OMGLER README FILE

Data Production Version 1.0

1. Overview

This document provides a description of the OMGLER data product. OMGLER provides Geometry-dependent surface Lambertian-Equivalent Reflectivity (GLER) for the Ozone Monitoring Instrument (OMI) field of view (FOV). Compared to traditional LER products/climatologies (e.g., Kleipool, et al., 2008), GLER captures surface reflectance changes due to changes of solar and viewing geometries. This is because GLER is calculated by coupling the atmosphere with anisotropic surface models such as the MODIS surface bidirectional reflectance distribution function (BRDF) model and BRDF/Albedo product for land, and a model of reflection and water-leaving radiance for water. The primary intended use of the product is to provide surface reflectance information for OMI cloud, aerosol and trace gas algorithms, and GLER is designed to easily replace currently-used LER climatologies within existing OMI algorithm infrastructure.

2. Algorithm description

The algorithm is based on top-of-atmosphere (TOA) radiances for a Rayleigh atmosphere simulated by the Vector Linearized Discrete Ordinate Radiative Transfer (VLIDORT), coupled with anisotropic surface models to account for the solar and viewing geometry dependence of LER in each OMI pixel. A MODIS Ross-Thick Li-Sparse kernel (RTLS) BRDF model is used for directional land surface reflectance, while for water, the Cox-Munk slope distribution is used for surface reflection, and a Case 1 water model simulates light backscattered by water column. GLER is derived by inversion of the TOA radiances calculated to include these directionally dependent surface contributions. Figure 1 shows schematically the data flow through the algorithm.

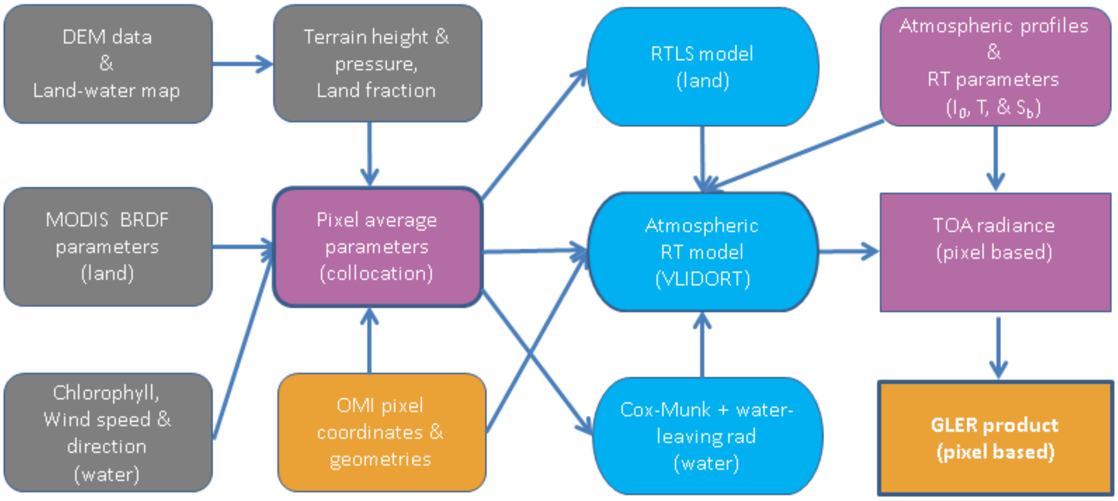

Figure 1. Schematic description of the GLER processing algorithm. Color scheme for data types/sources: grey for ancillary input for the land and water models, purple for collocated input parameters or atmospheric input parameters, gold for sensor-dependent pixel-related inputs/output, and blue ovals for the physical models used. I_0, T and S_b are atmospheric radiative transfer (RT) parameters that are needed for converting TOA radiance into GLER. Refer to Qin et al., 2019 for detailed description.

