Remote Sensing Data Products Now Available for Carbon Cycle and Ecosystems Science

LAND

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Ames Research Center

http://ecocast.arc.nasa.gov

OCEANS

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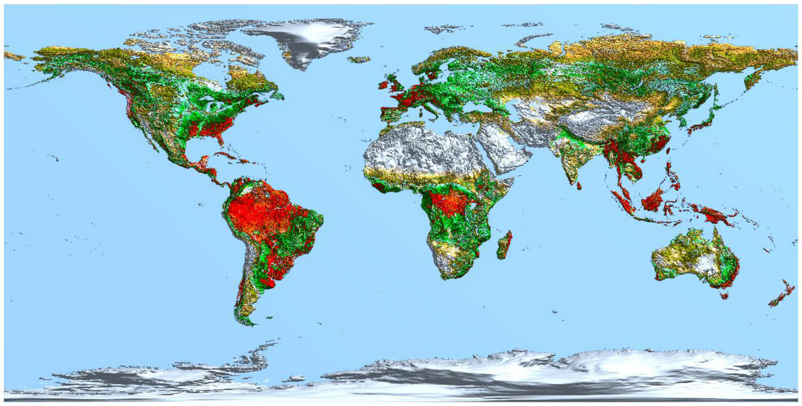
http://disc.sci.gsfc.nasa.gov/

NASA Carbon Cycle & Ecosystems

Joint Science Workshop, October 3, 2011

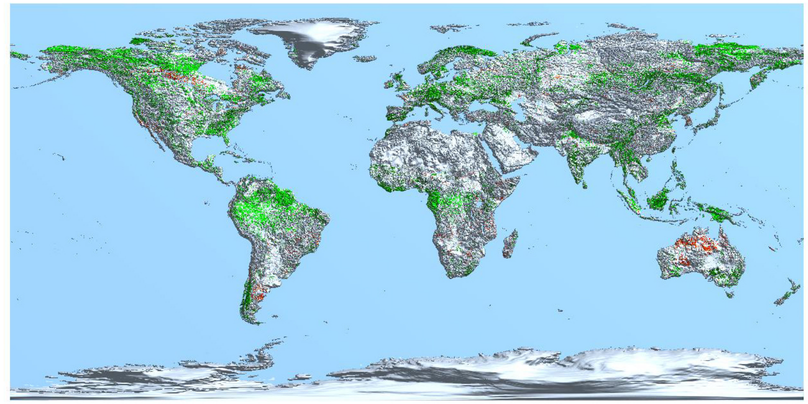
30 Years of Vegetation Greenness Measurements

Produced by GIMMS Group, GSFC/NASA



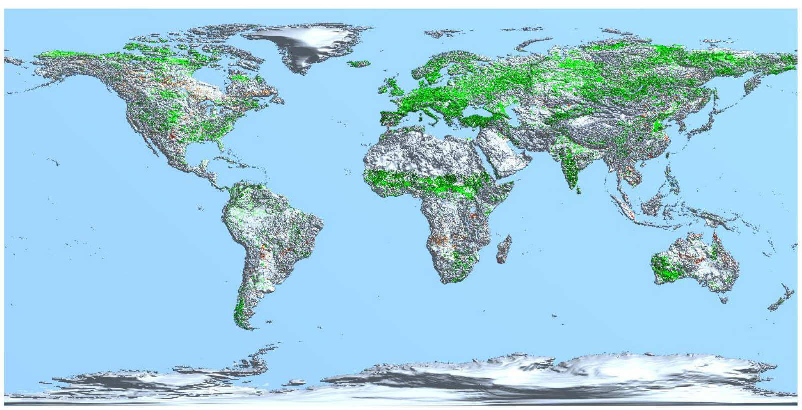
Vegetation Greenness (1981-2010)

0.1 0.4 0.7 1.0



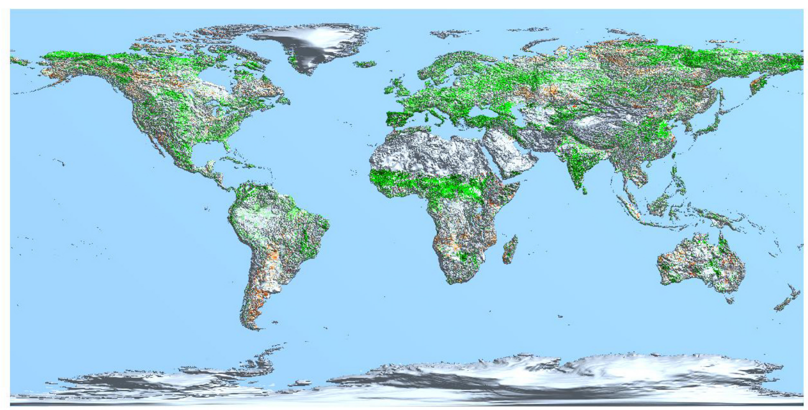
Vegetation Greenness Trend (%/yr) 1982-1990

<-2% -1% 1% >2%



Vegetation Greenness Trend (%/yr) 1982-2000

<-2% -1% 1% >2%



Vegetation Greenness Trend (%/yr) 1982-2010

<-2% -1% 1% >2%

Analysis by CLIVEG Group, Boston University

Largely a Greening Planet
With hints of browning

IGBP Land Cover Classes	GSI NDVI (%) (1982-1990)	GSI NDVI (%) (1982-2000)	GSI NDVI (%) (1982-2010)
Evergreen Broadleaf forest	(5.8,0.0,6.7)	(1.4,0.1,11.1)	(4.4,0.4,7.7)
Woody savannas	(2.0,0.2,9.7)	(2.1,0.5,9.3)	(3.3,1.5,7.2)
Croplands	(2.3,0.2,8.1)	(3.6,0.3,6.6)	(4.1,1.0,5.4)
Open shrublands	(2.9,0.7,12.9)	(4.6,0.3,11.5)	(5.2,2.3,8.9)
Grasslands	(1.6,0.4,11.1)	(3.2,0.2,9.6)	(4.0,1.3,7.8)
Savannas	(0.6,0.3,7.0)	(1.4,0.4,6.2)	(2.1,0.9,5.0)
Cropland/Natural vegetation mosaic	(1.3,0.1,5.1)	(1.8,0.2,4.5)	(2.4,0.5,3.6)
Mixed forest	(1.4,0.1,4.3)	(2.0,0.2,3.6)	(2.9,0.3,2.6)
Evergreen Needleleaf forest	(1.1,0.2,3.9)	(1.4,0.5,3.3)	(1.8,1.0,2.4)
Deciduous Broadleaf forest	(0.3,0.0,1.3)	(0.3,0.1,1.2)	(0.5,0.2,0.9)
Deciduous Needleleaf forest	(0.4,0.1,1.6)	(0.7,0.1,1.3)	(0.5,0.5,1.1)
Closed shrublands	(0.2,0.0,0.9)	(0.2,0.0,0.9)	(0.2,0.2,0.7)
Total	(19.9,2.5,72.5)	(22.6,2.9,69.0)	(31.4,9.8,53.3)

Aerial fractions only

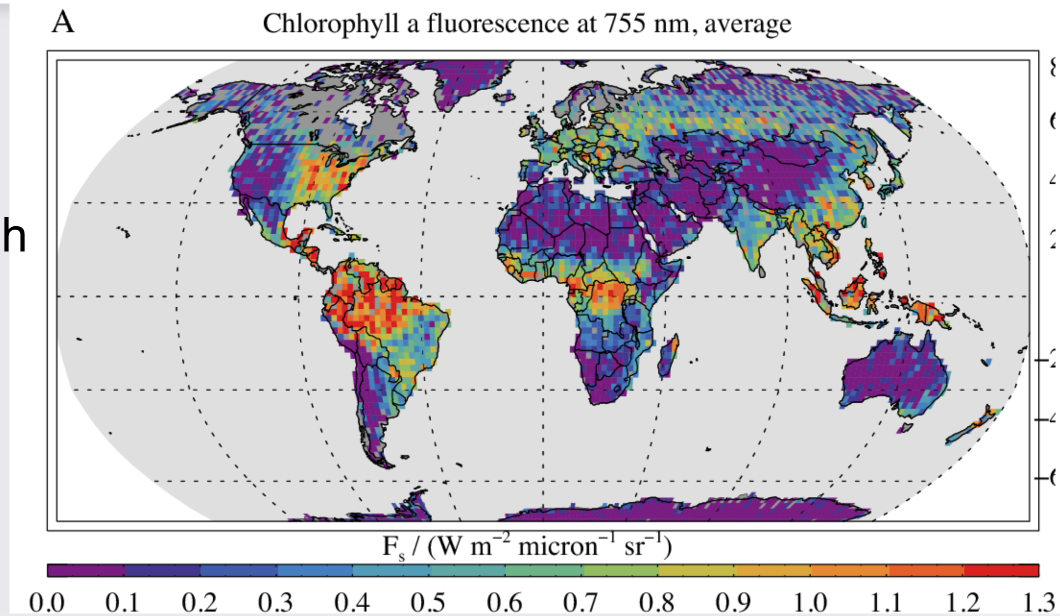
Analysis by CLIVEG Group, Boston University

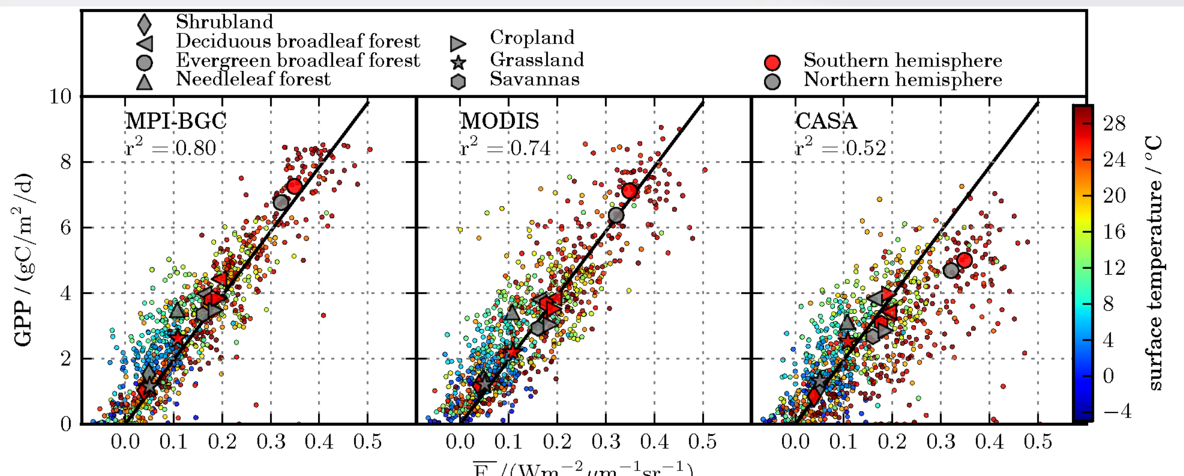
Satellite Measurements Of Chlorophyll Fluorescence

