Aura Validation Workshop H_2O vs AVE, AIRS, Radiosondes, and GPS

W. G. Read

21 September 2005

MLS H_2O Measurement

- Coverage is 82°S – 82°N 240 profiles per orbit, ~14.5 orbits per day (~3500 profiles daily).
- Vertical coverage is 316 hPa–0.1 hPa
  - Will focus on the 316, 215, 147 and 100 hPa levels here
  - Single profile estimated precision is 10—25% between 100 and 316 hPa.
  - Resolution is 160km (along track) X 6km (cross track) X 2.7 km Vertical.

Comparison Instruments

- AVE Oct/Nov 2004 and June 2005. In situ measurements from WB57
  - JLH JPL laser hygrometer, frost point (Nov 2004) and Harvard water (June 2005)
  - Vertical Resolution 10s of meters, horizontal 100s km (take-offs and landings)
  - Provides profile data on take-offs and landings and level flight data.

Radiosonde Network

- Many Instrument types
  - Capacitive and resistive hygrometers, goldbeaters skin, rolled hair and others.
  - Accuracy and vertical resolution limited by the response time of the humidity detector.
    - The best instrumentation using capacitive hygrometers (Vaisala RS90 and RS92) use a dual sensor with thermal decontamination cycling to improve accuracy and response
    - Older instrumentation, has poor sensitivity to low H_2O concentrations.
  - Horizontal footprint varies depending on upper atmospheric winds and is unknown.
- Reporting practices can vary by station and nationality.

Satellite

- Aqua-AIRS
  - Resolution is 45 X 45 km^2 (horizontal) X 2 km vertical
  - Accuracy is 20%
- GPS CHAMP
  - Vertical resolution is ~200 meters
  - Sensitivity is ~200 ppmv
  - Most of the coverage is at high latitude
  - Limited vertical overlap with MLS.

Methods

- AVE
  - Vertical profiles from take-offs and landings, we use the nearest MLS profile within 4 hours.
  - Along track we use a coincident track that is within 5° of the WB57.
- Radiosonde
  - 1° of arc and 3 hours.
  - Instrument types are segregated.
- AIRS V4.0.9
  - Closest AIRS pixel to MLS profile. Since Aura and Aqua fly in formation these are within about 50 km, offset by 8 minutes.
  - AIRS data screened by qual_temp_profile_mid flag.
- GPS CHAMP
  - 1° of arc and 3 hours.
  - H_2O > 200 ppmv.

Comparing Profiles

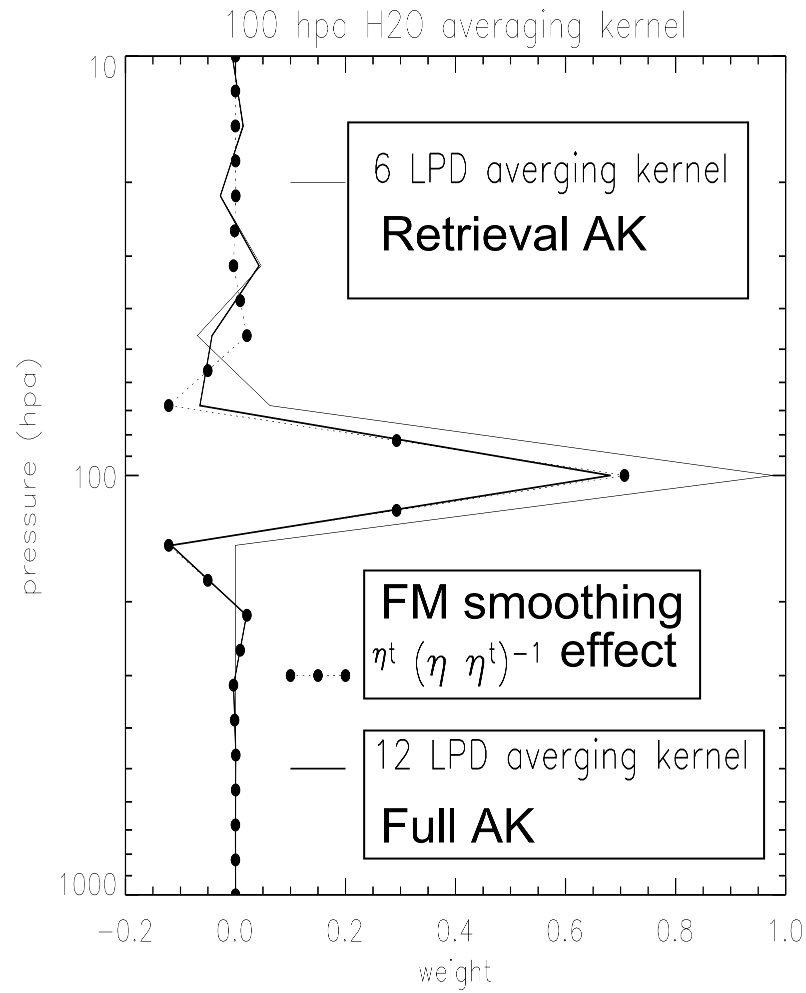
- Instruments have substantially different measurement “volumes”.
- Here we will deal only with vertical smoothing.
- The MLS forward model uses a profile representation that is identical to that retrieved.
  - The “true” averaging kernel is a convolution of the retrieval averaging kernel (Rodgers) and a forward model smoothing effect which is a least squares fit of the MLS representation to the finely sampled profile.
  - For MLS UTH, the retrieval averaging kernel is nearly an identity matrix, thus the forward model smoothing effect dominates.
  - This is different from other measurement systems that compute their forward models at much higher resolution than retrievals.

