Autonomously estimating particle size using high-frequency fluctuations in optical measurements

Results from a NASA Earth and Space Science Fellowship

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Special Thanks

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Andy Thomas
Jim Loftin
Crew of R.V. Knorr

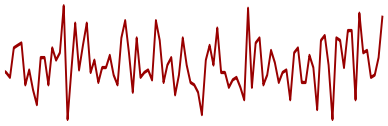
Fellowship goal:
autonomous estimates of particle size

Motivation

1. Greatly increase coverage of particle size measurements (using existing, widely available technology)

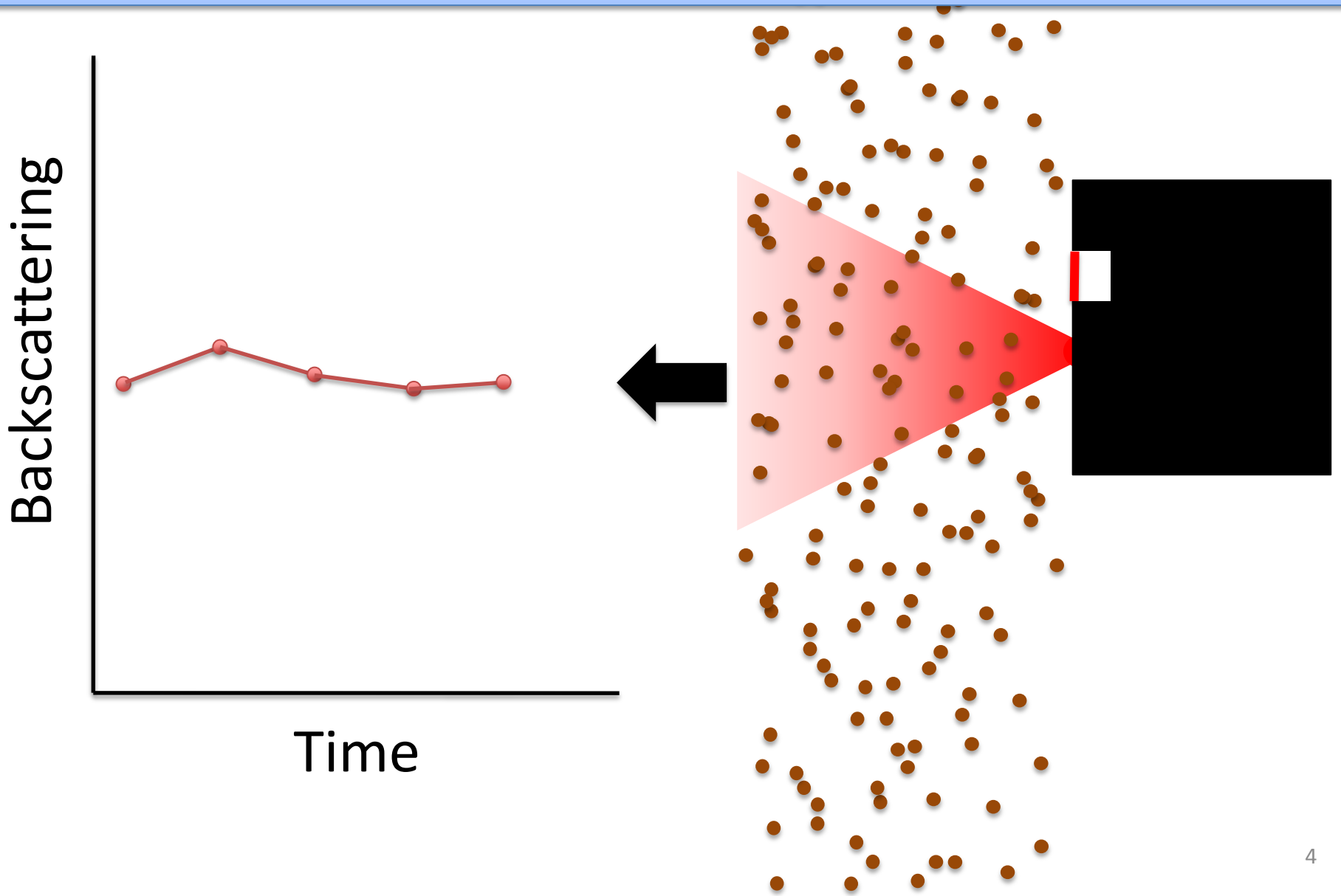
2. Connect size with other in situ measurements (e.g., export flux).

3. Test satellite size products globally

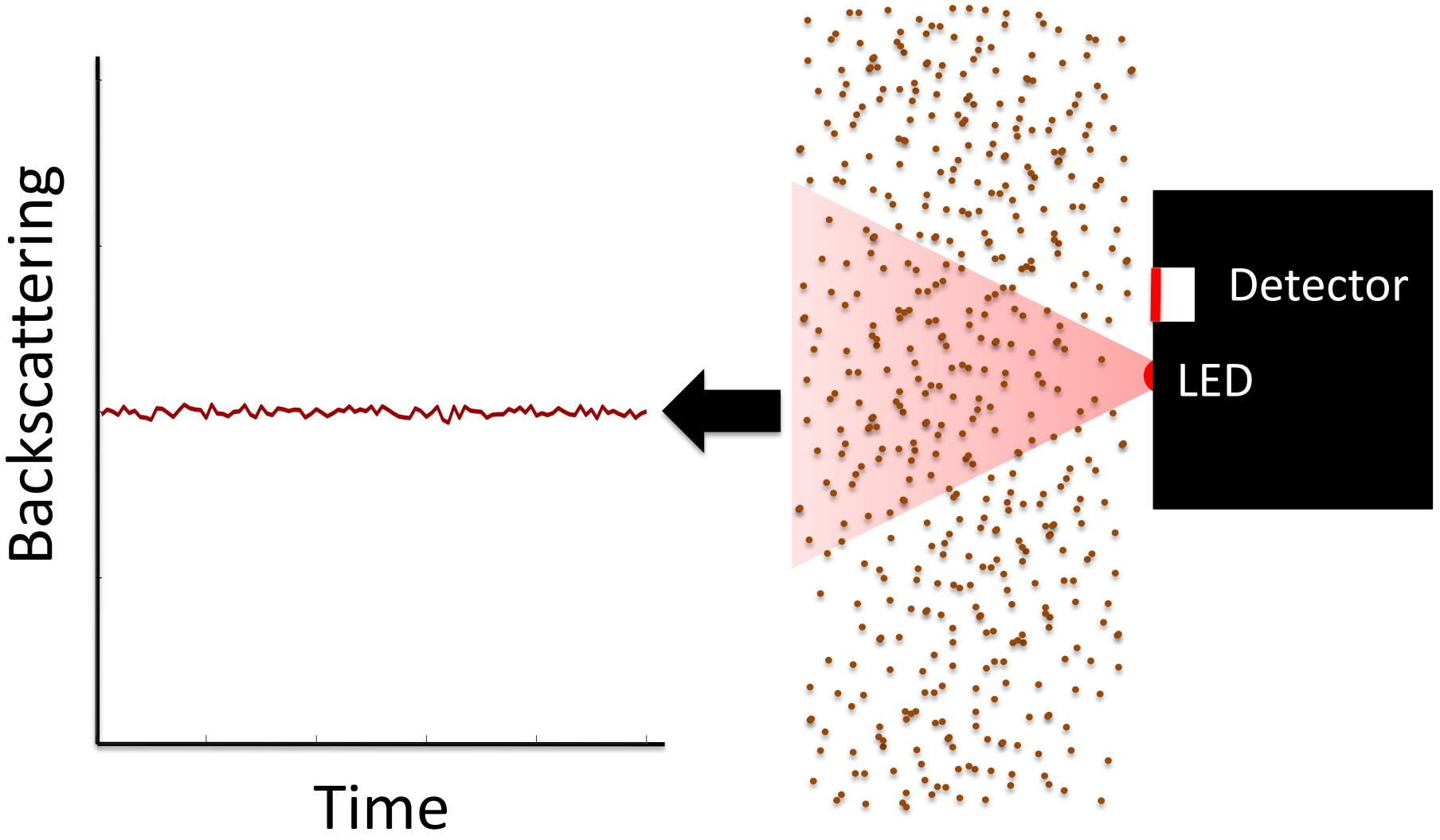


Method

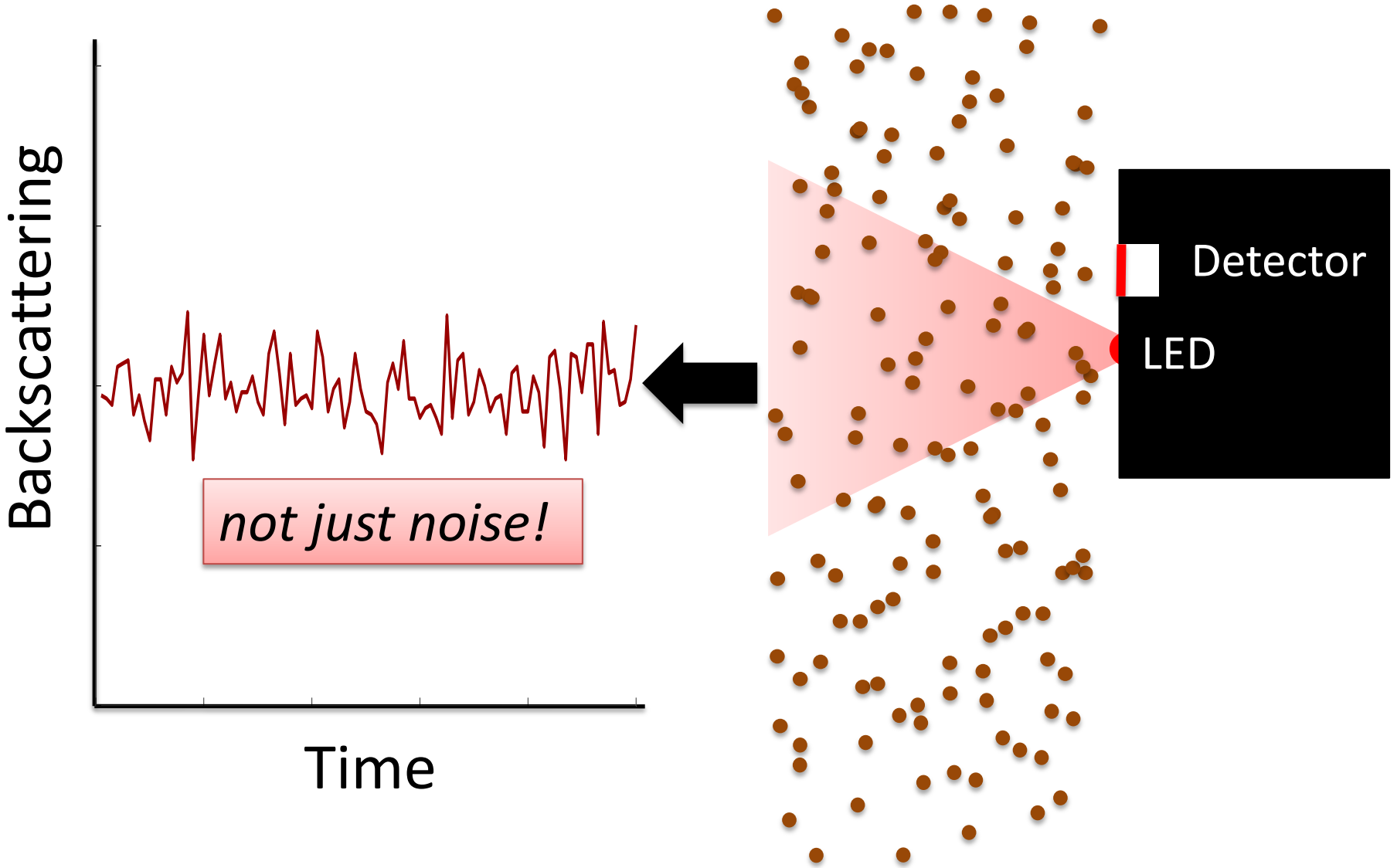
Randomly spaced particles moving through a sensor volume will create a variable signal



