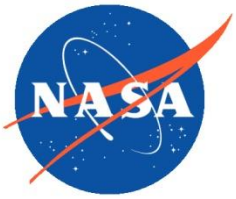

National Aeronautics and Space Administration
Goddard Earth Science
Data Information and Services Center (GES DISC)

README Document for the Earth Surface and Atmosphere Reflectivity Since 1979 from Multiple Satellites project

Multi-Satellite Lambertian Equivalent Reflectivity
Level-3 10-Day Gridded Products:

MSLERNNL3d10 (noon normalized)
MSLERLSTL3d10 (local satellite time)

Last Revised 07/22/2013

Goddard Earth Sciences Data and Information Services Center (GES DISC)
http://disc.gsfc.nasa.gov
NASA Goddard Space Flight Center
Code 610.2
Greenbelt, MD 20771 USA

Prepared By:

James E. Johnson	01/08/2013
Name GES DISC GSFC Code 610.2	Date

Reviewed By:

Jay Herman	03/15/2013
Name GSFC Code 614	Date

Peter Leonard	03/15/2013
Name GSFC Code 614	Date

Goddard Space Flight Center
Greenbelt, Maryland

Revision History

Revision Date	*Changes*	*Author*
03/18/2013	Original	James E. Johnson
07/22/2013	Describes changes regarding v1.02 data files: Revised end date to 2012, updated nTimes dimension size, etc.	James E. Johnson

Table of Contents

1. Introduction

This document provides basic information for using the gridded mean data products from the Earth Surface and Atmosphere Reflectivity Since 1979 from Multiple Satellites project. The corresponding zonal mean data products are described in a separate README document.

1.1 Data Product Description

The Multi-Satellite 340-nm Lambertian Equivalent Reflectivity (LER) 10-day 2-deg by 5-deg lat/lon gridded products are derived from multi-satellite Solar Backscatter UltraViolet (SBUV) observations from 1980 to 2012 (Herman et al., 2012).

There are two product types: Local Satellite Time (LST) and Noon Normalized (NN). The LST data are uncorrected for the drift of the spacecraft equator crossing time. The NN data have been corrected to local noon equator crossing time (see Labow et al., 2011). The NN correction could only be done satisfactorily at latitudes less extreme than 60 degrees due to insufficient diurnal data at higher latitudes.

1.1.1 SBUV in General

The primary purpose of the SBUV (Solar Backscatter UltraViolet) instruments is to monitor changes in Earth's atmospheric ozone, but several other interesting geophysical quantities are also measured, including various Earth reflectivities.

Each SBUV instrument is a double monochromator designed to make well calibrated nadir-view observations of Earth from space at twelve discrete wavelength bands between 250 and 340 nm with a spectral bandpass of approximately 1.1 nm. All of the LER calculations use 340 nm to avoid ozone absorption effects.

1.1.2 Nimbus-7 SBUV

The Nimbus 7 (N7) spacecraft, which included an SBUV instrument, was launched on October 4, 1978 into a sun-synchronous polar orbit with an initial local equator-crossing time of 11:45 a.m. The satellite drifted to slightly earlier times after the maneuvering fuel ran out in 1984.

The N7 SBUV instrument achieved full global coverage each week from approximately 81 degrees South to 81 degrees North latitude.

The instrument was operational from October 30, 1978 until June 26, 1990 when increasing chopper errors made the data unusable. The purpose of the chopper was to subtract noise

contamination that occurred from high energy particles, particularly when the satellite passed through the South Atlantic Anomaly.

The Lambertian Equivalent Reflectivity at 340 nm based on N7 SBUV observations has been included in the 340-nm LER Level 3 10-day 2-deg by 5-deg lat/lon gridded products. The Nimbus-7 observations before 1980 contain several data gaps, and so these data have been excluded.