Frankenberg et al., GRL, 2011

Chlorophyll fluoresces when performing photosynthesis
-> signal can be measured using high resolution O_2 A-band spectra (GOSAT, OCO-2)

New satellite based fluorescence measurements provide a spatial constraint on carbon uptake



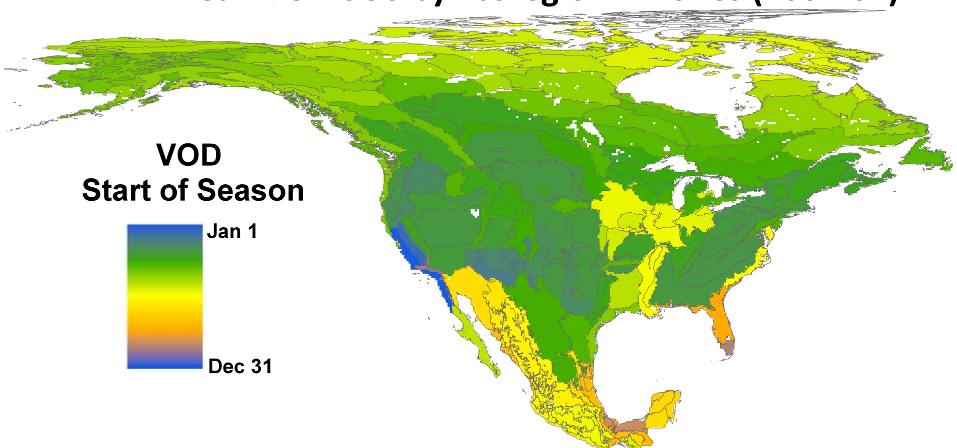


Uncertainty exists around absolute magnitudes, Welp et al' suggest 150-175 Pg of GPP compared to current estimates of 100-120 Pg

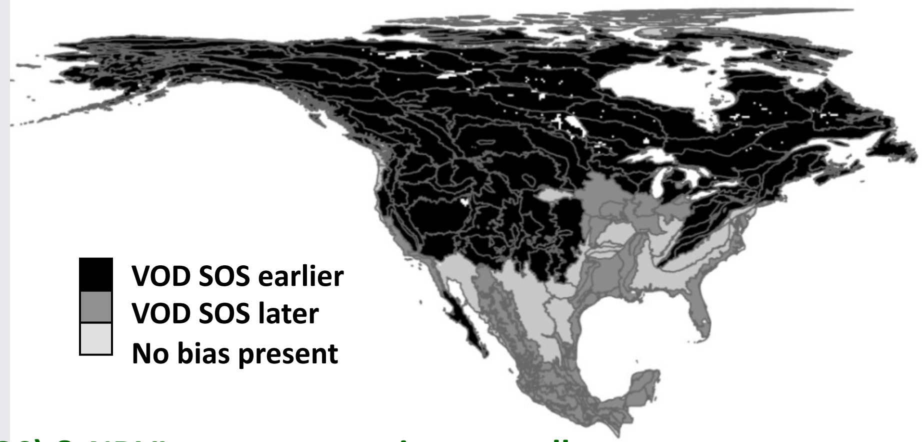
Welp et al., Nature, 2011

Microwave Vegetation Optical Depth (VOD) Phenology from AMSR-E

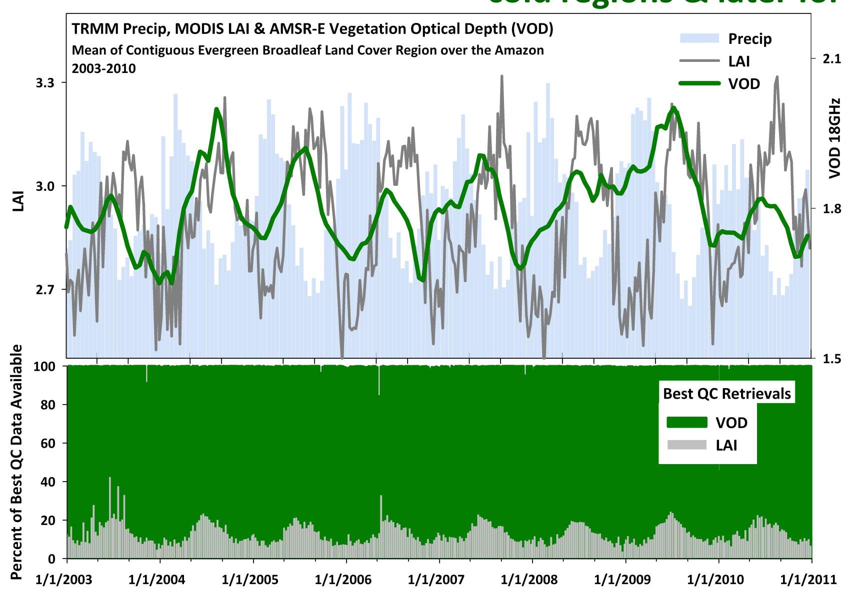
Mean VOD SOS by Ecoregion III zones (2004-07)



VOD SOS Bias Relative to NDVI Green-up



- **VOD start of season (SOS) & NDVI green-up metrics are well correlated but have seasonal bias; SOS earlier than green-up for cold regions & later for warmer, drier regions;**



- **AMSR-E VOD is sensitive to canopy water content & biomass changes, & is correlated with MODIS LAI;**
- **The VOD is insensitive to atmosphere (clouds, smoke) effects, enabling near-daily vegetation monitoring;**
- **The Amazon shows large VOD seasonality & dry-season canopy growth, but reduced growth under a large 2010 drought.**

http://freezethaw.ntsg.umt.edu

Matt Jones, John Kimball, Lucas Jones & Kyle McDonald

A Benchmark Map of Carbon Storage in Tropics

Saatchi et al. PNAS 2011

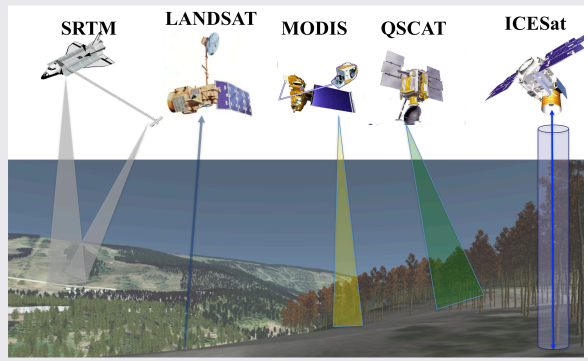
Different NASA satellites including more than 3 million ICESAT GLAS Lidar measurements of forest height are used to create the most precise map depicting where -- and how much -- carbon is stored in Earth's tropical forests. The high-resolution map is expected to provide a baseline for ongoing carbon monitoring and research, and serve as a useful resource for managing the greenhouse gas carbon dioxide.

Highlights:

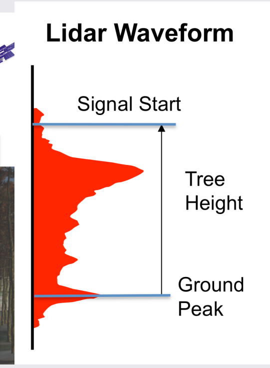
1. The map shows that in the early 2000s, forests in the 75 tropical countries studied contained 247 billion tons of carbon or an equivalent of 900 billion tons of carbon dioxide. For perspective, about 35 billion tons of carbon dioxide is released to the atmosphere annually as a result of human activities.

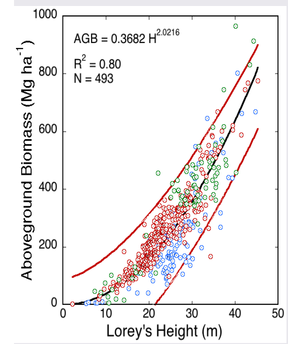
2. Forests in Latin America hold 49 percent of the carbon in tropical forests. For example, Brazil's carbon stock alone, at 61 billion tons, almost equals all of the carbon stock in sub-Saharan Africa, at 62 billion tons.

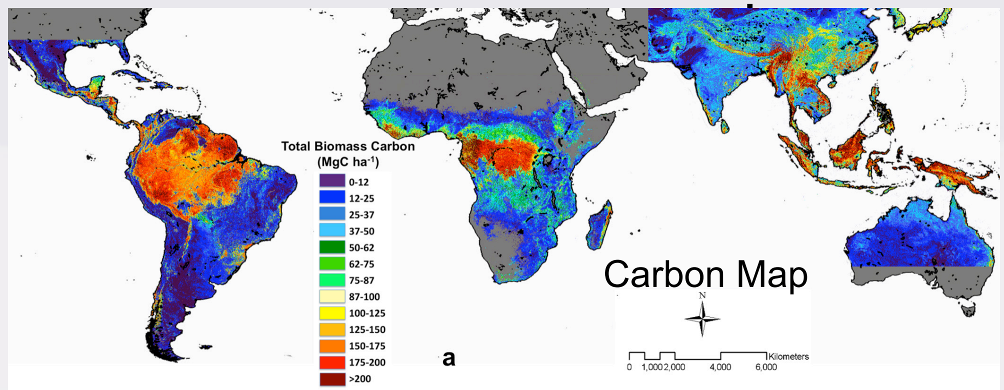
A Satellite and in situ Observations integrated in spatial carbon estimator



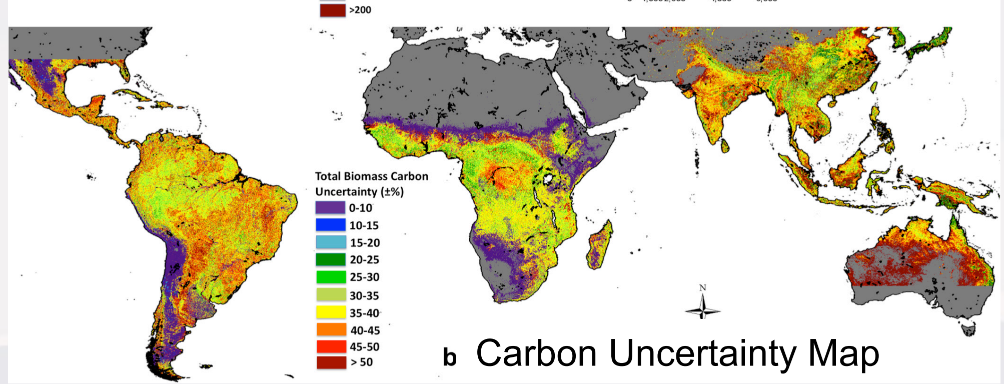
More than 3 million Lidar Shots converted to forest biomass







