

# **MODIS MCD43 Product User Guide V005**

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## **MODIS MCD43 Product User Guide V005**

This Guide is an archived document that describes the MODIS BRDF and Albedo Products of version 005. The purpose of the document is to give the potential user an understanding of the MCD43 products and the current state of the data in those products.

Note: The V005 MODIS BRDF/Albedo products have been assigned a "Validated (Stage 3) Status". Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications.

### **1 Introduction**

Due to its three dimensional structure, the Earth's surface scatters radiation anisotropically, especially at the shorter wavelengths that characterize solar irradiance. The Bidirectional Reflectance Distribution Function (BRDF) specifies the behavior of surface scattering as a function of illumination and view angles at a particular wavelength. The albedo of a surface describes the ratio of radiant energy scattered upward and away from the surface in all directions to the downwelling irradiance incident upon that surface. The completely diffuse bihemispherical (or white-sky) albedo can be derived through integration of the BRDF for the entire solar and viewing hemisphere, while the direct beam directional hemispherical (or black-sky) albedo can be calculated through integration of the BRDF for a particular illumination geometry. Actual clear sky albedos under particular atmospheric and illumination conditions can be estimated as a function of the diffuse skylight and a proportion between the black-sky and white-sky albedos. The MODerate resolution Imaging Spectroradiometer (MODIS) BRDF/Albedo Science Data Products provide white-sky albedos and black-sky albedos (at local solar noon) as both spectral and broadband quantities (MCD43A3).

The MODIS BRDF/Albedo Product also provides Nadir BRDF-Adjusted Reflectances (NBAR) -- surface reflectances corrected to a common nadir view geometry at the local solar noon zenith angle of the date assigned to product (MCD43A4). These anisotropically-corrected surface reflectances can serve as important inputs for studies using vegetation indices and for land cover classification efforts (they are used directly as the primary input to MOD12Q, the MODIS Land Cover/ Land Cover Dynamics Product).

The BRDF specification itself is supplied to the scientific community as a separate product (MCD43A1) since it is useful in specifying a surface radiation scattering model for boundary layer parameterization of surface vegetation atmospheric transfer schemes in global climate models. With the model weighting parameters (fiso, fvol, fgeo) and a simple polynomial equation, black-sky albedo can be realistically estimated at any solar zenith angle a user may require. And, since the BRDF is an intrinsic property characterizing the structure of the surface, the parameters themselves may also provide biophysical information of interest.

Note: V005 MODIS BRDF/Albedo products from Day 2000065 (5 March 2000 to present) have been assigned a "Validated (Stage 3) Status".

### 1.1 Algorithm

Every 8 days, the operational MODIS BRDF/Albedo algorithm makes use of 16 days' worth of multi-date data from both Terra and Aqua and a semiempirical kernel-driven bidirectional reflectance model to determine a global set of parameters describing the BRDF of the land surface (MCD43A1). These 500m gridded parameters are then used to determine directional hemispherical reflectance ("black-sky albedo"), and bihemispherical reflectance ("white-sky albedo") for seven spectral bands (MODIS channels 1-7) and three broad bands (0.3-0.7 $\mu$ m, 0.7-5.0 $\mu$ m, and 0.3-5.0 $\mu$ m) at the solar zenith of local solar noon (MCD43A3) of the first day of the period. The nadir BRDF-adjusted surface reflectances (NBAR) for the seven spectral bands are also computed for the local solar noon (MCD43A4).

The operational algorithm [1], [2], [3], [4] relies on a combination of the RossThick-LiSparseReciprocal kernels [6] as the semiempirical model used to invert 16 days' worth of aggregated, atmospherically corrected, 500m resolution, MODIS directional surface reflectance data and to fit a BRDF to each land surface pixel. Broad-band values are computed as well [5]. Combined data from the MODIS instruments on board both Aqua and Terra are used (with only Terra data available before mid-2002). The semiempirical kernel-driven BRDF model [7] represents the weighted sum of an iso-tropic 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 [8], while the other (*Kgeo*) is derived from surface scattering and geometric shadow casting theory [9]. The BRDF parameters (*fiso*, *fvol*, *fgeo*) computed in the operational product are the spectrally dependent weights of each of these kernels used in forming the overall anisotropic reflectances:

$$R = fiso + fvol Kvol + fgeo Kgeo$$

When insufficient high quality reflectances are available (currently set to less than seven observations) or a poorly representative sampling of high quality reflectances is obtained (as indicated in the quality flags and determined through weights of determination), it is not possible to perform a full inversion. Instead, use is made of a database of archetypal BRDF parameters [11], [12] to supplement the observational data available and perform a lower quality magnitude inversion.

