Forecasting the MJO with the CFS:

Factors affecting forecast skill of the MJO

Augustin Vintzileos

CPC/NCEP – CICS/ESSIC, University of Maryland College Park

Jon Gottschalck

CPC/NCEP

Problem statement:

- In general, the MJO can successfully be predicted up to lead times of 2-3 weeks. There is still room for improvement as MJO has a mean period around 40-60 days

- One critical reason which does not allow for more extended forecasts of the MJO is the Maritime Continent Prediction Barrier.

- This is defined as a sharp drop in forecast skill as the enhanced convective phase of the MJO approaches the Maritime Continent. The skill becomes dependent on target time instead of lead time

- Is this barrier a forecast model problem or a predictability issue?

Outline…

- We first explore model issues with the CFS:
  - Model Resolution
  - Better Atmospheric and Oceanic Initial Conditions
- We then explore Predictability issues:
  - In nature, MJO events sometimes traverse and sometimes collapse over the Maritime Continent
  - Is there a systematic difference between **Traversing** vs. **Collapsing** observed MJOs? If yes, this would mean that the Maritime Continent Barrier is a forecast model issue and not a real predictability barrier.

Forecast model issues

Sensitivity experiments

Atmosphere side (Ocean side unchanged)

Higher horizontal resolution: T62, T126, T256

Better initial conditions: Operational GDAS *versus* Reanalysis-2

Ocean side (Atmosphere side unchanged)

Better initial conditions: op GODAS *versus* Experimental analysis

The atmospheric model side:

Model Resolution and Initial Conditions

Compare re-forecasts with the CFS initialized every 5 days from May 23 to August 11 from 2002 to 2006 at resolutions of:

T62, equivalent to 200km x 200km
T126 "" 100km x 100km
T254 "" 50km x 50km

All resolutions are initialized by :

(1) Reanalysis-2 which is based on an older version of the GFS

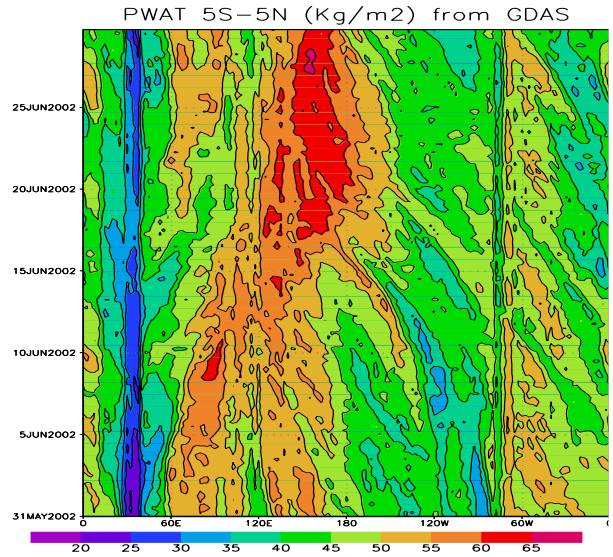
(2) GDAS which is the operational analysis at NCEP (the best possible initial state)

For these experiments ocean initial conditions are from the operational GODAS

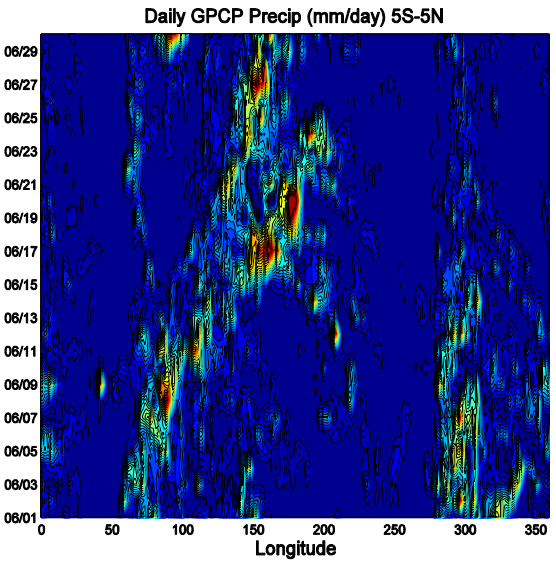
Experiments performed on the CTB computer

Why testing operational GDAS versus Reanalysis-2 ?

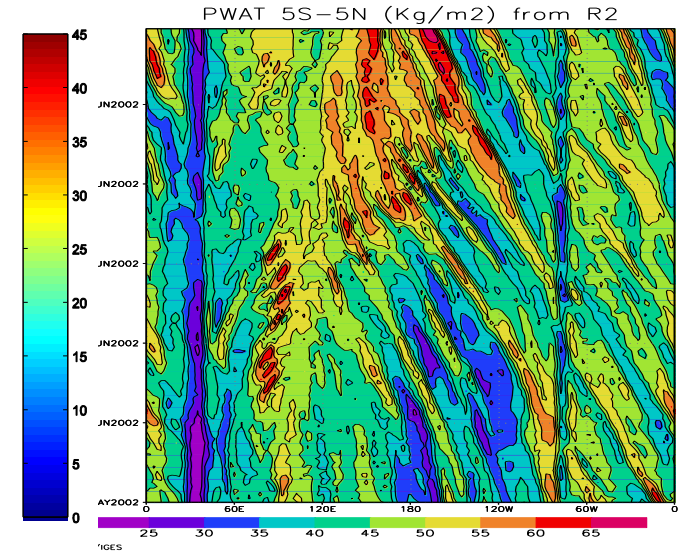
GDAS *vs. GPCP vs.* Reanalysis-2 for June 2002



GDAS Precipitable Water

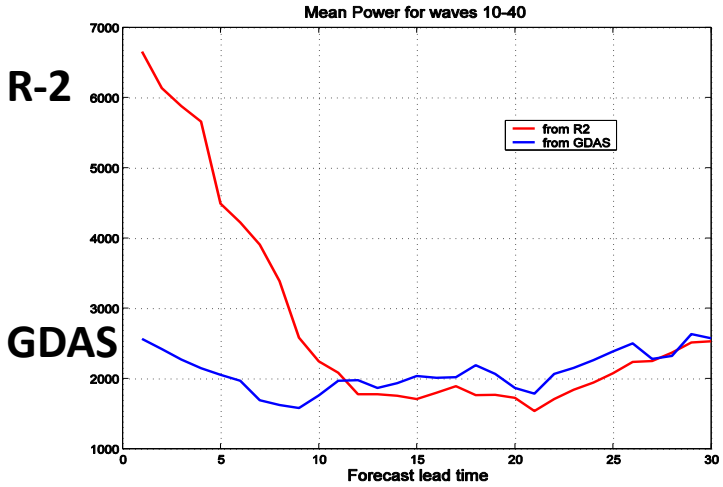


GPCP Precipitation

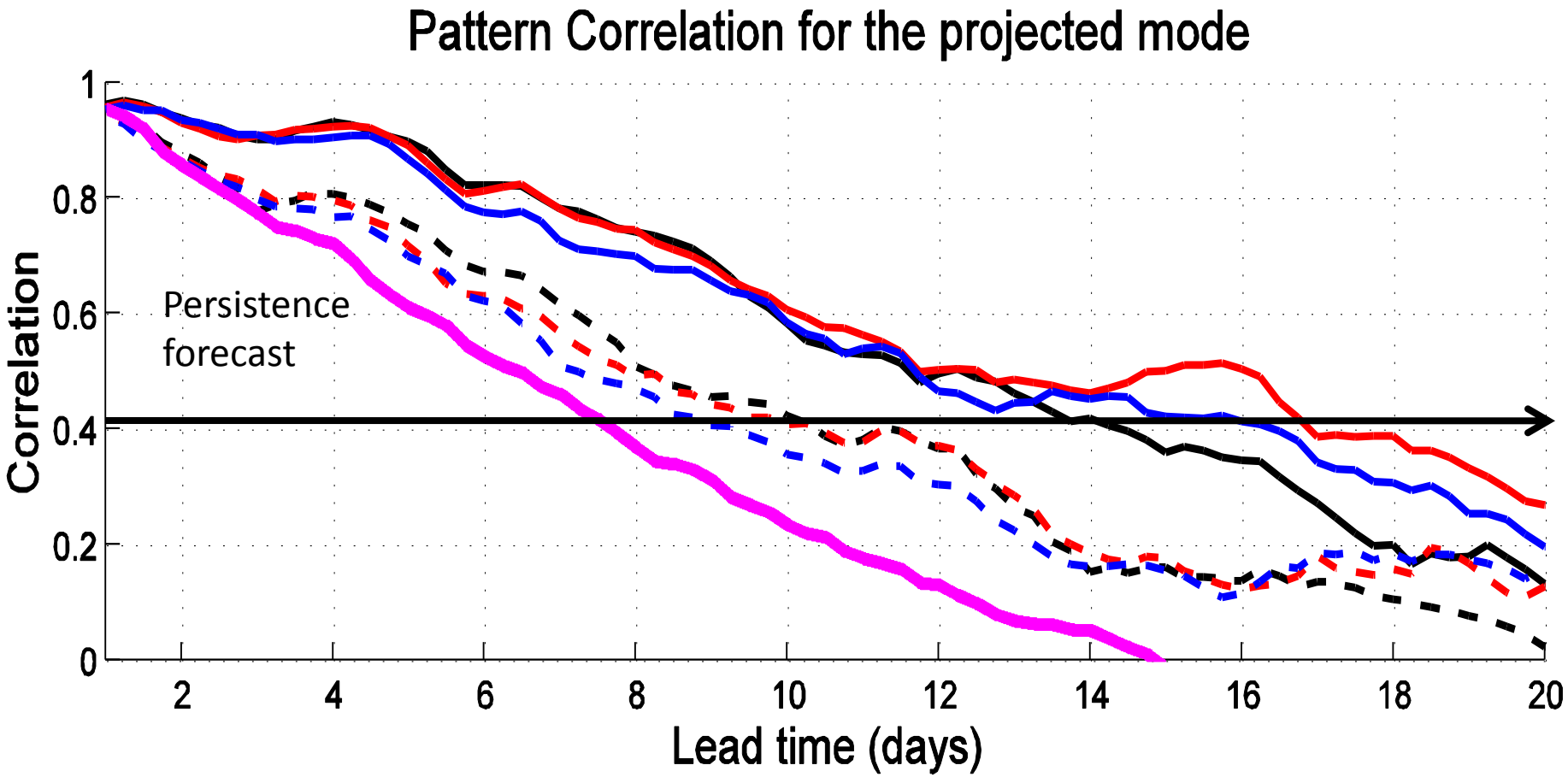


Reanalysis 2 Precipitable Water

When initialized by R-2 the CFS contains more energy in the high wave numbers (10-40). Then we observe a drift of energy as a function of forecast lead time. It takes ~10 days for converging to GDAS energy levels.



