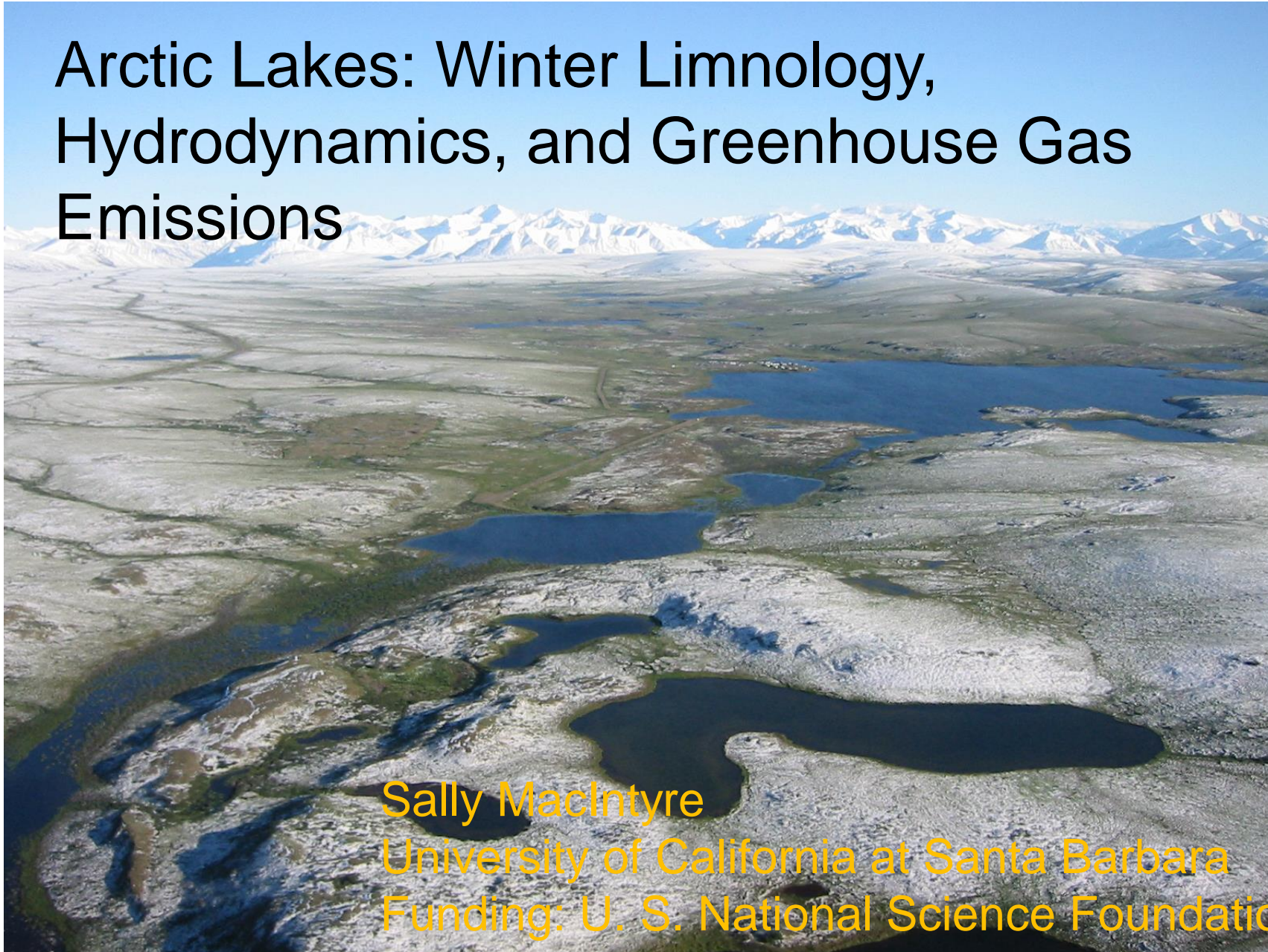


Arctic Lakes: Winter Limnology, Hydrodynamics, and Greenhouse Gas Emissions

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Funding: U. S. National Science Foundation



First, Lets Start with an Advertisement:

T-Mosaic

Executive Summary

Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections ([T-MOSAiC](#)) has been formulated as a research and synthesis project to provide an integrated, cross-disciplinary evaluation of how the changing Arctic Ocean affects terrestrial environments, from the coastal zone to the continental interior. The project will connect studies taking place throughout the Arctic and across disciplines in order to generate new insights into northern geosystems, ecosystems and human systems. Key aspects to be addressed include connectivity, gradients, discontinuities, thresholds, extreme events and emergent properties, with specific questions that bridge sites and disciplines. Data sets will be made available via open access repositories, with the intention to create merged, interoperable data compilations. T-MOSAiC will run in parallel to the ocean-based project Multidisciplinary drifting Observatory for the Study of Arctic Climate ([MOSAiC](#)), with temporal overlap in 2019-2020 and exchange of data sets such as climate observations from land and ocean stations.

T-Mosaic Will Test Hypotheses Related to Marine Influences on Coastal Land Environment

