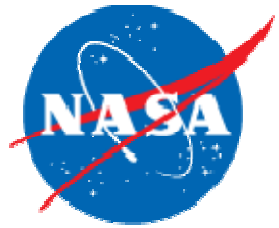
National Aeronautics and Space Administration



Validation of the Aura Microwave Limb Sounder Temperature Measurements

Michael J. Schwartz + MLS Team
Jet Propulsion Laboratory, California Institute of Technology

AIRS, TES, CHAMP, ACE Teams

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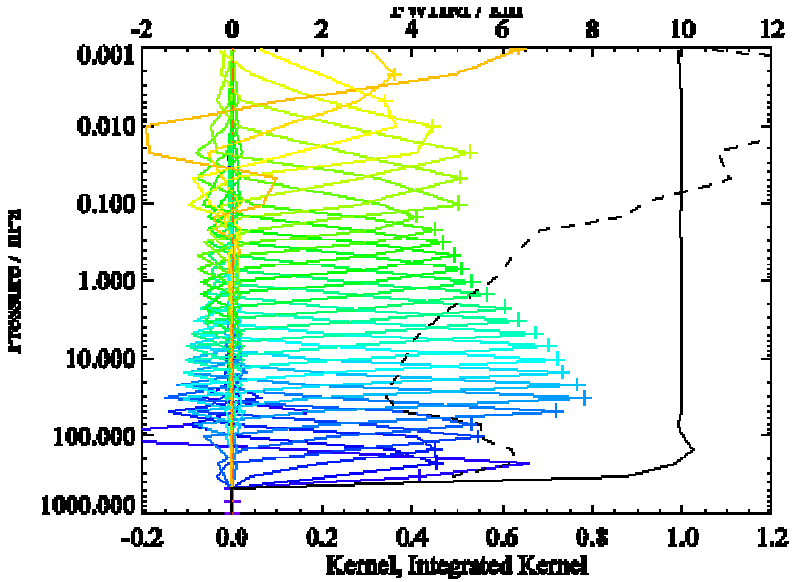
Overview of Aura MLS version 2.1 (v2.1) Temperature Data

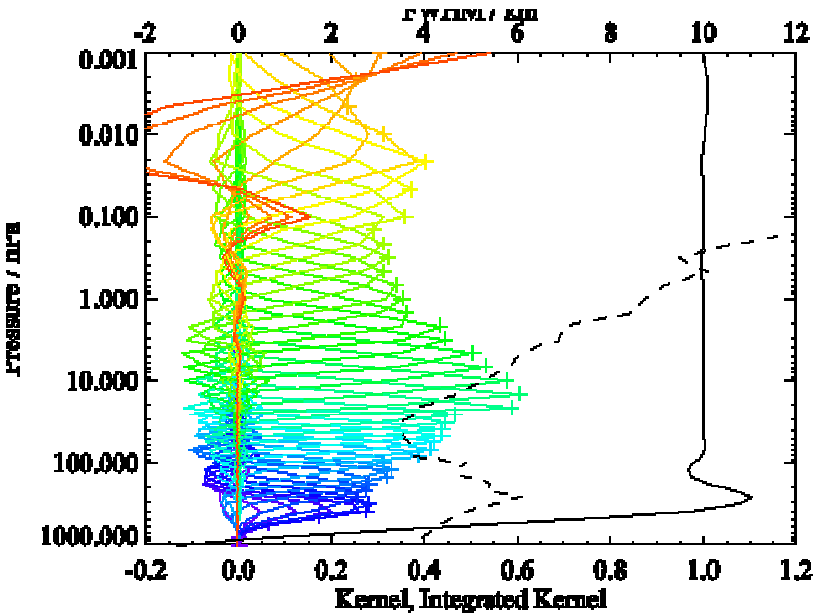
- The improvement of vertical resolution of the Temperature (and water vapor) retrievals in the UT/LS is a primary goal of v2.1 development.
- V2.1 uses radiances from the 234-GHz isotopic Oxygen line to improve the retrieval in the troposphere. Radiance closure is significantly better than in v1.5 CorePlusR3 temperature retrieval.
- The center (chs 6—20 mif>56) of the band-1 is no longer used to provide pressure from linewidth, and to indirectly provide Temperature from pressure and pointing. We still have not made internally-consistent sense of these radiances and wideband (32,34) and band 8.
- V2.1 retrieves on 12 surfaces-per-decade from 1000 hPa to 22 hPa (rather than the 6-per-decade of v1.5) with typical UT vertical averaging kernel widths of 4.5 km (vs 7—8 km for v1.5.)
- V2.1 Temperature retrieval indicates that it provides useful information down to the surface (the extent of the role of smoothing is under investigation), while v1.5 was stopped at 316 hPa.
- The upper retrieval cutoff in v2.1 is 0.0001 hPa (~112 km) rather than 0.001 hPa (~96 km) in v1.5. The usefulness of these retrieval levels is under investigation.
- Improved DACS radiance processing improves radiance closure for the highest scan positions and should improve the uppermost retrieval levels.

