Mathematics and Climate

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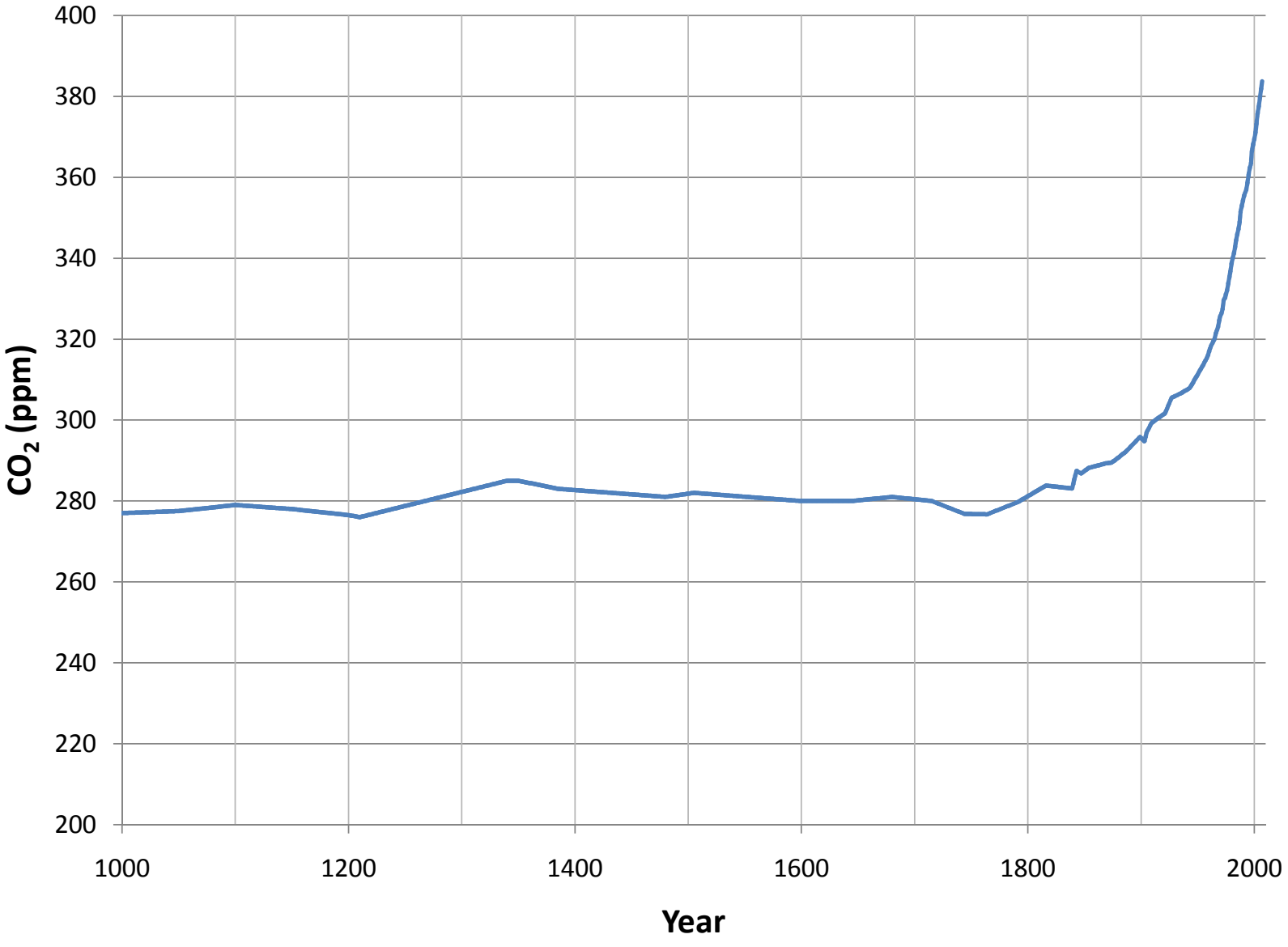
Why This Talk?

- Mathematics Awareness Month
  - How long will the summer Arctic sea ice pack survive?
  - Are hurricanes and other severe weather events getting stronger?
  - How much will sea level rise as ice sheets melt?
  - How do human activities affect climate change?
  - How is global climate monitored?
- Discuss what I do.
- Discuss what YOU have done.

Outline

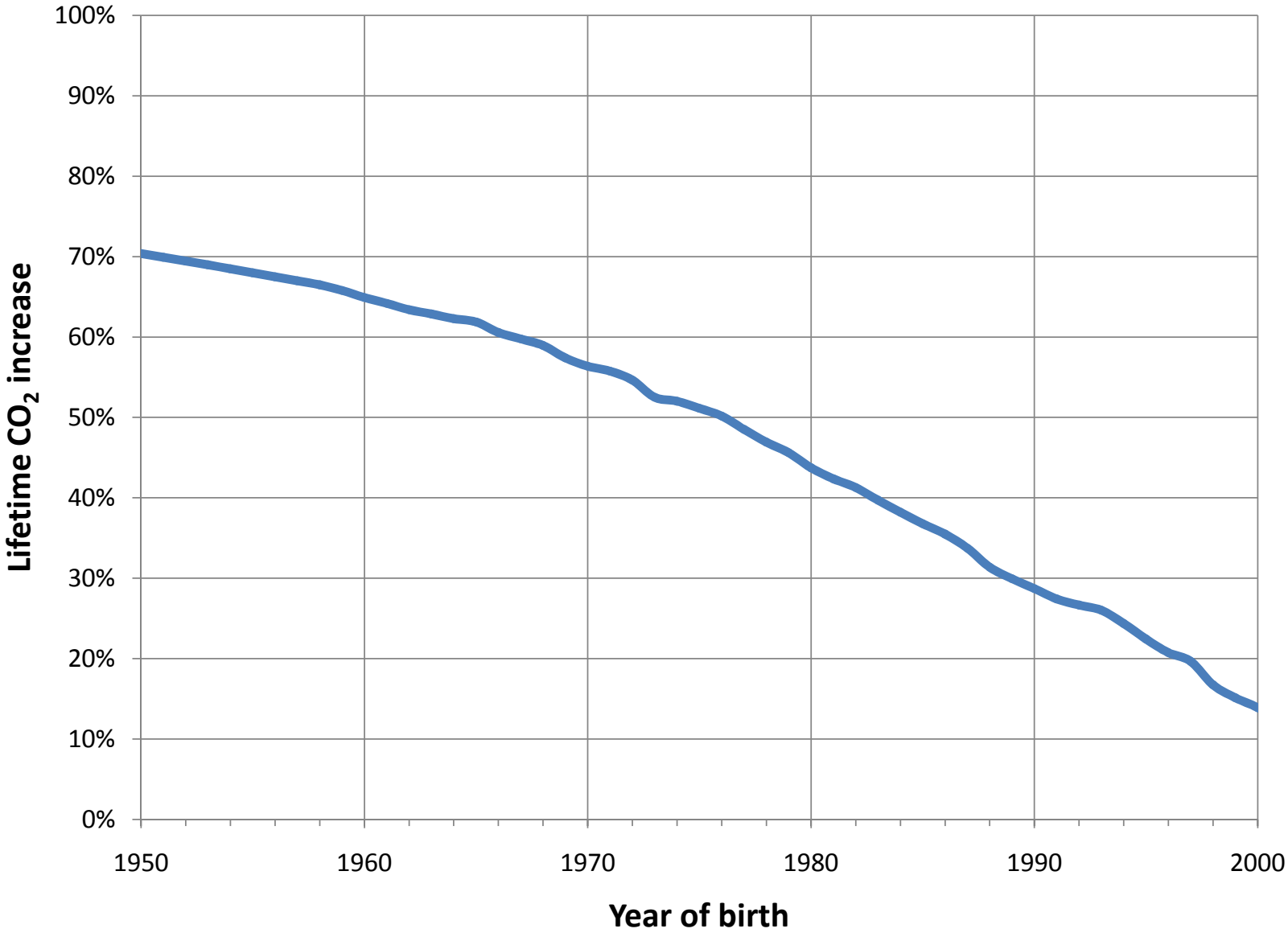
1. Rising CO_2 and its consequences
2. Modeling forest carbon uptake
3. Recent results from the literature
   - High-latitude ecosystems
   - Changes in the annual temperature cycle
   - Sea-ice predictions
   - The evolution of climate models

