Effects of surface BRDF on the OMI cloud and NO_2 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 NO_2 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 NO_2 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 O_2-O_2cloud algorithm to derive effective cloud fractions. A detailed comparison of the cloud fractions and pressures derived with climatological and GLERs is carried out. GLER and corresponding retrieved cloud products are then used as input to the OMI NO_2 algorithm. We find that replacing the climatological OMI-based LERs with GLERs can increase NO_2 vertical columns by up to 50 % in highly polluted areas; the differences include both BRDF effects and biases between the MODIS and OMI-based surface reflectance data sets. Only minor changes to NO_2 columns (within 5 %) are found over unpolluted and overcast areas.

Approach

In the OMI cloud and NO_2 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):

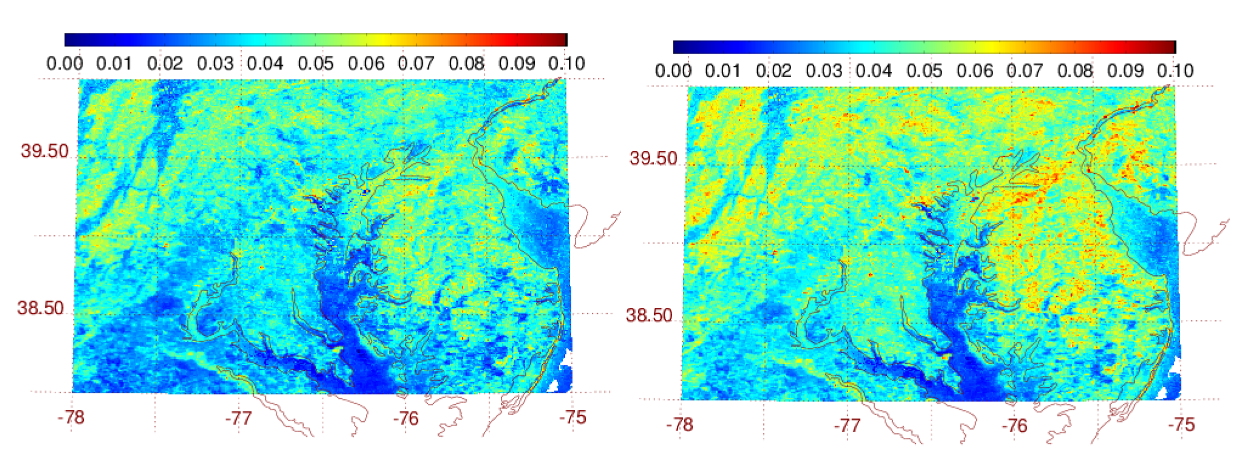
The ECF is calculated by inverting this equation and using precomputed . Effective cloud pressure, a.k.a. optical centroid pressure (OCP), is derived from O_2-O_2 absorption at 477 nm using look up tables (LUTs).

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

- Allows keeping the cloud and NO_2 algorithms relatively unchanged
- 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

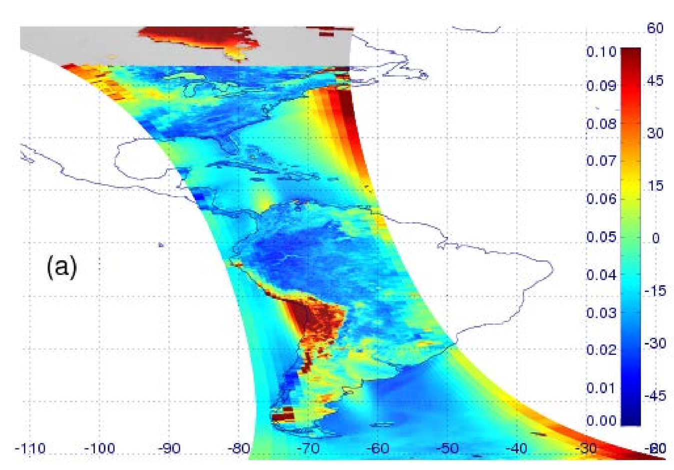
GLER and corresponding retrieved cloud fractions and pressures are used as inputs to the NO_2 algorithm.

