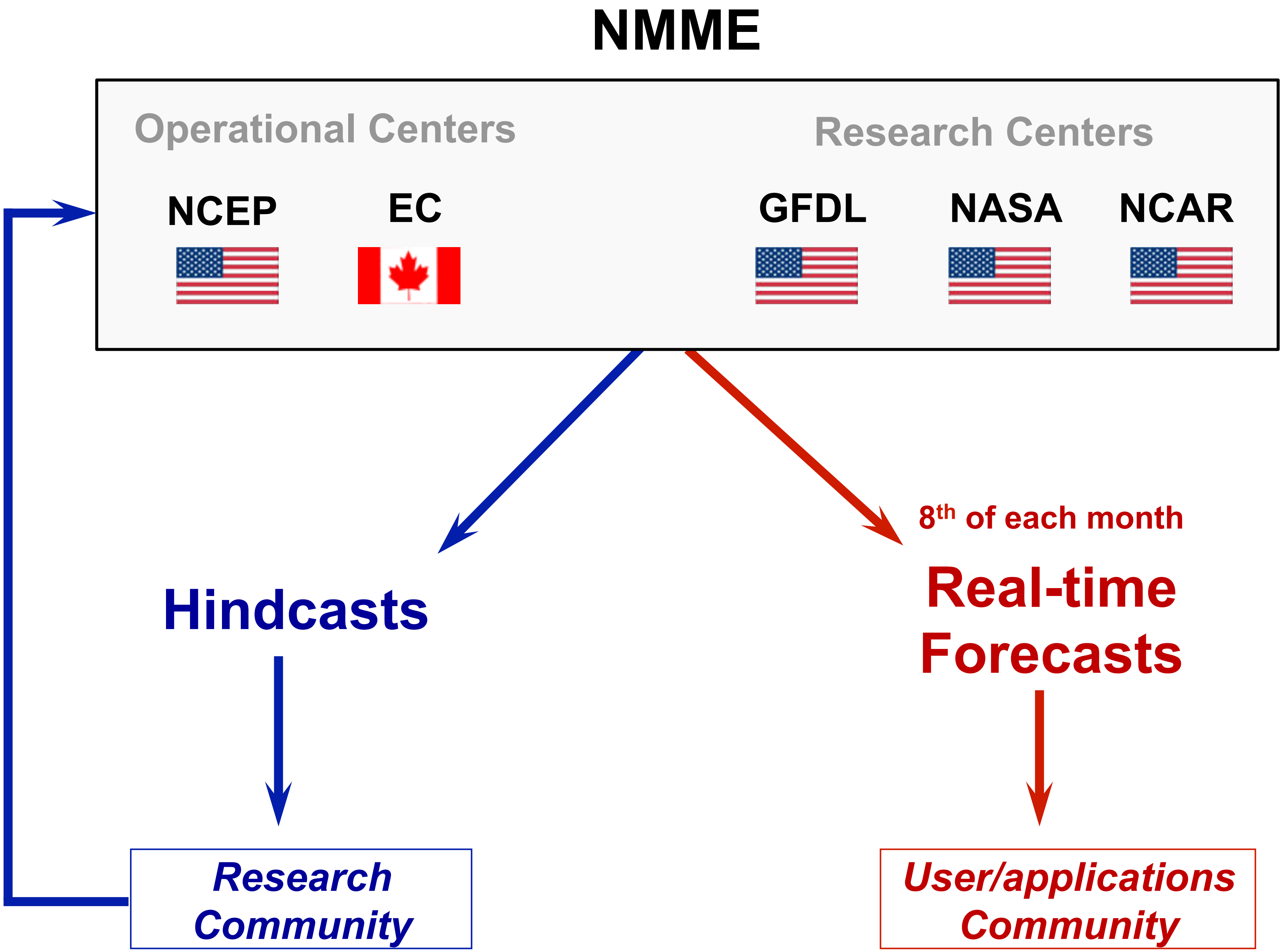

NMME
Operational Centers
Research Centers
NCEP
EC
GFDL
NASA
NCAR
8th of each month
Hindcasts
Real-time Forecasts
Research Community
User/applications Community

Currently contributing models

Nov 2016

	Model	Center	Ensemble size
	CFSv2	NCEP	24 (28)
	CanCM3	EC/CMC	10
	CanCM4	EC/CMC	10
	FLOR	GFDL	24
	CM2.1	GFDL	10
	CCSM4	NCAR	10
	GEOS-5	NASA	11
NEW	CESM1	NCAR	10
	Total ensemble size		109 (113)