CO_2: a modern problem



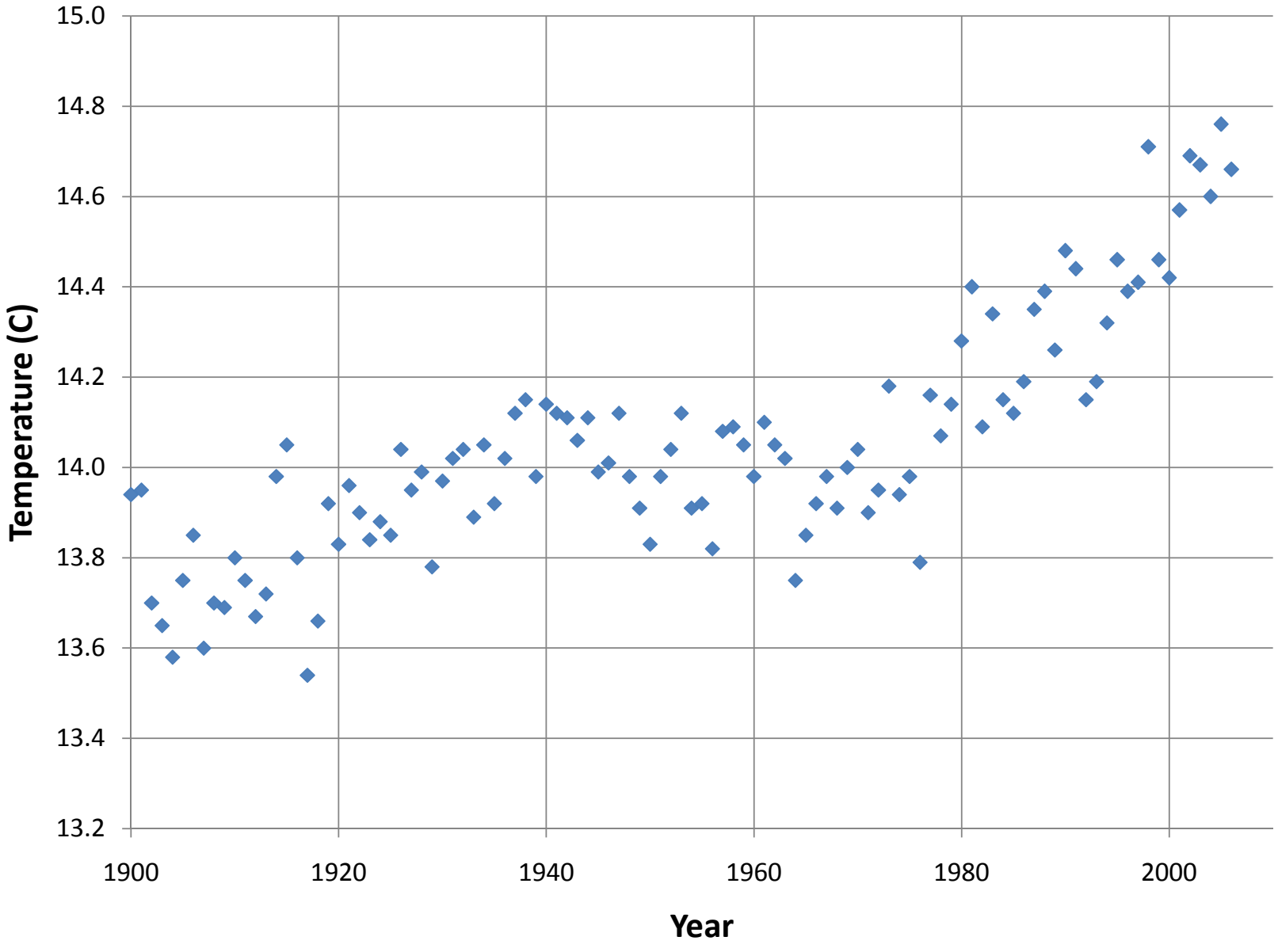
CO_2 data from NOAA

CO_2: a modern problem

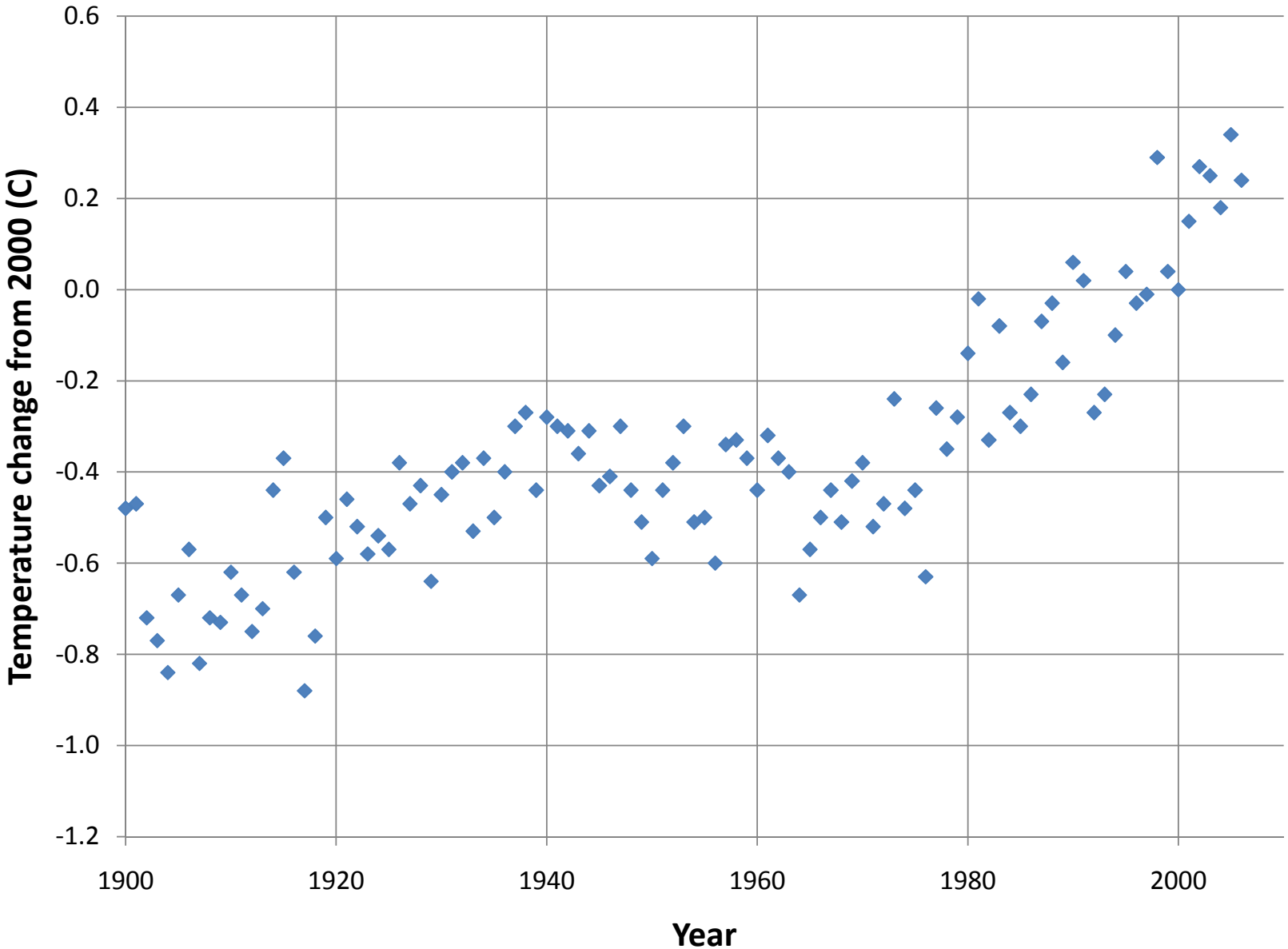


CO_2 data from NOAA

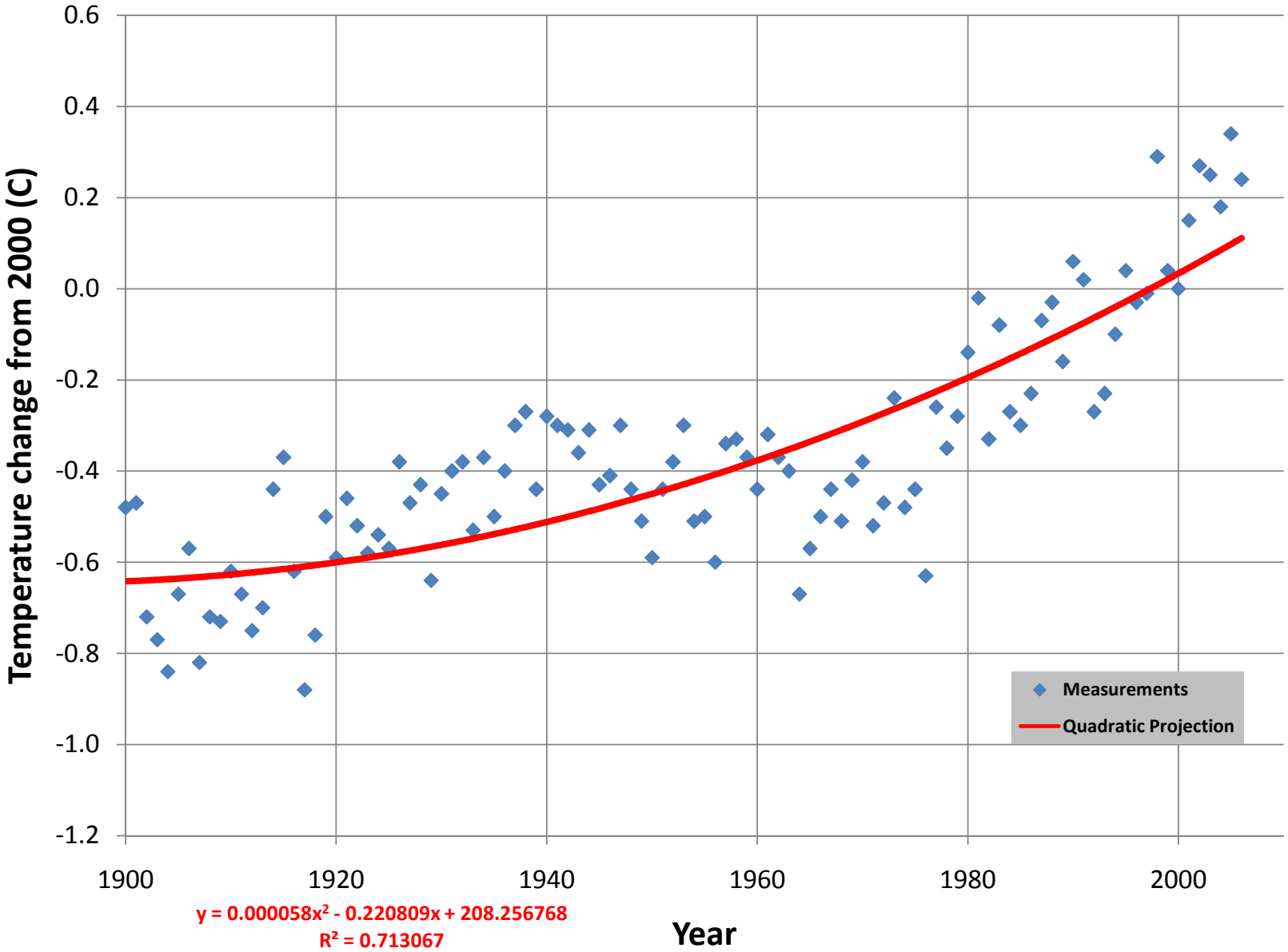
Changes in global temperature



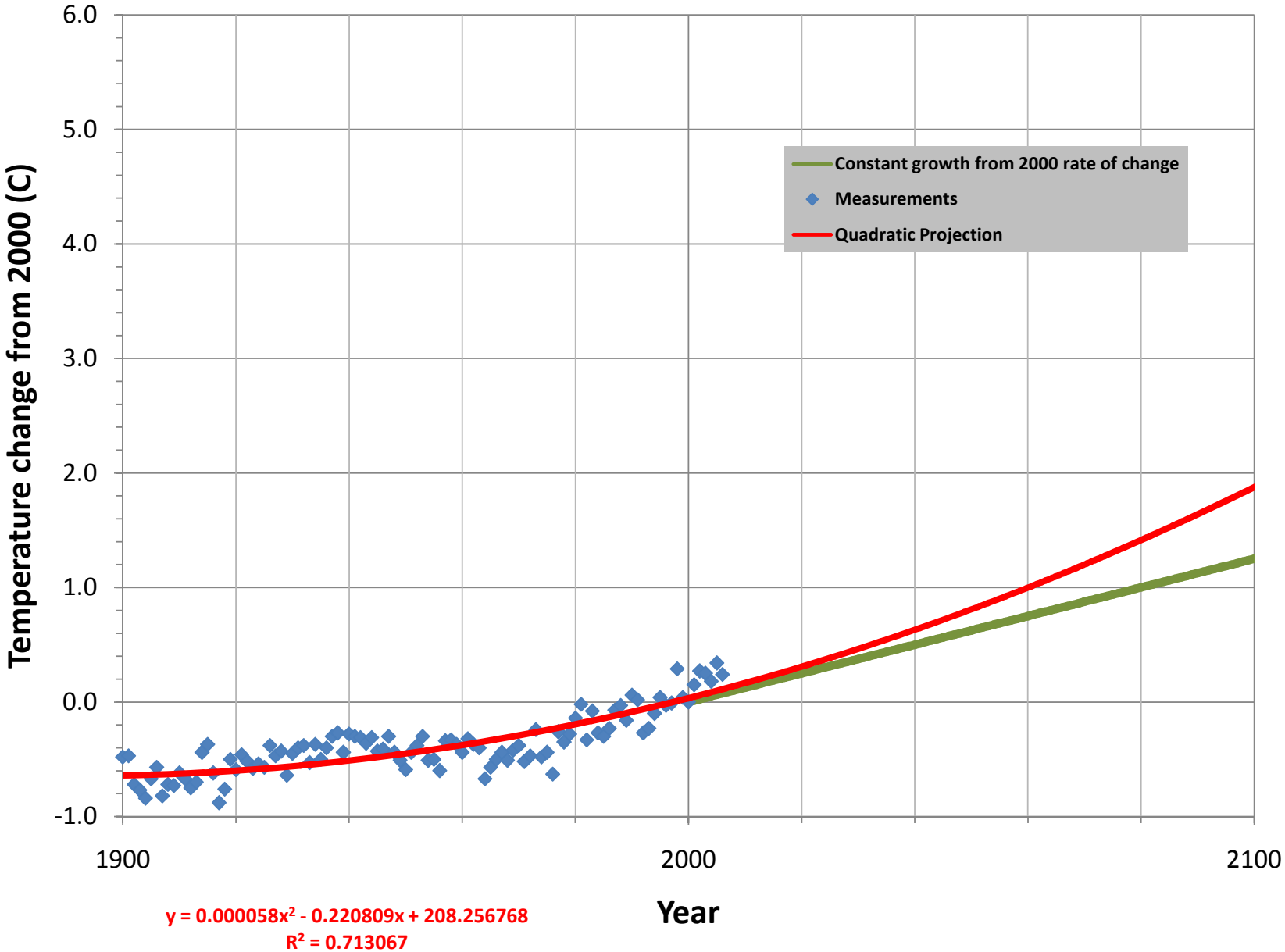
Changes in global temperature



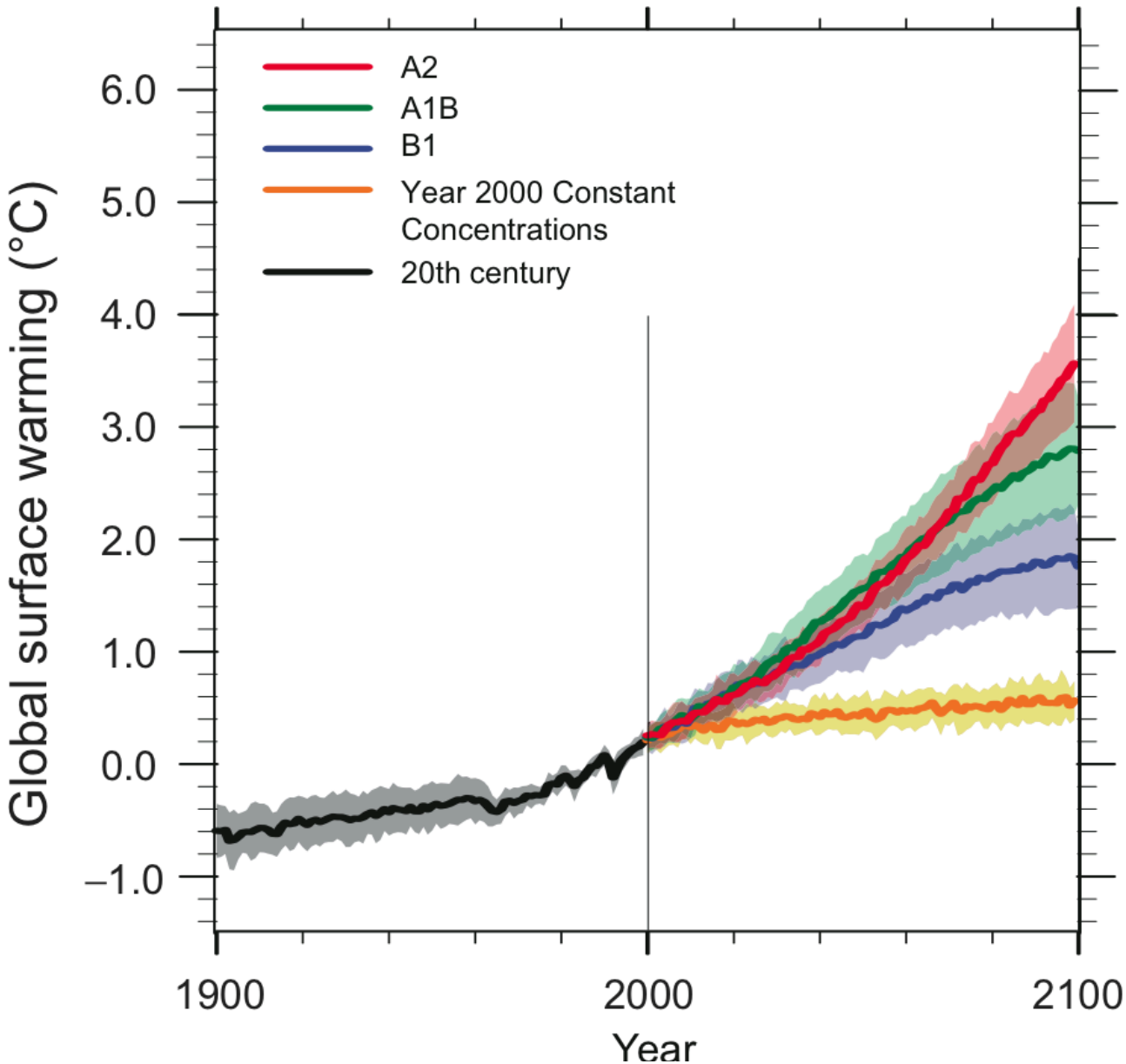
Changes in global temperature



Changes in global temperature

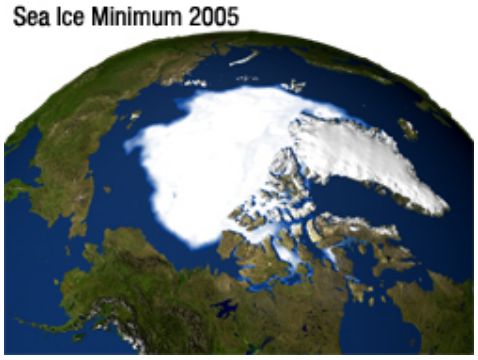


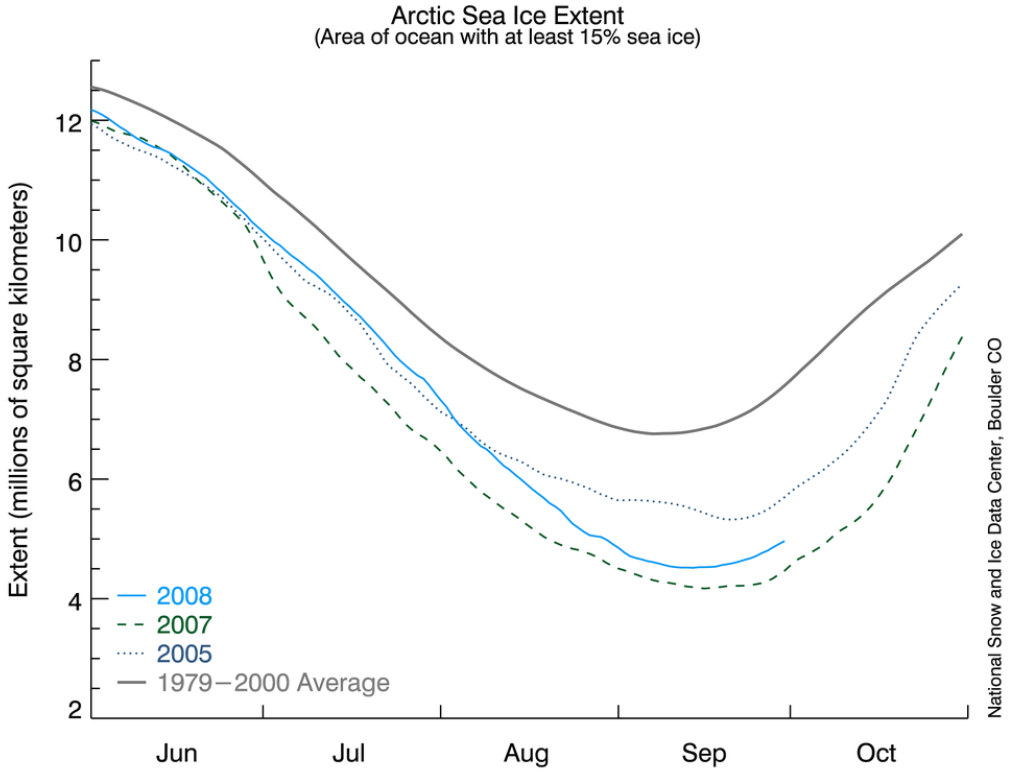
Modeling global temperature



IPCC 4th Assessment Report (2007)

Yearly Sea Ice Extent



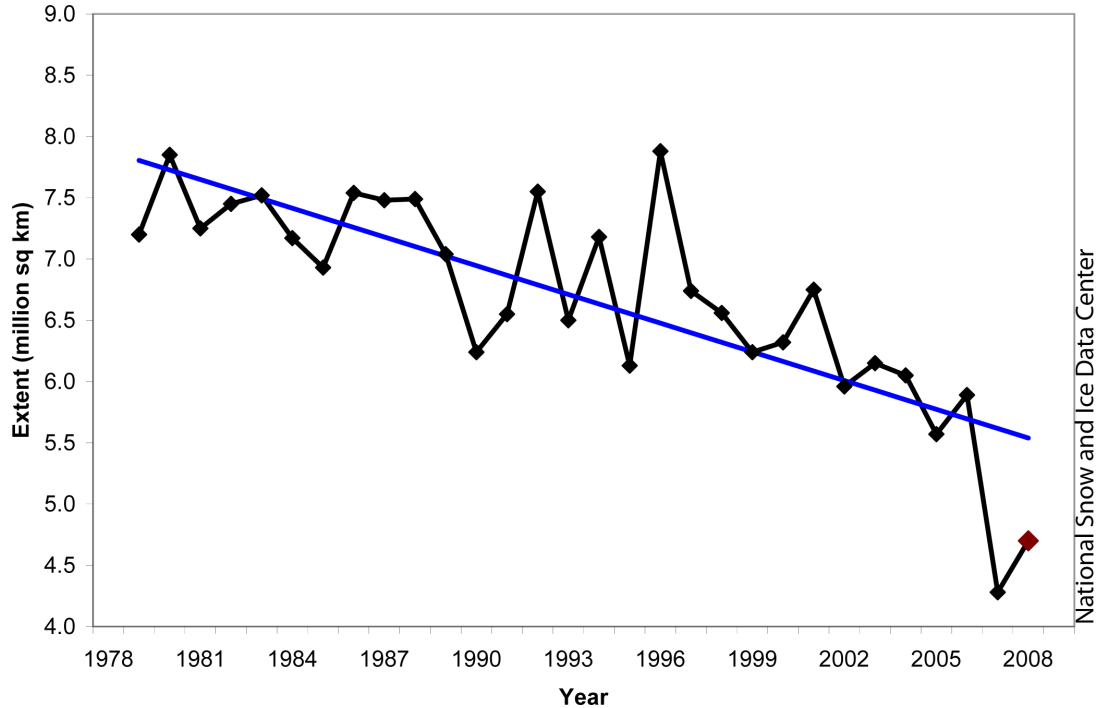


http://nsidc.org/arcticseaicenews/

Yearly Sea Ice Extent

Arctic Sea Ice from NASA:

