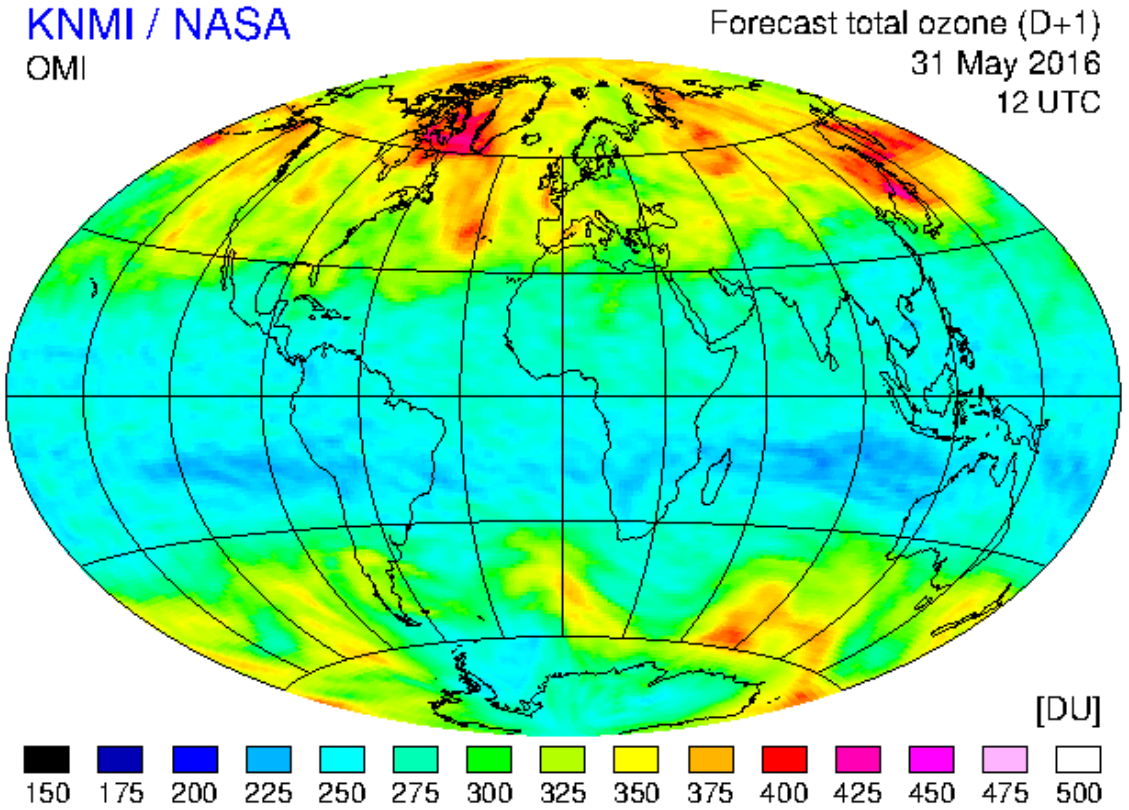
Probing tropospheric water vapor using stratospheric ozone line emission



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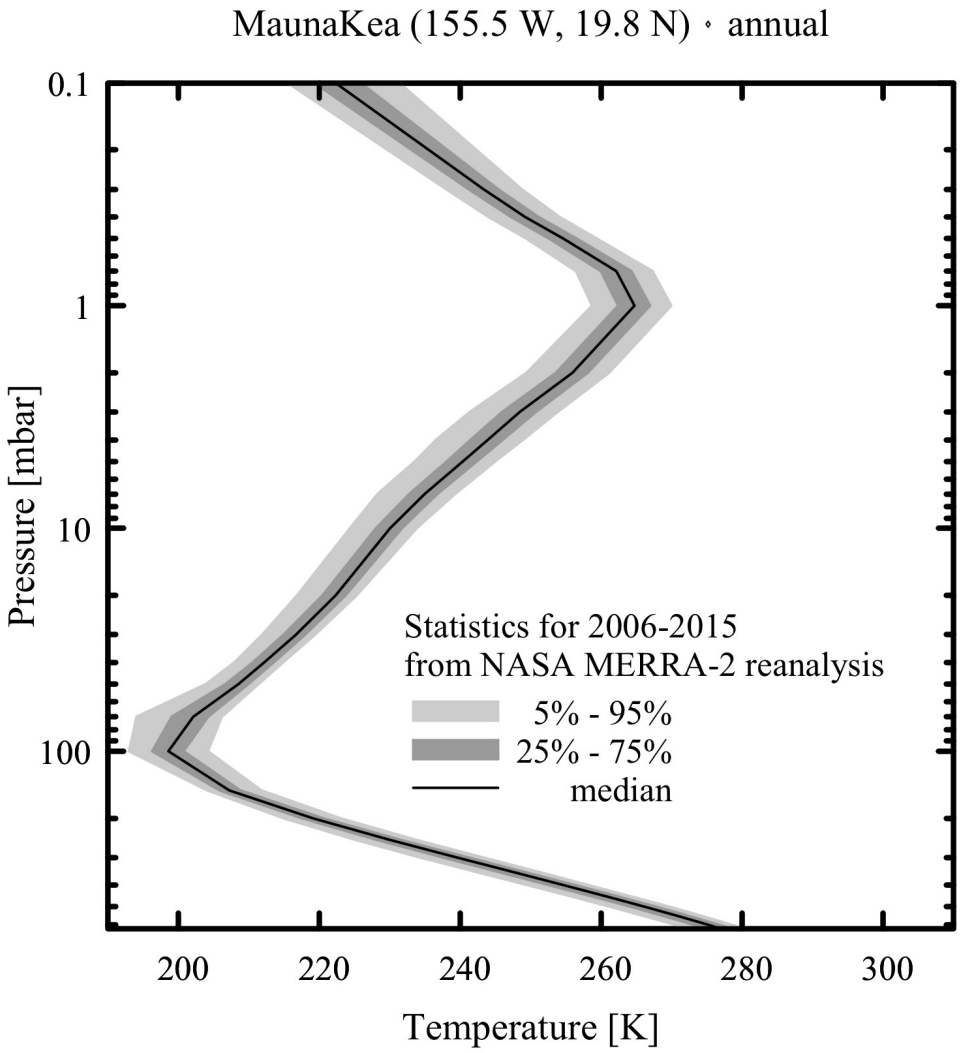
Outline

