A New Role for Earth Science: The Global Carbon Cops!

Steven W. Running
Numerical Terradynamic Simulation Group
College of Forestry and Conservation
University of Montana

MODIS SCIENCE TEAM MEETING

MaY 19, 2011

Fate of Anthropogenic CO_2 Emissions (2000-2009)

1.1±0.7 PgC y^{-1}

+

7.7±0.5 PgC y^{-1}

4.1±0.1 PgC y^{-1}

47%

2.4 PgC y^{-1}

27%

Calculated as the residual of all other flux components

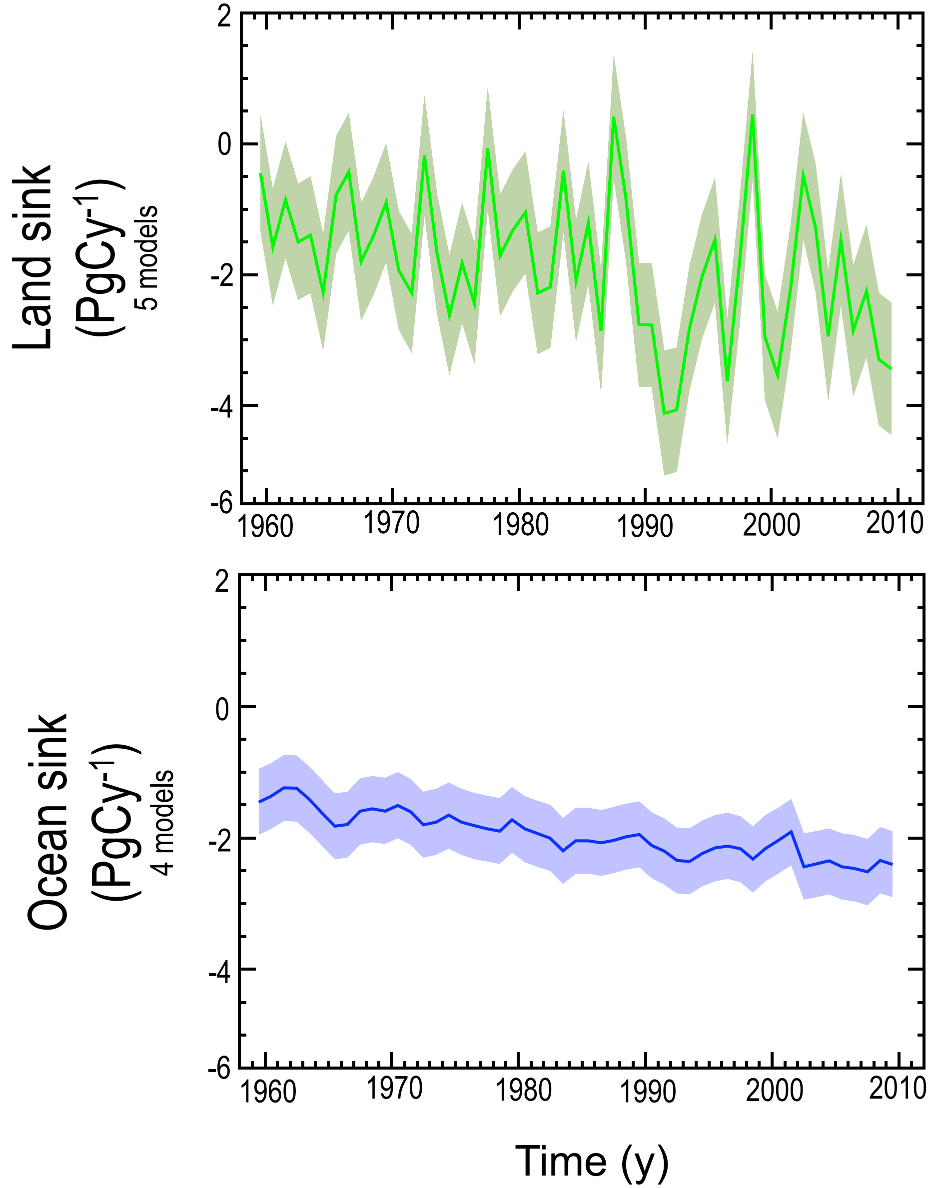
26%

2.3±0.4 PgC y^{-1}

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

Modelled Natural CO_2 Sinks

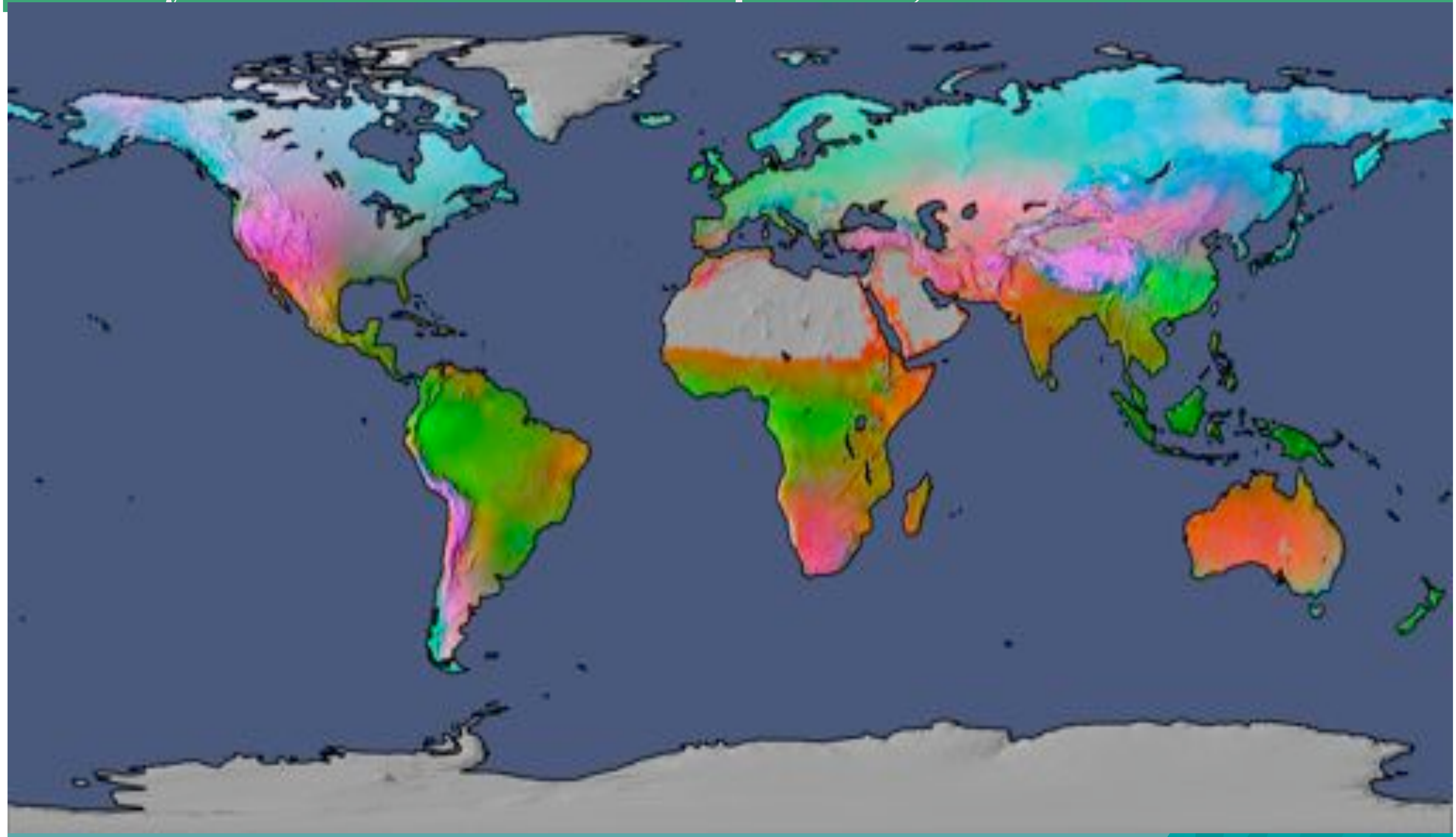


Updated from Le Quéré et al. 2009, Nature Geoscience

Global Carbon Project

Earth System Science Partnership DIVERSITAS GLOBAL IGBP CHANGE IHDP WCRP World Climate Research Programme

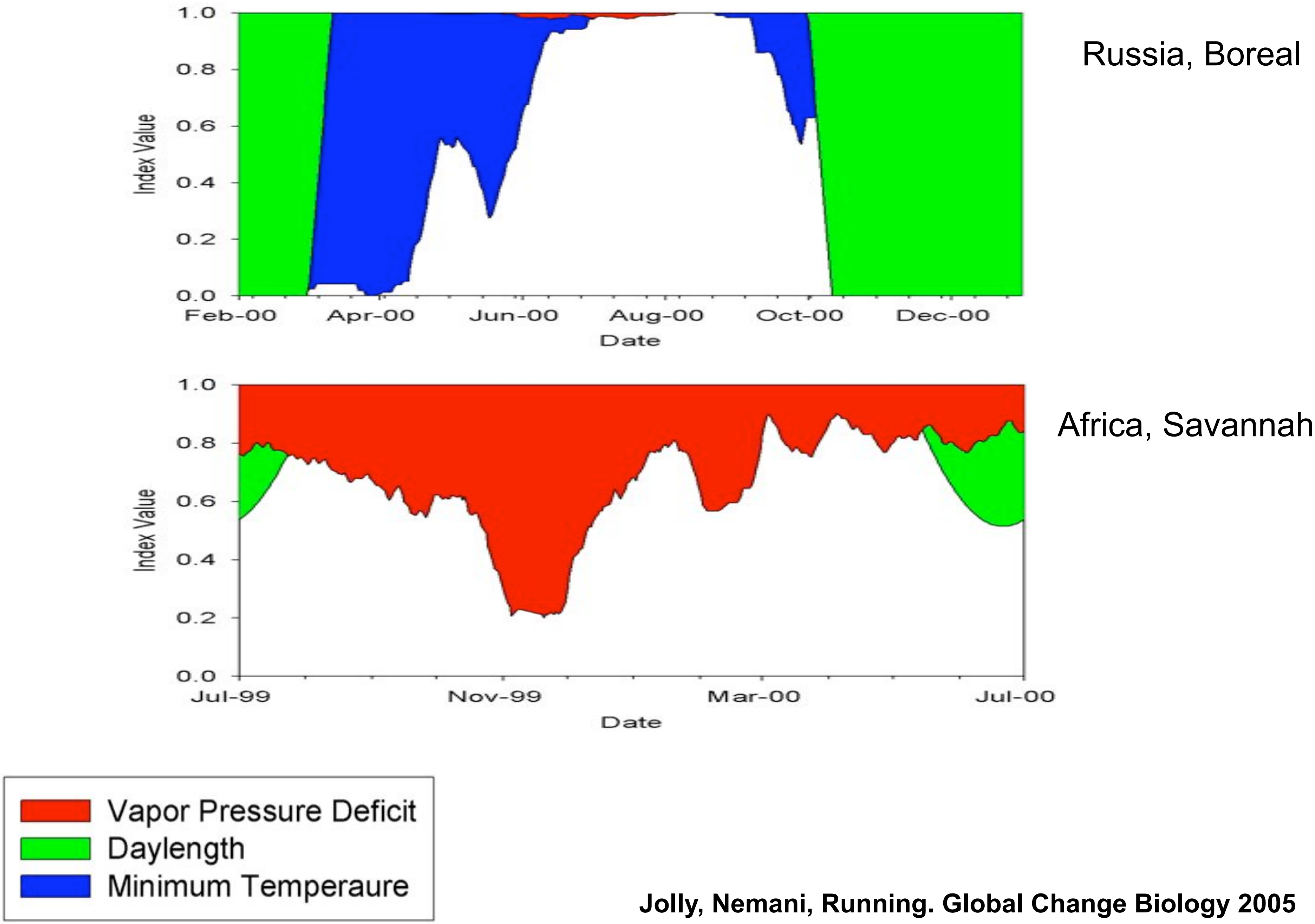
Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.



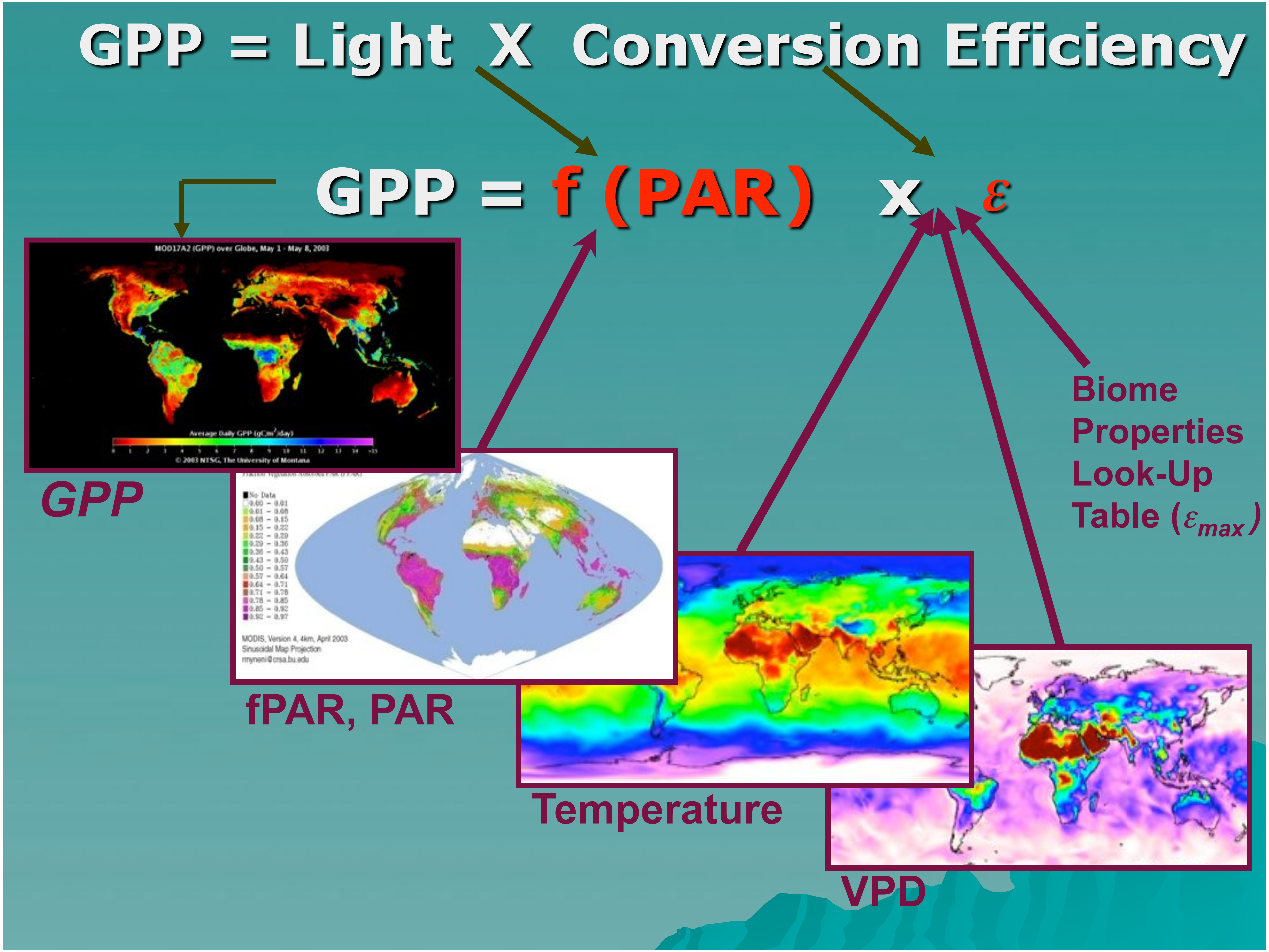
Water = 40%, Temperature = 33%, Radiation = 27%

