Seagliders capture manifestation of the North Atlantic spring bloom

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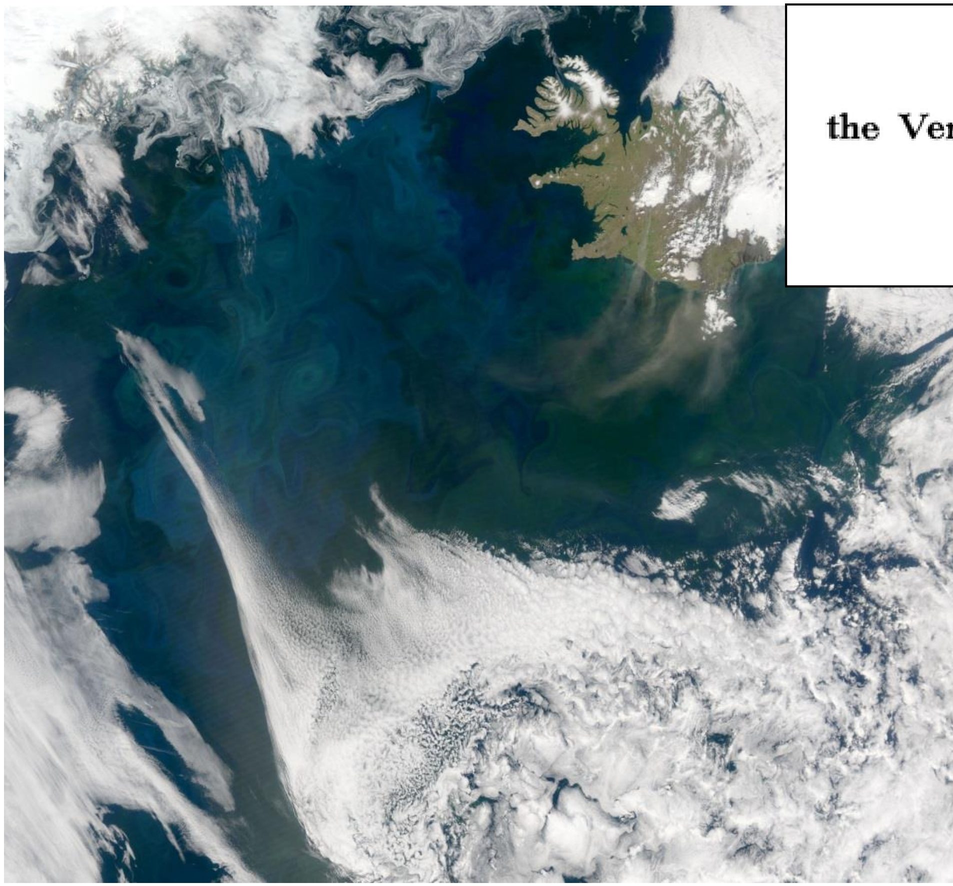
Ocean Surface Mixing Ocean Submesoscale Interactions Study (OSMOSIS) project funded by The Natural Environment Research Council, UK.

Spring bloom in the temperate and subpolar North Atlantic Ocean

It is been more that 60 years…

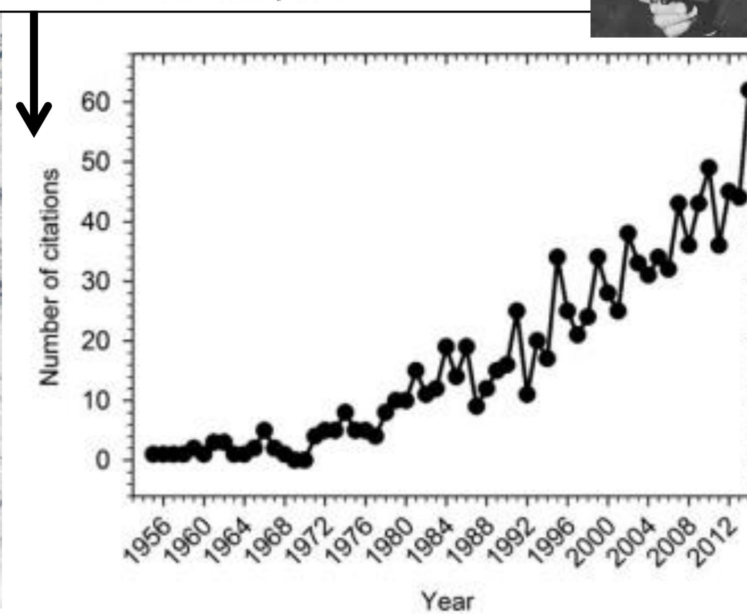


(image source: http://eoimages.gsfc.nasa.gov)

On Conditions for
the Vernal Blooming of Phytoplankton.

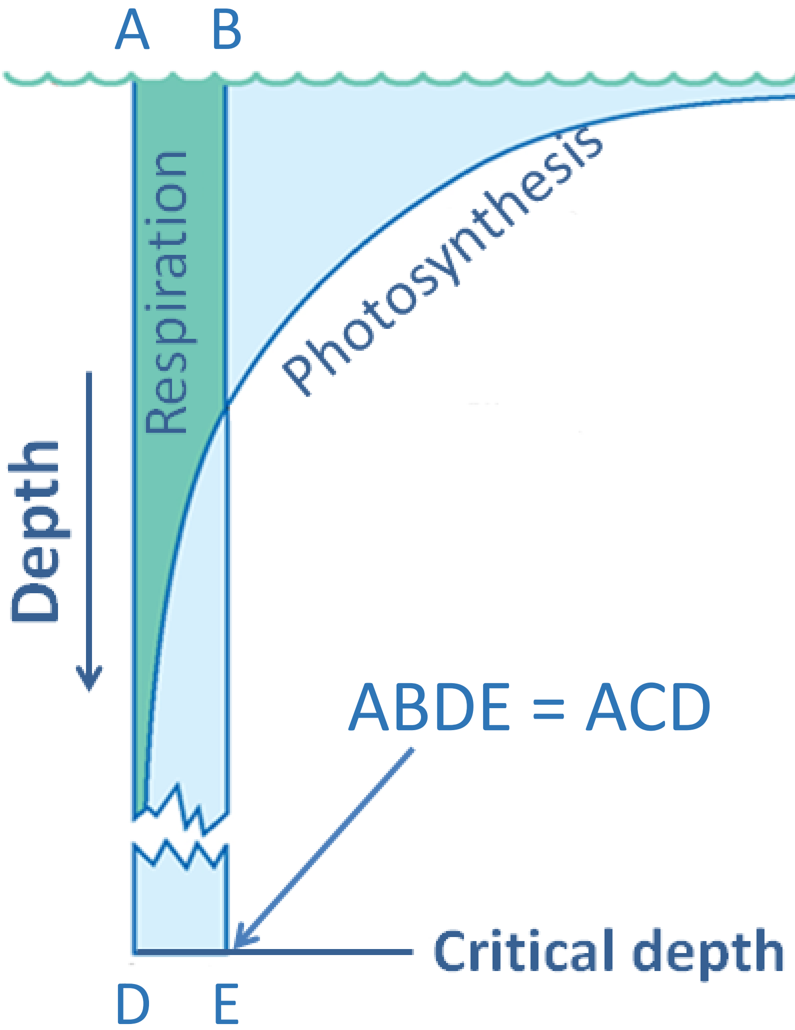
By

H. U. Sverdrup,
Norsk Polarinstitutt, Oslo.



(from Sathyendranath et al., 2015)

Sverdrup's critical depth model



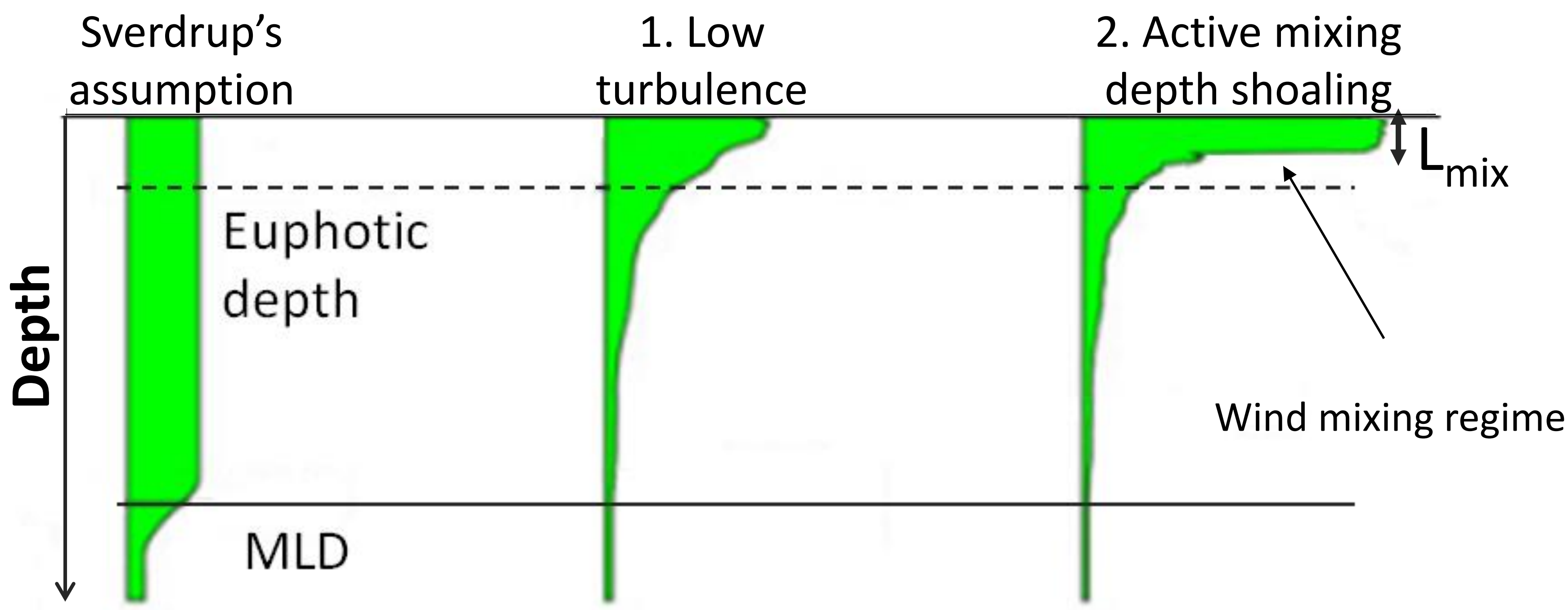
Spring bloom starts when
Mixed Layer Depth < Critical depth

