Impacts of Change in GEOS-5 Version on CALIOP Products†

In April 2013, the CALIPSO team released version 3.3 of its data products which incorporate updated GEOS-5 meteorological data provided by the Global Modeling and Assimilation Office (GMAO). Previously, CALIOP version 3.01 and 3.02 data products incorporated GEOS-5 version 5.2 meteorological data, but with the change to CALIOP version 3.3, GEOS-5 version 5.9.1 data are now used from the data product entitled “GEOS-5 Forward Processing – Instrument Teams (GEOS-5 FP-IT)”. Meteorological data provided by GMAO are required to calibrate CALIOP level 1B data products and are used to detect atmospheric layers, identify stratospheric features, and perform extinction retrievals in level 2 algorithms.

This document assesses changes in CALIOP level 1B, level 2, and level 3 products due to the change from GEOS-5 version 5.2 to version 5.9.1 by comparing two versions of CALIOP data products: one version incorporating GEOS-5 version 5.2 and the other incorporating GEOS-5 version 5.9.1. Two months are examined: September and December 2011.

GEOS-5 Changes and CALIOP Impact Summary:

- **Level 1B nighttime calibration:** GEOS-5 molecular number densities in the CALIOP nighttime calibration region increased by roughly 0.6% on average which caused the nighttime calibration coefficients to decrease on average by −0.6%. Since attenuated backscatter is inversely proportional to the calibration coefficient, nighttime attenuated backscatter will increase by 0.6% on average.
- **Level 1B daytime calibration:** GEOS-5 molecular number densities in the CALIOP daytime calibration region increased by 0.1% near the equator and increased by up to 0.4 – 0.7% near the poles which caused daytime calibration coefficients to decrease by <−0.2% near the equator and decrease by roughly −0.8% near the poles. Daytime attenuated backscatters will thereby increase by these same magnitudes.
- **Level 2 layer detection:** GEOS-5 molecular number densities increased in the CALIOP night and day calibration regions subsequently increasing night and day attenuated backscatters, causing the number of layers detected to increase slightly. For the two months examined, the number of aerosol and cloud layers increased by < 0.8% and < 0.2%, respectively.
- **Level 2 layer classification:** GEOS-5 tropopause height decreased by ~1 km at 30°S and 40°N and decreased by 1.5 km over the Antarctic in September 2011. Since CALIOP classifies layers detected above the tropopause as stratospheric features, about 3 – 5% of stratospheric features were instead classified as either cloud or aerosol. These changes are considered minor except in Sep. 2011 over the Antarctic where a 1 – 1.5 km reduction in tropopause height caused 100% of cloud and aerosol layers to be re-classified as stratospheric features. This latter effect may occur seasonally over the Antarctic.
- **Level 3 aerosol extinction and aerosol optical depth:** GEOS-5 molecular number densities increased by small amounts in the CALIPSO calibration regions and by smaller amounts at other altitudes, slightly increasing the number of aerosol layers detected and increasing their attenuated backscatter. Consequent small increases in aerosol extinction and aerosol optical depth are much smaller than uncertainties in these parameters.

Number Density Changes (GEOS-5)

Molecular and ozone number densities, N_{mol} and N_{O3}, are used to compute molecular attenuated backscatter profiles[1] β'_m for calibrating CALIOP level 1B data. For both months examined, N_{mol} increased on average by 0.44%, though the amount of increase varied with altitude (Fig. 1 a-b). N_{mol} increased by the largest amount (1 – 2%) above 34 km. On average, N_{O3} increased by 5 – 10% above 30 km for both months. Regions of increases and decreases are evident. Between 60°N and 60°S, N_{O3} increased and decreased by 10 – 30% depending on altitude and latitude (Figure 1 c-d). Over the Antarctic in September, N_{O3} decreased by 60% between 12 – 30 km while over the Arctic in December, N_{O3} increased by 40% between 8 – 15 km. Excluding the north and south poles, changes in N_{O3} of 10 – 30% are inconsequential to CALIOP calibration because N_{O3} is too low to significantly attenuate β'_m profiles used for calibration. However, the 60% reduction in N_{O3} over the Antarctic in September 2011 is enough to increase transmittance through the daytime CALIOP calibration region (8 – 12 km) and impact daytime calibration for that case.

