The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1956-27

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

West African monsoon Intraseasonal Variability.

TRZASKA Sylwia

The Earth Institute Columbia University
61 Route 9W, Monell Building
Lamont Campus Palisades 10964-8000
NY
U.S.A

West African Monsoon Intraseasonal Variability

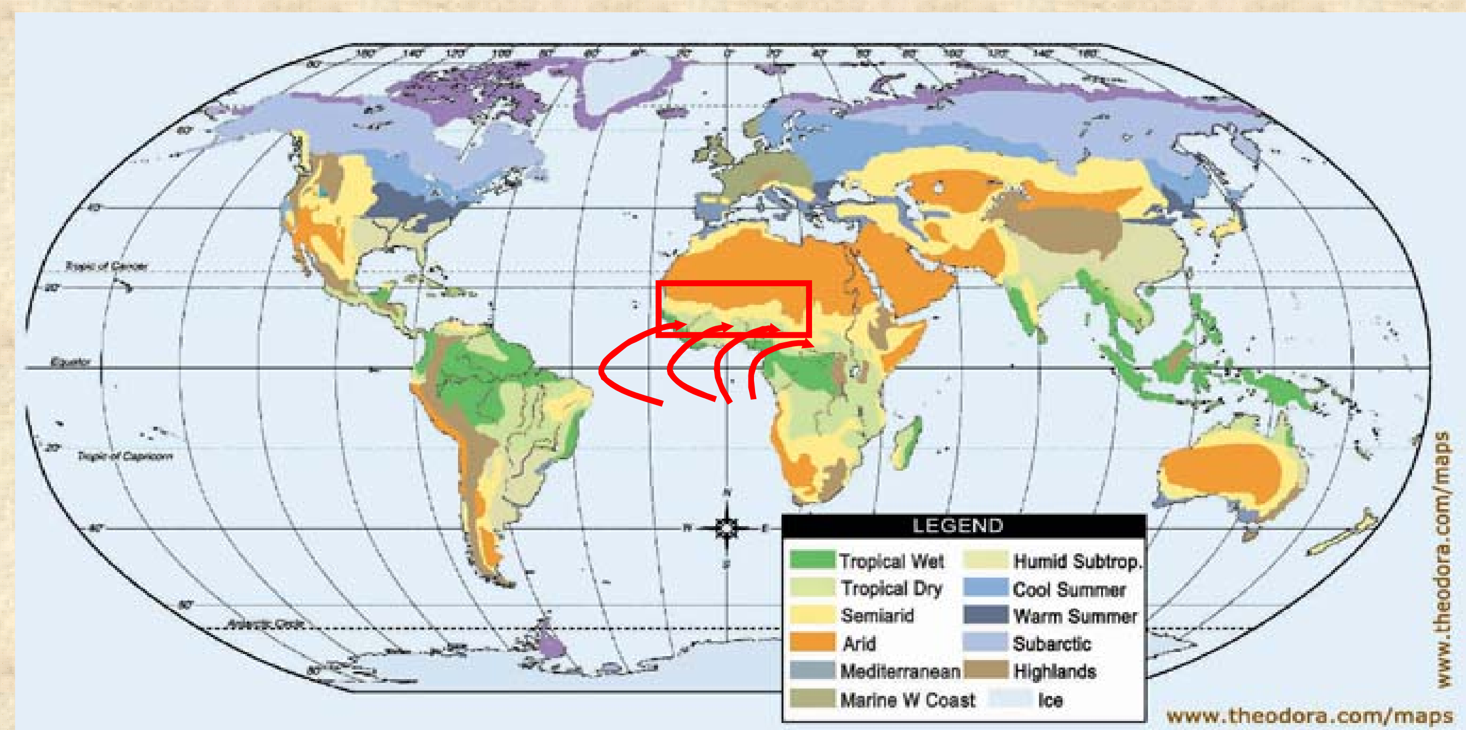
Sylwia Trzaska

International Institute for Climate and Society
Earth Institute at Columbia University
New York, USA

With contribution of many others

- **Mean Seasonal Cycle**
- **Interannual Variability**
- **Intraseasonal characteristics**
- **Onset**
- **Easterly waves**
- **African 30-90 day variability and MJO**
- **Statistical downscalling**

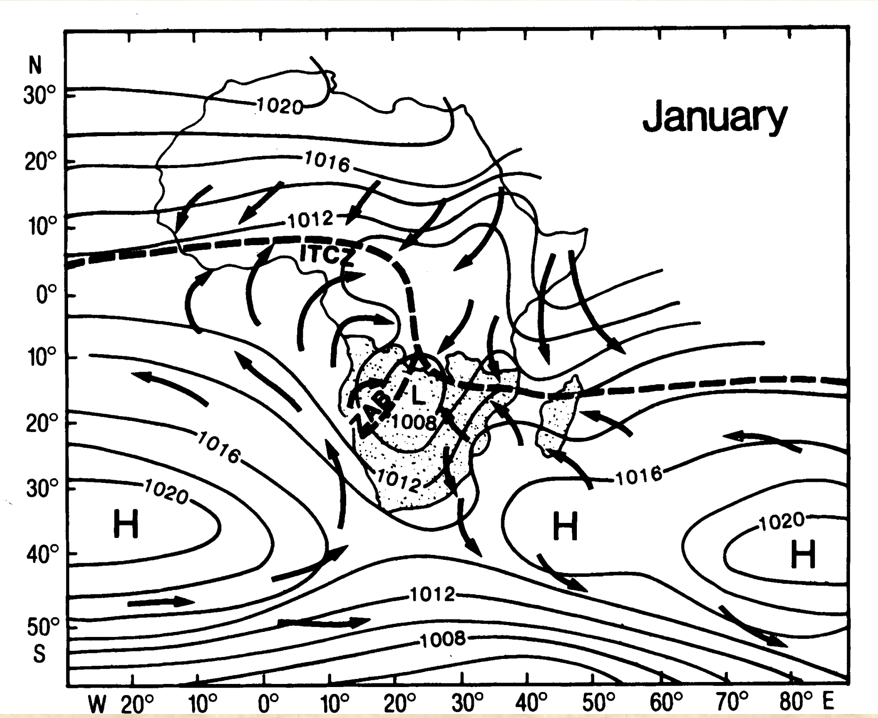
West African Monsoon

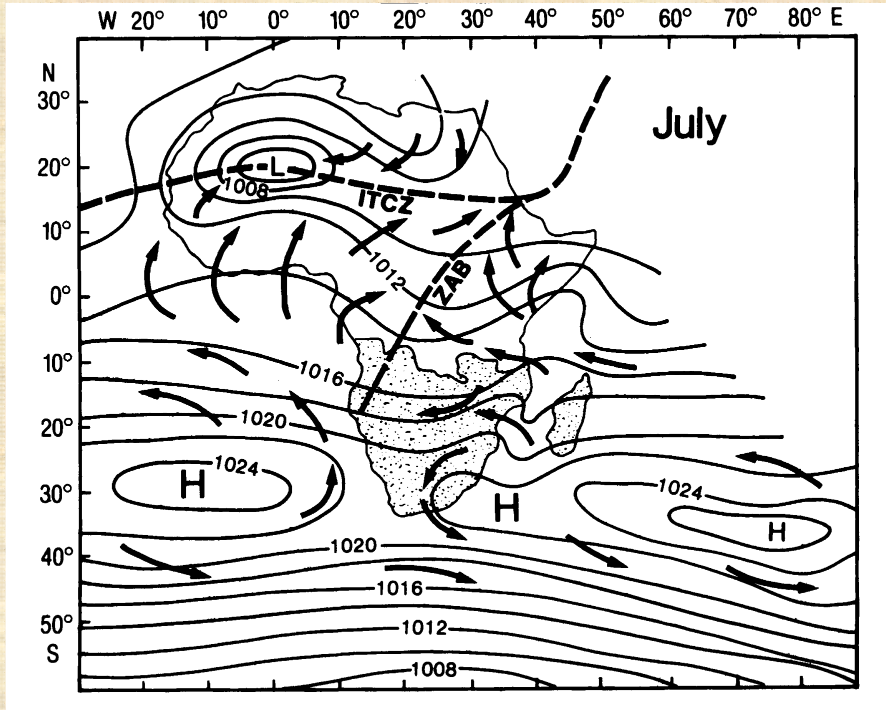


- Region in west Africa ca.10-20N
- One rainy season July-Sept
- Seasonal transequatorial south-westerly low level wind

Mean Seasonal Cycle

Seasonal circulations over Africa



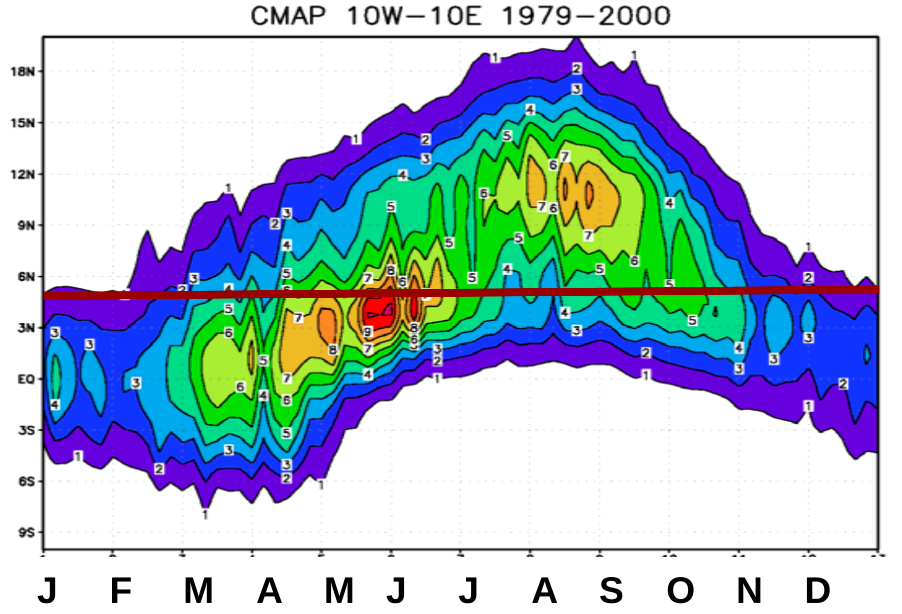


Jul-Sept

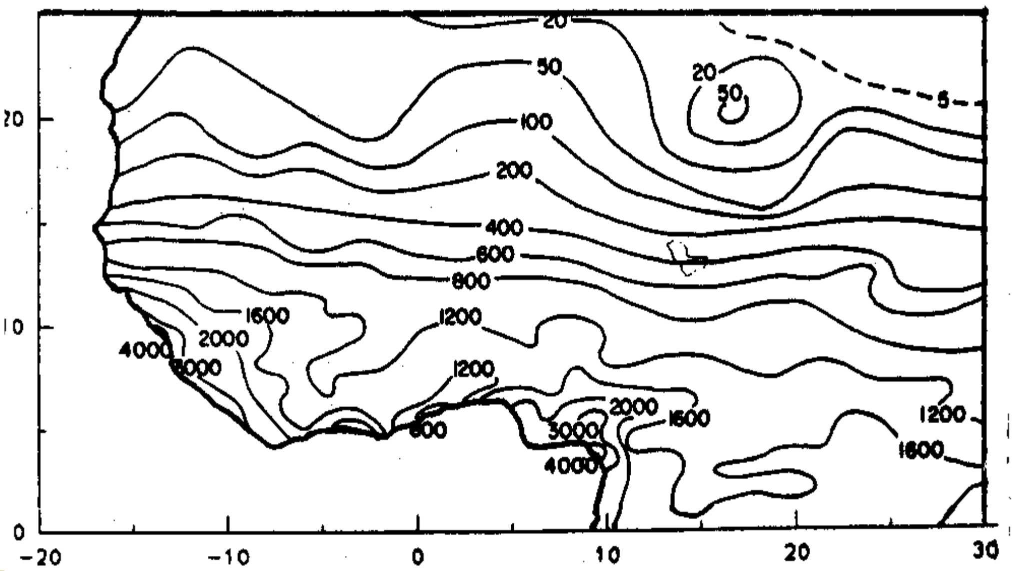
- Seasonality of the rainfall linked to seasonal large scale circulations
- SWly circulations bring moisture inland
- flux convergence forces ascent and precipitation
- moisture fluxes influenced by thestate of the SST and of the land surface

WAfr Monsoon – Seasonal cycle

Hoevmoller RR diagramme: 10E-10W



Annual Rainfall totals (in mm)



- AMJ – first rainy season on the coast
- JAS – rainy season in the Sahel, little dry season on the coast
- OND – slow southward retreat of the rainbelt, second rainy season on the coast

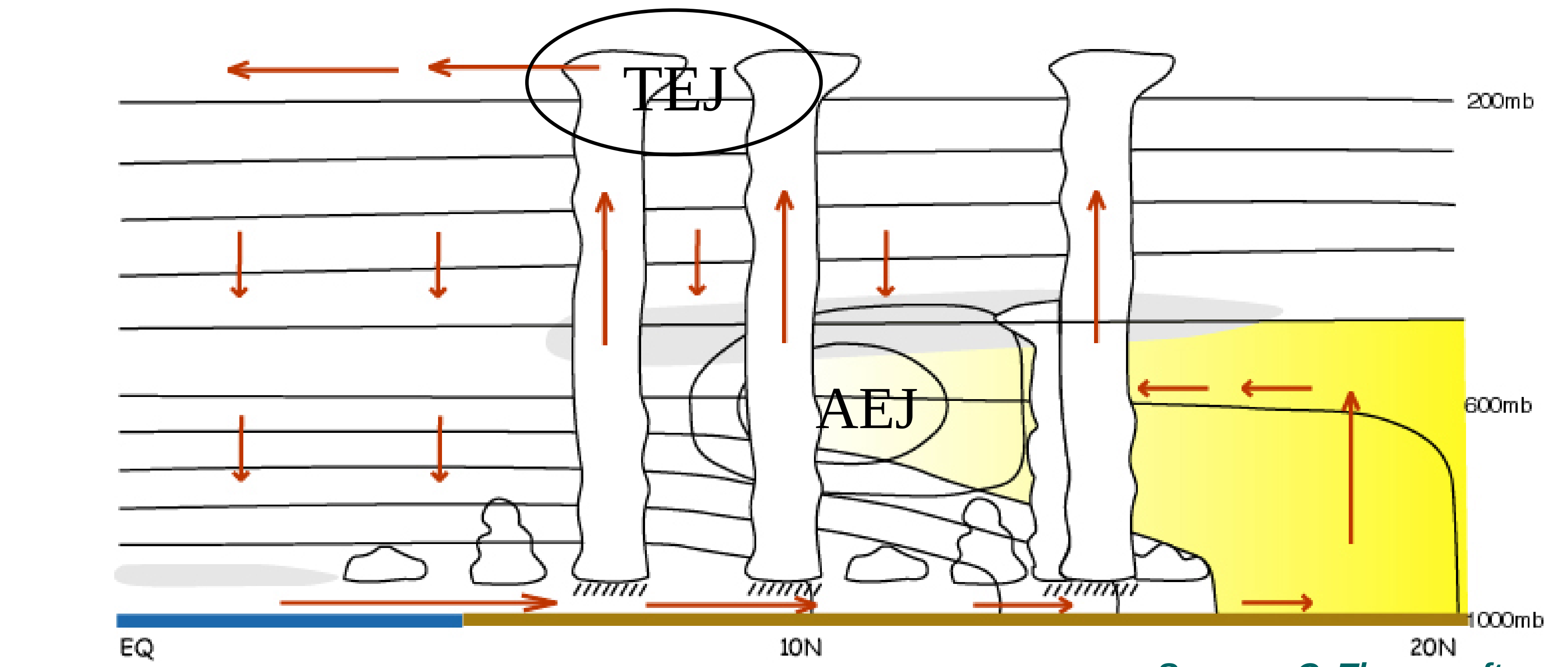
☛ the installation of the rainbelt in the Sahel is NOt progressive – 'monsoon jump'

- strong meridional gradient of annual totals; 100mm/100km

☛ Sahel region on the edge of sustainable agriculture (ca 600mm/yr), very sensitive to small rainfall deficits

