The role of turbulence on phytoplankton growth in the Ría de Vigo (NW Iberian Peninsula)

Doctoral Dissertation

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Phytoplankton

Control in:

- Marine-food-web dynamics
- The global carbon cycle
- Earth's climate

Net primary production

$$\text{NPP} = \underbrace{\mu}_{\text{Growth rate}} \times \underbrace{P}_{\text{Biomass}}$$

$$r = \frac{1}{P}\frac{\partial P}{\partial t} = \underbrace{\mu}_{\text{Growth rate}} - \underbrace{l}_{\text{Loss rate}}$$

Proximate drivers

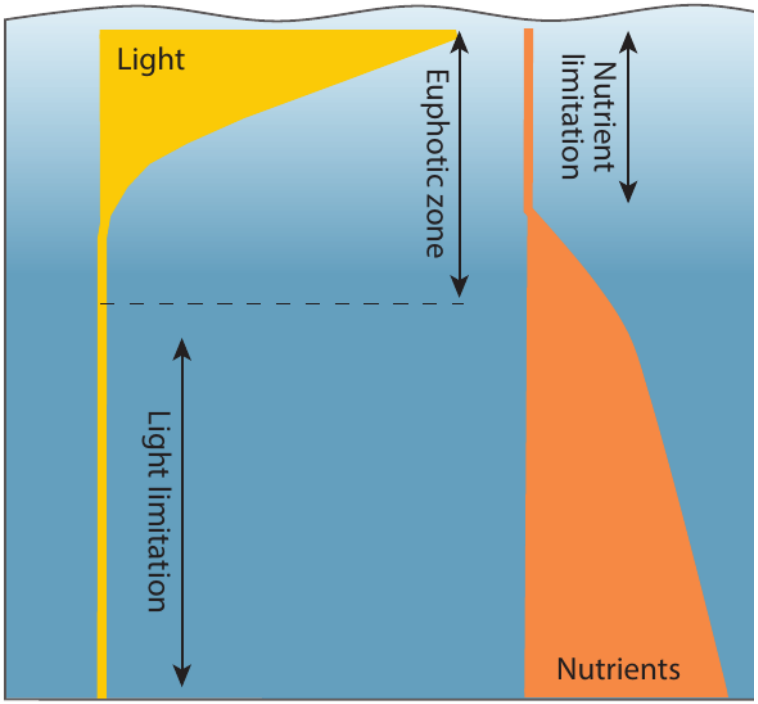
Bottom-up

- Light
- Nutrients
- Temperature

Top-down

- Grazing

Net primary production

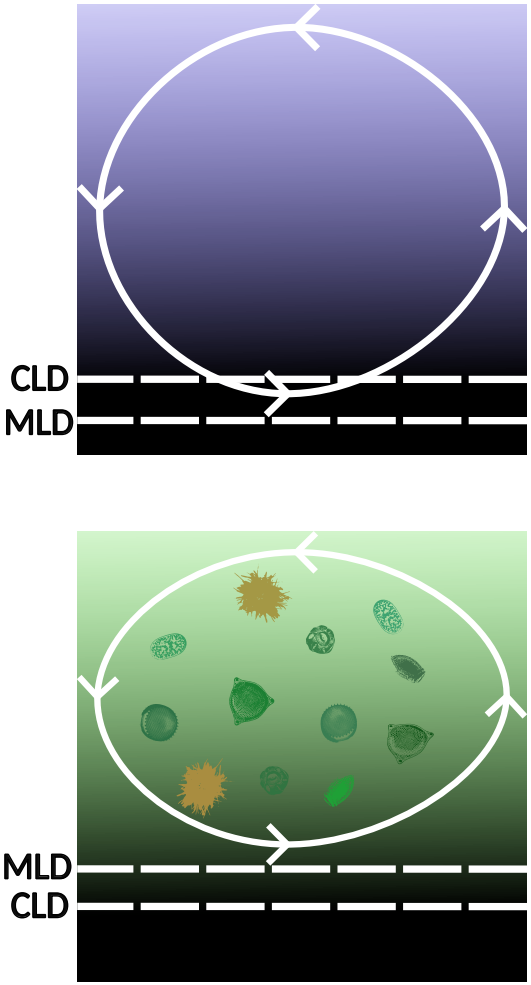


[Karlusich et al., 2020]

Ultimate drivers

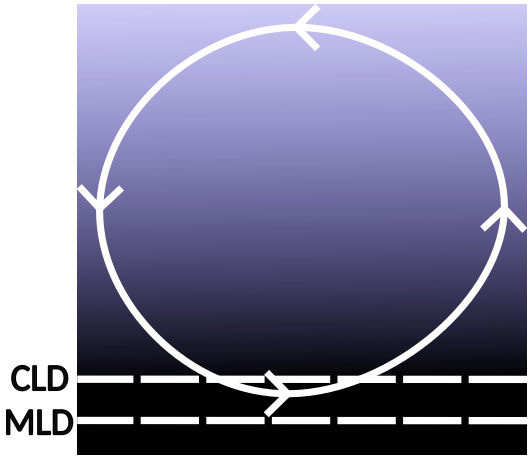
- Advection
- Turbulence

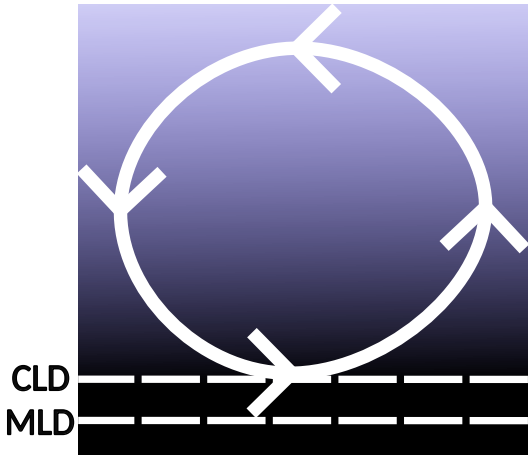
Turbulent mixing

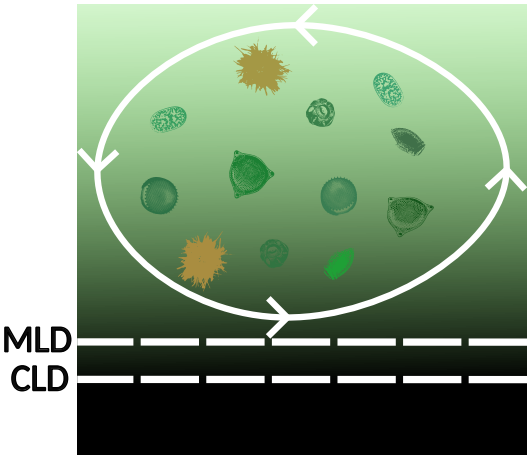


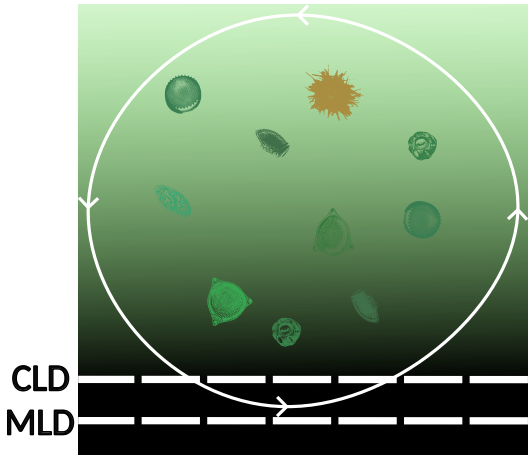
[Sverdrup, 1953]

Turbulent mixing





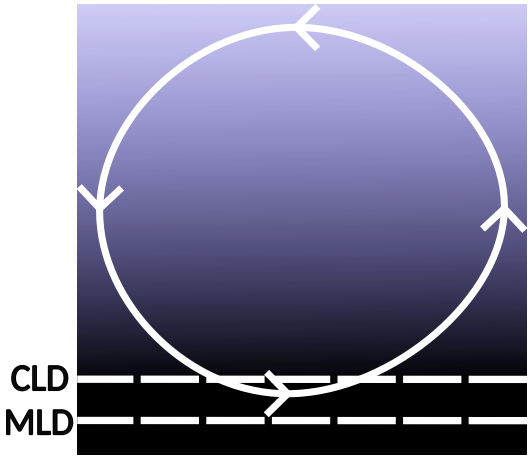


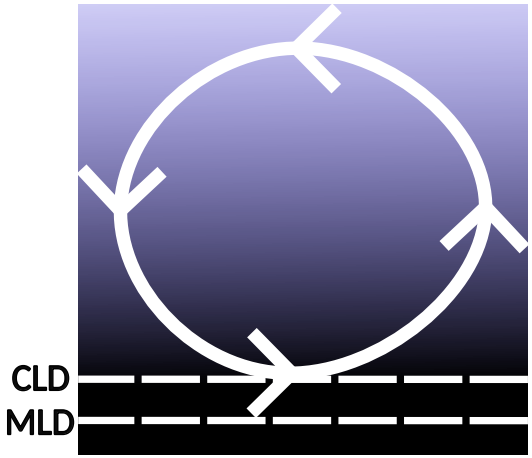


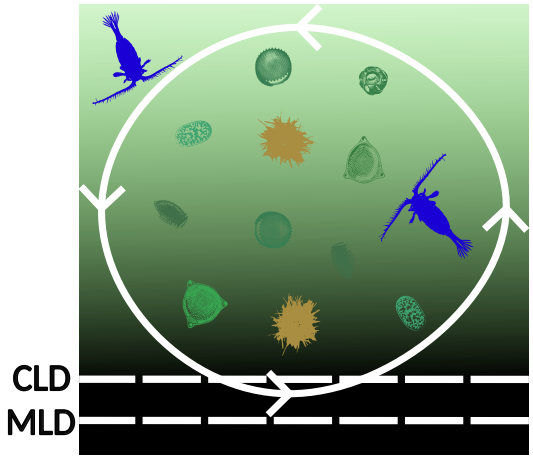
[Sverdrup, 1953]

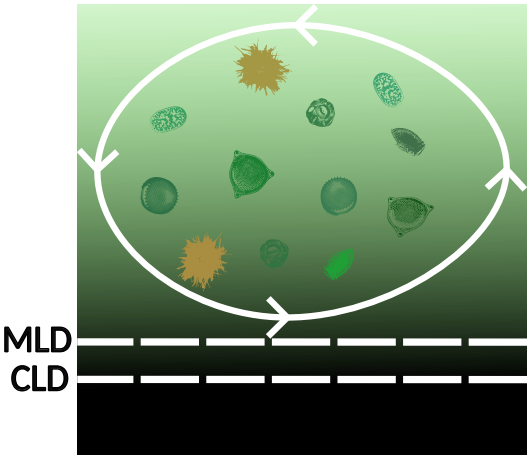
[Huisman et al., 1999]

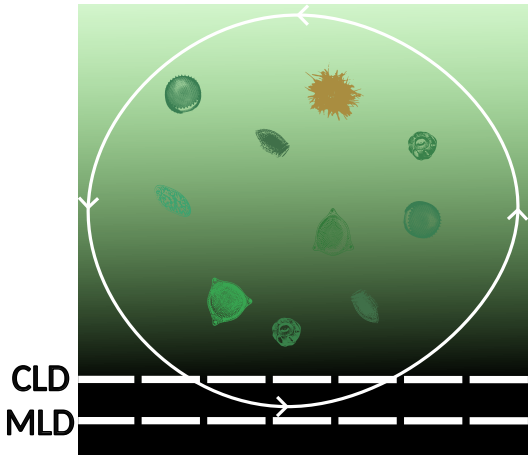
Turbulent mixing

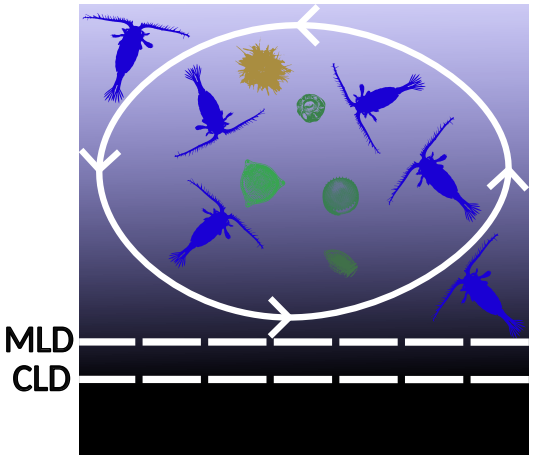












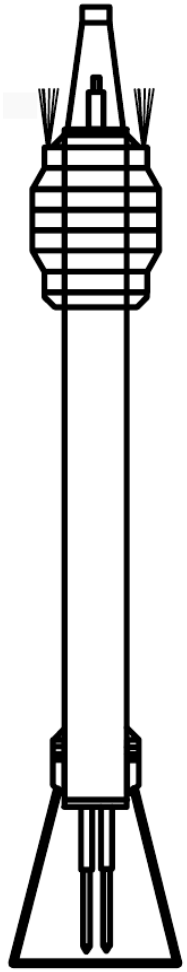
[Sverdrup, 1953] [Huisman et al., 1999] [Behrenfeld, 2010]

