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1945-6

Conference on African Drought: Observations, Modeling, Predictability, Impacts

2 - 6 June 2008

Predictability of (West) African Rainfall over timescale of days to years

Adrian Tompkins & Laura Feudale

Earth System Physics
ICTP

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Thanks to Andre Kamga and many others

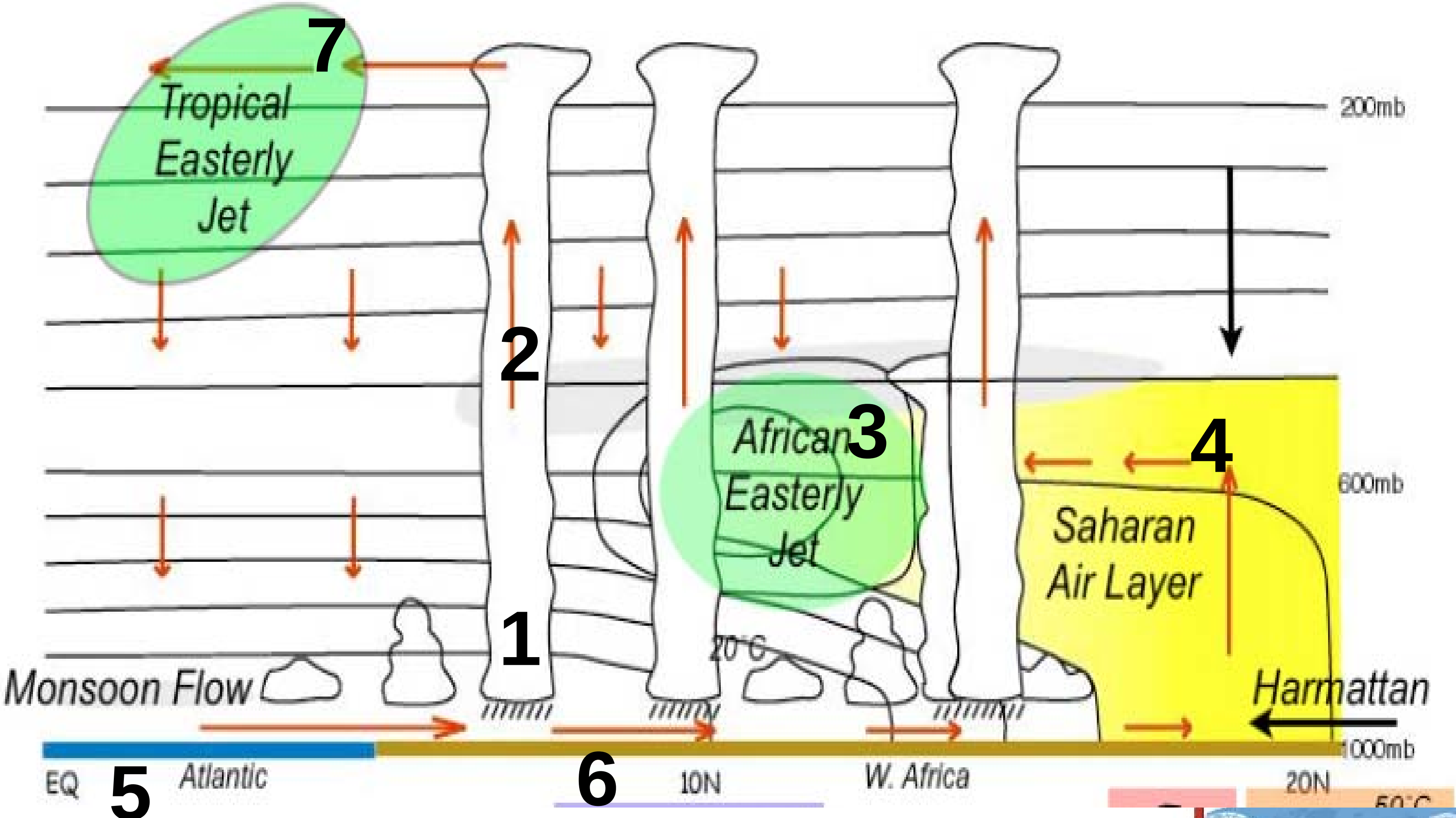
Outline:

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

It concentrates on West Africa and relies heavily on the ECMWF modelling system with which I am familiar

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

Radiative impact of aerosol changes



Schematic from Hall & Peyrillé

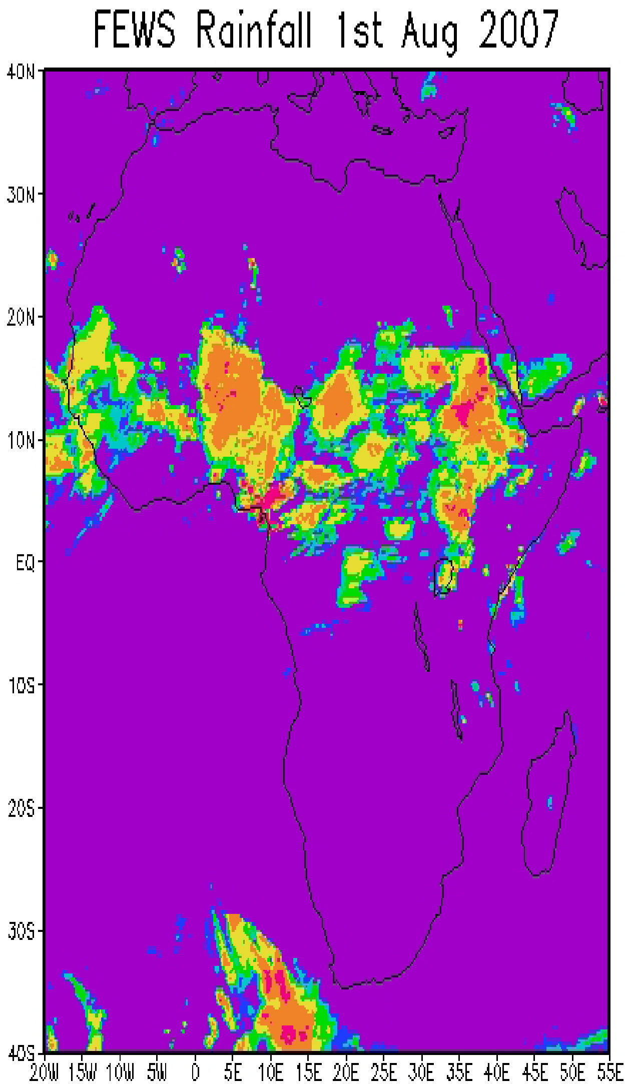
Predictability timescales

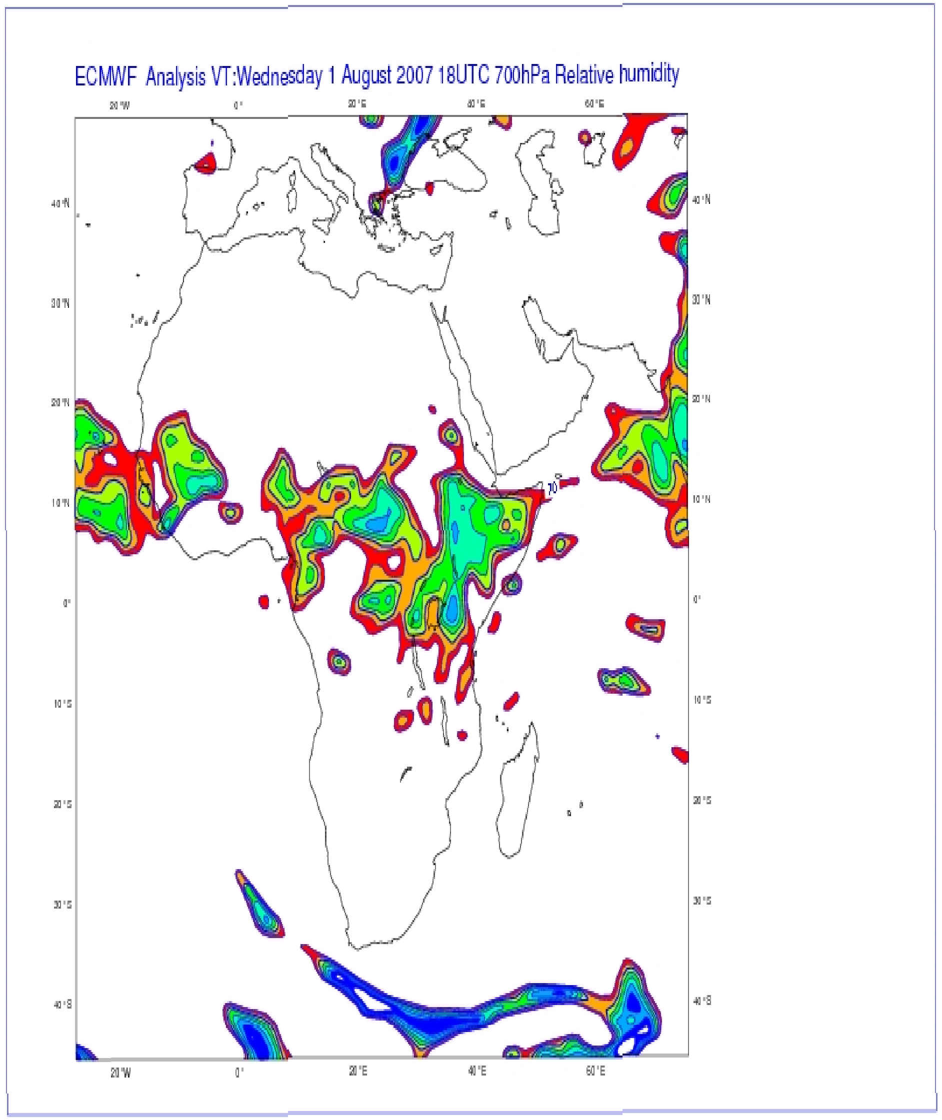
- Short-to-Medium Range: Day 0-15
  - **Prediction** of individual convective complexes, monsoon break cycles for local to regional scale
  - **Predictors**: Atmospheric relative humidity (RH), temperature, Wind shear, converge, CAPE... *exact list unknown*
- Monthly-to-Seasonal Range: Day 15-365
  - **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, Kelvin Wave and Madden Julian Oscillations

Short to Medium Range

- Models have problems with prediction of rainfall
- Even with good assessment of dynamics in analysis, the rainfall relies on uncertain convection and microphysics parametrizations
- WASF/AMMA, experienced forecasters can outperform models for short-range precip forecasts
- Room for improving forecasts using neural network or other statistical techniques?
- Predictors: humidity (particularly 700 hPa) and dynamical fields (vorticity - AEWs)

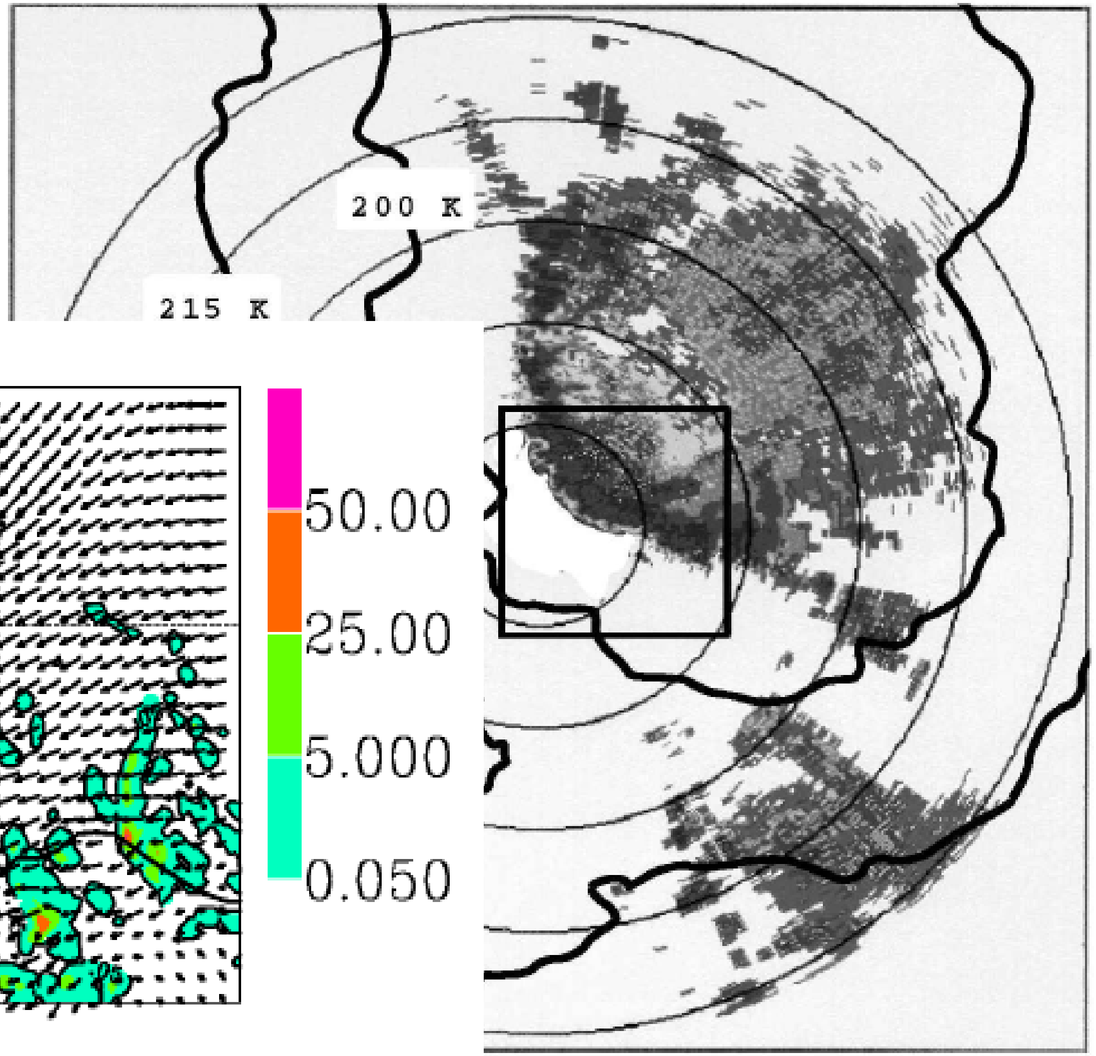
RH700 and FEWS rainfall (not 1-1 correspondence)

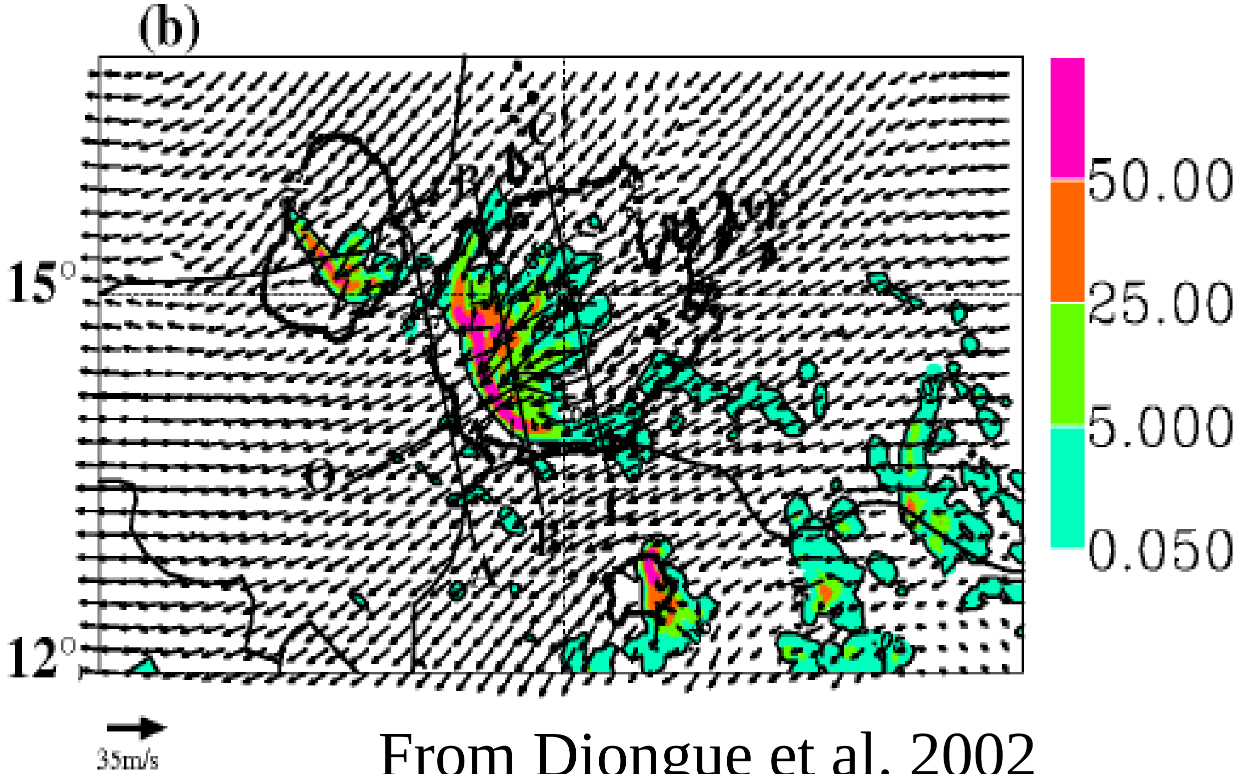




Short-range prediction of Squall line with CRM

Able to predict the evolution of squall line,but only if...

