How will Wisconsin's forests and wetlands respond to climate change?

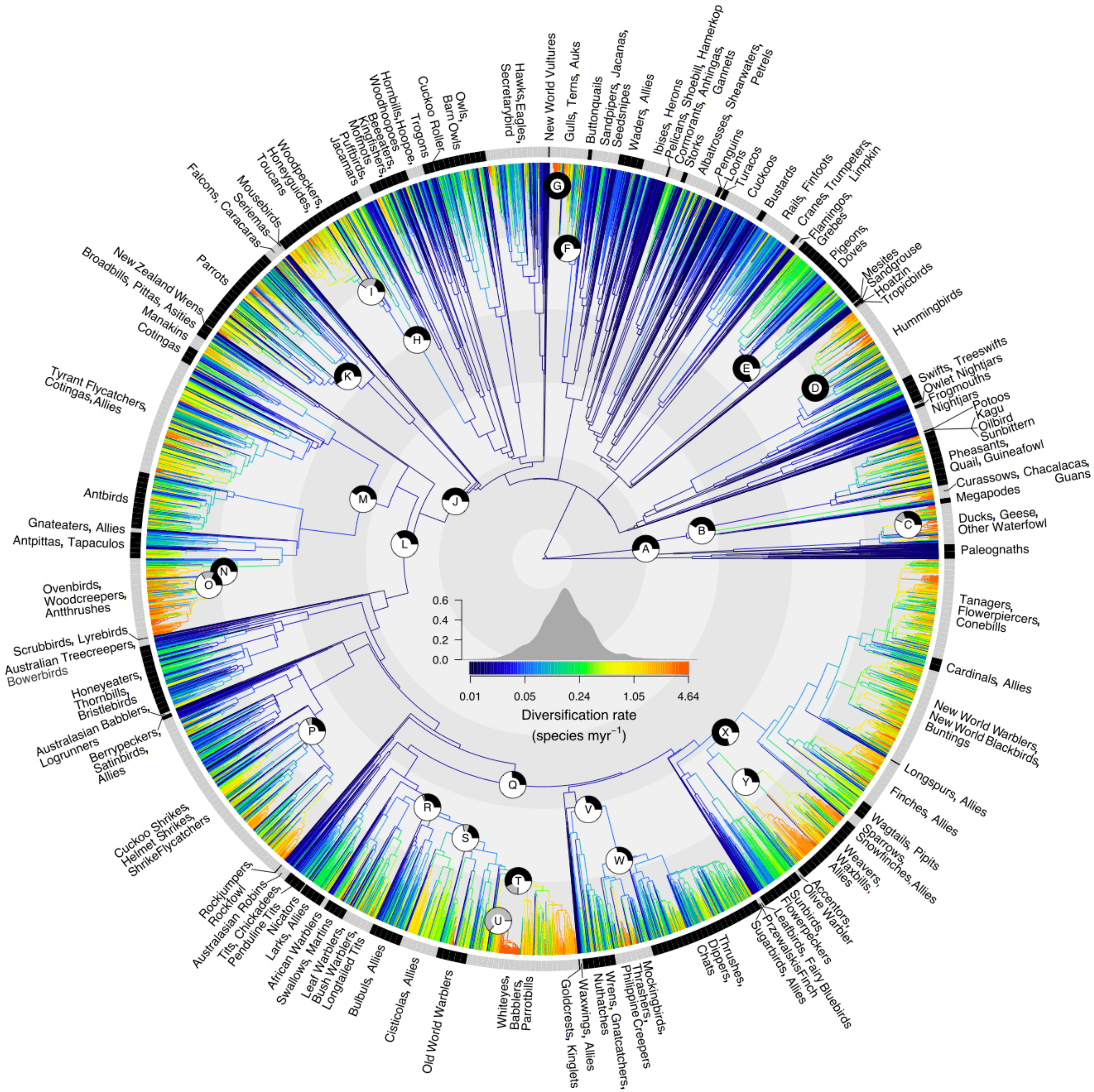
April 2013

Prof. Ankur Desai
University of Wisconsin-Madison

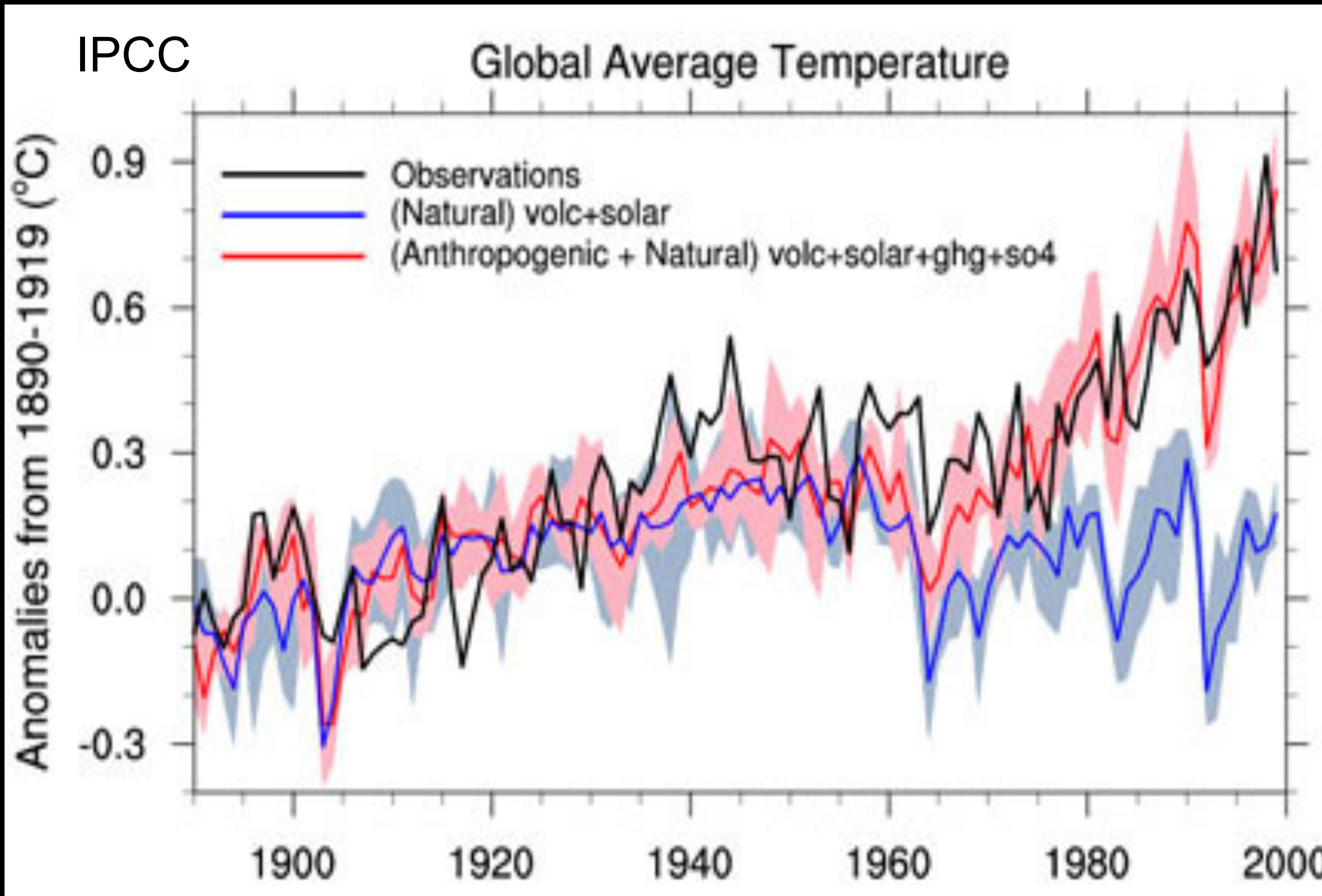
Image: NASA MODIS

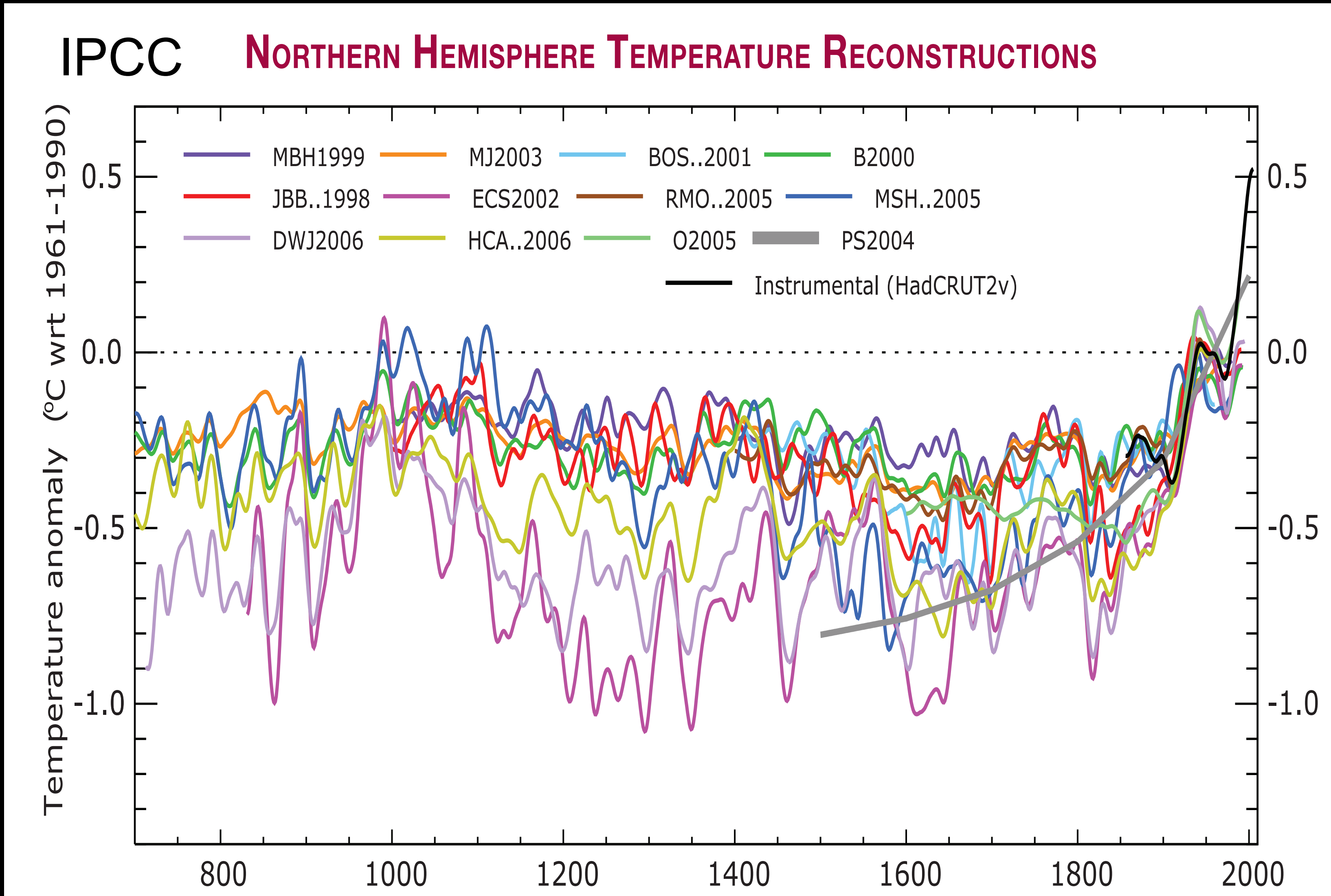

LAZY


Color Key
Breeding Range
Non-Breeding Range
Year-Round Range
Migration Range
Irruption Boundary
Vagrant Sightings



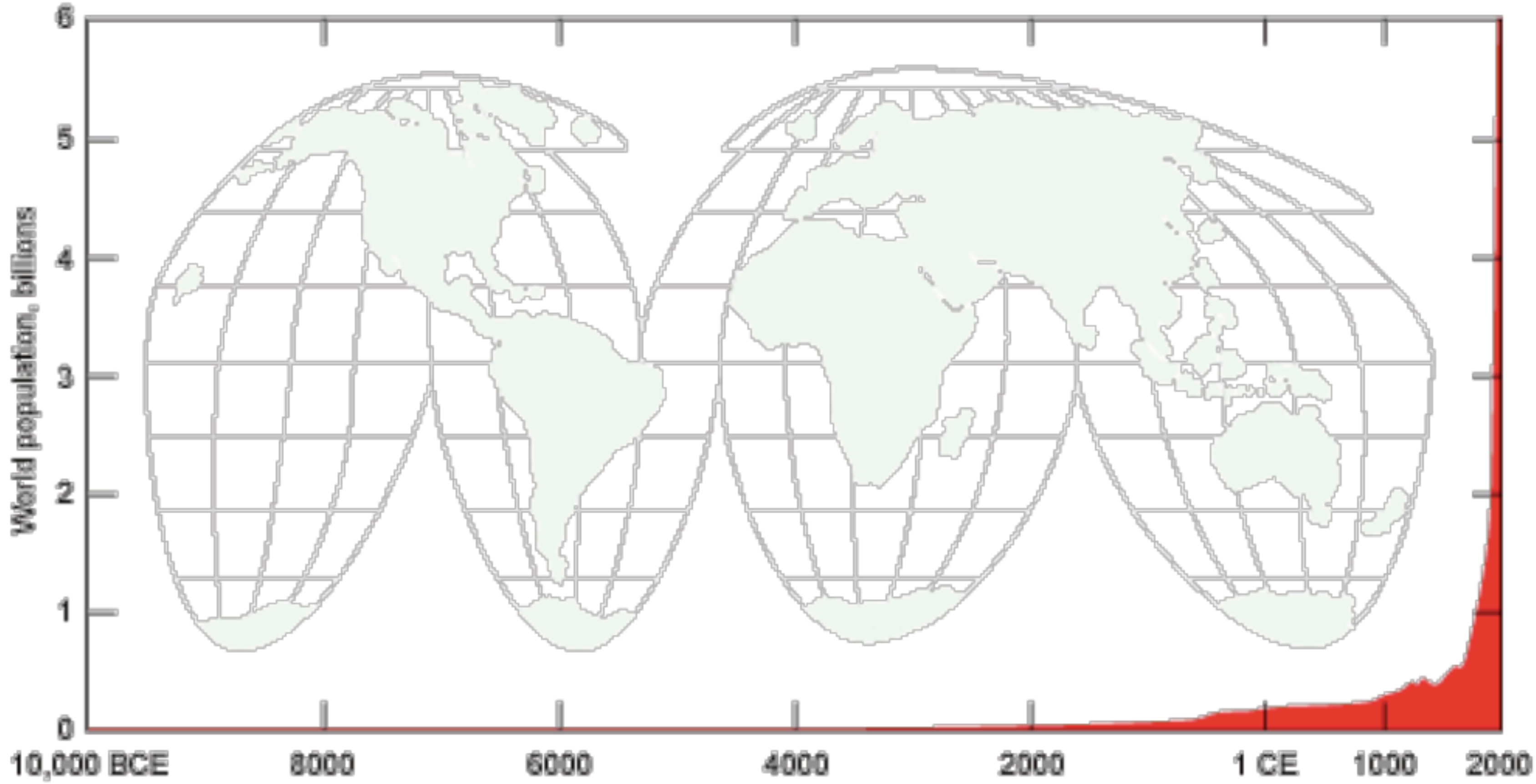
New World Vultures
Gulls, Terns, Auks
Buttonquails
Sandpipers, Jacanas, Seedsnipes
Waders, Allies
Ibises, Herons
Pelicans, Shoebill, Hamerkop
Cormorants, Anhingas, Gannets
Storks
Albatrosses, Shearwaters, Petrels
Penguins
Loons
Turacos
Cuckoos
Bustards
Rails, Finfoots
Cranes, Trumpeters, Limpkin
Flamingos, Grebes
Pigeons, Doves
Mesites
Sandgrouse
Hoatzin
Tropicbirds
Hummingbirds
Swifts, Treeswifts
Owlet Nightjars
Frogmouths
Nightjars
Potoos
Kagu
Oilbird
Sunbittern
Pheasants, Quail, Guineafowl
Curassows, Chachalacas, Guans
Megapodes
Ducks, Geese, Other Waterfowl
Paleognaths
Tanagers, Flowerpiercers, Conebills
Cardinals, Allies
New World Warblers, New World Blackbirds, Buntings
Longspurs, Allies
Finches, Allies
Wagtails, Pipits
Sparrows, Snowfinches, Allies
Weavers, Waxbills, Allies
Accentors, Olive Warbler
Sunbirds, Flowerpeckers
Leafbirds, Fairy Bluebirds
PrzewalskisFinch
Sugarbirds, Allies
Thrushes, Dippers, Chats
Mockingbirds, Thrashers, Philippine Creepers
Wrens, Gnatcatchers, Nuthatches
Waxwings, Allies
Goldcrests, Kinglets
Whiteyes, Babblers, Parrotbills
Old World Warblers
Cisticolas, Allies
Bulbuls, Allies
Leaf Warblers, Bush Warblers, Longtailed Tits
Swallows, Martins
African Warblers
Larks, Allies
Nicators
Tits, Chickadees, Penduline Tits
Australasian Robins
Rockjumpers, Rockfowl
Cuckoo Shrikes, Helmet Shrikes, ShrikeFlycatchers
Berrypeckers, Satinbirds, Allies
Australasian Babblers, Logrunners
Honeyeaters, Thornbills, Bristlebirds
Bowerbirds
Australian Treecreepers
Scrubbirds, Lyrebirds
Ovenbirds, Woodcreepers, Antthrushes
Antpittas, Tapaculos
Gnateaters, Allies
Antbirds
Tyrant Flycatchers, Cotingas, Allies
Cotingas
Manakins
Broadbills, Pittas, Asities
New Zealand Wrens
Parrots
Falcons, Caracaras
Seriemas
Mousebirds
Toucans
Honeyguides
Woodpeckers
Jacamars
Puffbirds
Motmots
Kingfishers
Beeeaters
Woodhoopoes
Hornbills, Hoopoe
Trogons
Cuckoo Roller
Owls, Barn Owls
Hawks, Eagles, Secretarybird
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
0.6
0.4
0.2
0.0
0.01
0.05
0.24
1.05
4.64
Diversification rate
(species myr^{-1})


