

Why should plankton ecologists care about microturbulence?

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José Luis Otero (FPI PhD fellowship)

Control of the structure of marine phytoplankton communities by turbulence and nutrient supply dynamics (CHAOS) (IP: B. Mouriño)

Why should we care about turbulence?

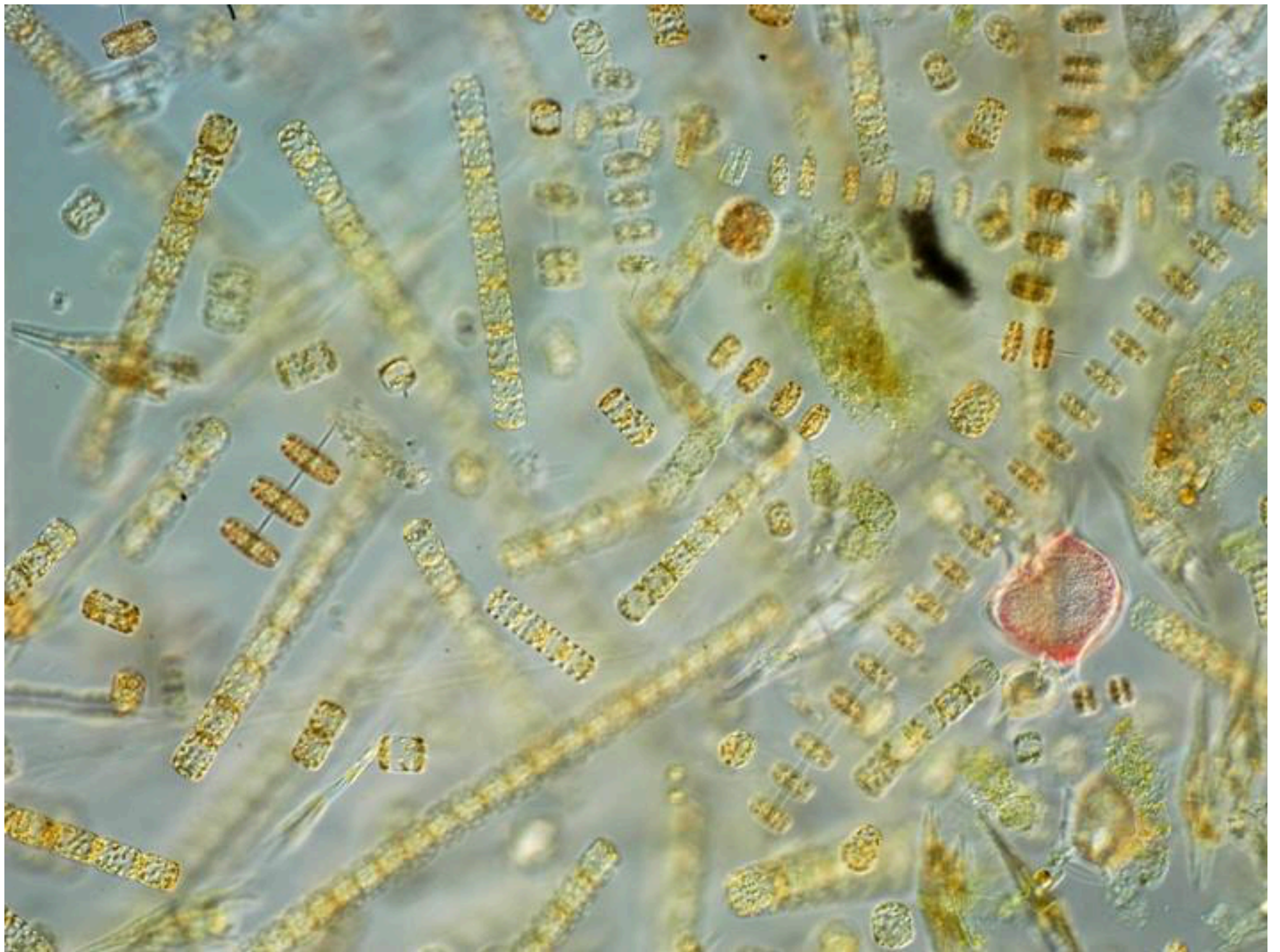
The kaleidoscope ocean



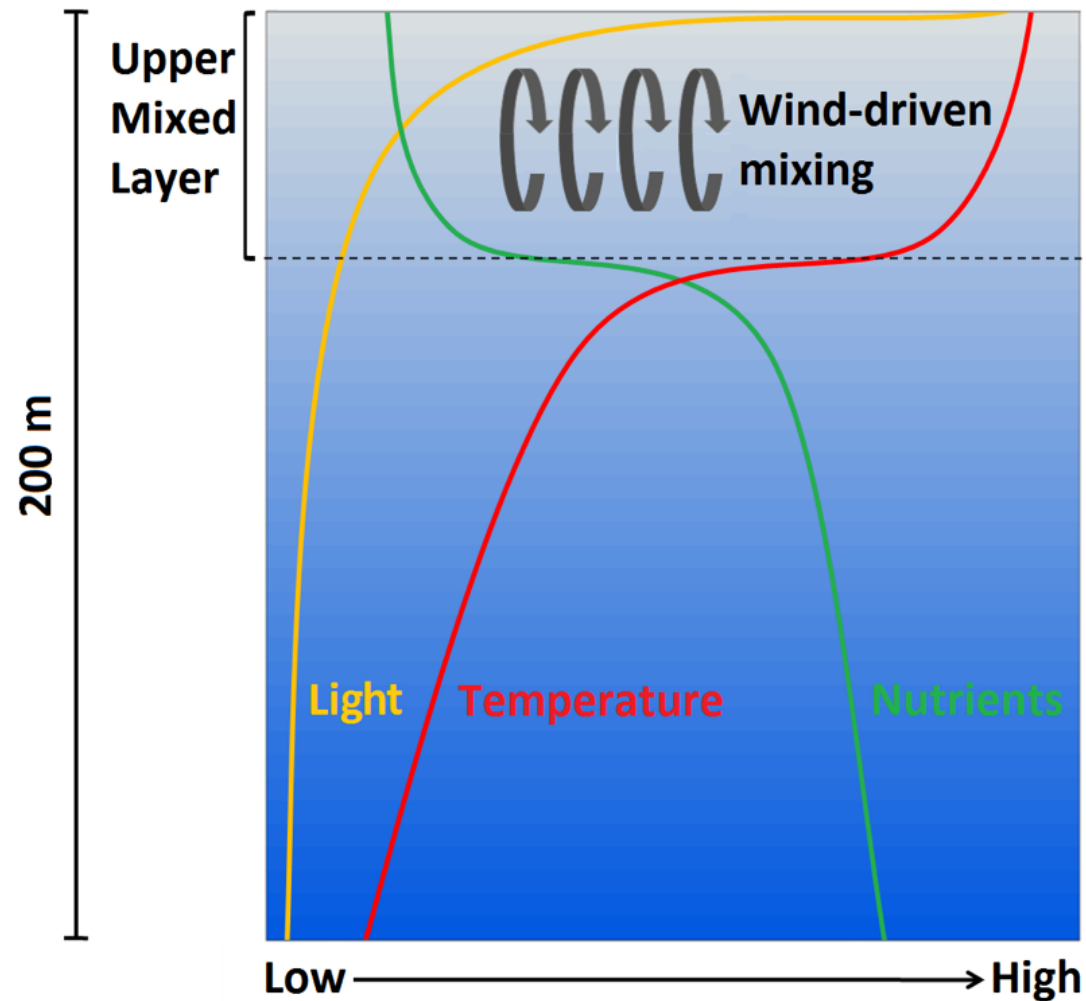
Martin (2005, PTRS)