Turbulent mixing

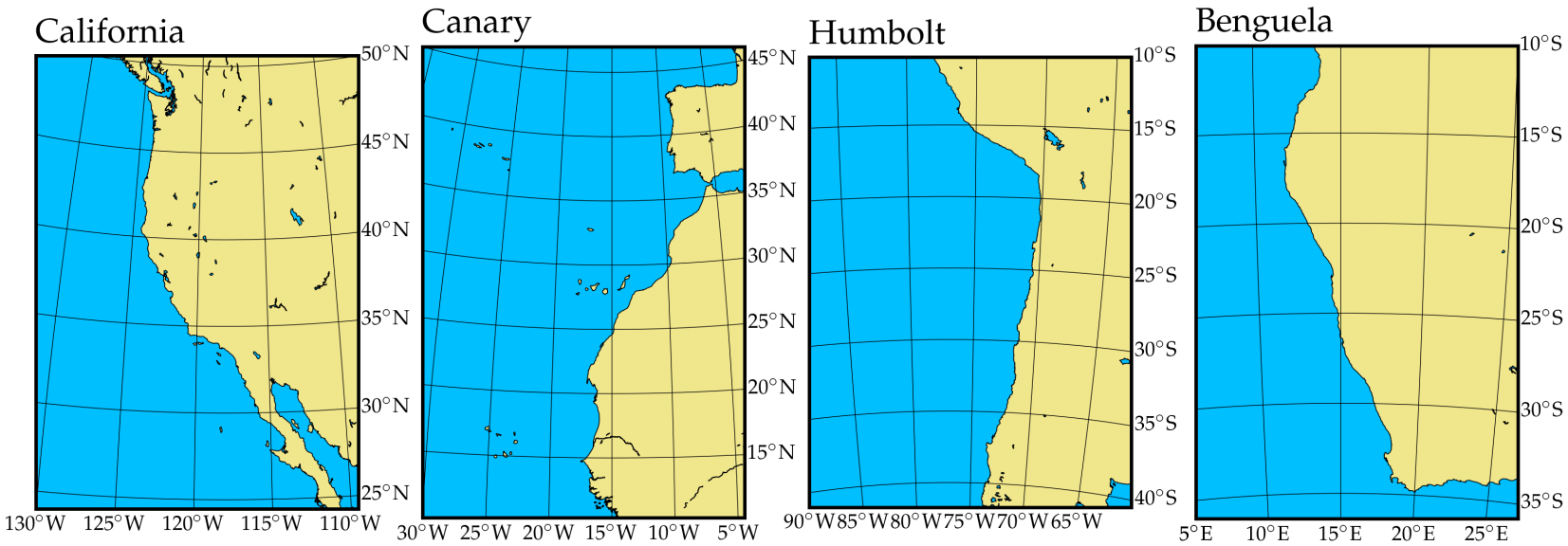
Mixed-layer depth (MLD) denotes the history of mixing

Turbulent layer depth (TLD) the actual state of mixing

The only reliable method to quantify mixing is through microstructure observations [Platt et al., 1994]



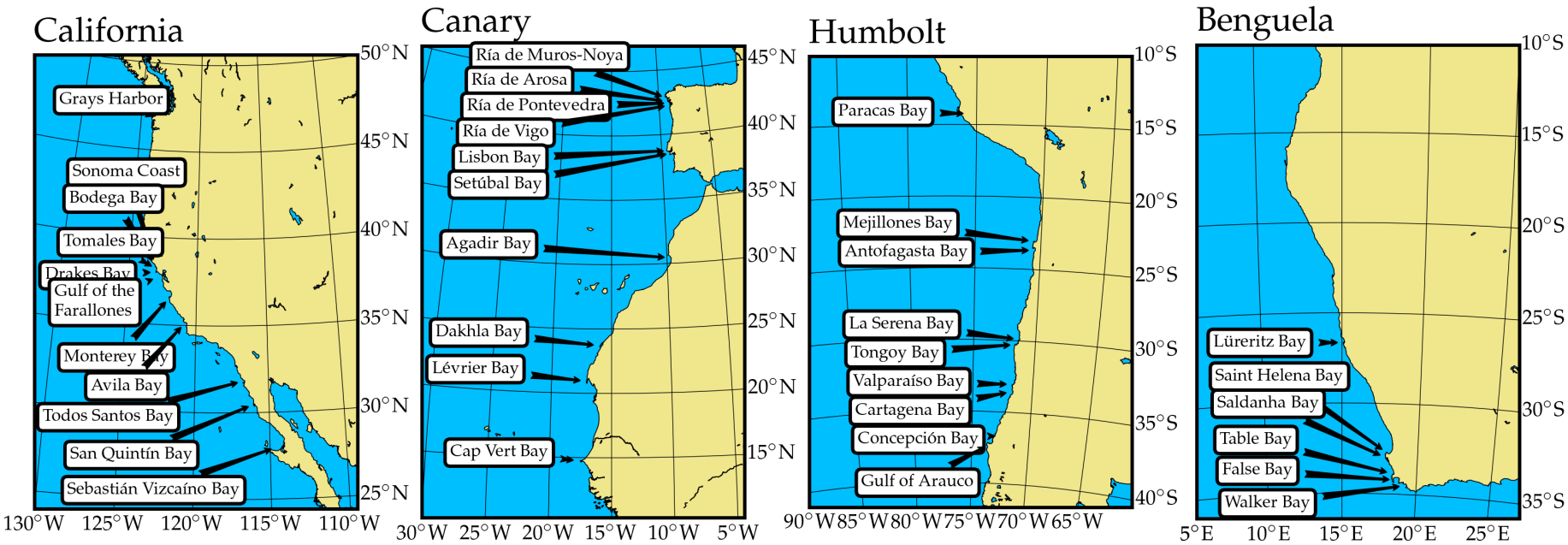
The Eastern Boundary Upwelling Systems (EBUS)



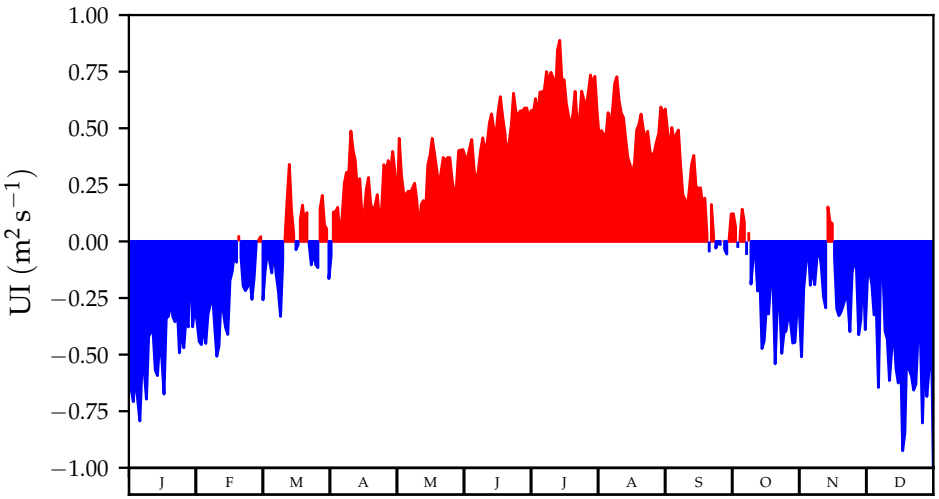
The nutrient supply mechanism by upwelling is not enough to explain productivity of EBUS [Messié and Chavez, 2015]

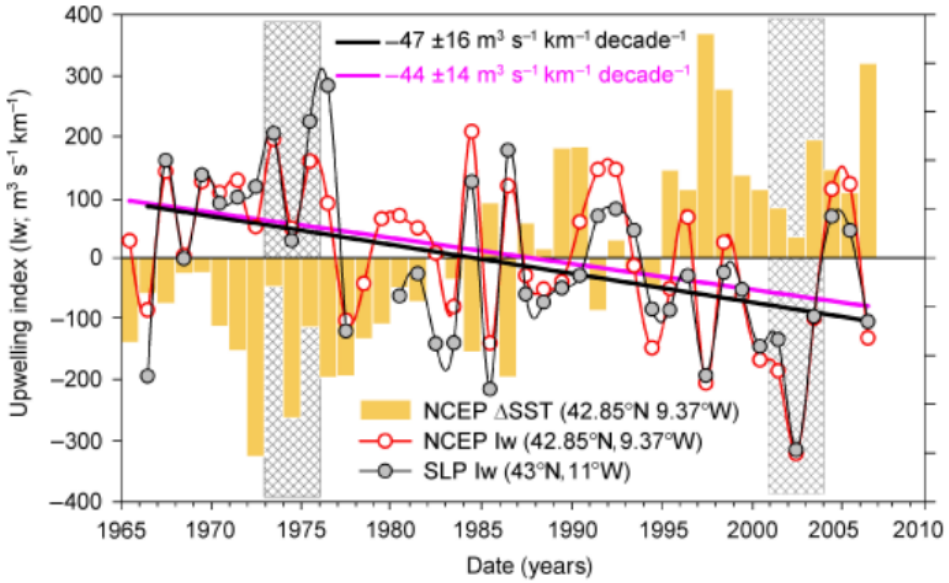
Upwelling bays

Ecological hot-spots and elevated productivity

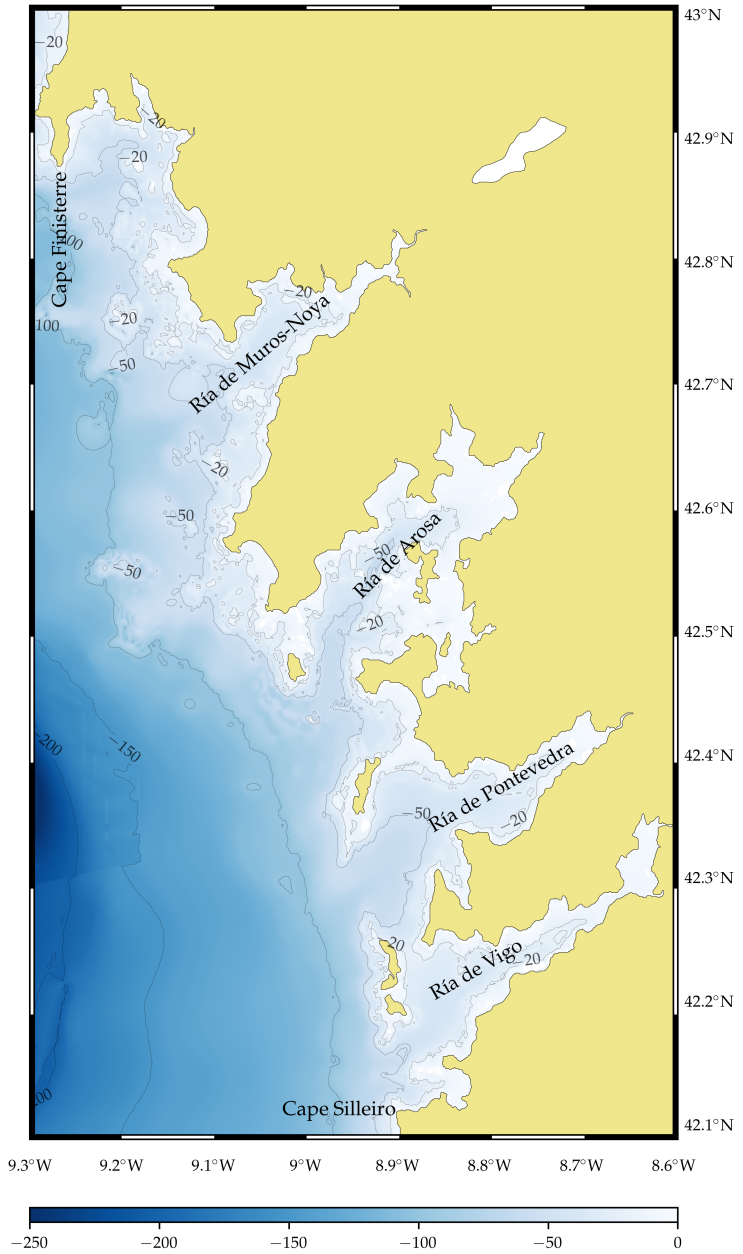


Rías Baixas





[Pérez et al., 2010]



