The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

1956-25

Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

4 - 15 August 2008

Rainfall predictability in W. African Monsoon.

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Earth System Physics Section
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Predictability and Prediction of (West) African Rainfall in the Operational forecast of ECMWF

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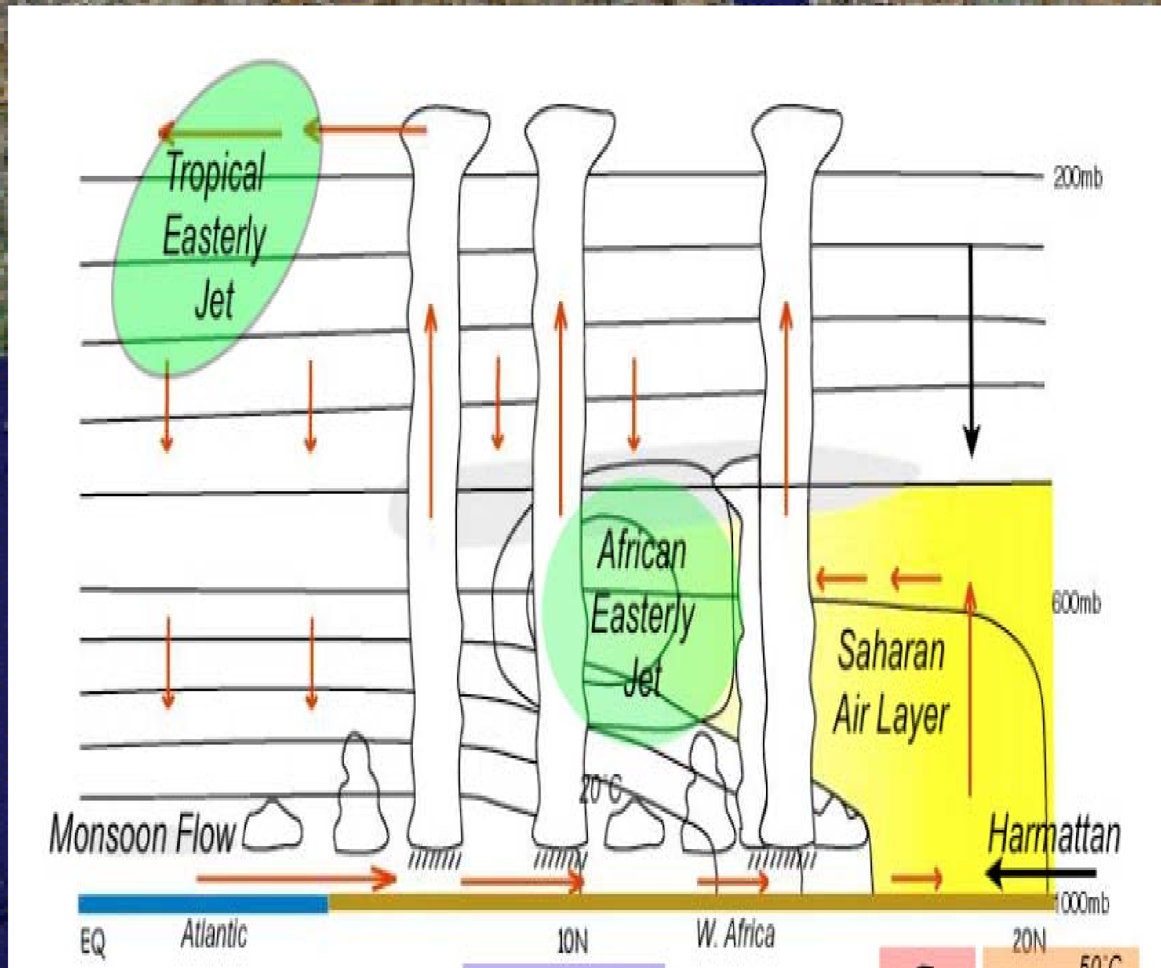


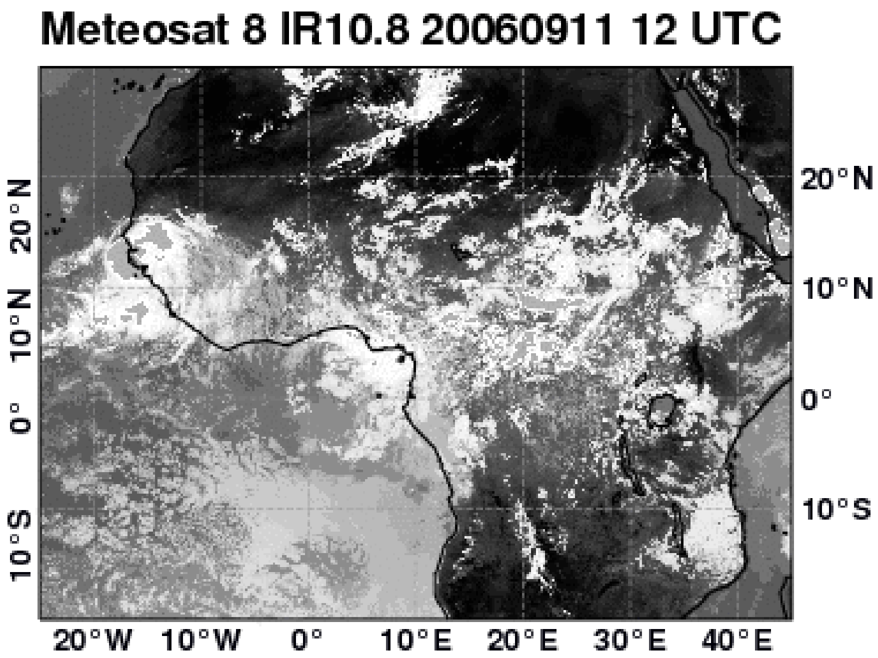
Schematic from Hall & Peyrillé

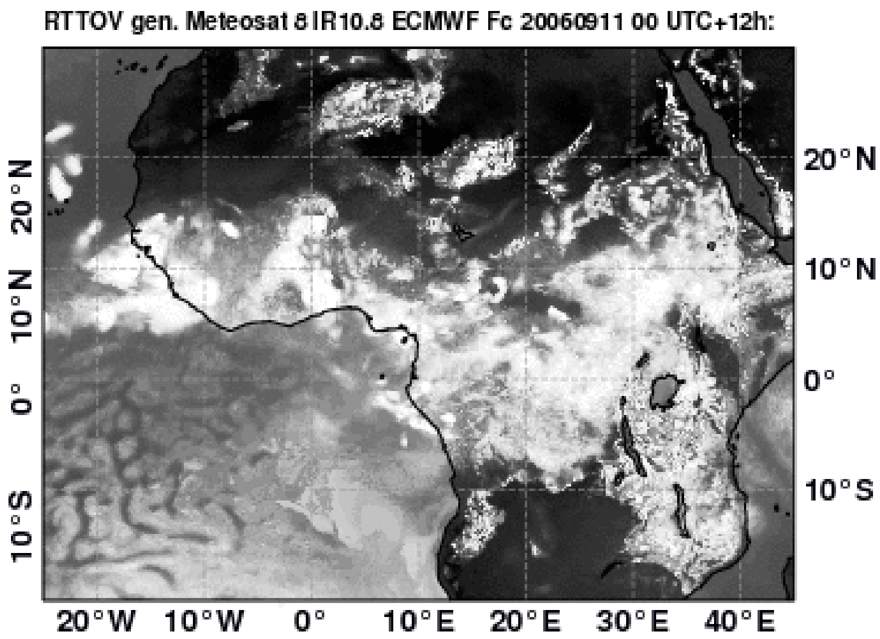
Outline:

This talk will consider various physical phenomena which determine rainfall predictability over a range of timescales and their representation in the dynamical seasonal prediction model of ECMWF

Why ECMWF? It is one of the major centres' models that contributes to the PRESAO. It *may* also be used in ICTP's predictability research using the new EC-EARTH climate model.

- Brief intro to the ECMWF prediction system
- Predictability
  - Water vapour
  - African Easterly Waves
  - Madden Julian Oscillation
  - Sea Surface Temperature





Left=MSG , Right=ECMWF

3. Introduction to the ECMWF System

T799 (25km)
no ocean
single forecast

10 days

T399/255 (50-80km)
ocean>10days
ensemble

15/30 days

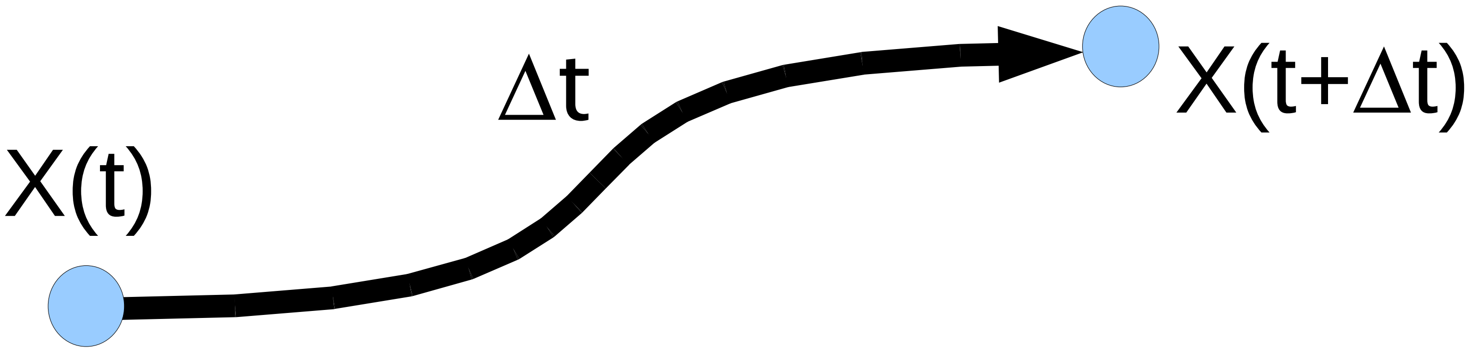
T159 (125km)
ocean
ensemble

6/12 months

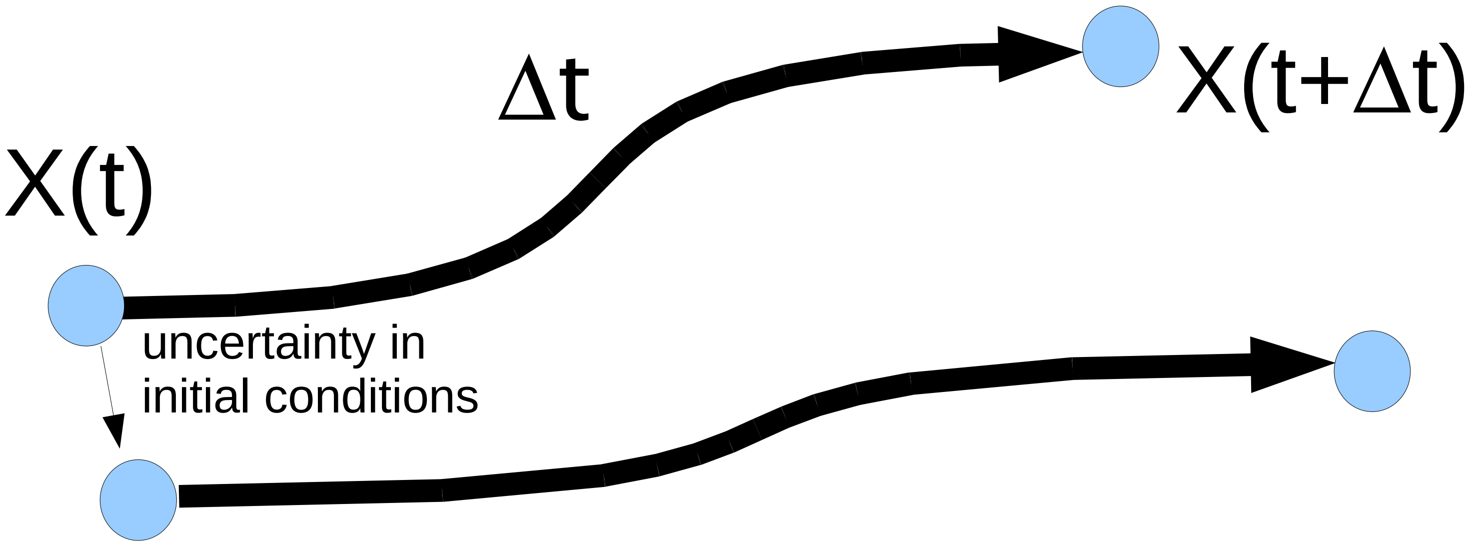
ATMOSPHERE MODEL VERSION
FREQUENTLY UPDATED

prehistory		ERA15 (13r?), System 1
.		
.		
23R4	2000	ERA40, System 2
24		
24R1		
24R2		
.		
.		
.		
31R1	2006	System 3, EC-Earth
.		
.		Current deterministic
32R3	2008	& monthly o-suite
		e-suite (now o-suite!)
33R1		

Uncertainty in numerical weather prediction
The two main causes are...?

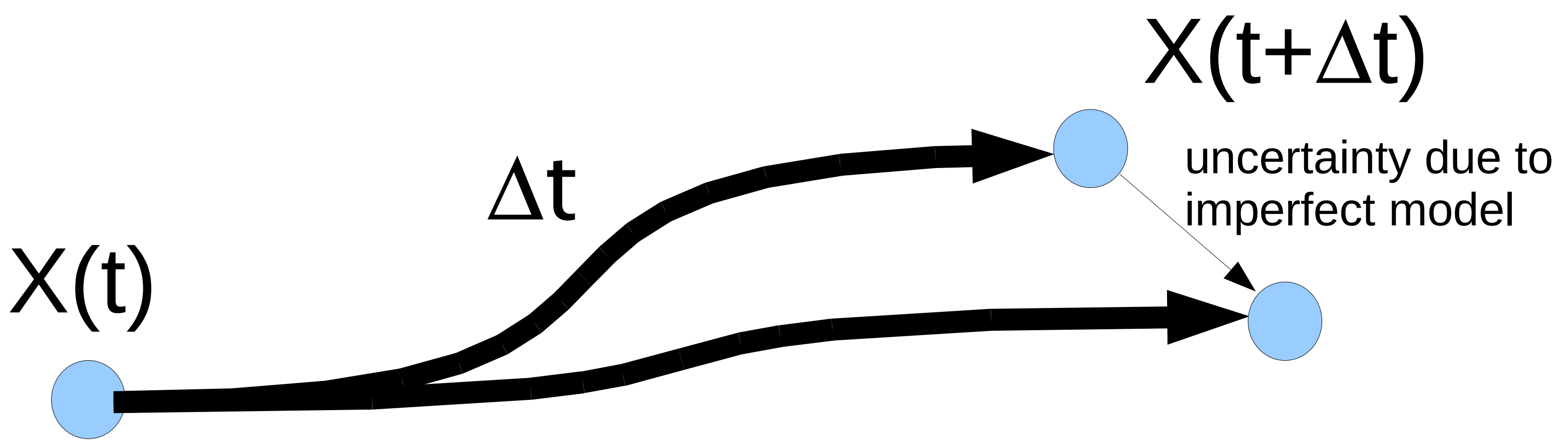


i. Uncertainty in initial conditions

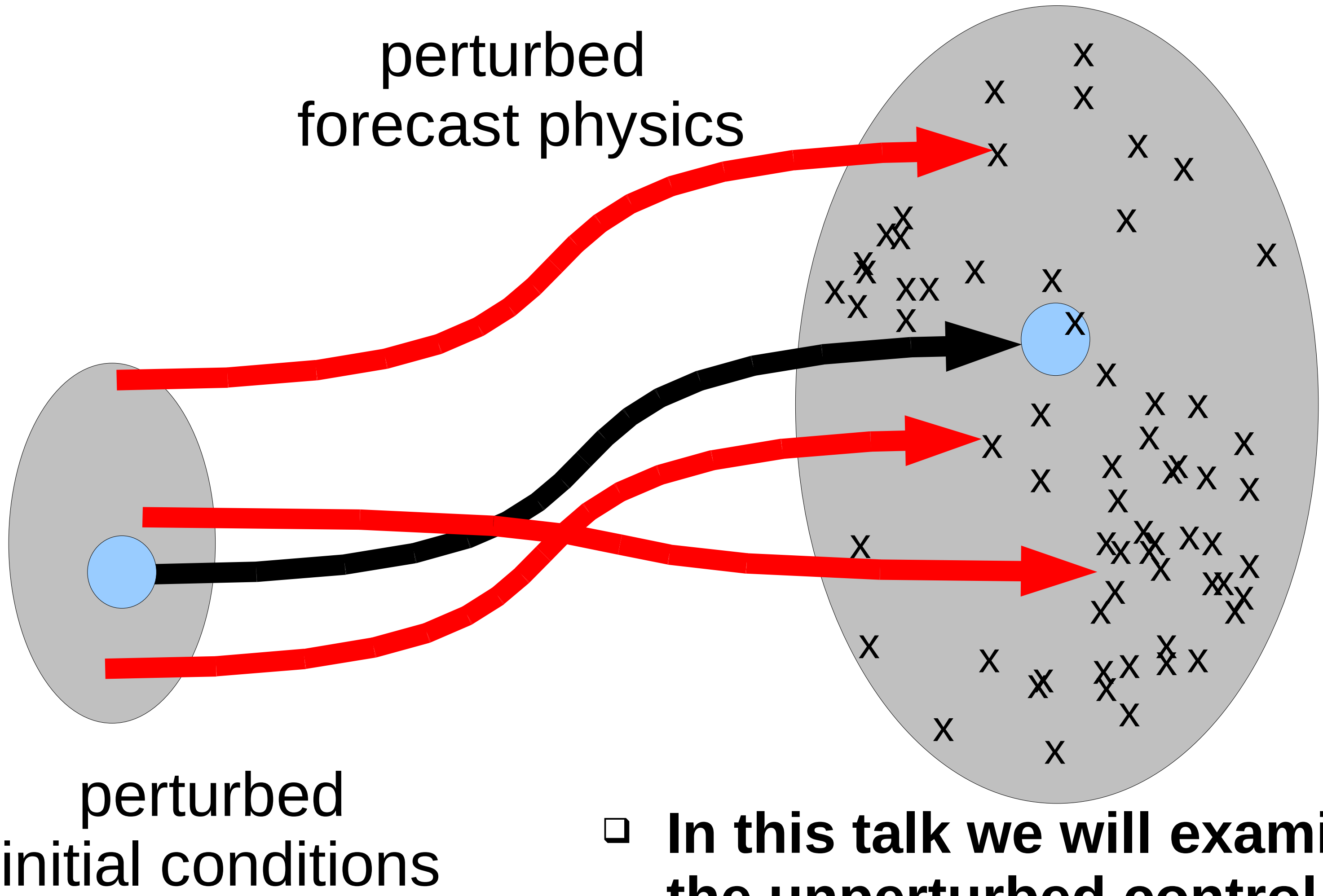


"Butterfly Effect"

ii. Imperfect model



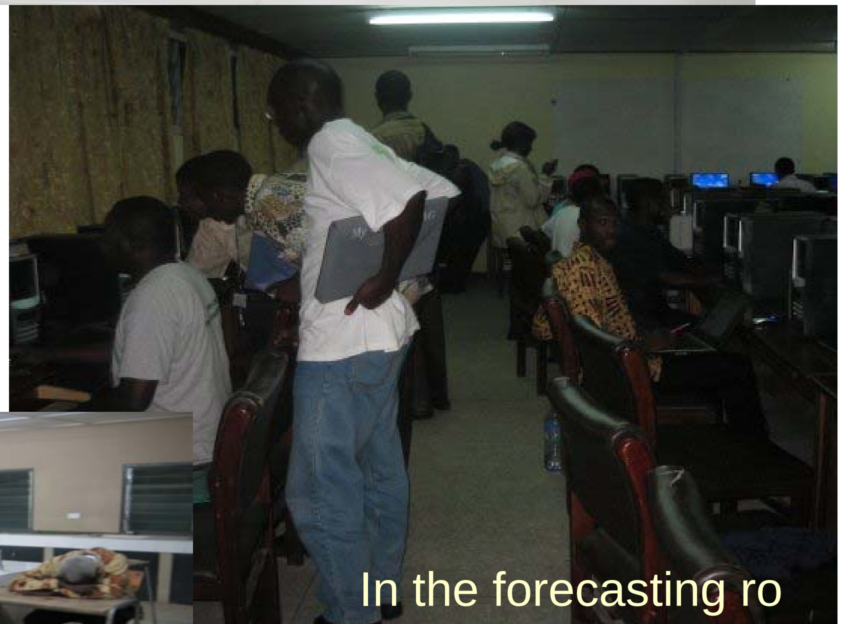
The ECMWF system



- **In this talk we will examine only the unperturbed control forecast deterministically**

Experience


ating the pilot balloon


In the forecasting ro

The AfriCARP pages

In the forecasting room

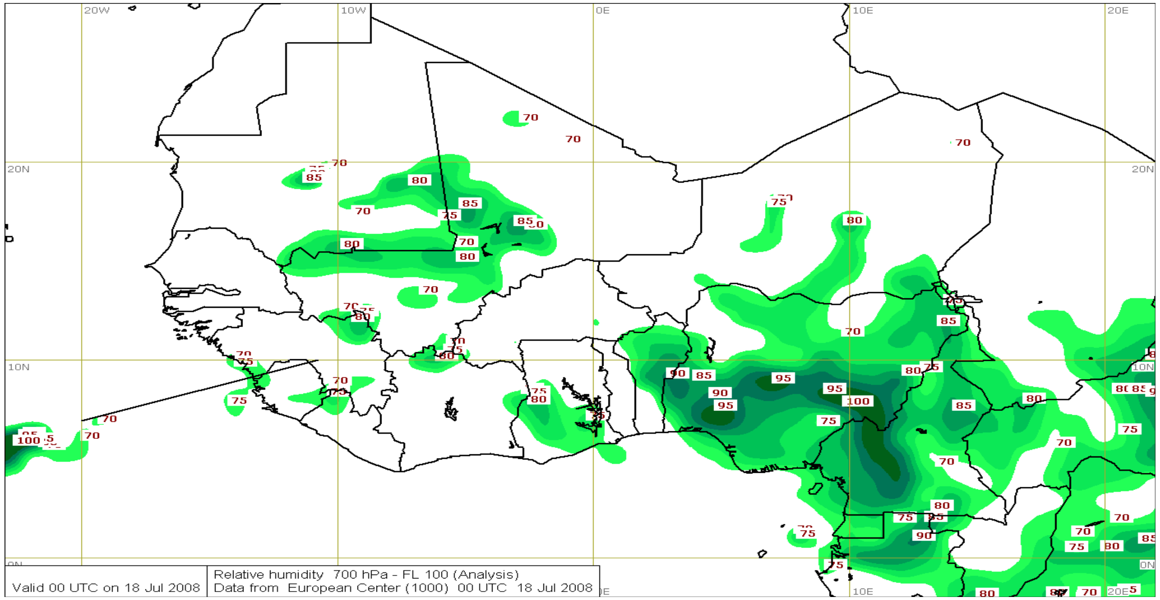
esp.ictp.it/africarp

More to come!!!