IRI

WAf Monsoon – Meridional View

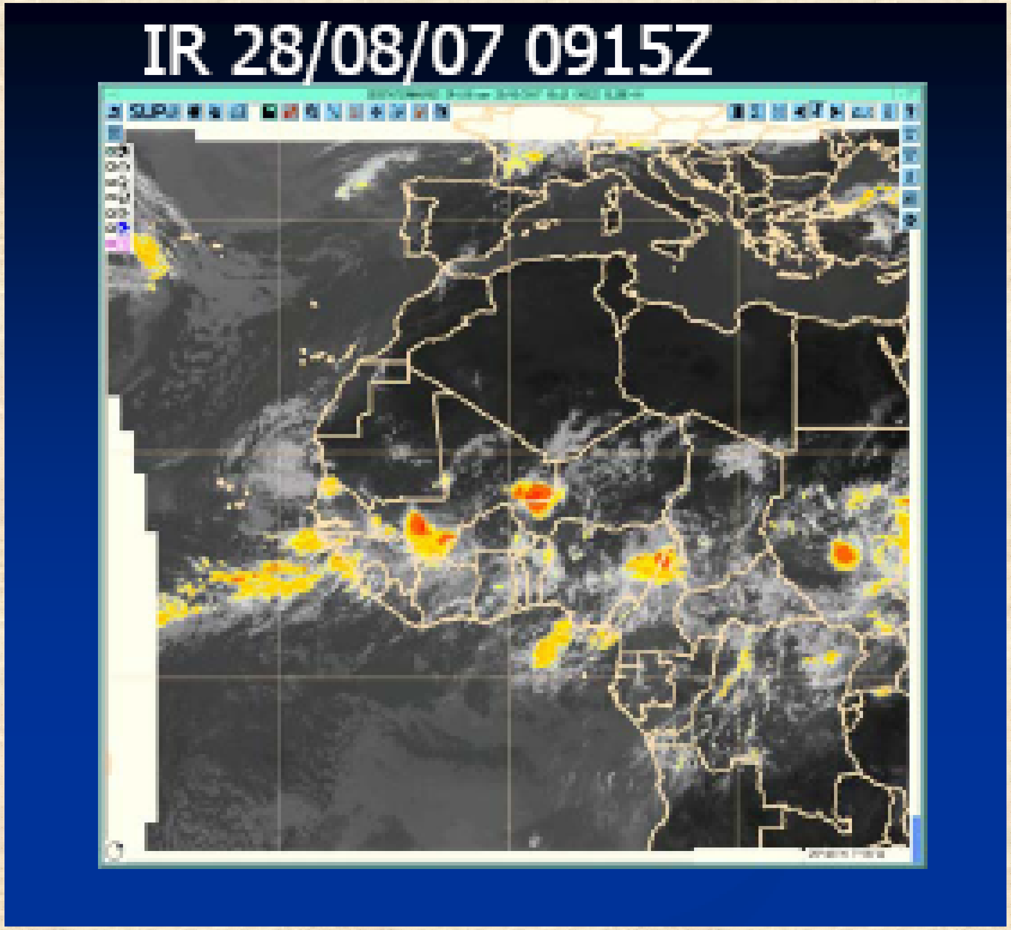


Source: C. Thorncroft

- **Intertropical discontinuity (ITD) – boundary btwn monsoon and saharan air masses**
- **Shallow heat low to the north of ITD**
- **Northern part of the rainbelt – intermittent convection**
- **More sustained convection ca 10N**

Rainy events

Rainfall occurs within Mesoscale Convective Systems (MCS) propagating westward

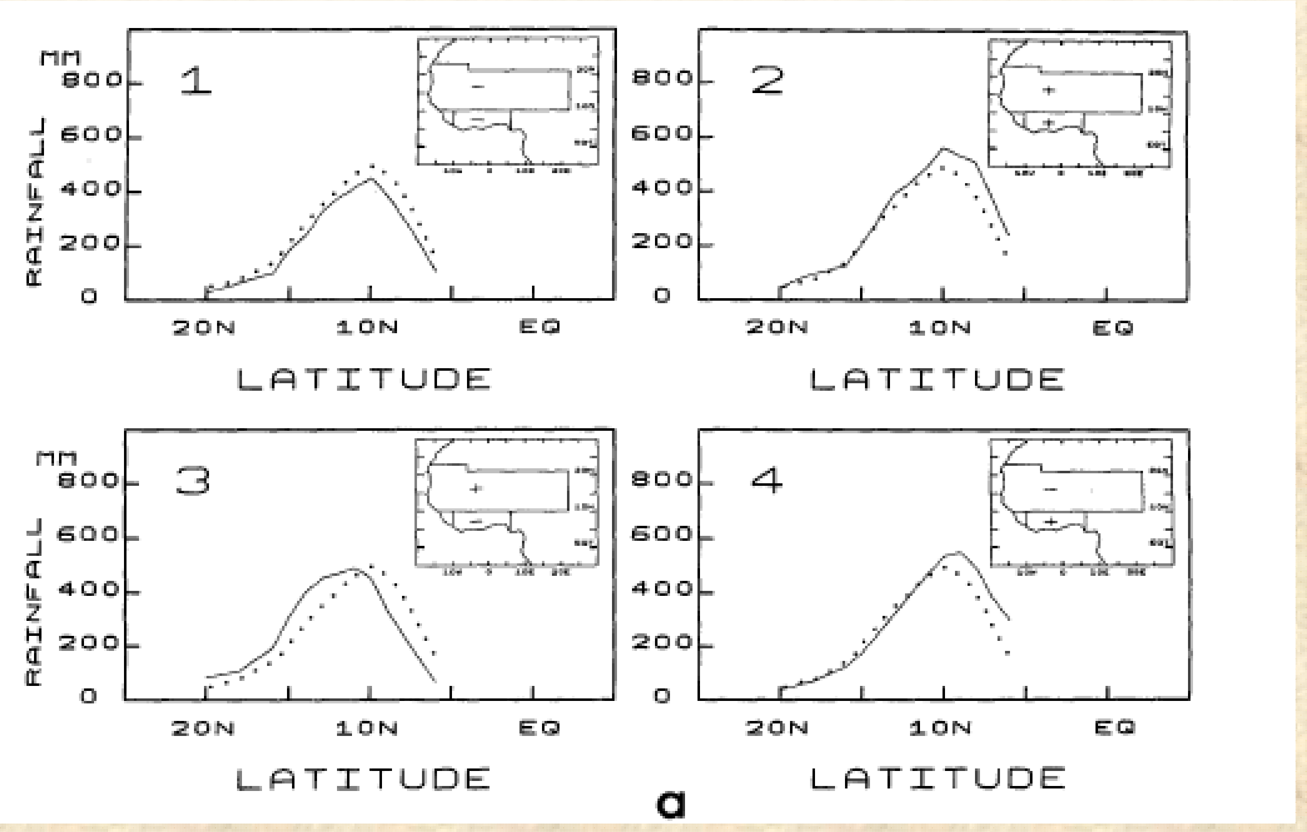


Interannual variability

WAfr Monsoon Variability

- **Rainfall Regionalization**

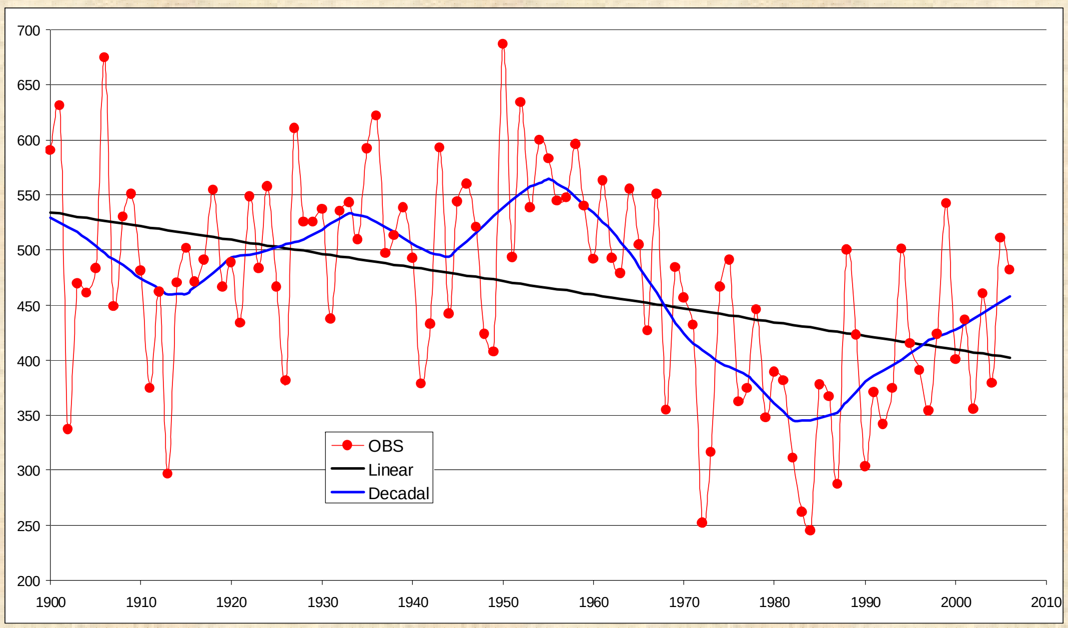
Based on automatic classification of station data

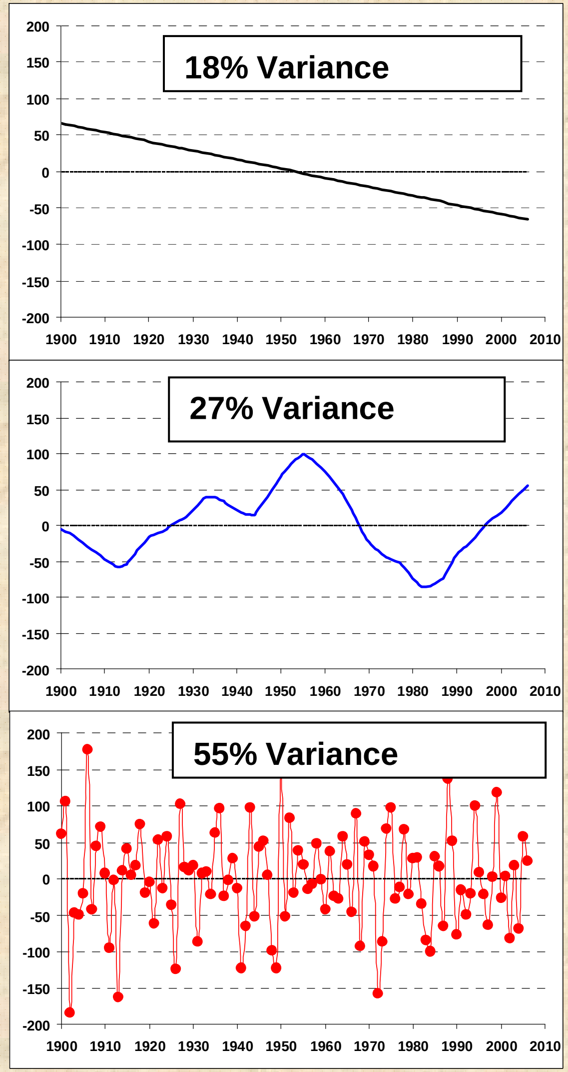


Janicot, 1991, J Clim

Sahel Rainfall – Variability

Observed rainfall in theSahel



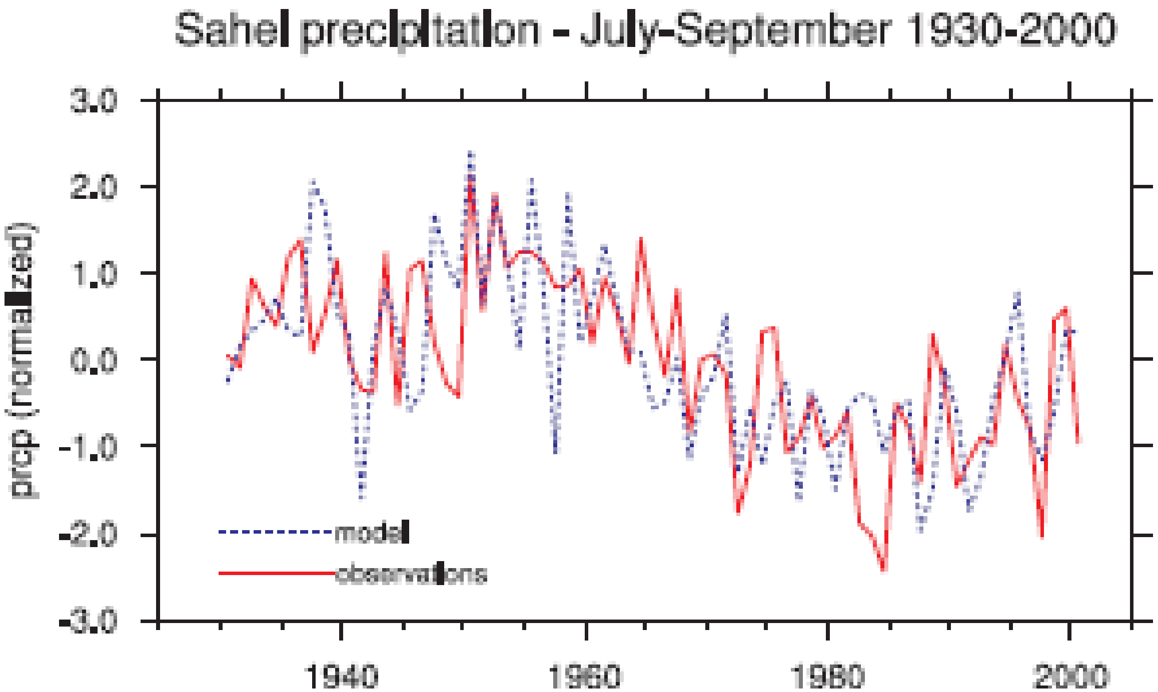


! Strong decadal component

☛It is the number of rainy events, not their intensity that have changed (Le Barbe and Lebel, 1997, JHydrol)

AGCM simulations

☛ **Models can usually capture decadal and interannual rainfall variability in the Sahel based on SST**



Giannini et al. 2003, Science

WAfr Monsoon Variability - Summary

- Strong decadal component

- SST primary driver of the variability
  - Land surface & vegetation may act as amplifiers

- Multiple influences

▪ Atlantic

Direct influence on thermal gradient and moisture fluxes; found in early works e.g. Lamb (1978); strong decadal component; teleconnexion not captured by models

▪ ENSO

Intstability in the teleconnections: periods of stronger Atlantic/ENSO influence;Captured by GCM forced by observed SST

▪ Indian Ocean/interhemispheric dipole

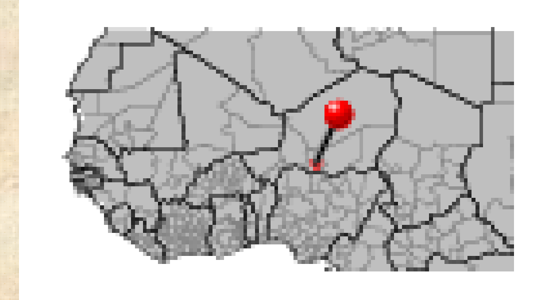
Role in Sahel-ENSO teleconnexion and trend