IPCC
Global Average Temperature
Observations
(Natural) volc+solar
(Anthropogenic + Natural) volc+solar+ghg+so4
Anomalies from 1890-1919 (°C)
0.9
0.6
0.3
0.0
-0.3
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 (ºC wrt 1961-1990)
0.5
0.0
-0.5
-1.0
800
1000
1200
1400
1600
1800
2000

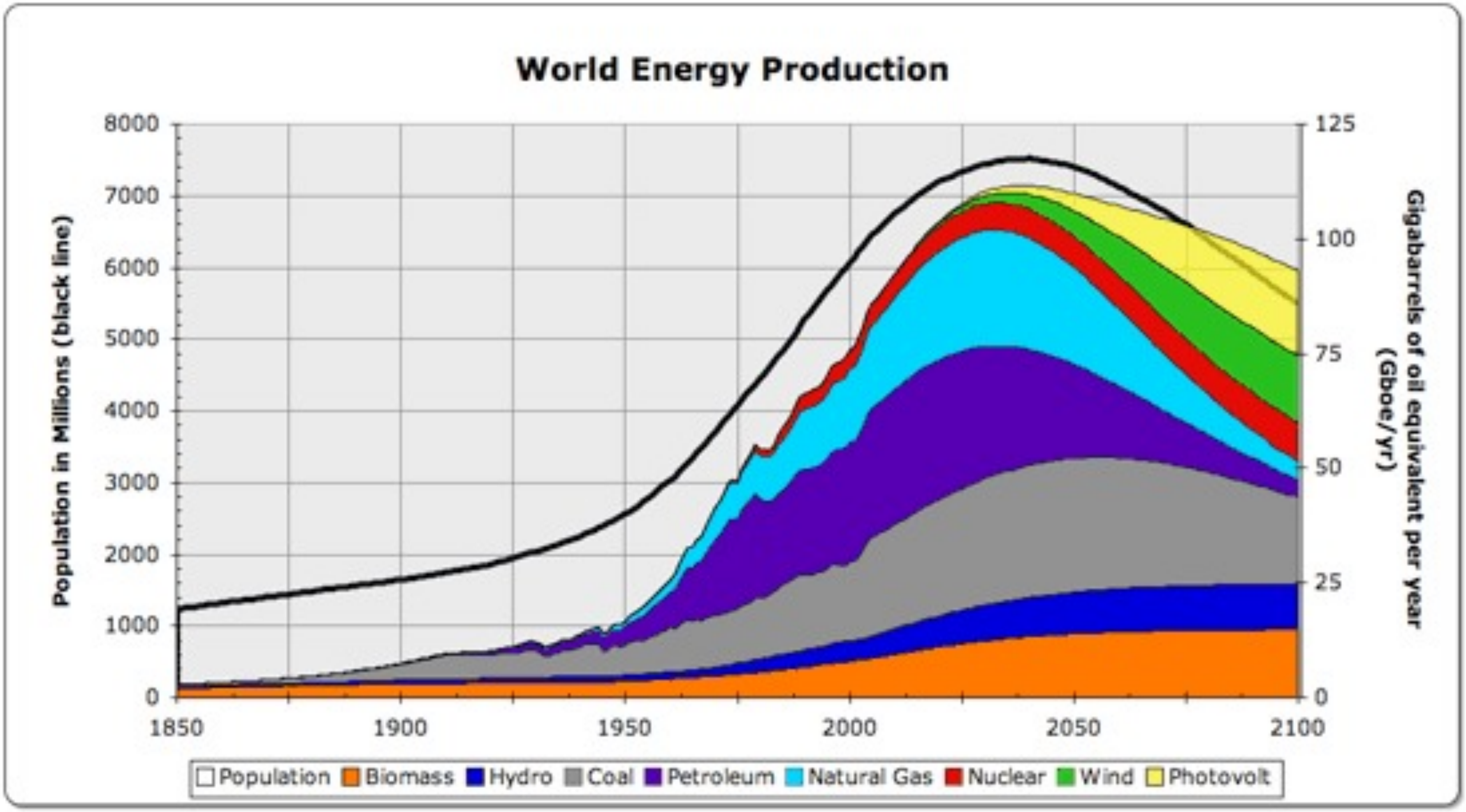

Willow Creek - NetCam SC IR - Thu Sep 20 11:31:17 2012
Temperature: 36.0 °C internal, 9.0 °C outside
RH: 0%, Pressure: 944.0 millibars
Exposure: 400

- 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!



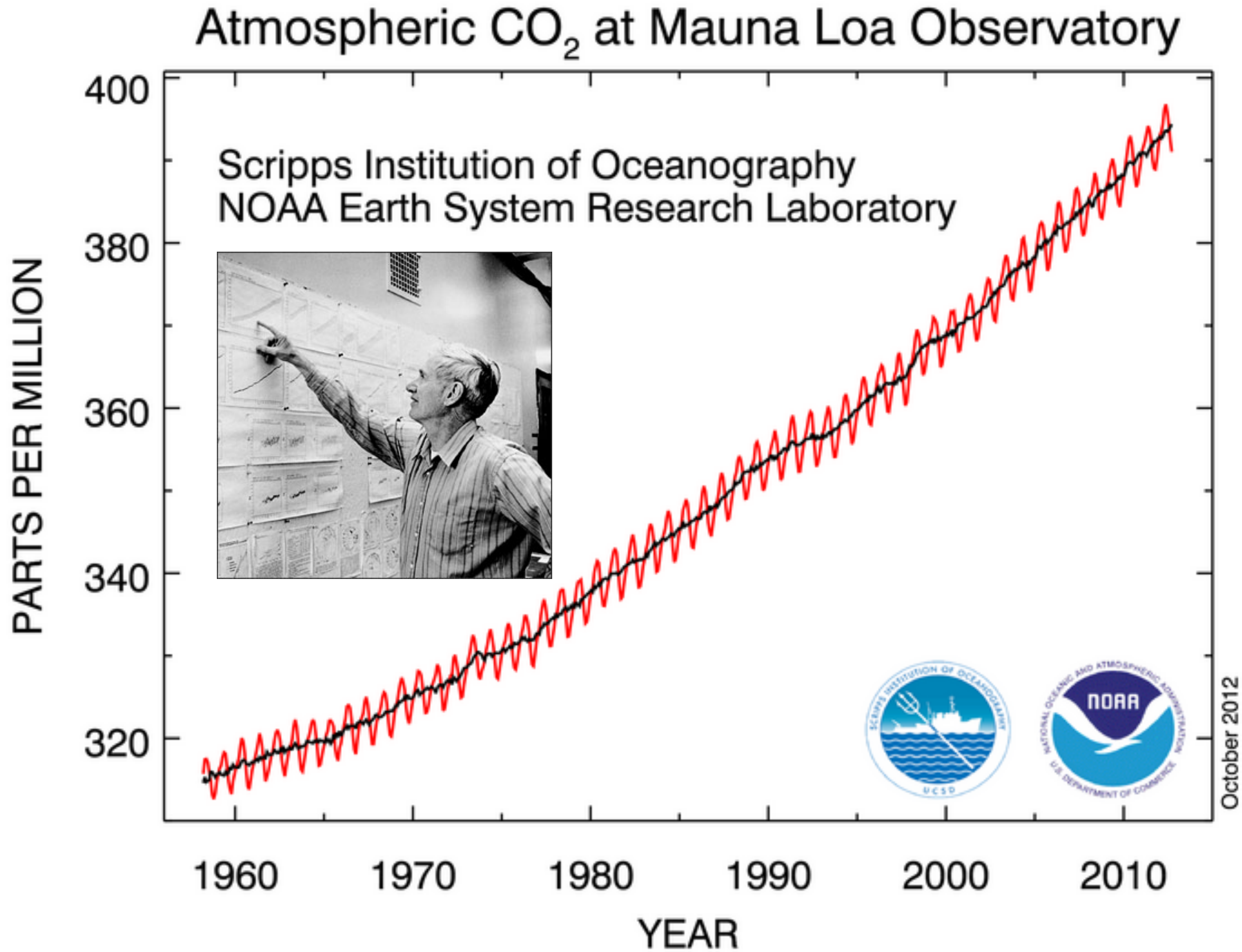
Human population increase (in red) from 10,000 BCE to 2000 CE

