Instrument Introduction

The Ozone Mapping and Profiler Suite (OMPS) Limb Profiler (LP) on the Suomi National Polar-orbiting Partnership (NPP) satellite views the Earth’s limb looking backwards along the orbit track, using three parallel vertical slits. One slit is aligned with the orbit track, and the other two slits are pointed 4.25° to each side, giving an effective cross-track separation of approximately 250 km at the tangent point. Each profile measurement takes approximately 19 seconds to complete, corresponding to along-track sampling of approximately 125 km. OMPS LP uses a 2-dimensional CCD detector that records atmospheric spectra covering the wavelength range 290-1000 nm at 1 km altitude intervals between 0 km and 80 km. These spectra are primarily used to retrieve vertical profiles of ozone and aerosol extinction coefficient. Additional description of the LP instrument is given in Jaross et al. [2014].

Retrieval Algorithm

We have developed a new aerosol extinction coefficient retrieval algorithm for use with OMPS LP measurements. This algorithm applies a version of the Chahine non-linear relaxation technique [e.g. Chahine, 1968] to retrieve the aerosol extinction profile from radiance measurements at 675 nm. We call the measurement vector used in this retrieval aerosol scattering index (ASI), which is defined as follows:

\[ \text{ASI}(\lambda,z) = \left[ I_m(\lambda,z) - I_c0(\lambda,z) \right] / I_c0(\lambda,z) \]  \[1\]

Where \( I_m \) is altitude-normalized measured radiance, and \( I_c0 \) is calculated assuming a pure Rayleigh scattering atmosphere, bounded by a Lambertian reflecting surface at 1013 hPa. Altitude normalization reduces sensitivity to instrument calibration and multiple scattering. To minimize instrumental errors, as well as errors in the meteorological data used in the calculation of radiances, it is desirable that the normalization altitude be set as low as possible, but it should also avoid aerosol contamination. We have selected 40.5 km as the normalization altitude by carefully examining our data to ensure that the limb radiances at this altitude have not been affected by aerosols during the LP record. We may have to revisit this assumption if a large volcanic eruption were to inject SO\(_2\) at very high altitudes.

In the single-scattering approximation the numerator of ASI in Equation [1] is called the path radiance, which is proportional to line-of-sight aerosol extinction and aerosol scattering phase function. However, when multiple scattering of the diffuse upwelling radiation (DUR) emanating from the lower atmosphere is considered, ASI becomes less dependent on the aerosol scattering phase function. Since the effect of DUR is relatively small, we estimate it approximately assuming a Lambertian reflector model. In this model one assumes a Rayleigh
scattering atmosphere bounded at 1013 hPa by a Lambertian reflecting surface. The reflectivity of this surface, called Lambert-equivalent reflectivity (LER), is calculated from un-normalized measured radiance at 675 nm and 40.5 km. We adjust the calibration to ensure that the minimum LER value observed in the tropics is approximately 0.03.

To calculate the effect of aerosols on LP radiance we assume spherical Mie scattering particles of refractive index $1.448 + 0i$ with a bi-modal log-normal size distribution. We assume nominal values for the parameters of this size distribution that do not change with altitude, latitude or time. These parameters are: modal radii of 0.09 $\mu$m and 0.32 $\mu$m, and sigma of 1.4 and 1.6, for fine and coarse mode particles respectively, and coarse mode fraction (ratio of total number of coarse mode particles to fine mode particles) of 0.003. These values are based on aircraft measurements from August 1991 [Pueschel et al., 1994], with the coarse mode fraction adjusted to provide an Angstrom Exponent (AE) of 2.0, in order to match the average value of AE determined from SAGE II data taken during 2000-2005.

Atmospheric pressure and temperature profiles used in this retrieval algorithm are derived from NASA GSFC Global Modeling Assimilation Office (GMAO) Forward Processing-Instrument Team (FP-IT) GEOS 5.9.1 data. The nearest spatial grid point ($\Delta$latitude = 0.5°, $\Delta$longitude = 0.625°) to each LP profile is identified, and the temperature and pressure profiles for time steps bracketing the LP measurement ($\Delta$t = 3 hours) are interpolated to the observation time.