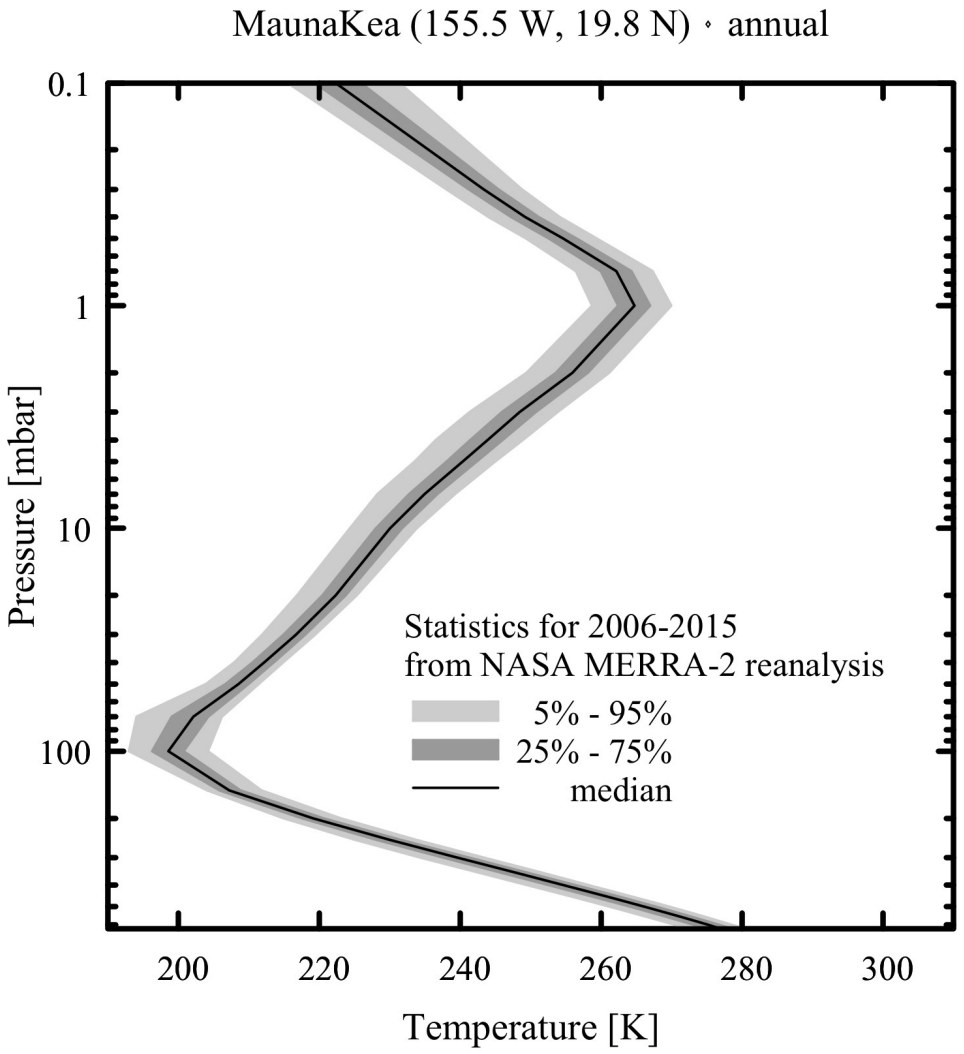
- Typical vertical profiles of temperature, water vapor, and ozone
- Radiative transfer
- Sensitivity comparison with 183 GHz WVR
- A sensitivity test at the SMA
- Concluding remarks

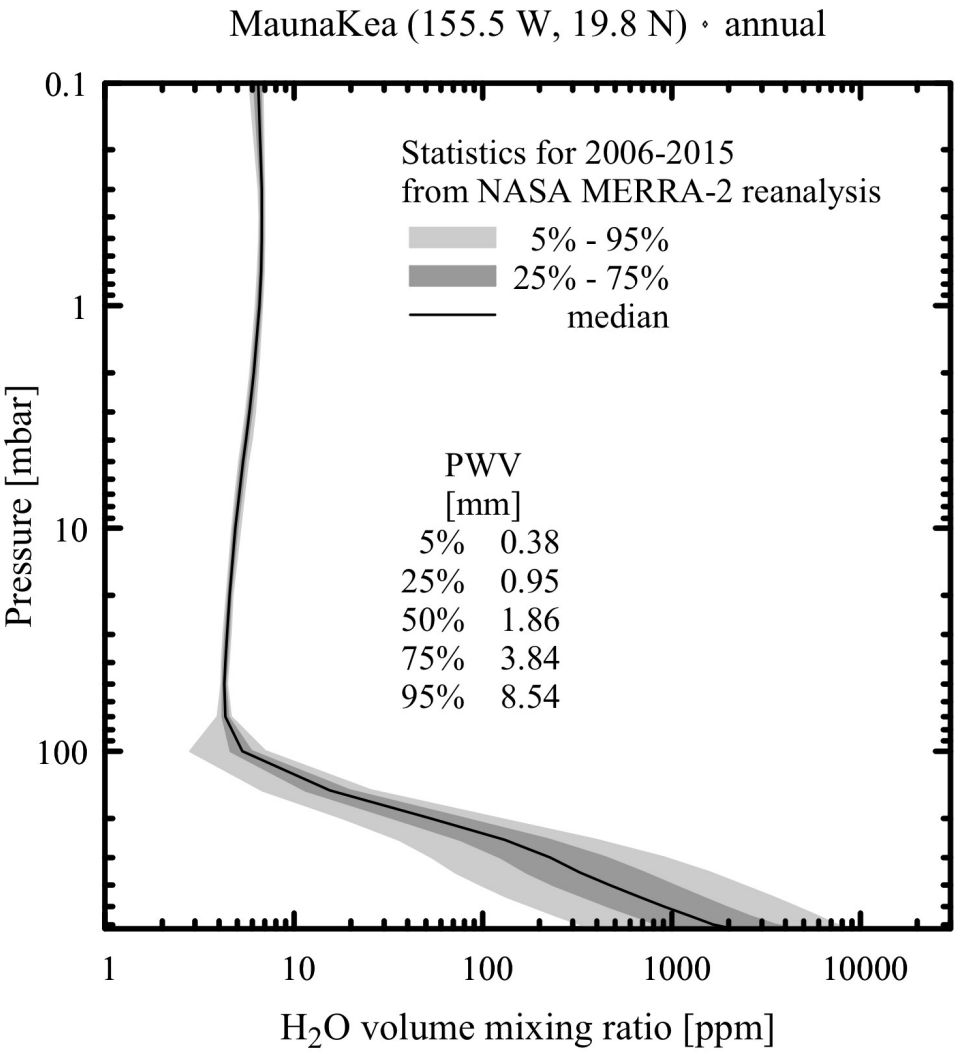
Temperature profile over Mauna Kea, Hawaii



