Indian Ocean Temperature Patterns Affect Climate

Until recently, climate researchers viewed sea surface temperature (SST) variations in the Indian Ocean merely as a thermodynamic response to atmospheric flux changes remotely forced by the El Niño-Southern Oscillation (ENSO). The consensus was that the Indian Ocean does not affect climate, and that its SST variations from one year to the next are not useful for seasonal prediction of such things as monsoon rainfall.

New research, however, is challenging this long-held view. On subseasonal as well as interannual timescales, structures in SST variability have been recorded that imply this ocean does influence climate. For example, modeling studies by **Xiouhua Fu** and colleagues at the IPRC have revealed that the ocean-atmosphere coupling in the Bay of Bengal is significant in predicting the wet and dry spells during the summer monsoon.

Interannual variations in Indian Ocean SST are also becoming important for climate prediction. **N.H. Saji**, a researcher with the Indo-Pacific Ocean Climate Team at the IPRC, and **Toshio Yamagata**, Frontier Program Director for the IPRC, along with researchers from the Indian Institute of Science, have noted large variations in the east-west SST gradient along the equatorial Indian Ocean. They termed the occurrence of a steep SST gradient "Indian Ocean Dipole" or IOD event. Analyzing observations, they found that positive IOD events are brought about by anomalous cooling of the eastern Indian Ocean, closely followed by anomalous warming of the western Indian Ocean. The opposite sequence, namely, negative IOD events with cooling in the western Indian Ocean and warming in the eastern, also occurs.

Modeling studies suggest that the evolution of this pattern is coupled to surface winds. When the surface wind is unusually easterly, the thermocline becomes shallower in the eastern, and deeper in the western Indian Ocean. The air-sea interaction results in a positive feedback loop between the induced SST anomaly and the easterly surface winds. Thus, once an IOD event is triggered, the anomalies may maintain themselves or even amplify (see also p. 7).

A strong SST dipole in the Indian Ocean typically persists for two to three seasons, from boreal spring to early winter. In a further study, Saji and Yagamata speculated that because these events occur in the warm pool region, where the atmosphere is highly sensitive to SST, they might affect local and distant climates. Analyzing observational data, they found that, indeed, positive IOD events are closely associated with floods over East Africa, northwest India and Sri Lanka, and with droughts over western Indonesia and southwestern Australia, while the opposite conditions are observed during the negative phase of IOD events (Figure 3).

Saji and Yamagata looked also at how IOD events impact distant climates. Figure 4 shows the association between land temperatures and IOD events, the effects of ENSO on Indian Ocean SST and on land temperatures being controlled for by means of a multiple regression analysis. The closest association between the IOD and land temperatures is over Brazil, where the partial correlation coefficient is +0.7. Correlation coefficients of +0.5 or greater are seen over parts of East Africa, southern Europe, northeast Asia and North America. Their analysis suggests that positive IOD events are associated with unusually warm temperatures and negative events with unusually cool temperatures in the extratropics. Since these results are similar to the composite world map of temperature anomalies observed during the absence of El Niño events (not shown), the correlations in Figure 4 appear to reflect a real link between IOD events and the observed temperatures.

Modeling studies are investigating these associations further. For instance the impacts of IOD events on India and Australia have been simulated using an atmospheric general circulation model (GCM), forced by prescribed SST (Ashok et al., 2001; 2003). The other local and remote impacts still remain to be dynamically verified.

These findings hold promise for predicting seasonal climate in the region based on Indian Ocean SST variations. The feasibility of such prediction depends on two conditions: (1) The dynamical simulation of the atmospheric response to IOD events given prescribed SST forcing. (2) Early prediction of the onset of IOD-related SST anomalies. Several coupled GCM studies have successfully simulated IOD-like variability, and one simulation (Wajsowicz, 2003) hinted at predicting IOD events at least 3 months in advance. Together these studies are throwing light on the air-sea interactions generating IOD events and their climate effects.