Carbon Map

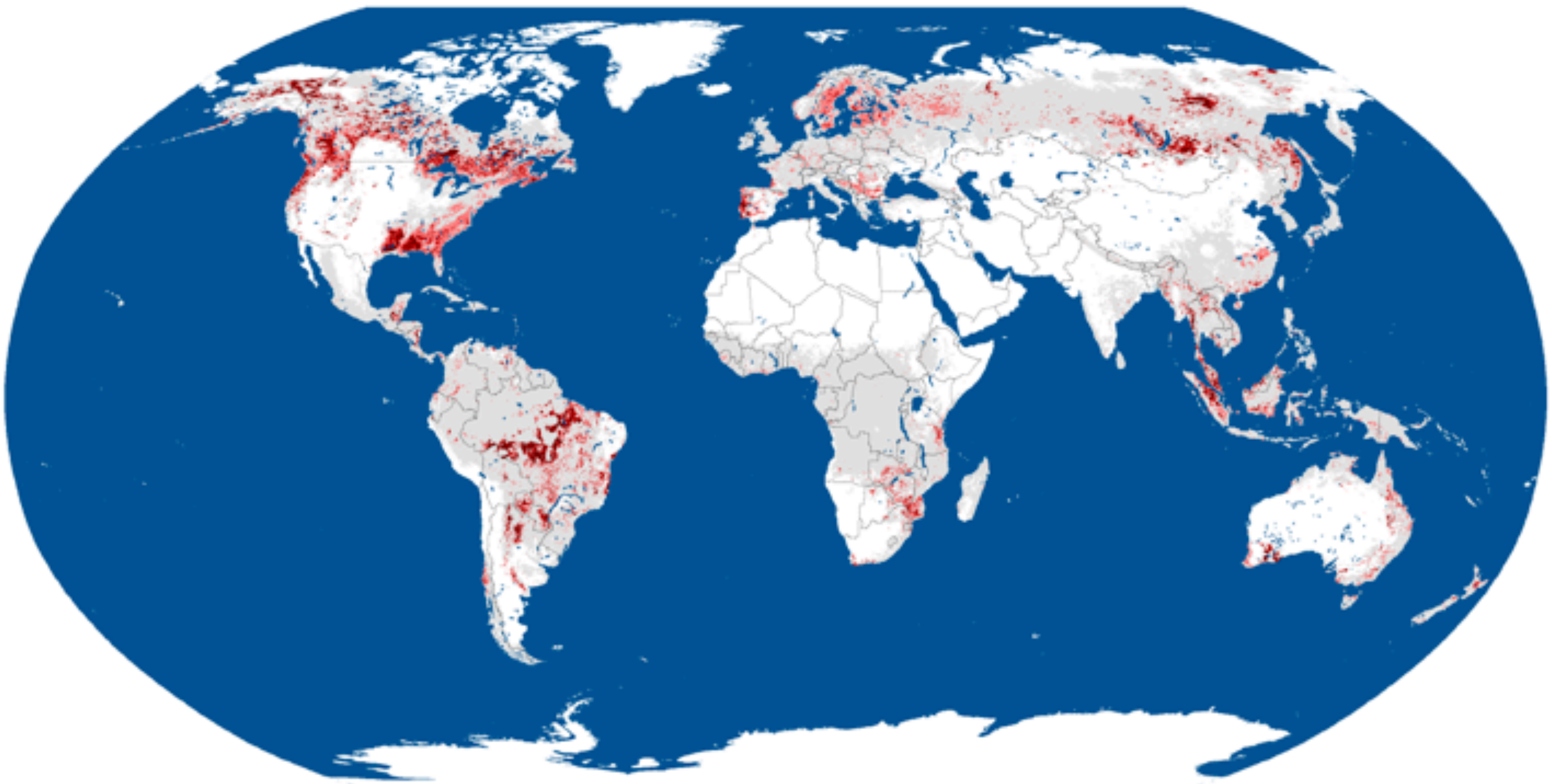


b Carbon Uncertainty Map

Quantification of global gross forest cover loss

Hansen et al., PNAS, 2010

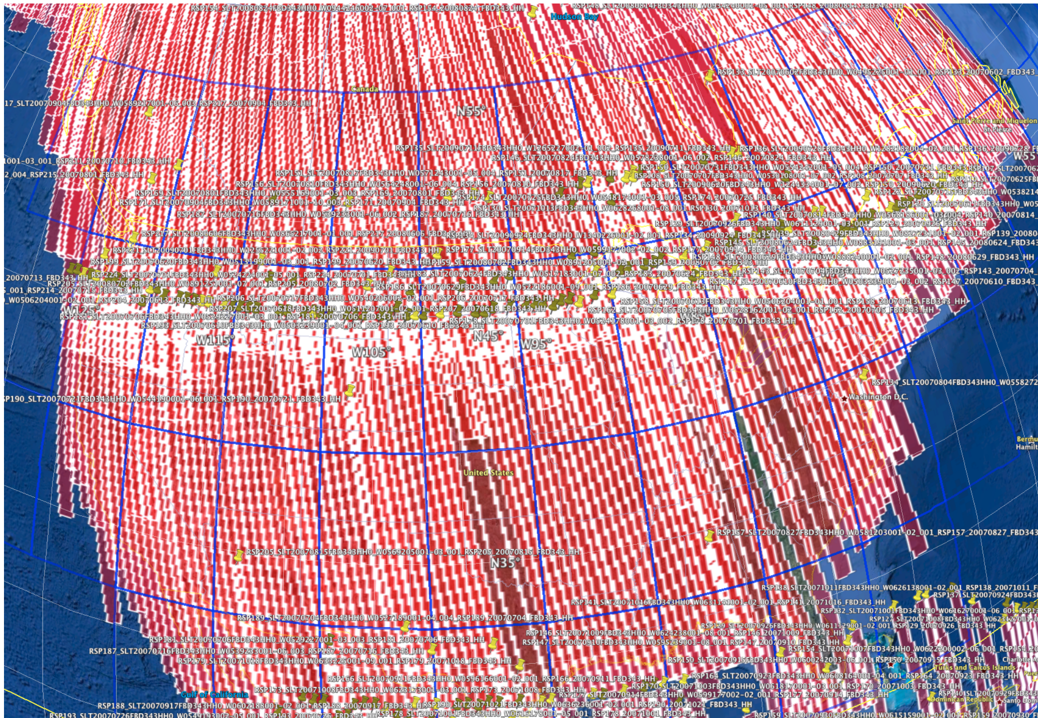
Percent forest cover loss, 2000 to 2005



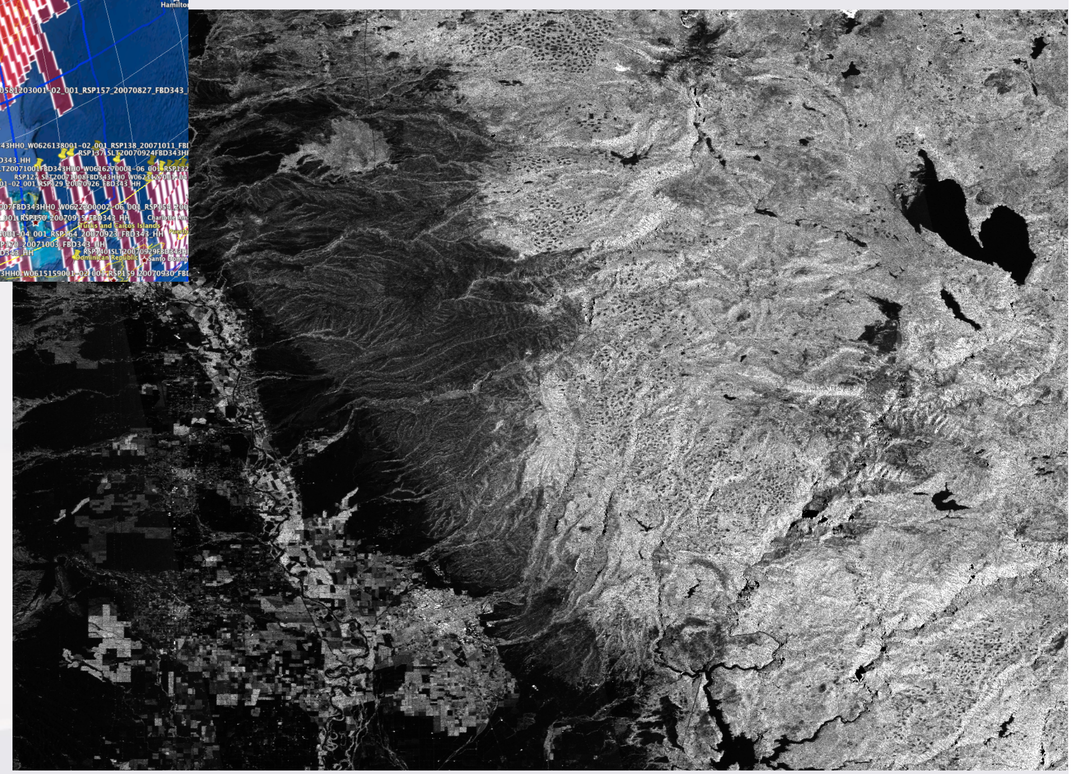
0 - 1.5% | 1.5 - 5% | 5 - 10% | >10%

SDSU

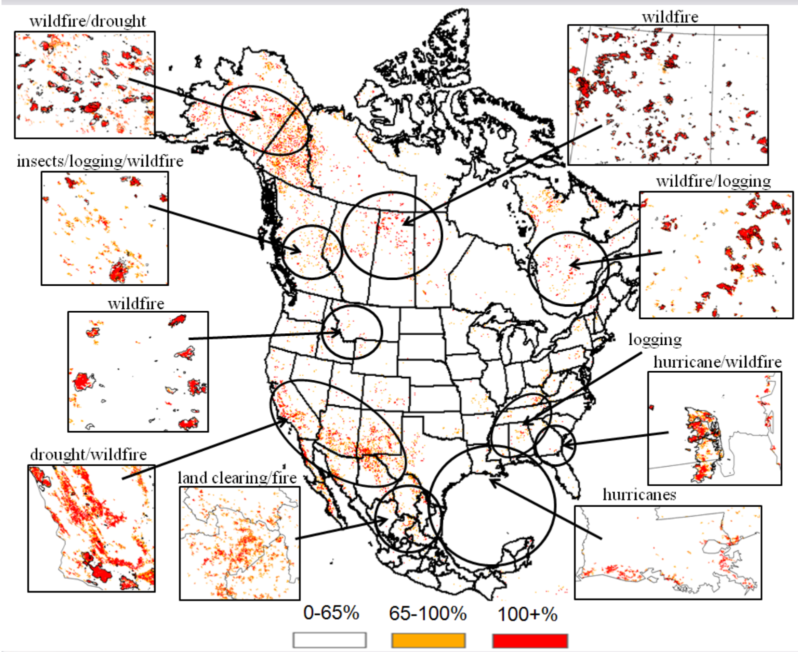
ALOS/PALSAR



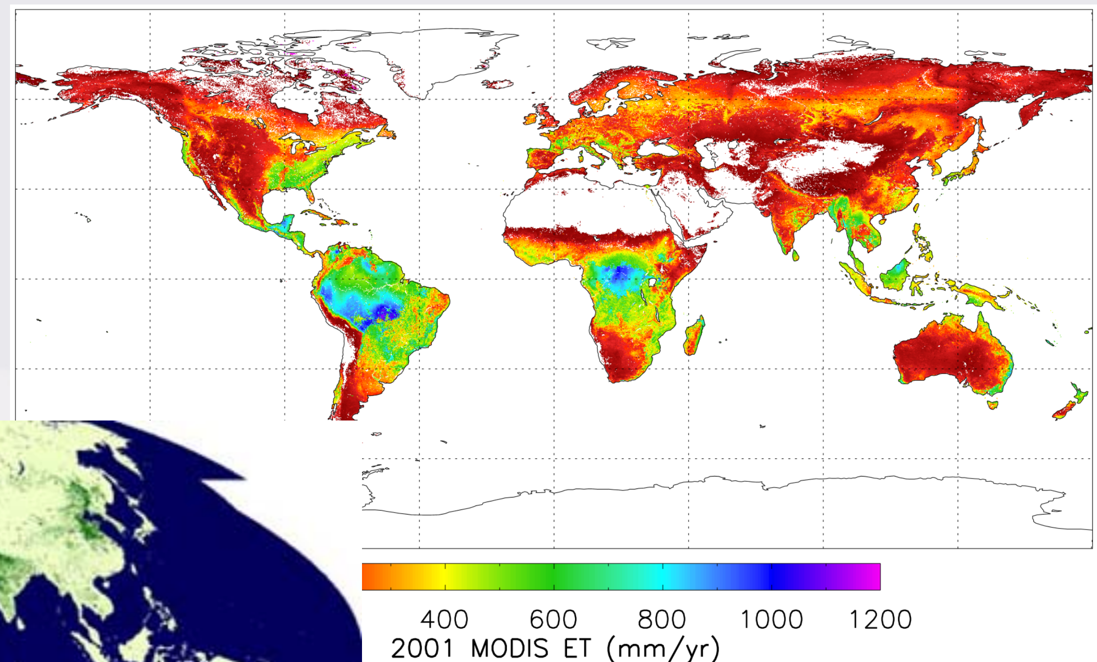
Actively used in biomass studies
Complex processing



