National Aeronautics and Space Administration

Results from Aura MLS and the In Situ Hygrometers During the Costa Rica AVE Campaign and modeling of Tropical UTLS H_2O, HDO, and CO.

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October 4, 2007

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Outline

❶ Overview of MLS H_2O and CO measurement capability.

- ➠ Measurement systematic error estimates.
- ➠ Validation.

❷ Convection and In Situ Freeze Drying in the TTL

- ➠ Present a 2-D model (Holton and Gettelman, 2001) incorporating the two column model (Folkins and Martin,2005, Folkins et al.,2006) for convection with microphysics.
- ➠ We will use zonal mean measurements of CO and HDO to determine how convection and transport work in the TTL.

❸ Conclusions.

MLS H_2O Measurement

- MLS resolves and fits the targeted molecule spectrum making it easier to distinguish target molecule from background emissions.
- MLS makes measurements in day and night and is much less impacted by thin clouds and aerosols than IR-VIS-UV techniques.
- MLS makes measurements every 1.5° along orbit track for ∼3500 profiles each day.
- Vertical profile points are every 1.35 km.
- Resolution is 3 × 200 × 7 km (vertical × along track × across track).
- Two H_2O validation papers (Read et al. and Lambert et al.) are accepted for publication in the JGR Aura Validation Issue.
- Usually validation is a rather pedestrian exercise of comparing closely coincident measurements between different sensors and noting whether the differences are within expected uncertainties.
- As we will show for H_2O validation was more interesting.
- The MLS end-to-end estimate for accuracy (random and bias) is given below.

Estimated systematic errors for 100 hPa H_2O

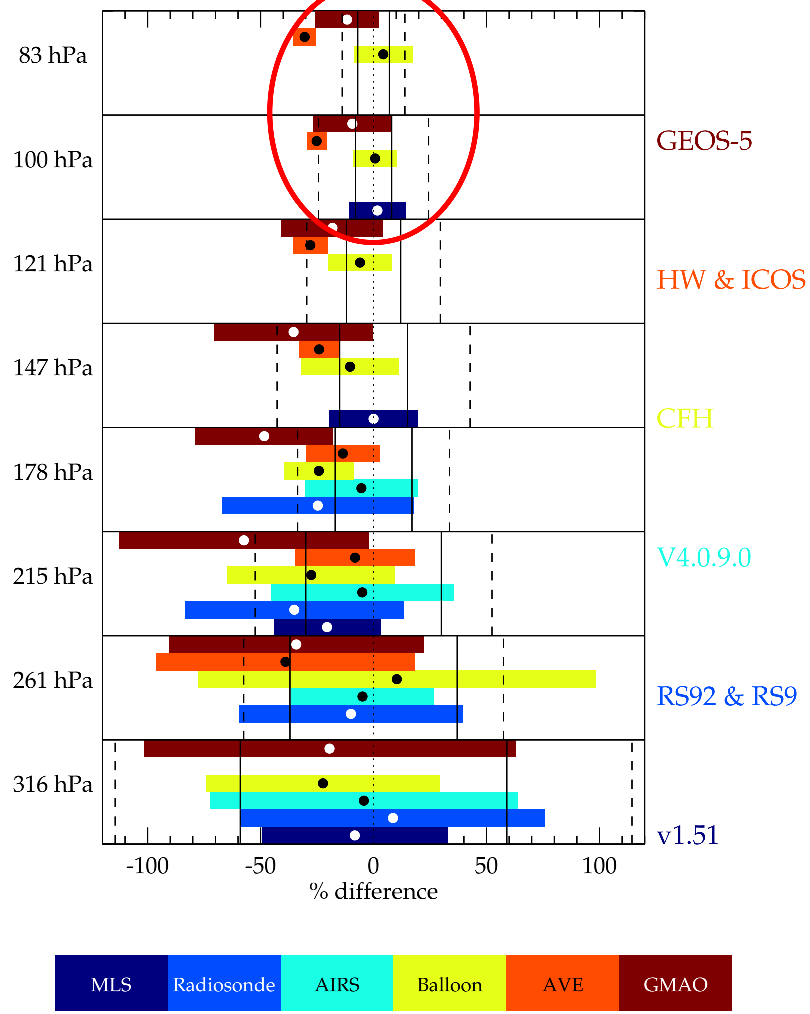
Systematic Error	Magnitude	H_2O Error Bias(Prec)
Radiometric	2%	2%(7%)
Antenna		1%(2%)
Fwd model		2%(4%)
H_2O strength	0.3%	
H_2O width	4%	
numerics	1%	

