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MLS science team

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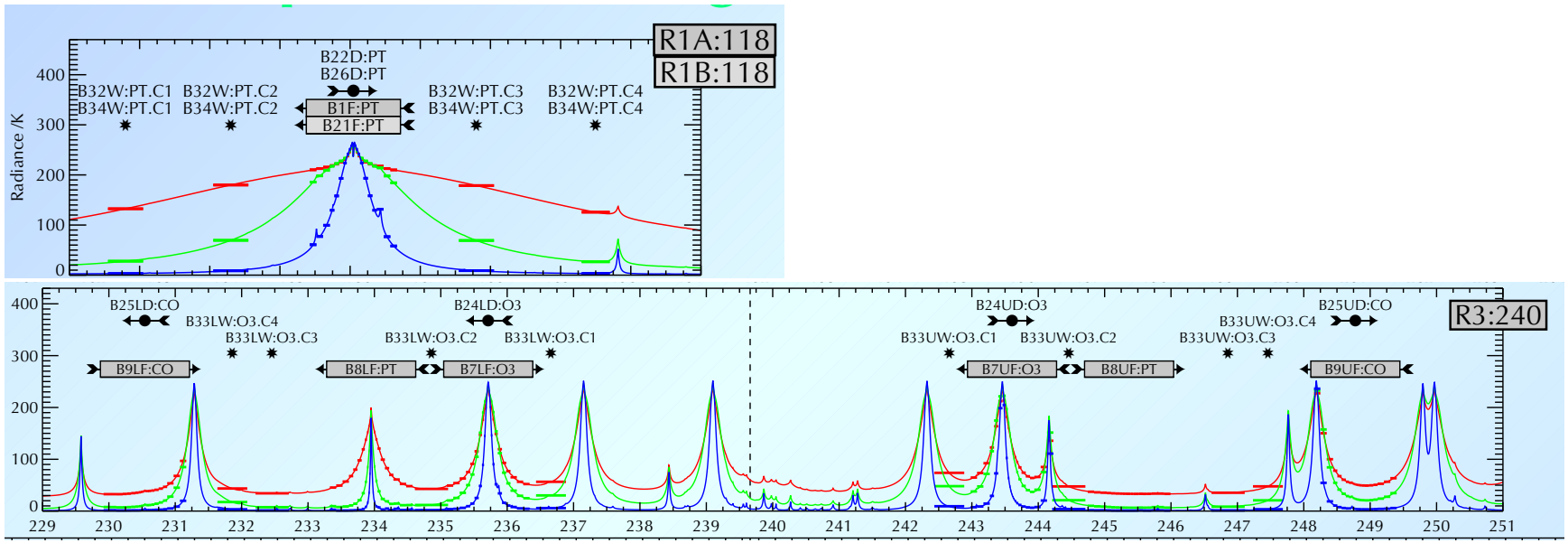
Overview of the EOS MLS Temperature product

- This talk describes Temperature data produced by version 01.51 of the EOS MLS data processing algorithms.
- MLS retrieval has multiple "phases," each of which uses optimal estimation with a different subset of MLS radiances, and each phase retrieves its own temperature.
  - ⇨ Each phase retrieves temperature and while successive phases may use a prior result as an initial guess, results are not constrained to agree.
  - ⇨ The standard temperature from 316 hPa to 1 hPa is from "Core." Core retrieve temperature from the 118-GHz radiance.
  - ⇨ The standard temperature from 0.68 hPa to 0.001 hPa is "CorePlusR2A," which add radiances from the 190-GHz radiometer.
  - ⇨ CorePlusR3, which uses the 118-GHz and 240-GHz radiometers should provide the best resolution in the troposphere, but this retrieval has significant biases at the lowest retrieval levels and is prone to vertical oscillation (largely managed in v01.51.)