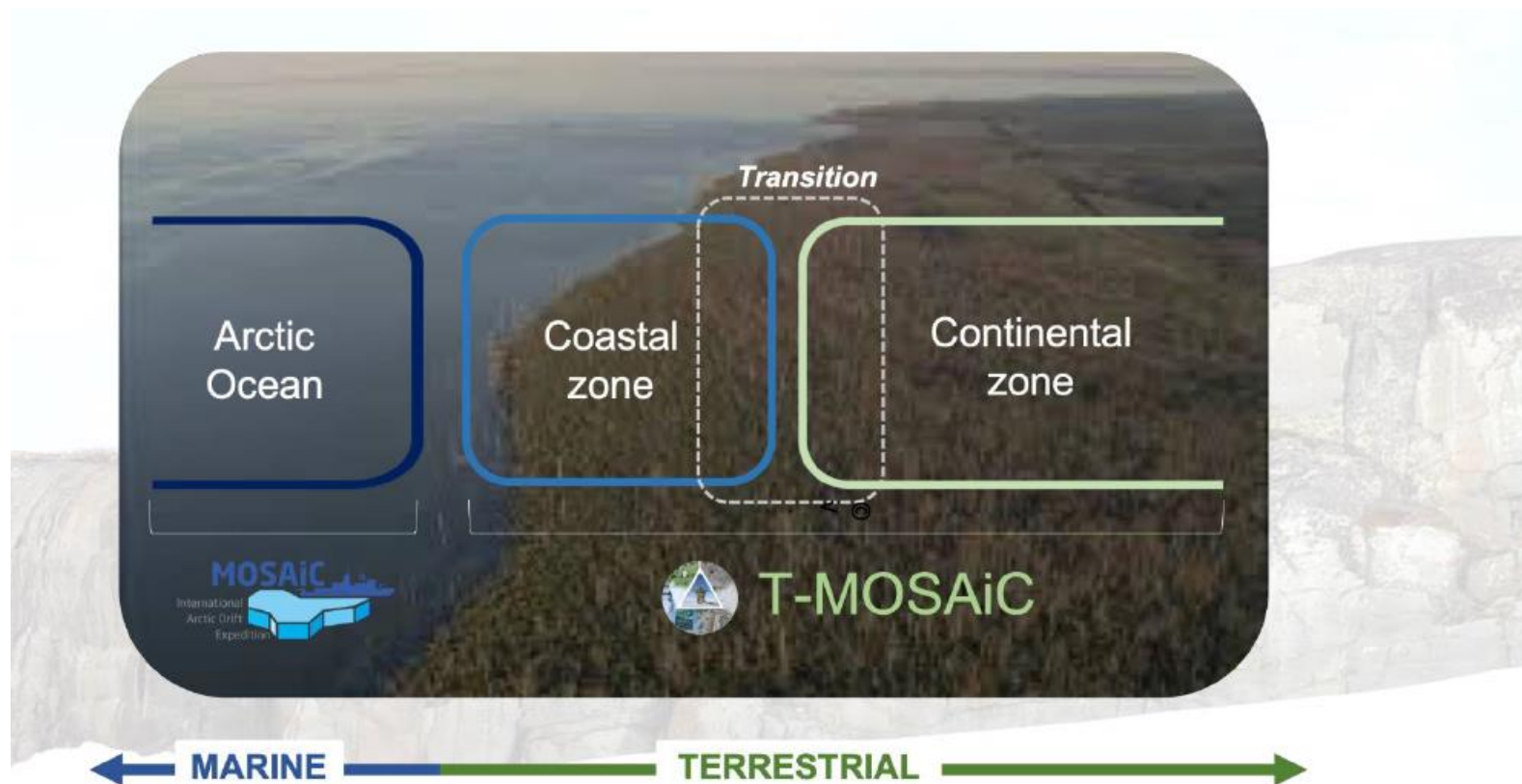


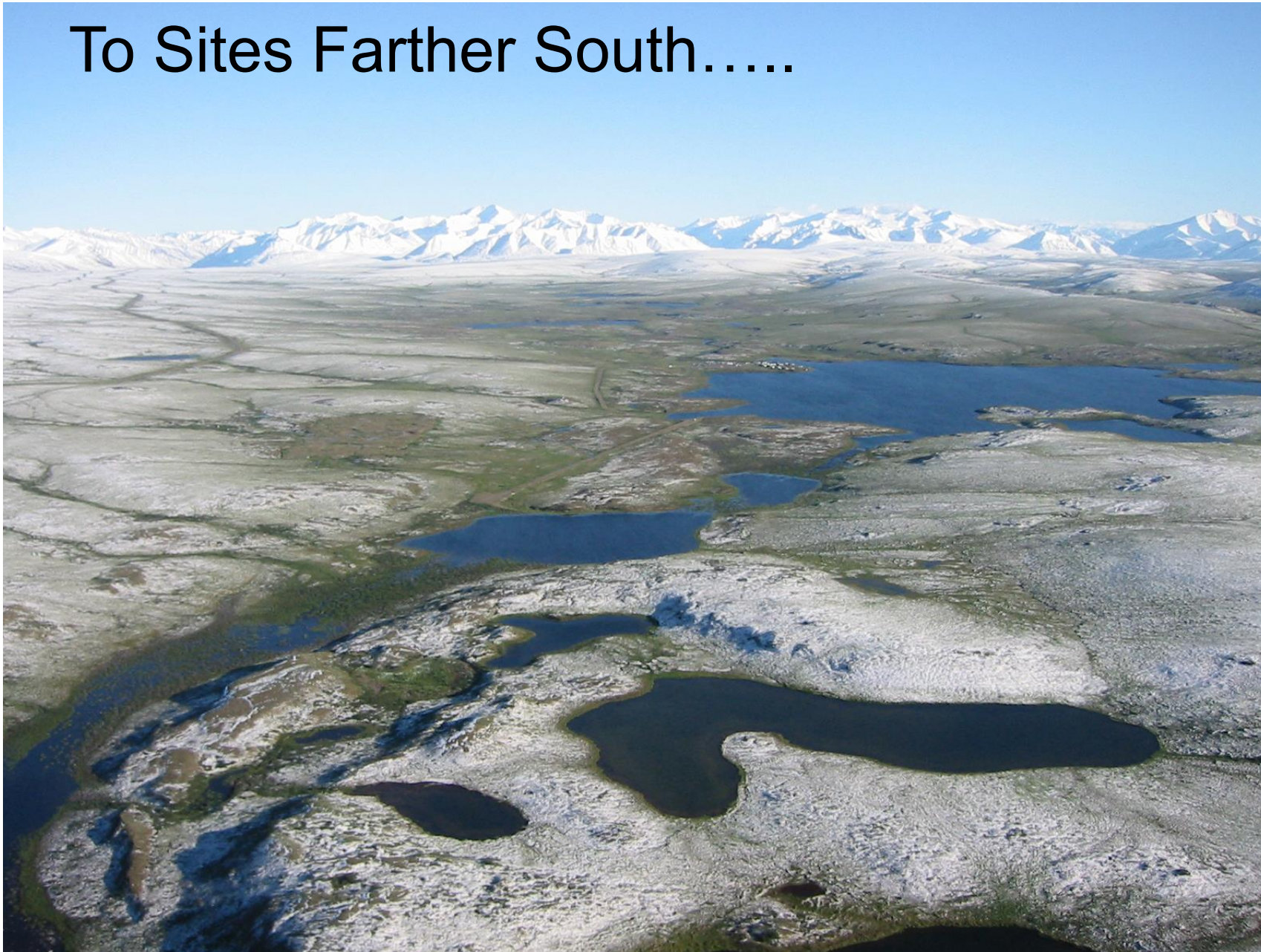
Figure 2. The terrestrial zones considered by T-MOSAIC.