- Source: UCAR Quarterly, Summer 2007

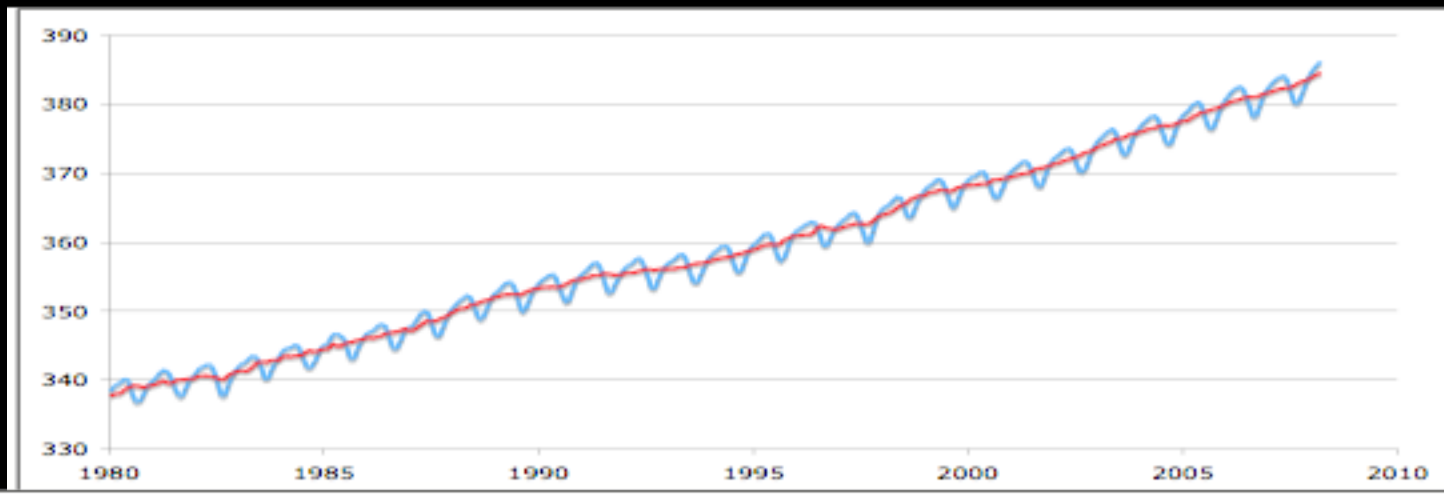


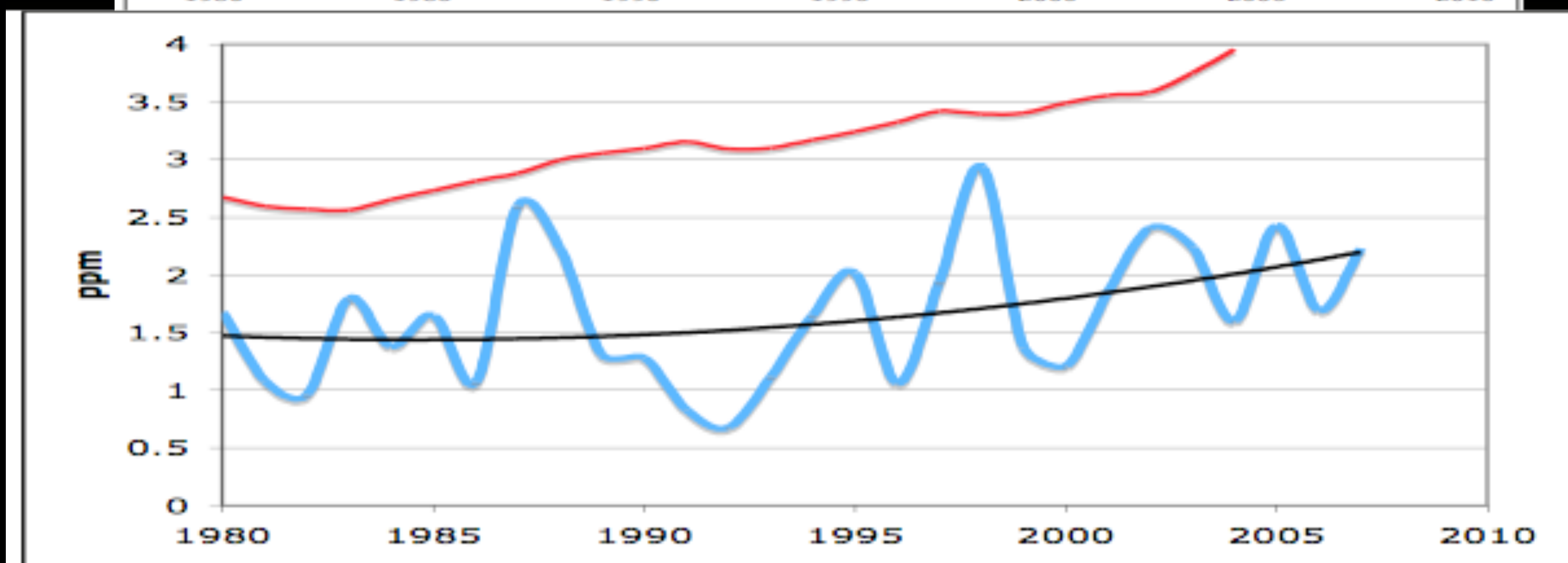
http://www.iceuls.com/_photo/b.jpg

CARBON

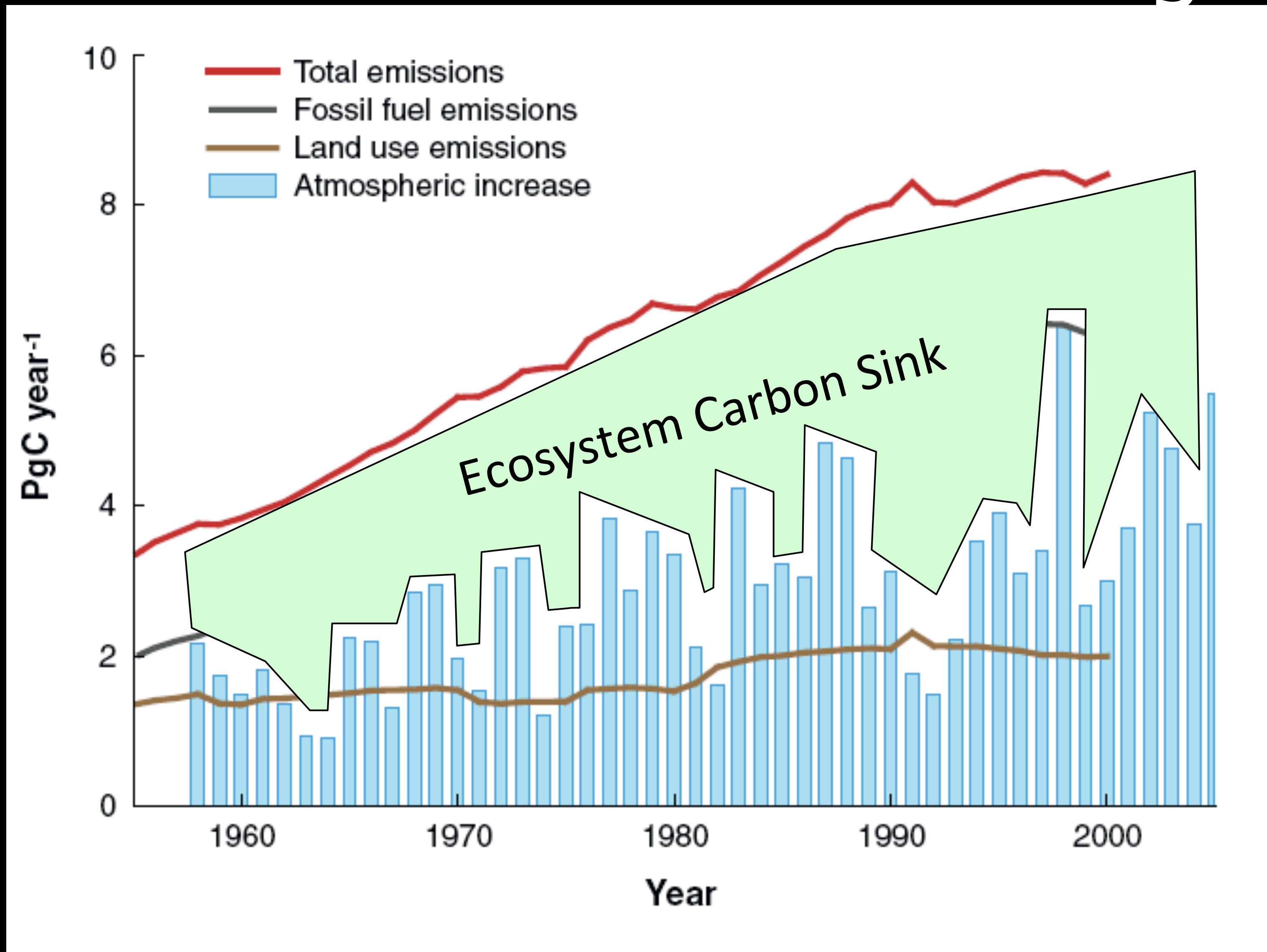


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
NOAA
October 2012

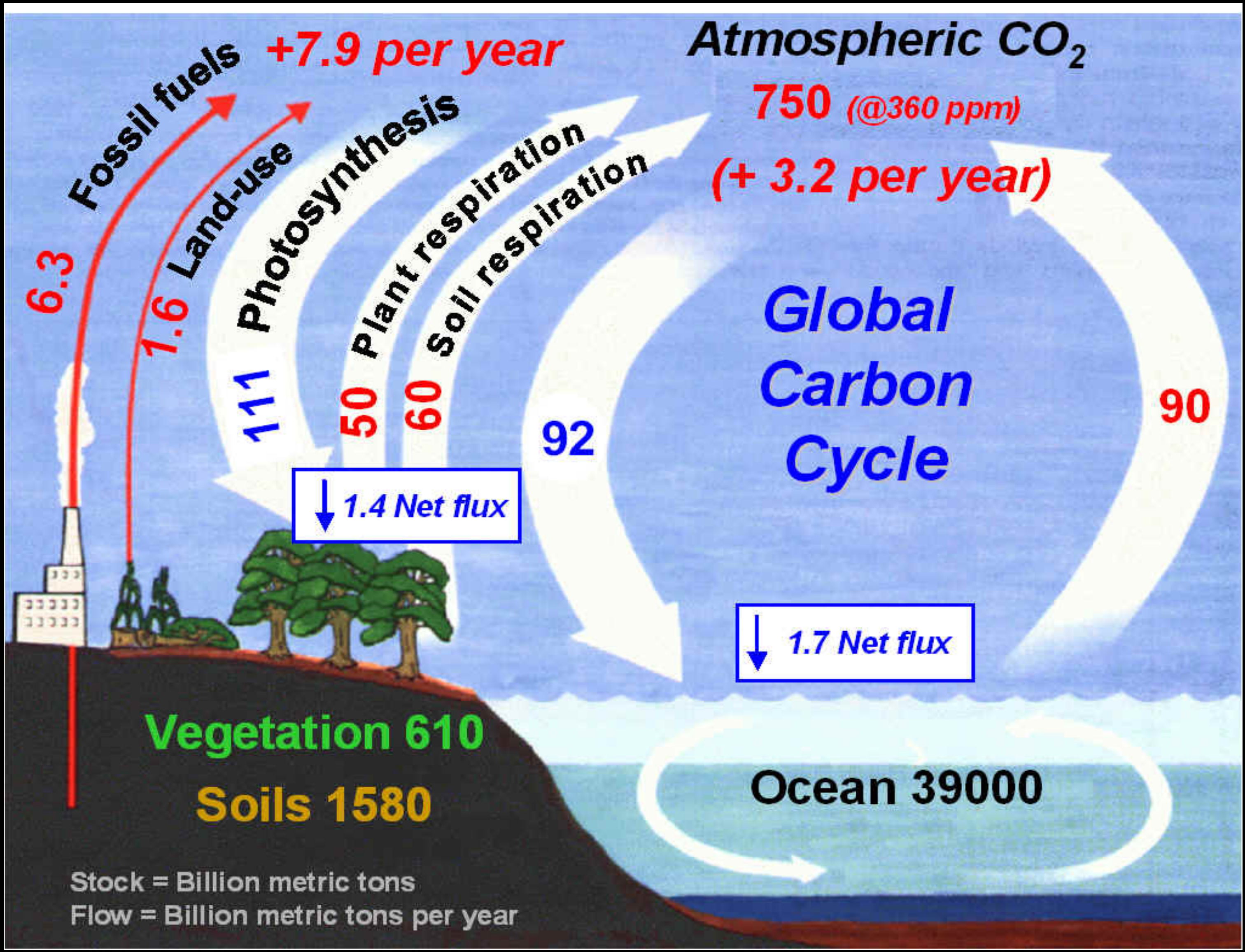

390
380
370
360
350
340
330
1980
1985
1990
1995
2000
2005
2010


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

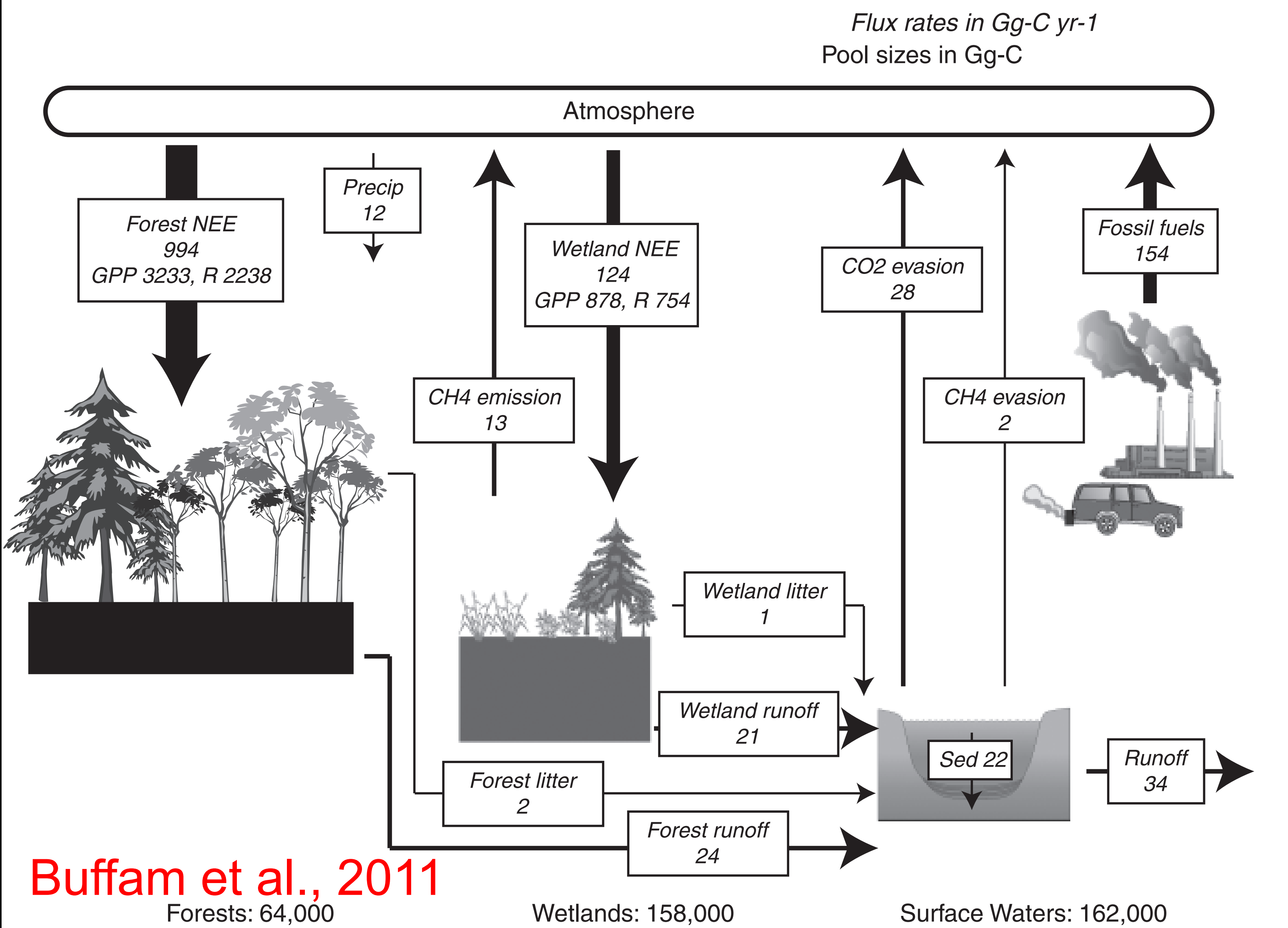
Where Is The Carbon Going?



Houghton et al. (2007)



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



Buffam et al., 2011

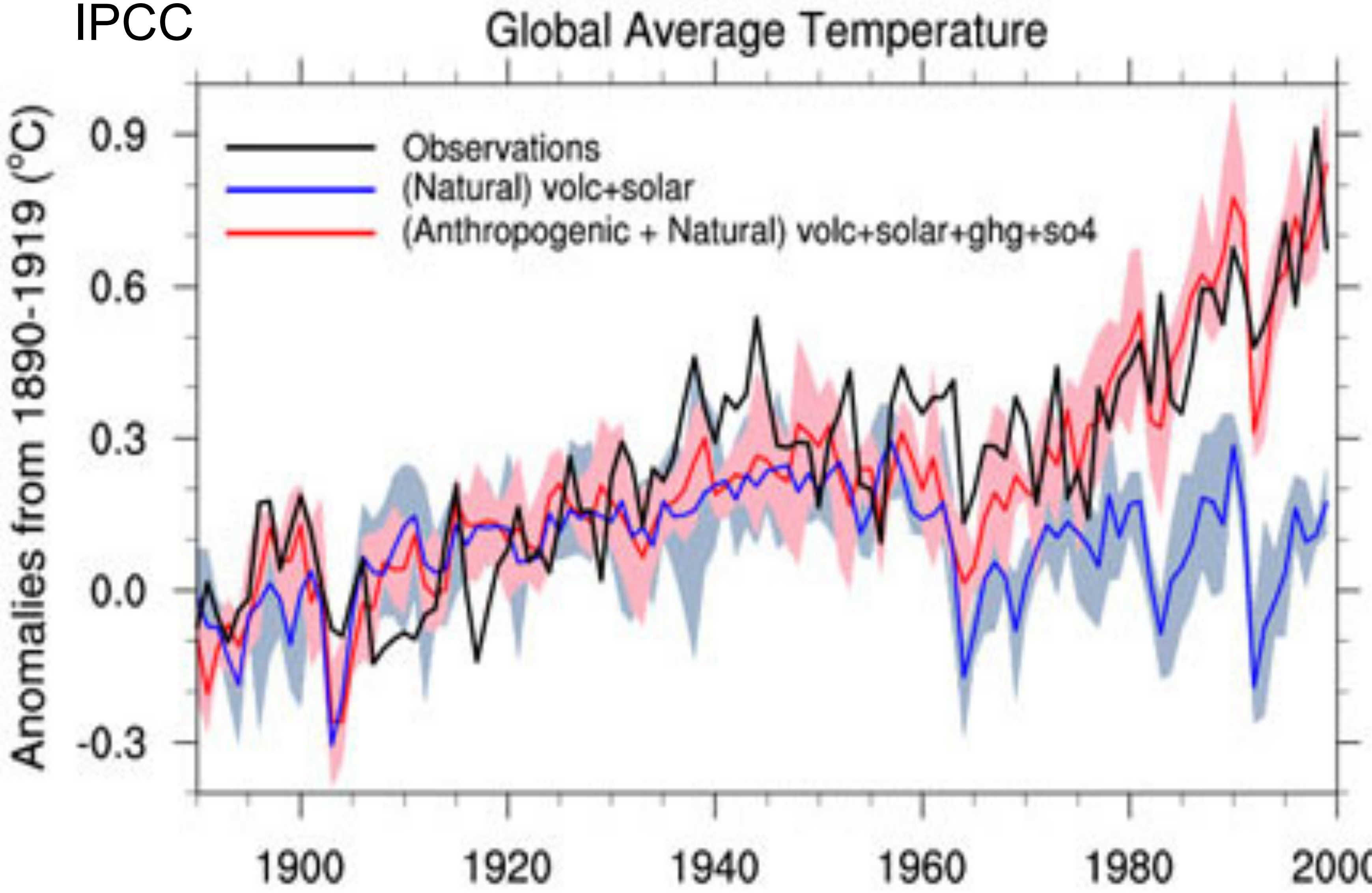
CLIMATE

Svante Arrhenius

Born	19 February 1859(1859-02-19) Vik, Sweden
Died	2 October 1927(1927-10-02) (aged 68) Stockholm, Sweden
Nationality	Swedish
Fields	Physics, chemistry
Institutions	Royal Institute of Technology
Alma mater	Uppsala University Stockholm University
Doctoral advisor	Per Teodor Cleve, Erik Edlund
Doctoral students	Oskar Benjamin Klein
Known for	Arrhenius equation Theory of ionic dissociation Acid-base theory
Notable awards	Nobel Prize for Chemistry (1903) Franklin Medal (1920

To explain the ice age, Arrhenius estimated that halving of CO_2 would decrease temperatures by 4 - 5 °C (Celsius) and a doubling of CO_2 would cause a temperature rise of 5 - 6 °C. In his 1906 publication, Arrhenius adjusted the value downwards to 1.6 °C (including water vapour feedback: 2.1 °C). Recent (2007) estimates from IPCC say this value (the Climate sensitivity) is likely to be between 2 and 4.5 °C. Arrhenius expected CO_2 doubling to take about 3000 years; it is now estimated in most scenarios to take about a century.