Skill for the MJO mode (verification CDAS2)



Initializing the CFS with GDAS instead of R-2 increase skill by ~7 days

R-2

GDAS

T62

T126

T254

The oceanic model side:

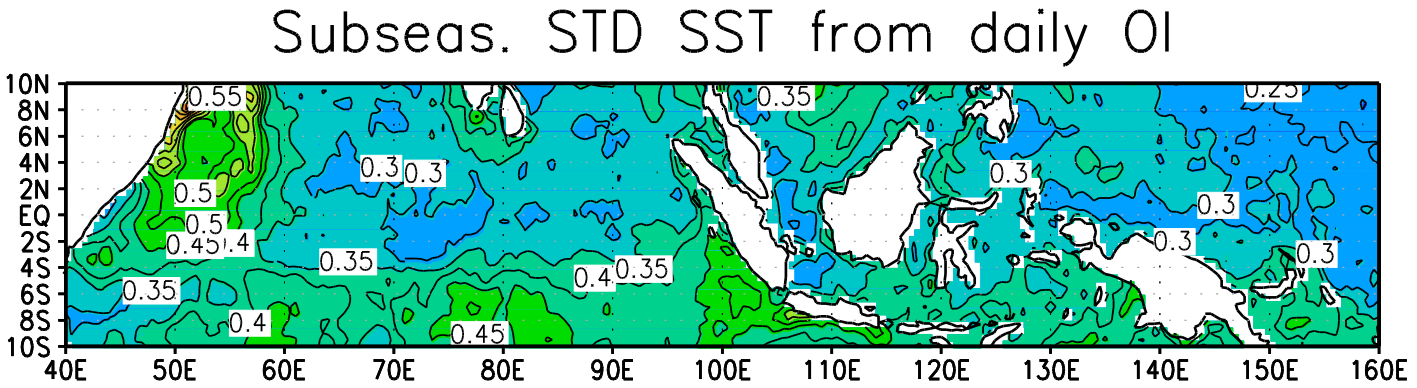
Sensitivity to ocean Initial Conditions

Rationale for these experiments

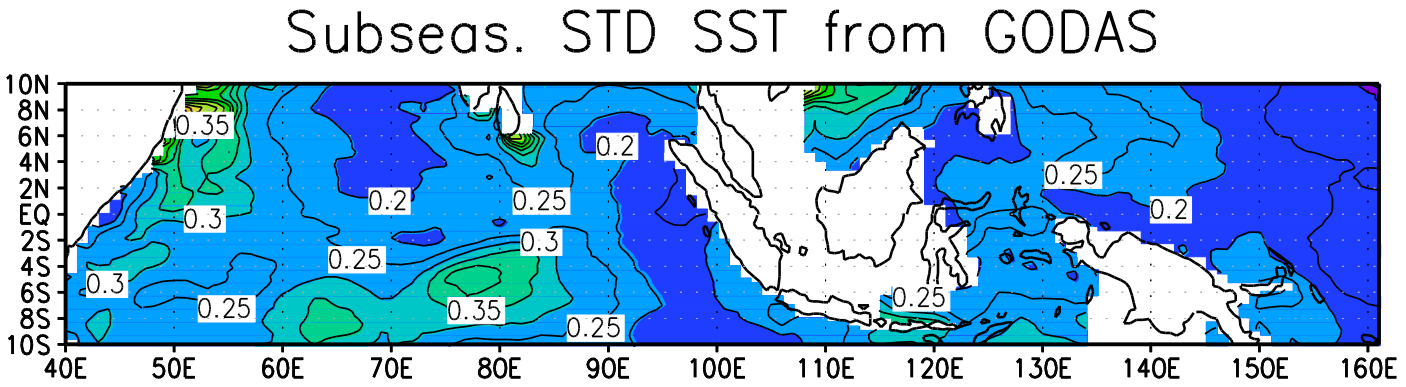
GODAS was designed for initializing the ocean model for seasonal predictions, using 28-day data windows and restoring SST to weekly OI

Standard Deviation of the 20-90 day filtered SST (2002-2006)

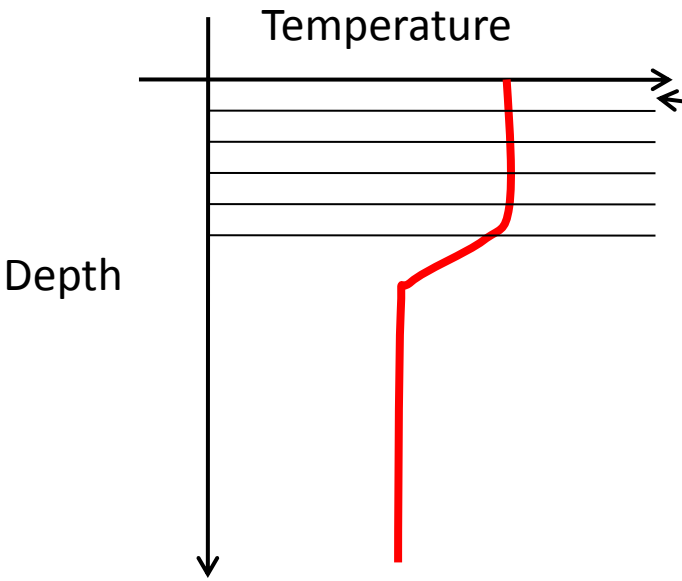
From daily observed SST



As expected GODAS generally presents weaker intra-seasonal variability than observations



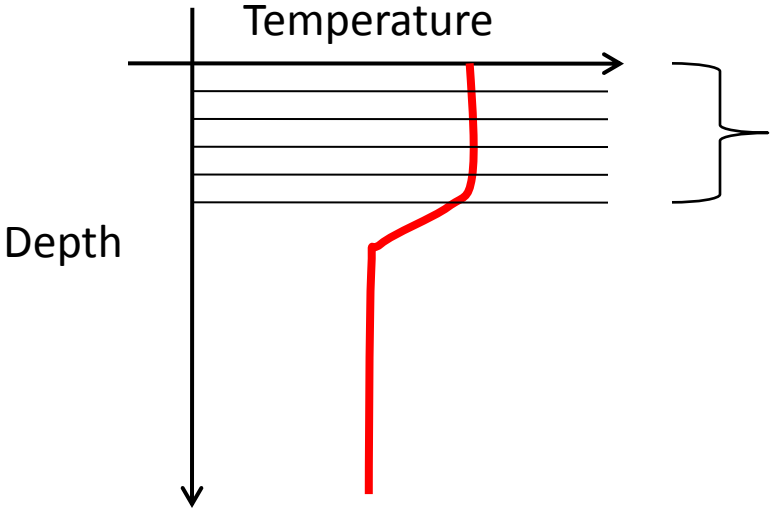
Operational Ocean Analysis: Restoring the surface layer to weekly OI



$$T_n^{l=1} = T_{n-1}^{l=1} + Q - a \cdot \left(T_{n-1}^{l=1} - T_{obs}^{l=1} \right)$$

Weekly Reynolds SST

Experimental Ocean Analysis: Restoring the whole mixed layer to daily OI

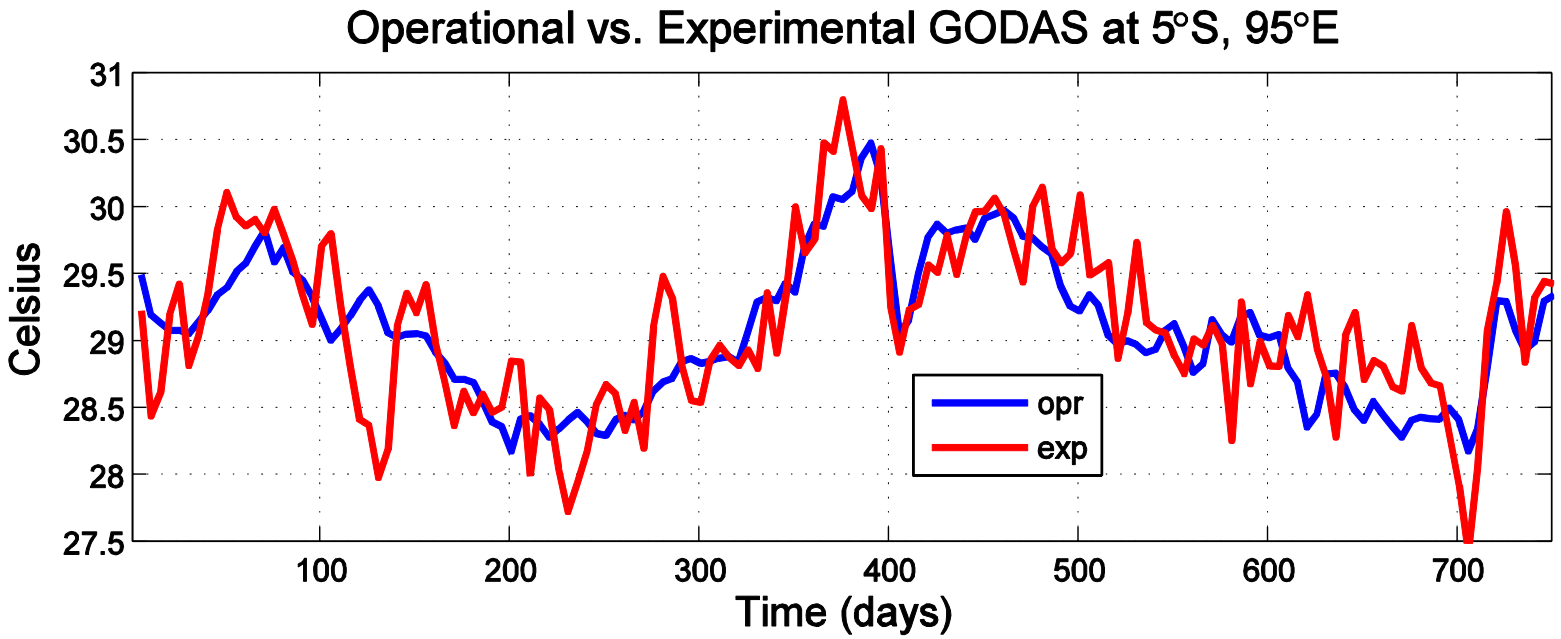


$$T_n^{l} = T_{n-1}^{l} + Q - a \cdot \left(T_{n-1}^{l} - T_{obs}^{l=1} \right)$$

