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1. TITLE

1.1 Data Set Identification

*****ISLSCP II Snow-Free, Spatially Complete, 16 Day Albedo, 2002

1.2 File Name(s)

The filenames for the various files in this data set use the following naming convention:

modis_f_xxx_ss_yyyymmdd_BB.asc

where,

modis_f stands for MODIS spatially-filled data.

xxx is the type of parameter:

bsa= Black_Sky_Albedo (Unitless)

wsa= White_Sky_Albedo (Unitless)

pc= Percentage of original MOD43B3 data per grid cell

ss is the spatial resolution of the data in both latitude and longitude:

1d 1-degree spatial resolution

hd half-degree spatial resolution

qd quarter-degree spatial resolution

yyyy is the year

mmdd **mm** is the month from 01 to 12 and **dd** is the day for the starting date of the 16-day period of coverage.

BB is the spectral band designation:

- b1** Albedo for MODIS band 1 (620-670 nm)
- b2** Albedo for MODIS band 2 (841-876 nm)
- b3** Albedo for MODIS band 3 (459-479 nm)
- b4** Albedo for MODIS band 4 (545-565 nm)
- b5** Albedo for MODIS band 5 (1230-1250 nm)
- b6** Albedo for MODIS band 6 (1628-1652 nm)
- b7** Albedo for MODIS band 7 (2105-2155 nm)
- bb1** MODIS broadband albedo 1 (300-700 nm)
- bb2** MODIS broadband albedo 2 (700-5000 nm)
- bb3** MODIS broadband albedo 3 (300-5000 nm)

As an example, the file named **modis_f_bsa_qd_20020728_b3.asc** is the spatially complete black sky albedo for MODIS band 3 for the 16-day period starting on July 28, 2002, and at a quarter-degree spatial resolution.

1.3 Revision Date of this Document

December 07, 2009

2. INVESTIGATOR(S)

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2.2 Title of Investigation

Snow-Free Spatially Complete Albedo Products derived from MODerate Resolution Imaging Spectroradiometer (MODIS) Albedo Products

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2.6 File Development

Moody, E.G., Schaaf, C., King, M., and Gao, F. 2009. ISLSCP II Snow-Free, Spatially Complete, 16 Day Albedo, 2002. In Hall, Forest G., G. Collatz, B. Meeson, S. Jos, E. Brown de Colstoun, and D. Landis (eds.). ISLSCP Initiative II Collection. Data Set. Available on-line [<http://daac.ornl.gov/>] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/960

2.5 Requested Form of Acknowledgment

Users of the International Satellite Land Surface Climatology (ISLSCP) Initiative II data collection are requested to cite the collection as a whole (Hall et al. 2006) as well as the individual data sets. Please cite the following publications when these data are used:

Hall, F.G., E. Brown de Colstoun, G. J. Collatz, D. Landis, P. Dirmeyer, A. Betts, G. Huffman, L. Bounoua, and B. Meeson, The ISLSCP Initiative II Global Datasets: Surface Boundary Conditions and Atmospheric Forcings for Land-Atmosphere Studies, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007366, 2006.

- Lucht, W., C.B. Schaaf, and A.H. Strahler. An Algorithm for the retrieval of albedo from space using semiempirical BRDF models, *IEEE Trans. Geosci. Remote Sens.*, 38, 977-998, 2000.
- Moody, E. G., M. D. King, S. Platnick, C. B. Schaaf, and F. Gao, 2004: Spatially complete global spectral surface albedos: Value-Added datasets derived from *Terra* MODIS land products. *IEEE Trans. Geosci. Remote Sens.*, 43:144-158, 2004.
- Schaaf, C. B., Feng Gao, Alan H. Strahler, W. Lucht, X. Li, T. Tsang, N. Strugnell, X. Zhang, Y. Jin, J.-P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts, M. Dunderdale, C. Doll, R.P. D'Entremont, B. Hu, S. Liang, J.L. Privette and D. Roy. First Operational BRDF, Albedo and Nadir Reflectance Products from MODIS, *Remote Sens. Environ.*, 83:135-148, 2002.

