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 850 hPa winds

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

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

ICTP AGCM JJAS rain and 850 hPa winds
Correlations of IMR, DMI and IMR_res, DMI_res with SSTs

Define deviations from IMR as $IMR_{res} = IMR - IMR_{ENSO}$, where

$IMR_{ENSO}(t) = b \cdot NINO34(t)$, same with DMI

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

Largest correlations of Residuals with south Tropical Atlantic SSTs

Earth System Physics, The Abdus Salam International Centre for Theoretical Physics
Regression of rainfall onto an STA_res index (average SSTs in 30W-20E, 20S-0N)

CRU 1950-2002

CMAP 1980-2002

GPCP 1980-2002

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

STA-Teleconnections 50/02

a) Reg STA-Res-prec JAS (CRU) 50/02

b) Reg STA-Res-prec (CMAP) JAS 80/02

c) Reg STA-Res-prec (GPCP) JAS 80/02
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 140E, 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
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 that IMR leading ENSO is do to phase locking of ENSO in autumn/Winter
Does our regionally coupled model reproduce the IMR_res-Tropical Atlantic correlations?

- **Correlation of IMR_res with SSTs**
  - a) CC IMR_res with SST (CRU) 50/99
  - b) CC IMR_res with SST (AIR) 50/99
  - c) CC IMR_res with SST (ATL_FULL) 50/99

CRU: Strongest CC in tropical Atlantic, but as well signal of IOZM
AIR: Strongest CC in tropical Atlantic
ICTPAGCM: Strongest CC in tropical Atlantic
Regression of a negative tropical Atlantic Index onto precipitation, surface wind, and streamfunction
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:

<table>
<thead>
<tr>
<th>50-74 75-99 Change</th>
<th>CC(CRU,NINO3)</th>
<th>CC(ENSM,NINO3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.69 -0.45 0.24</td>
<td>-0.79 -0.51 0.28</td>
<td></td>
</tr>
</tbody>
</table>

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

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

Results from the regionally coupled model integrations:

<table>
<thead>
<tr>
<th>50-74 75-99 Change</th>
<th>Model</th>
<th>Full forcing</th>
<th>No Atlantic</th>
<th>Full forc-No Atl</th>
</tr>
</thead>
</table>

- CRU
- Model
- Full forcing
- 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 identified 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

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

Define deviations from IMR as $\text{IMR}_{\text{res}} = \text{IMR} - \text{IMR}_{\text{ENSO}}$

where

$\text{IMR}_{\text{ENSO}}(t) = b \ \text{NINO34}(t)$

$\text{CC} (\text{CRU}, \text{SPEEDY}) = 0.42$

$\text{CC} (\text{AIR}, \text{SPEEDY}) = 0.31$

Correlation indicates Common SST forcing In obs and model

red: CRU

green: AIR

black: ICTP-AGCM
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