Smoothing Method

- The smoothed profile is (z=MLS, x = hi res); $z = a + A[(\eta^t\eta)^{-1}\eta^t x - a]$, η is the representation basis matrix that evaluates the MLS retrieved profile z_{ret} at any height. A is the retrieval averaging kernel, a is *a priori* information.
  - $z = (\eta^t\eta)^{-1}\eta^t x$ is a least squares fit of the MLS profile breakpoints to the hi resolution profile and is a good approximation for converting finely sampled UTH into MLS retrieval values for comparison.
  - Must be done on the Logarithm of H_2O.
  - Assumes linear (in logarithm of H_2O) forward model response to fluctuations in x about z.

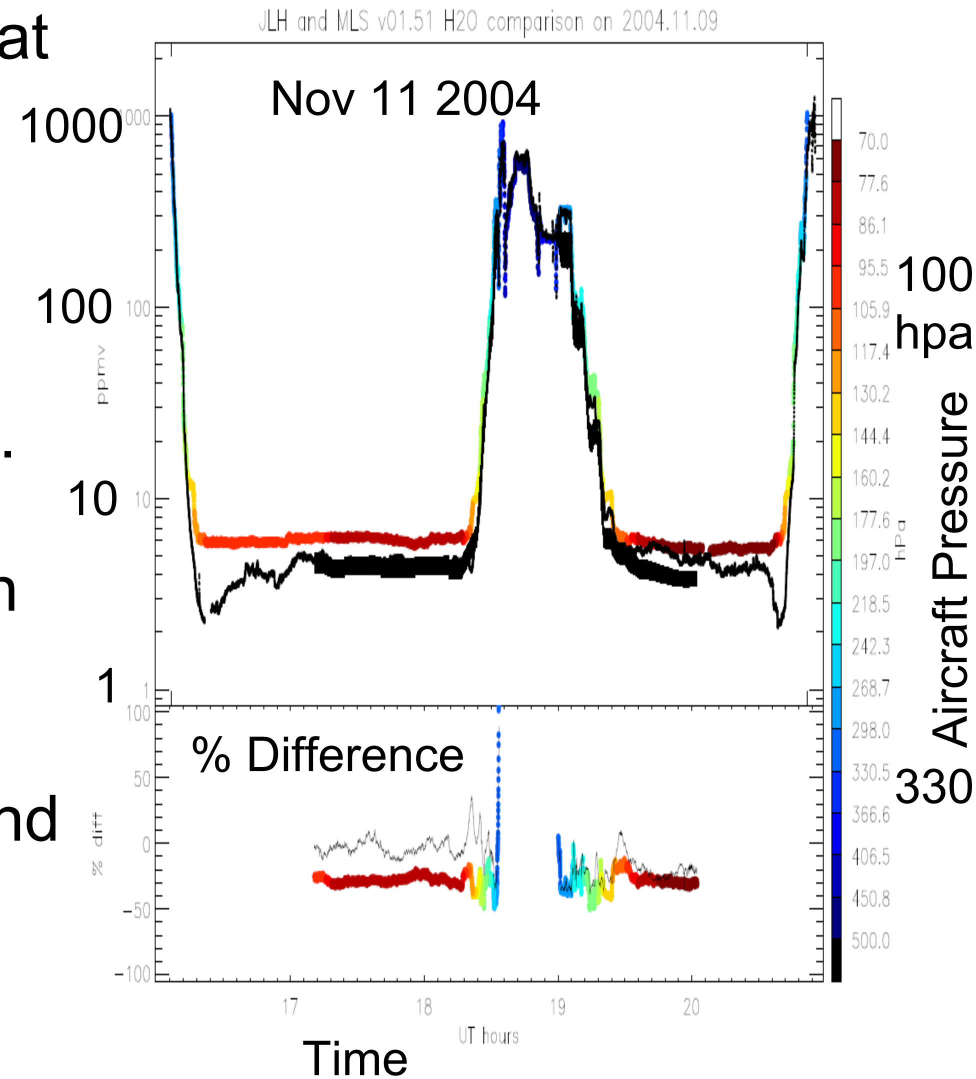
Smoothing function

- Example shown at right. Note the negative contributions from levels above and below the specified level.
- For H_2O at 100 hPa, there is little difference between the averaging kernel and the least squares fit (forward model smoothing effect).