3. INTRODUCTION

3.1 Objective/Purpose

The MODIS Bidirectional Reflectance Distribution Function (BRDF)/Albedo Product (MOD43B) provides measures of clear sky surface albedo every 16 days. Both white-sky albedo (bi-hemispherical reflectance) and black-sky albedo (directional hemispherical reflectance) at local solar noon are provided for 7 spectral bands and 3 broadbands (the narrowband to broadband conversion is based on Liang et al. (1999)). Since black-sky albedo represents the direct beam contribution while white-sky represents the completely diffuse contribution, these measures can be linearly combined as a function of the fraction of diffuse skylight (itself a function of optical depth) to provide an instantaneous albedo at local solar noon.

Cloud cover, which curtails retrievals, and the presence of ephemeral and seasonal snow limit the snow-free data to approximately half the global land surfaces on an annual equal-angle basis. An ecosystem-dependent temporal interpolation technique was developed to fill any missing or seasonally snow-covered data in the official MOD43B3 albedo product. The resulting dataset maintains the original resolution and data of the MOD43B3 product while replacing fill values to provide snow-free spatially complete maps.

3.2 Summary of Parameters

For this ISLSCP Initiative II data collection, snow-free, spatially complete 16-day global black-sky albedos at local solar noon, white-sky albedos and quality information based on MOD43B3 data are provided for 7 spectral bands (MODIS channels 1-7; centered at 648 nm, 858 nm, 555 nm, 1240 nm, 1640 nm, and 2130 nm, respectively) and 3 broadbands (0.3-0.7 μm , 0.7-5.0 μm , and 0.3-5.0 μm) for a full year of MODIS data (2002). The quality information in this case provides a percentage of the filled values to the total number of observations in each grid cell. The data are based on the so-called "collection 4" processing of the MODIS data.

3.3 Discussion

Measures of 1km snow-free spatially complete surface albedo from MODIS surface albedo are derived every 16 days. These albedos have been scaled to quarter-, half- and one-degree spatial resolutions for ISLSCP Initiative II. Products included here represent the collection 4 data from January 2002 through December 2002. See Lucht et al. (2000a), Schaaf et al. (2002), and Moody et al. (2004) for specifics. We note that the original MOD43B3 albedo data used to produce this data set are also available in this ISLSCP Initiative II data collection at the same spatial resolutions of $\frac{1}{4}$ degree, $\frac{1}{2}$ degree and 1 degree.

4. THEORY OF ALGORITHM/MEASUREMENTS

The MODIS instrument was launched on board NASA's *Terra* Spacecraft on 18 December 1999 and began acquiring imagery of the Earth in February 2000. The official MODIS BRDF/Albedo Product (MOD43B) relies on multi-spectral, multi-date, cloud-cleared, atmospherically-corrected surface reflectances and a kernel-driven semiempirical BRDF model (RossThick-LiSparseReciprocal) to derive the Bidirectional Reflectance Distribution Function (BRDF) associated with each 1km gridded pixel of land surface (Roujean et al. 1992; Ross 1981; Li and Strahler 1992). These BRDFs are then used to compute the wholly diffuse white-sky albedo (bihemispherical reflectance) and the direct beam black-sky albedo (directional hemispherical reflectance) at local solar noon (Lucht et al. 2000; Schaaf et al. 2002).

Spatial gaps in observations due to cloud cover, which curtails retrievals, and the presence of ephemeral and seasonal snow limit the snow-free data to approximately half the global land surfaces on an annual equal-angle basis. An ecosystem-dependent temporal interpolation technique was developed to fill these missing data in the official MOD43B3 albedo product. The method imposes pixel-level and local regional ecosystem-dependent phenological behavior onto retrieved pixel temporal data in such a way as to maintain pixel-level spatial and spectral detail and integrity. The phenological curves are derived from statistics based on the MODIS MOD12Q1 International Geosphere-Biosphere Programme (IGBP) land cover classification product geolocated with the MOD43B3 data. The resulting dataset maintains the original resolution and data of the MOD43B3 product while replacing fill values to provide snow-free spatially complete maps. These value-added albedo products have been scaled to quarter degree, half degree and one degree spatial resolutions for use by the modeling community.

