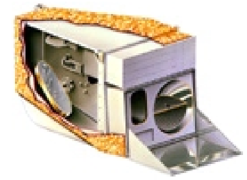


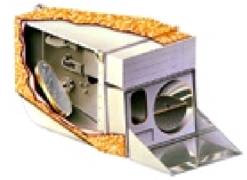
BRDF/Albedo (MOD43B): Early Products and Results

BU and UCL BRDF/Albedo Teams

Overview

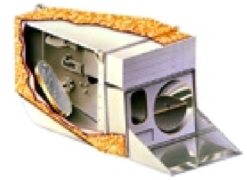
- Algorithm Review and Latest Prototyping
- Early Processing
- Early Products
- Concerns and Kudos
- Q/A and Validation
- Benchmarks

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

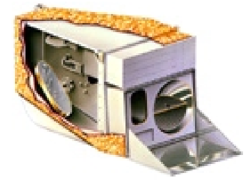
- Full inversion: ≥ 7 looks
  - Use least squares fitting to estimate BRDF parameters
- Magnitude inversion: 1–6 looks
  - Use BRDF database for shape of BRDF
  - Adjust magnitude of BRDF to fit measurements while retaining BRDF shape

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

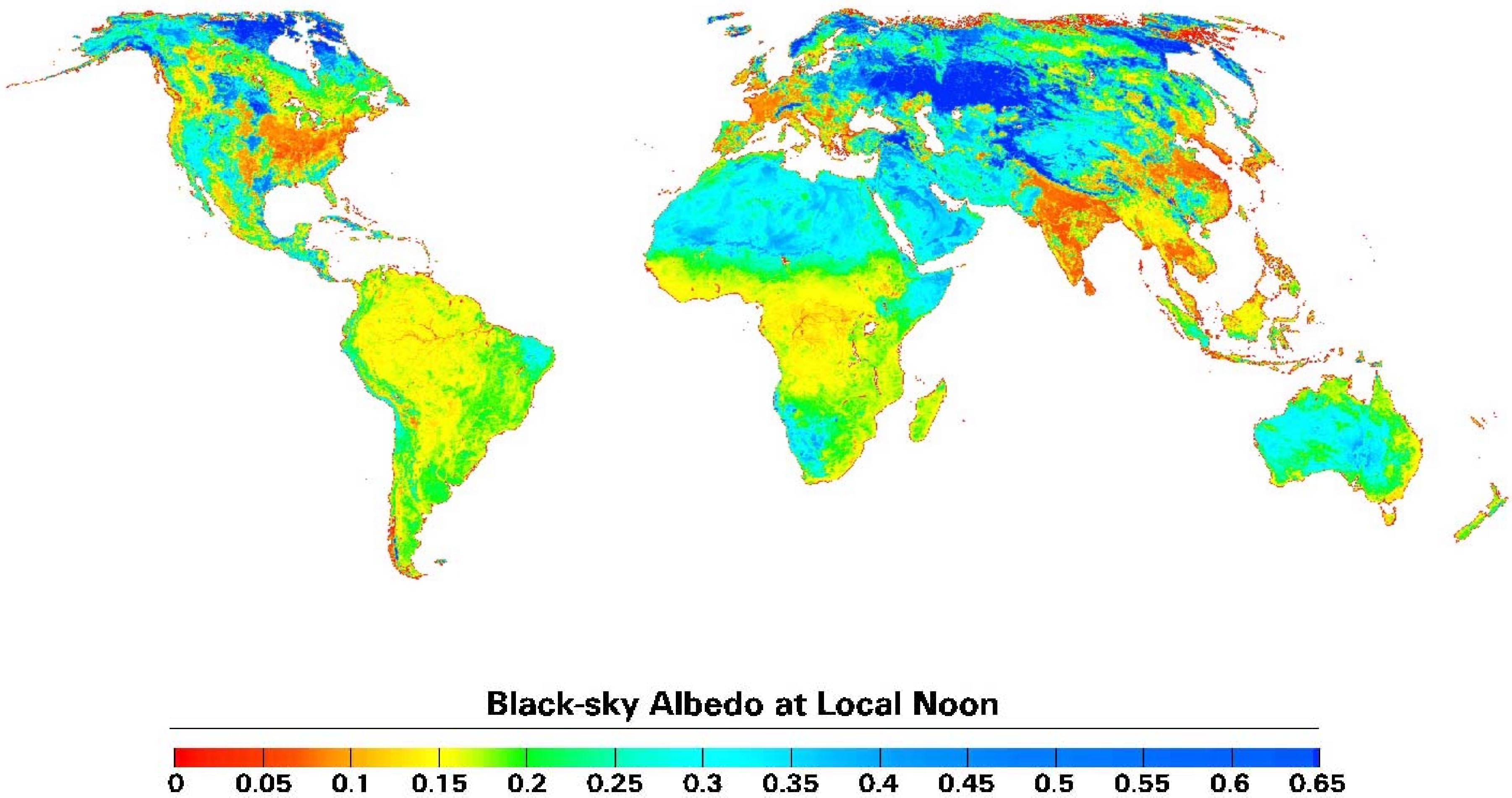
Global Albedo from AVHRR*



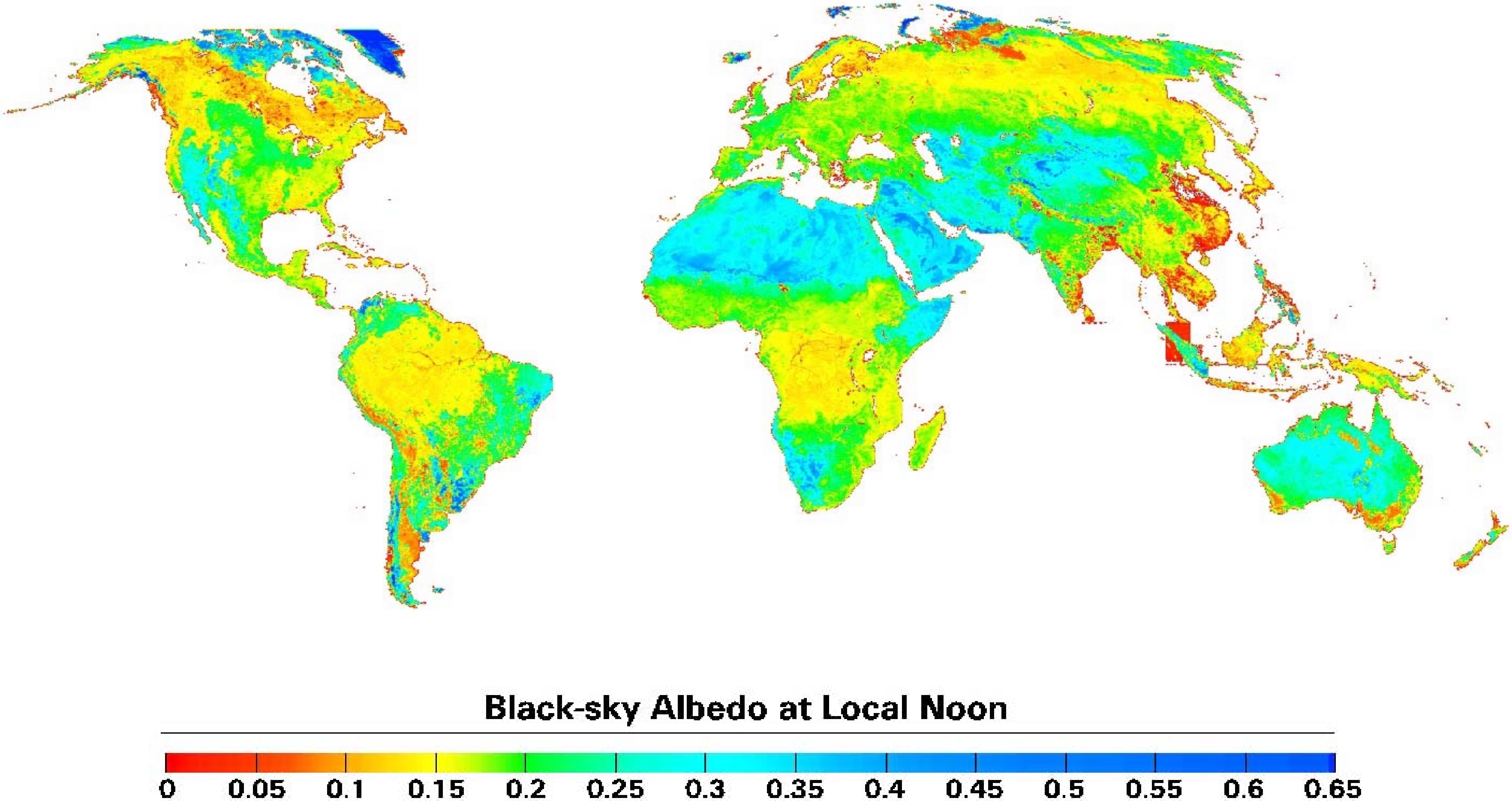
- Objective
  - Provide winter and summer spectral and broadband albedo database at 1 and 10 km spatial resolution
- Approach
  - Use composited AVHRR red and NIR band data for February and June, 1995
  - Go to BRDF/Albedo at-launch database, perform 1-look magnitude inversion in red and NIR
  - Extend 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