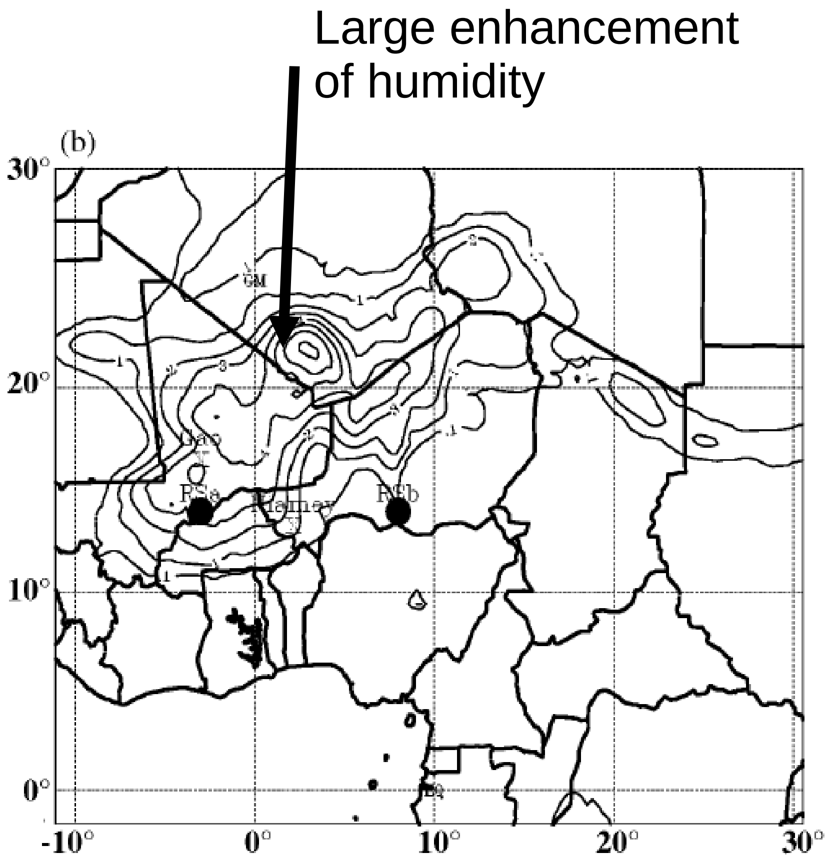




From Diongue et al. 2002

Importance of Humidity

- *...adjustment was made to the ERA-15 initial conditions using Meteosat*
- Lower tropospheric humidity is one of the main predictors for convective activity.
- Importance of getting the humidity information correct
  - Sondes: biased
  - q2m infrequently used
  - Meteosat: UTH only
  - SSMI over oceans only
- New bias correction for sondes at ECMWF... **used in AMMA reanalysis**



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

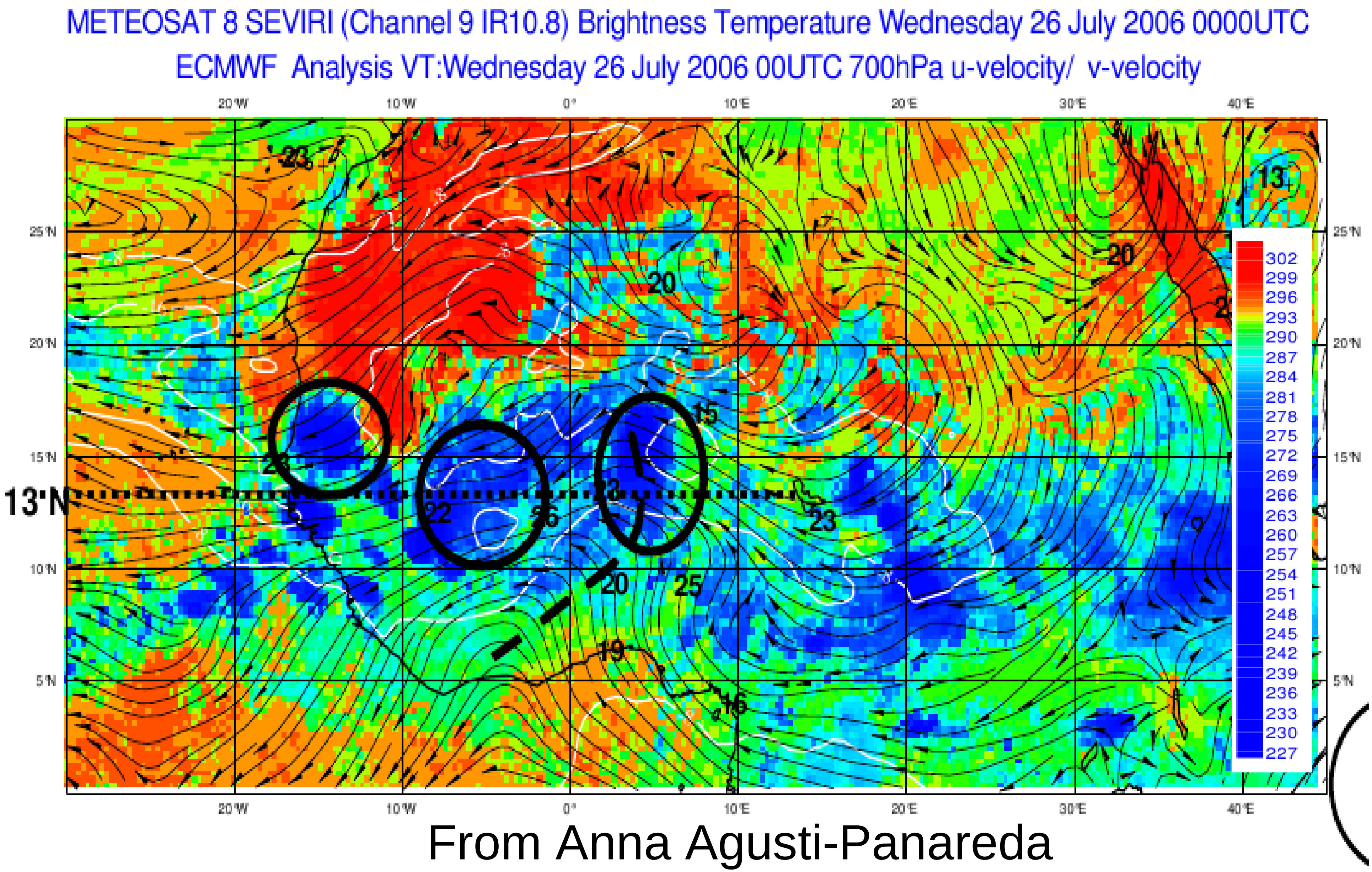
Summary: Humidity

- Structure of humidity crucial for convection
  - SSTs and soil moisture anomalies
  - Convection triggering
  - AEW dynamics
  - MJO
- 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

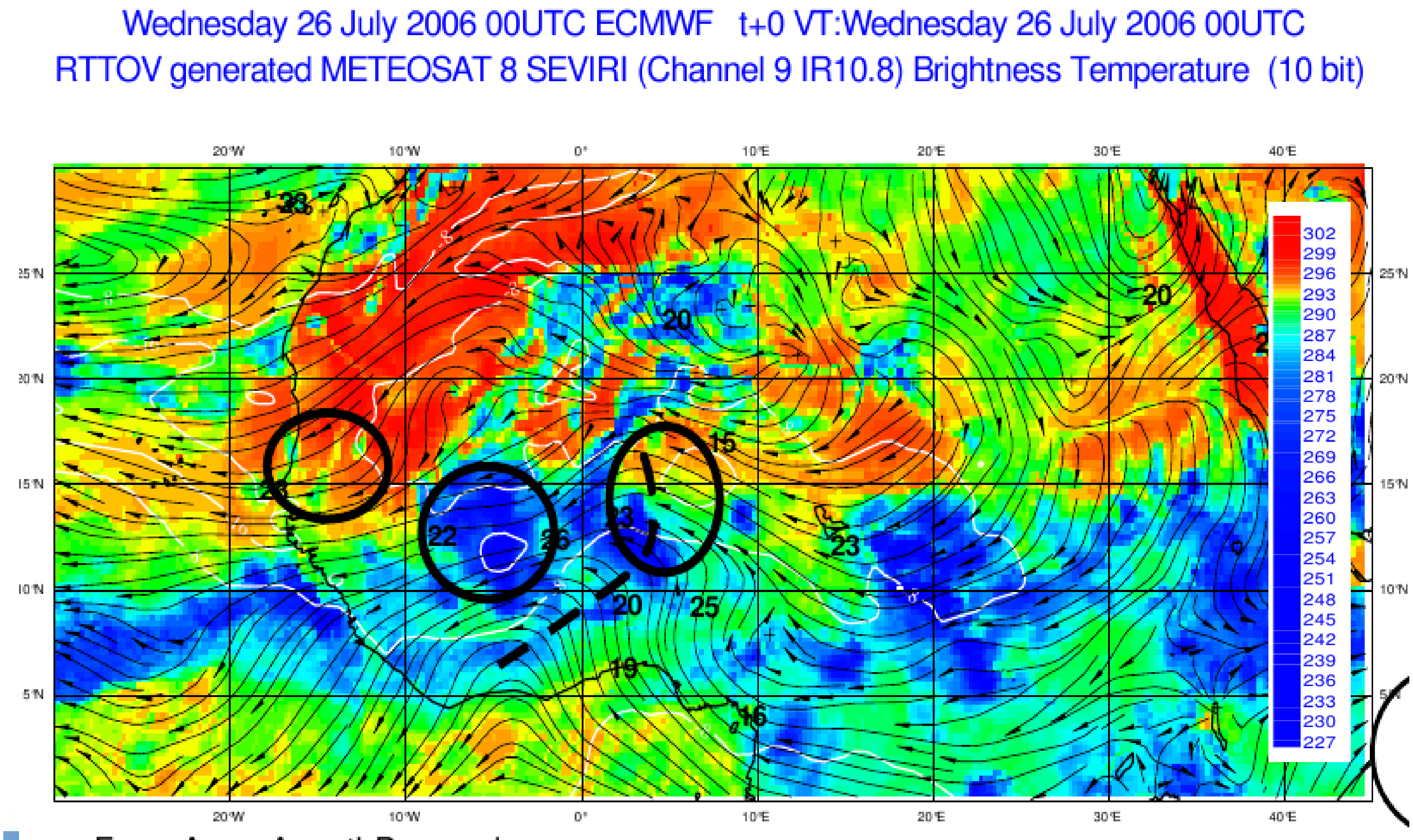
- Strongly coupled to convective activity
- A source of intraseasonal predictability
- Getting variability right on sub-seasonal scales required to get seasonal scales?

African Easterly Waves: MSG+Analysis winds



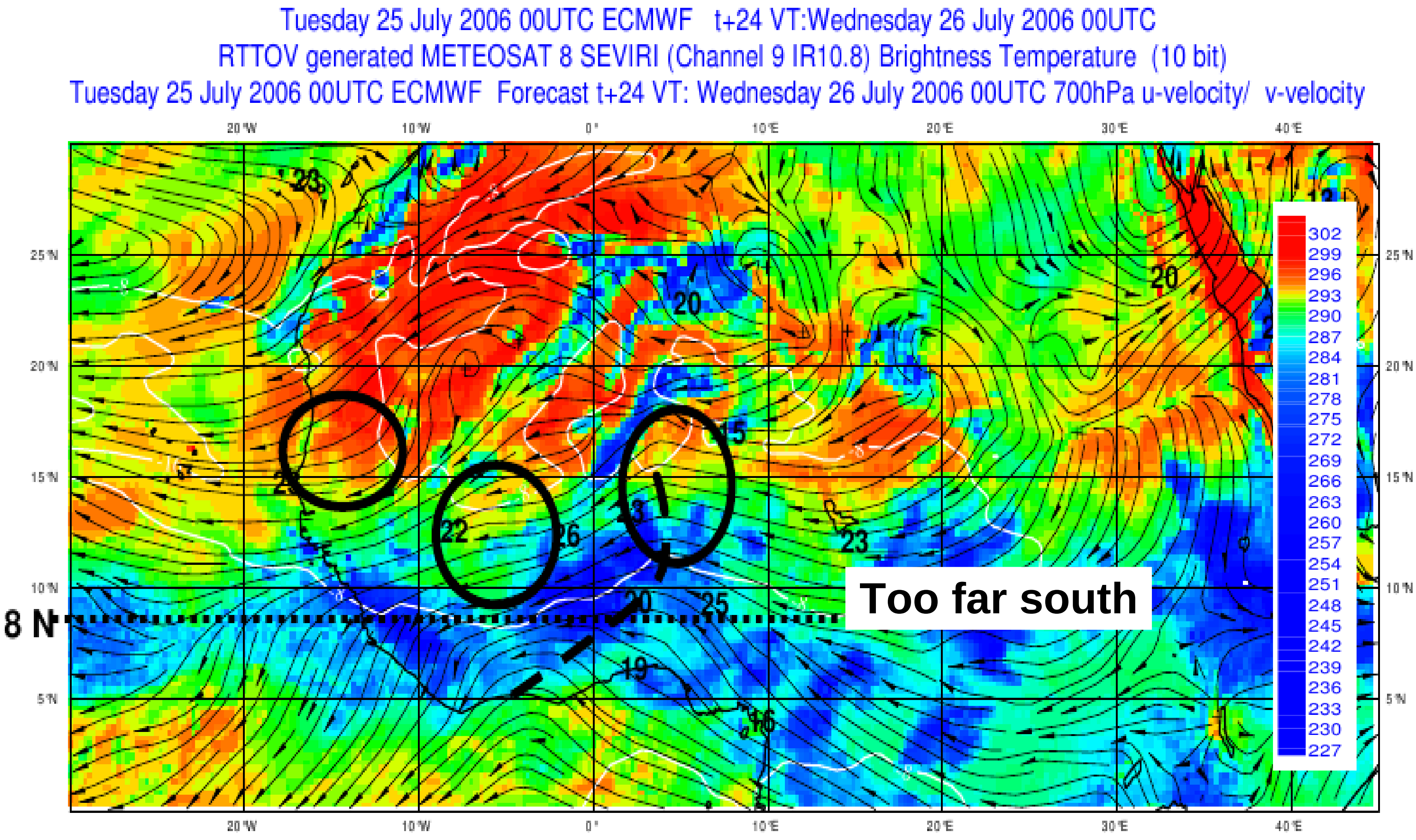
From Anna Agusti-Panareda

African Easterly Waves: Analysis



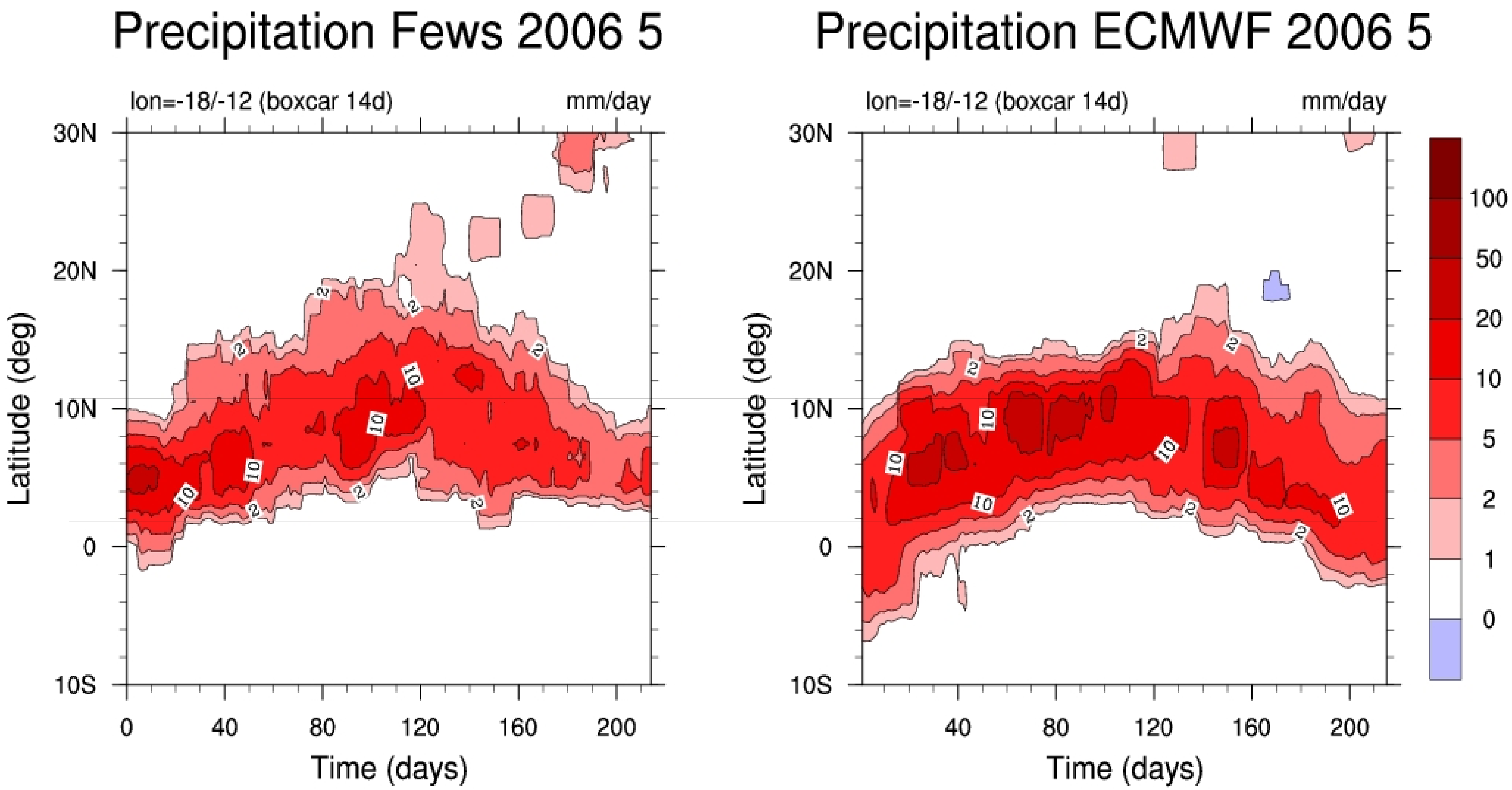
From Anna Agusti-Panareda

African Easterly Waves: 24 hour forecast



From Anna Agusti-Panareda

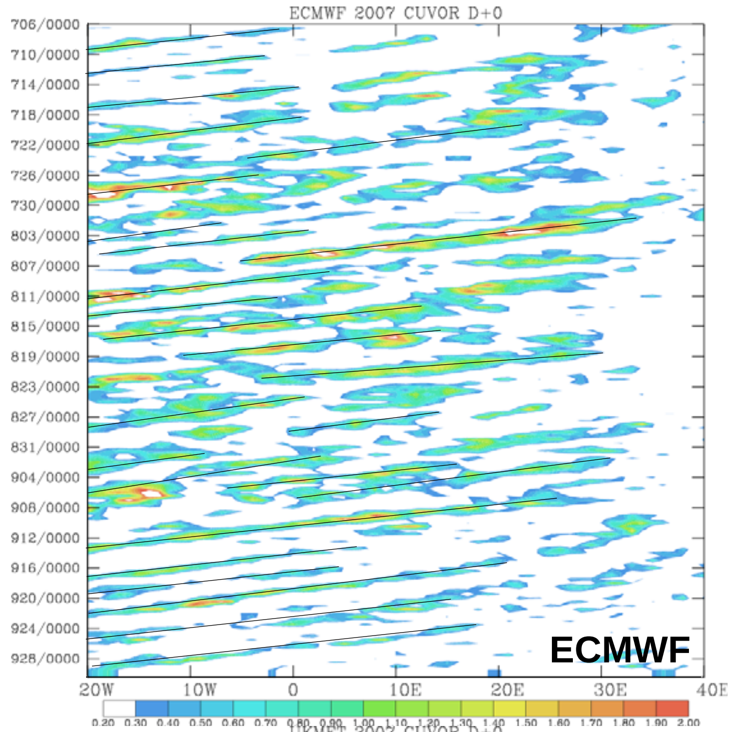
General Problem: Comparison of Rainfall with FEWS centred on Senegal