IPCC



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Observations
(Natural) volc+solar
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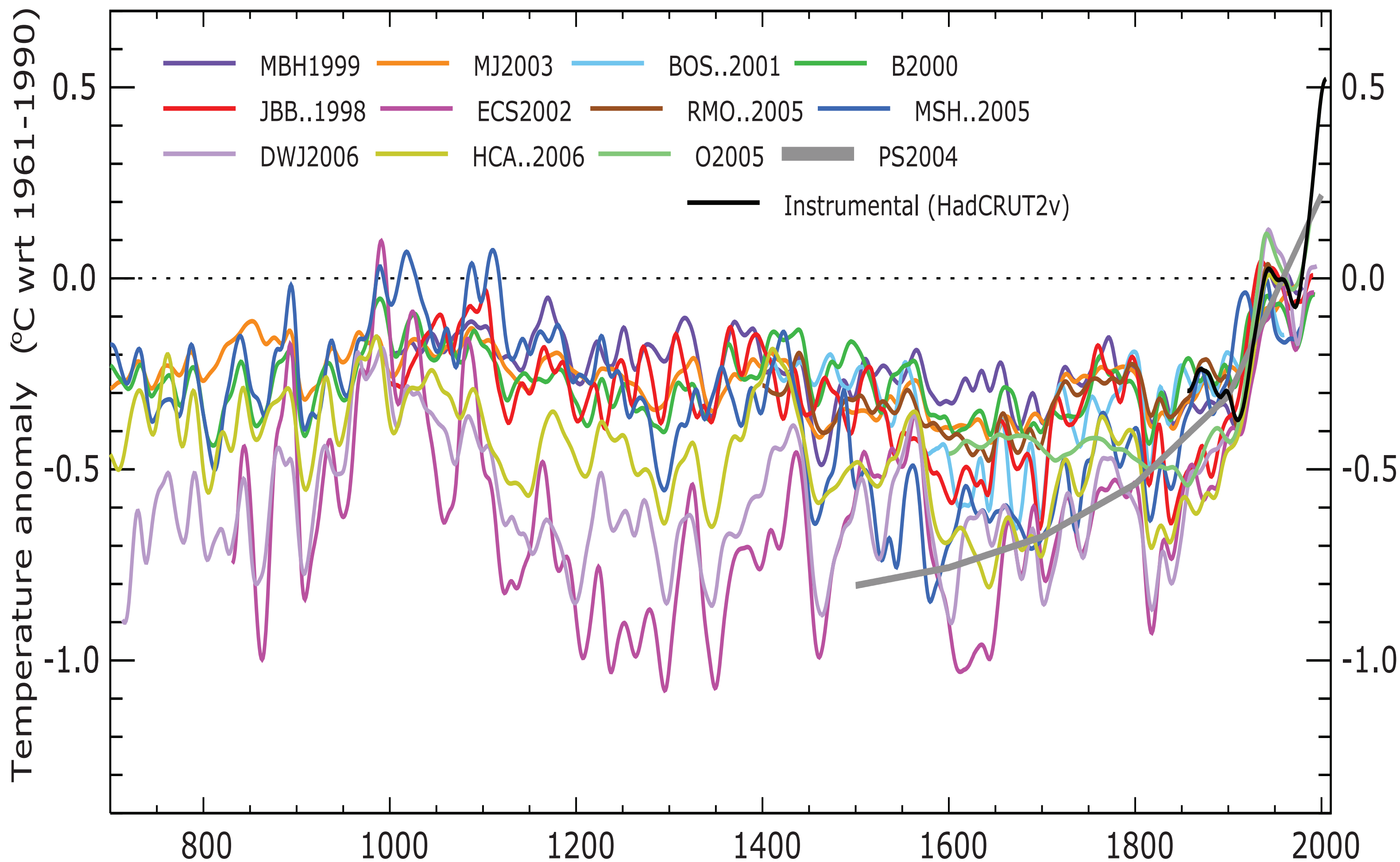
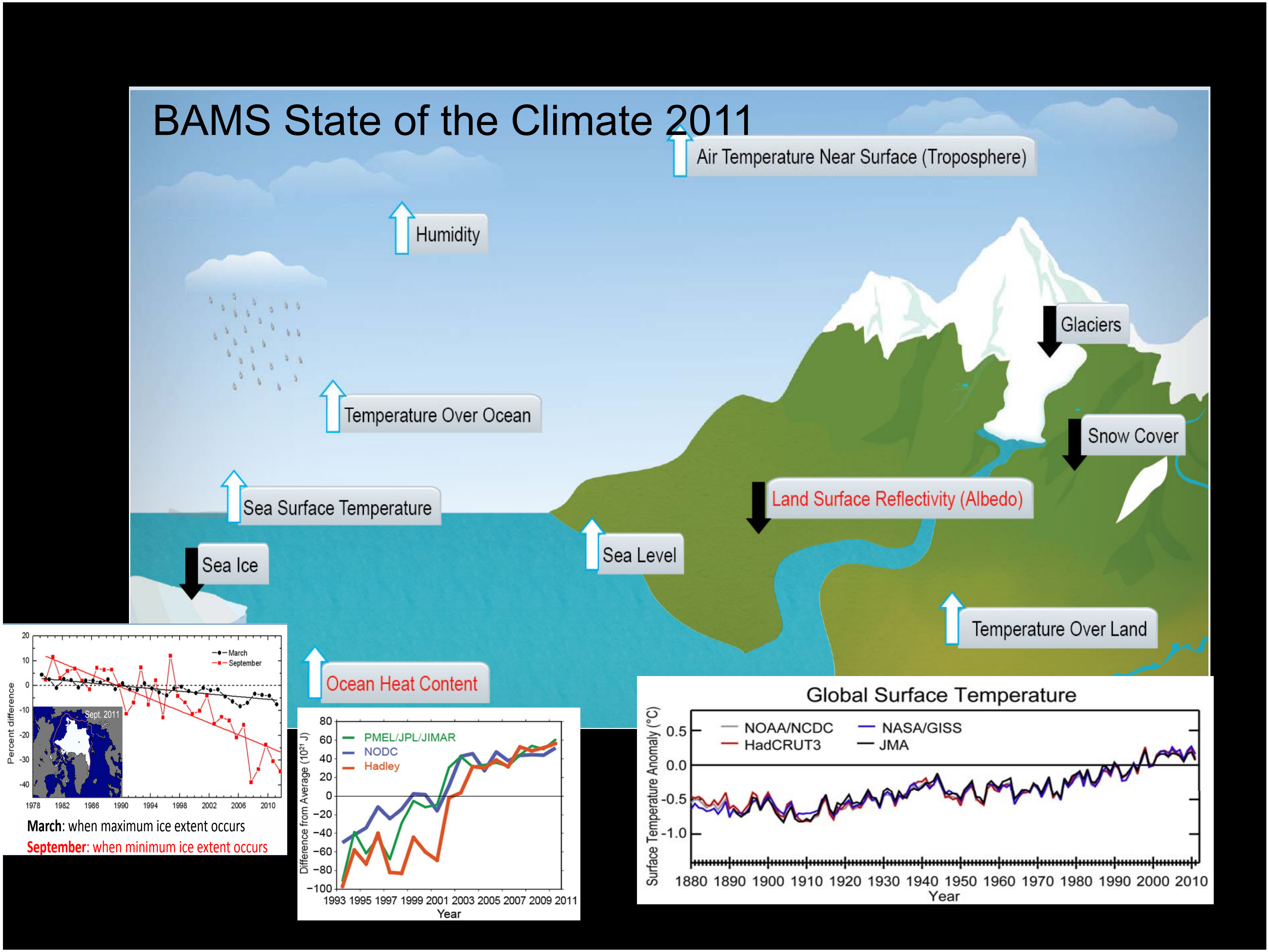
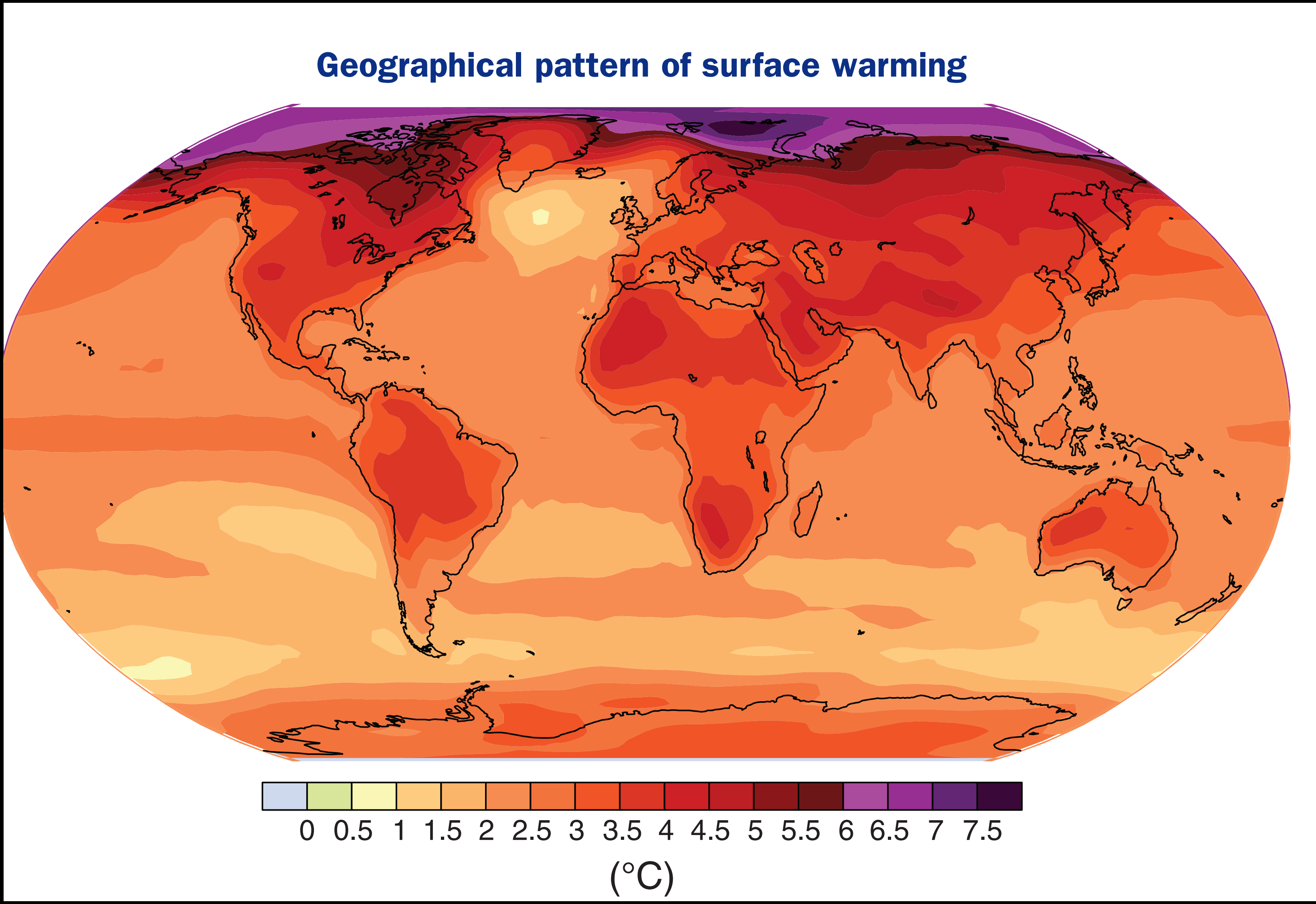
IPCC Northern Hemisphere Temperature Reconstructions



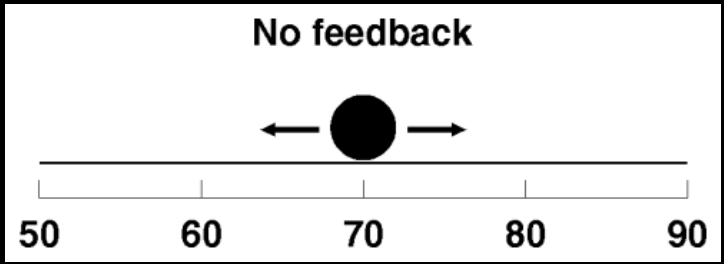


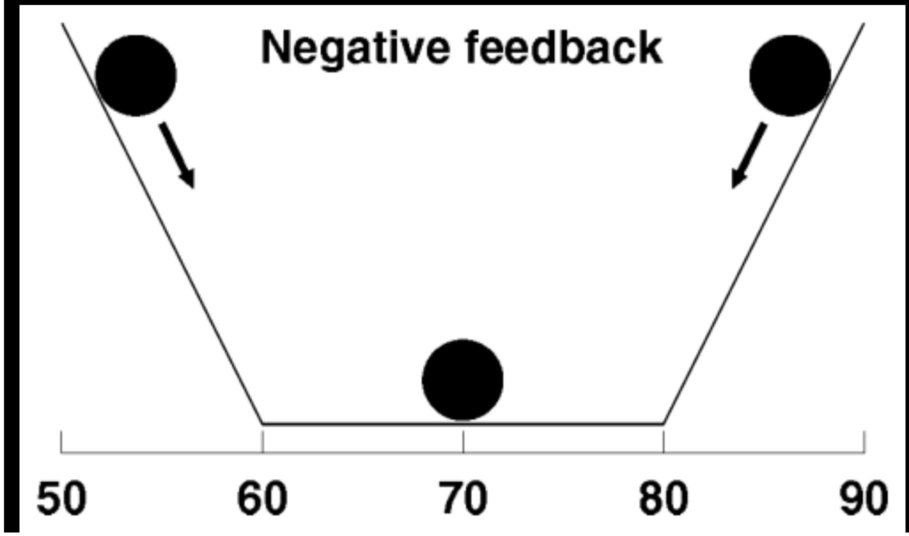
BAMS State of the Climate 2011
Air Temperature Near Surface (Troposphere)
Humidity
Glaciers
Temperature Over Ocean
Snow Cover
Sea Surface Temperature
Land Surface Reflectivity (Albedo)
Sea Ice
Sea Level
Temperature Over Land
Ocean Heat Content
March
September
Sept. 2011
Percent difference
March: when maximum ice extent occurs
September: when minimum ice extent occurs
PMEL/JPL/JIMAR
NODC
Hadley
Difference from Average (10^{21} J)
Year
Global Surface Temperature
NOAA/NCDC
NASA/GISS
HadCRUT3
JMA
Surface Temperature Anomaly (°C)
Year

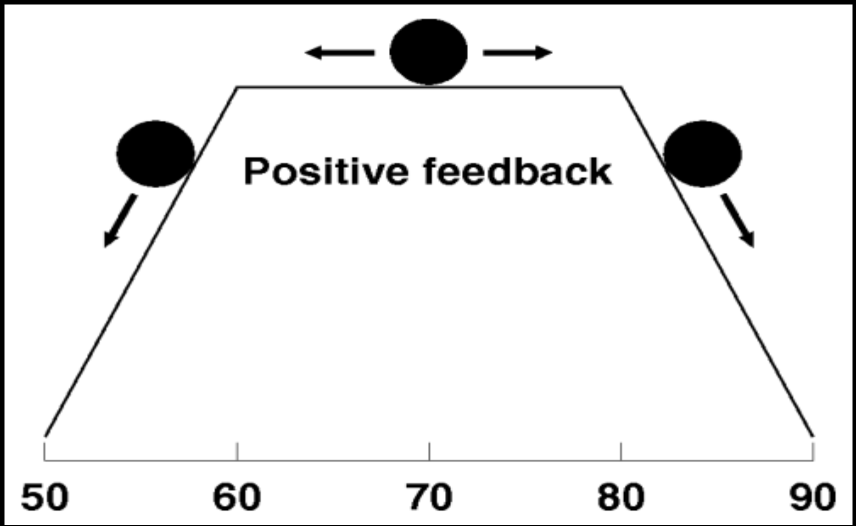


2090 (IPCC 4th Assessment)

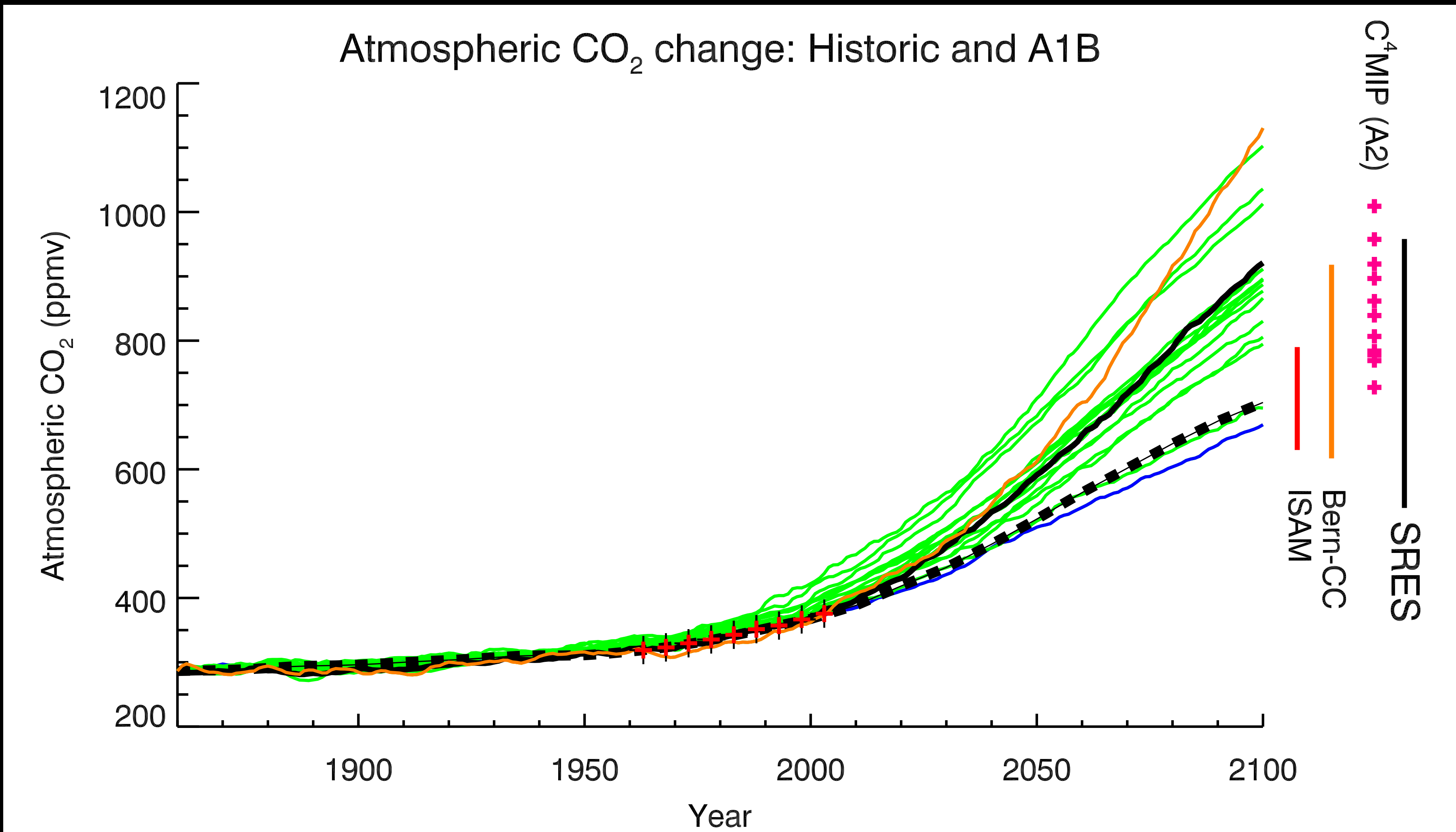
- Climate changes with:
  - A change in forcing (sun strength, Earth's orbit, volcano frequency, greenhouse gases)
  - Is amplified by positive feedbacks







The carbon cycle feedback is large and hard to predict



Booth et al., 2012

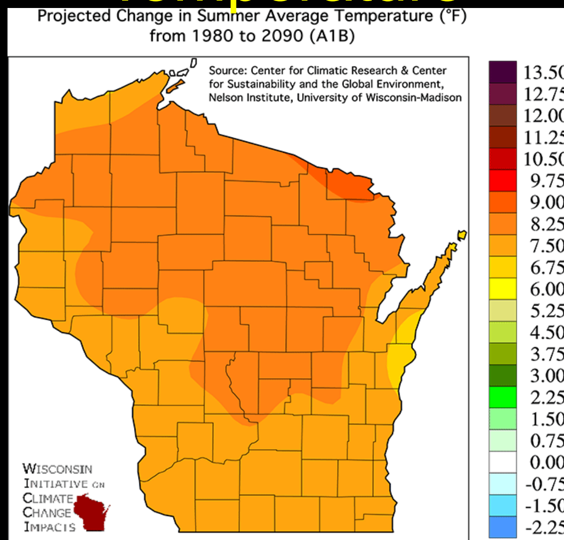
What drives this feedback?

