Findings of the Cayuga Lake Monitoring Effort, 2013

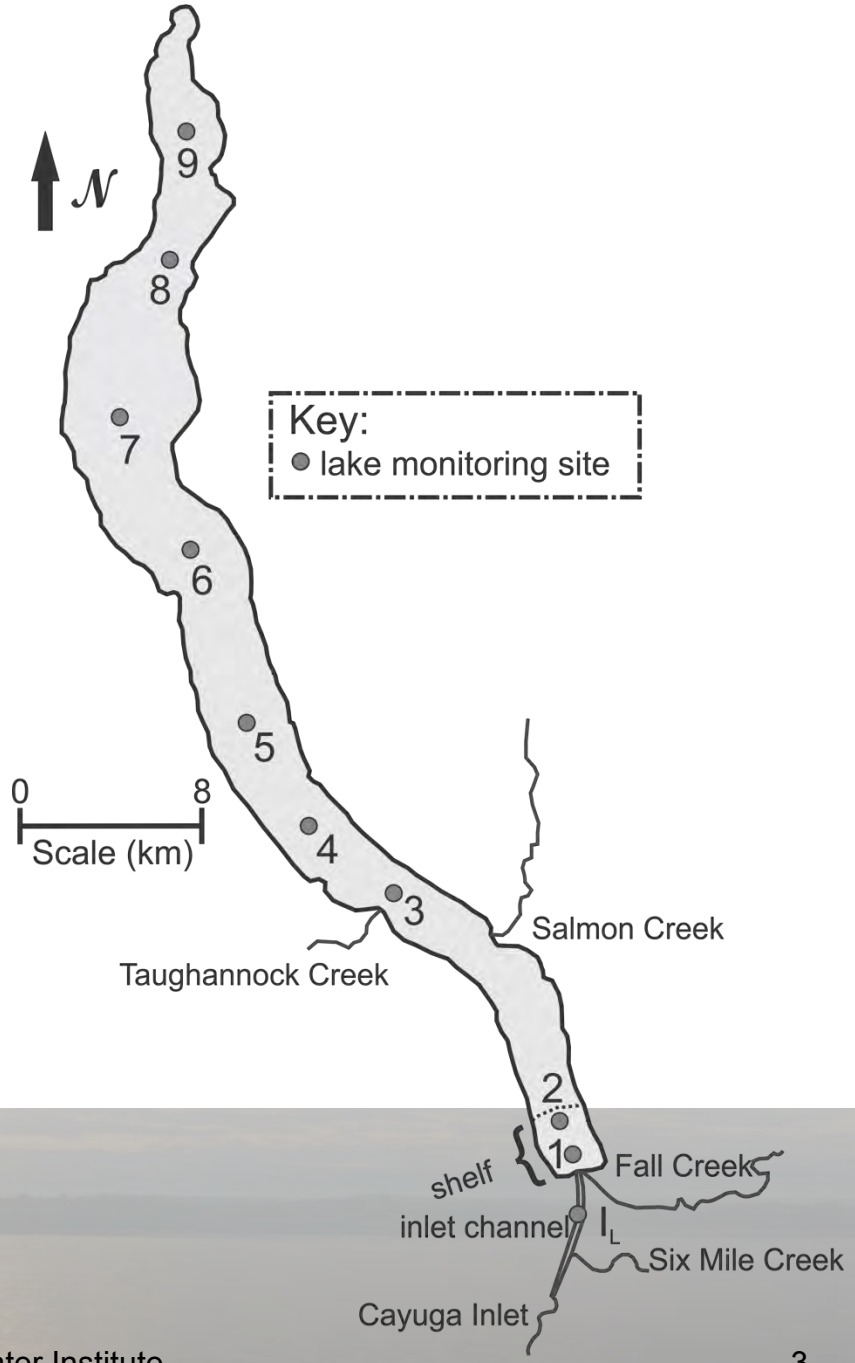
Cornell University

Talk Outline

1. patterns from field measurements
2. laboratory measurements
    a. spatial
    b. temporal
3. data analysis
    a. long-term trends
    b. chlorophyll *a*

Cayuga Lake, Sampling and Field Measurements for 2013

- bi-weekly, sites 1-9, Apr-Oct
- twice per week, sites 1, 2, and 3, June – Sept.



Temporal Signatures in Epilimnion Station 1

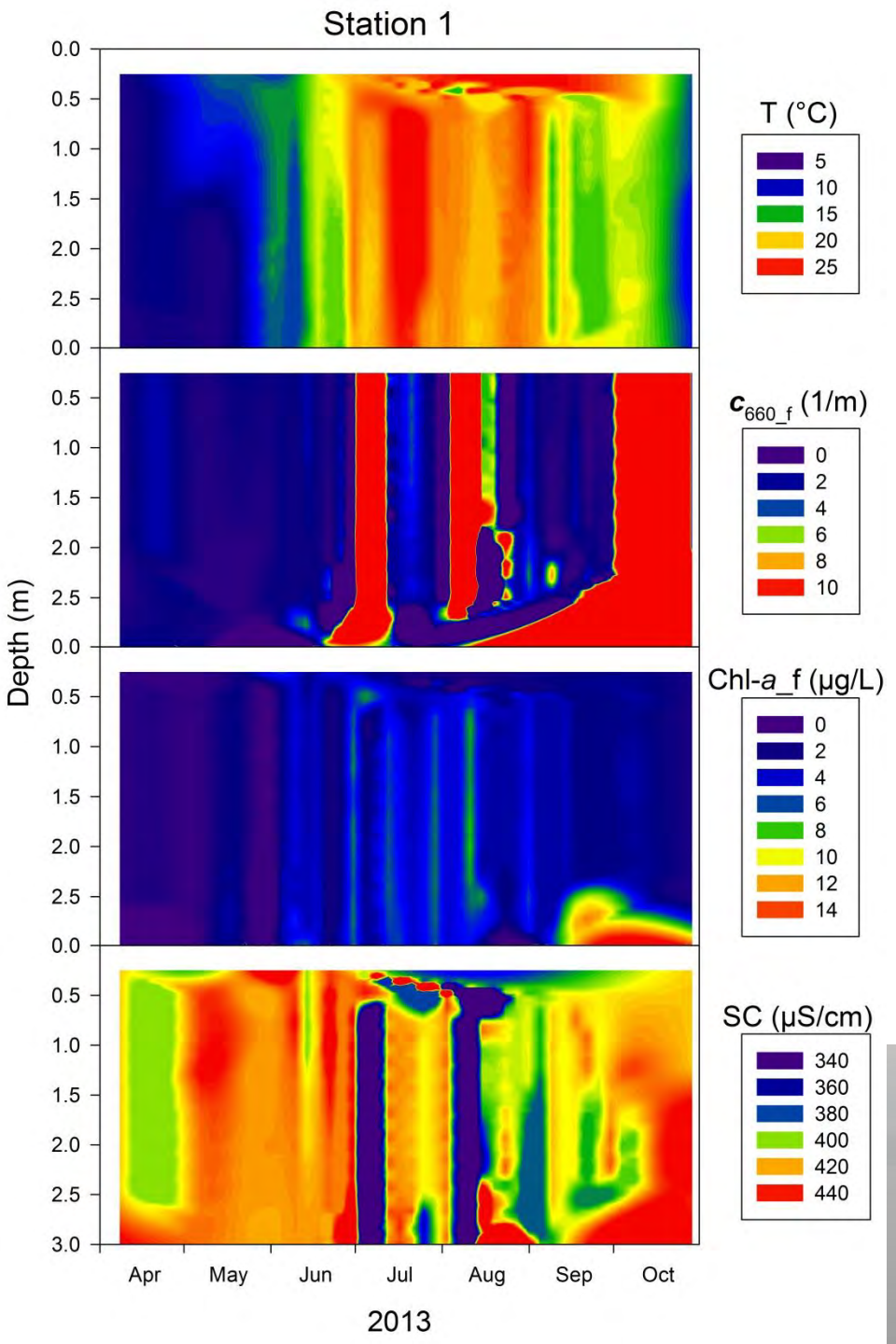
T - temperature

c_{660} – metric of light scattering coefficient

Chl-*a* - chlorophyll *a*

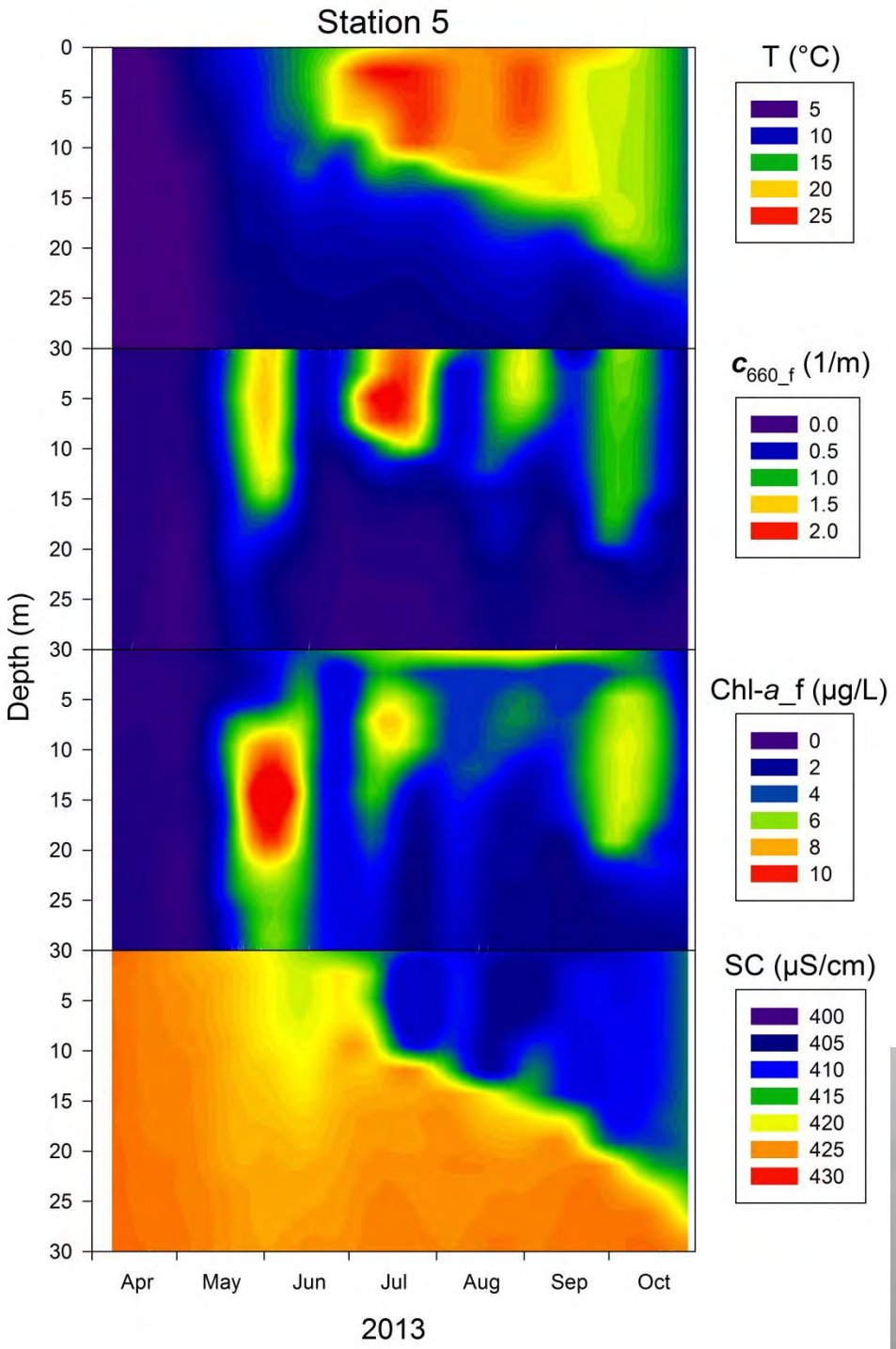
SC – specific conductance

strong dynamics on the shelf



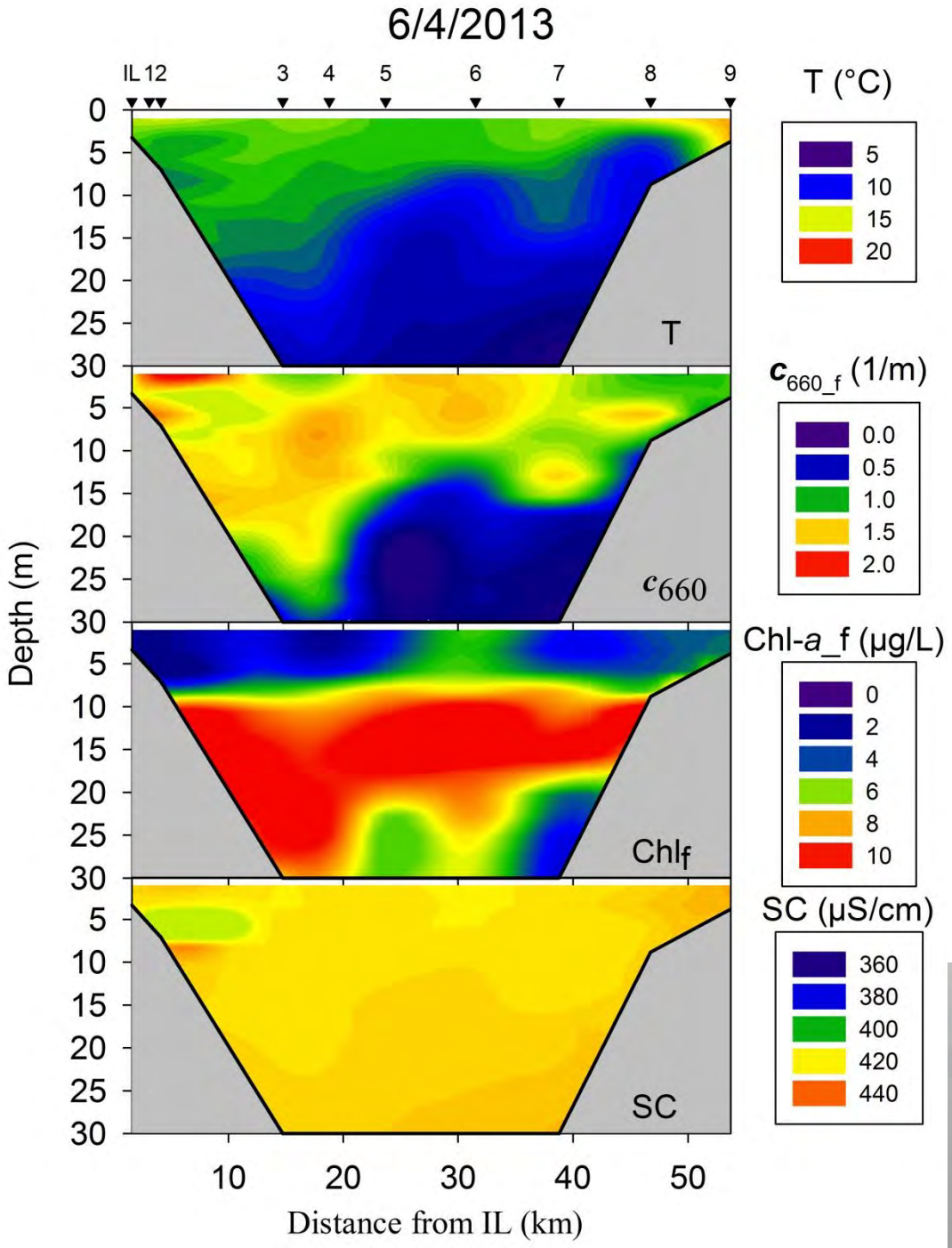
Seasonal Signatures in Epilimnion Station 5