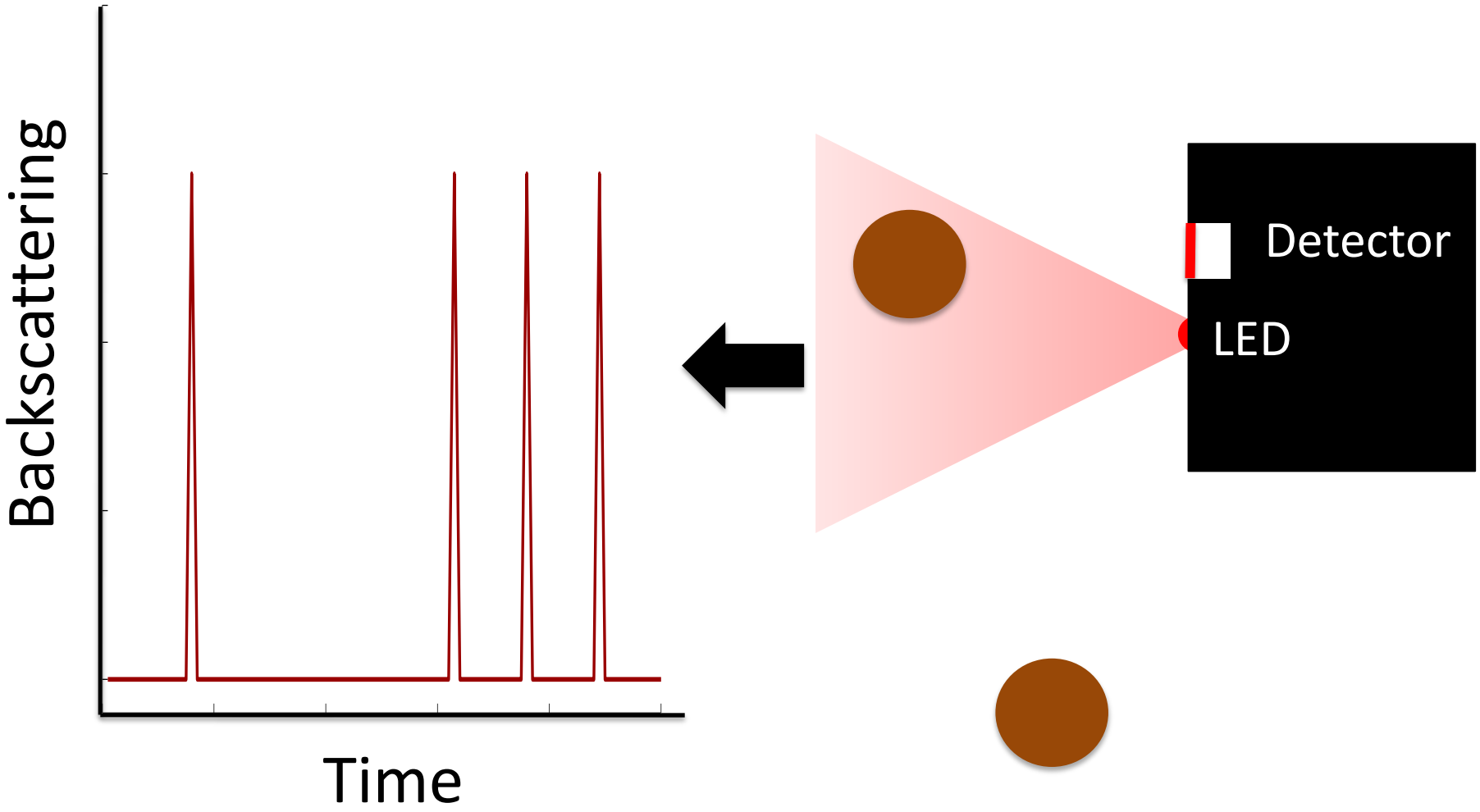
Many small particles yield a stable signal



Fewer, larger particles yield a more variable signal

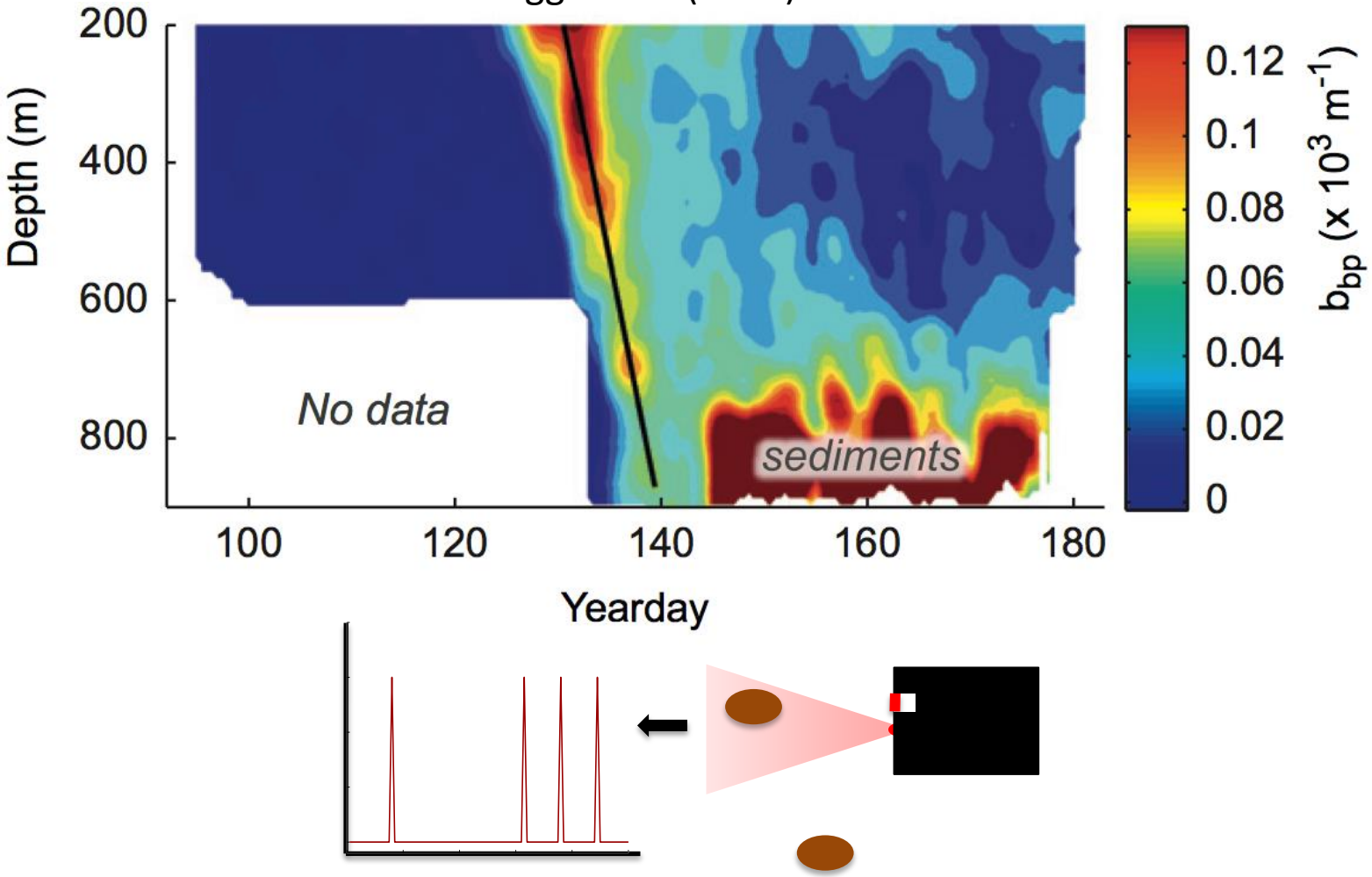


Really big, rare particles make big, isolated spikes

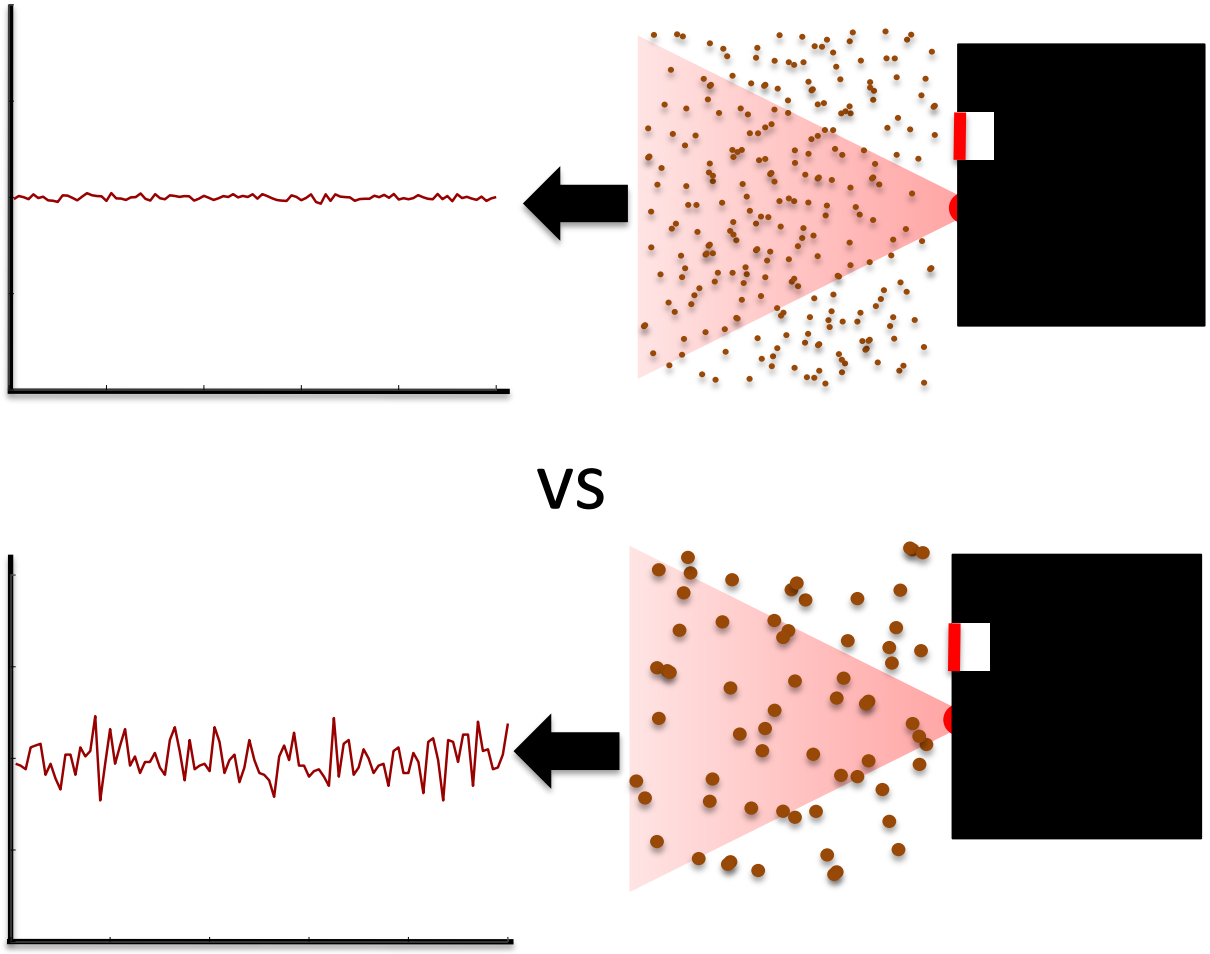


Such spikes can be analyzed separately
(e.g. sinking aggregates in the twilight zone)

