Role of the Indian Ocean SST anomalies in the coupling of the Atmosphere and Ocean

C.Perigaud (*),J.D.Neelin (UCLA) and J. McCreary (IPRC)
(* CALTECH/Jet Propulsion Laboratory, Pasadena, CA91109;
818-354-8203; e-mail: cp@pacific.jpl.nasa.gov)

Introduction

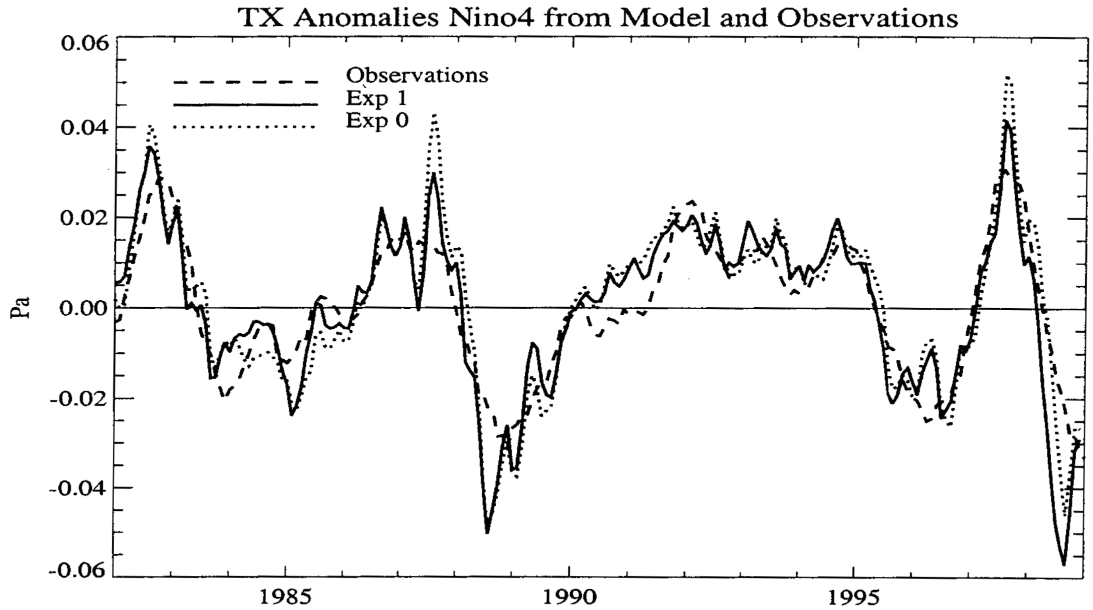
Today, very little is known about the coupling between the Indian Ocean and the atmosphere. Several studies have suggested that the interannual variability of the Indian Ocean climate is influenced by ENSO through changes in the Walker circulation, but fewer have investigated the influence of the Indian Ocean SST anomalies on the Monsoon rainfall variability and the changes in the North-South circulation.

This study investigates the role of the Indian Ocean halo-thermo-dynamics in the coupling between the Indian Ocean and the tropical atmosphere, using the Quasi-equilibrium Tropical Circulation Model (QTCM) of the atmosphere developed by Neelin and Zeng (2000) and the four-active-thermodynamic-layer model of the Indian Ocean (IO4) developed by Han et al. (1999). The coupler OASIS developed by Valcke et al. (2000) is used to exchange selected fields at the air-sea interface between the two models. In all experiments, the fields are decomposed into climatologies and anomalies, the former being prescribed to observed values. Also, outside the IO4 domain, QTCM is forced by the SST observations over 1980-2000 and a simple land surface model.