- pelagic dynamics
- deep chlorophyll maximum (DCM)
- tributary inputs low SC



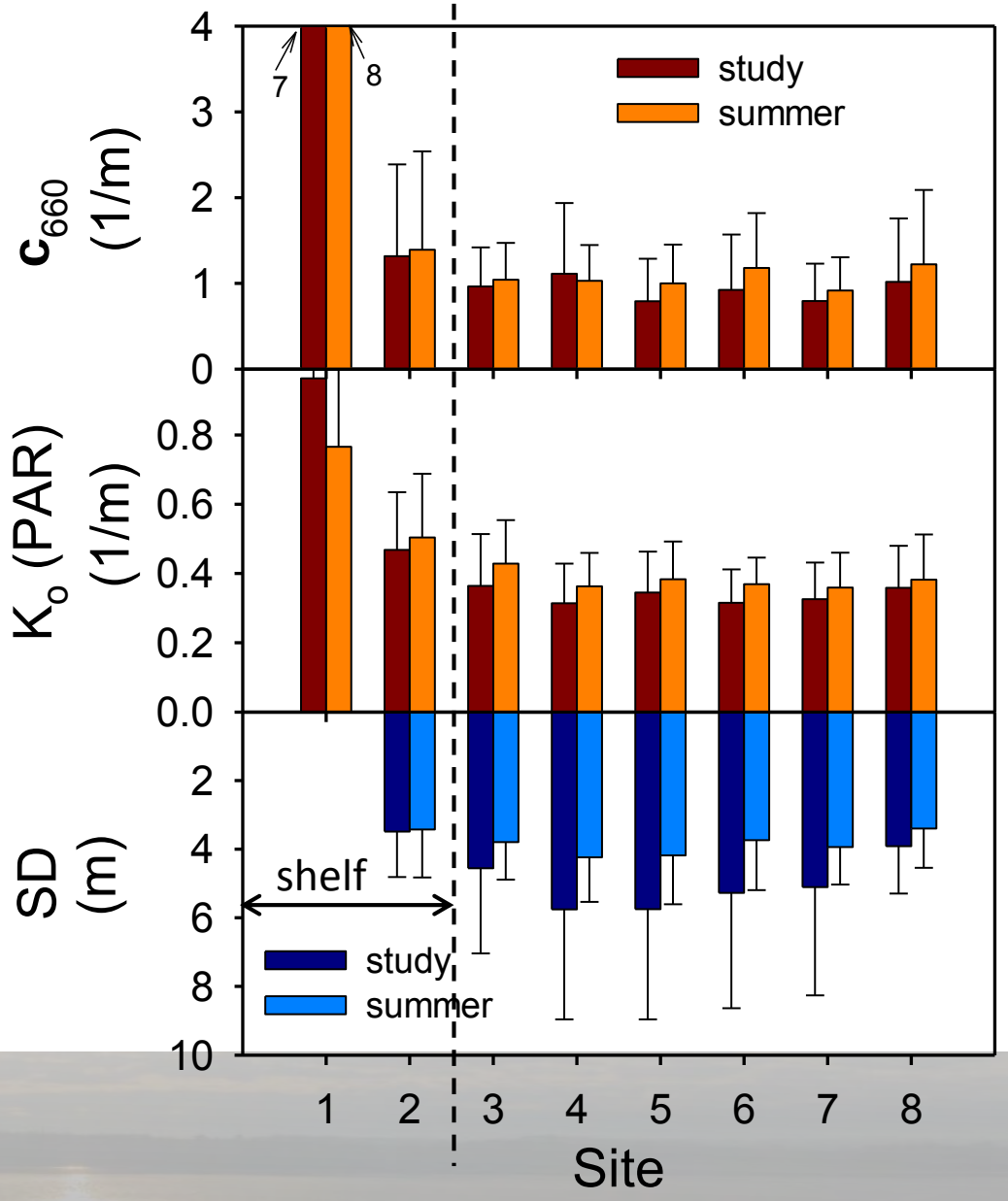
Longitudinal Variations

- June 4, 2013
- effects of a seiche
- DCM



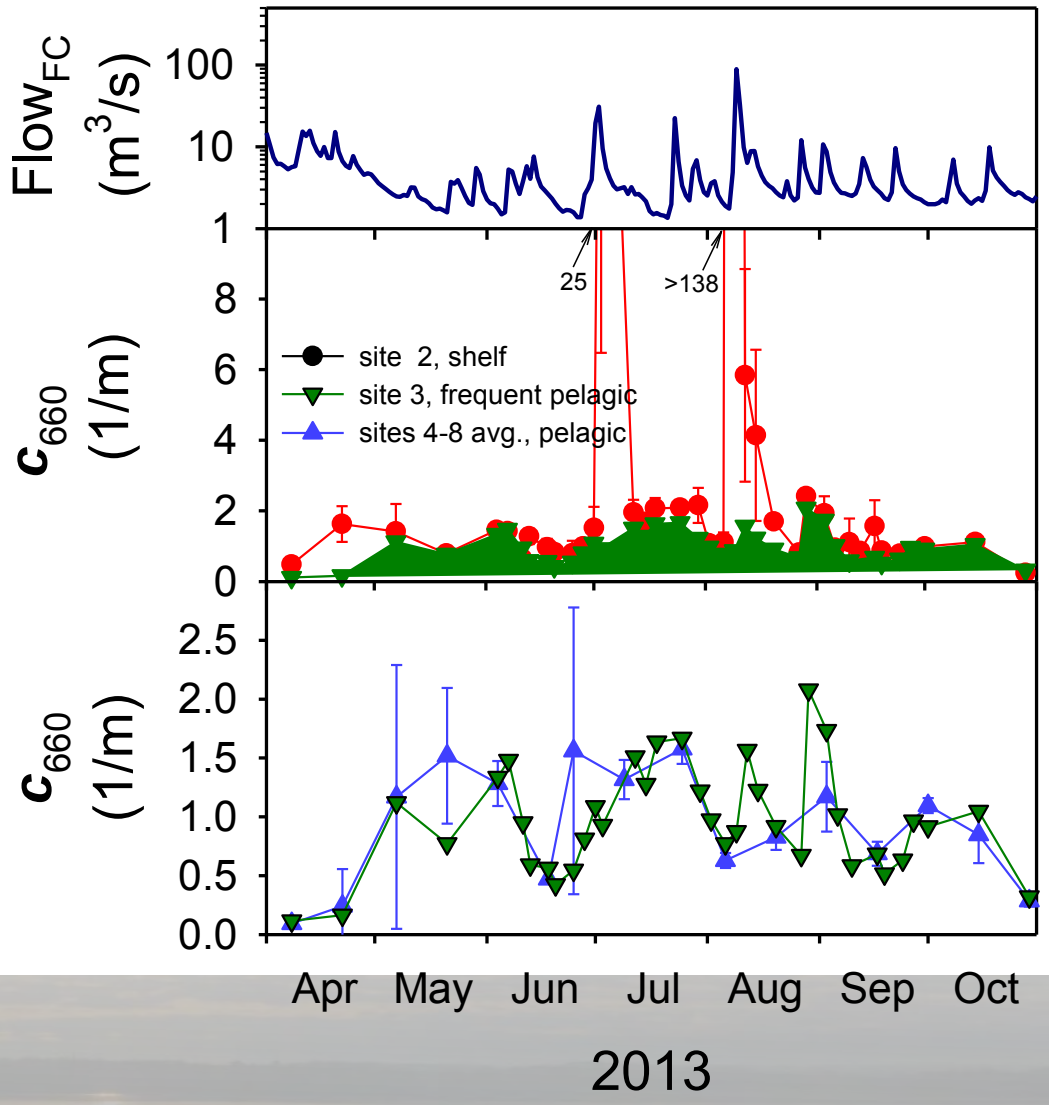
Optics Degraded on the Shelf

- K_o(PAR) – metric of light attenuation
- Secchi disk (SD) – metric of water clarity
- signatures of increased particle concentration on shelf



Runoff Event Effects on c_{660}

- greater on shelf, particularly after runoff events
- general uniformity in pelagic waters



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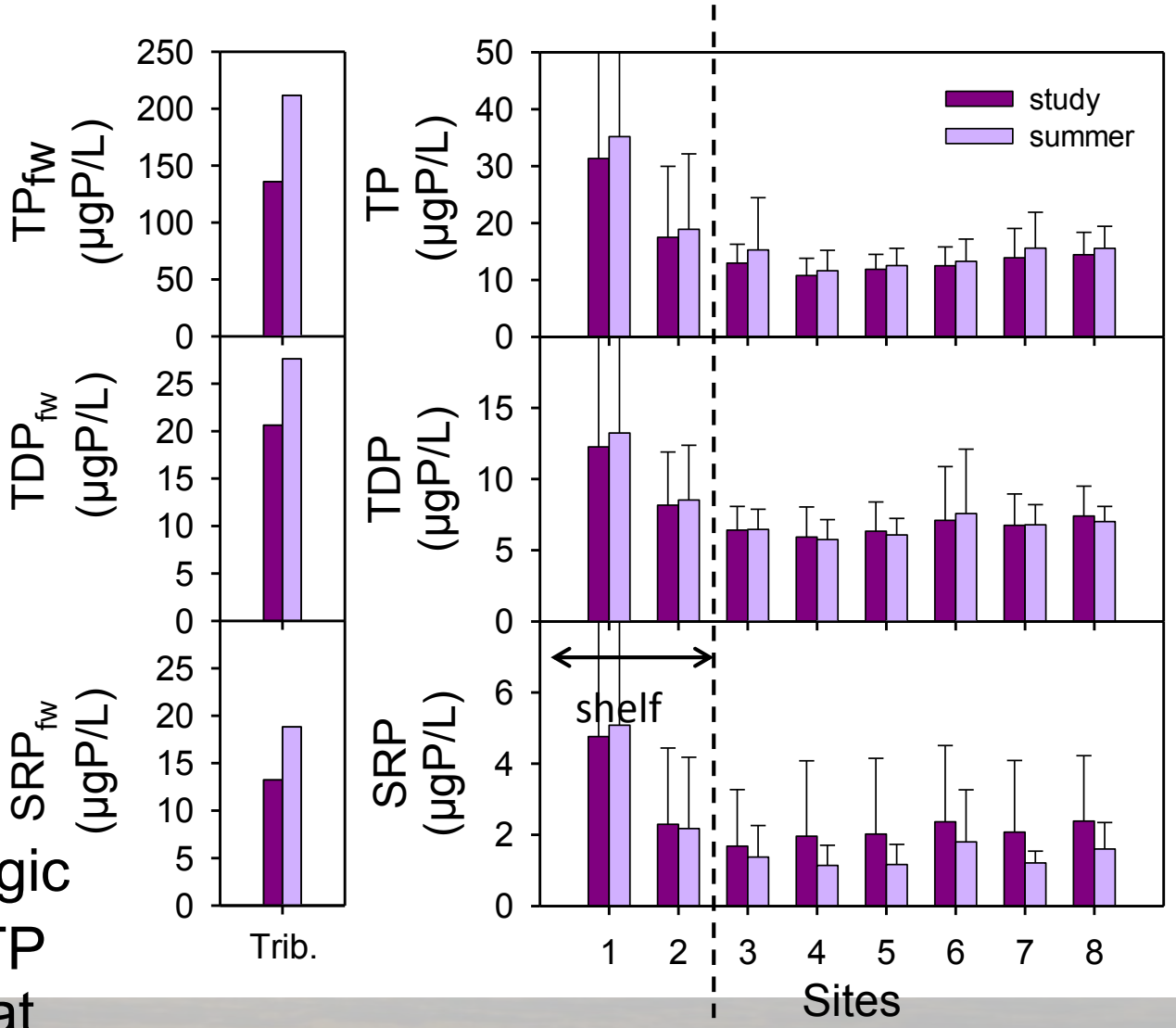
Lake Data Quality

- performance for triplicate samples

No.	Analyte	Abbreviation	Lake %CV (Sta. 5, 0m)	Salmon Creek %CV
1	dissolved organic carbon	DOC	3.8	2.1
2	chlorophyll *a*	Chl-*a*	5.6	--
3	particulate organic carbon	POC	13.0	--
4	nitrate + nitrite	NO_X	5.3	1.4
5	ammonia	t-NH_3	14.2	13.3
6	total nitrogen	TN	10.6	10.7
7	total dissolved nitrogen	TDN	7.2	--
8	total phosphorus	TP	5.0	6.9
9	total dissolved phosphorus	TDP	7.4	6.7
10	soluble reactive phosphorus	SRP	15.1	5.9
11	total suspended solids	TSS	11.4	8.3
12	fixed suspended solids	FSS	37.3	--
13	beam attenuation at 660 nm	c_{660}	5.7	--