Daily Reynolds SST

Vintzileos and Behringer

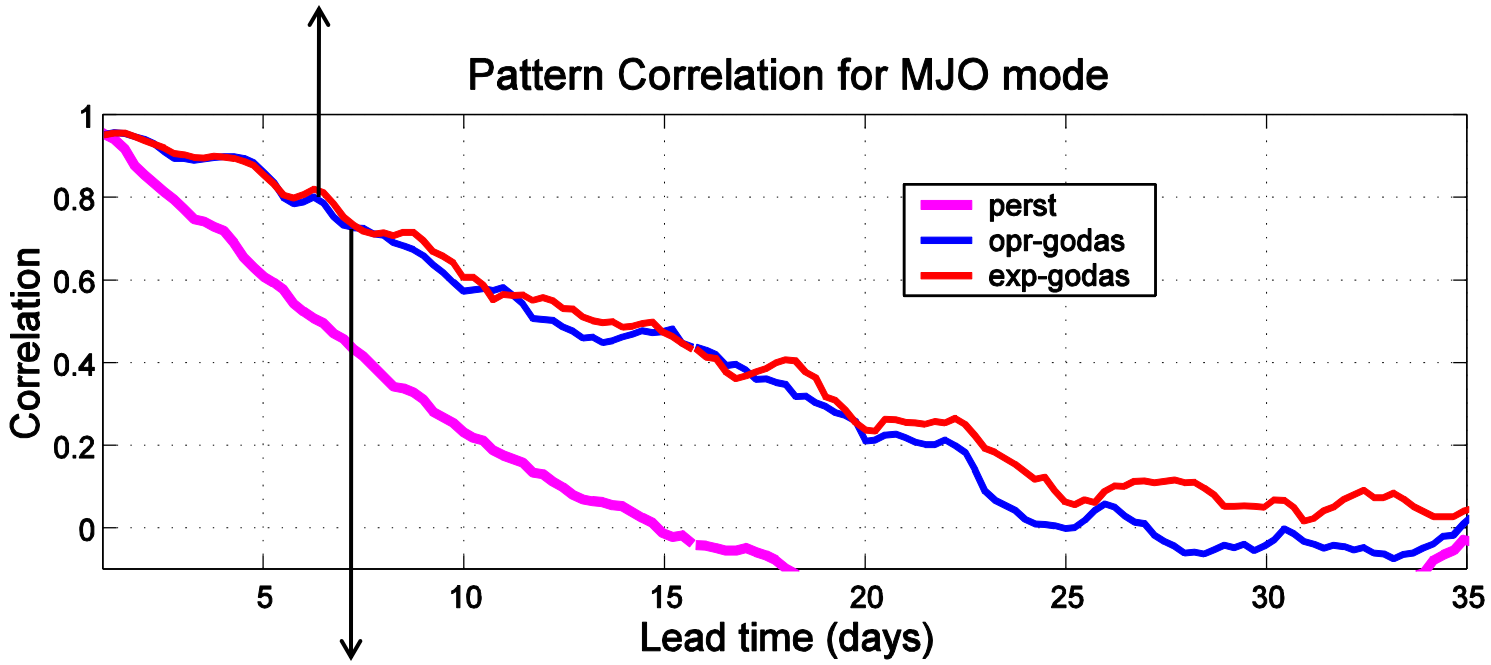
Comparison of operational GODAS (blue) with experimental GODAS (red)



The experimental GODAS clearly contains higher frequencies

Impact of Oceanic Initial Conditions on Forecast Skill

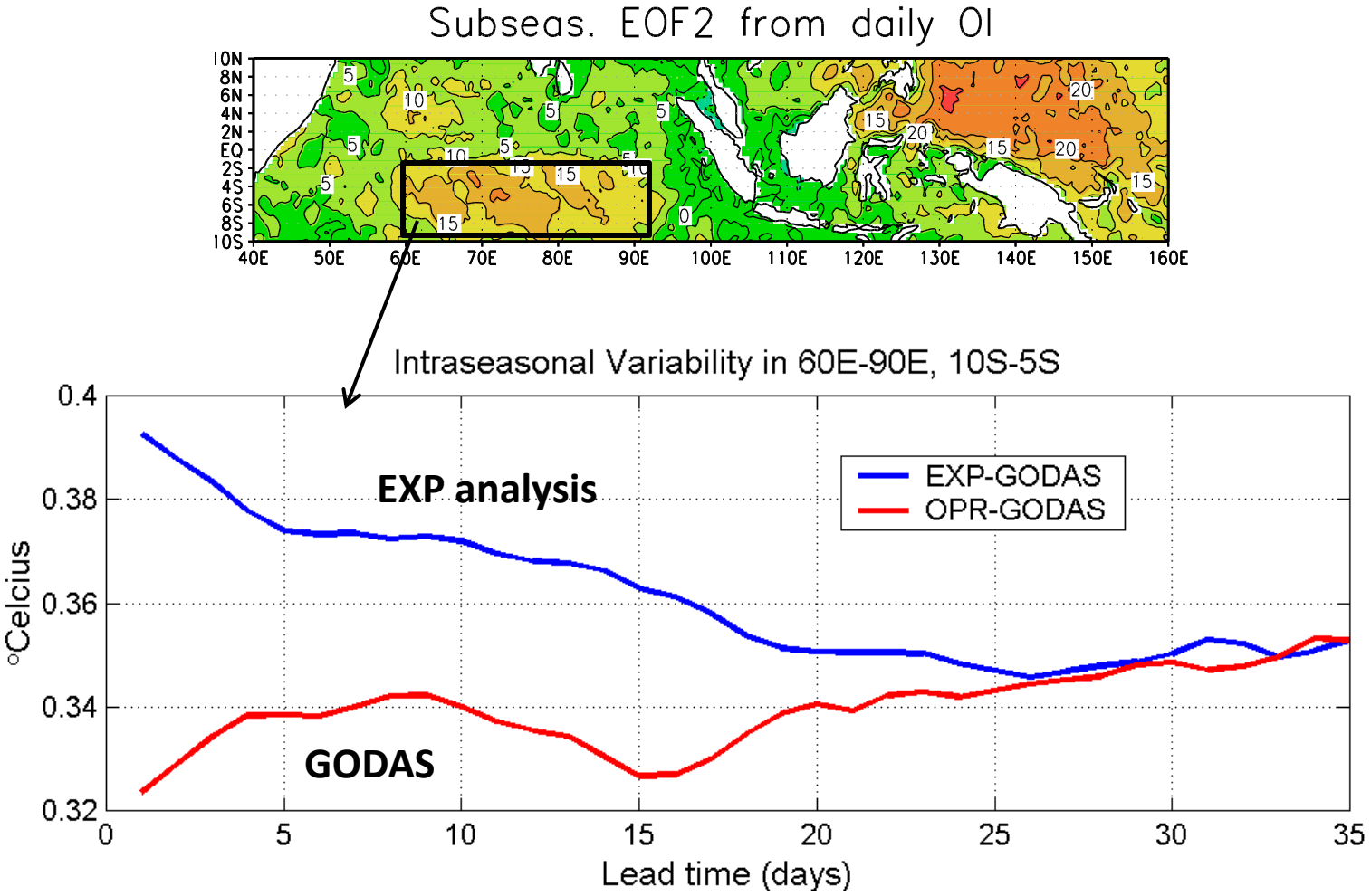
Up to day 6 the impact of atmospheric initial conditions is dominant. Even if oceanic I.C. are better there is no improvement in skill.



After day 6, the improved oceanic initial conditions lead to consistently, albeit marginally, better forecast.

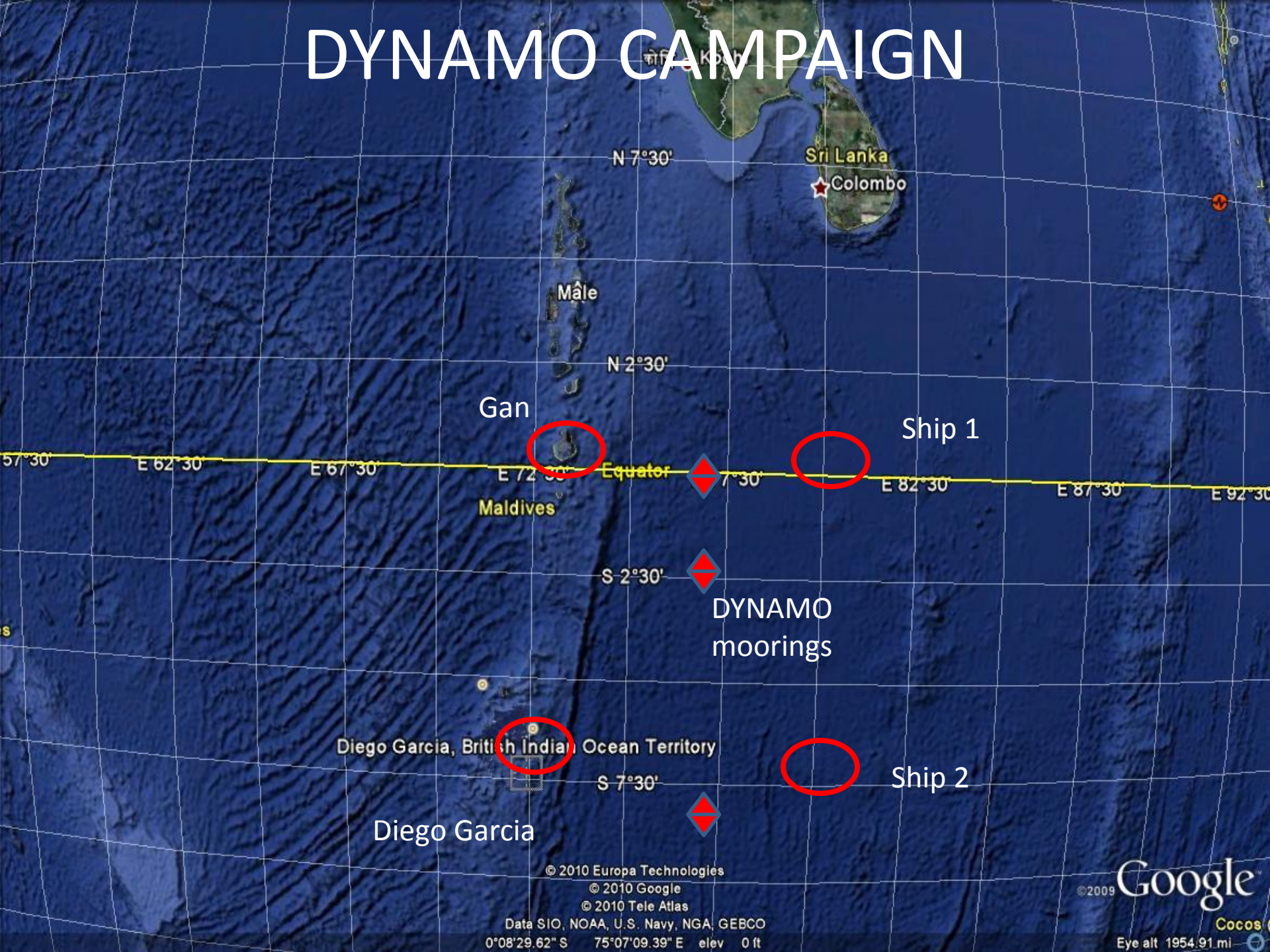
However, the amplitude of forecast intraseasonal SST modes weakens systematically as a function of lead time…

Drift of standard deviation of intra-seasonal SST as a function of lead time



Despite injection of more realistic intra-seasonal variability into the initial conditions the CFS dumps the ocean intra-seasonal modes converging to the CFS initialized by GODAS in ~4 weeks which suggest misrepresentation of ocean mixed layer processes

