The relationship of precipitation recycling to climate in the tropics through stable isotopes

Kurt C. Solander[1], Brent D. Newman[1], Nicolette Gonzales[1], Scott Jasechko[2] and Chonggang Xu[1]

[1] Los Alamos National Laboratory, Earth and Environmental Sciences Division, Los Alamos, NM

[2] University of California, Santa Barbara, Bren School of the Environment, Santa Barbara, CA

Contact information: ksolander@lanl.gov

Abstract

The study of stable precipitation isotopes is important to tropical ecohydrology due to the potential for moisture source detection, climate zone seasonality characterization and moisture recycling quantification (e.g. local re-precipitation of water vapor derived from ET). In this study, we used monthly precipitation isotope data from 395 sites within the IAEA Global Network of Isotopes in Precipitation (GNIP) database to assess the characteristics d^2H and $d^{18}O$ in precipitation at the pan-tropical scale (+/-30° North Latitude). We focus our efforts on investigating spatial patterns of d-excess calculated from this data due to its strong sensitivity to precipitation recycling. We employed a geospatial interpolation method to get a spatially continuous estimate of mean monthly d-excess across this latitudinal range and further classified these estimates into the three main Köppen-Geiger (KG) climate zones that occur within the tropics (e.g. tropical, temperate and arid) based on differences in d-excess values. Our results show the KG climate zones derived from D-excess match reality in greater than 60% of the land surface at 1° resolution. Spatial matching was highest over larger continental land masses and lower where data was too sparse to appropriately resolve the interpolation as well as in regions where precipitation was more seasonally controlled. We aim to improve upon these estimates by investigating the role of specific climate and geospatial variables on d-excess values that include distance from ocean, precipitation, temperature and evapotranspiration as well as how these relationships vary seasonally. Such an effort will be useful to integrate precipitation recycling into Earth System Models (ESMs) to determine how the spatial variability of moisture sources might be changing under a warming climate.

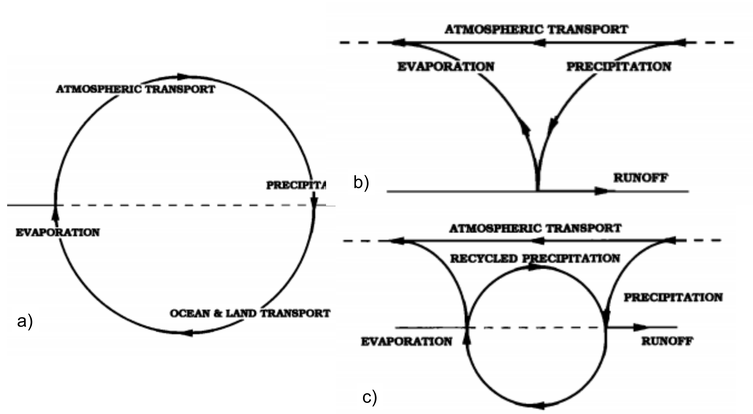
Background

What is Precipitation Recycling?

Precipitation recycling refers to the portion of evapotranspired water from precipitation events that is re-precipitated. The ratio of locally derived precipitation to total precipitation is known as the recycling ratio.

Why is recycling important?

- Estimates of the recycling ratio vary from ~10-50% depending on method and region, making recycling a significant part of the terrestrial water cycle (Eltahir and Bras, 1996)
- Vegetation-regulated moisture recycling is a critical ecosystem service that must be quantified and evaluated for its importance (Keys et al., 2016)
- Changes in climate and ecosystem disturbance may alter recycling ratios (Li et al., 2016)

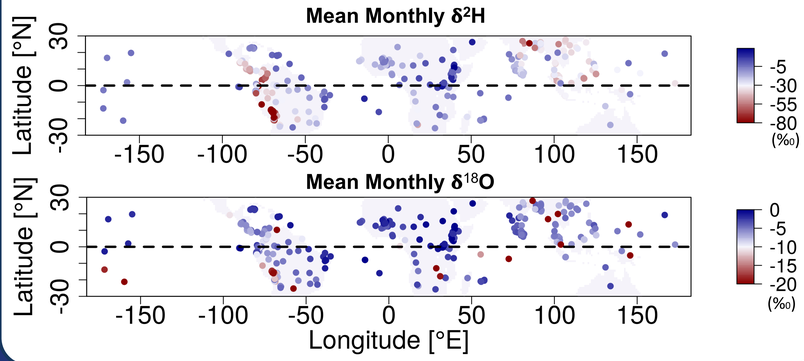


The hydrological cycle at multiple scales. (a) global, (b) local, and (c) regional (showing moisture recycling). From Eltahir and Bras (1996).

