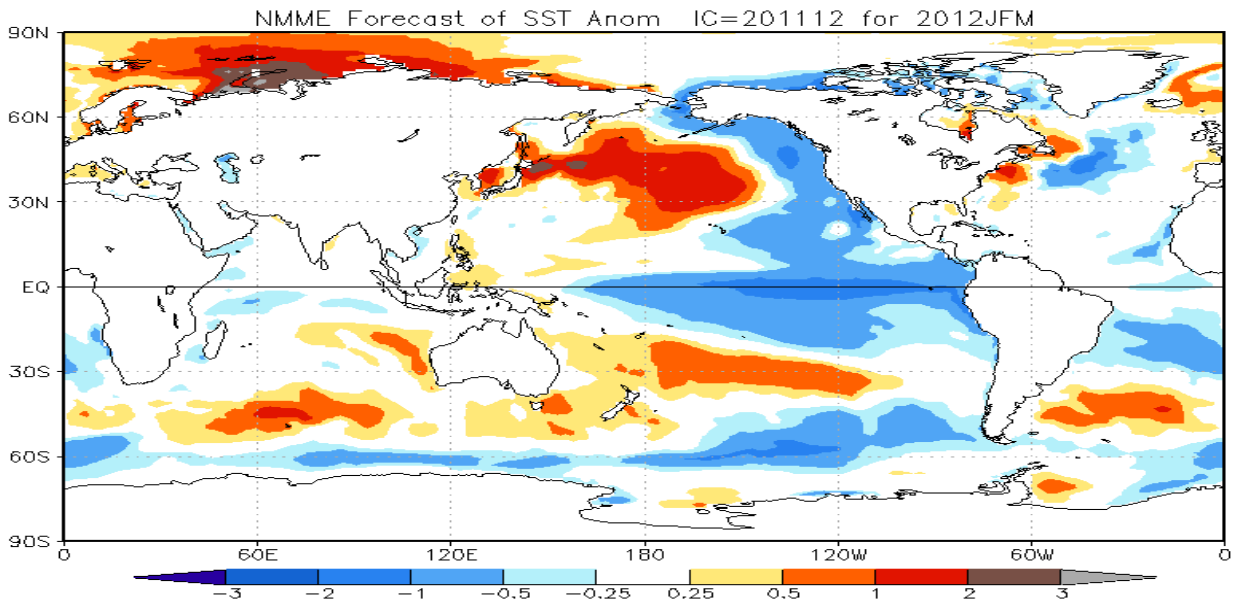
National Multi-Model Ensemble (NMME)



Jin Huang
NOAA/NCEP Climate Test Bed (CTB)

Acknowledgement: NMME Team, NOAA/CPO/MAPP, and other funding agencies (NSF, DOE, and NASA)

Outline

1. **NMME Overview**
2. **Forecast process and products**
3. **Ongoing research and applications**
4. **Summary**

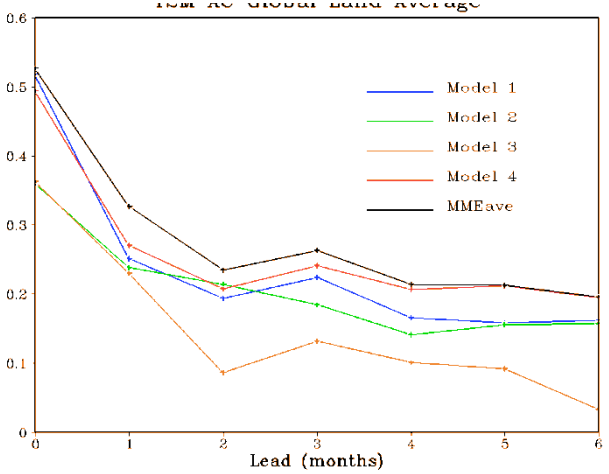
Why do we need NMME?

A multi-model system is the most practical approach to optimize skill and quantify uncertainties

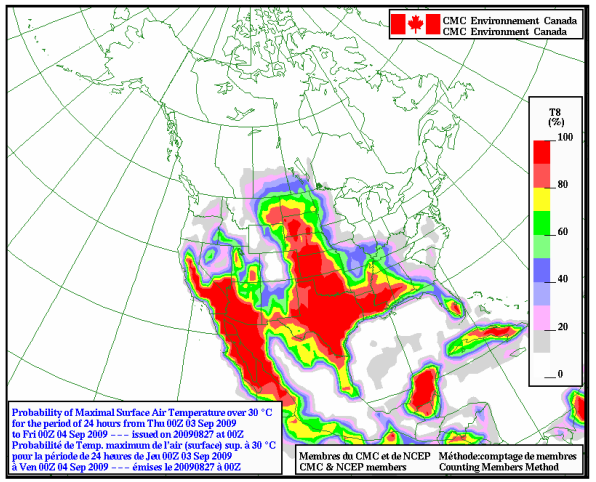
It is the current approach for climate forecasting in Europe (**but EUROSIP data is not open to the public**). It is the approach used at NCEP for weather forecasting

Many US modeling centers produce seasonal forecasts either to conduct research or to benchmark their modeling against observations **in forecast modes**

EUROSIP T2m AC over Land



North American Ensemble Forecast System (NAEFS)



NMME - Phase I

- **NCEP Climate Tests Bed (CTB) NMME Workshops February 18, April 8, 2011**
  - Establish Collaboration
  - Developed Protocol for Experimental Real-time Multi-Model Prediction
- **Funded by NOAA/CPO/MAPP Program in FY11**
- **Became Real-Time in August 2011**
  - Adhering to NOAA Operational Schedule
- **Continuously distributing Hindcast and Forecast Data to NOAA and the community**
  - Public Dissemination via IRI Data Library

NMME Partners

- **University of Miami**
- **COLA**
- **NCAR**
- **IRI**
- **U of Colorado – CIRES**
- **NASA – GMAO**
- **NOAA/NCEP**
- **NOAA/GFDL**
- **Princeton University**
- **Canada**

What is Climate Test Bed (CTB)?

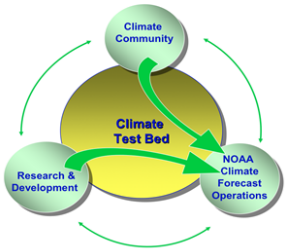
Mission:

To accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and service.

CTB Priorities:

1. **Multi-Model Ensembles (MME)**
2. NCEP CFS model evaluation and improvement
3. Climate forecast tools/products

- ***Basic Research***
- ***Applied Research***
- ***Research to Operation (R2O) Transition***
- ***Operations***



Mission: To accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services.

http://www.cpc.ncep.noaa.gov/products/ctb/

CTB is jointed supported by NCEP and /CPO/MAPP

NMME Phase-I Forecast Providers

Model	Hindcast Period	Ensemble Size	Lead Times	Arrangement of Ensemble Members	Contact and reference
CFSv1	1981-2009	15	0-8 Months	1st 0Z +/-2 days, 21st 0Z +/-2d, 11th 0Z+/- 2d	Saha (Saha et al. 2006)
CFSv2	1982-2009	24(28)	0-9 Months	4 members (0,6,12,18Z) every 5th day	Saha (Saha et al. 2010)
GFDL-CM2.2	1982-2010	10	0-11 Months	All 1st of the month 0Z	Rosati (Zhang et al. 2007)
IRI-ECHAM4-f	1982-2010	12	0-7 Months	All 1st of the month 0Z	DeWitt (DeWitt 2005)
IRI-ECHAM4-a	1982-2010	12	0-7 Months	All 1st of the Month 0Z	DeWitt (Dewitt 2005)
CCSM3.0	1982-2010	6	0-11 Months	All 1st of the Month 0Z	Kirtman (Kirtman and Min 2009)
GEOS5	1981-2010	6	0-9 Months	1 Member every 5th day	Schubert (Vernieres et al. 2011)