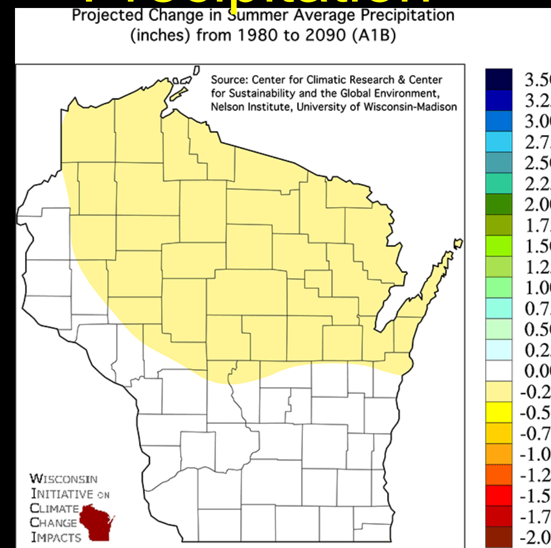
- Terrestrial ecosystems carbon assimilation and decomposition respond to:
  - Temperature
  - Light quantity and quality
  - Moisture availability
  - Nutrients (Nitrogen, CO_2, Phosphorous)
  - Disturbance (Fire, insects, hurricanes, …)
  - Land use (Logging, draining wetlands, …)
  - Competition,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