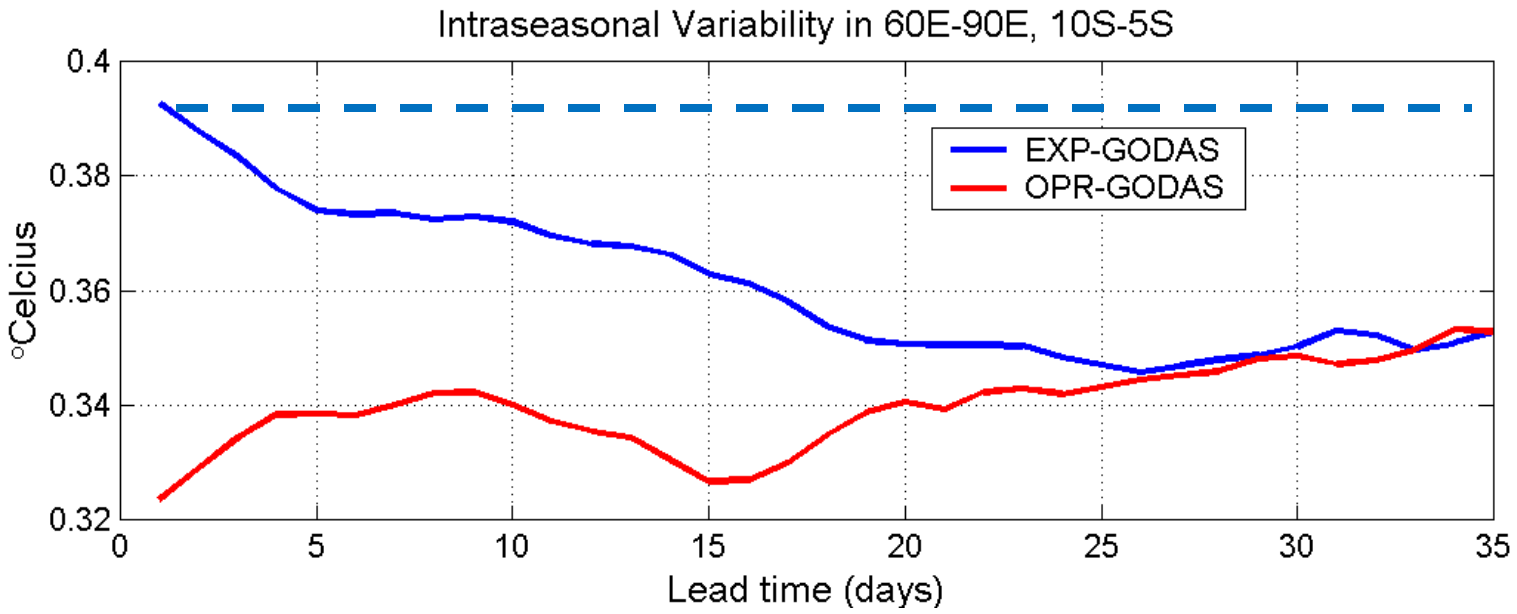
DYNAMO CAMPAIGN



Proposed Research:

Use DYNAMO and other observations for improving the representation of oceanic processes relevant to MJO. This is a collaborative effort between NCEP, CICS/ESSIC and COLA

Example of target deliverable:



This proposed research will directly help the definition of the CFS version 3

Predictability issues

(how up can we expect to put the forecast skill bar)

Is there a ‘real’ Maritime Continent Prediction Barrier?

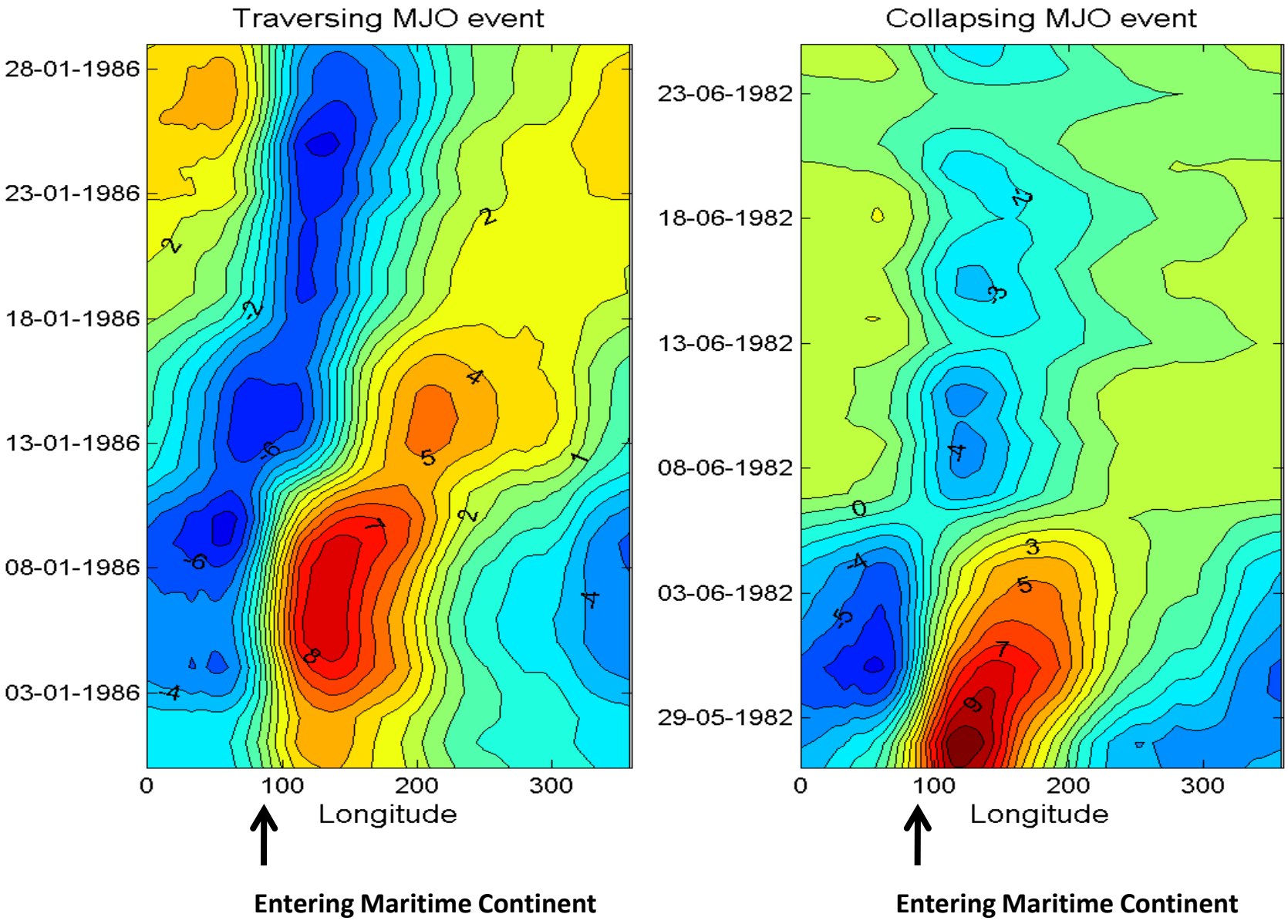
Observed MJO events may sometimes crash on the Maritime Continent

We classify observed MJO events in **Traversing** and **Collapsing** using Reanalysis-2 data from 1980 to 2007

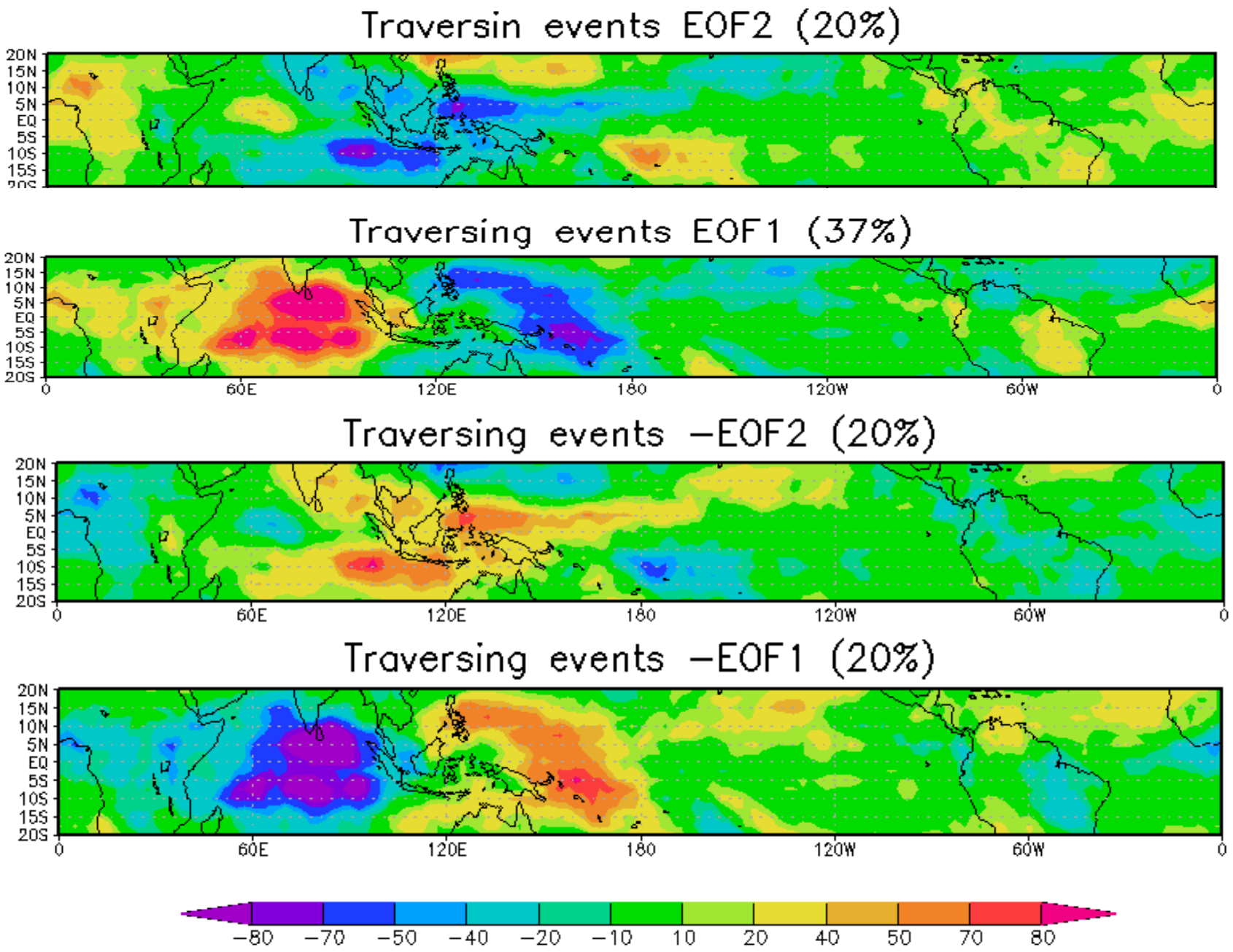
We composite observed OLR anomalies for Traversing and for Collapsing events

