Climate, carbon, and forests: The changing Northwoods

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Aug 7, 2015 TEC Talk
Welcome to CCR

- Biogeochemistry

CCR researchers are investigating global and regional biogeochemistry, with a particular focus on the carbon cycle of the land biosphere, oceans and Great Lakes. Using data and elucidate natural carbon fluxes and the factors controlling them, and work to use this information to improve predictive models.

- Climate Impacts
- Land Surface Processes
- Oceanography and Limnology
- Past Climates

Welcome to NTL-LTER

North Temperate Lakes

Member of the US LTER Network

Welcome to NTL-LTER

Our primary study sites are established by changing land use, land cover and changing land use. Their primary study sites include the surrounding lands of Limnology at the University of Wisconsin-Madison.

Department of Atmospheric and Oceanic Sciences

Who We Are

Since 1948 we have grown into one of the leading departments in our field of Atmospheric and Oceanic Sciences. We have strong graduate and undergraduate programs which are nationally recognized. We graduate about 15 Ph.D. and M.S. students each year; our graduates are active in research labs and universities around the world. We graduate approximately 20 B.S. students each year; they choose options allowing a focus on weather systems or general atmospheric science.

Our faculty of 15 has long maintained breadth and special strength in three areas:

- Climate systems, including the ocean
- Satellite and remote sensing
- Weather systems, including synoptic-dynamic meteorology
Human population increase (in red) from 10,000 BCE to 2000 CE

- Source: UCAR Quarterly, Summer 2007
Since 1990

- Global annual CO\textsubscript{2} emissions grew 30% to 33,000,000,000 tons of CO\textsubscript{2} per year

- CO\textsubscript{2} in the atmosphere grew 15% to 2.9 trillion tons of CO\textsubscript{2} (400 ppm)

- At current rates, CO\textsubscript{2} is likely to exceed 550 ppm sometime this century

- But: Rate of atmospheric CO\textsubscript{2} increase is about half the rate of emissions increase. Why?
The cumulative contributions to the Global Carbon Budget from 1870
Contributions are shown in parts per million (ppm)


Figure concept from Shrink That Footprint
Weather Station Network for Wisconsin
(Daily temperature and precipitation data since 1950)

Source: Map from Serbin and Kucharik (2009); photos from C. Kucharik, UW-Madison
Anomalies are deviation from baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-term linear trend.
Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).
The greatest amount of warming is occurring in Winter and Spring, especially in northwest Wisconsin.
Statewide average 15% increase, but highly variable across Wisconsin

(from Serbin and Kucharik 2009)
Change in Date of Last Spring Freeze from 1950 to 2006

Change in Date of First Fall Freeze from 1950 to 2006

(from Serbin and Kucharik 2009)
Lake Mendota Ice Duration 1855-6 to 2008-9

10 longest

10 shortest
## Earlier arrival of spring in Wisconsin

<table>
<thead>
<tr>
<th>Bird migration</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geese Arrival: 29 days</td>
<td><em>Baptista</em> first bloom: 18 days</td>
</tr>
<tr>
<td>Cardinal first song: 22 days</td>
<td><em>Butterfly weed</em> first bloom: 18 days</td>
</tr>
<tr>
<td>Robin arrival: 9 days</td>
<td><em>Marsh milkweed</em> first bloom: 13 days</td>
</tr>
</tbody>
</table>

55 ecological indicators of spring occurred on average 1.2 days earlier per decade from 1936 to 1998.


Slide adapted from C. Kucharik, UW-Madison
from May to October. While the gap-filling algorithm used a one-month moving window for computing ER, the curves shown in Fig. 5 represent the average response curve for the entire growing season. At Willow Creek, the soil temperature to ER relationship did not significantly change from 2002 to 2003. However, at Sylvania, there was significantly smaller ER in 2003 compared to 2002 for soil temperatures above 15°C. Sylvania ER is greater than Willow Creek for all temperatures above 5.0°C in both years. The data suggest that while the respiration base rate at Sylvania is greater than Willow Creek, the slope of the response curves are roughly similar. The ratio of ER from 20 to 10°C (Q10) was found to be 2.8 in 2002 and 1.9 in 2003 at Sylvania and 2.5 in 2002 and 2.3 in 2003 at Willow Creek, similar to typical Q10 value of 2.0 observed for forests (Ryan, 1991). Q10 at both sites decreased from 2002 to 2003, suggesting a coherent response to change in growing season climate; however, the change at Willow Creek was small.

ER at Sylvania was much larger than Willow Creek from June to October in both years (Fig. 5b); however, the uncertainty is larger than the difference for June. ER peaks at both sites in June and steadily declines afterwards. ER from June to September was smaller in 2002 than in 2003.
Houghton et al. (2007)
Wetlands are interesting...