Systematic Error	Magnitude	H_2O Error Bias(Prec)
Pointing	170m	7%(10%)
Temperature	2K	2%
Retrieval numerics & a priori	+50%	3%(20%)
Total	RSS	8%(23%)

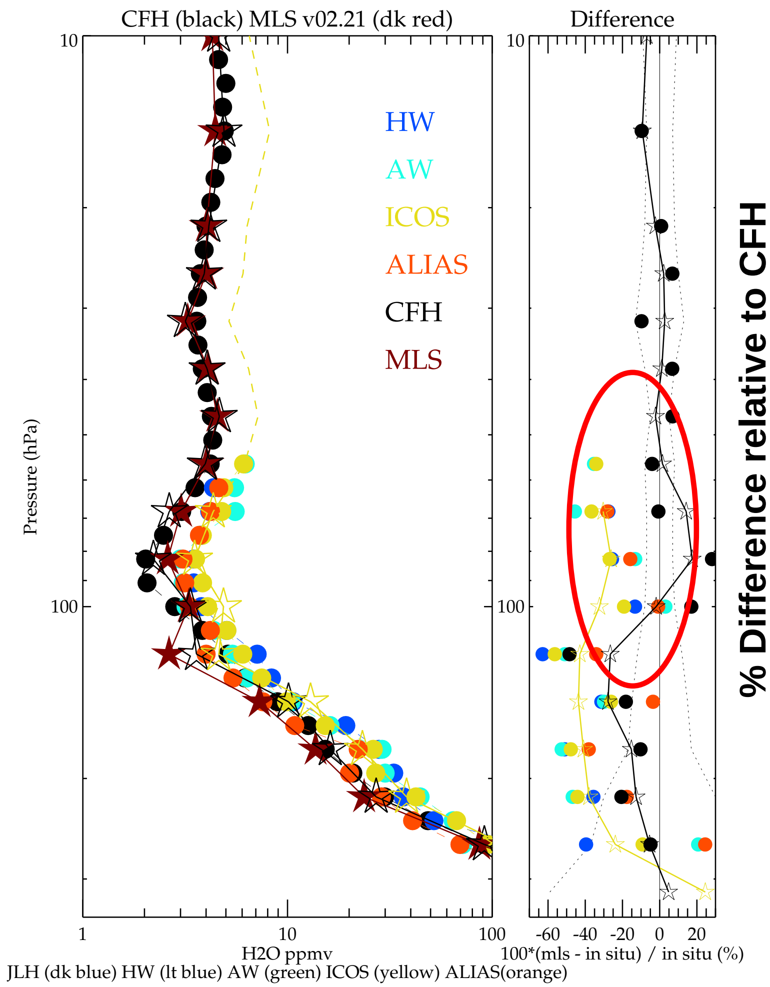
From Read et al. Aura MLS H_2O and RHi validation 2007, (accepted for publication). Errors on tropospheric H_2O are larger.

VALIDATION SUMMARY

Global Summary



ALL CR-AVE
Measurements 14 Jan.—9 Feb. 2006



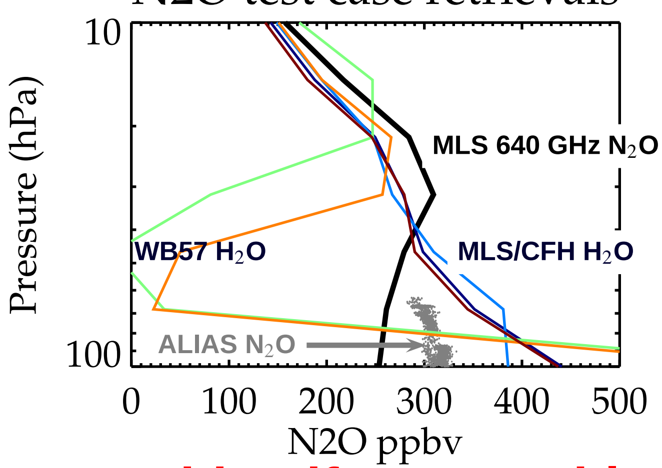
- ➢ **MLS shows agreement within its systematic error estimate with most sensors.**
- ➢ **A notable exception is the poor agreement with the WB57 hygrometers during CR-AVE for pressures P≤100 hPa.**