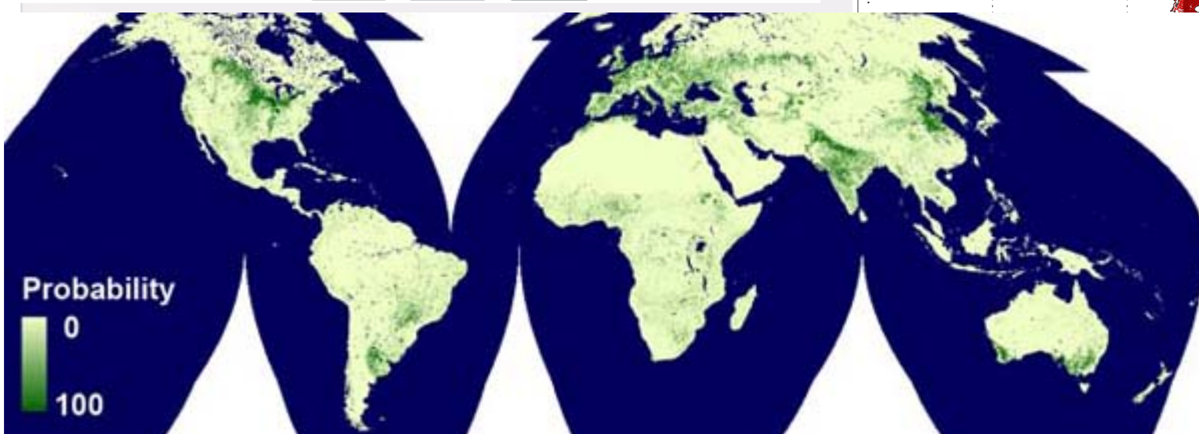
MODIS



MODIS Disturbance Index
Mildrexler et al., 2009, RSE

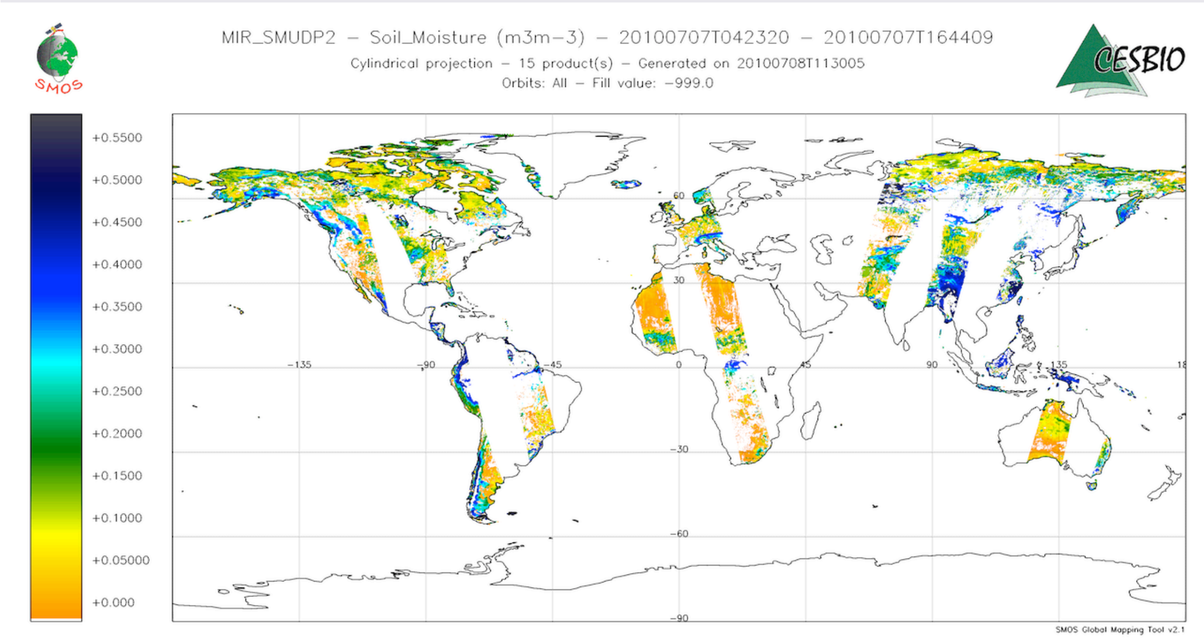


MODIS Evapotranspiration
Mu et al., 2011, RSE

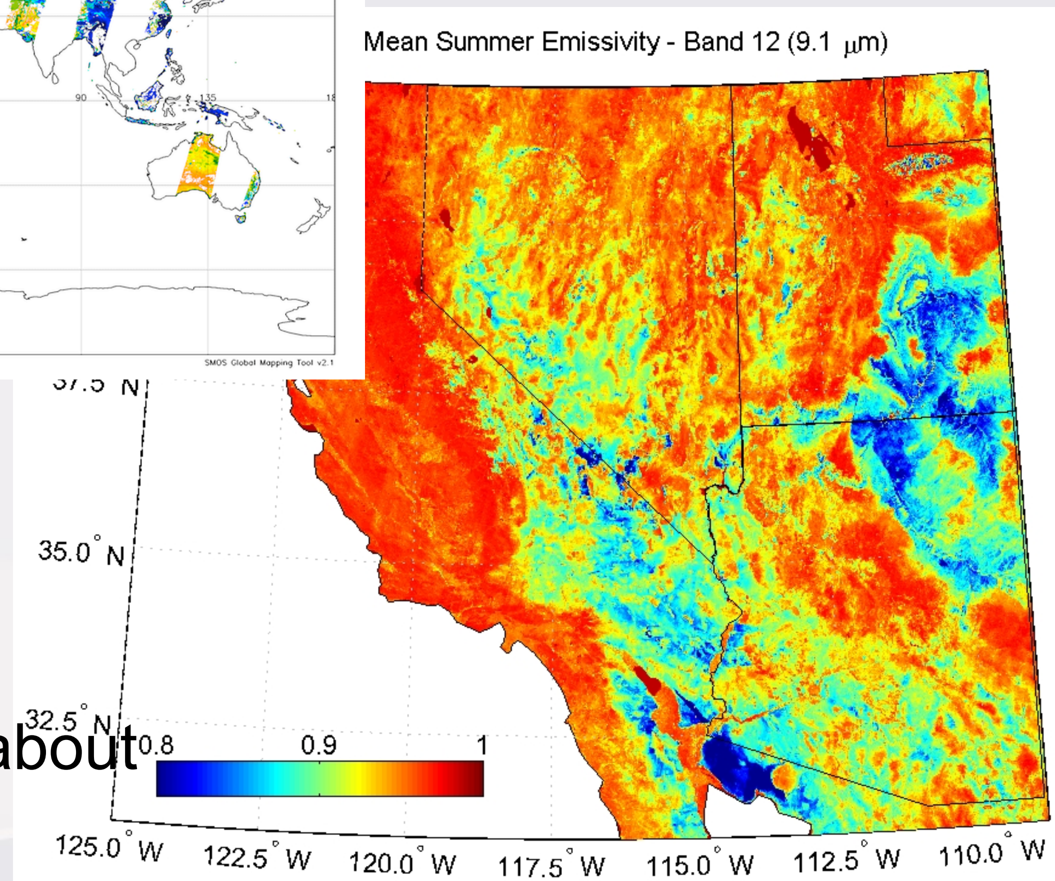


Global Crop Lands, Pittman et al., 2011, RSE

Soil Moisture from ESA/SMOS



Surface Emissivity



http://lst.jpl.nasa.gov/about

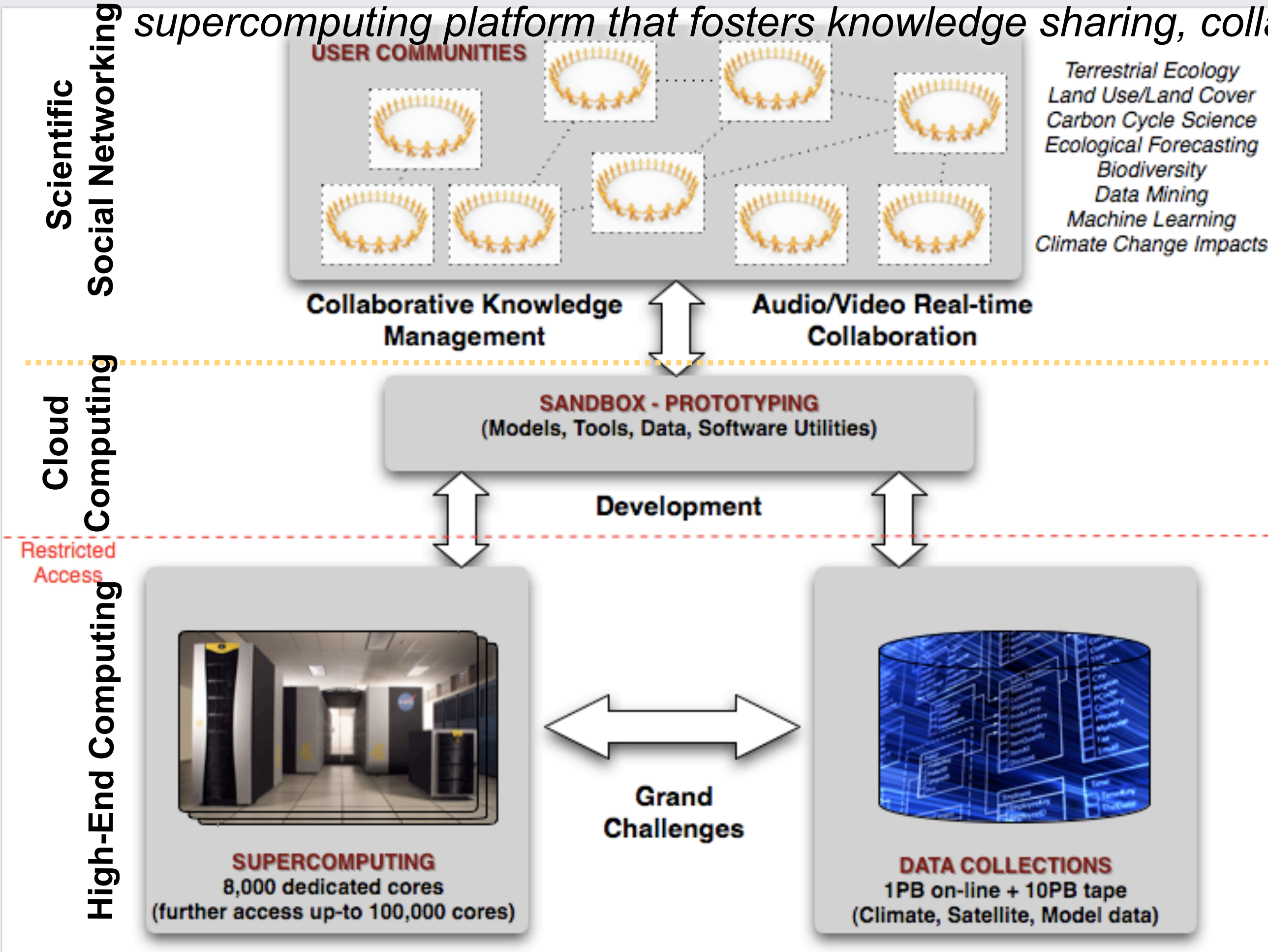
- National Geospatial Intelligence Agency (NGA) Commercial Archive contains 4+ million high resolution (<1m) images.
- Global coverage exists between IKONOS, GeoEye 1, Quickbird, Worldview 1, & Worldview 2 satellites.
- Currently Beta testing data distribution to the LCLUC community, soon it will be a resource for all NASA Investigators.

cad4nasa.gsfc.nasa.gov

NASA Earth Exchange

Collaborative supercomputing for global change science

