MODIS MOD43 Product User Guide V004

PIs
Alan Strahler, Crystal Schaaf

CoIs
Feng Gao, Xiaowen Li, Wolfgang Lucht

Collaborators
Peter Muller, Philip Lewis, Mike Barnsley

Boston University
675 Commonwealth Avenue
Boston, MA 02215

Table of Contents

MODIS MOD43 Product User Guide V004

1 Introduction

The MODIS Bidirectional Reflectance Distribution Function (BRDF) and Albedo Product (MOD43B) is an MODIS Standard Data Product that began routine production in 2000 shortly after the launch of Terra. Global Albedo (MOD43B3), BRDF Model Parameters (MOD43B1), and Nadir-BRDF Adjusted Reflectance (NBAR) Products (MOD43B4) are operationally produced every 16 days at a 1km spatial resolution and archived as equal area tiles of 1200 by 1200 pixels in a sinusoidal projection (HDF-EOS format) at the EROS Data Center (EDC) DAAC.

In addition the global Albedo (MOD43C1), BRDF Parameters (MOD43C2) and NBAR (MOD43C3) data are also provided as Climate Modeling Grid (CMG) products in a global geographic projection (lat/long) at a 0.05 degree spatial resolution every 16 days (HDF-EOS format). CMG Data Products are also available in a binary format from this Science Team Facility. The MODIS BRDF/Albedo products can also be viewed as Browse Imagery.

An additional Filled Land Surface Albedo Product is also being developed from the MOD43 data by the MODIS atmosphere team. This product is provided at a 1 minute resolution in a geographic projection and aims to provide temporally and spatially consistent albedo maps throughout the year. The Filled Land Surface Albedo Product is available at: http://modis-atmos.gsfc.nasa.gov/ALBEDO/index.htm.

Collection 4 (V004) reprocessing encompasses data from March 2000 to present and contains a V004 designator in the data labels. MODIS BRDF/Albedo V004 data begin with the period labeled 2000049 (although only data from 2000055 to 2000064 contributed to this first period). The entire V004 data set is classified as "Validated Stage-1" (see Jin et al., 2003a; b and the MOD43 Validation section of the MOD43B User's Guide for a description of the validation work underway).

1.1 Team members

Principal Investigators are Alan H. Strahler and Crystal Schaaf (at Boston University) with Co-Investigators Feng Gao (Boston University), Xiaowen Li (Boston University), and Wolfgang Lucht (Potsdam-Institut für Klimafolgenforschung). The European Principal Investigator is Jan-Peter Muller (University College London) with associate team members Philip Lewis (University College London) and Mike Barnsley (University of Wales, Swansea). The research and development team is currently made up of Crystal Schaaf, Feng Gao, Wolfgang Lucht, Xiaowen Li, Jonathan Salomon, Xiaoyang Zhang, and Elena Tsvetsinskaya (all of Boston University). Active validation efforts are underway at the Beltsville Agricultural Research Center (BARC) in Maryland by Shunlin Liang (University of Maryland); at Mongu, Zambia (woodland) and Skukuza, South Africa (savanna) which are both Southern African Regional Science Initiative (SAFARI) sites by Jeff Privette (NASA/GSFC); at the Barton Bendish, UK agricultural site by Mat Disney (University College London) and Mike Barnsley (University of Wales, Swansea); and at the Liangchen, Shunyi and Yucheng agricultural sites in China by Xiaowen Li. Evaluation of

the product is monitored by David Roy (University of Maryland) at the MODIS Land Data Operational Product Evaluation (LDOPE) facility at GSFC. Contributors have included Yufang Jin, Paul Hobson (University of Wales, Swansea), Mike Dunderdale (University College London), Chris Doll (University College London), Bob d'Entremont (AER), Trevor Tsang, Nick Strugnell, and Baoxin Hu (York University Ontario).

1.2   Data Source

The MODIS BRDF/Albedo Product is generated with data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) and on NASA's Earth Observing System (EOS) Terra and Aqua satellite platforms. Terra is on a polar orbit with a 10:30 AM equatorial crossing time while Aqua is on a polar orbit with a 1:30 PM crossing time. MODIS is an across-track wide-field-of-view scanner. The MODIS BRDF/Albedo Product is one of the many standard products provided by the MODIS Land Team (MODLAND).

1.3   Product Description

The BRDF, albedo and nadir surface reflectance of each pixel of the global land surface is modeled at a spatial resolution of 1 km by inverting multidate, multiangular, cloud-free, atmospherically corrected, surface reflectance observations acquired by MODIS in a 16-day period (MODIS orbital double repeat cycle). Data from MODIS on board Terra will soon be augmented by additional MODIS data from Aqua (the Aqua products are currently running in parallel) and eventually with MISR data from on board Terra. The product is derived in seven spectral bands, as well as in the visible, the near/mid-infrared and the total shortwave broadbands. The BRDF parameters retrieved quantify intrinsic surface properties decoupled from the prevailing atmospheric state and hence are suited for applications requiring characterization of the directional anisotropy of Earth surface reflectance. The parameters are also applicable for the computation of both the directional hemispherical reflectance (black-sky albedo) and the bihemispherical reflectance (white-sky albedo). This can be achieved through the use of a simple polynomial (Lucht et al, 2000) although white_sky and black-sky (at local solar noon) albedo computations are provided in the product for user convenience. Nadir BRDF-Adjusted Reflectances (NBAR) at the mean solar zenith angle of the observation period are also provided to the user community. A complete set of quality control flags accompanies each product and should be accessed by the user. For more product details, refer primarily to the MOD43B User's Guide, as well as Schaaf et al. (2002), Lucht et al. (2000), and Wanner et al., (1997).

1.4   MOD43 Product Summary

- MOD43B1 BRDF/Albedo Model-1 16-Day L3 Global 1km SIN Grid V004 (semiempirical RTLSR)
    - int16 BRDF_Albedo_Parameters (7 Bands, 3 Broadbands)
    - uint8 BRDF_Shape_Indicators
    - uint32 BRDF_Albedo_Quality
    - uint8 BRDF_Type

- MOD43B2 BRDF/Albedo Model-2 16-Day L3 Global 1km SIN Grid V004
- MOD43B3 Albedo 16-Day Global 1km SIN Grid V004
    - o int16 Albedo (black_sky at local solar noon and white_sky: 7 Bands, 3 Broadbands)
    - o uint32 Albedo_Quality
- MOD43B4 Nadir BRDF-Adjusted Reflectance 16-Day L3 Global 1km SIN V004 (NBAR)
    - o int16 Nadir_Reflectance (at mean szn)
    - o uint32 Nadir_Reflectance_Quality
- MOD43C1 MODIS/Terra Albedo 16-day L3 Global 0.05Deg CMG V004
    - o int16 Black_Sky_Albedo
    - o int16 White_Sky_Albedo
    - o uint32 Albedo_Quality
- MOD43C2 MODIS/Terra BRDF/Albedo Parameters 16-day L3 Global 0.05Deg CMG V004 (Model-1)
    - o int16 BRDF_Albedo_Parameter0
    - o int16 BRDF_Albedo_Parameter1
    - o int16 BRDF_Albedo_Parameter2
    - o uint32 BRDF_Albedo_Quality
- MOD43C MODIS/Terra Nadir BRDF-Adjusted Reflectance 16-day L3 Global 0.05Deg CMG V004 (NBAR)
    - o int16 Nadir_Reflectance
    - o uint32 Nadir_Reflectance_Quality

1.5   BRDF Model

The product is derived using a kernel-driven semiempirical BRDF model, utilizing the RossThick-LiSparse kernel functions for characterizing isotropic, volume and surface scattering (Wanner et al., 1995; 1997; Lucht et al., 2000; Schaaf et al., 2002). A reciprocal version of the LiSparse kernel is employed. When sufficient MODIS (Terra alone or Terra plus Aqua) observations are available, a full inversion can be utilized --- otherwise a magnitude inversion is performed by relying on MODIS-derived archetypal BRDFs associated with that location and season as a first guess and adjusting these by the available observations (Strugnell and Lucht, 2001, Strugnell et al., 2001).