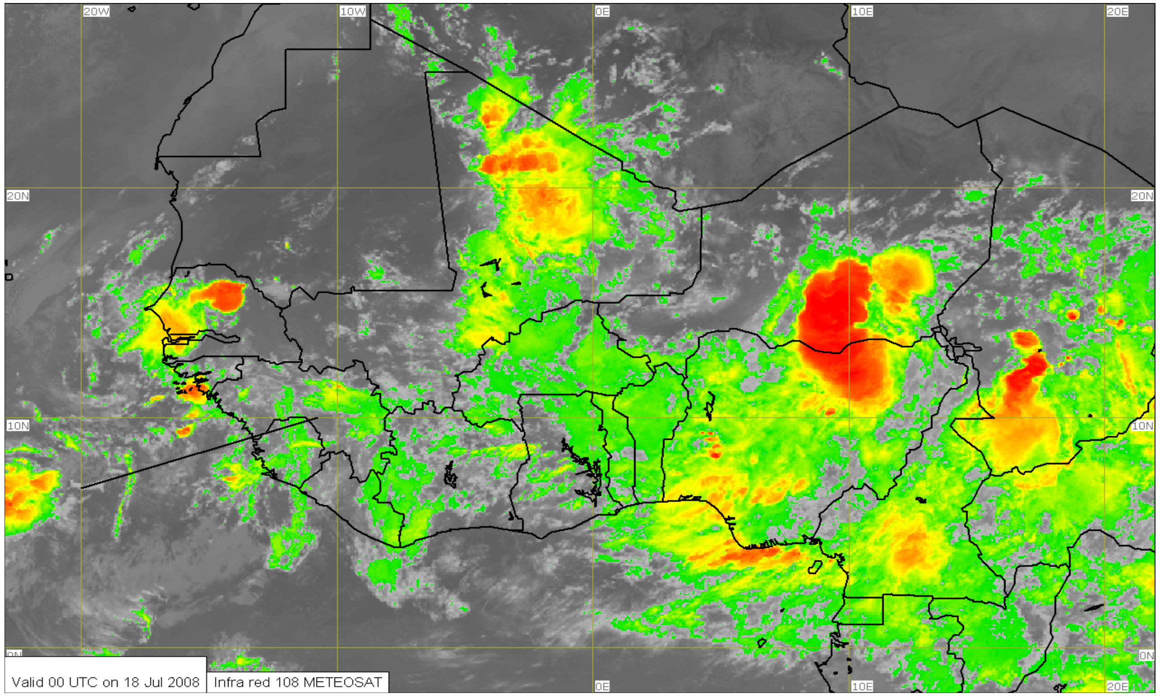
Predictability timescales

- Short-to-Medium Range: Day 0-15
  - **Prediction** of individual convective complexes, monsoon break cycles for local to regional scale
  - **Predictors**: Pre-existing disturbances, Atmospheric relative humidity (RH), flow direction, CAPE, (temperature, Wind shear, converge) African Easterly Waves, Kelvin and MJO waves...
- Monthly-to-Seasonal Range: Day 15-365
  - **Prediction** of monsoon onset, seasonal mean statistics, subseasonal variability, and cessation date on regional scale (latitudinal defined?)
  - **Predictors**: Local and remote sea surface temperatures (SST), NAO, soil moisture, Saharan heat low, cold surges, vegetative state, Madden Julian Oscillations

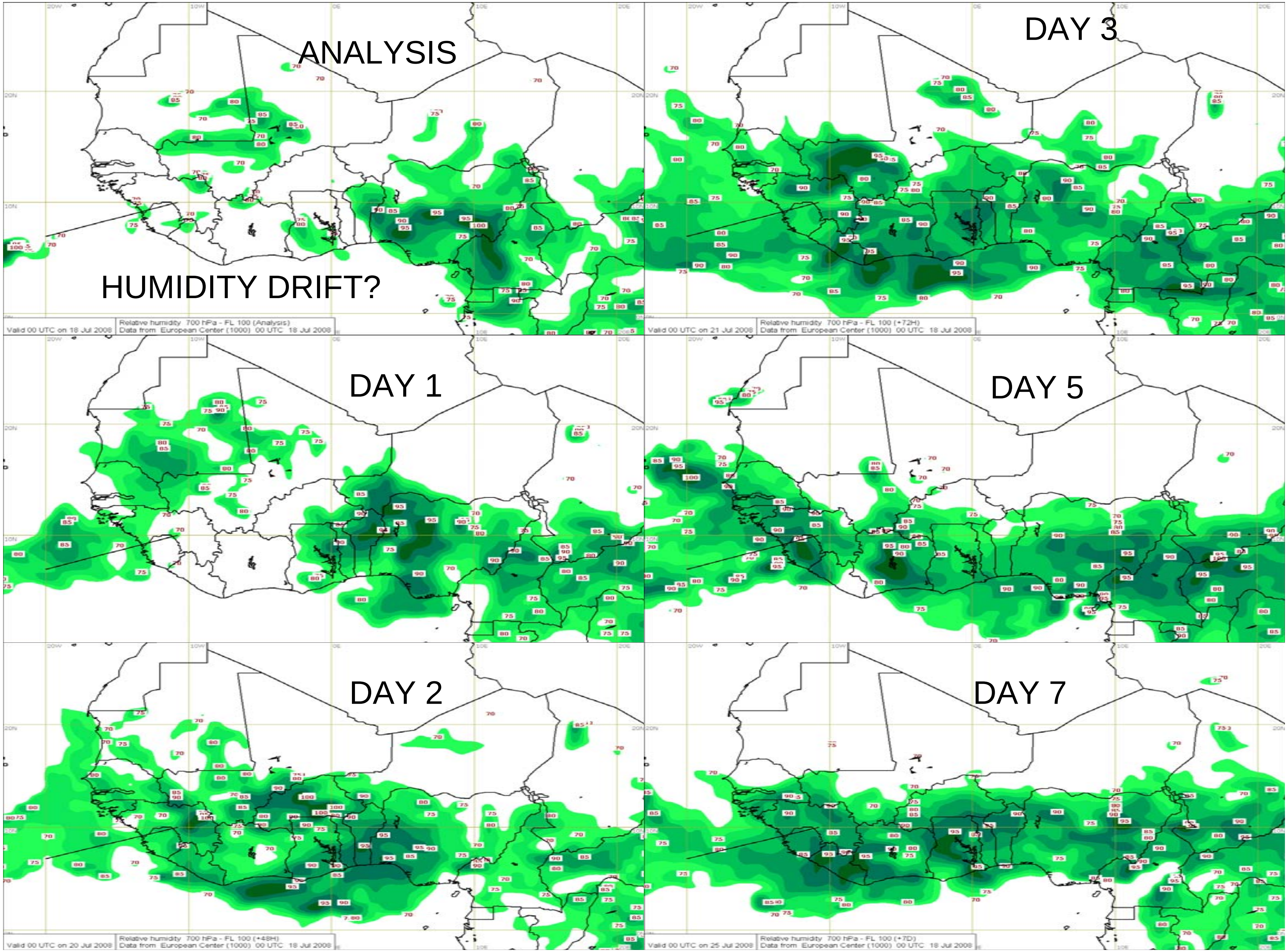
RH700
18.07.08
00 UTC
ECMWF
ANALYSIS



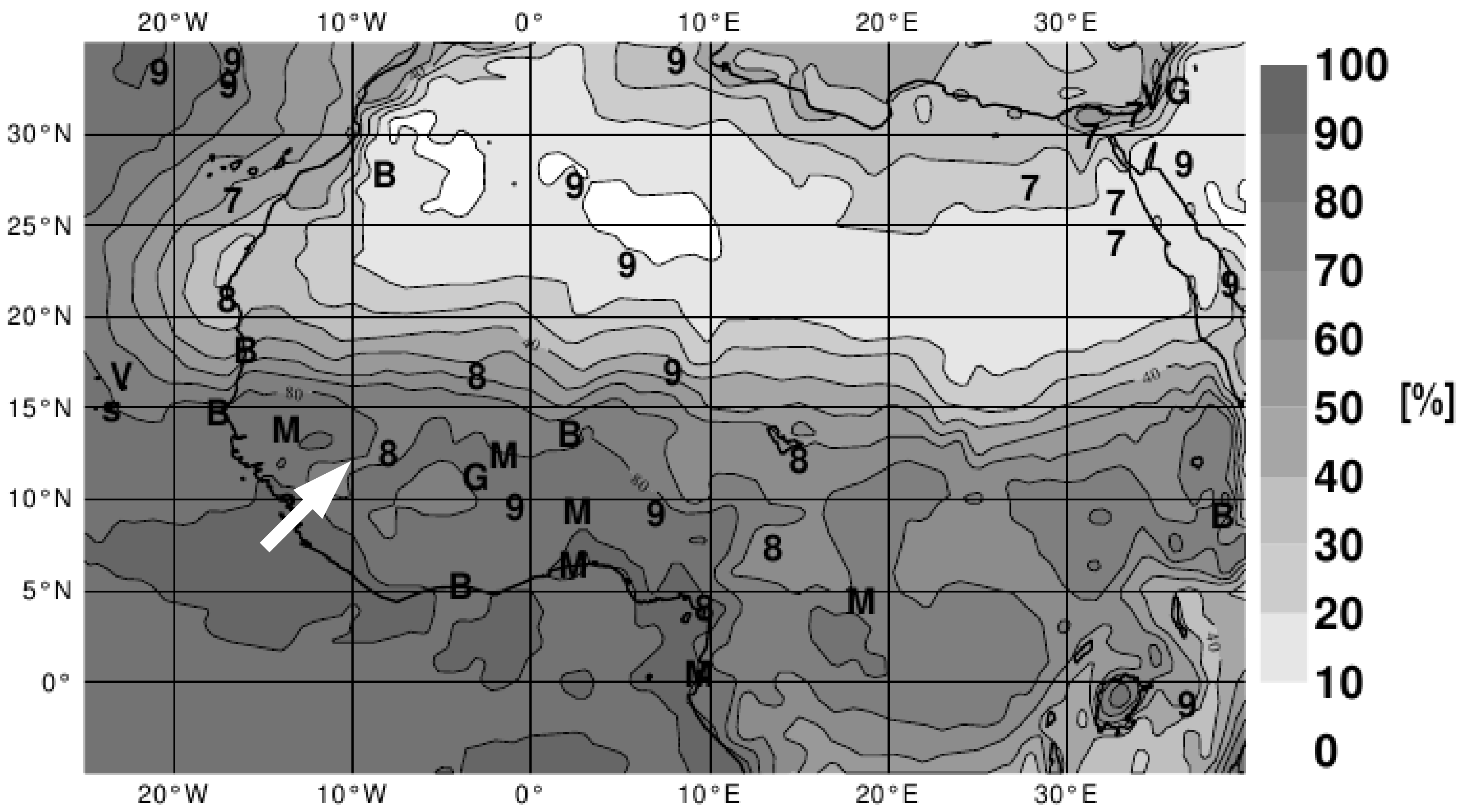
OLR
18.07.08
0030 UTC



Plots from PUMA Messir vision


ANALYSIS
HUMIDITY DRIFT?
DAY 1
DAY 2
DAY 3
DAY 5
DAY 7
Valid 00 UTC on 18 Jul 2008
Relative humidity 700 hPa - FL 100 (Analysis)
Data from European Center (1000) 00 UTC 18 Jul 2008
Valid 00 UTC on 21 Jul 2008
Relative humidity 700 hPa - FL 100 (+72H)
Data from European Center (1000) 00 UTC 18 Jul 2008
Valid 00 UTC on 20 Jul 2008
Relative humidity 700 hPa - FL 100 (+48H)
Data from European Center (1000) 00 UTC 18 Jul 2008
Valid 00 UTC on 25 Jul 2008
Relative humidity 700 hPa - FL 100 (+7D)
Data from European Center (1000) 00 UTC 18 Jul 2008

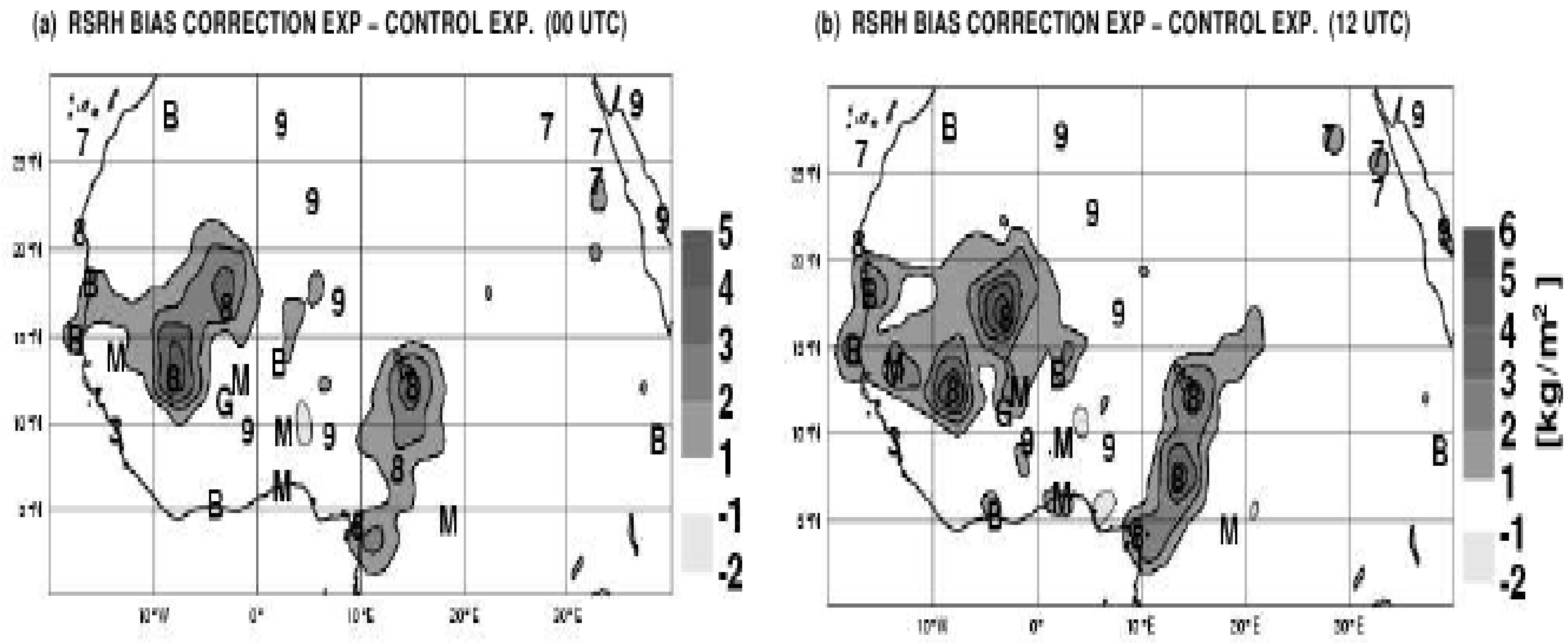
925 hPa RH August 2006
8=RS80, 9=RS92 M=Modem



Note apparent drying impact of RS82

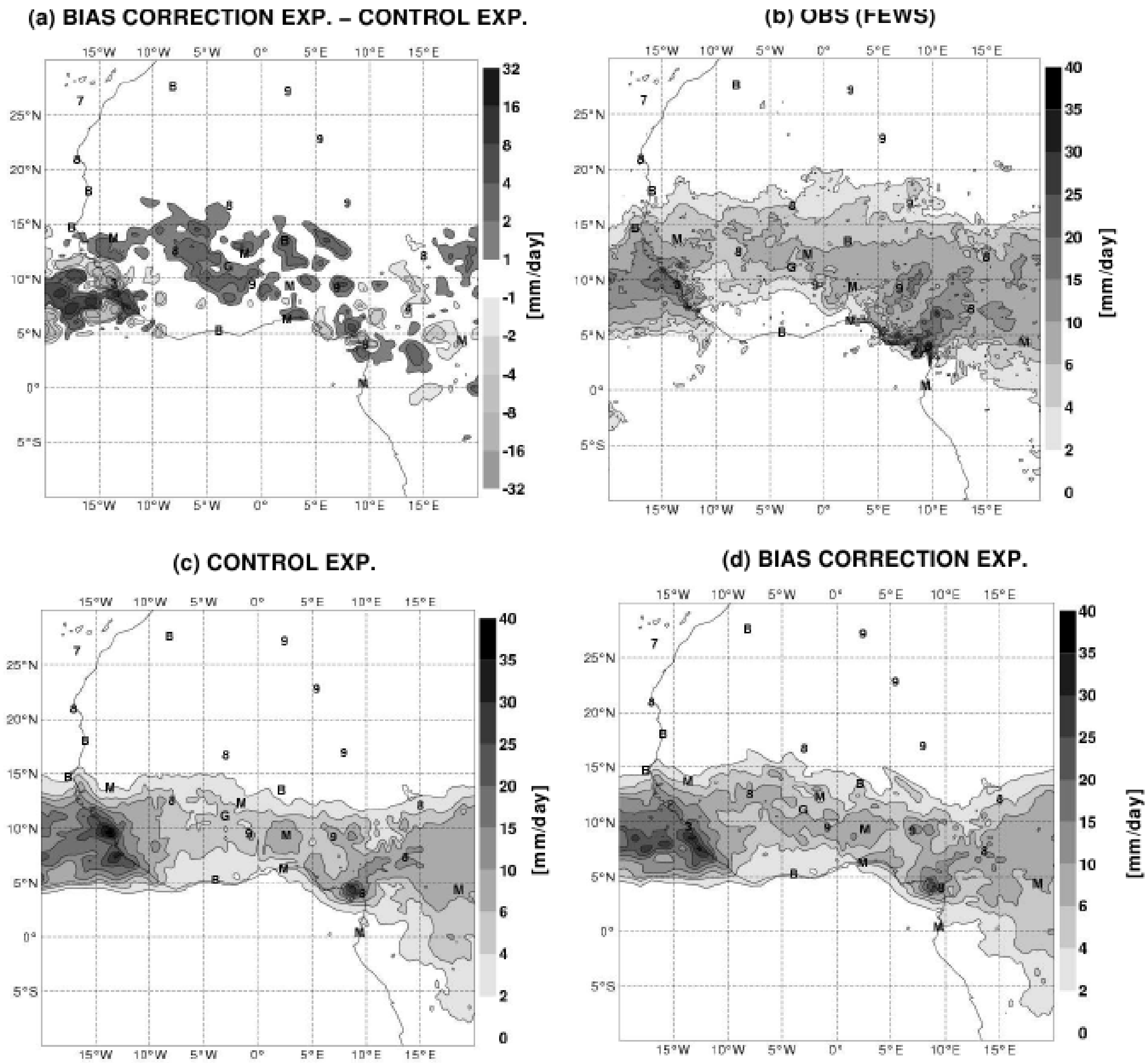
source: Agusti-Panareda

TCWV correction at 00Z and 12Z by new automated bias correction



Please see manuscript submitted to QJRMS by Agusti-Panareda et al. for methodology

Impact on Forcasts (18-42 hr)



rain still too far south

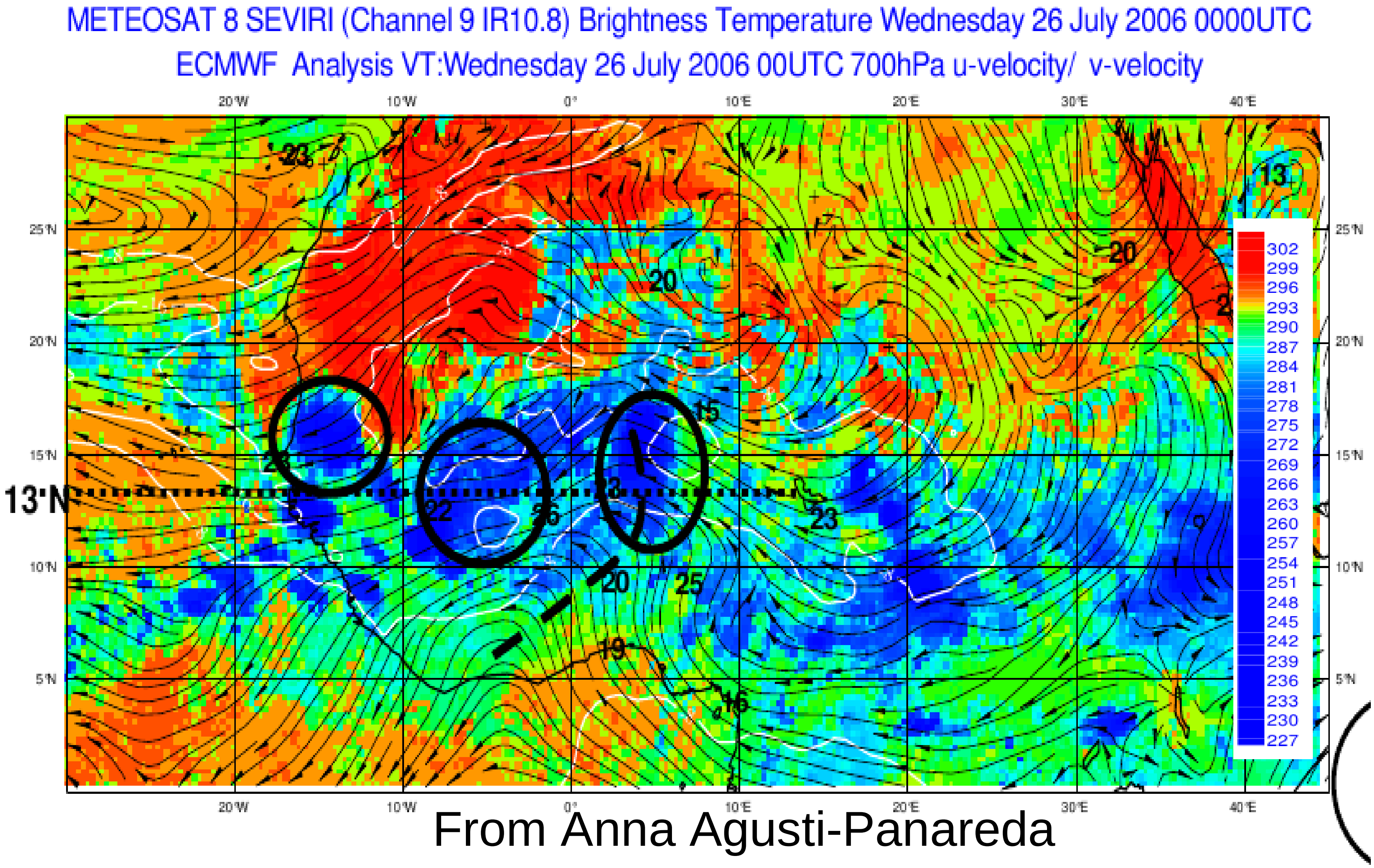
Humidity relationship

- Increased humidity in lower troposphere associated with increased convective activity
- Mid-tropospheric humidity more complex
  - generally entrainment of dry air reduces buoyancy, suppressing convection
  - however, squall-lines propagate by downdraught generated coldpools
  - Diedhiou et al note increase in convective activity with drier mid-troposphere over region
- As 80% of rainfall in Sahel produced by organised systems, then one of the few areas where dry mid tropospheres considered beneficial
- Therefore critical that dynamical models are able to model humidity structures and the convective-humidity interaction
  - Adequate vertical resolution, non-Diffusive advection scheme, convective entrainment processes

African Easterly Waves

- Strongly coupled to convective activity
- A source of intraseasonal predictability
- Getting variability right on sub-seasonal scales required to get seasonal scales?

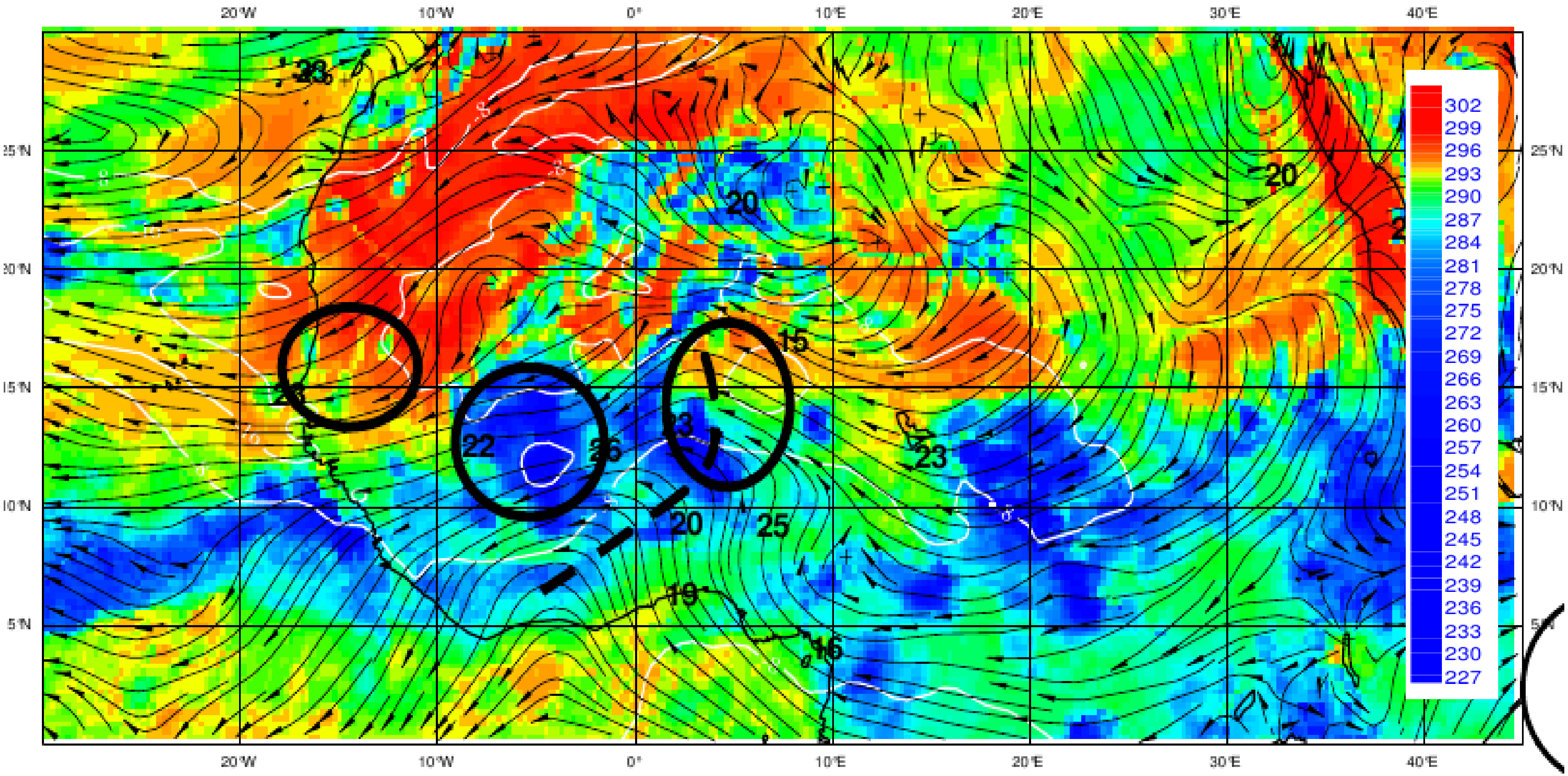
African Easterly Waves: MSG+Analysis winds



From Anna Agusti-Panareda

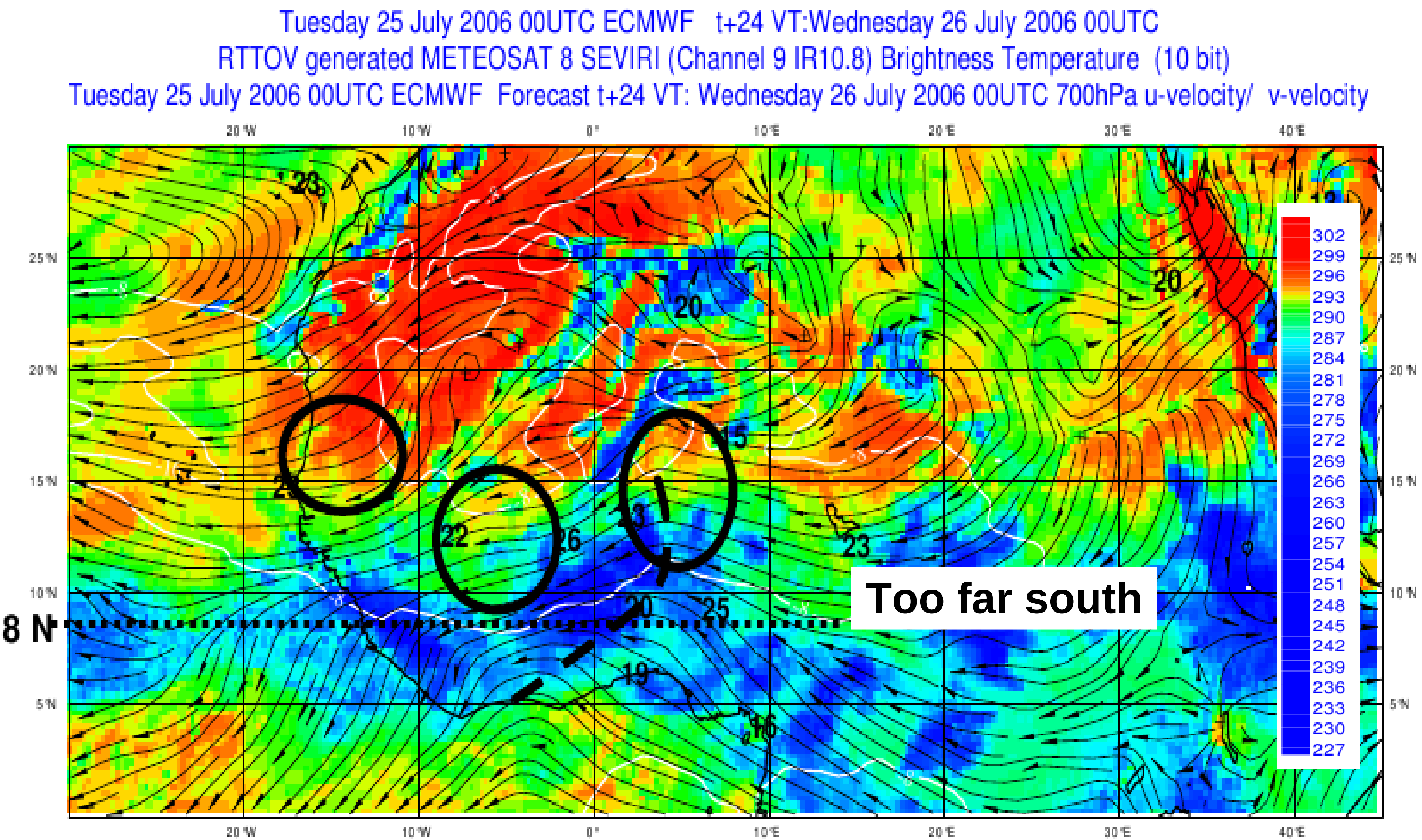
African Easterly Waves: Analysis

Wednesday 26 July 2006 00UTC ECMWF t+0 VT:Wednesday 26 July 2006 00UTC
RTTOV generated METEOSAT 8 SEVIRI (Channel 9 IR10.8) Brightness Temperature (10 bit)



