The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1968-39

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

A Gill-Matsuno-type response explains the tropical Atlantic-Indian monsoon teleconnection

KUCHARSKI Fred

the Abdus Salam International Centre For Theoretical Physics
Earth System Physics Sect.Physics of Weather and Climate Group
Strada Costiera 11, P.O. Box 586
34014 Trieste
ITALY

A Gill-Matsuno-type response explains the tropical Atlantic-Indian monsoon teleconnection

F Kucharski, A Bracco, JH Yoo, F Molteni, A Tompkins, L Feudale, P Ruti, A Dell'Aquila

Presenting Author: Fred Kucharski, Abdus Salam ICTP, Trieste, Italy

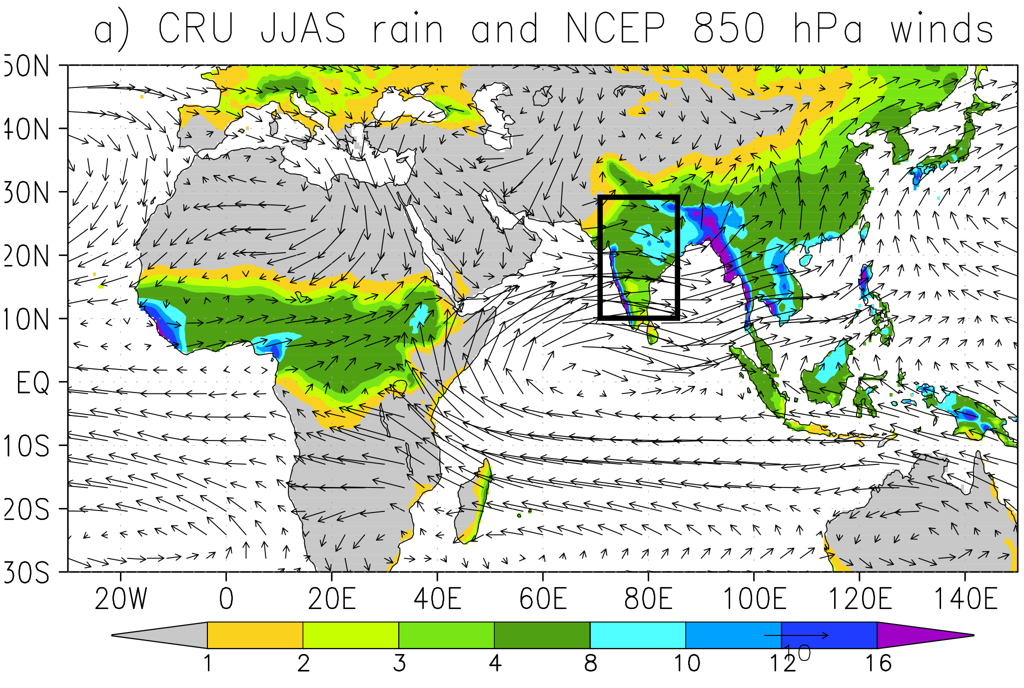
Motivation

The tropical Atlantic and in particular the Gulf of Guinea coast SSTs has a strong influence on the surrounding South American and African monsoon systems (Giannini et al. 2003, Vizey and Cook 2001, Doyle and Barros 2002, Barreiro and Tippmann 2008). On the other hand Rodriguez de Fonseca in a previous talk (and in a paper submitted to Nature Geoscience) showed that the tropical Atlantic may have far reaching influences on the Pacific region. Here we will analyze the *off-equatorial* signature in the Indian monsoon region of the same response. It is as well shown that this tropical Atlantic-Indian Monsoon teleconnection may have contributed to the weakening of the ENSO-Indian monsoon relationship observed in the recent decades, which has spurred many scientific papers (Krishna-Kumar 1999, Krishnamurty and Goswami 2000, Gershunov 2001, Kinter 2002, Chang et al 2001, Krishnan and Sugi 2003, Annamalai et al. 2005, Wang et al. 2008,Webster et al. 1999, Saij et al. 1999 and probably many more……..)

Outline

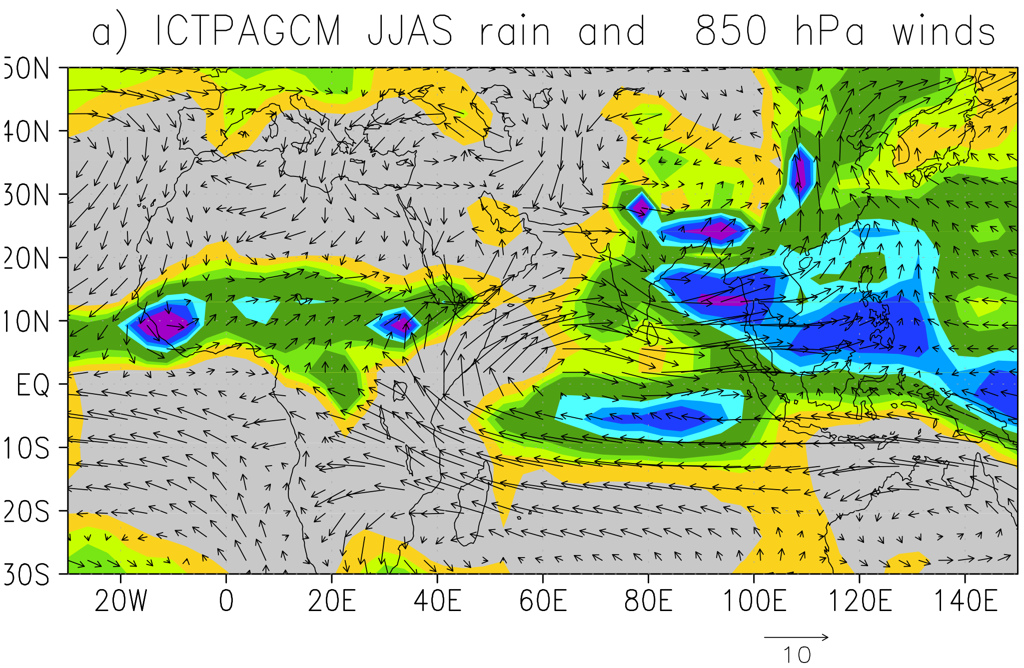
1. **Observational evidence of the tropical Atlantic-Indian monsoon teleconnection**
2. **Reproduction of teleconnection with numerical models and proposed mechanism**
3. **Relevance for ENSO-Indian monsoon decadal teleconnection changes**
4. **Conclusions**

Results are published in Kucharski, Bracco et al., 2007, J Climate, 20, 4255-4266, Kucharski, Bracco, et al., 2008a, GRL, 35, L04706 and Kucharski et al, 2008b, QJRMS, submitted.



CRU JJAS rain and NCEP/NCAR 850 hPa re-analysis winds

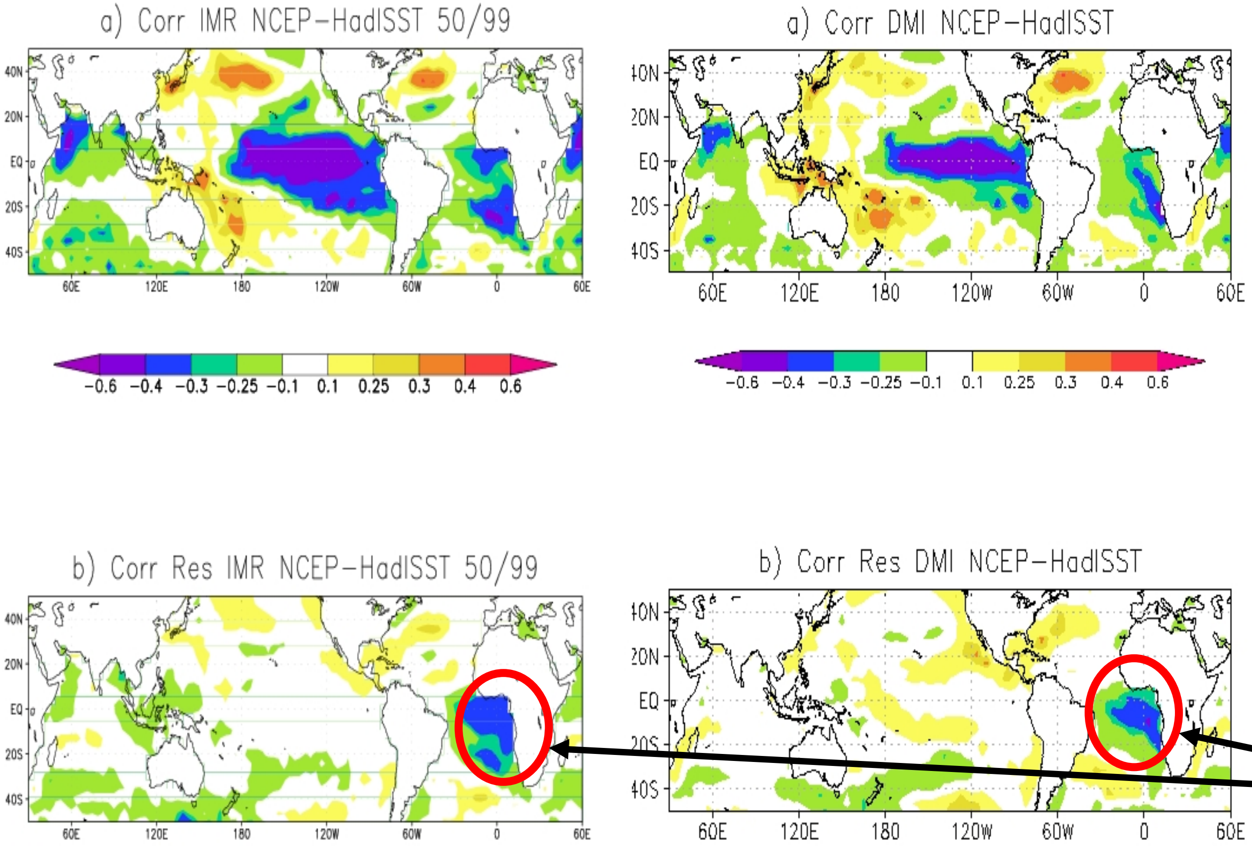
Definition of IMR: JJAS mean rainfall in the region 70 to 85E, 10 to 30 N, over land points only.



