The Abdus Salam International Centre for Theoretical Physics

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Description of an MJO forecast metric.

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Description of an MJO Forecast Metric

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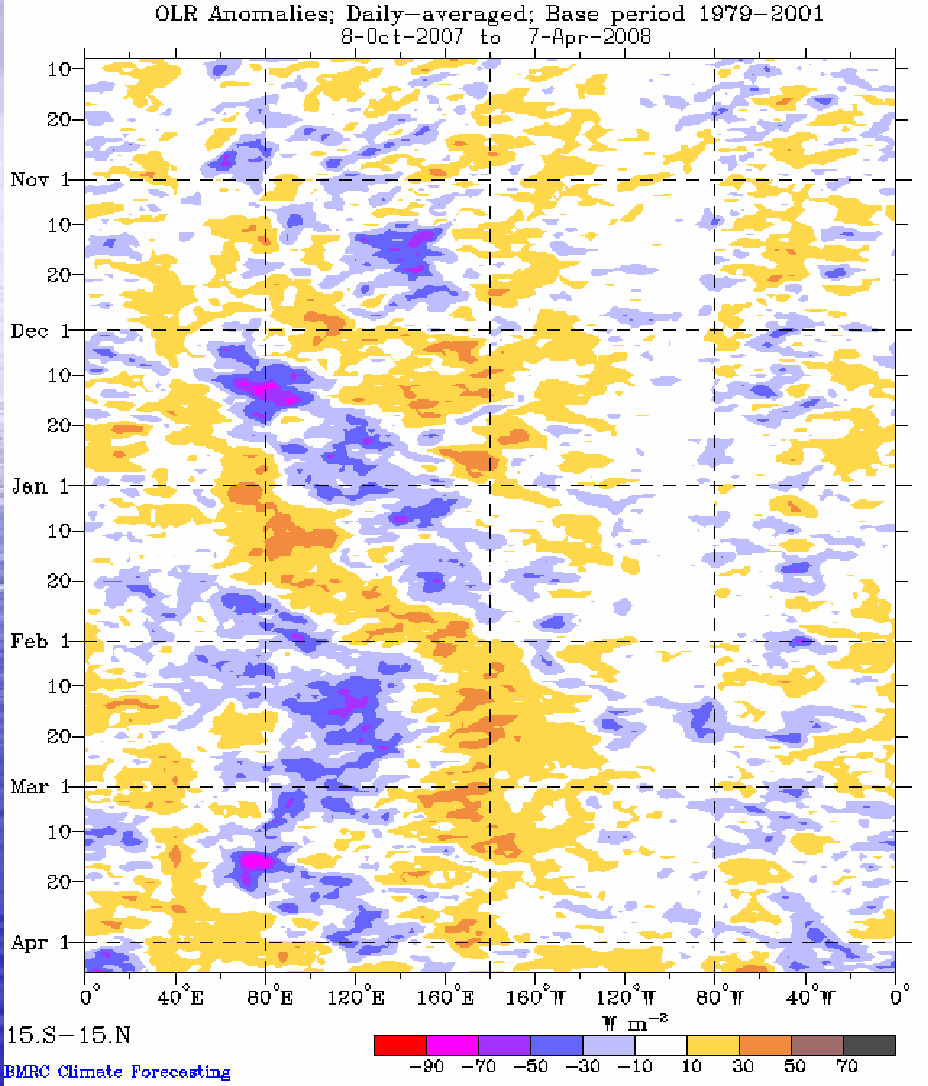
With significant contributions from the U.S.-CLIVAR MJO Working Group and others……

Plan for this talk

1. Motivation for development of chosen forecast metric
2. Wheeler-Hendon combined EOF metric: Derivation and properties
3. Example applications to observed data
4. Example applications to forecast models
5. Some caveats/issues
6. The specific US-CLIVAR/WGNE recipe for forecast models
7. Forecast verification and a statistical benchmark

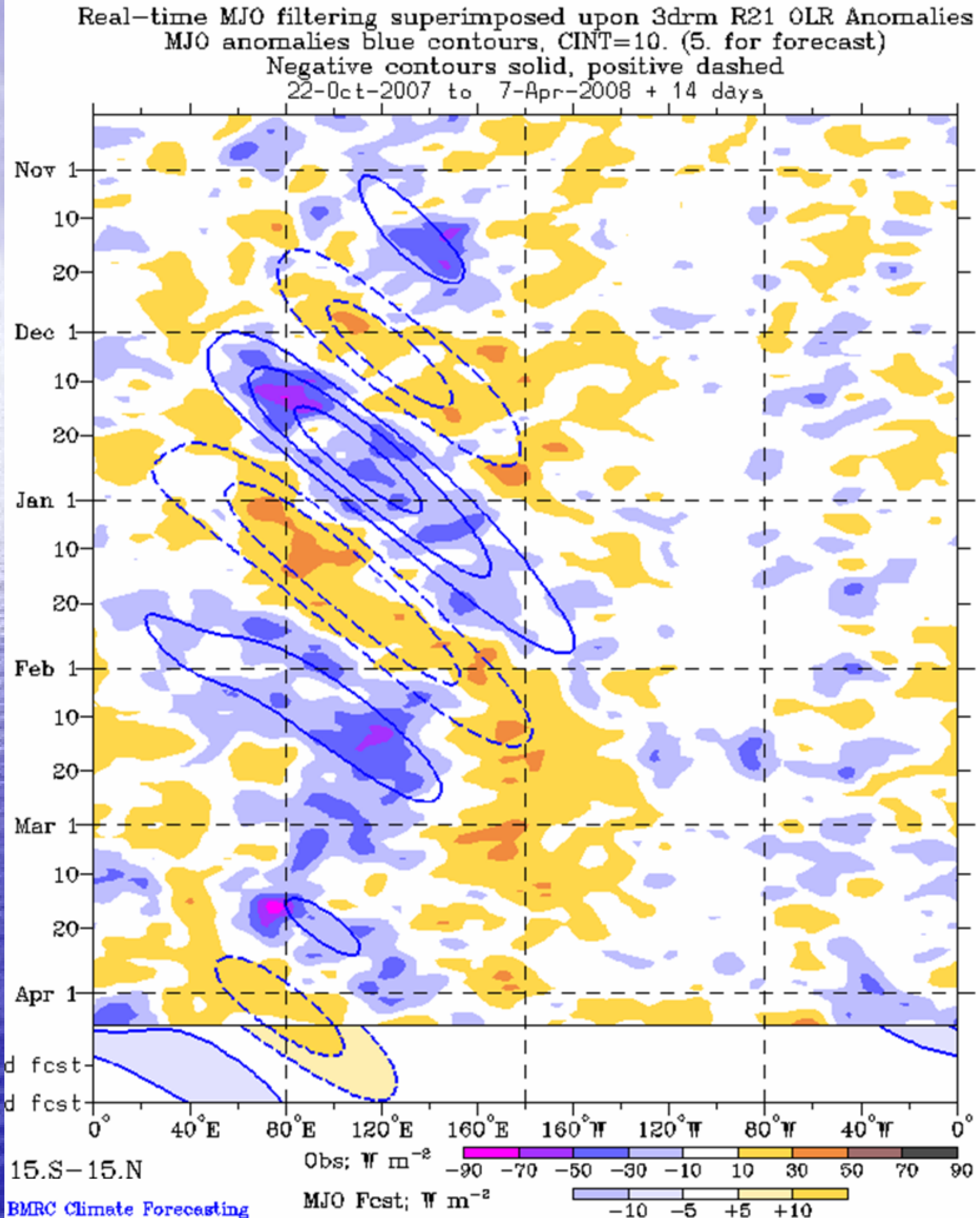
1. Motivation for development of chosen forecast metric



Detection of the MJO has traditionally been performed by examination of time-longitude diagrams of a single field (e.g. OLR or zonal wind).

But with this approach, difficulty sometimes arises in determining the approximate state or phase of the MJO, especially near the end-points of the data.

MJO filtering: eastward waves 1-5, periods 30-90 days



Band-pass time filtering helps for providing a more precise MJO phase in continuous data.

But still there is uncertainty near the end-points, and if applied to model forecasts, an ambiguous spread of forecast information across time occurs.

This lead us to consider: Can an appropriate MJO index be derived with only daily, non-time-filtered, data?

Yes, by using multiple fields (satellite OLR and winds at multiple levels) to better extract the MJO signal from the noise.

Such an index allows for the unambiguous determination of the MJO in real-time, and is readily applied to forecast model output as well.

2. Wheeler-Hendon (WH04) combined EOF metric: Derivation and properties

Building on much previous research, we applied Empirical Orthogonal Function (EOF) analysis to observed data in the Tropics.

(e.g. Lau and Chan 1985; Knutson and Weickmann 1987; Maloney and Hartmann 1998; Slingo et al. 1999; Matthews 2000)

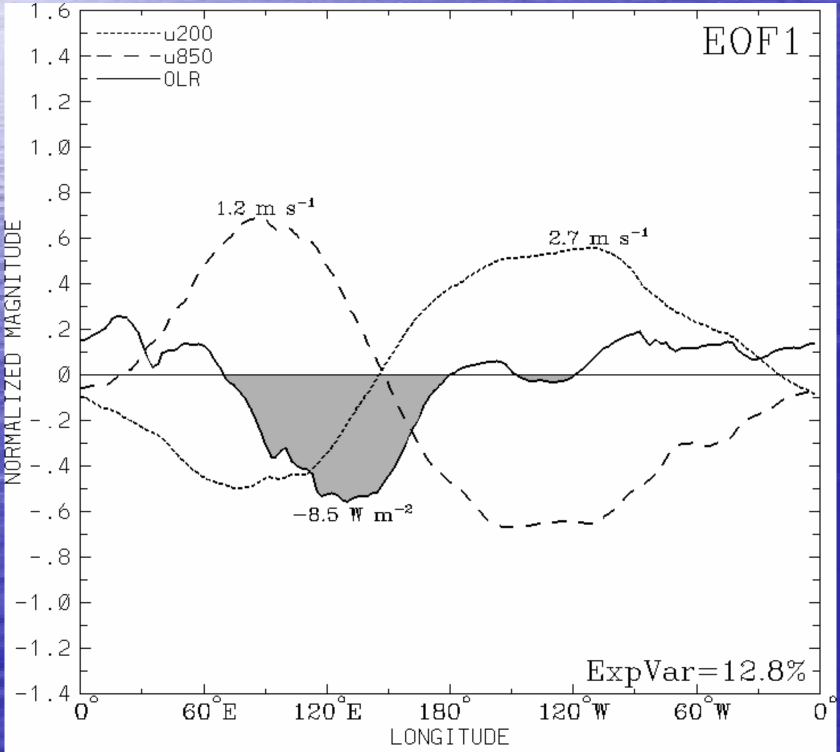
However, instead of applying EOFs to a single field of bandpass filtered data, we applied it to unfiltered data with multiple fields combined.

