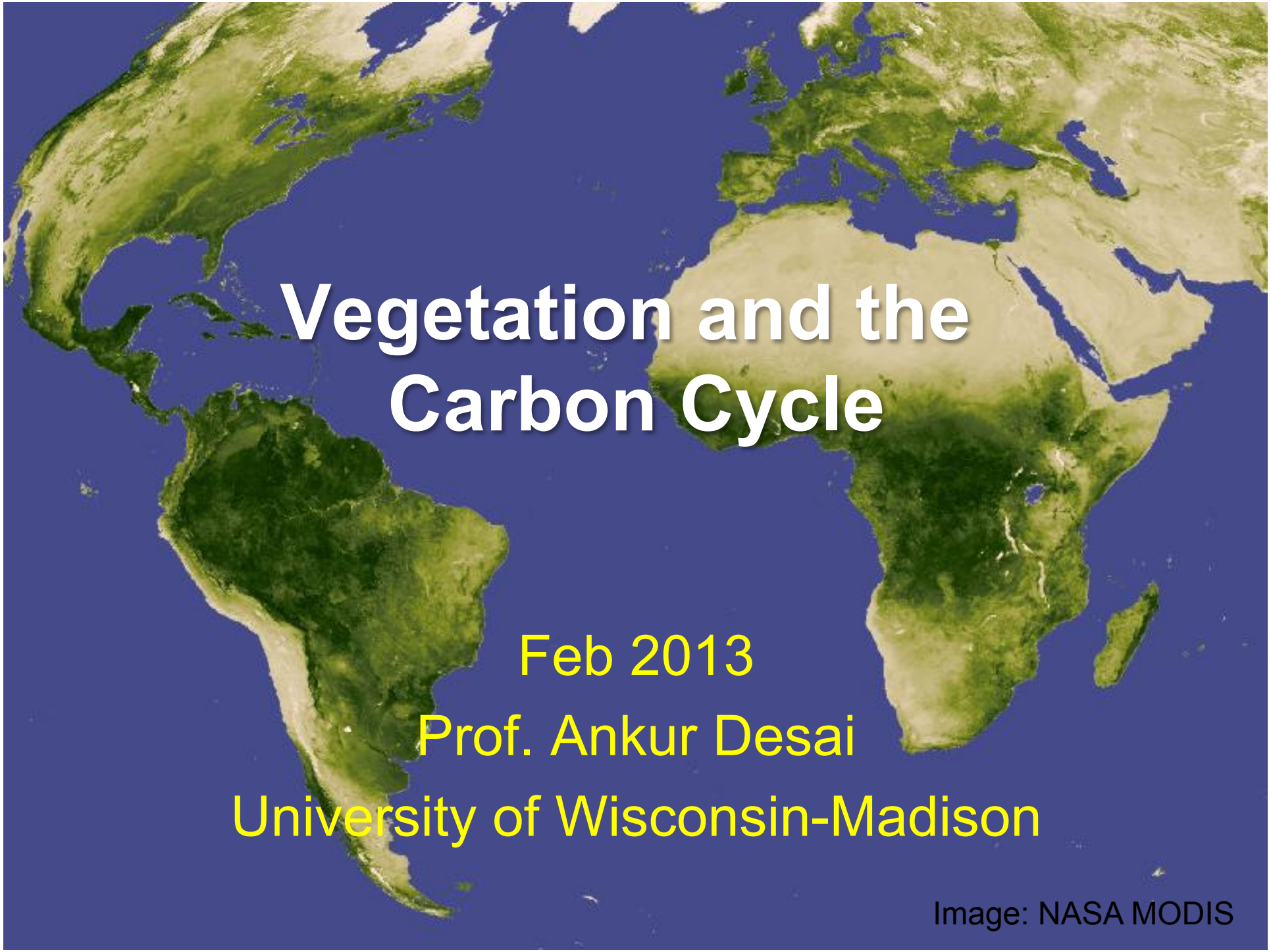


Vegetation and the Carbon Cycle

Feb 2013

Prof. Ankur Desai

University of Wisconsin-Madison

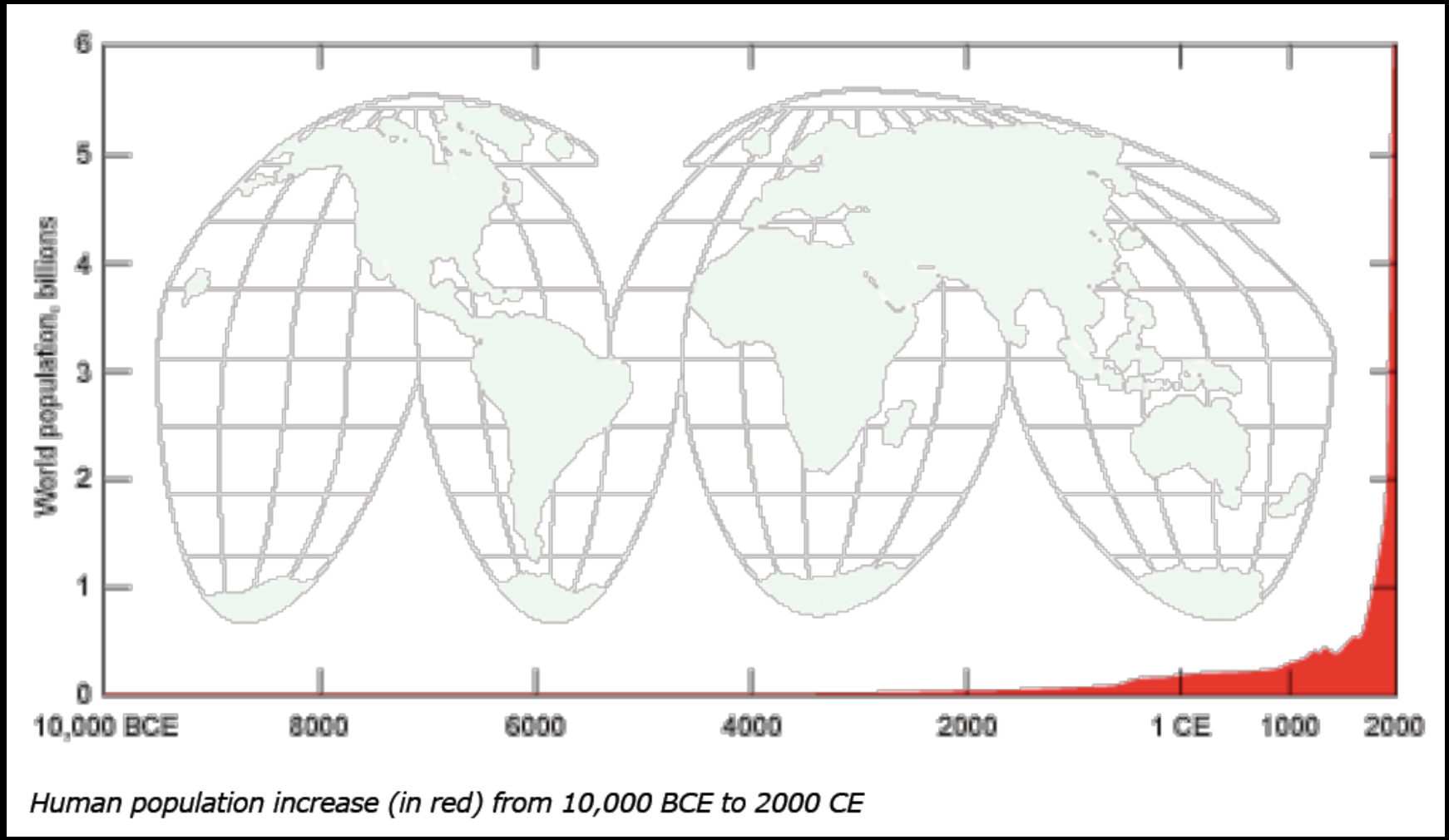
Image: NASA MODIS

Acknowledge

- My lab: Jonathan Thom (scientist), Malgorzata Golub (PhD), Ke Xu (PhD), Tommy Jasmin (MS/scientist), Sean DuBois (MS), Dong Hua (postdoc), Ben Sulman (postdoc), Justin Bagley (postdoc)
- Collaborators: Penn State, U Illinois, U Minnesota, Boston U, CalTech, NOAA
- Funding: NSF, DOE

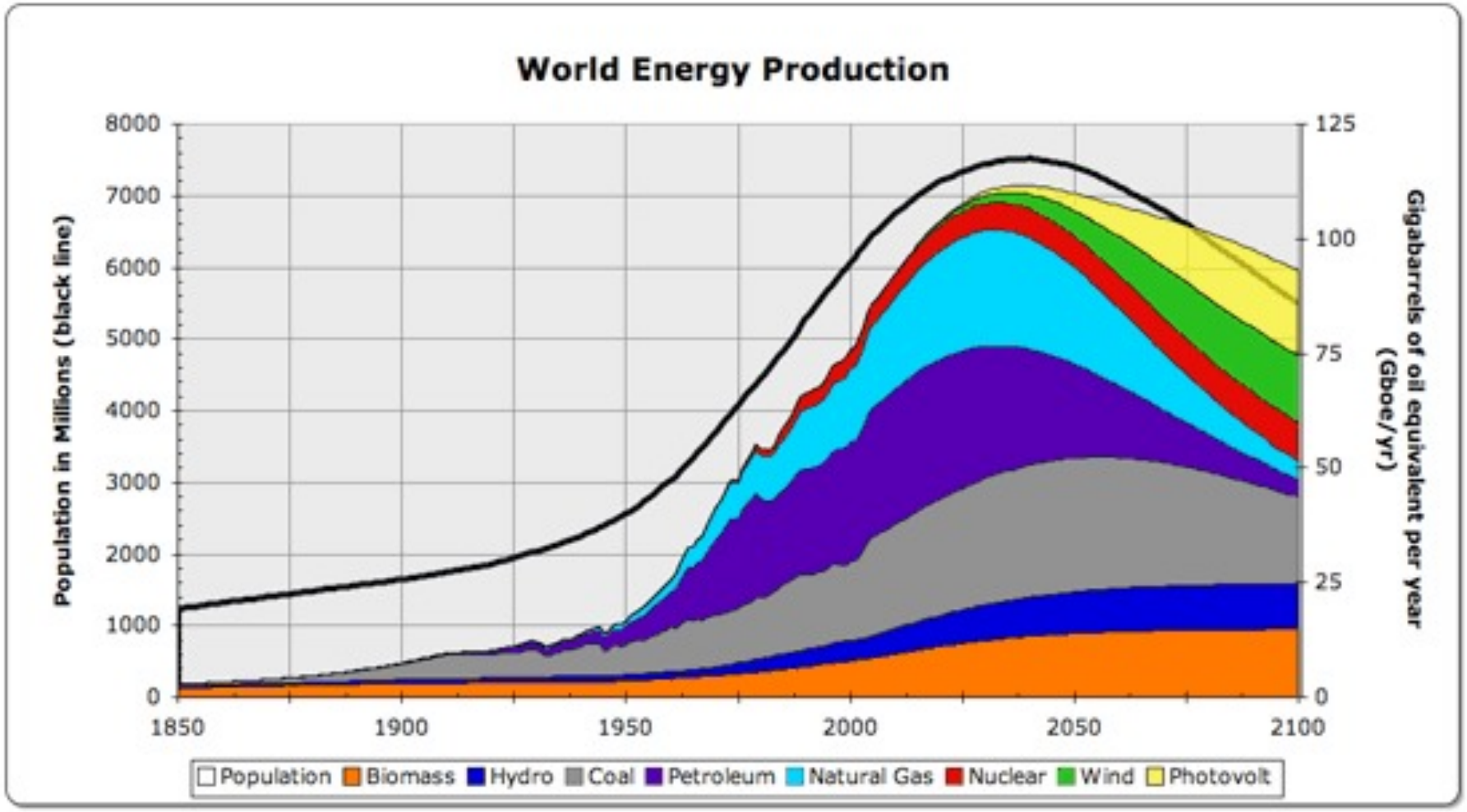

LAZY
BUT


Willow Creek - NetCam SC IR - Thu Sep 20 11:31:17 2012
Temperature: 36.0 °C internal, 9.0 °C outside
RH: 0%, Pressure: 944.0 millibars
Exposure: 400



