Integrating remote sensing with ecosystem modeling at multiple scales

NASA Carbon Cycles

and Ecosystems Meeting

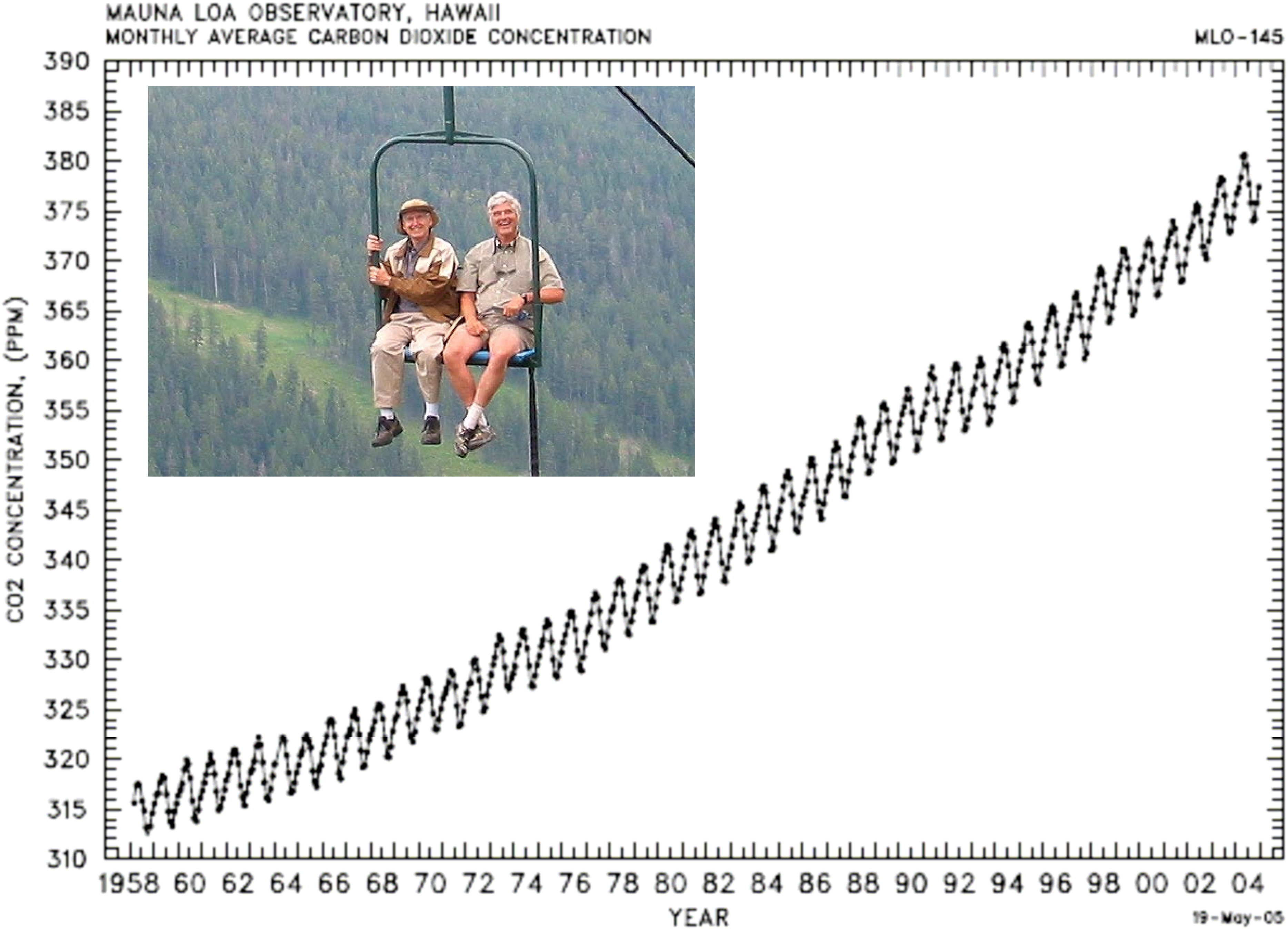
Univ. of Maryland

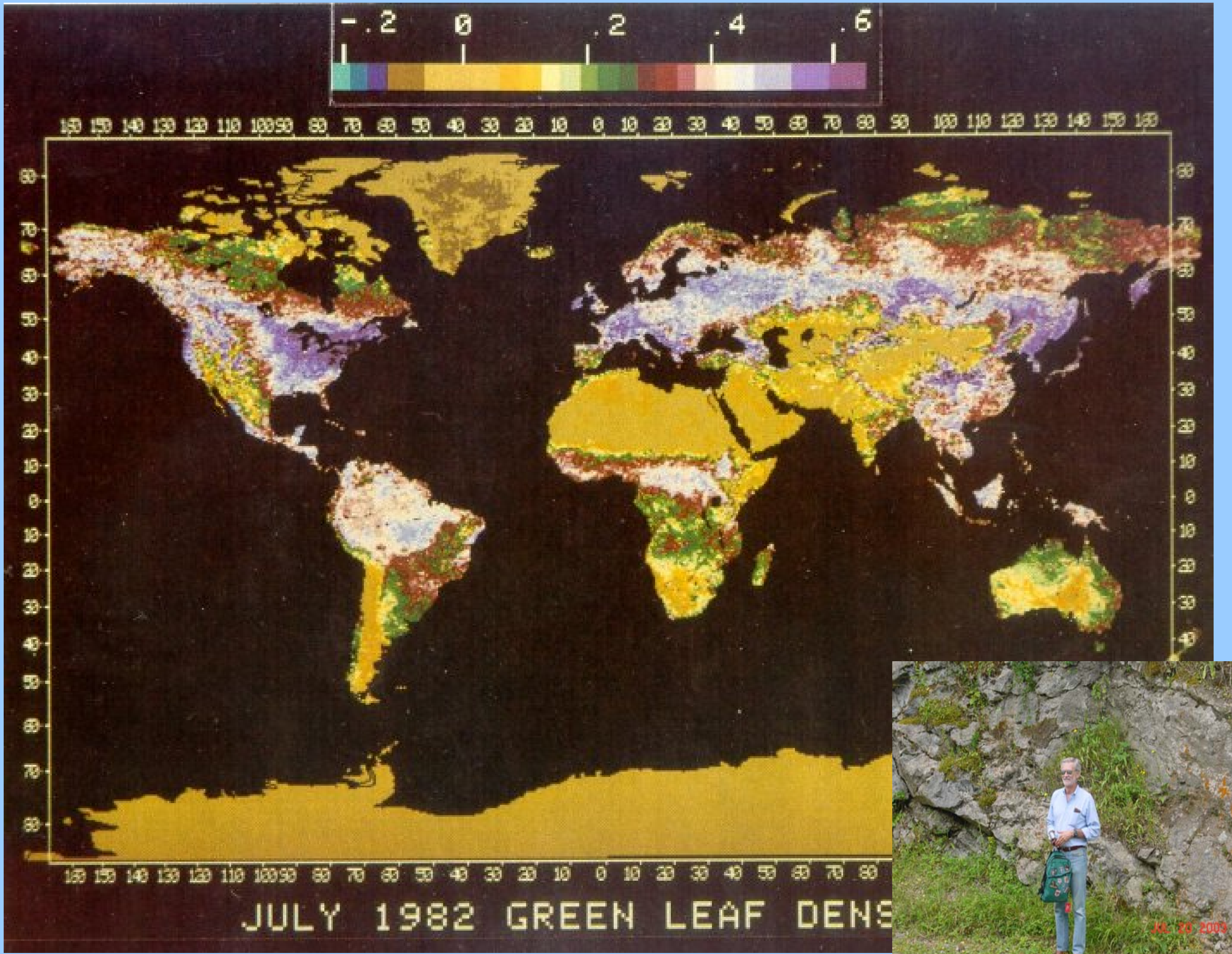
August 23 2006

Steven W. Running

University of Montana

Missoula, MT. USA


MAUNA LOA OBSERVATORY, HAWAII
MONTHLY AVERAGE CARBON DIOXIDE CONCENTRATION
MLO-145
CO2 CONCENTRATION, (PPM)
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
1958 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04
YEAR
19-May-05


-.2 0 .2 .4 .6
JULY 1982 GREEN LEAF DENS

Driving ecosystem models with satellite data, concept for NASA Global Habitability, 1983

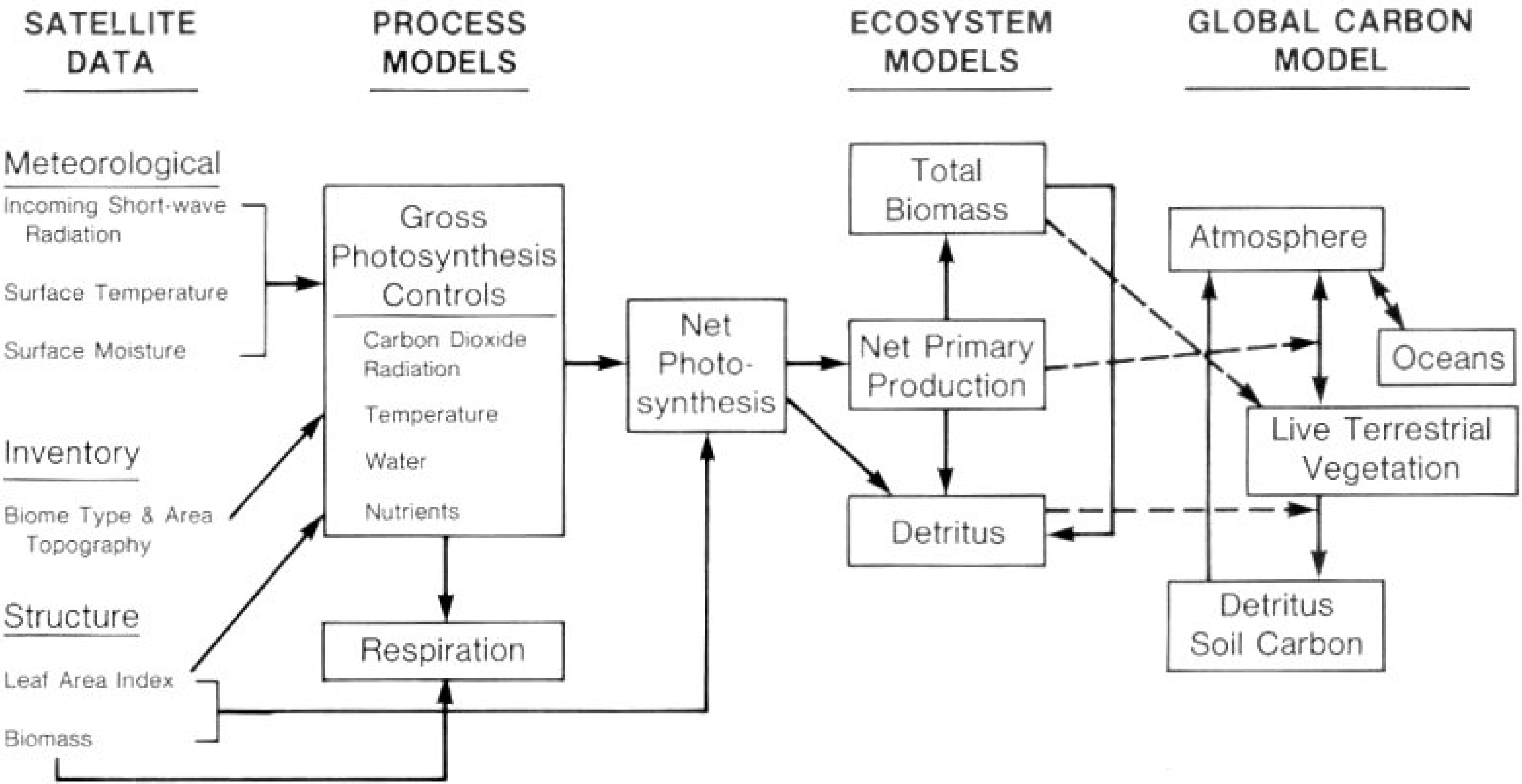
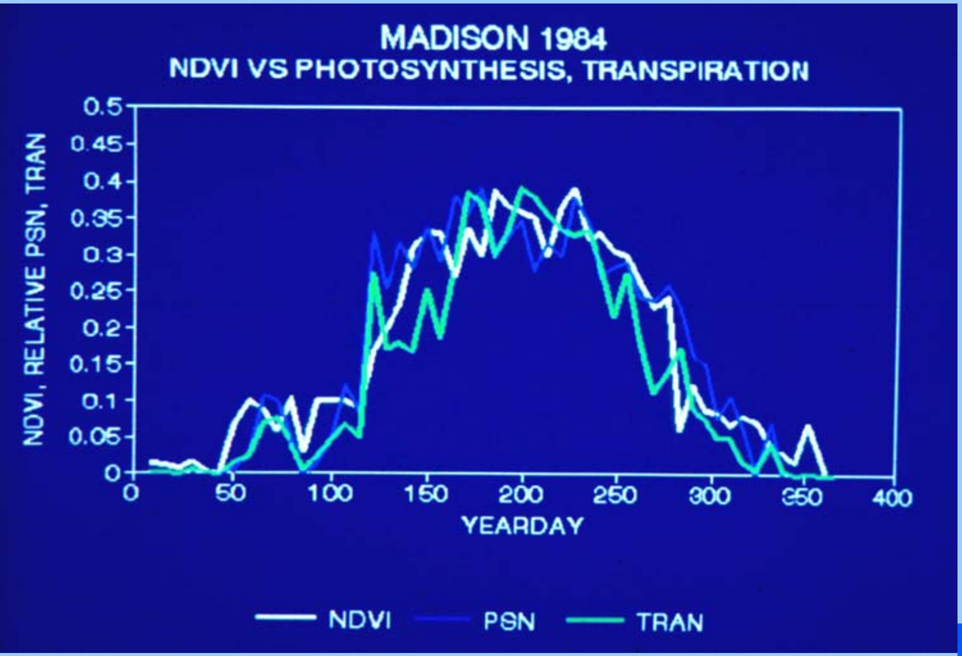
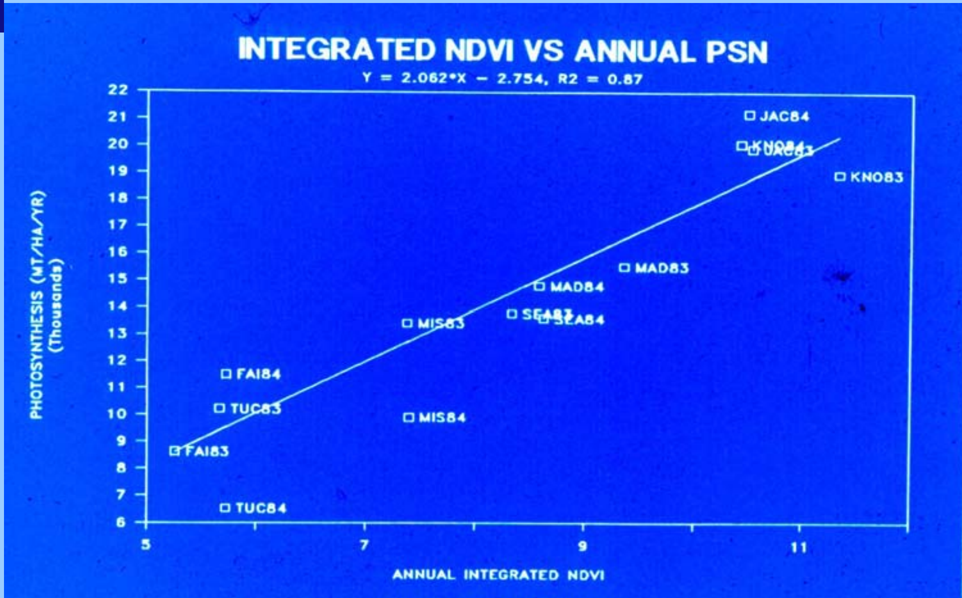


Figure 2. Organizational diagram of a proposed model of net primary production for a coniferous forest. All driving variables are derived from satellite data. Potential linkages to a global carbon model are shown by dashed lines (Running, 1984).

