The North American Multi-Model Ensemble: An Introduction

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Introduction and Background

- What is the North American Multi-Model Ensemble (NMME)?
  - A collaborative experimental multi-model forecasting system with coupled climate models from North American Forecasting centers
- Delivers real-time intra-seasonal to inter-annual predictions on NOAA Climate Prediction Center (CPC) operational schedule
  - Currently used as guidance for Operational CPC Forecasts
- Why Multi-Model?
  - On average, better prediction quality than a single model forecast
  - Statistically reliable probabilistic forecast
- NMME is scheduled to continue through July 2018, and operational on July 1st 2015

DATA ACCESS AND ADDITIONAL INFORMATION

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

NMME: Phase-1 (2011)

Model	Hindcast Period	Ensemble Members	Lead (Month)
NCEP/CFSv2	1982-2010	24	0-9
GFDL/CM2.1	1982-2010	10	0-11
GFDL/CM2.5 (FLOR)	1982-Present	24	0-11
CMC1-CanCM3	1981-2010	10	0-11
CMC1-CanCM4	1981-2010	10	0-11
NCAR/CCSM3	1982-2010	6	0-11
NCAR/CCSM4	1982-2010	10	0-11
NCAR/CESM1	1982-2010	10	0-11
NASA/GEOS5	1981-2010	11	0-9
IRI-ECHAM4f	1982-2010	12	0-7
IRI-ECHAM4a	1982-2010	12	0-7
SUM OF ENSEMBLE MEMBERS		139	

- **Experimental Real-Time and Hindcast prediction**
  - Lead time up to 9 months required
  - Model configuration (ensemble generation strategy, resolution, version, parameterization, initialization of forecasts/hindcasts, etc.) are open to forecast provider
  - Monthly means of global grids of **SST, 2-meter temperature, and precipitation rate** are provided for both hindcasts and real-time forecasts

BAMS: Kirtman et al. 2014

NMME: Phase-2 (2012-)

- **Models Included:** NCEP/CFSv2; NASA GEOS5; NCAR/CCSM4; NCAR/CESM; GFDL/CM2.1; GFDL/CM2.5; Can-CM3, Can-CM4

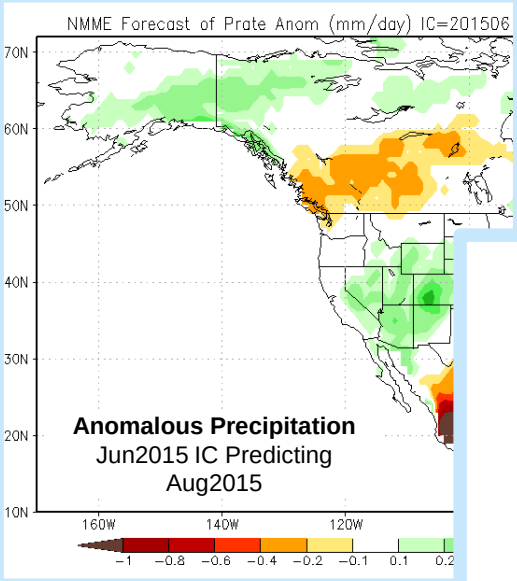
Real-Time Monthly Fields (8)							
200 mb Geopotential Height	Total Precipitation*	Total Soil Moisture	Surface Temperature	Surface Runoff	Daily Min 2-Meter Temp	Daily Max 2-Meter Temp	Daily Mean 2-Meter Temp

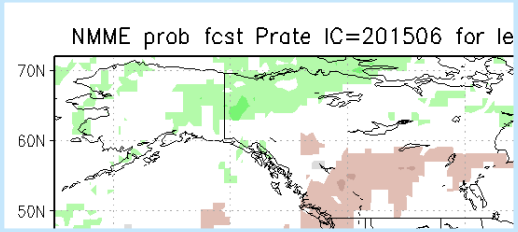
Daily Atmospheric and Land Surface Fields (23)							
Mean Sea Level Pressure	Snow Water Equivalent	Total Soil Moisture	Total Precipitation*	Total Cloud Cover	Daily Min 2-Meter Temp	Daily Max 2-Meter Temp	Daily Mean 2-Meter Temp
Downward Surface Solar Radiation	Downward Surface Longwave Radiation	Net Surface Solar Radiation	Net Surface Longwave Radiation	Downward Top Solar Radiation	Downward Top Longwave Radiaiton	Net Top Solar Radiation	Net Top Longwave Radiation
Surface Latent Heat Flux	Surface Sensible Heat Flux	Surface Stress (x and y)	10m Wind (u and v)	Surface Specific Humidity		*Convective/Large-Scale Precip Provided by some Forecast Centers	

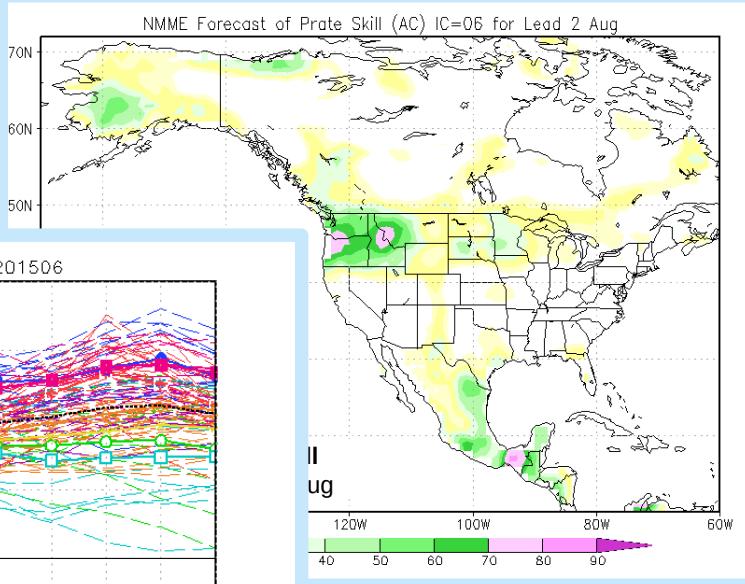
Daily Atmospheric Pressure Level Fields (5)						Monthly Sea Ice Fields (2)	
Geopotential Height	Air Temperature	Zonal Velocity	Meridional Velocity	Specific Humidity		Sea Ice Concentration	Sea Ice Thickness