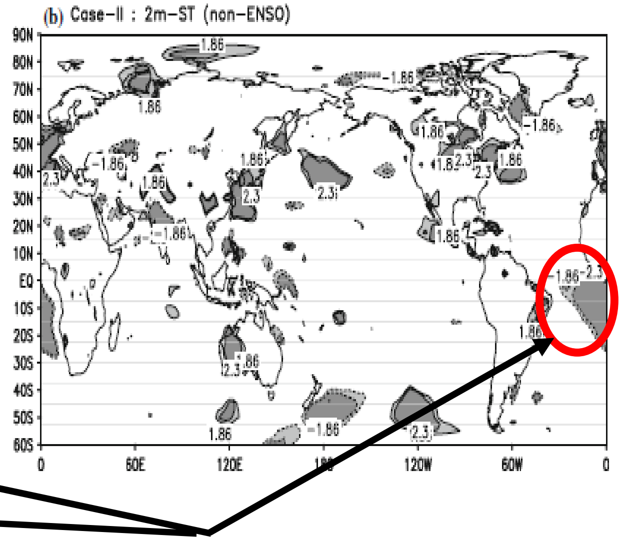
NCEP DMI index (u850[5-15N,40-80E]-u850[20-30N,60-90E])

ICTPAGCM JJAS rain and 850 hPa winds

Correlations of IMR, DMI and IMR_res, DMI_res with SSTs



Yadav, Clim Dyn, 2008, Fig. 5b, central Indian Rainfall-SST correlations in non-ENSO years



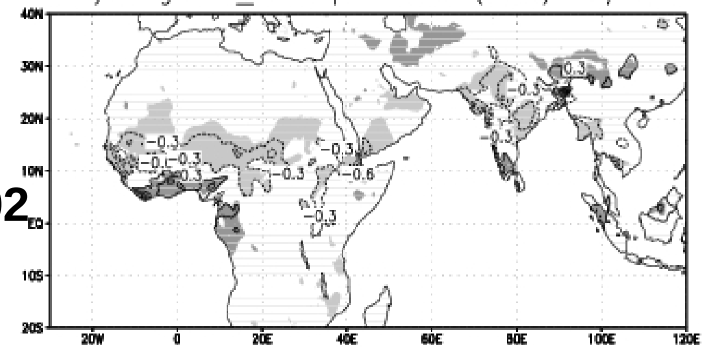
Largest correlations of Residuals with south Tropical Atlantic SSTs

Define deviations from IMR as IMR_res = IMR-IMR_ENSO,
where
IMR_ENSO(t) = b NINO34(t), same with DMI

Regression of rainfall onto an STA_res index (average SSTs in 30W-20E, 20S-0N)

a) Reg STA_RES−prec JAS (CRU) 50/02

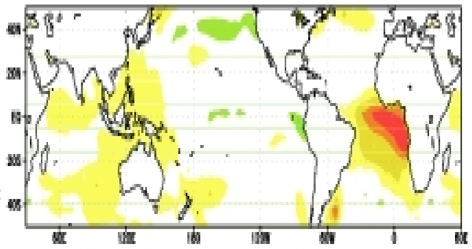
CRU 1950-2002



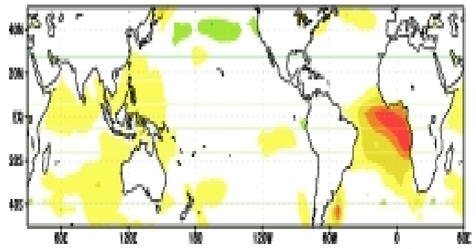
STA-Teleconnections

50/02

a) Reg STA−HadISST 50/02

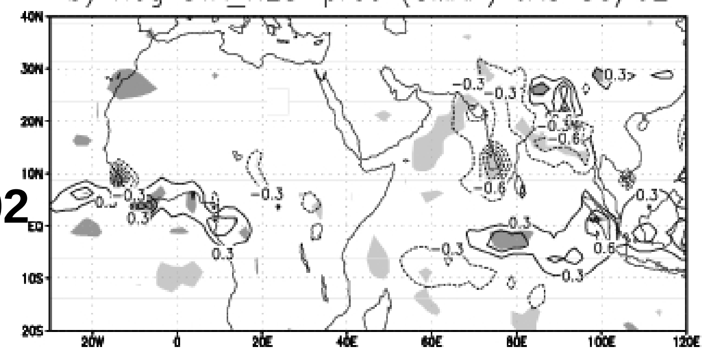


b) Corr Res STA−HadISST 50/02



b) Reg STA_RES−prec (CMAP) JAS 80/02

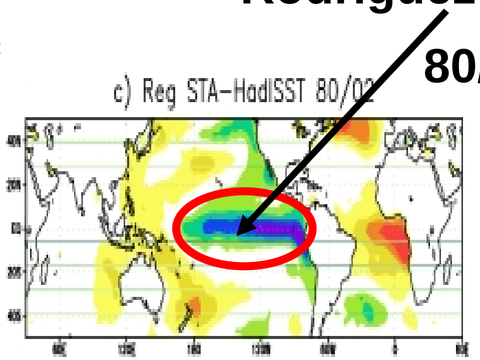
CMAP 1980-2002



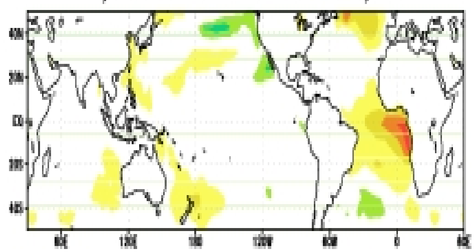
Co-variability with ENSO (as presented by Rodriguez de Fonseca)