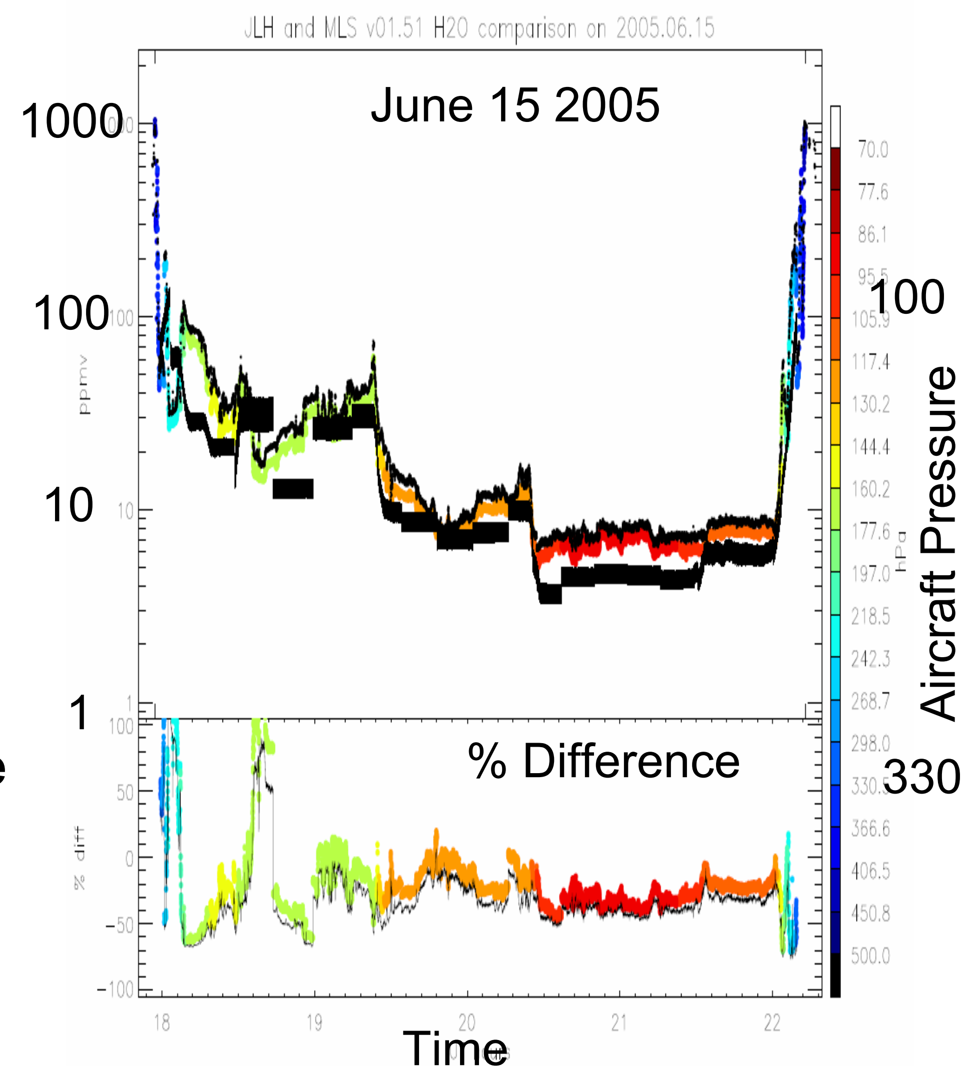
Ave Comparison

- Nov 04 AVE showed that JLH (color) is ~30% wetter than MLS (thick black) at 90—100 hPa.
- Frostpoint (thin black) shows hysteresis effect. Usually in good agreement (< 10%) with MLS after takeoff then agreeing well with JLH following a deep dive and ascent.