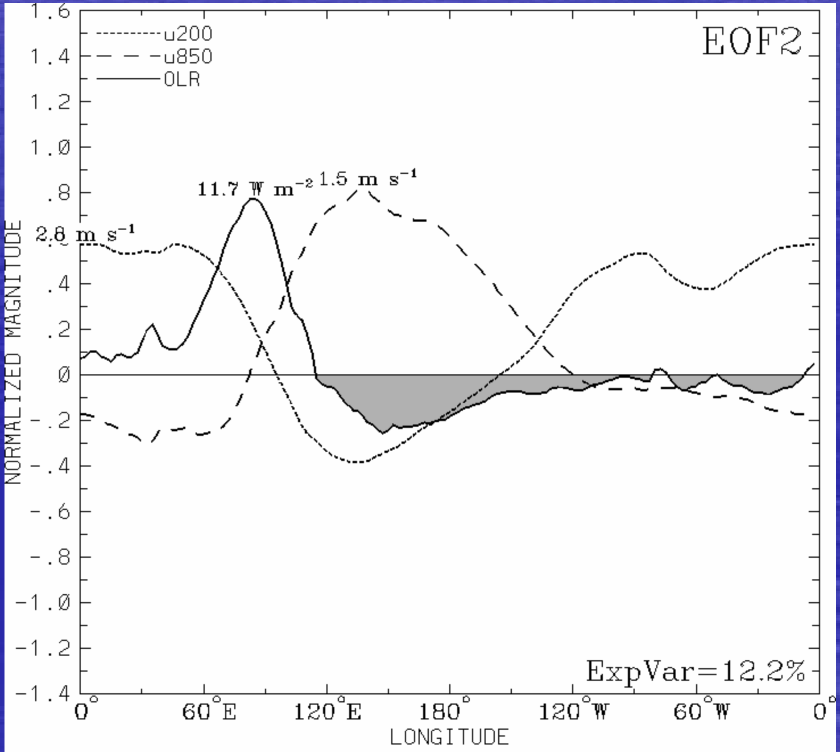
In particular, fields chosen were:

15°S-15°N averaged OLR, u850, and u200.

Only minimal prior removal of lower-frequency variability (e.g. ENSO) was required.

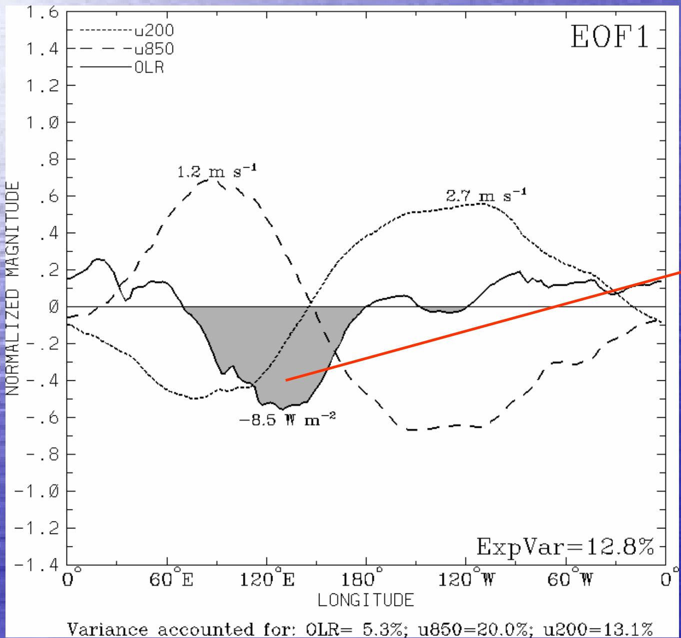
Computed using all seasons of data.

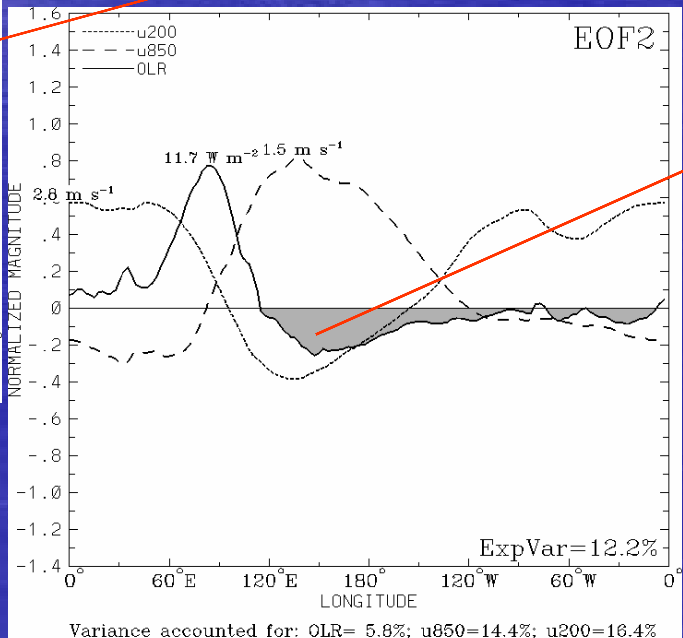


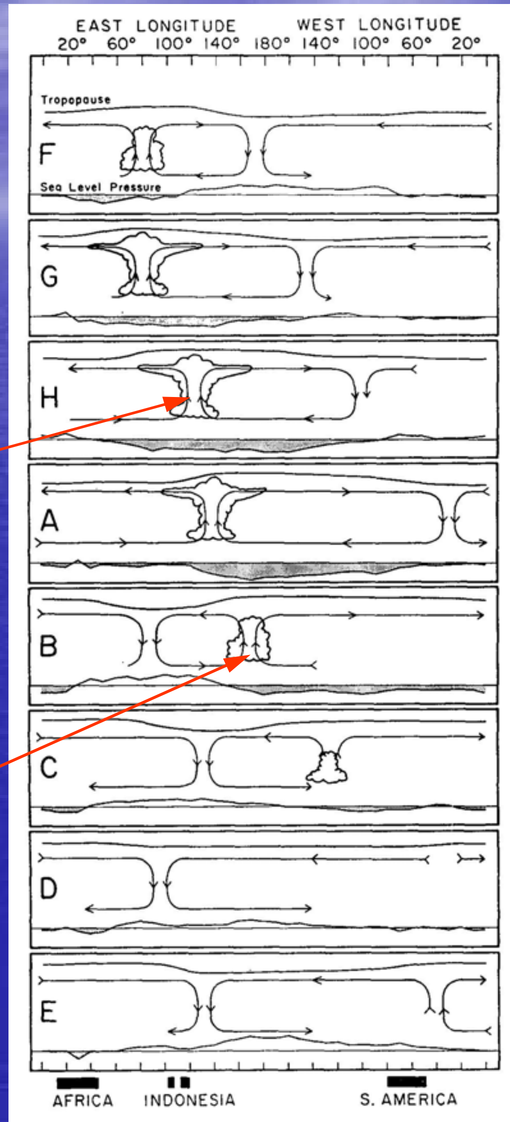


Wheeler and Hendon (Mon. Wea. Rev., 2004)

The EOFs describe the convectively-coupled vertically-oriented circulation cells of the MJO that propagate eastward along the equator.