NMME Current Forecast Providers

Model	Hindcast Period	No. of Member	Arrangement of Members	Lead (months)	Model Resolution: Atmosphere	Model Resolution: Ocean	Reference
NCEP-CFSv2	1982-2010	24(20)	4 members (0,6,12,18Z) every 5th day	0-9	T126L64	MOM4 L40 0.25 deg Eq	Saha et al. (2010)
GFDL-CM2.1	1982-2010	10	All 1st of the month 0Z	0-11	2x2.5deg L24	MOM4 L50 0.30 deg Eq	Delworth et al. (2006)
CMC1-CanCM3	1981-2010	10	All 1st of the month 0Z	0-11	CanAM3 T63L31	CanOM4 L40 0.94 deg Eq	Merryfield et al. (2012)
CMC2-CanCM4	1981-2010	10	All 1st of the month 0Z	0-11	CanAM4 T63L35	CanOM4 L40 0.94 deg Eq	Merryfield et al. (2012)
NCAR-CCSM3.0	1982-2010	6	All 1st of the month	0-11	T85L26	POP L40 0.3 deg Eq	Kirtman and Min (2009)
NASA-GEOS5	1981-2010	11	4 members every 5th days; 7 members on the last day of the previous month	0-9	1x1.25deg L72	MOM4 L40 1/4 deg at Eq	Rienecker et al. (2008)

* This slide is by courtesy of Huug Vandendool, Qin Zhang, and Emily Becker.

NMME - Phase II

NMME-Phase II will feature an improved experimental system including upgraded models compared to Phase-I and research on the system's design and evaluation

Funded by NOAA as a MAPP-CTB research project with contributions from NSF, DOE and NASA (Aug. 2012- July 2014)

Continue real-time experimental operations

Enhance the current system with model upgrades

GFDL-CM2.5 (20 km AGCM); NCAR (CCSM4, CESM1)

Phase-II data (30+ year daily hindcasts) will be distributed at NCAR

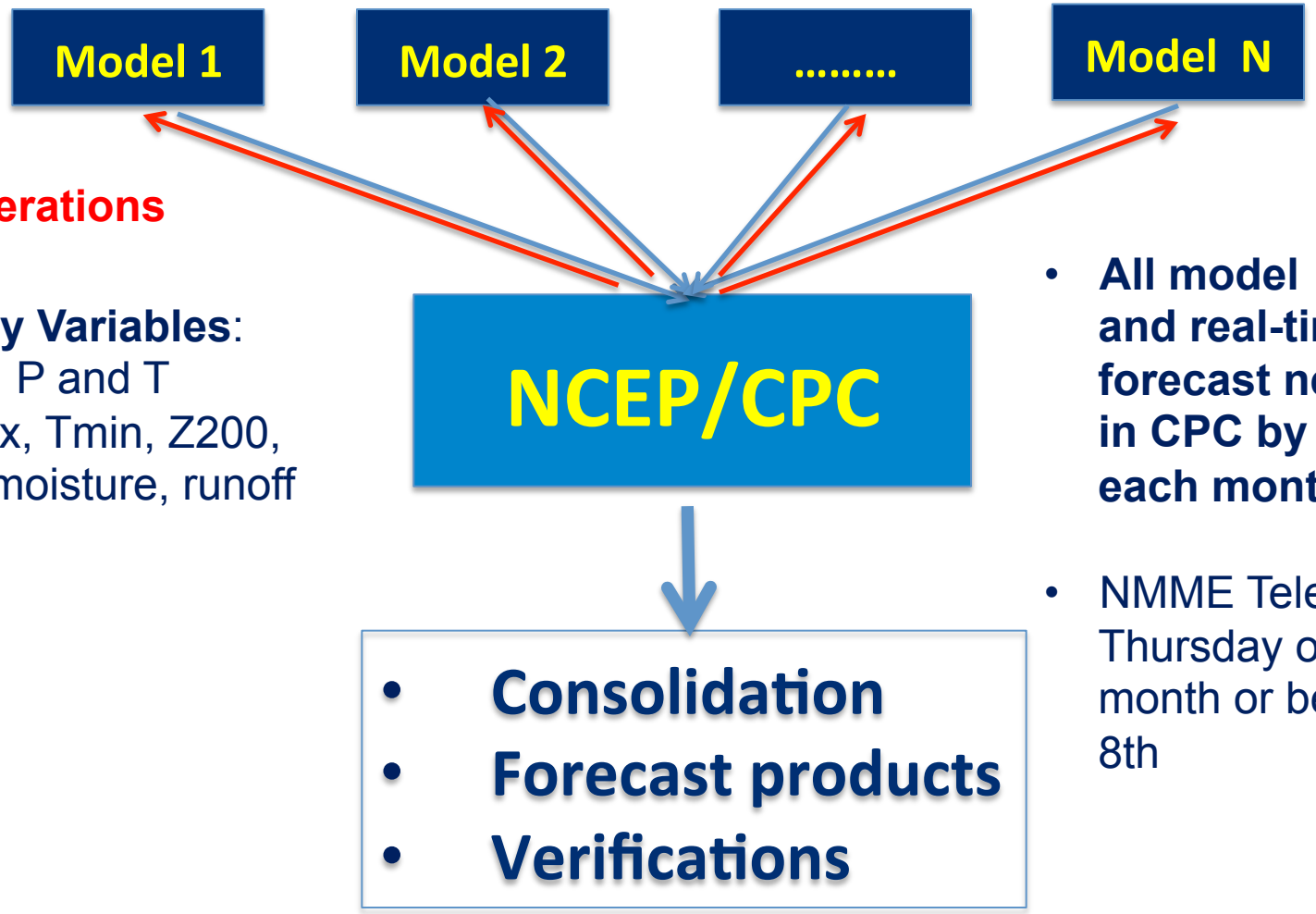
Evaluation & Research during Phase-II

- Seasonal forecast quality assessment: consolidation, drought.
- Sub-Seasonal Assessment: forecast protocols
- Initial condition sensitivity experiments: Ocean, Land

Hindcast/Forecast Protocol

- **Real-time prediction system must be identical to hindcasts system**
- **Hindcast start times must include all 12 calendar months**
  - Ensemble generation strategy is left open.
- **Lead-times up to 7 months are required - longer leads are encouraged**
- **The target hindcast period is 30 years (typically 1981-2010)**
- **All model outputs will be on 1x1 grid**
- **The ensemble size is left open - larger ensembles are encouraged**
- **Data distributed includes each ensemble member**
  - Total fields are required
  - Systematic error corrections to be coordinated by NOAA/CPC
  - Forecast providers are welcome to also provide bias-corrected forecasts and to develop their own MME combinations
- **Required output is monthly means of global grids of SST, T2m, and precipitation rate**

NMME Real-time Forecast Process



Monthly Variables:
- SST, P and T
- Tmax, Tmin, Z200, soil moisture, runoff

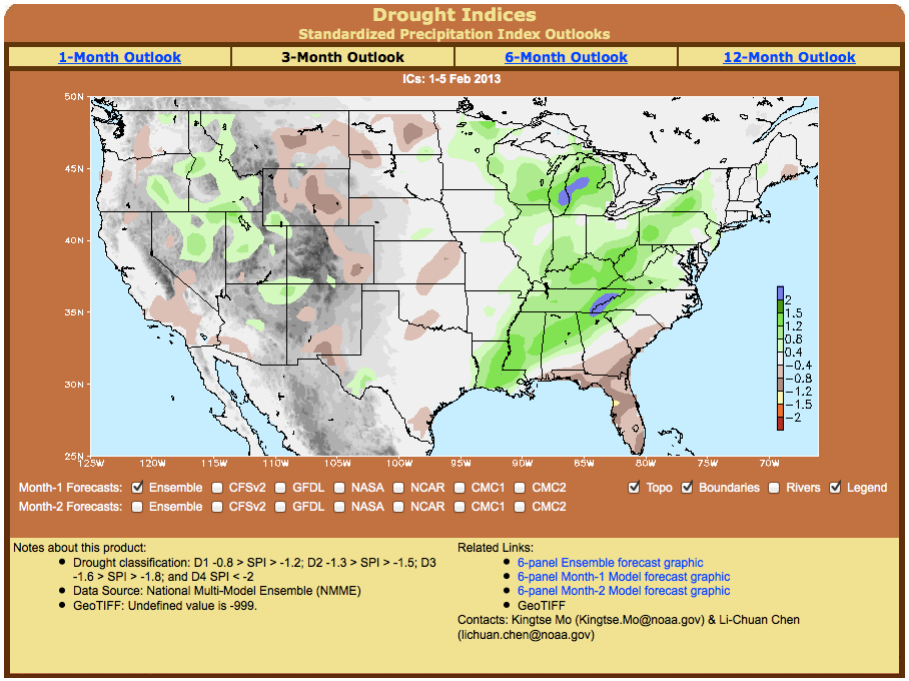
- **All model hindcast and real-time forecast need to be in CPC by the 8th of each month**
- NMME Telecon 1st Thursday of each month or before the 8th

