Are long-term trends in lake pCO_2 responsive to climatic variability and change?

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LMS Seminar

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Motivation

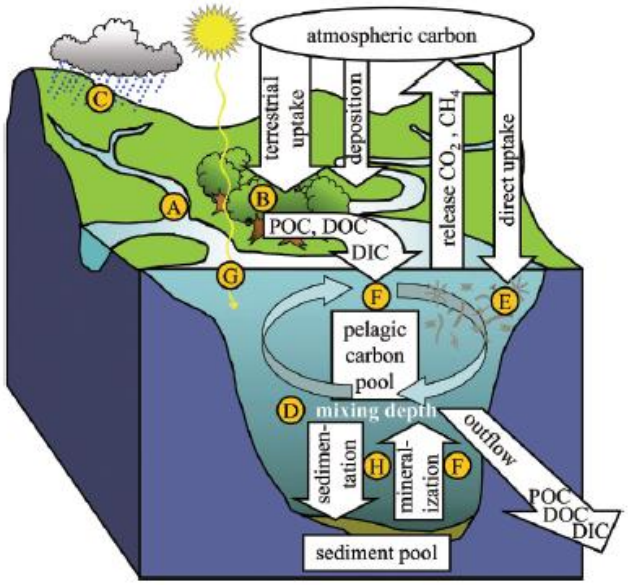
- Recent findings show many climatic effects on lakes

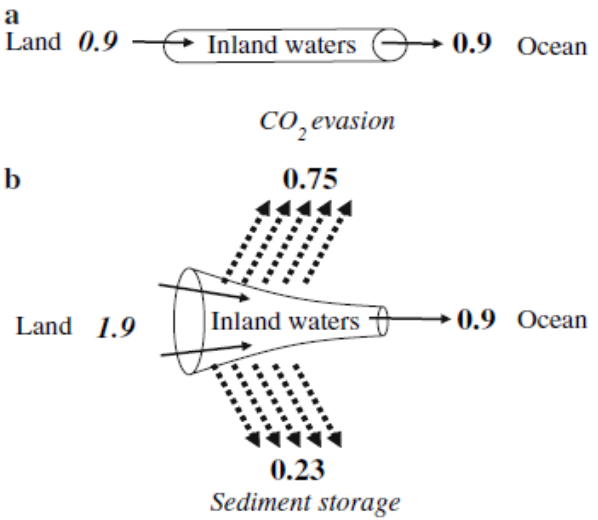
(First affect lake physical properties, then influence chemistry and biology)

✓ Warming temperature
✓ Shorter growing season
✓ Decoupling lake phenological processes

- Relatively little known climate – lake carbon cycle feedbacks

✓ Rather more driven by precipitation
✓ Generally predicted increases of GHG emissions
✓ Boreal zone more studied than temperate

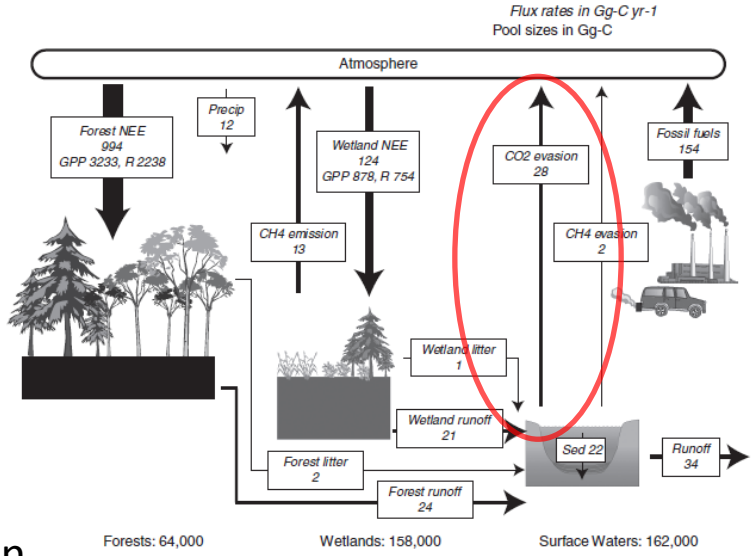




Winder and Schindler, 2004, Sobek et al., 2005, Cole *et al.* , 2007, Tranvik *et al.* 2009, Adrian *et al.* 2009