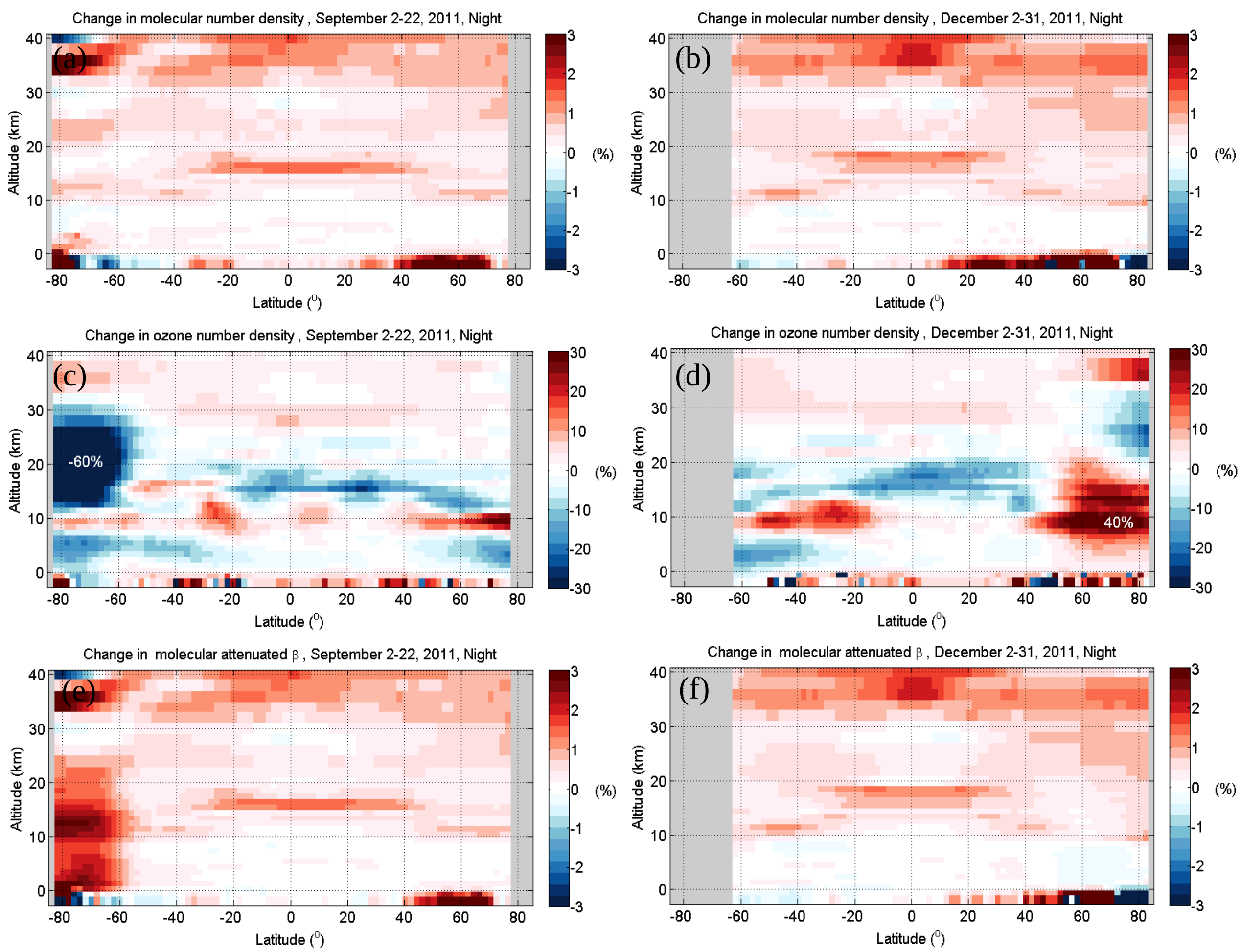

Figure 1. Nighttime zonal average changes in molecular number density (a, b), ozone number density (c, d) and molecular attenuated backscatter (e, f). Daytime changes are similar.

