Using OOI Pioneer Array data to understand: What drives ephemeral surface chlorophyll enhancements at the New England shelf break?

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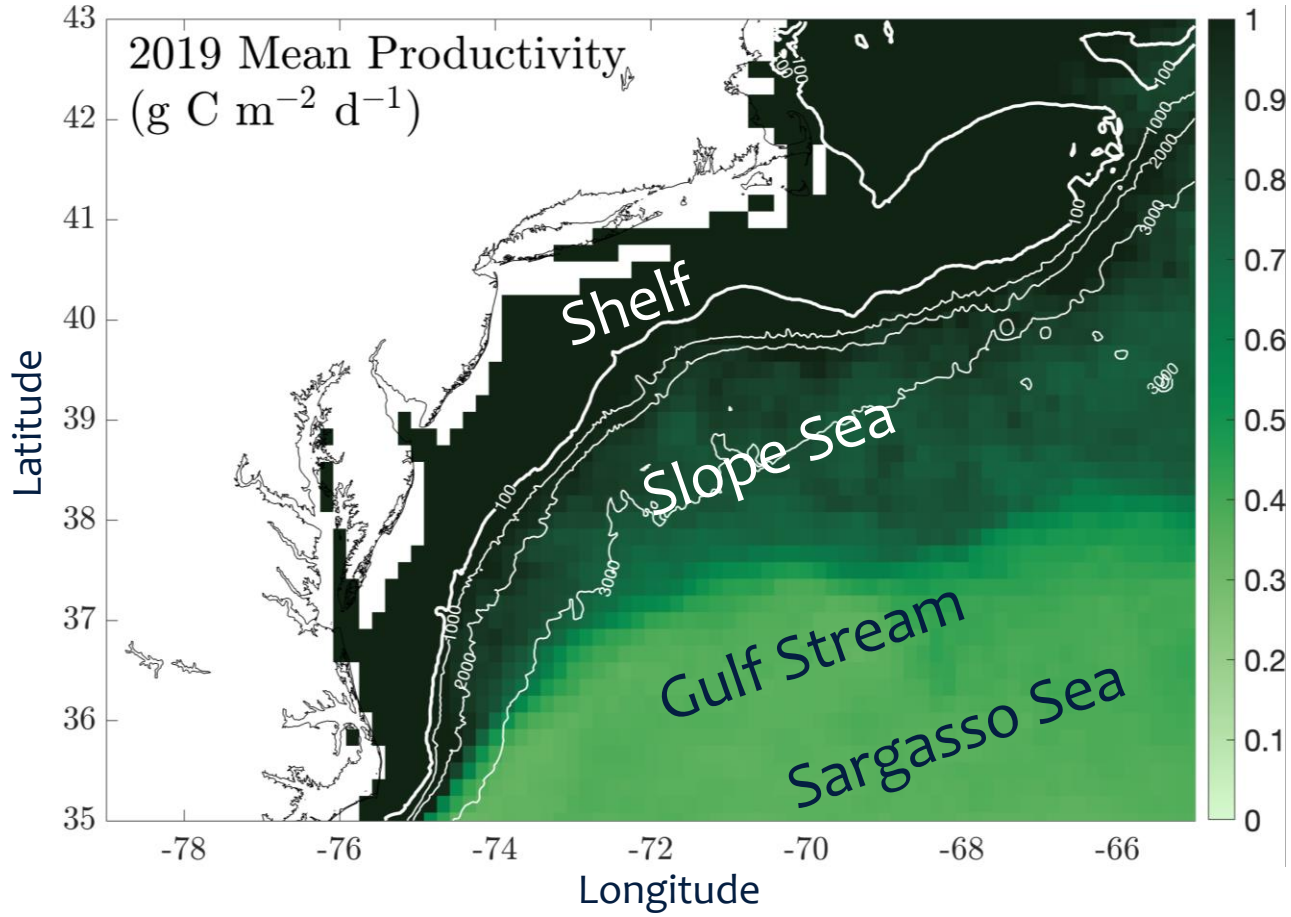
WOODS HOLE
OCEANOGRAPHIC
INSTITUTION

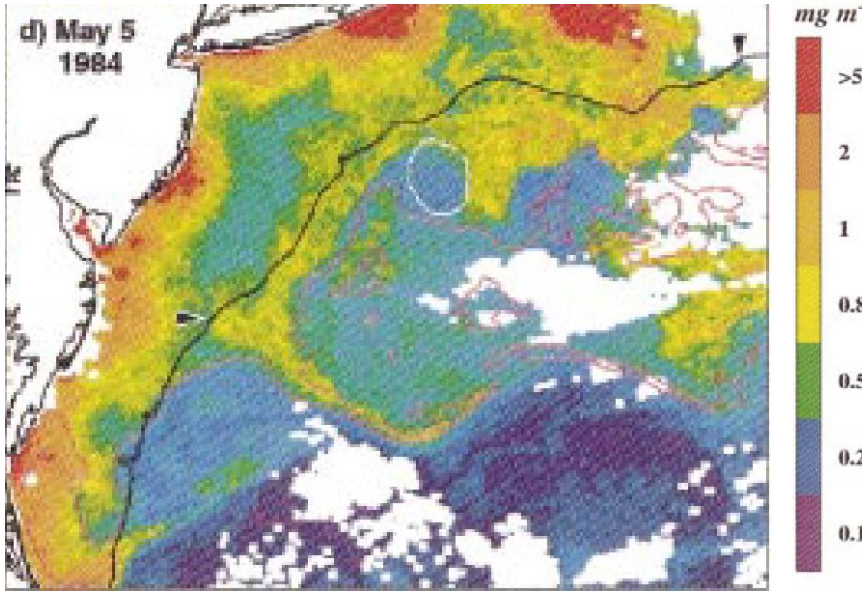
Middle Atlantic Bight (MAB) Productivity

Shelf Productivity > Slope Sea Productivity > Sargasso Sea Productivity



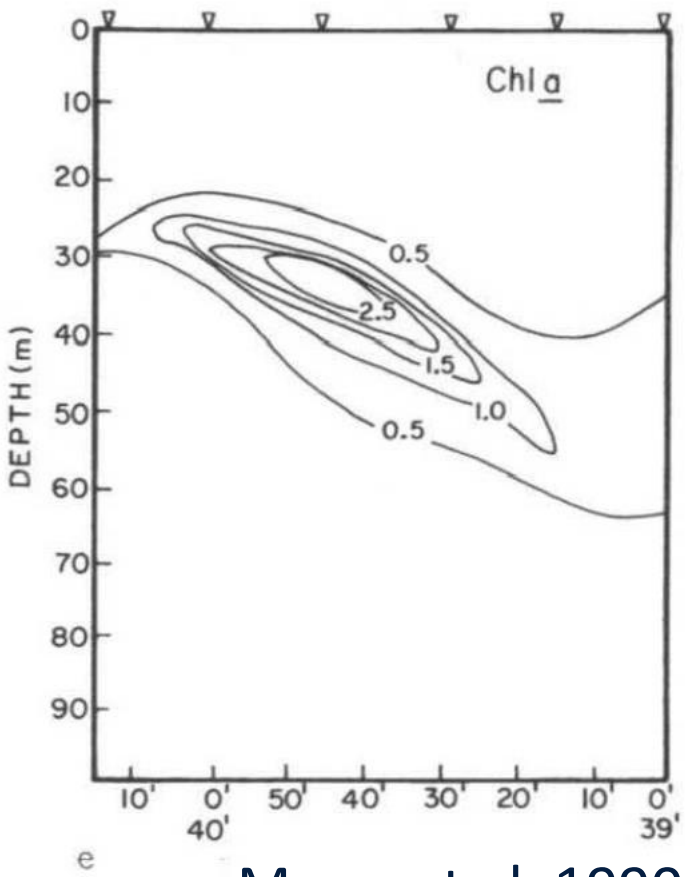
Is productivity enhanced at the shelfbreak?