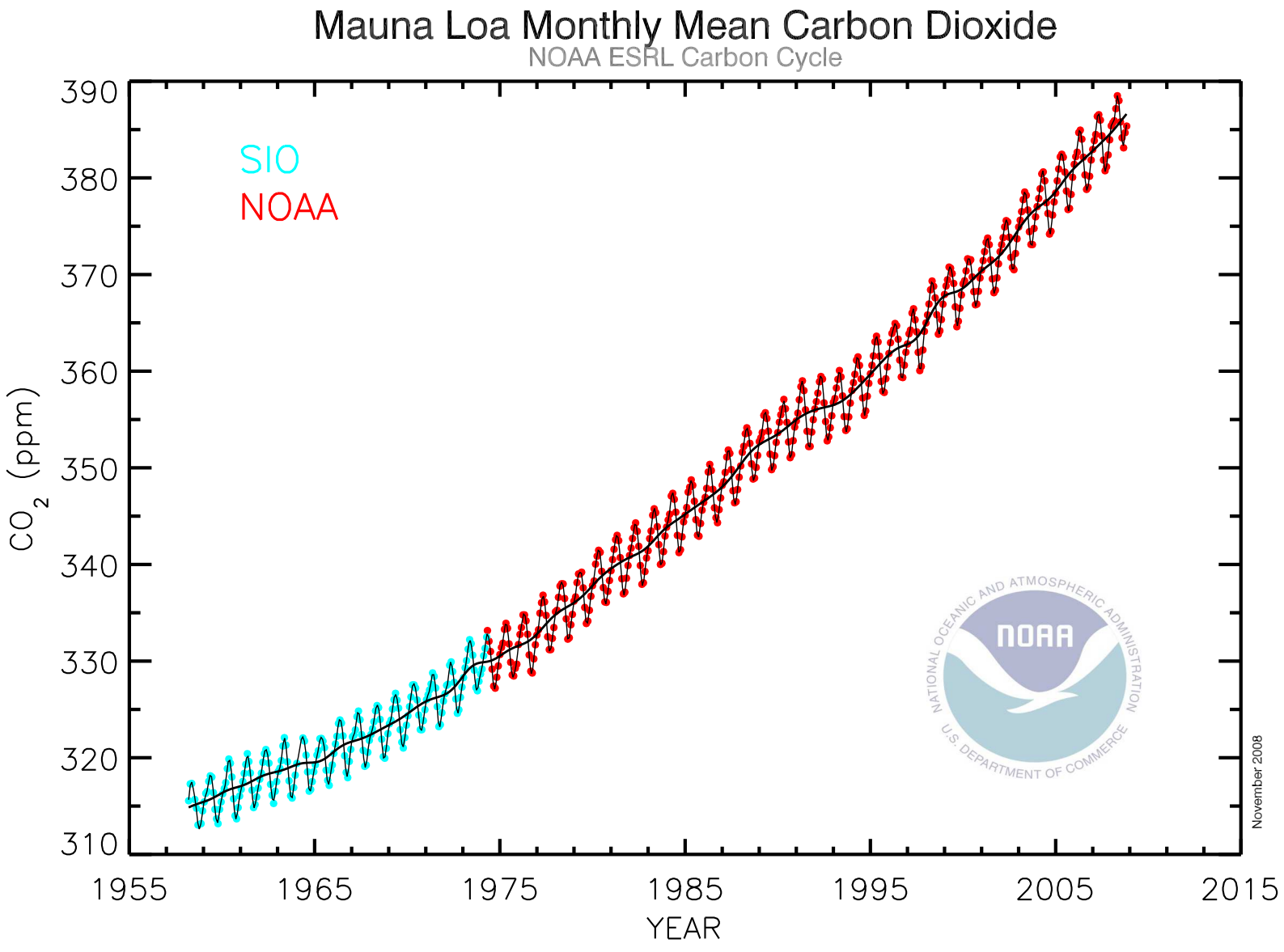
September sea-ice extent:



http://nsidc.org/arcticseaicenews/

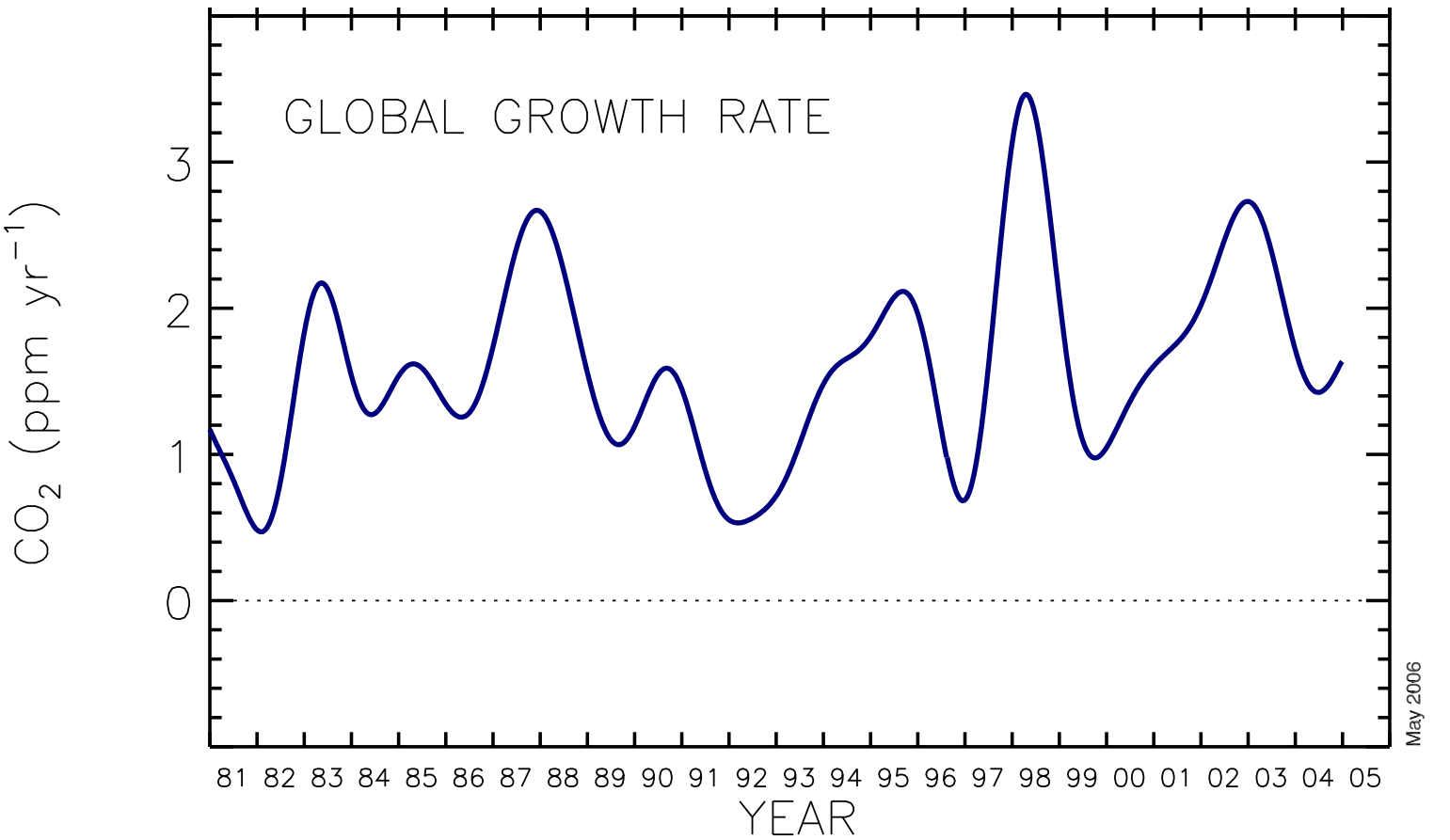
Outline

Modern CO_2 measurement record



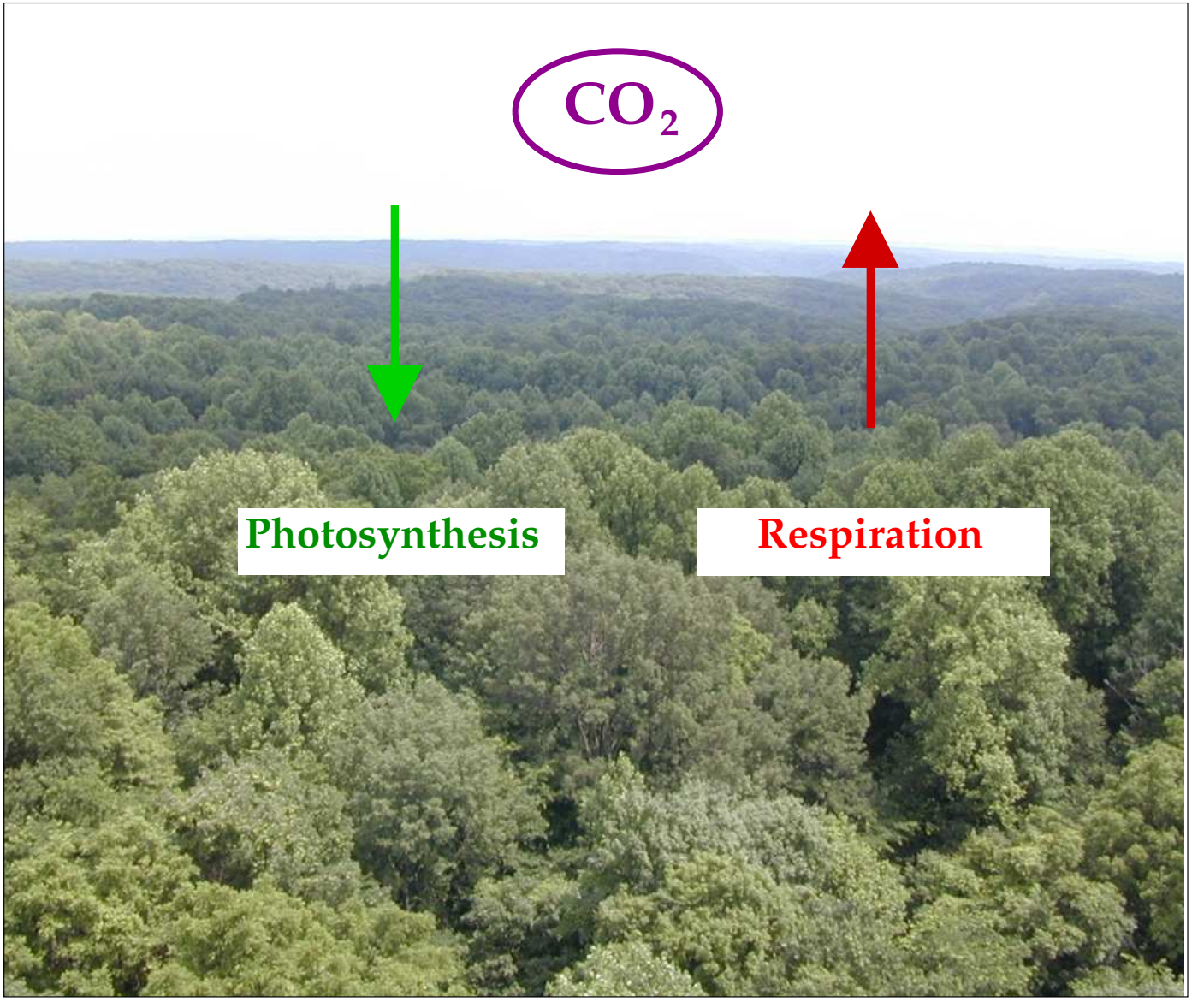
Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (SIO, blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (NOAA, red). A long-term trend curve is fitted to the monthly mean values. Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, and Dr. Ralph Keeling, SIO GRD, La Jolla, California, (858) 534-7582, rkeeling@ucsd.edu.

