

**Some lessons learned from MODIS:  
the land product validation approach and  
applications for time series data.**

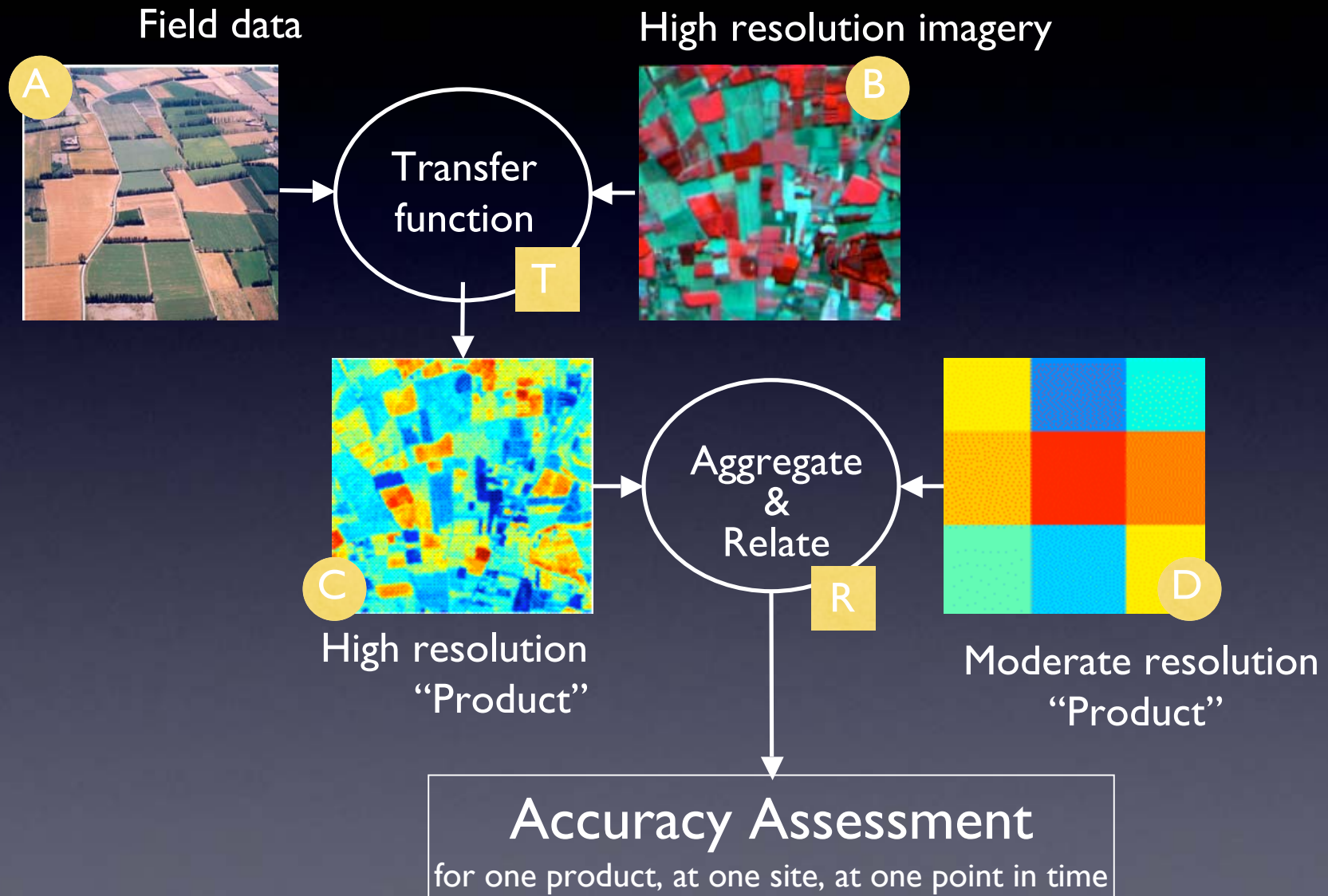
Jeffrey T. Morisette, PhD  
NASA Goddard Space Flight Center

Building on the work of the MODIS land discipline team  
(Chris Justice, Jaime Nickeson, and Sebastien Garrigues et al.)

# Top Lesson Learned from MODIS Land Product Validation

1. There is a need for scaling from field data to moderate resolution pixels.
2. There is still a need to better define land product accuracy requirements.
3. Validation results must be clearly and concisely communicated to users.
4. There are advantages to focusing on “Core Sites”.
5. Validation efforts should utilize the CEOS validation infrastructure and hierarchy.
6. There is a need for global land product Inter-comparisons.
7. Algorithm improvement is the primary use of validation results.

# Need for scaling from field to moderate resolution



# There is now a significant amount of land product validation literature on “scaling”

## Special issue on Global Land Product Validation

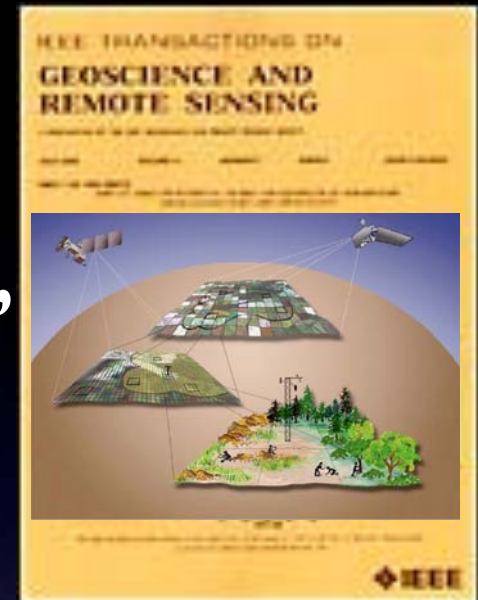
- Three “framework” papers  
19 “validation results” and  
four “user response” papers - an attempt to solicit “user feedback”.

Morisette, J.T., F. Baret, S. Liang, 2006. Special issue on Global Land Product Validation, *IEEE TGARS* 44(7) 1695-1697.

## MODIS Framework

- Fairly thorough overview of the validation approach for each of the MODIS land products

Morisette, J. T., J.L. Privette, and C.O. Justice, 2002. A framework for the validation of MODIS land products, *Remote Sensing of Environment*, 83 (1-2) 77-96.



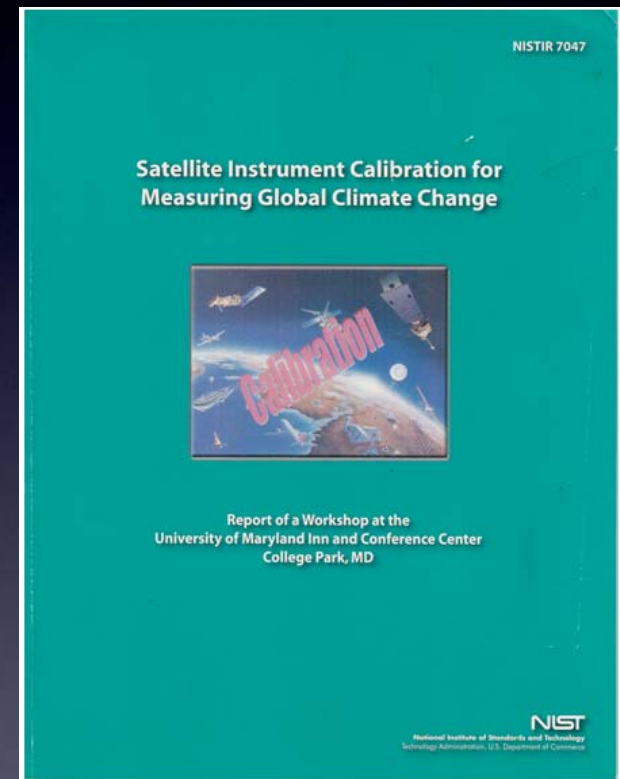
# There is still a need to define land product accuracy requirements

The land validation community could build on the experience of the calibration community.



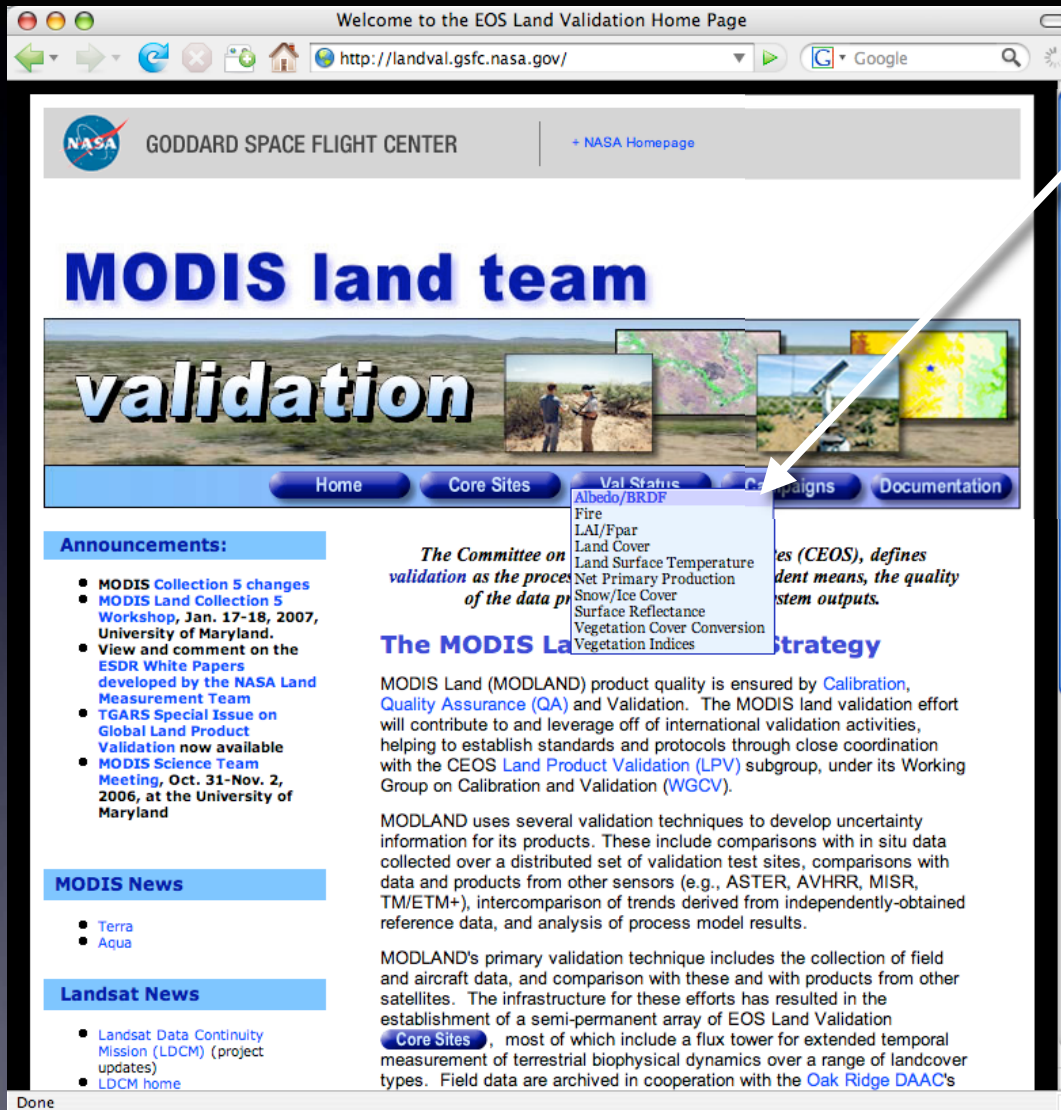
*Achieving Satellite Instrument  
Calibration for climate Change  
May 16-18, 2006*

