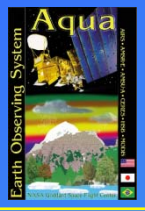


The MODIS Reflectance, Anisotropy and Albedo Product: Applications and Enhancements

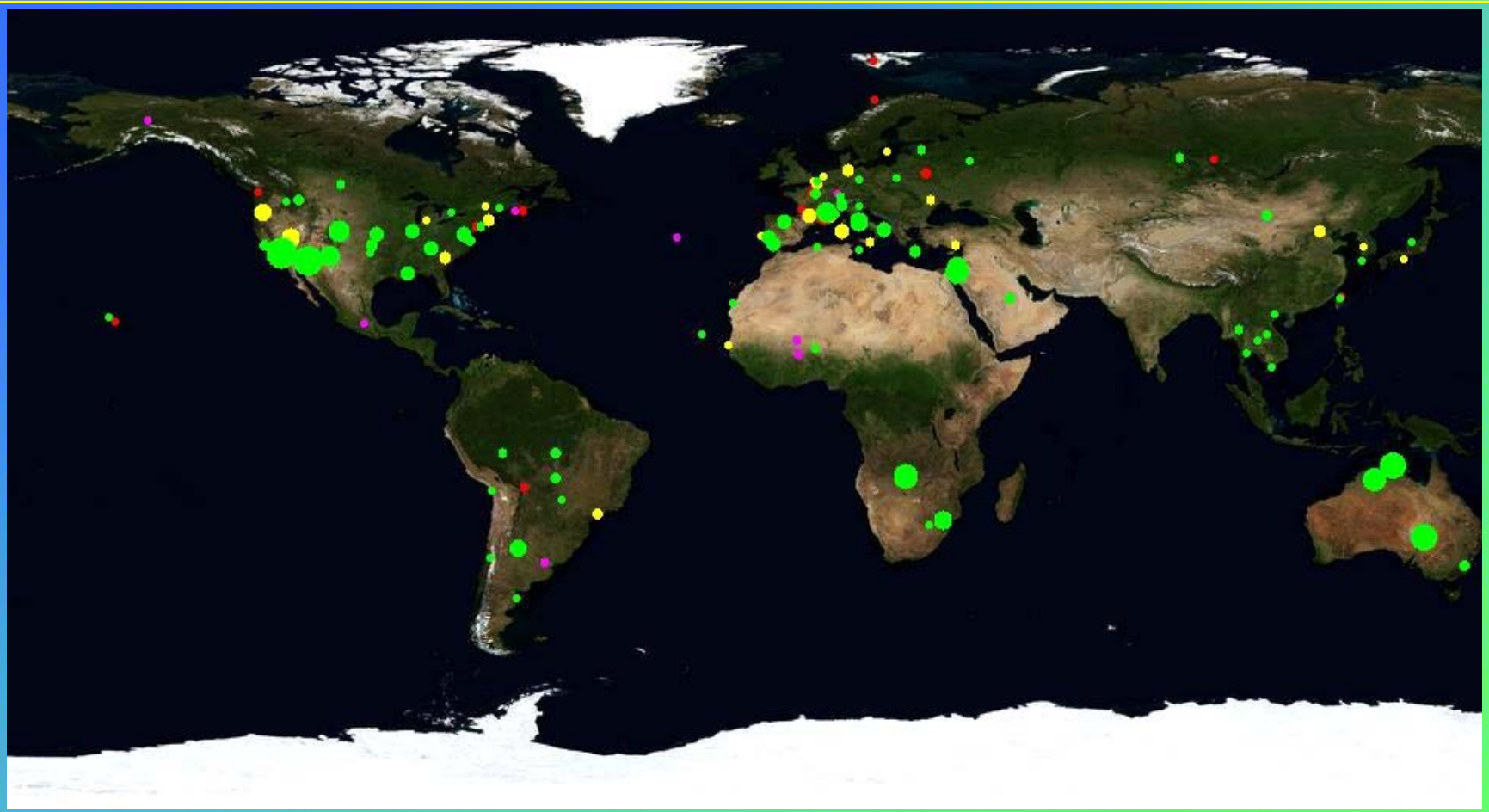
Crystal Schaaf, Alan Strahler, Zhuosen Wang,
Yanmin Shuai, Miguel Román, Qingling Zhang,
Ziti Jiao, Jindi Wang, and Xiaowen Li

Center for Remote Sensing,
Department of Geography and Environment,
Boston University, Boston MA, USA

School of Geography
Beijing Normal University
Beijing, China

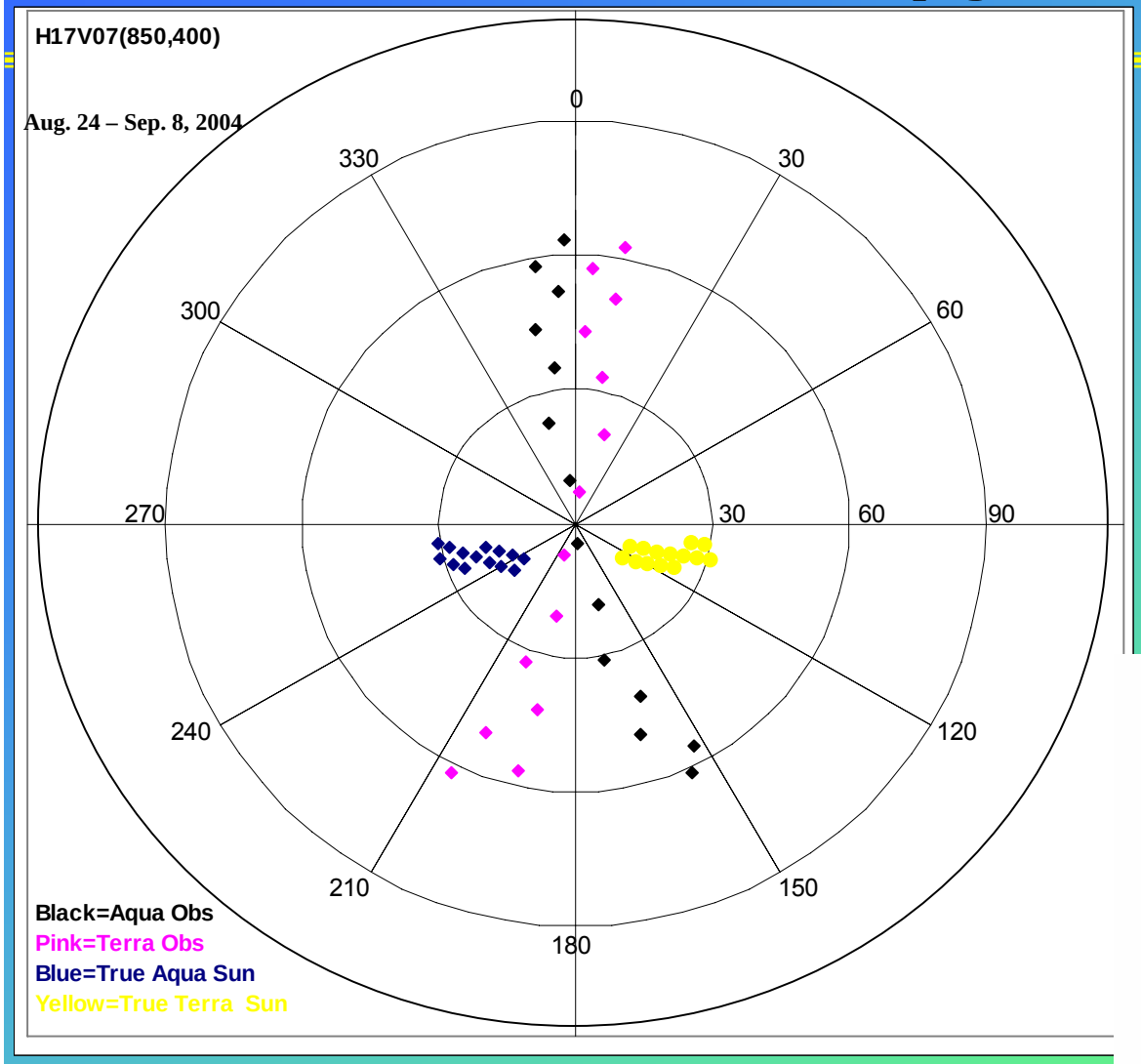
MOD09 Land Surface Reflectance

Eric Vermote, UMD



Global annual comparison of MODIS band 1 red with 6SV/**Aeronet** computations 2003 results about 5000 cases analyzed (green percentage within one sigma >80%, yellow 80-65%, magenta 65-55%, red < 55%).

