

MJO Forecasting Activities at NOAA's Climate Prediction Center

Monsoon Intraseasonal Variability Modeling Workshop
June 15-17, 2010
Busan, Korea

Jon Gottschalck

NOAA / National Centers for Environmental Prediction
Climate Prediction Center

Outline

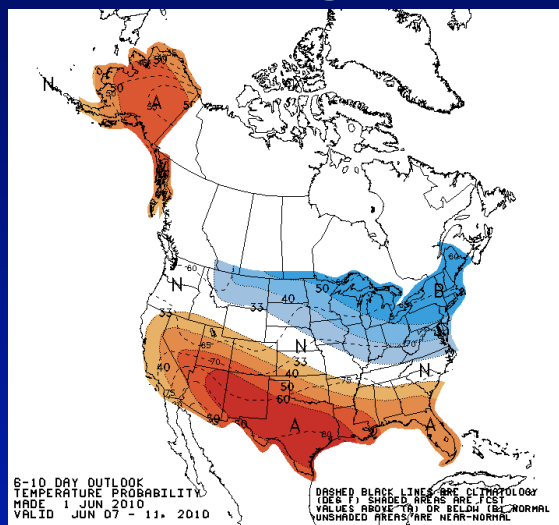
- Overview of CPC and the importance of the MJO
- MJO prediction activities at CPC
 - Statistical forecasts
 - Dynamical model forecasts and research
 - MJO Task Force forecast metric activity
- Operational applications
- CPC's role in DYNAMO

Overview of CPC Mission

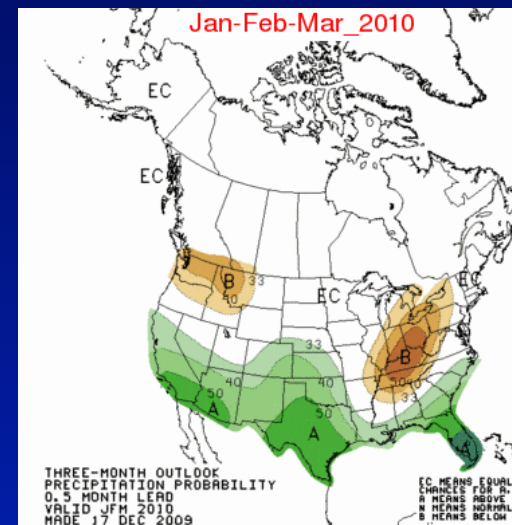
*We deliver climate **prediction, monitoring, and assessment** products for timescales from **weeks to years** to the **Nation and the global community** for the protection of life and property and the enhancement of the economy.*

- Produce U.S. national temperature and precipitation outlooks
- Focus on short term climate variability not climate change
- Monitoring of tropical climate modes (ENSO, MJO and monsoons)

Extended Range Forecast



Seasonal Outlook



Importance of the MJO

Why CPC monitors and predicts the MJO?

- Modulates the strength, timing and impacts of ENSO events both through both atmospheric and the oceanic processes
- Forecasts of opportunity for large scale mid-latitude circulation changes related to tropical convection to support Week 2-4 prediction
- Advanced lead time for extreme events to support U.S. and Global Tropics Hazard Assessments
 - ➔ Tropical cyclone activity
 - ➔ Heavy rainfall events
 - ➔ Cold air outbreaks
 - ➔ Wet/dry monsoon periods

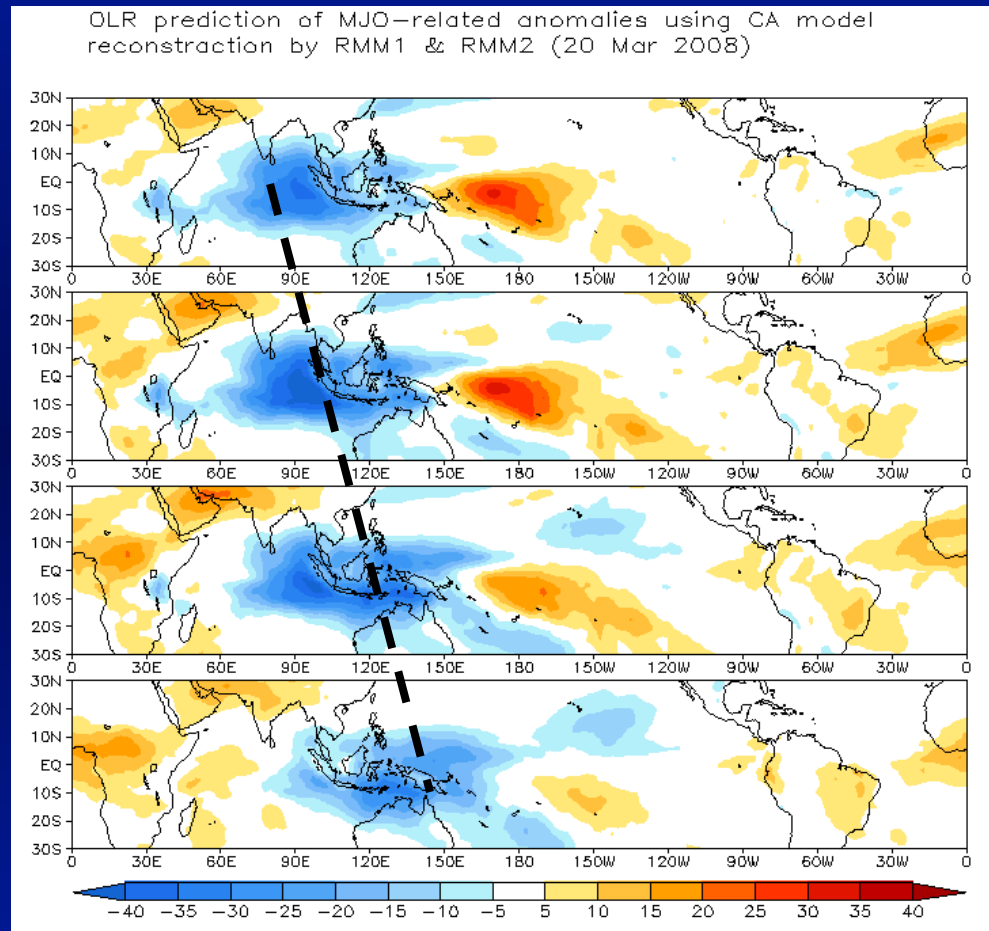
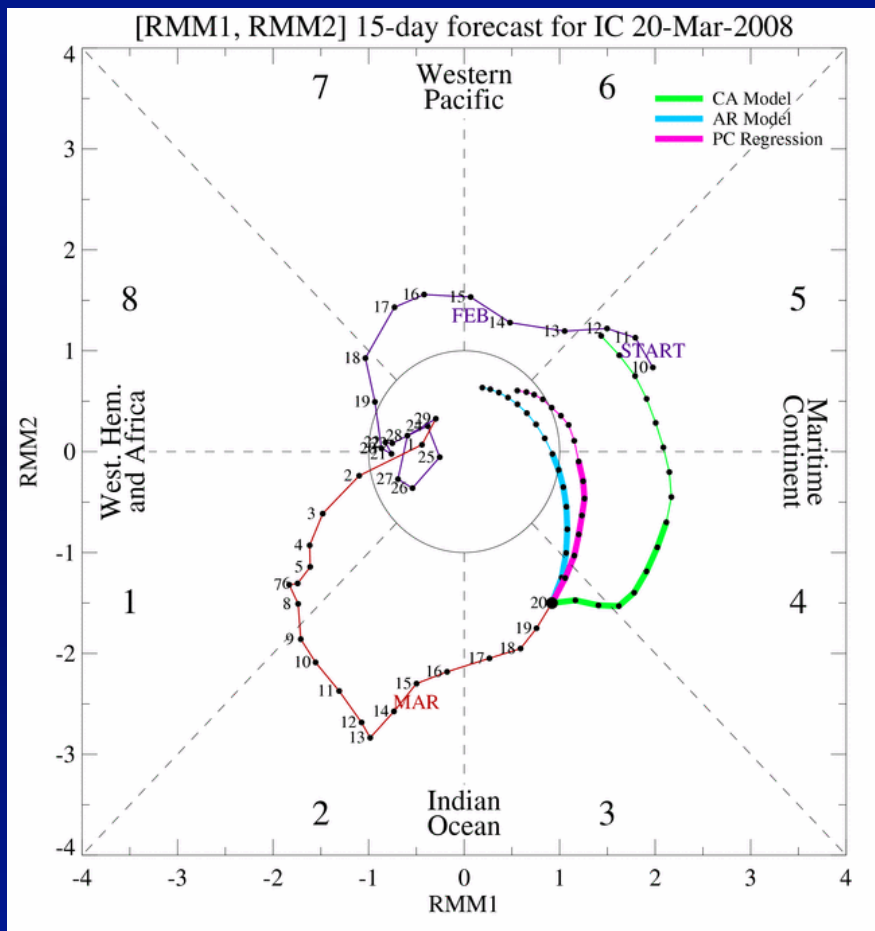
MJO Prediction Methods

- No substitute for detailed monitoring of the MJO through inspection of OLR, zonal wind, velocity potential, SST, etc.
- Statistical MJO forecasts
 - Regression
 - Empirical wave propagation
 - Constructed analogue
- Dynamical model MJO forecasts
 - Global Ensemble Forecast System (GEFS)
 - MJO Task Force MJO forecast metric activity
 - Climate Forecast System (CFS)

