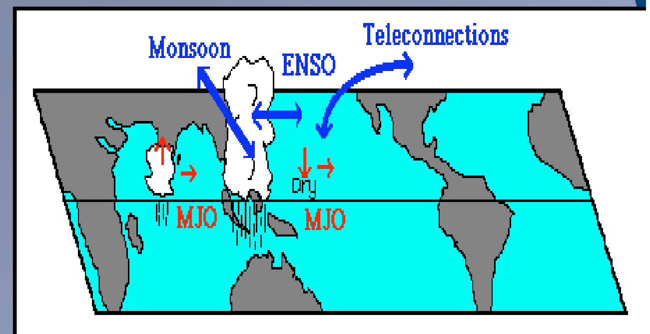
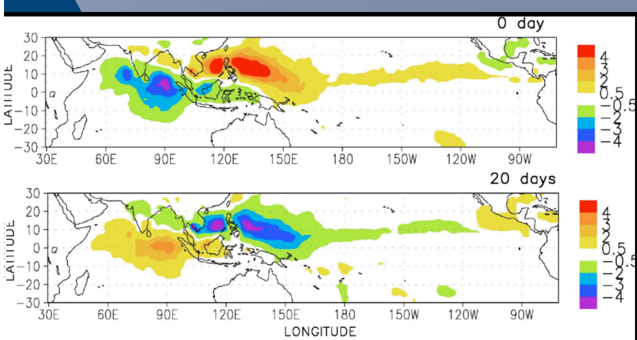
US CLIVAR MJO Working Group:
Progress Report

D. Waliser/JPL and K. R. Sperber/PCMDI
on behalf of the MJO Working Group





US CLIVAR SUMMIT
July 2007

http://www.usclivar.org/Organization/MJO_WG.html

U.S. CLIVAR MJO Working Group

last updated July 3, 2007

Name	*Affiliation*	*Term*
Bill Stern	NOAA GFDL	
Eric Maloney	Oregon State University	
Mitch Moncrief	NCAR	
Sigfried Schubert	NASA GSFC	
Ken Sperber (co-chair)	Lawrence Livermore	
Bin Wang	University of Hawaii	
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Klaus Weickmann	NOAA CDC	
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Additional Contributing Scientists		
John Gottschalck	NOAA - NCEP	
Harry Hendon	BMRC	
Wayne Higgins	NOAA-NCEP	
Daehyun Kim/In-Sik Kang	Seoul National University	
Frederic Vitart	ECMWF	
Matt Wheeler	BMRC	
Steve Woolnough	Univ. Reading	

MEETINGS | DOCUMENTS | REFERENCES | LINKS

MJO & Weather-Climate | MJO Simulation Diagnostics

Terms of Reference

- Develop a set of diagnostics to be used for assessing MJO simulation fidelity and forecast skill.
- Develop and coordinate model simulation and prediction experiments, in conjunction with model-data comparisons, which are designed to better understand the MJO and improve our model representations and forecasts of the MJO.
- Raise awareness of the potential utility of subseasonal and MJO forecasts in the context of the seamless suite of predictions.
- Help to coordinate MJO-related activities between national and international agencies and associated programmatic activities.
- Provide guidance to US CLIVAR and Interagency Group (IAG) on where additional modeling, analysis or observational resources are needed.

Membership & Terms of Reference

International participation is facilitated/ supported by International CLIVAR

Goals/Progress: Summary

1) Develop MJO WG Web Site. Done, Some Additions - Diagnostics Link, Meeting/Telecon Updates, Theme Pages
2) Diagnostics for Asessing Model Simulations of the MJO. ~Done, May still try to include codes and data sets
3) Diagnostics Application to Models. Just Beginning, GCMs and partners identified and data being gathered, Analysis by Kim.
4) Prediction Targets and Metrics for MJO Forecasts. Under Discussion, ~50% Done
5) Workshop/Experimentation Planning. Underway

MJO Weather Climate Interactions

- ENSO
- Hurricanes
- Australian Monsoon
- High Latitude Weather
- Ocean Chlorophyll
- Global Benefits and Hazards
- African Rainfall
- MJO and Atmospheric Composition: Total Column Ozone
- Atmospheric Angular Momentum and Length of Da

New

MEETINGS

Relevant Science Meetings and Workshops

- Workshop on the Organization and Maintenance of Tropical Convection and the Madden Julian Oscillation 13-17 March 2006 (Trieste, Italy)
- Diagnosing, Modeling and Forecasting Subseasonal Atmospheric Variability, AGU, 23-25 May 2006(Balitmore, MD)
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  - Presentation from the workshop (pdf)
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Working Group Meetings/Teleconferences

- Teleconference Agenda (pdf) and Minutes (pdf) from 3 May 2006
- Teleconference Agenda (pdf), Minutes (pdf) and Attachment 1 (pdf) from 31 May 2006
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Web Site Resources

Theme Pages & WG Activities

MJO Weather-Climate Theme Pages

The U.S. contribution to

Climate Variability and Predictability

MJO Weather-Climate Interactions

The MJO and Hurricanes:

Could MJO Predictions Help Forecast Periods of Enhanced Hurricane Activity?

Motivation

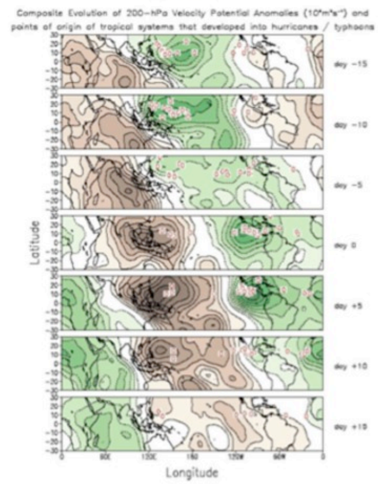
The MJO produces a strong modulation of tropical cyclone activity in many regions of the tropics, including the Atlantic Ocean, Gulf of Mexico, and east Pacific Ocean. The MJO is associated with variations in sea surface temperature, organized precipitation, low-level winds, vertical wind shear, and atmospheric humidity and temperature, important factors in tropical cyclone formation and maintenance. Forecasts of the MJO at 2-3 week lead times might aid in forecasting periods of enhanced tropical cyclone formation.

