BRDF/Albedo (MOD43B): Early Products and Results

BU and UCL BRDF/Albedo Teams
Overview

- Algorithm Review and Latest Prototyping
- Early Processing
- Early Products
- Concerns and Kudos
- Q/A and Validation
- Benchmarks
Bidirectional Reflectance/Albedo Product (MOD43)

**Objective:**
- Quantify angular variation in reflectance of land surface covers and estimate albedo for energy balance and climatic studies

**Features:**
- Utilizes seven land bands of MODIS data as gridded in a 16-day period
- Adds MISR, MODIS-Aqua data in postlaunch
- BRDF shape is fit to a semiempirical model derived from simplifications of physical models of surface scattering
- BRDF is integrated to provide spectral albedo measures independent of atmospheric effects
- Narrowband and broadband spectral albedos provided
- Level 3, land only, 1-km grid, 16-day repeat
Kernel-Driven Semiempirical BRDF Model

- **BRDF Model**
  - Linear combination of two BRDF shapes and a constant
  - BRDF shapes described by *kernels*, which are
    - Trigonometric functions of incidence and view angles
    - Derived from physical models for surface scattering

- **Analytical Form**

  \[ R = f_{iso} + f_{geo}k_{geo} + f_{vol}k_{vol} \]

  - where
    - \( f_{iso} \) is a constant for isotropic scattering;
    - \( k_{geo}, k_{vol} \) are trigonometric functions providing shapes for geometric-optical and volume-scattering BRDFs; and
    - \( f_{geo}, f_{vol} \) are constants that weight the two BRDFs
Fitting the BRDF Model: Inversion Strategies

- **Full inversion**: \( \geq 7 \) looks
  - Use least squares fitting to estimate BRDF parameters

- **Magnitude inversion**: 1–6 looks
  - Use BRDF database for shape of BRDF
  - Adjust magnitude of BRDF to fit measurements while retaining BRDF shape
Global BRDF/ Albedo At-Launch Database*

- **Objective**
  - Provide a global, at-launch, albedo database to initialize BRDF/Albedo algorithm
  - Merge field BRDF observations, land cover, and AVHRR data

- **Approach**
  - Defined 25 land cover classes with contrasting BRDF shapes
    - Used Olsen classification (94 labels) from USGS 1-km database
    - Created summer (July) and winter (February) versions (e.g., with and without background snow)
  - Fit Li-sparse/Ross-thin BRDF kernel model to 68 field BRDF datasets to provide BRDF shapes for these classes
  - (Note that database is also useful for global atmospheric correction and aerosol studies.)

- **Postlaunch Database**
  - Repopulate at-launch database with good inversions from prior time periods

*Doctoral dissertation work of Nick Strugnell, BU
Global Albedo from AVHRR*

- **Objective**
  - Provide winter and summer spectral and broadband albedo database at 1 and 10 km spatial resolution

- **Approach**
  - Use composited AVHRR red and NIR band data for February and June, 1995
  - Go to BRDF/Albedo at-launch database, perform 1-look magnitude inversion in red and NIR
  - Extend from red and NIR bands to broadband using
    - Typical vegetation/soil spectra
    - Typical downwelling irradiance spectrum
    - Local solar noon

*Doctoral dissertation work of Nick Strugnell, BU
Global Albedo from February 1995 AVHRR Data
Global Albedo from July 1995 AVHRR Data

Black-sky Albedo at Local Noon
Early MODIS BRDF/Albedo Processing

● Production
  ❑ Two 16-day global products made at MODAPS
    ✦ Days 97–112 (4/6–21)
    ✦ Days 113–128 (4/22–5/7)
    ✦ Data are incomplete; some tiles lost due to bugs in our code
  ❑ Awaiting 16-day runs from global “golden month” (May)

● Bugs and Fixes (v. 2.1.14)
  ❑ Metadata—Several problems fixed here
  ❑ Memory Leak—cause of lost tiles due to crashing
  ❑ Science bugs—Out of range parameter problems fixed
  ❑ Improvements—Addition of remaining spectral bands to albedo product
  ❑ Walthall model broken, to be fixed in 2.1.15
Early Examples and Products

- **North Carolina: March 5–8 and April 6–21**
  - NBAR false-color composites
  - Broadband white-sky albedos
  - Shows green-up particularly well