Use of NMME by NCEP Operations

Although experimental, real-time NMME data is being used at NCEP in support of operations and it is regularly being consulted by CPC forecasters

- The official Monthly and Seasonal Climate Outlook
- The official U.S. Seasonal Drought Outlook
- In the preparation of experimental SPI Outlook for drought prediction.
- CPC Ocean Briefing

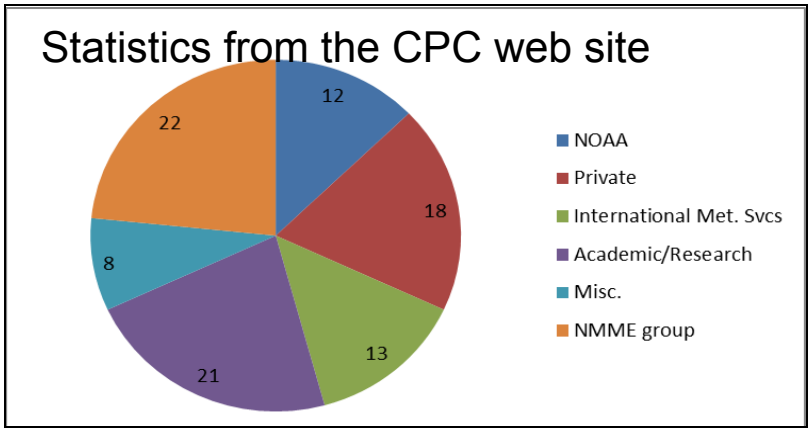
Experimental CPC NMME-based Drought Products



NMME Data Available to Users

NMME is the only system with a strict protocol that openly provides real-time climate forecasts and hindcasts for research and applications

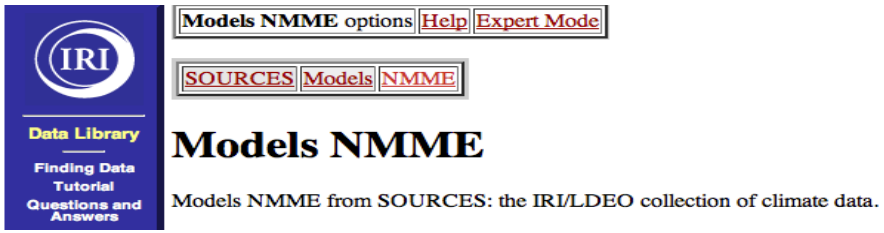
Realtime forecasts from CPC website



www.cpc.ncep.noaa.gov/products/NMME

- Data Aug. 2011-present
- Number of subscribers: 100
- Number of countries: 16

Hindcast data from the IRI website



iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/

- Data 1982-2010
- Number of visits; over 1200
- Number of individual users: ~500
- Number of hits: over 480,000
- Bandwidth: 457 GB

Ongoing Evaluation and Research

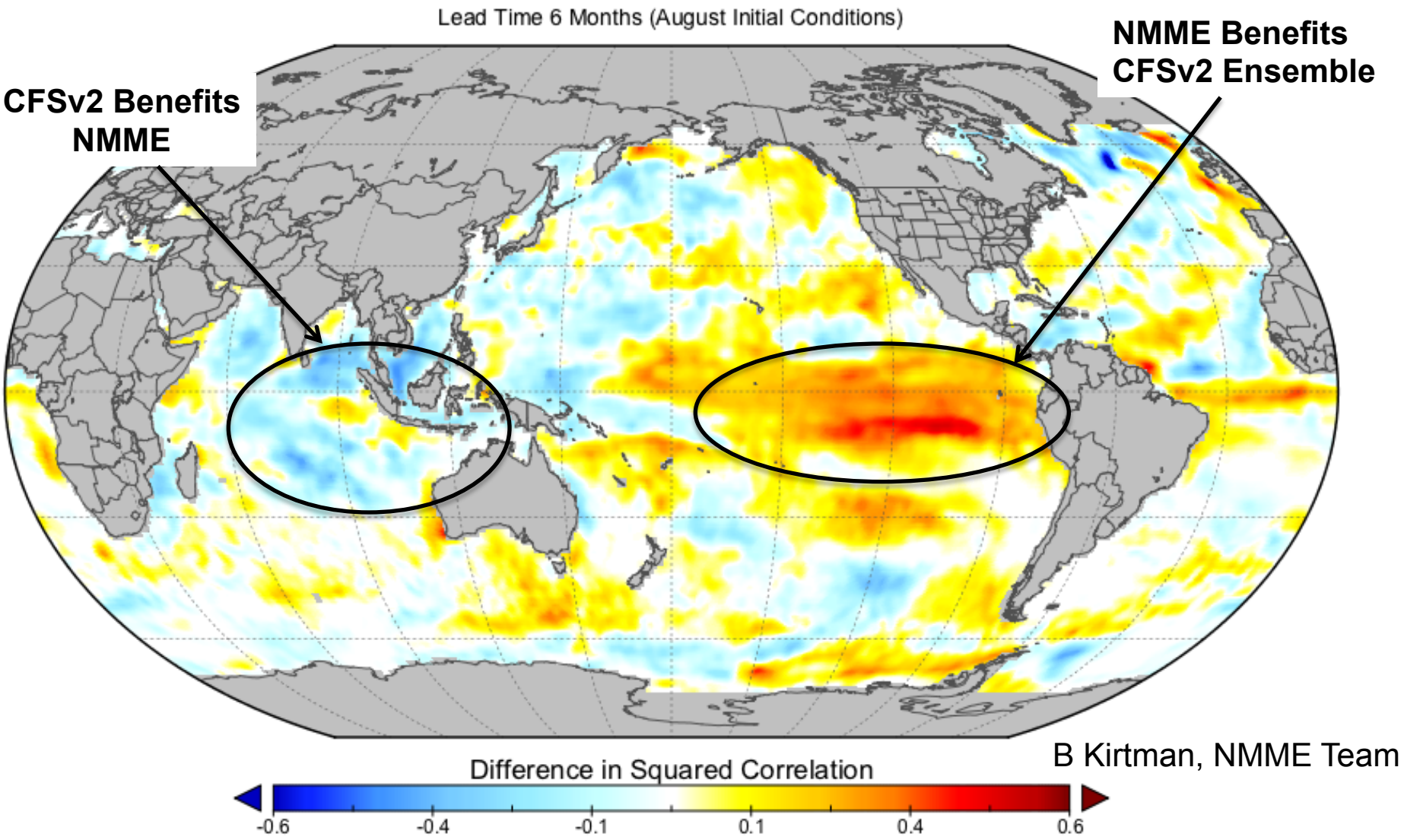
NMME data is being widely used for system evaluation, research on ISI climate prediction and predictability, and applications

- Evaluation of skill and improvements
- Predictability analyses
- Application to drought and hydrologic prediction
- ……

