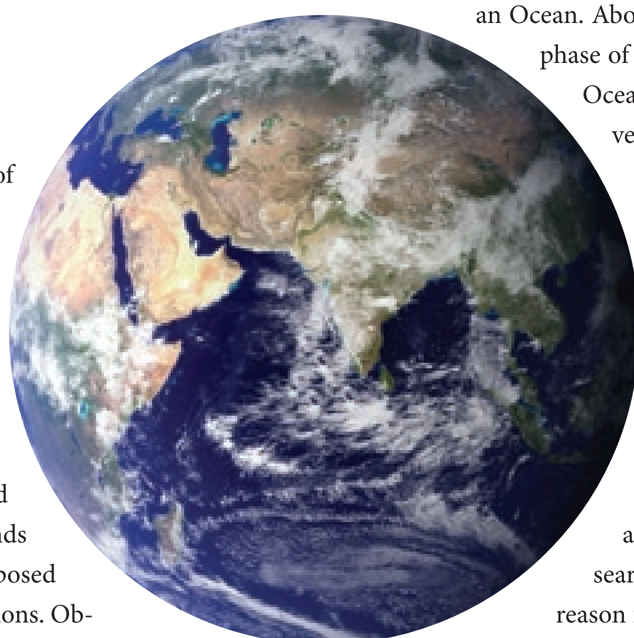
ISO Impact on Indian Ocean Depends on Season



An intriguing aspect of the tropical climate system is that the occurrence of weather events is modified by the phase of the intraseasonal oscillation (ISO). The ISO is an atmospheric disturbance with alternating periods of increased and decreased surface westerly winds or convective activity, superimposed on the usual background conditions. Observations show that during a strong westerly wind phase one can expect a greater number of tropical cyclones. The ISO may even trigger or terminate El Niño and Indian Ocean Dipole events. Understanding the ISO is thus crucial for successful prediction of tropical weather and climate.

Recent studies show that the ISO affects both the atmosphere and the ocean. Sparse observations over the open ocean, however, limit our ability to thoroughly explore the oceanic component. Numerical models can be helpful tools in this endeavor. At the IPRC, postdoctoral fellow **Chi-Yung Francis Tam** and **Tim Li**, co-leader of the Asian-Australian Monsoon System Team, used an ocean model to study the interplay between Indian Ocean conditions and elements of the ISO.

The model results for sea surface temperature (SST), outgoing longwave radiation (OLR), and surface wind stress composited by ISO phase are shown in Figure 1 for the Northern Hemisphere winter and summer months. In winter, after a period of strong convection (green contours) and westerly wind stress (arrows) associated with the ISO, anomalously cold SST (shading) appears in a band along 10°S in the Indian Ocean. About 10–15 days after the convective phase of the ISO passes the western Indian Ocean northeast of Madagascar, convection in that region is suppressed (red contours) in response to the cold SST forcing. This evolution suggests that ocean conditions help to start the next phase of the ISO over the western Indian Ocean.

During summer, these signals are almost absent, something already noted in satellite analyses conducted by IPRC researcher **N.H. Saji**. To understand the reason for such large seasonal differences, Tam and Li compared how certain processes affect the sea surface in winter and in summer during the phase of the ISO with the strongest westerly winds and convection. Figure 2 gives the contribution of incoming solar radiation, evaporation, mixing of cold sub-surface water and horizontal advection to the SST response for winter and summer during this ISO phase.

In northern winter, the dramatic cooling of the sea surface is seen in a band around 10°S. There are several reasons for this cooling. The strong westerly ISO winds strengthen the background surface wind, which during this season is also eastward along 5–10°S; the strong winds increase evaporation and ocean mixing. Moreover, convection, accompanied by clouds, reduces the amount of incoming solar radiation (Figure 2a, 2c, and 2e).

In contrast, in summer during this phase of the ISO, surface easterlies prevail south of the equator, opposing the westerly winds of the ISO and reducing both evaporation and mixing of deeper, colder ocean water with surface water. The sea surface warming that should result is counteracted,