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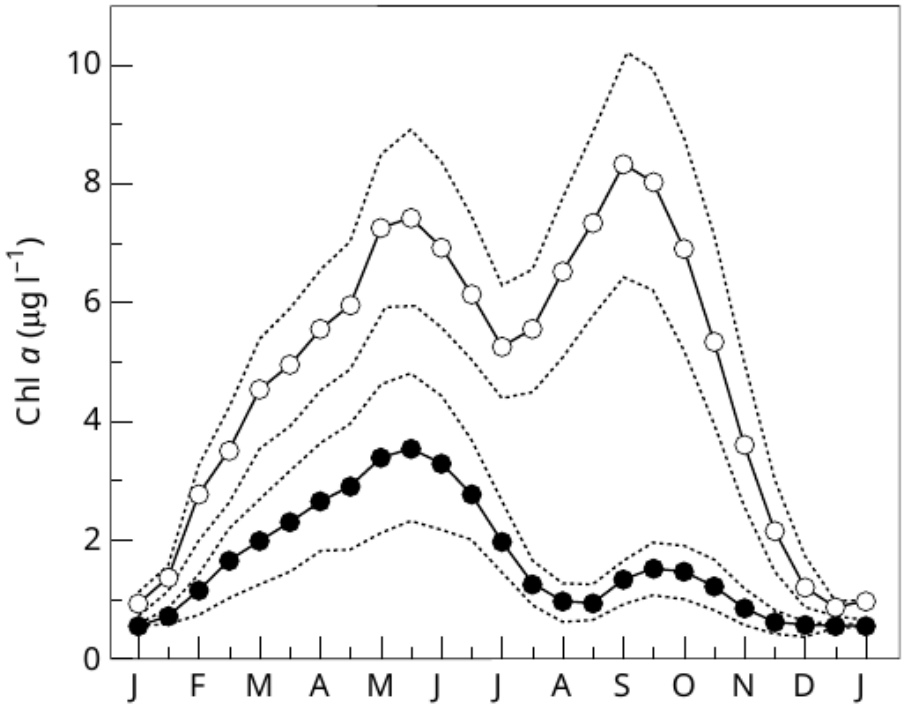
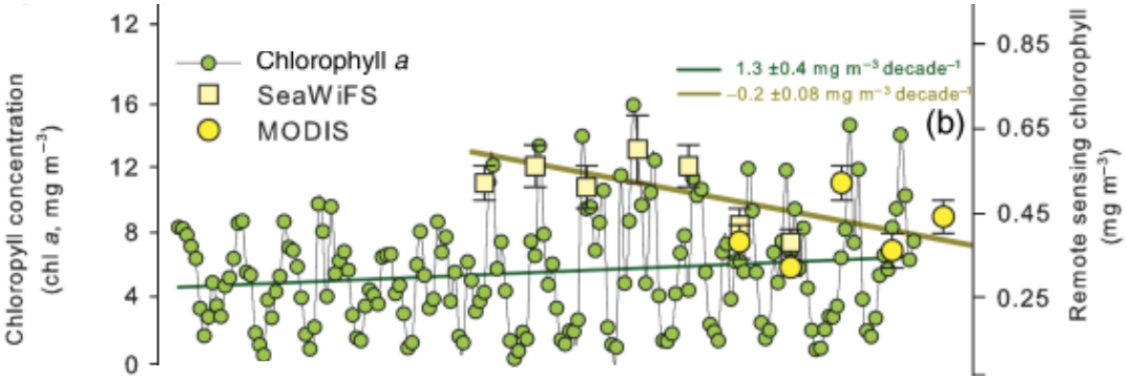
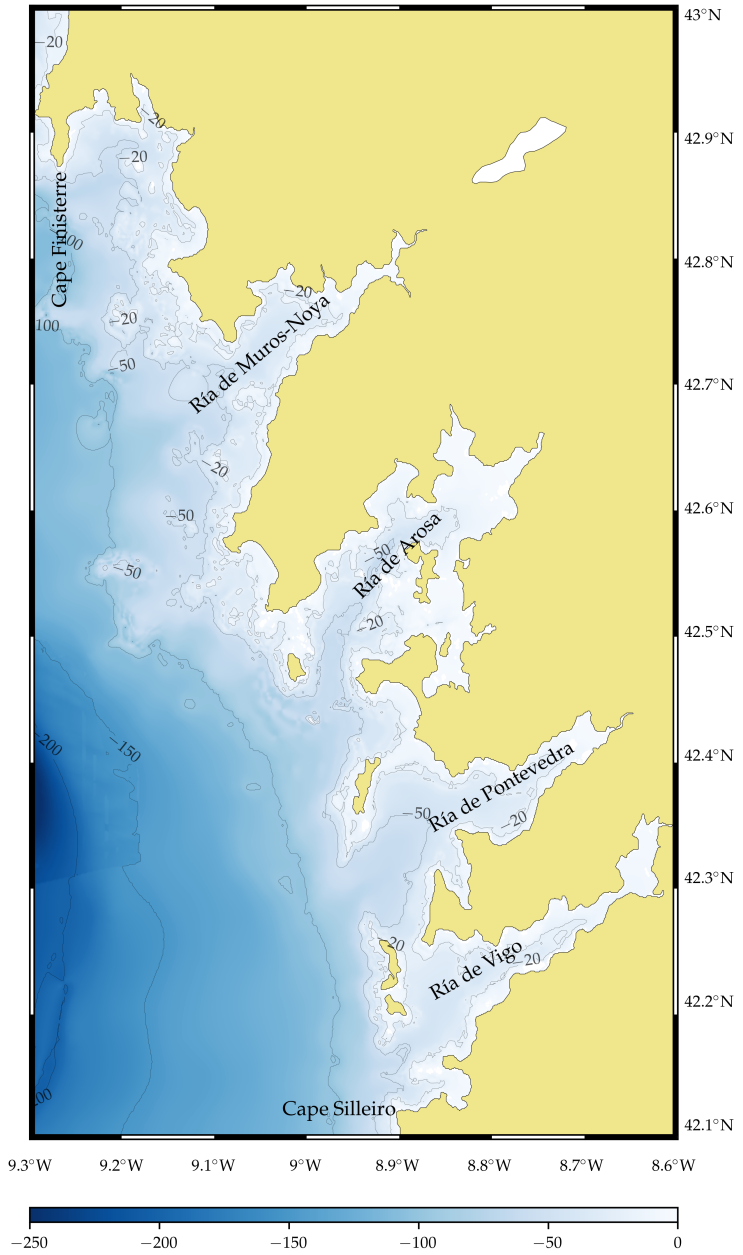
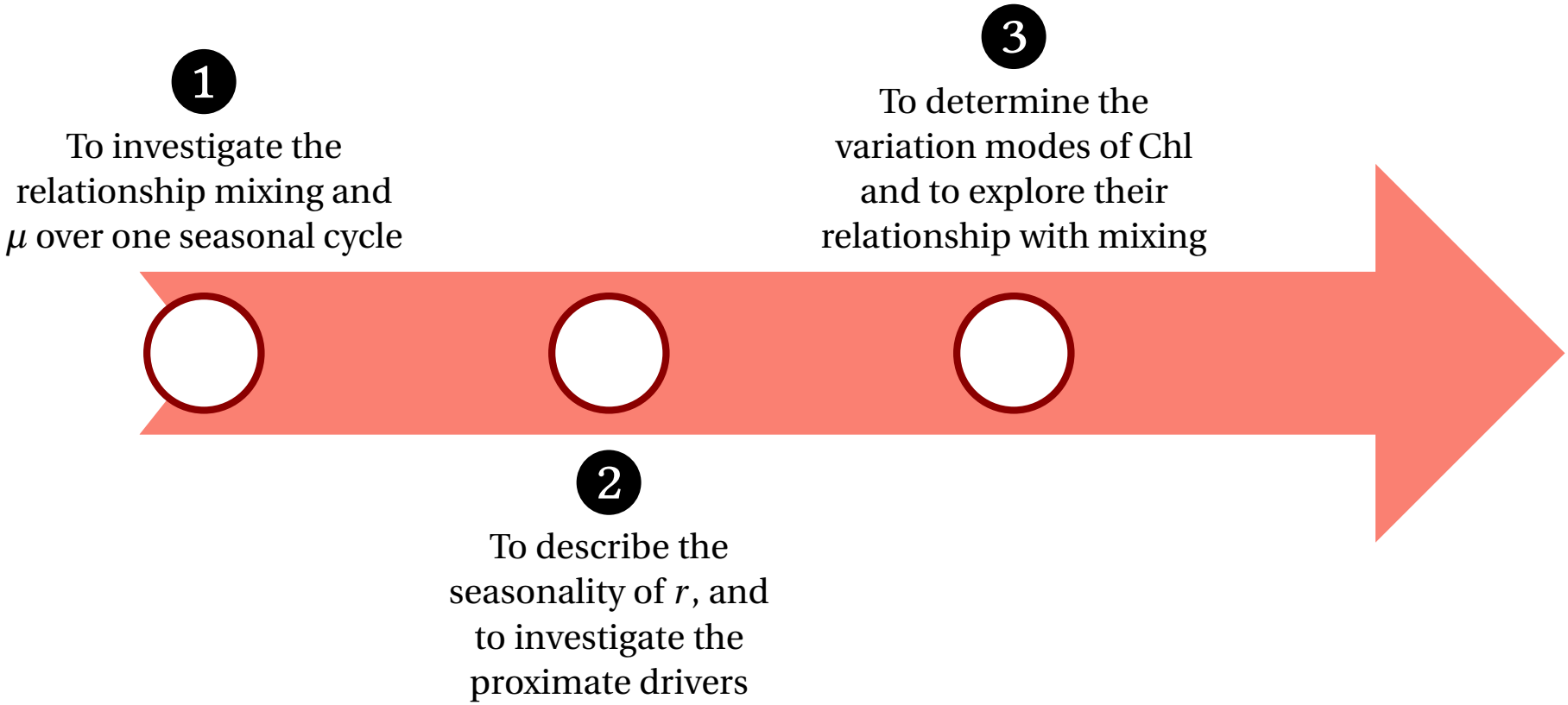


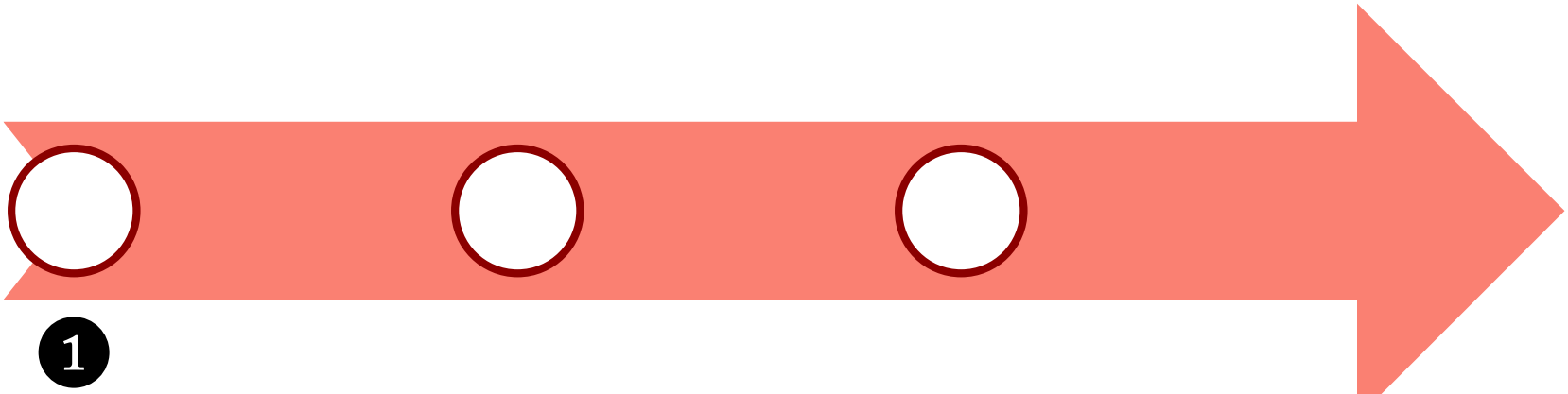
[Nogueira et al., 1997]



[Pérez et al., 2010]