- Adaptation of plants to drying conditions leads to increases in water use efficiency, especially for fens

Sulman et al. (in prep)
Trout Lake

May

June

July

Flux CO₂ (µMol/m²s)

hour

M. Balliett, UW
<table>
<thead>
<tr>
<th>a) IKONOS.</th>
<th>b) WISCLAND.</th>
<th>c) MODIS-UMD and IGBP.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>—</strong> Mixed Forest</td>
<td><strong>7.1%</strong> Mixed Forest</td>
<td><strong>100%</strong> Mixed Forest</td>
</tr>
<tr>
<td><strong>13.3%</strong> Upland Conifer</td>
<td><strong>13.0%</strong> Upland Conifer</td>
<td></td>
</tr>
<tr>
<td><strong>34.8%</strong> Aspen-Birch</td>
<td><strong>25.3%</strong> Aspen-Birch</td>
<td></td>
</tr>
<tr>
<td><strong>5.7%</strong> Upland Hardwood</td>
<td><strong>14.5%</strong> Upland Hardwood</td>
<td></td>
</tr>
<tr>
<td><strong>12.0%</strong> Upland Opening/Shrub</td>
<td><strong>6.8%</strong> Upland Opening/Shrub</td>
<td></td>
</tr>
<tr>
<td><strong>0.9%</strong> Grassland</td>
<td><strong>1.8%</strong> Grassland</td>
<td></td>
</tr>
<tr>
<td><strong>17.8%</strong> Lowland Conifer</td>
<td><strong>10.7%</strong> Lowland Conifer</td>
<td></td>
</tr>
<tr>
<td><strong>0.7%</strong> Lowland Deciduous</td>
<td><strong>1.9%</strong> Lowland Deciduous</td>
<td></td>
</tr>
<tr>
<td><strong>10.6%</strong> Lowland Shrub</td>
<td><strong>16.3%</strong> Lowland Shrub</td>
<td></td>
</tr>
<tr>
<td><strong>0.6%</strong> Wet Meadow</td>
<td><strong>1.0%</strong> Wet Meadow</td>
<td></td>
</tr>
<tr>
<td><strong>2.6%</strong> Open Water</td>
<td><strong>1.8%</strong> Open Water</td>
<td></td>
</tr>
<tr>
<td><strong>1.0%</strong> Road</td>
<td>— Road</td>
<td></td>
</tr>
</tbody>
</table>
Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial levels. Large and sustained mitigation is required to keep below 2°C.

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown. Data: CDIAC/GCP/IPCC/Fuss et al 2014.

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014
Projected Change in Seasonal Temperatures
1980 to 2055 (° F)

Winter

Spring

Summer

Fall

Warming is most pronounced in winter
Projected change in the frequency of $<0^\circ$ F nights per year from 1980 to 2055

Fewer extremely cold winter nights

Projected change in the frequency of $\geq 90^\circ$ F days per year from 1980 to 2055

More hot summer days
Current & Developing Working Groups

Wisconsin Climate

- Water Resources
- Human Health
- Milwaukee
- Coldwater Fish
- Agriculture
- Stormwater
- Loss of Winter
- Wildlife
- Plants & Natural Communities
- Central Sands Hydrology
- Forestry
- Coastal Communities
- Green Bay
Coldwater Brown Trout
losing about 33,000 km
of habitat (-88 percent)

Brook Trout
losing about 29,000 km
(-100 percent)

Coolwater Northern Pike
losing 11,000 km (-72 percent)

Walleye
losing 4,000 km (-88 percent)

Whereas:

Warmwater Channel Catfish
gaining 1,600 km (+32 percent)

Largemouth Bass
gaining 7,000 km (+34 percent)

+4.3°F = 94% loss
+7.2°F = total loss

Predicted distribution of brook trout in Wisconsin streams under current climate conditions and predicted losses under three climate-warming scenarios for Wisconsin by mid-century.
+1°C

4,800 km of streams -73%

16,000 km of streams +28%

Present Gain Loss

Matt Mitro & John Lyons WDNR
Forestry Working Group

Loss of Northern Tree Species

Impacts of Warmer Winters on Logging


Photo: Karrn Fassnacht, WDNR
PROJECTED SNOW

Species range shifts:

Iverson et al. 2008
Stormwater Working Group

Damage to communities and transportation systems from extreme storm events

Rock Springs, WI, June 2008
Photo: Michael Kienitz

Madison, WI, July 2006
Photo: Gordy Stephenson

Jamie McCartney
Hwy 60 near Excelsior, WI
August 20, 2007
Human Health Working Group

Increase in waterborne infectious diseases from more intense storms

Increase in vector-borne infectious diseases

Increase in respiratory health problems from air pollution and climate change
Climate Change Impacts on Summertime Tourism

U.S. Tourism Climatic Index

- Unfavorable
- Acceptable
- Very Good/Good
- Ideal/Excellent

July 1970s

July 2050s
1990
SO, THIS CLIMATE CHANGE THING COULD BE A PROBLEM...