Surface Chlorophyll



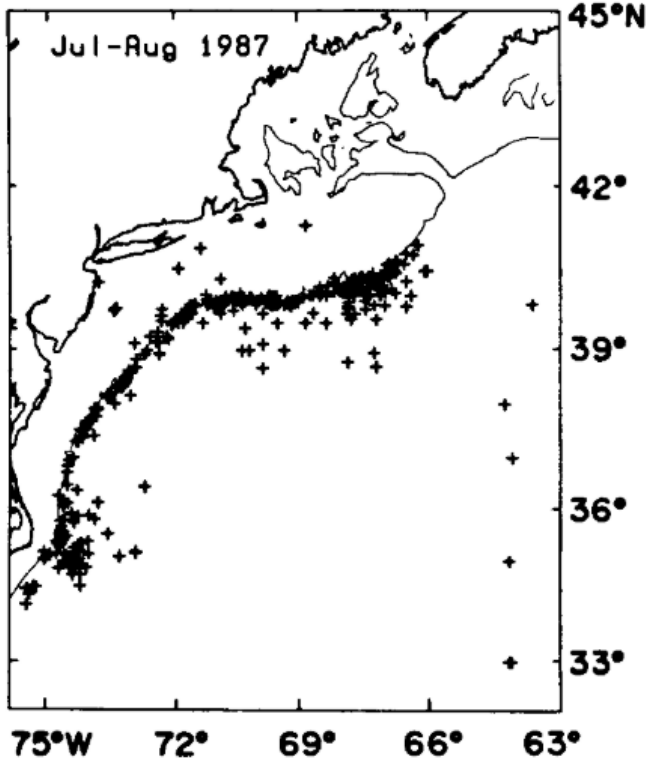
Ryan et al. 1999

Subsurface Chlorophyll

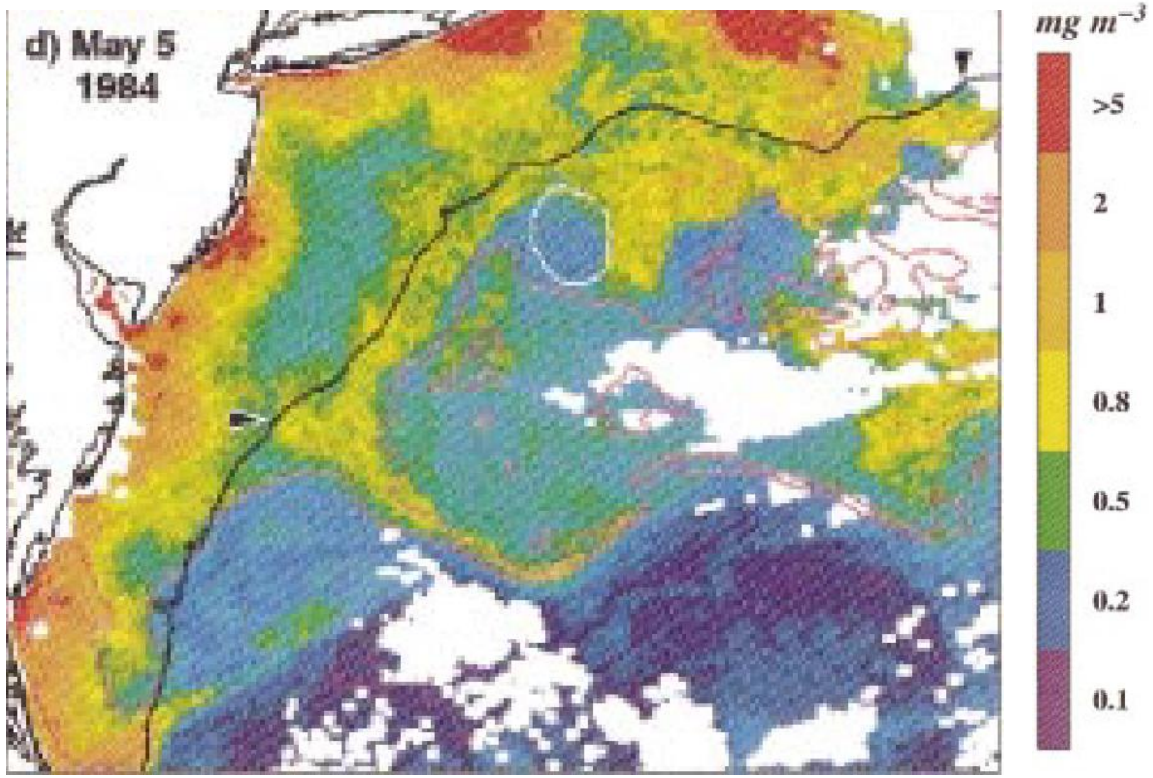


Marra et al. 1990

Swordfish Distributions

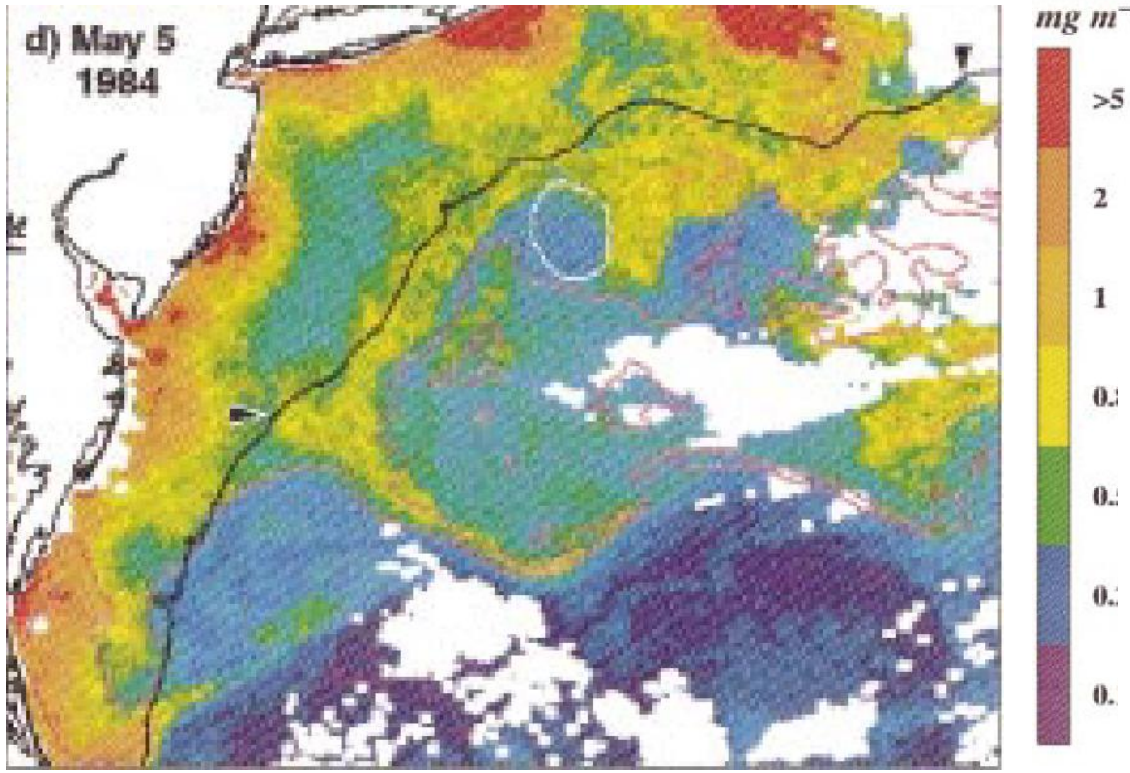


Podestá et al. 1993



Long-documented enhanced chlorophyll at the shelfbreak front

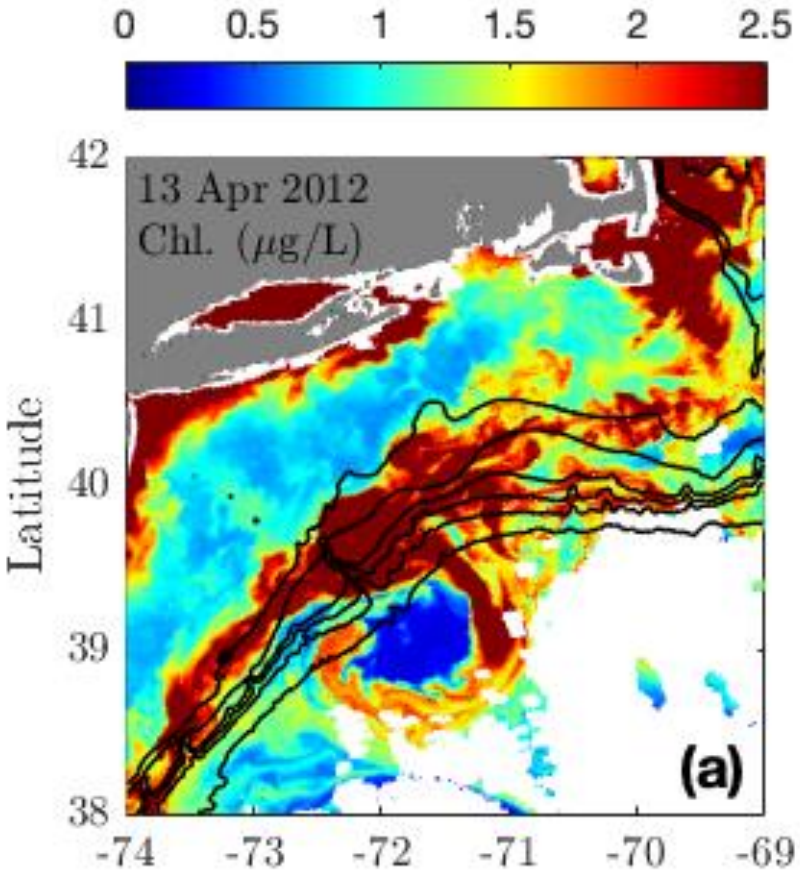
Ryan et al. 1999



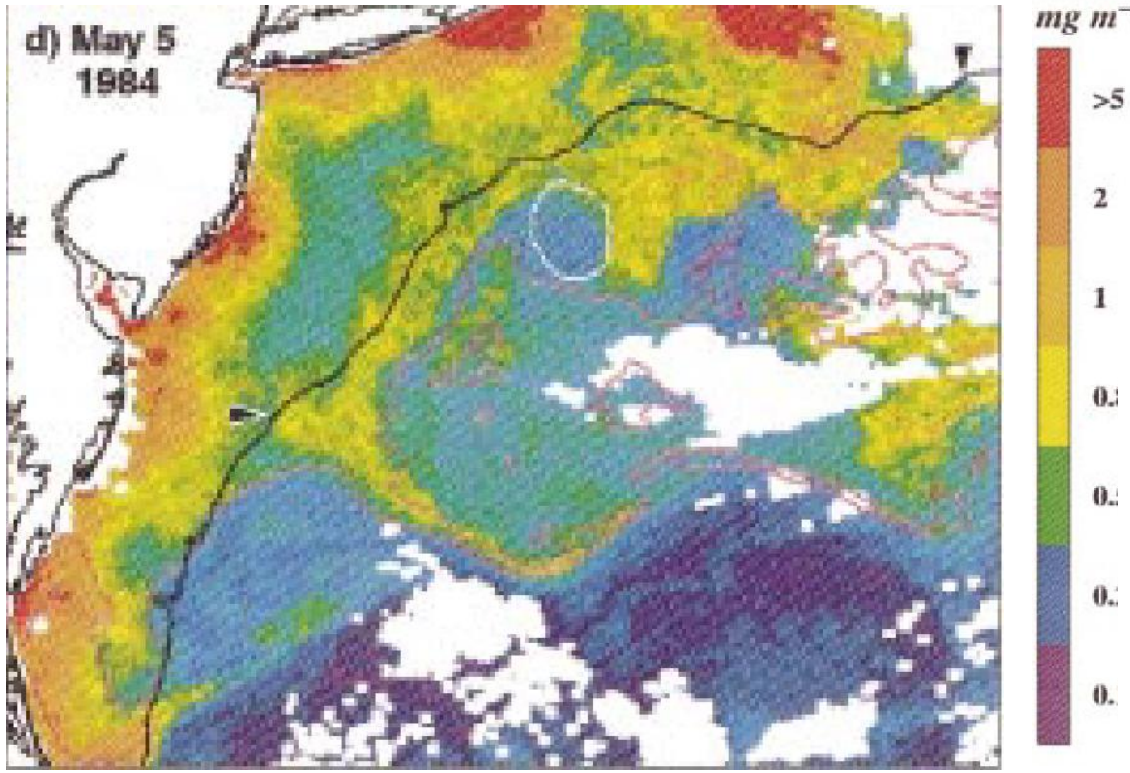
Ryan et al. 1999

Cloudy -> rare complete images of enhancement

Long-documented enhanced chlorophyll at the shelfbreak front



(SPIROPA logo)