Research Summary

Tropical cyclogenesis preferentially occurs during certain phases of the MJO. Figure 1 shows the composite eastward propagation of Northern Hemisphere summer velocity potential and tropical cyclone genesis locations associated with the MJO during 1979-1997 (adapted from Higgins and Shi [2001]). Green areas indicate anomalous upper level divergence, where precipitation is enhanced and tropical cyclogenesis preferentially occurs. Brown areas indicate anomalous upper level convergence, where precipitation and tropical cyclogenesis are suppressed. One notable feature is the enhancement of tropical cyclogenesis in the Americas during periods of enhanced upper level divergence and enhanced precipitation (e.g. Day 0 and Day +5 of Figure 1). For example, an analysis during 1949-1997 indicates that the MJO strongly modulates Gulf of Mexico and Caribbean Sea hurricanes and tropical storms (Figure 2, adapted from Maloney and Hartmann 2000). Gulf of Mexico and Caribbean Sea hurricanes are four times more likely to occur when the MJO is producing enhanced precipitation and divergent upper level winds than when precipitation is suppressed and upper level winds are convergent. The modulation of major hurricanes (Categories 3-5) by the MJO is even more pronounced. Similarly, when the divergent (convergent) phase of the MJO is located over the Indian or west Pacific Ocean, typhoon activity in increased (decreased).

Example: MJO & Hurricanes by Eric Maloney

Figure 1.



Adapted from Higgins and Shi (2001)

Figure 2.

Maloney and Hartmann (2000)

Implications

Given the evidence that the MJO is predictable with 2-3 week lead-times, periods of enhanced or suppressed hurricane activity may be predicted at similar lead times. Such knowledge would have implications for public safety, energy production, recreation/tourism, among other interests.

Future Work

Two avenues of further investigation include: 1) understanding how the MJO modulates hurricane activity, and 2) determining whether 2-3 week predictions of the MJO can be used to predict periods of enhanced tropical cyclone activity.

Selected References

- Bessafi, M., and M. C. Wheeler. 2006: Modulation of south Indian Ocean tropical cyclones by the Madden–Julian Oscillation and convectively coupled equatorial waves. *Mon. Wea. Rev.*, **134**, 638–656.
- Hall, J. D., A. J. Matthews and D. J. Karoly. 2001: The Modulation of tropical cyclone activity in the Australian region by the Madden–Julian oscillation. *Mon. Wea. Rev.*, **129**, 2970–2982.
- Higgins, W and W. Shi, 2001: Intercomparison of the principal modes of interannual and intraseasonal variability of the North American monsoon system. *J. Climate*, **14**, 403-417.
- Liebmann, B., H. H. Hendon, and J. D. Glick, 1994: The relationship between tropical cyclones of the western Pacific and Indian Oceans and the Madden-Julian oscillation. *J. Meteor. Soc. Japan*, **72**, 401-411.
- Maloney, E. D., and D. L. Hartmann, 2000: Modulation of hurricane activity in the Gulf of Mexico by the Madden-Julian Oscillation. *Science*, **287**, 2002-2004
- Mo, K. C., 2000: The association between intraseasonal oscillations and tropical storms in the Atlantic basin.

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Web Site Resources

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Web Site Diagnostics

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last updated July 3, 2007

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Link to Metrics

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Daehyun Kim/SNU

Madden Julian Oscillation (MJO) Metrics

An activity led by US CLIVAR and supported by International CLIVAR

Introduction | Description | Observations | Simulations

DESCRIPTION
- LEVEL 1
- LEVEL 2
- OTHER

Description

This section describes the metrics developed by the US CLIVAR MJO Working Group for assessing the fidelity of the simulatio
Madden-Julian Oscillation and the boreal summer intraseasonal oscillation in climate models. For brevity, the term MJO will be us
includes the broader category of eastward (and northward) intraseasonal oscillations that occur on time scales of 30-70 days. Th
metrics was a protracted procedure carried out by the MJOWG, with exhaustive sensitivity tests using observational data to assess
for such issues as stratifying the analysis by season, domains for analysis, the need (or lack thereof) of using tapering or de-tre
analysis, developing simple methods for assessing statistical significance etc.

The information and discussion below are meant to provide a brief description of the metrics chosen and the specific steps used
and in some cases the motivation for these choices and steps. The metrics are categorized into two levels of increasing complexity:

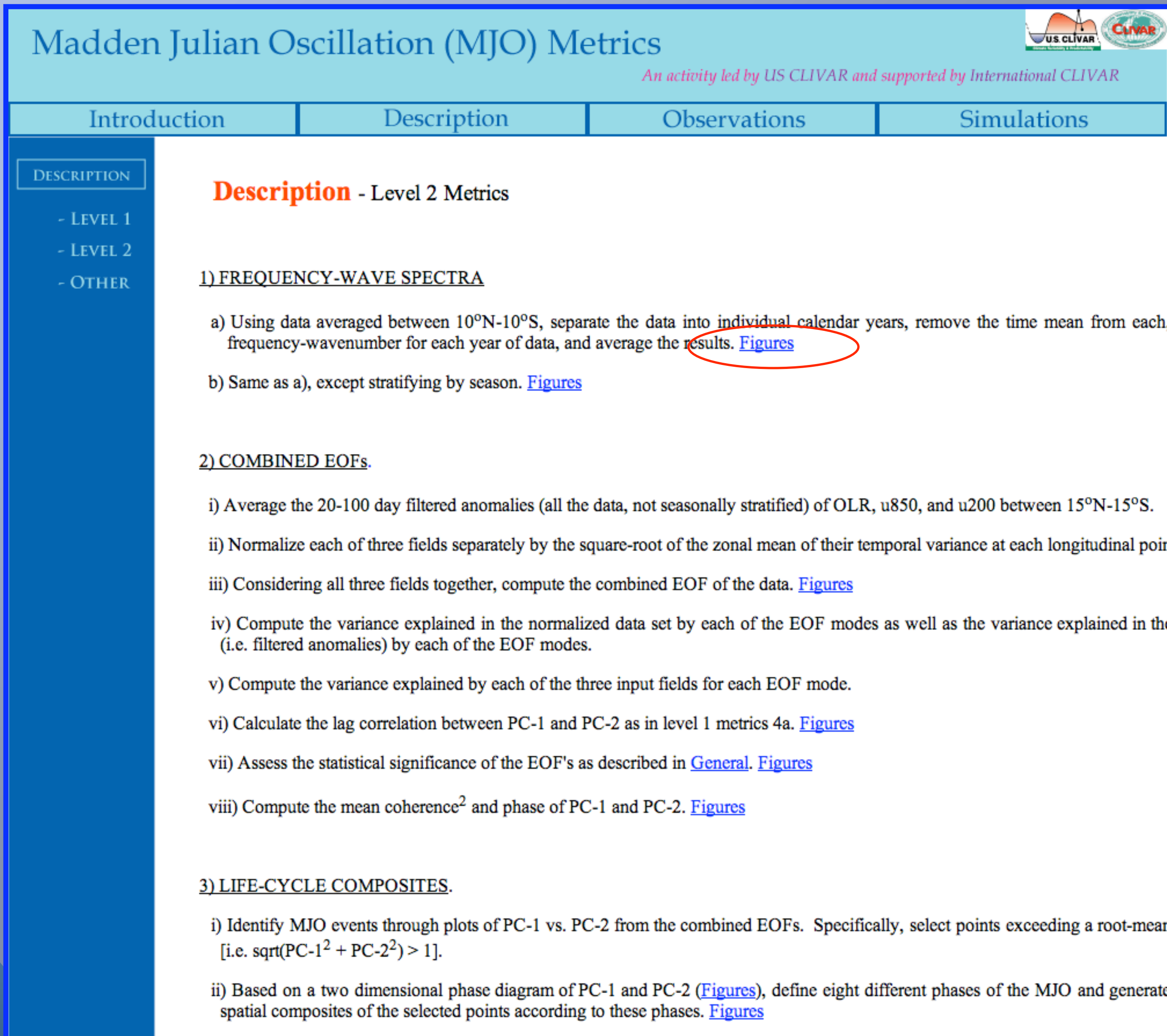
Level 1: These metrics are meant to provide a basic indication of the spatial and temporal intraseasonal variability that can be easi
calculated by the non-MJO expert. Ease of use dictated that the analytic procedures be as simple as possible and as similar as poss
winter calculations. These metrics include assessing variance in preferred frequency bands, spectral analysis over key domains
orthogonal function (EOF) analysis of bandpass filtered data, statistical significance assessment of the EOFs, and lead-lag assess
intraseasonal principal component (PC) time series. Variables include OLR, precipitation and zonal wind at 850 and 200 hPa
discussion.

