MODIS Research and Operations to VIIRS Research and Operations

formerly titled

MODIS to VIIRS: Research to Operations

Chris Justice

with contributions from the

MODIS and VIIRS Land Discipline Teams

and special thanks to Bob Murphy

MODIS Land Products Ten Years and Counting

- The MODIS standard products were selected to meet the needs of the **Science Community**
  - have been peer reviewed
  - have routine Quality Assessment
  - are Validated (accuracy assessment)
  - new Products have been added through ATBD and Recompetition

- As Products matured so they have been widely adopted by the **Land Operational Community** – who get their data from NASA (via the DAACs)

- There is an expectation from **both** communities that
  - This will continue from MODIS until both instruments fail
  - Product Continuity will be provided by VIIRS

Hence the Title of the Talk

MODIS Land Products

Energy Balance Product Suite

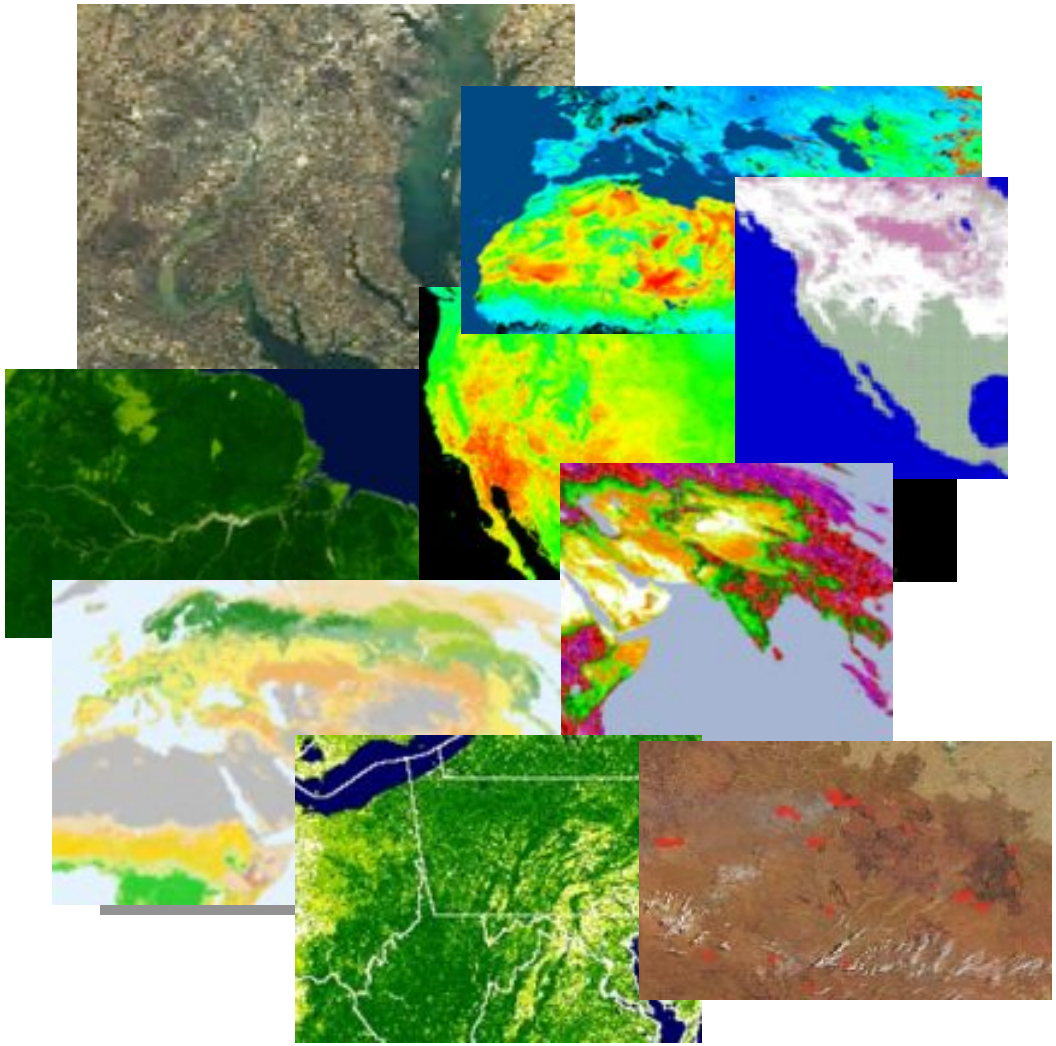
- Surface Reflectance
- Land Surface Temperature, Emmisivity
- BRDF/Albedo
- Snow/Sea-ice Cover

Vegetation Parameters Suite

- Vegetation Indices
- LAI/FPAR
- GPP/NPP

Land Cover/Land Use Suite

- Land Cover/Vegetation Dynamics
- Vegetation Continuous Fields
- Fire and Burned Area



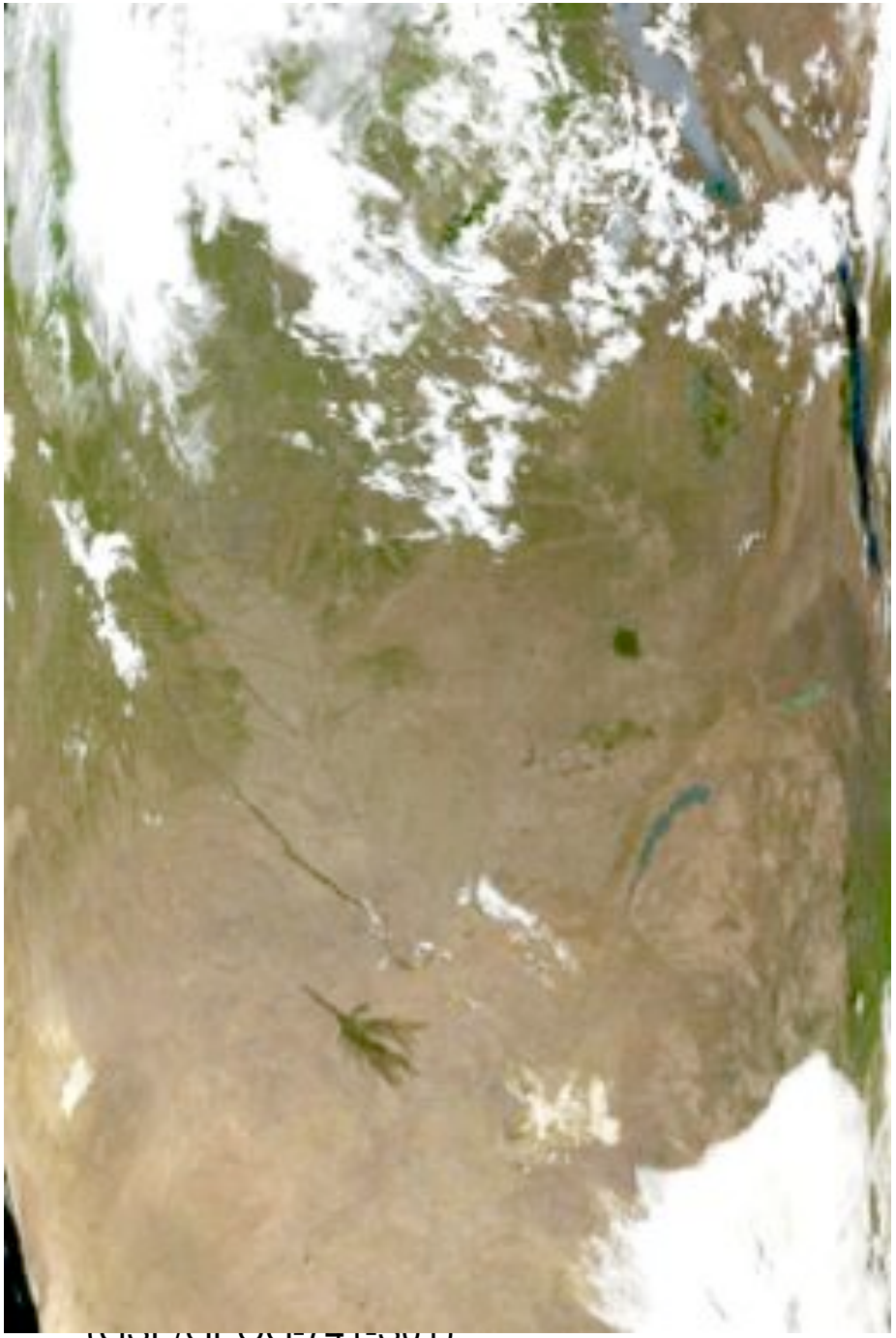
MODIS Granule over Southern Africa
(Sept 13,2001, 8:45 to 8:50 GMT)

Red, Green, Blue MODIS top of atmosphere reflectance

No atmospheric correction

Surface Reflectance: Atmospheric effect has a strong impact on remotely sensed data

(E. Vermote)



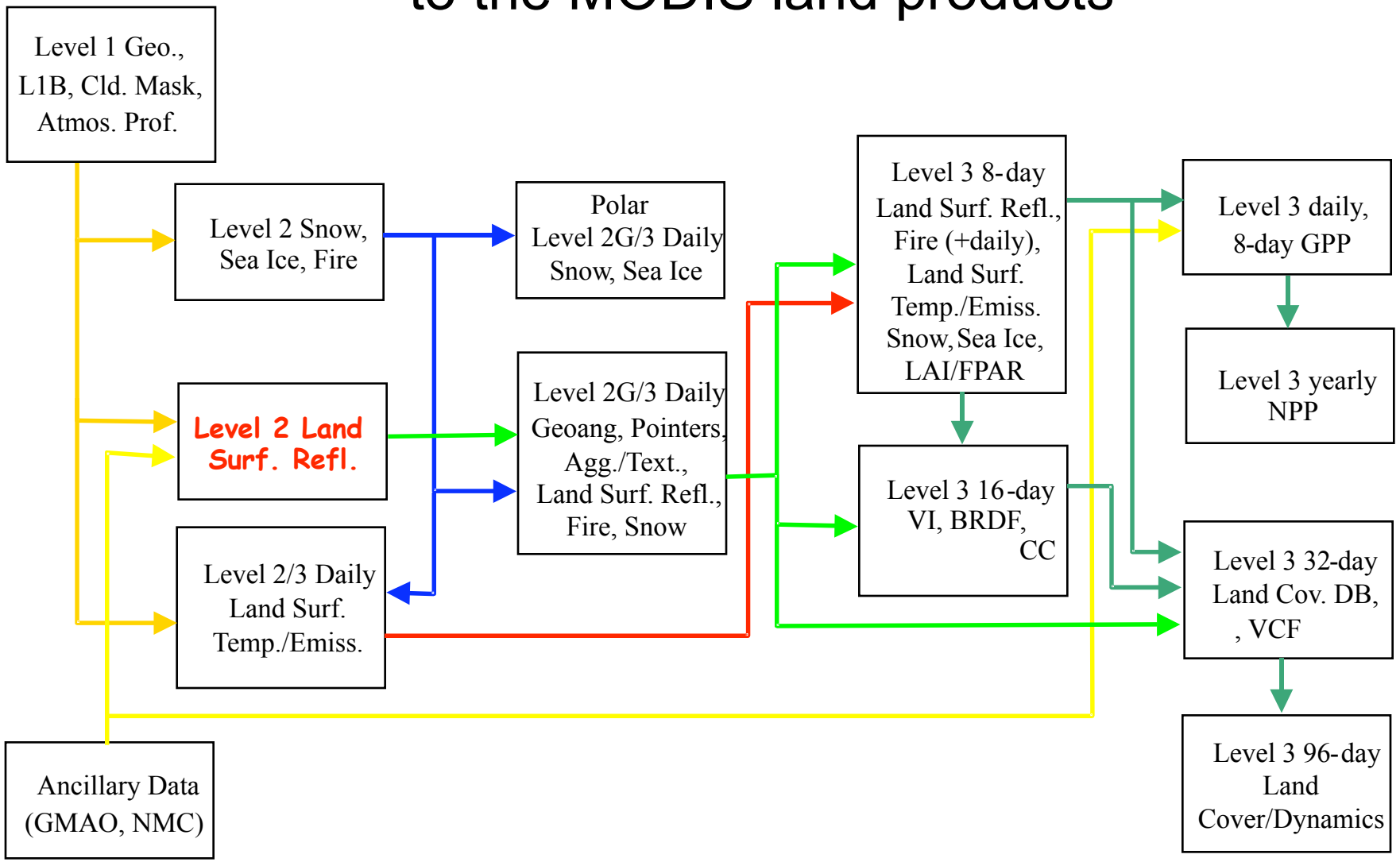
MODIS Granule over Southern Africa
(Sept 13,2001, 8:45 to 8:50 GMT)