[1] "Molecular attenuated backscatter", includes molecular and ozone contributions; i.e., $\beta'_m \equiv (\beta_{mol} + \beta_{O_3}) T^2_{mol} T^2_{O_3}$

Molecular Attenuated Backscatter Changes (derived from GEOS-5)

Profiles of molecular attenuated backscatter β'_m derived from GEOS-5 N_{mol} and N_{O3} are not only used to calibrate CALIOP – they are also used to detect atmospheric layers with level 2 algorithms. The magnitude of changes in β'_m are similar to changes in N_{mol}, except south of 60°S and below 25 km in September (Fig. 1e) where the increase in transmittance caused by an overlying decrease in N_{O3} (Fig. 1c) allowed β'_m to increase by 2 – 3%. Otherwise, the β'_m increased on average by < 0.5% below 30 km and by 1 – 2% above 30 km. Since β'_m increased more in the CALIOP nighttime calibration region (30 – 34 km) than it increased at lower altitudes, more atmospheric layers could be detected by CALIOP level 2 algorithms because level 1B attenuated backscatter will be calibrated higher without a commensurate increase in β'_m at lower altitudes, allowing calibrated level 1B attenuated backscatter to rise above β'_m more often at lower altitudes. However, this impact is predicted to be minor due to the small magnitude of changes in β'_m at all altitudes.

Tropopause Height Changes (GEOS-5)

Tropopause heights z_{trop} provided by GEOS-5 are used by CALIOP level 2 algorithms to separate clouds and aerosols from stratospheric features based on whether the layer is above or below the tropopause. Changes in z_{trop} can therefore change layer classification. For the two months examined (Fig. 2), changes in z_{trop} are similar between day and night. Though z_{trop} changes little near the equator, it decreases by −0.9 km and −1.2 km at ~30°S and ~40°N. During September 2011, z_{trop} decreases by −1.5 km over Antarctica.

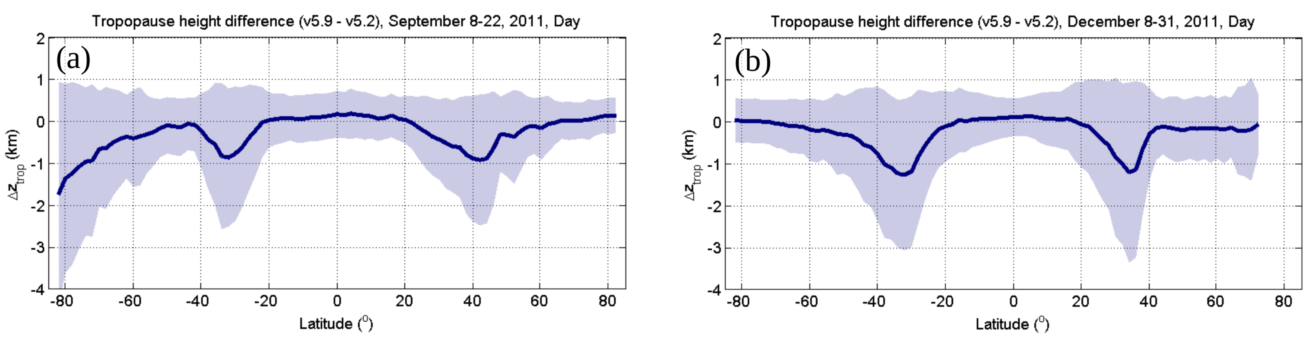

Figure 2. Daytime mean difference of tropopause heights (GEOS-5 ver. 5.9.1 – ver. 5.2) and standard deviation of differences (shaded) for (a) September and (b) December 2011.

Impact on CALIOP Nighttime 532 nm Calibration

CALIOP level 1B nighttime attenuated backscatter is calibrated between altitudes 30 – 34 km by normalizing the lidar signal to β'_m computed from GEOS-5 N_{mol} and N_{O3}. Within the nighttime calibration region, N_{mol} – which dominates β'_m – increased on average by 0.6% which caused the 532 nm calibration coefficients to decrease by 0.6 – 0.8% in the two months examined (Fig. 3).

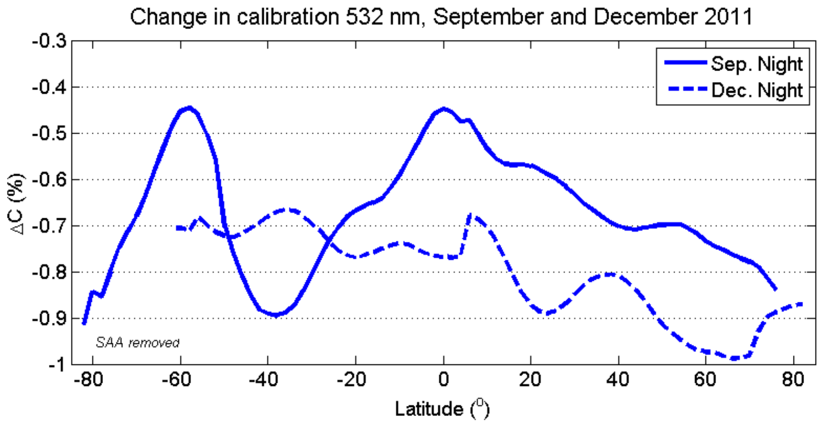

Figure 3. Global nighttime changes in nighttime 532 nm calibration coefficients with the South Atlantic Anomaly removed.

