Geochemical, Biological and Limnological Responses of Arctic Lakes in Relation to a Changing Cryosphere

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Introduction

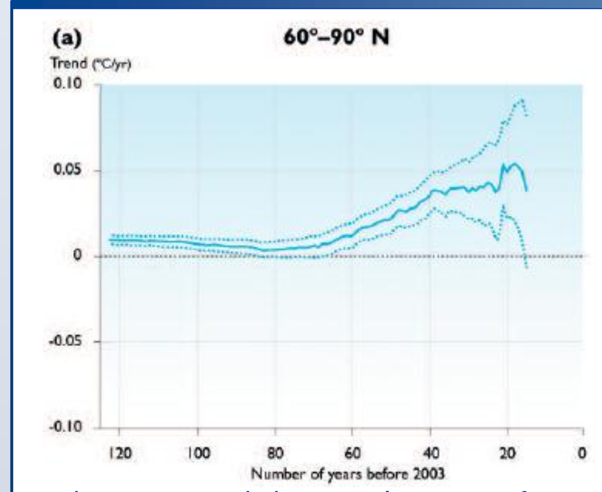

Figure 1. Trends in annual mean surface air temp. and their 95% significance levels. (ACIA 2005)

Climate Variability and Change:

- Increases in average temperatures over the Arctic have been approximately twice as large as the rest of the world, significantly reducing the duration and extent of key cryopsheric components (SWIPA, 2012)
- Arctic freshwater ecosystems have been identified as being sensitive to climate variability and change (CVC) (SWIPA, 2012)
- Increases in temperature, precipitation, and permafrost-thaw are likely to continue augmenting nutrient levels in Arctic lakes (ACIA, 2005)
- Consequently, developing an improved mechanistic understanding of the expected consequences of climate change on Arctic lake productivity is needed

Arctic Aquatic Productivity:

- Flanagan et al. (2003) developed a mechanistic model for predicting algal biomass (Chl a) from Total Phosphorous (TP) in Arctic lakes using a data set of 113 different lakes (≥60ºN)

$$\log(\text{Chl } a) = -0.418 + 0.332\log(TP)$$

($r^2 = 0.07$, n =113, $P<0.05$)

- A second analysis generated a regression equation, through backward stepwise regression, incorporating landscape variables, in addition to nutrient data, across a broader latitudinal gradient (40 to 70ºN)

$$\log(\text{Chl } a) = 0.38 + 1.74\log(TP) – 0.28(\log(TP))^2 – 0.03lat$$

($r^2=0.7$, n = 269, $P<0.05$)

- However, no such equation was developed exclusively for Arctic lakes

Goals and Objectives

Goal:

- To improve understanding of the limnological relationships between aquatic productivity, nutrients, and geochemistry across a gradient of lakes within the circumpolar Arctic in the context of a changing cryosphere (ie., alternations in permafrost and lake-ice conditions)

Objectives:

1) Using both the Flanagan et al. (2003) data set and new metadata, describe aquatic productivity relationships in Arctic across spatial gradients in the 4 different ACIA regions
2) With the inclusion of data from 500 new lakes (all ≥ 60ºN), determine if the nutrient, chlorophyll, and latitude relationships agree with the Flanagan et al. (2003) model
3) Describe under-ice limnological characteristics of a typical upland Arctic tundra lake

Methodologies

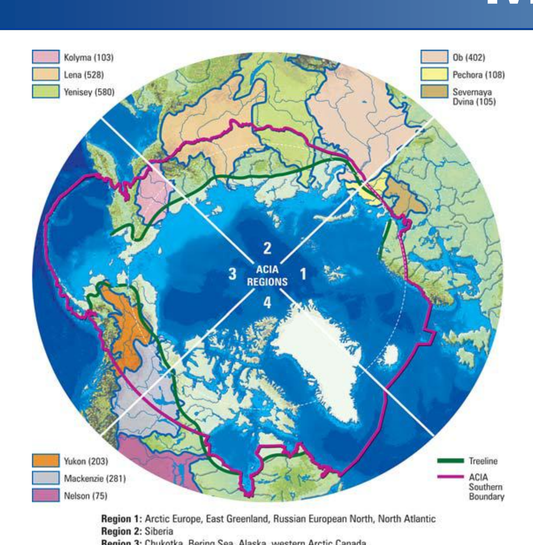

Figure 2. The 4 ACIA Regions, the southern boundary of the Arctic, and the major river systems flowing through these regions to the Arctic Ocean. (ACIA 2005)

1) New Metadata from 34 published sources, spanning 7 countries and comprising 485 sets of Arctic lake data, were compiled and analysed
2) Flanagan et al. (2003) analyses were duplicated using only metadata
3) Analysis of data from an automated ice buoy and subsurface mooring system as well as an under-ice field campaign

Results

Objective 1:

Table 1. Environmental, productivity, and nutrient characteristics of the 4 ACIA Regions.

