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

Results from a NASA Earth and Space Science Fellowship

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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.

not just noise!
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.

VS
Here I focus on the first two cases
If we assume random distribution of particles and no other sources of variance, we obtain this proxy for size:

\[
\frac{\text{var(Chl F)}}{\text{Chl F}} = \text{mean Chl F per particle} \rightarrow \text{phytoplankton size proxy}
\]

\[
\frac{\text{var}(b_{bp})}{b_{bp}} = \text{mean } b_{bp} \text{ per particle} \rightarrow \text{particle size proxy}
\]

More details in Briggs et al. (2013)
Lab validation: Backscattering size proxy accurately predicts mean diameters above 10 µm

$r^2 = 0.89$ (log scale)
Lab validation: Backscattering size proxy accurately predicts mean diameters above 10 µm

$r^2 = 0.89$ (log scale)

**Controlled conditions:**
- 1 particle type
- Known $b_{bp}$ efficiency
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

\[ \frac{\text{var(Chl F)}}{\text{Chl F}} \]

(from ship in-situ chl fluorometer)

(From ship-based FlowCAM imaging and flow cytometer)

\[ y = 11.0 + 3.7x + 0.128 + 1.228 \]

\[ r^2 = 0.7 \]
Particle size proxy not yet validated in situ

\[ \text{var}(b_{bp}) = \overline{\text{mean } b_{bp}} \text{ per particle} \rightarrow \text{particle size proxy} \]
Glider chl fluorescence and backscattering show surface bloom evolution.

Chl (mg m$^{-3}$)

$b_{bp}$ (m$^{-1}$)

data from 3 gliders
2-day running mean, top 50 m

Spring Bloom

April | May | June
Chl (mg m\(^{-3}\))

\(b_{bp} \text{ (m}^{-1}\))

data from 3 gliders
2-day running mean,
top 50 m

Spring Bloom
Chl (mg m$^{-3}$)

b$_{bp}$ (m$^{-1}$)

phytoplankton size proxy

Spring Bloom

data from 3 gliders 2-day running mean, top 50 m

Preliminary data

April | May | June
Chl (mg m$^{-3}$) & b_{bp} (m$^{-1}$) & phytoplankton size proxy

Preliminary data

Spring Bloom

data from 3 gliders
2-day running mean, top 50 m
Chl (mg m\(^{-3}\))

\(b_{bp} \text{ (m}^{-1}\))

**Preliminary data**

Data from 3 gliders
2-day running mean, top 50 m

Spring Bloom

**phytoplankton size proxy**

**particle size proxy**

April May June
Chl (mg m\(^{-3}\))

\[ b_{bp} (m^{-1}) \]

phytoplankton size proxy

particle size proxy

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data from 3 gliders 2-day running mean, top 50 m

Spring Bloom

Preliminary data

Preliminary data

April  May  June
Chl (mg m\(^{-3}\))

\(b_{bp} (m^{-1})\)

phytoplankton size proxy

particle size proxy

data from 3 gliders
2-day running mean, top 50 m

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

phytoplankton size proxy

Preliminary data

particle size proxy

Preliminary data

Diatoms

small phytoplankton

Aggregation

April May June
Chl (mg m\(^{-3}\))

phytoplankton size proxy

particle size proxy

Preliminary data

data from 3 gliders
2-day running mean,
top 50 m

Preliminary data

April

May

June
Chl (mg m\(^{-3}\))

phytoplankton size proxy

particle size proxy

export at 100 m (mg C m\(^{-2}\) d\(^{-1}\))

data from 3 gliders 2-day running mean, top 50 m

Preliminary data

Diatoms

small phytoplankton

Aggregation

Preliminary data

April | May | June
Chl (mg m\(^{-3}\))

phytoplankton size proxy

particle size proxy

export at 100 m (mg C m\(^{-2}\) d\(^{-1}\))

data from 3 gliders  2-day running mean, top 50 m
From Satellite

- Ciotti & Bricaud (2006)
- Mouw & Yoder (2010)
- Kostadinov et al. (2009)
- Svetlana Milutinović (poster on Mon)

Preliminary data

Phytoplankton size proxy

Export at 100 m (mg C m^{-2} d^{-1})

April

May

June

Chl (mg m^{-3})