Nemani et al. 2003
Running et al 2004

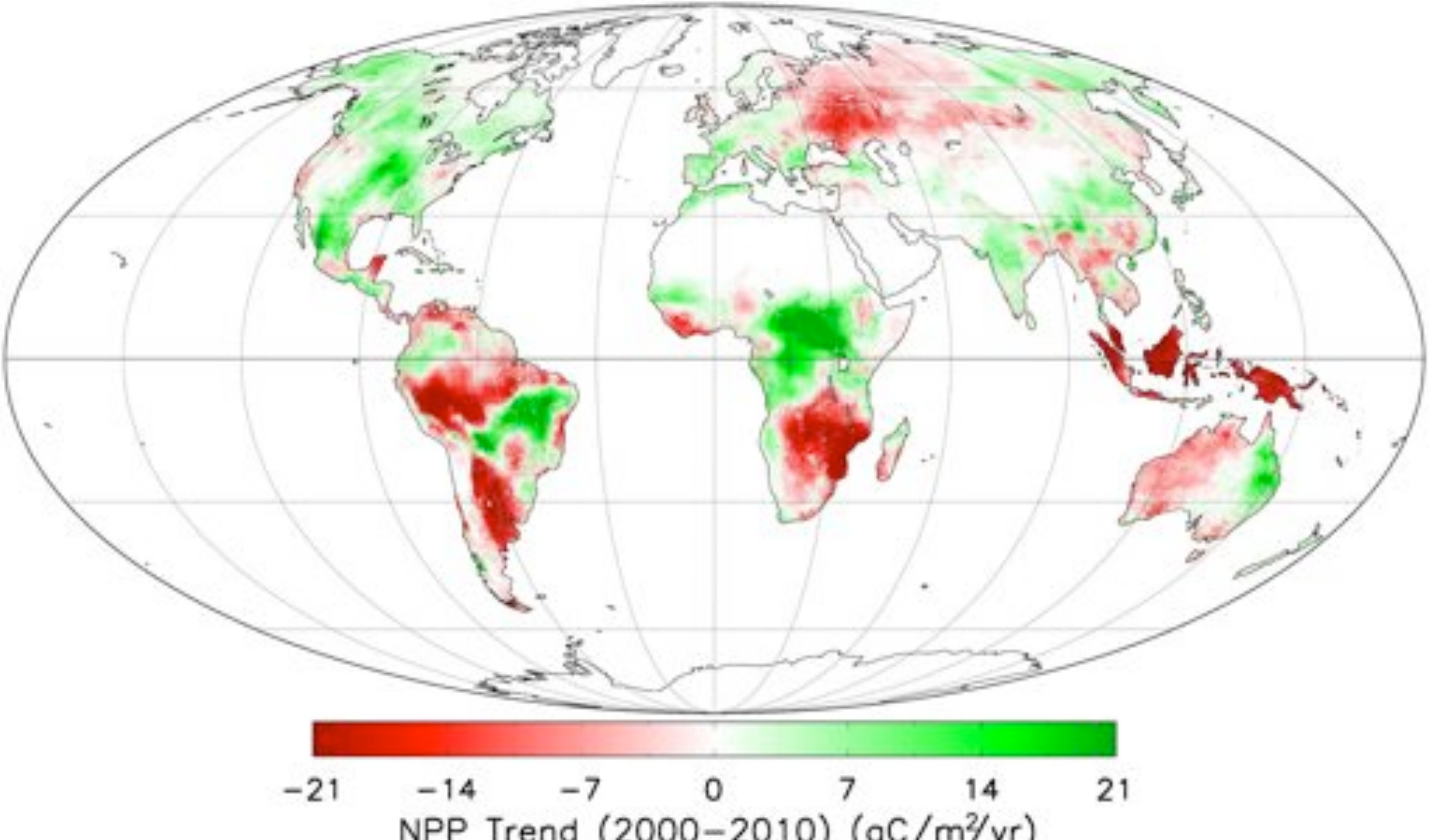
Seasonal Growing Season Constraints



Jolly, Nemani, Running. Global Change Biology 2005

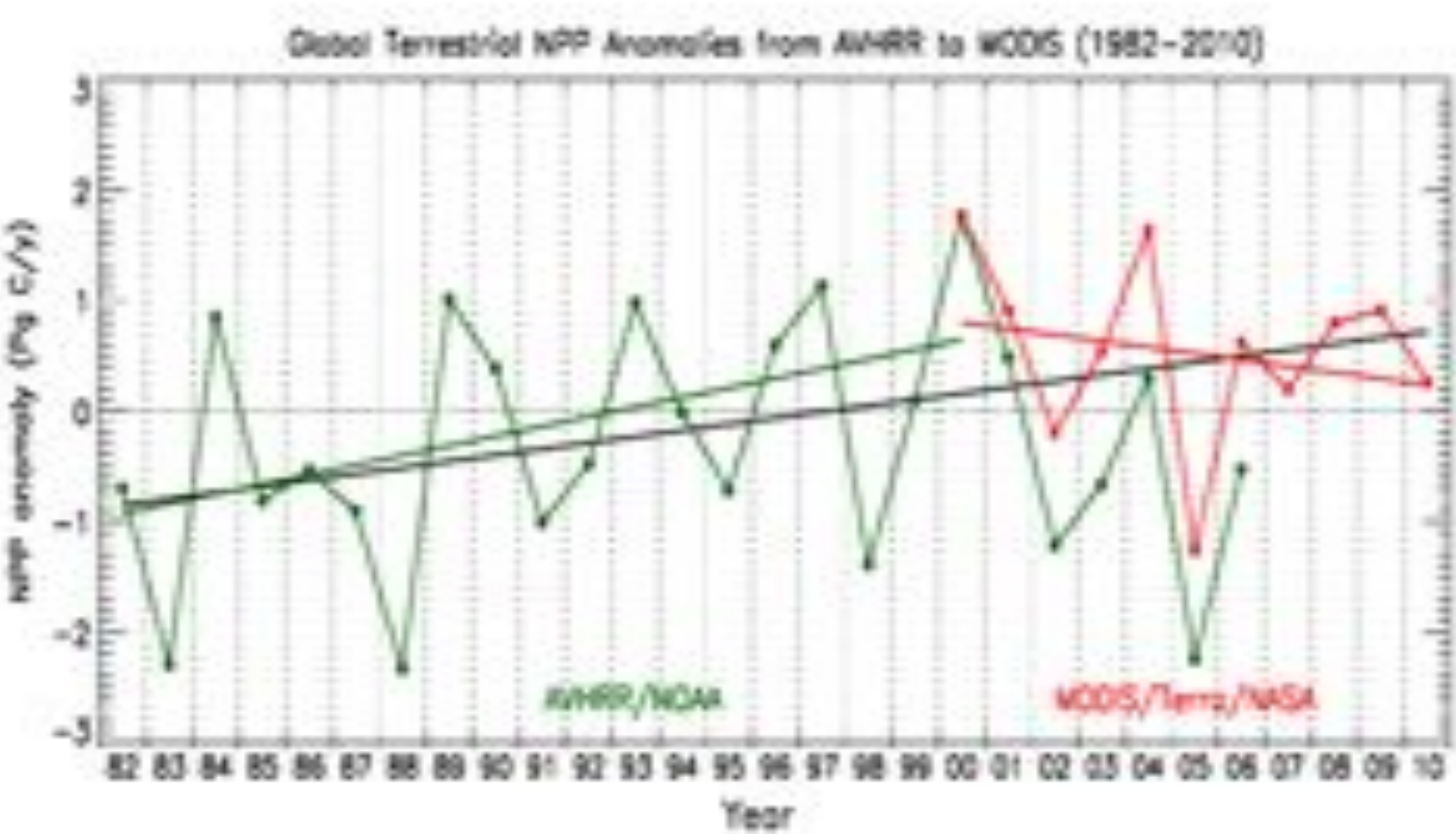

GPP = Light X Conversion Efficiency
GPP = f (PAR) x ε
MOD17A2 (GPP) over Globe, May 1 - May 8, 2003
Average Daily GPP (gC/m²/day)
© 2003 NTSG, The University of Montana
GPP
No Data
MODIS, Version 4, 4km, April 2003
Sinusoidal Map Projection
rmyneni@crsa.bu.edu
fPAR, PAR
Temperature
VPD
Biome Properties Look-Up Table (ε max)

Net Primary Production trend (2000-2010)



