ENSO teleconnections and their decadal variability

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Abstract

Using ensemble integrations of a General Circulation Model (GCM) with three different treatments of the lower boundary conditions at the sea surface in the Indian Ocean, the ENSO teleconnections and their decadal variabilities are investigated. These simulations are conducted within ENSEMBLES RT4. The focus here is on the ENSO-monsoon teleconnection, but as well other components of the ENSO teleconnection are investigated. The three settings are: a) An Atmospheric GCM (AGCM) is forced globally with observed sea surface temperature (SST) anomalies. b) The Indian Ocean SSTs are computed using a simple 1-dimensional thermodynamic slab ocean. c) The slab in the Indian Ocean is replaced by a full ocean model (MICOM). The integrations in b) and c) are performed from 1950 to 1999 and consist of 10-member ensembles, whereas a) is performed throughout the 20th century (1872 to 2002) and consist of a 25-member ensemble. It is shown that the interannual teleconnection between ENSO and the Indian Summer monsoon is reproduced much better if a slab- or full ocean model is used in the Indian Ocean instead of prescribing observed SSTs. The best reproduction of the ENSO-monsoon teleconnection is obtained with the full ocean model. In the latter case as well the change of the ENSO-monsoon relationship that occurred in the mid 70s can be reproduced at least partially. Finally, it is shown that the observed decadal Indian monsoon rainfall (IMR) variability can be reproduced in case a), where an AGCM is forced by observed SSTs.

Model and Configuration

The model used in this study consists of the ICTP AGCM (Molteni, 2003) nickname SPEEDY for Simplified Parameterization, PrimitivE-Equation Dynamics, in its 8-layer configuration and T30 horizontal resolution. In the first experiment (ENS1) the AGCM is forced globally with the reanalysis SST dataset provided by the Hadley Centre (HadISST, Rayner et al. 2003) from 1872 to 2002. Examples of applications of the AGCM component can be found e.g. Bracco et al. 2004, Kucharski et al. 2006a and 2006b. In the second experiment (ENS2) the AGCM is coupled in the Indian basin to MICOM version 2.9 (Bleck et al. 1992) in a regional domain with 20 vertical levels a 1 degree horizontal resolution. The ocean model domain extends from 35S to 30N and from the coast of Africa to about 140E. Outside the Indian Ocean the AGCM is forced with observed SSTs from 1950 to 1999. In the third ensemble (ENS3), MICOM is replaced by a thermodynamic mixed-layer model over the same domain. In the fourth ensemble (ENS4), a mixed-layer is used as for ENS3, but SST forcing outside the Indian Ocean domain is restricted to the tropical Atlantic. A fifth ensemble (ENS5) has observed SSTs (1872 to 2002) in the Indian Ocean and climatological SSTs elsewhere. ENS1 consists of a 25-member ensemble, ENS2, ENS3, ENS4 and ENS5 of 10-member ensembles each.

Data and Methodology

Observed Data used:

- Sea surface temperature from the Hadley centre available from 1871 to present (Rayner et al. 2003).
- Precipitation from climate Research Unit Dataset (CRU) available over land-points from 1900 to present (Doherty et al. 1999).

Method:

As analytical tool we use simple linear regression techniques as well as Principal Component Analysis (PCA). All data is averaged over the June-to-September season. For the analysis of decadal variability, an 11-year running mean is applied to the data The Indian Monsoon Rainfall (IMR) is defined here as the rainfall over land points in the region 70E to 95E, 10N to 30N. If not stated otherwise, the ensemble mean is considered for the analysis.

Literature

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Results

1. Interannual ENSO-monsoon teleconnection

Fig.1 **CRU** **ENS1** **ENS3** **ENS2**

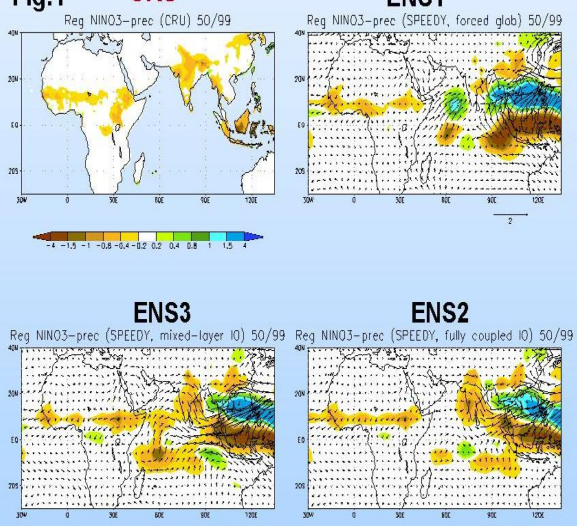

Fig.1: Regression of rain (June-to-September average) onto the NINO3 index for CRU Data (upper left), the globally SST-forced ensemble (ENS1, upper right), the ocean mixed-layer Ensemble (ENS3, lower left) and the full ocean model (ENS3,lower right). For the model results, 925 hPa wind regressions are plotted additionally. Units are mm/day for rain and m/s for wind.