Human population increase (in red) from 10,000 BCE to 2000 CE

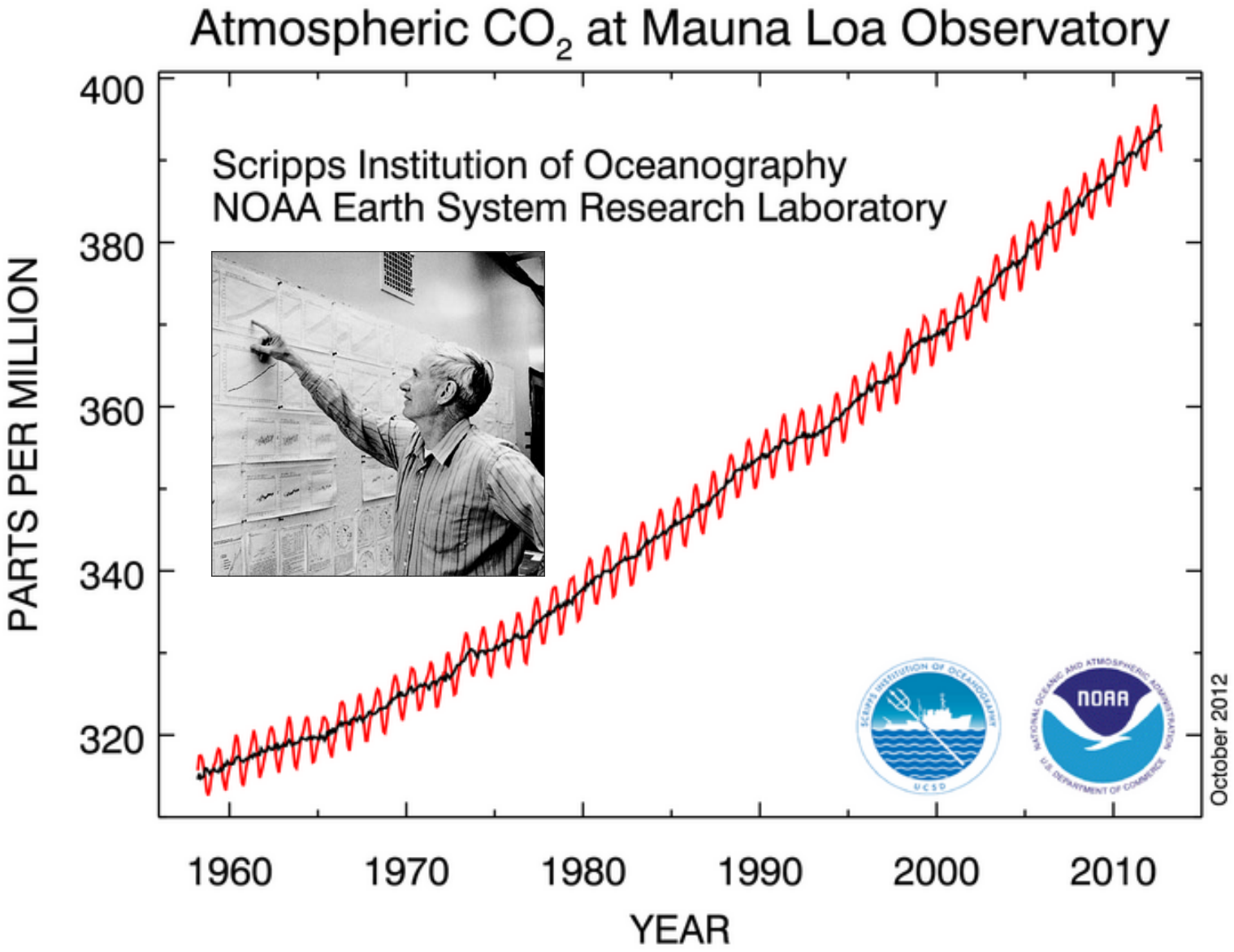
- Source: UCAR Quarterly, Summer 2007

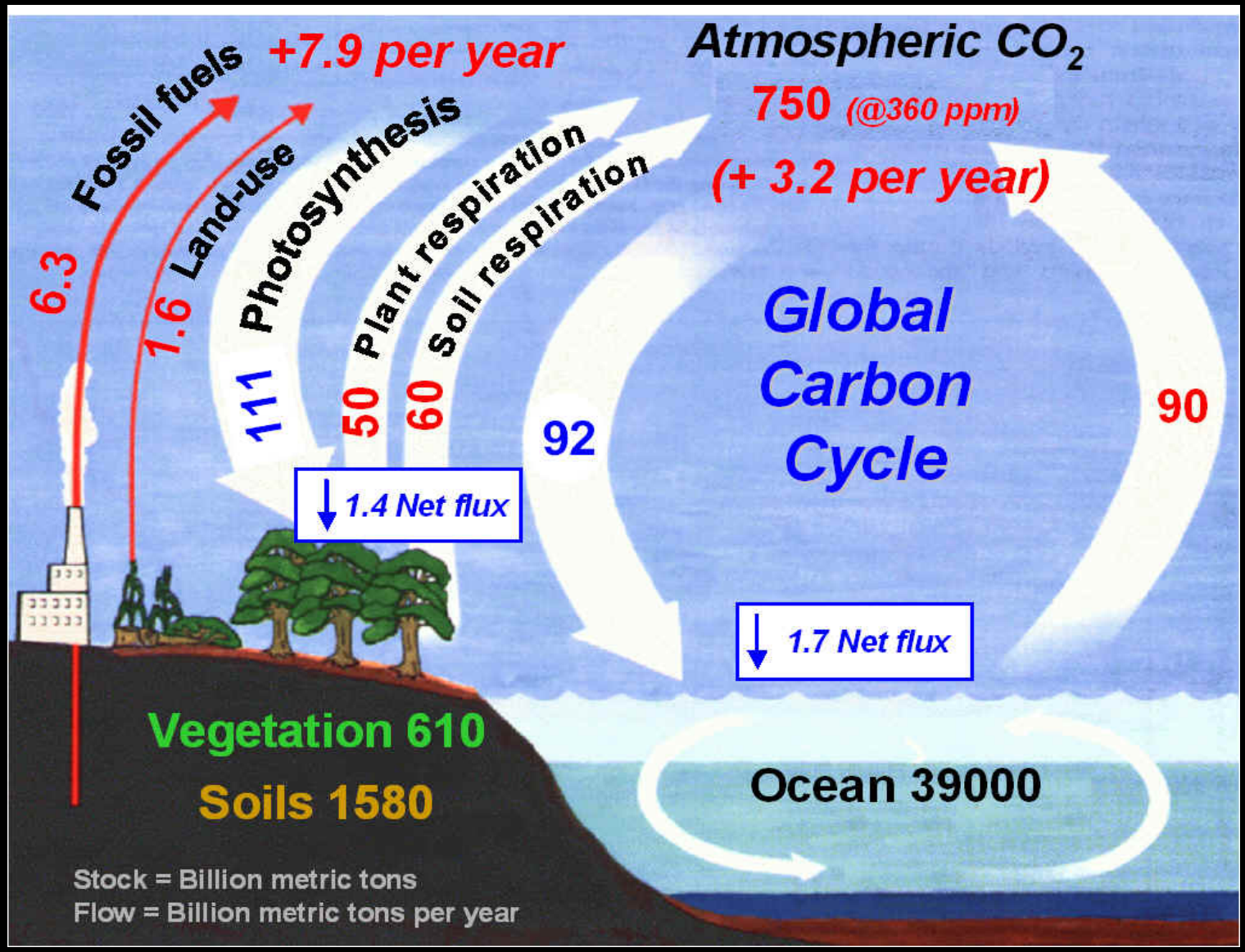


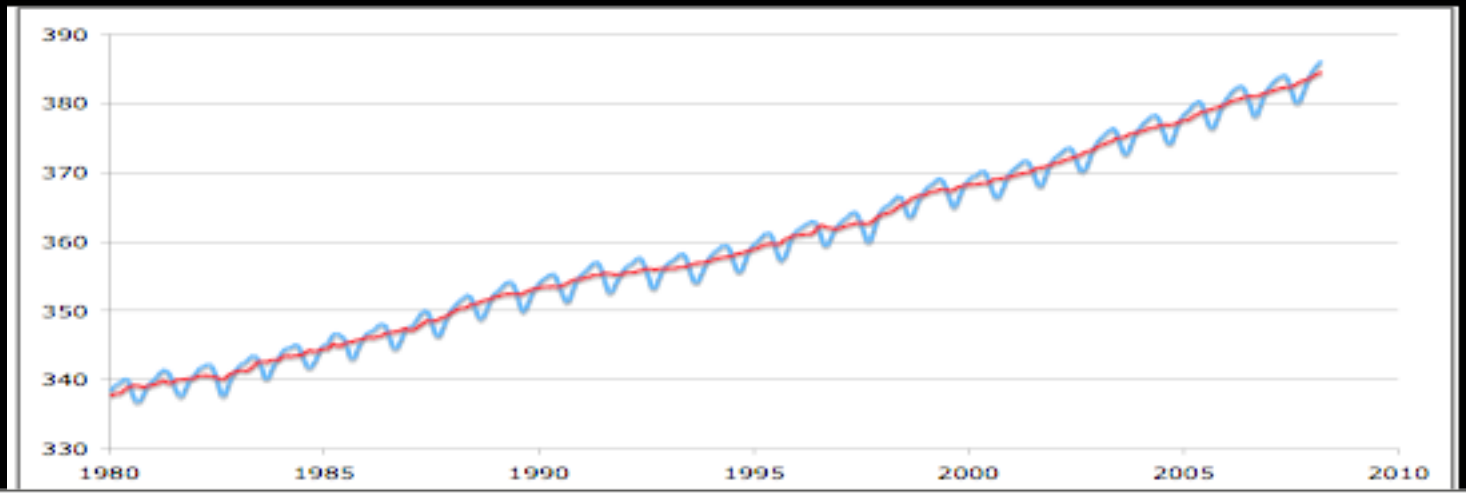
http://www.iceuls.com/_photo/b.jpg

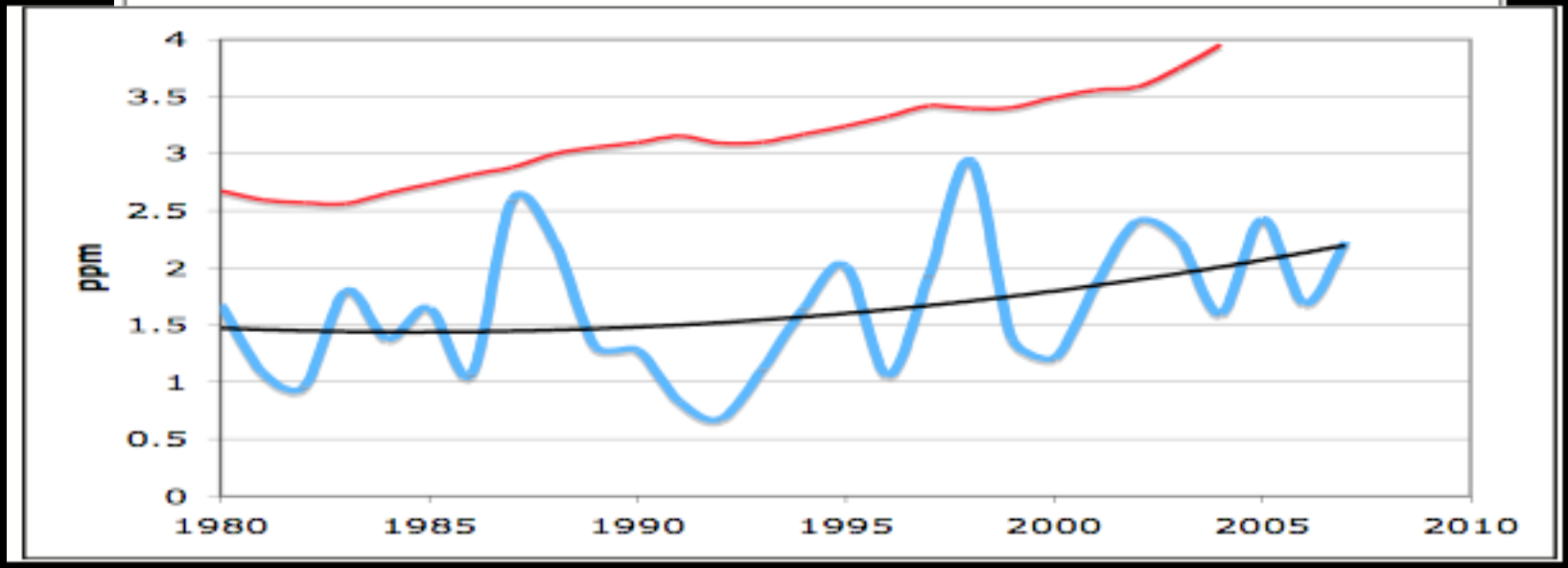
- Global change science research involves:
  - Analysis of observations of air, water, land, humans over space and time
  - Lab and field experiments of these quantities
  - Theory and math about the physics, chemistry, biology, geology, and economics of the Earth System
  - Computational simulation of various Earth system models to test hypotheses against observations
  - Synthesis, communication, and application of findings from all of the above
- All require:
  - good questions, precise observations, and working in diverse teams!