V2.1 and V1.5 Vertical Averaging Kernels

v01.51



v02.10



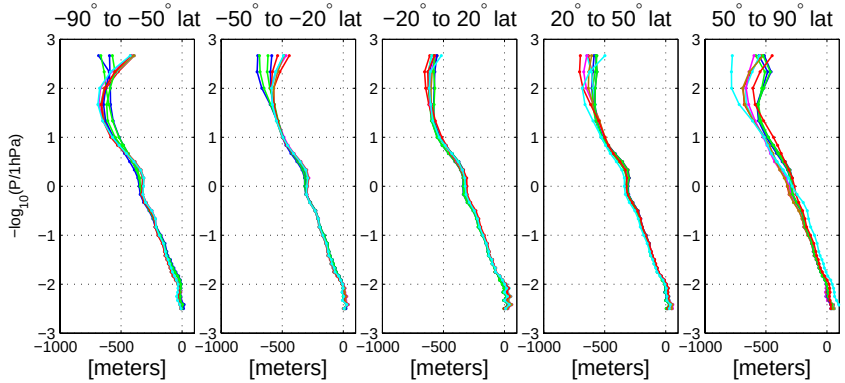
- Vertical resolution (VAK FWHM) of v02.10 is improved in the troposphere and tropopause region, but still a work in progress.
- V02.10 VAK FWHMs are worse in the upper stratosphere and mesosphere

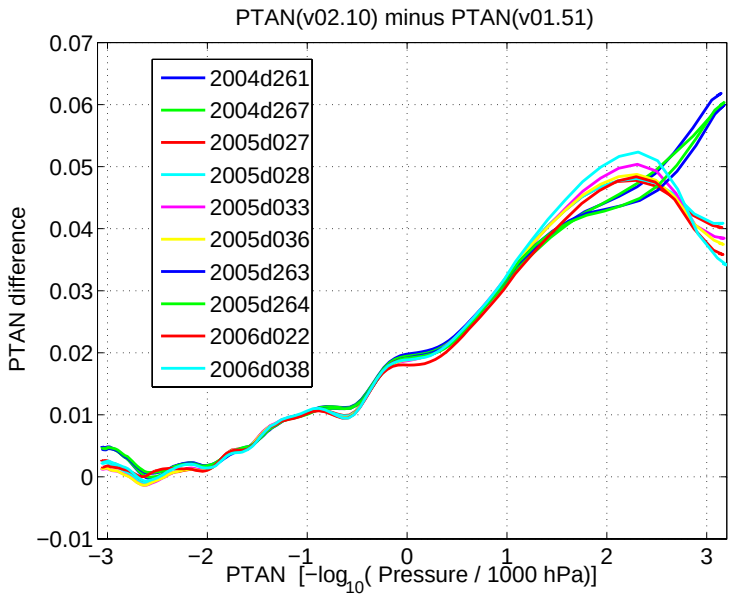
VAK FWHM

	v01.51	v02.10
1hPa	6km	8.5km
68hPa	4km	4km
100 hPa	6km	4km
147 hPa	8km	5km
215 hPa	8km	5.5km
316 hPa	7km	6km