Ohring, G., J. et al. (2007), Achieving Satellite Instrument Calibration for Climate Change, *Eos Trans. AGU*, 88(11), 136





# Validation results must be clearly and concisely communicated to users...



Welcome to the EOS Land Validation Home Page  
http://landval.gsfc.nasa.gov/

NASA GODDARD SPACE FLIGHT CENTER + NASA Homepage

## MODIS land team validation

Home Core Sites Val Status Campaigns Documentation

**Announcements:**

- MODIS Collection 5 changes Workshop, Jan. 17-18, 2007, University of Maryland.
- View and comment on the ESDR White Papers developed by the NASA Land Measurement Team
- TGARS Special Issue on Global Land Product Validation now available
- MODIS Science Team Meeting, Oct. 31-Nov. 2, 2006, at the University of Maryland

**MODIS News**

- Terra
- Aqua

**Landsat News**

- Landsat Data Continuity Mission (LDCM) (project updates)
- LDCM home

*The Committee on validation as the process of the data product (CEOS), defines validation means, the quality of the data product.*

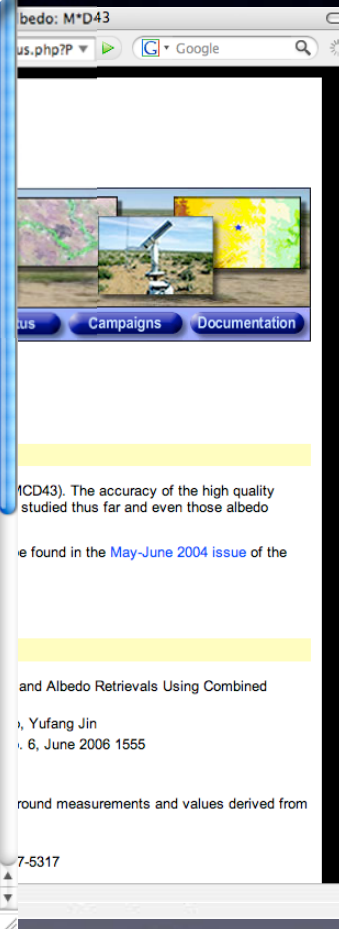
### The MODIS Land Product Validation Strategy

MODIS Land (MODLAND) product quality is ensured by Calibration, Quality Assurance (QA) and Validation. The MODIS land validation effort will contribute to and leverage off of international validation activities, helping to establish standards and protocols through close coordination with the CEOS Land Product Validation (LPV) subgroup, under its Working Group on Calibration and Validation (WGCV).

MODLAND uses several validation techniques to develop uncertainty information for its products. These include comparisons with in situ data collected over a distributed set of validation test sites, comparisons with data and products from other sensors (e.g., ASTER, AVHRR, MISR, TM/ETM+), intercomparison of trends derived from independently-obtained reference data, and analysis of process model results.

MODLAND's primary validation technique includes the collection of field and aircraft data, and comparison with these and with products from other satellites. The infrastructure for these efforts has resulted in the establishment of a semi-permanent array of EOS Land Validation **Core Sites**, most of which include a flux tower for extended temporal measurement of terrestrial biophysical dynamics over a range of landcover types. Field data are archived in cooperation with the Oak Ridge DAAC's

Product "pick-list"



bedo: M\*D43  
us.php?P

Home Campaigns Documentation

MOD43). The accuracy of the high quality studied thus far and even those albedo


e found in the May-June 2004 issue of the

and Albedo Retrievals Using Combined

, Yufang Jin  
6, June 2006 1555

ground measurements and values derived from

7-5317



ne--MOD43  
its.php?TitleID+

Home Campaigns Documentation

### ice albedo product using region on the Tibetan Plateau

Ma, Zhan Sun, and Wenhua Jiang  
004

ctroradiometer (MODIS) global land : studies. We evaluate the accuracy any 2001 to July 2003) of ground in (32.30 deg N, 84.06 deg E, 4420 consists of semidesert or desert soil. field measurements shows that the curacy requirement of 0.02. There is id the ground-measured albedo, with if 0.036.

as observed from AWS and derived

- daily albedo  
= ground  
= MODIS

# Communicating results...

Accuracy statement for each product

EOS Validation Status for MODIS BRDF/Albedo: M\*D43  
http://landval.gsfc.nasa.gov/ProductStatus.php?P

## MODIS land team

### validation

Home Core Sites Val Status Campaigns Documentation

#### Status for: BRDF/Albedo (M\*D43)

#### General Accuracy Statement

Validation at [stage 1](#) has been achieved for the surface reflectance product (MCD43). The accuracy of the high quality MODIS operational albedos is well less than 5% albedo at the validation sites studied thus far and even those albedo values with low quality flags have been found to be within 10% of field data.

Further work on albedo validation is planned. A summary of these plans can be found in the [May-June 2004 issue](#) of the Earth Observer.

*Product status updated: October 2004 (modified January 2007)*  
*Product version: Collection 4*

#### Supporting Studies:

**Title:** Validation of the MODIS Bidirectional Reflectance Distribution Function and Albedo Retrievals Using Combined Observations From the Aqua and Terra Platforms  
**Author:** Jonathan G. Salomon, Crystal B. Schaaf, Alan H. Strahler, Feng Gao, Yufang Jin  
**Source:** IEEE Transactions on Geoscience and Remote Sensing, Vol. 44, No. 6, June 2006 1555  
[View Summary Results From This Document](#)

**Title:** Comparison of MODIS broadband albedo over an agricultural site with ground measurements and values derived from Earth observation data at a range of spatial scales  
**Author:** M. Disney, P. Lewis, G. Thackrah, T. Quaife, M. Barnsley  
**Source:** Int. J. Remote Sensing, 10 December, 2004, vol. 25, no. 23, pp. 5297-5317  
[View Summary Results From This Document](#)

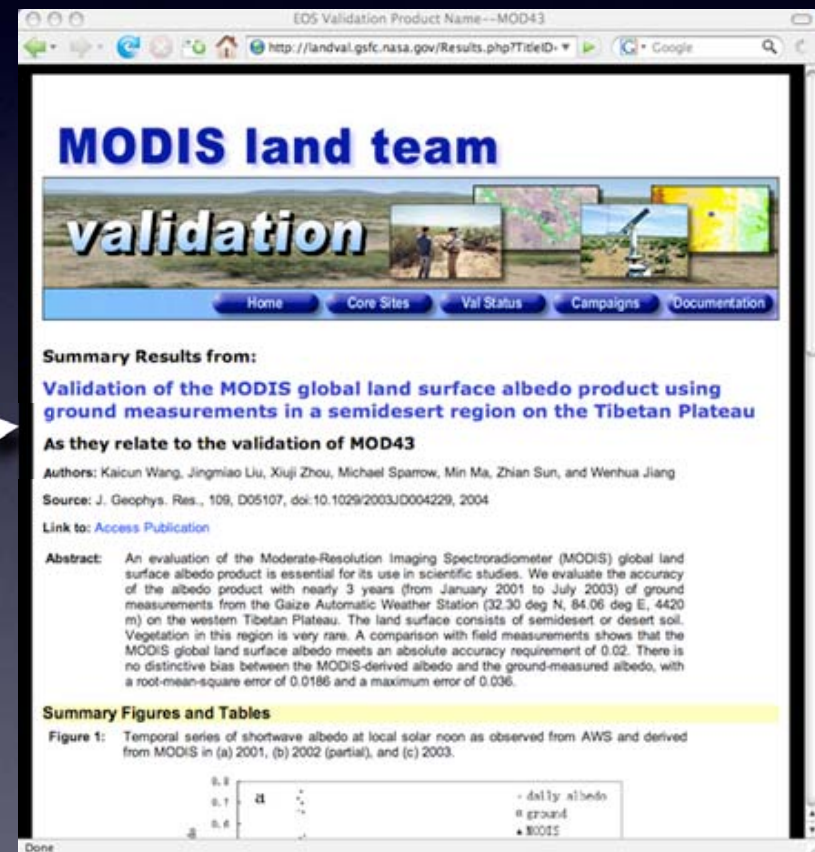
ion earth observation.  
proved spectral band  
d in the development  
is for global change  
ODIS and is used in  
Algorithm builds on the  
(HRR) and SeaWiFS  
MODIS. Atmospheric  
s improvements over  
ies, which will extend  
first evaluation of the  
r data products and in  
The MODIS surface  
for quantifying global

continuing to validate  
on to AERONET data  
shows that the error on  
optical thickness are well within the error bars adopted to derived the accuracy statement on  
surface reflectance (see [here](#), and the ATBD available from [PDF file](#)). Figure 1 shows the

# Communicating results...

Support material for each accuracy statement

- *updated by product producer and the validation community.*



EOS Validation Product Name--MOD43  
http://landval.gsfc.nasa.gov/Results.php?TitleID=

## MODIS land team validation

Home Core Sites Val Status Campaigns Documentation


**Summary Results from:**  
**Validation of the MODIS global land surface albedo product using ground measurements in a semidesert region on the Tibetan Plateau**  
**As they relate to the validation of MOD43**

**Authors:** Kaicun Wang, Jingmiao Liu, Xiuji Zhou, Michael Sparrow, Min Ma, Zhian Sun, and Wenhua Jiang  
**Source:** J. Geophys. Res., 109, D05107, doi:10.1029/2003JD004229, 2004  
**Link to:** [Access Publication](#)

**Abstract:** An evaluation of the Moderate-Resolution Imaging Spectroradiometer (MODIS) global land surface albedo product is essential for its use in scientific studies. We evaluate the accuracy of the albedo product with nearly 3 years (from January 2001 to July 2003) of ground measurements from the Gaize Automatic Weather Station (32.30 deg N, 84.06 deg E, 4420 m) on the western Tibetan Plateau. The land surface consists of semidesert or desert soil. Vegetation in this region is very rare. A comparison with field measurements shows that the MODIS global land surface albedo meets an absolute accuracy requirement of 0.02. There is no distinctive bias between the MODIS-derived albedo and the ground-measured albedo, with a root-mean-square error of 0.0186 and a maximum error of 0.036.