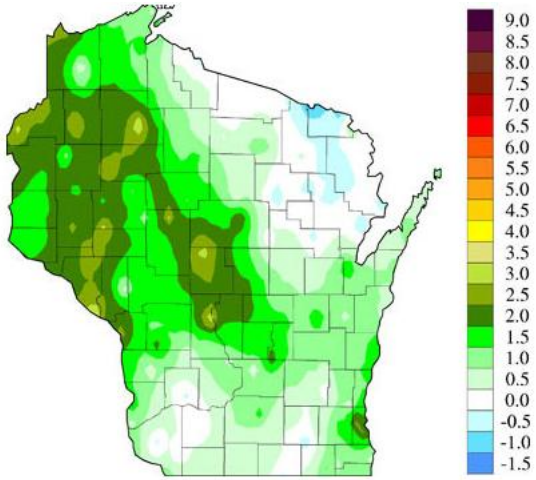
Wisconsin as an excellent testbed

- Lake-rich region
- Experiencing significant climatic warming
- NTL-LTER program

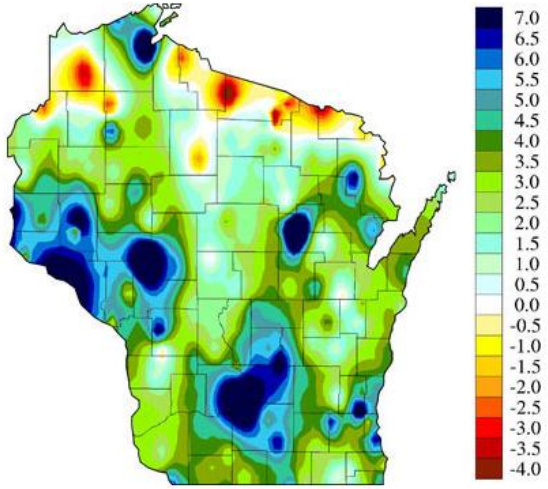


Buffam *et al.* 2010

Temperature



Precipitation



WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

My questions

What are the long-term trends in pCO_2 and (CO_2 flux) in NTL - LTER lakes?

Are they responsive to climatic variability and change?

Today I will focus only on trends in pCO2

Outline

1. Air Temperature and Precipitation Trends

2. Lakes in a warming world

3. Long-term trends in pCO2 in NTL-LTER lakes

Methods

- 16-26-year time series of measurements for eleven lakes monitored by NTL-LTER program

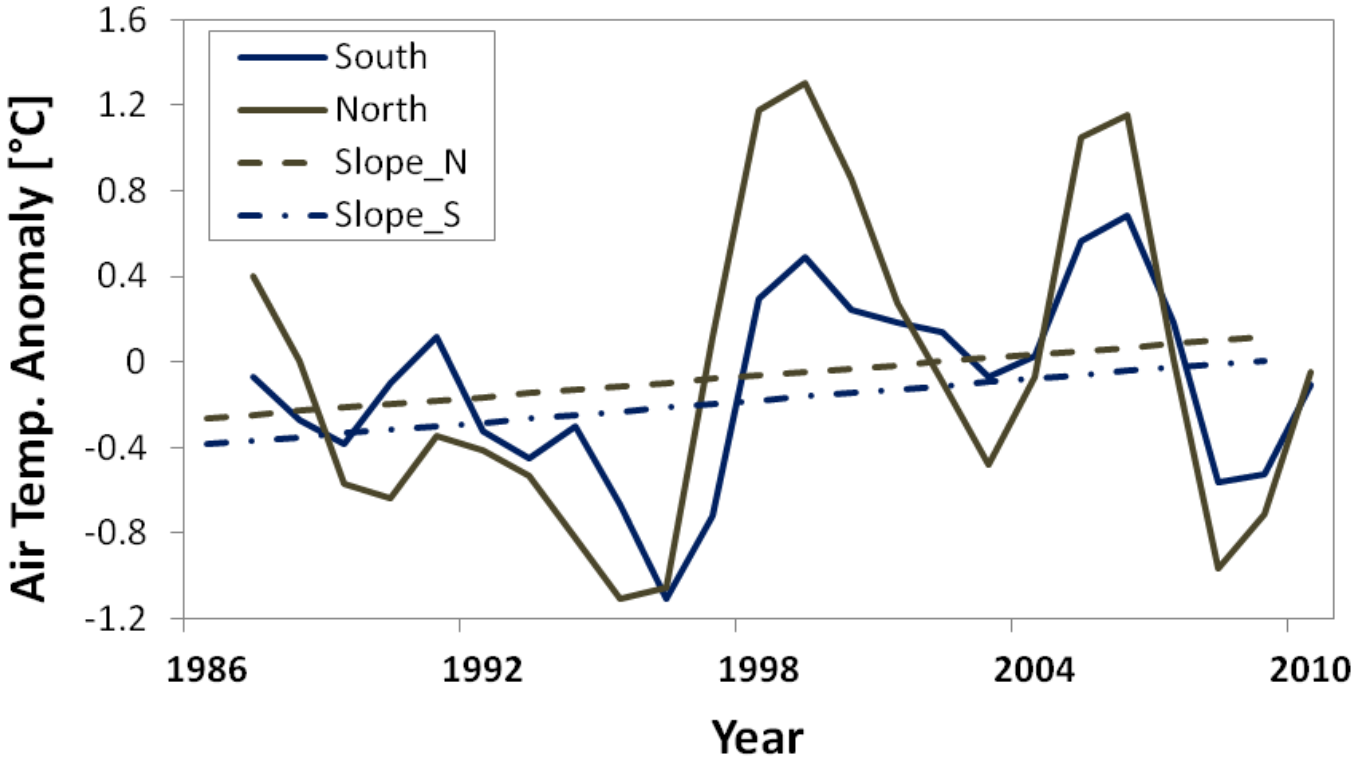
- pCO_2 estimated from temperature, pH, and DIC (Weiss 1974 and Gelbrecht 1998)

