Progress and Status of Land Products and Collection 5

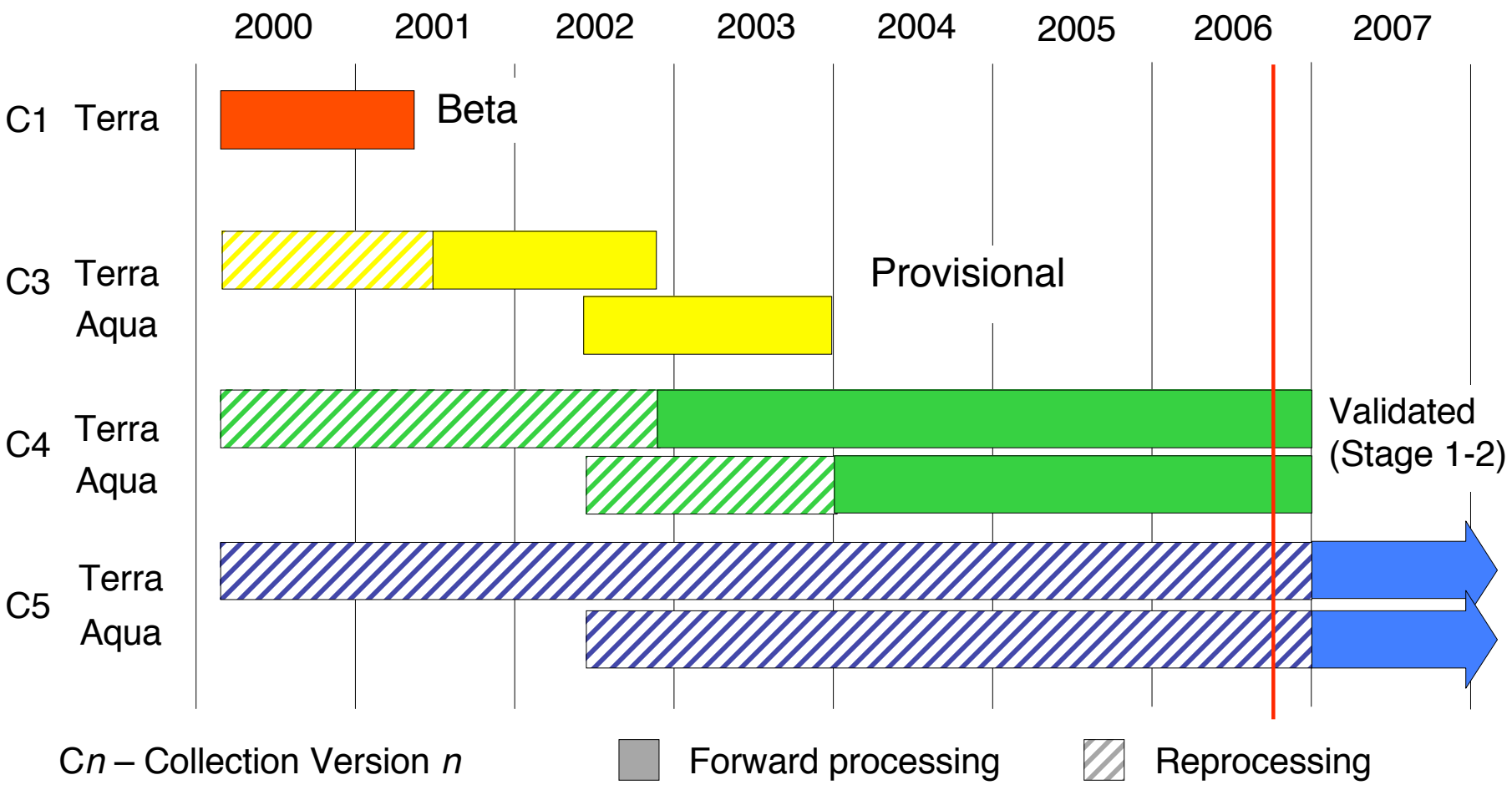
Chris Justice

and the MODLand Team

Summary Overview

- **Collection 5 Land Testing has been extensive and is completed for Terra**
  - Terra Retrospective processing 2000 onwards has started
  - On advice from the EDC DAAC we will start Terra forward processing Jan 1 (giving users a full calendar year of C4)
  - Aqua testing currently underway
    - One baseline test (global), one 8-day global test, and one recent 24-day global test (which also included a 16-day Terra test to support the combined products).
- **Validation coordination activities continuing – e.g. Montana V.I workshop**
- **MODIS Land data being widely used**
  - Number and Topic of scientific papers increasing
  - Increasing User Community and Demands on the SCF's
    - Established users increasingly sophisticated
    - New users continue to discover MODIS data
  - Applications users growing (agriculture, forestry, rangelands, fire, etc.)
    - Concerns about data continuity from operational users

MODIS Land Collections



Each collection represents an improvement in science quality

Collection 5 Land Science Testing

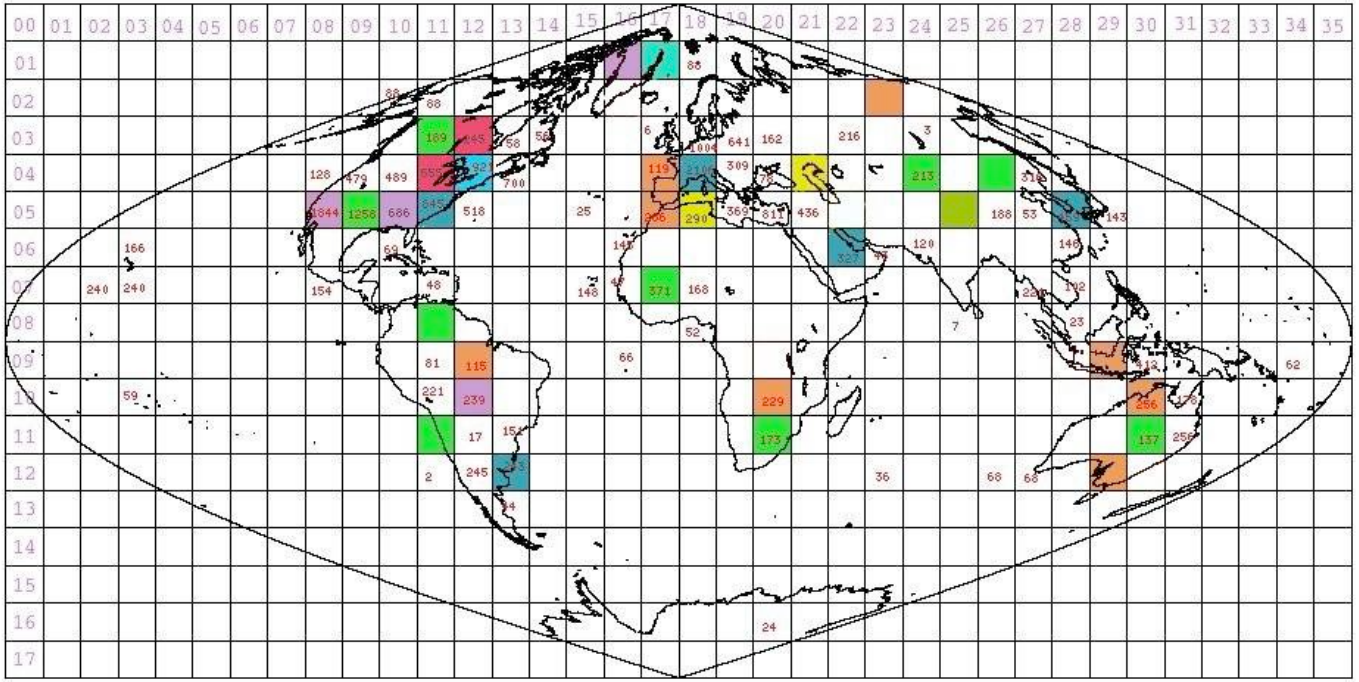
- C5 driven by science improvements and accumulated significant ‘fixes’
- The Collection 5 Science Test process for the Terra PGE’s
  - **Collection 4 baselines using Collection 5 L1 codes** were established for the global intervals and for 33 tiles for the time series intervals
  - Two summer/winter 16-day standard time intervals in 2003 were adopted for **global tests**
  - A standard 6-month interval in 2003 was adopted for **time-series tests**
  - All test products were generated on a dedicated MODAPS test machine and were **distributed to the Land Science Team using the LAADS**

Science Tests – Types and Purpose

- **Global Tests**
  - Data products are produced globally for a 16-day data period
  - Useful in evaluating the sensitiveness of algorithm change to different land cover types and remote sensing condition such as geometry.
  - Two 16-day data period used (2003017-2003032, 2003193-2003208).
    - Evaluation of complete suite of land product requires at least one16-day period of data.
    - Algorithm change could be sensitive to winter and summer data.
- **Time Series Tests**
  - Test is done at a number of fixed globally distributed locations
  - Two time series test conducted 1-year and 5-month time series
  - Time series test can capture algorithm sensitivity to phenology, atmospheric conditions and remote sensing conditions that change temporally.
  - Compared the time series of summary statistics derived from all the gridded C4 and C5 land products.
- **Test of Validation Sites**
  - Test was run for tiles containing the validation sites and data periods when validation data were available.
  - Correlation of C4 and C5 data to the validation data is used to quantify the improvement in C5 compared to C4.

Science Tests – Types and Purpose

- Patch Test
  - Targeted tests conducted for selected PGEs to evaluate algorithm fix with little or no effect on downstream products
- Tiles used in the 1 year time series test



Issues Addressed During C5 Testing

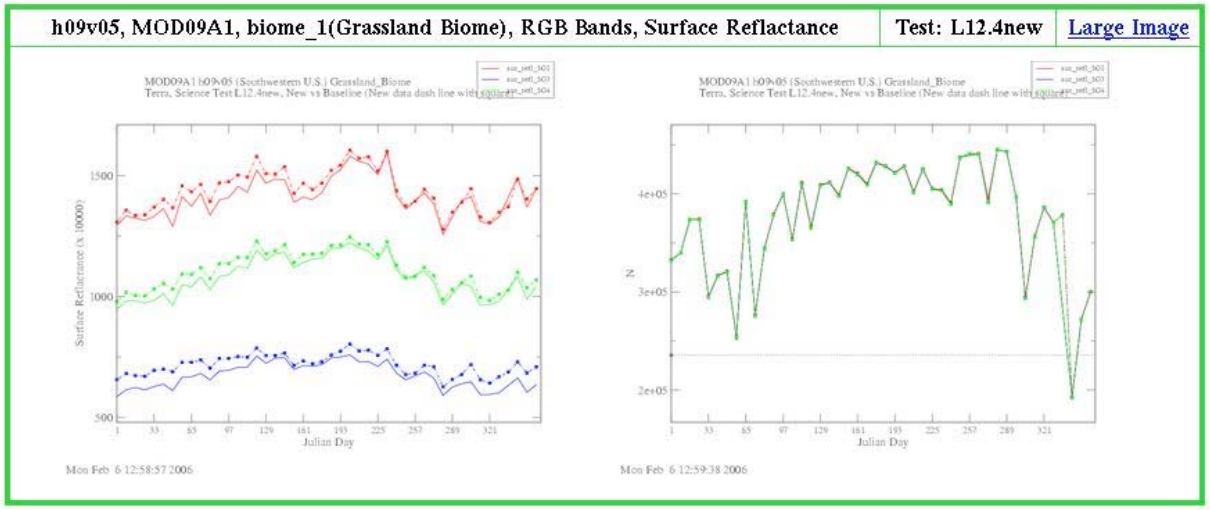
- **Land Surface Reflectance and Down Stream**
  - Incorrect flagging of AOT interpolation in LSR reduced the number of usable pixels in the downstream.
  - Inconsistent flagging of aerosol in LSR at high latitude (snow/cloud) degraded all the downstream n-day products.
  - In the first implementation of dynamic aerosol model dust model was found to be highly unreliable resulting in blocky artifact in most of the downstream products.
  - Incorrect labeling of atmospheric correction QA flag resulted in bad VI values at very high altitude where no atmospheric correction was applied.
  - Summary:
    - The current C5 LSR operational algorithm produces on the average more usable observations compared to C4
    - For usable observations (good quality) the percentage error in the retrieved reflectance is 10%.
    - Improvement in LSR has improved the quality of all downstream land products using the LSR.

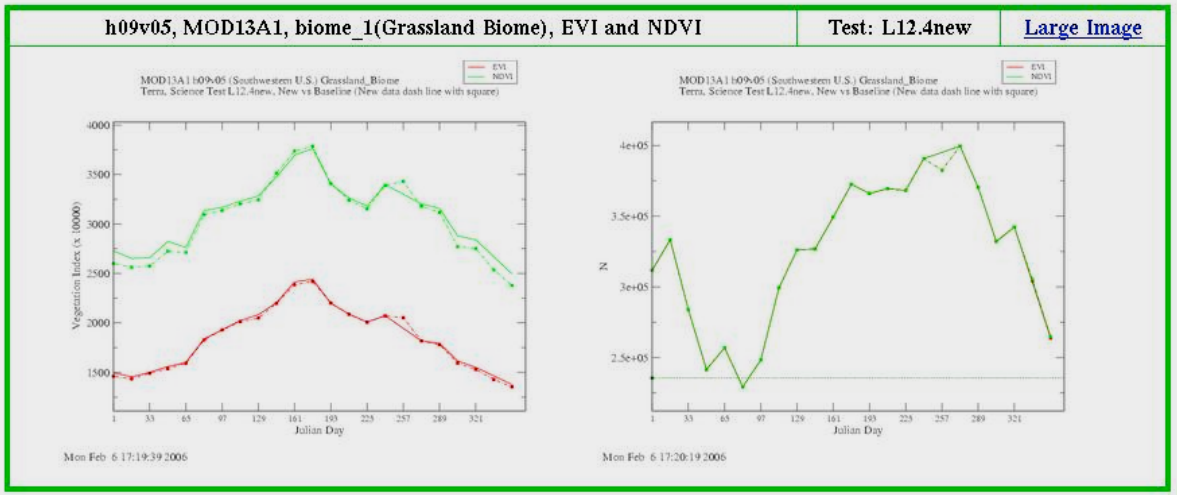
C5 Product Testing Issues

- LAI/FPAR
  - LAI/FPAR values from the initial version of C5 algorithm were found to be very low for some of the biome classes. Many of the retrieved values were found to be retrieved using the empirical algorithm
  - Algorithm was later refined to improve the quality of the LAI/FPAR retrievals. The problem was fixed using the new LUT created using the new stochastic RT model which allows a better representation of canopy structure.
- GPP/NPP
  - In the initial version of C5 data a spatial non-linear interpolation of DAO had banding effect on output which was very clear in data produced over Amazon. The problem was later fixed.
- LST
  - Problem with the interpolation of atmospheric profile at the edges of the granule resulted in artifacts on the edge of LST granules. The problem was addressed in the later versions of the algorithm.
  - Stripes in atmospheric profile resulted in severe stripes in the LST product. Atmospheric profiles were smoothed to fix the problem.
- MODAGAGG
  - Inspection of degraded products at higher latitude revealed error in scoring of the observations based on 1km data state. Fixing of the scoring in the later version of the algorithm improved the quality of the product. .
- VI
  - Noise in VI observed in the initial version of the algorithm was attributed to the selection of one observation from many good input observations. Limiting the minimum view angle improved the quality of the product.
  - Computation of VI over inland water continue to be a problem.