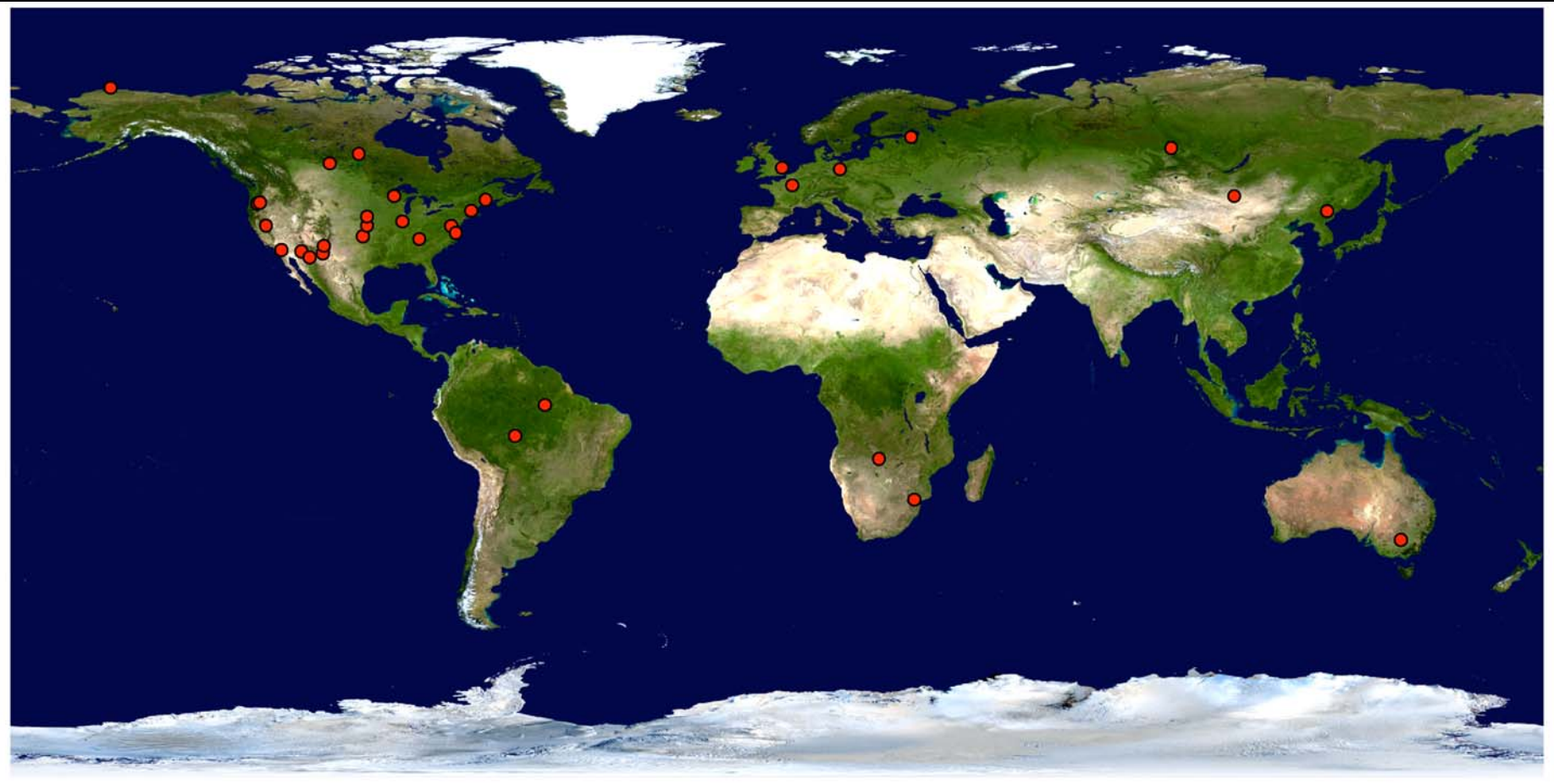
**Summary Figures and Tables**

**Figure 1:** Temporal series of shortwave albedo at local solar noon as observed from AWS and derived from MODIS in (a) 2001, (b) 2002 (partial), and (c) 2003.





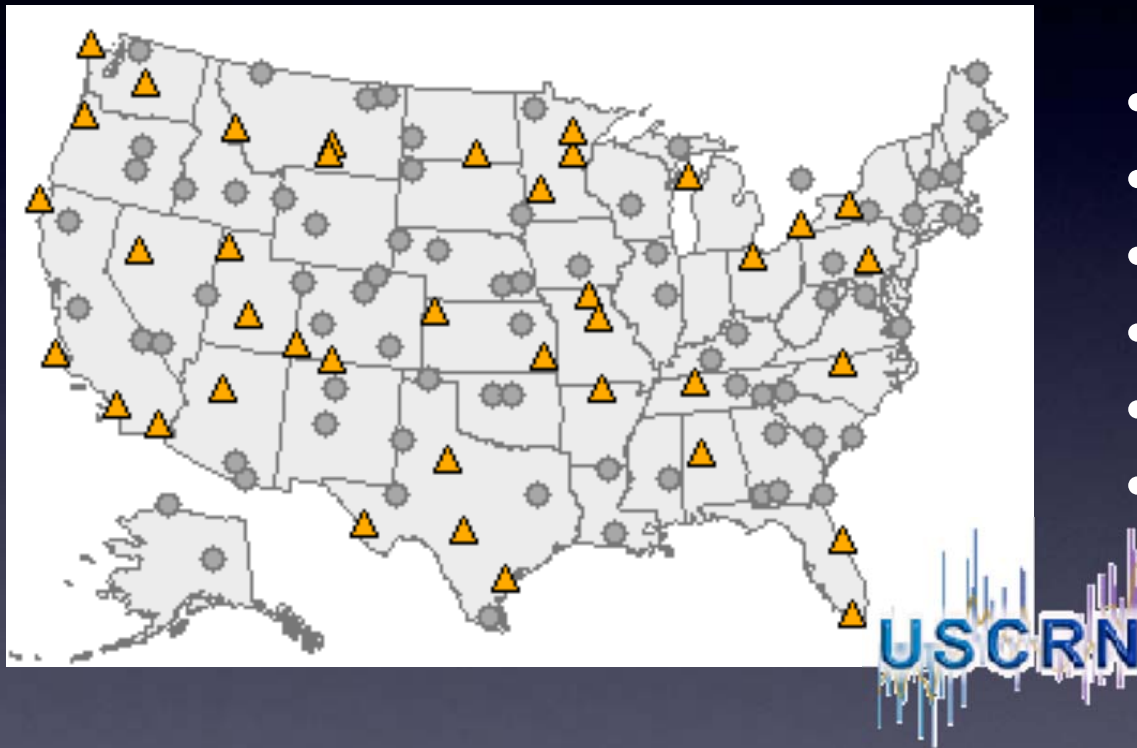
# There are advantages to focusing on “Core Sites”



*EOS Core Sites*



# Core Sites can be connected to other science networks

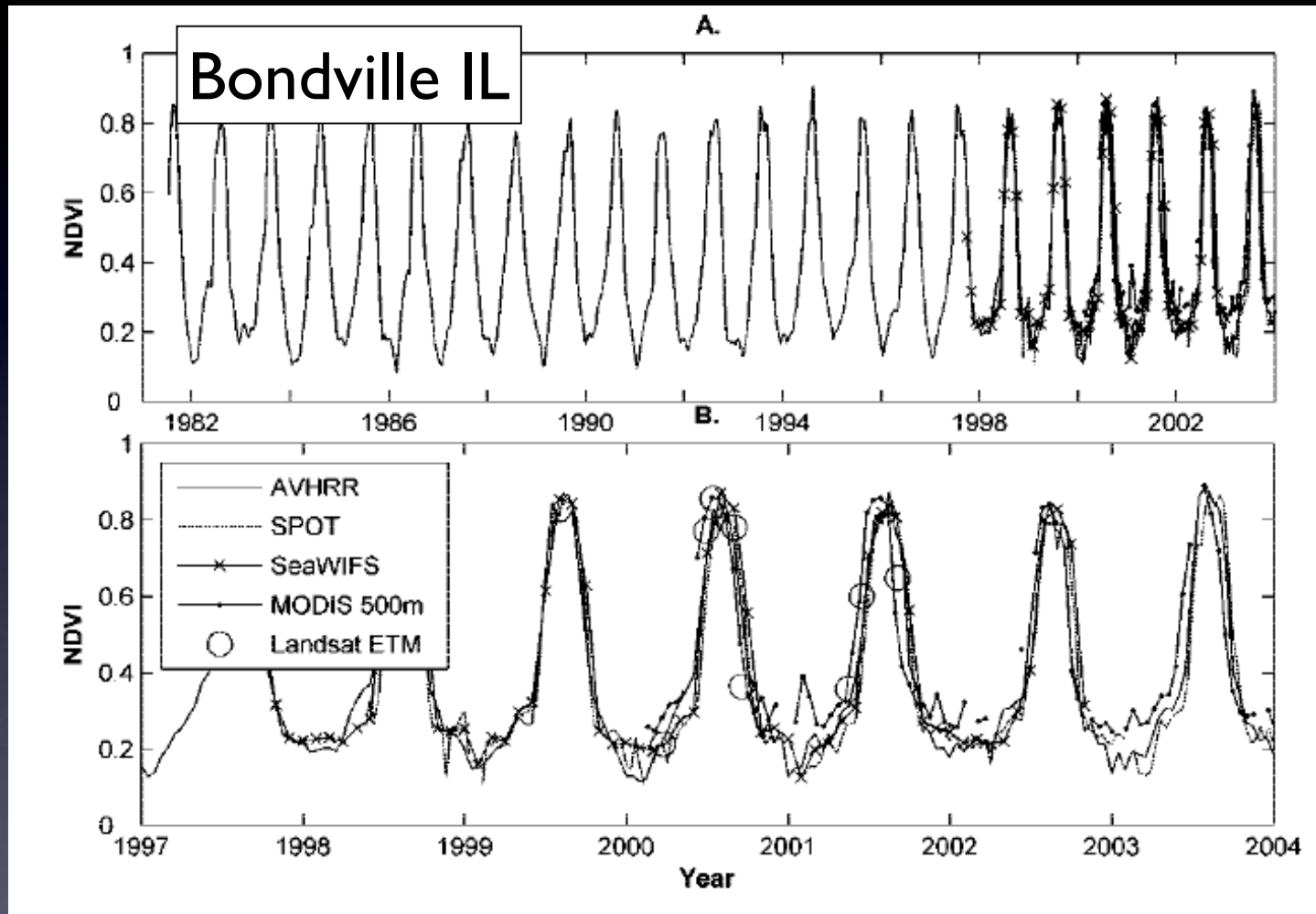


- Air temperature
- Precipitation
- Solar radiation
- Wind speed
- Surface temperature
- Relative humidity (2004/2005)

NOAA's Climate Reference Network

● Existing      ▲ Planned

# Core Sites can be used for multi-sensor analysis



Brown, M. E. et al., 2006. Inter-Sensor Validation of long-term NDVI time series from AVHRR, SPOT-Vegetation, SeaWiFS, MODIS, and LandSAT ETM+, *IEEE TGARS*, 44(7)1787-1793.



# Validation efforts should utilize the CEOS infrastructure

CEOS Land Product Validation subgroup's goals are:

- to foster quantitative validation of ***higher level global land products*** derived from remote sensing data and relay results so they are relevant to users
- to increase the quality and economy of global satellite product validation *via* developing and promoting ***international standards and protocols*** for field sampling, scaling, error budgeting, data exchange for global land product validation
- to ***advocate mission-long validation*** and inter-comparison programs for current and future earth observing satellites.



# CEOS Documents

Example from Land Cover...

Primary finding:

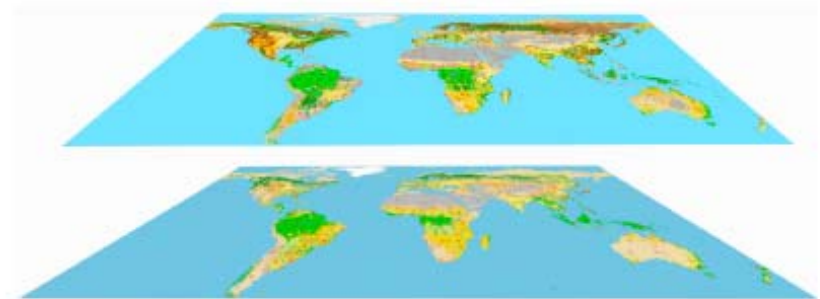
- Call for global inter-comparisons
- “Hybrid” statistical sampling using fixed sites
- Confidence layers (model-based accuracy)

Edited by: Strahler

Authors: Boschetti, Foody, Friedl, Hansen, Herold, Mayaux, Morisette, Stehman, Strahler, & Woodcock

available through the LPV web site.