Sketch of turbulent flow by Leonardo da Vinci

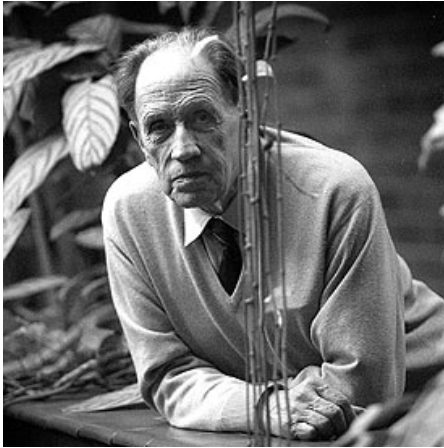




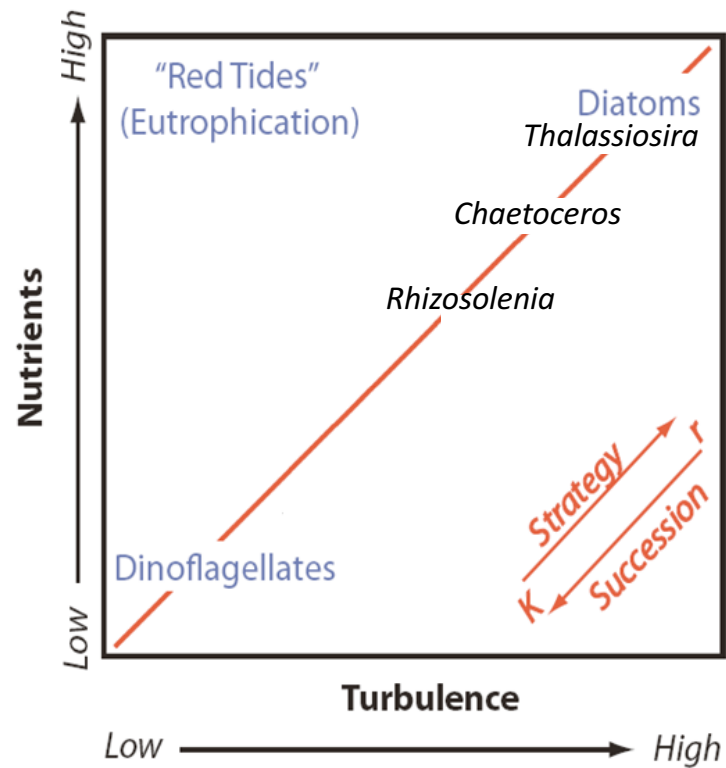
Vertical distribution of temperature, light and nutrients

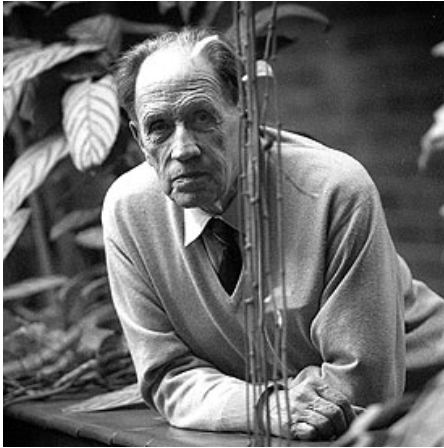


Turbulence controls light and nutrient availability for plankton cells

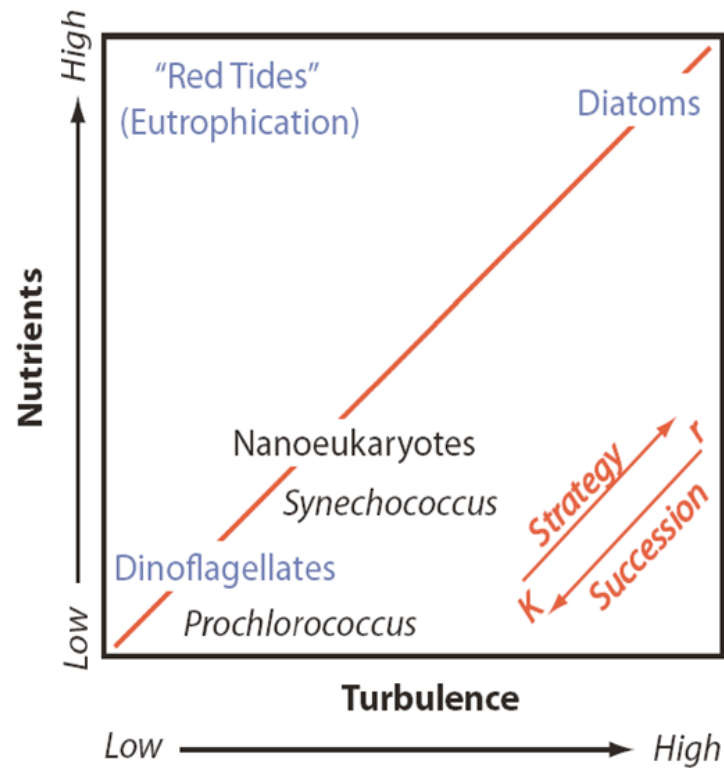


The mandala of Margalef (1978)



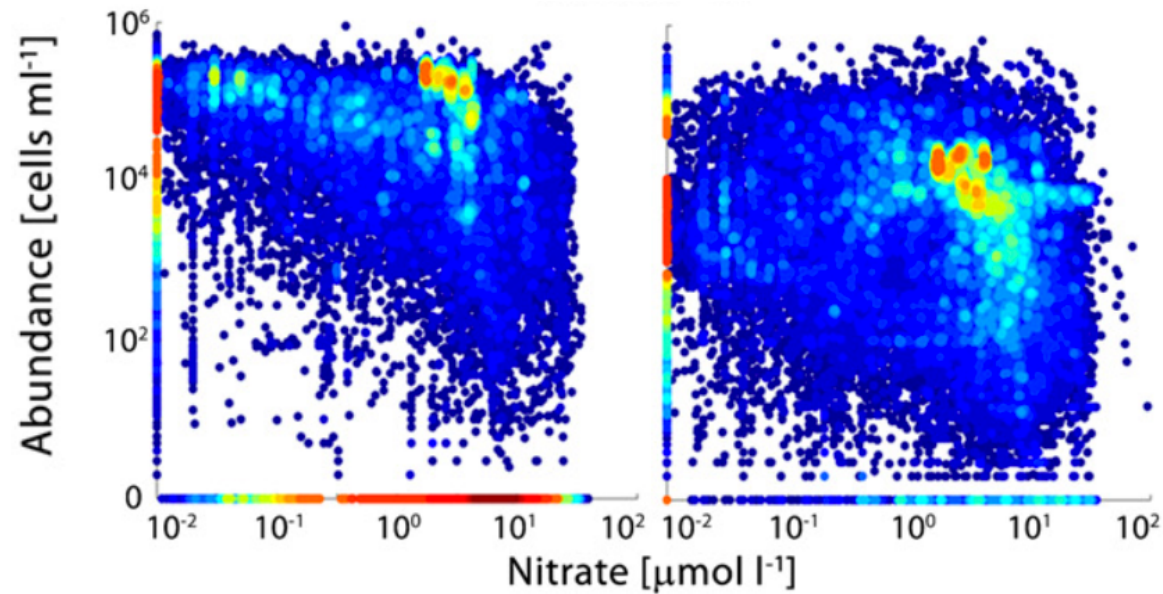


The mandala of Margalef (1978)