NDVI Related to Photosynthesis





- Running and Nemani 1988

Original FOREST-BGC flow diagram, emphasizing dual time steps, critical role of LAI, C-H2O-N interactions, and remote sensing applications, 1988

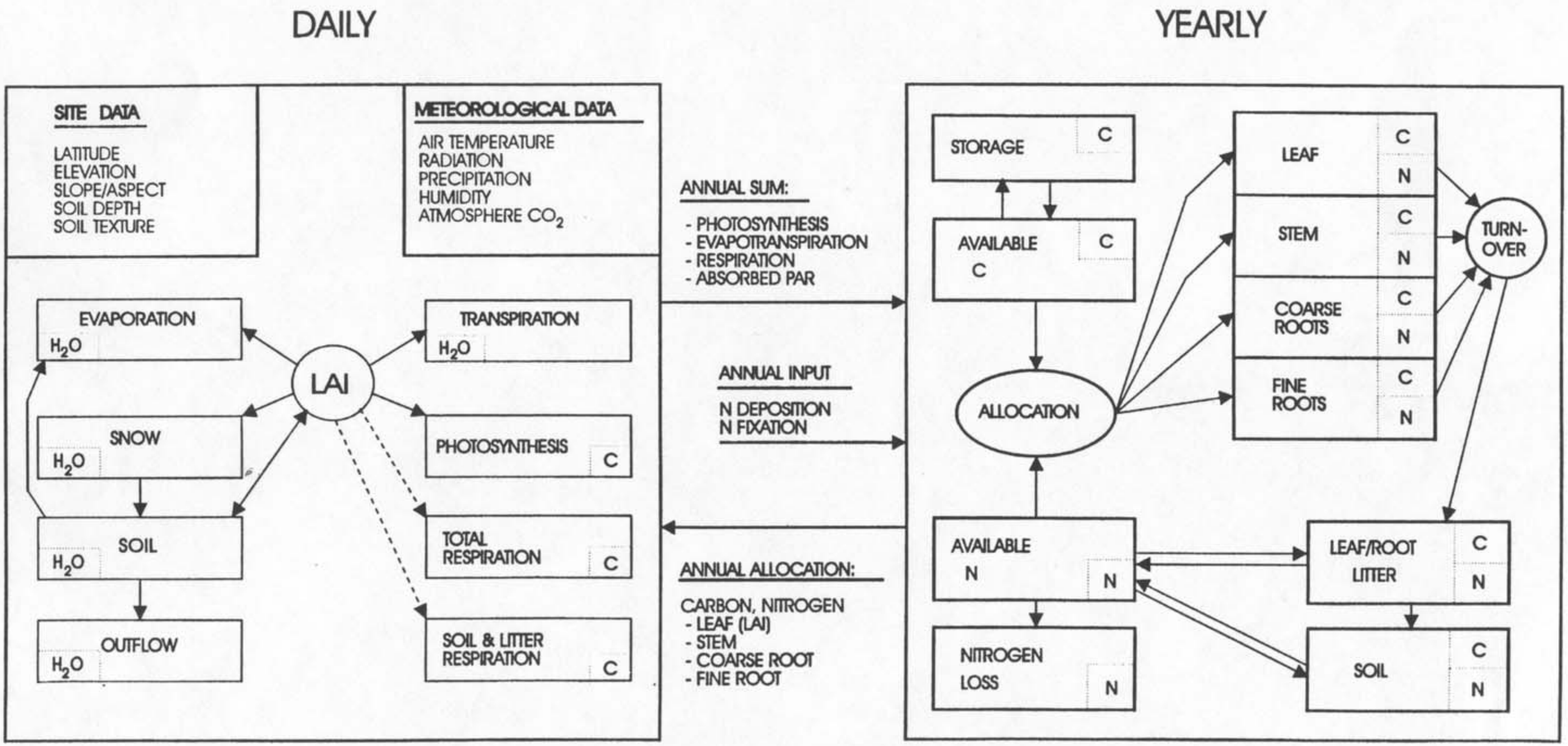
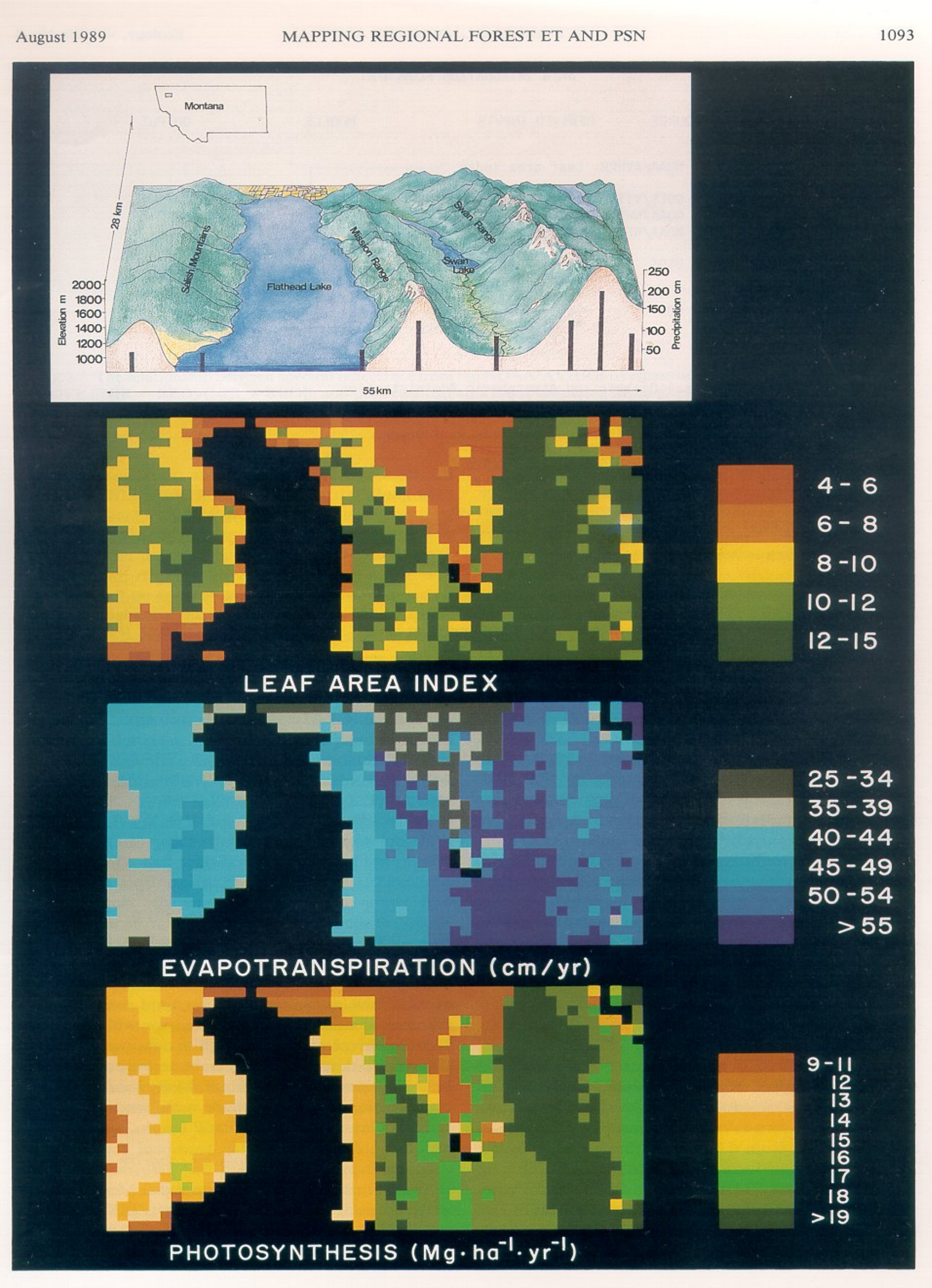


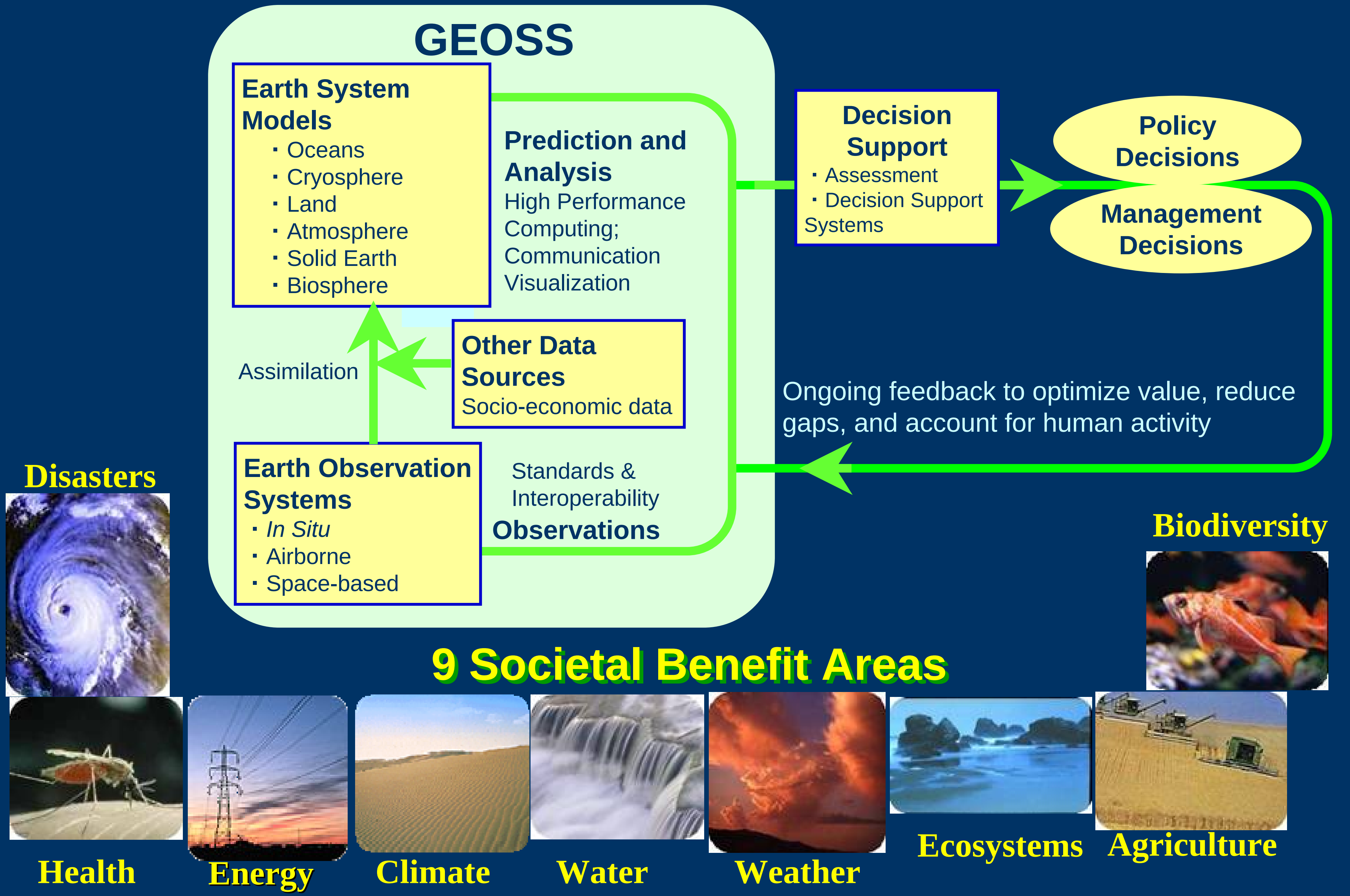
Figure 1.2. Compartment flow diagram for the FOREST-BGC ecosystem simulation model. This diagram illustrates the state variables of carbon, water, and nitrogen, the critical mass flow linkages, the combined daily and annual time resolution, and the daily meteorological data required for executing the model. The major variables and underlying principles associated with the model were developed specifically for application at multiple time and space scales, and for compatibility with remote-sensed definition of key ecosystem properties.

First? spatial ecosystem model driven by remote sensing



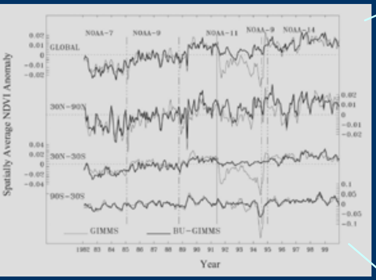
Running et al. Ecology 1989

GEOSS
(Global Earth Observation System of Systems)

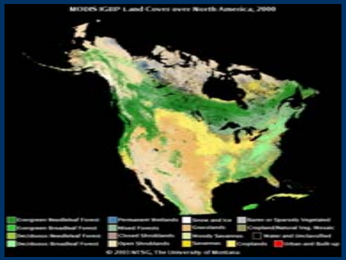


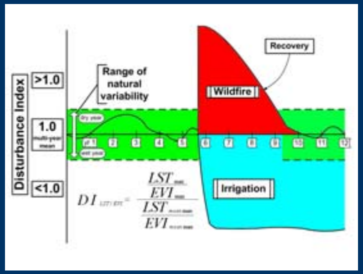
Terrestrial Carbon Monitor

SATELITE DATA

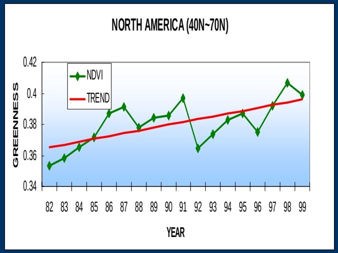


LANDCOVER

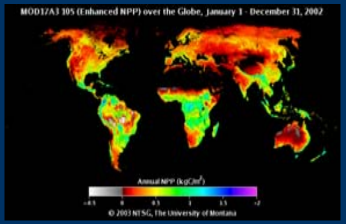


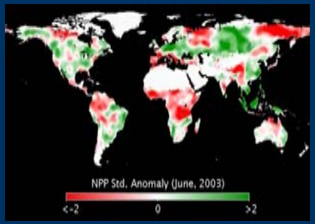


GROWING SEASON

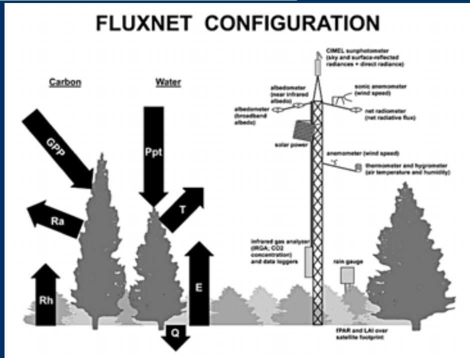


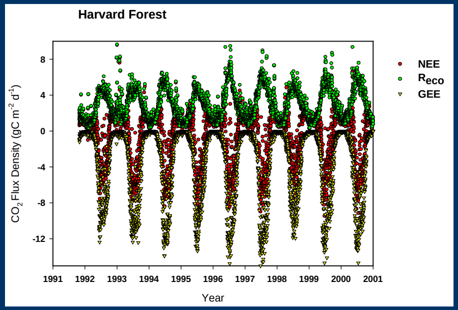
PRIMARY PRODUCTION





GROUND DATA

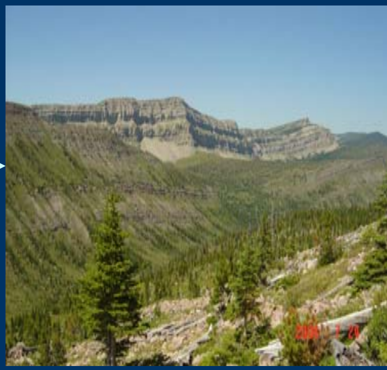




DYNAMIC GLOBAL LAND TRANSITIONS

LANDUSE ⟷ **LANDCOVER**

[Human control] [Biophysically controlled]



Human Systems ⟵ **HUMAN DECISION MAKING** ⟶ **Ecological Systems**

political/economic choices

Human Systems
- **Institutions**
- **Culture**
- **Technology**
- **Population**
- **Economic**