Climate change and CO_2

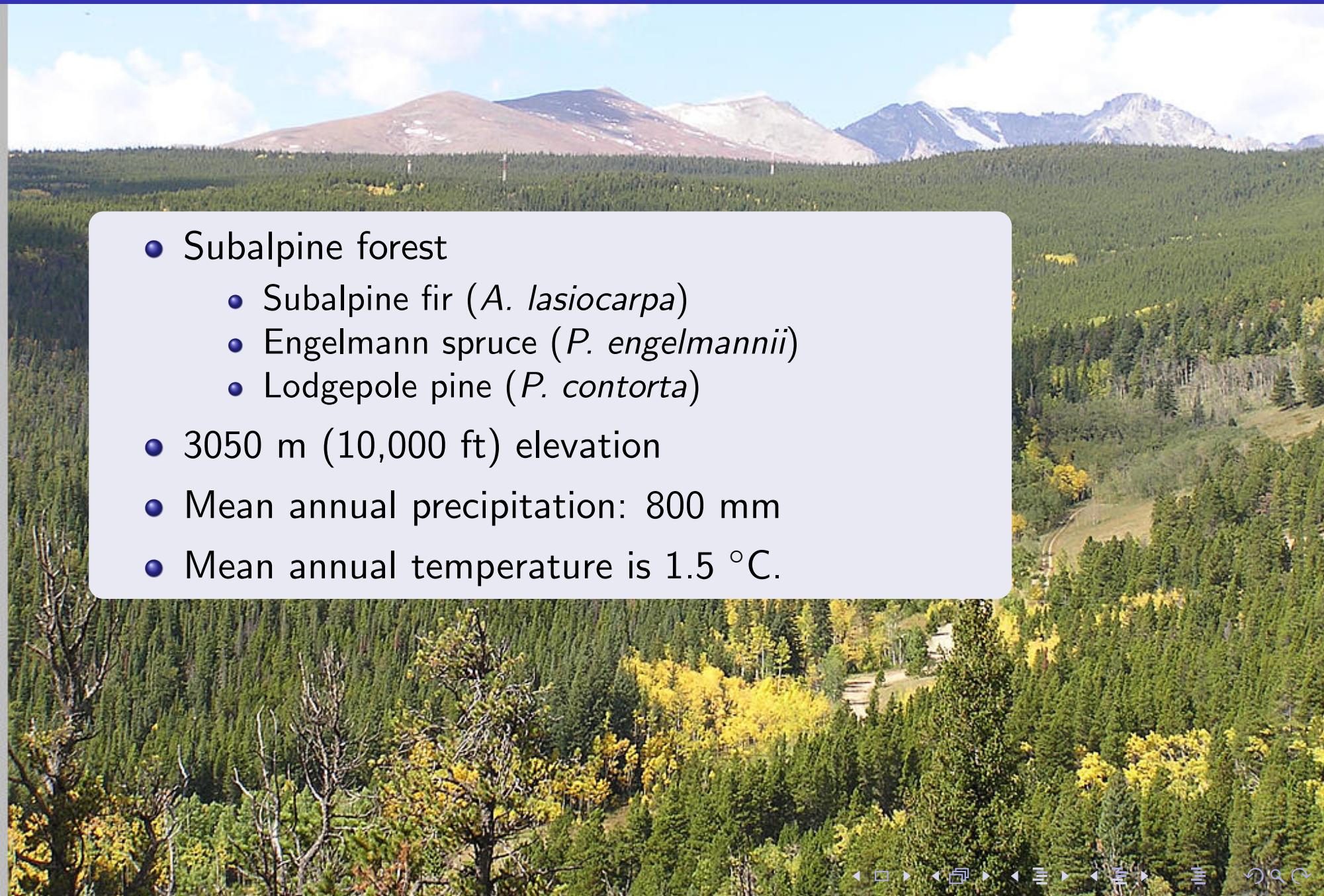


http://www.cmdl.noaa.gov/ccgg

Forest carbon uptake

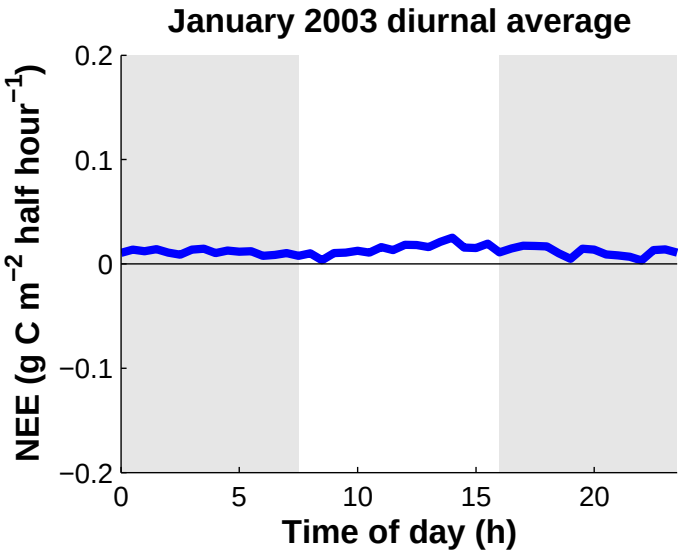


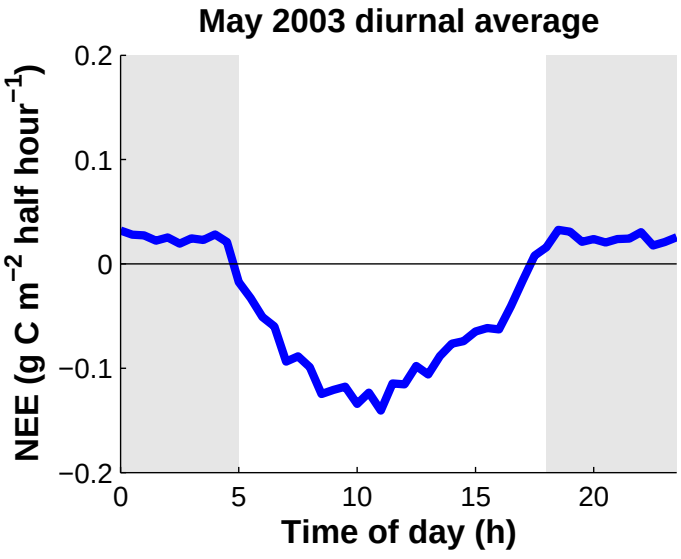
Niwot Ridge, Colorado

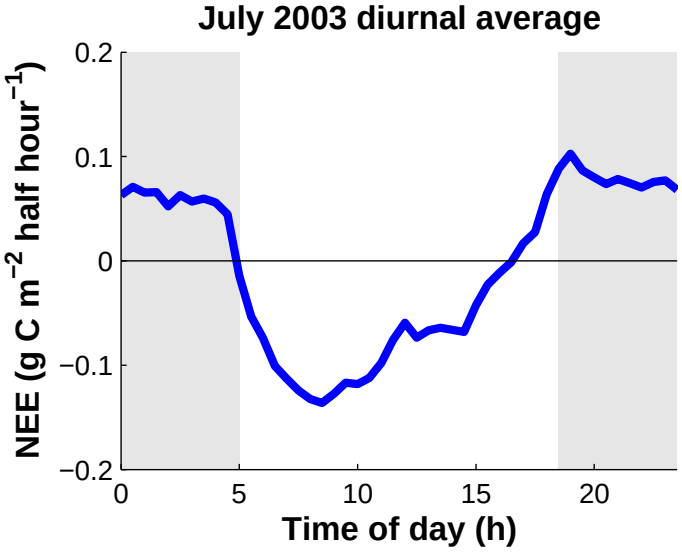


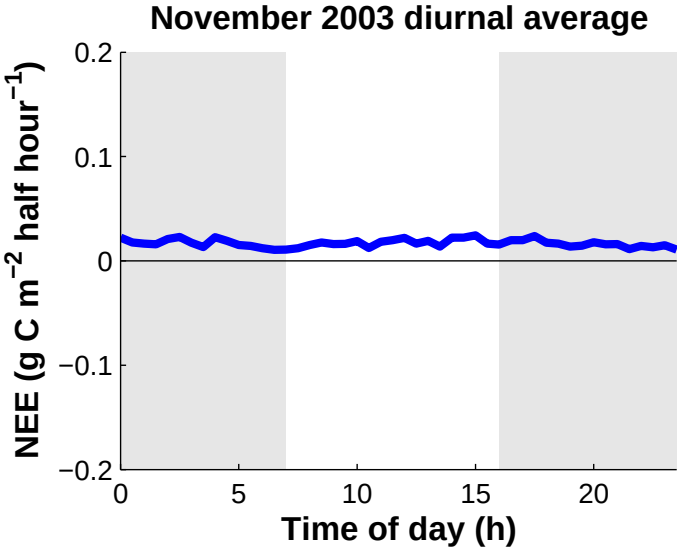
- Subalpine forest
  - Subalpine fir (*A. lasiocarpa*)
  - Engelmann spruce (*P. engelmannii*)
  - Lodgepole pine (*P. contorta*)
- 3050 m (10,000 ft) elevation
- Mean annual precipitation: 800 mm
- Mean annual temperature is 1.5 °C.

NEE seasonal variability

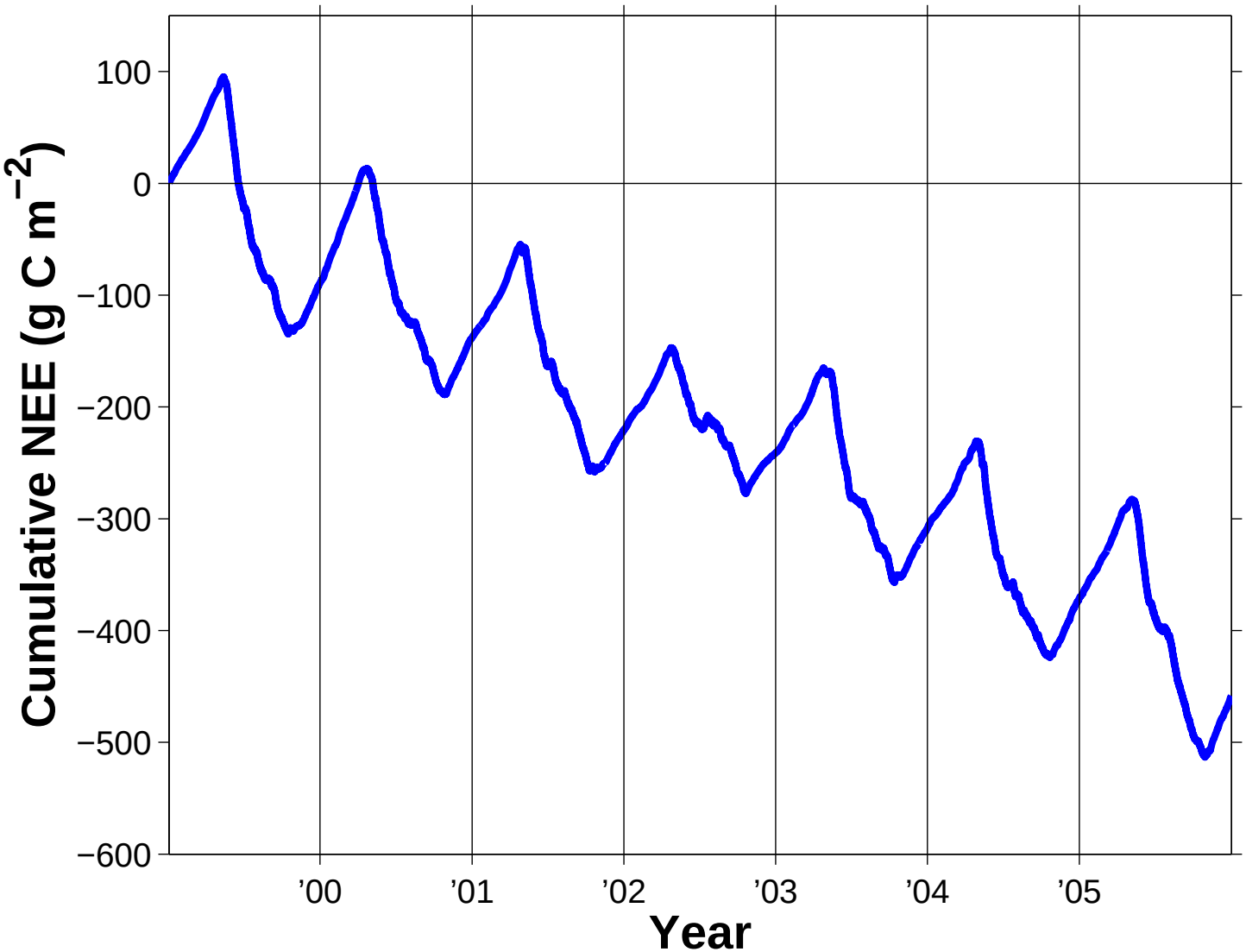




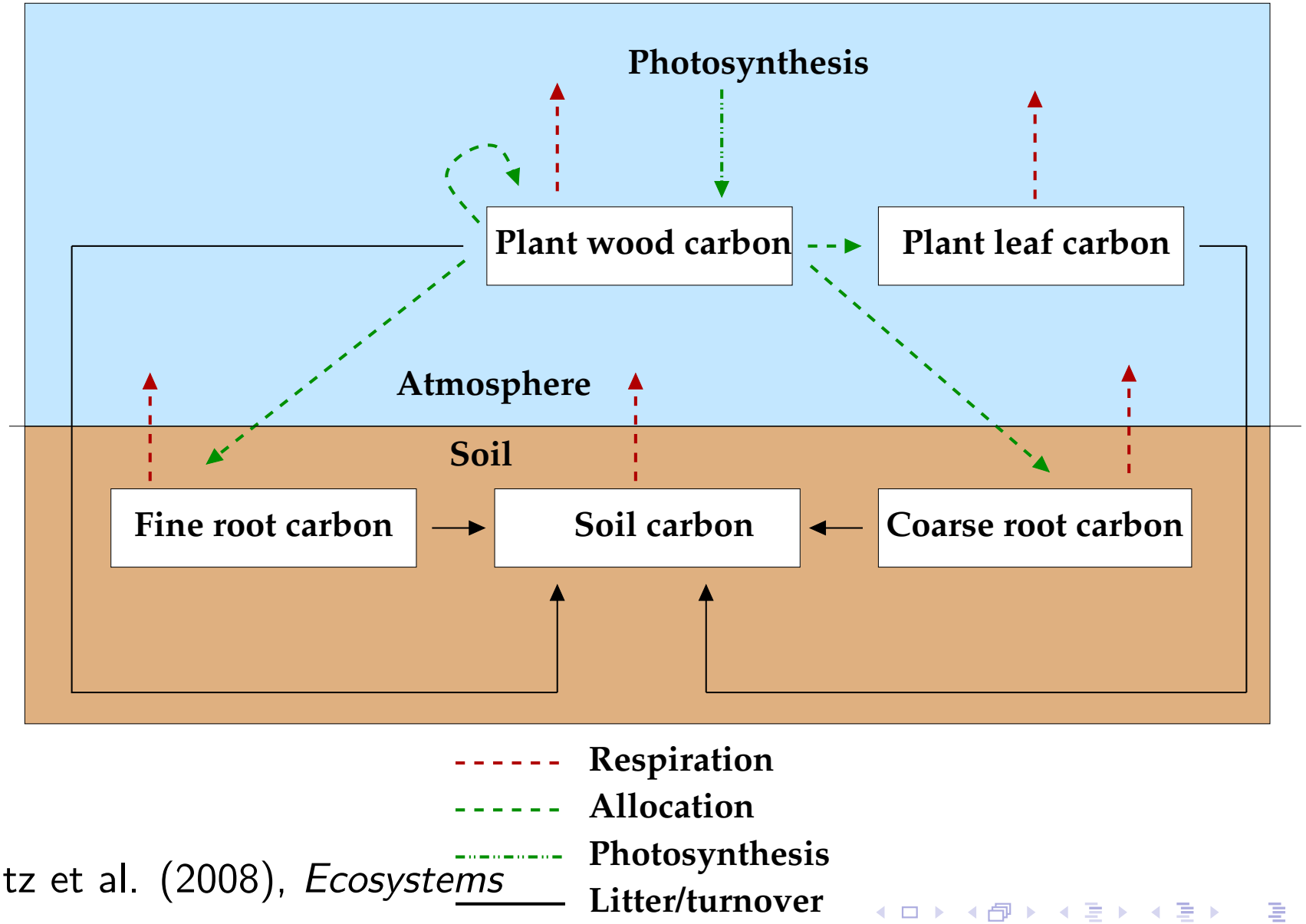




NEE long term variability

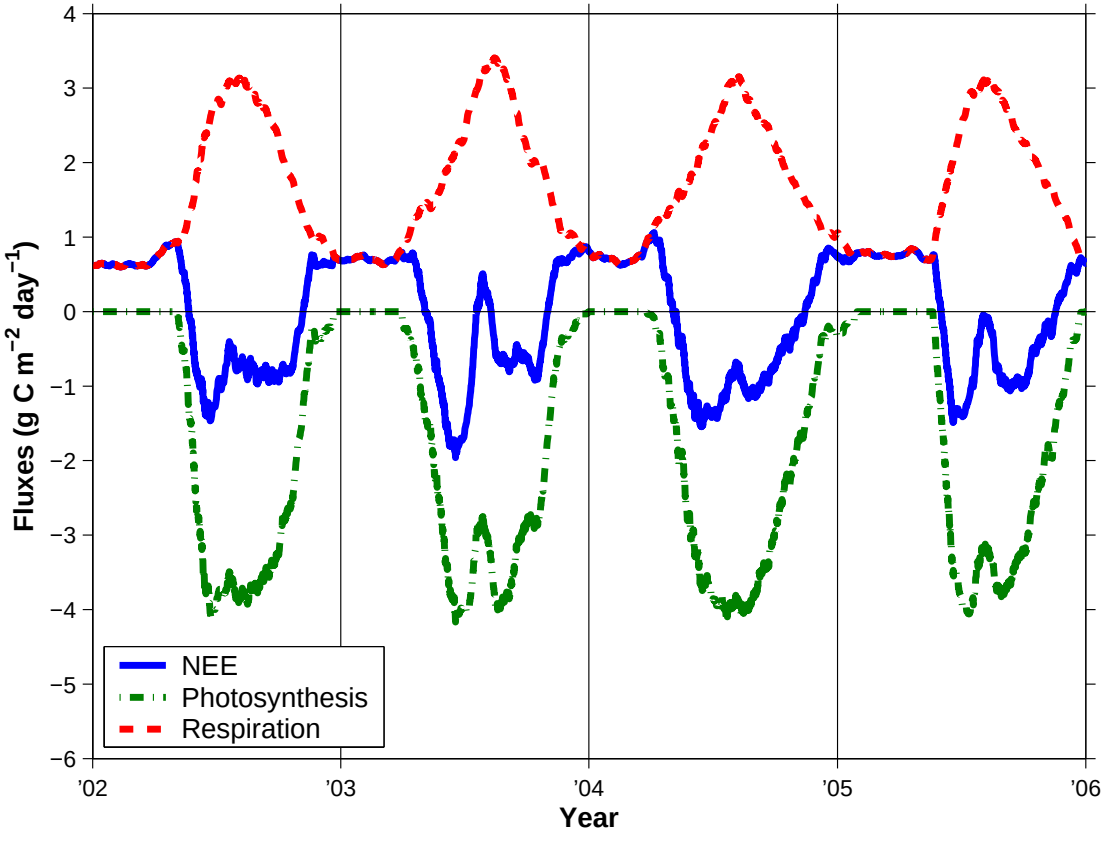


Ecosystem model (structure)

