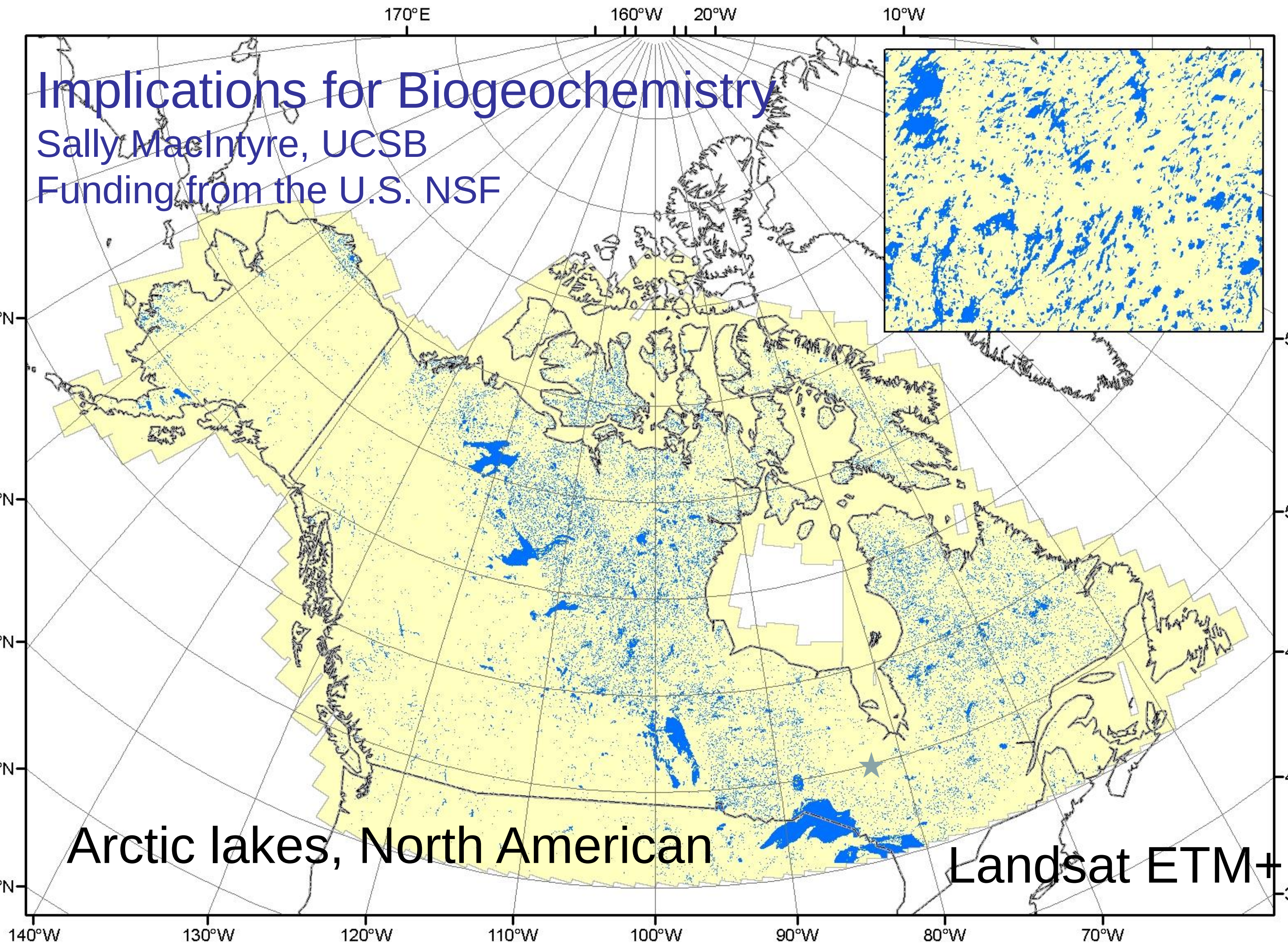
Climate Related Variations In Lake Mixing Dynamics:

Implications for Biogeochemistry

Sally MacIntyre, UCSB

Funding from the U.S. NSF



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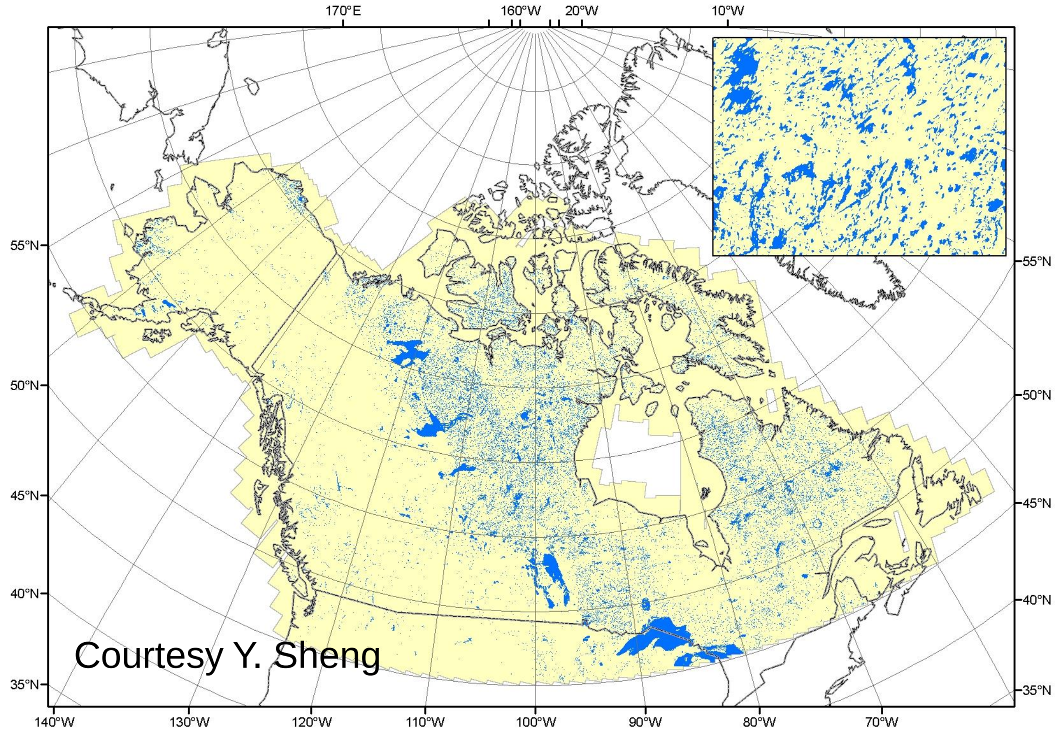
5.6 M Arctic and Subarctic Lakes 0.5 ha or larger in NA . Courtesy of Yongwei Sheng.