Locally: Warmer winters, drier summers

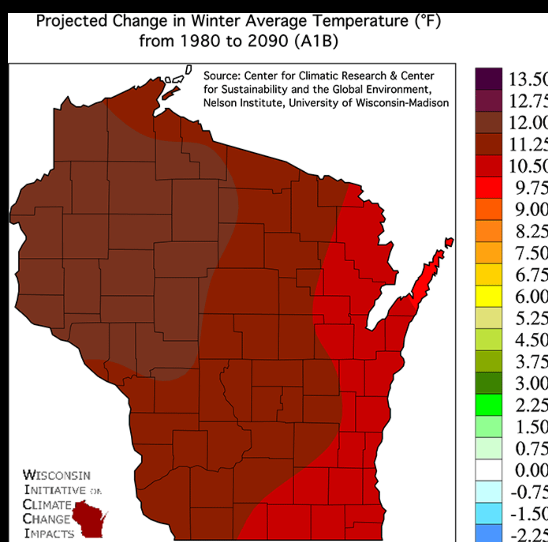
Temperature | **Precipitation**

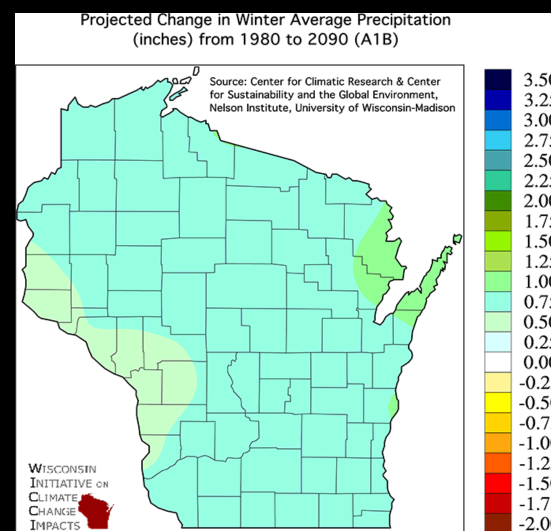
Summer





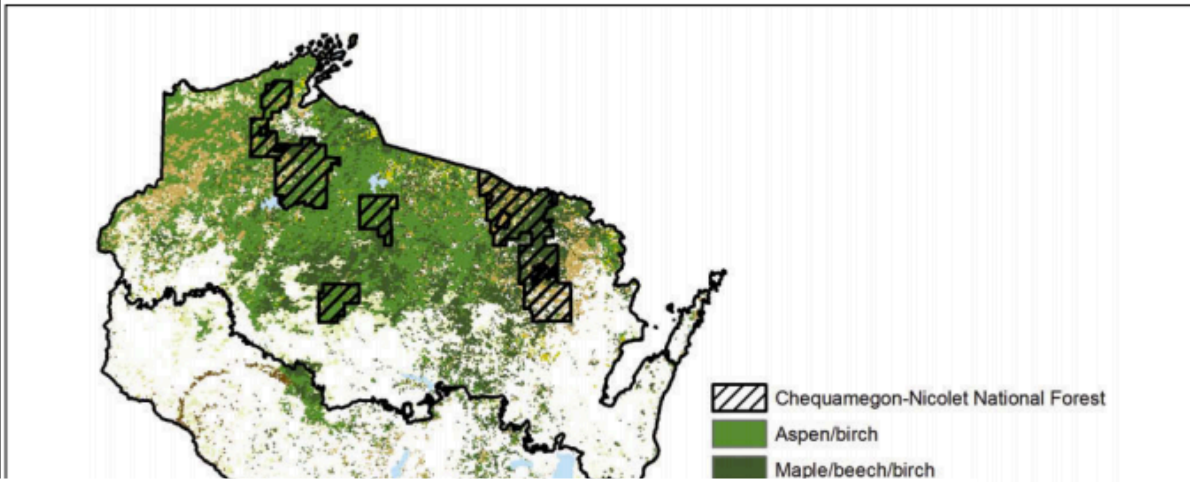
Winter

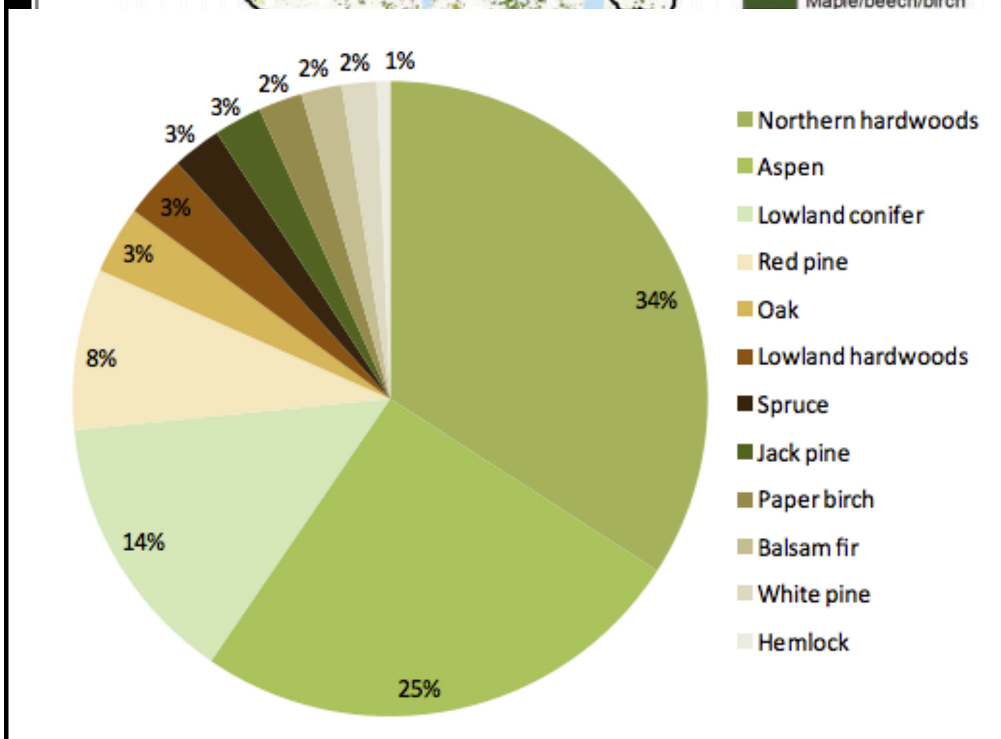


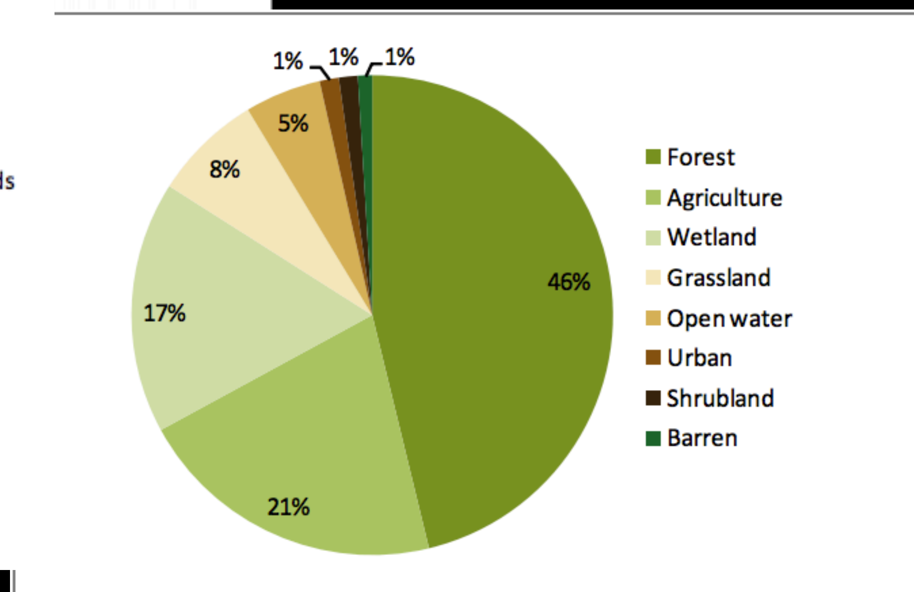


http://www.wicci.wisc.edu/

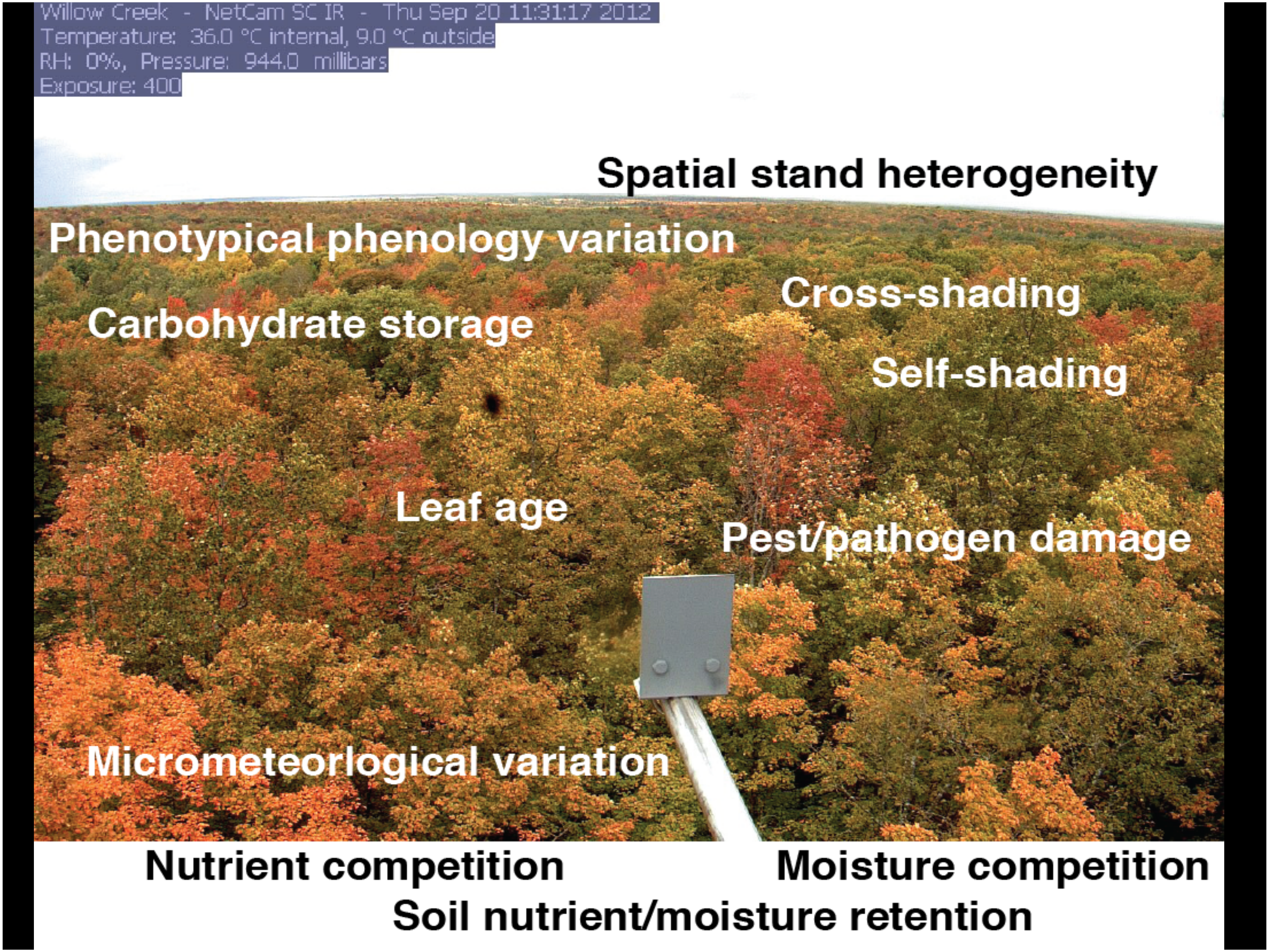
FORESTS





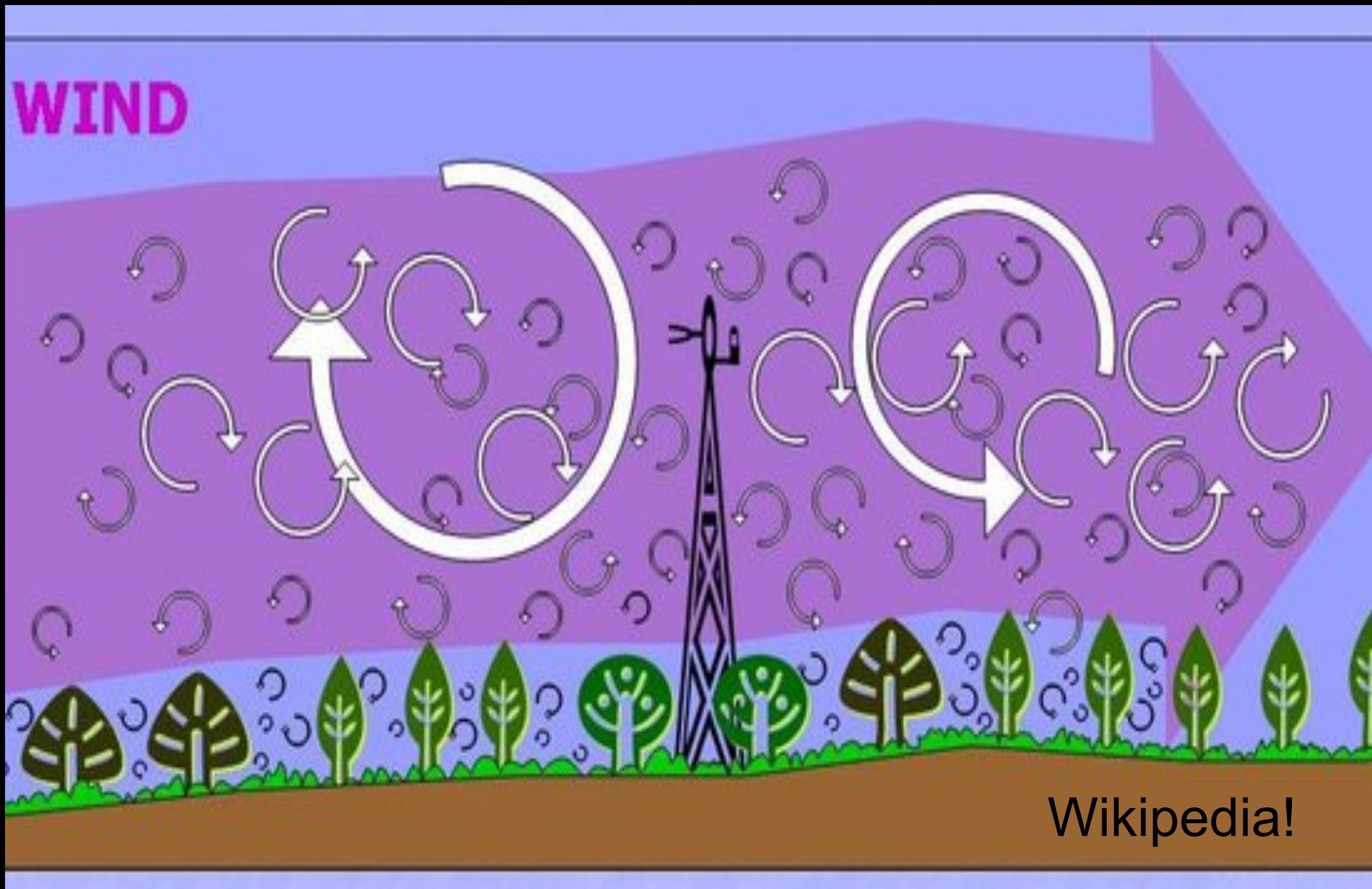


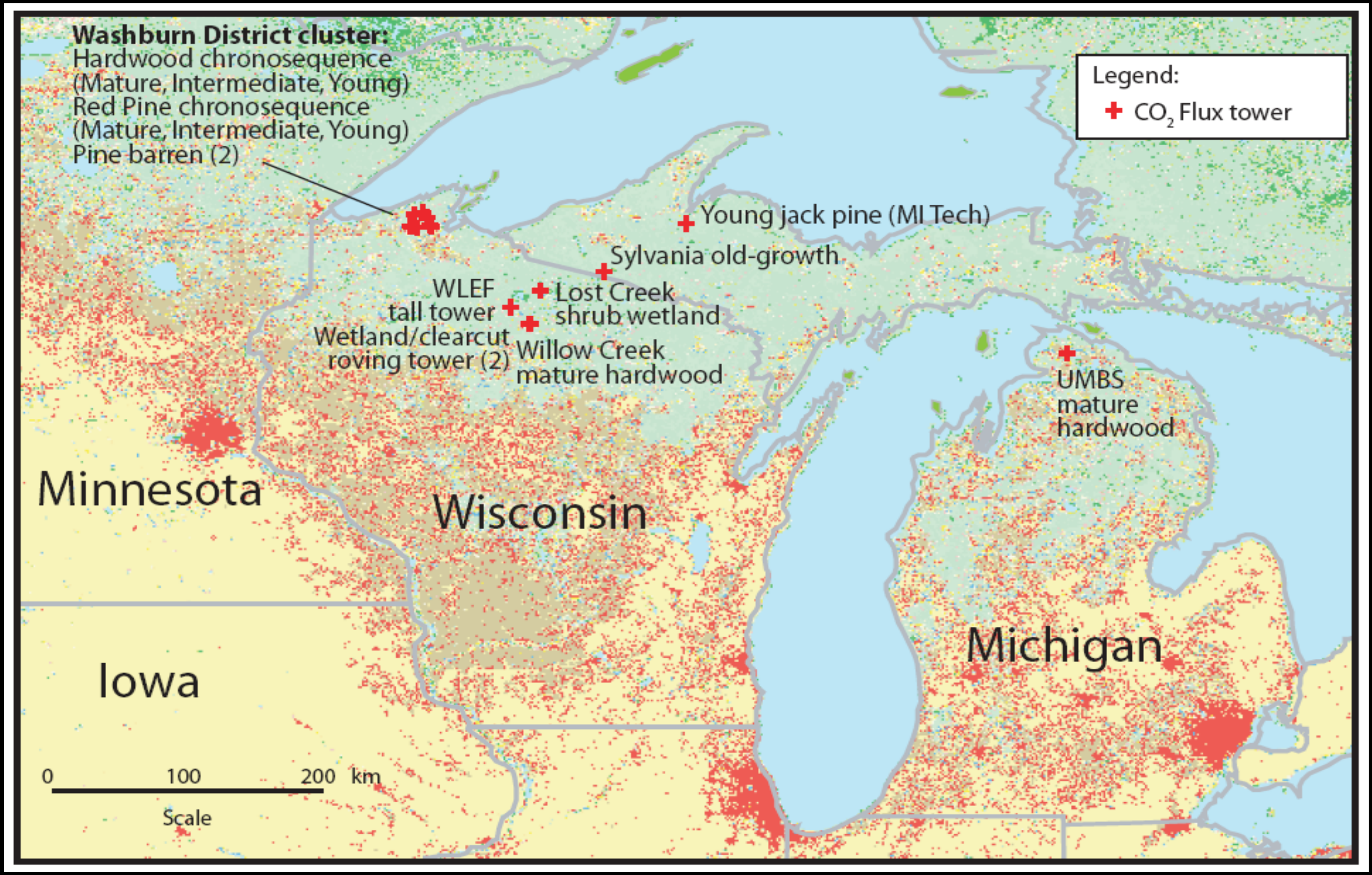
- Source: NIACS, USFS


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

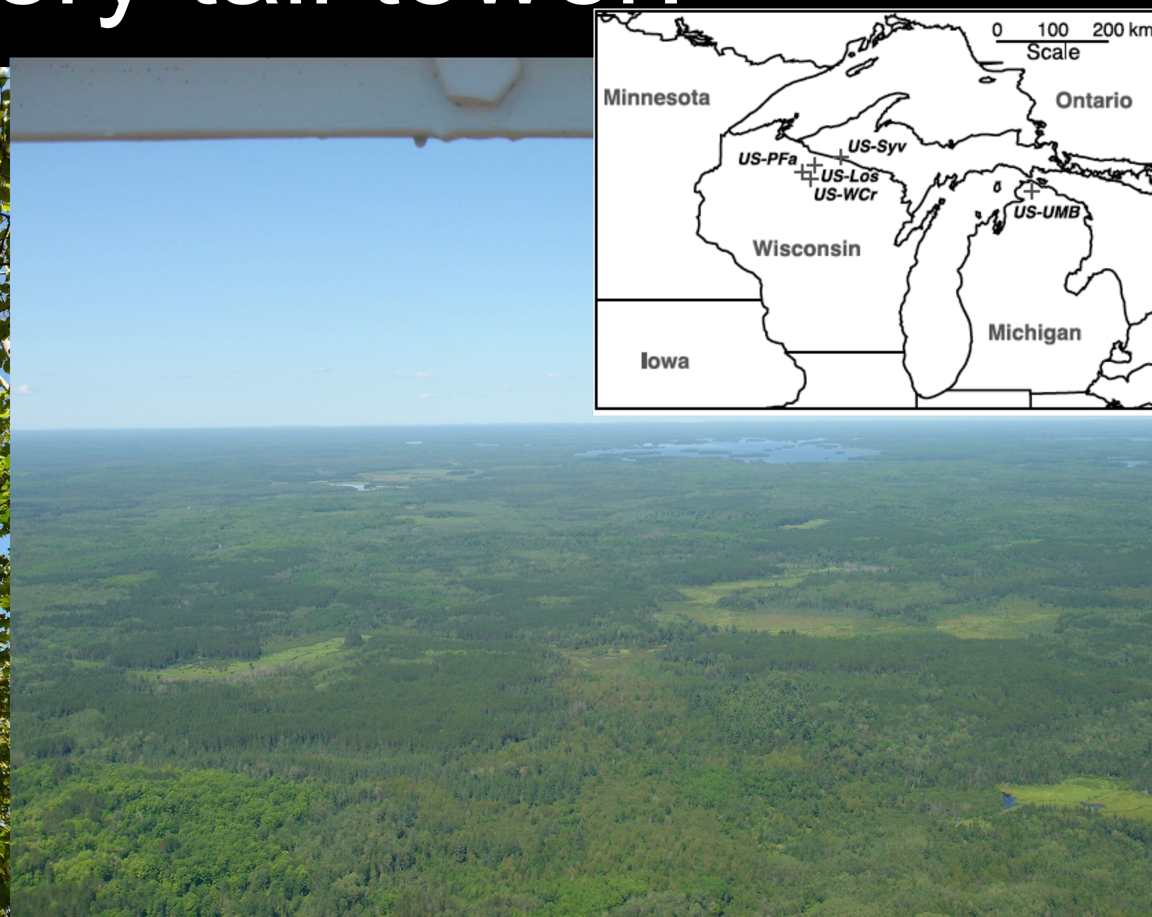

For-CLIMATE: Forest and Climate
Leaders In Menominee And The Environment

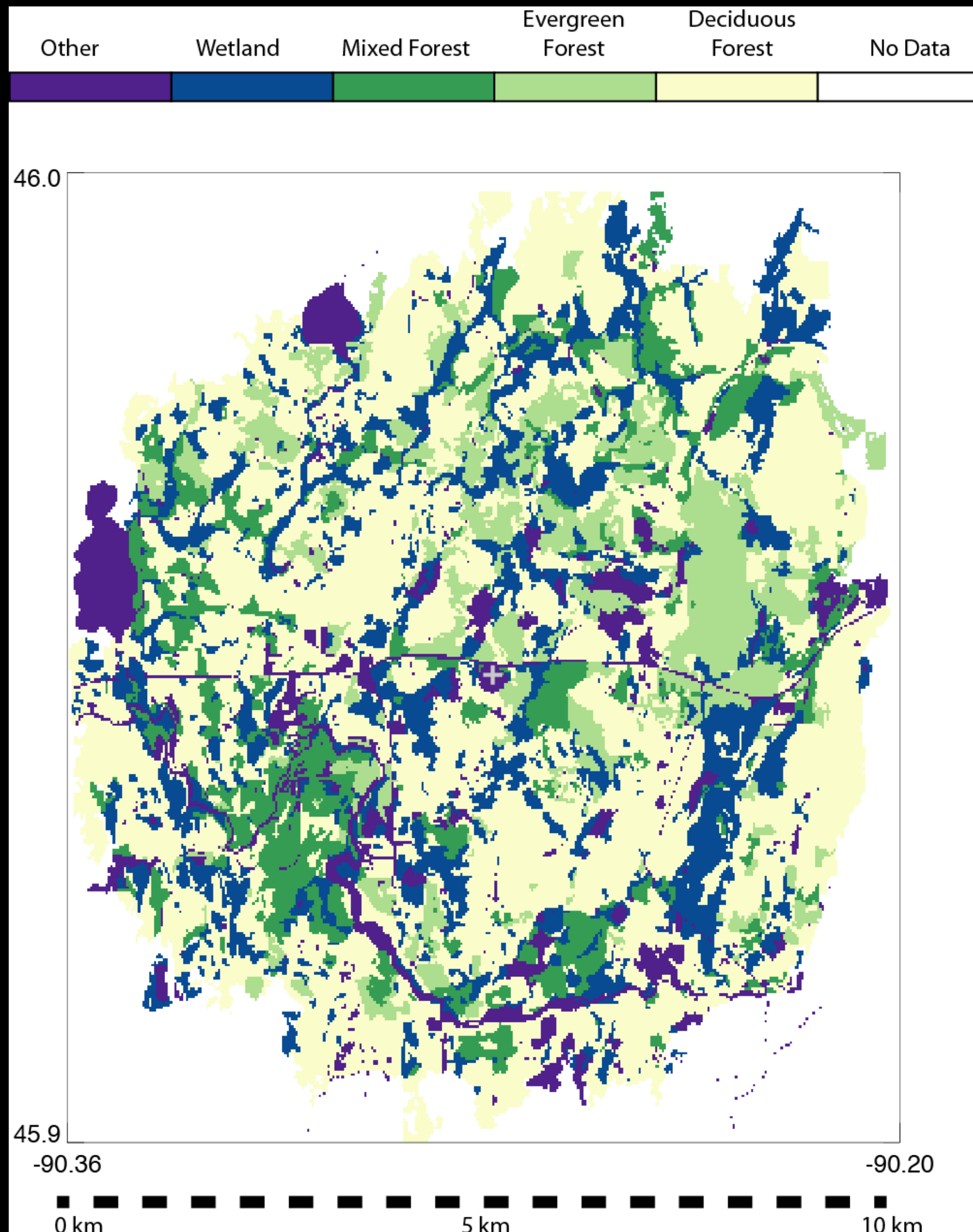

WS 3153

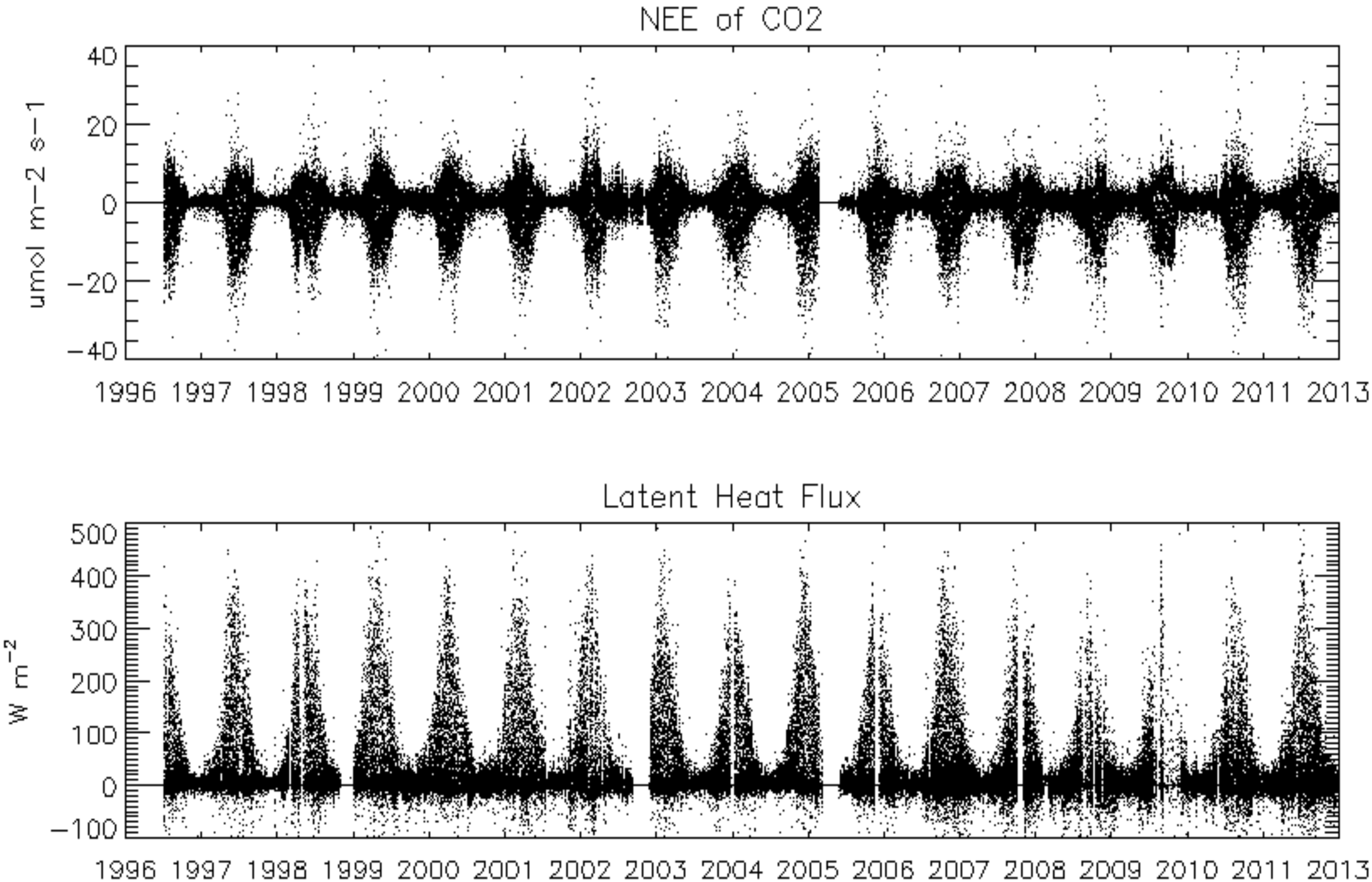

WIND
Wikipedia!

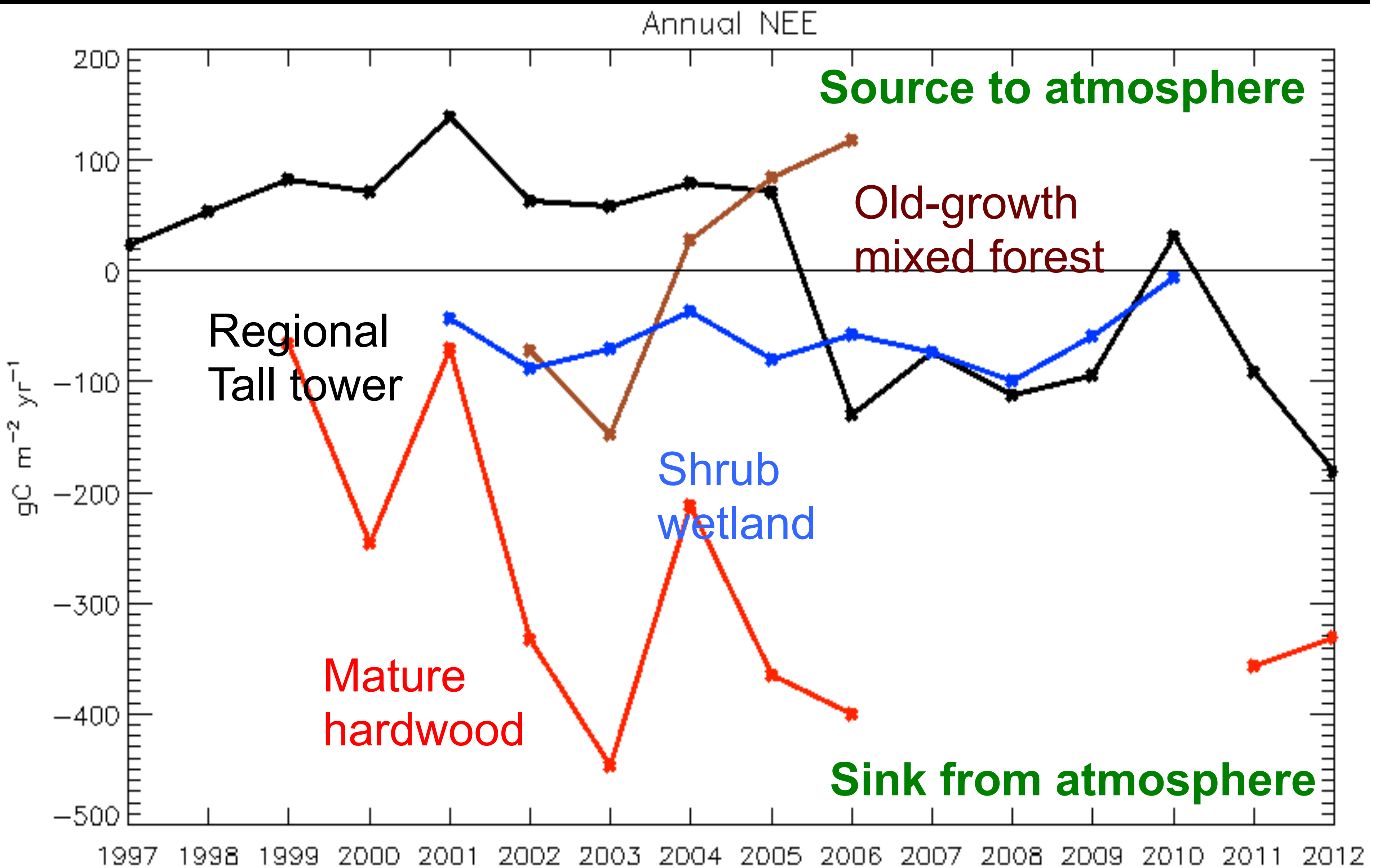

Washburn District cluster:
Hardwood chronosequence
(Mature, Intermediate, Young)
Red Pine chronosequence
(Mature, Intermediate, Young)
Pine barren (2)
Legend:
CO2 Flux tower
Young jack pine (MI Tech)
Sylvania old-growth
WLEF
tall tower
Lost Creek
shrub wetland
Wetland/clearcut
roving tower (2)
Willow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

A very tall tower!



