Experiments conducted under NOAA's Climate Test Bed

Importance of Atmospheric and Oceanic Initial conditions in forecasting the MJO with the NCEP-CFS

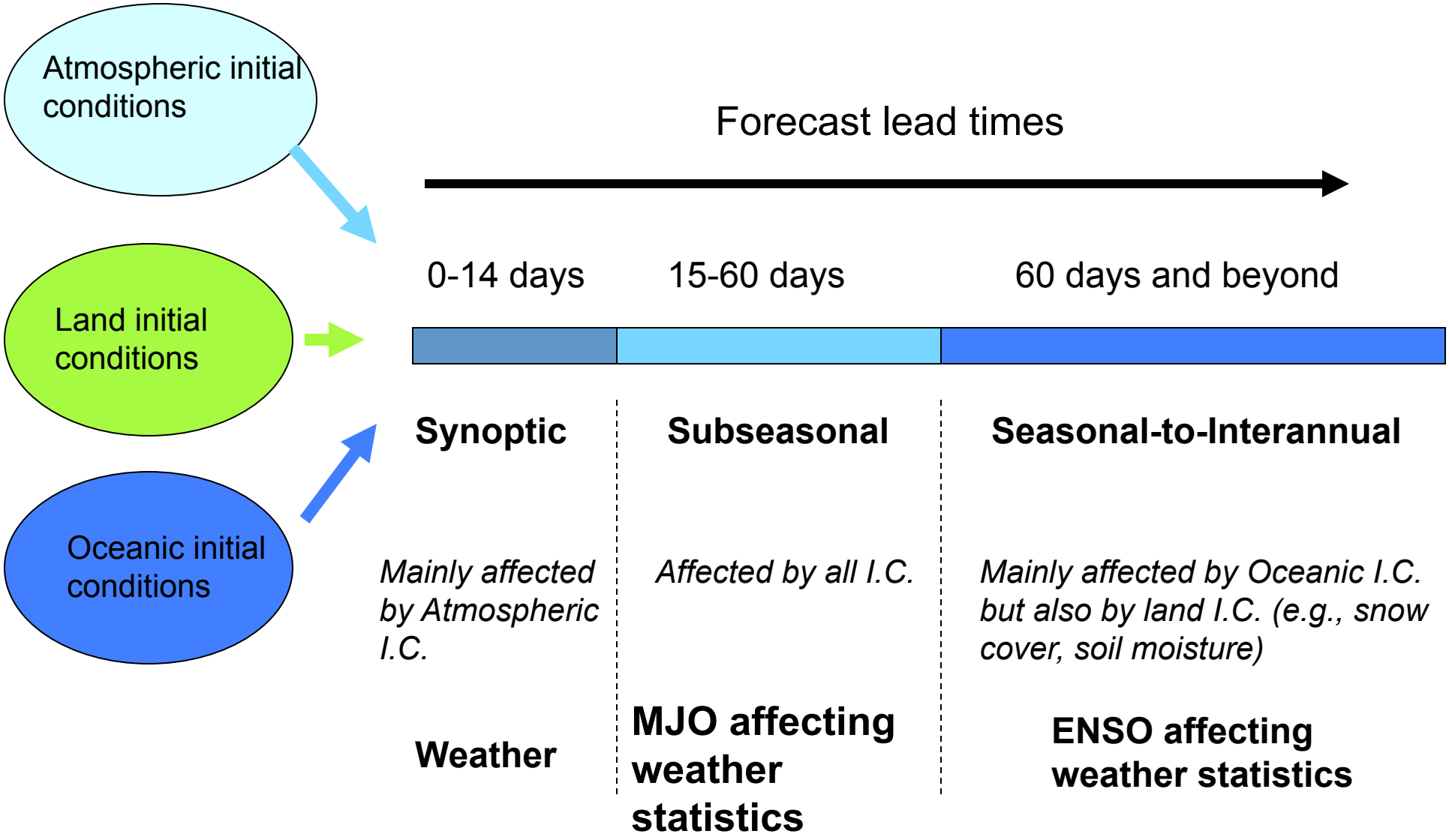
Augustin Vintzileos

and

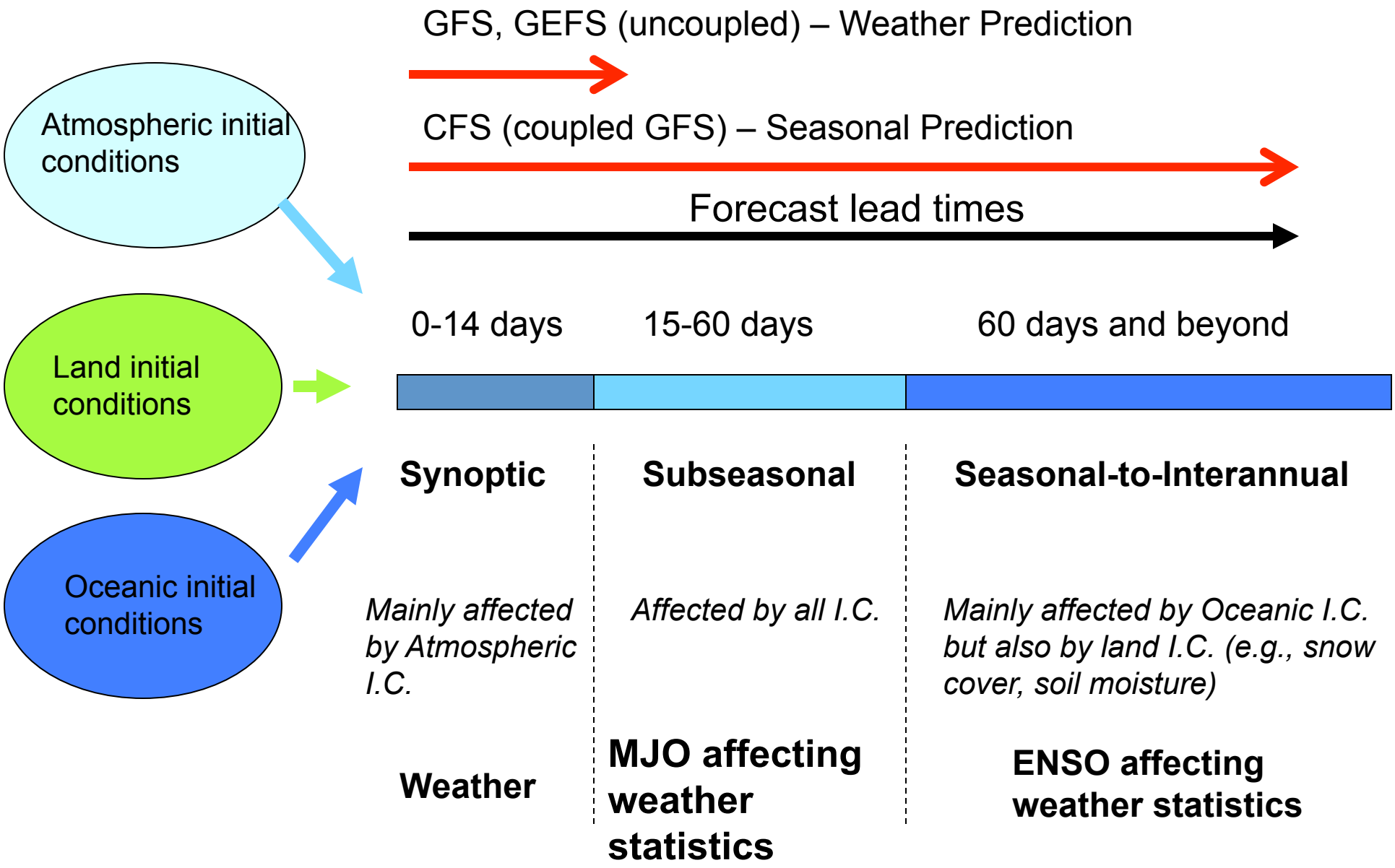
Hua-Lu Pan, David Behringer

EMC/NCEP/NWS/NOAA - SAIC

The seamless forecasting suite: from Weather to Climate



Current global operational forecasting suite at NCEP



Model Characteristics

Weather Prediction:

GFS = T382L64 → T190L64 up to 15 days, initialized by operational NCEP analysis (GDAS), SSTs are dumped to mean seasonal values.

GEFS = Ensemble forecast with GFS at T190L28 up to 15 days.

Seasonal Prediction:

CFS = coupled GFS at T62L64 up to month 10, initialized by Reanalysis-2, interactive SST by MOM3 initialized by operational NCEP ocean analysis (GODAS)

Open questions for subseasonal forecast:

-- How important is resolution?

-- How important is initialization?

-- Atmospheric vs. Oceanic I.C.

-- How to generate ensemble forecasts?

Outline:

Subseasonal forecasting with the CFS

-- A metric for MJO

-- Some initial forecast experiments with the CFS:

The Maritime Continent Prediction Barrier

-- Multi-resolution and multi-I.C. re-forecast experiments

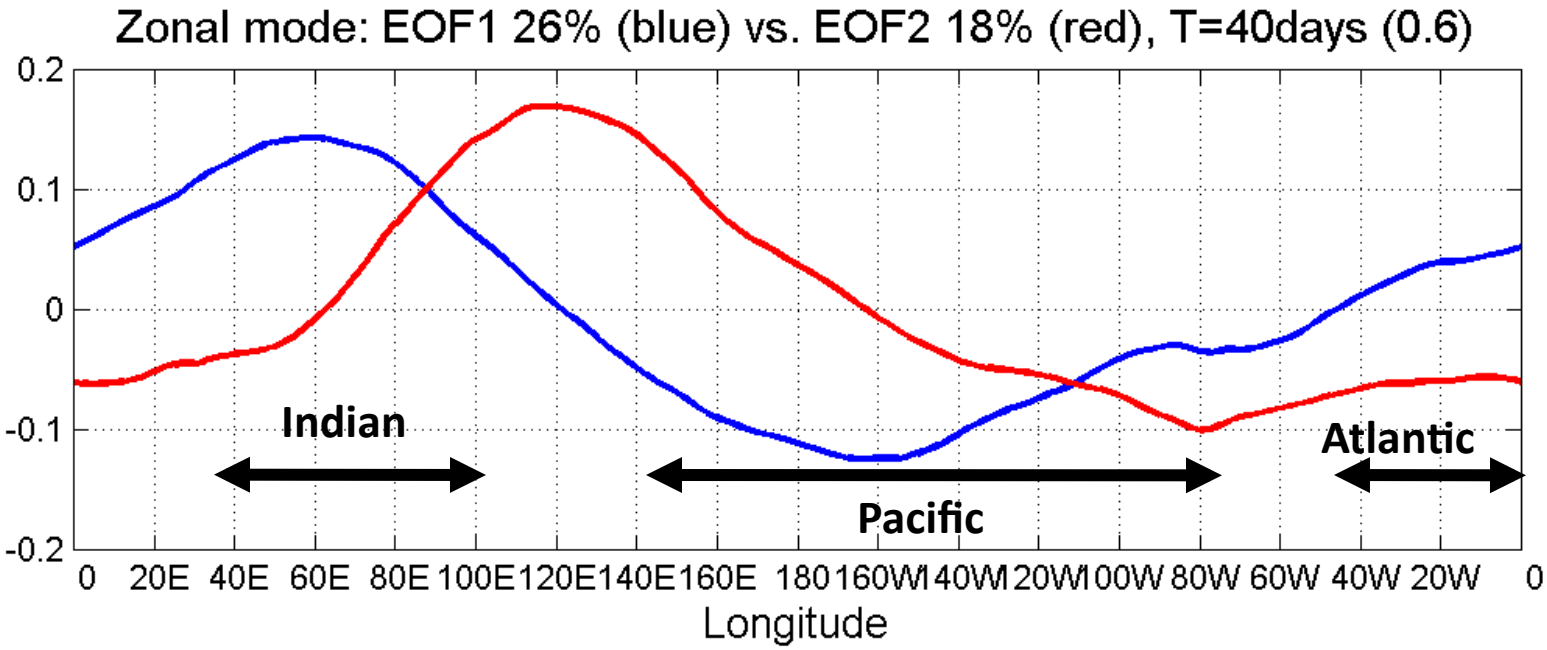
-- Conclusions and work to follow

Defining a metric for the MJO

We use a simplified version of the Wheeler and Hendon Index:

- Verifying fields are from Reanalysis-2
- Use the zonal wind at 200 hPa from 2002 to 2006 averaged between 20°S-20°N
- Compute and remove the mean annual cycle and the zonal mean
- Perform and EOF analysis of the resulting field (no time filtering)

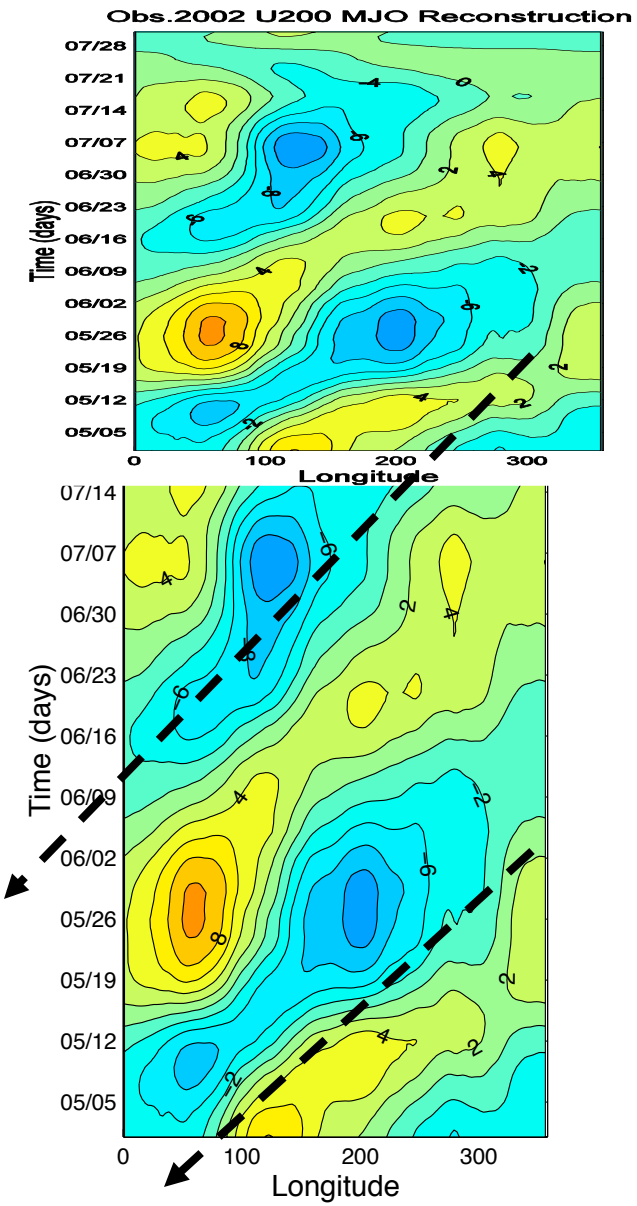
First and second EOFs of the zonal wind at 200 hPa averaged between 20°S – 20°N

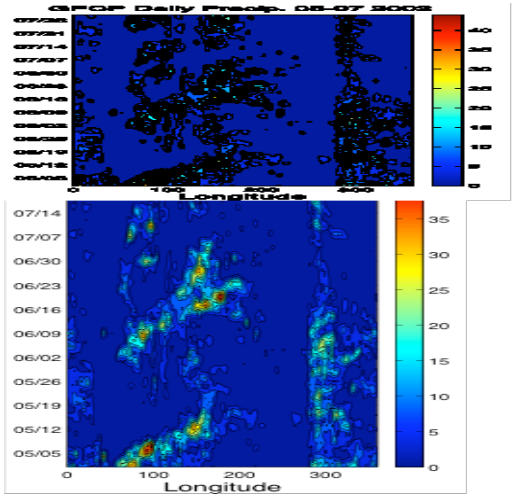


EOF1 —10 days, r=0.6→ EOF2 → -EOF1 → -EOF2

A full oscillation in 40 days

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





Upper level divergence

20S-20N averaged, filtered U200 anomaly field

5S-5N averaged, total unfiltered precipitation field

Forecasting the MJO with the CFS

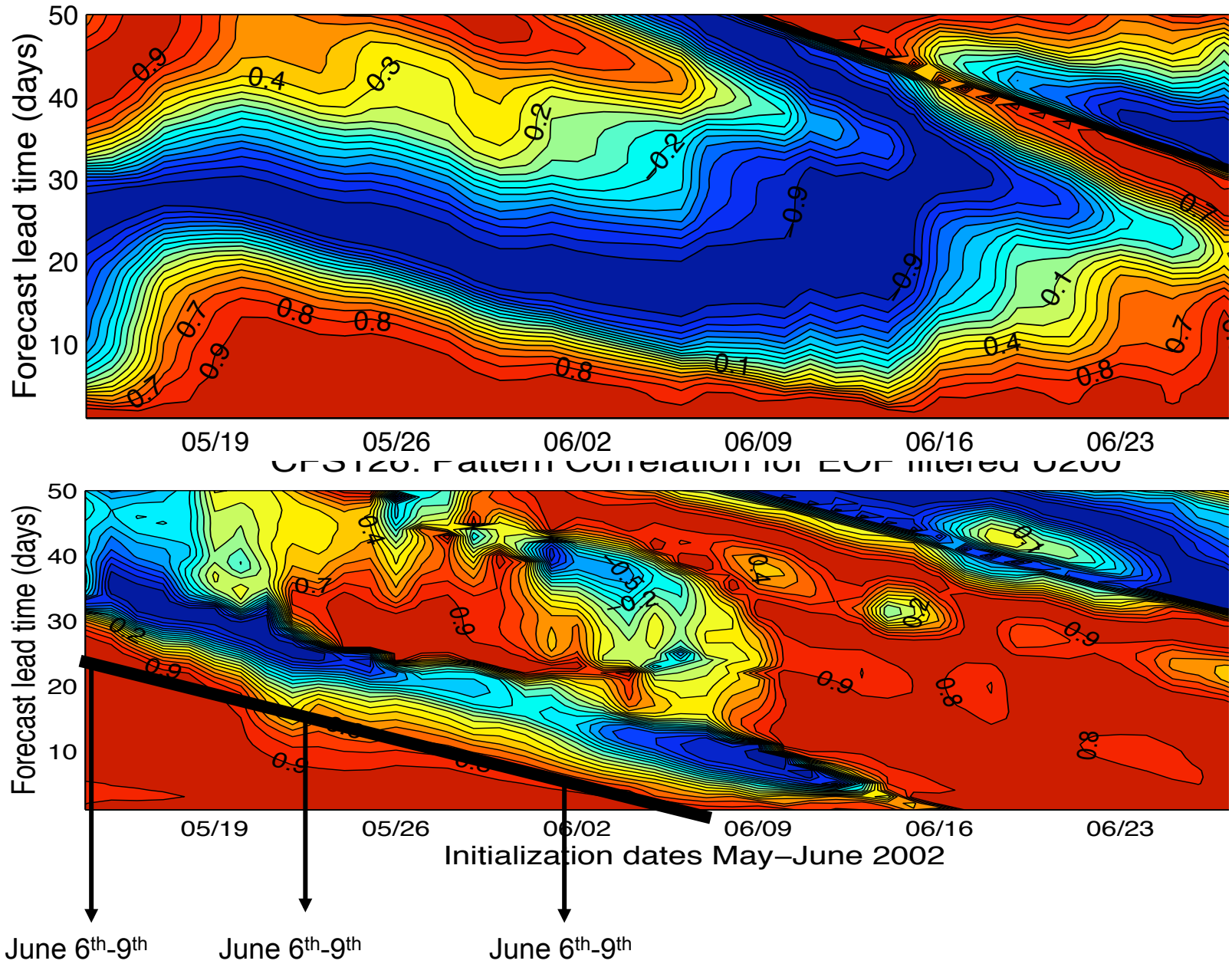
In a first set of experiments the operational CFS at T126 was initialized 4 times per day by Reanalysis-2 and GODAS at 00Z, 06Z, 12Z and 18Z from 2000 to 2005

Forecast skill is obtained by:

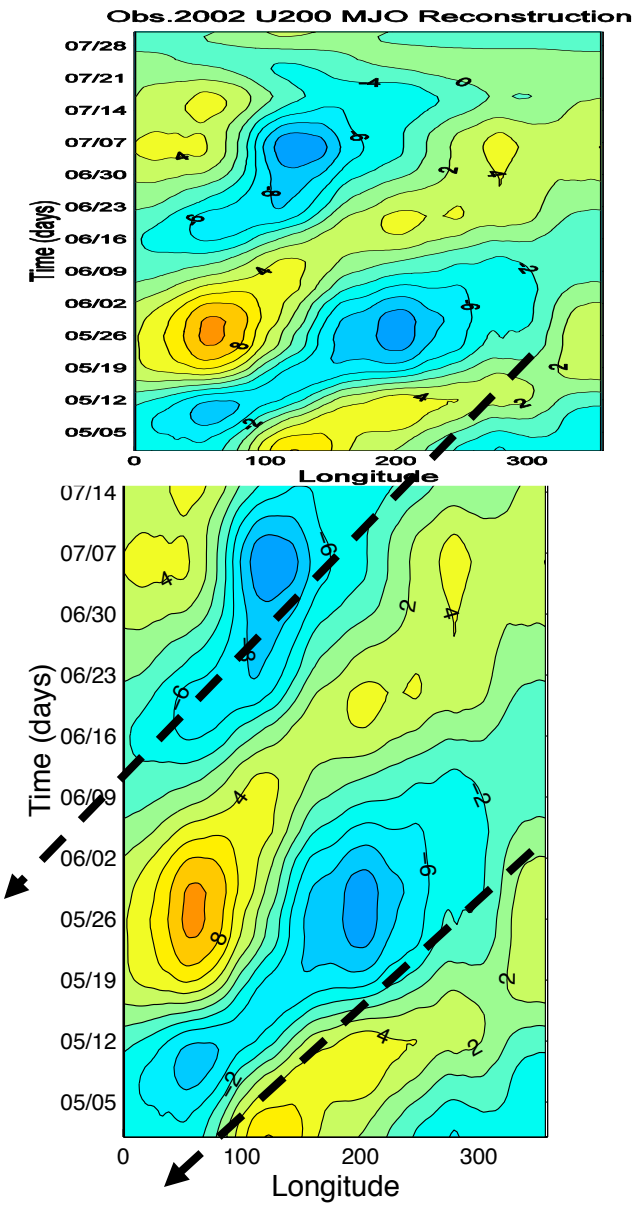
❖ Projecting forecast and observed fields on the two MJO EOFs

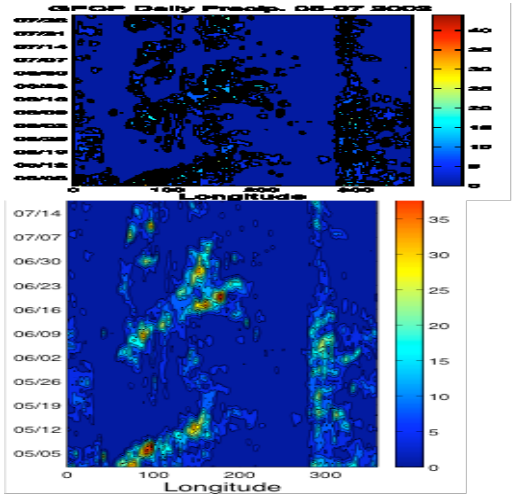
❖ Computing the pattern correlation between forecast and observed MJO

Forecast Skill as a function of initialization day and lead time for: May – June 2002



