A THEORY FOR THE TROPICAL TROPOSPHERIC BIENNIAL OSCILLATION

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The key questions of how the tropospheric biennial oscillation (TBO) maintains the same phase as the monsoon convection moves from northern summer in South Asia to southern summer in Australia, and how the reversed phase can last through three locally inactive seasons to the next monsoon, are studied by a simple tropical atmosphere-ocean-land model. The model has five boxes representing, respectively, the South Asian and Australian monsoon regions and the equatorial Indian, and western and eastern Pacific oceans. The five regions interact with each other through the SST-monsoon, evaporation-wind, monsoon-Walker circulation, and wind stress-ocean thermocline feedback.

A biennial oscillation emerges in a reasonable parameter regime, with model SST and wind variations resembling many aspects of the observed TBO. A warm SST anomaly in July in the equatorial Indian ocean causes an increase of surface moisture convergence into South Asia, leading to a stronger monsoon. The monsoon heating on one hand induces a westerly wind anomaly in the Indian Ocean, and on the other hand intensifies a planetary-scale east-west circulation leading to anomalous easterlies over the western and central Pacific. The westerly anomaly over the Indian Ocean decreases the local SST, primarily due to evaporation-wind feedback. The easterly anomaly in the central Pacific causes a deepening of the ocean thermocline therefore increases the subsurface and surface temperatures. This effect overwhelms those of the cold zonal advection and anomalous upwelling. The net result is an anomalous warm SST persisting in the western Pacific through the northern fall, leading to a stronger Australia monsoon.

Meanwhile, the warming in the western Pacific also induces a stronger local Walker cell and thus a surface westerly anomaly over the Indian Ocean. This westerly anomaly helps the cold SST anomaly to persist through the succeeding seasons, leading to a weaker Asian monsoon in the following summer. During the northern winter the westerly anomaly associated with the stronger Australia monsoon, through anomalous ocean downwelling, reinvigorates the warm SST in the western Pacific, which has been weakened by the slow cold advection from the eastern Pacific. This further intensifies the eastern Walker cell and helps to keep the eastern Pacific cold.

Our theory indicates that the TBO is an inherent result of the interactions between northern summer and winter monsoon and between the Asian-Australian monsoon region and the eastern equatorial Pacific. It also implies a potential role of the monsoon on the irregularity and phase locking characteristics of the El Niño-Southern Oscillation.

Key words: *Tropical Biennial Oscillation, Monsoon, El Niño*