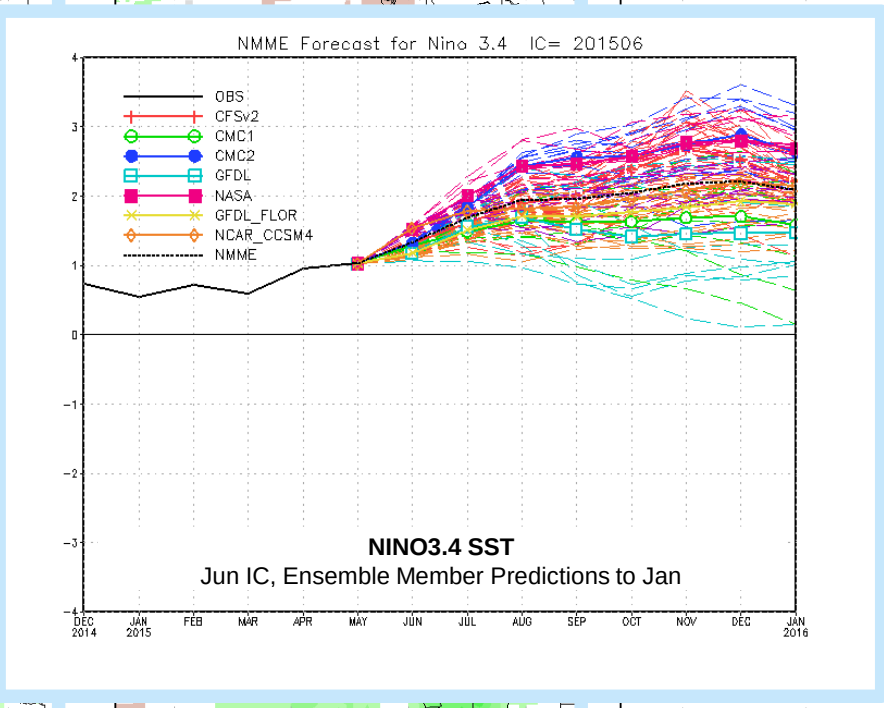
Monthly Ocean Fields (7)							
Potential Temperature	Salinity	Zonal Velocity	Mericidonal Velocity	Sea Level	Mixed Layer Depth	Vertical Velocity	

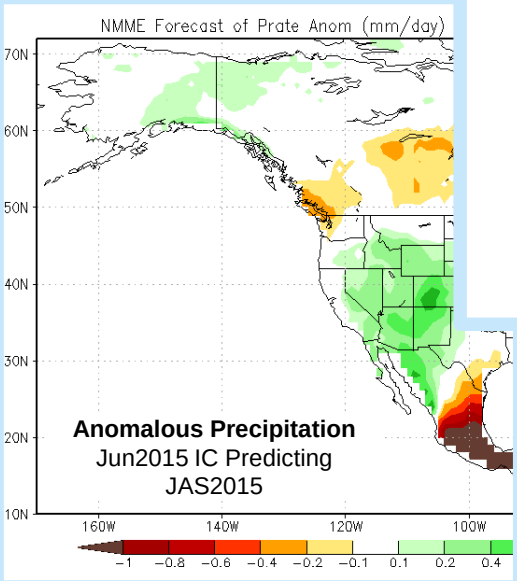
Example NMME Forecasts

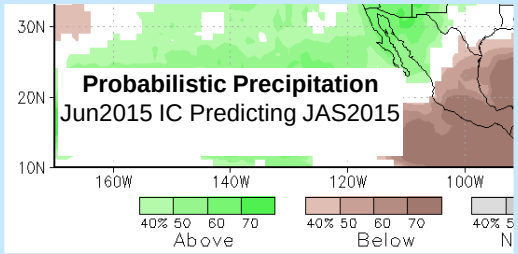


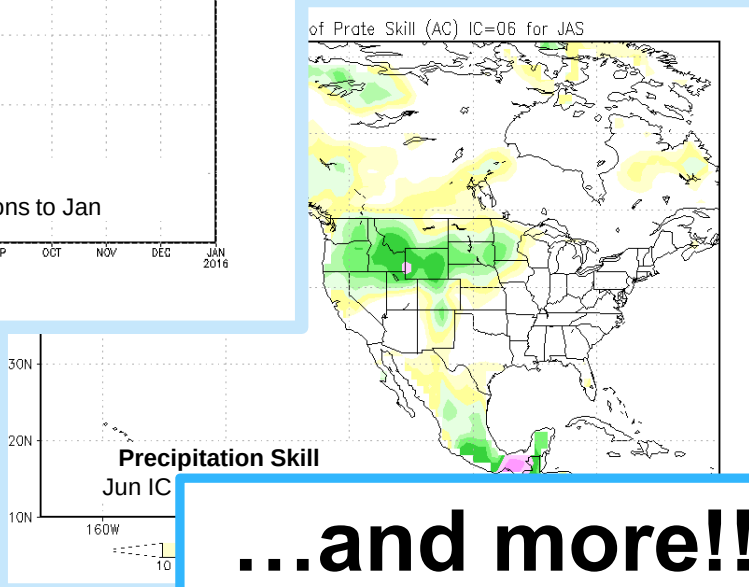












...and more!!

Data Access and Availability

- **Phase 1 Hindcasts:**
  - Hosted through the International Research Institute Data Library http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/
- **Phase 2 Hindcasts:**
  - Hosted through Earth System Grid https://www.earthsystemgrid.org/search.html?Project=NMME
- **Realtime Forecast Anomalies (FTP):**
  - ftp://ftp.cpc.ncep.noaa.gov/NMME/realtime_anom/
- **Users Guide:**
  - http://www.cpc.ncep.noaa.gov/products/NMME/users_guide.html
- **NMME Input available as boundary conditions for regional modeling/etc:**
  - Contact forecasting center (such as University of Miami)