CARBON

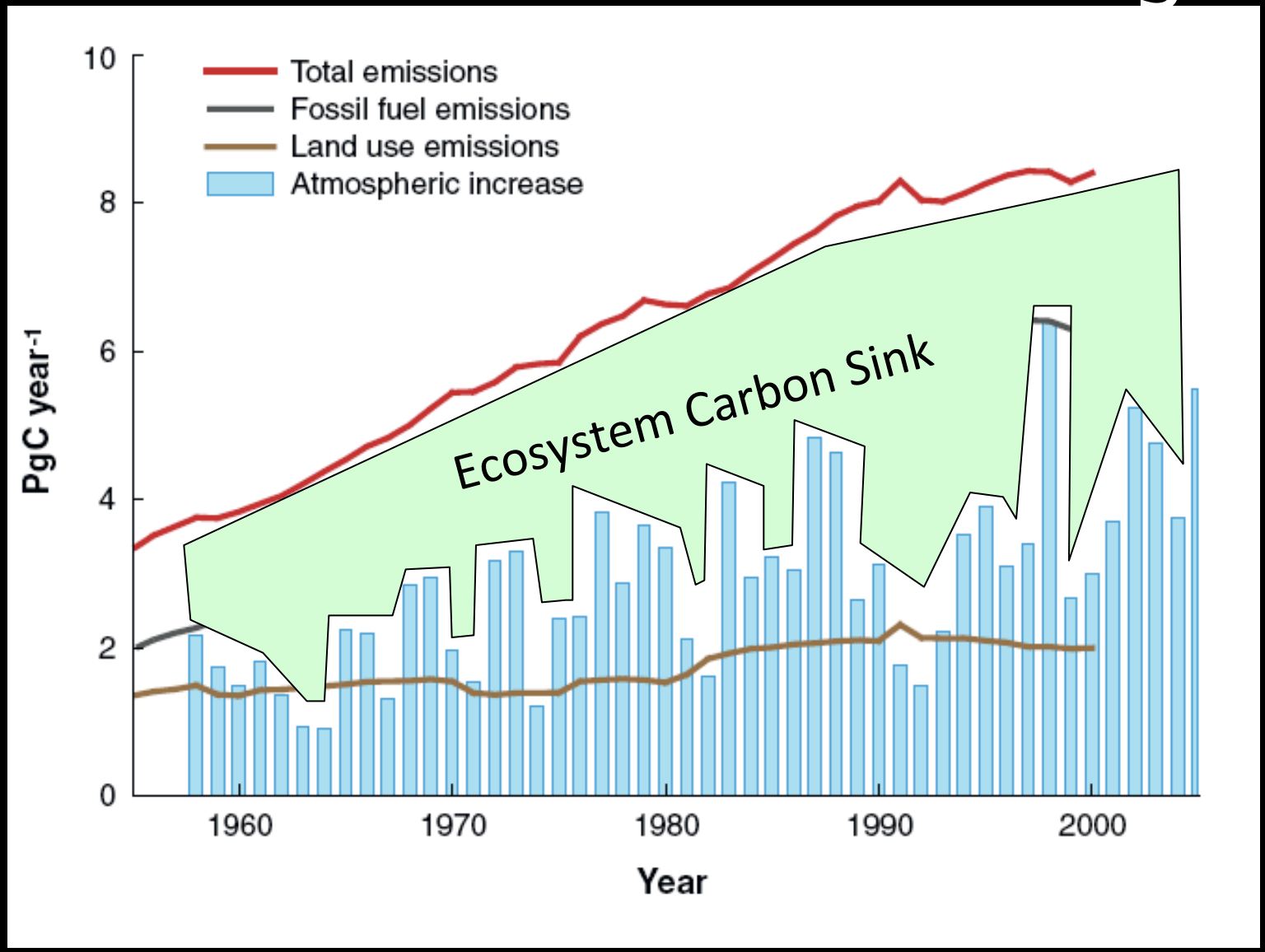

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
October 2012


Fossil fuels
+7.9 per year
Atmospheric CO_2
750 (@360 ppm)
(+ 3.2 per year)
6.3
Land-use
1.6
Photosynthesis
111
Plant respiration
50
Soil respiration
60
92
Global Carbon Cycle
90
1.4 Net flux
1.7 Net flux
Vegetation 610
Soils 1580
Ocean 39000
Stock = Billion metric tons
Flow = Billion metric tons per year


390
380
370
360
350
340
330
1980
1985
1990
1995
2000
2005
2010

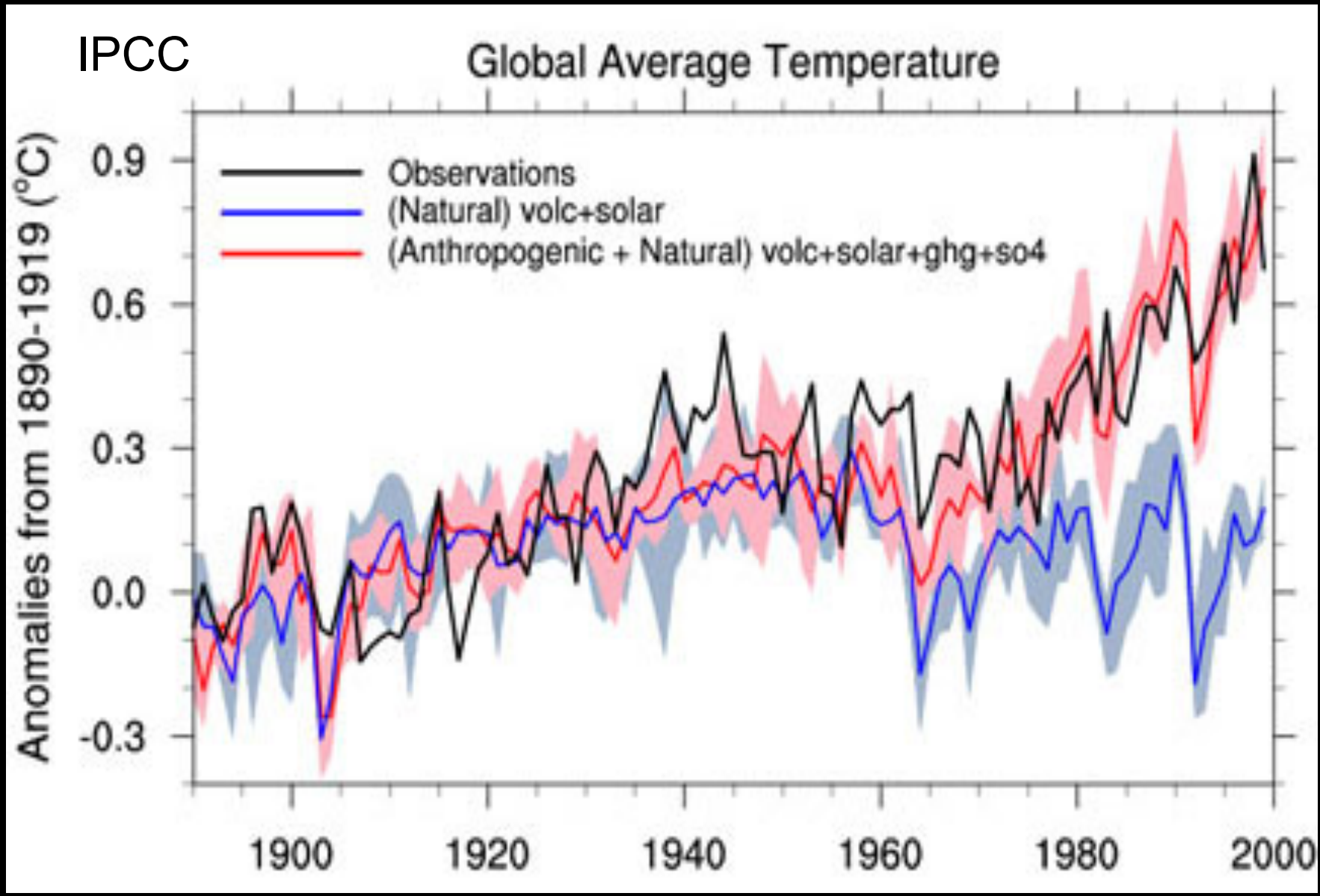

ppm
4
3.5
3
2.5
2
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
2010

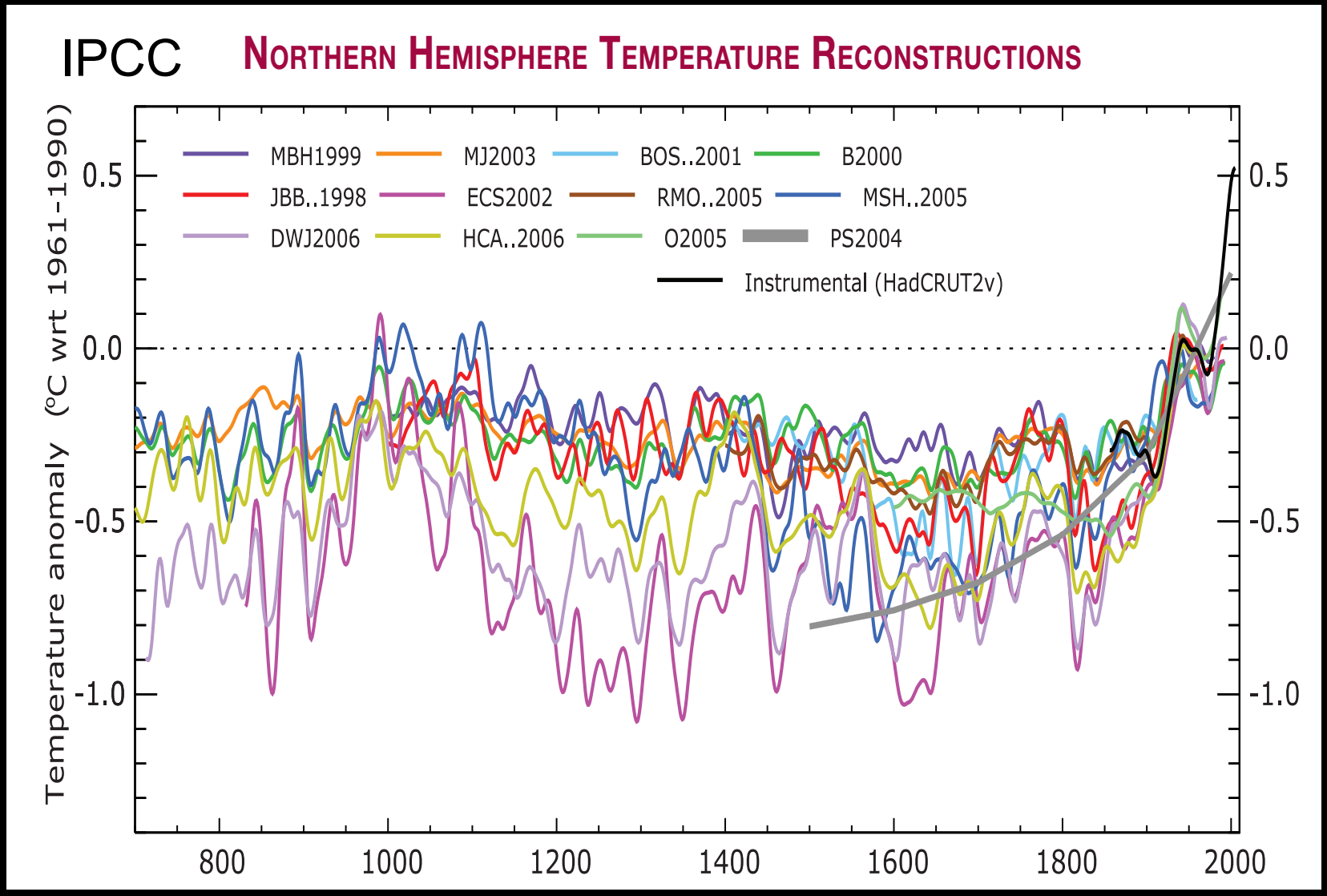
Where Is The Carbon Going?



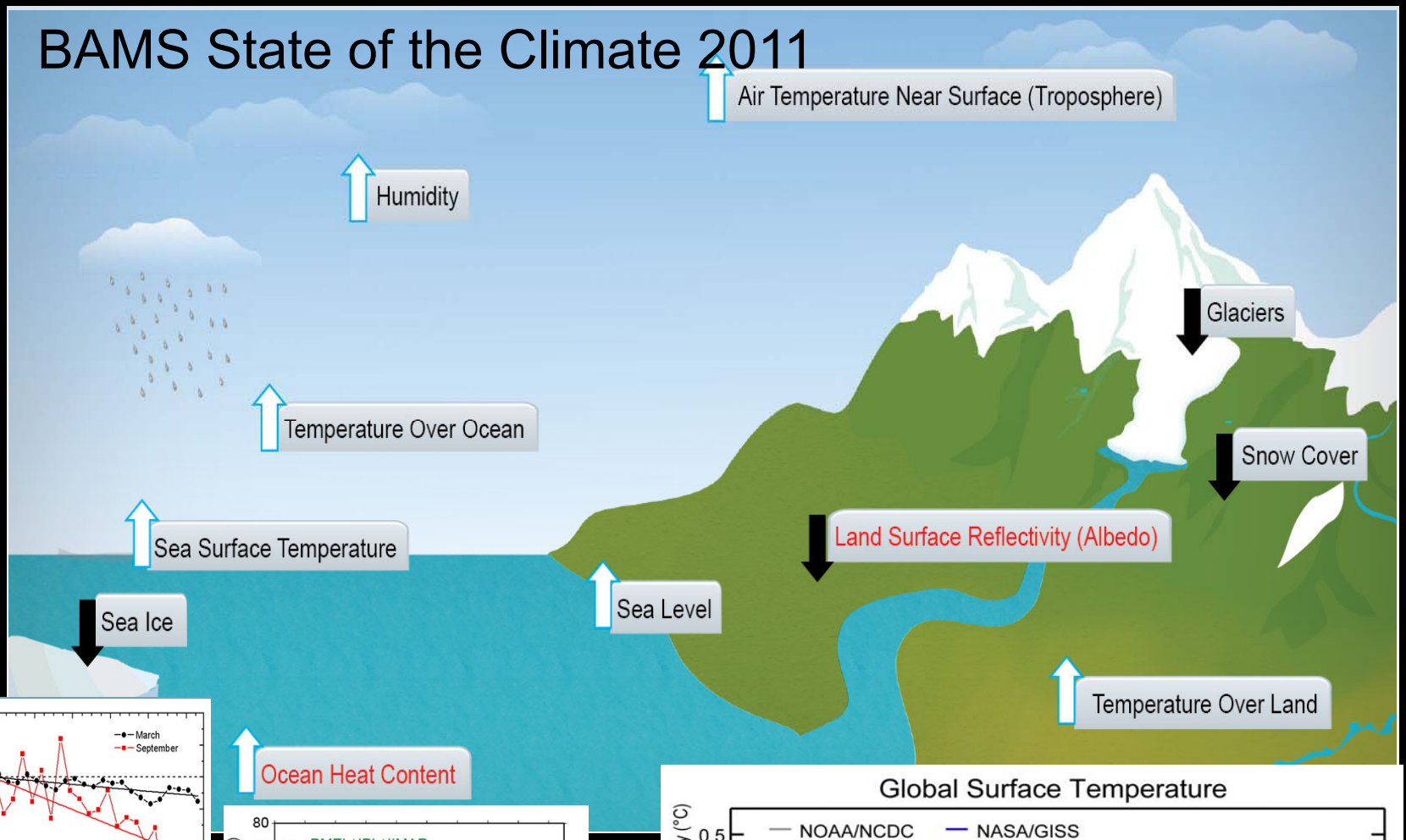
Houghton et al. (2007)