1.1.3 NOAA SBUV/2 Series 9, 11, 14, 16, 17, 18 and 19

The second generation Solar Backscatter UltraViolet (SBUV/2) instruments are an improved design over the Nimbus-7 SBUV instrument, and have been flown on the NOAA Polar-orbiting Operational Environment Satellites (POES).

The NOAA series of satellites were launched into near sun-synchronous polar orbits, mostly with an initial equator-crossing time of approximately 2:00 p.m., except for NOAA-17, which was launched into a morning orbit. These satellites drift towards later equator-crossing times (or to earlier times for NOAA-17) during their mission, leading to higher solar zenith angles at all latitudes. This orbital drift affects the availability of the SBUV/2 measurements, since the data are less accurate when the orbit is near- terminator (i.e., local equator crossing times outside of the 8:00 a.m. to 4:00 p.m. range). The orbital drift problem was especially bad for the NOAA-9 and -11 satellites.

Each SBUV/2 instrument provided global coverage from 80 degrees South latitude to 80 degrees North latitude every 7 to 10 days.

The NOAA-9 satellite was launched on December 12, 1984, and the others were subsequently launched every two to six years to result in continuous coverage to present. Only the SBUV/2 instruments aboard the NOAA-16, -17 and -19 satellites remained in operation at the end of 2012. The SBUV/2 instrument aboard NOAA-18 failed on December 12, 2012.

The Lambertian Equivalent Reflectivity at 340 nm based on NOAA SBUV/2 observations has been included in the 340-nm LER Level 3 10-day 2-deg by 5-deg lat/lon gridded products.

1.2 Algorithm Background

A mathematical description of the algorithm is given in Herman et al. (2012). It is based on a numerical solution of the radiative transfer equation applied to a formal solution in terms of the radiation at the top of the atmosphere and a single free parameter representing the LER. The LER value is adjusted in the range from 0.0 to 1.0 until the calculated radiance at the top of the atmosphere matches the measured radiance.

1.3 Data Disclaimer

These data were produced under the NASA MEaSUREs program with the goal being to apply a consistent instrument-to-instrument calibration so that the data could be used for long term trend analysis. The quality of the LER data varied depending on the instrument. In particular, the SBUV/2 data from NOAA-9, -11 and 14 are of somewhat lower quality due to various issues (Herman et al., 2012).

2. Data Organization

The Multi-Satellite Lambertian Equivalent Reflectivity Gridded Product files contain the merged reflectivity values at 340 nm for the entire time period from 1980 to 2012 from the Nimbus-7 SBUV, and NOAA 9, 11, 14, 16, 17, 18 and 19 SBUV/2 instruments. The data files are written in the HDF-EOS5 (grid) format.

2.1 File Naming Convention

The data product files are named according to the following convention:

<Product>_<Version>.<Suffix>

where:

- Product = product short name in format <Variable><Type><Format> where
  1. Variable = Multi-Satellite Lambertian Equivalent Reflectivity (MSLER)
  2. Type = either noon normalized (NN) or local satellite time (LST)
  3. Format = Level-3 10 day 2° x 5° lat/lon grid (L3d10)
- Version = product collection version in format <Major>-<Minor> where
  4. Major = 2 digit major version (e.g. 01)
  5. Minor = 2 digit minor version (e.g. 00)
  6. Created = file creation time in format YYYYmMMDDtHHMMSS (e.g. 2012m1125t023922)
- Suffix = the file format (always he5)

```
File name example: MSLERLSTL3d10_v01-00-2012m1125t023922.he5
```

2.2 File Format and Structure

The data files are written in the HDF-EOS5 format, which is an extension of the Hierarchical Data Format Version 5 (HDF-5), developed by the HDF Group, formerly the National Center for Supercomputing Applications (http://www.hdfgroup.org/). HDF-EOS5 employs standard HDF5 objects: data arrays, attributes, and groups. Using these HDF5 objects it defines four data structures for Earth Observing System data: grid, point, swath, and zonal average. These data structures allow the file contents to be referenced to Earth coordinates, such as latitude and longitude, and to time. The HDF-EOS5 files are self-describing, portable, and platform independent. The files can be read with applications which understand HDF5, HDF-EOS5 and even the netCDF4 format.