Intraseasonal characteristics

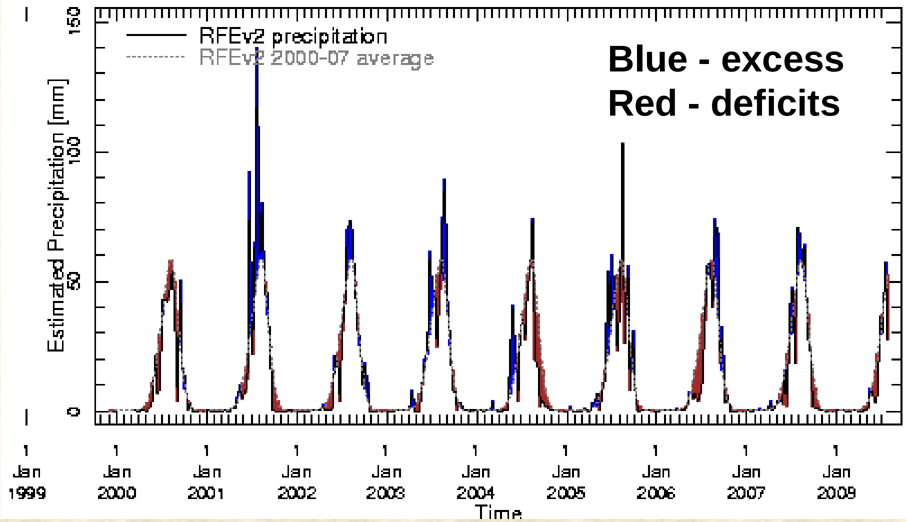
Intraseasonal evolution of rain

Dekadal rainfall for Maradi district, Niger

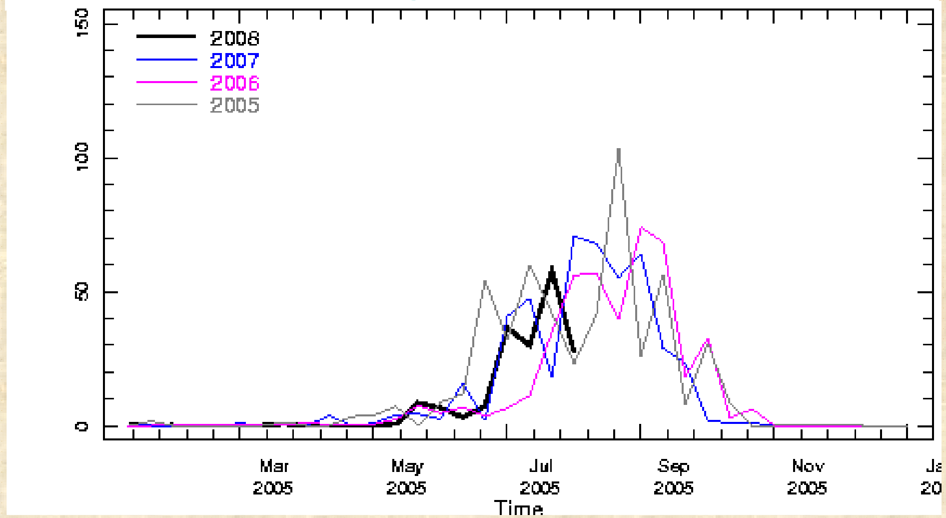
Data: **CPC/FEWS RFE2.8**
Dec1 1999-Jul26 2008
0.1°x0.1°



Comparison with mean seas cycle

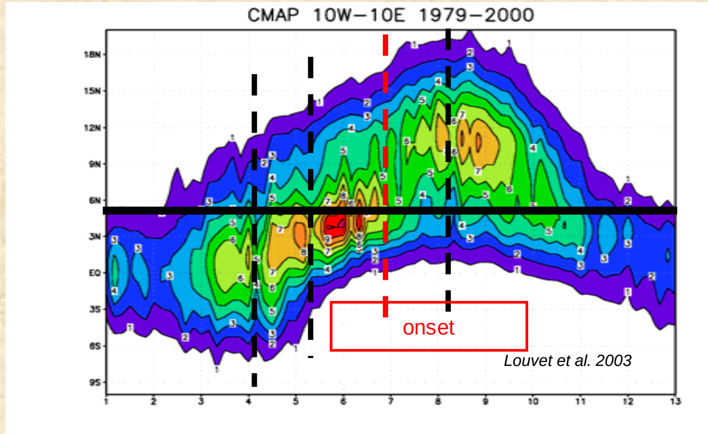


Individual years 2005-2008

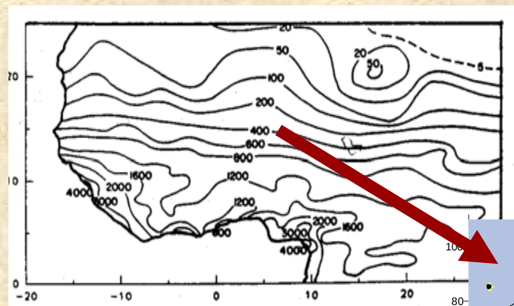


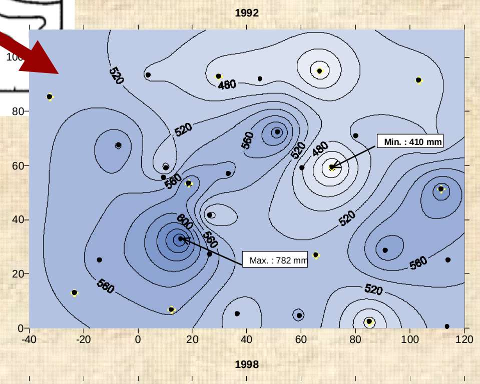
- **2005 long dry spell end of July**
- **2006 late onset**
- **2004 & 2007 early termination**

Subseasonal Characteristics



Niamey supersite
Hundreds of gauges on 1°x1°
1997 totals



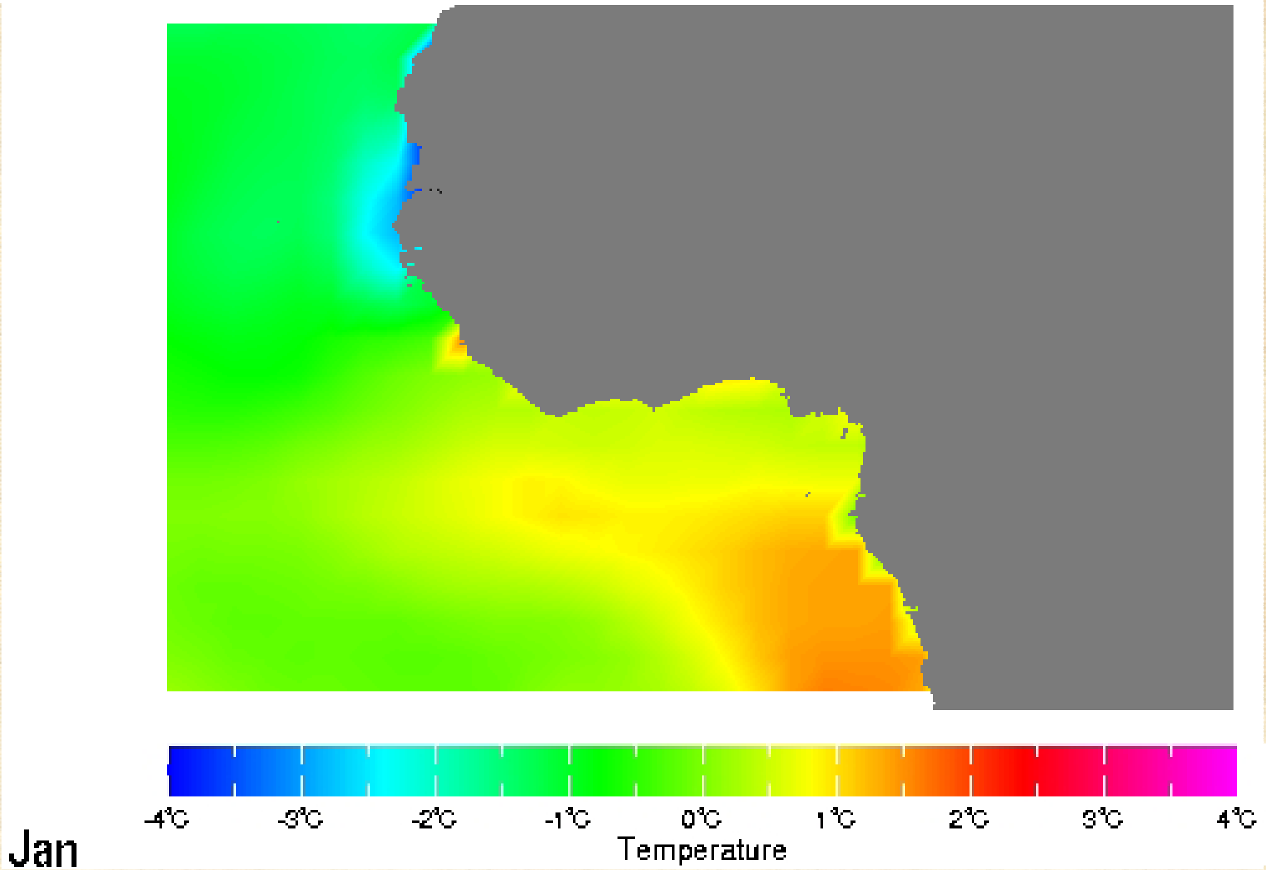


- **Several ‘breaks’**
- **Complex spatial pattern, different each year**
- **Scales for applications, e.g. agriculture**

Onset

SST

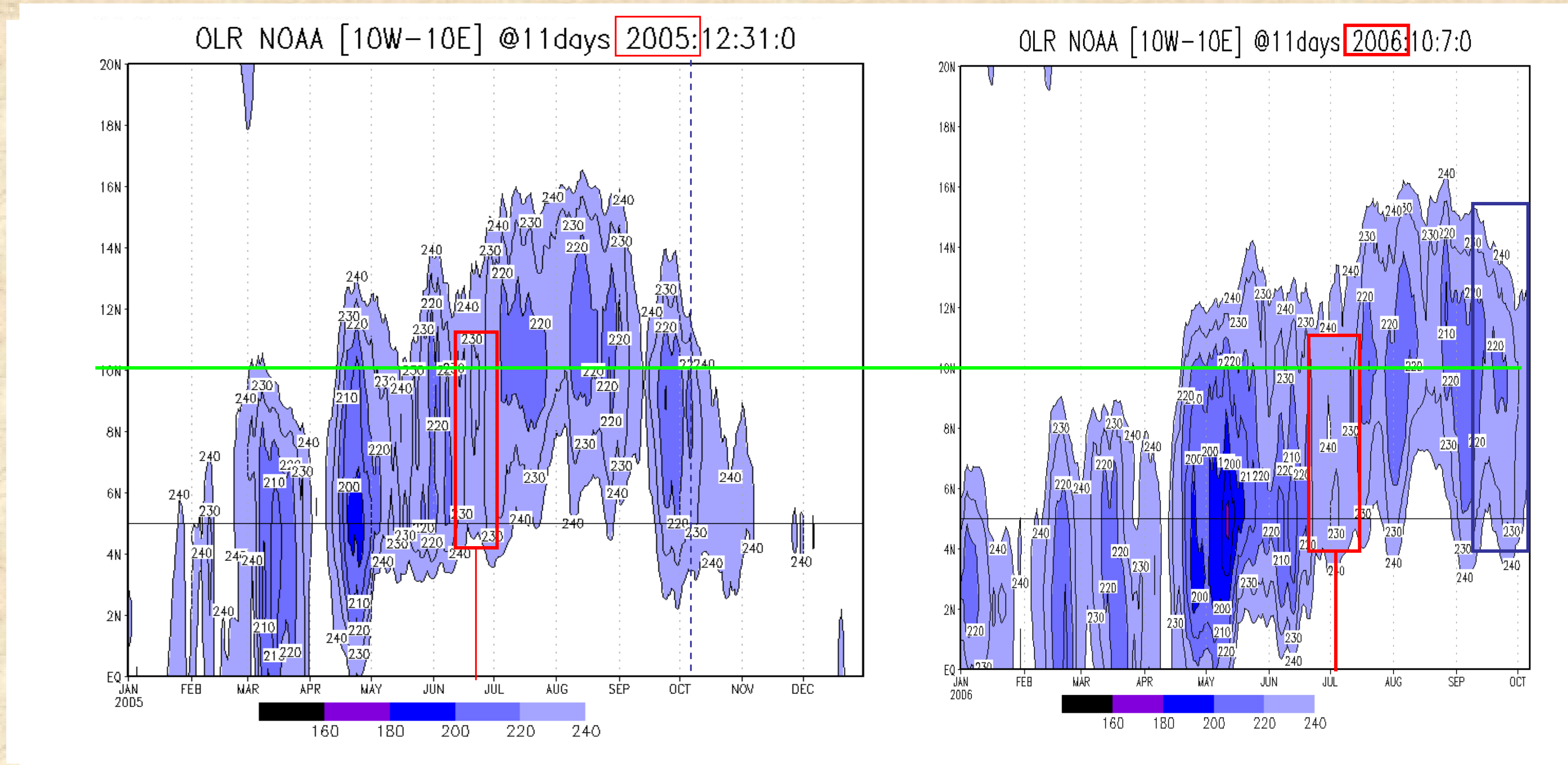
SST anomalies / mean annual SST



JAS – equatorial and coastal upwelling in the Gulf of Guinea

☛ **Enhances meridional sea-land thermal gradient**

2005 & 2006 WAfr Monsoon seasons

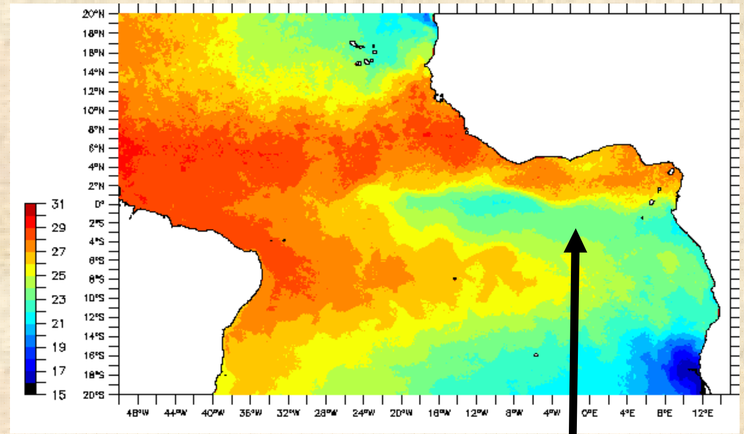


Source: S. Janicot

2005 & 2006 WAfr Monsoon seasons

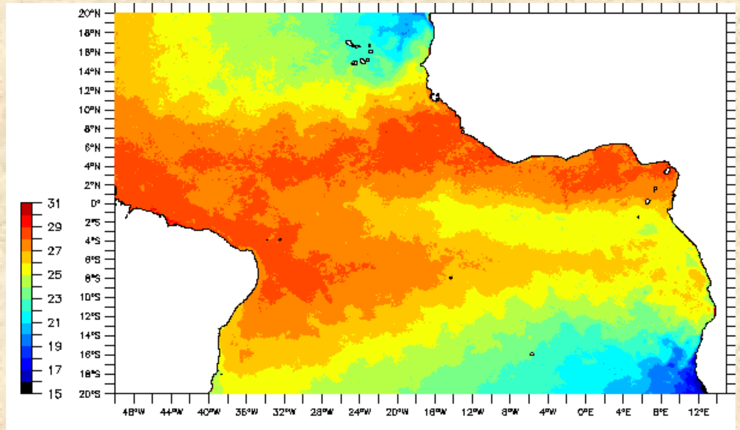
Field Campaigns EGEE

15 Jun 2005



cold tongue in place

15 Jun 2006



SST warmer than normal

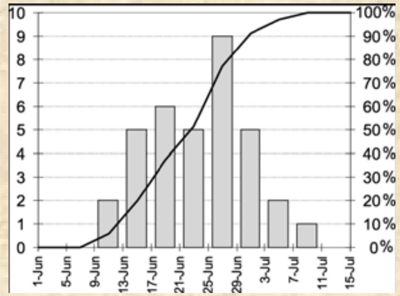
☛ In situ observations suggest local wind-SST interactions

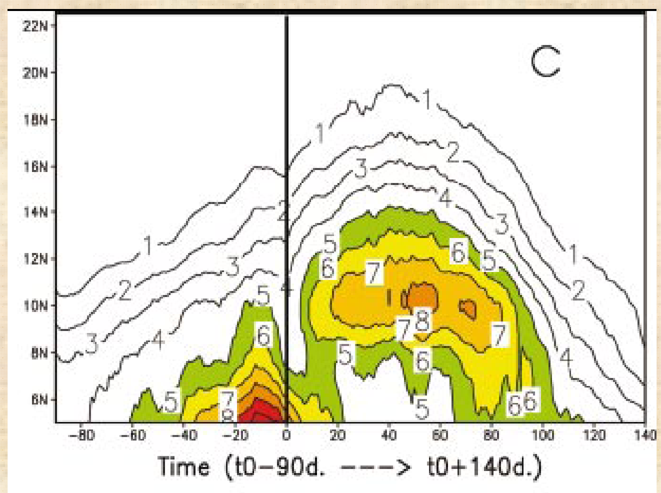
Source: S. Janicot

Inland conditions

❑ **10W–10E Composite time–latitude diagram of daily rainfall, 1968-90 with date of ITCZ shift as reference (t=0)**