Overview of the EOS MLS Temperature product

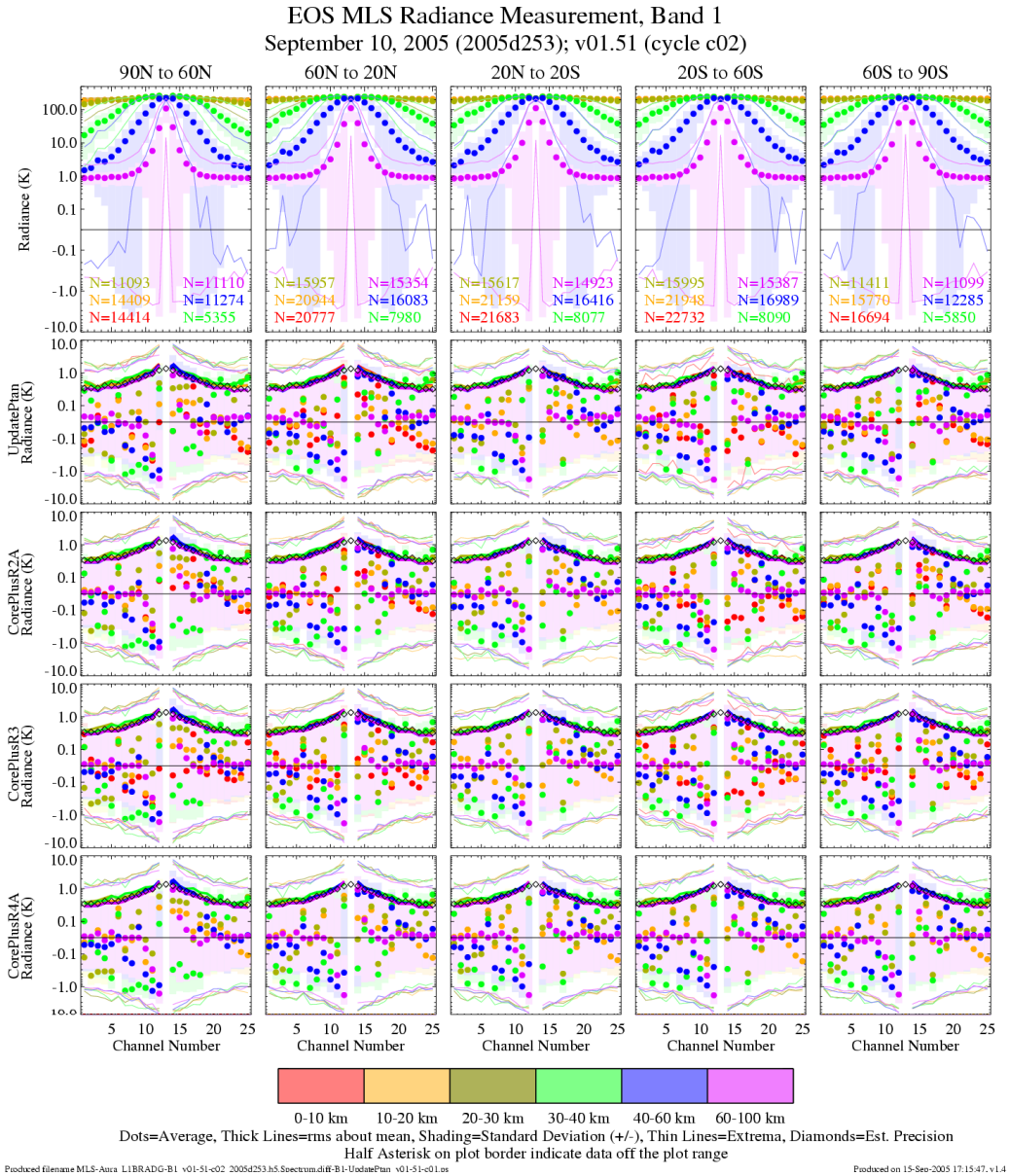
- Temperature profiles are retrieved on a grid with pressure as the vertical co-ordinate: six pressure levels per decade of pressure ($\sim$2.5 km) from 316 hPa to 0.1 hPa and three per decade ($\sim$5 km) for pressures from 0.1 hPa to 0.001 hPa.
- The MLS representation of the atmosphere is a linear interpolation of temperature between the retrieval points.
- Information from five successive limb-scans of the atmosphere is used to retrieve each profile.
- Horizontally, profiles are spaced by 1.5° great circle angle along the orbit track ($\sim$160 km, 24.6 s).
- Retrieval of temperature is complicated by its central role in conversion of height to pressure through the assumption of hydrostatic balance. Derivatives (dependence of radiances upon a particular temperature profile point) used in the forward model include effects of hydrostic balance in ways that are not immediately obvious.

MLS O_2 (Pressure-Temperature) Radiances



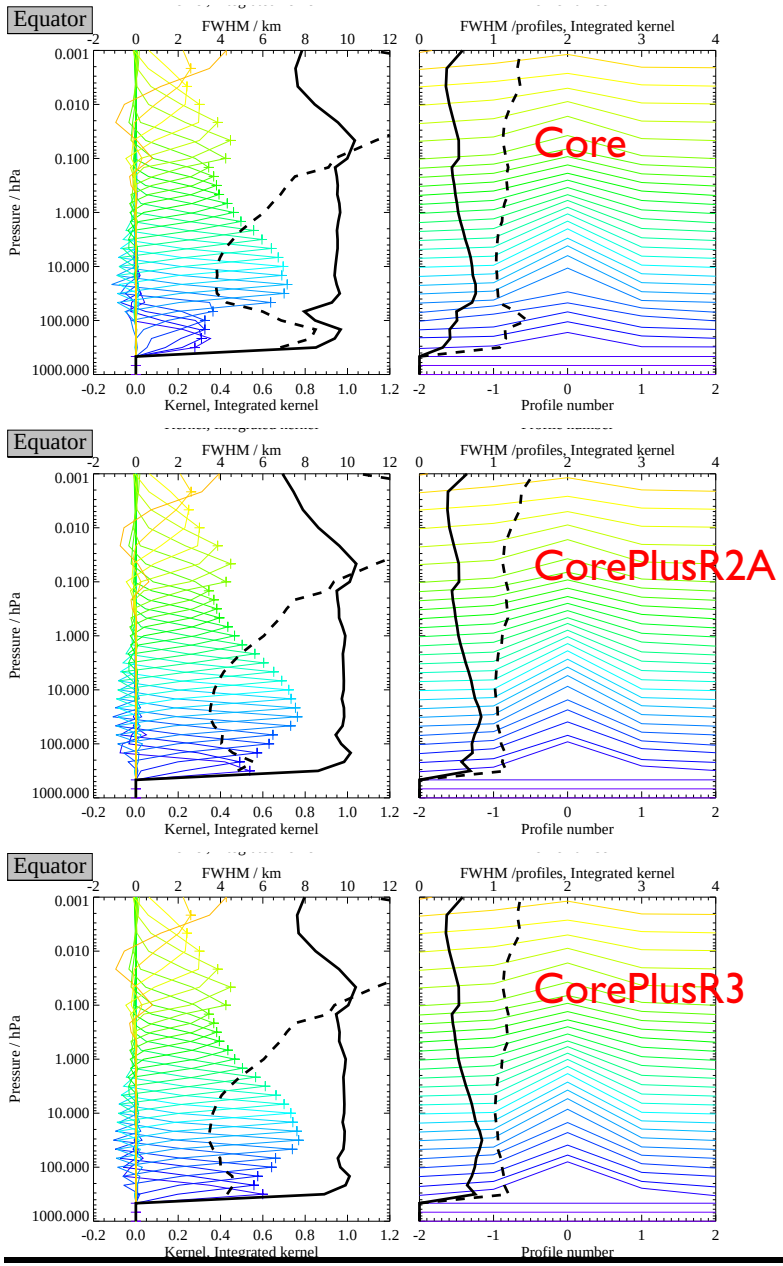
- O_2 is well-mixed, with a fixed VMR into the mesosphere, and reasonably certain VMR into the lower thermosphere. O_2 radiances provide pressure and temperature.
- Spectra shown are for typical limb tangents at 100 hPa, 30 hPa, and 10 hPa.
- The upper plot shows typical radiances over 9 GHz about the 118-GHz O_2 line, which is a primary source of MLS pressure/temperature information. There is a 25-channel filterbank on the line center and four discrete channels at $\sim\pm 1.7$ GHz and $\sim\pm 3.5$ GHz from the line center. Radiances at 100 hPa are becoming opaque, even in outer channels.
- The lower plot shows the "R3" radiances, including the much weaker 234 GHz O_2 line. This line provides information into the troposphere but continuum from upper sideband and baseline uncertainties make the measurement problematic.