5. EQUIPMENT

5.1 Instrument Description

The MODIS instrument provides high radiometric sensitivity (12 bit) in 36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm . For more details about the MODIS instrument see: <http://modis.gsfc.nasa.gov/about/specifications.php>

5.1.1 Platform (Satellite, Aircraft, Ground, Person)

The MODIS scanning spectroradiometer is being flown on board both the *Terra* (morning equatorial crossing) and *Aqua* (afternoon equatorial crossing) satellite platforms. Only data from the *Terra* platform were used here.

5.1.2 Mission Objectives

MODIS' objective is to provide a comprehensive series of global observations of the Earth's land, oceans, and atmosphere in the visible and infrared regions of the spectrum in such a way as to view the entire surface of the Earth every two days. Here, the word "comprehensive" refers to the wide spectral range and spatial coverage, as well as the continuous coverage MODIS provides over time.

5.1.3 Key Variables

See above web site for more information.

5.1.4 Principles of Operation

See above web site for more information.

5.1.5 Instrument Measurement Geometry

A ± 55 degree cross-track scanning pattern with an orbit altitude of 705 km achieves a 2,330-km swath width and provides global coverage every one to two days.

5.1.6 Manufacturer of Instrument

Raytheon/Santa Barbara Research, Santa Barbara, CA.

5.2 Calibration

See the following web site for details on MODIS calibration:

[j wr <lo qf ku0 uhe0pcue0 qx lcdqwl](http://www.srl.caltech.edu/ISLSCP/ISLSCP2/ISLSCP2DataCollection/ISLSCP2DataCollection.html)

5.2.1 Specifications

5.2.1.1 Tolerance

See web site above.

5.2.2 Frequency of Calibration

See web site above.

5.2.3 Other Calibration Information

See web site above.

6. PROCEDURE

6.1 Data Acquisition Methods

MODIS Top-Of-Atmosphere (TOA) directional radiances are available from the Goddard Distributed Active Archive Center (DAAC) as are Level 2 Surface Reflectances (product MOD09). Gridded Level 2G and 3 surface reflectances are available from the Ncpf "Rtqeguugu (NR) DAAC. MODIS Level 3 one km and quarter degree albedos and one km nadir BRDF adjusted surface reflectances are also available from the NR DAAC.

Multiple years of the snow-free spatially complete albedo products are available at <http://modis-atmos.gsfc.nasa.gov/ALBEDO/index.html>. Those products have been gridded onto a 1-minute (2 km at the equator) equal-angle climate modeling grid.

6.2 Spatial Characteristics

6.2.1 Spatial Coverage

The coverage is global. The data in the files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North. No data are provided over Polar Regions during the northern/southern hemisphere winters due to low solar zenith angles. The size of the areas with no data varies with solar zenith angle.

6.2.2 Spatial Resolution

The data are given in an equal-angle lat/long (geographical) grid. This data set contains data in the same grid but at three spatial resolutions of 1 by 1 degree lat/long, 0.5 by 0.5 degree lat/long, and 0.25 by 0.25 degree lat/long.

6.3 Temporal Characteristics

6.3.1 Temporal Coverage

Data are provided for January 2002 through December 2002.

6.3.2 Temporal Resolution

Data are provided every 16 days.

7. OBSERVATIONS

7.1 Field Notes

Not applicable to this data set.

8. DATA DESCRIPTION

8.1 Table Definition with Comments

Not applicable to this data set.

8.2 Type of Data

8.2.1 Parameter/ Variable Name	8.2.2 Parameter/ Variable Description	8.2.3 Data Range	8.2.4 Units of Measurement	8.2.5 Data Source
Snow-Free Spatially Complete White Sky Albedo	White sky albedo under entirely diffuse solar illumination conditions for MODIS bands 1-7 and 3 broadband. Data derived from Terra MODIS data using phenological interpolation technique.	Min: 0 Max: 1 Water=-99 No Data over land=-88	unitless	MODIS MOD43B3

Snow-Free Spatially Complete Black Sky Albedo	technique. Surface black-sky albedo at local solar noon derived from MODIS multirate surface reflectances in bands 1-7 and 3 broadbands. Albedo is the fraction of incident solar radiation that a surface reflects -- in this case a direct beam solar illumination condition.	Min: 0 Max:1 Water=-99 No Data over land=-88	unitless	MODIS MOD43B3
Albedo Quality Information	Percentage of original MOD43B3 data per grid cell	Min: 0 Max: 100 Water=-99 No Data over land=-88	Percent	MODIS MOD43B3

8.3 Sample Data Record

Not applicable to this data set.