Impact of v1.5—v2.1 Temperature Differences on GPH

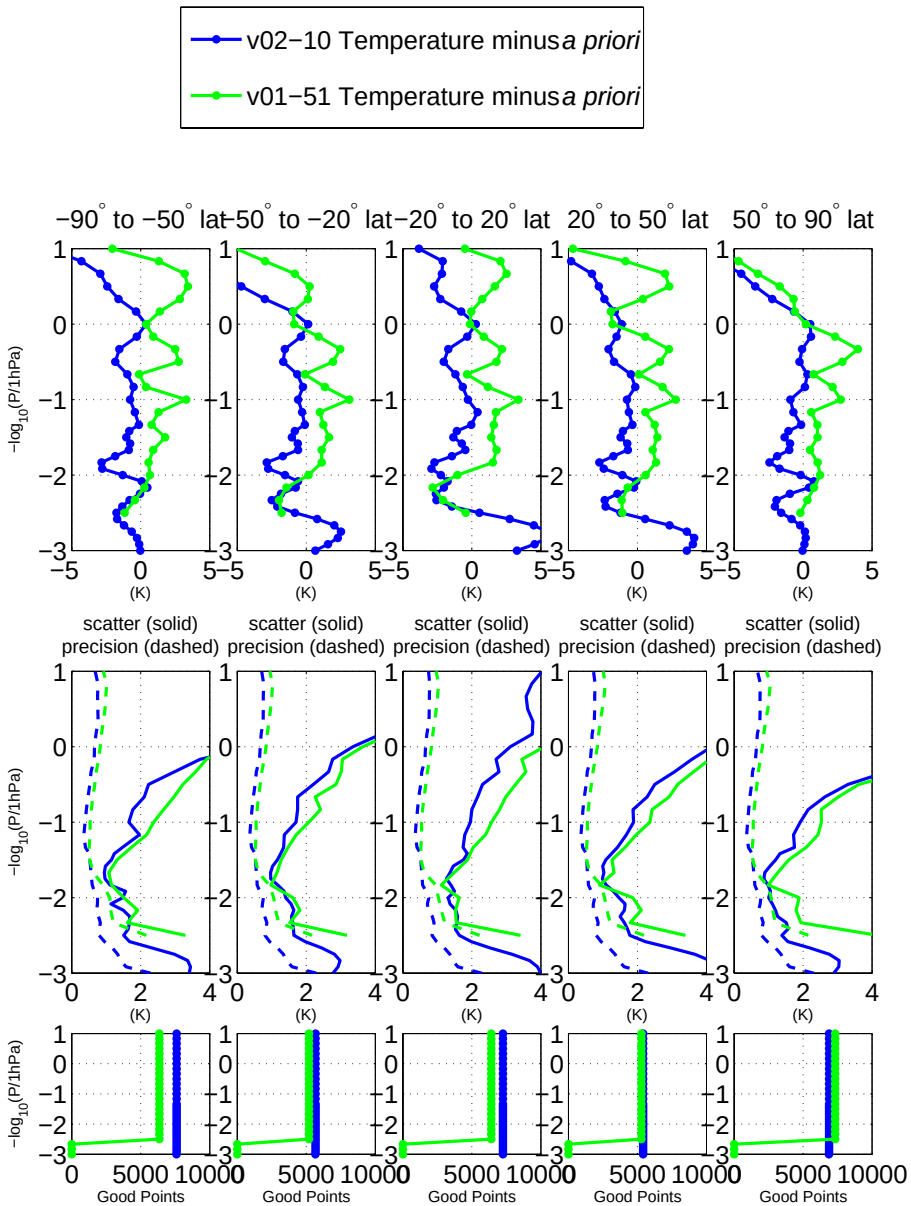
v02.10 GPH minus v01.51 GPH





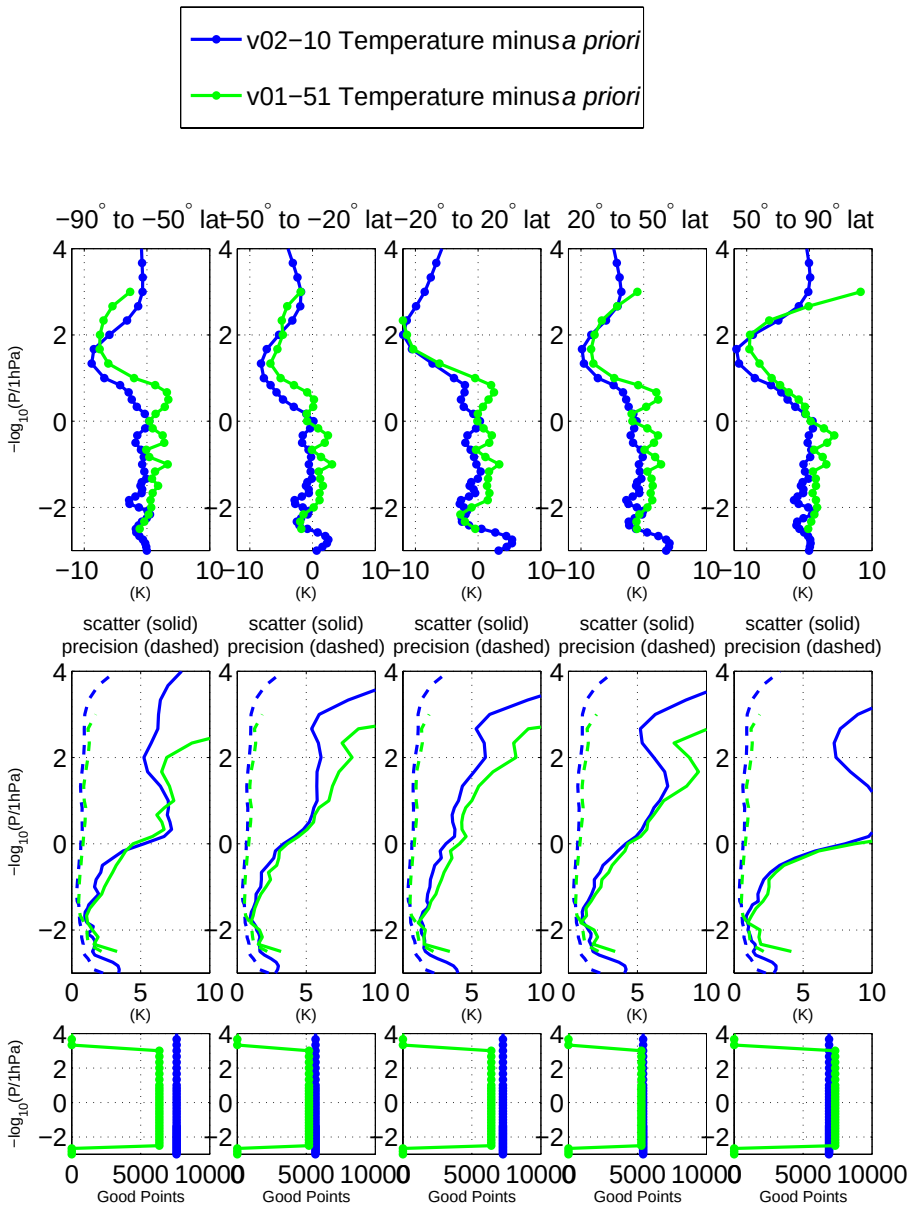
- MLS retrieval imposes hydrostatic balance so inferred pointing and retrieved Geopotential Heights are affected by temperature. Lower v2.1 temperatures result in thinner slabs between pressure surfaces.
- Pressure coordinate is minus-log-pressure (Z=-2 → 100 hPa)
- GPH v2.1 minus GPH v1.5
  - 0.01 hPa → -600 m
  - 0.1 hPa → -500 m
  - 1 hPa → -300 m
  - 10 hPa → -200 m
  - 100 hPa → 0 ± 10 m
  - 316 hPa → 0—40 m
- PTAN (lower figure) difference at 0.1 hPa is 0.032 →500m when scaled by 16km/decade.
- Radiance information is shifted to higher altitudes (lower pressures) in v02.10.