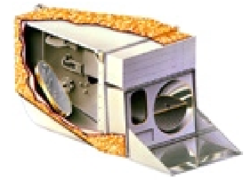
Global Albedo from July 1995 AVHRR Data



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

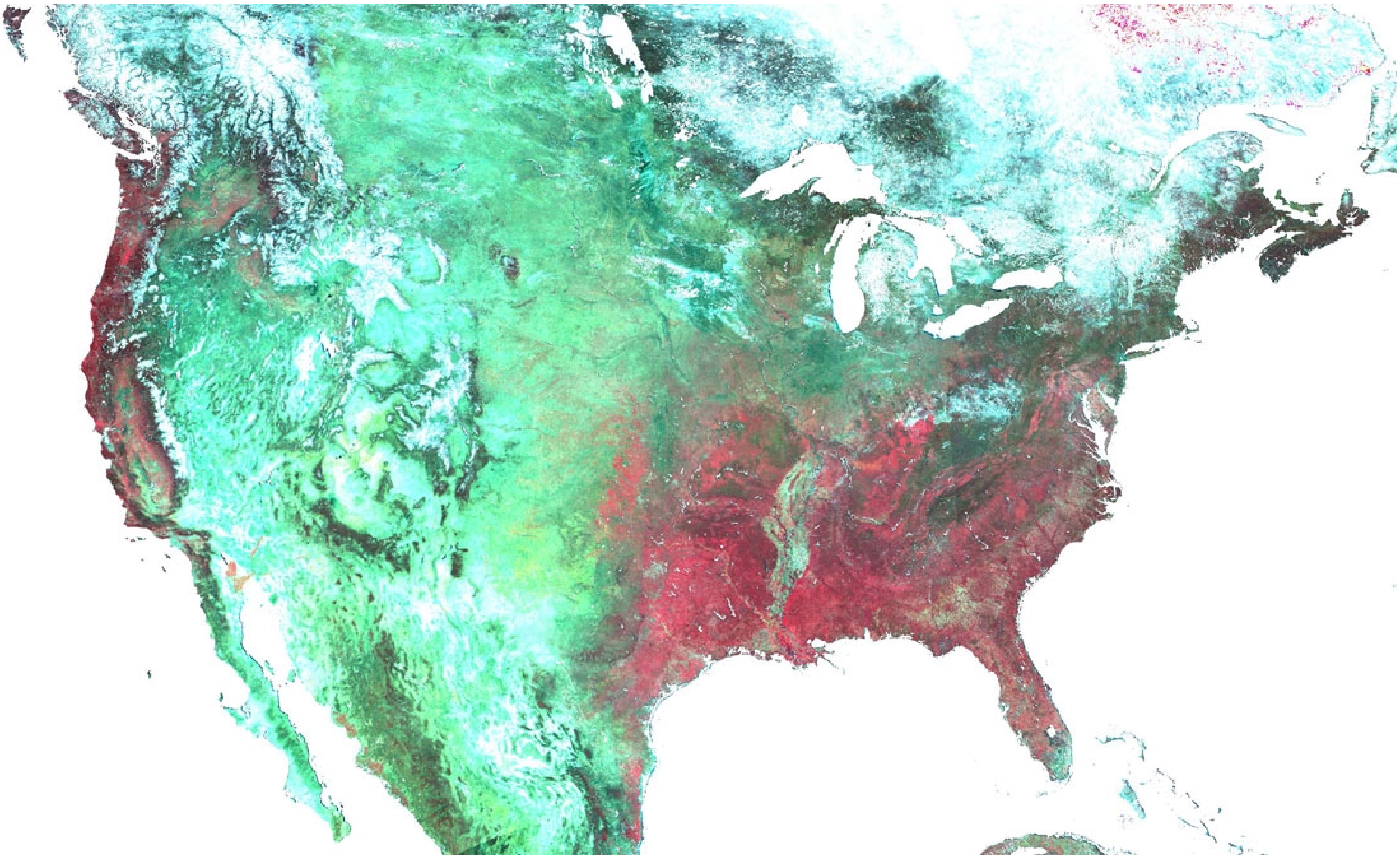
Early Examples and Products



- 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

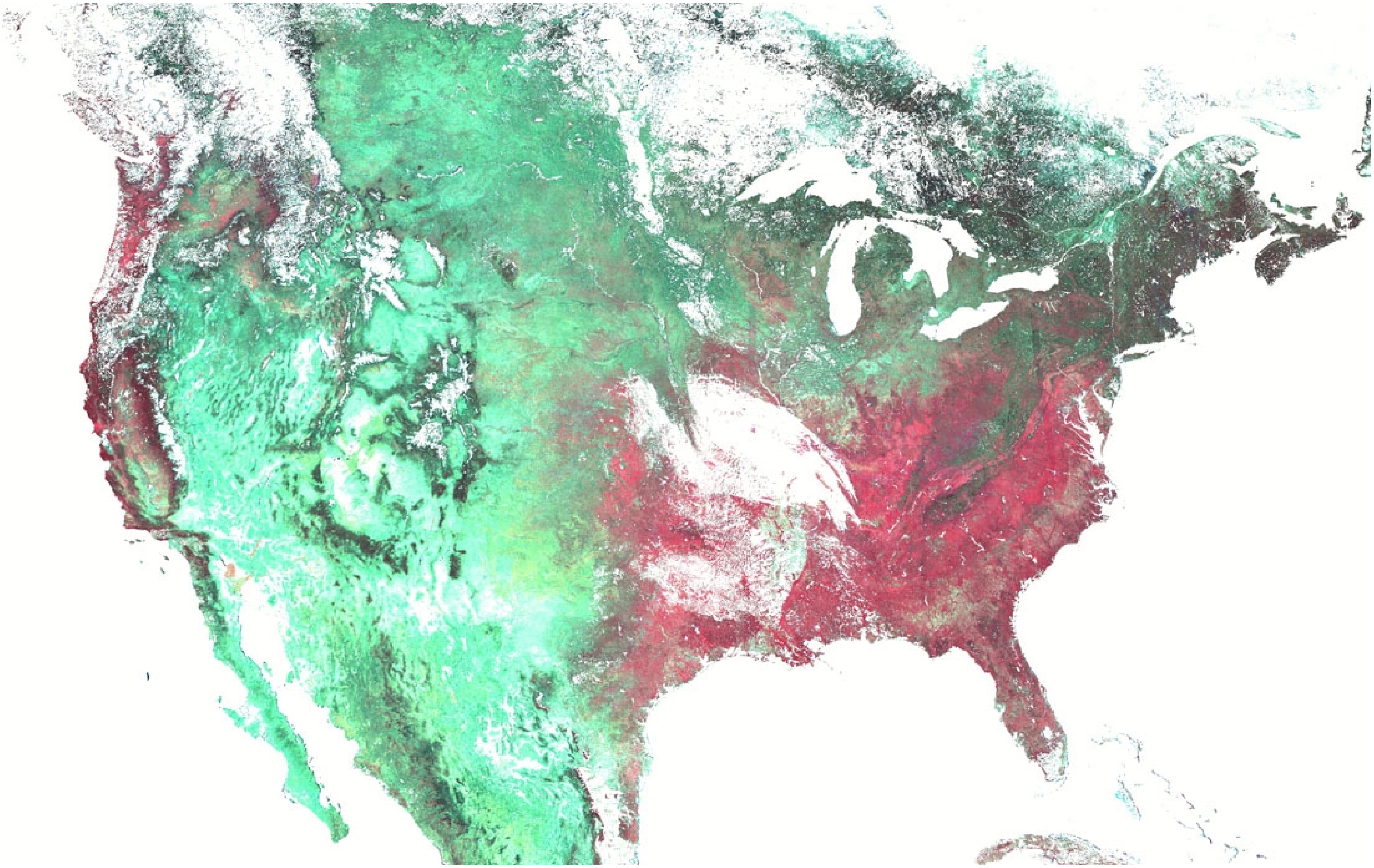


NIR (0.10–0.40)   Red (0.00–0.16)   Green (0.00–0.18)

BU/UCL

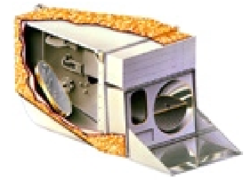
Composite Map of Nadir BRDF-Adjusted Reflectance (NBAR)