MERRA-2 reference:
http://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

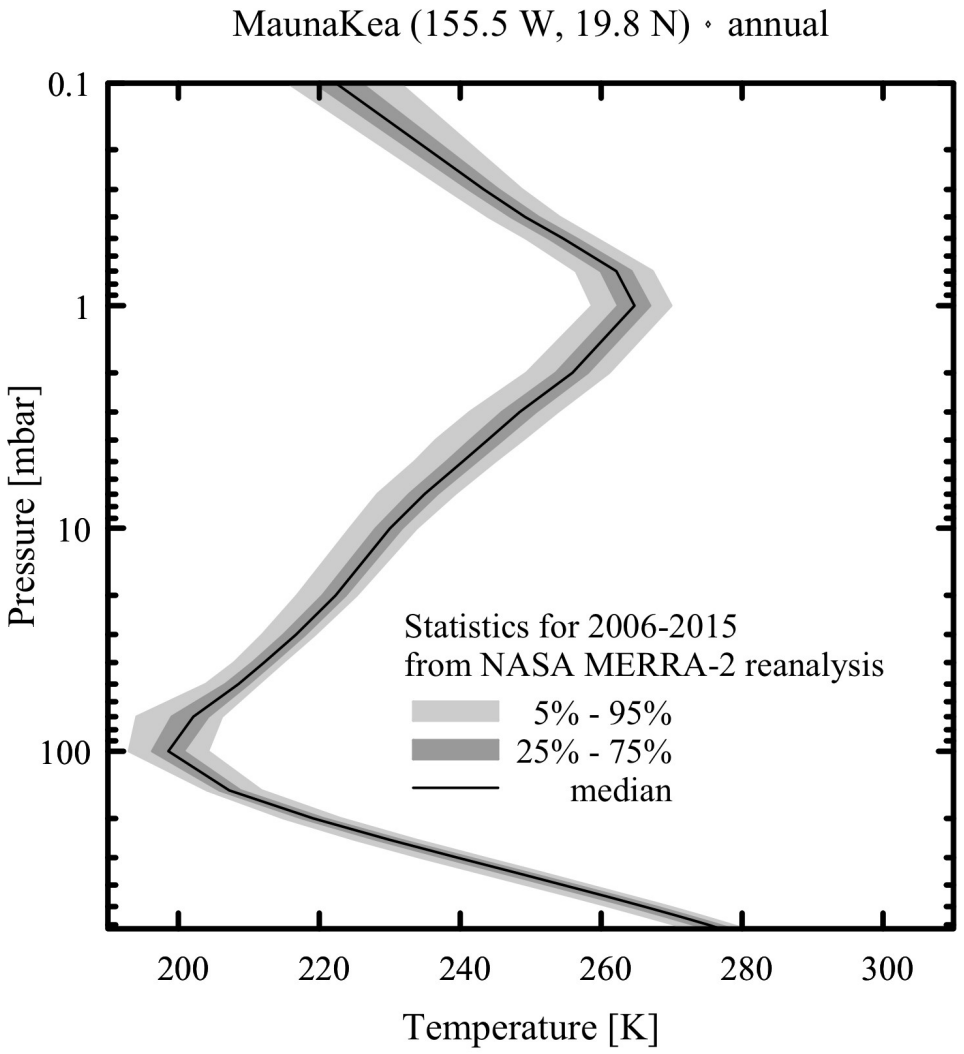
Temperature and water vapor