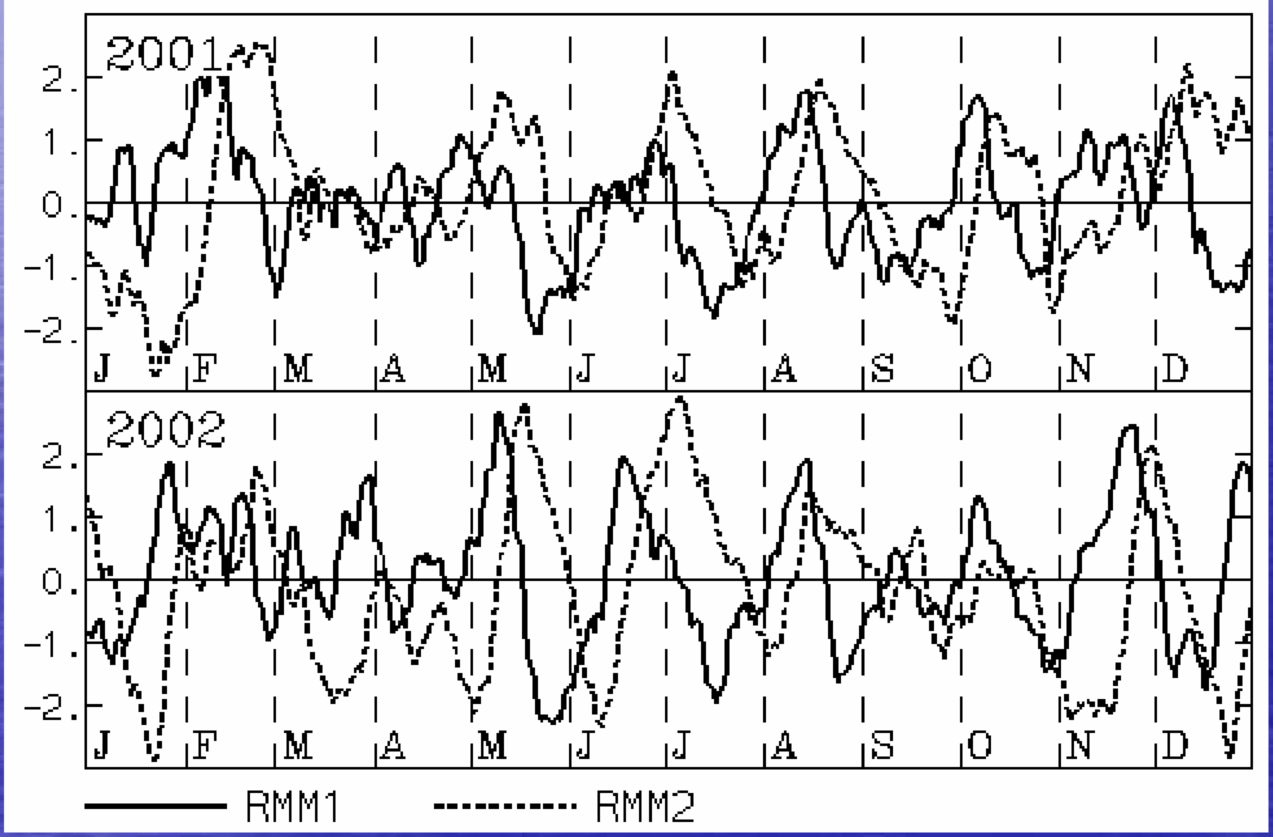






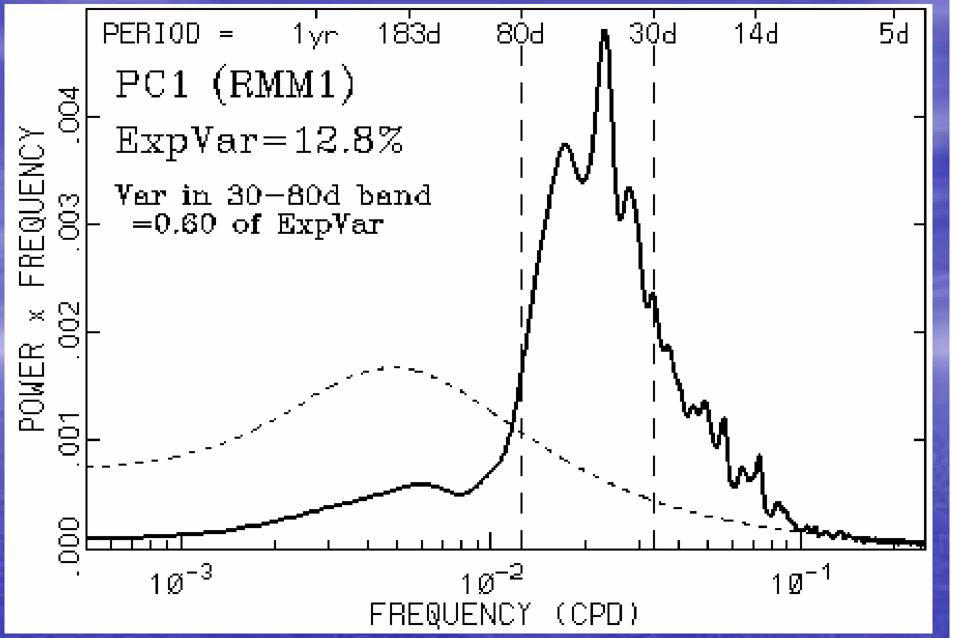
Madden and Julian (1972)

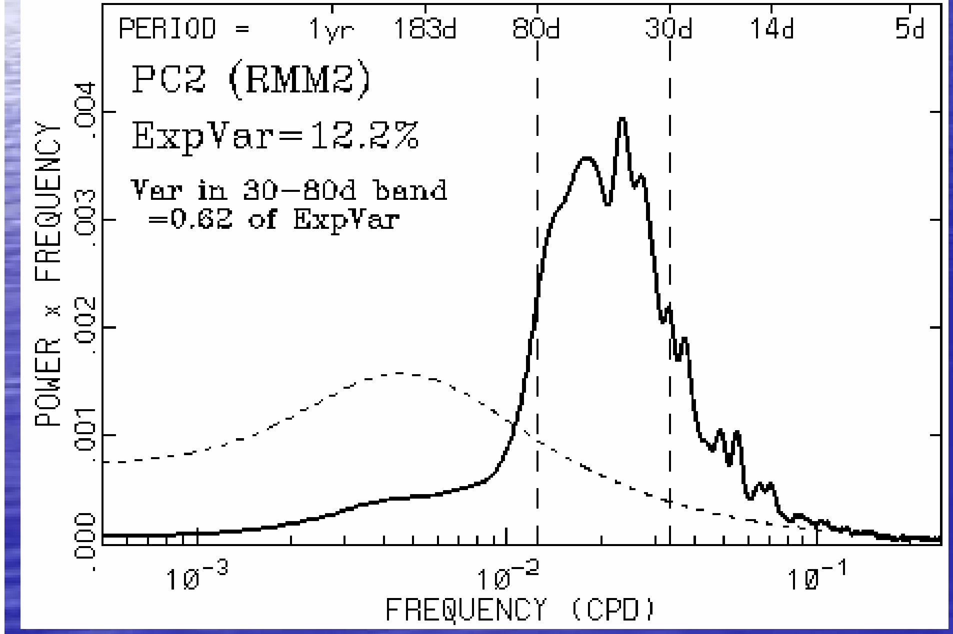
The time-series coefficients associated with each EOF vary mostly on the time-scale of the MJO only, and are in approximate quadrature for eastward propagation.

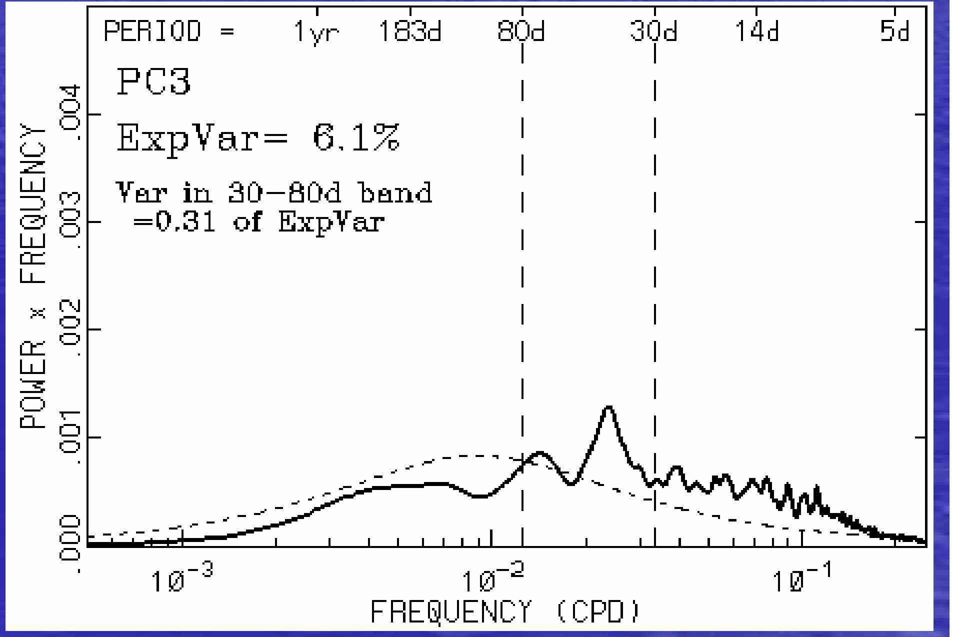


We call them Real-time Multivariate MJO 1 (RMM1), and RMM2.

Power spectra confirm the dominance of the MJO in the leading pair of EOFs (but not in the 3rd EOF).

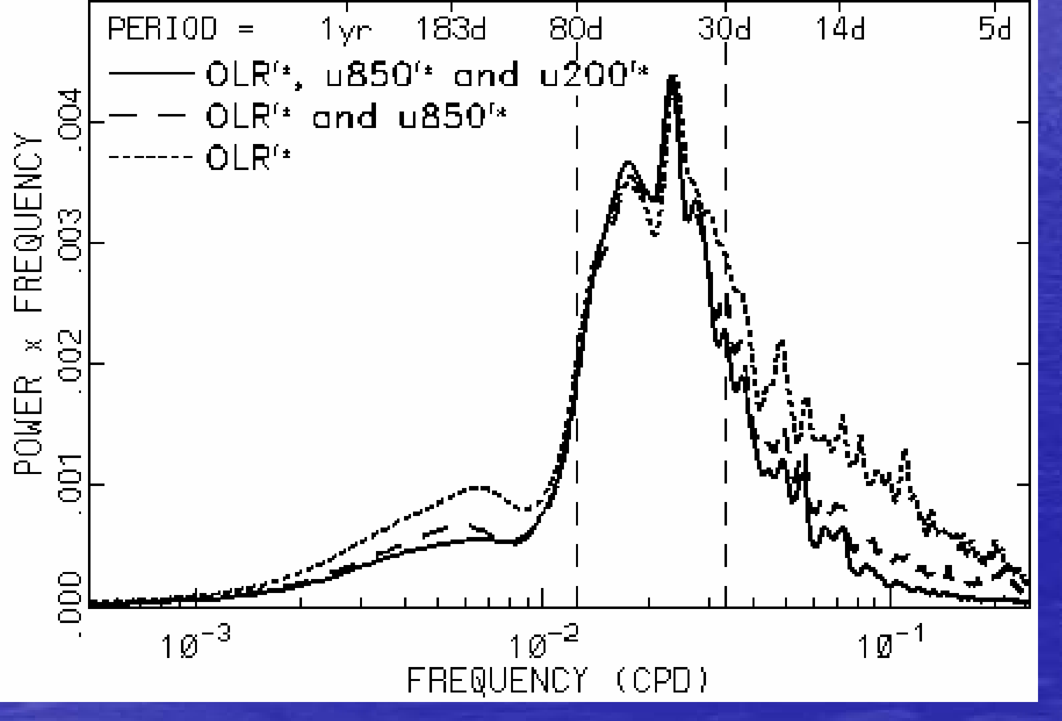






.....and our testing reveals that this dominance of the MJO is helped by the use of multiple fields.

Mean power spectra of leading PCs for three different EOF analyses



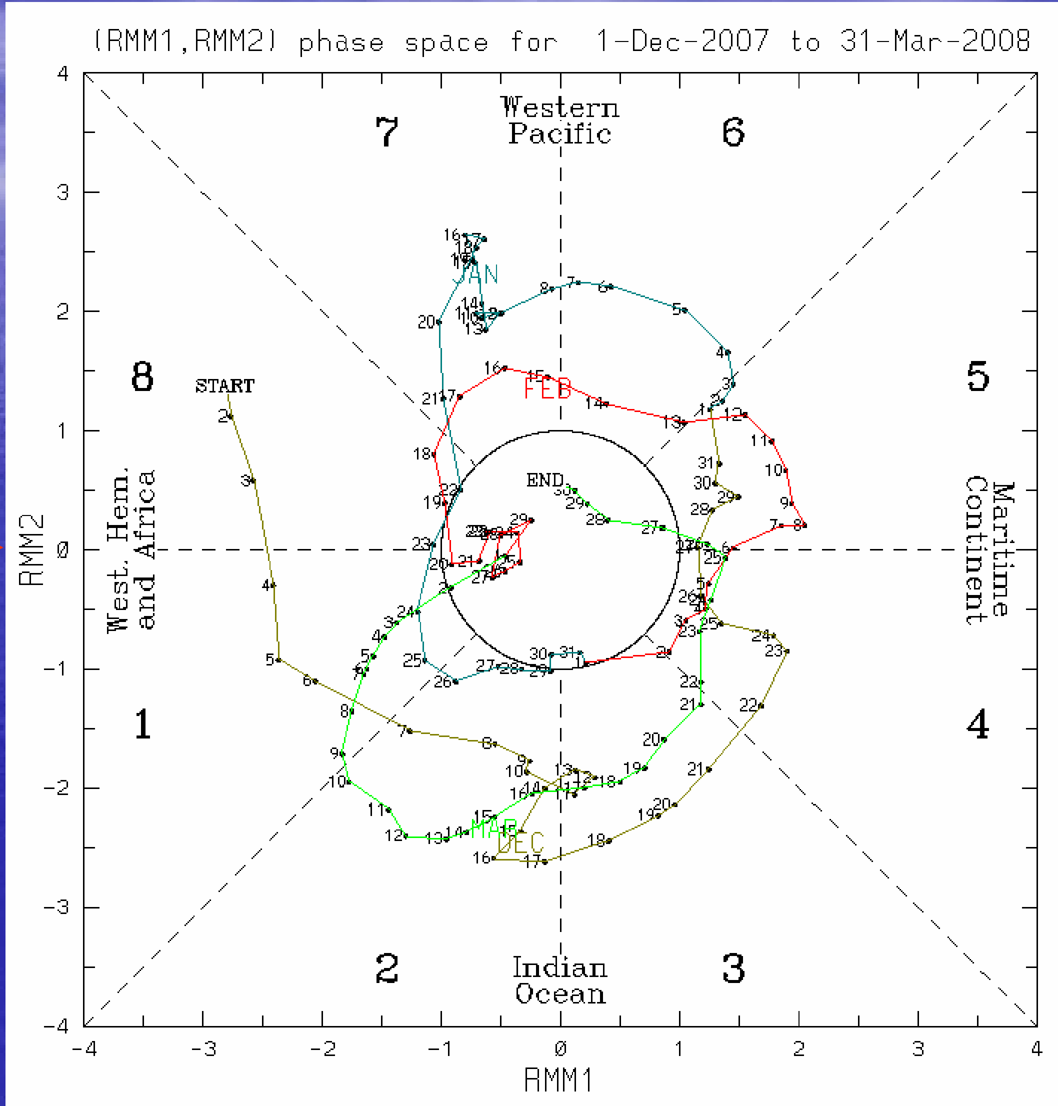
3. Example applications to observed data

Defining an MJO phase space

Define MJO Phases 1-8 for the generation of composites and impacts studies.