The smaller-size picophytoplankton ($\sim < 2 \mu\text{m}$) groups were not included in the original diagram

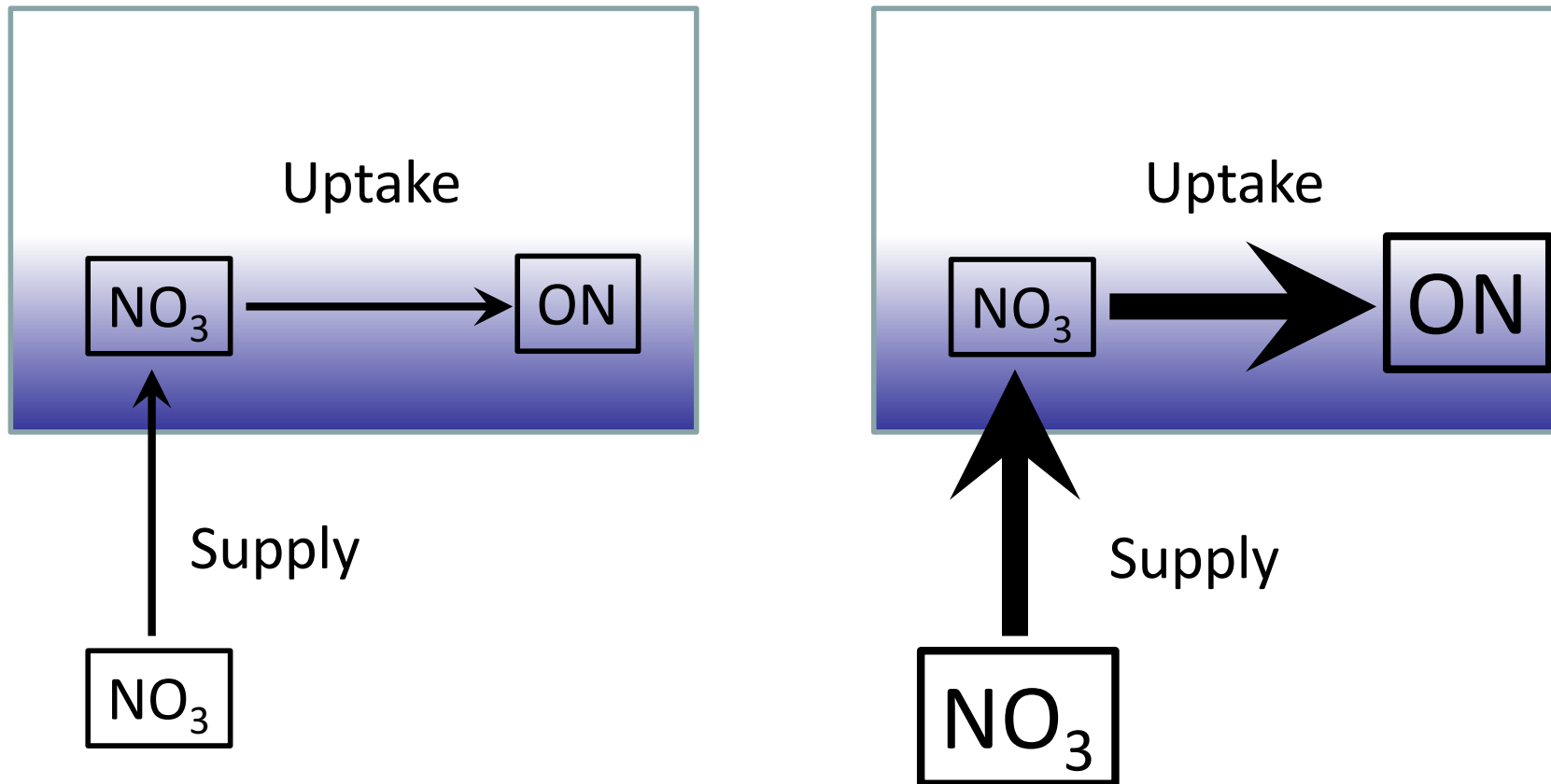
Control factors on *Prochlorococcus* and *Synechococcus* regional distributions



Flombaum et al. (2013, PNAS)

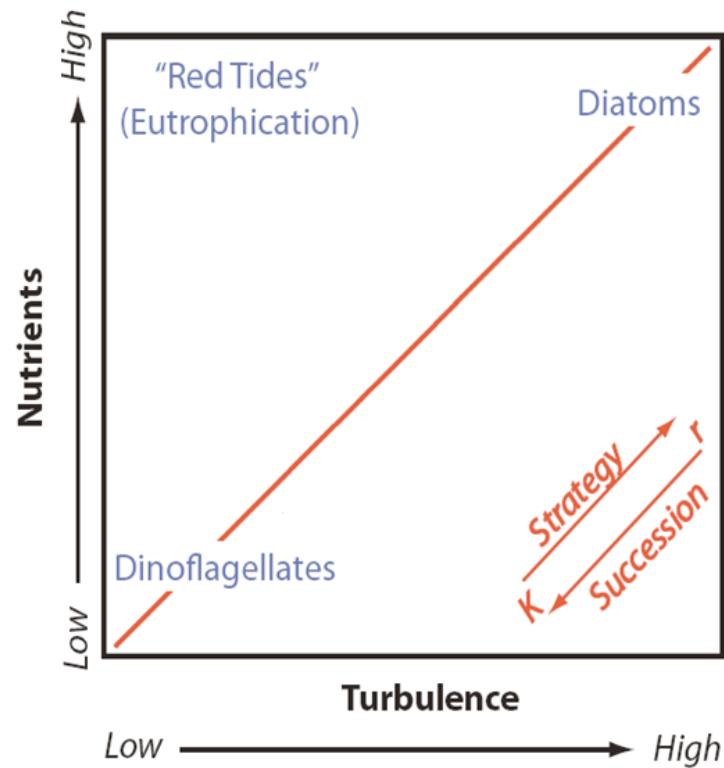
No relationship between nutrient concentration and cell abundance