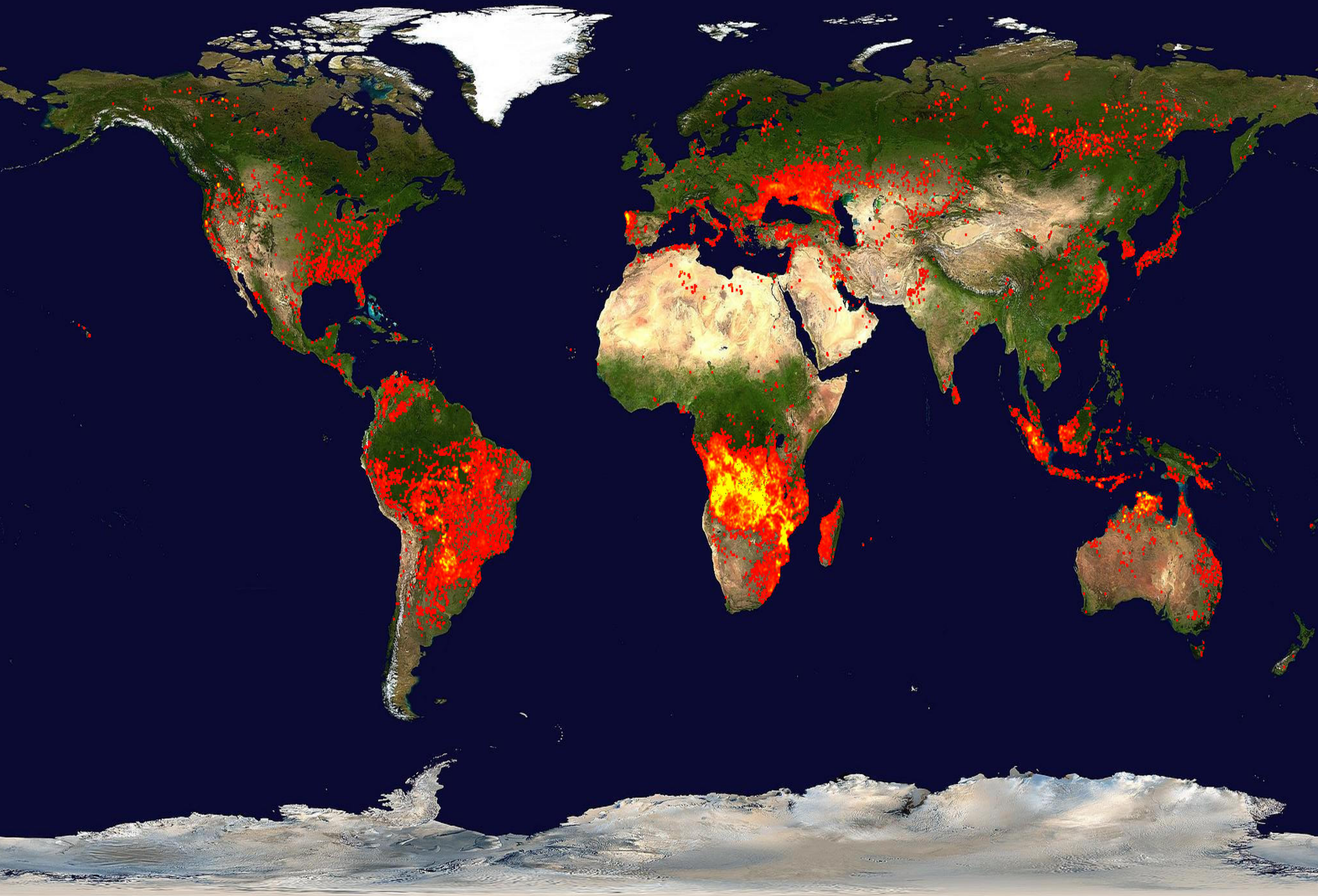
Ecological Systems
- **Biogeochemistry**
- **Genetic bank**
- **Water**
- **Air**

Economic Problems
-poverty
-unequal wealth
-war
-globalization

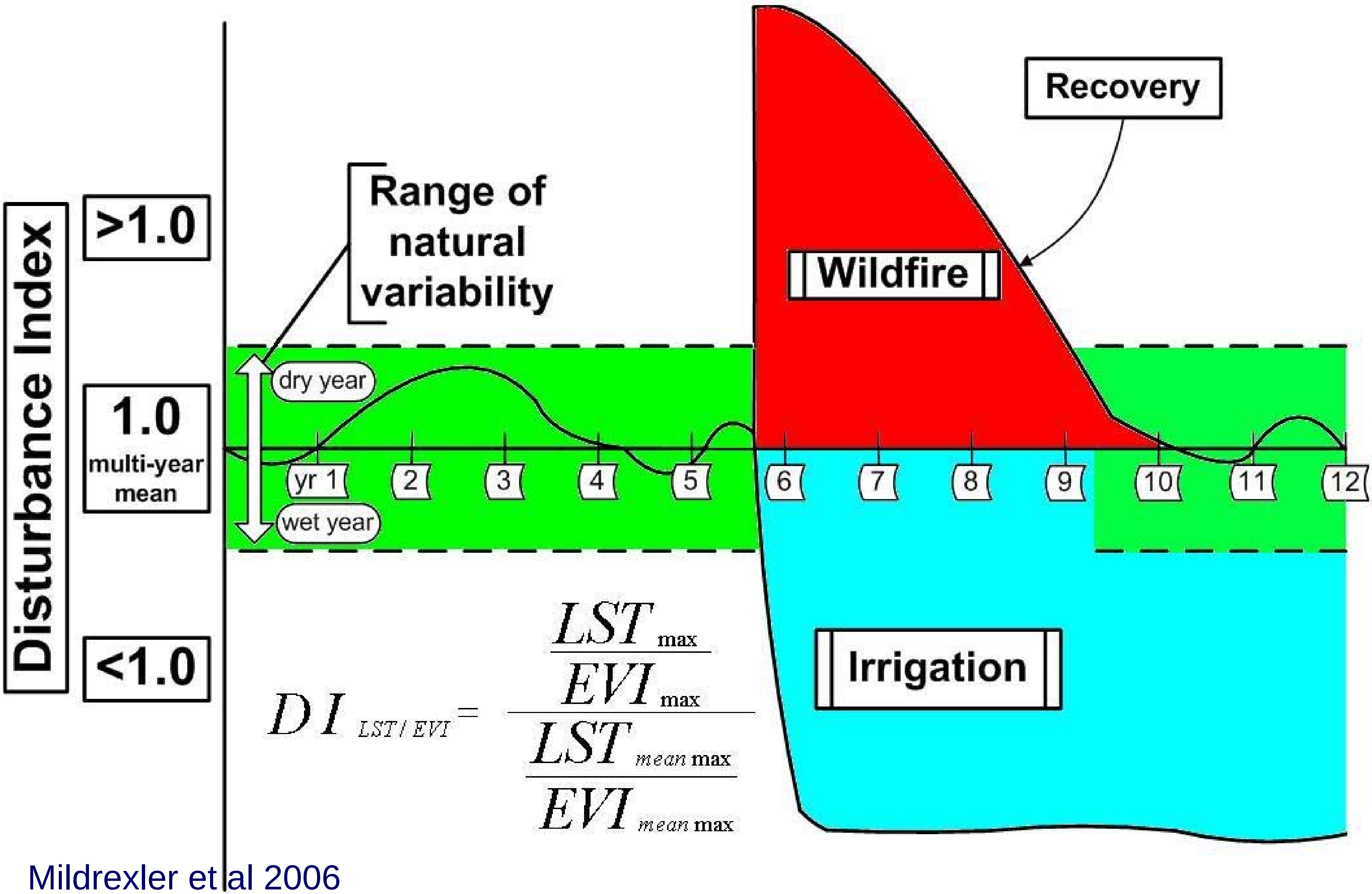
Ecological Problems
-pollution
-diseases
-food/fibre/fuel shortages
-overcrowding

Ecosystem goods & services
-clean air/water
-waste recycling
-food/fibre/fuel
-recreation

MODIS Fire Detection YD 211-220, 2006



GLOBAL Generalized Disturbance Index



$$DI_{LST/EVI} = \frac{\dfrac{LST_{max}}{EVI_{max}}}{\dfrac{LST_{mean\,max}}{EVI_{mean\,max}}}$$

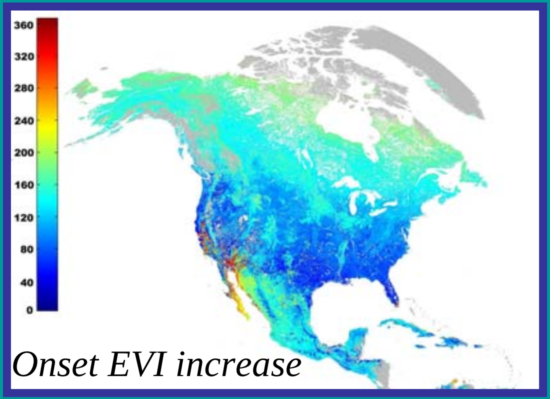
Mildrexler et al 2006

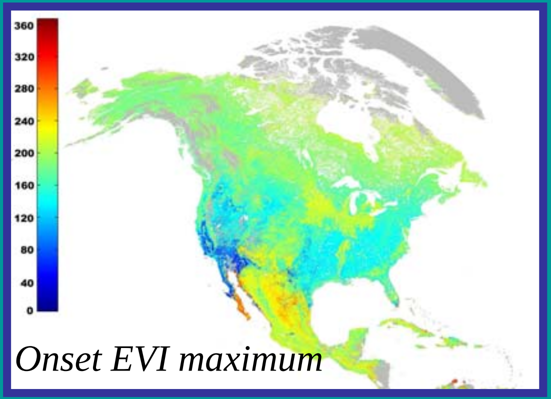
MOD12Q2: Global Vegetation Phenology

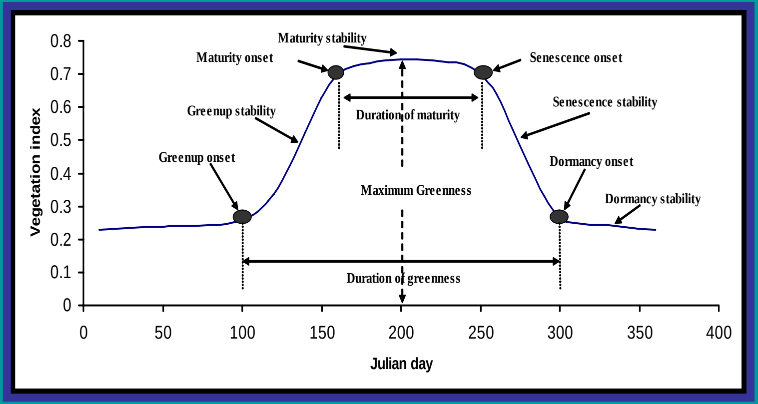
From Mark Friedl, Boston Univ.

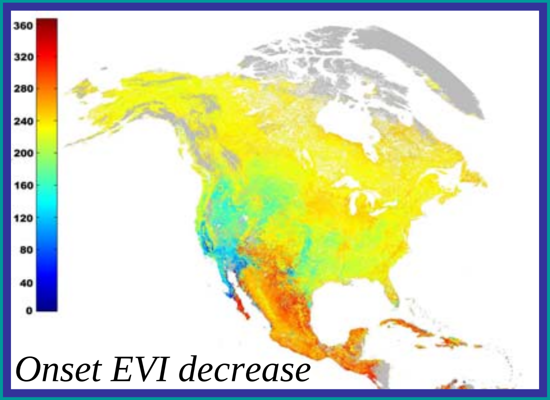
First global products for vegetation phenology based on MODIS EVI data released for 2001-2004

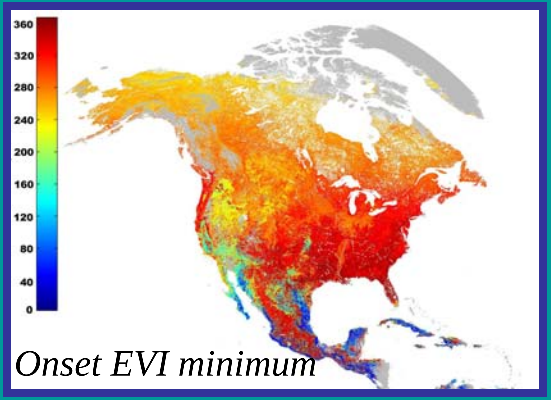
- Identifies key transition dates in growing season