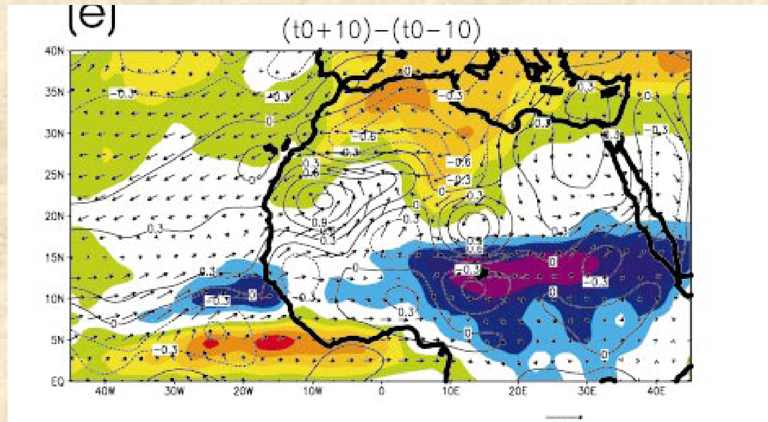
Histogramme of onset dates





❑ **Composite of daily NCEP–NCAR difference between *t*0+10 and *t*0 -10**

Vectors - Wind at 925hpa
Shading - OLR
Isolines- relative vorticity

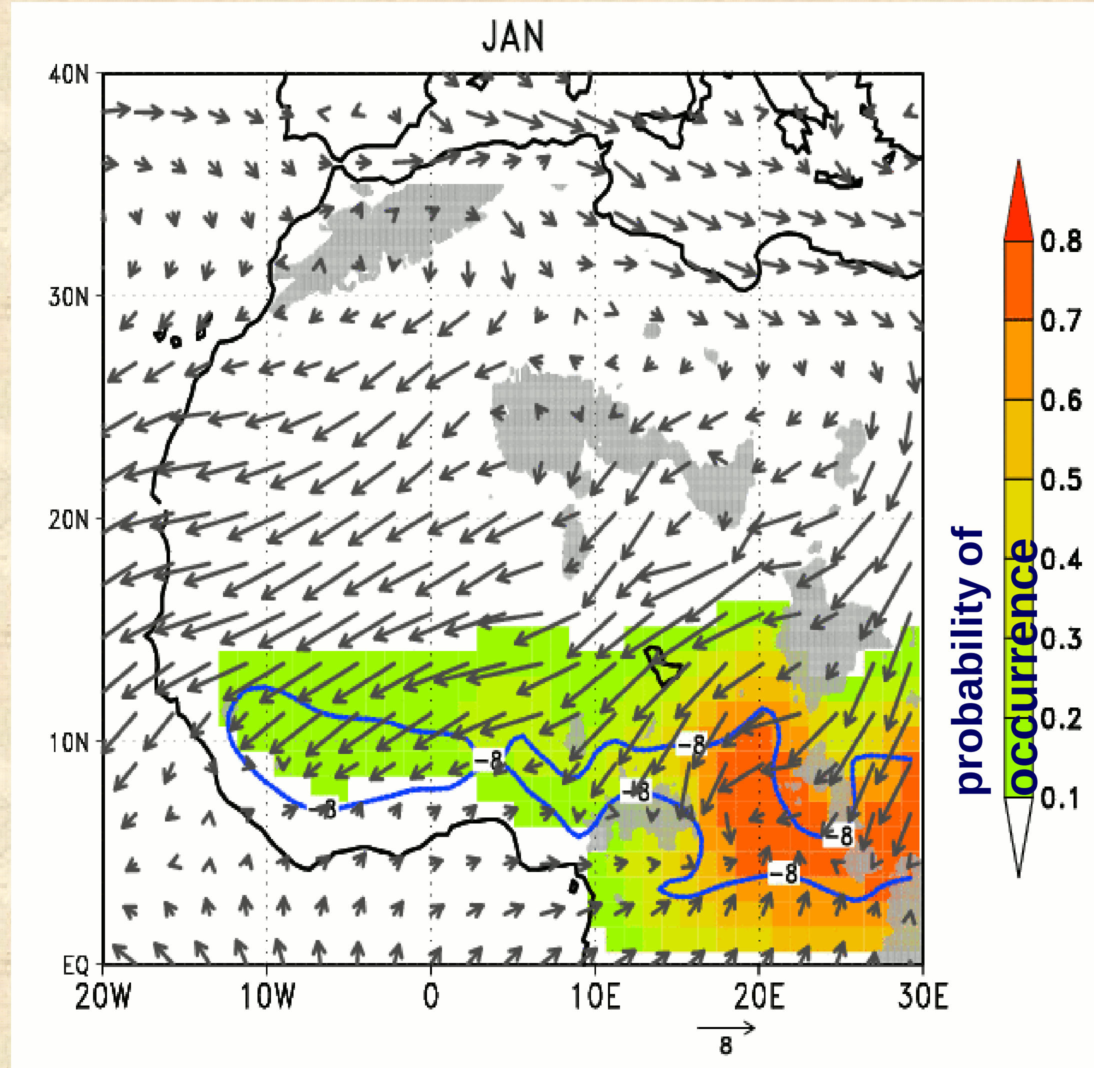


☛ **Significant change in low level relative vorticity in SW Sahara**

Sultan and Janicot, 2003 JClim

Heat Low

Mean seasonal evolution of the Heat Low location



Climatological HL detection
ERA 40: 1967-2001 ERA 40
1 value / day (0600 UTC)

Using the Low Levels Atmospheric Thickness (LLAT).

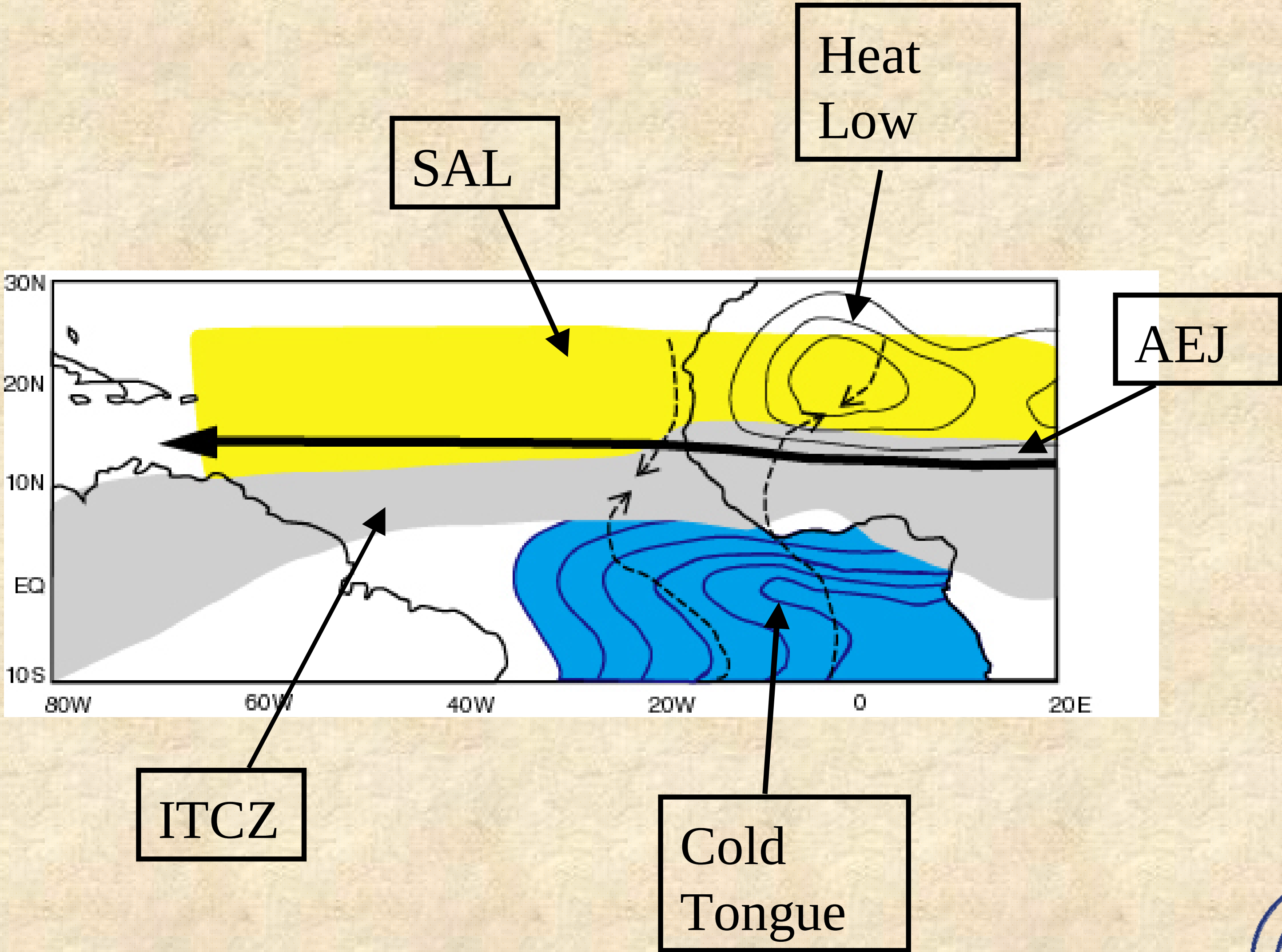
- **upper boundary : 700 hPa,**
- **top of upward wind**
- **lower boundary : 925 hPa**
- **☛to avoid topography below 800m**

- HL occ prob- shaded
- 925hPa wind
- Horizontal wind CV - blue lines

Courtesy C. Laveysse

IRI

Onset main features



Source: C. Thorncroft

5-25 day variability

&

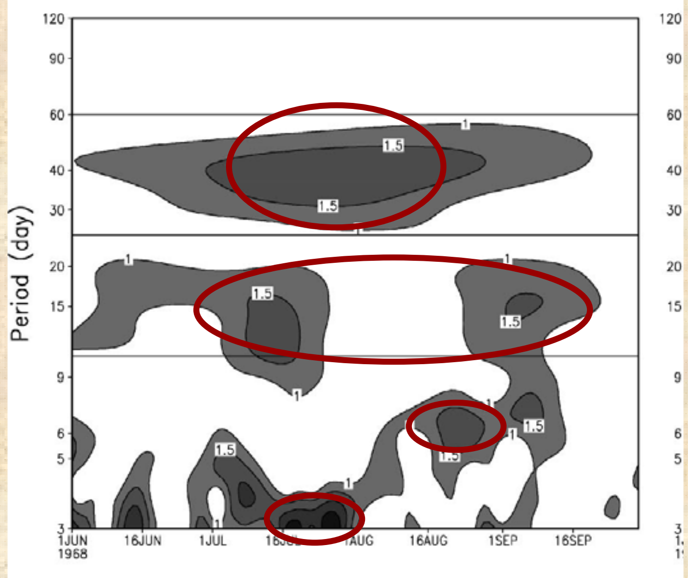
African easterly Waves

Intraseasonal Rainfall Variability

Wavelet or Spectral analyses of daily rainfall over West Africa show distinct periodicities:

- **3-5 and 6-9 days associated with African Easterly Waves**
- **Ca 15 days clearly separated from AEW**
- **30-60 days (cf specific discussion)**

Modulus of the wavelet analysis of the daily rainfall time series June-October

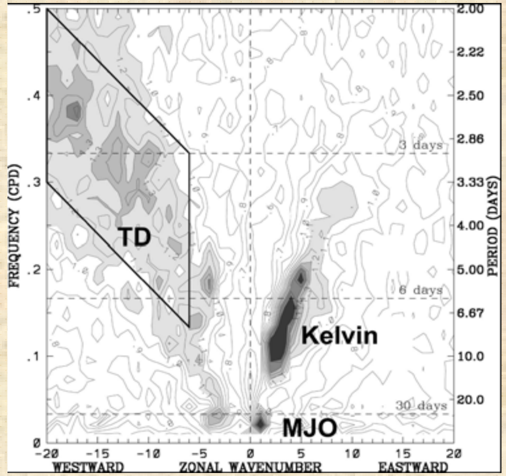


Sultan et al. 2003 JClim

Synoptic scale and AWS

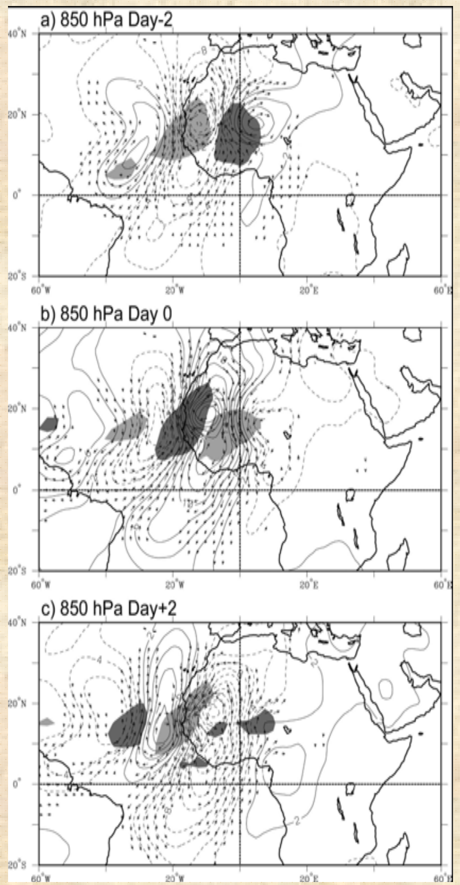
AWS have been long associated with synoptic weather systems over WAfrica (Burpee 1972, Thorncroft and Hoskins 1994, Thorncroft 1995, Cook 1999 etc)

- **best detected in 700hPa V wind**
- **occur in the vicinity of the AEJ**
- **generated through barotropic conversion but late growth supported by baroclinic conversion and non-linear processes (Thorncroft and Hoskins, 1994, Throncroft 1995)**
- **initiated over the highland region of Sudan (Berry and Thorncroft 2005, Mekonnen et al. 2006)**
- **2 main regimes (Diedhiou et al. 1999)**
  - **•3-5 days, on both sides of AEJ (5N & 15N), more active in Aug-Sept, modulate convection and monsoon flow over WAfrica**
  - **•6-9 days, northern side of AEJ (17.5N), more intermittent, active in Jun-Jul, opposite RR anomalies in the coastal and Sahel regions**



Wheeler and Kiladis 1999 JAS

Composites of anomalies of OLR and 850-hPa circulation from ERA-15centered on OLR perturbation at 15°N, 17.5 °W, Jun–Sept 1979–93



Dark/light shading OLR –/+ ano
Contour - streamfunction

Kiladis et al. 2006 JAS

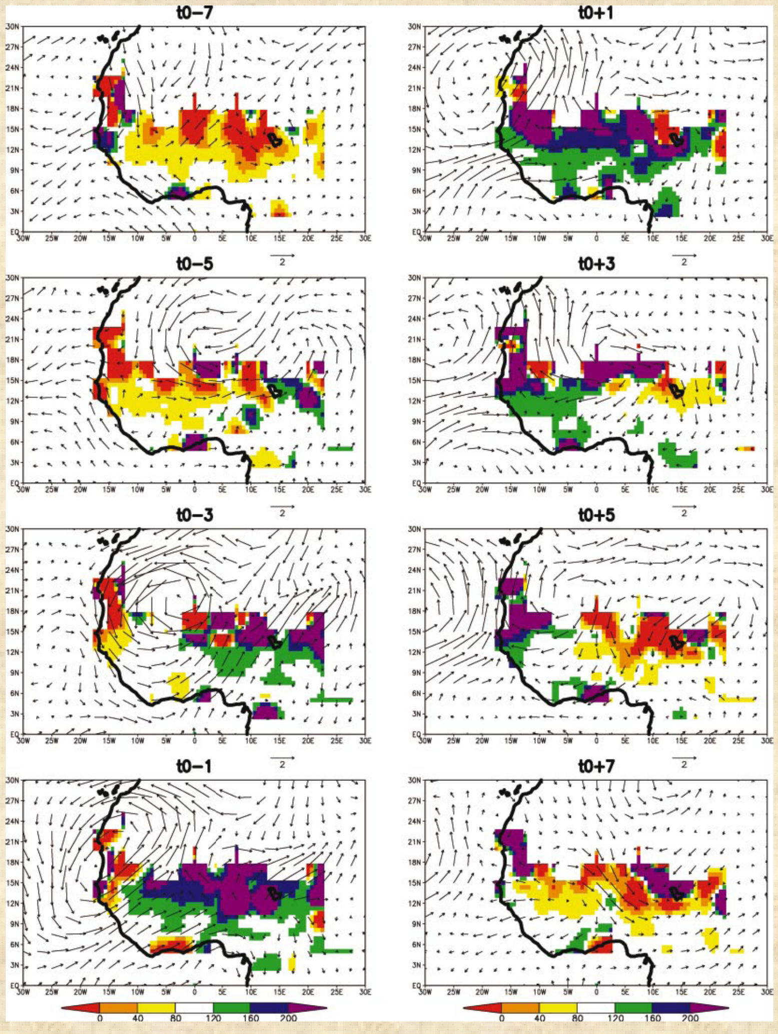
10-25 days

Represent fluctuations within monsoon season

- Enhanced convection over Sahel
- Northward shift of rainbelt
- EAJ decreases
- TEJ increases