Nitrate concentration versus nitrate supply in steady-state



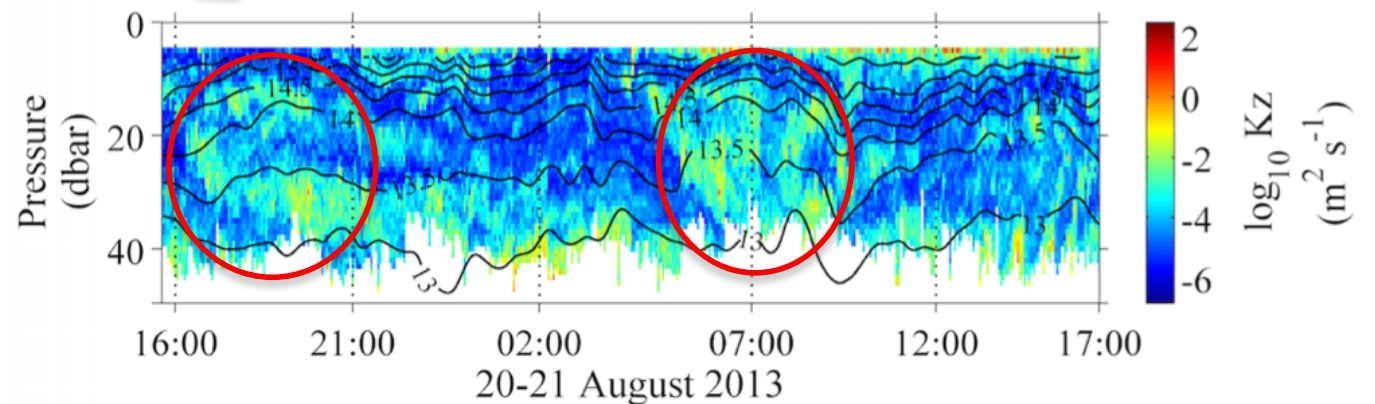
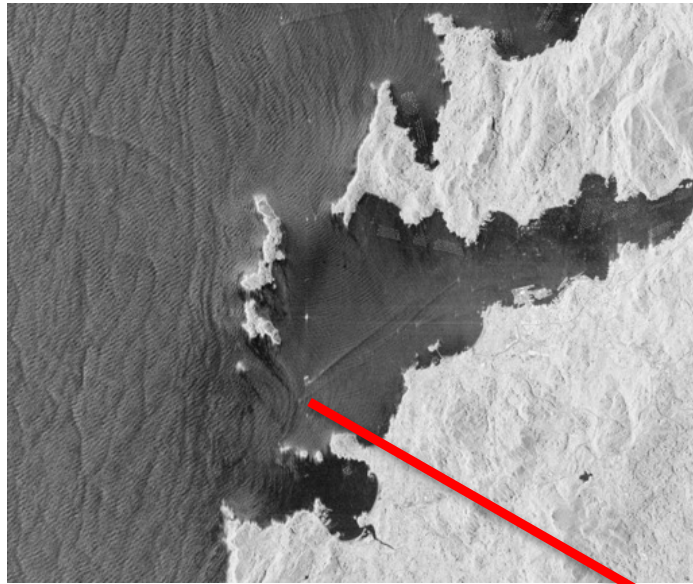
Variability in nutrient concentration can be disconnected from changes in nutrient supply

The mandala of Margalef (1978)



Methodological difficulties to quantify mixing (K_z) in the field

Internal wave mixing on the shelf off Ría de Vigo (NW Spain)



Villamaña-Rodríguez et al (2017,L&O)

Mixing and stratification: related but not the same

Microstructure turbulence profiler by Miquel Alcaraz (CSIC-Barcelona)

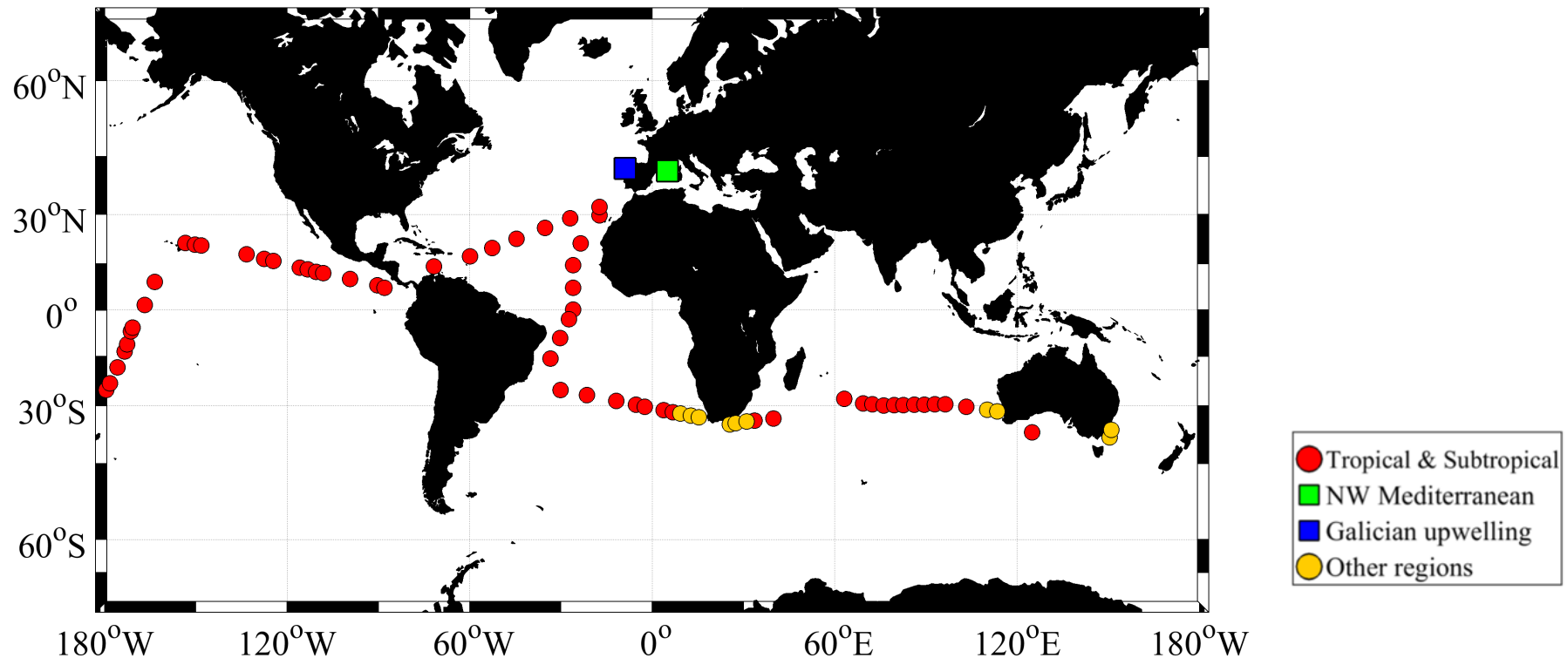


Our goal

To validate the Margalef's mandala in the field for
the whole phytoplankton community

How...?

Data set of microturbulence, pico- & microphytoplankton (2006-2015)



102 stations (12 cruises)

- Microturbulence (MST profiler, 30-300 m)
- Nitrate concentration (30-300 m)
- **Flow cytometry** (photic layer): picoplankton abundance and cell properties
- **HPLC pigments** (photic layer): Letelier et al. (1993))

Biomass (C)

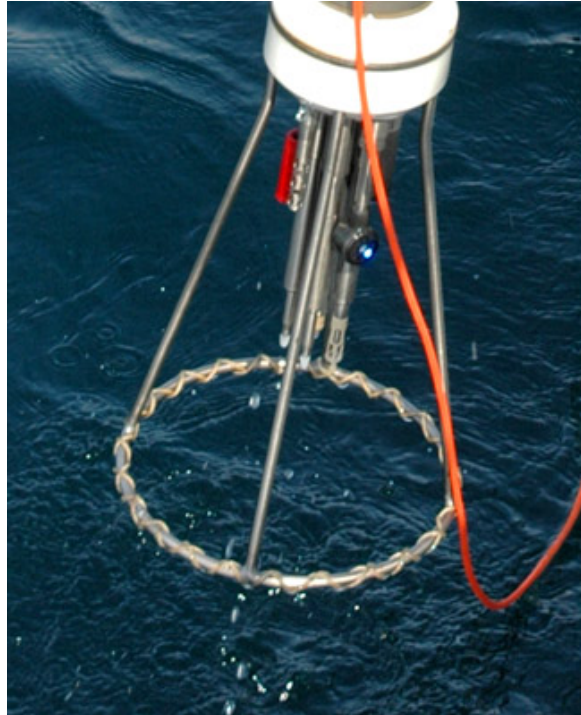
Prochlorococcus
Synechococcus
Small picoEuk

Biomass (% chl-a)

Diatoms
Dinoflagellates
Pico- & nanoeuk
Cyanobacteria

How did we quantify nitrate supply and light availability?