- Seasonality of variables removed by calculating anomalies

- Linear regression used to analyze deseasonalized trends (performed on smoothed curves to minimize influence of outliers, after Taylor *et al.* 2012)

Climate

Air Temperature Trends

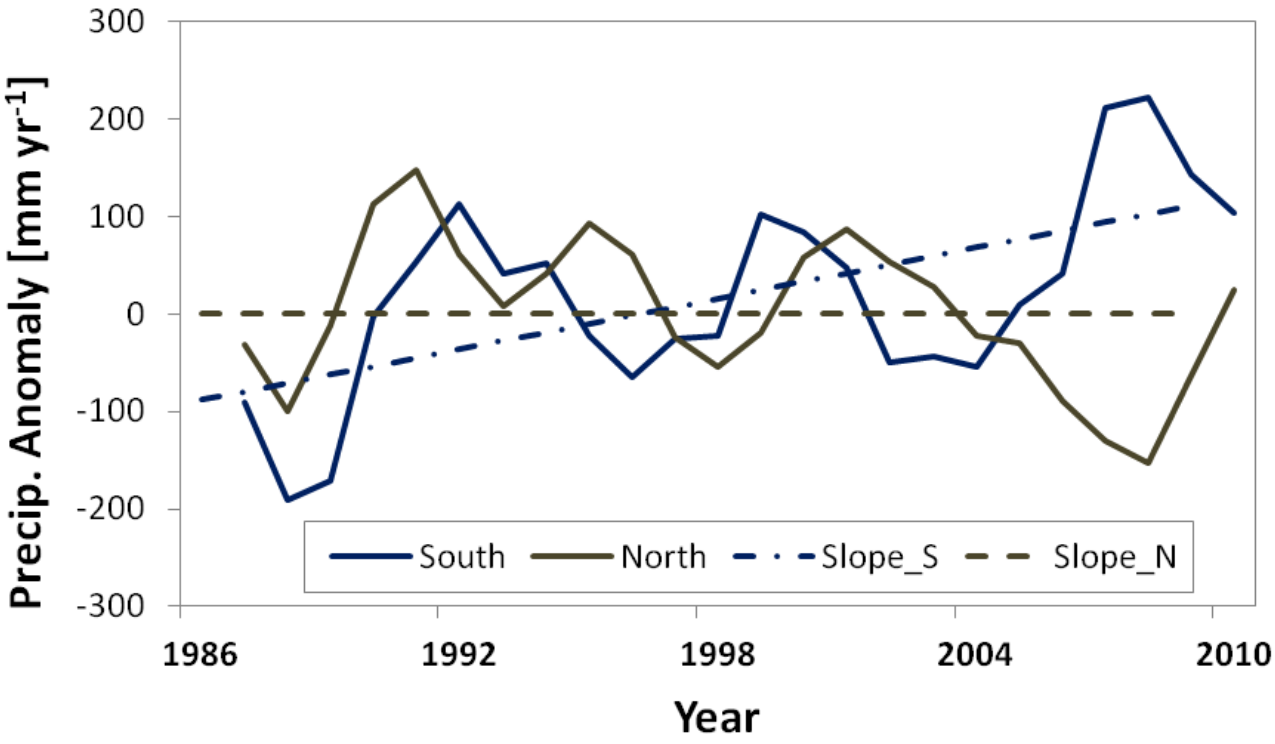


- Mean Annual Temperature Trends insignificant

✓ North – + 0.017 °C yr^{-1}

✓ South – + 0.016 °C yr^{-1}

Precipitation trends



- Annual Precipitation Trends

✓ North – - 0.01 mm yr^{-1}

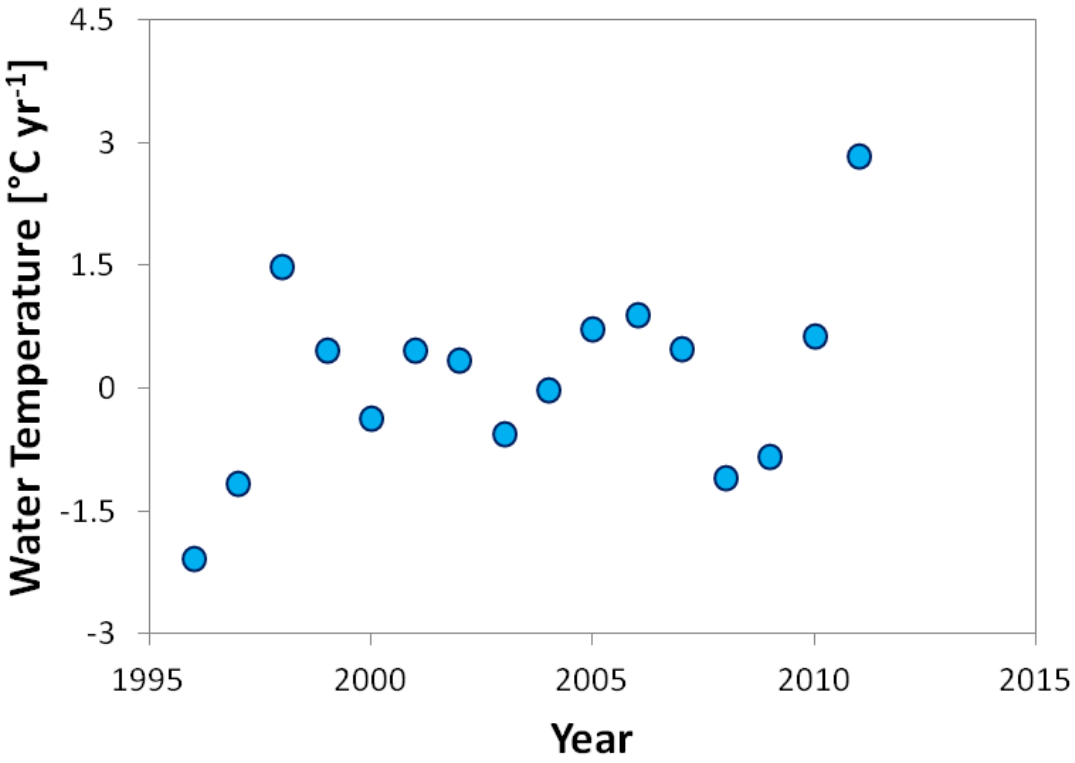
✓ South – **+ 8.7 mm yr^{-1} ****

Lake Physical Properties

Jake W.

Air Temp. vs. Water Temp.