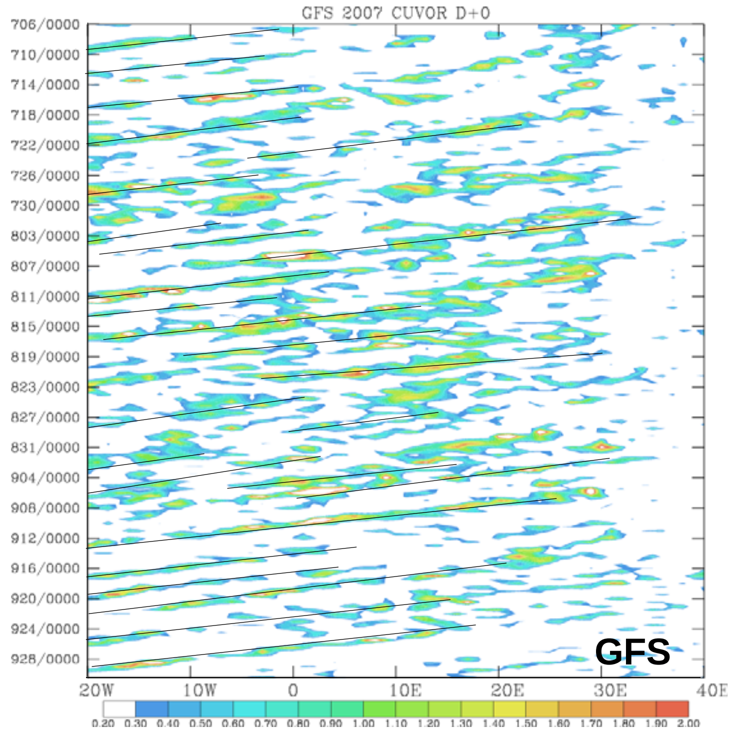


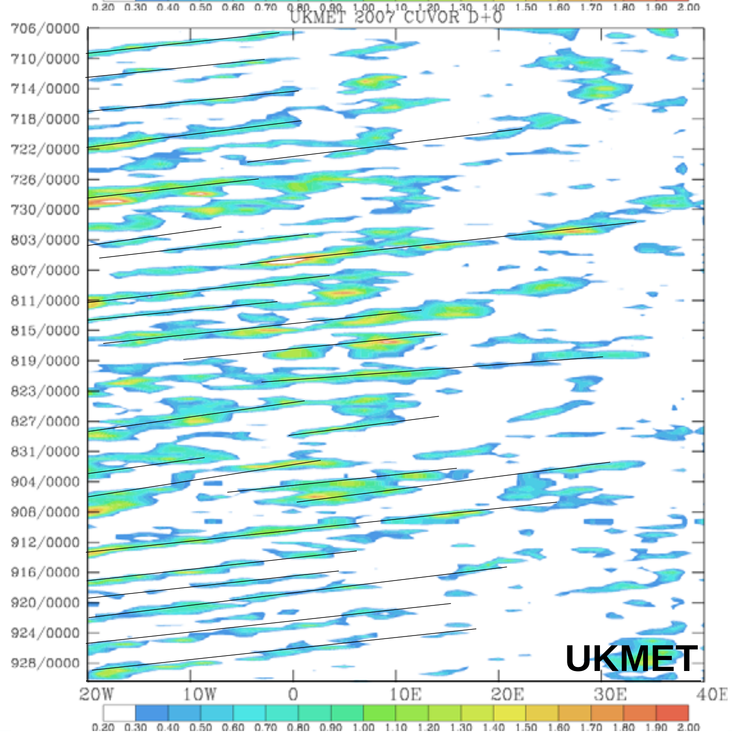
RAINFALL too far south

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

JJA

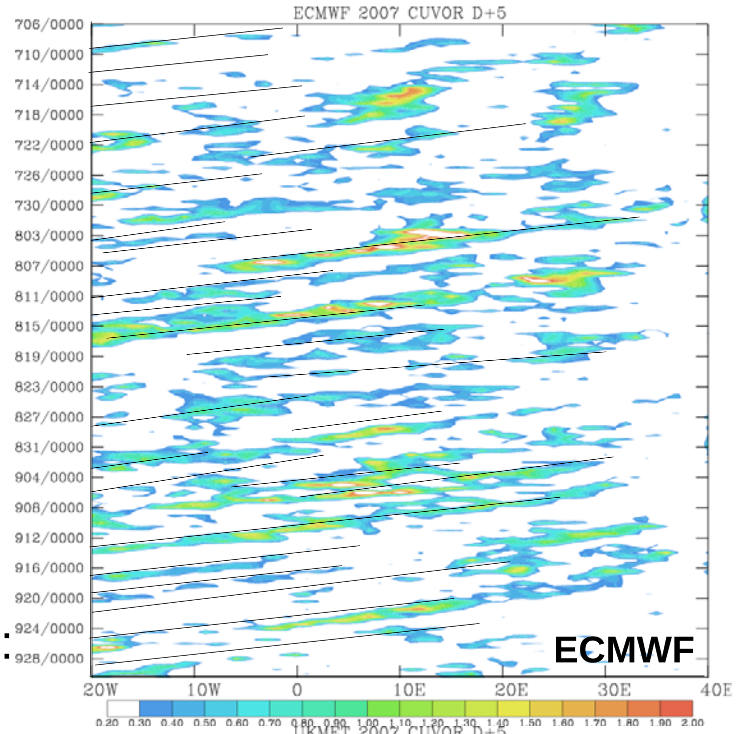


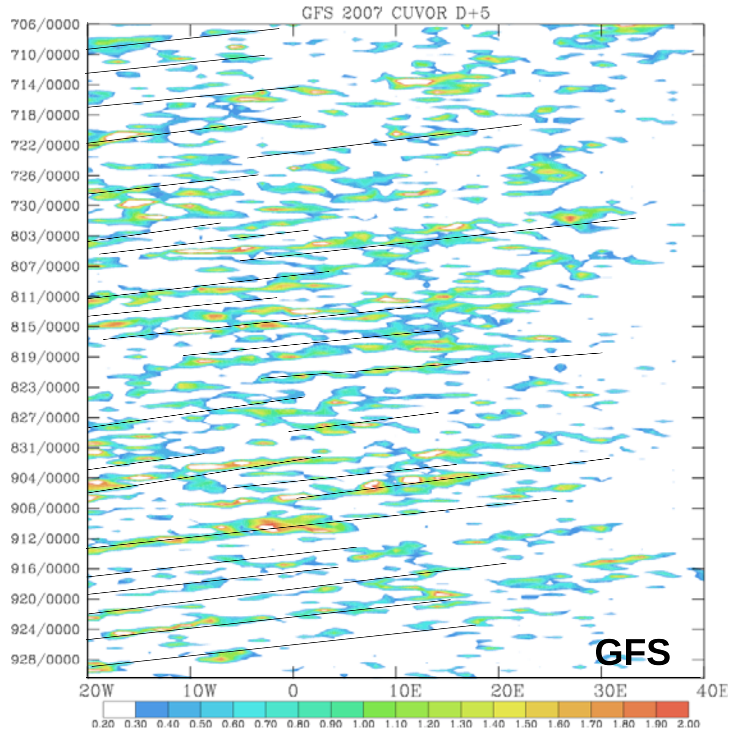


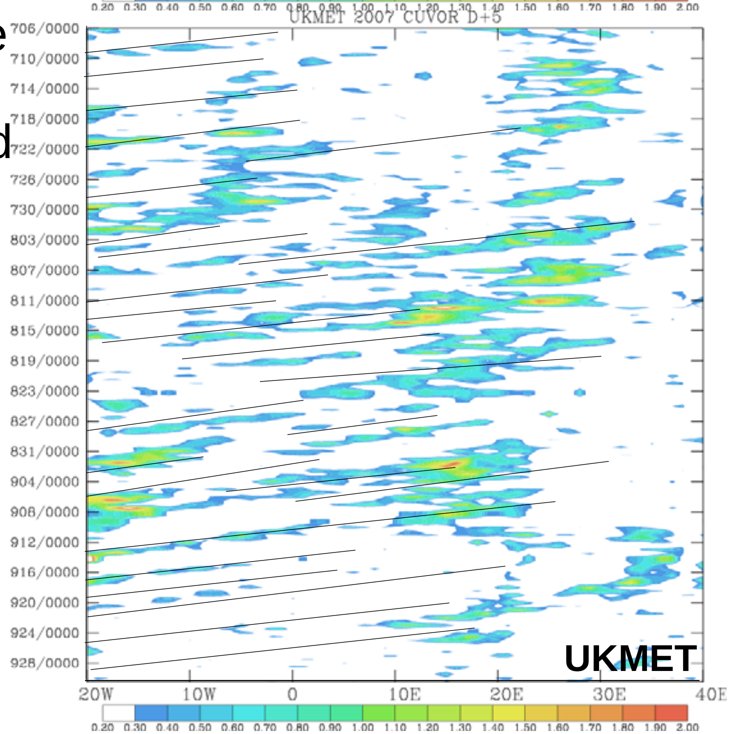


from Berry and Thorncroft

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





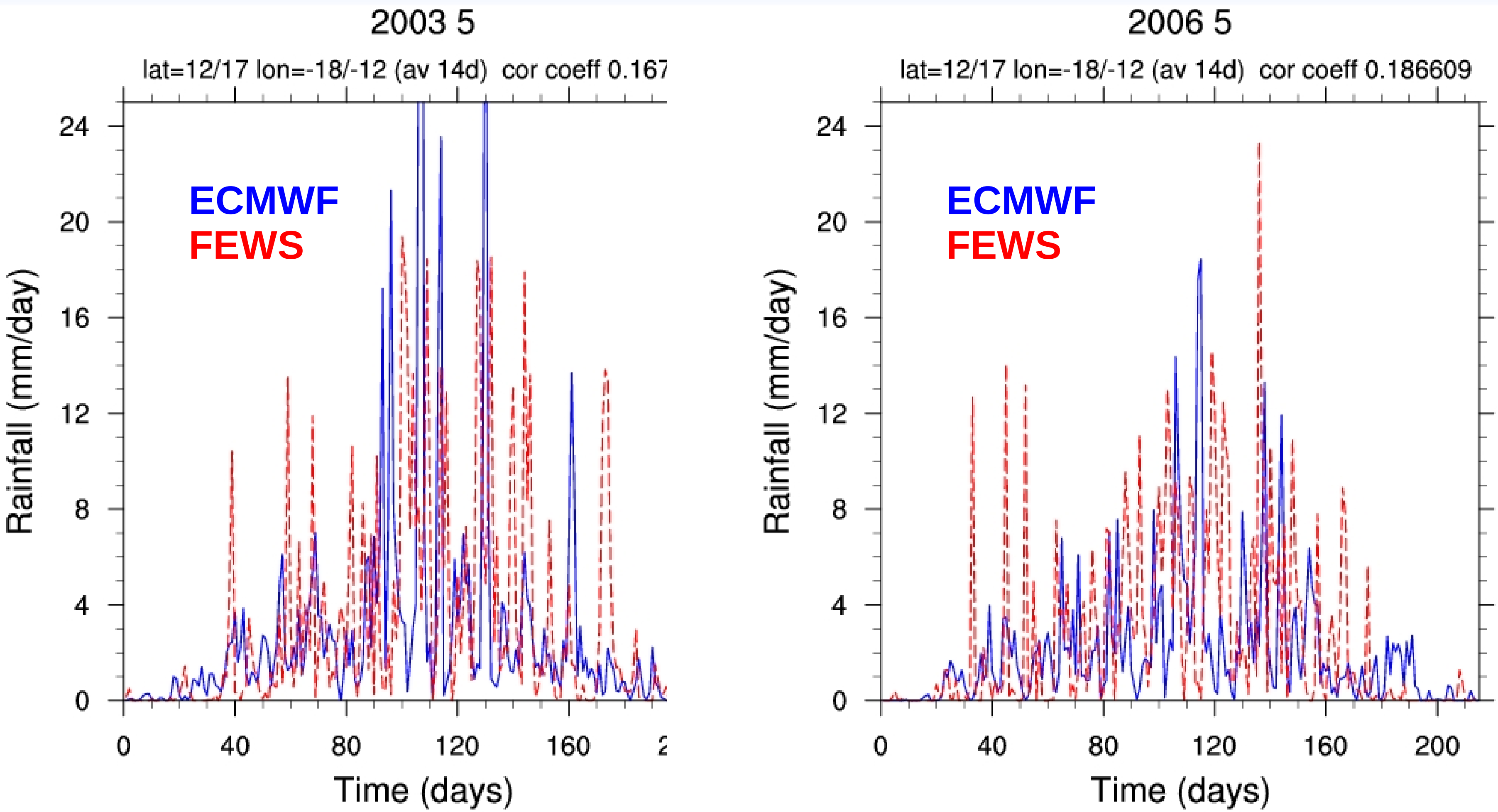


If AEW exists in analysis models can propagate feature

But initiation can be a problem

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

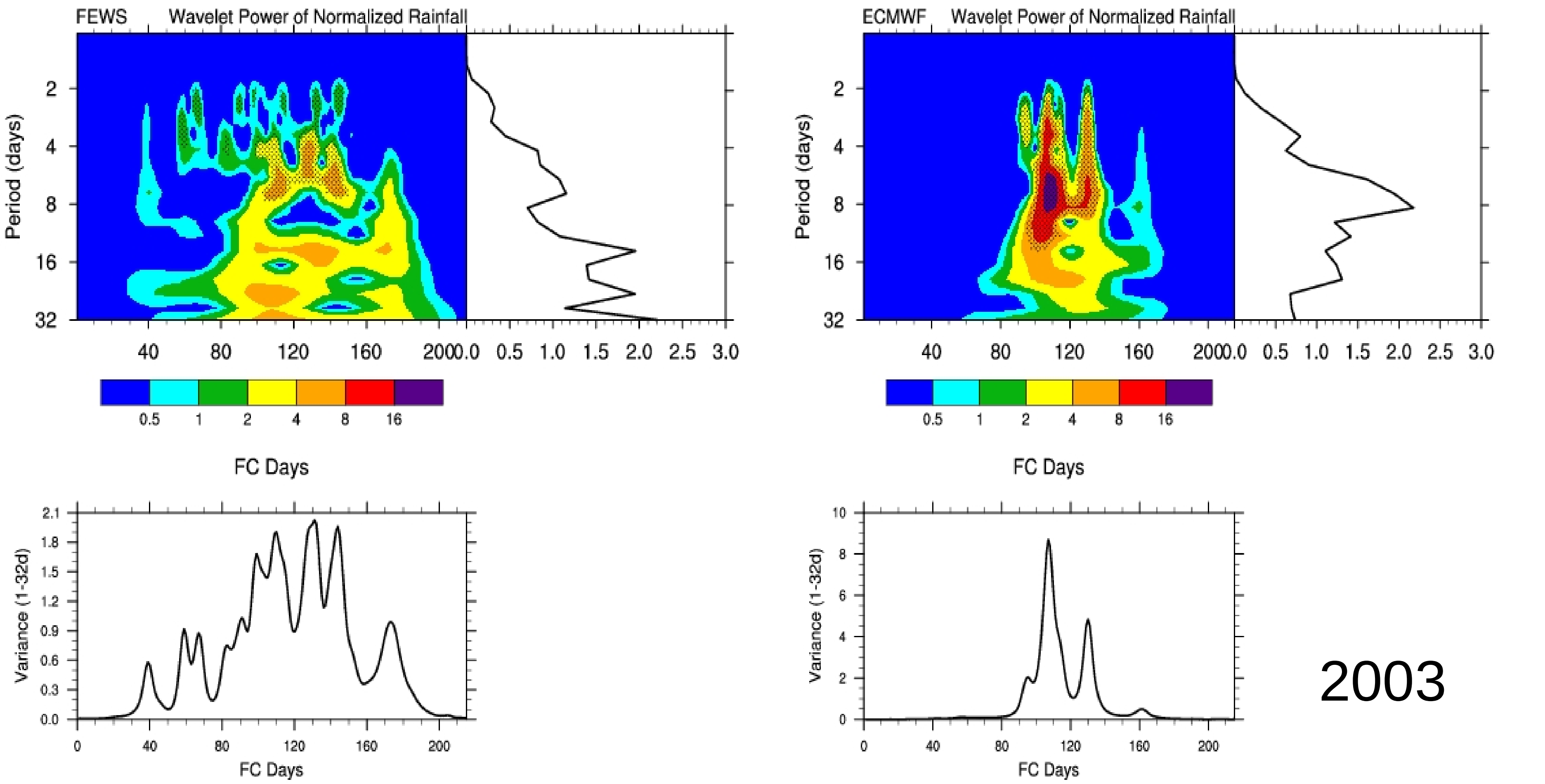
Comparison of Rainfall with FEWS for Senegal