*Providing **direct** access to data, models, analysis tools, and scientific results through a supercomputing platform that fosters knowledge sharing, collaboration, and innovation.*



Scientists spend nearly 80% of their time dealing with data - less than 20% on analysis - ***work towards 20/80***

By

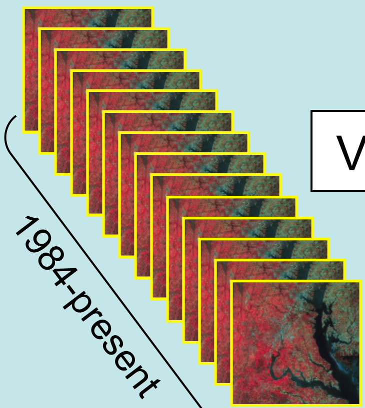
- Moving the code to where data is
- Sharing/re-using code
- Capturing and sharing the workflows

Currently NEX has 200 members and 22 research teams

North American Forest Dynamics Disturbance Products

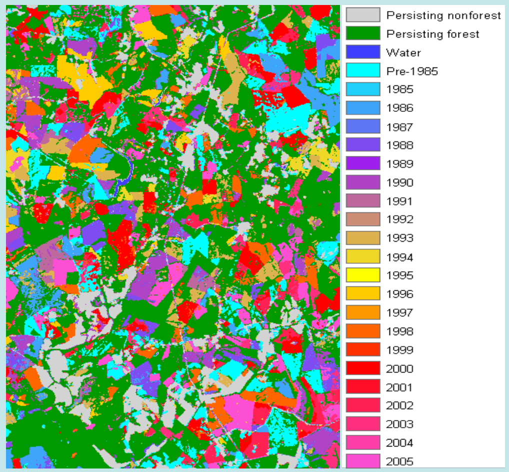
http://www.geog.umd.edu/nacp.goward/

LTSS-VCT Approach to Disturbance Mapping



Landsat time series stack (LTSS)

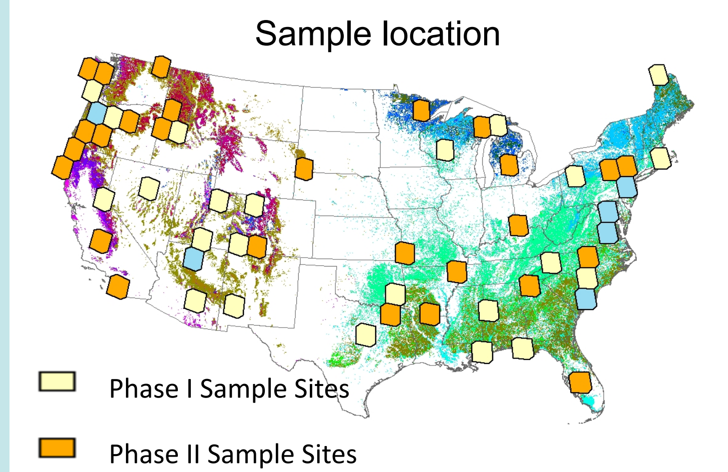
VCT

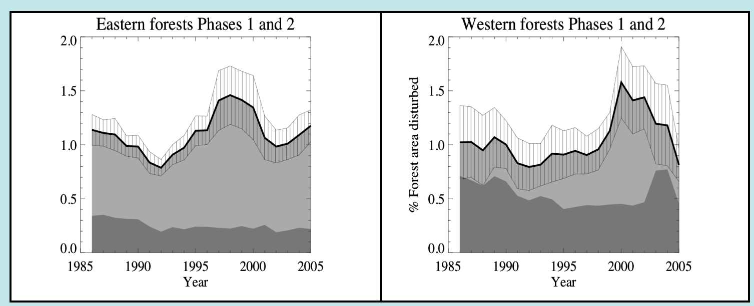


Annual disturbance map

NAFD Phase I & II

- Disturbance mapped at ~50 sample locations
- Disturbance rates estimated from the samples





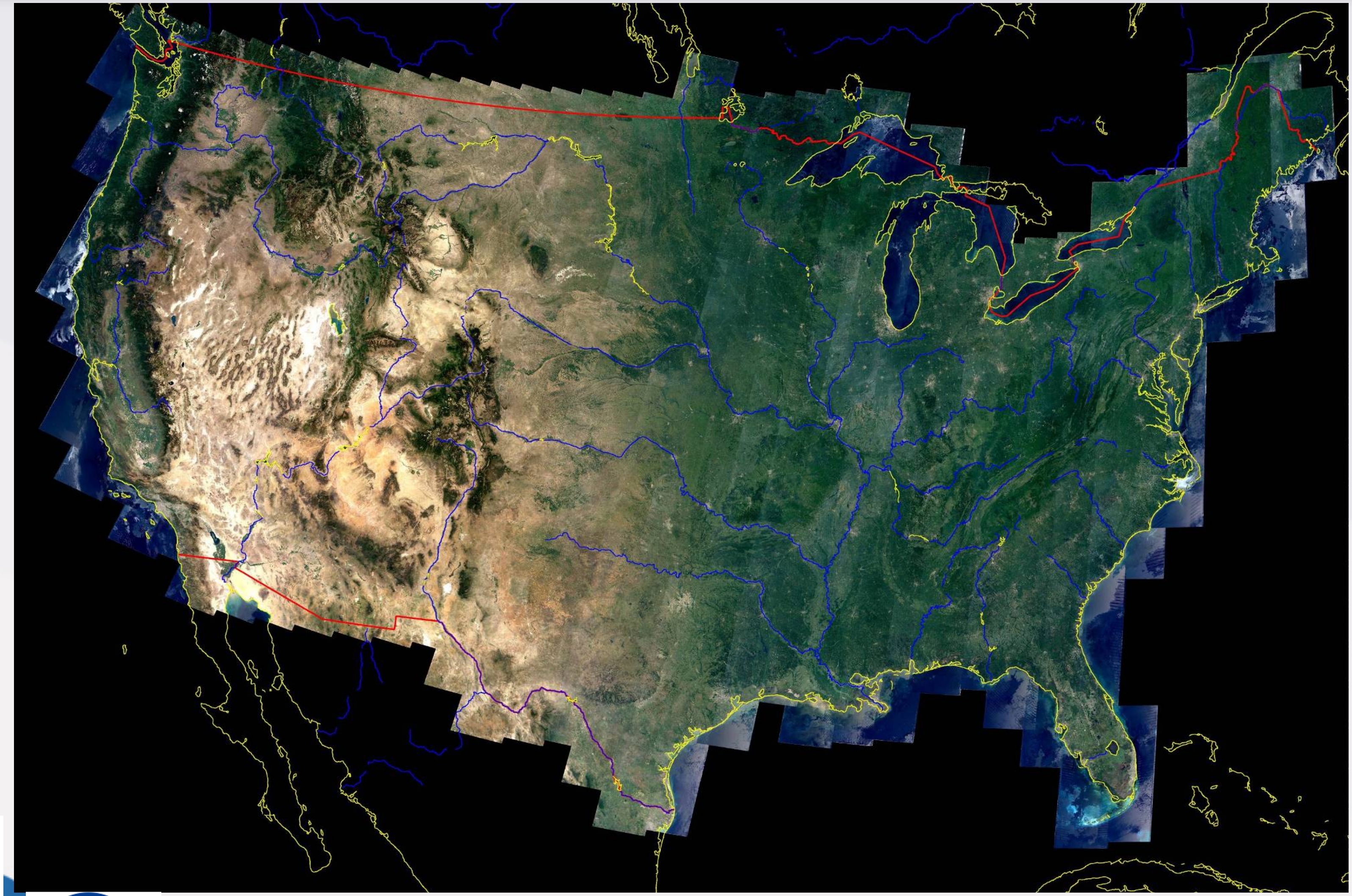
Disturbance rates in eastern and western US