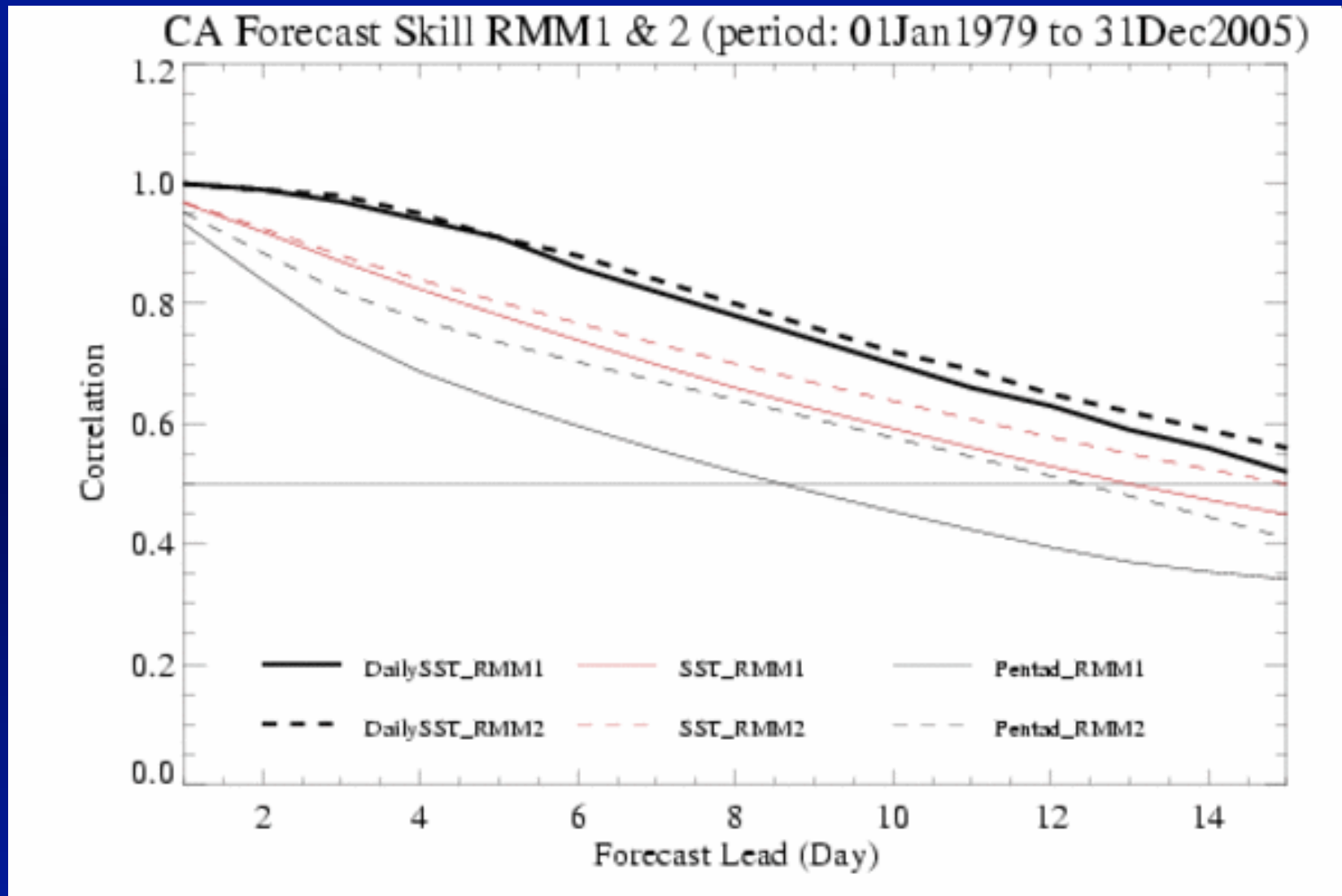
Constructed Analogue MJO Forecast

- Identifies closely related events in the historical record to current observed activity
- Calculates weights using recent observations and applies equivalent weights to those past events to make a forecast
- At CPC, applied to (1) filtered OLR anomalies and the (2) Wheeler and Hendon (2004) MJO index

Constructed Analogue MJO Forecast



Constructed Analogue MJO Forecast



Courtesy: Qin Zhang, CPC

Dynamical Model MJO Forecasts

- Realtime forecasts of the MJO are increasingly being recognized for their potential to improve extended range weather forecasting
- MJO prediction studies using operational realtime dynamical models have increased in recent years but have used varying methodologies, datasets, and validation metrics

MJO Task Force Forecast Activity

- The US CLIVAR MJO Working Group (MJOWG) designated a team to adopt a uniform diagnostic for MJO identification and skill metrics
- Standard measures allow for consistent evaluation and display of MJO forecasts from multiple sources over time
- Invitation letter from the MJOWG and Working Group on Numerical Experimentation (WGNE) was distributed to operational centers around the world to introduce the project and request participation

Gottschalck et al. 2010: A Framework for Assessing Operational Model MJO Forecasts: A Project of the CLIVAR Madden-Julian Oscillation Working Group
Bull. Amer. Met. Soc., In press.

Center Participation



US – NCEP



ECMWF



United Kingdom



Brazil



US – NRL



India



Taiwan



Australia



Japan



Canada – CMC

MJO Diagnostic Details

Slight variant of the WH2004 MJO index was chosen:

- (1) Widespread acceptance as a relatively well-characterized measure of the MJO and its evolution
- (2) Well suited for real-time application as it requires only spatial, no temporal, filtering – an important consideration when applied to real-time operational model data
- (3) The method is relatively straightforward to adopt

MJO Diagnostic Details

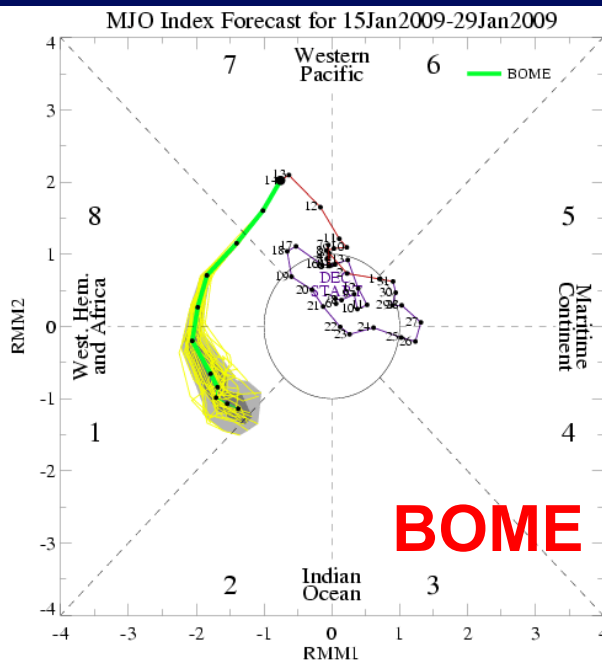
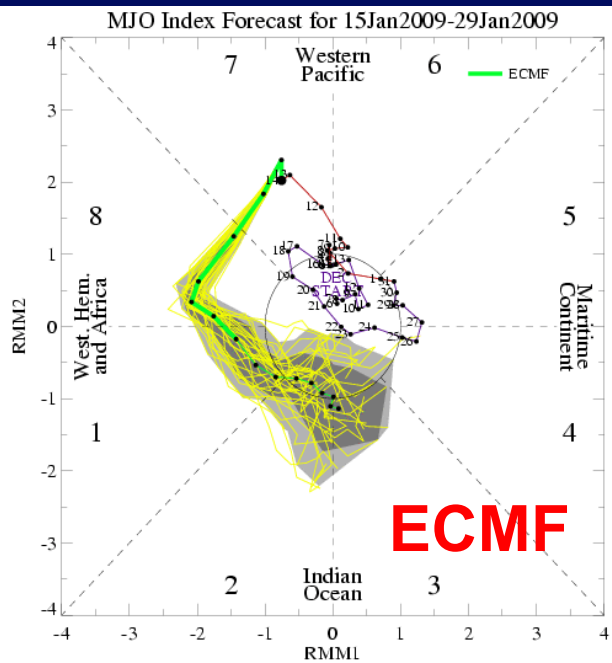
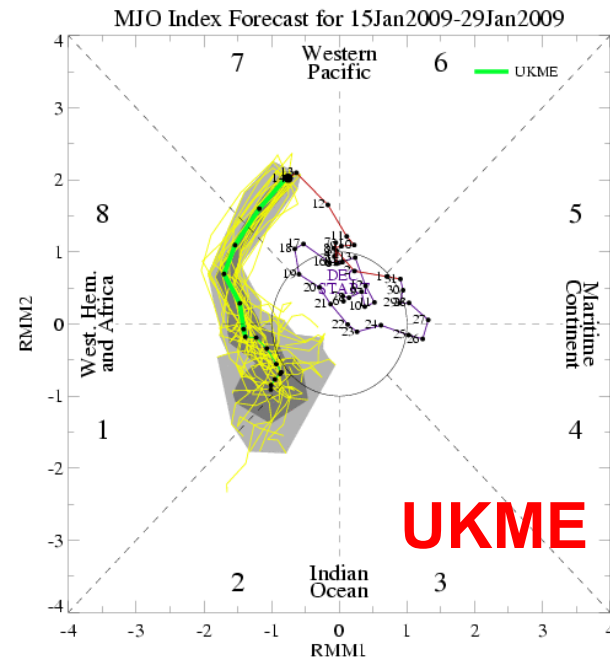
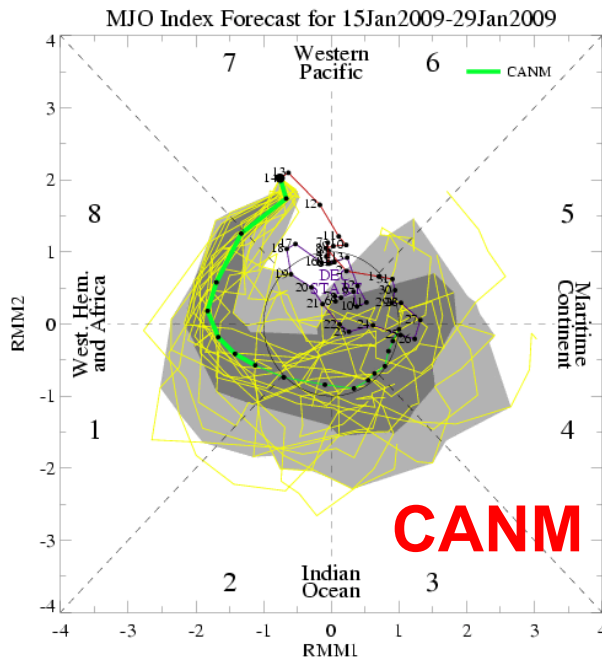
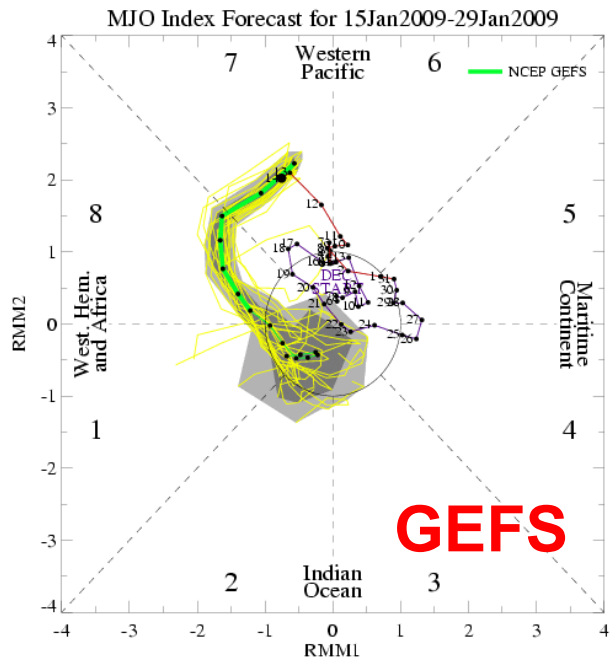
Application to operational model output:

- (1) Centers send total OLR, u850, u200 data to CPC ftp site in realtime
- (2) Model forecast anomalies based on observational climatological data from NCEP Reanalyses and NOAA satellite OLR
- (3) The most recent 120 day mean of model analysis/forecast anomaly data is subtracted to remove low-frequency variability
- (4) Forecast data are projected onto *observed* EOFs currently
- (5) Resulting RMM1 and RMM2 values displayed in phase space

Center Data Specifics

Center	Model	Data Stream ID	Ensemble Members	Forecasts Start	Length (Days)	Realtime Data FTP	Version 1 Plots	Model Climatology
NCEP	GFS EPS T126 ¹	NCPE	21	Nov 2007	15	-----	Yes	No
NCEP	GFS T382 ¹	NCPO	1	Jan 2008	15	-----	Yes	No
NCEP	CFS T62 ¹	NCFS	4	Jan 2007	40	-----	Yes	Yes
CMC	GEMDM 400x200 ²	CANM	20	Jun 2008	16	Yes	Yes	No
UKMO	MOGREPS ³	UKMA	1	Oct 2007	15	Yes	Yes	No
UKMO	MOGREPS ³	UKME	23	Oct 2007	15	Yes	Yes	No
ABOM	GASP T239 ⁴	BOMA	1	Jan 2008	10	Yes	Yes	No
ABOM	GASP EPS T119 ⁴	BOME	32	Aug 2008	10	Yes	Yes	No
ABOM	POAMA1.5bT47 ⁴	BOMC	1	Jan 2008	40	Yes	Yes	No
ABOM	POAMA1.5T47 ⁴	BOMH	1	-----	40	No	No	Yes
ECMWF	VAREPS T299/T255 ⁵	ECMF	51	Jun 2008	15	Yes	Yes	No
ECMWF	VAREPS T299/T255 ⁵	ECMM	51	Jun 2008	15	Yes	Yes	Yes
ECMWF	SFSv3 T159 ⁵	EMON	51 (W)	Jun 2008	32	Yes	Yes	No
ECMWF	SFSv3 T159 ⁵	EMOM	51 (W)	Jun 2008	32	Yes	Yes	Yes
JMA	GSM WEPS T319 ⁶	JMAN	51	Nov 2008	9	Yes	Yes	No
CPTEC	GWEFS T126 ⁷	CPTC	15	Feb 2009	15	Yes	No	No
IMD	NCMRWF T254 ⁸	IMDO	1	Jun 2009	7	Yes	Yes	No
IMD	NCMRWF EPS T80 ⁸	IMDE	8	-----	7	No	No	No
FNMOC	NOGAPS T119 ⁹	NGAP	10	-----	10	No	No	No
TCWB	CWB EPS T119 [^]	TCWB	1	Oct 2009	40	Yes	Yes	No

- Multiple contributions for several centers
- High-resolution operational run data as well as data from ensemble prediction systems
- Varying forecast duration



Differences in:

- (1) Ensemble spread
- (2) Propagation speed
- (3) Amplitude

Updates to Activity Webpage

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

Climate Prediction Center

Home Site Map News

HOME > Climate & Weather Linkage > MJO Task Force Dynamical Model

MJO Task Force

Dynamical Model MJO Fore

**** Please Note:** This website will see updates as additional models become available. The products at this site are to be considered EXPERIMENTAL.

Forecasts

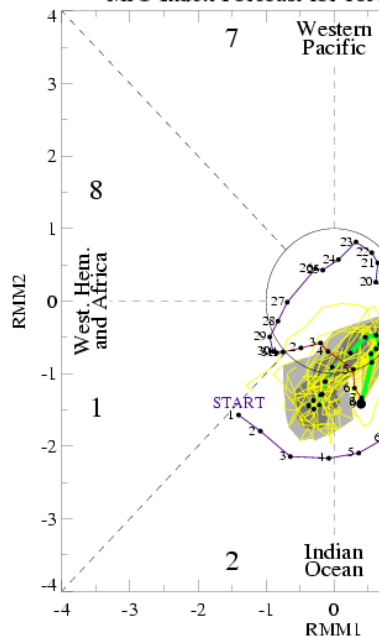
A key for the label headings in the figure box is provided below. Information for specific model-related information such as the forecast duration and climatologies used.

Note: Move cursor over product name to display.

Phase Plots of MJO Index Fore

NCPE	NCPO	NCFS	CMET
IMDO	BOME	BOMA	BOMC

MJO Index Forecast for 10J



Phase diagram showing the evolution of the last 40 days of observations along with the 15 day ensemble UK Met Office forecast. The yellow lines are the ensemble members and the green line is the ensemble mean (thick-week 1, thin-week 2). The dark gray shading depicts 50% of the members fall in this area and the light gray shading indicates 90% of the members.

Datastream Specific Information

Name and PID: UK Meteorology Office Ensemble System (UKME)
Number of Members: 23
Forecast Duration: 15 Days
Climatology for anomalies: NCEP Reanalyses
Previous 120 Day Analysis Mean Used: UKMet analysis

Verification

Heading Key:

NCPO: National Centers for Environmental Prediction - Operational Global Forecast System

Forecast System
 System

m

Control Run
 Ensemble System

tem

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closely to that described in
 between WH2004 and the
 related by the BMRC SST1
 it was decided that this step
 sufficient to remove much of

operational centers. For
 link below the table. This
 along with directions for

out to no more than 40 days
 0)
 Agency
 (is data for past 120 days)

[\(NE\) Letter](#)