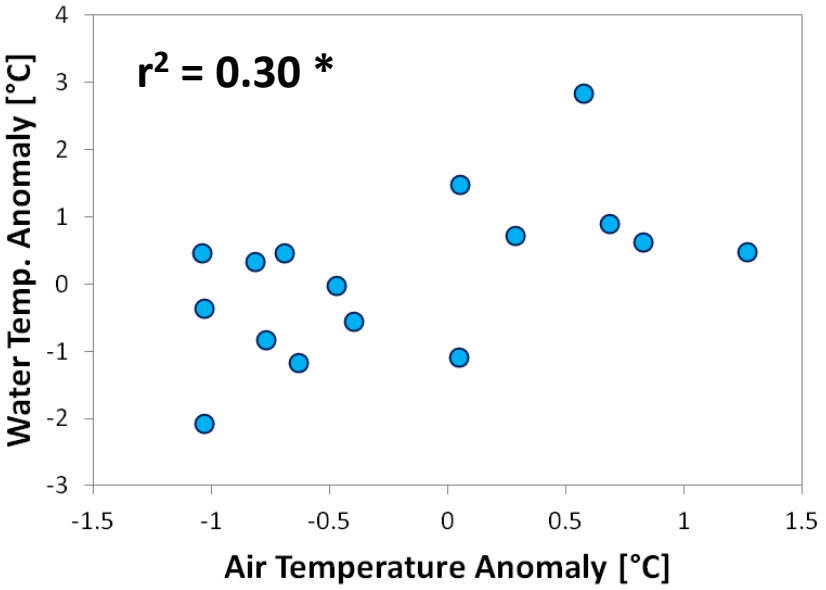
Lake Mendota

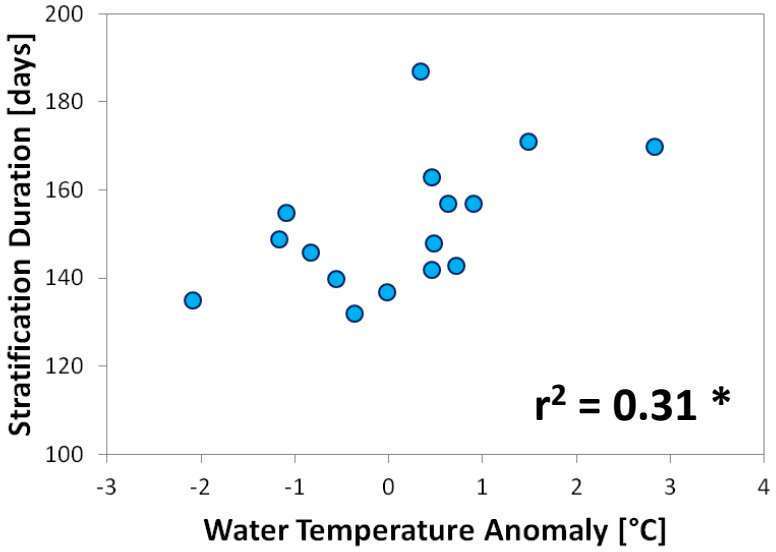


- Mean Annual Temperature Trends – **+ 0.1 °C yr^{-1} ***
- Even though Air Temperature increase is insignificant (min/max)