Example of LDOPE of Time Series

- Examples on the right show time series plots from the 1-year time series test.
- The image on the top shows the plots of time series statistics of LSR for the bands 1, 3, and 4 from C4 and C5 data for a tile in southwestern US.
- The image below shows the plots of time series statistics of EVI and NDVI from C4 and C5 data for the same tile.





Collection 5 Land Science Testing

- **7 major Terra land science tests were performed**
  - This included 5 global 16-day or 32-day tests and 2 6-month time series tests
  - Each major test included 30-40 PGEs
  - Typically each test cycle for a major test (update PGE versions, integrate PGEs into MODAPS, implement test, review test results) was 3 months
  - During the test program 41 land PGEs were evaluated and on the average each PGE was updated 7.4 times over the test program
- **Numerous (50+) smaller tests were performed:**
  - Chain tests in support of developing the Collection 5 L1 codes and cloud mask/profiles
  - Targeted tests for single PGE's (e.g. LSR and LST) to support code development
  - Chain tests for the improved land water mask
  - Single PGE tests to inter-compare performance in Linux and IRIX environments
  - Performance tests for Collection 4 and 5 PGE versions to assess MODAPS production performance
  - LP and NSIDC DAAC ESDT insert tests
  - LP and NSIDC DAAC load tests to assess feasibility of DAAC ingest at the MODAPS production rate of 10x

MODIS Land C5 Reprocessing Schedule

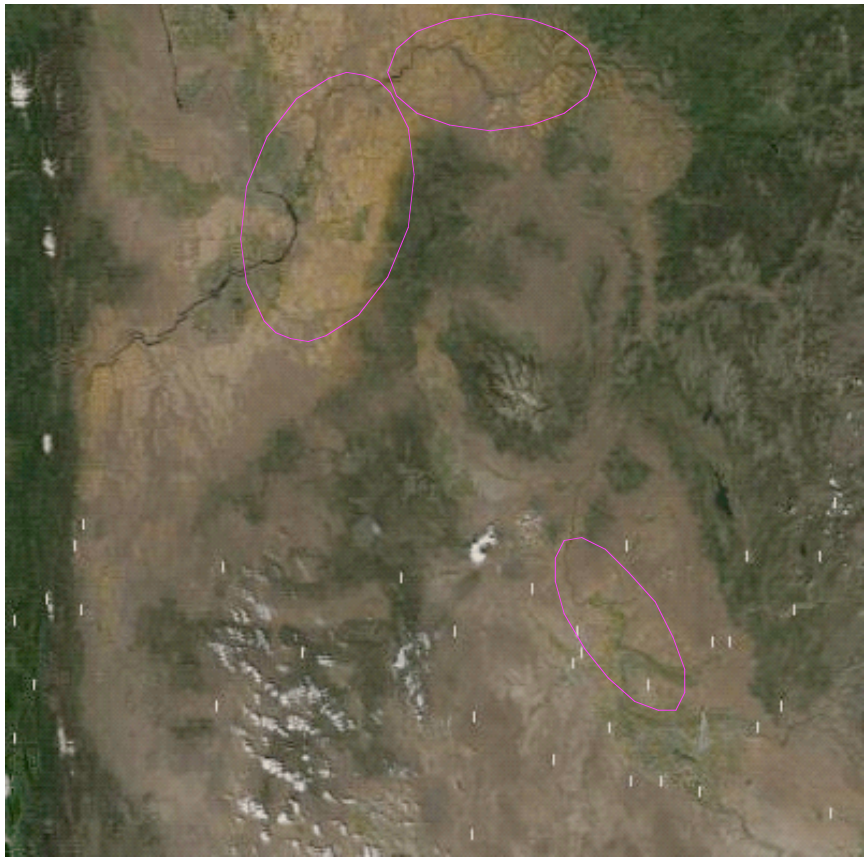
June 30, 2006	Started C5 Land Terra-only reprocessing
Sept. 8, 2006	Restarted C5 Land Terra only reprocessing (@ ~3.6x)
Dec. 1, 2006	Complete year 2000 of C5 Terra only reprocessing
Mar. 12, 2007	Complete year 2001 of C5 Terra only reprocessing
Jan. 1, 2007	Start C5 Land Terra, Aqua and Combined forward processing (@ ~7.2x)
Late-May 2007	Finish Terra-only reprocessing
Sept. 2008	End C5 reprocessing

MODIS Land Collection 5 Changes – Summary

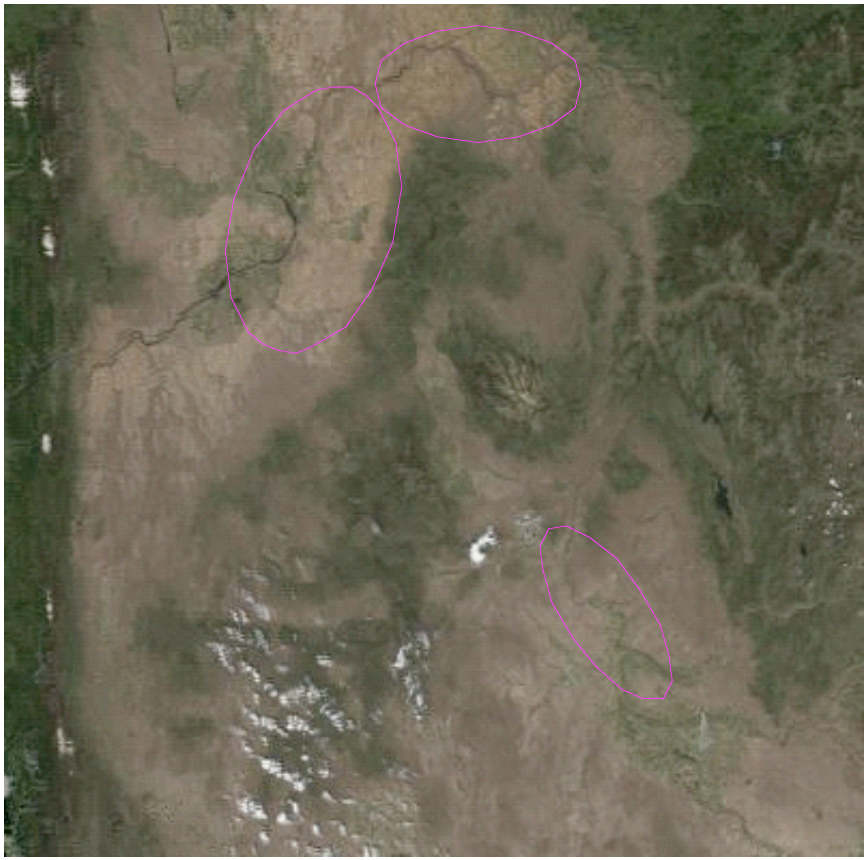
- Used improved Land/Water mask and new Land Cover map based on 3 years of Collection 4 data
- Refined surface reflectance by adopting a dynamic aerosol model in atmospheric correction and implementing BRDF coupling and adjacency effect correction schemes
- Reduced size and complexity of daily surface reflectance products
- Improved quality of the Land Surface Temperature by revising the day/night algorithm and improving the detection and filtering of cloud contaminated observations
- Increased resolution of BRDF/Albedo products to 500m
- Refined LAI/FPAR LUTs to improve numerical accuracy of the radiative transfer simulations
- Added fractional snow algorithm in the snow product
- Burned area product added
- Improved ancillary data interpolation to remove artifacts in the NPP product
- Reduced size of all Land products through HDF internal compression

Surface Reflectance – C5 Changes

- The Collection 5 surface reflectance algorithm retrieves the aerosol model along with the aerosol optical thickness.
- This leads to less overcorrection in the surface reflectance product



C004



C005

(Source: Eric Vermote, UMD)

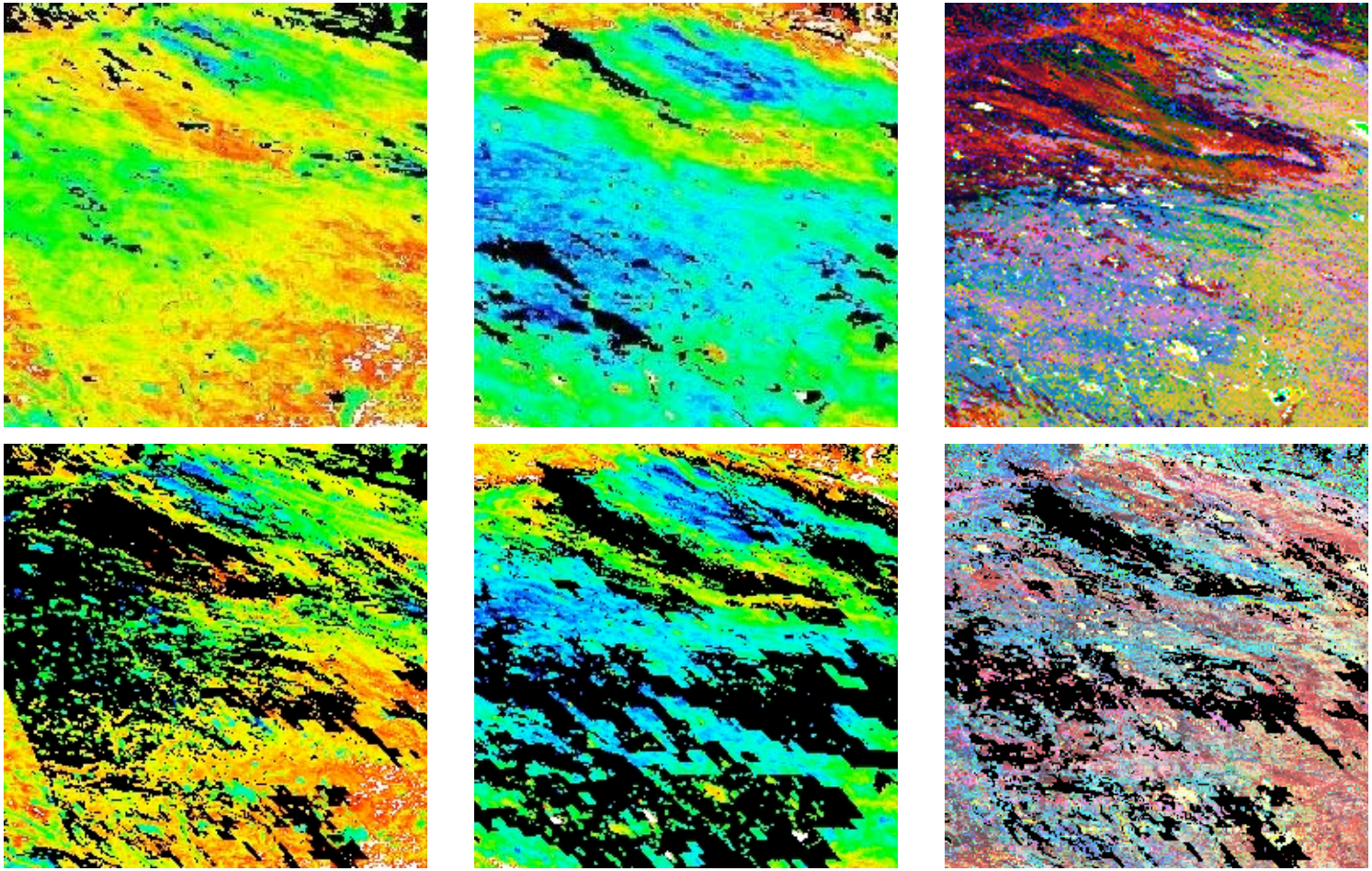
Improvements of the C5 LST Products over C4 (I)

due to using cloudmask combined with surface elevation

shown in example of MOD11B1 in tile h25v05 retrieved from Terra MODIS data acquired on 21 January 2003.