As examples of NMME data based research

Comparison of CFSv2 skill vs rest of NMME

All Others (24 Member Ensemble) vs. CFSv2

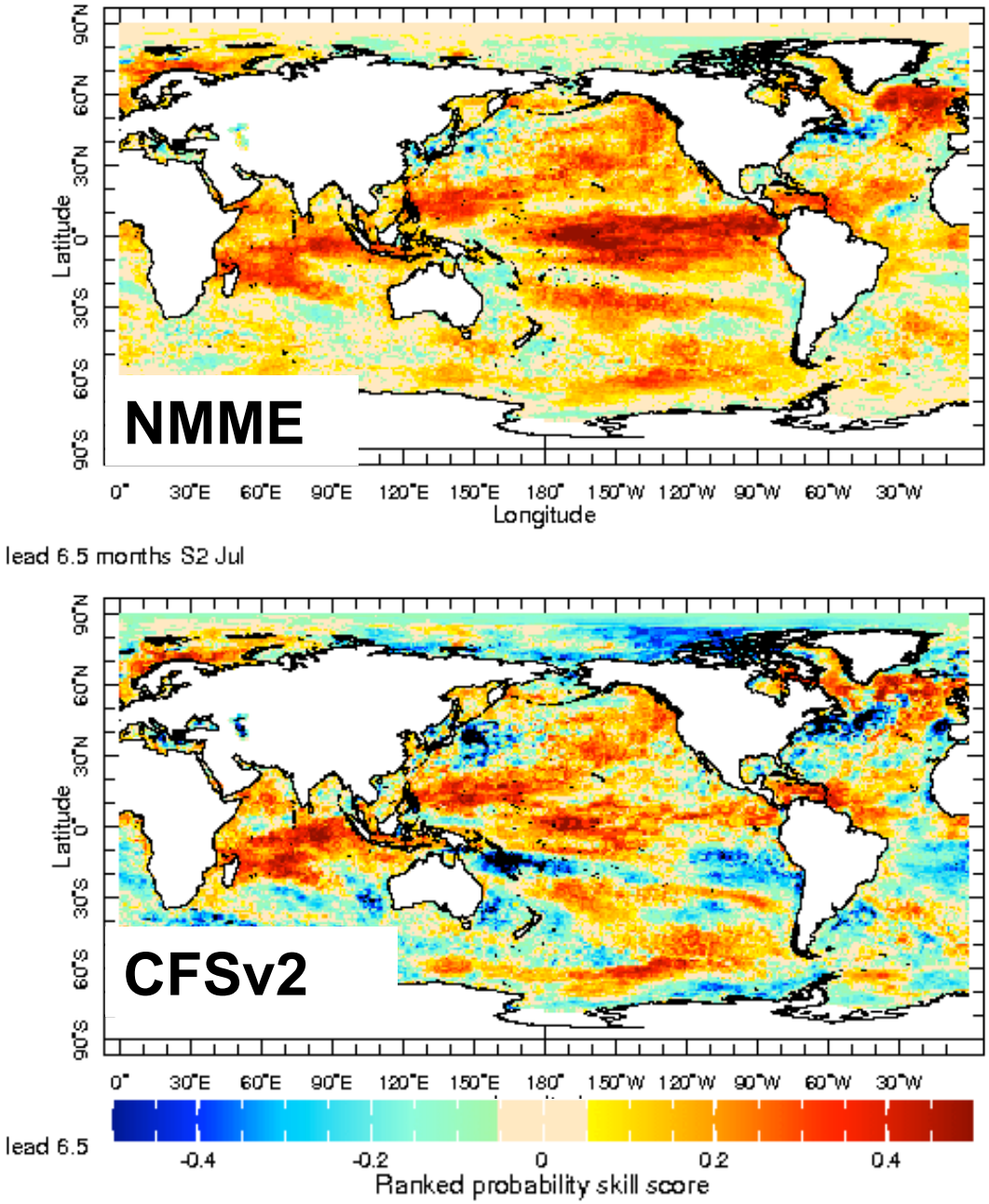


B Kirtman, NMME Team

CCSM3(4)+IRIa(4)+IRId(4)+CM2.1(4)+GEOS5(4)+CFSv1(4) vs. CFSv2(24)

Comparison of CFSv2 skill vs NMME

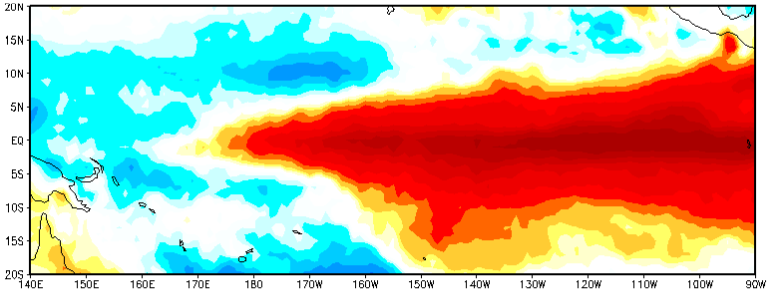
July 1 start
DJF SST forecast
Ranked Probability Skill Score



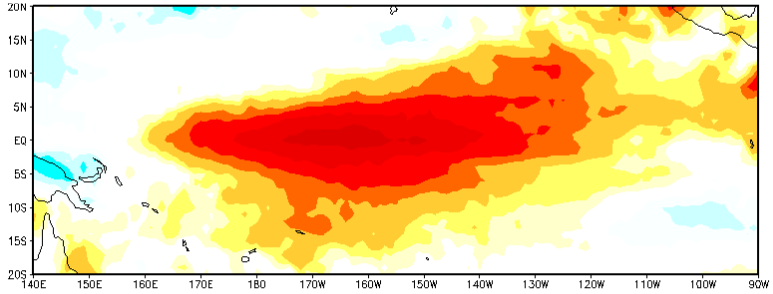
B Kirtman, NMME Team

NMME ENSO Prediction (EP and CP) (after B.Kirtman)

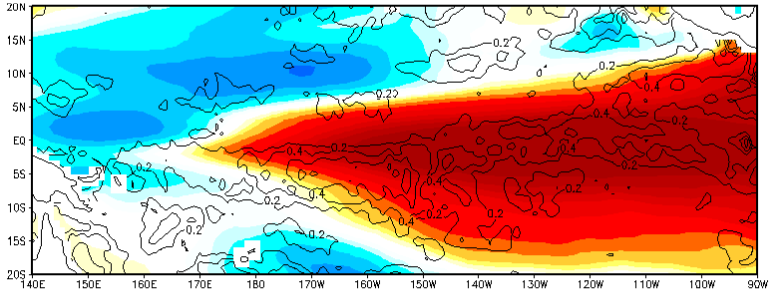
Observed JFM EP Composite



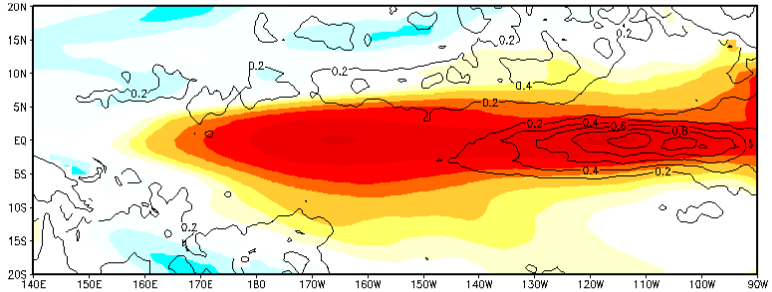
Observed JFM CP Composite



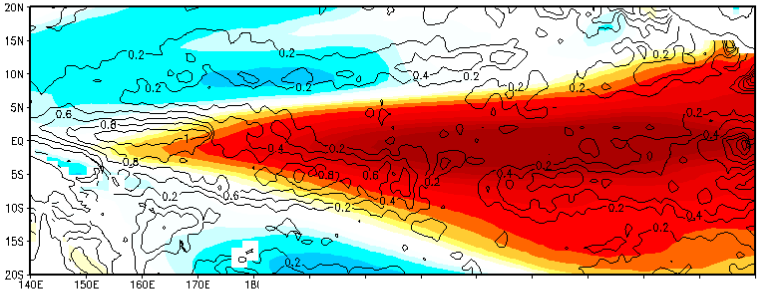
NMME JFM EP Composite SL (Shading) RMSE (Contours)