Measurements will be conducted in the same time frame as those for MOSAIC – Jan – Dec 2020

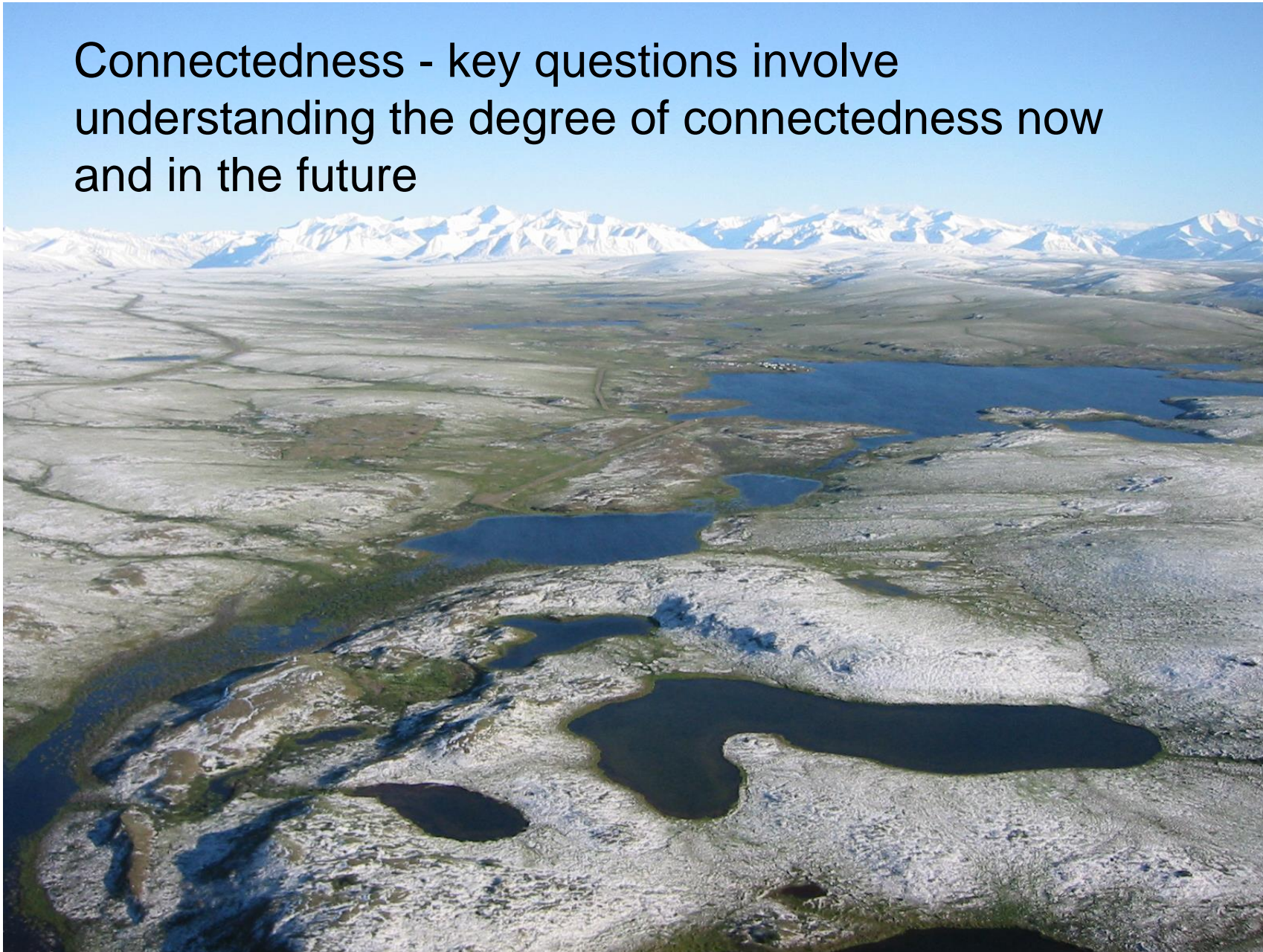


In Alaska, transects could run from the coastal plain...

To Sites Farther South.....



Connectedness - key questions involve understanding the degree of connectedness now and in the future

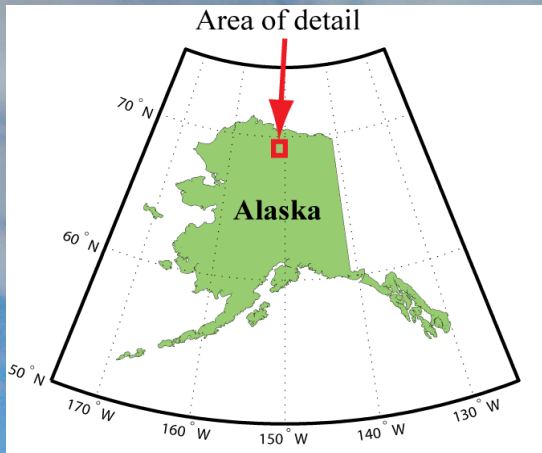


Despite their Small Surface Area relative to the Surrounding Terrestrial Environment