Temperature v2.1 and v1.5 minus a priori



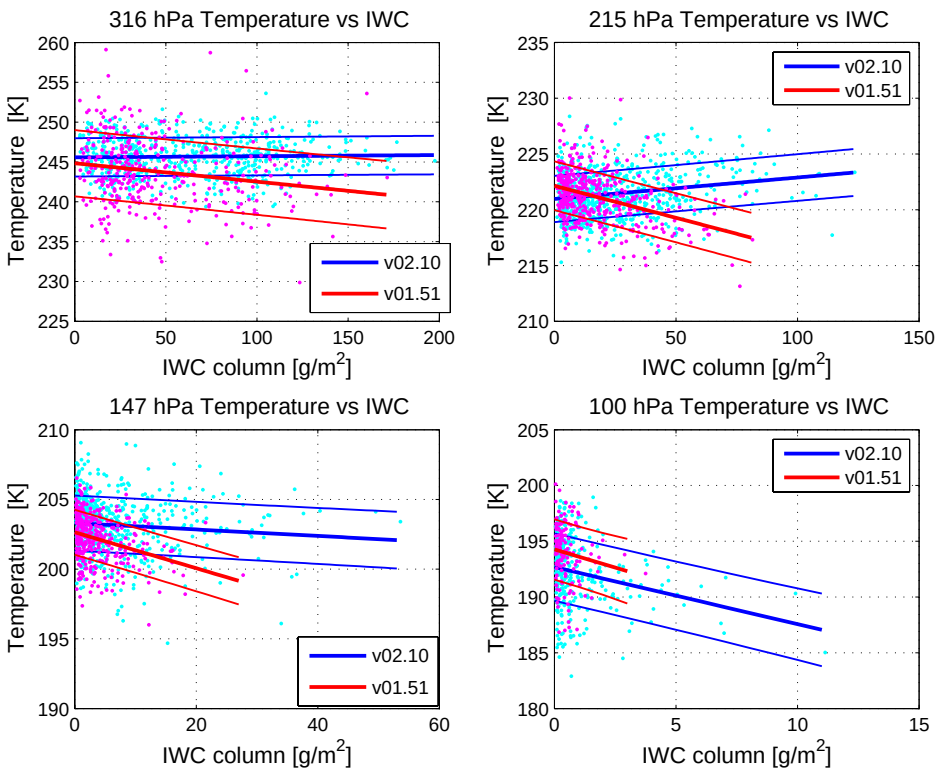
- Data is the average of the first 10 days of v2.1 processing.
- *A priori* is GEOS-4 to 3 hPa, climatology above.
- V1.5 had a persistent 1—3 K warm bias in the stratosphere relative to GEOS-4.
- Both v1.5 and v2.1 are ~2 k cooler than GEOS-4 at 215 hPa – 316 hPa.
- V2.1 has a 2—3 K peak-to-peak vertical oscillation 316 hPa – 46 hPa relative to GEOS-4.
- The spike in v1.5 at 10 hPa is gone.
- V2.1 has smaller scatter of differences from GEOS-4 (middle plots, solid lines) at most levels

Temperature v2.1 and v1.5 minus a priori



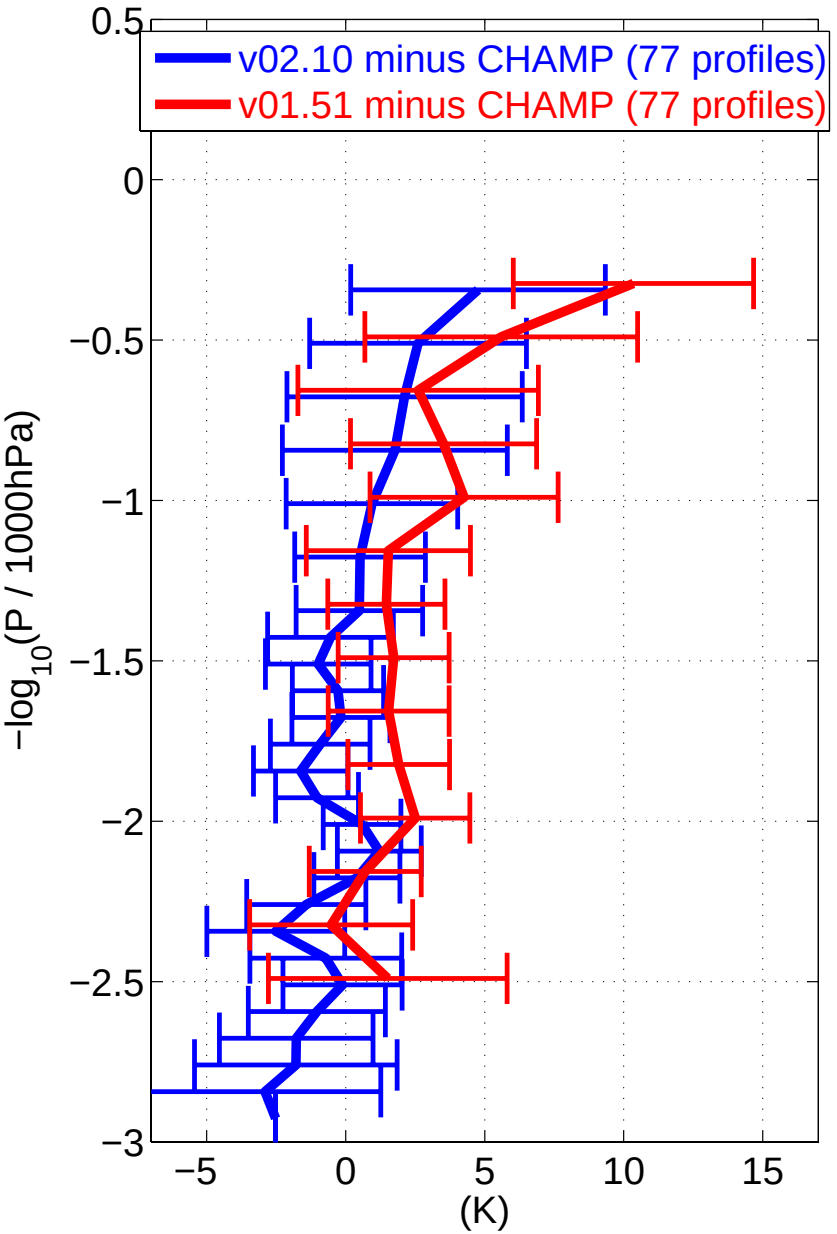
- Same data, zoomed out
- V2.1 retrieves higher.
- V2.1 has significantly better agreement with climatology at highest retrieval levels, as indicated by scatter (solid lines) of second row of plots.