## GLOBAL LAND COVER VALIDATION: RECOMMENDATIONS FOR EVALUATION AND ACCURACY ASSESSMENT OF GLOBAL LAND COVER MAPS



2006

EUR 22156 EN

# CEOS Land Product Validation web site

<http://lpvs.gsfc.nasa.gov>

Matches WGCV  
page layout and  
graphic

Welcome to the Land Product Validation Subgroup - Microsoft Internet Explorer

File Edit View Favorites Tools Help

**CEOS** WORKING GROUP ON CALIBRATION & VALIDATION  
Committee on Earth Observing Satellites  
**Land Product Validation Subgroup**

Home Landcover Biophysical Fire/Burn Surface Rad

**WGCV**  
Land Product Validation Subgroup

**Mission**

To foster quantitative validation of higher-level global land products derived from remote sensing data and to relay results so they are relevant to users

**Background**

The subgroup on Land Product Validation (LPV) is one of six subgroups of the Working Group on Calibration and Validation (WGCV), which itself is one of two standing working groups within the Committee on Earth Observing Satellites (CEOS; see also [CEOS structure](#)). The six WGCV subgroups are:

- Infrared and Visible Optical Sensors (IVOS)
- Atmospheric Chemistry (AC)
- Microwave Sensors (MS)
- Synthetic Aperture Radar (SAR)
- Terrain Mapping (TM)
- Land Product Validation (LPV)

The Land Product Validation subgroup arose out of the recognition in the late nineties that standardized approaches to global product validation were essential for wide acceptance and use of proposed global land products. Several programs at the time were aimed at global monitoring of Earth processes, many with plans to distribute higher level data products. A common approach to validation would encourage widespread use of validation data, and thus help us to move toward standardized approaches to global product validation. With the high cost of in-situ data collection, the potential benefits from international cooperation are considerable and obvious.

Previous requests for assistance from the original International Global Observing Strategy (IGOS) pilot projects and two subsequent ad hoc meetings of the WGCV identified a clear need for improved international collaboration concerning the validation of land products derived from Earth observing satellites. A new subgroup within the WGCV was proposed to the CEOS Plenary in Stockholm at the end of 1999, receiving full support. The LPV was officially adopted as a subgroup at the WGCV-17 meeting in October of 2000.

The LPV subgroup activities are divided up into four themes that compliment the research agenda of the Global Observations of Forest and Land Cover Dynamics (GOFCC/GOLD) program, namely biophysical products, fire/burn scar detection, and land cover mapping. In addition to the GOFCC/GOLD themes, the LPV subgroup includes an Albedo/Surface Radiation thematic group. Working with GOFCC/GOLD, who seek the common goal of coordinated validation of fire products by standardized protocols, LPV aims for similar coordination for all land products.

**Subscribe!**

LPV subgroup topical mailing lists:

Subscribe:

Unsubscribe:

List:

**Announcing...**

[All for papers](#) for LPV special issue in IEEE Transactions on Geoscience and Remote Sensing.

**Organization:**

LPV is a subgroup of the Working Group on Calibration and Validation.

WGCV is a standing Working Group of the Committee on Earth Observing Satellites

[link to 2004](#)

**CEOS Calendar**

Pull-down menu for  
main topical areas:

- Land cover
- Biophysical
- Fire/Burn
- Surface Radiation

Each pull-down lists:

- Background
- Producers \*
- Meetings
- Case studies
- Intercomparisons

\* input needed

Quick links to:

- List-serves
- Announcements
- WGCV
- CEOS and
- CEOS calendar

web curator: Jaime Nickeson, NASA GSFC

# Producers should subscribe to the CEOS Validation Hierarchy

**Stage 1 Validation:** Product accuracy has been estimated using a small number of independent measurements obtained from **selected locations and time periods** and ground-truth/field program efforts.

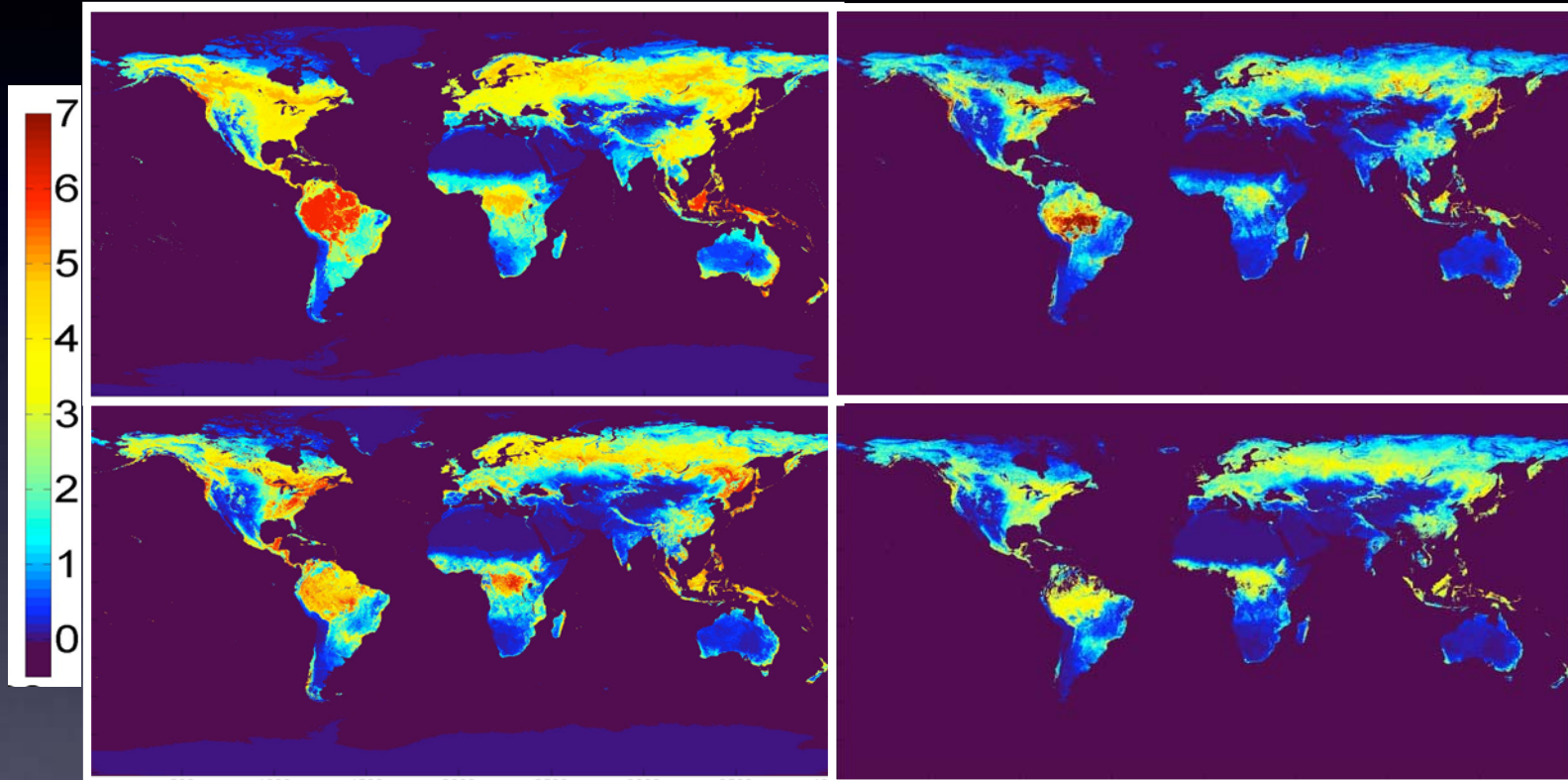
**Stage 2 Validation:** Product accuracy has been assessed over a **widely distributed set of locations and time periods** via several ground-truth and validation efforts.

**Stage 3 Validation:** Product accuracy has been assessed, and the uncertainties in the product well-established via independent measurements made in a **systematic and statistically robust way that represents global conditions**.

# There is a need for global land product Inter-comparisons

ECOCLIMAP

GLOBCARBON



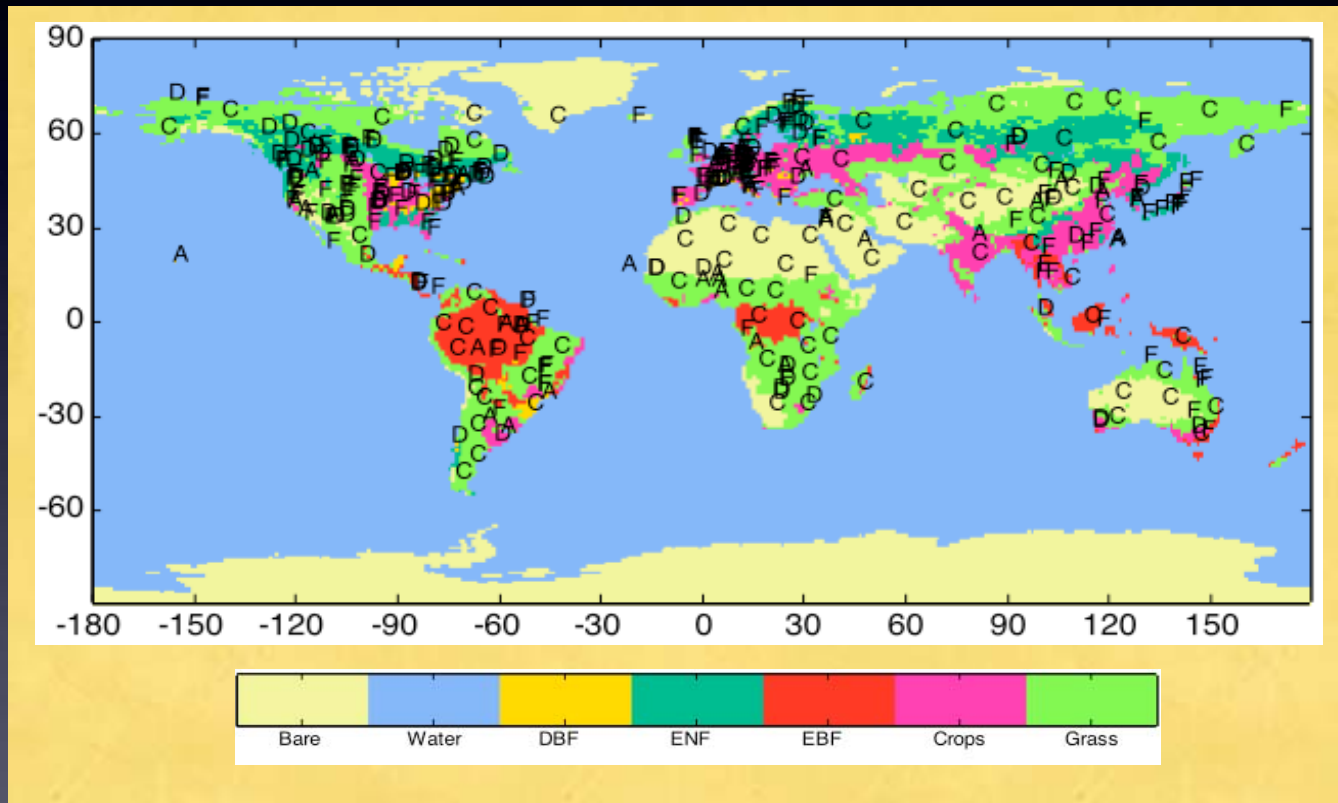
MODIS

CYCLOPES

Morisette, J., F. Heinsch, S. Running, 2006. Monitoring Global Vegetation, *EOS Transactions*, 87(50)568.