Critical Limnological Questions:

How are organisms adapting to changing temperatures and mixing dynamics?

What are the fluxes of green house gases from lakes?



Regional and Global limnology:

Kling et al. (1991; 1992). Net heterotrophy
Downing et al. (2006). Abundance of lakes
Richey et al. (2004) and Cole et al. (2007).

Integrating lakes into regional and global carbon budgets requires scaling using tools of physical limnology.

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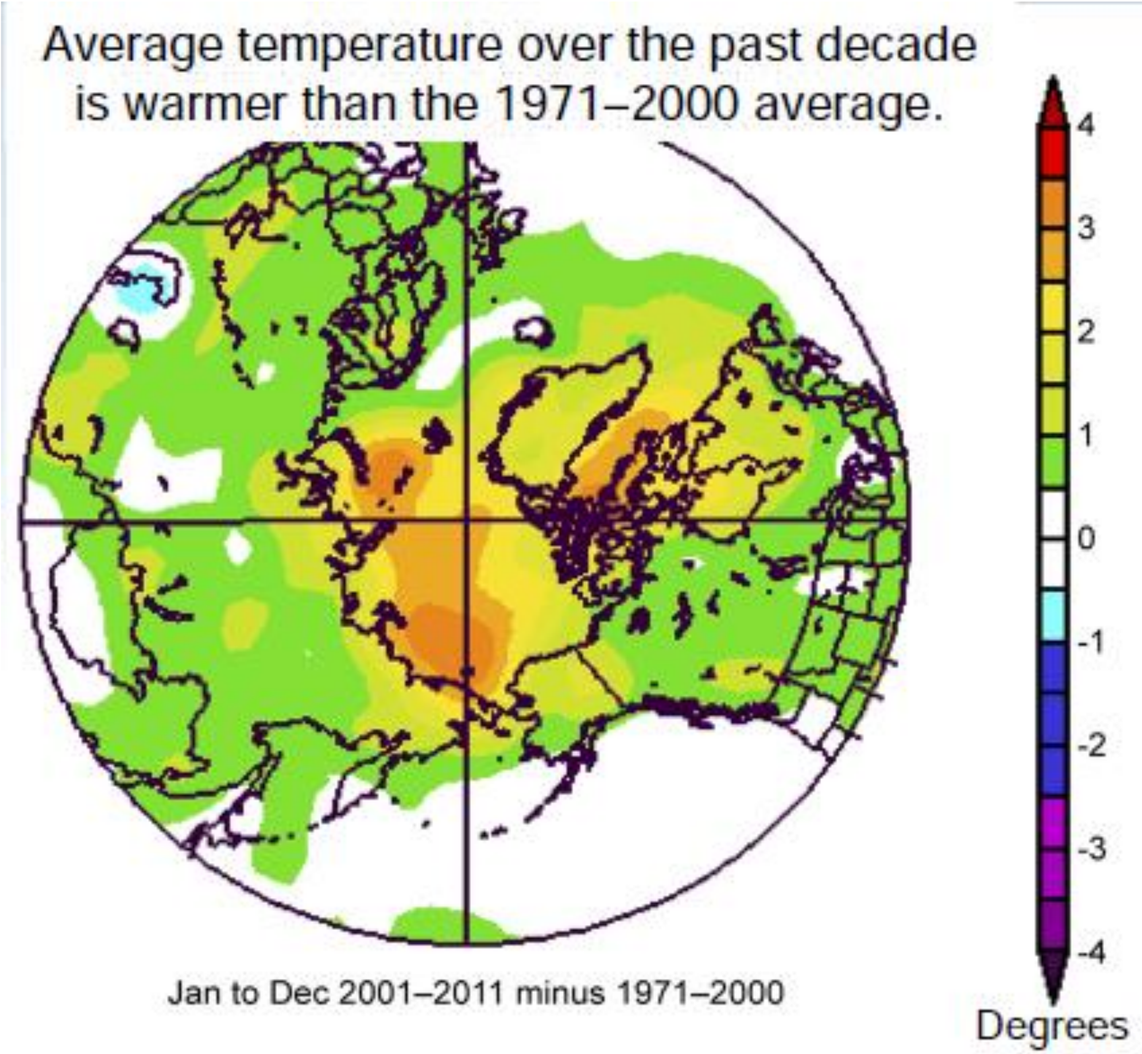
Collaboration is essential for scaling:



Jeffries and Richter-Menge (2012)