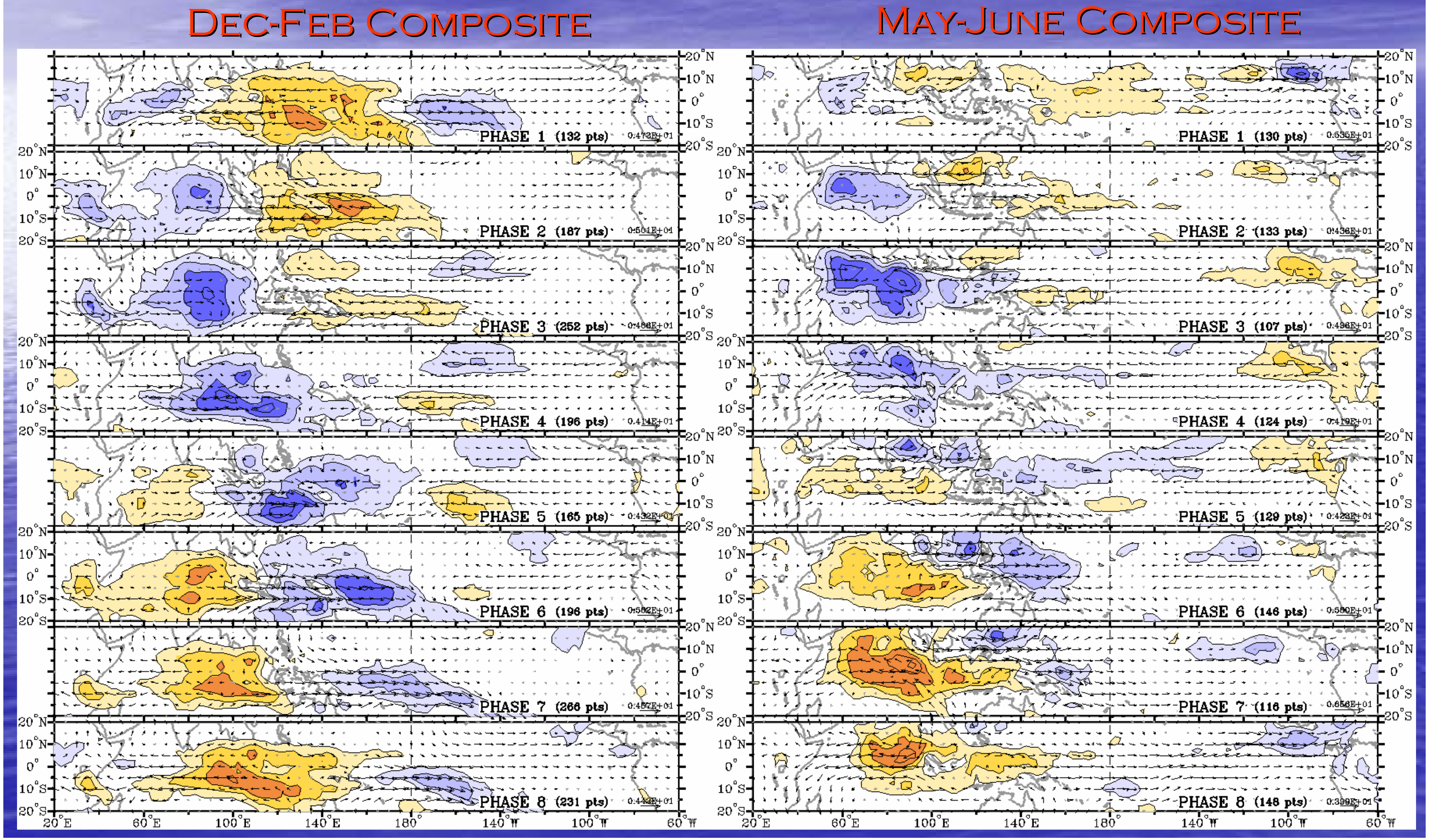
'Weak MJO' when amplitude < 1.0

PROJECTION ON EOF2

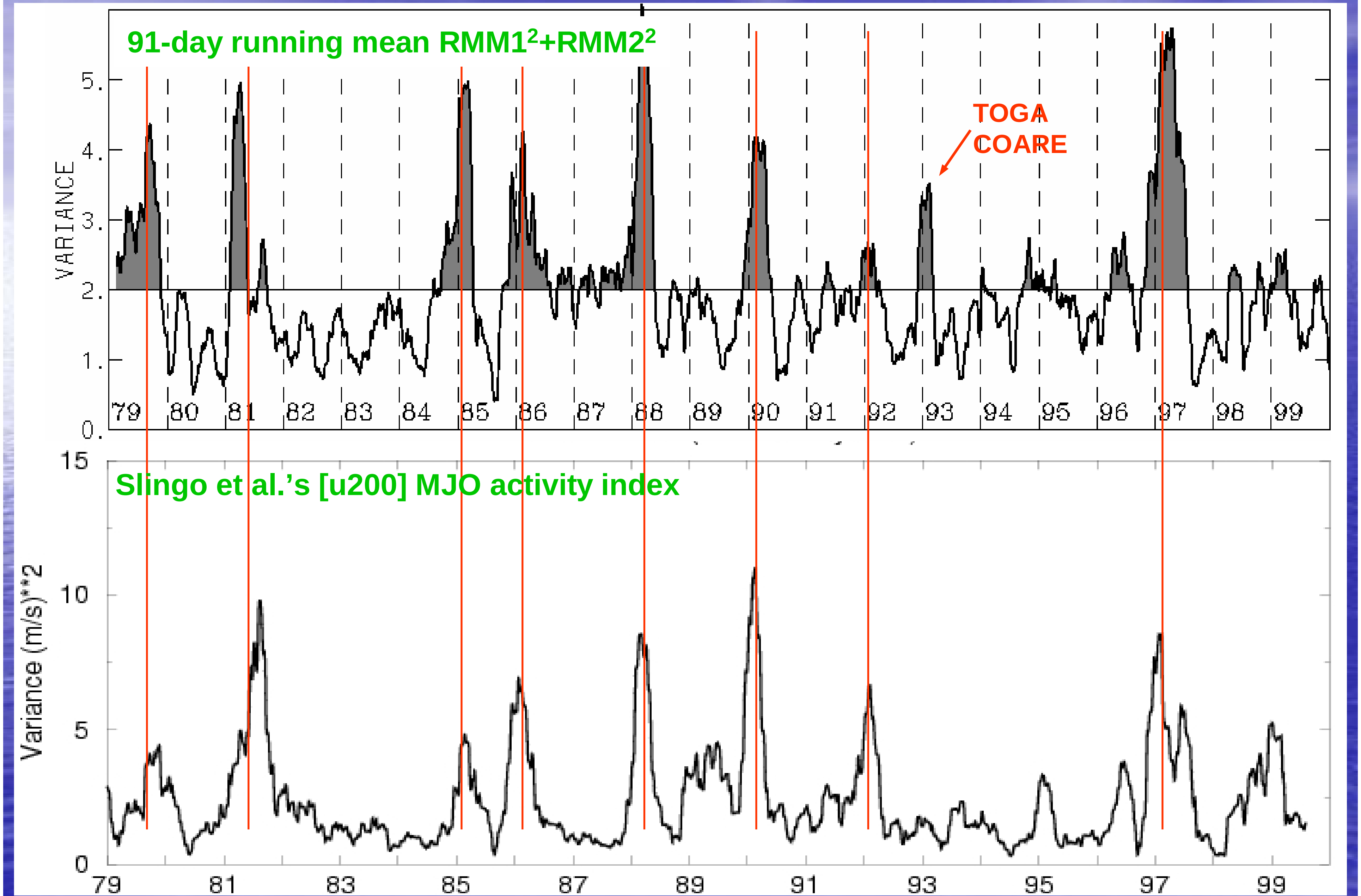


PROJECTION ON EOF 1

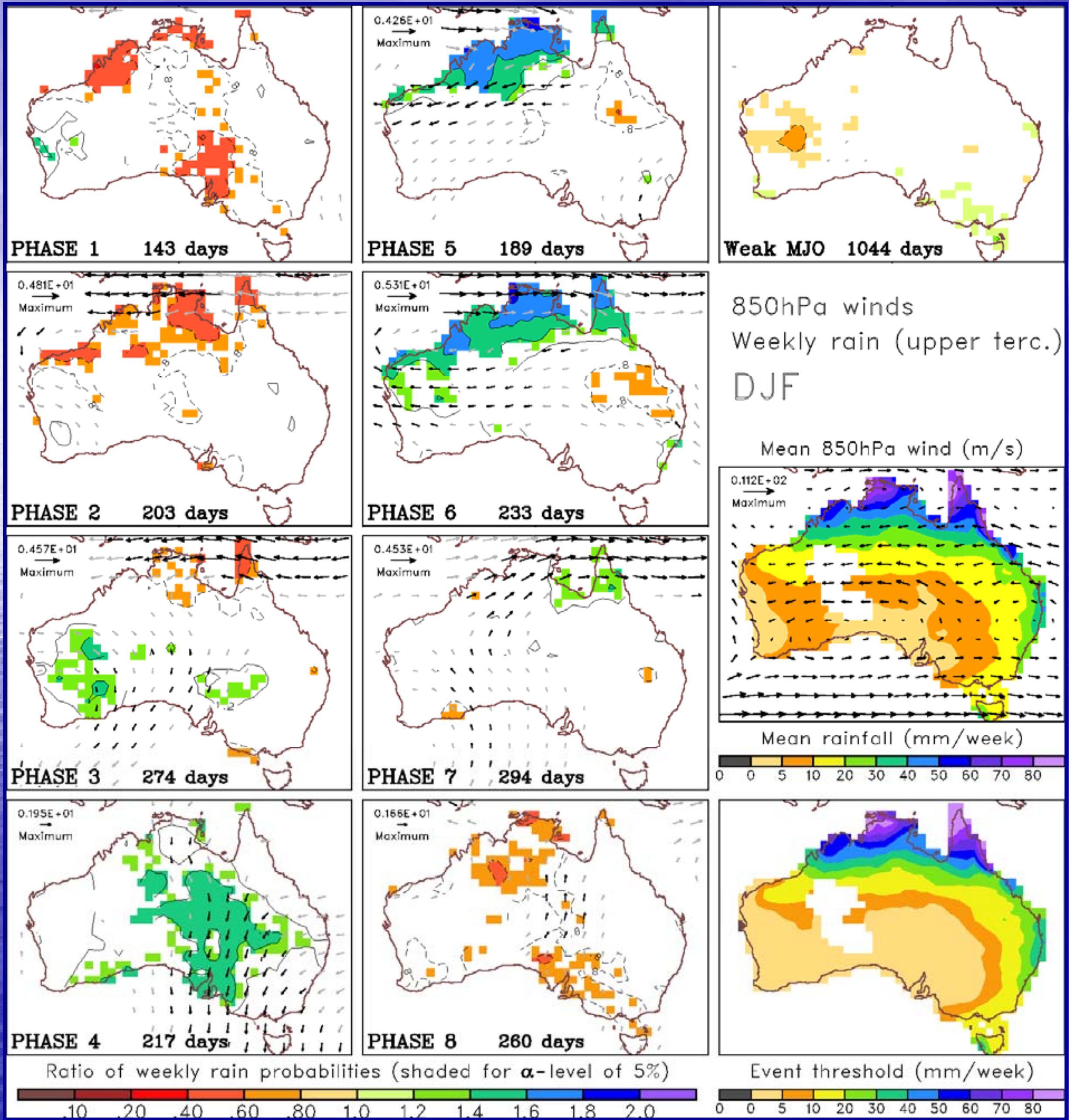
Composites for different seasons demonstrate that the all-season index still captures the strong seasonality exhibited by the MJO.