Briggs et al. (2011)



Here I focus on the first two cases



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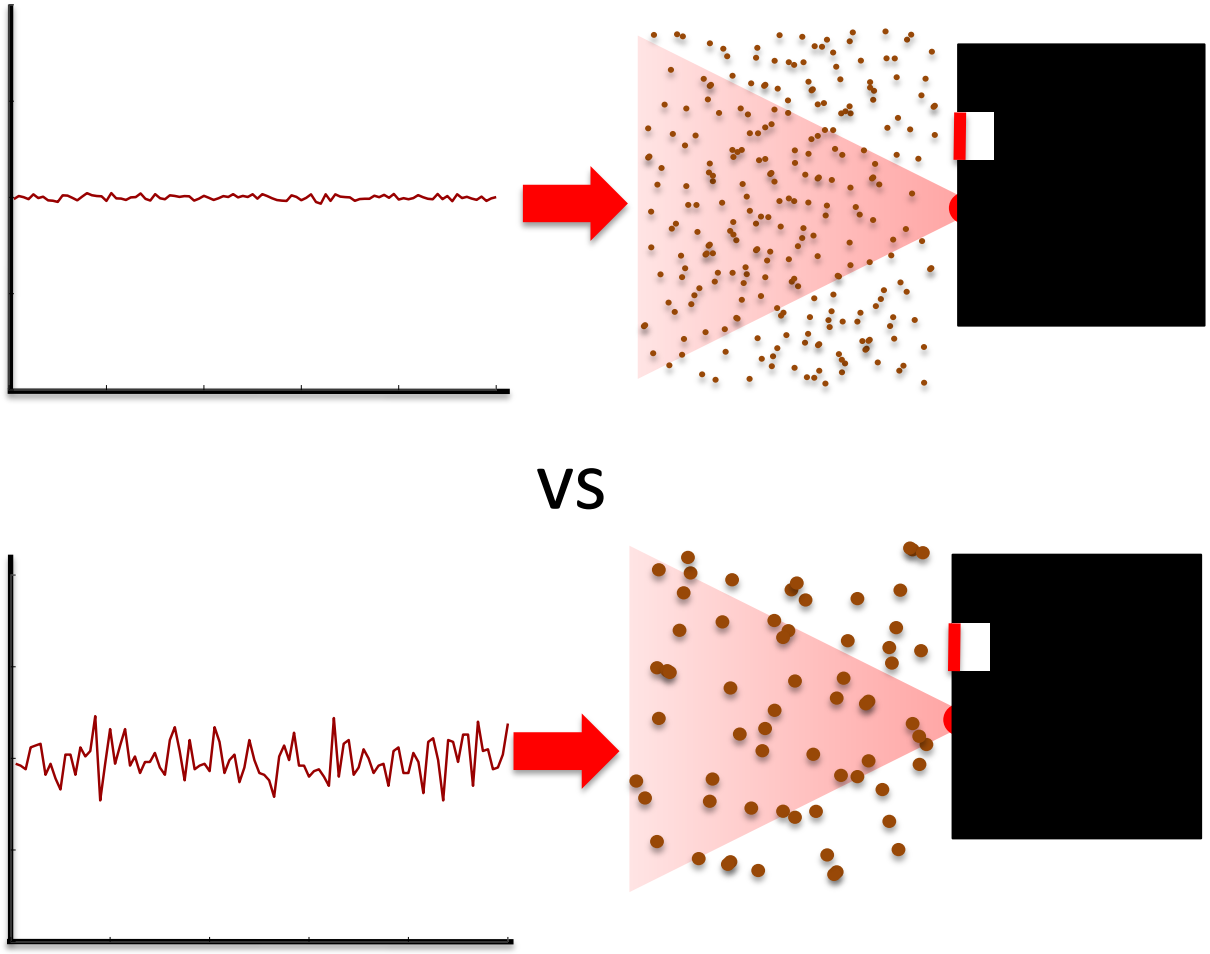


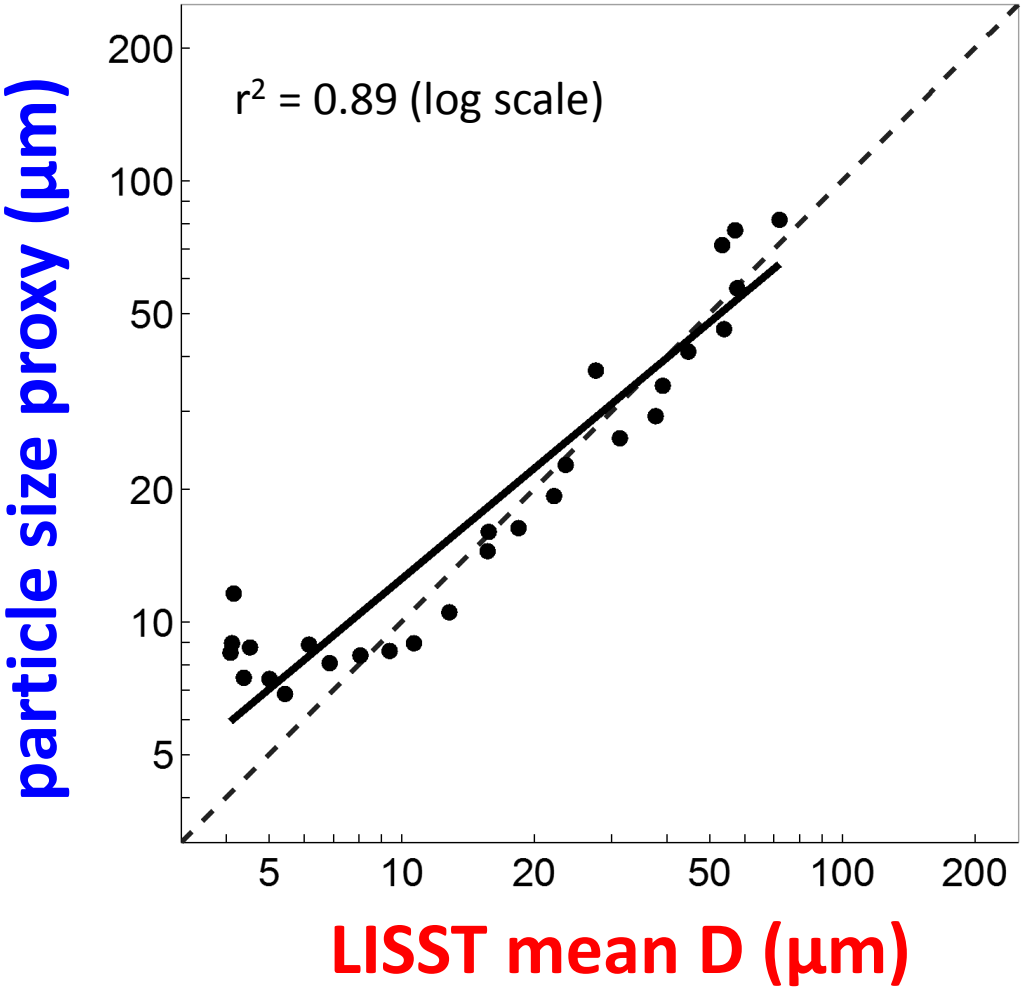
If we assume random distribution of particles and no other sources of variance, we obtain this proxy for size:

$$\frac{\mathrm{var}(\text{Chl F})}{\overline{\text{Chl F}}} = \text{mean Chl F per particle} \rightarrow \text{phytoplankton size proxy}$$

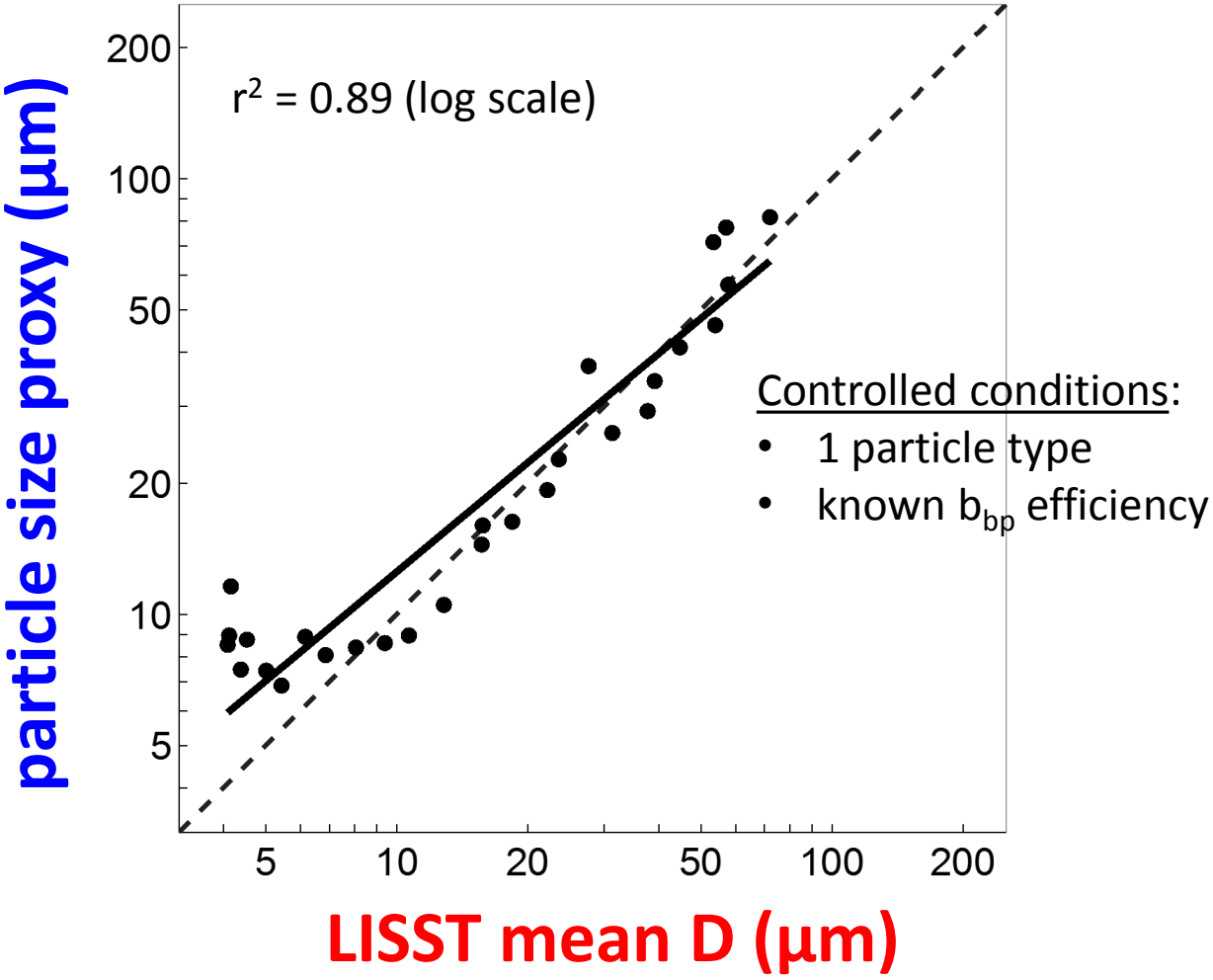
$$\frac{\mathrm{var}(b_{bp})}{\overline{b_{bp}}} = \text{mean } b_{bp} \text{ per particle} \rightarrow \text{particle size proxy}$$