80/02

c) Reg STA−HadISST 80/02

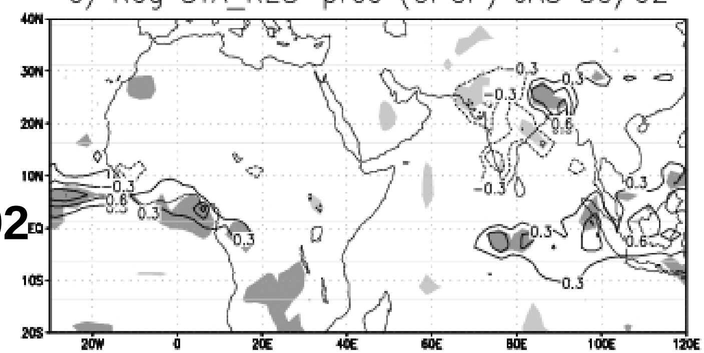


d) Corr Res STA−HadISST 80/02



c) Reg STA_RES−prec (GPCP) JAS 80/02

GPCP 1980-2002



Model set-up, experimental design

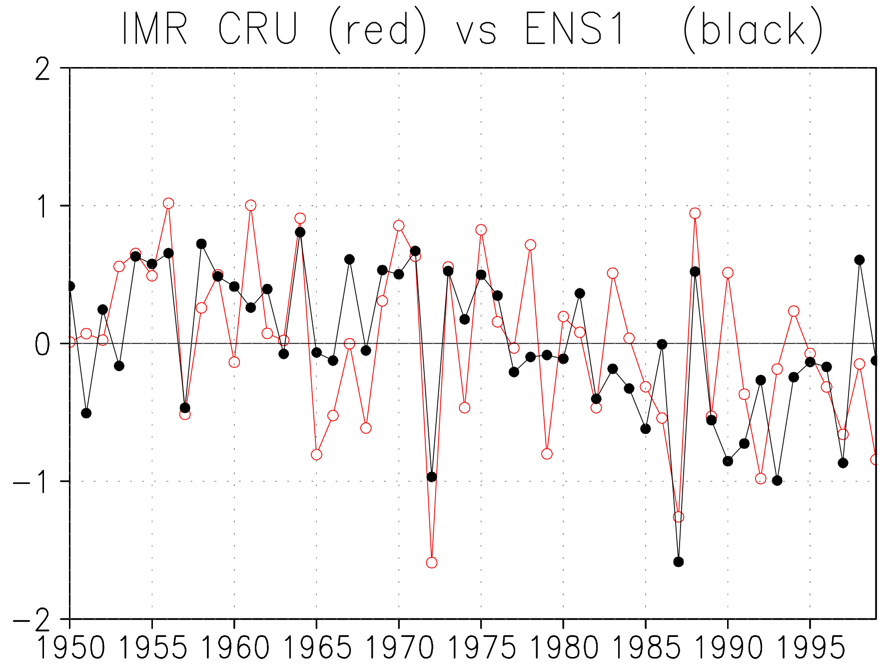
Two sets of integrations were used to analyze the Tropical Atlantic-Indian monsoon teleconnection:

1. Regionally coupled model
Here observed SSTs are prescribed everywhere to force the ICTP-AGCM apart from the Western Pacific and Indian Ocean (Africa to 140 E, 35S to 30N). Here the AGCM is coupled model to the MICOM OGCM. We perform an ensemble of 10 runs from 1950 to 1999.

2. Idealized AGCM integrations
Here a constant, idealized SST anomaly is prescribed in the tropical Atlantic

Timeseries of IMR:
SPEEDY (IO coupled) vs CRU

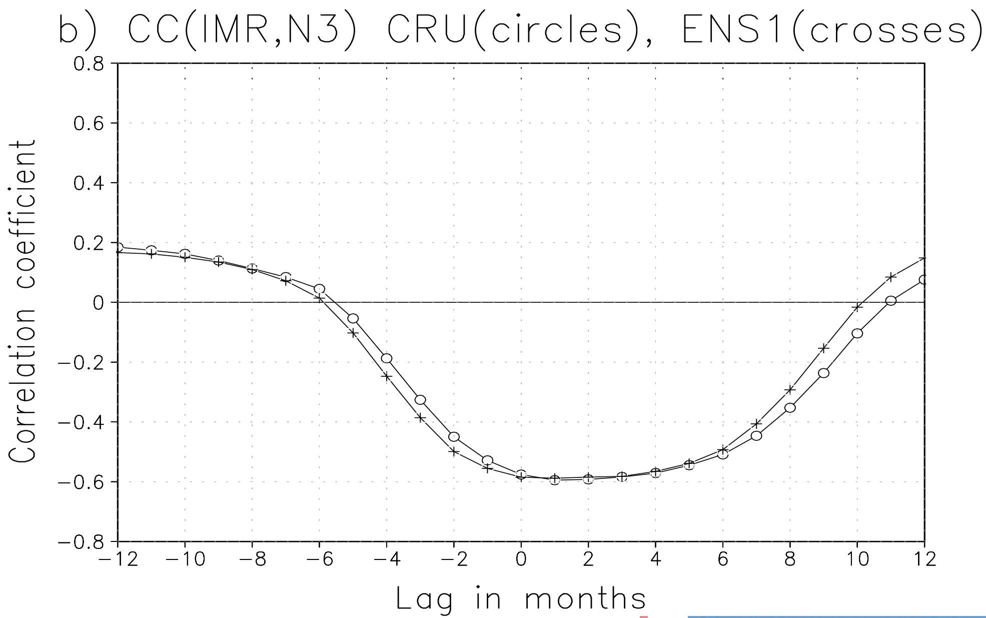
in mm/day



Indian Monsoon rain:
Mean rain (JJAS) in land-points of box:
70-95E, 10-30N

Corr(CRU,speedy_iocoup) = 0.63

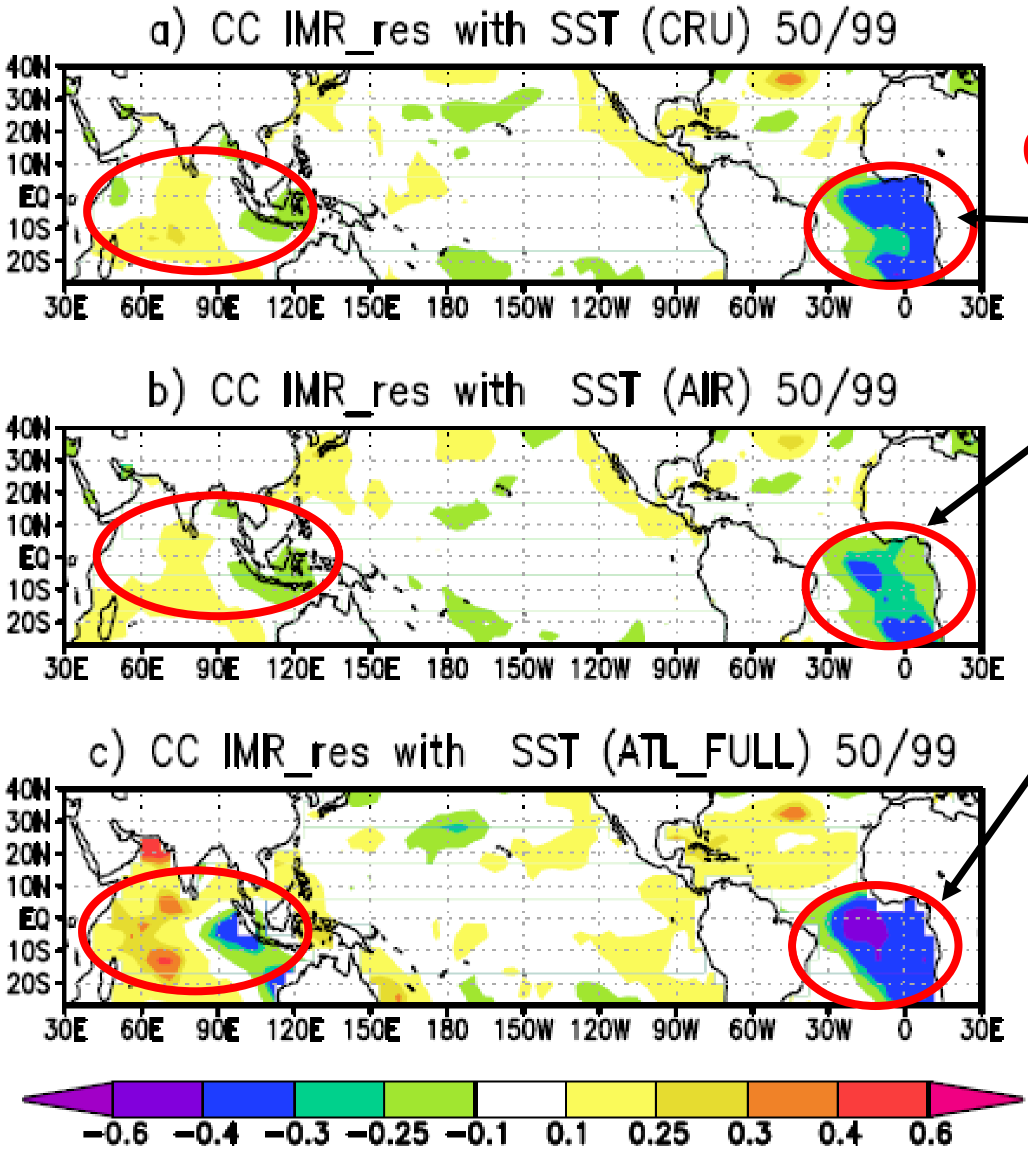
Lagged correlation between IMR (JJAS) and 4-month average NINO3 index for IO_coup



Support for Goswami's Hypothesis the that IMR leading ENSO is do to phase locking of ENSO in autumn/Winter

Correlation of IMR_res with SSTs

Does our regionally coupled model reproduce the IMR_res-Tropical Atlantic correlations?



