The dominant controls on tropospheric hydrology over continental convective regions using isotope measurements from space

Derek Brown and David Noone
Cooperative Institute for Research in Environmental Sciences (CIRES),
University of Colorado at Boulder, CO, USA (email: derek.brown@colorado.edu)

The hydrologic regimes of convectively active regions contain intricate balances of large-scale advective supply of water, surface exchange, and atmospheric condensation/evaporation. The isotopic composition provides information about these balances and thus is useful to explore the way hydrology is represented in models, and specifically identify model limitations. To this end, a goal of this work is to explore limitations in General Circulation Model (GCM) hydrology, especially in regions of convection. Although the large-scale control on the isotopic composition of atmospheric moisture is primarily fractionation during evaporation from the oceans, isotopic fractionation during local condensation, evaporation, and evapotranspiration events lead to unique deuterium signals over convectively active regions (Gat, 1996). The seasonal variations in the deuterium content of water vapor seen by the Tropospheric Emission Spectrometer (TES) reflect these changes in convective regimes and give insight into the seasonally dependent influences of land surface conditions on regional hydrologic cycles. In turn, this additional knowledge based on observations can be used to refine parameterized physics in GCMs.

The relative amount of deuterium in a moist air mass is commonly compared to the average deuterium content of seawater and expressed in delta notation as δD (‰). A global map of seasonal differences in airborne δD values (**figure 1**) shows that continental convective regions with well defined monsoon seasons tend to produce the largest seasonal differences in δD values, yet large differences between convective regions of similar latitude exist. Specifically, the Amazon Basin, Asian Monsoon, and Congo regions show more deuterium depletion during their respective wet seasons (DJF for the SH, JJA for the NH), where as the N. Australia and SW United States regions show the opposite. Since regional monsoonal flow and strength is dictated by the regional topography, moisture flux, and heat and moisture exchange via land surface interactions, one must consider how all these inputs may change the seasonal δD values shown in **figure 1**.

Since the strength of the regions' monsoon events is linked to the intensity of rainfall, the variation in δD values as a function of rainfall rates (**figure 2**) during the regional wet seasons gives initial insight into monsoonal effects of isotopic fractionation during condensation for each region. This 'amount effect' (Dansgaard, 1964) of increasing isotopic depletion in precipitation with increasing precipitation rates in monsoonal regions has been statistically documented in Andean and Himalayan snow packs (Wushiki, 1977; Grootes, 1989), yet the physics underlying the process is not currently constrained by airborne δD measurements. The figure shows that while the Amazon, N. Australian, Asian Monsoon, and Congo regions' monsoon seasons show decreasing δD values with increasing precipitation rates (slopes of –3, -9, -3, and –3 ‰/mm/day, respectively), the SW United States region does not (slope of 0 ‰/mm/day). The amount effect appears as a fairly robust component causing deuterium depletion of water vapor during the tropical continents' rainy seasons and can be shown to be the dominant feature producing seasonal δD differences in the Amazon, Congo, and Asian Monsoon regions; however, it does not explain the unique seasonal differences in δD values for the N. Australian or SW United

States regions (**figure 1**). Instead, the TES δD measurements indicate that the δD seasonal differences over N. Australia and the SW United States are linked to inter-seasonal variations in moist convection and moisture advection.

A comparison of models in the Stable Water Isotope Intercomparison Group (SWING) has shown that while regional precipitation and atmospheric vapor amounts are fairly well modeled, the failure of these models to accurately represent isotopic variations, like those of the TES δD measurements, suggests they do so for the wrong reasons. By looking at the relationships between the isotope measurements and the various meteorological parameters, validation requirements for isotope-enabled GCMs are established.