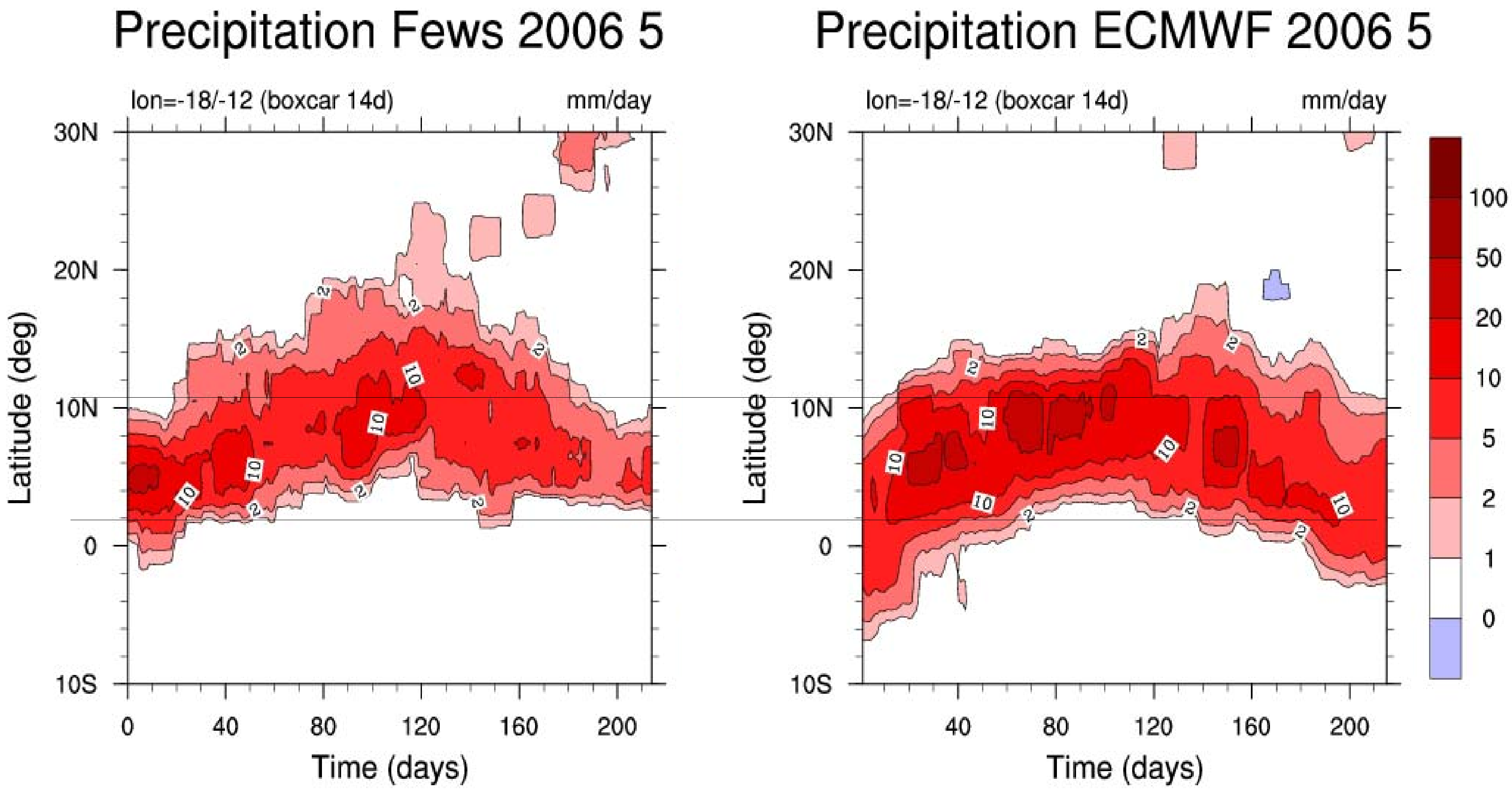
From Anna Agusti-Panareda

African Easterly Waves: 24 hour forecast



From Anna Agusti-Panareda

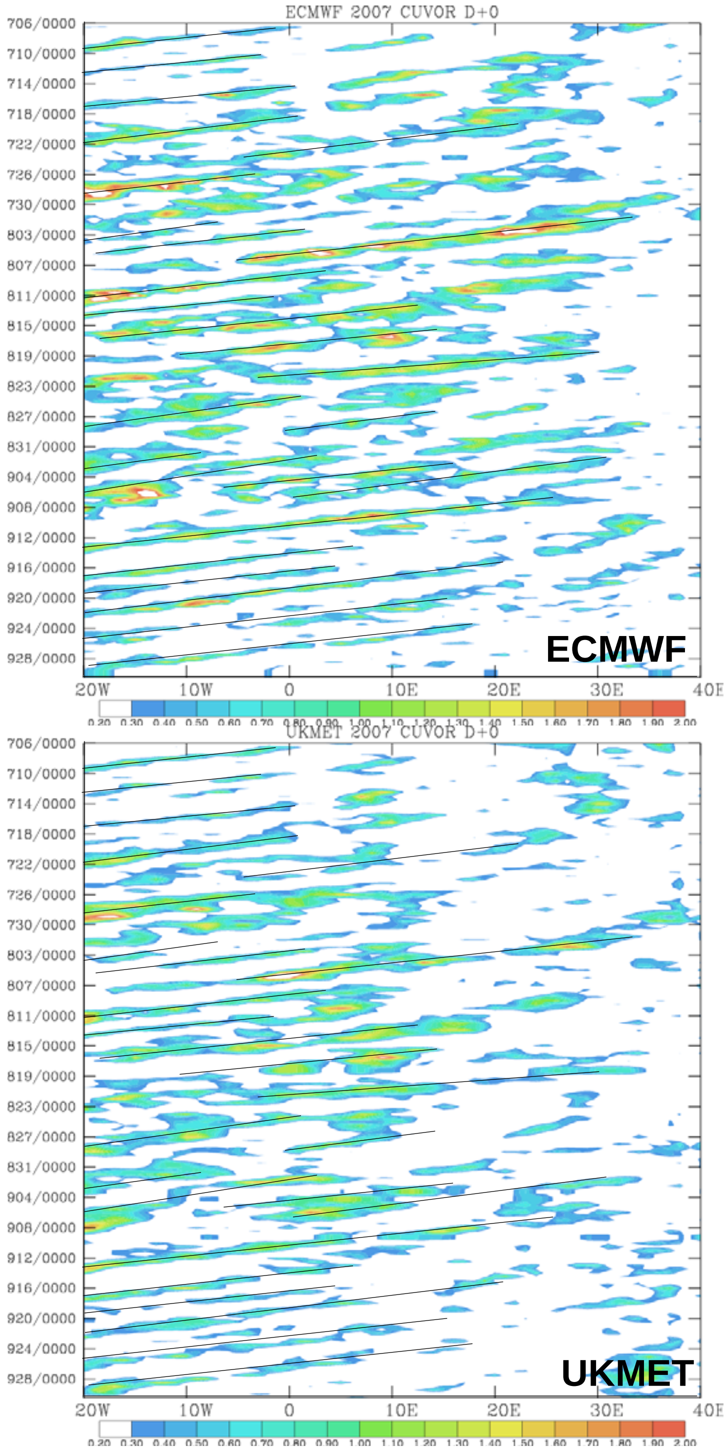
General Problem: Comparison of Rainfall with FEWS centred on Senegal



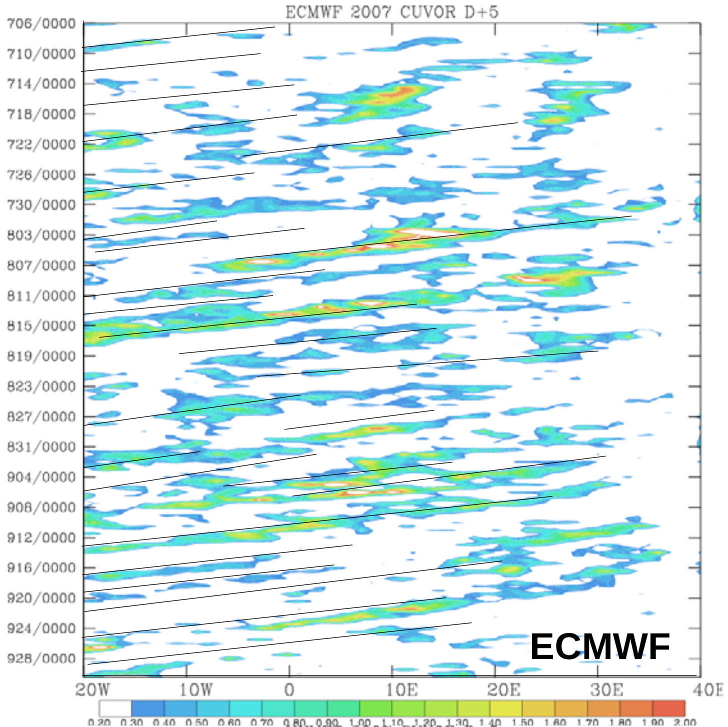
RAINFALL too far south

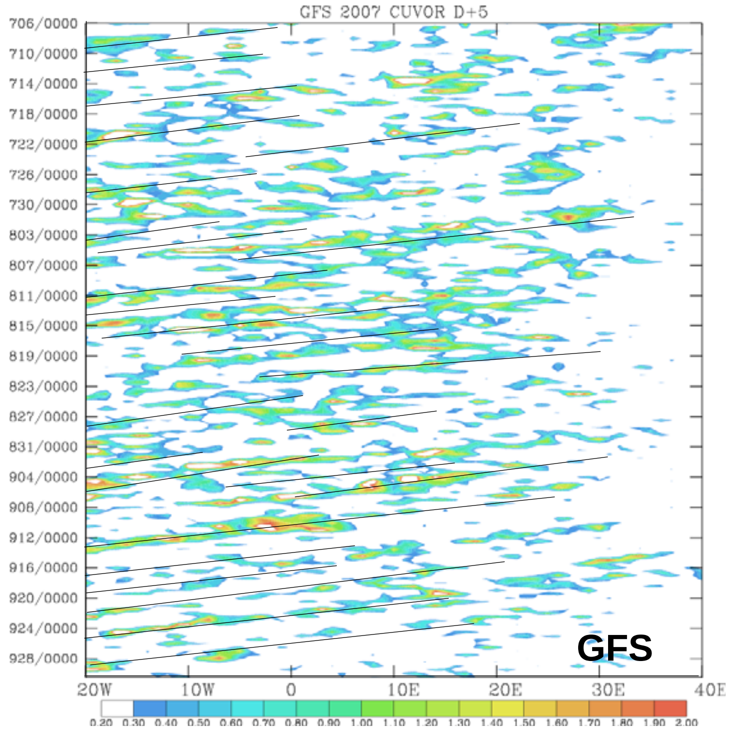
Analysis: 700hPa curvature vorticity. Averaged 5-15N.

JJA

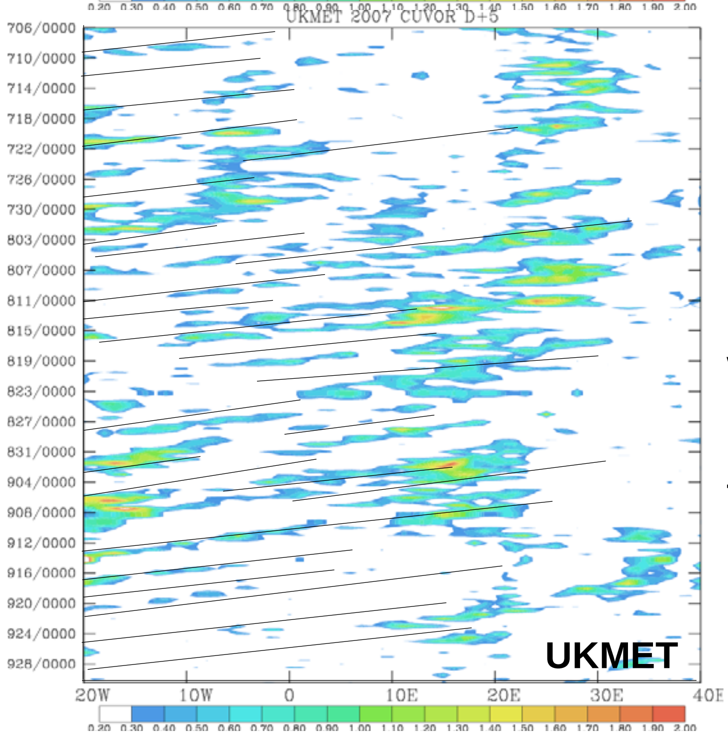


from Berry and Thorncroft





t+120hrs: 700hPa curvature vorticity. Averaged 5-15N.

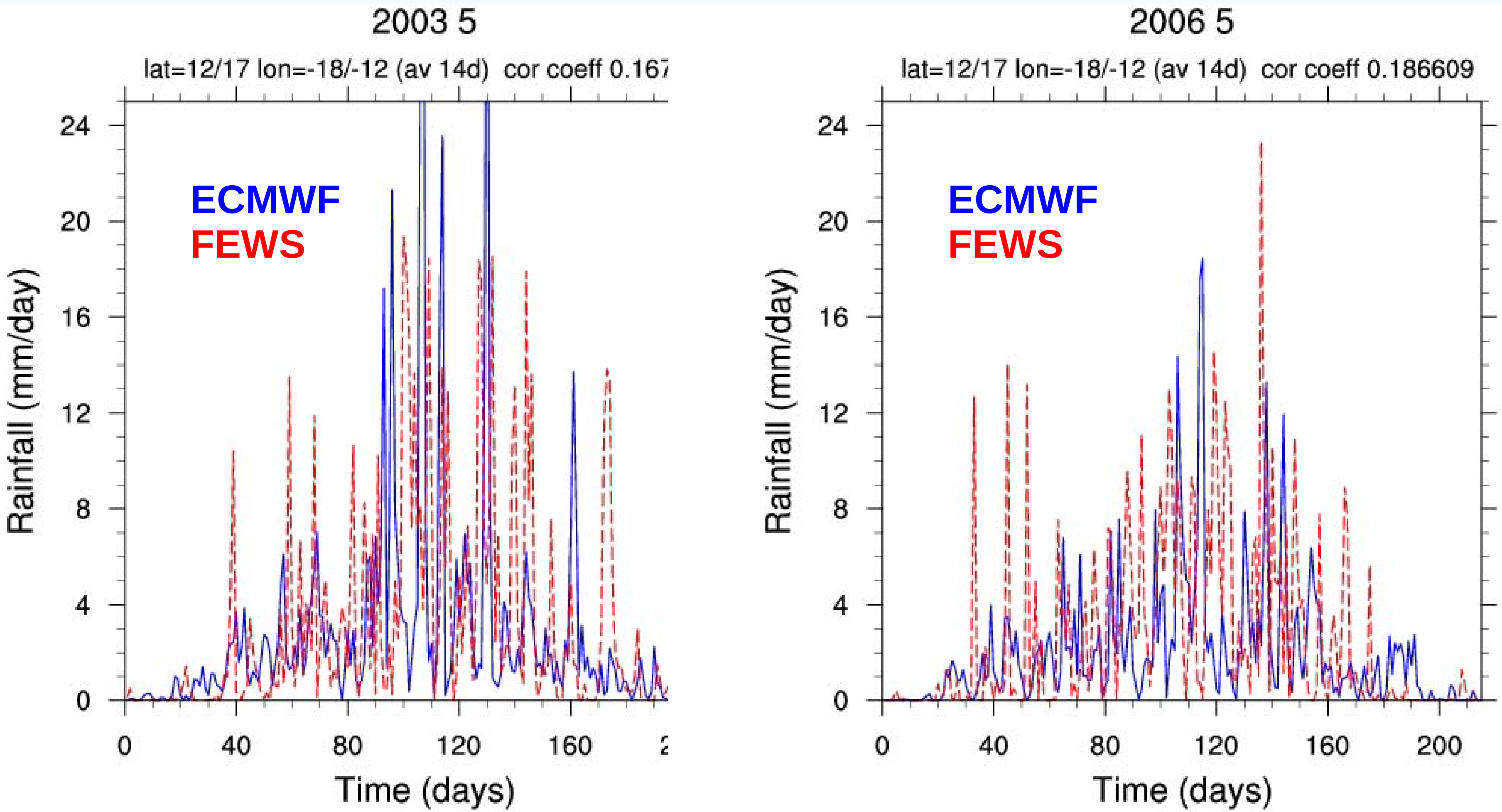


If AEW exists in analysis models can propagate feature

But initiation can be a problem

We will next examine the convective coupling to AEWs in the seasonal forecasting system

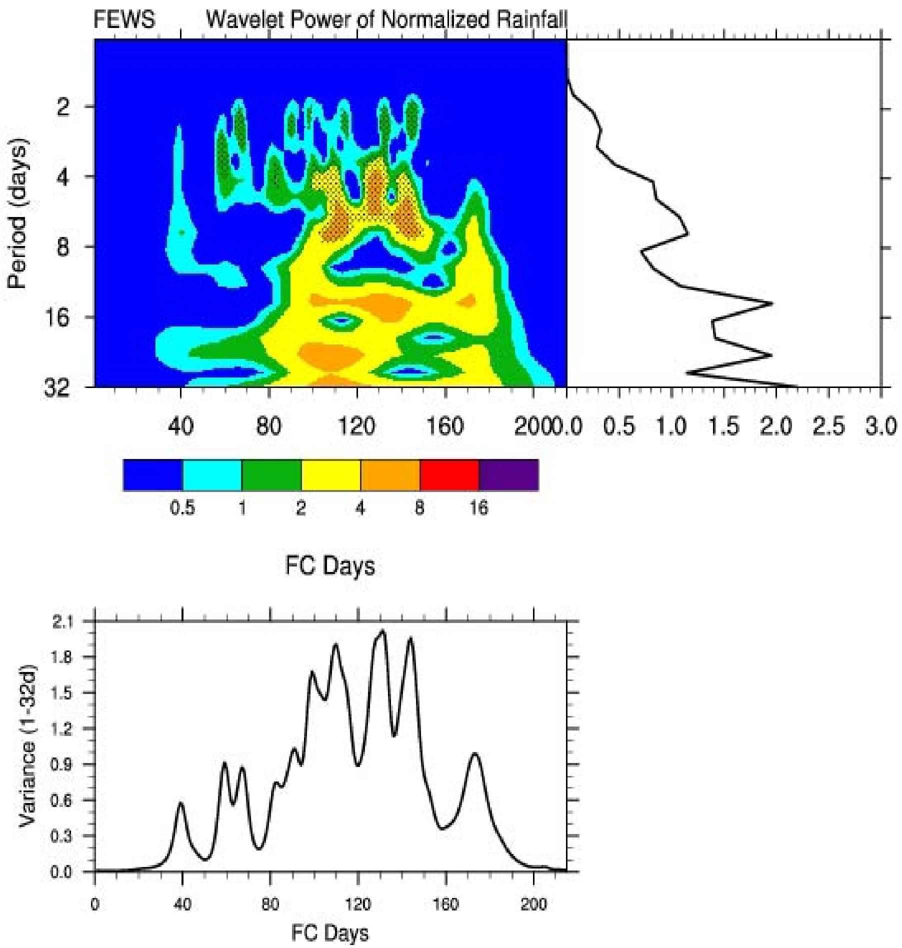
Comparison of Rainfall with FEWS for Senegal

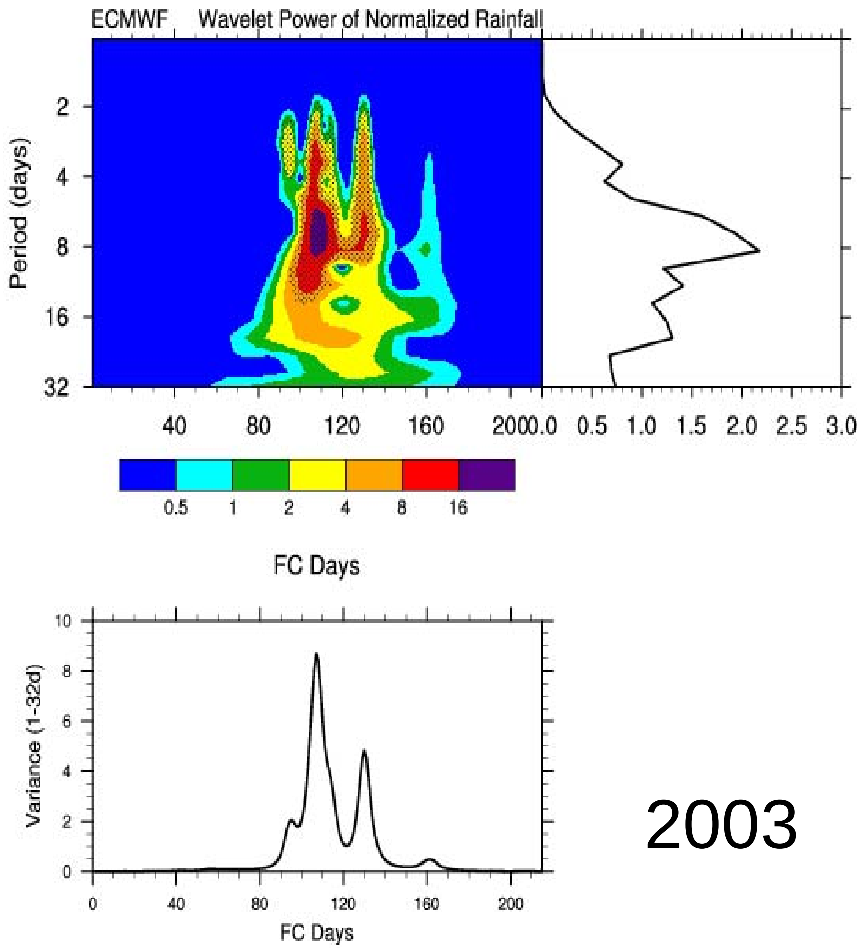


The variability of the rainfall is important for agriculture, water resources and health impacts

Timeseries assessed using wavelet analysis

Comparison of Rainfall with FEWS

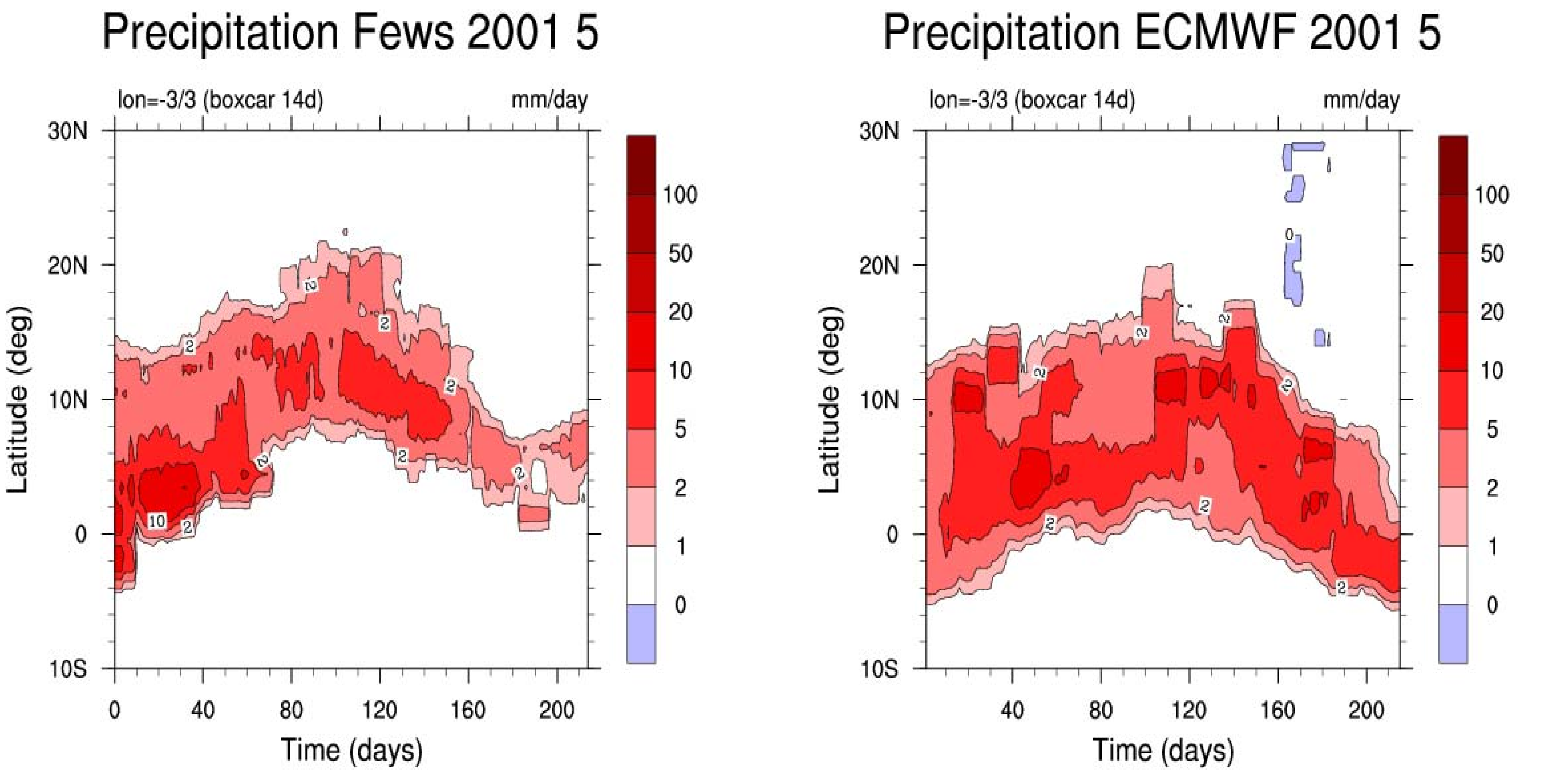




2003

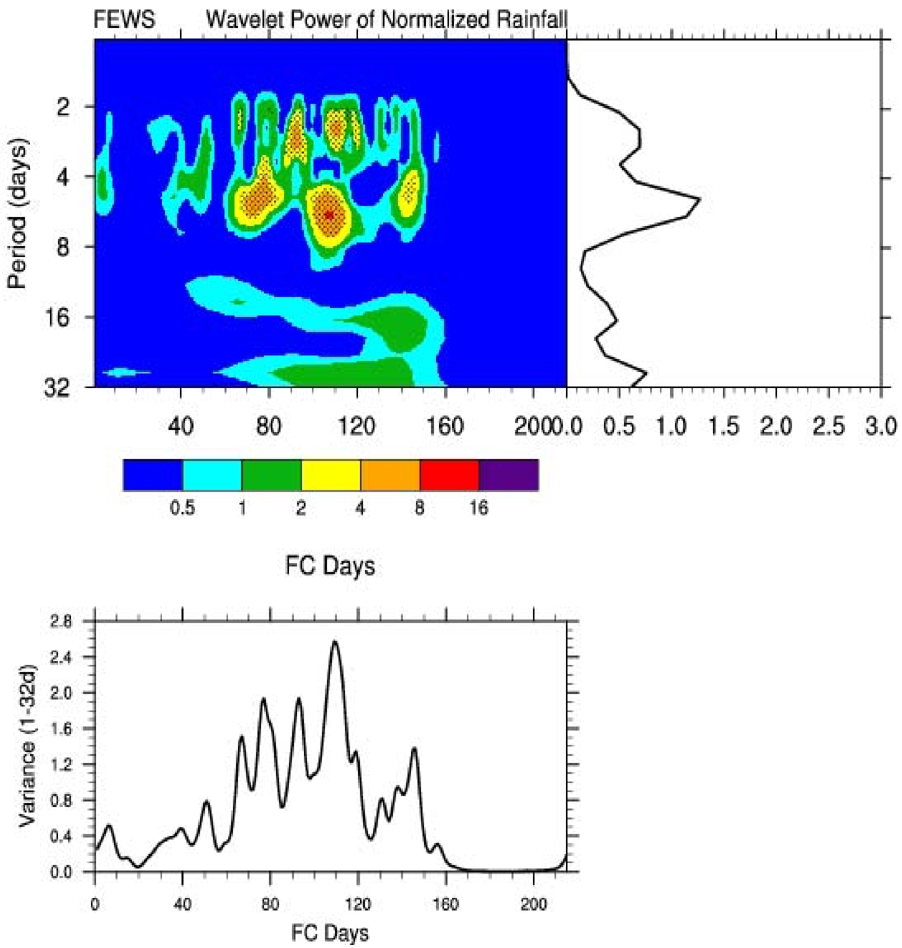
ECMWF forecast has peak variability in 8-16 day band – observations have peak in 4-7 day band = coupling with AEWs, lacking in model