BRF changes for the same area

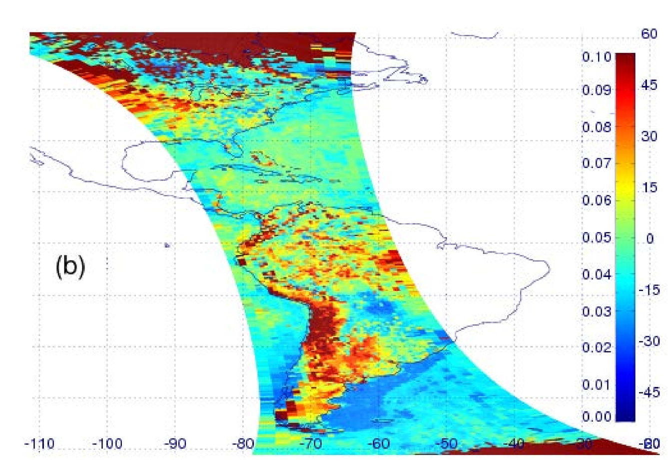


The Washington-Baltimore Corridor: high-resolution GLER computed from MODIS BRDF for OMI geometries for two consecutive days: Jan. 17 and 18, 2006.

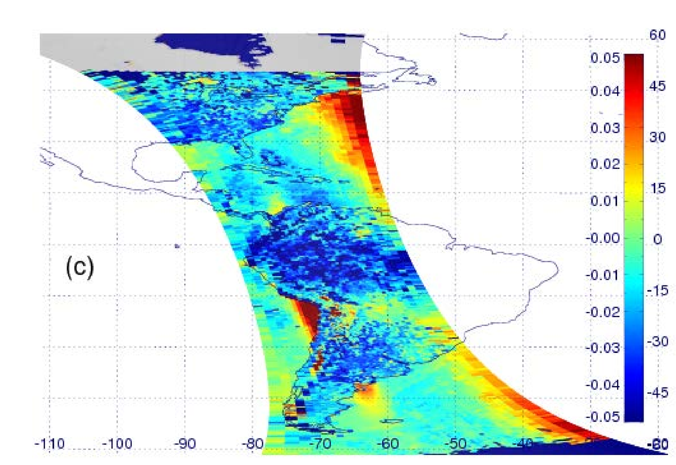
Comparison of LER climatology with BRDF



Surface GLER computed at 466 nm



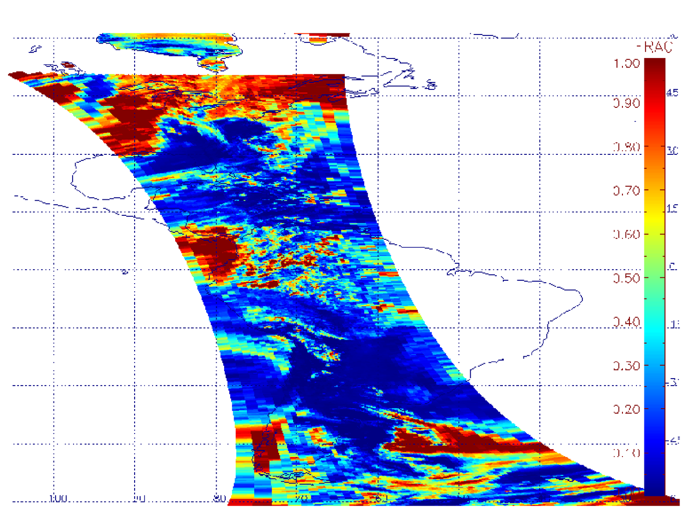
Surface LER climatology at 466 nm derived from OMI observations