ADAPT Project, CA
- W. Vincent
- I. Laurion

GRIL Project, CA
- P. DelGiorgio
- Y. Prairie

NW Canada:
- F. Wrona
- L. Lesack

ABISKO – Sweden
- P. Crill
- J. Karlsson

Finland – T. Vesala,
- A. Ojala
- P. Kortelainen

Greenland – J. Anderson

CALON –GLEON-GLTC

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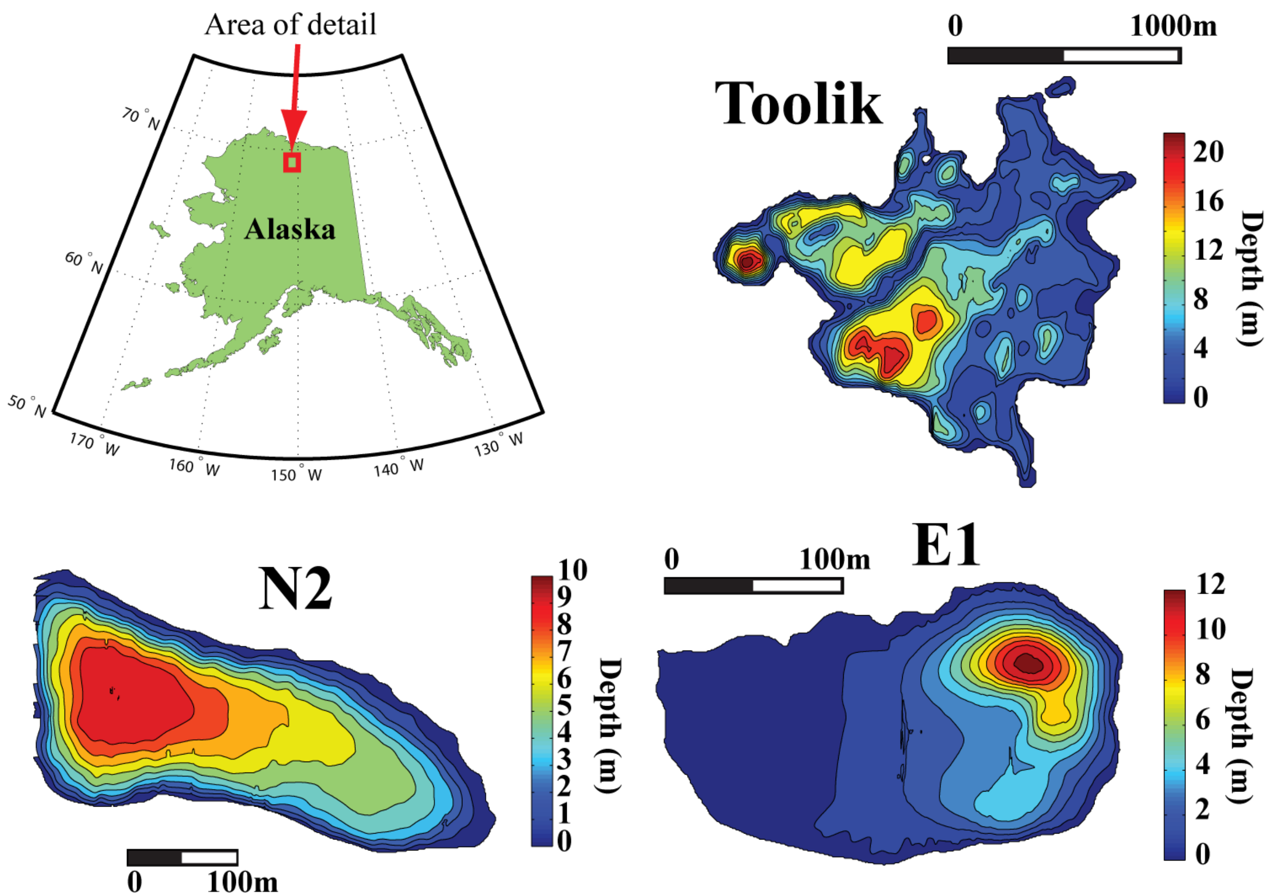

* Arctic Lakes

Highly variable bathymetry! Require good GIS.

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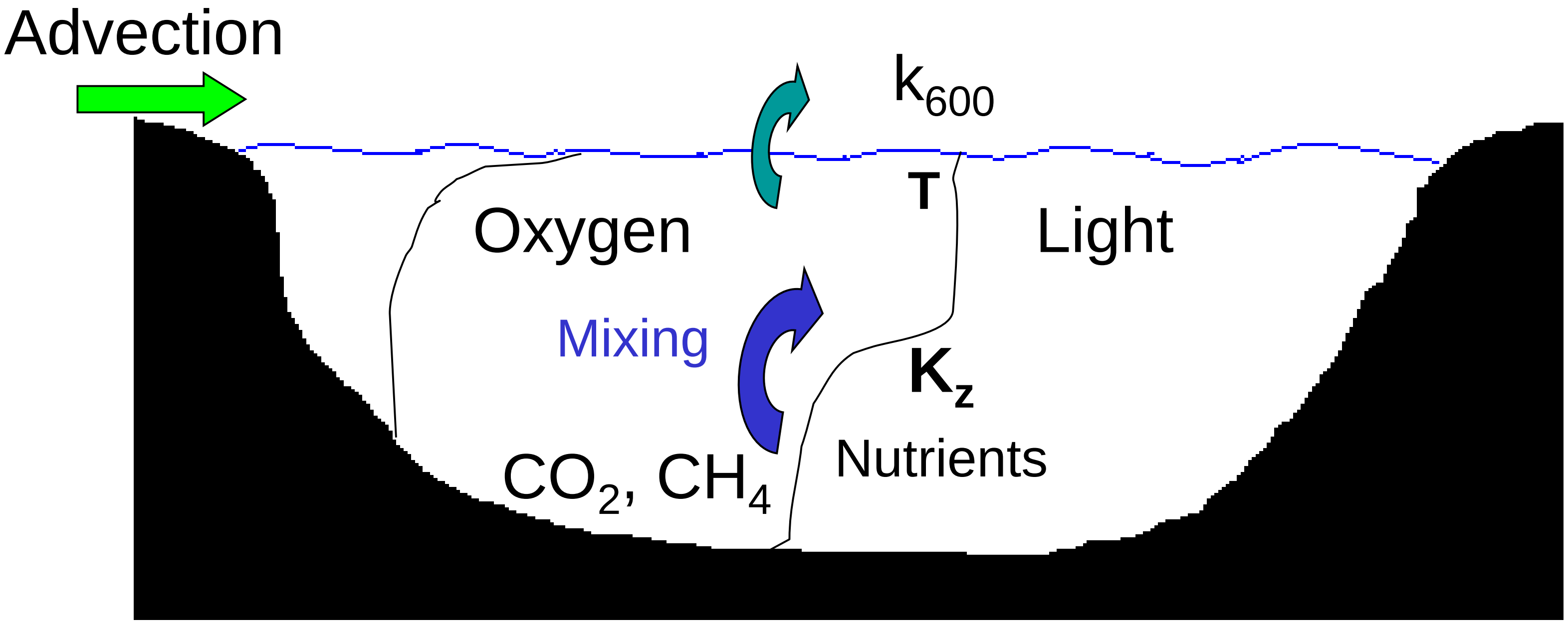
Aquatic Ecosystem Studies –

Hydrodynamics allows us to compute fluxes.