Zhao & Running 2010, *Science*

Global NPP Trend
From + in the 1980s-90s to a – in the 2000s

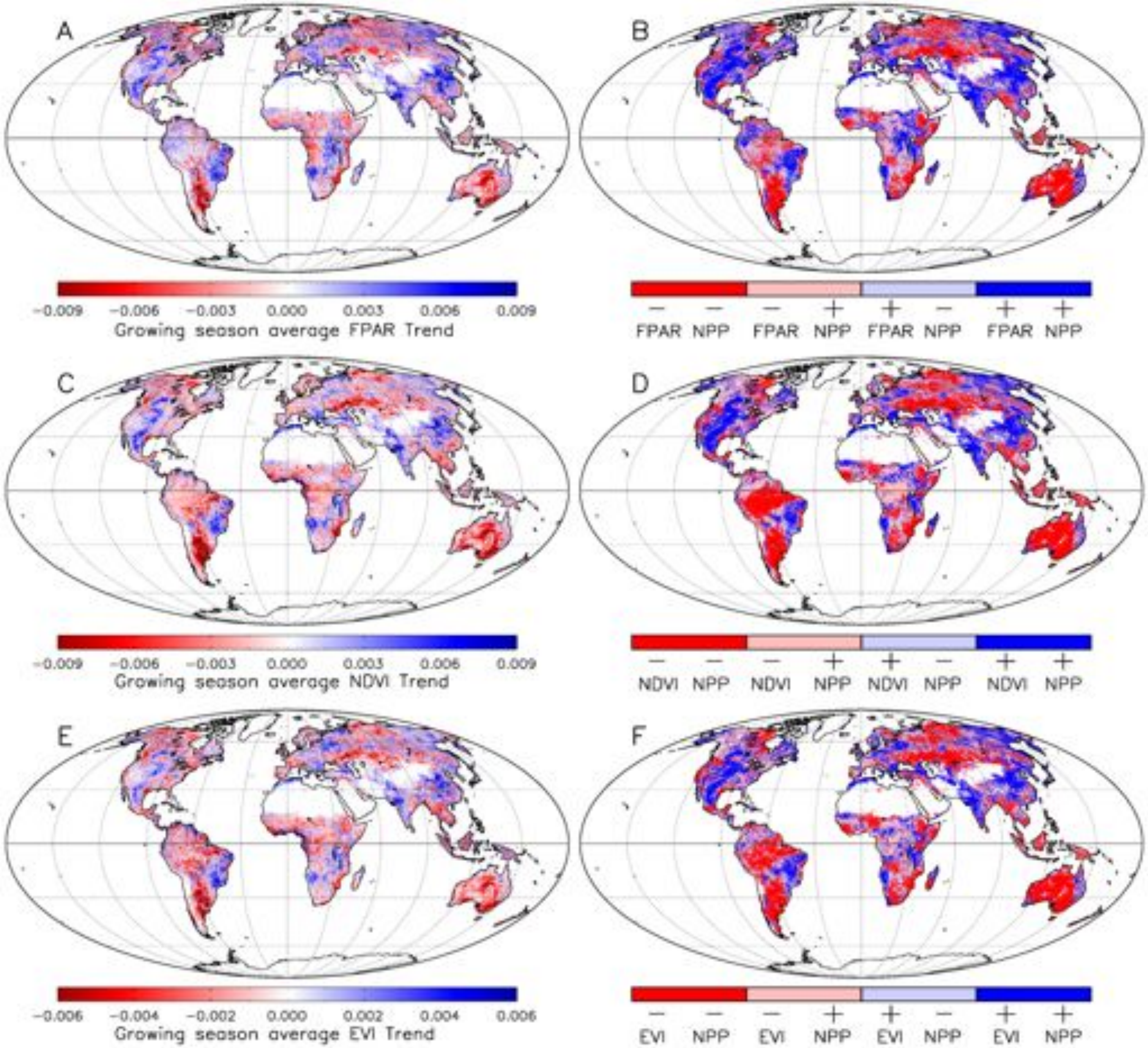


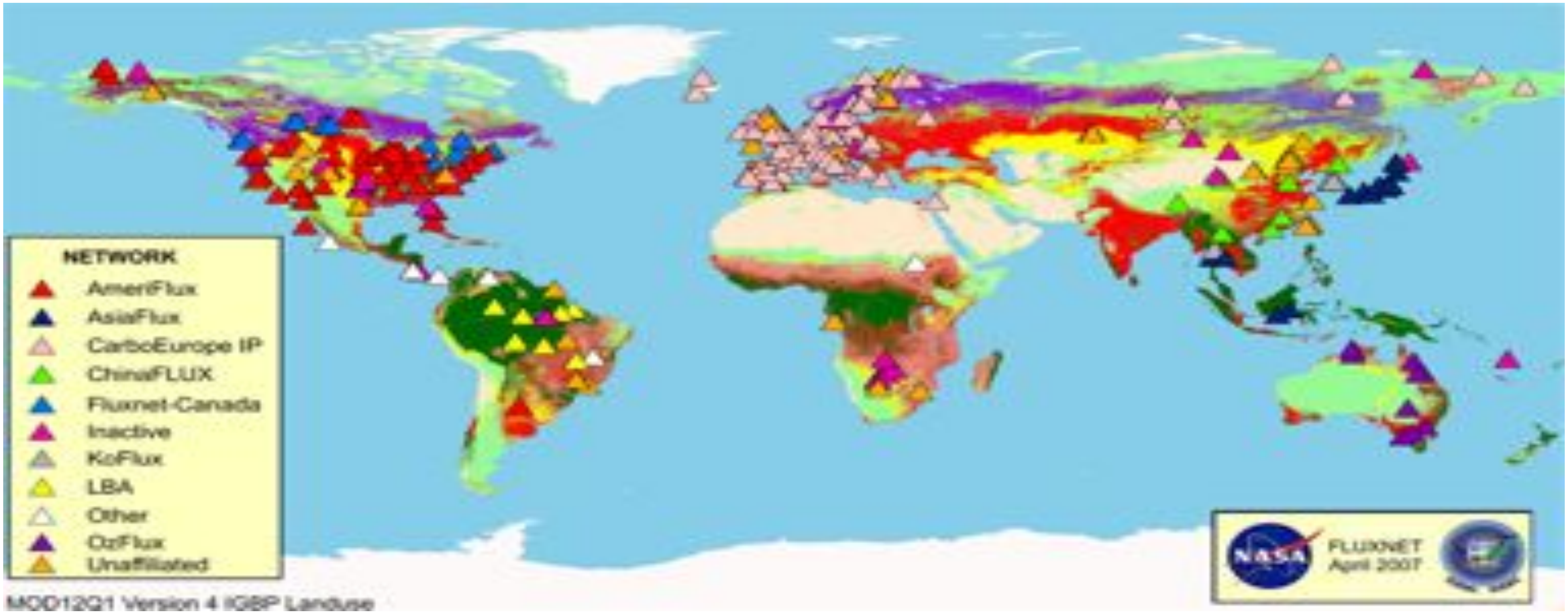
Consistency in changes between vegetation indices and NPP

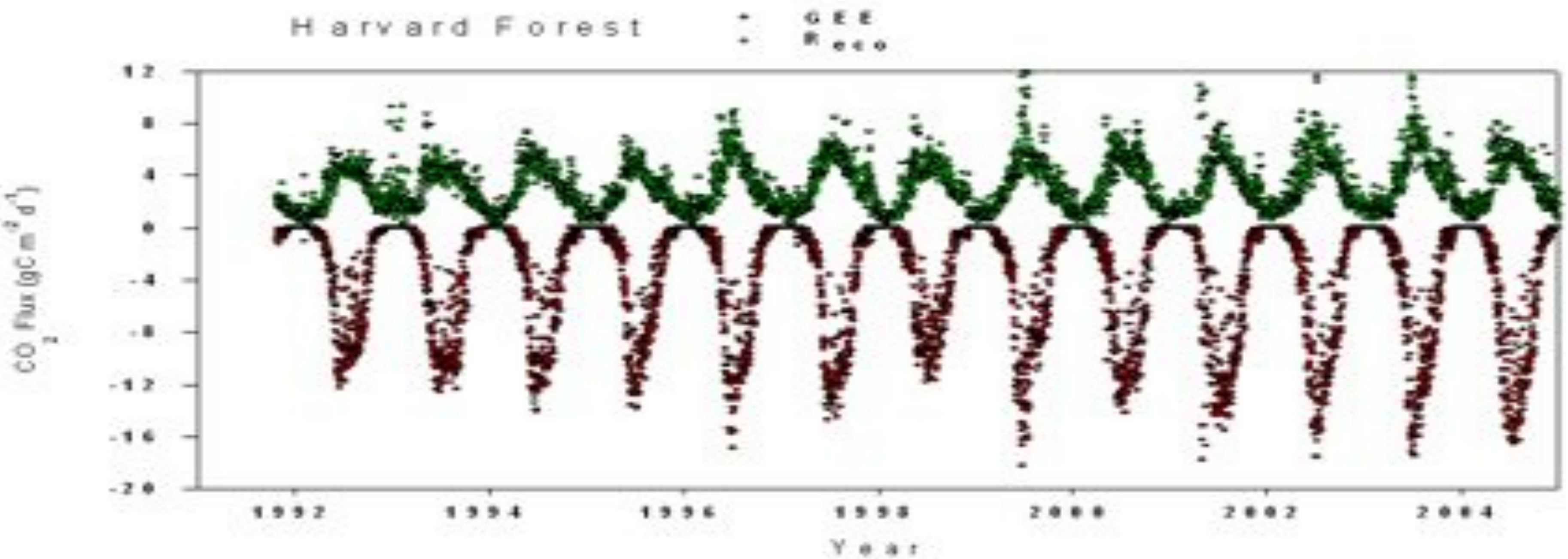
FPAR

NDVI

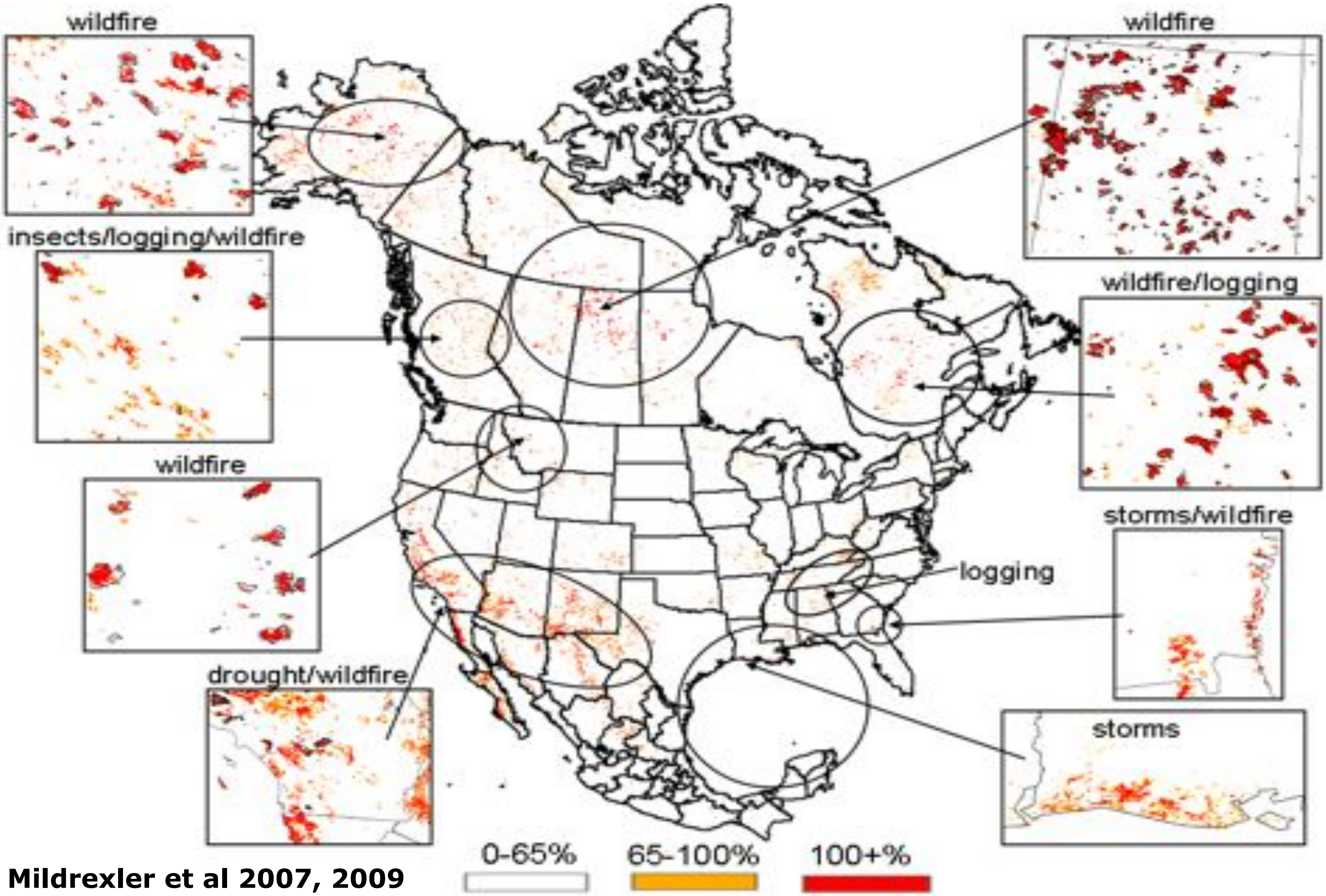
EVI




NETWORK
AmeriFlux
AsiaFlux
CarboEurope IP
ChinaFLUX
Fluxnet-Canada
Inactive
KoFlux
LBA
Other
OzFlux
Unaffiliated
FLUXNET
April 2007
MOD12Q1 Version 4 IGBP Landuse

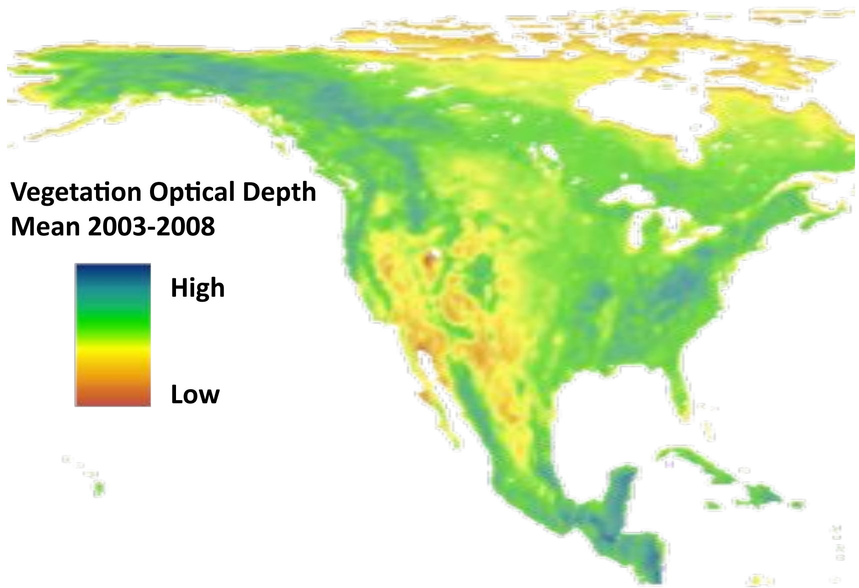

Harvard Forest
GEE
Reco
12
8
4
0
-4
-8
-12
-16
-20
CO2 Flux (gC m-2 d-1)
1992
1994
1996
1998
2000
2002
2004
Year

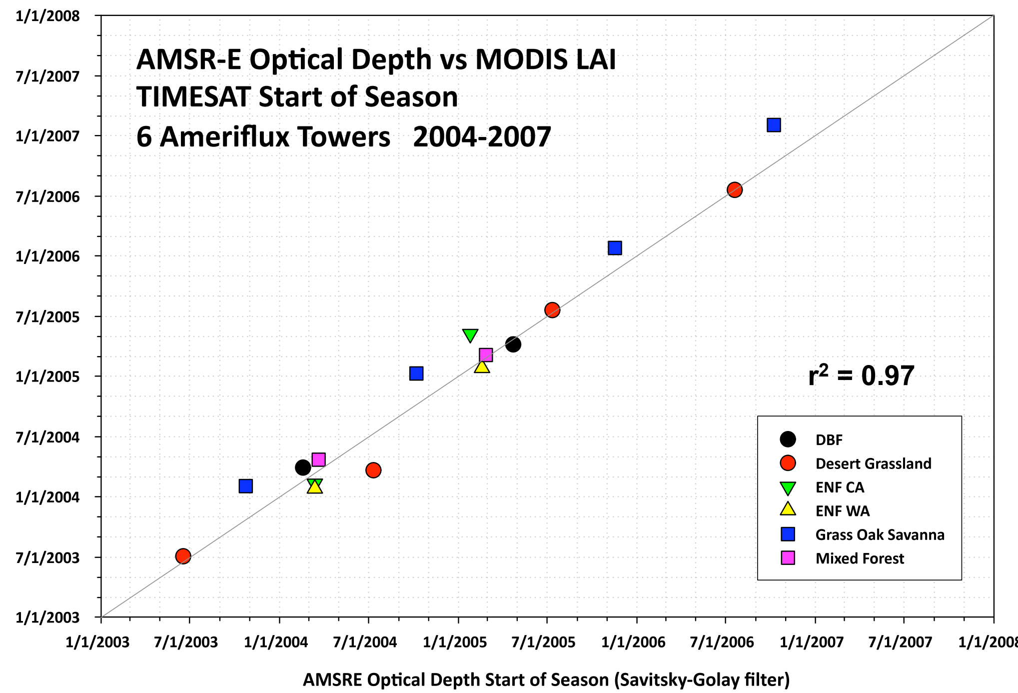
MODIS Annual Disturbance Index

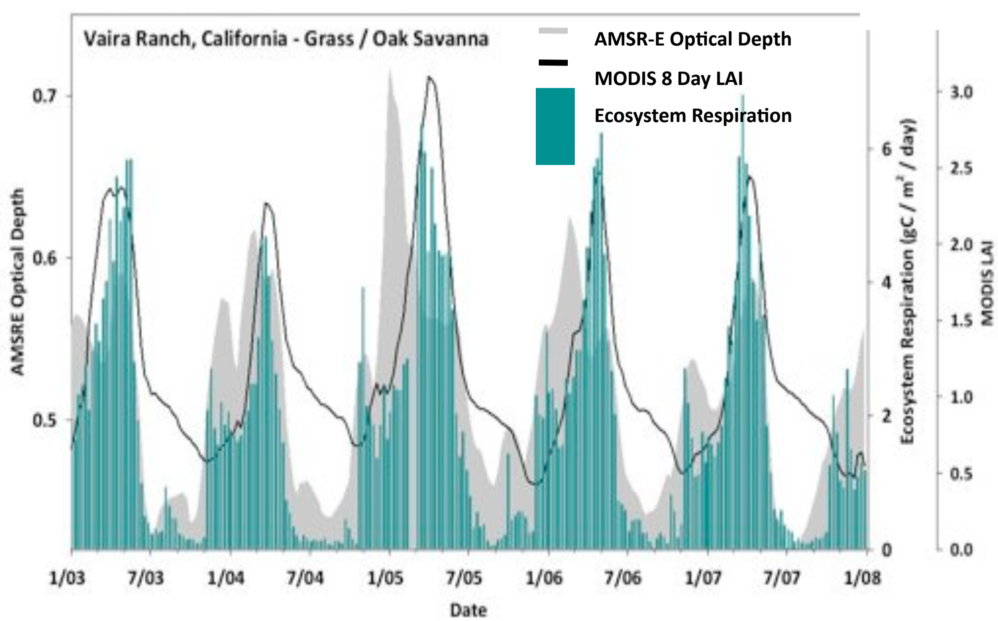


Mildrexler et al 2007, 2009

Monitoring Vegetation Phenology using AMSR-E Optical Depths: Comparison with MODIS LAI & Tower CO_2 fluxes