MSS (Micro-Structure-Turbulence) profiler



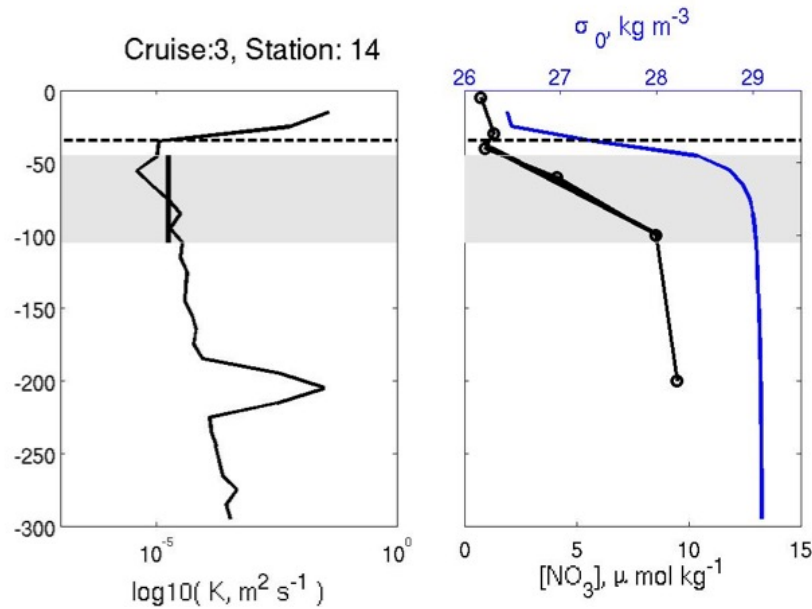
Vertical diffusivity (K_z):

$$K_z = 0.2 \frac{\varepsilon}{N^2} \quad \text{Osborn (1980)}$$

ε Dissipation rate of turbulent kinetic energy

N Brünt Väissälä frequency

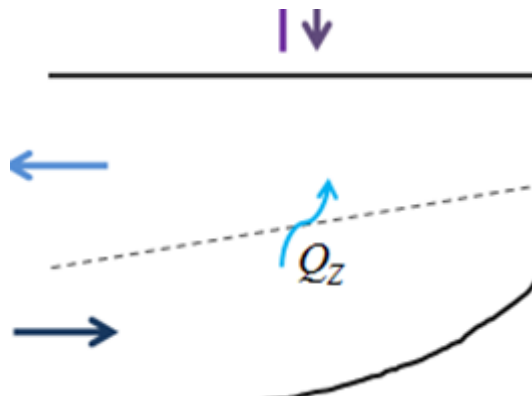
1. Calculation of nitrate supply



Diffusion across the nutricline

$$NO_3 Flux = -K_z \cdot \left(\frac{d[NO_3^-]}{dz} \right)$$

Vertical advection



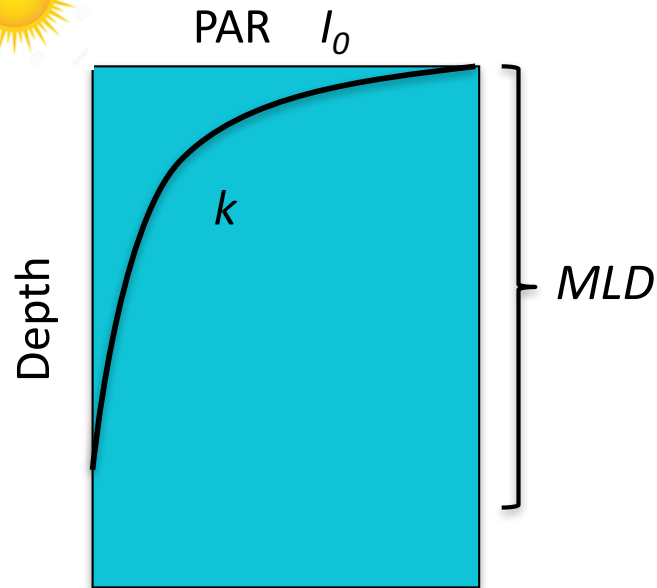
$$Q_z = \frac{I_w \times D}{A_{basin}} [NO_3^-]_{bottom}$$

I_w = Upwelling index

D = Coast length

A_{basin} = Surface area

2. Calculation of light availability (LA)



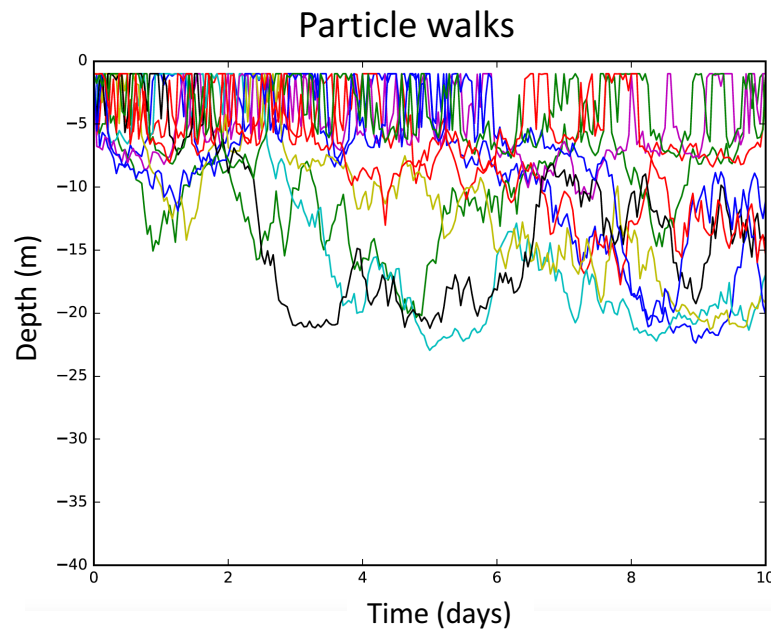
$$LA = \frac{I_0}{k \cdot MLD} (1 - e^{-k \cdot MLD})$$

