Abstract:

The theme of this research is to study the tropical water vapor and clouds, especially their relation with the large-scale environment at the interannual time scale as well as their changes in the future climate. The study employs extensive data analysis with high-quality satellite observations that have not been made available until recently, the NCEP and ECMWF reanalyses and the model simulations archived for the CMIP (coupled-model intercomparison project) phase-3 and phase-5 projects. A simple radiative-convective equilibrium (RCE) model is also used to interpret some of the analysis results.

The current interannual variability of tropical upper tropospheric humidity (UTH) is examined. The correlation between UTH and SST anomalies over the tropical convection region is found to be generally higher than that between the UTH and the SST anomalies over the entire tropics, corroborating the role of deep convection in the vertical transport of moisture. The variability over each tropical ocean basin is investigated and discloses the discrepancies between models and observations on such regional-scale variability. How the atmospheric bridge and the tropical eastern Pacific affect the climate in other basins are further highlighted.

Though each GCM-simulated ice water path (IWP) differs from others by a factor ~10, this study shows that the models agree much better on the fractional variation of IWP with vertical velocity at 500 hPa ($\omega_{500}$). The models and observations also agree on such a fractional change. Moreover, a relation can be found between the interannual variability in the current climate and the long-term future change regarding the IWP and $\omega_{500}$ anomalies. It can be estimated that over the tropical Pacific region, such a relation projects a $\sim3.38\pm0.42\%$ decrease of IWP associated with circulation change due to every 1K global warming, which can then imply a $\sim0.37\text{Wm}^{-2}$ decrease in the net atmospheric absorption of radiation. The contribution of radiative cooling to the circulation change based on a RCE framework and NOAA GFDL simulations are further examined. The change of vertical velocity, which is inferred from this simple RCE framework, is consistent with what GFDL GCM simulated. For the middle and lower troposphere, the changes of the lapse rate and of the clear-sky radiative cooling are equally important for weakening of the circulation.