Red, Green, Blue MODIS surface reflectance

With atmospheric correction

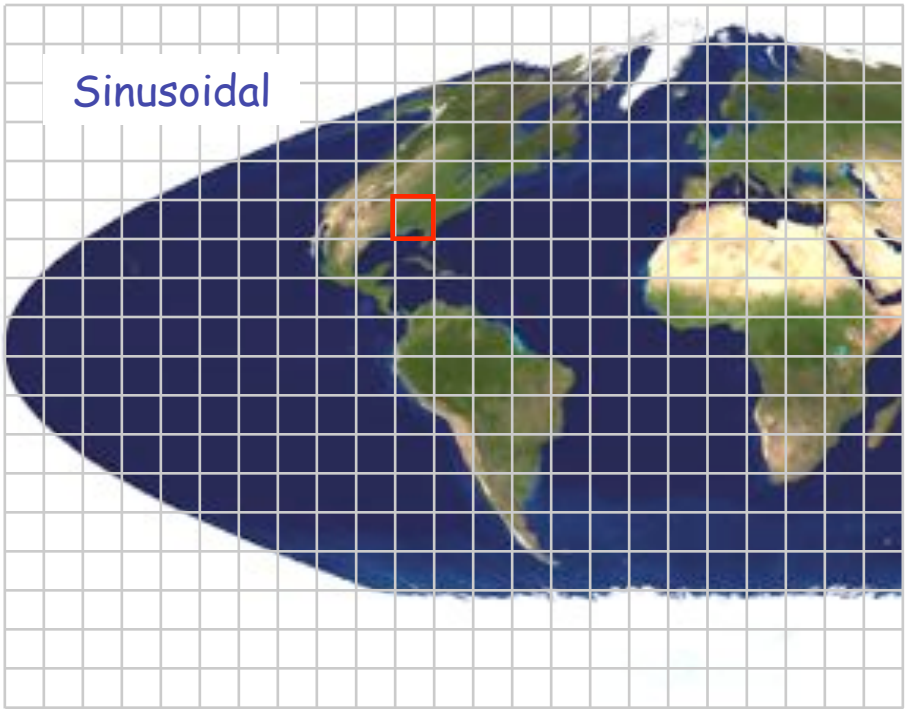
MODIS Land Production Processing Chart

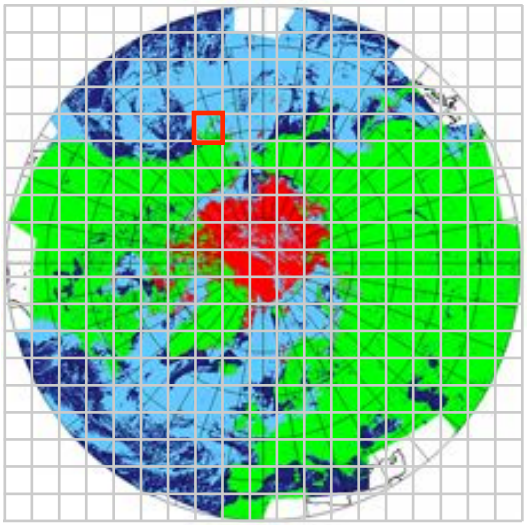
Atmospheric Correction Product (MOD09) crucial input to the MODIS land products

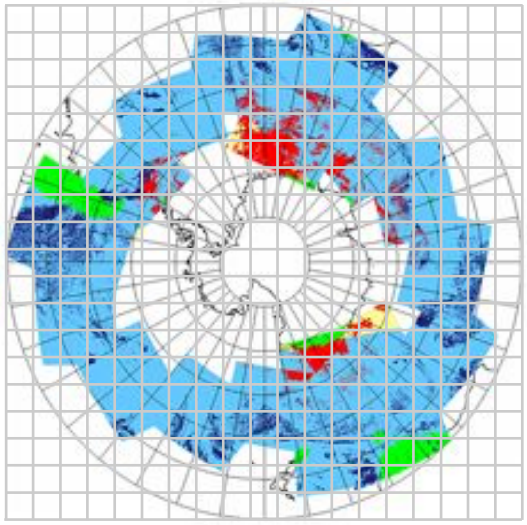


Nazmi el Saleous

Level 2G, 3 and 4 Products (fine resolution)





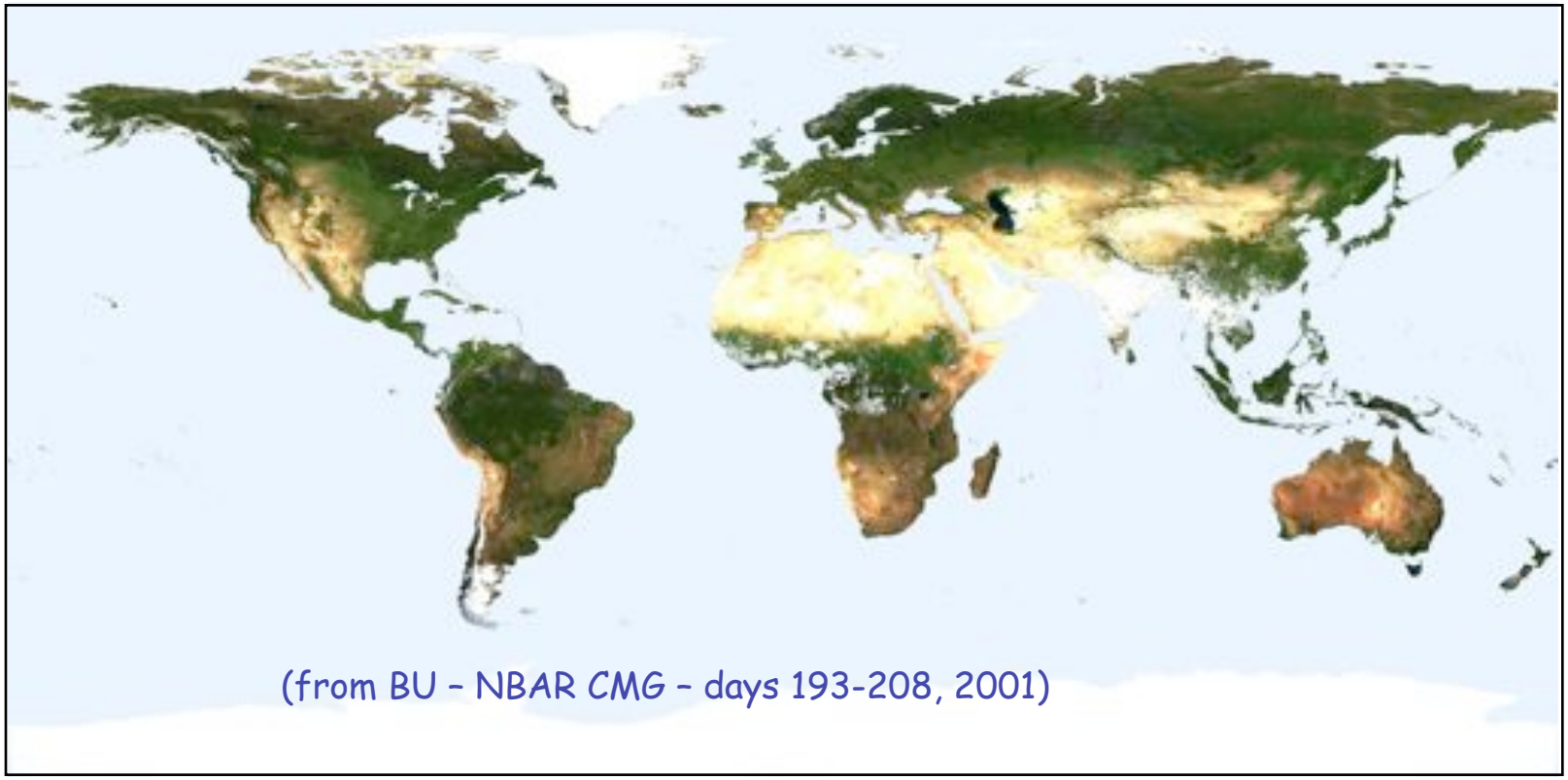


- Level 2G/3: earth-gridded geophysical parameters
- Level 4: earth-gridded model outputs
- Daily, 8-day, 16-day, 32-day, monthly and yearly products
- 10º x 10º Tiles ( )
- Sinusoidal (equatorial); 7.5, 15 and 30 arcsec. resolution (roughly 250m, 500m and 1 km)
- LAEA (sea-ice products, polar projection)

Lambert Azimuthal Equal Area (LAEA)

Climate modeling grid products

- The land products were driven in large part by the modeling community through ATBD review
  - At the outset most 'land' models were not using satellite data
- Resolution: 0.05º and 0.25º degrees
- Almost all products are lat/long
  - sea-ice is current exception – in polar grid (snow in C5)