Air Temp. vs. Physical Properties

Lake Mendota

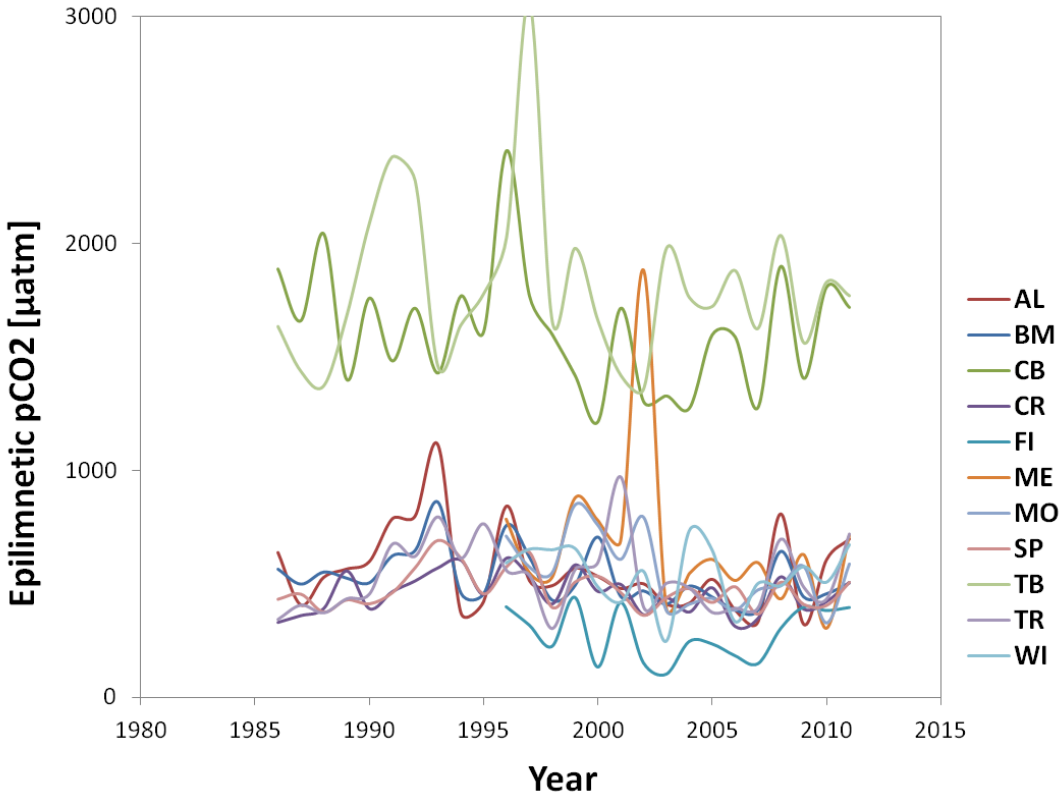


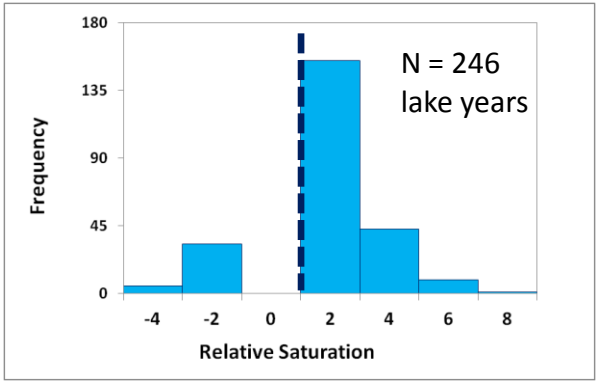


Carbon

Trends in epilimnetic pCO_2

Open-water means



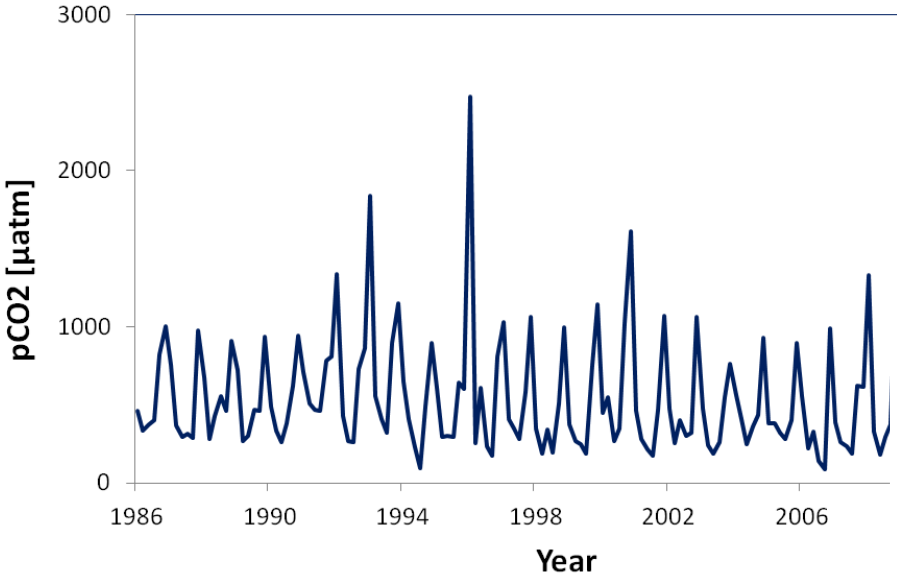