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



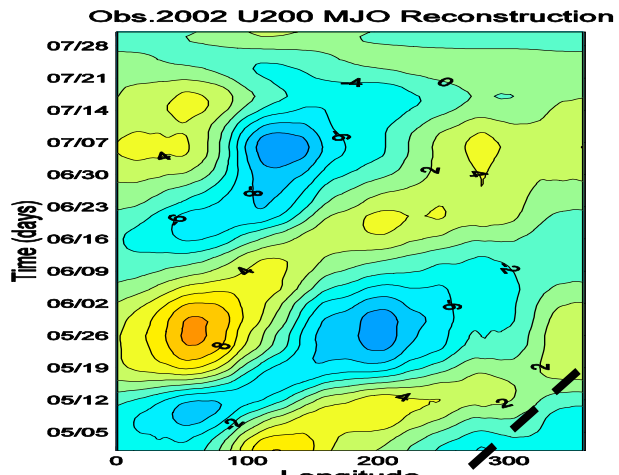


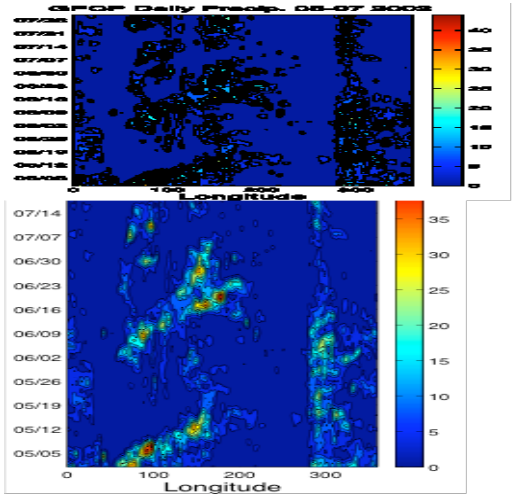
Upper level divergence

20S-20N averaged, filtered U200 anomaly field

5S-5N averaged, total unfiltered precipitation field

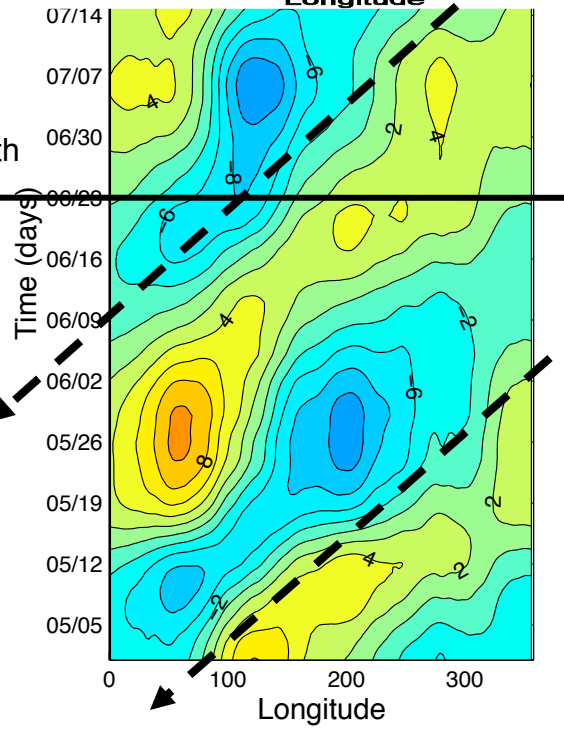
Reconstructed U200 vs. GPCP Precipitation, May – July, 2002





June 9th

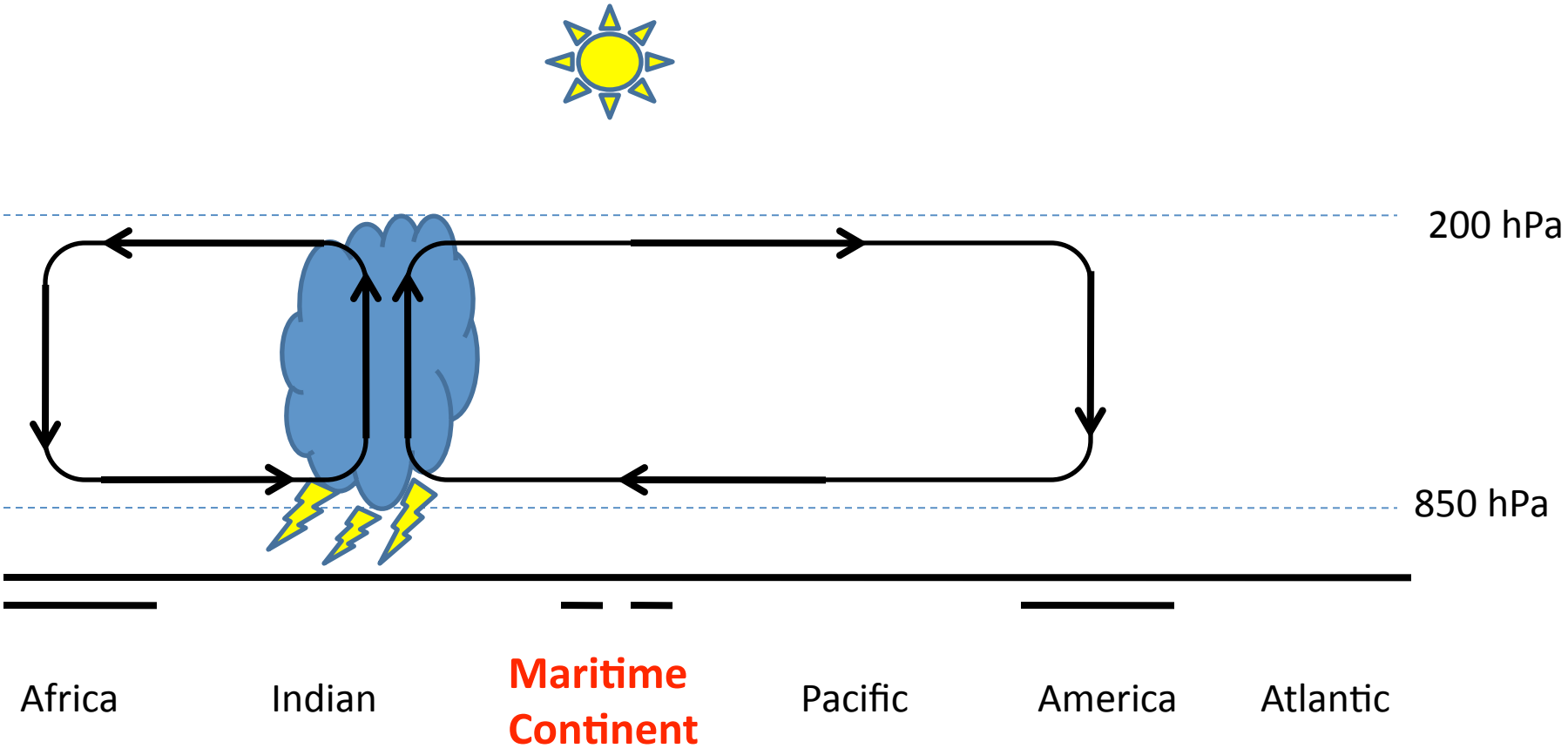
Upper level divergence



20S-20N averaged, filtered U200 anomaly field

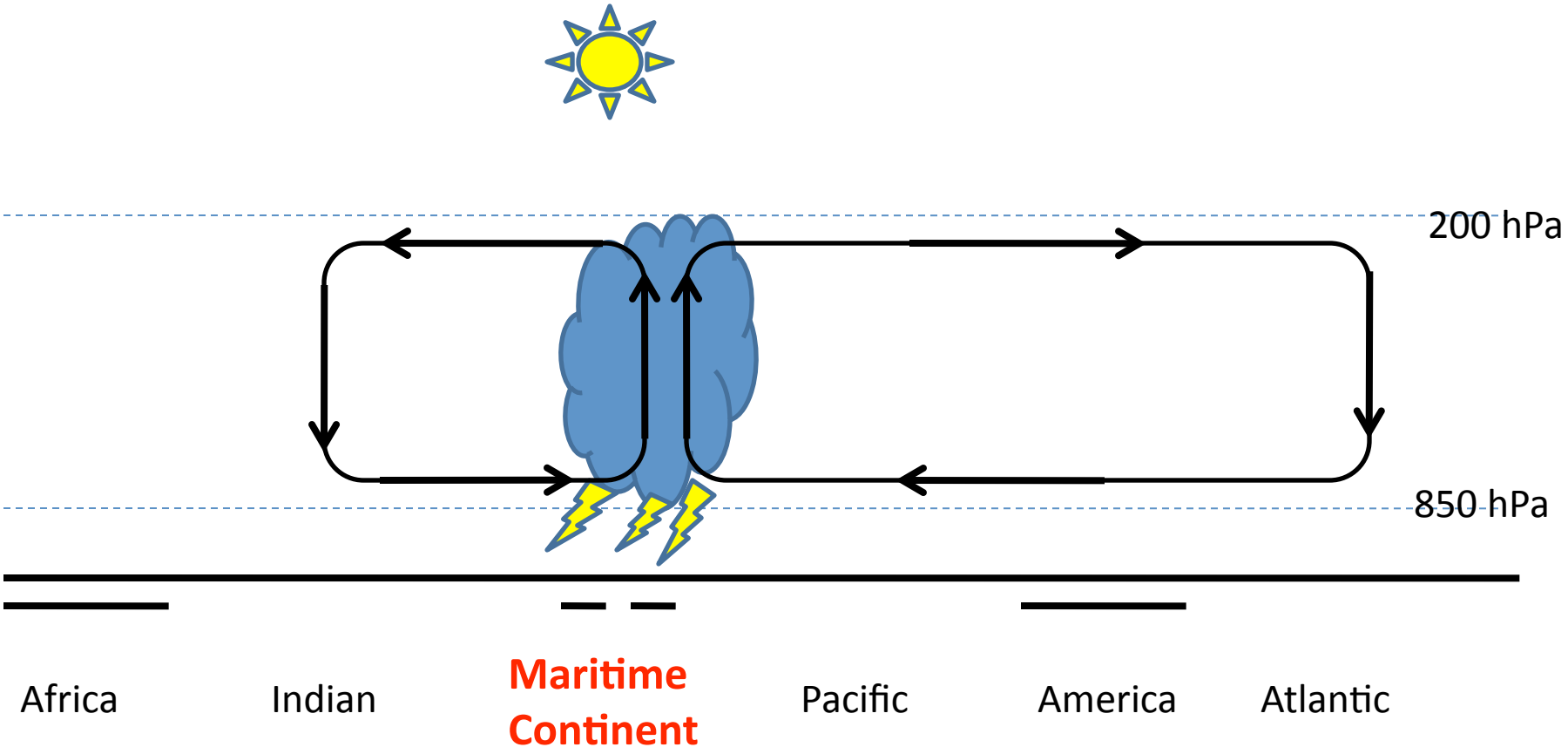
5S-5N averaged, total unfiltered precipitation field