C5

C4

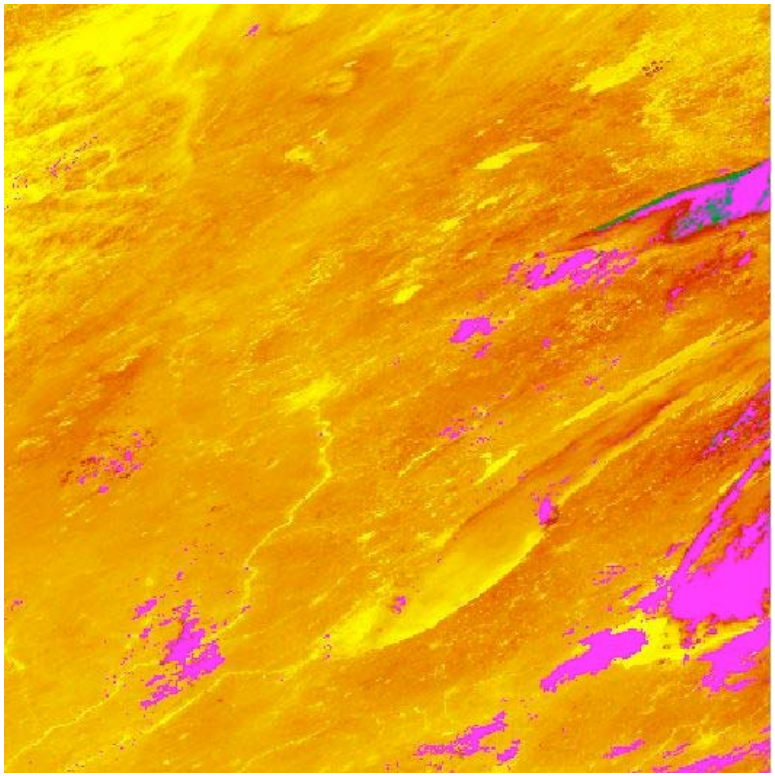


Daytime LST Nighttime LST Emissivity RGB

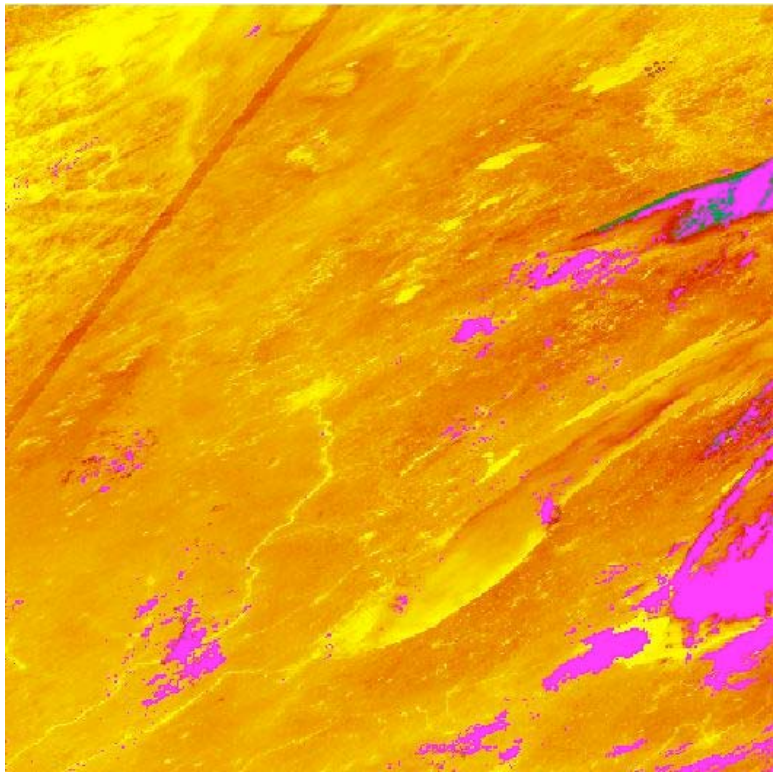
Improvements of the C5 LST Products over C4 (II)

due to applying an empirical correction for optical leak to band 32 in the last four pixels each scan line in the Terra MODIS L1B granules, where the leak cannot be corrected
by a physical model, shown in nighttime LSTs in MOD11A1.A2003194.h11v04. Note that LST values in the dark stripe (right) are cooler than their neighboring by 2-4K.

C5

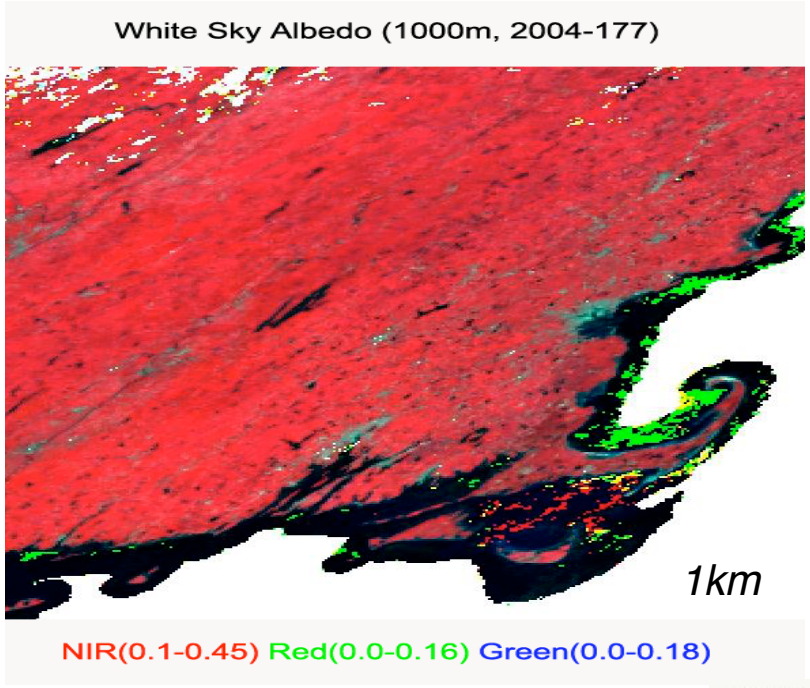


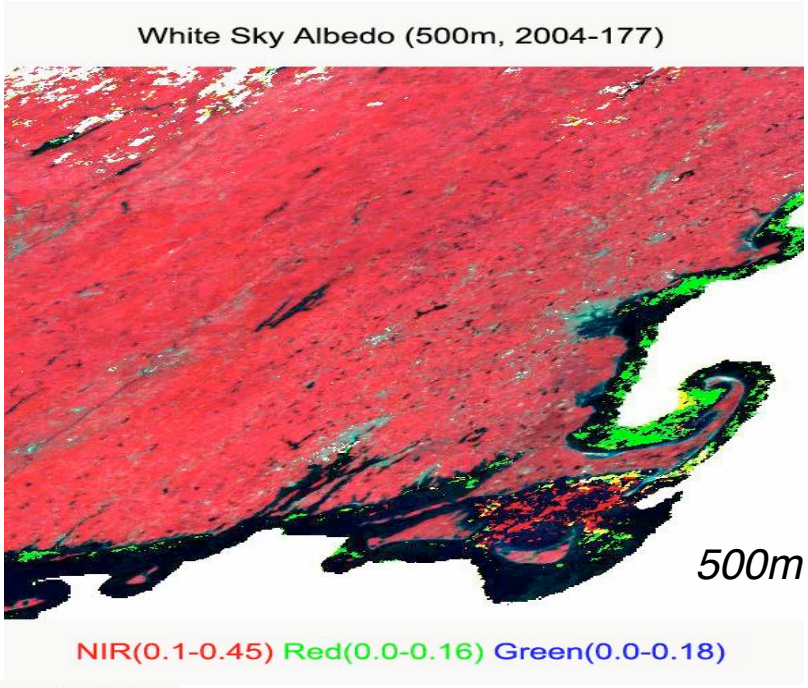
C4



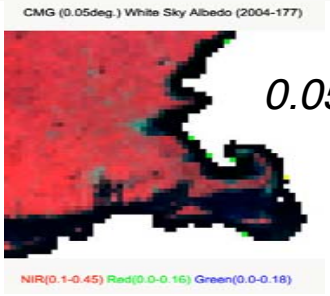
BRDF/Albedo – C5 Changes

- The Collection 5 BRDF/Albedo product is produced at a resolution of 500m which provides better spatial detail and will allow the production of a global Land Cover at 500m.





Collection 5 White Sky Albedo products in New England area at different resolutions

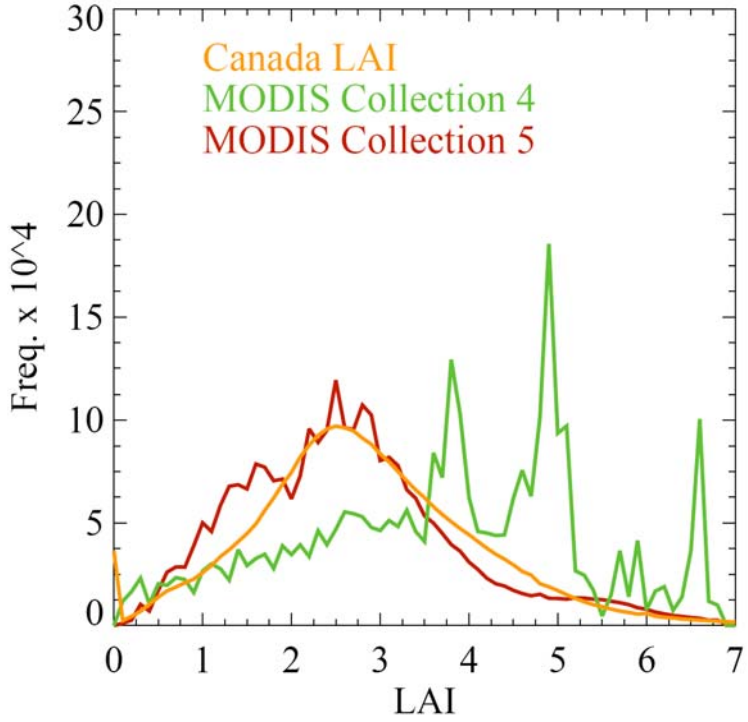


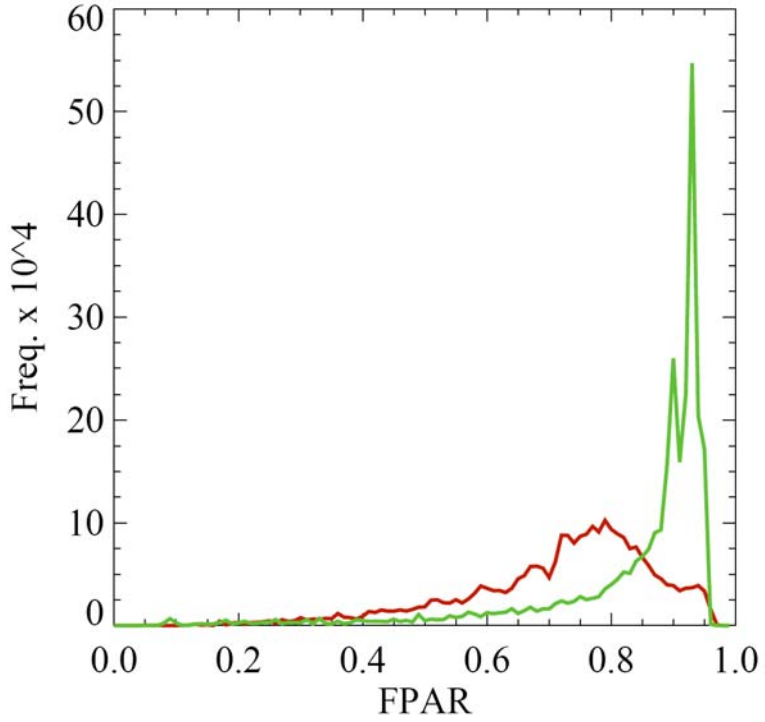
0.05 deg.

(Source: Crystal Schaaf, BU)

LAI/FPAR – C5 Changes

- Collection 5 has refined Lookup Tables (LUTs) for all biomes to improve numerical accuracy of radiative transfer simulations and to better match simulated reflectances and MODIS observations.
- Examples of resulting improvements are a reduction in over-stimulation of LAI and FPAR for needle leaf forest (below) and an increase in the rate of best quality retrievals.



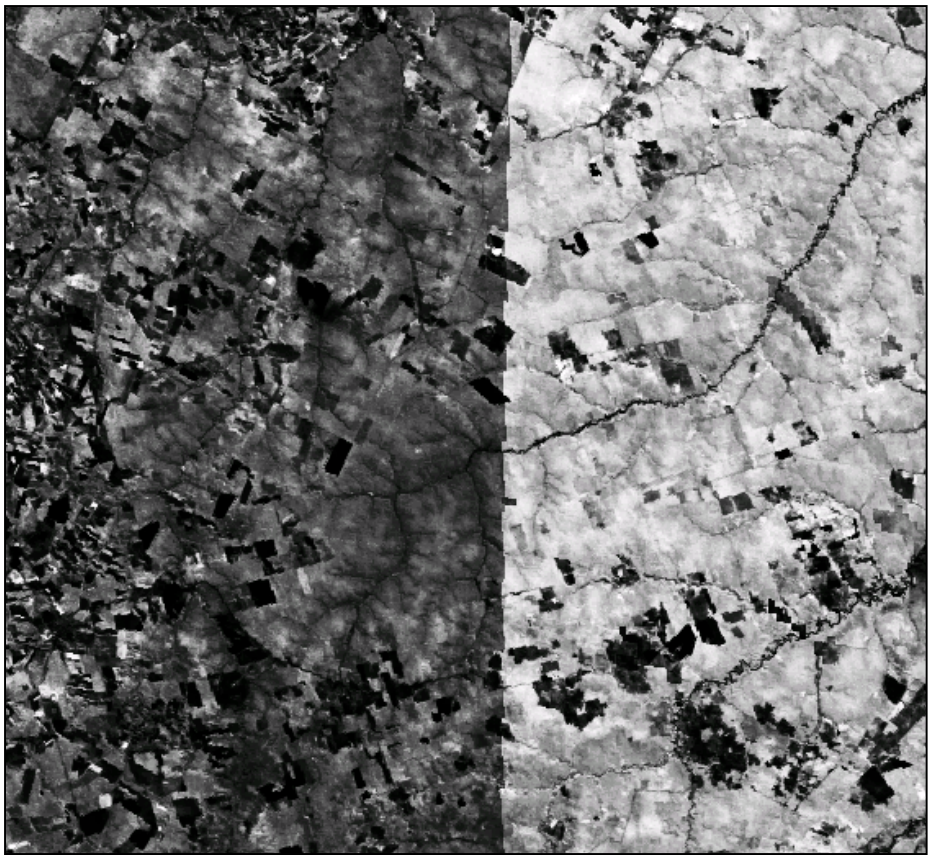


Comparison of Collection 4, Collection 5 and CCRS (Canadian Center of Remote Sensing) LAI and FPAR over Canada. MODIS data are for data-days 201-208, 2003.