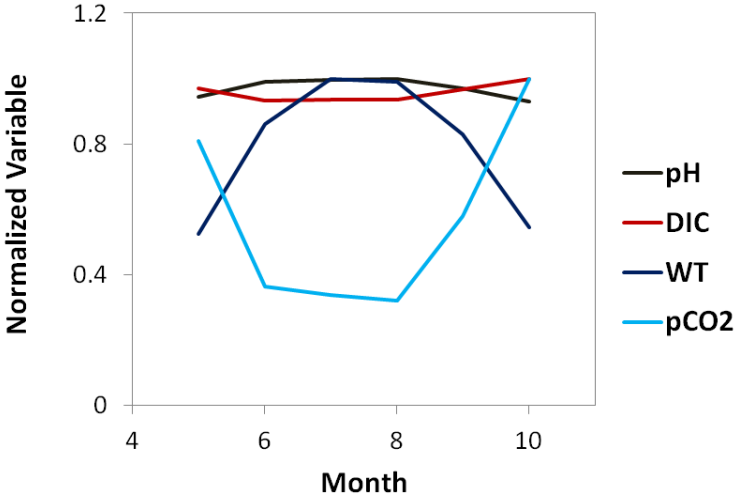
- Dashed line indicates equilibrium with atmosphere
- 75% of lakes are CO_2 supersaturated

- Bog lakes are pretty distinctive
- High between and in-lake variability
- Fish Lake undersaturated