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

Timeseries assessed using wavelet analysis

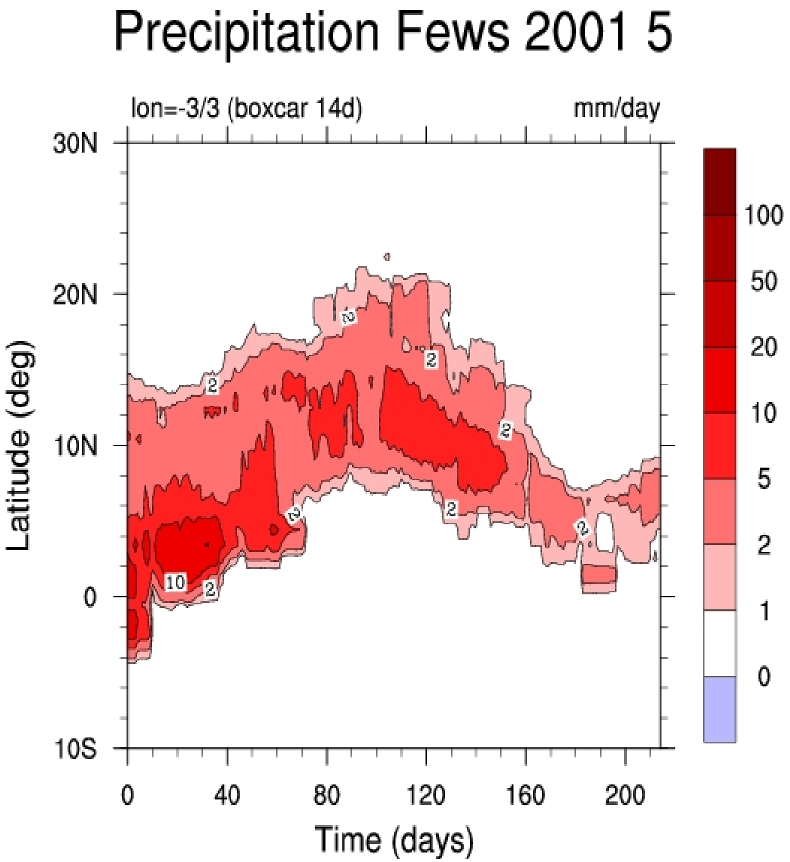
Comparison of Rainfall with FEWS

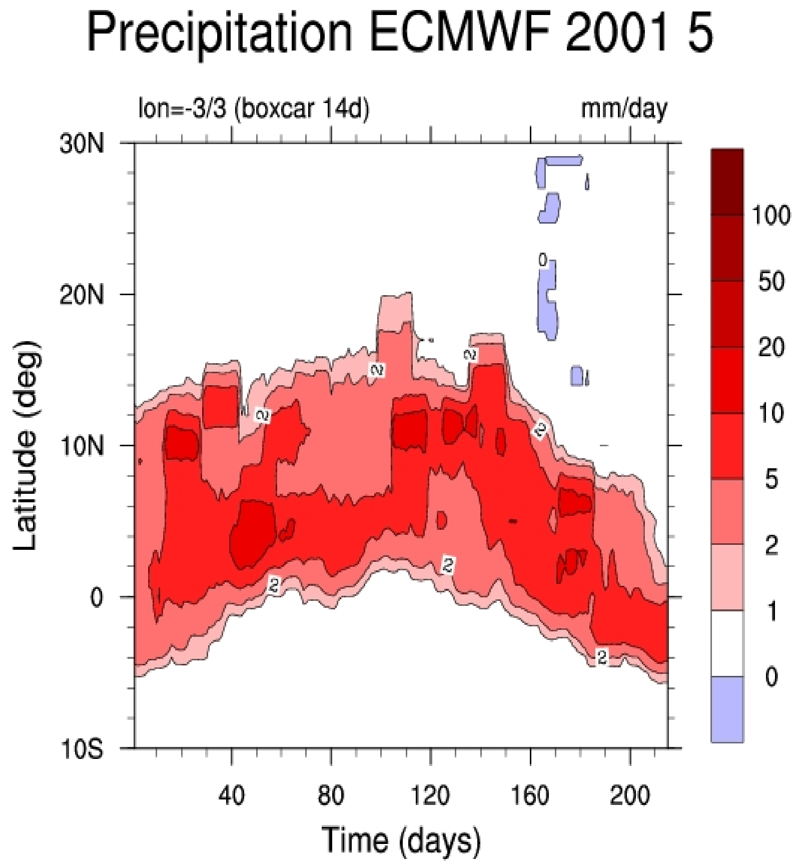


2003

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

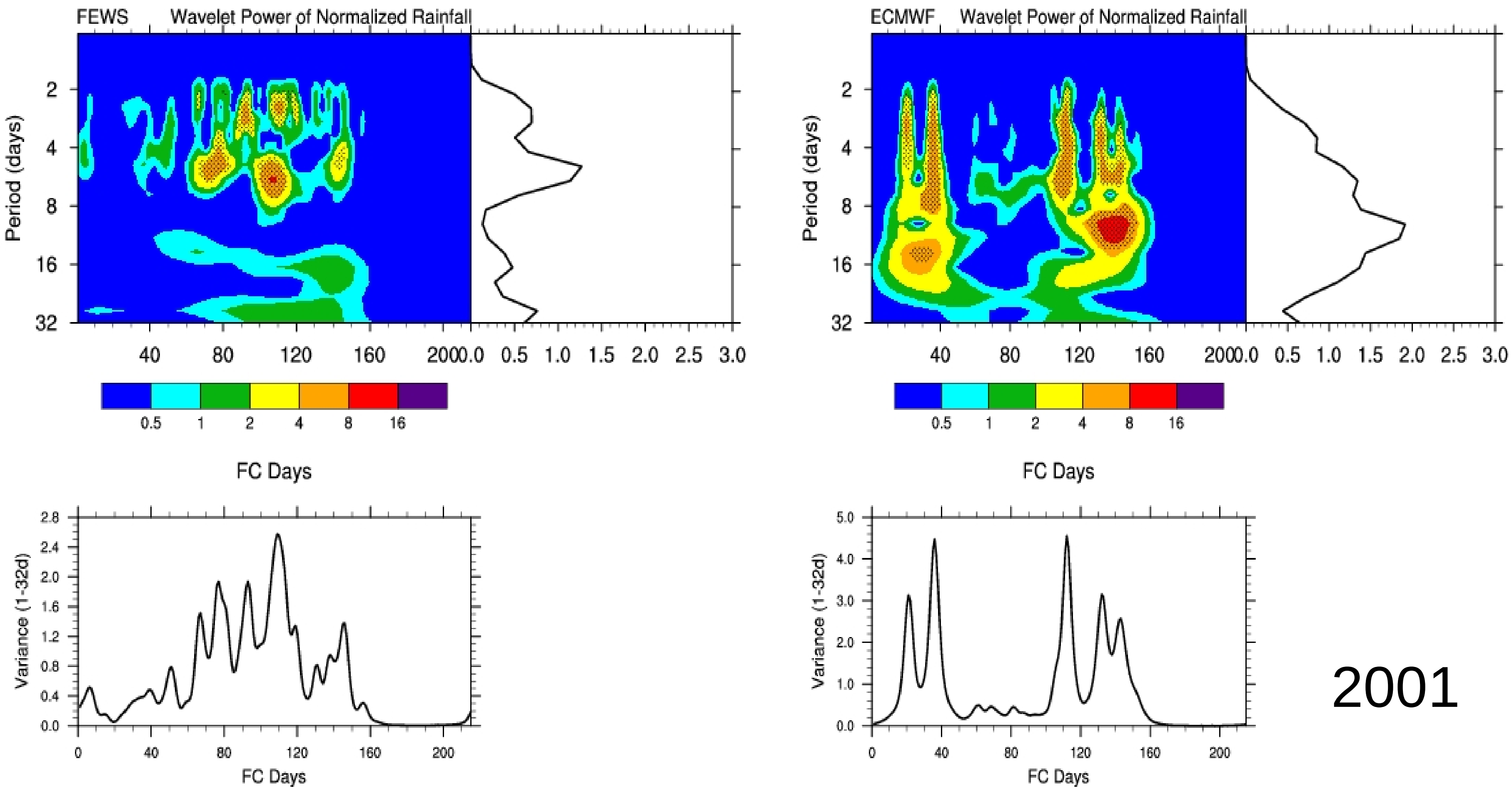
Example 2: Comparison of Rainfall with FEWS Band centred on lon=0, from 10N to 20N





Sometimes the onset can be very poor in model

Comparison of Rainfall with FEWS



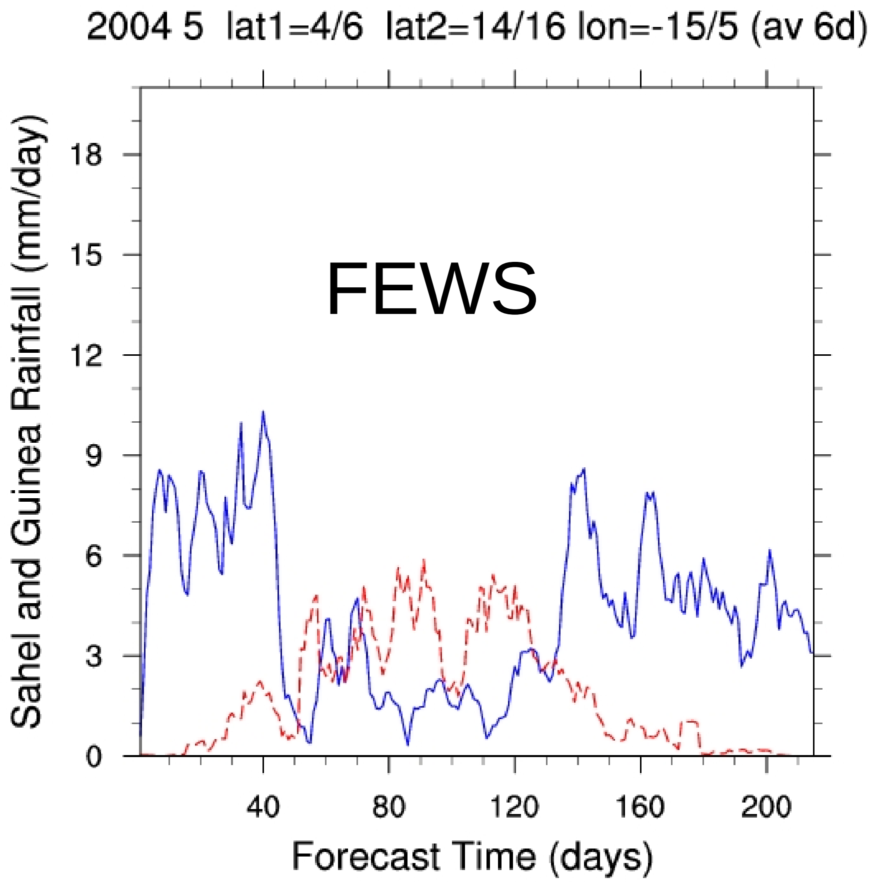
2001

FEWS: Two 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

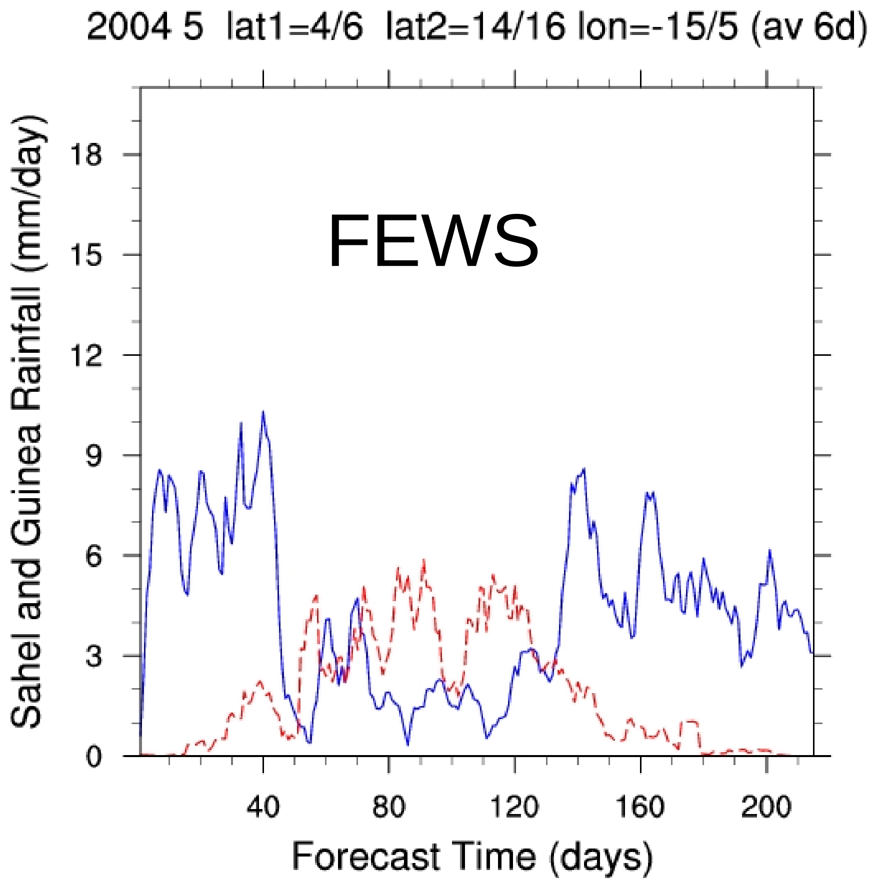
- Predictors: SST anomalies, soil moisture, JET position, Madden-Julian Oscillation (MJO)
- Predictants:
  - precipitation and temperatures over larger spatial and temporal scales
  - higher order seasonal statistics: onset, cessation, sub-seasonal variability
- Take example of seasonal forecast system of ECMWF
  - System 3: Atmospheric model cy31r1 (also ERA-interim and EC-Earth) coupled to HOPE
  - Integrations at T159L91 resolution
  - 6 months 1/month, 12 months 4/year

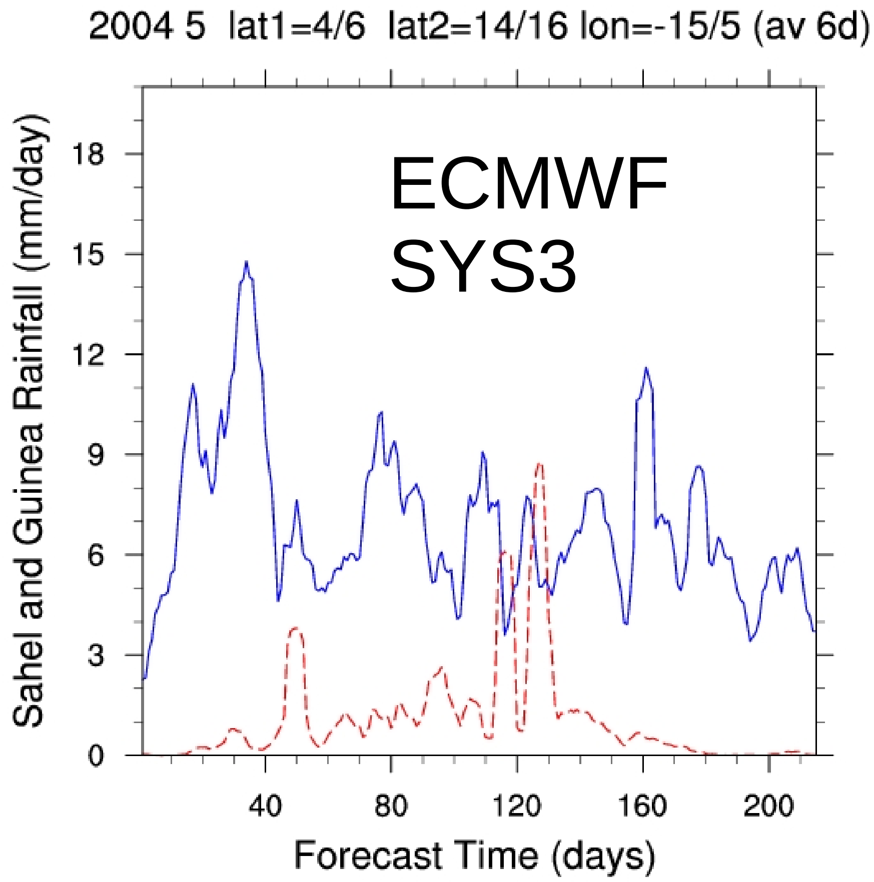
A closer look at the onset
Definitions as per Prof Cook yesterday (lon?)



Not all years work so well

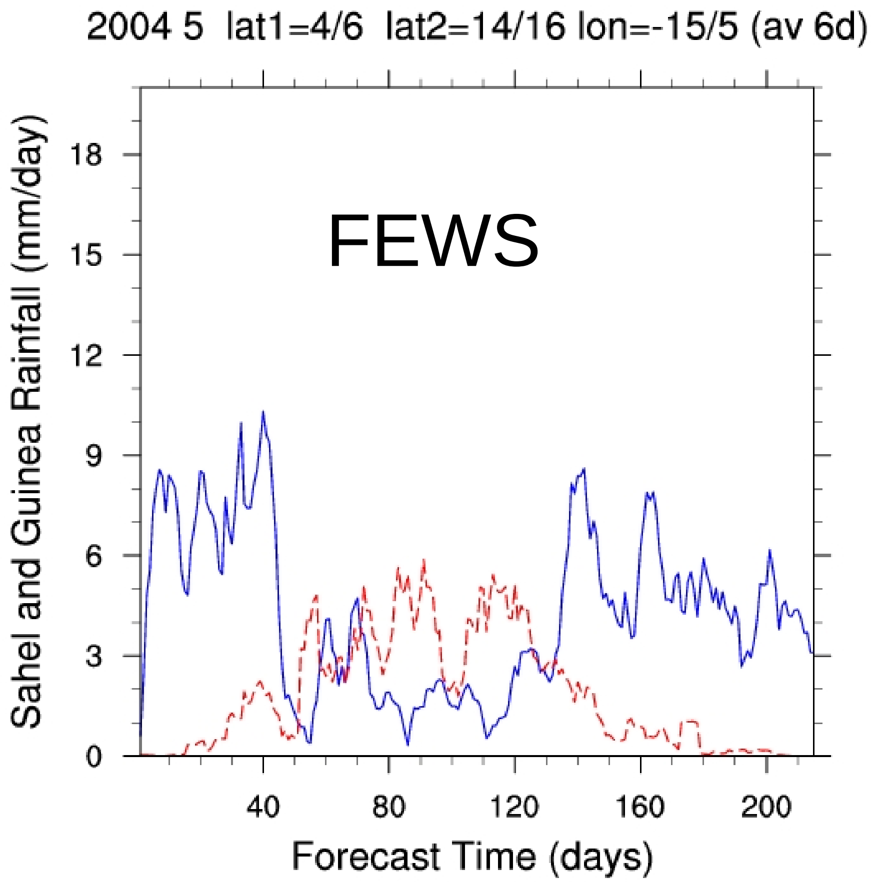
A closer look at the onset
Definitions as per Prof Cook yesterday (lon?)

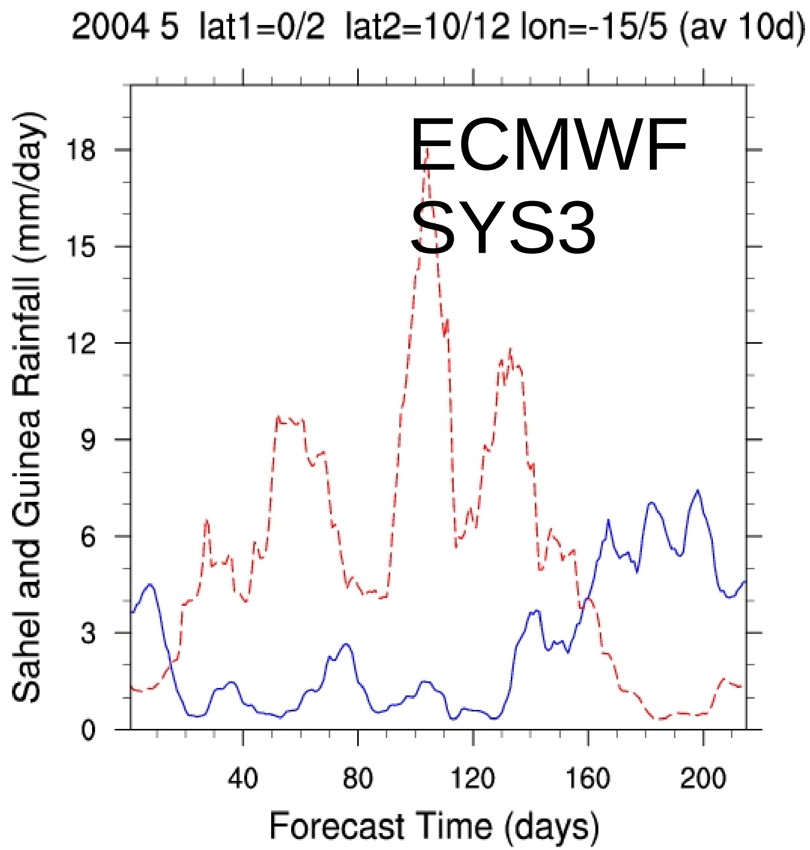




Due to southerly shift in rainfall patterns in model

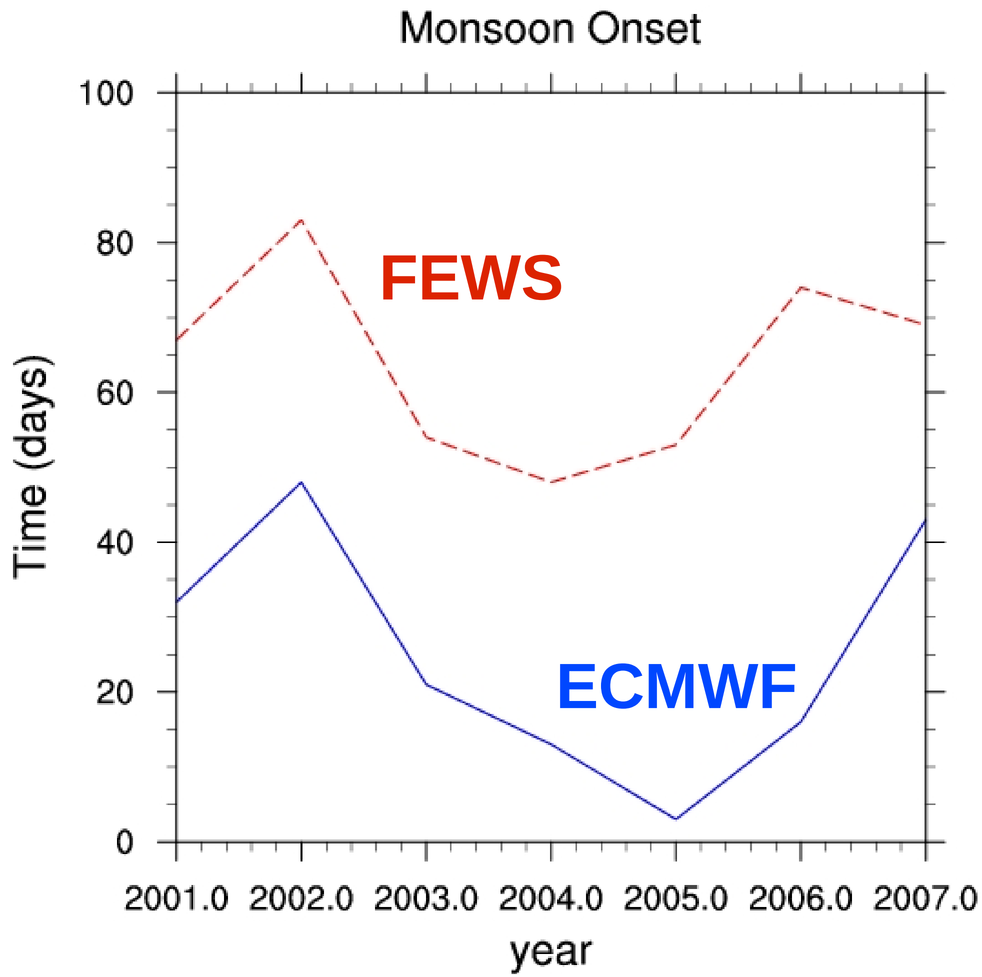
Apply 4 degree offset and more smoothing