Level 2: These metrics provide a more comprehensive diagnosis of the MJO through multivariate EOF analysis and freq
decomposition. Sensitivity tests indicated that the multivariate EOF analysis could be performed on data encompassing the full y
compromise in capturing the more complex intraseasonal variations that occur during the boreal summer (e.g., including the north
convection that occurs over the Asian monsoon domain). The dominant intraseasonal PC's are also used to generate composites
MJO life-cycle (alternatively, they can be used in lag regression to assess the mechanisms of MJO variability), and coherence-square
the PC's are calculated to determine the fidelity of the eastward propagation. Multivariate EOF analysis is based on OLR and zonal
hPa. However, a number of other variables are included in life cycle composites and mean field descriptions. See more specific disc

General: For both level 1 and level 2 metrics, unfiltered anomalies are computed by subtracting the climatological daily (or penta
means calculated using all years of the data. The 20-100 day filtering discussed below is based on applying an 201-points Lanczo
while the EOF analysis is performed on 20-100 day filtered data, the statistical significance of the EOFs is assessed by projecting the
(with only the seasonal cycle removed) back on to the EOFs to ascertain the significance of spectral peaks at intraseasonal time scal
background. Note that when the EOF analysis is applied to models, one can calculate and examine the EOFs of the model data dir
recommended that the bandpass filtered anomalies from the models be projected onto the observed modes of variability to assess
simulates the observed MJO. For these metrics, the seasons have been defined as: 1) boreal summer is May through October, a
November through April. For some metrics, computations are performed for specific domains of interest. These domains are giv
were determined from examination of the VARIANCE MAPS to isolate regions where the observed variability is large. Finally, fo
unless otherwise noted, no windowing/tapering or de-trending was applied.

MJO Diagnostics

General Strategy & Description



Madden Julian Oscillation (MJO) Metrics

An activity led by US CLIVAR and supported by International CLIVAR

Introduction | Description | Observations | Simulations

DESCRIPTION
- LEVEL 1
- LEVEL 2
- OTHER

Description - Level 2 Metrics

1) FREQUENCY-WAVE SPECTRA

a) Using data averaged between 10°N-10°S, separate the data into individual calendar years, remove the time mean from each, frequency-wavenumber for each year of data, and average the results. Figures

b) Same as a), except stratifying by season. Figures

2) COMBINED EOFs.

i) Average the 20-100 day filtered anomalies (all the data, not seasonally stratified) of OLR, u850, and u200 between 15°N-15°S.

ii) Normalize each of three fields separately by the square-root of the zonal mean of their temporal variance at each longitudinal poin

iii) Considering all three fields together, compute the combined EOF of the data. Figures

iv) Compute the variance explained in the normalized data set by each of the EOF modes as well as the variance explained in the (i.e. filtered anomalies) by each of the EOF modes.

v) Compute the variance explained by each of the three input fields for each EOF mode.

vi) Calculate the lag correlation between PC-1 and PC-2 as in level 1 metrics 4a. Figures

vii) Assess the statistical significance of the EOF's as described in General. Figures

viii) Compute the mean coherence^2 and phase of PC-1 and PC-2. Figures

3) LIFE-CYCLE COMPOSITES.

i) Identify MJO events through plots of PC-1 vs. PC-2 from the combined EOFs. Specifically, select points exceeding a root-mean [i.e. $\mathrm{sqrt}(PC\text{-}1^2 + PC\text{-}2^2) > 1$].

ii) Based on a two dimensional phase diagram of PC-1 and PC-2 (Figures), define eight different phases of the MJO and generate spatial composites of the selected points according to these phases. Figures

MJO Diagnostics

Recipe for Calculating Diagnostics

Calculation Codes Available - Need Feedback

Madden Julian Oscillation (MJO) Metrics

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Introduction | Description | Observations | Simulations

OBSERVATIONS
- LEVEL 1
- LEVEL 2
- OTHER

Observations - Level 2 metrics figure tables

1) FREQUENCY-WAVE SPECTRA (see Description)

a) Annual data

OLR	PRCP	U200	U850	Usfc
All season sptectra (with annual cycle)				
AVHRR	CMAP TRMM GPCP	NCEP1 NCEP2 ERA40	NCEP1 NCEP2 ERA40	NCEP1

b) Seasonally stratified data

OLR	PRCP	U200	U850	Usfc
Seasonally stratified spectra (Winter : November to April, without annual cycle)				
AVHRR	CMAP TRMM GPCP	NCEP1 NCEP2 ERA40	NCEP1 NCEP2 ERA40	NCEP1
Seasonally stratified spectra (Summer : May to October, without annual cycle)				
AVHRR	CMAP TRMM GPCP	NCEP1 NCEP2 ERA40	NCEP1 NCEP2 ERA40	NCEP1

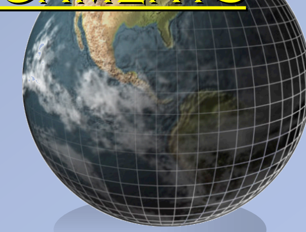
2) COMBINED EOFs (see Description)