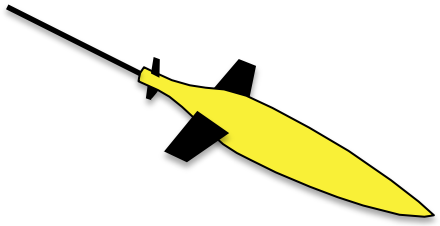
More details in Briggs et al. (2013)

Lab validation: Backscattering size proxy accurately predicts mean diameters above 10 µm



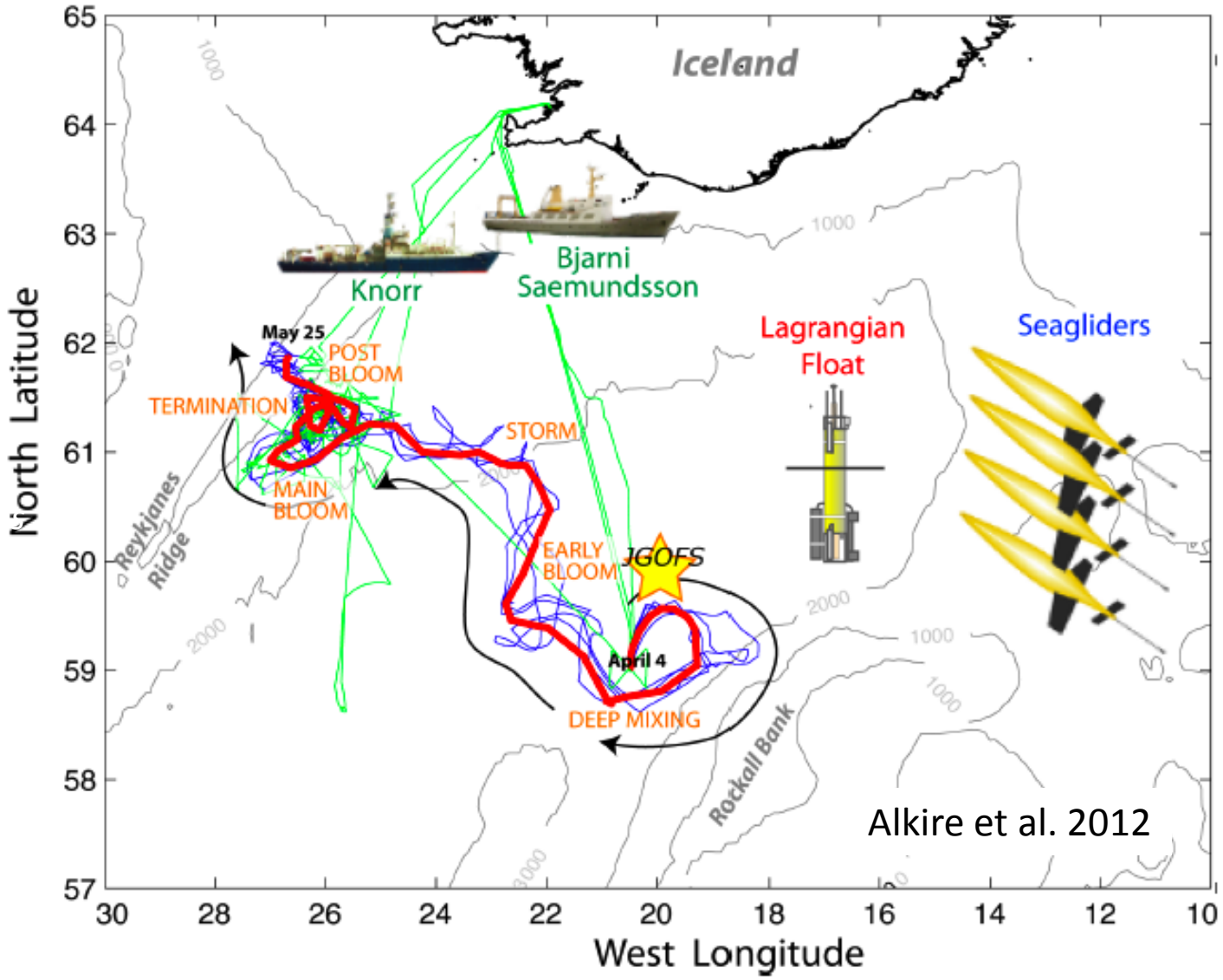
Lab validation: Backscattering size proxy accurately predicts mean diameters above 10 µm





Field application

Showing ship and glider data from the 2008 North Atlantic Bloom project (NAB08)

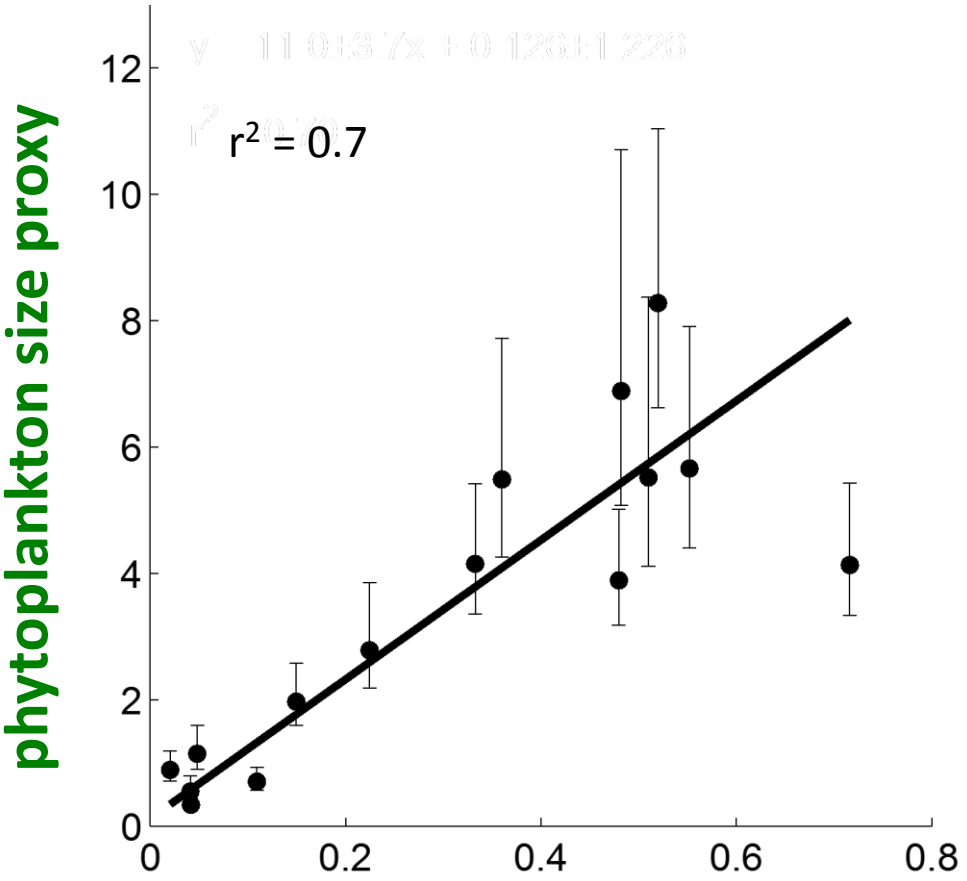


Alkire et al. 2012

Phytoplankton size proxy correlates with diatom fraction during the North Atlantic spring bloom

$$\frac{\text{var(Chl F)}}{\overline{\text{Chl F}}}$$

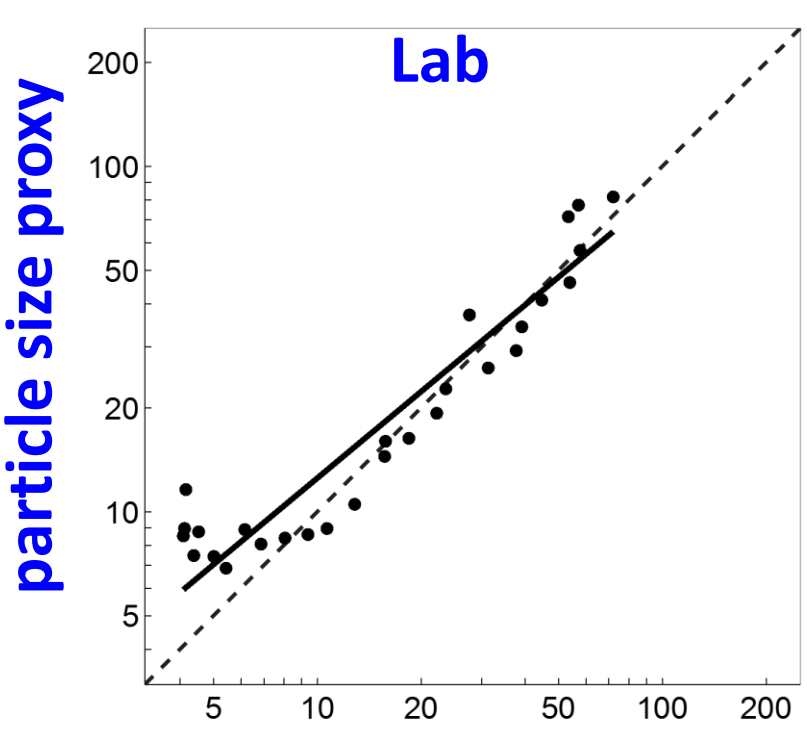
(from ship in-situ chl fluorometer)

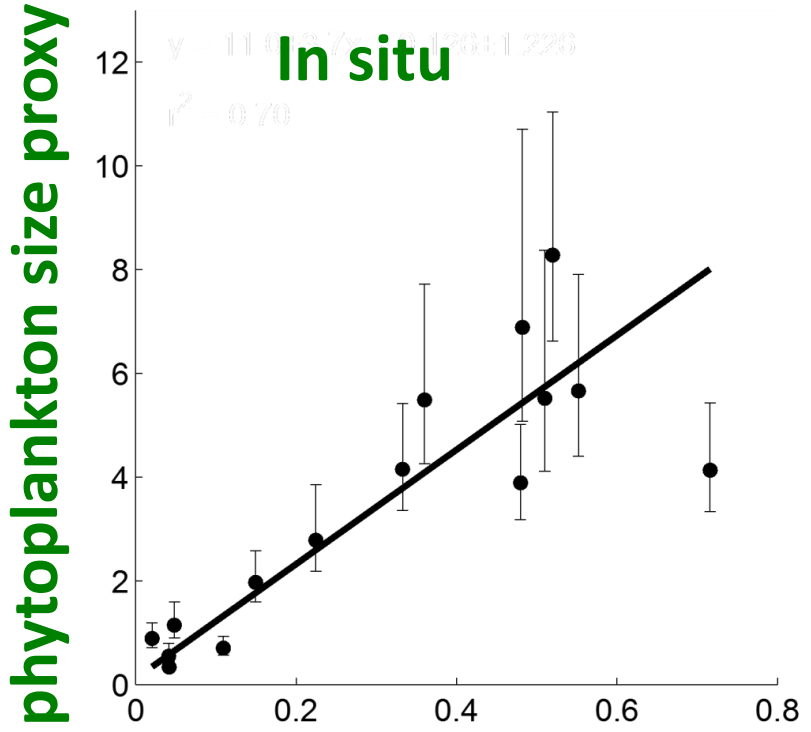


(From ship-based FlowCAM imaging and flow cytometer)