One of the most criticized assumption of the theory:

Phytoplankton is uniform within the mixed layer

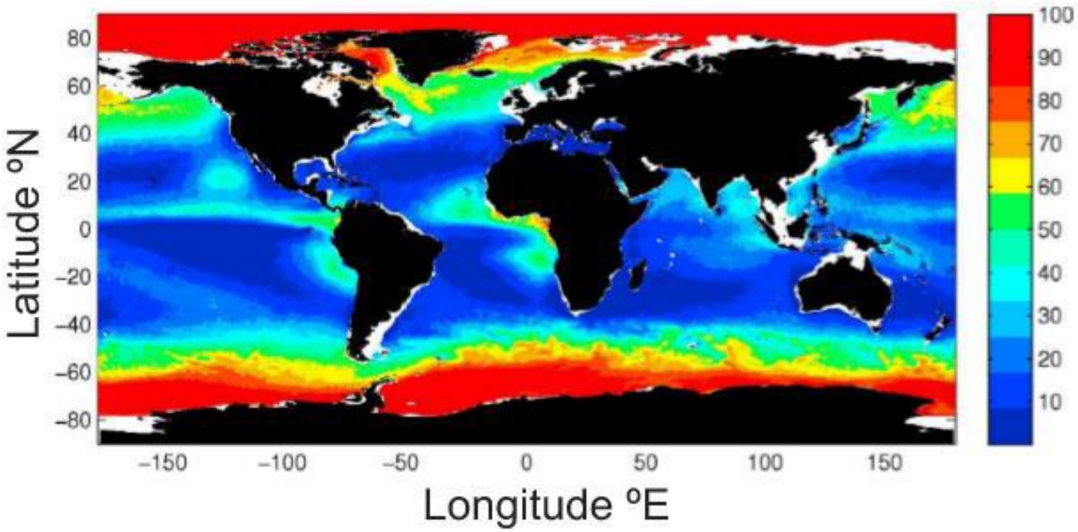
Non-uniform phytoplankton distribution

1. Growth timescale < mixing timescale (*critical turbulence* theory)
2. Decoupling between the hydrographically defined mixed layer (MLD) and the layer of *active mixing* (L_{mix})



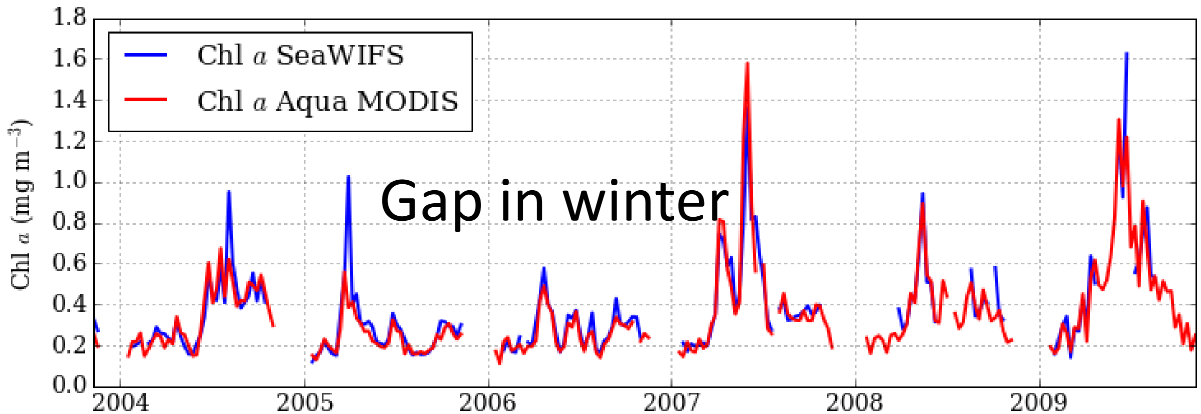
Observational gap

Map of the percentage of missing data in the satellite ocean colour record

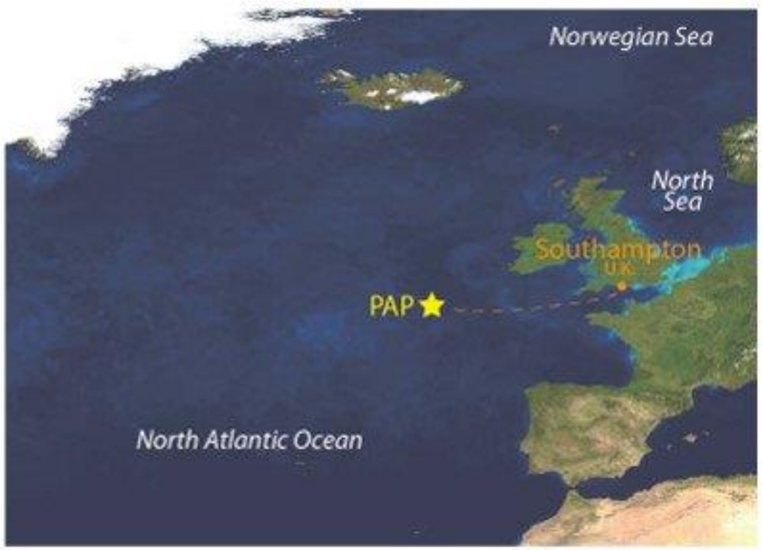


- No data in winter
- Surface data only

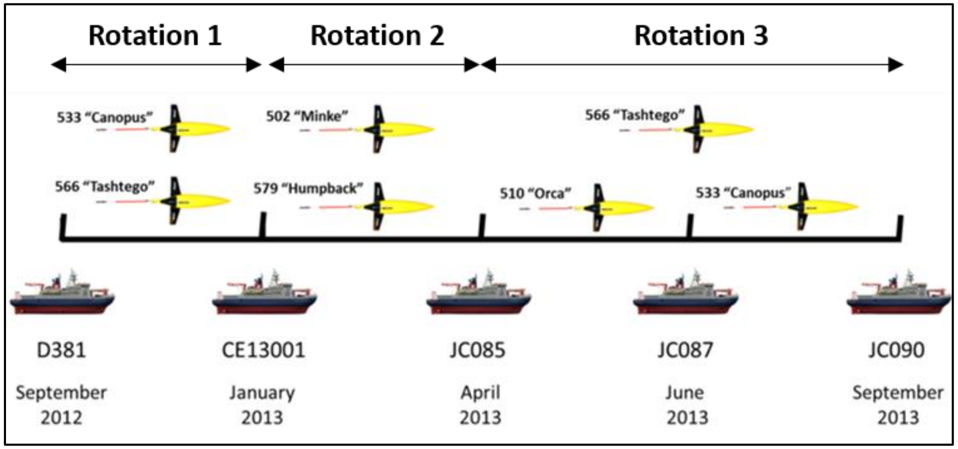
(Cole et al., 2012)