Several publications document the algorithm and its evaluation. Vasilkov et al. (2017) introduced the concept of GLER and described implications for improving retrievals of effective cloud fraction (ECF) and NO_2 vertical columns. Qin et al. (2019) discussed the implementation of GLER for OMI and evaluated the performance of GLER over land by comparison with OMI-derived LER. Fasnacht et al. (2019) presented the implementation and evaluation of the water models used for GLER over open oceans for OMI. Users may refer to these publications for further scientific and technical details about the product.

2.1 Ancillary data collocation

The ancillary input data that drive the land and ocean models in the GLER product have different temporal and spatial resolutions (see Table 1), therefore collocation of these datasets onto OMI pixel FOV is required. The OMPIXCOR product that provides coordinates of the OMI pixel corners is used to collocate and average higher resolution input data over the OMI FOV. For ancillary data with coarser spatial resolution than OMI, values are interpolated linearly to the OMI pixel center.

Table 1. Spatial and temporal resolutions of ancillary data used for GLER calculation.

Name	Source	Spatial	Temporal
DEM	ETOPO2v2	2 arcmin	Fixed
Land-water flag	MODIS	30 arcsec	Fixed
Land BRDF parameters	MCD43GF/MODIS	30 arcsec	8 days
Chlorophyll-a concentration	MODIS/Aqua	2.5 arcmin	Monthly
Wind speed (before Oct 2011)	AMSR-E/Aqua	0.25 deg	N/A
Wind speed (after Oct 2011)	SSMIS/F16	0.25 deg	N/A
Wind direction	FP-IT/GMAO	0.625 x 0.5 deg	3 hours

2.2 Pixels mixed with land and water

For OMI FOVs with a mixture of land and water, the TOA radiance is estimated following the independent pixel approximation (IPA). In this approximation, the total TOA radiance is a weighted sum of the land and water sub-pixel TOA radiances based on the land and water area fractions in heterogeneous OMI FOVs. The fraction is calculated based on a time-independent dataset of land-water classification generated from MODIS data, and sub-pixel TOA radiances are computed with land or water models independently.

3. Data quality assessment

3.1 Preliminary validation

Validation of the GLER product has been carried out over land (Qin et al., 2019) and open ocean (Fasnacht et al., 2019), separately by comparison with OMI-derived LER measured under clear sky conditions. Globally, GLER is biased low relative to OMI by 0.01 to 0.02 LER at the visible wavelengths for both surface types. The difference is attributed to several factors, including small calibration differences between MODIS and OMI and possible residual cloud and/or aerosol contamination in the OMI data.

3.2 Snow/ice covered regions

The MODIS V005 BRDF product (MCD43GF) provides BRDF parameters for snow-free land and permanent snow and ice cover. However, there are no data over seasonally snow-covered regions. A current temporary solution for this shortcoming over these regions is to substitute OMI-derived LER up to an albedo of 0.6, which is a commonly used value for snow albedo such as in the KNMI's daily OMI NO_2 (DOMINO) product (Boersma et al., 2011; McLinden et al., 2014). Our classification of snow is based on the binary snow flag provided by the Near-real-time Ice and Snow Extent (NISE) product created using passive microwave data (Nolin et al., 2005). NISE data are provided by the National Snow and Ice Data Center (NSIDC) and are included in the OMI L1b data set.

Since NISE data also provides the percentage of sea ice, OMI-measured radiance was used to estimate the TOA radiance over the sea ice, which is mixed with TOA radiance from water model simulation using the sea ice fraction as an averaging weight. GLER is then calculated based on this combination of the measured OMI TOA radiance and calculated ocean TOA radiance. This is only applied to seasonal ice cover, not including permanent ice from MCD43GF.

3.3 440 nm over land

The shortest wavelength in MCD43GF is band 3 (centered at 470 nm) which does not cover the shorter blue and the ultraviolet (UV) wavelengths that OMI trace-gas/aerosol/cloud algorithms use, and spectral dependence of surface reflectance is a consideration. For this version of the GLER release, 1^{o} x 1^{o} climatological values of the ratio of LER at 440 nm and 466 nm was generated based on clear-sky OMI measurements at these two channels. This ratio is then used to scale 466 nm GLER to produce 440 nm GLER.