VALIDATION DISCUSSION

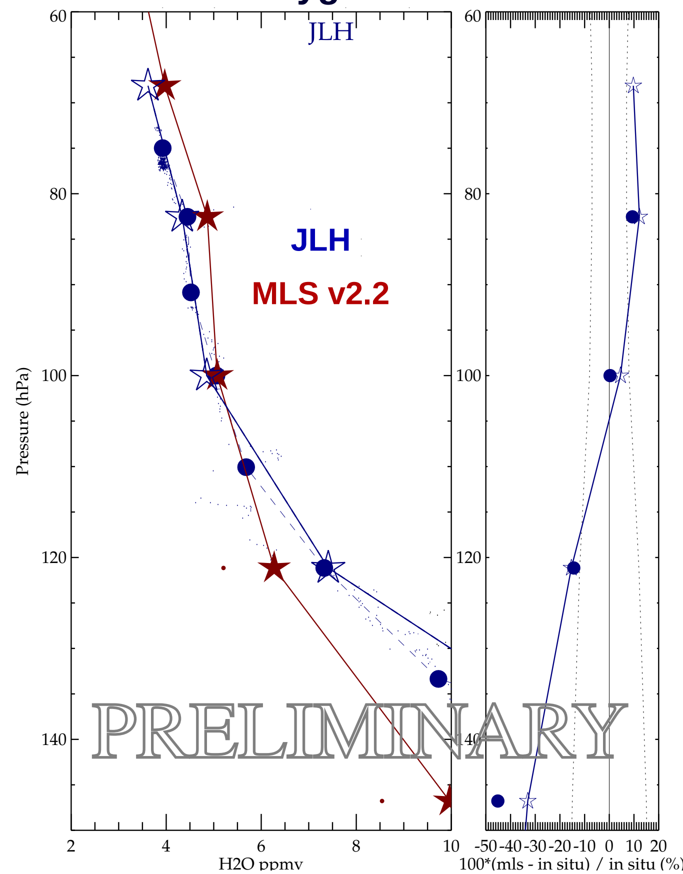
I presented a paper at the CR-AVE workshop discussing the implications of such a large difference on the MLS measurement system.

- ➢ Not consistent with systematic error analysis.
- ➢ MLS measurements of other trace gases (e.g. O_3) show ∼10% agreement with other correlative measurements (both in situ and remote). Most remote measurements of H_2O agree within 10% of MLS in the stratosphere.
- ➢ Not caused by horizontal or vertical smoothing by MLS.
- ➢ Forward model radiance calculations using the CFH H_2O measurement agrees well with MLS radiance measurements but the wetter WB57 profile shows poor agreement. In addition the quality of N_2O which is retrieved alongside H_2O is degraded.

N2O test case retrievals



TC4 3 Aug 2007
JPL Laser Hygrometer and MLS



➢ JLH, a WB57 hygrometer that recently underwent a major calibration effort is now measuring low H_2O concentrations consistent with CFH and MLS.

☞ **Can not identify any problem in the MLS measurement . . . But the higher H_2O would be a significant discovery!**

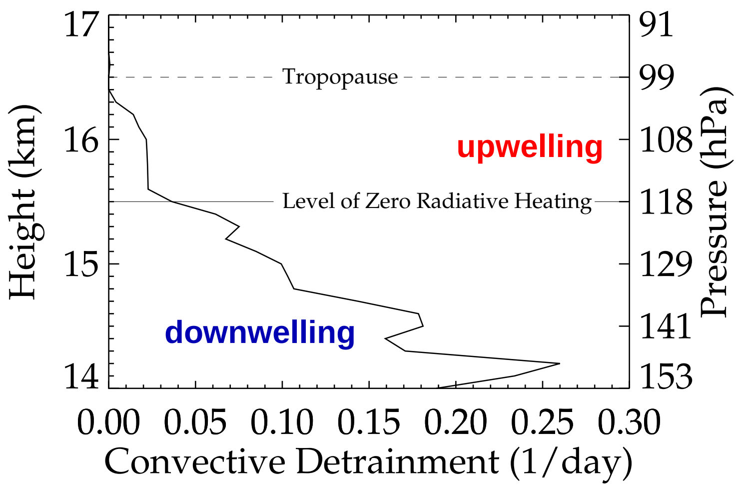
CCT-TTL Model Description

Convective Cold Trap Tropical Tropopause Layer model based on Holton and Gettelman (2001) paper with Two Column Model (TCM) from Folkins and Martin (2005). Vapor/Ice partitioning equations

$$\frac{Dq_v}{Dt} = -\alpha(q_v - q_{ex}) + K\frac{\partial^2 q_v}{\partial z^2} + eq_i - c(q_v - q_s) - d(q_v - q_v^{conv}),$$

$$\frac{Dq_i}{Dt} = -\alpha(q_i - q_{ex}) + K\frac{\partial^2 q_i}{\partial z^2} - eq_i + c(q_v - q_s) - d(q_i - q_i^{conv})$$

α is exchange rate to higher latitudes, K is diffusion, e is evaporation rate, c is condensation rate and d is convective mass flux divergence.