Coefficient of eddy diffusivity, K_z, characterizes turbulence. Flux = K_z * (dC/dz)

Gas transfer coefficient, k_{600}, used to estimate gas fluxes.

Flux = K * (C_w – C_{aq})

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Surface meteorology, time series sensor data, and CTD profiling

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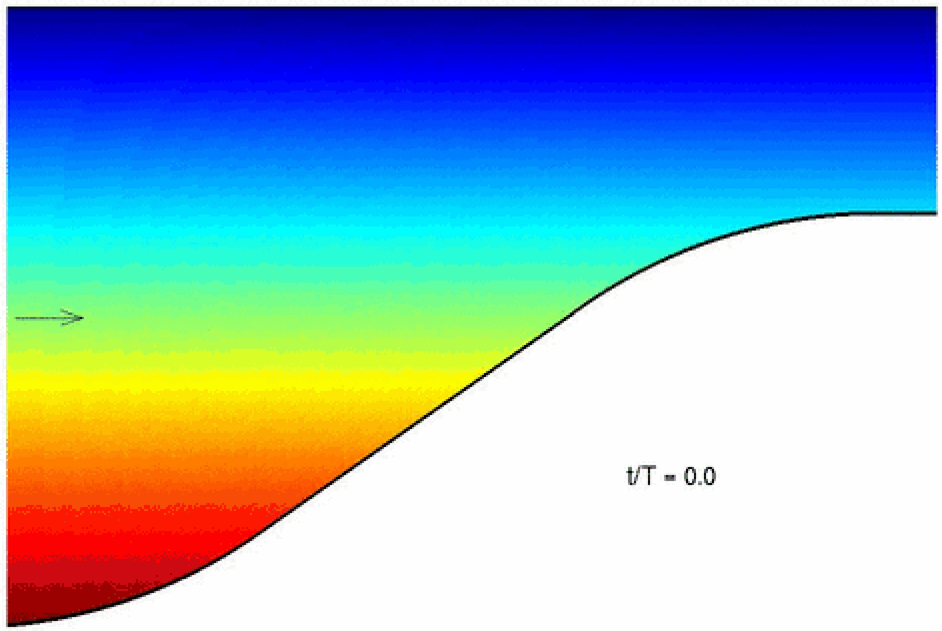
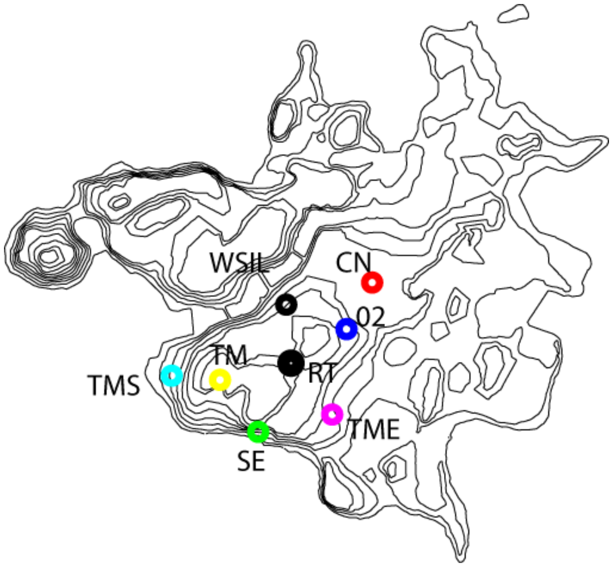
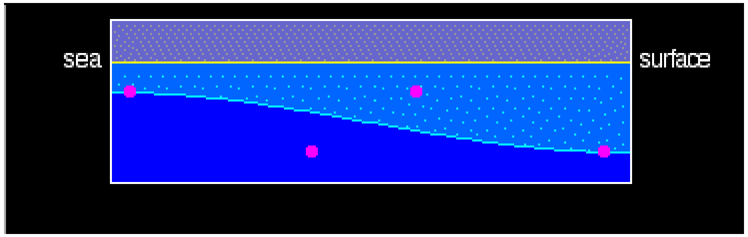
Arctic Lakes







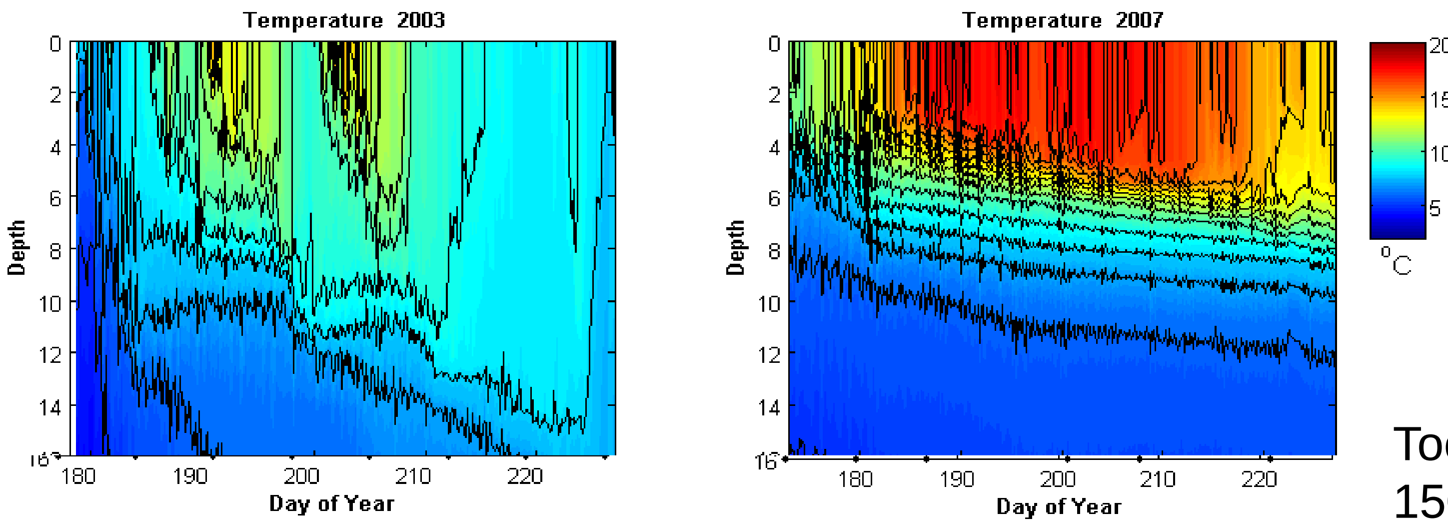
Weakly stratified
Support internal waves
Extent of wave breaking
depends on thermocline tilt; Vertical fluxes result.
Predicted from Lake number – allows scaling to other lakes @