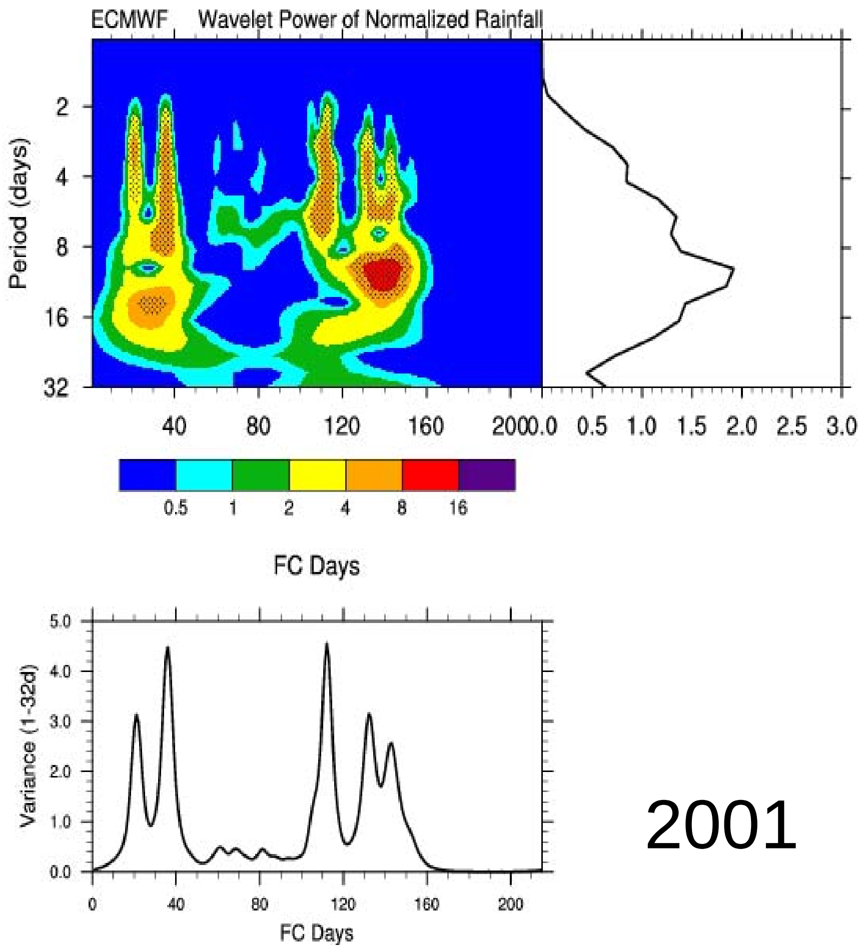
Example 2: Comparison of Rainfall with FEWS Band centred on lon=0, from 10N to 20N



Sometimes the onset can be poor in model

Comparison of Rainfall with FEWS





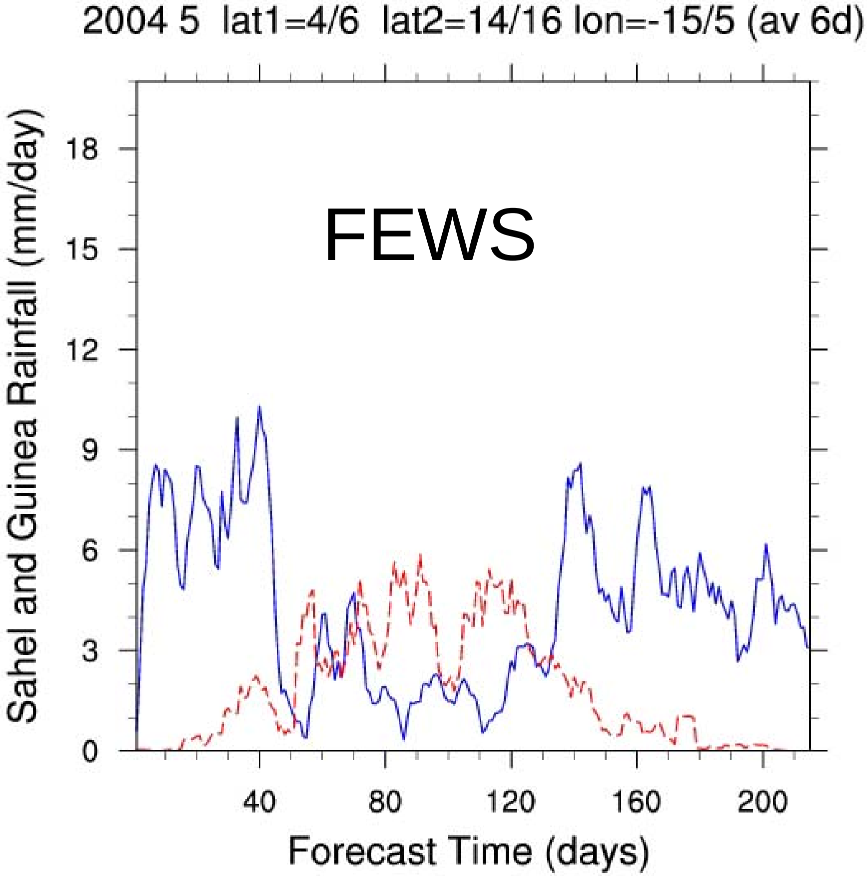
2001

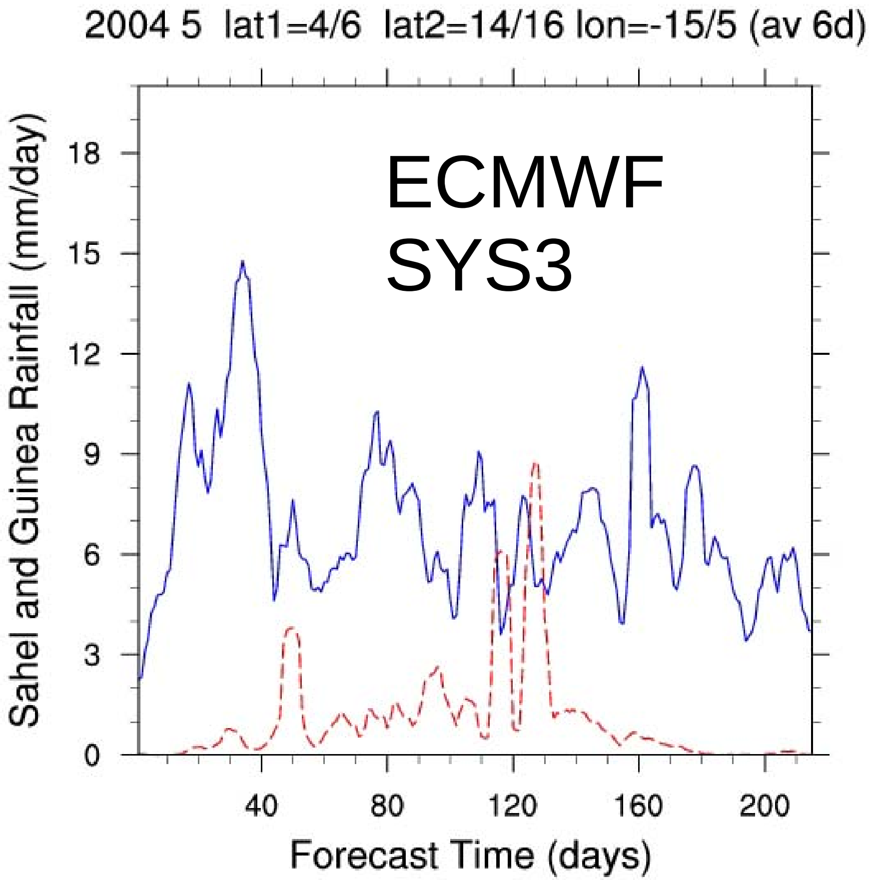
FEWS: Too distinct peaks in 2001 (not each year) 3-5 days and 6-9 days
ECMWF: Again coupling of convection and AEWs poor in sys3 here

Seasonal Forecasting

- Predictors: SST anomalies, soil moisture, JET position, Madden-Julian Oscillation (MJO)
- Predictants:
  - precipitation and temperatures over larger spatial and temporal scales
  - higher order seasonal statistics: onset, cessation, sub-seasonal variability

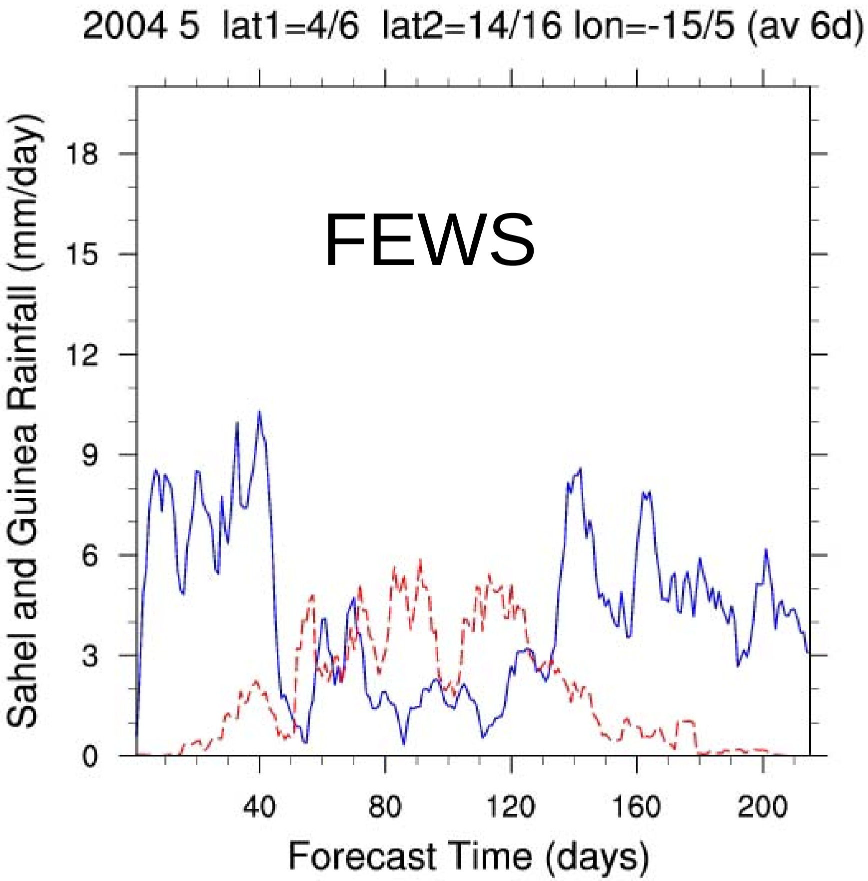
Onset of monsoon

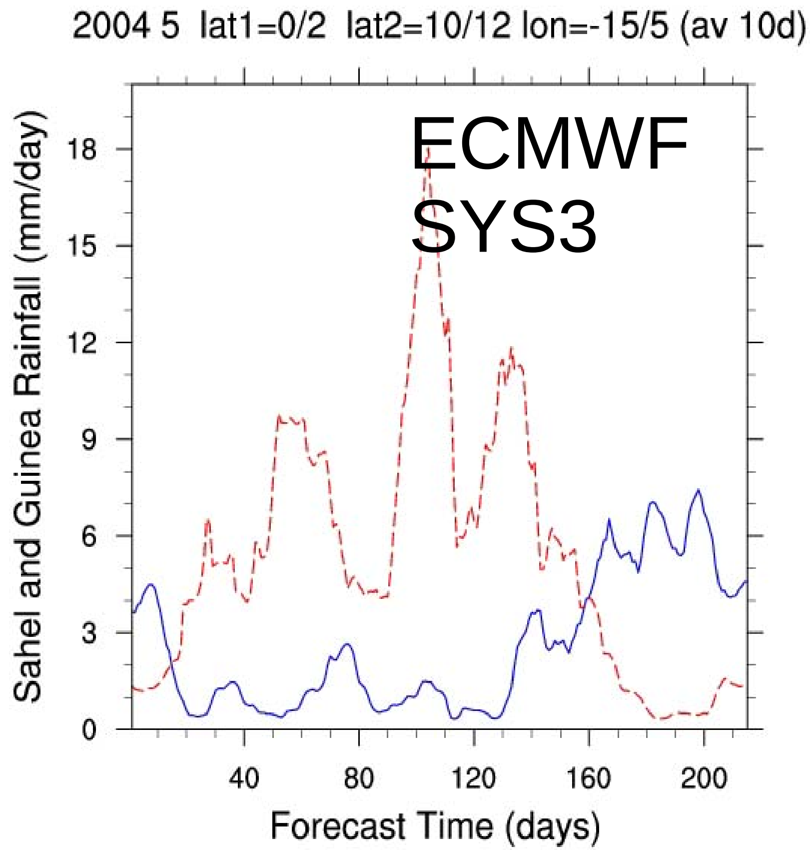




Due to southerly shift in rainfall patterns in model

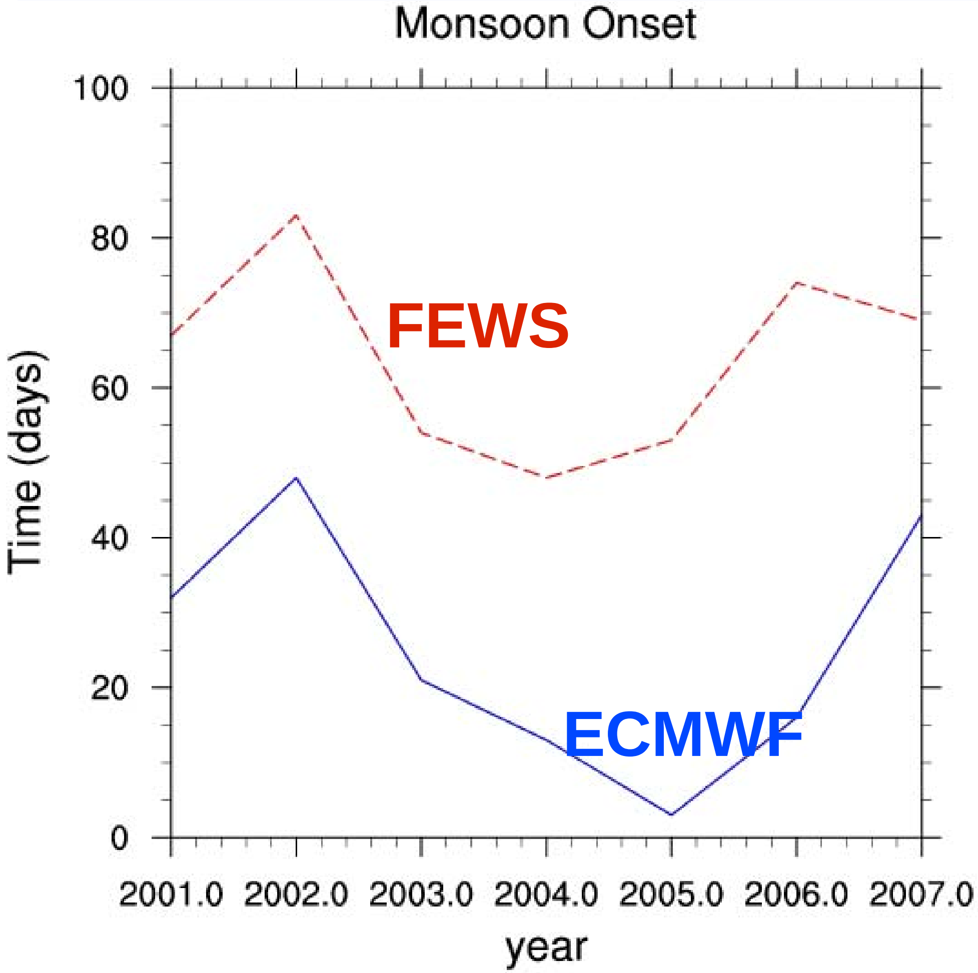
Apply 4 degree offset





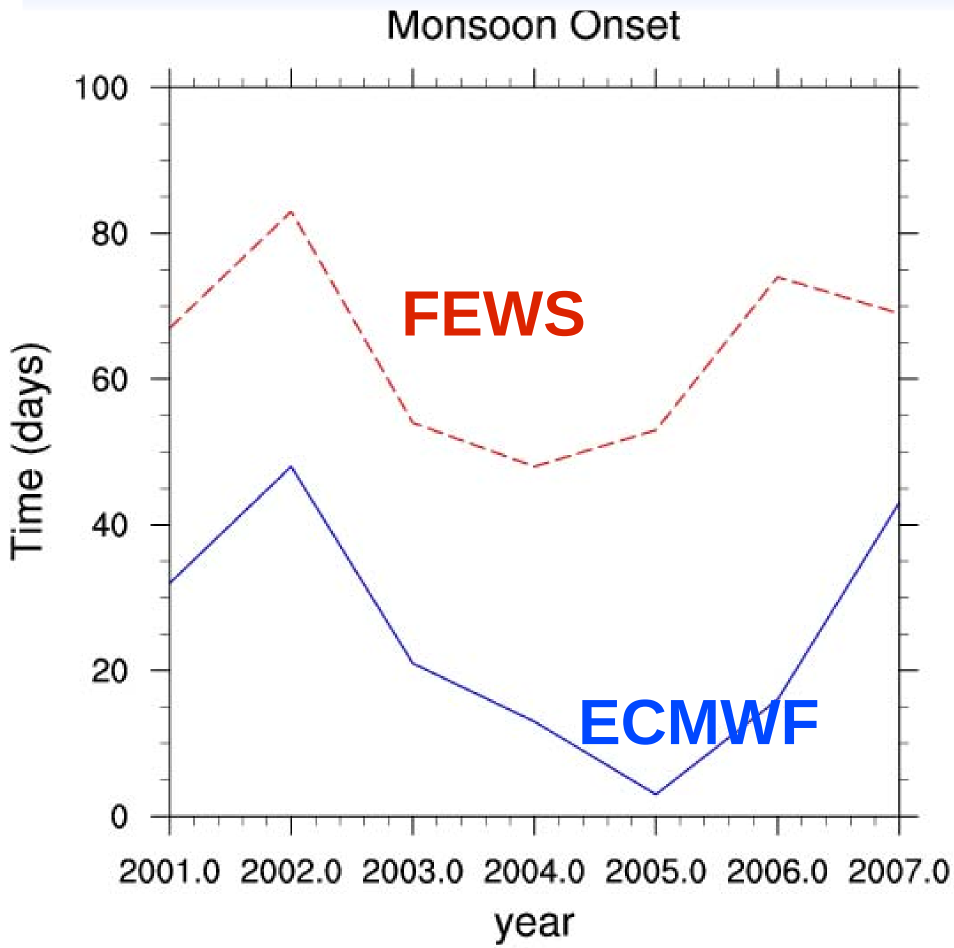
Due to southerly shift in rainfall patterns in model

Shift the model target areas 4 deg south



Conclusions?

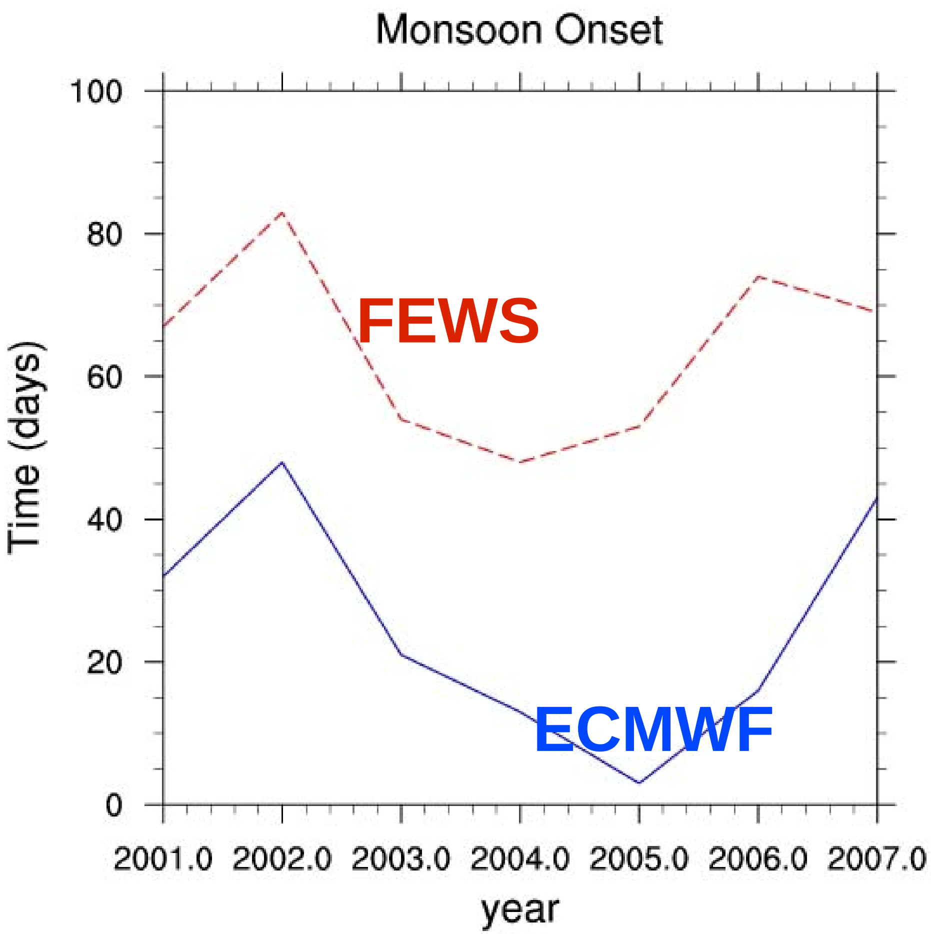
Shift the model target areas 4 deg south



Conclusions?

"The offset onset has an offset!!!"

Shift the model target areas 4 deg south



Conclusions?

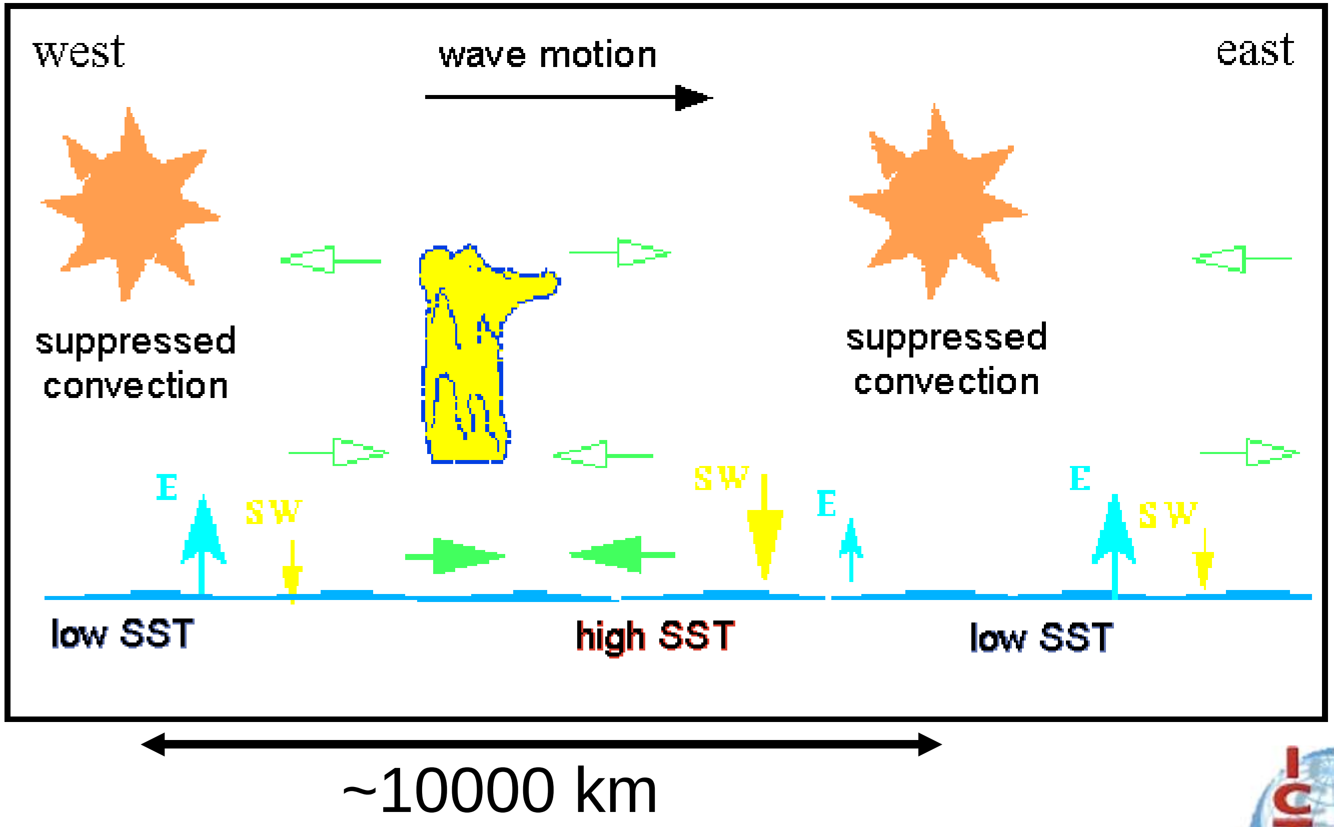
"The offset onset has an offset!!!"