Longitude – height Equatorial section



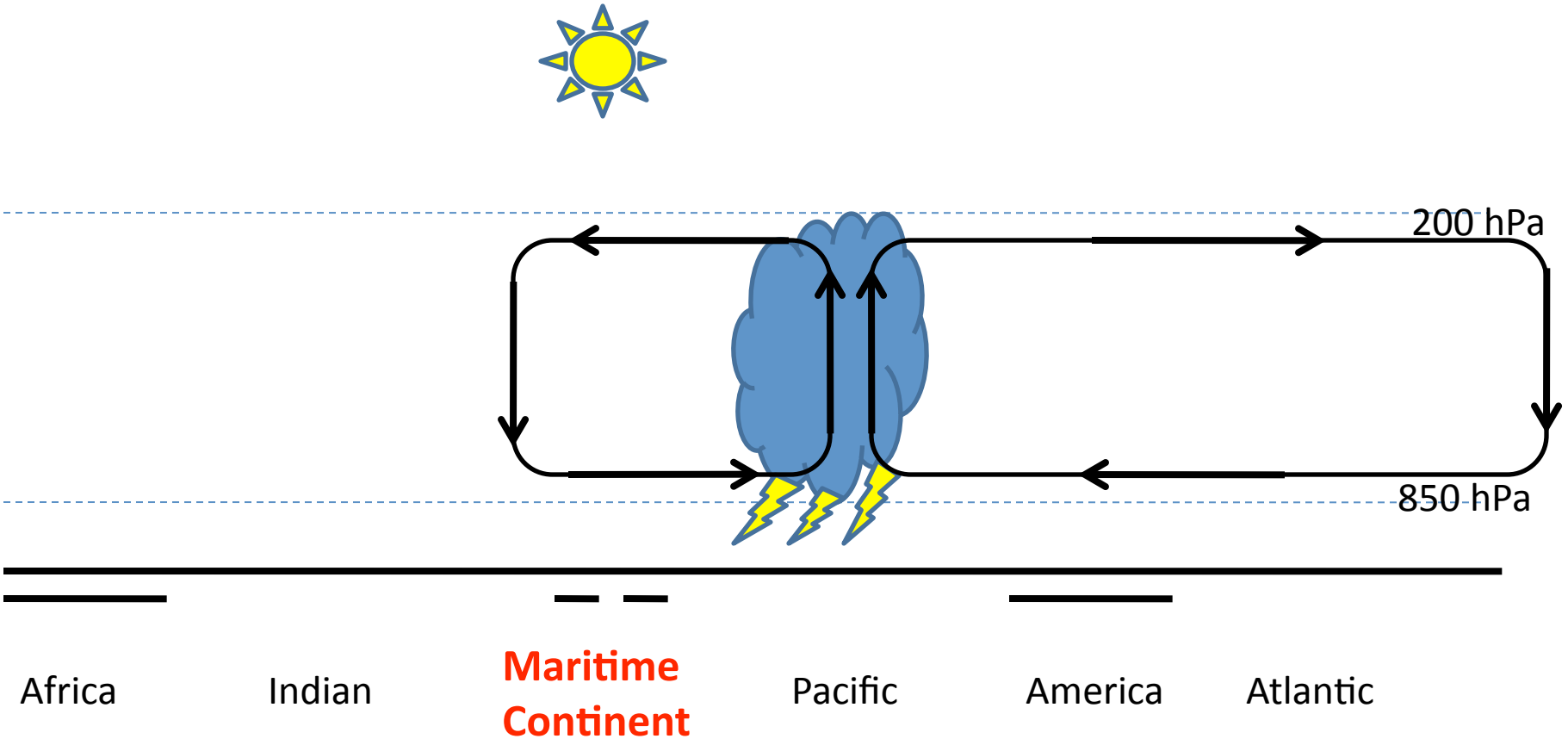
Observations

Longitude – height Equatorial section



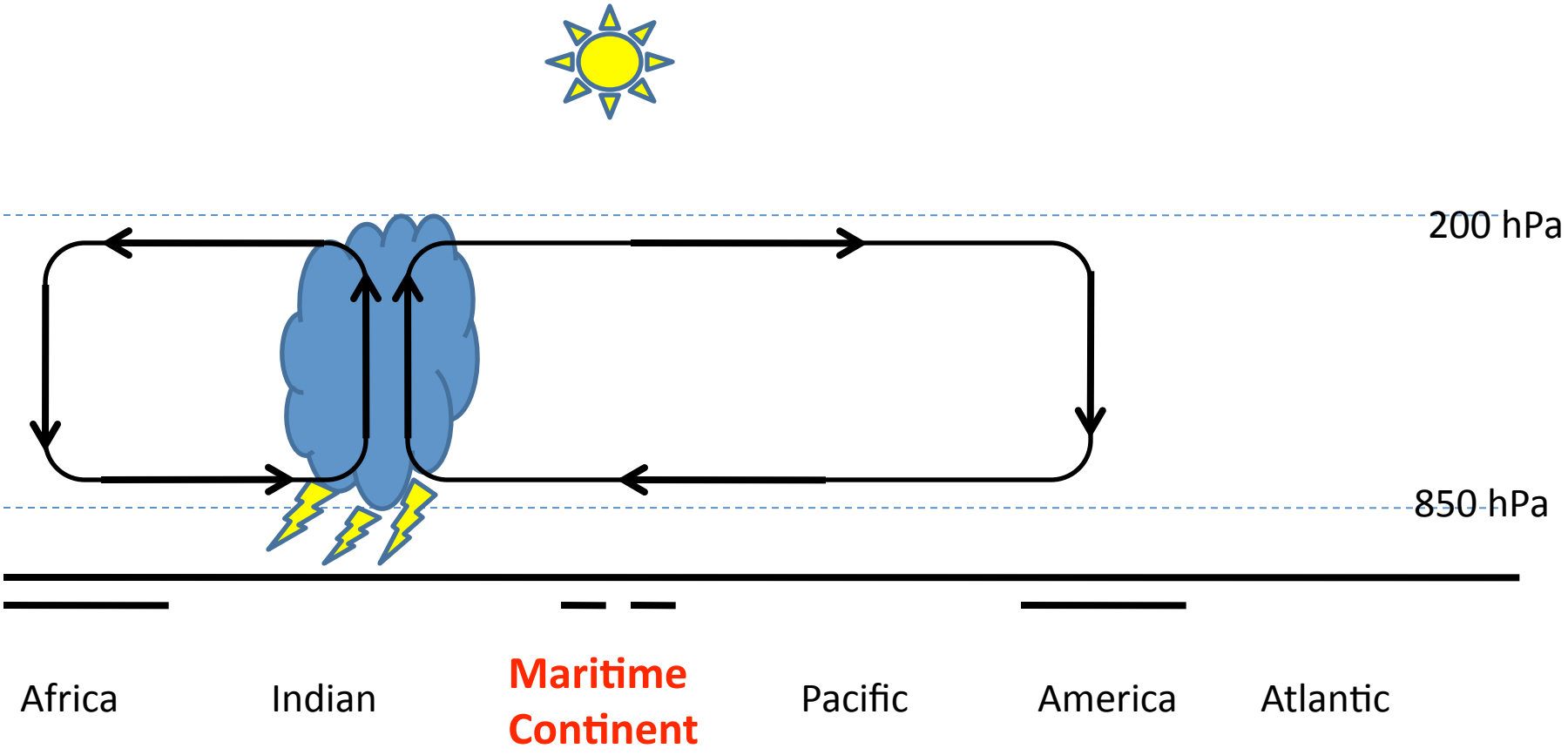
Observations

Longitude – height Equatorial section



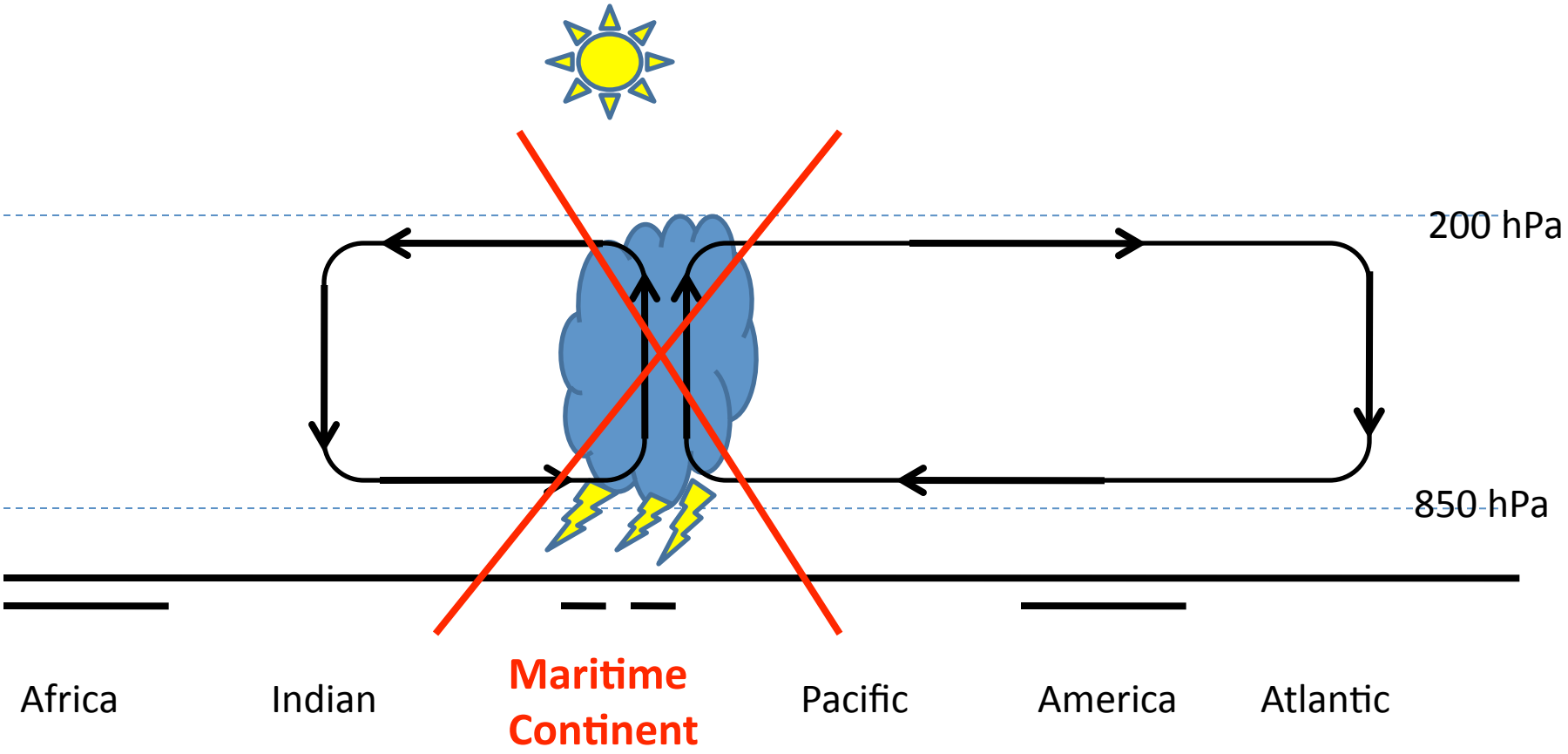
Observations

Longitude – height Equatorial section



Model

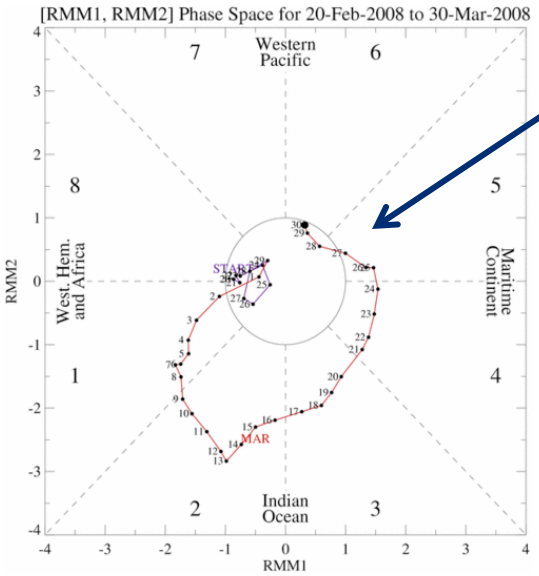
Longitude – height Equatorial section



Model

A real time GEFS forecast example of the barrier

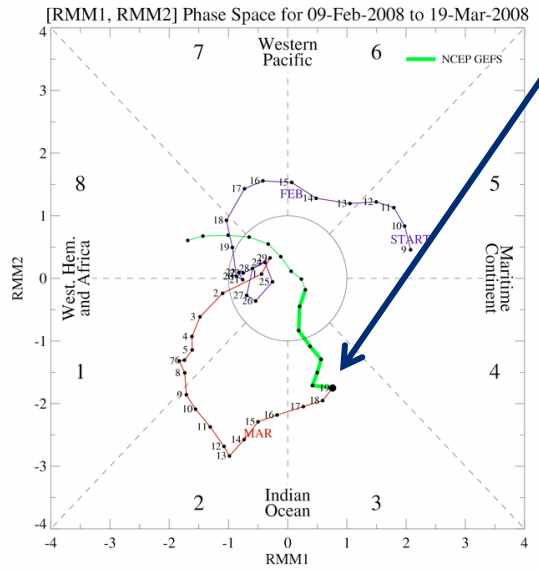
(graphs courtesy Jon Gottschalck CPC)