Impact of Cloud on MLS v01.51 and v02.10 Temperature



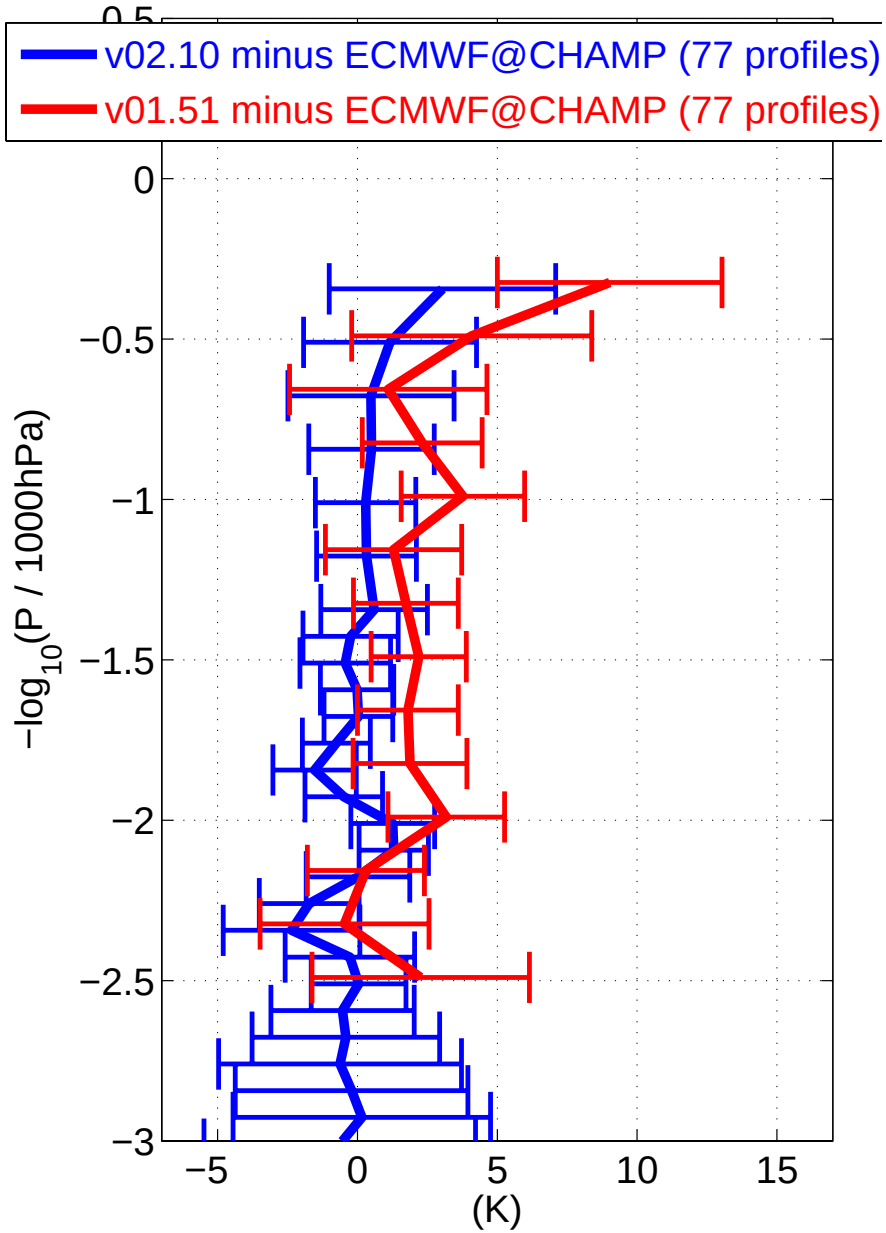
- In the tropics, 316hPa and 215 hPa, convection is expected to be releasing latent heat, giving a warm anomaly
- MLS v01.51 temperature decreases with increasing IWC at all retrieved levels in the troposphere..
- MLS v02.10 has an improved radiance screening in the presence of clouds and has a positive correlation with IWC at 215 hPa and is nearly flat at 316 hPa and 147hPa.
- Fewer v02.10 profiles are marked bad in the presence of IWC than v01.51.

Comparison with CHAMP



- Coincidence 250 km and 3 hours yields 77 CHAMP profiles.
- High resolution CHAMP profile is least-square fit to linear interpolation of MLS log-pressure grid points.
- Comparison with CHAMP indicates that 1.5 K warm bias of v1.5 in stratosphere is less than 0.5 K in the upper stratosphere in v2.1.
- MLS v1.5 has a ~1 K cool bias in the UTLS plus a ~2 K peak-to-peak vertical oscillation, as suggested in comparison with a priori.
- Scatter of differences (1 sigma) are shown as errorbars. Scatter is consistently smaller in v2.1 at almost all levels.