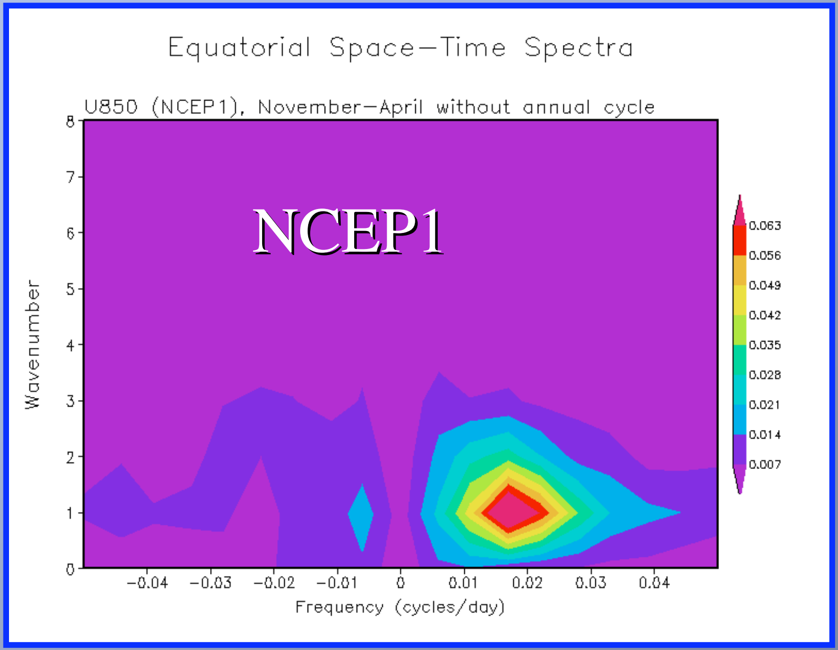
a) Combined EOFs

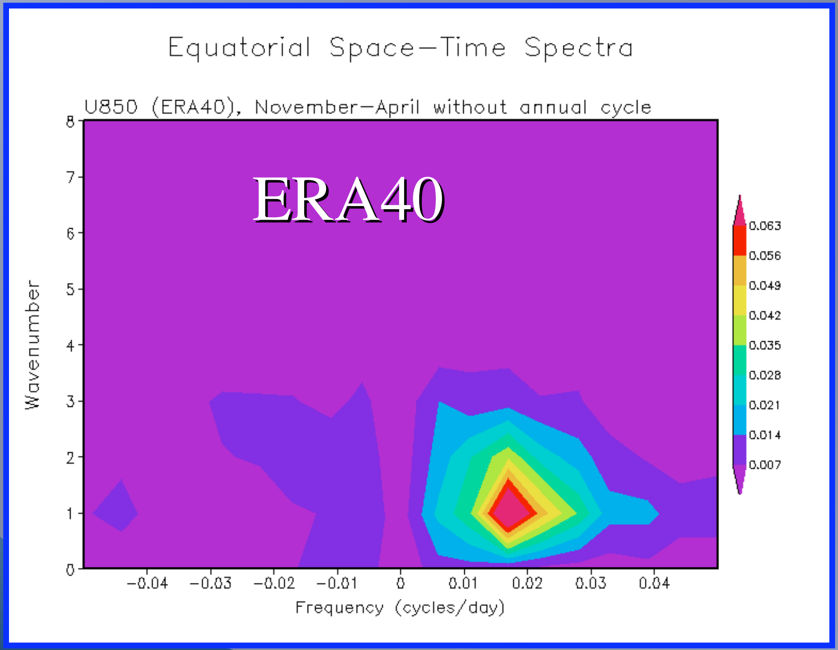
MJO Diagnostics

Plan To Make The Actual Map/Plot Data Available

Summarize Results in a Journal Article - About To Divide Writing Assignments



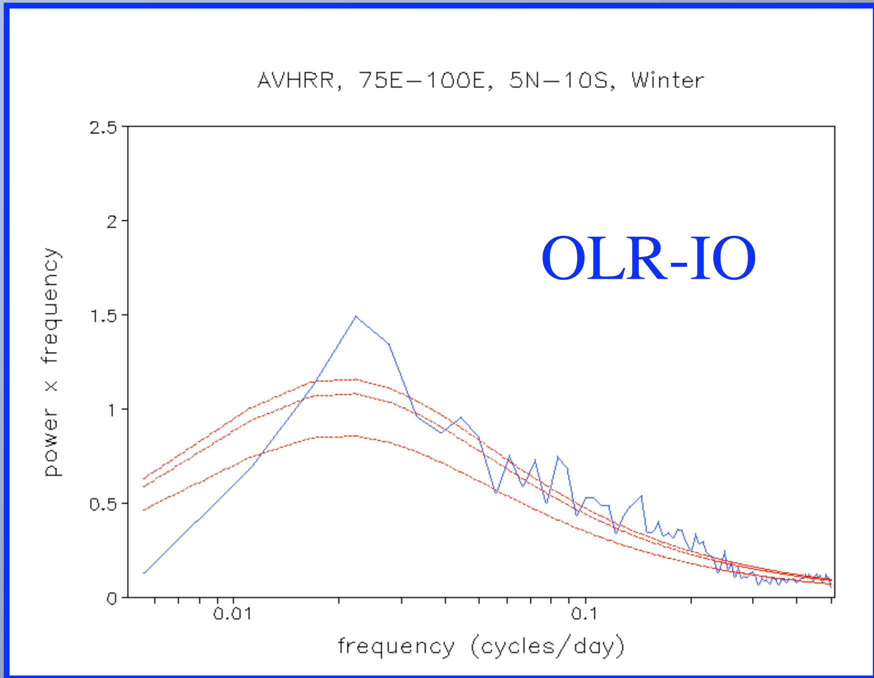


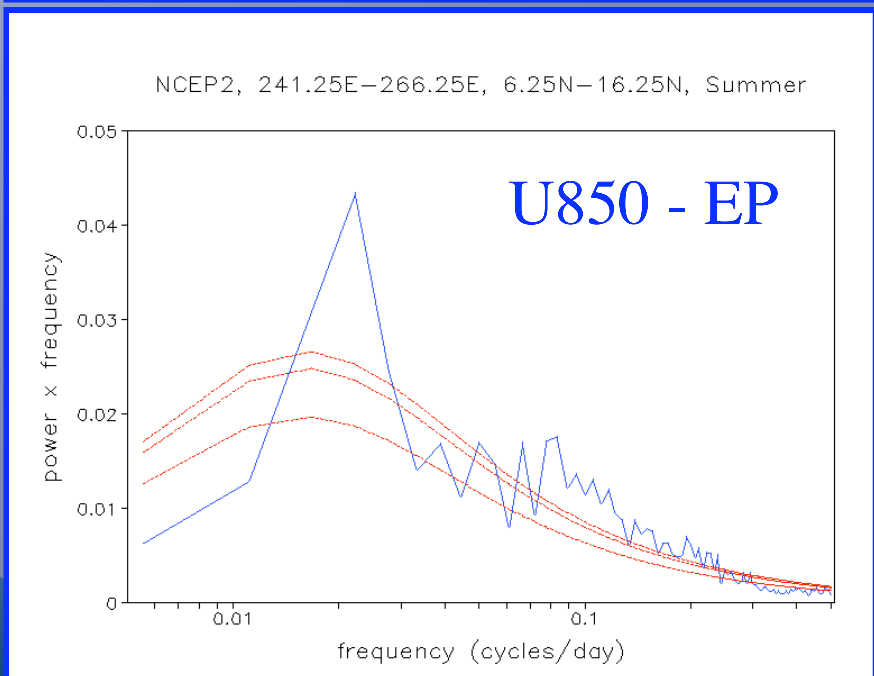


MJO Diagnostics

Equatorial Space-Time Spectra U, Rain, OLR

NCEP1, NCEP2, & ERA40





MJO Diagnostics

Time Series Spectra U, Rain, OLR

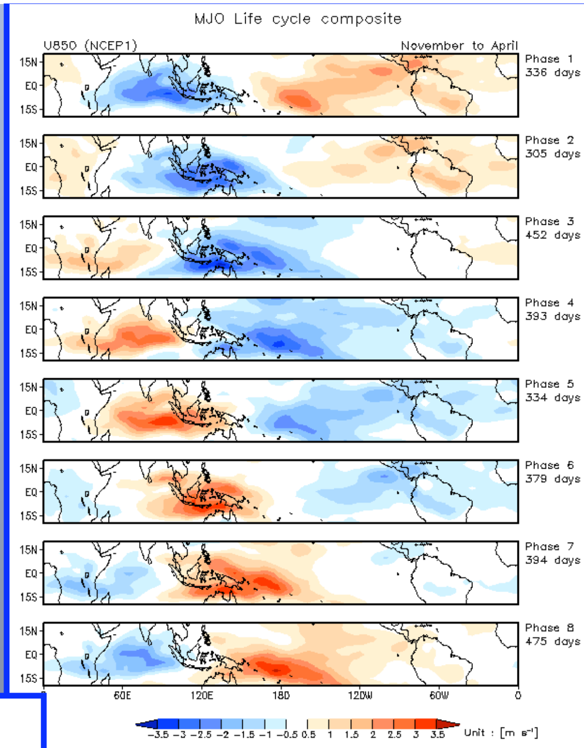
Domains of Interest

Table 1. Domains for time series power spectra metrics

	OLR	Precipitation	u_{850}	u_{200}
	Boreal Winter (November to April)			
IO	10S-5N, 75-100E	10S-5N, 75-100E	1.25°S-16.25°S, 68.75°E-96.25°E	3.75N-21.25N, 56.25E-78.75E
WP	20S-5S, 160E-185E	20S-5S, 160E-185E	1.25°N-13.75°S, 163.75°E-191.25°E	3.75N-21.25N, 123.75E-151.25E
MC	2.5S-17.5S, 115-145E	2.5S-17.5S; 115-145E		
EP				1.25N-16.25S, 256.25E-278.75E
	Boreal Summer (May to October)			
IO	10S-5N, 75-100E	10S-5N, 75-100E	21.25°N-3.75°N, 68.75°E-96.25°E	1.25°N-16.25°S, 43.75°E-71.25°E
BB	10-20N, 80-100E	10-20N, 80-100E		
WP	10-25N, 115-140E	10-25N, 115-140E	3.75°N-21.25°N, 118.75°E-146.25°E	3.75N-21.25N, 123.75E-151.25E
EP			6.25N-16.25N, 241.25E-266.25E	1.25°N-16.25°S, 238.75E-266.25E