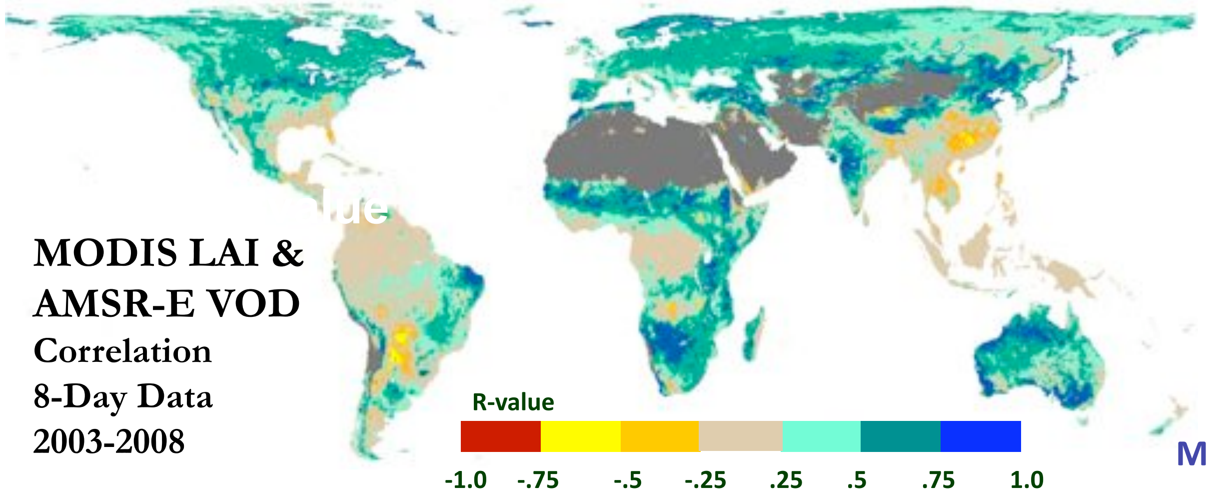






Vegetation phenology assessment using AMSR-E optical depth retrievals. Seasonal changes in AMSR-E optical depths coincide with MODIS LAI derived start of the growing season (**above**) and seasonal shifts in ecosystem respiration from tower eddy covariance CO_2 measurements (**left**). The AMSR-E optical depths provide a unique measure of seasonal changes in canopy biomass that is less impacted by atmospheric contamination than optical-IR remote sensing, enabling near daily observations of vegetation conditions.

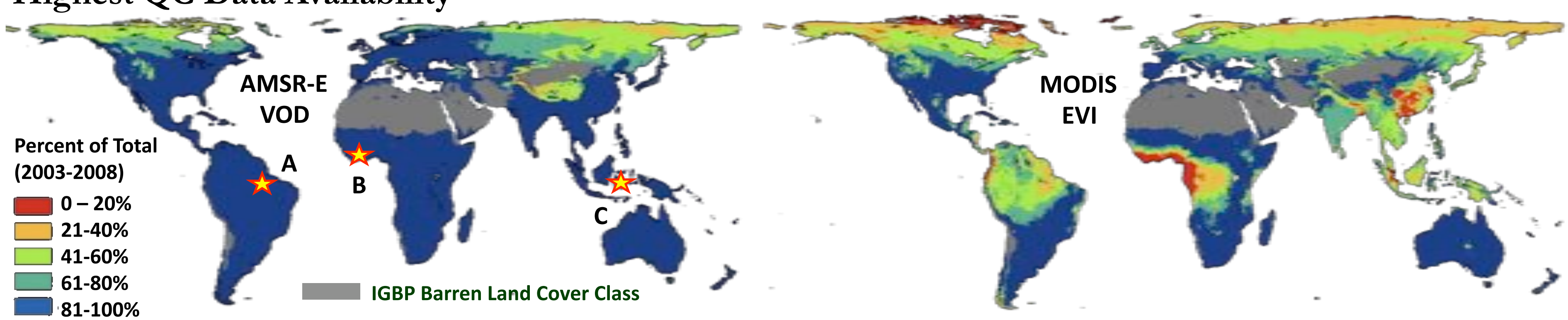
Global Phenology Monitoring using Vegetation Optical Depth (VOD) from AMSR-E

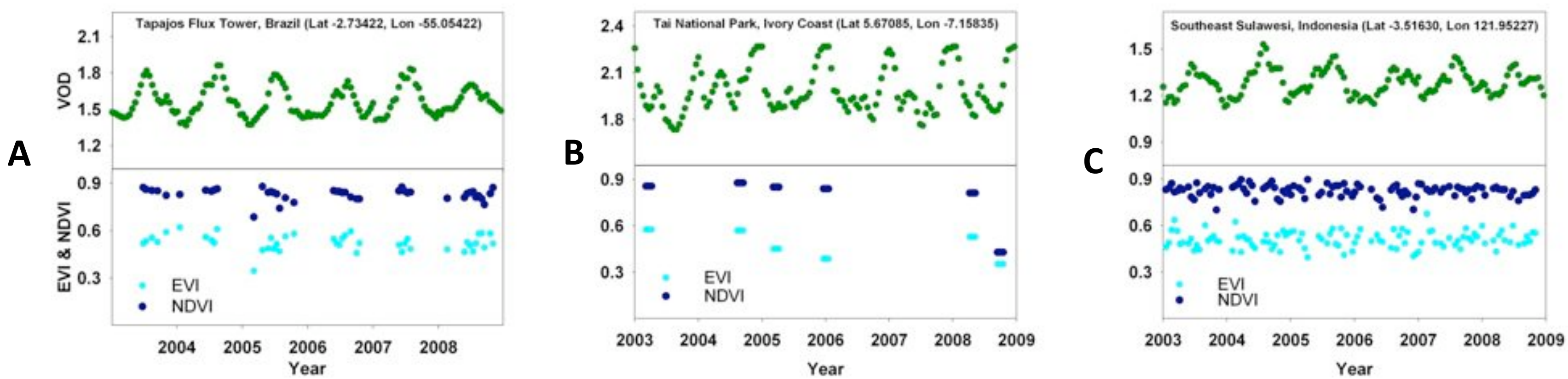


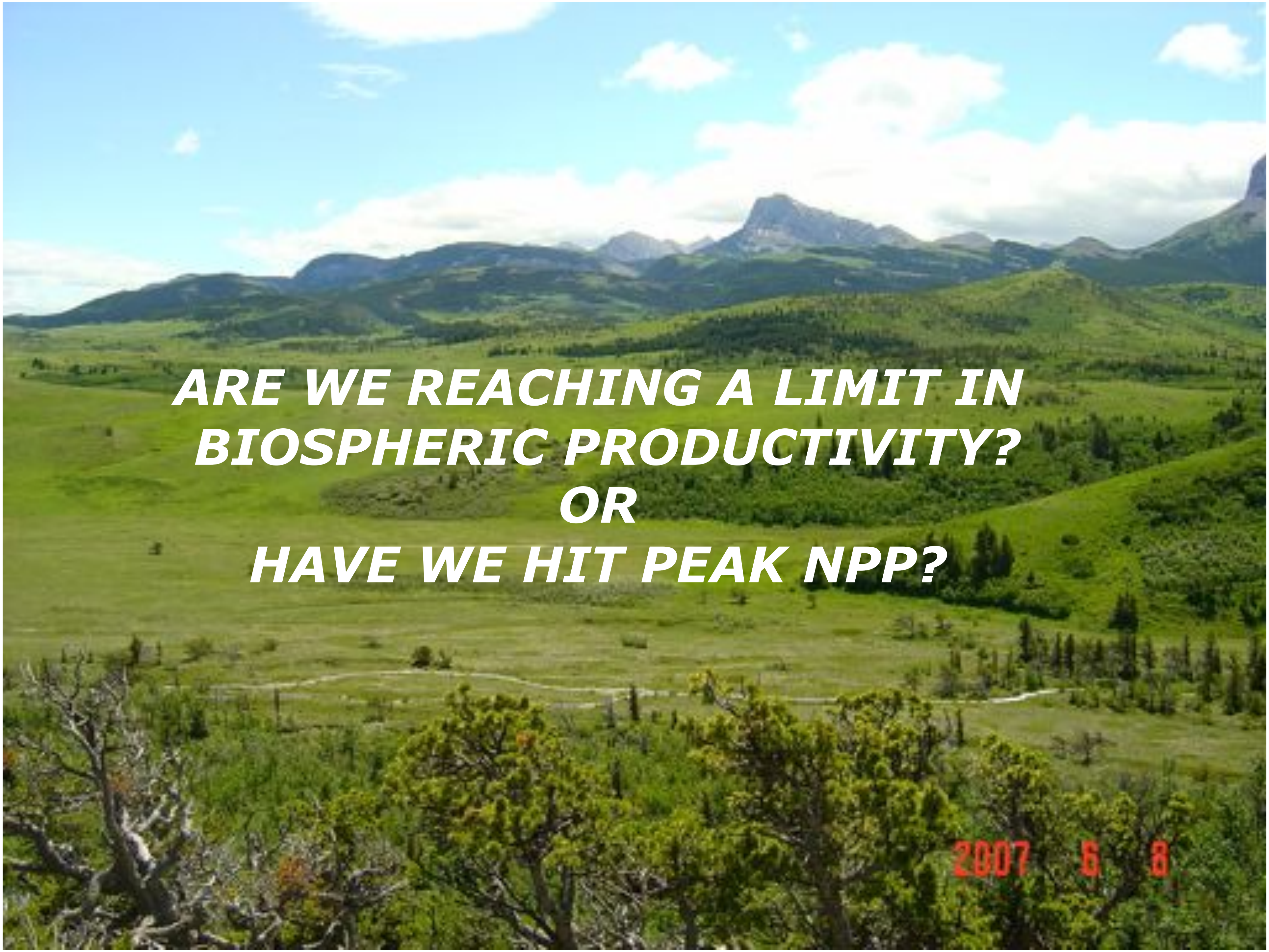
- AMSR-E VOD (10.65GHz) is sensitive to vegetation canopy biomass & is well correlated with MODIS LAI, EVI & NDVI;
- The VOD is largely unaffected by clouds & solar illumination, with potentially continuous global, daily monitoring;
- The AMSR-E VOD provides a unique & complimentary phenology dataset.

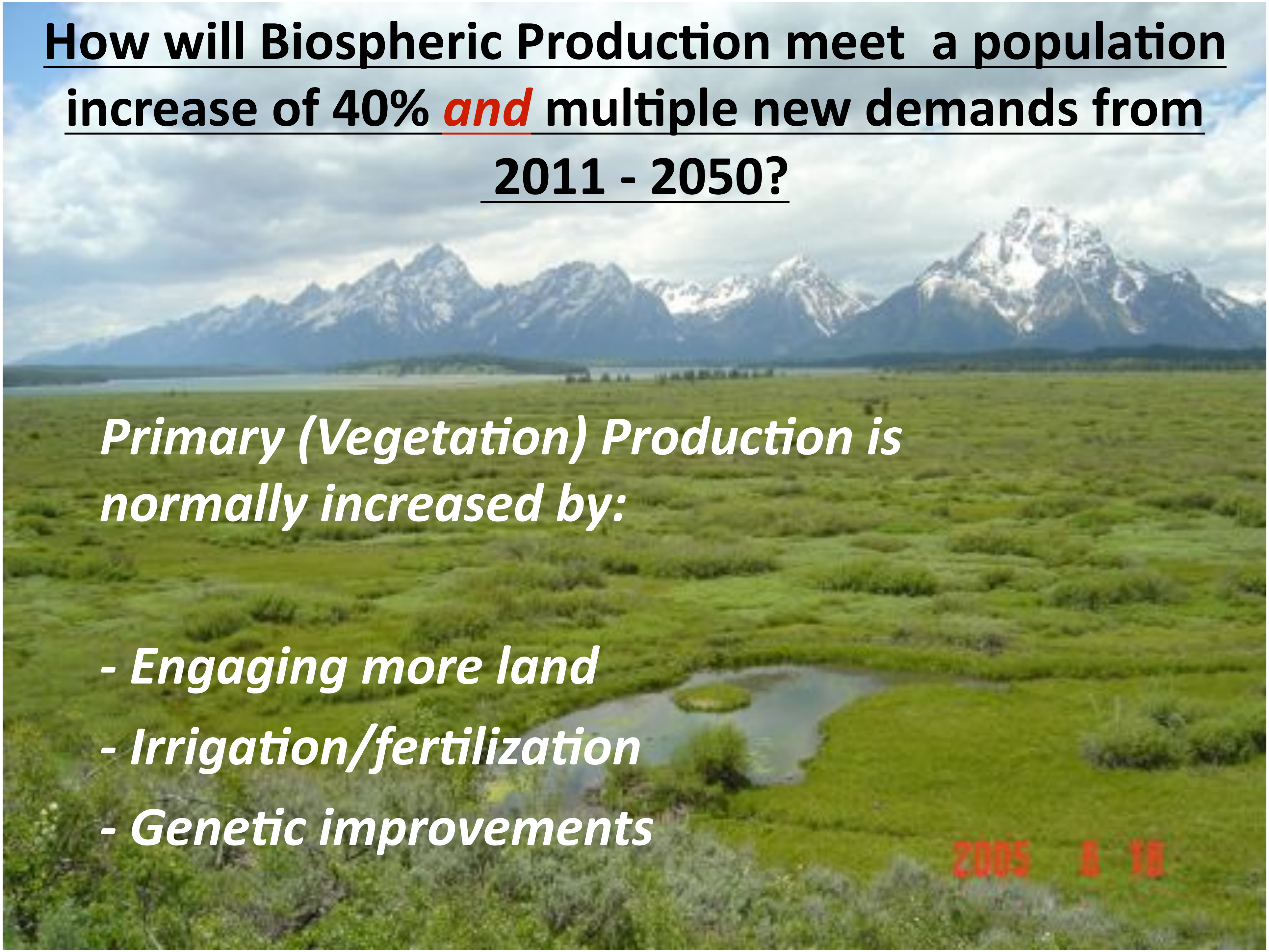
M.O. Jones et al. 2010. *Rem Sens. Environ*. 115