2   MOD43B1 BRDF/Albedo Model Parameters Product

The MOD43B1 BRDF/Albedo Model Parameters Product (MODIS/Terra BRDF/Albedo Model_1 16-Day L3 Global 1km SIN Grid) supplies the weighting parameters associated with the RossThickLiSparseReciprocal BRDF model that best describes the anisotropy of each pixel. These three parameters (f_{iso}, f_{vol}, f_{geo}) 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 MOD43B4 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 MOD43B3). 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:

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

The appropriate constants are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
g_0	1.0	-0.007574	-1.284909
g_1	0.0	-0.070987	-0.166314
g_2	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

In addition to the model parameters, the MOD43B1 BRDF/Albedo Model Parameters Product also provides extensive quality information. Band-averaged quality information and band-independent data are stored in the first 32-bit word, while band-specific quality information and inversion status information are stored in the second 32-bit word [1], [2], [3], [4].

Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

2.1   Science Data Sets

While the full MOD43B4 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), the BRDF_Shape_Indicators (containing 8 computed shape factors), BRDF_Albedo_Quality (containing two 32-bit words of quality flags) and BRDF_Type (containing descriptors of the BRDF model used).

The BRDF_Albedo_Parameters SDS is specified as:

- Data Field Name: INT16 BRDF_Albedo_Parameters ("YDim", "XDim", "Num_Land_Bands_Plus3", "Num_Parameters")
- Description: BRDF and albedo model parameters (fiso, fvol, fgeo) for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o file data=(BRDF_Albedo_Parameters / scale_factor) + add_offset
    o BRDF_Albedo_Parameters=(file data - add_offset)*scale_factor

The BRDF_Shape_Indicators SDS is specified as:

- Data Field Name: UINT8 BRDF_Shape_Indicators ("YDim", "XDim", "Num_Shape_Fields")
- Description: Provides simple indicators of BRDF shape and properties
- Num_Shape_Fields #1 is the red band ratio of nadir to 45 degree forward scattering at 45 degrees sun angle.
- Num_Shape_Fields #2 is the NIR band ratio of nadir to 45 degree forward scattering at 45 degrees sun angle.
- Num_Shape_Fields #3 is the red band ratio of 45 degree backward scattering to 45 degree forward scattering at 45 degrees sun angle. (anisotropy index (here denoted as ANIX_red))
- Num_Shape_Fields #4 is the NIR band ratio of 45 degree backward scattering to 45 degree forward scattering at 45 degrees sun angle. (denoted as ANIX_nir)
- Num_Shape_Fields #5 is the red band ratio of white-sky albedo to BRDF isotropic parameter value.
- Num_Shape_Fields #6 is the NIR band ratio of white-sky albedo to BRDF isotropic parameter value.
- Num_Shape_Fields #7 is normalized difference anisotropy index (NDAX) at 45 degrees sun angle.

- NDAX=(ANIX_red-ANIX_nir)/(ANIX_red+ANIX_nir)
- Num_Shape_Fields #8 void, reserve for future us
- (Note: All shape indicators are only applied to the pixels with full inversion)
- Data conversions:
    - file data=(BRDF_Shape_Indicators * scale_factor) + add_offset
    - BRDF_Shape_Indicators=(file data - add_offset)/scale_factor

The BRDF_Albedo_Quality SDS is specified as:

- Data Field Name: UINT32 BRDF_Albedo_Quality ("YDim","XDim", "Num_QC_Words")
- Description: BRDF and albedo quality information
- Num_QC_Words #1 holds band-averaged quality and inversion status information and band-independent data (bits 00-01 are the MODLAND mandatory QA)
    - 00-01 Mandatory QA
        - 0 = processed, good quality
        - 1 = processed, see other QA
        - 2 = not processed due to cloud effects
        - 3 = not processed due to other effects
    - 02-03 Period used
        - 0 = 16 days
        - 1 = 32 days
    - 04-07 land/water
        - 0 = Shallow ocean
        - 1 = Land (Nothing else but land)
        - 2 = Ocean coastlines and lake shores
        - 3 = Shallow inland water
        - 4 = Ephemeral water
        - 5 = Deep inland water
        - 6 = Moderate or continental ocean
        - 7 = Deep ocean
    - 08-10 AM/MISR/PM
        - 0 = AM
        - 1 = AM/PM
        - 2 = AM/PM/MISR
        - 3 = AM/MISR
        - 4 = PM
        - 5 = PM/MISR
        - 6 = MISR
    - 11-15 Mean Szn of obs (overpass time)
        - 0 = 0-5 degrees
        - 1 = 5-10 degrees
        - 2 = 10-15 degrees
        - 3 = 15-20 degrees
        - 4 = 20-25 degrees
        - 5 = 25-30 degrees

- ▪ 6 = 30-35 degrees
- ▪ 7 = 35-40 degrees
- ▪ 8 = 40-45 degrees
- ▪ 9 = 45-50 degrees
- ▪ 10 = 50-55 degrees
- ▪ 11 = 55-60 degrees
- ▪ 12 = 60-65 degrees
- ▪ 13 = 65-70 degrees
- ▪ 14 = 70-75 degrees
- ▪ 15 = 75-80 degrees
- ▪ 16 = 80-90 degrees
  - o 16-17 snow/no snow
    - ▪ 0 = no Snow
    - ▪ 1 = Snow present
  - o 18-30 TBD
  - o 31 QAfill
- Num_QC_Words #2 holds band-specific quality and inversion status information
  - o 00-03 Band1 Quality
    - ▪ 0 = RMSE good, WoD(ref) good, WoD(WSA) good
    - ▪ 1 = RMSE good, WoD(ref) good, WoD(WSA) moderate
    - ▪ 2 = RMSE good, WoD(ref) moderate, WoD(WSA) good
    - ▪ 3 = RMSE good, WoD(ref) moderate, WoD(WSA) moderate
    - ▪ 4 = RMSE moderate, WoD(ref) good, WoD(WSA) good
    - ▪ 5 = RMSE moderate, WoD(ref) good, WoD(WSA) moderate
    - ▪ 6 = RMSE moderate, WoD(ref) moderate, WoD(WSA) good
    - ▪ 7 = RMSE moderate, WoD(ref)moderate, WoD(WSA)moderate
    - ▪ 8 = magnitude inversion (numobs >=7)
    - ▪ 9 = magnitude inversion (numobs >3&<7)
    - ▪ 10 = magnitude inversion (numobs <=3)
    - ▪ 11 = Bus-in DB parameters (not currently used)
    - ▪ 15 = Fill value
  - o 04-07 Band2 Quality (see explanation for band1)
  - o 08-11 Band3 Quality (see explanation for band1)
  - o 12-15 Band4 Quality (see explanation for band1)
  - o 16-19 Band5 Quality (see explanation for band1)
  - o 20-23 Band6 Quality (see explanation for band1)
  - o 24-27 Band7 Quality (see explanation for band1)
  - o 28-30 TBD
  - o 31 QAFill

Note that while the RMSE indicates the fit of the full inversion, the Weights of Determination (WoD) give some indication of noise expected in the full retrieval and are dependent on the angular sampling of the available surface reflectances [4],[5],[6].

The BRDF_Type SDS is specified as:

- Data Field Name: UINT8 BRDF_Type ("YDim", "XDim", "Num_Type_Fields")
- Description: Identifier for BRDF model used (RossThickLiSparseReciprocal).

2.2   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

For the BRDF_Shape_Indicators SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"BRDF_Shape_Indicators"
units	HDF-STRING	"ratio or coefficient, no units"
valid_range	HDF-uint8	0, 254
_FillValue	HDF-uint8	255
add_offset	HDF-float64	25.0
add_offset_err	HDF-float64	0.0
calibrated_nt	HDF-int32	5
scale_factor	HDF-float64	0.04
scale_factor_err	HDF-float64	0.0

For the BRDF_Albedo_Quality SDS, they include:

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

For the BRDF_Type SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"BRDF_Type"

units	HDF-STRING	"model/type number"
valid_range	HDF-uint8	0, 254
_FillValue	HDF-uint8	255

2.3   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 MOD43B1 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 MOD43B1 specification for the complete listing).

