Effects of surface BRDF on the OMI cloud and NO₂ retrievals: a new approach based on geometry-dependent Lambertian equivalent reflectivity (GLER) derived from MODIS

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Abstract

The Ozone Monitoring Instrument (OMI) cloud and NO₂ algorithms use a monthly gridded surface reflectivity climatology that does not depend upon the observation geometry. In reality, reflection of incoming direct and diffuse solar light from land or ocean surfaces is sensitive to the sun–sensor geometry. This dependence is described by the bidirectional reflectance distribution function (BRDF). To account for the BRDF, we propose to use a new concept of geometry-dependent Lambertian equivalent reflectivity (GLER). Implementation within the existing OMI cloud and NO₂ retrieval infrastructure requires changes only to the input surface reflectivity database. GLER is calculated using a vector radiative transfer model with high spatial resolution BRDF information from MODIS over land and the Cox–Munk slope distribution over ocean with a contribution from water-leaving radiance. We compare GLER and climatological LER at 466 nm, which is used in the OMI O₂O₂cloud algorithm to derive effective cloud distribution over ocean with a contribution from water-leaving radiance. We compare GLER and corresponding retrieved cloud products are then used as input to the OMI NO₂ algorithm. We find that replacing the climatological OMI-based LERs with GLERs can increase NO₂ vertical columns by up to 50% over polluted areas; the differences include both BRDF effects and biases between the MODIS and OMI-based surface reflectance data sets. Only minor changes to NO₂ columns (within 5%) are found over unpolluted and overcast areas.

Approach

In the OMI cloud and NO₂ algorithms, ground and cloud are treated as Lambertian surfaces with pre-defined reflectivities; and =0.8. The measured TOA radiance is a sum of clear sky and overcast subpixel radiances that are weighted with an effective cloud fraction (ECF):

The ECF is calculated by inverting this equation and using precomputed . Effective cloud pressure, a.k.a. optical centroid pressure (OCP), is derived from O₂O₂ absorption at 477 nm using look up tables (LUTs).

To account for surface BRDF, we propose to replace climatological with geometry-dependent LER (GLER)

The GLER is derived from computed TOA radiance

TOA radiance is calculated for Rayleigh scattering using VLIDORT with:

(a) MODIS-derived, spatially averaged over an OMI pixel BRDF coefficients over land

(b) the Cox–Munk slope distribution and water-leaving radiance model over ocean

GLER and corresponding retrieved cloud fractions and pressures are used as inputs to the NO₂ algorithm.

Conclusion

- Developed a new approach of accounting for BRDF effects on cloud and trace gas retrievals.
- No major changes to existing algorithms are required.
- Can be easily applied to current and future instruments.

Comparisons of the standard cloud products with those derived with GLER

Mean ECF and OCP differences are small, however they can be substantial for individual pixels: up to +0.05 for ECF and up to 200 hPa for OCP.

The use of GLER can increase the NO₂ vertical columns by up to 50% over polluted areas. Only minor changes within 5% are over unpolluted and overcast areas.

Reference


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