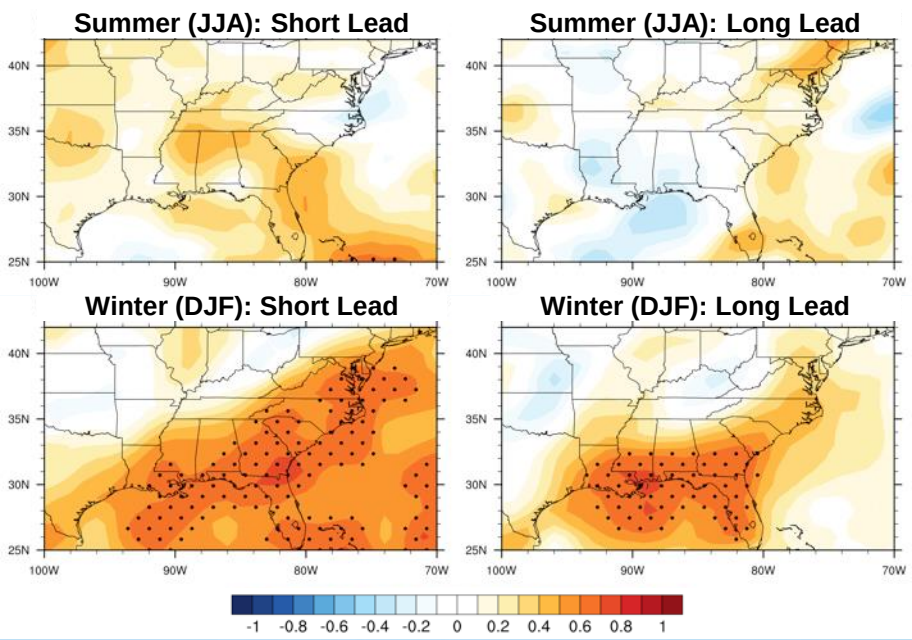
Community Climate System Model version 4.0 Hindcasts and Forecasts

- **Community Climate System Model:** Coupled climate model consisting of atmosphere, ocean, land surface, and sea ice components
- Real-time and hindcast data available as part of NMME Phase-2
- Partnership between **University of Miami (RSMAS)**, **George Mason University Center for Ocean Land Atmosphere Research (COLA)**, and the **National Center for Atmospheric Research (NCAR)**
  - Model provided by NCAR
  - Initial Data created at COLA
  - Hindcasts and forecasts run at RSMAS

Seasonal CCSM4 Skill in the Southeastern US

- **Anomaly Correlation:** Measurement of the quality of a forecast system by correlating forecasts and observations. An anomaly correlation of 0.6 is typically considered "skillful" for large scale patterns
  (http://old.ecmwf.int/products/forecasts/guide/Measure_of_skill_the_anomaly_correlation_coefficient.html)

Precipitation

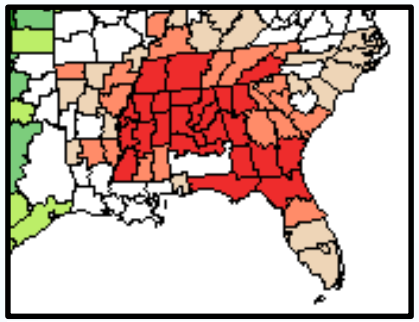


Seasonal Mean Predictions Initialized in June, Jan, Dec, Jul
1º latitude x 1º longitude grid

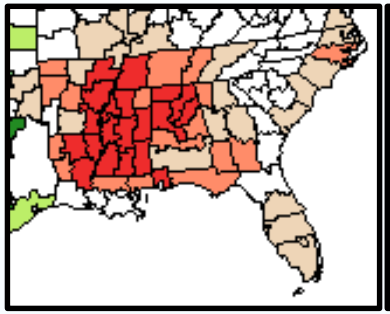
Case Study: Predicting Below Normal Rainfall in 2007 using CCSM4 Hindcasts

OBSERVED

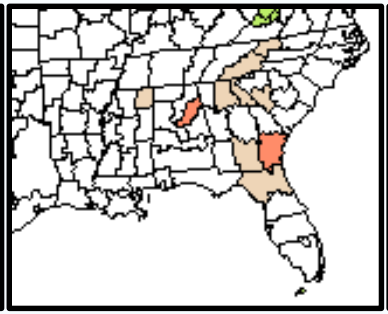
SPI Through May07 (3-Month)