I_0 = Surface PAR

k = Light extinction coefficient

MLD = ACTIVE MIXING layer depth

Random-walk simulations

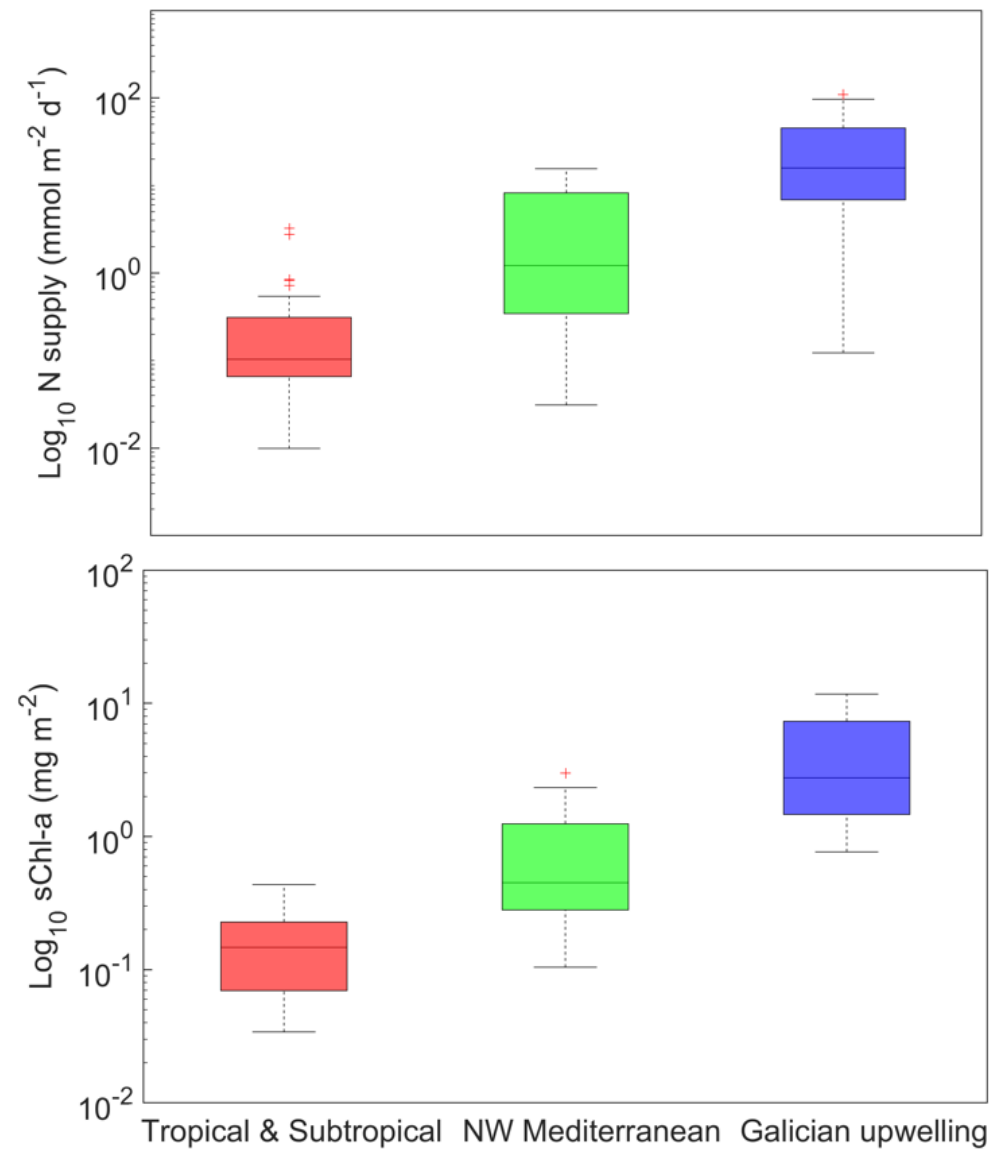


100 particles 24 h diffusing in the background
K profile

MLD = Depth above 99% particles were found

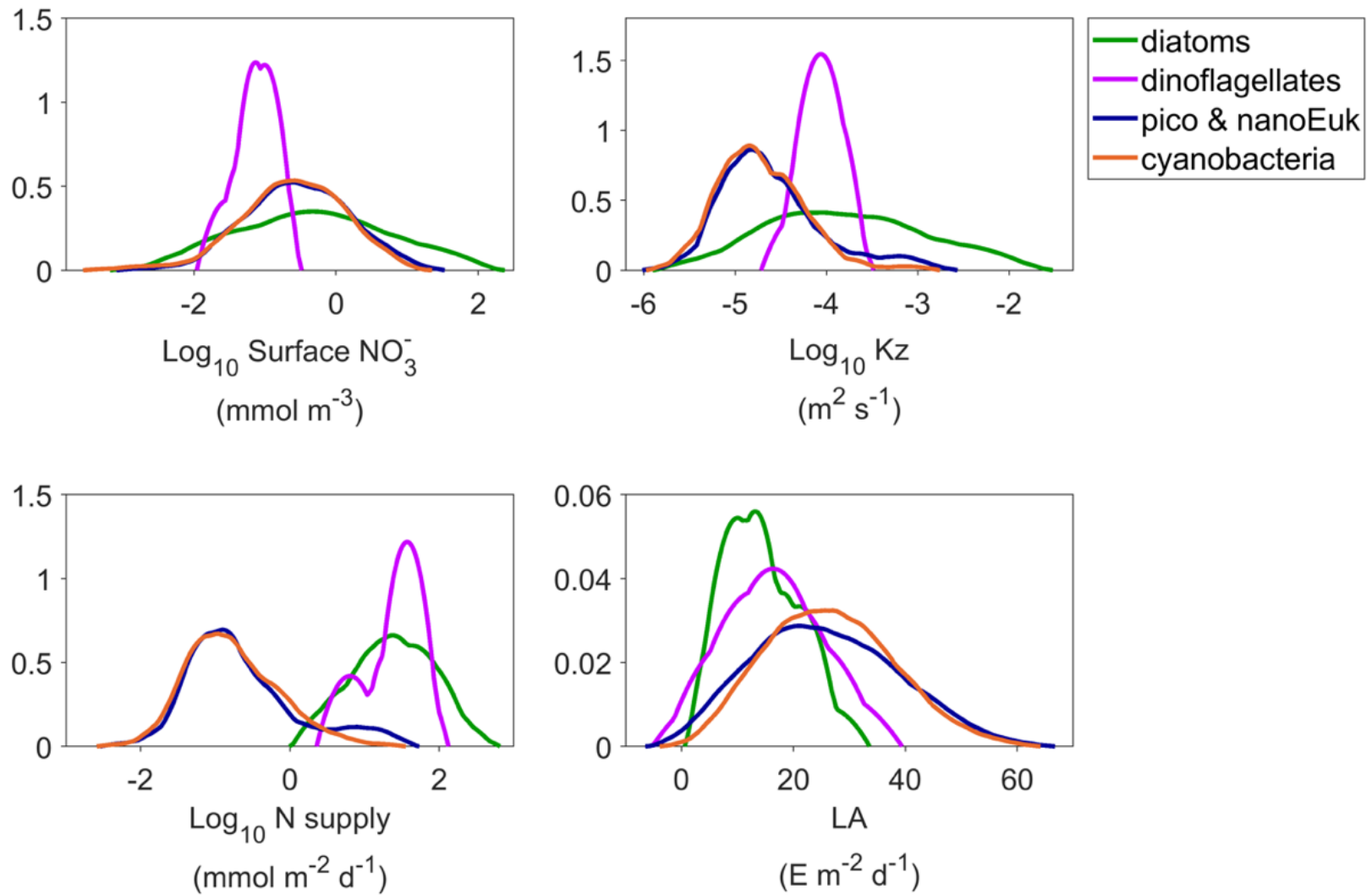
What did we find...?