References Cited

1. 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, and D. P. Roy, First Operational BRDF, Albedo and Nadir Reflectance Products from MODIS, Remote Sens. Environ., 83, 135-148, 2002.

2. 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.

3. Lucht, W., Expected retrieval accuracies of bidirectional reflectance and albedo from EOS-MODIS and MISR angular sampling, J. Geophys. Res., 103, 8763-8778, 1998.

4. 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.

3 MOD43B3 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]. 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].

The MOD43B3 Albedo Product (MODIS/Terra Albedo 16-Day L3 Global 1km 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 (0.3-0.7µm, 0.7-5.0µm, and 0.3-5.0µm). While the total energy reflected by the earth's surface in the shortwave domain is characterized by the shortwave (0.3-5.0µm) broadband albedo, the visible (0.3-0.7µm) and near-infrared (0.7-5.0µm) 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] used observed spectra and numerical simulations to produce the conversion coefficients for MODIS and MISR 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] 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].

In addition to the spectral and broadband albedo quantities themselves, the MOD43B3 Albedo Product also provides extensive quality information. Band-averaged quality information and band-independent data are stored in the first 32-bit word, while band-specific quality information and inversion status information are stored in the second 32-bit word [4],[5],[6],[7].

Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

3.1 Science Data Sets

While the full MOD43B3 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) and Albedo_Quality (containing two 32-bit words of quality flags).

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

The Albedo_Quality SDS is specified as:

- Data Field Name: UINT32 Albedo_Quality("YDim","XDim", "Num_QC_Words")
- Description: BRDF and albedo quality information
- Num_QC_Words #1 holds band-averaged quality and inversion status information and band-independent data (bits 00-01 are the MODLAND mandatory QA)
  - 00-01 Mandatory QA
    - 0 = processed, good quality
    - 1 = processed, see other QA
    - 2 = not processed due to cloud effects
    - 3 = not processed due to other effects
  - 02-03 Period used
    - 0 = 16 days
    - 1 = 32 days
  - 04-07 land/water
    - 0 = Shallow ocean
    - 1 = Land (Nothing else but land)
    - 2 = Ocean coastlines and lake shores
    - 3 = Shallow inland water
    - 4 = Ephemeral water
    - 5 = Deep inland water
    - 6 = Moderate or continental ocean
    - 7 = Deep ocean
  - 08-10 AM/MISR/PM
    - 0 = AM
    - 1 = AM/PM
    - 2 = AM/PM/MISR
    - 3 = AM/MISR
    - 4 = PM
    - 5 = PM/MISR
    - 6 = MISR
  - 11-15 Szn of Local Solar Noon
    - 0 = 0-5 degrees
    - 1 = 5-10 degrees
    - 2 = 10-15 degrees
    - 3 = 15-20 degrees

- - - 4 = 20-25 degrees
    - 5 = 25-30 degrees
    - 6 = 30-35 degrees
    - 7 = 35-40 degrees
    - 8 = 40-45 degrees
    - 9 = 45-50 degrees
    - 10 = 50-55 degrees
    - 11 = 55-60 degrees
    - 12 = 60-65 degrees
    - 13 = 65-70 degrees
    - 14 = 70-75 degrees
    - 15 = 75-80 degrees
    - 16 = 80-90 degrees
  - 16-17 snow/no snow
    - 0 = no Snow1 = Snow present
  - 18-30 TBD
  - 31 QAfill
- Num_QC_Words #2 holds band-specific quality and inversion status information
  - 00-03 Band1 Quality
    - 0 = RMSE good, WoD(ref) good, WoD(WSA) good
    - 1 = RMSE good, WoD(ref) good, WoD(WSA) moderate
    - 2 = RMSE good, WoD(ref) moderate, WoD(WSA) good
    - 3 = RMSE good, WoD(ref) moderate, WoD(WSA) moderate
    - 4 = RMSE moderate, WoD(ref) good, WoD(WSA) good
    - 5 = RMSE moderate, WoD(ref) good, WoD(WSA) moderate
    - 6 = RMSE moderate, WoD(ref) moderate, WoD(WSA) good
    - 7 = RMSE moderate, WoD(ref)moderate, WoD(WSA)moderate
    - 8 = magnitude inversion (numobs >=7)
    - 9 = magnitude inversion (numobs >3&<7)
    - 10 = magnitude inversion (numobs <=3)
    - 11 = Bus-in DB parameters (not currently used)
    - 15 = Fill value
  - 04-07 Band2 Quality (see explanation for band1)
  - 08-11 Band3 Quality (see explanation for band1)
  - 12-15 Band4 Quality (see explanation for band1)
  - 16-19 Band5 Quality (see explanation for band1)
  - 20-23 Band6 Quality (see explanation for band1)
  - 24-27 Band7 Quality (see explanation for band1)
  - 28-30 TBD
  - 31 QAFill

Note that while the RMSE indicates the fit of the full inversion, the Weights of Determination (WoD) give some indication of noise expected in the full retrieval and are dependent on the angular sampling of the available surface reflectances [4],[5],[6].

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 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

And for the Albedo_Quality SDS, they include:

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

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 a Level 3 MOD43B3 Albedo 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 MOD43B3 specification for the complete listing).

References Cited

1. Lewis, P., and M. J. Barnsley, Influence of the sky radiance distribution on various formulations of the earth surface albedo, in Proc. Conf. Phys. Meas. Sign. Remote Sens., Val d'Isere, France, pp. 707-715, 1994.

2. Liang, S., A. H. Strahler, and C. W. Walthall, Retrieval of land surface albedo from satellite observations: A simulation study, J. Appl. Meteorol., 38, 712-725, 1999.

3. 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.

4. 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.

5. Lucht, W., Expected retrieval accuracies of bidirectional reflectance and albedo from EOS-MODIS and MISR angular sampling, J. Geophys. Res., 103, 8763-8778, 1998.

6. 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.

4   MOD43B4 NBAR Product

The MOD43B4 Nadir BRDF-Adjusted Reflectance (NBAR) Product (MODIS/Terra Nadir BRDF-Adjusted Reflectance 16-Day L3 Global 1km SIN Grid) is computed for each of the MODIS spectral bands (1-7) at the mean solar zenith angle of each 16 day period. 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 MOD12Q1 [1]. It is anticipated that the user community will be quick to take advantage of the NBAR data for those situations where composited surface reflectances may have been traditionally used.

In addition to the spectral NBAR values, the MOD43B4 NBAR Product also provides extensive quality information. Band-averaged quality information and band-independent data are stored in the first 32-bit word, while band-specific quality information and inversion status information are stored in the second 32-bit word [2],[3],[4],[5].

Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

4.1   Science Data Sets

While the full MOD43B4 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 mean solar zenith angle of the 16 day period) and Nadir_Reflectance_Quality (containing two 32-bit words of quality flags).