The Multi-Satellite Lambertian Equivalent Reflectivity 10-day gridded products use the HDF-EOS Grid data structure. All data fields are represented on a global map of size 72x90 (columns x rows) using the simple lat/lon coordinate system. In the HDF-EOS5 format, the location of a data field array within a file is given by its **path** (similar to a Unix directory) and takes the form:

/HDFEOS/GRIDS/<grid_name>/Data Fields/<field_name>.

The grid_name for the LER data is always “Lambertian Equivalent Reflectivity”. For example the location of the data field named “LER340” is given by:

/HDFEOS/GRIDS/Lambertian Equivalent Reflectivity/Data Fields/LER340

Within each file there is a set of global attributes which define the metadata for that data product. Section 3.0 (below) describes the dimensions, global attributes, and data fields in more detail.

2.3 Key Science Data Fields

The primary science data field for these data products is the Lambertian Equivalent Reflectivity at 340 nm or LER340 that can be formed into time series for each grid box. Each time series can be fitted with a linear least squares straight line. The slopes of those straight lines (Reflectivity Units/Decade) are shown in Figure 1 for the non-noon normalized case (Herman et al., 2013).

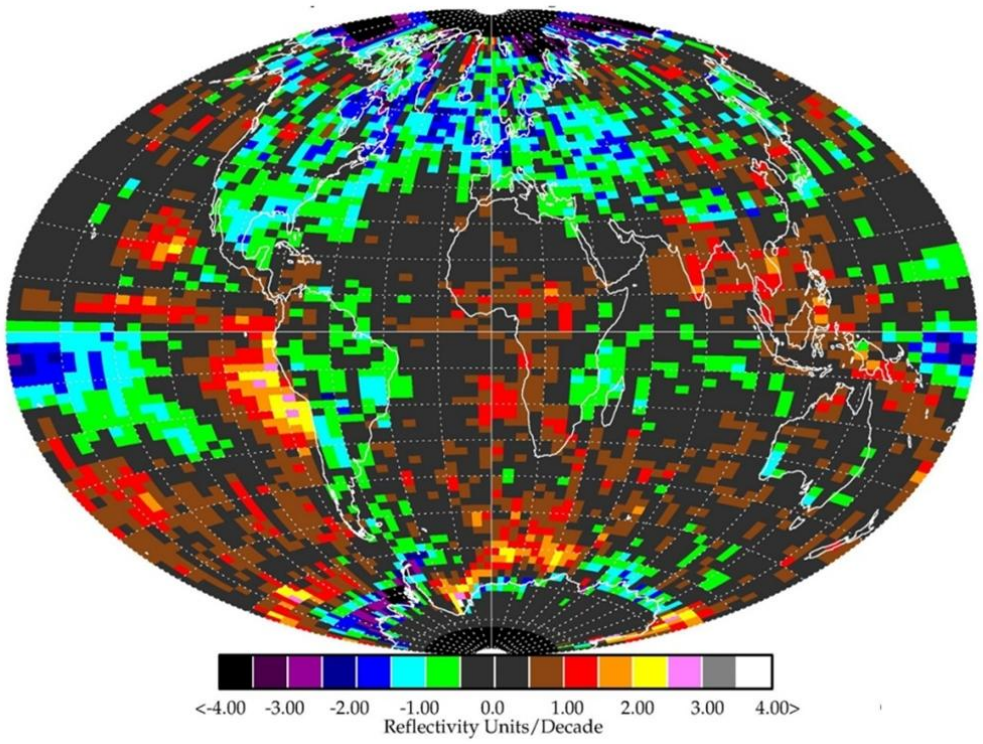

Figure 1. LER linear trends as a function of latitude and longitude (Reflectivity Units/Decade).