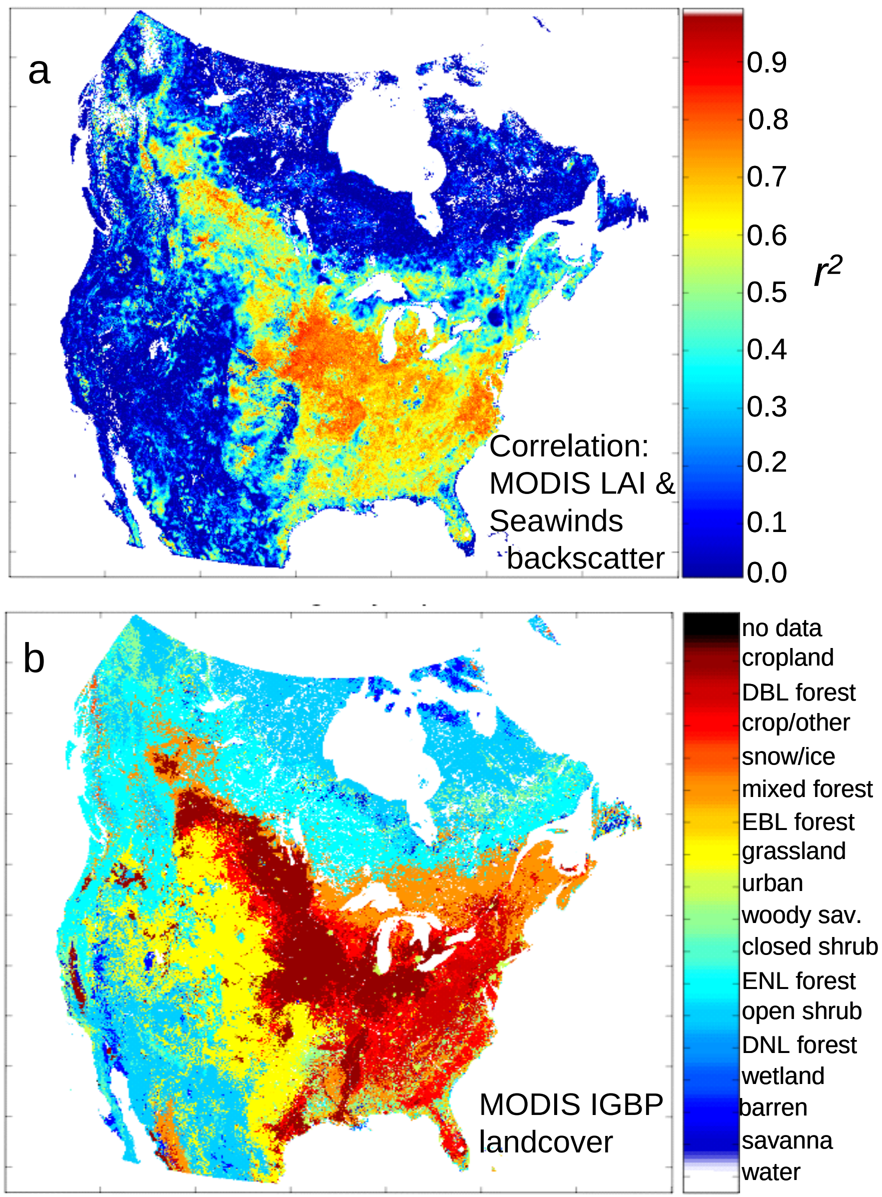








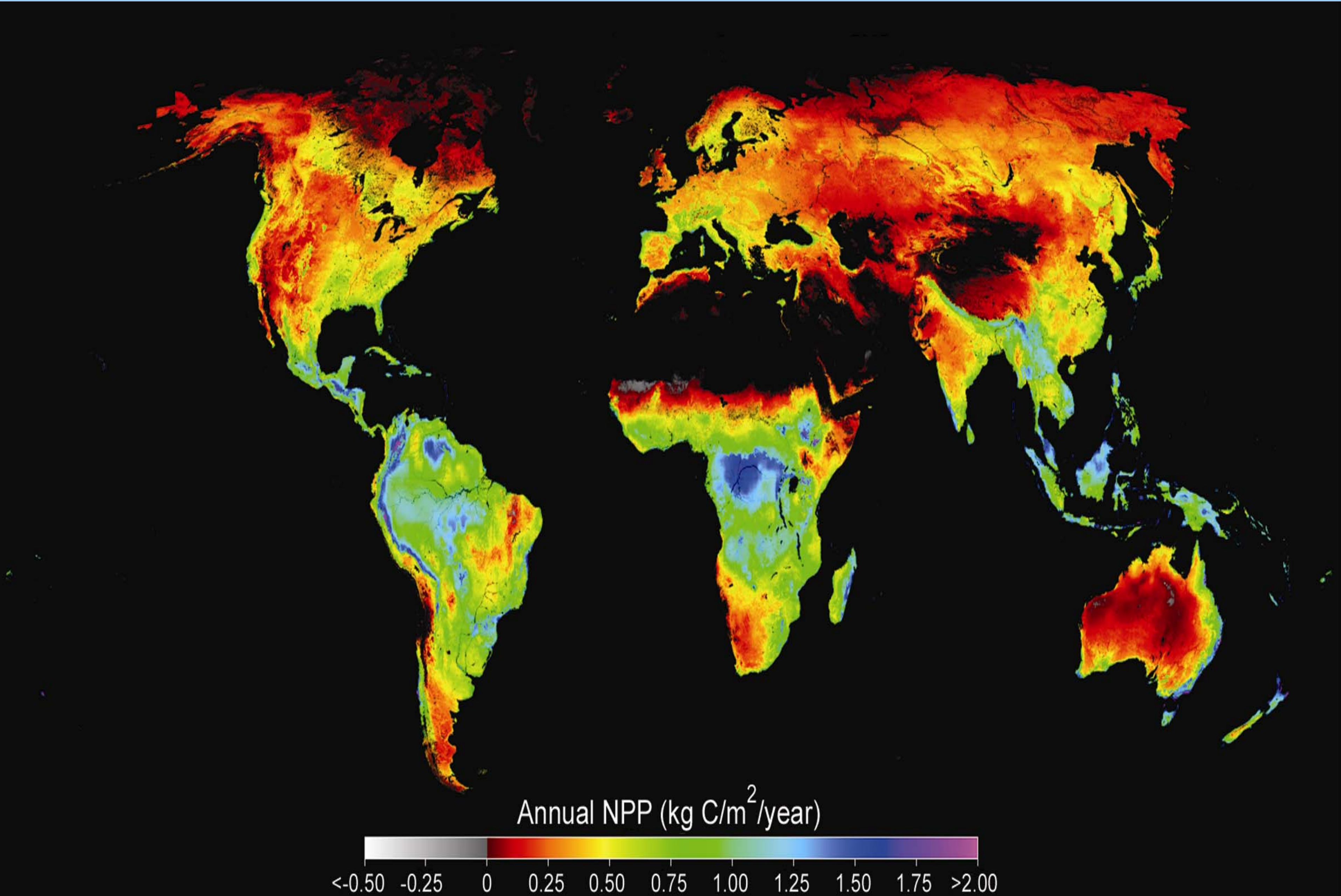
Developing an Integrated MODIS-SeaWinds Phenology Measure



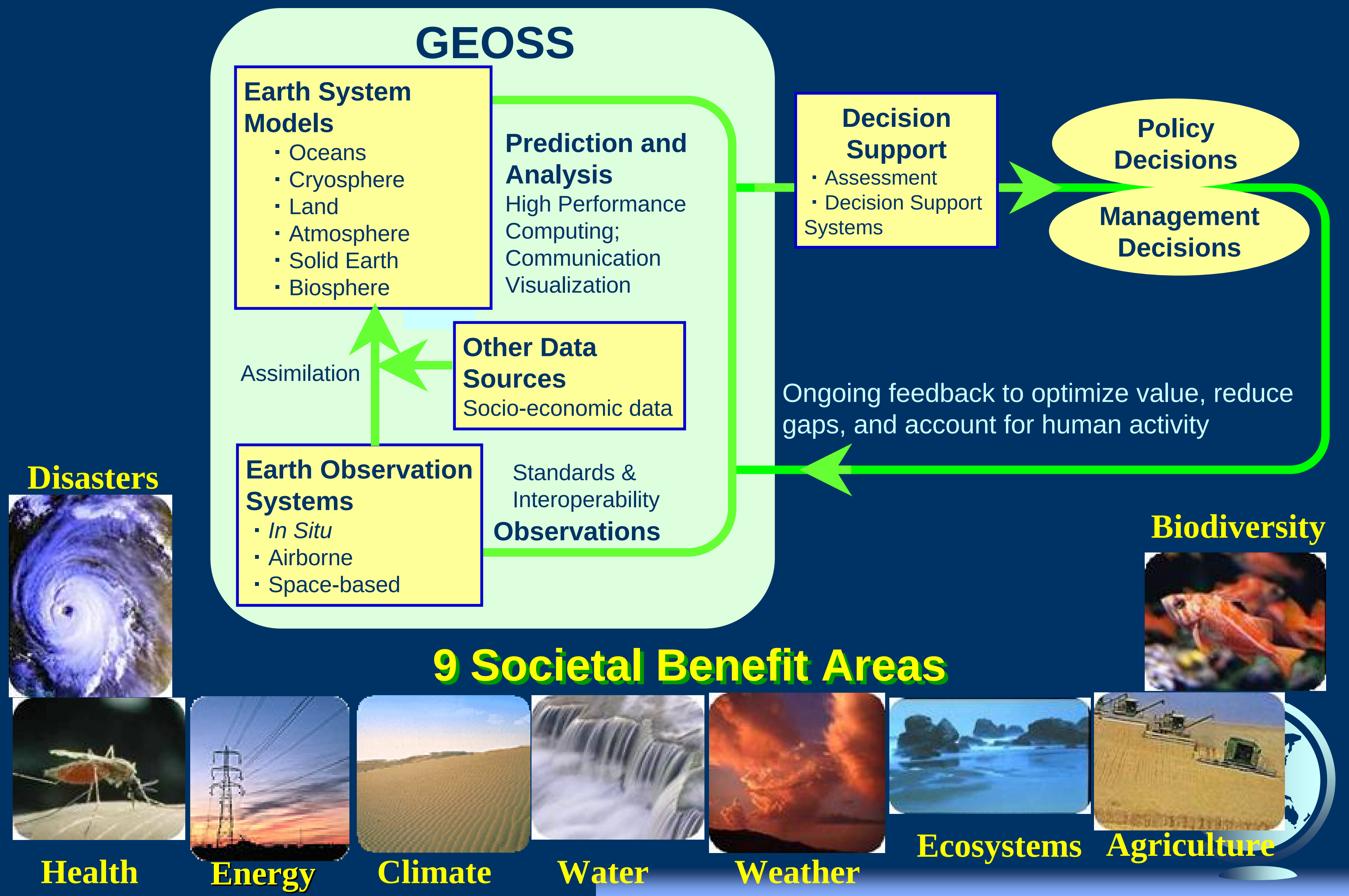
Map (a) of the statistical correspondence (r^2) between growing season 8-day composite MODIS LAI (MOD15A2) and SeaWinds Ku band backscatter for January 2000 through August 2002 for North America. Statistical correspondence is lower where LAI seasonal variability is small (e.g., evergreen forests) and where biomass is low (arid and semiarid shrublands). **The combined information from MODIS and SeaWinds may provide an improved measure of vegetation phenology that is less constrained by atmospheric aerosol contamination (e.g., clouds, smoke) and solar illumination effects.**

Source: Frolking, S., T. Milliman, K.C. McDonald, J. Kimball, M. Zhao, and M. Fahnestock, 2006. *J. Geophys. Res.* 111, doi:10.1029/2005JD006588.

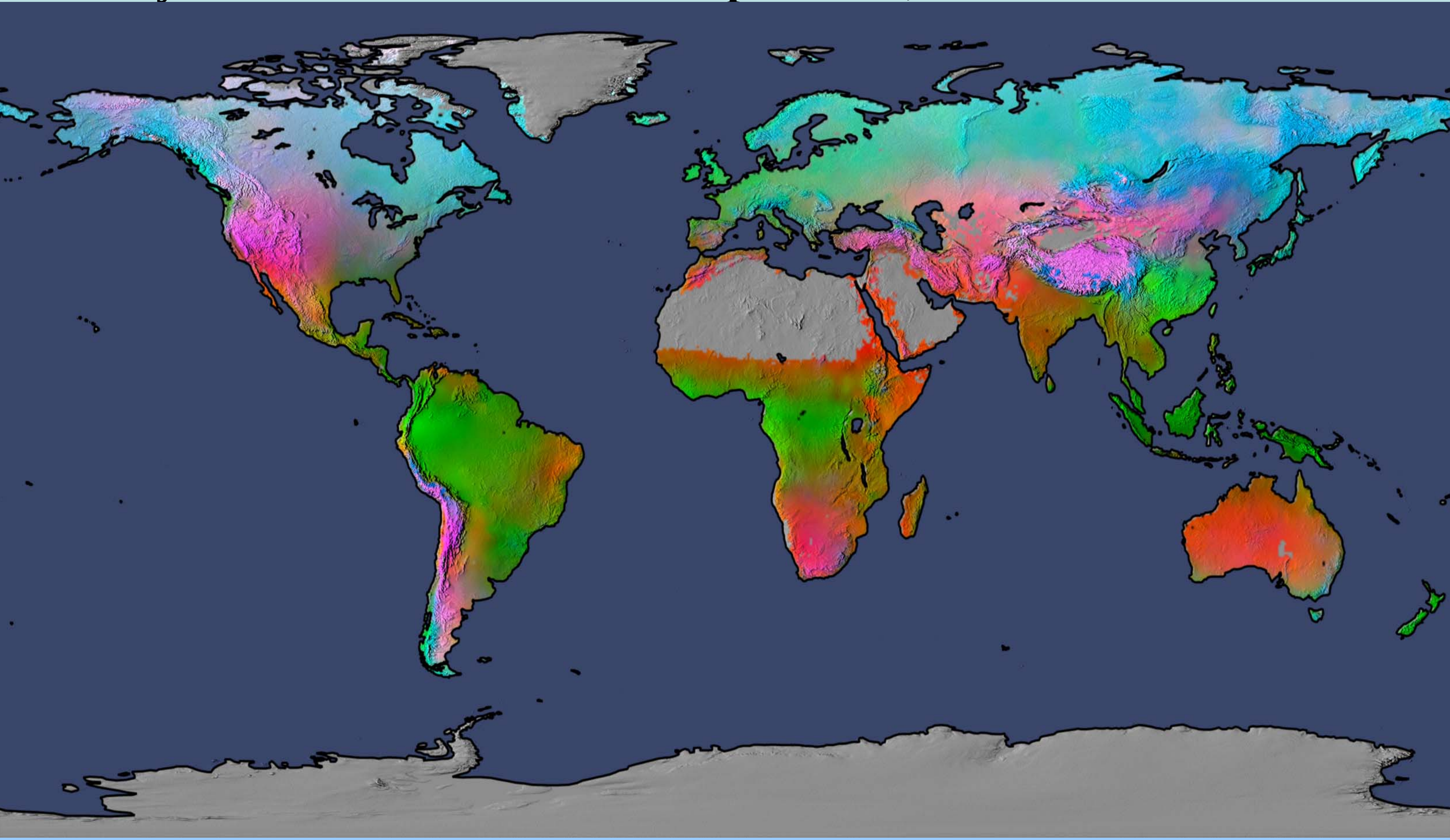
MODIS ANNUAL LAND NPP



GEOSS
(Global Earth Observation System of Systems)



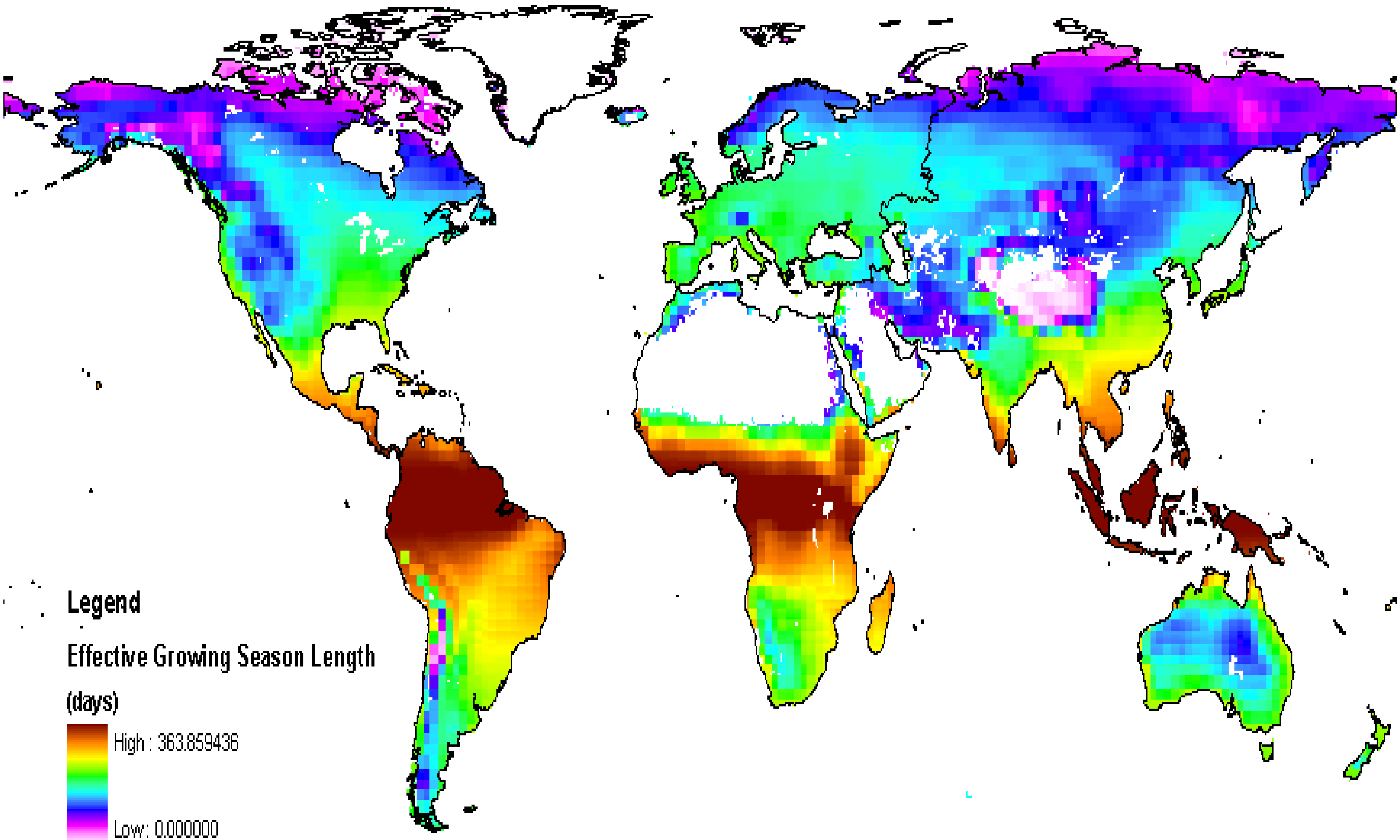
Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.