This approach, however, is not necessary for oceans, since the water reflectance and water leaving radiance models are parameterized for shorter wavelengths (Fasnacht et al., 2019).

3.4 Known issues

3.4.1 High solar zenith angles

Since the MCD43GF product is not recommended for solar zenith angles (SZAs) beyond 70^{o} (Schaaf et al., 2011), GLERs at OMI SZA larger than that have reduced accuracy.

3.4.2 MODIS BRDF data after 2015

The current version of OMGLER uses the Collection 5 gap-filled MODIS BRDF/Albedo product that was produced through 2015. Data from 2015 are used for OMGLER for all years after. Future versions of this product will use Collection 6 MODIS products that provide data in recent years.

3.4.3 Gap-filling of snow/ice free OMI pixels

For snow/ice free OMI pixels but with no values of surface BRDF parameters from MCD43GF, the OMI LER climatology (Kleipool et al., 2008) is applied to fill the data gaps of OMGLER. And a flag in processing flags (see Table 3) is set in such cases.

3.4.4 High elevation with no snow

It has been noticed that GLER tends to be slightly overestimated at high elevation (terrain pressure less than 600 hPa) if it is snow-free. However, since snow may exist most time of year at such high terrain, the affected area is very limited.

3.4.5 Seasonal snow or sea ice covered pixels

GLER is found to be slightly underestimated for fully snow-covered pixels with seasonal snow cover based on NISE snow flag. The coarse resolution for snow classification (e.g., misclassifying pixels with partial snow-covered and partial cloud-covered) further complicates this because the binary NISE snow flag does not provide pixel snow fraction information.

For partial sea ice covered pixels, applying measured TOA radiance to sea ice may also lead to underestimate of sea ice TOA radiance because OMI measured TOA radiance over a pixel mixed with ice and water consists of contribution from ice-free water which is much darker than sea ice.

Also, users should note that aerosols and/or clouds could contaminate the measured TOA radiance because no filter/ screening was applied for gap-filling of seasonal snow or sea ice pixels.

For these reasons, users are cautioned when using data at very high elevation or under seasonal snow/sea ice cover. For example, the NO_2 algorithm only uses values not larger than 0.2 to mitigate the effect of snow/ice and possible cloud contaminations on the retrievals of NO_2 columns.

We are working to resolve these issues and have plans to improve GLER retrievals over snow or sea ice in the next release.

4. Product description

4.1 File name

The OMGLER product is written as an HDF-EOS5 swath file and has the following naming convention:

<InstrumentID>_<ProcessingLevel>-
<ProductName>_<ObservationDateTime>-
o<Orbit#>_v<Collection#>-<ProductionDateTime>.<Suffix>.

Below is an example of an OMGLER file name:
OMI-Aura_L2-OMGLER_2005m0601t202555-o04683_v003-2019m0515t015134.he5

where:

<InstrumentID>	= OMI-Aura
< ProcessingLevel>	= L2
< ProductName >	= OMGLER
<ObservationDateTime>	= 2005m0601t202555
<Orbit#>	= 04683

<Collection#>	= 003
<ProductionDateTime>	= 2019m0515t015134
<Suffix>	= he5

The observation time and the processing time are stated to the second (6 digits).

4.2 File organization

The HDF-EOS5 file structure is shown in Figure 2.

As HDF-EOS5 files, OMGLER files contain a single swath, called Geometry Dependent Surface LER, composed of a Geolocation Fields group and a Data Fields group. This section briefly describes the more commonly-used data fields.