The MODIS BRDF/Albedo Science Data Products are provided in a Sinusoidal Grid (SIN) projection with standard tiles representing 10degree by 10 degree (2400 by 2400 pixels) on the Earth [12]. While the projection becomes increasingly sheared poleward, the equal area properties of the SIN projection mean that it is a good data storage format and it is possible to convert each tile to other, more common projections through the use of any one of a number of commercial or public software packages. These Level-3 MODIS Land (MODLAND) products are being released in Hierarchical Data Format - Earth Observing System (HDF-EOS) for each of the 10 degree by 10 degree land tiles (see MODIS grids) on the globe (see HDF-EOS FAQ).

The operational product is stored in MCD43A1, A2, A3 & A4, with extensive quality information provided in A2, so that users can reconstruct the processing methodology used for each tile or pixel if they choose. MCD43A2 supplies a per-pixel quality flag indicating whether the algorithm produced results or not for that pixel and if so, whether the result is of the highest quality or whether

(due to some uncertainties in the processing) the user should check the extensive additional product-specific quality assurance to make sure the output is appropriate for their application. Note that the per-pixel data and the quality information are computed for all land and coastal areas and for shallow water regions (pixels that are within 5 km of land OR are less than 50 meters deep). The products and quality flags are not computed for moderate or deep water regions (pixels greater than 5km from land and with water depths greater than 50m). The EOS land-water mask (which is static for Level 1B products) is passed along through the production chain with the reprojection and aggregation of the reflectance data to Level 2GLite and is stored for the user's convenience as bit flags in the per-pixel quality information associated with the MCD43A2 product.

## *1.2 Data Flow*

The Level 2 Surface Reflectance Product (MOD09, MYD09) for MODIS provides daily, cloud-cleared, atmospherically-corrected directional surface reflectances. The data from channels 1-7 are stored in Level 2G lite gridded SIN tiles. This binning occurs on a daily basis and at the higher latitudes, and up to 4 layers of valid data will be used for each pixel for each day. The data from sixteen days' worth of MOD09 (and MYD09) are then used as the primary input for the MCD43 BRDF/Albedo Product. The algorithm fits a BRDF model to these directional surface reflectances and the parameters of the model (RossThick-LiSparseReciprocal) are provided to the community as a Science Data Product (MCD43A1). These same parameters are used to compute the albedo measures provided in MCD43A3 and the NBAR values provided in MCD43A4. These parameters are also produced in a 1km averaged tiled product (MCD43B) in a Sinusoidal Grid projection (although it is not recommended that this product be used as it only represents the average conditions and therefore is a lower quality product). There is also a V005 30 arc-second resolution Climate Modeling Grid (CMG) in a global geographic lat-long projection (MCD43D). Finally there are 0.05 degree resolution Climate Modeling Grid (CMG) Products in a global geographic lat/long projection (MCD43C1, MCD43C2 (snow free BRDF parameters), MCD43C3, MCD43C4). The CMG quality flags only indicate the majority quality of the underlying 30 arc-second data.

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## **2 MODIS MCD43 Specification**

For specification, please visit [ladsweb.nascom.nasa.gov/filespec/collection5/](http://ladsweb.nascom.nasa.gov/filespec/collection5/)

### 3 MCD43A1 BRDF/Albedo Model Parameters Product

The MCD43A1 BRDF/Albedo Model Parameters Product (MODIS/Terra BRDF/Albedo Model\_1 L3 Global 500m SIN Grid) supplies the weighting parameters associated with the RossThickLiSparseReciprocal BRDF model that best describes the anisotropy of each pixel. These three parameters (fiso, fvol, fgeo) are provided for each of the MODIS spectral bands as well as for three broad bands (0.3-0.7µm, 0.7-5.0µm, and 0.3-5.0µm). These parameters can be used in a forward version of the model to reconstruct the surface anisotropic effects and thus correct directional reflectances to a common view geometry (this is the procedure that is used to produce MCD43A4 Nadir BRDF-Adjusted Reflectances - NBAR) or to compute the integrated black-sky (at some solar zenith angle) and white-sky albedos (as are done for MCD43A3). Alternately, the parameters can be used with a simple polynomial to easily estimate the black-sky albedo with good accuracy for any desired solar zenith angle.