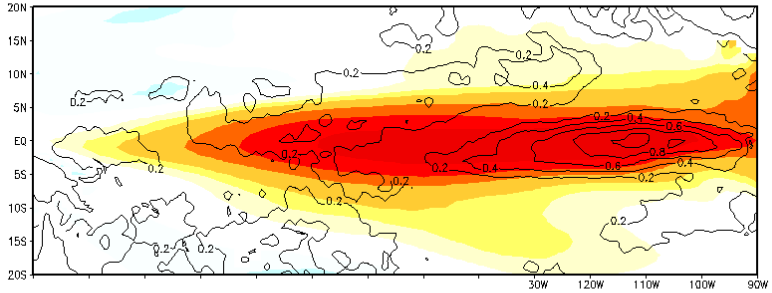
NMME JFM CP Composite SL (Shading) RMSE (Contours)

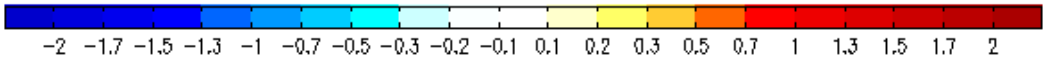


NMME JFM EP Composite LL (Shading) RMSE (Contours)

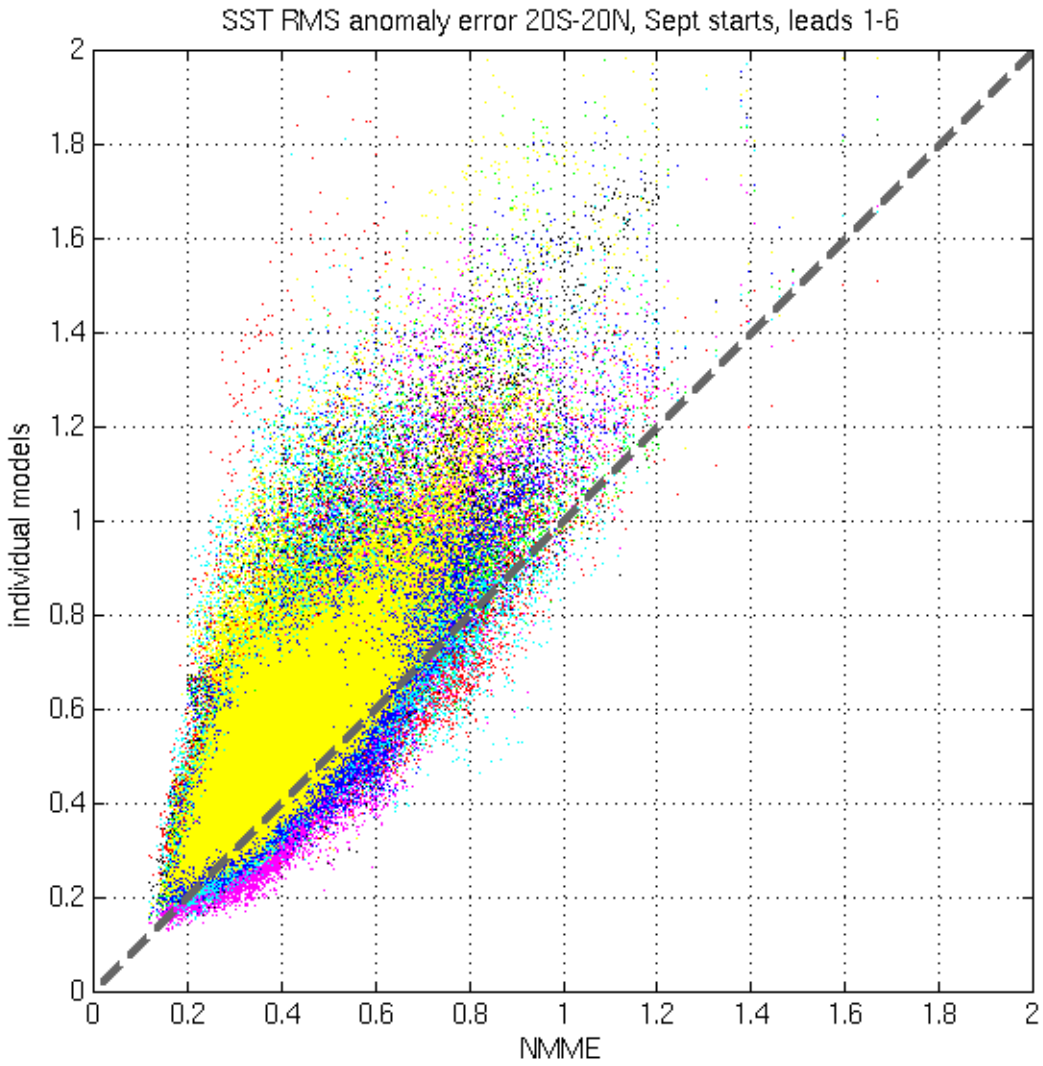


NMME JFM CP Composite LL (Shading) RMSE (Contours)





Comparison of NMME RMSE with Individual Models



SST RMS anomaly error 20S-20N, September starts, leads 1-6.

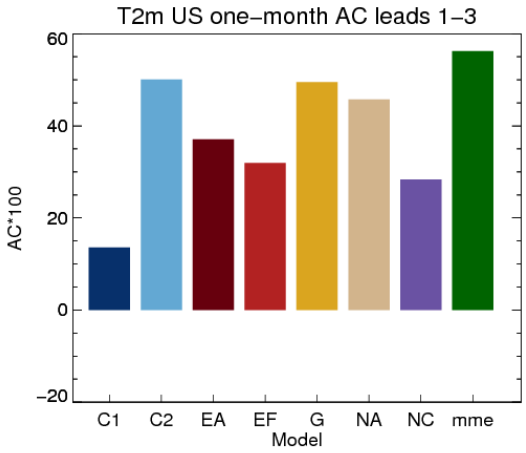
Individual colors correspond to individual models.

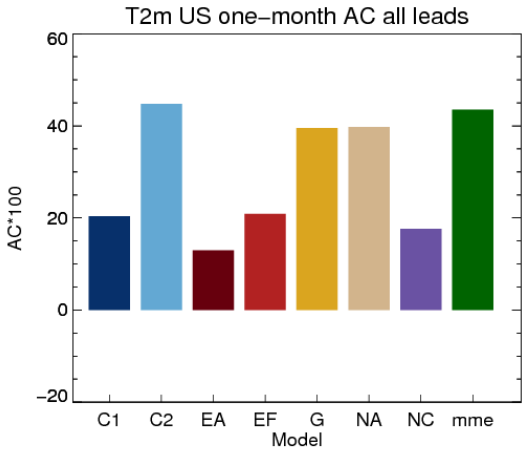
Dots above the diagonal imply NMME has smaller RMSE.