• 5 d before: cyclonic circulation ca 20E induces enhanced southerly winds
• Westward propagation and extended area of enhanced monsoon flow
• Followed by reduced convection

Wet – dry sequencies



Sultan et al. 2003 JClim

30-90 day variability and MJO

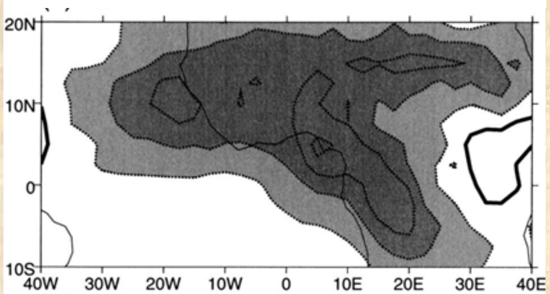
30-90 day variability

- **Earlier works showed very weak or no connection to MJO**

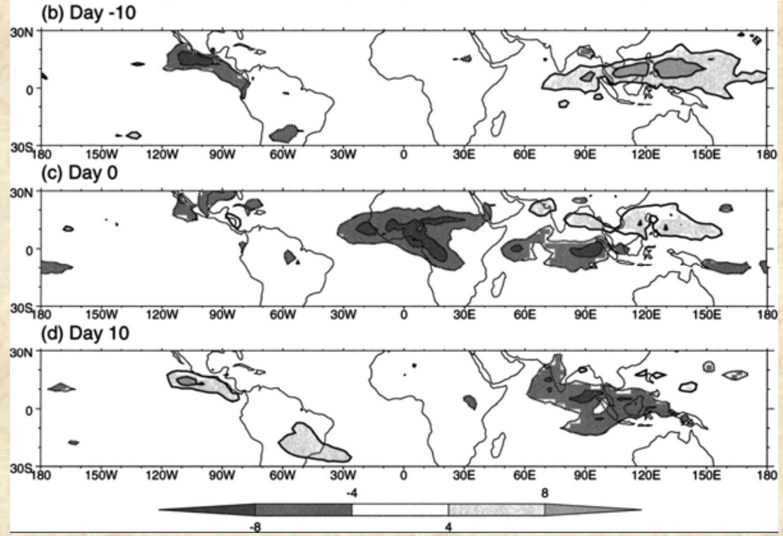
e.g. Knutson et al. 1986, Murakami et al. 1986, Knutson and Weickmann 1987,Maloney and Hartmann 2000, Annamali and Slingo 2001, Wheeler and Weickmann 2001

- **Recent works (Matthews, 2004; Maloney and Shaman 2008) revisited this issue**

EOF1 of 20-200 day filtered OLR , JAS 1975-2000



Lagged regression maps of OLR anom



Matthews, 2004 JClim

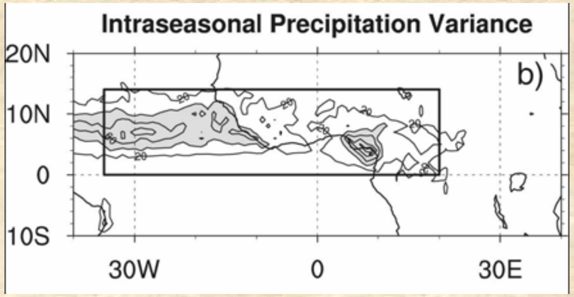
- **First mode: enhanced/suppressed convection over W&eq Africa**
- **10 days before/after: suppressed/enhanced convection in Warm Pool region**

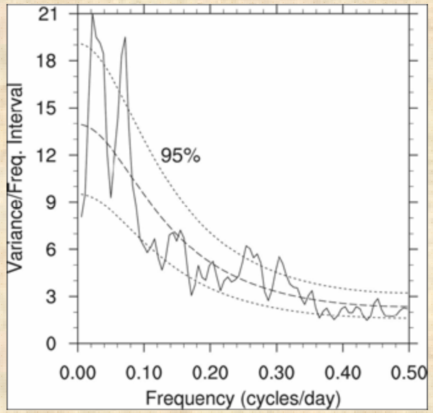
☛ **Kelvin and Rossby waves generated in Warm Pool region meet over Africa and trigger convection**

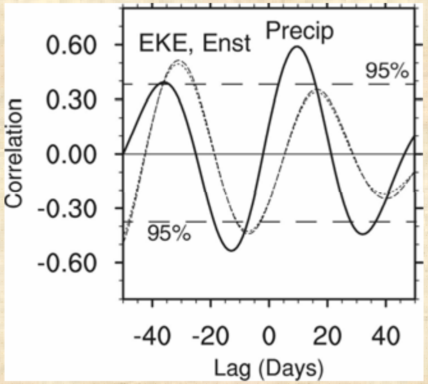
IRI

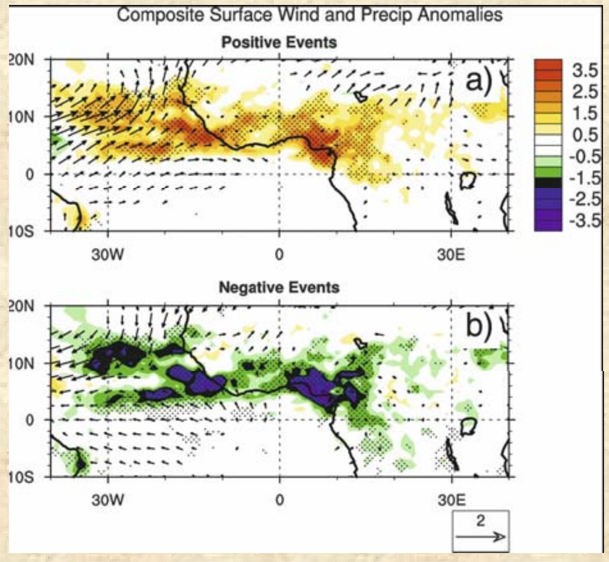
30-90 day variability

- Detected in the spectrum of Jun-Oct filtered intraseasonal rainfall
- (TRMM 1986-2007)
- R~ 0.6 with MJO when RR lags by 10 days (intraseas)
- Composites of enhanced/reduced convection : decreased/increased N trade winds, incr/decr weesterly flow in W Atlantic; no anomalies colocated with main monsoon region

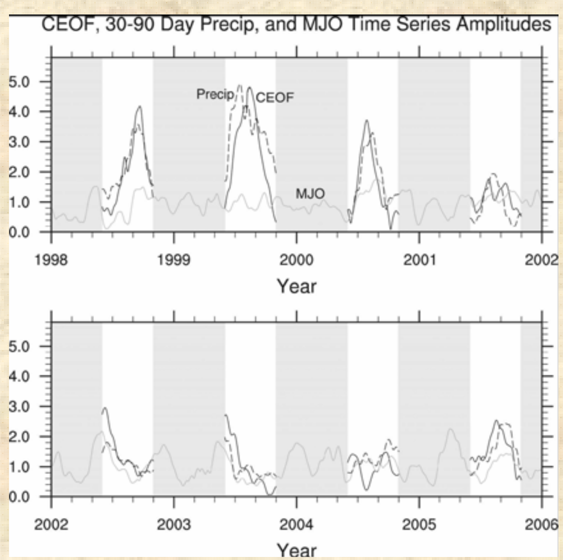








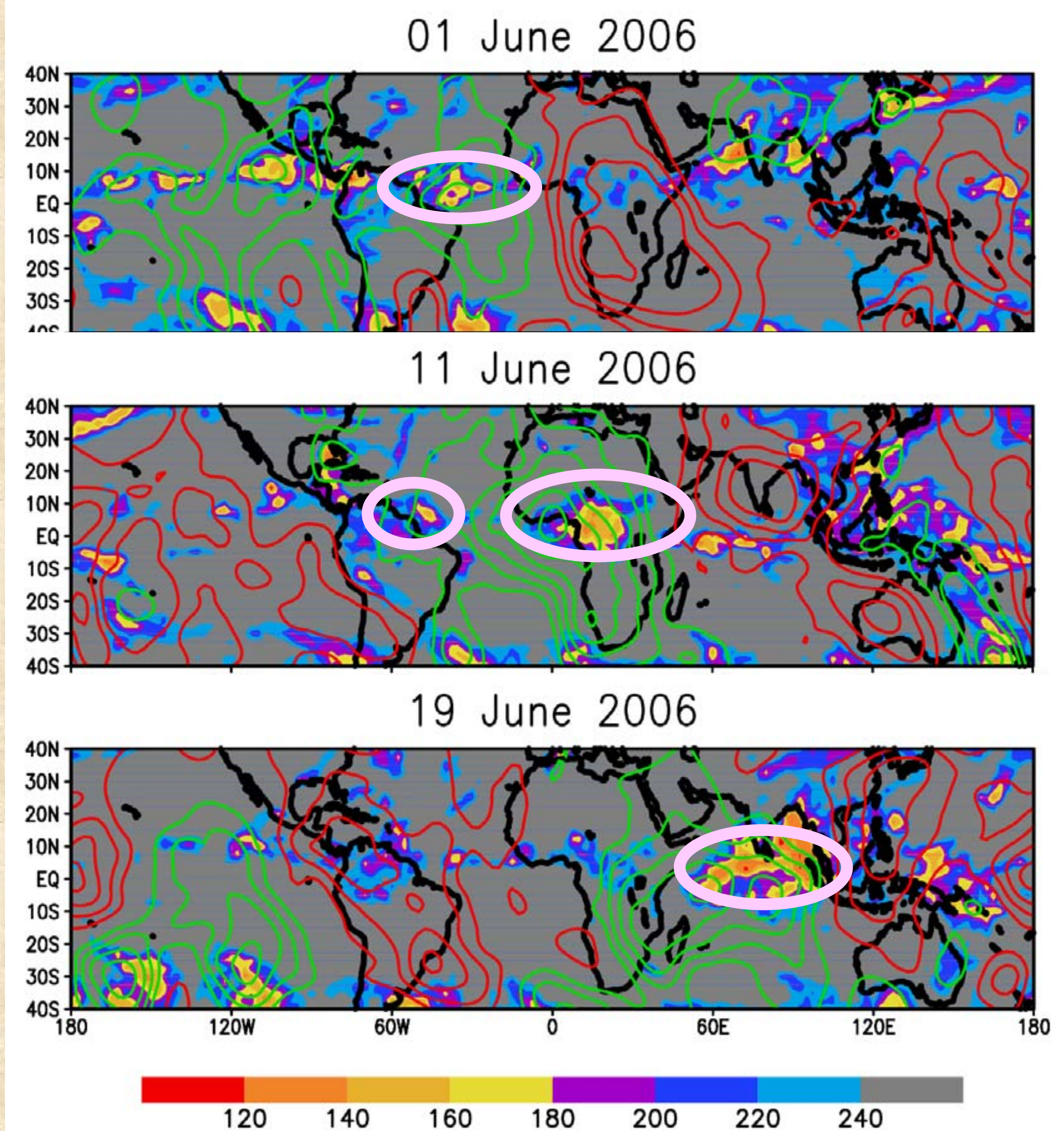
- Significant interannual modulation of 30-90d activity but no correlation with MJO activity



Maloney and Shaman. 2008 JClim

Remote Influence on 2006 onset

OLR & Velocity potential at 200hpa



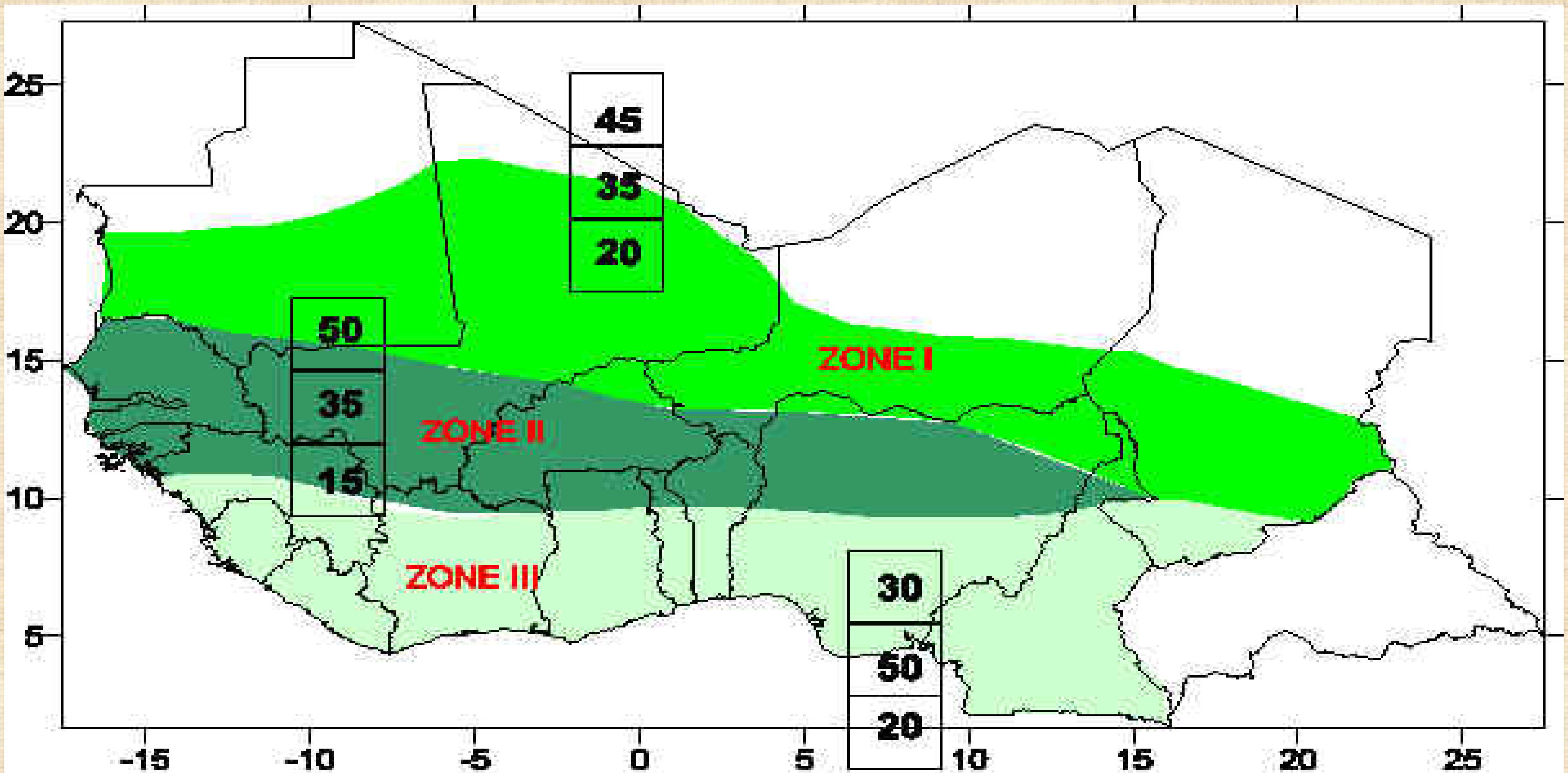
- Propagation of a Kelvin wave around end of June-begining of July 2006 (delayed onset)
- Suppression of the convection over Atlantic-Africa end June – beg July
- Associated wind burst could modufy eq ocean dynamics in the Atlantic

Courtesy S. Janicot & F. Mounier

Forecasting Intraseasonal Characteristics

Seasonal Forecast in West Africa PRESAO

Consensus Rainfall Forecast for JAS2008 issued early June 2008



Zone 1 : Humid ; Zone 2: Very Humid; Zone 3: Normal
NB: Chances of rainfall deficit are negligible