The polynomial is as follows:

$$\alpha_{bs}(\Theta, \lambda) = f_{iso}(\lambda) (g_{0iso} + g_{1iso} \Theta_1^2 + g_{2iso} \Theta_1^3) + f_{vol}(\lambda) (g_{0vol} + g_{1vol} \Theta_1^2 + g_{2vol} \Theta_1^3) + f_{geo}(\lambda) (g_{0geo} + g_{1geo} \Theta_1^2 + g_{2geo} \Theta_1^3)$$

The appropriate constants are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
g0	1.0	-0.007574	-1.284909
g1	0.0	-0.070987	-0.166314
g2	0.0	0.307588	0.041840

Similarly, the white-sky albedo can be computed by using the equation:

$$\alpha_{ws}(\lambda) = f_{iso}(\lambda) g_{iso} + f_{vol}(\lambda) g_{vol} + f_{geo}(\lambda) g_{geo}$$

And the estimates of the white-sky kernel integrals are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
White-sky integral g	1.0	0.189184	-1.377622

#### 3.1 Science Data Sets

While the full MCD43A1 specification should be consulted for the most current description, the product includes four Science Data Sets (SDS) for each pixel in the tile. These SDSs are BRDF\_Albedo\_Parameters (three model parameters representing fiso, fvol, fgeo for the RossThickLiSparseReciprocal BRDF model that are computed for bands 1-7 and three broad bands).

### 3.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data. For the BRDF\_Albedo\_Parameters SDS they include:

Name:	Type:	Value:
long_name	HDF-STRING	"BRDF_Albedo_Parameters"
units	HDF-STRING	"no units"
valid_range	HDF-int16	0, 32766
_FillValue	HDF-int16	32767
add_offset	HDF-float64	0.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.001
scale_factor_err	HDF-float64	0.0

### 3.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-pixel level, each tile of the Level 3 MCD43A1 Parameters Product also includes three types of Global Attributes or Metadata which summarize the tile. These are Core, Archive, and Structural Metadata. Of particular interest to the user community are the Core Metadata QAFlags of SCIENCEQUALITYFLAG and SCIENCEQUALITYFLAGEXPLANATION and some of the Additional Attributes which identify the tile number or which summarize the quality of the product over that entire tile (see the full MCD43A1 specification for the complete listing).

## 4 MCD43A2 BRDF/Albedo Quality Product

The MCD43A2 BRDF/Albedo Quality Project provides extensive band independent quality information. [1], [2], [3], [4], [5].

Please refer to the Specification for more information.

<http://ladsweb.nascom.nasa.gov/filespec/collection5/>

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## 5 MCD43A3 Albedo Product

Albedo is defined as the ratio of upwelling to downwelling radiative flux at the surface. Downwelling flux may be written as the sum of a direct component and a diffuse component. Black-sky albedo (directional hemispherical reflectance) is defined as albedo in the absence of a diffuse component and is a function of solar zenith angle. White-sky albedo (bihemispherical reflectance) is defined as albedo in the absence of a direct component when the diffuse component is isotropic. Black-sky albedo and white-sky albedo mark the extreme cases of completely direct and completely diffuse illumination. Actual albedo is a value which is interpolated between these two as a function of the fraction of diffuse skylight which is itself a function of the aerosol optical depth [1], [4], and [8]. The underlying assumption of an isotropic distribution of the diffuse skylight is approximate but avoids the expense of an exact calculation while capturing the major part of the phenomenon [2]. However, for large angles and bright surfaces it's more appropriate to use the full anisotropic expression [8].

The MCD43A3 Albedo Product (MODIS/Terra Albedo L3 Global 500m SIN Grid) provides both the white-sky albedos and the black-sky albedos (at local solar noon) for MODIS bands 1-7 as well as for three broad bands (0.3-0.7 $\mu$ m, 0.7-5.0 $\mu$ m, and 0.3-5.0 $\mu$ m). While the total energy reflected by the earth's surface in the shortwave domain is characterized by the shortwave (0.3-5.0 $\mu$ m) broadband albedo, the visible (0.3-0.7 $\mu$ m) and near-infrared (0.7-5.0 $\mu$ m) broadband albedos are often also of interest due to the marked difference of the reflectance of vegetation in these two spectral regions. Liang et al. [3], Stroeve et al. [9] used observed spectra and numerical simulations to produce the conversion coefficients for MODIS used by the operational algorithm. One should keep in mind that spectral-to-broadband conversion is a function of atmospheric state to the extent that the spectral distribution of the solar downwelling flux depends on atmospheric properties and the solar zenith angle. The conversion coefficients computed by Liang et al. [3], Stroeve et al. [9] are derived for typical average cases. Variations of the exact results with aerosol optical depth and solar zenith angle are small but affect retrieval accuracies on the level of a few percent [4].