Real-time Verification

Year 1 One-month T2m by lead*

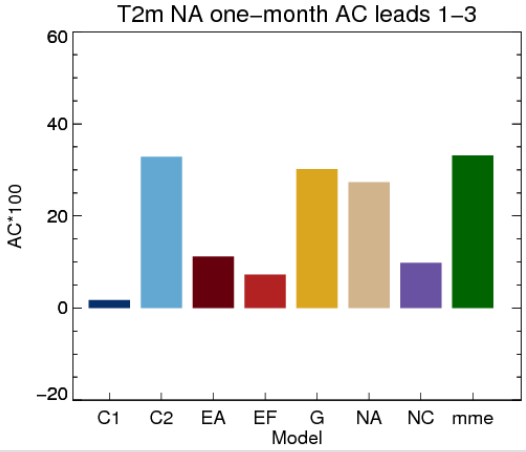
CONUS

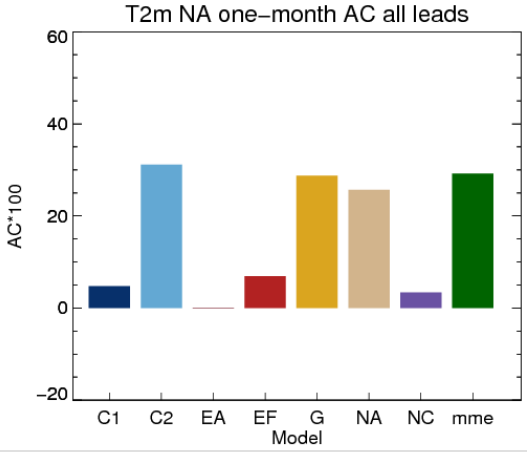




C1: NCEP CFSv1
C2: NCEP CFSv2
EA: IRI/ECHAM4-A
EF: IRI/ECHAM4-F
G: GFDL/CM2.0
NA: NASA/GEOS5
NC: NCAR/CCSM3.0
MME: NMME

North America





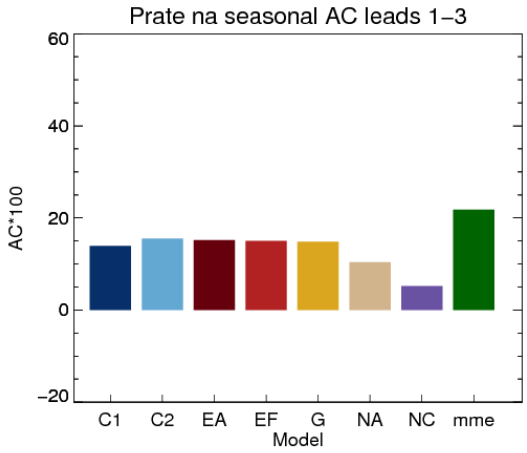
* Calculated for August 2011 – July 2012 initial conditions

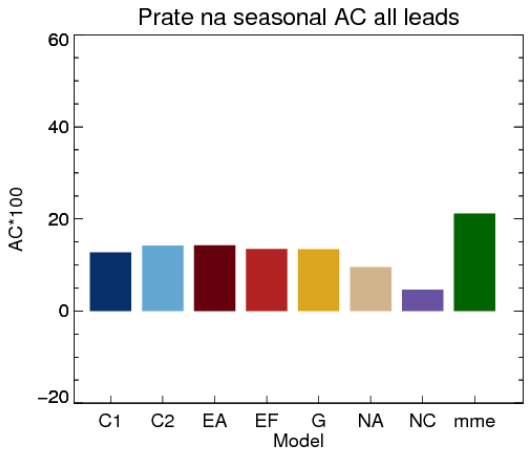
NMME Team

2011 was quite predictable (La Nina conditions). NMME showed consistently the best skill compared to individual systems

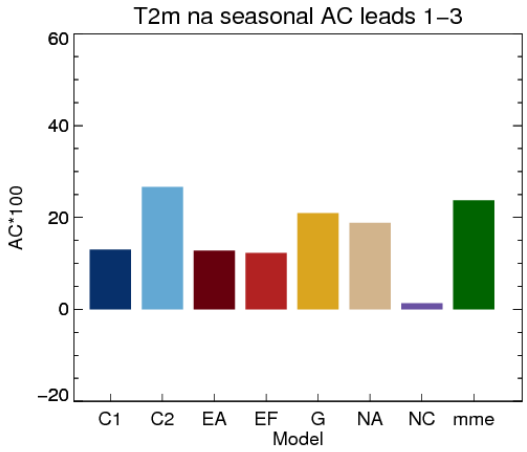
NMME Hindcast Verification (1982-2010): North America Seasonal Forecasts