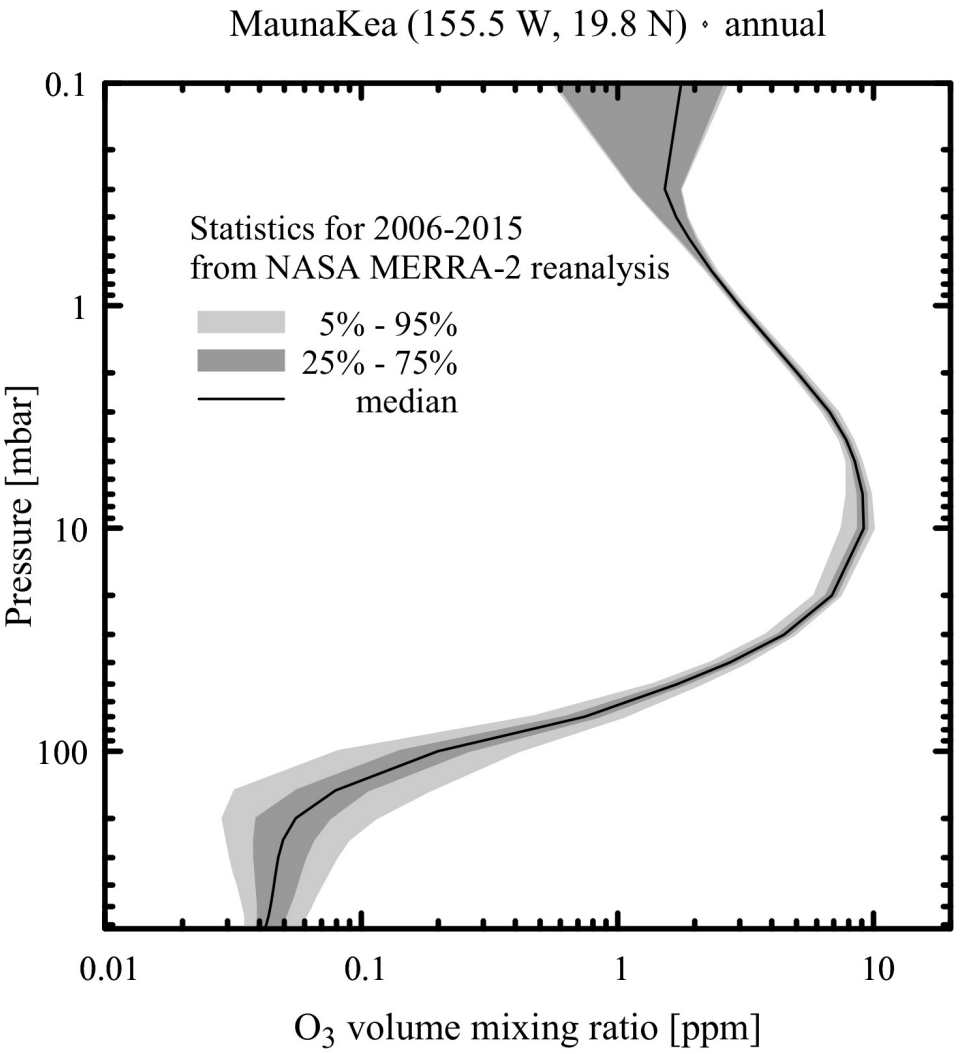




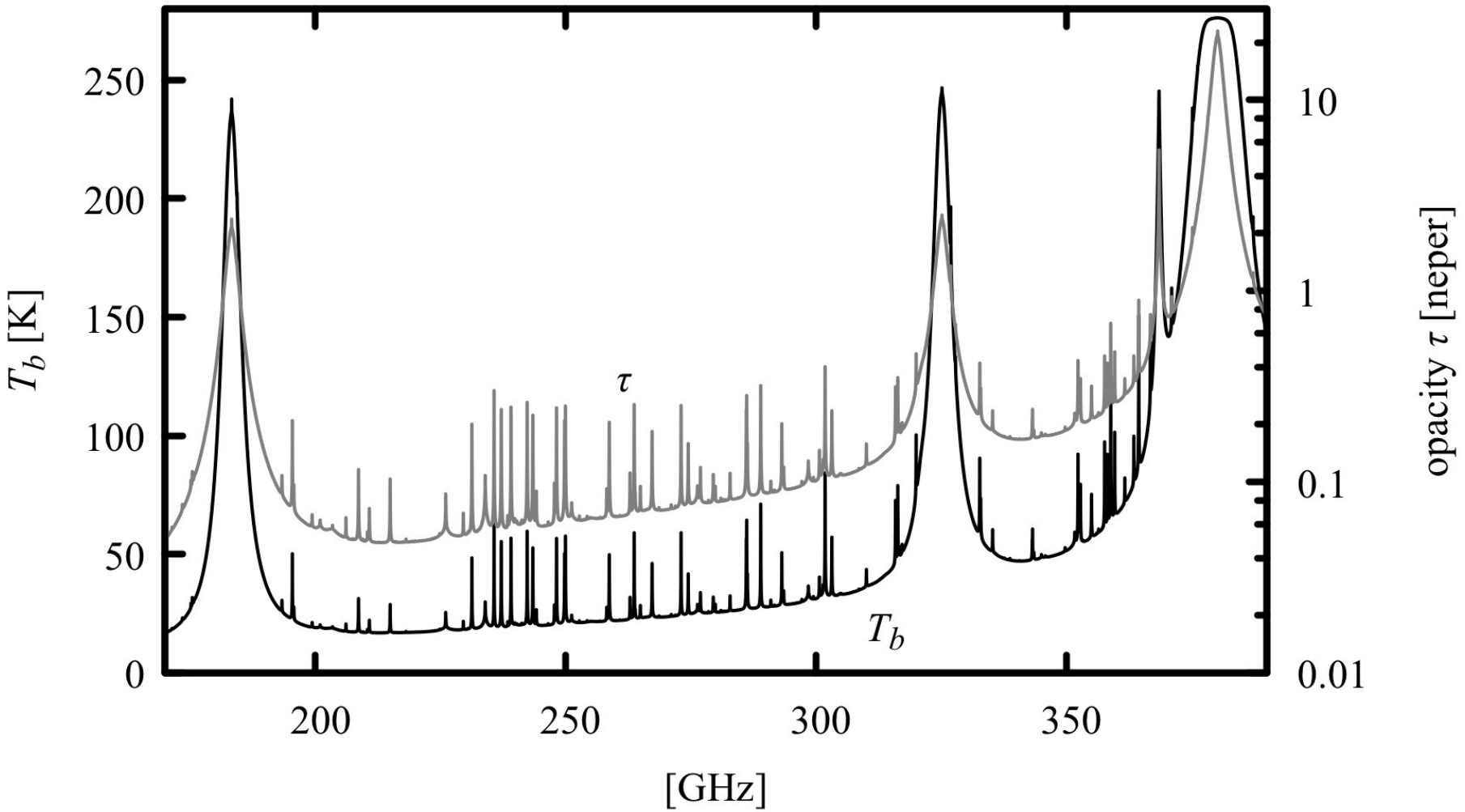
H_2O column density and its variability are largely confined to the troposphere.