Parameter Mean	Region 1	Region 2	Region 3	Region 4
Latitude	61.38	69.4	68.29	65.13
Longitude	22.12	86.65	-134.55	-95.91
Elevation (m)	110.8	127	272.5	108
Mean Depth (m)	5	3.5	7.5	5
Chl *a* (µg/L)	2.3	1.4	1.1	1
Total Phos. (µg/L)	14	6.85	7.5	7
Total Nit. (µg/L)	446.68	--	131.83	34.6
Ice Durat-ion (days)	208.6	--	265.4	274
Sample Size	59	5	302	324

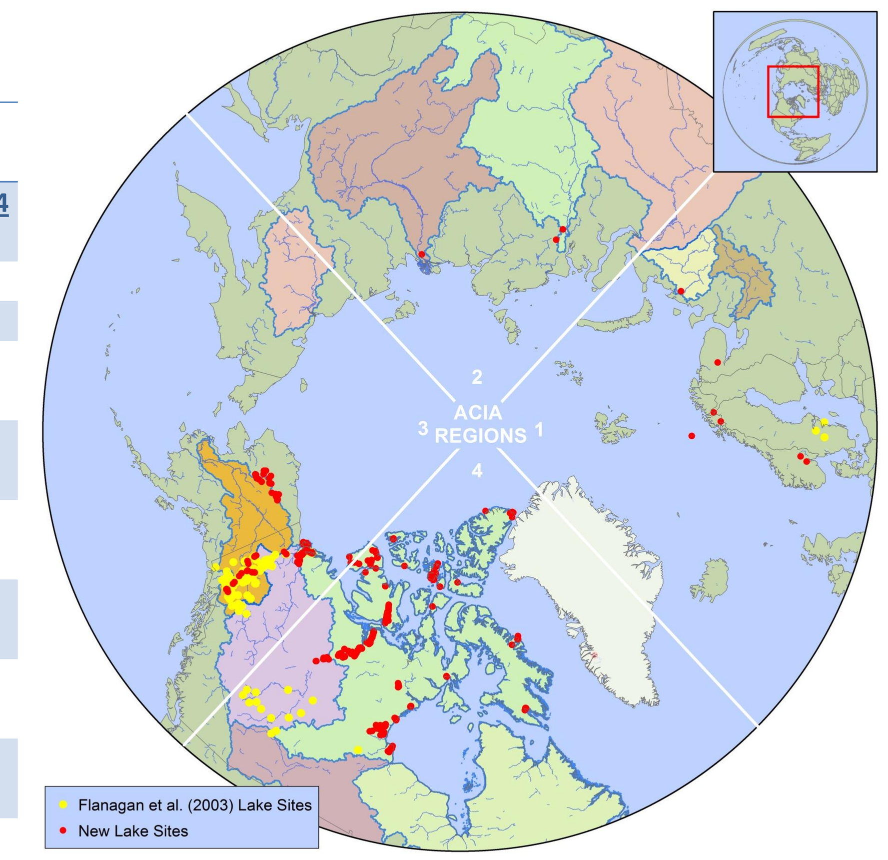

Figure 3. Spatial distribution of study sites.

Objective 2:

- The Chl a – TP analysis run in Flanagan et al. (2003) was repeated using the new metadata:

$$\log(\text{Chl } a) = -0.14 + 0.197\log(TP)$$

($r^2 = 0.054$, n = 427, $P<0.05$)

- Similarly, the multiple linear regression model was applied to the metadata:

$$\log(\text{Chl } a) = 0.565 + 0.205\log(TP) + 0.115(\log(TP))^2 – 0.0121lat$$

($r^2=0.129$, n = 427, $P<0.05$)