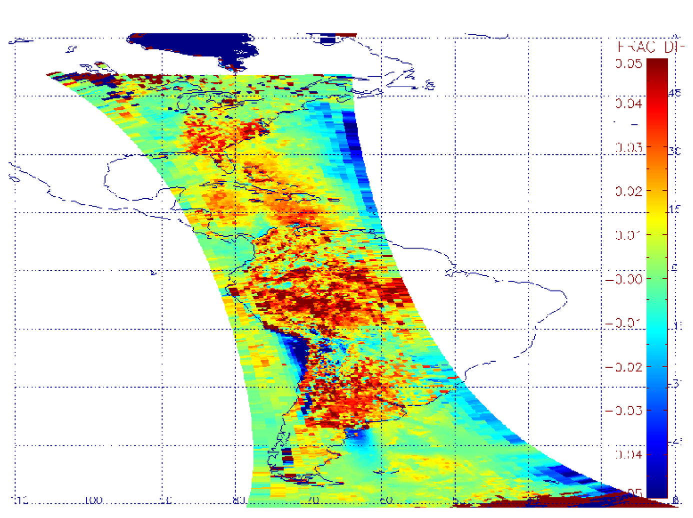
LER differences (GLER – Climatology)

Comparison of effective cloud fractions (ECF)

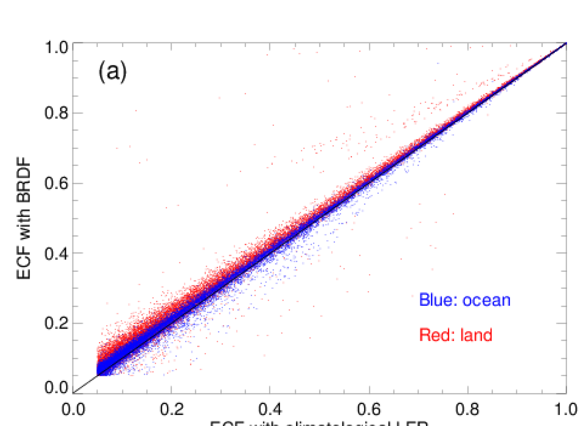
Data from OMI orbit 12414 of Nov. 14, 2006



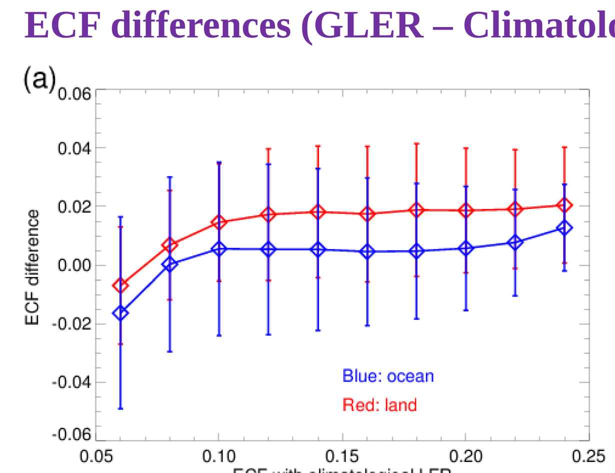
ECF calculated with GLER



ECF differences (GLER – Climatology)