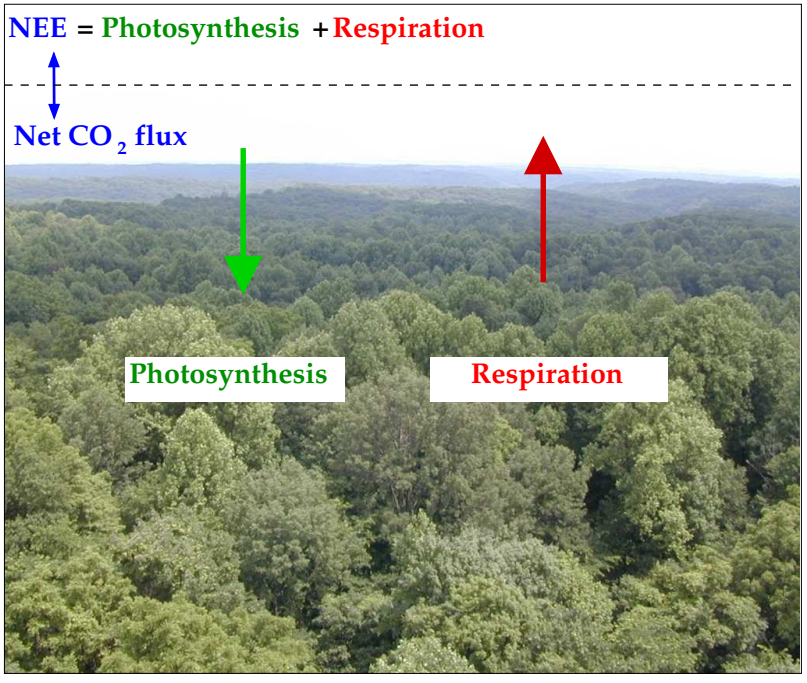


Zobitz et al. (2008), *Ecosystems*

Results: Whole-ecosystem partitioning



Zobitz et al. (2008) *Ecosystems*



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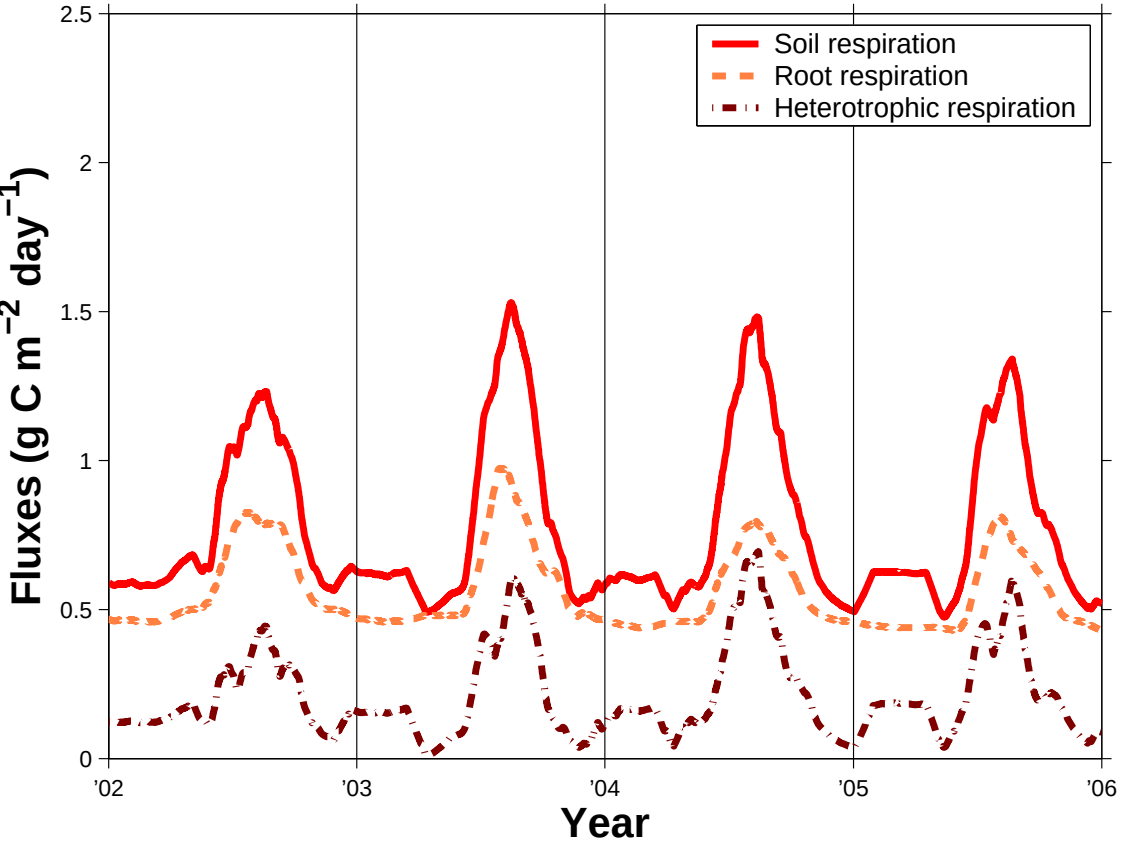
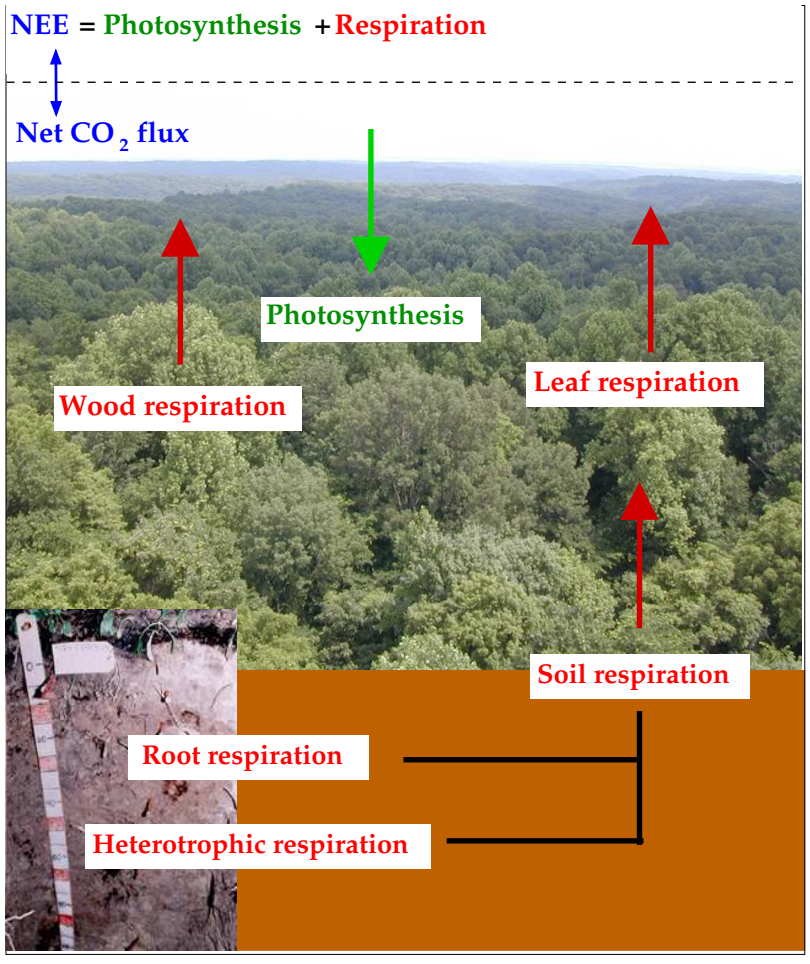
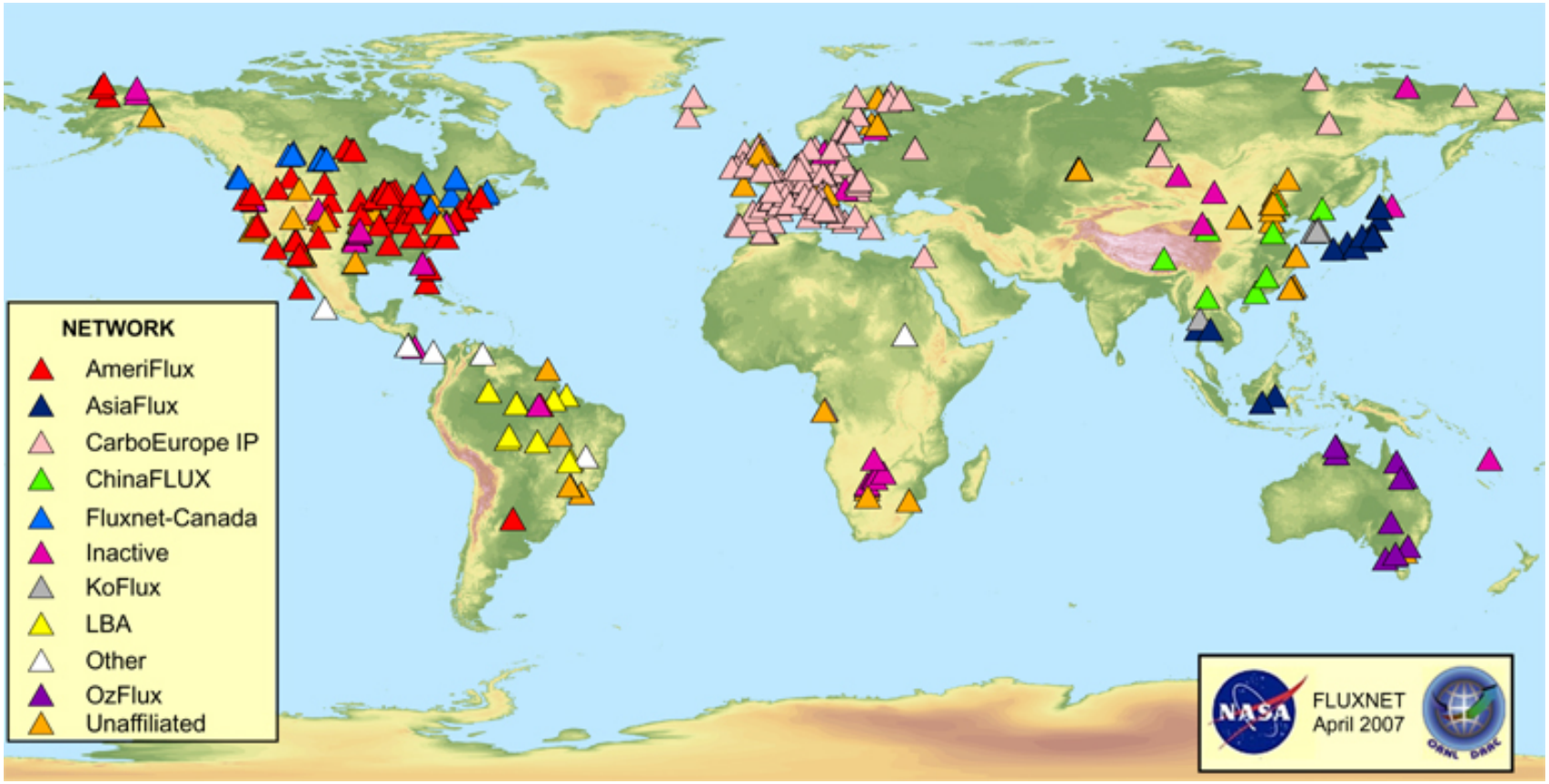


Zobitz et al. (2008) *Ecosystems*



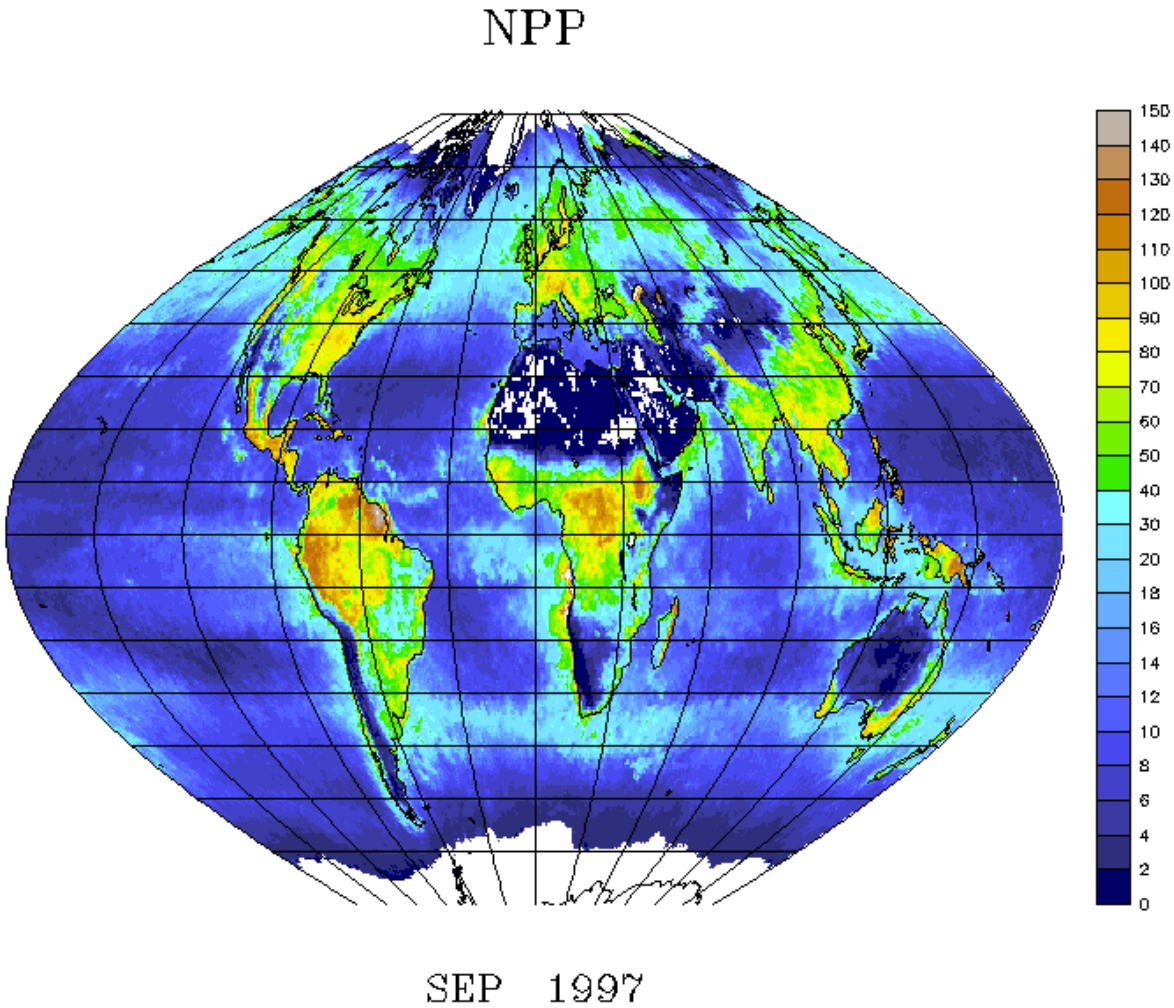
Global measurement network



- `www.fluxnet.ornl.gov`
- As of January 2009: 500 sites = 2600 site years of data
- Some sites provide 15 years of continuous data.
- $\approx$ 40 million half-hourly measurements of biosphere-atmosphere carbon exchange
- All data are **FREE** and publicly available.