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:
    - o   file data=(Nadir_Reflectance / scale_factor) + add_offset
    - o   Nadir_Reflectance=(file data - add_offset)*scale_factor

The Nadir_Reflectance_Quality SDS is specified as:

- Data   Field   Name: UINT32   Nadir_Reflectance_Quality("YDim","XDim", "Num_QC_Words")
- Description: BRDF and albedo quality information
- Num_QC_Words #1 holds band-averaged quality and inversion status information and band-independent data (bits 00-01 are the MODLAND mandatory QA)
    - o   00-01 Mandatory QA

15

- 0 = processed, good quality
- 1 = processed, see other QA
- 2 = not processed due to cloud effects
- 3 = not processed due to other effects
- o 02-03 Period used
  - 0 = 16 days
  - 1 = 32 days
- o 04-07 land/water
  - 0 = Shallow ocean
  - 1 = Land (Nothing else but land)
  - 2 = Ocean coastlines and lake shores
  - 3 = Shallow inland water
  - 4 = Ephemeral water
  - 5 = Deep inland water
  - 6 = Moderate or continental ocean
  - 7 = Deep ocean
- o 08-10 AM/MISR/PM
  - 0 = AM
  - 1 = AM/PM
  - 2 = AM/PM/MISR
  - 3 = AM/MISR
  - 4 = PM
  - 5 = PM/MISR
  - 6 = MISR
- o 11-15 Mean Szn of obs
  - 0 = 0-5 degrees
  - 1 = 5-10 degrees
  - 2 = 10-15 degrees
  - 3 = 15-20 degrees
  - 4 = 20-25 degrees
  - 5 = 25-30 degrees
  - 6 = 30-35 degrees
  - 7 = 35-40 degrees
  - 8 = 40-45 degrees
  - 9 = 45-50 degrees
  - 10 = 50-55 degrees
  - 11 = 55-60 degrees
  - 12 = 60-65 degrees
  - 13 = 65-70 degrees
  - 14 = 70-75 degrees
  - 15 = 75-80 degrees
  - 16 = 80-90 degrees
- o 16-17 snow/no snow
  - 0 = no Snow
  - 1 = Snow present
- o 18-30 TBD

- o 31 QAfill
- Num_QC_Words #2 holds band-specific quality and inversion status information
    - o 00-03 Band1 Quality
        - ▪ 0 = RMSE good, WoD(ref) good, WoD(WSA) good
        - ▪ 1 = RMSE good, WoD(ref) good, WoD(WSA) moderate
        - ▪ 2 = RMSE good, WoD(ref) moderate, WoD(WSA) good
        - ▪ 3 = RMSE good, WoD(ref) moderate, WoD(WSA) moderate
        - ▪ 4 = RMSE moderate, WoD(ref) good, WoD(WSA) good
        - ▪ 5 = RMSE moderate, WoD(ref) good, WoD(WSA) moderate
        - ▪ 6 = RMSE moderate, WoD(ref) moderate, WoD(WSA) good
        - ▪ 7 = RMSE moderate, WoD(ref)moderate, WoD(WSA)moderate
        - ▪ 8 = magnitude inversion (numobs >=7)
        - ▪ 9 = magnitude inversion (numobs >3&<7)
        - ▪ 10 = magnitude inversion (numobs <=3)
        - ▪ 11 = Bus-in DB parameters (not currently used)
        - ▪ 15 = Fill value
    - o 04-07 Band2 Quality (see explanation for band1)
    - o 08-11 Band3 Quality (see explanation for band1)
    - o 12-15 Band4 Quality (see explanation for band1)
    - o 16-19 Band5 Quality (see explanation for band1)
    - o 20-23 Band6 Quality (see explanation for band1)
    - o 24-27 Band7 Quality (see explanation for band1)
    - o 28-30 TBD
    - o 31 QAFill

Note that while the RMSE indicates the fit of the full inversion, the Weights of Determination (WoD) give some indication of noise expected in the full retrieval and are dependent on the angular sampling of the available surface reflectances [4],[5],[6].

4.2   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

And for the Nadir_Reflectance_Quality SDS, they include:

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

4.3   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 MOD43B4 NBAR 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 MOD43B4 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.

2. 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.

3. Lucht, W., Expected retrieval accuracies of bidirectional reflectance and albedo from EOS-MODIS and MISR angular sampling, J. Geophys. Res., 103, 8763-8778, 1998.

4. 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.

5   MOD43C1 CMG Albedo Product

The MOD43C1 Climate Modeling Grid (CMG) Albedo Product (MODIS/Terra Albedo 16-Day 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 (0.3-0.7µm, 0.7-5.0µm, and 0.3-5.0µm) at a 0.05 degree spatial resolution in global files in a geographic (lat/long) projection. These albedo values are based on spatial averages of the underlying 1-km albedo data. Note that along coastlines, this means that the 1-km 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 MOD43C1 CMG Albedo Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 1-km pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered.

Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

5.1   Science Data Sets

While the full MOD43C1 specification should be consulted for the most current description, the product includes three Science Data Sets (SDS) for each cmg-pixel in the tile. These SDSs are Black-Sky Albedo (at local solar noon), White-Sky Albedo (both for 10 bands -- 7 spectral and 3 broad or) and Albedo_Quality (containing one 32-bit word of quality flags). They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 10 bands)).

The Black-Sky Albedo SDS is specified as:

- Data Field Name: INT16 Albedo ("YDim", "XDim", "Num_Albedo_Bands"")
- Description: Black-Sky Albedo (at local solar noon) for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o   file data=(Albedo / scale_factor) + add_offset
    o   Albedo=(file data - add_offset)*scale_factor

The White-Sky Albedo SDS is specified as:
- Data Field Name: INT16 Albedo ("YDim", "XDim", "Num_Albedo_Bands"")
- Description: White-Sky Albedo for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o   file data=(Albedo / scale_factor) + add_offset
    o   Albedo=(file data - add_offset)*scale_factor

The Albedo_Quality SDS is specified as:
- Data Field Name: UINT32 Albedo_Quality("YDim","XDim")=
- Description: BRDF and albedo quality information

- 00-01 Mandatory QA
  - 0 = Majority processed, good quality
  - 1 = Majority processed, see other QA
  - 2 = Majority not processed due to cloud effects
  - 3 = Majority not processed due to other effects
- 02 Period used
  - 0 = 16 days
  - 1 = 32 days
- 03-05 AM/MISR/PM
  - 0 = AM
  - 1 = AM/PM
  - 2 = AM/PM/MISR
  - 3 = AM/MISR
  - 4 = PM
  - 5 = PM/MISR
  - 6 = MISR
- 06-07 BRDF Quality
  - 0 = Majority full inversion
  - 1 = Majority magnitude inversion
  - 2 = Majority Bus-in DB parameters (not currently used)
  - 3 = Majority Fill Value
- 08-15 Percent Inputs
  - 0-100 (percent of the processed finer resolution data that contributed to this CMG pixel)
- 16-23 Percent Snow
  - 0-100
- 24-27 Szn of Local Solar Noon
  - 0 = 0-5 degrees
  - 1 = 5-10 degrees
  - 2 = 10-15 degrees
  - 3 = 15-20 degrees
  - 4 = 20-25 degrees
  - 5 = 25-30 degrees
  - 6 = 30-35 degrees
  - 7 = 35-40 degrees
  - 8 = 40-45 degrees
  - 9 = 45-50 degrees
  - 10 = 50-55 degrees
  - 11 = 55-60 degrees
  - 12 = 60-65 degrees
  - 13 = 65-70 degrees
  - 14 = 70-75 degrees
  - 15 = 75-80 degrees
  - 16 = 80-90 degrees
- 28-30 TBD
- 31 QAfill

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 Black-Sky and White-Sky Albedo SDS, they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Global_Black_Sky_Albedo (or Global_White_Sky_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

And for the 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

5.3 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 MOD43C1 CMG Albedo Product also includes three types of Global Attributes or Metadata which summarize the file. 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 summarize the quality of the product over that entire file (see the full MOD43C1 specification for the complete listing).

6   MOD43C2 CMG BRDF/Albedo Model Parameters Product

The MOD43C2 Climate Modeling Grid (CMG) BRDF/Albedo Model Parameters Product (MODIS/Terra BRDF/Albedo Parameters 16-Day 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 (f_{iso}, f_{vol}, f_{geo}) 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) at a 0.05 degree spatial resolution in global files in a geographic (lat/long) projection. These model parameters are based on the underlying 1-km model parameters. Note that along coastlines, this means that the 1-km 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 MOD43C2 CMG BRDF/Albedo Model Parameters Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 1-km pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered. 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 MOD43B4 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 MOD43B3). 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:

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

The appropriate constants are:

Term	Isotropic (iso)	RossThick (vol)	LiSparseR (geo)
g_0	1.0	-0.007574	-1.284909
g_1	0.0	-0.070987	-0.166314
g_2	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)

MOD43 User Guide Version 004

| White-sky integral *g* | 1.0 | 0.189184 | -1.377622 |

Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

6.1   Science Data Sets

While the full MOD43C2 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 (containing one 32-bit word of quality flags).They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 10 bands)).