Hybrid statistical-dynamical techniques can extract information content -

Current work to define robust onset using EOFs

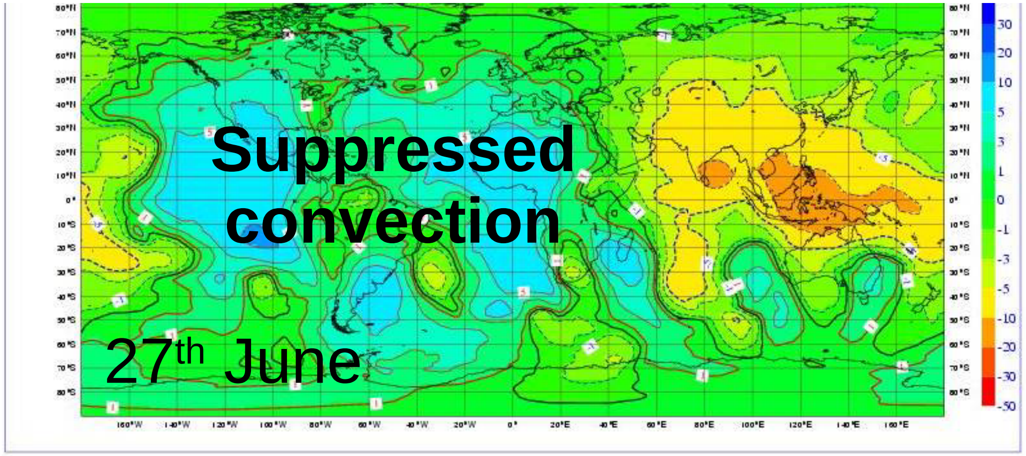
Madden-Julian Oscillation (MJO)

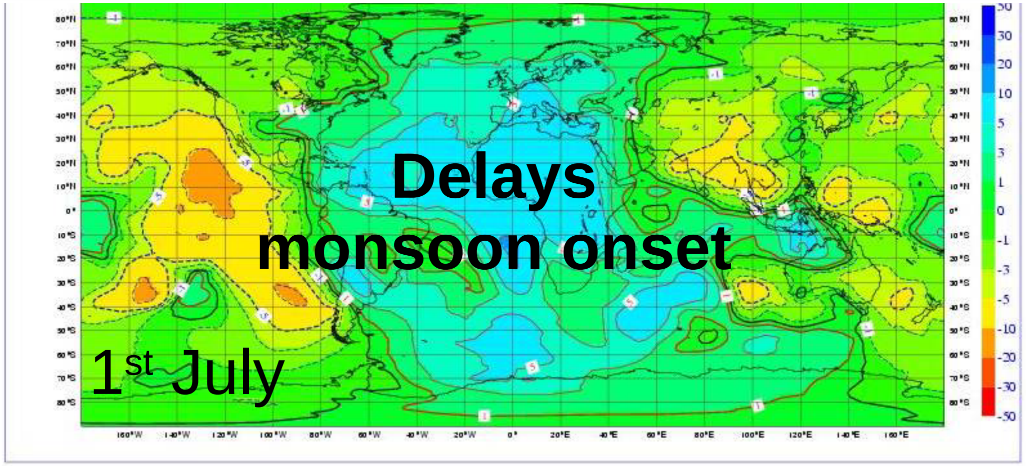
- Wave number 1-3 convectively-coupled eastward propagating (40-60 days) large-scale oscillation in the tropics

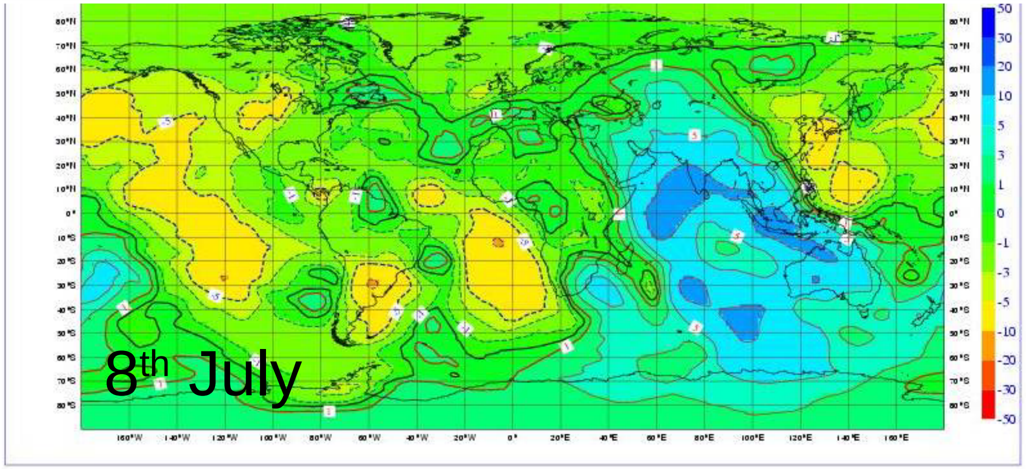


wheeler

ECMWF Analysis of the 200 hPa Velocity potential Anomaly

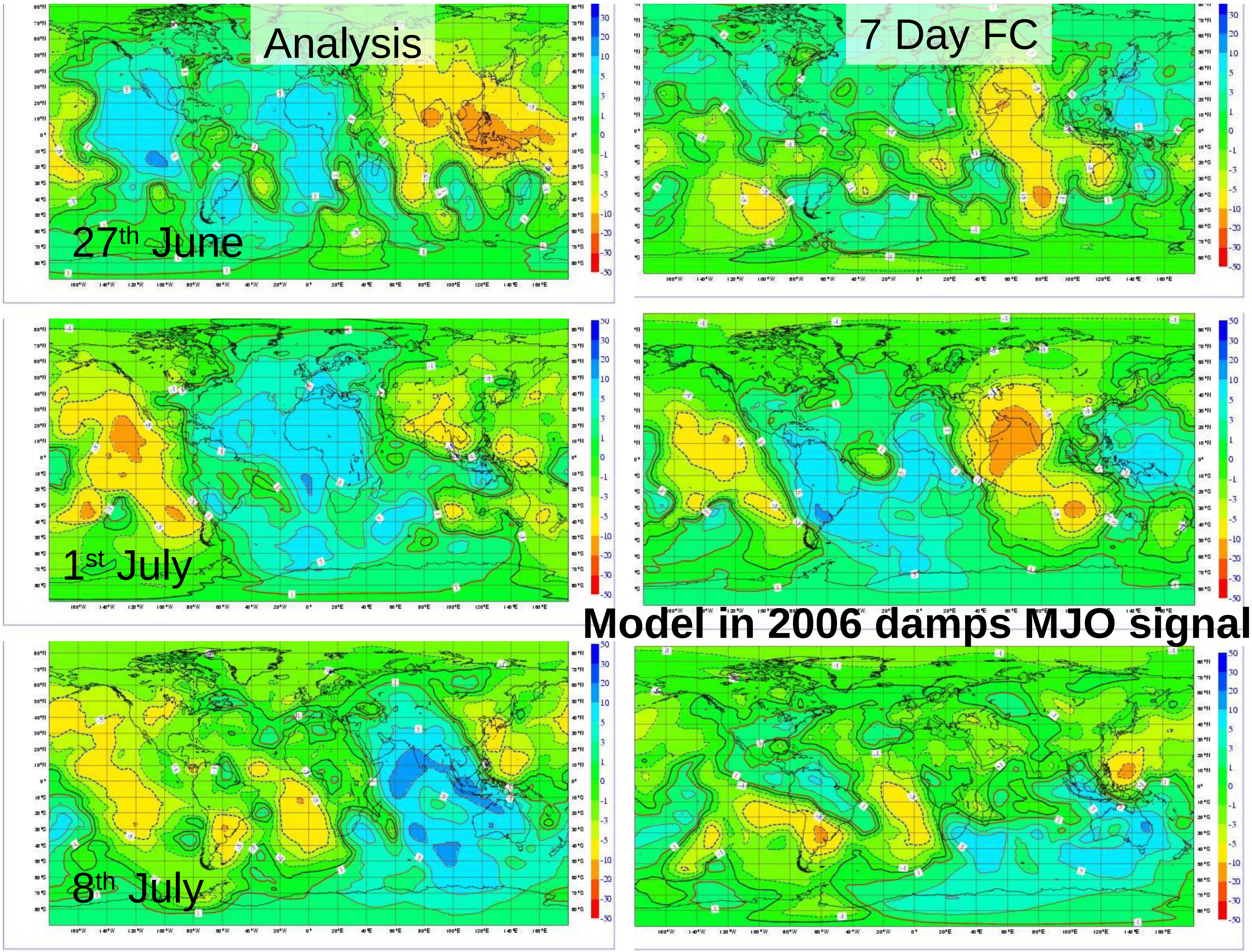






Large-scale wave-number 1 pattern associated with an MJO event

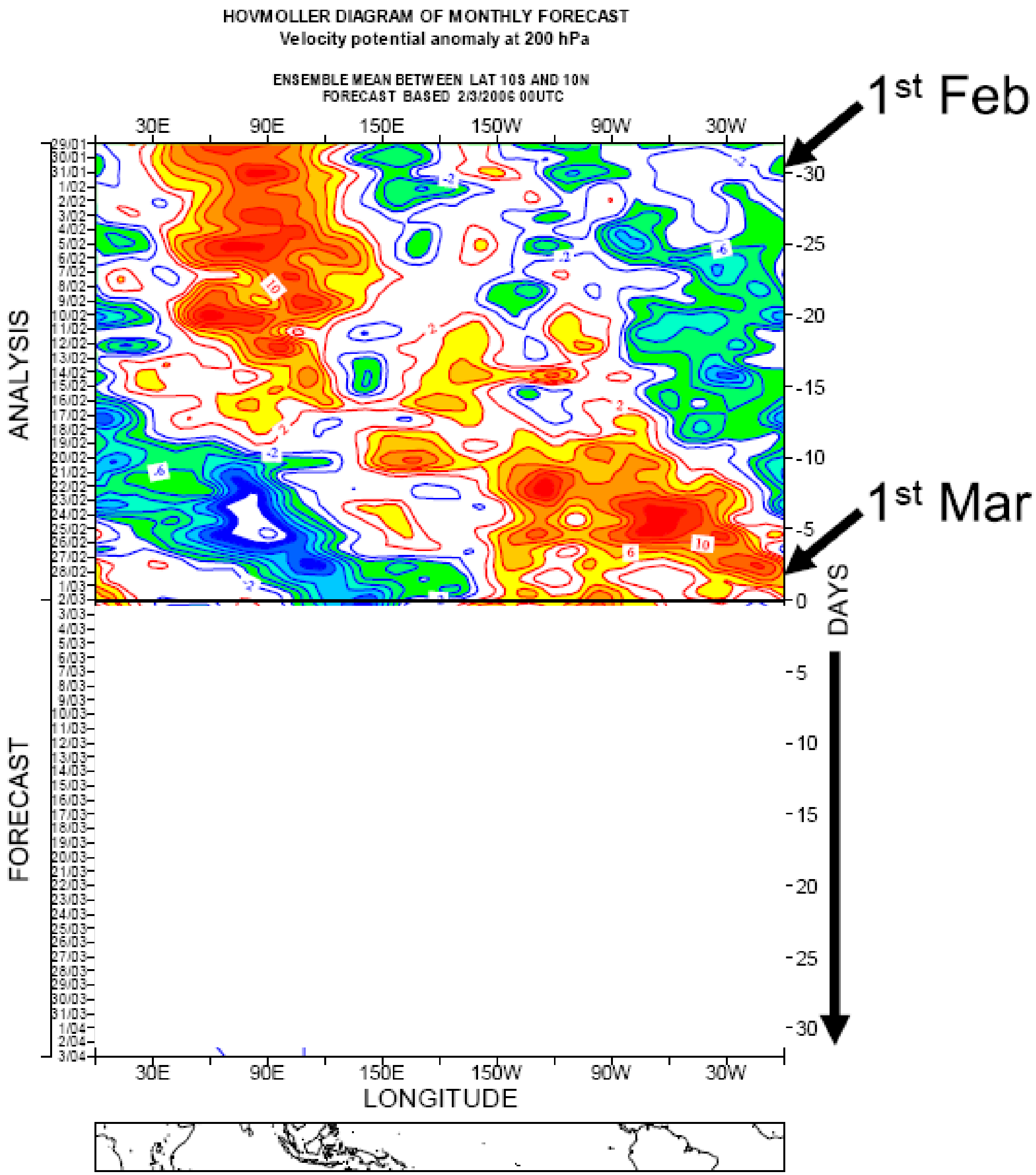
Using this, Andre Kamga of ACMAD in Niamey (correctly) predicted a late monsoon onset in 2006


Analysis
7 Day FC
27th June
1st July
8th July
Model in 2006 damps MJO signal

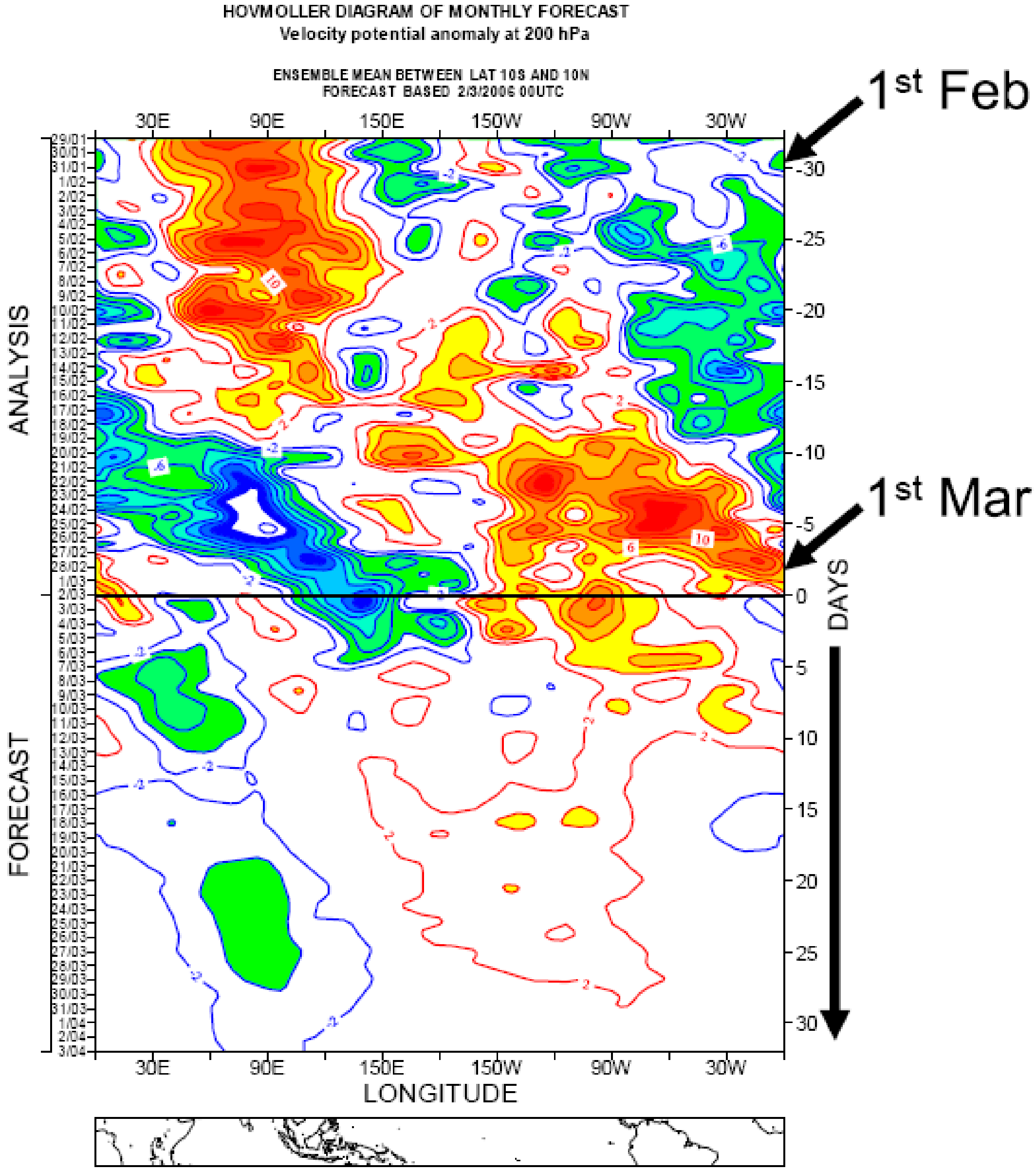
Typical MJO forecast at ECMWF

200hPa Velocity Potential Anomalies

February – March 2006



The top half of the plot monitors the preceding month using the analysis



Typical MJO forecast at ECMWF

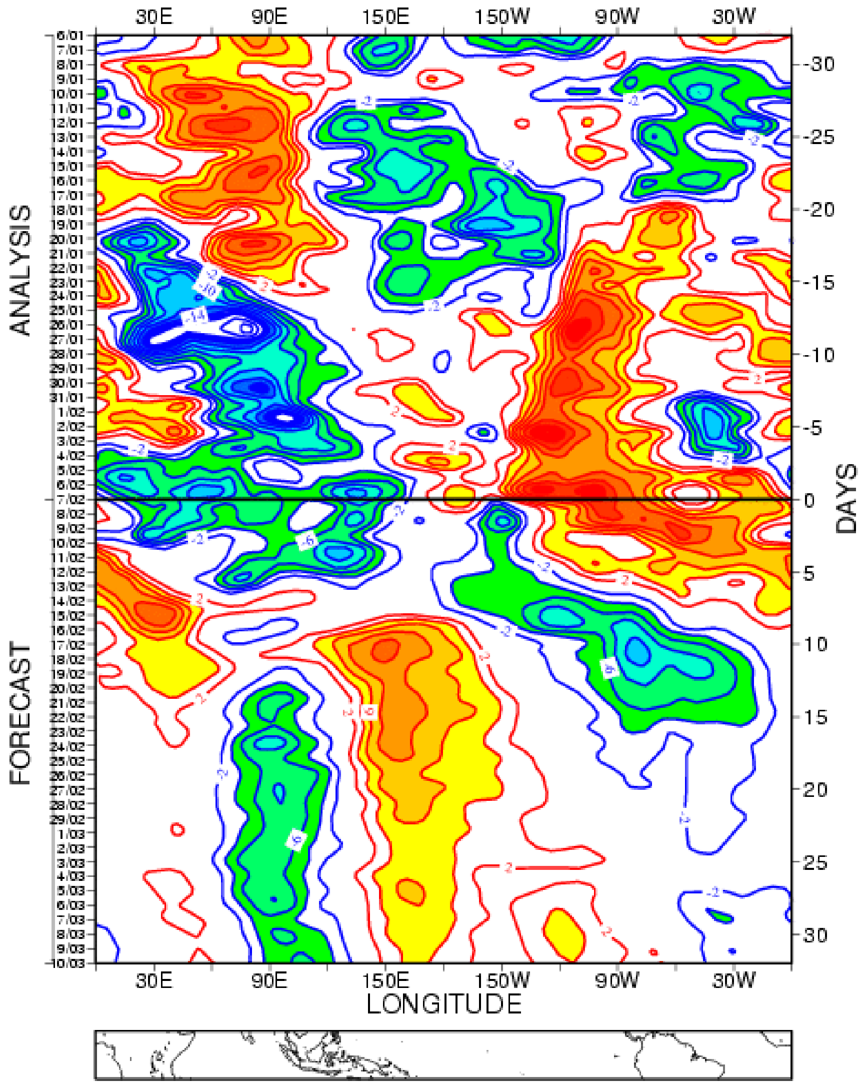
200hPa Velocity Potential Anomalies

February – March 2006

The top half of the plot monitors the preceding month using the analysis

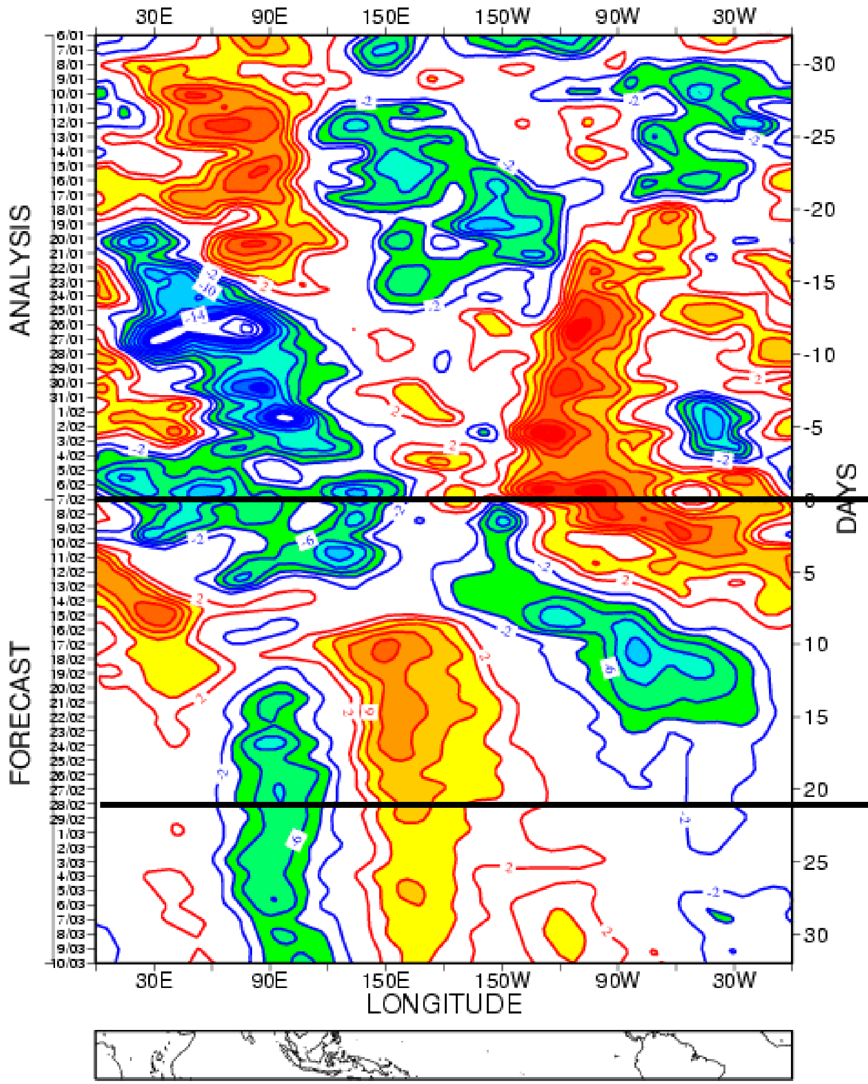
The lower half shows the monthly forecast using same model cycle as system 3