Temperature and ozone



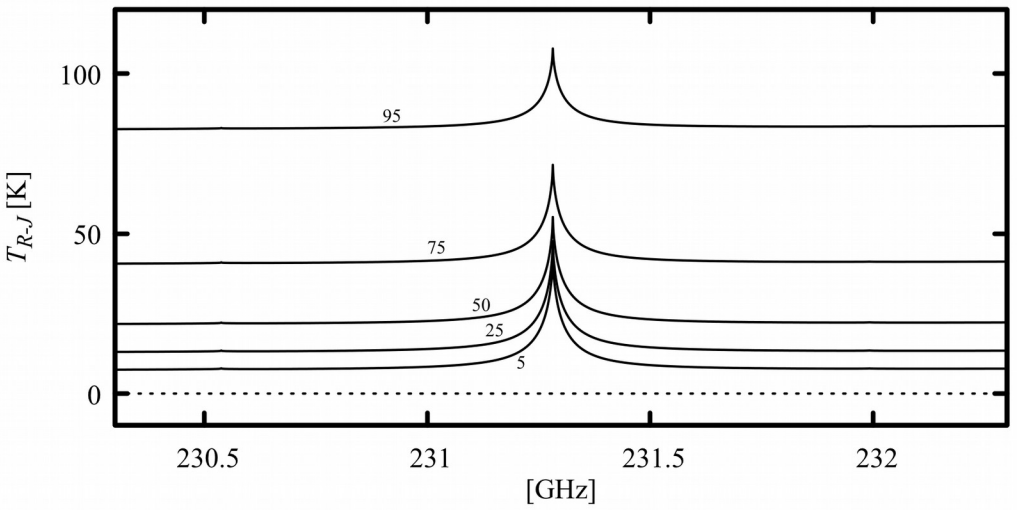


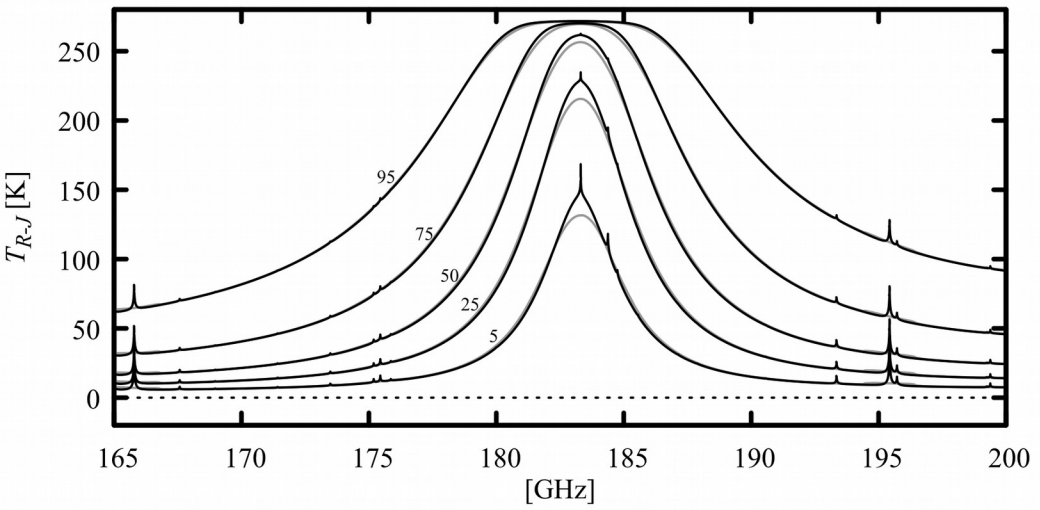
O_3 column density mostly in stratosphere, stable and slowly varying.