Water = 40%, Temperature = 33%, Radiation = 27%

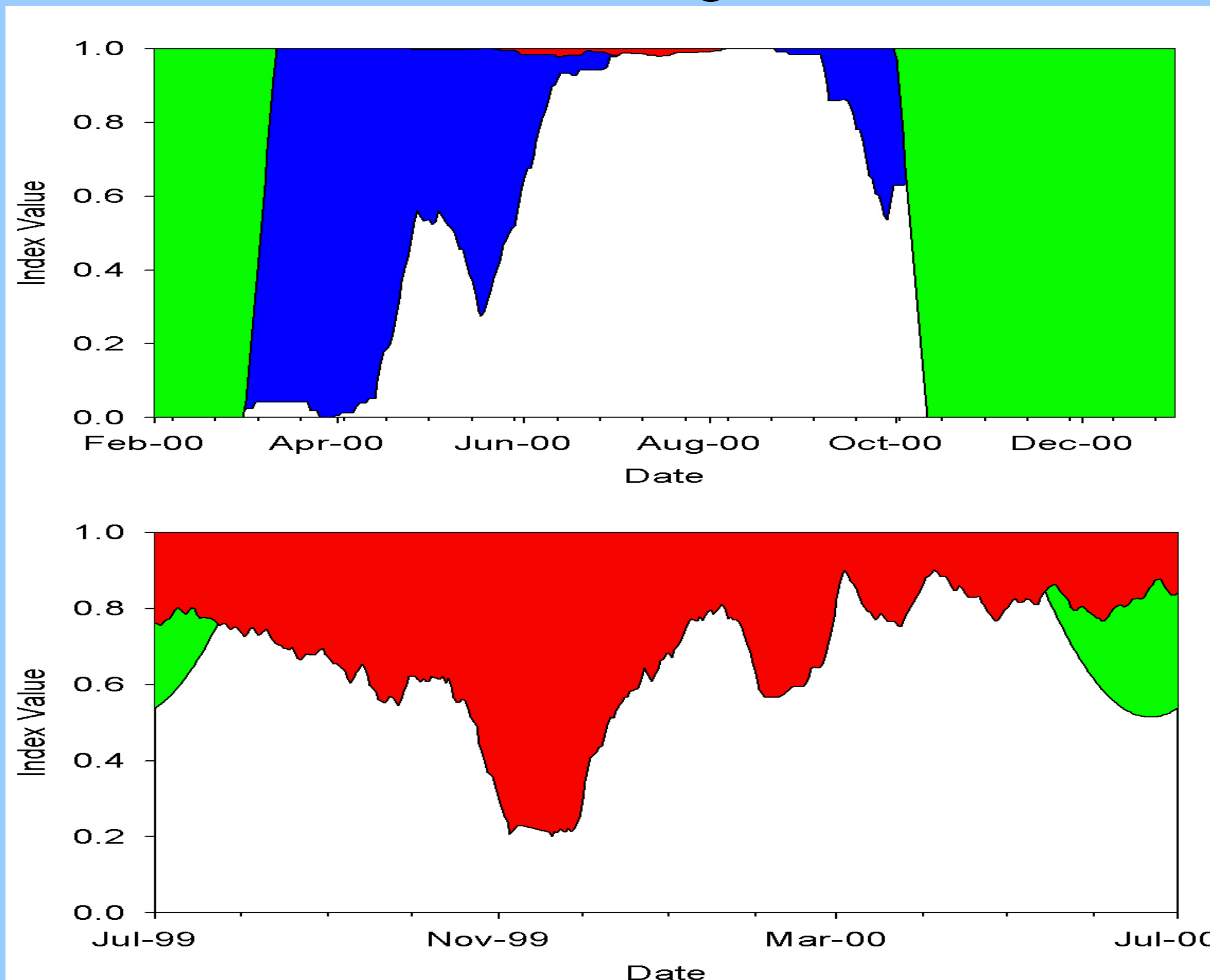
Nemani et al., Science June 6th 2003

Global Effective Growing Season Length



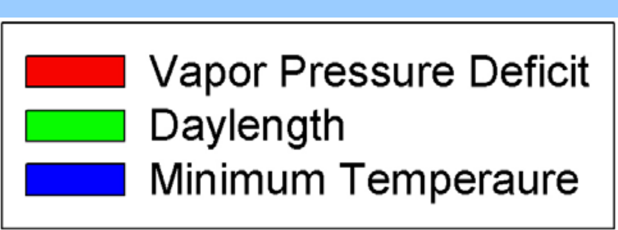
Jolly, Nemani, Running. Global Change Biology 2005

Seasonal Growing Season Constraints



Russia, Boreal

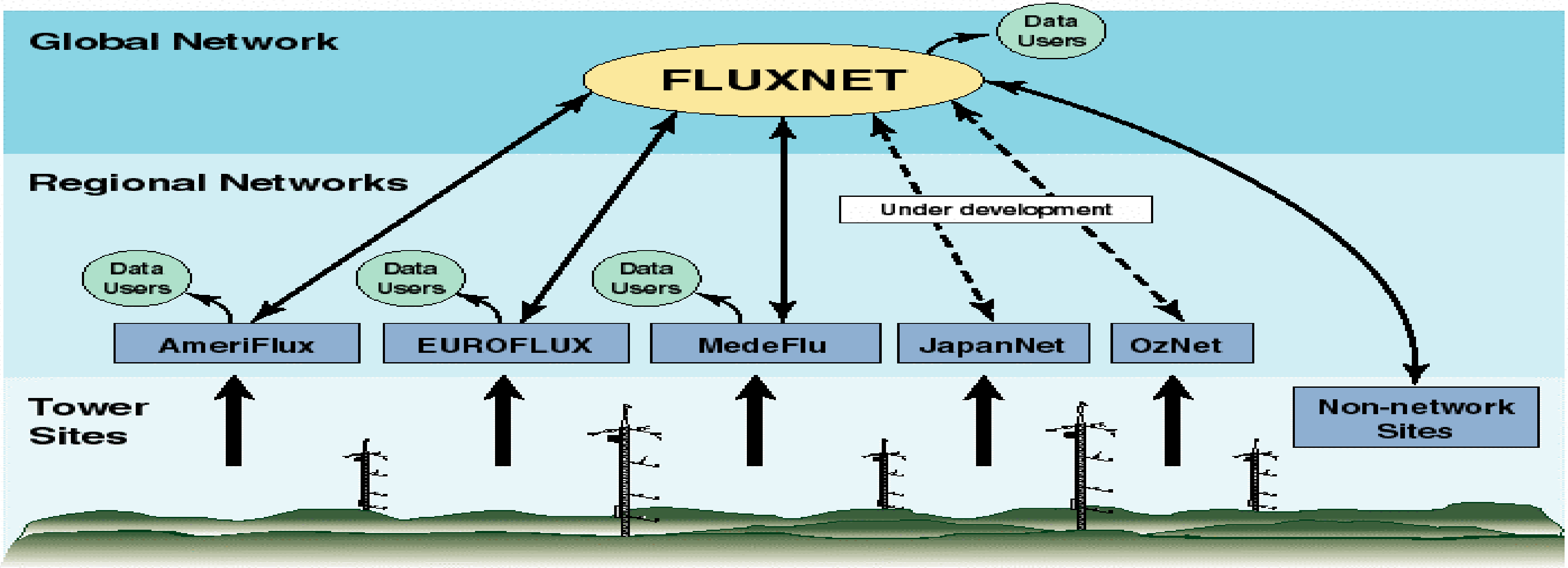
Africa, Savannah

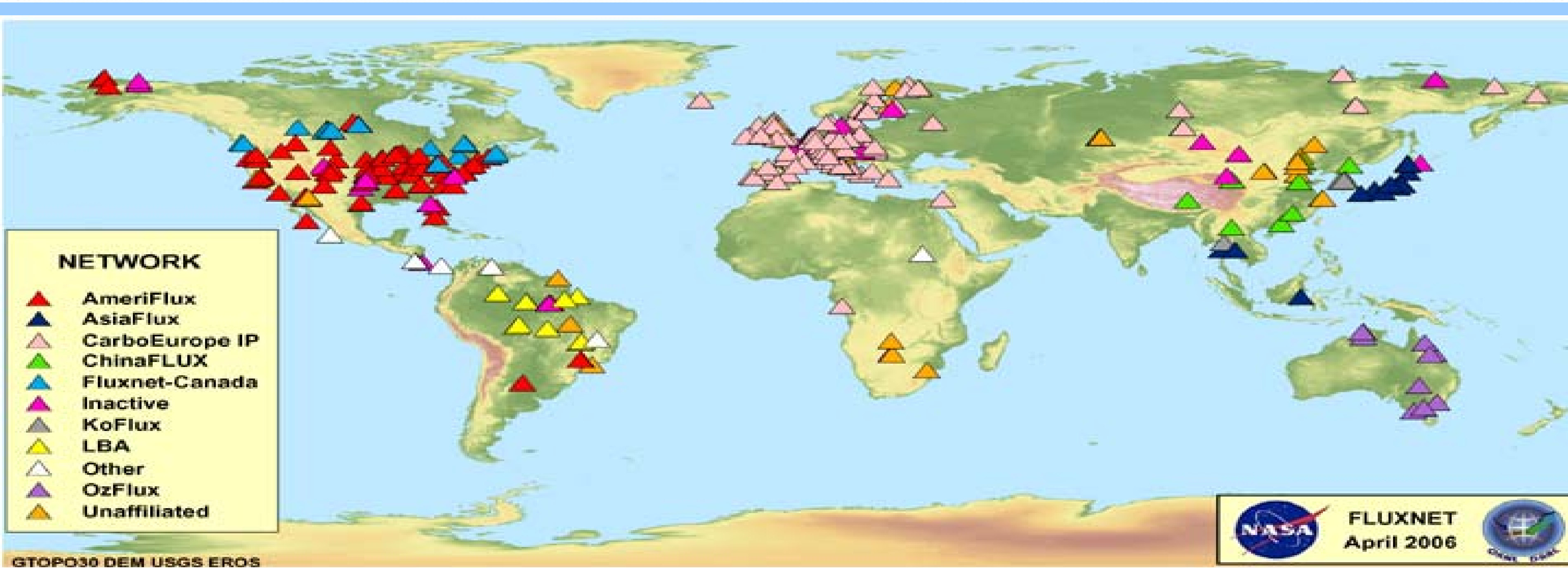


Jolly, Nemani, Running. Global Change Biology 2005

ORNL 98-914/lmh

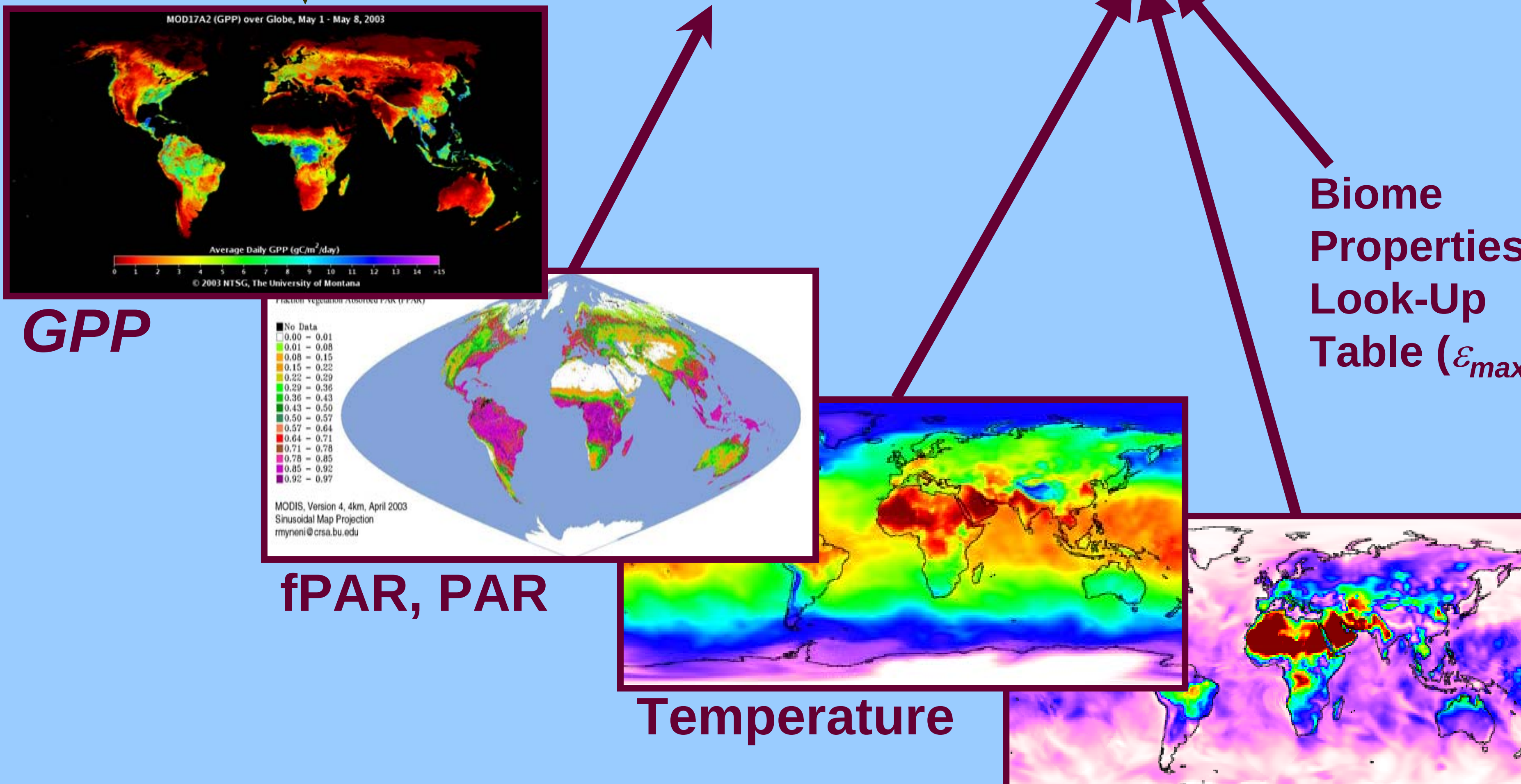
Architecture of Global/Regional Flux Networks