Nadir BRDF-adjusted Reflectance (NBAR)
North Africa

RGB true color

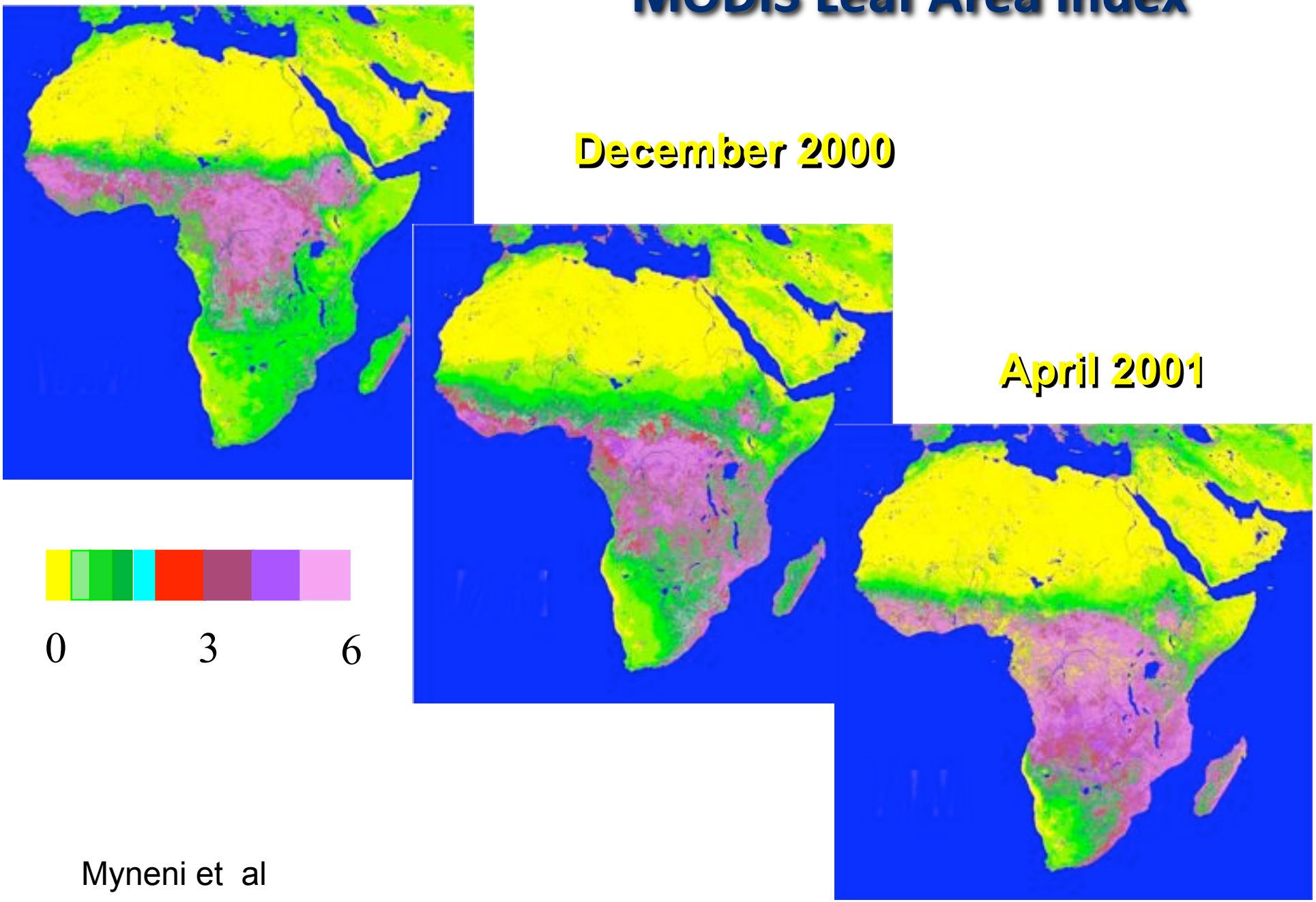
(Schaaf)

MODIS ON THE EOS TERRA AND AQUA MISSIONS

Terra Launch: Dec. 18, 1999
First Image: Feb. 24, 2000

Aqua Launch: May 04, 2002
First Image: June 26, 2002

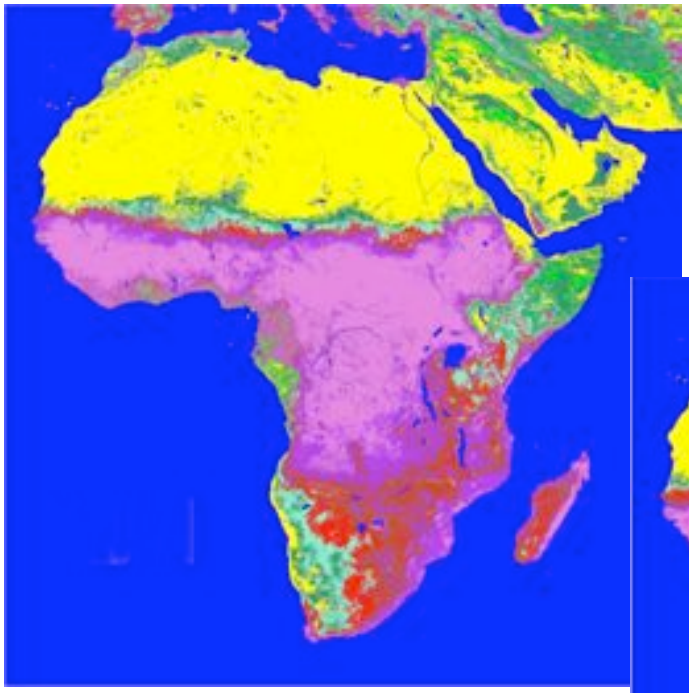
MODIS Leaf Area Index



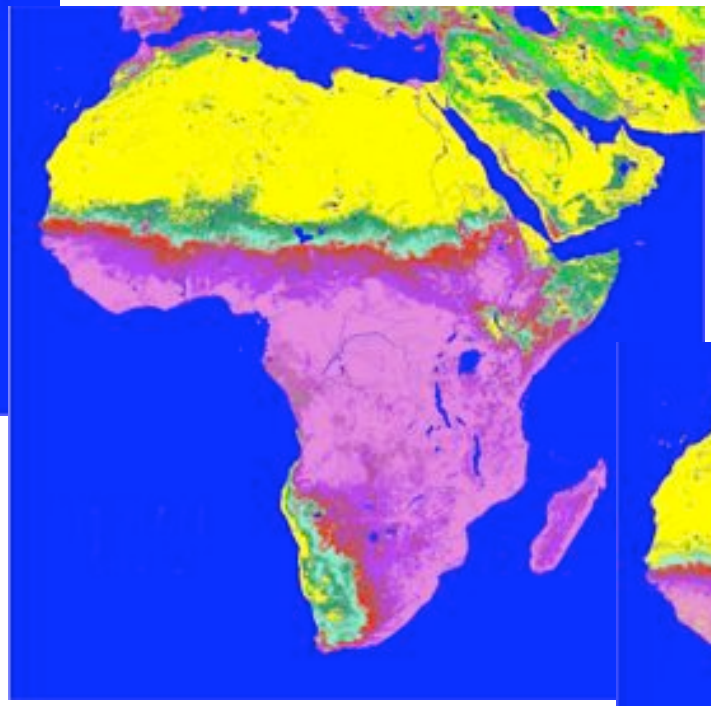
Myneni et al

MODIS FPAR
(Fraction of absorbed Photosynthetically Active Radiation)