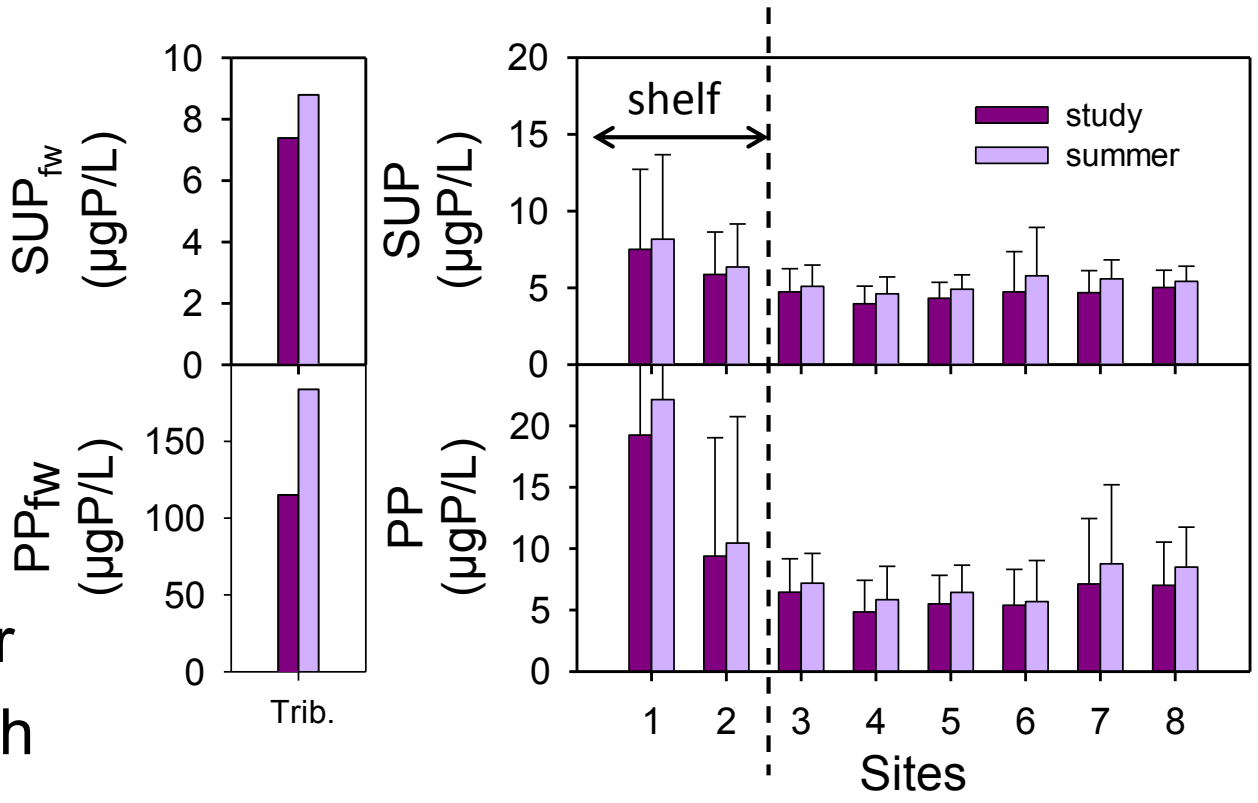
Spatial Patterns in P

- tributary concentrations much greater
- shelf concentrations higher then pelagic
- exceedance of TP guidance value at site 1



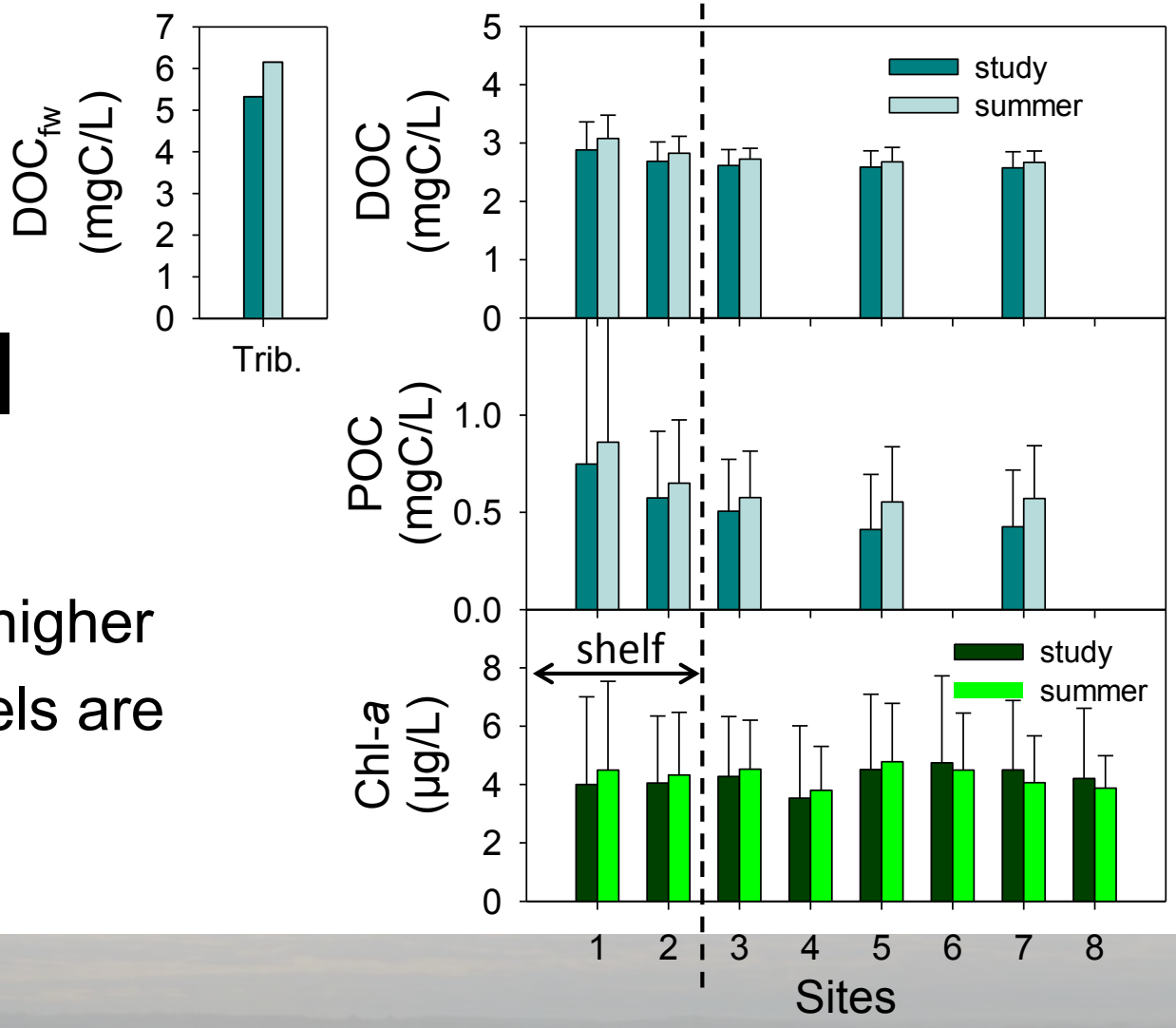
Spatial Patterns in P

- tributary SUP somewhat higher
- tributary PP much higher
- shelf levels higher



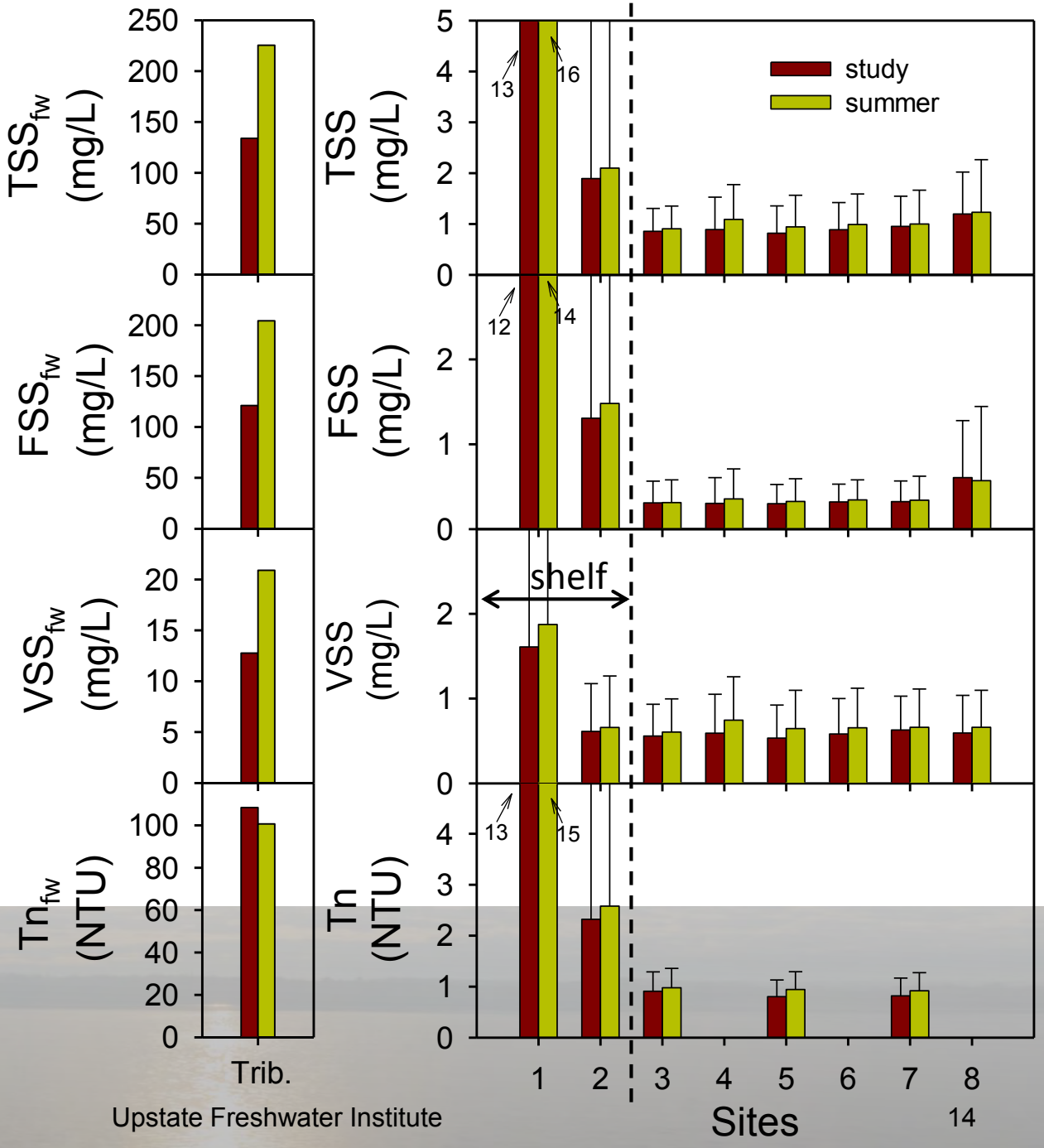
Spatial Patterns in C and Chl

- tributary DOC higher
- shelf Chl-*a* levels are not higher



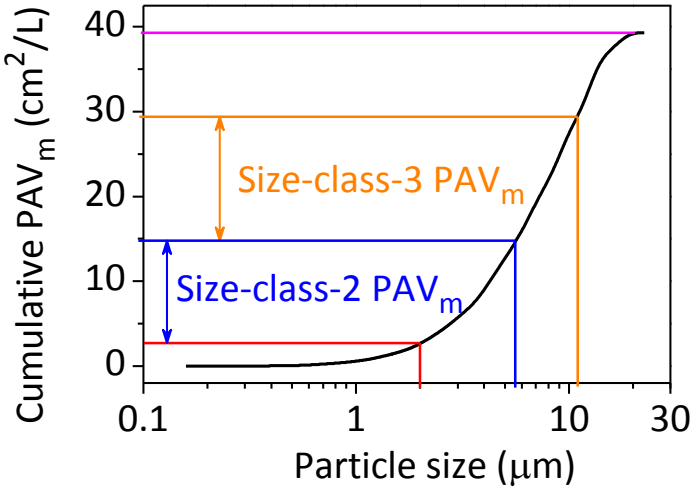
Spatial Patterns in Solids and Tn

- tributaries much higher
- shelf high



PAV_m Partitioned According to Particle Size Classes

- PAV_m – projected area of minerogenic particles per unit volume
- proportional to metrics of light scattering including turbidity; also associated P
- example size dependency of PAV_m

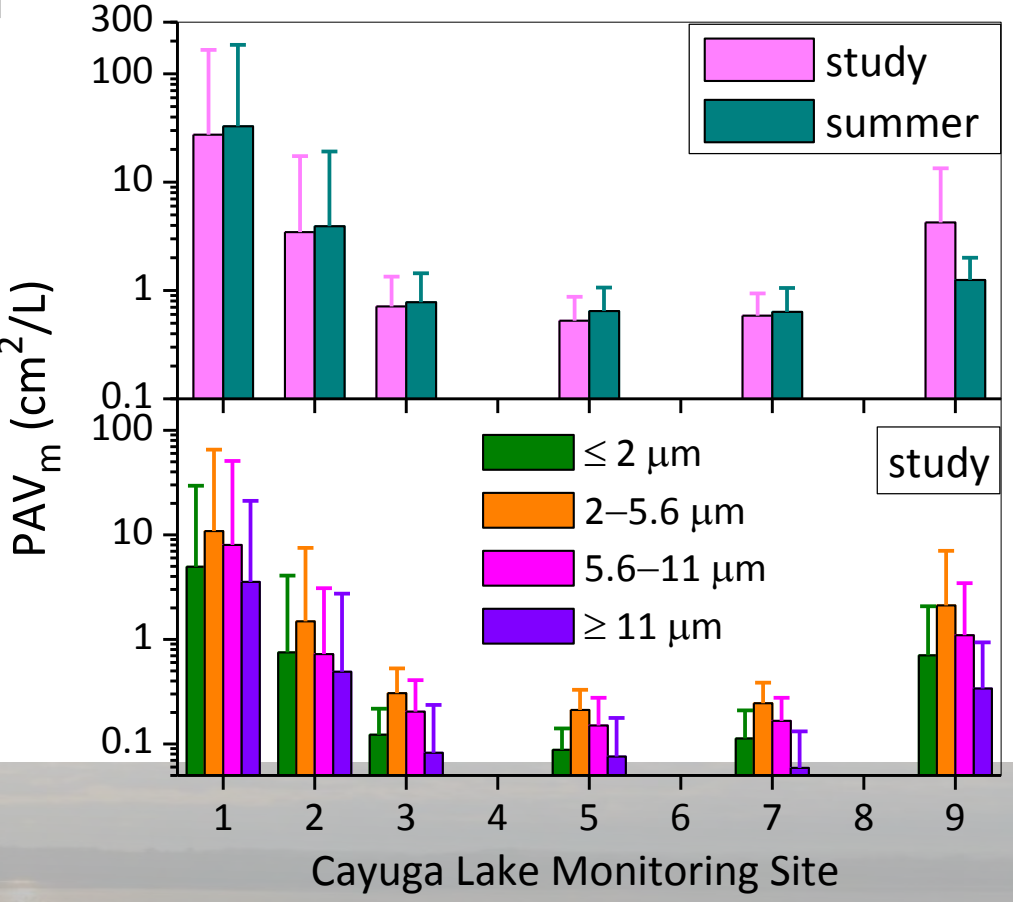


4 particle size classes:
Class 1: ≤ 2 μm
Class 2: 2–5.6 μm
Class 3: 5.6–11 μm
Class 4: ≥ 11 μm

- size classes allow for representation of time-dependent settling losses (e.g., persistency)
- general approach applied for modeling turbidity in NYC reservoirs (Gelda et al., 4 papers)