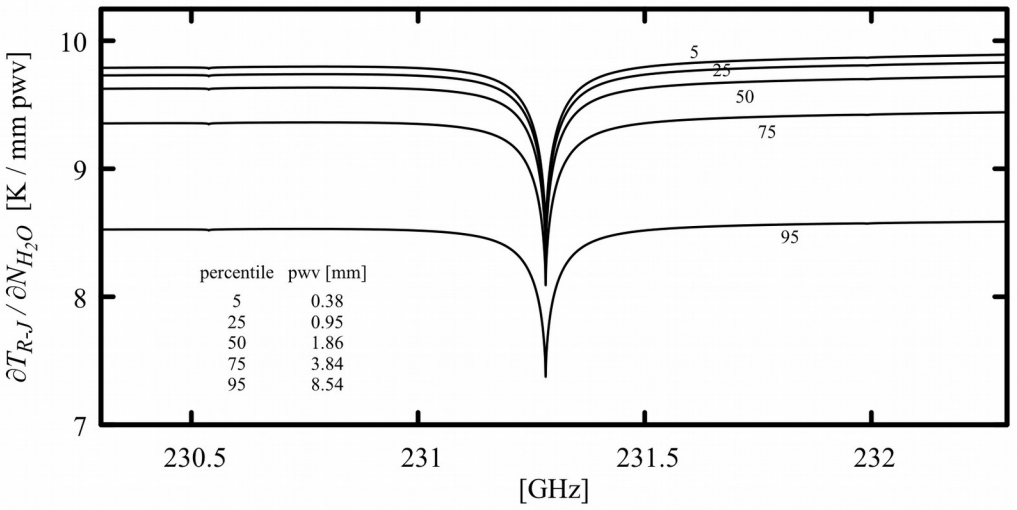


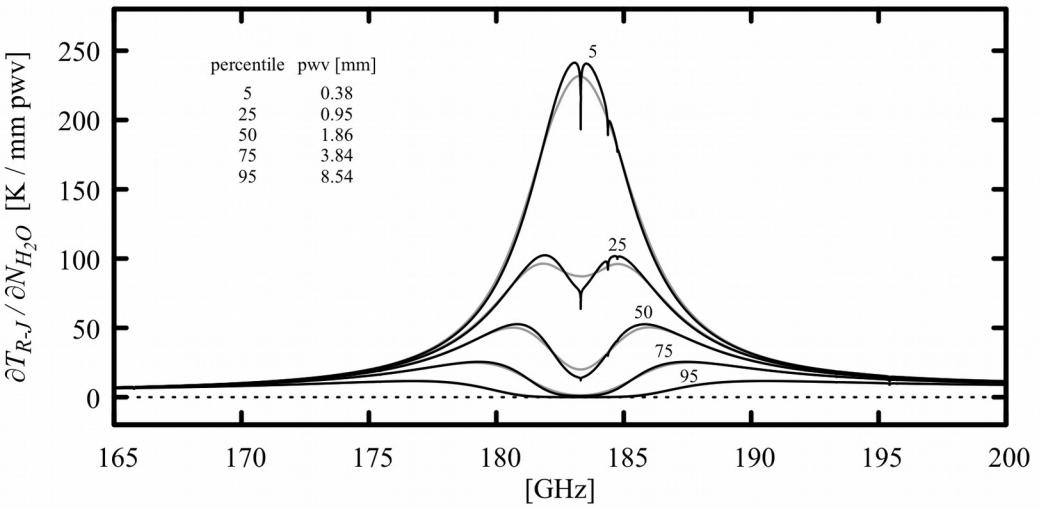
- Many O_3 rotation lines throughout submillimeter observing bands.
- Complementary vertical structure and variability suggests using O_3 line emission as a "backlight" to monitor foreground H_2O line wing and continuum attenuation.