2008 – Cycle 32r3

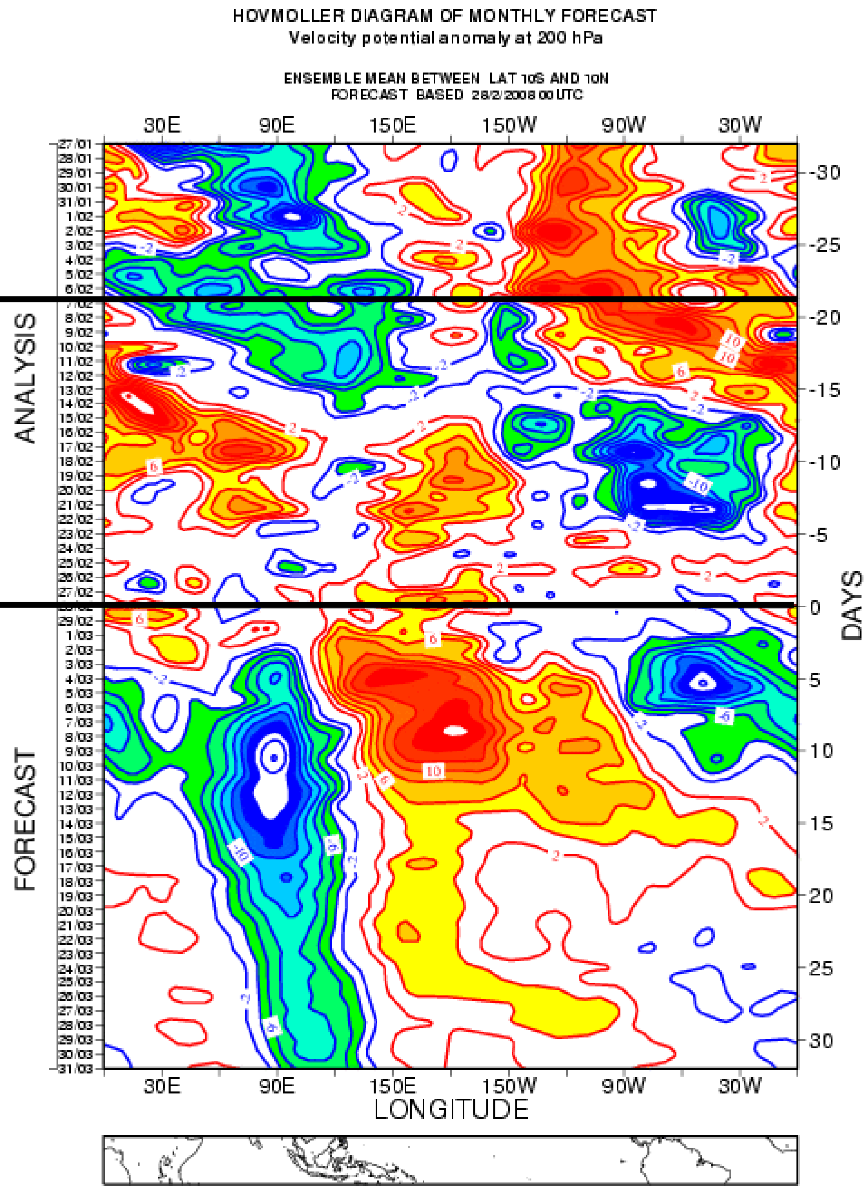


FC from 7/2

2008 – cycle 32r3



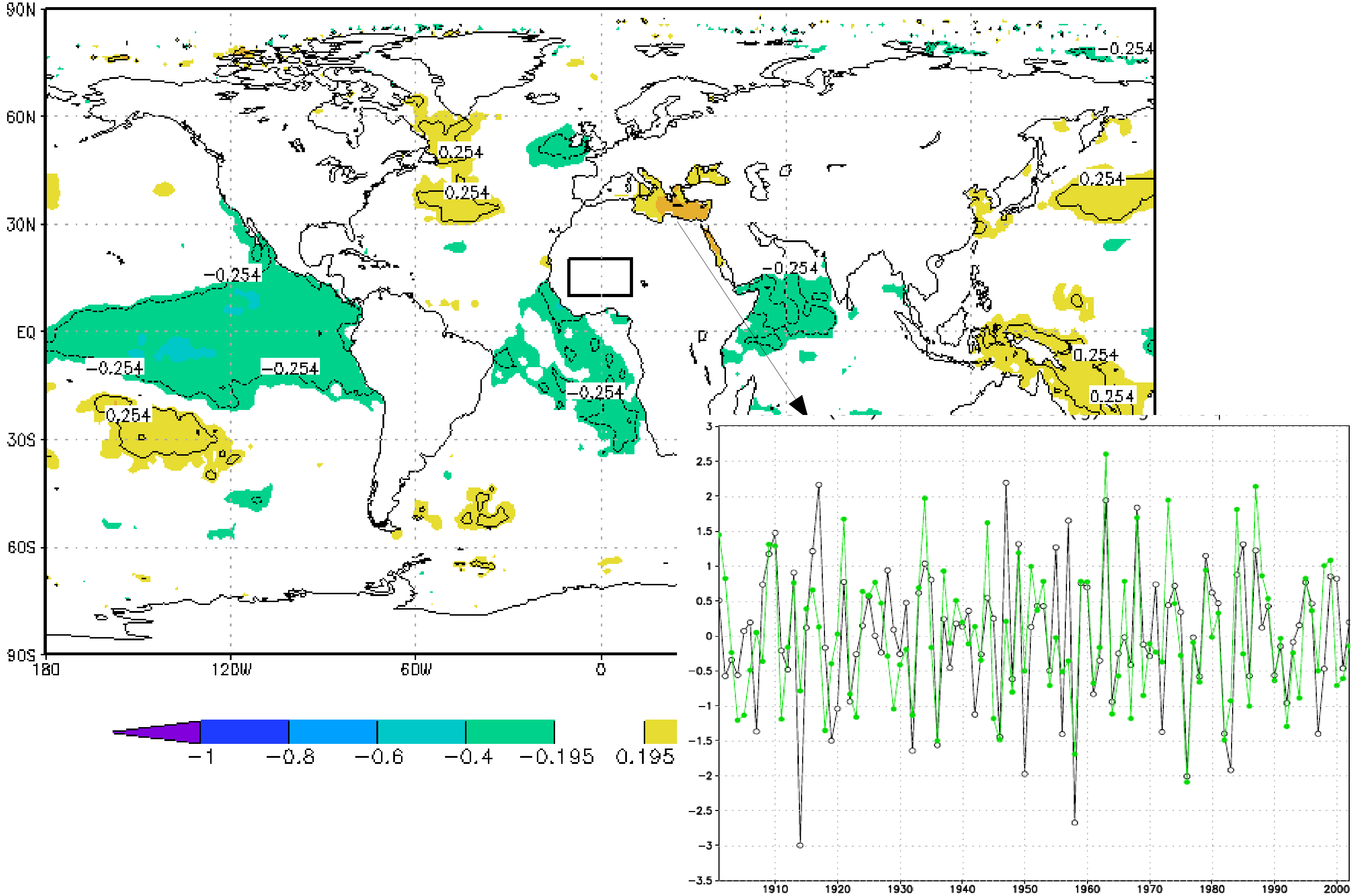
FC from 7/2
FC from 28/2



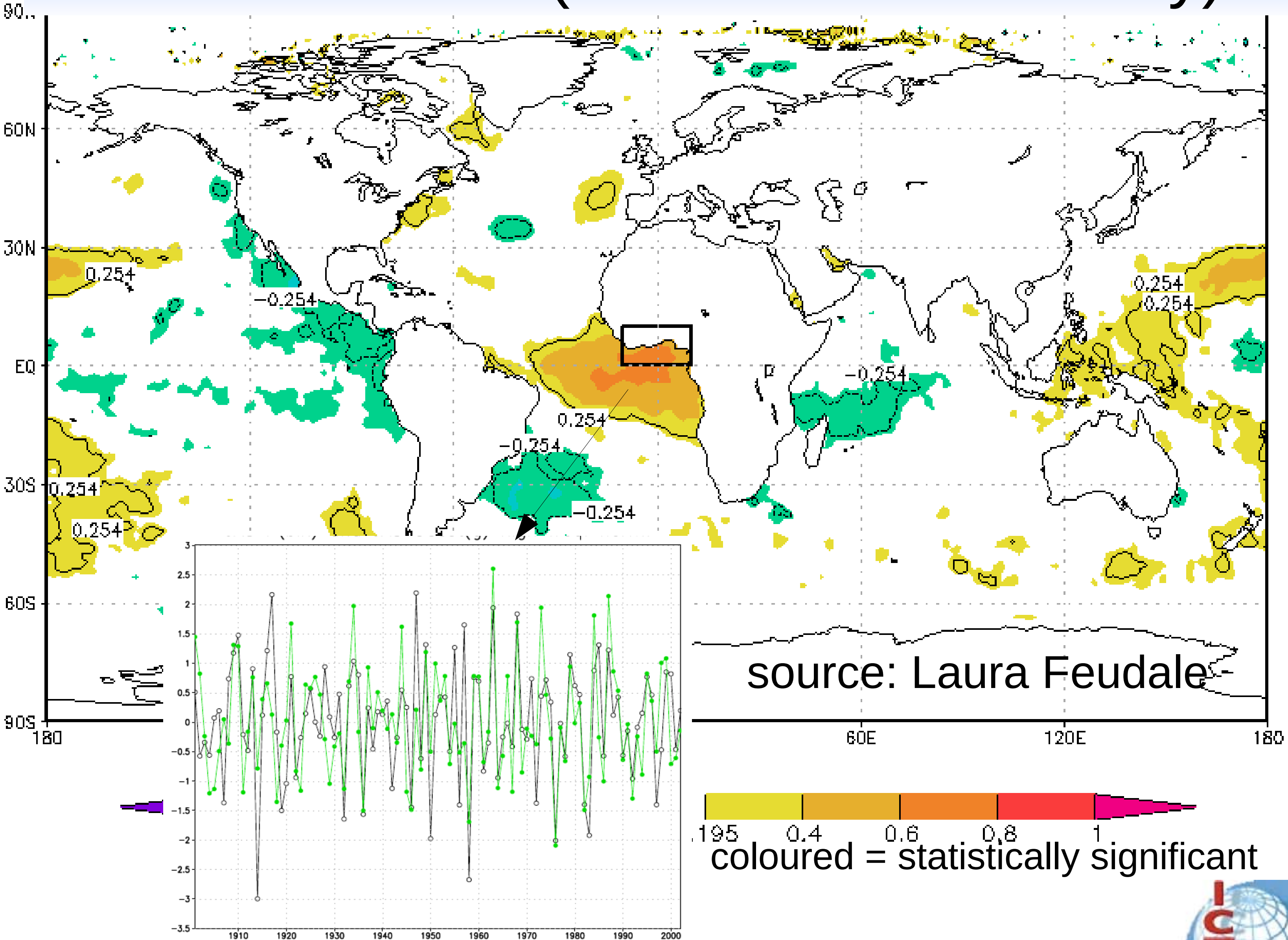
Sea Surface Temperature (SST) Role

- Host of literature document the influence of SSTs on West African Rainfall
  - ENSO
  - Gulf of Guinea
  - North Atlantic
  - Indian Ocean
  - Mediterranean Sea
- Investigations using
  - Observed correlations between rainfall and SSTs
  - Model integrations with imposed SSTs (e.g. Held et al. 2003, Giannini 2003)
  - coupled models

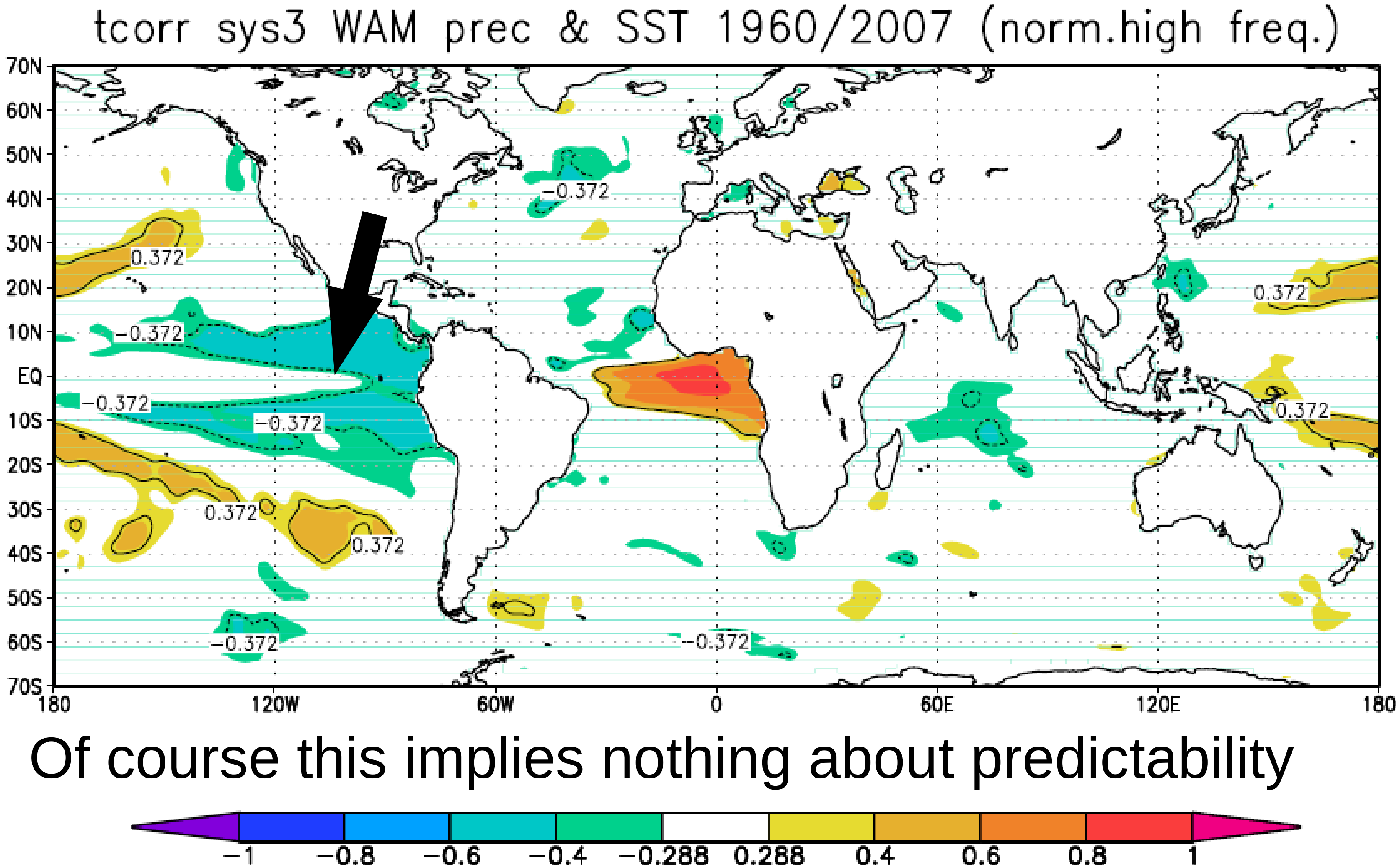
High freq (<10 years) correlations of (HAD) SST with Sahel rainfall (CRU)



Strong positive correction of boxed rainfall with GG SSTs (interannual variability)

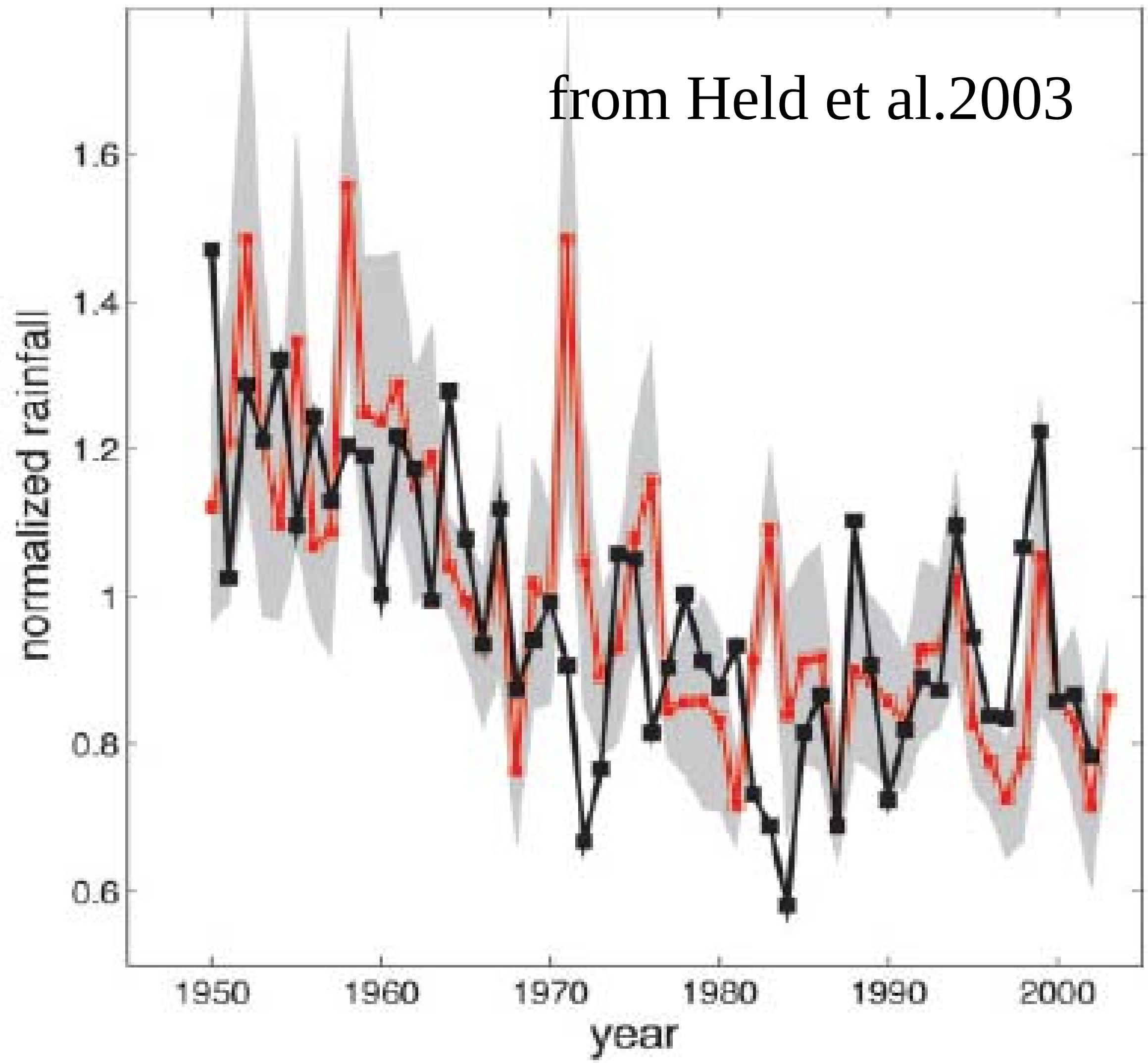


Does SYS 3 reproduce these correlation patterns ?



Of course this implies nothing about predictability

Imposing observed SSTs allows simulation of 70s and 80s drought conditions



Note Rainfall
is normalized

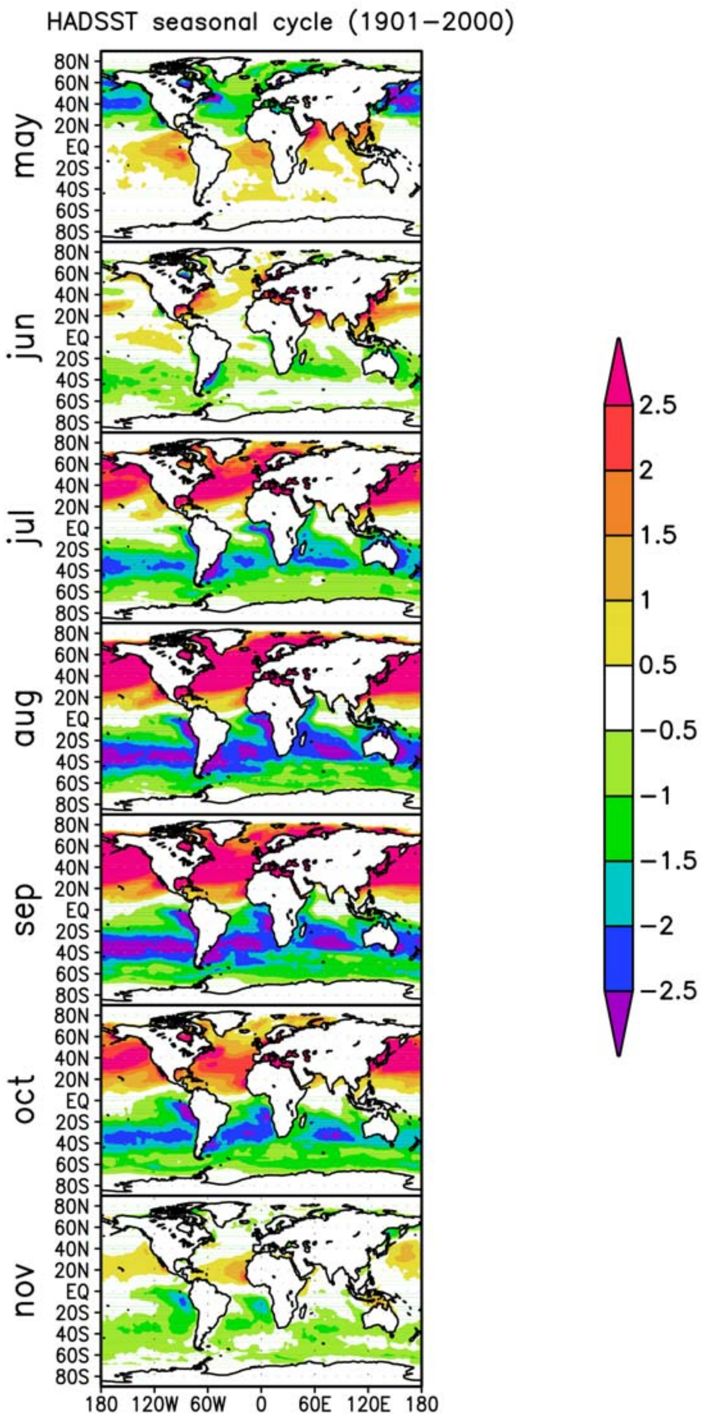
Actual signal weaker
in models than
observations

SST predictability

- Fixed SSTs may exaggerate the atmospheric response as the heat budget is not closed
- Moreover, as noted, the correlation maps reveal nothing concerning predictability
- Indeed, the equatorial Atlantic is a tightly coupled system
- SSTs anomalies impact convection & trade winds, but trade winds also drive SST anomalies

- "*Slowly evolving SSTs determine the atmospheric response in terms of the local and remote distribution and intensity of convection*"

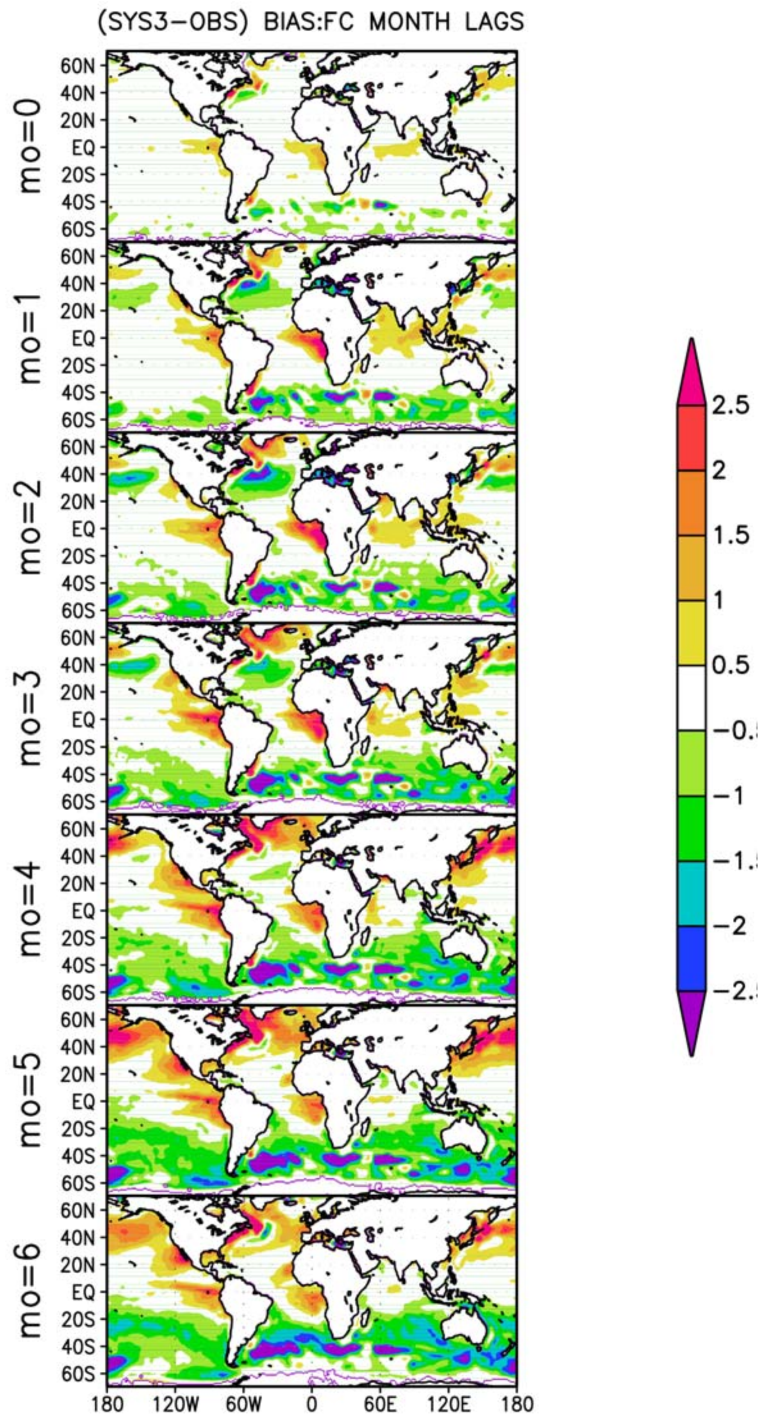
- "*The dominant SST variability is determined by atmospheric forcing only, dynamical processes in the ocean...are not important*" Dommenget and Latif 2000