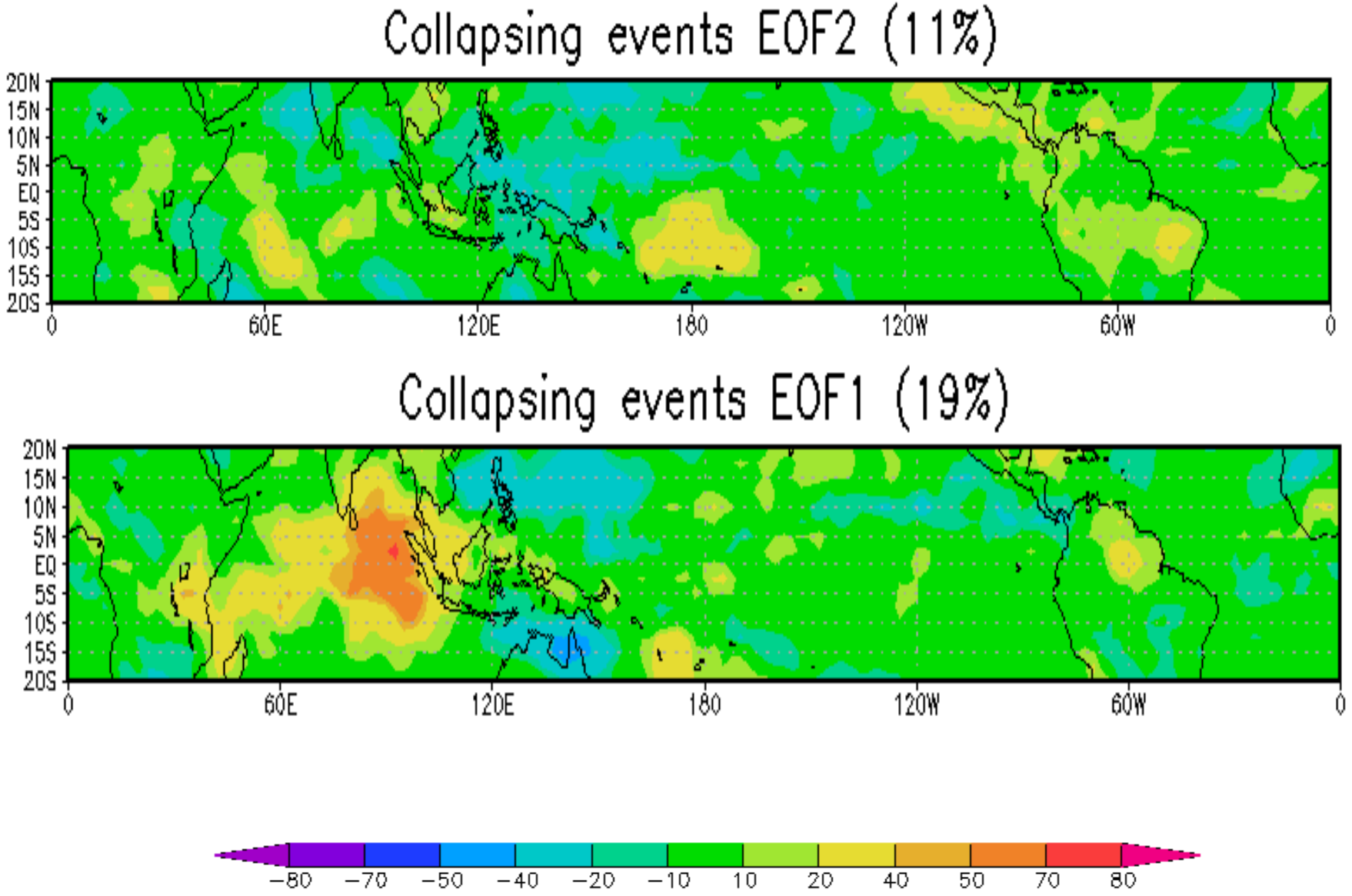
If the composites of traversing and collapsing events are different then we may conclude that the Maritime Continent Barrier is not due to predictability issues

Reconstruction of observed **Traversing** (January 1986) *versus* **Collapsing** (June 1982) MJO events



Composite of a Traversing MJO event




Collapsing events EOF2 (11%)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
0
60E
120E
180
120W
60W
0
Collapsing events EOF1 (19%)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
0
60E
120E
180
120W
60W
0
−80
−70
−50
−40
−20
−10
10
20
40
50
70
80

Summary and conclusions

One of the most important obstacles for extending MJO forecasting is the Maritime Continent Prediction Barrier.

Increasing the atmospheric model resolution up to 50km x 50km did not improve forecast skill.

Better atmospheric initial conditions improved forecast skill by 3-4 days but did not help in breaking through the Maritime Continent Barrier.

Oceanic initial conditions with a better representation of subseasonal variability improved forecasts but only marginally. However, a systematic loss of amplitude of subseasonal oscillations with forecast lead time should be addressed.

In nature, MJO events can both traverse and collapse over the Maritime Continent.

Events that collapse are clearly distinct from events that traverse as far back as the Indian Ocean. This means that the Maritime Continent Prediction Barrier is most likely a modeling problem rather than a predictability issue.

These distinct structures of traversing vs. collapsing events may be used by MJO forecasters.

Actions

We are participating to the DYNAMO campaign in the Indian Ocean which targets to observe atmospheric and oceanic processes relevant to the MJO

This participation is through a number of proposals submitted to the Earth System Science program element of the Climate Program Office

-- Provide real time monitoring and forecast to the campaign (see poster for details)

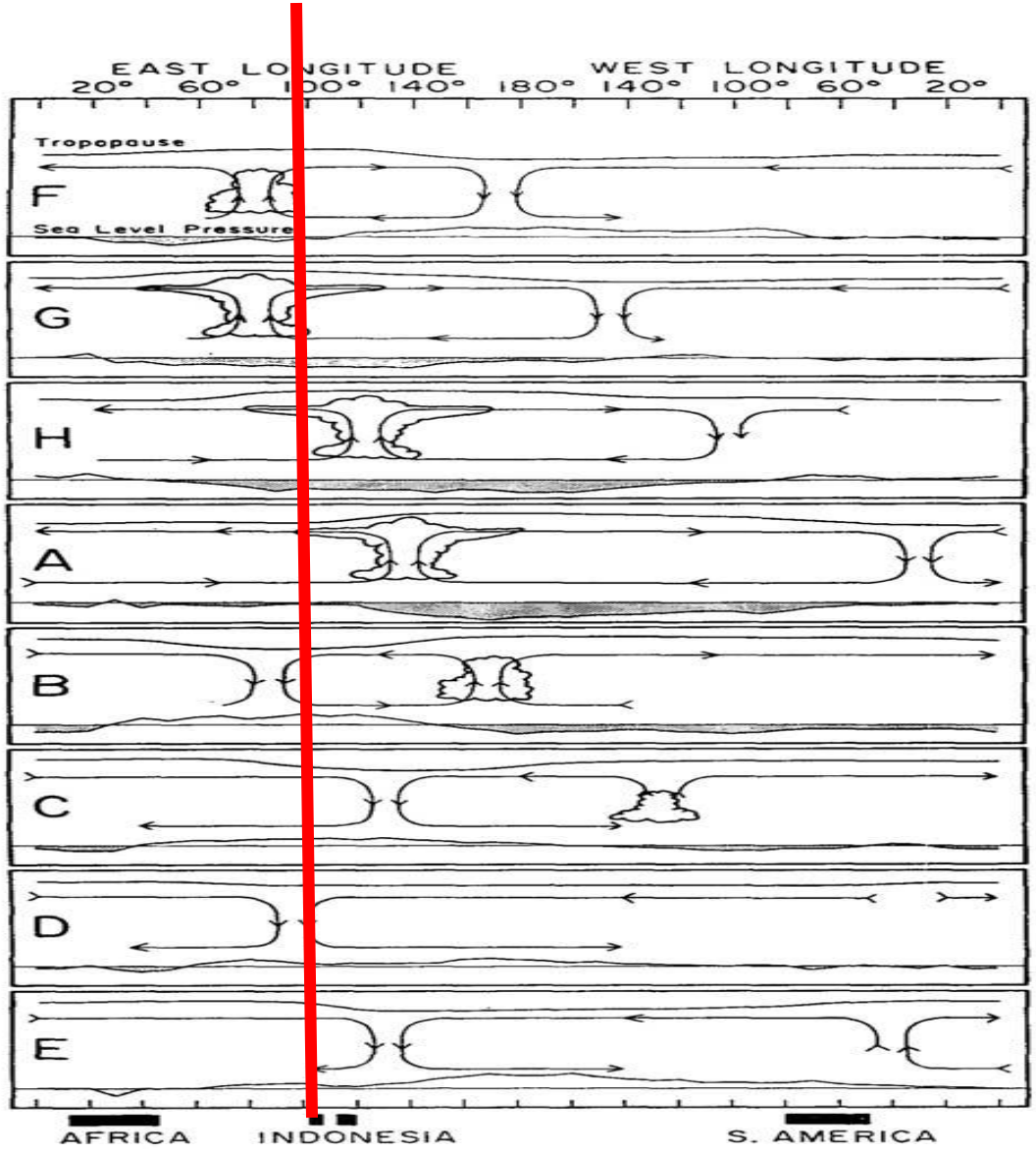
-- Use DYNAMO and other data to investigate oceanic processes that are relevant to the MJO and provide model improvements for the next version of the CFS

-- Investigate the role of convective momentum transport

-- Monitoring of convective activity

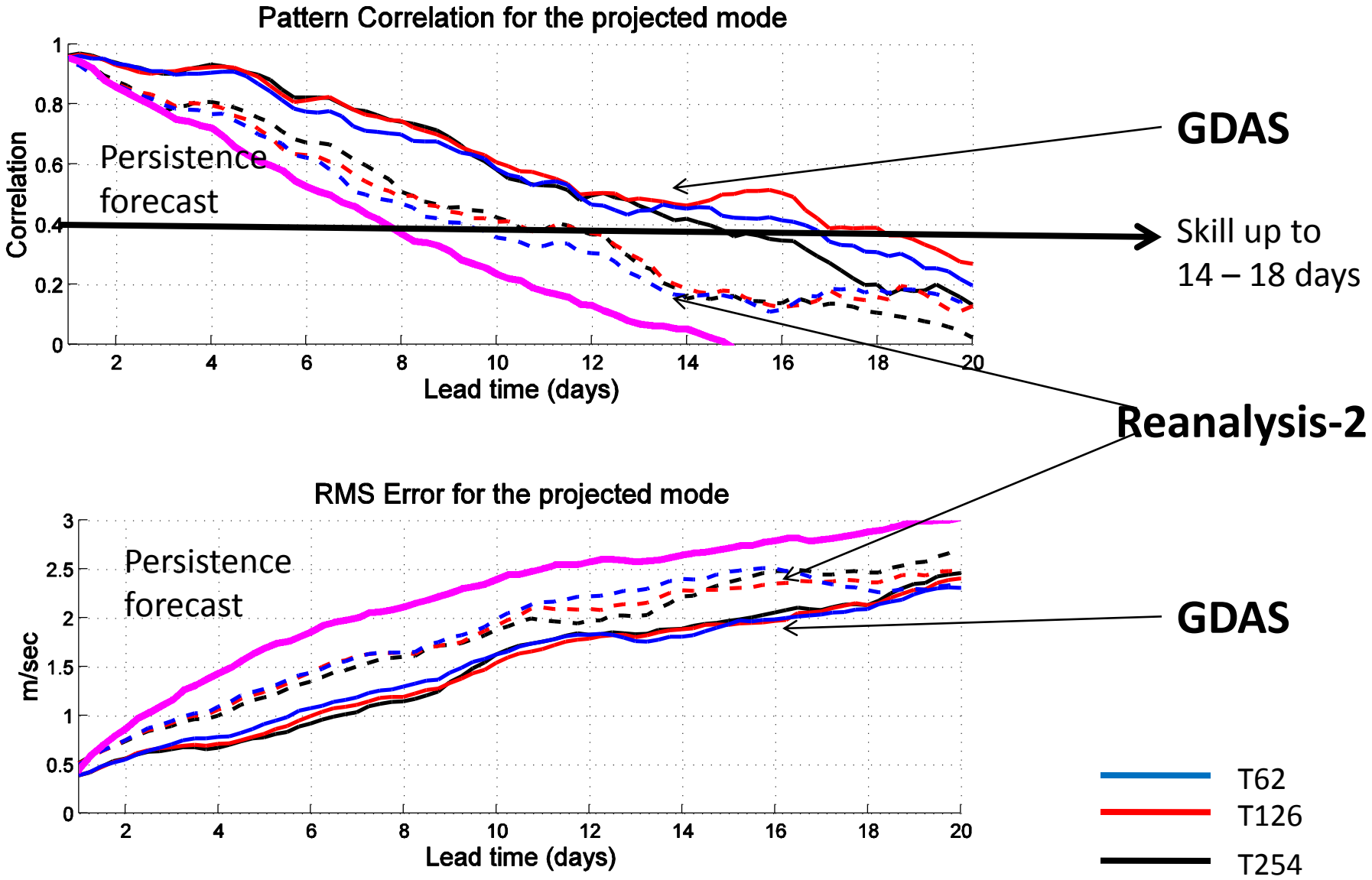
Collaboration between: NCEP, CICS/ESSIC, COLA, University of Miami and UCLA