3. Data Contents

3.1 Dimensions

The dimension information is located under the following HDF5 group path:

"/HDFEOS/GRIDS/Lambertian Equivalent Reflectivity"

Table 3-1: List of dimensions associated with data fields.

Name	Size	Description
XDim	72	The dimension representing the X or longitude direction of the grid.
YDim	90	The dimension representing the Y or latitude direction of the grid.
nTimes	1188	The dimension representing the observation times in the granule.

3.2 Global Attributes

The global (file) attributes are located under the following HDF5 group path:

"/HDFEOS/ADDITIONAL/FILE_ATTRIBUTES"

Table 3-2: Global metadata attributes associated with the file.

Name	Type	Size	Description
AuthorAffiliation	STRING	Scalar	The affiliation of the author of the product.
AuthorName	STRING	Scalar	The name of the author of the product.
Conventions	STRING	Scalar	The metadata conventions used.
DayNightFlag	STRING	Scalar	The flag that indicates whether the product includes day-side observations, night-side observations, or both.
EastBoundingCoordinate	32-BIT FLOAT	1	The terrestrial longitude (in degrees) of the easternmost data in the granule.
HDFVersion	STRING	Scalar	The version of HDF used to create the product.
LocalGranuleID	STRING	Scalar	The actual name of the product file.
LocalityValue	STRING	Scalar	The geographic locality of the product.

LongName	STRING	Scalar	The ESDT Long Name of the product.
NorthBoundingCoordinate	32-BIT FLOAT	1	The terrestrial latitude (in degrees) of the northernmost data in the granule.
NumLats	32-BIT SIGNED INTEGER	1	The number of latitudes in the granule, which is also the size of the YDim dimension.
NumLons	32-BIT SIGNED INTEGER	1	The number of longitudes in the granule, which is also the size of the XDim dimension.
NumTimes	32-BIT SIGNED INTEGER	1	The number of times in the granule, which is also the size of the nTimes dimension.
PGEVersion	STRING	Scalar	The version of the PGE or App that was used to create the product file.
ParameterName	STRING	Scalar	The measured science parameter expressed in the product.
ProcessLevel	STRING	Scalar	The process level of the product.
ProcessingCenter	STRING	Scalar	The processing center where the product was created.
ProductionDateTimeASCII	STRING	Scalar	The date and time of the v8.6 SBUV processing that produced the ASCII.
ProductionDateTimeHDF	STRING	Scalar	The date and time of the ASCII to HDF-EOS5 conversion processing.
RangeBeginningDate	STRING	Scalar	The UTC year, month and day when the granule began.
RangeBeginningTime	STRING	Scalar	The UTC hour, minute and second when the granule began.
RangeEndingDate	STRING	Scalar	The UTC year, month and day when the granule ended.
RangeEndingTime	STRING	Scalar	The UTC hour, minute and second when the granule ended.
ShortName	STRING	Scalar	The ESDT Short Name of the product.
SouthBoundingCoordinate	32-BIT FLOAT	1	The terrestrial latitude (in degrees) of the southernmost data in the granule.
TimeSpacing	32-BIT FLOAT	1	The increment of spacing in time.
TimeSpacingUnit	STRING	Scalar	The units of the spacing in time.
VersionID	STRING	Scalar	The Collection Version of the product.
WestBoundingCoordinate	32-BIT FLOAT	1	The terrestrial longitude (in degrees) of the westernmost data in the granule.
identifier_product_doi	STRING	Scalar	The Digital Object Identifier (DOI) value.
identifier_product_doi_authority	STRING	Scalar	The authoritative service for use with DOI values in resolving to the URL.

3.3 Grid Attributes

The grid attributes are located under the following HDF5 group path:

"/HDFEOS/GRIDS/Lambertian Equivalent Reflectivity"

Table 3-3: Attributes associated with the grid.

