Efforts to optimize TCCON retrievals

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Introduction

To support carbon cycle research and satellite validation, TCCON retrievals require highly accurate and precise total column greenhouse gas (GHG) measurements.

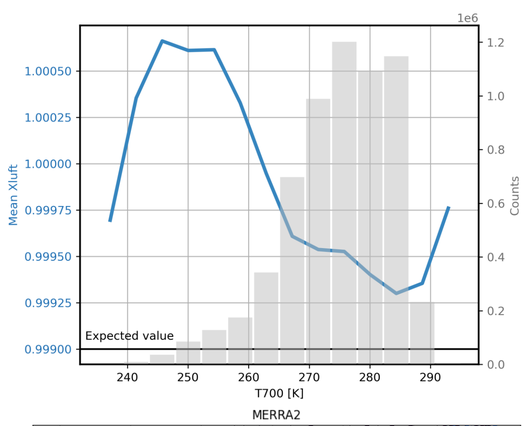
Here, we investigate different sources of uncertainty to identify potential areas for improvement.

A priori uncertainties

GGG2020 uses GEOS FPIT to estimate the water vapor, pressure, density, temperature, potential vorticity, ozone, and CO priors. Here, we compare GEOS FPIT and MERRA-2 to evaluate the sensitivity of the retrievals to the choice of meteorological input.

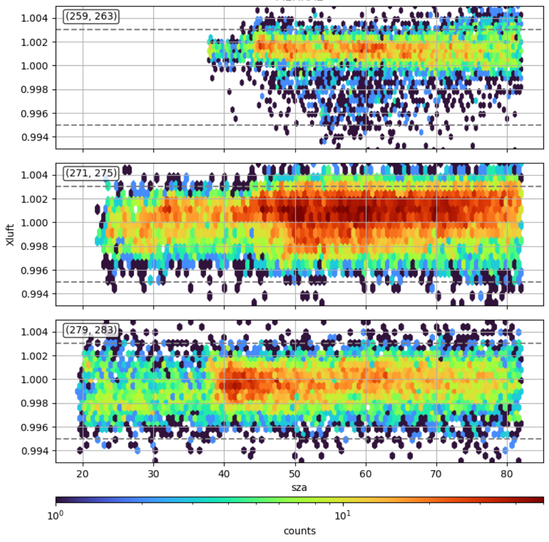
Although GEOS FPIT and MERRA-2 share the same underlying GEOS framework, MERRA-2 assimilates a broader set of observations using a frozen data assimilation and modeling system. In contrast, GEOS FPIT is periodically updated as improvements are made to the assimilation system and atmospheric model representation but assimilates fewer observations.

To evaluate the impact of the priors we use Xluft.
Xluft is defined as 0.20905 x V_{DRY_AIR} / V_{O2}, where V is a column density, and V_{DRY_AIR} is estimated from measured surface pressure. Xluft is expected to be 0.999.



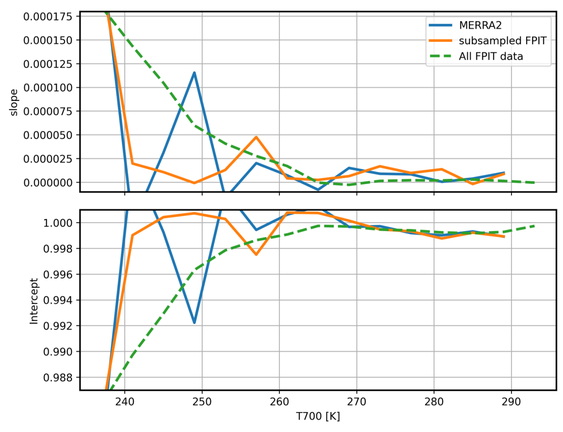
Xluft binned using t700.

Xluft values show a clear bias at colder temperatures.



Xluft values for Pasadena, Lamont, Edwards, Park Falls, Sodankylä and East Trout Lake were analyzed over several months and binned by T700.

Linear fits applied to these binned Xluft values are expected to have a slope of 0 and an intercept of 1.