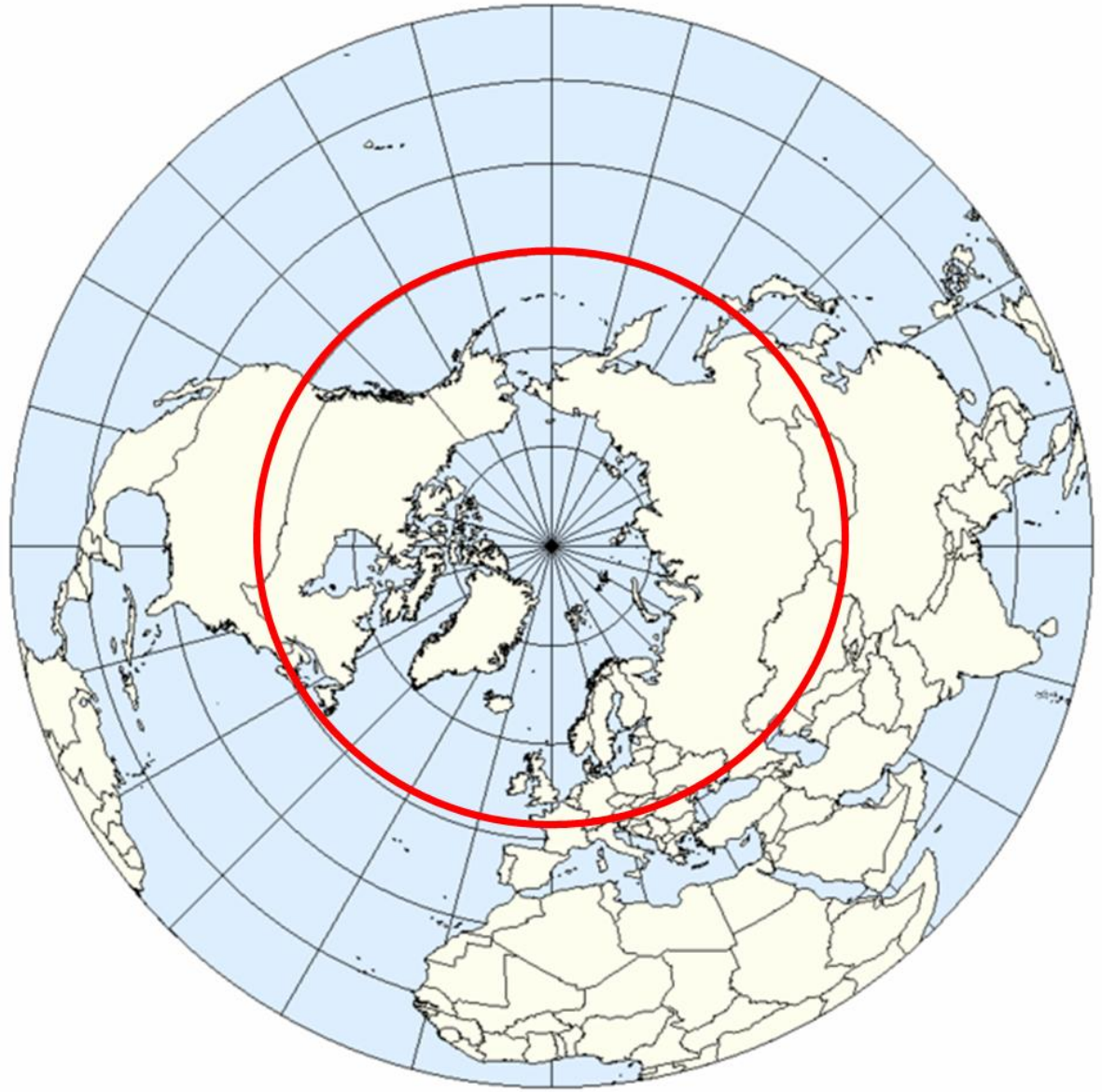
Global NPP

Global NPP



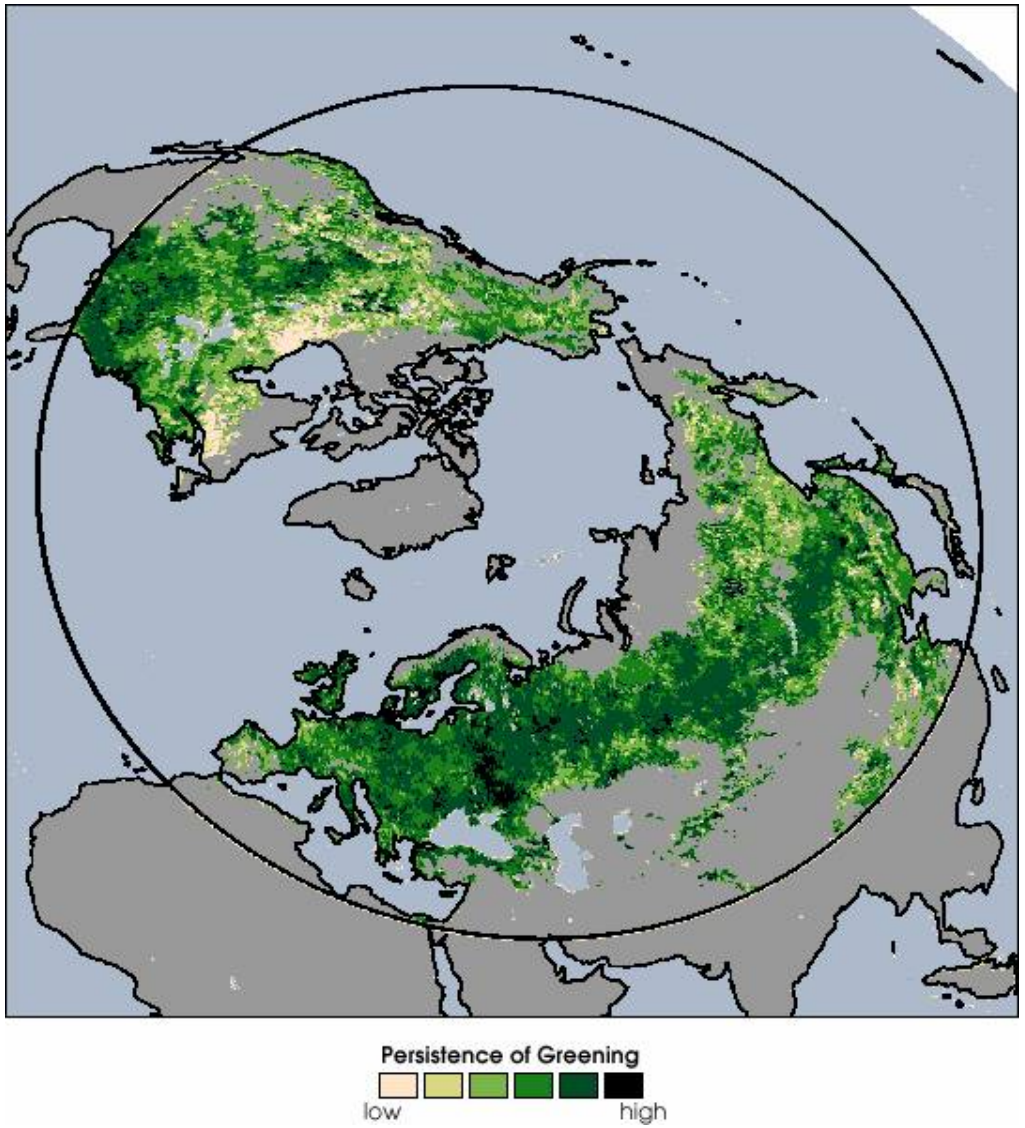
Outline

High latitude ecosystems



High latitude ecosystems

High latitude greening



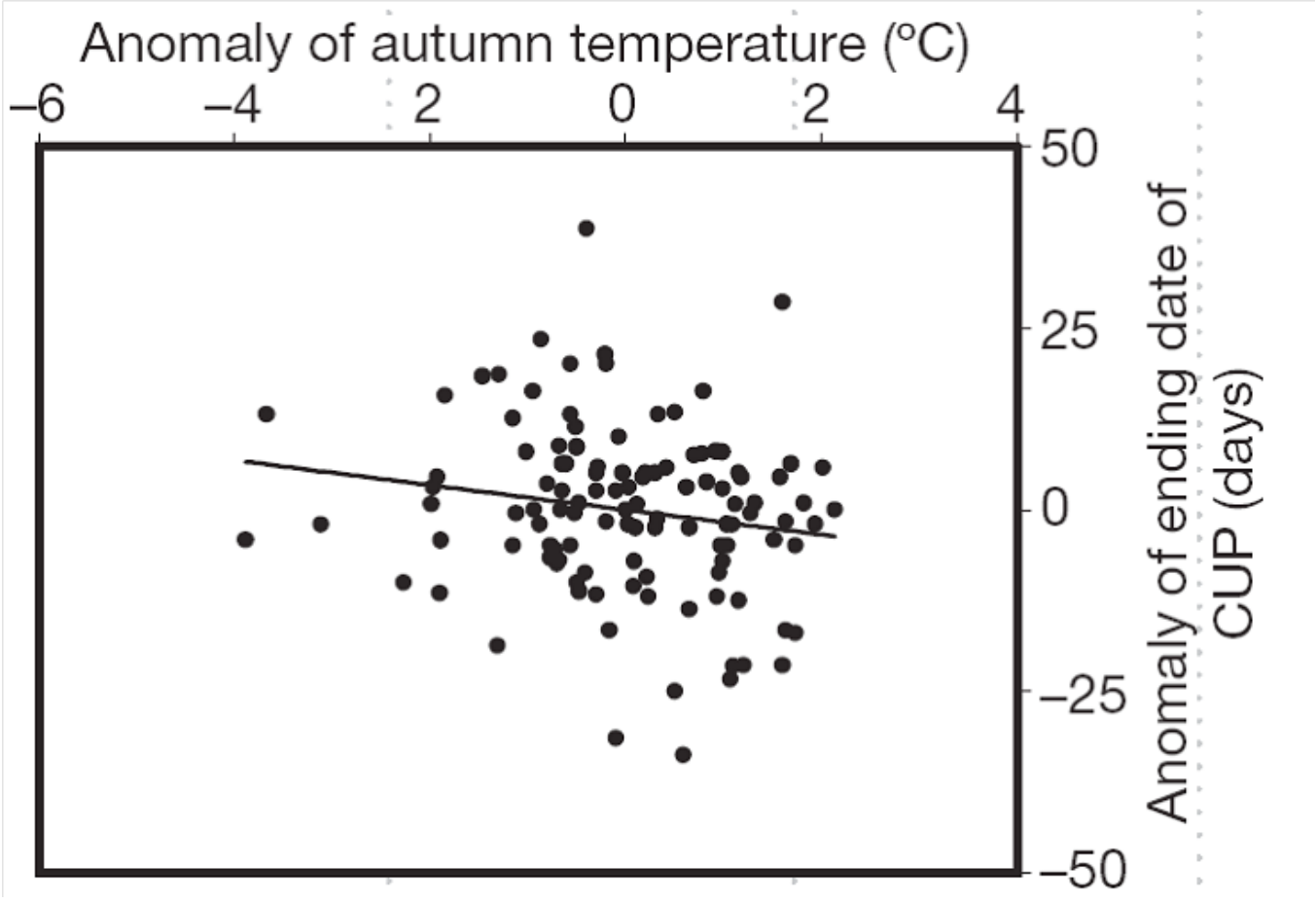
Courtesy of Liming Zhou

www.nasa.gov

CO_2 is life

Carbon uptake in high latitude ecosystems

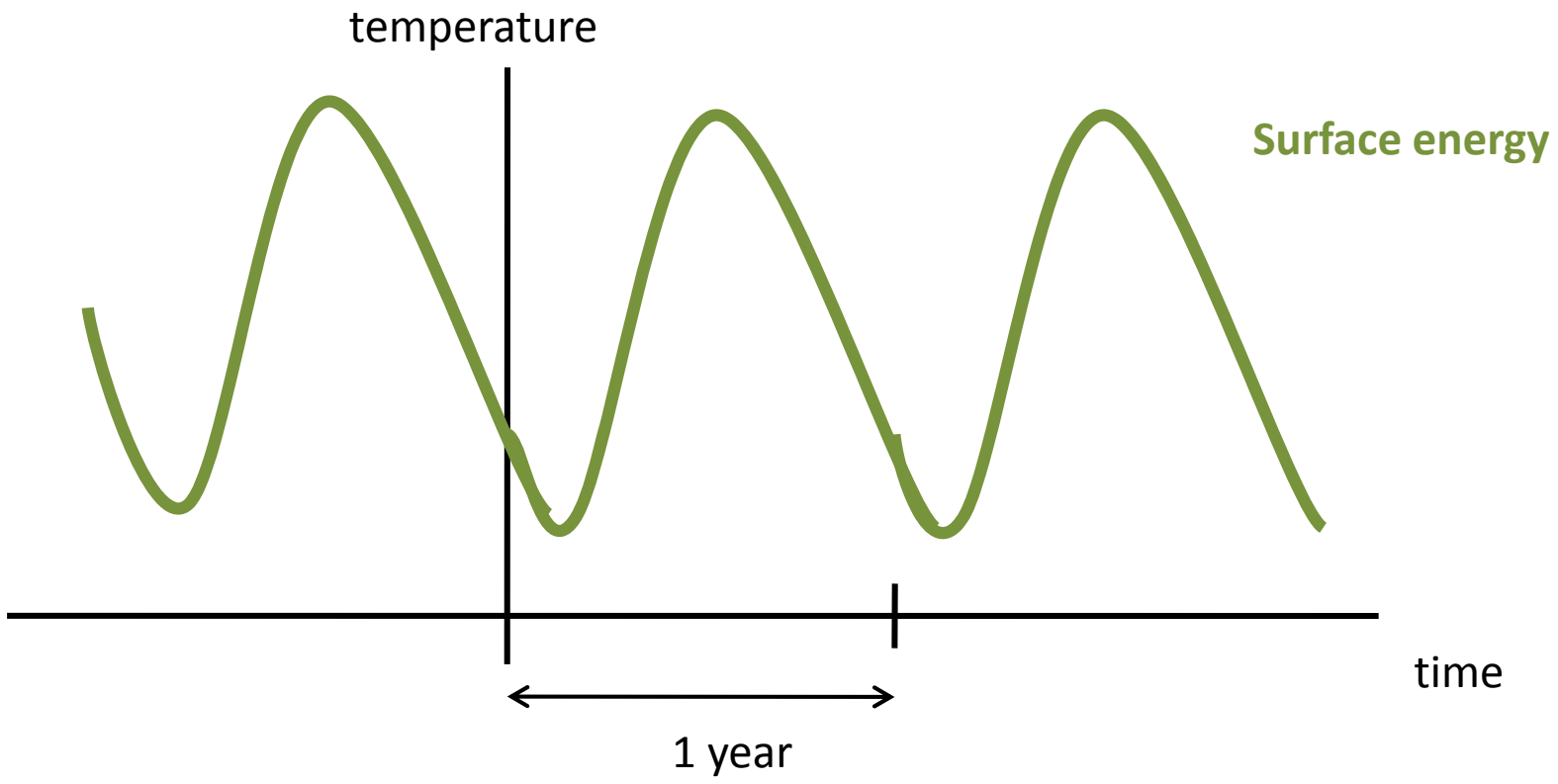
CUP = **C**arbon **U**ptake **P**eriod = summer length



Cooler autumn = carbon uptake period increases

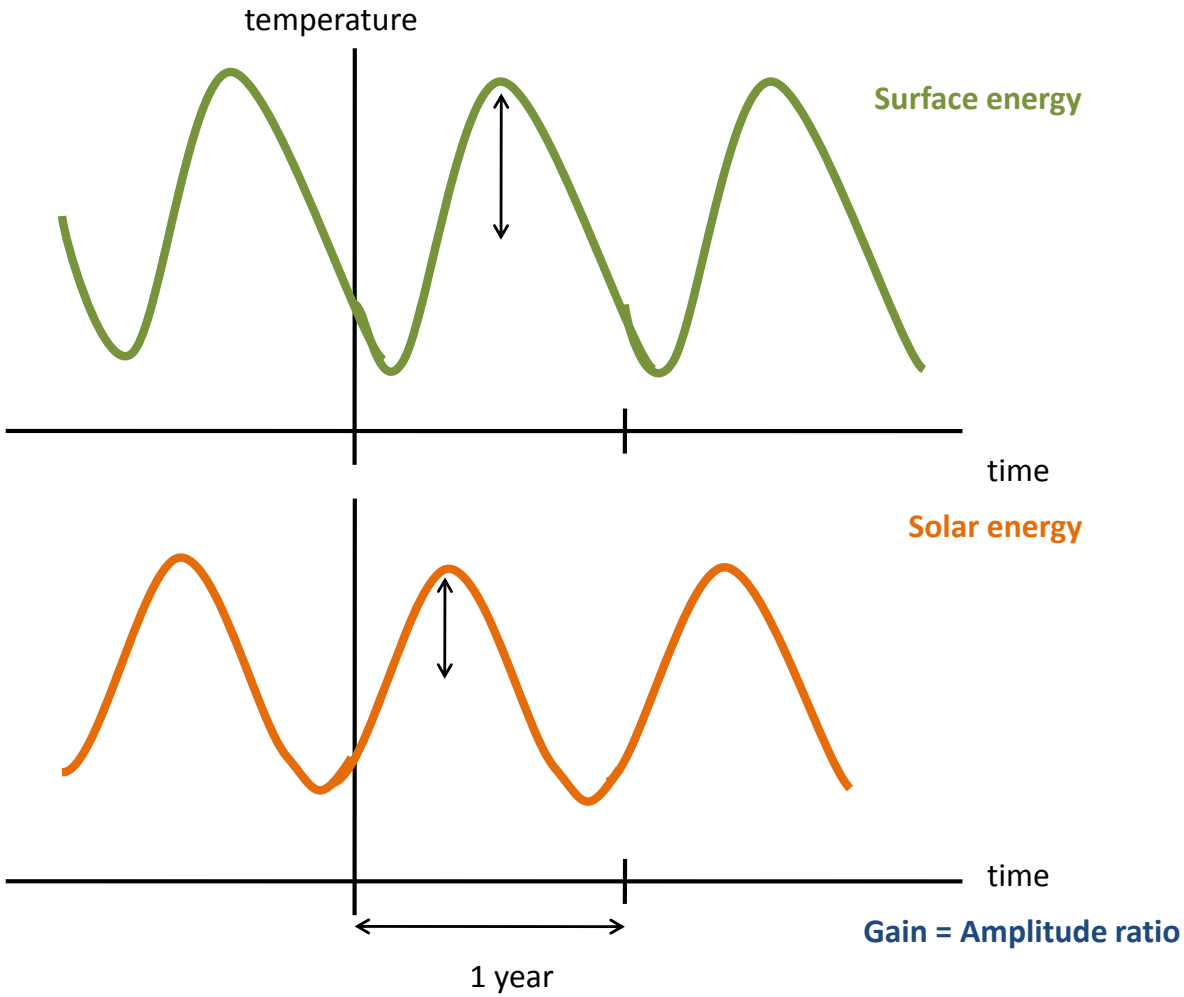
Piao et al. (2008), *Nature*

Changes in surface temperature



Stine et al. (2009)