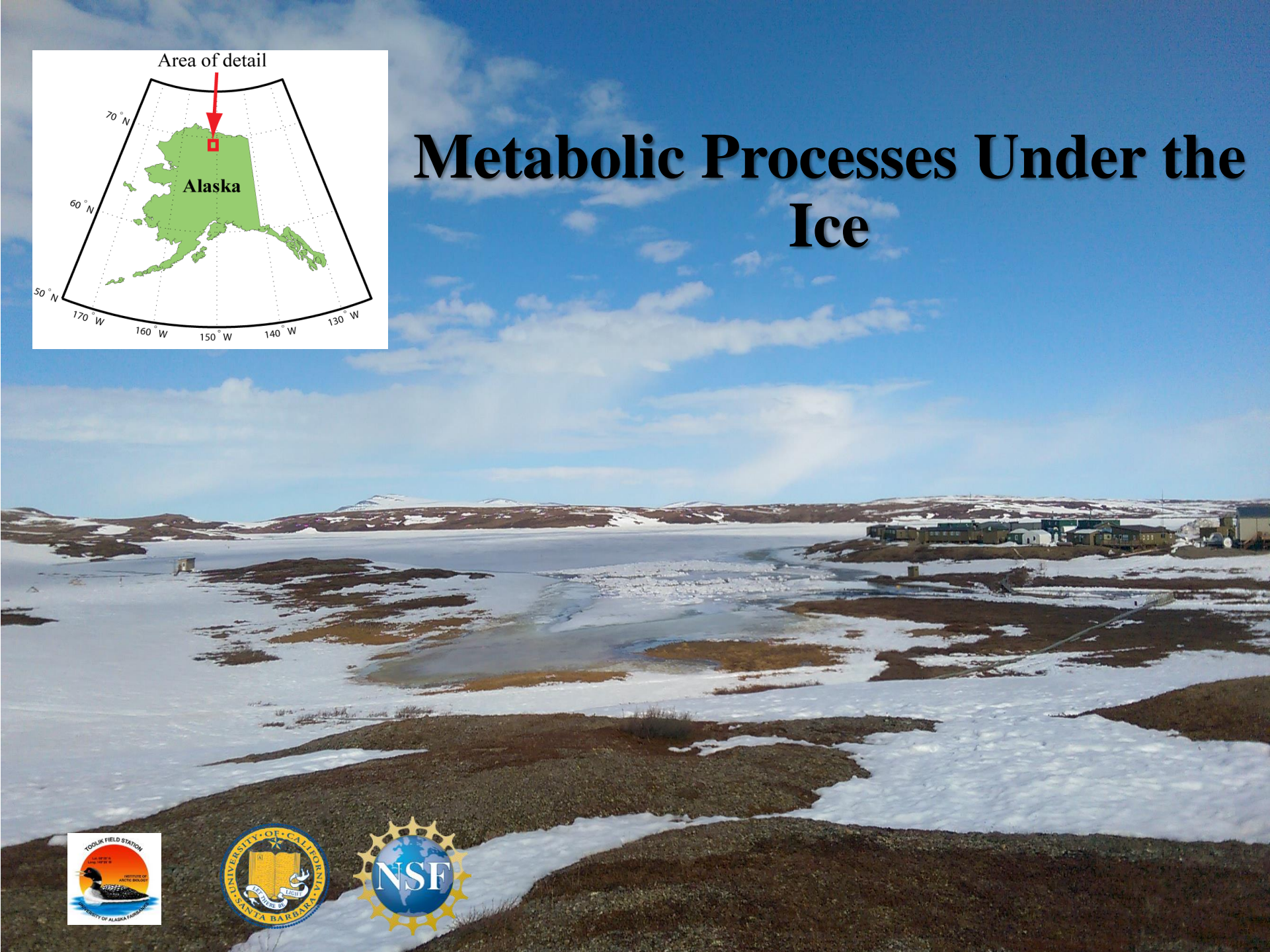
Lakes, Streams and Rivers make a large contribution to
Terrestrial Carbon Budgets.

They sequester carbon in their sediments and they emit
greenhouse gases to the atmosphere

What are the links between terrestrial and aquatic systems
that determine the magnitude of emissions?



Metabolic Processes Under the Ice

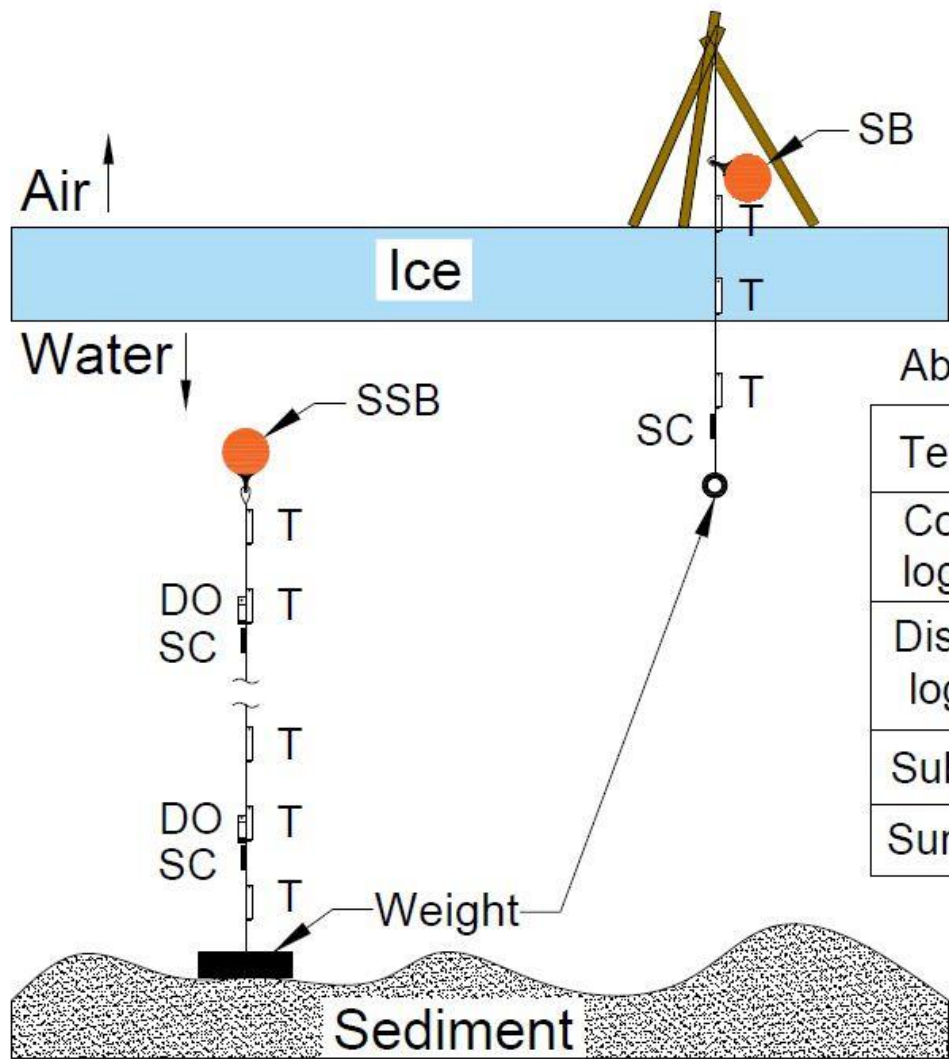


Incoming Snowmelt and Stream Water



How much is retained? How is it processed? Does it just flow out of the lake?