Typical Band 1 radiance fits



- This is a standard radiance inspection plot showing residuals for band 1, a standard MLS filterbank centered on the 118-GHz O_2 line.
- Residuals are shown for four retrieval phases
  - ⇨ Residuals for different phases are very similar
  - ⇨ RMS of residuals is consistent with estimated precision.
  - ⇨ Residuals are asymmetric about the line center, with some mean residuals more than 1 K.
  - ⇨ There is difficulty fitting ozone lines near band extremes.

Averaging Kernels

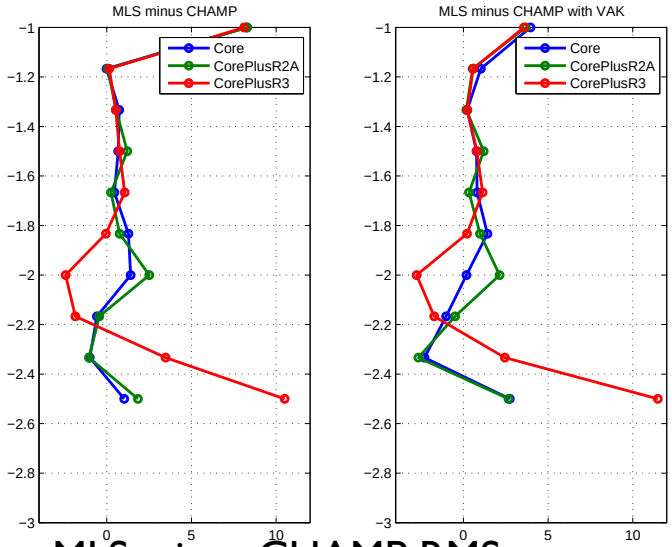


- Left column is vertical averaging kernels (VAK) and right column is horizontal averaging kernels (HAK) for the three temperature products.
- Dashed black lines are FWHM (ideally 2.5 km to 0.1 hPa), solid are integrated kernels (ideally 1).
- Vertical Averaging kernel FWHM near tropopause:
  - ⇨ Core 8.5 km
  - ⇨ CorePlusR2A 5.5 km (opaque H_2O line)
  - ⇨ CorePlusR3 4.5 km ($O_{18}O$ line)
- Core horizontal resolution is also poorer at levels below 46 hPa.
- Above 46 hPa, differences between phases are minor.
- In theory, CorePlusR3 temperature should be our best product.
- These VAKs cut off sharply at 316 hPa and 0.001 hPa, which is non-physical. Their utility in convolution of correlative data is questionable. This is an area of current work.