CRU

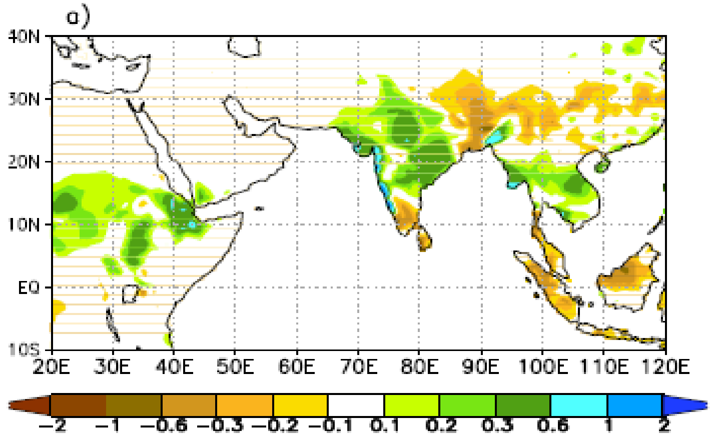
Strongest CC in tropical Atlantic, but as well signal of IOZM

AIR

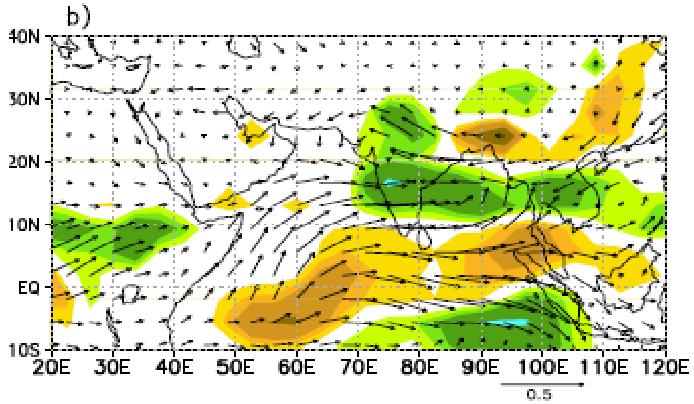
ICTPAGCM

Results from the regionally coupled model experiments

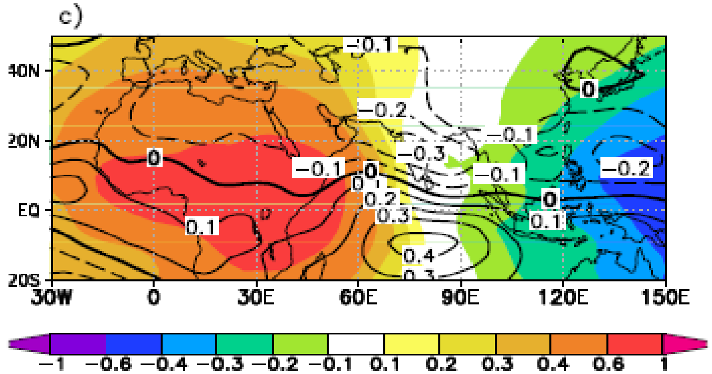
Regression of a negative tropical Atlantic Index onto precipitation, Surface wind and streamfunction