MODIS Anisotropy Model Retrieval



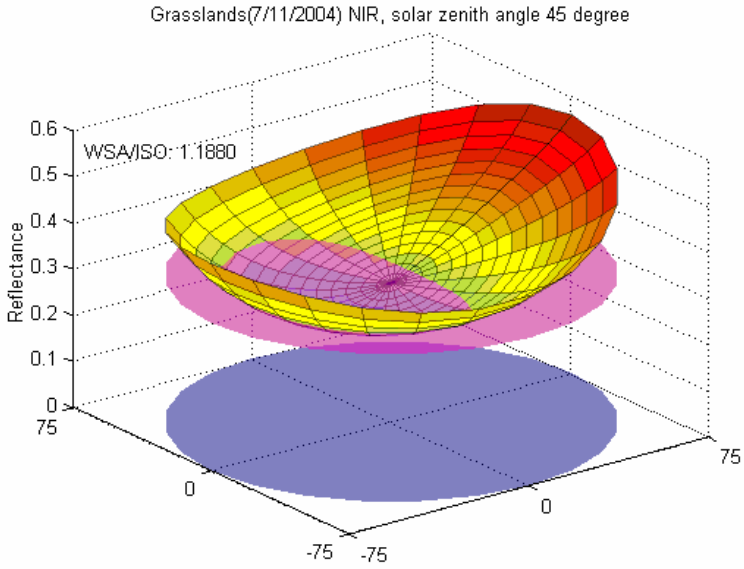
RossThickLiSparseReciprocal model via best fit and WoD

*kvol, k*geo kernels of view and illumination geometry

kvol radiative transfer theory (Ross,1981),

*k*geo geometric-optical surface scattering (Li & Strahler, 1992)

*f*iso, *f*vol, *f*geo are spectrally dependent best fit weights



$$\alpha_\lambda(\theta_i, \Phi_i; \theta_r, \Phi_r) = f_{iso} + f_{vol}k_{vol} + f_{geo}\,k_{geo}$$

Roujean et al., 1992

MODIS Anisotropy Retrievals

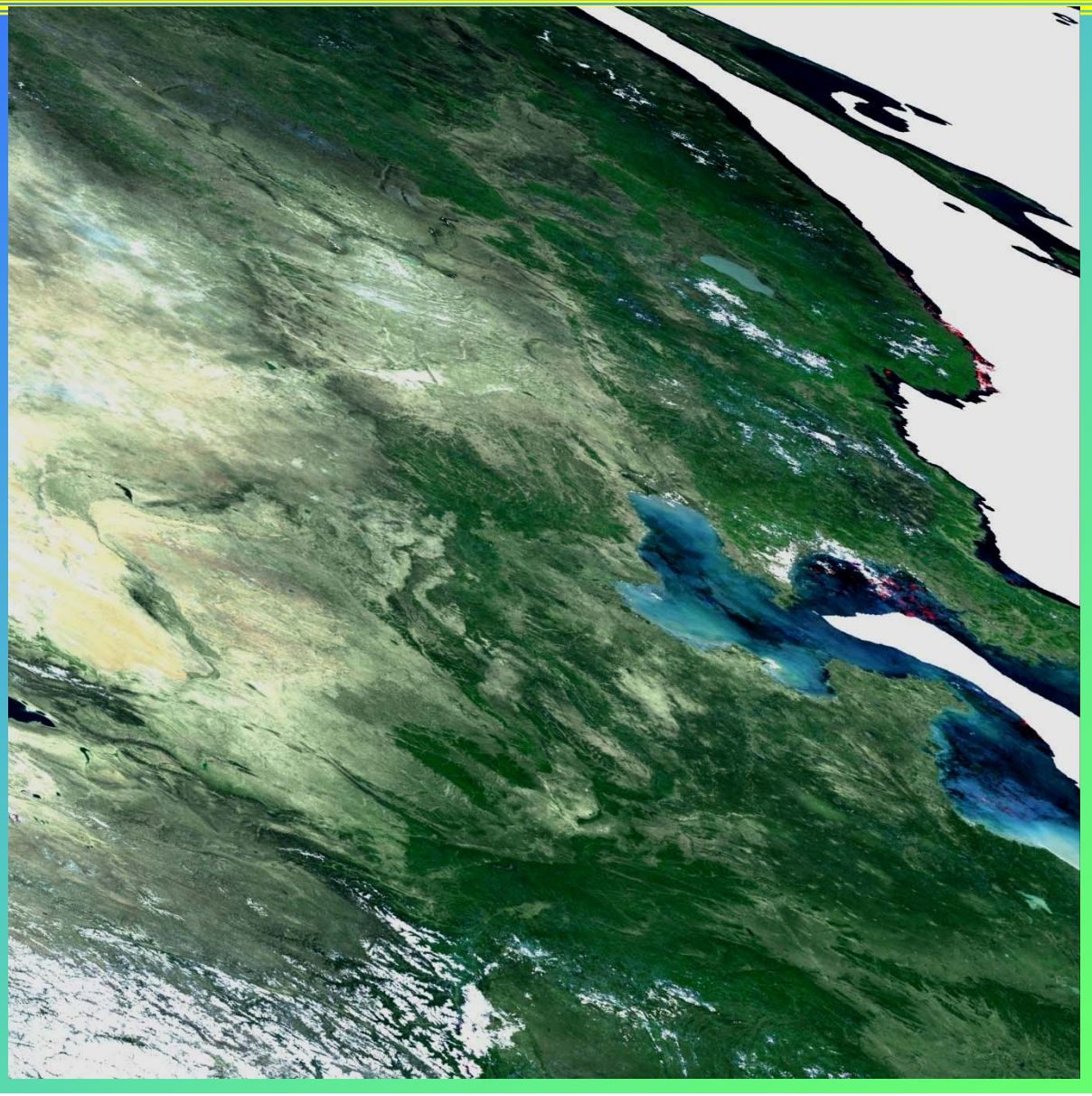
- **Inputs**
  - **Aqua and Terra** cloud-free, atmospherically-corrected, spectral **surface reflectances** (MOD09/MYD09 BRFs) used to sample surface anisotropy over a 16 day period

- **Output**
  - **High quality full inversions** provide well-sampled, best-fit RTLSR anisotropy models of global land surfaces every 8 days
  - **Lower quality** back-up algorithm provide **magnitude inversions** by coupling available reflectances with *a priori* BRDF database
  - **Majority** condition (**snow/no-snow**) retrieved

MODIS Anisotropy and Albedo Products

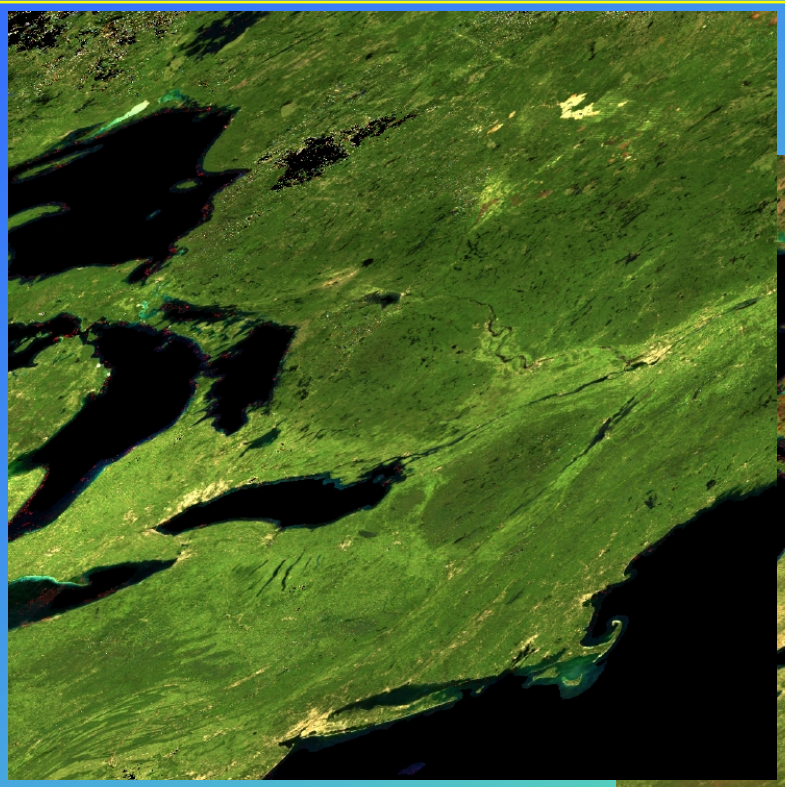
- **BRDF Model parameters (MCD43A1/B1/C1/D1-30)**
  - RossThickLiSparseR model parameters
    - Simple polynomial to estimate albedo
    - Simple shape factors calculated
    - 7 spectral bands, 3 broad bands
    - 500m, 1km sinusoidal 10deg tiles
    - 0.05deg global geographic lat/lon (Climate Model Grid –CMG)
    - 30 arc second CMG only available from http://ladsweb.nascom.nasa.gov/
- **Albedo quantities (MCD43A3/B3/C3)**
  - White-sky albedo or bihemispherical reflectance under isotropic illumination (BHRiso)
  - Black-sky albedo or directional-hemispherical reflectance (DHR) at local solar noon
- **Nadir BRDF-Adjusted Reflectance NBAR (MCD43A4/B4/C4)**
  - View angle corrected surface reflectances
  - Primary input to MODIS land cover, phenology
- **Quality Flags (MCD43A2/B2/D31-34)**
  - Quality still embedded in MCD43C* 0.05deg products, C2 is snow-free parameters