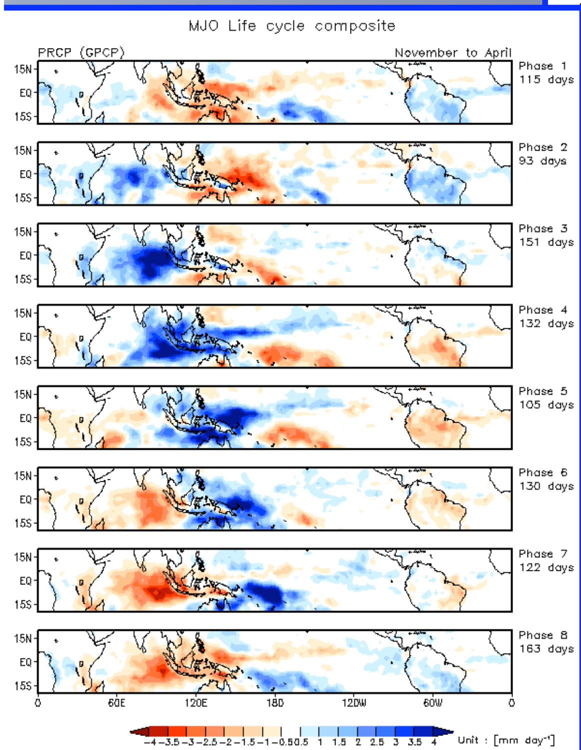
MJO Diagnostics

Life-Cycle Composites
U, Rain, OLR, SLP, SF



U850

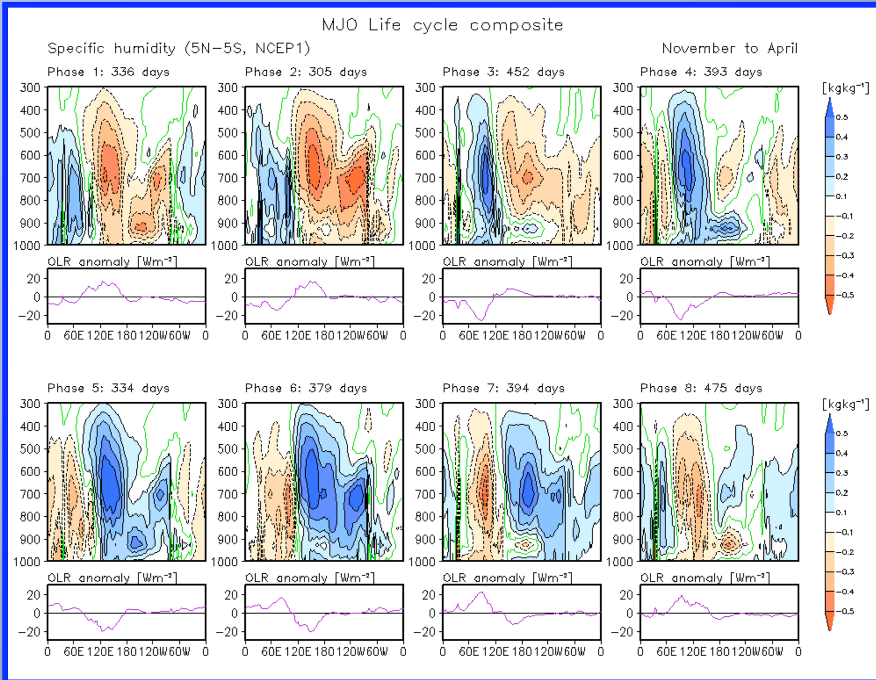
Rainfall



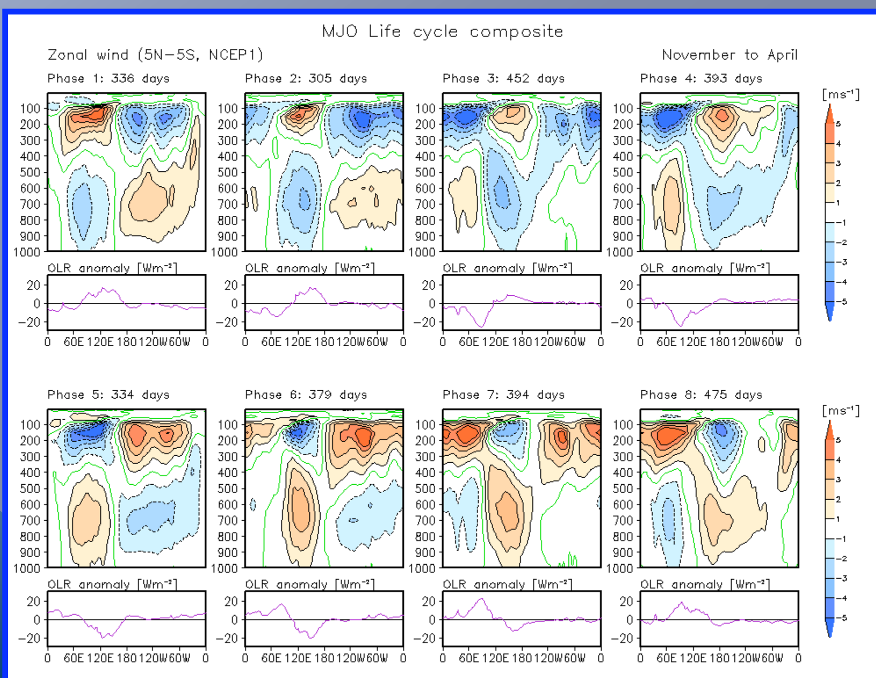
<u>Satellite Rain/Cloud</u>: AVHRR, GPCP, TRMM
<u>Analysis Data:</u> NCEP1,NCEP2

MJO Diagnostics

Life-Cycle 3D Composites T, Q, U, W



Specific Humidity (x,p)

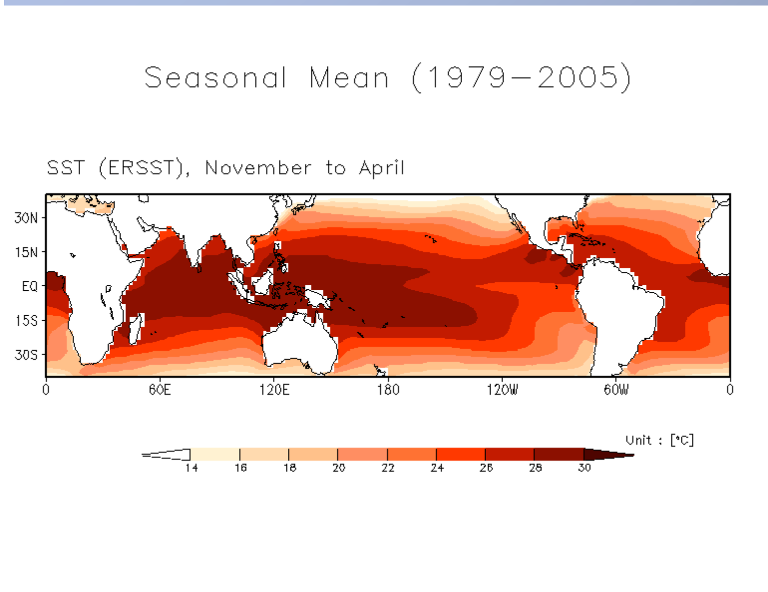


Zonal Wind (x,p)