(Source: Nikolay Shabanov, BU)

Vegetation Cover Change

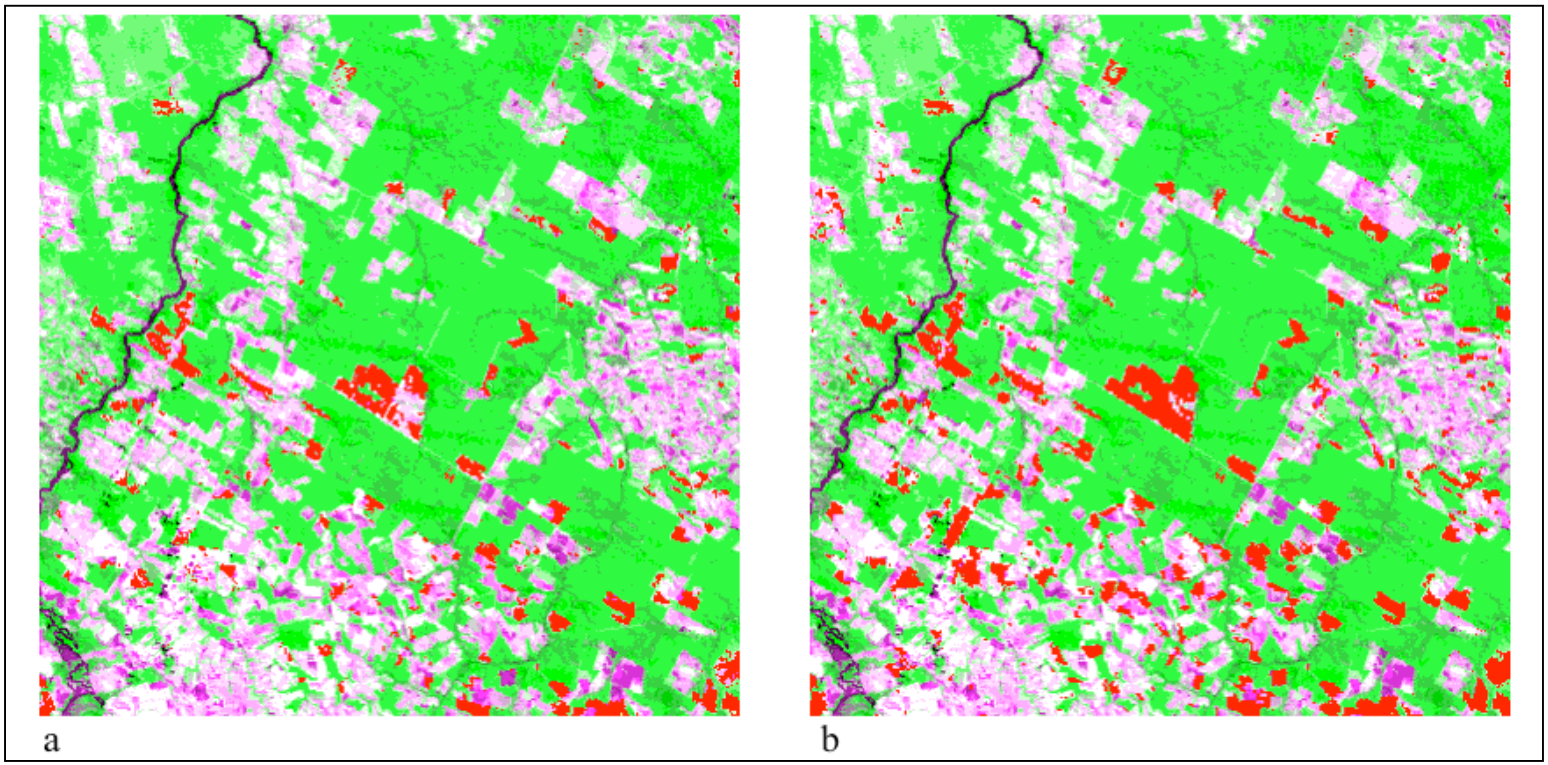
C5 Will Account for Effect of BRDF on Land Cover Change Detection



This near infra-red (MODIS band 2) example from the Brazilian Amazon shows the effect of BRDF on a 16 day composite product. If BRDF is not accounted for, this 2-5% difference in reflectance is sufficient to confuse land cover change detection algorithms.

Townshend, Hansen, Sohlberg, DeFries (MST 10/31/06)

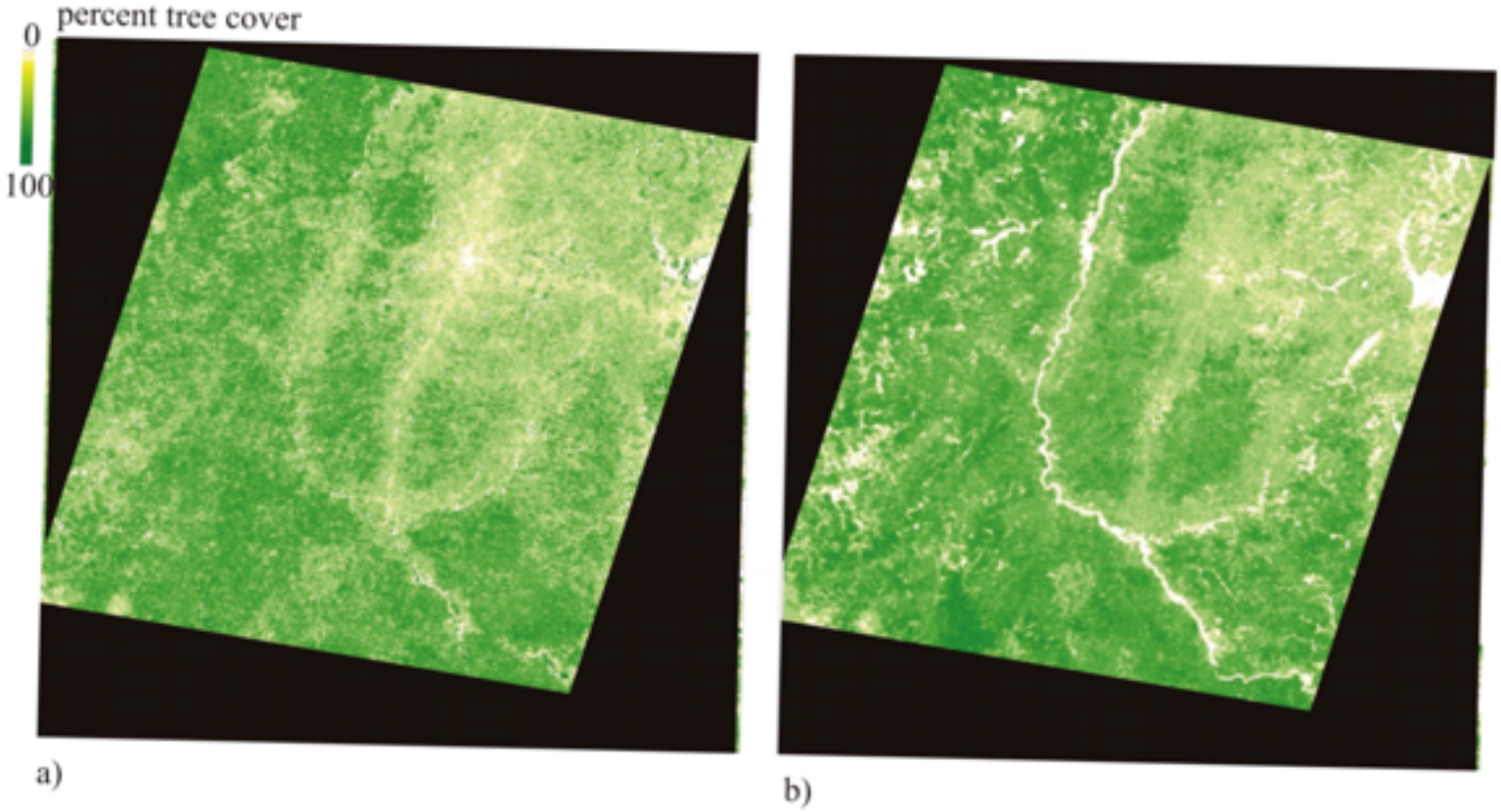
C5 MOD44A Vegetative Cover Conversion Accounting for BRDF



Full resolution image of the 2001 - 2005 change detection in Mato Grosso, Brazil. Image in (a) depicts the standard MODIS VCC; (b) depicts improved results using a ratio method to mitigate BRDF. Areas that have changed are shown in red in both images. Note the increased area and additional change observations in (b).

Townshend, Hansen, Sohlberg, DeFries (MST 10/31/06)

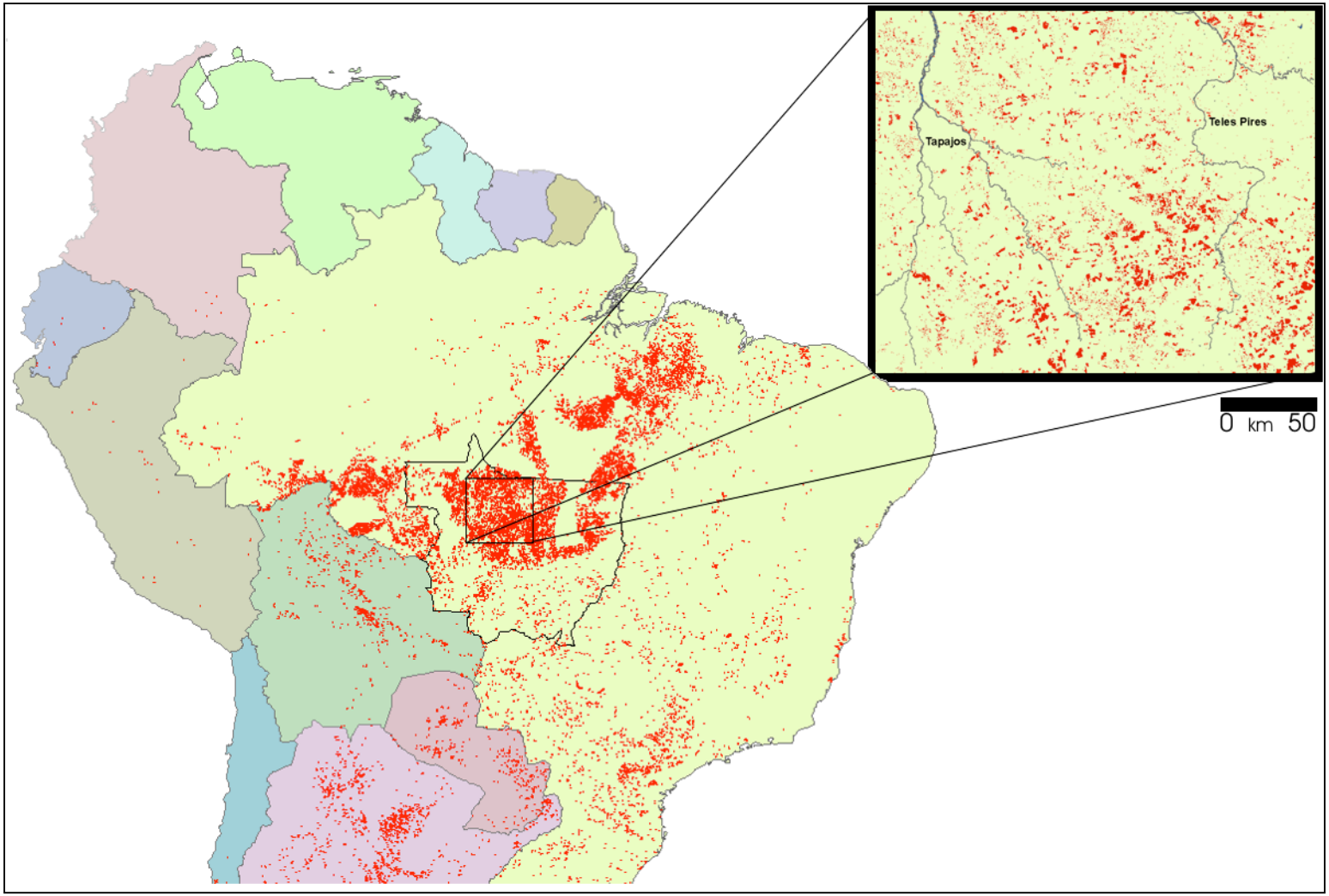
C5 Will Employ Regionally Tuned MOD44B Vegetation Continuous Fields



Global and biome-specific VCF tree cover maps covering the footprint of Landsat path/row 172/068 on the Congo and Zambia border where a) is the global product, and b) is a biome specific map for the tropical savanna and woodland biome.

Townshend, Hansen, Sohlberg, DeFries (MST 10/31/06)

Five Year Vegetative Cover Conversion Showing Tropical Deforestation

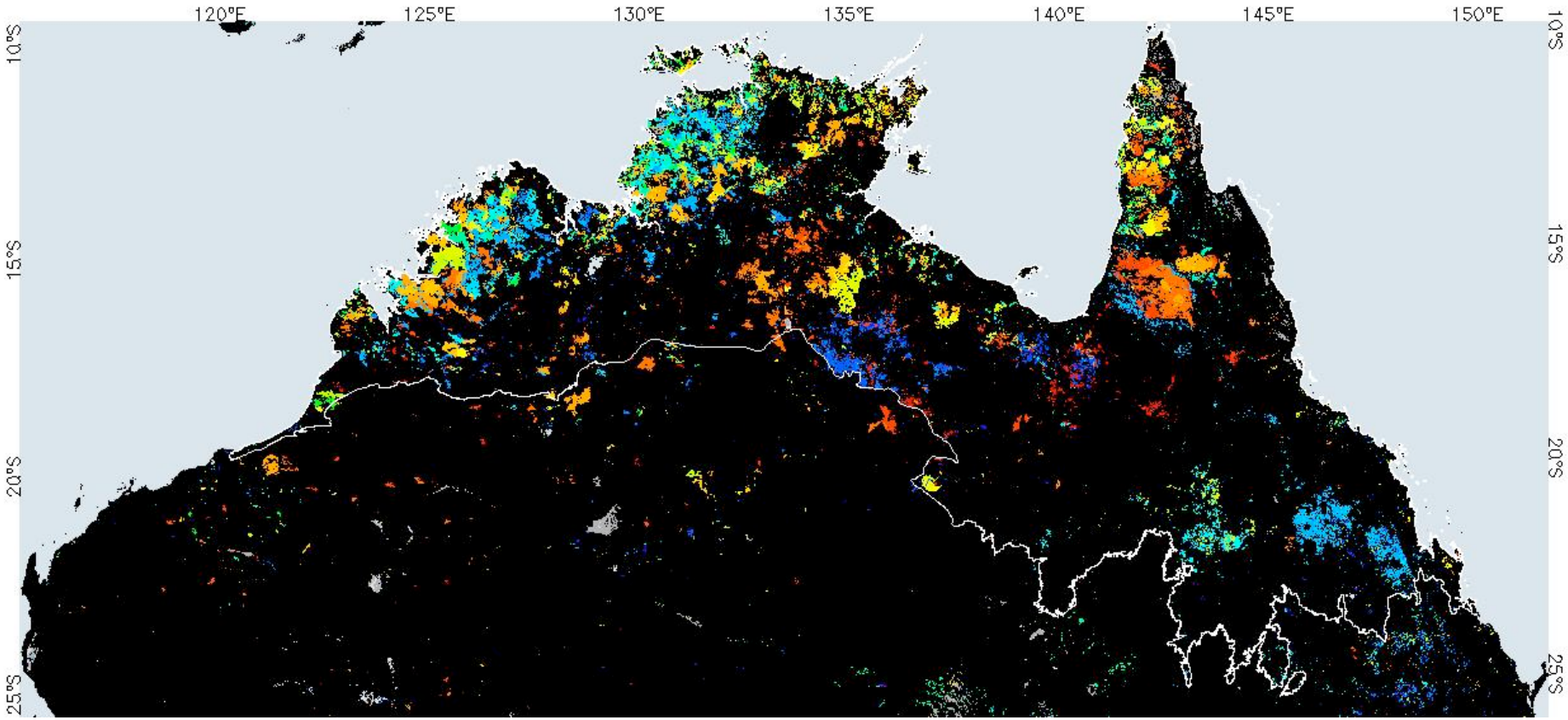


MODIS VCC showing deforestation for South America from 2001 to 2005. The outline box in the large image shows the location of the full resolution data in the upper image from Mato Grosso, Brazil. Change is shown in red.