Highest QC Data Availability





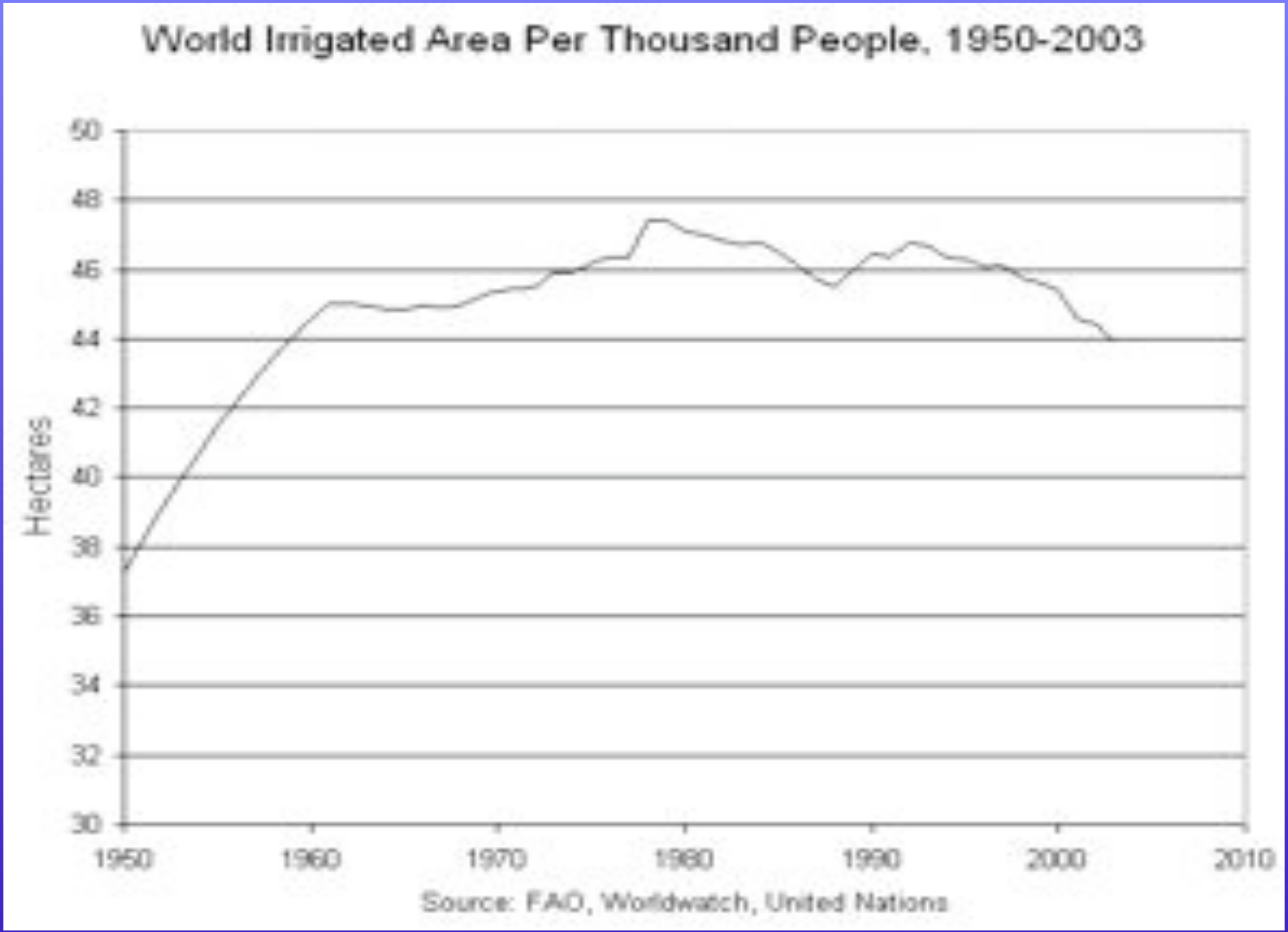

ARE WE REACHING A LIMIT IN
BIOSPHERIC PRODUCTIVITY?
OR
HAVE WE HIT PEAK NPP?
2007 6 8


How will Biospheric Production meet a population increase of 40% *and* multiple new demands from 2011 - 2050?
Primary (Vegetation) Production is normally increased by:
- Engaging more land
- Irrigation/fertilization
- Genetic improvements

Land area is NOT increasing

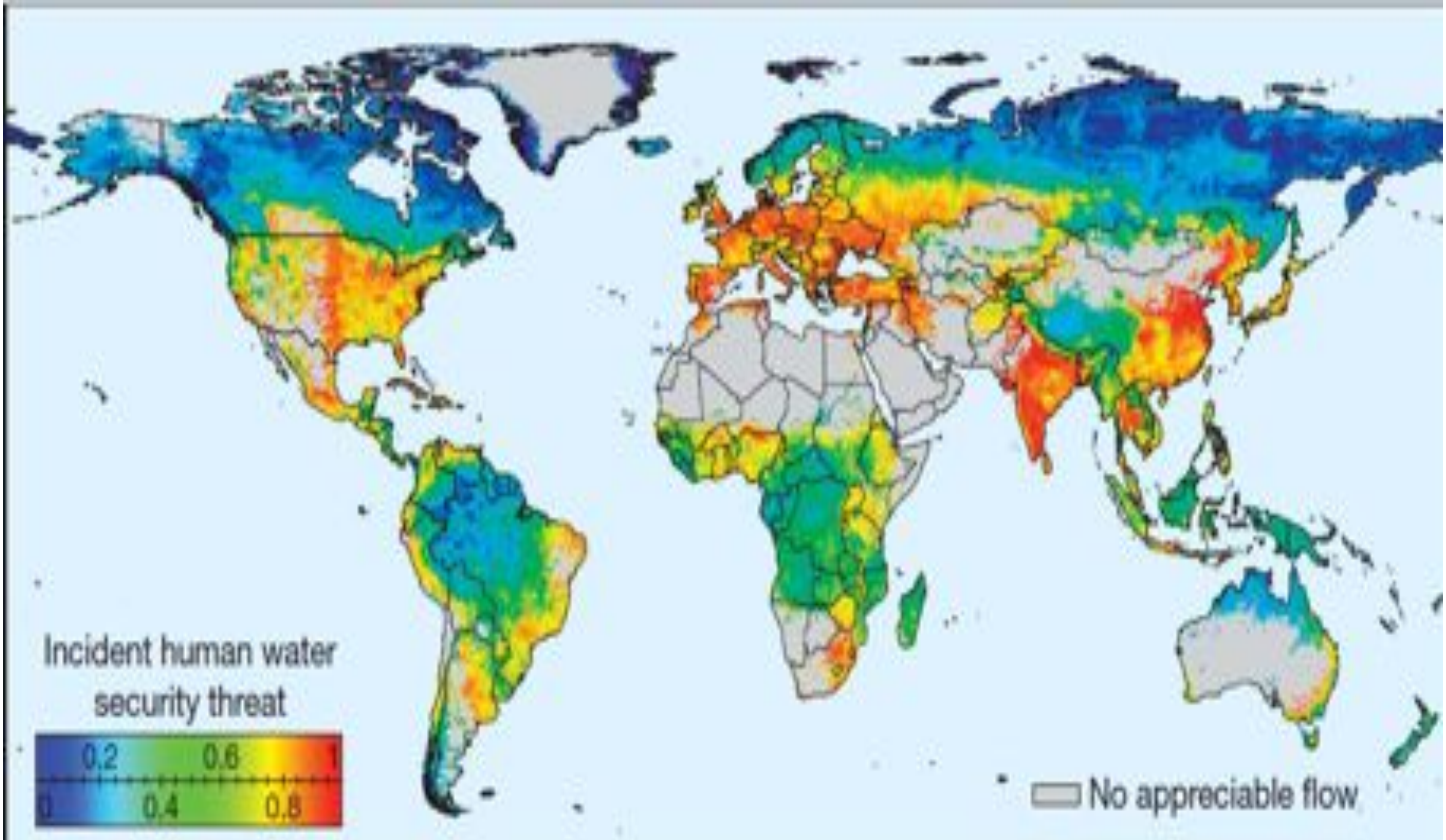
Figure 3.11 Arable land and area under cereals

Irrigated Land Area is NOT Increasing



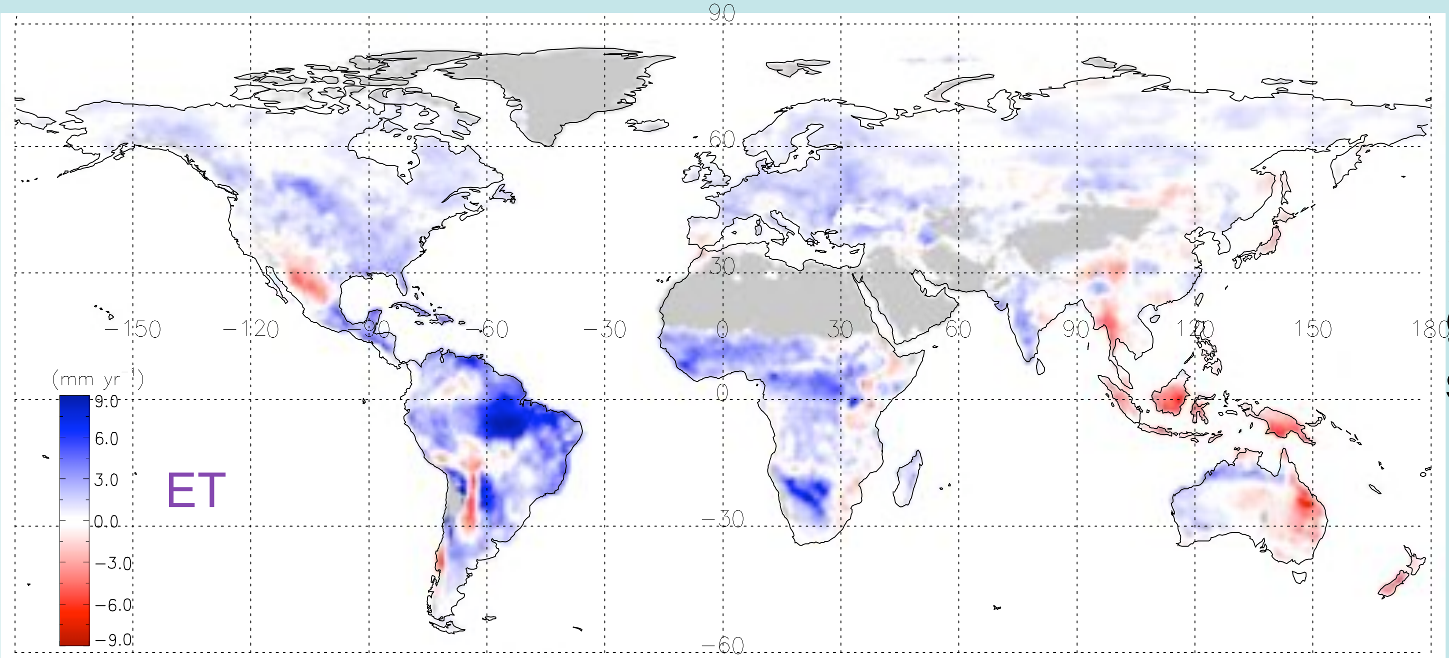
Lester Brown Plan 3.0, 2008

Global Water Availability Risk



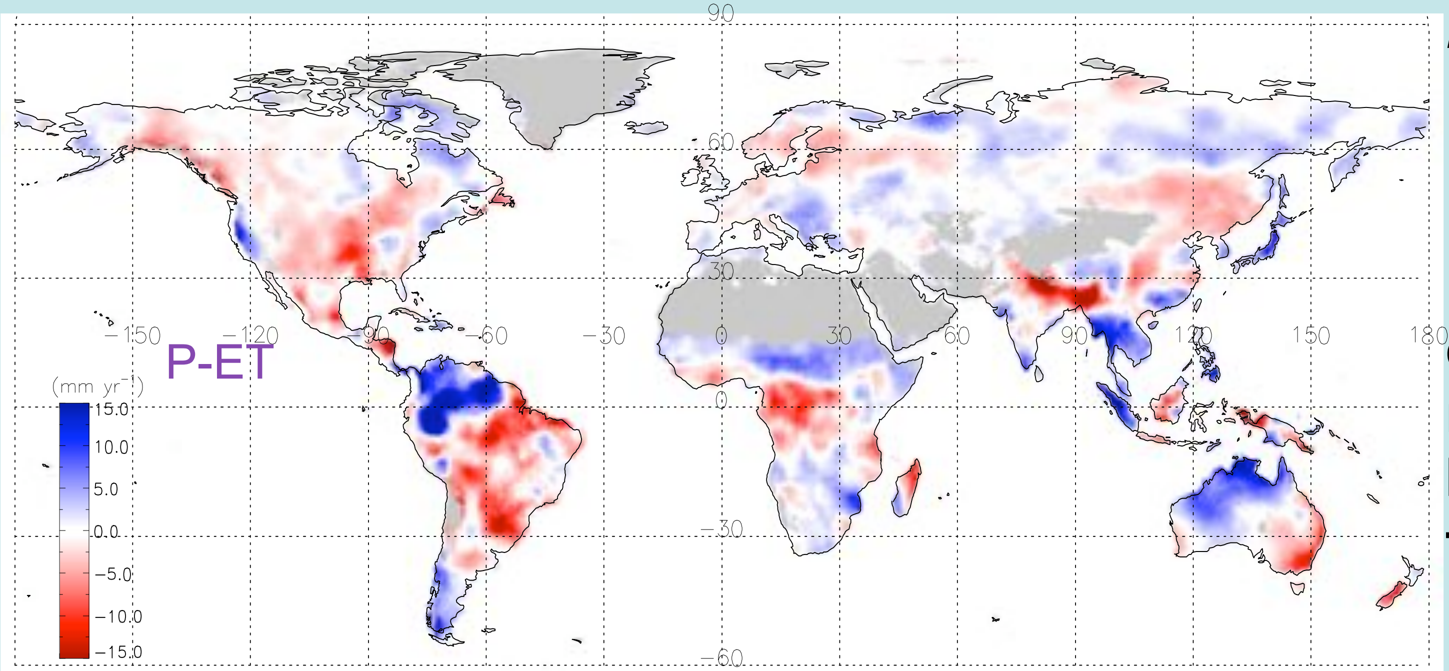
Vorasmairty et al Nature 2010

Multi-Year Trend in Estimated Mean Annual ET and P-ET (1983-2006)



