Water Vapor Isotope Ratio Measurements at NOAA GMD Sites to Constrain the Isotope-enabled Community Earth System Model

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Introduction

Global climate sensitivity is strongly tied to the atmospheric hydrologic cycle, particularly the role of clouds in a warming environment. Thus making sure global climate models accurately simulate the atmospheric water cycle, particularly physical processes related to clouds and precipitation, is vital if one wants to use the model to quantify future global climate change. One tool that can now be leveraged thanks to new observational technologies is water isotopes, which are sensitive to phase changes of water, and the environmental conditions present during the phase change.

This poster examines the use of three new datasets of water isotope ratios in water vapor, including two from NOAA GMD sites, and a third from a location in Colorado. The objective is to determine if these data can be used to help constrain model parameters in the new, isotope-enabled NCAR CESM, which is an IPCC-class model used to generate future climate projections.

A Picarro water isotope vapor analyzer has been installed in three locations: 1) Mauna Loa[1,2], HI, Niwot Ridge, CO, and Summit, Greenland[2]. A fourth analyzer has been installed at the Boulder Atmosphere Observatory in Erie, CO, but is not used here (see poster by Aleya Kaushik for more information). The analyzers measure water vapor concentration and the δD and δ18O of water vapor, although only δD will be examined here.

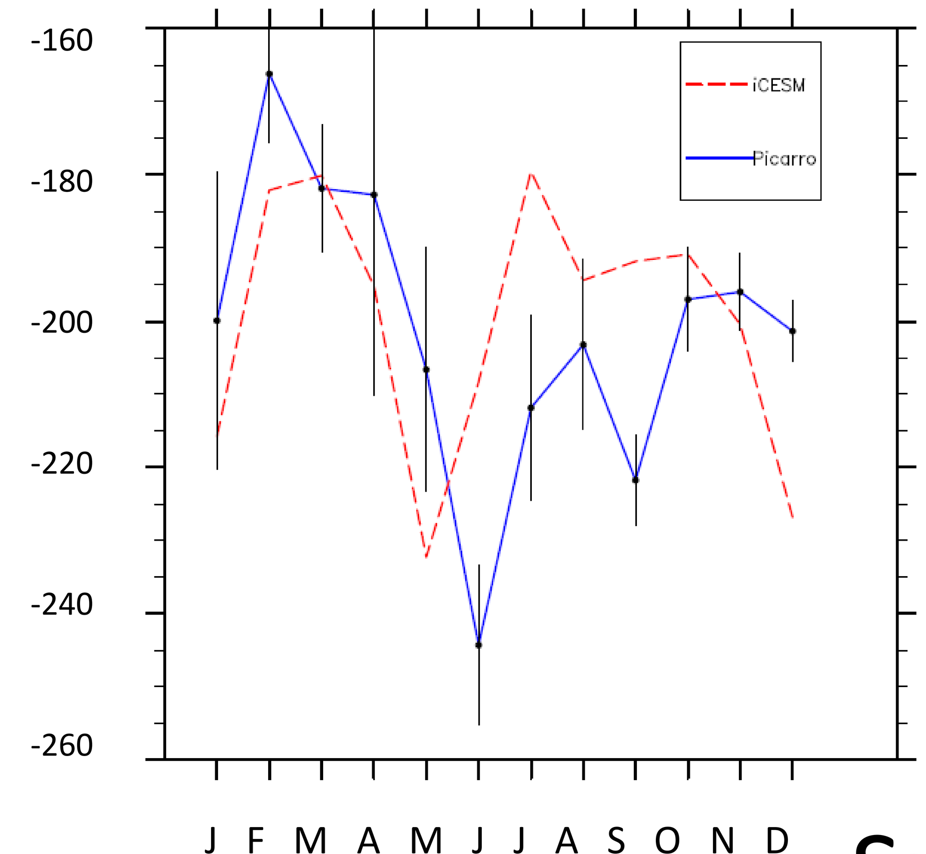
$$R = \frac{HDO}{H_2O}$$

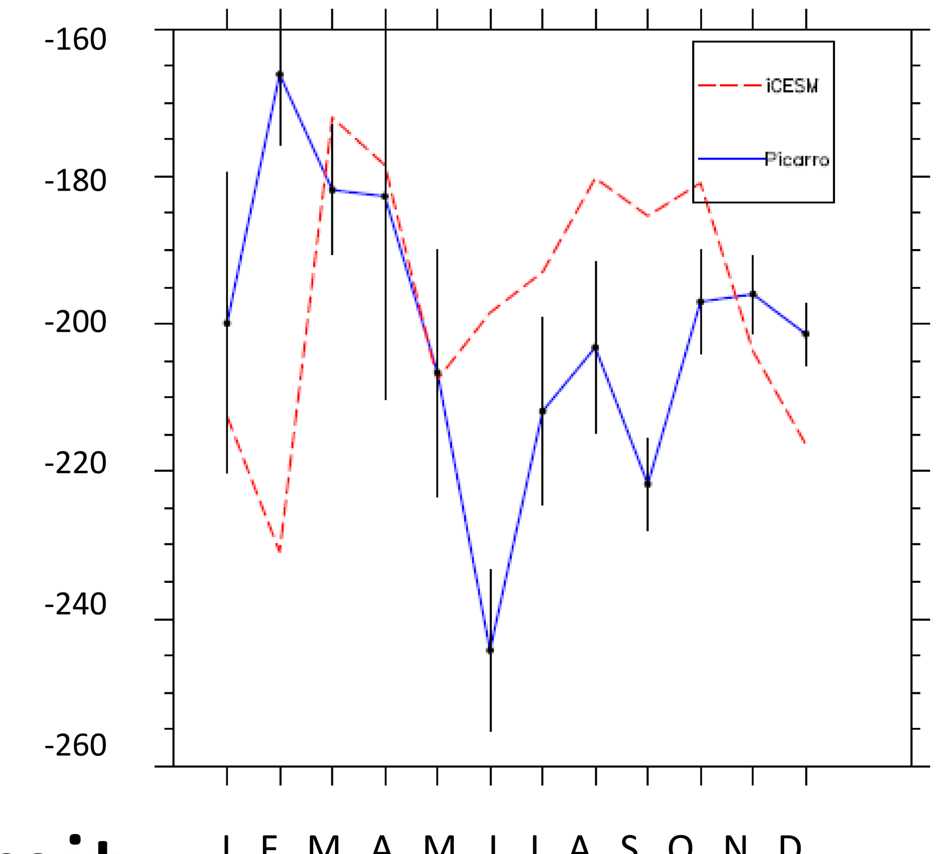
$$\delta D = \left(\frac{R}{R_{std}} - 1\right) * 1000$$

Control run — "prec_half" run

Mauna Loa

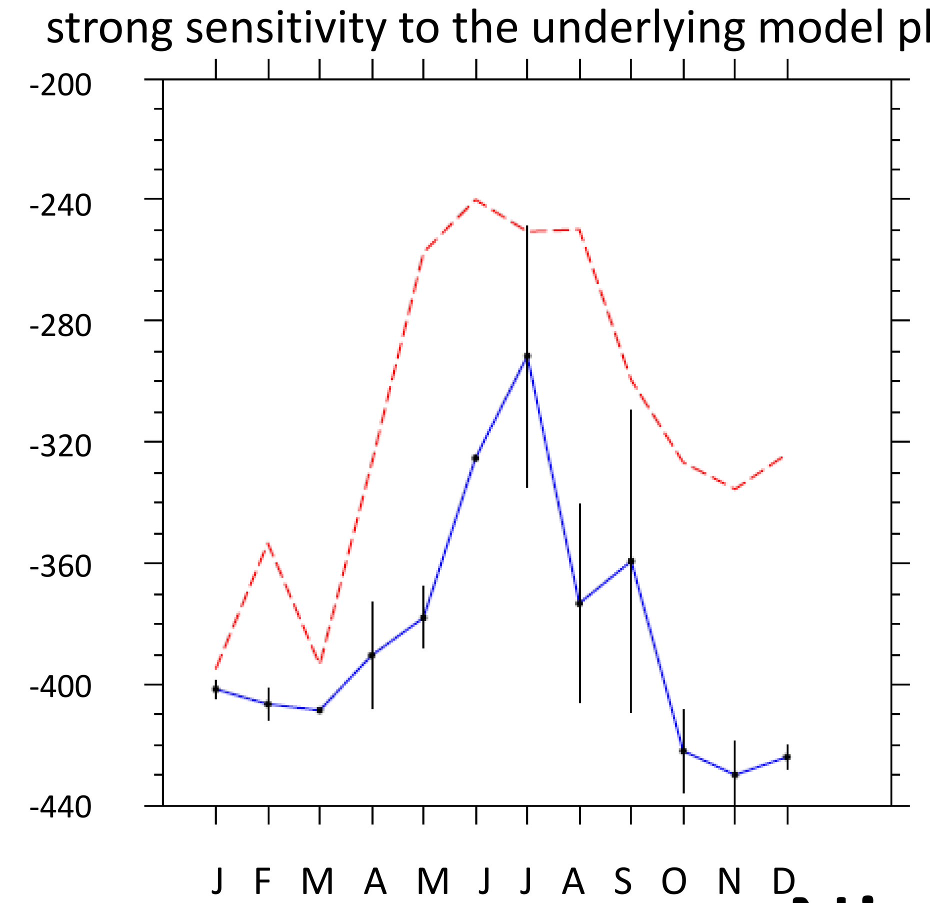
Mauna Loa is unique in that it doesn't have a clear seasonal cycle, but is generally well-simulated. However, it does not appear that tuning the model improves the fit (Red = model, blue/black = obs).