Maritime Continent



From Madden and Julian [1972]

Skill for the MJO mode (verification CDAS2)

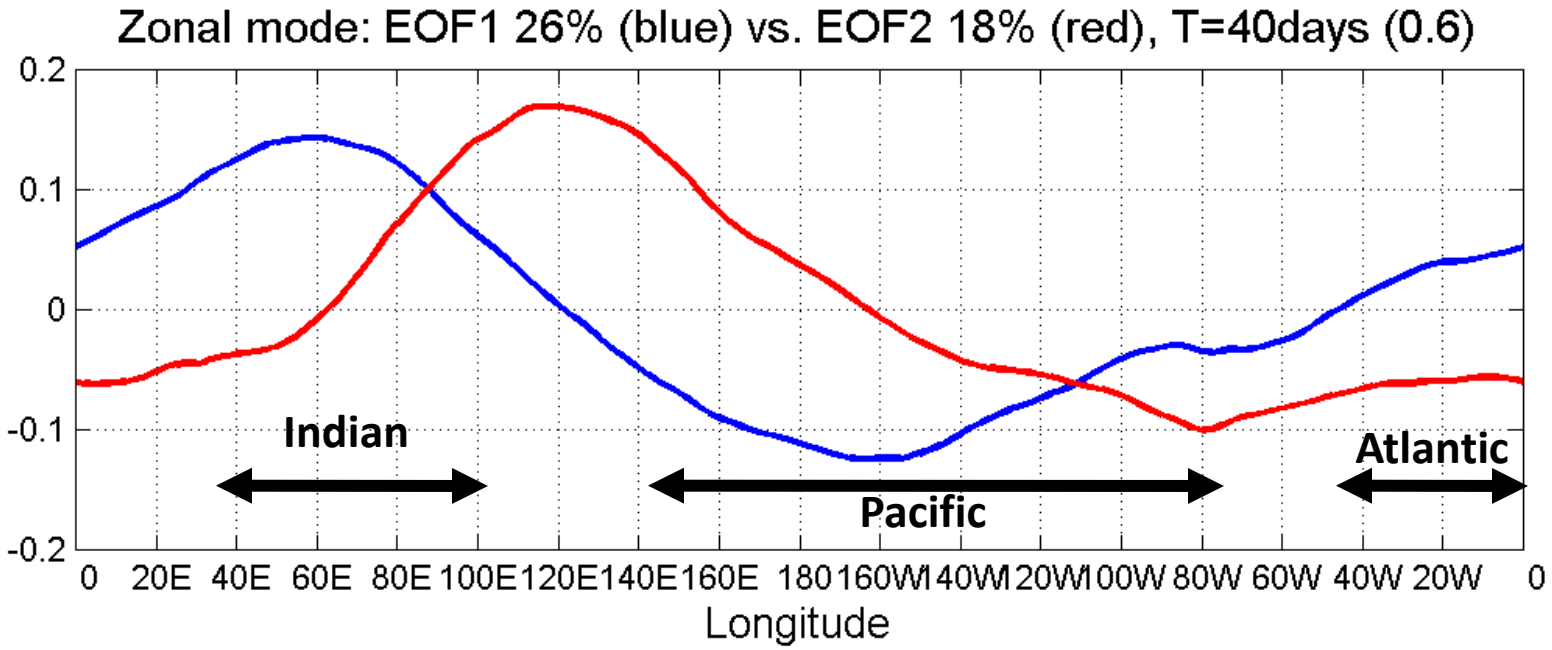


A simplified Wheeler – Hendon MJO index

Quantifying MJO through a simplified version of the Wheeler – Hendon CLIVAR index

Consider zonal wind at 200 hPa from Reanalysis-2, average between 20°S-20°N and then remove annual mean, zonal mean and ENSO (when necessary)

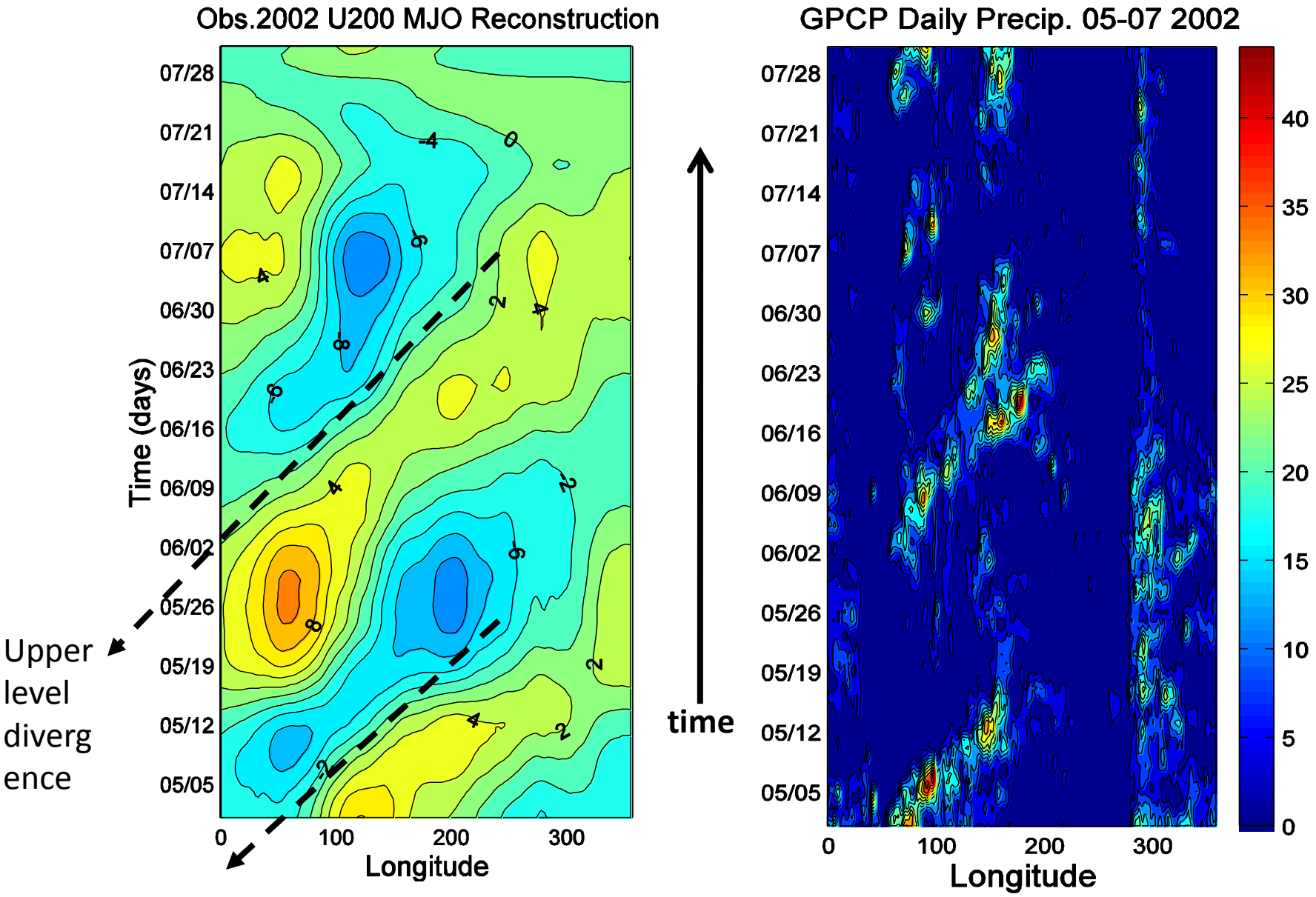
First and second EOFs of the zonal wind



EOF1 $\xrightarrow[r=0.6]{10\ \text{days}}$ EOF2 $\longrightarrow$ -EOF1 $\longrightarrow$ -EOF2