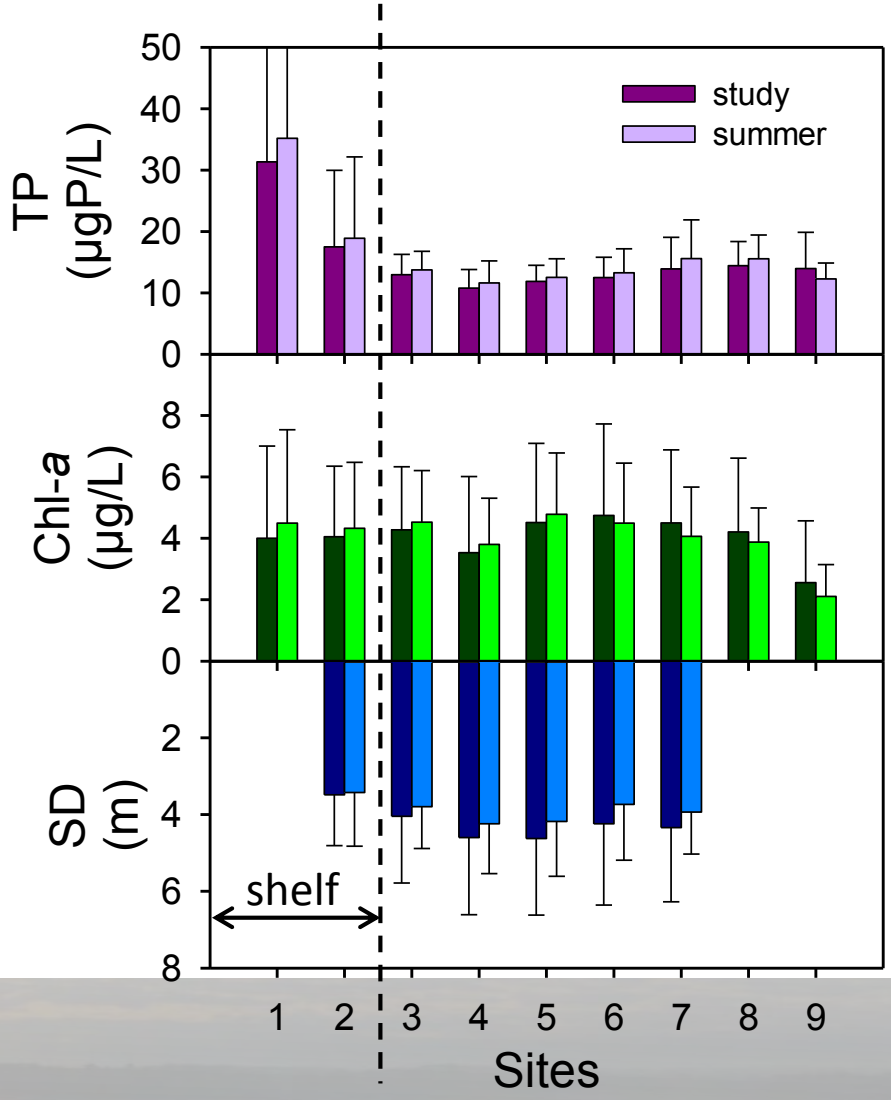
Spatial Differences in PAV_m

- PAV_m, much higher on shelf than pelagic
- decreased contribution of smallest size class in pelagic waters suggests the operation of the aggregation process



Spatial Patterns in Trophic State Indicators

- TP higher on shelf
- SD lower on shelf
- Chl-*a* no difference
- “the disconnect” discussed in water quality modeling presentation in more detail



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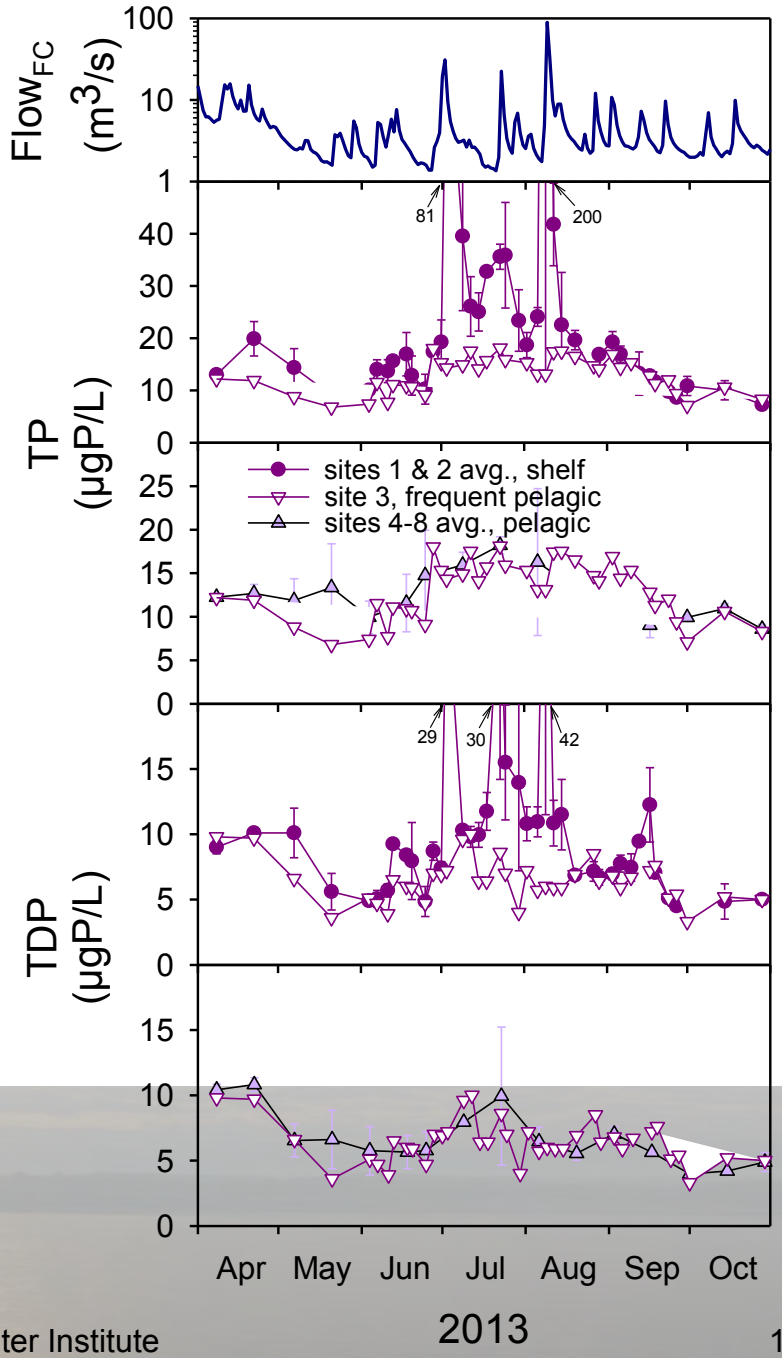
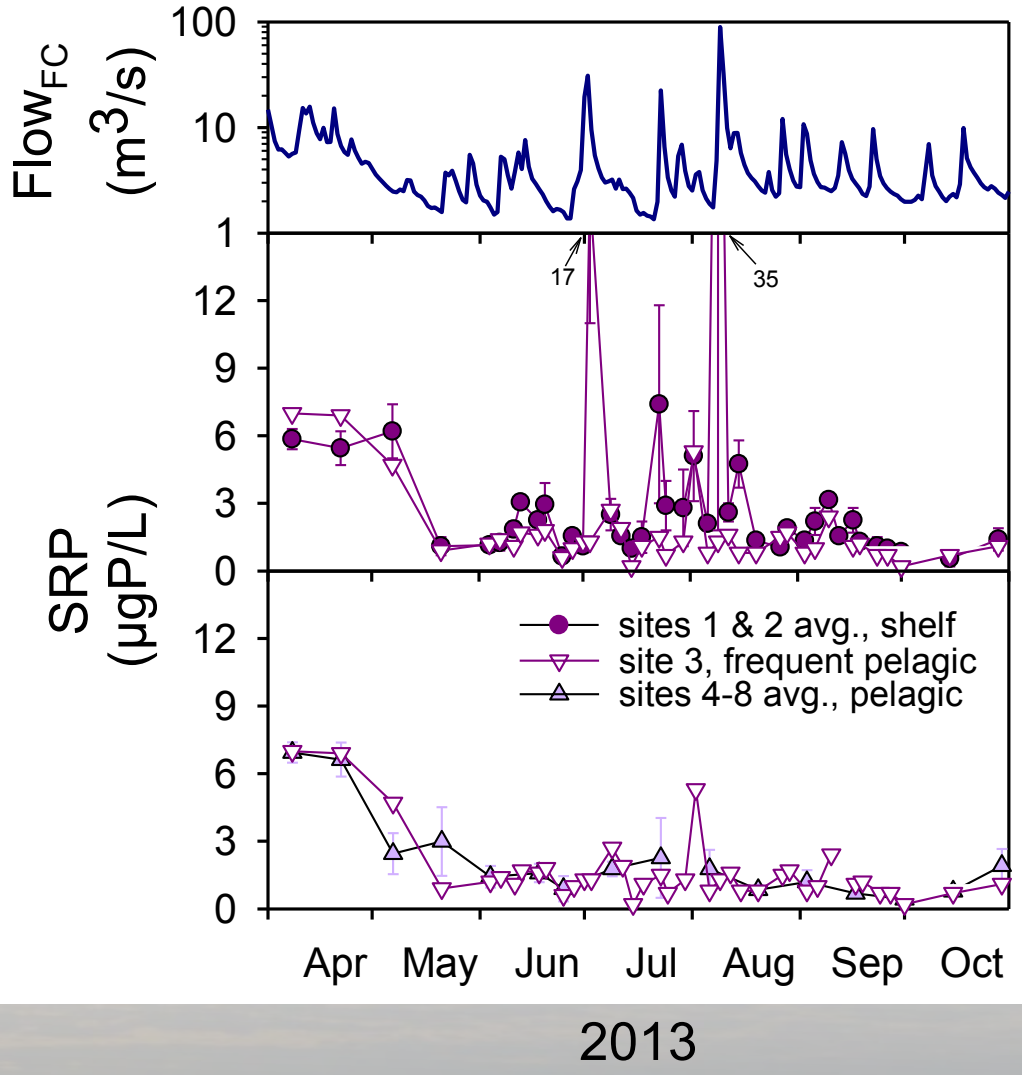
Temporal Patterns TP and TDP

- high P on shelf driven primarily by runoff event



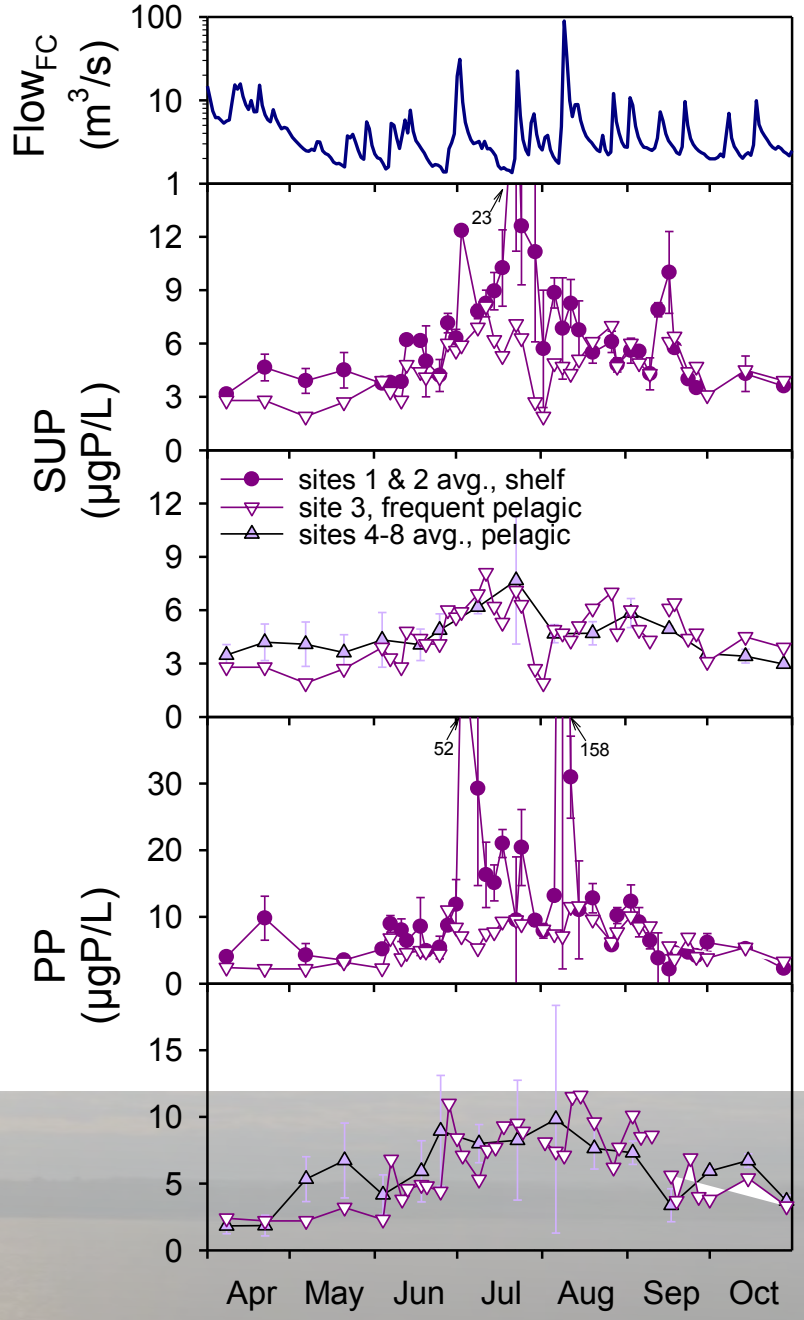
Temporal Patterns in SRP

- higher SRP on shelf mostly runoff events
- pelagic – spring depletion to ~ 1µg/L (detection limit levels)
- relative uniformity in pelagic waters