Courtesy of J. Vidal

Arctic Lakes - Summer

High interannual variability in average summer temperatures

L_N frequently below 3 **L_N > 10**



Toolik Lake
150 ha
2003 – cold
2007 - hot

Weakly stratified – Low evaporation - windy

Biological questions: Nutrient fluxes, gas fluxes, fate of stream inflows, dilution of phytoplankton and bacteria, changes in phenology

Modified from MacIntyre et al. (2009)

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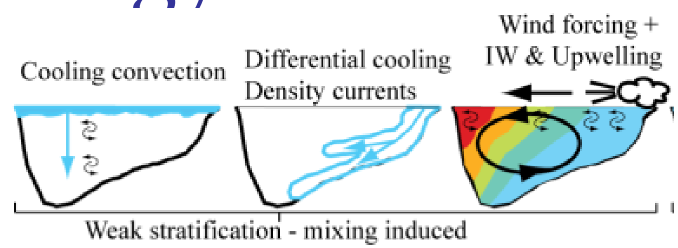
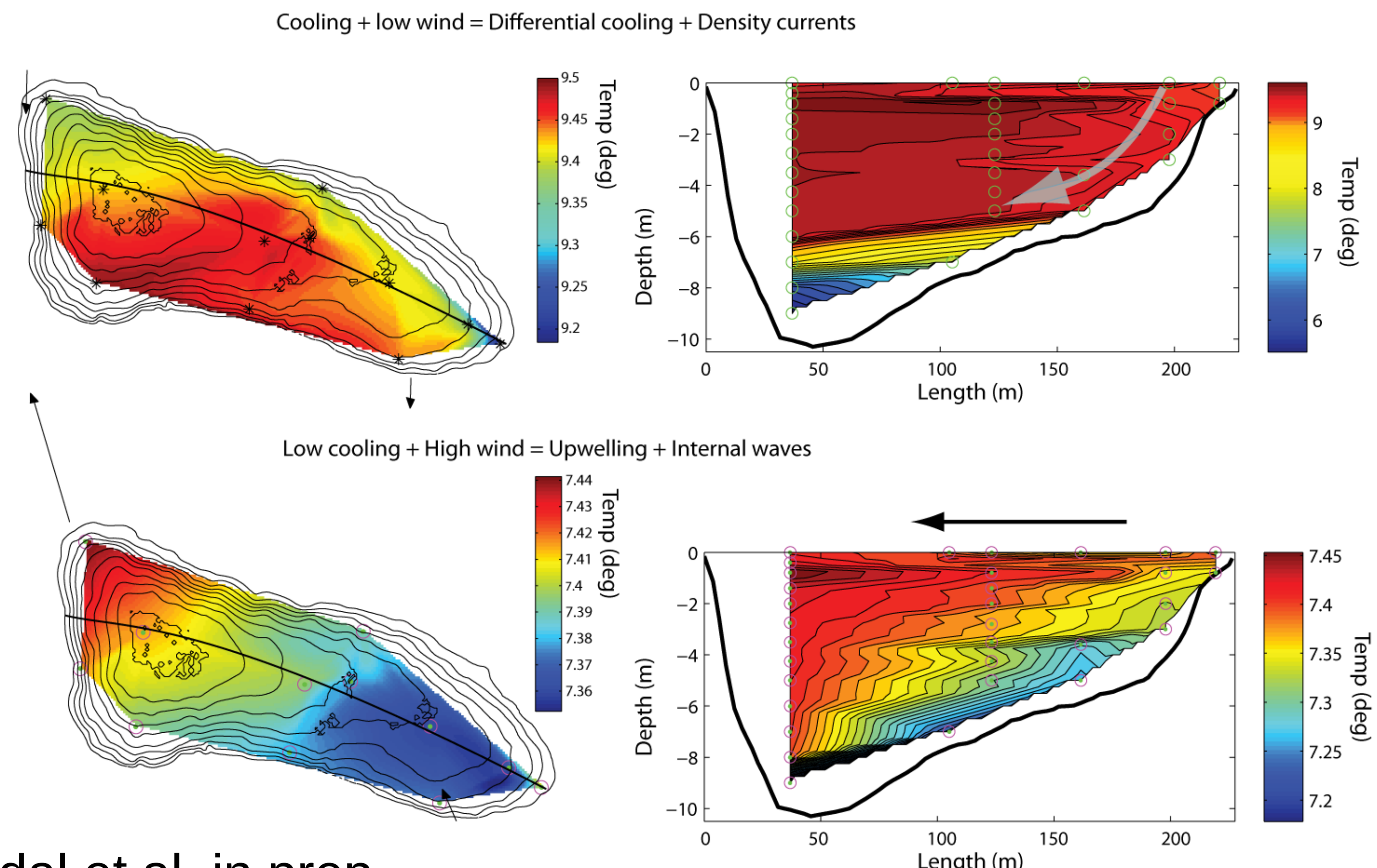
Mixing – Processes and Rates vary with bathymetry and meteorology





Lake N2
2011.
1.6 ha

Vidal et al. in prep.