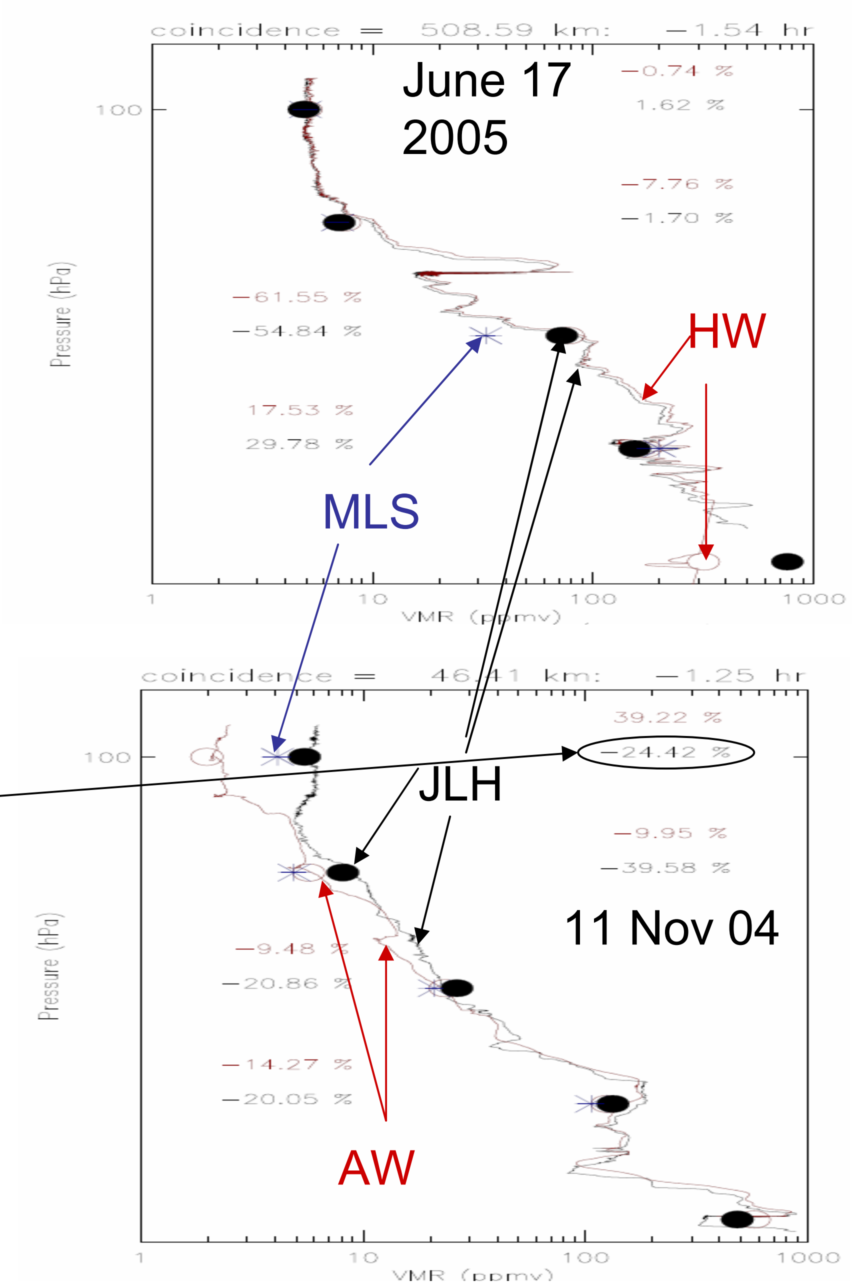
AVE Comparison

- JLH (color), MLS (thick black) and HW (thin black) from the June 05 AVE are shown.
- Here MLS is 20% drier than JLH and 30% drier than HW.
- Could vertical smoothing be responsible for these differences?
  - Not possible to apply vertical smoothing because of level flight.
  - Time to look at profiles.



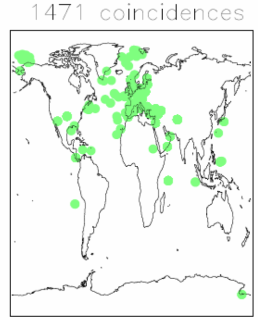
AVE profiles

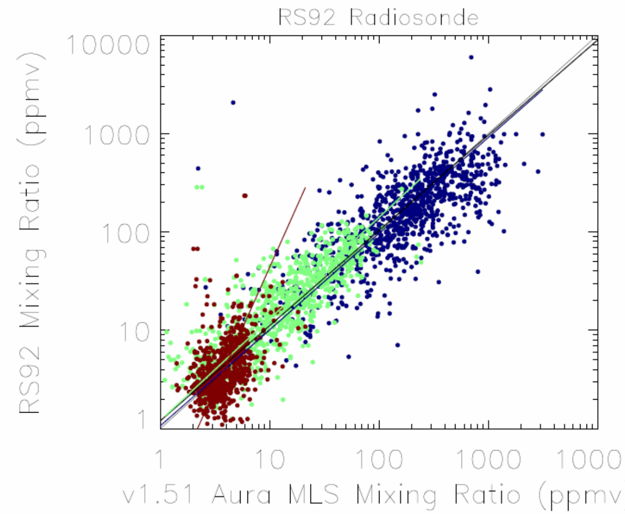
- Decided to look at take-off and landing data.
  - Allows us to apply smoothing correction
  - Poorer coincidence
- JLH and HW track very well.
- JLH and Frostpoint(AW) have large differences especially near the tropopause.
- During level flight this is -31%
  - Applying vertical smoothing reduces the bias to -24%.
- Profile comparisons indicate that 1/3 of the bias seen in level flight is due to neglecting vertical smoothing.