Currently contributing models

Since Apr 2017

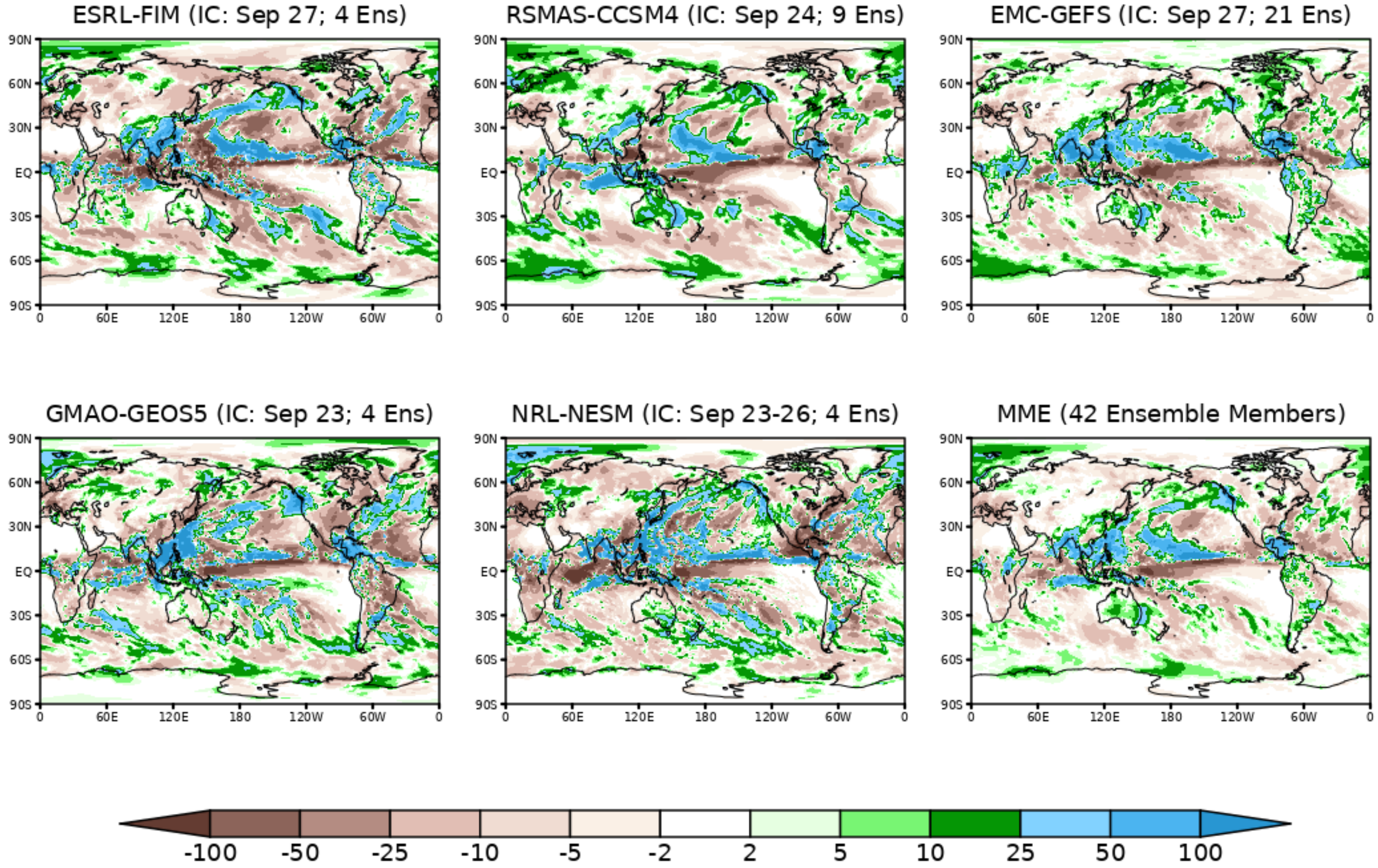
Model	Center	Ensemble size
CFSv2	NCEP	24 (28)
CanCM3	EC/CMC	10
CanCM4	EC/CMC	10
FLOR	GFDL	24
CM2.1	GFDL	10
CCSM4	NCAR	10
GEOS-5	NASA	11
CESM1	NCAR	10
Total ensemble size		99 (103)

SubX = NMME Subseasonal Experiment

- Weekly initialization
- Forecast length ≥ 32 days (45 days encouraged), with emphasis on weeks 3-4
- Hindcast period 1999-2015 (additional years encouraged)
- ≥ 4 ensemble members (more encouraged)
- Hindcasts and real-time forecasts made available by Wednesday of each week, published on Friday

SubX Week 3-4 Total Precipitation Anomalies (mm)

Valid Oct 14-27



http://cola.gmu.edu/kpegion/subx/forecasts/forecasts.html

New in 2017

- NMME/SubX Science meeting
  NOAA Center for Weather and Climate Prediction (NCEP)
  College Park, MD 13-15 September 2017

- Daily data for 13 real time forecast variables (in progress)

NMME (North-American Multi-Model Ensemble) is to improve intra-seasonal to interannual (ISI) operational predictions based on the leading US and Canada climate models.