CRU

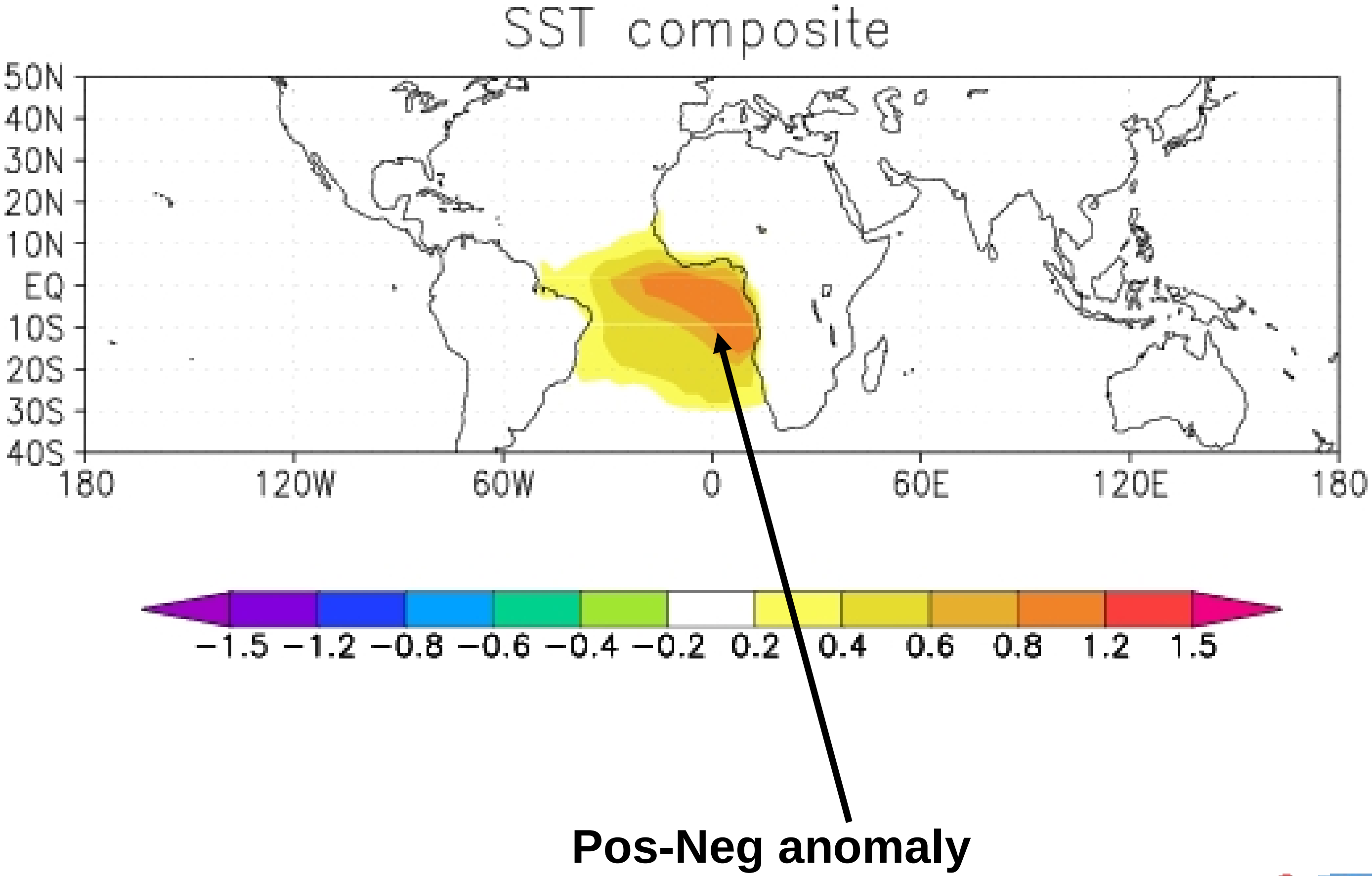


SPEEDY

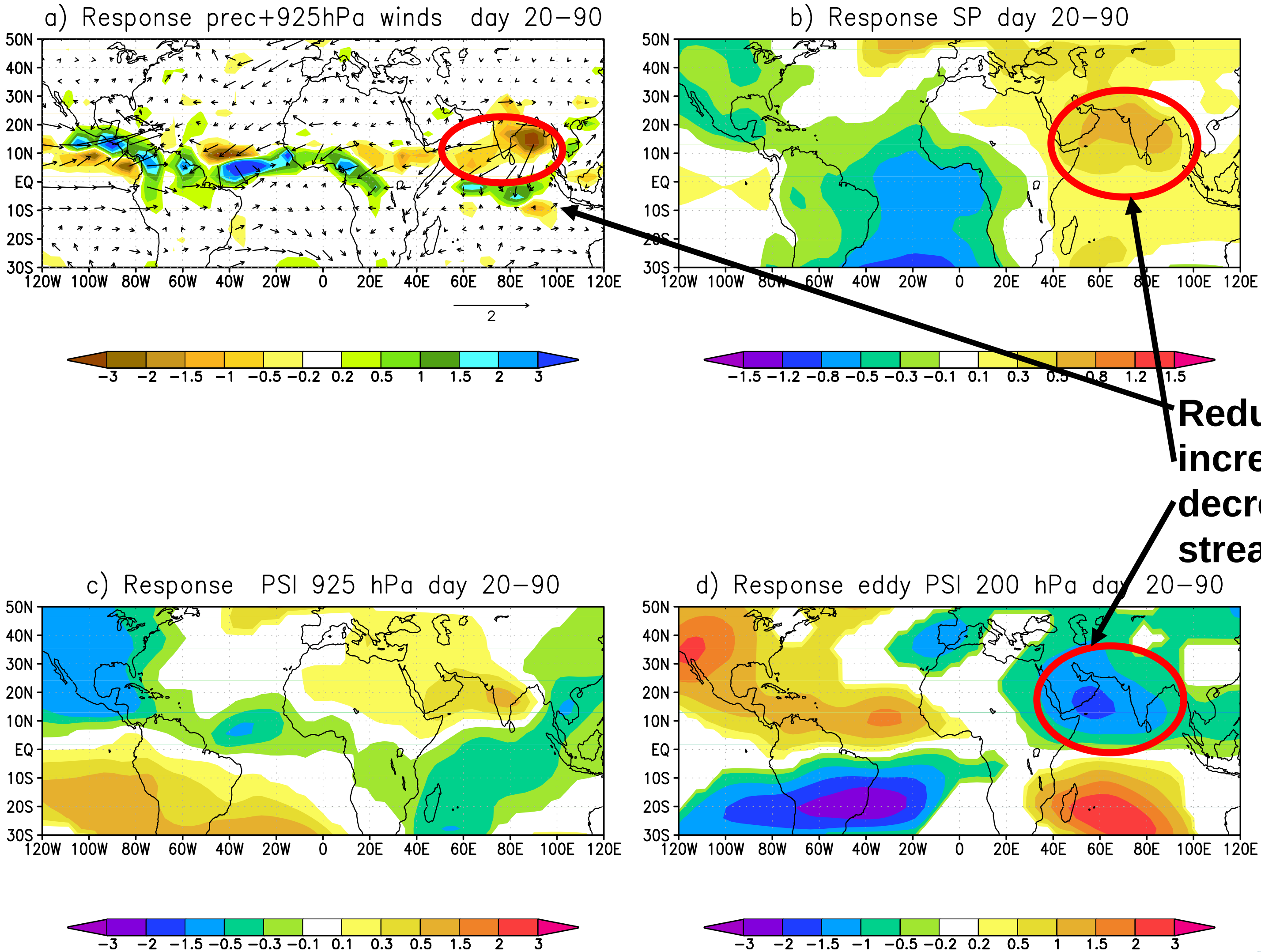


SPEEDY ENS1-ENS2

Results from idealized 'switch-on' experiments prescribing a SST anomaly in the tropical South Atlantic; 100 seasonal JAS pairs of integrations, one with positive, one with negative anomaly;
All responses shown are Pos-Neg

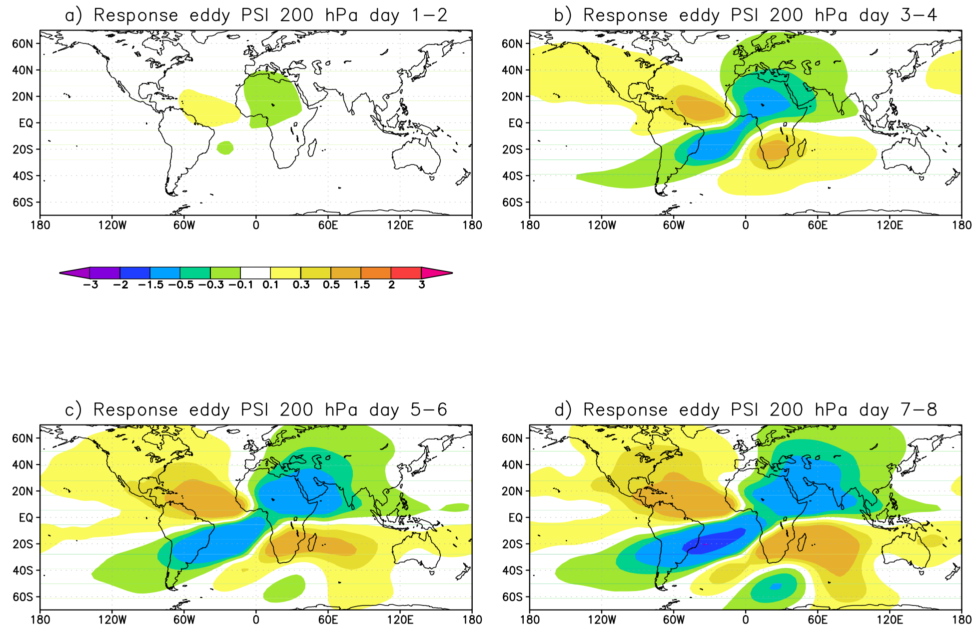


Results from idealized 'switch-on' experiments prescribing a SST anomaly in the tropical South Atlantic: Gill-Matsuno-type response to a (positive) heating in Tropical Atlantic



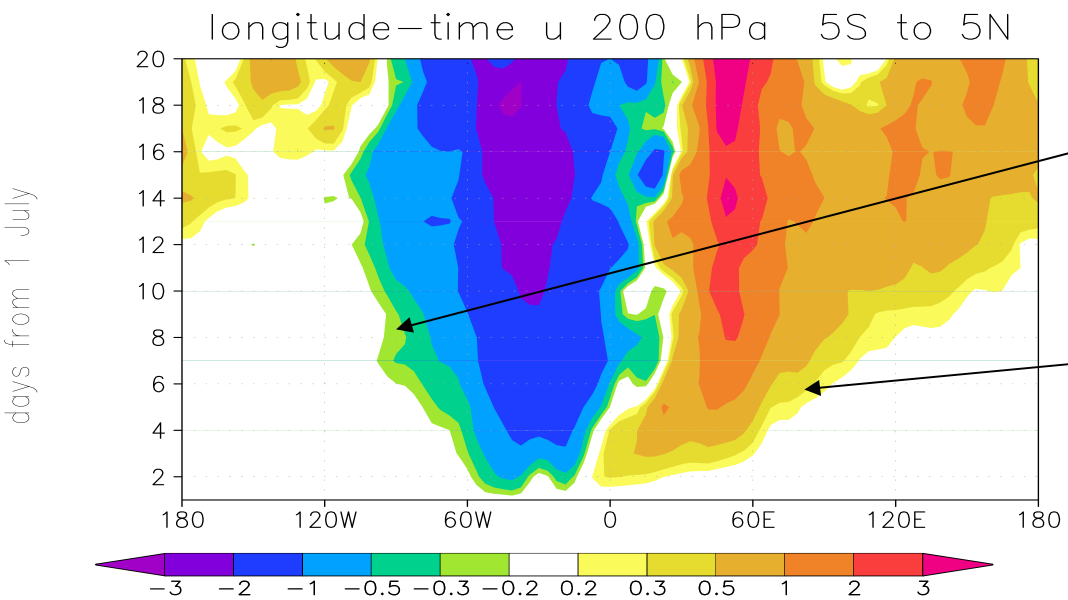
Reduced rainfall, increased SLP, decreased upper-level streamfunction

Time-evolution of Response



Initial 200 hPa Streamfunction response

Everything consistent with Gill-Matsuno-type quadrupole Response as in Jin and Hoskins (1995), JAS



Equatorial Rossby waves (speed: 6 m/s)

Convectively coupled Kelvin waves (speed: 20 m/s) (e.g. Ciang and Sobel, 2002)

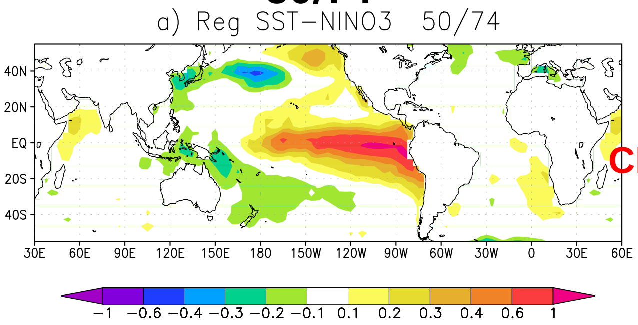
How does this go along with the ENSO-Indian monsoon teleconnection changes?