8.4 Data Format

All of the files in the ISLSCP Initiative II data collection are in the standard ArcGIS ASCII Grid format. The file format consists of numerical fields of varying length, which are delimited by a single space and arranged in columns and rows. The files at different spatial resolutions each contain the following numbers of column and rows:

- 30 degree: 360 columns by 180 rows
- 20 degree: 720 columns by 360 rows
- 207 degree: 1440 columns by 720 rows

All files are gridded to a common equal-angle lat/long grid, where the coordinates of the upper left corner of the files are located at 180 degreesW, 90 degrees N and the lower right corner coordinates are located at 180 degrees E, 90 degrees S. Data in the files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North. The files have all had the ISLSCP II land/water mask applied to them. Water bodies are encoded as -99 and any missing data over land as -88.

The multi-spectral albedo files are all stored as real number values from 0 to 1 and the albedo quality information files are all stored with values from 0 to 100. Each pixel corresponds to the same pixel in the multi-spectral albedo files for each measurement period. The value describes the percentage of original MOD43B3 data contained in each grid cell.

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8.5 Related Data Sets

There are multiple albedo data sets in the ISLSCP Initiative II data collection, each with specific temporal and/or spatial attributes. Users should refer to Hall et al. (2006) for a more in depth discussion of these products. Other albedo data sets in this collection include the official MODIS albedo product (MOD43B3) for 2002, an albedo product for February and July 1995 from the Advanced Very High Resolution Tcfkqo gvgt "CXJ TT+'c'7/{gct'CXJ TT"crldgf q'erko cvqmqi {'r tqf wegf "d{'P QCC/P GUF KU"

(National Environmental Satellite Data and Information Service), coarse scale albedos from the Earth Radiation Budget Experiment (ERBE) and a snow-free albedo produced using the FASIR-NDVI (Fourier-Adjusted, Sensor and Solar zenith angle corrected, Interpolated, Reconstructed-Normalized Difference Vegetation Index) data set.

9. DATA MANIPULATIONS

9.1 Formulas

For details on the original MOD43B3 data from which the snow-free spatially complete product is derived from, refer to Lucht et al. (2000a) and Schaaf et al. (2002). For the MOD43B3 product, the semiempirical kernel driven BRDF model represents the weighted sum of an isotropic parameter (fiso) and two functions (or kernels) of viewing and illumination geometry. One of these kernels (Kvol) is derived from volume scattering radiative transfer models, while the other (Kgeo) is derived from surface scattering and geometric shadow casting theory. The BRDF parameters (fiso, fvol, and fgeo) computed are the spectrally dependent weights of each of these kernels used in forming the overall reflectance (R):

$$R = fiso + fvol Kvol + fgeo Kgeo \quad (1)$$

9.1.1 Derivation Techniques/Algorithms

As described in Section 4, MODIS clear sky surface reflectances are accumulated over a 16-day period and used with a BRDF model to characterize the spectral BRDF associated with each land surface location at a 1km resolution. Once the BRDF has been determined, it is integrated over all view angles to compute the black-sky albedo and additionally over all solar angles to compute the wholly diffuse white sky albedo. The spectral albedos are converted to broadband albedos with narrow to broadband factors based on the modeling work of Liang et al. (1999).