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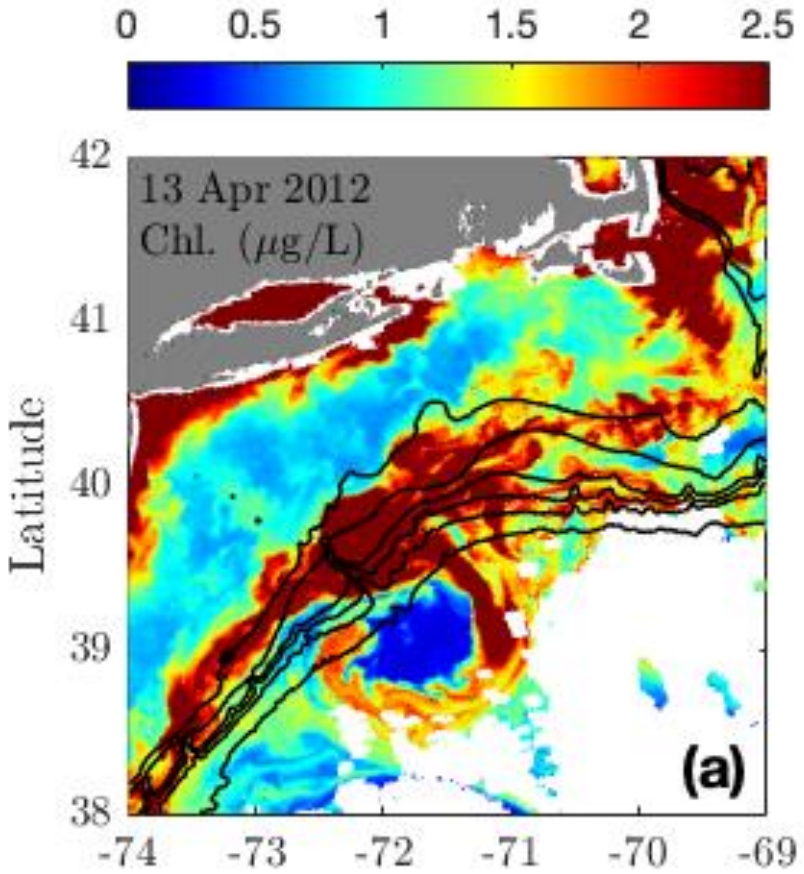
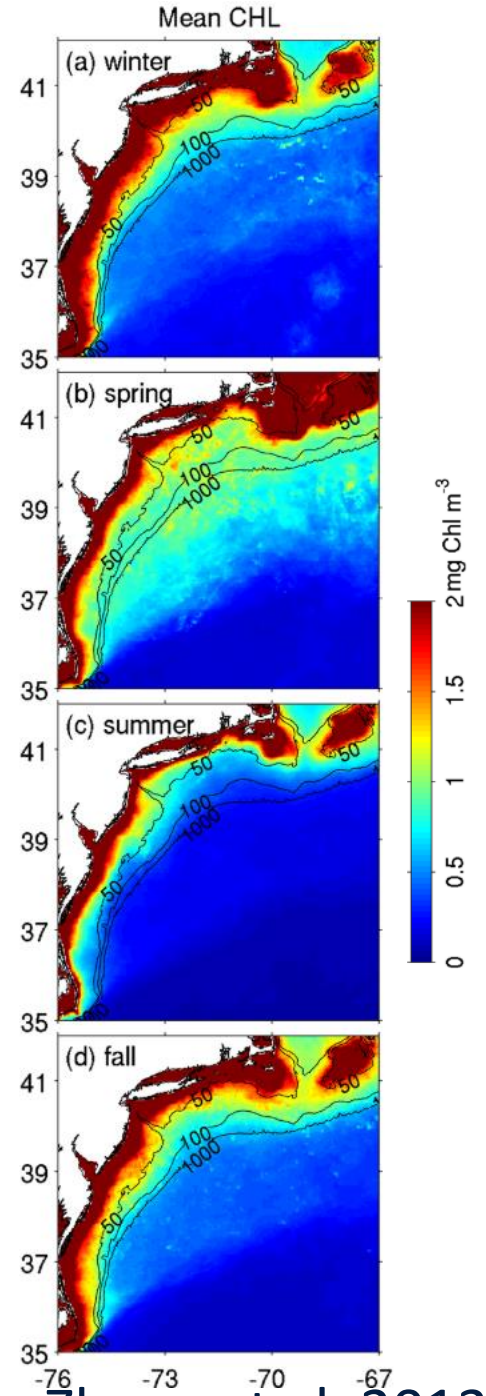


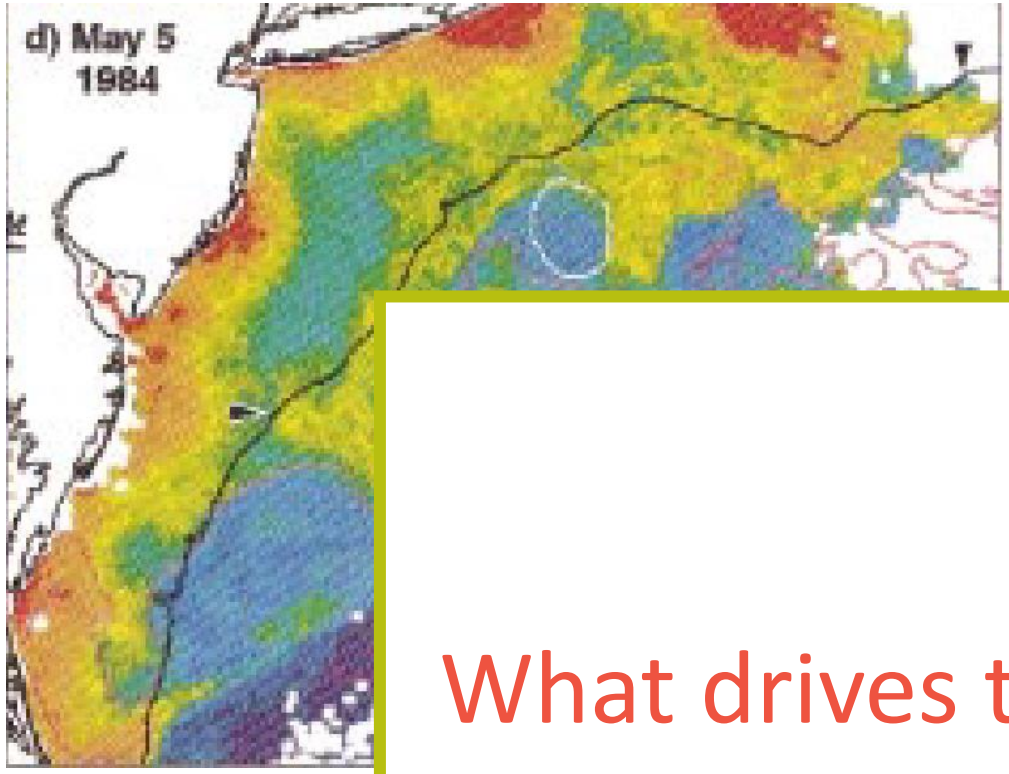
(SPIROPA logo)

Cloudy -> rare complete images of enhancement



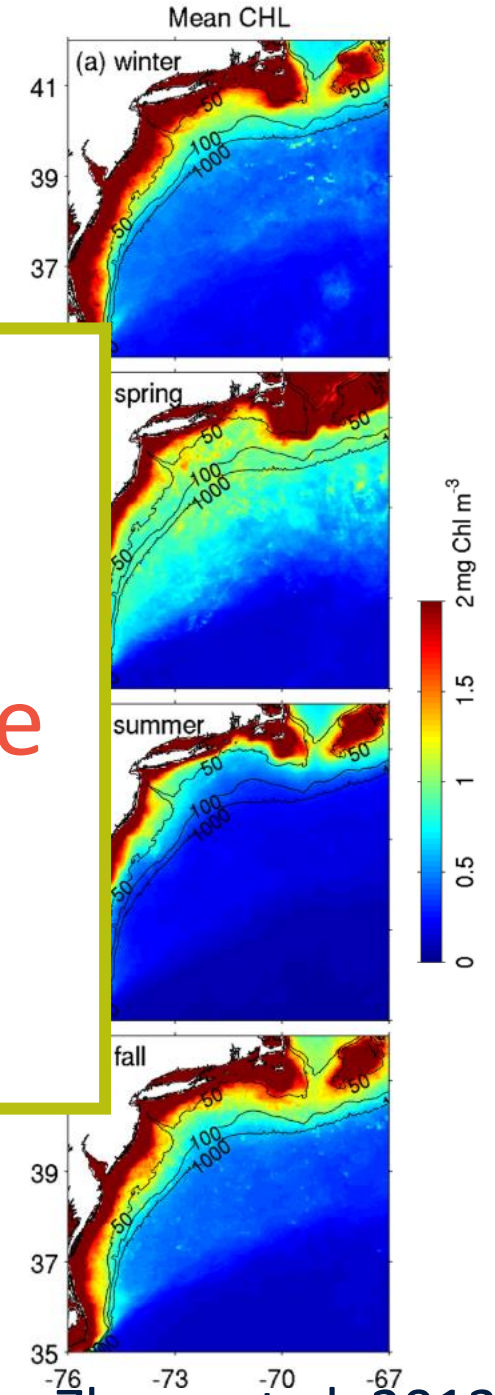
Shelfbreak chlorophyll enhancements are ephemeral -> not visible in seasonal climatologies

Zhang et al. 2013



Long-documented enhanced chlorophyll at the shelfbreak front

0 0.5 1 1.5 2 2.5



Question:
What drives these short-lived surface chlorophyll enhancements?

Cloudy -> rare
enhancement

-74 -73 -72 -71 -70 -69

(SPIROPA logo)

Shelfbreak chlorophyll enhancements are ephemeral -> not visible in seasonal climatologies