- **Convective mass flux divergence penetrates the level of zero radiative heating up to the tropopause.**

Consider Three Scenarios

① **Slow Ascent: $d = 0$, Constant upward vertical velocity. Emulates Fueglistaler et al. 2005.**

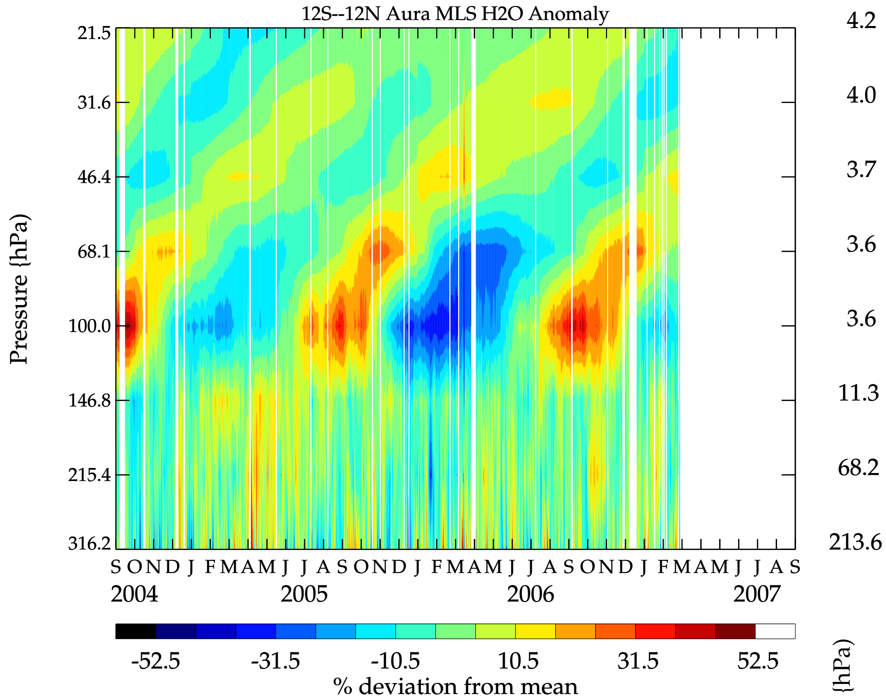
② **Convection: $q_v^{conv} = q_s$ and $q_i^{conv} = 0$.**

③ **Sherwood and Dessler (SD01) Convection: $q_v^{conv} \ll q_s$ and $q_i^{conv} = q_s - q_v^{conv}$.**