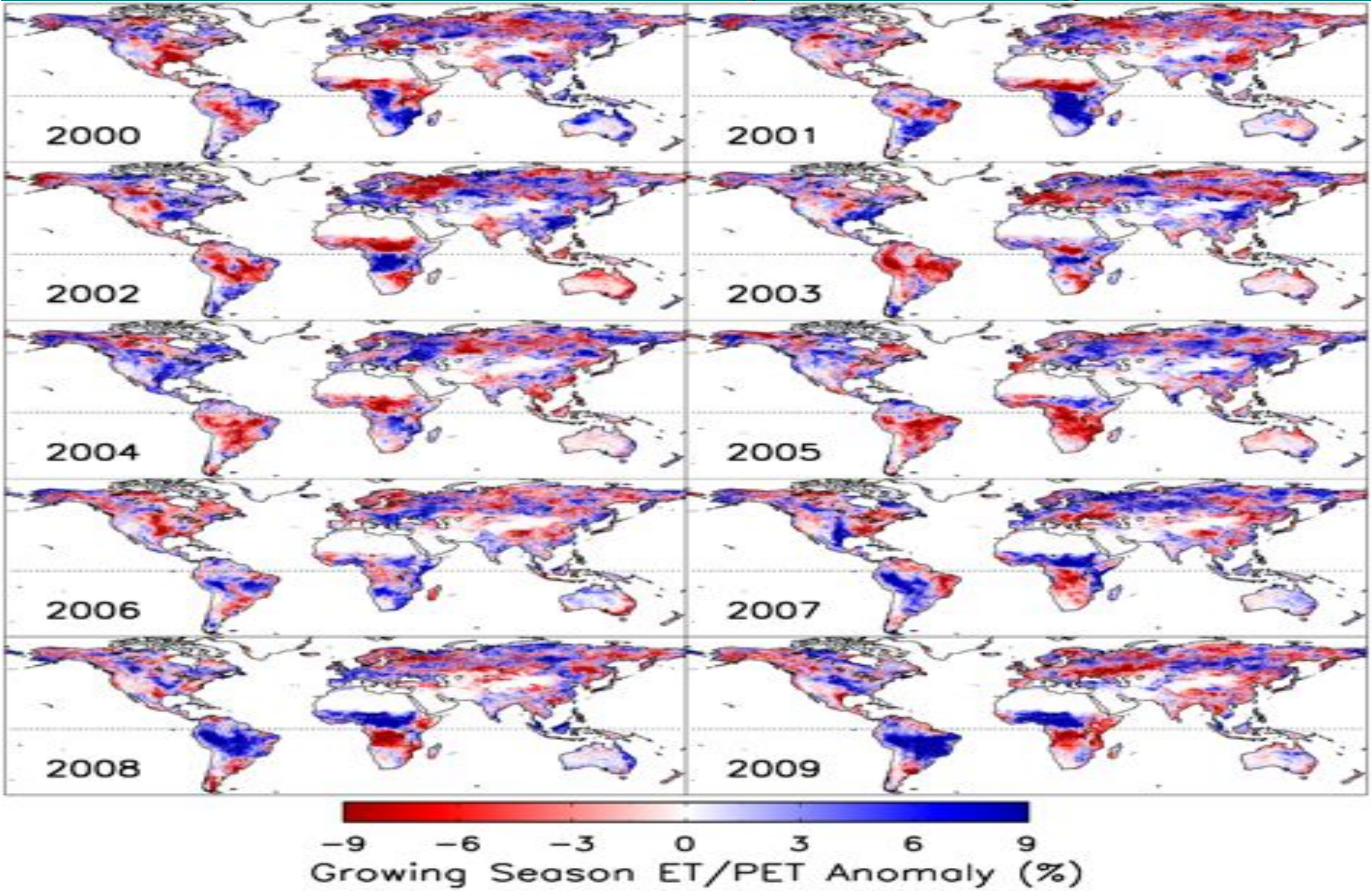
- ~73% of the global domain shows a positive ET trend;

BUT



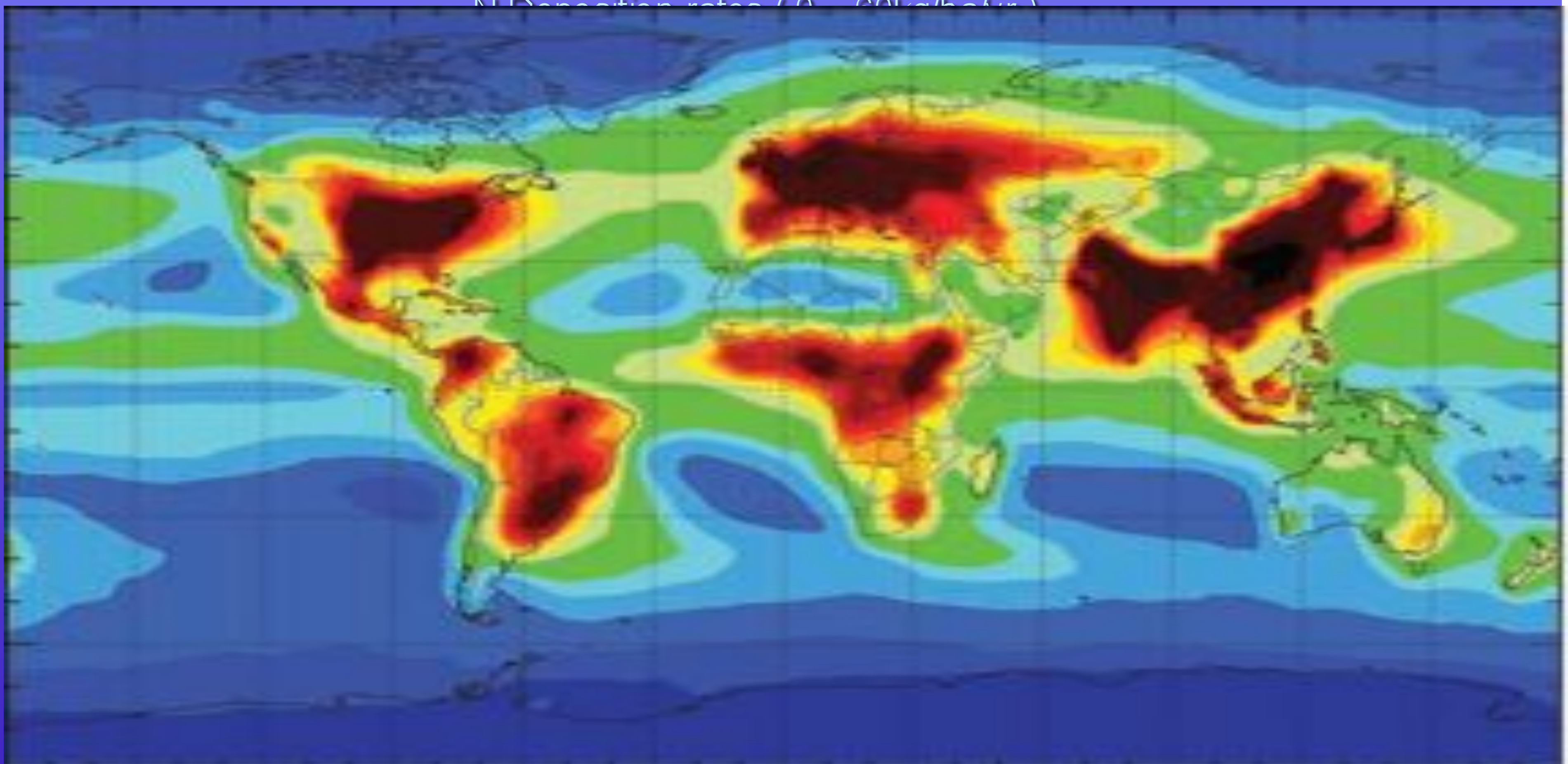
- ~51% of the domain shows a negative water balance (P-ET) trend.

MODIS ET (MOD 16)



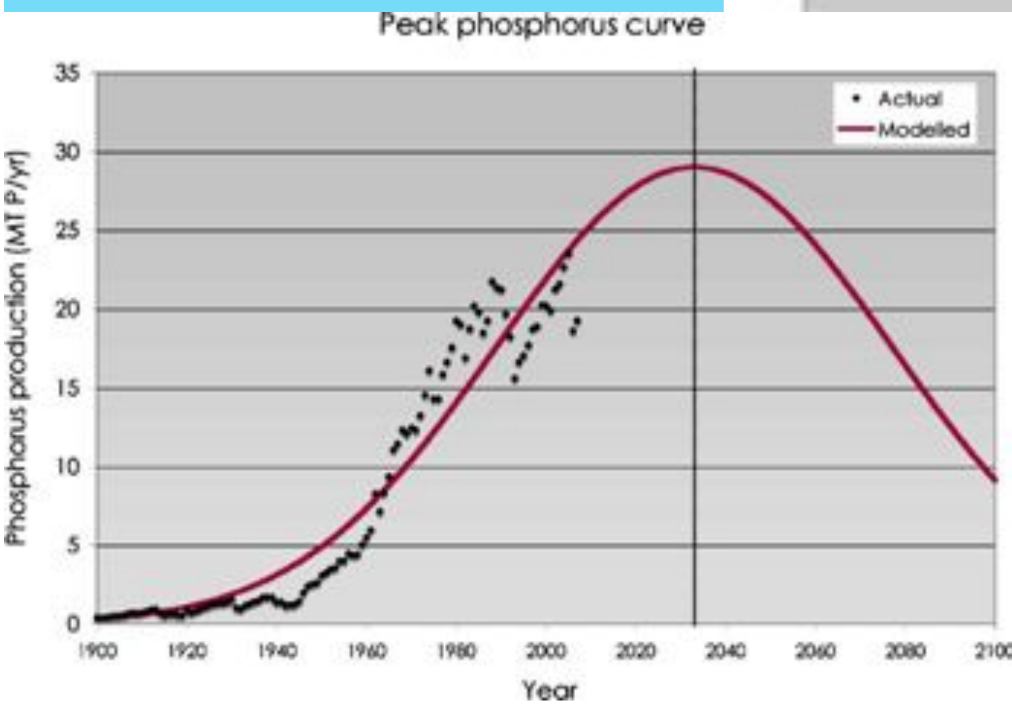
Nitrogen Loading is already damaging the biosphere

N Deposition rates (0 - 60kg/ha/yr)



Galloway et al Science 2008

Future Phosphorus Limitations ?