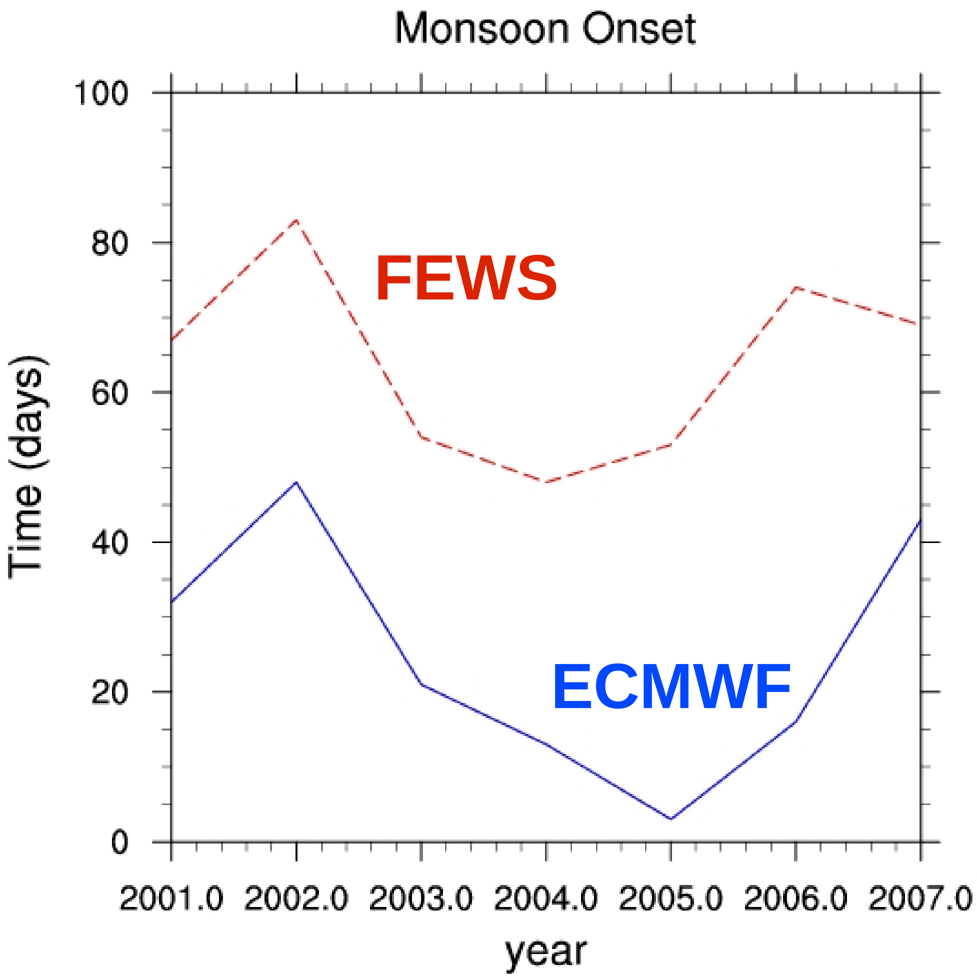
Due to southerly shift in rainfall patterns in model

Year to year variations in onset date captured?



Conclusions?

Shift the model target areas 4 deg south

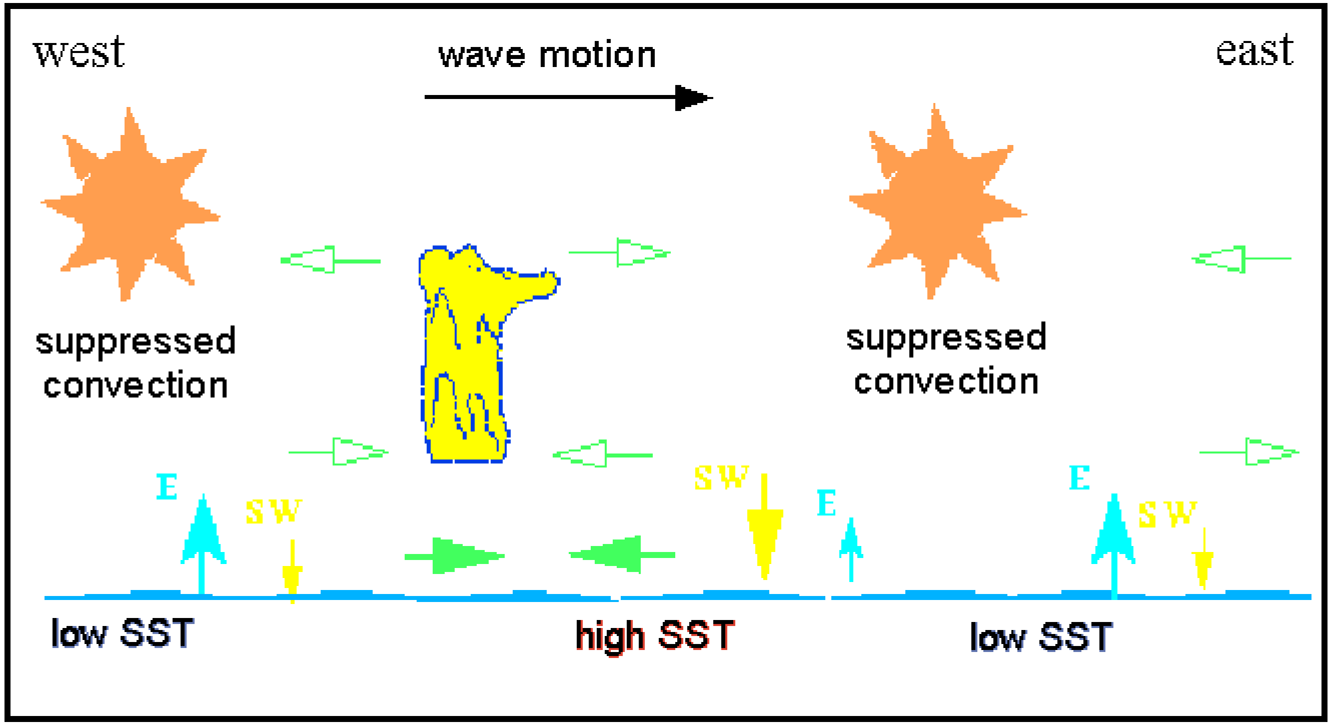


Conclusions?

"The offset onset has an offset!!!"

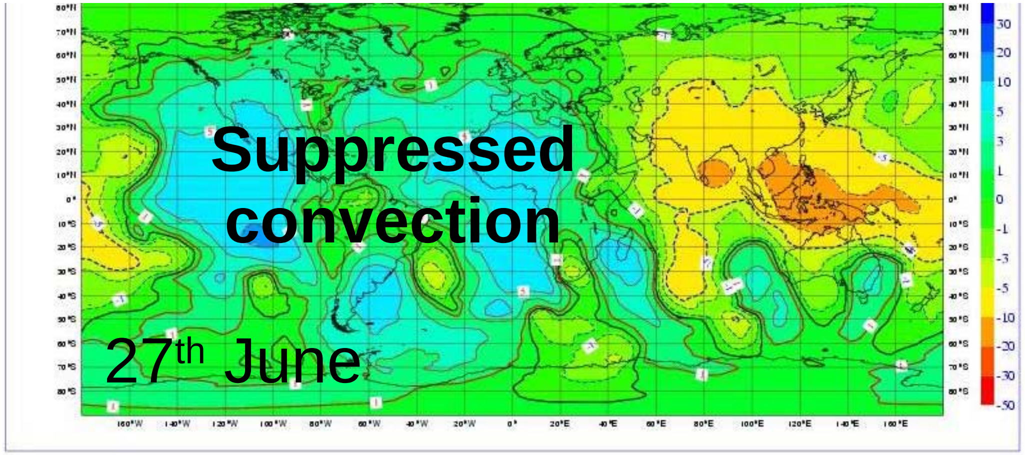
3. Madden-Julian Oscillation (MJO)

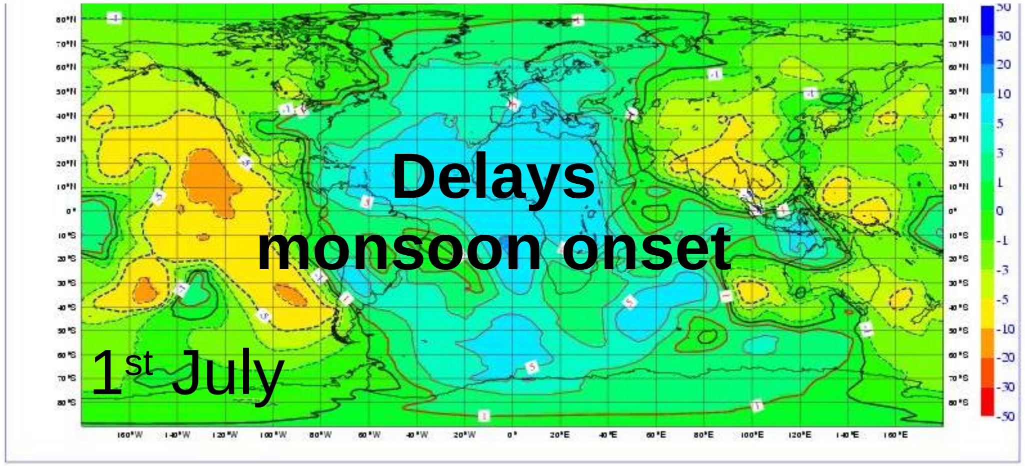
- Wave number 1-3 convectively-coupled eastward propagating (40-60 days) large-scale oscillation in the tropics

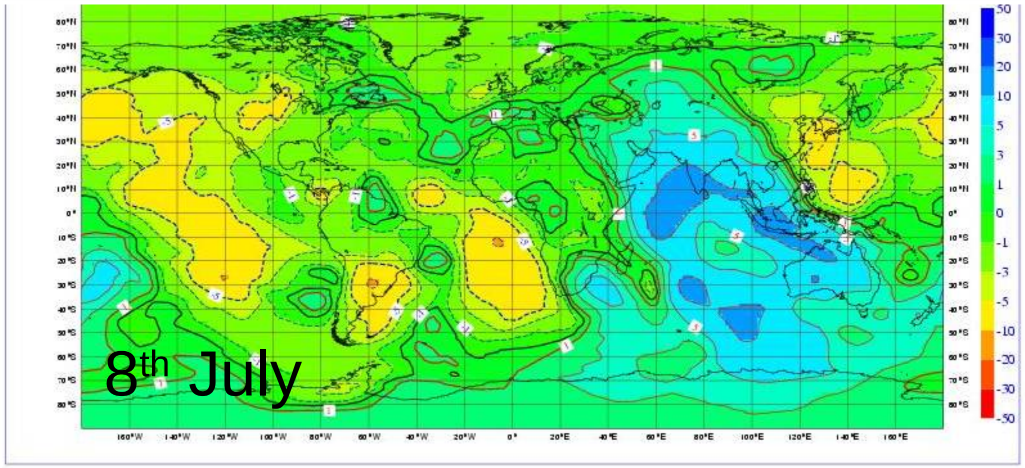


wheeler

~10000 km







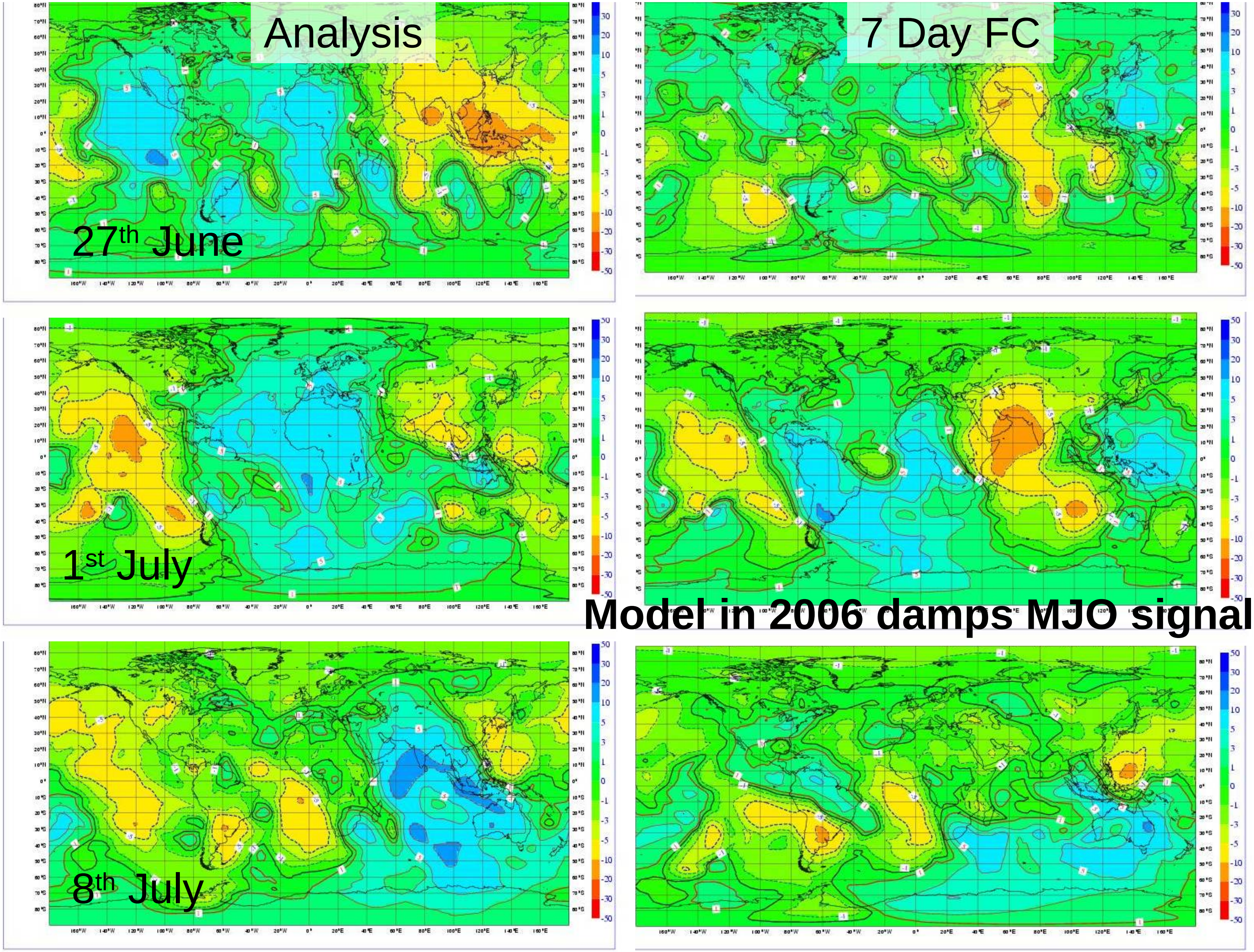
ECMWF Analysis of the 200 hPa Velocity potential Anomaly

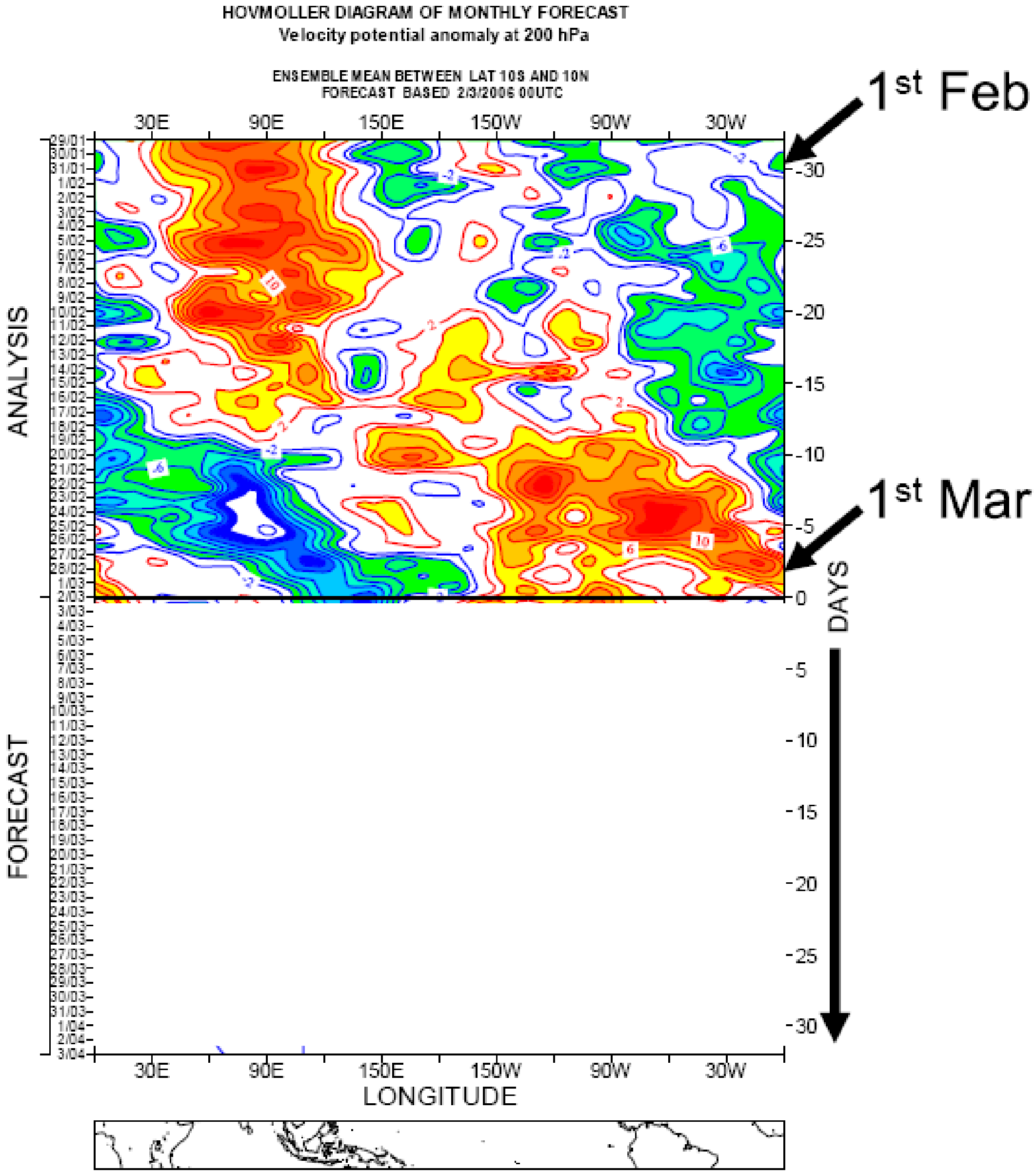
Large-scale wave-number 1 pattern associated with an MJO event

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

MJO in global models

- Global models have notorious difficulty in representing the MJO
- Lack of understanding concerning the convective coupling mechanism: SSTs feedbacks, cloud-radiative feedbacks, water vapour feedbacks…
- No “magic bullet” (convection scheme, coupled ocean…) has yet been documented for MJO
- How does the ECMWF forecast do?