A full oscillation in 40 days

Reconstructed U200 vs. GPCP Precipitation, May – July, 2002



20S-20N averaged, filtered U200 anomaly field

5S-5N averaged, total unfiltered precipitation field

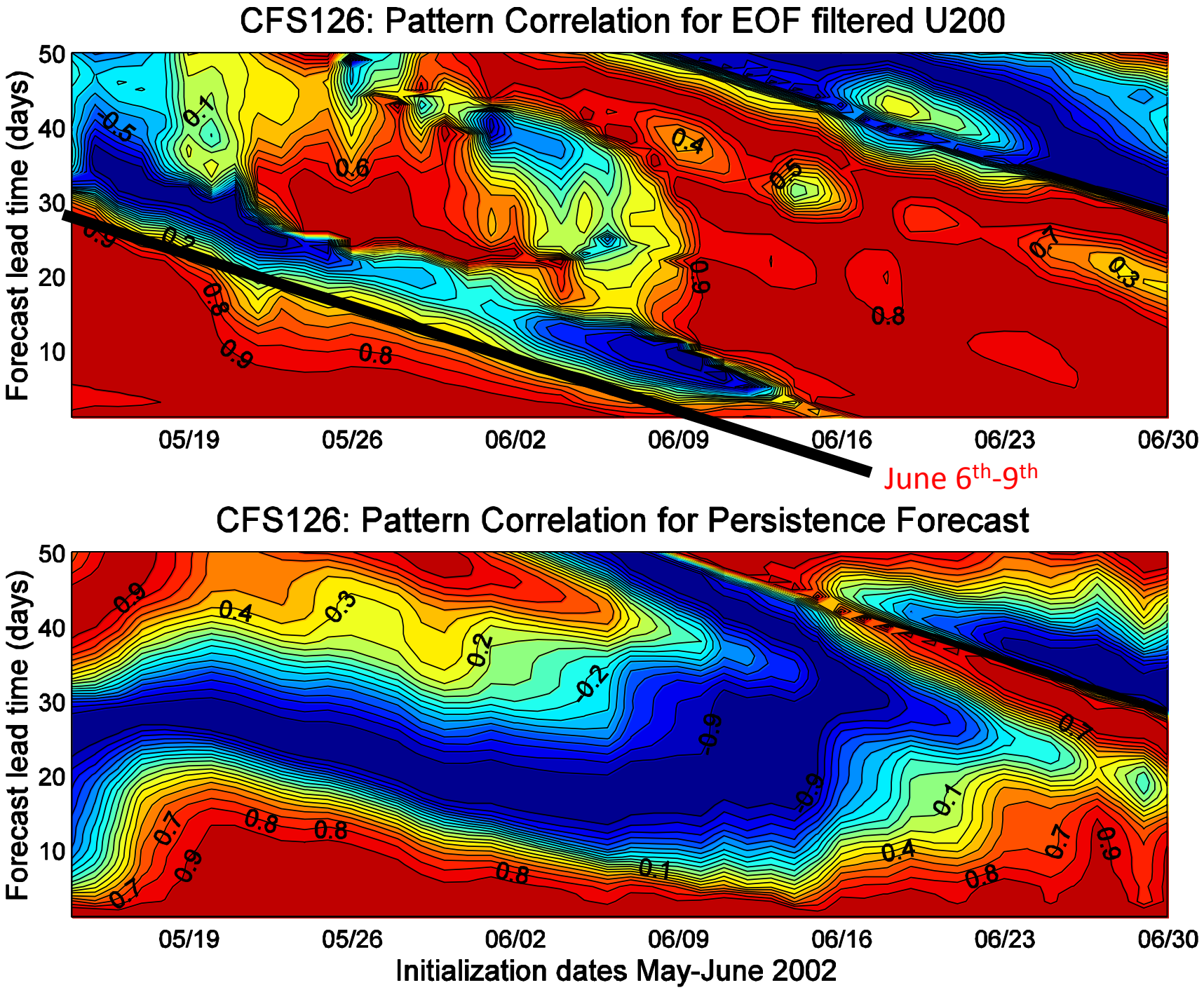
What is the Maritime Continent Prediction Barrier?

Forecast Skill of the CFS as a function of:

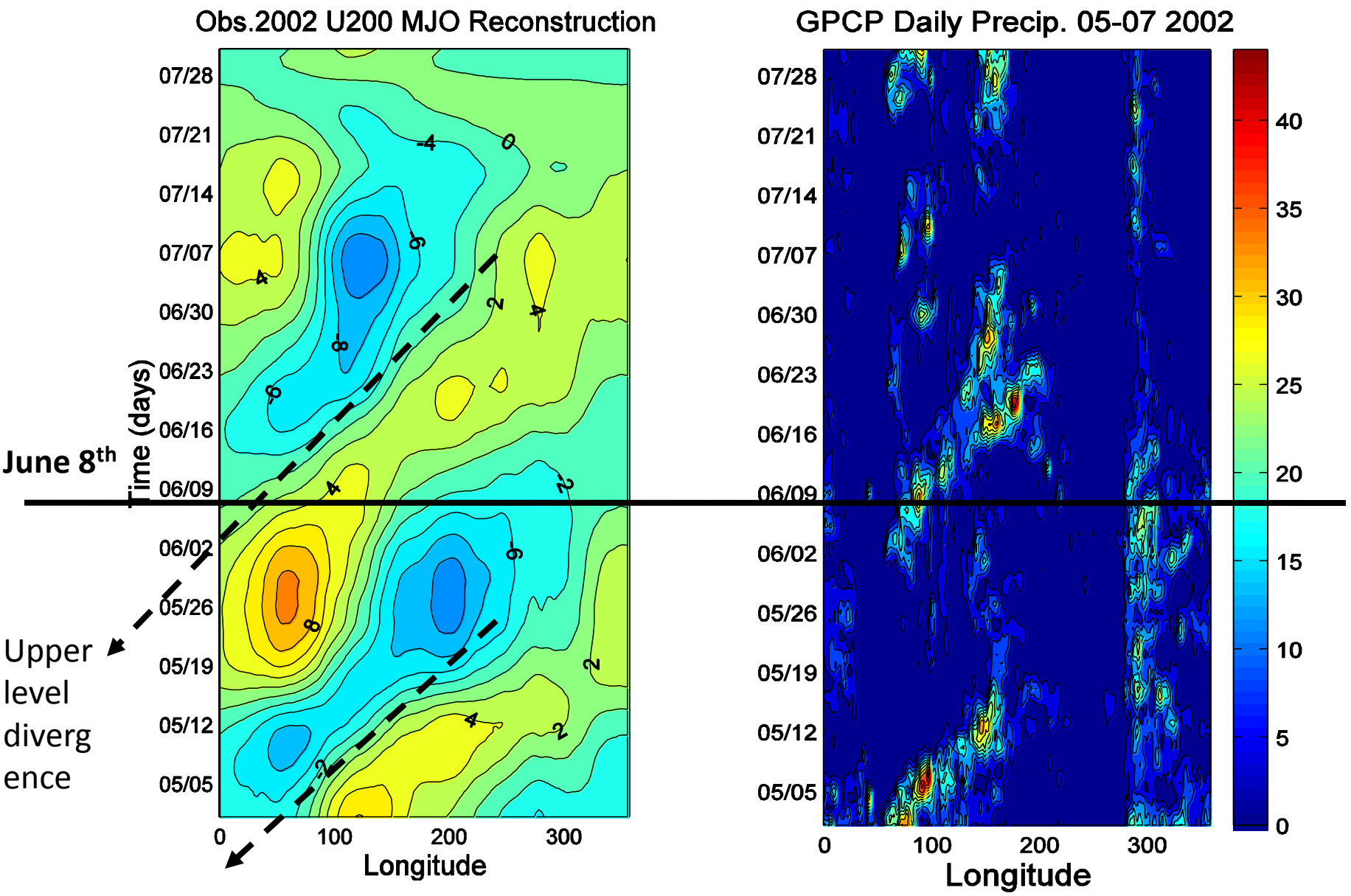
(x) initialization day (May – June 2002) and

(y) lead time

– Reforecasts for summers from 2000 to 2005


CFS126: Pattern Correlation for EOF filtered U200
Forecast lead time (days)
50
40
30
20
10
05/19
05/26
06/02
06/09
06/16
06/23
06/30
June 6th-9th
CFS126: Pattern Correlation for Persistence Forecast
Forecast lead time (days)
Initialization dates May-June 2002

Reconstructed U200 vs. GPCP Precipitation, May – July, 2002



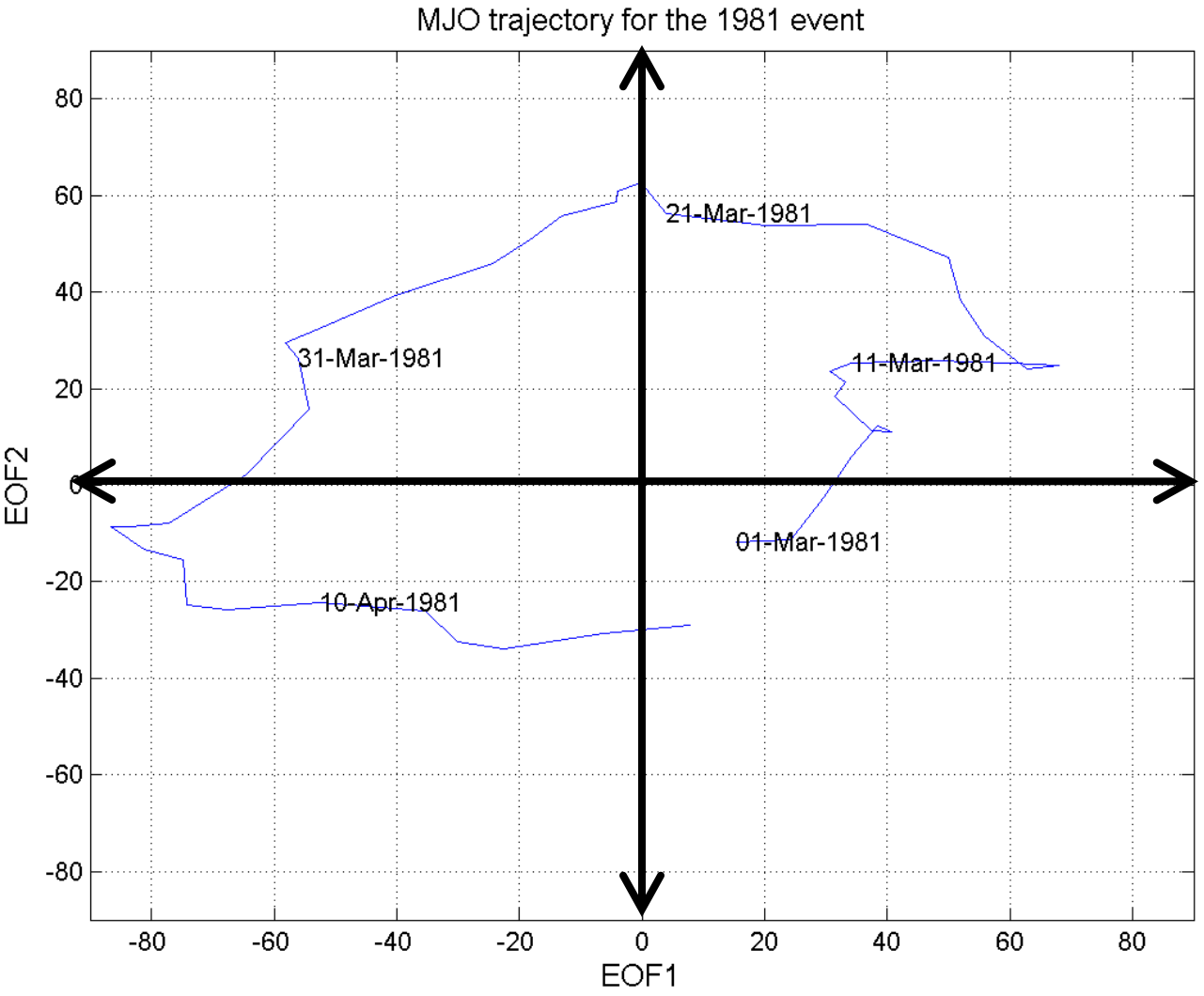
20S-20N averaged, filtered U200 anomaly field