GPP = Light X Conversion Efficiency

GPP = f (PAR) x ε



GPP

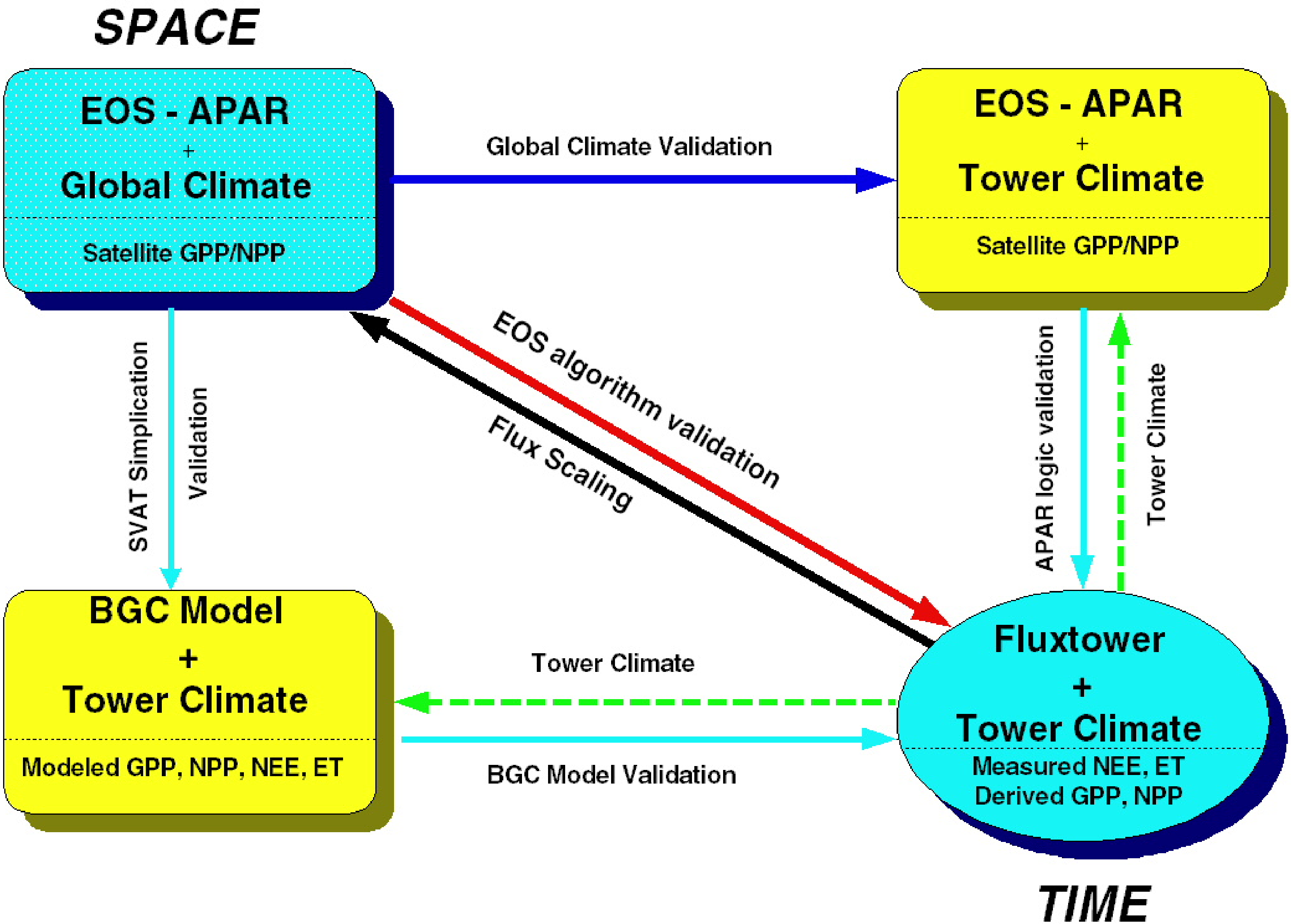
fPAR, PAR

Temperature

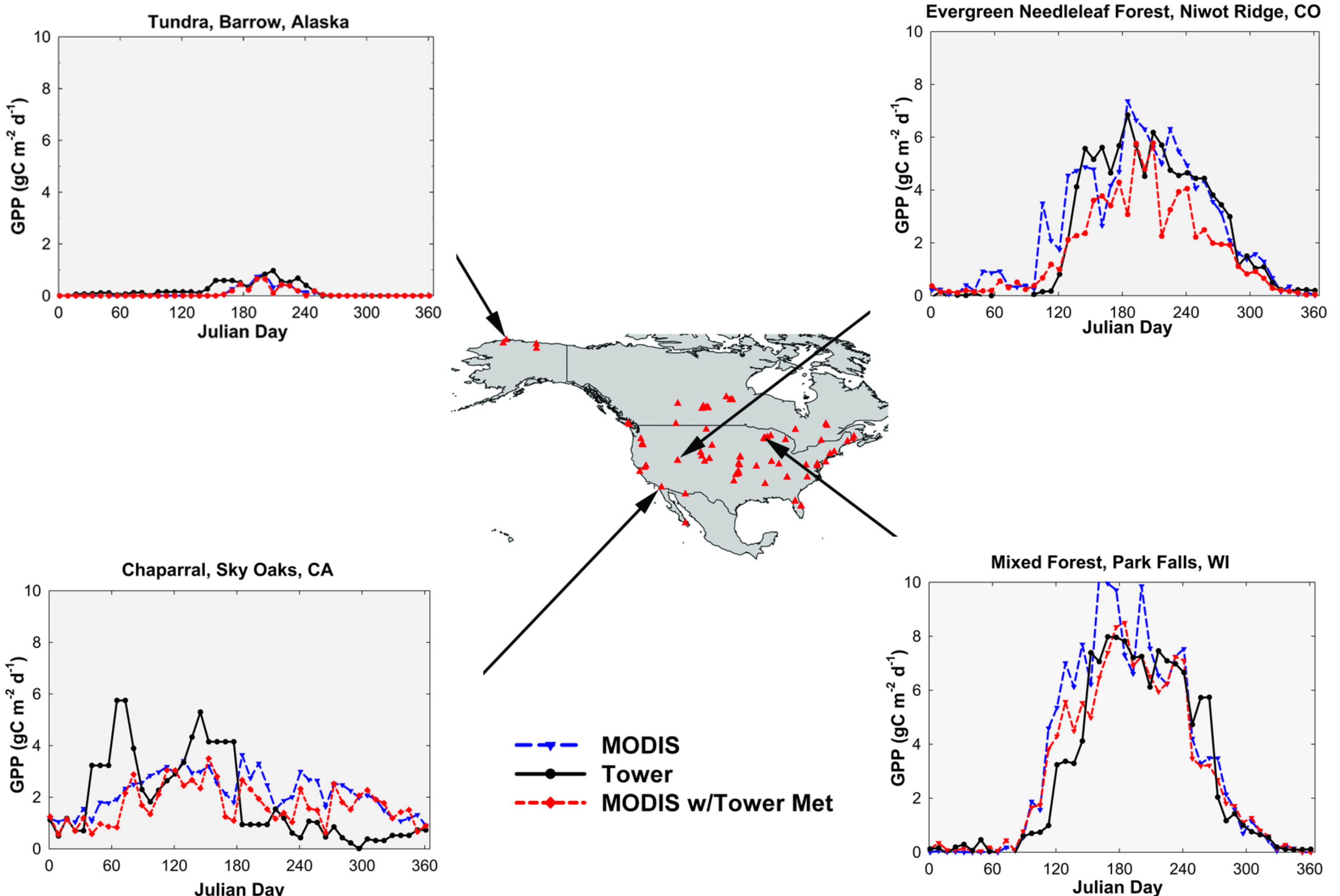
VPD

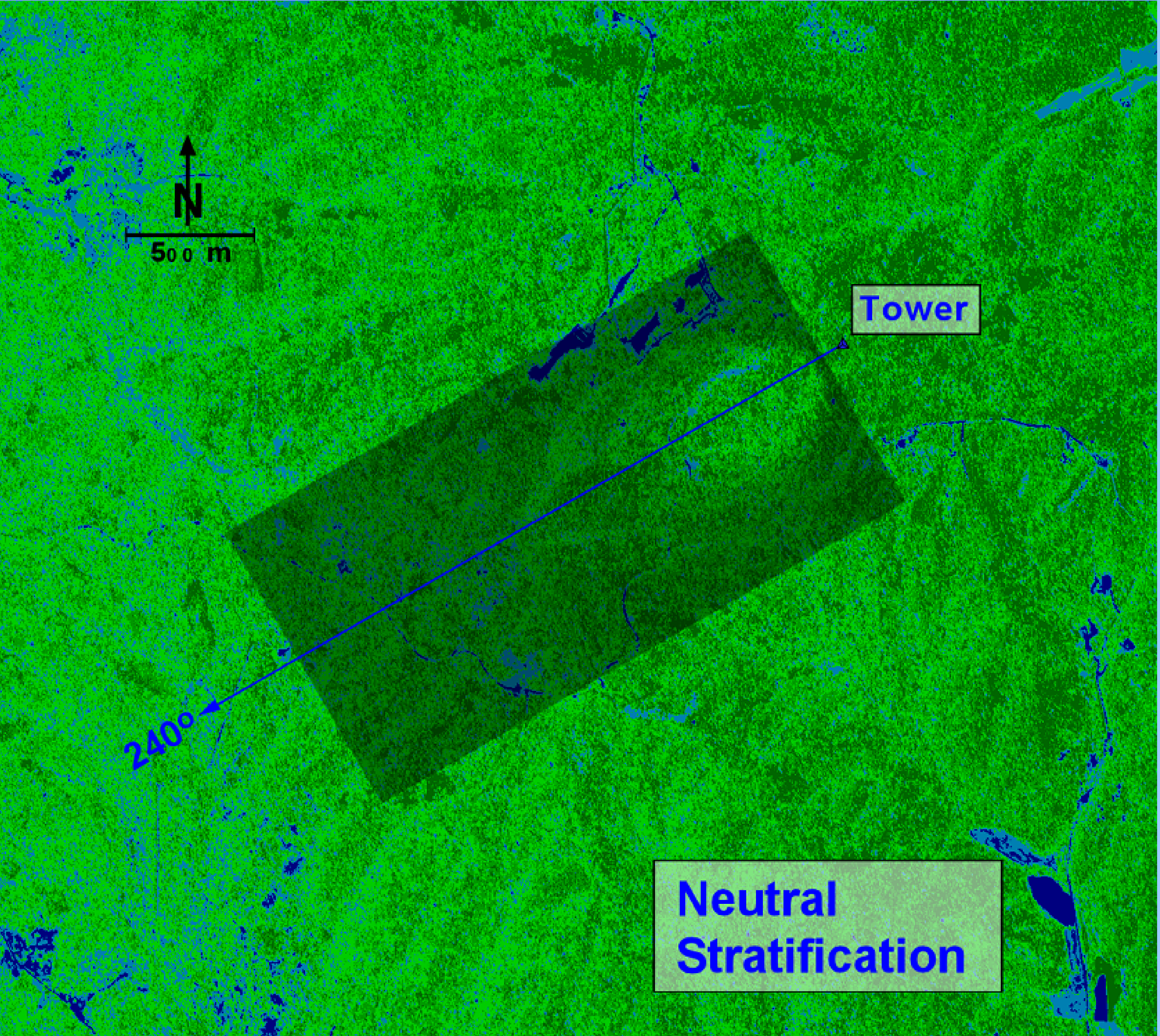
Biome Properties Look-Up Table (ε_{max})