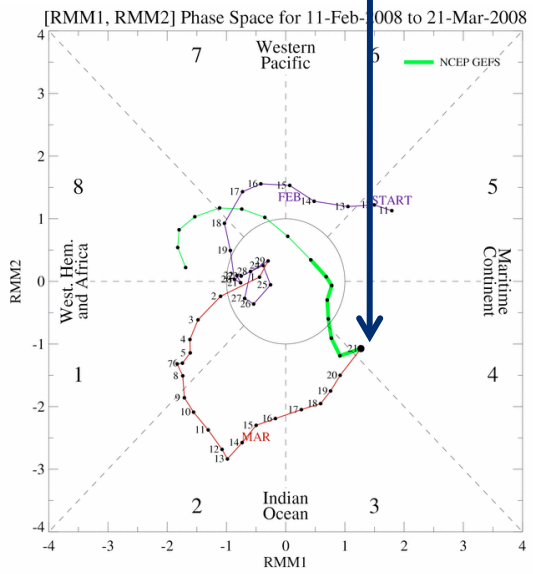


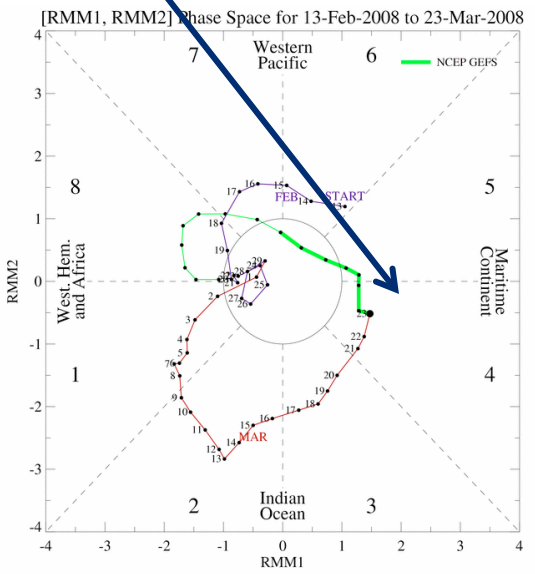
Observed MJO event of March 2008 is crossing the Maritime Continent

Based on the Wheeler and Hendon (2004) index

Forecast MJO 'collapses' immediately after initialization before crossing the Maritime Continent







Horizontal resolution and atmospheric I.C.:

Reforecasts:

May 23rd to August 11th from 2002 to 2006, 1 forecast every 5 days

Forecast lead: 60 days

Model resolution:

***Atmosphere*: T62 = 200Km x 200Km**

T126 = 100Km x 100Km

T254 = 50Km x 50Km

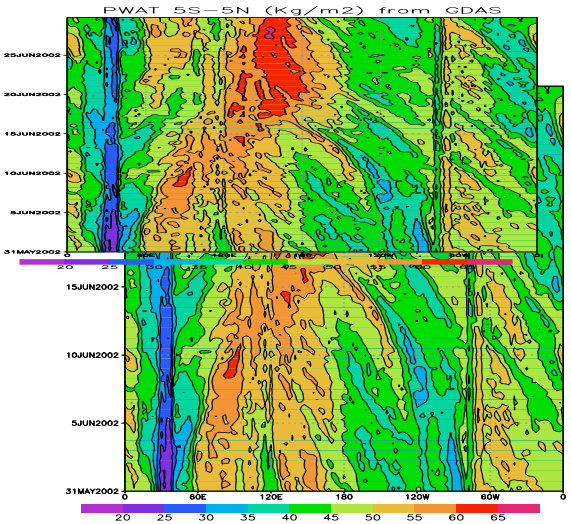
***Ocean*: the standard CFS resolution**

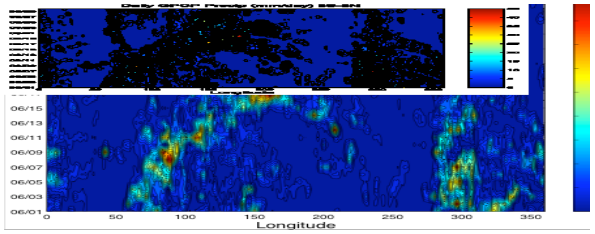
Initial conditions:

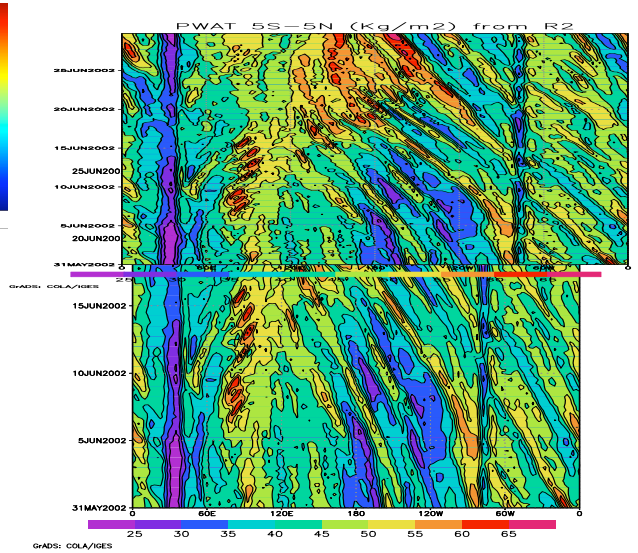
***Atmosphere, Land*: from Reanalysis 2 (CDAS2) and from GDAS**

***Ocean*: from GODAS**

Operational GDAS versus Reanalysis-2 initial conditions: June 2002

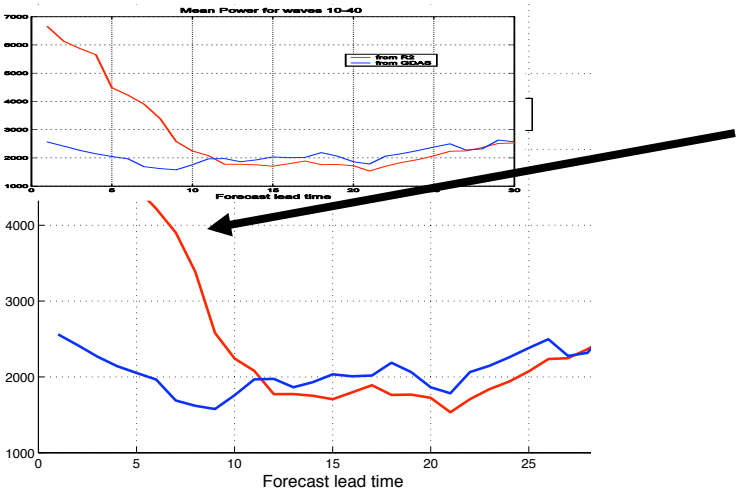






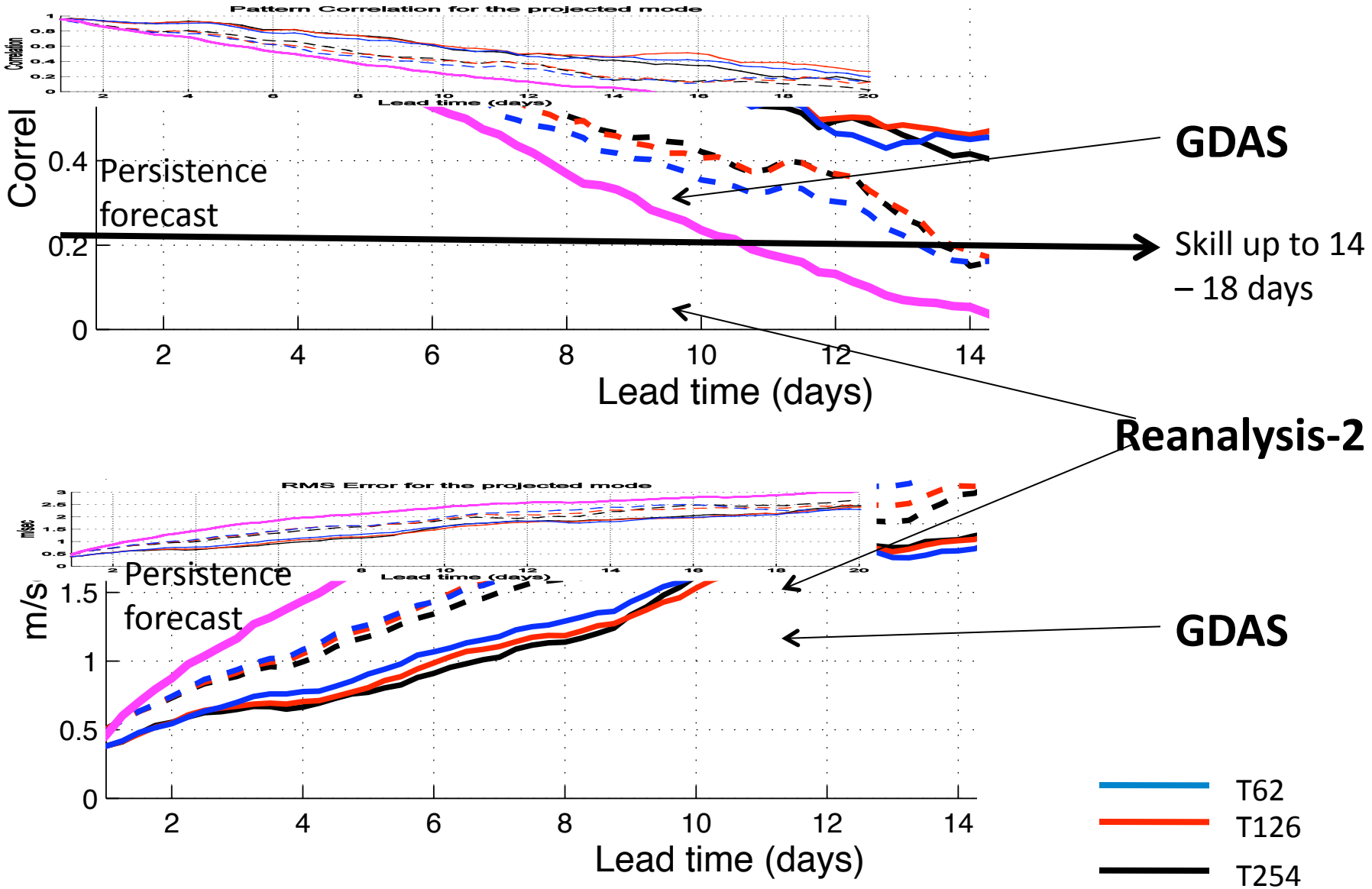
GDAS Precipitable Water GPCP Precipitation **Reanalysis 2 Precipitable Water**

Time evolution of mean energy at wave numbers 10-40 when CFS is initialized by R-2 (red) or by GDAS (blue).

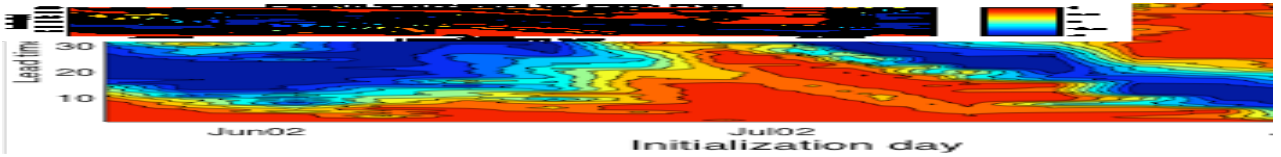


drift

Skill for the MJO mode (verification CDAS2)

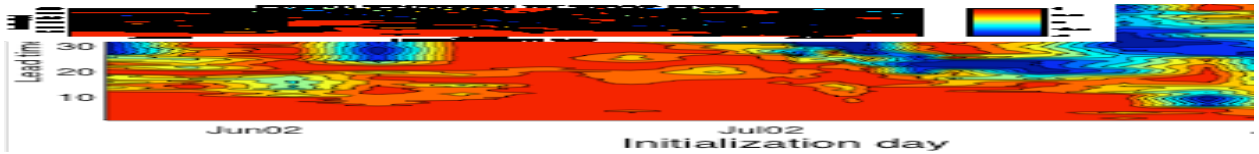


Pattern correlation as a function of initialization day and lead time



The CFS has better skill than persistence during the propagation of the dry phase of the MJO through the Maritime Continent.