### 5.1 Science Data Sets

While the full MCD43A3 specification should be consulted for the most current description, the product includes two Science Data Sets (SDS) for each pixel in the tile. These SDSs are Albedo (containing both black-sky and white-sky values for 10 bands -- 7 spectral and 3 broad).

The Albedo SDS is specified as:

- Data Field Name: INT16 Albedo ("YDim", "XDim", "Num\_Albedo\_Bands", "Num\_Albedos")
- Description: Black-Sky Albedo (at local solar noon) and white-sky albedo for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
  - file data=(Albedo / scale\_factor) + add\_offset
  - Albedo=(file data - add\_offset)\*scale\_factor

## 5.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data. For the Albedo SDS they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Albedo"
units	HDF-STRING	"albedo, no units"
valid_range	HDF-int16	0, 32766
_FillValue	HDF-int16	32767
add_offset	HDF-float64	0.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.001
scale_factor_err	HDF-float64	0.0

## 5.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-pixel level, each tile of the Level 3 MCD43A3 Parameters Product also includes three types of Global Attributes or Metadata which summarize the tile. These are Core, Archive, and Structural Metadata. Of particular interest to the user community are the Core Metadata QAFlags of SCIENCEQUALITYFLAG and SCIENCEQUALITYFLAGEXPLANATION and some of the Additional Attributes which identify the tile number or which summarize the quality of the product over that entire tile (see the full MCD43A1 [specification](#) for the complete listing).

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## 6 MCD43A4 NBAR Product

The MCD43A4 Nadir BRDF-Adjusted Reflectance (NBAR) Product (MODIS/Terra Nadir BRDF-Adjusted Reflectance L3 Global 500m SIN Grid) is computed for each of the MODIS spectral bands (1-7) at local solar noon of the first day of the 16 days. Since the view angle effects will have been removed from the directional reflectances, this will result in a more stable and consistent product. NBAR values are being directly used as the primary input to the advanced technique classifiers used in the production of the global MODIS Land Cover Product MCD12Q1 [1]. The user community has been taking advantage of the NBAR data for those situations where composited surface reflectances were traditionally used.

Note: Reprocessed (V005) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000 to present) have been assigned a ["Validated \(Stage 3\) Status"](#).

### 6.1 Science Data Sets

While the full MCD43A4 specification should be consulted for the most current description, the product includes two Science Data Sets (SDS) for each pixel in the tile. These SDSs are Nadir\_Reflectance (computed for bands 1-7 at the local solar noon zenith angle) and is defined in the specification.

The Nadir\_Reflectance SDS is specified as:

- Data Field Name: INT16 Nadir\_Reflectance ("YDim", "XDim", "Num\_Land\_Bands")
- Description: Nadir BRDF-adjusted reflectance (NBAR) at mean szn of the period
- Data conversions:
  - $\text{file data} = (\text{Nadir\_Reflectance} / \text{scale\_factor}) + \text{add\_offset}$
  - $\text{Nadir\_Reflectance} = (\text{file data} - \text{add\_offset}) * \text{scale\_factor}$

### 6.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data. For the Nadir\_Reflectance SDS they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Nadir_Reflectance"
units	HDF-STRING	"reflectance, no units"
valid_range	HDF-int16	0, 32766
_FillValue	HDF-int16	32767
add_offset	HDF-float64	0.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.0001

scale_factor_err	HDF-float64	0.0
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### 6.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-pixel level, each tile of the Level 3 MCD43A4 Parameters Product also includes three types of Global Attributes or Metadata which summarize the tile. These are Core, Archive, and Structural Metadata. Of particular interest to the user community are the Core Metadata QAFlags of SCIENCEQUALITYFLAG and SCIENCEQUALITYFLAGEXPLANATION and some of the Additional Attributes which identify the tile number or which summarize the quality of the product over that entire tile (see the full MCD43A4 specification for the complete listing).

#### References Cited

1. Friedl, M. A., D. Muchoney, D. McIver, F. Gao, J. F. C. Hodges and A. H. Strahler, Characterization of North American land cover from NOAA-AVHRR data using the EOS MODIS land cover classification algorithm, *Geophys. Res. Let.*, 27, 977, 2000.
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4. Lucht, W., Expected retrieval accuracies of bidirectional reflectance and albedo from EOS-MODIS and MISR angular sampling, *J. Geophys. Res.*, 103, 8763-8778, 1998.
5. Lucht, W., and P. Lewis. Theoretical noise sensitivity of BRDF and albedo retrieval from the EOS-MODIS and MISR sensors with respect to angular sampling, *Int. J. Remote Sensing*, 21, 81-98, 2000.