Sub-surface and in-ice over winter thermister chain deployment



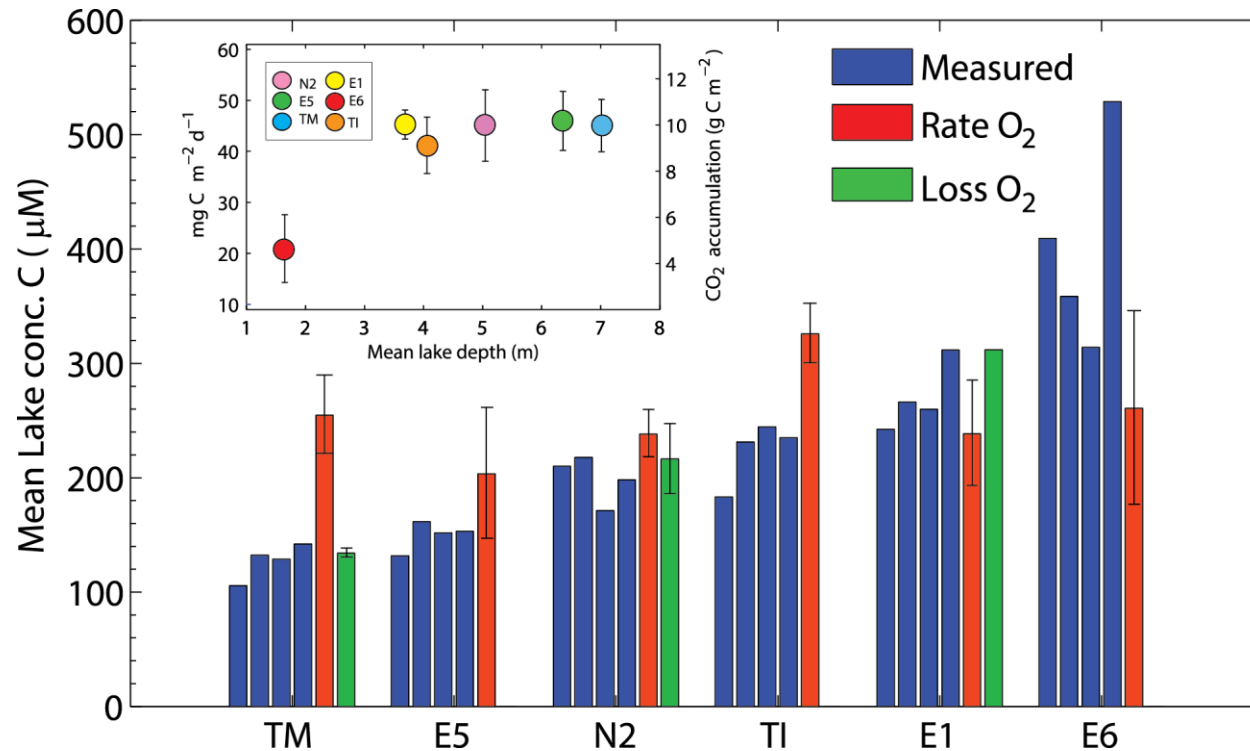
Abbreviations:

Temperature logger	T
Conductivity logger	SC
Dissolved oxygen logger	DO
Sub-surface buoy	SSB
Surface buoy	SB

Combined with samples for dissolved gases and DOC



Production of CO₂ during the Winter



Produced by sediment respiration.

What is the source of the organic matter?

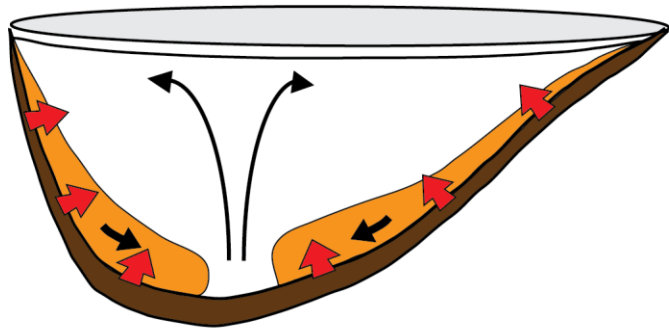
Landscape?

Phytoplankton- Unlikely

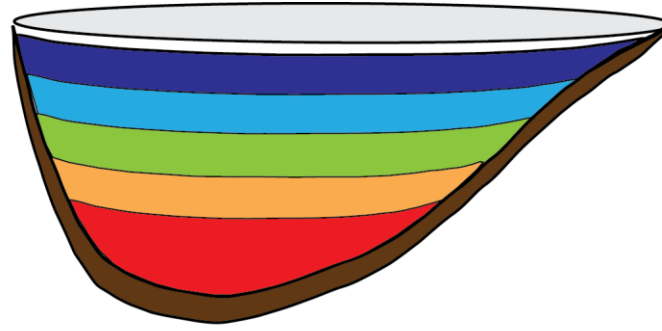
Macrophytes?

With changing hydrology, expect greater loading of POC and DOC. Effects on foodwebs and GHG production depend on CDOM.

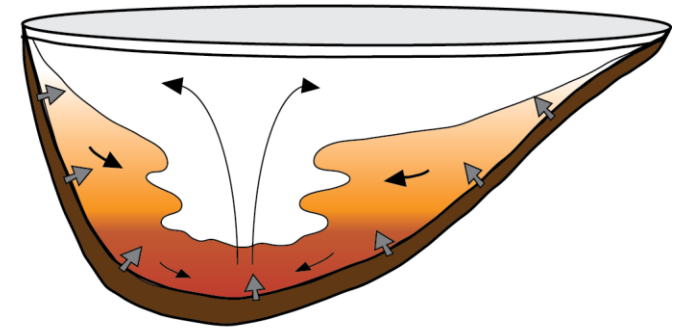
Sediment Respiration Drives Convective Circulation Under the Ice