The BRDF_Albedo_Parameters SDS are specified as:

- Data Field Name: INT16 BRDF_Albedo_Parameter0 ("YDim", "XDim", "Num_Land_Bands_Plus3")
- Description: BRDF and albedo model parameter fiso for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o file data=(BRDF_Albedo_Parameter0 / scale_factor) + add_offset
    o BRDF_Albedo_Parameter0=(file data - add_offset)*scale_factor
- Data Field Name: INT16 BRDF_Albedo_Parameter1 ("YDim", "XDim", "Num_Land_Bands_Plus3")
- Description: BRDF and albedo model parameter fvol for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o file data=(BRDF_Albedo_Parameter1 / scale_factor) + add_offset
    o BRDF_Albedo_Parameter1=(file data - add_offset)*scale_factor
- Data Field Name: INT16 BRDF_Albedo_Parameter2 ("YDim", "XDim", "Num_Land_Bands_Plus3")
- Description: BRDF and albedo model parameter fgeo for bands 1-7, and the vis, NIR and SW broadbands
- Data conversions:
    o file data=(BRDF_Albedo_Parameter2 / scale_factor) + add_offset
    o BRDF_Albedo_Parameter2=(file data - add_offset)*scale_factor

The BRDF_Albedo_Quality SDS is specified as:
- Data Field Name: UINT32 BRDF_Albedo_Quality ("YDim","XDim")
- Description: BRDF and albedo quality information

- o 00-01 Mandatory QA
  - 0 = Majority processed, good quality
  - 1 = Majority processed, see other QA
  - 2 = Majority not processed due to cloud effects
  - 3 = Majority not processed due to other effects
- o 02 Period used
  - 0 = 16 days
  - 1 = 32 days
- o 03-05 AM/MISR/PM
  - 0 = AM
  - 1 = AM/PM
  - 2 = AM/PM/MISR
  - 3 = AM/MISR
  - 4 = PM
  - 5 = PM/MISR
  - 6 = MISR
- o 06-07 BRDF Quality
  - 0 = Majority full inversion
  - 1 = Majority magnitude inversion
  - 2 = Majority Bus-in DB parameters
  - (not currently used)
  - 3 = Majority Fill Value
  - 08-15 Percent Inputs
  - 0-100 (percent of the processed finer resolution data that contributed to this CMG pixel)
- o 16-23 Percent Snow
  - 0-100
- o 24-27 Mean Szn of Obs
  - 0 = 0-5 degrees
  - 1 = 5-10 degrees
  - 2 = 10-15 degrees
  - 3 = 15-20 degrees
  - 4 = 20-25 degrees
  - 5 = 25-30 degrees
  - 6 = 30-35 degrees
  - 7 = 35-40 degrees
  - 8 = 40-45 degrees
  - 9 = 45-50 degrees
  - 10 = 50-55 degrees
  - 11 = 55-60 degrees
  - 12 = 60-65 degrees
  - 13 = 65-70 degrees
  - 14 = 70-75 degrees
  - 15 = 75-80 degrees
  - 16 = 80-90 degrees
- o 28-30 TBD

- o 31 QAfill

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 BRDF_Albedo_Parameter* 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

6.3 Global Attributes (Metadata)

In addition to the parameter and quality information (SDSs and Local Attributes) that is provided at a per-CMG-pixel level, each Level 3 MOD43C2 BRDF/Albedo Parameters Product also includes three types of Global Attributes or Metadata which summarize the file. 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 summarize the quality of the product over that entire file (see the full MOD43C2 specification for the complete listing).

References Cited
1. 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.

2. 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.

7   MOD43C3 CMG NBAR Product

The MOD43C3 Climate Modeling Grid (CMG) Nadir BRDF-Adjusted Reflectance (NBAR) Product (MODIS/Terra Nadir BRDF-Adjusted Reflectance 16-Day L3 Global 0.05Deg CMG) is computed for each of the MODIS spectral bands (1-7) at the mean solar zenith angle of each 16 day period. 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, this results in a stable and consistent reflectance product. These NBAR values are based on spatial averages of the underlying 1-km NBAR data. Note that along coastlines, this means that the 1-km 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 MOD43C3 CMG NBAR Product also provides extensive quality information. The quality and inversion status of the majority of the underlying 1-km pixels is provided as well as the percentage of the underlying pixels that were present or were snow covered. Note: Reprocessed (V004) MODIS BRDF/Albedo products from Day 2000065 (5 March 2000) have been assigned a "Validated (Level 1) Status". Users are urged to use the quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products will continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

7.1   Science Data Sets

While the full MOD43C3 specification should be consulted for the most current description, the product includes two Science Data Sets (SDS) for each cmg-pixel in the tile. These SDSs are Nadir_Reflectance (NBAR) at the mean solar zenith angle of the 16 day period for 7 spectral bands and Nadir_Reflectance_Quality (containing one 32-bit word of quality flags). They are provided in global files in a geographic (lat/long) projection (3600 rows X 7200 columns (X 7 bands)).

The Nadir_Reflectance (NBAR) SDS is specified as:

- Data Field Name: INT16 ("YDim", "XDim", "Num_Land_Bands"")
- Description: Nadir BRDF-adjusted reflectance (NBAR) at mean solar zenith angle for bands 1-7
- Data conversions:
    o   file data=(NBAR / scale_factor) + add_offset
    o   NBAR=(file data - add_offset)*scale_factor

The Nadir_Reflectance_Quality SDS is specified as:
- Data Field Name: UINT32 Nadir_Reflectance_Quality("YDim","XDim")
- Description: BRDF and albedo quality information
    o   00-01 Mandatory QA
        ▪   0 = Majority processed, good quality
        ▪   1 = Majority processed, see other QA
        ▪   2 = Majority not processed due to cloud effects
        ▪   3 = Majority not processed due to other effects
    o   02 Period used
        ▪   0 = 16 days

27

- 1 = 32 days
  o 03-05 AM/MISR/PM
    - 0 = AM
    - 1 = AM/PM
    - 2 = AM/PM/MISR
    - 3 = AM/MISR
    - 4 = PM
    - 5 = PM/MISR
    - 6 = MISR
  o 06-07 BRDF Quality
    - 0 = Majority full inversion
    - 1 = Majority magnitude inversion
    - 2 = Majority Bus-in DB parameters (not currently used)
    - 3 = Majority Fill Value
  o 08-15 Percent Inputs
    - 0-100 (percent of the processed finer resolution data that contributed to this CMG pixel)
  o 16-23 Percent Snow
    - 0-100
  o 24-27 Mean Szn of Obs
    - 0 = 0-5 degrees
    - 1 = 5-10 degrees
    - 2 = 10-15 degrees
    - 3 = 15-20 degrees
    - 4 = 20-25 degrees
    - 5 = 25-30 degrees
    - 6 = 30-35 degrees
    - 7 = 35-40 degrees
    - 8 = 40-45 degrees
    - 9 = 45-50 degrees
    - 10 = 50-55 degrees
    - 11 = 55-60 degrees
    - 12 = 60-65 degrees
    - 13 = 65-70 degrees
    - 14 = 70-75 degrees
    - 15 = 75-80 degrees
    - 16 = 80-90 degrees
  o 28-30 TBD
  o 31 QAfill

7.2   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 (NBAR) SDS they include:

Name:	Type:	Value:
long_name	HDF-STRING	"Global_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	0.001
scale_factor_err	HDF-float64	0.0

And for the Nadir_Reflectance_Quality SDS, they include:

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

7.3   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 MOD43C3 CMG NBAR Product also includes three types of Global Attributes or Metadata which summarize the file. 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 summarize the quality of the product over that entire file (see the full MOD43C3 specification for the complete listing).

8 MOD43 Validation

Reprocessed (V004) MODIS BRDF/Albedo products have been assigned a "Validated (Level 1) Status". This section describes some of the initial evaluations that led to this upgrade in status. Users are urged to use the band specific quality flags to isolate the highest quality full inversion results for their own science applications. MOD43B and MOD43C products continue to be evaluated and validated by the MODIS Science Team and MODIS Validation Scientists.