## **7 MCD43B1 BRDF-Albedo Model Parameters 16-Day L3 Global 1km**

The MODerate-resolution Imaging Spectroradiometer (MODIS) BRDF/Albedo Model Parameters product (MCD43B1) contains three-dimensional (3D) data sets -- representing averages of the underlying 500m values and providing users with weighting parameters for the anisotropy models used to derive the Albedo and NBAR products (MCD43B3 and MCD43B4). The models support the spatial relationship and parameter characterization best describing the differences in radiation due to the scattering (anisotropy) of each pixel, relying on multi-date, atmospherically corrected, and cloud-cleared input data measured over 16-day periods.

The BRDF/Albedo Model Parameters can be used with a simple polynomial to easily estimate the black-sky albedo with good accuracy for any desired solar zenith angle. BRDF shape and properties are further described by the shape indicators included in the product.

Both Terra and Aqua data are used in the generation of this product, providing the highest probability for quality input data and designating it as an MCD, meaning Combined, product. Version-5 MODIS BRDF & Albedo products have attained Validation Stage 3.

## **8 MCD43B2 BRDF-Albedo Quality 16-Day L3 Global 1km**

The MODerate-resolution Imaging Spectroradiometer (MODIS) BRDF/Albedo Quality product (MCD43B2) describes the overall condition of the other BRDF and Albedo products. The MCD43B2 product includes albedo quality, snow conditions, ancillary information, and inversion status of the majority of the underlying 500m pixels.

Both Terra and Aqua data are used in the generation of this product, providing the highest probability for quality input data and designating it as an "MCD," meaning "Combined," product.

Version-5 MODIS BRDF & Albedo products have attained Validation Stage 3.

## **9 MCD43B3 Albedo 16-Day L3 Global 1km**

The MODerate-resolution Imaging Spectroradiometer (MODIS) Albedo product (MCD43B3) provides 1-kilometer data describing both directional hemispherical reflectance (black-sky albedo) at local solar noon and bihemispherical reflectance (white-sky albedo). These MCD43B3 albedo quantities are produced from the 16-day anisotropy models provided in MCD43B1. If black-sky albedos at different solar zenith angles are required then the MCD43B1 values should be used directly to generate them. The MCD43B3 albedo quantities are provided as a level-3 gridded product in the Sinusoidal projection.

Both Terra and Aqua data are used in the generation of this product, providing the highest probability for quality input data and designating it as an "MCD," meaning "Combined," product.

Version-5 MODIS BRDF & Albedo products have attained Validation Stage 3.

## **10 MCD43B4 Nadir BRDF- Adjusted Reflectance Reflectance 16-Day L3 Global 1km**

The MODerate-resolution Imaging Spectroradiometer (MODIS) Nadir BRDF Adjusted Reflectance (NBAR) product MCD43B4 provides 1-kilometer reflectance data adjusted using the bidirectional reflectance distribution function (BRDF) of MCD43B1 to model values as if they were acquired from a nadir view. MCD43B4 reflectance represents that best characterization of the surface possible from the inputs available over a 16-day period. If observations at view and illumination angles other than nadir are required, the MCD43B1 models should be used directly in the BRDF Forward Model. The MCD43B4 NBAR quantities are provided as a level-3 gridded product in the Sinusoidal projection.

Both Terra and Aqua data are used to generate this product, providing the highest probability for quality input data and designating it as an "MCD," meaning "Combined," product.

Version-5 MODIS BRDF and Albedo products have attained Validation Stage 3.

## **11 MCD43C1 CMG BRDF/Albedo Model Parameters Product**

The MCD43C1 Climate Modeling Grid (CMG) BRDF/Albedo Model Parameters Product (MODIS/Terra BRDF/Albedo Parameters L3 Global 0.05Deg CMG) supplies the weighting parameters associated with the RossThickLiSparseReciprocal BRDF model that best describes the anisotropy of each pixel. These three parameters (*fiso*, *fvol*, *fgeo*) are provided for each of the MODIS spectral bands as well as for three broad bands (0.3-0.7 $\mu$ m, 0.7-5.0 $\mu$ m, and 0.3-5.0 $\mu$ m) at a 0.05 degree spatial resolution in global files in a geographic (lat/long) projection. These model parameters are based on the underlying 30arcsecond model parameters. Note that along coastlines, this means that the 30arcsecond pixels that lie over shallow water will be averaged into the 0.05 degree CMG pixel. In addition to the spectral and broadband parameters themselves, the MCD43C1 CMG BRDF/Albedo Model Parameters Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 30arcsecond pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered. The uncertainty layer gives the quality of the full inversion from the measure of the angular sampling of input surface reflectance for the BRDF retrieval.