Results from the regionally Coupled model integrations

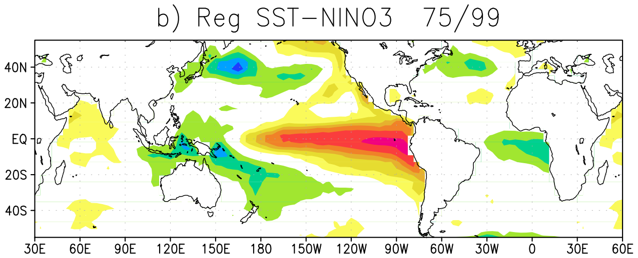
	50-74	75-99	Change
CC(CRU,NINO3)	-0.69	-0.45	0.24
CC(ENSM,NINO3)	-0.79	-0.51	0.28

Change of ENSO-Monsoon relationship very similar in model and observation

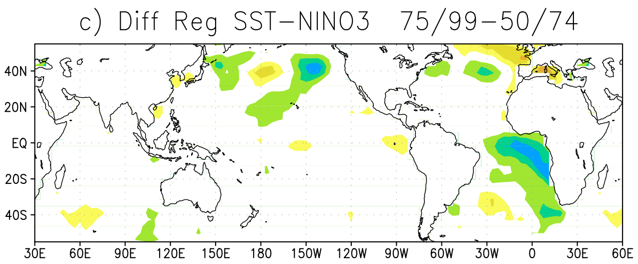
50/74

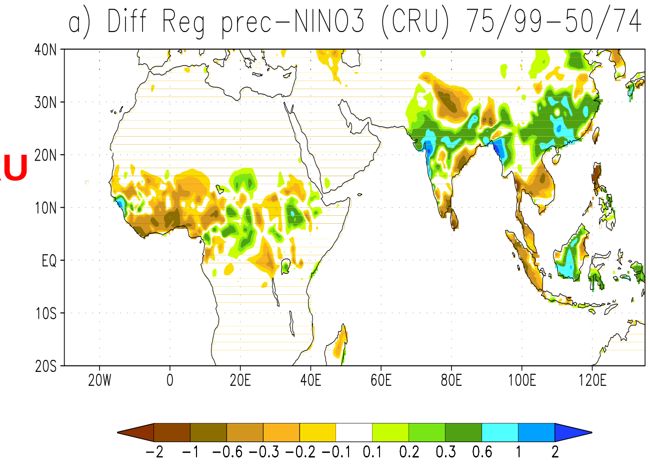


75/99

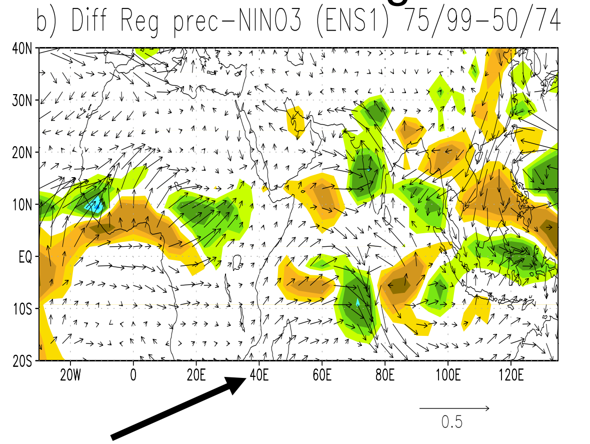


75/99 – 50/74



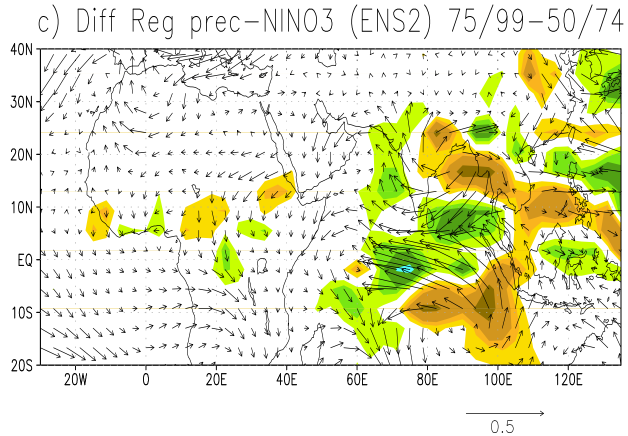


Full forcing

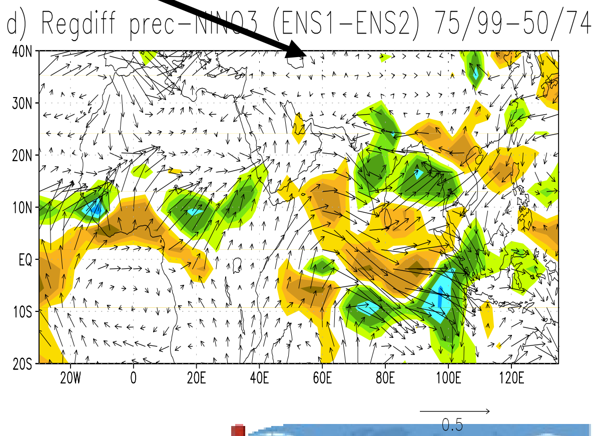


Model

No Atlantic



Full forc-No Atl



Conclusions

- A teleconnection between the tropical Atlantic and the Indian monsoon has been found in observations and in model integrations.

- A Gill-Matsuno-type response, modified by the local heating anomalies in the Indian region, has been indentified as the physical mechanism behind this teleconnection.

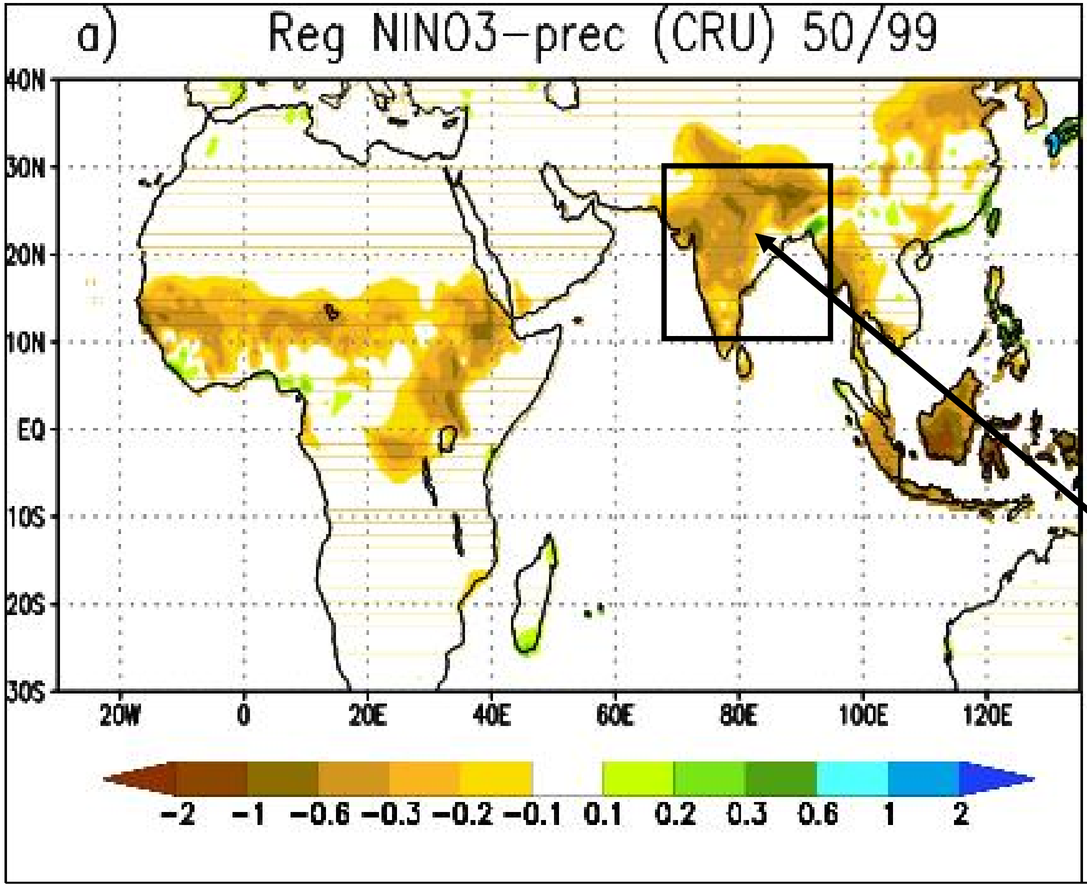
- This tropical Atlantic-Indian monsoon teleconnection, in combination with a change of the SST teleconnections between the tropical Atlantic and ENSO, has contributed (at least in our numerical model integrations) to the weakening of the ENSO-Indian monsoon relationship.

- Before the mid 70's ENSO and the tropical Atlantic were forcing the same signal of Indian rainfall, afterwards an opposite signal, thus weakening both, the ENSO-Indian monsoon and tropical Atlantic-Indian monsoon relationships (mutual cancellation).