Beijing, China

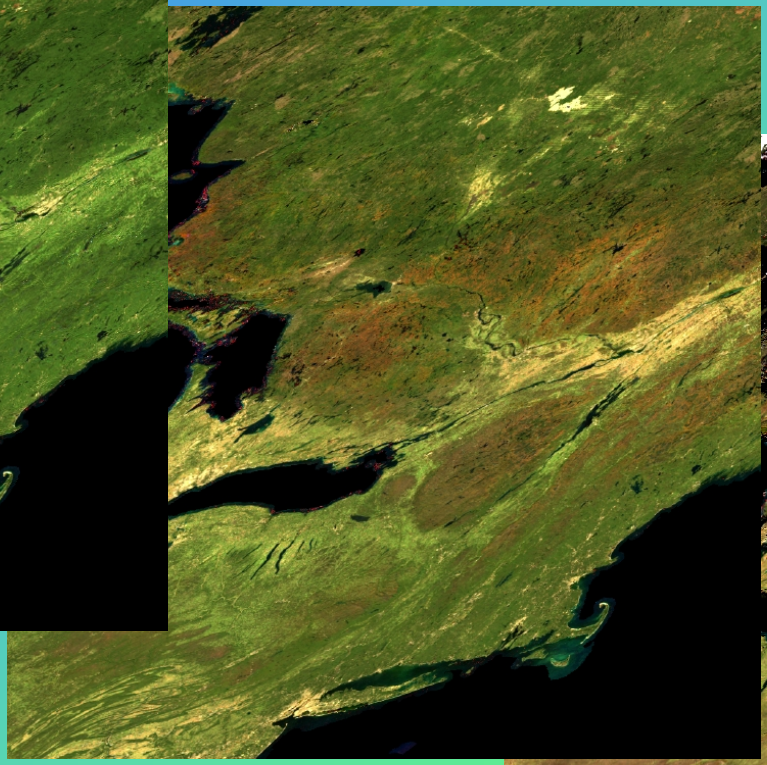


5/8/2008

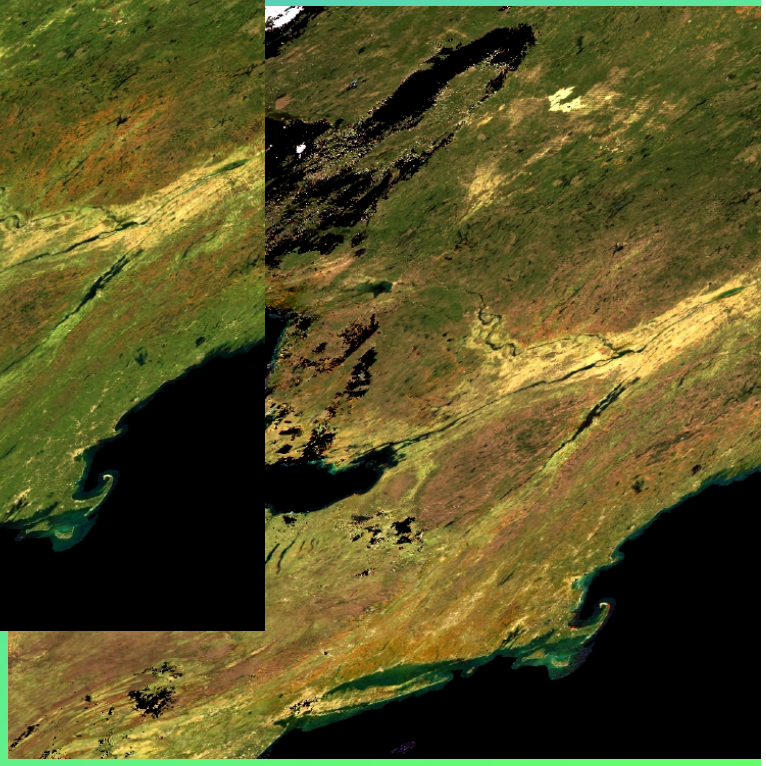
New England Foliage



8/28/04

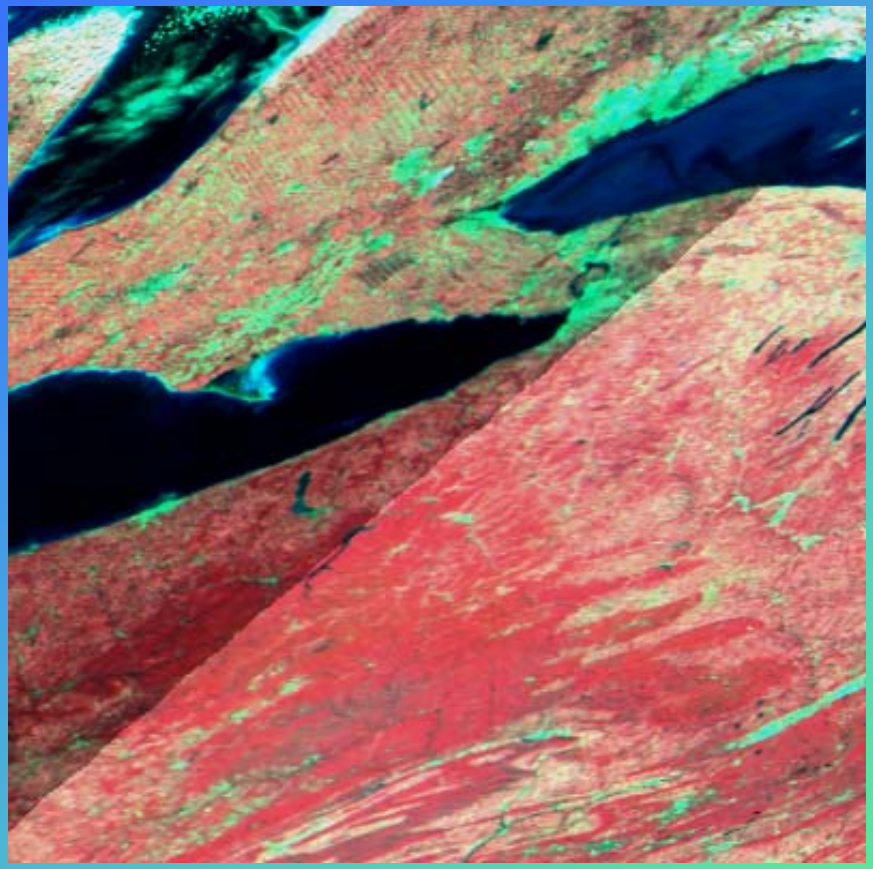


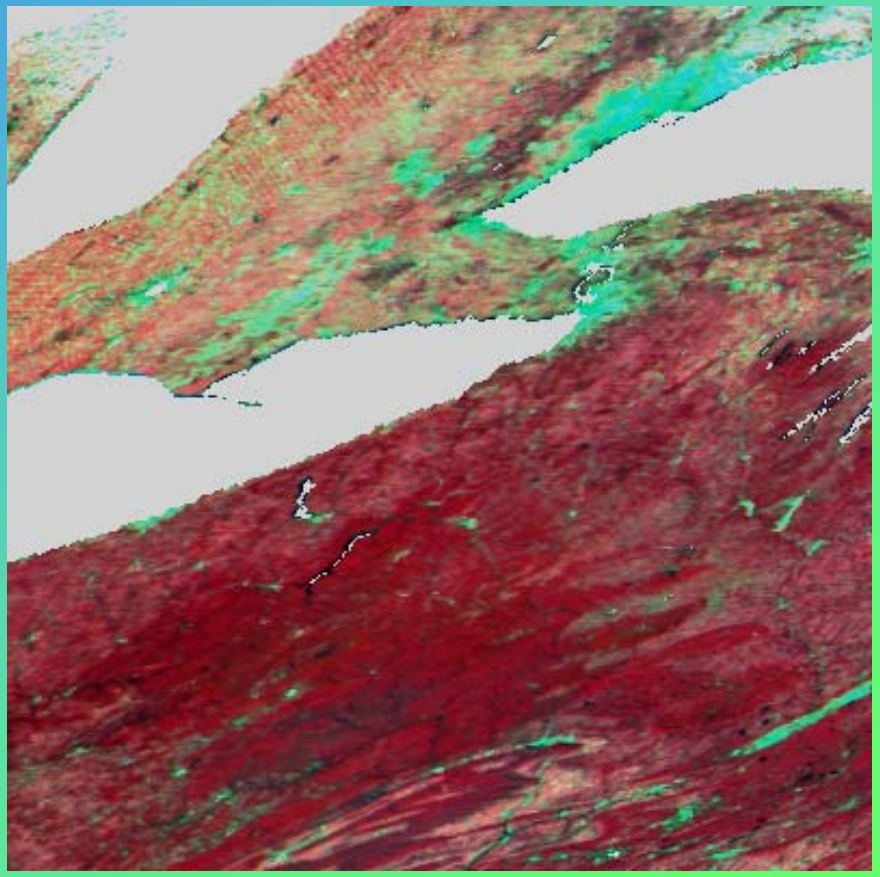
9/29/04



10/15/04

NBAR