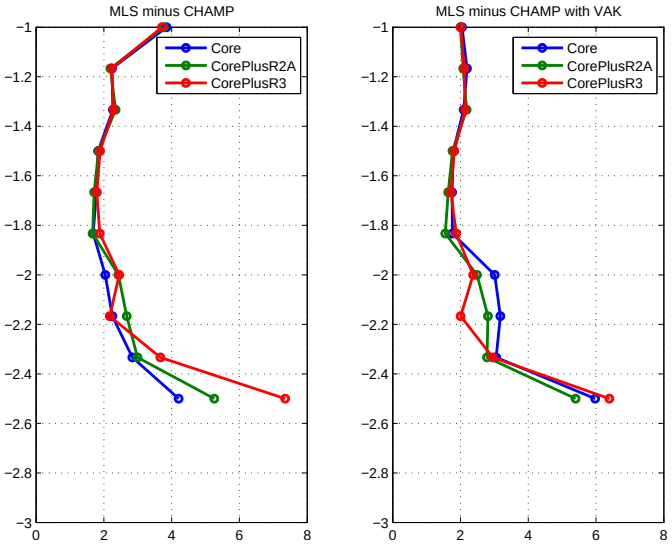
CHAMP data and MLS Temperature Phases

- CHAMP is a GPS occultation instrument (~10x MLS vertical resolution) from the surface to ~10 hPa. It's absolute calibration is simple and well-regarded.
- Plots are averages of more than 5000 coincidence closer than 3 hrs and 250 km, August 2004 to August 2005.
- Plots show Bias (top) and Scatter (bottom) of MLS minus CHAMP for MLS Core (the standard product), CorePlusR2A and CorePlusR3 temperatures. In the left-hand column, CHAMP has been least-squares fit to the linear interpolation of MLS six-per-decade profile points. In the right-hand column, CHAMP has been subsequently convolved with VAKs to degrade CHAMP to MLS resolution.
- Biases are made slightly worse by application of VAKs.
- CorePlusR3 has -3 K bias at 100 hPa and >10 K at 316 hPa.
- 1-σ scatter of differences is 2 K at 100 hPa to 14.7 hPa.