North America, April 22 – May 7, 2000



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

BU/UCL

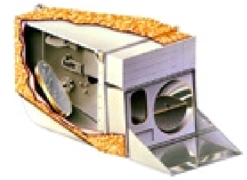


Concerns and Kudos

- 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

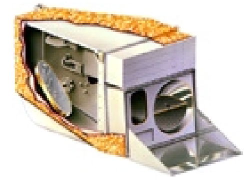


Benchmarks

- 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

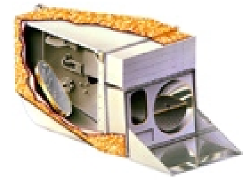
Boston University Land Cover Team



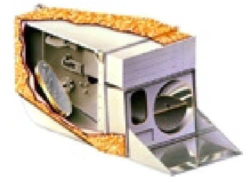
Overview

- 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

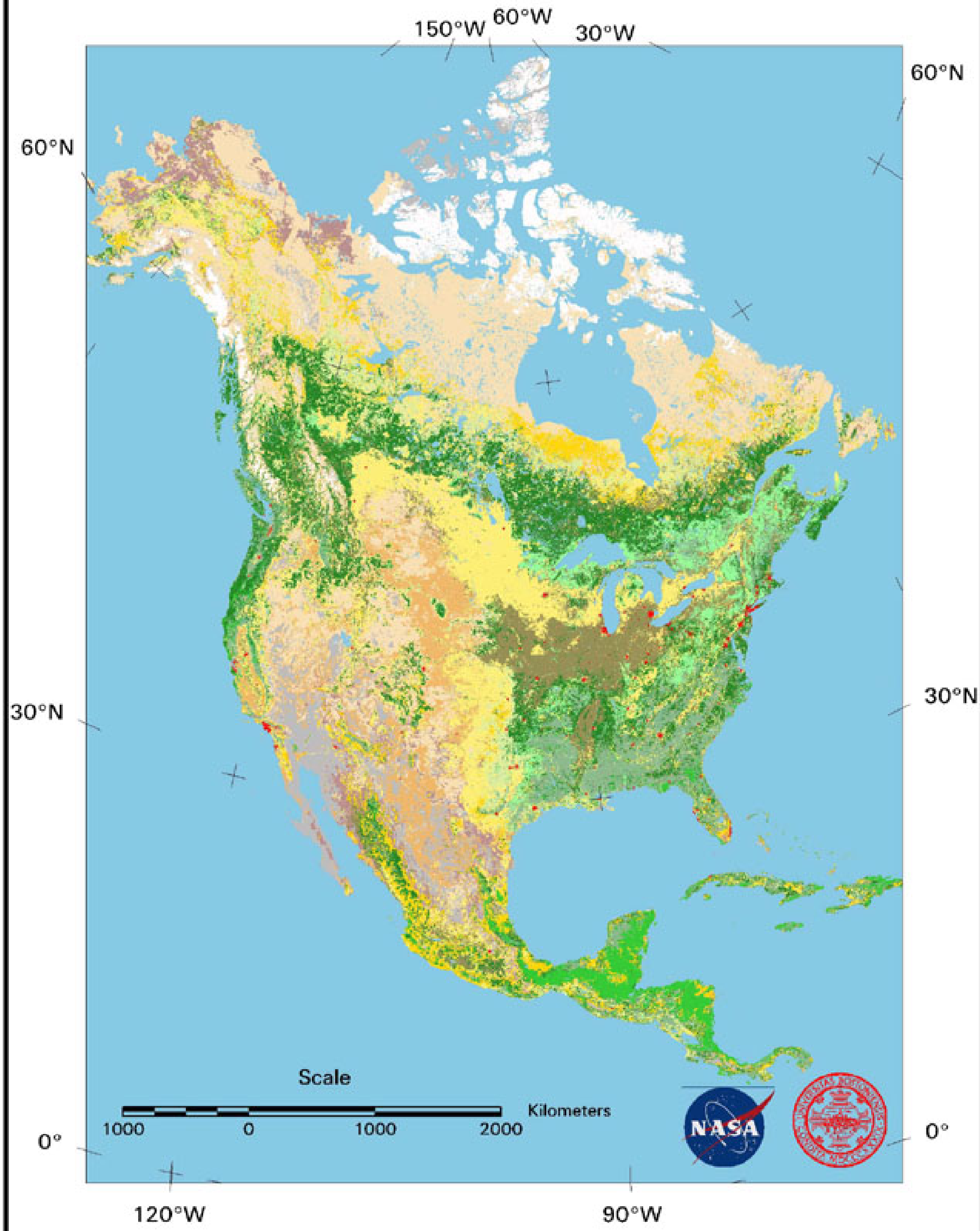
Advanced Technology Classifiers