Variability in N supply and surface chlorophyll-a



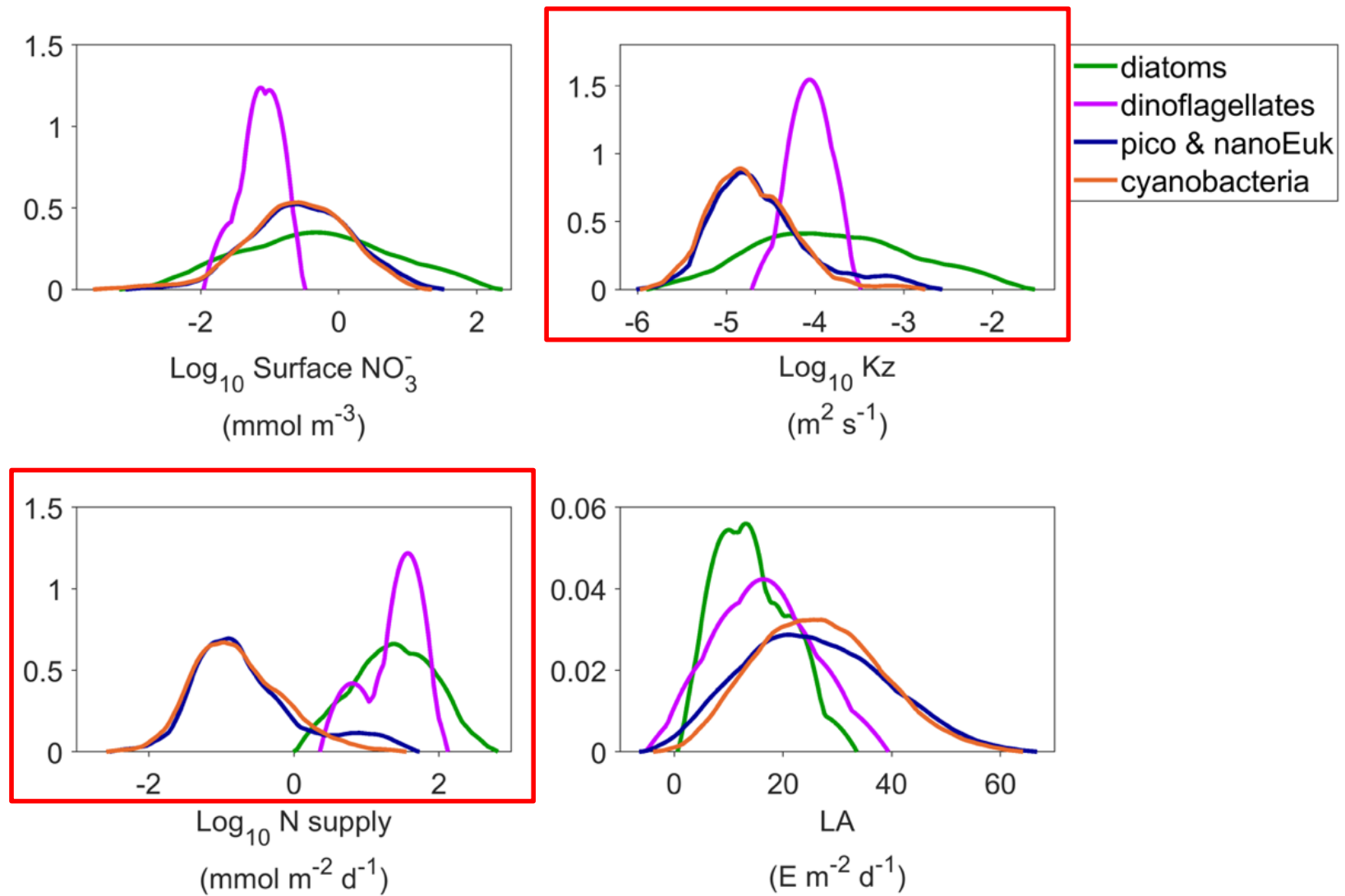
(Villamaña et al., under rev in Progr. Oceanogr.)

Kernel density functions for chl-a (HPLC) of four phytoplankton groups



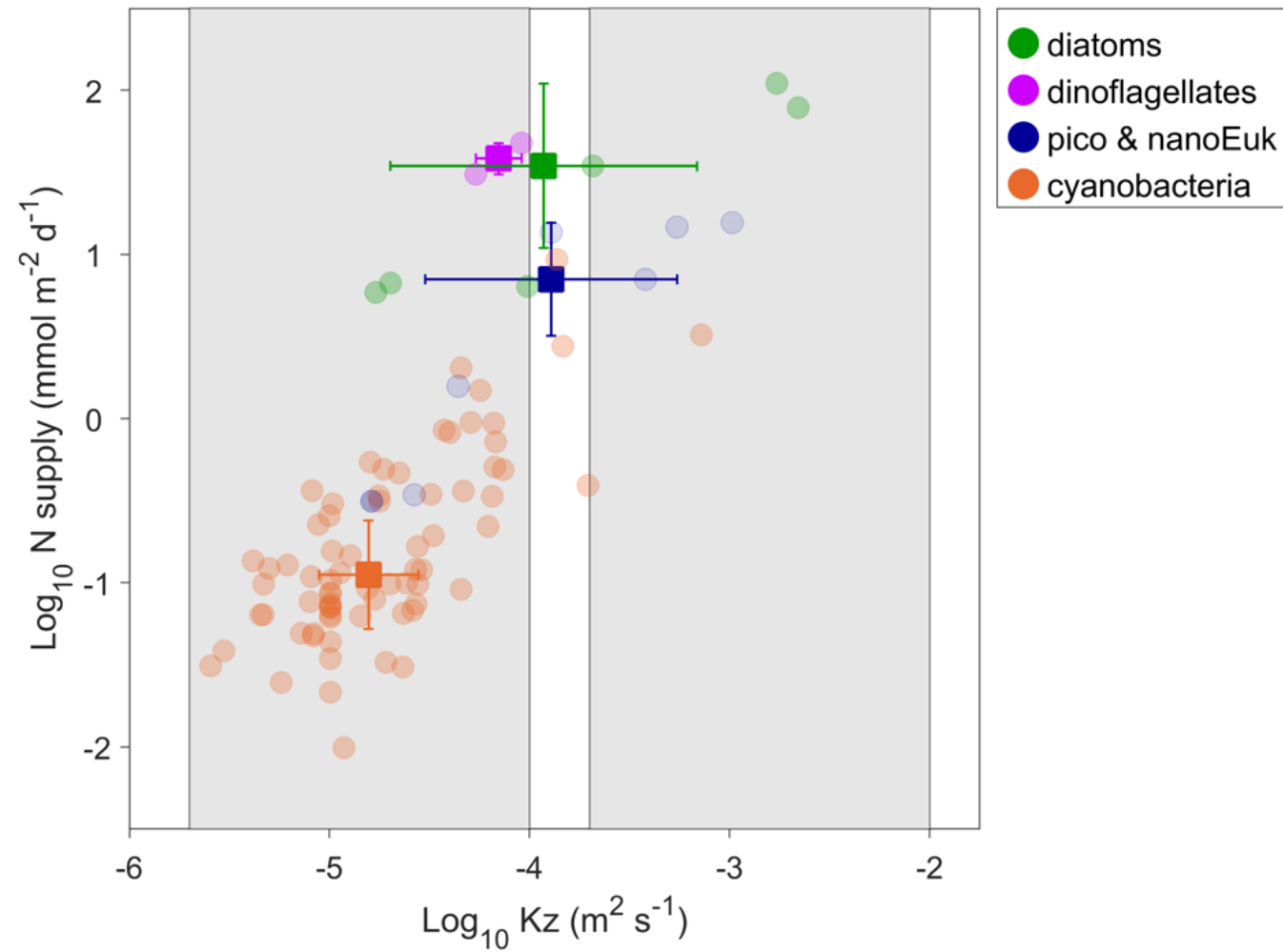
(Villamaña et al., under rev in Progr. Oceanogr.)