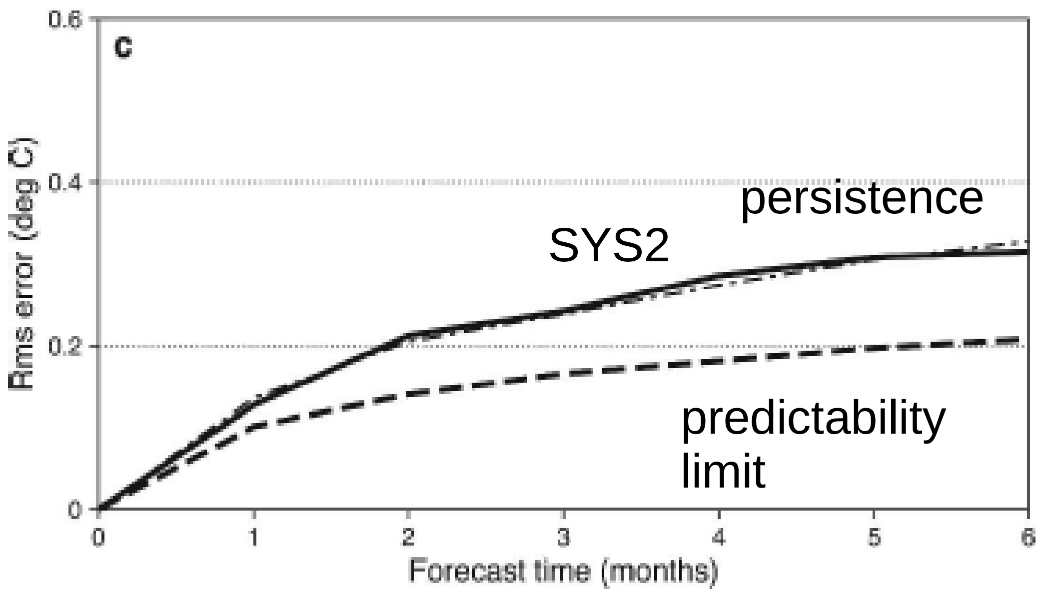
Seasonal Anomaly

SYS3 May 1st start SST bias

Model warm during cold tongue development



ECMWF system 2 coupled seasonal model

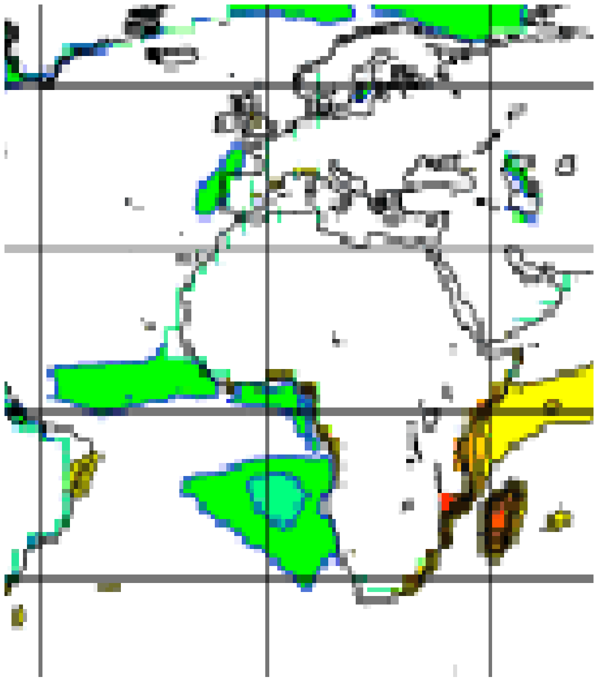


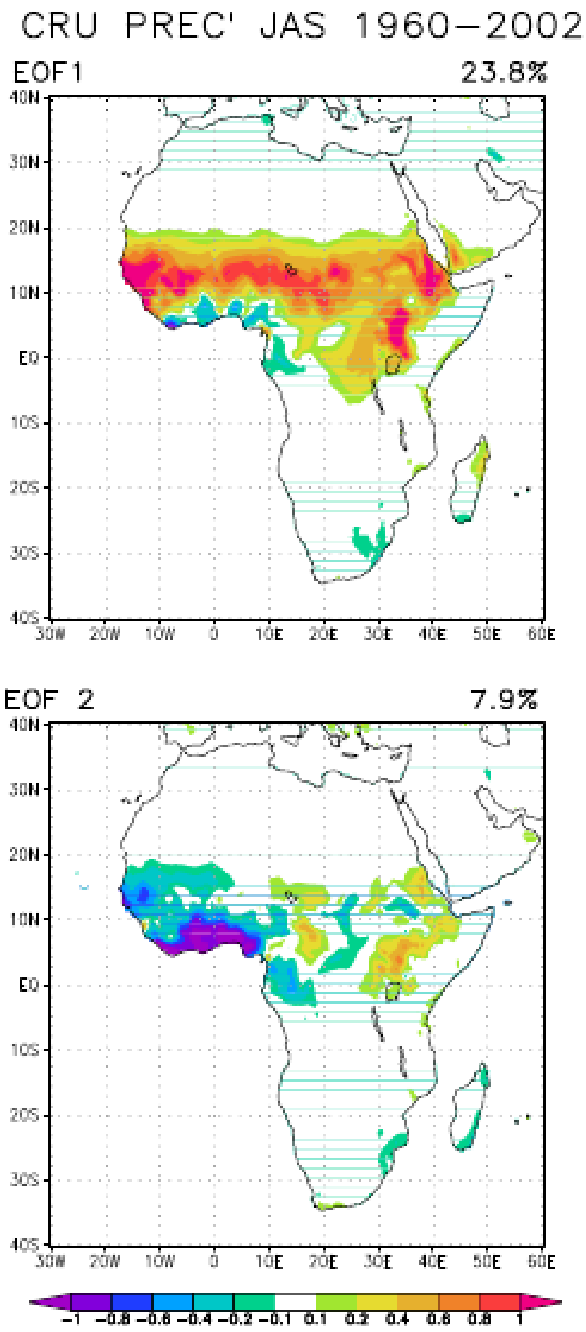
Dotted = Persistence
Solid = SYS 2
Dashed = Limit of predictability

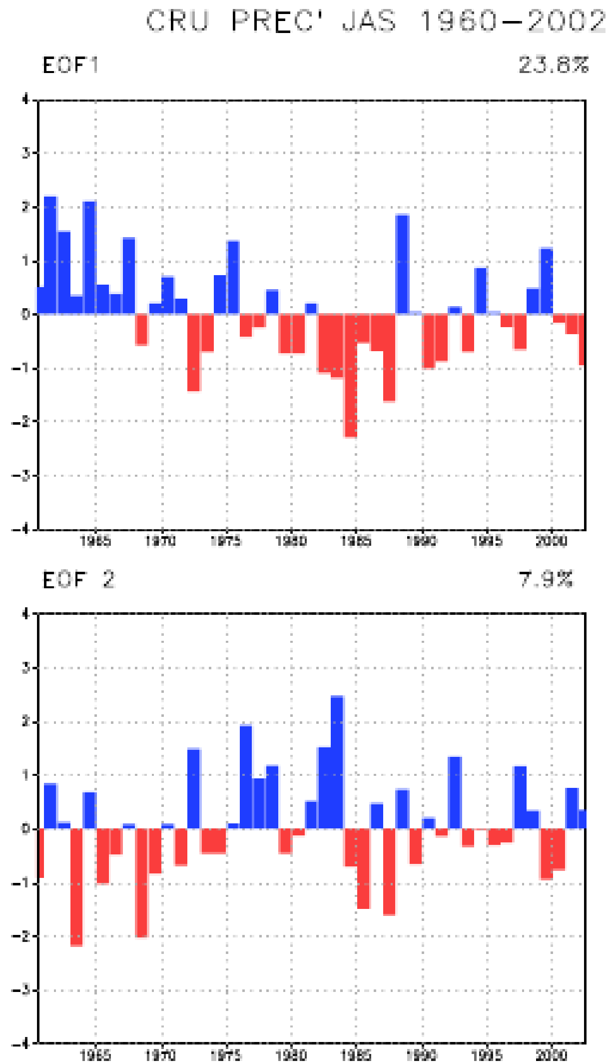
Stockdale et al. 2006: No skill above persistence in Equatorial Atlantic – Also showed little influence by accounting for sub-thermocline oceanic information

Equatorial Atlantic SSTs

- Strong coupling implies other sources of model bias will affect predictability limit. e.g. Stratocumulus
- Improvements in convection parametrization will help!!!