Name	Type	Size	Description
GCTPProjectionCode	32-BIT SIGNED INTEGER	1	The code number of the General Cartographic Transformation Package (GCTP) projection used for the grid.
GridOrigin	STRING	Scalar	The position or origin of grid cell values.
GridSpacing	STRING	Scalar	The grid spacing longitude and latitude pair values.
GridSpacingUnit	STRING	Scalar	The units of the grid spacing values.
GridSpan	STRING	Scalar	The extent of the grid span given as four values longitude min/max and latitude min/max.
GridSpanUnit	STRING	Scalar	The units of the grid span values.
Projection	STRING	Scalar	The name of the projection used for the grid.

3.4 Data Fields

The data fields are located under the following HDF5 group path:

"/HDFEOS/GRIDS/Lambertian Equivalent Reflectivity/Data Fields"

Tables 3-4: Data fields

Name	LER340
Type	32-BIT FLOAT
Dimensions	XDim x YDim x nTimes
Description (MSLERNNL3d10)	The gridded average of the noon-normalized Lambertian Equivalent Reflectivity at 340 nm based on SBUV observations from multiple satellites.
Description (MSLERLSTL3d10)	The gridded average of Lambertian Equivalent Reflectivity at 340 nm at the local satellite time based on SBUV observations from multiple satellites.

Attributes

Name	Type	Size	Value
units	STRING	Scalar	%
long_name (MSLERNNL3d10)	STRING	Scalar	Lambertian Equivalent Reflectivity at 340 nm (Noon Normalized)

long_name (MSLERLSTL3d10)	STRING	Scalar	Lambertian Equivalent Reflectivity at 340 nm (Local Satellite Time)
valid_range	32-BIT FLOAT	2	0.0, 100.0
_FillValue	32-BIT FLOAT	1	-1×2.0^{100} (-1.2676506e+30)

* The name of this data field is the same in both MSLERNNL3d10 and MSLERLSTL3d10 products.

Name	Latitude		
Type	32-BIT FLOAT		
Dimensions	YDim		
Description	The terrestrial latitudes at the centers of the grid cells. The values are in degrees north of the equator.		
Attributes			
Name	Type	Size	Value
units	STRING	Scalar	degrees_north
long_name	STRING	Scalar	Latitude
valid_range	32-BIT FLOAT	2	-90.0, 90.0
_FillValue	32-BIT FLOAT	1	-1×2.0^{100} (-1.2676506e+30)

Name	Longitude		
Type	32-BIT FLOAT		
Dimensions	XDim		
Description	The terrestrial longitudes at the centers of the grid cells. The values are in degrees east of the International Reference Meridian.		
Attributes			
Name	Type	Size	Value
units	STRING	Scalar	degrees_east
long_name	STRING	Scalar	Longitude
valid_range	32-BIT FLOAT	2	-180.0, 180.0
_FillValue	32-BIT FLOAT	1	-1×2.0^{100} (-1.2676506e+30)

Name	Time		
Type	64-BIT FLOAT		
Dimensions	nTimes		
Description	The TAI93 time (in continuous seconds since 12 a.m. UTC on January 1, 1993) of the start times of the observations.		
Attributes			
Name	Type	Size	Value
units	STRING	Scalar	seconds since 1993-01-01
long_name	STRING	Scalar	Time of Observation (TAI93)
valid_min	64-BIT FLOAT	2	-1.0e+10, 1.0e+10
_FillValue	64-BIT FLOAT	1	-1×2.0^{100} (-1.2676506e+30)

Name	UTCStartDayNumber
Type	32-BIT SIGNED INTEGER
Dimensions	nTimes
Description	The UTC day number of the start times of the observations. The values are in days since 1978-01-01.

Attributes

Name	Type	Size	Value
units	STRING	Scalar	days since 1978-01-01
long_name	STRING	Scalar	Days Since 1978-01-01
valid_min	32-BIT SIGNED INTEGER	2	0, 12783
_FillValue	32-BIT SIGNED INTEGER	1	-2147483647

Name	UTCStartDayOfYear
Type	32-BIT SIGNED INTEGER
Dimensions	nTimes
Description	The UTC day of year of the start times of the observations.