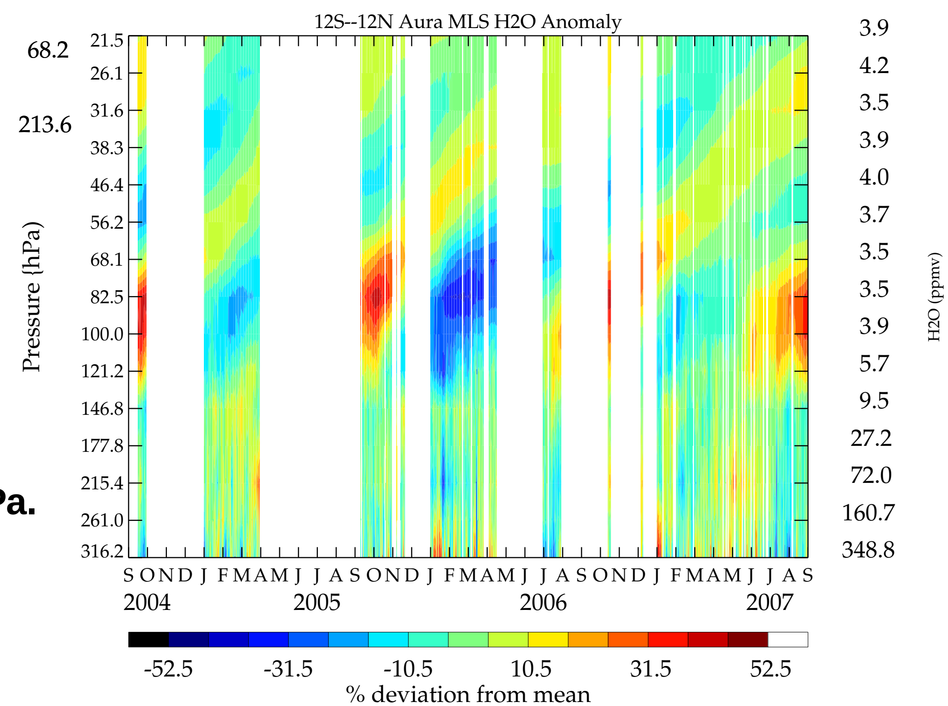
Diagnostics

- **CO: Doesn't condense and is an excellent diagnostic of convection and large scale upwelling. This has been noted in several papers by Schoeberl et al. (2006 and 2007), Randel et al. (2007) and Folkins et al. (2006).**
- **HDO: Microphysics test. (see Dessler and Sherwood, 2003, Gettelman and Webster, 2004, and Dessler et al., 2007)**

TTL H_2O

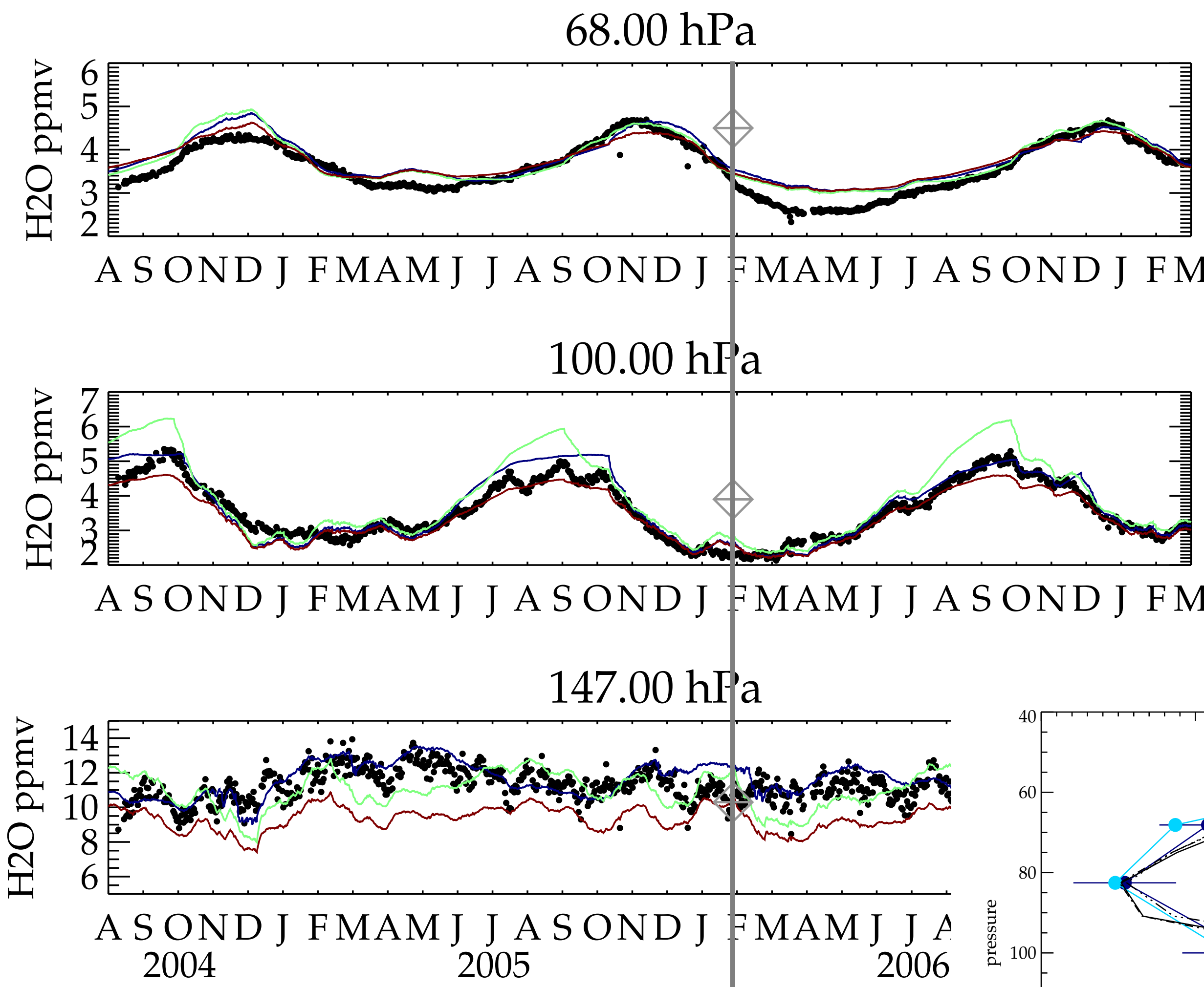


- ➢ Left MLS v1.5 H_2O.
- ➢ Vertical grid is 2.7 km.
- ➢ H_2O annual cycle maximum at 100 hPa.
- ➢ V1.5 discontinued after 28 Feb 2007.