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Preliminary Verification

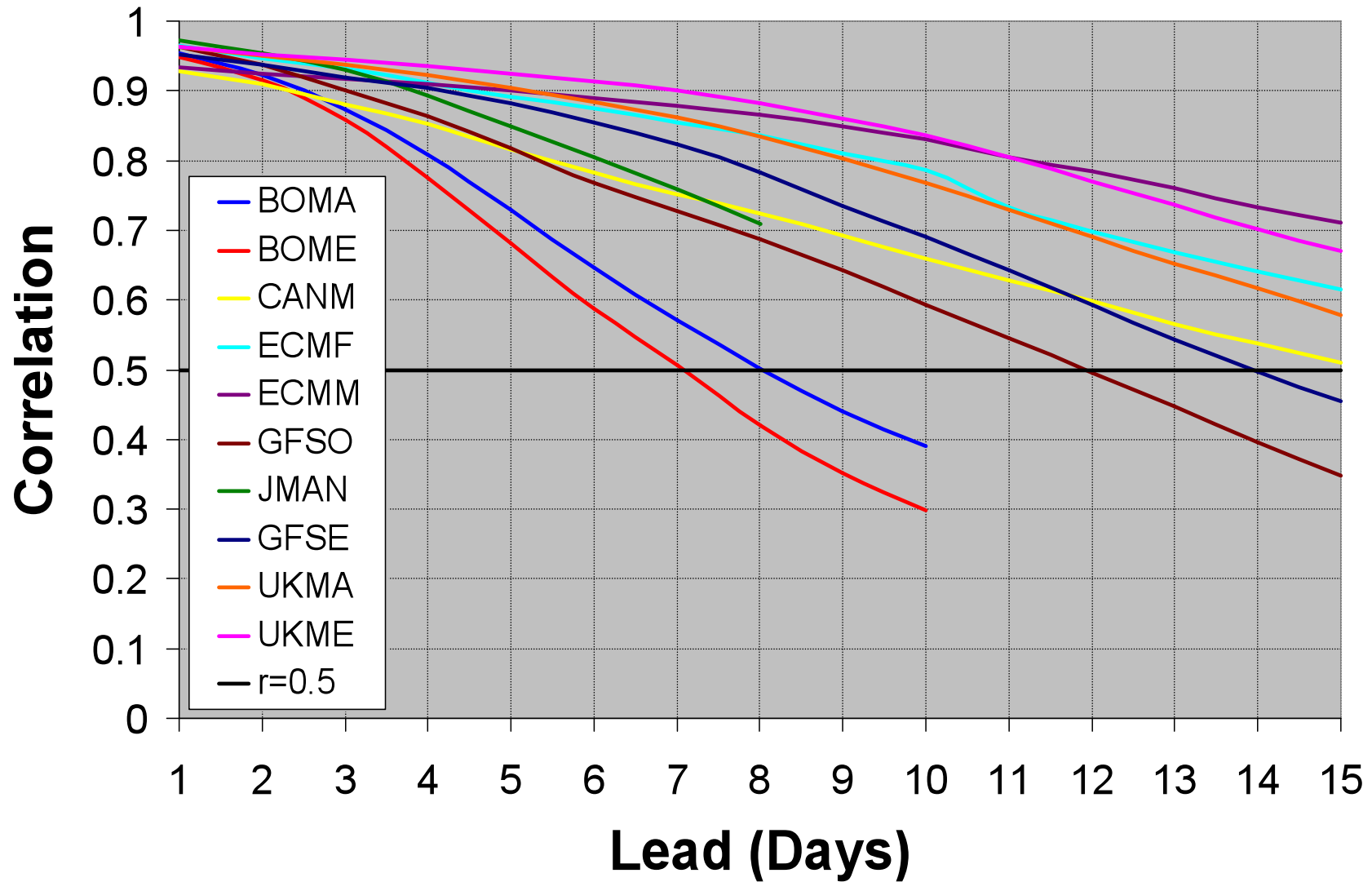
$$COR(\tau) = \frac{\sum_{t=1}^N [a_1(t)b_1(t, \tau) + a_2(t)b_2(t, \tau)]}{\sqrt{\sum_{t=1}^N [a_1^2(t) + a_2^2(t)]} \sqrt{\sum_{t=1}^N [b_1^2(t, \tau) + b_2^2(t, \tau)]}}$$

$$RMSE(\tau) = \sqrt{\frac{1}{N} \sum_{t=1}^N [a_1(t) - b_1(t, \tau)]^2 + [a_2(t) - b_2(t, \tau)]^2}$$

- November 2008 – May 2010 time period
- Some forecast data is missing, but not much
- Calculate using NCEP Reanalysis first as one benchmark (shown here)
- Calculate using a “multi-model analysis” for the final measure (ongoing)
- Stratification by MJO phase, season as additional data is obtained