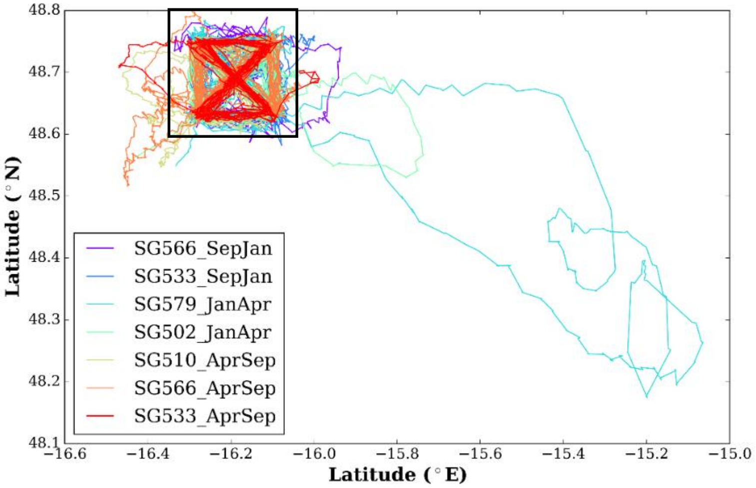
OSMOSIS glider mission



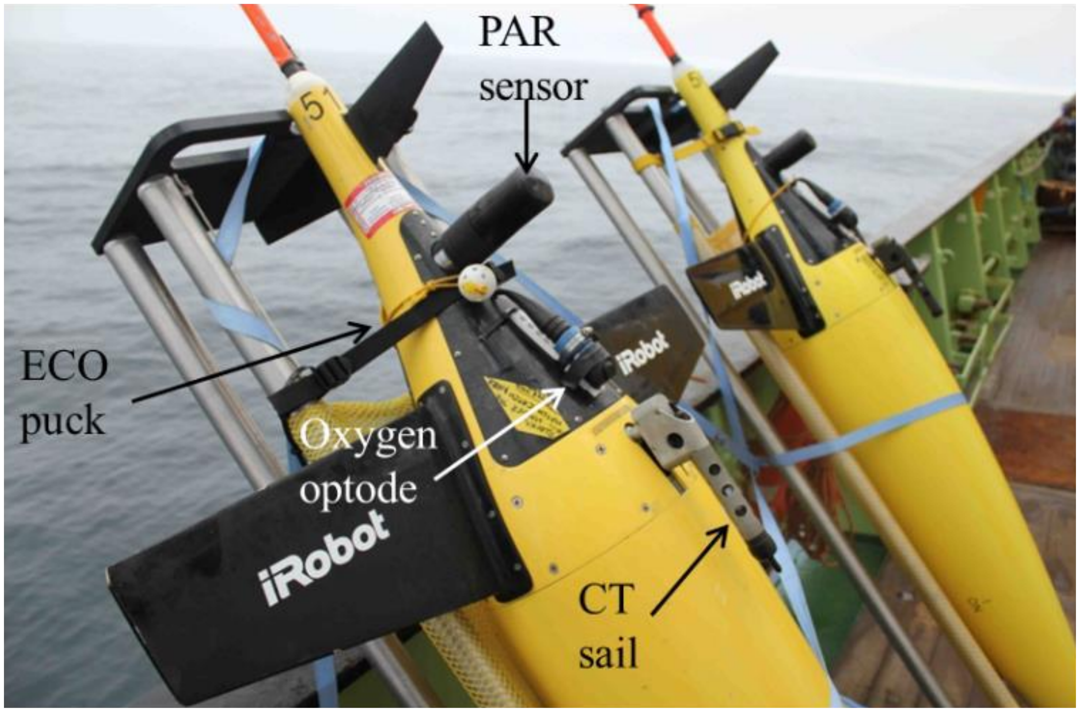
A pair of Seagliders at the **Porcupine Abyssal Plain (PAP) site** (September 2012 – September 2013)



Size of the sampling area: 20x20 km^2



OSMOSIS glider mission



- ECOpuck (chlorophyll a fluorescence, optical backscatter)
- CT sensors
- PAR sensors (light attenuation, surface PAR)

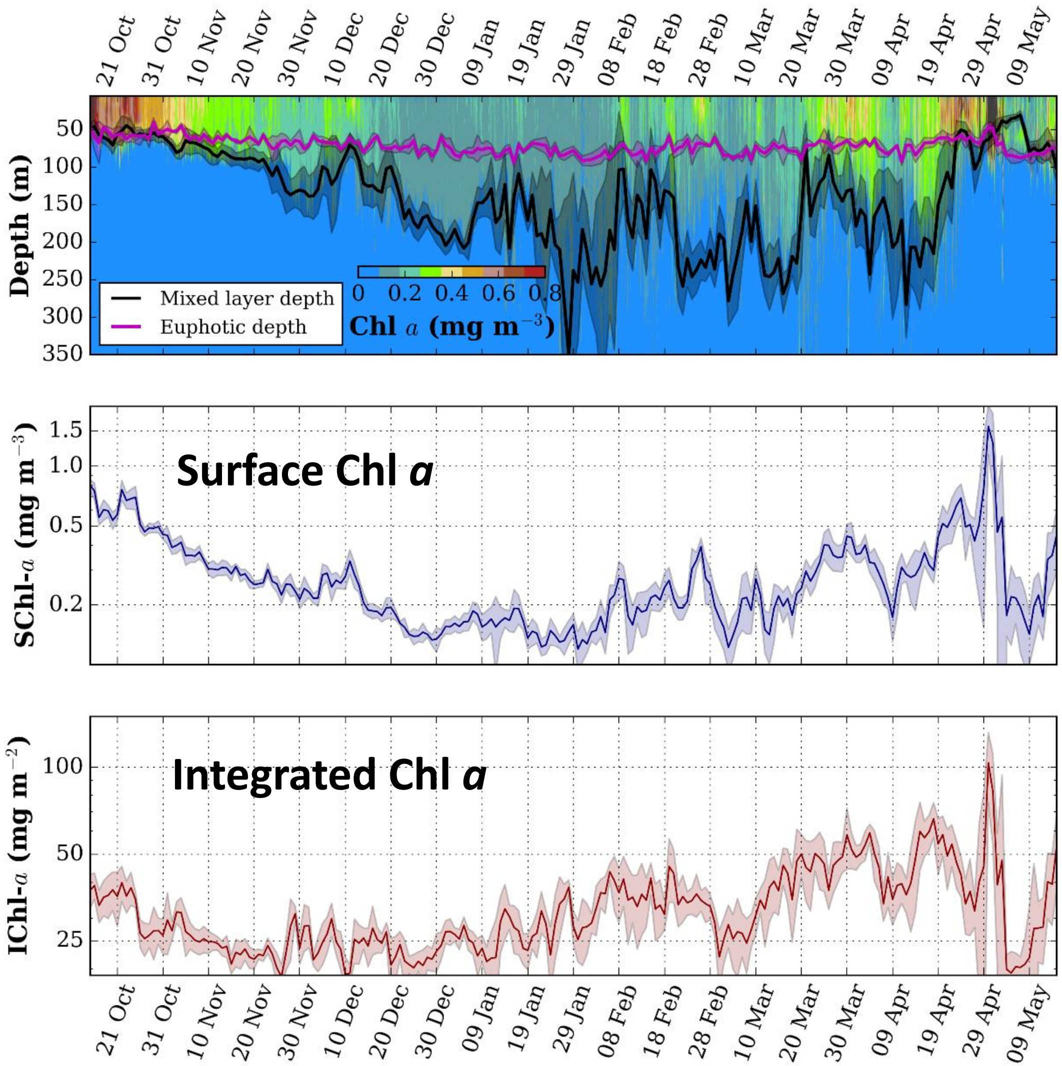
Mission outcome: 8458 vertical profiles of biophysical ocean properties and light

Objectives

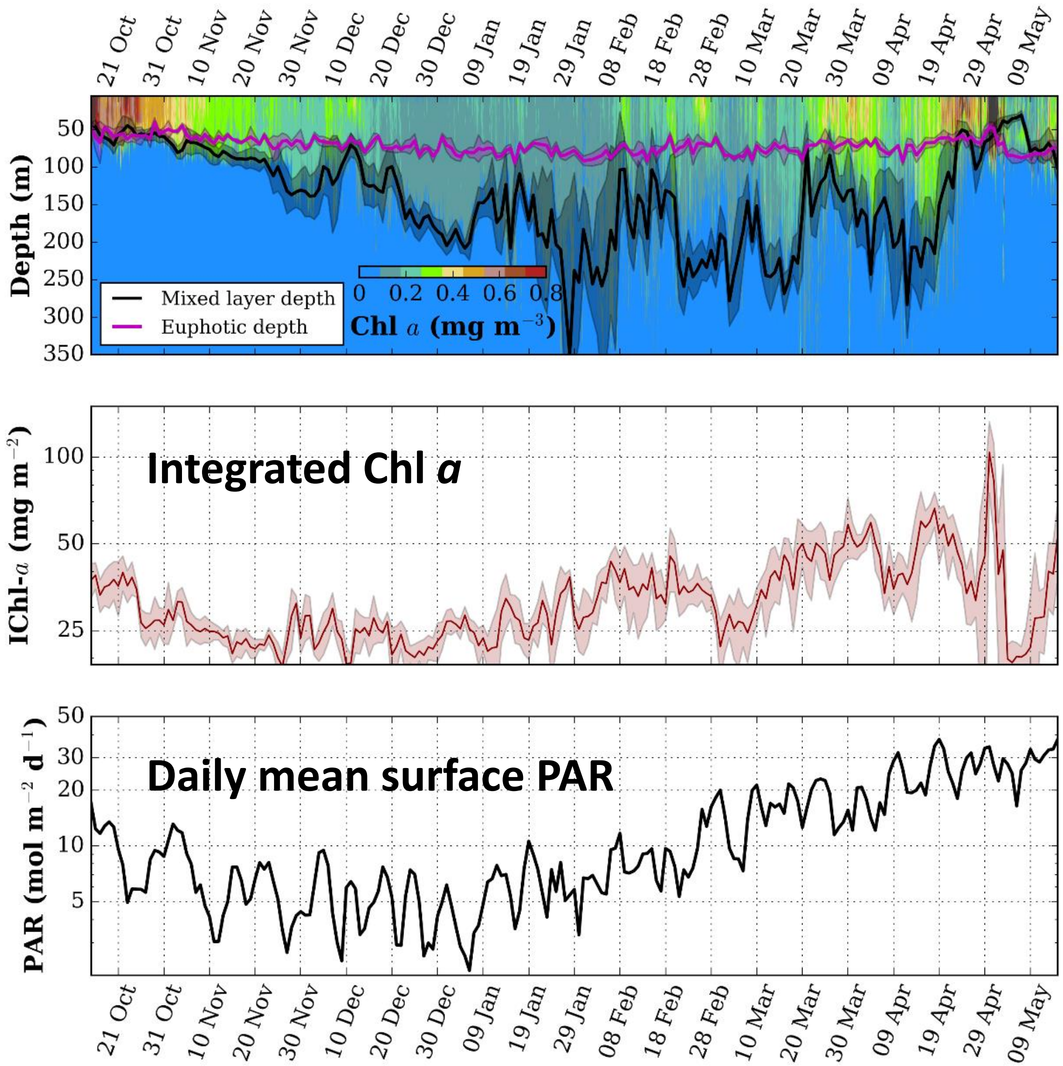
- Test the critical depth hypothesis
- Test the critical turbulence hypothesis by comparing mixing and growth timescales
- Study the impact of atmospheric forcing on the phytoplankton bloom and vertical distribution of phytoplankton