Source: ACMAD

Examples of Use of forecast

Using PRESAO forecast in the food security Early Warning System in Niger

CHRONOGRAMME DES ACTIONS DE PREVENTION DES CRISES ALIMENTAIRES							
Evénement et échelle (Fréquence)	Population potentiel-lement affectée	Impact	I				
			Mai	Juin	Juillet	Août	Sept
Famine à échelle régionale (1 an sur 10)	Millions d'habitants	Survie dépendante de l'aide alimentaire et de l'action des Organisations internationales	Alerte par PRESAO	Confirmation alerte par le FIT. Mobilisation internationale	Prévision ZAR et mission terrain pour dimension catastrophe Planification logistique et mobilisation aide alimentaire	Identification zones les plus vulnérables - Distribution des stocks de sécurité dans ces zones prioritaires	Distribution des stocks nationaux de sécurité Envoi de l'aide alimentaire internationale
Crise alimentaire diffusée dans plusieurs pays (1 an sur 5)	Centaines de milliers d'habitants	Survie dépendante de l'aide alimentaire internationale	Pre-alerte par IPRESAO	Alerte par le FIT.	Confirmation des alertes par ZAR - Front de Végétation	Suivi des zones à risque par biomasse et FV - Prévision des rendements (DHC-SISP) Mission terrain Mobilisation aide alimentaire internationale	Identification des zones et groupes vulnérables Mobilisation stocks nationaux leur distribution dans les zones les plus vulnérables
			Suivi des marchés à la suite de la campagne précédente				
Crise alimentaire dans zones de différents pays (1 an sur 2)	Dizaines de milliers d'habitants	Provision alimentaire par système national à travers l'aide alimentaire et le commerce régional		Pré-alerte par le FIT.	Alerte par ZAR - et Front de végétation	Suivi des zones à risque et confirmation des alertes par DHC - SISP et d'autres modèles (Biomasse Front de végétation)	Identification des zones vulnérables Mobilisation des stock nationaux de sécurité
			Suivi des marchés à la suite de la campagne précédente				Suivi des marchés

Courtesy Adamou Aïssatou SITTA, DMN Niger

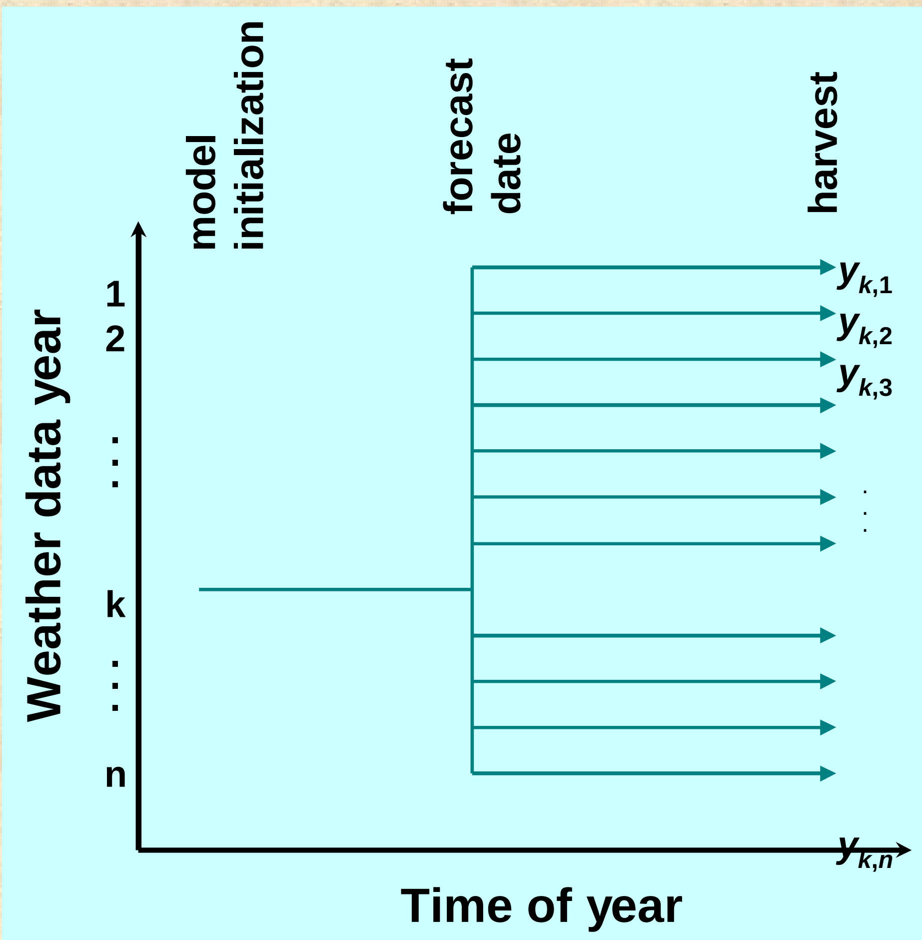
Climate Prediction Information relevant for Agriculture

- Farmers' climate information needs:
  - Local spatial scale, lead time,temporal resolution, adequate, well-characterized accuracy
  - **Interpret as agricultural impacts, management responses**
- Information needs for market, early warning:
  - Aggregate scale, Information useful at shorter lead time
  - Institutional decision making might require higher probability threshold for action
- Climate-Crop Model Connection Challenge: ***Scale mismatch***
  - Crop models: homogeneous plot spatial scale, daily time step (w.r.t. weather)
  - GCMs: Spatial scale 10,000-100,000 km^2, sub-daily time step, BUT... Averaging within GCM distorts daily variability
  - Temporal scale problem more difficult than spatial scale

Courtesy J. Hansen, IRI

Incorporating uncertainty in yield prediction

- Estimate yields by simulating with antecedent weather for a current (*k*=*n*) or hindcast year, sample weather for remainder of season from all other years
- past years similar to the predicted seas total
- weather generator ev. constrained by seas fcst
- other daily scenarios

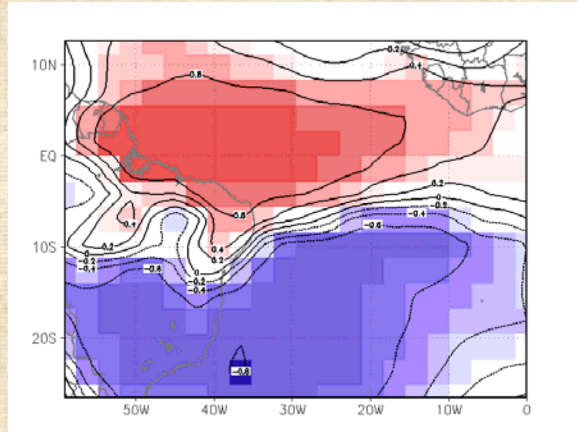


Courtesy J. Hansen, IRI

Spatial downscaling

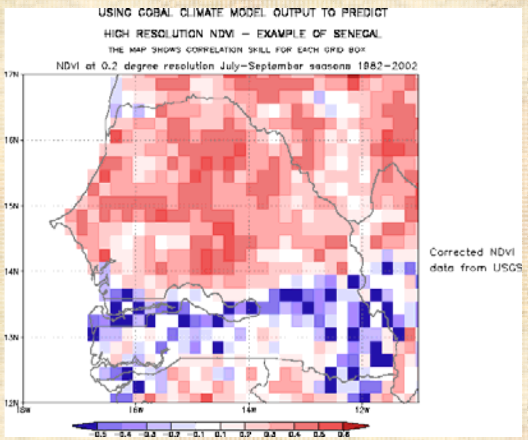
Vegetation – good proxy for mapping/forecasting health risk (e.g. Rift Valley Fever) or yields

Using low level (925hPa) wind EOF
in the tropical Atlantic
from seasonal GCM forecast (T42 ~2.8x2.8)
as predictor for seasonal NDVI (USGS 0.2x0.2).

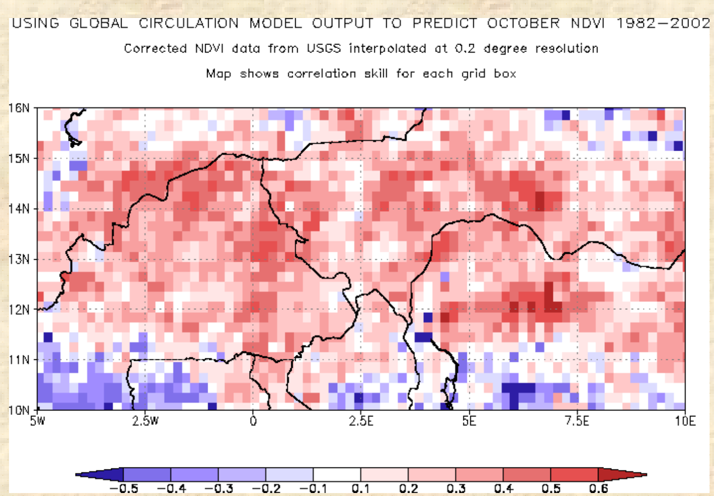


Cross-validated correlation btwn observed
and predicted NDVI, 1982-2002

JAS



Oct

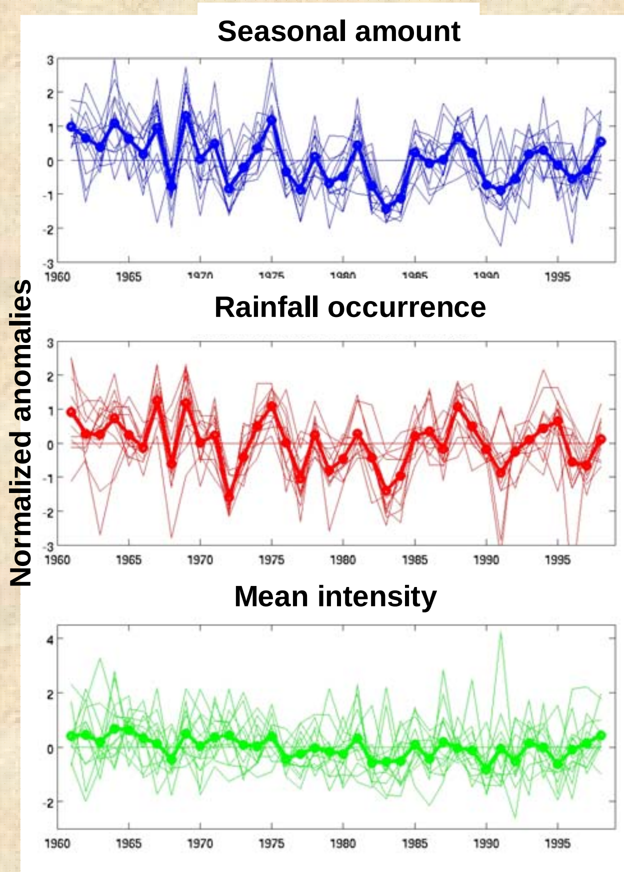


Spatial variations in skill may reflect
- variations in climate predictability
- variations in climate-NDVI coupling

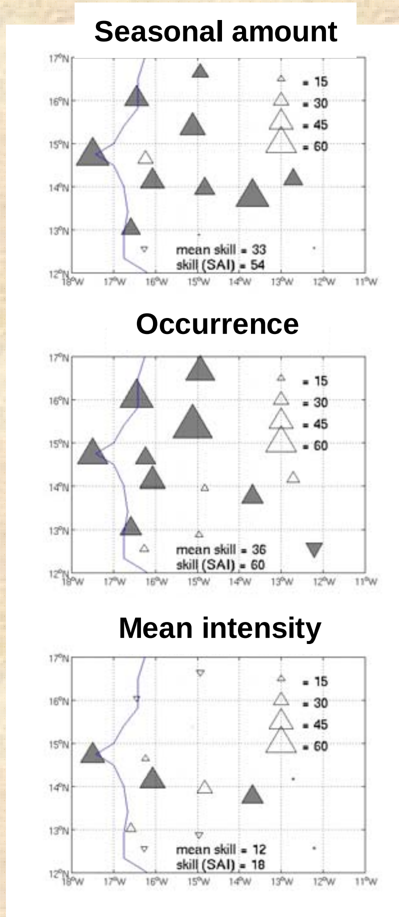
Courtesy O. Ndiaye, IRI

Temporal downscaling

Which characteristics are predictable ? Senegal JAS Daily rainfall, 13 stations,1960-1998



Correlation between observed and MOS corrected GCM time series



Highest predictability Occurrence

- At individual station scale equal contribution of occurrence and intensity to seasonal totals ~30-40%
- Stronger consistency of occurrence and seasonal total in individual station with the regional index

Moron et al. 2007 JClim

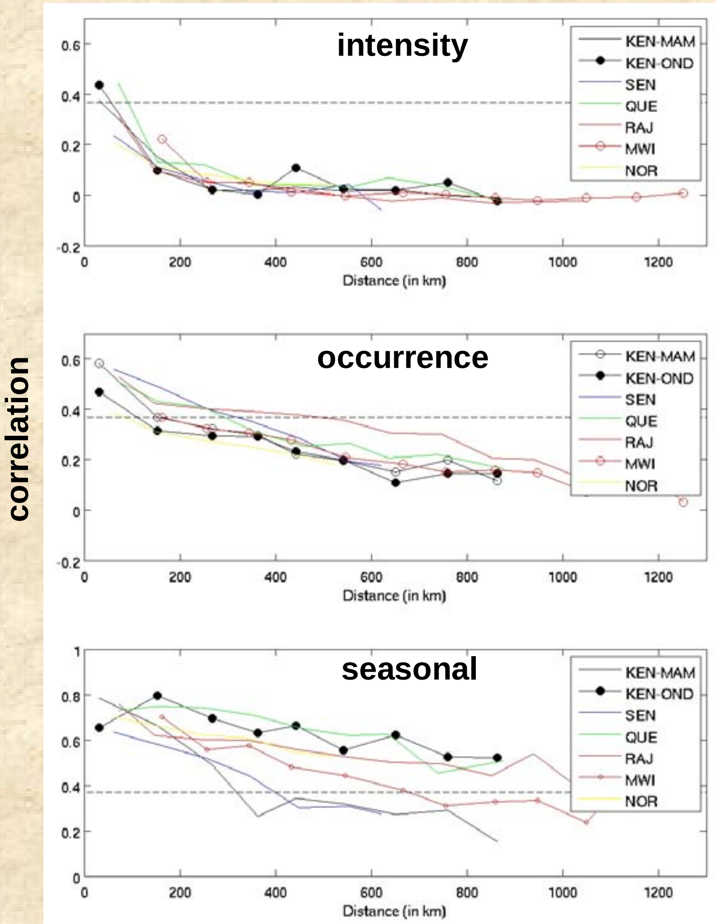
IRI

Temporal downscaling

How robust is this result ?