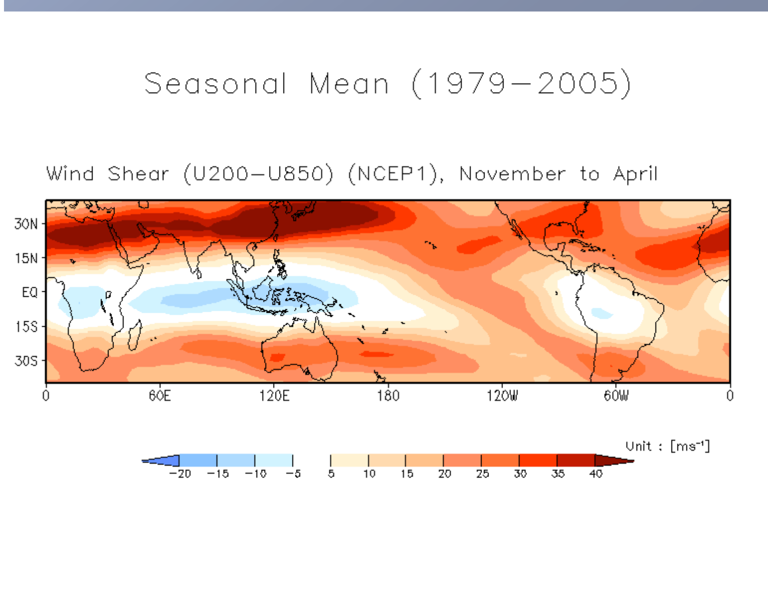
MJO Diagnostics

Important Mean State Quantities

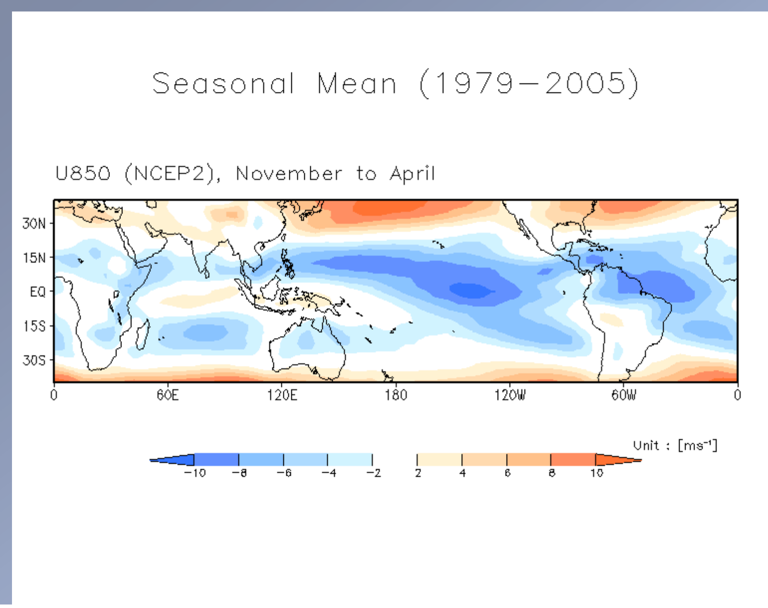
Mean SST



Mean Zonal Wind Shear



Mean 850 hPa Zonal Wind



Application of MJO Diagnostics to GCMs

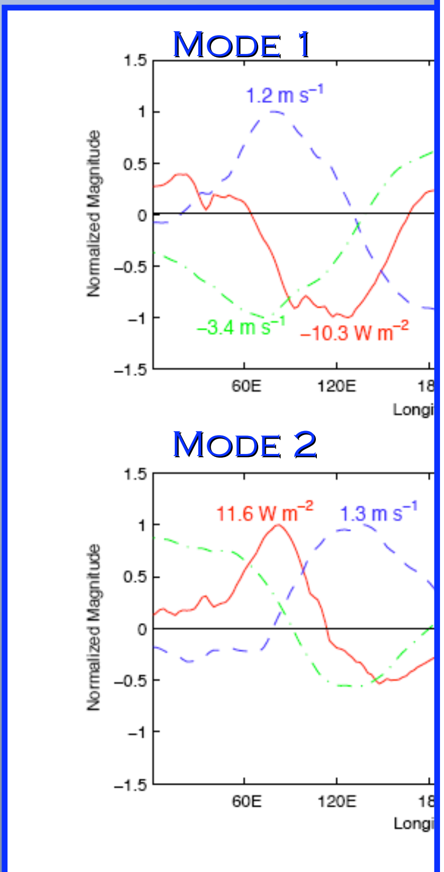
Undertaking a uniform application of MJO diagnostics to a number of contemporary GCMs. D. Kim has agreed to undertake the analysis and we plan to present these results at the MJO Workshop and write up the results into a journal article. The GCMs and associated institution leads are:

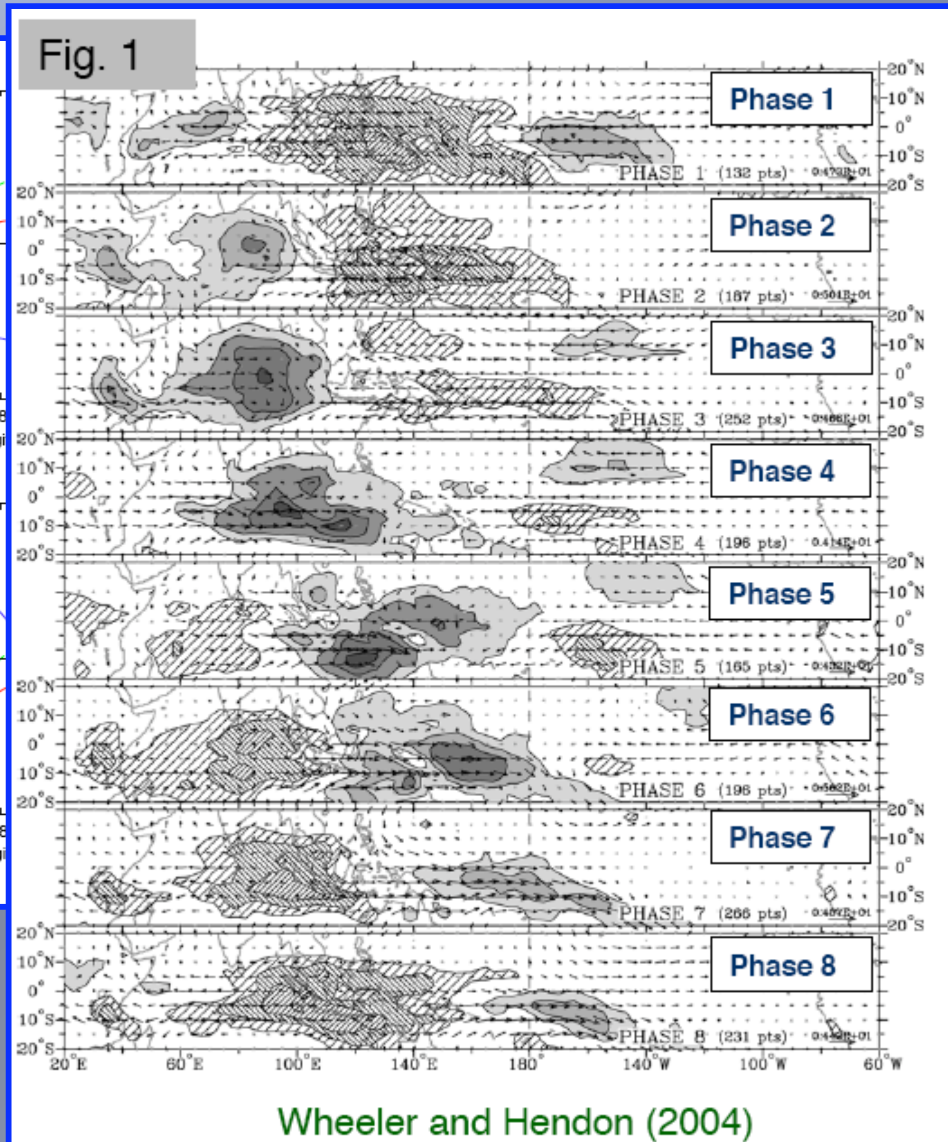
- GEOS-5 - S. Schubert/M.I. Lee
- GFDL - W. Stern
- NOAA-CFS - W. Wang
- CSU/superparam - M. Khairoutdinov
- Echam4/OPYC - K. Sperber
- SNU - I.S. Kang
- NCAR - R. Neale

Developing MJO Forecast Metrics/Diagnostics