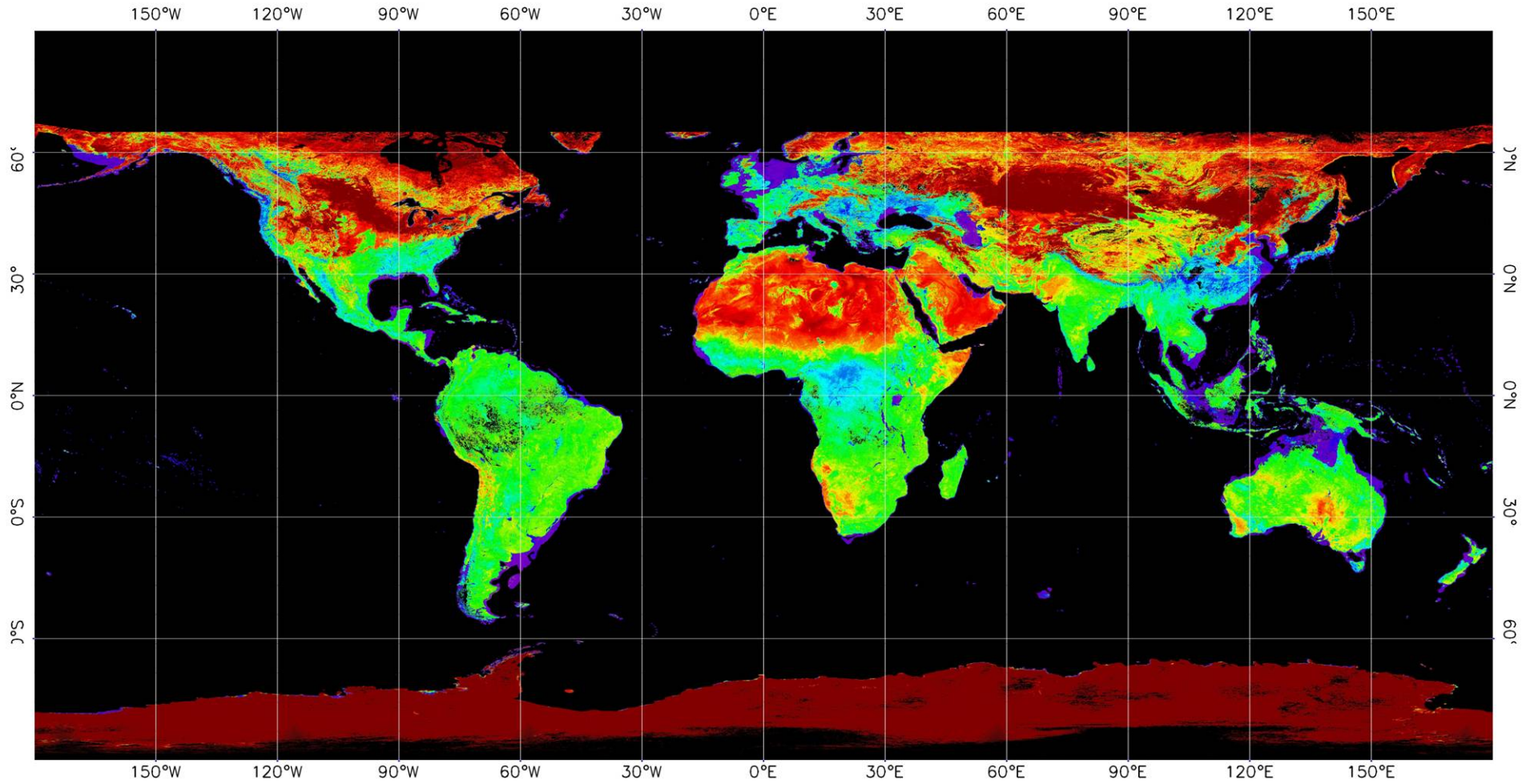




NIR (0.10-0.45) Red (0.0-0.1) Green (0.0-0.15)

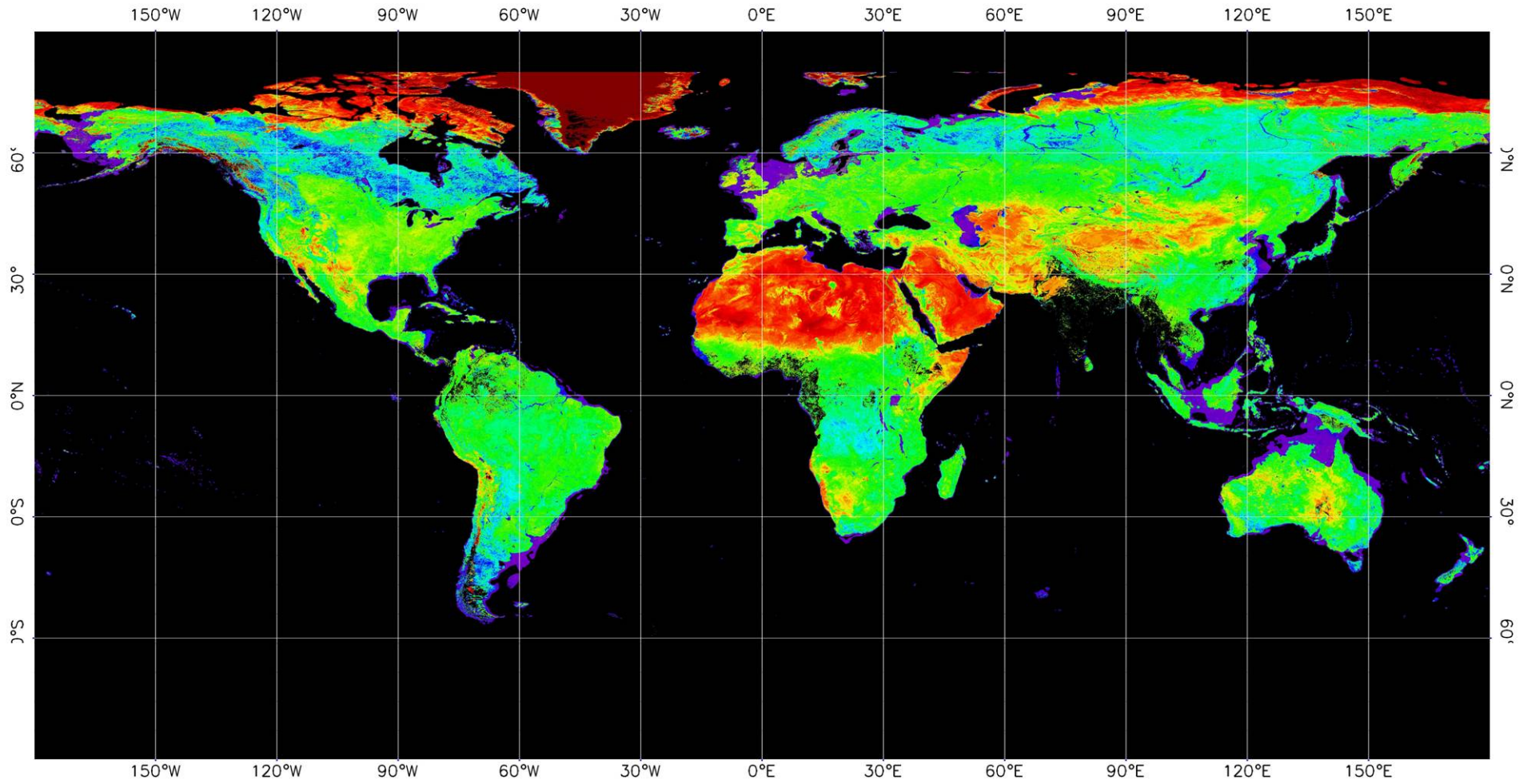
Differences between MODIS surface reflectances from adjoining swaths and MODIS NBAR (Great Lakes/NY, 6 Sep 2000).