Radiosondes

Vaisala RS92



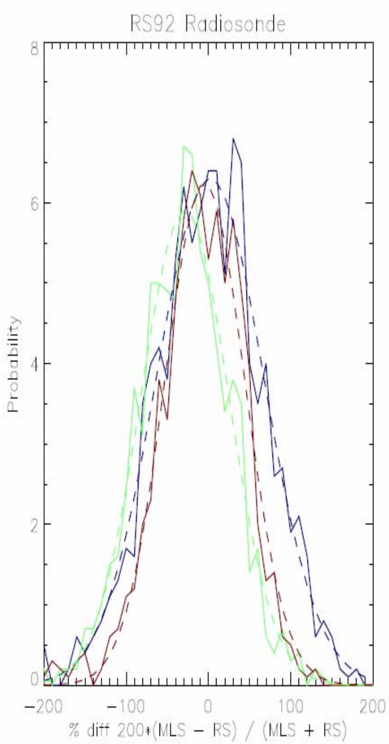


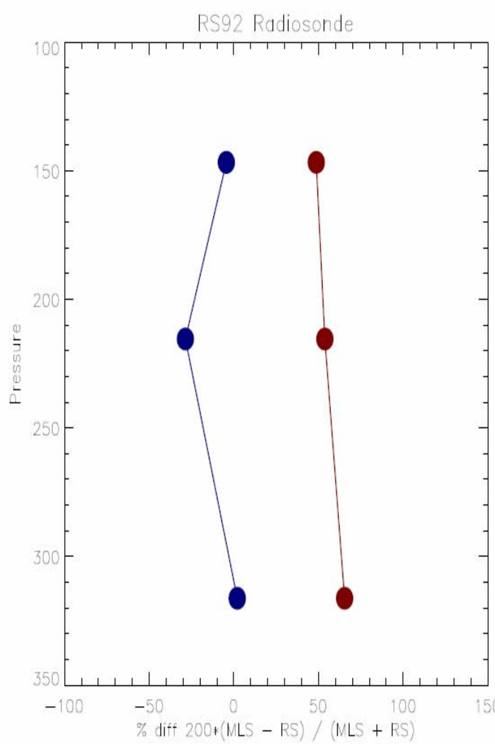
316 215 147

PDFs

Mean Difference

Std dev of differences



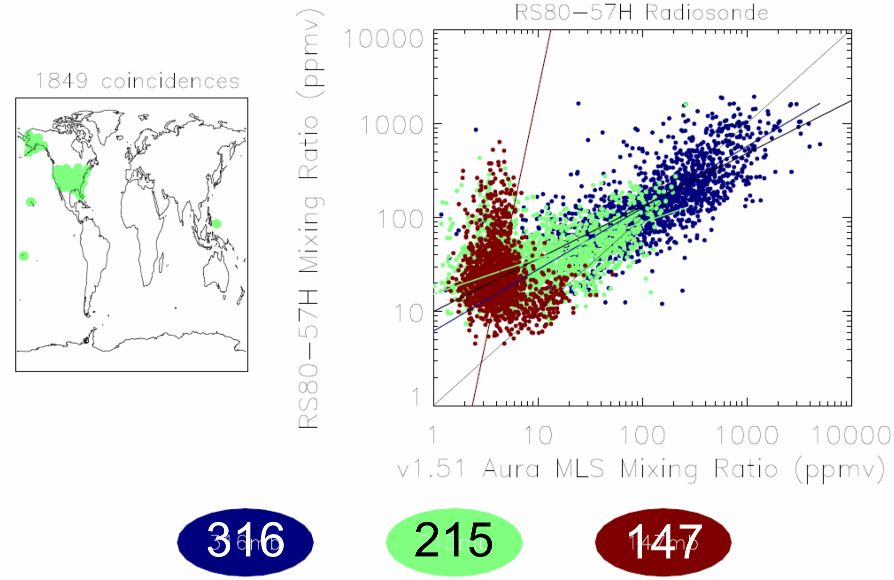


- RS92 radiosonde shows good agreement
- Lots of scatter
- RS90 is similar but with poorer agreement at 215 and 147 hPa.