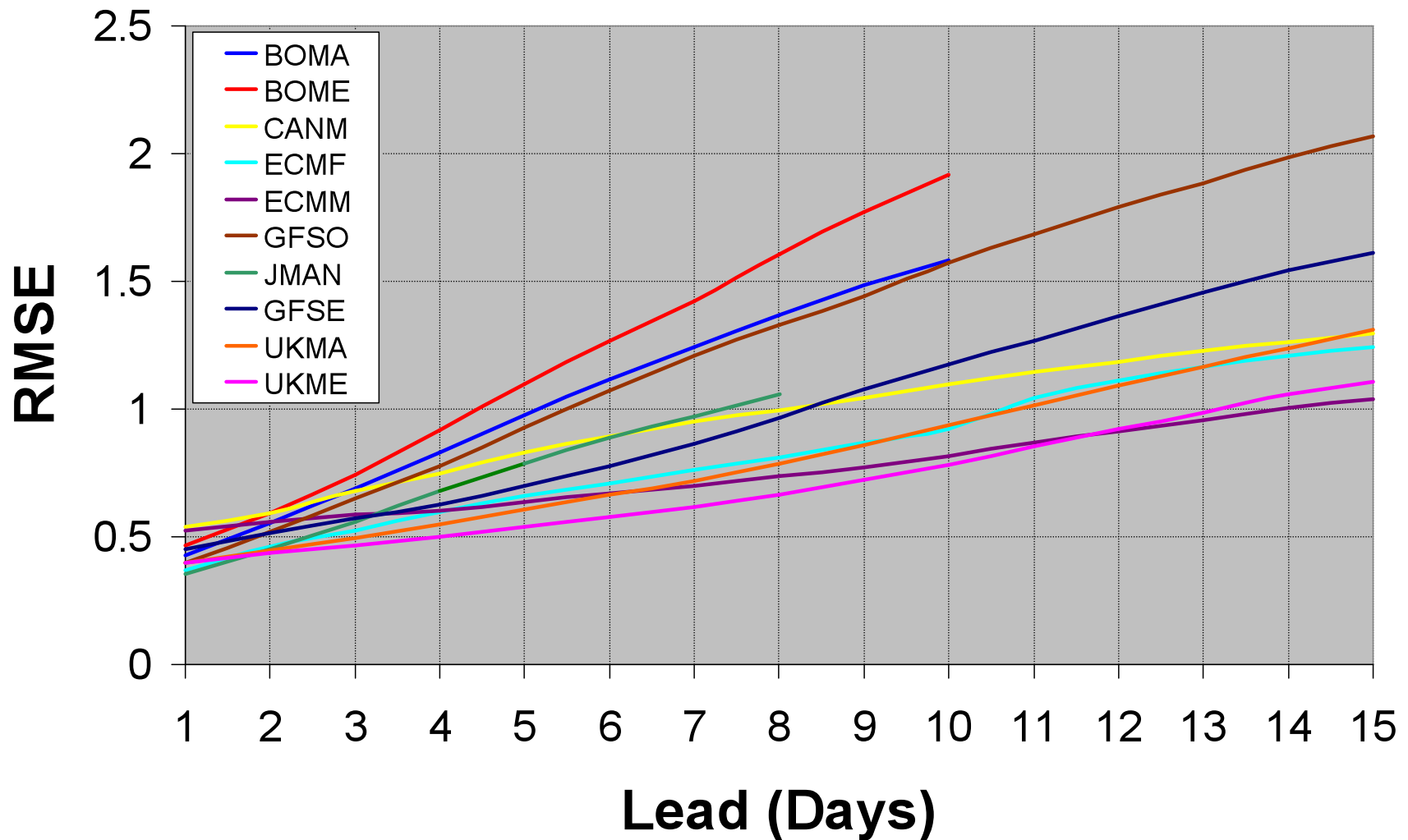
Preliminary Verification

Bivariate Correlation for MJOTF Models

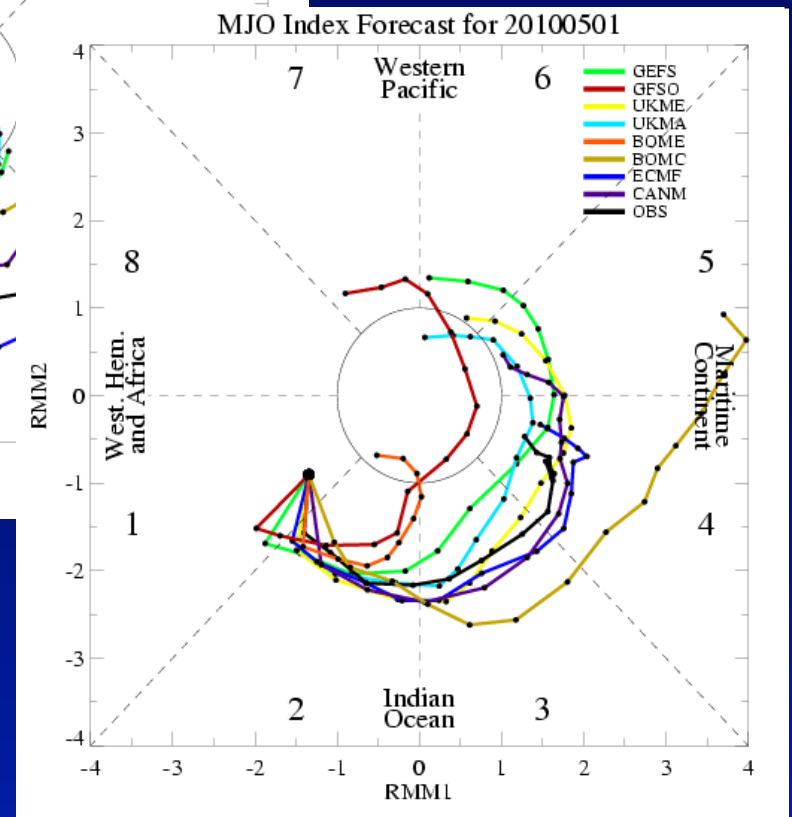
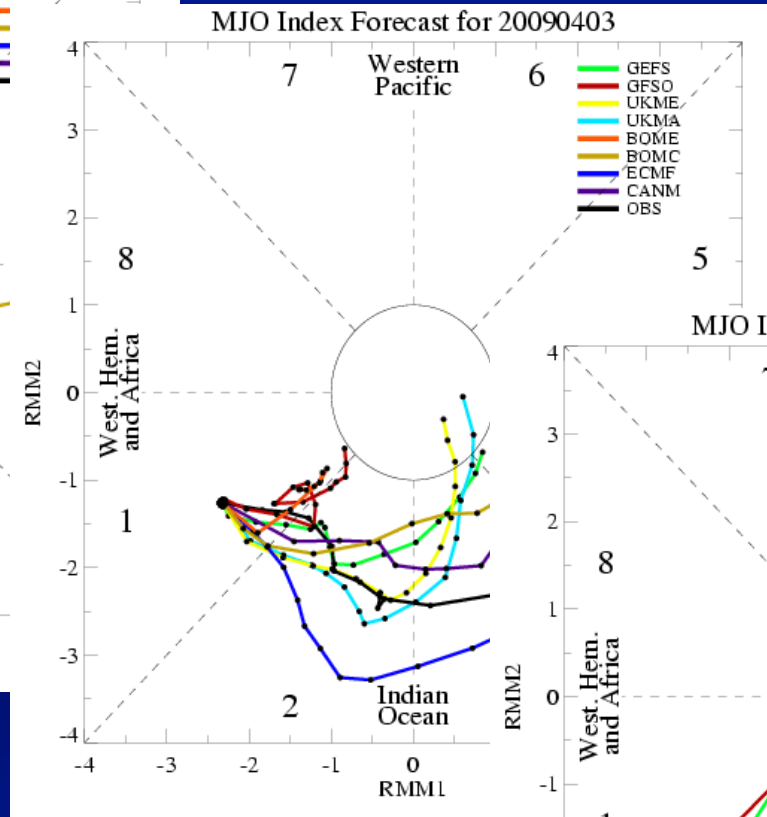
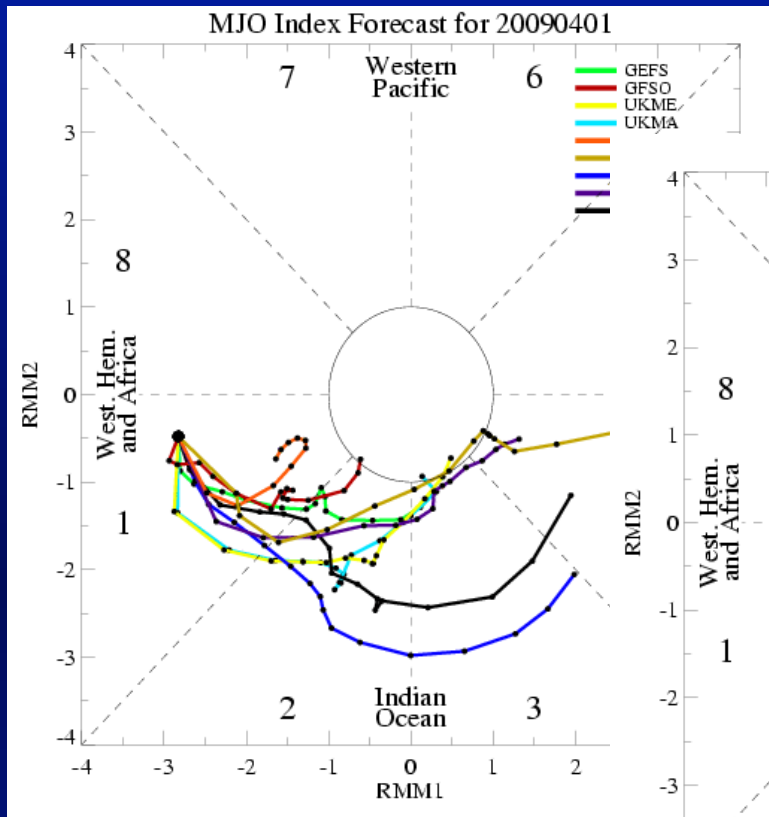


Preliminary Verification

Bivariate RMSE for MJOTF Models



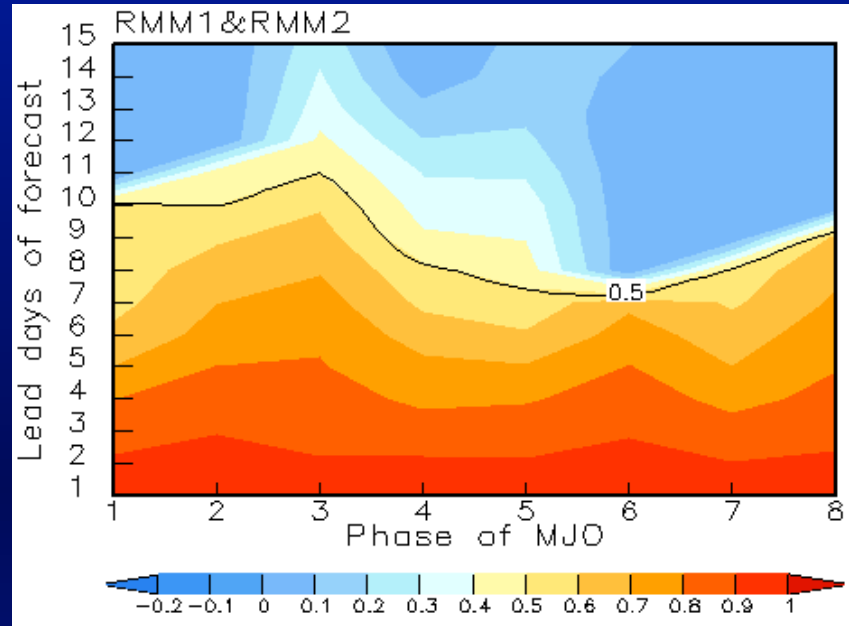
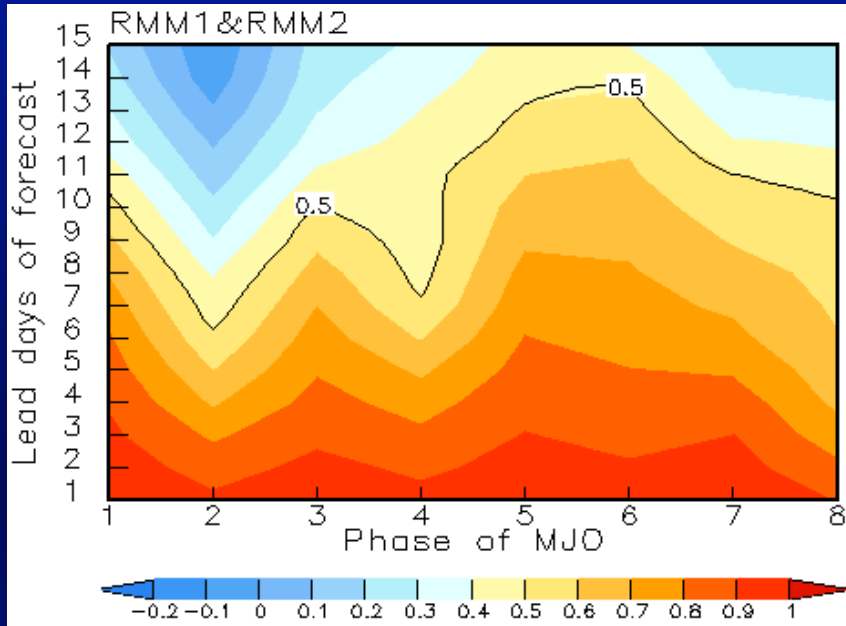
Example Cases



