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The impact of ENSO on water vapor isotopologues in the tropical pacific: Evidence for changes in long-range transport and convective activity

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ENSO (El Niño-Southern Oscillation) is characterized by quasi-periodic changes of tropical sea surface temperature (SST), near-global atmospheric circulation and associated changes in precipitation patterns. Due to the profound effects of ENSO on the global water cycle and on the associated fractionation processes of the water isotopologues, many isotope-based studies have been carried out to study the ENSO variability in the tropics. These studies conclude that "the isotope amount effect" is a key factor controlling the isotopic signature of water vapor and precipitation close to the surface. The goal of this study is to investigate the hydrologic processes governing the changes in isotopic composition of water vapor at the surface and at higher altitudes during ENSO events. We used the isotopic composition of water vapor modeled by an isotope-enabled GCM (ECHAM4), and measured by the TES (Tropospheric Emission Spectrometer) instrument onboard the Aura satellite. The isotopic composition of precipitation was modeled by ECHAM4 and observed by the GNIP network (Global Network of Isotopes in Precipitation). The amount of precipitation was modeled by ECHAM4 and ERA-Interim (ECMWF Re-Analysis), and measured by the TRMM (Tropical Rainfall Measuring Mission) satellite. Our results agree with previous studies focusing on the lower atmosphere: rainout processes, less rain re-evaporation of falling droplets, and increase of convective updrafts and diffusive exchange within the convective systems (all these processes contribute to "the isotope amount effect") isotopically deplete the water vapor during wet conditions (e.g. El Niño in Central Pacific and La Niña in West Pacific). However, we find that the isotope signal of water vapor at higher altitudes (e.g. 500 hPa) associated with ENSO events diverges from the near surface signature. Analysis suggests that at higher altitudes, transport of enriched water vapor from lower atmospheric layers through convective updrafts controls the enrichment of upper tropospheric water vapor over the Pacific Ocean. In the observations, a strong positive correlation between the increase of convective precipitation and the isotopic composition of water vapor isotope (δD, R2 of 0.8 in Central Pacific and 0.6 in West Pacific) clearly points to such a mechanism. Interestingly, in the model, a good correlation is only found between the percentage of convective precipitation and δD, with R2 values of 0.6 in the Central Pacific and 0.5 in the West Pacific. This points towards deficiencies in the ability of the model to reproduce convective precipitation. This finding opens interesting perspectives for the use of water isotopologues to improve the tropical cloud parameterization in the model.