Validation Efforts Currently Underway

- SURFRAD Comparisons -- Y Jin (BU), J. Salomon (BU), M. Roman (BU)
- BARC Field Campaigns -- S. Liang (UMD)
- BSRN Field Campaigns -- A. Roesch
- SAVE/SAFARI Field Campaigns -- J. Privette (GSFC), G. Roberts (UCL)
- Barton Bendish Field Campaigns -- M. Barnsley (UWales,Swansea), P. Lewis (UCL), M. Disney
- China Field Campaigns -- X. Li (BU & BNU), K. Wang
- Greenland Field Campaigns -- J. Stroeve

8.1 SURFRAD Comparisons

MODIS albedo pixel values created using combined observations (V004) from MODIS instruments aboard the Terra (EOS AM-1) and Aqua (EOS PM-1) platforms showed good agreement in direct comparisons to tower data from the six SURFRAD sites and two ARM/SGP sites in the United States for the years 2003 and 2004. In addition, pixel values from combined observations matched well with pixel values created from Terra observations alone. For specifics, see:

- Salomon, J., C. B. Schaaf, A. H. Strahler, F. Gao, Y. Jin, Validation of the MODIS Bidirectional Reflectance Distribution Function and Albedo Retrievals Using Combined Observations from the Aqua and Terra Platforms, IEEE Trans. Geosci. Remote Sens., to be published, 2006.
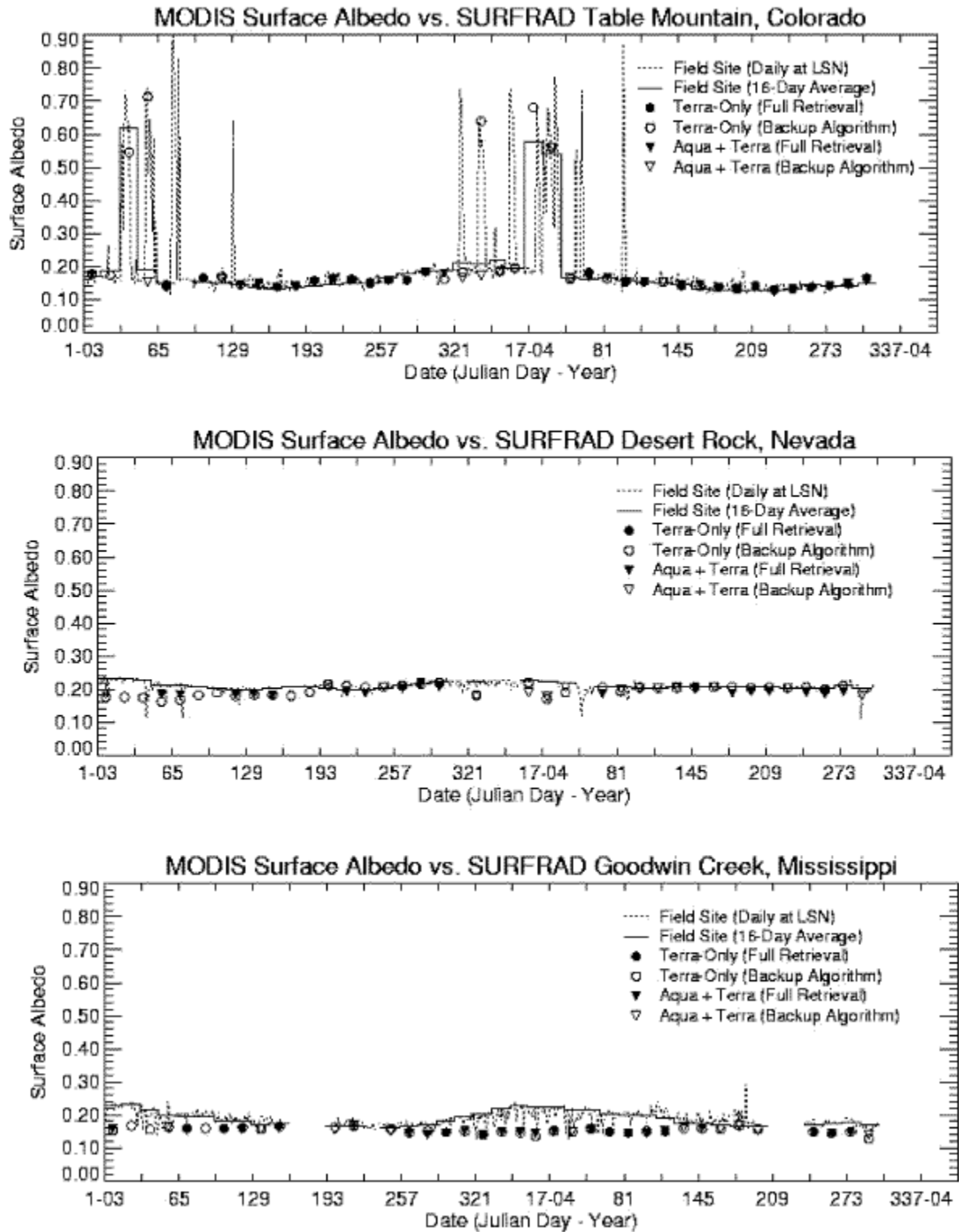
Figure 1a. Comparisons between MODIS pixel albedos and SURFRAD tower albedos in 2003 and 2004 at Fort Peck, MT, Penn State, PA, and Bondville, IL. Large changes in MODIS albedo during