The algorithm starts from a nominal first guess aerosol profile and refines the solution iteratively. The maximum number of iterations is set to 4. The maximum allowed change in the retrieved extinction is set to a factor of 5 per iteration, or a factor of 625 in 4 iterations. We estimate ozone absorption at 675 nm in two steps. Initially, we use an ozone climatology from McPeters and Labow [2012], which is updated in the final step by estimating a correction derived from a Chappius band wavelength triplet (510, 600, 675 nm). The magnitude of this correction rarely exceeds 5%.

We flag the lowest level of the retrieved aerosol profile at the cloud-top altitude, which is determined using the algorithm described in Chen et al. [2016]. This algorithm also flags aerosols from fresh volcanic eruptions, which tend to be too optically thick for accurate aerosol retrieval. Since the retrieval error is inversely proportional to ASI, data with ASI less than 0.01 become unreliable and are also flagged. Such values typically occur at high altitudes where the aerosol amounts are too small, but they can also occur below 12 km where 675 nm radiances becomes insensitive to aerosols due to strong Rayleigh attenuation. Though we provide the flagged data in the orbital files for special studies, we do not recommend them for routine use. Therefore, we replace them with fill values (-999.) in creating the daily files that we recommend to most users.

Data Summary

Data Coverage. The first OMPS LP measurements were taken on January 10, 2012. LP data for January-March 2012 have numerous gaps due to variations in instrument operations and changes in sample tables. Regular operations began on April 2, 2012. Note that there is very little or no
LP data on days when the OMPS Nadir Mapper conducts high-resolution measurements. This sequence occurred approximately one day per week from April 2012 to June 2016.

**Data Quality.** Fill values are inserted into the extinction coefficient array for any sample where the derived ASI value is less than 0.01. Fill values are also inserted into the extinction coefficient profile for all altitudes below the cloud detection height if a cloud is identified. Extinction coefficient values less than $1 \times 10^{-5}$ km$^{-1}$ should be considered unreliable for evaluation of both individual profiles and ensemble averages.

**Measurement Flags.** The AER675 data product contains important information about spacecraft position and orientation for each measurement in the ‘SwathLevelQualityFlags’ dataset of the GeolocationFields group (see the AER675 Product Description document for details). The ‘SAA’ value of this dataset indicates the probability of South Atlantic Anomaly (SAA) charged particle effects on raw CCD data. The ‘NonNominalAttitude’ value of this dataset indicates when the S-NPP spacecraft orientation is temporarily changed, such as during roll maneuvers for VIIRS lunar calibrations. Both flags indicate an increased possibility of abnormal aerosol extinction profiles. Users should check these flags when selecting observations for their analysis to ensure maximum data quality.

**Retrieved Extinction Errors**

The LP retrieved aerosol extinction data can include contributions from four types of errors.

1) **Error in calculating Rayleigh scattering.** This error is determined at the 40.5 km normalization altitude, using meteorological pressure and temperature profiles supplied by GMAO. The extinction error bars provided in the daily product data file include only this quantity. It is estimated by assuming a 1% error ($\pm 1\sigma$) in calculating 675 nm scattered radiances at 40.5 km.

2) **Error in assumed aerosol microphysical parameters.** These parameters include the real and imaginary refractive indices, as well as the five parameters that define our assumed bimodal lognormal size distribution. The errors in these parameters may vary with season, altitude, and latitude, and may change significantly after a volcanic eruption. The error bars provided in the daily product data files do not include this term. Further work is necessary to estimate these errors accurately. Our preliminary estimate is that the bias in retrieved extinctions can be up to $\pm 20\%$ and varies with scattering angle, and thus with season and latitude in the LP data product.

3) **Loss of sensitivity of 675 nm radiances to aerosols.** This effect is caused by Rayleigh and aerosol attenuation of the limb scattered radiation, and becomes most pronounced below ~17 km. We advise caution in using LP V1.0 aerosol extinction data below 17 km. The error bars provided in the daily product data files do not include this term. This error can be reduced by using longer wavelength radiances already measured by the LP instrument in the aerosol retrieval, which we plan to do in a future release of the data.
4) **Clouds and thick aerosols.** The LP extinction retrieval becomes unreliable in the presence of clouds and thick aerosols. The cloud height detection flag described above identifies most of these cases, including fresh volcanic plumes that are too optically thick for accurate aerosol extinction retrieval.

**References**


**Contact**

Please contact Matt DeLand (matthew.deland@ssaihq.com) with any questions about this data product.