Interannual modulation of the MJO amplitude/variance



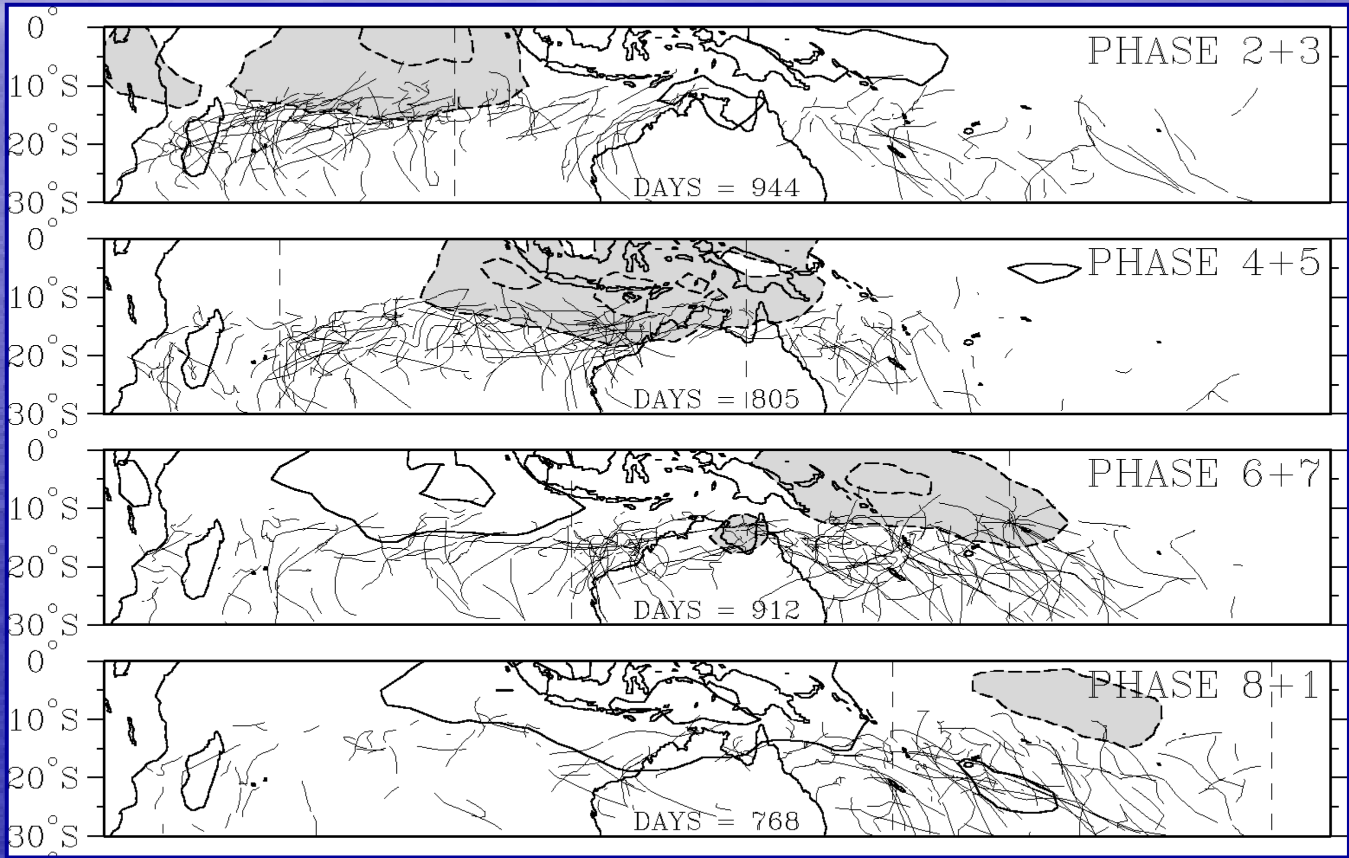
Impacts on rainfall and extreme weather



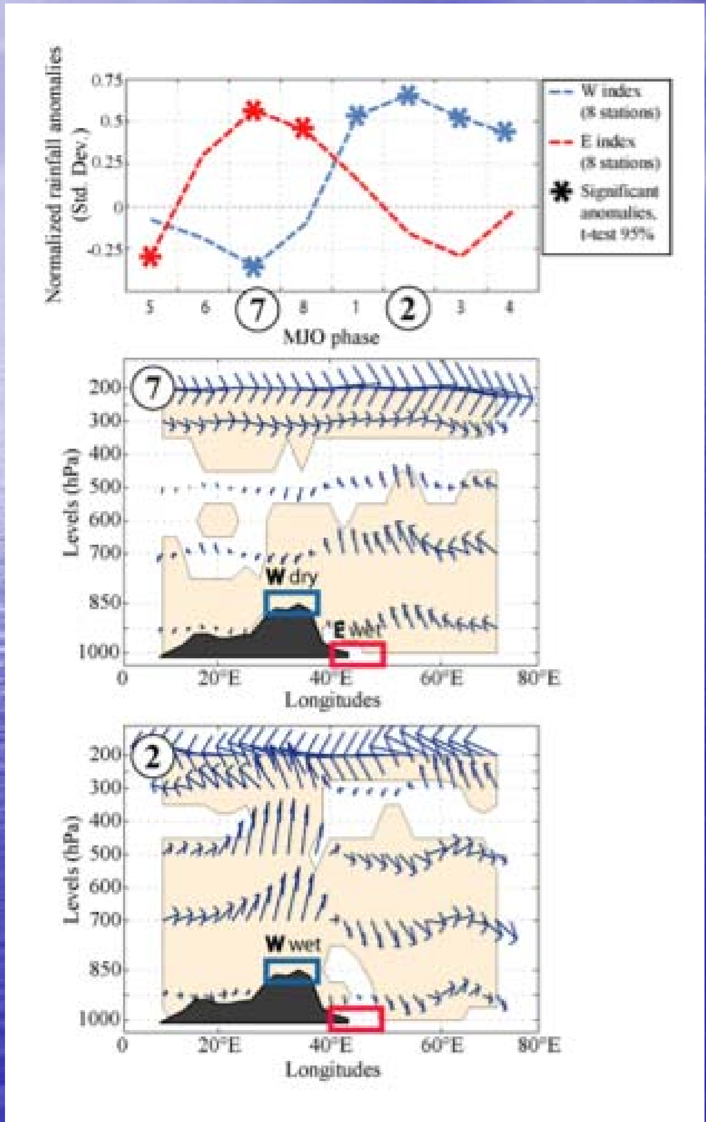
RAIN EVENT PROBABILITIES

Impacts on rainfall and extreme weather

TC Tracks



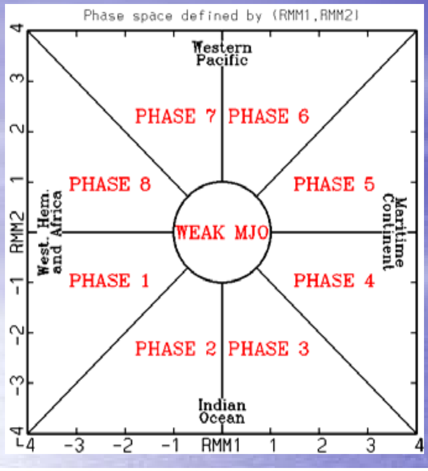
East African example: Pohl and Camberlin (2006)