Townshend, Hansen, Sohlberg, DeFries (MST 10/31/06)

Burned Area – New C5 Product

- Collection 5 includes a monthly burned area product produced at 500m from Terra and Aqua.



Burned Area 2003 dry season in Australia (March-November)

(Source: David Roy, Luigi Boschetti)

C5 Reduced Product Sizes

	MODAPS Production (GB/day)		Export Volume (GB/day)			
			LP DAAC		NSIDC DAAC	
	C4	C5	C4	C5	C4	C5
L2 – L3 Daily	456	140	265	31	7	<1
Level 3 8-day +	23	26	70	19	1	<1
Total	479	166	335	50	8	1

Reduced size of all Land products through HDF internal compression

MODIS Collection 5 User Workshop

- Will provide an in-depth look at the Collection 5 changes to the MODIS Land products, MODAPS production status and reprocessing schedule and QA status.
- Will provide an opportunity for feedback from the user community on MODIS Land products and access and discussion of future land product plans.
- Will consist of presentations, tutorials and discussion.

January 17–18, 2007 @ UMD
University College Inn and Conference Center

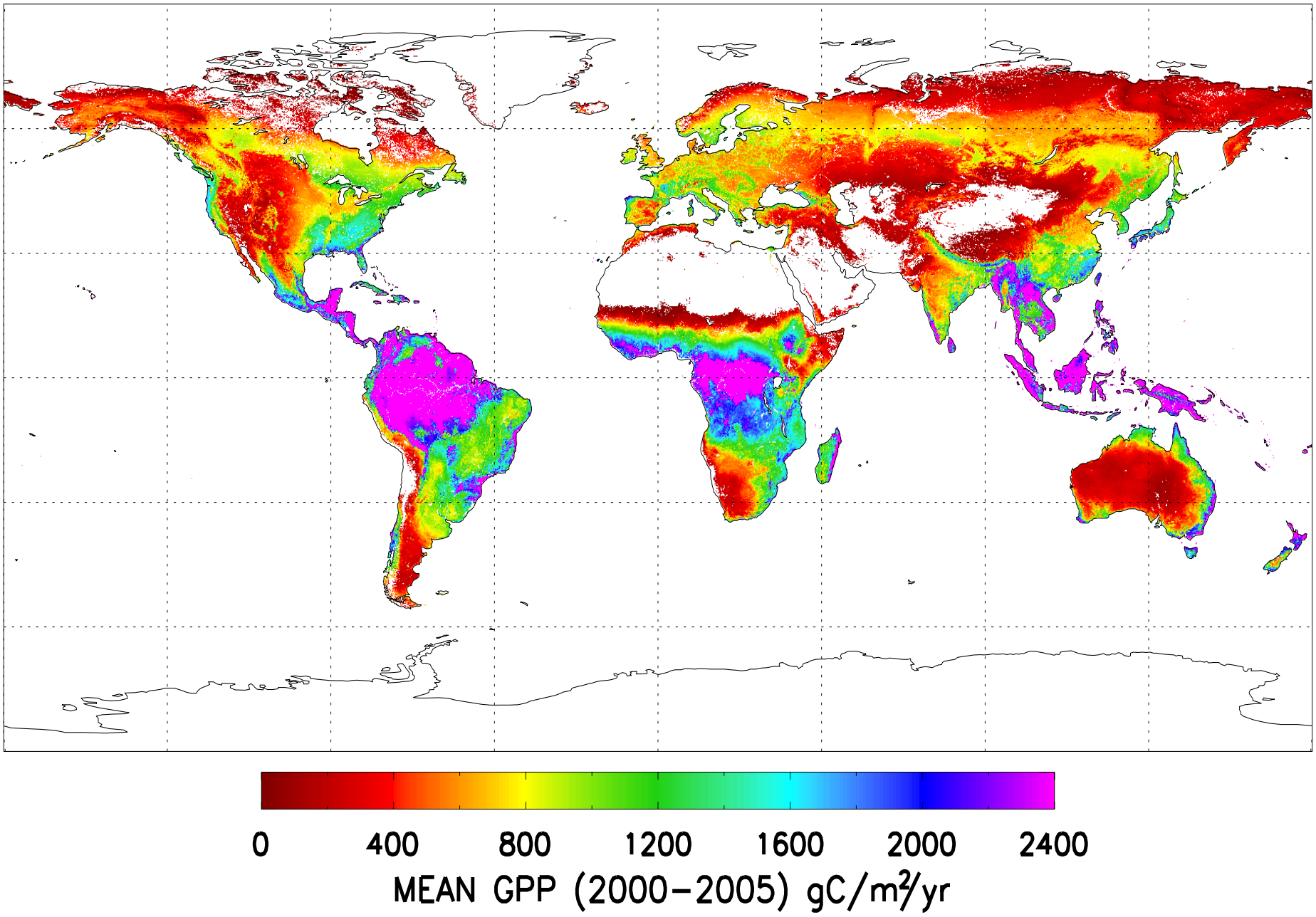
Time Series Analysis
Collection 4 Continues

Level 4 Product Improvements and Time Series

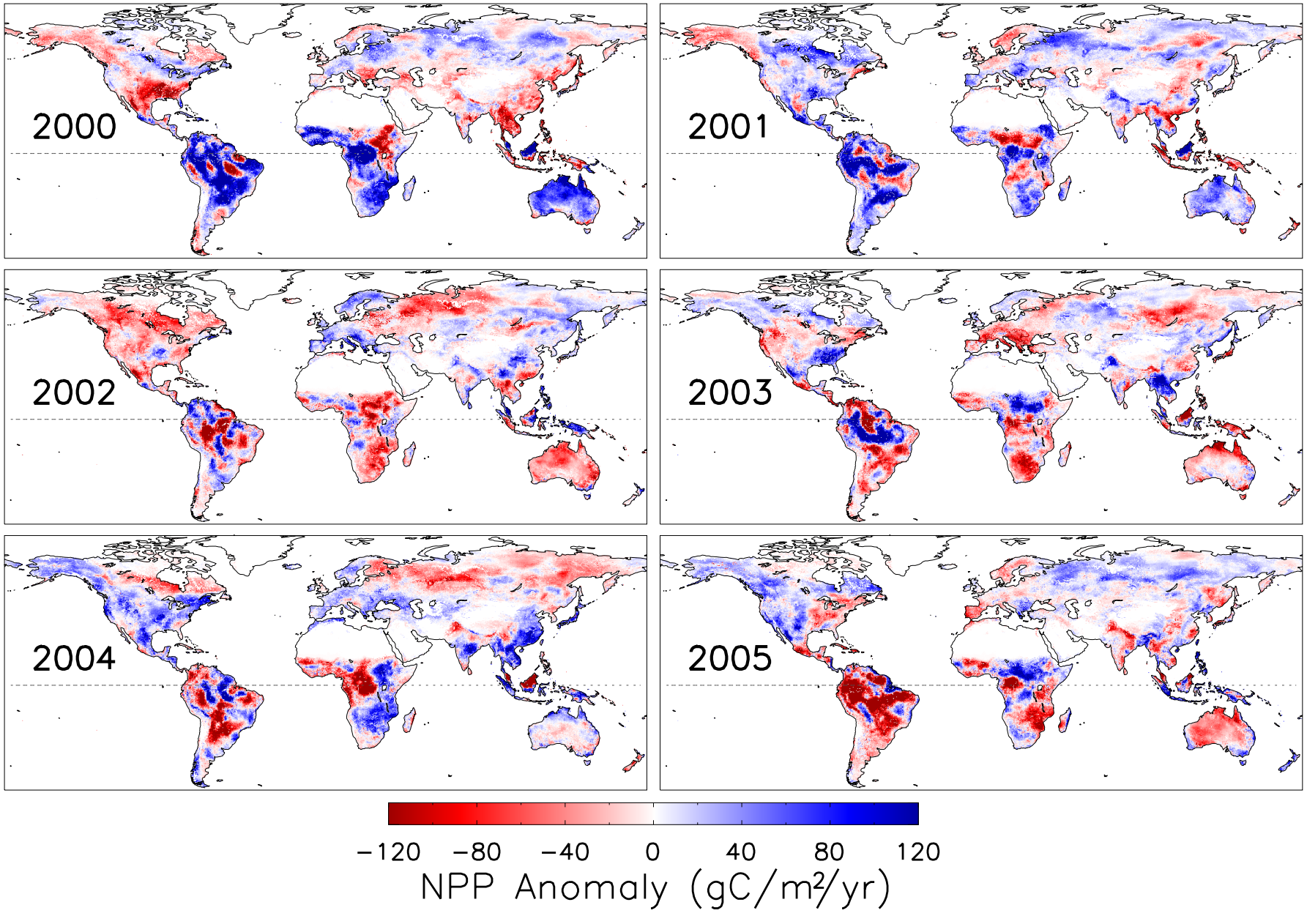
C4.8 MOD17 (GPP/NPP)

- ***Data processing (both for C4.5 and C4.8)***
  - Spatially smoothing DAO (1° X 1.25 °)
  - Temporally filling the contaminated/missing MODIS inputs
  - Retuned Biome-Property-Lookup-Table (BPLUT) based on validation at eddy flux towers (different for C4.5 and C4.8)
- ***Algorithm (only for C4.8)***
  - Growth respiration is 25% of NPP, instead of the function of annual maximum LAI
  - Acclimation of Q_{10} value for leaf maintenance respiration to temperature (Q_{10} = 3.22-0.046 * Tavg), instead of a constant value 2.0
- ***C4.8 provides a marked improvement***
  - The improved C4.8 global terrestrial GPP/NPP are superior to the previous version, and C4.5 is not consistent from 2004 due to change in meteorological inputs
  - The C4.8 data will be released at NTSG ftp site ftp://ftp.ntsg.umt.edu late this month.

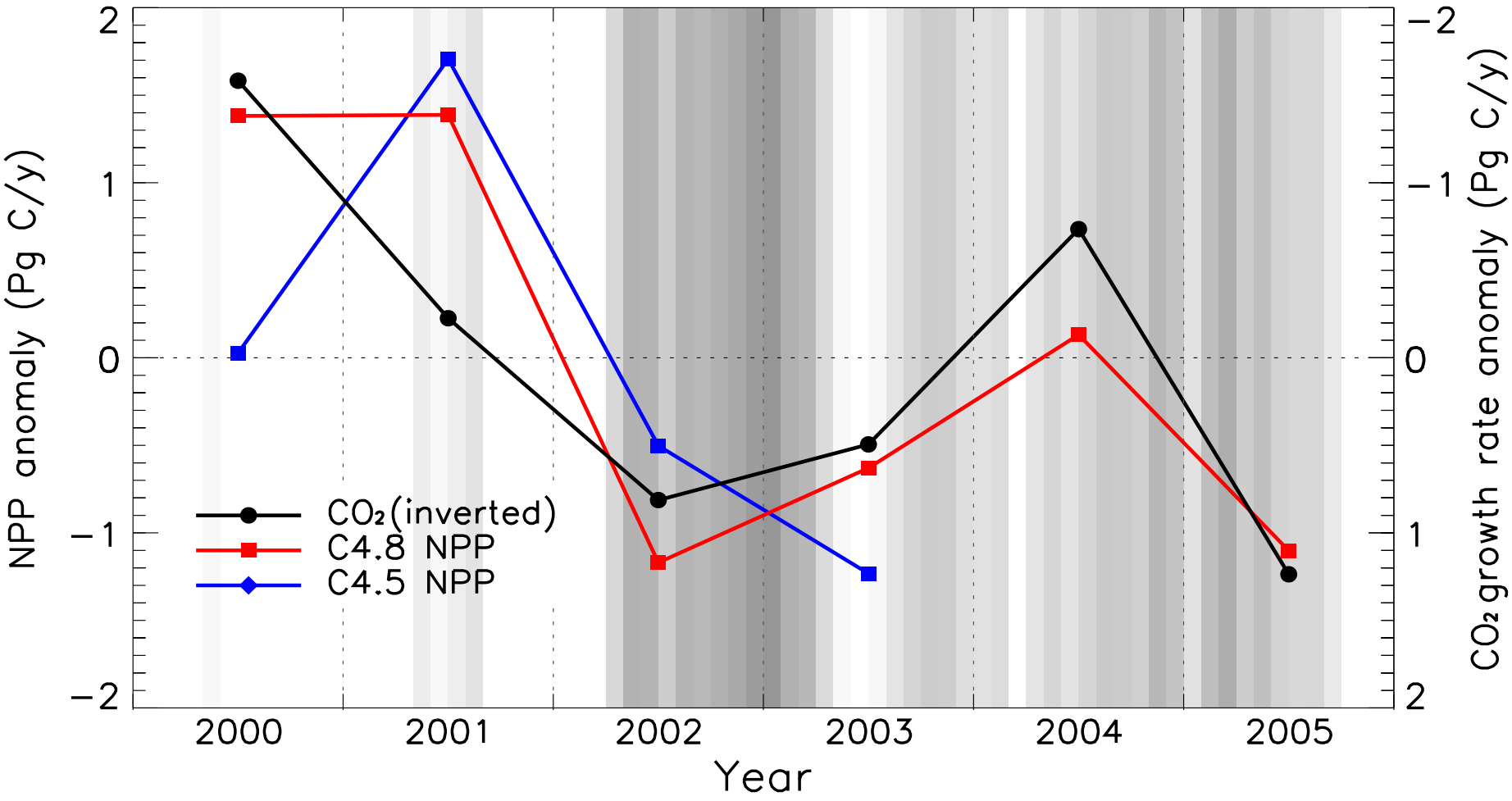
Mean annual GPP



Inter-annual variations of MODIS NPP (Spatial)



Inter-annual variations of MODIS Global NPP (Temporal)