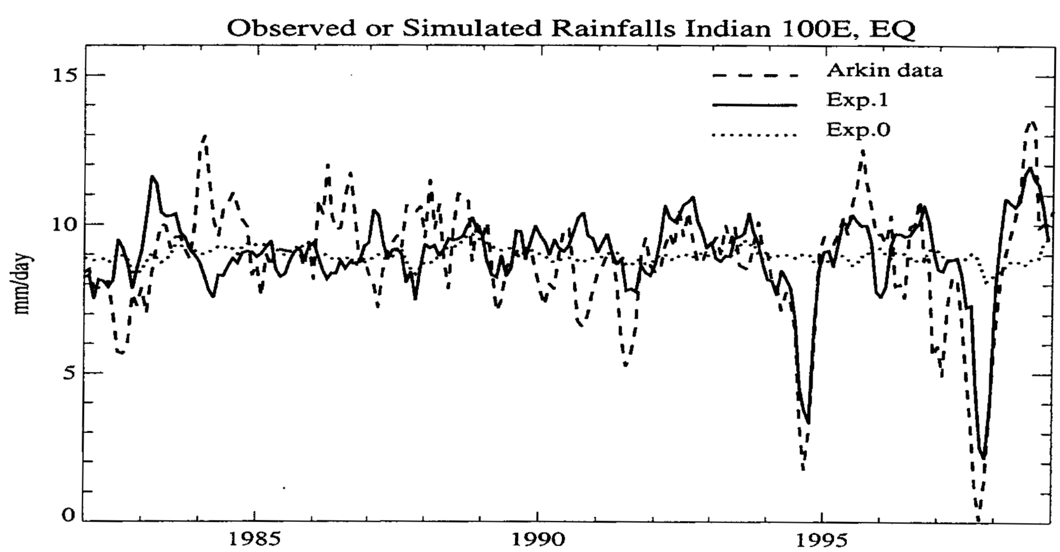
The investigation is focused on the role of rainfall and salinity in the coupled system by comparing two experiments over 1980-2000. In Experiment 1, QTCM is forced by the Indian SST observations, In Experiment 0, QTCM is forced by the Indian SST climatological mean values. In both experiments, IO4 is forced by the FSU winds observed between 1980 and 2000 and by the rainfall values simulated by QTCM during the experiment.

Results of the Atmospheric Experiments

Whereas in both experiments, the model is reasonably successful in simulating the westerlies and easterlies associated with El Niño and La Niña in the central Pacific (Fig 1), Experiment 0 and Experiment 1 significantly differ from each other in the wind and rainfall anomalies simulated in the Eastern Indian Ocean (Fig 2).



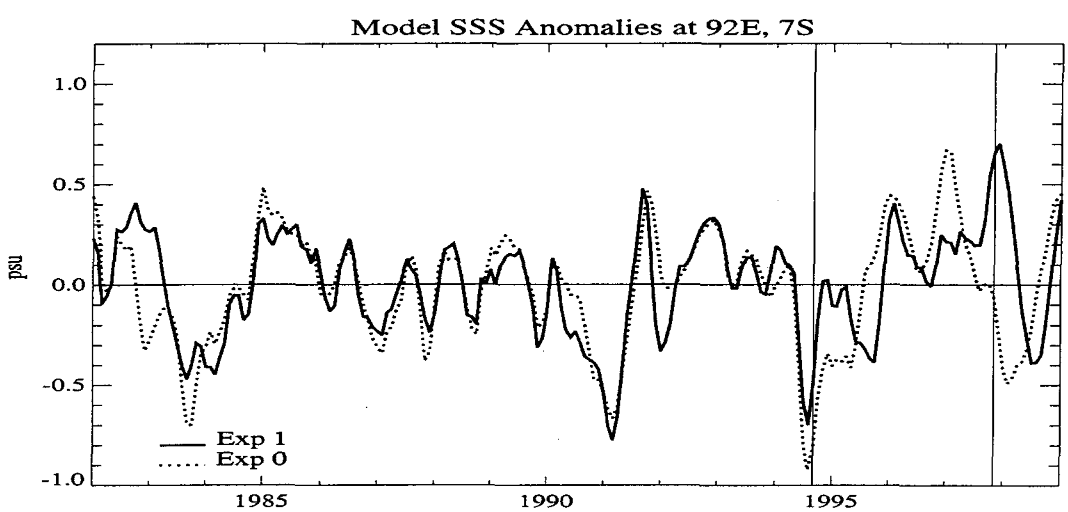
Experiment 1 is successful in simulating the major Indian Ocean events of this period in 1994 and 1997, but Experiment 0 fails to reproduce the two very large rainfall deficits that occured then in the Indian ocean.