Changes in surface temperature



Stine et al. (2009)

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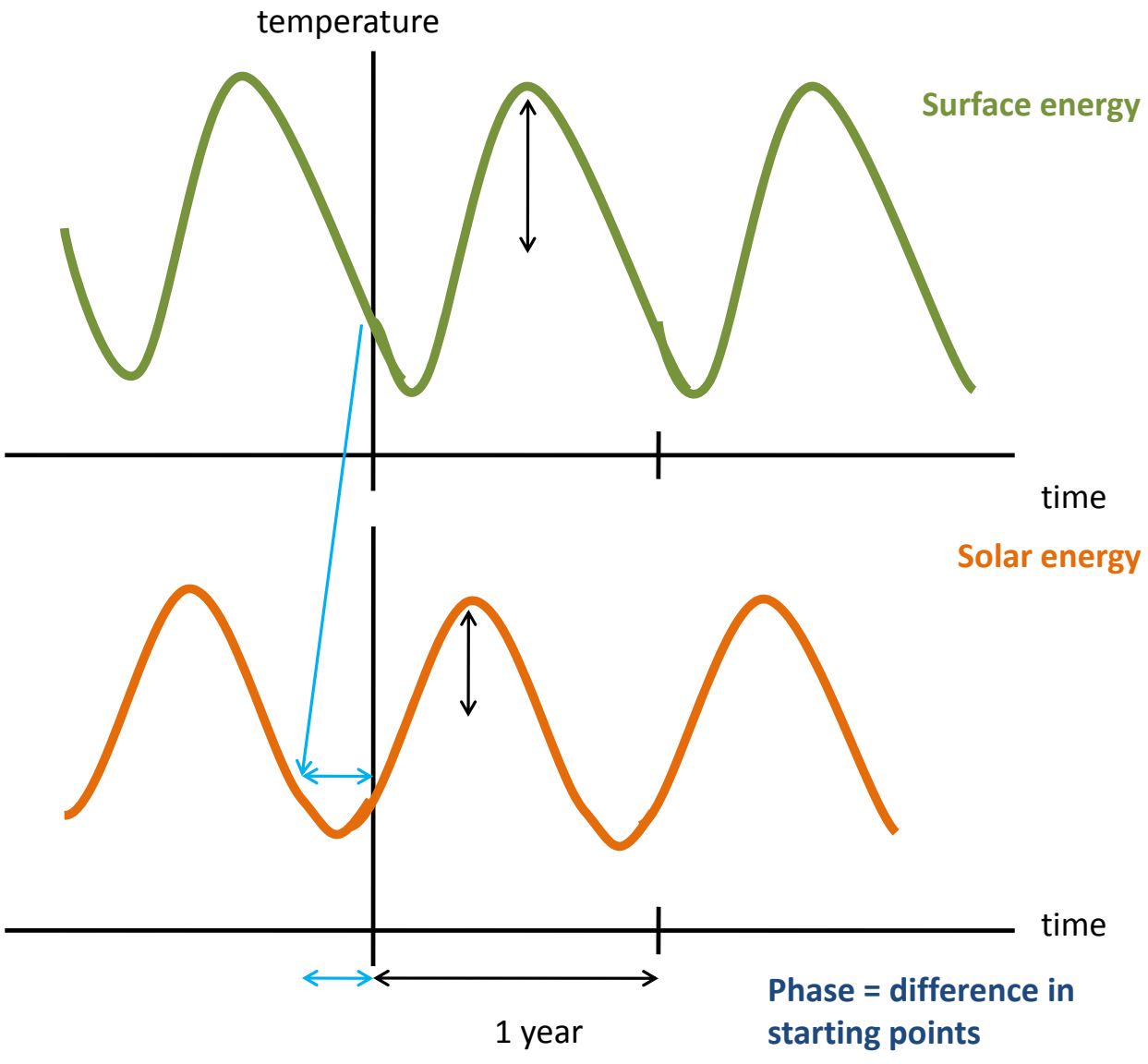
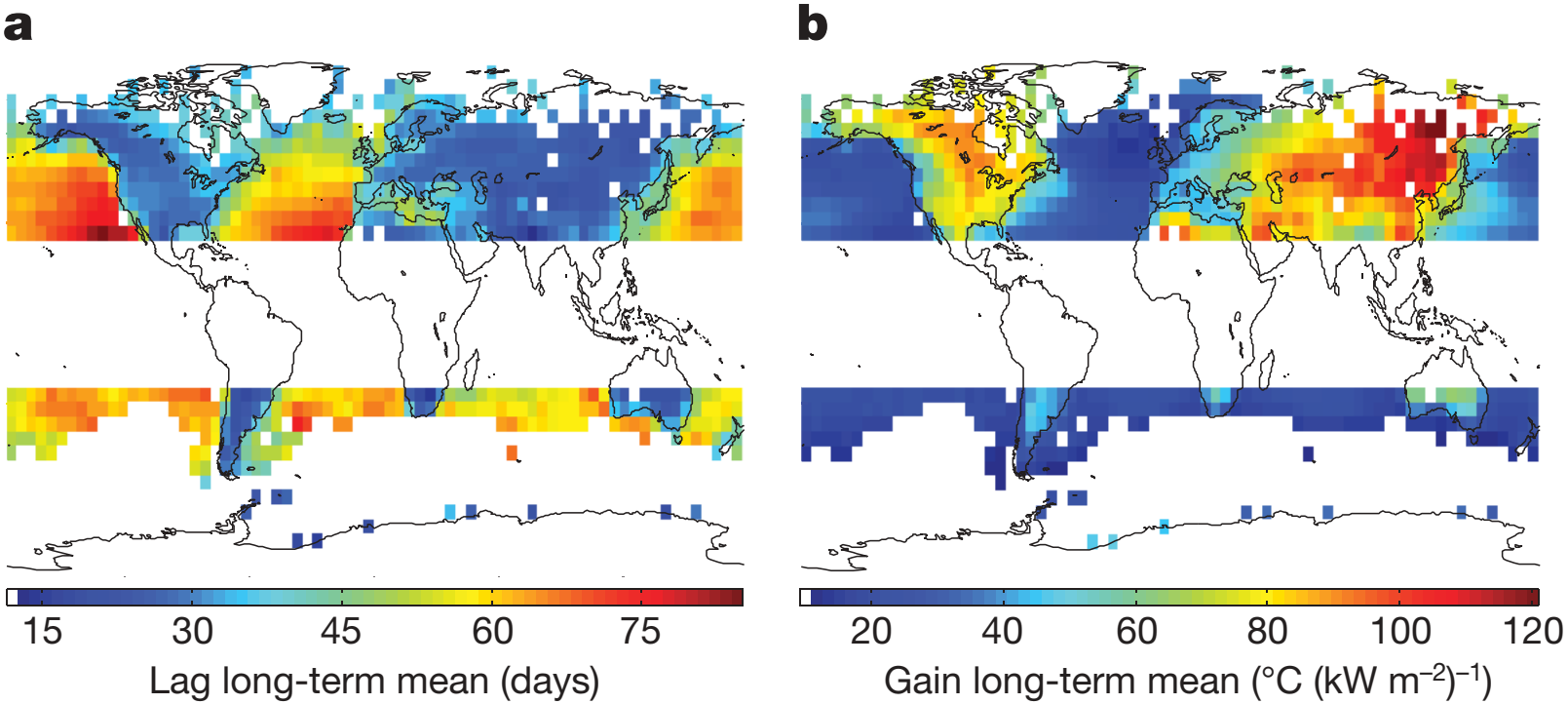


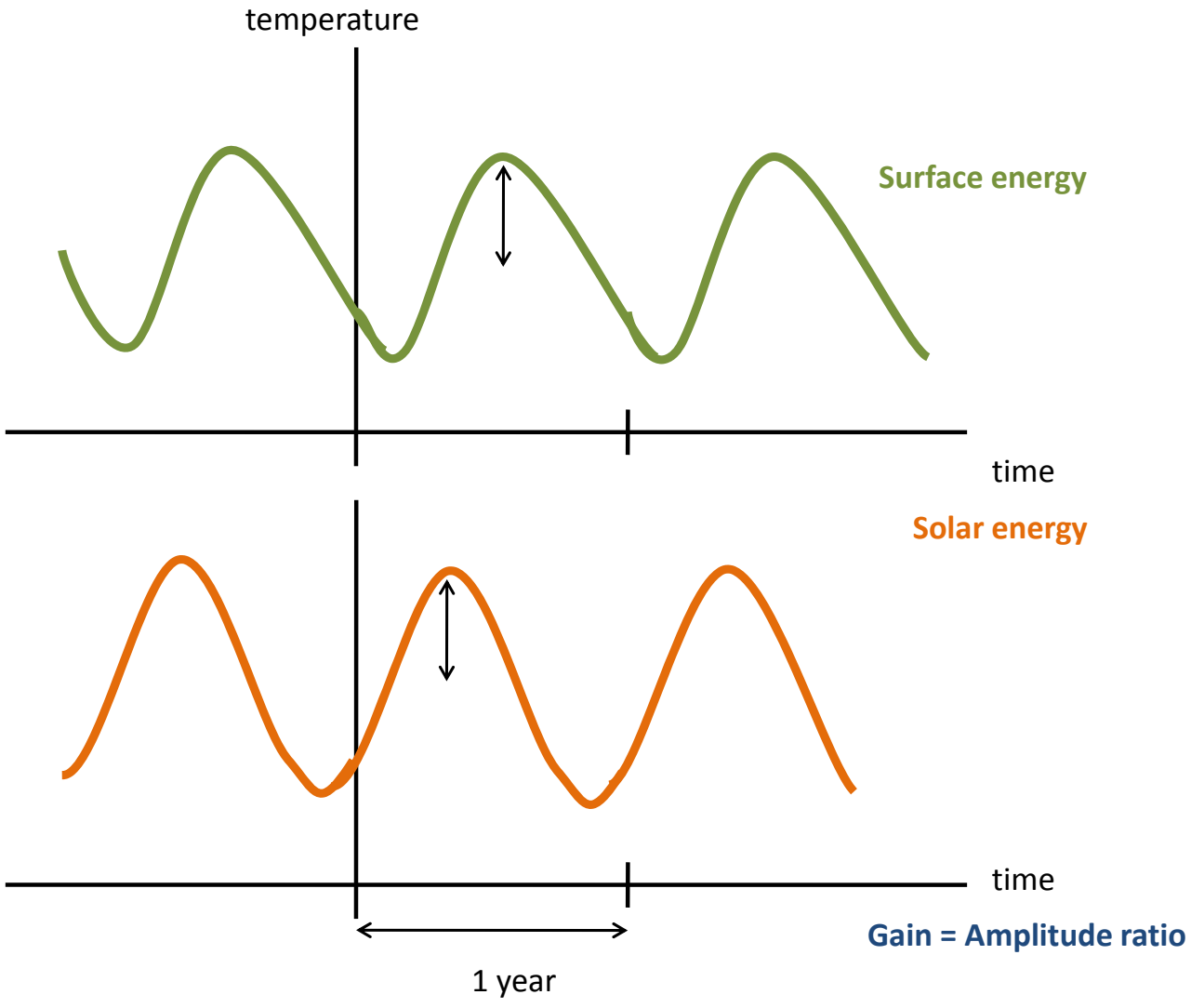
Stine et al. (2009)

Changes in surface temperature



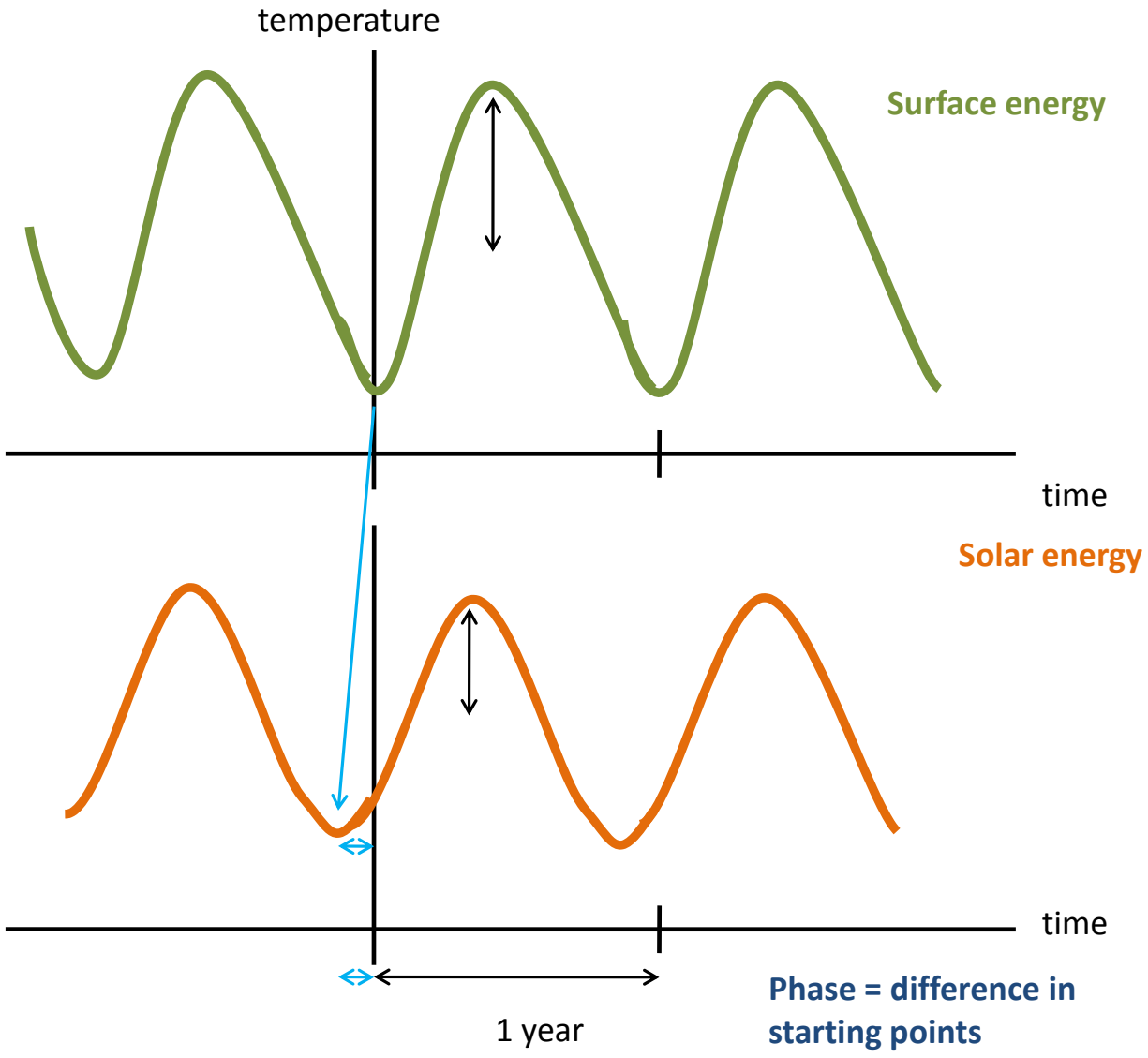
Stine et al. (2009)