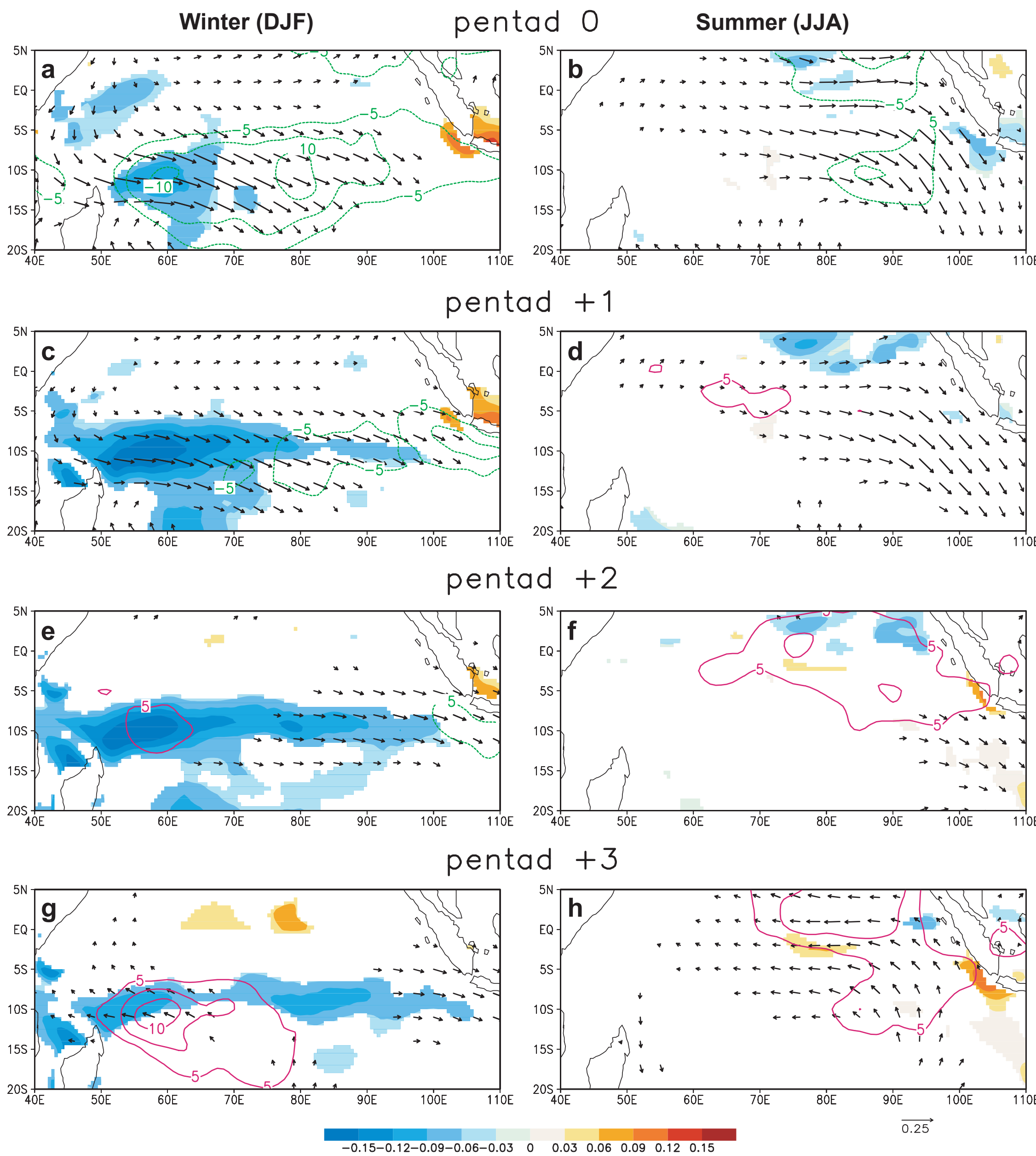


Figure 1. For northern winter (**left panels**), and northern summer (**right panels**), model-simulated SST (shading: see scale bar at bottom, in units of °C), wind stress (arrows: see scale at bottom right, in units of dyn/cm^2) and outgoing long-wave radiation (red contours for positive and green contours for negative values, in intervals of 2.5W/m^2, starting from 5W/m^2) during pentads 0 (panels **a** and **b**), +1 (**c** and **d**), +2 (**e** and **f**), and +3 (**g** and **h**). Pentad refers to a 5-day period; pentad 0 refers to the ISO phase when the 25–90 day bandpass filtered zonal wind stress anomaly is most positive over 50–65°E, 5–12.5°S in winter, and over 75–90°E, 2.5–10°S in summer.

however, by less solar radiation in the Indian Ocean along 5–10°S (Figure 2b, 2d and 2f). Furthermore, the strong westerly ISO winds induce a northward Ekman flow that brings cold water from the south, further counteracting the warming. This advection effect is much stronger in boreal summer than in winter (see also Figure 2g and 2h) because during northern summer the north-south SST gradient is sharper than during winter. The interaction of all these processes explains why the SST in the southern Indian Ocean changes so little in response to the summertime ISO, further highlighting the sensitivity of the ISO-related SST changes to the mean state of the atmosphere and the ocean.