# The BELMANIP Global Network of Sites

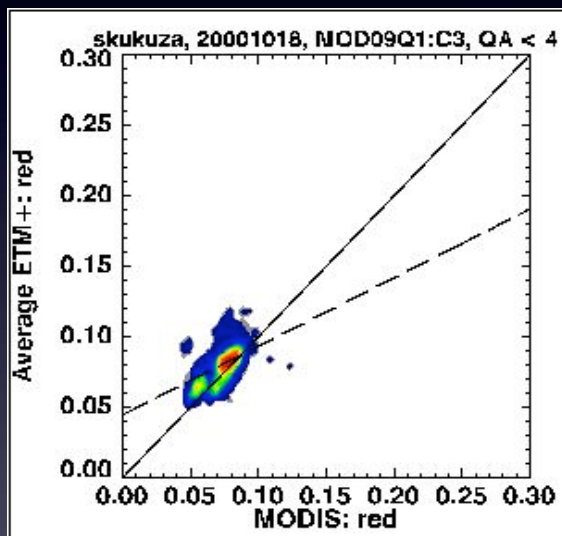
- representative sampling of global land surface types
- about 400 sites from several networks: direct validation sites (D: BIGFOOT, VALERI... ), AERONET (A), FLUXNET (F)...



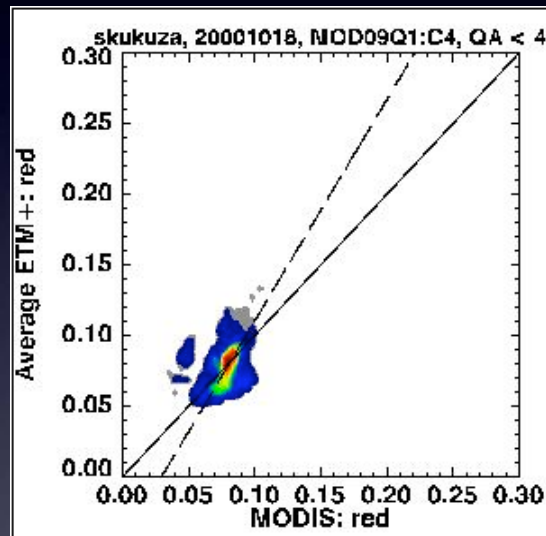
Baret, F., et al. 2006, Evaluation of the representativeness of networks of sites for the validation and inter-comparison of global land biophysical products. Proposition of the CEOS-BELMANIP, *IEEE TGARS*, 44(7)1794-1803.



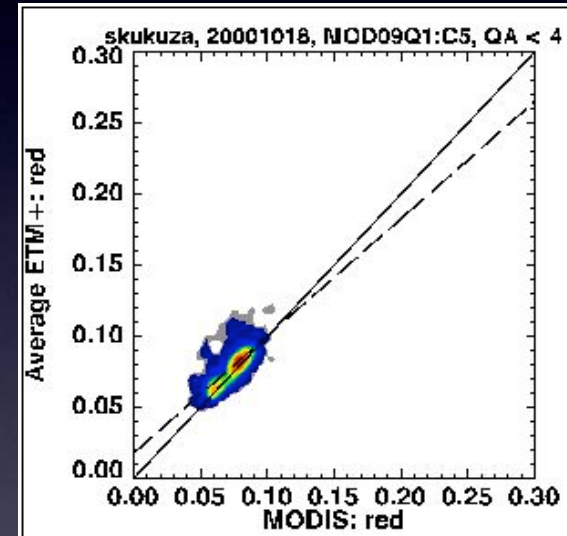
# Algorithm improvement is the primary use of validation results



collection 3



collection 4



collection 5

Scatterplots showing Aeronet-based atmospherically corrected, aggregated, ETM+ red reflectance compared to MODIS red reflectance.

# Top Lesson Learned from MODIS Land Product Validation

1. There is a need for scaling from field data to the moderate resolution pixel.
2. There is still a need to better define land product accuracy requirements.
3. Validation results must be clearly and concisely communicated to users.
4. There are advantages to focusing on “Core Sites”.
5. Validation efforts should utilize the CEOS validation infrastructure and hierarchy.
6. There is a need for global land product Inter-comparisons.
7. Algorithm improvement is the primary use of validation results.

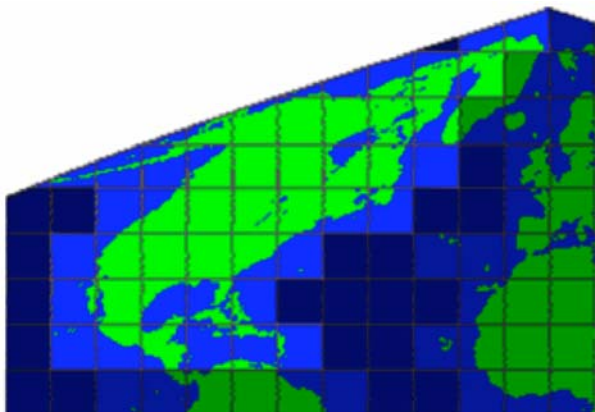
# Time-Series and Phenology

GEOSS Data Management Task (DA-07-05):

*...encourage the reprocessing of historic data to develop composite time series and temporal phenologic metrics to enable monitoring of vegetation condition and change over time...*

- Carbon modeling
- Invasive species habitat
- Validation of phenology parameters

# New Approach to Delivering Time Series Data



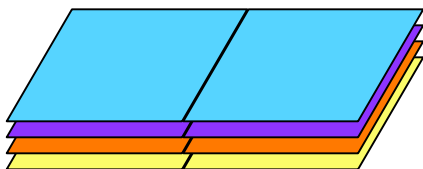
## 1. Order Data

Six years over North America implies:  
7314 files, 1.013GB, ~20 8-hour days to order



### Current MODIS granule:

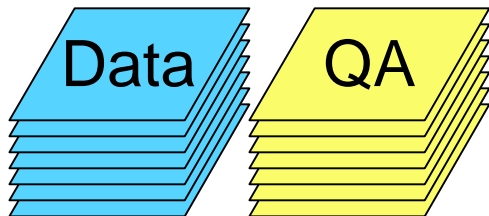
one time step  
Several “bands” or science data sets  
One or more associated QA layers  
Fixed area (1200km x 1200km)



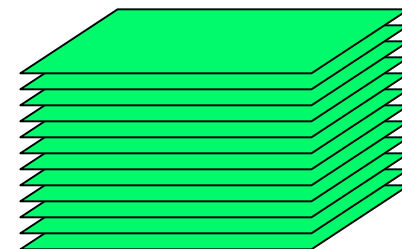
## 2. Reproject & Mosaic tiles

The “MODIS reprojection tool”  
is one tool available for this  
operation

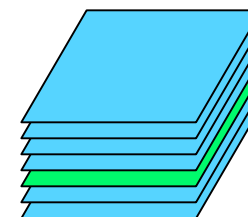
3. Extract  
data layer  
of interest  
& its associated  
QA and “stack”  
through time



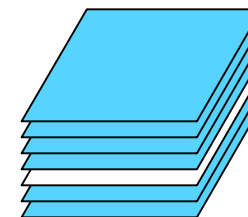
Product that meets  
researcher’s needs:  
Data through time  
User-defined area  
One data set, appropriately  
filtered by the  
associated QA layer



5. Fill gaps  
“TIMESAT” or  
other tools



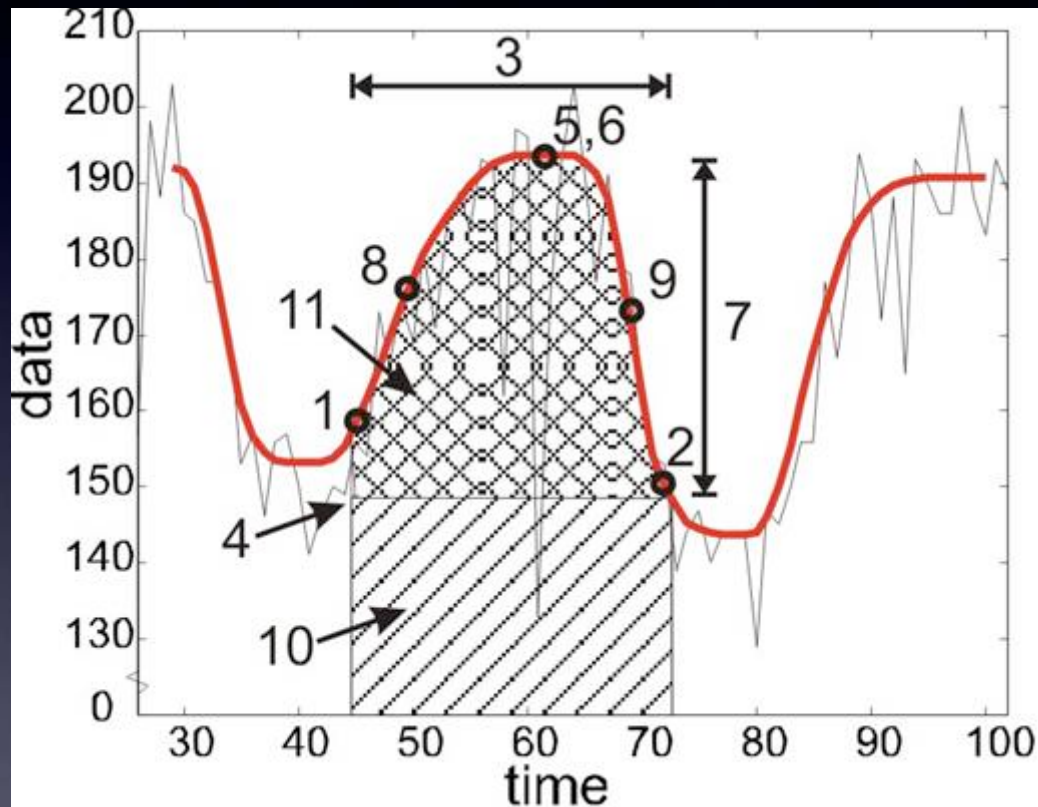
4. Filter data  
“LDOPE” tools can  
be used to interpret  
QA layers to filter out  
low quality data



*In this diagram, we suppose  
this layer indicates low quality  
for this time step*