7 tropical regions, different seasonal cycles, different network density…

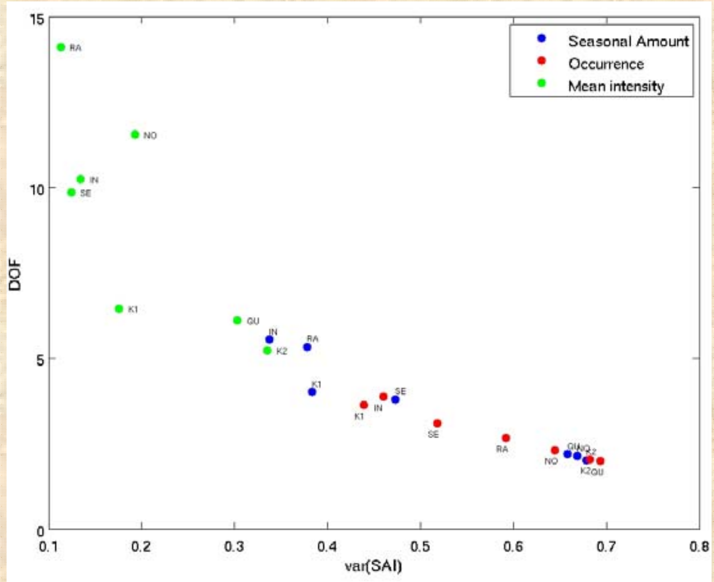
Correlation as f(distance)



Rapid decrease in covariance with distance in all regions

Quasi linear decrease, consistent among regions

Higher spatial consistency at seasonal scales
Higher spread accross regions



Number Degrees of freedom vs Variance of regional index

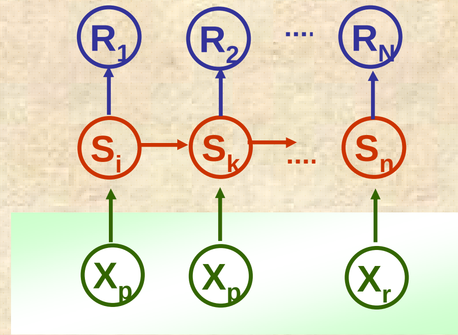
Intensity – higher DOF, lower var

Moron et al. 2007 JClim

Temporal downscalling

Hidden Markov Model

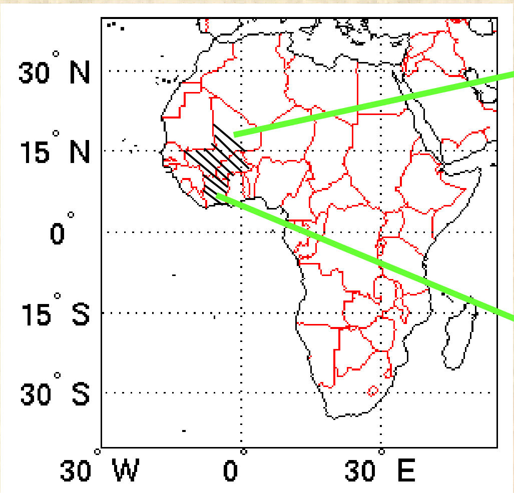
- Daily rainfall in a spatial network described by a few weather states + probabilistic link between state and rainfall in each location
- Rainfall observed at t_0 independent of any factor prior to t_0; markovian transitions between states
- **non-homogeneous HHM** transition matrix non stationary in time – influenced by external predictors

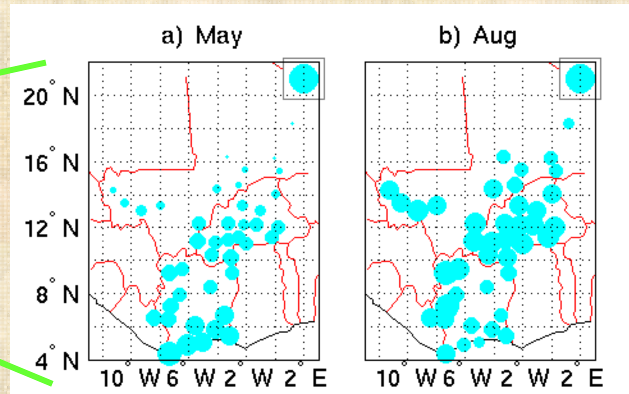


External predictors: SST, GCM outputs, local conditions etc

Central West Africa

- 42 stations,
- daily data 1951-98
- May-October
- **Daily occurrence**



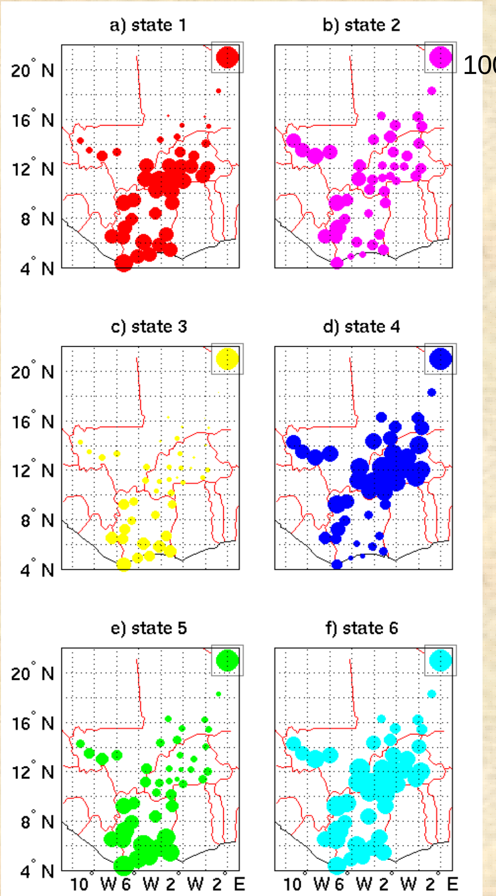


Trzaska et al, in progress

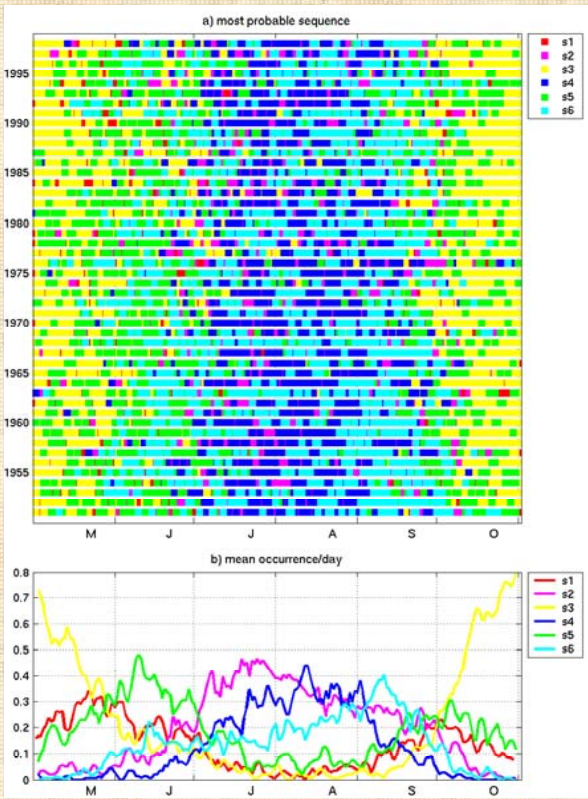
Temporal downscaling

6-state decomposition

Rainfall probability associated with each state

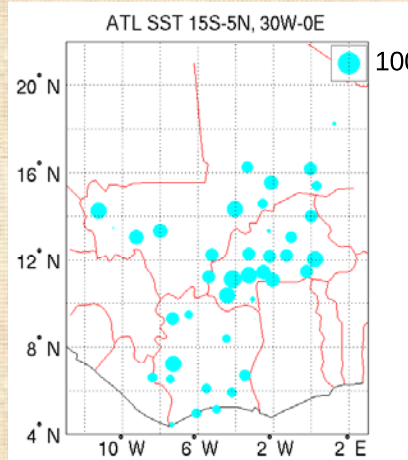


Mean seasonal cycle Most probable sequence of states



Correlations btwn nb of rainy days observed and predicted using Non-homogenous HMM and SST index (e.g.Atl, Pacif)

r up to 0.7



- **3 pre-season & 3 peak states**
- **HMM captures a wet state in spring and a dry spell during the peak**

Trzaska et al. in progress

Temporal downscaling

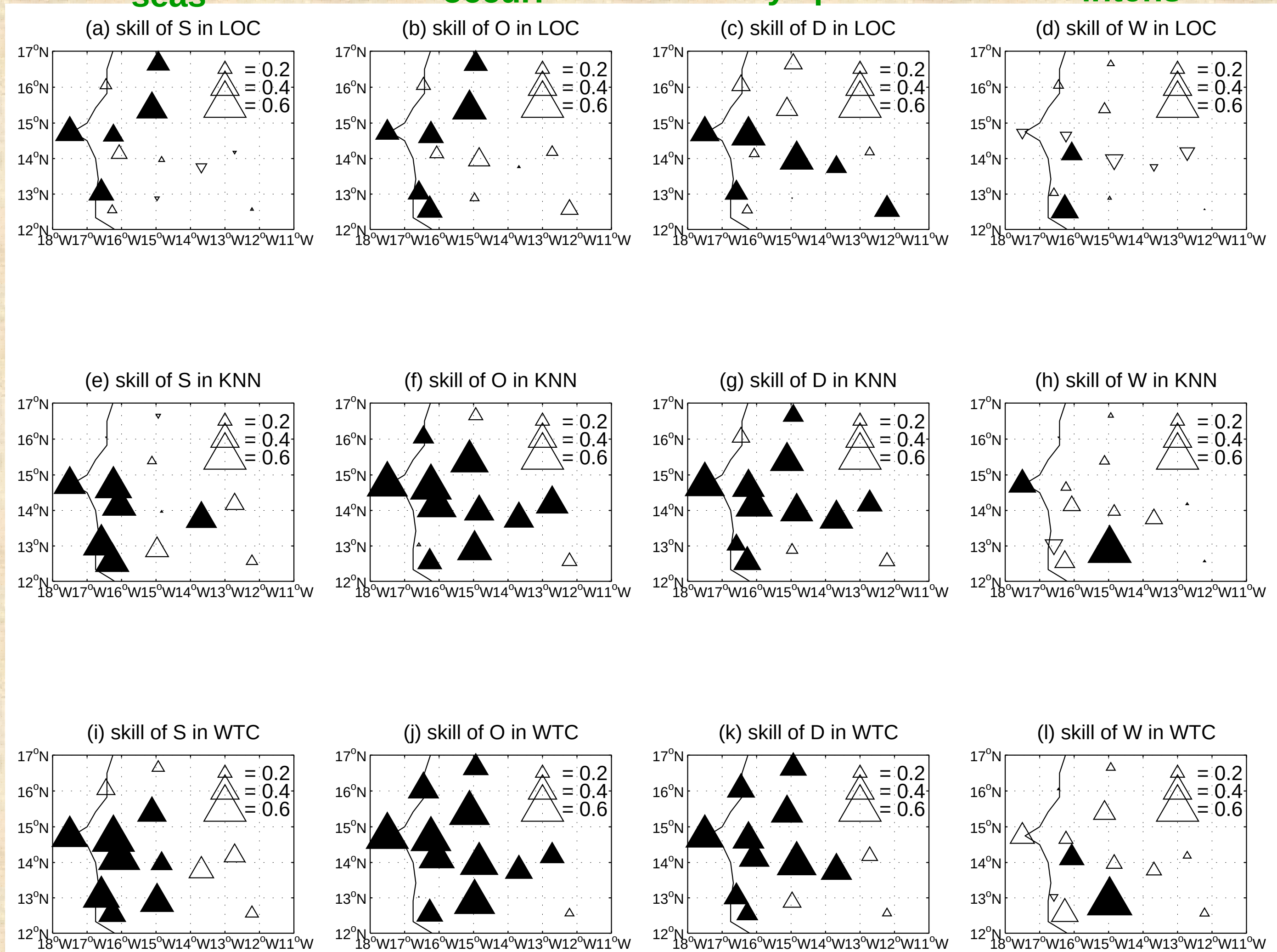
Correlation btwn observed and simulated time series in each station

seas | occurr | dry spell | intens

LOC

KNN

WTC



Overall low skill for intensity

Better results with methods based on atmospheric fields

Moron et al. 2007 JClim

Summary

- Strong decadal component and multiple SST influences make the seasonal forecasting of West African Monsoon challenging

- Several subseasonal scales of variability
  - 3-5&6-9d - associated with AEW
  - 10-25d – active/break cycles
  - 30-90d – associated with MJO => some predictability

- Onset and dry spells - sub-seasonal features important for end-users, esp. agriculture and food security, some hope for predictability

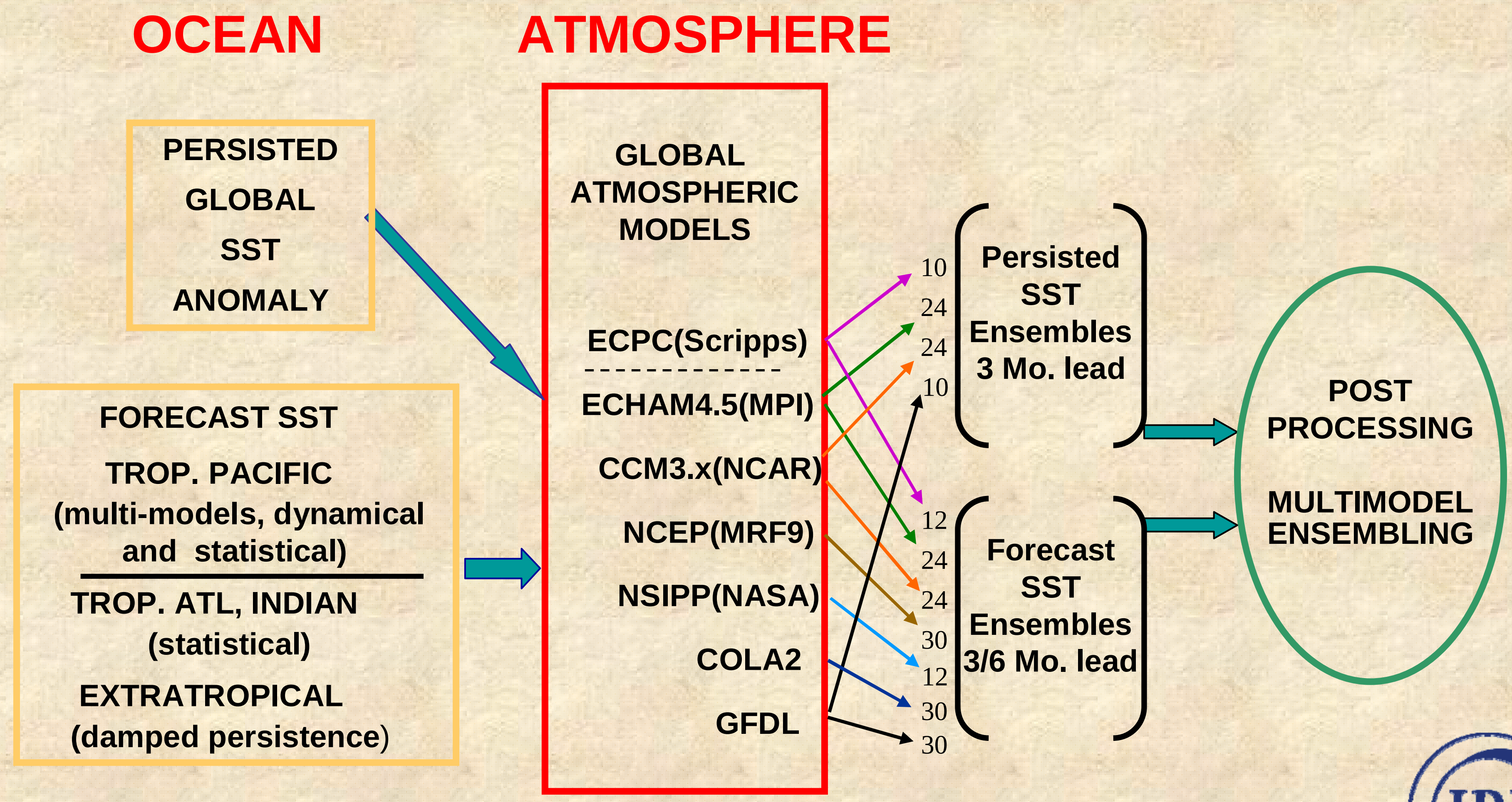
- Numerous improvements in understanding and simulation WAfr Monsoon are expected from recent AMMA (African Monsoon Multidsciplinary Analysis) programme (2004-2009)