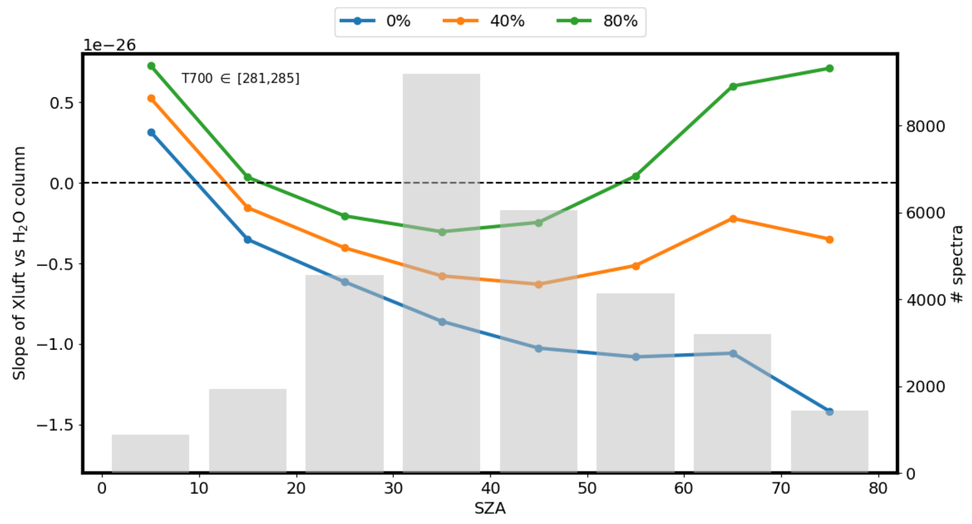


Slopes and intercepts of the linear fits to the binned Xluft values for both meteorological fields

Slopes and intercepts clearly deviate at colder temperatures

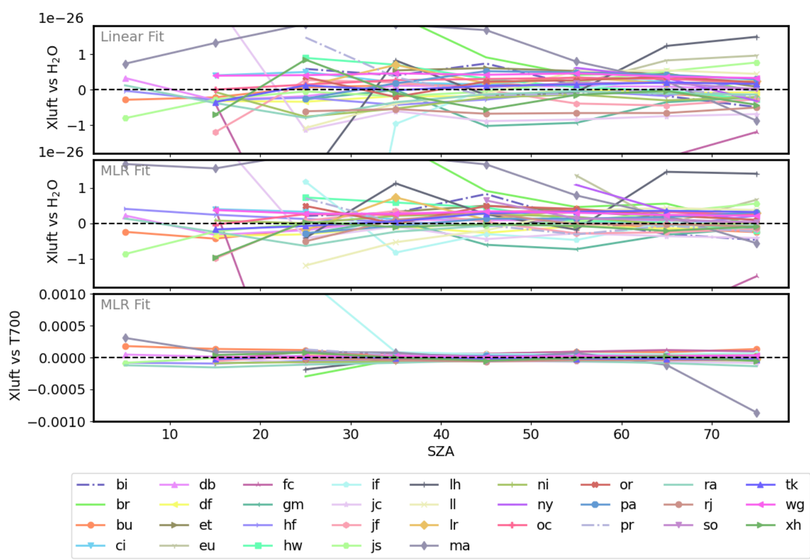
Neither meteorological field improves Xluft

Water vapor broadening



Slopes of X_{luft} vs. water column in 10° SZA bins at Darwin, with water broadening of O_2 set to be equal to zero, 40 % greater, and 80 % greater than air. The gray bars give the number of spectra in each bin.

Previous work showed that a water broadening of 1.4 times that of air minimized the dependence of X_{luft}; however, those results used non-corrected DIP interferograms. Updated Darwin results suggest that a water vapor broadening factor of 1.8 may provide better agreement.



Slopes of X_{luft} vs. water *slant* column in 10° SZA bins for several stations, with O_2 water vapor broadening set to 40% (the previous recommendation).

The scatter among the stations make it difficult to draw conclusions, Fitting T700 along with slant water column reduces the scatter among the stations, however further work is needed.

Conclusions

- Xluft shows a temperature-dependent bias at colder temperatures across TCCON stations.
- Replacing GEOS FPIT with MERRA-2 meteorological priors does not improve Xluft performance, suggesting that the observed bias is not primarily driven by the choice of meteorological input.
- Updated analyses of the Darwin O_2 water vapor broadening suggest that a factor larger than the previous recommendation may reduce the dependence of Xluft on water vapor.
- However, variability among stations prevents a definitive recommendation. More work is needed to better constrain O_2 water vapor broadening.
- After the O_2 analysis, future work will look at CO_2.

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