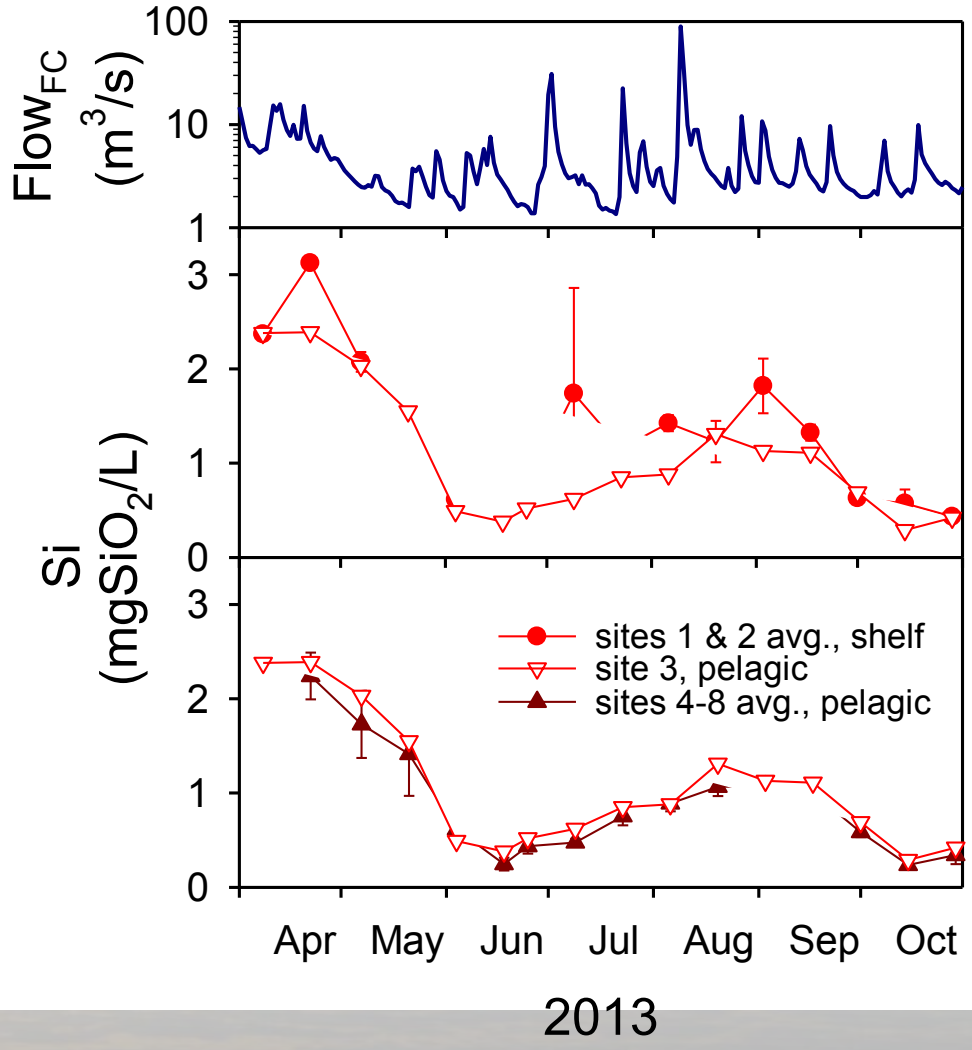
Temporal Patterns in SUP and PP

- shelf – higher SUP and PP, runoff events
- pelagic –summer increase in SUP and PP
- relative uniformity in pelagic waters

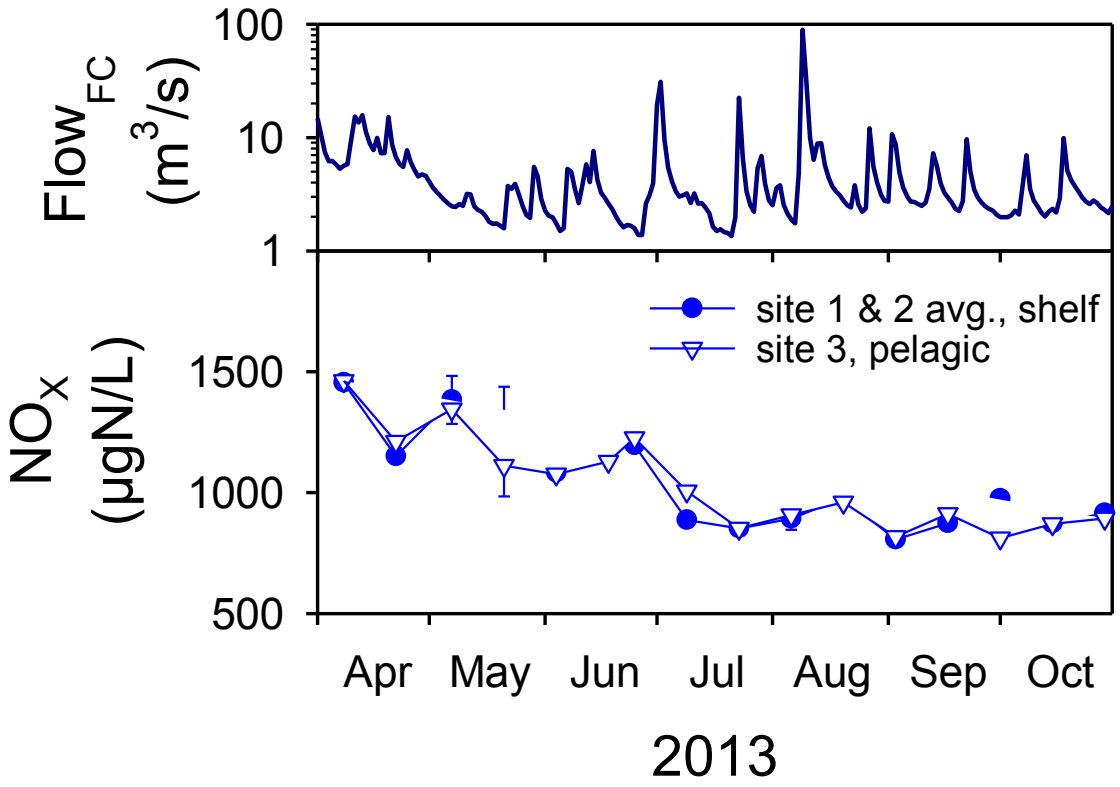


Temporal Patterns in Silica

- spring depletion
- late summer increase
- fall decrease
- connection to diatoms



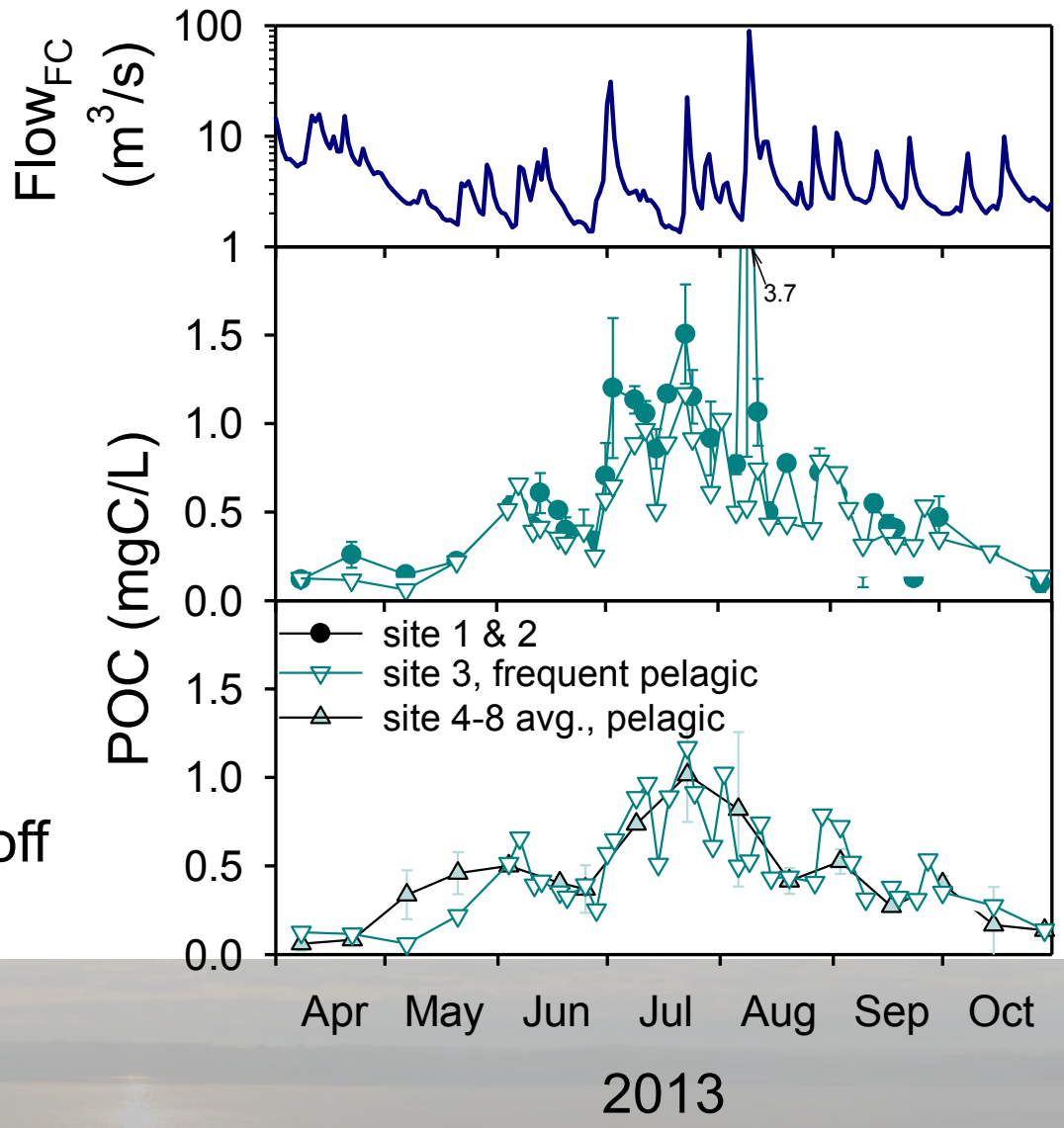
Temporal Patterns in NO_X



- decrease to mid-summer, uniform thereafter
- above potentially limiting concentrations

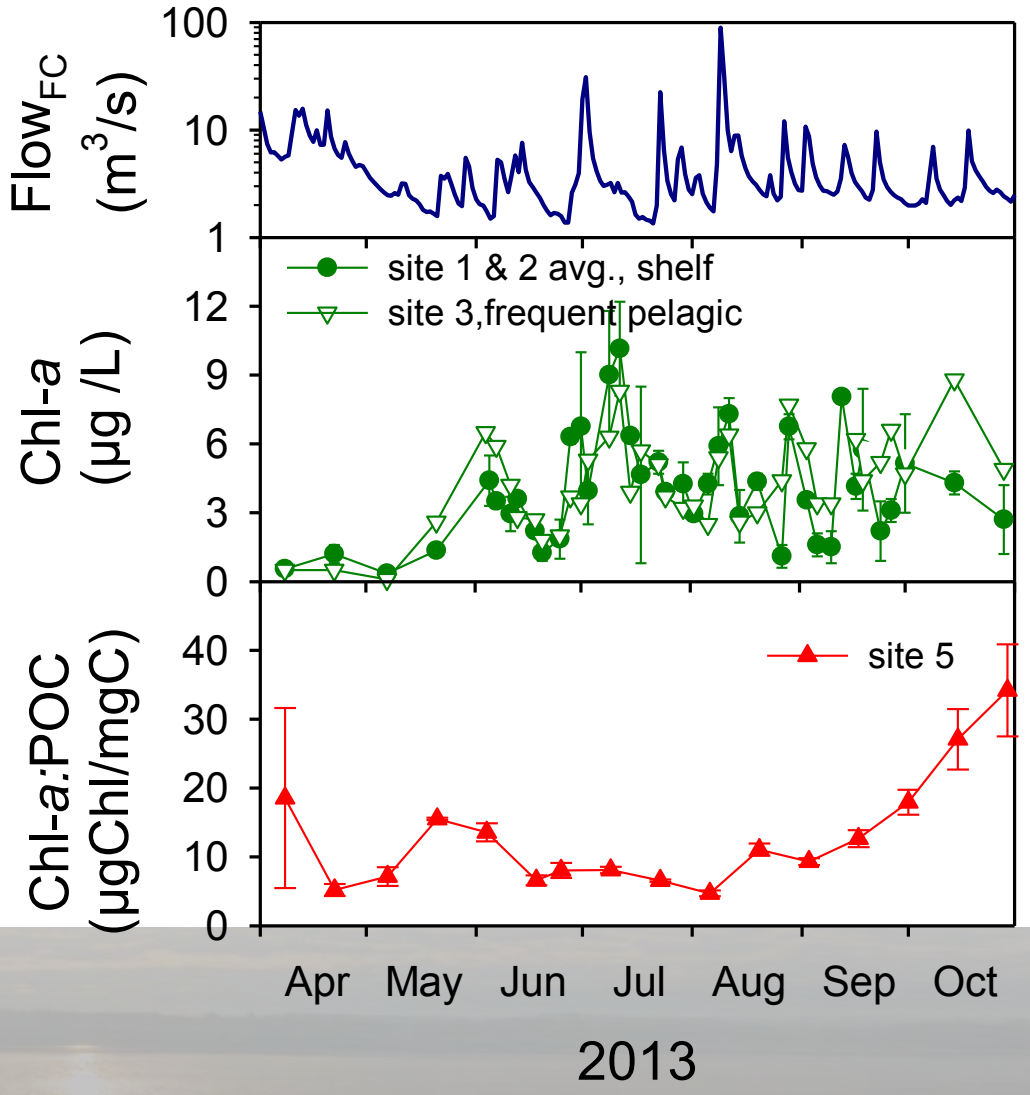
Temporal Patterns in POC

- POC metric of phytoplankton biomass; multiple peaks; patterns similar for the shelf and pelagic sites
- higher on shelf-runoff events
- pelagic – mid-summer peak