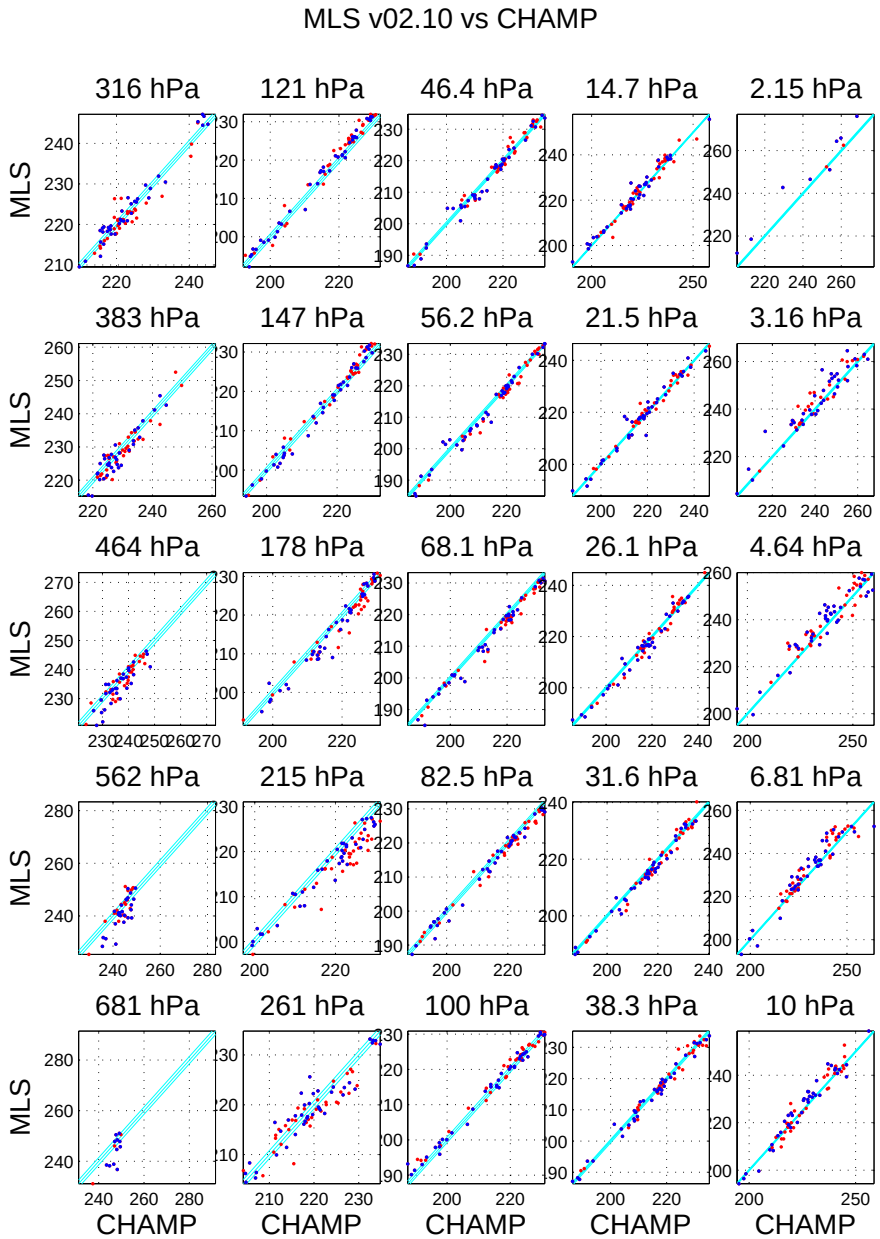
ECMWF at CHAMP Profile Positions



- ECMWF is in good agreement with CHAMP and so shows very similar biases with respect to MLS.
- CHAMP has an increasing warm bias (~2 K at 2.15 hPa) relative to ECMWF at its highest retrieval levels. Here ECMWF agrees better with MLS v2.1.
- Coincidence criteria are:
  - 250 km
  - 3 hours

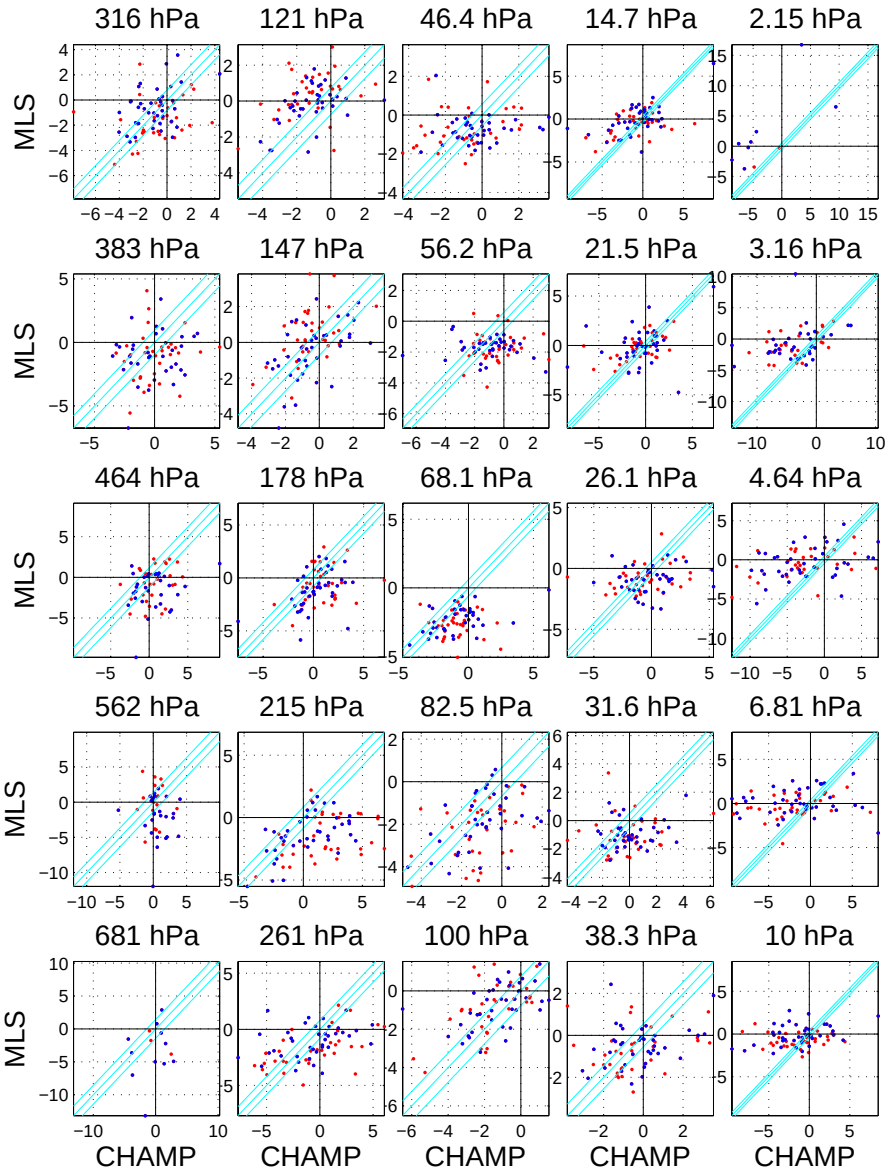
MLS vs CHAMP

- All points are coincidences within 250 km.
- Blue is time difference < 1.5 hours
- Red is 1.5 hours < time diff < 3 hours
- Cyan is 1:1 line and plus/minus MLS precision.