Comparing Jacobians for O_3 radiometry and WVR



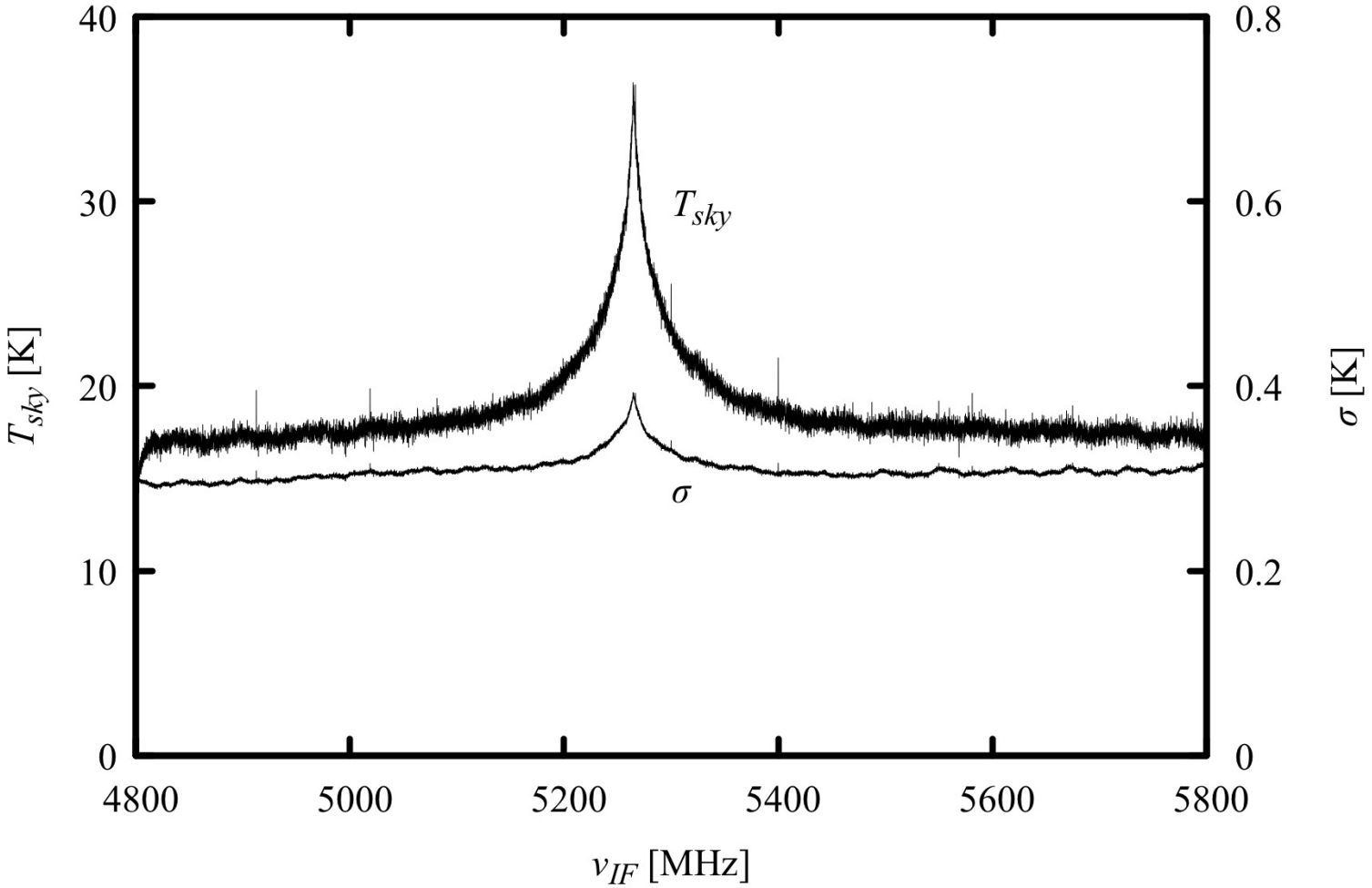






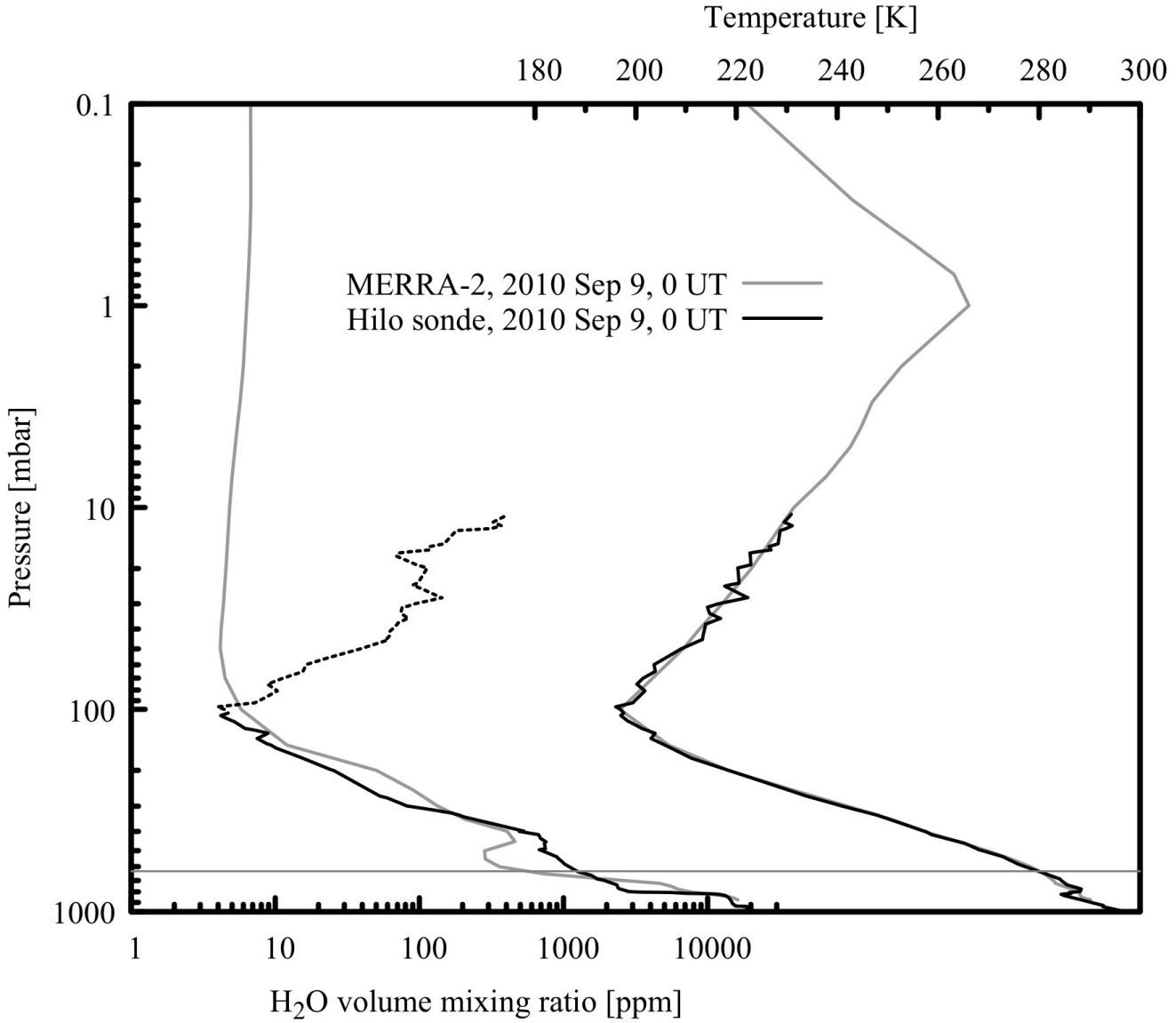
- WVR has ~10x bandwidth advantage and higher inherent sensitivity
- O_3 radiometry can catch up using astronomical receivers for ~10x lower T_{sys}
- Compared with total power radiometry, O_3 line gives extra degree of freedom to track rx stability.