snow periods (changes in surface albedo greater than 0.5) are due to reversals of the QA snow flag (see referenced text).
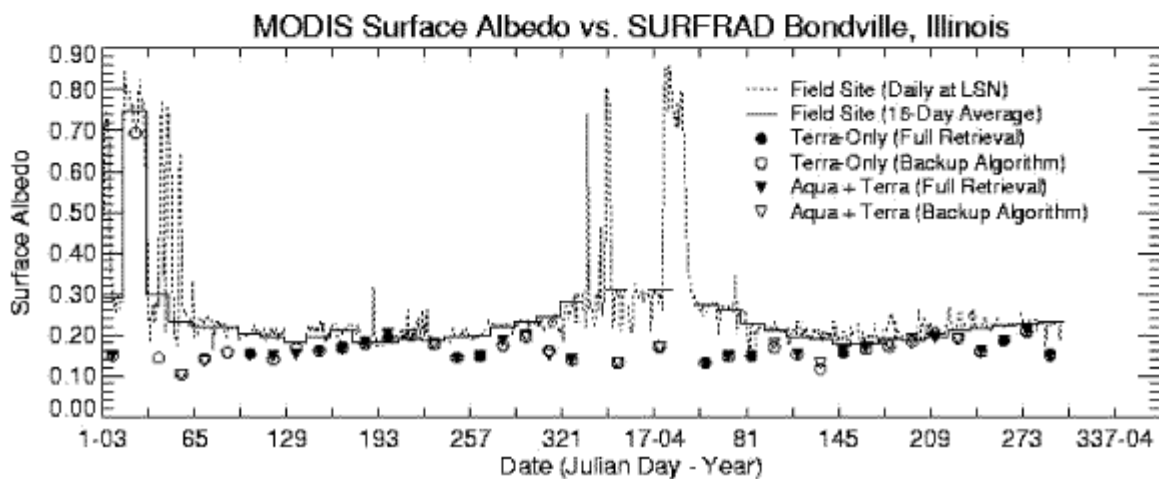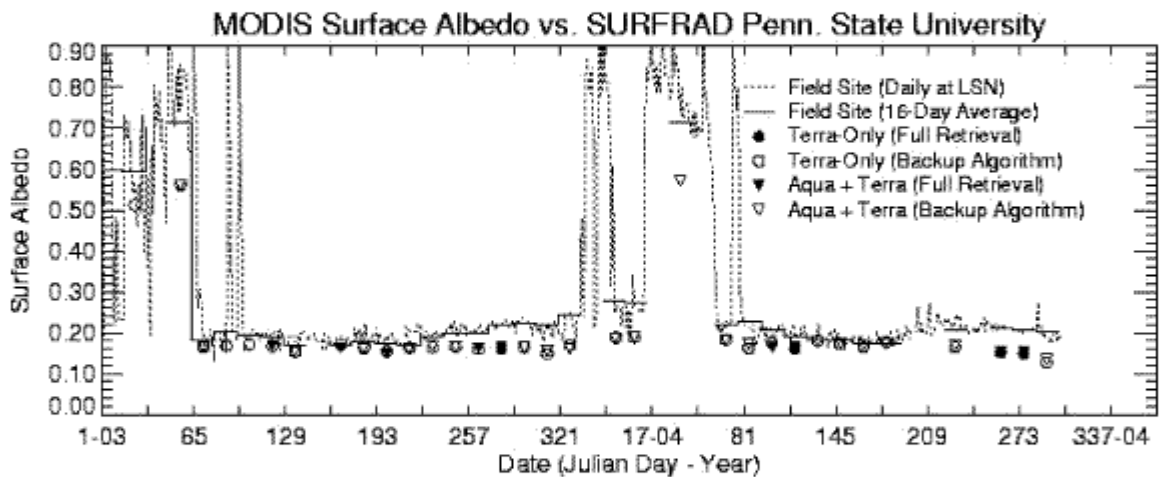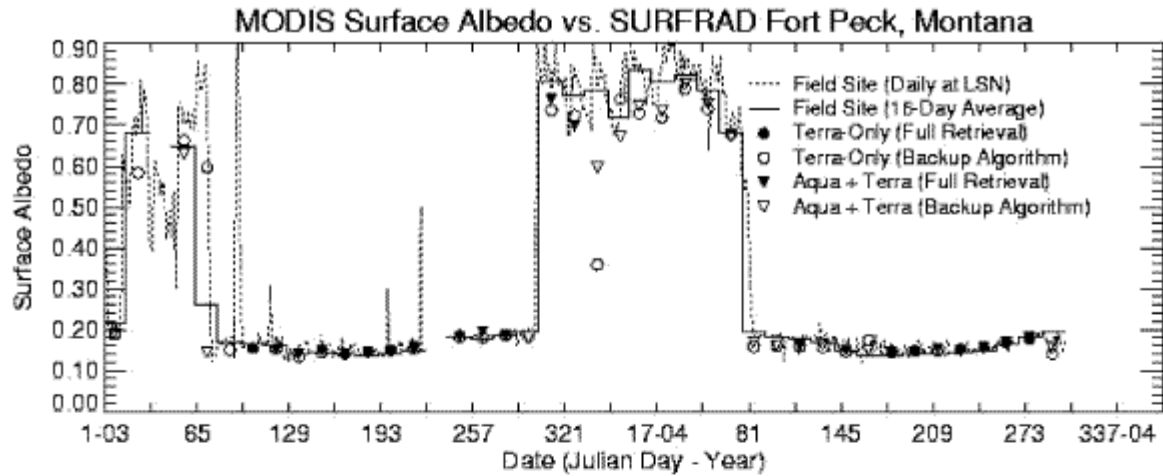
Figure 1b. Comparisons between MODIS pixel albedos and SURFRAD tower albedos in 2003 and 2004 at Table Mountain, CO, Desert Rock, NV, and Goodwin Creek, MS. Large changes in MODIS albedo during snow periods (changes in surface albedo greater than 0.5) are due to reversals of the QA snow flag (see referenced text).

High quality reprocessed MODIS albedo pixel values from 2001 (V003) showed good agreement during the growing season in direct comparisons to tower data from the six SURFRAD sites in the United States. For specifics, see:

- Jin, Y., C. B. Schaaf, C. E. Woodcock, F. Gao, X. Li, A. H. Strahler, W. Lucht, S. Liang, Consistency of MODIS surface BRDF/Albedo retrievals: 1. Algorithm performance, J. Geophys. Res., 108(D5), 4158, doi: 10.1029/2002JD002803, 2003.
- Jin, Y., C. B. Schaaf, C. E. Woodcock, F. Gao, X. Li, A. H. Strahler, W. Lucht, S. Liang, Consistency of MODIS surface BRDF/Albedo retrievals: 2. Validation, J. Geophys. Res., 108(D5), 4159, doi: 10.1029/2002JD002804, 2003.
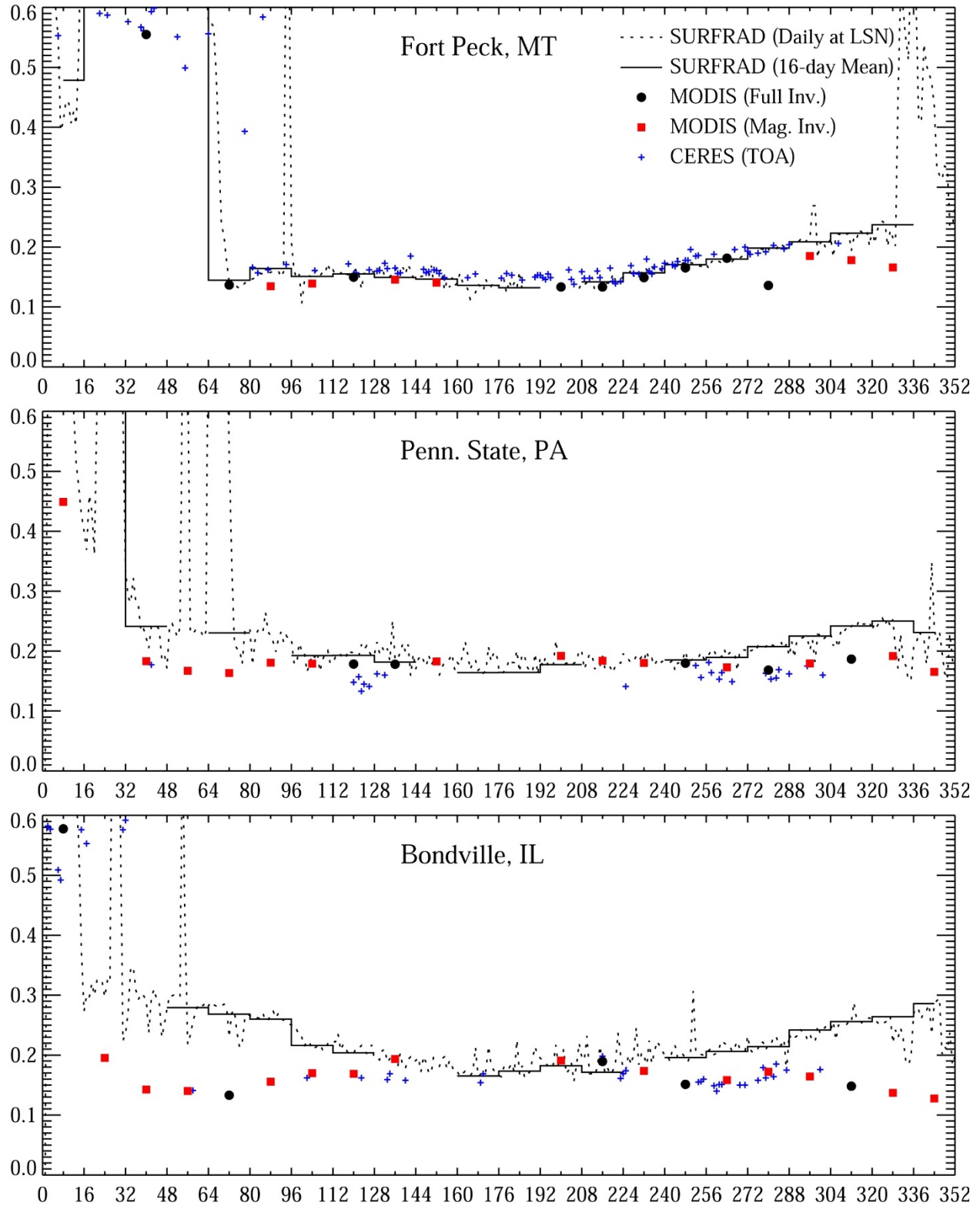
Figure 2a. Comparisons between MODIS pixel albedos, SURFRAD tower albedos, and CERES TOA albedos in 2001 at Fort Peck, MT, Penn State, PA, and Bondville, IL.
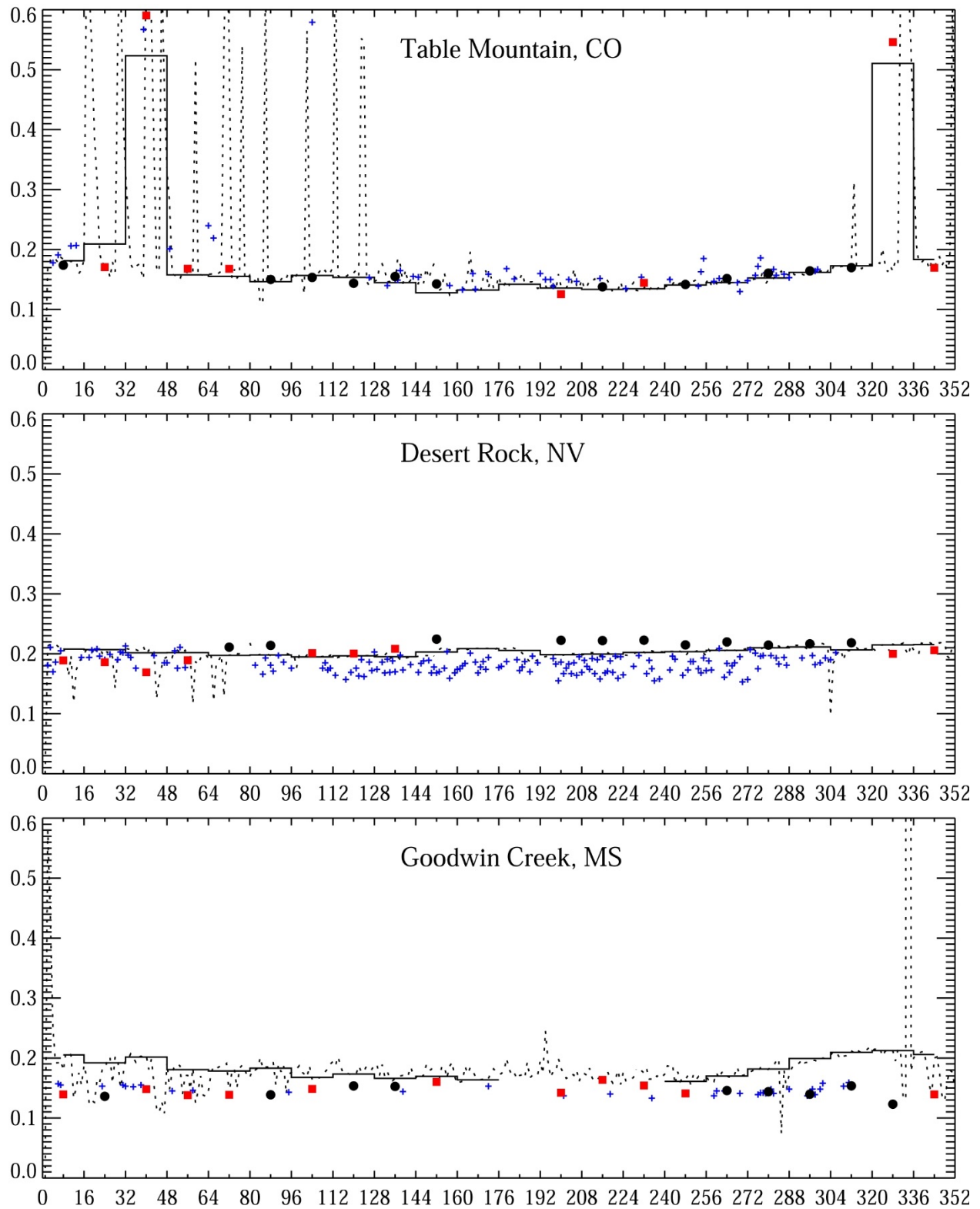
Figure 2b. Comparisons between MODIS pixel albedos, SURFRAD tower albedos, and CERES TOA albedos in 2001 at Table Mountain, CO, Desert Rock, NV, and Goodwin Creek, MS.