CMG Broadband White-Sky Albedo (0.3-5.0mm) January 2001



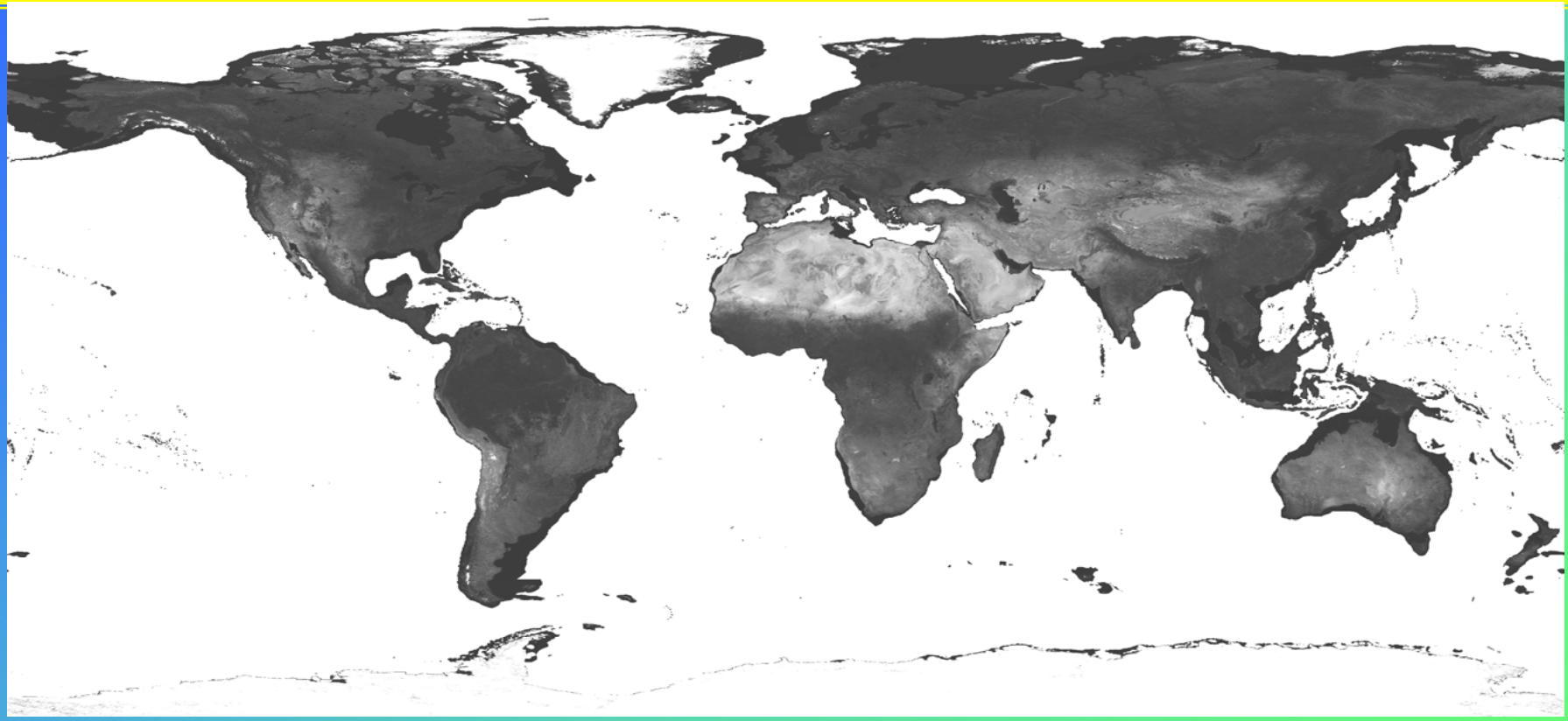
No Data

CMG Broadband White-Sky Albedo (0.3-5.0mm) June 2001



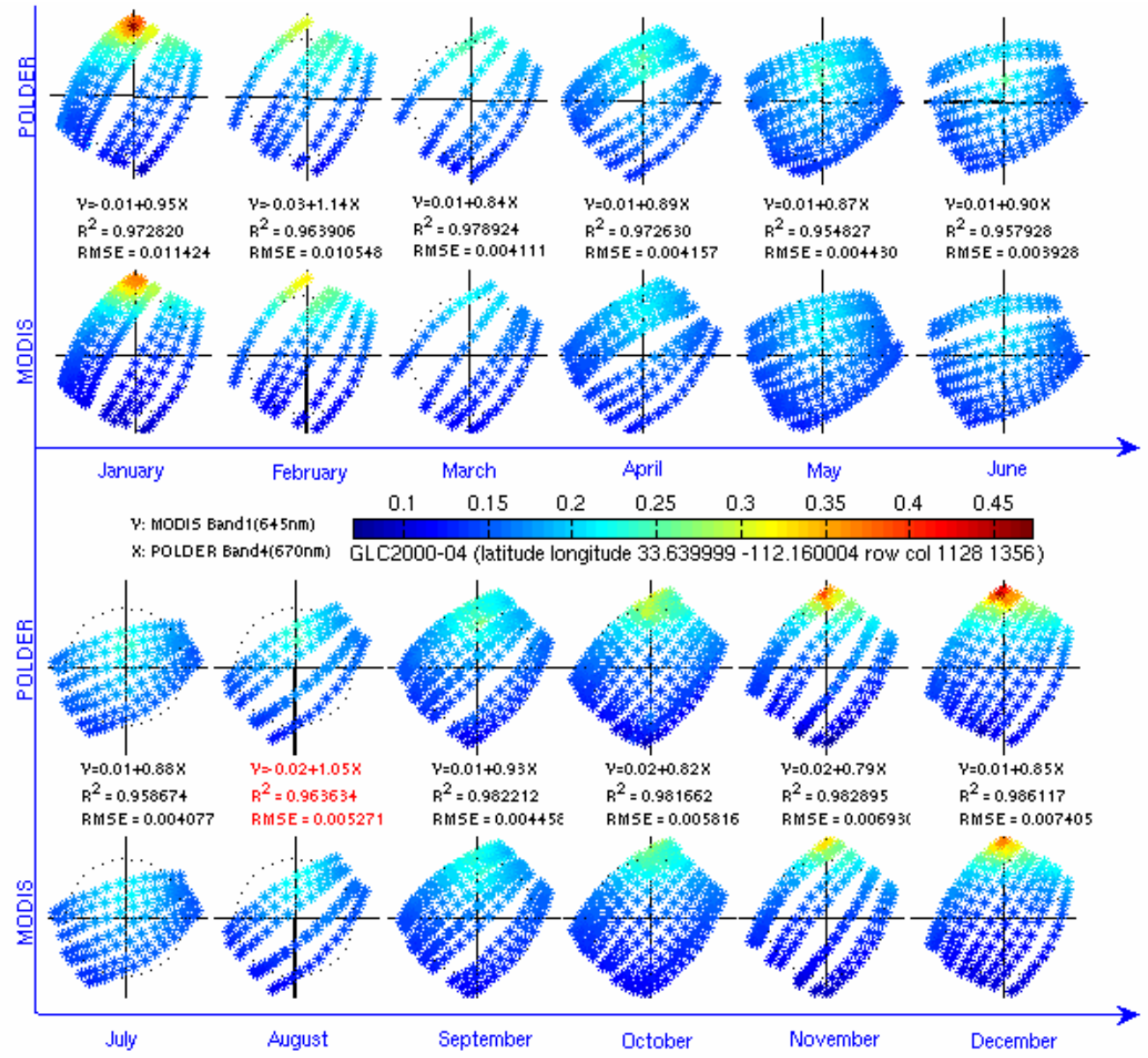
No Data

Gap-filled BRDF (Aug 2006)



Gap-filled Snow-Free Products

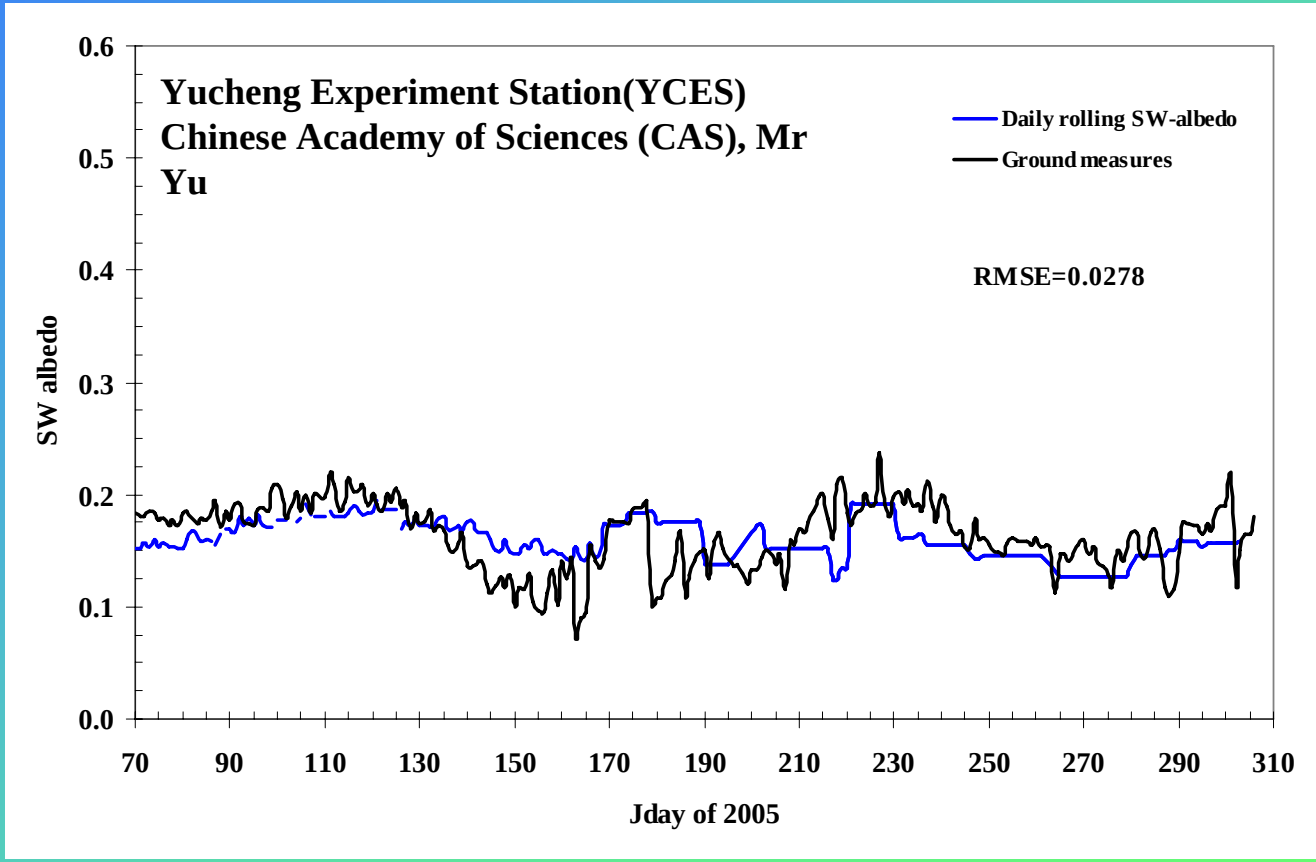
- **1arc min V004 *Albedo* (2000-2004) Moody et al., 2005; 2008**
  - **Collaboration between MODIS Land and Atmospheres**
- **0.05 degree *BRDF* V004 CMG (2001-2005)**
- **500m *BRDF* 10deg^2 tiles V005 (2000-present)**
  - **Collaboration with NACP**
- **30arc sec *BRDF* V005 CMG (2000-present) under production**



BRDF of an Evergreen Needle Leaf Forest site in North America during the course of one year as observed by POLDER at band 670 nm and simulated by MODIS at band 645nm and the relationship between these two sets of data. (Red text indicates gap-filled MODIS BRDF CMG model parameters).