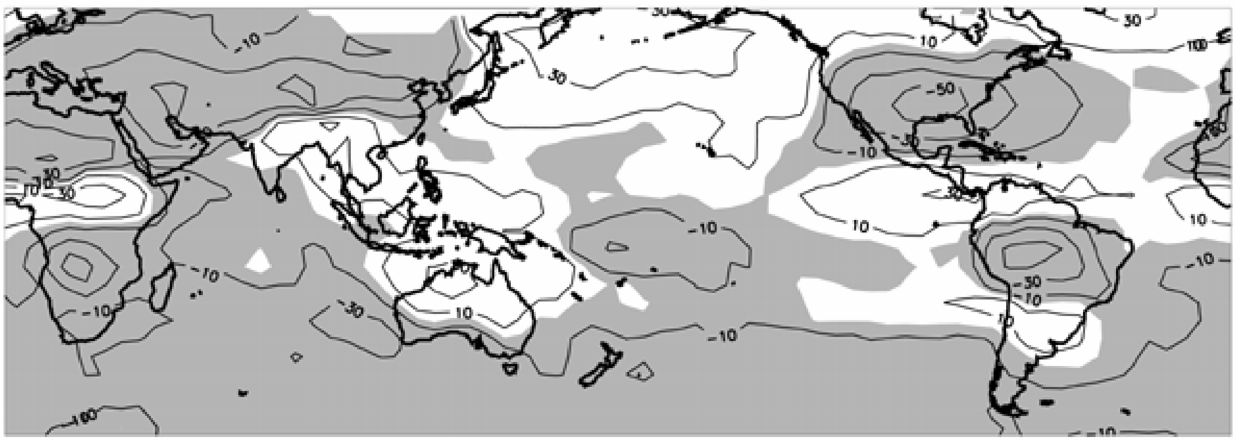

Figure 1: DJF-JJA δD values (‰) for the atmospheric level 300-850mb derived from TES retrievals during 2004-2006. Shaded areas indicate negative values, while solid line contour intervals are 20‰.

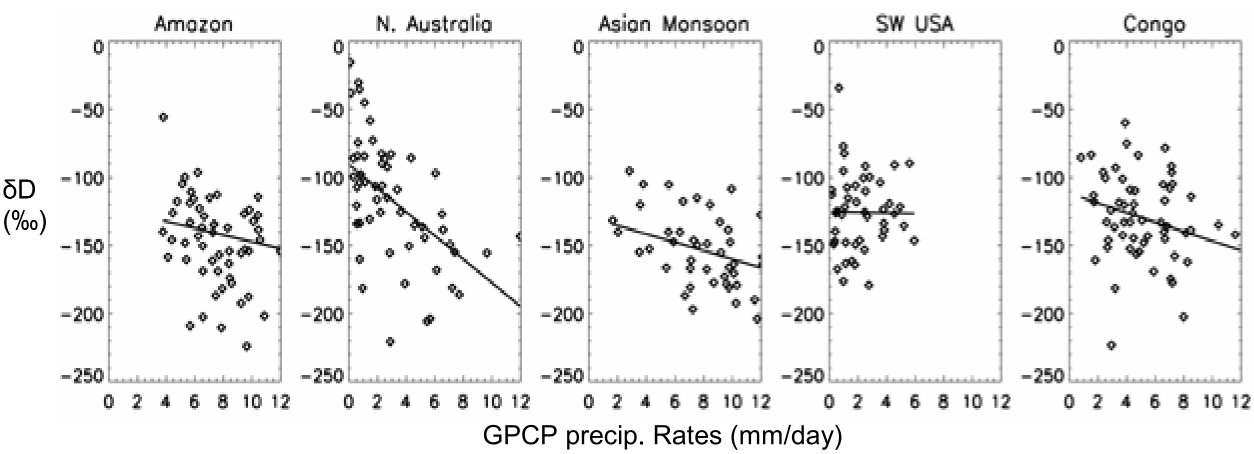

Figure 2: Daily averaged wet season (DJF for SH, JJA for NH) TES δD (‰) as a function of Global Precipitation Climatology Project (GPCP) precipitation rates (mm/day) for five convectively active regions around the globe.

References

1) Dansgaard, W. (1964): Stable isotopes in precipitation. *Tellus* **16**, 436-468

2) Gat, J.R. (1996): Oxygen and hydrogen isotopes in the hydrologic cycle. *Ann. Rev. Earth Planet Sci.* **24**, 225-262

3) Grootes, P. M., M. Stuiver, L.G. Thompson, and E. Mosley-Thompson (1989): Oxygen Isotope Changes in Tropical Ice, Quelccaya, Peru. *Journal of Geophysical Research* **94**,1187-1194.

4) Werner, M., et al., 2004: SWING - The Stable Water Isotope Intercomparison Group: Eos Trans. AGU, 85 Fall Meet. Assem. Suppl., Abstract C51B-1034

5) Wushiki, H. (1977): Deuterium content in the Himalayan precipitation at Khumbu District, observed in 1974/1975. SEPPY0 *(Journal of the Japanese Society of snow and ice)* **39** (Special Issue), 50-56.