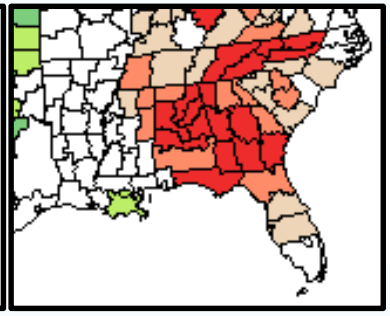
March 2007



Apr 2007

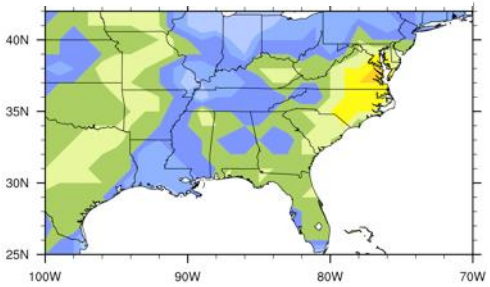


May 2007

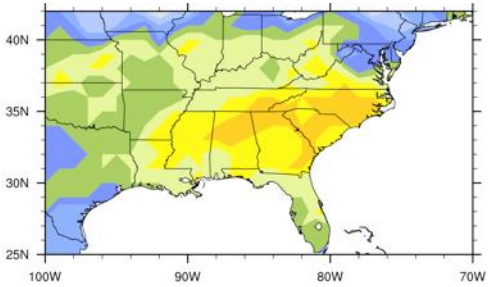


http://drought.unl.edu/MonitoringTools/ClimateDivisionSPI/ArchivedSPIMaps.aspx

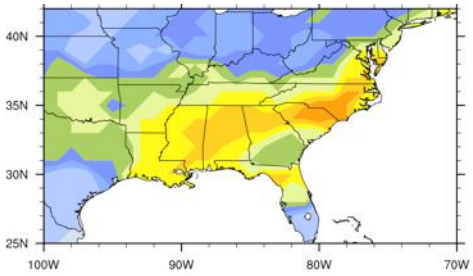
Feb07 Forecast for MAM07



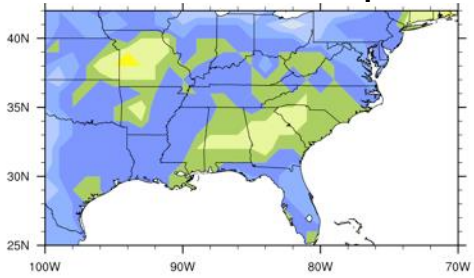
Mar07 Forecast for MAM07



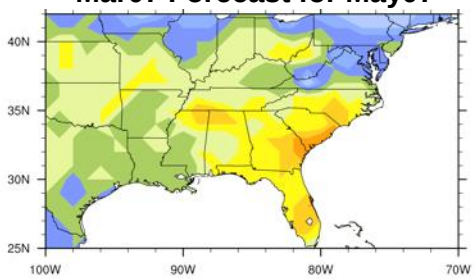
Mar07 Forecast for Mar07

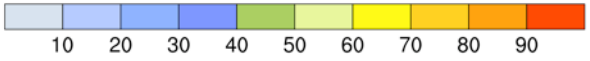


Mar07 Forecast for Apr07



Mar07 Forecast for May07

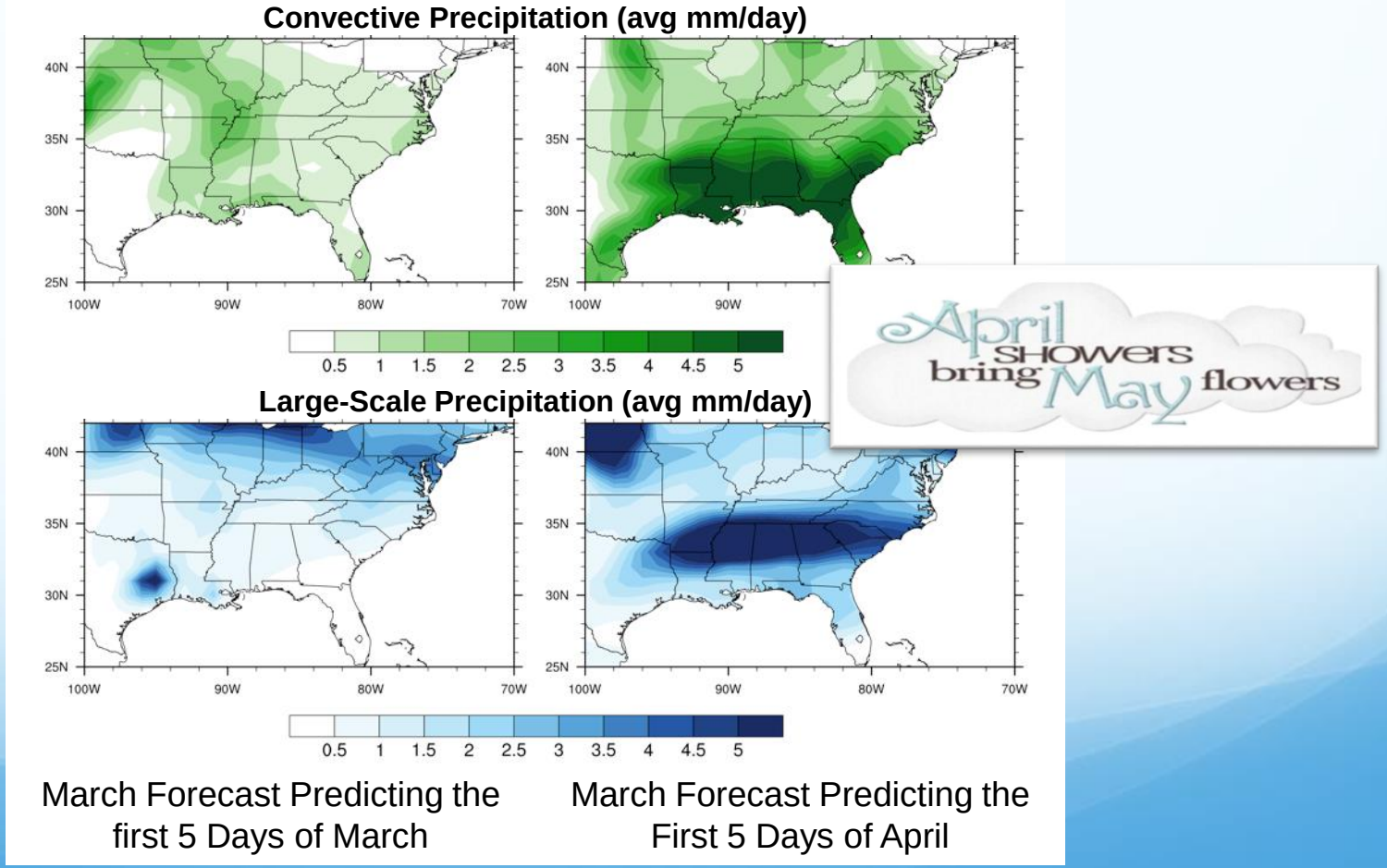




Percent of ensemble members (out of 10) that predict SPI below -0.5

Case Study: 2007
Daily Convective and Large Scale Precipitation Forecasts

- Convective Precipitation: Occurring due to evaporative processes from convective clouds (e.g. cumulonimbus). Short lived and limited in horizontal extent.
- Large-Scale (Synoptic) Precipitation: Occurs due to movement of large air-masses



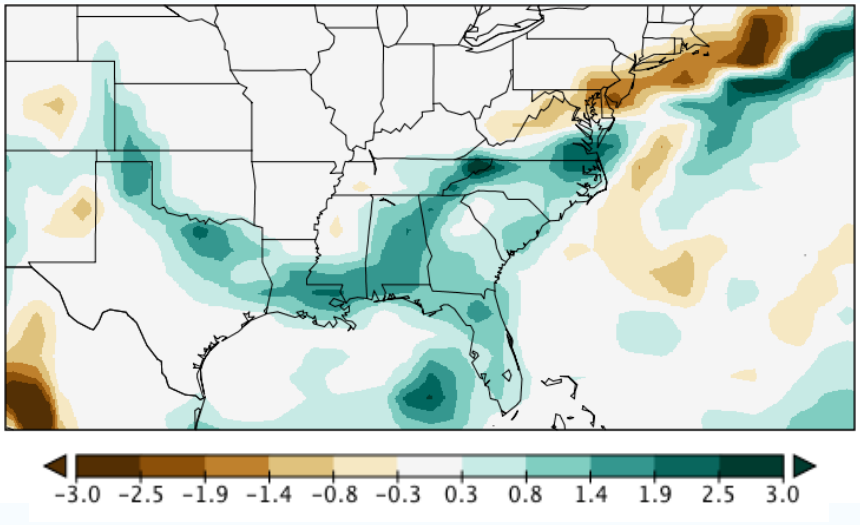
3-Hourly Precipitation, Winds, Temperature
August 1st Hindcast