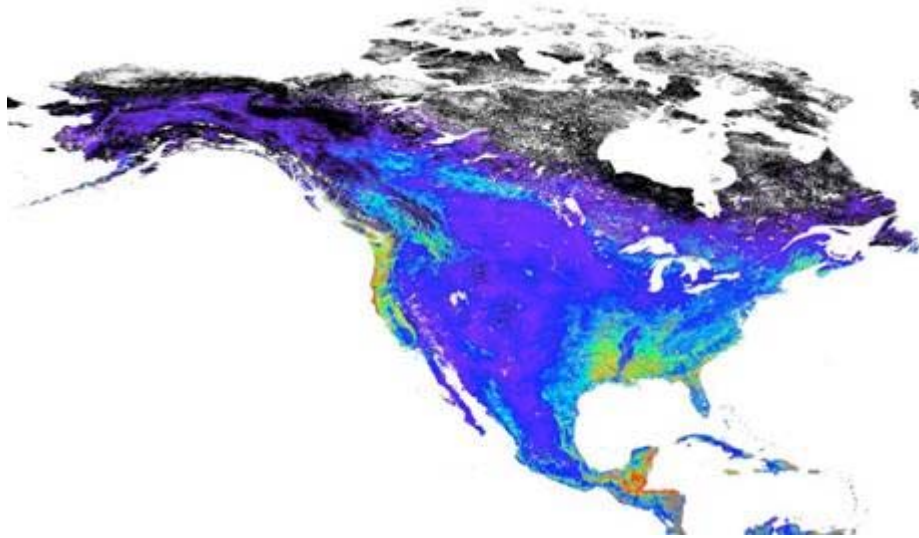
# TIMESAT software



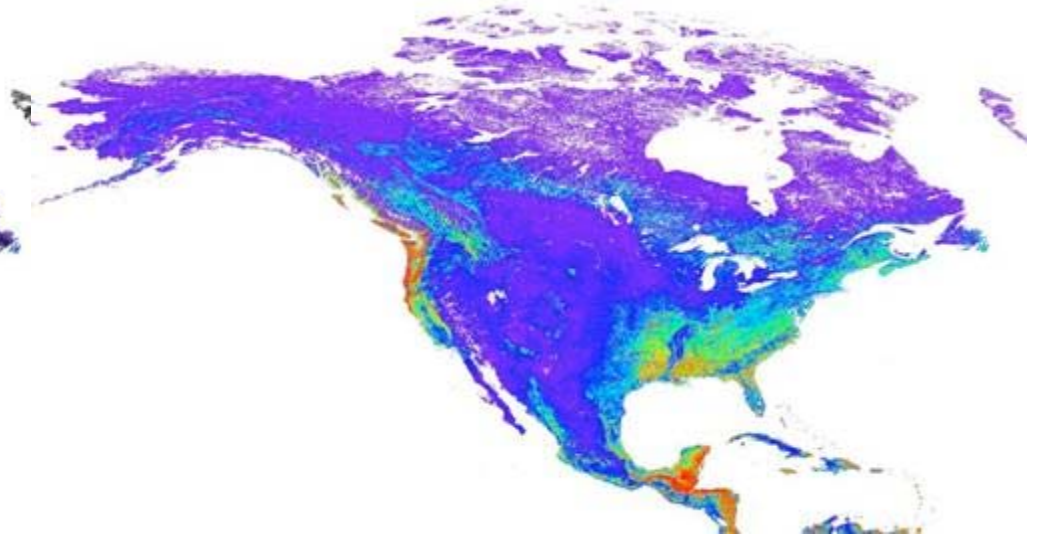
- 1.time for the start of the season
- 2.time for the end of the season
- 3.length of the season
- 4.base level
- 5.time for the middle of the season
- 6.peak value of the fitted function
- 7.seasonal amplitude
- 8.left slope
- 9.right slope
- 10.large seasonal integral
- 11.small seasonal integral

TIMESAT - a program for analyzing time-series of satellite sensor data  
Per Jonsson & Lars Eklund, Computers & Geosciences 30:833-845, 2004.

