Using Isotopic Constraints to Model Monsoonal Moisture Exchange

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The transfers of heat and moisture from the land surface to the atmosphere are substantial over monsoonal regions, yet these mechanisms are poorly resolved in current land-atmosphere models (*Dirmeyer et al*., 2006). There is a need for further understanding of the seasonal variations in the sources of moisture over monsoonal regions, including the contributions from evapotranspiration and re-evaporation of falling rain (*Henderson-Sellers et al*., 2004). Stable water isotope measurements from the Tropospheric Emission Spectrometer (TES) are useful in this regard since isotopic fractionations occurring during evaporation and condensation give rise to measurable variations in the isotopic composition of water vapor, which can be used to estimate the strength of the contributing processes. The present study uses TES isotopic values and five day back trajectories to constrain a Lagrangian isotopic exchange model that estimates the ratio of evaporative supply of water vapor to losses from precipitation (*E/P*), as well as the rainfall evaporation fraction (*F*), for the 500-825 hPa layer (*Brown et al*., 2008). Given the advection pathways from the well constrained NCEP wind fields, the isotopes allow the hydrology of the reanalysis to be tested.

Results show that very strong isotopic depletion *en route* during the wet season in the Amazon and Asian monsoon regions (**Figure 1**) exceeds that from Rayleigh distillation expectations, which can be explained by the simple rainfall evaporation model that also assumes mixing with an evaporative source. Using an oceanic source for low-level vapor, this model best fits the data using *F* values of 26% and 34% for the Amazon and Asian monsoon regional wet seasons (**Table 1**), respectively, which are consistent with the mean tropical value of 30% found by *Worden et al*. (2007). The *E/P* ratio of approximately 1.04 for the N. Australian wet season suggests a net gain of water from the surface to the layer 500-825 hPa, which contrasts with the stronger monsoons of the Amazon and the Asian monsoon regions. *E/P* estimates for the dry season indicate that supply of near-surface water vapor over the five-days prior to observation approximately balances losses due to condensation. However, the isotopic constraints in the model were only met for the Amazonian dry season when the assumed near-surface δD values were raised above the typical value of near-surface air in equilibrium with tropical ocean waters (-79‰). This anomaly suggests that the water vapor supply for the Amazon dry season is partially composed of transpired moisture.

Comparison of the best-fit *E/P* ratios with surface-based *E/P* ratios from the NCEP and ECMWF reanalyses shows reasonable agreement for the Amazon wet and dry seasons, but disagreement for both seasons of the N. Australian and Asian monsoon (which contain several oceanic grid points). These differences are largely due to large-scale subsidence which acts to increase oceanic evaporation values (via dry conditions) yet inhibit vertical transport of surface moisture to the level of the parcels (via increased stability). Future comparisons with vertical vapor flux at the 825 hPa level from the reanalysis data sets may resolve these issues.

Ultimately, this work will provide methods for spatially resolved assimilation of TES isotope data into the hydrologic cycles of monsoonal regions.