15:00 to 18:00
(3pm to 6pm)

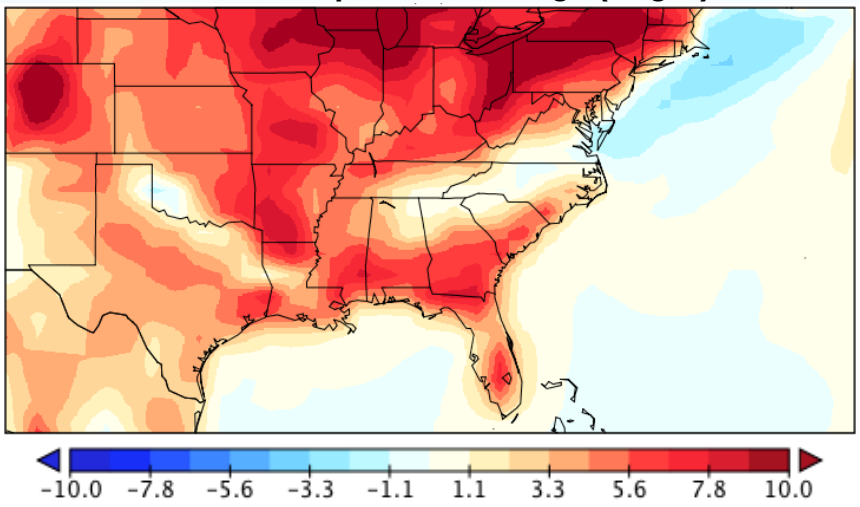
minus

00:00 to 03:00
(Midnight to 3am)

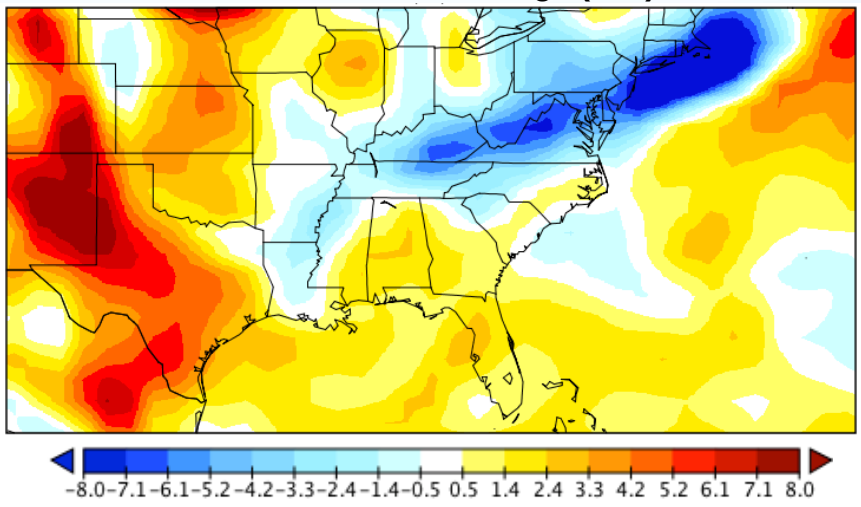
Convective Precipitation Change (Thunderstorms)
(scaled m/s)



2-Meter Temperature Change (Deg K)

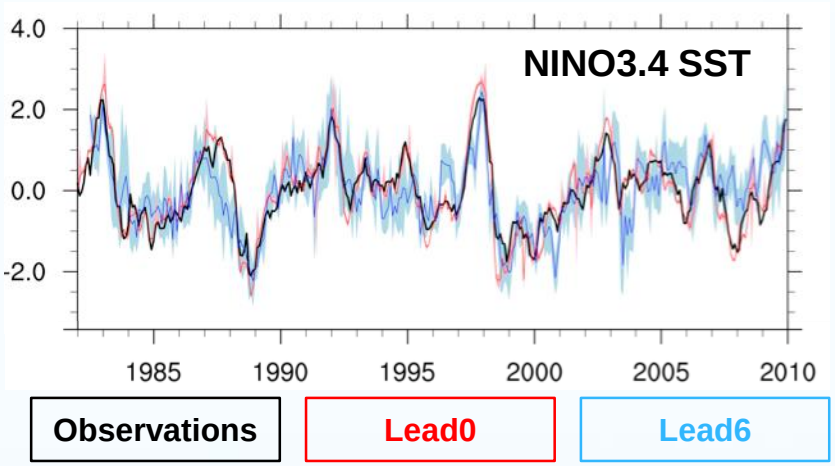


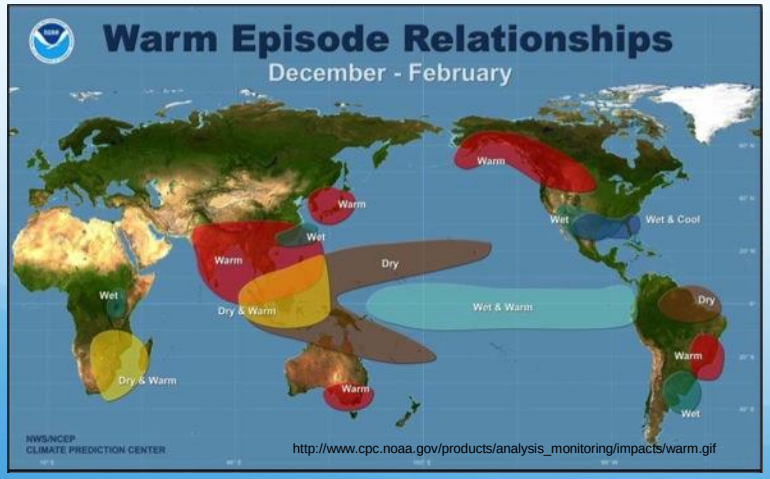
Surface U-Wind Change (m/s)