To create the snow-free spatially complete maps, an ecosystem-dependent temporal interpolation technique was developed to fill missing or seasonally snow-covered data in the official MOD43B3 albedo product. The method imposes pixel-level and local regional ecosystem-dependent phenological behavior onto retrieved pixel temporal data in such a way as to maintain pixel-level spatial and spectral detail and integrity (see Moody et al. 2004). The phenological curves are derived from statistics based on the MODIS MOD12Q1 IGBP land cover classification product geolocated with the MOD43B3 data. These 1 km products have then been scaled up to 1 degree, half degree and quarter degree and provided on a global geographical (lat/lon) grid.

9.2 Data Processing Sequence

Multi-spectral, multi-date, cloud-free, atmospherically corrected, directional reflectances from each 16-day period are used to derive the official MODIS surface albedos, MOD43B3. For MOD43B3, if insufficient high quality observations are available (due to cloud cover etc.) to perform a full inversion, an a priori determination of the shape of the surface BRDF is coupled with the available surface reflectances to derive the surface BRDF and albedos (see Strugnell and Lucht, 2001; Strugnell et al. 2001 for a description of the a priori BRDF database).

The snow-free spatially complete surface albedo maps are derived from the collection 4 MOD43B3 product as described in Moody et al. (2004).

9.2.1 Processing Steps and Data Sets

For MOD43B3, see Lucht et al. (2000a) and Schaaf et al. (2002). For the snow-free spatially complete product processing see Moody et al. (2004).

9.2.2 Processing Changes

The products provided here represent the first processing of the snow-free spatially complete albedo products, derived from MOD43B3 data.

9.2.3 Additional Processing by the ISLSCP II Staff

All of these files were processed using the ISLSCP Initiative II land/water masks for consistency. However, a small number of cells in this data set still did not match with the land portion of the land/sea mask and were filled either from the ISLSCP Initiative II version of the MODIS albedo (used to construct this data set), or by averaging from neighboring cells. In cases of missing data over land with actual values in the MODIS albedo data set, the cells of this spatially-complete data set were filled directly from the MODIS albedo data set for ISLSCP II. In cases with missing data over land on both the spatially-complete and standard MODIS albedo products, the cells were filled from the average albedo of all surrounding cells. Users wishing to replicate these points should compare the quality information layers with the data and with the MODIS albedo data as well. Any filled point will have an albedo value ≥ 0 and the quality information will be -88.000 (i.e. missing data over land).

9.3 Calculations

The snow-free spatially complete albedo products are stored on 1-minute equal-angle grids. For inclusion in the ISLSCP Initiative II collection, mean values were computed from all minute pixels within quarter/half/one degree grid cells. The QA stored on quarter/half/one degree grid cells contains the percentage of data that was original MOD43B3 data.

9.3.1 Special Corrections/Adjustments

The original MOD43B3 data and the snow-free spatially complete albedo data provide both the direct beam (black-sky) albedo at local solar noon and wholly diffuse (white-sky) albedo. As these represent the two atmospheric extremes, the albedo under a particular atmospheric condition at local solar noon can be modeled quite accurately as an interpolation between the two as a function of the fraction of diffuse skylight (which is a function of optical depth). For specifics see Lucht et al. (2000a) and Schaaf et al. (2002).

9.4 Graphs and Plots

See Moody et al. (2004).

10. ERRORS

10.1 Sources of Error

Errors in MOD43B3 clear-sky albedo come from cloud contamination of the scene, instrument errors, and uncertainties in the models used in modeling the BRDF. Errors in producing the snow-free spatially complete albedo products come from the errors in the original MOD43B3 product as well as uncertainty in describing the phenological temporal trends that are used to fill missing values in the MOD43B3 product.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The MODIS Albedo product (MOD43B3) was validated with field campaigns in Beltsville, MD, USA (Liang et al. 2002); Barton Bendish, UK; Mongu Zambia; Skukuza, South Africa; and Liangchen, Shunyi and Yucheng, China. Pre-launch validation activities are described in Lucht et al. (2000b) and Barnsley et al. (2000).

An estimate of the snow-free spatially complete albedo product technique's error for cloud covered cases can be produced by simulating cloud cover for validated MOD43B3 pixels that have nearly complete temporal coverage. With such an approach, pixel-level errors (residuals) can be defined as the difference between the original validated MOD43B3 values and the simulated cloud cover values filled with the temporal interpolation technique. This error estimate is described in Moody et al. (2004).