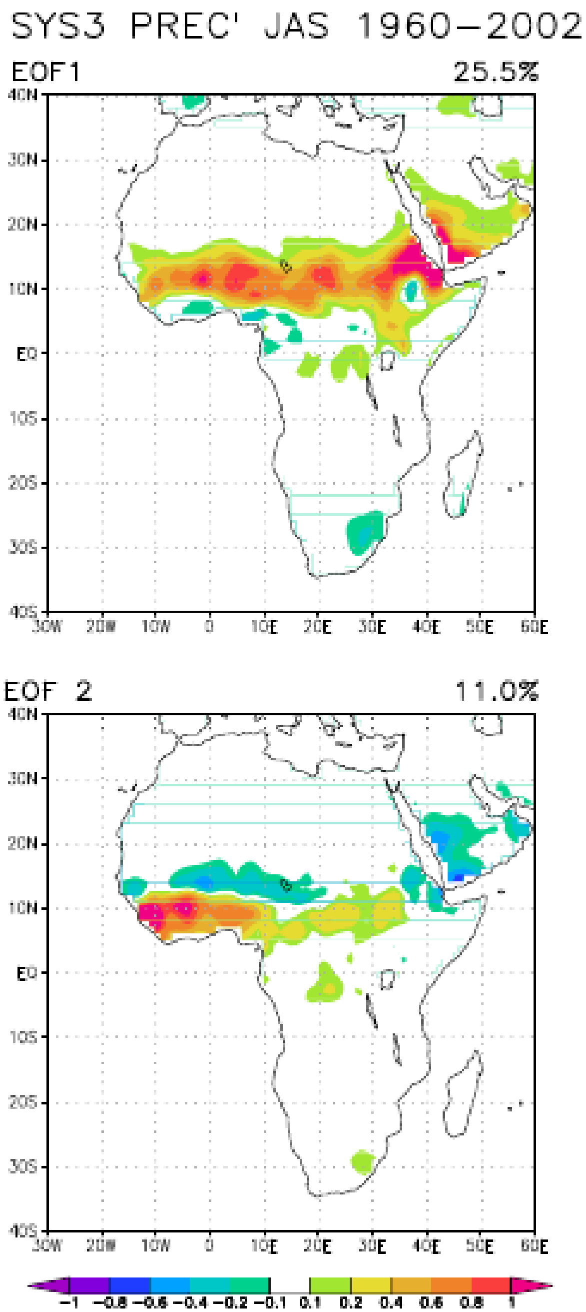


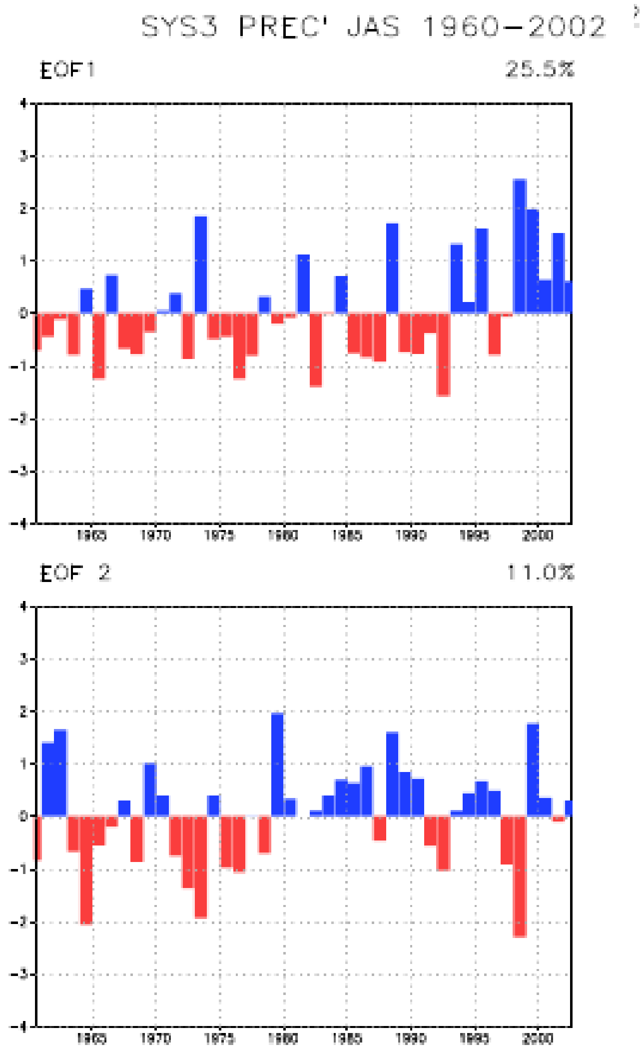


Prediction of decadal trends

CRU rainfall

EOFs

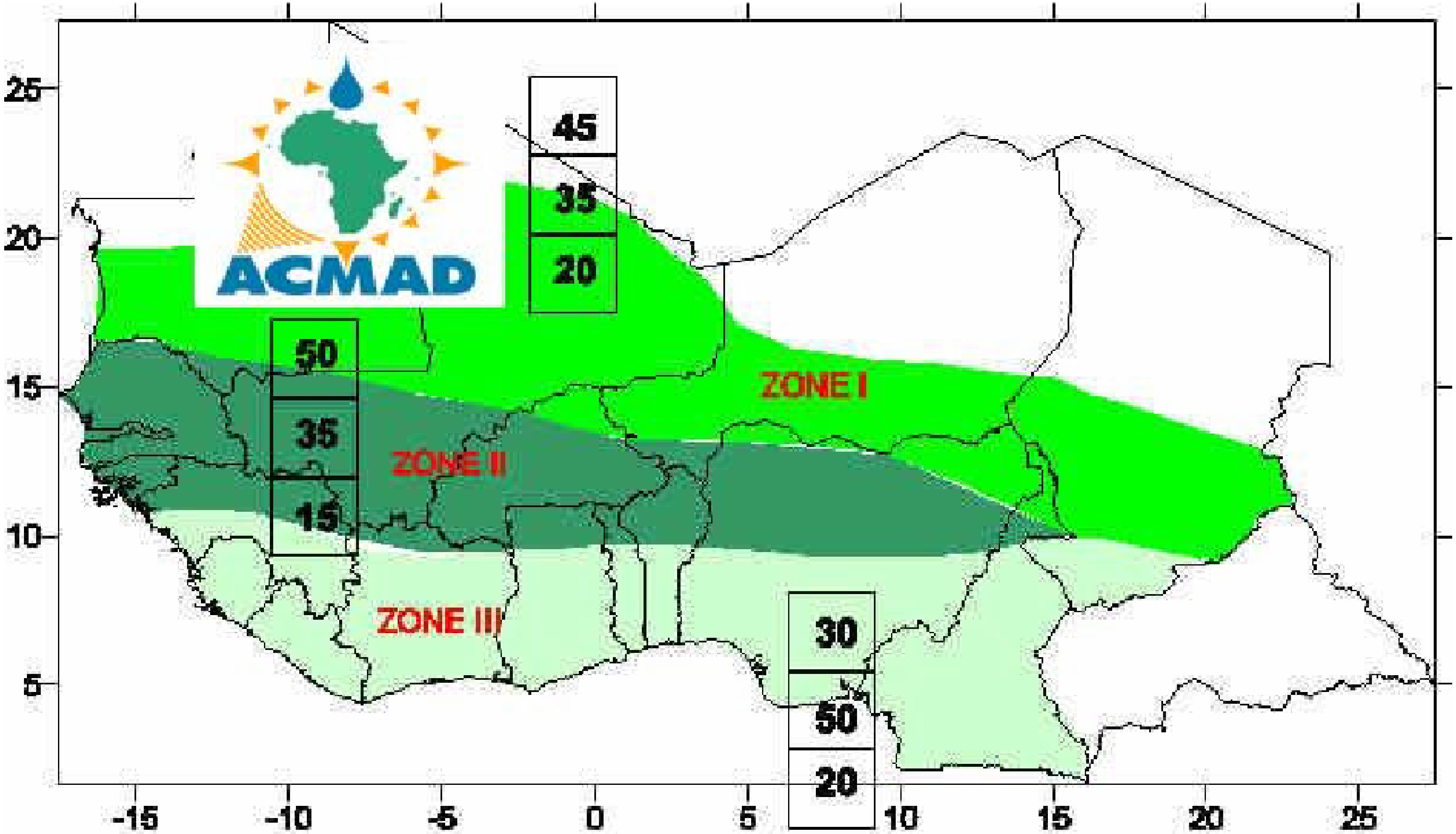




SYS3 rainfall

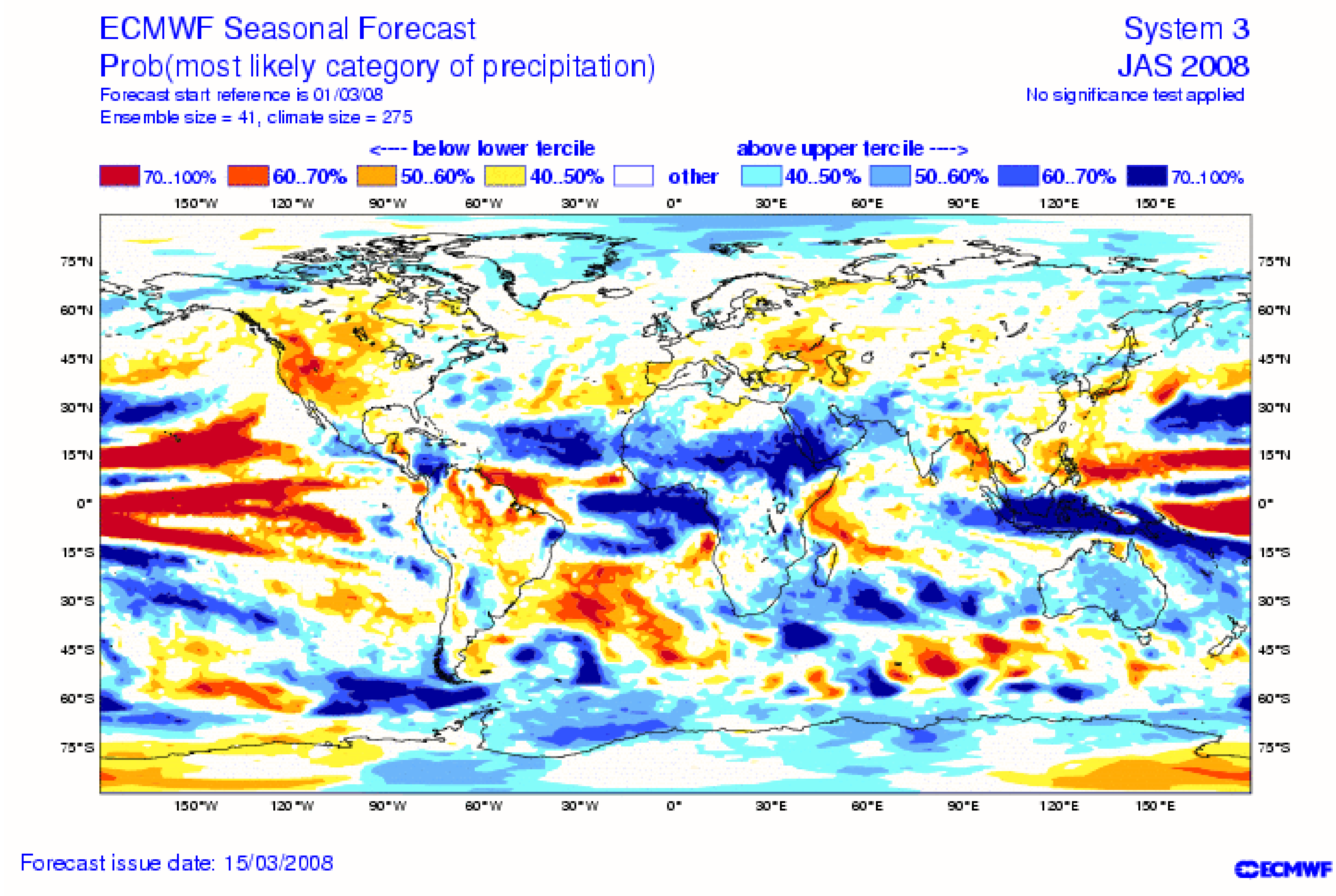
EOFs

PRESAO 2008
from dynamical and statistical models

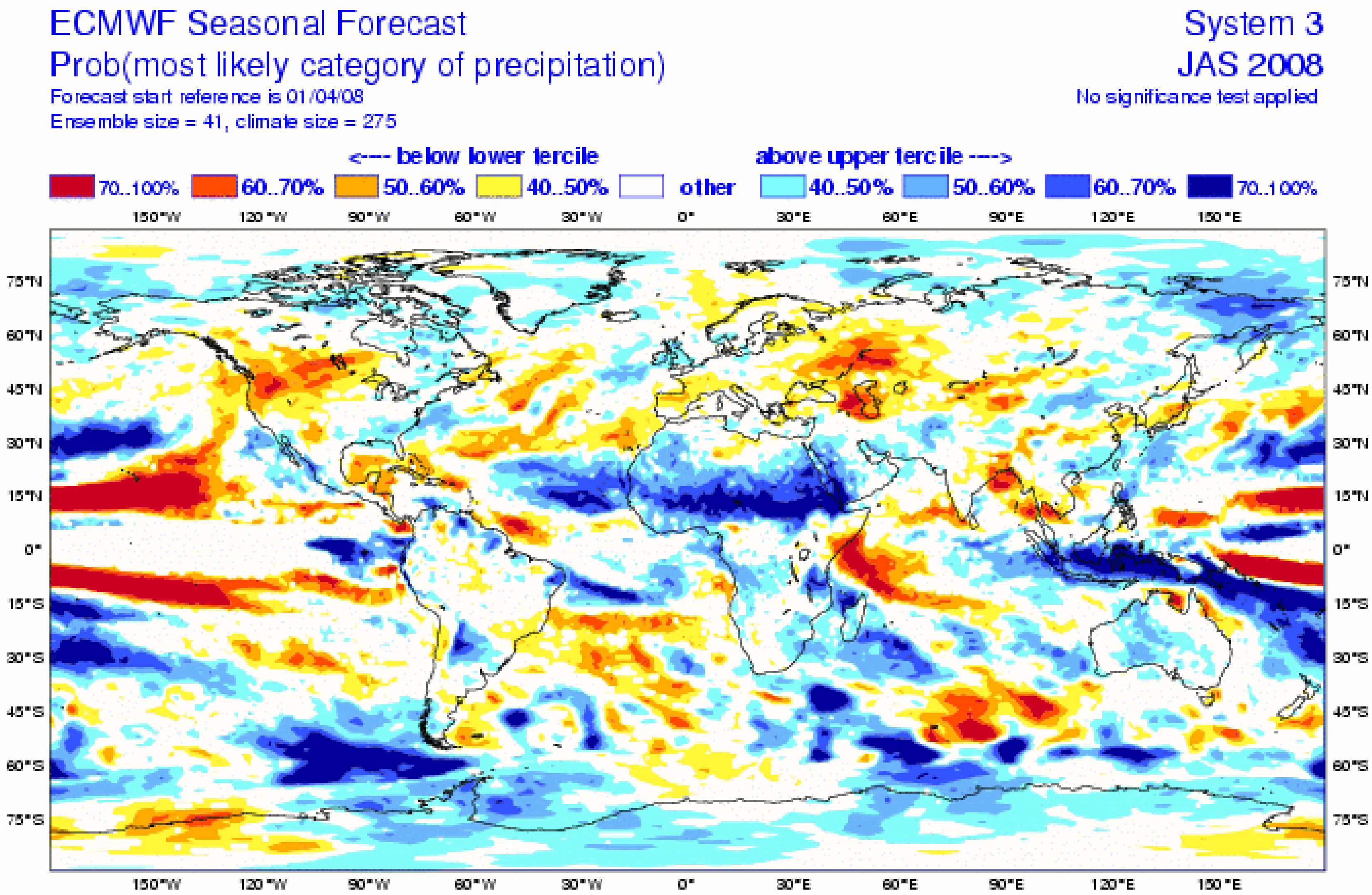


ZONE 1 : Humide - ZONE 2 : Très humide - ZONE 3 : Normale

July-Aug-Sept (JAS) Rainfall prediction March

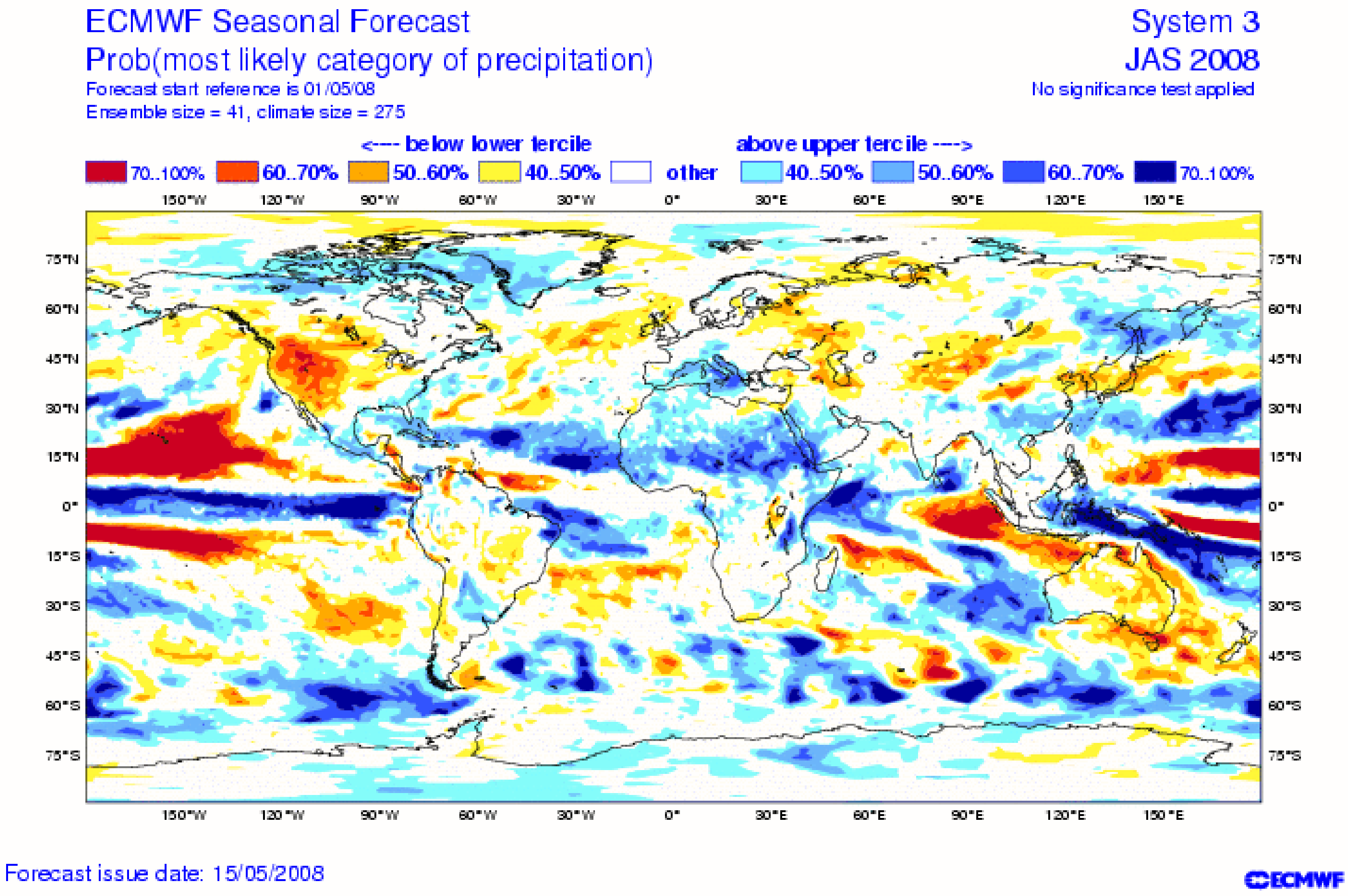


July-Aug-Sept (JAS) Rainfall prediction April

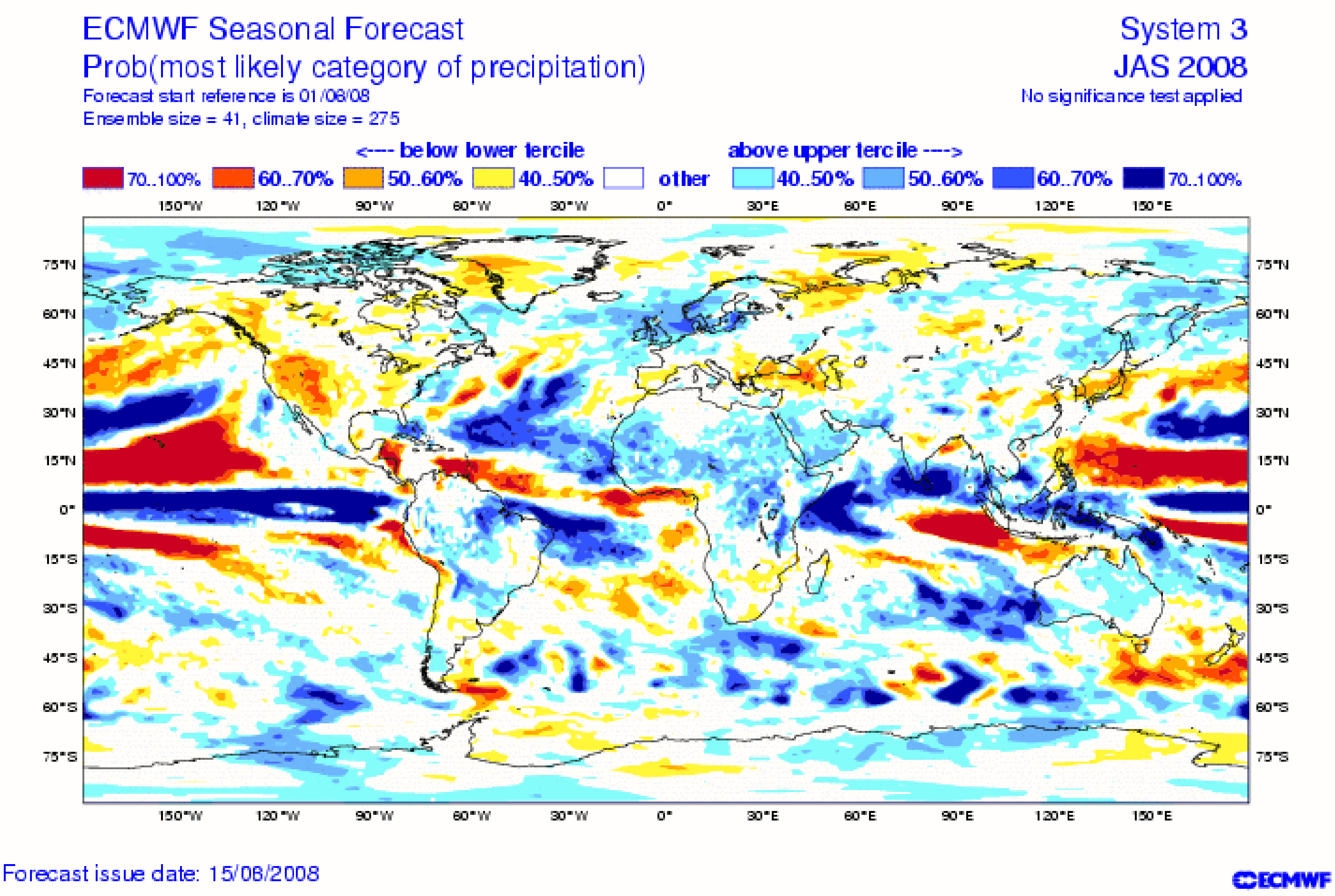


Forecast issue date: 15/04/2008

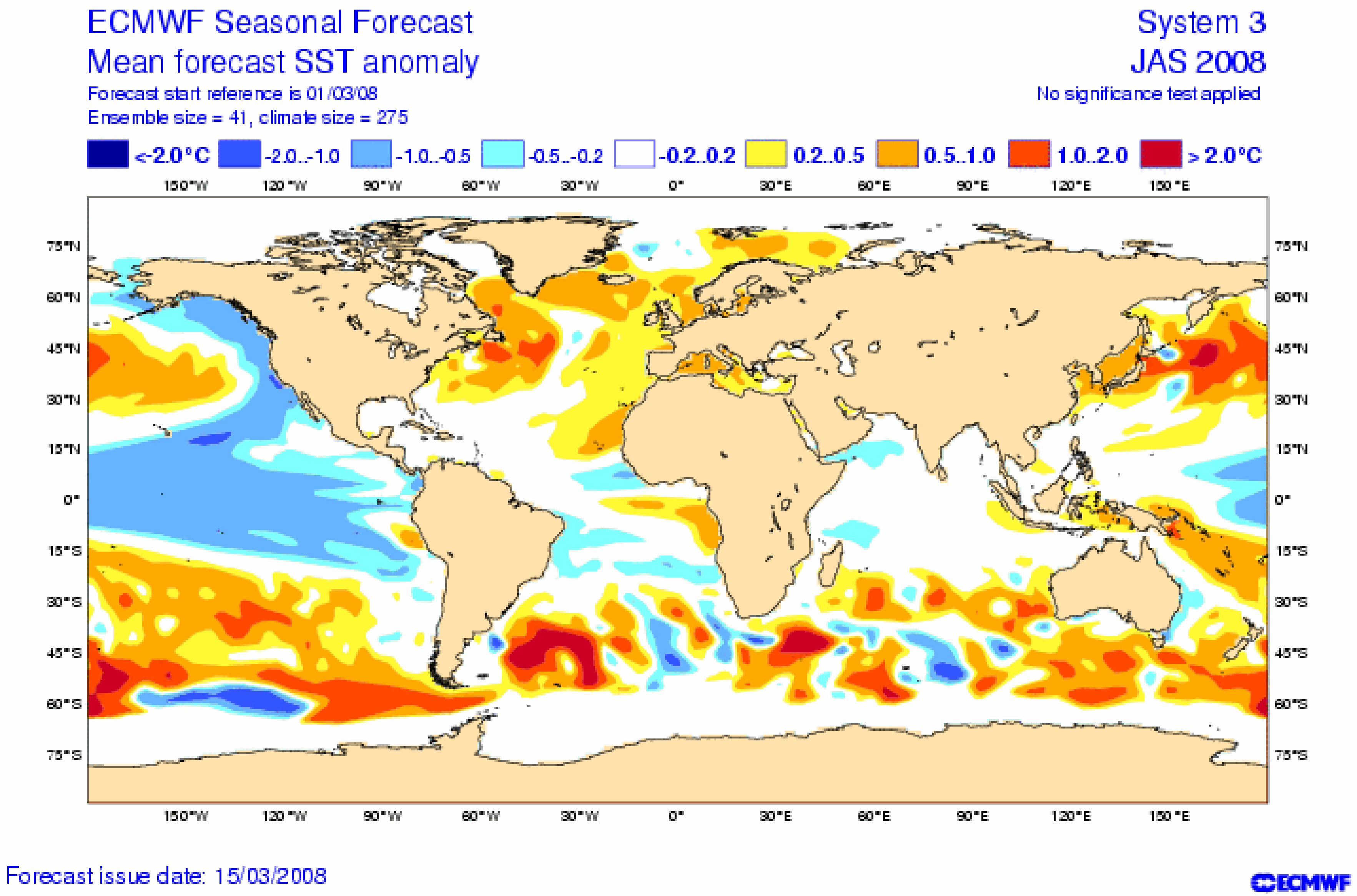
July-Aug-Sept (JAS) Rainfall prediction May



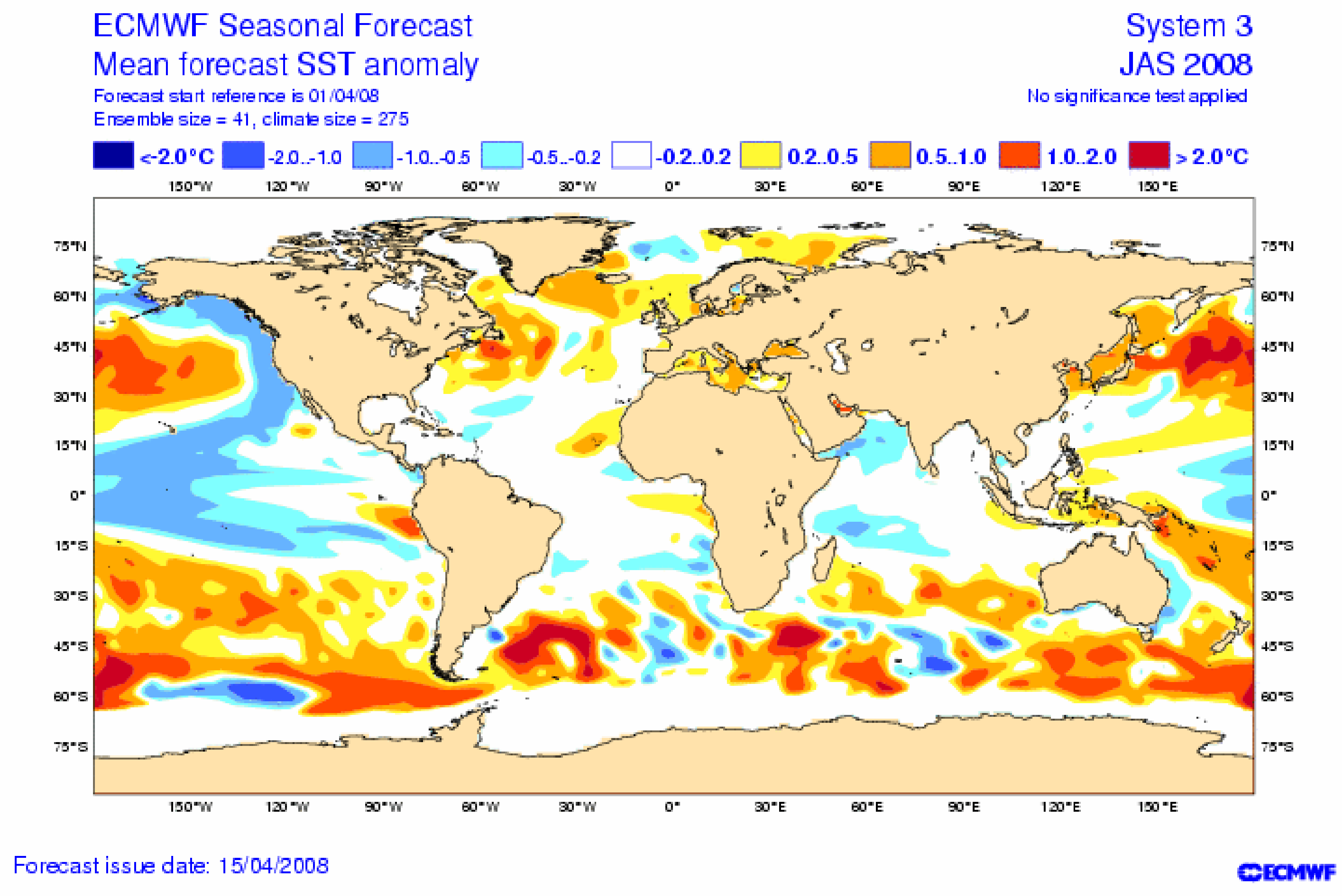
July-Aug-Sept (JAS) Rainfall prediction June



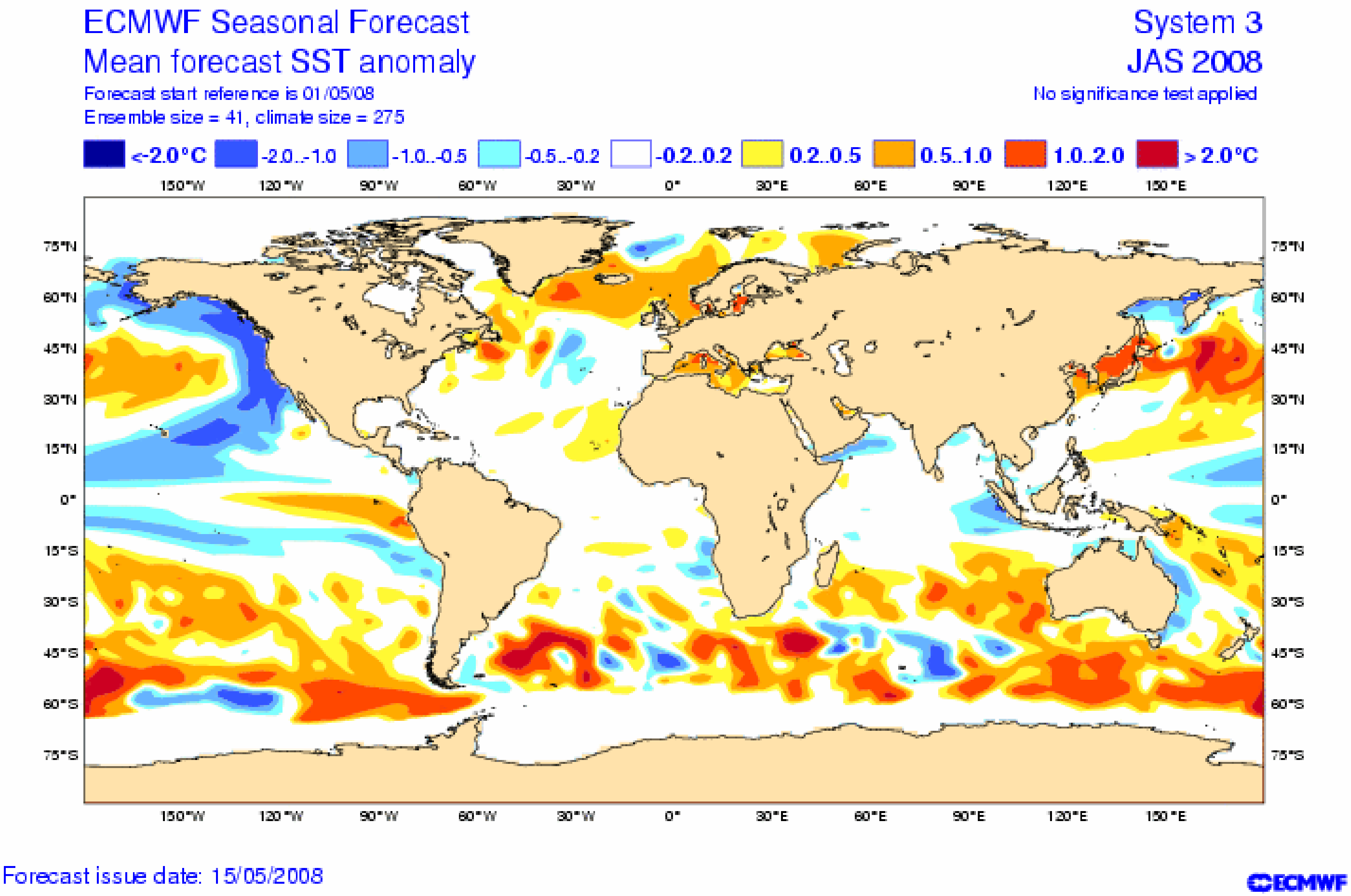
July-Aug-Sept (JAS) SST prediction March



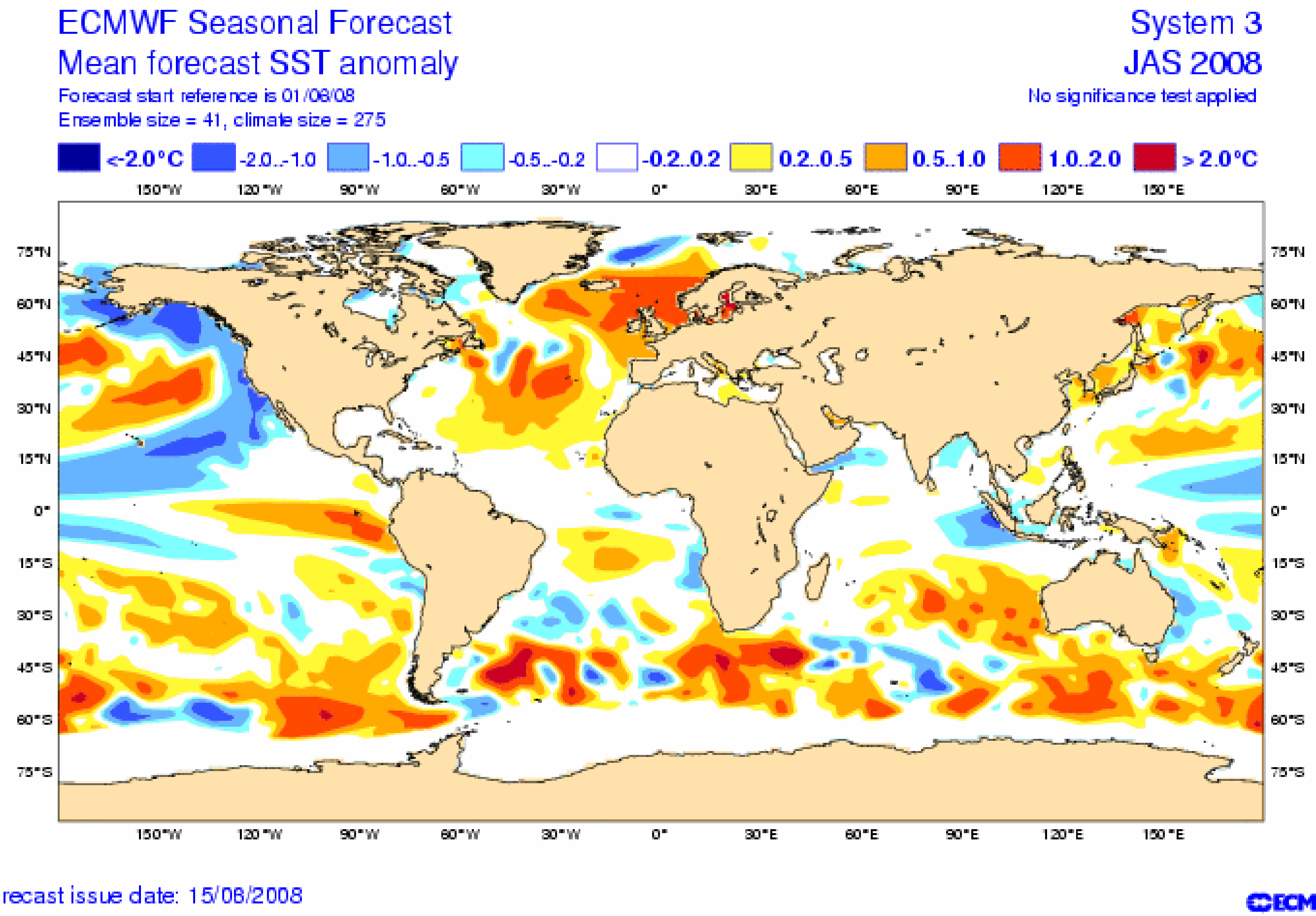
July-Aug-Sept (JAS) SST prediction April



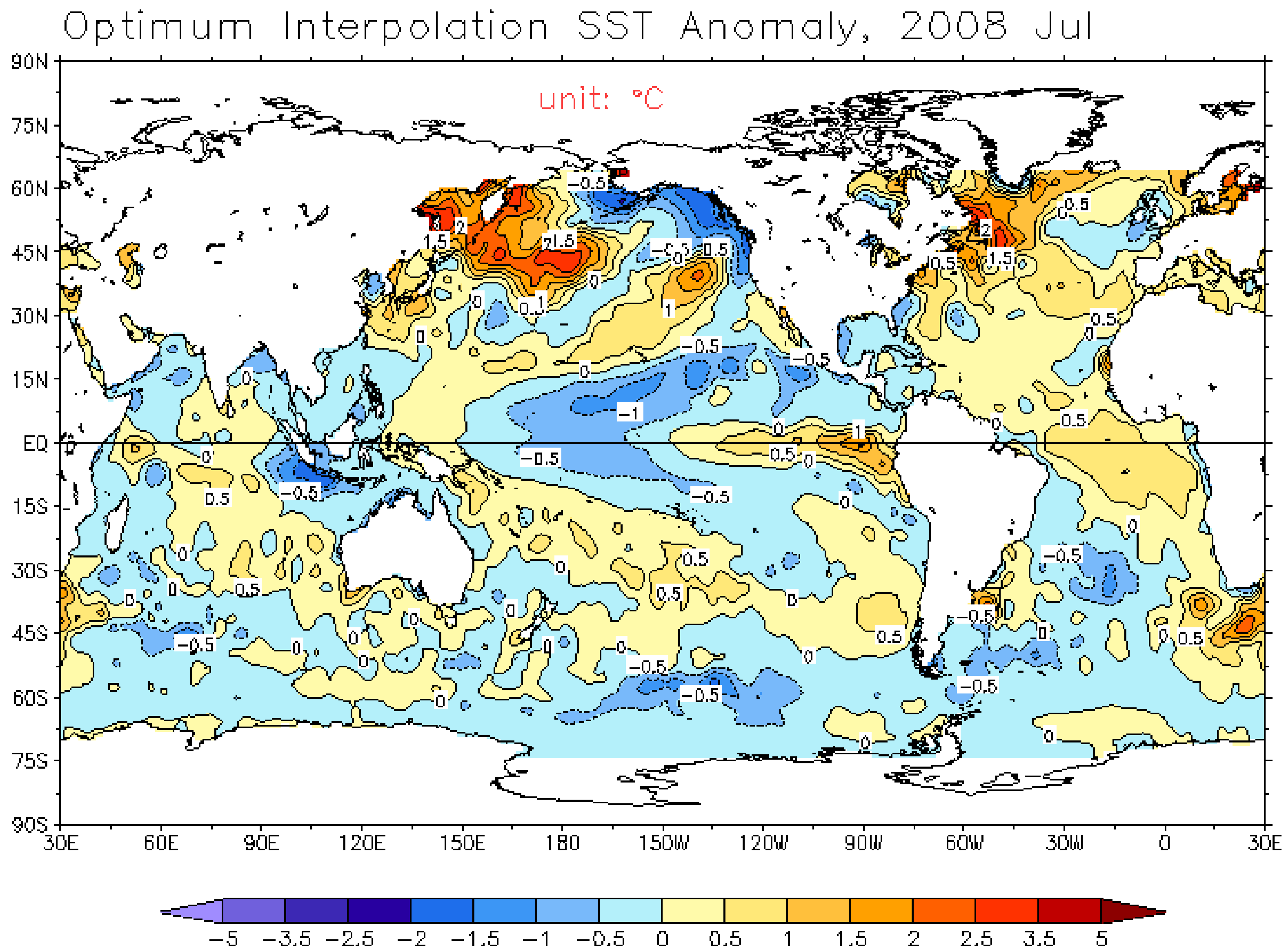
July-Aug-Sept (JAS) SST prediction
May



July-Aug-Sept (JAS) SST prediction June

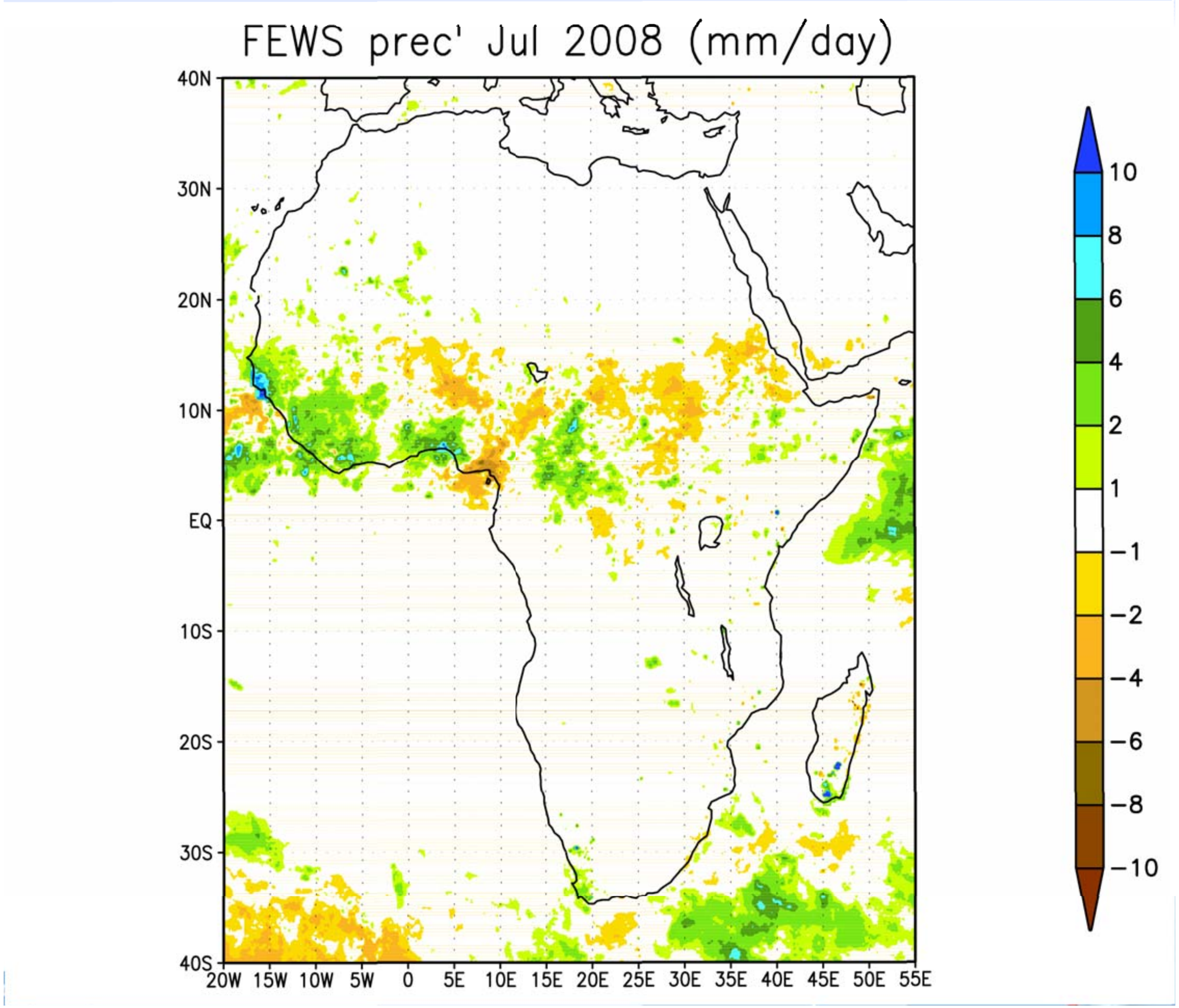


SOURCE: CPC



Optimum Interpolation SST Anomaly, 2008 Jul
unit: °C
90N
75N
60N
45N
30N
15N
EQ
15S
30S
45S
60S
75S
90S
30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0 30E
−5 −3.5 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3.5 5

July precipitation



Summary

- Humidity, AEWs, AEJ, TEJ, MJO, SSTs, all affect predictability and are all interlinked.
- Dynamical models developments are promising
  - Data assimilation of water vapour
  - improved convection-water vapour feedback, better MJO, (African Easterly Waves?)
- Hybrid statistical techniques required to maximize information content... (e.g. onset signal)
- SST modelling in the Atlantic and Med difficult due to strong coupling and mid-latitude forcing