How the dynamics of the Indian Ocean influences the evolution of the Indian summer monsoon

Annalisa Cherchi(1), S. Gualdi(1), S. Behera(2), J.-J. Luo(2), S. Masson(2), T. Yamagata(2) and A. Navarra(1)

(1) National Institute of Geophysics and Volcanology, Bologna, Italy
(2) Frontier Research System for Global Change, Yokohama, Japan
Main themes

Seasonal variability of temperature and wind over the Indian Ocean and over India: the growth of the Indian summer monsoon

The interannual variability of SST over the Indian Ocean and interannual variability of the Indian summer monsoon: connections?

The analyses have been made comparing amip-type and coupled model experiments at high resolution
Models used & Experiments performed

**Atmosphere**: Echam4
- Developed at MPI in Hamburg
- Spectral model
- Horizontal resolution: T106
- Vertical resolution: 19 sigma layers
- Message Passing Interface version (Roeckner et al., 1996)

**Ocean**: OPA 8.2
- Developed at LODYC in Paris
- Free surface
- Vertical resolution: 31 levels (10 in the first 100m)
- Horizontal resolution: 2x1.5deg (0.5 deg around the Equator)
  (Madec et al., 1998)

**Coupler**: OASIS 2.4
- Developed at CERFACS in Toulouse
- Message passing based on MPI2
  (Valcke et al., 2000)

**CGCM**: exp at T106 for 100 yrs

**AGCM**: exp at T106 with observed SST (1956-2001)

**SST**

**Wind & Fluxes**

**SINTEX-F CGCM**
  (Luo et al., 2004)
Datasets for comparison

**SST (Sea Surface Temperature)** from HadSST1.1

1955-2002 *(Rayner et al., 1997)*

**Surface land T from CRU**

1955-2000 *(Mitchell et al., 2004)*

**Total precipitation from CMAP dataset**

1979-2002 *(Xie and Arkin, 1996)*

**Winds (850 and 200 mb)** from ERA40 reanalysis

1958-2001 *(http://www.ecmwf.int)*
Seasonal 1000 mb wind (m/sec)
JJA 850mb moisture transport (m/sec) & water flux (mm/day, E-P)
JJA total precipitation (mm/day)
Mean JJA 850 mb wind (m/sec)
**Monsoon index:** Seasonal mean (typically summer) of a field (circulation-based and precipitation-based indices) averaged over a particular area

**IMI:**
Mean JJA U850(1)-U850(2)

*Wang et al., 2001*

**Linear correlation:**
IMI vs JJA TPREP
Strong minus weak
JJA 850 mb wind (m/sec)
Strong minus weak
JJA SST (°C)
JJA tprep anom (mm/day) regressed to JJA SSTA averaged over 55-75E, 10-25N
**Coupled Manifold tecnique**

A new method to detect the portion of variability connected between two climatic fields following the Procrustes formulation, that is a method to analyze covariation between fields.

Mathematical formulation:

\[ Z = AS \]  \( \text{the atmospheric field is some linear combination of the SST field} \)

\[ \text{min} ||Z-AS||^2 = 0 \quad \Rightarrow \quad A=(ZS')(SS')^{-1} \]

Similarly

\[ S = BZ \]

Using the operators A and B each field can be separated into 2 parts:

\[ Z_{\text{for}} = AS \quad \text{Forced Manifold is the subspace where variation of one field are connected to variations of the other field} \]

\[ Z_{\text{free}} = Z-AS \quad \text{Free Manifold is the subspace where variations are independent} \]

The "Coupled Manifold" is the ratio of forced manifold to the total, it represents the percentage of variance of an atmospheric field explained by the SST field.

From Navarra and Tribbia, 2004
(in press on JAS)
% of variance of tprep anom explained by Indian Ocean SST
(Coupled Manifold)
Conclusions

A coupled model experiment is able to reproduce the Indian summer monsoon precipitation in a more realistic way respect to an atmospheric model experiment forced with observed SST.

The Indian monsoon index defined by Wang et al., 2001 as the difference of the low-level zonal wind over two specific regions over India has been found to be good to represent the sequence between strong and weak Indian monsoon years.

The variability of the Indian monsoon affect the precipitation and circulation also far from the zone of interest. These spatial teleconnections are well reproduced by the model experiments.

A statistic method (coupled manifold) have been used to measure the variance of precipitation anomalies over India explained by SST over the Indian Ocean.

In an amip-type exp the explained variance is more than 60% over the western continent and in the Bay of Bengal. In a coupled model experiments the variance is more than 60% only over the eastern Indian Ocean.

Typically over the Indian continent the variance of precipitation explained by SST over the Indian Ocean is around 30-40%.