Seaglider data + atmospheric forcing reanalysis

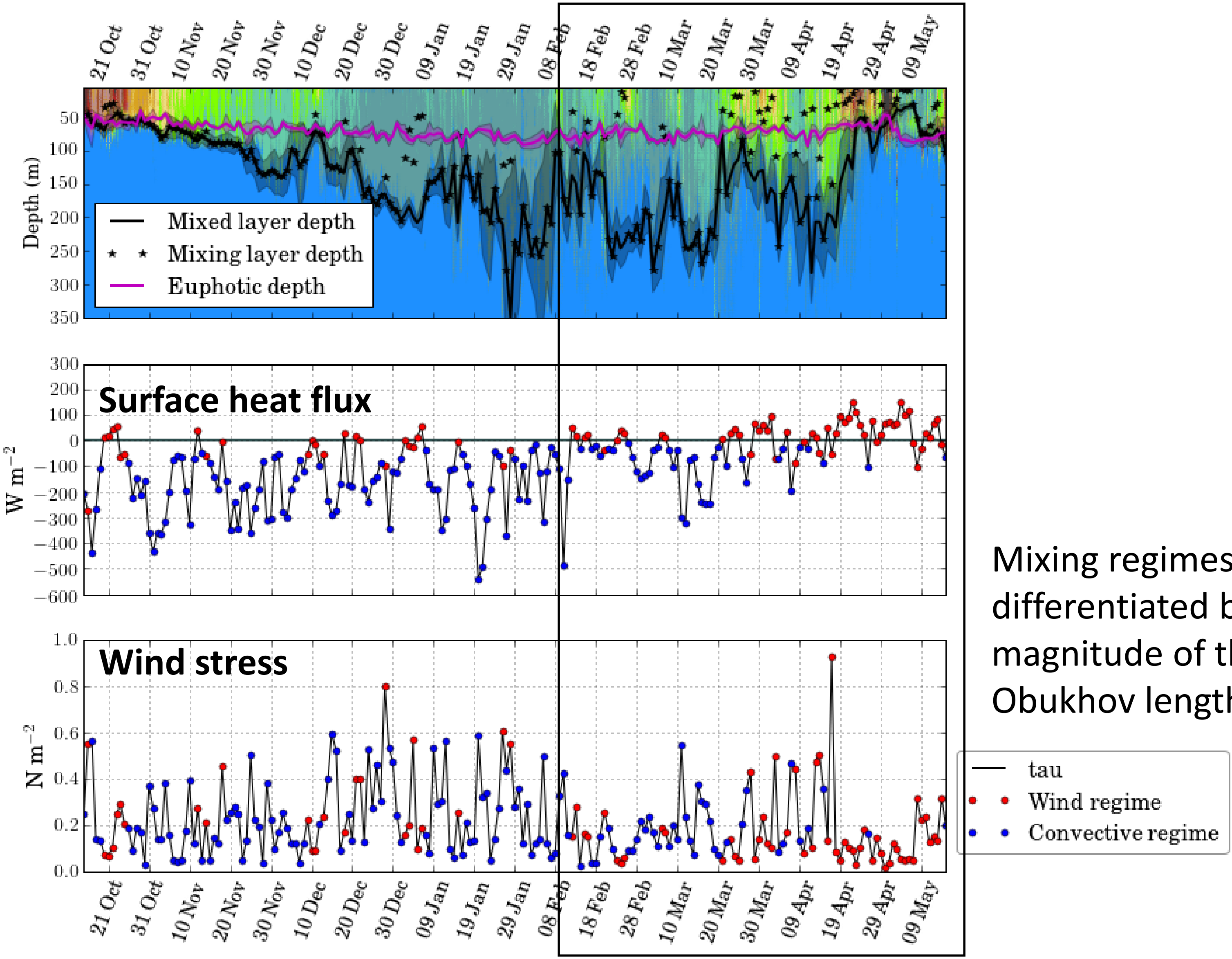
Chlorophyll *a* variability



Light conditions



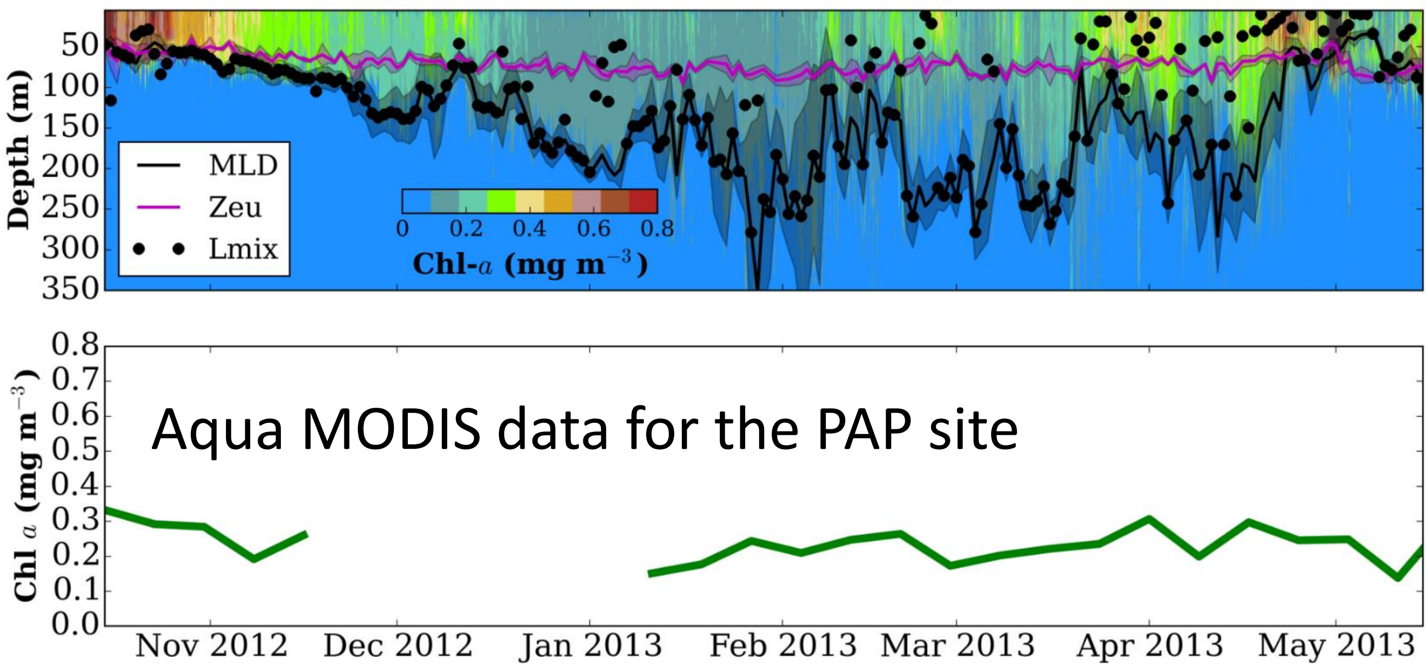
Meteorological conditions



Mixing regimes were differentiated based on the magnitude of the Monin-Obukhov length scale