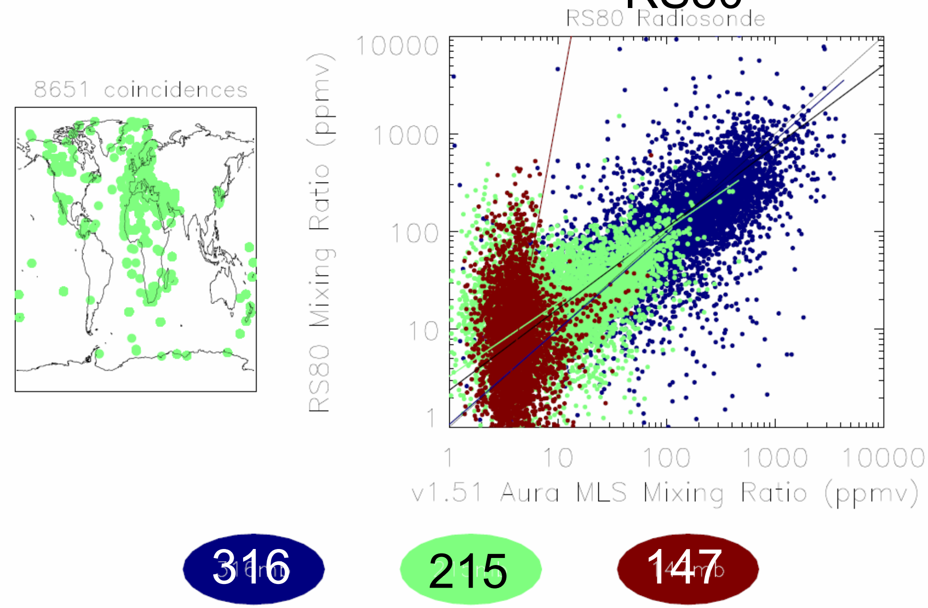
RS80/RS80-57

- RS80 is the workhorse instrument in the network – 316 and 215 levels are decent but starts to lose it at 147 hPa
- RS80—57H is a variant of the RS80 (presumably using the H dielectric) adopted by the US.
  - It shows much worse agreement than RS80
  - Don't know why. Possibly uses a data reporting practice to make data consistent with older US radiosondes?

Vaisala RS80-57H



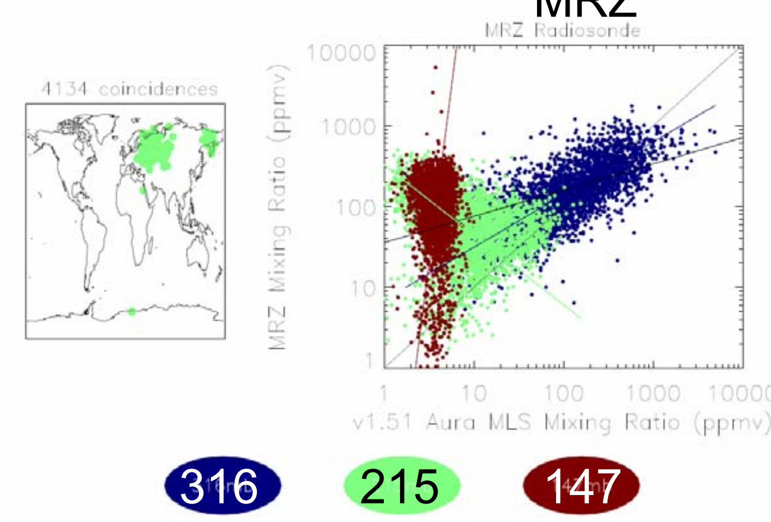
RS80



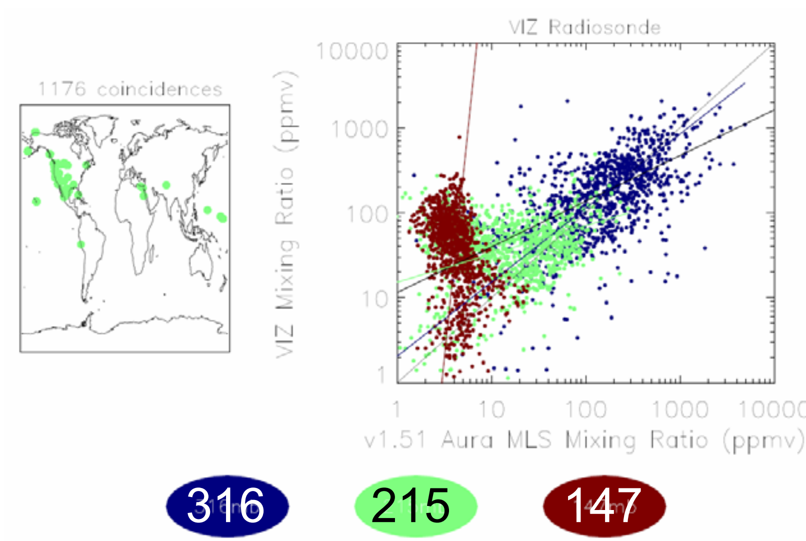
US VIZ / Russia MRZ

- Relative to MLS x-axis, these radiosondes show a severe degradation of performance at 215 and 147 hPa.
- Agreement at 316 hpa is better but not as good as the Vaisala.