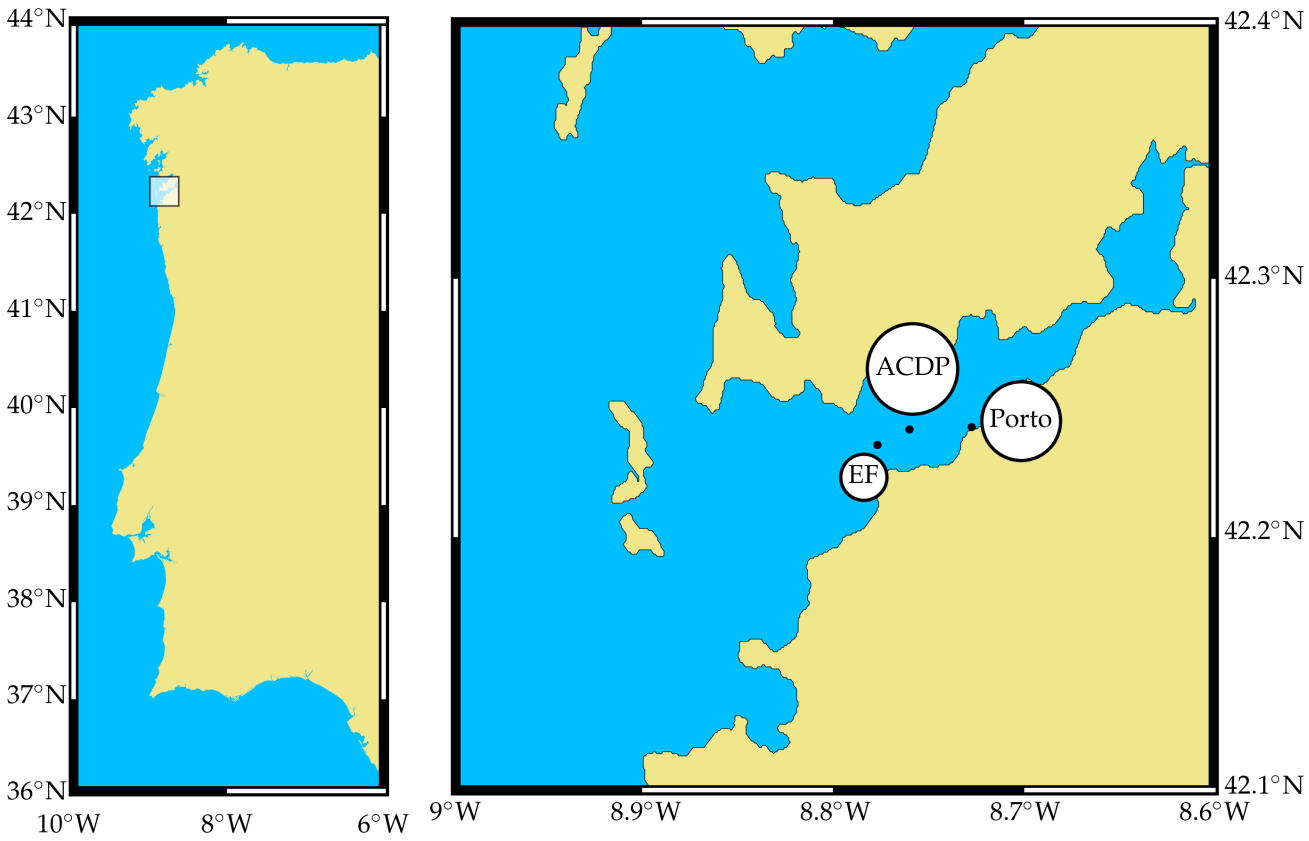

1
To investigate the relationship mixing and μ over one seasonal cycle
2
To describe the seasonality of r, and to investigate the proximate drivers
3
To determine the variation modes of Chl and to explore their relationship with mixing



1

To investigate the relationship mixing and μ over one seasonal cycle

1 Methods



March 2017 - May 2018

EF

Weakly measurements
T, S, ϵ, Chl with 1 m resolution.
NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, SiO_4^{3-} at 8 depths.
PP at the surface and 10 m depth.

$K = \gamma \frac{\epsilon}{N^2}$ [Osborn, 1980]