Sensitivity test at the SMA

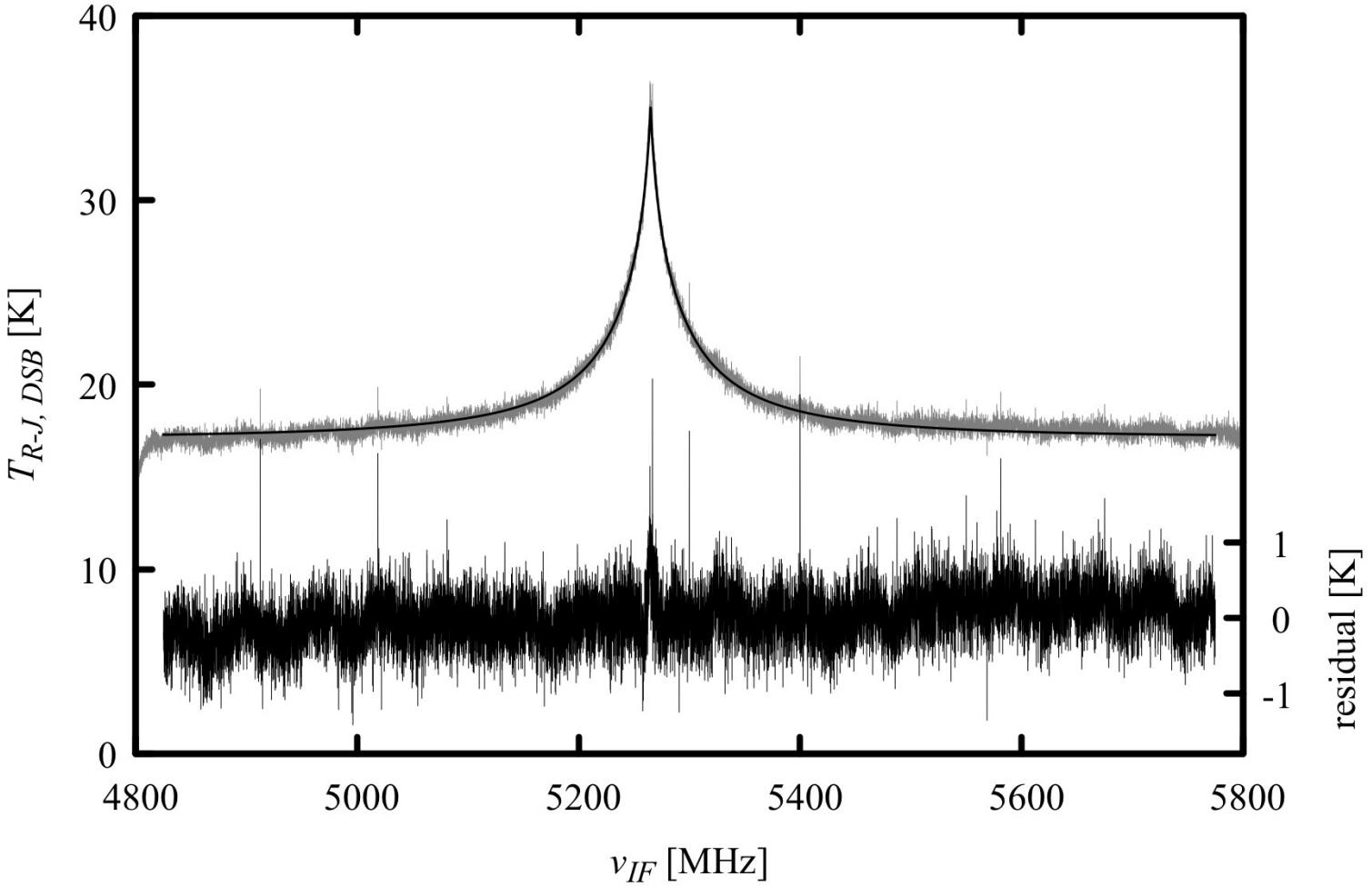


- DSB measurement of 231.3 GHz O_3 line, 1 second integration time, using "cabin spectrometer"
- Calibrated with channel-by-channel sky dip plus several seconds stare at cal load
- Not production mode – this is an especially good example with excellent receiver stability

Sensitivity test at the SMA – initial guess profiles

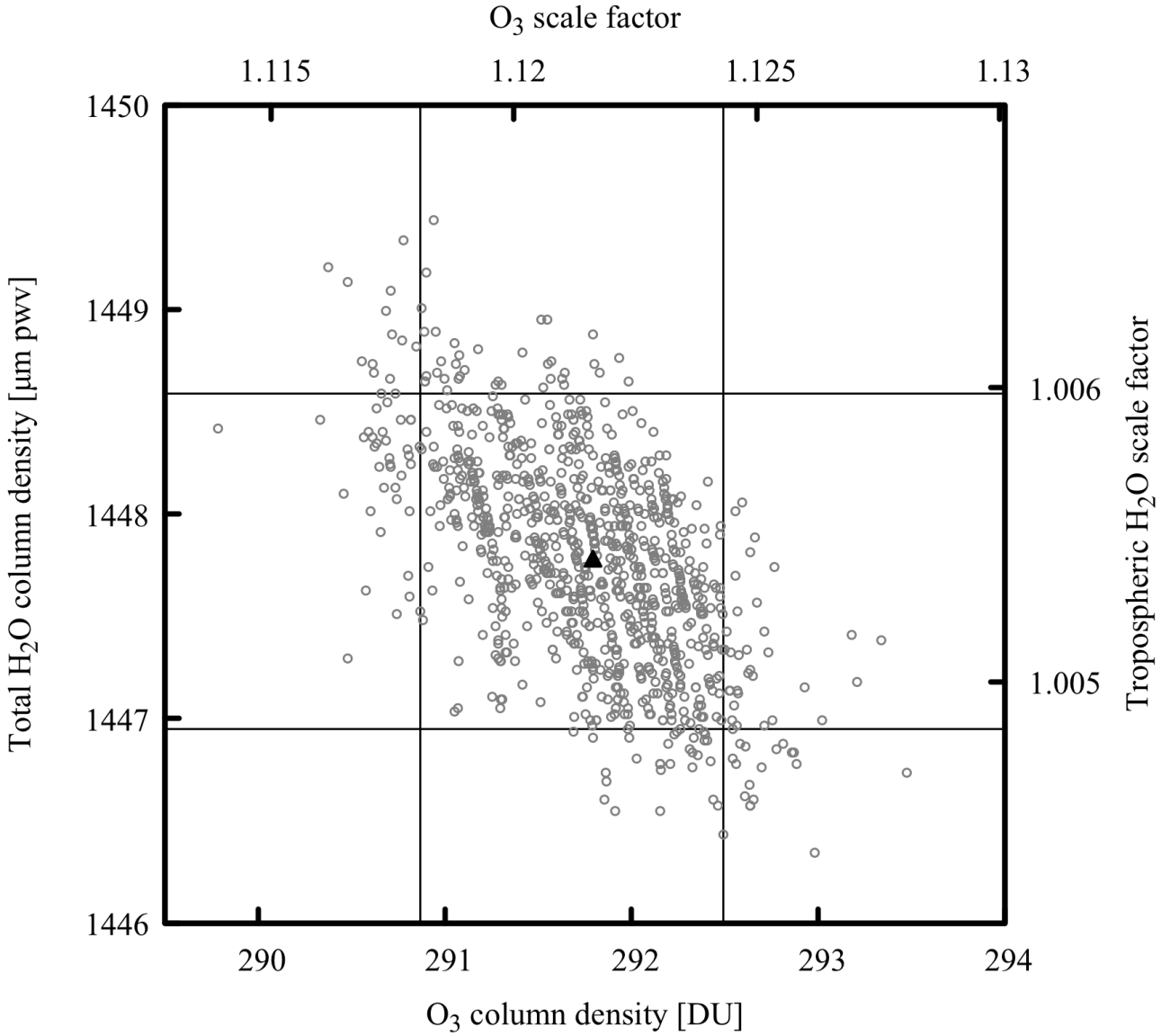


Sensitivity test at the SMA – fit H_2O and O_3 scale factors



Note that here we fit O_3, but in a phase correction scheme O_3 column density would be a common-mode parameter over the whole array.

Sensitivity test at the SMA – bootstrap analysis of parameter sensitivity



Concluding remarks

- Greater inherent sensitivity of WVR means that a stable, Dicke-switched Schottky radiometer can be used.
- O_3 radiometry requires astronomical receiver sensitivity combined with high spectral bandpass stability.
- Reasons to try O_3 radiometry:
  - Don't have / can't afford WVRs
  - Potentially better systematics – exact match to astronomical beam