MLS minus CHAMP Bias

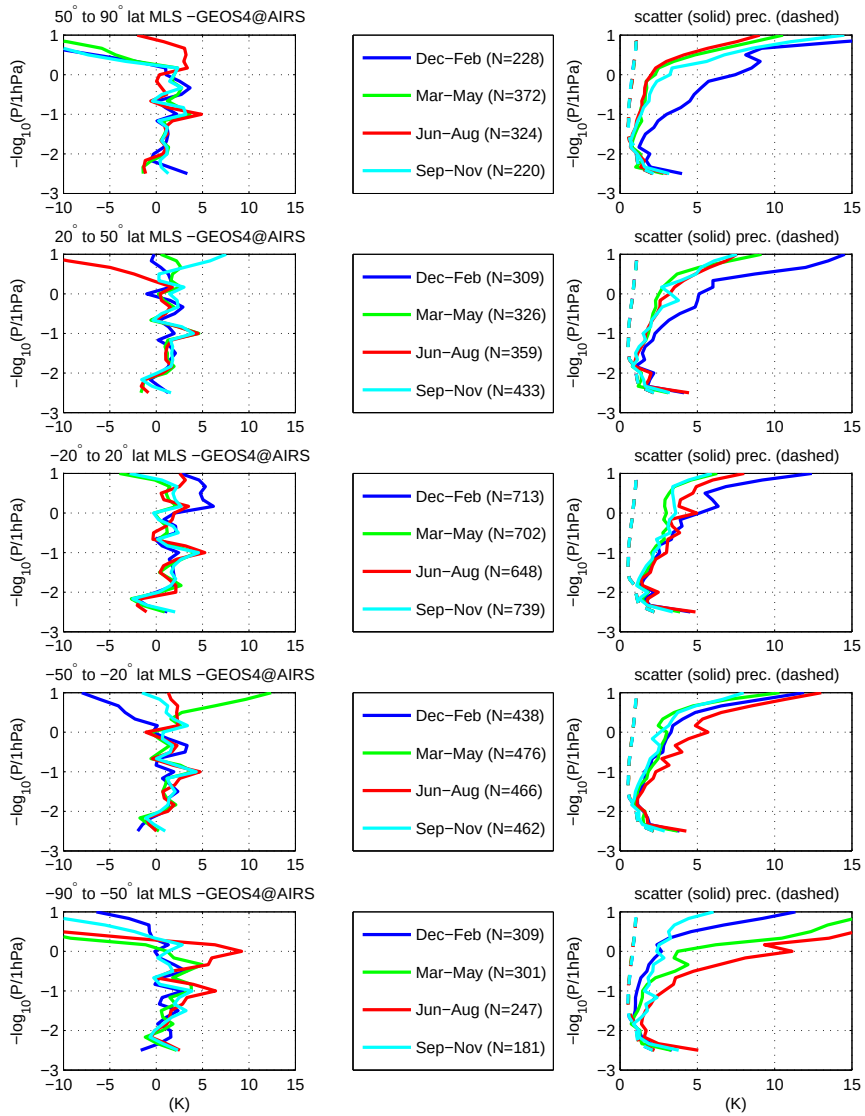


MLS minus CHAMP RMS



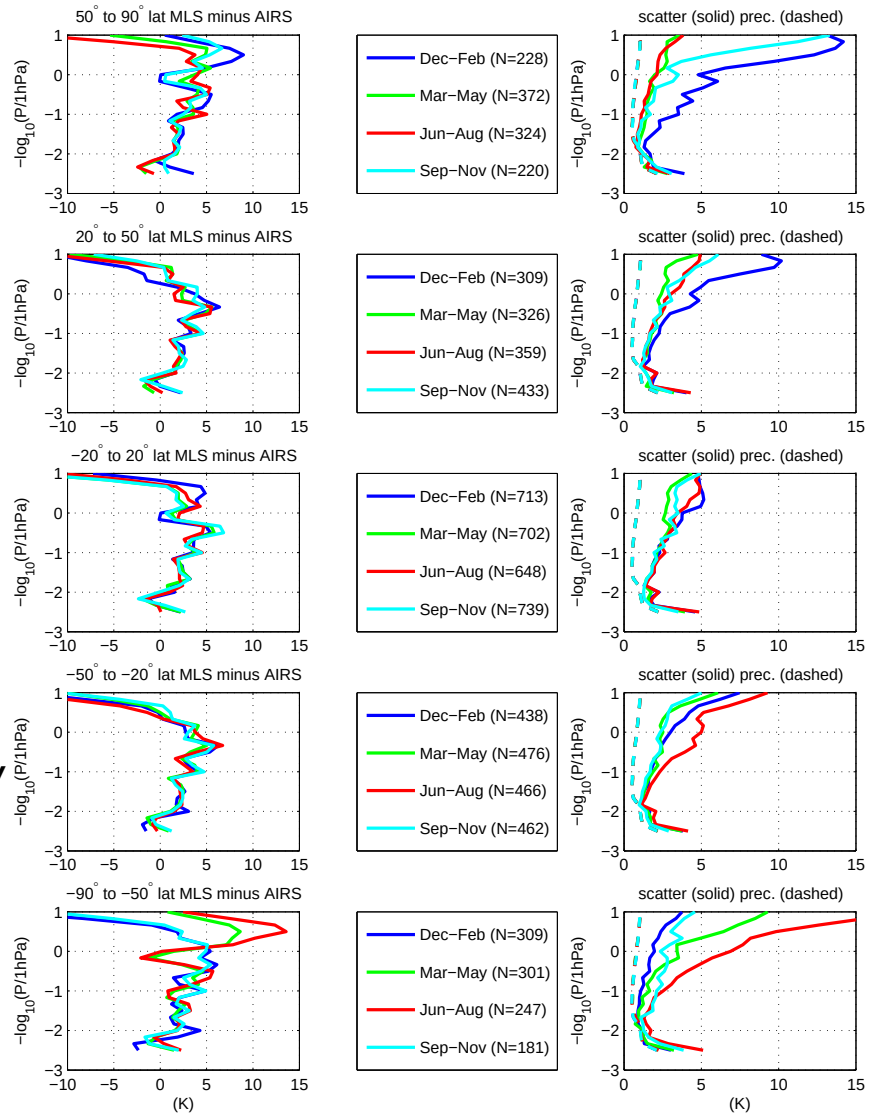
Comparison: GEOS-4 with MLS Std. Temp.

- The GMAO GEOS-4 first-look product is MLS *a priori* temperature. This is the late-look product, interpolated to MLS. This plot has two days (~7000 pts) per 3-month bin.
- GEOS-4 is not convolved with MLS VAKs.
- Lowest level 316 hPa (Z=-2.5) and top level shown is 0.1 hPa (Z=1).
- GEOS-4 model is not constrained by data above ~1 hPa, (Z=0)
- Seasonal and latitudinal bins show MLS is consistently warmer ~1 K throughout most of the stratosphere, and 2-5 K warmer at 0.1 hPa. MLS is ~ K colder near tropopause in mid-latitude and Tropics.
- Scatter (RMS) of differences is ~2.5 K or less below Z=0 except for winter mid-high latitudes (planetary waves and gravity waves.)
- GEOS-4 is not constrained by data above ~1 hPa (Z=0).