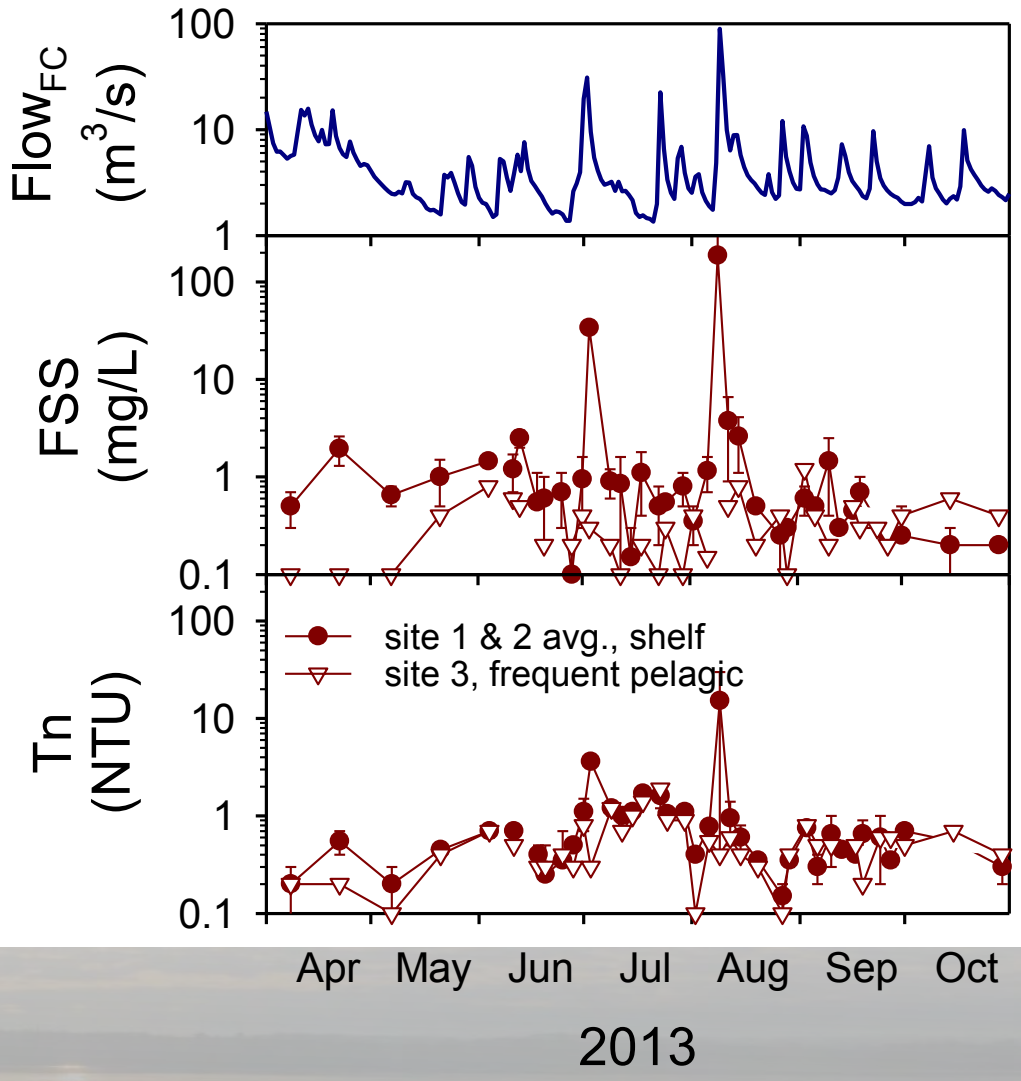
Temporal Patterns in Chl-*a* and Chl-*a*:POC

- Chl-*a* – metric of phytoplankton biomass; multiple peaks; patterns similar for the shelf and pelagic sites
- Chl-*a*:POC – wide variations (4 – 42)
- disparity in biomass indicators



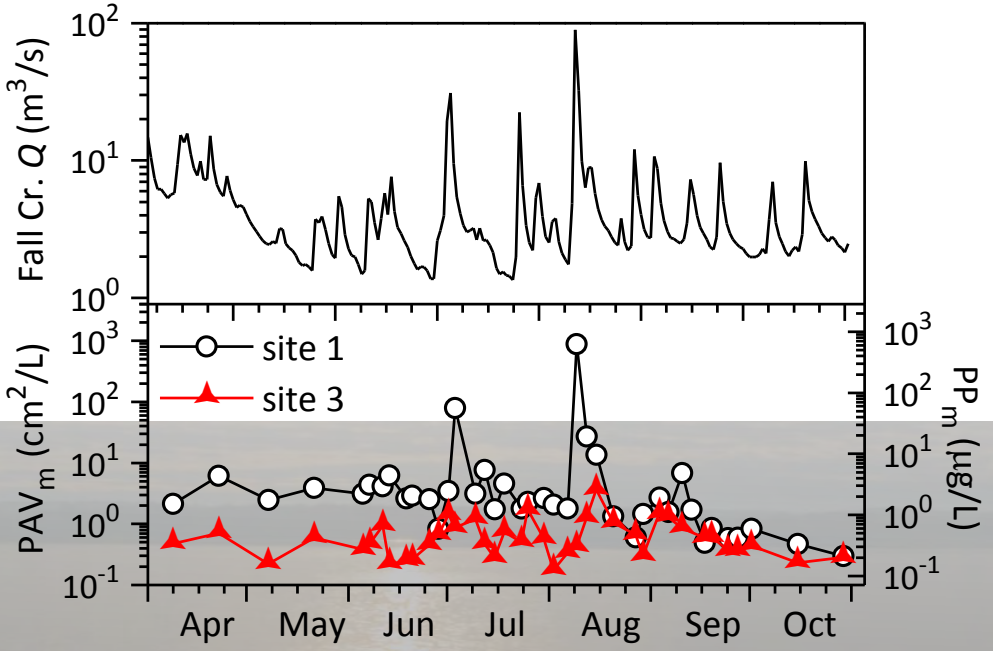
Temporal Patterns in TSS and Tn on shelf

- log y-axis
- shelf higher – runoff events



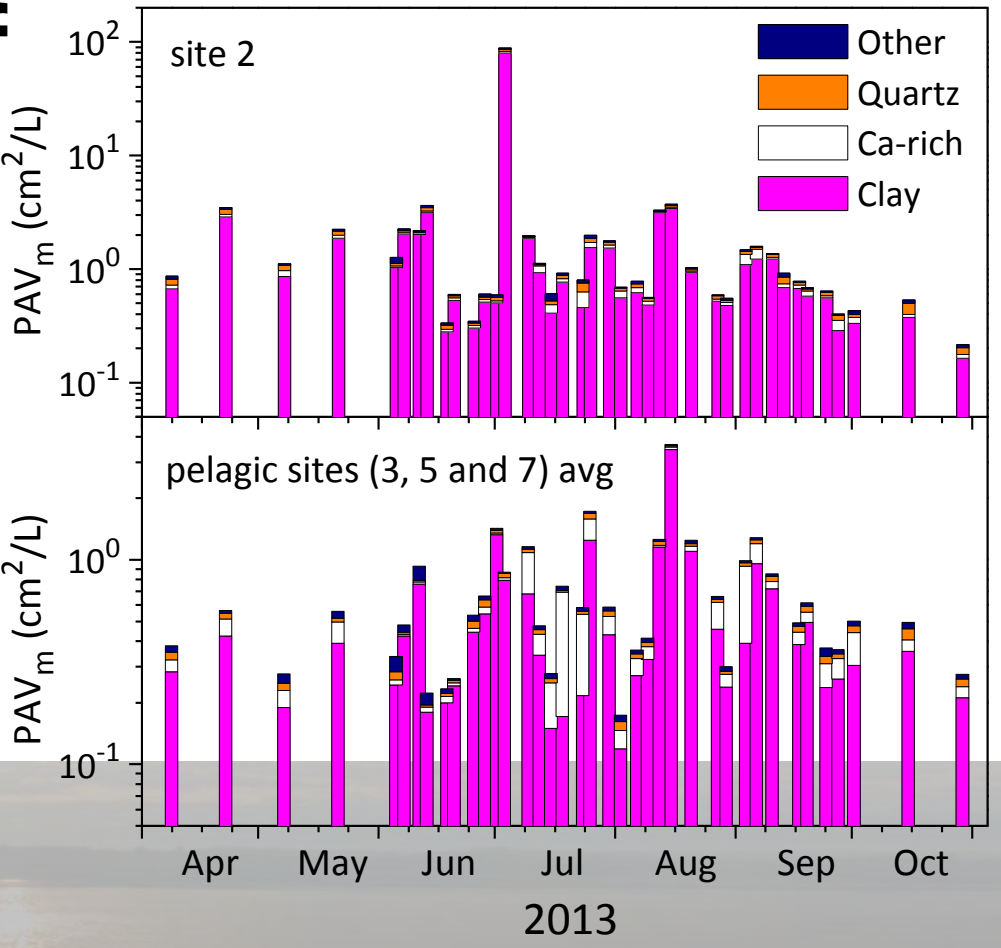
Dynamics of Minerogenic Particle Levels (PAV_m) on the Shelf and Pelagic Waters

- PAV_m increases in response to runoff events
  - lake-wide, but much more on the shelf
- first approximations of coupled increases in PP_m, y-axis on the right (Effler et al. 2014)



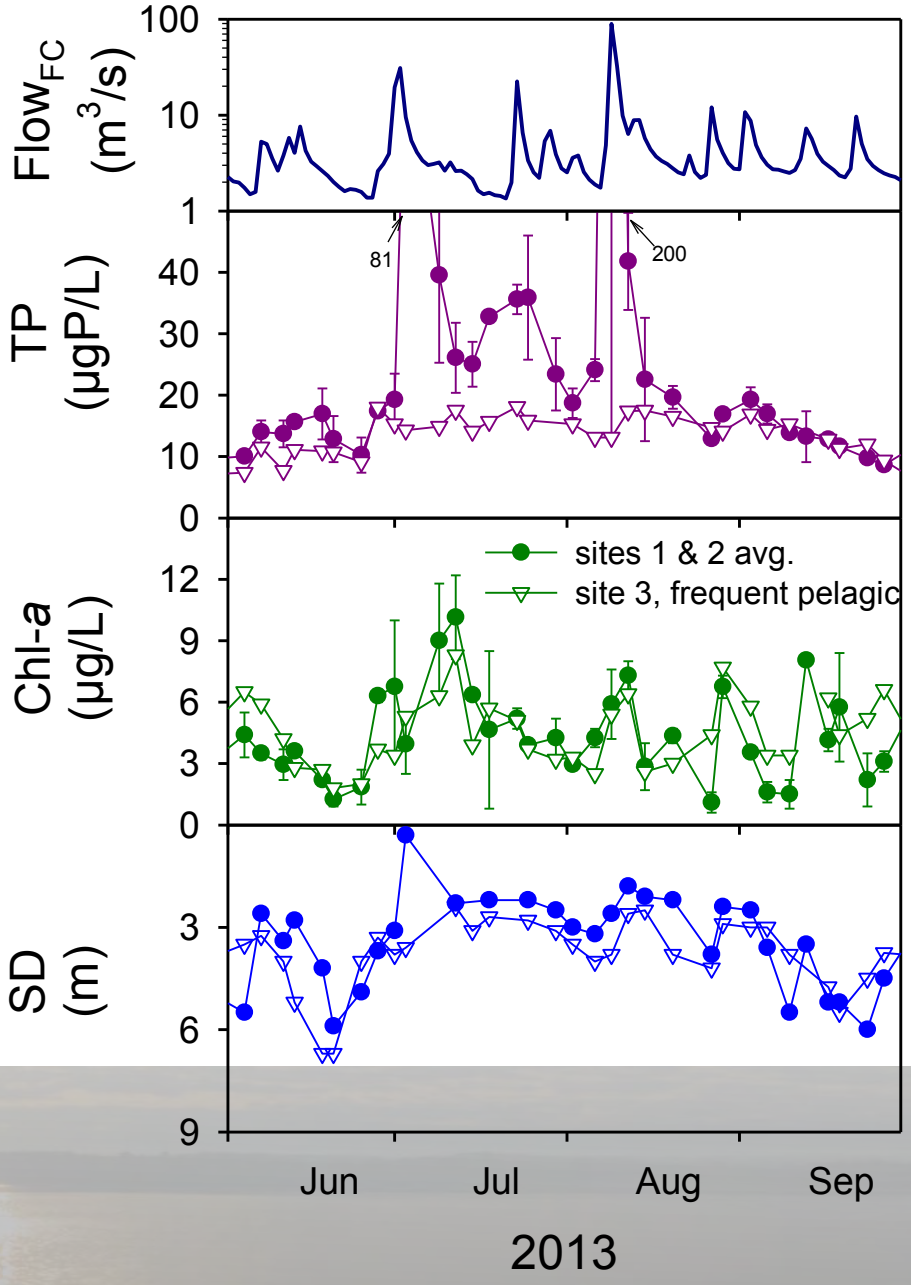
Chemical Composition and Origins of PAV_m

- clay minerals dominate, particularly on the shelf
  - i.e., PAV_m primarily has terrigenous origins
- Ca-rich (calcite $CaCO_3$) is formed within the lake; “whiting” events in July, usually in August (Effler and Peng 2014)
  - primarily in pelagic waters



Temporal Patterns in Trophic State Indicators

- 2013 trends
- runoff events drive TP higher on shelf
- runoff events drive SD lower on shelf
- runoff events linked to “the disconnect”