Temperature range is *damped*



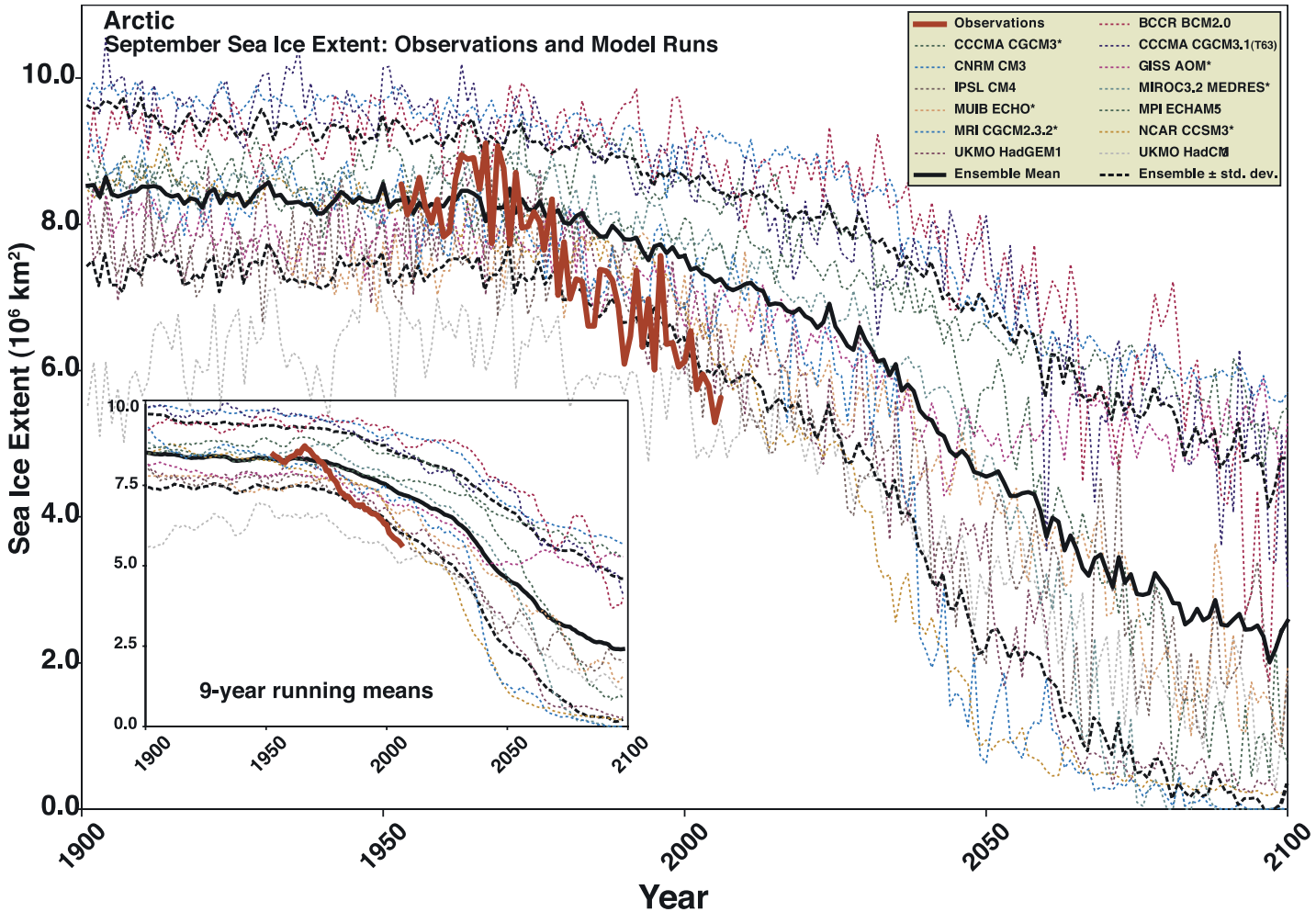
Stine et al. (2009)

Seasons are happening *earlier*



Stine et al. (2009)

Sea ice decline: faster than modeled

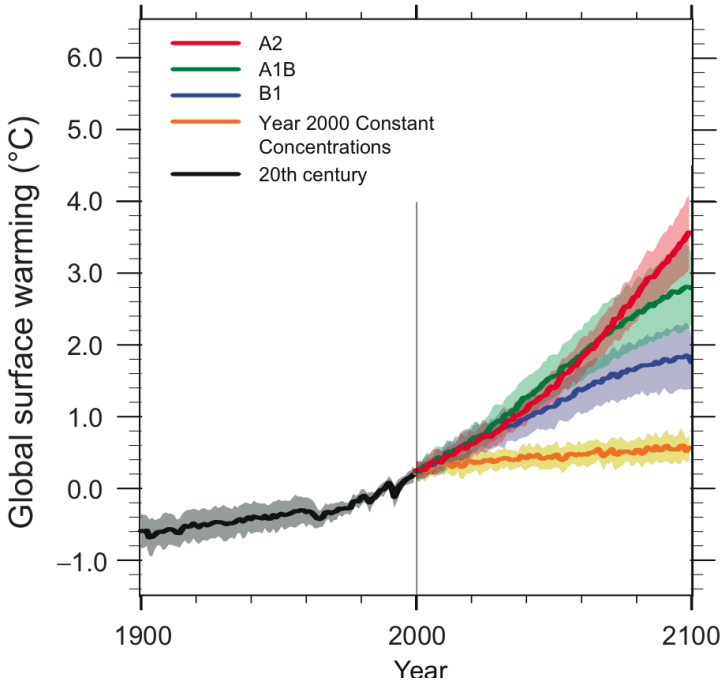


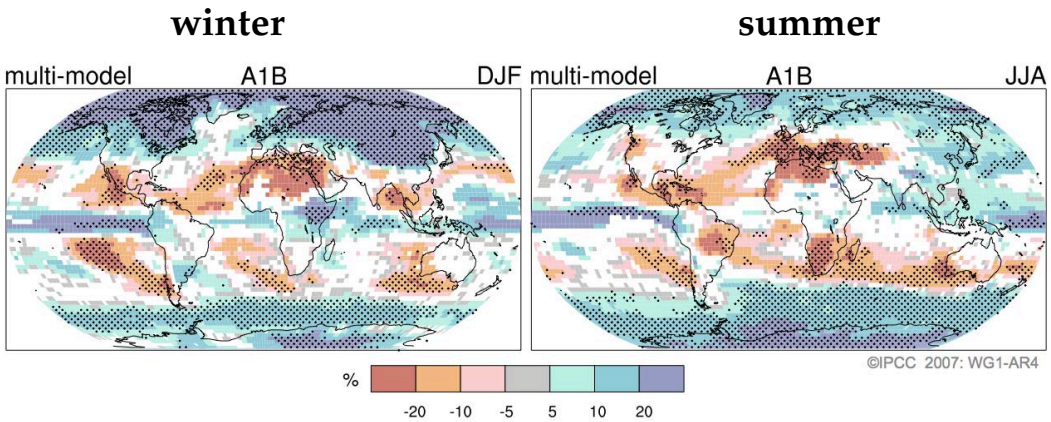
Stroeve et al. (2007)

Future climate changes

- Climate models predict both warming and change in global patterns of precipitation.
- How will climate change affect the world locally *and* globally?

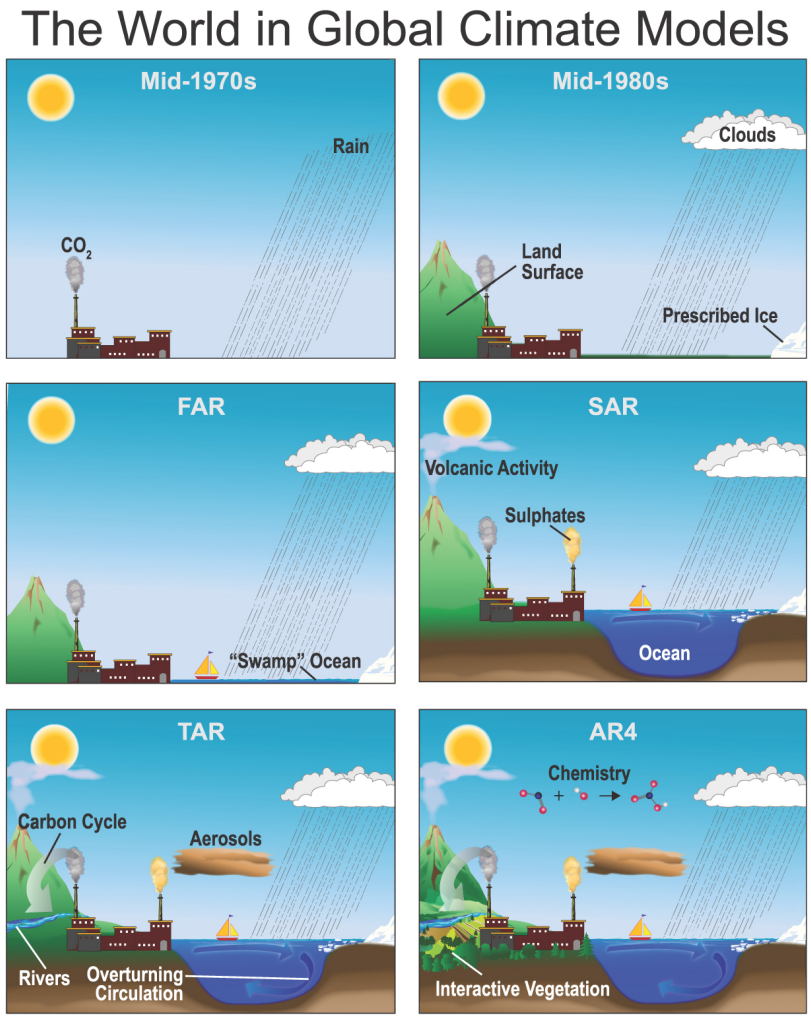
IPCC 4th Assessment Report (2007)





Precipitation changes 2090–2099, relative to 1980–1999

Climate models are becoming more realistic



IPCC 4th Assessment Report (2007)

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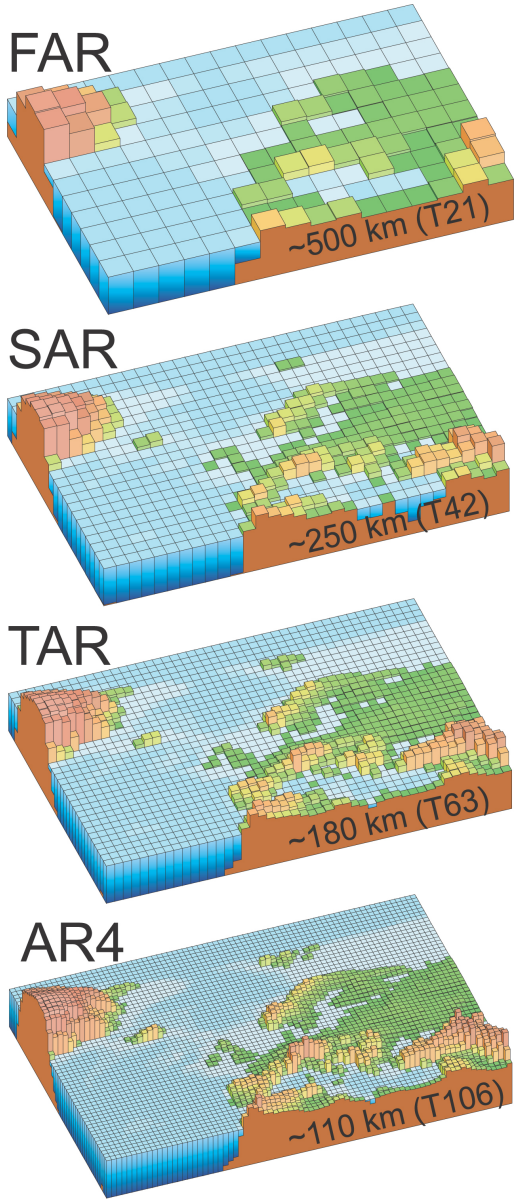
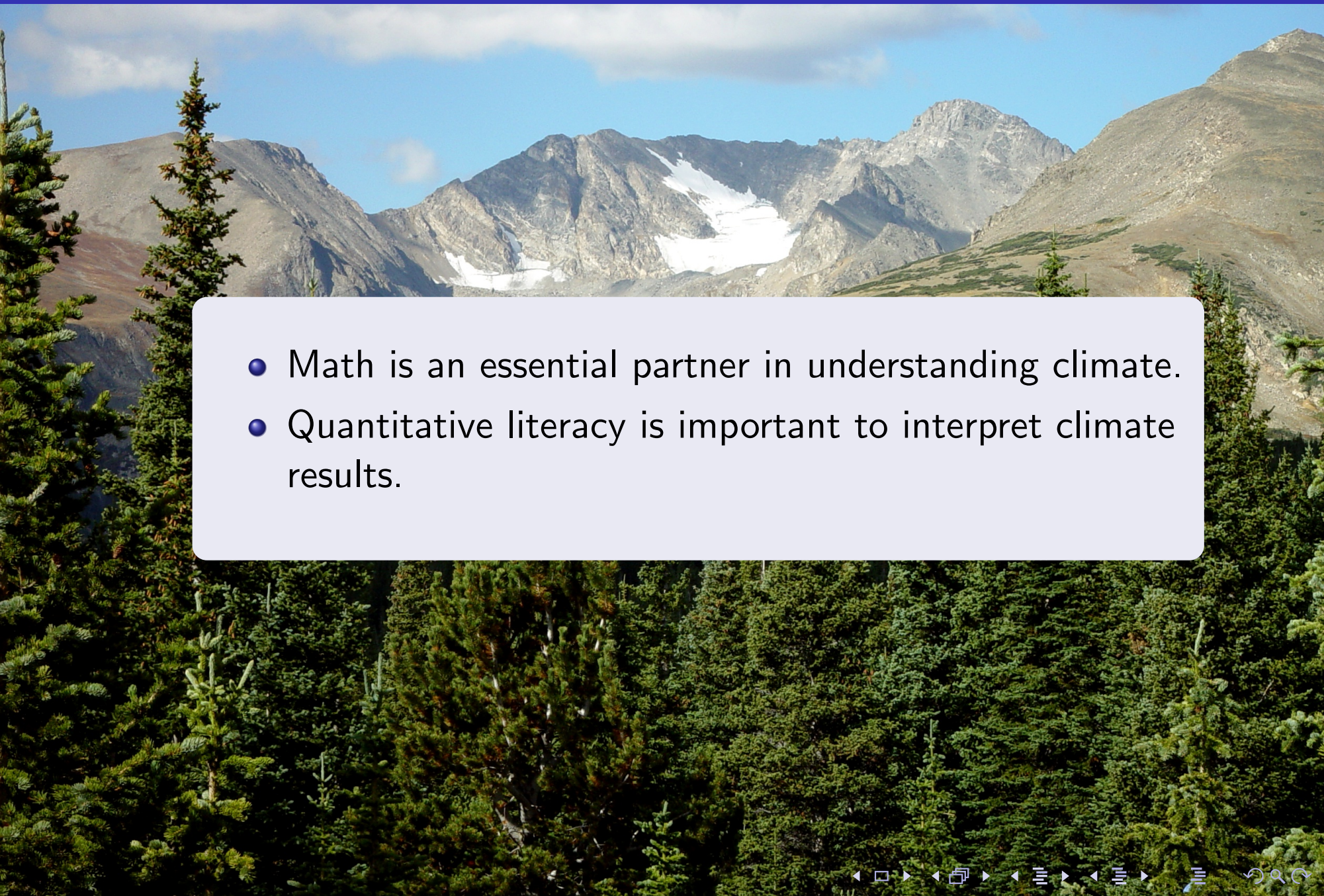


IPCC 4th Assessment Report (2007)


I WANT YOU

Summary

Summary



- Math is an essential partner in understanding climate.
- Quantitative literacy is important to interpret climate results.

Acknowledgments

- YOU

- Undergraduate students: Andrew Bergeson
- Collaborators: David Schimel (UCAR), Russell Monson (University of Colorado), David Moore (King's College), Bill Sacks (University of Wisconsin).

- Sustainability Calculus

- NSF Utah IGERT Math Biology grant
- Augsburg College Mathematics Department
- Augsburg College NASA Space Grant

This talk will be available at my website:
`http://www.augsburg.edu/home/math/zobitz.html`