$\mu = \frac{1}{\text{C:Chl}\,a} \frac{\text{PP}}{\text{Chl}\,a}$

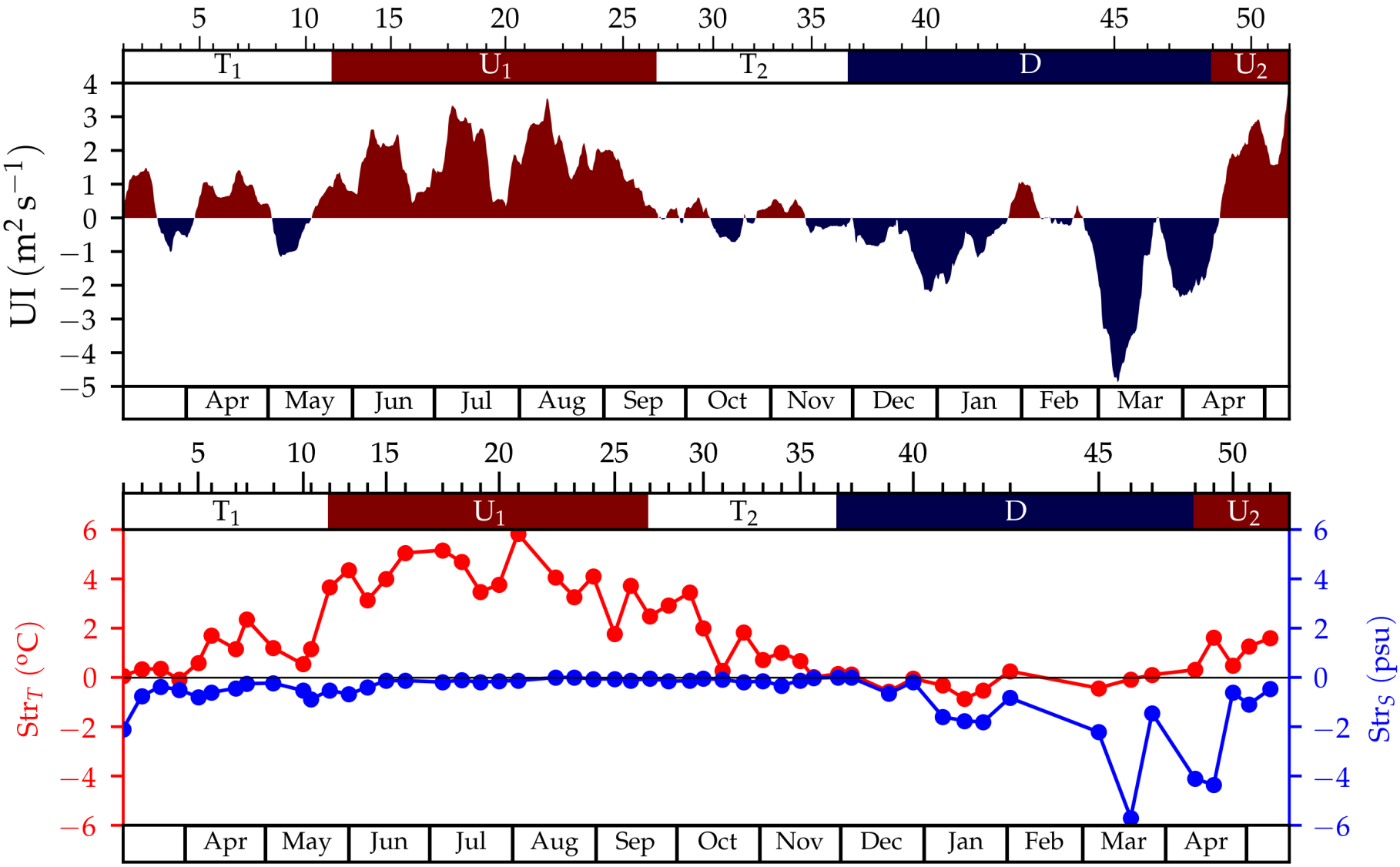
ADCP

Continuous current measurements

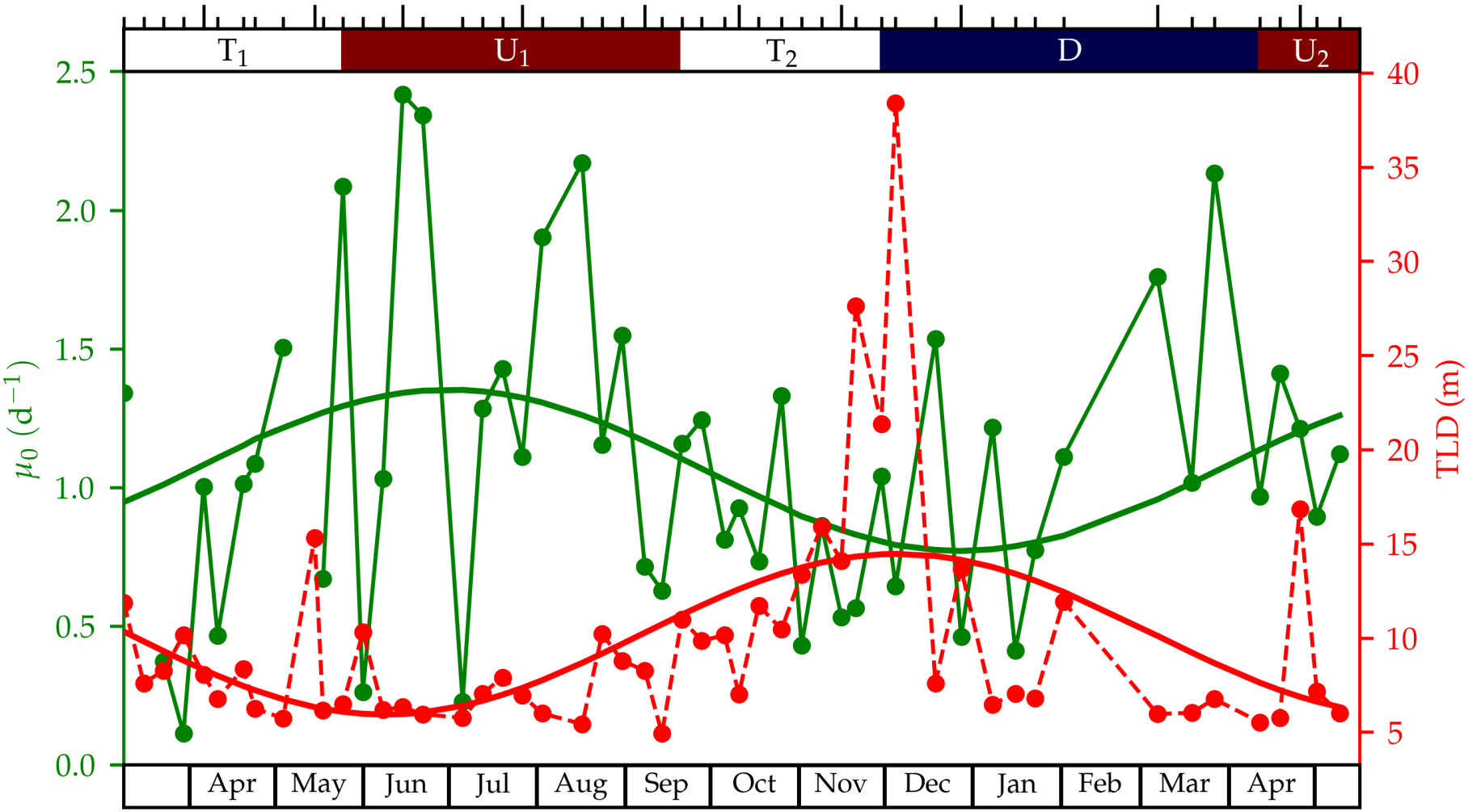
Porto

Continuous irradiance measurements

1 Hydrography

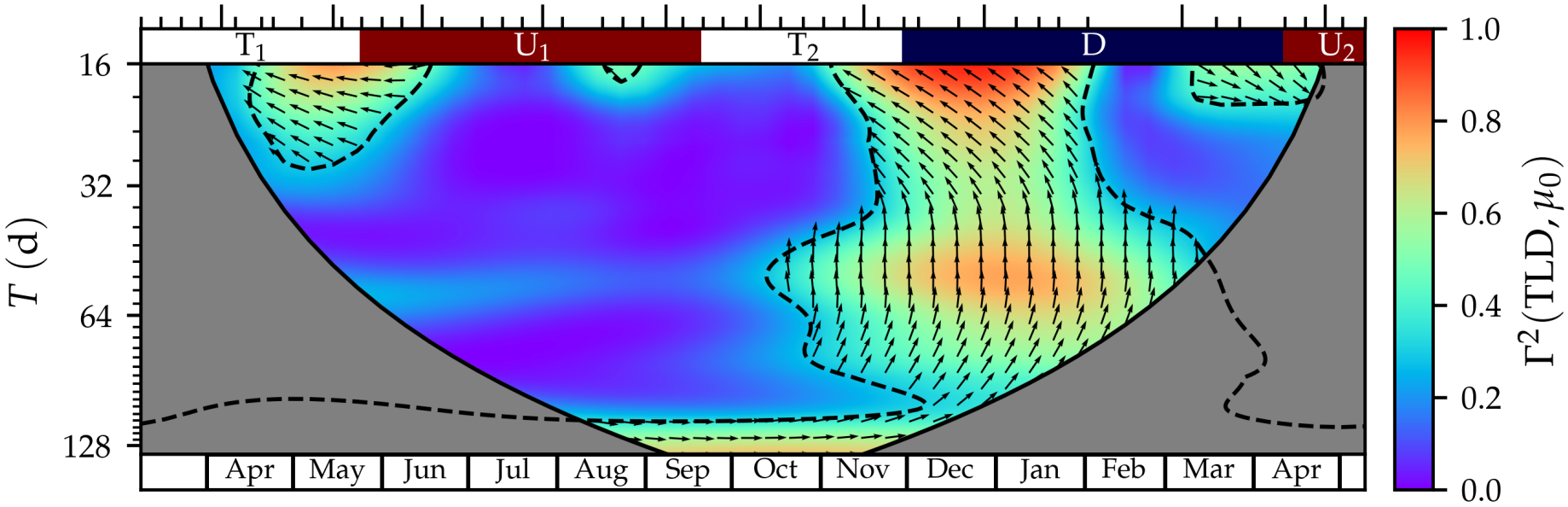


❶ Seasonal μ_0 vs. TLD

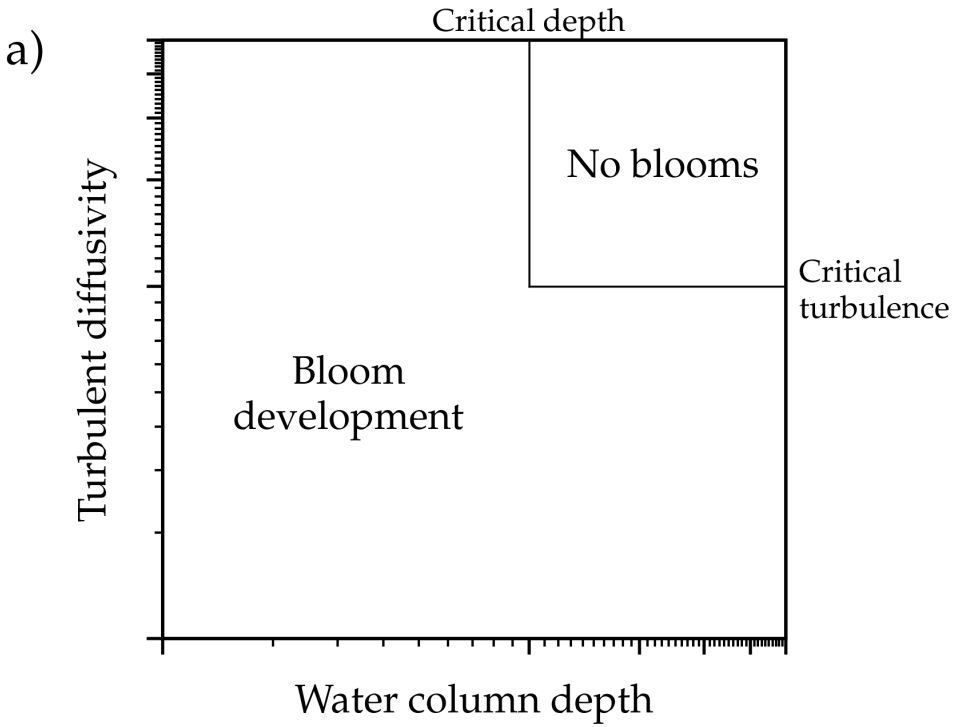


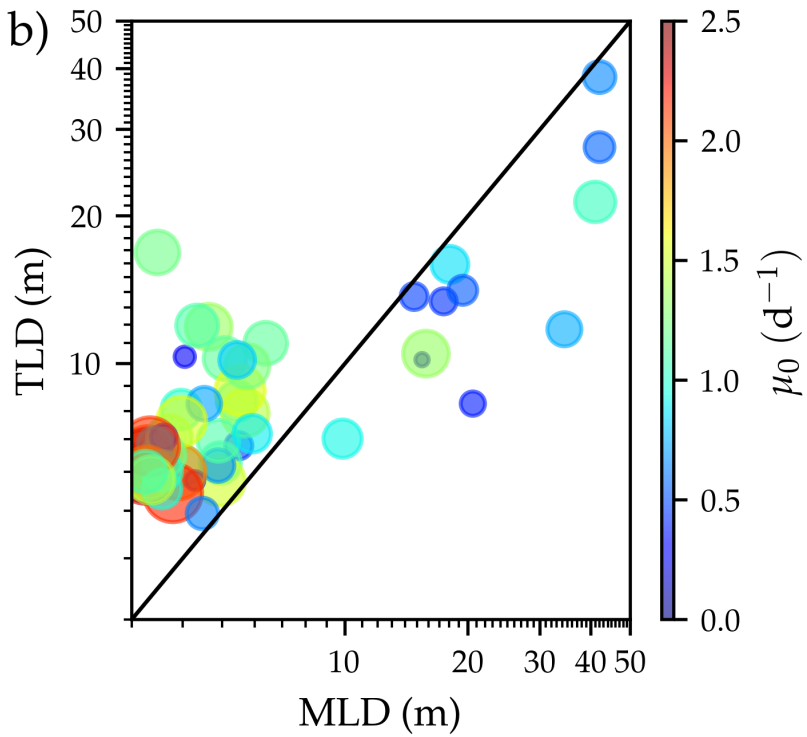
$$R^2(\mathrm{MLD}, \mathrm{TLD}) = 0.66$$

❶ Short-term μ_0 vs. TLD



❶ Short-term μ_0 vs. TLD





1 Conclusions

Objective

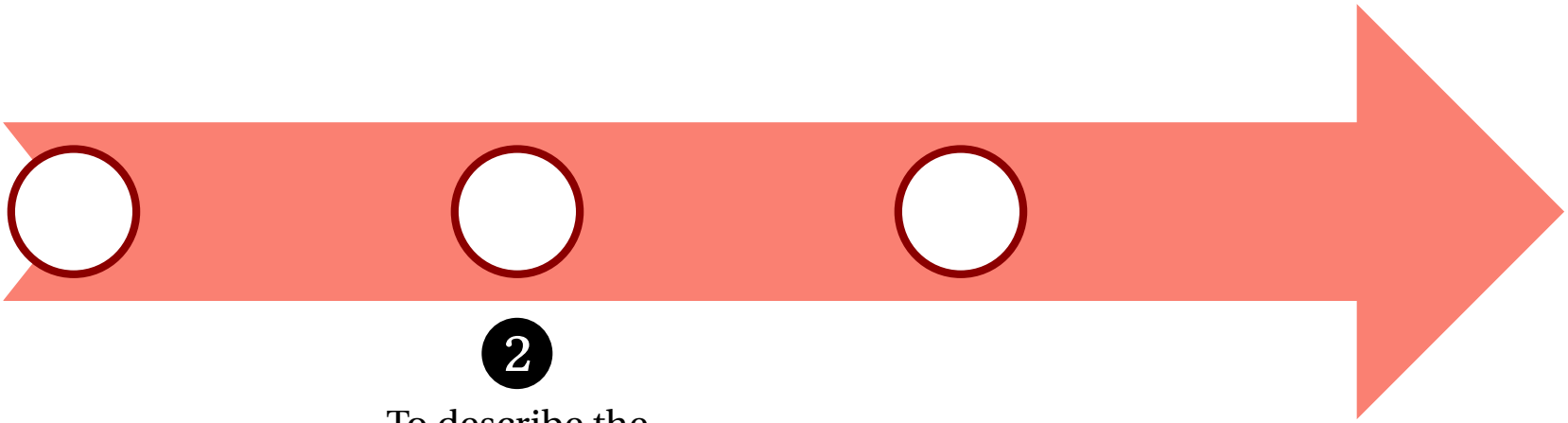
To investigate the relationship mixing and μ over one seasonal cycle

Conclusions

μ_0 and TLD had an opposite annual pattern.