Courtesy: J. Vidal

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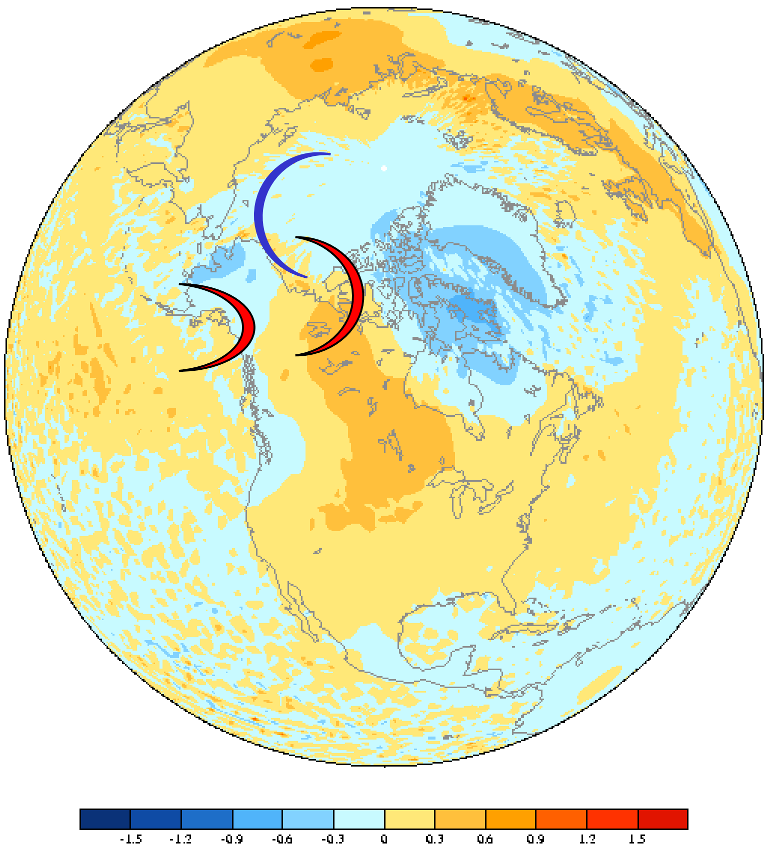
Local and Global Variability

AO summer (May through October) temperature anomalies, 1979-97



Cool summers – Low pressure to the North – AO may dominate
Considerable mixing.
Warm summers – High pressure to the North –Arctic Dipole may dominate
More persistent stratification.

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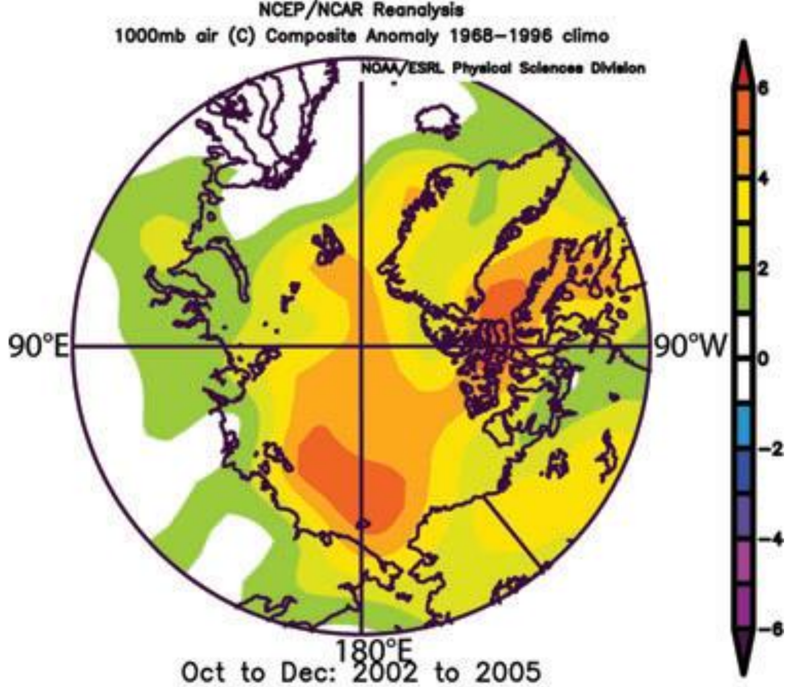

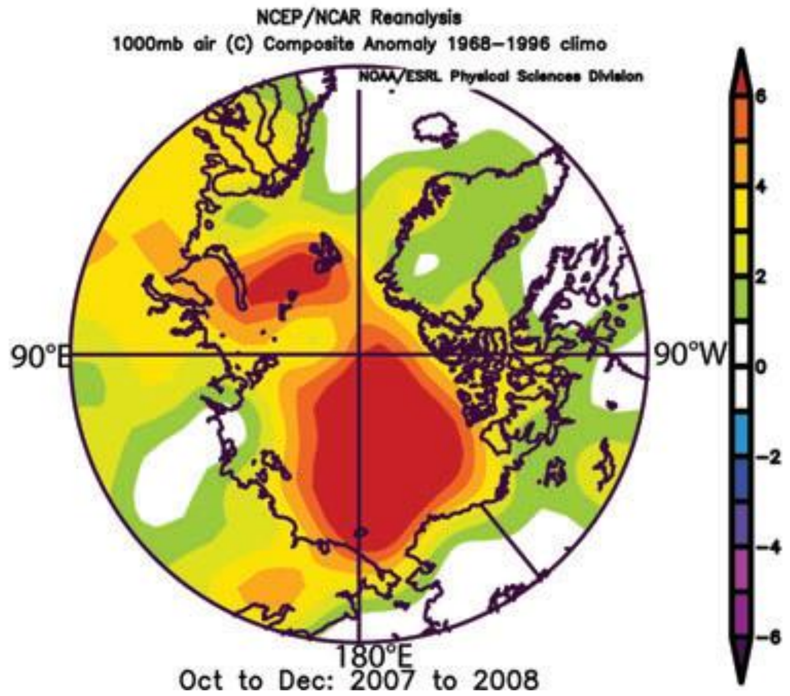

Fall Warming in the Arctic –

related to loss of ice cover over the Arctic Ocean

How does it affect the limnology of arctic lakes in winter?