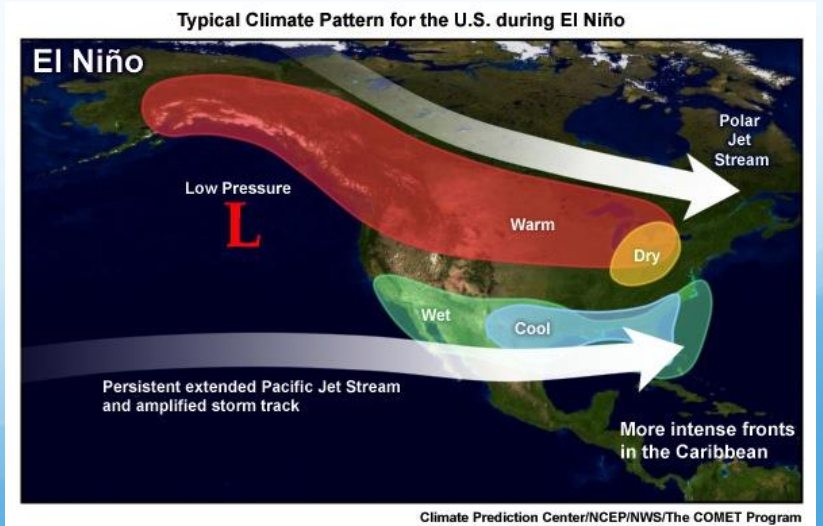


"Forecasts of Opportunity"

- Forecast skill for variables such as land-based precipitation, 2-meter temperature, etc. may be inflated during events such as El Niño
  - Particularly in Southeast US, which shows better model predictions of precipitation/T2m with increasing strength of El Niño events in short lead multi-model forecasts (Infanti and Kirtman 2015)



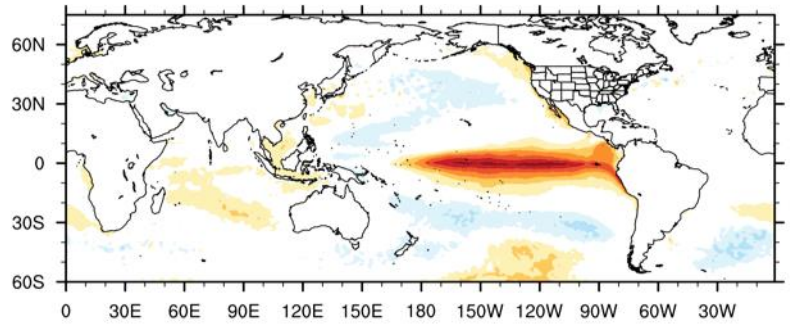




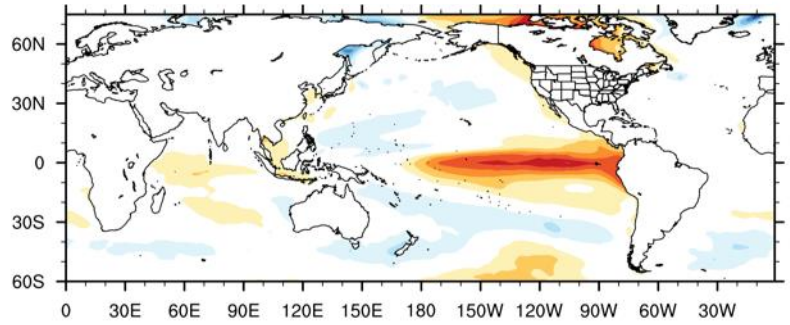
Forecasts during El Niño Years

Composite (average) of observations, short-lead, and long-lead predictions during winter (DJF) El Niño Years (1983, 1987, 1988, 1992, 1995, 1998, 2003, 2005, 2007)