GEFS MJO Index Forecast Skill

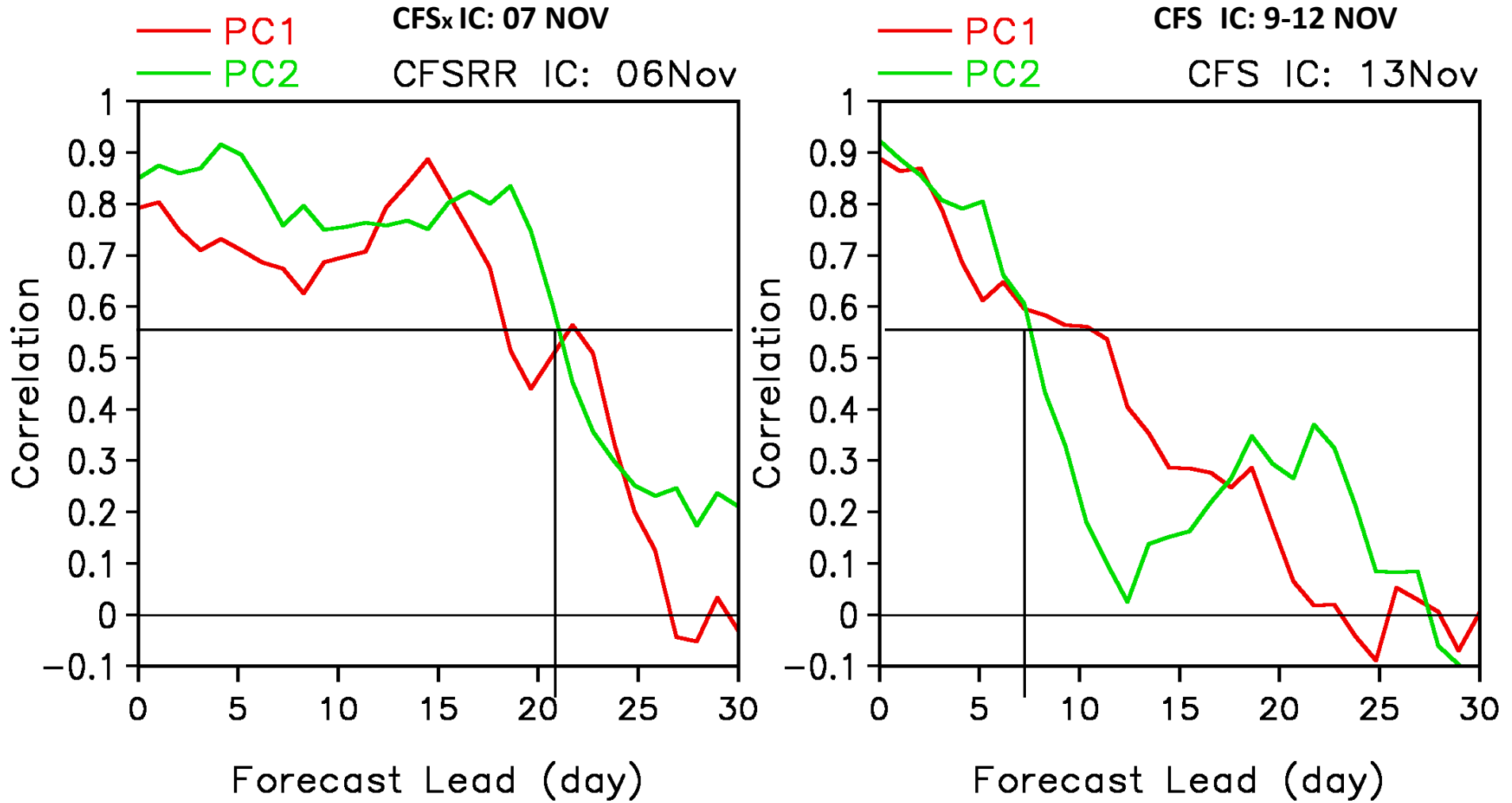
Keyed to MJO Initial Phase

Keyed to MJO Forecast Phase



CFS MJO Forecast Skill

PC1 & PC2 (CHI) forecast correlation skill CFSx & CFS



Courtesy: Scott Weaver, CPC

Weekly MJO Assessment

<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjouupdate.pdf>



Madden-Julian Oscillation: Recent Evolution, Current Status and Predictions

Update prepared by
Climate Prediction Center / NCEP
December 3, 2007

--Review of weekly changes in the MJO

--Includes some of the monitoring and prediction products described here



Overview

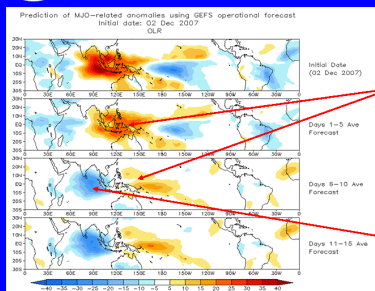
- The MJO has strengthened to a moderate level during the past week.
- The enhanced phase has shifted eastwards and is now centered in the western hemisphere while large-scale suppressed convection is evident across much of the eastern hemisphere.
- Forecast tools, both statistical and dynamical, indicate continued propagation of the MJO at moderate strength for at least the next week with enhanced convection slowly shifting into the Indian Ocean by week 2.
- Likely near-term impacts across the global tropics include wet conditions for northeast South America and central and southeast Africa. Dry conditions can be expected from the eastern Maritime continent into the western Pacific Ocean.
- Other than the short-term cold across eastern areas, MJO associated impacts for the US are expected to be minimal during the upcoming week.

--Provides an assessment in compact form

--Anticipated evolution and impacts of the MJO during the next 1-2 weeks



Experimental GFS MJO OLR Forecast



The GFS forecasts a moderate MJO for the coming 1-2 weeks with suppressed convection impacting the Maritime continent and far western Pacific Ocean during much of the period.

Wet conditions are expected across northeast South America early in the period while convection is forecast to enter the Indian Ocean during week 2.

--Released every Monday ~ 4 PM LT

Global Tropics Hazards / Benefits Assessment

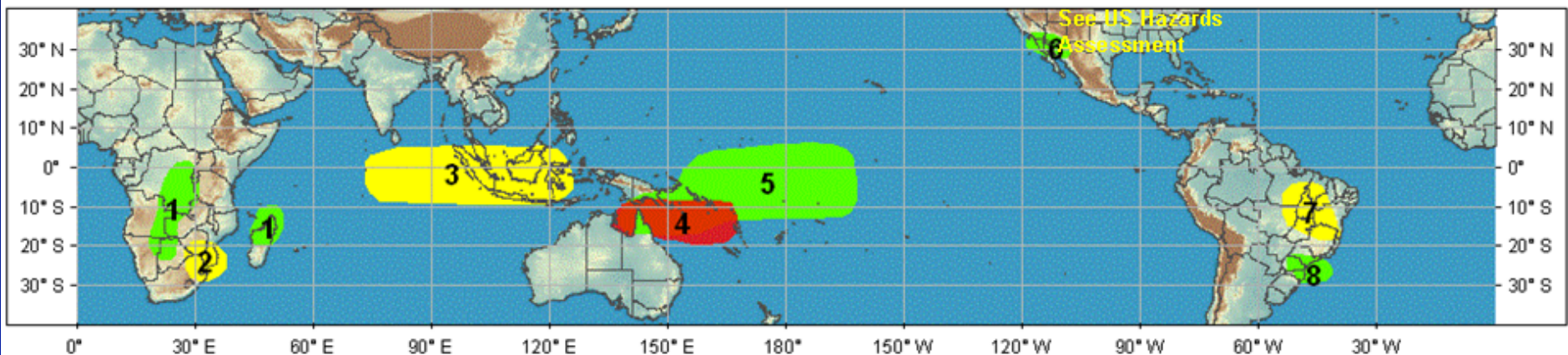
- Outlooks for above (top 33%) / below (bottom 33%) precipitation and favorable/unfavorable conditions for tropical cyclone activity
- Outlooks for Week 1 and Week 2
- Synthesizes information related to climate variability on multiple time scales and from various sources
- Physical basis: MJO, ENSO, monsoons, other coherent tropical variability (*i.e.*, atmospheric Kelvin waves, equatorial Rossby waves, AEWs) and interaction with the extratropics

Global Tropics Hazards/Benefits Assessment - Climate Prediction Center - Issued: 1/19/2010

Product issued once per week with no updates. Conditions are subject to change after issuance time and before next outlook.
Product targets broad scale conditions integrated over a 7 day period for US interests only. Please also consult your local responsible forecast agency.



Week 1 Outlook – Valid: January 20 - 25, 2010



CPC's Potential Role in DYNAMO

- Develop briefing web page of realtime MJO monitoring and prediction products for use by field campaign staff
- Provide assessment for future evolution of the MJO to field campaign staff (Week 2-3)
- Participate in campaign briefing conference calls when possible
- Analyze DYNAMO data after campaign and take part in an NCEP reanalysis project (proposed) focused on domain and time period