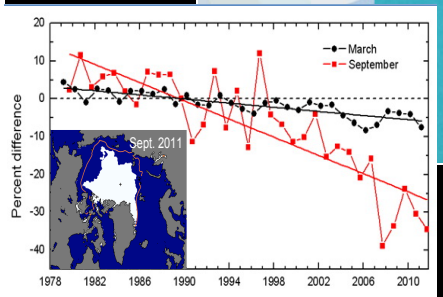
CLIMATE


IPCC
Global Average Temperature
Anomalies from 1890-1919 (°C)
0.9
0.6
0.3
0.0
-0.3
Observations
(Natural) volc+solar
(Anthropogenic + Natural) volc+solar+ghg+so4
1900
1920
1940
1960
1980
2000


IPCC
NORTHERN HEMISPHERE TEMPERATURE RECONSTRUCTIONS
MBH1999
MJ2003
BOS..2001
B2000
JBB..1998
ECS2002
RMO..2005
MSH..2005
DWJ2006
HCA..2006
O2005
PS2004
Instrumental (HadCRUT2v)
Temperature anomaly (°C wrt 1961-1990)
0.5
0.0
-0.5
-1.0
800
1000
1200
1400
1600
1800
2000

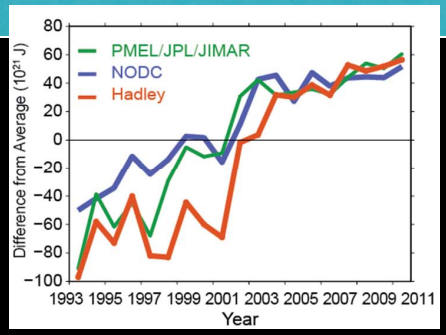
BAMS State of the Climate 2011

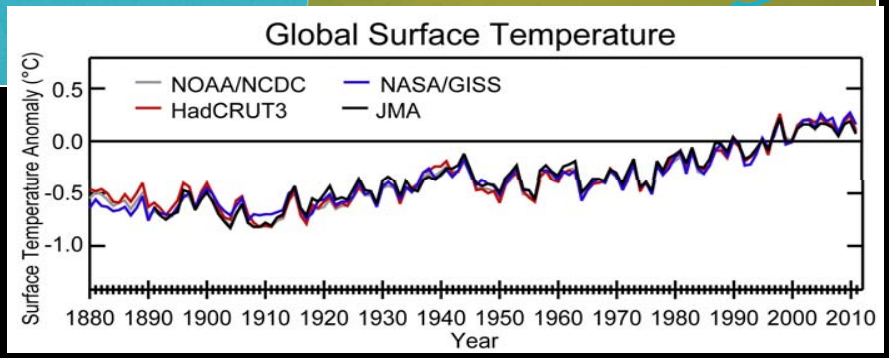




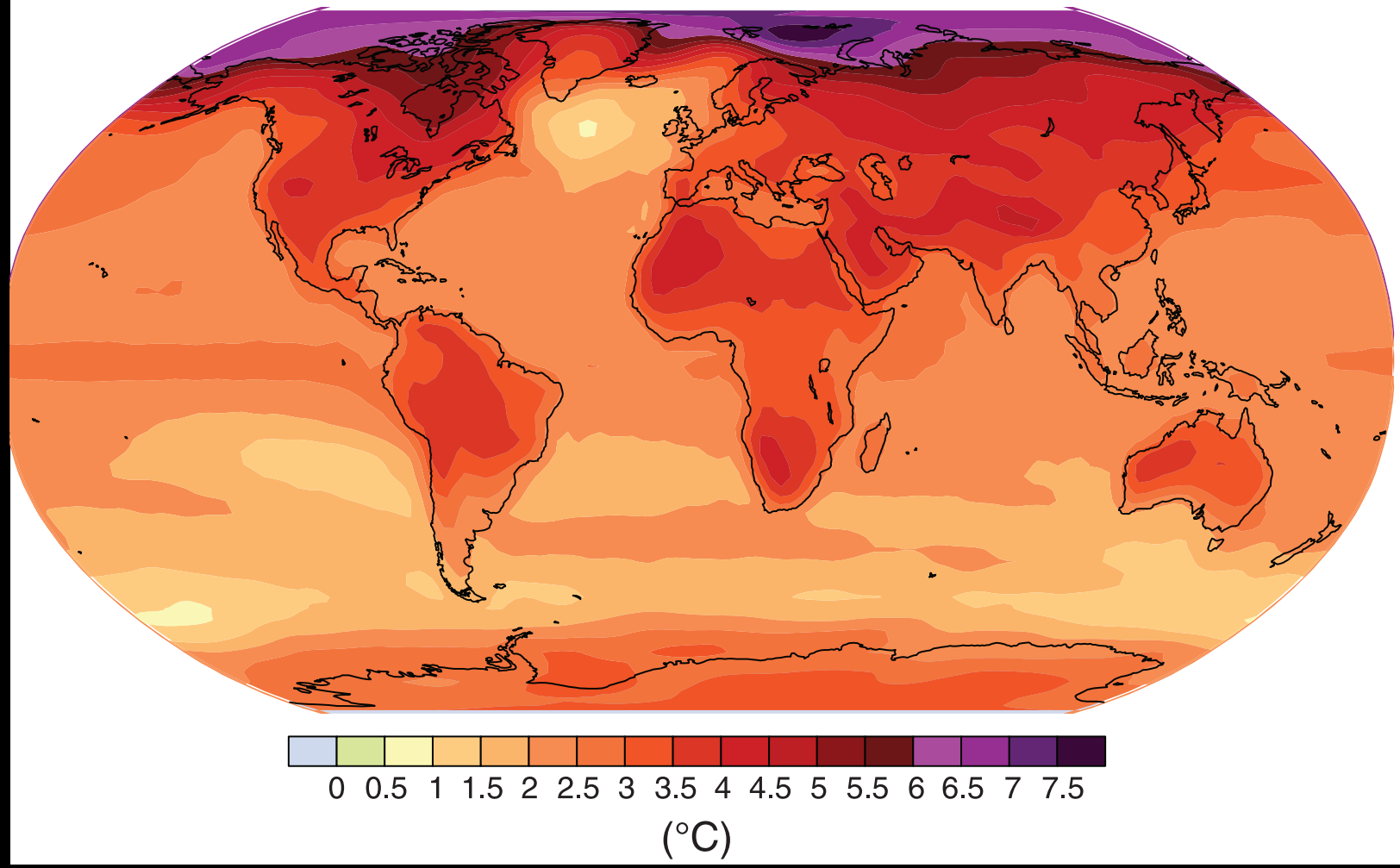
March: when maximum ice extent occurs

September: when minimum ice extent occurs



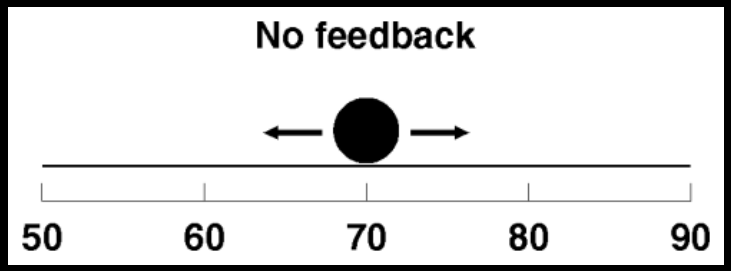


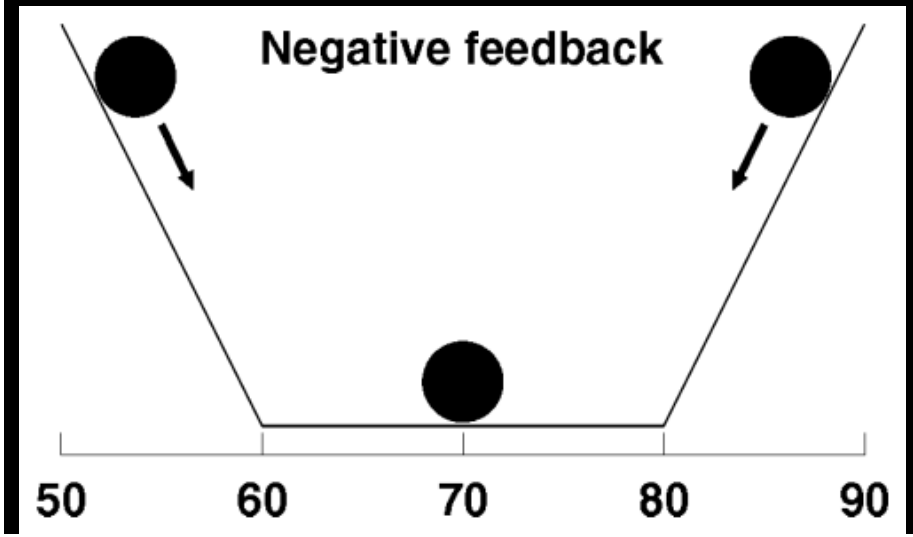
Geographical pattern of surface warming

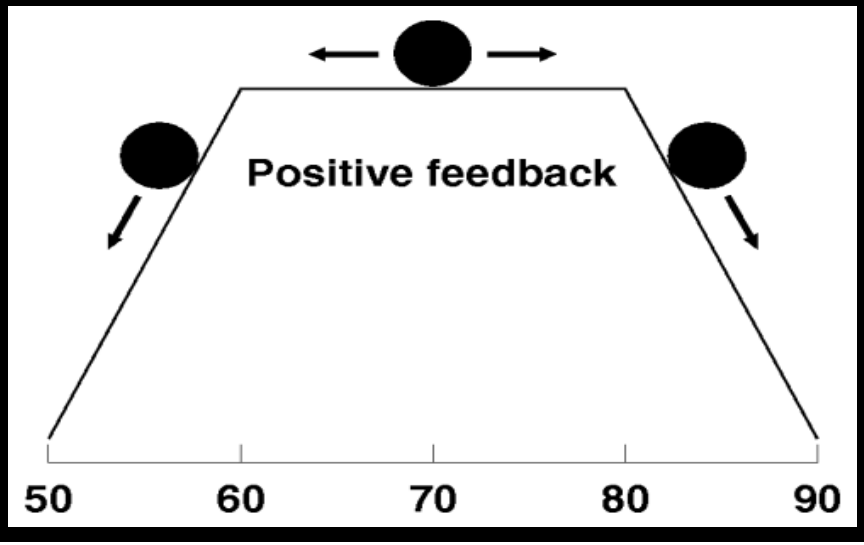


2090 (IPCC 4th Assessment)

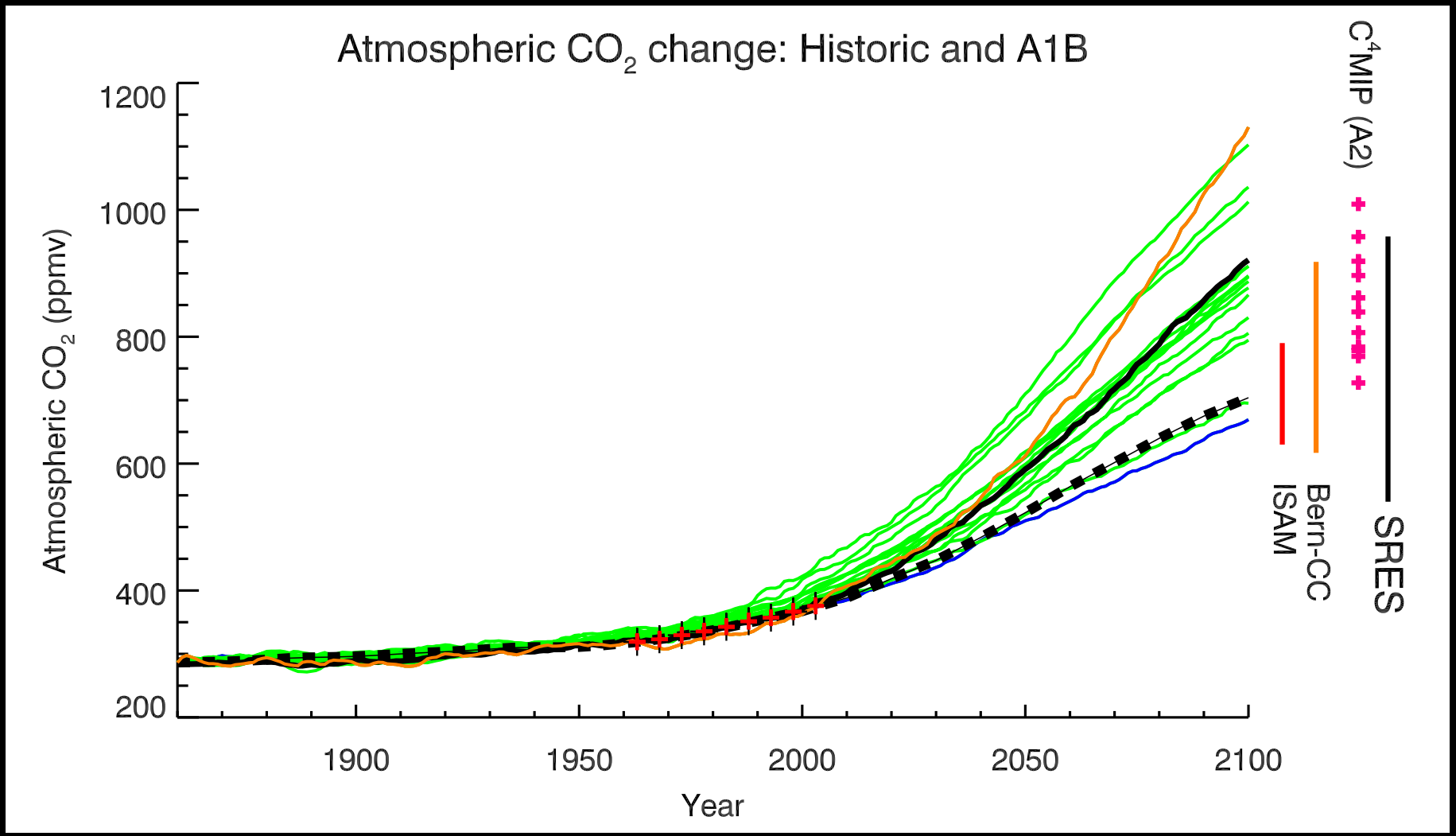
- Climate changes with:
  - A change in forcing (sun strength, Earth's orbit, volcano frequency, greenhouse gases)
  - Is amplified by positive feedbacks







The carbon cycle feedback is large and hard to predict



Booth et al., 2012

What drives this feedback?