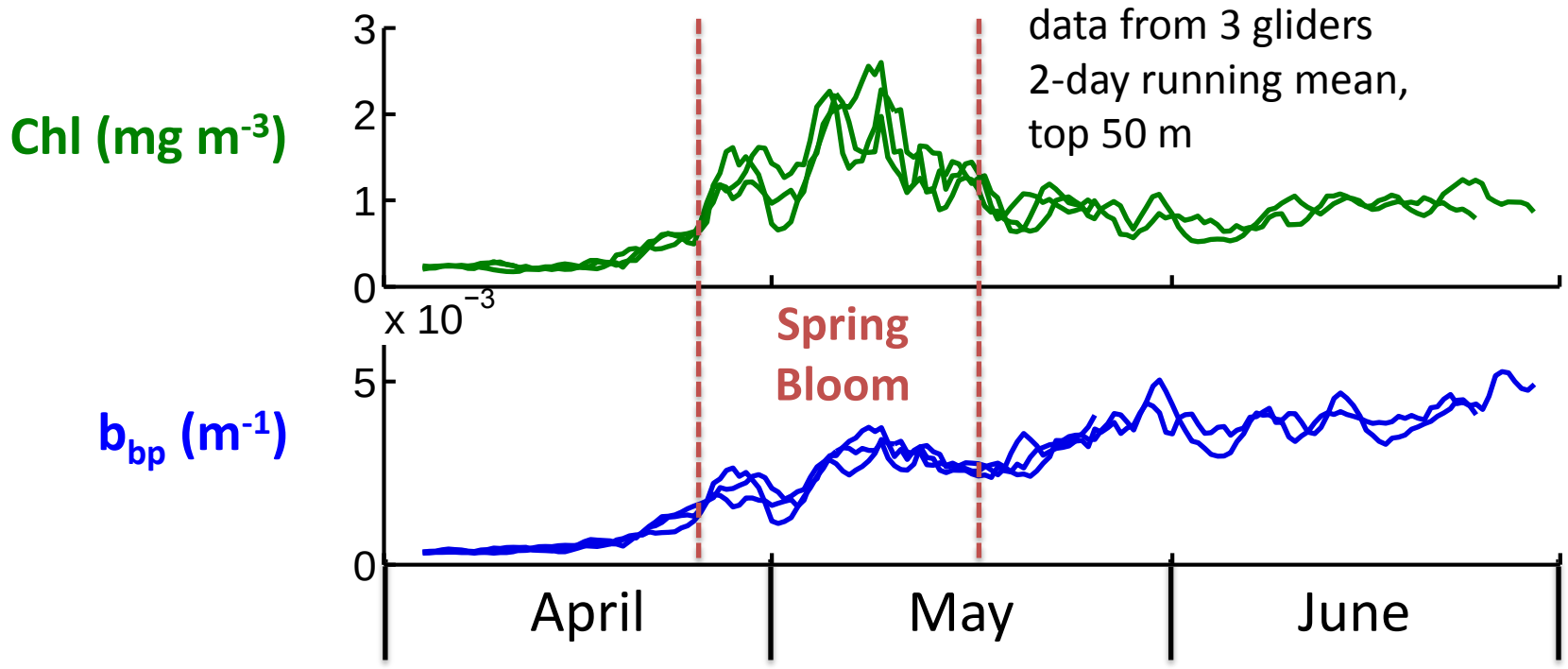
Particle size proxy not yet validated in situ

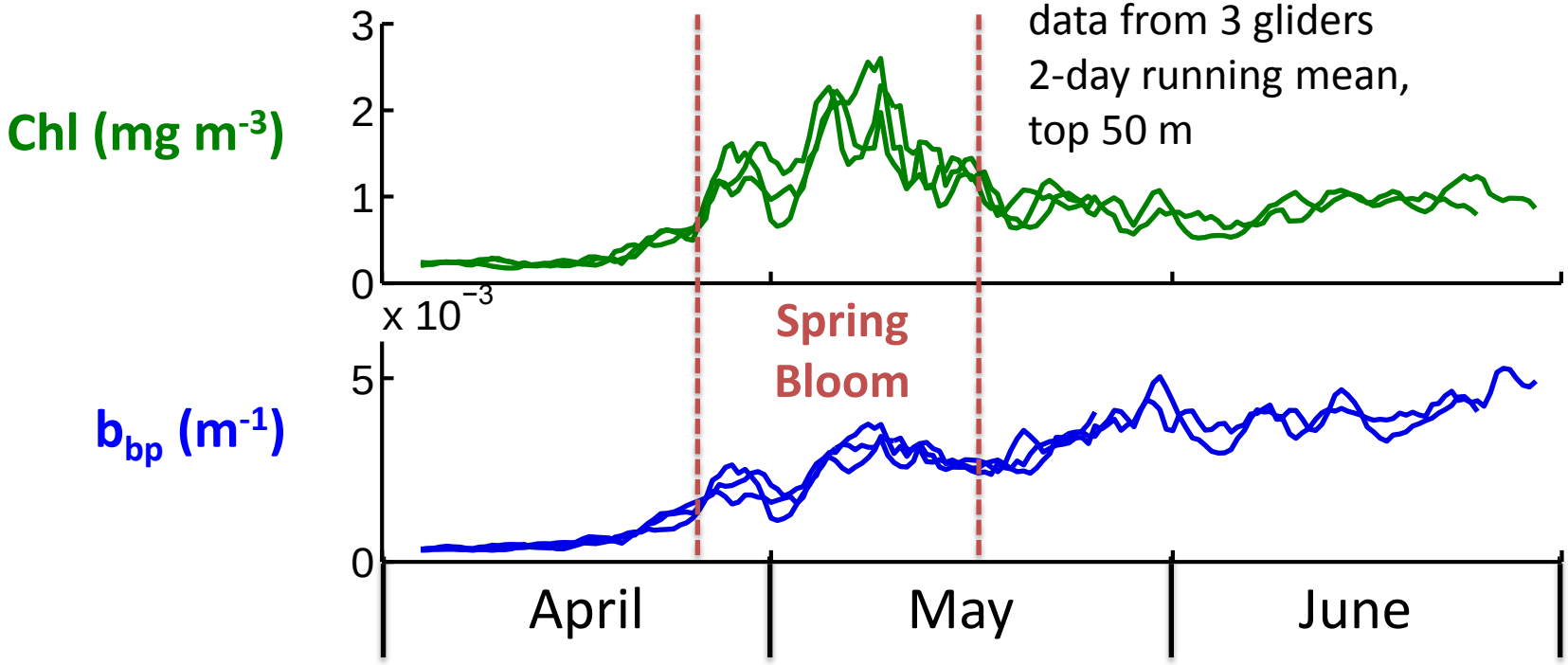
$$\frac{\mathrm{var}(b_{bp})}{\overline{b_{bp}}} = \text{mean } b_{bp} \text{ per particle} \rightarrow \text{particle size proxy}$$