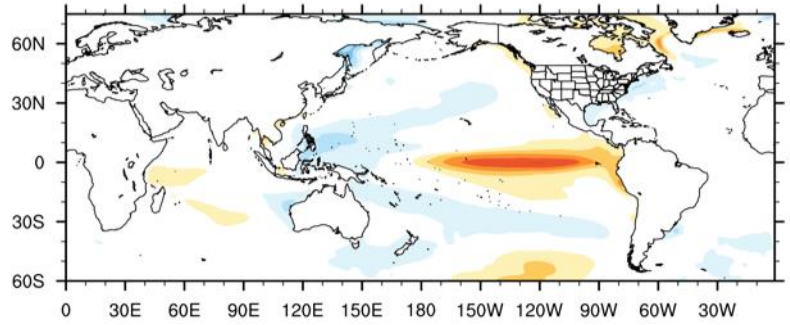
Observed El Niño SST

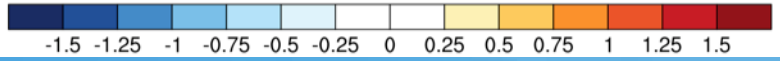


Short Lead Predicted El Niño SST

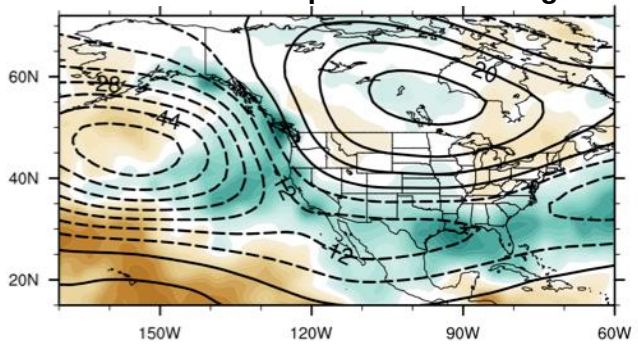


Long Lead Predicted El Niño SST

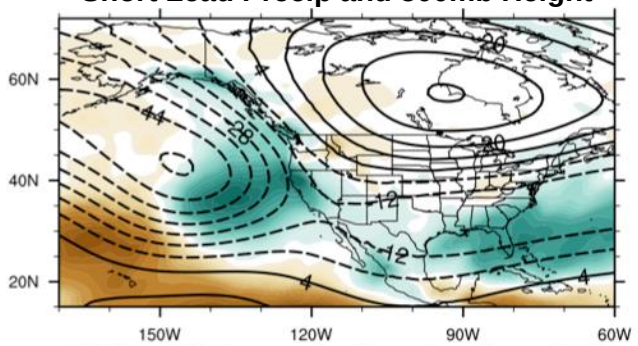




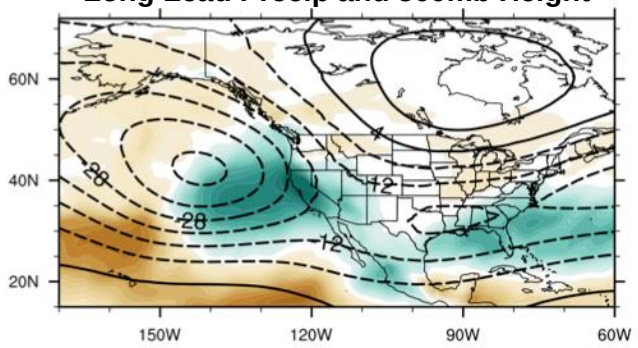
Observed Precip and 500mb Height

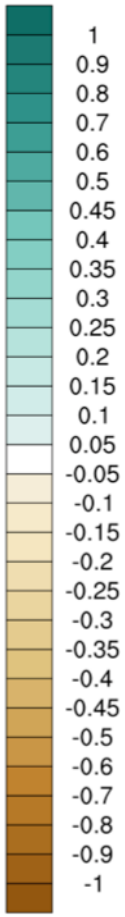


Short Lead Precip and 500mb Height



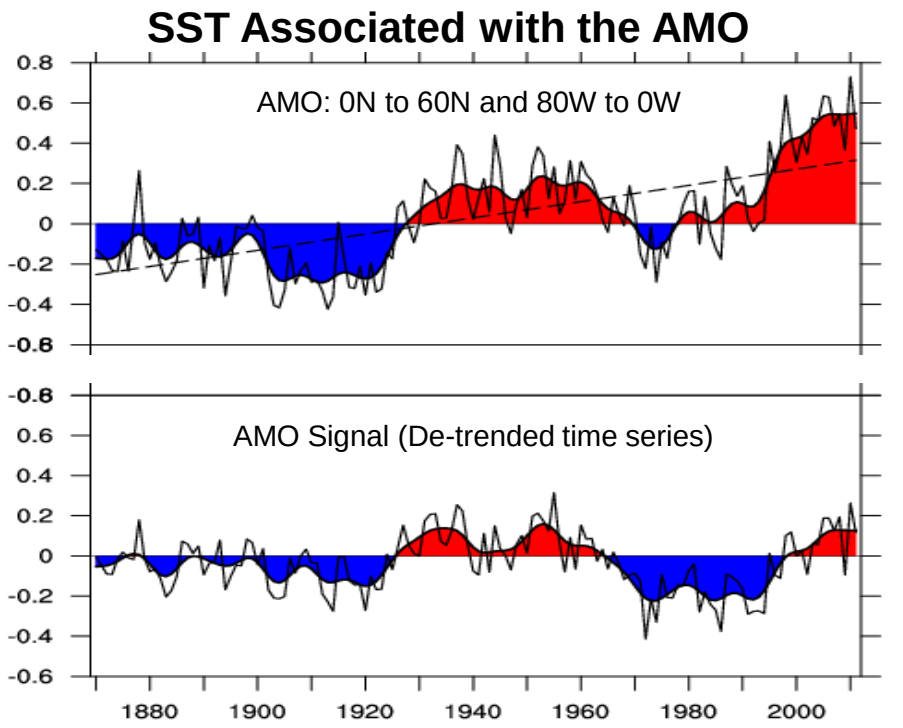
Long Lead Precip and 500mb Height



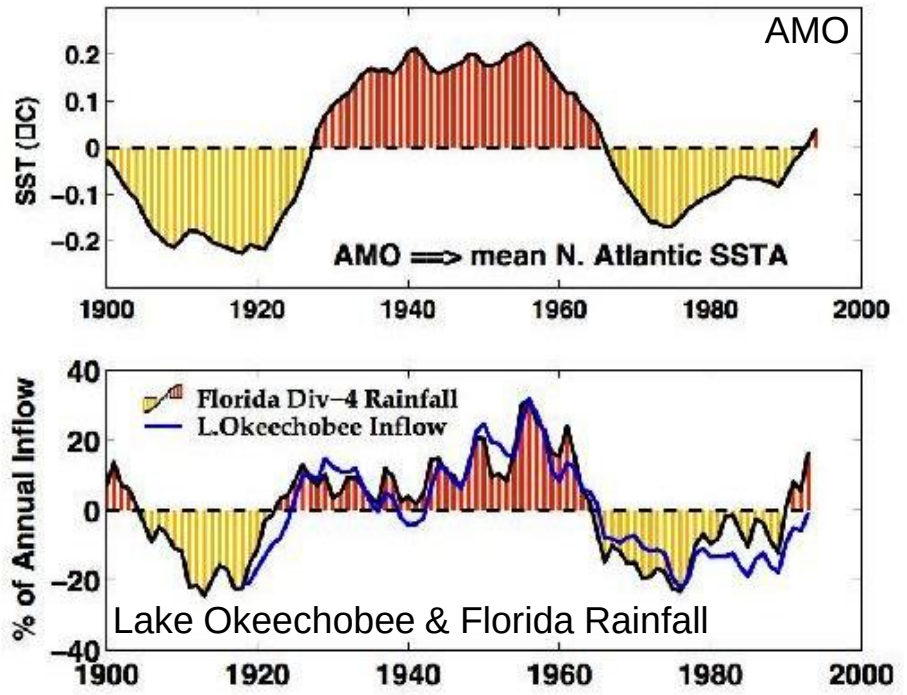


The Atlantic Multi-Decadal Oscillation (AMO)

- What is the Atlantic Multi-Decadal Oscillation (AMO)?
  - A mode of natural variability occurring in the North Atlantic Ocean, expressed in SST and is an ongoing series of long-duration changes
  - Basin-wide North Atlantic SST with a period of 60 to 80 years