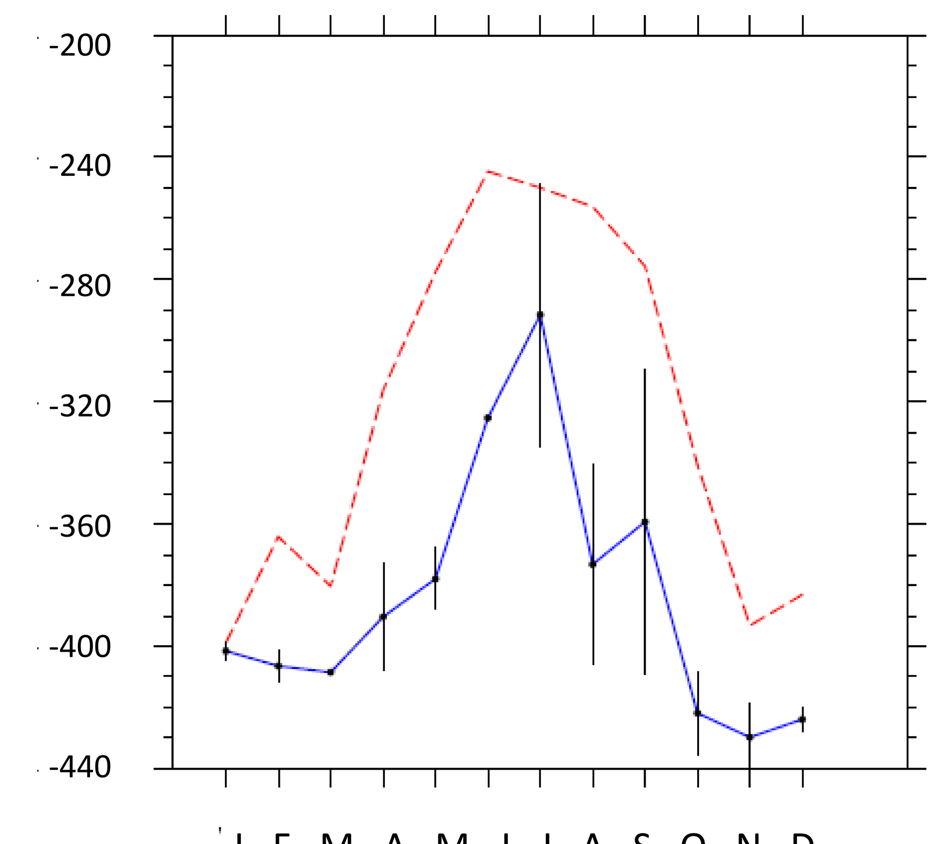




Summit

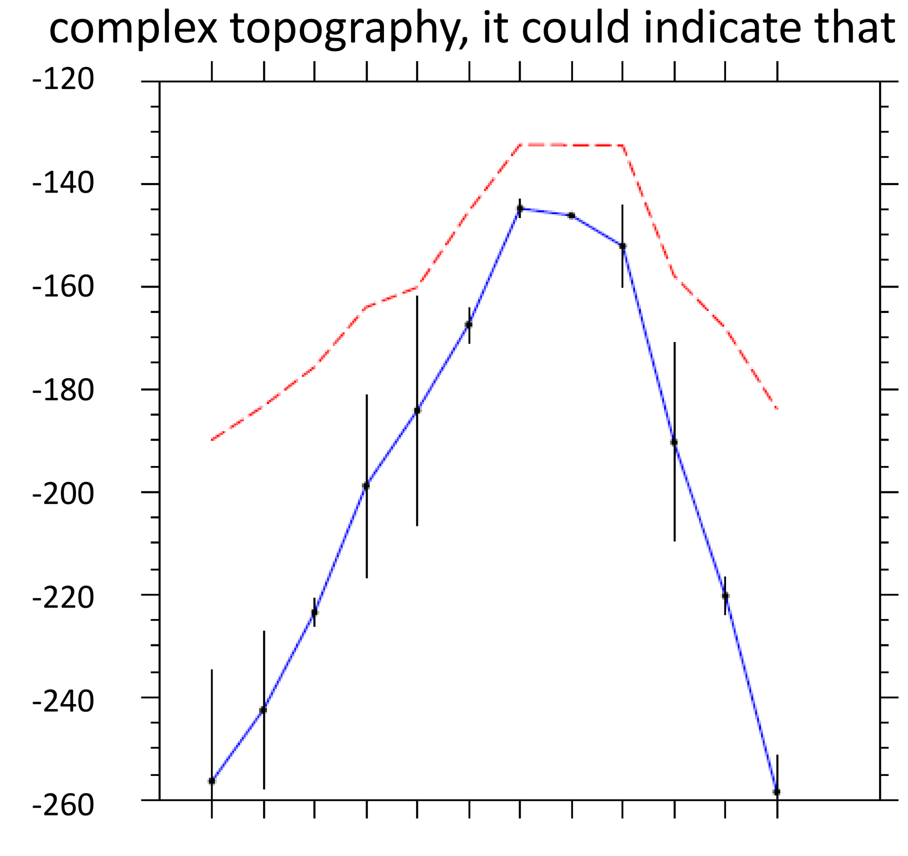
Summit is unique in that it experiences a strong improvement from the model tuning, indicating strong sensitivity to the underlying model physics.