These parameters can be used in a forward version of the model to reconstruct the surface anisotropic effects and thus correct directional reflectances to a common view geometry (this is the procedure that is used to produce MCD43A4 Nadir BRDF-Adjusted Reflectances - NBAR) or to compute the integrated black-sky (at some solar zenith angle) and white-sky albedos (as is done for MCD43A3). Alternately, the parameters can be used with a simple polynomial to easily estimate the black-sky albedo with good accuracy for any desired solar zenith angle [1], [2]. The polynomial is as follows:

$$\alpha_{bs}(\Theta, \lambda) = f_{iso}(\lambda) (g_{0iso} + g_{1iso} \Theta_1^2 + g_{2iso} \Theta_1^3) + f_{vol}(\lambda) (g_{0vol} + g_{1vol} \Theta_1^2 + g_{2vol} \Theta_1^3) + f_{geo}(\lambda) (g_{0geo} + g_{1geo} \Theta_1^2 + g_{2geo} \Theta_1^3)$$

The appropriate constants are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
g0	1.0	-0.007574	-1.284909
g1	0.0	-0.070987	-0.166314
g2	0.0	0.307588	0.041840

Similarly, the white-sky albedo can be computed by using the equation:

$$\alpha_{ws}(\lambda) = f_{iso}(\lambda) g_{iso} + f_{vol}(\lambda) g_{vol} + f_{geo}(\lambda) g_{geo}$$

And the estimates of the white-sky kernel integrals are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
White-sky integral g	1.0	0.189184	-1.377622

### 11.1 Science Data Sets

While the [full MCD43C1 specification](#) should be consulted for the most current description, the product includes four Science Data Sets (SDS) for each pixel in the tile. These SDSs are BRDF\_Albedo\_Parameter0, BRDF\_Albedo\_Parameter1, and BRDF\_Albedo\_Parameter2 representing the three model parameters fiso, fvol, fgeo for the RossThickLiSparseReciprocal BRDF model (each for bands 1-7 and three broad bands), and BRDF\_Albedo\_Quality. They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 10 bands)).

### 11.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data. For the BRDF\_Albedo\_Parameter\* SDS they include:

For the BRDF\_Albedo\_Quality SDS, they include:

Name:	Type:	Value:
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long_name	HDF-STRING	"BRDF_Isotropic_Weight (or BRDF_Volumetric_Weight or BRDF_Geometric_Weight)"
units	HDF-STRING	"no units"
valid_range	HDF-int16	0, 32766
_FillValue	HDF-int16	32767
add_offset	HDF-float64	0.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.001
scale_factor_err	HDF-float64	0.0

For the BRDF\_Albedo\_Quality SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Aggregated_Albedo_Quality"
units	HDF-STRING	"concatenated flags"
valid_range	HDF-uint32	0, 4294967294
_FillValue	HDF-uint32	4294967295

### 11.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-cmg-pixel level, each Level 3 MCD43C1 CMG Albedo Product also Metadata which summarize the file (see the [full MCD43C1 specification](#) for the complete listing).

#### References Cited

Schaaf, C. L. B., J. Liu, F. Gao and A. H. Strahler, MODIS Albedo and Reflectance Anisotropy Products from Aqua and Terra, In Land Remote Sensing and Global Environmental Change: NASA's Earth Observing System and the Science of ASTER and MODIS, Remote Sensing and Digital Image Processing Series, Vol.11, B. Ramachandran, C. Justice, M. Abrams, Eds, Springer-Cerlag, 873 pp.,2011.