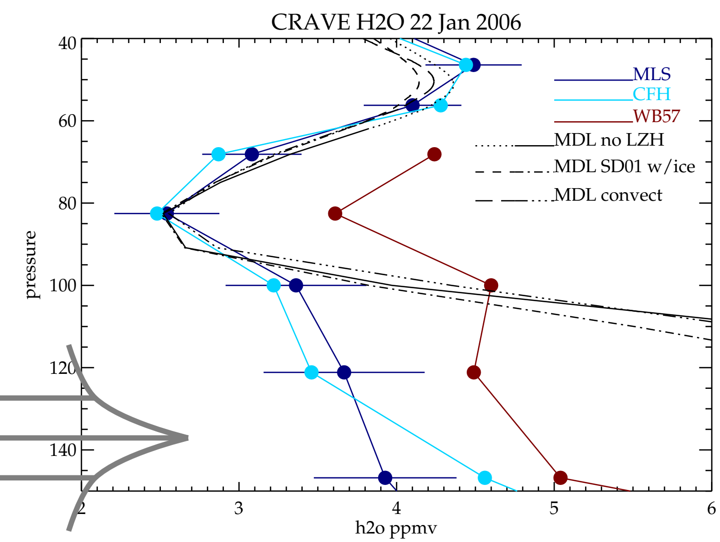


- ➢ Right MLS v2.2 H_2O.
- ➢ Vertical grid is 1.35 km.
- ➢ H_2O annual cycle maximum at 83 HPa.