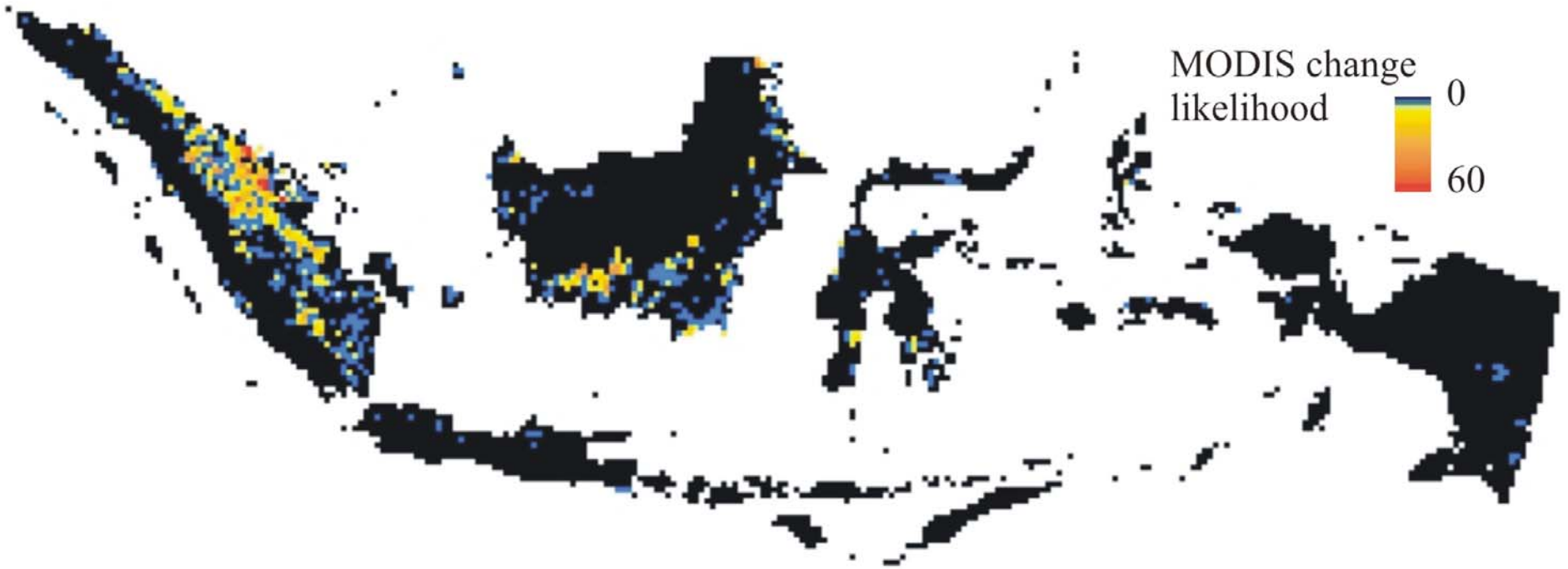
Correlation of NPP to inverted CO_2 growth rate

C4.8 **0.85** 2000~2005 $p < 0.016$

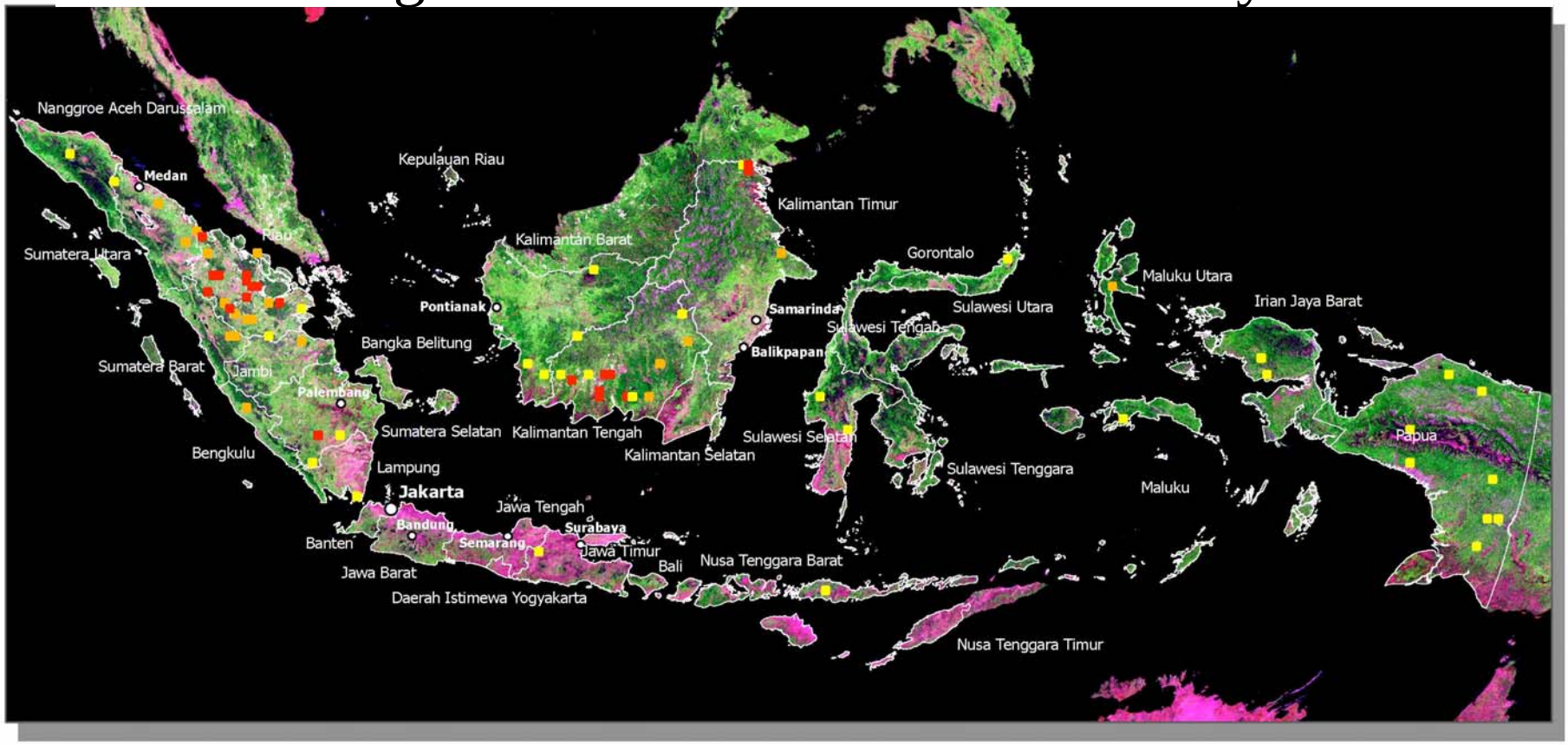
C4.8 **0.85** 2000~2003

C4.5 **0.36** 2000~2003

MODIS VCC – Collection 4
change indicator map, resampled to 20km by 20km blocks



Stratified sample of MODIS low, medium and high change classes for Landsat-scale analysis



Verification sample blocks

- Low forest cover change
- Medium forest cover change
- High forest cover change

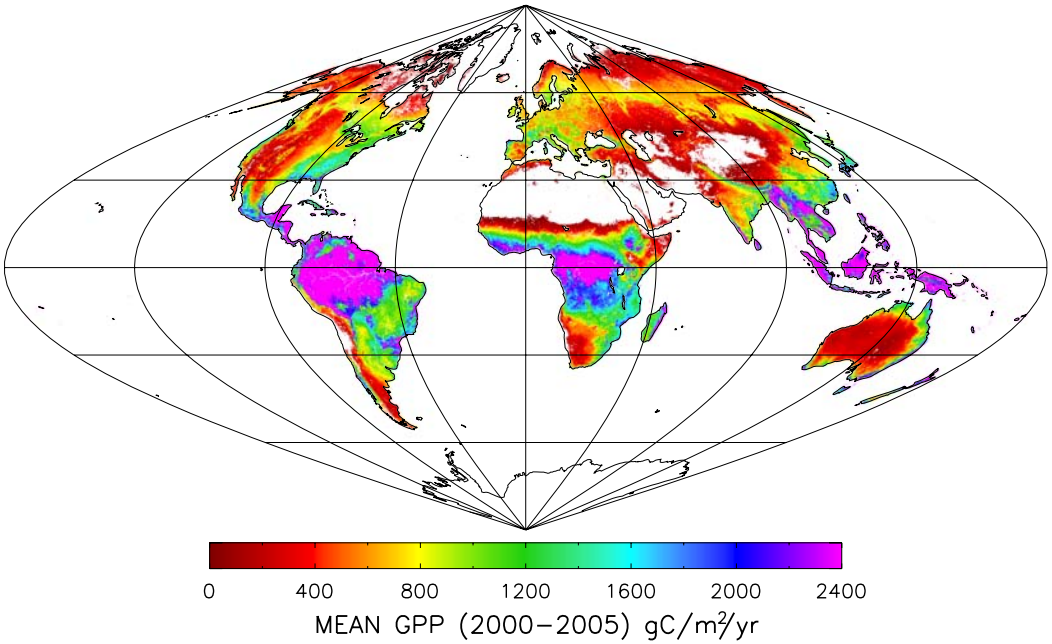
MODIS analysis – SDSU/SUNY-ESF
Landsat analysis – SDSU/MoF
MODIS pre-processing – NASA/UMd/SDSU
Landsat data provision – USGS/GFW/UMd
Indonesia land cover – MoF

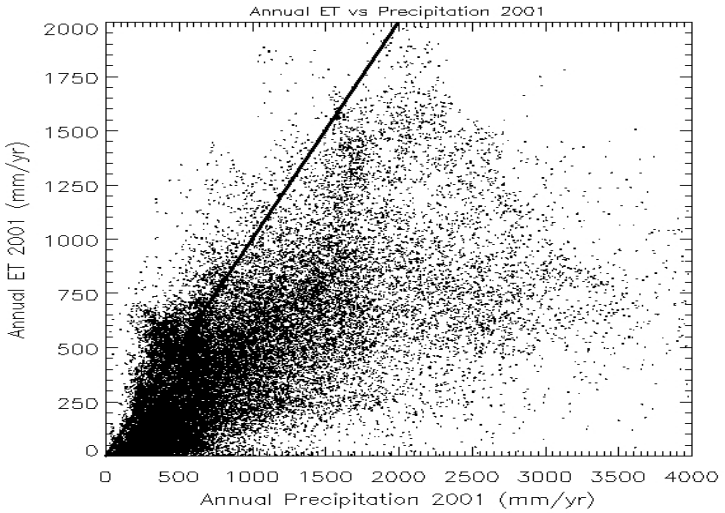
The Six-Year (2000-2005) Global MODIS Evapotranspiration (Collection 4 Analysis)

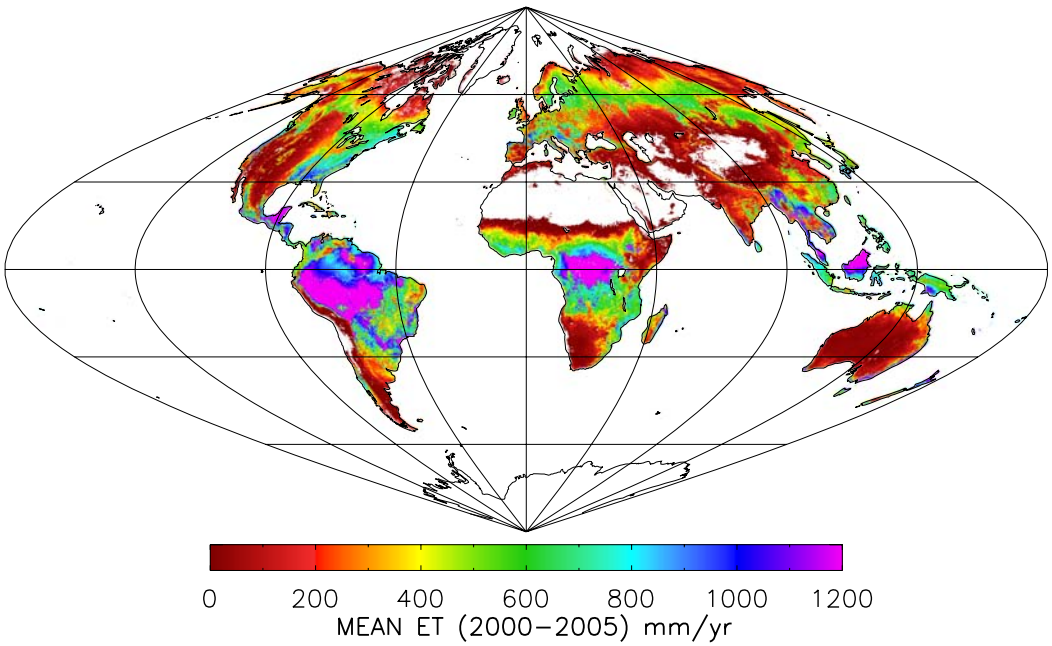
Qiaozhen Mu, Maosheng Zhao, and Steven W. Running

NTSG, University of Montana, Missoula, MT

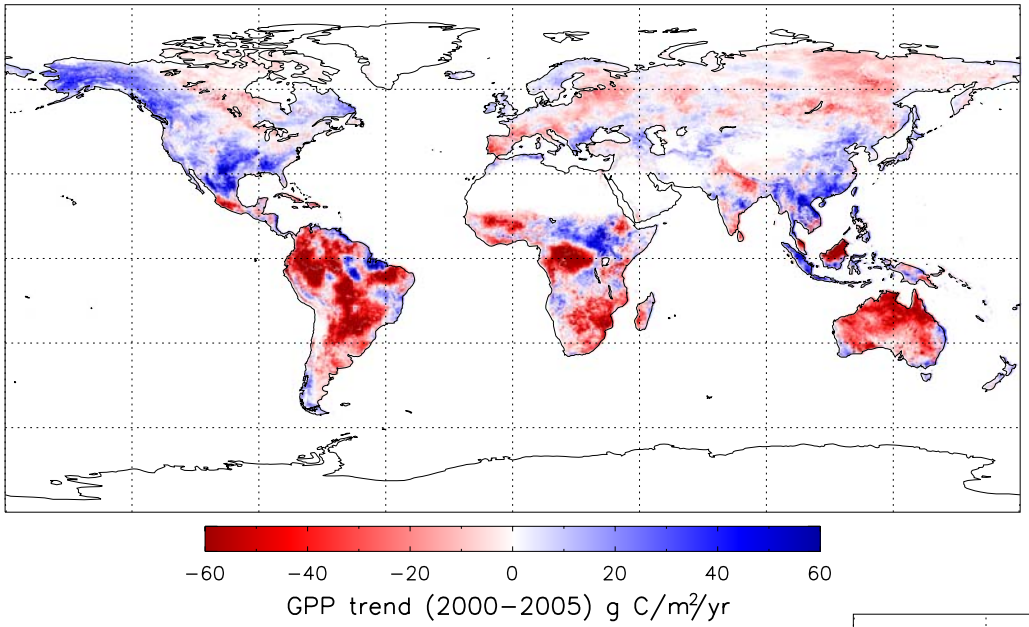
Spatial patterns of mean MODIS NPP and ET (2000-2005)