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

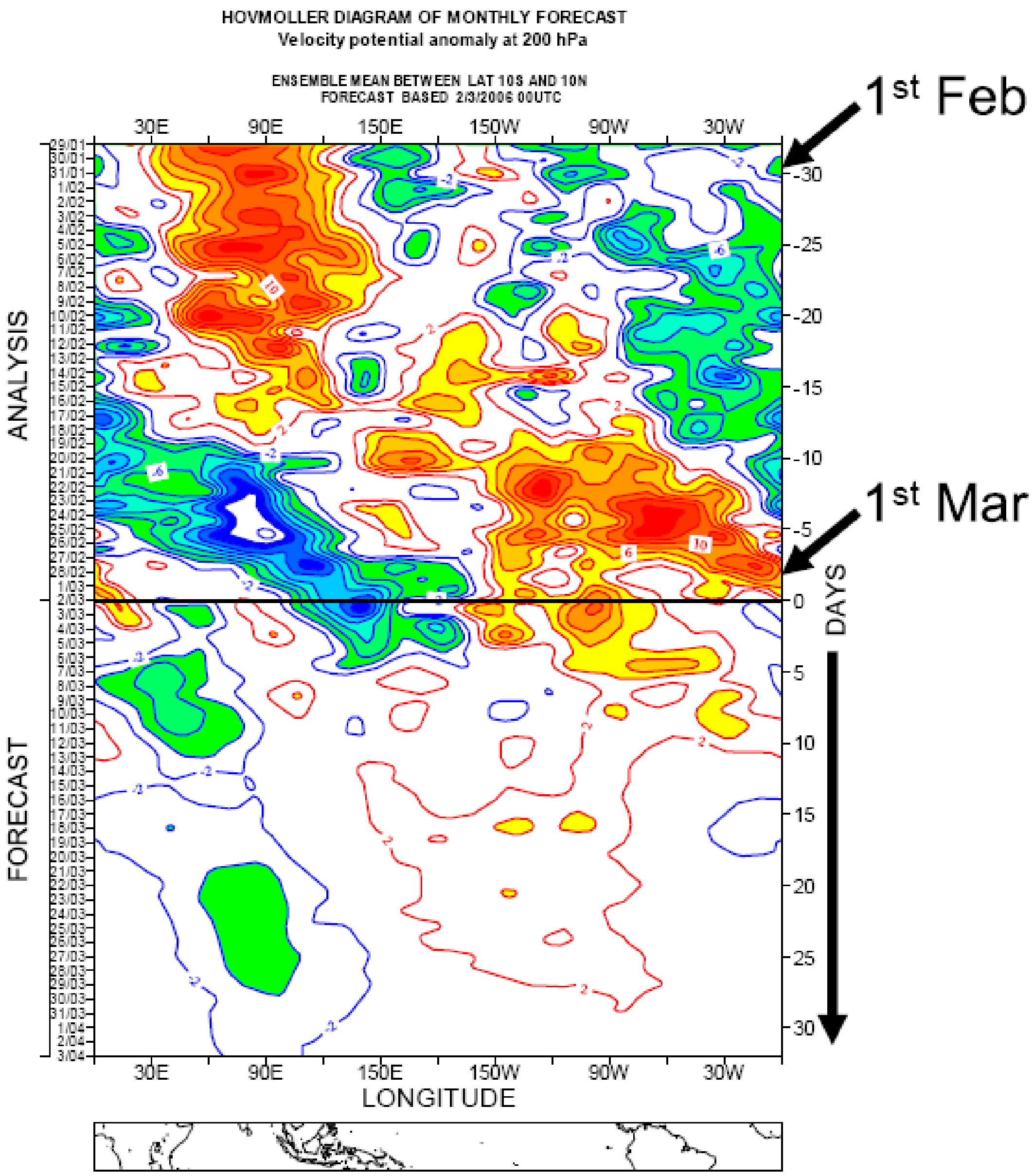


Typical MJO forecast at ECMWF

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

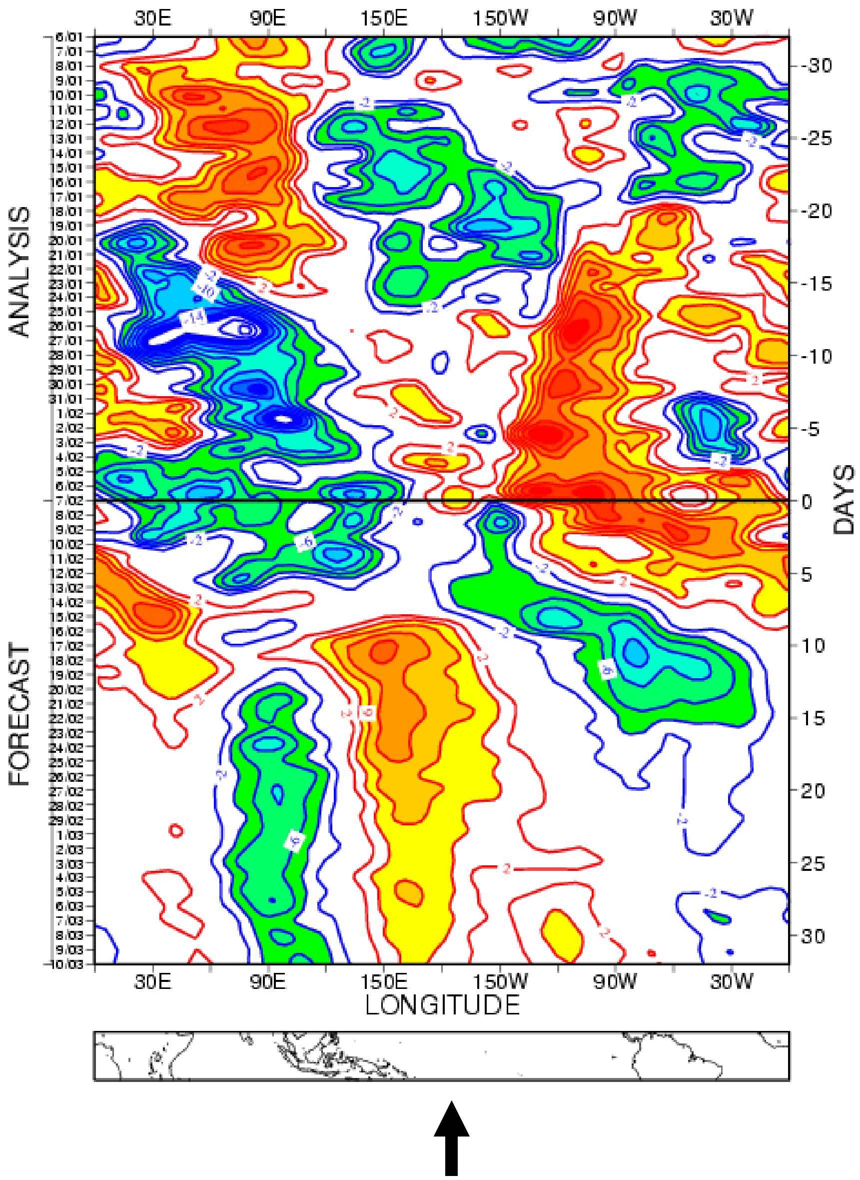
200hPa Velocity Potential Anomalies

February – March 2006

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

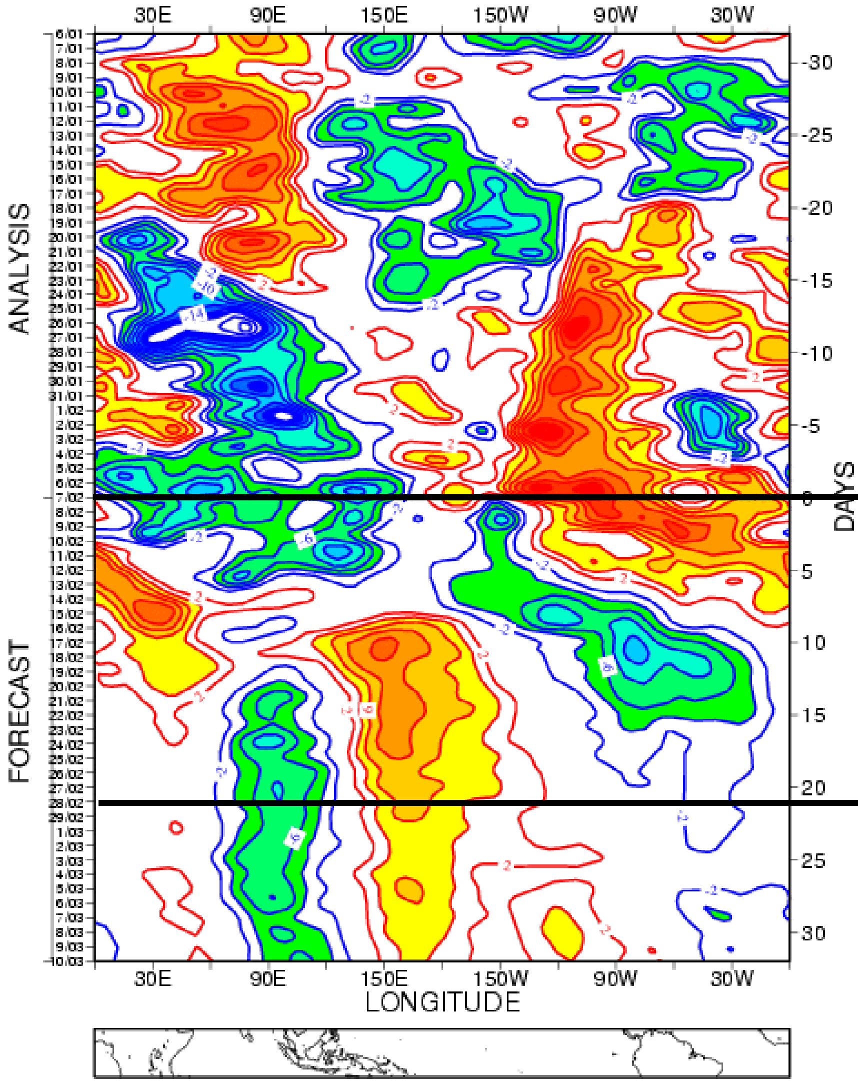
The lower half shows the monthly forecast using same model cycle as system 3