Outline

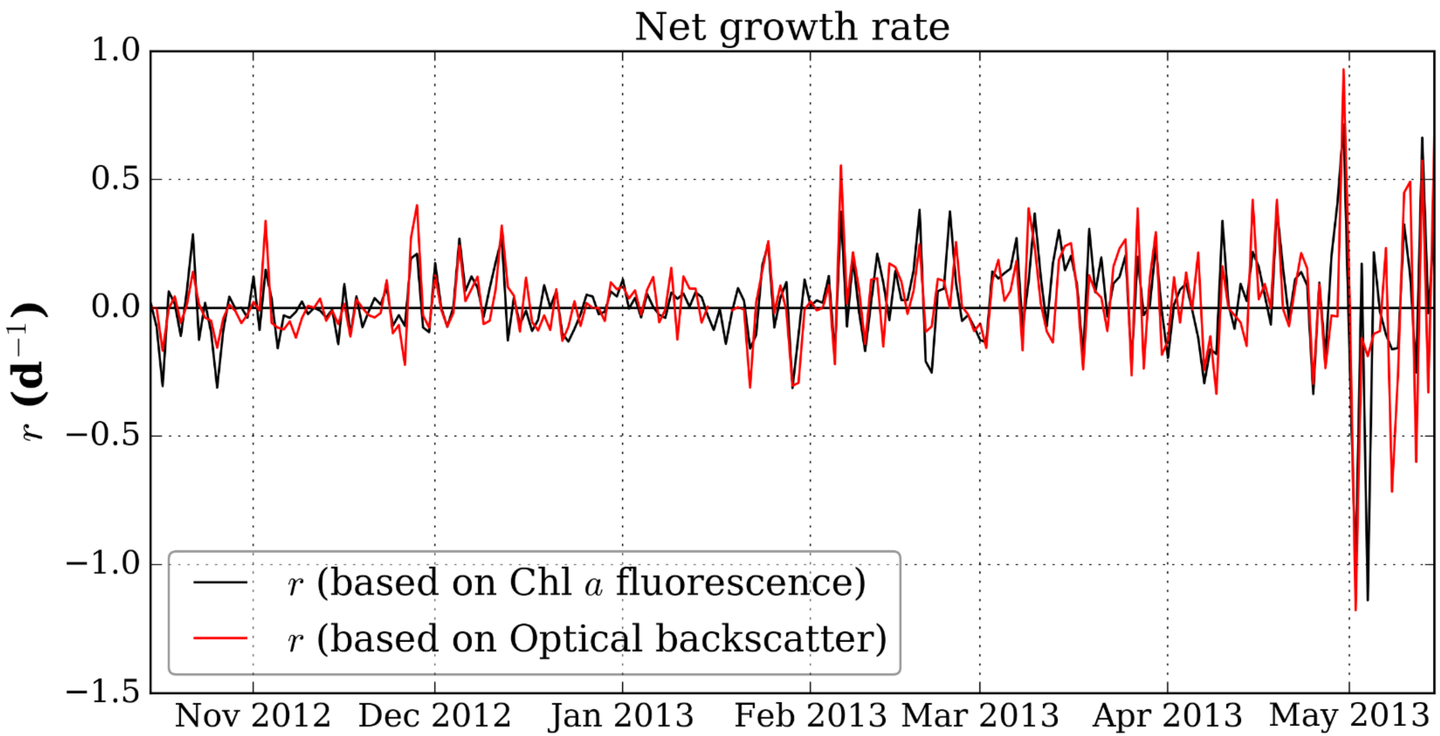
Slow positive growth of phytoplankton in unstratified conditions under increasing surface light intensity and frequent passage of storms and periods of convective mixing



Phytoplankton net growth rate

Two optical proxies for phytoplankton biomass:

- Chlorophyll a fluorescence
- Optical backscatter



Consistent temporal patterns between two optical proxies

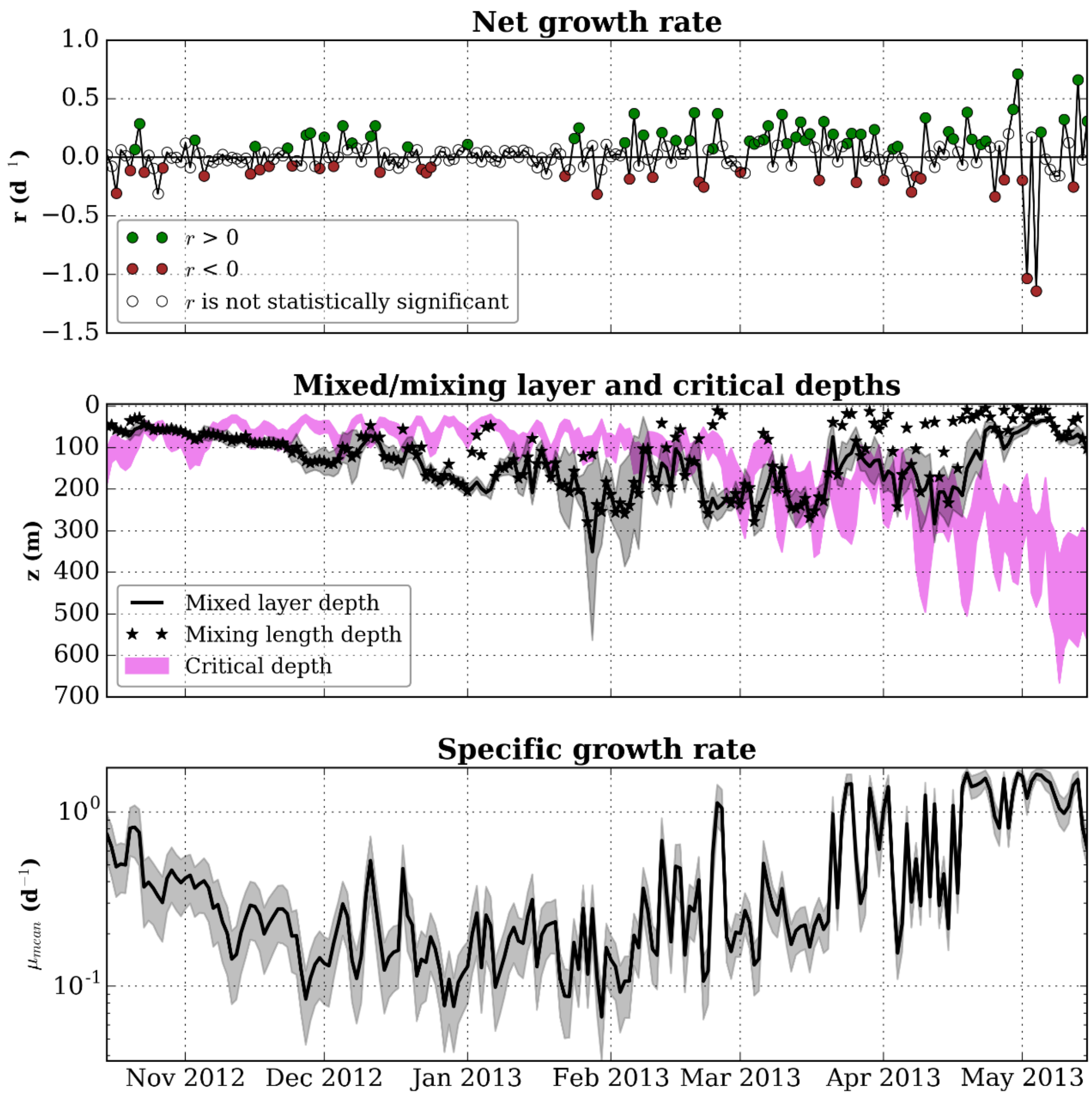
$R^2 = 0.72$

Test of the critical depth hypothesis

$r = \mu - l$

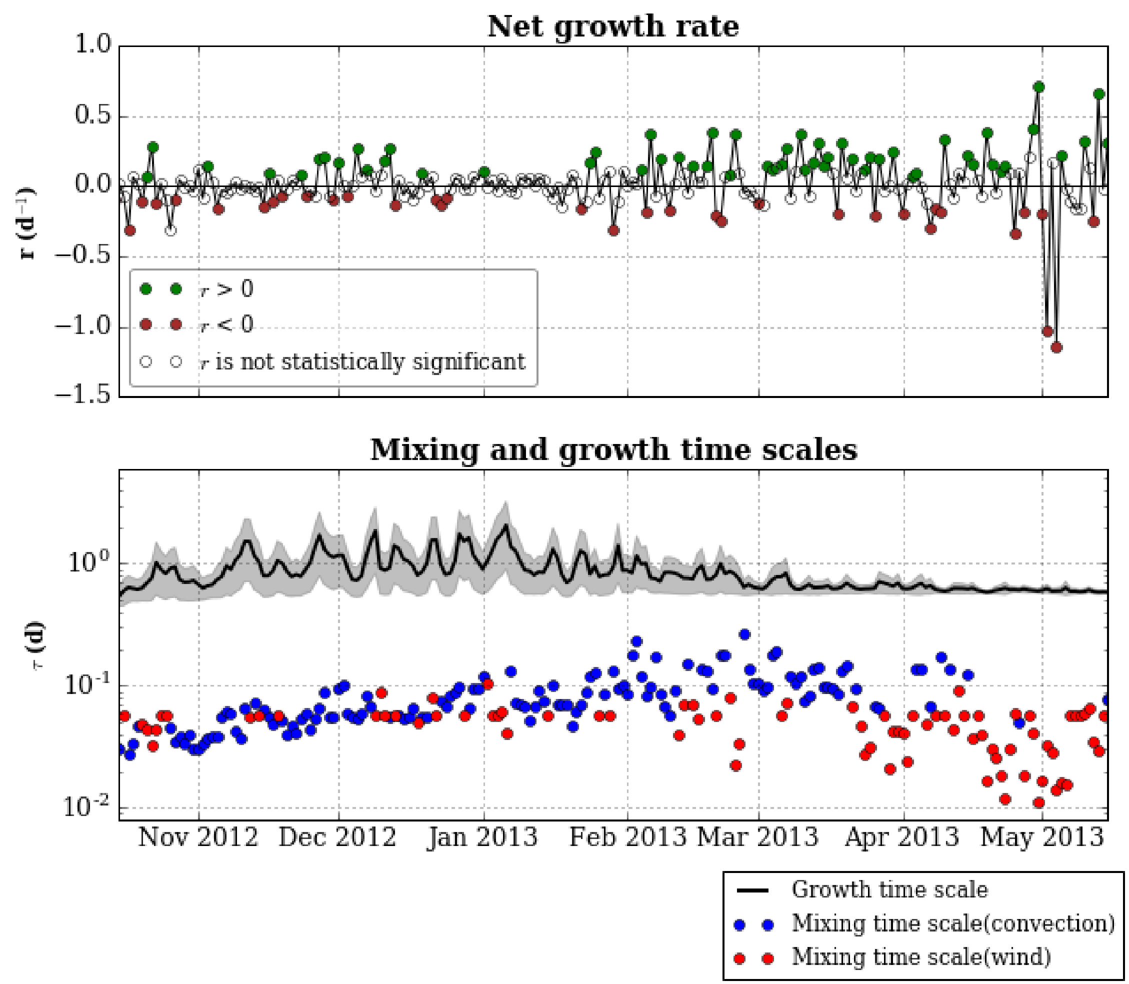
r – net growth rate
l – loss rate
μ - specific growth rate (depends on light and mixing layer depth)