- 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 Univariate 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

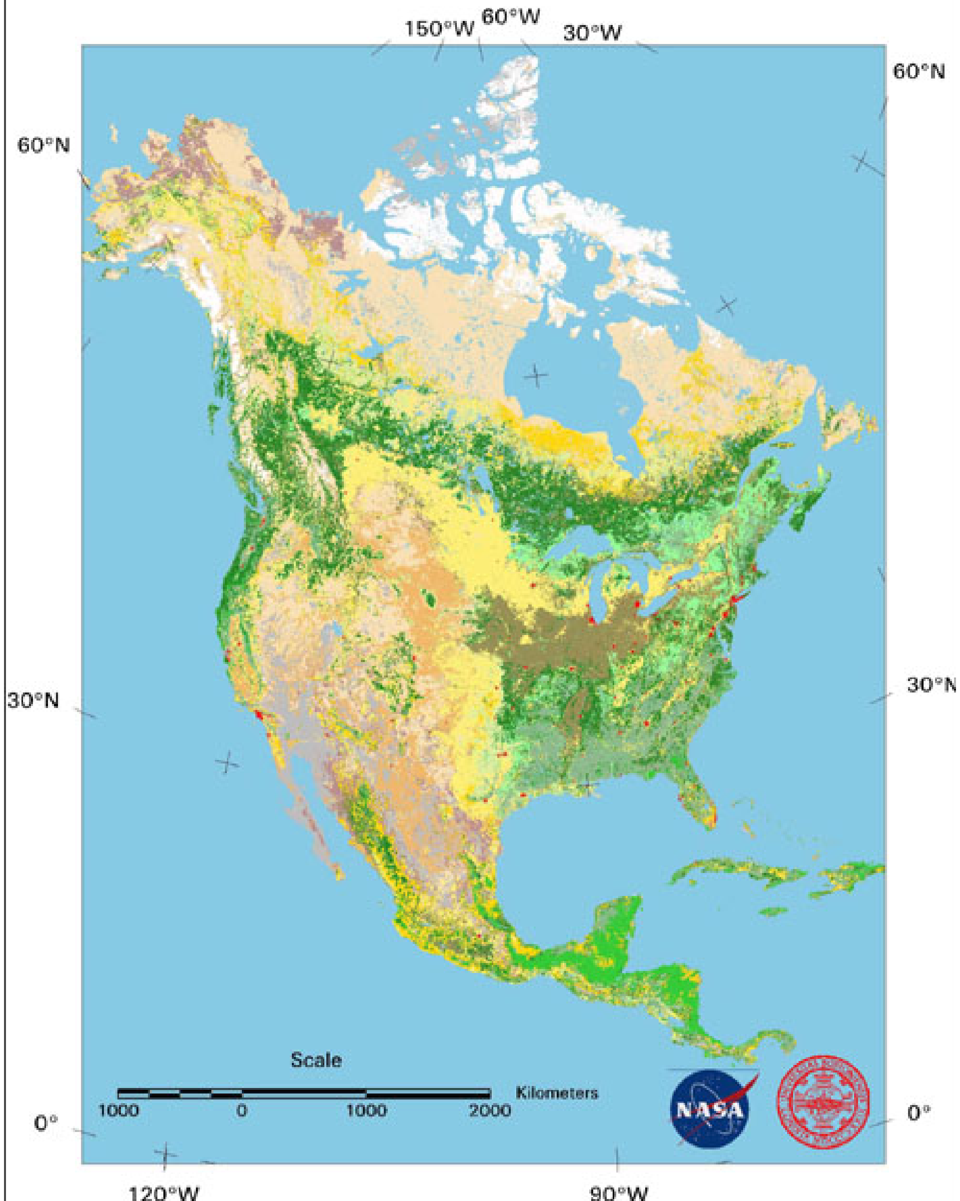
Prototyping North America With AVHRR

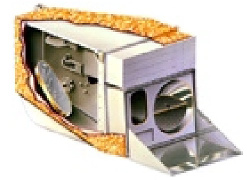
- IGBP Classification Scheme (17 classes)
- Prototype released Fall, 1999, as poster, web database, and CD-ROM
- Accuracies, based on unseen training sites
  - ❑ Overall: 65%
  - ❑ Collapsed classes: 79%
- ***New Science***
  - ❑ Uncertainties derived from boosting allow confidence mapping
  - ❑ Use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