June 8th



However, during the transition of the wet phase of the MJO through the Maritime Continent the CFS is not better than persistence

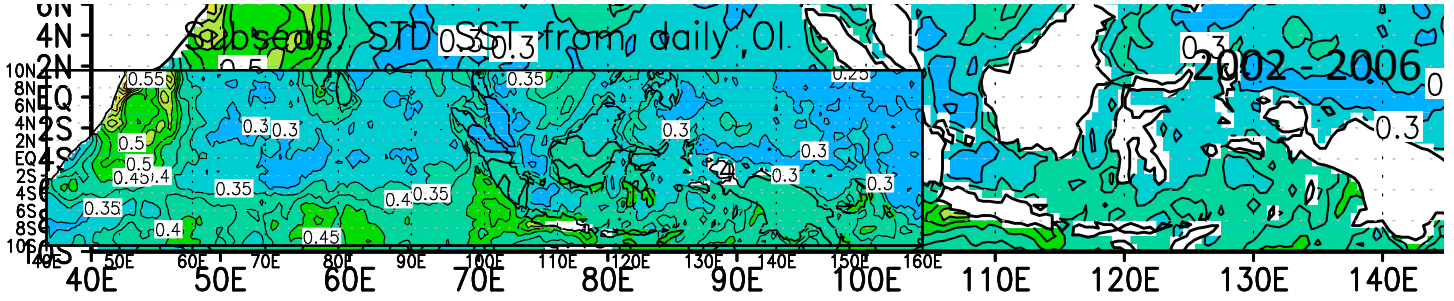
June 8th

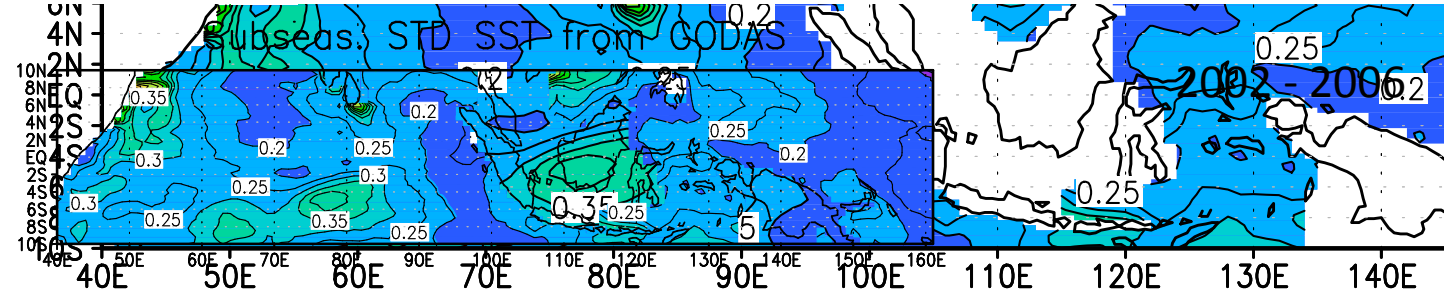
…and the Ocean?

- There is consensus that the ocean plays an important role for the evolution of the MJO
- CFS is initialized by GODAS which is optimized for Seasonal-to-Interannual forecast
  - Its SST is damped to the weekly Reynolds SST
  - Contains information from 2 weeks before and two weeks after

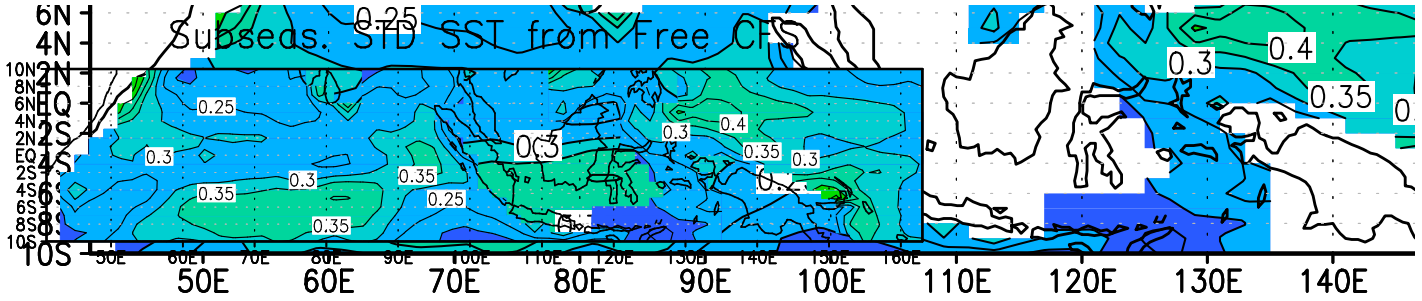
Standard Deviation of the 20-90 day filtered SST

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





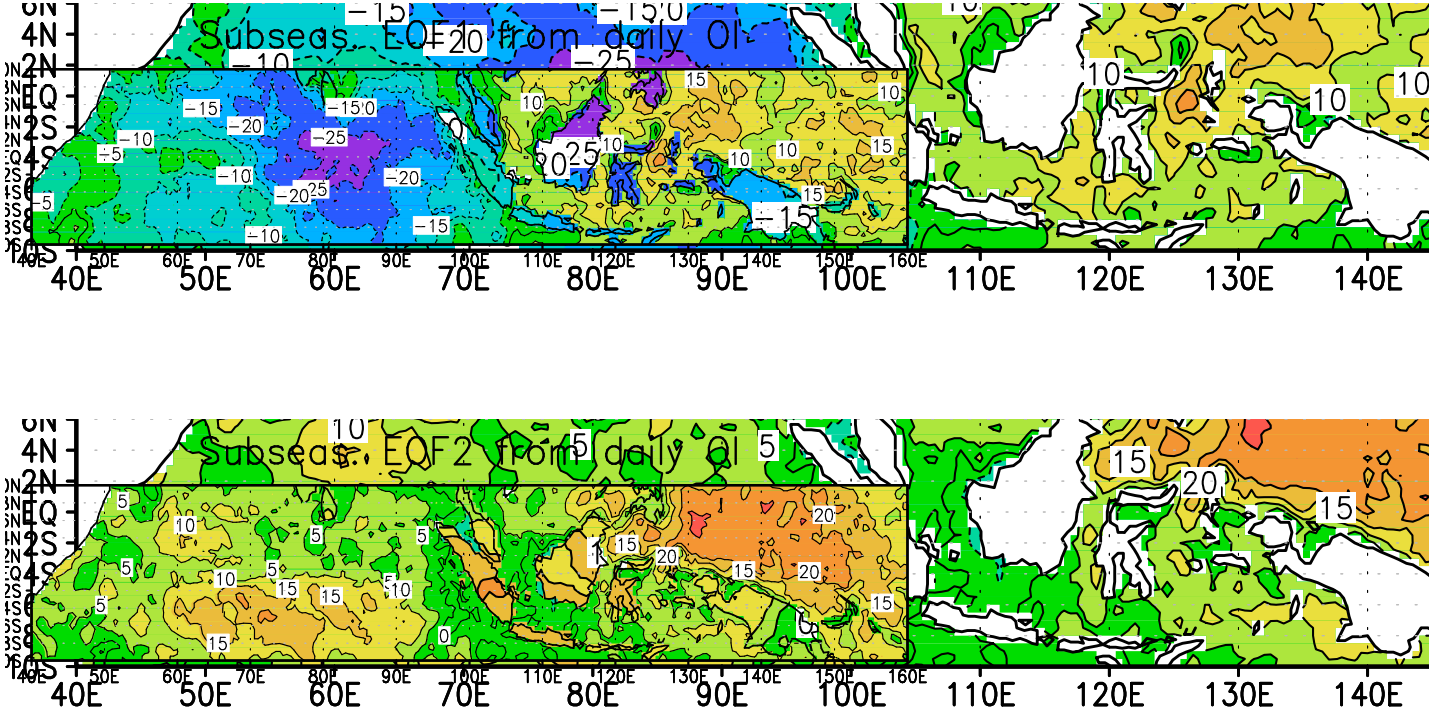
Intraseasonal variability increases in free runs with the coupled CFS



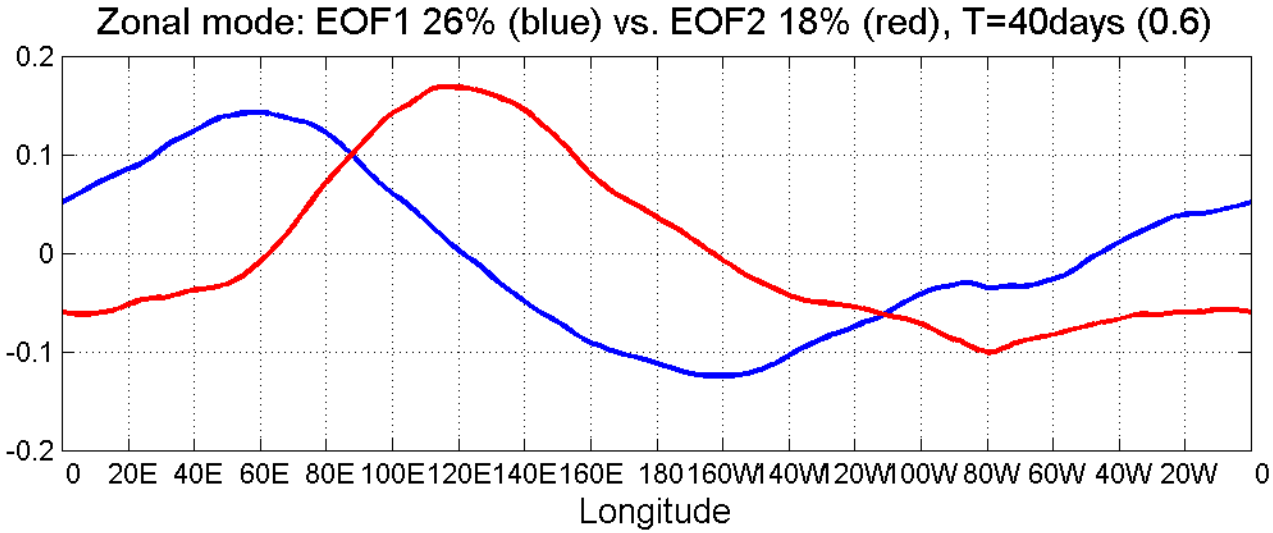
Is there any relation between oceanic intra-seasonal variability and the MJO?