Model H_2O

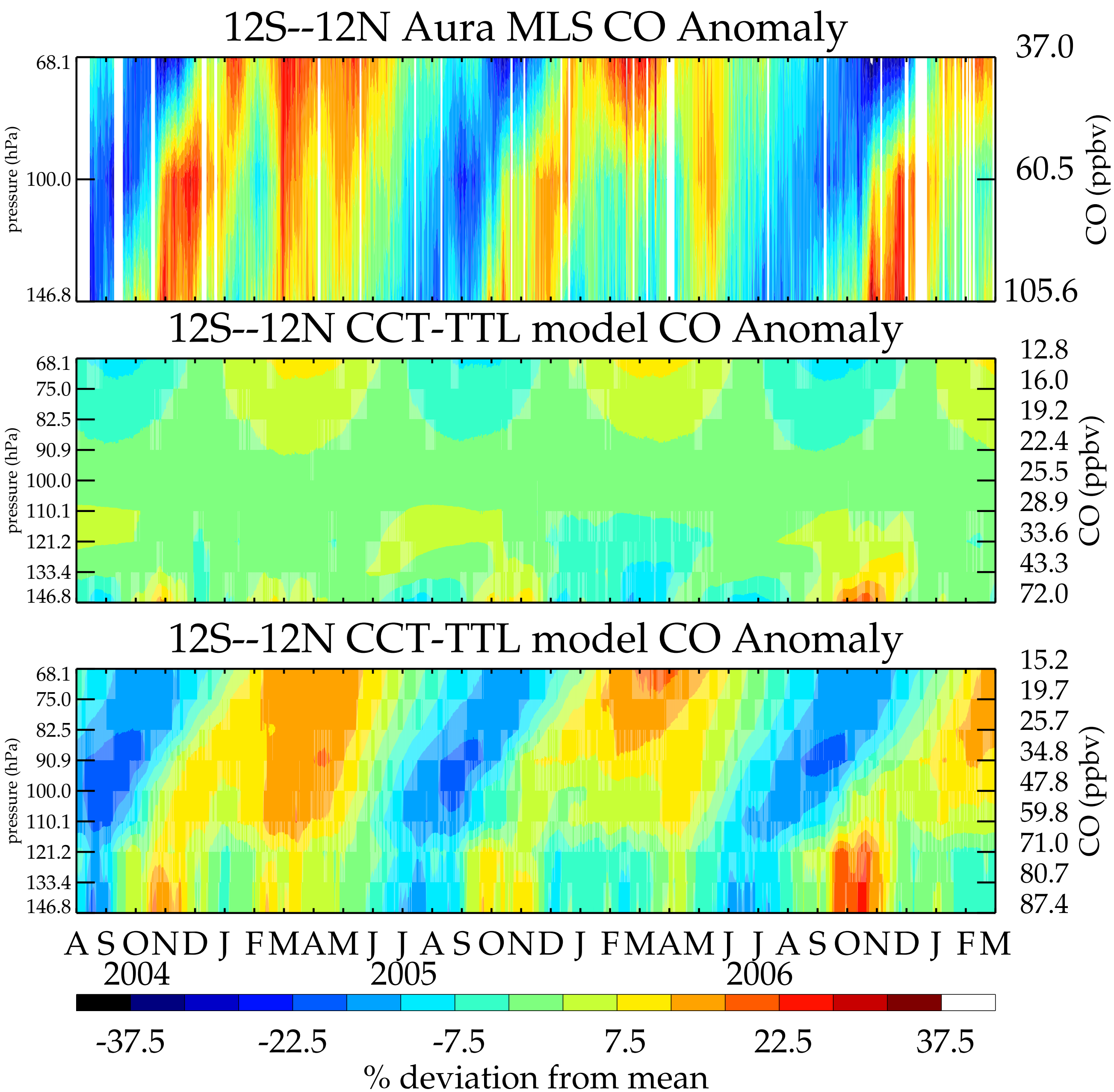


- Left MLS v1.5 H_2O 12°S–12°N Daily Zonal Mean.
- + in diamond is WB57.
- Slow Ascent.
- Convection.
- SD01 Convection.



- H_2O profiles near Costa Rica on 22 Jan. 2006 from the WB57, CFH, and MLS v2.2 H_2O compared to model.

TTL CO



MLS CO:

CO(red colors) are Biomass burning events brought up by convection to 100 hPa, then becomes a tape recorder and blends into an annual oscillation signature.

No Convection/ Slow Ascent:

Annual cycle at the top of the model domain is from the annual oscillation in the upwelling.

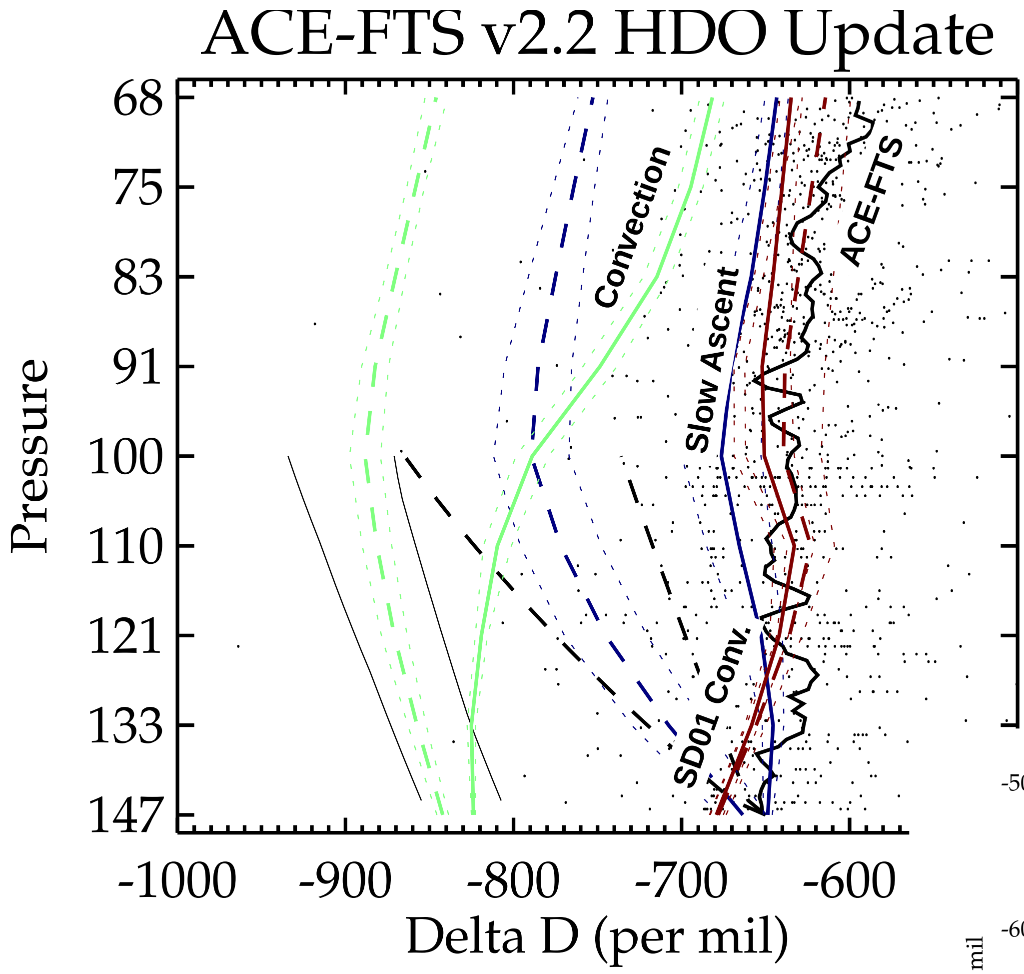
Convection:

captures the basic features seen in the data.

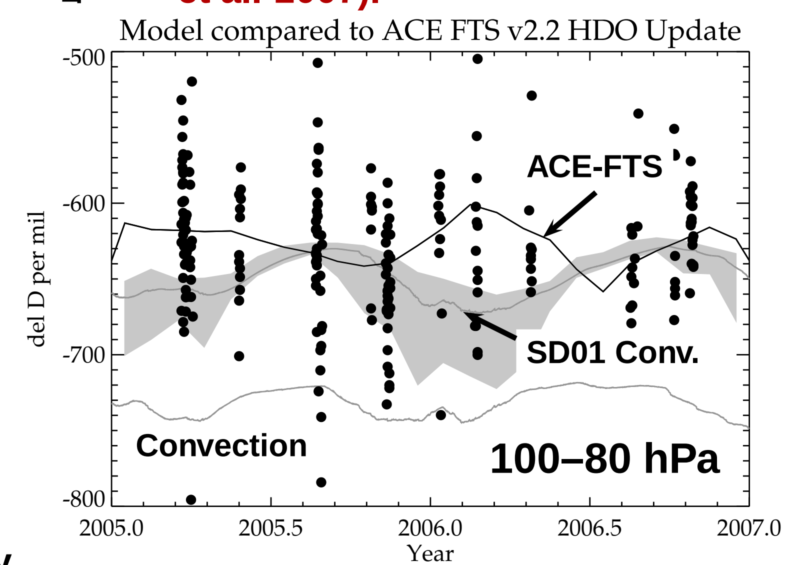
Convection better represents transport of air into the TTL

TTL HDO FROM ACE-FTS

R. Nassar et al., JGR, 112, doi:10.1029/2007JD008417 (2007).



- Dashed colored lines have no extratropical influence.
- Rayleigh distillation lines from surface (thin black lines) and bottom of TTL (thick dashed black lines).
- Slow ascent.
- Convection detrains only vapor at $q_v^{\mathrm{conv}} = q_s$(Rayleigh) all ice is removed.
- SD01 convection mostly detrains ice $q_i^{\mathrm{conv}} \approx q_s$(-550$^\circ/_{\circ\circ}$). Convective retention of ice is consistent with cloud resolving model studies (Smith et al. 2007 and Jensen et al. 2007).



- Deuterium enriched ice supplied by the SD01 convection model fits the data best and is compatible with observed extratropical HDO.
- Seasonal cycle relative to data spread shown at right is weak.

HDO data: courtesy of the Canadian Space Agency

Conclusions

- ☆ Unable to reconcile the large difference seen between MLS and WB57 H_2O measurements in the lower stratosphere.
  - ➟ MLS agrees well with CFH and most other remote sensors.
  - ➟ Preliminary result from JLH fbwn on WB57 during TC4 also shows good agreement.
  - ➟ MLS H_2O measurements are consistent with current microphysical models.
  - ➟ The moist H_2O observed by WB57 (ex. JLH) if accurate imply a major deficiency in low temperature microphysical models.
- ☆ CO is a good diagnostic of convective transport and upwelling into the TTL.
  - ➟ Convection is necessary for transporting tropospheric air across the zero radiative heating mixing barrier.
- ☆ Convection must detrain ice into the TTL.
  - ➟ Convectively detrained ice provides enriched HDO needed to match the observations.
  - ➟ Prevents the SD01 convection mechanism from dehydrating the TTL.
  - ➟ The SD01 mechanism matches the ACE-FTS HDO profile well.
- ☆ Future work
  - ➟ Use MLS CO, O_3, HNO_3, and HCl to derive convective mass flux divergence and upwelling.
  - ➟ Hook-up the model physics with a trajectory analysis and a radiation calculation.