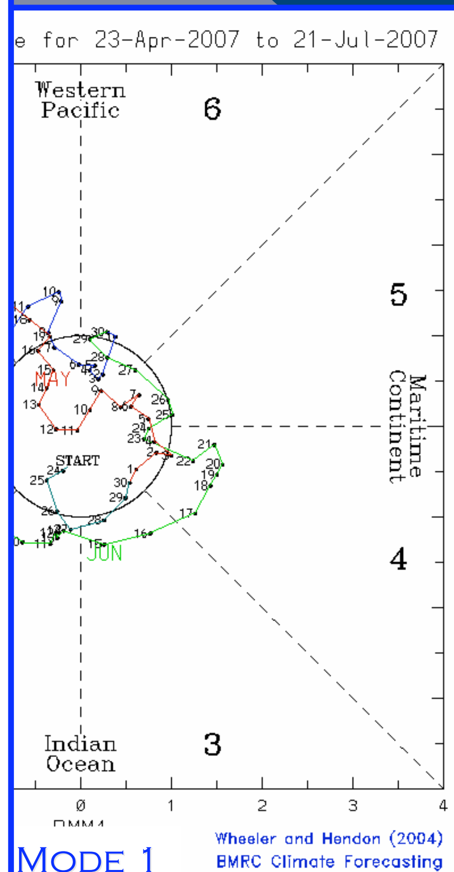
- Discussions to date have led to the adoption of the so-called Wheeler-Hendon combined EOF (u200, u850, OLR) index.
- A number of centers (BMRC, NCEP, ECMWF, UKMO, CMA) are using this operationally.
- We (i.e. K. Weickmann) are beginning to acquire these indices in real-time to post on the Experimental MJO Prediction website as a proof-of-concept.
- We may move this acquisition/dissemination process to CPC/NCEP via W. Higgins/J. Gottshalck.
- Our plans are eventually to produce a multi-model ensemble (MME) of these values. Standard calculations need to be agreed upon in order to properly implement and interpret this MME measure.
- We expect/hope that this may lead to a journal article.
- Additional measures, particularly applicable to the Asian Monsoon may be needed.