Improving light conditions->net phytoplankton growth



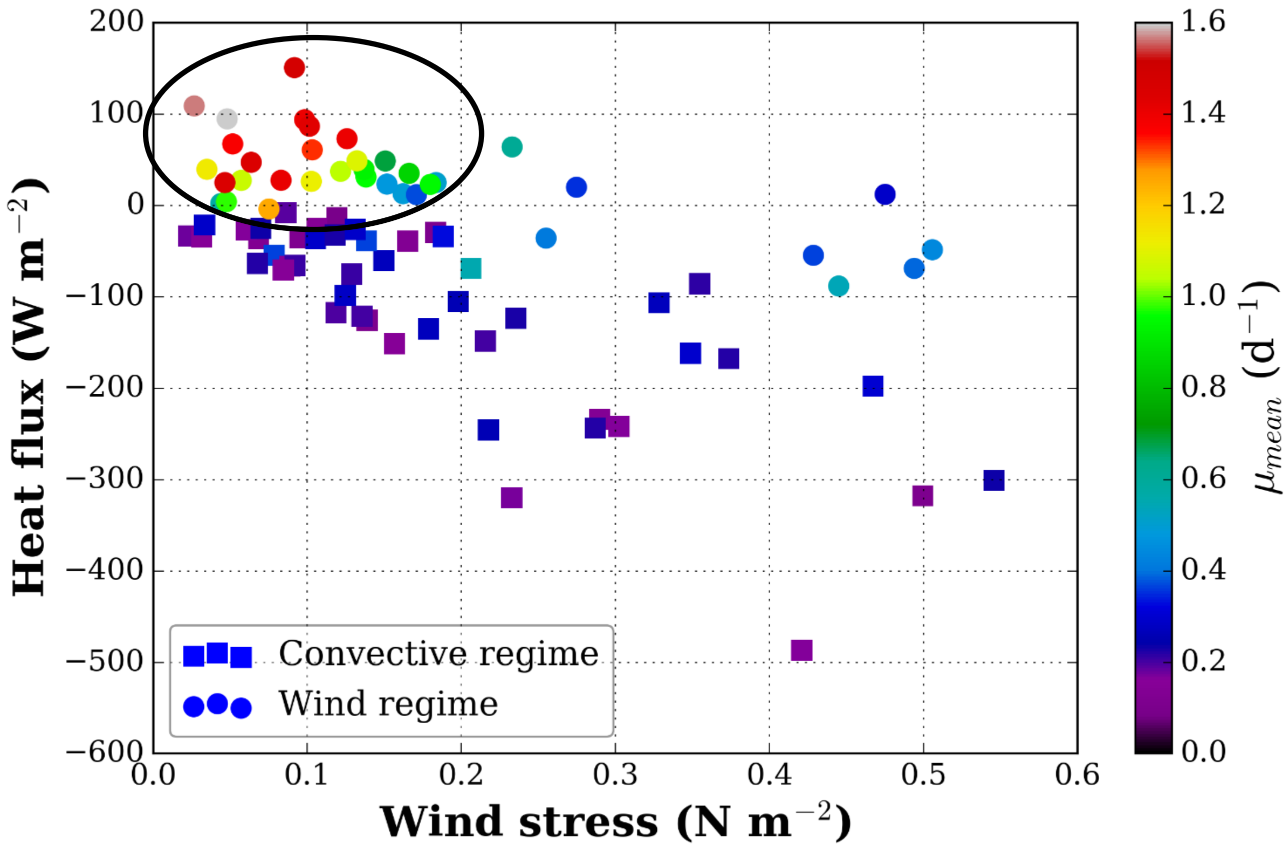
Test of the critical turbulence hypothesis

$\tau_{growth} = 1/\mu$



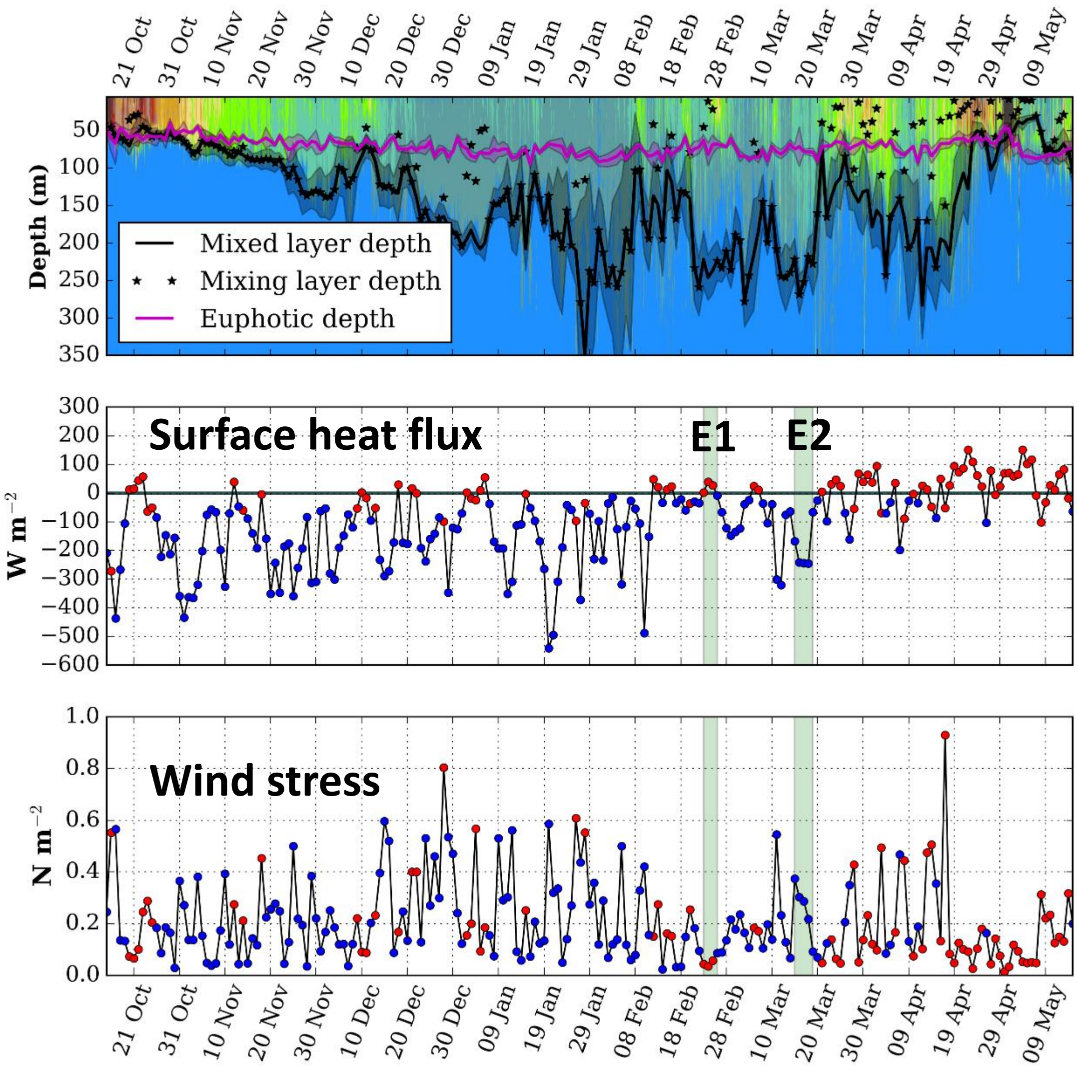
Mixing time scales < Growth time scales (test failed)