MODIS Prototype Classification of North American Land Cover



MODIS Prototype Classification of North American Land Cover

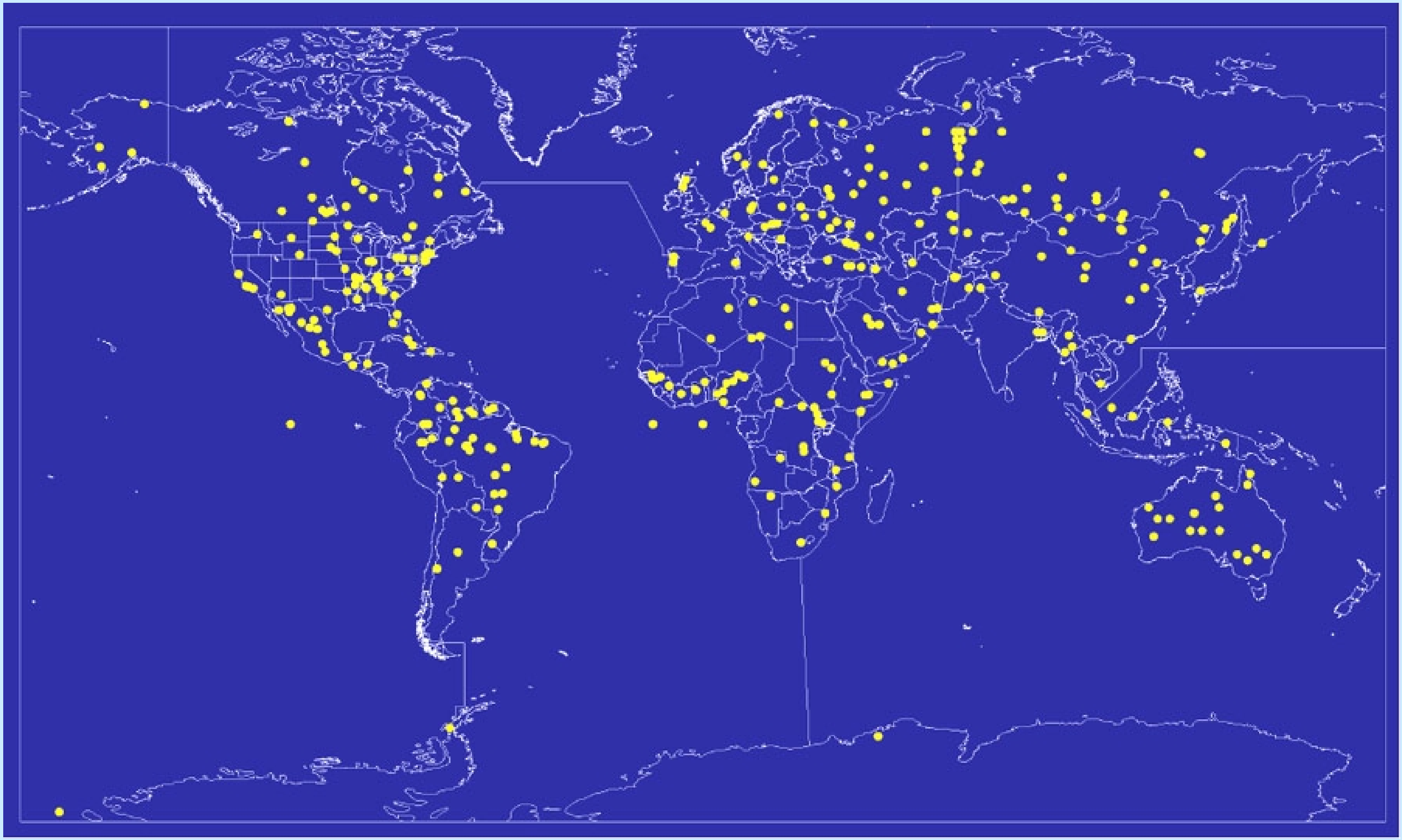




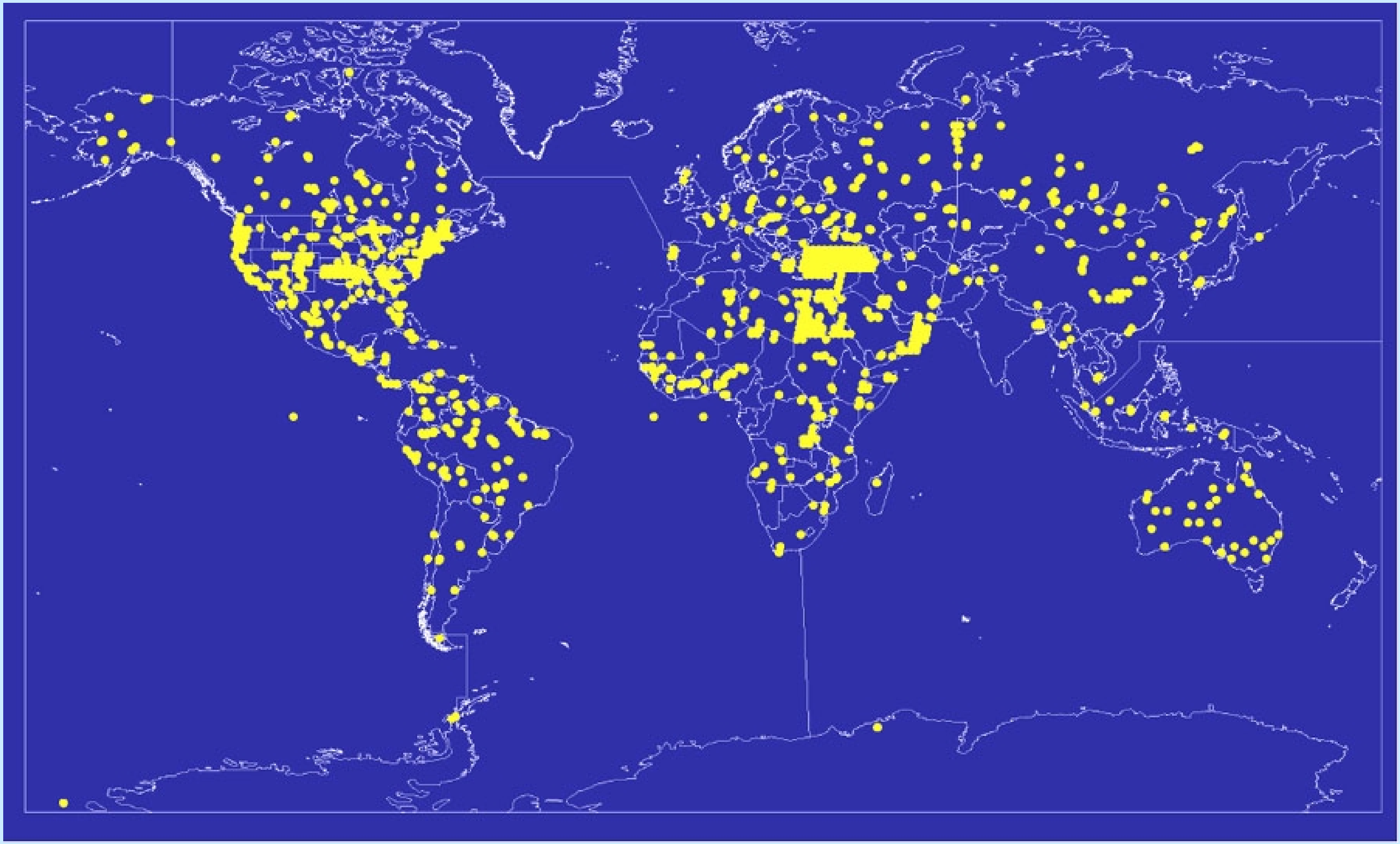
Test Sites

- 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

