Evaluation and correction of GEOS-5 pressure and temperature profiles between 40 and 70 km using Suomi/OMPS-LP data

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From Science to Solutions

Abstract

The Ozone Mapping and Profile Suite Limb Profiler (OMPS-LP) on board the NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite is a limb-scattering hyperspectral sensor designed to retrieve ozone profiles at 1.8 km vertical resolution. Radiances are acquired over a wavelength range covering 290 nm to 1000 nm and an altitude range covering 0 km to 80 km for every event. The OMPS LP retrieval algorithm calculates simulated radiances for each event using a radiative transfer forward model that uses pressure and temperature profiles interpolated from Goddard Earth Observing System Model Version 5 (GEOS-5) products. The assimilation and forecast procedure used by GEOS-5 yields accurate pressure and temperature profiles up to approximately 5 hPa when compared to ground-based observations. Above 5 hPa, the GEOS-5 profiles are effectively determined by modeling, and need to be validated against measurements.

The LP radiance residuals are defined as the difference between measured and calculated radiances. We choose a reference wavelength with minimal atmospheric absorption (353 nm) and a reference altitude with good GEOS-5 accuracy (37.5 km) to create normalized radiance residual (NRR) profiles. This approach removes diffuse upwelling radiation effects, and also reduces the impact of any LP altitude registration and calibration errors. The NRR profiles above 37.5 km are then governed primarily by the accuracy of the GEOS-5 pressure profiles (and secondarily by the temperature profiles). We use an iterative process to reduce the magnitude of the NRR values, and thus improve the accuracy of the GEOS-5 profiles, between 37.5 km and 65 km. We evaluate these results by comparing to pressure profiles derived from Aura Microwave Limb Sounder (MLS) geopotential height measurements.

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This poster presents :

- Sample plots of GEOS-5 pressure and temperature profiles from 38 km to 65 km, and calculated changes based on OMPS-LP measurements.
- Zonal mean pressure changes along the orbit for 4 seasonal days in 2014 from 38 km to 65 km.
- Zonal mean temperature changes along the orbit for a single day in 2014 from 38 km to 65 km.
- Comparisons between pressure and temperature profiles from collocated GEOS-5 FPIT version-5.9.1 data and MLS version 3.3 datasets.
- Temperature profile errors based on hydrostatic evaluation with LP data.

OMPS-LP pressure and temperature corrections

The normalized radiance residual (NRR) definition:

- $NRR(i) = log(Im(z))/Im(37.5))-log(Ic(z,i-1)/Ic(37.5,i-1))$ *(1)*
  - $Im(z)$ = measured radiance at 353 nm at tangent height z;
  - $Ic(z,i)$ = calculated radiance at 353 nm at z with the pressure and temperature profiles from the $(i-1)^{th}$ iteration. $i=1$ represents the initial GEOS-5 pressure and temperature profiles.

For z higher than 37.5 km, the i^{th} iterated pressure is given by:

- $p(z,i) = F*exp(tNRR(i))*p(z,i-1)$ *(2)*
  - $tNRR$ = the Tikhonov regularization of NRR;
  - F = the constant factor applied for convergence.

The new temperature profile is derived under the hydrostatic assumption:

- $t(i) = -g*dz/R/dp(i)$ *(3)*
  - R = dry gas constant = 287.058 *J/kg/K*; and g = gravity at altitude z.
  - Equation *(3)* should be a good approximation in the general situation.

Preliminary Results

Pressure and temperature profiles and changes

Figure 1 shows typical pressure and temperature profiles at three locations along the orbit, and the changes after the LP correction procedure. The pressure and temperature changes gradually increase with altitude from 40 km to 65 km.

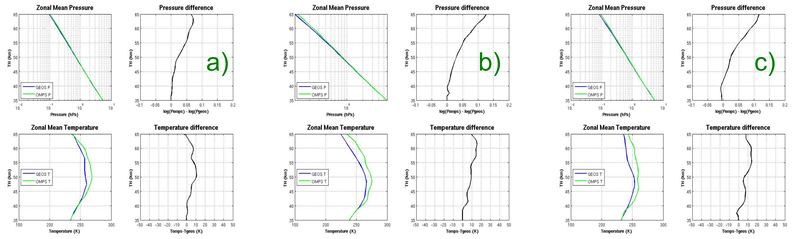

Figure 1: Zonal mean pressure and temperature profiles and the calculated difference from GEOS-5 inputs for 03/10/14. a) event #20 (77°S); b) event #80 (13°S); c) event #140 (52°N).

Pressure and temperature profile changes along the orbit

Figure 2 shows the calculated pressure profile changes along the orbit from 37.5 km to 65 km for 4 selected days in 2014. a) 3/10, b) 6/19, c) 9/23 and d) 11/14. In general, our results indicate that the GEOS-5 pressures are underestimated by about 3% at 50 km, with the difference increasing to about 6-12% at 65 km.