Attributes

Name	Type	Size	Value
units	STRING	Scalar	1
long_name	STRING	Scalar	Day of Year
valid_min	32-BIT SIGNED INTEGER	2	1, 366
_FillValue	32-BIT SIGNED INTEGER	1	-2147483647

Name	UTCStartYear
Type	32-BIT SIGNED INTEGER
Dimensions	nTimes
Description	The (four-digit) UTC year of the start times of the observations.

Attributes

Name	Type	Size	Value
units	STRING	Scalar	1
long_name	STRING	Scalar	Year
valid_min	32-BIT SIGNED INTEGER	2	1980, 2012
_FillValue	32-BIT SIGNED INTEGER	1	-2147483647

4. Options for Reading the Data

There are many tools and visualization packages (free and commercial) for viewing and dumping the contents of HDF5 files. Libraries are available in several programming languages for writing software to read HDF5 files. A few simple to use command-line and visualization tools, as well as programming languages for reading the L2 HDF5 data files are listed in the sections below. For a comprehensive list of HDF5 tools and software, please see the HDF Group's web page at http://www.hdfgroup.org/products/hdf5_tools/.

4.1 Command Line Utilities

4.1.1 h5dump (free)

The h5dump tool, developed by the HDFGroup, enables users to examine the contents of an HDF5 file and dump those contents, in human readable form, to an ASCII file, or alternatively to an XML file or binary output. It can display the contents of the entire HDF5 file or selected objects, which can be groups, datasets, a subset of a dataset, links, attributes, or datatypes. The h5dump tool is included as part of the HDF5 library, or separately as a stand-alone binary tool at:

http://www.hdfgroup.org/HDF5/release/obtain5.html

4.1.2 ncdump (free)

The ncdump tool, developed by Unidata, will print the contents of a netCDF or compatible file to standard out as CDL text (ASCII) format. The tool may also be used as a simple browser, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables. To view HDF5 data files, version 4.1 or higher is required. The ncdump tool is included with the netCDF library. **NOTE: you must include HDF5 support during build.**

http://www.unidata.ucar.edu/downloads/netcdf/

4.1.3 H5_PARSE (IDL/commercial)

The H5_PARSE function recursively descends through an HDF5 file or group and creates an IDL structure containing object information and data values. You must purchase an IDL package, version 8 or higher, to read the L2 HDF5 data files.

http://www.exelisvis.com/language/en-US/ProductsServices/IDL.aspx

4.2 Visualization Tools

4.2.1 HDFView (free)

HDFView, developed by the HDFGroup, is a Java-based graphic utility designed for viewing and editing the contents of HDF4 and HDF5 files. It allows users to browse through any HDF file, starting with a tree view of all top-level objects in an HDF file's hierarchy. HDFView allows a user to descend through the hierarchy and navigate among the file's data objects. Editing features allow a user to create, delete, and modify the value of HDF objects and attributes. For more info see:

http://www.hdfgroup.org/hdf-java-html/hdfview/

For the EOS perspective you can add the HDF-EOS5 plugin which is available at:

http://newsroom.gsfc.nasa.gov/sdptoolkit/HDFView/HDFView_hdfeos_plugin.html

4.2.2 Panoply (free)

Panoply, developed at the Goddard Institute for Space Studies (GISS), is a cross-platform application which plots geo-gridded arrays from netCDF, HDF and GRIB dataset required. The tool allows one to slice and plot latitude-longitude, latitude-vertical, longitude-vertical, or time-latitude arrays from larger multidimensional variables, combine two arrays in one plot by differencing, summing or averaging, and change map projections. One may also access files remotely into the Panoply application.