Impact on CALIOP Daytime Calibration

CALIOP level 1B daytime attenuated backscatter is calibrated between 8 – 12 km by normalizing the uncalibrated daytime attenuated scattering ratios (ratio of measured attenuated backscatter to β'_m) in this region to the seven-day average of nighttime attenuated scattering ratios at the same altitude and latitude. Thus, both day and night N_{mol} and N_{O3} in this altitude range impact daytime calibration. Changes in N_{mol} and N_{O3} were similar between day and night to within 0.1% and 3 – 10%, respectively. On average, N_{mol} increased by 0.1% for ±20° about the equator and 0.4 – 0.7% near the poles. N_{O3} increased by 0 – 30% depending on latitude and month at this altitude range.

Daytime 532 nm calibration coefficients subsequently decreased by about −0.5% on average with the smallest decrease (< 0.2%) at ±20° about the equator and the largest decreases of 0.8 – 1.0% near the poles (Fig. 4).

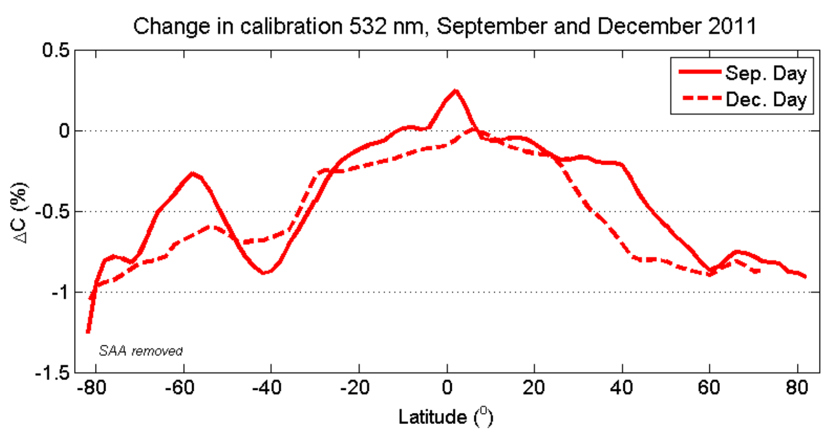

Figure 4. Global daytime changes in nighttime 532 nm calibration coefficients with the South Atlantic Anomaly removed.

Impact on CALIOP Level 2 Layer Detection and Classification

CALIOP level 2 layer detection algorithms compare attenuated backscatter measured by the lidar to molecular attenuated backscatter β'_m computed from GEOS-5 N_{mol} and N_{O3}. When the measured attenuated backscatter rises above β'_m, a layer is detected. Therefore, changes in profiles of N_{mol} and N_{O3} impact CALIOP level 2 layer detection. Changes in tropopause height also impact CALIOP level 2 layer classifications since layers detected above the tropopause are automatically classified as stratospheric features. However, since changes in β'_m and z_{trop} are small (Figs. 1e-f and 2), changes in level 2 layer detection and classification are also small.

Globally, the number of aerosol and clouds layers layers increased by less than 0.8% and 0.2%, respectively, while the number of stratospheric layers decrease by 3 – 5% with the exception of September 2011 at night. For that case, the 1.5 km decrease in tropopause height over the Antarctic (Fig. 2a) caused 100% of clouds and aerosol above 10 km to be instead classified as stratospheric. Elsewhere, as expected, the lower tropopause height reduced the number of layers classified as stratospheric features near the tropopause (Figs. 5e-f) and increased the number of cloud layers instead (Figs. 5c-d).