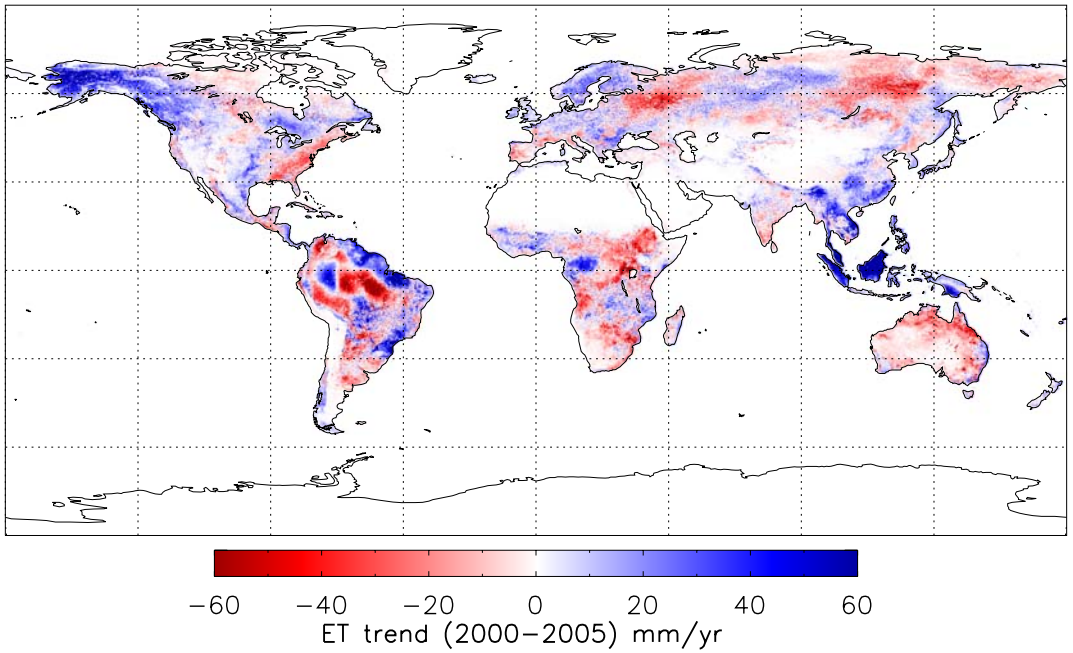




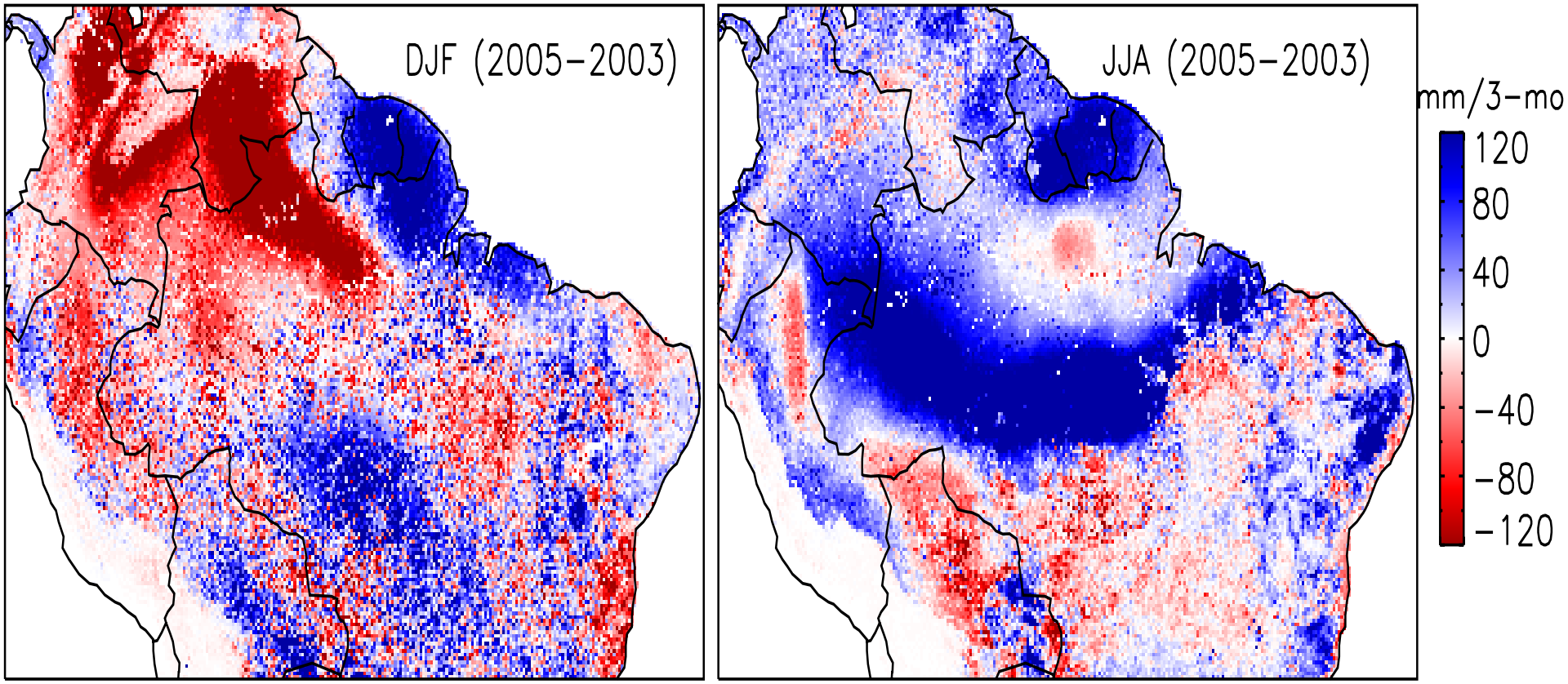


Global MODIS GPP and ET anomaly trends, 2000-2005



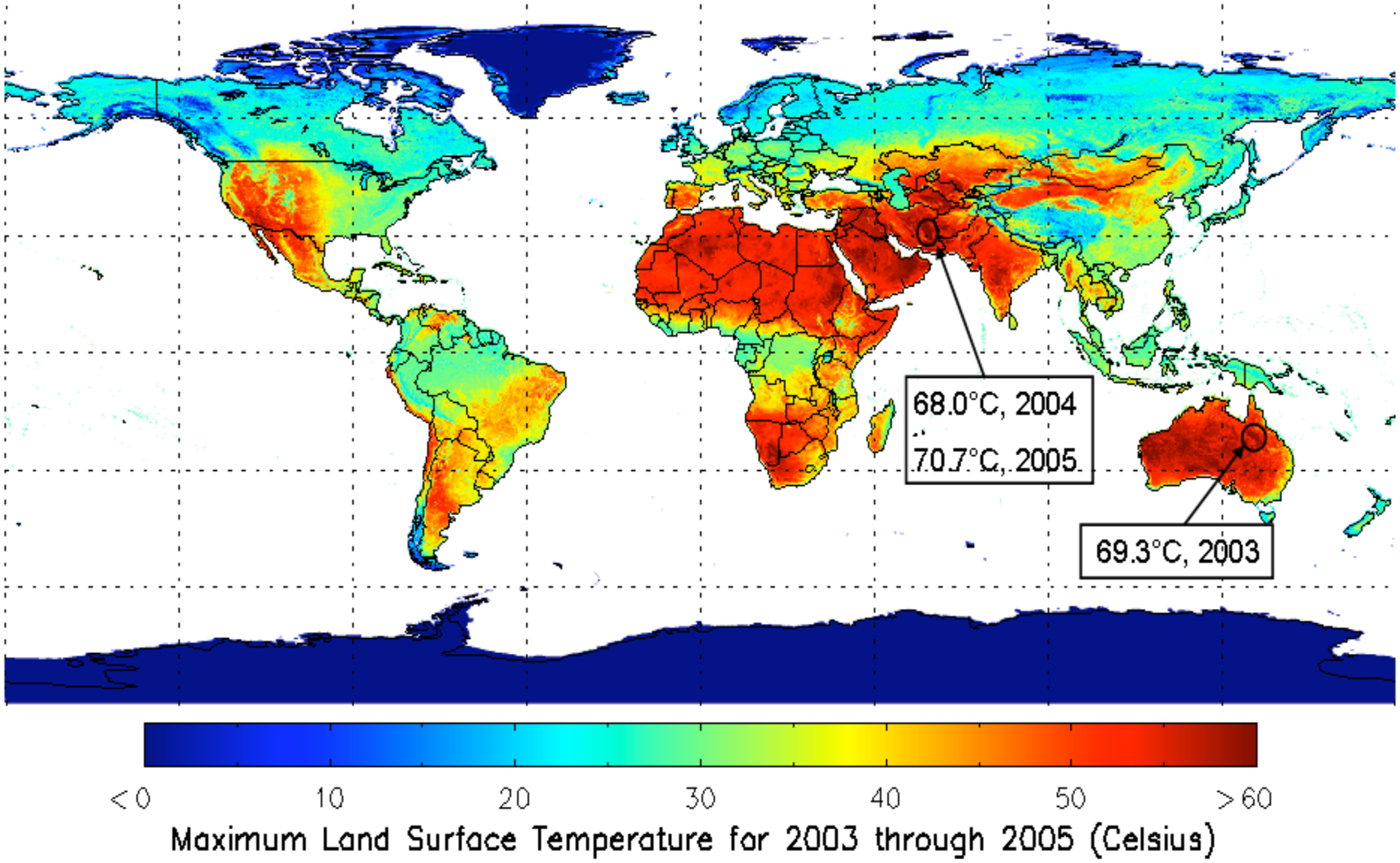


MODIS ET anomaly analysis



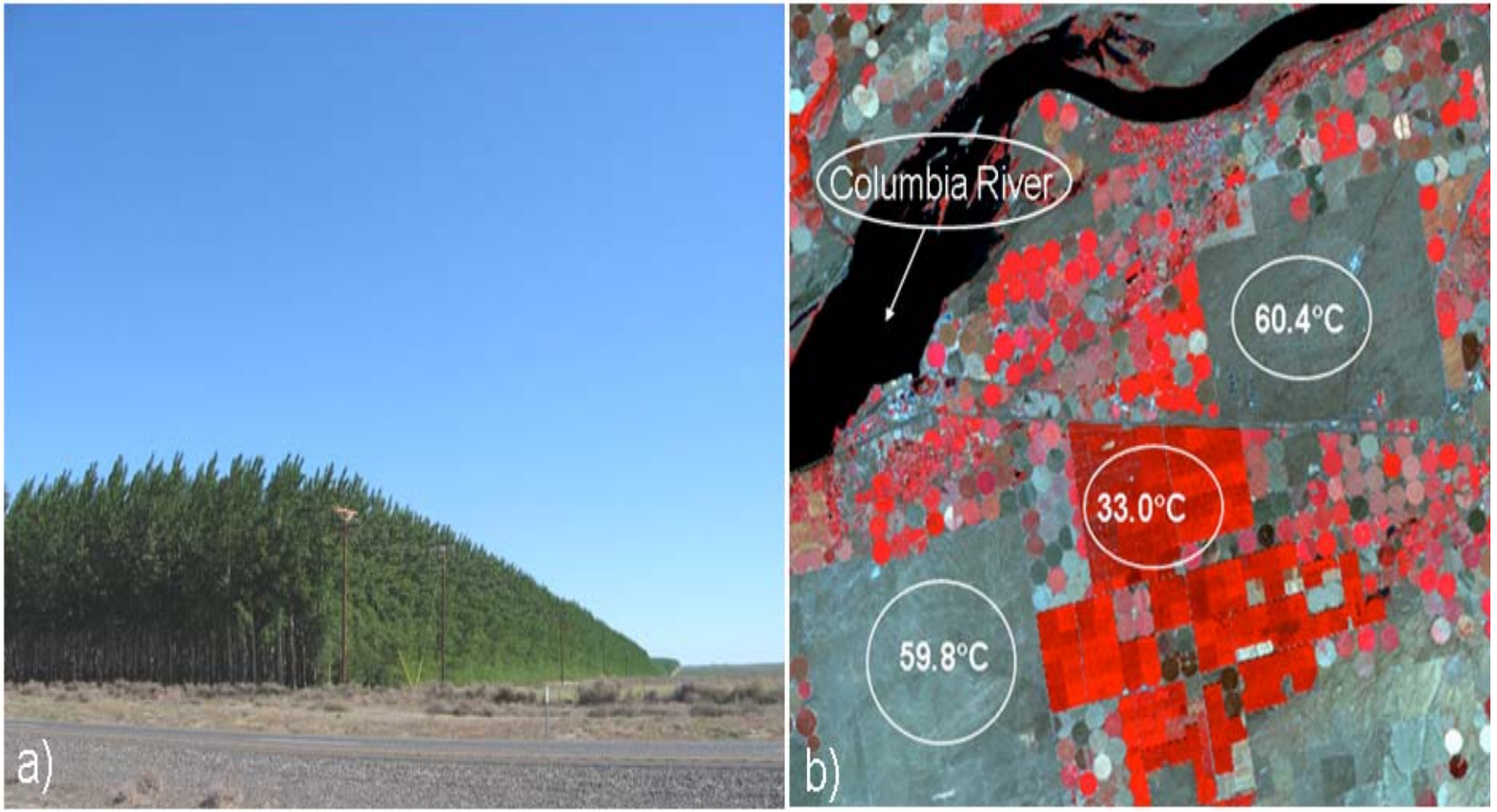
The differences between MODIS ET (2003, 2005) for the Amazon region in DJF (left) and JJA (right). The MODIS ET captures the drought during the 2005 growing season.