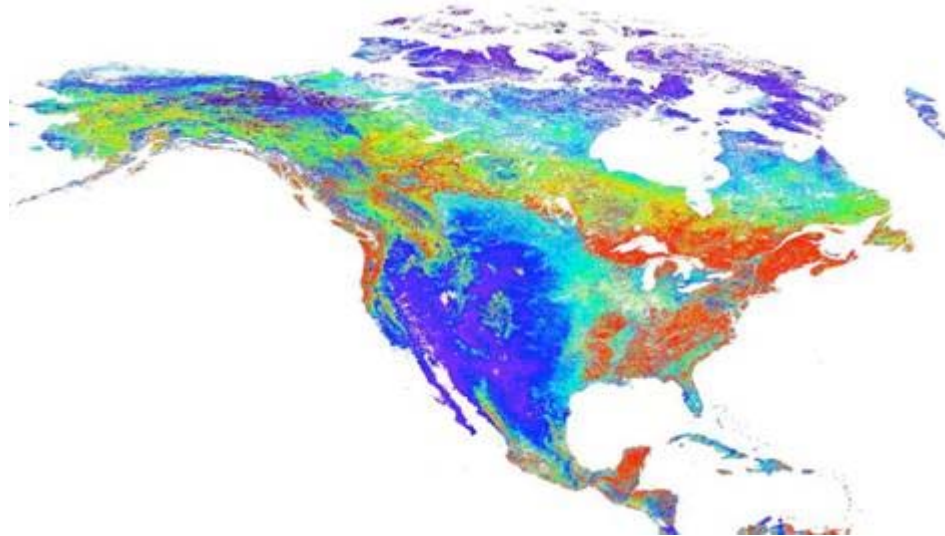




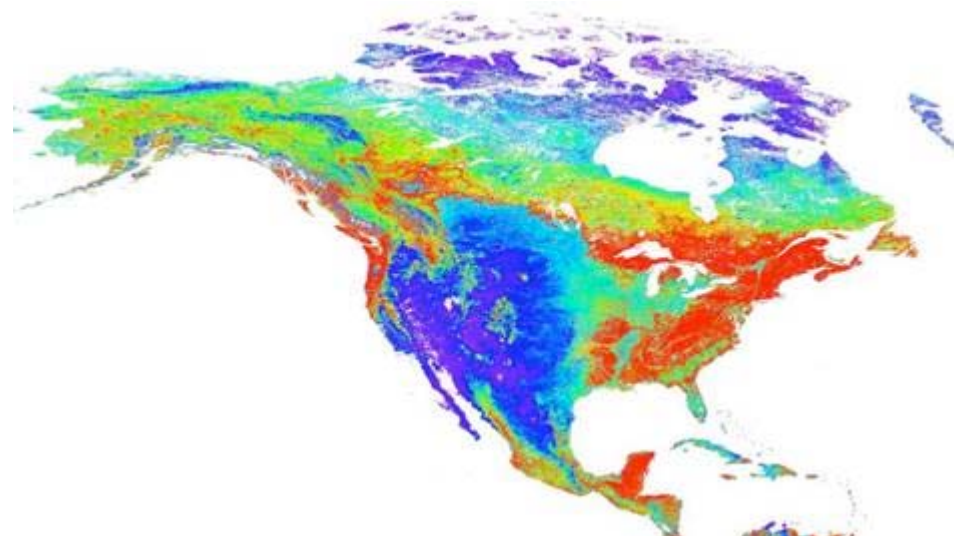
(a) Original LAI, January 1, 2004



(b) Smoothed LAI, January 1, 2004



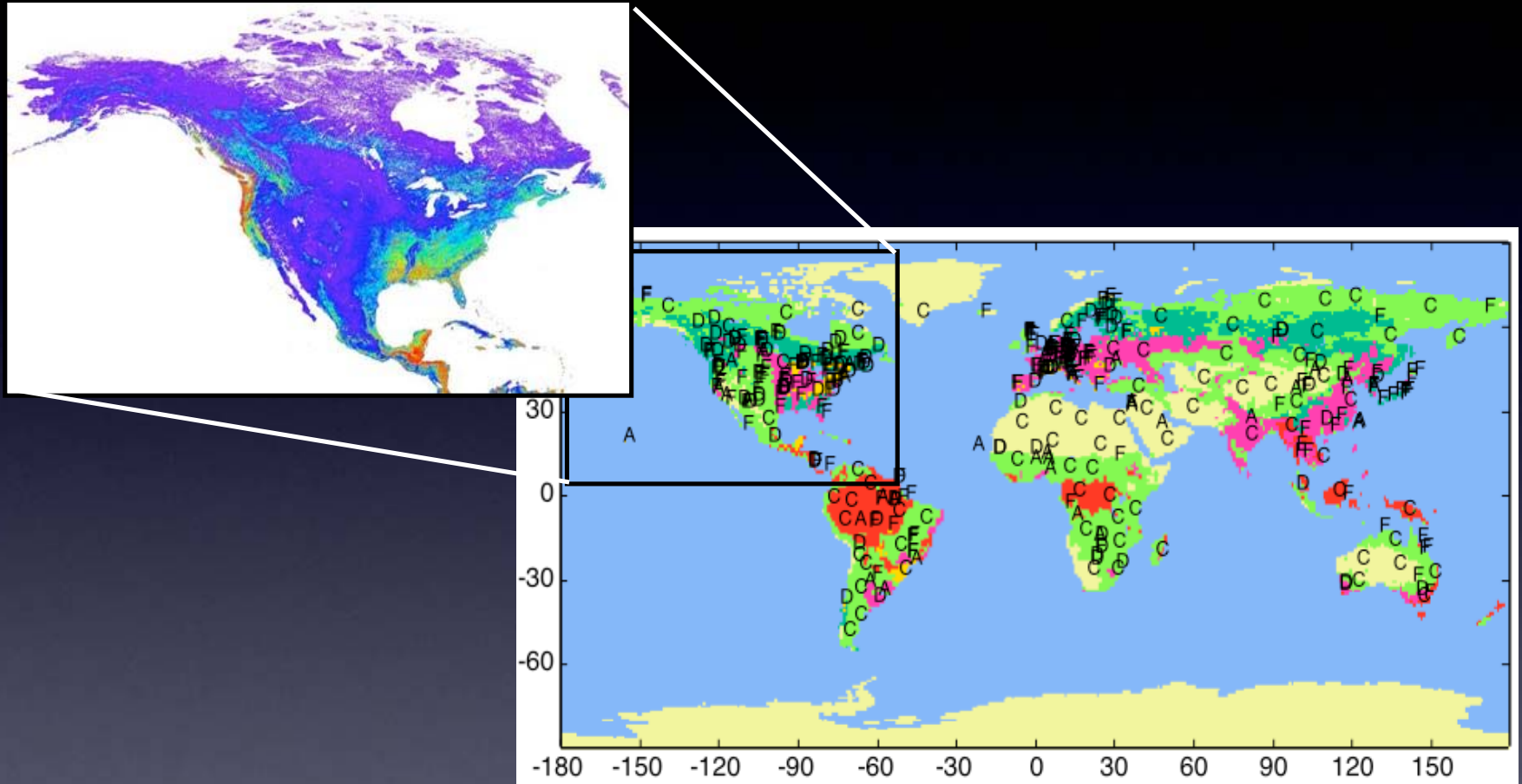
(c) Original LAI, July 11, 2004



(d) Smoothed LAI, July 11, 2004

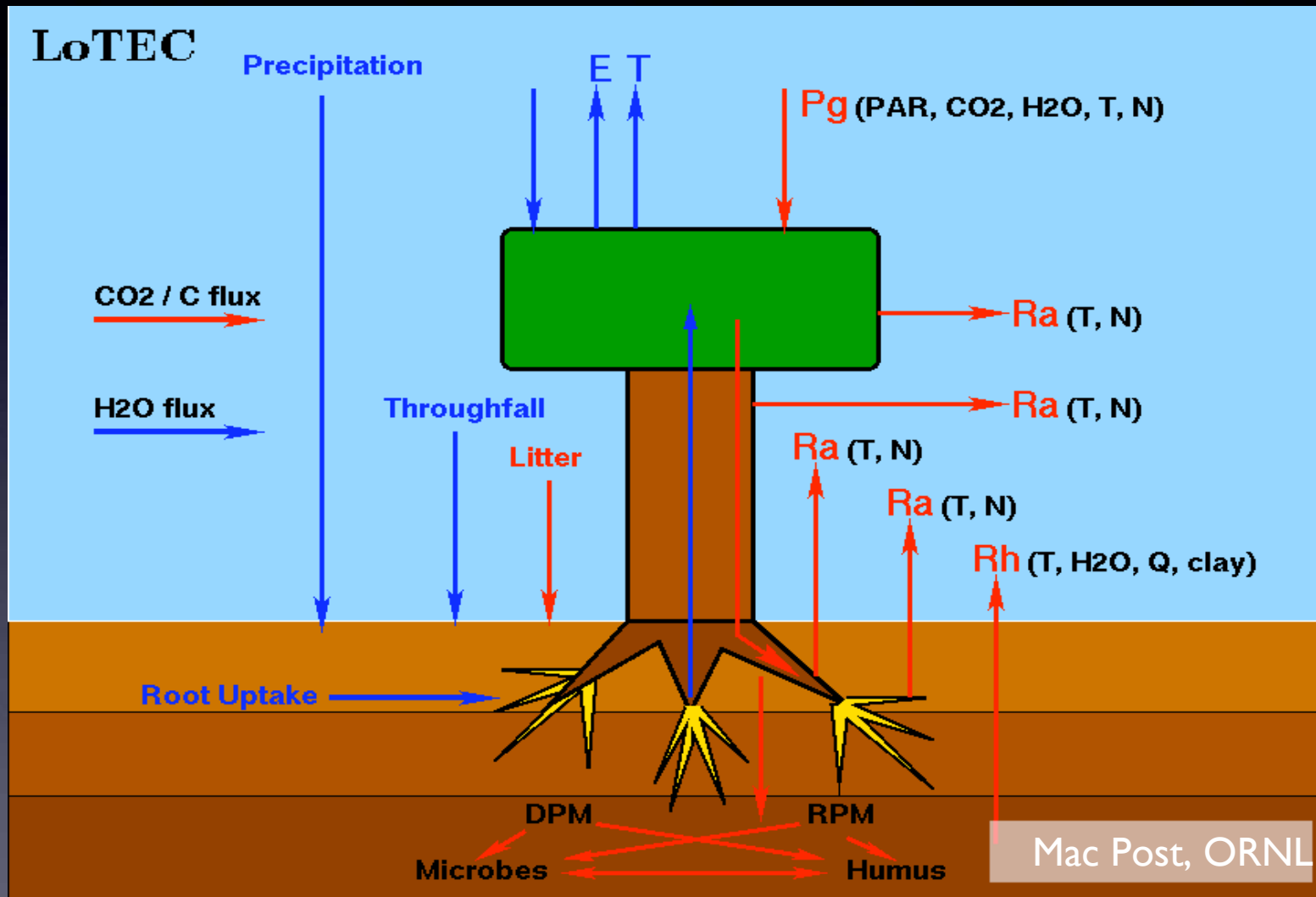


# Assessing the smoothed data...



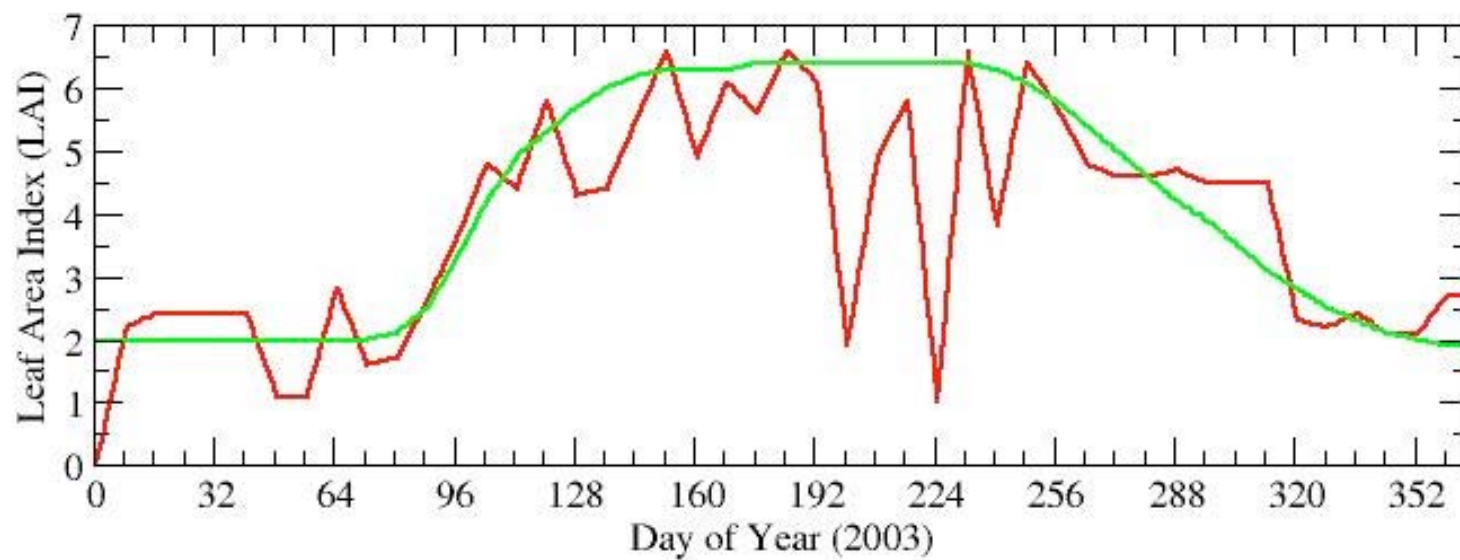
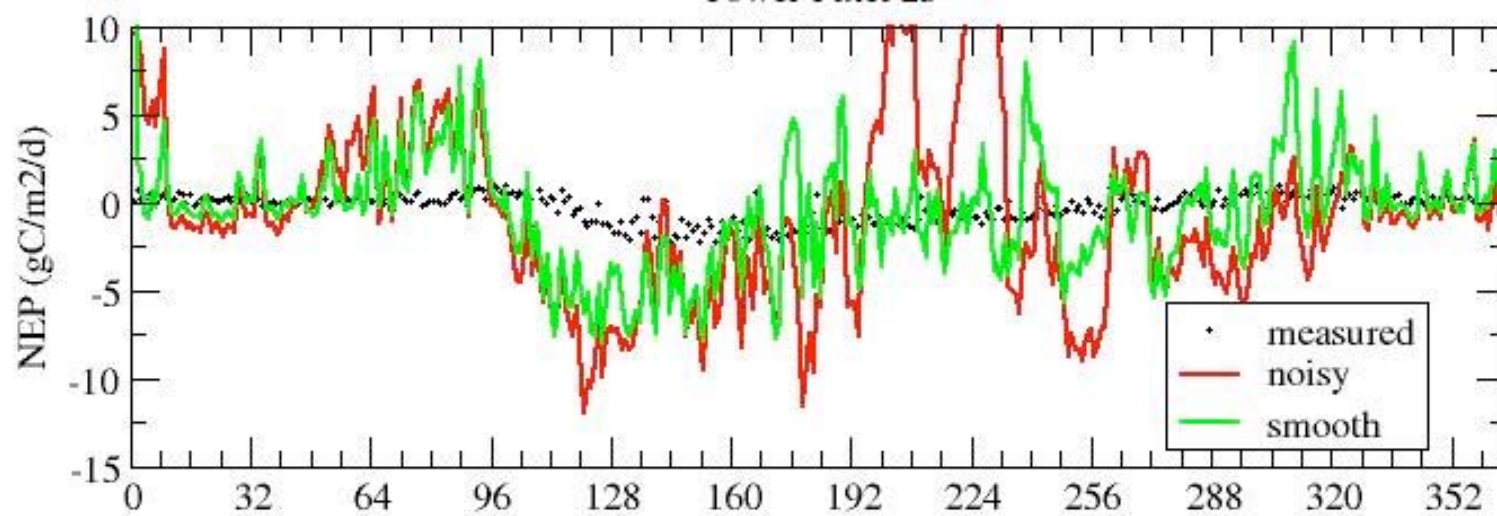
...will leverage off of the LAI inter-comparison by being included in the 1km study being done over North America.