NAFD Phase III (2011-2014)

- **Wall-to-wall disturbance mapping for conterminous US, annual step, Landsat resolution**
- Characterization of disturbance type and intensity
- Post-disturbance recovery analysis

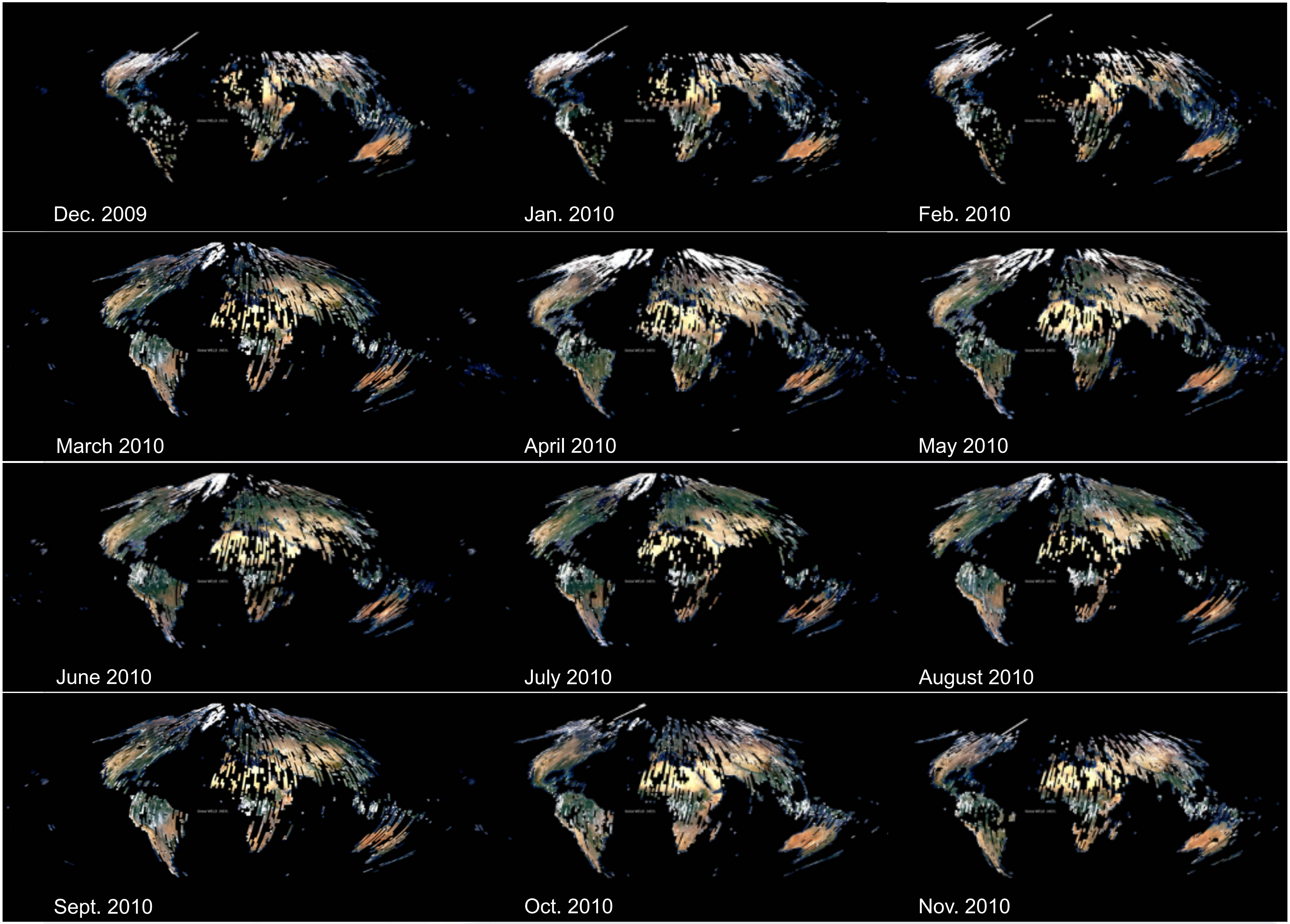
WEB-ENABLED LANDSAT DATA (WELD)

Roy et al., Remote Sensing of Environment. 2010



MEaSUREs,

globalmonitoring.sdstate.edu/projects/weld/


Dec. 2009
Jan. 2010
Feb. 2010
March 2010
April 2010
May 2010
June 2010
July 2010
August 2010
Sept. 2010
Oct. 2010
Nov. 2010

Inherently Obvious Progress (IOP): New Ocean Data Products for Carbon Cycle Research

James Acker

NASA Goddard Earth Sciences Data and Information Services Center/Wyle IS LLC

1978-1986: *Coastal Zone Color Scanner*

- "Proof –of-concept" provided pigment concentrations, ocean patterns of biological activity, initial views of large-scale processes like El Niño; discontinuous observational coverage

1996-2010: *Sea-viewing Wide Field-of-view Sensor, SeaWiFS [with help from the Ocean Color and Temperature Scanner (OCTS)]*

- Global estimation of chlorophyll *a* concentration, full-time global scanner, complete observation of La Niña and El Niño impact; decreased accuracy in productive coastal waters

1999-present: *Moderate Resolution Imaging Spectroradiometer (MODIS) and Medium Resolution Imaging Spectrometer (MERIS)*

- Higher spatial resolution data globally, new data products allowing better discrimination of chromophoric components, more bands, innovative algorithms; potential for better quantification of ocean carbon cycle

The current focus of much ocean color research is on the development of semi-analytic algorithms, in contrast to empirical algorithms.

These algorithms provide data that is more diagnostic of the relative contributions of the chromophoric components that contribute to the total ocean color signal.

So, in contrast to phytoplankton chlorophyll concentrations, the total signal can be deconvoluted into contributing elements using inherent optical properties (IOPs):

- **Absorption by dissolved and detrital material (a_{dg})**
- **Absorption by phytoplankton chlorophyll (a_{ph})**
- **Backscattering by suspended matter (b_{bp})**

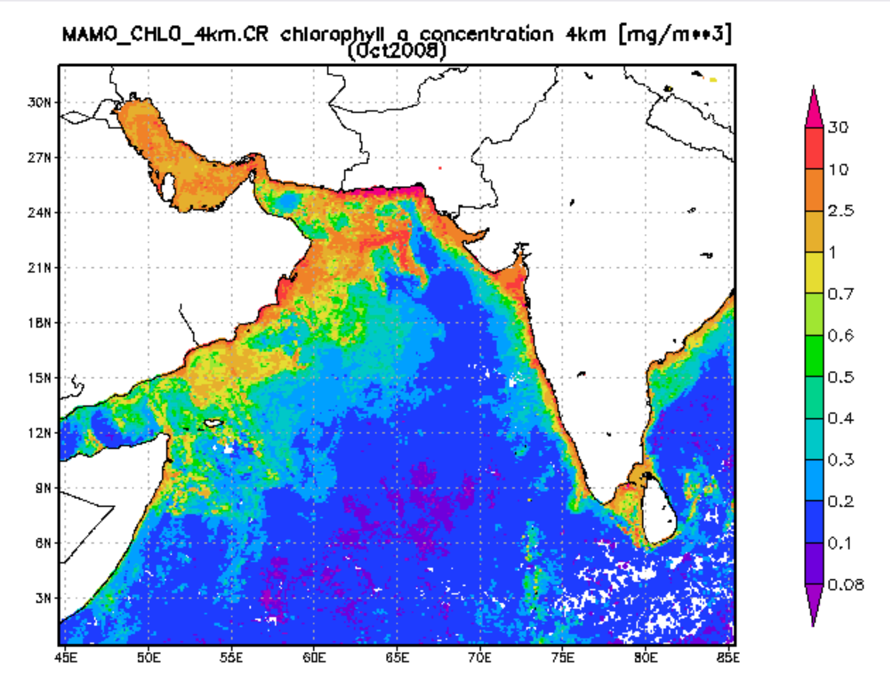
New standard data products from NASA

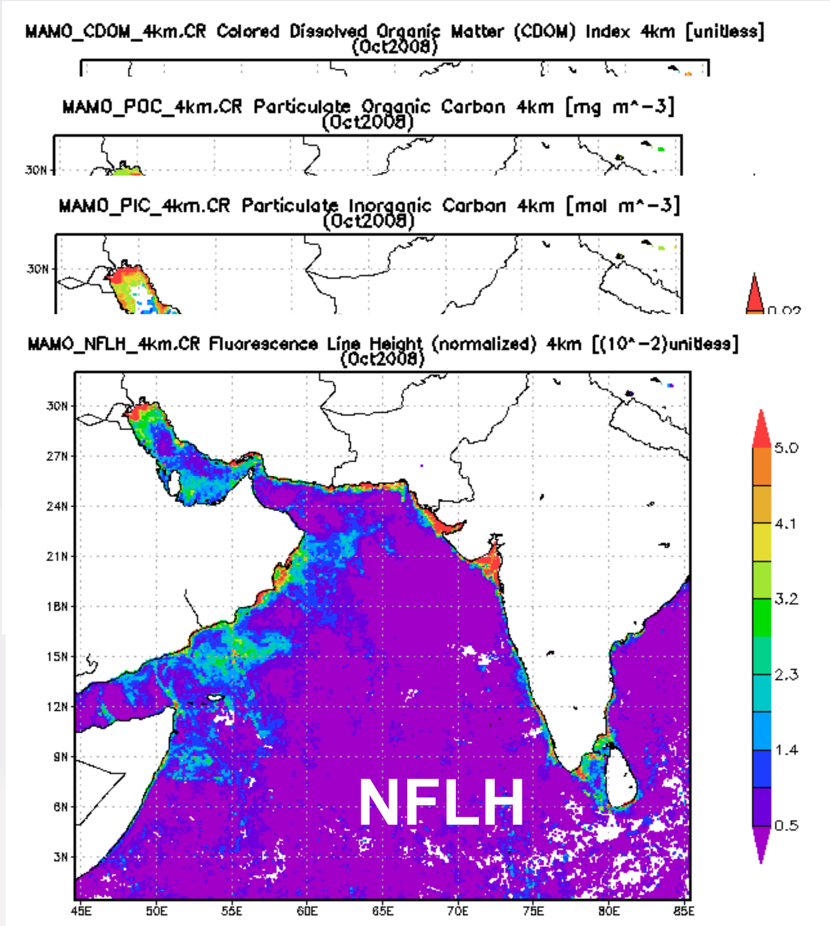
Algorithm development has resulted in several new standard data products from NASA, in addition to chlorophyll
These products are:

- Particulate Organic Carbon (POC)
- Particulate Inorganic Carbon (PIC) – aka $CaCO_3$
- Photosynthetically Available Radiation (PAR)*
- Normalized fluorescence line height (NFLH)
- Colored Dissolved Organic Matter (CDOM) Index

* employed in primary production calculations

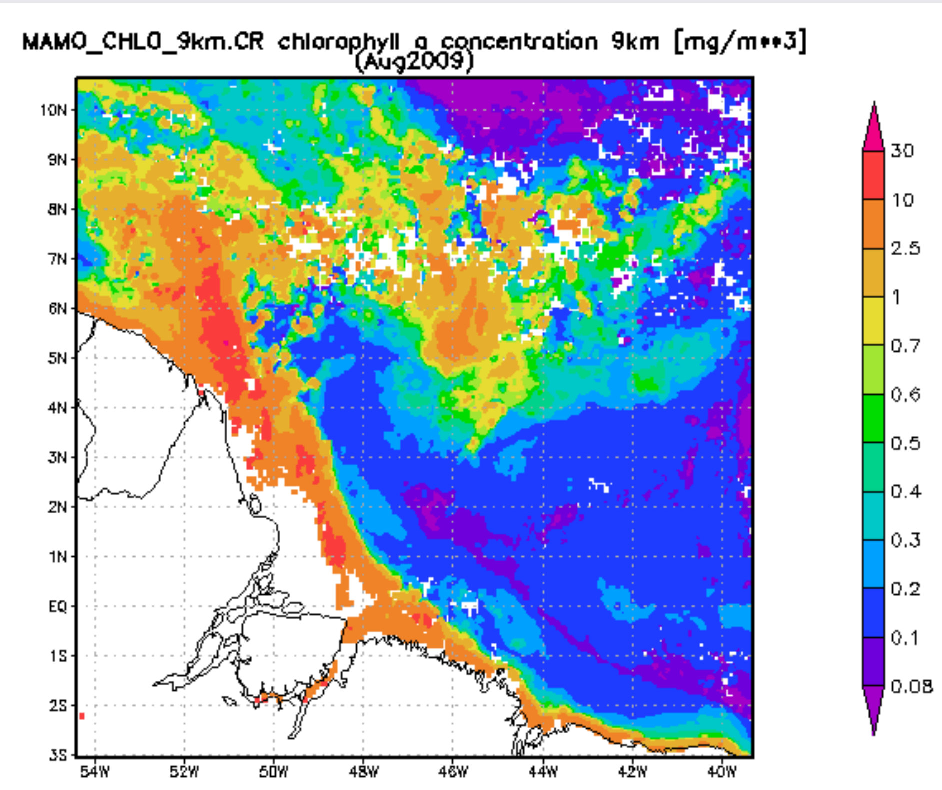
These products provide multi-faceted views of ocean processes. The example shown is the Arabian Sea in October 2008, near the end of the summer monsoon season.

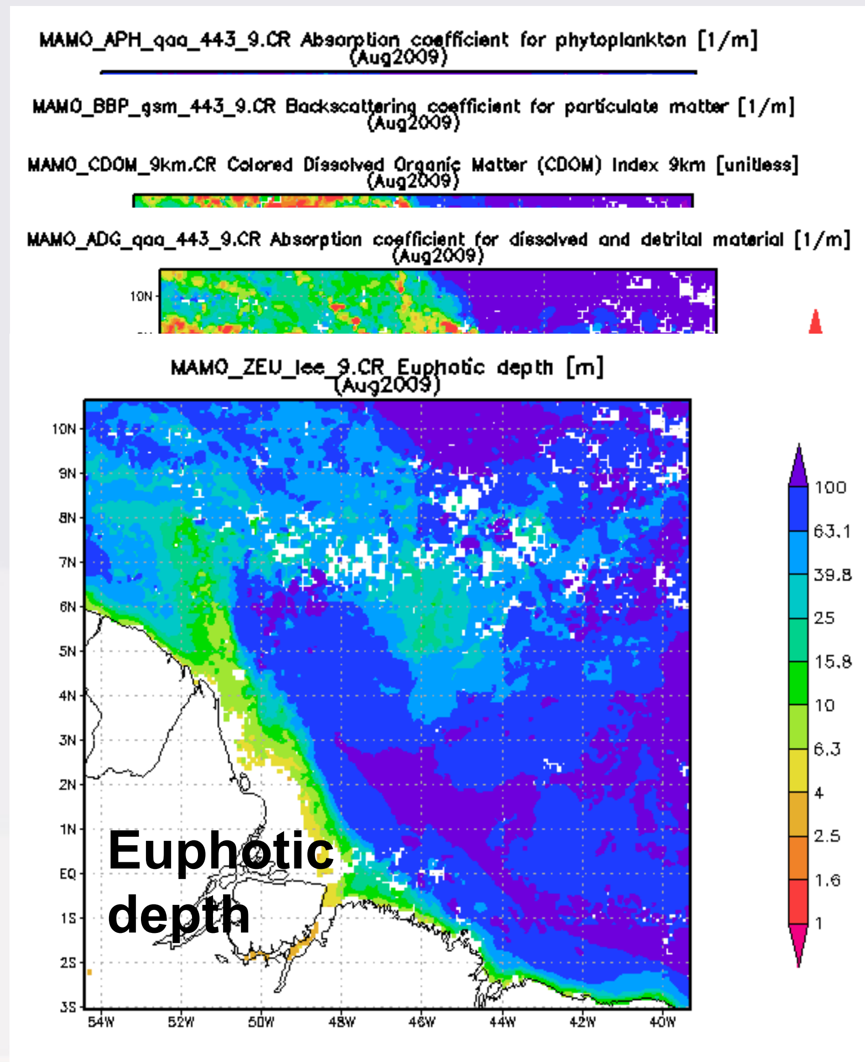




Created with the NASA Giovanni system

The IOP-based products, absorption and backscattering coefficients, provide additional insight into the constituents of color, particularly in the coastal zone.



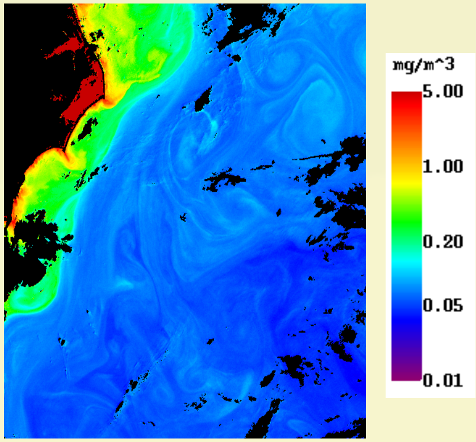


Created with the NASA Giovanni system

Current fields of fruitful research

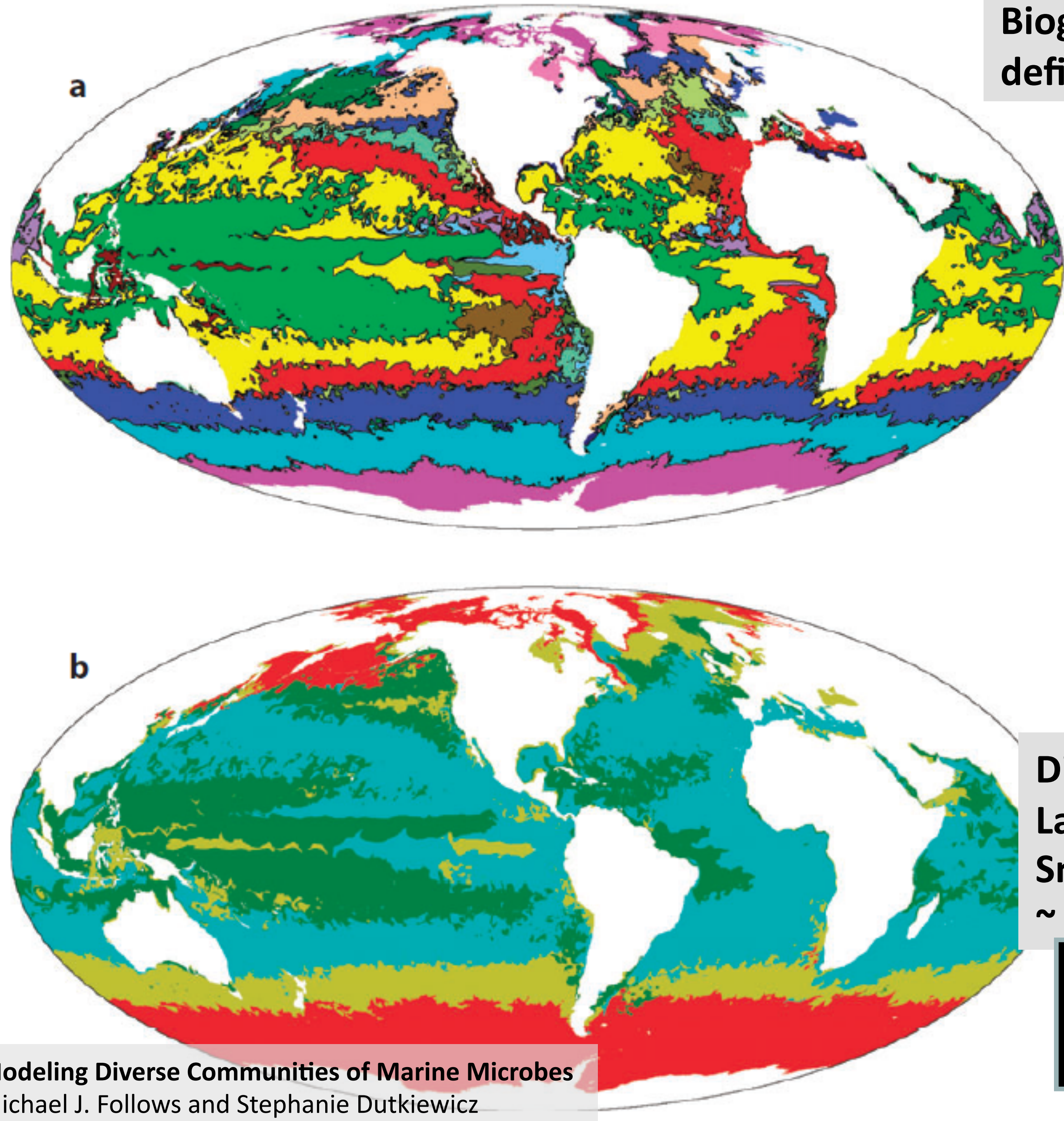
- Global dissolved organic matter budgets
- Refinement of particulate inorganic carbon estimates
- Advanced algorithms for chlorophyll utilizing fluorescence line height
- Detection of phytoplankton functional groups
- Better estimates in oligotrophic (low concentration) waters