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## 12 MCD43C2 CMG BRDF/Albedo Model Snow-Free Parameters Product

The MCD43C2 Climate Modeling Grid (CMG) BRDF/Albedo Model Snow-Free Quality Parameters Product (MODIS/Terra BRDF/Albedo Snow Free Quality Parameters L3 Global 0.05Deg CMG) supplies the weighting parameters associated with the RossThickLiSparseReciprocal BRDF model that best describes the anisotropy of each pixel. These three parameters (*fiso*, *fvol*, *fgeo*) are provided for each of the MODIS spectral bands as well as for three broad bands (0.3-0.7 $\mu$ m, 0.7-5.0 $\mu$ m, and 0.3-5.0 $\mu$ m) at a 0.05 degree spatial resolution in global files in a geographic (lat/long) projection. These model parameters are based on the underlying 30arcsecond model parameters. Note that along coastlines, this means that the 30arcsecond pixels that lie over shallow water will be averaged into the 0.05 degree CMG pixel. In addition to the spectral and broadband parameters themselves, the MCD43C2 CMG BRDF/Albedo Model Parameters Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 30arcsecond pixels is provided as well as the percentage of the underlying pixels that were present.

These parameters can be used in a forward version of the model to reconstruct the surface anisotropic effects and thus correct directional reflectances to a common view geometry (this is the procedure that is used to produce MCD43A4 Nadir BRDF-Adjusted Reflectances - NBAR) or to compute the integrated black-sky (at some solar zenith angle) and white-sky albedos (as is done for MCD43A3). Alternately, the parameters can be used with a simple polynomial to easily estimate the black-sky albedo with good accuracy for any desired solar zenith angle [1], [2]. The polynomial is as follows:

$$\alpha_{bs}(\Theta, \lambda) = f_{iso}(\lambda) (g_{0iso} + g_{1iso} \Theta_1^2 + g_{2iso} \Theta_1^3) + \\ f_{vol}(\lambda) (g_{0vol} + g_{1vol} \Theta_1^2 + g_{2vol} \Theta_1^3) + \\ f_{geo}(\lambda) (g_{0geo} + g_{1geo} \Theta_1^2 + g_{2geo} \Theta_1^3)$$

The appropriate constants are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
g <sub>0</sub>	1.0	-0.007574	-1.284909
g <sub>1</sub>	0.0	-0.070987	-0.166314
g <sub>2</sub>	0.0	0.307588	0.041840

Similarly, the white-sky albedo can be computed by using the equation:

$$\alpha_{ws}(\lambda) = f_{iso}(\lambda) g_{iso} + f_{vol}(\lambda) g_{vol} + f_{geo}(\lambda) g_{geo}$$

And the estimates of the white-sky kernel integrals are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
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White-sky integral g	1.0	0.189184	-1.377622
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### 12.1 Science Data Sets

While the [full MCD43C1 specification](#) should be consulted for the most current description, the product includes four Science Data Sets (SDS) for each pixel in the tile. These SDSs are BRDF\_Albedo\_Parameter0, BRDF\_Albedo\_Parameter1, and BRDF\_Albedo\_Parameter2 representing the three model parameters fiso, fvol, fgeo for the RossThickLiSparseReciprocal BRDF model (each for bands 1-7 and three broad bands), and BRDF\_Albedo\_Quality. They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 10 bands)).

### 12.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data. For the BRDF\_Albedo\_Parameter\* SDS they include:

For the BRDF\_Albedo\_Quality SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"BRDF_Isotropic_Weight (or BRDF_Volumetric_Weight or BRDF_Geometric_Weight)"
units	HDF-STRING	"no units"
valid_range	HDF-int16	0, 32766
_FillValue	HDF-int16	32767
add_offset	HDF-float64	0.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.001
scale_factor_err	HDF-float64	0.0

For the BRDF\_Albedo\_Quality SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Aggregated_Albedo_Quality"
units	HDF-STRING	"concatenated flags"
valid_range	HDF-uint32	0, 4294967294
_FillValue	HDF-uint32	4294967295

### *12.3 Global Attributes (Metadata)*

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-cmg-pixel level, each Level 3 MCD43C2 CMG Albedo Product also Metadata which summarize the file (see the [full MCD43C2 specification](#) for the complete listing).

#### *References Cited*

Schaaf, C. L. B., J. Liu, F. Gao and A. H. Strahler, MODIS Albedo and Reflectance Anisotropy Products from Aqua and Terra, In Land Remote Sensing and Global Environmental Change: NASA's Earth Observing System and the Science of ASTER and MODIS, Remote Sensing and Digital Image Processing Series, Vol.11, B. Ramachandran, C. Justice, M. Abrams, Eds, Springer-Cerlag, 873 pp.,2011.

Gao, F., C. Schaaf, A. Strahler, A. Roesch, W. Lucht, and R. Dickinson, The MODIS BRDF/Albedo Climate Modeling Grid Products and the Variability of Albedo for Major Global Vegetation Types, J. Geophys. Res., 110, D01104, doi: 10.1029/2004JD00519, 2005.