In summary, the different SST response to the ISO in the southern

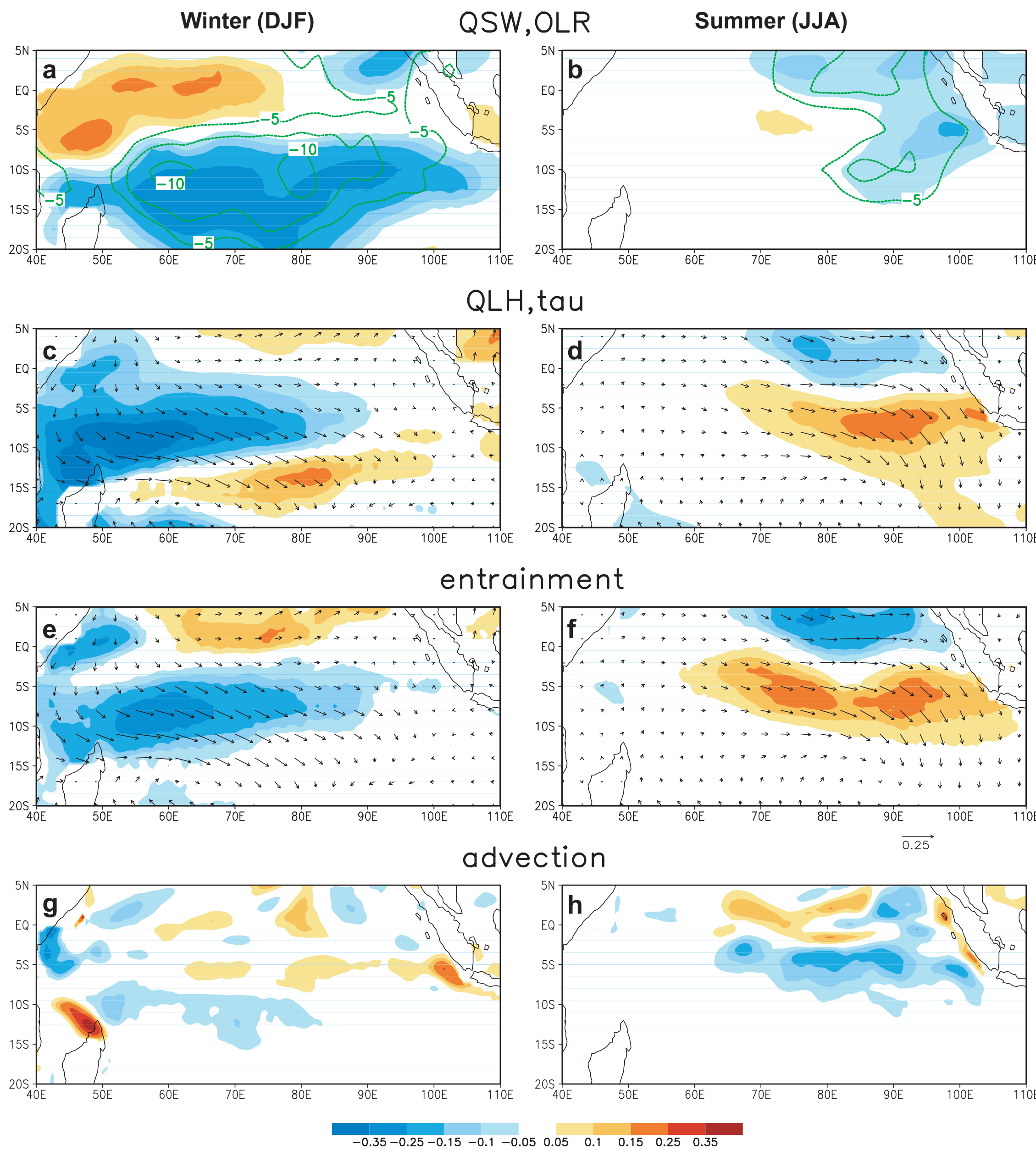


Figure 2. For northern winter (left panels) and northern summer (right panels), the simulated SST tendency (scale bar unit in °C/month) during pentad –1 to 0 of the ISO phase as a function of solar radiation (panels a and b), evaporation (c and d), entrainment (e and f), and horizontal temperature advection (g and h). Also shown for this phase of the ISO are in panels a and b, the anomalous outgoing longwave radiation (contours in intervals of 2.5W/m^2, starting from 5W/m^2), and in panels c, d, e, and f, wind stress anomalies (arrows: unit in dyn/cm^2).

Indian Ocean during summer and winter can be explained by the interplay among the various ISO forcing components and the different background states during the two seasons. Many coupled general circulation models do not simulate the impact of the ISO well. A reason is that they do not have the correct background climate state, such as the surface wind condition near the intertropical convergence zone. This study, demonstrating the sensitivity of the ocean to the mean climate, sheds light on ways to improve simulation of the ISO in general circulation models.

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