Turbulent mixing and phytoplankton growth also related at short-term scale

CTH could establish a necessary but not sufficient condition for growth

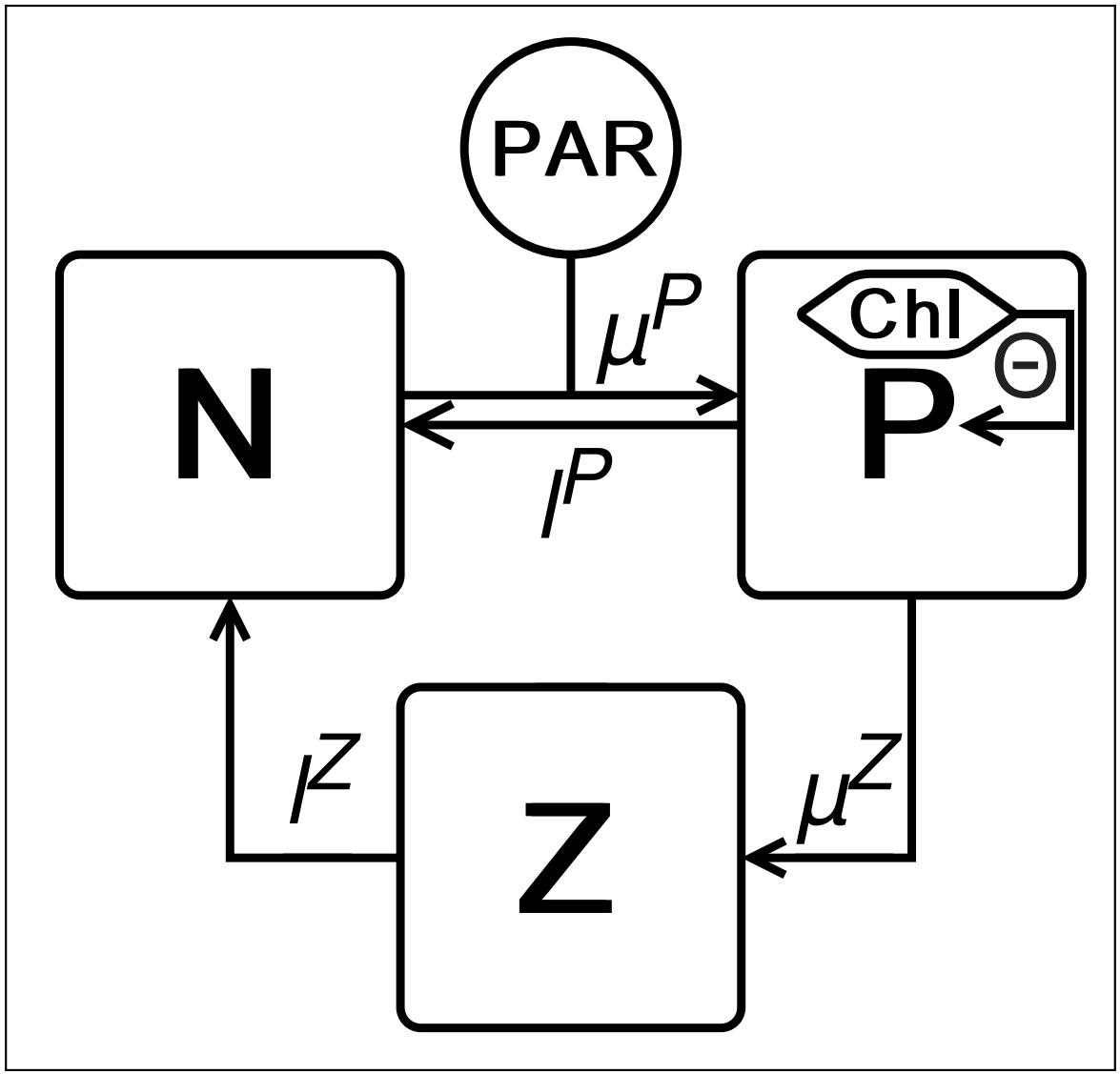


2

To describe the seasonality of r, and to investigate the proximate drivers

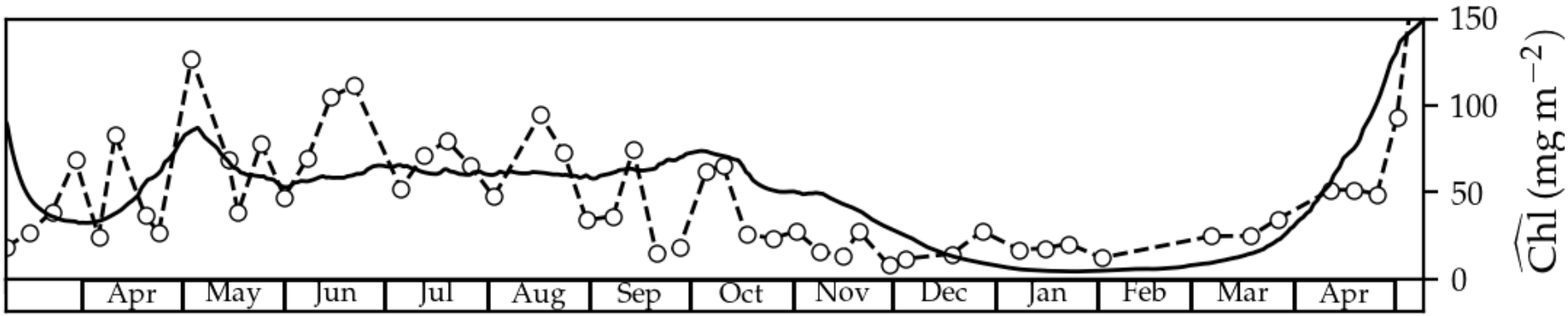
❷ Methods

1D model, closed box



$+$ K

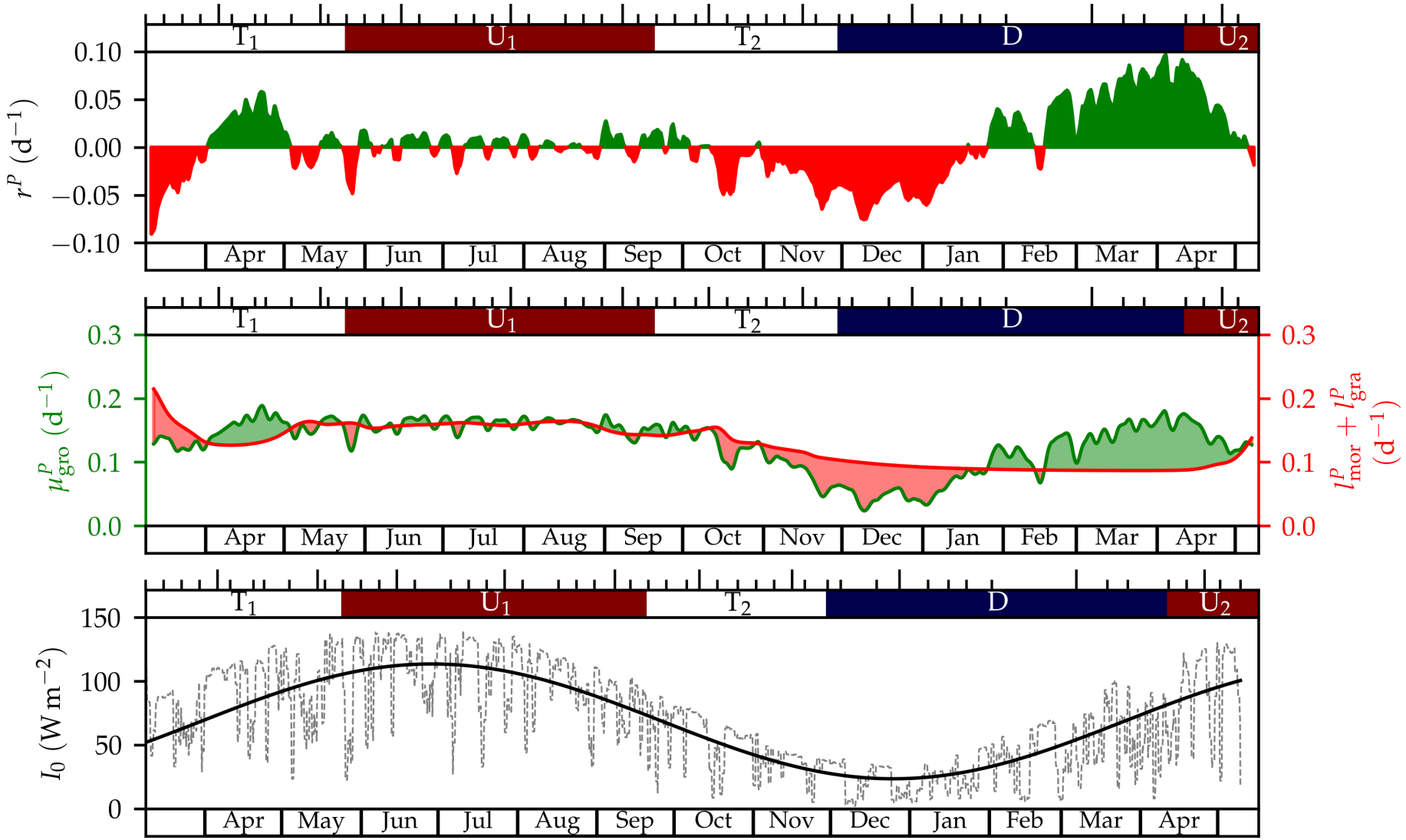
❷ Calibration



∘ Observations

– Model output

❷ Accumulation rate

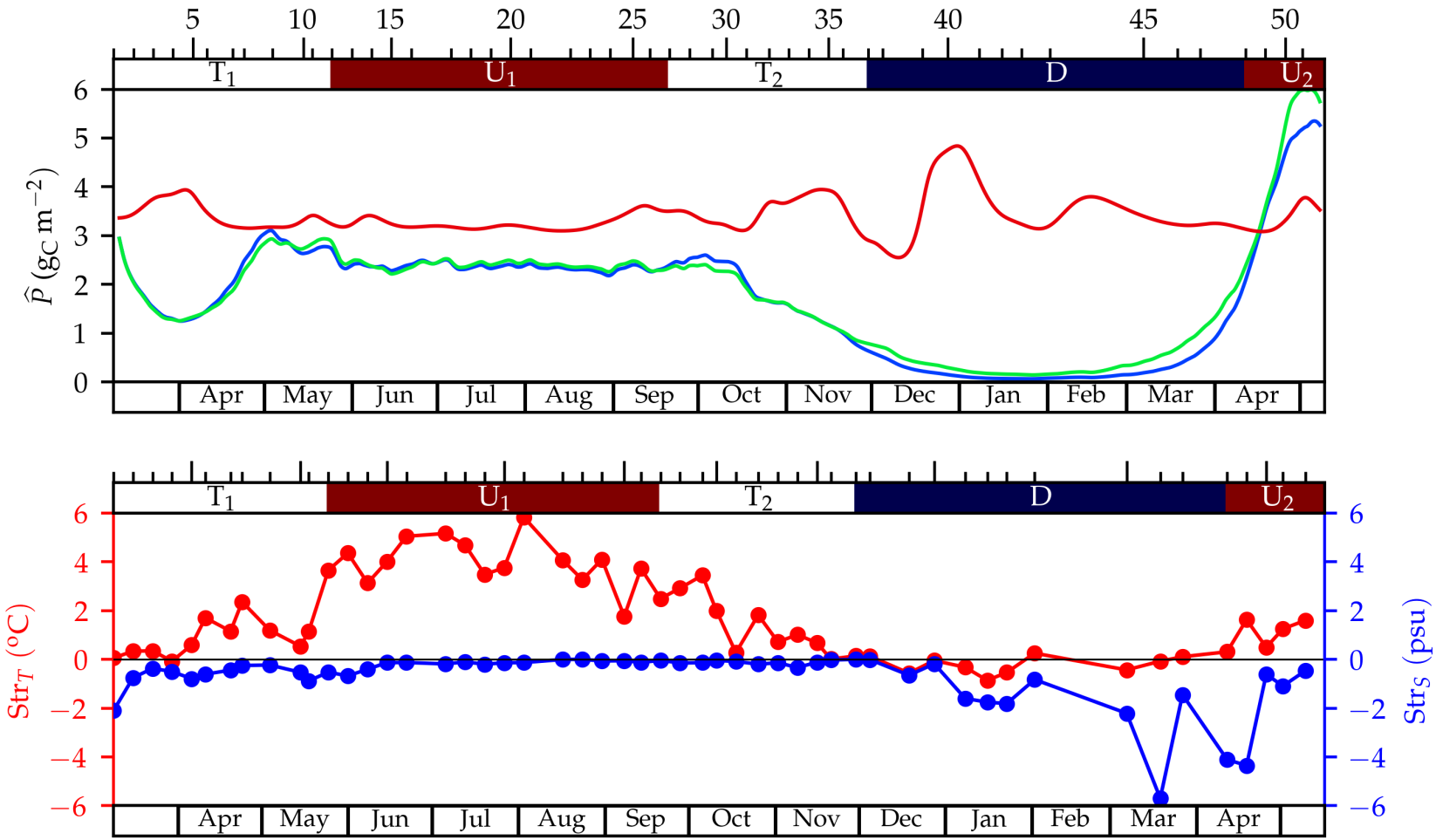


❷ Mixing role

A. Both time-evolving observations of I and K.

B. Only time-evolving observations of I. The first K profile is maintained over time.

C. Only time-evolving observations of K.



❷ Conclusions

Objectives

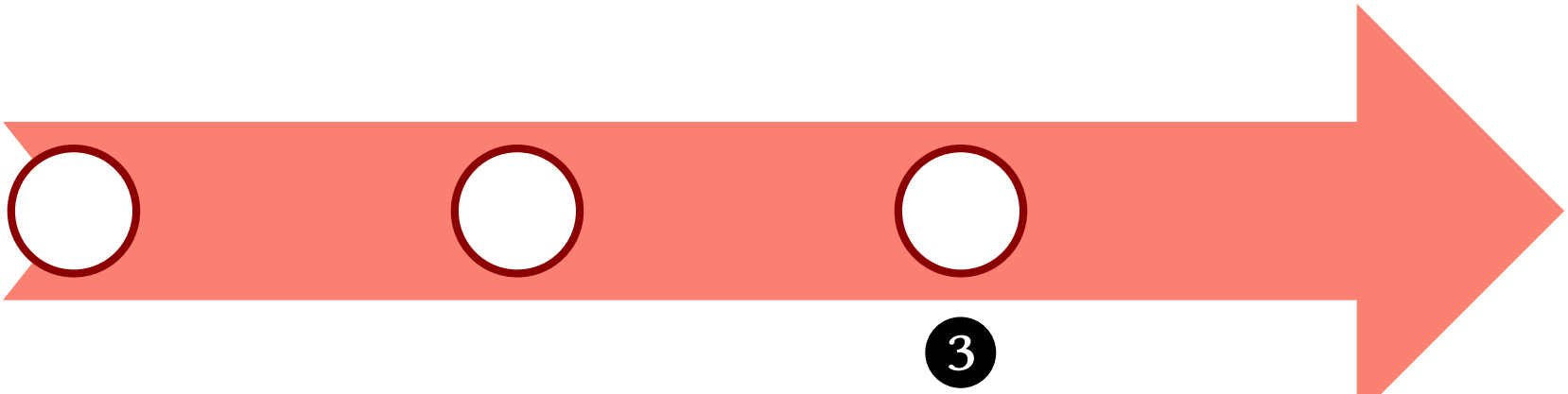
To describe the seasonality of r

To investigate the proximate drivers of r

Conclusions

Variability of r points out to relevance of bottom-up control

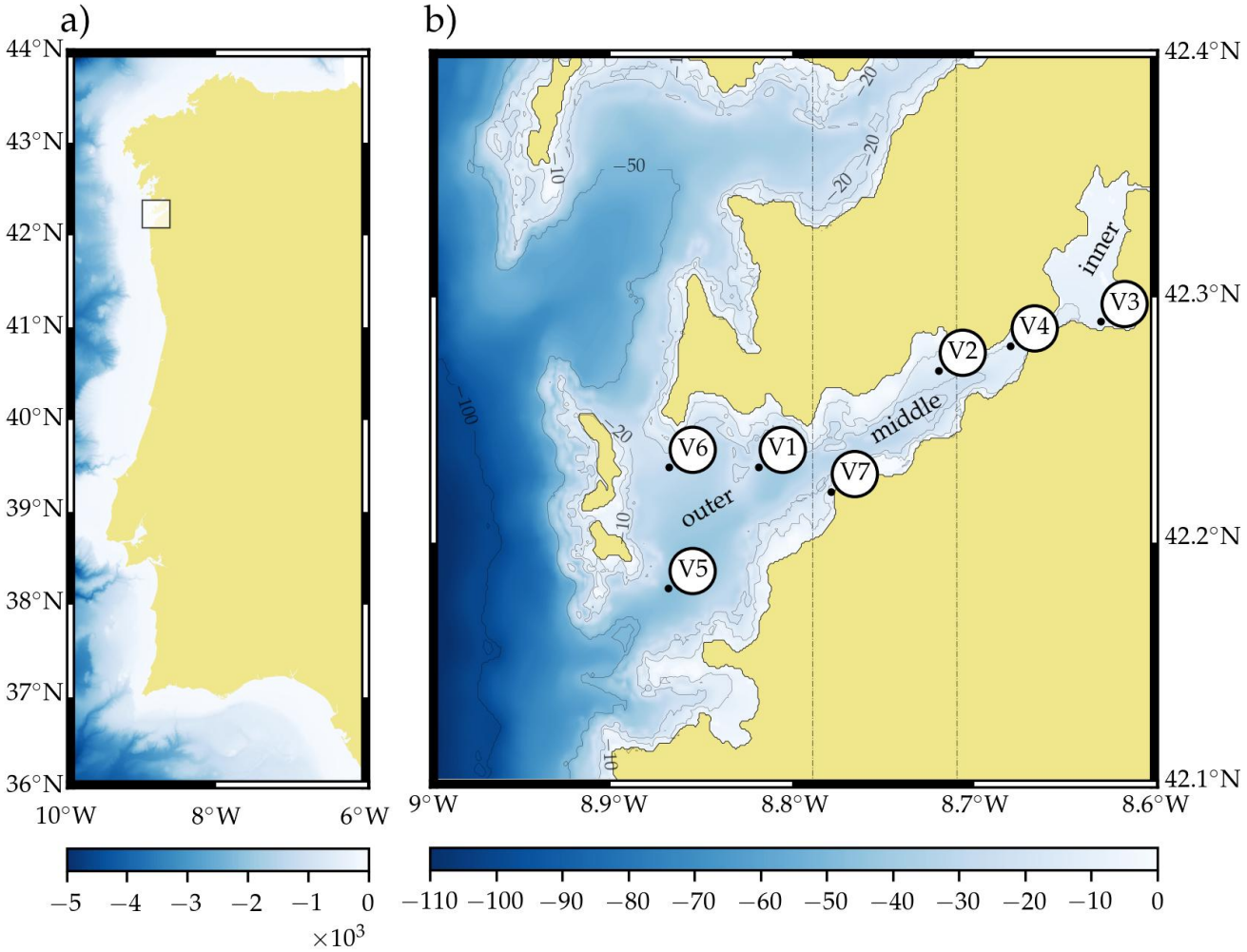
Seasonality of r driven mainly by I seasonality, whereas mixing variability played minor role