FLUX TOWER BASED VALIDATION FOR MODIS GPP/NPP

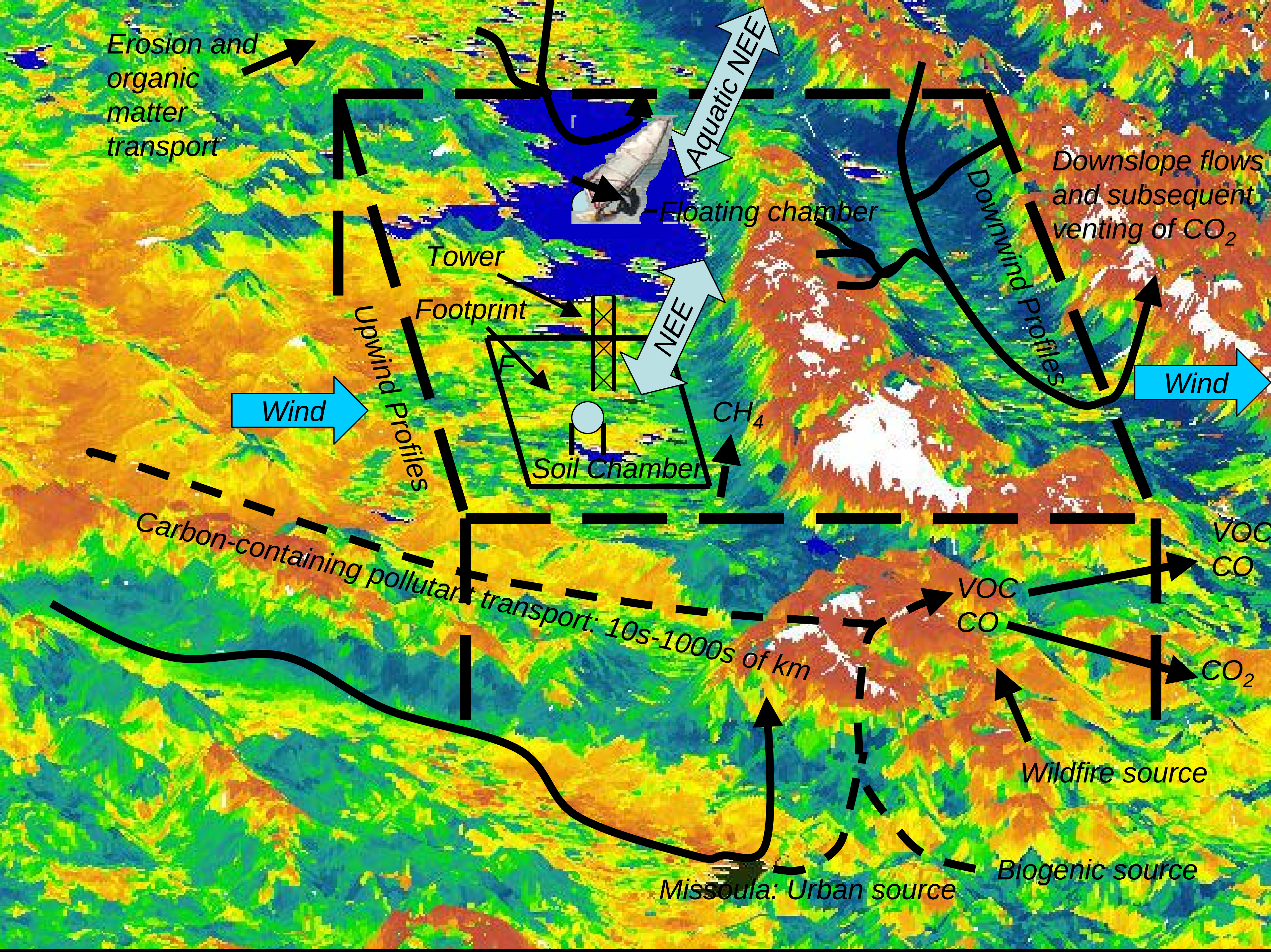


MODIS GPP Validation with Fluxnet



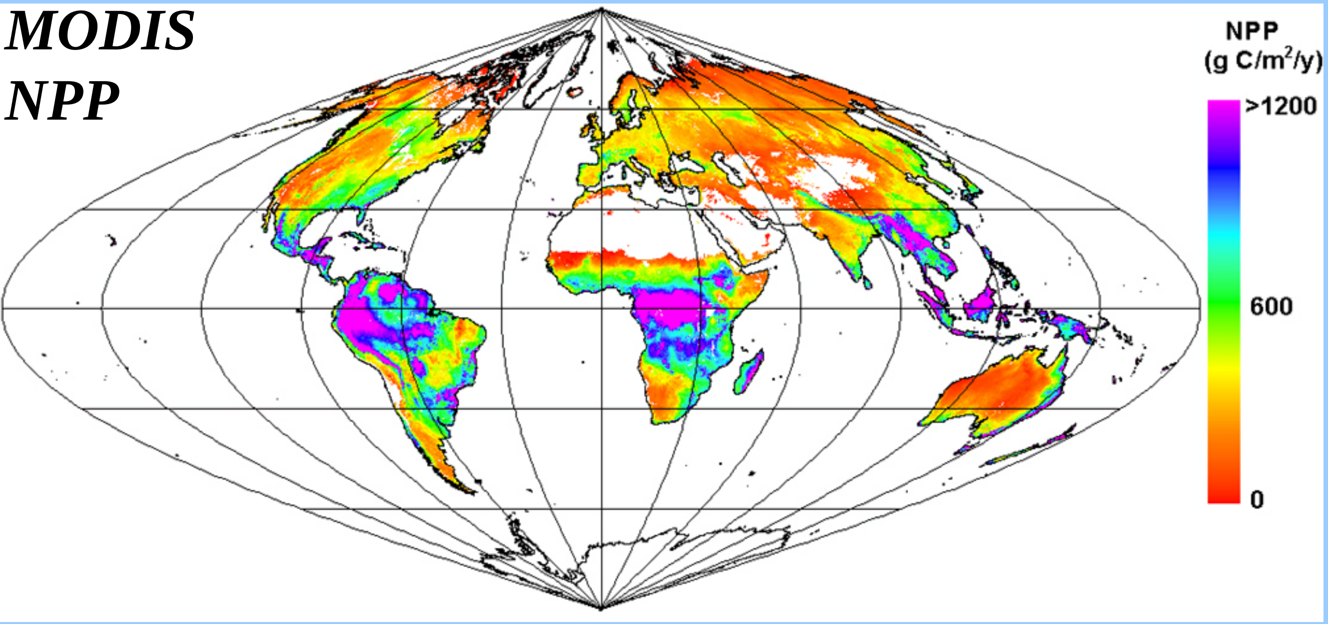


Schmid, 2005

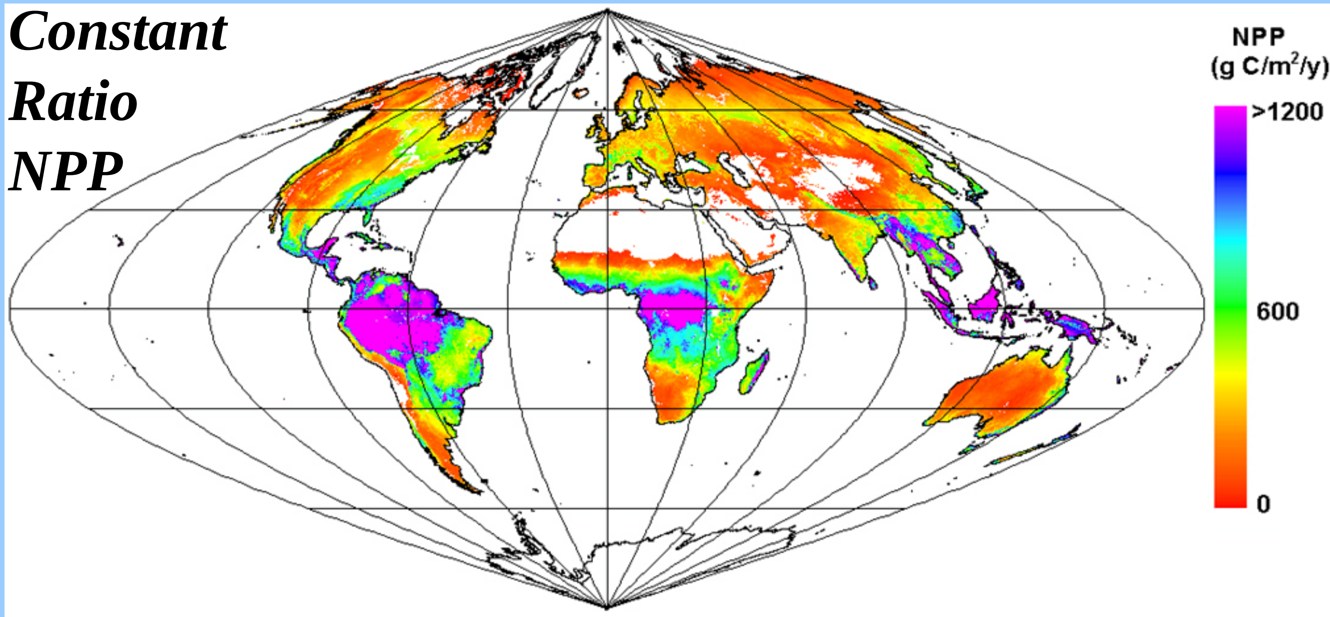


Erosion and organic matter transport
Aquatic NEE
Floating chamber
Downslope flows and subsequent venting of CO_2
Downwind Profiles
Tower
Footprint
F
NEE
Upwind Profiles
Wind
Wind
CH_4
Soil Chamber
Carbon-containing pollutant transport: 10s-1000s of km
VOC
CO
VOC
CO
CO_2
Wildfire source
Biogenic source
Missoula: Urban source

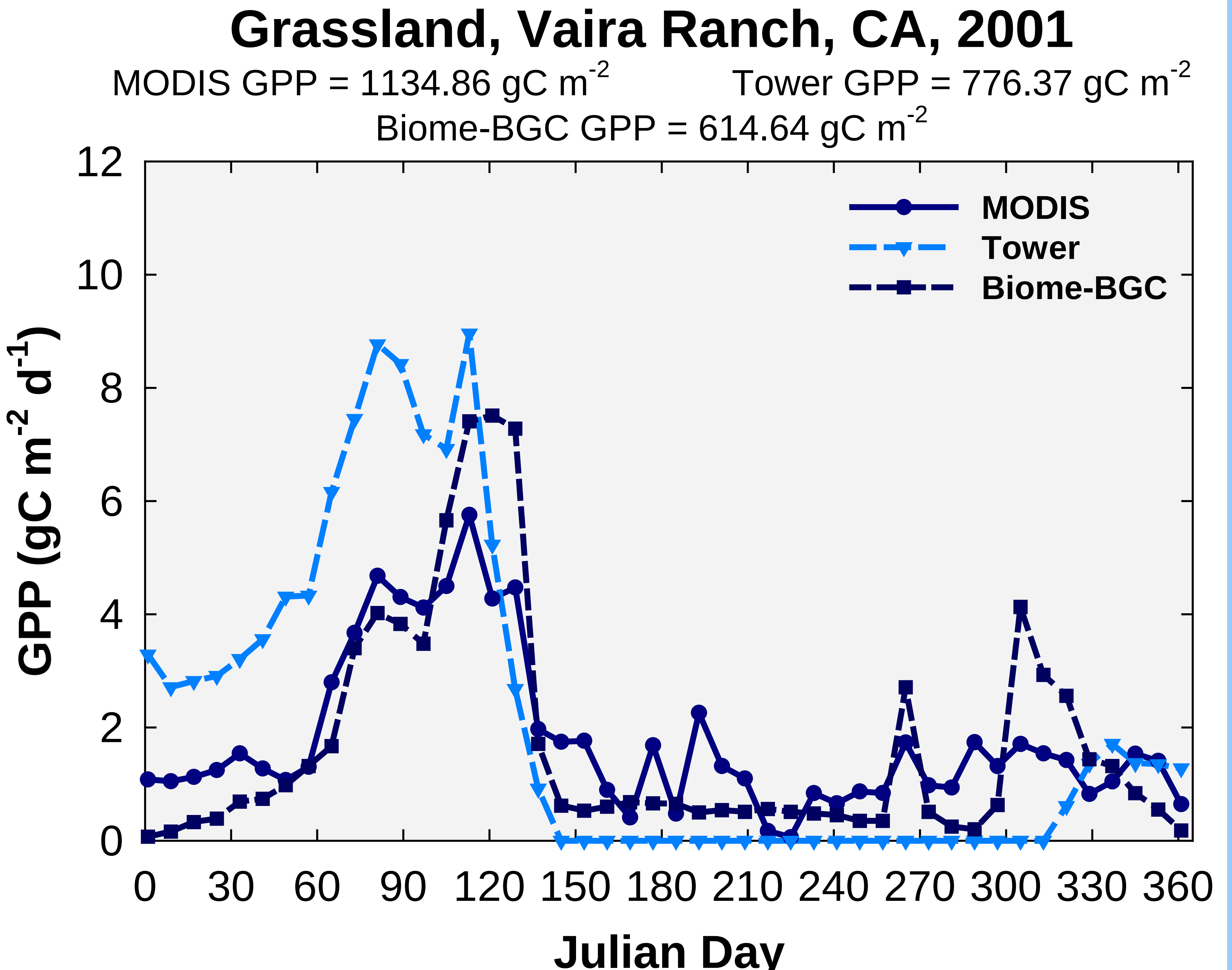
Uncertainties from Algorithm and BPLUT



•Large algorithm uncertainty is in estimating respiration coefficients

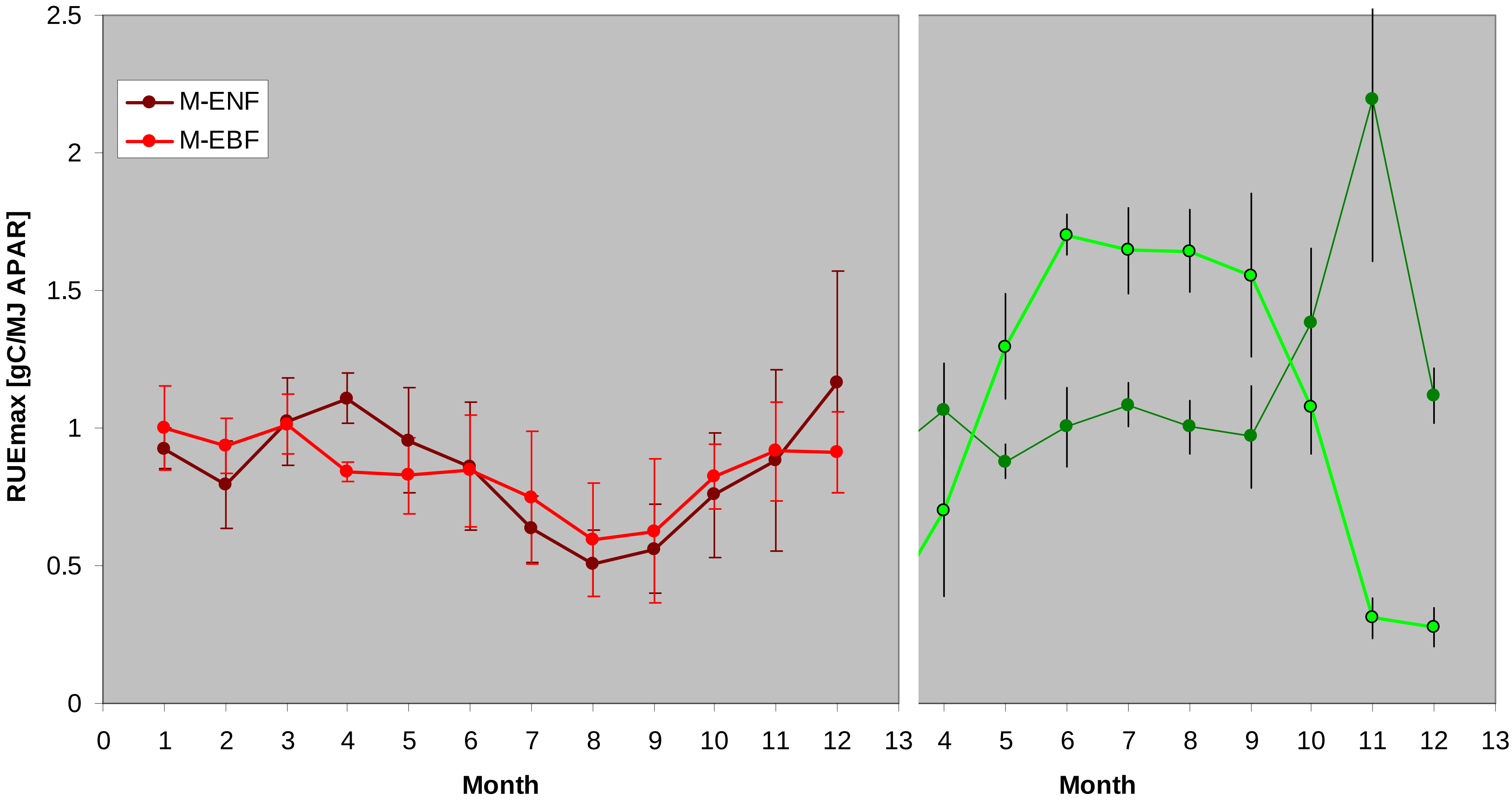


- Assume ratio of NPP:GPP = 0.47 across all biomes (*Waring et al., 1998*)

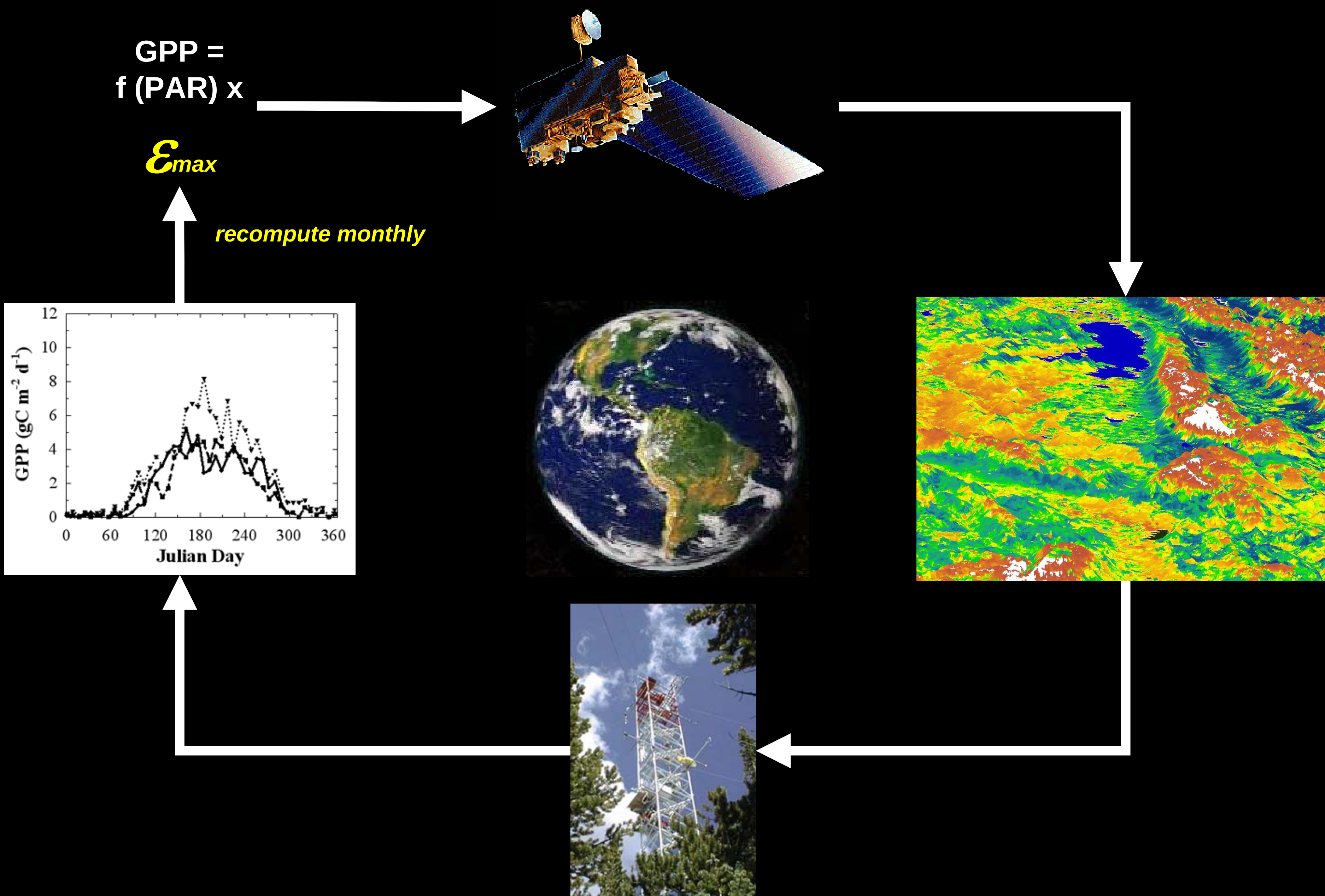


Grassland, Vaira Ranch, CA, 2001
MODIS GPP = 1134.86 gC m-2
Tower GPP = 776.37 gC m-2
Biome-BGC GPP = 614.64 gC m-2
MODIS
Tower
Biome-BGC
GPP (gC m-2 d-1)
Julian Day
0
2
4
6
8
10
12
0
30
60
90
120
150
180
210
240
270
300
330
360