10.2.2 Confidence Level/Accuracy Judgment

See Lucht (1998), Lucht and Lewis (2000), and Moody et al. (2004) for more details.

10.2.3 Measurement Error for Parameters and Variables

See Lucht (1998), Lucht and Lewis (2000), and Moody et al. (2004) for more details.

10.2.4 Additional Quality Assessment Applied

Not available at this revision.

11. NOTES

11.1 Known Problems with the Data

The original MOD43B3 data have been assigned a validated status. The dark target atmospheric correction applied to the TOA radiances is not used over snow surfaces and other very bright surfaces. Instead a uniform optical depth value is used to represent aerosols over these regions. The QA quality flags assigned to each location take into consideration the quality of the input surface reflectances.

The snow-free spatially complete products have not been validated. Areas where there are persistent clouds (tropics) and seasonally snow-impacted regions are particularly difficult to describe phenologically. The QA quality flags assigned to each location describe the state of the original MOD43B3 data as well as processing efforts. These flags are available in the companion MODIS Albedo data set for 2002, also available in this ISLSCP Initiative II collection.

11.2 Usage Guidance

Usage guidance for the snow-free spatially complete albedo product is provided at <http://modis-atmos.gsfc.nasa.gov/ALBEDO/index.html>. For user guidance on the MODIS albedo products see <http://geography.bu.edu/brdf/userguide/index.html>. The ISLSCP Initiative II albedo overview document and Hall et al. (2006) provide useful information on the various albedo data sets available in the collection

11.3 Other Relevant Information

None.

12. REFERENCES

12.1 Satellite/Instrument/Data Processing Documentation

<http://modis-atmos.gsfc.nasa.gov/ALBEDO/index.html>

<http://modis-atmos.gsfc.nasa.gov/>

<http://geography.bu.edu/brdf/userguide/index.html>

<http://modis.gsfc.nasa.gov/>

<http://modis-land.gsfc.nasa.gov/>

12.2 Journal Articles and Study Reports

- Barnsley, M. J., P. D. Hobson, A. H. Hyman, W. Lucht, J.-P. Muller, and A. H. Strahler, Characterizing the spatial variability of broadband albedo in a semi-desert environment for MODIS validation, *Remote Sens. Environ.*, 74, 58-68, 2000.
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- Ross, J. K., *The Radiation Regime and Architecture of Plant Stands*, Dr W. Junk, Norwell, MA, 392pp, 1981.
- Roujean, J.-L., M. Leroy, and P. Y. Deschamps, A bidirectional reflectance model of the Earth's surface for the correction of remote sensing data, *J. Geophys. Res.*, D-97, 20455-20468, 1992.
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13. DATA ACCESS

13.1 Data Access Information

*****The ISLSCP Initiative II data are archived and distributed through the Oak Ridge National Laboratory (ORNL) DAAC for Biogeochemical Dynamics at <http://daac.ornl.gov>.

13.2 Eqpvcw/hqt 'Archive

G/o ckn^wuqB f cceQtprfl qx
 "*****Vgrgr: j qpg<- 3"*: 87+463/5; 74'"

13.4 Archive/Status/Plans

The ISLSCP Initiative II data are archived at the ORNL DAAC. Vj gtg'ctg'pq'r rpu'q'wr f cvg'yj gug'f cvc0

16. GLOSSARY OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
BRF	Bidirectional Reflectance Factor
BRDF	Bidirectional Reflectance Distribution Function
BSA	Black-Sky Albedo
DAAC	Distributed Active Archive Center
ERBE	Earth Radiation Balance Experiment
FASIR-NDVI	Fourier Adjusted, Solar and view zenith angle correction, Interpolation, and Reconstruction of NDVI
GSFC	Goddard Space Flight Center (NASA)
IGBP	International Geosphere-Biosphere Programme
ISLSCP	International Satellite Land Surface Climatology Project
MODIS	MODerate resolution Imaging Spectroradiometer
MOD43B3	MODIS land surface albedo product
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite Data and Information Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
WSA	White-Sky Albedo