5S-5N averaged, total unfiltered precipitation field

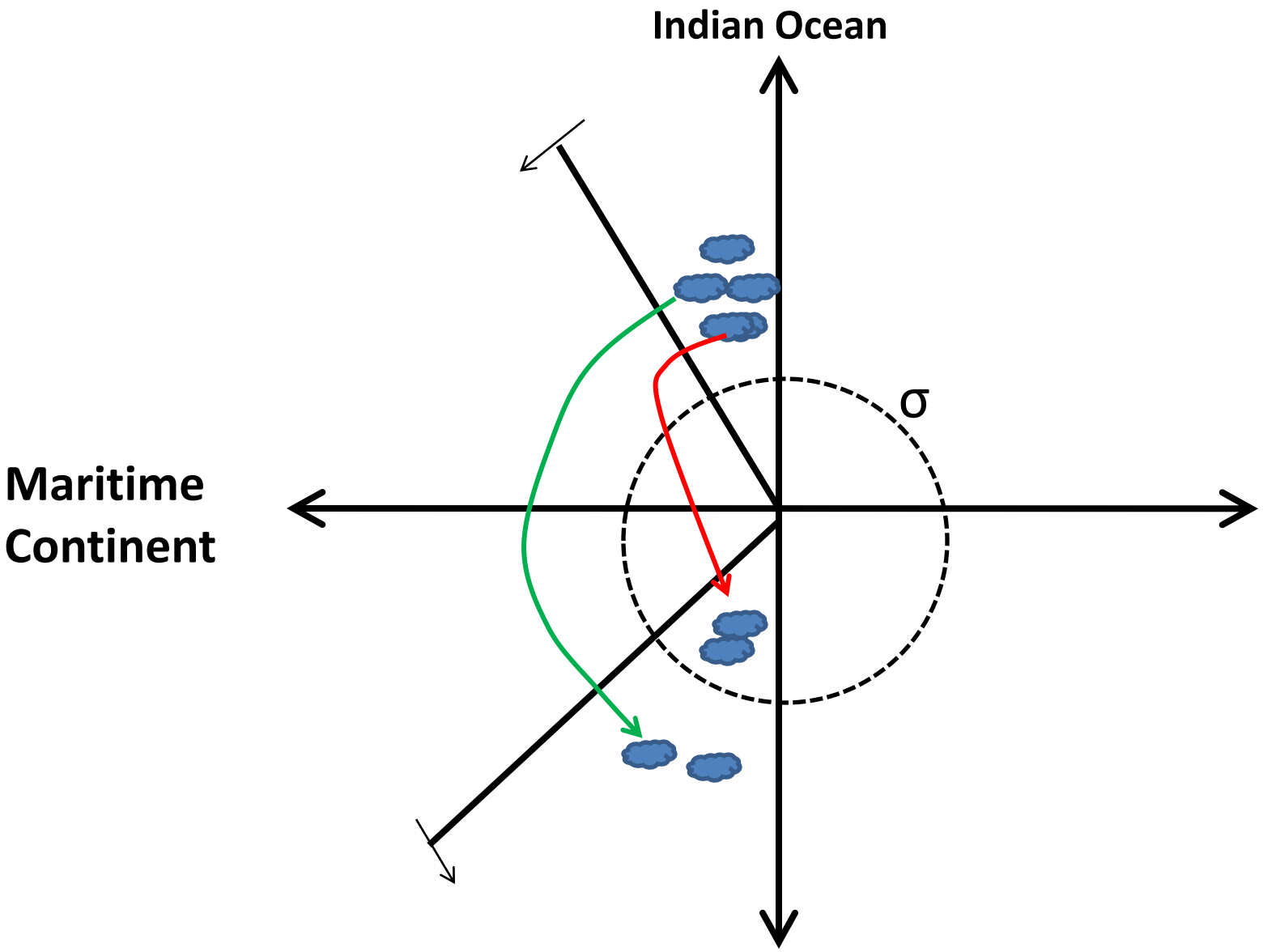
Special case of first event in 1981 as viewed by the simplified index

Indian Ocean

Maritime Continent

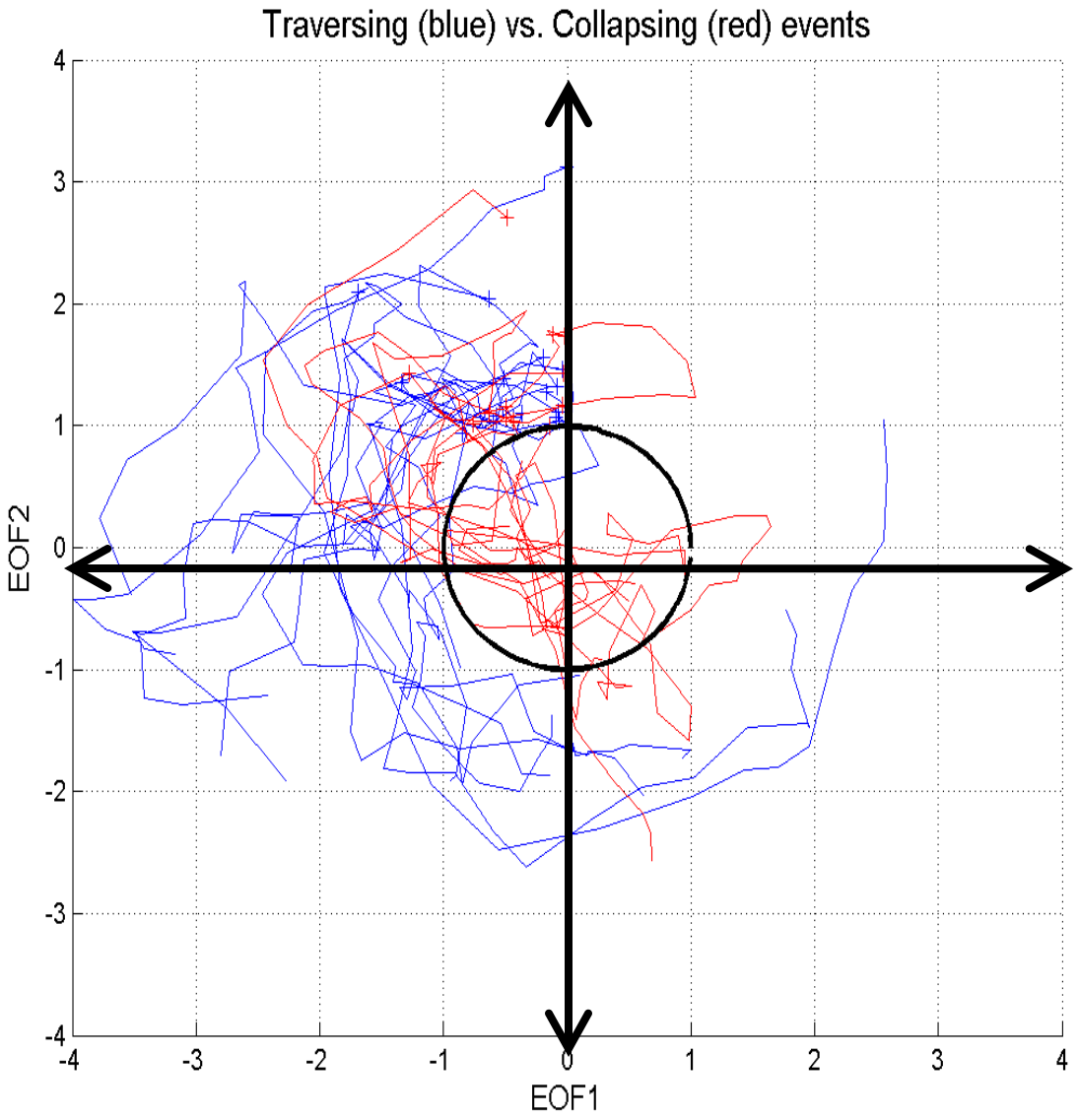


Classifying strong Indian Ocean events that collapse over the Maritime Continent *versus* events that are traversing

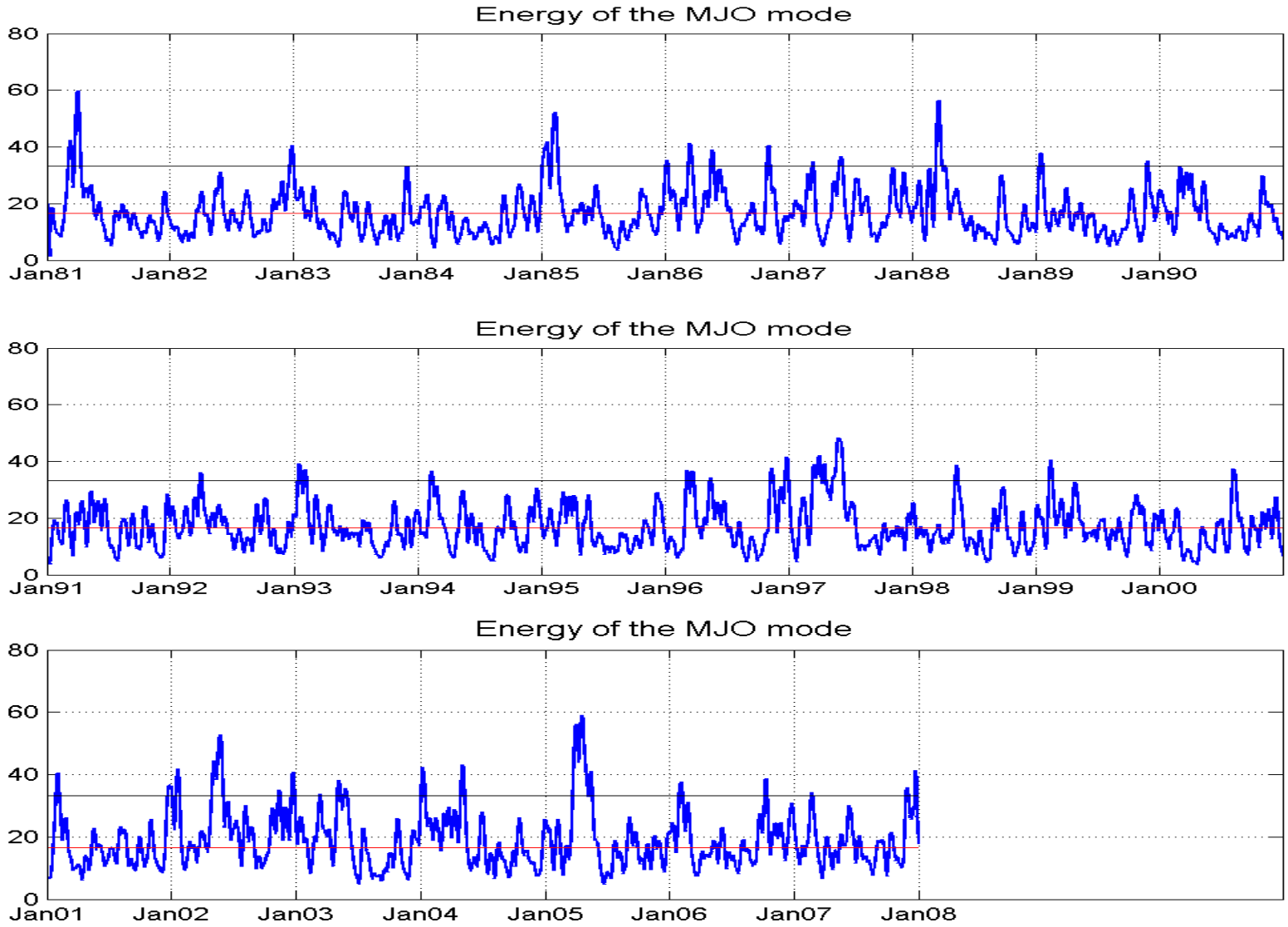


Classification of Traversing versus Collapsing MJO events

Maritime Continent



Observed MJO events from 1980 to 2007 as seen by the simplified index



Classification between Collapsing and Traversing MJO events