a) Initial density currents



b) Stratification

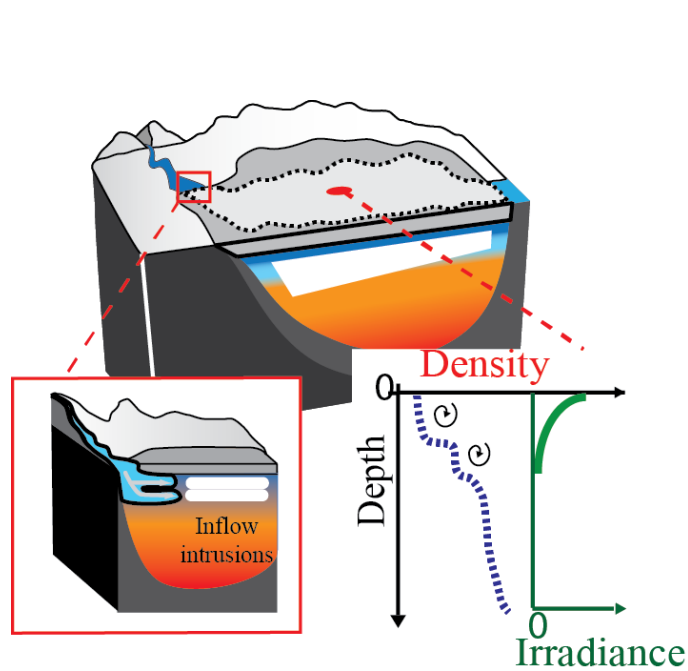


c) Intermediate density currents

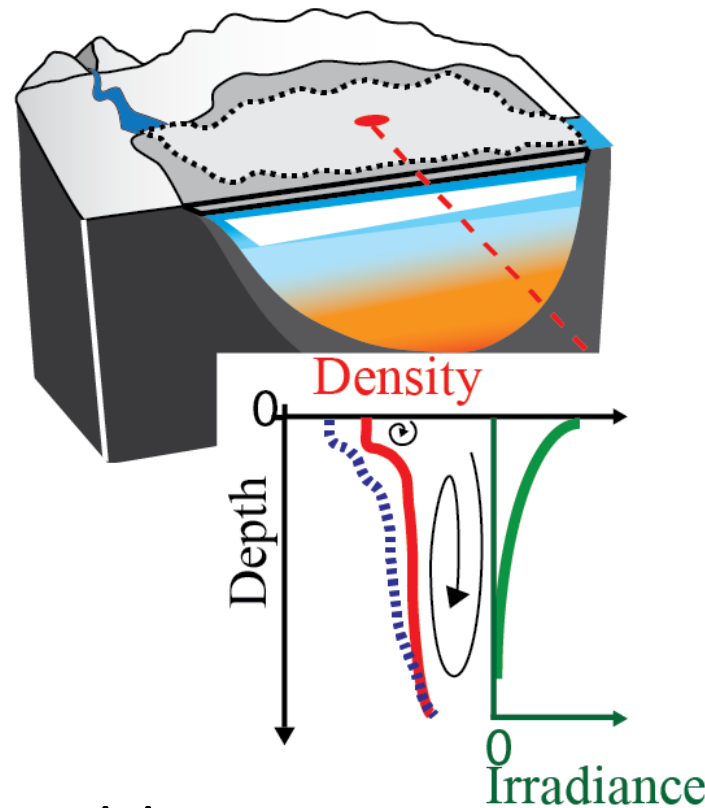
The degree of lake warming in summer plus allochthonous and autochthonous labile organic matter will moderate flow rates.

How will those drivers affect density stratification and resultant extent of anoxia, fish habitat, and production of CO_2 , CH_4 ?

Are solutes in snowmelt retained or do they flow downstream?



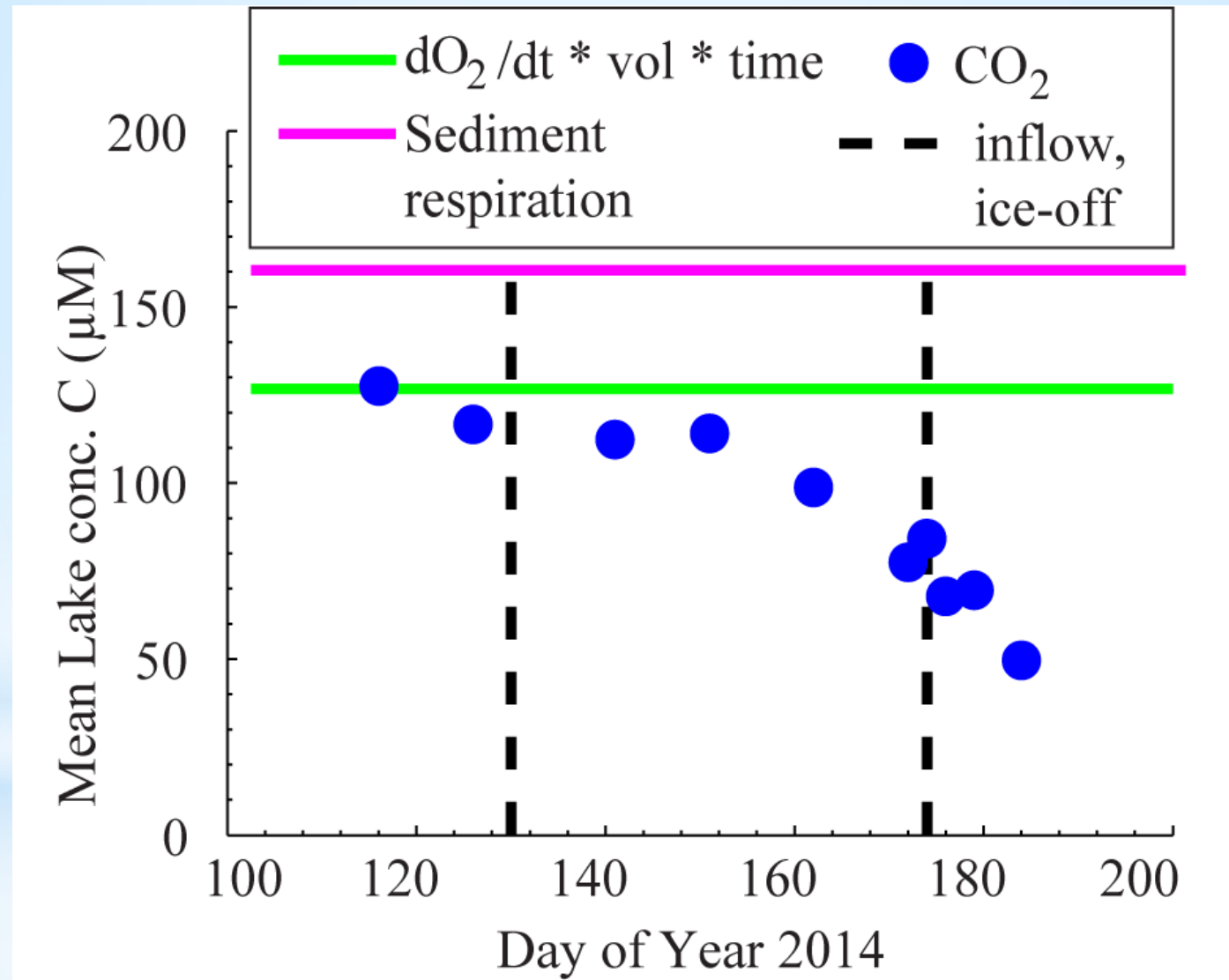
Thick ice and snow cover limit convective mixing .
Snowmelt largely passes through.