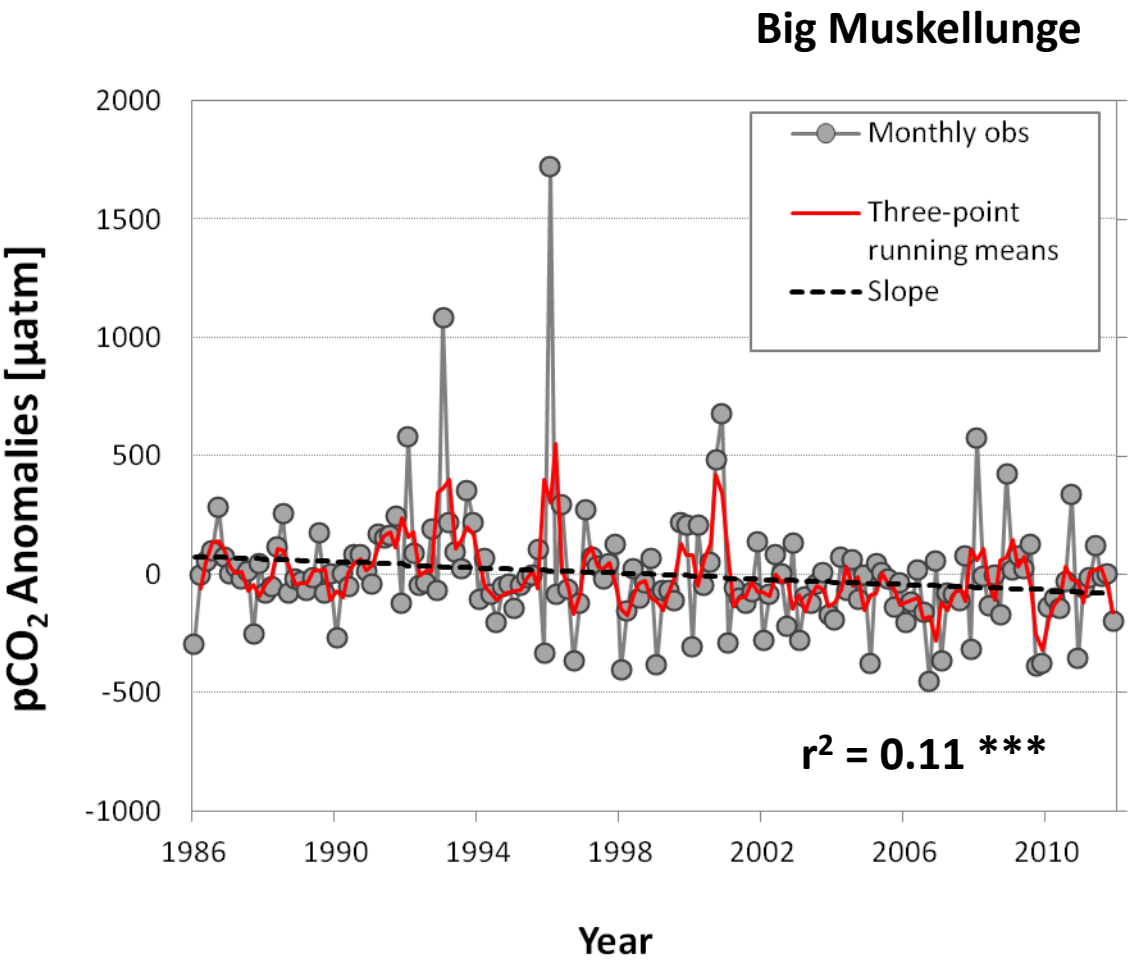
Trends in epilimnetic pCO_2

- Seasonality of CO_2 saturation (e.g. summer lows)