Fig.2 **ENS2 cc=0.62** **ENS3 cc=0.44** **ENS1 cc=0.28**

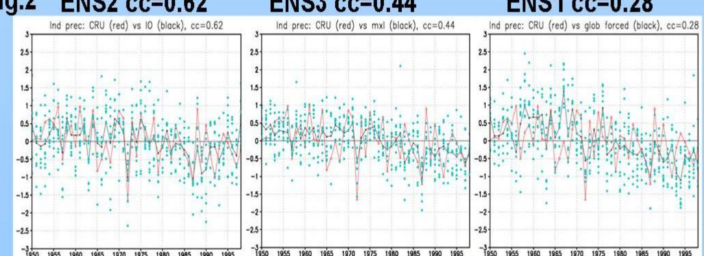

Fig. 2: Time series of IMR, defined as averaged rain over land points in the box 70E to 95E, 10N to 30N for the globally SST-forced ensemble (in black, ENS2, right), for the ensemble with a mixed-layer in the Indian Ocean (in black, ENS3, middle), and for the ensemble with full ocean model in the Indian Ocean (in black, ENS2, left). In each panel is plotted in red the IMR time series of the CRU dataset. The blue dots are the Results from individual ensemble members. Units are mm/day.

2. Decadal change of Interannual ENSO-monsoon teleconnection

Fig.3

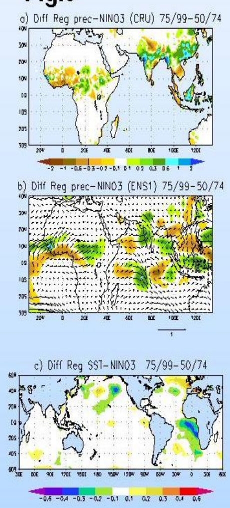

Fig.4

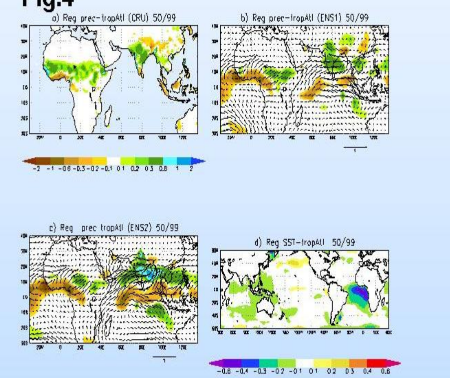

Fig.4: Regression of rain and SST onto a tropical Atlantic index (average SSTs in box 30W to 20E, 20S to 0N). a) CRU rain, b) ENS2 rain and wind, c) ENS4 rain and wind, d) HadISST. Units are mm/day for rain and K for SST.

Fig.3: NINO3 regression difference 1975/1999-1950/1974 for a) CRU rain, b) ENS2 rain and wind and c) HadISST. Units are mm/day for rain and K for SST.

3. Decadal IM R variability

Fig.5

CRU vs ENS1 and ENS5 cc=0.77

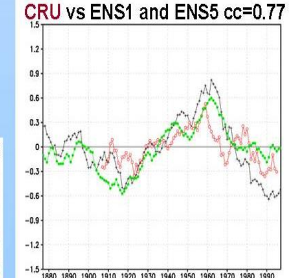

Fig. 5: Time series of observed (CRU, red Versus ENS1 (black) and ENS5 (green) decadal IMR (averaged over land point of the region 70E to 95E, 10N to 30N). All time series have been filtered with an 11-year running mean. Units are mm/day.

Conclusions

A series of ensembles integrations have been performed to analyze the ENSO-Monsoon relationship on interannual and decadal time scales. It is found that the observed ENSO-Monsoon relationship can be significantly better reproduced if interactive air-sea coupling is allowed in the Indian Ocean. The best results are obtained using a full ocean model in the Indian Ocean. In this case there is a large correlation between observed and modeled IMR anomalies (cc=0.62). The change on the ENSO-Indian-Monsoon relationship that occurred in the mid 70s can also partially be reproduced in the fully coupled case. The observed change of correlation between ENSO and IMR of the period 1975-1999 with respect to 1950-1974 is 0.24. In the fully coupled case the correlation change is very similar (0.28). Further experiments suggest that these changes are due to the SST teleconnection changes that occurred simultaneously in the tropical Atlantic region. Finally the decadal IMR variability can be reproduced well in the ensemble that is globally forced with observed SST, indicating that although eastern Pacific SST anomalies play a similar role on interannual and decadal time scale. This is not true for the Indian Ocean SST. Indian Ocean SST anomalies are acting to reduce the ENSO effect on the Indian Monsoon on interannual time scale, whereas the are increasing the ENSO effect on Indian Monsoon on decadal time scale.

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