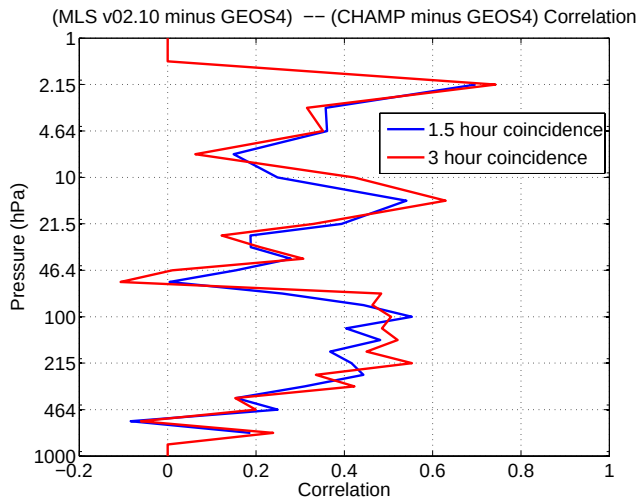


MLS minus GEOS4 vs CHAMP minus GEOS4

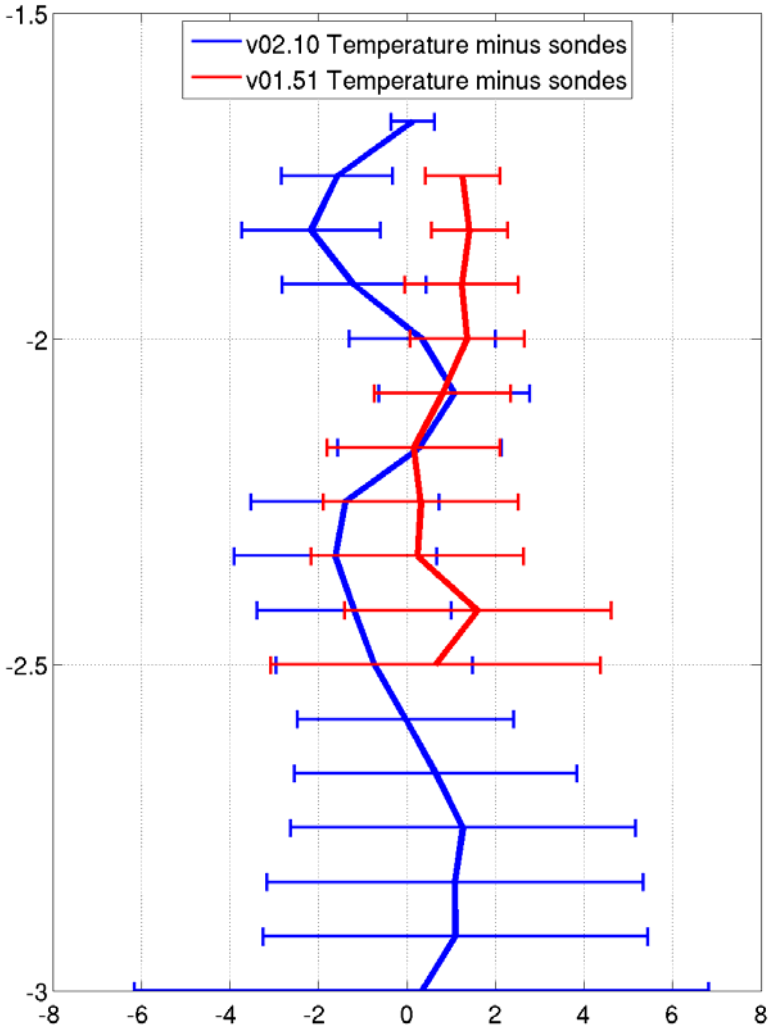
(MLS v02.10 minus GEOS4) vs (CHAMP minus GEOS4)



- Information added by MLS is actually difference from GEOS4 *a priori*. This is a preliminary look
- MLS does not do a very good job of predicting (CHAMP-GEOS4)
- Blue points <1.5 hour
- Red points <3 hour