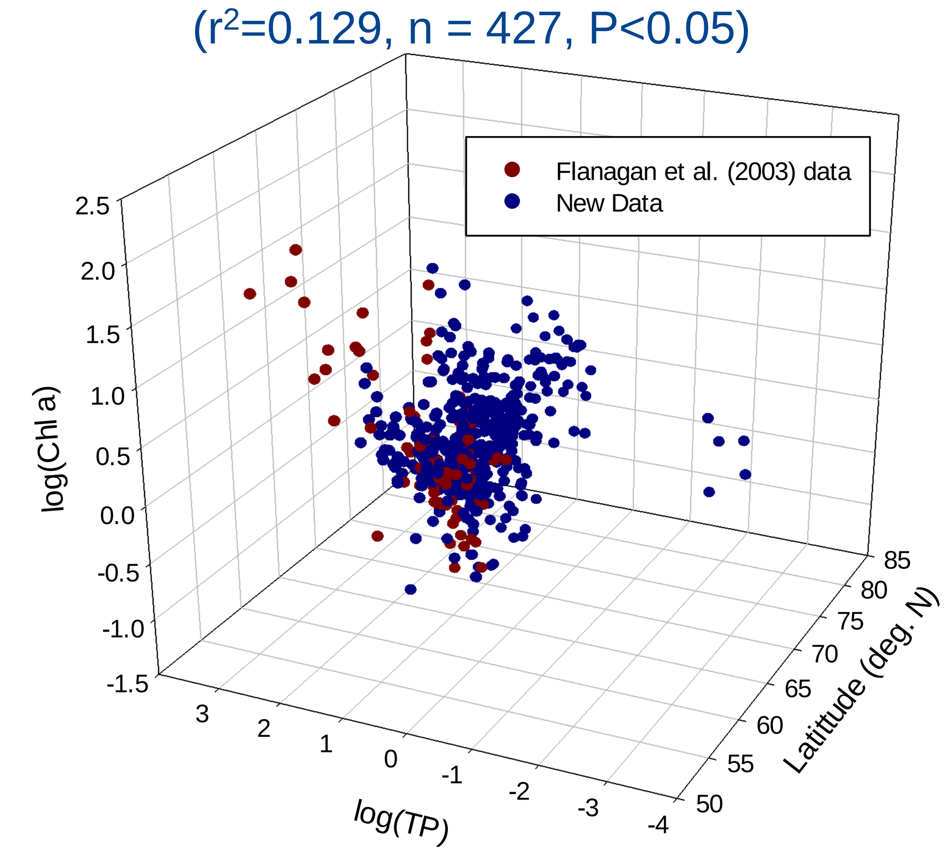

Figure 4. Graphical representation of the multiple regression model generated by Flanagan et al. (2003) including both data sets.

Results

Objective 3:

Figure 5. Location of Noell Lake, NWT.

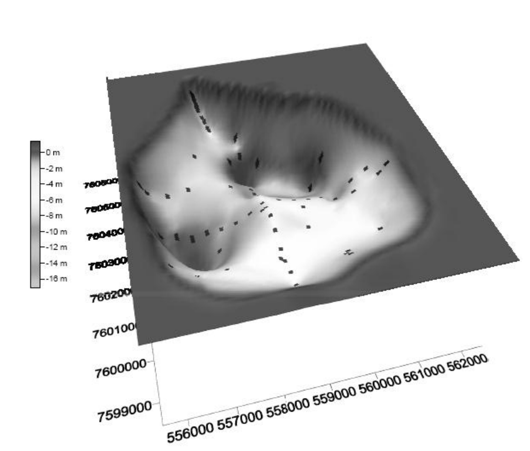

Figure 6. Bathymetry map of Noell Lake, NWT. (de Rham and Carter 2009).

Table 2. Environmental characteristics of Noell Lake, NWT.

Latitude[a]	68º31’37’’N
Longitude[a]	133º30’48’’W
Elevation (m)[a]	89.93
Surface Area (km^2)	30
Maximum Depth (m)[a]	17.8
Terrain[b]	Rolling tundra

SOURCES: [a]de Rham and Carter 2009, [b]Read and Roberge 1986

Results

Objective 3:

- Analyzed data were from an Arctic Lake Monitoring System (ALMS) ice-buoy and sub-surface mooring system which relay constant real-time meteorological and limnological data
- Under-ice sampling was performed in mid-May of 2012