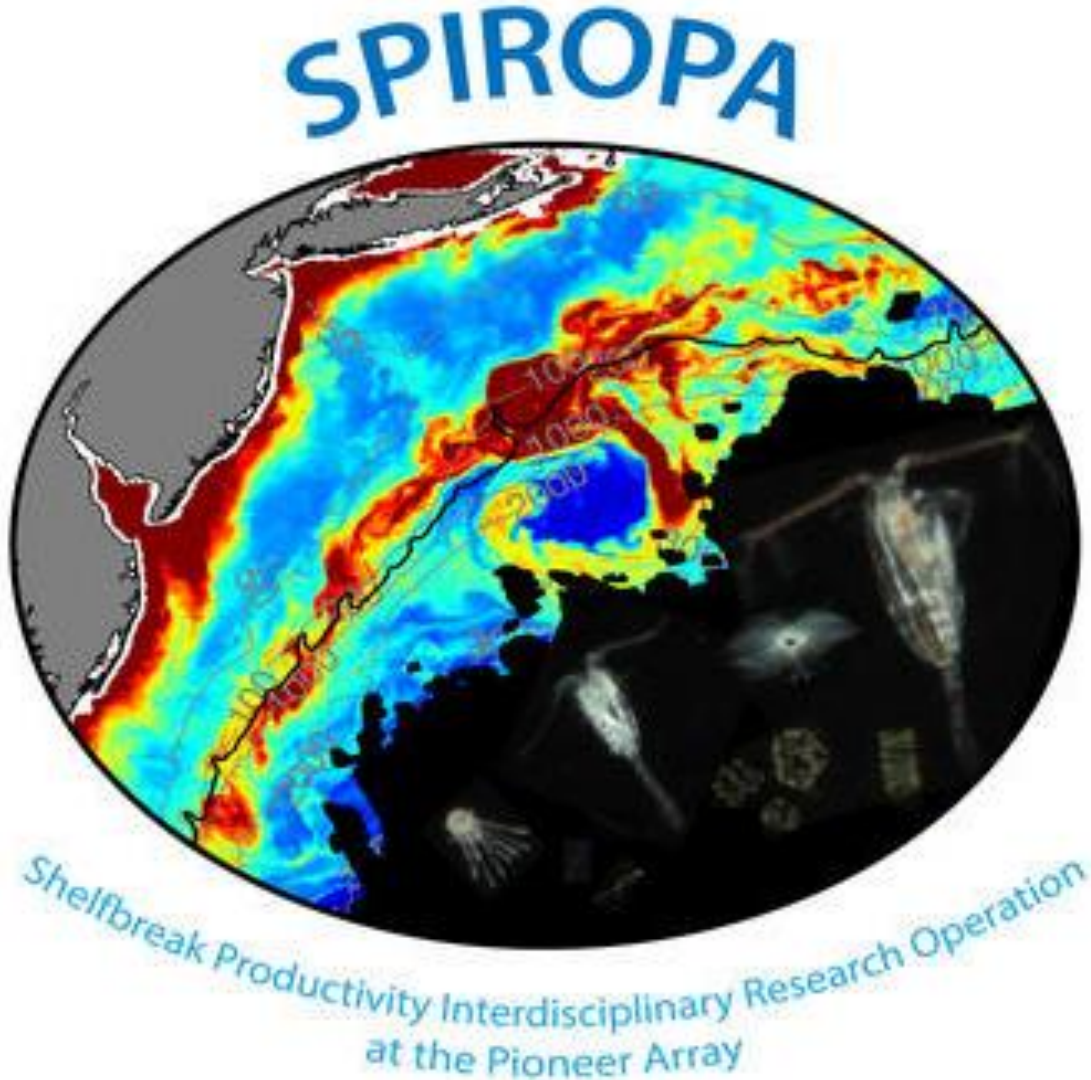
Zhang et al. 2013

Shelfbreak Productivity Interdisciplinary Research Operation at the Pioneer Array (SPIROPA)

1. April 2018, R/V Neil Armstrong
   AR29

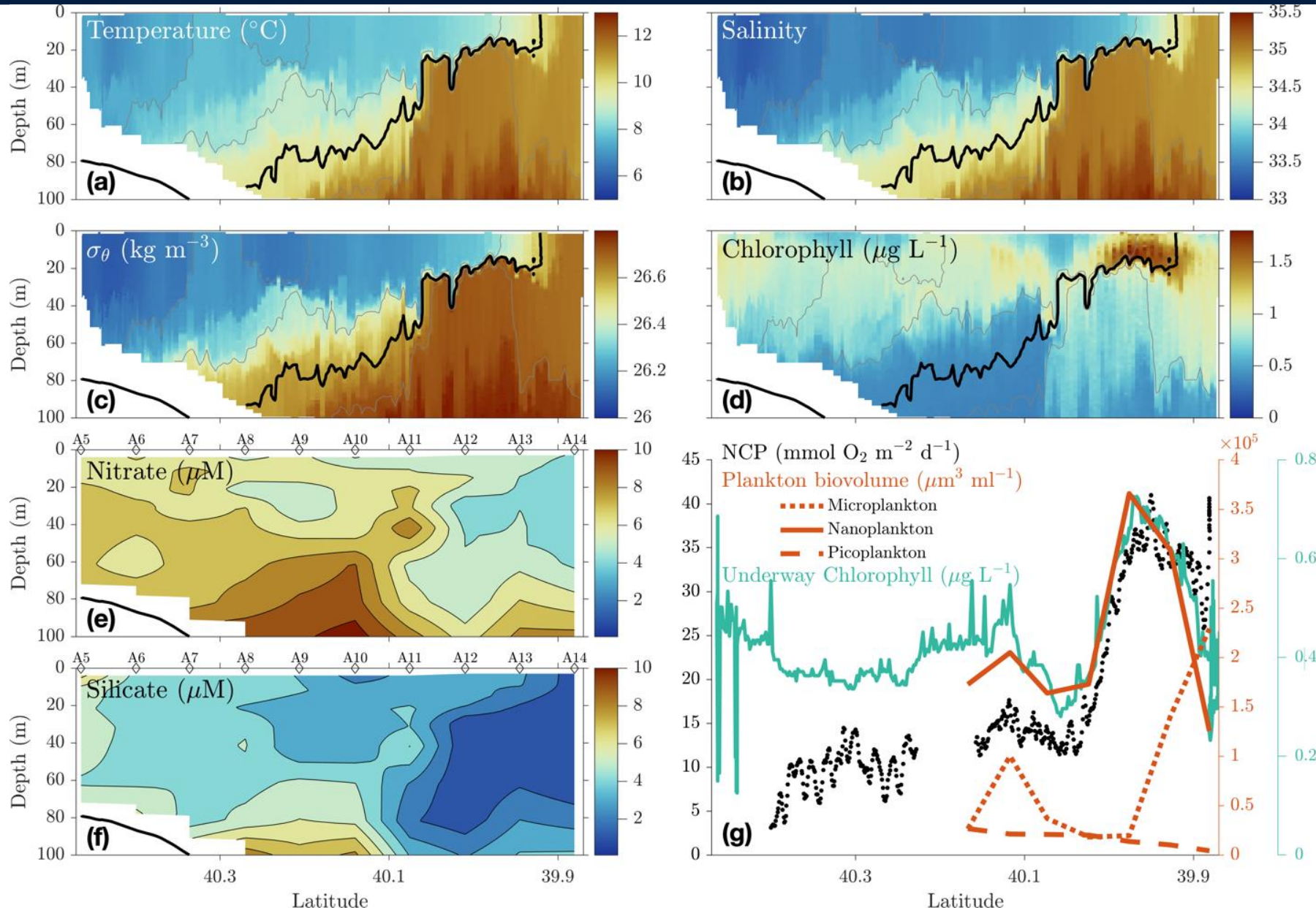
2. May 2019, R/V Ronald H. Brown
   RB1904