Thank You

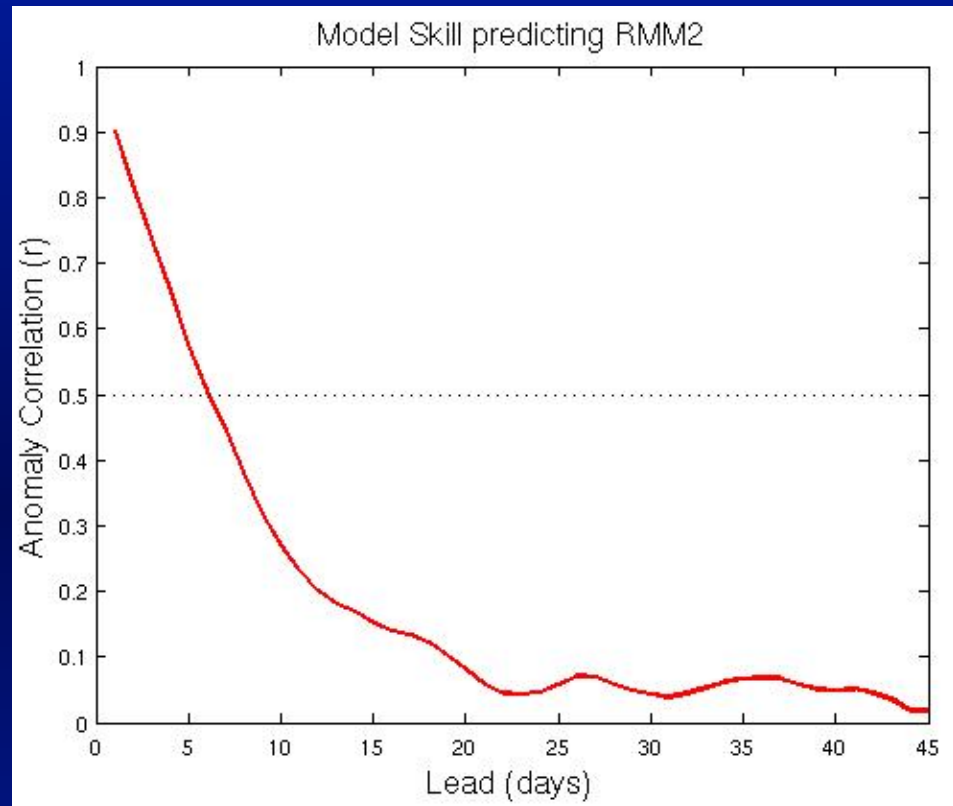
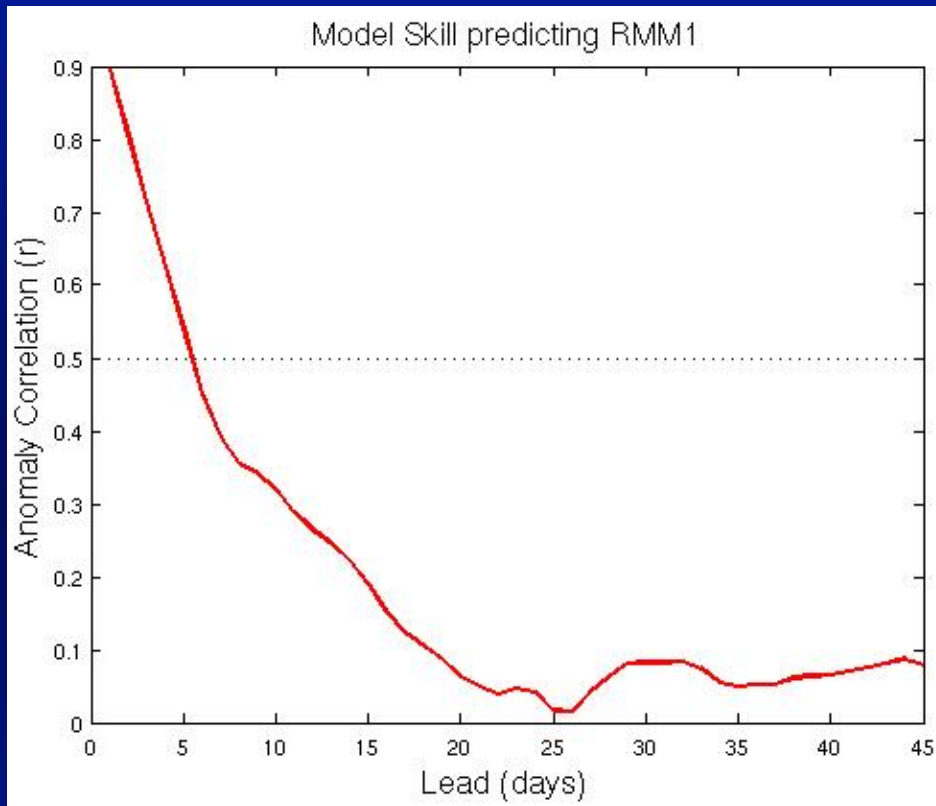
Comments and Questions

Jon.Gottschalck@noaa.gov

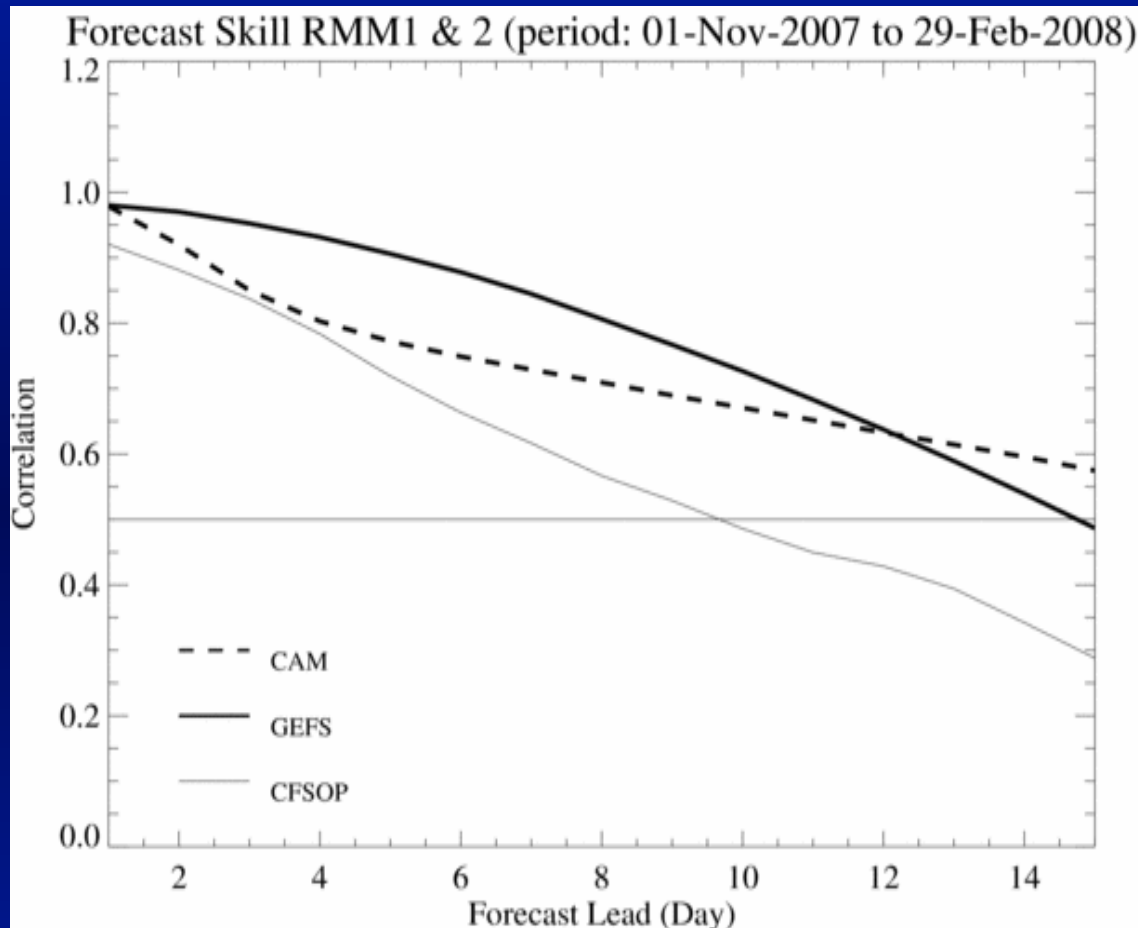
Backup Slides

CFS MJO Index Forecast Skill

Historical CFS v1



MJO Index Forecast Skill – 2007-2008 Event



--Days during strong MJO event of the boreal winter 2007-2008 (skill higher)

--Only 4 months of data

--GEFS comparable to CAM

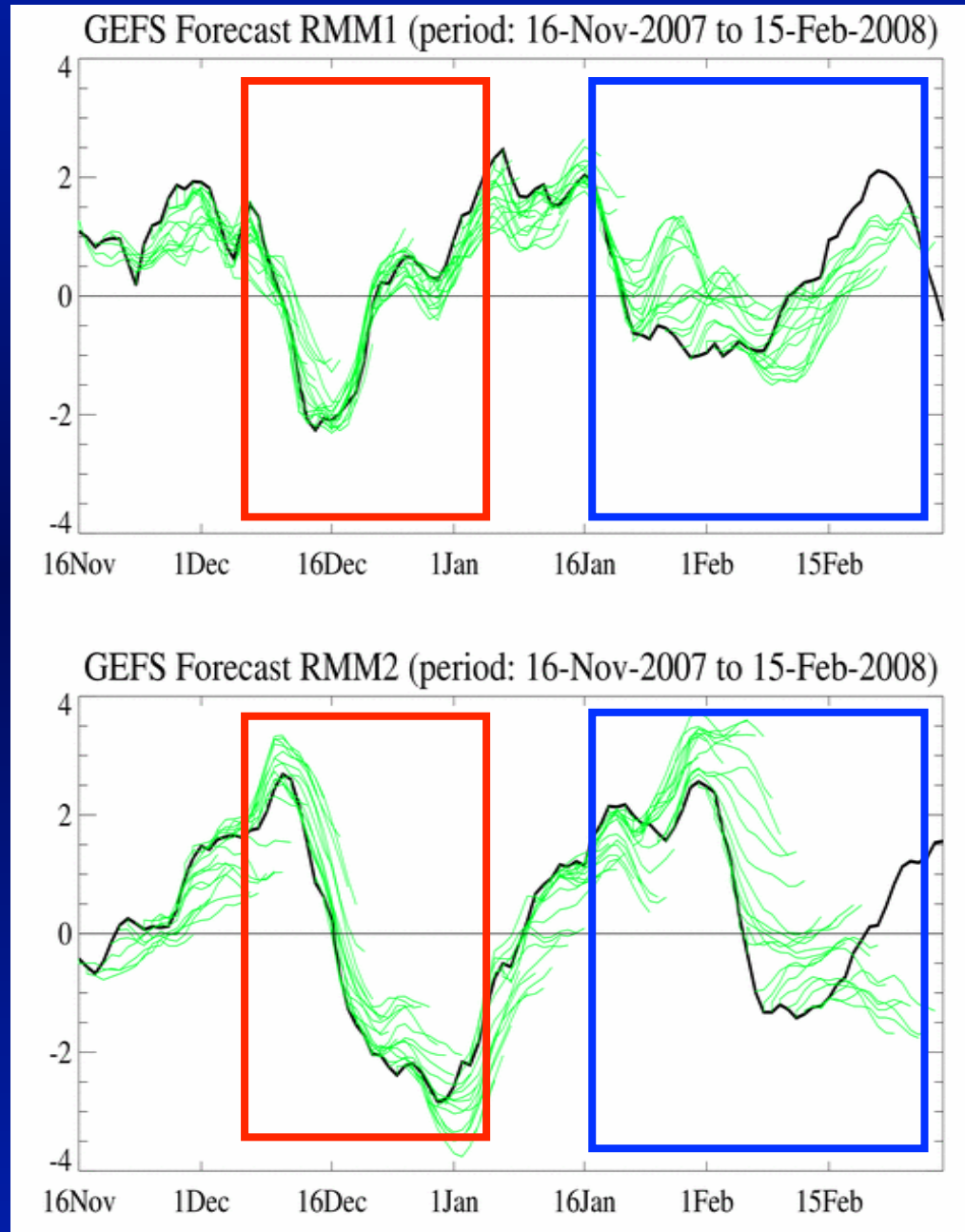
--GEFS performed better than CFSOP

GEFS → Ensemble GFS (21 members)