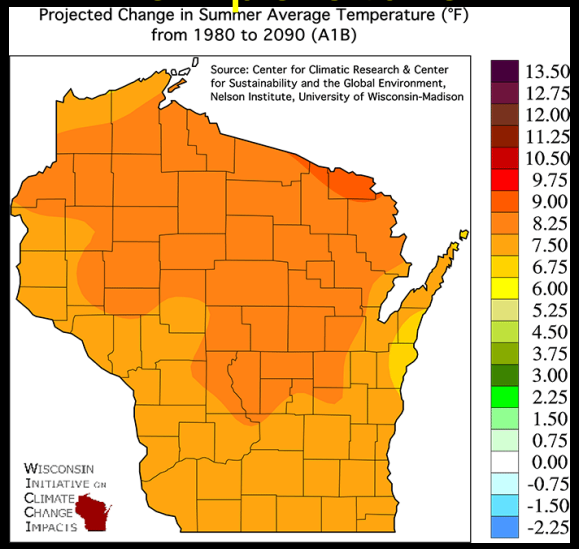
- Terrestrial ecosystems carbon assimilation and decomposition respond to:
  - Temperature
  - Light quantity and quality
  - Moisture availability
  - Nutrients (Nitrogen, CO_2, Phosphorous)
  - Disturbance (Fire, insects, hurricanes, …)
  - Land use (Logging, draining wetlands, …)
  - Competition, adaptation, evolution