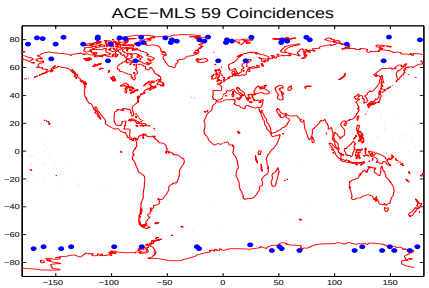


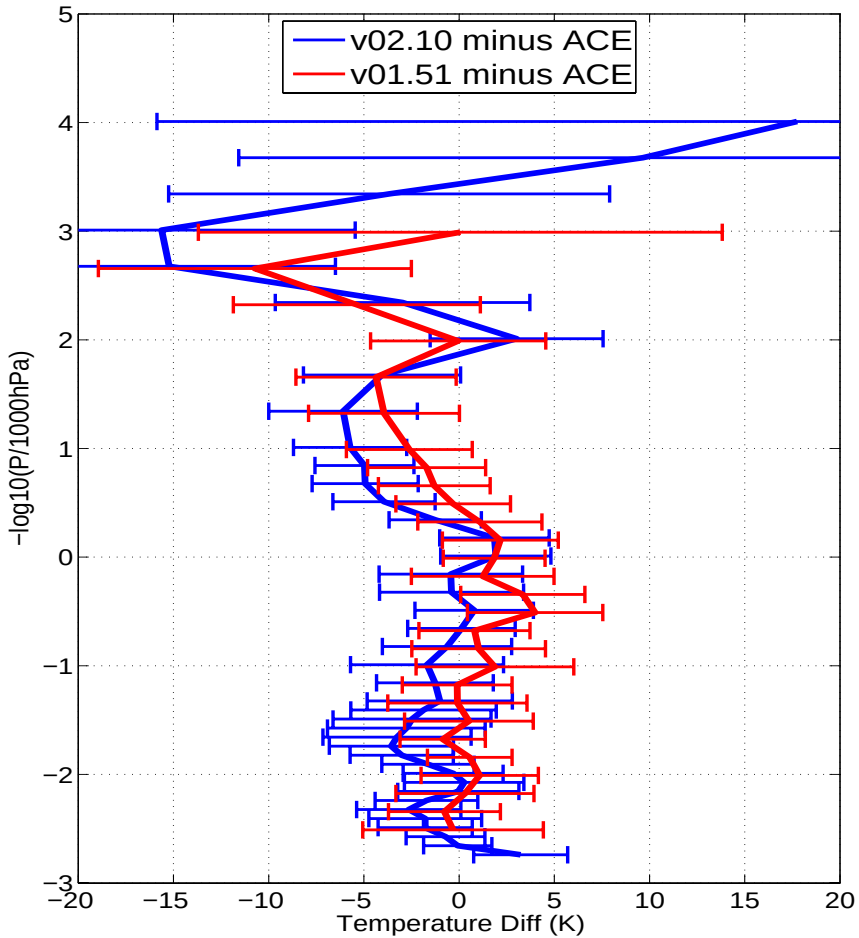
Comparison with NCEP Routine Sondes



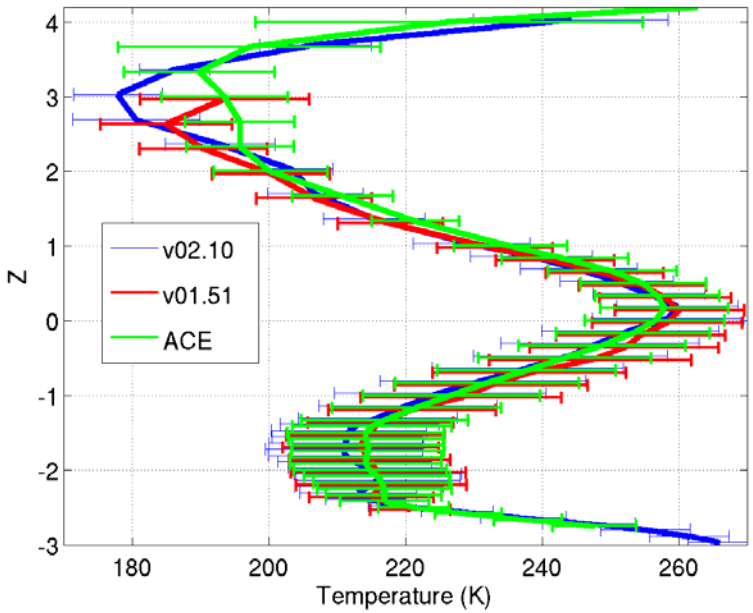
- 1345 sonde coincidences are averaged.
- Errorbars are 1-sigma scatter of differences.
- V02.10 has oscillation ~2 K p-t-p through tropopause region.
- V01.51 is linearly interpolated to give values shown on odd surfaces.
- V01.51 has a 0—1 K positive bias relative to the sondes
- V02.10 has smaller scatter wrt sondes at 316 hPa and 215 hPa, but larger scatter in stratosphere.

Comparison with ACE





- ACE has 59 coincidences with v02.10, all at high latitude.
- V01.51 has better agreement with ACE at almost all levels except near 1 hPa. ACE is warmer than many other correlative sets in the stratosphere.
- MLS has a sharper, colder Mesopause.
- V02.10 closes radiances much better at highest scan positions due to a change in the digital autocorrelator calibration algorithm, but the pointing (height vs P) differences between the two versions are significant and we don't know which is right.



SABER Comparison

- Between 0.01hPa and 0.001hPa, preliminary analyses show MLS Temperature to be significantly lower than SABER, in general agreement with ACE. Dennis Riggan, Ruth Lieberman have been looking at these comparisons. I have more work to do.

Conclusions

- V2.1 Temperature is still a work in progress, but time to v02.20 (release version) is very short.
- Vertical resolution is improved in the troposphere (8km→5km), although the impact of smoothing needs to be investigated further.
- The 0—3 K warm bias of v1.5 in the stratosphere has been replaced by, perhaps a slight cold bias plus ~2K persistent vertical structure in the decade around 100 hPa in v2.1.
- The persistent ~2K zigzag near 100 hPa is in v2.1 bias relative to GEOS4, ECMWF, CHAMP and sondes. This structure is associated with the knitting together of radiances from different bands (and radiometers) in the retrieval.
- Generally lower temperatures in v2.1 result in increasingly lower GPH values on pressure surfaces through the stratosphere and into the mesosphere (~0m @ 100hPa ≈ 16km; 500m @ 0.1 hPa ≈ 64 km)
- Radiance closure for the highest altitude is significantly improved, but comparison with ACE does not reflect this improvement.