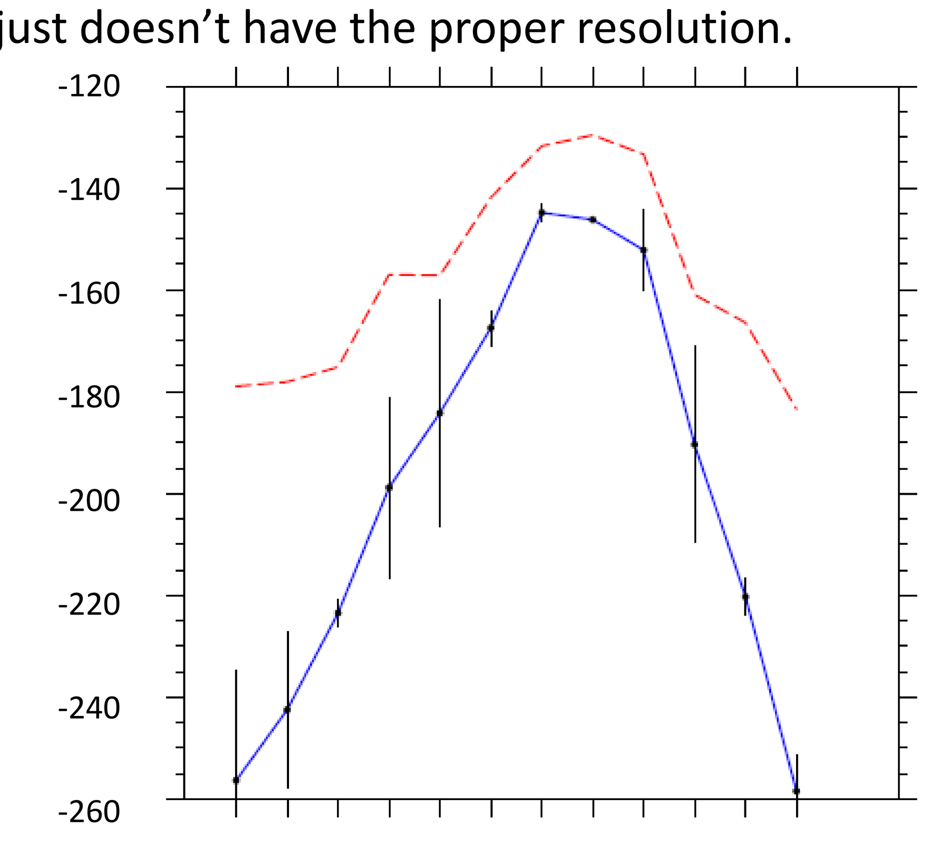




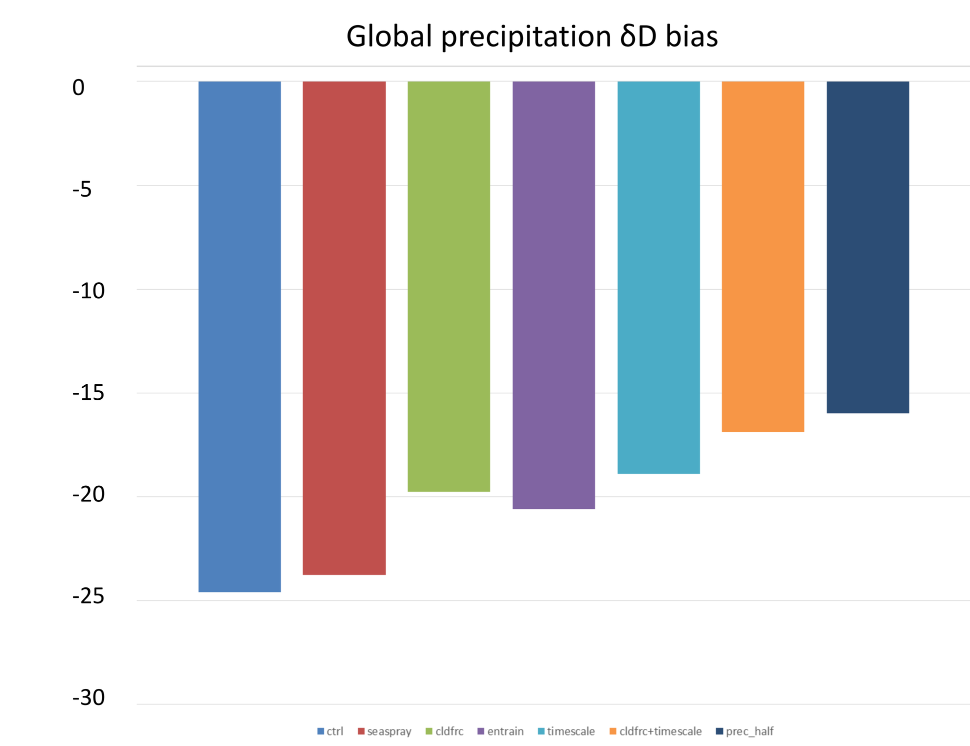
Niwot Ridge

Niwot Ridge is poorly simulated in both runs. However, given that it is located in a region of complex topography, it could indicate that model just doesn't have the proper resolution.





Tuning parameters:



Numerous tuning parameters were adjusted to try and minimize the error between the model and global precipitation isotope values. The most effective was to reduce the rate of cloud condensate being converted into precipitation. This run is designated "prec_half", and it's results compared to the vapor measurements are shown in the center section.

ctrl: The standard model run with no changes

seaspray: The addition of isotopic sea spray at the surface, to increase isotopic evaporation

cldfrc: An increase in the grid-scale RH needed to generate a cloud (RH = 0.99 everywhere).

entrain: An increase in the deep convective parcel entrainment rate (100x larger)

timescale: An increase in the deep convective CAPE consumption timescale (4x larger)

cldfrc+timescale: The cldfrc change and timescale change combined

prec_half: The precipitation in both convection and the large-scale cloud physics is halved.

Conclusions

Three new data sets of water isotopes in vapor now exist , and can provide a unique way to examine the hydrologic and physical processes present in global climate models. These data are compared to the new isotope-enabled CESM, both for a control run and a run where the condensate-> precipitation conversion rate was halved. The model does an ok job simulating the isotope values at Mauna Loa and Summit, with potentially strong sensitivity to model physics at the Summit location. However, the model does a poor job simulating the isotope values at Niwot Ridge. This could indicate the importance of model resolution, and of properly capturing complex topography, and the atmospheric flows they generate.

1. Bailey, A., Nusbaumer, J., and D. Noone. Precipitation efficiency derived from isotope ratios in water vapor distinguished dynamical and microphysical influences on subtropical atmospheric constituents. *Journal of Geophysical Research*. Submitted.

2. Bailey, A., Noone, D., Berkelhammer, M., Steen-Larsen, H. C., and P. Sato. The stability and calibration of water isotope ratio measurements during long-term deployments. *Atmospheric Measurement Techniques*. Submitted.