- **North America: April 6–21 and April 22–May 7**
  - NBAR false-color composites
  - Broadband white-sky albedos
Composite Map of Nadir BRDF-Adjusted Reflectance (NBAR)
North America, April 6 – April 21, 2000

NIR (0.10–0.40)     Red  (0.00–0.16)     Green  (0.00–0.18)

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Composite Map of Nadir BRDF-Adjusted Reflectance (NBAR)
North America, April 22 – May 7, 2000

NIR (0.10–0.40)   Red (0.00–0.16)   Green (0.00–0.18)

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Concerns and Kudos

● Data Quality
  ❑ Some striping in Bands 3, 5, 6, 7 leaking into final product
  ❑ Confident that these will repaired shortly
  ❑ Geolocation now performing well

● Production
  ❑ Hoping for more complete 16-day intervals soon

● Upstream Products
  ❑ Surface reflectance, cloud mask have greatly improved

● Kudos
  ❑ Special thanks to:
    ✦ SSI&T Team for handling bug fixes so quickly
    ✦ LDOPERs for spotting problems and keeping us up to date
MOD43B BRDF/Albedo Product Validation

- **Routine Q/A**
  - Golden tiles
  - Use MOD43B BRDF parameters to predict future observations

- **Evaluations**
  - Compare albedo results with existing global databases
  - AVHRR, POLDER, METEOSAT, MISR

- **Field Efforts:**
  - Shunlin Liang—Validation Scientist (BARC EOS core site)
  - Mike Barnsley—EOS core site (Barton Bendish)
  - P. Lewis—EOS core sites (Africa)
  - Peter Muller—BSRN albedo data
  - BU—(Participation limited by funds)
    - Albedometers with Rachel Pinker at Jornada EOS core site
    - Local EOS core site—Harvard Forest
Benchmarks

- **DAAC Release**
  - August 1: Complete documentation and user guide
  - September 1: DAAC releases product

- **MISR Data Incorporation**
  - Prototyping in October–December period
  - Add MISR to production data stream by January 1, 2001

- **MODIS-AQUA**
  - Add MODIS-ACQA to data stream first quarter. 2001, depending on launch
MODIS Land Cover Prototyping Activities

Boston University Land Cover Team
Overview

- Quick Review
  - Product description
  - Algorithm
  - IGBP Classification

- Global Training Site Database Status

- Recent Prototyping with AVHRR
  - North America
  - New England

- Code and Processing Status
- Benchmarks
Land Cover Product Summary

Objective:
- Provide a simple land-cover categorization for biophysical parameterization for GCM, hydrologic, and carbon cycling models

Features
- Categorizes land cover according to life-form, cover and height of dominant vegetation type following IGBP-DIS scheme
- Uses data from spectral, spatial, temporal, directional domains as derived from other MODIS products
- Relies on advanced classifier technology—e.g., neural nets, decision trees
- Network of global test sites planned for algorithm calibration and validation
- At-launch 1-km database derived from AVHRR heritage
- Level 3, 1-km spatial resolution, 96-day product; Climate Modeler’s Grid (1/4°) product also available
IGBP Land Cover Units (17)

- **Natural Vegetation (11)**
  - Evergreen Needleleaf Forests
  - Evergreen Broadleaf Forests
  - Deciduous Needleleaf Forests
  - Deciduous Broadleaf Forests
  - Mixed Forests
  - Closed Shrublands
  - Open Shrublands
  - Woody Savannas
  - Savannas
  - Grasslands
  - Permanent Wetlands

- **Developed and Mosaic Lands (3)**
  - Croplands
  - Urban and Built-Up Lands
  - Cropland/Natural Vegetation Mosaics

- **Nonvegetated Lands (3)**
  - Snow and Ice
  - Barren
  - Water Bodies
Advanced Technology Classifiers

- **Supervised Mode**
  - Classifiers operate in supervised mode with training sites
  - Allows multiple classification

- **Neural Networks—** *Fuzzy ARTMAP*
  - Uses Adaptive Resonance Theory in building network
  - Nonlinear partitioning of measurement space
  - Significantly outperforms backpropagation algorithms
  - New Gaussian version adjusts for covariance

- **Decision Trees—** *C5.0 Univariante Decision Tree*
  - Fast algorithm
  - Uses boosting to create multiple trees and improve accuracy