http://www.giss.nasa.gov/tools/panoply/

4.2.3 H5_BROWSER (IDL/commercial)

The H5_BROWSER function presents a graphical user interface for viewing and reading HDF5 files. The browser provides a tree view of the HDF5 file or files, a data preview window, and an information window for the selected objects. The browser may be created as either a selection dialog with Open/Cancel buttons, or as a standalone browser that can import data to the IDL main program. You must purchase an IDL package, version 8 or higher to view the L2 HDF5 data files.

http://www.exelisvis.com/language/en-US/ProductsServices/IDL.aspx

4.3 Programming Languages

Advanced users may wish to write their own software to read HDF5 data files. The following is a list of available HDF5 programming languages:

Free:

C/C++ (http://www.hdfgroup.org/HDF5/release/obtain5.html)
Fortran (http://www.hdfgroup.org/HDF5/release/obtain5.html)
Java (http://www.hdfgroup.org/hdf-java-html/)
Python (http://alfven.org/wp/hdf5-for-python/)
GrADS (http://www.iges.org/grads/)

Commercial:

IDL (http://www.exelisvis.com/language/en-US/ProductsServices/IDL.aspx)
Matlab (http://www.mathworks.com/products/matlab/)

For a list of available HDF-EOS5 libraries (requires HDF5 libraries) see:

http://hdfeos.org/software/library.php

5. Data Services

5.1 Mirador

The GES DISC provides basic temporal and advanced (event) searches through its Mirador search and download engine:

http://mirador.gsfc.nasa.gov/

Mirador offers various download options that suit users with different preferences and different levels of technical skills. Users can start from a point where they don't know anything about these particular data, its location, size, format, etc., and quickly find what they need by just providing relevant keywords, such as a data product (e.g. "MSLERNNL3d10"), or a parameter such as "reflectivity".

5.2 OPeNDAP

The Open Source Project for a Network Data Access Protocol (OPeNDAP) provides remote access to individual variables within datasets in a form usable by many OPeNDAP enabled tools, such as Panoply, IDL, Matlab, GrADS, IDV, McIDAS-V, and Ferret. Data may be subsetted dimensionally and downloaded in an ASCII, netCDF3 or binary (DAP) format. The GES DISC offers the SBUV L2 data products through OPeNDAP:

http://measures.gsfc.nasa.gov/opendap/LER/contents.html

6. More Information

6.1 Web Resources

For other reflectivity and related data, please search NASA's Global Change Master Directory at http://gcmd.nasa.gov.

6.2 Point of Contact

Name: GES DISC Help Desk
URL: http://disc.gsfc.nasa.gov/
E-mail: gsfc-help-disc@lists.nasa.gov
Phone: 301-614-5224
Fax: 301-614-5228
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
Code 610.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771, USA

Principal Investigator

Dr. Jay Herman
Code 614
NASA Goddard Space Flight Center
Greenbelt, MD 20771, USA
jay.r.herman@nasa.gov

7. Acknowledgements

This project was funded by NASA's Making Earth Science Data Records for Use in Research Environments (MEaSUREs) Program.

References

Herman, J.R., G. Labow, N.C. Hsu, and D. Larko, "Changes in cloud and aerosol cover (1998-2006) from reflectivity time series using SeaWiFS, N7-TOMS, EP-TOMS, SBUV-2, and OMI radiance data", Journal of Geophysical Research, 2009, Volume 114, D01201 doi:10.1029/2007JD009508

Herman, J.R., M.T. DeLand, L.-K. Huang, et al., "A net decrease in the Earth's cloud plus aerosol reflectivity during the past 33 yr (1979-2011) and increased solar heating at the surface", Atmospheric Chemistry and Physics Discussions, 2012, Volume 12, Pages 31991-32038 doi:10.5194/acpd-12-31991-2012

Labow, G.J., J.R. Herman, L.-K. Huang, et al., "Diurnal variation of 340 nm Lambertian Equivalent Reflectivity due to clouds and aerosol over land and oceans", Journal of Geophysical Research, 2011, Volume 116, D11202 doi:10.1029/2010JD014980