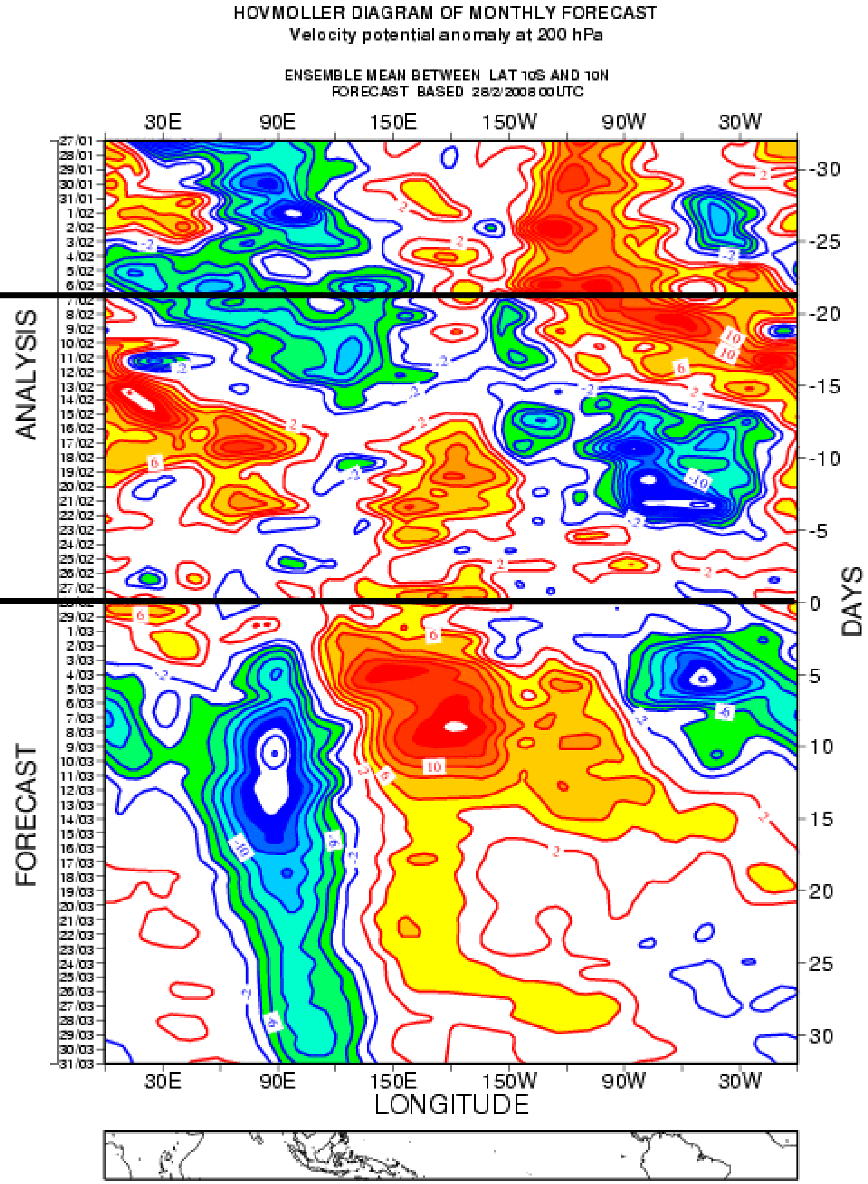
2008 – Cycle 32r3



FC from 7/2

2008 – cycle 32r3





FC from 7/2

FC from 28/2

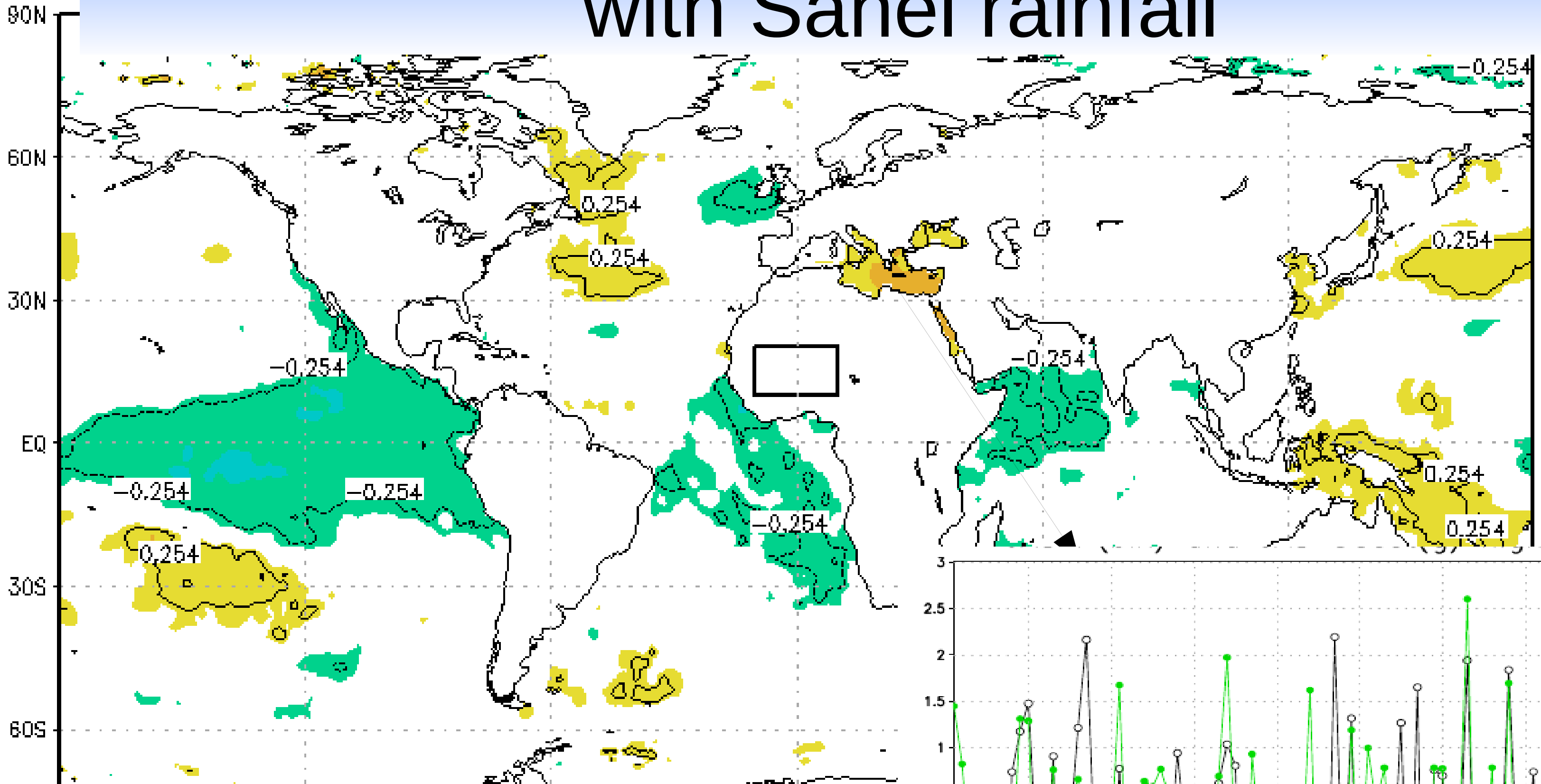
Soil Moisture

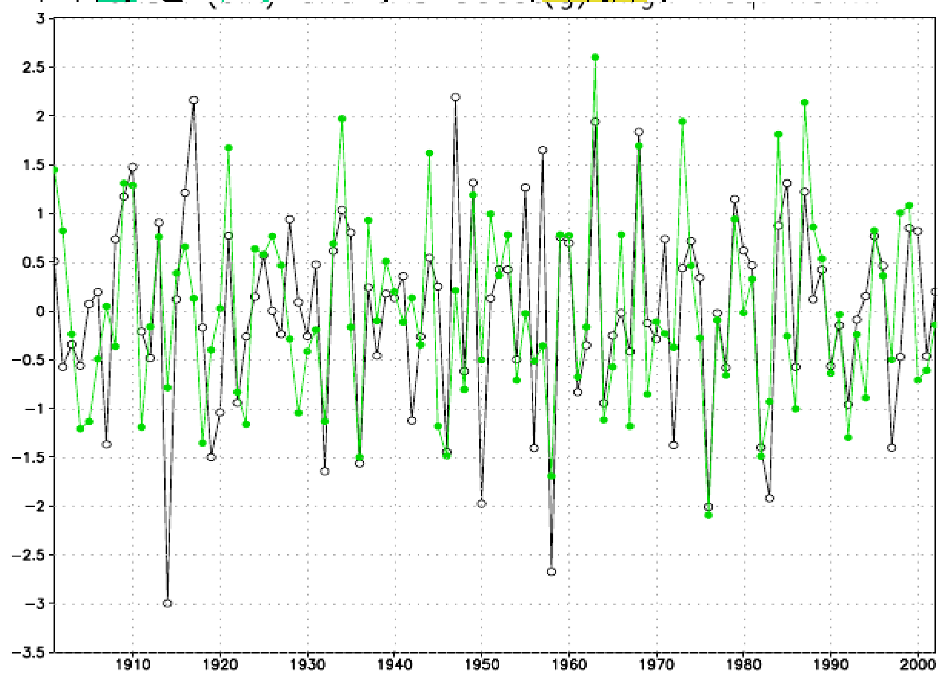
- Soil moisture impact on West African dynamics demonstrated by e.g. Vizy and Cook
- Taylor has shown local influence on convection
  - Wet surfaces increase rainfall in organised systems
  - Dry (hot) surfaces near moist cool areas can trigger convection (re. land-sea breeze effect)
- While soil moisture can impact sub-seasonal predictability, "*soil moisture memory decreases rapidly during dry season and does not contribute to the predictability of the summer monsoon rainfall*" (Douville et al. 2006)
- Role through vegetation possible.

Sea Surface Temperature (SST) Role

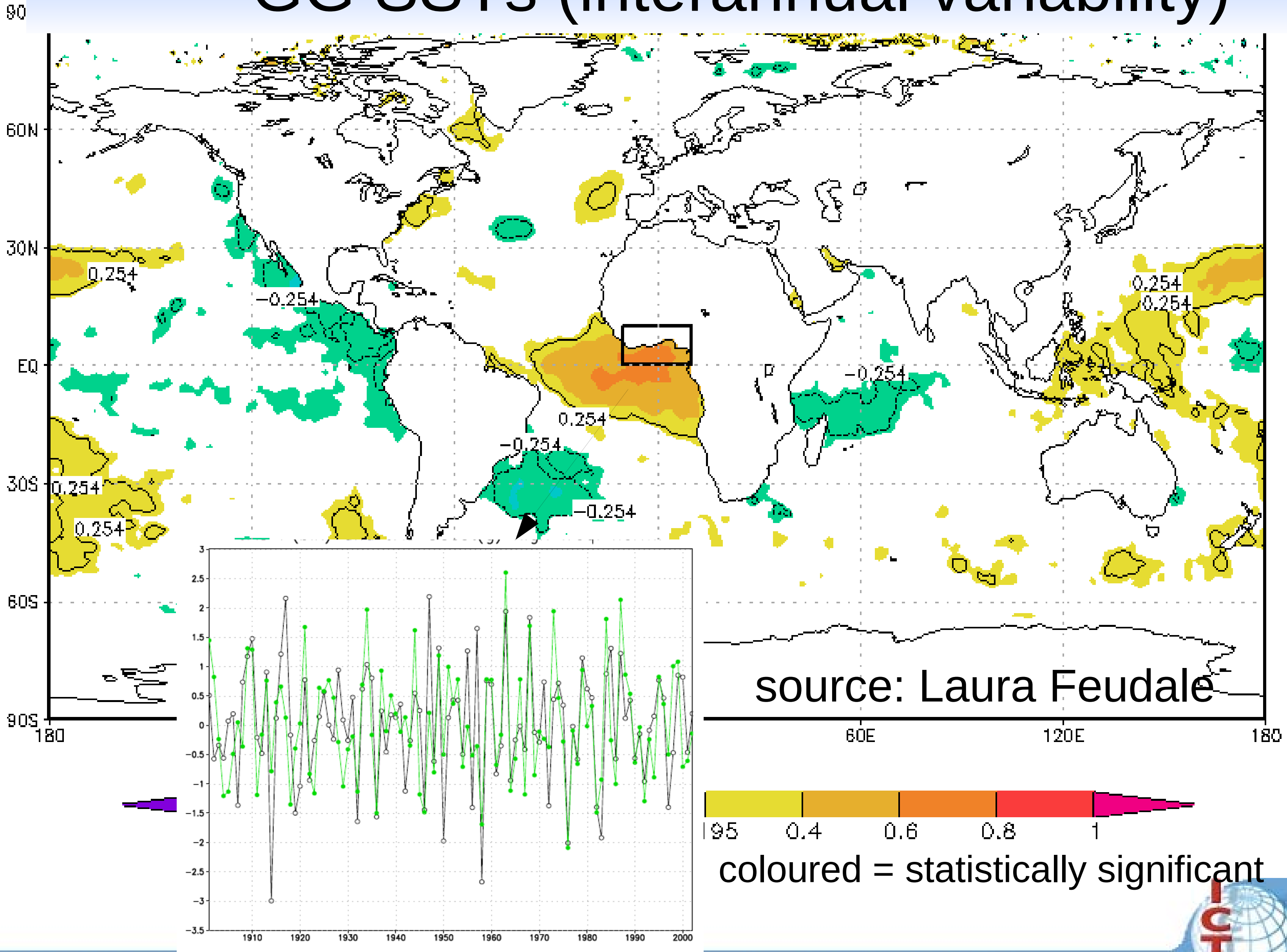
- Host of literature document the influence of SSTs on West African Rainfall
  - ENSO
  - Gulf of Guinea
  - North Atlantic
  - Indian Ocean
  - Mediterranean Sea
- Investigations using
  - Observed correlations between rainfall and SSTs
  - Model integrations with imposed SSTs (e.g. Held et al. 2003,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

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





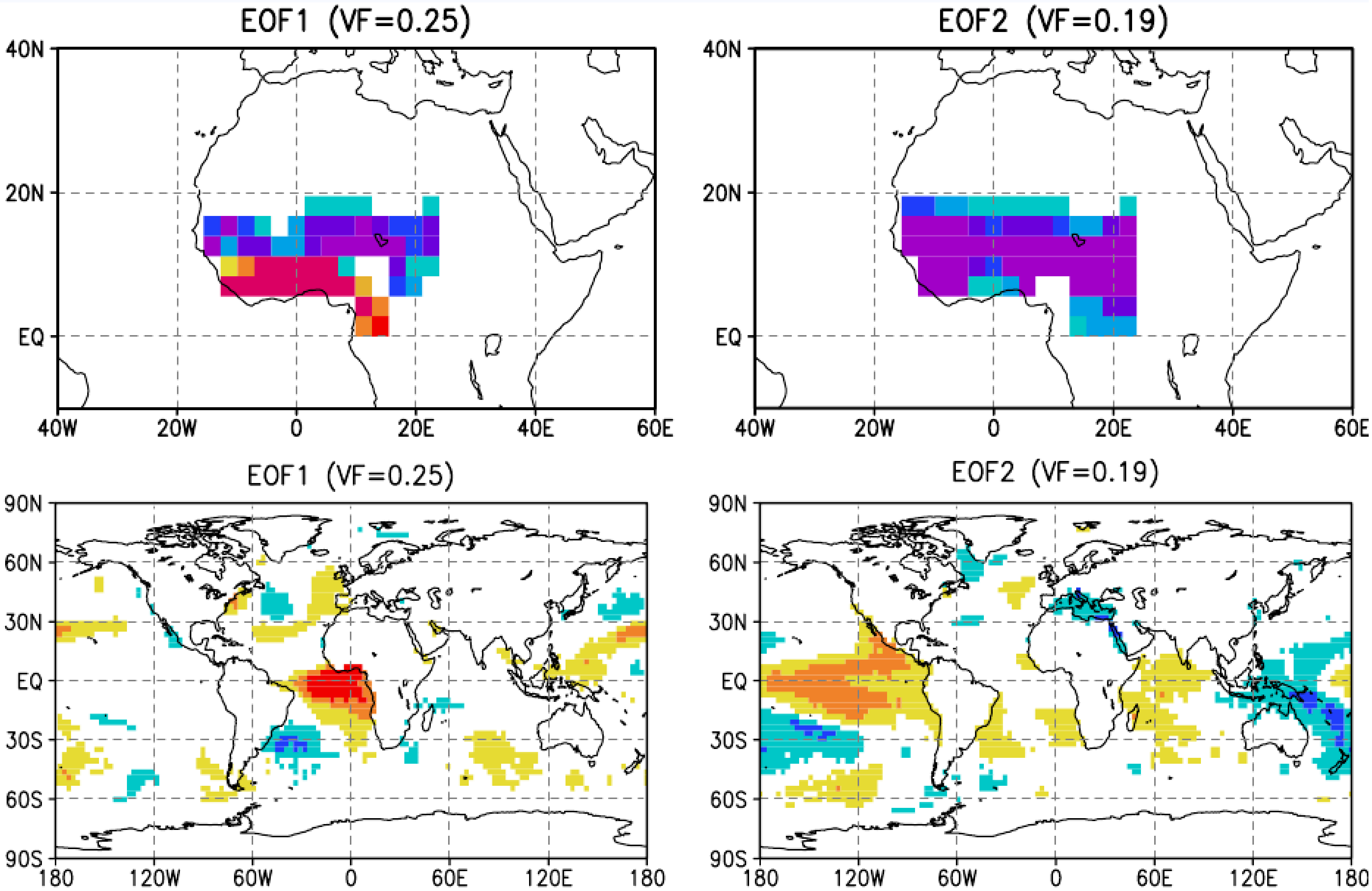
Strong positive correction of boxed rainfall with GG SSTs (interannual variability)



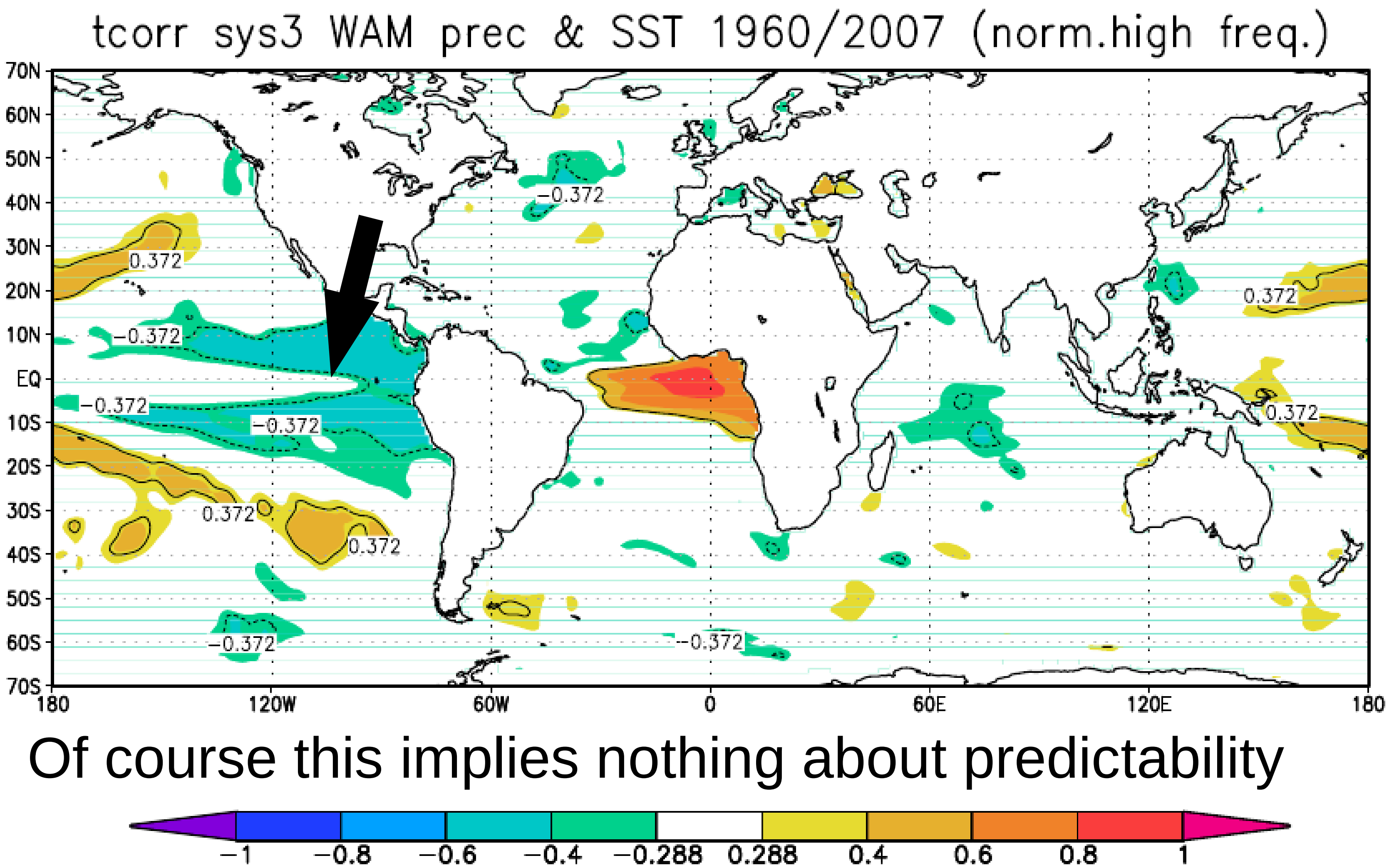
source: Laura Feudale

coloured = statistically significant

Douville et al 2006 – Correlation SST to Rain EOFs

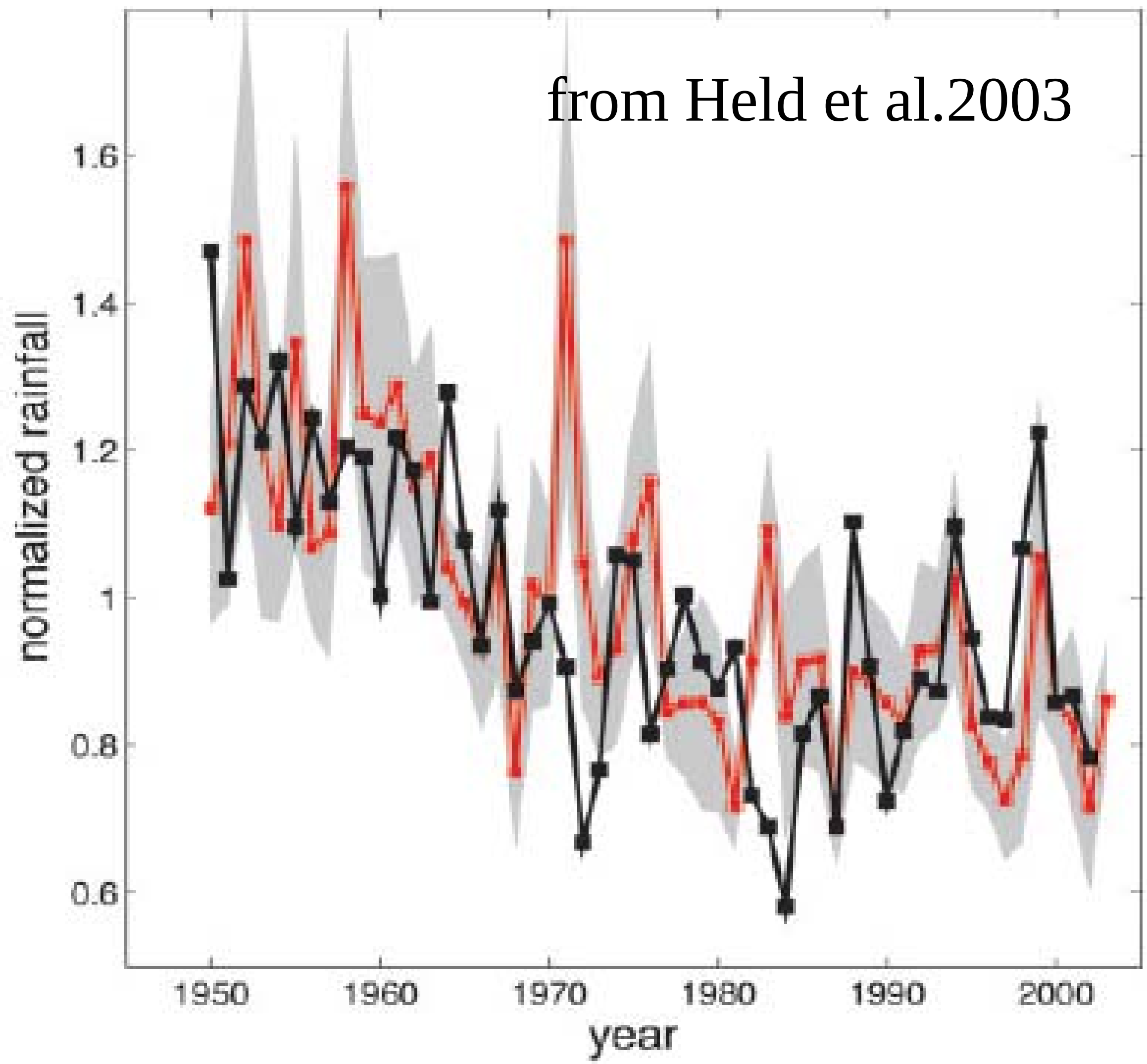


Does SYS 3 reproduce these correlation patterns ?