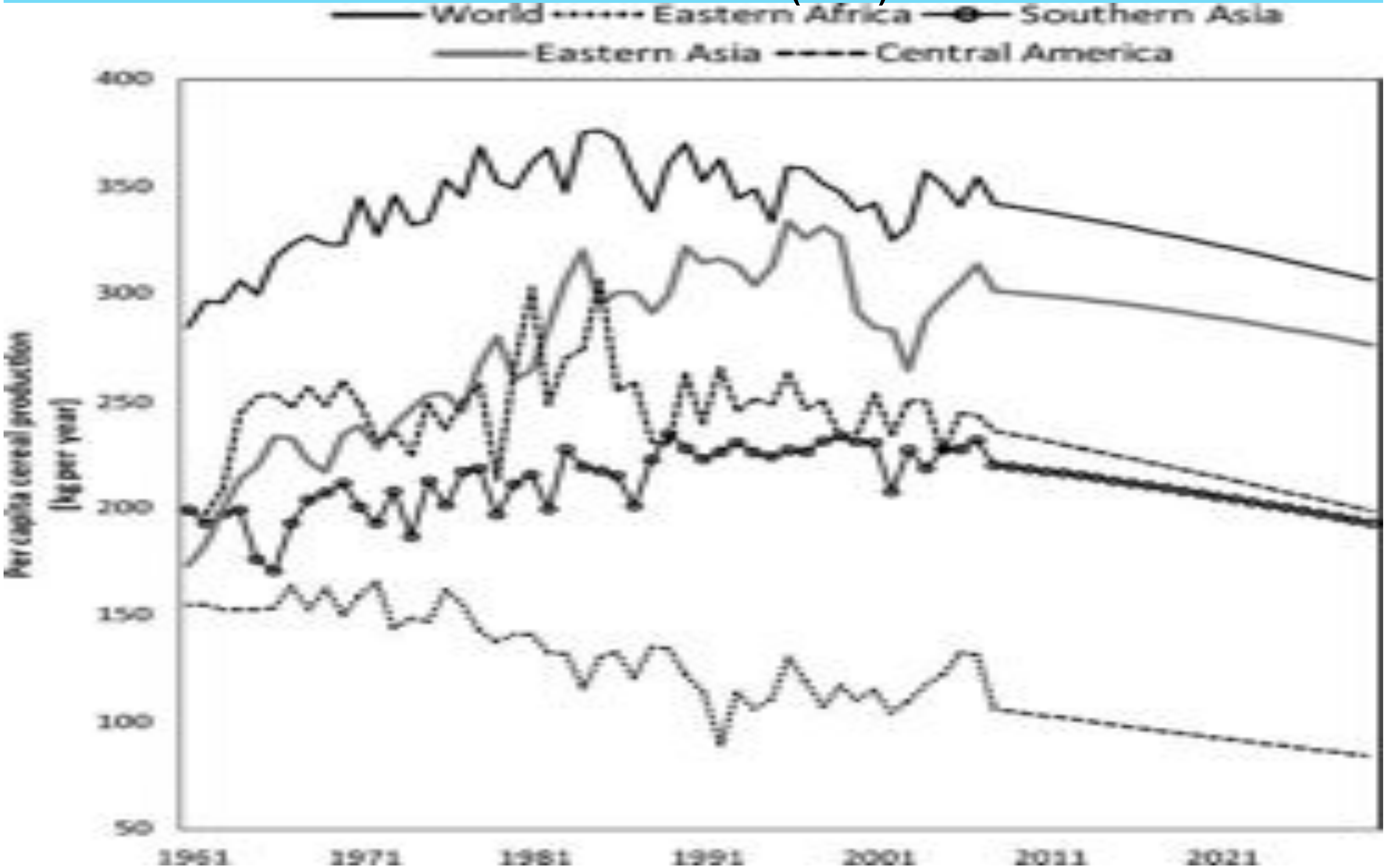


Cordell et al 2009.
Global Env Change 19: 292-305

Per Capita Agricultural Production trends.

Global 14% Per capita reduction projected by 2030

Funk and Brown (2009)



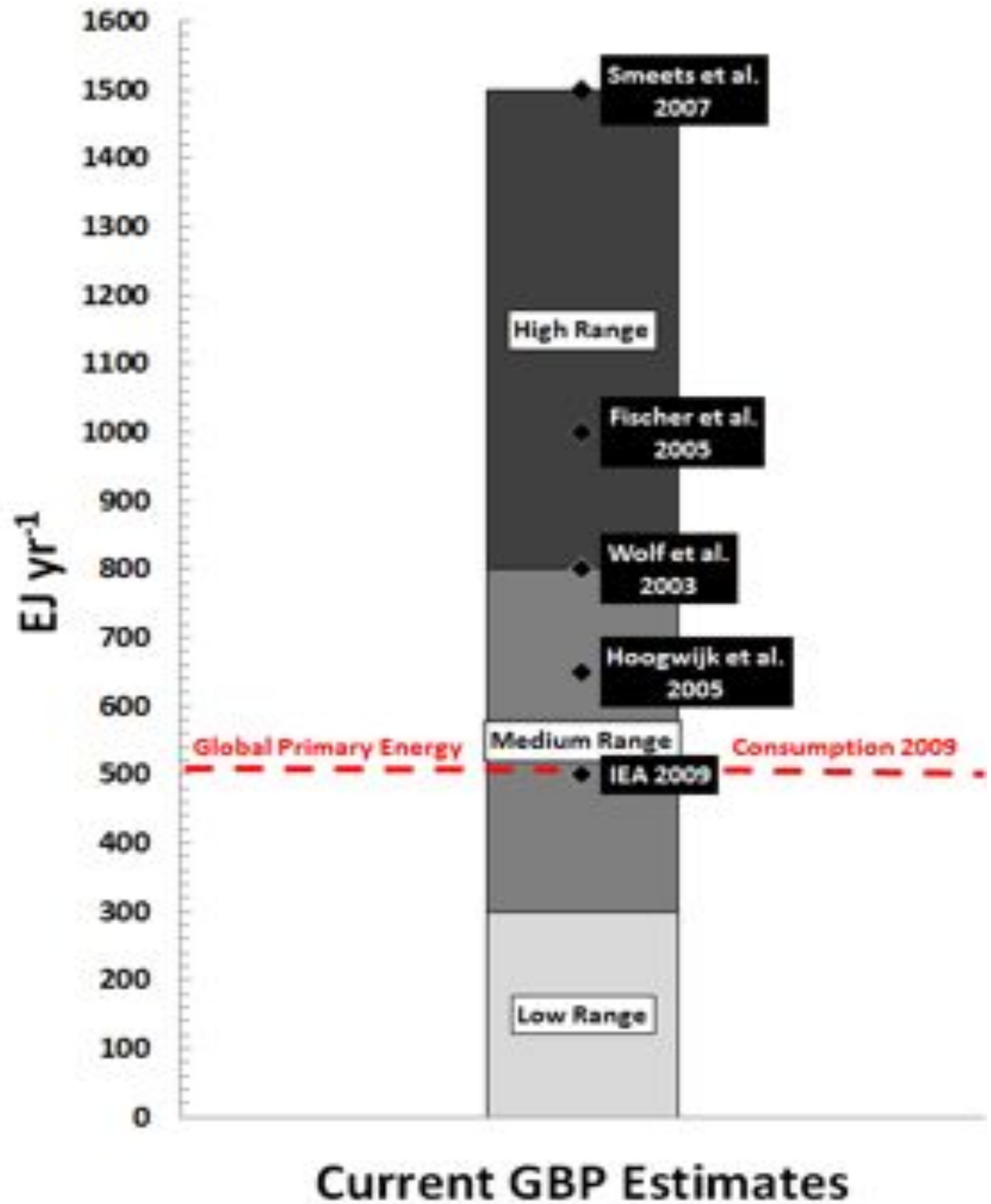
IS OUR CURRENT BIOSPHERIC CONSUMPTION OF NPP Sustainable*?

*Meeting needs and values of today's generation, while preserving the planet's life-support systems for the needs and values of future generations.

Current Global Bioenergy Potential Estimates

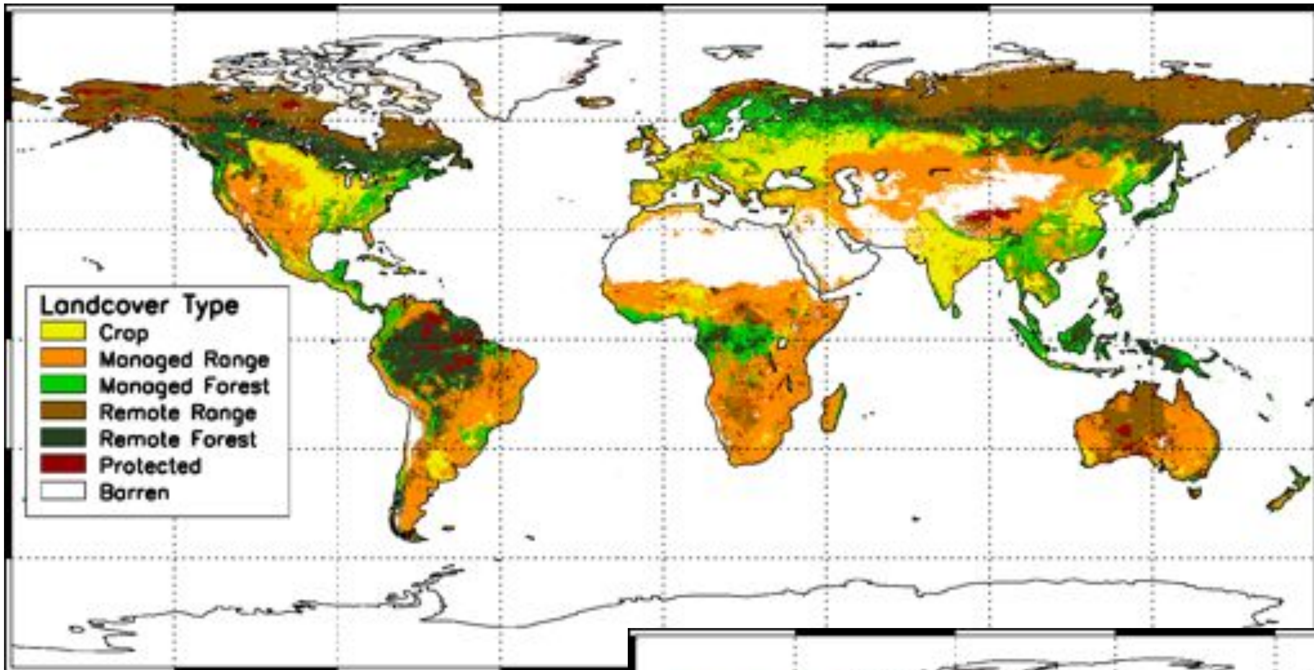
- **Current GBP estimates range up to 300% of global primary energy consumption 2009.**

- **Bioenergy alone, *adequate to fully replace fossil fuels*?**



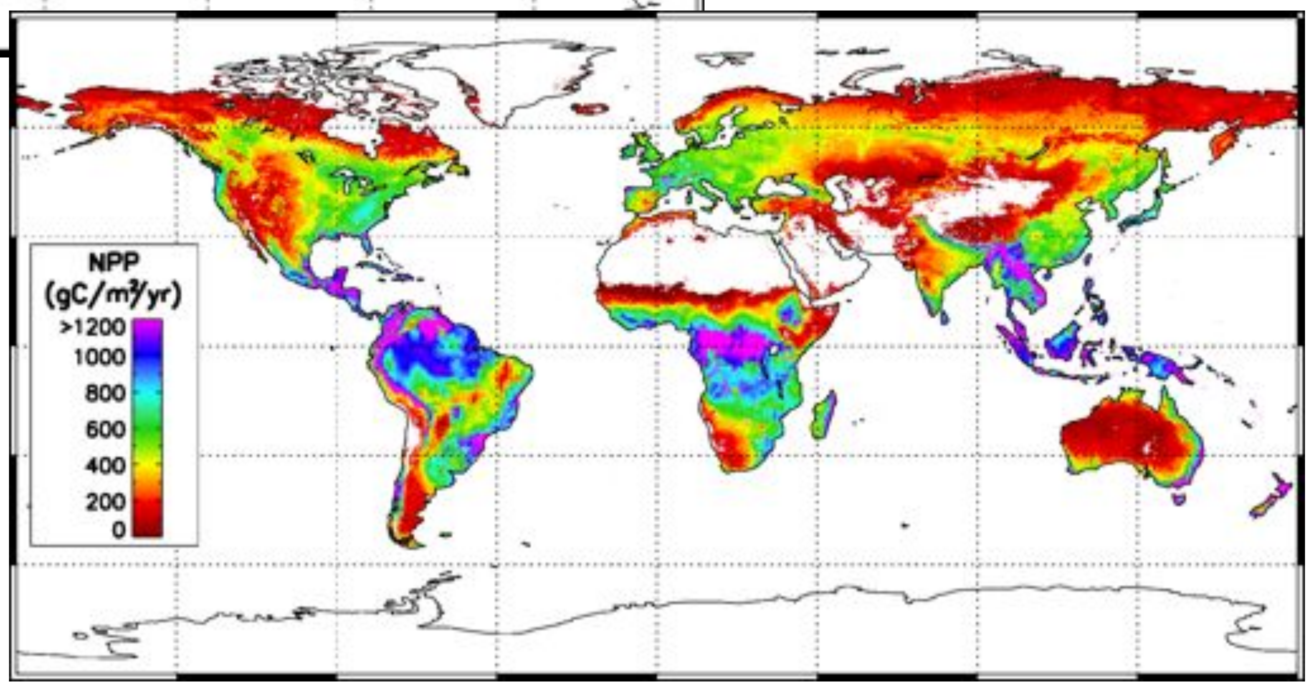
Adapted from Dornburg et al. 2010

Methods

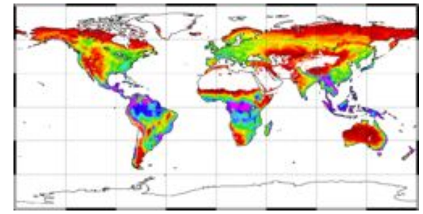
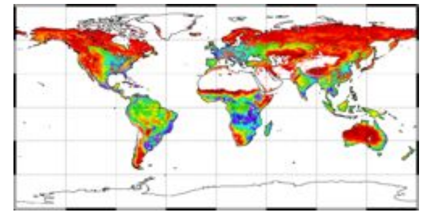
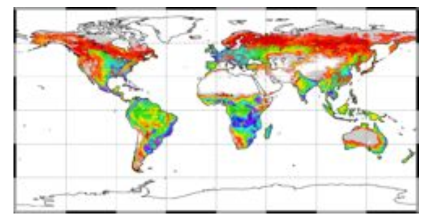
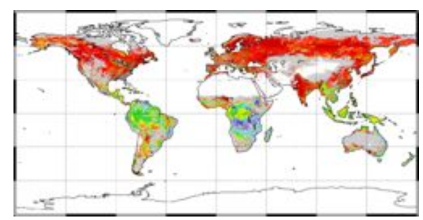
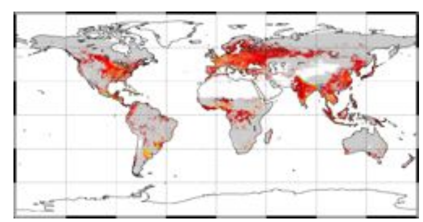


Global landcover:

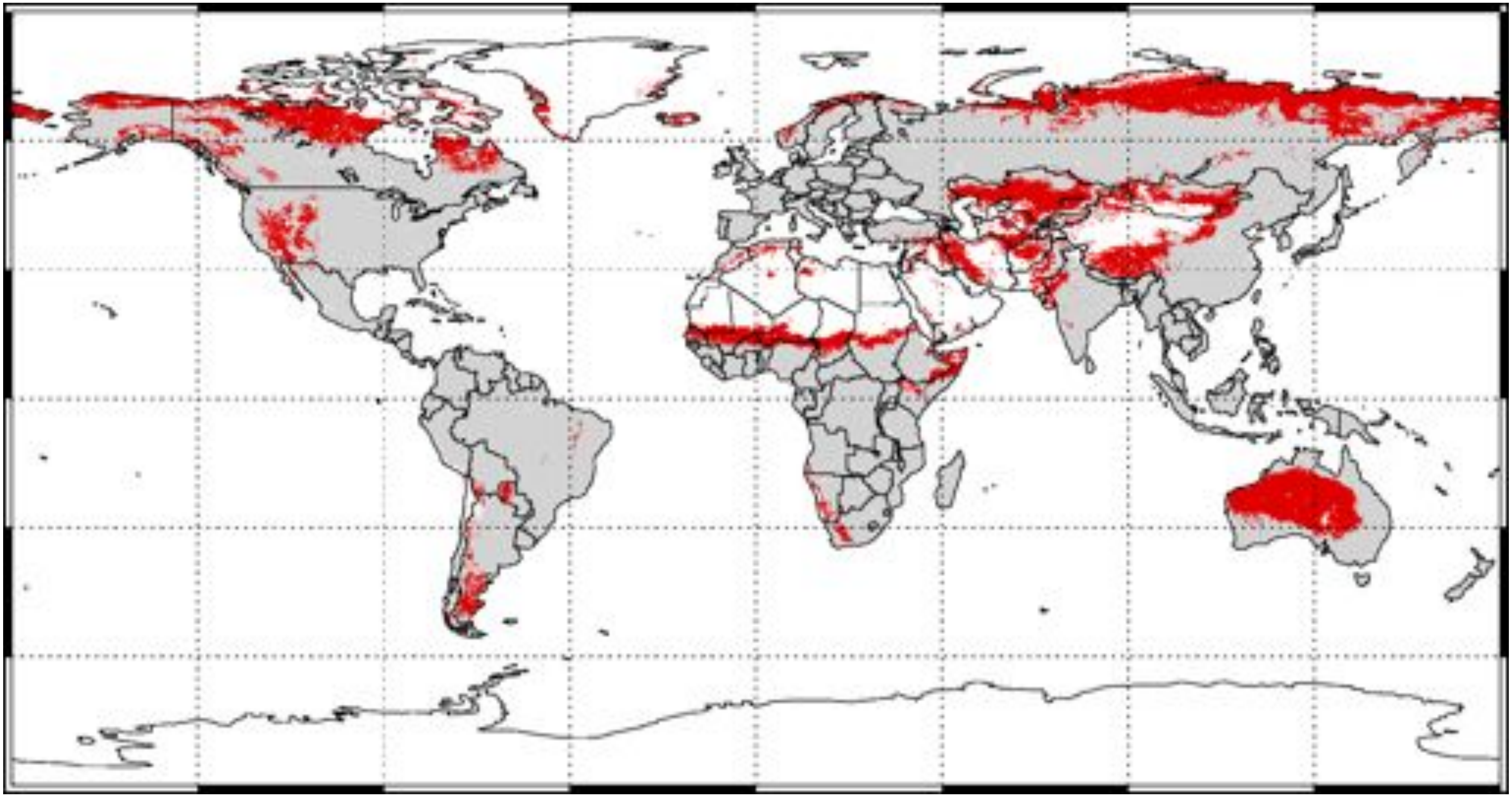
- MODIS NPP
- MODIS LC
- AGR2000
- WDPA
- GHF



Average global NPP (2000-2006) estimated from the MODIS GPP/NPP algorithm

Scenario	Definition	Spatial
NPP	**Total net primary production**	
GBP_{CAP}	**Sustainable harvest of *all* aboveground NPP**	
GBP_{BIO}	**GBP_{CAP} *without low productivity areas***	
GBP_{AVAIL}	**GBP_{BIO} *without HANPP***	
GBP_{RES}	**Sustainable harvest of *current harvest residues only***	

Low Productivity Areas



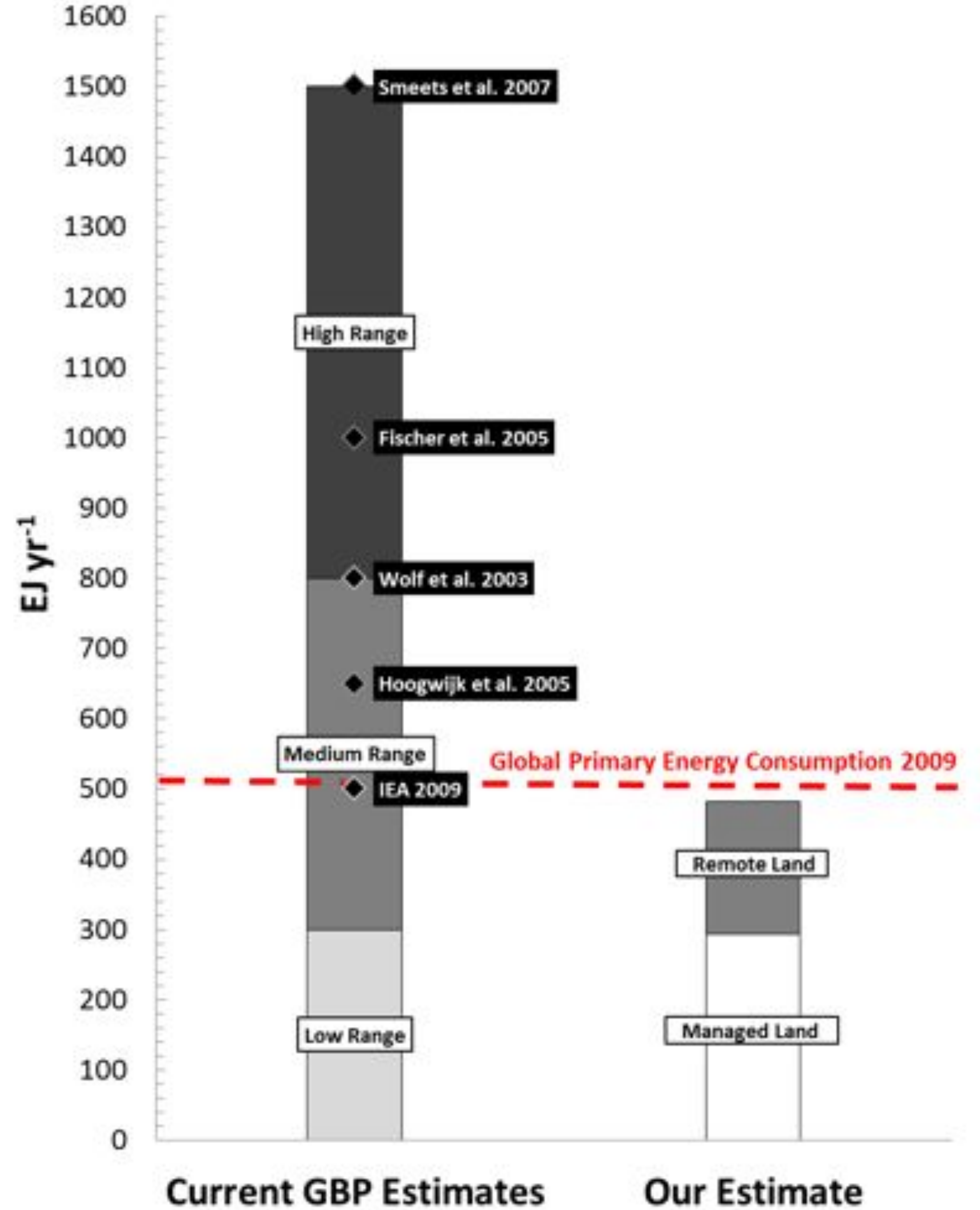
150 gC m^{-2} yr^{-1}: threshold at which harvest energy requirements *exceed* potential bioenergy output

Current Global Bioenergy Potential Estimates

- **Achievable GBP:**
  Managed Land:
  20-57% of GPEC09

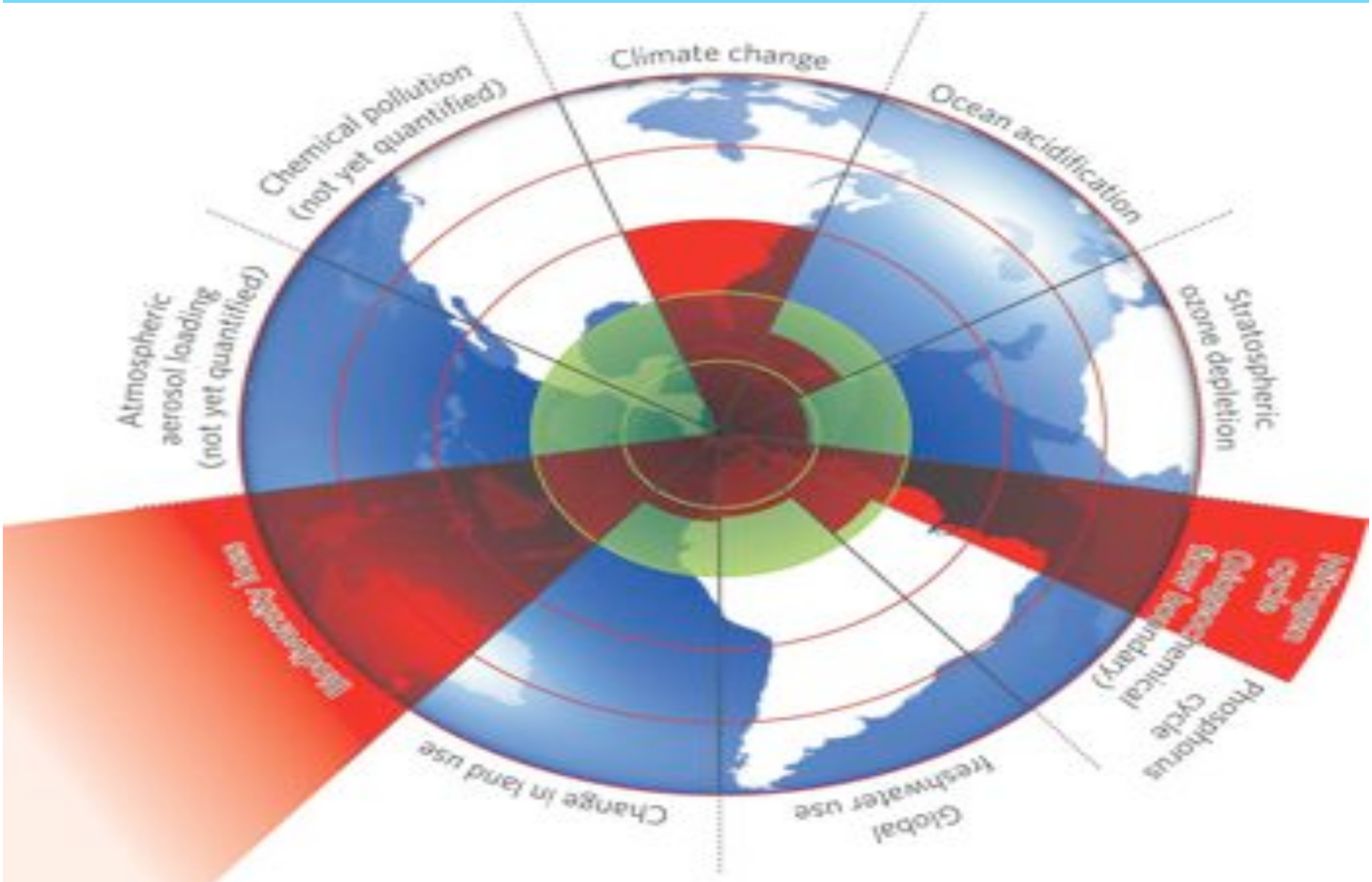
  Remote Land:
  0-36% of GPEC09

- **We integrate current natural and human management factors, which are inherent in the MODIS NPP data**



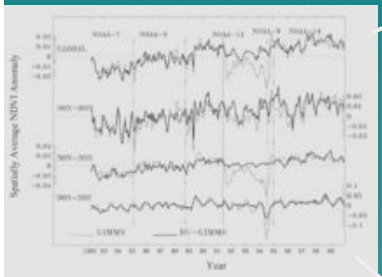
PLANETARY BOUNDARIES

Rockstrom et al. *Nature* 2009



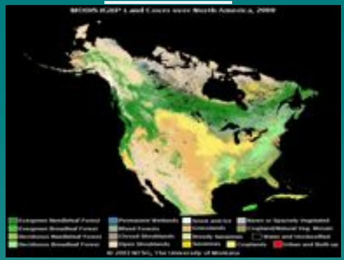
Terrestrial Carbon Monitor

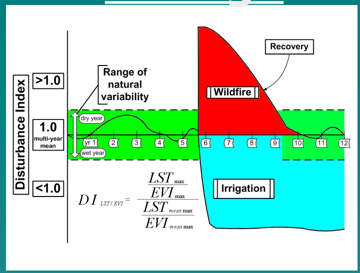
SATELLITE DATA



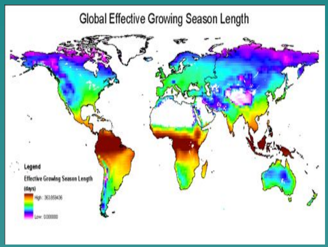
State | **Change**

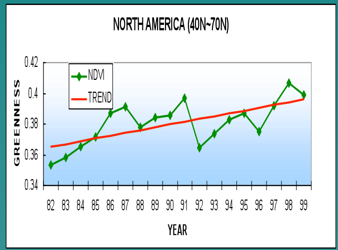
LANDCOVER



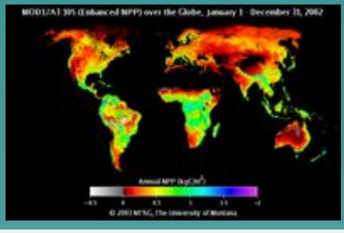


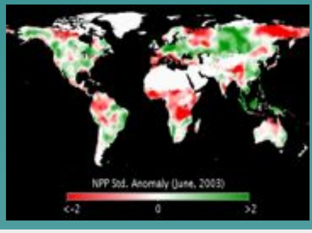
GROWING SEASON





PRIMARY PRODUCTION





GROUND DATA