Aqua MODIS Maximum Annual Land Surface Temperature (2003-2005)



Mildrexler, Zhou, Running. AGU Eos 87:461, 2006

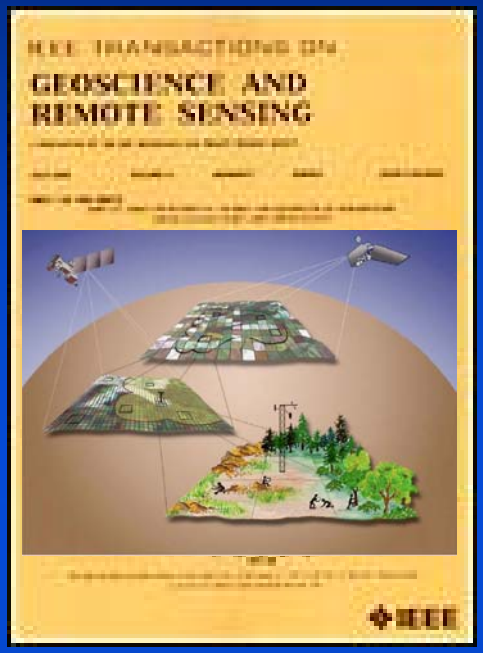
Comparison of Land Surface Temperatures from Aqua MODIS
Irrigated Poplar vs arid Sagebrush, central Oregon



Mildrexler, Zhou, Running. AGU Eos 87:461, 2006

LPV "Special Issue" of IEEE TGRS

- Special Issue: describing the state of the art research on both protocol and results for validation and accuracy assessment of global land products
  (Morisette, Baret, and Liang guest editors)
- Three "framework" papers
  19 "validation results" and
  four "user response" papers - an attempt to solicit "user feedback".



	2004									2005												2006			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	N	D	J	F	M
Announcement																								
Validation papers				submissions						reviews				revisions			review			final/profs				
User perspective papers							submissions							reviews			revisions				final/profs			
Publication date																								

July 2006

Recent workshops

1) LPV workshop on long-term VI record
   Aug 7, University of Montana, Missoula, Montana
   Reported in NASA EOS "Earth Observer"
   http://eospso.gsfc.nasa.gov/eos_observ/pdf/Nov-Dec06.pdf

2) Long term global monitoring of vegetation variables using moderate resolution satellites
   Aug 8-10, University of Montana, Missoula Montana
   Accepted to AGU's EOS Transactions

Presentations and posters from both meetings are posted on-line at //www.ntsg.umt.edu/VEGMTG/

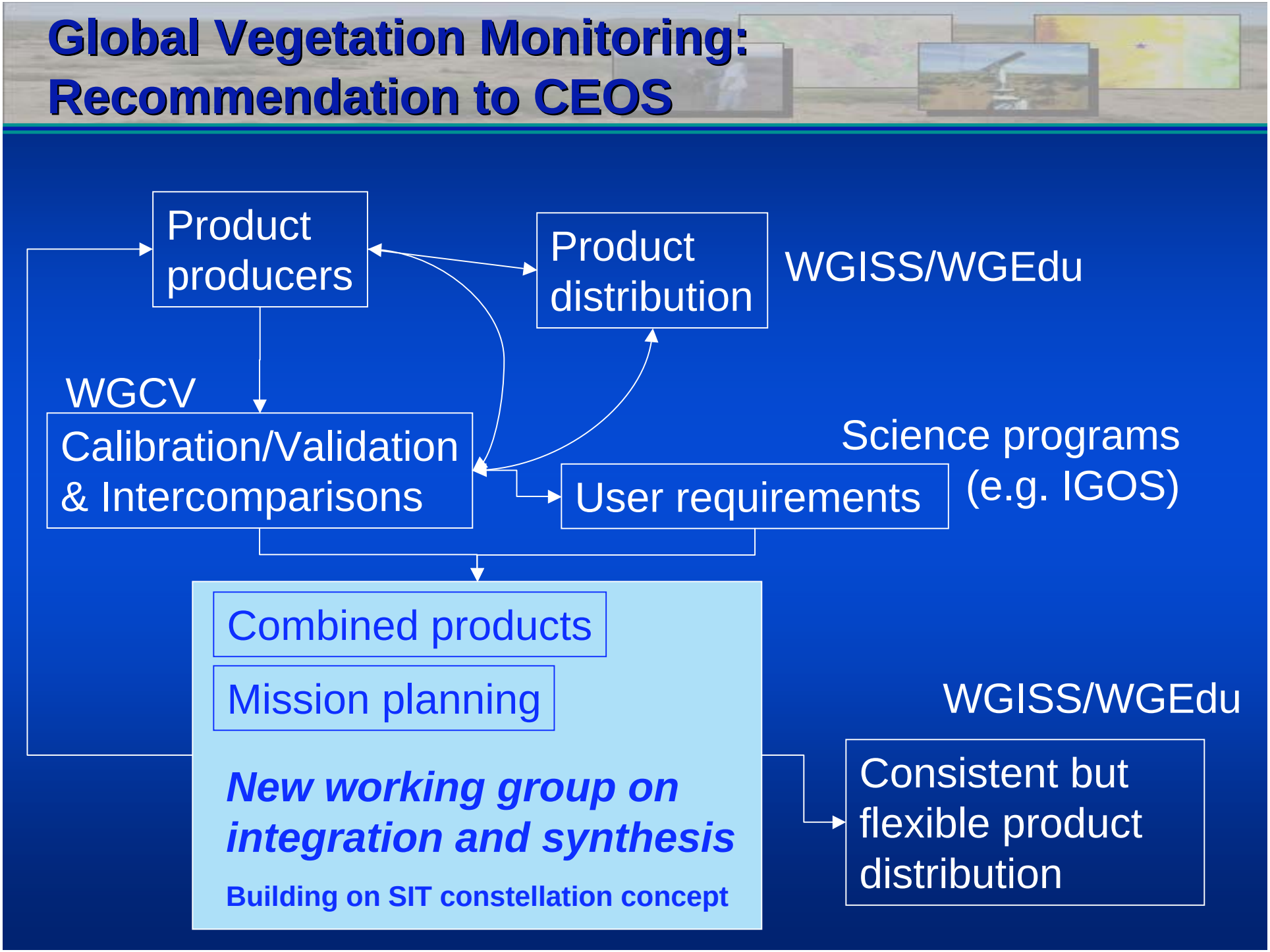
Recommendation for VI validation

CEOS, through GEOSS, help maintain collaboration and coordination with in-situ data collection networks and users with the objective of demonstrating how the combined long-term time-series data can impact climate research and societal benefits.

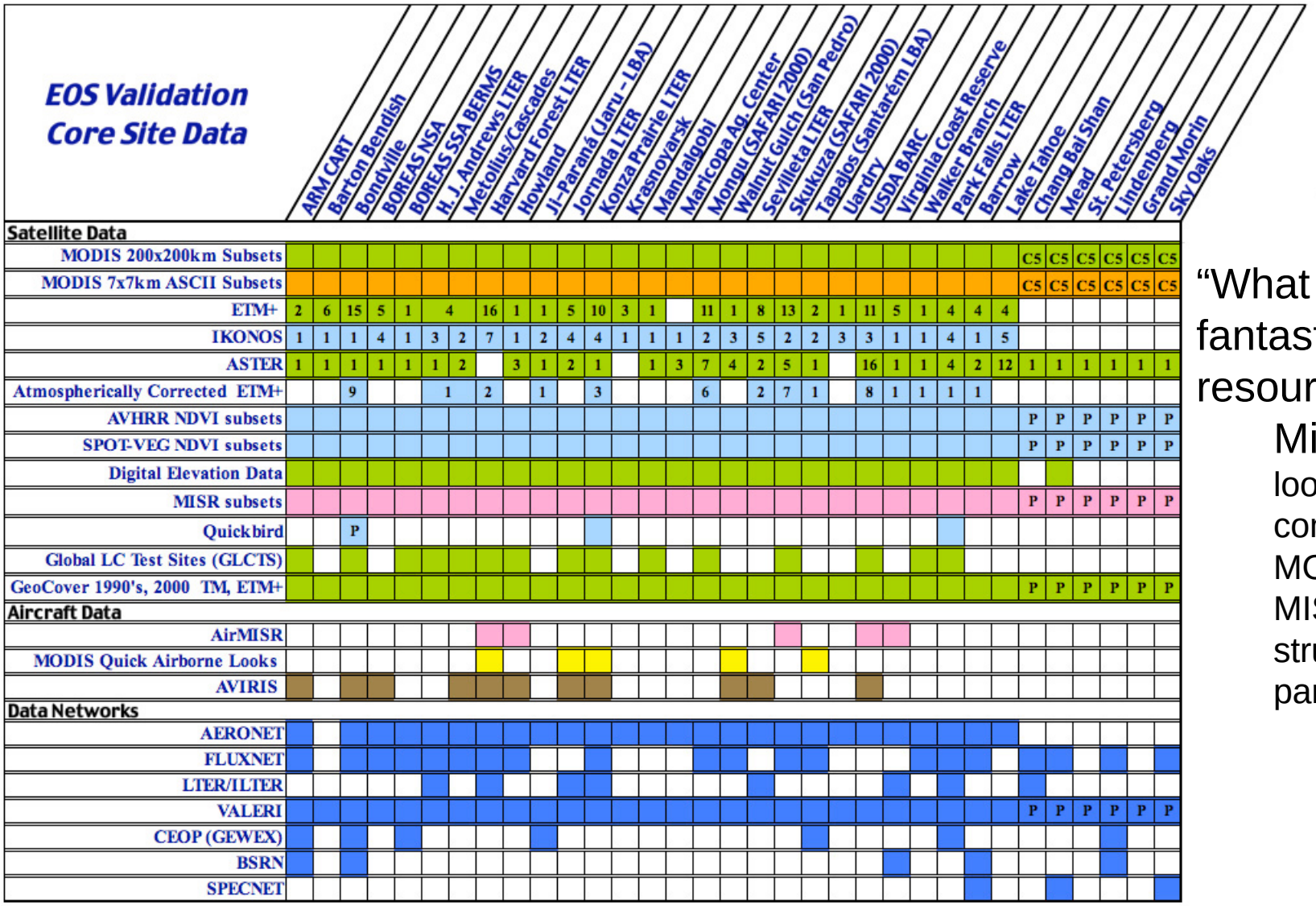
Specific examples include:

- Phenological Networks
  - European Phenology Network is setting the standard
  - US National Phenology Network is currently being initiated
- Fluxnet
  - Existing studies have demonstrated the ability of flux tower to connect remote sensing time series with surface processes.
- Existing ground networks would be greatly enhanced if they were augmented with spatially distributed measurements of transmittance in the photosynthetically active radiation (PAR) domain and reflectance measurements of the canopy in the red and near-infrared

Global Vegetation Monitoring: Recommendation to CEOS



EOS Land Validation Core Sites



"What a fantastic resource!"

Michael Hill

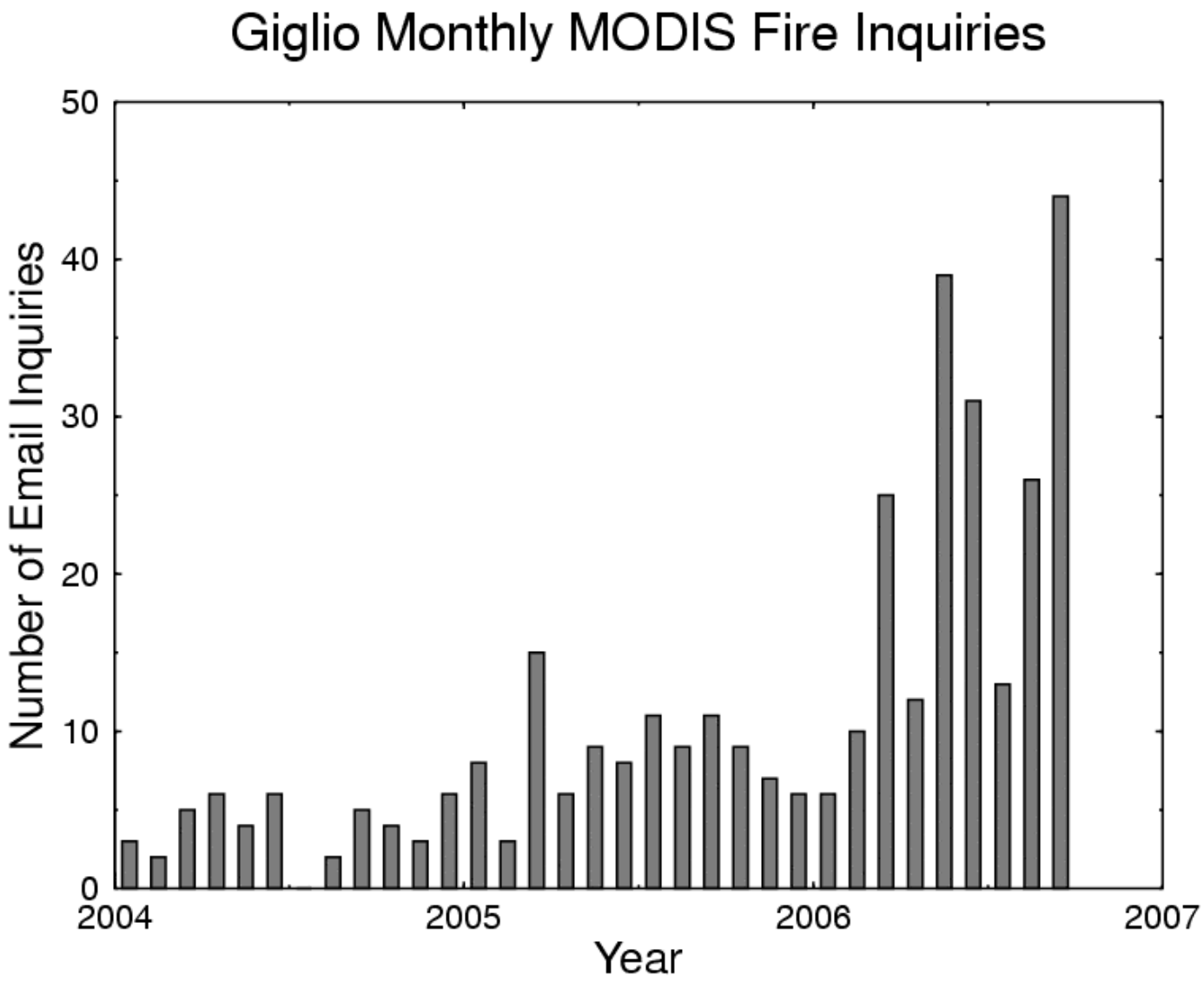
looking at the combined MODIS and MISR data for structural parameters

Esperanza Fires, Ca (Oct 26)

UAV overflights of MODIS Fires (Ambrosia) – More Thursday

With an increasing user community comes increasing demands on the SCF's

- In addition to the DAAC User Services
- Despite an Up to Date ATBD
- A User Guide
- FAQ's



Video

Issues for Land Discipline Group

- MODIS C5 Land Workshop Planning
- 2007 Senior Review input – why we shouldn’t turn off MODIS am or pm
- Continuing shift from the MODIS mission to Land Measurements - breakout topics
  - Prioritizing Land Measurement activities
  - Mid Decadal Global Land Survey product specifications (Phase 2/3)
  - Land product inconsistencies