NMME

NORTH AMERICAN MULTI-MODEL ENSEMBLE

Publications *2017*

Data Analyses and Applications

Rebecca A. Bolinger, Andrew D. Gronewold, Keith Kompoltowicz, and Lauren M. Fry, 2017: Application of the NMME in the Development of a New Regional Seasonal Climate Forecast Tool. *Bull. Amer. Meteor. Soc.*, **98**, 555-564. doi: 10.1175/BAMS-D-15-00107.1

Li-Chuan Chen, Huug van den Dool, Emily Becker, and Qin Zhang, 2017: ENSO Precipitation and Temperature Forecasts in the North American Multimodel Ensemble: Composite Analysis and Validation. *J. Climate*, **30**, 1103–1125. doi: 10.1175/JCLI-D-15-0903.1

Renaud Barbero, John T. Abatzoglou, and Katherine C. Hegewisch, 2017: Evaluation of Statistical Downscaling of North American Multimodel Ensemble Forecasts over the Western United States. *Wea. Forecasting*, **32**, 327-341. DOI: 10.1175/WAF-D-16-0117.1

N. Wanders, A. Bachas, X. G. He, H. Huang, A. Koppa, Z. T. Mekonnen, B. R. Pagán, L. Q. Peng, N. Vergopolan, K. J. Wang, M. Xiao, S. Zhan, D. P. Lettenmaier, and E. F. Wood, 2017: Forecasting the Hydroclimatic Signature of the 2015/16 El Niño Event on the Western United States. *J. Hydrometeor.*, **18**, 177-186. DOI: 10.1175/JHM-D-16-0230.1

Timothy DelSole and Arindam Banerjee, 2017: Statistical Seasonal Prediction Based on Regularized Regression. *J. Climate*, **30**, 1345-1361. DOI: 10.1175/JCLI-D-16-0249.1

Zengchao Hao, Xing Yuan, Youlong Xia, Fanghua Hao, and Vijay P. Singh, 2017: An overview of drought monitoring and prediction systems at regional and global scales. *Bull. Amer. Meteor. Soc.* , e-View, DOI: 10.1175/BAMS-D-15-00149.1

Huug van den Dool, Emily Becker, Li-Chuan Chen, and Qin Zhang, 2017: The Probability Anomaly Correlation and Calibration of Probabilistic Forecasts. *Wea. Forecasting*, **32**, 199-206. DOI: 10.1175/WAF-D-16-0115.1

Saleh Satti, Benjamin F. Zaitchik, Hamada S. Badr, and Tsegaye Tadesse, 2017: Enhancing dynamical seasonal predictions through objective regionalization. *J. Appl. Meteor. Climatol.* e-View, DOI: 10.1175/JAMC-D-16-0192.1

Liwei Jia, Xiaosong Yang, Gabriel Vecchi, Richard Gudgel, Thomas Delworth, Stephan Fueglistaler, Pu Lin, Adam A. Scaife, Seth Underwood, and Shian-Jiann Lin, 2017: Seasonal Prediction Skill of Northern Extratropical Surface Temperature Driven by the Stratosphere. *J. Climate*, e-View, DOI: 10.1175/JCLI-D-16-0475.1

Louise Arnal, Andrew W. Wood, Elisabeth Stephens, Hannah L. Cloke, and Florian Pappenberger, 2017: An Efficient Approach for Estimating Streamflow Forecast Skill Elasticity. *J. Hydrometeor.*, e-View, DOI: 10.1175/JHM-D-16-0259.1

Model and System Improvements

Jessie C. Carman, Daniel P. Eleuterio, Timothy C. Gallaudet, Gerald L. Geernaert, Patrick A. Harr, Jack A. Kaye, David H. McCarren, Craig N. McLean, Scott A. Sandgathe, Frederick Toepfer, and Louis W. Uccellini, 2017: The National Earth System Prediction Capability: Coordinating the Giant. *Bull. Amer. Meteor. Soc.*, **98**, 239-252. DOI:10.1175/BAMS-D-16-0002.1

http://www.nws.noaa.gov/ost/CTB/nmme_pub.htm

67 NMME publications as of Apr 2017