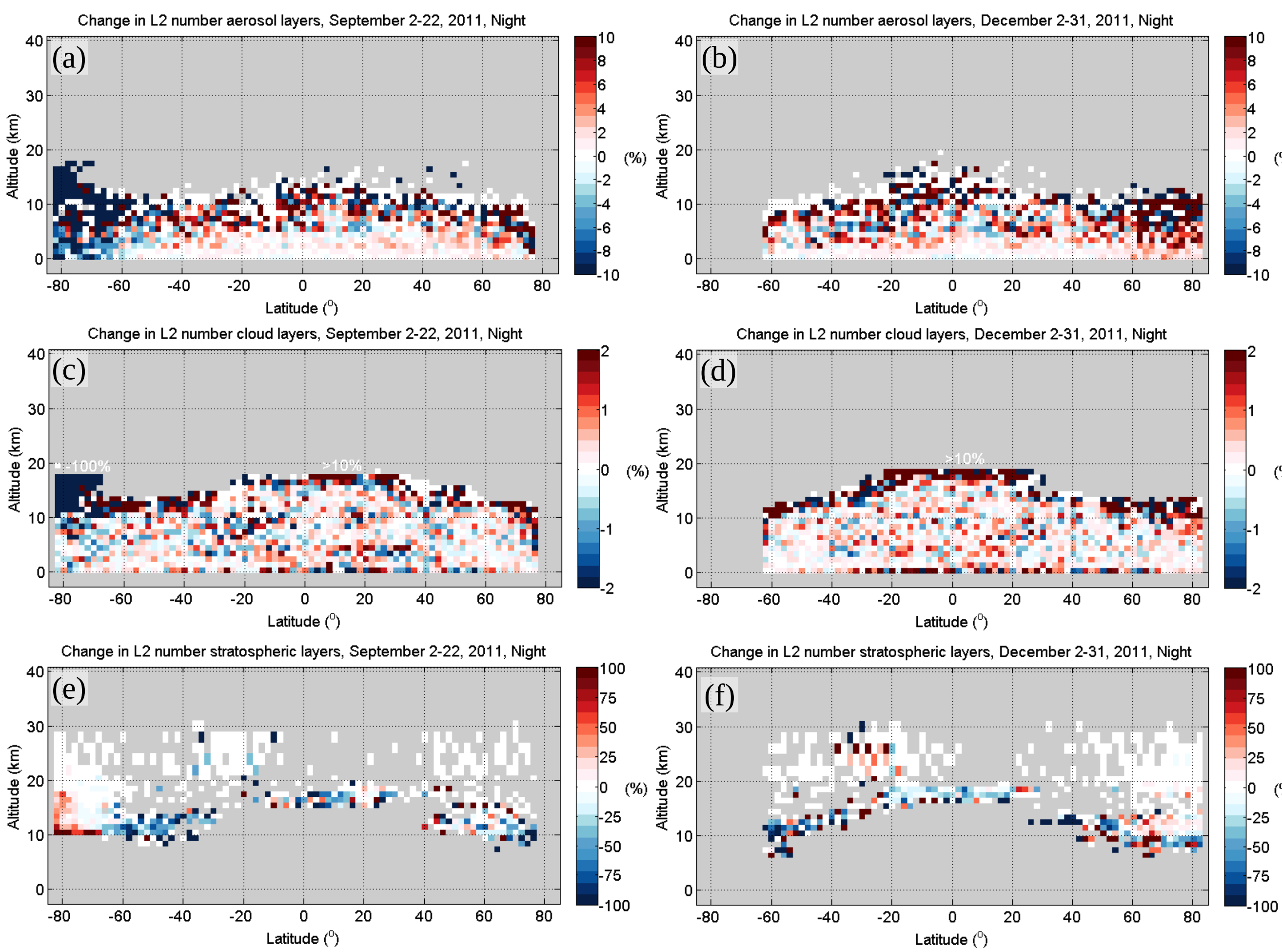

Figure 5. Nighttime zonal average change in number of CALIOP level 2 (a, b) aerosol layers, (c, d) cloud layers and (e, f) stratospheric layers for September and December 2011. Trends in daytime changes are similar.

Impact on CALIOP Level 3 Aerosol Profile Product

Aerosol extinction retrieved in the level 2 aerosol profile product is impacted by changes in calibration, β'_m profiles, layer detection, and layer classification. Since aerosol extinction is summarized in the CALIOP level 3 aerosol profile product, it too is impacted by the GEOS-5 version change. For the two months examined, global mean level 3 aerosol optical depth (AOD) increased by < 1.8% at night and < 0.8% during day. Mean aerosol extinction increased by < 2 – 5% below 4 km in altitude. These changes in AOD and aerosol extinction are small relative to the uncertainty in CALIOP extinction retrievals and are therefore considered minor.

† *Report prepared by Jason L. Tackett (jason.l.tackett at nasa.gov) on April 22nd, 2013.*