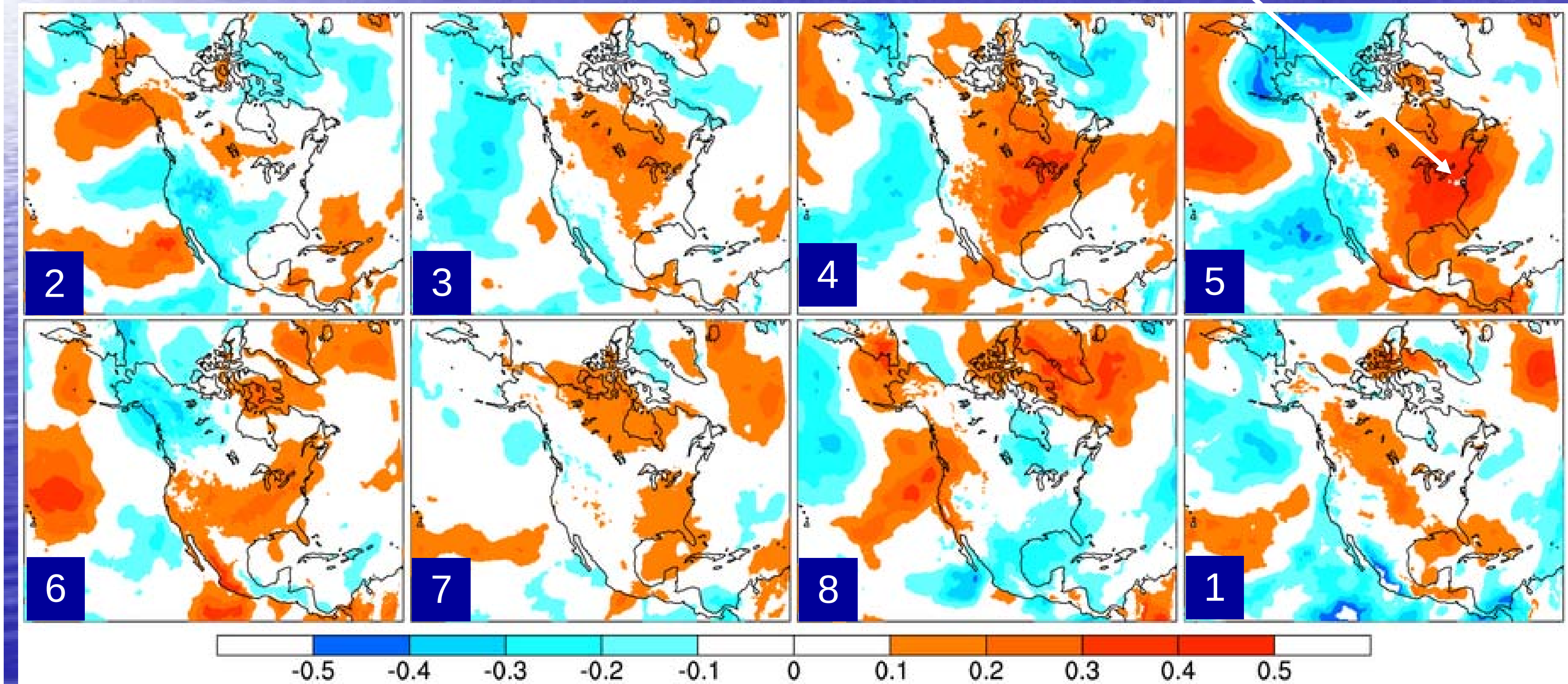
***Top*:** Composite rainfall anomalies for different MJO phases (defined using the RMM index) during the March-May rainy season in two regions of Kenya / Northern Tanzania (blue : Western region ; red : Eastern region, as located in Fig.1 and on the lower panels). The rainfall anomalies are obtained after extraction of the mean annual cycle.

Middle : Composite wind anomalies (zonal and vertical) for MJO phases 7 and 2, along an equatorial cross-section between the Congo Basin and the Western Indian Ocean. Shading indicates anomalies statistically significant at the 5% level.

Example impacts in North America based on RMM phases (K. Weickmann)



Signal/Noise for 2 meter air temperature
Eight MJO Phases, DJF 1979-2006
Max ~+0.5 sigma => 67% prob > 0 anomaly



YOU may compute the impact for your own region!

Simply get the index from:
http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/RMM/index.htm

4. Example applications to forecast models

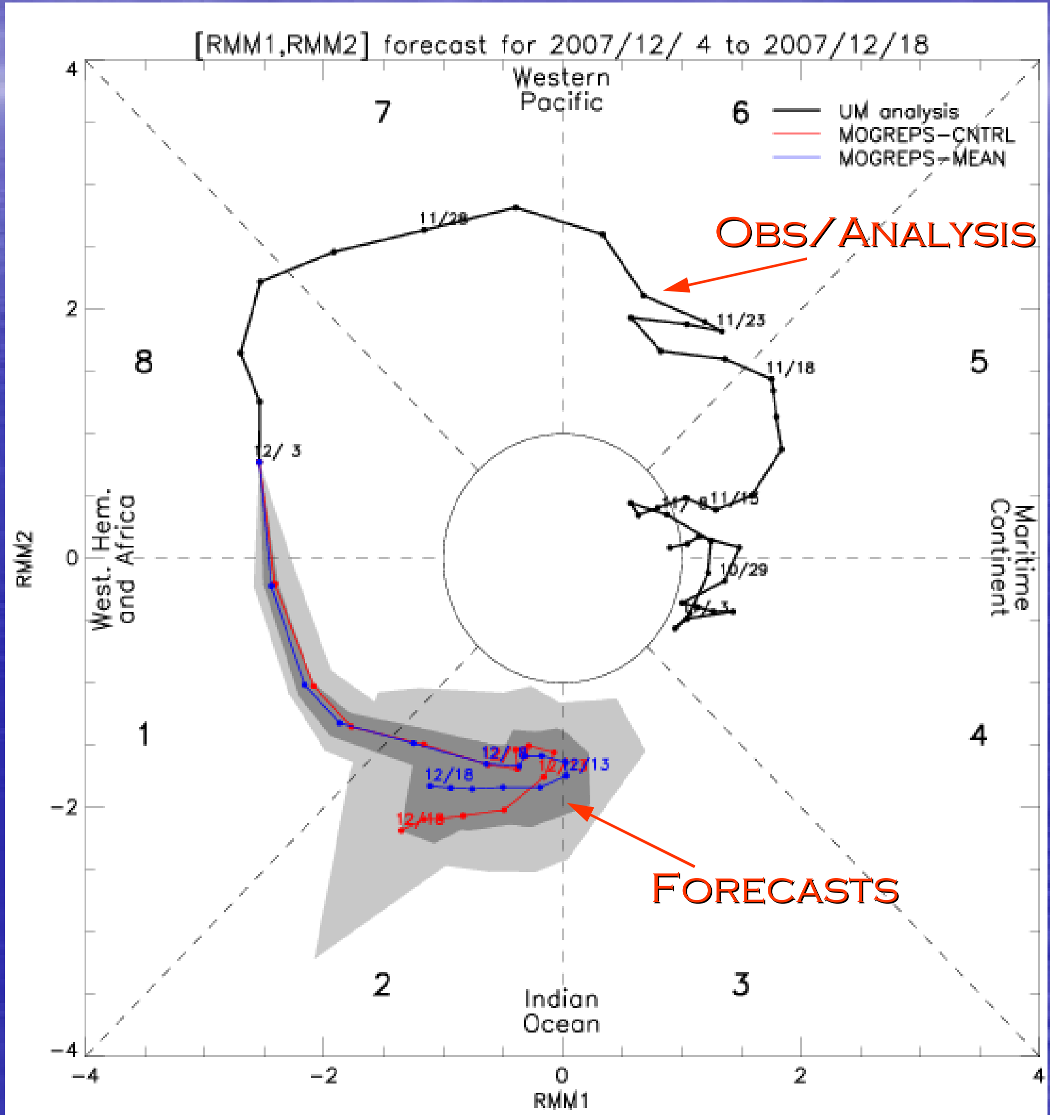
UK Met Office
(Nick Savage)

15-day ensemble prediction system

Uses same EOFs as WH04.

For the “observed” trajectory, uses their own model analyses (incl. for OLR).

Climatologies are computed from the NCEP Reanalyses (same as WH04).



Others leading the way in the application of the WH04 EOFs to model forecast data are:

NCEP – J. Gottschalck, W. Higgins, and M. L'Heureux

ECMWF – F. Vitart

CMC (Canada) – H. Lin

NOAA/PSD – K. Weickmann

ABOM (Australia) – H. Rashid, A. Charles, L. Rikus

NRL (USA) – M. Flatau

You will hear much more in the next lectures.

5. Some caveats/issues

- There is still some day-to-day noise retained in the index. For some diagnostic work, this may be removed with a 5-day running mean.
- The WH04 EOFs do not fully capture the northward-propagating intraseasonal variability in the Asian monsoon.
- Removal of interannual variability in WH04 involved two steps, one of which is not easily reproduced. (This has been simplified for the US-CLIVAR/WGNE recipe.)
- Re-computing the EOFs on different sets of observations may result in a linear exchange between the MJO pair of EOFs. This is equivalent to a rotation in the RMM phase space. We thus recommend the use of the WH04 EOFs.

6. The specific US-CLIVAR/WGNE recipe for forecast models

Initially it has been very informative to see the different calculation and presentation strategies of the different Operational Centres.

However, in a meeting of the US-CLIVAR MJO Working Group in Nov 2007, it was decided to standardize the RMM calculation and presentation, and help entrain further Centres by offering to perform the RMM projection for them (at NCEP!).

This activity has been formalized through the involvement of WGNE and a letter sent to all Operational Modelling Centres.

The “WGNE letter” specifies the data requirements and recipe in full. In brief, they are:

Data requirements

Daily fields of OLR, u850, and u200, averaged for 15°S-15°N from the model analysis and forecasts (out to at least 10 days), with a longitudinal resolution of 2.5°.

Plus a model analysis history of the past 120 days.

US-CLIVAR/WGNE recipe

1. Create anomalies from seasonal cycle

2. Also remove lower-frequency variability by subtracting the most recent 120-day mean.

3. Divide each field by its observed normalization factor from WH04 (OLR=15.1 Wm^{-2}, u850=1.81 ms^{-1}, u200=4.81 ms^{-1})

4. Project this data onto the pre-computed WH04 EOFs.

5. Divide the projection coefficients by their respective observed standard deviations.

For Centres wishing to compute the index themselves, the WH04 EOFs and normalization factors are available as an ascii file from me or Jon Gottschalck.