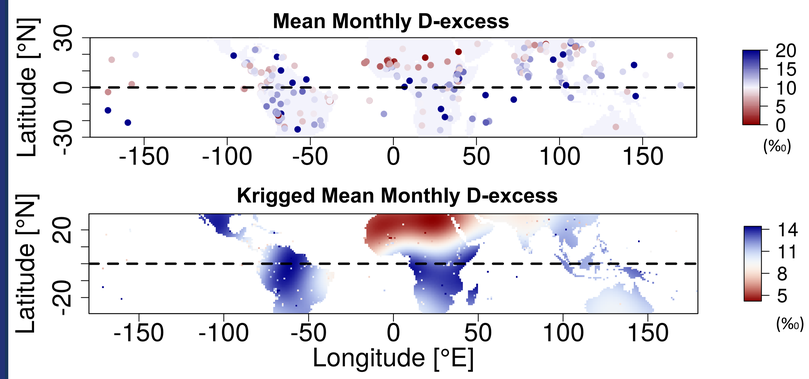
Methodology and Data Sources

Calculation of d-excess

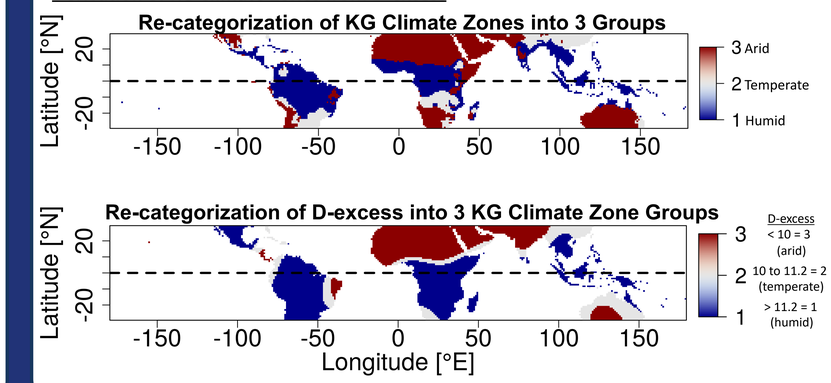
- d-excess values of precipitation are sensitive to recycling, making them a good indicator of this process
  - ➢ High values (>10) indicate greater recycled precipitation, often found in less arid climates where relative humidity is higher
  - ➢ Low values (<10) indicate less recycled precipitation, often found in more arid climates where relative humidity is lower (Bershaw, 2018)
- Equation: d-excess = $\delta^2H - 8 * \delta^{18}O$ (Froelich et al., 2008)



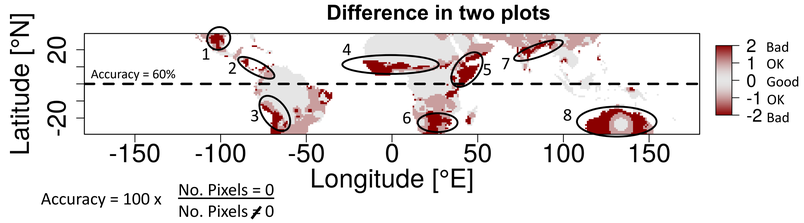
Results and Discussion



Derivation of KG Climate Zones from D-excess

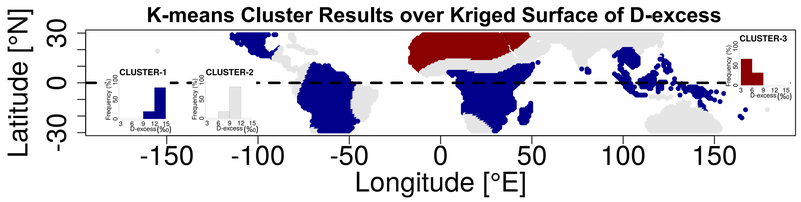


Results and Discussion

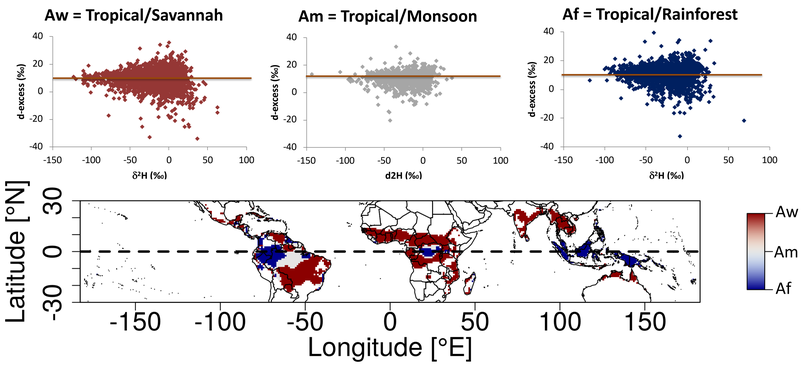


Accuracy = 100 x $\frac{\text{No. Pixels} = 0}{\text{No. Pixels} \neq 0}$

1: Mexico: poor data coverage
2: Latin America: anomalously low D-excess because rainfall largely ocean fed due to constricted land area
3: Atacama Desert – poor data coverage
4: Sahel: seasonal rainfall pattern (ITCZ-controlled) not captured with annual
5: Ethiopia: scientific mystery = anomalously high D-excess for high elevation (Levin et al., 2009)
6: Namib Desert: poor data coverage
7: India: seasonal rainfall pattern (ITCZ-controlled) not captured with annual
8: Australia: central desert region – only 1 data point



Next Steps: Precipitation Recycling



- Above shows zonal statistics of D-excess for major KG Climate Zones of Tropics
- Previous studies show precipitation recycling substantial when D-excess > 10 ‰
- 14-15% of D-excess above 15 ‰ across Af, Am and Aw indicating not much difference in precipitation recycling across three regions

References and Acknowledgements

- Bershaw, J. (2018), Controls on Deuterium Excess across Asia, Geosciences, 8, 1-11.
- Eltahir, E. A., and R.L. Bras (1996), Precipitation recycling, *Reviews of geophysics*, *34*(3), 367-378.
- Froelich, K., J.J. Gibson and P.K. Aggarwal, 2002, Deuterium excess in precipitation and its climatological significance, Study of environmental change using isotope techniques, C&S Papers Series 13/P, 54-65, International Atomic Energy Agency: Vienna, Austria.
- Keys, P. W., L. Wang-Erlandsson and L.J. Gordon (2016), Revealing Invisible Water: Moisture Recycling as an Ecosystem Service, *PloS one*,*11*(3), e0151993.
- Li, R., C. Wang and D. Wu, 2018, Theoret. Appl. Clim., Changes in precipitation recycling over arid regions in the Northern Hemisphere, 131, 489-502.

This work was supported by the U.S. Department of Energy, Office of Biological and Environmental Research as part of the NGEE-Tropics