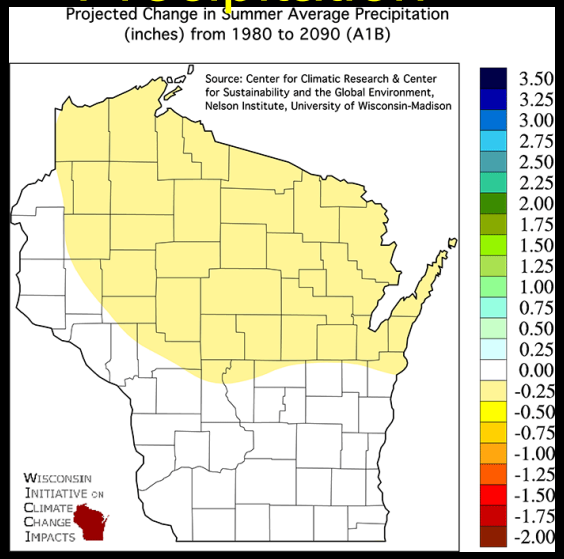
Locally: Warmer winters, drier summers

Temperature

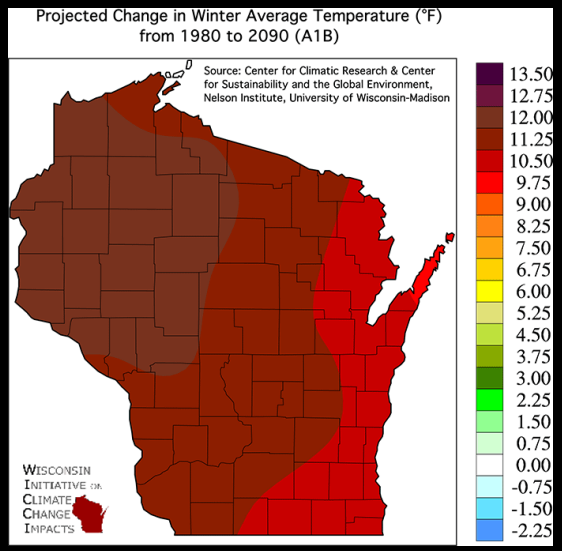
Precipitation

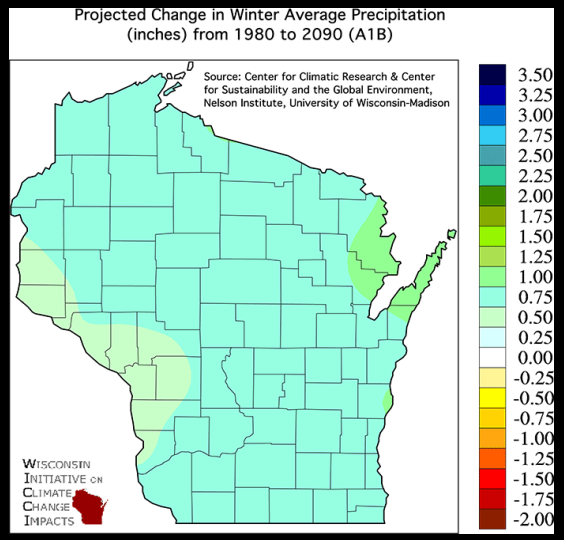
Summer





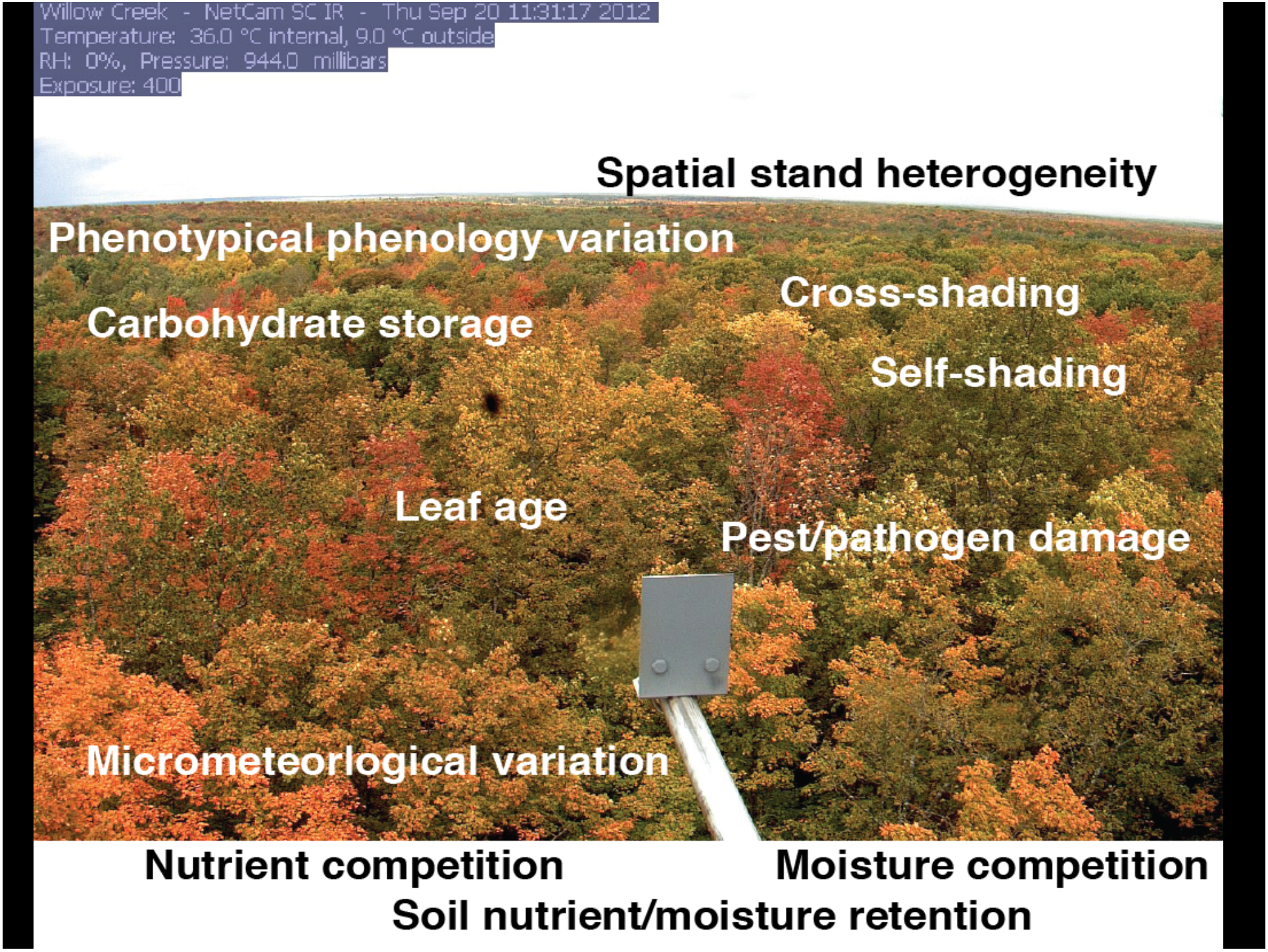
Winter





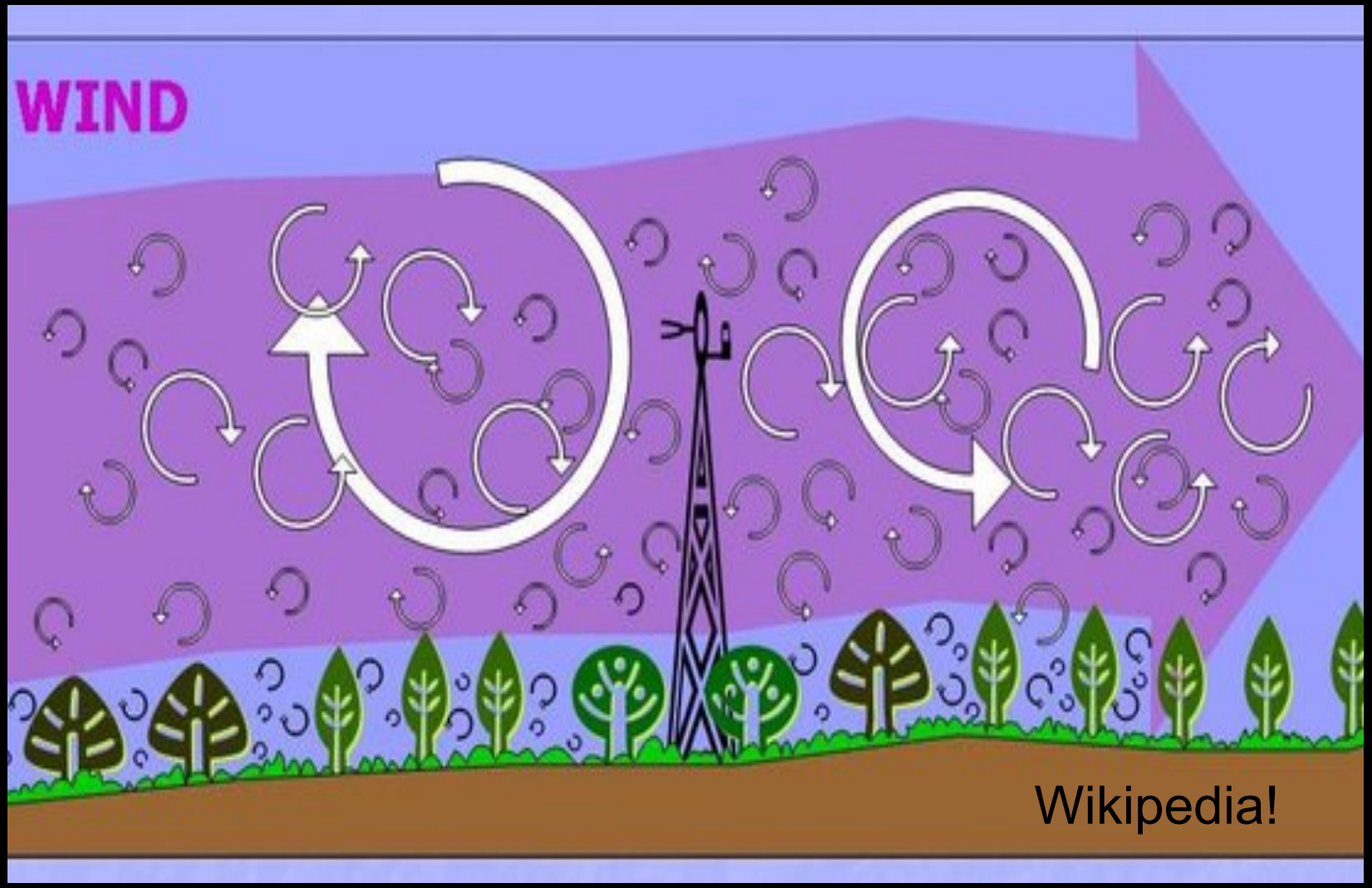
http://www.wicci.wisc.edu/

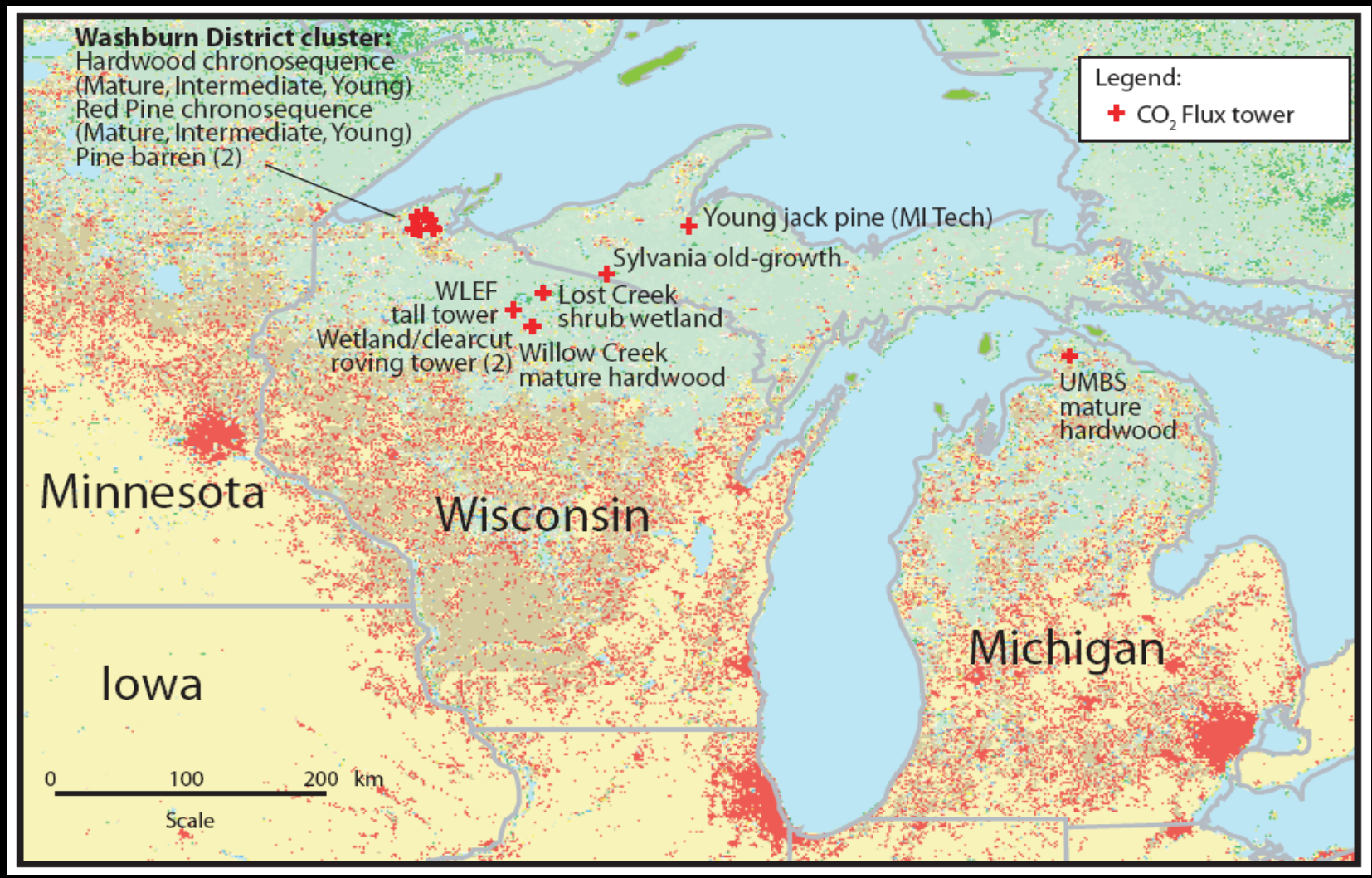
FORESTS


Willow Creek - NetCam SC IR - Thu Sep 20 11:31:17 2012
Temperature: 36.0 °C internal, 9.0 °C outside
RH: 0%, Pressure: 944.0 millibars
Exposure: 400
Spatial stand heterogeneity
Phenotypical phenology variation
Cross-shading
Carbohydrate storage
Self-shading
Leaf age
Pest/pathogen damage
Micrometeorlogical variation
Nutrient competition
Moisture competition
Soil nutrient/moisture retention

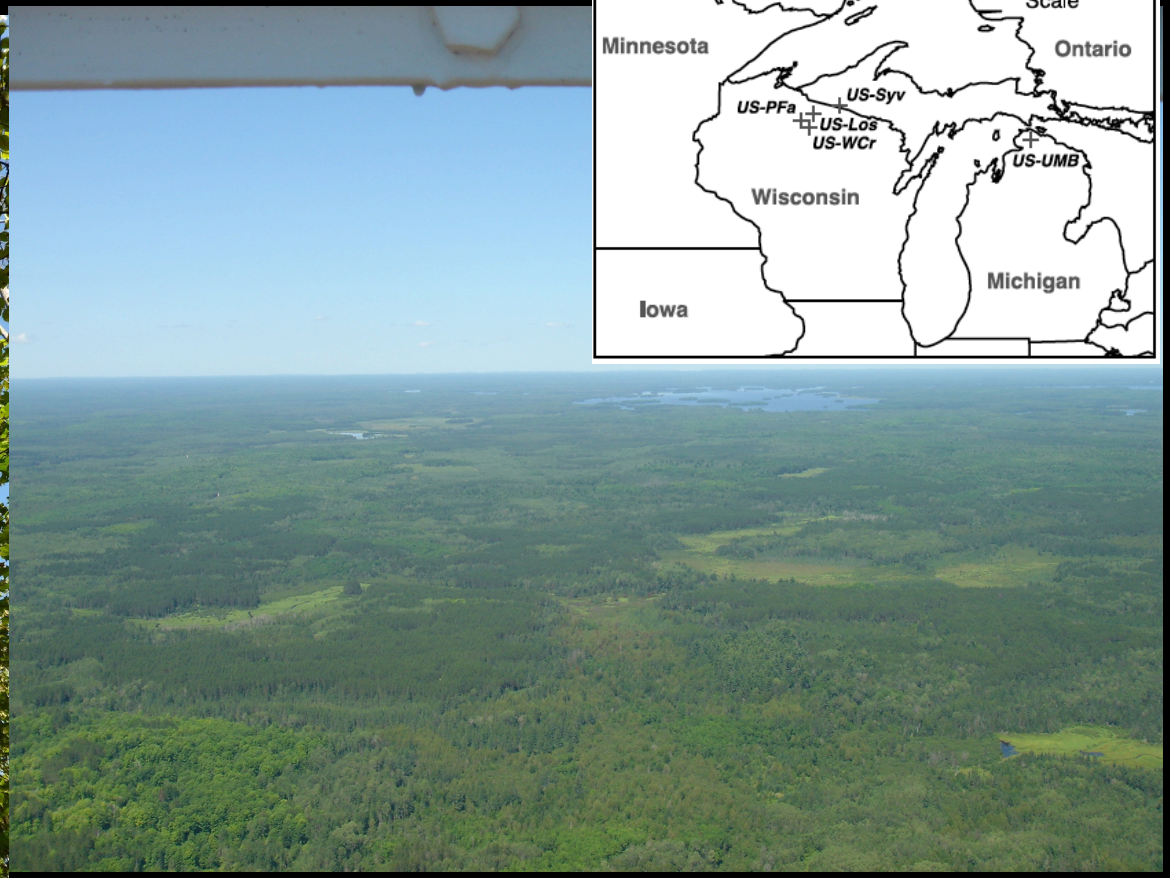

For-CLIMATE: Forest and Climate
Leaders In Menominee And The Environment

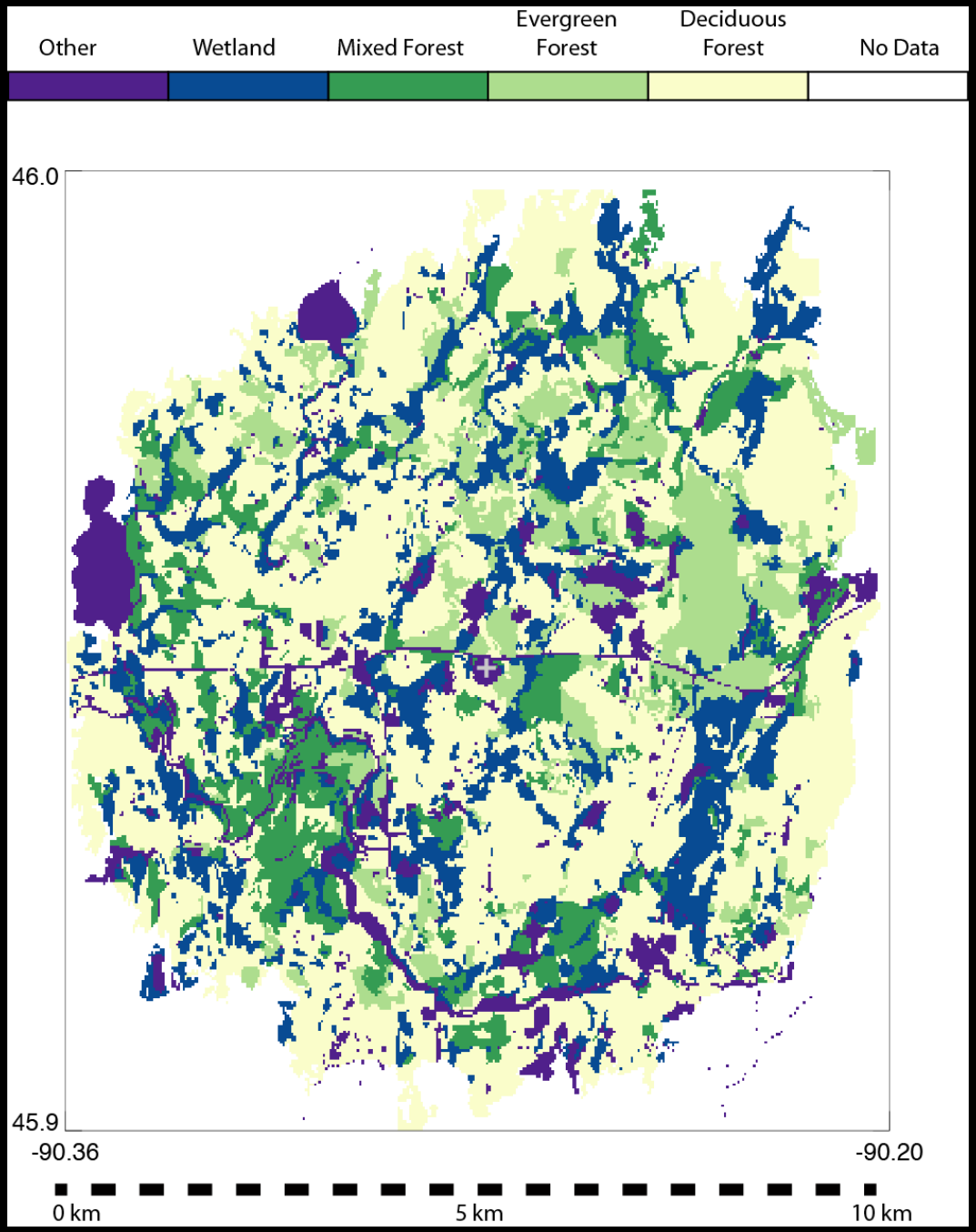

WS 3153

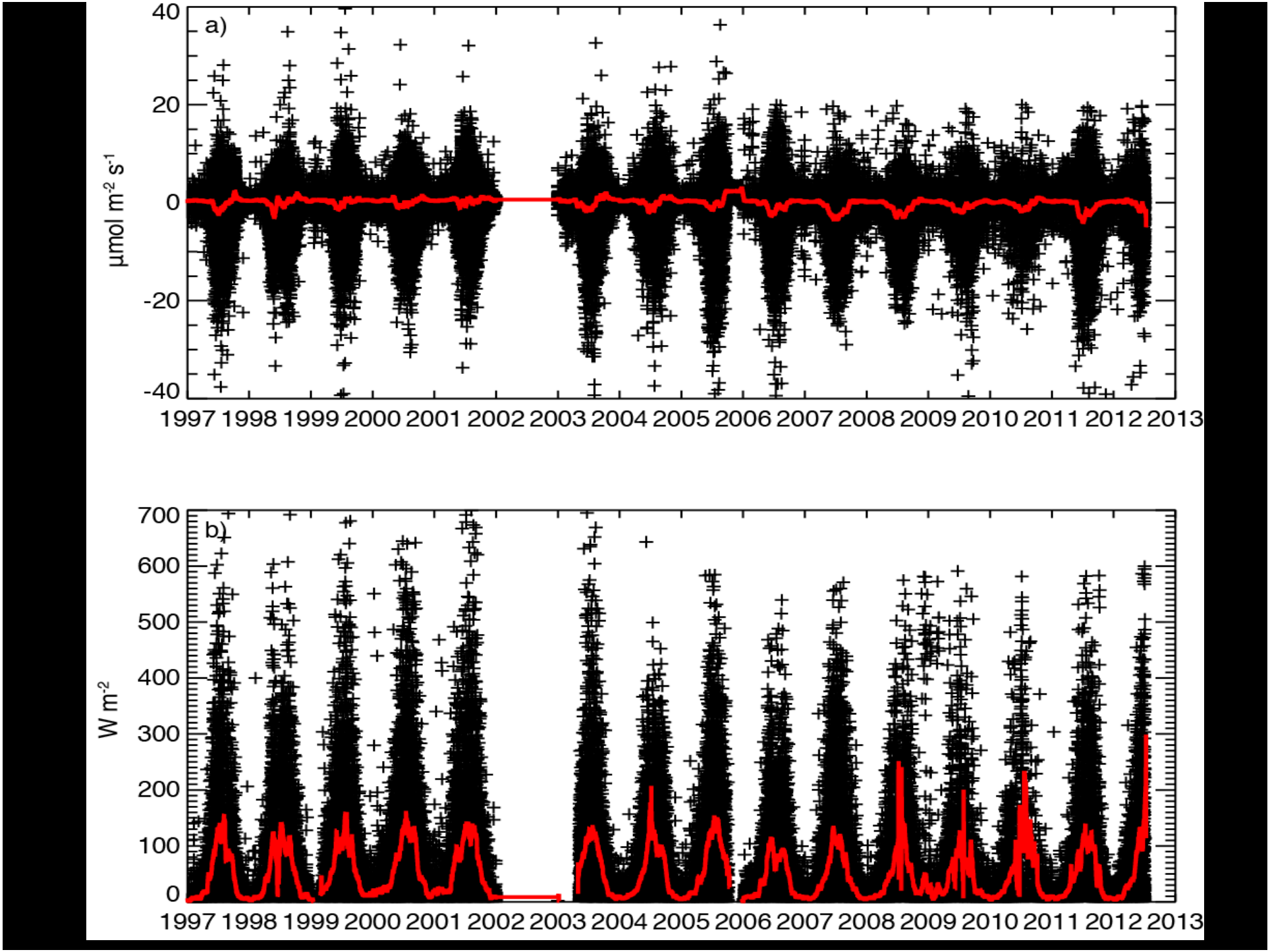

WIND
Wikipedia!