3

To determine the variation modes of Chl and to explore their relationship with mixing

❸ Methods



Seven locations
Weakly measurements T, S, ρ with 1 m resolution from 2010.
Chl 0-15 m from 1998

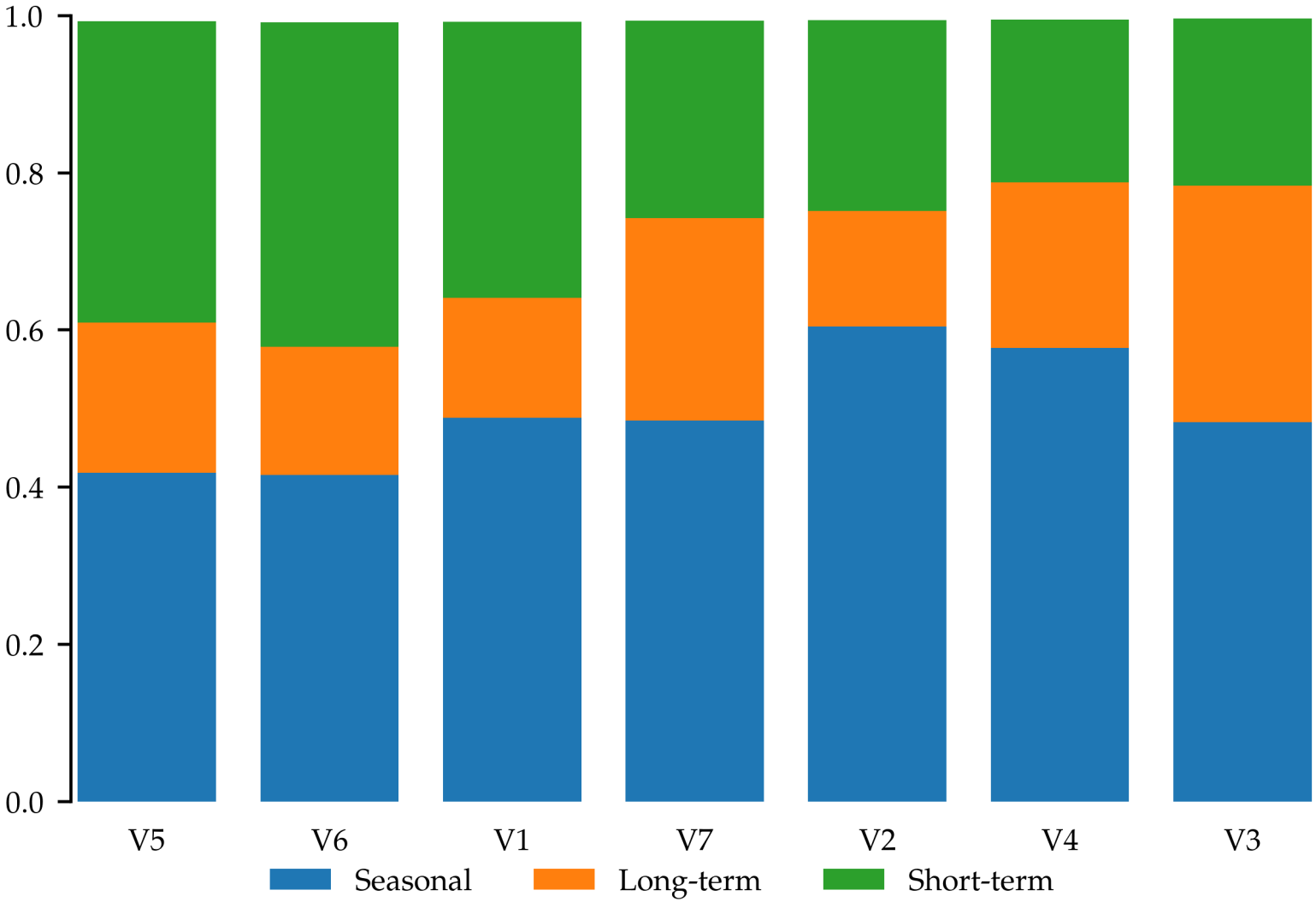
Continuous irradiance measurements

Chl proxy of biomass

MLD proxy of turbulent mixing

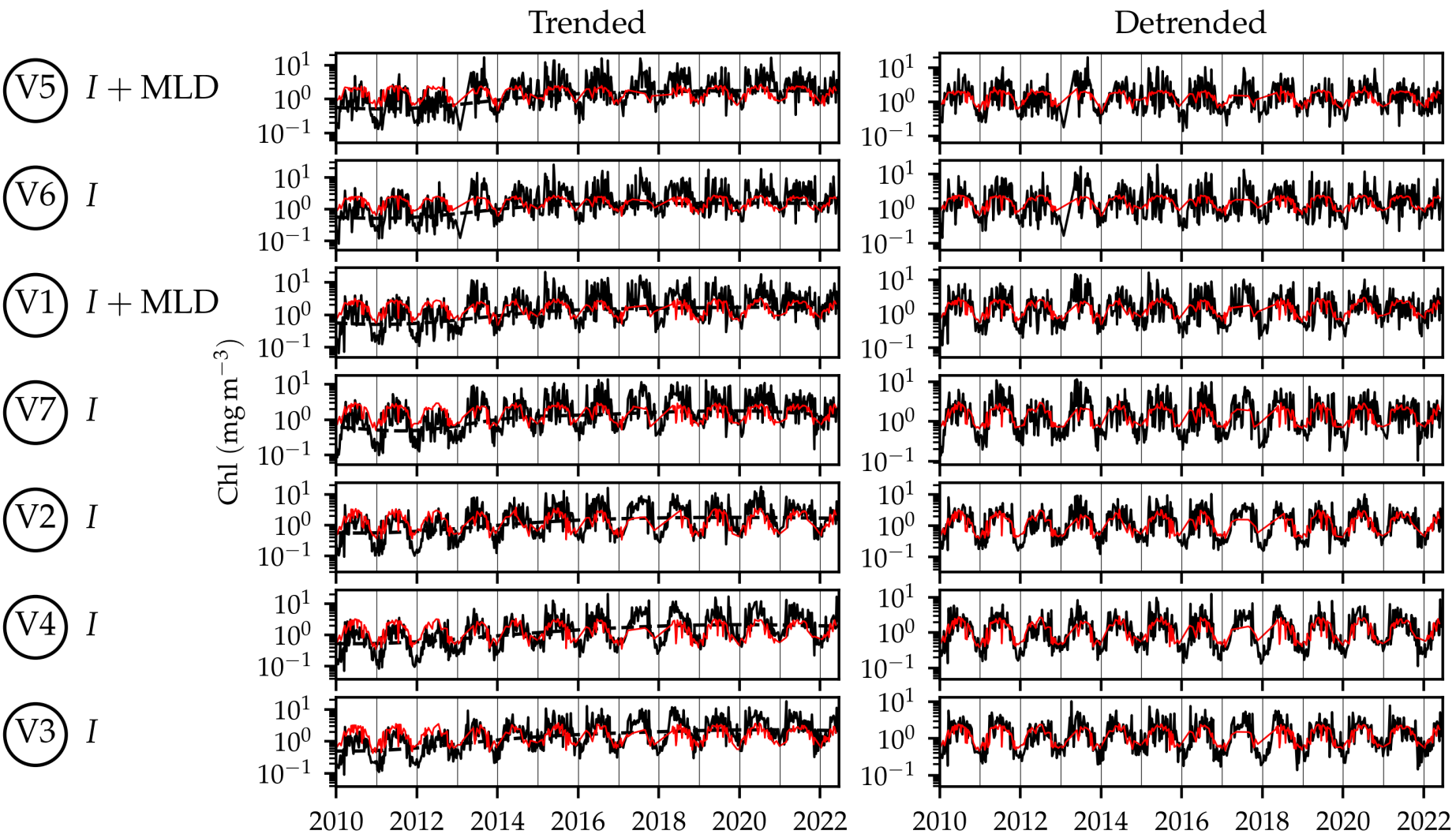
❸ Chl decomposition

$$\log \mathrm{Chl}_i = a + S(\mathrm{doy}_i) + T(t_i) + \epsilon_i$$

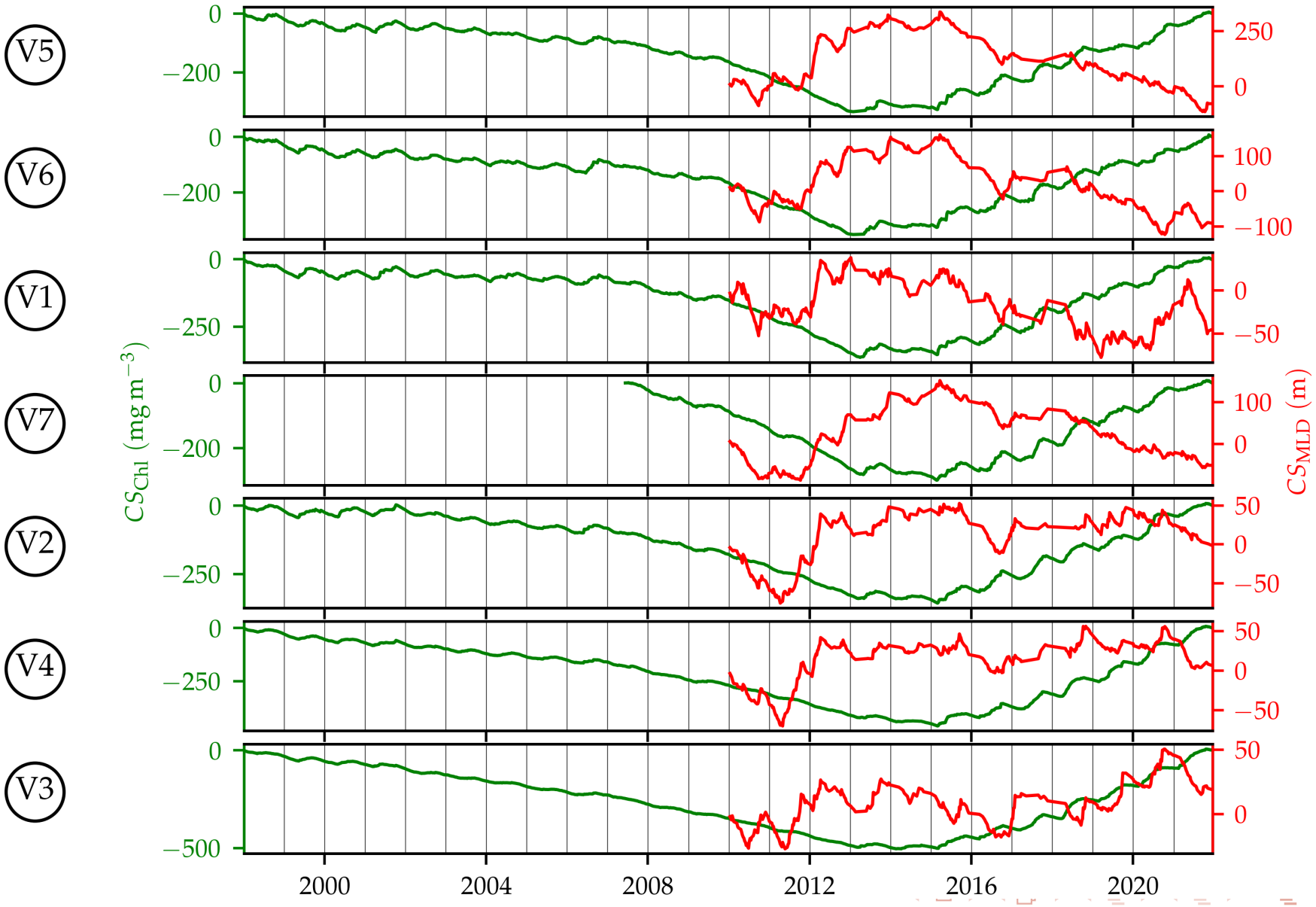


❸ Seasonal Chl vs. I, MLD

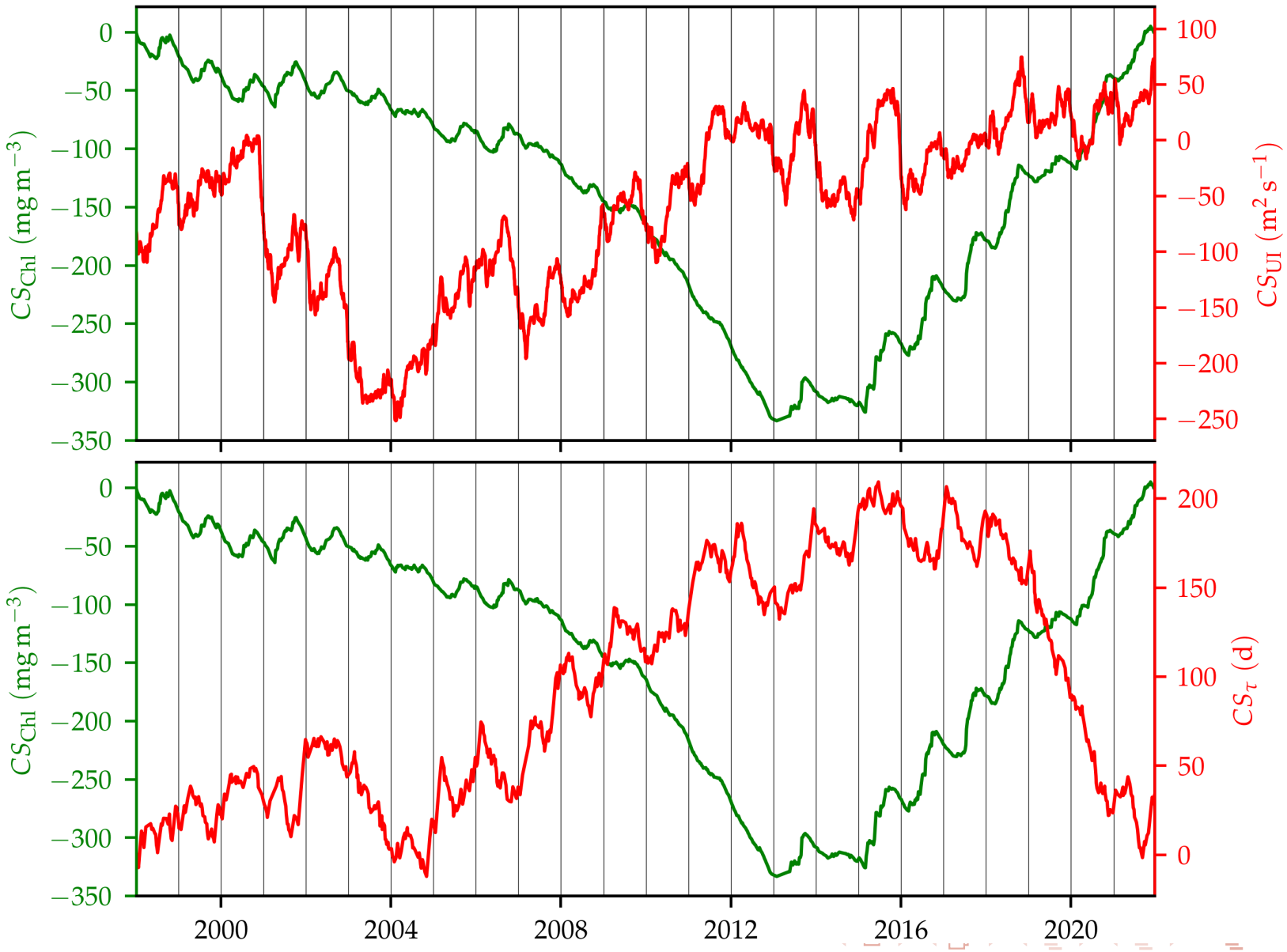
$$\log \mathrm{Chl}_i = a + f(I_{0_i}) + g(\mathrm{MLD}_i) + \epsilon_i$$



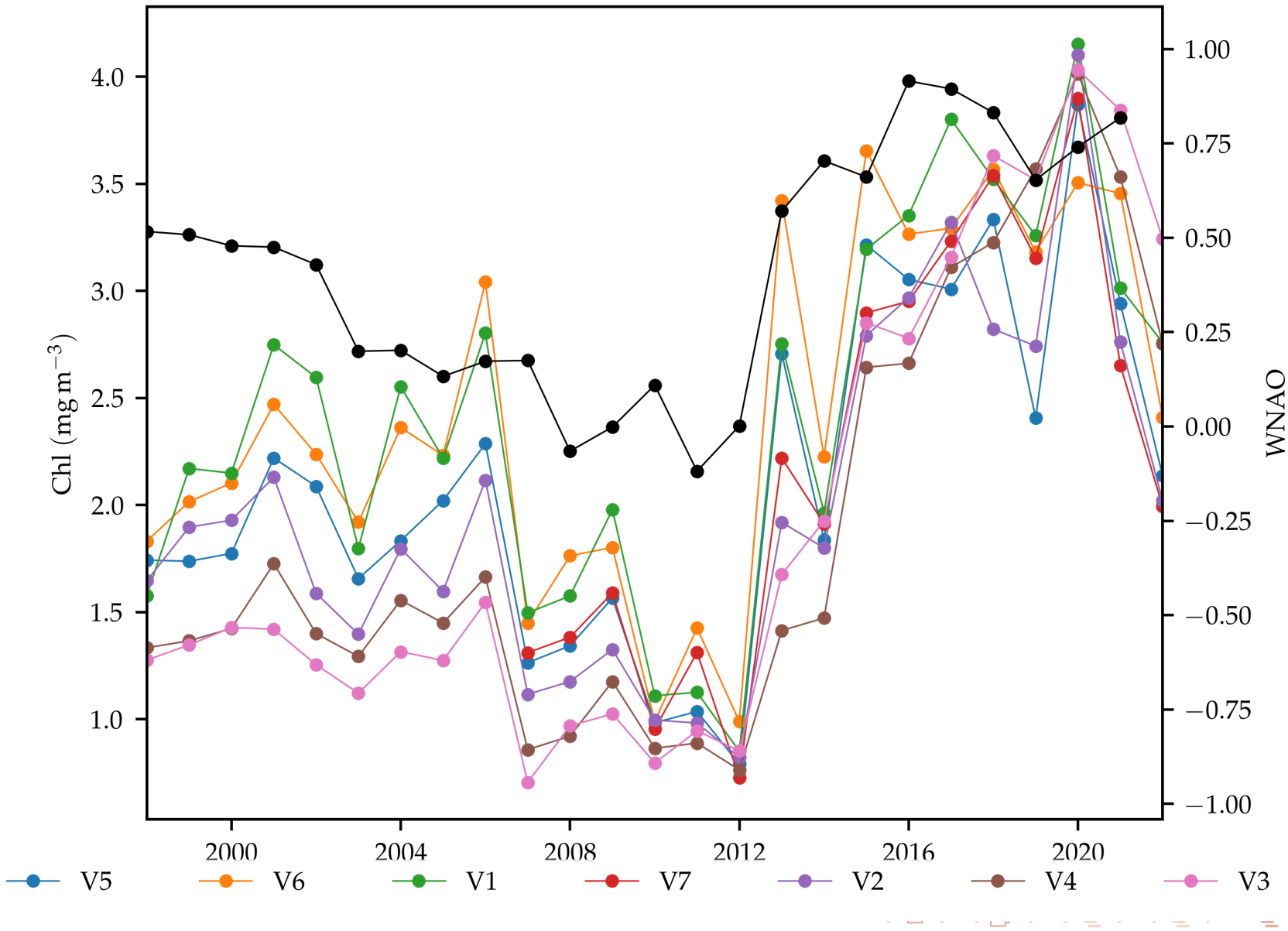
❸ Long-term Chl vs. MLD



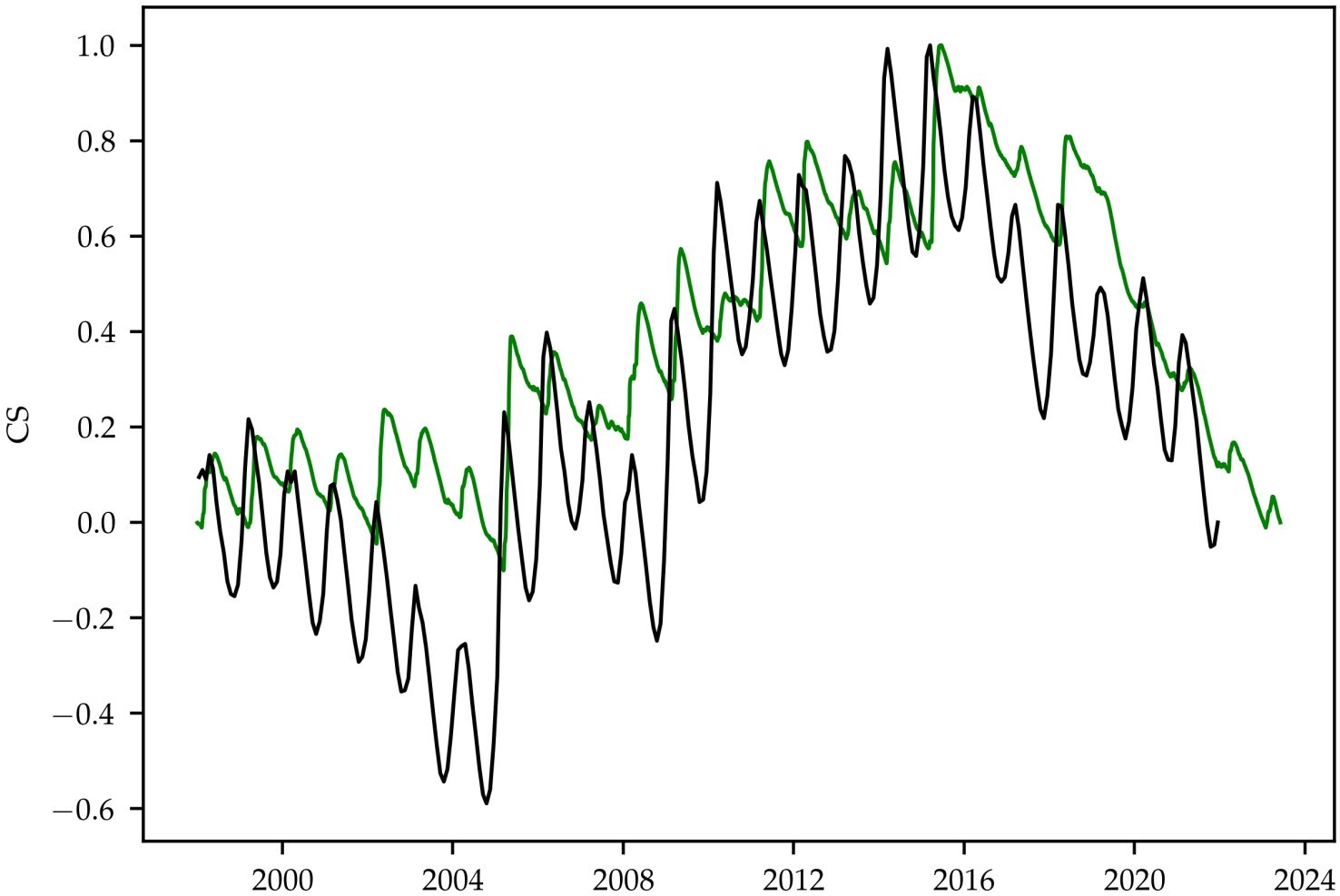
❸ Long-term Chl vs. upwelling



❸ Long-term Chl vs. NAO



❸ Long-term Chl vs. MLD shelf



❸ Conclusions

Objectives

To determine the variation modes of Chl

To explore the relationship between variation modes of Chl and mixing

Conclusions

Seasonality most important component of variability (~50 %), followed by shorter-term (~30 %) and long-term trend (~20 %).

No relationship at seasonal and long-term scales

Main conclusions

Short-term scale

Mixing could be involved in formation of short-lived phytoplankton blooms

Seasonal scale

No relationship could be established

Long-term scale

Whereas a positive relationship exists at the shelf, no relationship could established in the Ría

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