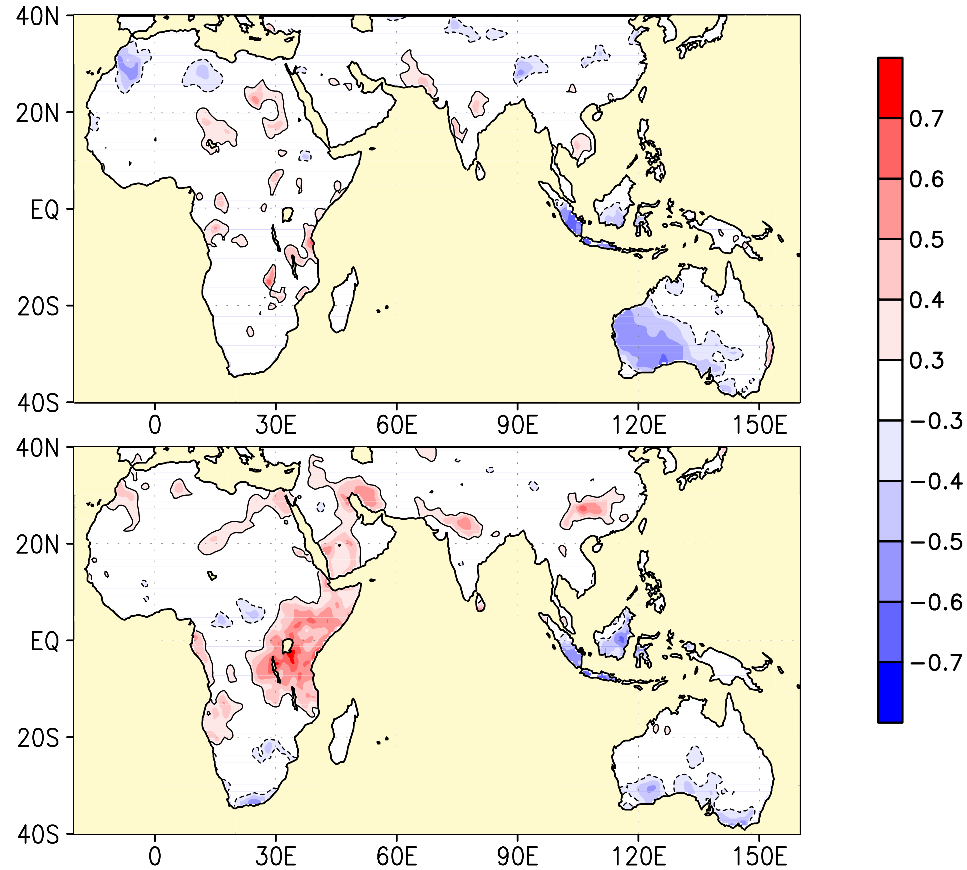

Figure 3. *Correlation between the Dipole Mode Index (DMI) and rainfall over land from June through August (top panel) and from September through November (bottom panel). The DMI is defined as the monthly SST anomaly difference between the western (60ºE–80ºE, 10ºS–10ºN) and the eastern (90ºE–110ºE, 10ºS to the Equator) Indian Ocean, where the monthly SST anomaly for each region is the deviation of each month's SST from the average monthly mean for each region from 1958 to 1997.*

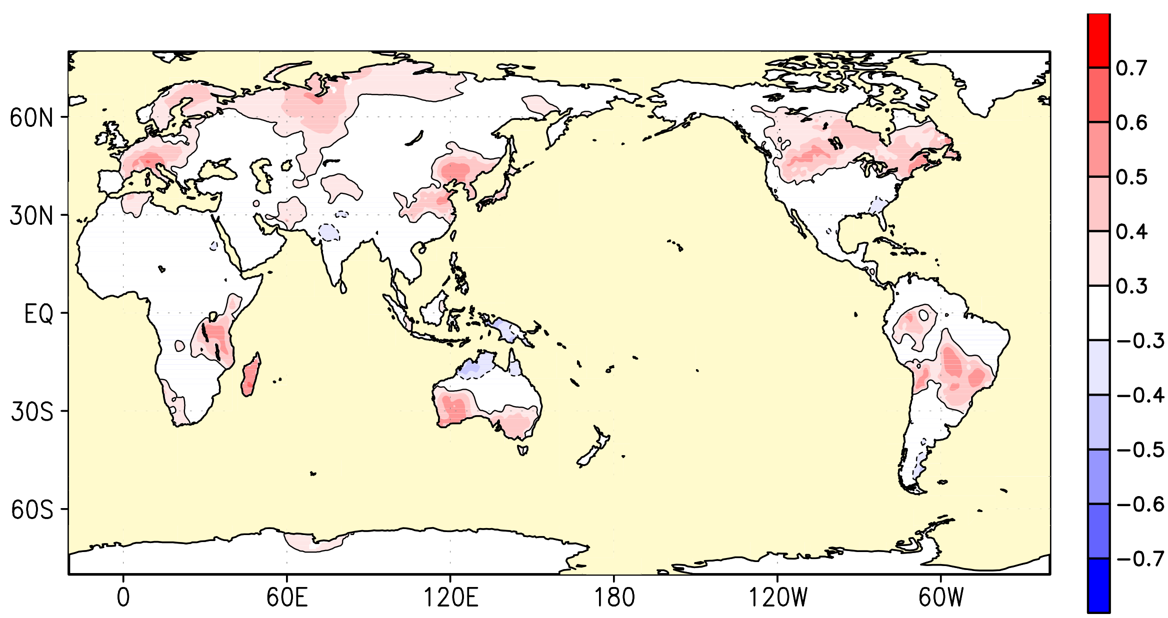

Figure 4. *Correlation between the Dipole Mode Index and land temperature anomalies from June through October.*