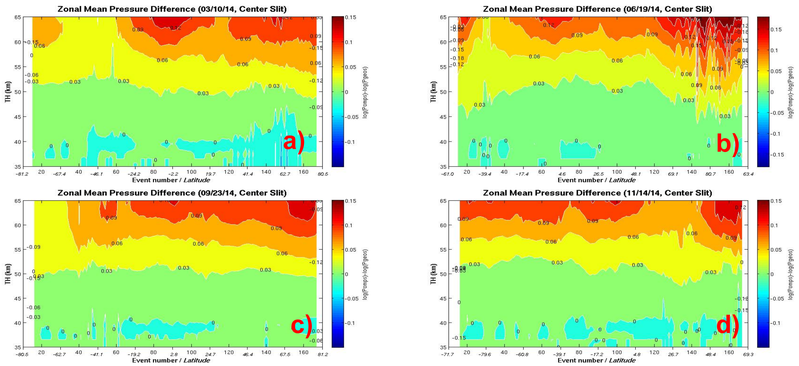

Figure 2: Zonal mean pressure differences between OMPS-LP and GEOS-5. Dates shown: a) 03/10/14, b) 06/19/14; c) 09/23/14; d) 11/14/14.

Figure 3 shows the calculated temperature profile changes along the orbit from 37.5 km to 65 km for 03/10/14. In general, our results indicate that the GEOS-5 temperatures have about 5-10 K negative bias. In some regions between 55 km to 65 km, calculated differences as large as 15 K were found.

Note that the mean error of the temperature profile derived from the calculated pressure profile (based on the hydrostatic equation) is smaller than 1-2 K in general.

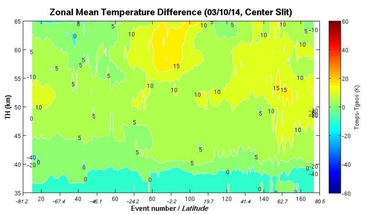

Figure 3: Zonal mean temperature differences between OMPS-LP and GEOS-5 for 03/10/14

Comparisons between GEOS-5 and MLS

- Figure 4(a) shows that zonal mean pressure differences between GEOS-5 and MLS data for 3/21/13 are generally less than 2%. The standard deviation (not shown) is less than 2%.
- Figure 4(b) shows that zonal mean temperature differences between GEOS-5 and MLS data are generally within 5 K, except near 55 km from 70S to 50S. The standard deviation (not shown) is generally less than 2 K.
- Similar results are found for other cardinal days in 2013 (6/21/13, 09/21/13, and 12/21/13).
- These results show that the GEOS-5 and MLS data agree very well in pressure and temperature profiles.
- We conclude that differences observed between OMPS-LP and GEOS-5 data are also present between OMPS-LP and MLS data.

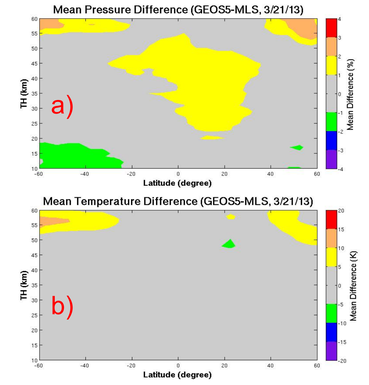

Figure 4: Zonal mean differences of pressure (top) and temperature (bottom) between GEOS-5 and MLS for 3/21/13.

Discussions

Polar mesospheric cloud (PMC) effects

Polar mesospheric clouds (PMCs) exist at 80-85 km during summer months, but can affect LP radiances down to ~50 km tangent height due to the LP viewing geometry. Most PMCs are flagged in LP processing. Figure 2(b) shows an example of residual PMC effects in calculated pressure profiles at high NH latitudes.

Stray light

LP measurements can be affected by uncorrected stray light. The successful NRR analysis indicates that residual LP stray light at 353 nm and 65 km should be smaller than 0.5-1%.

Error of temperature estimates

Equation (3) assumes hydrostatic equilibrium and dry air. High winds or humidity can cause errors in the estimated temperature. Figure 5 for 9/23/14 shows that conditions in the SH polar vortex can produce larger temperature differences and variability at 45 km compared to normal values.

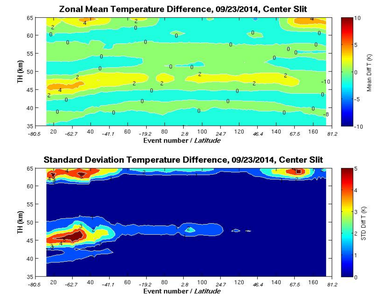

Figure 5: (top) Zonal mean differences between temperature values derived from hydrostatic equilibrium with GEOS-5 pressures and the actual GEOS-5 inputs. (bottom) Standard deviation of temperature differences.

Summary

- Our preliminary results indicate that both the GEOS-5 and MLS pressures are generally underestimated by about 3% at 52 km, 6% at 58 km, and 9-10% at 65 km.
- There is a slight seasonal and orbital variation. In March and September, SH high latitude difference are reduced to 3-6% between 52-65 km. In June, the reduced differences are seen at 20S-45S, and in November, the reduced differences are seen at 20N-50N.
- In general, the temperature error based on hydrostatic equilibrium is small between 50-65 km. We estimate that the GEOS-5 temperatures typically have a 5-10 K negative bias.
- Future plans: Refine the algorithm for operational use, and begin validation of our results.

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