CFSOP → Operational CFS (4 members)

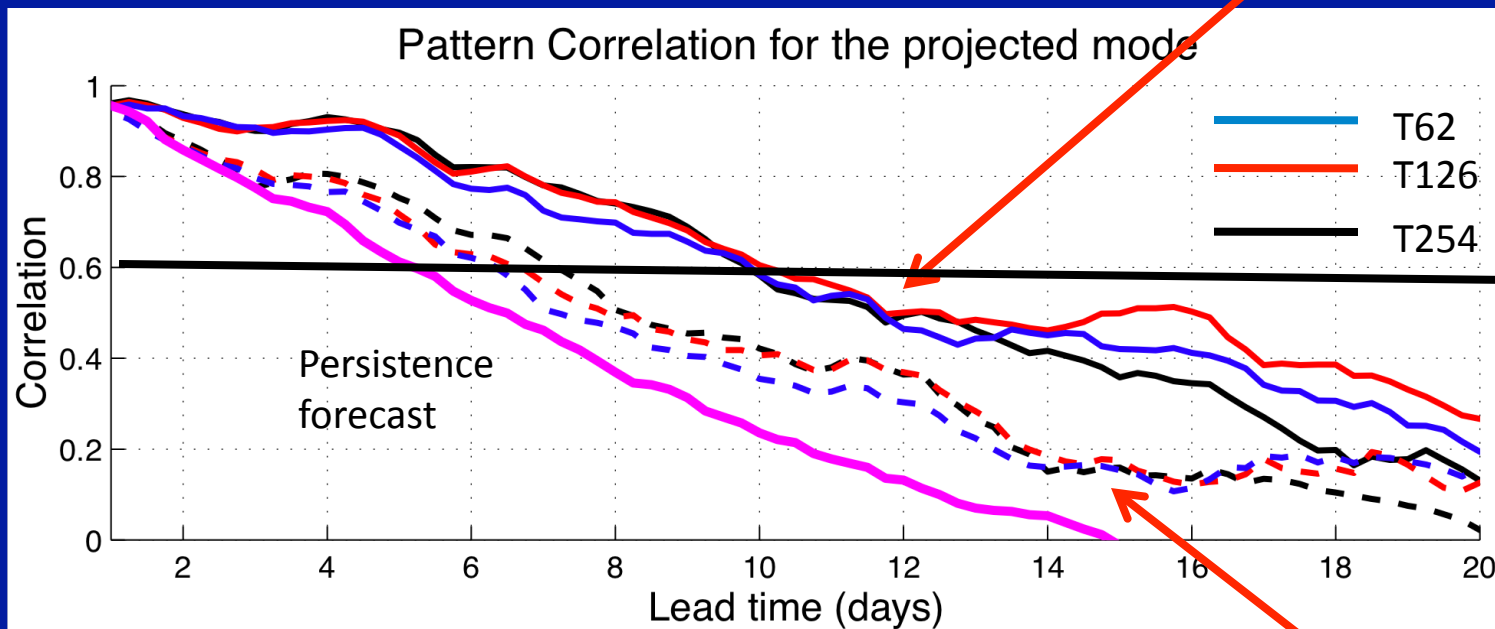
CAM → Constructed Analogue statistical forecast

MJO Index Forecast Skill – 2007-2008 Event



MJO Prediction – CFS Model Sensitivity

IC = GDAS (Operational NCEP analysis)



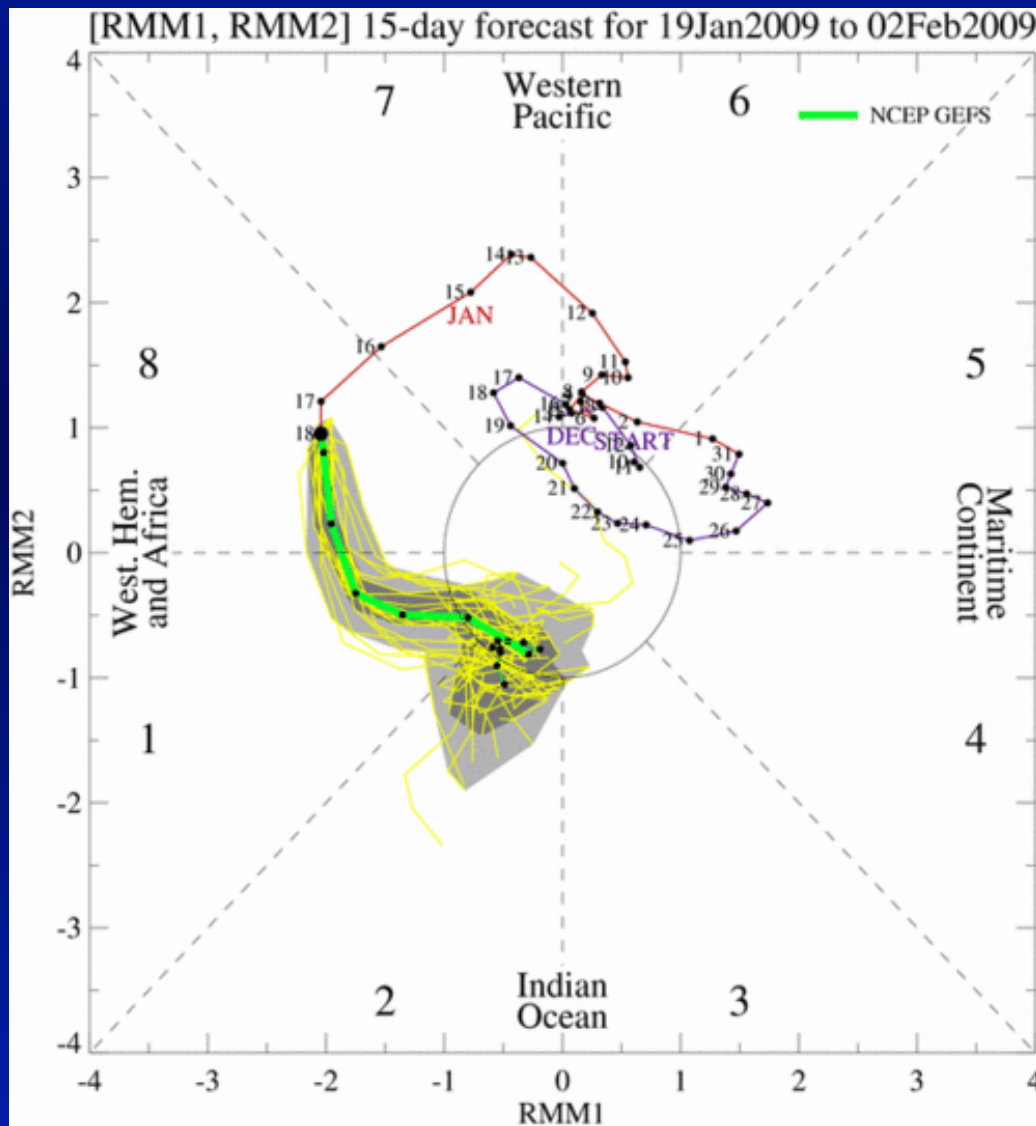
IC= Reanalysis-2

Courtesy: Augustin Vintzilos, CPC

GEFS MJO Forecast

Yellow Lines – 20 Individual Members

Green Line – Ensemble Mean



RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading:
90% of members

dark gray shading:
50% of forecasts

MJO Diagnostic Details

Several MJO extraction methodologies were considered:

(1) Combined EOF analysis (OLR, u850, u200)

Wheeler and Hendon (2004)

(2) Fourier filtering of OLR anomalies for zonal wavenumbers and frequencies consistent with the MJO

Wheeler and Kiladis (1999)

Wheeler and Weickmann (2001)

(3) EOF analysis of 20-90 day bandpassed OLR anomalies

Jones et al. (2004)

Global Tropics Hazards / Benefits Assessment

- Released each Monday ~ 4 PM ET
- Technical input conference call and applications briefing
- Integrates a number of CPC activities (ENSO, monsoon and MJO monitoring teams, U.S. Hazards forecasters, etc.)
- Supports tropical international crises when relevant

Global Tropics Hazards / Benefits Assessment

Objective verification:

- Both rainfall and tropical cyclone areas are verified with standard skill measures
- Forecast maps are digitized and verified on a grid using observational rainfall