3. July 2019, R/V Thomas G. Thompson
   TN368

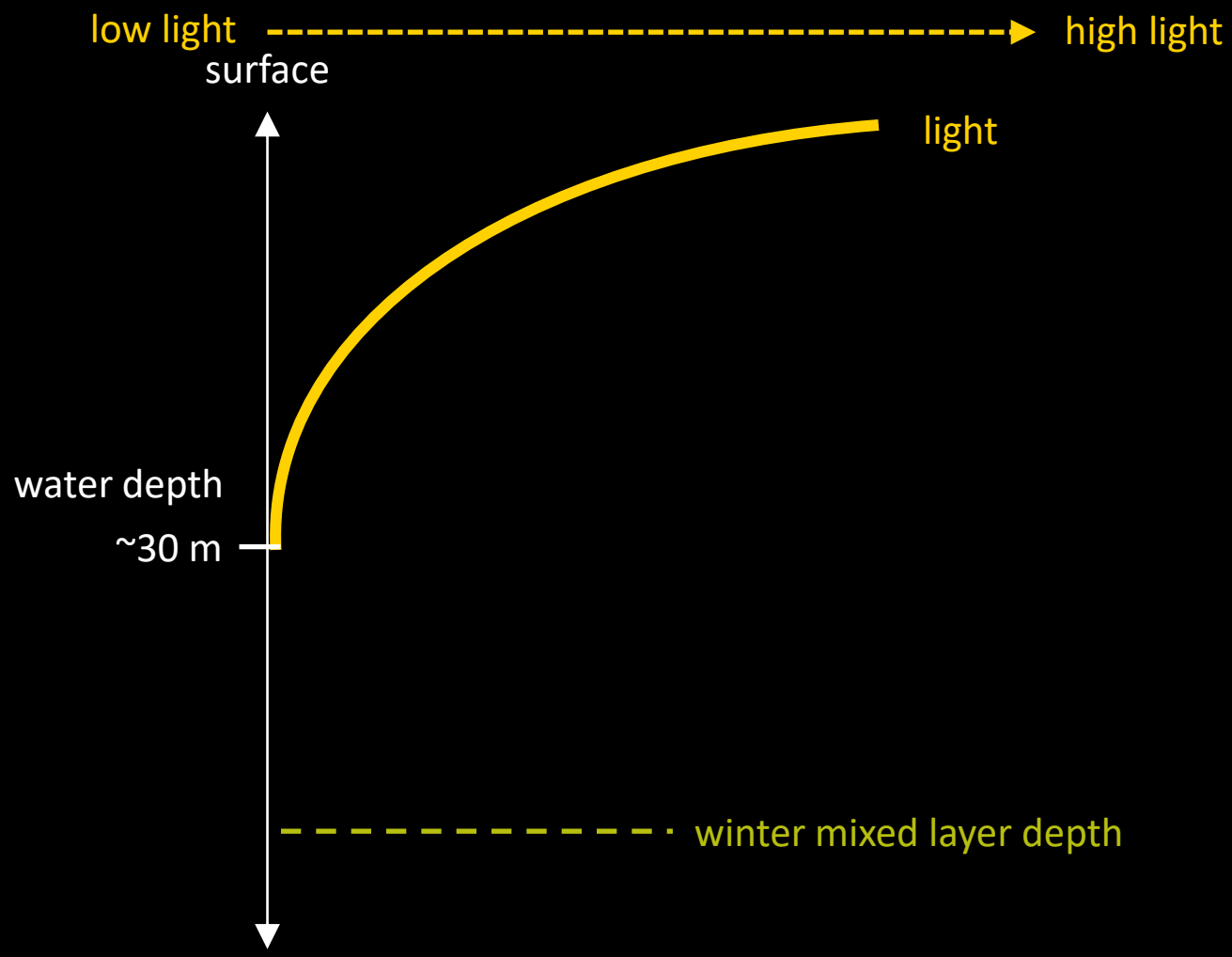


A Frontal Chlorophyll Enhancement in April 2018

- Enhanced chlorophyll at high horizontal and vertical stratification

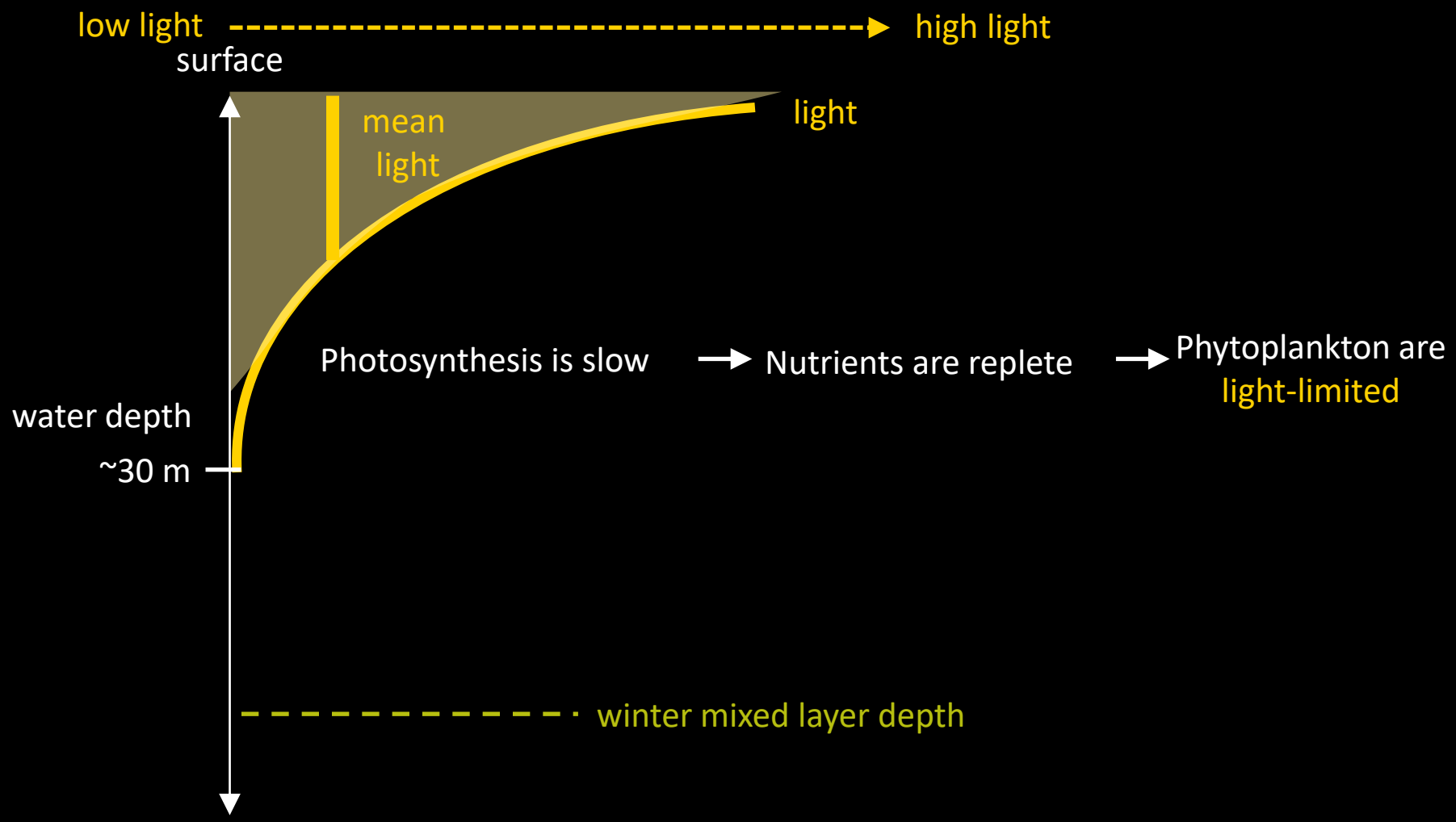


Spring Transition



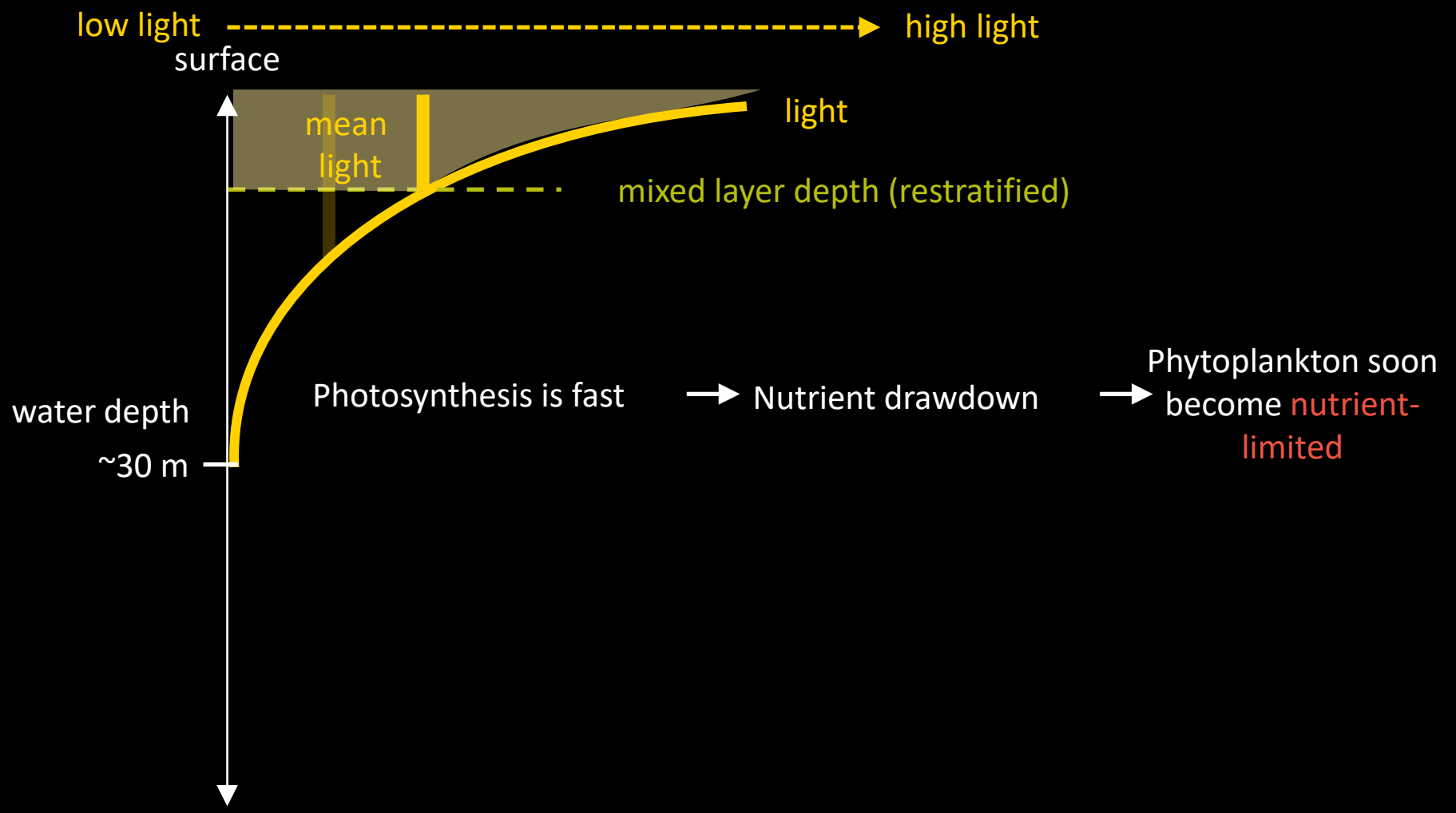
Sverdrup 1953

Spring Transition



Sverdrup 1953

Spring Transition

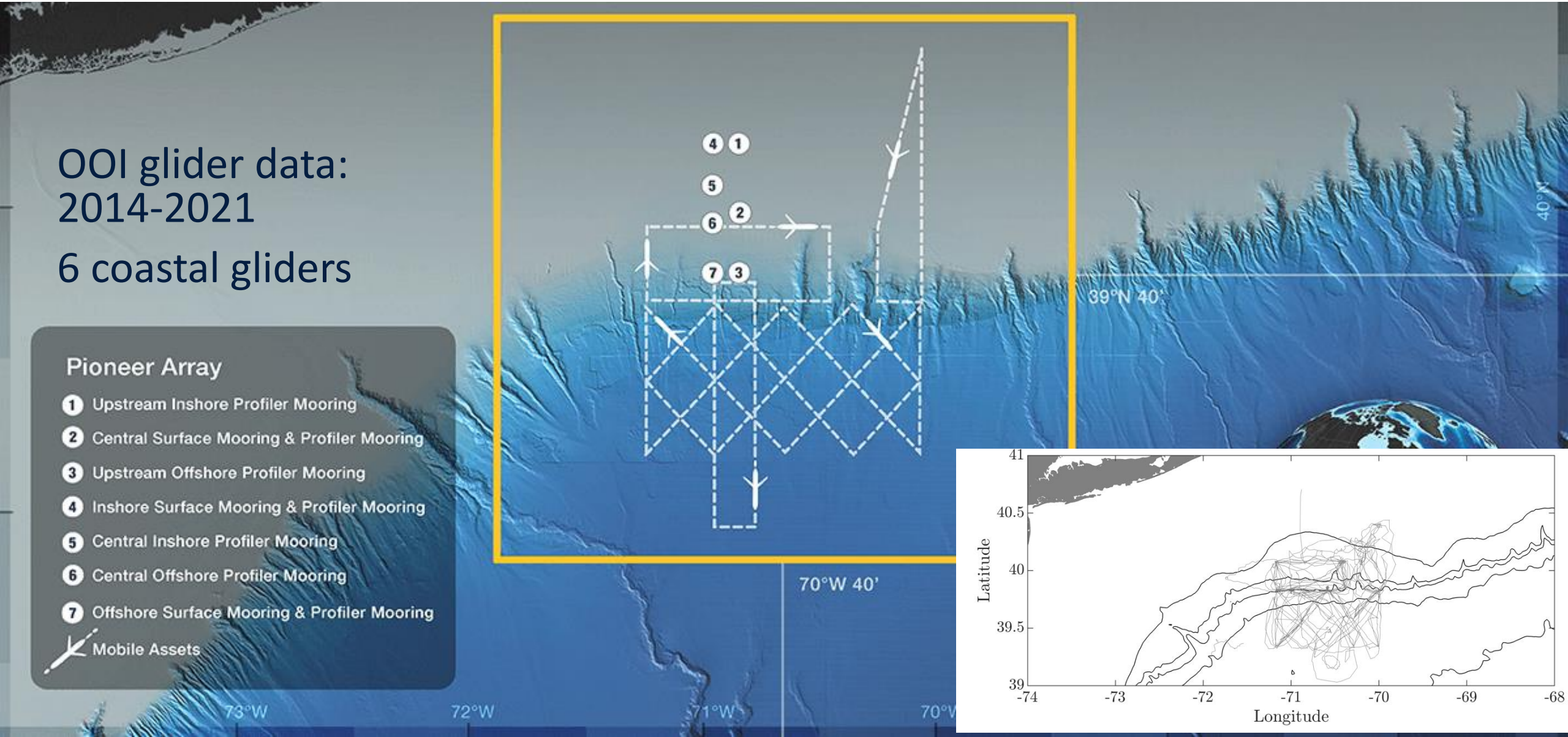


Sverdrup 1953

What drives the enhanced shelfbreak chlorophyll?