7. Forecast verification and a statistical benchmark

A statistical benchmark forecast of RMM1 and RMM2 can be provided through a first-order vector autoregressive model:
(Maharaj and Wheeler, *Int. J. Climatol.*, 2005)

Southern summer

$$\hat{x}_{t+1} = 0.9561x_t - 0.1207y_t$$
$$\hat{y}_{t+1} = 0.1256x_t + 0.9837y_t$$

Northern summer

$$\hat{x}_{t+1} = 0.9786x_t - 0.1049y_t$$
$$\hat{y}_{t+1} = 0.0936x_t + 0.9545y_t$$

Which provides a very similar forecast to lagged linear regression (e.g., Jiang et al., *Mon. Wea. Rev.*, 2008)

Example statistical benchmark forecasts with VAR model

Spirals heading around the origin

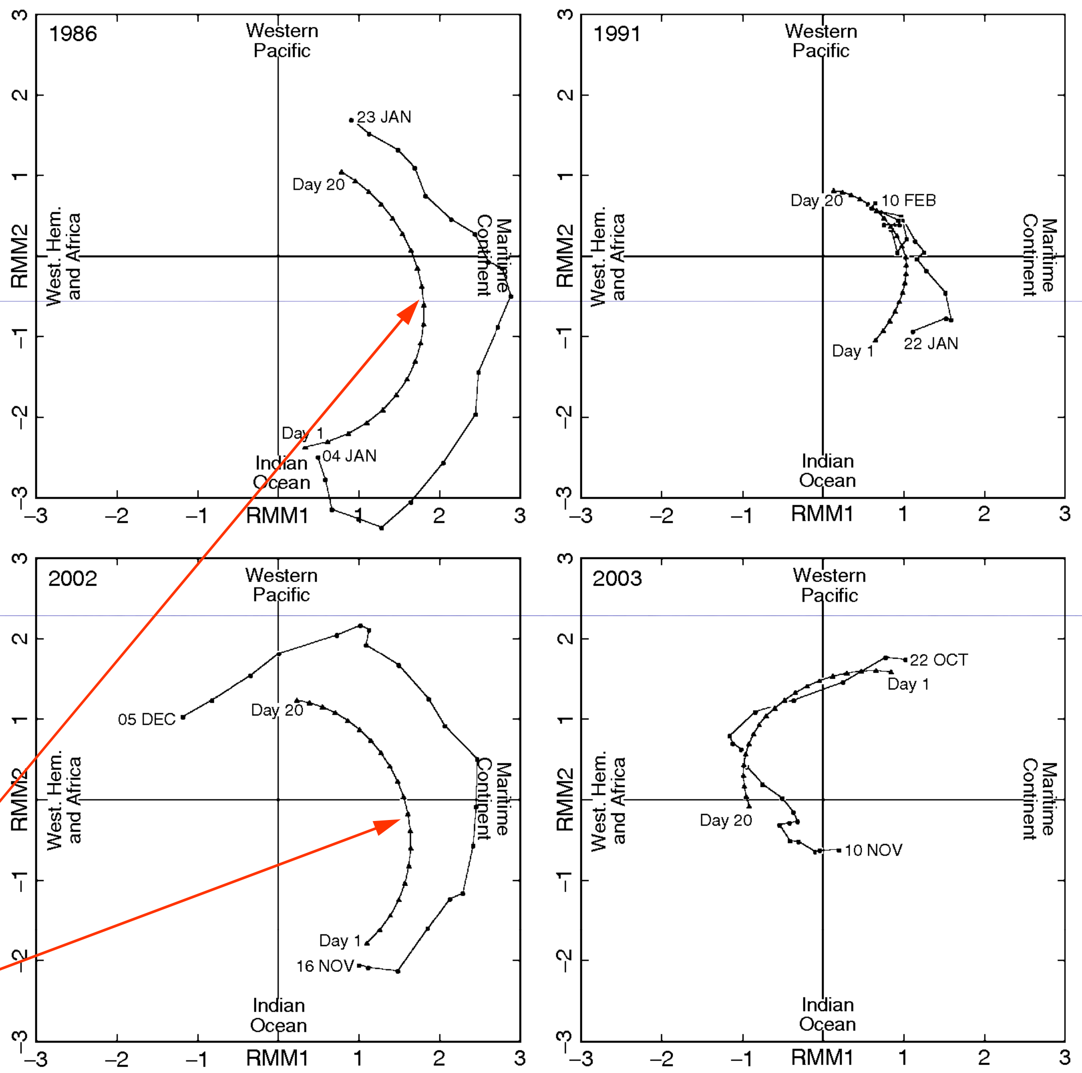
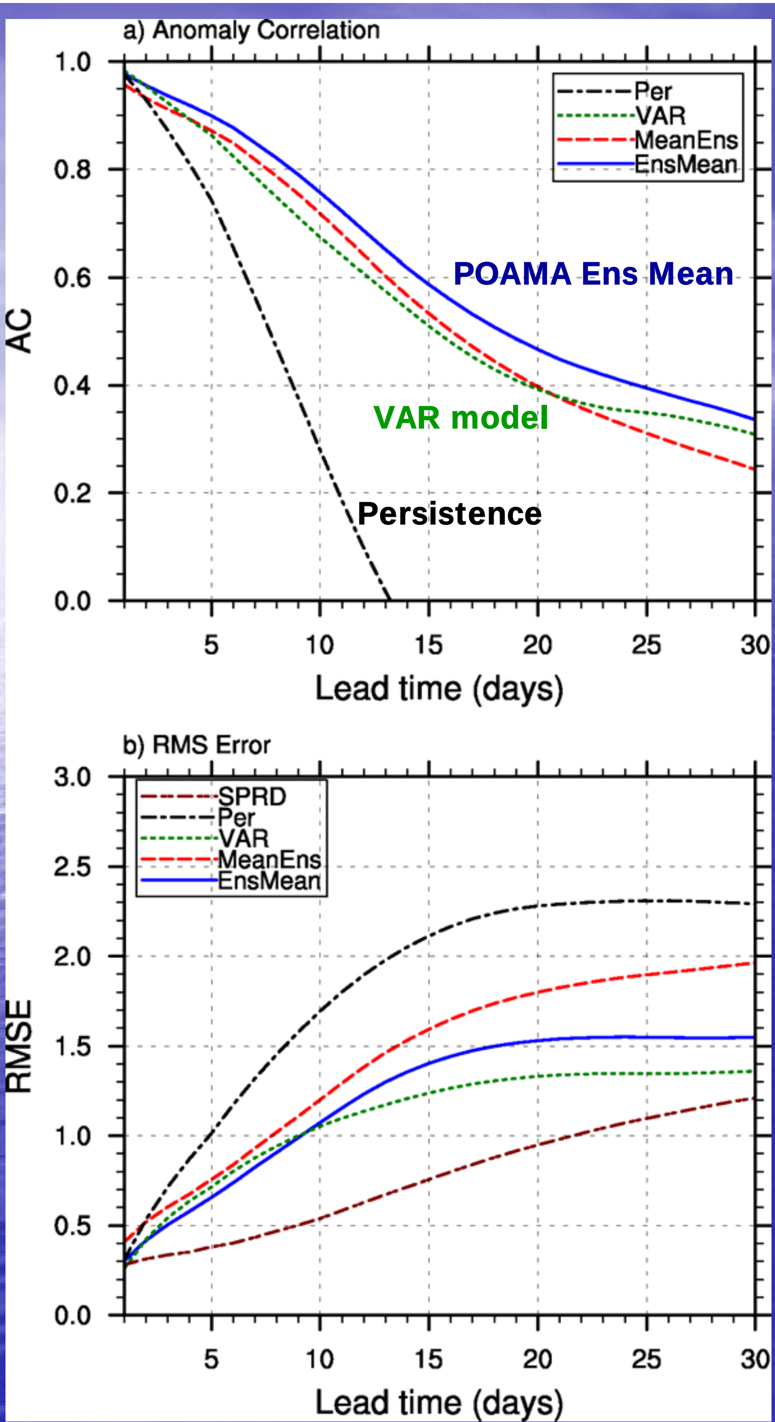


Figure 3. RMM1 and RMM2 forecasts (triangles) and their validating observations (circles) for four example periods, as represented in the two-dimensional phase space they define. Initialisation dates of the 1- to 20-day ahead forecasts are 3 January 1986, 21 January 1991, 15 November 2002, and 21 October 2003. Also labelled are the approximate locations around the earth where the enhanced convective signal of the MJO will be located for that part of the (RMM1, RMM2) phase space (e.g. 'Indian Ocean' for the MJO signal in convection located over the near-equatorial Indian Ocean)

Forecast Verification

The easiest verification statistics to calculate are the correlation between the forecasted and observed RMM1/2 values, and the root mean square error (RMSE).



For example:

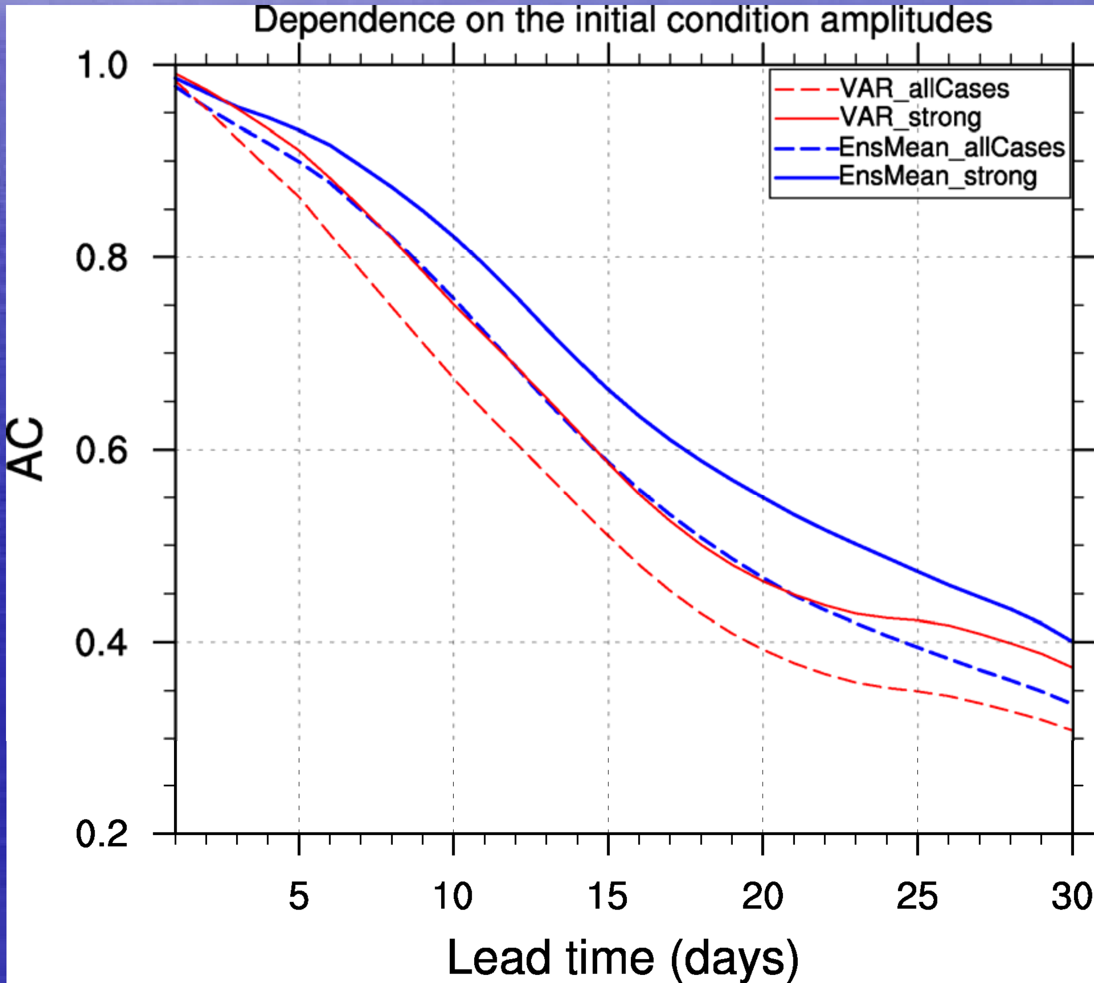
Comparison of the VAR benchmark and hindcasts from the POAMA dynamical model

POAMA hindcasts: 10 members run from 1st of each month over 25 years.