ICTP AGCM stand-alone model: GCM of intermediate complexity

- Spectral dynamical core (Held and Suarez 1994)
- Truncation currently at T30 (~3.75x3.75 degrees)
- 5, 7 or (recently) 8 vertical levels
- Variables: Vor, Div, T, log(ps) and Q
- Physical parameterizations of
  - Convection (mass flux)
  - Large-scale condensation (RH criterion)
  - Clouds (diagnosed)
  - Short-wave radiation (two spectral bands)
  - Long-wave radiation (four spectral bands)
  - Surface fluxes of momentum and energy (bulk formulas)
  - Vertical diffusion
- Land-temperature calculated in simple model of 1-m soil layer
- Mixed-layer option

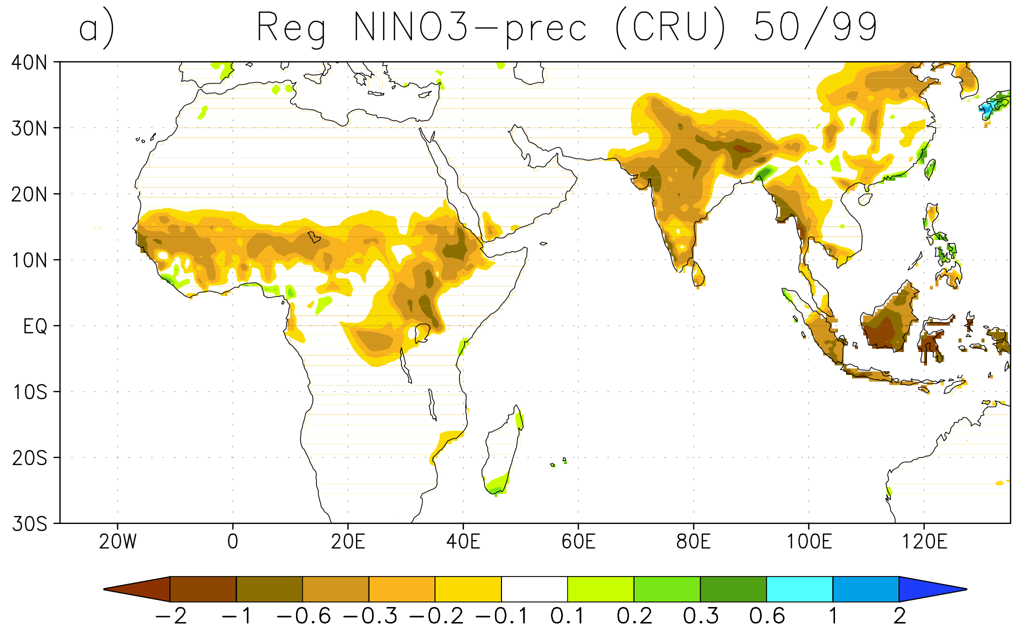
Definition of IMR: JJAS mean rainfall in the region 70 to 95E, 10 to 30 N, over land points only.



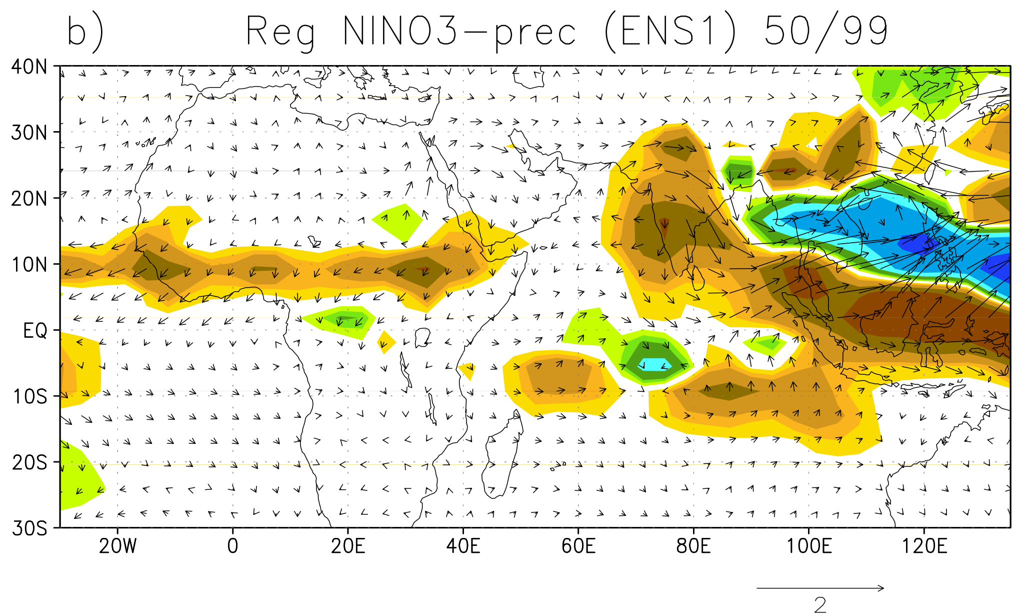
ENSO Teleconnection

Regression of NINO3 index onto rainfall

CRU

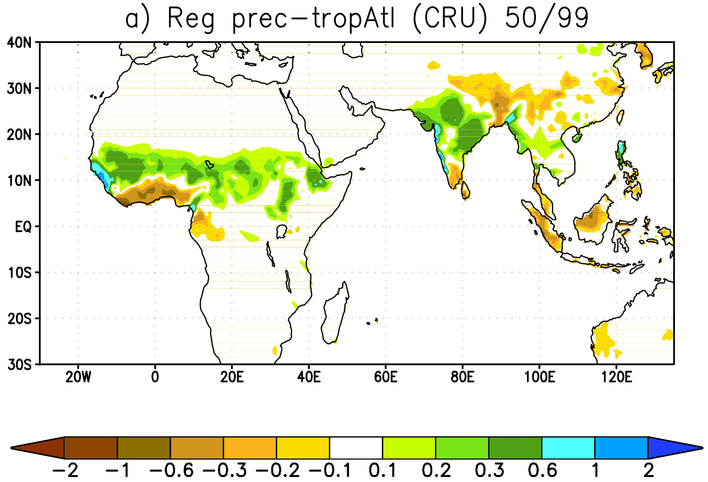


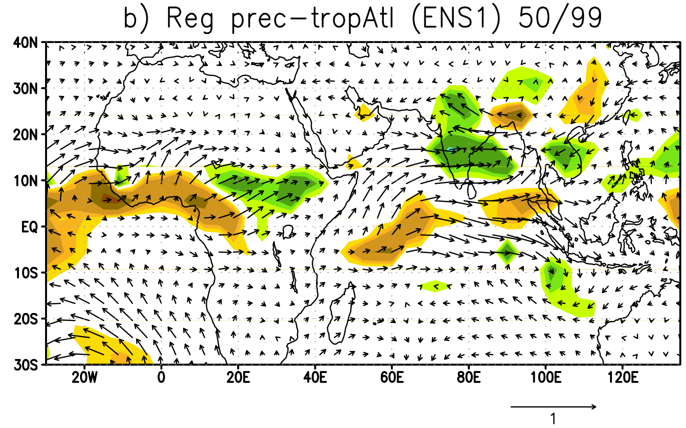
ICTP-AGCM



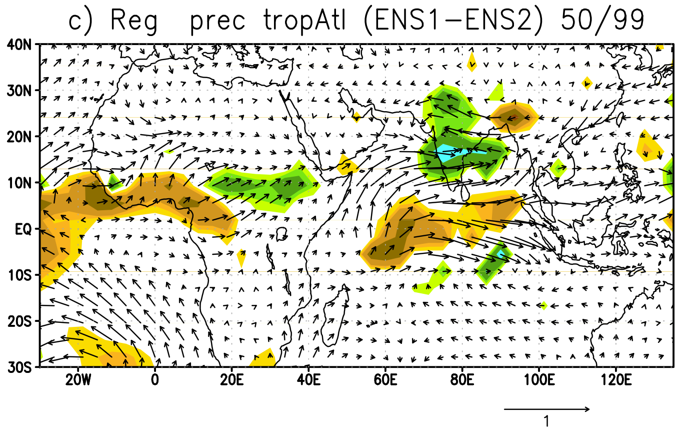
We may conclude that ICTP-AGCM reproduces ENSO Monsoon relation well.