- **Voting Rules**
  - Multiple trained networks and decision trees used as voters in ultimate decision rule
Prototyping North America With AVHRR

- IGBP Classification Scheme (17 classes)
- Prototype released Fall, 1999, as poster, web database, and CD-ROM
- Accuracies, based on unseen training sites
  - Overall: 65%
  - Collapsed classes: 79%
- New Science
  - Uncertainties derived from boosting allow confidence mapping
  - Use of prior probabilities to improve accuracy
Test Sites

- IGBP-DIS Core/Confidence Sites
  - Random sampling of classes on 1992 IGBP Global Land Cover Product
  - 425 sites identified; 413 SPOT and TM scenes acquired; 91% migrated to WWW by BU (6/6/00)

- BU STEP Database
  - 2614 training sites from 645 TM scenes (6/6/00)

- Status (6/6/00)
  - North America: In second level Q/A analysis after prototype release, Fall, 1999
  - South America: In prototype classification development
  - Africa: Initial analysis complete, waiting Q/A
  - Eurasia, Pacifica: In progress and awaiting new scenes and samples
New Ideas for Land Cover Classification

- **Confidence Mapping**
  - Use classifier trials to map confidence in classification on a pixel-by-pixel basis
  - Example—North American classification confidence map

- **Prior Probabilities**
  - Use ancillary data as prior probabilities to adjust classification to favor more likely classes
  - Example—reduce confusion between agriculture and natural vegetation types in central midwestern US
Mapping Classification Confidence

Confidence

- Low: 0
- 25
- 50
- 75
- High: 100
Inclusion of Prior Probabilities for Agriculture

Change Legend:
- No Change
- Change from Agricultural Class to Natural Vegetation Class
- Change from Natural Vegetation Class to Agricultural Class

Change: Ag. To Natural Veg. – 8.7%; Natural Veg. To Ag. – 8.2%
MODLand Support Products

- **Six Biomes for LAI/FPAR**
  - Six-biome map needed to support LAI-FPAR algorithm
  - Provisional map from revised IGBP-DISCover Product
    - North American test product prepared

- **Modified IGBP for Net Primary Productivity (NPP)**
  - NPP uses IGBP, but needs more information on leaf type and cover for some classes
  - Working with Montana and Maryland to fill their need
Code and Processing Status

- MOD12M (Monthly Composite Database)
  - Ran once at MODAPS
- Bugs and Fixes
  - Metadata and fill value problems in input datasets are being worked
Benchmarks

- Completion of IGBP-DIS core and confidence WWW info 7/1/00
- Completion of first-generation global training set 9/1/00
- Begin test classifications by continents 9/1/00
- Release continental prototypes 1/1/01–4/1/01
- Release global prototype 6/1/01
- Release final product stream 8/1/01
Land Cover Validation

● Statistical Assessment Based on Site Data
  ❑ Cross-validation provides probability estimate for errors of omission/commission
  ❑ Two sets of site data:
    ✦ IGBP-DIS Core/Confidence sites—Random stratified sample based on IGBP Land Cover map (Loveland et al., EDC)
    ✦ Supplemental sites compiled at BU—no explicit sampling design, but large N

● Comparison with Community Benchmark Datasets
  ❑ Comparison with independent maps derived from high resolution data, e.g.,
    ✦ Humid Tropics: Landsat Pathfinder
    ✦ Forest Cover: FAO Forest Resources Assessment
    ✦ Western Europe: CORINE
    ✦ United States: USGS/EPA MLRC

● Collaboration with Regional Expertise
Land-Cover Change Overview

- **Technical Approach**
  - *Change Vectors*
    - Compares the position in measurement space of observations made in successive years
    - Simple, direct
    - Will be primary tool for change detection and characterization

- **Development Status**
  - Algorithm prototyped for Africa with AVHRR data by Lambin et al.
  - Requires multitemporal MODIS data, so postlaunch status
**Land-Cover Change**

- **Change-Vector Analysis**
  - Time-trajectory of each pixel through a year taken as a point in multidimensional measurement space
  - Change vector quantifies distance and direction of change for points from two successive years

![Multidimensional measurement space diagram](image)

- **Multidimensional measurement space**
  - Year 1
  - Year 2
  - Change Vector