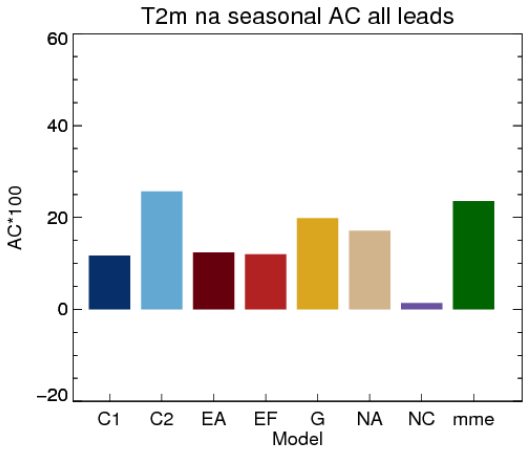
PRATE





Tmp2m





C1: NCEP CFSv1
C2: NCEP CFSv2
EA: IRI/ECHAM4-A
EF: IRI/ECHAM4-F
G: GFDL/CM2.0
NA: NASA/GEOS5
NC: NCAR/CCSM3.0
MME: NMME

2012 MJJ P and T NMME Forecasts

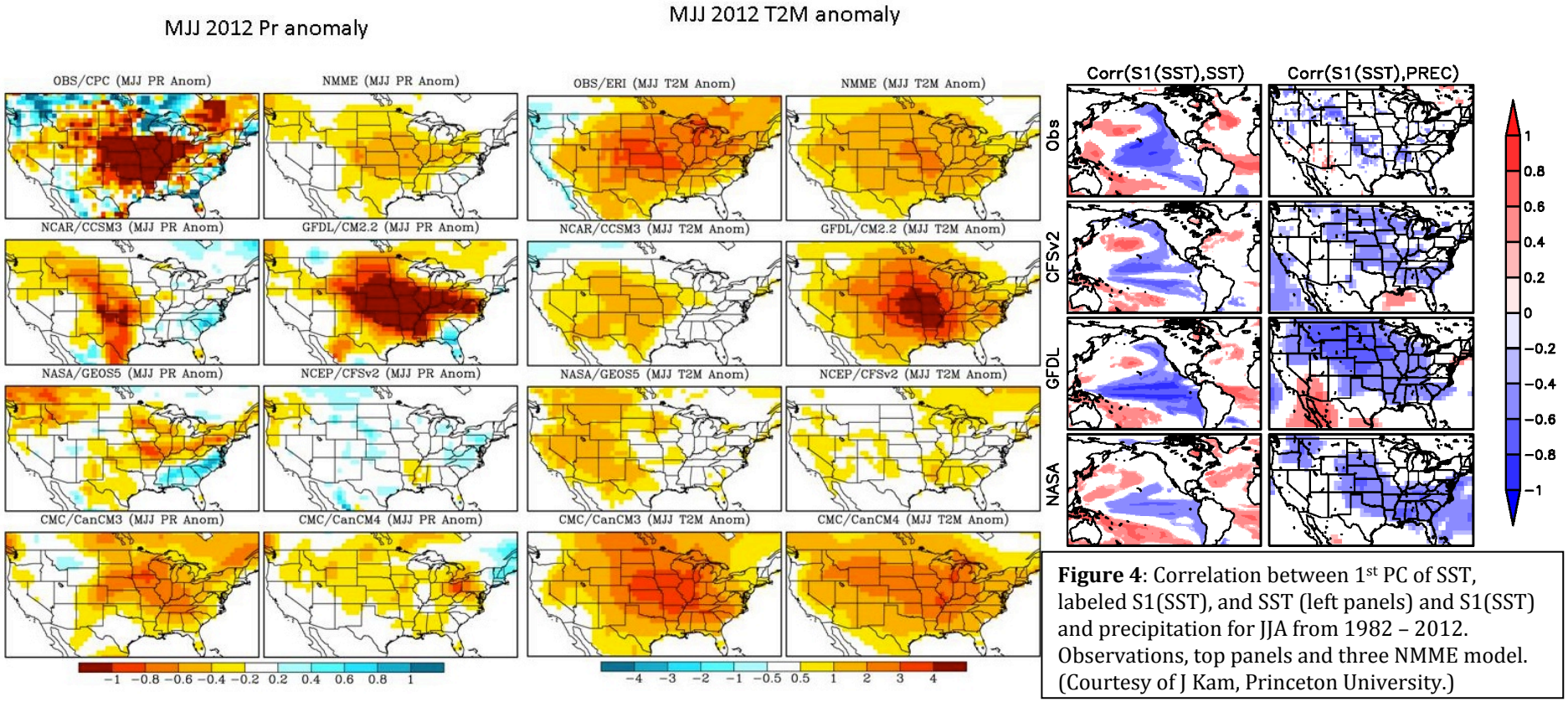


Figure 4: Correlation between 1st PC of SST, labeled S1(SST), and SST (left panels) and S1(SST) and precipitation for JJA from 1982 – 2012. Observations, top panels and three NMME model. (Courtesy of J Kam, Princeton University.)

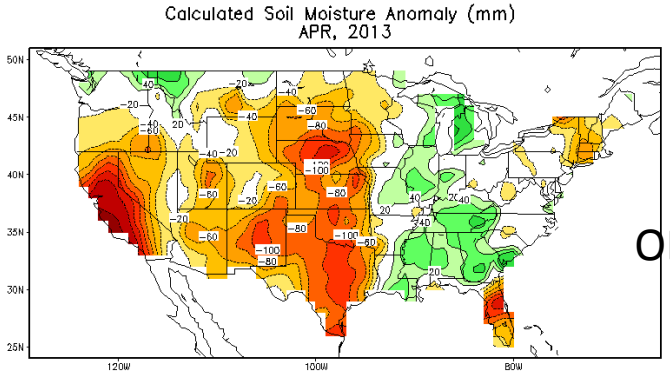
E. Wood, NMME Team

The model-predicted precipitation variability is too highly coupled to SST variability, or that they are underestimating atmospheric noise that would also reduce the teleconnection strength

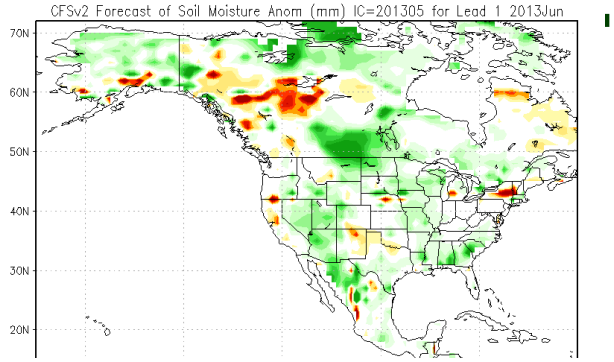
NMME real-time forecast effort is integral to the model development, prediction protocol, and predictability

Recent examples:

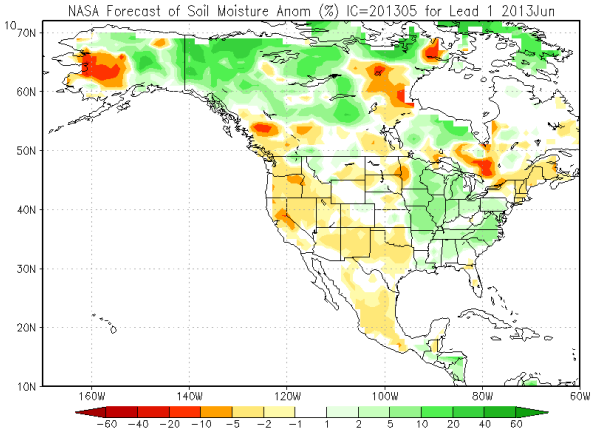
- land surface initial conditions are developed?
- How is the evolving external forcing (e.g., anthropogenic greenhouse gases and aerosols) prescribed and how this forcing impacts bias correction and skill assessments?