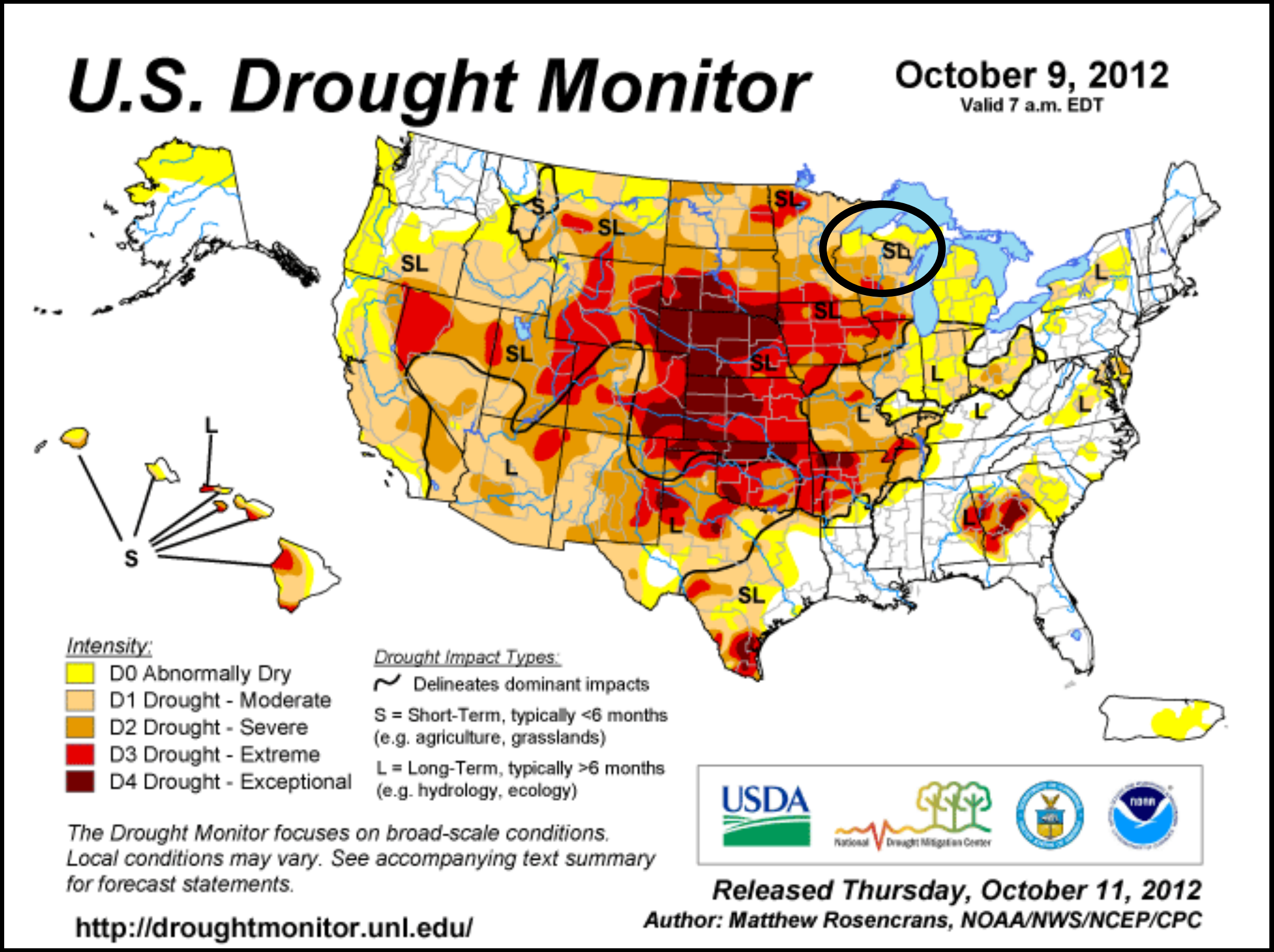

Other
Wetland
Mixed Forest
Evergreen Forest
Deciduous Forest
No Data
46.0
45.9
-90.36
-90.20
0 km
5 km
10 km

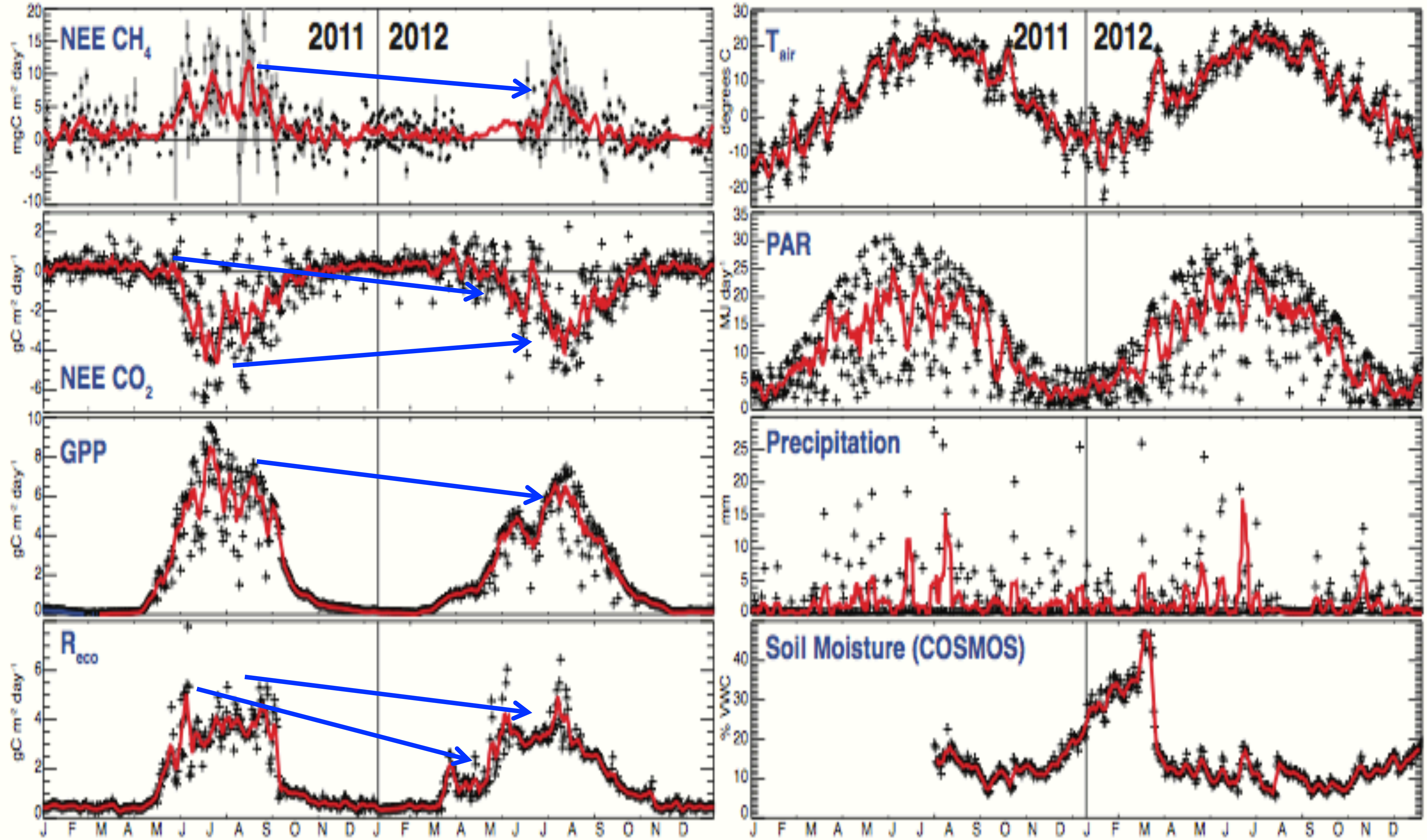

NEE of CO2
umol m−2 s−1
40
20
0
−20
−40
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2013
Latent Heat Flux
W m−2
500
400
300
200
100
0
−100
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2013



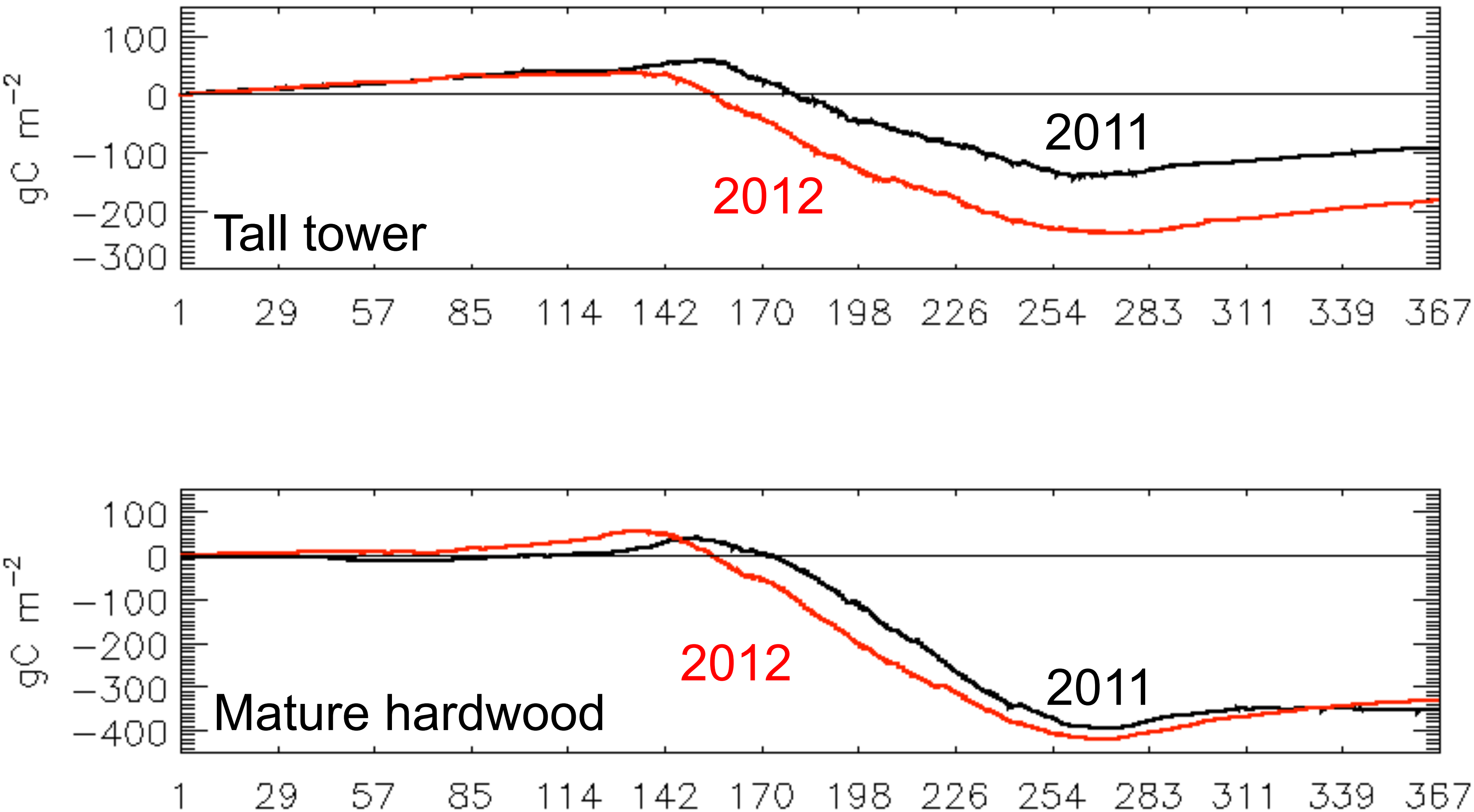
Annual NEE
Source to atmosphere
Old-growth mixed forest
Regional Tall tower
Shrub wetland
Mature hardwood
Sink from atmosphere
gC m⁻² yr⁻¹
200
100
0
−100
−200
−300
−400
−500
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

What about 2012?



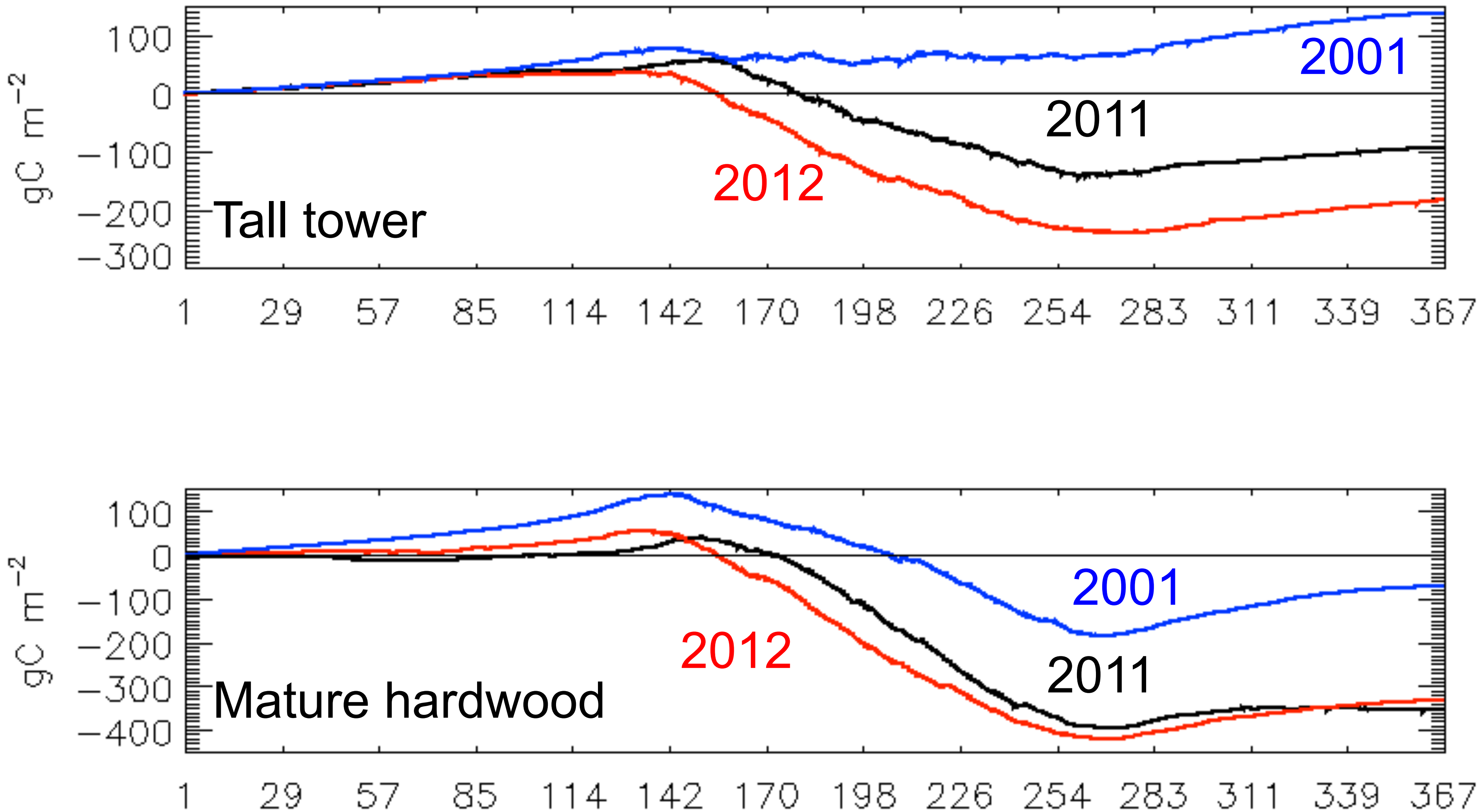

NEE CH4
2011
2012
mgC m⁻² day⁻¹
NEE CO2
gC m⁻² day⁻¹
GPP
gC m⁻² day⁻¹
Reco
gC m⁻² day⁻¹
J F M A M J J A S O N D J F M A M J J A S O N D
Tair
2011
2012
degrees C
PAR
MJ day⁻¹
Precipitation
mm
Soil Moisture (COSMOS)
% VWC
J F M A M J J A S O N D J F M A M J J A S O N D