IGBP-DIS Core Validation Sites



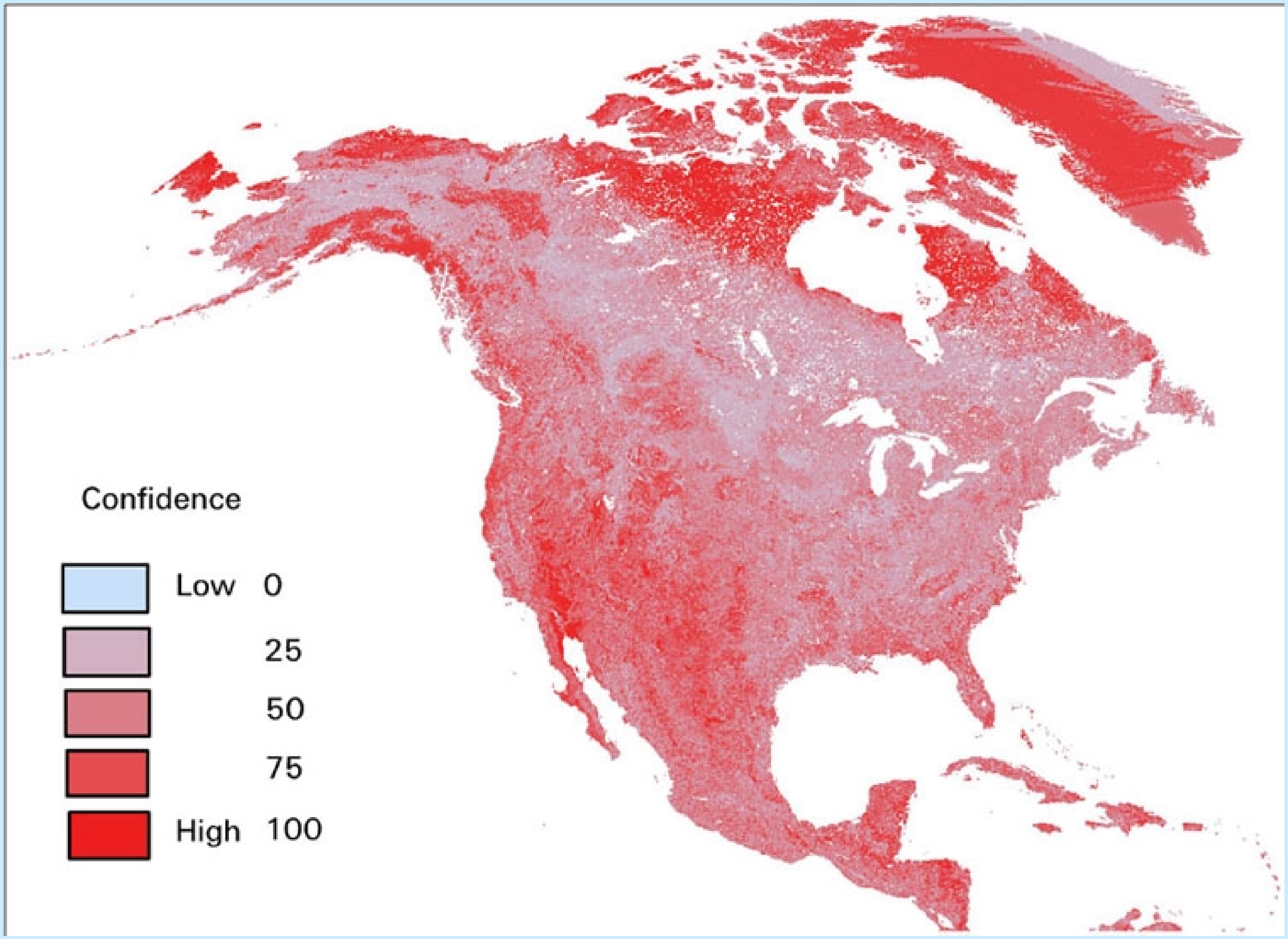
Supplemental Sites Compiled at BU



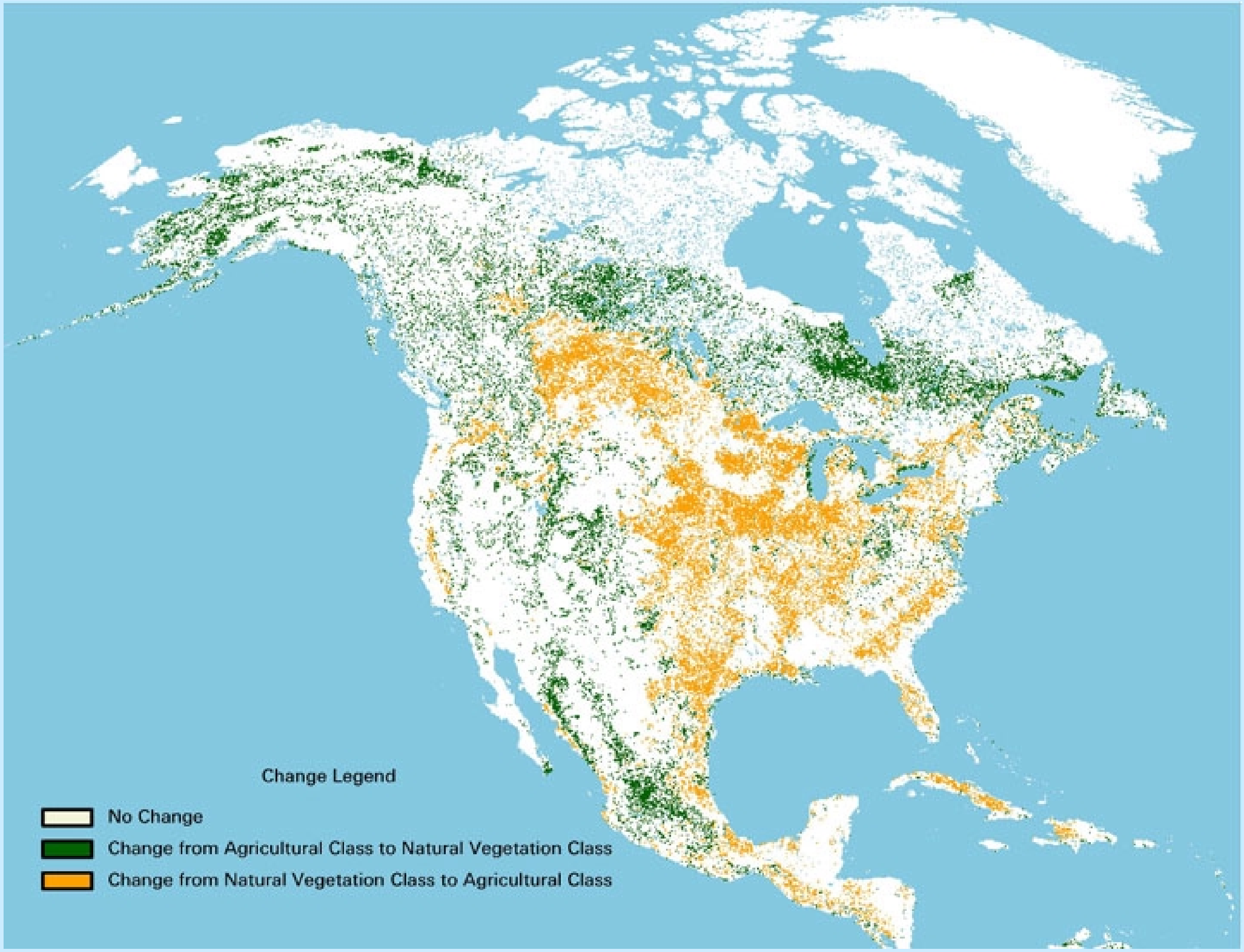
New Ideas for Land Cover Classification

- 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



Inclusion of Prior Probabilities for Agriculture



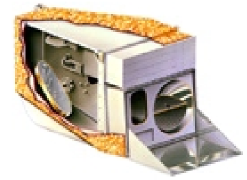
Change: Ag. To Natural Veg. – 8.7%; Natural Veg. To Ag. – 8.2%

MODLand Support Products

- Six Biomes for LAI/FPAR
  - ❑ Six-biome mapneeded 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