Satellite and model constraints on water cycling responses to ENSO and tropical variability using water isotopes: Annual Report Year 1

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The work for this proposal is spread over three centers (NASA GISS, JPL, and U. Colorado), three PIs and three co-investigators, Allegra LeGrande (NASA GISS), Camille Risi (U. Colorado), and Jeonghoon Lee (JPL). The first year focus has been on a) improving the characterization of the TES water vapor isotope retrievals (JPL), b) improvements to the data-model comparisons (GISS/JPL/UC), c) completion of nudged GCM simulations with water vapor isotopes (GISS/UC) and d) assessments of the needed collaboration and work for the proposed elements for Year 2 onwards. Each of these aspects are discussed in turn below.

Improvements in TES water vapor isotope retrievals

Lee et al. (subm) has explored the impact of cloud distributions on the water vapor isotope retrievals from TES. Because of the impact of clouds on the measurements, the atmospheric sensitivity of the retrievals will change. As shown in Figure 1, the presence of cloud increases the height at which the retrieval is most sensitive to water vapor isotope variability.

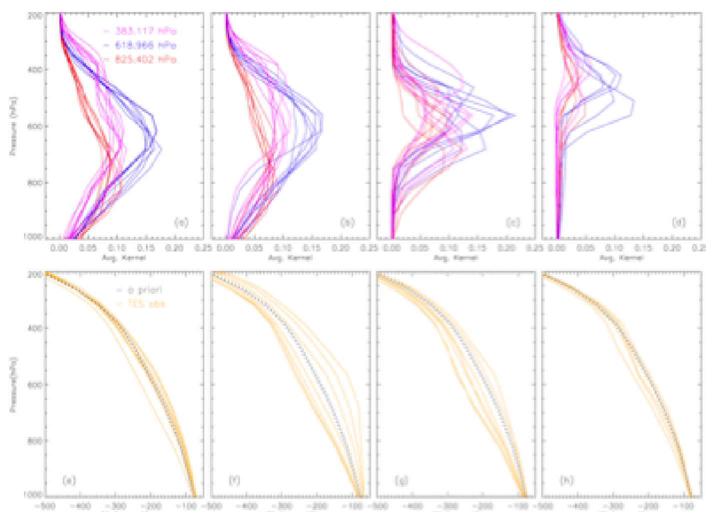


Figure 1. *TES averaging kernel rows corresponding to 825, 619 and 383 hPa and the a priori and the retrieved TES δD profile. Selected TES observations are over tropical ocean during 1 August, 2007 (Run ID, 5889) except precipitating clouds. (a) and (e) Clear sky (The degrees of freedom, DOF, is greater than 1.25), (b) and (f) non-precipitating clouds (DOF is greater than 1.0), (c) and (g) boundary layer clouds (DOF is greater than 0.5) and (d) and (h) precipitating clouds from August 1, 2007 to August 8, 2007 (Run ID, 5889, 5918 and 5948 and DOF is greater than 0.5).*

Taking a broader view, tropical ocean transects across the Pacific and Atlantic (fig. 2) demonstrate clearly that different environments have distinct isotope and humidity profiles that will be of use in assessing the degree of rainfall evaporation and mixing up of boundary layer air. δD values are isotopically depleted in Western Pacific where H_2O and the number of precipitating clouds are relatively large high indicating rainfall evaporation significantly affects water vapor distribution in this region. Relatively enriched values east of Africa indicate significant mixing of PBL air into free troposphere. Depleted values in Eastern Pacific in conjunction with high fraction of boundary layer flags indicate subsidence and/or lack of mixing between PBL and free troposphere.