Impact of weather on specific growth rates



Cold, stormy weather = low specific growth rates for phytoplankton

Impact of weather on vertical distribution

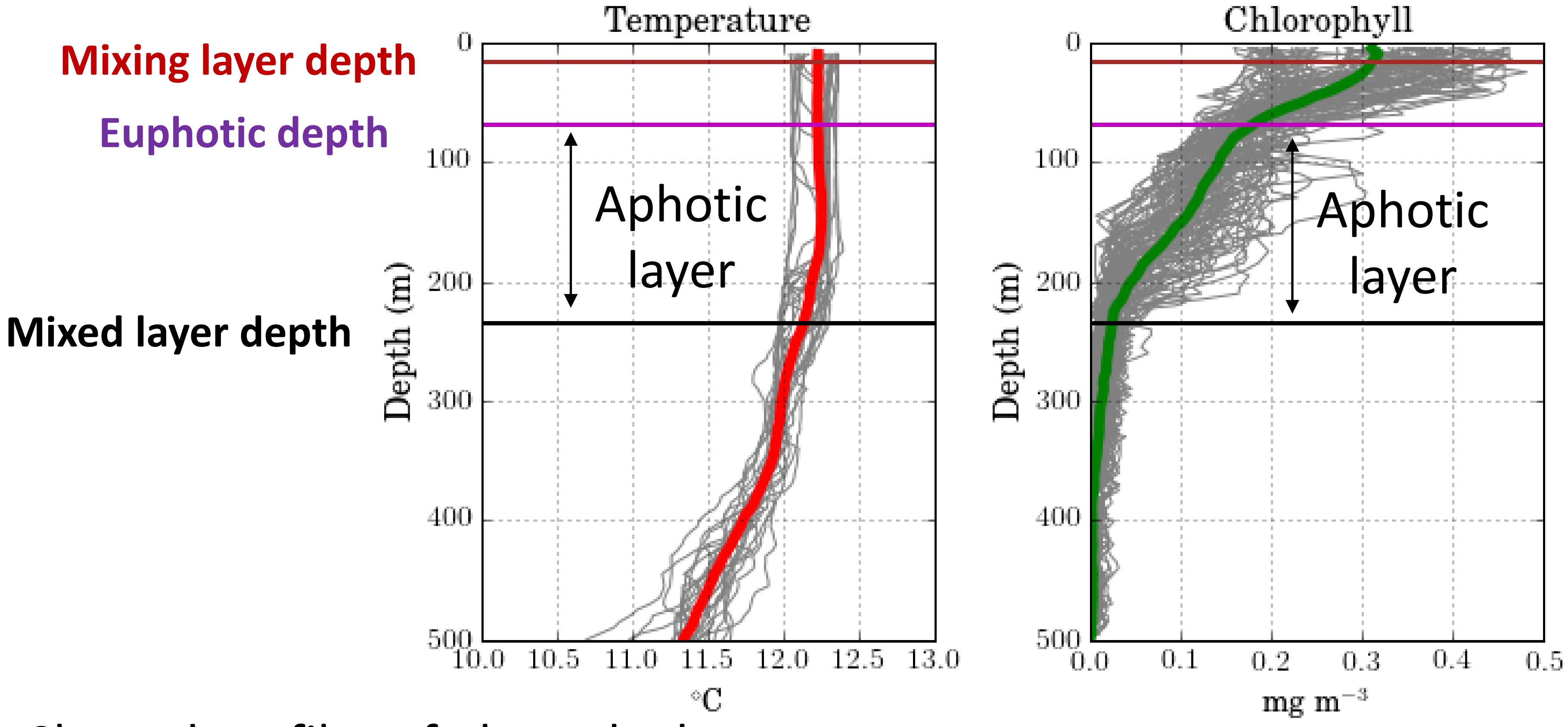


E1: wind mixing example

E2: convective mixing example

Impact of weather on vertical distribution
E1: **Wind mixing example**

$Q \approx 20$ (W m^{-2})
$\tau \approx 0.05$ (N m^{-2})

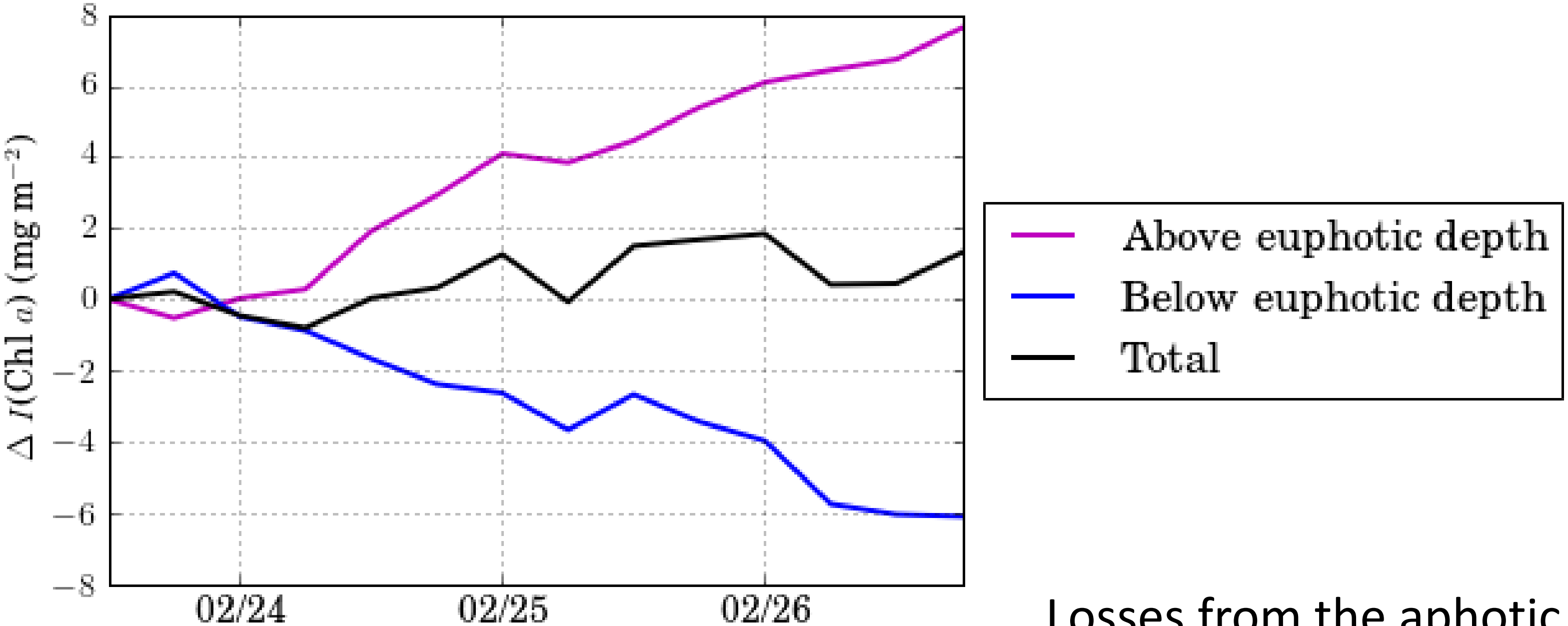


Skewed profiles of phytoplankton

Impact of weather on vertical distribution
E1: **Wind mixing example**

$Q \approx 20$ (W m^{-2})
$\tau \approx 0.05$ (N m^{-2})