8.2   BARC Field Campaigns

Good agreement was achieved in a limited number of comparisons in November and December 2000 between field data associated with an instrumented tower at the Beltsville Agricultural Research Center (BARC) and MODIS pixel values. For specifics see:

- Liang, S., H. Fang, M. Chen, C. J. Shuey, C. Walthall, C. Daughtry, J. Morisette, C. Schaaf and A. Strahler, Validating MODIS Land Surface Reflectance and Albedo Products: Methods and Preliminary Results, Remote Sens. Environ., 83, 149-162, 2002.

8.3   BSRN Field Campaigns

A paper comparing MODIS albedos with field data from BSRN core sites was completed and published by Andreas Roesh in JGR. For specifics see:

- A. Roesch, C. Schaaf, and F. Gao, Use of Moderate-Resolution Imaging Spectroradiometer bidirectional reflectance distribution function products to enhance simulated surface albedos, J. Geophys. Res., 109, D12105, doi: 10.1029/2004JD004552, 2004.

8.4   Barton Bendish Field Campaigns

A paper comparing MODIS albedos with field data at the Barton Bendish core site was completed by our British colleagues and published in IJRS. For specifics see:

- Disney, M., P. Lewis, G. Thackray, T. Quaife, and M. Barnsley, Comparison of MODIS broadband albedo over an agricultural site with values derived from multi-scale EO data and ground measurements. Int. J. Remote Sens., 25, 5297-5317, 2004.

8.5   China Field Campaigns

A paper comparing MODIS albedos with field data in Tibet was completed by our Chinese colleagues and published in JGR. For specifics see:

- Kaicun Wang, Jingmiao Liu, Xiuji Zhou, Michael Sparrow, Min Ma, Zhian Sun, and Wenhua Jiang, alidation of the MODIS global land surface albedo product using ground measurements in a semidesert region on the Tibetan Plateau, J. Geophys. Res., 109, D05107, doi: 10.1029/2003JD004229, 2004.

8.6   Greenland Field Campaigns

A paper comparing snow albedos from the MODIS data product with field sites in Greenland was completed by Stroeve, et al. and published in RSE. For specifics see:

- J. Stroeve, J. E. Box, F. Gao, S. Liang, A. Nolin, and C. Schaaf, Accuracy assessment of the MODIS 16-day albedo product for snow: comparisons with Greenland in situ measurements, Remote Sensing of Environment, 94, 46-60, 2005.

9   BRDF/Albedo Data Download

Available data sets are:

- Albedo:
  - o Download Binary Data:
    - ▪ Here are binary data sets, exports of publicly released data, as well as prototypes and user requested materials. These are not the official, original data sources from the LPDAAC at EDC.
  - o Source data:
    - ▪ The official operational MODIS data sets at nominal 1 kilometer (MCD43B* and MOD43B*) and 0.05 degree (MCD43B* and MOD43C*) spatial resolutions are freely available in native HDF-EOS format from the **EROS Data Center (EDC)**.
  - o Gap-filled Snow-free Land Surface Albedo Products:
    - ▪ Gap-filled Albedo Products have been developed in collaboration with the MODIS Atmospheres Team. This data set is a spatially and temporally averaged product derived from the nominal 1km x 1km, 16-day MODIS Albedo. The result is at 30 arc-second resolution in a geographic projection for the first 7 Landsat-like MODIS narrow land bands and 3 modeled broad bands.
    - ▪ We are also developing snow-free gap-filled MODIS BRDF Model Parameters. **CMG gap-filled data** for all 10 bands mosaicked over 2001 through 2005 are available (added on May 17, 2007)
  - o Pre-Launch Prototypes:
    - ▪ Before the 1999 launch of the MODIS instrument on the Terra orbital platform, we developed our algorithms and operational code for BRDF and Albedo with AVHRR data. We retain data from **February and July, 1995**.
- *Land Cover:*
  - o ***MODIS Land Cover and Land Cover Dynamics Data Sets (MOD12 V004 CMG) for 2001 through 2004***
- *Urban:*
  - o **Urban Areas Research Project (2002-2003)**