With thinner,
clear ice, solutes
are mixed
downwards

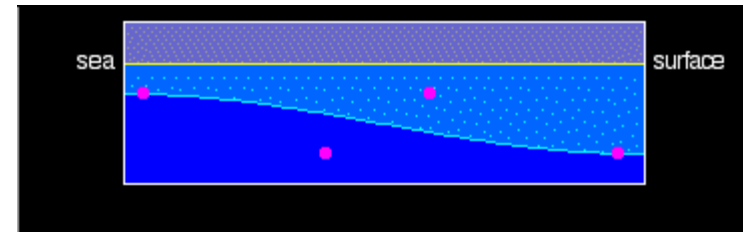
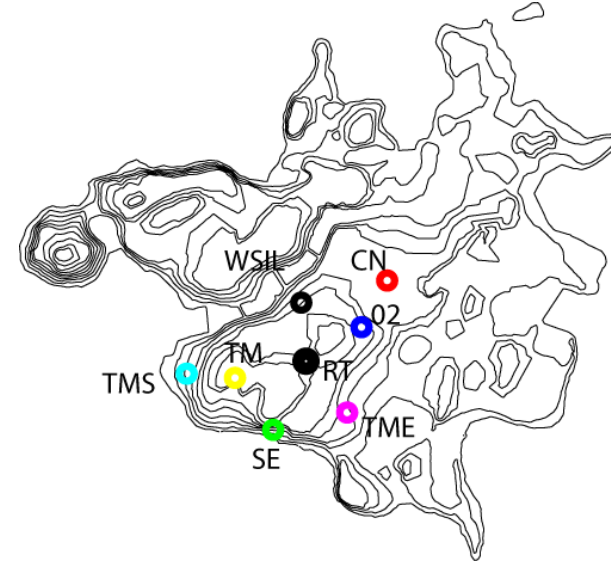
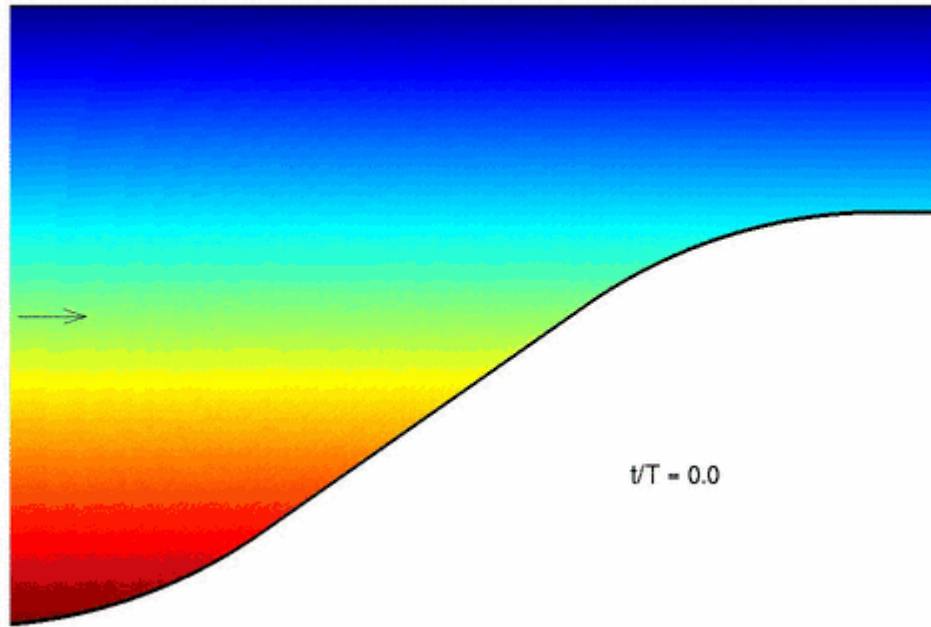
In Future Climates, how will quantify of snow and ice
vary and, in response, the loading to arctic lakes and
connections downstream?

CO₂ produced over the winter flows out the outlet, is mixed at ice-off such that it evades, and some is retained.



Toolik Lake, AK.

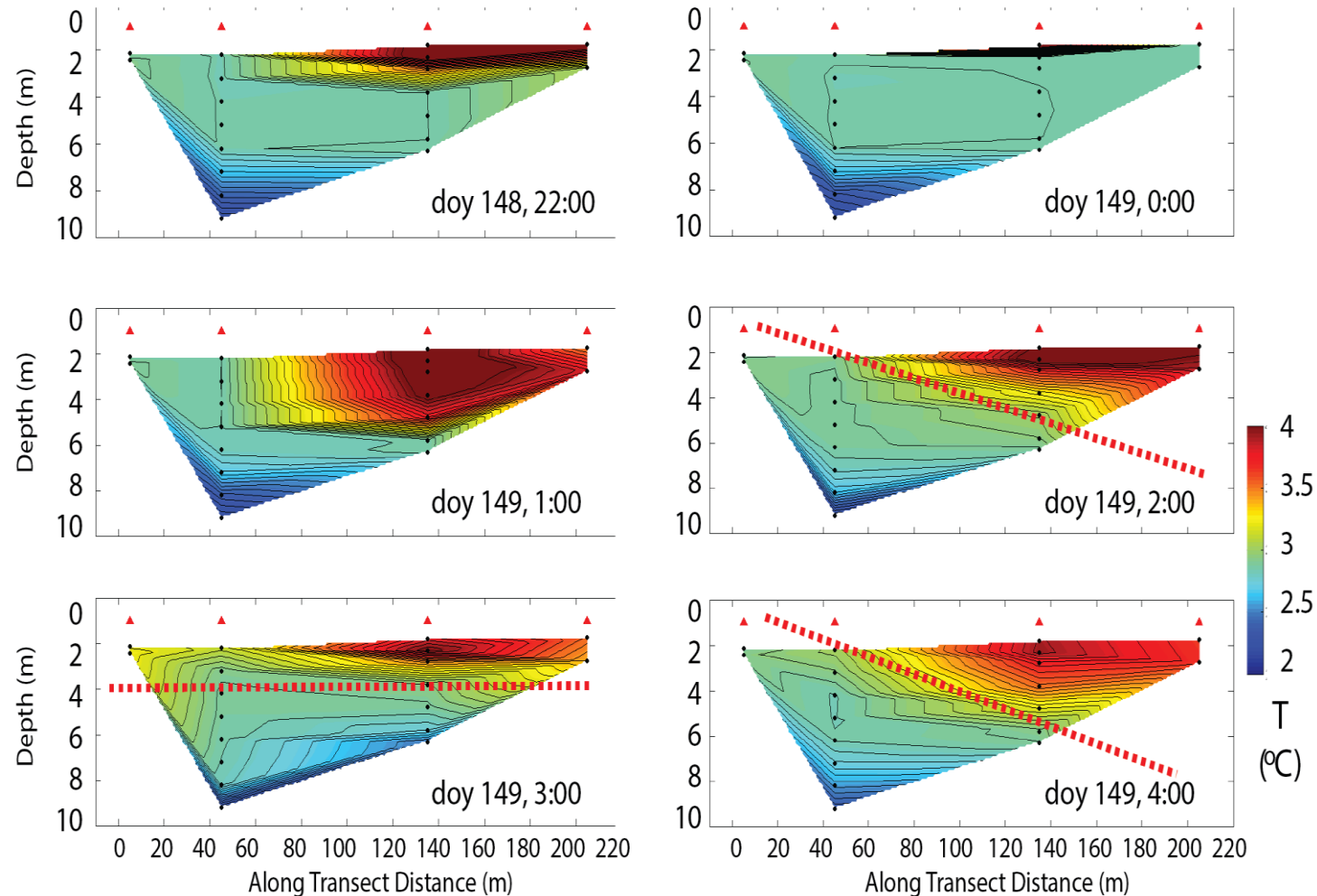
Retention of Solutes Introduced or Produced Depends on Mixing at Ice-off