It is also possible to inter-compare by checking differences in model output



# Duke Hardwoods

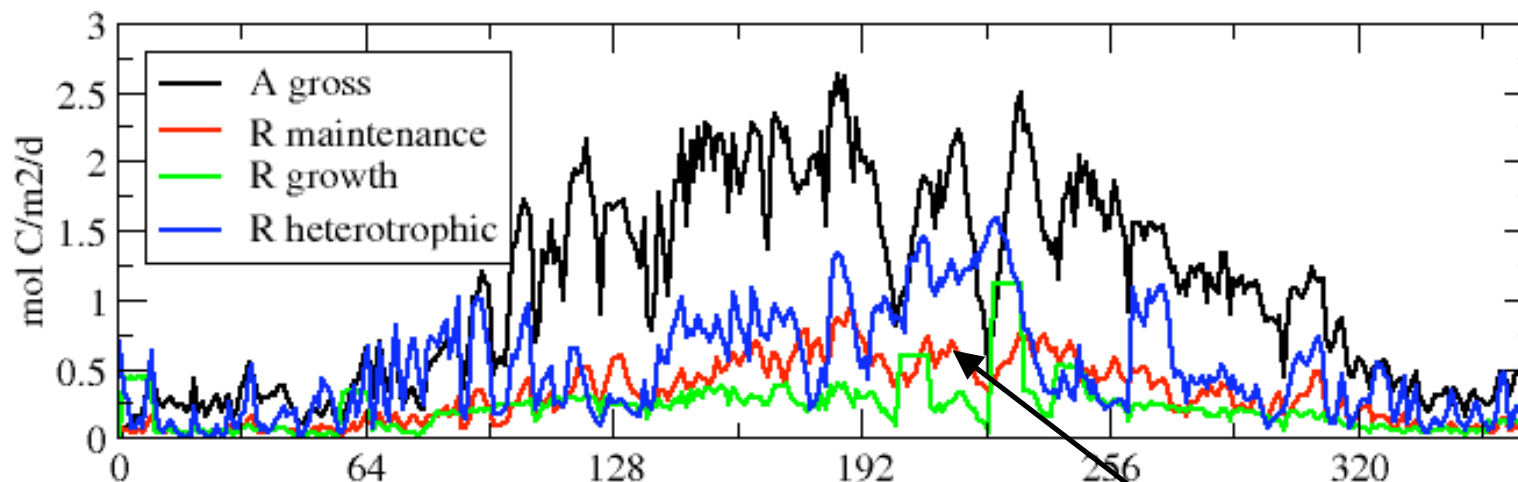
Tower Pixel 25



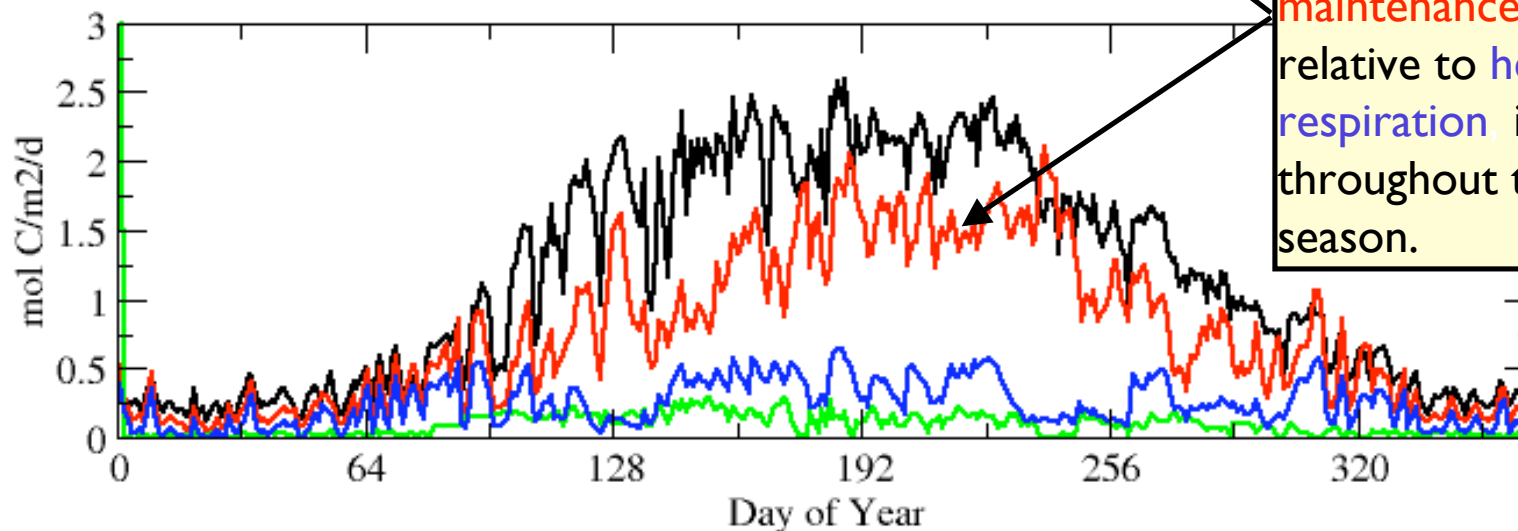


# Duke Hardwoods, 2003

Noisy LAI, Tower Pixel



Smooth LAI, Tower Pixel



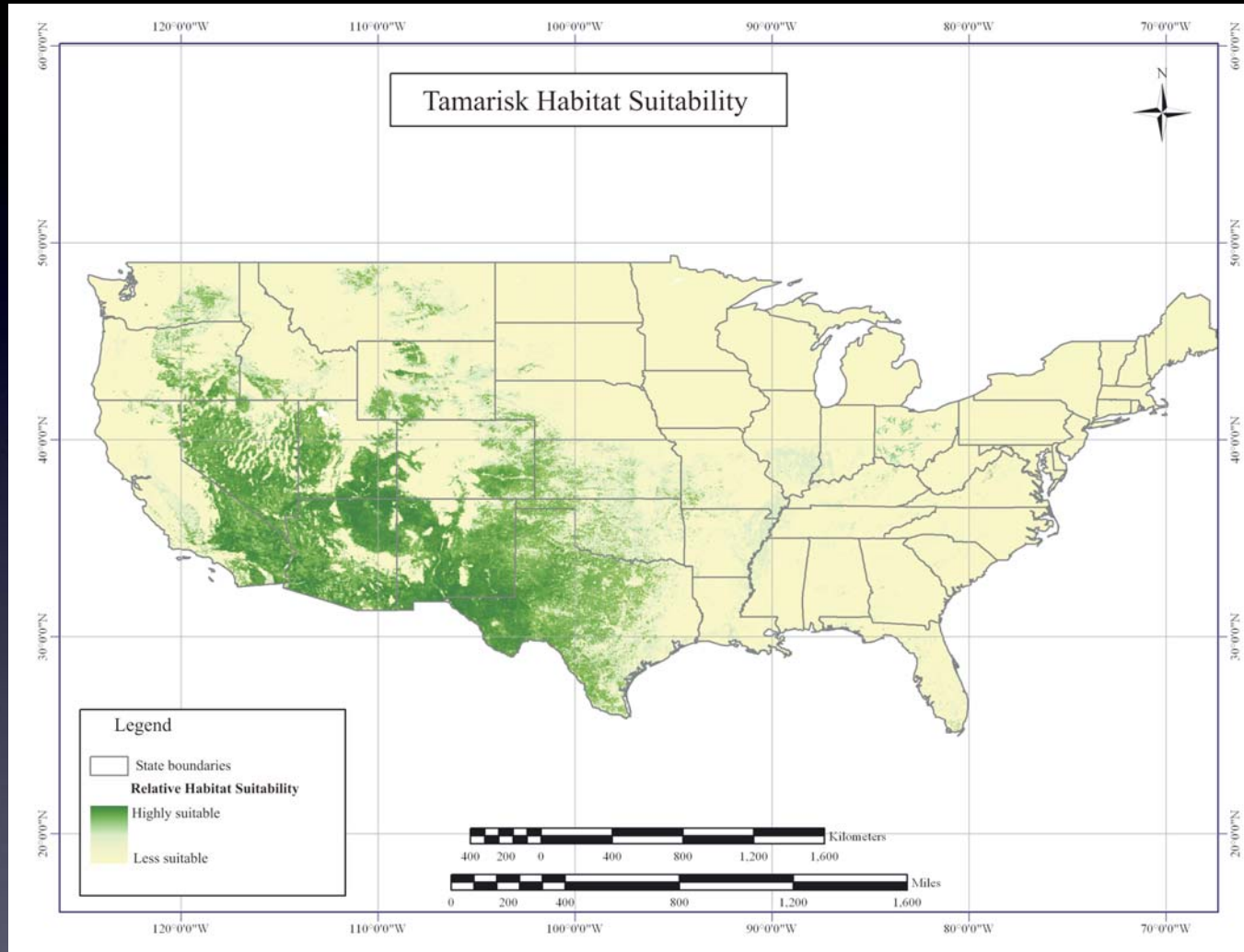
For healthy plants, higher maintenance respiration relative to heterotrophic respiration is expected throughout the growing season.



# Invasive species through the seasons...



# National map of habitat suitable for tamarisk

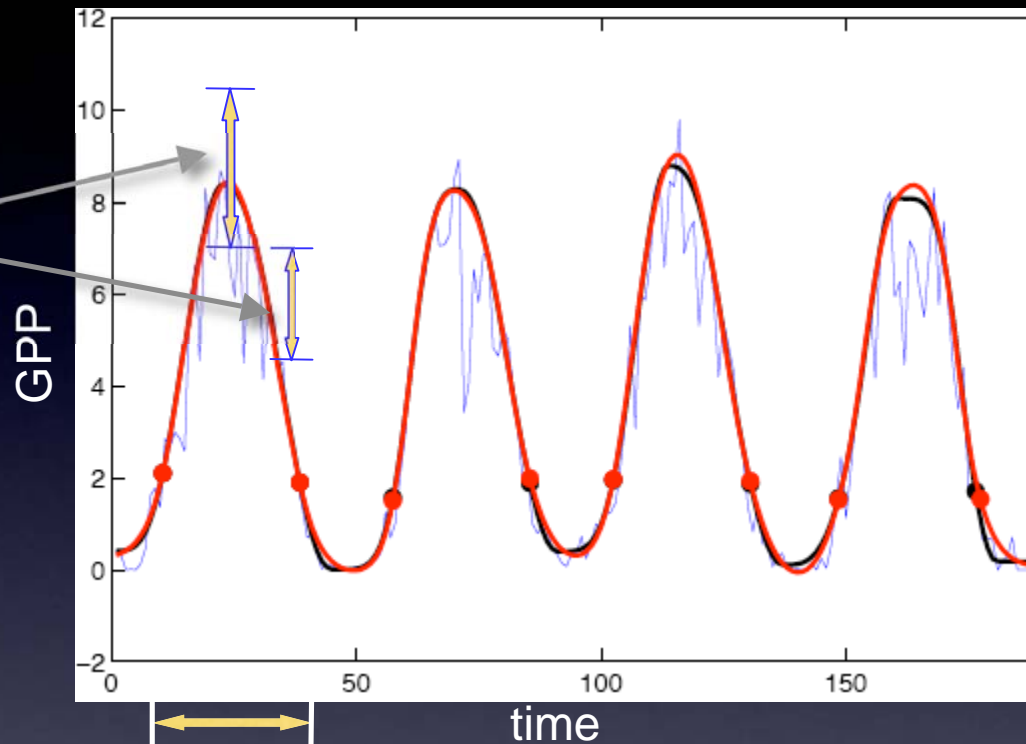


Tamarisk habitat map derived from logistic regression using MODIS land cover and the range in MODIS NDVI and EVI.

Morisette, J.T., C. S. Jernech, A. Ullah, W. Cai, J.A. Pedelty, J. Gentle, T.J.Stohlgren, J.L. Schnase, A tamarisk habitat suitability map for the continental US., *Frontiers in Ecology*, February 2006.

# How do we validate temporal signals?

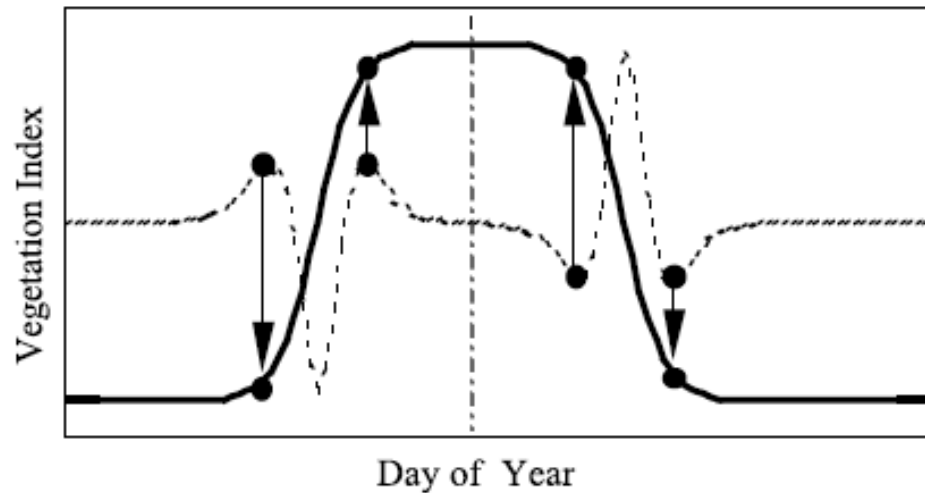
Current validation activities address the accuracy of a specific parameter at one or more points in time.



Validation of phenological parameters requires quantifying the uncertainty in the time domain.

Morisette, J. T., et al. (2006), Report from the CEOS Land Product Validation topical workshop on the Validation of global vegetation indices and their time series, *Earth Obs.*, 18(6)34-35,37

# MODIS Phenology



Extremes in  $K'$  define seasonal parameters.

Can we estimate the uncertainty in  $K'$ ?

$$K' = b^3 cz \left\{ \frac{3z(1-z)(1+z)^3 [2(1+z)^3 + b^2 c^2 z]}{[(1+z)^4 + (bcz)^2]^{\frac{5}{2}}} - \frac{(1+z)^2 (1+2z-5z^2)}{[(1+z)^4 + (bcz)^2]^{\frac{3}{2}}} \right\}$$

# Validation could take advantage of related science networks

- National Phenology Network
- NOAA's Climate Reference Network
- NSF's National Ecological Observation Network (NEON)
- Ameriflux and Fluxnet Flux tower networks
- GEOSS/CEOS could help bring together ground phenology networks (via task DA-07-05)



# Conclusion

- The lessons learned from MODIS land product validation present reasonable and feasible opportunities for NPOESS product validation.
- The extended time series of AVHRR/MODIS/NPP/NPOESS presents exciting potential for modeling and monitoring, yet there are outstanding issues related to the validation of time-series data.

# Thanks!

Jeff Morisette

[jeff.morisette@nasa.gov](mailto:jeff.morisette@nasa.gov)

301-614-5498