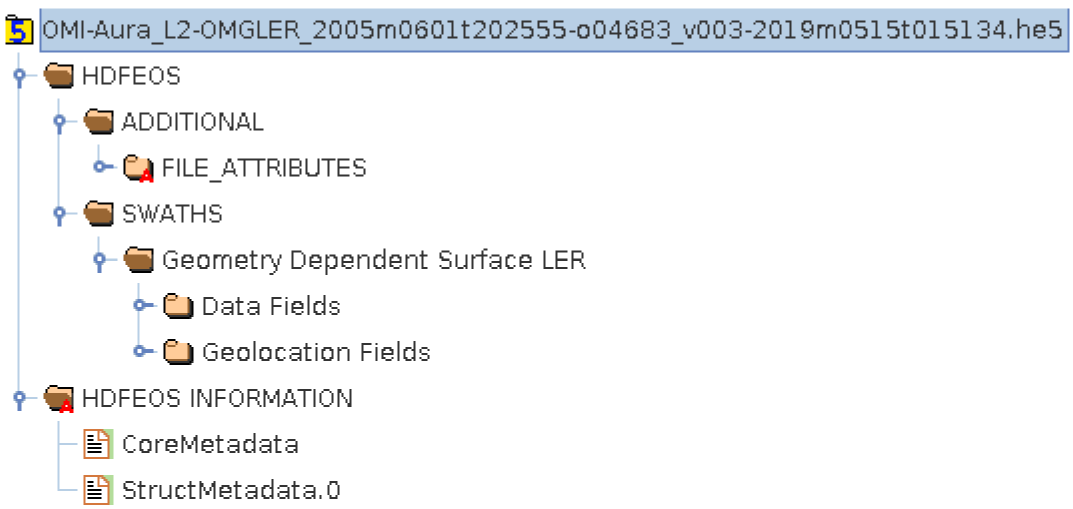

Figure 2: OMGLER HDF-EOS5 file structure.

OMGLER file contains GLER and the computed TOA radiance from which GLER is derived. The relevant products are called *GLER* and *ComputedTOARadiance*, respectively. The output file also contains associated input parameters for each OMI pixel from the sun-lit portion of an Aura orbit. A large number of ancillary/

input parameters in Data Fields that are used to compute TOA radiance are provided for data quality assessment.

4.3 Which data should be used?

OMGLER product contains two groups of flags (*GLERQualityFlags* and *ProcessingFlags*) to aid the user in selection of which data to use. By far the most important flags are the GLER quality flags (see Table 2). Users should only use GLER data where none of the 16 bits is set. Users are also advised to check the processing flags (Table 3) to see if any gap-filling is applied (bits 0-2) before using the data.

Table 2. Definitions of GLER quality flags

Bit	Definition
0	invalid land fraction
1	Invalid solar azimuth angle (SAA)
2	high SZA (> 86 deg)
3	warning flag for SZA > 70 deg in MCD43GF
4	missing land radiance component for mixed pixel
5	missing water radiance component for mixed pixel

Table 3. Definitions of processing flags

Bit	Definition
0	Kleipool LER climatology
1	OMI-derived LER for snow land
2	OMI-derived LER for sea ice portion
3	FP-IT wind speed
4	AMSR-E wind speed
5	F16 SSMIS wind speed
6	Wind speed <0.4 m/s
7	Chlorophyll monthly climatology
8	Chlorophyll yearly mean
9	Chlorophyll default for open ocean (0.1)

10	Chlorophyll default for inland water (1.0)
11	Chlorophyll fill value
12	Chlorophyll concentration >10.0 mg/m^3
13	default value (0.95) of 440/466 LER ratio climatology

4.4 Data description and availability

For a complete list of the parameters besides bit settings for quality control and processing flags, please read the OMGLER file specification document (see attached omgler.fs). The OMGLER product is archived and distributed from the Goddard Earth Sciences Data & Information Services center (GES DISC). The files can be directly downloaded from the GES DISC website which provides parameters and spatial subset capabilities.

Questions related to the OMGLER dataset should be directed to the GES DISC. Users interested in this product or with questions regarding the OMGLER dataset are advised to contact Wenhan Qin (wenhan.qin@ssaihq.com) who has the overall responsibility for this product.

References

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