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Secular warming trend and climate variability of the tropical Indian Ocean

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Sea surface temperature (SST) has been increasingly steadily over the tropical Indian Ocean (TIO) since 1950s despite the lack of a clear trend in net surface heat flux. Fritz Schott called this the "heat flux dilemma" for the TIO warming. Scale analysis shows that for slow warming as is observed over the TIO, the time tendency term of the ocean mixed layer heat content is one order of magnitude smaller than the changes in components of surface heat flux. We then turn to the IPCC AR4 Climate of 20th Century simulations and examine how the balance among heat flux components determines the magnitude of the warming.

Models are generally successful in simulating the TIO warming trend under greenhouse gas and other climate forcing. In models, the changes in net surface heat flux are indeed small and the warming is trapped in the top 125 m depth. Analysis of the model output suggests the following quasi-equilibrium adjustments among various surface heat flux components. The warming is triggered by the increased downward longwave radiation in response to the increasing greenhouse gas concentrations, amplified by the water vapor feedback and atmospheric adjustments such as weakened winds that act to suppress latent and sensible heat flux from the ocean. The sea surface temperature dependency of evaporation is the major damping mechanism. The simulated changes in surface solar radiation are highly correlated with inter-model variability in SST trend, indicating that uncertainties in cloud change are responsible for the spread in the simulated SST trend. To resolve Fritz's heat-flux dilemma, it is important to monitor changes in radiative flux and key parameters to turbulent heat flux such as relative humidity and stability.

The warming of tropical oceans in response to increased greenhouse gas concentrations could cause changes in modes of climate variability. The Walker circulation, in particular, is projected to weaken, reducing the westerly winds in the equatorial Indian Ocean and raising the thermocline in the east. By itself, the thermocline shoaling would lead to an intensified Indian Ocean dipole (IOD) mode but the interannual IOD variance remains nearly constant in global warming simulations. We will present results from our analysis to resolve this dilemma of TIO climate change.