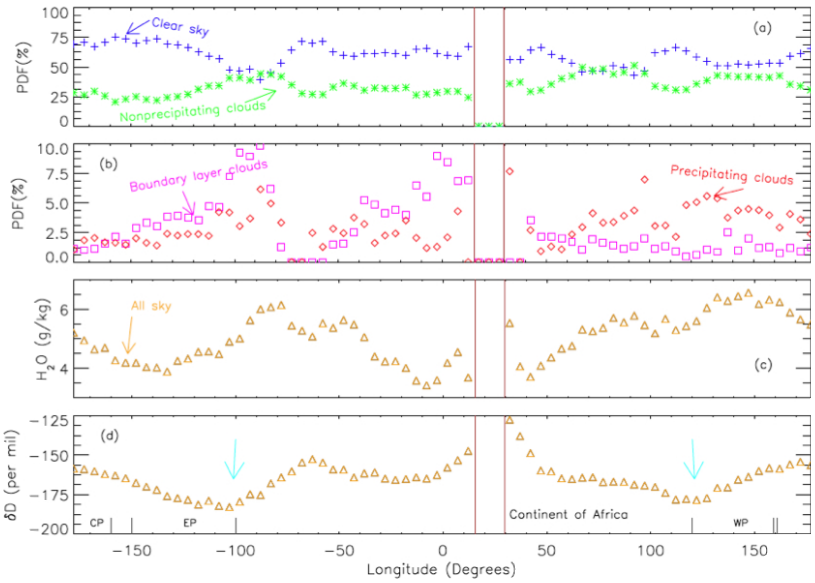


Figure 2. *Tropical mean ocean profiles (15°S - 15°N) binned every 5° of longitude, starting in the central Pacific. (a) Clear sky (blue cross) and nonprecipitating clouds (green asterisk). (b) Boundary layer clouds (cyan square) and precipitating clouds (red diamond). (c) Water vapor (g/kg) for all sky conditions (d) Water vapor isotope (‰). The two cyan arrows indicate isotopically depleted regions. The cloud types were defined based on the ISCCP classification.*

Other improvements in retrievals (mostly being developed under the core TES grant) will allow for greater vertical resolution in the TES product. We have prototyped and tested a new approach to the HDO and H_2O retrieval that uses the mid-IR between 1170 cm^{-1} through 1320 cm^{-1} to co-estimate HDO, H_2O, and all other species in this band such as N_2O and CH_4. The old approach used small "spectral-windows" in this same range that reduced the interference from these now co-retrieved species but also significantly reduced the vertical resolution. With this new capability we expect to refine our estimates of mixing and cloud processes in the upper troposphere as well as resolve exchange between the PBL and lower troposphere, a key source of moisture in the tropics.

Data-model comparisons

As discussed above, the retrievals of TES water vapor isotope values nominally provide a mean lower tropospheric value. However, there will be variations in the weighting as a function of clouds and surface temperatures. Taking output from the GCMs and applying a naïve filter is the zeroth order way to make a comparison, but our results to date indicate that applying a more sophisticated post-processing gives an important improvement to model-data fidelity. In figure 3, we show the relationship between water vapor amount and isotope ratios

Figure 3: *H_2O vs dD in a region 40ºS-15ºN, 30ºW-60ºE in JJA. Cyan=NCAR CAM, Magenta=GISS ModelE, Green=TES (observations). a) using a naïve weighting, b) using a TES diagnostic operator to approximate the retrieval characteristics.*

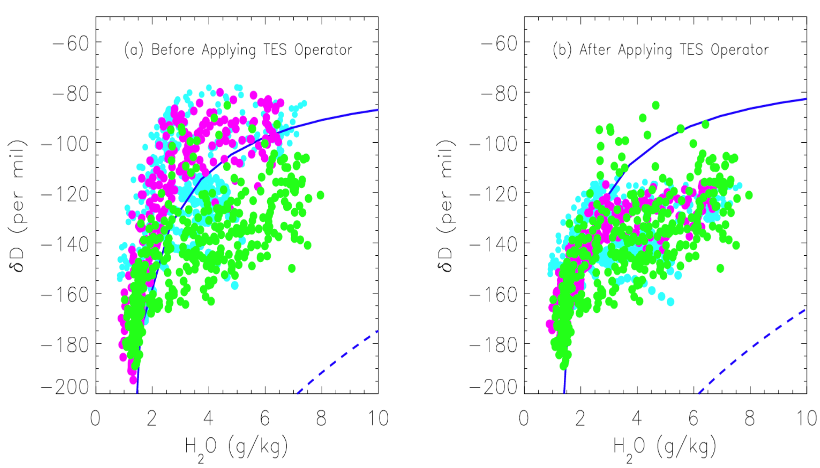
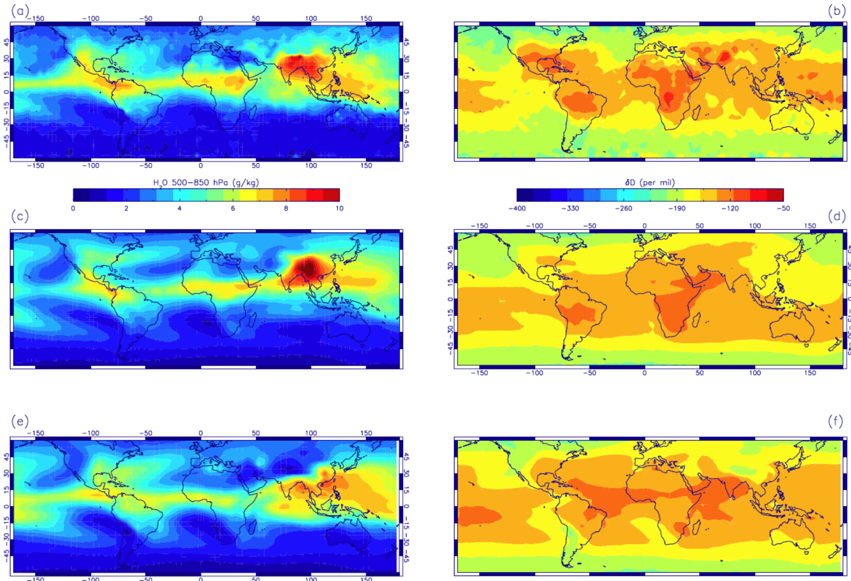