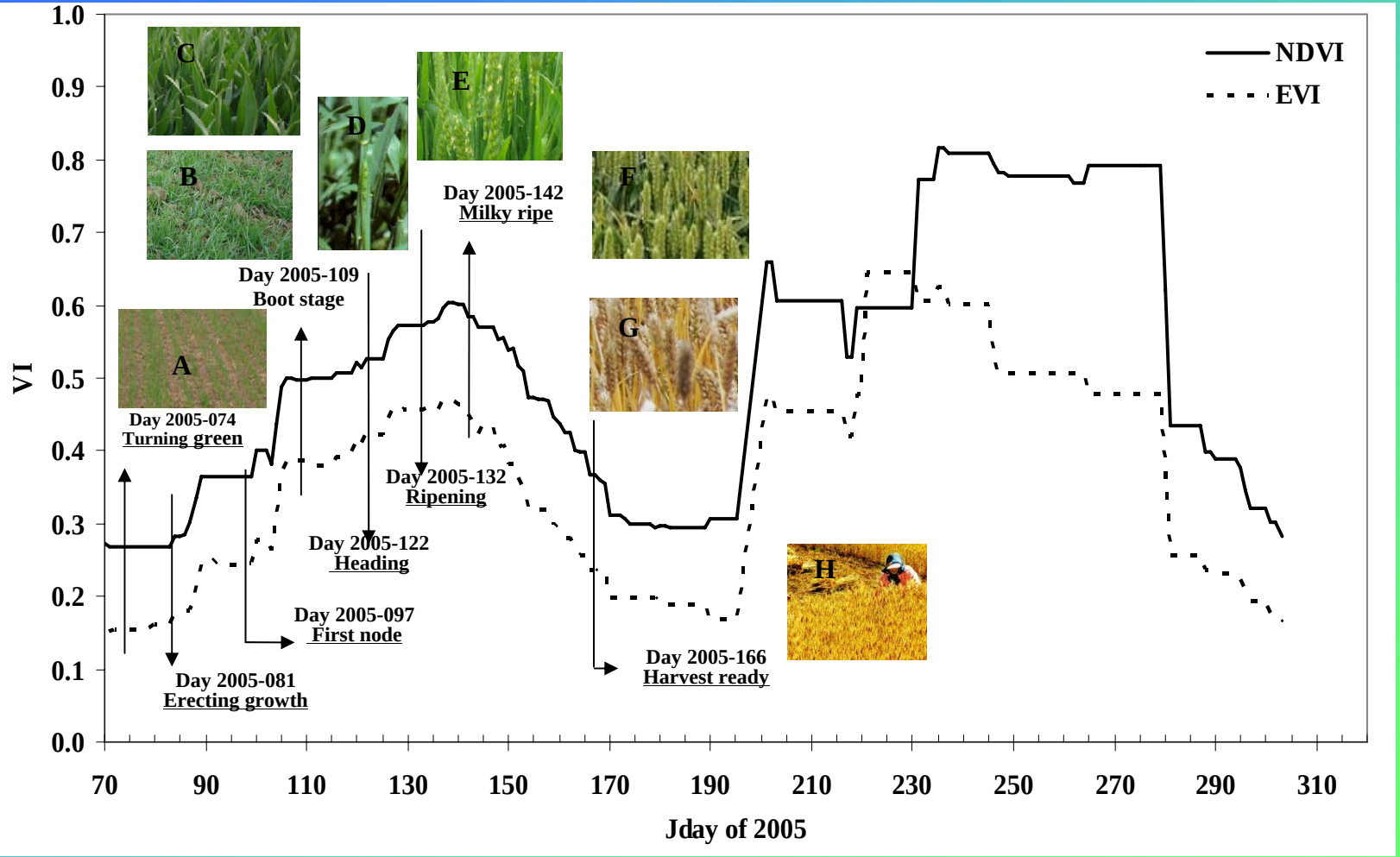
Direct Readout Products

- Stand alone code for gridding and BRDF/Albedo computation
- Daily rolling retrievals with the most recent day weighted
- Deployed in Australia, China, South Africa, Denmark, US



SW albedo between ground measurements and daily rolling retrievals

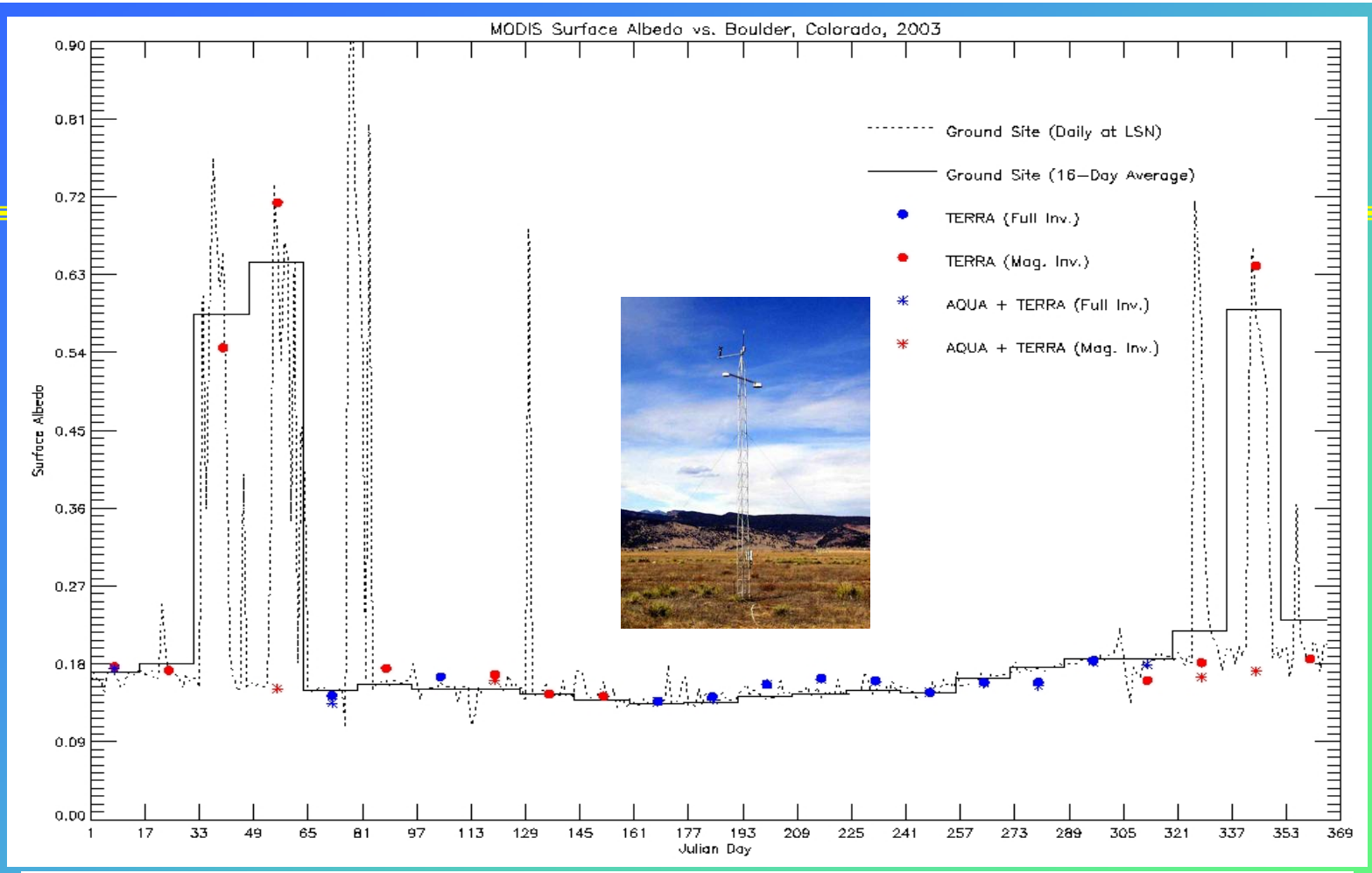
Direct Readout Products

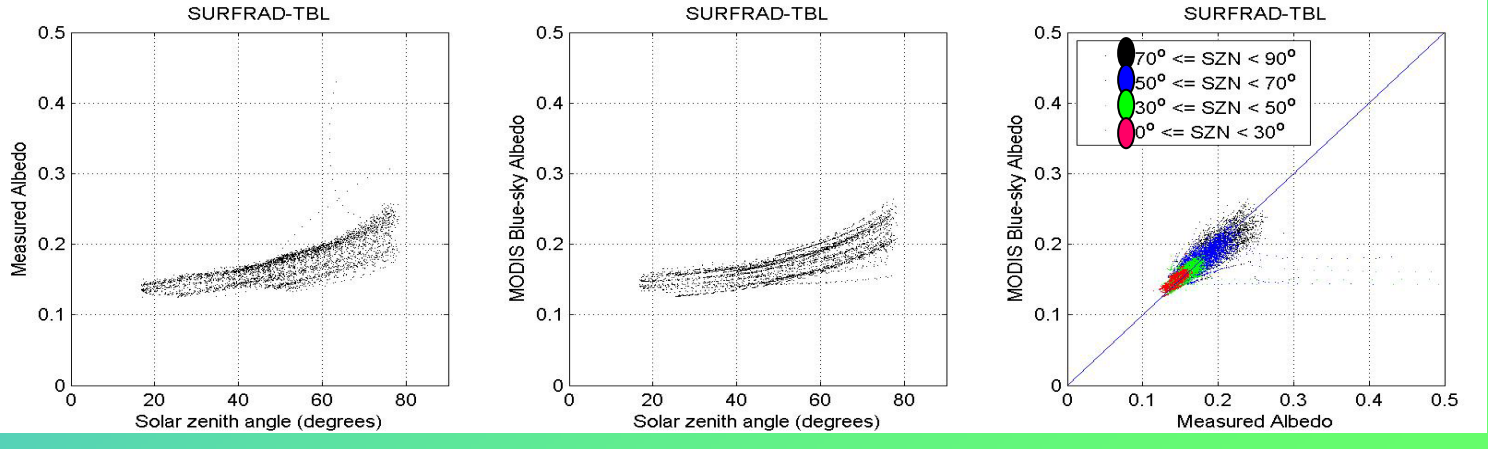


Time series of VI for Yucheng site (Pixel (761,794) with embedded phenological event pictures and labeled by relative date. (Ground phenology data collected by Yucheng Experiment Station (YCES), Chinese Academy of Sciences (CAS), Mr. Yu)