Schaaf, C. B., F. Gao, A. H. Strahler, W. Lucht, X. Li, T. Tsang, N. C. Strugnell, X. Zhang, Y. Jin, J.-P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts, M. Dunderdale, C. Doll, R. d'Entremont, B. Hu, S. Liang, and J. L. Privette, First Operational BRDF, Albedo and Nadir Reflectance Products from MODIS, Remote Sens. Environ., 83, 135-148, 2002.

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.

## 13 MCD43C3 CMG Albedo Product

The MCD43C3 Climate Modeling Grid (CMG) Albedo Product (MODIS/Terra Albedo L3 Global 0.05Deg CMG) provides both the white-sky albedos and the black-sky albedos (at local solar noon) for MODIS bands 1-7 as well as for three broad bands (0.3-0.7 $\mu$ m, 0.7-5.0 $\mu$ m, and 0.3-5.0 $\mu$ m) at a 0.05 degree spatial resolution in global files in a geographic (lat/long) projection. These albedo values calculated from MCD43C1. Note that along coastlines, this means that the 30arcsecond pixels that lie over shallow water will be averaged into the 0.05 degree CMG pixel. In addition to the spectral and broadband albedo quantities themselves, the MCD43C3 CMG Albedo Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 30arc pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered.

### 13.1 Science Data Sets

While the [full MCD43C3 specification](#) should be consulted for the most current description, the product includes data sets for each cmg-pixel in the tile. These data sets include the Black-Sky Albedo (at local solar noon), White-Sky Albedo (both for 10 bands -- 7 spectral and 3 broad bands) and a number of Albedo Quality and Uncertainty flags. They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 10 bands)).

### 13.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data.

### 13.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-cmg-pixel level, each Level 3 MCD43C3 CMG Albedo Product also Metadata which summarize the file (see the [full MCD43C3 specification](#) for the complete listing).

## 14 MCD43C4 CMG NBAR Product

The MCD43C4 Climate Modeling Grid (CMG) Nadir BRDF-Adjusted Reflectance (NBAR) Product (MODIS/Terra Nadir BRDF-Adjusted Reflectance L3 Global 0.05Deg CMG) is computed for each of the MODIS spectral bands (1-7) at the local solar noon zenith angle. The data are provided in global files in a geographic (lat/long) projection. Since the view angle effects have been removed from the directional reflectances, the result is a stable and consistent reflectance product. These NBAR values are calculated from MCD43C1. Note that along coastlines, this means that the 30arcsecond pixels that lie over shallow water will be averaged into the 0.05 degree CMG pixel. In addition to the spectral and broadband albedo quantities themselves, the MCD43C4 CMG NBAR Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 30arcsecond pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered.

### 14.1 Science Data Sets

While the [full MCD43C4 specification](#) should be consulted for the most current description, the product includes Nadir Reflectance (NBAR) at the local solar noon zenith angle for 7 spectral bands. They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 7 bands)).

### 14.2 Local Attributes

In addition to the actual SDS data values produced at each pixel in a tile, each SDS is associated with a number of standard Local Attributes that apply to the data.

### 14.3 Global Attributes (Metadata)

In addition to the albedo and quality information (SDSs and Local Attributes) that is provided at a per-cmg-pixel level, each Level 3 MCD43C4 CMG Albedo Product also Metadata which summarize the file (see the [full MCD43C4 specification](#) for the complete listing).

## **15 MCD43D CMG 30 Arc-Second Products**

For details of the MCD43D CMG 30 Arc-Second Products see the [full specification](#). The V005 MCD43D is converted from the 500m MCD43A1. Because of the large size of the products, each Parameter for each of the 7 MODIS bands and the 3 broadbands are stored in a separate MCD43D file. Therefore MCD43D1 is MODIS band 1 (red) fiso parameter, MCD43D2 is MODIS band 1 fvol parameter and so on through to MCD43D30. MCD43D31-MCD43D34 are the 30arc second BRDF/Albedo Quality, Local Solar Noon, Percent of Input, and Snow Status.

## **16 MCD43GF CMG Gap-Filled Snow-Free Products**

MODIS BRDF/Albedo/NBAR CMG Gap-Filled Products (MCD43GF) are produced from V005 MCD43D data. These are currently [available from our UMass Boston ftp server](ftp://rsftp.eeos.umb.edu/data02/Gapfilled/) (ftp://rsftp.eeos.umb.edu/data02/Gapfilled/) and will eventually be placed at the DAACs. Please review the associated readmes to full understand the processing and data quality issues.