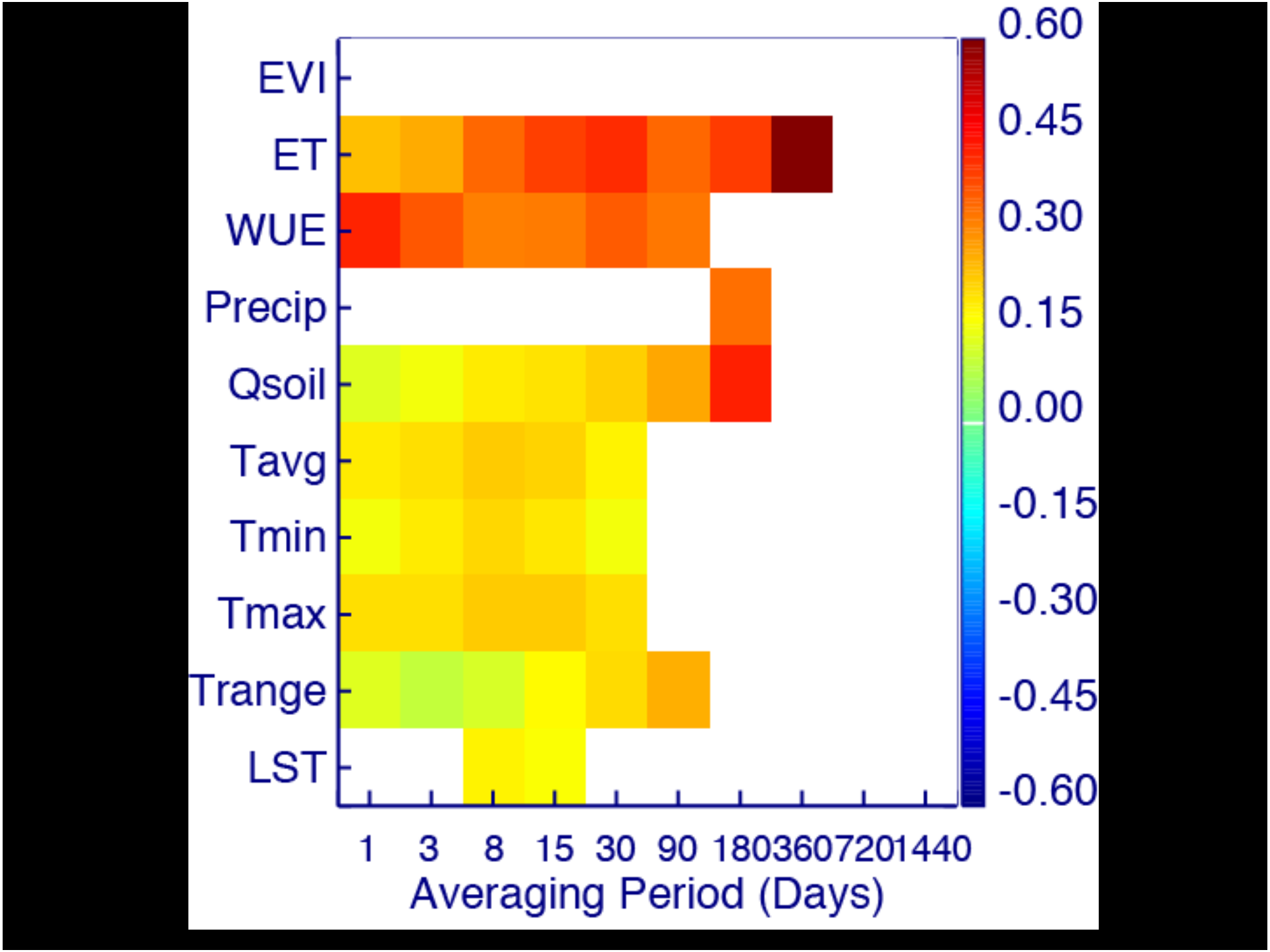

Washburn District cluster:
Hardwood chronosequence
(Mature, Intermediate, Young)
Red Pine chronosequence
(Mature, Intermediate, Young)
Pine barren (2)
Legend:
CO2 Flux tower
Young jack pine (MI Tech)
Sylvania old-growth
WLEF
tall tower
Lost Creek
shrub wetland
Wetland/clearcut
roving tower (2)
Willow Creek
mature hardwood
UMBS
mature
hardwood
Minnesota
Wisconsin
Michigan
Iowa
0
100
200 km
Scale

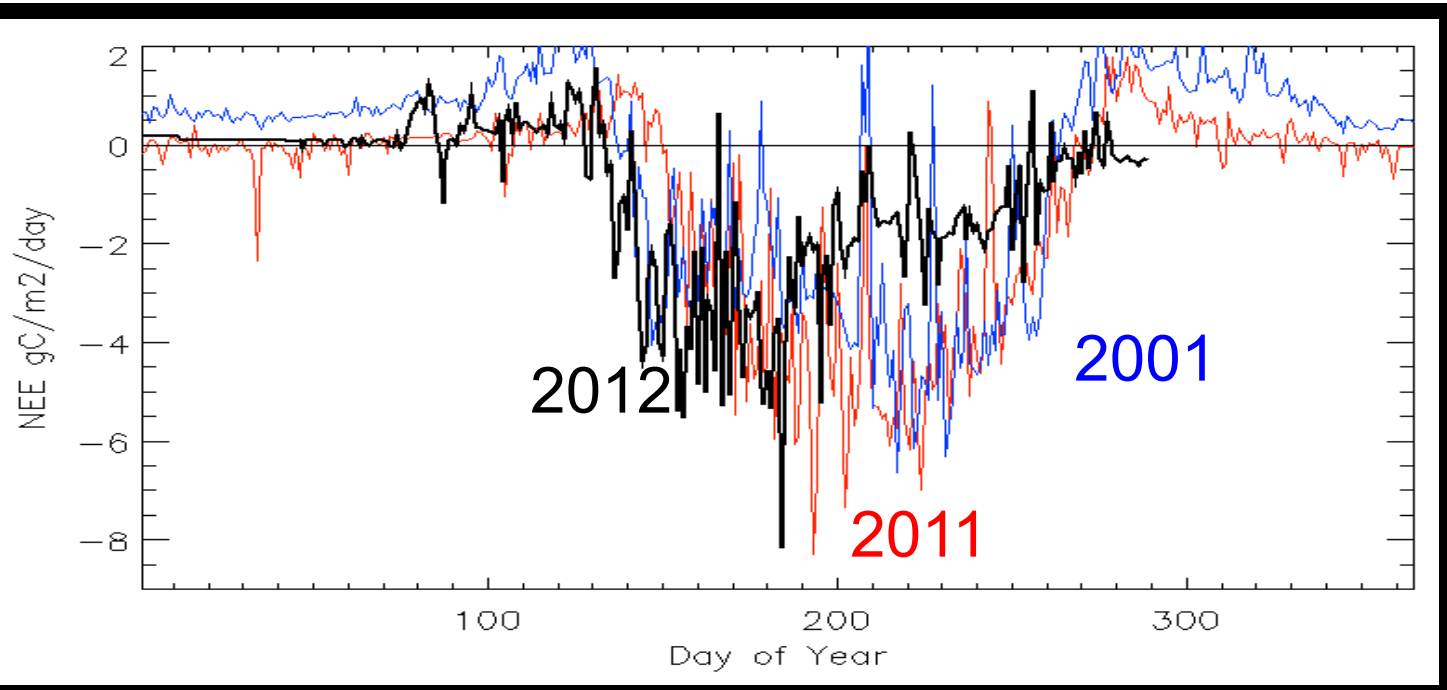
A very tall tower!