MRZ

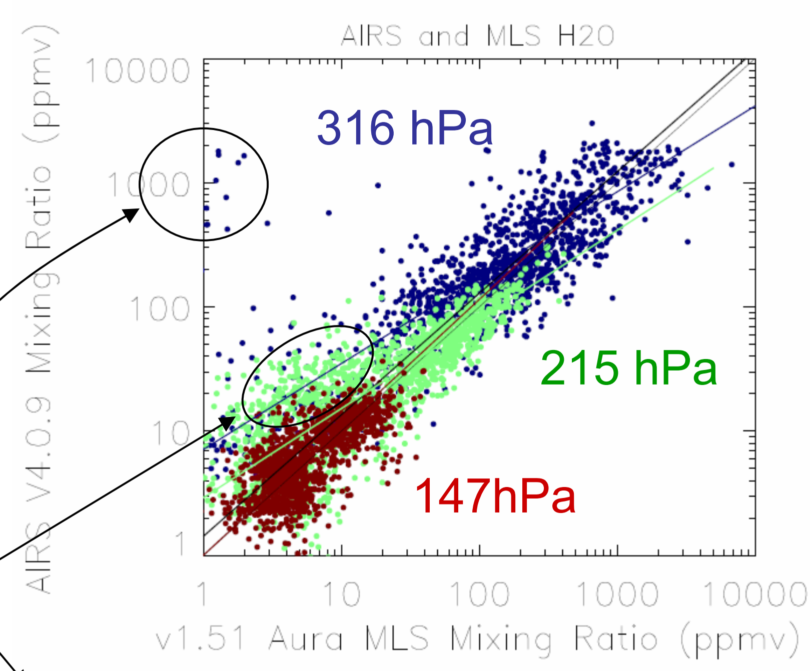


VIZ

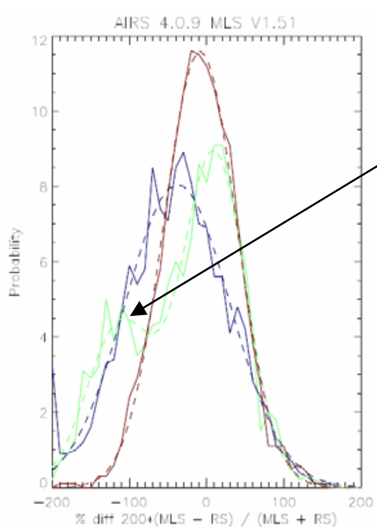


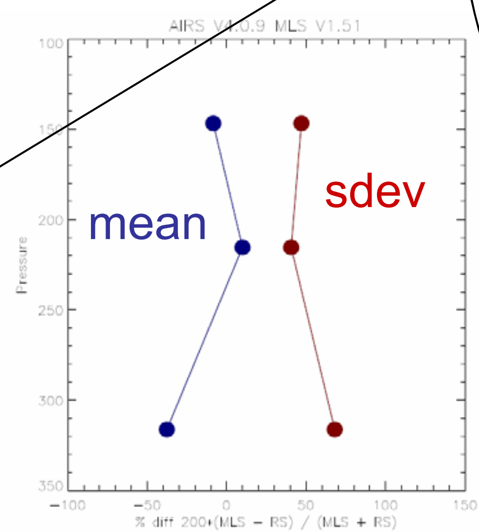
AIRS V4.0.9

- Two days per month from Aug 04 to Aug 05. (86445 profiles, 82°S--82°N).
- As with other comparisons, scatter is LARGE
  - Almost identical to RS at 316 hPa.
  - Smaller than RS at 215 hPa
  - Increases again at 147 hPa