OBS mm

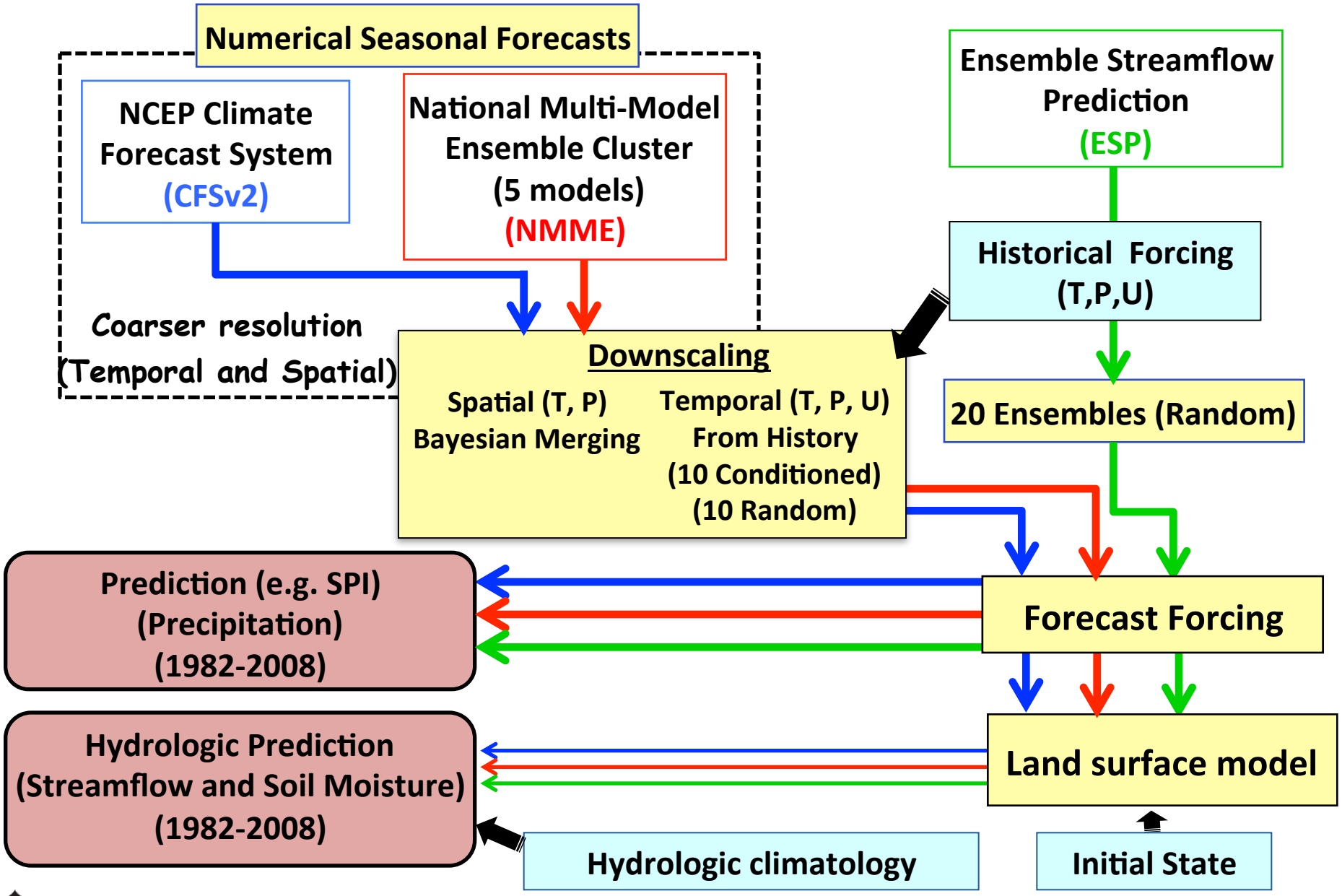


CFSv2: mm



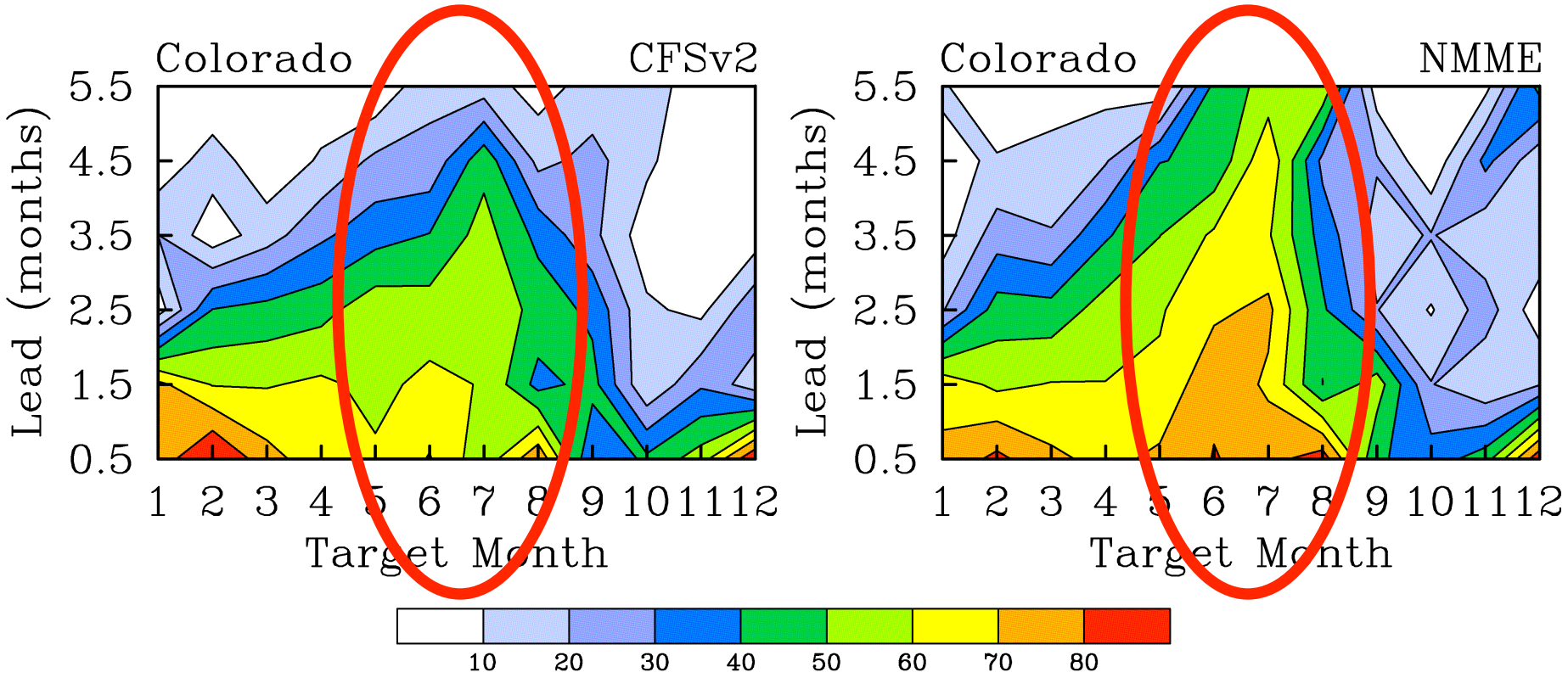
GEOS5: %

Princeton University's Hydrologic Forecast Methodology



PRINCETON UNIVERSITY

R^2 (%) of ensemble mean forecasts of drought area (Drought Index <30%)



NMME adds value for drought forecasting during summer time. Essentially it shows that the NMME has higher correlation R2 with observed drought compared to CFSv2

Leveraging Coupled Climate Model Projections for SERVIR Applications Science

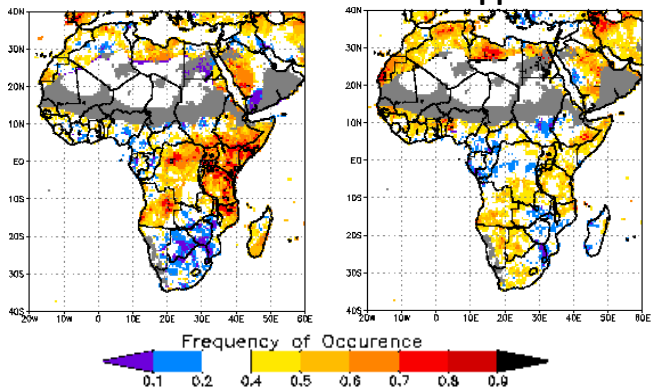
Pete Robertson, PI,; Brent Roberts, Co-I, NASA/MSFC;
Chris Funk, Co-I, USGS/UCSB; Brad Lyon, Co-I, Columbia U. /IRI;
Mike Bosilovich, Co-I, NASA/GSFC/GMAO; Siegfried Schubert, Collaborator, NASA/GSFC/GMAO

Via support from the NASA Applied Sciences Program this investigation begun in FY13 supports the NASA / USAID SERVIR Applied Science Team (SERVIR→ Spanish: "To Serve"). Potential linkages to NMME include:

- *Critically assess and employ US NMME climate model projections of seasonal / interannual hydrometeorological climate variability affecting SERVIR Hub regions (East Africa, Southern Asia, Mesoamerica).*
- *Develop and refine scenarios through downscaling and stochastic modeling to enable Applications Science Team Investigators to drive decision support system models of hydrologic processes, crop production, water availability on seasonal time horizons.*

OND Precipitation Frequency

La Nina lower-tercile **El Nino upper-tercile**



How well can nonlinearities in El Nino / La Nina teleconnections, additional Indian Ocean forcing, and MJO / intraseasonal variability phase be handled in NMME projections.

NMME Linkage/Contributions to ESPC

- **ESPC Purpose** – Develop and Deploy a ***National Earth System Prediction Capability***
  - Addresses short, medium, and extended or long range prediction needs (0 to 30 Years) (lately re-scoped to **0 – several years**)
- **ESPC Partners**:
  - NOAA, Navy, AF, NASA, DOE, NSF
  - Built from existing and planned capabilities through partnerships and cooperation

- **NMME potentially provides prediction capability on time scales of week 2 to 9 months.**
  - Need to sustain the experimental NMME system beyond FY14
  - Need to enhance its current system to meet the stakeholder and user requirements, such as, predicting hurricane and extremes; intra-seasonal time scales, forecasts in Arctic region

Summary

- NMME is a MAPP-CTB research project until July 2014
- NMME has provided an advanced prediction tool that although experimental has been used in NCEP operations
- NMME is openly distributing real-time forecasts enabling community-wide climate prediction and predictability research benefiting NOAA
- NMME provides a real-time prediction platform for model diagnosis and evaluation in an operational setting
- NMME is leveraging investments in model development and expertise across the U.S.
- The NMME long-term strategy is under development to
    - operationalize NMME, and
    - enhance the NMME forecast capabilities to meet stakeholder/user requirements

NOAA's 38th Climate Diagnostics and Prediction Workshop

21-25 October 2013

NOAA Center for Weather and Climate Prediction (NCWCP)

College Park, MD

Objective: to accelerate improvements in NOAA operational products and datasets, and delivery of climate information on intra-seasonal to interannual (ISI) time scales

Themes:

- Explore **Potential predictability**;
- Improve **prediction skill**
- Enhance monitoring and timely **attribution and assessment**
- Improve **forecast evaluation** process
- Develop **applications and products**
- NMME special session
- MAPP Prediction TF meeting

Workshop Web Site:
http://www.cpc.ncep.noaa.gov/products/outreach/CDPW38.shtml

Abstracts submission due date: July 15