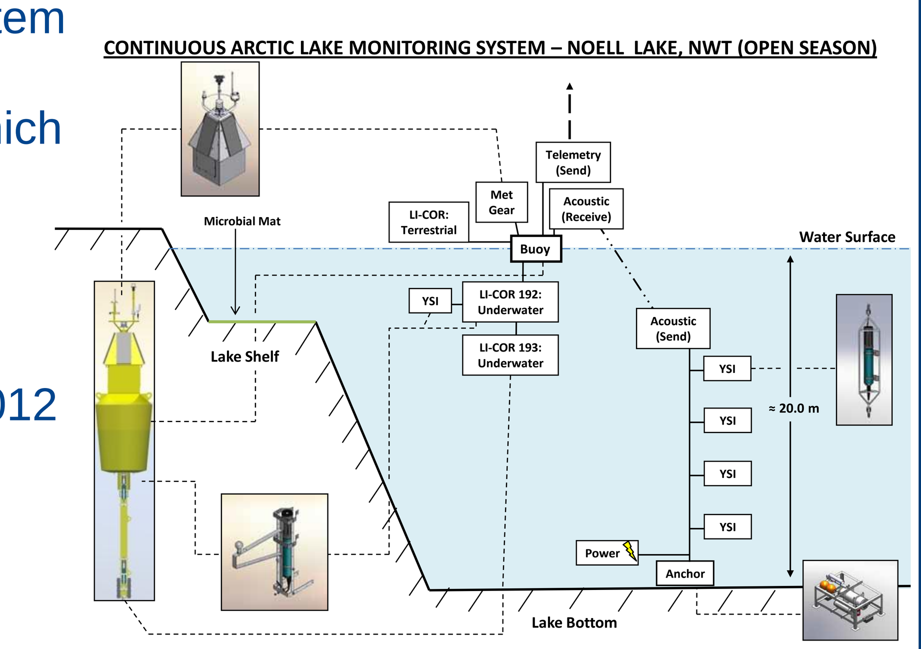

Figure 7: Schematic representation of the ALMS Ice Buoy and Mooring System used in Noell Lake, NWT.

Figure 8. Sampling locations of under-ice field campaign on Noell Lake, NWT.

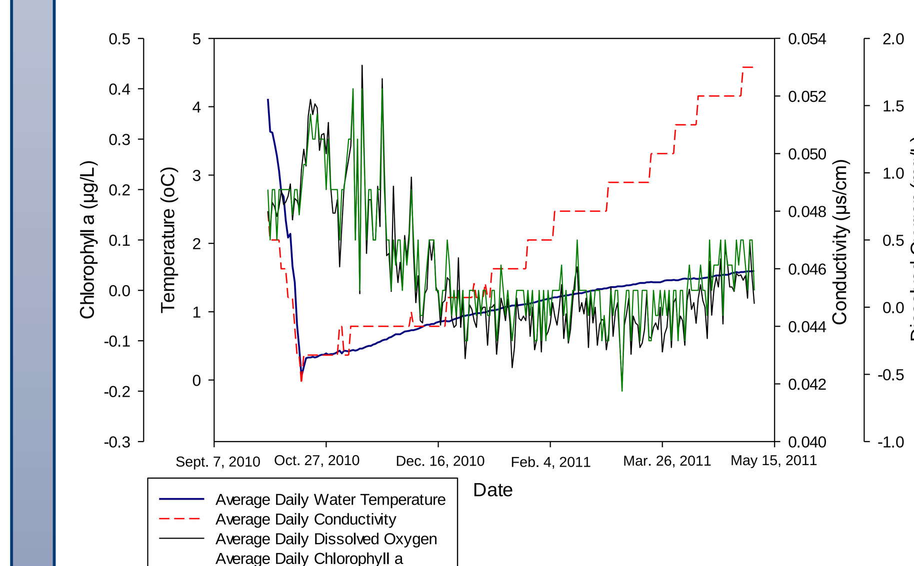

Figure 9. Under–ice environmental parameters of Noell Lake, NWT from Sept. 7, 2010 – May 15, 2011.

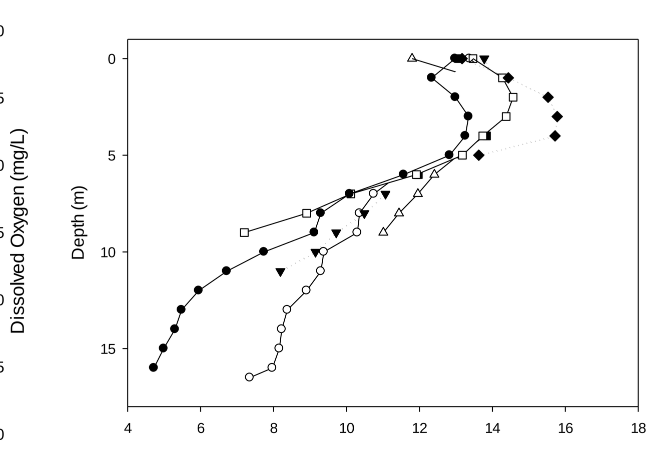

Figure 10. Under–ice dissolved oxygen profiles from various locations across Noell Lake, NWT, May 13th and 14th, 2012.

Conclusions

- Modeling with new metadata indicates that the Flanagan et al. (2003) model may not be robust with respect to the new data set
- ALMS Ice Buoy and Subsurface Mooring systems have generated promising information awaiting further analysis and exploration

Future Research

- Improve spatial coverage of lake data, with special focus on ACIA Regions 1 and 2
- Incorporate available ice data into existing data sets for inclusion in multiple linear regression analysis
- Further analysis of new metadata and ALMS data

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