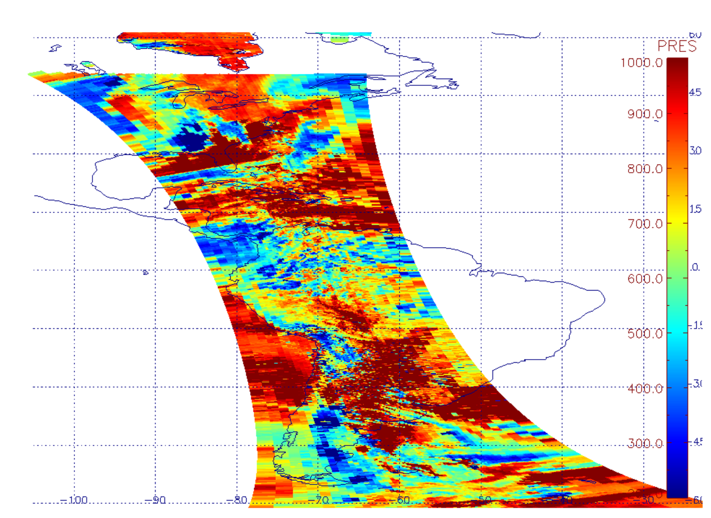


ECF comparison of GLER vs Climatology: smaller differences for higher ECF

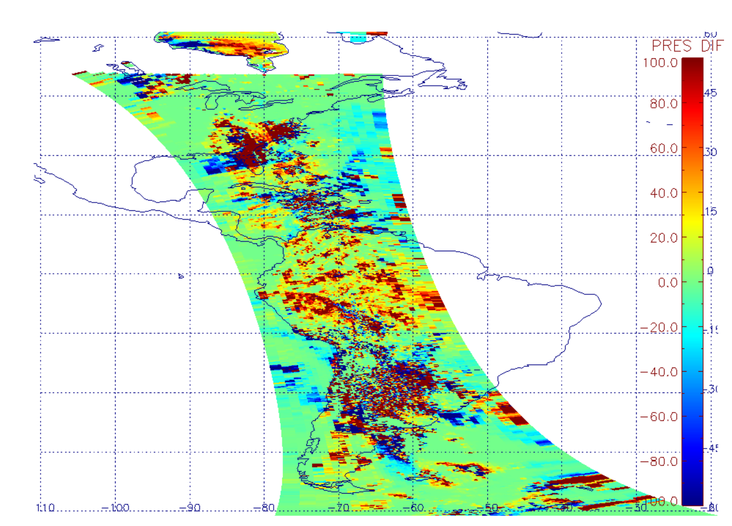


ECF differences (GLER – Climatology) for most interesting range of ECF < 0.25

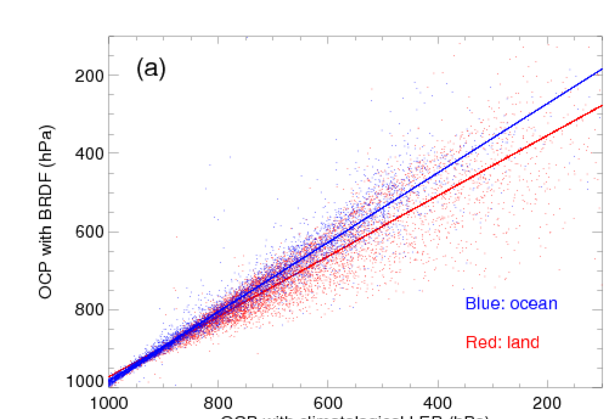
Comparison of cloud pressures, a.k.a. optical centroid pressure (OCP)



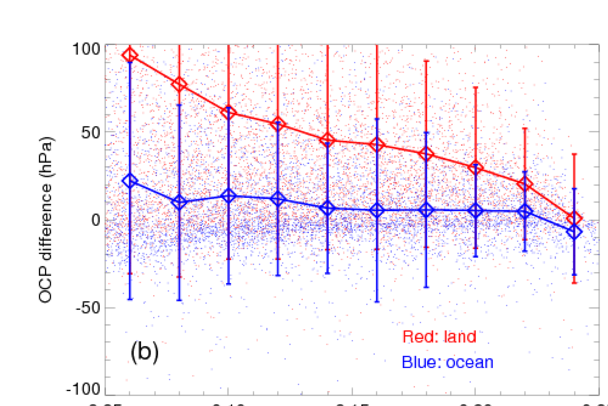
OCP calculated with GLER



OCP differences (GLER – Climatology)