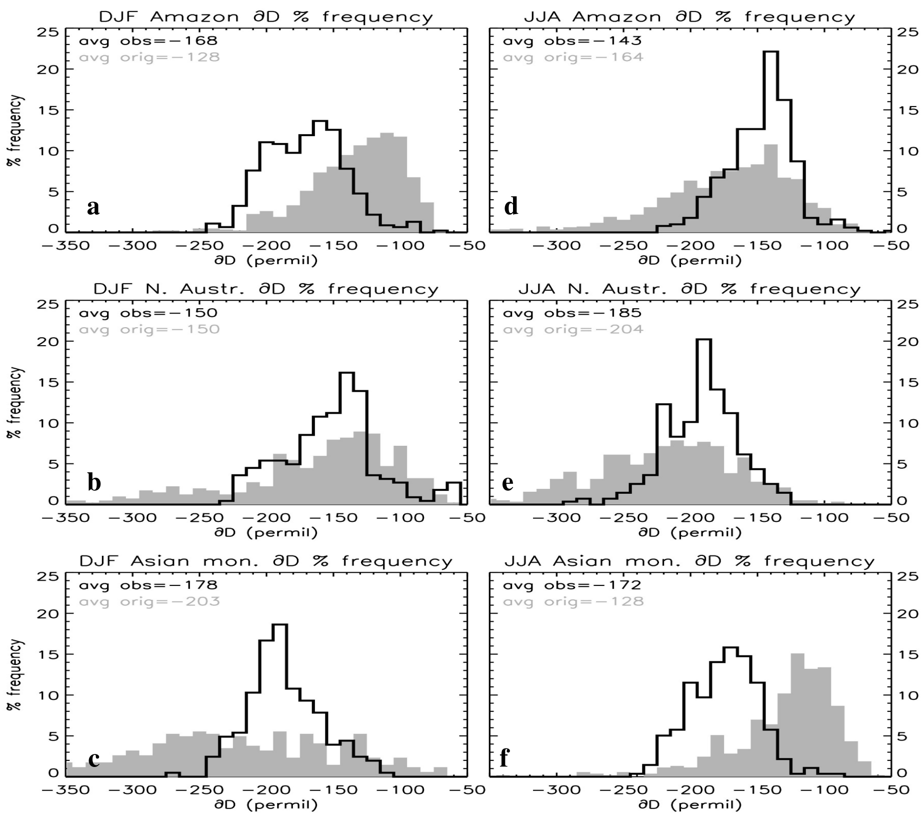

Figure 1: Frequency distribution of δD values over the layer 500-825 hPa for DJF (a,b,c) and JJA (d,e,f) seasons for the Amazon (a,d), N. Australian (b,e), and Asian Monsoon (c,f) regions. Grey shading represents δD value distribution close to the five-day back trajectory origins, while black line indicates that of the regions. Amazon= 0°S-20°S,290°-310°E, N. Australia=10°S-22.5°S,120°-140°E, and Asian monsoon=15°N -30°N,80°E-100°E.

		Oceanic source		*Continental source*		*NCEP*	*ERA*
Region	*Season*	*E/P*	*F (%)*	*E/P*	*F (%)*	*E/P*	*E/P*
Amazon	DJF	0.00 < **0.72** < 0.80	21 < **26** < 28	0.00 < **0.76** < 0.80	21 < **53** < 54	**0.63**	**0.55**
	JJA	0.94 < **0.95** < 0.95 *	00 < **00** < 03 *	0.78 < **0.86** < 0.95	00 < **28** < 45	**0.90**	**1.05**
N. Austr.	DJF	0.00 < **1.04** < 1.09	00 < **28** < 58	0.00 < **1.03** < 1.09	00 < **59** < 59	**0.63**	**0.59**
	JJA	0.87 < **0.91** < 0.96	00 < **18** < 36	0.76 < **0.94** < 0.96	11 < **62** <64	**12.9**	**13.4**
Asian mon.	DJF	0.85 < **0.88** < 0.93	00 < **06** < 25	0.69 < **0.86** < 0.93	00 < **52** < 61	**3.22**	**3.50**
	JJA	0.00 < **0.72** < 0.79	33 < **34** < 42	0.00 < **0.78** < 0.79	39 < **59** < 59	**0.42**	**0.30**

Table 1: Modeled rainfall evaporation fractions and ratios of net evaporation to net precipitation over the five-day transport pathways. Model was run for both an oceanic source, with a δD source value of the near-surface air of -79‰, and for a continental source with δD value of the source vapor set to that of regional precipitation (deduced from GNIP). Bold indicates best fit, while range indicates valid output using the constraint that modeled δD must be within one standard deviation of the mean regional δD values. Asterisk indicates that model constraints could only be met with δD source value greater than -65‰, and so the source can not be purely oceanic (-79‰).

References

1. Brown, D., J. Worden and D. Noone (2008), Comparison of atmospheric hydrology over convective continental regions using water vapor isotope measurements from space, submitted to Journal of Geophysical Research – Atmospheres, December, 2007.
2. Dirmeyer, P.A., R.D. Koster, and Z. Guo (2006), Do global models properly represent the feedback between land and atmosphere?, *J. Hydrometeor., 7*, 1177-1198.
3. Henderson-Sellers, A., K. McGuffie, D. Noone, and P. Irannejad (2004), Using Stable Water Isotopes to Evaluate Basin-Scale Simulations of Surface Water Budgets, *J. Hydrometeor.*, *5*, 805–822.
4. Worden J, D. Noone, K. Bowman, et al. (2007), Importance of rain evaporation and continental convection in the tropical water cycle, Nature, *445*(7127), 528-532, doi:10.1038/nature05508