(subject of Chuanmin Hu's presentation Thursday)



Ultimately trying to achieve better estimates of global net primary productivity

Biogeographical provinces defined by dominant species



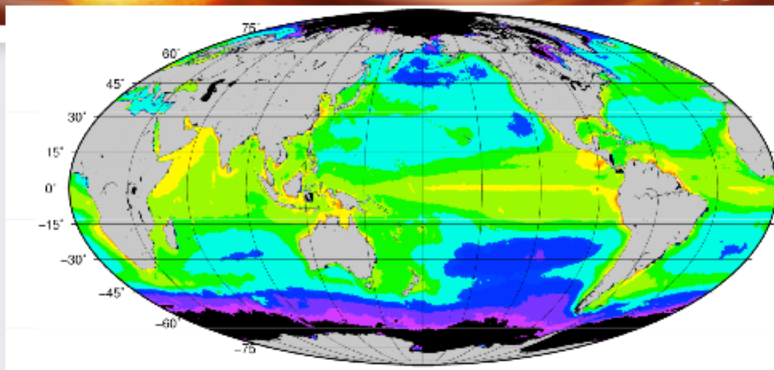
Species diversity in the global ocean complicates NPP estimation;

Species dominance will shift with climate change and general warming of ocean waters

Diatoms (red)
Large phytoplankton (yellow)
Small phytoplankton (blue)
~ Prochlorococcus (green)

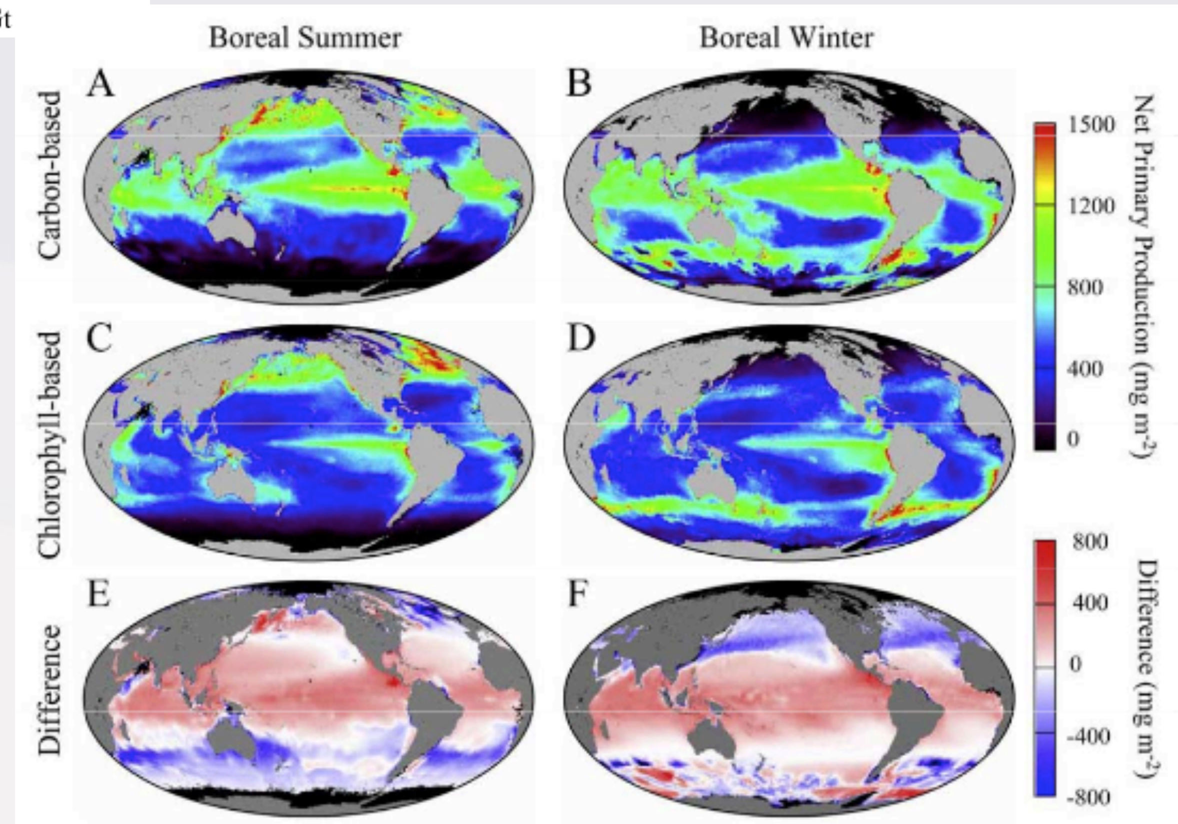
Modeling Diverse Communities of Marine Microbes
Michael J. Follows and Stephanie Dutkiewicz
Annual Reviews in Marine Science 3, 427-451.

Net Primary Production



Global PP from GlobColour chlorophyll (~60 Gt

- Several models exist
- Chl-based mostly (+ SST, PAR)
- Carbon-based estimates are *recent*
- Not fully reconciled



Figures courtesy of Stephane Maritorena

Five great questions still to be answered (definitively):

1. Can we continue to improve estimates of the pools of carbon in the oceans – living phytoplankton, POC, PIC, dissolved organic carbon – with current remote sensing capabilities? How much better are estimates based on new products, such as a_{ph}?

2. How much better can ocean primary productivity estimates be made utilizing "physiological" data, such as NFLH? Does this enable better quantification of iron stress in low-Fe waters?

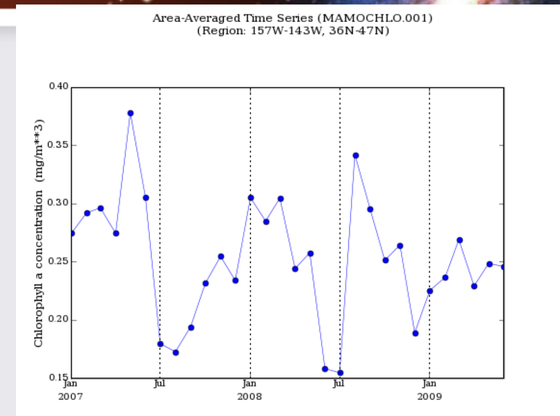
3. How much will coastal zone primary productivity estimates change with improved chlorophyll algorithms?

4. Will ocean primary productivity ultimately increase or decrease with increasing surface temperatures associated with climate change? How will altered species composition and distribution affect this?

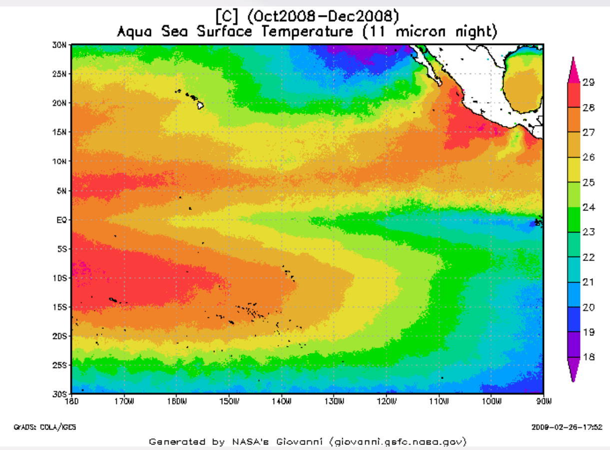
5. Beyond ocean color radiometry, what other kinds of data – both in situ and remotely-sensed – are most vital to aid quantification of the ocean carbon cycle?

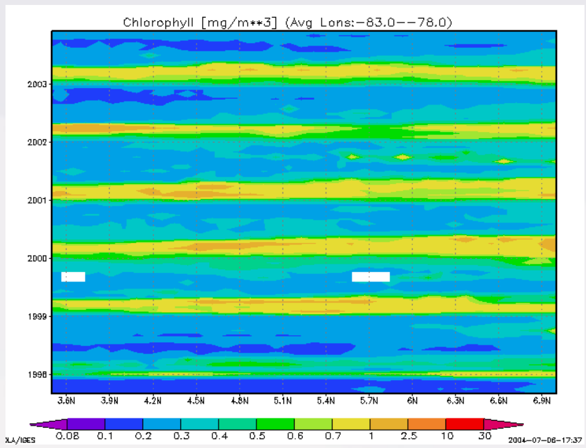
Improving data product ease-of-use:

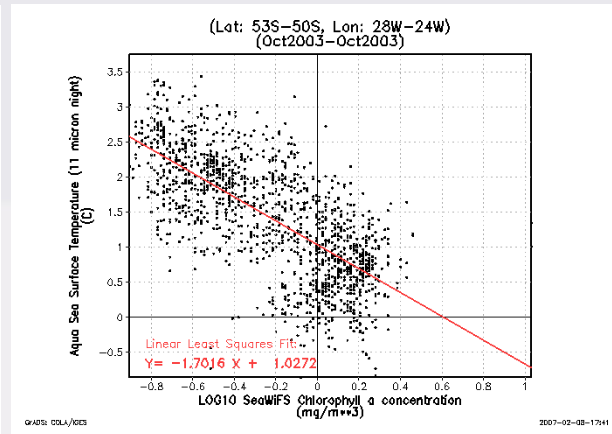
✓ **NASA OBPG and Water Quality for Coastal and Inland Waters data products available in Giovanni**



✓ **Bio-optical profiling buoy (NOPP) users will be able to access data for any profile location**







Giovanni has been used for many ocean ecosystem studies to provide oceanographic context!