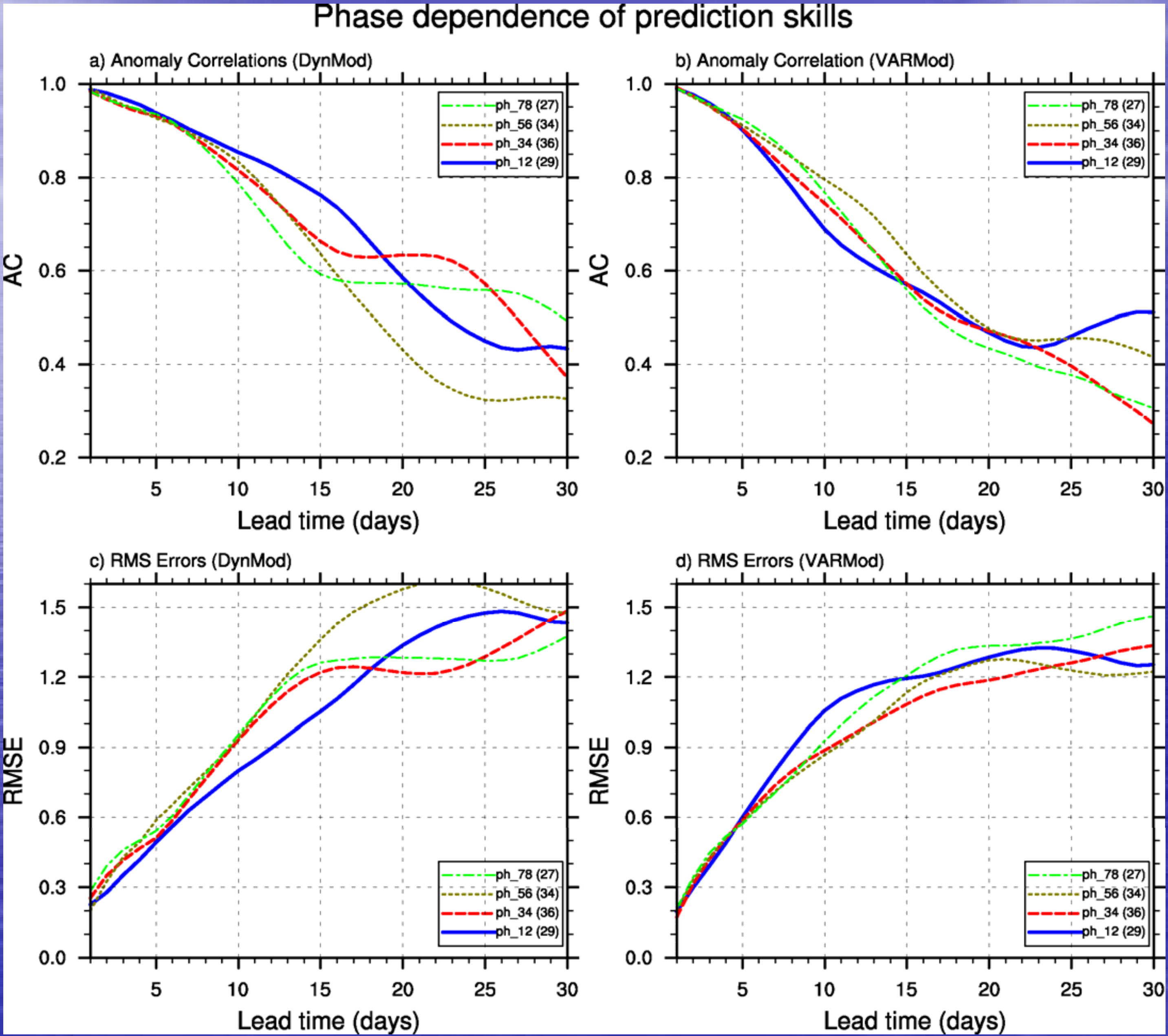
POAMA is run with observed atmospheric initial conditions.

But we can also categorize the forecasts in many different ways

Dependence on the initial MJO amplitude



Dependence on the initial MJO phase



Summary

- We have available an MJO index that is useful for impacts studies, real-time monitoring, statistical forecasting, basic MJO understanding, and as a dynamical forecast model metric.
- Applicable in all seasons, and available for 1974 to the present (except 1978).
- Obtainable from my web-site.
- The next few speakers will discuss in detail its application to dynamical forecast model output.

Further Metrics?

So far we have concentrated only on the canonical eastward-propagating MJO. A metric designed specifically to the northward propagation in the Asian monsoon would also be desirable.

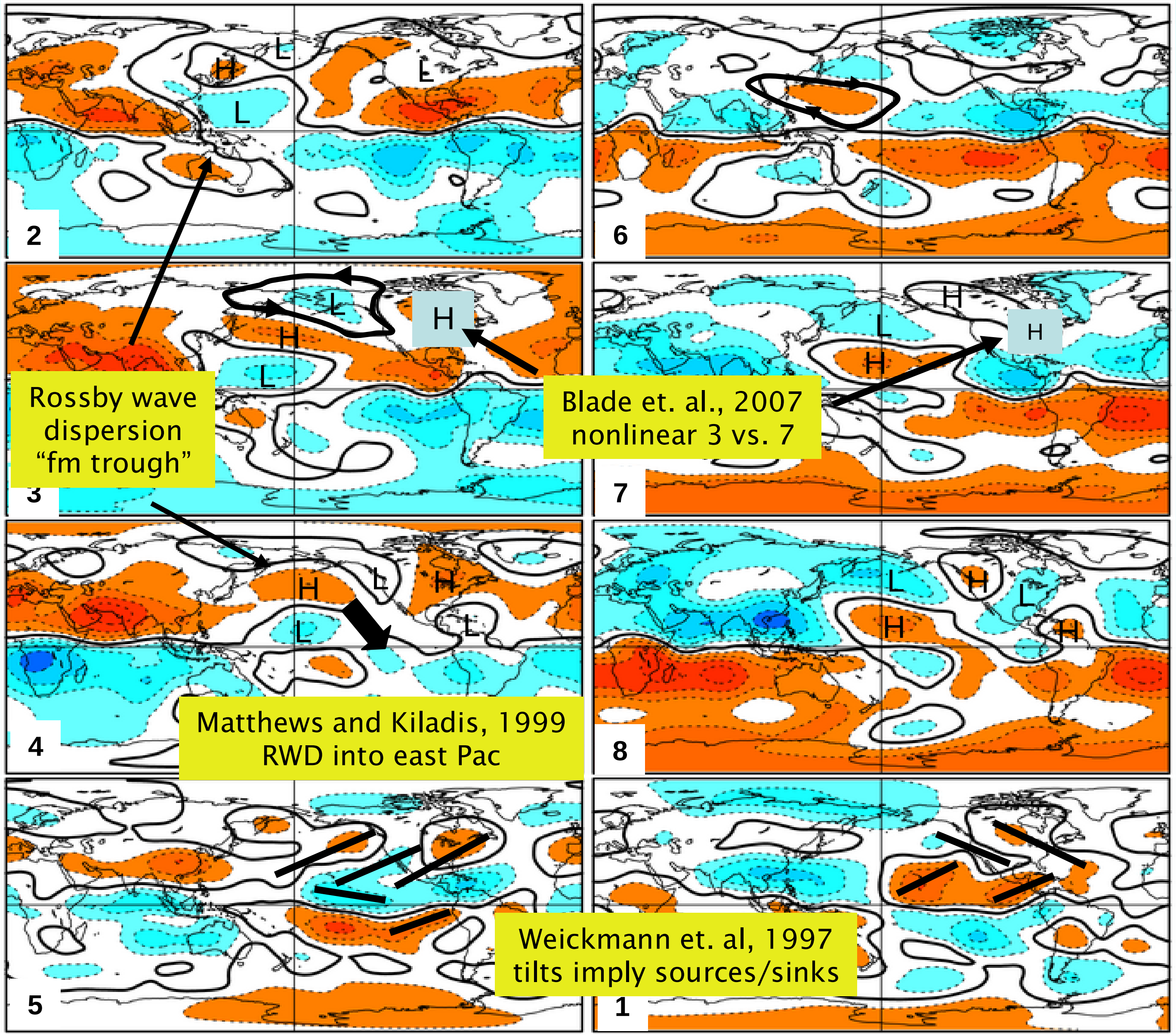
THE END

MJO's global teleconnection pattern
250 mb Ψ, DJF 1979-05, 8 phases, ~27 cases/phase

Indian Ocean

4-7 days between phases

Maritime Continent



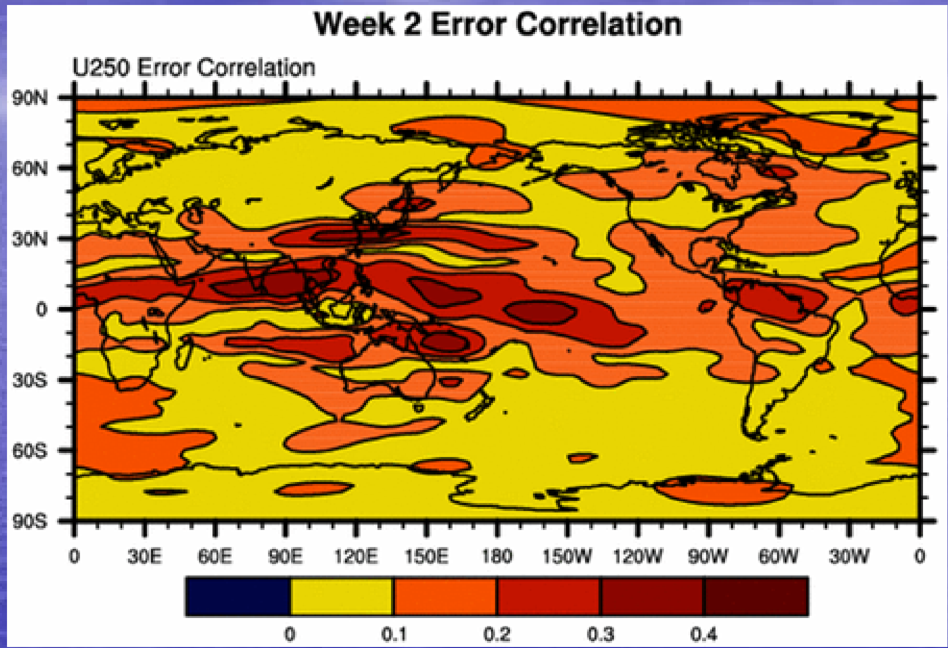
Western Pacific Ocean

Signals:
0.2-0.4σ
0.4-0.8σ
for > 1σ index

Western Hemisphere Africa

The global wind oscillation (GWO) is lurking!

Regression of RMM1 and 2 at initial time with week 2 verification, forecast or forecast error



1 m/s

3 m/s