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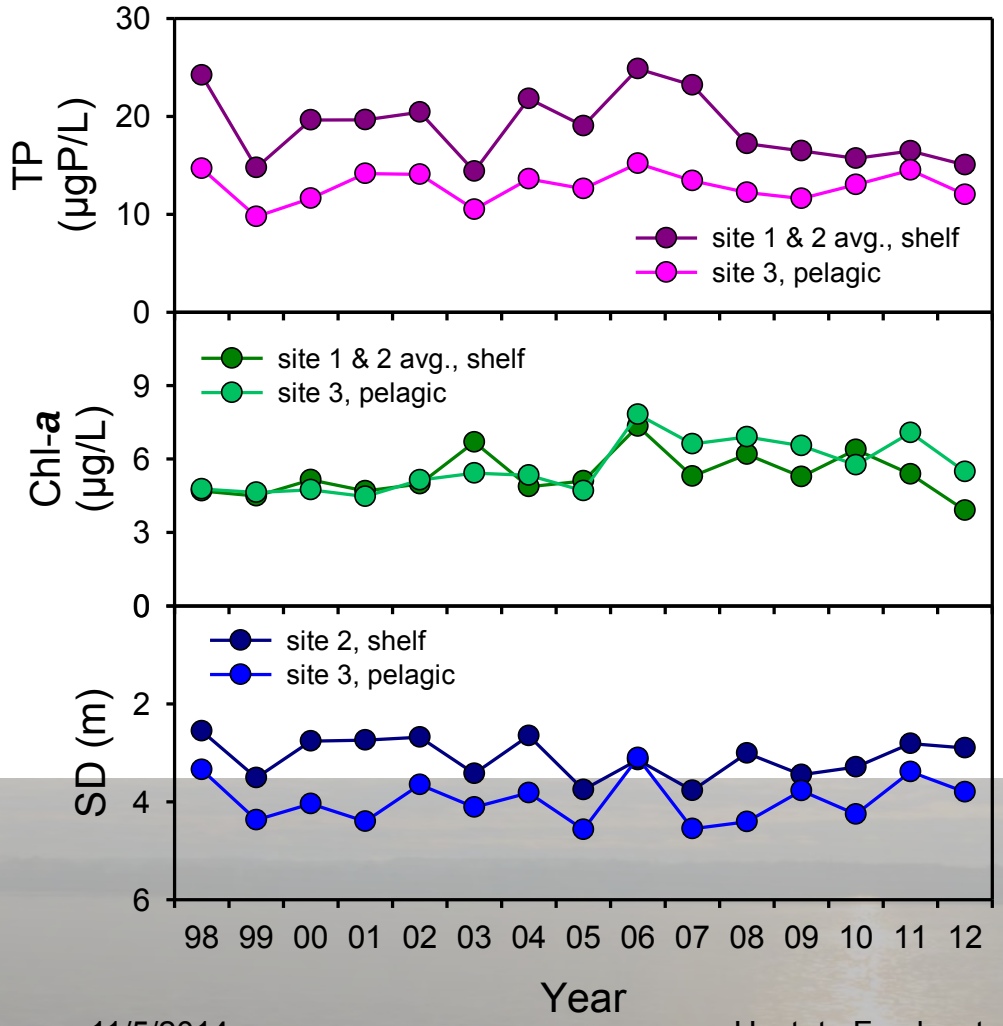
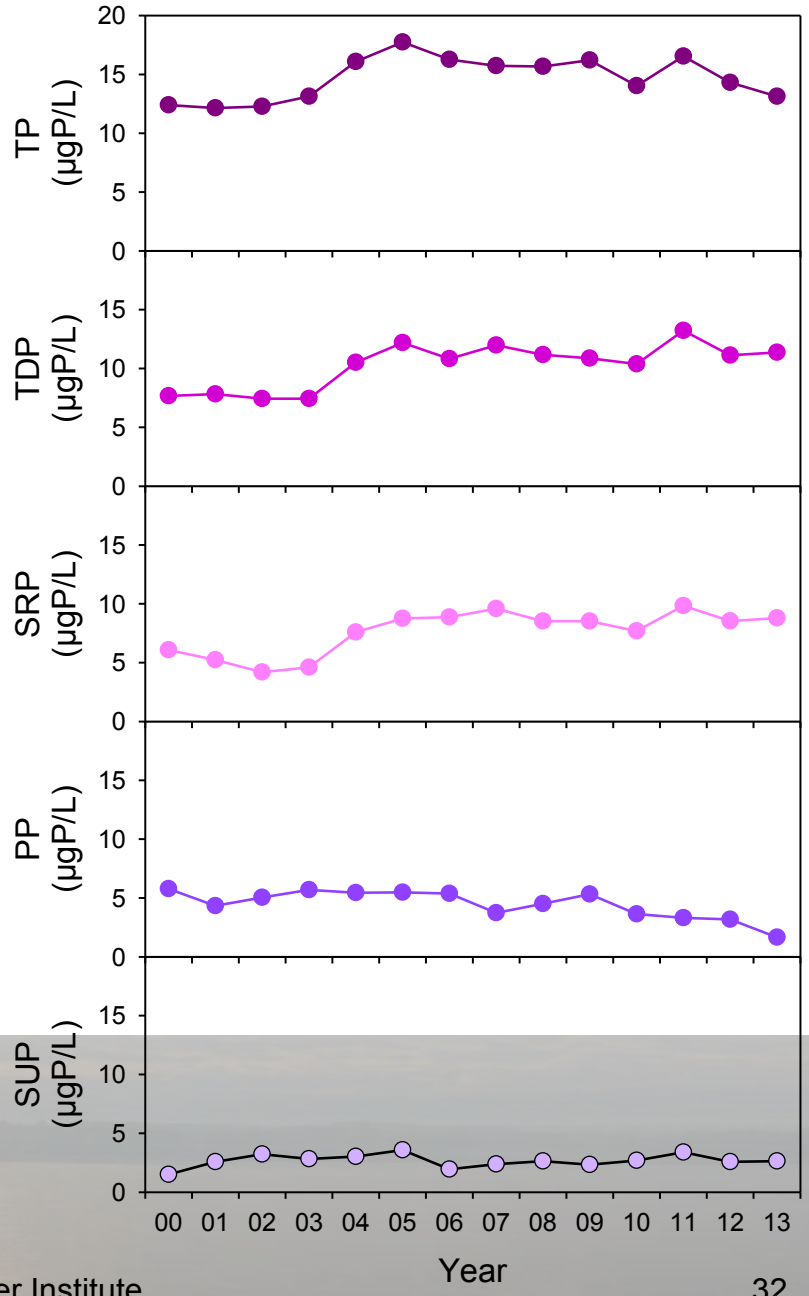
Temporal Patterns in Trophic State Indicators Long-Term



- from LSC sampling, 1998 - 2012
- TP higher shelf then pelagic
- Chl-a same on shelf and pelagic
- SD lower on shelf then pelagic

Trends in LSC Effluent P Concentrations

- a good indication of lower water P concentrations
- 2000-2013



Trends in LSC Effluent Phosphorus Concentrations 2000- 2012

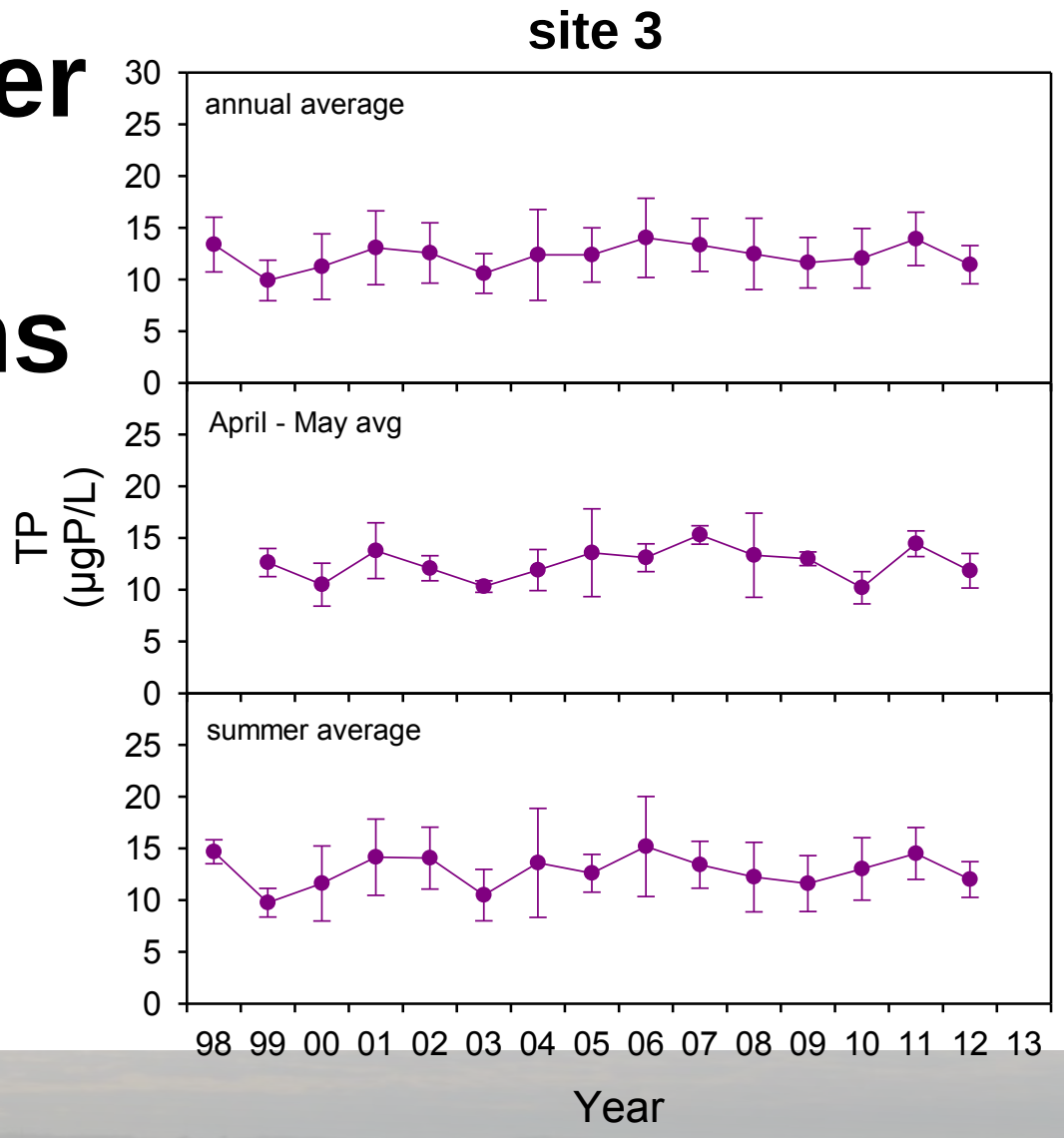
Parameter	Regression[1]		Seasonal Kendall [2]		T-test[3]		
	direction	p-value	direction	p-value	2000-2003 (n=4) avg. (µg/L)	2004-2012 (n=9) avg. (µgP/L)	p-value
TP	+	0.2088	+	0.2595	12.5	15.6	<0.0001
TDP	+	0.0018	+	0.0024	7.6	11.4	<0.001
SRP	+	0.0025	+	0.0075	5.0	8.7	<0.001
PP	-	0.0014	-	0.0026	5.2	4.2	0.153
SUP	+	0.5881	+	0.255	2.5	2.7	0.586

[1] regression based on yearly average of 13 years of data 2000-2012.
[2] Seasonal Kendall based on all the data for all 13 years.
[3] T-test based on comparing the average of 2000-2003 to the average of 2004-2012.

- hypolimnetic increases in SRP, and TDP
- hypolimnetic decreases in PP

Trends in Upper Waters TP Concentrations

- no trends found shelf sites 1 and 2
- site 3 annual, spring and summer averages no trends found for TP



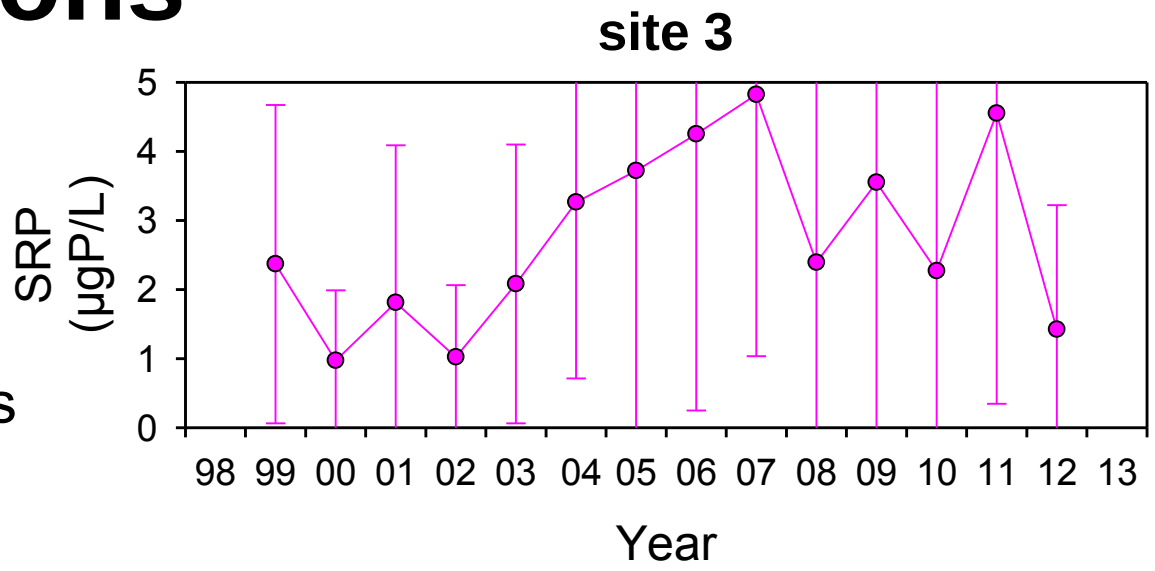
Trends in Upper Waters TP Concentrations

Time Period	Regression[1]		T-test					
	direction	p-value	2000-2003 (n=4) avg. (µg/L)	2004-2012 (n=9) avg. (µgP/L)	p-value	2000-2005(n=4) avg. (µg/L)	2004-2012 (n=9) avg. (µgP/L)	p-value
annual average	+	0.4517	11.9	12.6	0.233	12.0	12.7	0.265
spring	+	0.5102	11.7	13.0	0.187	12.0	13.0	0.278
summer	+	0.7586	12.6	13.1	0.523	12.8	13.1	0.631

[1] regression based on yearly average of 15 years of data 1998-2012.

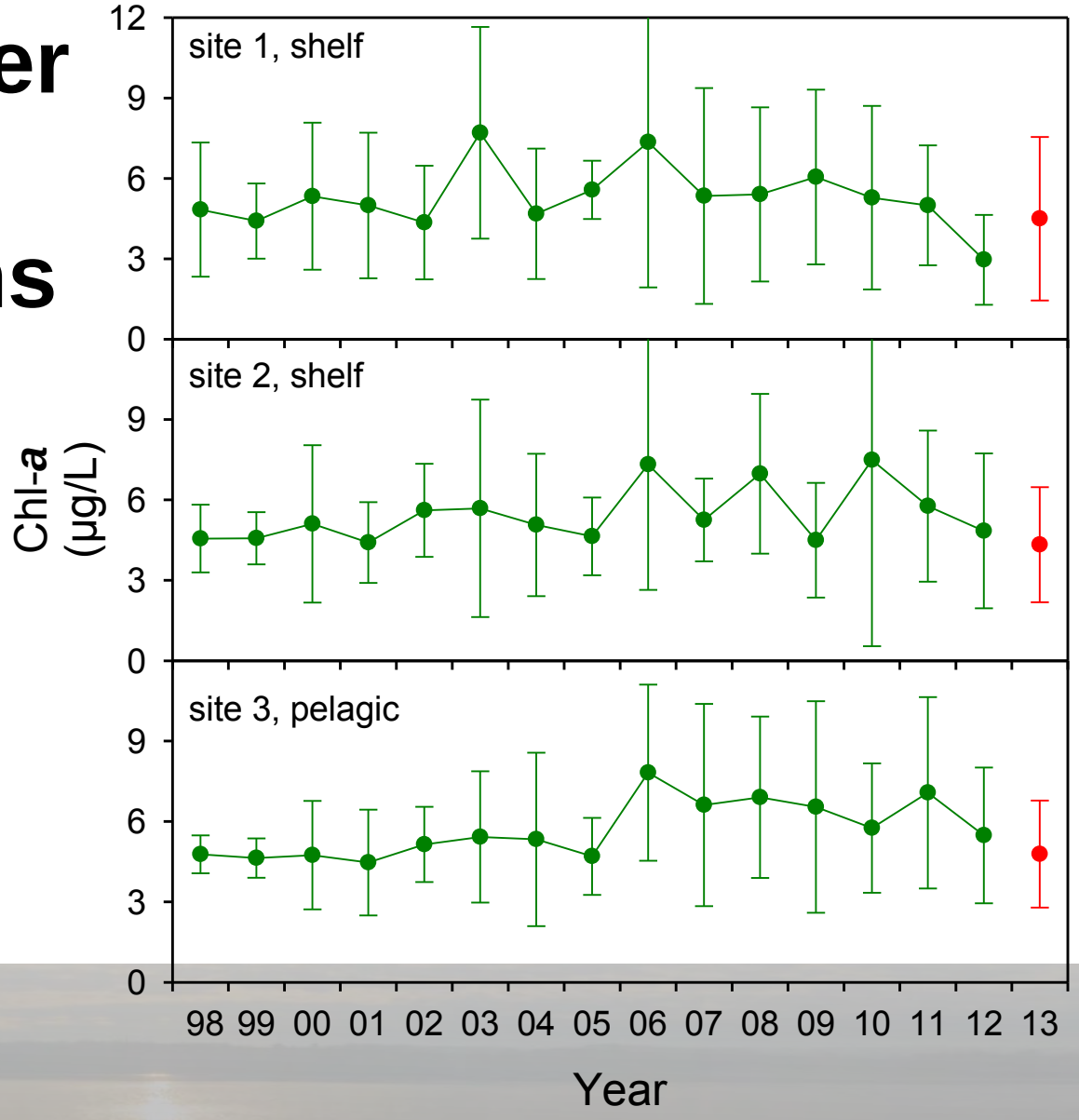
Trends in Upper Waters SRP Concentrations