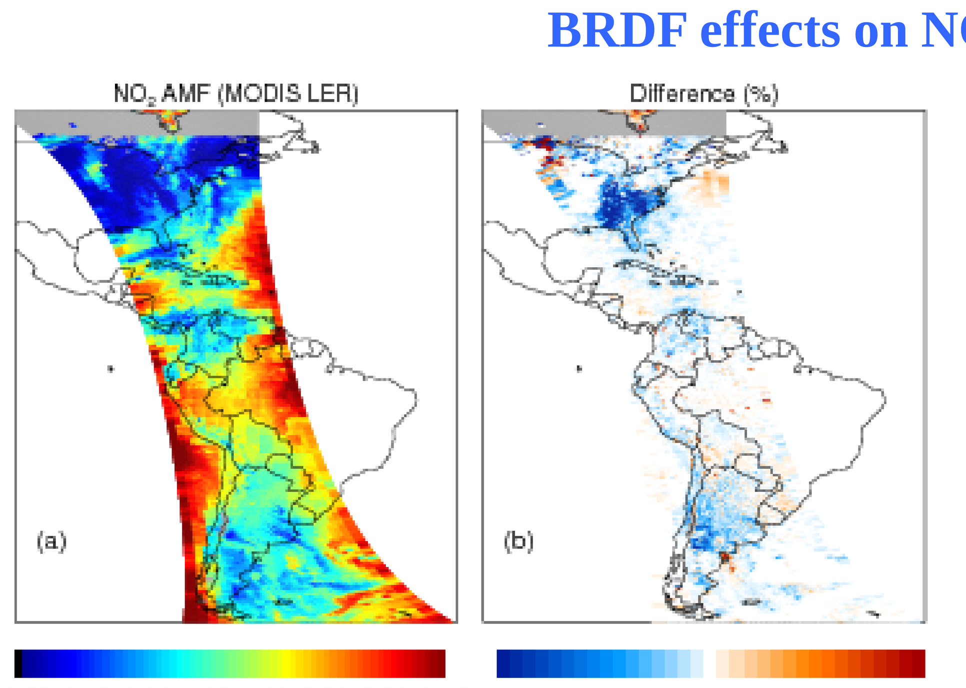
OCP comparison: GLER vs Climatology



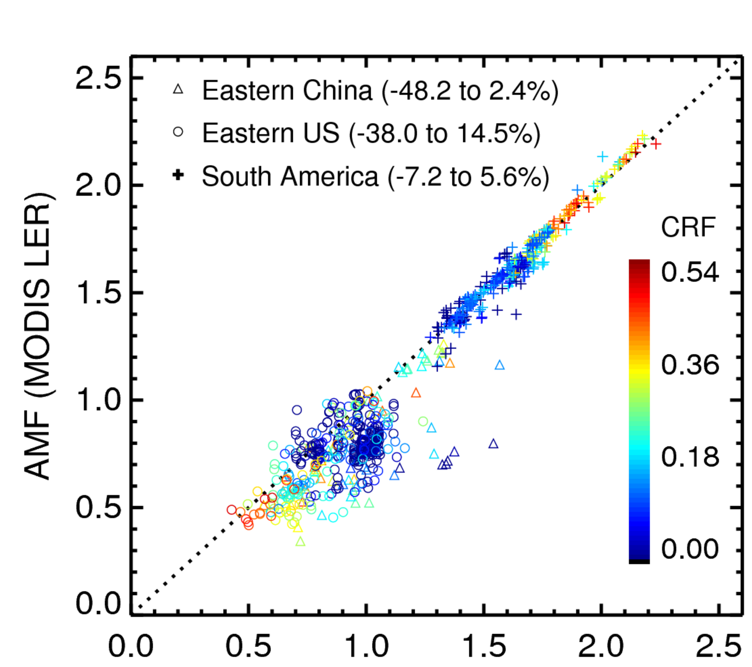
OCP differences (GLER – Climatology)

Mean ECF and OCP differences are small on average.
They can be substantial for individual pixels:
up to ±0.05 for ECF
up to 200 hPa for OCP.

BRDF effects on NO_2 retrievals



NO_2 amount is inversely proportional to Air Mass Factor (AMF). Left: AMF calculated with GLER; Right: AMF differences (GLER – Climatology)



AMF comparison of GLER vs Climatology for different regions: AMF differences up to 50% over polluted areas ; within 5% over unpolluted and cloudy areas.

Conclusions

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 NO_2 vertical columns by up to 50% over polluted areas. Only minor changes within 5% are over unpolluted and overcast areas.

Reference
A. Vasilkov et al., Accounting for the effects of surface BRDF on satellite cloud and trace-gas retrievals: A new approach based on geometry-dependent Lambertian-equivalent reflectivity applied to OMI algorithms, *Atmos. Meas. Tech*., 10, 333-349, doi:10.5194/amt-10-333-2017, 2017.

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