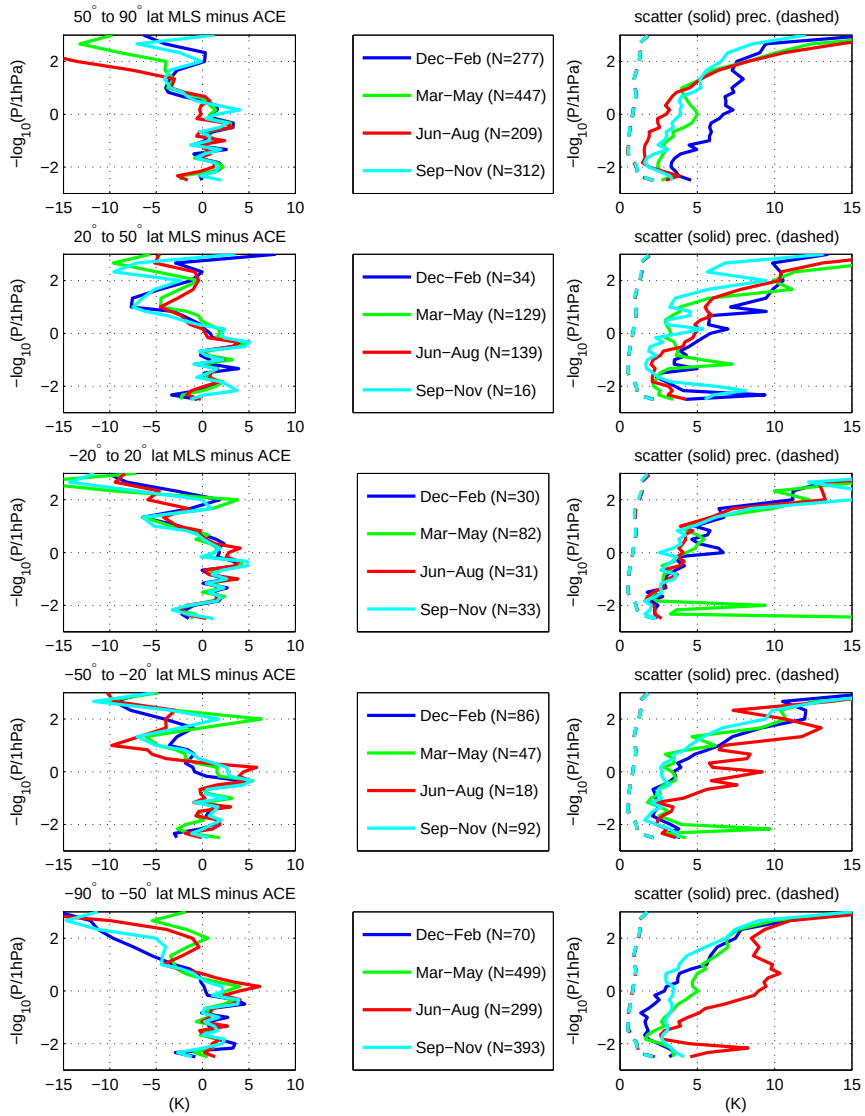
Comparison with AIRS

- We have coincidences within 500$\pm$100 seconds and of order 10 km for almost every MLS measurement. AIRS data screened by high+middle+low quality flags all good. MLS screened as usual (Status=0 $\longrightarrow$ not strongly influenced by cloud.)
- Data shown is average of two days (the first day of the second and third month) for each 3-month bin.
- Latitude bins show a generally consistent picture: AIRS is 1.5-2.5 K cooler than MLS 100 hPa to 10 hPa and 2.5-5 K cooler 10 hPa-1 hPa.
- Increased scatter differences in the in the winter hemisphere indicates variation (gravity waves?) on scales that different viewing geometries resolve differently.



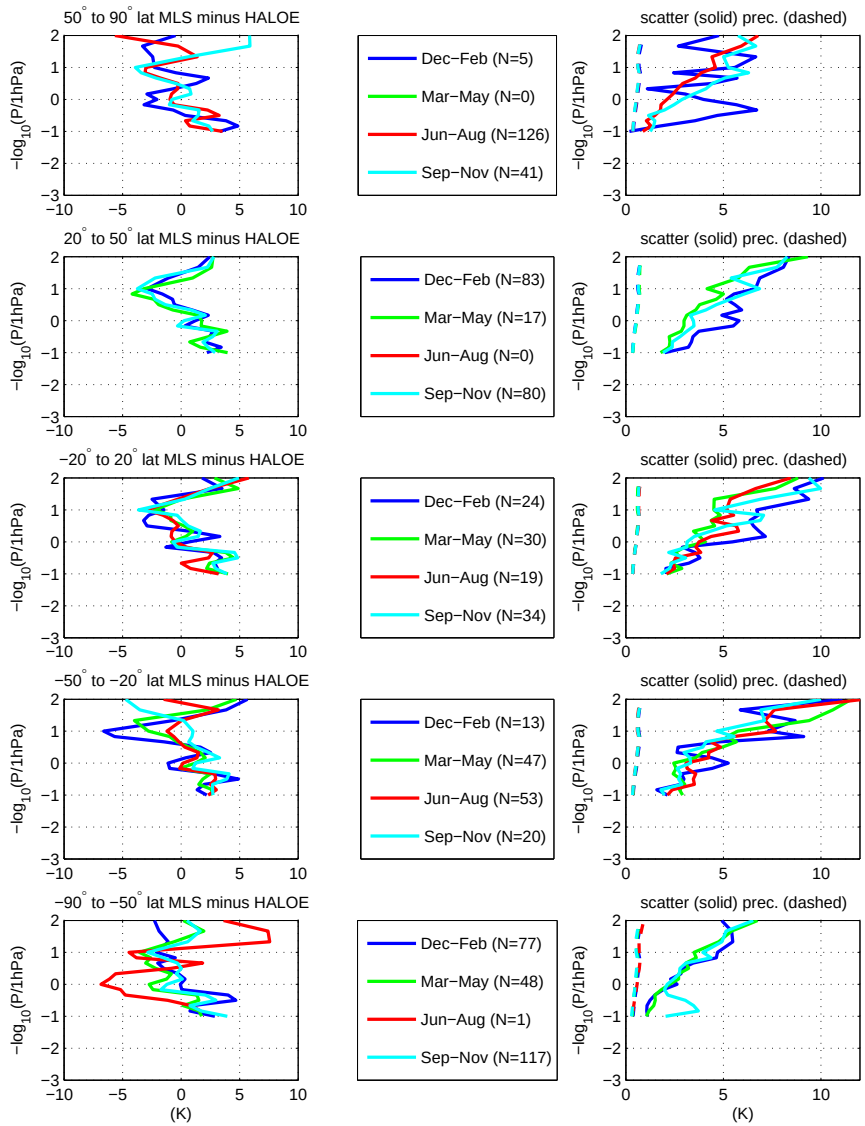
Comparison with ACE

- ACE is a solar occultation instrument, and profiles are retrieved into the thermosphere. The coincidences criteria used are 10° of lat, 20° of lon and 6 hrs of time. Coincidences are sparse in the tropics.
- Biases in the troposphere and stratosphere are consistent with previous datasets, so the vote seems to be pretty unanimous that MLS has a warm bias in the stratosphere.
- MLS is colder than ACE by of order 5 K in the mesosphere, and this bias increases into the thermosphere, to the 0.001 hPa top of MLS retrievals. A low bias in MLS is consistent with radiance residuals showing under-fit line centers at the highest paintings. Something is pulling MLS down, as the retrieval minimizes χ^2. This is an area of current research.
- There is significant seasonal variation in the highest altitude biases.