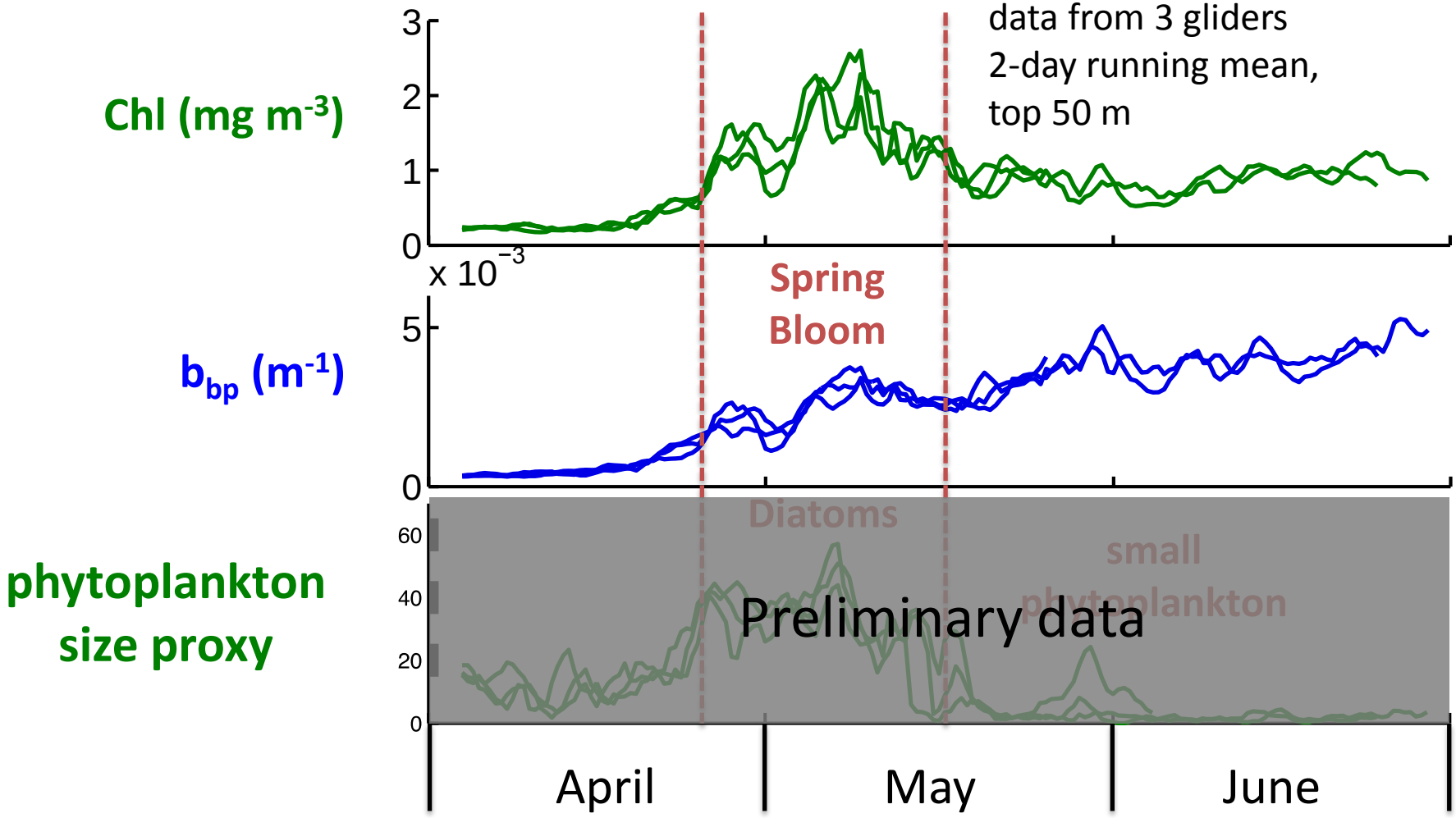


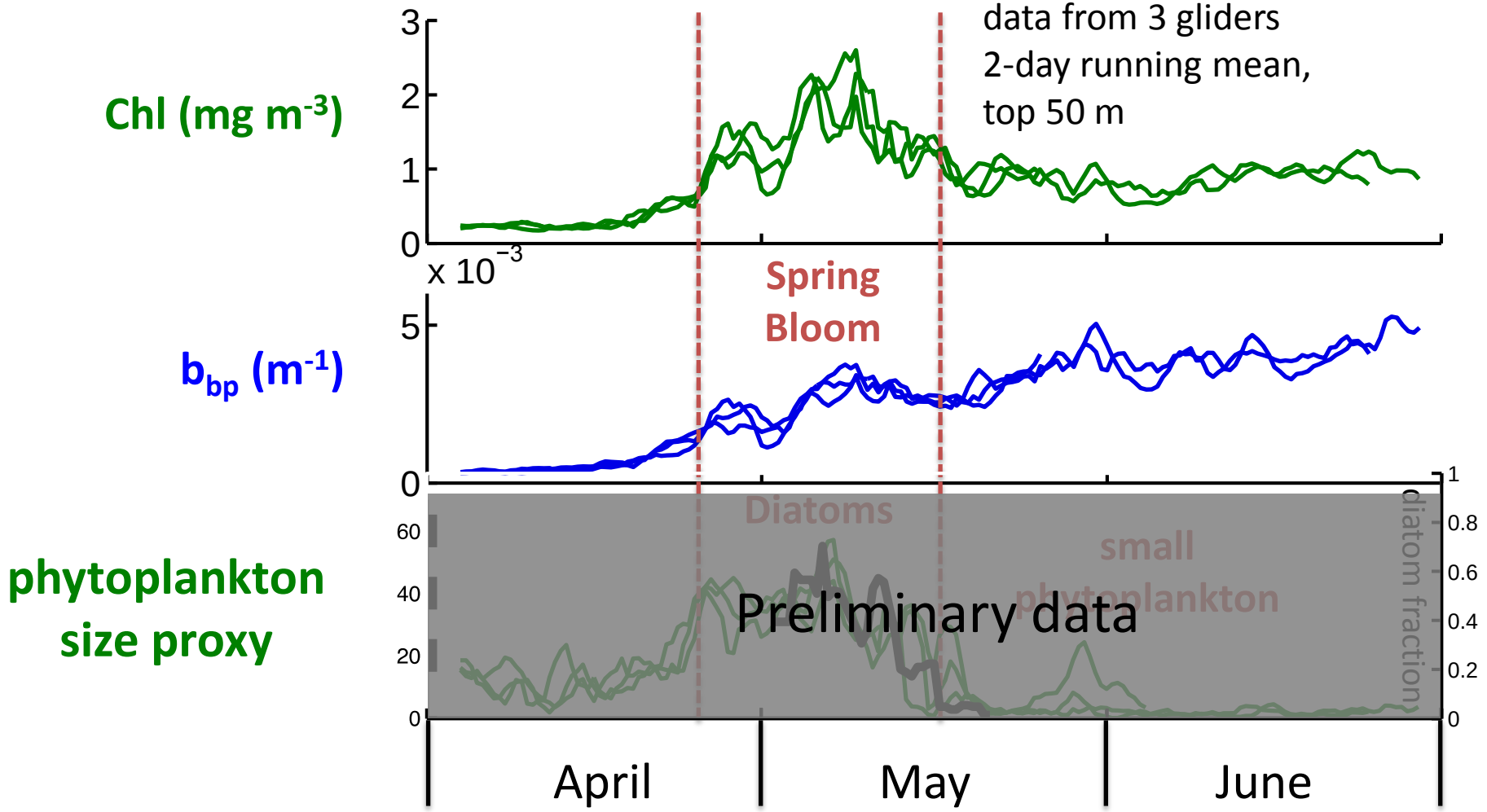


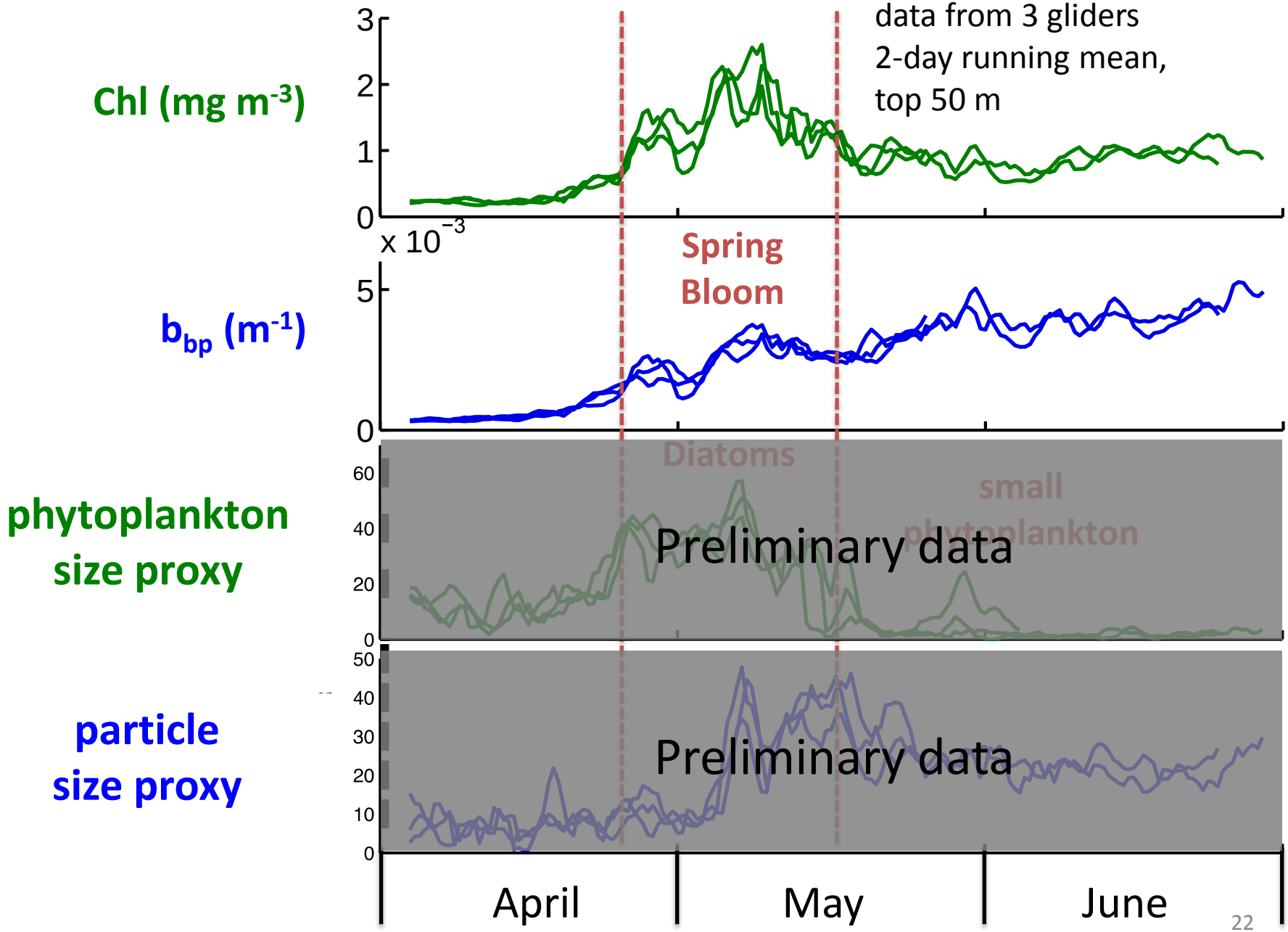
Glider chl fluorescence and backscattering show surface bloom evolution