[redacted]

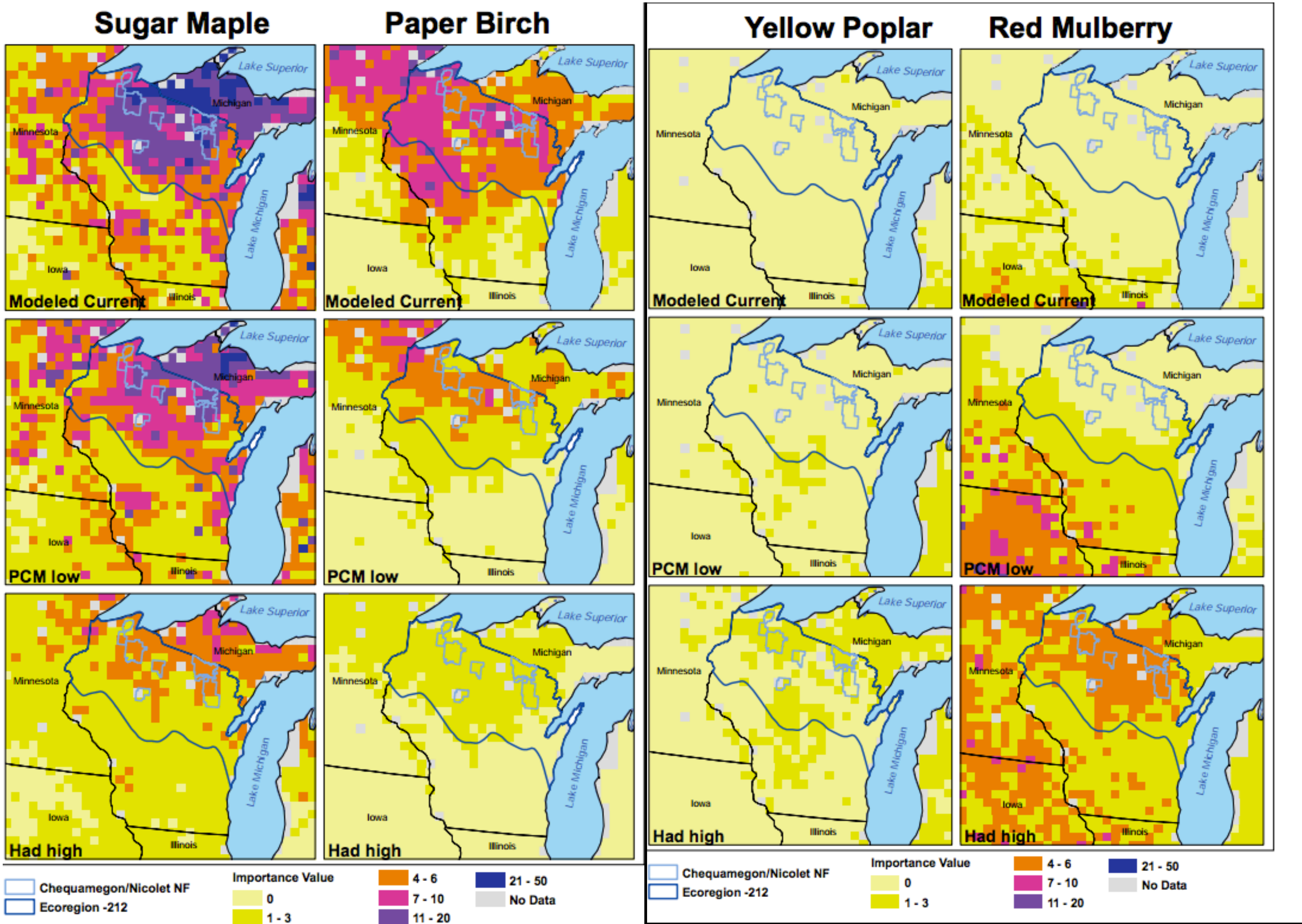


[redacted]

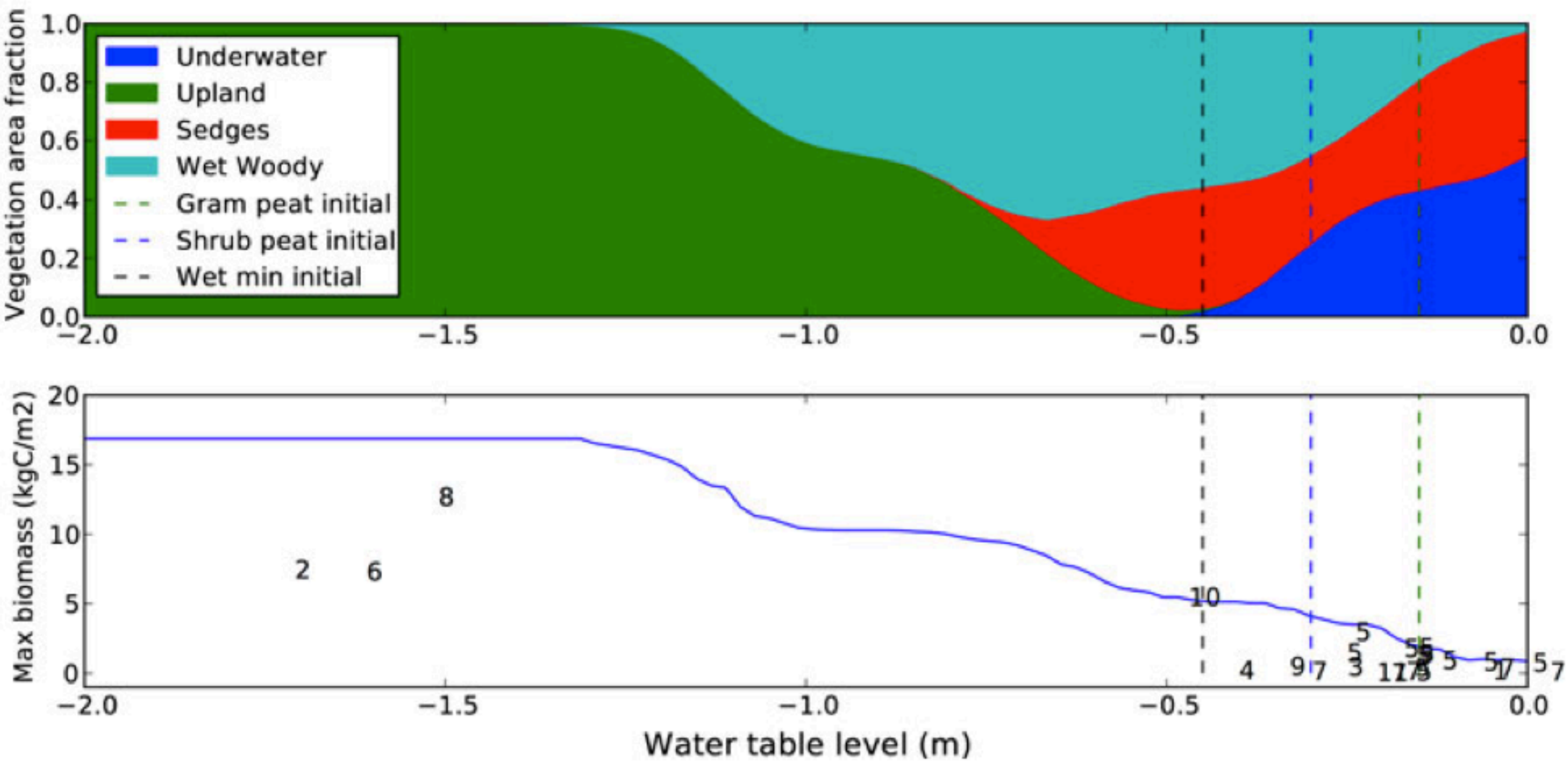
[redacted]



[redacted]



Source: NIACS, CCRF



Source: Sulman et al, 2013 (Ecosystems)

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?

BIRDS?

WICCI:

BIRD MIGRATION	VEGETATION
Geese arrival: 29 days earlier	Baptista first bloom: 18 days earlier
Cardinal first song: 22 days earlier	Butterfly weed first bloom: 18 days earlier
Robin arrival: 9 days earlier	Marsh milkweed first bloom: 13 days earlier

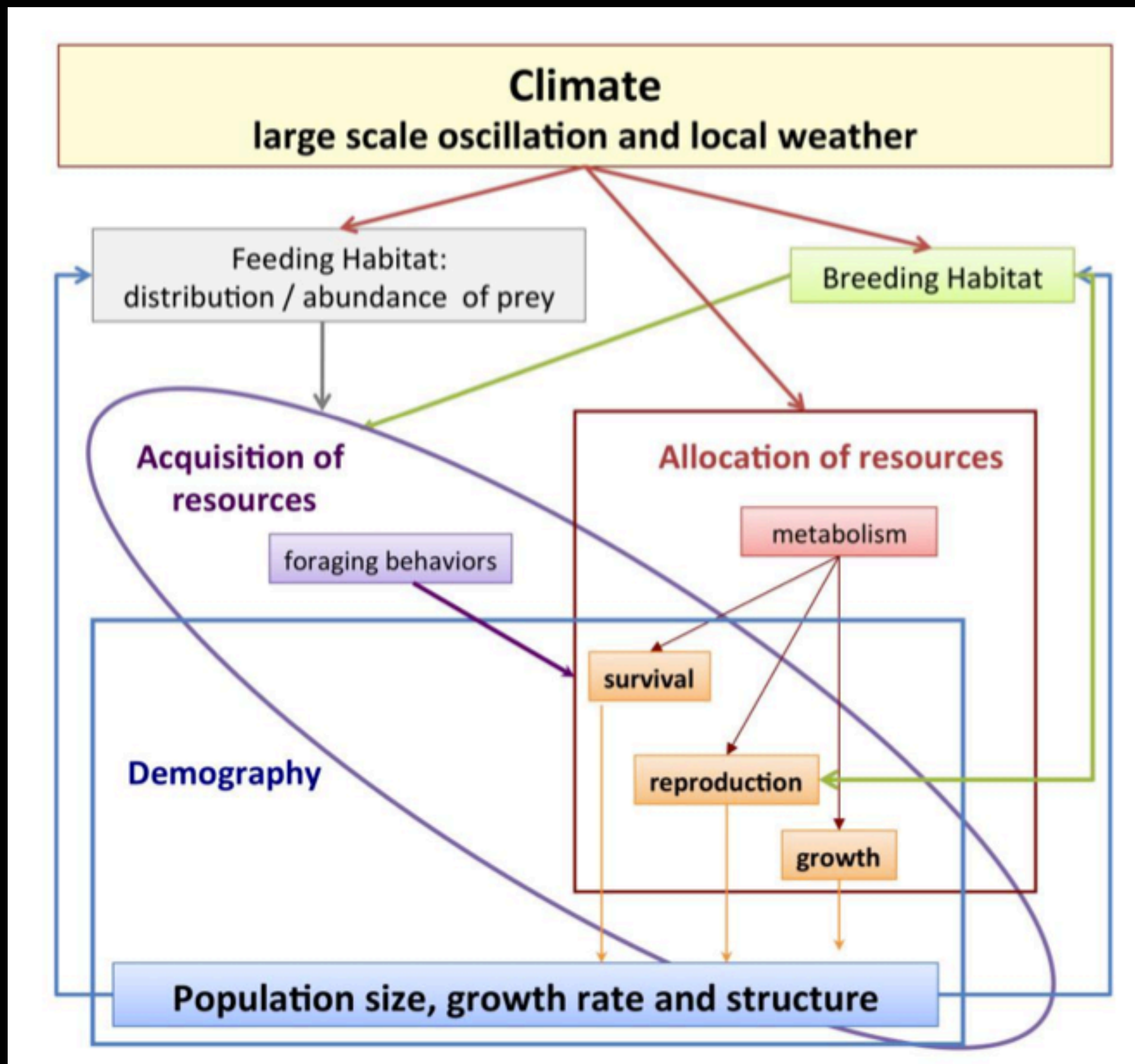
Table 1. Evidence of earlier arrival of spring in Wisconsin from 1936-1998.

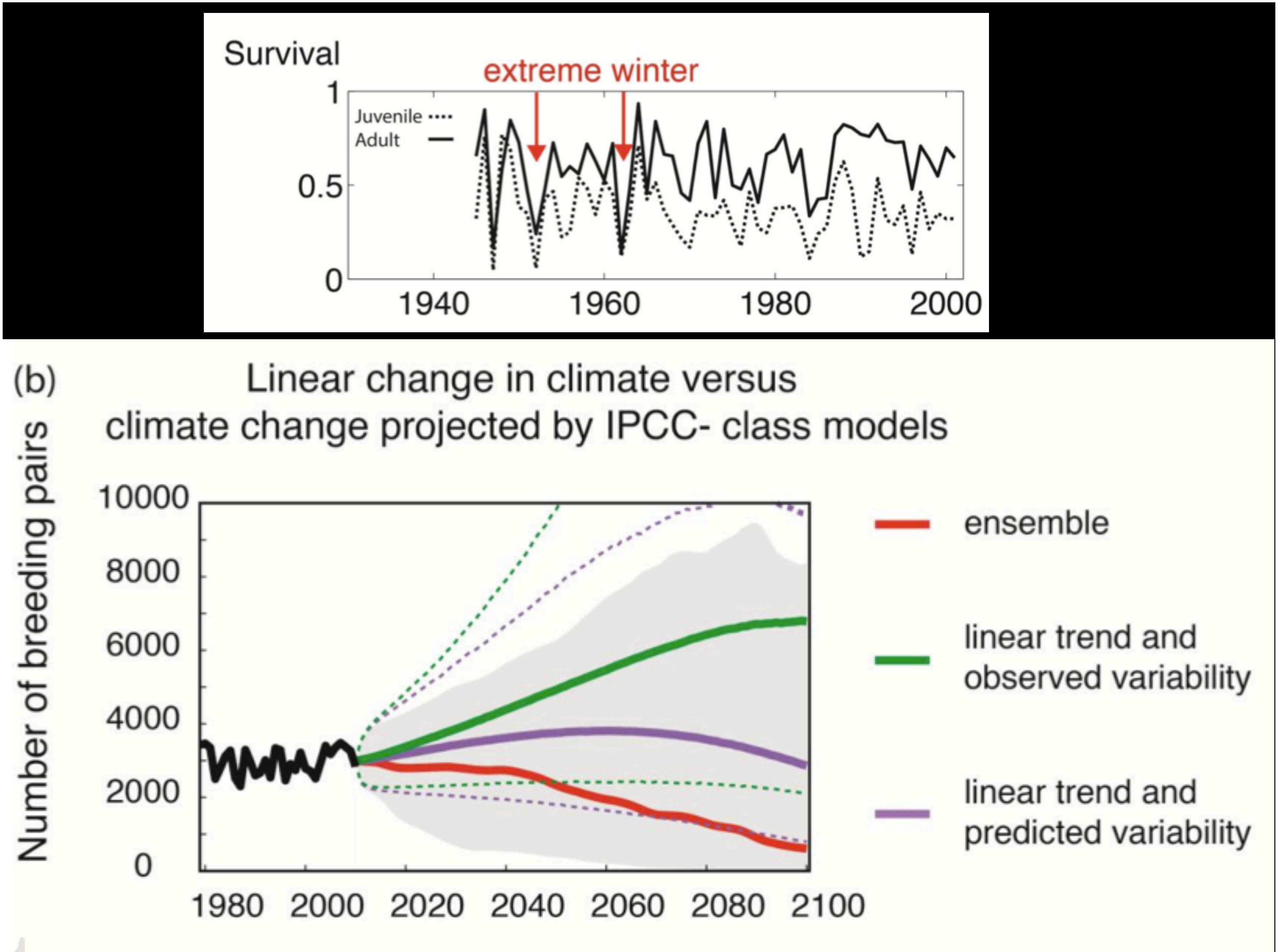
Source: Bradley et al., 1999. Phenological changes reflect climate change in Wisconsin. Proc. Natl. Acad. Sci., 96: 9701-9704.

Impacts of climate change on avian populations

Stéphanie Jenouvrier[1,2]

March 6, 2013




Survival
extreme winter
1
0.5
0
Juvenile
Adult
1940
1960
1980
2000
(b)
Linear change in climate versus
climate change projected by IPCC- class models
Number of breeding pairs
10000
8000
6000
4000
2000
0
1980
2000
2020
2040
2060
2080
2100
ensemble
linear trend and
observed variability
linear trend and
predicted variability

Thanks!