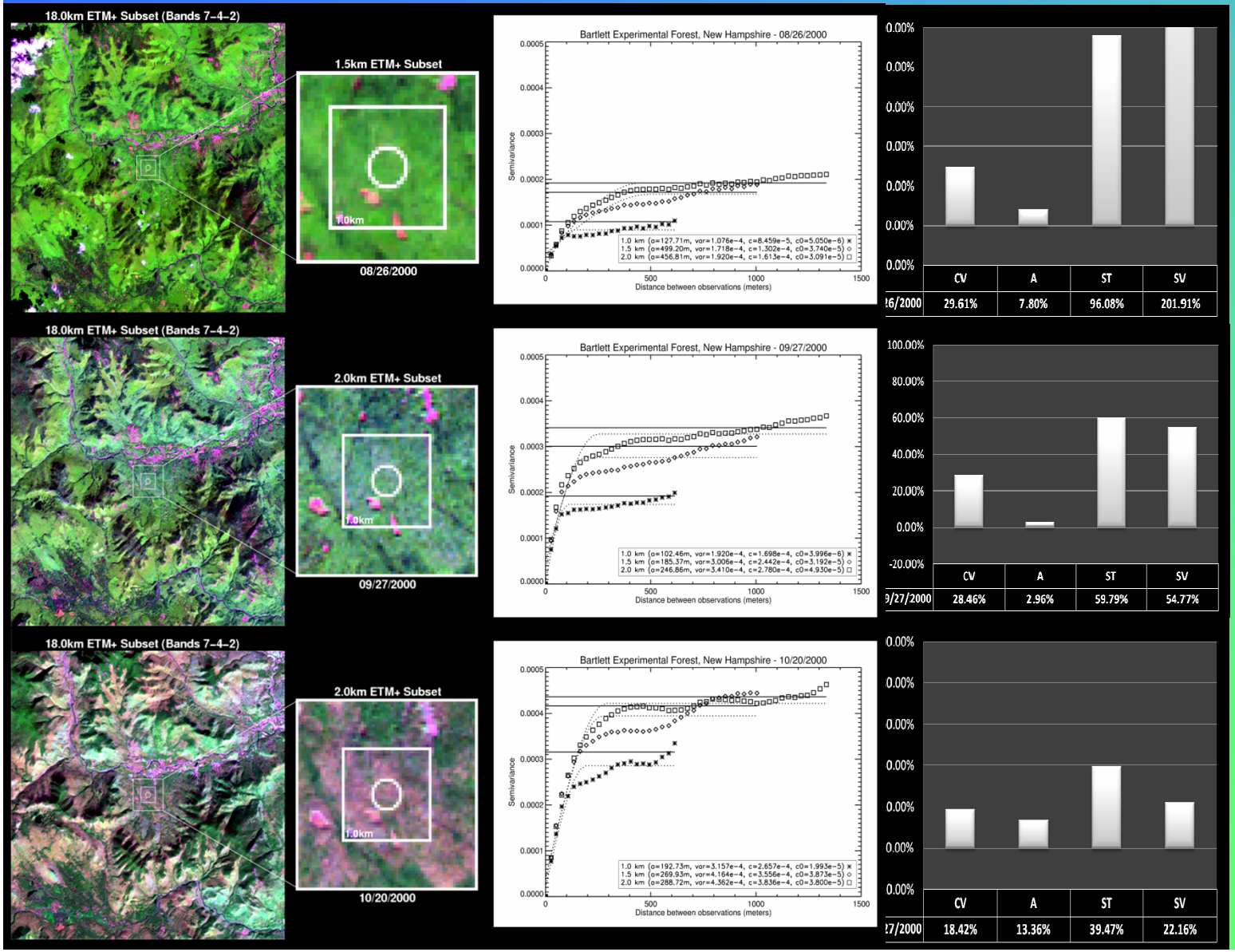
Current Emphasis on Validation

- Albedo relies on **Baseline Surface Radiation Network - BSRN**
  - Calibrated albedometers
  - World Radiation Monitoring Center Alfred Wegener Institute (AWI) in Bremerhaven, Germany
    - http://www.bsrn.awi.de/
    - http://www.gewex.org/bsrn.html
  - CERES/ARM Validation Experiment (CAVE)
    - http://www-cave.larc.nasa.gov/cave/cave2.0/SfcObs.html
- Surface Reflectance, Aerosols, Albedo Products also highly dependent on **Aeronet** sun photometers for validation
  - http://aeronet.gsfc.nasa.gov/


MODIS Surface Albedo vs. Boulder, Colorado, 2003
Surface Albedo
Julian Day
Ground Site (Daily at LSN)
Ground Site (16-Day Average)
TERRA (Full Inv.)
TERRA (Mag. Inv.)
AQUA + TERRA (Full Inv.)
AQUA + TERRA (Mag. Inv.)


SURFRAD-TBL
Measured Albedo
Solar zenith angle (degrees)
SURFRAD-TBL
MODIS Blue-sky Albedo
Solar zenith angle (degrees)
SURFRAD-TBL
70° <= SZN < 90°
50° <= SZN < 70°
30° <= SZN < 50°
0° <= SZN < 30°
MODIS Blue-sky Albedo
Measured Albedo

Key Measures of Spatial Representativeness



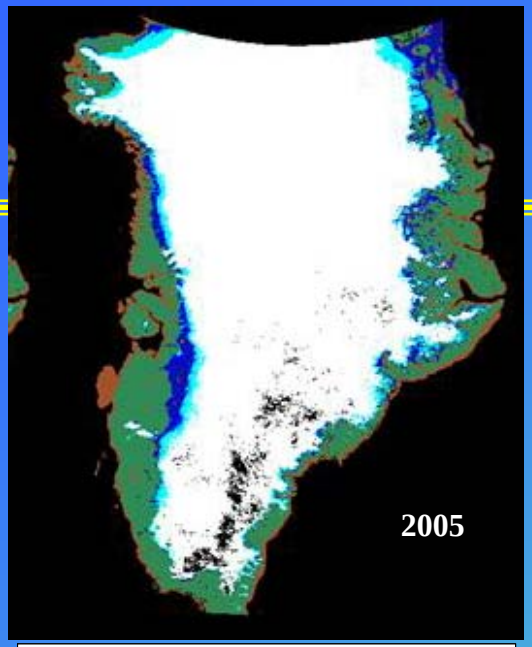
CV:A useful measure of the overall spread in the data that is independent of spatial scale.

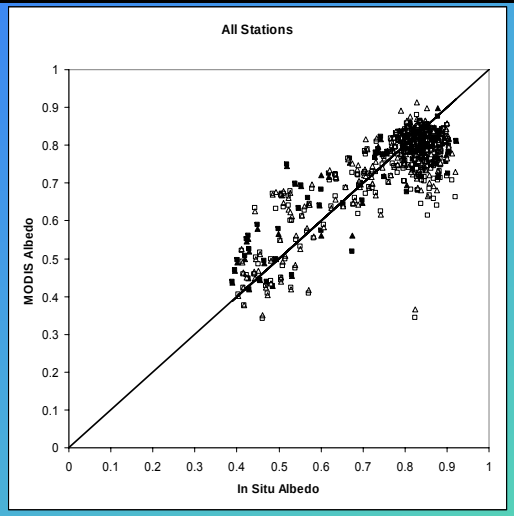
A: Measures the spatial extent of the landscape w.r.t both the ground instrument field of view and the satellite footprint.

ST: Measures the relative strength of spatial autocorrelation.