1995
CLIMATE CHANGE: DEFINITELY A PROBLEM.

2001
TYP, WE SHOULD REALLY BE GETTING ON WITH SORTING THIS OUT PRETTY SOON...

2007
LOOK, SORRY TO SOUND LIKE A BROKEN RECORD HERE...

2013
WE REALLY HAVE CHECKED AND WE'RE NOT MAKING THIS UP.

2019
IS THIS THING ON?

TAP TAP TAP
Without prompt, aggressive limits on CO₂ emissions, the Earth will likely warm by an average of 4°-5°C by the century’s end.

**How Big a Change Is That?**

In the coldest part of the last ice age, Earth’s average temperature was 4.5°C below the 20th century norm. Let’s call a 4.5°C difference one “Ice Age Unit.”

-2 IAU

**Snowball Earth (-4 IAU)**

20,000 years ago

*My Neighborhood:*

*Half a mile of ice.*

-1 IAU

**Where We Are Today**

*Average During Modern Times*

*My Neighborhood:*

*Hi!*

0

**Where We’ll Be in 86 Years**

*Where We’ll Be in 86 Years*

*My Neighborhood:*

*Creteaceous Hothouse (+200m Sea Level Rise)*

*No Glaciers *Palm Trees at the Poles*
“I am not a scientist myself, but my best assessment of the data is that the world is getting warmer, that human activity contributes to that warming, and that policymakers should therefore consider the risk of negative consequences.”
– Sept. 2012

http://www.sciencedebate.org/debate12/
“Higher temperatures and less-predictable weather would hurt poor farmers, most of whom live on the edge and can be devastated by a single bad crop. [...] It would be a terrible injustice to let climate change undo any of the past half-century’s progress against poverty and disease—and doubly unfair because the people who will be hurt the most are the ones doing the least to cause the problem.”
“If you look at global warming alarmists, they don't like to look at the actual facts and the data. The satellite data demonstrate that there has been no significant warming whatsoever for 17 years. [...] I read this morning a Newsweek article from the 1970s talking about global cooling. And it said the science is clear, it is overwhelming, we are in a major cooling period... Now, the data proved to be not backing up that theory. So then all the advocates of global cooling suddenly shifted to global warming [...] and the solution interestingly enough was the exact same solution -- government control of the energy sector and every aspect of our lives.”

Washington Post, 2 Aug 2015
What Are The Options?

• Adaptation
  – Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  – Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)

• Mitigation
  – Economic (taxes, cap and trade, R&D)
  – Political (treaties, bans, compacts, fuel/energy standards, public transit, voluntary agreements)
  – Societal (sustainable development)
  – Technological (CO$_2$ capture, geoengineering, green tech, alternative energy, energy efficiency)
US forests annually sequester the equivalent of 10% of US carbon dioxide emissions from burning fossil fuels.

Forestry activities could remove another 100 to 200 Tg C/yr

### Life of Wood and Paper Products:

<table>
<thead>
<tr>
<th>End use</th>
<th>Half-life of carbon (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-family homes (pre-1980)</td>
<td>80</td>
</tr>
<tr>
<td>Single-family homes (post-1980)</td>
<td>100</td>
</tr>
<tr>
<td>Multifamily homes</td>
<td>70</td>
</tr>
<tr>
<td>Mobile homes</td>
<td>20</td>
</tr>
<tr>
<td>Nonresidential construction</td>
<td>67</td>
</tr>
<tr>
<td>Pallets</td>
<td>6</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>12</td>
</tr>
<tr>
<td>Furniture</td>
<td>30</td>
</tr>
<tr>
<td>Railroad ties</td>
<td>30</td>
</tr>
<tr>
<td>Paper (free sheet)</td>
<td>6</td>
</tr>
<tr>
<td>Paper (all other)</td>
<td>1</td>
</tr>
</tbody>
</table>

*Skog and Nicholson 2000*
“Power plants are the single biggest source of harmful carbon pollution that contributes to climate change. Until now, there have been no federal limits to the amount of carbon pollution plants dump in the air.”
Ankur Desai and the Ecometeorology Lab
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Dept of Atmospheric & Oceanic Sciences,
UW-Madison
http://www.aos.wisc.edu

Center for Climatic Research
http://ccr.aos.wisc.edu

North Temperate Lakes LTER
https://lter.limnology.wisc.edu/

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University of Wisconsin Foundation
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NASA
U.S.D.A. USFS
State of Wisconsin DNR and ECB

“The Wisconsin idea”
Lake States Aspen-Birch:

- Soil
- Forest floor
- Understory
- Stand dead wood
- Standing dead
- Live tree

![Graph showing carbon content over stand age.](image)

**Figure data:** Smith et al. 2005