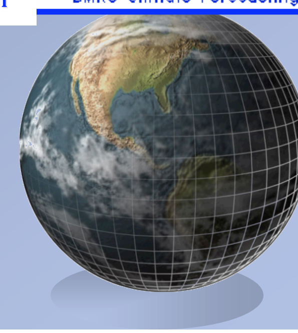
Developing MJO Forecast Metrics/Diagnostics





Wheeler and Hendon (2004)





New Approaches to Understanding, Simulating, and Forecasting the Madden-Julian Oscillation

November 5-7, 2007

Beckman Center of the National Academies, Irvine, CA

DRAFT

BACKGROUND: The Madden-Julian Oscillation (MJO) has persistently posed great challenges in our ability to understand, simulate, and forecast it. The US CLIVAR MJO Working Group was formed in 2006 to address some of these challenges. Building upon a series of workshops on the subject of the MJO, the MJO Working Group has organized this workshop to discuss new thinking and approaches that may help meet the MJO challenges in the context of weather-climate connections by the means of integrative approaches of observations, modeling, and theories.

OBJECTIVES: (1) Introduce to the MJO research and forecast communities new diagnostics designed to systematically and consistently evaluate model performance of simulating and forecasting the MJO. (2) Identify key unknowns that might be crucial to MJO simulations and forecast. (3) Propose new initiatives of innovative and integrative approaches to tackle the problems associated with understanding, simulating and forecasting the MJO.

FORMAT: This is an invitation-only workshop. The focal point of the workshop is the poster and discussion sessions. A few keynote talks will provide overviews, introduce new tools and new thinking, and stimulate discussions. Posters will be grouped based on theme, and they will be kept up during most of the workshop period. Interactions of the MJO with other components of the weather and climate system are considered important to this workshop only if they are crucial to understanding, simulating, and forecasting the MJO itself. Participants are encouraged to present posters on any topics relevant to the workshop objectives.

EXPECTED OUTCOME: Identify research opportunities and teams, integrative approaches, and coordination mechanisms necessary to accelerate (a) model improvement, development and assessment, (b) integration of existing and future observations, and (c) innovative modeling experiments associated with understanding, simulating and forecasting the MJO

MJO Workshop

Monday, November 5, 2007 ; MJO DIAGNOSTICS/METRICS

07:30-08:30 Breakfast

08:30-08:40 Opening Remarks

- Duane Waliser/Jill Reisdorf/Cathy Stephens, Welcome and Logistics
- David Legler, US CLIVAR
- Program Manager/Other Support, TBD

Session 1: Diagnostics and Models, Frederic Vitart, Chair

08:40-09:15 Ken Sperber, PCMDI, US CLIVAR MJO Simulation Diagnostics

09:15-09:40 Daehyun Kim, SNU, Application of Diagnostics to Models – Part 1

09:40-10:05 Eric Maloney, OSU, Application of Diagnostics to Models – Part 2

10:05-11:00 Poster viewing and coffee break

11:00-12:00 Discussion Led by Chair

12:00-13:30 Lunch break (lunch served from 12:00 to 13:00)

Session 2: Forecasting Metrics, Matt Wheeler, Chair

13:30-14:05 Klaus Weidkmann, ESRL/NOAA, New Forecasting Diagnostics

14:05-14:30 Frederic Vitart, ECMWF, Operational Perspective and Model Evaluation/Sensitivities

14:30-14:55 Augustin Vintzileos, NCEP/NOAA – Operational Perspective and Model Evaluation/Sensitivities

14:55-16:00 Coffee and poster viewing

16:00-17:00 Discussion

18:00-21:00 Reception, TBD

Tuesday, November 6, 2007 ; VERTICAL AND MULTI-SCALE STRUCTURE

07:30-08:30 Breakfast

Session 3: Vertical Structure, Chidong Zhang, Chair

08:30-09:05 George Kiladis, ESRL/NOAA, Overview

09:05-09:30 Graeme Stephens, CSU, CloudSat and the A-Train

09:30-09:55 W.K. Tao, GSFC/NASA, Latent Heating Estimates from TRMM

09:55-11:00 Coffee and poster viewing

11:00-12:00 Discussion

12:00-13:30 Lunch break (lunch served from 1200 to 1300)

MJO Workshop

Session 4: Theory and Modeling, Harry Hendon, Chair

13:30-14:05 SUGGESTED/TBD: Andy Majda, NYU, Multi-scale analytic modeling

14:05-14:25 Richard Neale, NCAR Improved parameterization in CAM

14:25-14:45 TBD

14:45-16:00 Coffee and poster viewing

16:00-17:00 Discussion

<u>Wednesday, November 7, 2006 : INTEGRATIVE MODELING APPROACHES</u>

07:30-08:30 Breakfast

Session 5: Existing and Planned Efforts, Siegfried Schubert, Chair

08:30-09:05 Dave Randall, CSU, Multi-scale modeling

09:05-09:30 Steve Klein, LLNL/DOE, Initial value approach.

09:30-09:55 Mitch Moncrieff, NCAR, Multi-scale modeling at NCAR

09:55-11:00 Coffee and poster viewing

11:00-12:00 Discussion

12:00-13:30 Lunch break (lunch served from 1200 to 1300)

Session 6: New Initiatives and Future Steps, Mitch Moncrieff, Chair

13:30-14:00 Steve Woolnough, NERC Cloud/MJO Modeling Initiative

14:00-14:15 Dick Johnson, Upcoming and Needed Field Campaigns

14:15-14:30 Duane Waliser; Year of Tropical Convection

15:30-15:45 Coffee break

15:45-16:30 Wrap-up and next steps

16:30 Adjourn

MJO Workshop

Invitations To Be Sent This Week

Goals/Progress: Summary

1) Develop MJO WG Web Site. Done, Some Additions - Diagnostics Link, Meeting/Telecon Updates, Theme Pages
2) Diagnostics for Asessing Model Simulations of the MJO. ~Done, May still try to include codes and data sets
3) Diagnostics Application to Models. Just Beginning, GCMs and partners identified and data being gathered, Analysis by Kim.
4) Prediction Targets and Metrics for MJO Forecasts. Under Discussion, ~50% Done
5) Workshop/Experimentation Planning. Underway