Changes in Chl a stocks



Losses from the aphotic layer

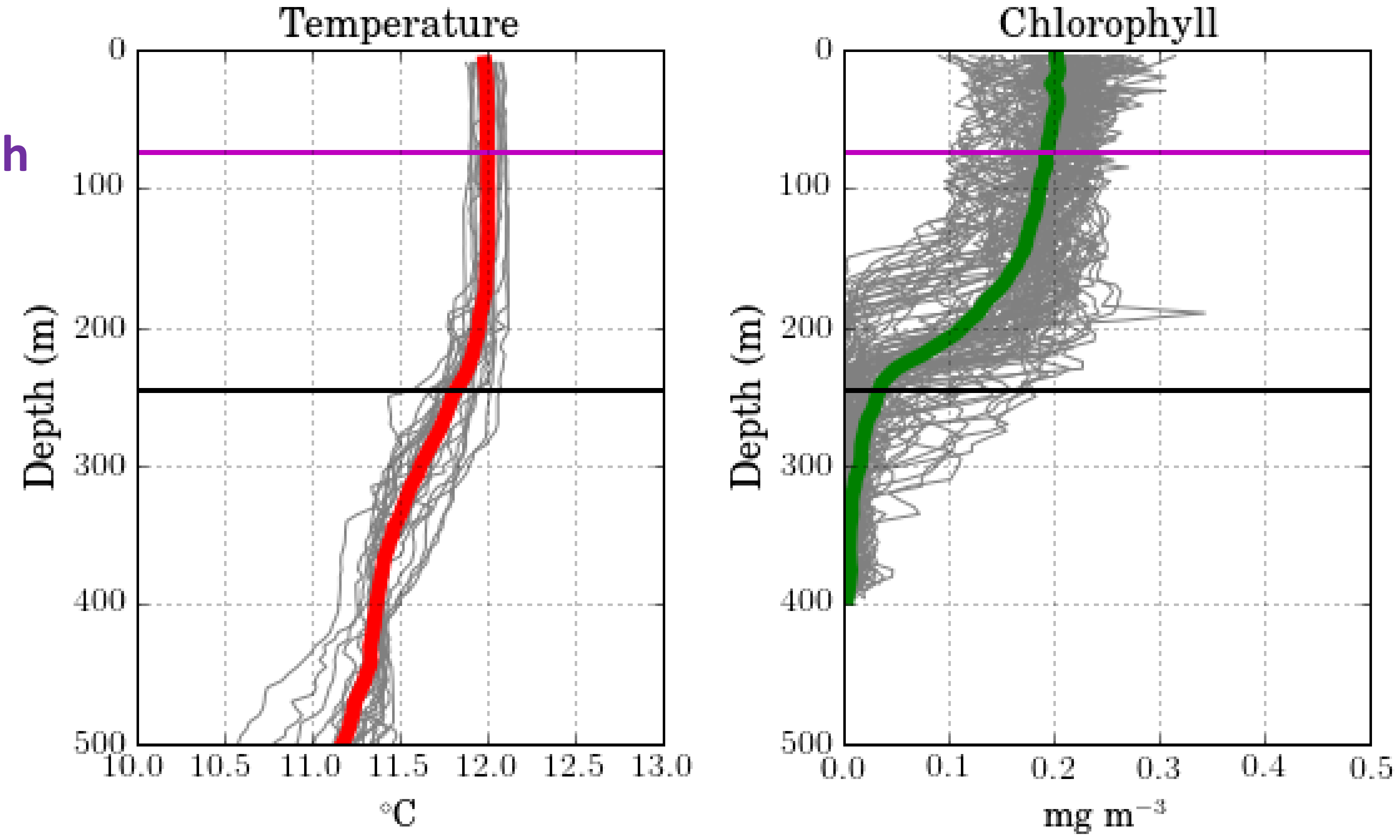
Impact of weather on vertical distribution
E2: **Convective mixing example**

Q ≈ -300 (W m^{-2})

τ ≈ 0.3 (N m^{-2})

Euphotic depth

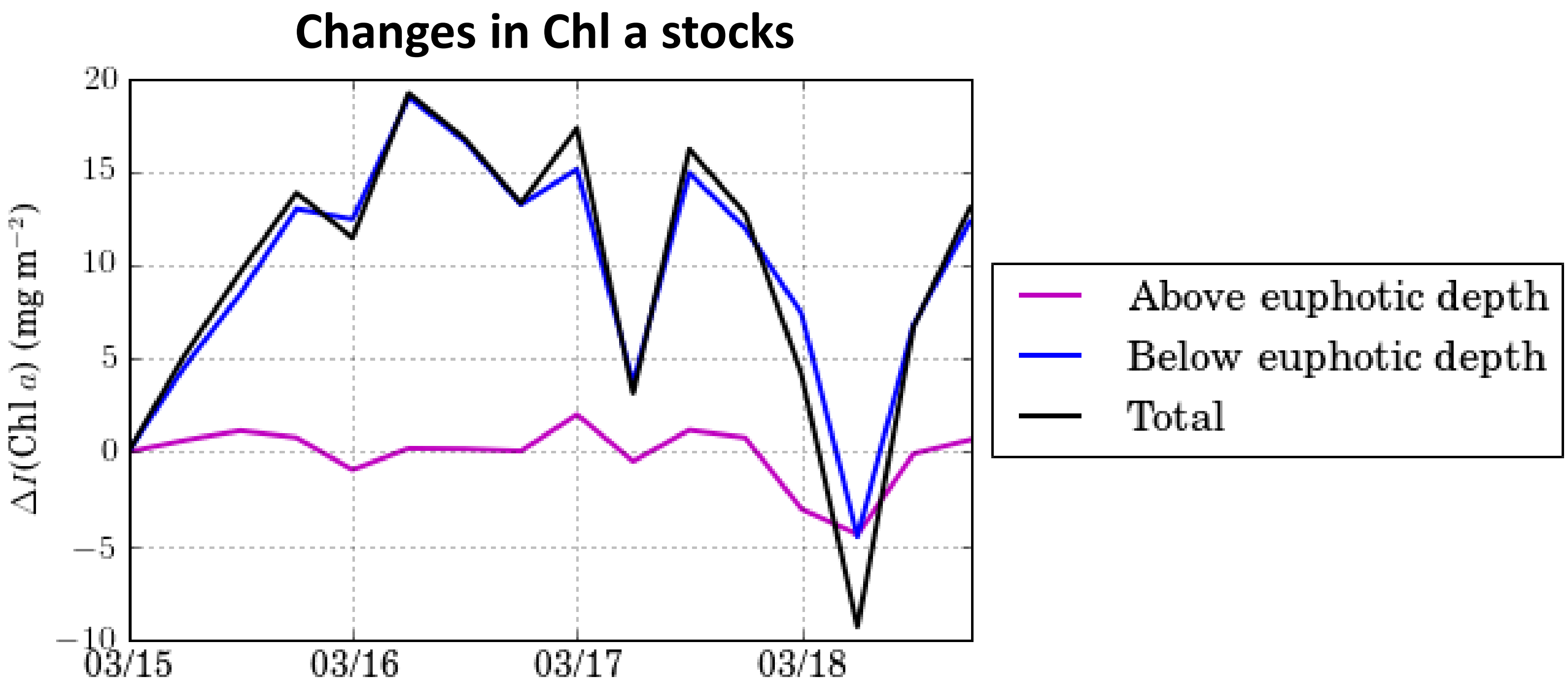
Mixed layer depth



Uniform profiles of phytoplankton

Impact of weather on vertical distribution
E2: **Convective mixing example**

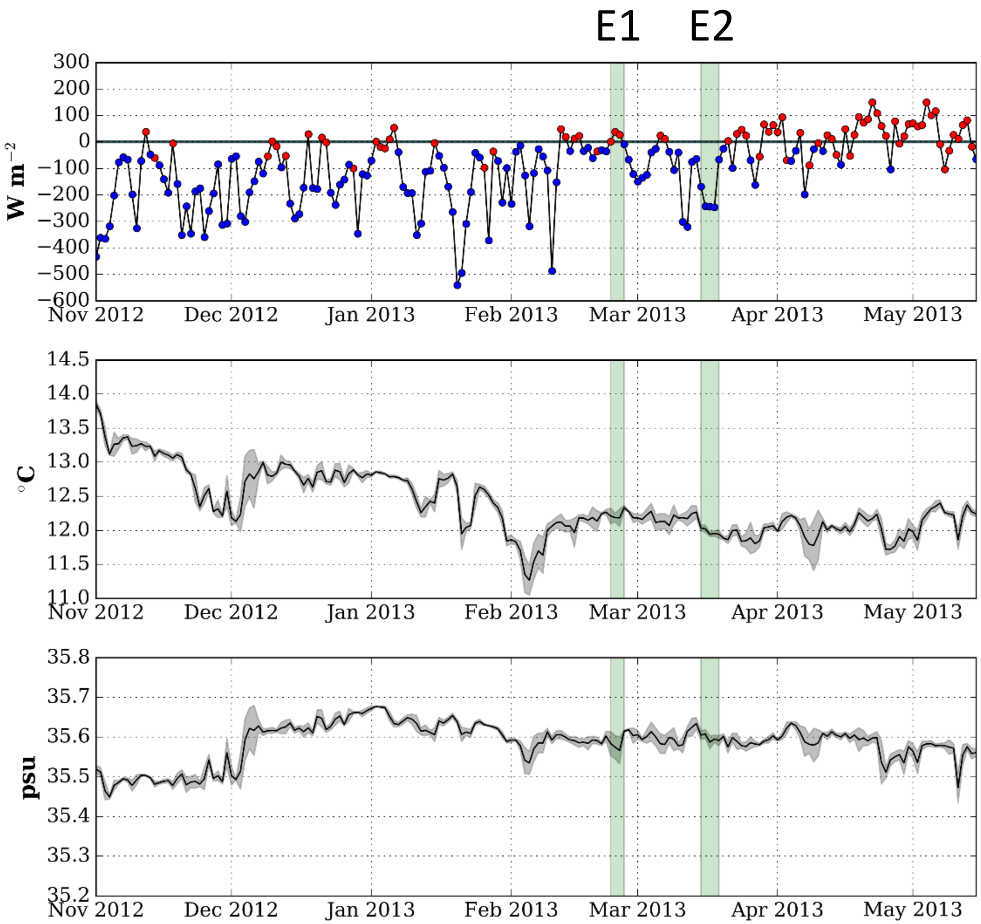
$Q \approx -300$ (W m^{-2})
$\tau \approx 0.3$ (N m^{-2})



Conclusions

- Gliders provide unique insights into subsurface dynamics of phytoplankton
- Phytoplankton starts to grow before the seasonal restratification
- The net growth was mainly consistent with the Critical Depth hypothesis (mind potential changes in losses)
- High winds and periods of convective mixing in spring can prevent high-magnitude blooms

Extra slide 1



E1: wind mixing example

E2: convective mixing example

Extra slide 2