Overland and Wang (2010)

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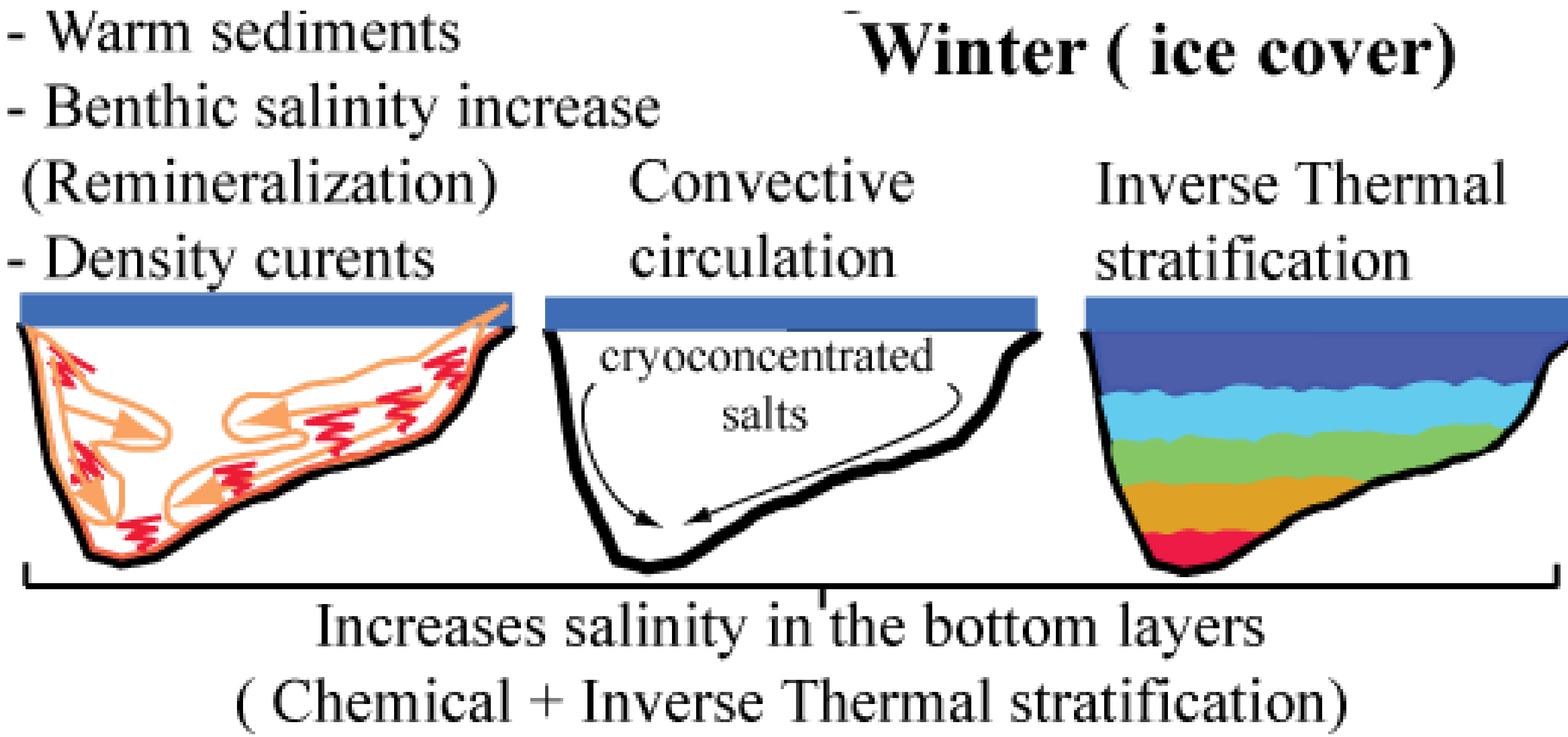
Under Ice Circulation



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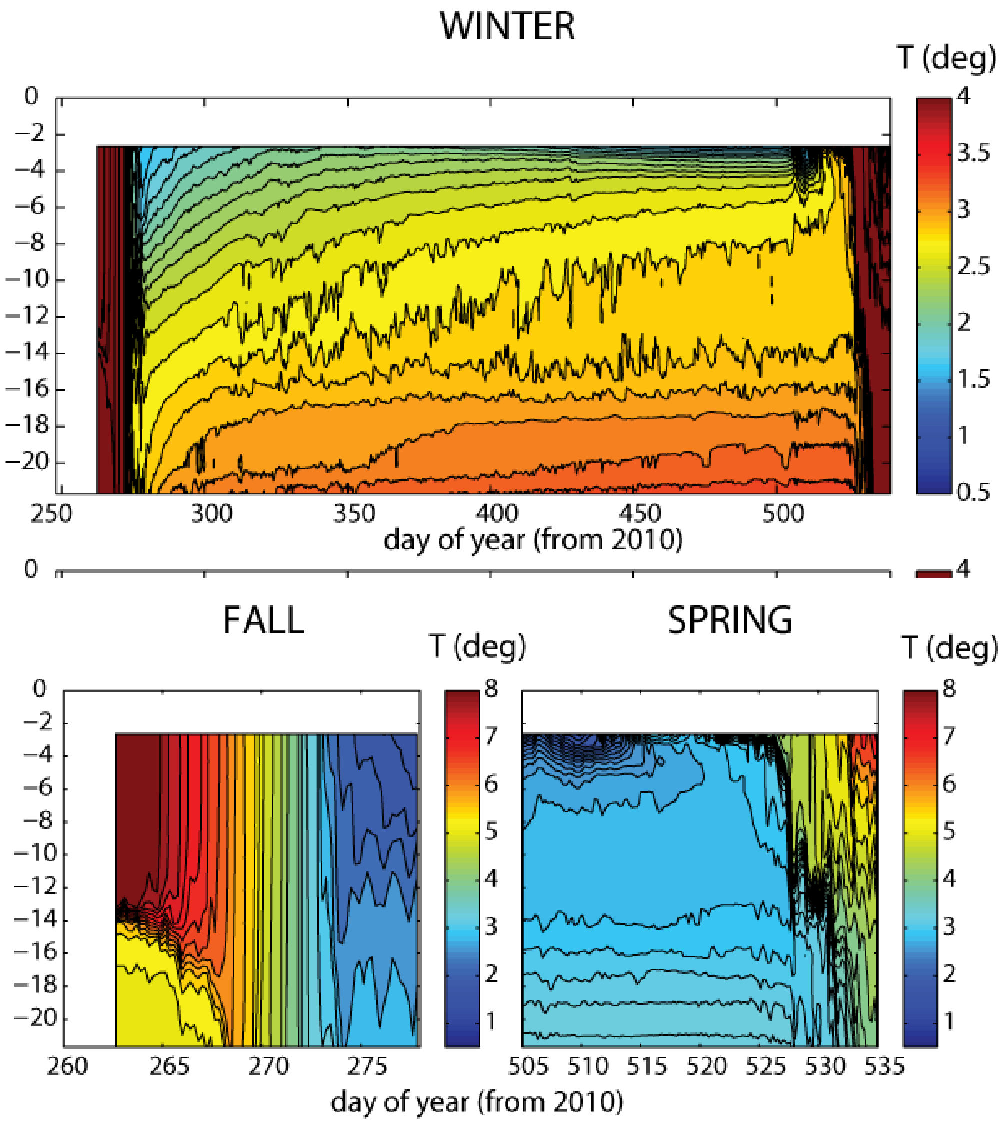