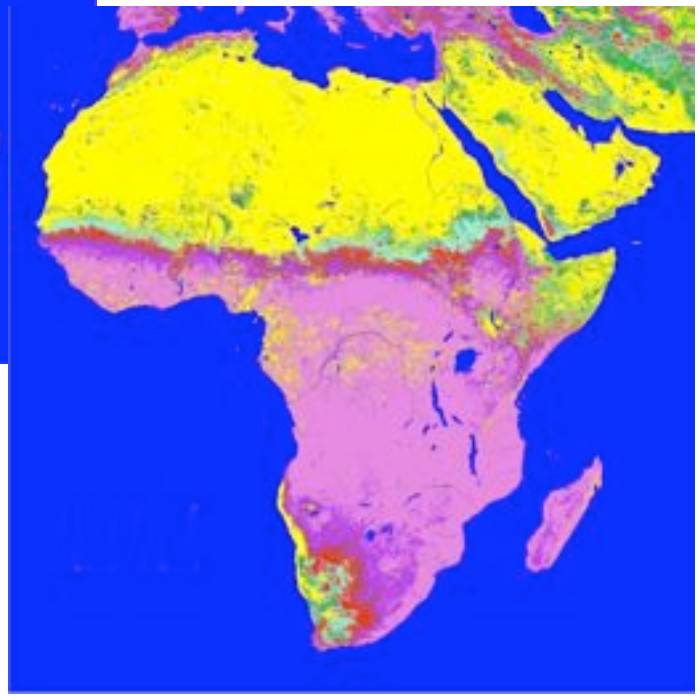
September 2000



December 2000



April 2001

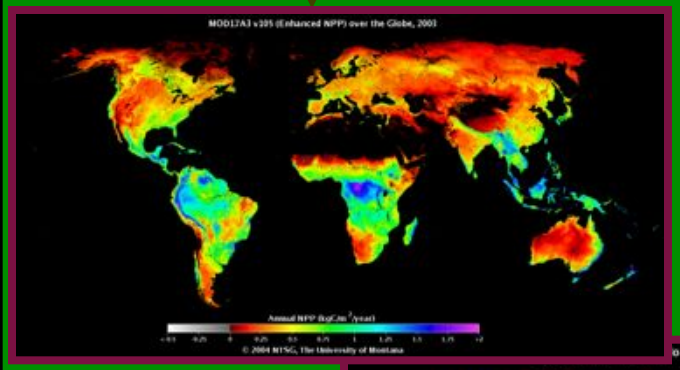


0 0.5 0.9

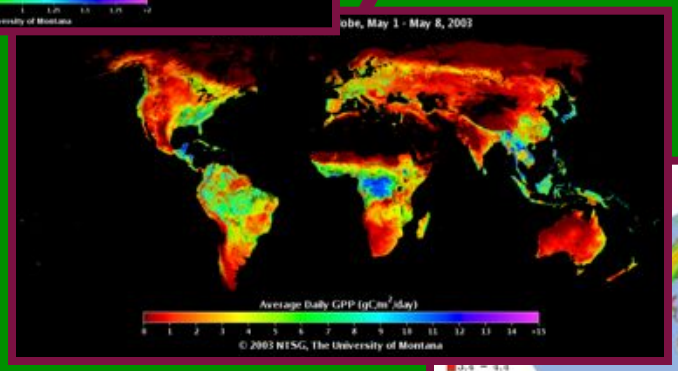
Myneni et al

MODIS NPP = Annual GPP - Autotrophic Respiration

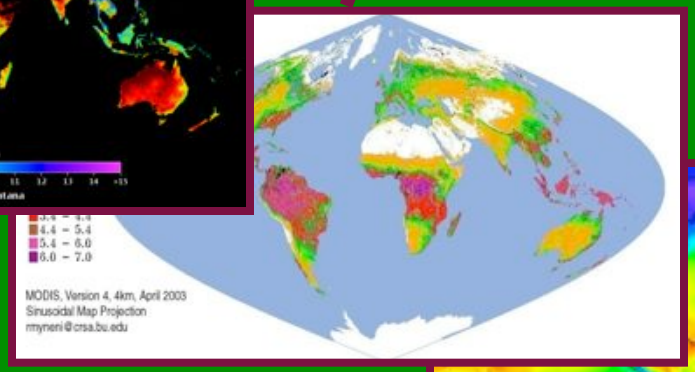
$$NPP = GPP - (R_m + R_g)$$



NPP

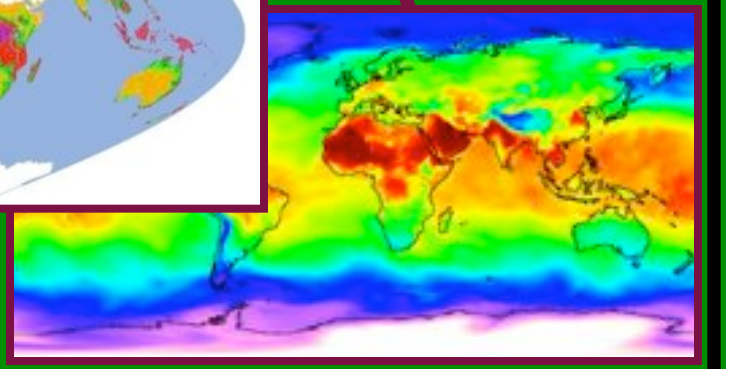


GPP



LAI

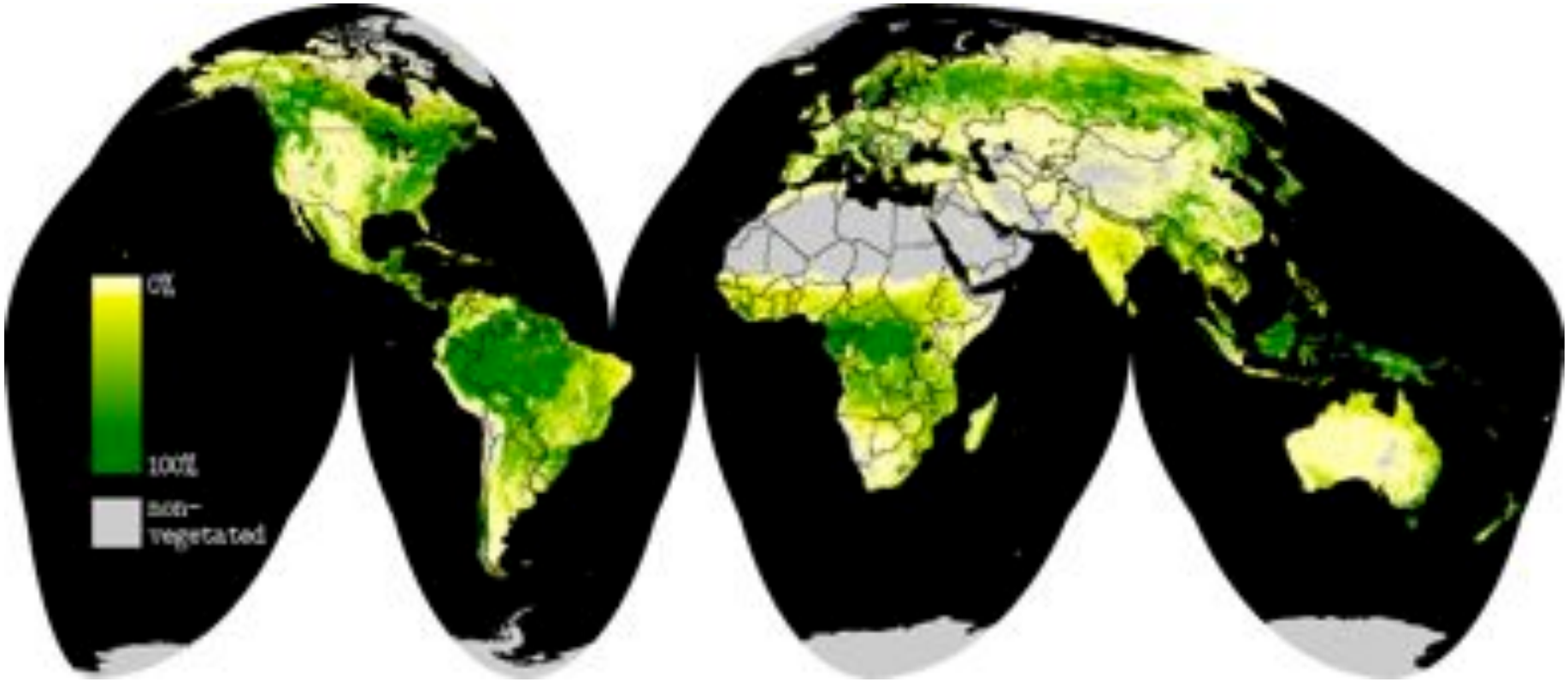
Biome Properties Look-Up Table



Temperature

S. Running Univ. Montana

Vegetation Continuous Fields produced by year from MODIS at 250 m

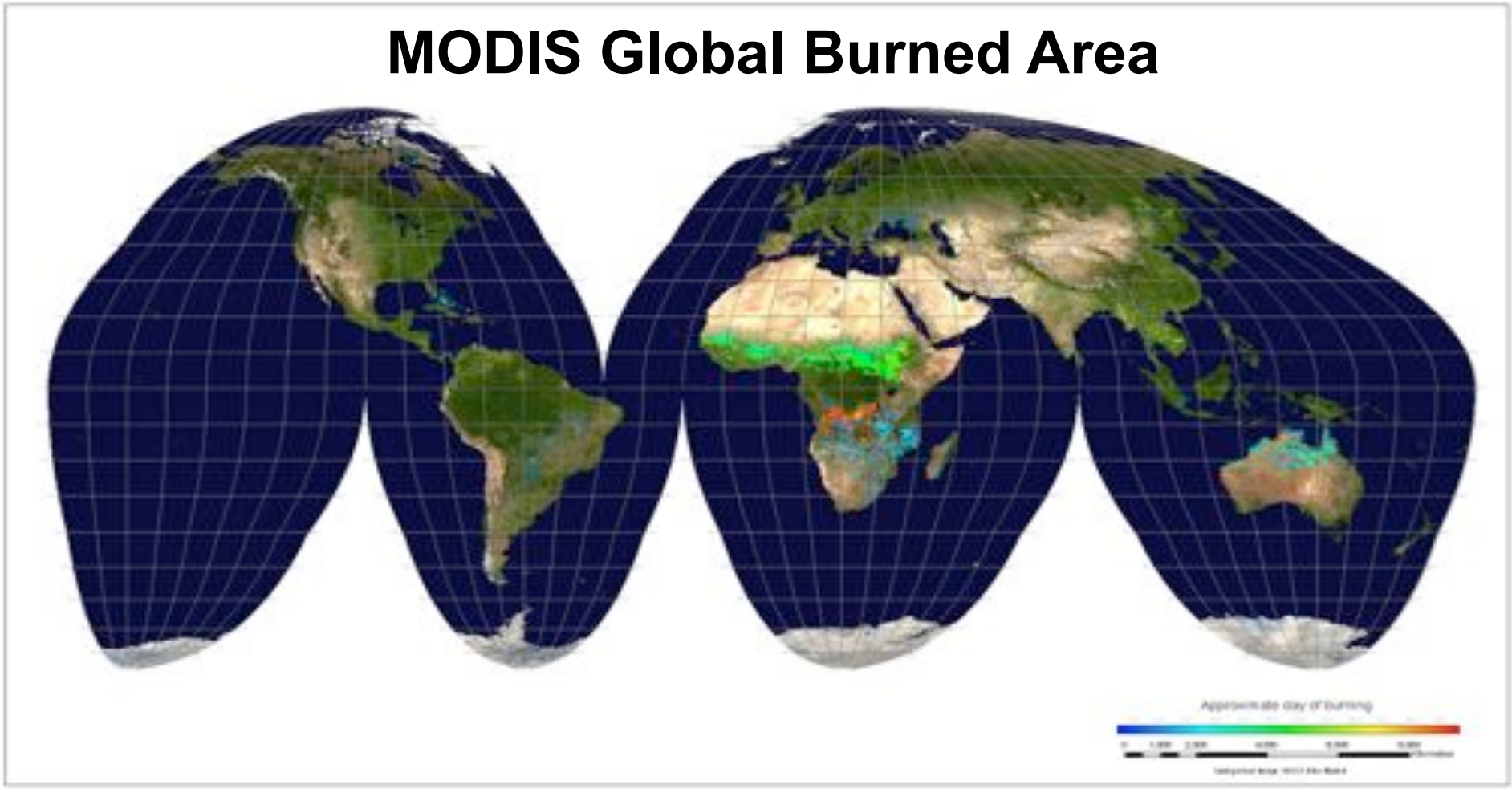


Vegetation Continuous Fields Percent tree cover from MODIS year 2001.

Slide from J. Townshend, UMd

UNIVERSITY OF MARYLAND 18 56

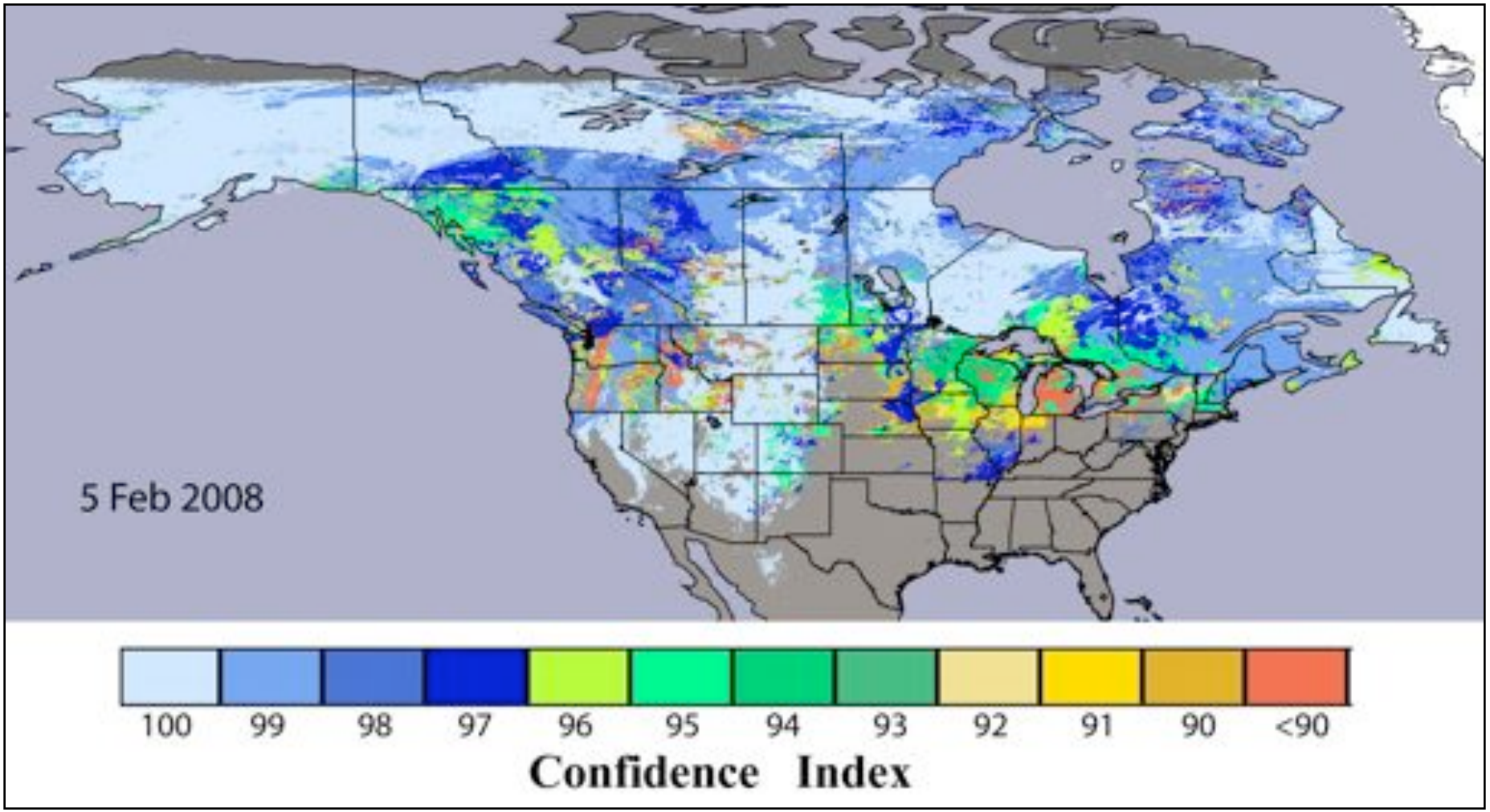
MODIS Global Burned Area



- Burned Area algorithm run globally for first time in MODIS C5 - purposefully running to map burned areas conservatively

Roy, Boschetti et al.