OOI glider data:
2014-2021

6 coastal gliders

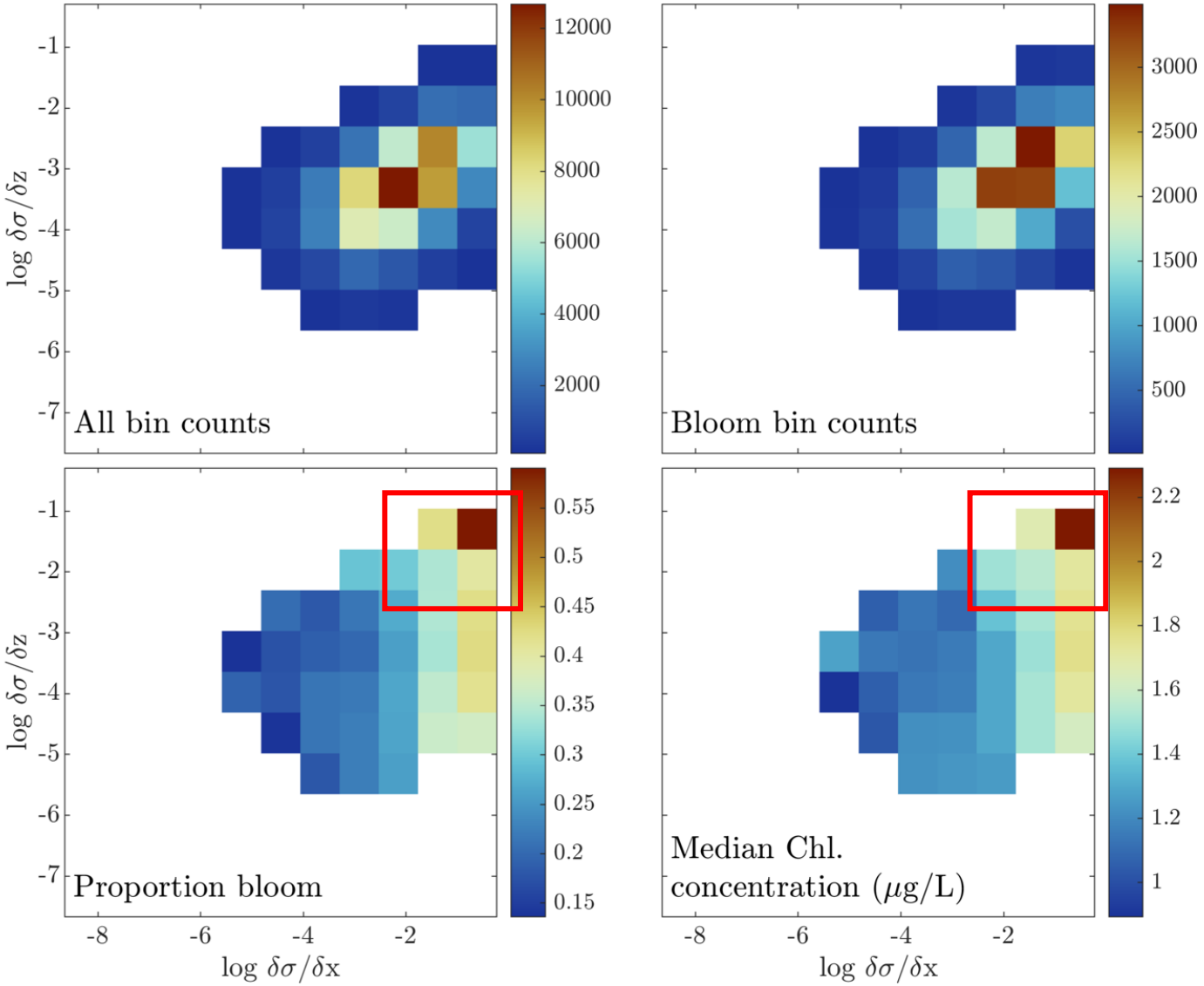


What drives the enhanced shelfbreak chlorophyll?

- Top 30 m glider data binned by horizontal density gradient ($\frac{\delta\sigma}{\delta x}$) and vertical density gradient ($\frac{\delta\sigma}{\delta z}$)
- High $\frac{\delta\sigma}{\delta x}$ -> near the shelf-slope front
- High $\frac{\delta\sigma}{\delta z}$ -> front stratified near surface -> shallow MLD

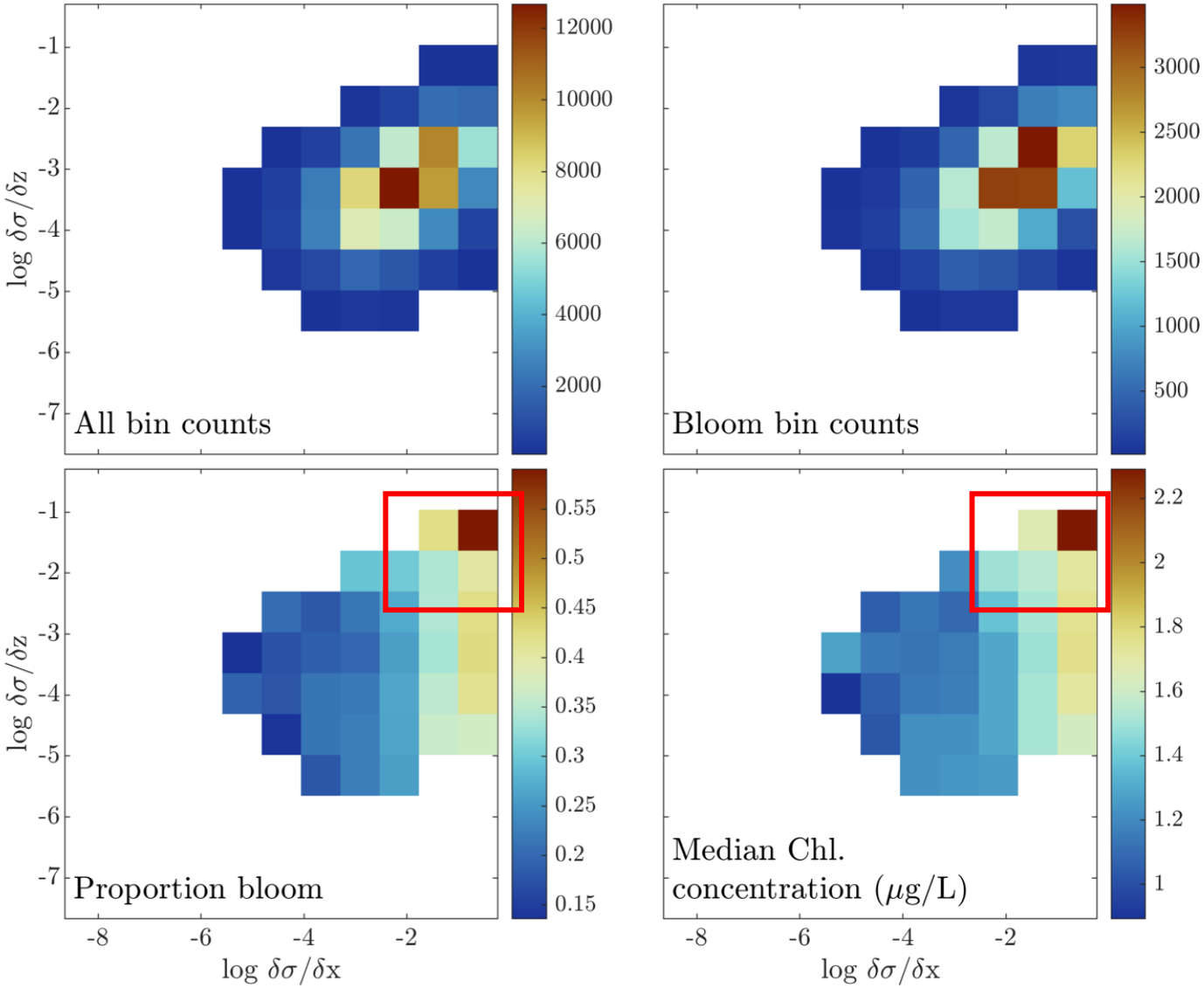
What drives the enhanced shelfbreak chlorophyll?

- Higher proportion of bins classified “bloom” (> 2 µg/L) and highest binned chlorophyll with high horizontal and vertical density gradients

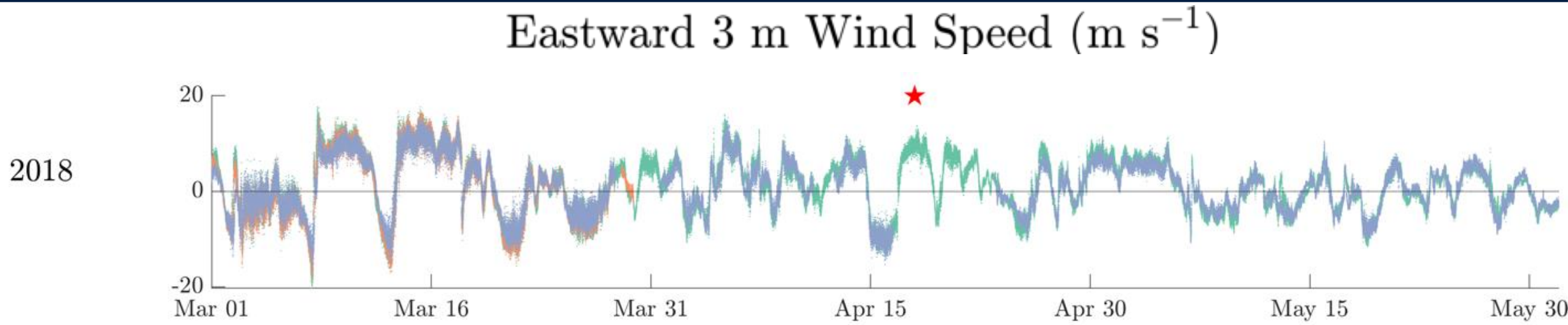


What drives the enhanced shelfbreak chlorophyll?

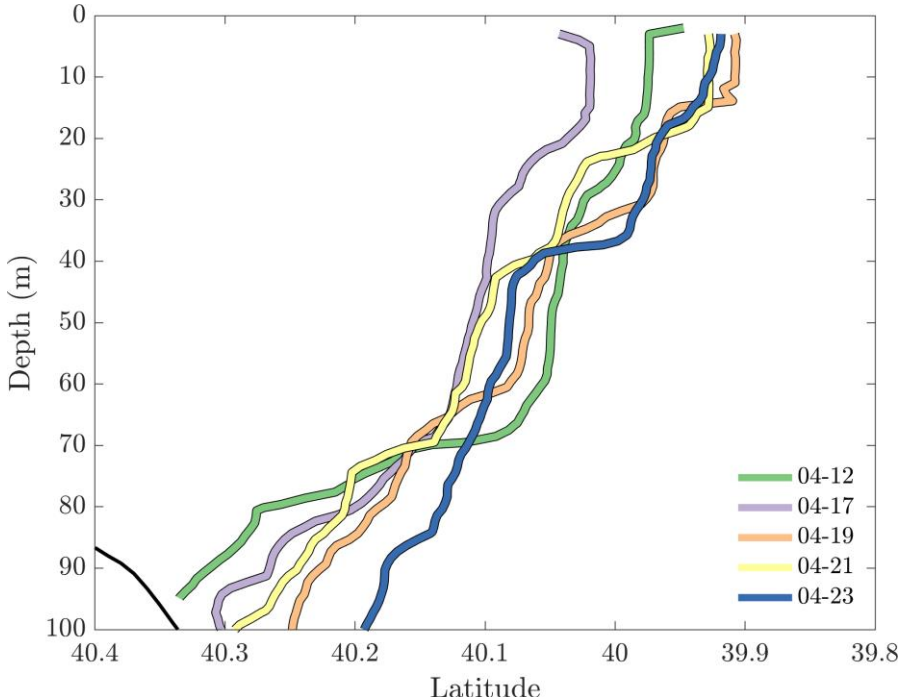
- Higher proportion of bins classified “bloom” (> 2 µg/L) and highest binned chlorophyll with high horizontal and vertical density gradients
- Suggests that restratification associated with shelfbreak chlorophyll enhancements, reducing light limitation



What drives frontal restratification?