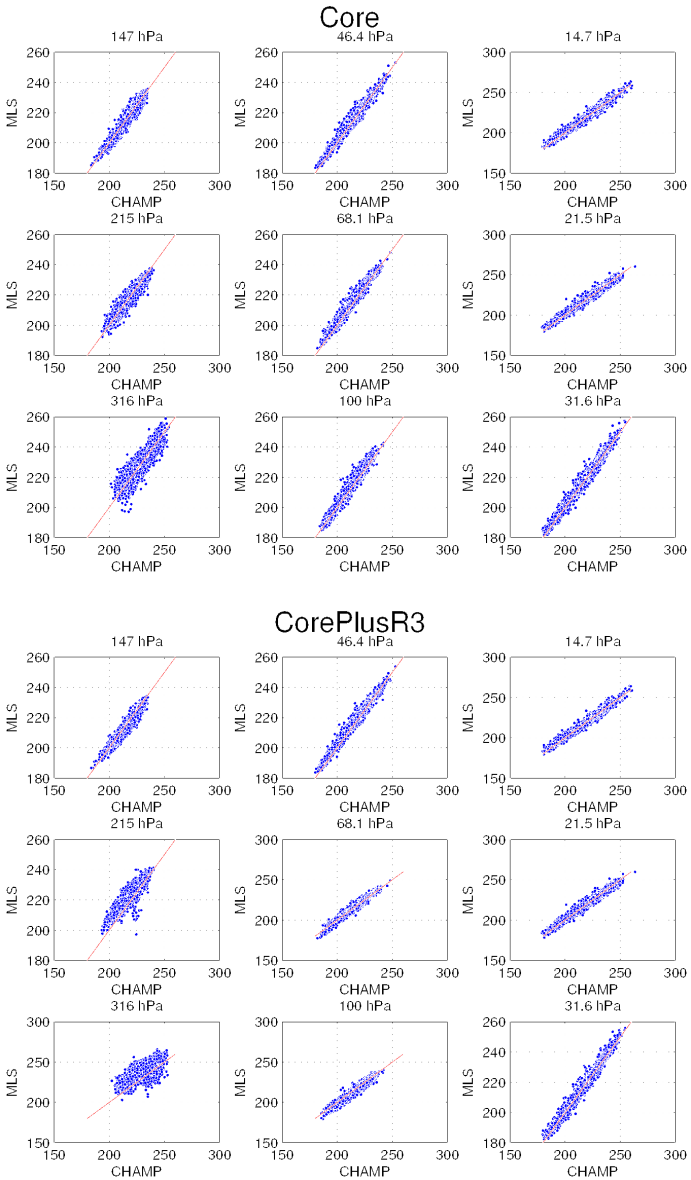


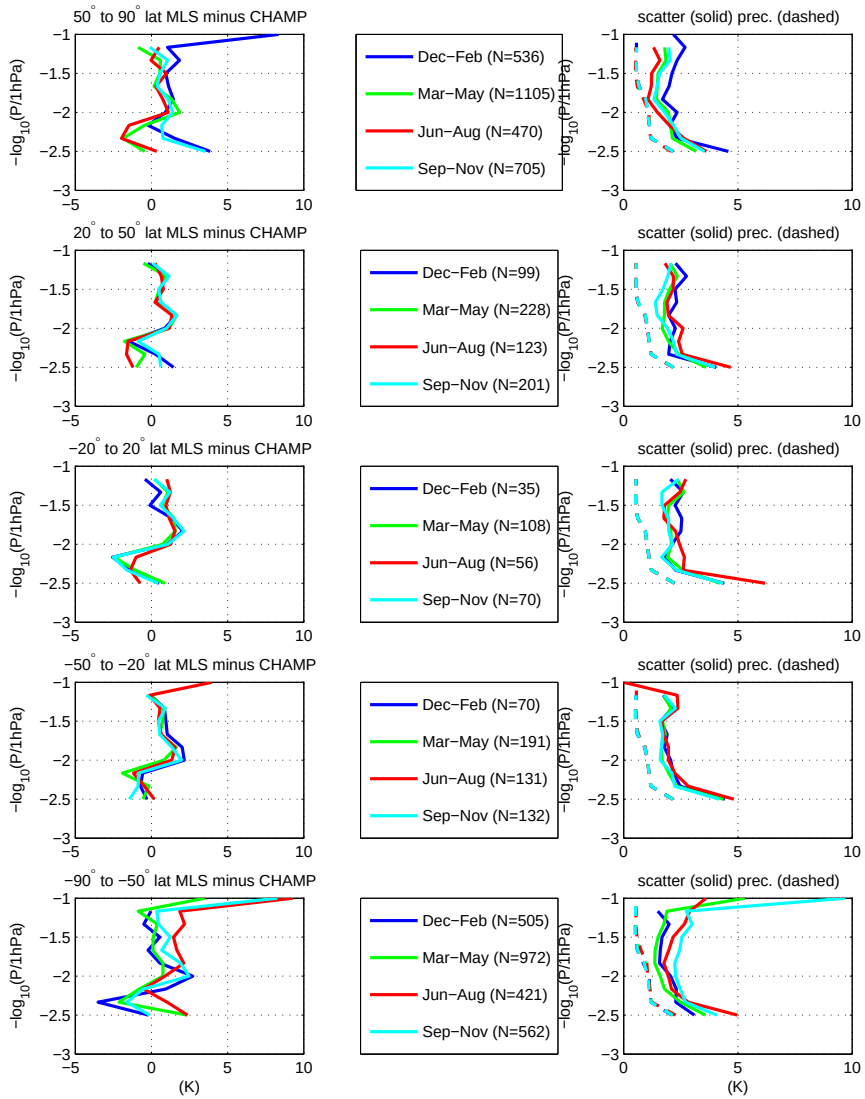
Comparison with HALOE

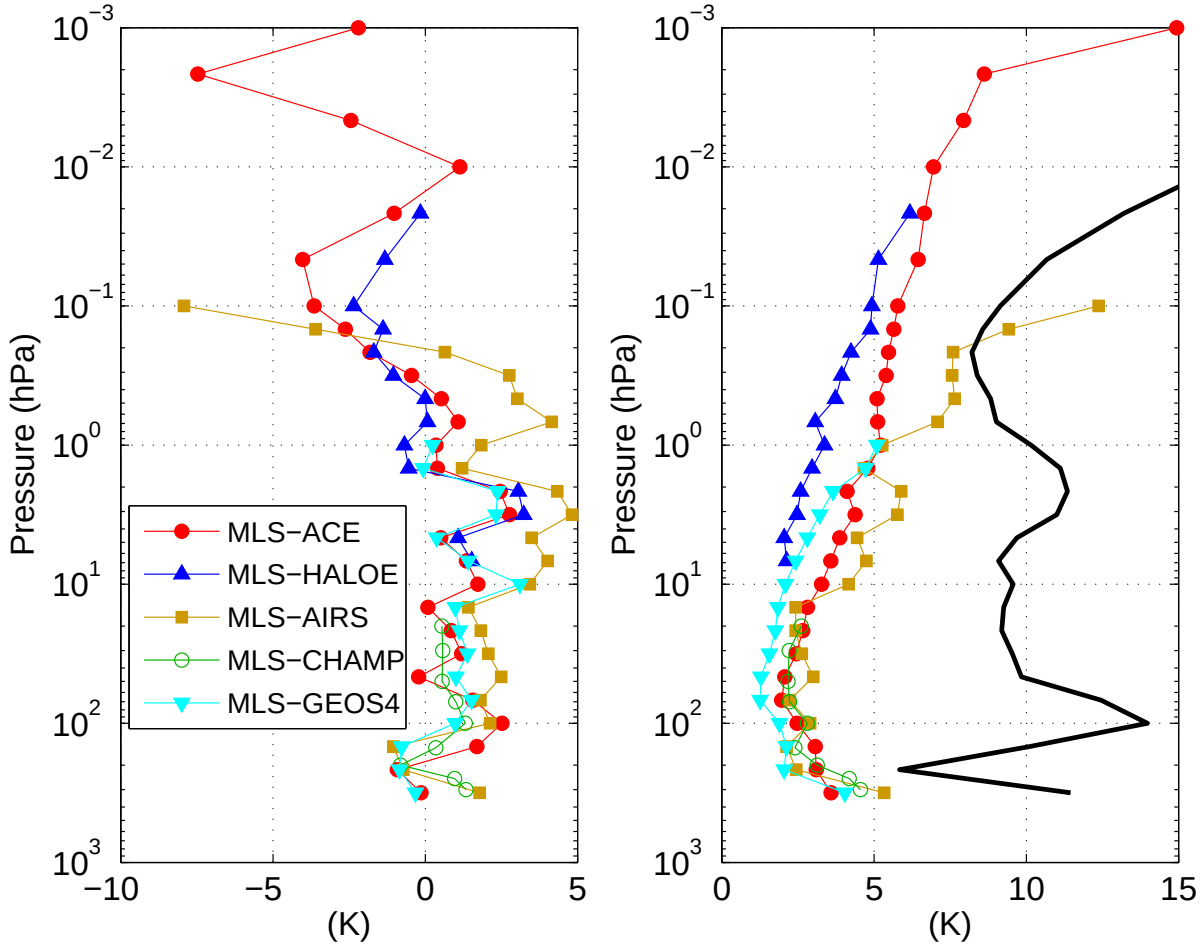
- HALOE is a solar occultation instrument on UARS.
- Coincidence criteria are within 250 km and 6 hrs for sunrises and sunsets.
- In the mesosphere (~1 hPa to ~0.01 hPa, Z=0–2) MLS-minus-HALOE biases are less than 5 K, and at 0.01 hPa (Z=2), they are of the opposite sign (MLS is generally warmer than HALOE.)
- I have only begun to look at this mesospheric data, so there is much to be done.
- Biases are consistent with MLS being warm in the upper stratosphere, except near 1 hPa in S. high-latitude winter. A similar bias was observed in AIRS



More Comparison with CHAMP





Comparison Summary

- A reasonably consistent picture of MLS biases has emerged.
- This summary plot is for the first part of 2005, standard temperature. (the Core/CorePlusR2A hybrid is very similar to pure Core.) The black line is MLS RMS.
- There is much work to be done, particularly in improving MLS temperature in the troposphere, where the use of information (R3 radiances) that would improver resolution leads to large biases.