Thank you

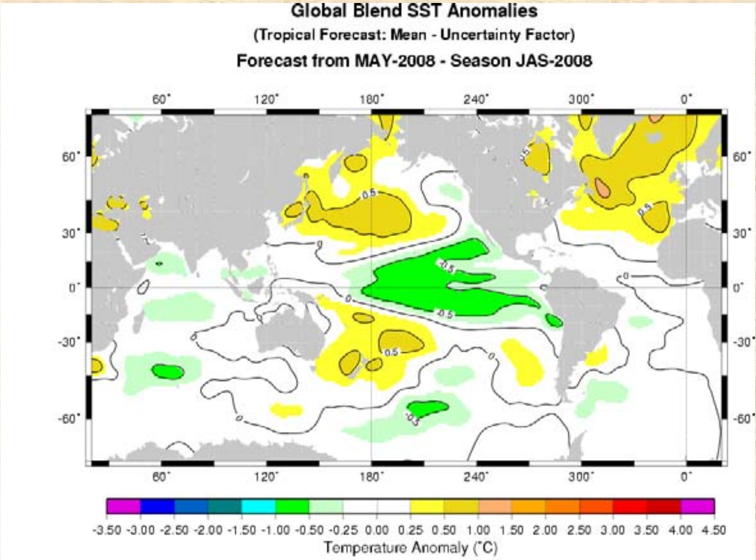
About the IRI

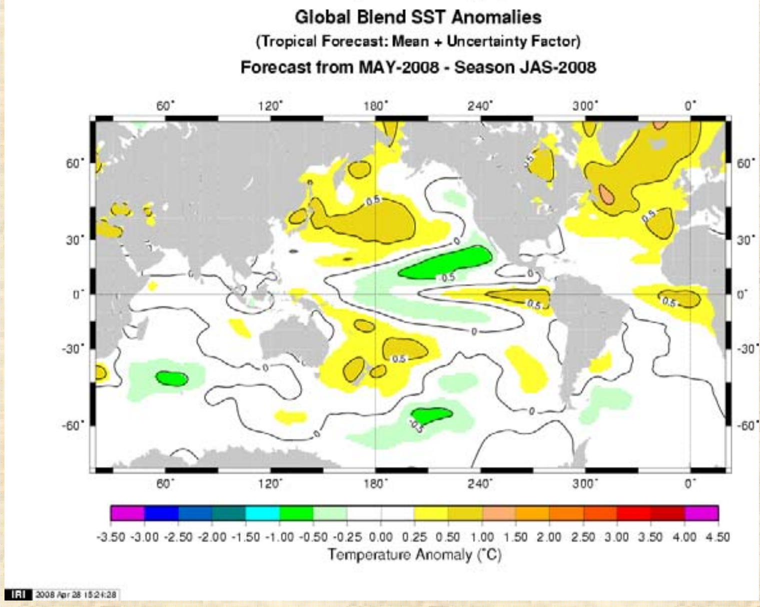
IRI dynamical Forecast System

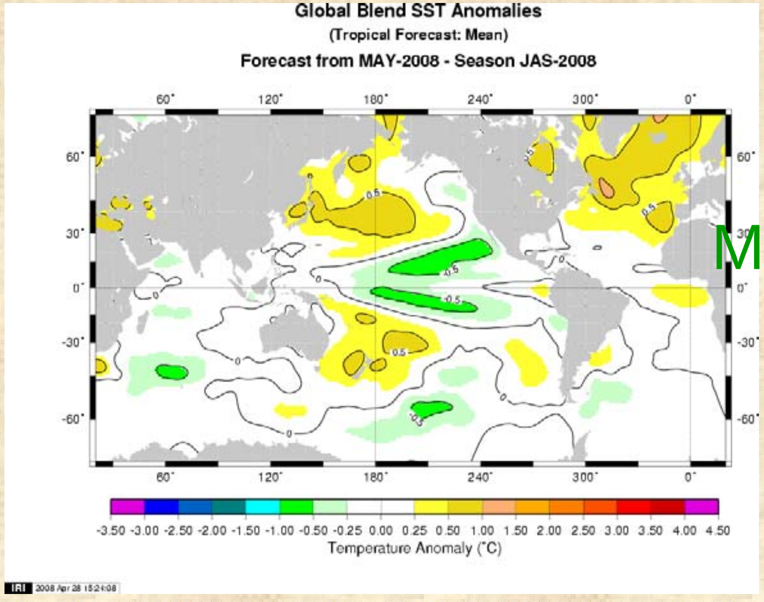
2-tier system



SST Scenarios







MEAN

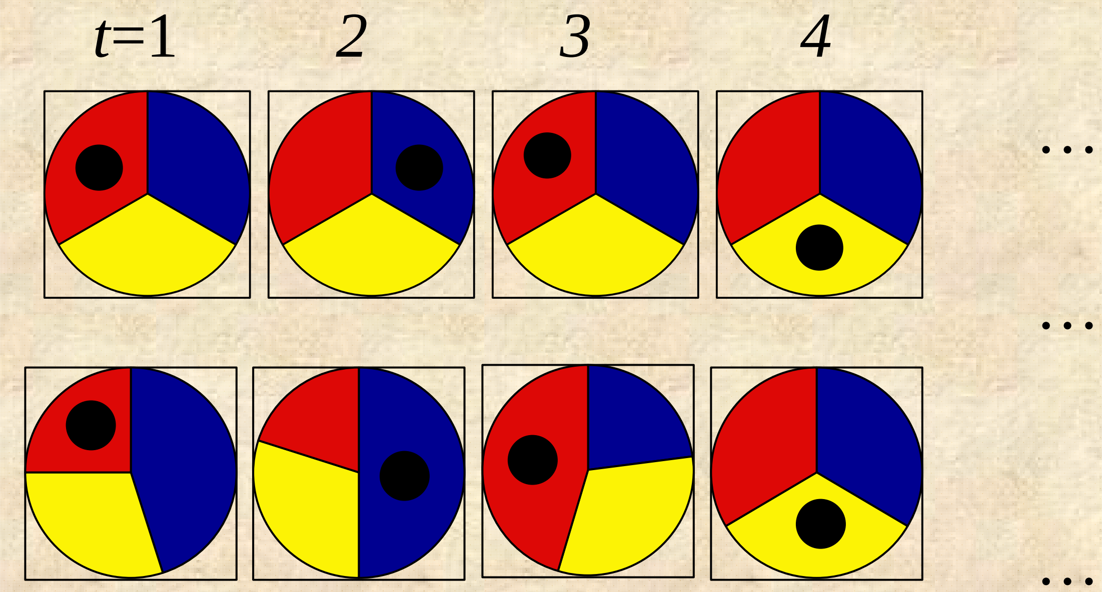
JAS 2008
SST forecast

Model Outputs postprocessing
Combining based on model

- **Bayesian Model Combination**

Climo Fcst
"Prior"

GCM Fcst
"Evidence"



Combine "prior" and "evidence" to produce weighted "posterior" forecast probabilities, by maximizing the likelihood.

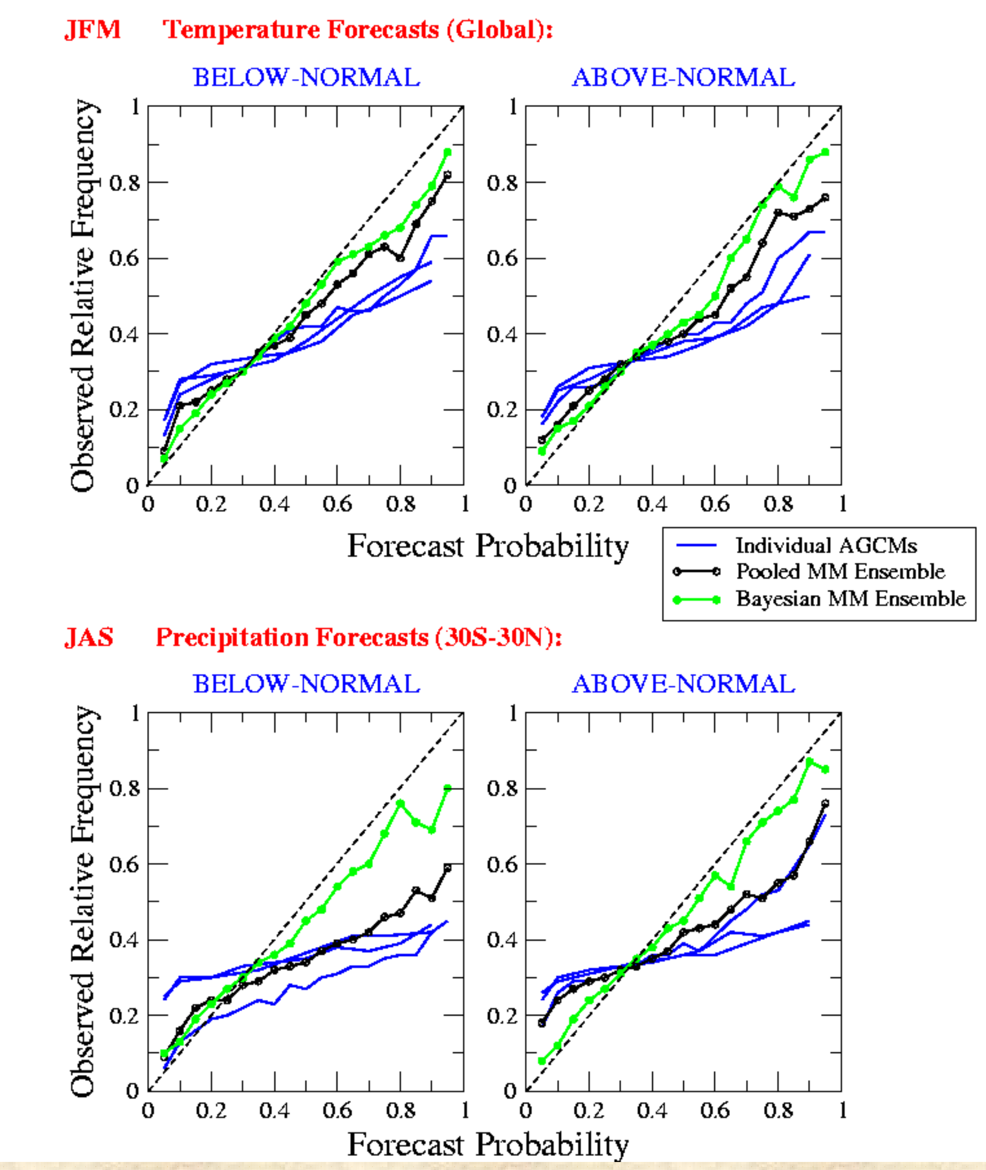
(Rajagopalan et al. 2001, MWR; Robertson et al., 2004, MWR)

Multimodel Ensemble Verification

Major Goal of Probabilistic Forecasts

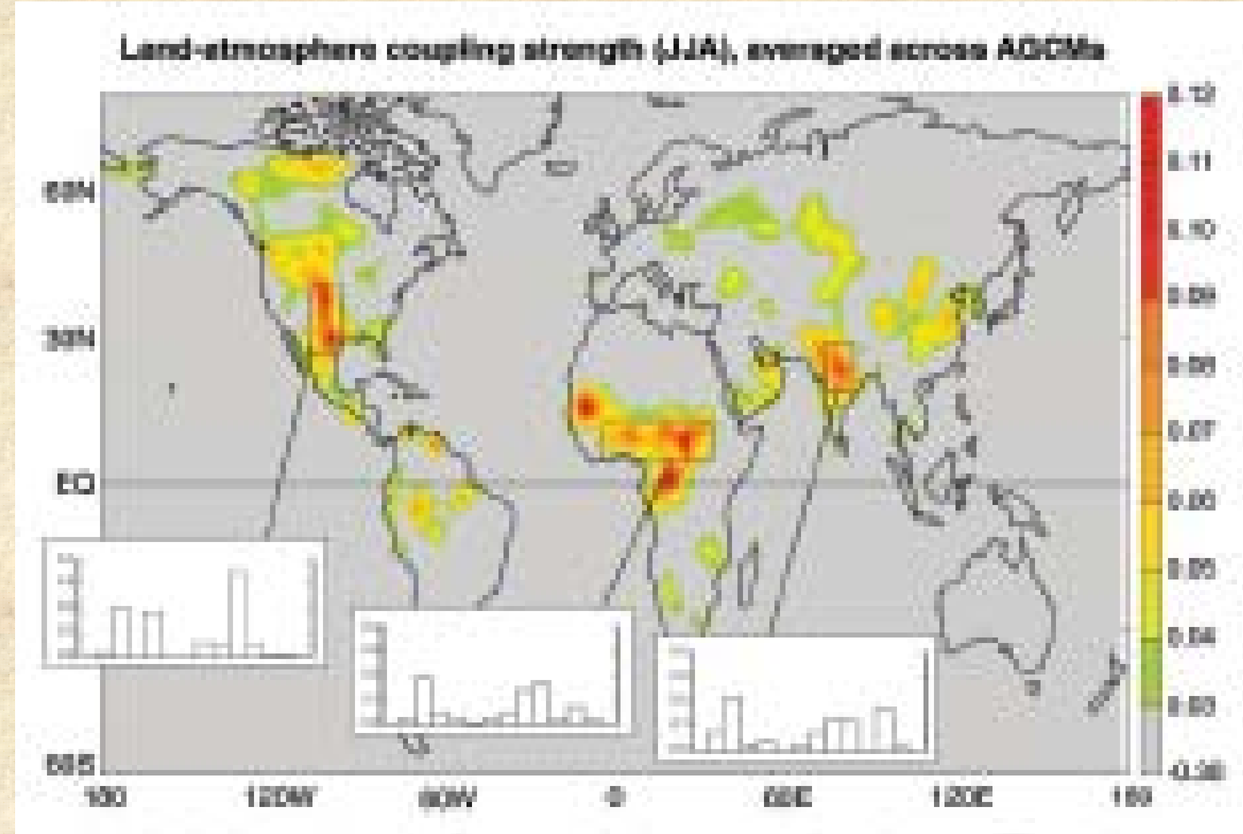
Reliability!

Forecasts should "mean what they say".



Courtesy Tony Barnston

WAfr Monsoon – Land surface



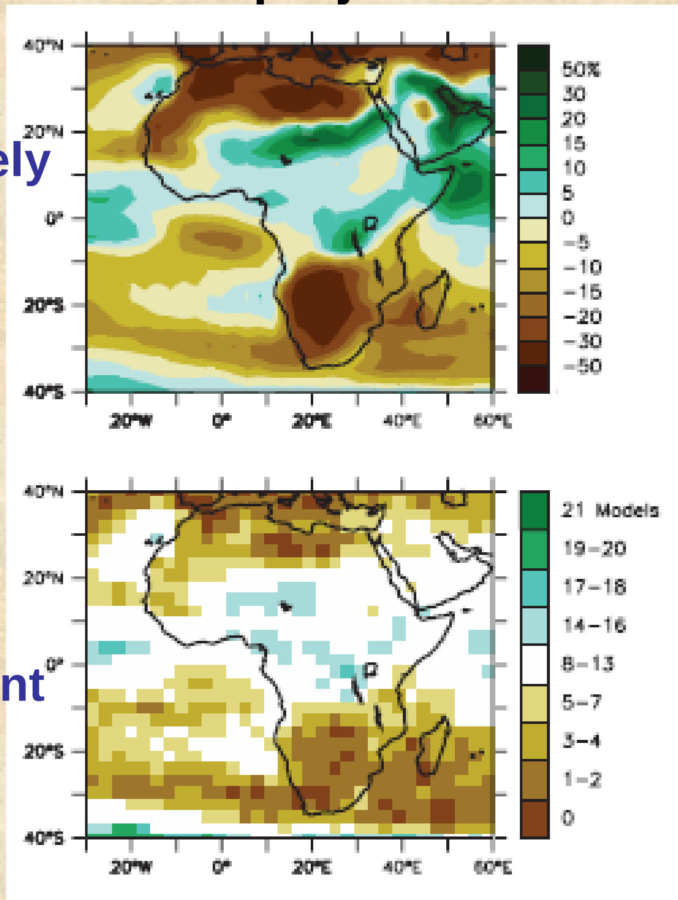
Koster et al. 2004, Science

WAfr Monsoon – Climate Change

IPCC rainfall projection in JJA

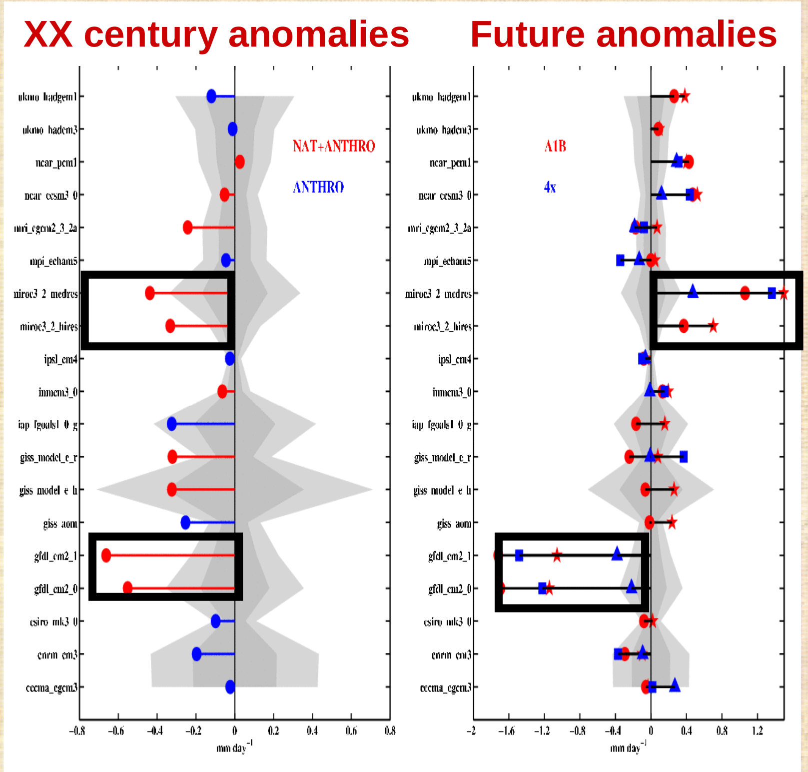
most likely change

model agreement



IPCC 2008

Inconsistency between models



Biasutti and Giannini, 2006

Models that reproduced late XX century drying disagree in the future

IRI