Snow Cover Cloud-Gap Filled (CGF) Product



MODLAND Validation

http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL

Val Summaries

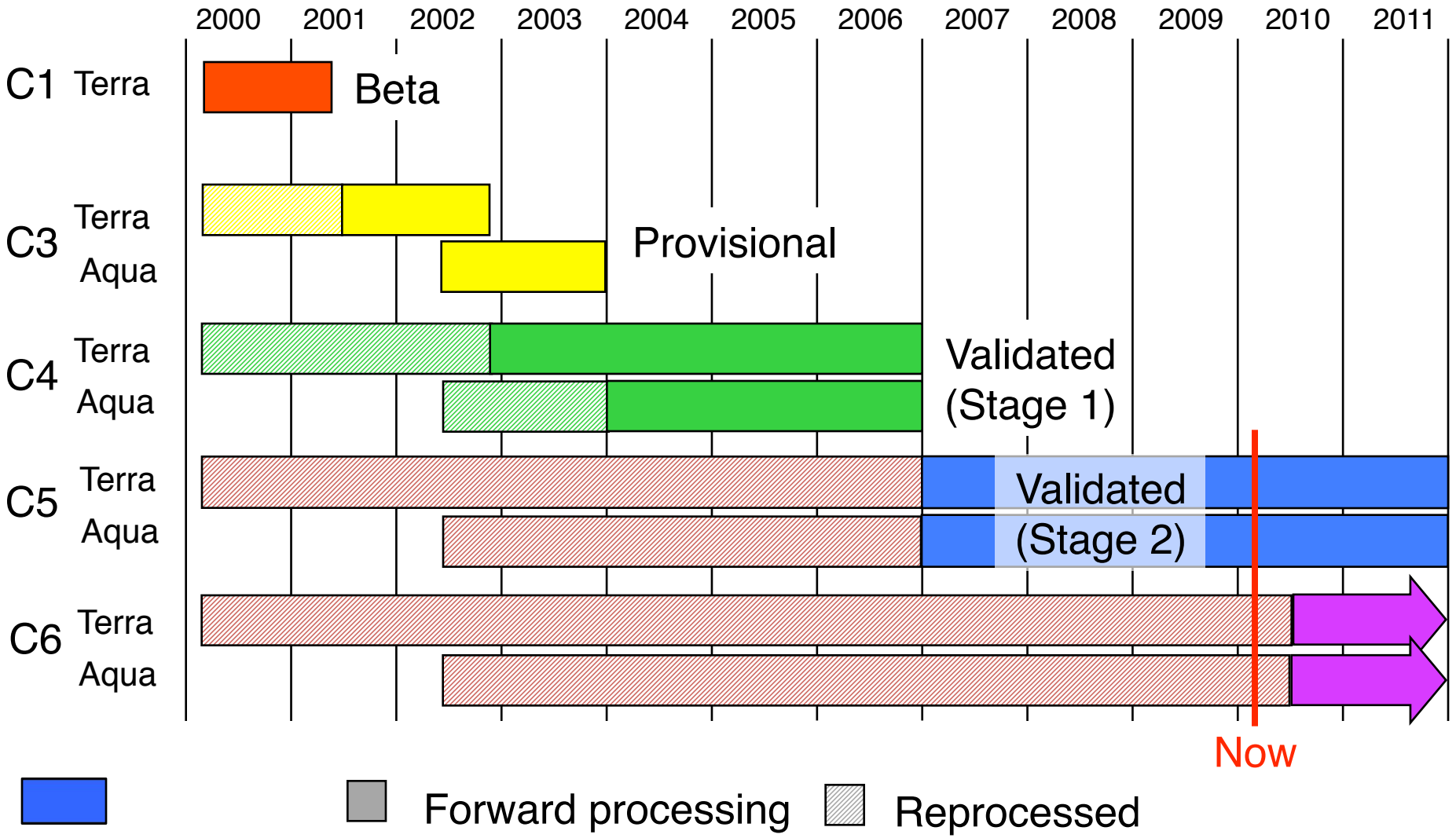
EOS Core Sites

Major Campaigns

Val Metadata w. ORNL

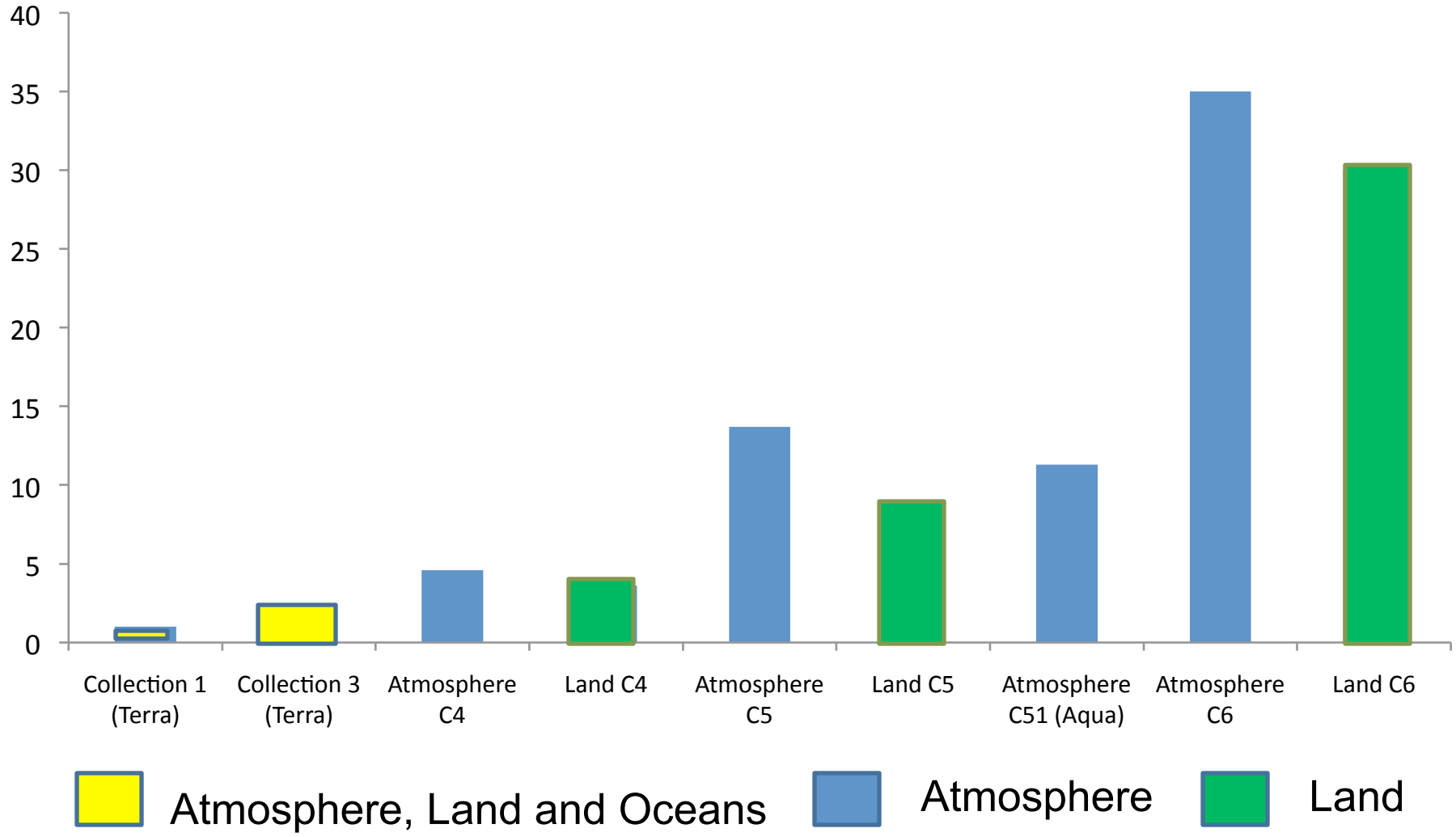
MODIS Validation Data sub sets w. EDC

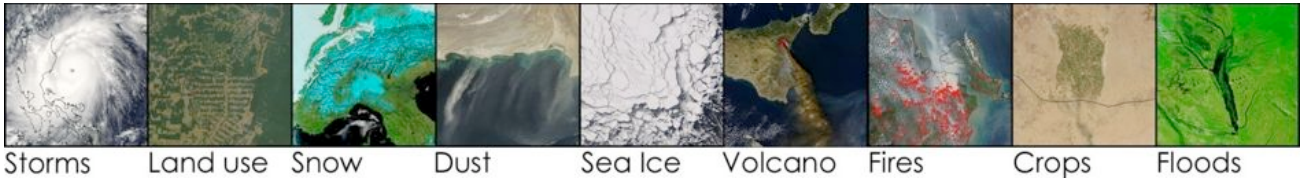
MODIS Production Versions



Each collection represents an improvement in science quality

Reprocessing Rates (data-days/day)

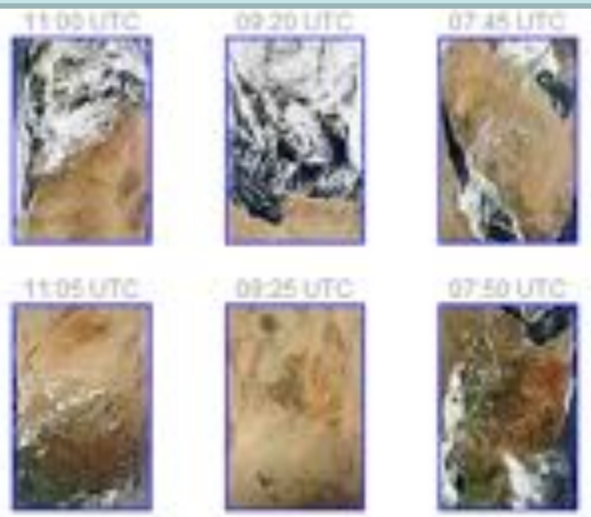




MODIS Land Rapid Response

- Funding provided by Senior Review process for Aqua and Terra
- Coordination with Applied Sciences Program
- Fully Integrated with LANCE- MODIS near-real-time system
- Science Advisory through the LANCE User Working group

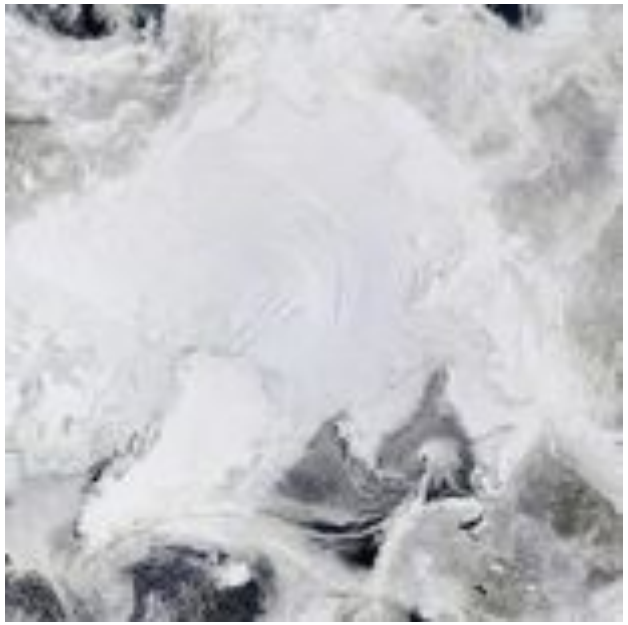
- Over 50,000 unique users downloading over ½ million images per month