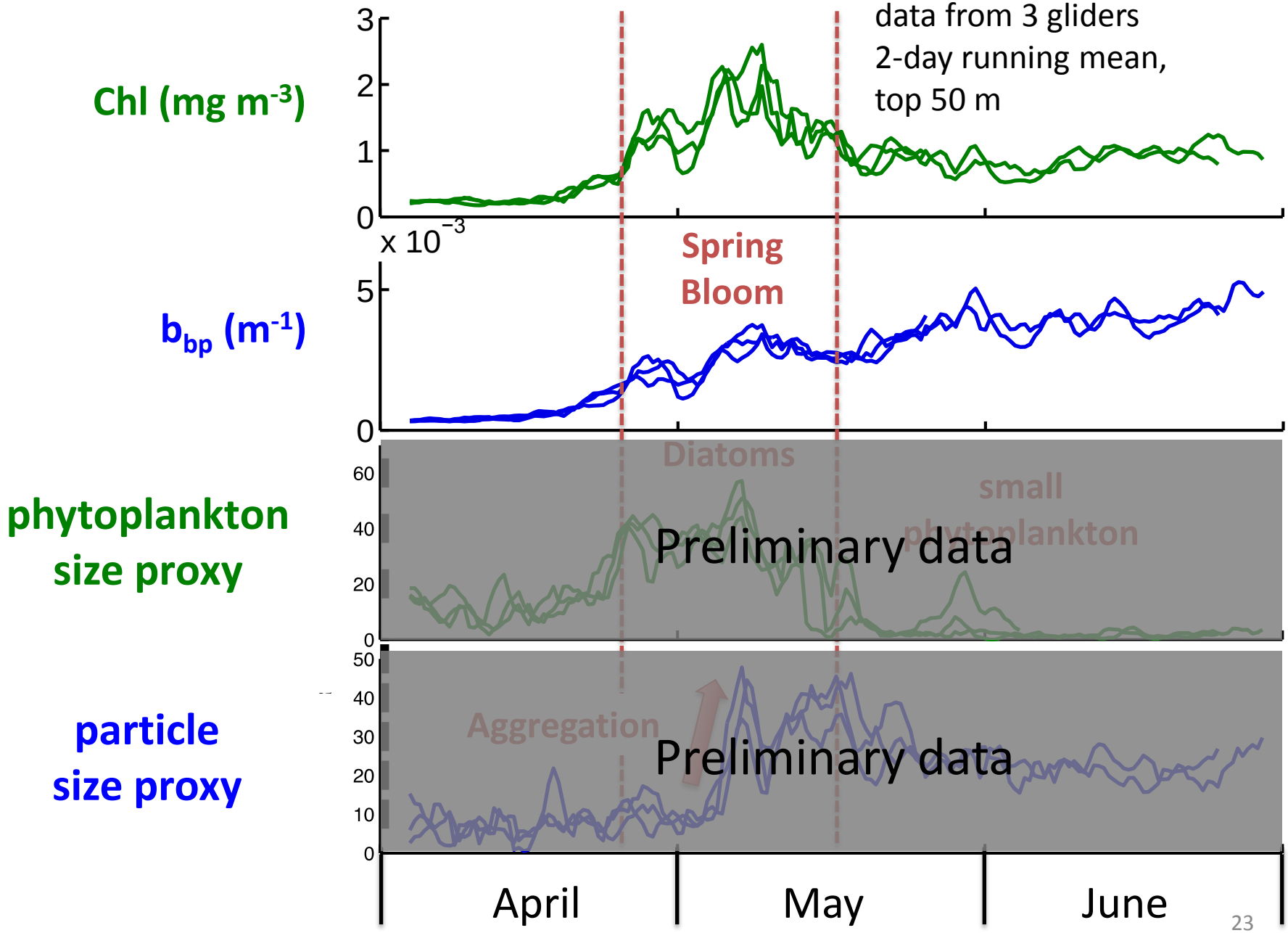


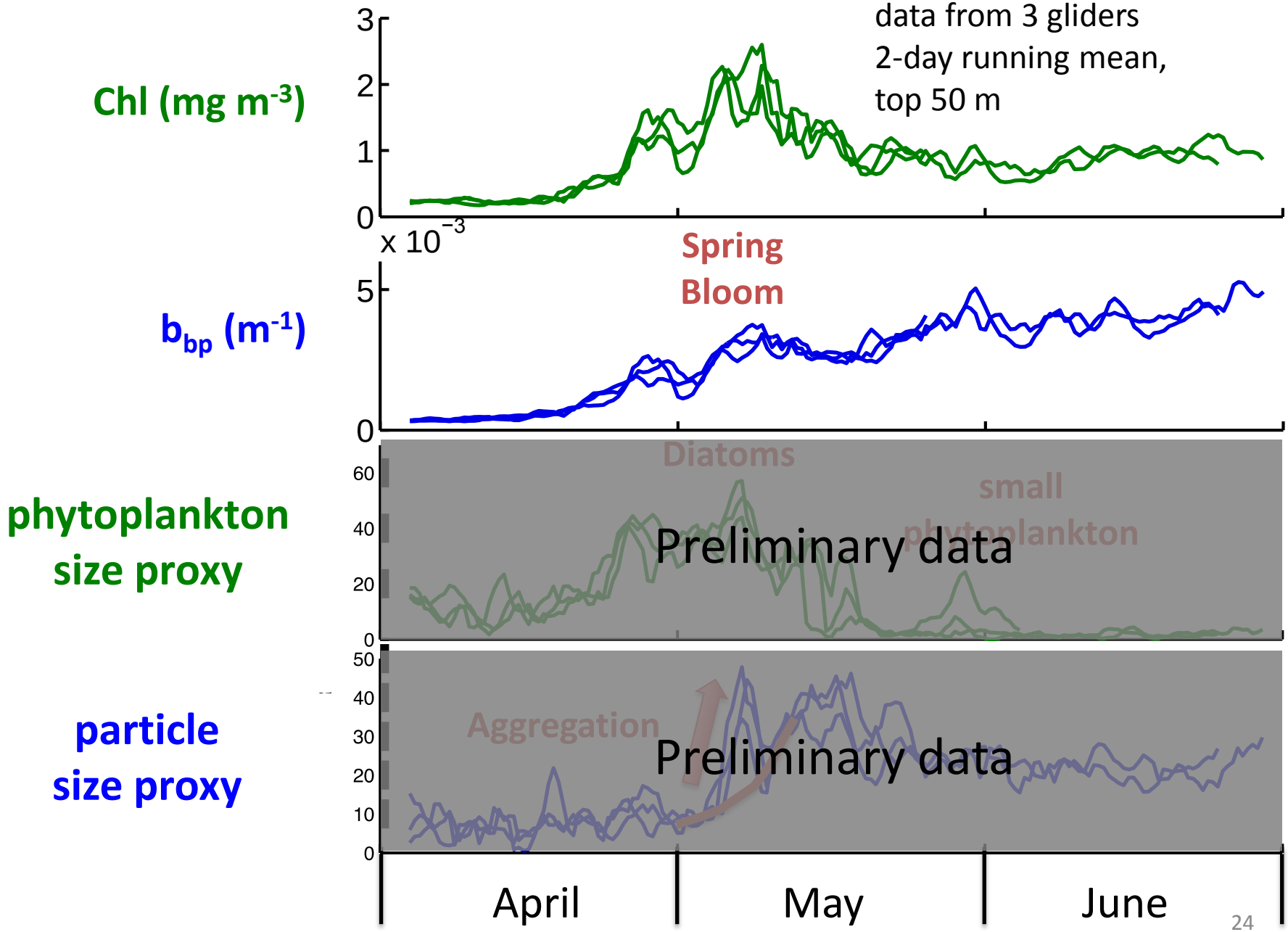

Chl (mg m-3)
bbp (m-1)
data from 3 gliders
2-day running mean,
top 50 m
3
2
1
0
x 10−3
5
0
Spring
Bloom
April
May
June


Chl (mg m-3)
bbp (m-1)
phytoplankton size proxy
data from 3 gliders
2-day running mean,
top 50 m
x 10−3
Spring Bloom
Diatoms
small phytoplankton
Preliminary data
April
May
June

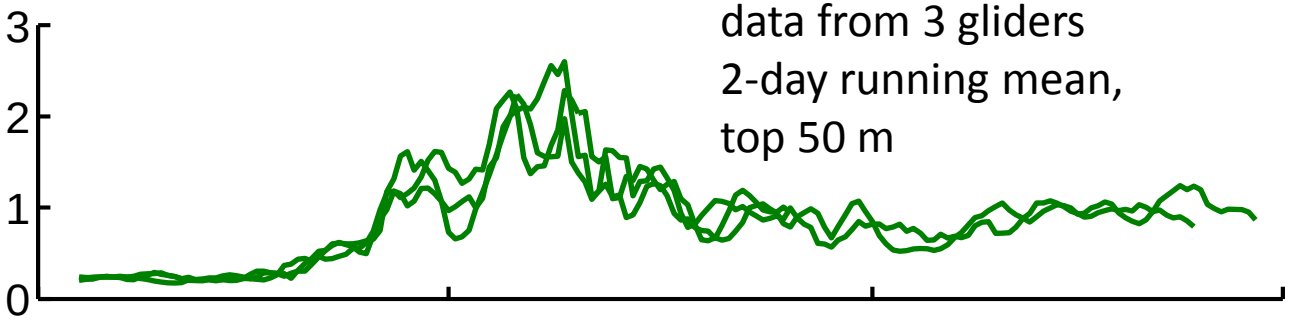

Chl (mg m-3)
bbp (m-1)
phytoplankton size proxy
data from 3 gliders
2-day running mean,
top 50 m
x 10−3
Spring Bloom
Diatoms
small phytoplankton
diatom fraction
Preliminary data
April
May
June


Chl (mg m-3)
bbp (m-1)
phytoplankton size proxy
particle size proxy
data from 3 gliders
2-day running mean,
top 50 m
x 10−3
Spring Bloom
Diatoms
small phytoplankton
Preliminary data
Preliminary data
April
May
June


Chl (mg m-3)
bbp (m-1)
phytoplankton size proxy
particle size proxy
data from 3 gliders
2-day running mean,
top 50 m
x 10−3
Spring Bloom
Diatoms
small phytoplankton
Preliminary data
Aggregation
Preliminary data
April
May
June

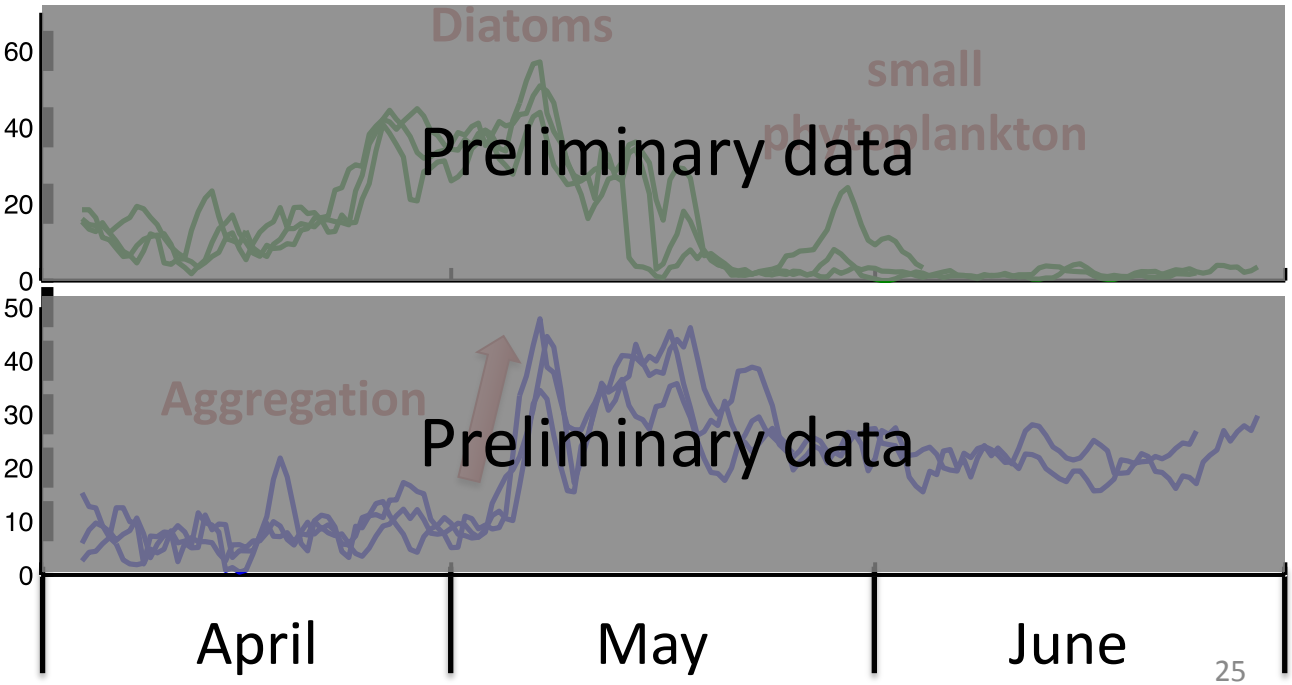

Chl (mg m-3)
data from 3 gliders
2-day running mean,
top 50 m
3
2
1
0
x 10−3
Spring
Bloom
bbp (m-1)
5
0
phytoplankton
size proxy
Diatoms
small
phytoplankton
Preliminary data
60
40
20
0
particle
size proxy
Aggregation
Preliminary data
50
40
30
20
10
0
April
May
June