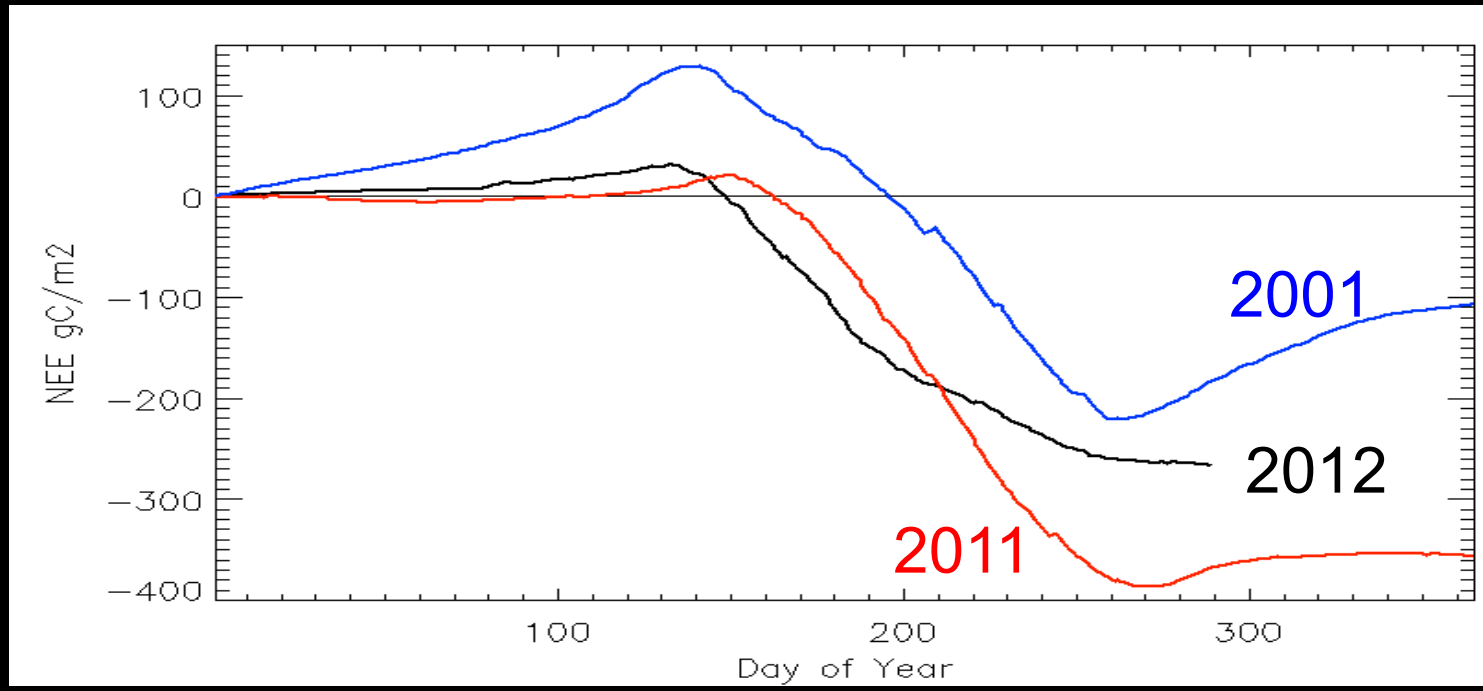


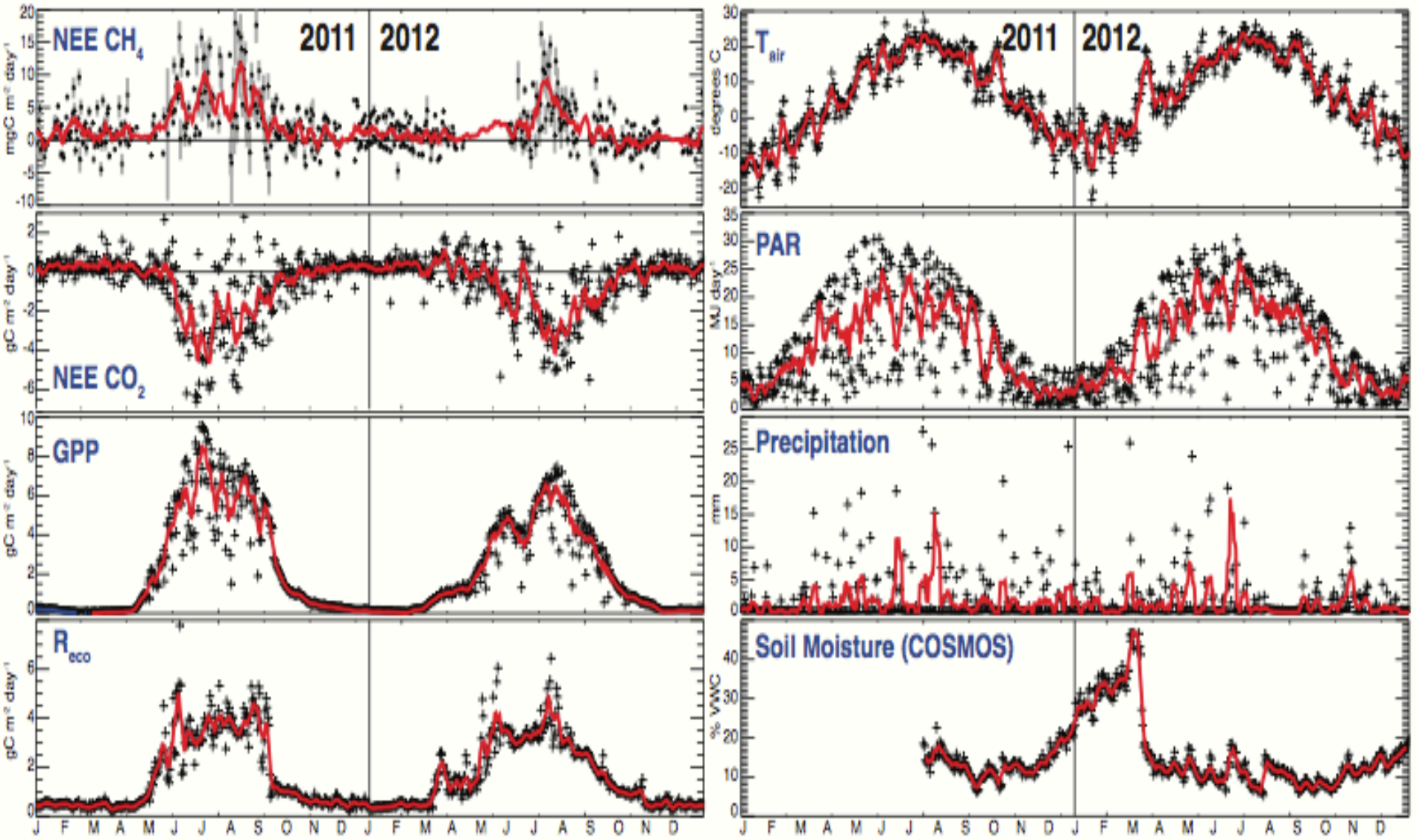

Other
Wetland
Mixed Forest
Evergreen Forest
Deciduous Forest
No Data
46.0
45.9
-90.36
-90.20
0 km
5 km
10 km

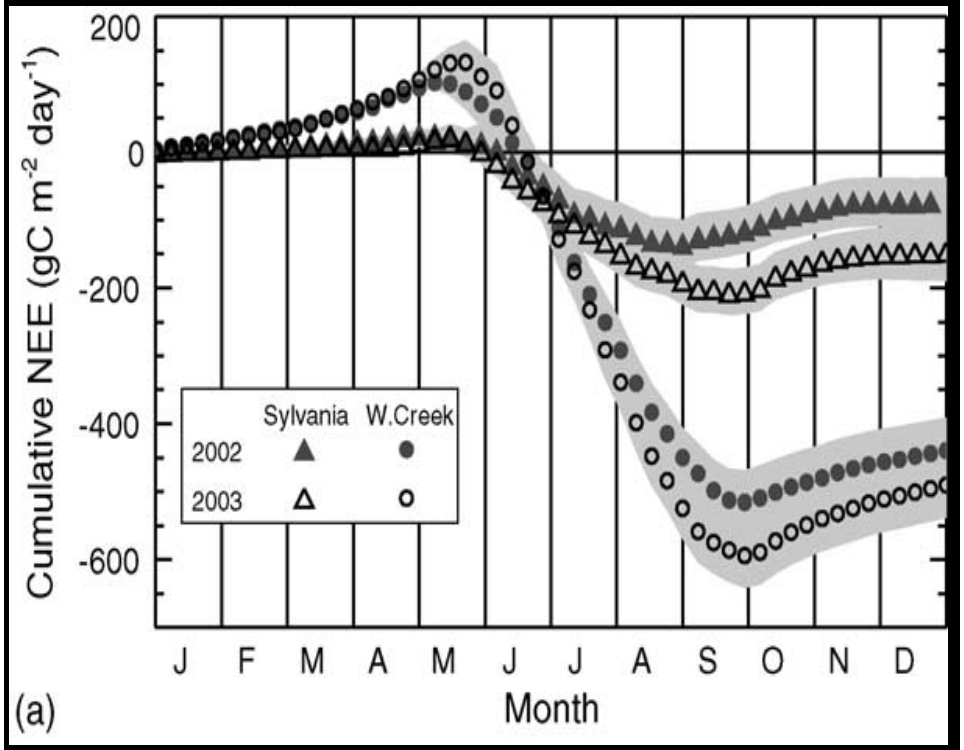

a)
40
20
0
-20
-40
µmol m-2 s-1
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
b)
700
600
500
400
300
200
100
0
W m-2
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013

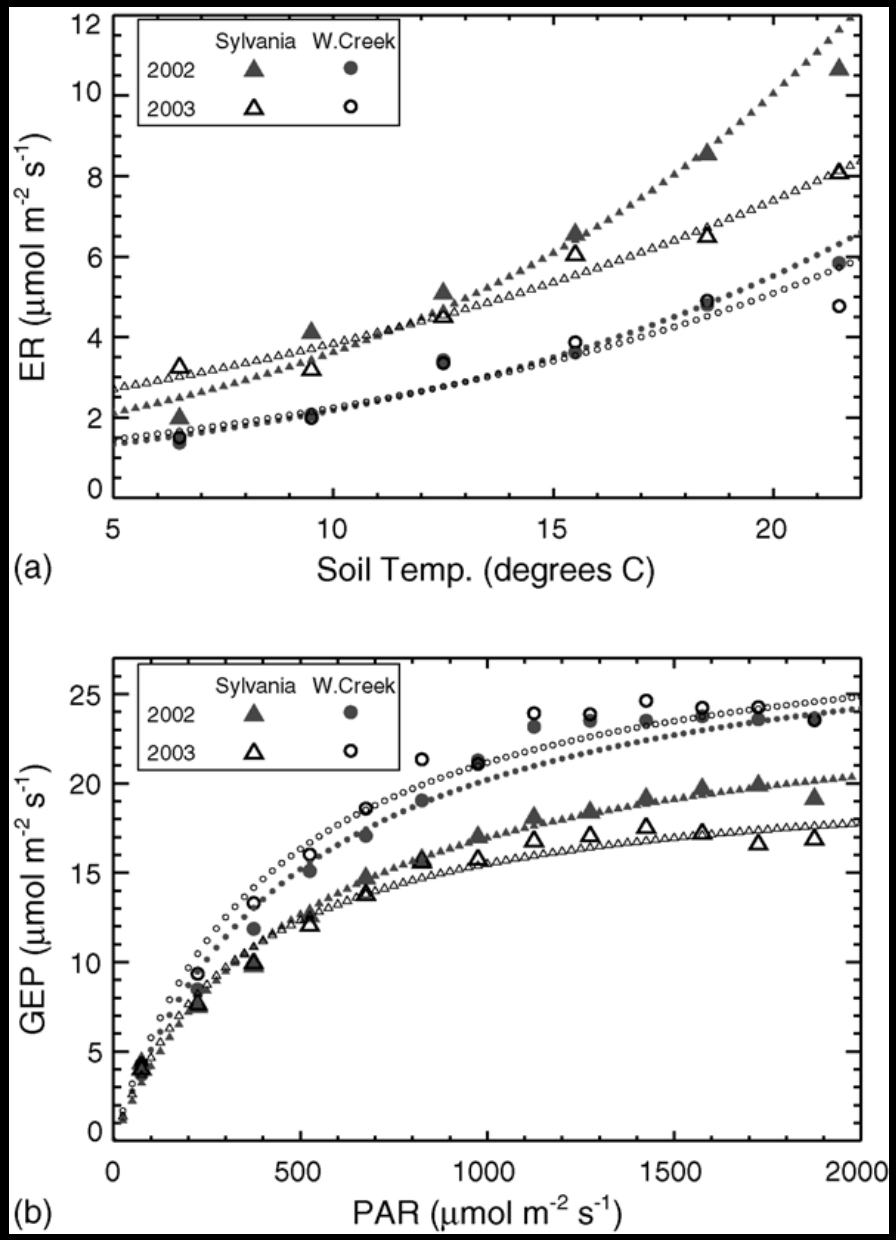

EVI
ET
WUE
Precip
Qsoil
Tavg
Tmin
Tmax
Trange
LST
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1
3
8
15
30
90
180
360
720
1440
Averaging Period (Days)


NEE gC/m2/day
2
0
−2
−4
−6
−8
100
200
300
Day of Year
2012
2001
2011

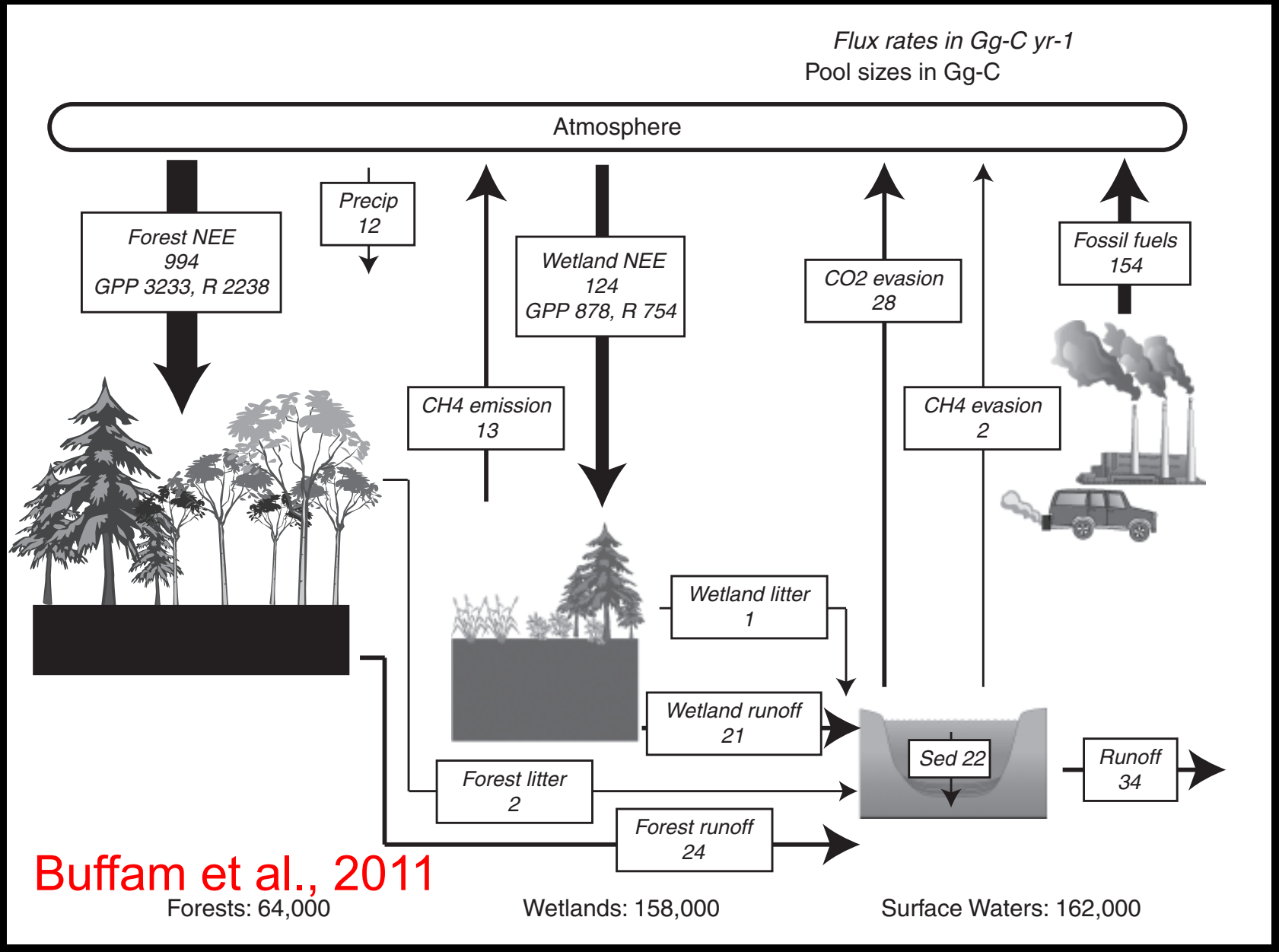

NEE gC/m2
100
0
−100
−200
−300
−400
100
200
300
Day of Year
2001
2012
2011


NEE CH4
2011
2012
mgC m-2 day-1
NEE CO2
gC m-2 day-1
GPP
Reco
Tair
degrees C
PAR
MJ day-1
Precipitation
mm
Soil Moisture (COSMOS)
% VWC
J F M A M J J A S O N D J F M A M J J A S O N D





Desai et al., 2006


Flux rates in Gg-C yr-1
Pool sizes in Gg-C
Atmosphere
Forest NEE
994
GPP 3233, R 2238
Precip
12
Wetland NEE
124
GPP 878, R 754
CO2 evasion
28
Fossil fuels
154
CH4 emission
13
CH4 evasion
2
Wetland litter
1
Wetland runoff
21
Sed 22
Runoff
34
Forest litter
2
Forest runoff
24
Buffam et al., 2011
Forests: 64,000
Wetlands: 158,000
Surface Waters: 162,000

Big Questions About Our Forests

- PAST: How has the legacy of land management influence the trajectory of carbon uptake?
- FUTURE: What changes to the land should we expect to see with warmer, wetter winters and drier summers for this area?
- PRESENT: How might we manage the land to mitigate future climate change and how do we adapt our relationship with land to sustain forest production, biodiversity, recreation, culture?

Thanks!