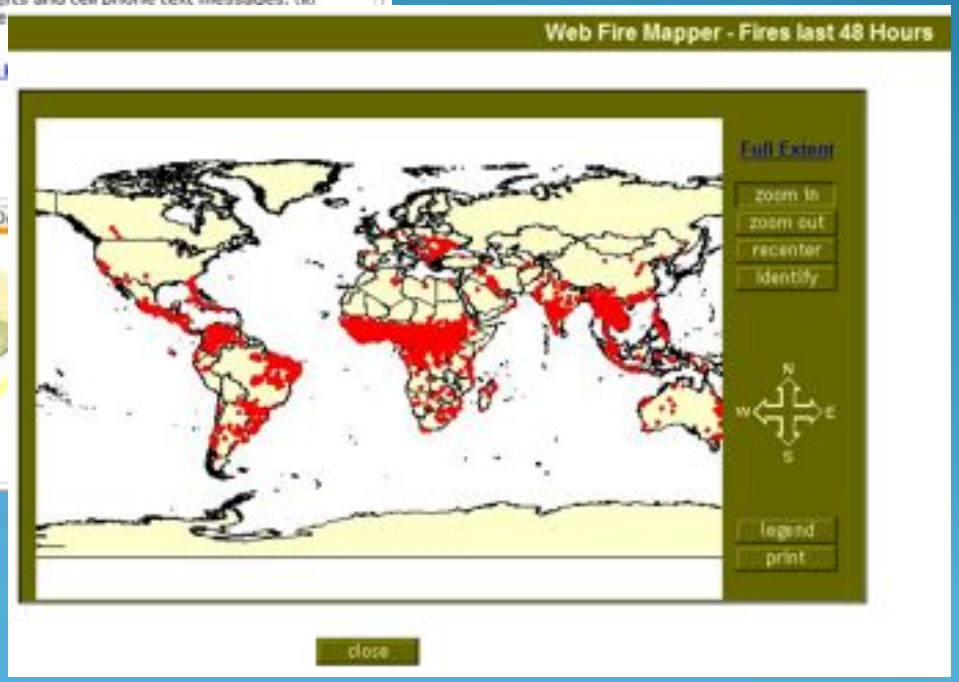
- "Geographic" layout of realtime swath

- Antarctic mosaic (Dec 08)

- Arctic mosaic (Mar 09)



Fire Information for Research Managers



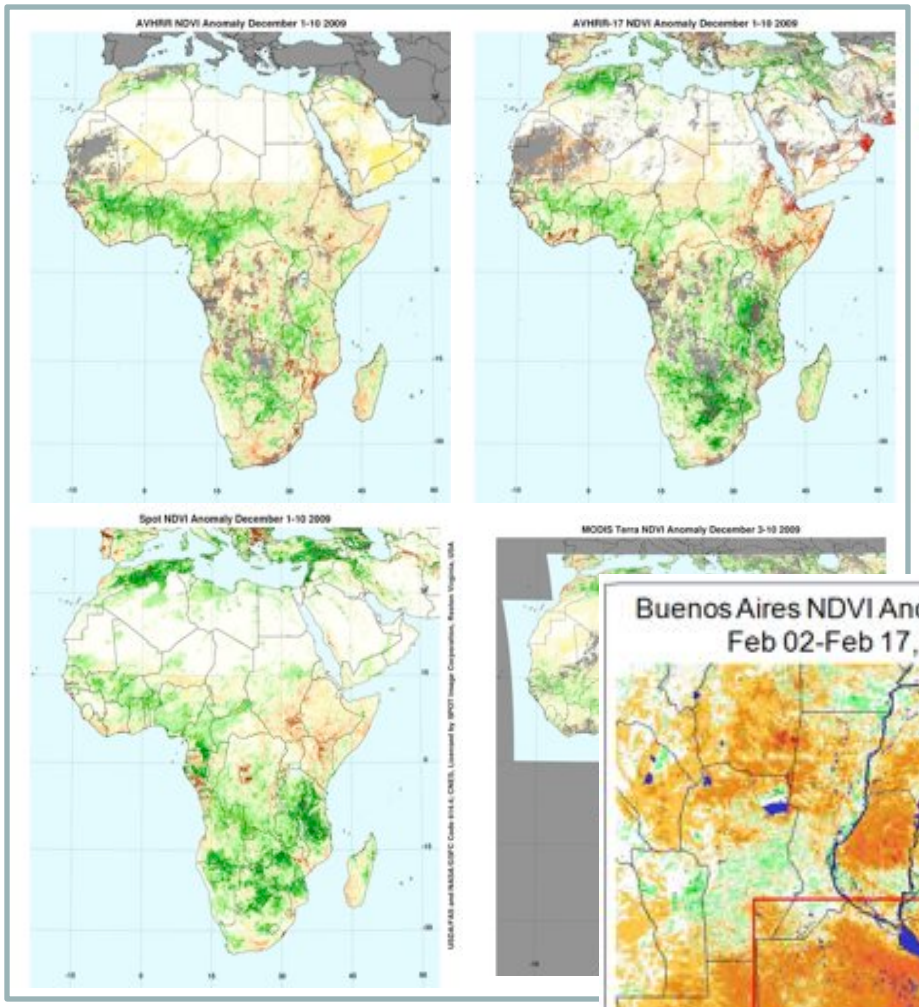
- Active fires
- Email alerts
- Subsets

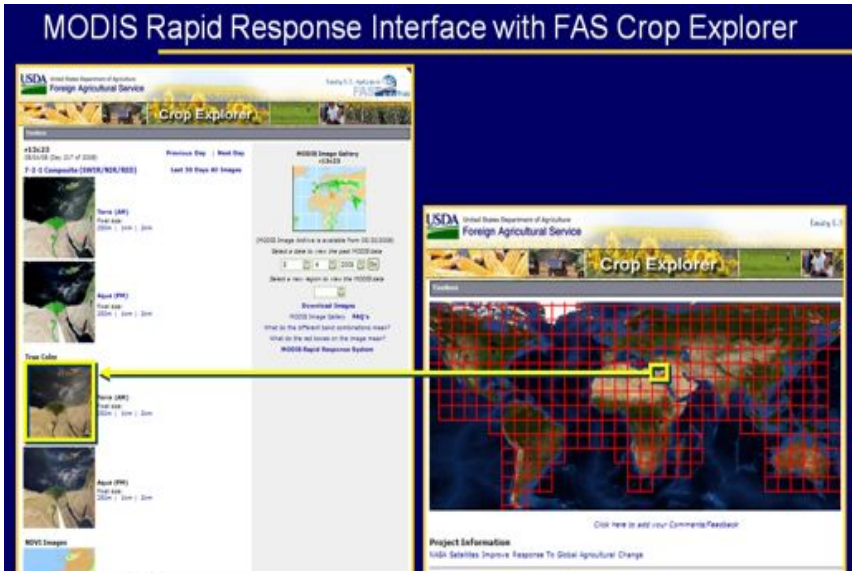
http://http://maps.geog.umd.edu/

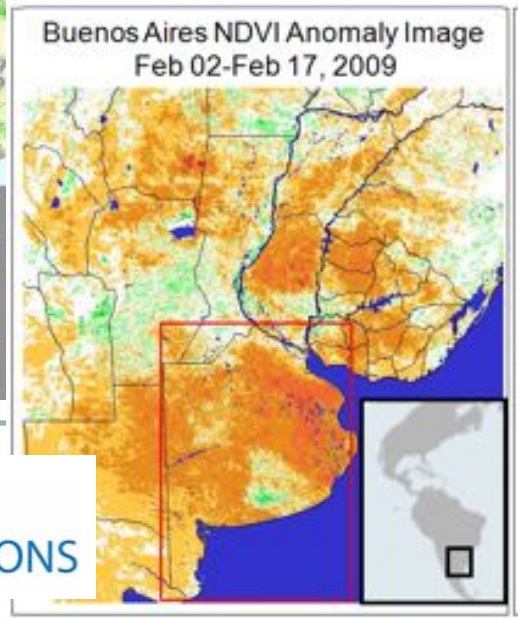
USDA United States Department of Agriculture
Foreign Agricultural Service

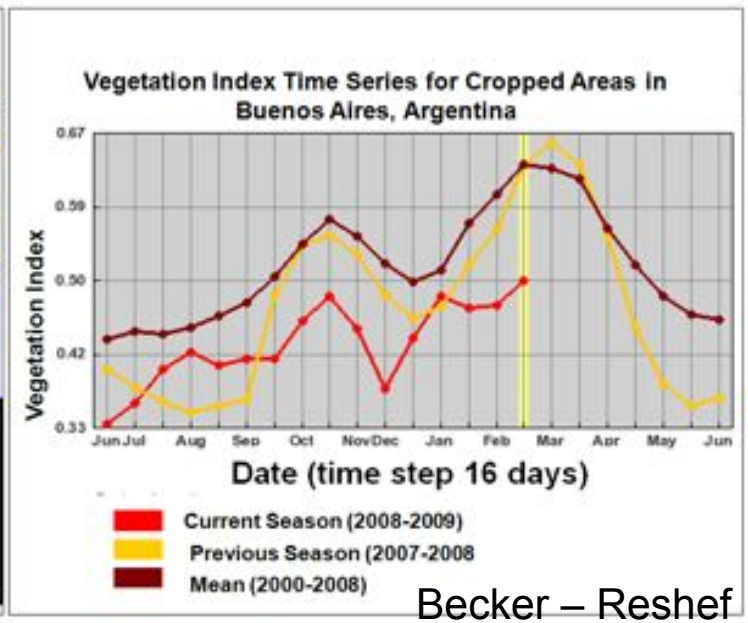
USDA Crop Explorer

Using Rapid Response and MODIS VI Time Series









GEO GROUP ON EARTH OBSERVATIONS

Becker – Reshef

What is LANCE?

- Building on existing EOSDIS elements (MODAPS/LAADS; OMI SIPS, GES DISC), provides data from MODIS, OMI, AIRS, MLS, and AMSR-E instruments in near real-time (< 3 hours from observation)
- Utilizes PGE Code from Standard Science Products, but:
  - All products generated with a "nrt" extension to distinguish them from standard products
  - Requirements for ancillary data inputs have been relaxed (e.g., MODIS cloud mask, aerosols, clouds, and land surface reflectance)
- High operational availability achieved by:
  - Extra compute and ftp servers
  - Redundant power sources
  - Redundant production strings on separate networks (in progress)
- Applications of LANCE data include:
  - Numerical weather & climate prediction/forecasting
  - Monitoring of Natural Hazards
  - Disaster Relief
  - Agriculture
  - Air quality
  - Homeland Security

LANCE Product Categories

Instrument	Product Categories	Average Latency	Status
AIRS	Radiances, Temperature and Moisture Profiles, Clouds and Trace Gases, Ephemeris/Attitude	75 – 140 minutes	Operating
AMSR-E	L1A Raw Data, Soil Moisture, Snow Water Equivalent, Temperature	N/A	Under Development
MLS	Ozone, Temperature, Ephemeris/ Attitude Data	75 – 140 minutes	Operating
MODIS L1 & L2	Radiances, Cloud/Aerosols, Water Vapor, Fire, Snow Cover, Sea Ice, Land Surface Reflectance, Ephemeris/attitude	90 – 145 minutes	Operating
OMI	Ozone, Clouds, Aerosols, Trace Gases	100 – 165 minutes	Operating

LANCE Architecture

EDOS
Level Zero Processing Facility

Format: RBD → AIRS
Format: RBD → MLS
Format: S-PDS → MODIS*
Format: RBD → AMSR-E
Format: RBD → OMI

GES DISC
AIRS
MLS

MODAPS
MODIS*
AMSR-E

OMI SIPS
OMI

Protocols: HTTP/FTP
Data Available:
-AIRS L1 and L2
-MLS L2

Protocols: HTTP/FTP
Data Available:
-MODIS L1, L2, L2G*
and selected L3*
-AMSR-E L1, L2 and L3

Protocols: HTTP/FTP
Data Available:
-OMI L1B and L2

Users
GMAO
NRL
SPoRT
UMBC
USGS
Others

Observation to availability latency: 30-180 min.