Of course this implies nothing about predictability

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



Note Rainfall is normalized

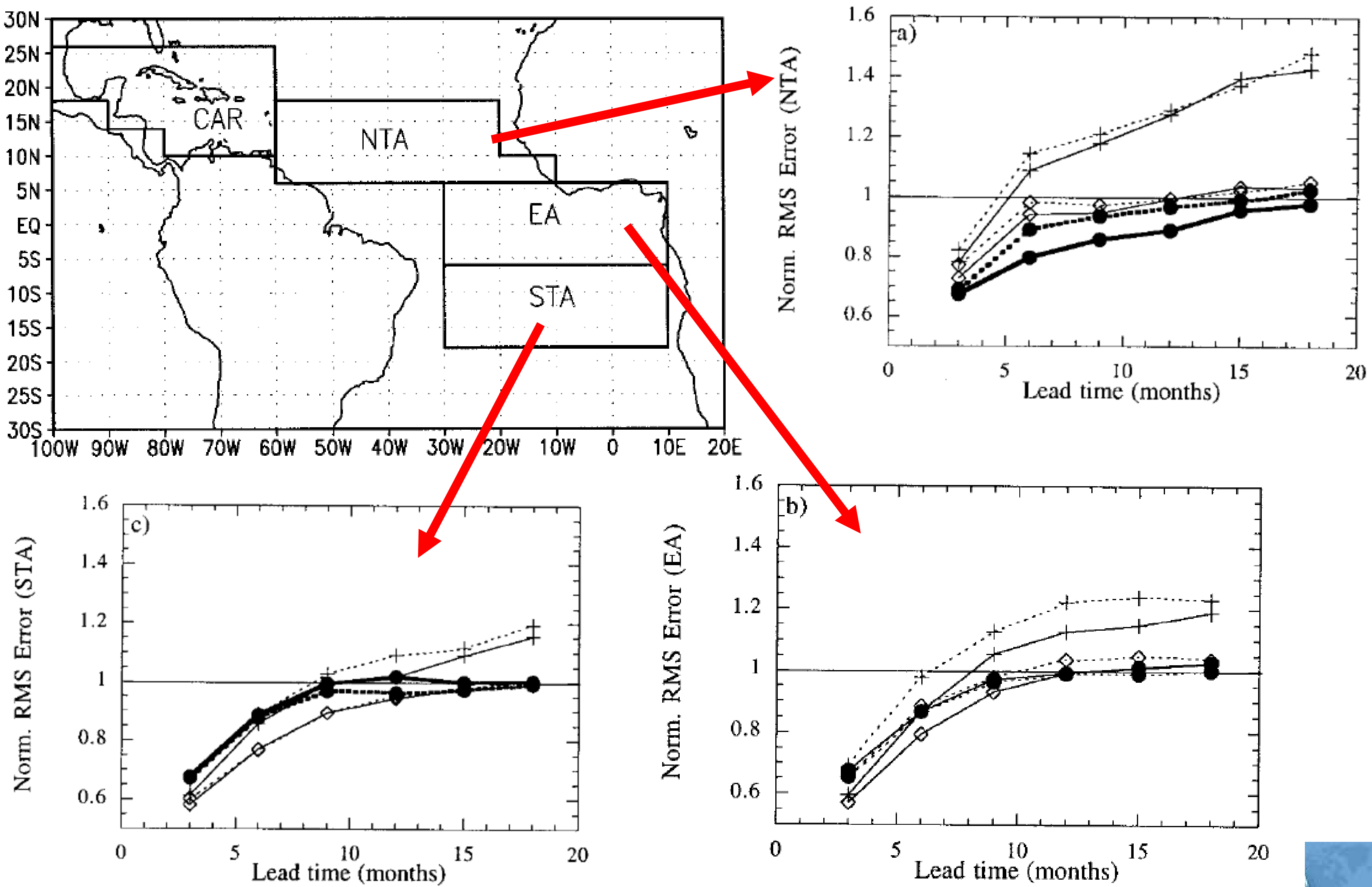
SST predictability

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

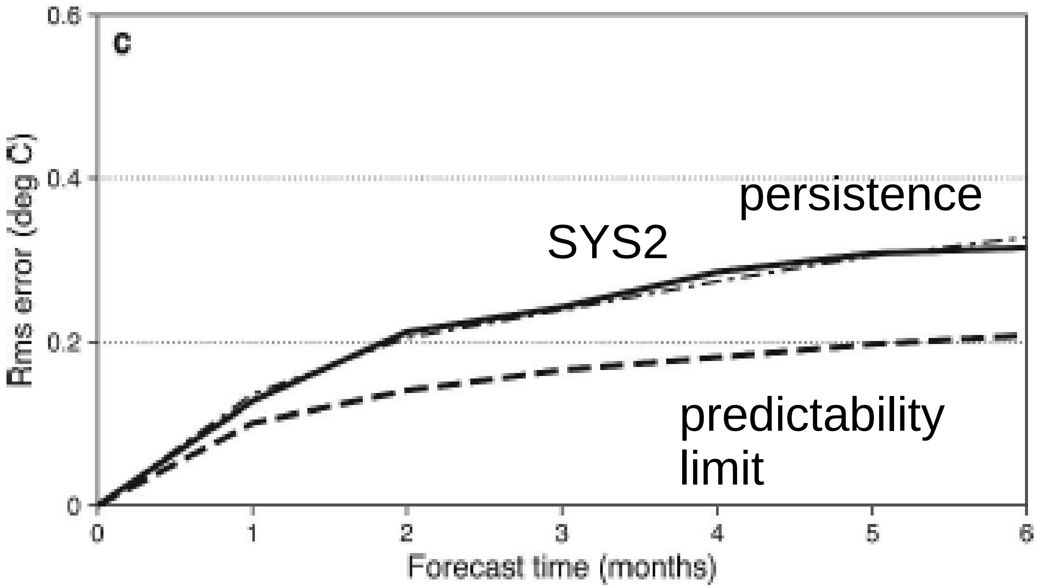
- "*Slowly evolving SSTs determine the atmospheric response in terms of the local and remote distribution and intensity of convection*"

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

Penland et al: statistical model shows worse skill in equatorial Atlantic



ECMWF system 2 coupled seasonal model

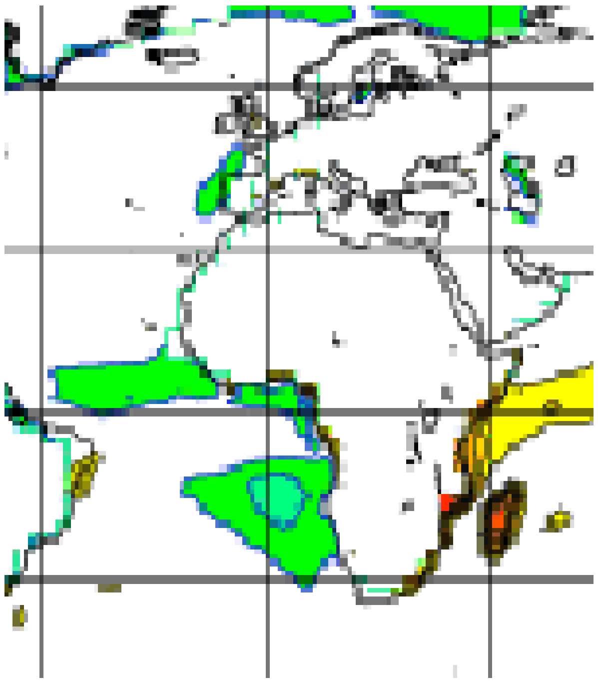


Dotted = Persistence
Solid = SYS 2
Dashed = Limit of predictability

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

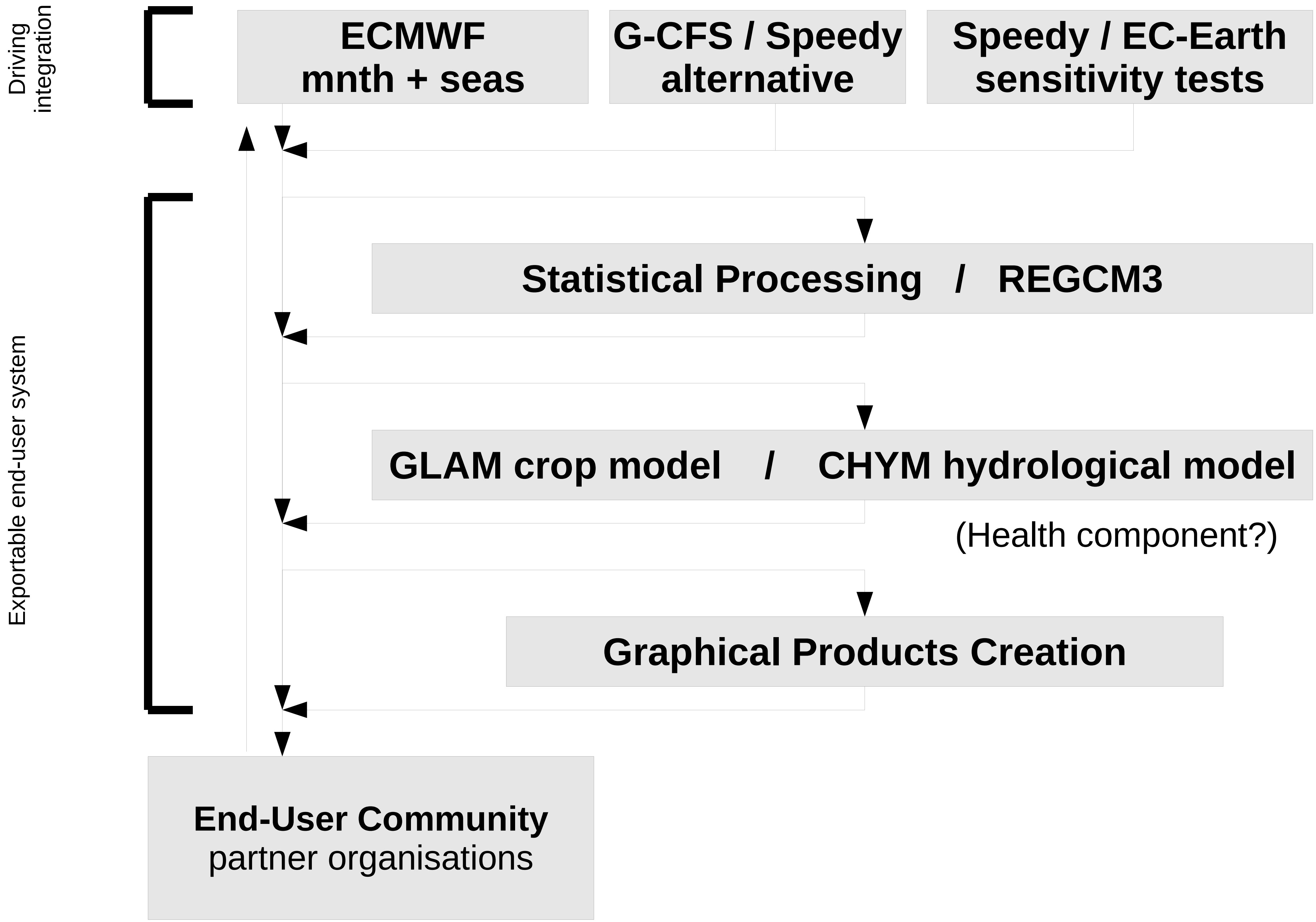
Equatorial Atlantic SSTs

- Strong coupling implies other sources of model bias will affect predictability limit. e.g. Stratocumulus
- However, there is predictability in the persisted anomalies
- Likewise there is a predictable component from ENSO and other areas (N. Atl, Indian Ocean – not Med)
- Improvements in convection parametrization will help!!!



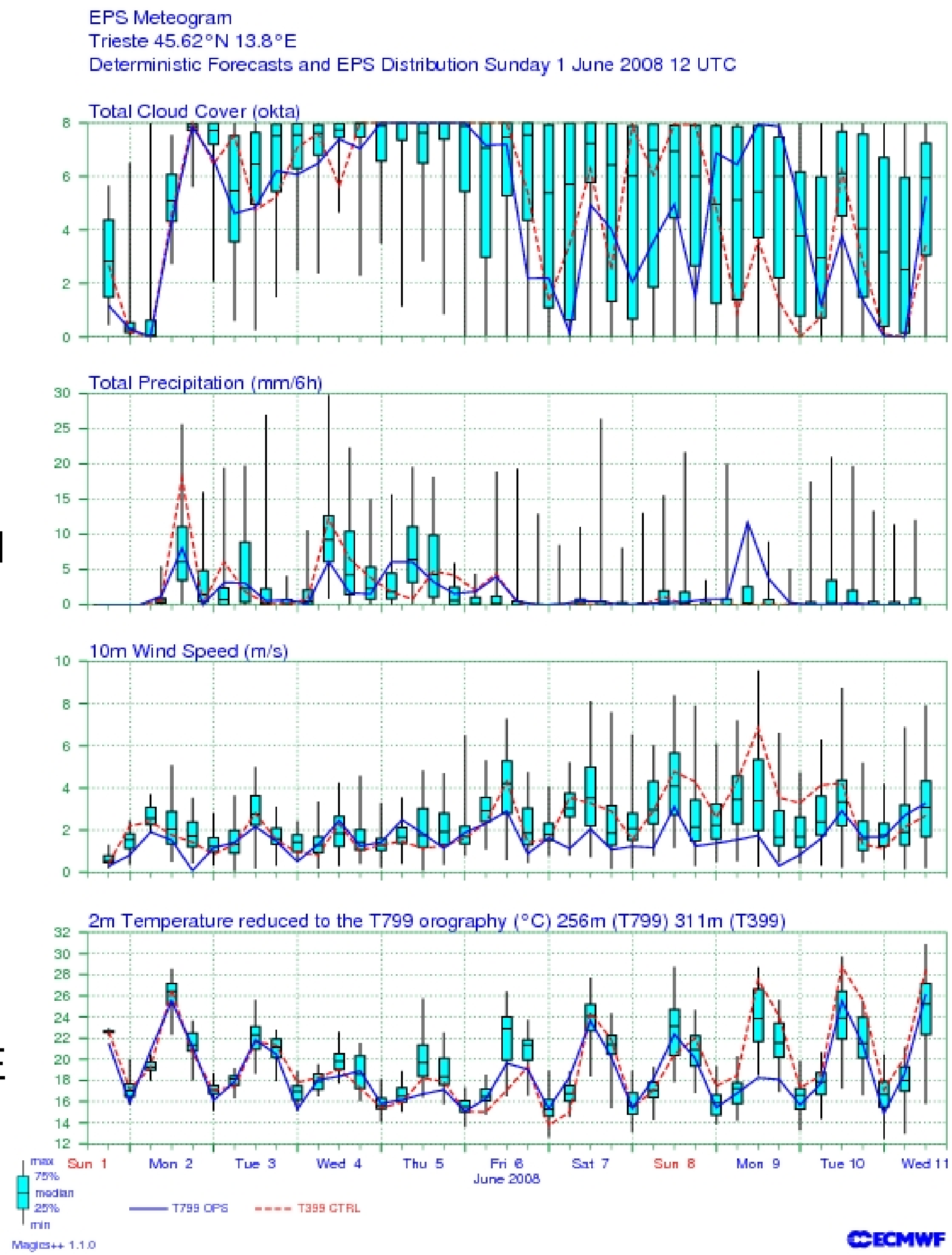
Summary

- 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
- Future plans at ICTP?

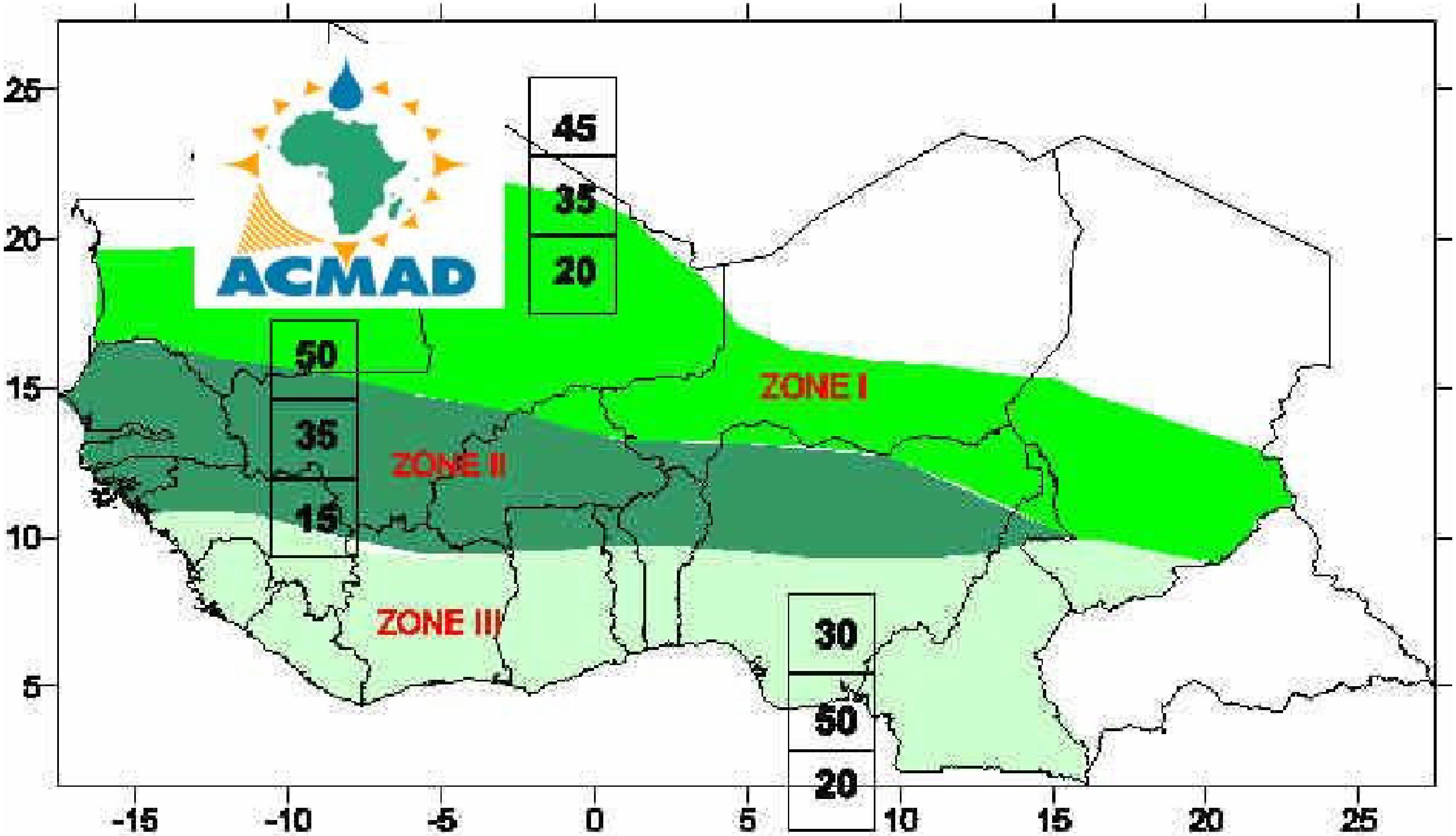

Driving integration
ECMWF mnth + seas
G-CFS / Speedy alternative
Speedy / EC-Earth sensitivity tests
Exportable end-user system
Statistical Processing / REGCM3
GLAM crop model / CHYM hydrological model
(Health component?)
Graphical Products Creation
End-User Community
partner organisations

RAIN

TEMPERATURE



PRESAO 2008
from dynamical and statistical models



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