Toolik Lake

Questions: Do differing conditions between years favor different species? life histories? biogeochemical rates?

Require: High Quality Year Round Meteorological Data: Pyrgeometers, replication of instruments. CTD profilers; snow cover; ice thickness; Winter lab facilities and instruments.

Stratifies before fully mixing in spring

MacIntyre, Vidal, and Tedford (in prep).

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Scaling up across the landscape and over time.

Use dimensionless indices to understand influence of meteorology and bathmetry.

Reanalysis data for air temperature and wind.

Link hydrodynamics and biogeochemistry.

Efforts in all seasons.

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Needs for TFS

- High quality year round meteorological data including stream discharge
- Conductivity-temperature-depth profilers – research grade
- Winter facilities
- GIS for mapping of terrain and lake bathymetry
- Rapid sharing of data – real time with on-line QA/QC for sensor data; quick upload of CTD data.
- Group discussions and educational workshops for improved ways of integrating different research perspectives. International outreach.
- Training of young scientists in working with extensive, multi-disciplinary data sets

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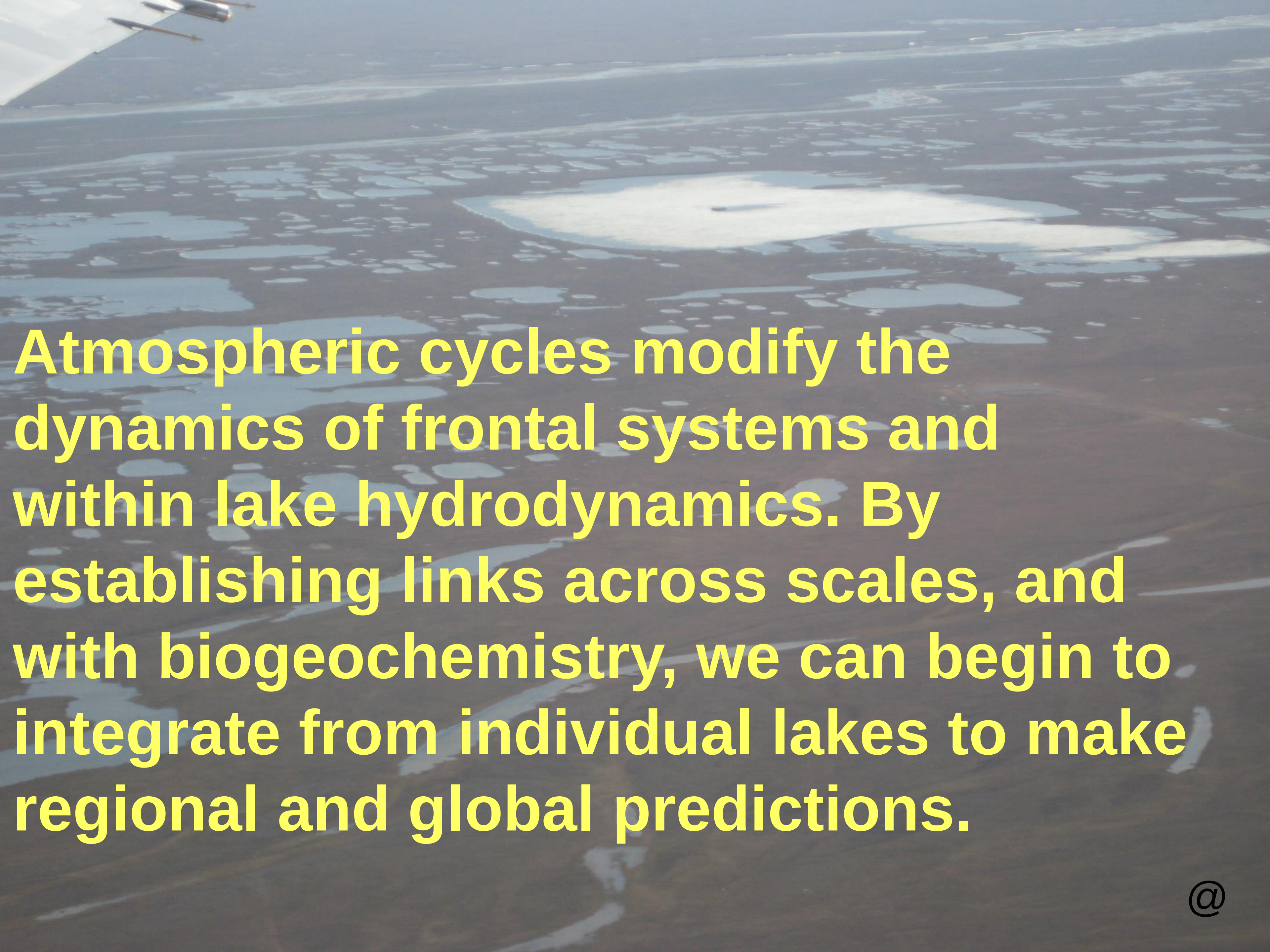
Atmospheric cycles modify the dynamics of frontal systems and within lake hydrodynamics. By establishing links across scales, and with biogeochemistry, we can begin to integrate from individual lakes to make regional and global predictions.
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