Transfer latency: bandwidth dependent

LANCE Element Under Development

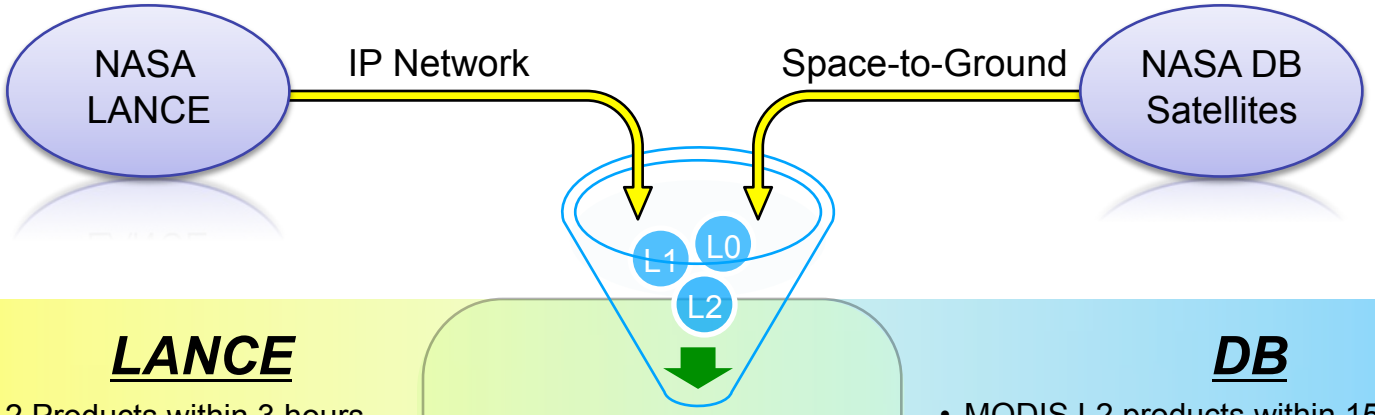
Operating LANCE Element

RBD: Rate Buffered Data
S-PDS: Session Based Production Data Set
* L2G and L3 daily products have latency of 27-28 hours. The Climate Modeling Grid (CMG) is the only L3 MODIS product produced by LANCE.

NRT LAND Products from LANCE-MODIS

Short-name	PGE Description	Product Description
MxD09	**Land Surface Reflectance**	**MODIS Surface Reflectance 5-Min L2 Swath 250m, 500m and 1km**
MxD09CMA/ MxD09CMG	**L3 Daily Land Surface Reflectance**	**MODIS Surface Reflectance L3 0.05 deg Tile Climate Modeling Grid**
MxD09GST/GHK/ GQK	**L2G Land Surface Reflectance**	**MODIS L2G Daily, tiled 1km/500m/250m surface reflectance**
MxD09GA/GQ	**L2G Land Surface Reflectance**	**MODIS Light L2G Daily, tiled 500m and 1km/250m**
MxDTBGD	**L2G Land Surface Reflectance**	**MODIS L2G Daily, tiled daytime thermal bands 1km**
MxD14	**L2 Thermal Anomalies/Fire**	**MODIS Thermal Anomalies/Fire 5-Min L2 Swath 1km**
MxD00F	Session-Based L0 PDS file splitter	Session-Based L0 PDS file, 5-min Swath
MxD00S	Session-Based L0 PDS	Original Session-Based L0 file from EDOS
MxD02SSH	L1B Calibration	5 km subsampled L1B
MYDGB0	Aqua Attitude and Ephemeris	Aqua Attitude and Ephemeris in Session L0 format

A Combined Capability to Support NRT Data and Products to Decision Support Systems



LANCE

- L2 Products within 3 hours
- Require IP for distribution
- Other sensor products available
- No upfront costs to the end-user
- Global Data Access

Overlap

- L2 MODIS product availability
- Autonomous access and generation of products
- Distribute user requested MODIS/AIRS/AMSR-E L2 products to community

DB

- MODIS L2 products within 15 minutes
- L0 (raw) product of all spacecraft instruments available
- L2 product availability for MODIS
- Spacecraft downlink redundancy
- Cost $5-20M to implement on spacecraft
- $150K Ground System for Real-Time L0 data access
- Conduit for science to applications
- Enabling via algorithms and tools
- Outreach

Combined Capability

- Global Multi-Instrument L2 Products 15min to 3hrs
- Real-time DB science algorithms
- Science Product Processing Tools
- Data Product Support

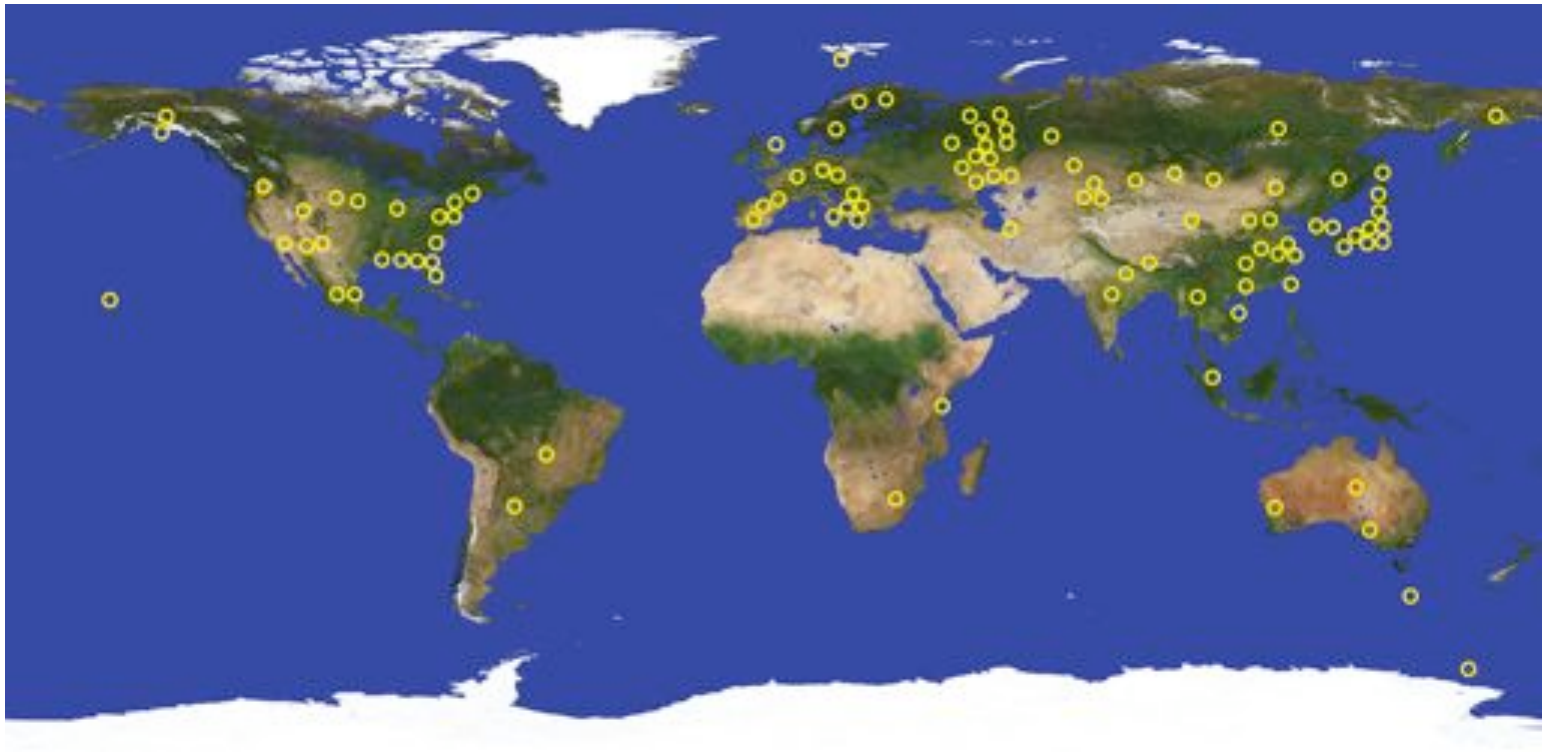
NRT Applications for Decision Support Systems

NASA's Direct Readout Community

Over 200 EOS and NPP–compatible direct readout ground systems world-wide

Cover over 80% of Earth's land mass

50% owned by government agencies and organizations
35% owned by educational institutions, 15% owned by the commercial sector
Over 30 countries have DB reception capability



• 100% of DB sites use at least one of NASA's DR algorithms/tools

• 85% of these ground stations support real-time applications

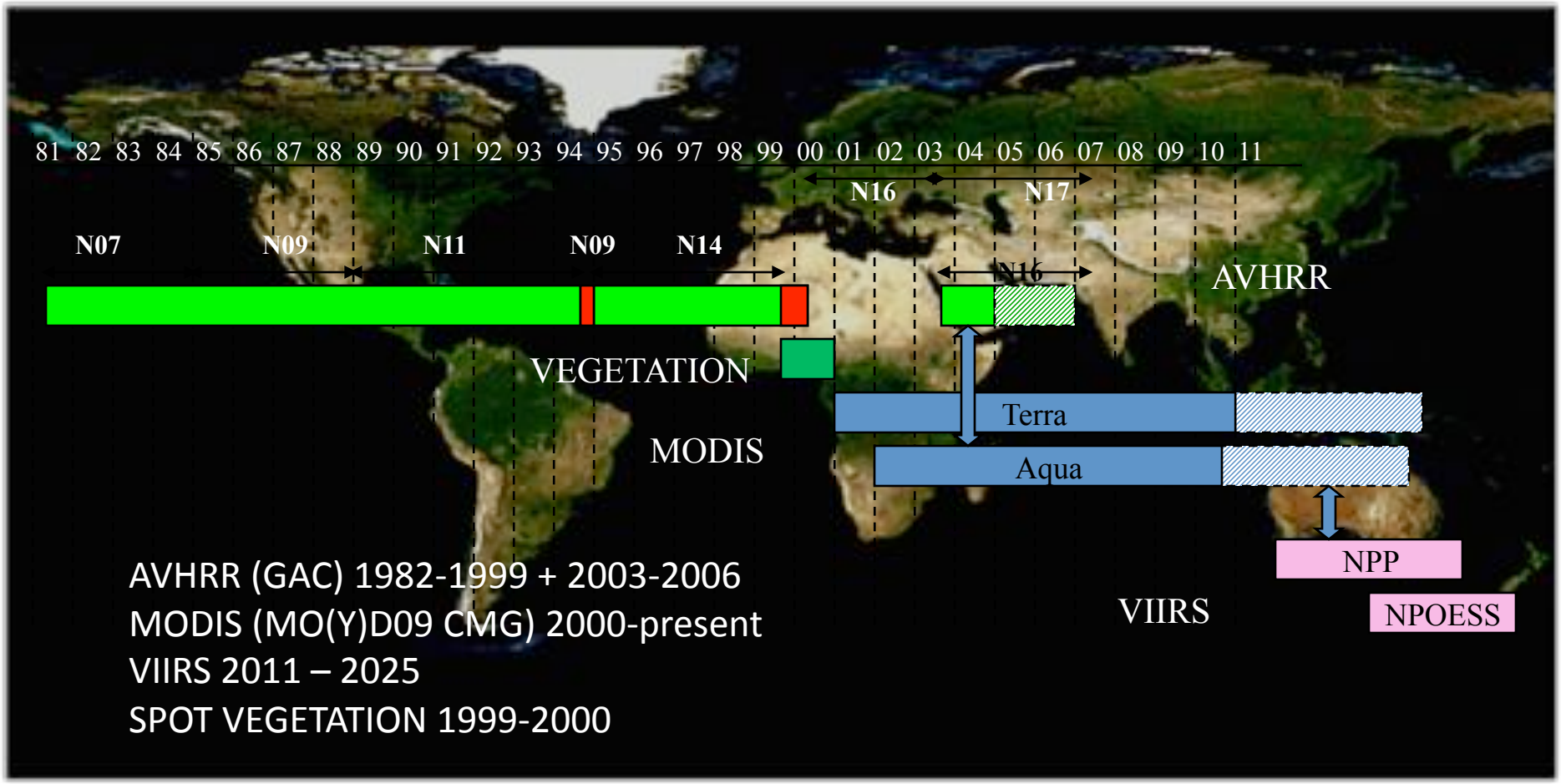
Supporting over 3000 users

So why should NASA care about NPP VIIRS and VIIRS in the NPOESS Era?