Figure 4: *H_2O and δD in a) and b) TES, c) and d) NCAR CAM, e) and f) GISS ModelE, using a naïve weighting.*

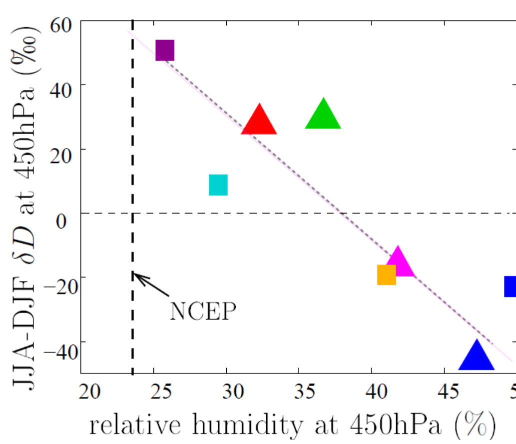


The best naïve comparisons between models and the TES data are achieved by considering only clear sky conditions. However, “clear sky” is not the same thing in the TES data and the models because of the difference in grid resolution and satellite footprint, as well as how 'clouds' are defined (via optical depth limits for instance). These are similar problems to that seen in model comparison to ISCCP or CALIPSO data, and there is a deep literature and code for dealing with this as a model diagnostic. Specifically, the 'cloud simulators' subsample model grid boxes with a random vertical profile of clouds reflecting different overlap assumptions. Thus even a cloudy grid box can have a small chance of returning a clear sky profile. The pseudo-TES retrievals can then be classified as in the real case.

Nudged GCM simulations

For comparisons with time-series of observed data , it is very useful for simulations to be 'nudged' using observed wind fields in order to better coincide with the actual weather at any one moment. This does not give identical weather patterns to those seen in the re-analysis, but it does improve the fidelity of the simulation – particularly in the mid-latitudes. Both the GISS ModelE and the NCAR CAM isotope-enabled codes were run for the last 50+ years (1957-2009) in this fashion, using NCEP wind fields as input. These simulations will be the basis of many of the comparisons we plan to do. Both sets of data have been submitted to the SWING2 archive (http://people.su.se/~cstur/SWING2) and analyses of these models and others are ongoing.

Figure 5: *Relationship between relative humidity at the altitude TES observes (15-30ºN) and the seasonal variation in δD from models that contributed to the second Stable Water isotopic Inter-comparison Group (SWING2) experiment. These models are all AR4-class models. The green and blue triangles correspond to a single model but with two configurations, the latter with a strong tropospheric humidity moist bias.*



As an example of what we are hoping to achieve through multi-model/TES data comparisons, we have found a strong relationship (fig. 5) between the seasonal variations in dD and the mid-troposphere (450 hPa) relative humidity across a number of models. The reason for the relationship is that in drier (and apparently more realistic) models, the effect of convection on isotopes is an enrichment of the mid-troposphere whereas it is a depletion in the moister models (particularly in the West Pacific warm pool), suggesting that better focus on monsoon and convective processes using isotope constraints may be able to pin down the causes of model errors.

Work Assessment for Year 2 onwards

Communications between the PIs occur via regular telecons and email exchanges, but our first face-to-face meeting PI meeting occurred at the WAVACS workshop in April 2010 (GAS, JW, DN, JL and CR) where we discussed in detail the progress and needs for improved model-data comparisons. Planning for our next meeting is underway. Work is ongoing to use the new cloud discriminated retrievals as the basis for a TES-water vapor simulator within the GCMs themselves, piggy-backing on the existing ISCCP/CALIPSO simulators that already exist. Additionally, a number of new sources of remotely sensed isotope data are now becoming available, each with a unique atmospheric profile. For instance, the European SCIAMACHY instrument (using reflected solar IR) has a more even weighting through the atmosphere and may provide complementary information to that seen by TES. The cloud effects on this product will also need to be taken into account.

References stemming from this award

Submitted papers

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