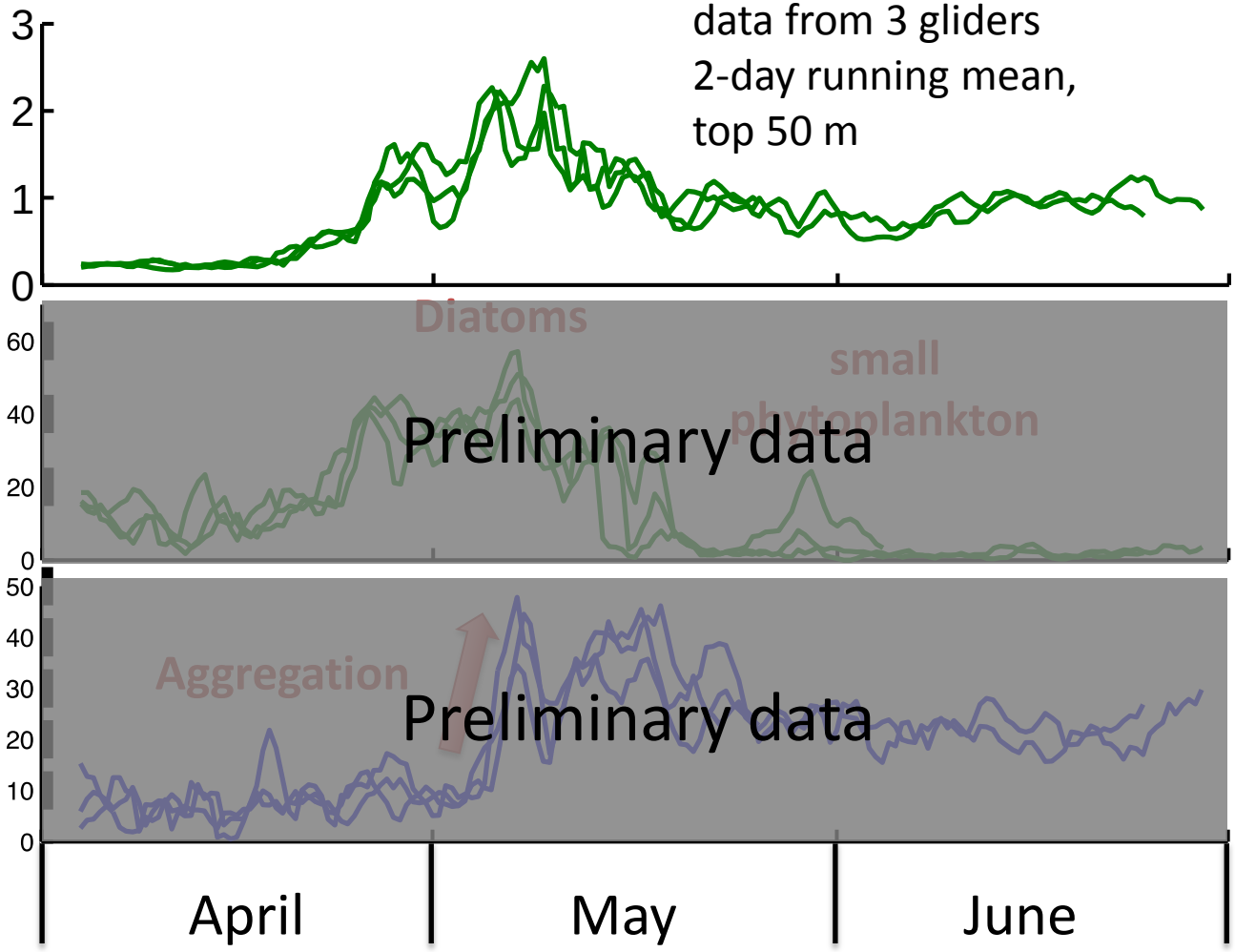
Chl (mg m^{-3})

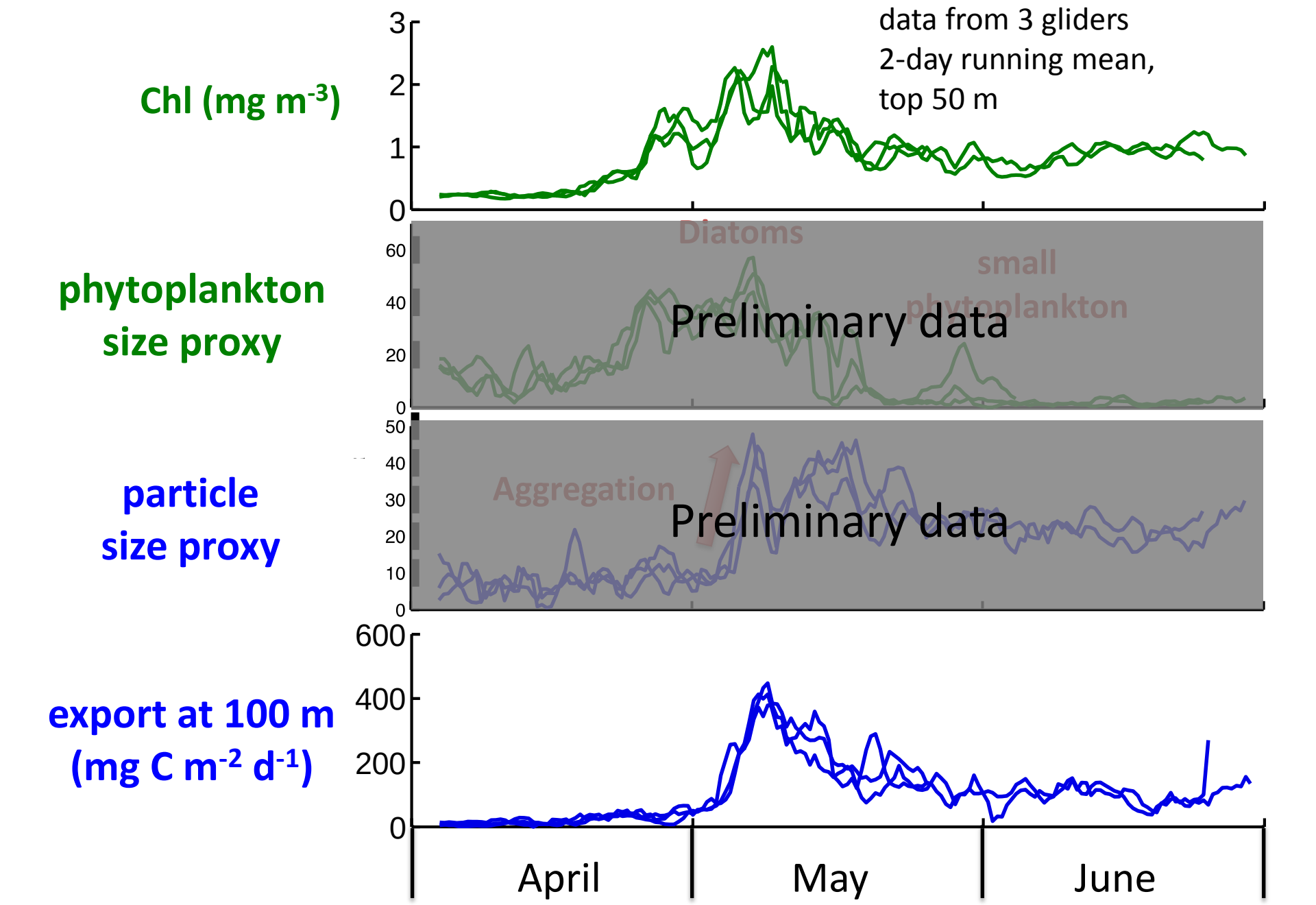


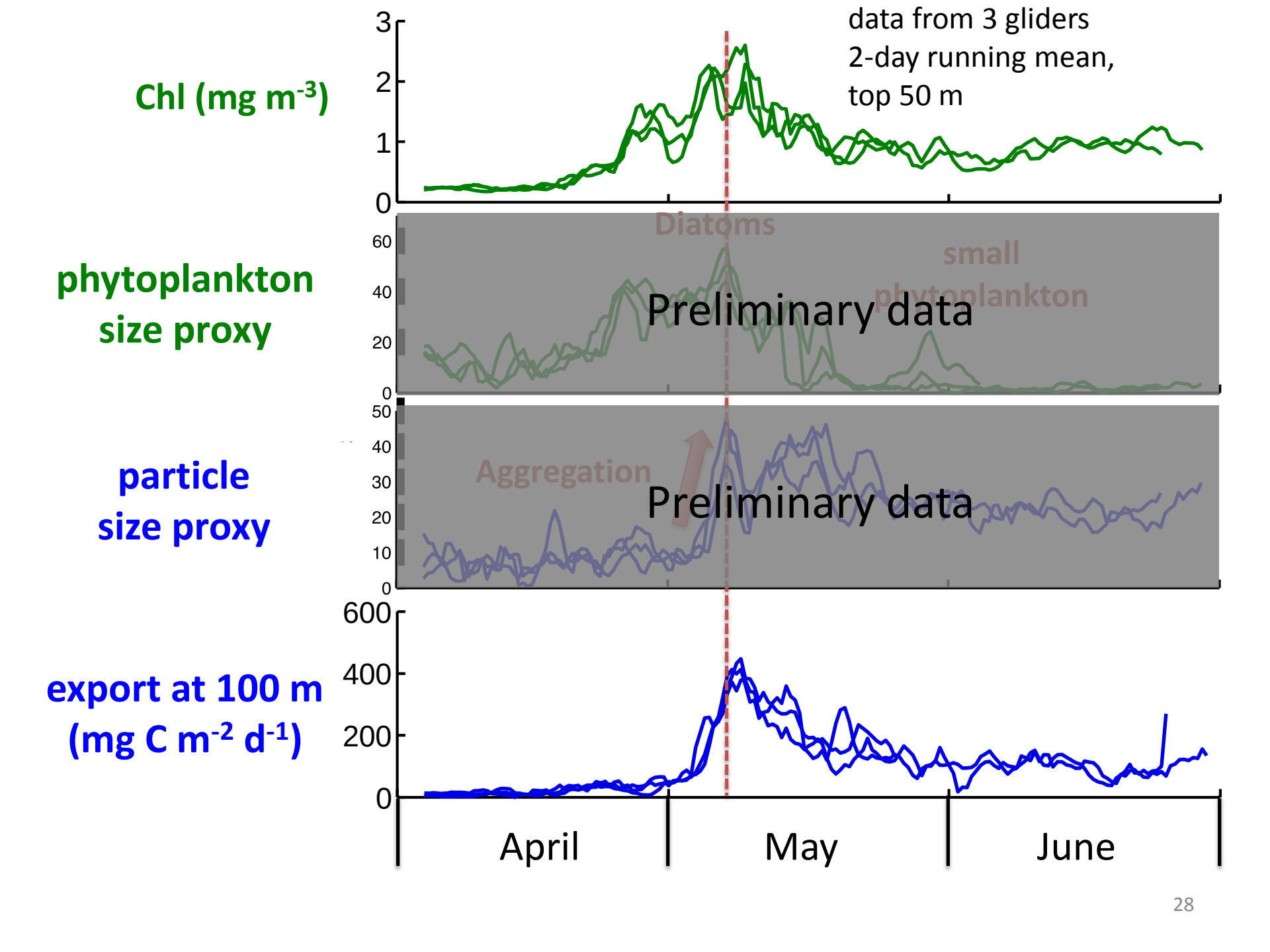
phytoplankton size proxy

particle size proxy




Chl (mg m-3)
data from 3 gliders
2-day running mean,
top 50 m
3
2
1
0
phytoplankton
size proxy
Diatoms
small
phytoplankton
Preliminary data
60
40
20
0
particle
size proxy
Aggregation
Preliminary data
50
40
30
20
10
0
April
May
June


Chl (mg m-3)
data from 3 gliders
2-day running mean,
top 50 m
3
2
1
0
phytoplankton
size proxy
Diatoms
small
phytoplankton
Preliminary data
60
40
20
0
particle
size proxy
Aggregation
Preliminary data
50
40
30
20
10
0
export at 100 m
(mg C m-2 d-1)
600
400
200
0
April
May
June


Chl (mg m-3)
data from 3 gliders
2-day running mean,
top 50 m
phytoplankton
size proxy
Diatoms
small
phytoplankton
Preliminary data
particle
size proxy
Aggregation
Preliminary data
export at 100 m
(mg C m-2 d-1)
April
May
June

From Satellite

☑

☑ e.g. Ciotti & Bricaud (2006), Mouw & Yoder (2010)

☑ Kostadinov et al. (2009), Svetlana Milutinović (poster on Mon)

☐ Models