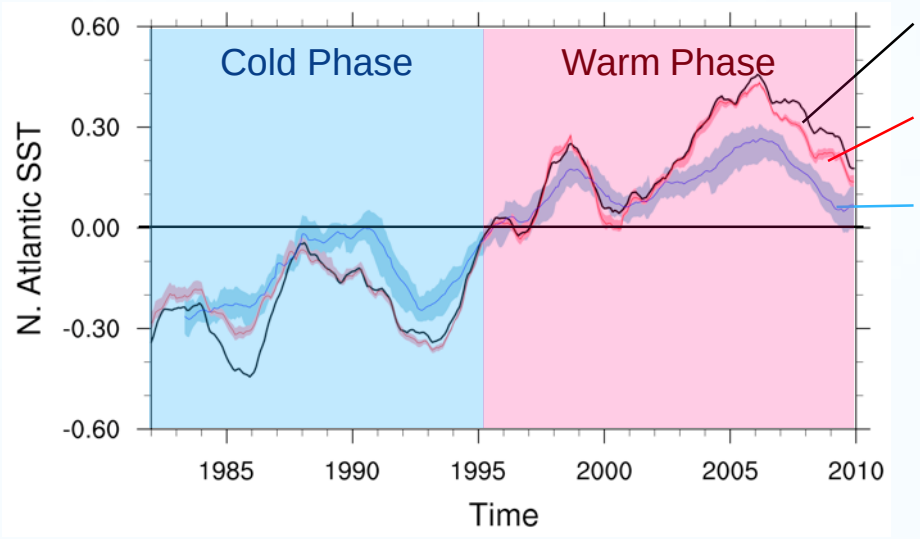
When the AMO is warm, drought is more frequent and prolonged (Midwest, Southwest). Florida and the Pacific Northwest are opposite.



In Central Florida, rainfall becomes more plentiful during warm AMO phases, with drought and wildfire in cold phase. Opposite in Northern Florida.

Information from: http://www.cgd.ucar.edu/cas/catalog/climind/AMO.html and http://www.aoml.noaa.gov/phod/amo_faq.php
Left Figure from: http://www.cgd.ucar.edu/cas/catalog/climind/AMO.html Right Figure from: http://www.aoml.noaa.gov/phod/amo_faq.php

Predicting AMO Phases in SST and Overall Impacts

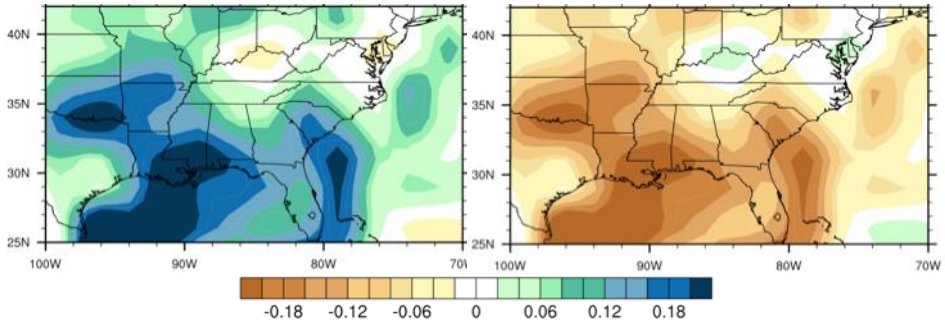


Observations

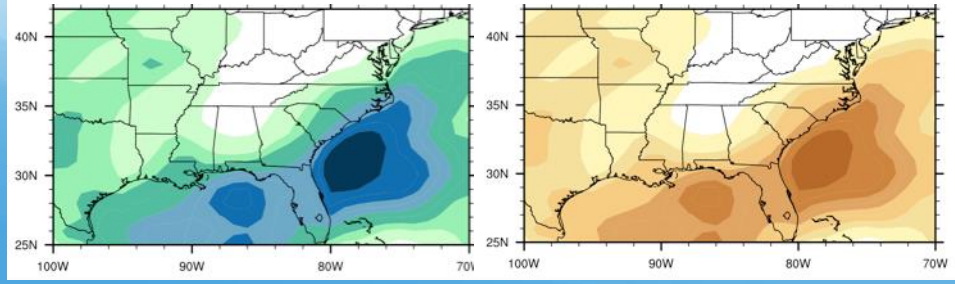
Lead0

Lead6

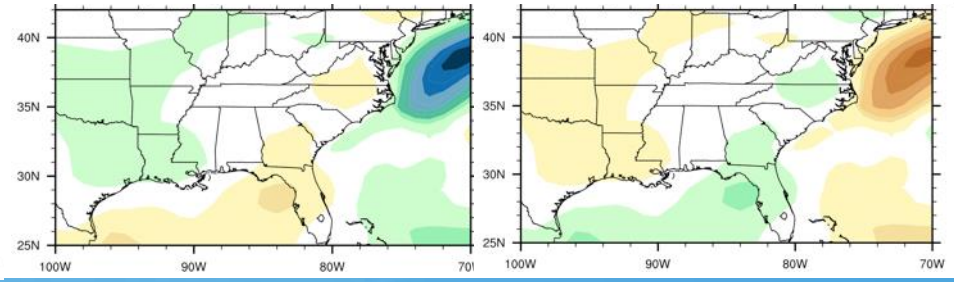
Observed Precipitation



Lead-0 Precipitation



Lead-6 Precipitation



Summary

- The North American Multi-Model Ensemble (NMME)
  - Intra-Seasonal to Inter-annual multi-model climate predictions
  - Data and more information available at http://www.cpc.ncep.noaa.gov/products/NMME/
- Community Climate System Model v. 4.0 Predictions
  - Part of the NMME
  - Partnership between University of Miami (RSMAS), COLA, and NCAR
  - Monthly, Daily, 3-Hourly prediction data available
  - Input data for boundary forcing of regional model(s) available

JOIN THE NMME MAILING LIST!

http://www.cpc.ncep.noaa.gov/nwscwi/forms/comment-form-NMME.html

Thank You!

Special Thanks and Acknowledgements:

The NMME Program Partners, International Research Institute Climate Data Library, Earth System Grid, NCAR Command Language (NCL)

References

Print:

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- Xie P, Arkin PA (1997) Global precipitation: A 17-year monthly analysis based on guage estimates, and numerical model outputs. Bulletin of the American Meteorological Society 78:2539–2558.

Web:

- http://www.cpc.ncep.noaa.gov/products/NMME/
- http://droughtmonitor.unl.edu
- http://old.ecmwf.int/products/forecasts/guide/Measure_of_skill_the_anomaly_correlation_coefficient.html
- http://drought.unl.edu/MonitoringTools/ClimateDivisionSPI/ArchivedSPIMaps.aspx
- http://www.cgd.ucar.edu/cas/catalog/climind/AMO.htm
- http://www.aoml.noaa.gov/phod/amo_faq.php
- http://www.cgd.ucar.edu/cas/catalog/climind/AMO.html
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