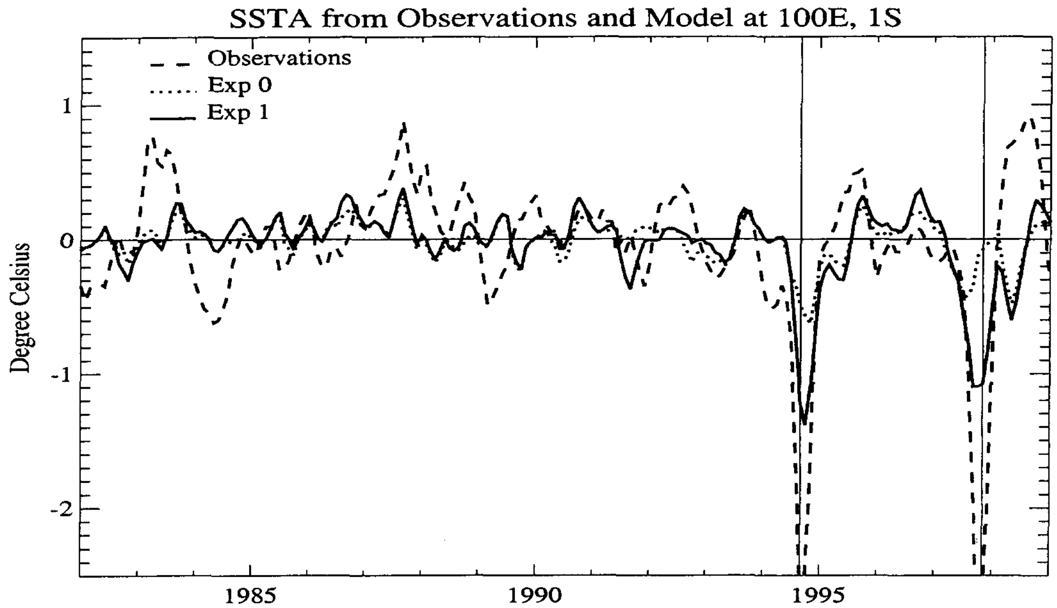
These results demonstrate that the Indian SST-s play a role in the atmopsheric conditions (winds and rainfalls) over the Indian Ocean. In particular, the displacement of the Walker circulation associated with the strong El Nino of the Pacific in 1997-1998 is not the only responsible for the easterlies and rainfall deficits of the eastern Indian Ocean. The SST anomalies over the Indian Ocean play a role in generating the strong atmospheric anomalies of 1997-98. Note that this does not mean that the Indian anomalies were not influenced by the Pacific. Indeed, the QTCM experiment forced by the Indian SSTs only and a climatological Pacific does not reproduce the Indian atmospheric anomalies correctly either. Nevertheless, Experiments 1 and 0 highlight the role of the Indian SST-anomalies in 1997-1998. The case of 1994 when there was no El Nino in the Pacific is even more convinving: it is a very strong event in the Indian Ocean during which local Indian processes of coupling were fully at work and involving important North-South displacements.

Results of the Indian Ocean Experiments

As expected, the Sea Surface Salinity (SSS) is drastically affected by the rainfall values exchanged at the air-sea interface. SSS in the Indian ocean is saltier for Experiment 1 than for Experiment 0 in 1994 and 1997 when the rainfall deficits were large. However, rainfall is not the only driving force for SSS variations. Indeed, the SSS simulated by both experiments happen to be at a minimum in 1994 instead of a maximum like in 1997 (Fig 3). The surface waters are anomalously fresh in 1994 because anomalous anticyclonic winds blowing in the SEIO are blocking the arrival of salty waters from the western Indian Ocean which is normally activated by the Wyrtki jets at this season.



The second striking result is that the SST is significantly affected by rainfall (Fig 4). It is mostly affected on the eastern side of the equator offshore of Java. While Experiment 0 simulates an anomaly smaller than 0.5C, Experiment 1 simulates two cold anomalies of 1.5C, in much better agreement with the observed SSTs. In both events, SST is cooled by the rainfall deficit because colder waters is upwelled from underneath, but in 1994, the relatively cold subsurface waters are being advected from the western Indian ocean along the equator whereas in 1997, they are upwelled from below the thermocline along the coast of Java South of the equator and advected northward along the coast.



Conclusion

These experiments demonstrate the important role of the Indian Ocean dynamics in the haline and thermal structure of this ocean (Perigaud et al., 2002) and on its coupling with the tropical atmosphere. Rainfall and salinity cannot be neglected in the coupling processes at work in the Indian Ocean as they can be when studying El Niño in the Pacific.

References

Han W., J.P. McCreary, D.L.T.Anderson, A.J. Mariano, 1999: " Dynamiccs of the eastern Surface Jets in the equatorial Indian ocean", *J. Phys. Oceanogr.*, **29**, 2191-2209.

Neelin J. D. and N. Zeng, 2000: A Quasi-equilibrium Tropical Circulation Model - formulation", *J. Atmos. Science*, **57**, 1741-1766.

Perigaud C., J.P. McCreary and K. Zhang, 2002: "Influence of rainfall interannual anomalies on the salinity and temperature changes of the Indian Ocean", submitted to *J. Geophys. Res.*

Valcke S., L. Terray, and A. Piacenti, "OASIS Version 2.4: Ocean Atmosphere Sea-Ice Soil: User's guide, CERFACS, TR/CMGC/00/10.