Extent of wave breaking depends on thermocline tilt;
Vertical fluxes result.

Predicted from **Lake number** – allows scaling to other lakes

Rapid Introduction of Heat, despite Cross Basin Upwelling, leads to persistence of anoxia and CH₄ in Small Lakes



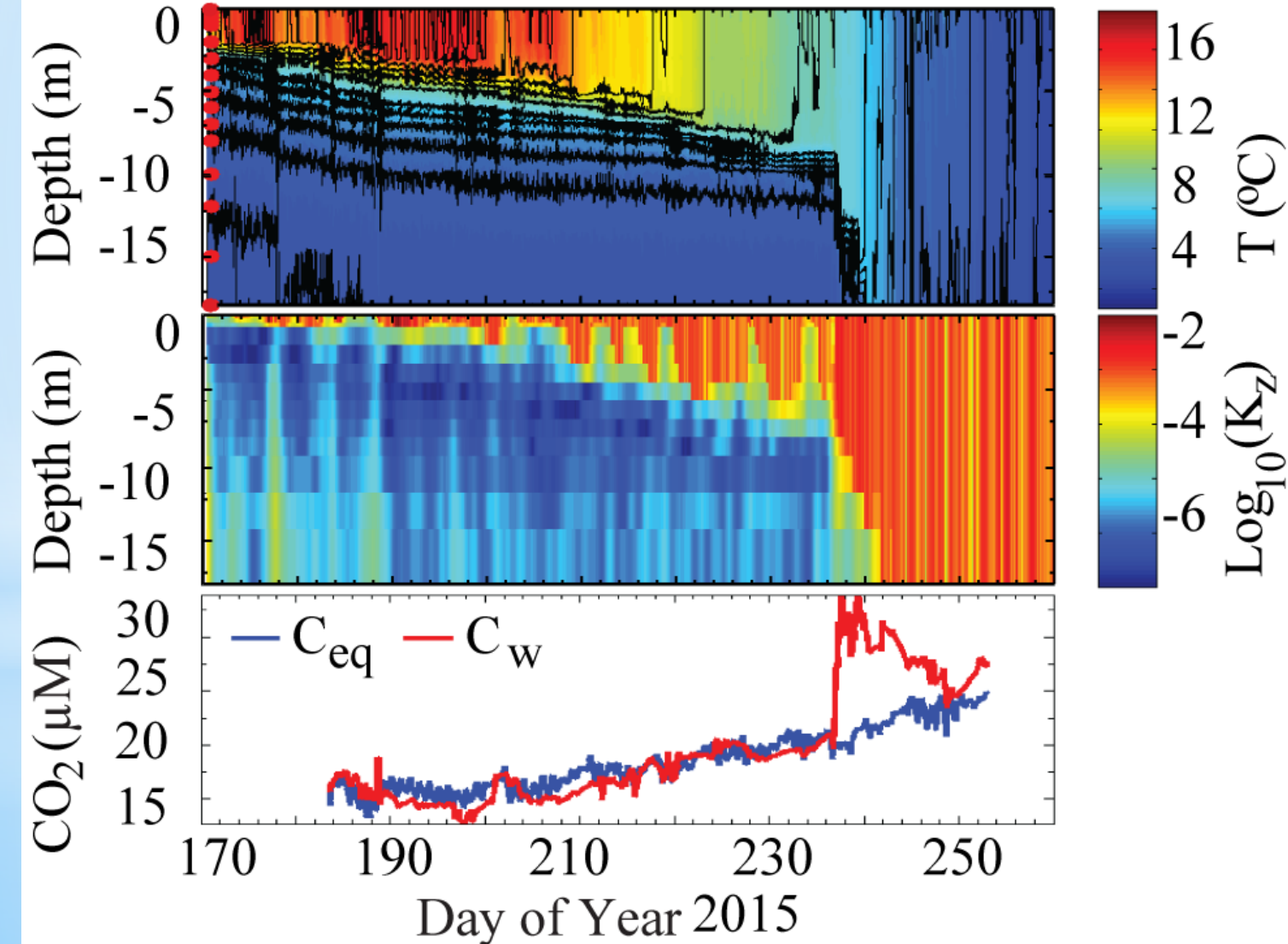
Lake N2
at Ice Off, $W < 1$

Emissions in Summer- $\text{Flux} = k (C_w - C_{eq})$
When was the CO_2 produced? Summer or Winter?



K from Tedford et al. (2014); MacIntyre et al. (2018)

Mixing in Summer allows Release of Dissolved Gases Are they residual from Winter or Produced during Summer?



Emissions in summer 2015 were $1/6^{\text{th}}$ of winter production.

In some years, the summer emissions were equal to the residual left after ice off.

What is being respired?

Isotope studies are required.

Future Studies:

Questions as posed by T-mosaic linking the atmosphere, ocean, cryosphere and all components of the terrestrial landscape

What is the connection between processes in winter and the functioning of lakes in summer?

What is the contribution of benthic processes to full lake metabolism including aquatic macrophytes and epiphytic communities

And.....

What are Metabolic Rates in Small Ponds? Are they a Source of GHG?



Linking Hydromechanics and Metabolism in Small Ponds





Themokarst Thaw Ponds
Northeastern Canada

Streams During Snowmelt —

Bubbles which mediate gas exchange – are current estimates from Arctic Streams and Rivers too low?



As a start on this topic, working with informal international group, KITEX, to quantify emissions of GHG from an Arctic River in Finland with techniques including eddy covariance, chambers, gas concentrations, and turbulence measurements.



Overarching Goal: Linking processes across the landscape and including influences of the adjacent Arctic Ocean

Linking processes across the landscape including influences of the adjacent Arctic Ocean