- MODIS will eventually go away (*hopefully not too soon – as we need at least 2 years overlap with VIIRS*) !
- NASA is the agency for satellite-based Earth System Science and the climate is changing.
- The Decadal Survey recognized the heavy reliance on the NPOESS Missions for providing key climate variables
  - For Land this translates to VIIRS
  - NASA and Climate Variables ?
- It looks as though we will have an instrument (at least for land) that will serve most of the communities needs for coarse resolution observations
  - And will in some ways will be better characterized than MODIS

Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes



Emphasis on data consistency – characterization rather than degrading/smoothing the data

Eric Vermote et al.

An Evaluation of the NPOESS Preparatory Project (NPP) Visible/Infrared Imager Radiometer Suite (VIIRS) and the Associated Environmental Data Records for Land Science

The VIIRS Land Team[#] with contributions from:
Ivan Csiszar, Evan Ellicott, Mark Friedl, Louis Giglio, Dorothy K. Hall, Alfredo Huete, Jeffrey R. Key, Alexei Lyapustin, James Maslanik, Edward J. Masuoka, Jeffrey L. Privette, George A. Riggs, Peter Romanov, Crystal B. Schaaf, Wilfrid Schroeder, Eric F. Vermote, Yujie Wang, Robert E. Wolfe, and Yunyue Yu

Editors: *Miguel O. Román and Chris Justice*

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Support for the research activities underpinning this document was provided by the National Aeronautics and Space Administration and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO).

VIIRS LAND Evaluation White Paper

Circulating
For Review by Land Team - will be posted soon

Intended to help NASA, NOAA, IPO on how to address land science needs

EDR Utility for Science Use

- **The Cryosphere EDRs as currently scoped will in general provide useful input to the Cryospheric Science Community.**
  - The Snow EDR could be enhanced by the inclusion of fractional snow cover and daily snow albedo.
  - Ice Surface Temperature EDR should be enhanced by extension to coastal and land ice areas.
  - The Ice Characterization EDR could be improved by inter-use of data from passive microwave sensors.
- **Land EDRs, derived from the Surface Reflectance IP, will be of insufficient quality to support many current and future NASA Land science needs.**
  - The accuracy of the current Surface Reflectance IP could be improved for shorter wavelengths
  - The VIIRS Cloud Mask algorithm adopts a “one-size-fits-all” approach that has proven ineffective for MODIS and could potentially lead to systematically substandard NPOESS operational products.
  - While the Enhanced Vegetation Index (EVI) EDR is atmospherically corrected, there are blue-band discrepancies that will impact the continuity with MODIS EVI.
  - Surface Albedo EDR supplies a single broadband value which will not provide the underlying spectral albedos or anisotropy information currently produced by EOS.
  - The quality and accuracy of the current surface type EDR (70% classification accuracy) will be insufficient for most regional land cover related applications.

Science Product and Processing needs beyond the VIIRS Land EDRs

- If continuity is to be provided with MODIS, then product consistency is also needed to:
  - Provide temporally composited and spatially re-sampled forms of the Land products; e.g. 8-day and 16-day surface reflectance and VI, as well as Climate Modeling Grid versions of the products.
  - Continue production of LAI/FPAR, Net Primary Productivity, Vegetation Continuous Fields and Dynamics (phenology) or Burned Area products.
- Additional products could be considered to meet the needs of the UN Framework Convention on Climate Change for sustained coordinate processing of Essential Climate Variables (ECV's).
- Agencies concerned with science data use will need to provide the capability for data reprocessing to develop consistent data records.

White Paper Recommendations

- ***A suite of Land 'Science' products should be generated from VIIRS (i.e. VIIRS Land Earth Science Data Records –ESDRs), which meet the needs of the Land science community and at least provides continuity with the current suite of MODIS Land products.***

- ***For consistency and continuity with the MODIS Land products, these products should:***
  - utilize the same algorithmic theoretical basis as their MODIS counterparts.
  - be generated by the Land PEATE, following guidance from and in close cooperation with the VIIRS Land Science Community.
  - be made broadly available to the science and applications community through the LAADS system, once the products have progressed beyond the Beta (test) level.
  - each have a scientist responsible for product refinement and well developed product documentation (i.e. User Guide).
  - be reprocessed at periodic intervals following refinement of the algorithms, based on instrument performance, product QA and Validation.

The Land PEATE is in place

- **MODIS processing heritage applied to the VIIRS data**
  - MODAPS and LAADS software for processing and distribution, LDOPE supporting product assessment,
  - Products generated in HDF-EOS with Level 3 gridded multi-day products produced to facilitate comparison with MODIS products from Terra and Aqua.
- **At Launch Capacity**
  - Storage for all RDR (L0) and ancillary data products
  - Capacity to generate IDPS operational products in parallel with products produced with improved algorithms at 12x, (12 data-days per day per product stream). Includes generation of Level 3 products and browse.
  - Capacity to store multiple versions of products produced during evaluation, 1PB of online archive.
- **Additions to the Land PEATE's computing resources (e.g. increasing the at-launch processing rate and amount of disk storage) will be needed**
  - Accommodate the increased volume from storing the SDRs and full land product suite for the entire data record.
  - Facilitate convergence on the best suite of algorithms for reprocessing the Land Science products at periodic intervals.

Recommendations Cont'd

• ***Support should be provided for Quality Assessment of the products and Validation for each VIIRS Land science product to at least Stage 2, building on the approaches developed for MODIS.***

- **`It is recommended that a small group be responsible for product validation coordination and liaison with both NPOESS-funded activities and international partner programs.**
- **NASA should coordinate with other cross-agency programs to ensure access to platforms and airborne sensor resources for which dedicated airborne campaigns or campaigns of opportunity are available.**
- **The IPO supported Land Validation Team should continue to contribute to the definition and implementation of internationally accepted validation protocols as defined by the CEOS Land Product Validation Working Group (LPV WG) which is part of the CEOS Cal/Val program.**

Recommendations Cont'd

- ***Discussions should be held between NASA, NOAA and the IPO on the roles and responsibilities for supporting VIIRS Land science products in the NPOESS era, identifying pathways for the eventual entrainment of desired science products into operational production streams (IDPS or NDE), once the Land science products have been validated to Stage 2.***

This is the to Research to Operations Part

- ***A mechanism should be set up by NASA in collaboration with the IPO for identifying, assessing the cost-benefit and funding improvements to the follow-on VIIRS instruments to meet the needs of the Land science community.***
    - ***Instrument improvements to meet Land needs would be modest***

The VIIRS Science Team Recommended Instrument Improvements ?

High Priority Recommendations for FU2 (1 of 2)

- Improve VNIR IFA to address the optical crosstalk problem
- Improve optical design in SWMWIR and LWIR to address the dewar window ghosting features
- Improve VNIR Read Out Integrated Circuit (ROIC) to address static electrical crosstalk problem
- Perform end-to-end testing of the solar diffuser/monitor/screen on-board calibration system relative to earth view
- Eliminate the noise in the gain switch regions of the VIIRS dual gain bands
- Maintain calibration and characterization of all GSE between successive VIIRS flight units
- Improve saturation handling for single gain bands (i.e. on-board aggregation) and resolve the saturation rollover effect
- Employ tunable lasers (e.g. NIST SIRCUS) in measurements of system level spectral response of VIIRS bands
- Report well defined sub-scene statistics of the impact of crosstalk and near field response particularly in regions of scientific interest such as coastlines and cloud edges (i.e. currently full scene statistics are reported)
- Improve requirement (i.e. exclusion zone), testing and data analysis of near field and far field stray light VIIRS response

Recommendations Cont'd

- ***A mechanism should be set up to allow the prototyping and testing of new VIIRS land products as new products and algorithms come on-line to meet emerging needs of the science community. Also the NPOESS IORD should be revisited after L+6 months to include the EDR needs of the operational 'land' agencies e.g. USDA, USFS.***

- ***Given the well-known fragility of the post-Nunn McCurdy NPOESS program,NASA should work with NOAA to develop data agreements and pathways with international partners to assure access to substitute global coarse resolution multispectral satellite observations in the NPOESS timeframe (e.g. Sentinel 3). These should be pursued now, to allow algorithm testing and minimize possible disruptions to downstream users.***
  - Analysis should be supported to evaluate the utility of combining VIIRS (PM) and Metop (AM) for Land science product generation, in the context of continuity of the current MODIS combined Aqua/Terra products.

The VIIRS DRL Component is also in place

- IPOPP – the International Polar-Orbit Processing Package is a framework consisting of a suite of technologies to process Earth science instrument algorithms
  - Contain instrument specific Science Processing Algorithms (SPAs) as modules
  - The embedded technologies come from the NPP In-Situ Ground System (NISGS)
  - Sponsored by the Direct Readout Program and the NPP and NPOESS missions

- IPOPP directly supports the Technology Insertion and NPOESS Risk Reduction objectives:
  - Provides technology insertion for NPOESS, which will assure that the NPOESS High Rate Data (HRD) design will be readily usable for Field Terminal users.
  - Enables the user community to transition from existing POES/ Terra/Aqua DB data to NPP and NPOESS HRD data.

What the DRL will Provide to the Community

- Provide IPOPP Package with MODIS DB algorithms to the public 1 yr prior to launch
  - Released in December 2009 (IPOPP version 1.6b)
- Direct Readout Science Data Record (SDR) Algorithms for all Instruments
  - Ported, DB standalone with common interface (as an SPA)
  - CERES SDR not currently included
- Technology Tools to enable ingest, pre-processing, transport and real-time visualization/monitoring of any direct broadcast data record (xDR)
  - Provided incrementally with every IPOPP version release
- Select DB Environmental Data Record (EDR) Algorithms for VIIRS, CrIS and ATMS
  - Standalone with common interface (as an SPA)
  - Ported to function in a DB environment
  - Initial source is baseline IDPS algorithms
- Provide post-launch S/C Direct Broadcast verification and algorithm updates

In Summary

- Continue MODIS Am/Pm Science and Operations
  - With increased attention as the systems age
- Capitalize on NASA's MODIS Science Success
- Build on current NASA VIIRS Investments
  - EDR Evaluation, Land PEATE, DR Lab
- **Establish a Land Science Product Suite from VIIRS**
- Explore Agency partnerships on Land Product Stewardship and Long Term Data Records
  - Avoid critical components falling through the cracks
  - Make sure the commitments are real and sustainable
- Consider science improvements to VIIRS FU2 and beyond