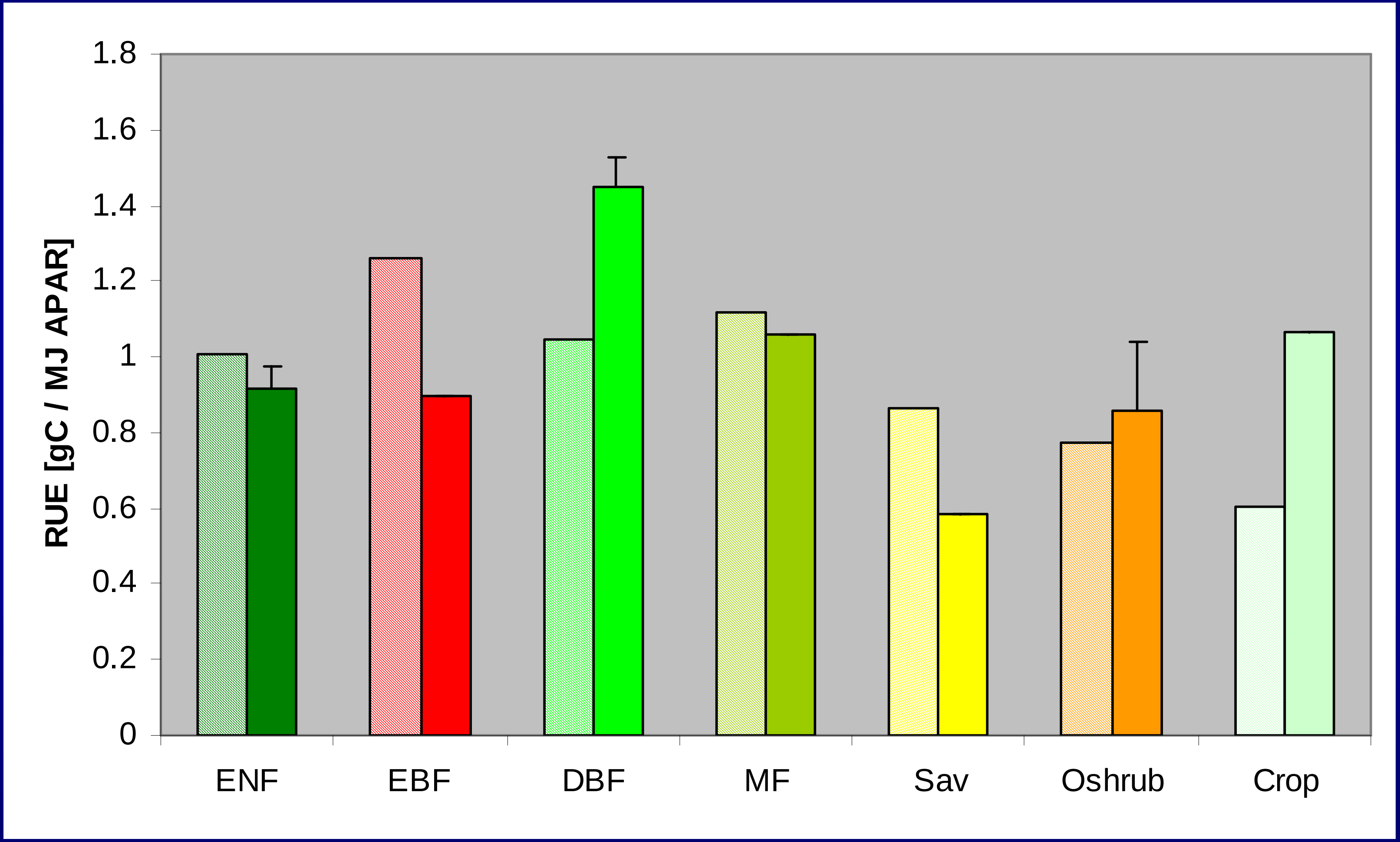
Seasonal Light Use Efficiency



Dynamic recalibration of satellite GPP algorithm with flux tower data

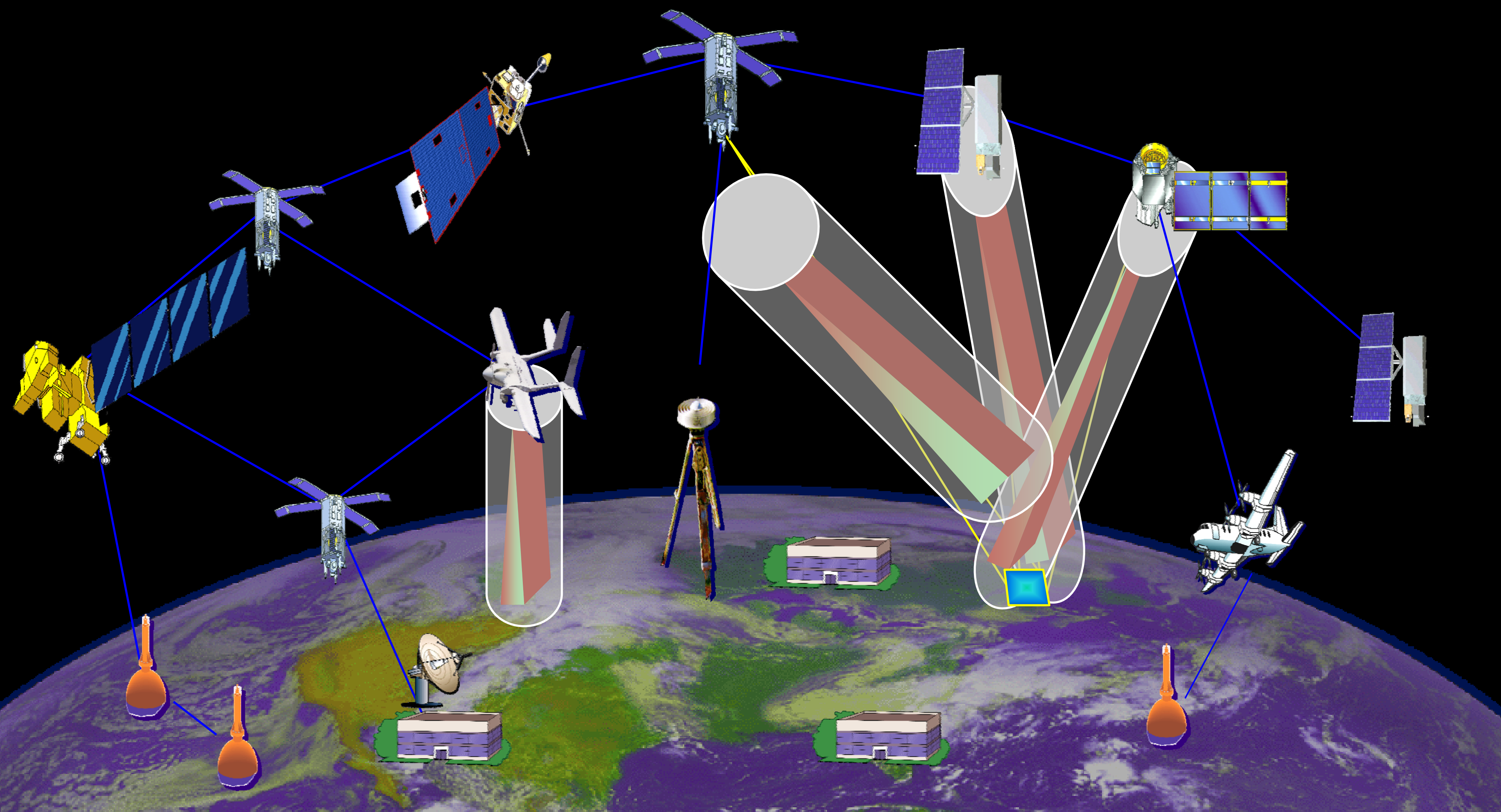


LUE_{max} estimates by PFT versus LUE_{max} in BPLUT



Sensor webs

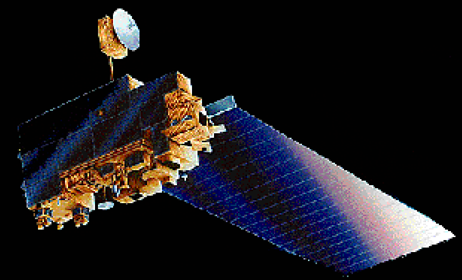
A sensor web is a coherent set of distributed "nodes", interconnected by a communications fabric, that collectively behave as a single, dynamically adaptive, observing system.



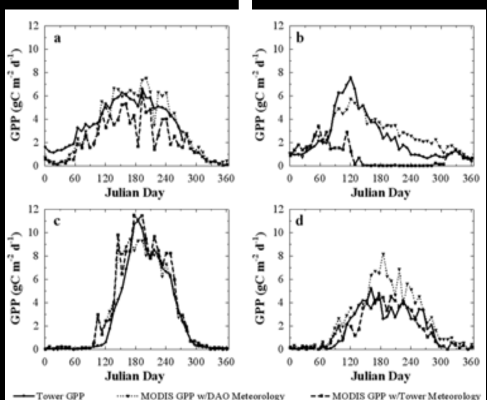
GEOSS - Integrated Biospheric Monitoring concept for Global GPP

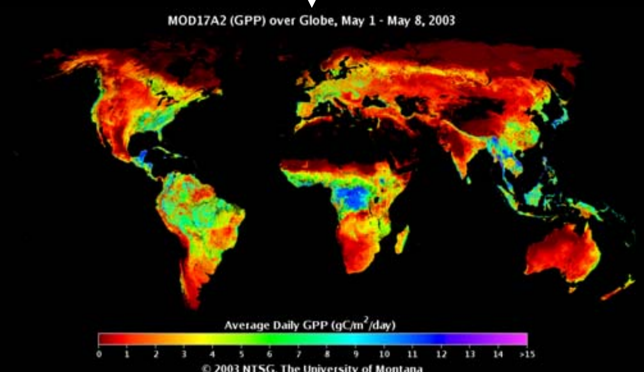
GPP =
f (PAR) x

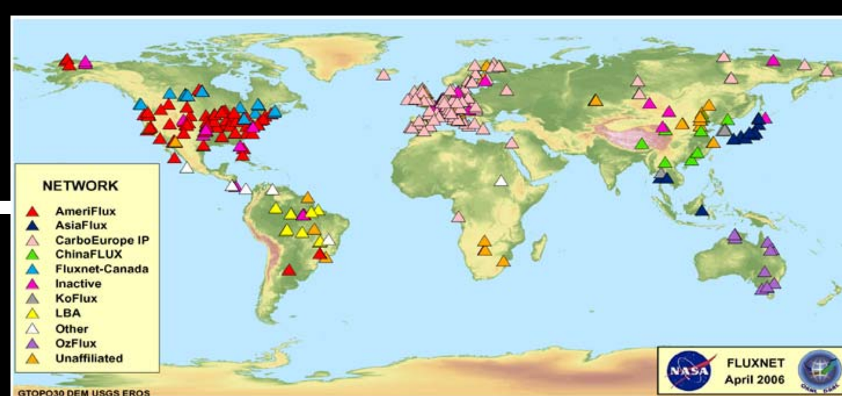
ε_{max}

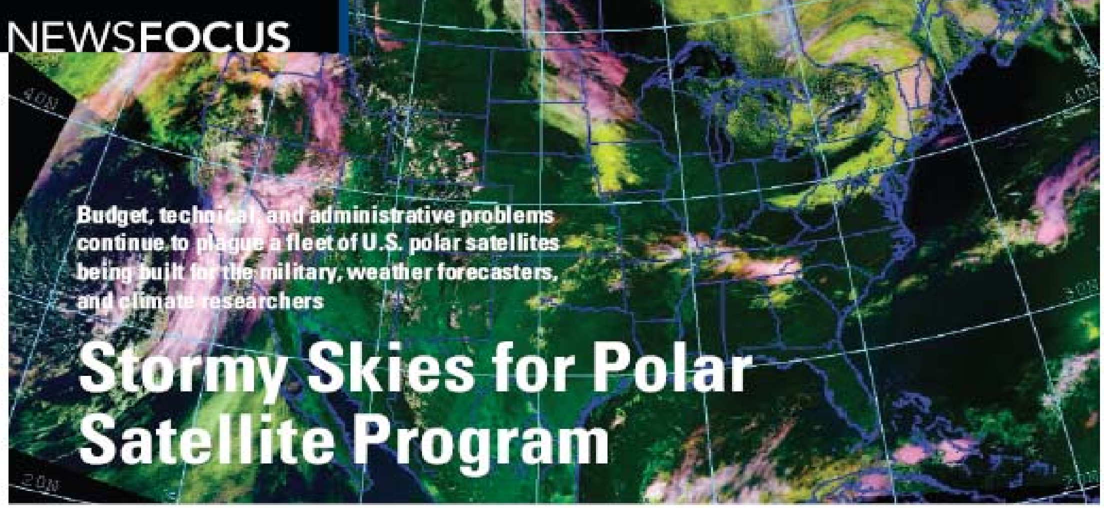


recompute monthly









Budget, technical, and administrative problems continue to plague a fleet of U.S. polar satellites being built for the military, weather forecasters, and climate researchers

Stormy Skies for Polar Satellite Program

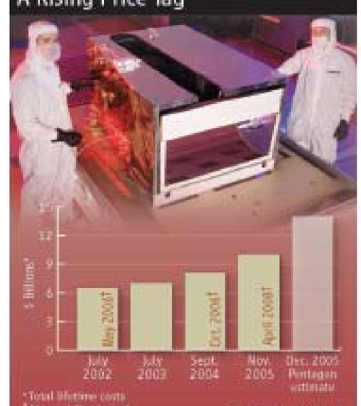
WITH MORE USES THAN A SWISS ARMY knife, the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) was supposed to be the world's most sophisticated series of weather satellites. But somewhere in its 12-year history, the multibillion-dollar NPOESS has also become one of the country's most troubled technology projects. Next week, the Pentagon will issue binding plans on how to fix a project now behind schedule and massively over budget. The expected overhaul could shape for decades how well U.S. forces prepare for battle, civilian authorities anticipate killer storms, and scientists understand Earth's ever-changing climate.

Since the 1960s, the U.S. Department of Defense and the National Oceanic and Atmospheric Administration (NOAA) have used separate north-south orbiting satellite systems to provide daily global weather coverage and crucial multiday forecast data. In 1994, President Bill Clinton proposed to merge those systems in a $6.5 billion project that was to save an estimated $1.8 billion over its lifetime. The system would pack 14 sensors—half of them new—onto six 7-meter-long crafts, with three flying at a time until 2018. Sounders would probe the air column, sensors would look through clouds as well as watch for space weather, and the crafts' capabilities would be a quantum leap over decades-old NOAA and Pentagon polar systems. "We have made major strides to converge military and civil weather requirements," Air Force Maj. Gen. Robert Dickman told Congress in 1995.

But now, more than a decade later, technical problems on one of the sensors have rippled through the program and pushed estimated cost overruns into the billions of dollars. As currently configured, the system is as much as 3 years behind schedule and carries, by the Pentagon's latest estimate, a lifetime price tag of $14 billion (see graph). The overrun triggered an automatic top-to-bottom review, which the Secretary of Defense is set to present to lawmakers next week.

The delay could leave U.S. forces without the best data on sandstorms or ocean currents, military planners worry, not to mention a possible weakening of civilian weather coverage if there are problems with a NOAA satellite scheduled to be launched in 2007. What the Government Accountability Office (GAO) calls a "program in crisis" is really the "fleecing of America," according to Representative Bart Gordon (D–TN), ranking Democrat on the House Science Committee, who wants NOAA Administrator Conrad Lautenbacher to resign for ignoring what Gordon says were clear warning signs about NPOESS. "This is a program that is dangling by a thread," says one congressional staffer who follows the project.

A Rising Price Tag



Skyward. The Pentagon's estimate for the program is much higher than what NPOESS staff assume.

NPOESSing a challenge

Polar satellites are wonderfully useful because their 100-minute orbits provide coverage of nearly every point on Earth. But their attractiveness didn't forge an automatic alliance between defense and research bureaucrats operating in two different cultures. "NOAA looked at the Air Force and said, 'Huh, goose-stepping fascists.' And the Air Force looked at NOAA and said, 'Fish-kissing tree huggers,'" said former program manager John Cunningham at a 2003 briefing on the project.

Their needs were different as well: The Pentagon wanted sensors with high resolution and speedy delivery of the data, whereas NOAA sought instruments with a multitude of spectral bands for weather research. NASA agreed to join in, canceling planned follow-ons for environmental missions while adding environmental and climate sensors to the NPOESS fleet after its scientists lusted after the chance to use systems whose sequential platforms will stay aloft for 20 years rather than the usual 5-year window. "I thought [NPOESS] was the right thing to do, and in some ways, the only way to do it," says biogeochemical modeler Berrien Moore of the University of New Hampshire, Durham, who has long advised the government on behalf of the climate community.

The initial cooperation went "surprisingly well," says the Navy's Robert Winokur, then head of NOAA's satellite program. The package would include everything from an ozone detector to a device for aerosol studies (see graphic, p. 1297). The microwave imager would provide more channels for detailed moisture profiles than existing instruments. And the Visible/Infrared Imager Radiometer

Published by AAAS


THE END