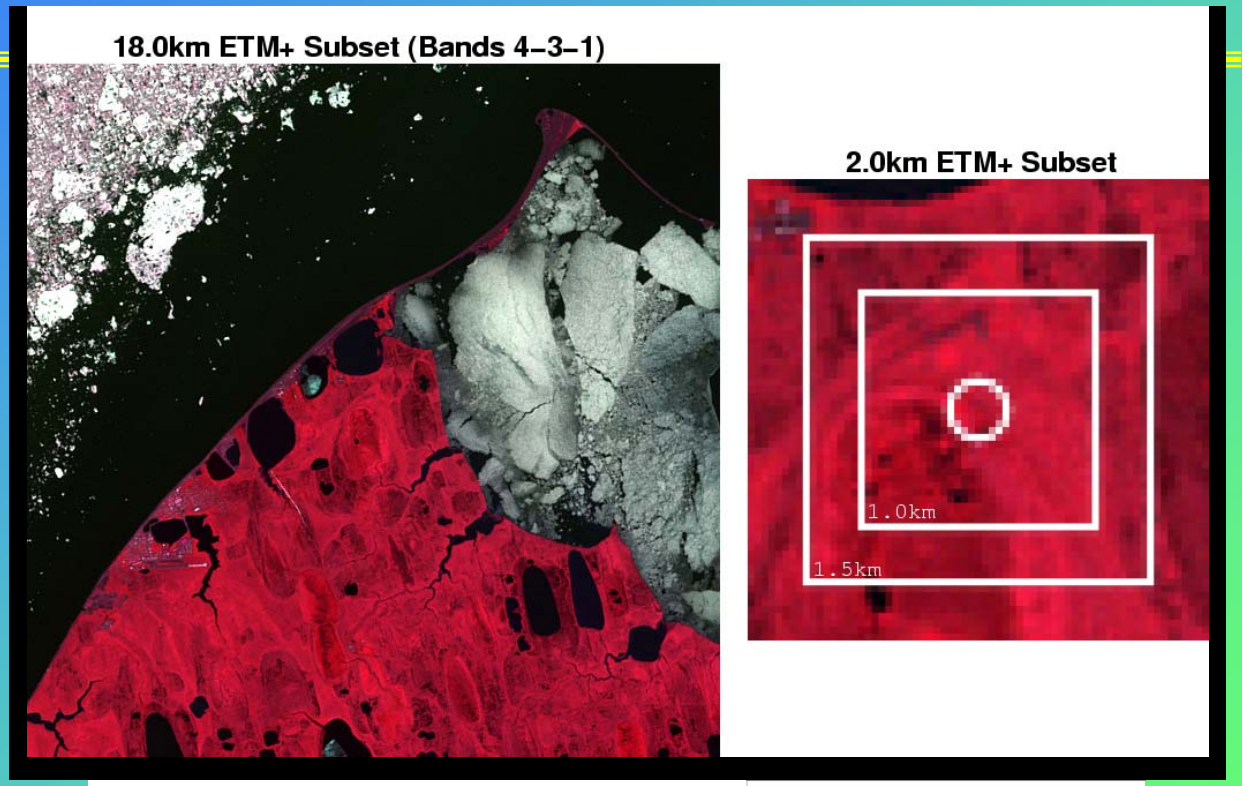
SV: A relative measure of structural variability (as opposed to random variability).

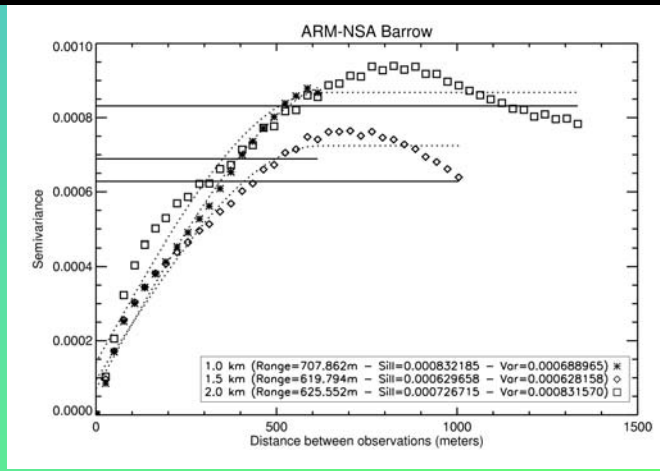
MODIS Albedo over Snow

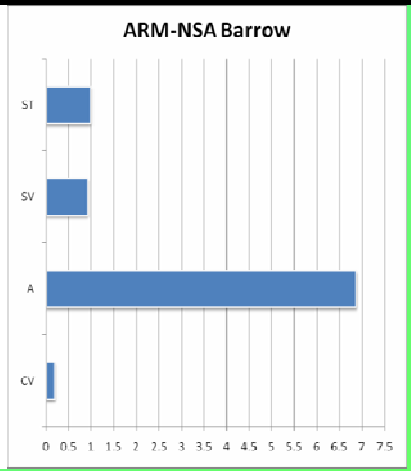




Comparison between MOD43 16-day albedo and 16-day in situ albedo for both black sky (triangles) and white sky (squares) albedo for 15 Greenland AWS stations. (Stroeve et al, 2005).



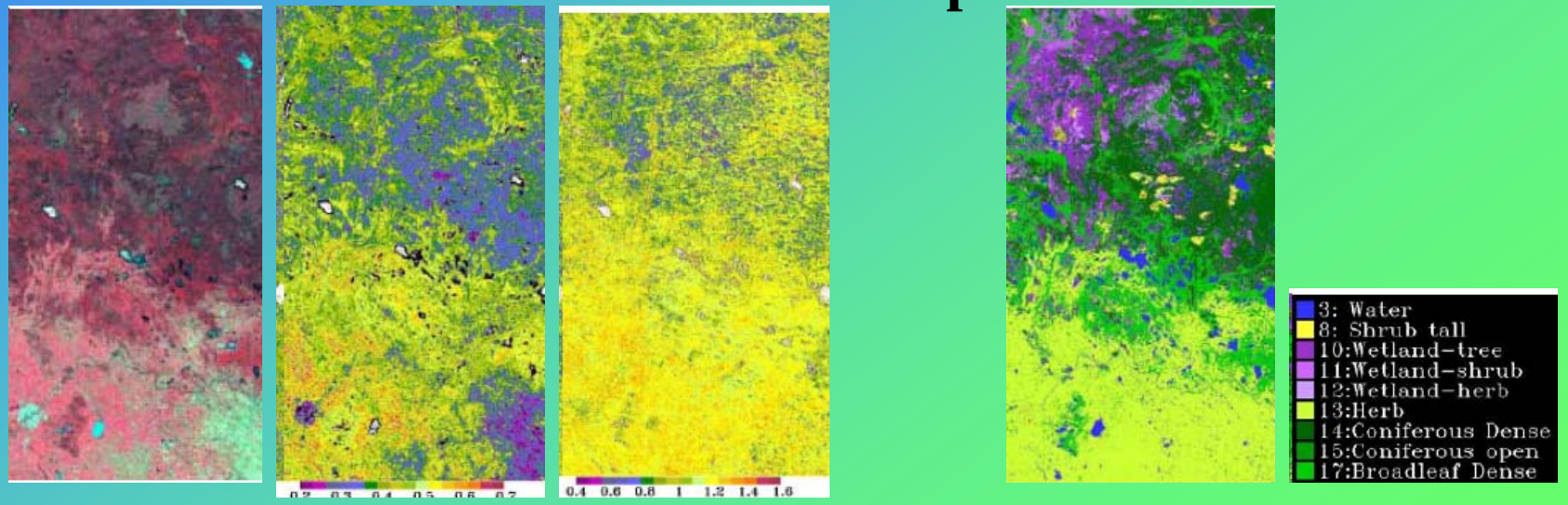




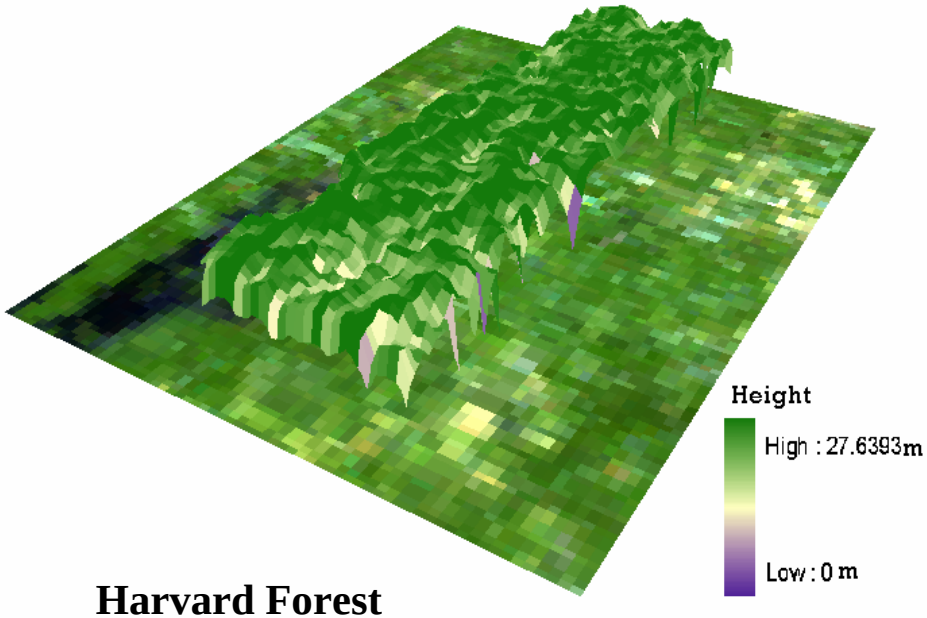
Most Recent Work

- **Exploring the use of BRDF shape factors to contribute additional ancillary surface structure information to aid in land cover classification**

NBAR NBAR-EVI + AFXN = Improved Land Cover

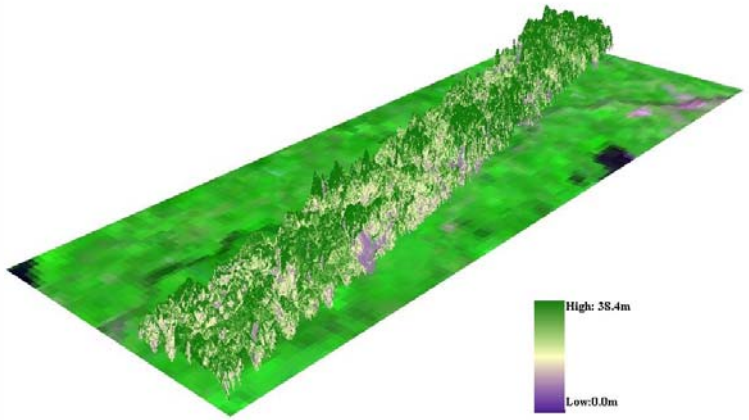


Most Recent Work
MODIS Multi-angle vs LVIS



Harvard Forest

MODIS NBAR draped over LVIS Heights 2003



Howland Forest