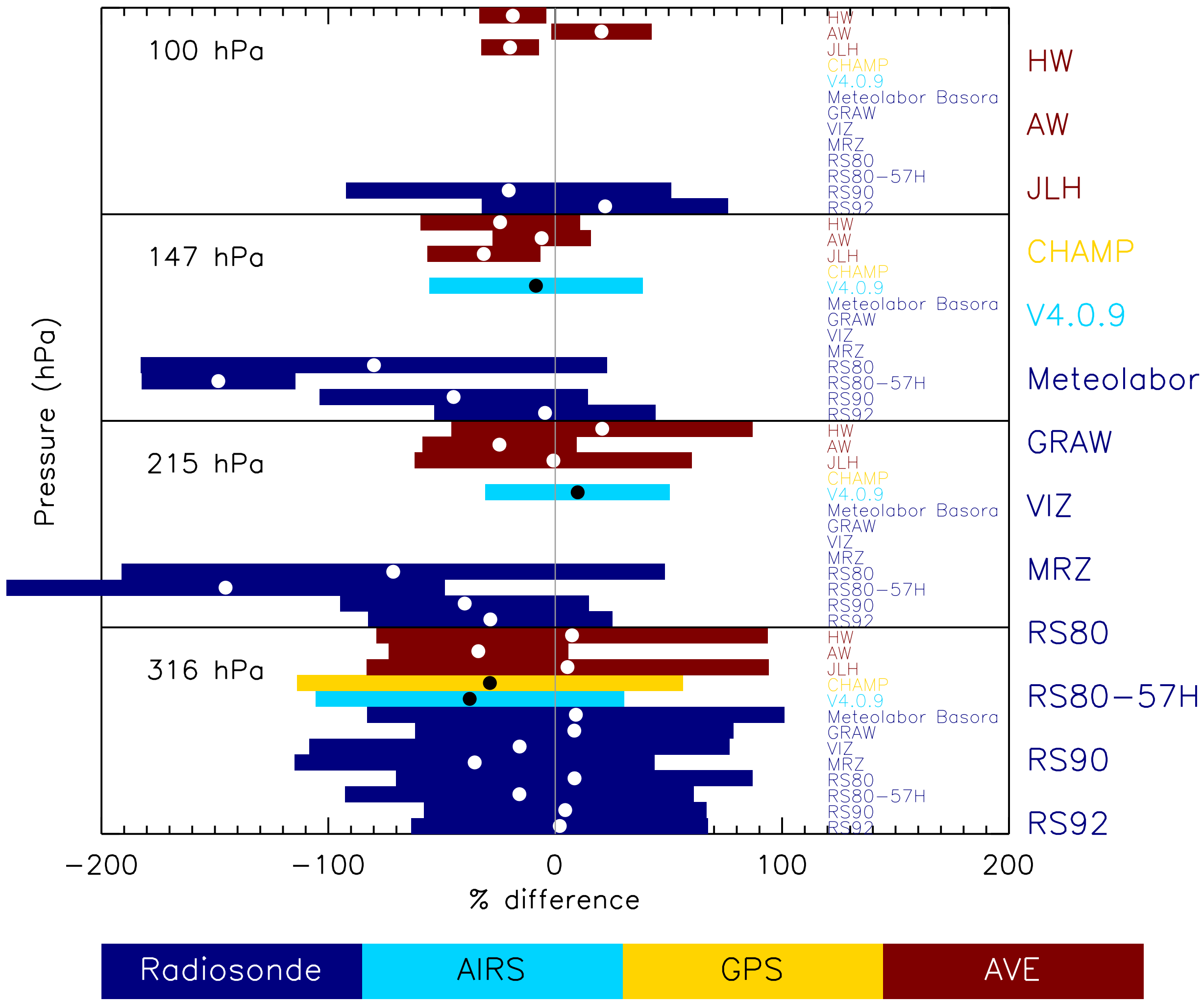


- MLS-AIRS PDF at 215 hPa is bimodal.
  - Probably a data screening problem
  - These occur north of 60°N.
- Dry fliers in MLS data.
- The increased scatter at 147 is not a good sign.





Summary


100 hPa
147 hPa
215 hPa
316 hPa
HW
AW
JLH
CHAMP
V4.0.9
Meteolabor Basora
GRAW
VIZ
MRZ
RS80
RS80−57H
RS90
RS92
Pressure (hPa)
−200
−100
0
100
200
% difference
HW
AW
JLH
CHAMP
V4.0.9
Meteolabor
GRAW
VIZ
MRZ
RS80
RS80−57H
RS90
RS92
Radiosonde
AIRS
GPS
AVE

Conclusions

The Good

- Mean differences with radiosondes are very small with most instrument types at 315 hPa. They are larger at higher altitudes.
  - The RS90/92 appear useful up to 200 hPa.
- JLH and HW are self consistent and their mean difference with MLS is < 30% at all heights.
- The ~30% bias seen in the '04 AVE level flights near 100 hPa reduces to ~20% when vertical smoothing is accounted for.
- Mean difference with AIRS at 215 and 147 is ~10%.
- AVE shows decreasing variability about the mean difference with height. Consistent with UARS MLS UTH study showing the same. (AIRS also at 316/215 hPa)
  - Horizontal smearing is less of an issue at higher altitudes

The Ugly

- Standard deviation about the mean difference is LARGE, especially at 316 hPa.
  - Complicates usage and interpretation (especially for data assimilation).
  - Without further thought H_2O is a factor of two measurement at 316 hPa. With good instrumentation MLS suggests that this drops steadily to 10% at 100 hPa.
  - Radiosondes are not useful at 100 hPa and probably marginally useful at 147 hPa (RS92/90 only).
  - Scatter with AIRS at 147 is worse than at 215 (opposite of that seen for AVE) suggesting that AIRS is also marginally useful at 147 hPa.
- Large mean difference with AIRS at 316 hPa (largest amongst all comps)
- MLS - AIRS 215 H_2O PDF is bimodal.
- Frostpoint and JLH/HW show large (>20%) height and time dependent differences