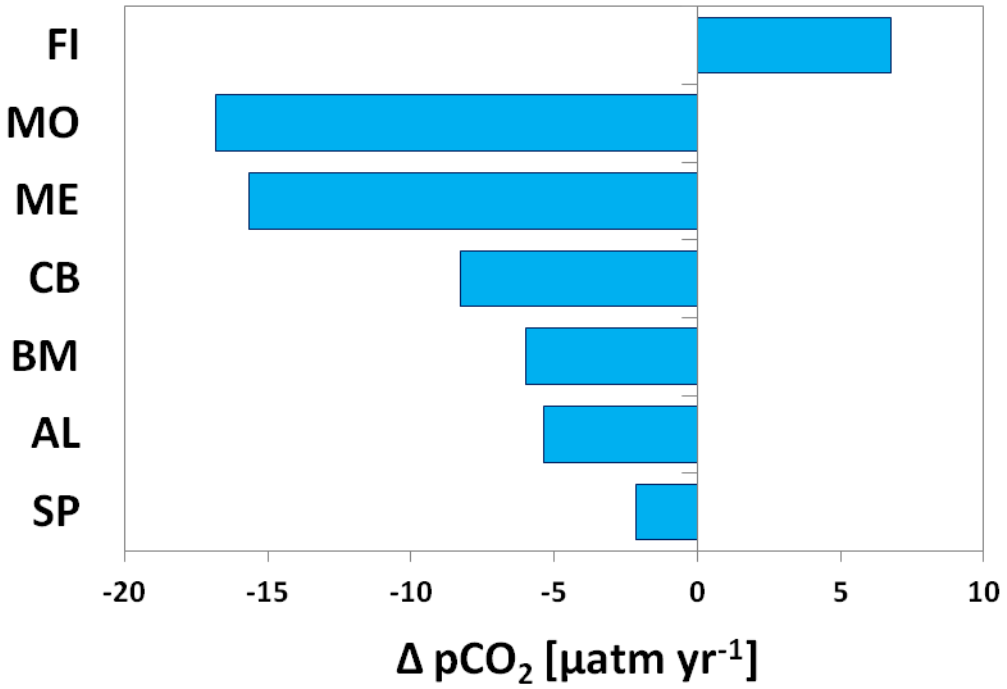




Deseasonalized trends in pCO_2



Rate of change in pCO_2



* Only significant trends are shown

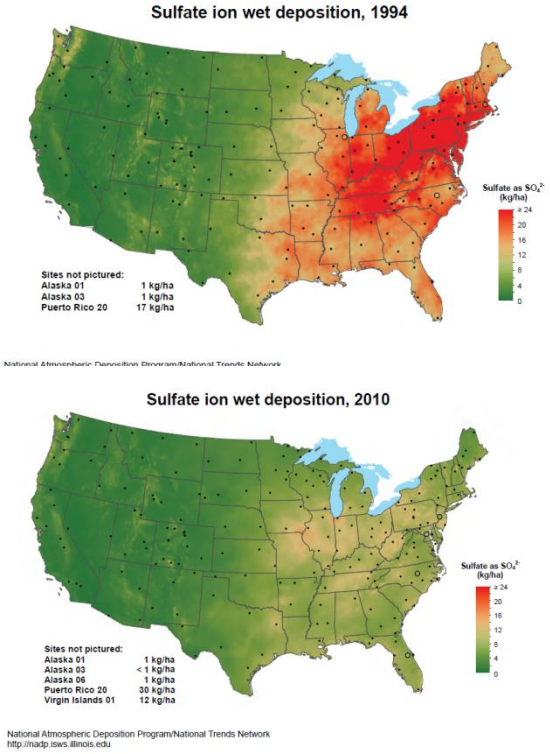
- All trends were highly significant
- 2 - 21 % of variability explained
- A weakening source of C to atmosphere

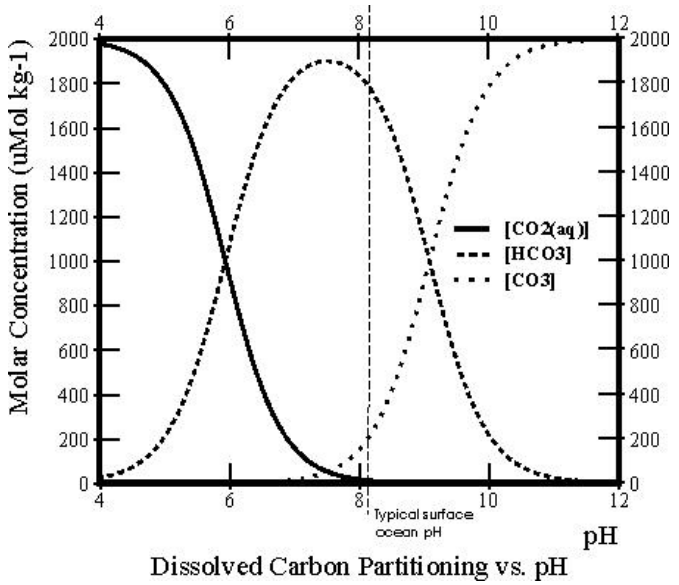
Climatic variability and change?

Var . / Lake	**AL**	**BM**	**CB**	**SP**
Air Temp.	ns	ns	ns	ns
Precip.	**0.41 ***	ns	ns	ns
ENSO	ns	ns	ns	ns
PDO	ns	ns	ns	ns
WT	**-0.62 ****	**-0.64 *****	ns	**-0.55*****

- Air temperature effect via water temperature (min/max not shown)
- Water temperature used for pCO_2 calculation

Other drivers of pCO2 decline?





- Use of SO_4^{2-} concentrations as a proxy of acid rains

Summary

What are the long-term trends in pCO_2 and (CO_2 flux) in NTL - LTER lakes?

- Trends show declining lake CO_2 saturation, indicating a weakening source of carbon to atmosphere
- Drivers of declining trends must be confirmed

Are they responsive to climatic variability and change?

- Climatic oscillations (ENSO, PDO) - No
- Air Temperature trends – Yes
- Precipitation trends – Yes (but in a couple of lakes)

Future directions

- Explore effect of other possible drivers of pCO_2 decline (e.g. acid rains, eutrophication)
- Calculate air-water CO_2 exchange
- Under – ice CO_2 dynamics

Thank you !
&
Happy Thanksgiving !