- no trends found shelf sites 1 and 2
- site 3 annual, spring and summer averages no trends found for SRP by regression
- SRP spring average 00-03 verses 04-12 only P form statistically significantly different



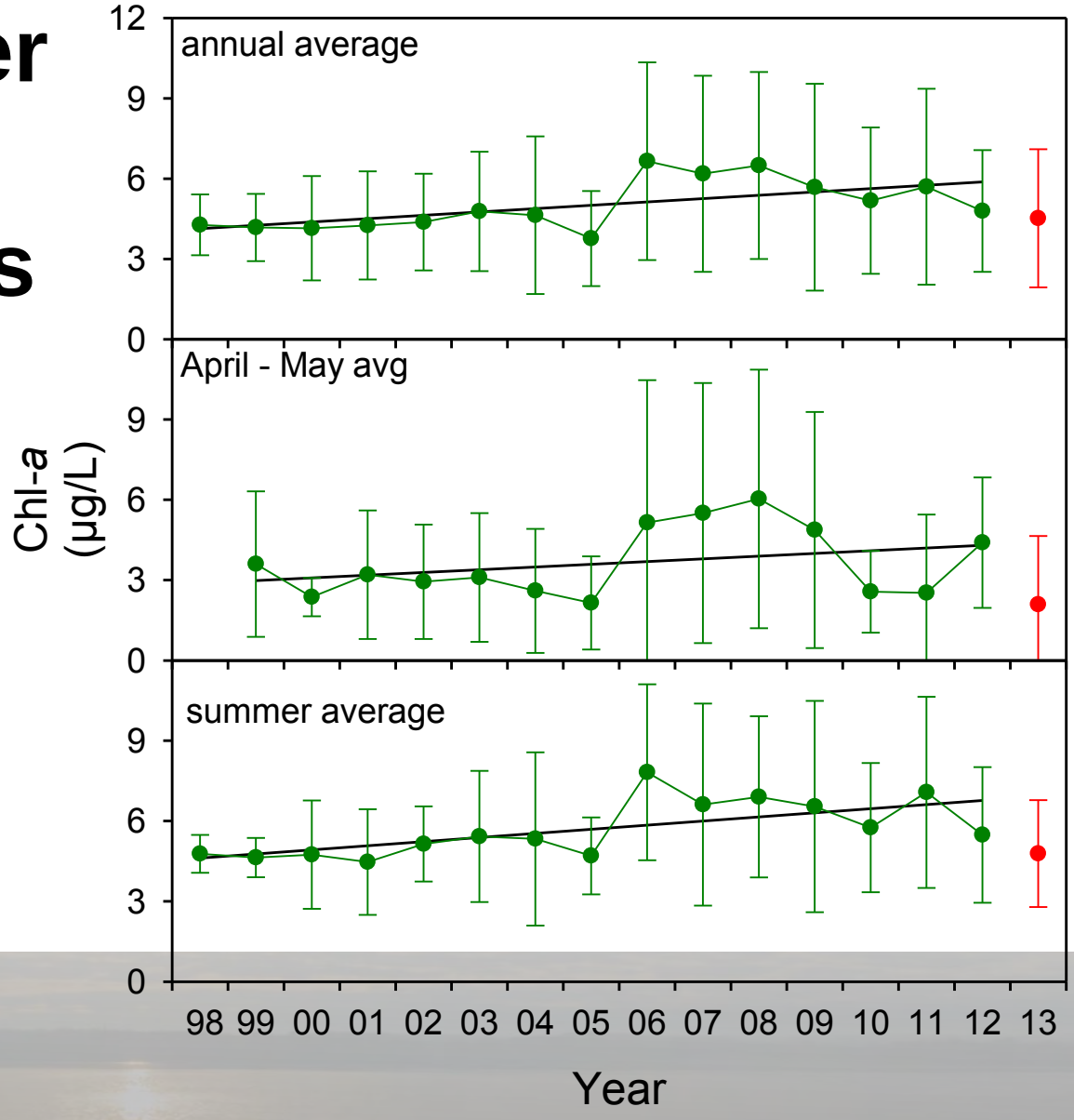
Trends in Upper Waters Chl-*a* Concentrations

- summer averages at sites 1, 2, and 3
- no trends found shelf sites 1 and 2



Trends in Upper Waters Chl-*a* Concentrations

- site 3 annual, spring and summer trends



Trends in Upper Waters Chl-*a* Concentrations at Site 3

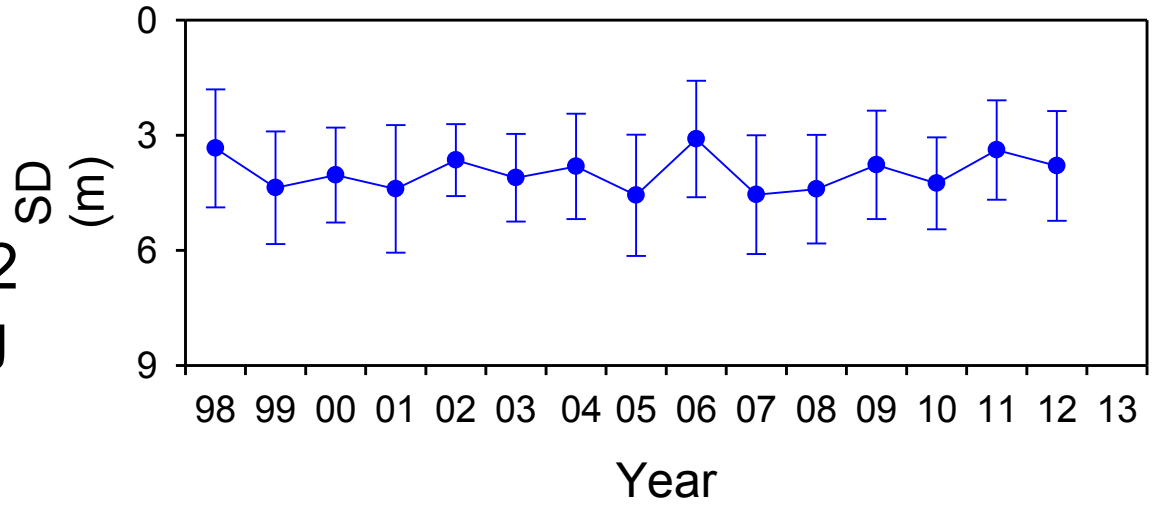
Time Period	Regression[1]		Seasonal Kendall [2]		T-test[3]		
	direction	p-value	direction	p-value	2000-2005 (n=6) avg. (µg/L)	2006-2012 (n=10) avg. (µgP/L)	p-value
annual average	+	<0.0177	+	<0.2054	4.3	5.8	<0.001
spring	+	<0.2514	+	<0.2440	2.7	4.4	<0.015
summer	+	<0.0079	+	<0.2691	4.9	6.2	<0.031

[1] regression based on yearly average of 13 years of data 2000-2012.
[2] Seasonal Kendall based on all the data for all 13 years.
[3] T-test based on comparing the average of 2000-2003 to the average of 2004-2012.

- no trends at site 1 and 2
- more variation within a year then between the years so Seasonal Kendall found no significant trends

Trends in SD

- summer averages
- site 3
- no trend from regressions at sites 2 or 3 seasonal, spring or summer
- no statistical significant differences in summer averages using multiple demarcation years



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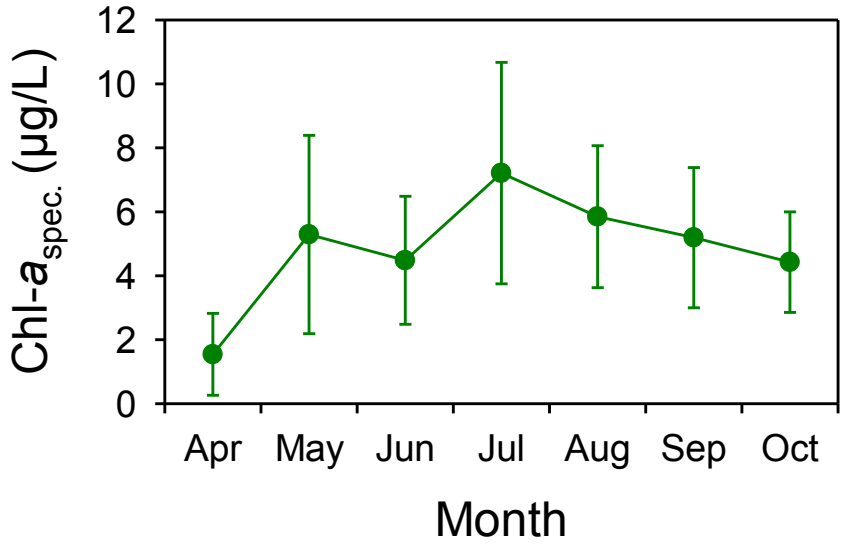
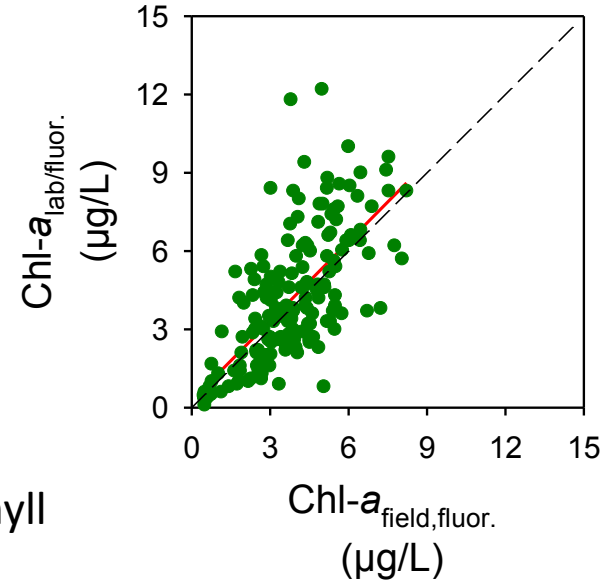
Historic Monthly Average Chl-*a*

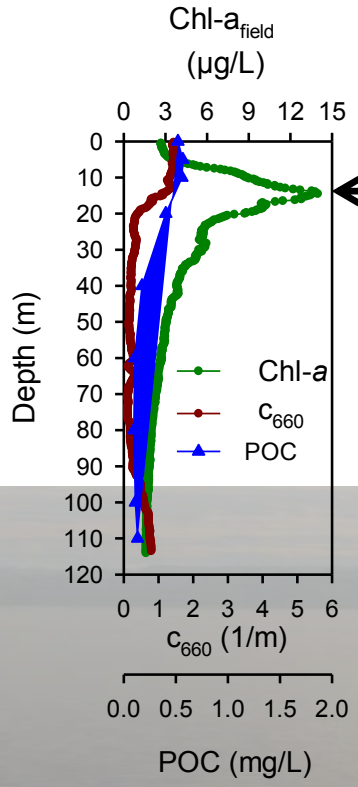


- monthly average ± 1 std.
- lack of recurring seasonality at monthly time step, except April is lower

Chlorophyll *a* (Chl-*a*), Some Limitations: Field Signatures

- conceptual, cellular content dependent on species and ambient conditions
- Chl-$a_{field,\ fluor.}$ coarse indicator



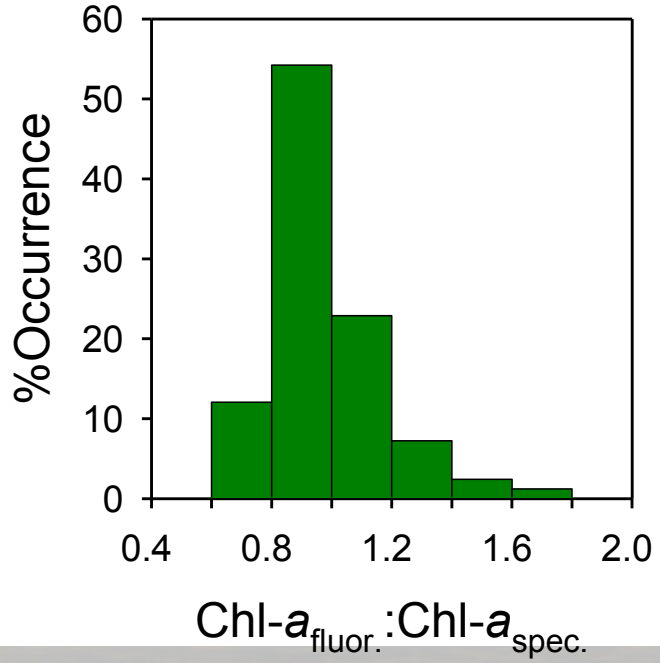


DCM – deep chlorophyll maximum

- not a valid indicator of deep production
- no corresponding POC or light scattering signature
- DCM not a primary modeling target

Comparison of Chl-*a* Results from Two Laboratory Protocols

- split samples, 2013
- fluorometric vs. spectrophotometric
- reasonably good closure in 2013
- fluorometric, 2013
- spectrophotometric historically (LSC monitoring) 1998-2012



Summary

1. shelf highly dynamic
2. shelf strongly influenced by runoff events
3. shelf vs. pelagic differences
4. inorganic (minerogenic) particle concentration higher on shelf
5. relative uniformity within pelagic waters
6. longer-term trends
    a. pelagic epilimnetic Chl-a, minor increase since 2006
    b. pelagic epilimnetic TP - No
    c. pelagic SD - No
    d. hypolimnetic P (LSC) – SRP increase since 2004, SUP unchanged, PP decreasing

The End

Questions?