What is the role of frontal systems in lake mixing dynamics?

Characteristics of Arctic Lakes

- Cool summer: 2003
  - Cool epilimnion. Thin thermocline
  - Higher \( K_s \) in UML and in stratified waters below
  - Time scale for mixing across thermocline, \( L/K_s \), is days.
  - Many low \( L_9 \) events
- Warm summer: 2007
  - Warm epilimnion. Thick thermocline.
  - \( K_s \) is low by mid-summer
  - Time scale for mixing across thermocline, \( L/K_s \), is months.
  - \( L_9 > 10 \) frequently

Site Location: Toolik Lake, Arctic Long Term Ecological Research Program

Summer epilimnion temperature at Toolik lake measured by weekly CTD casts (green) and continuous sensors (red) show large variations in mean temperature and an insignificant \( (R^2 = 0.01, p = 0.97) \) warming trend. Epilimnetic temperatures in summers are warm or cold, and occasionally moderate. The lakes are weakly or strongly stratified depending on surface temperature.

Effect of Large Scale Forcing on Thermal Regime and Mixing Dynamics of Lakes in the Alaskan Arctic. S. MacIntyre, J. P. Fram, Paul J. Kushner, and B. Emery

Wind activity occurs on synoptic scales in cooler summers and vertical mixing, as indicated by Lake numbers and eddy diffusivities, is greater. Can we use these findings about inter-annual differences in synoptic activity at one lake to predict mixing dynamics in lakes over larger spatial scales?

Cool summers feature counter-clockwise atmospheric circulation offshore; warm summers feature a clockwise (anticyclonic) one.

The frequency of events which cause vertical exchange (low Lake numbers) can be predicted from lake temperature which depends on pressure differences between land and water.

Warm air temperatures occur at the Arctic LTER site when pressure is high to the north; such warm temperatures occur over a broad spatial region suggesting our findings about air temperatures, synoptic activity, and mixing dynamics at one lake will be applicable to others.

Summary

- Temperatures in Arctic lakes vary from cold, normal, warm to hot in summer. When cold, many more mixing events occur allowing nutrients, particulates and gases to be exchanged between the upper and lower water column with ecosystem consequences.
- Epilimnetic temperatures during summer in Alaskan Arctic lakes depend on air temperature and the variance in the wind field on synoptic scales.
- The wind field depends on the pressure difference. The windiest and coldest summers occur when the pressure difference is more strongly negative.

We hypothesize our findings about mixing dynamics in one lake will enable predictions about mixing dynamics in other Arctic lakes.

ECOLOGICAL CONSEQUENCES OF FRONTS AND RESULTING LOW LAKE NUMBERS

- Nutrients are mixed from the lake bottom.
  - Cold Summers - Non-linear internal waves form when Lake numbers go low and nutrients are entrained in the lower water column. The coefficient of eddy diffusivity \( K_e \) gets high so connectivity between upper and lower water column is high enabling increased growth.
  - Warm Summers - Connectivity is lower. Increased Chlorophyll in Upper water column in warm years when nutrients are added to surface waters. Lake numbers stay high and vertical mixing is suppressed. Thus nutrients are retained to support growth.

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