First two eigenvectors of the daily observed SST correlation matrix

(10% and 7% of total intraseasonal variance)

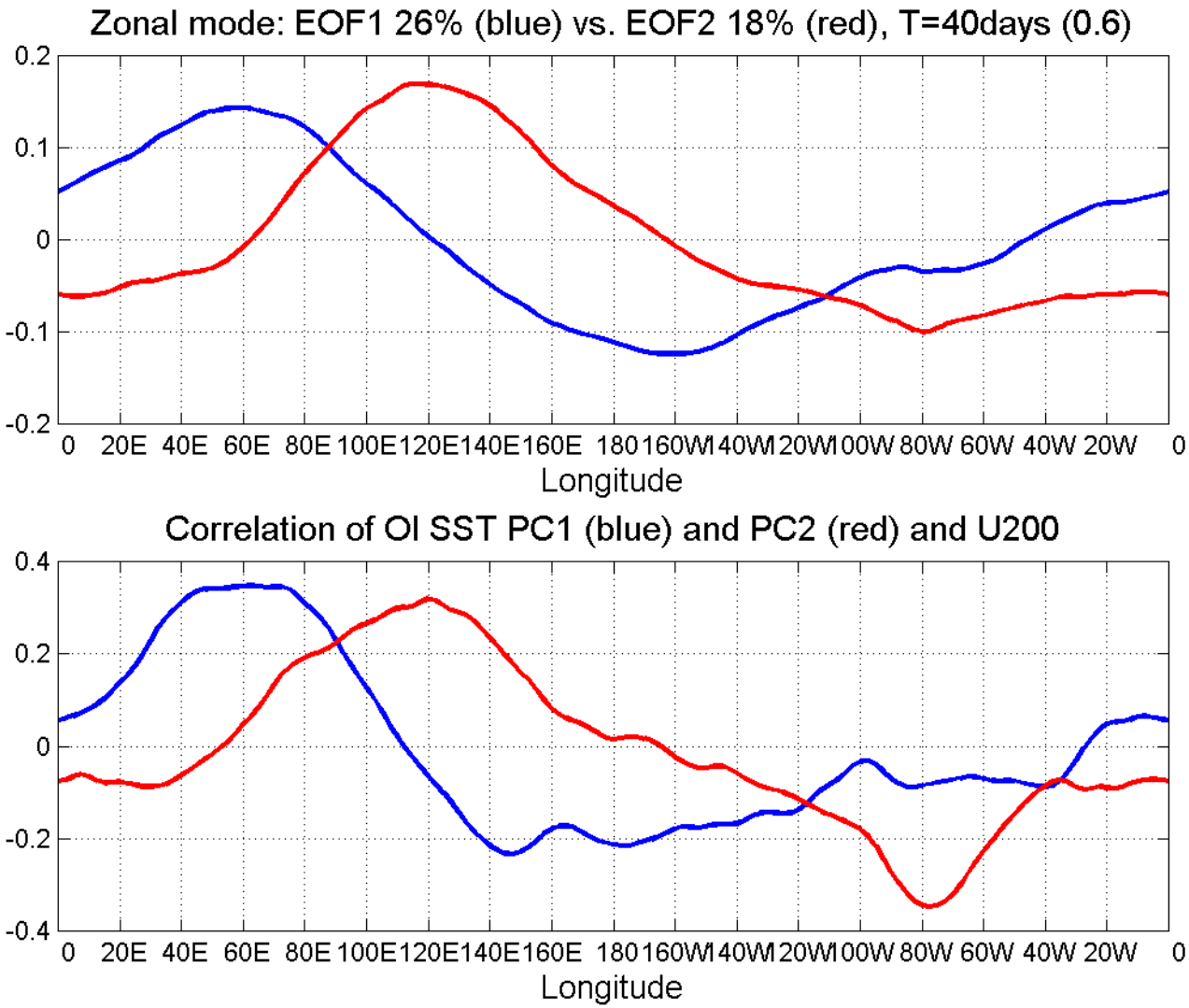


The MJO EOFs



Compare to the correlation between Principal Component 1 and Principal Component 2 of the daily OI SST and the anomalies of Zonal Wind at 200 hPa at each grid point

The MJO EOFs



There is remarkable resemblance between the U200 EOFs and the correlation of U200 anomalies and the SST Principal components

There is an empirical relationship between the SST and the MJO suggesting that initial states for the ocean and the atmosphere should be coherent

Ocean Initial Conditions:

Reforecasts

May 23rd to August 11th from 2002 to 2006, 1 forecast every 5 days

Forecast lead: 45 days

Model resolution:

***Atmosphere*:**

T126 = 100Km x 100Km

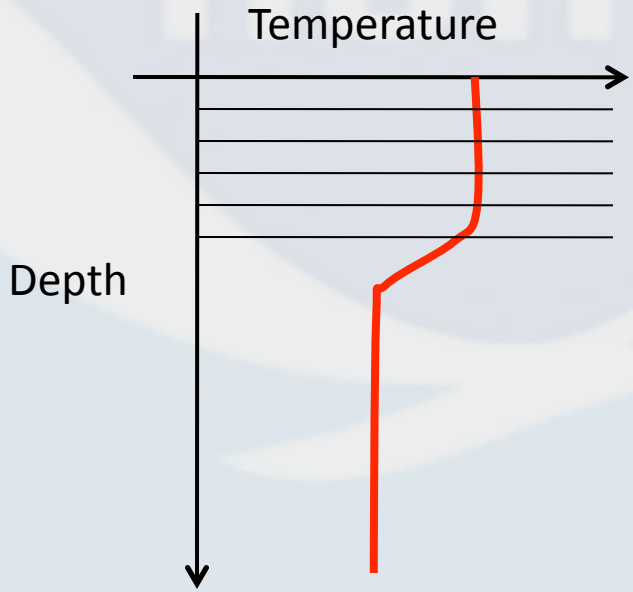
***Ocean*:** the standard CFS resolution

Initial conditions:

***Atmosphere, Land*:** from **GDAS**

***Ocean*:** (a) from operational GODAS and (b) Experimental Ocean Analysis

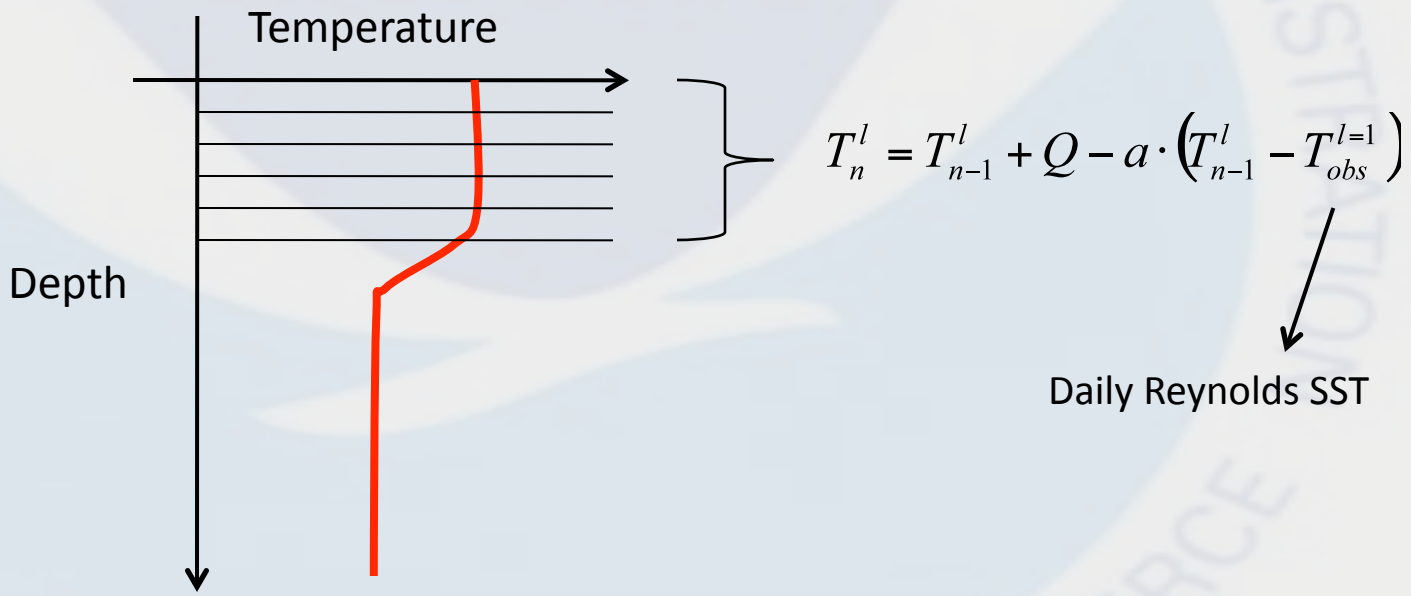
Operational Ocean Analysis



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

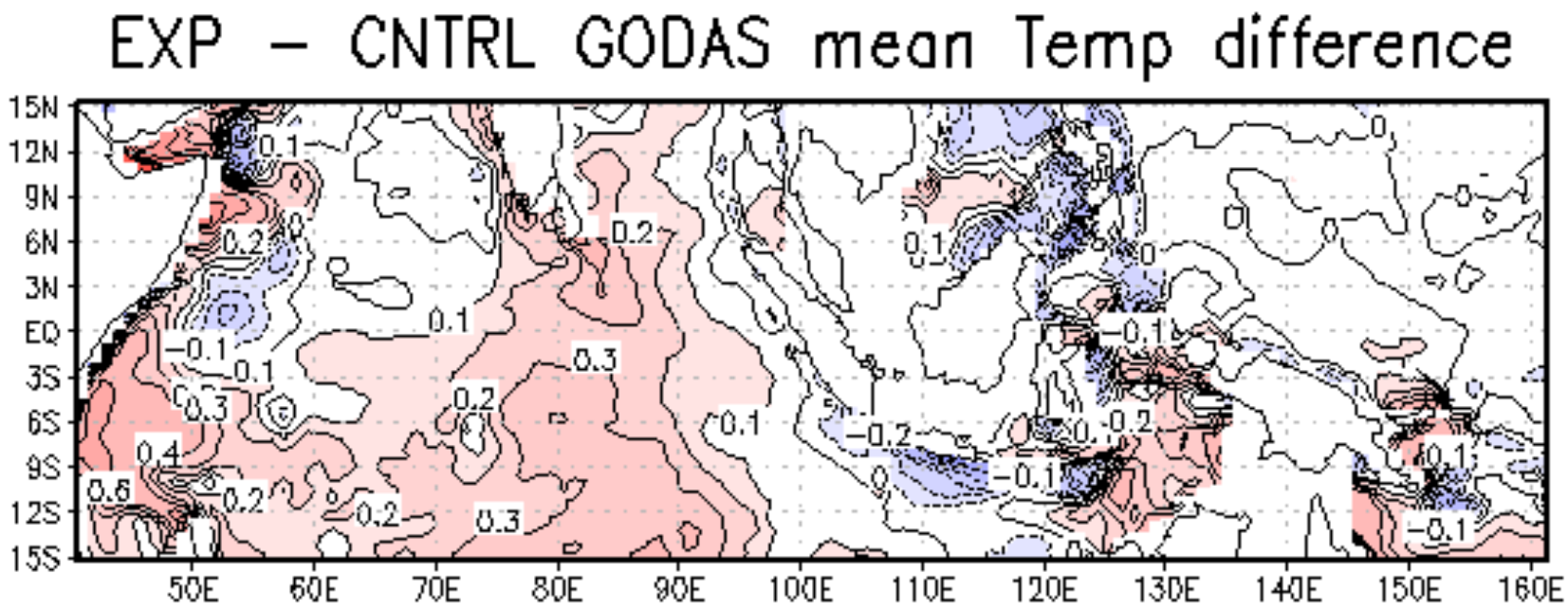
Weekly Reynolds SST

Experimental Ocean Analysis



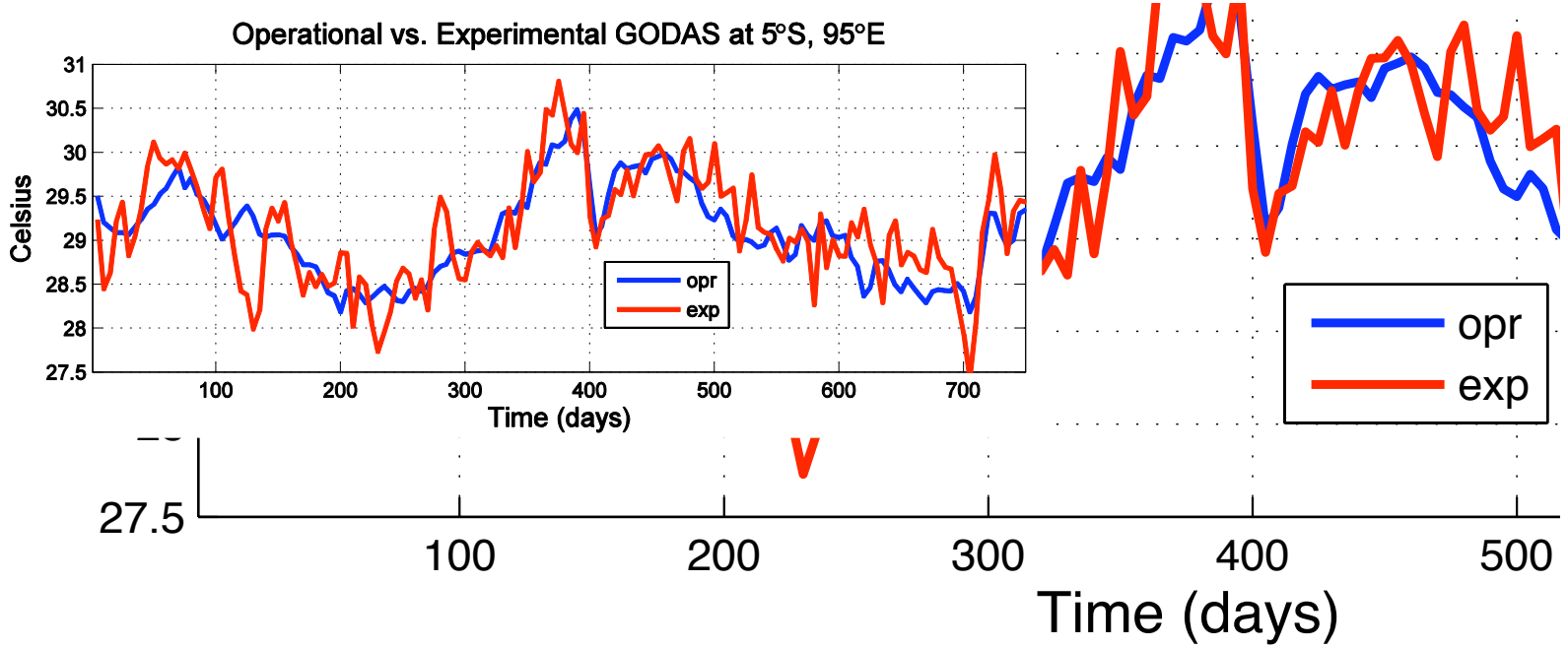
Analysis from January 2002 to December 2006

Impact of the new analysis on the 2002-2006 Mean SST



in Celsius

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



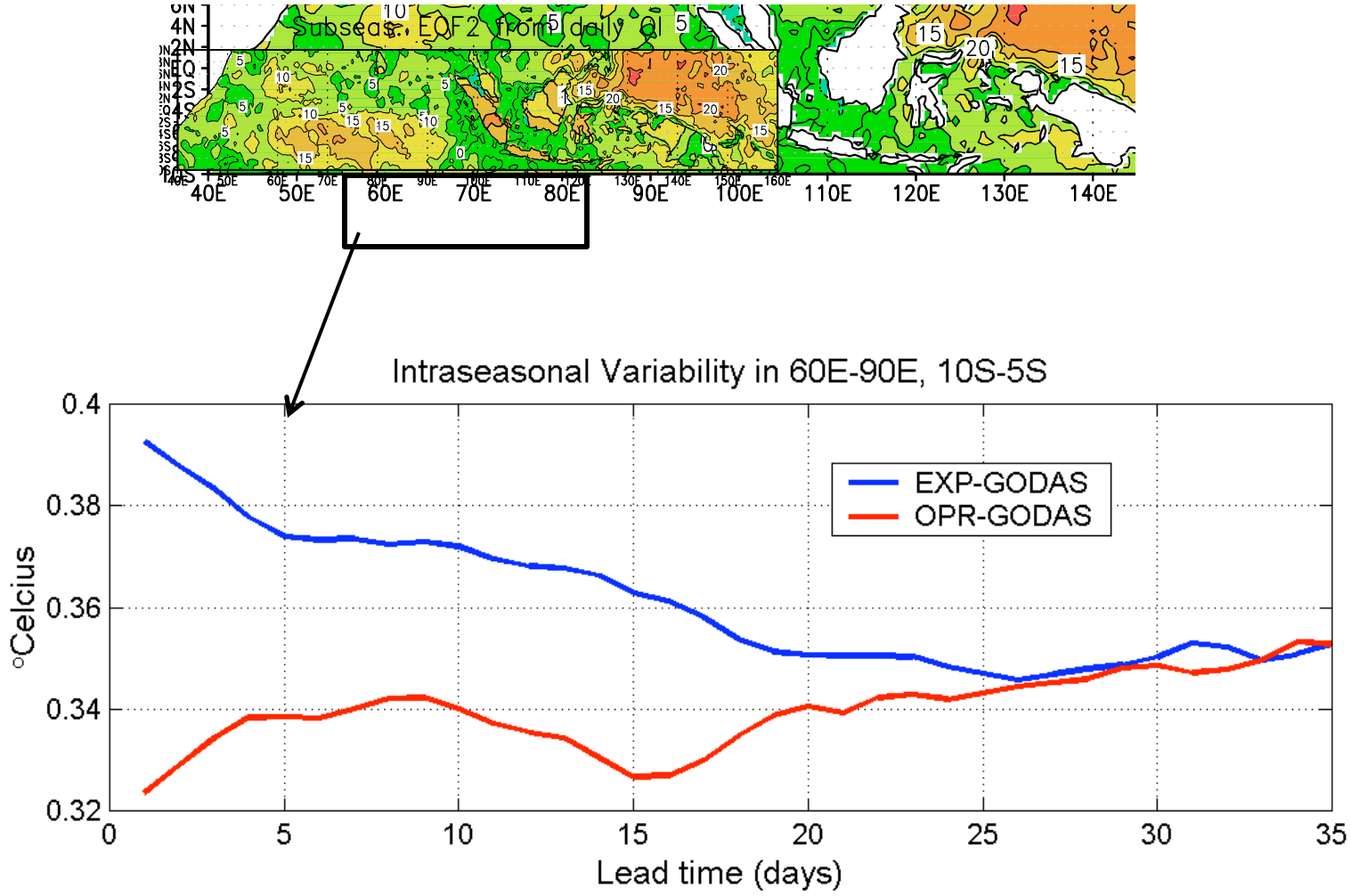
The experimental GODAS clearly contains higher frequencies

We managed to inject a more realistic intra-seasonal variance to the ocean initial condition without any visible spurious effects.

But…

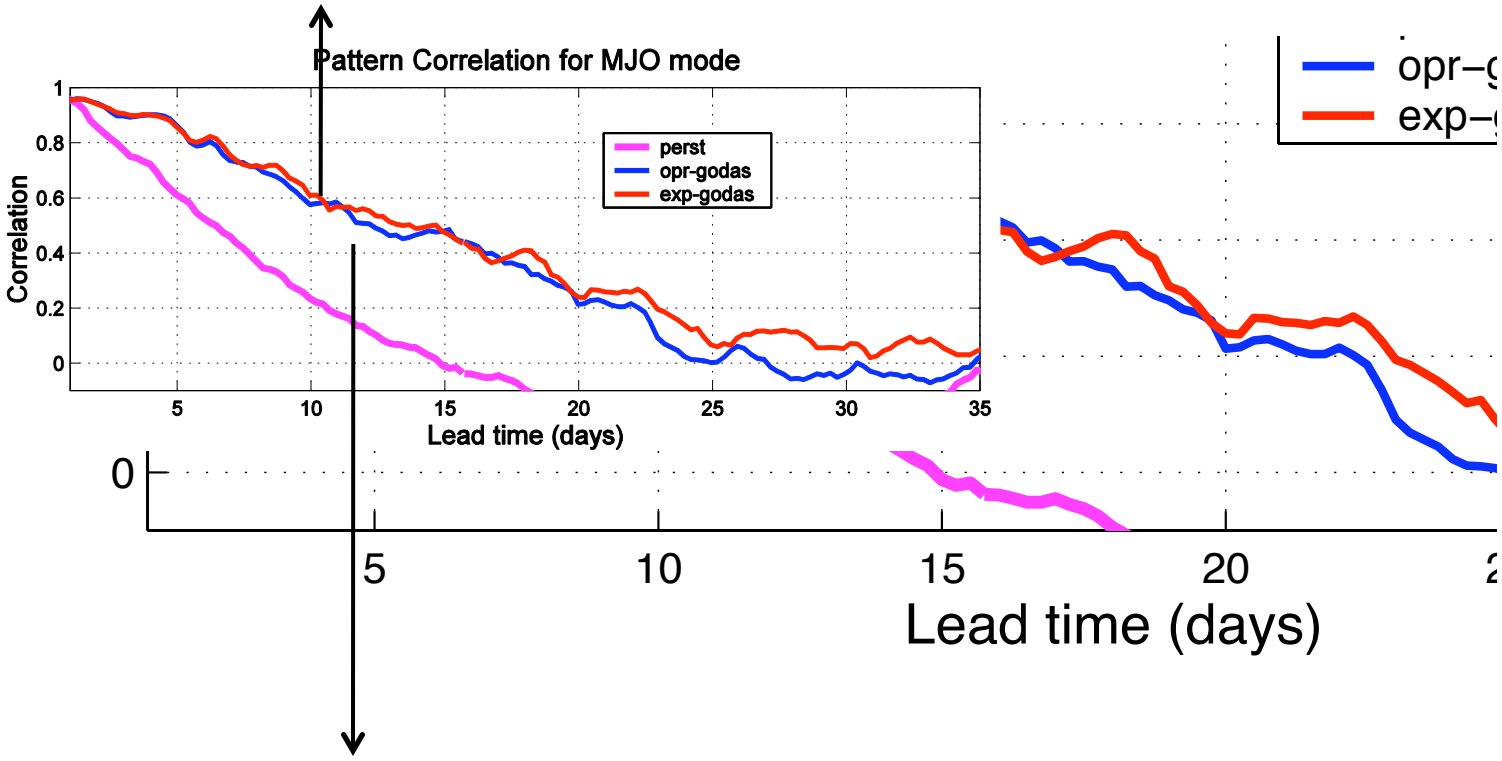
Can the coupled model retain these intra-seasonal modes or is this new information quickly lost?

Drift of average standard deviation of intraseasonal SST as a function of lead time



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, during this period the intraseasonal SST modes weaken.

Conclusions:

Atmospheric Initial Conditions are shown to be quite important for forecasting the MJO. This is due to both weaker initialization shocks and better quality of the representation of the atmospheric state. We expect that the new CFS-Reanalysis will provide even higher quality initial conditions.

We have shown that there is an empirical relation between intraseasonal SST modes and the MJO. This finding adds to the argument of most forecasting centers that coupling to the ocean improves forecast of the MJO.

Oceanic Initial Conditions were shown to improve only marginally forecast skill and that for lead times beyond day 7. However we have to note that there is a relatively fast systematic decrease in amplitude of the SST intraseasonal modes which most probably affects forecast skill.

Neither AIC nor OIC were capable to break through the Maritime Continent Prediction Barrier.

Issues concerning subseasonal forecasting that we are addressing:

The CFS is a useful tool for forecasting the MJO; its skill can be significantly improved by resolving the **Maritime Continent Prediction Barrier**. We have prioritized a number of issues that will help to further improve the skill of the model:

- **Advanced diagnostic studies of atmospheric processes** in the hindcast experiments presented here will allow to **determine reasons for the Maritime Continent Prediction Barrier**. Refinement of existing or addition of missing atmospheric parameterizations will allow to break through this barrier

- However the Maritime Continent is sometimes a Barrier for the observed MJO. Determining reasons for which MJO re-organizes or not as it crosses the Indonesia region is important:

  - Improving the ability of the ocean model to simulate intraseasonal modes i.e., experimenting with horizontal and vertical resolution and mixed layer formulation. We expect that this work will result to a lesser weakening of the intraseasonal SST modes and consequently to more skillful forecasts


Questions?