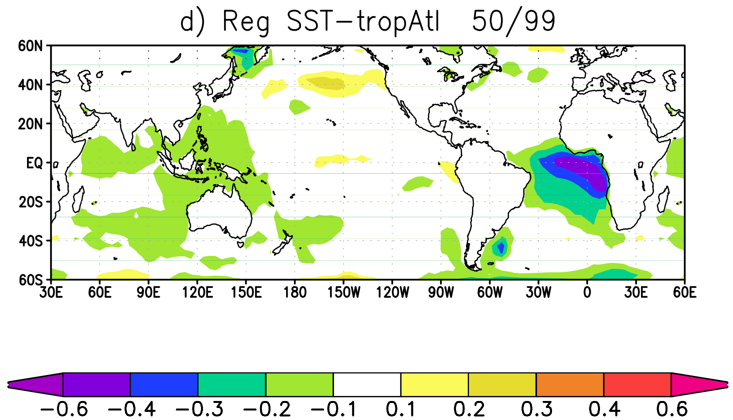
Tropical Atlantic Index: Average negative SST in box 30W-20E, 20S-0N





Difference between ENS1 and ENS2





Analysing in more detail the Atlantic Impact: IMR now defined in 70-85 E, 10-30 N, but as well AIR is considered

red: CRU
green: AIR
black: ICTP-AGCM

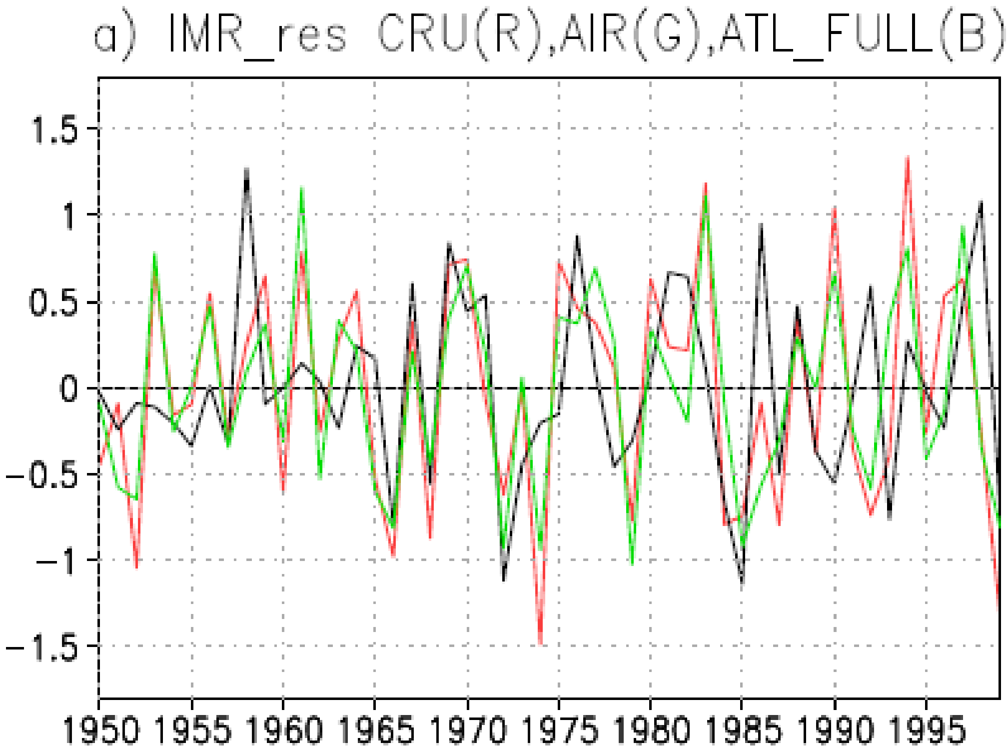
Define deviations from IMR as IMR_res = IMR-IMR_ENSO,

where

IMR_ENSO(t) = b NINO34(t)

CC(CRU,SPEEDY) = 0.42
CC(AIR,SPEEDY = 0.31

Correlation indicates Common SST forcing In obs and model

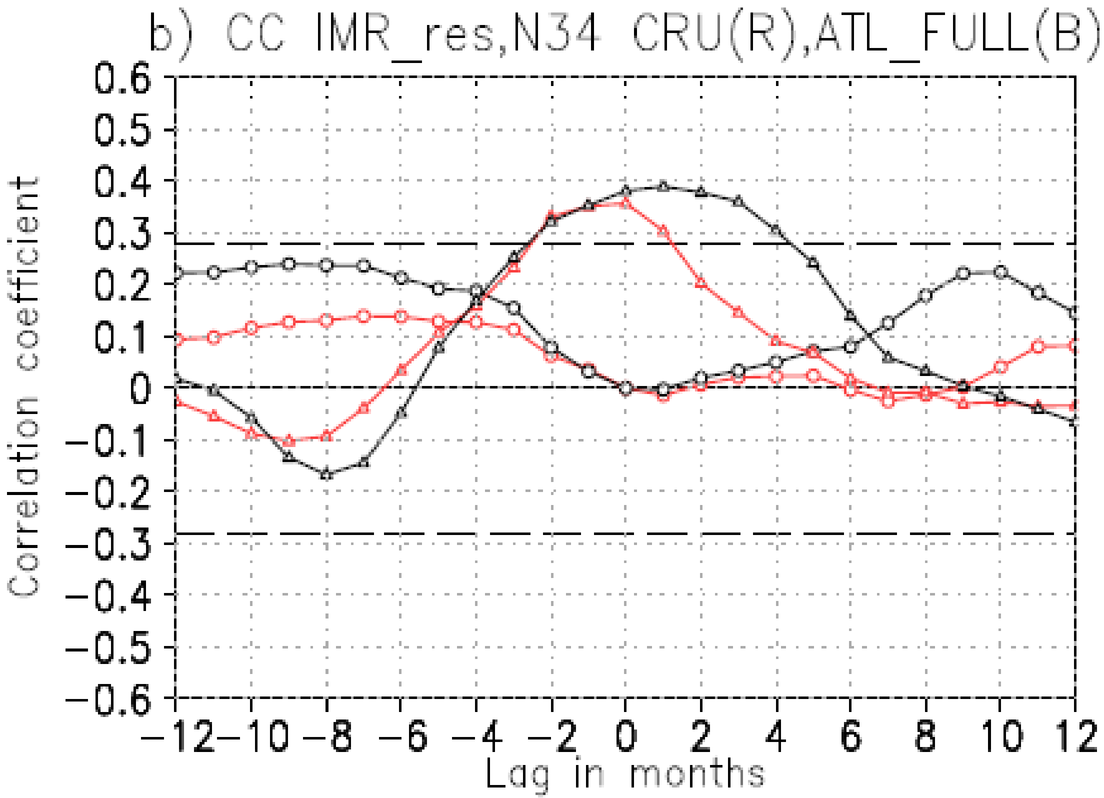


Lagged CC between CRU and model IMR_res and a tropical Atlantic Index (30W-10E, 20S-0)

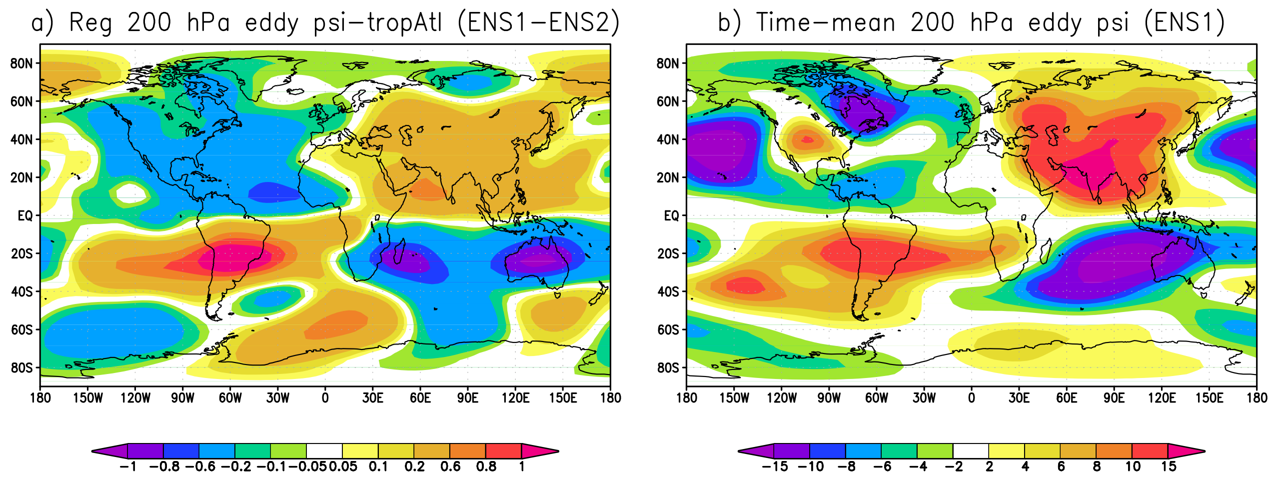
CRU

SPEEDY

(triangles)



Response to heating in tropical Atlantic: Regression of Tropical Atlantic Index onto 200 hPa eddy streamfunction



Response to heating in tropical Atlantic: Regression of Tropical Atlantic Index onto 200 hPa velocity potential