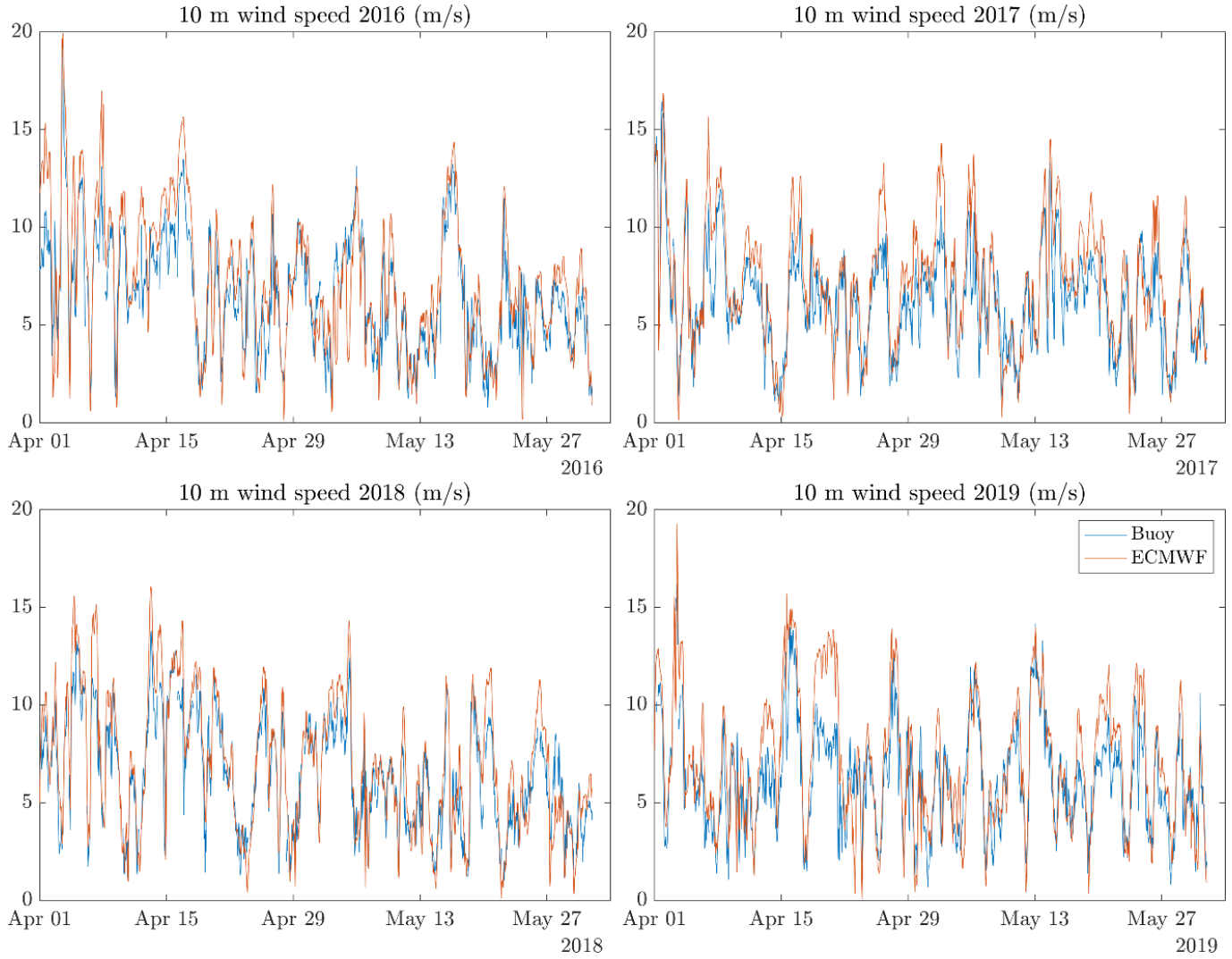
Ekman restratification can be triggered by winds opposing the surface frontal current (**upfront winds**)



Early April profiles from OOI Cruise AR28B

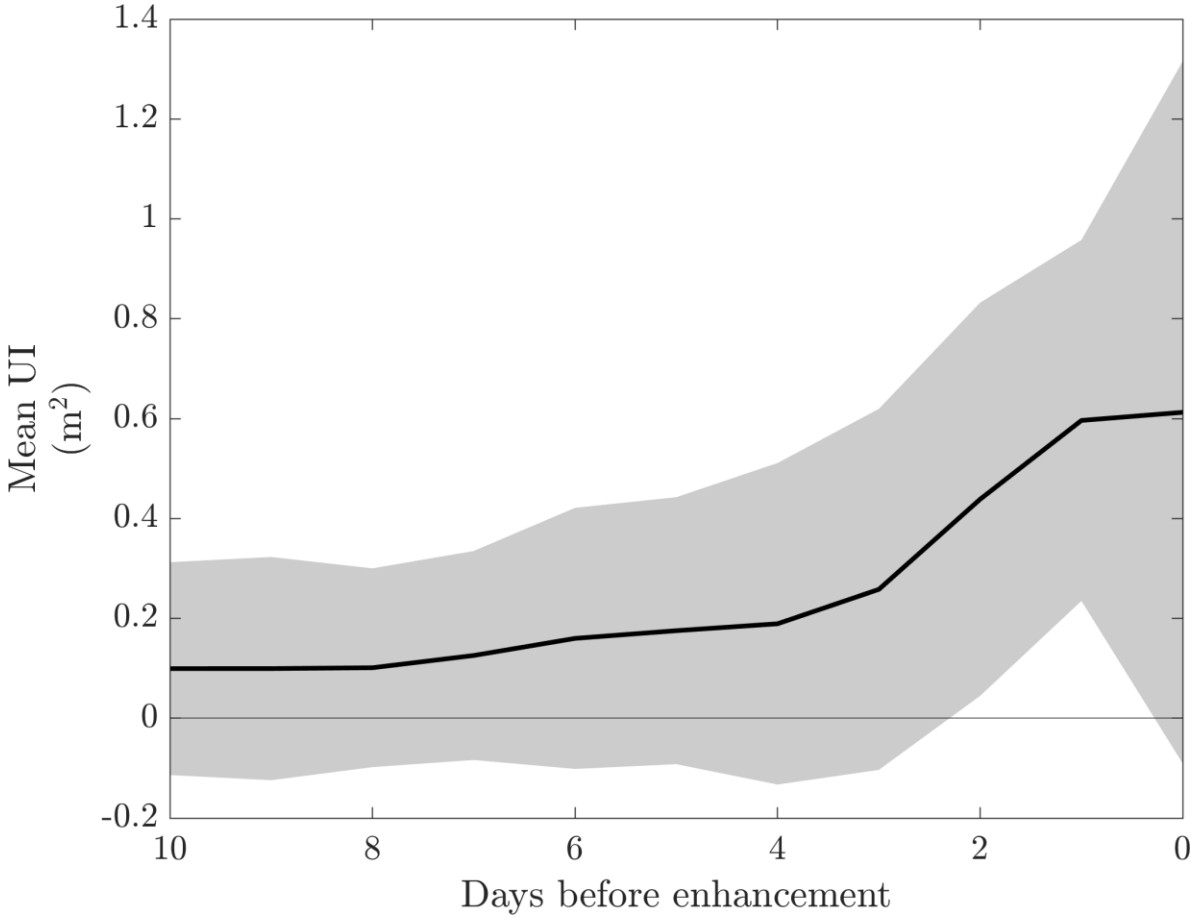
OOI vs. ECMWF winds

OOI buoy 10 m wind speed measurements (blue) and ECMWF ERA5 reanalysis 10 m wind speeds (red) for April – May 2016 – 2019.



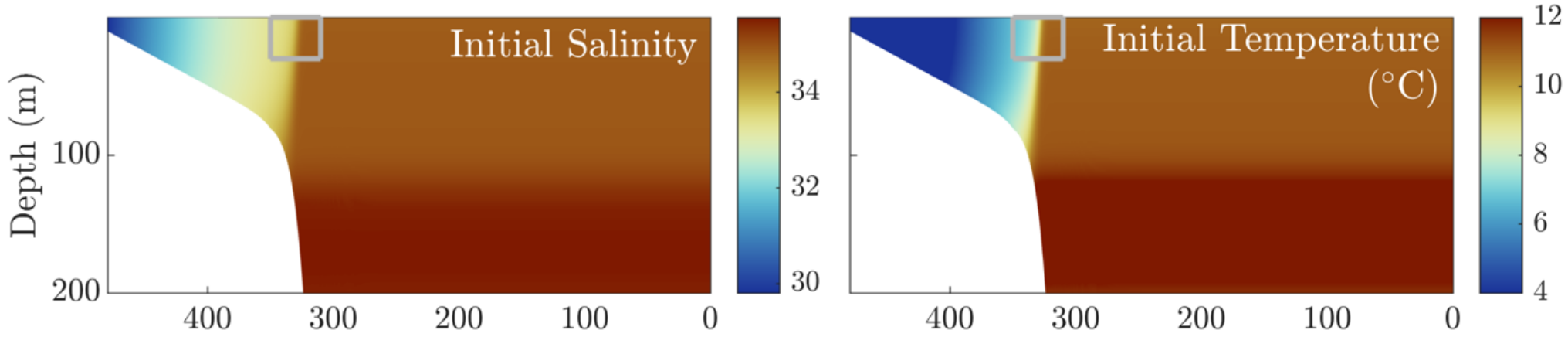
What drives frontal restratification?

- Mean winds (ECMWF reanalysis) n days preceding all shelfbreak enhancements 2003-2020
- Upfront wind speeds increase in the 3 days preceding an enhancement (t=3.8, 95% confidence interval: 0.17-0.65 m2, p<0.01)



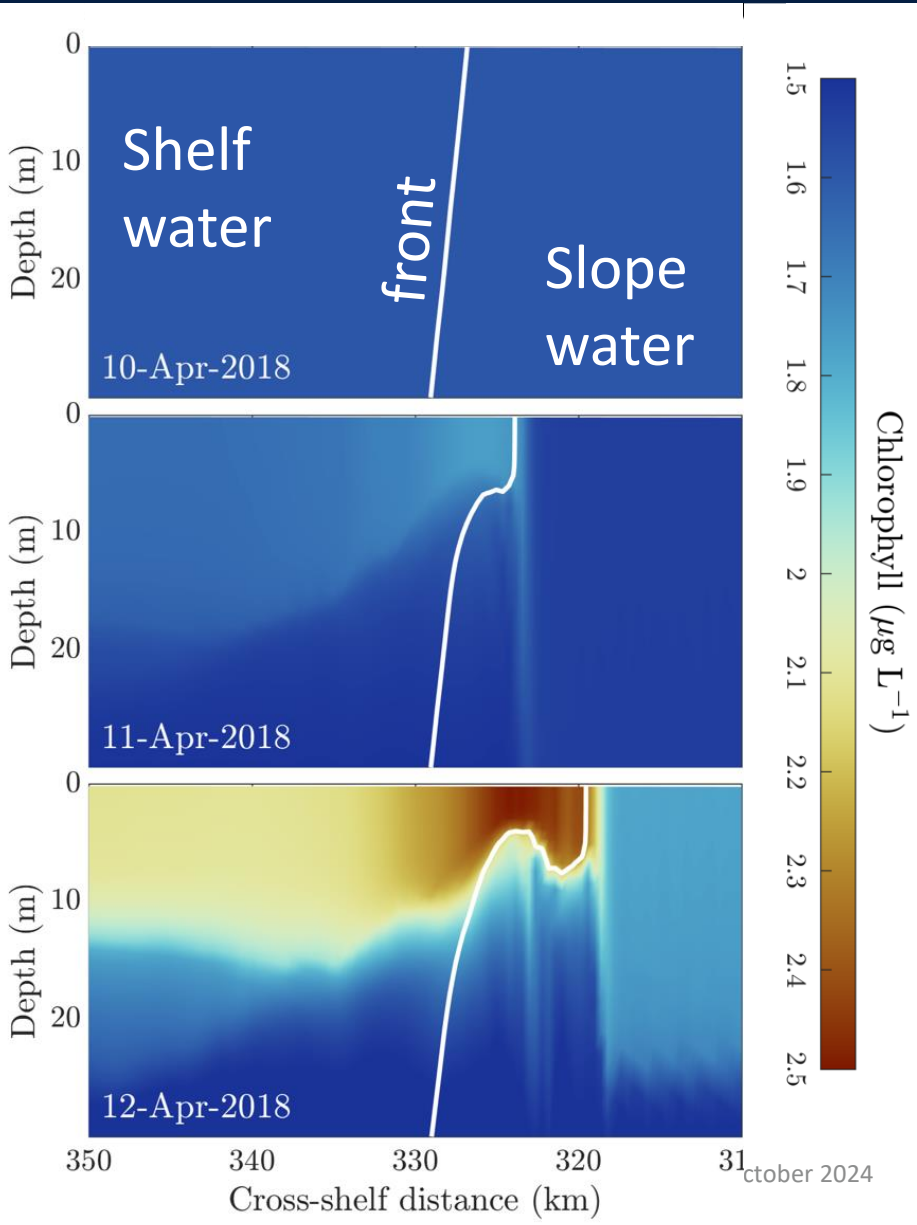
What drives frontal restratification?

- Test role of upfront/downfront winds with 2D ROMS with NPZD-Powell (from Zhang et al. 2013)
- Initialized with climatological N profile and low values of P, Z & D



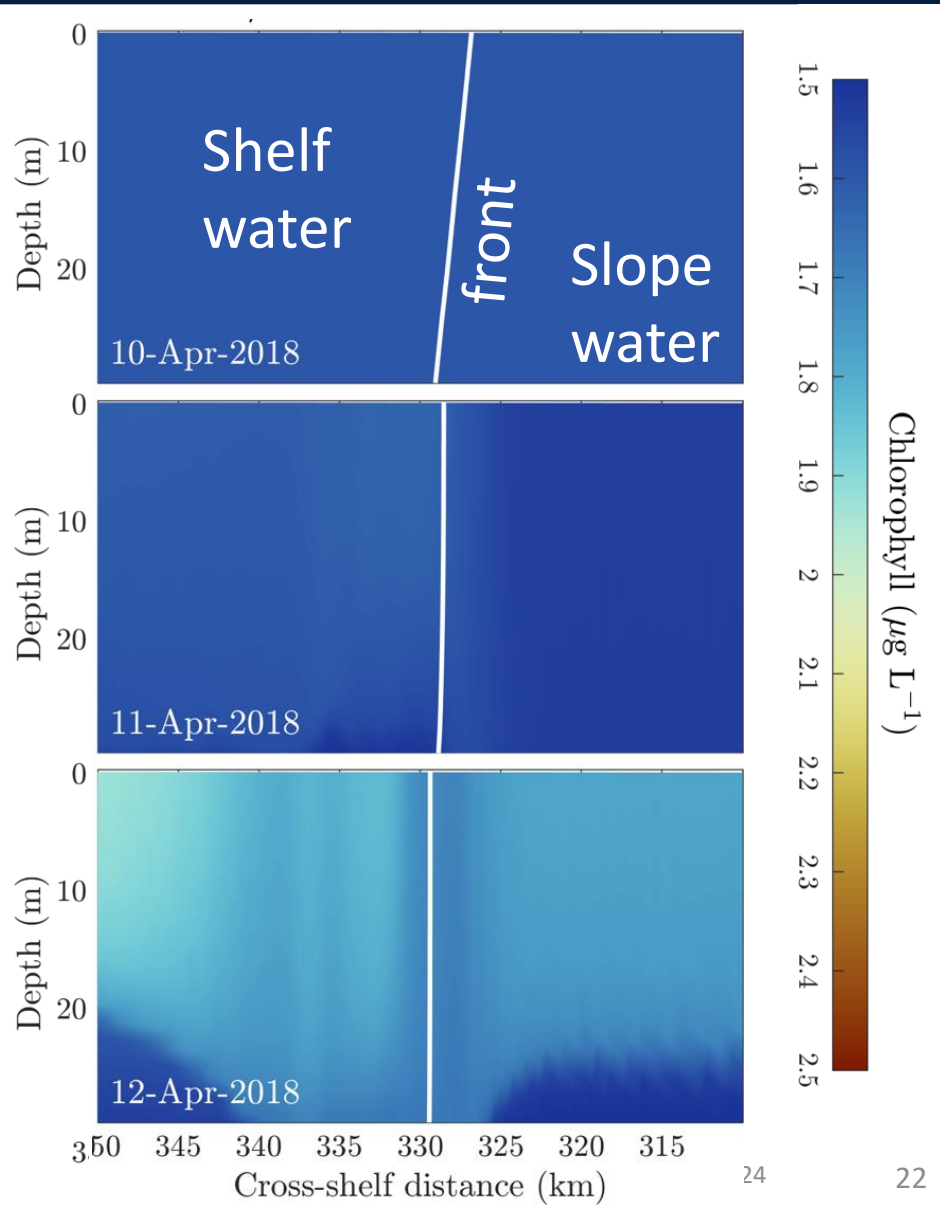
What drives frontal restratification?

5 m/s upfront winds -> mixed layer shoals -> rapid accumulation



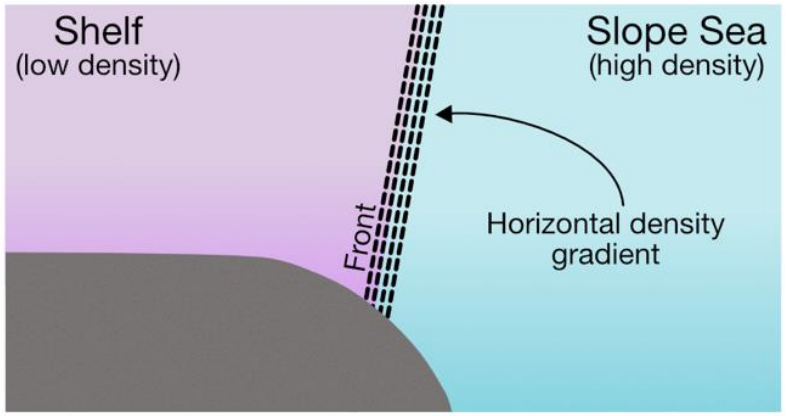
What drives frontal restratification?

5 m/s downfront winds -> denser water advected over less dense water -> convective overturning -> Chl diluted

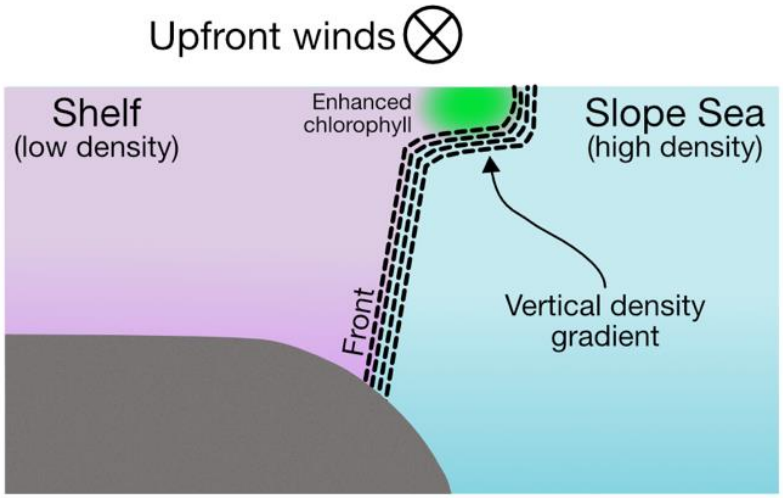


Conclusions

- Upfront winds precede enhancements
  - Driven by Ekman restratification



Winter frontal configuration



Frontal restratification

OOI datasets used

- Glider T/S/Fluorescence
- AR28 profiles
- 3 m winds

Thank you!

JGR Oceans

RESEARCH ARTICLE
10.1029/2021JC017715

Key Points:

- Spring enhancements of surface chlorophyll at the New England shelf break are short-lived and thus are not visible in seasonal means
- Surface chlorophyll enhancements are associated with offshore displacement of the upper part of the shelf-break front in spring

Ephemeral Surface Chlorophyll Enhancement at the New England Shelf Break Driven by Ekman Restratification

Hilde Oliver[1], Weifeng Gordon Zhang[1], Kevin M. Archibald[1], Andrew J. Hirzel[1], Walker O. Smith Jr[2,3], Heidi M. Sosik[1], Rachel H. R. Stanley[4], and Dennis J. McGillicuddy Jr[1]

[1]Woods Hole Oceanographic Institution, Woods Hole, MA, USA, [2]Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA, USA, [3]School of Oceanography, Shanghai Jiao Tong University, Shanghai, China, [4]Department of Chemistry, Wellesley College, Wellesley, MA, USA