Kernel density functions for HPLC chl-a of four phytoplankton groups



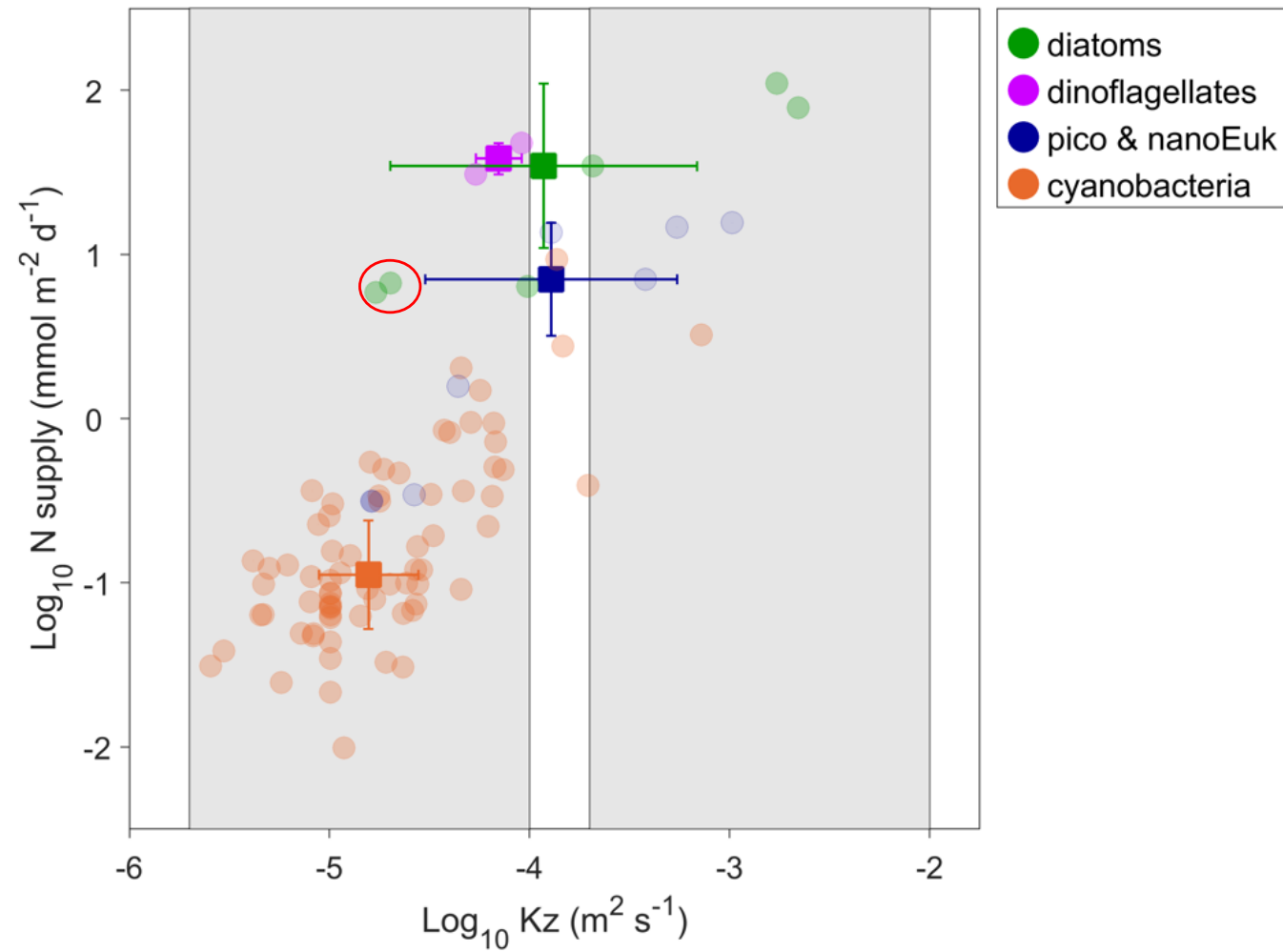
(Villamaña et al., under rev in Progr. Oceanogr.)

Dominance of phytoplankton groups vs mixing and N supply



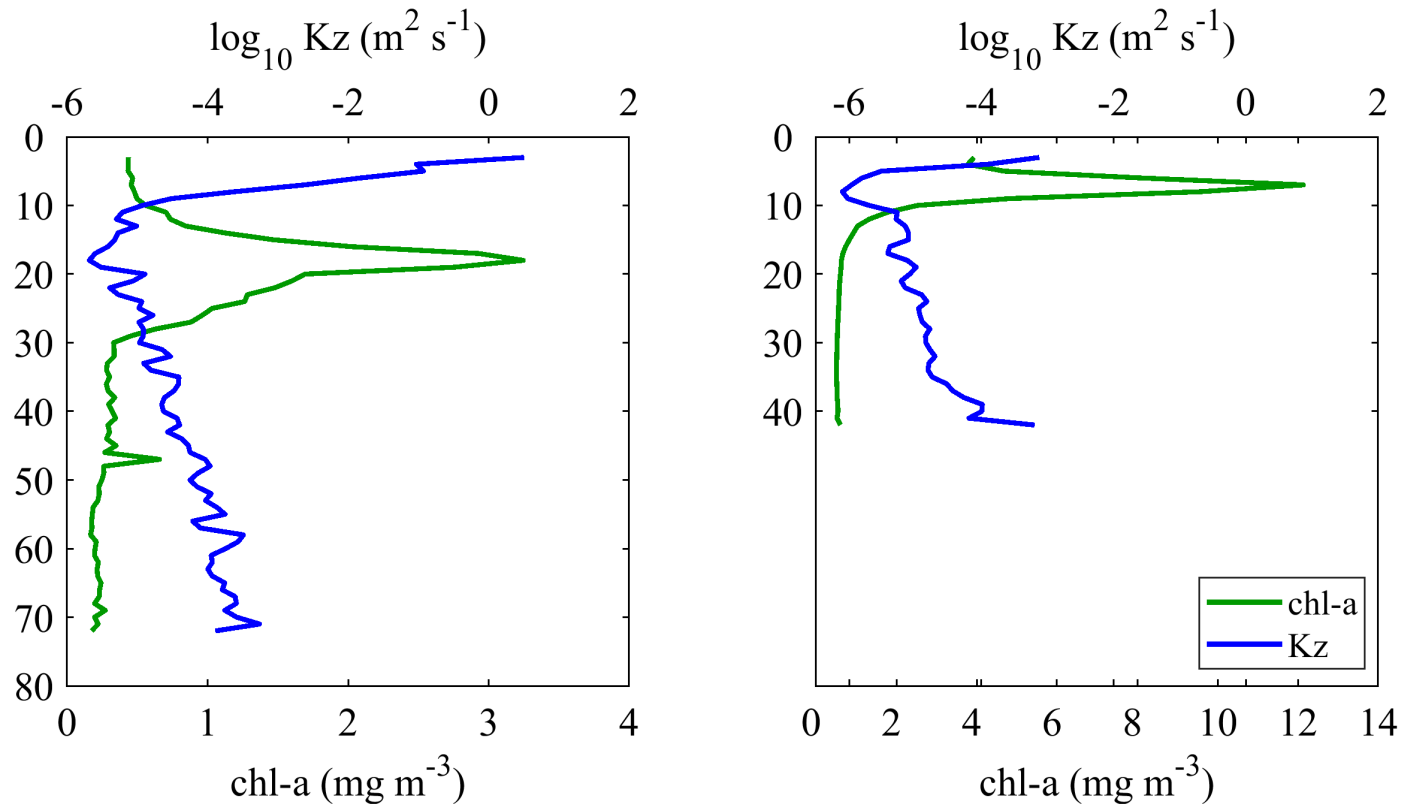
(Villamaña et al., under rev in Progr. Oceanogr.)

Dominance of phytoplankton groups vs mixing and N supply



(Villamaña et al., under rev in Progr. Oceanogr.)

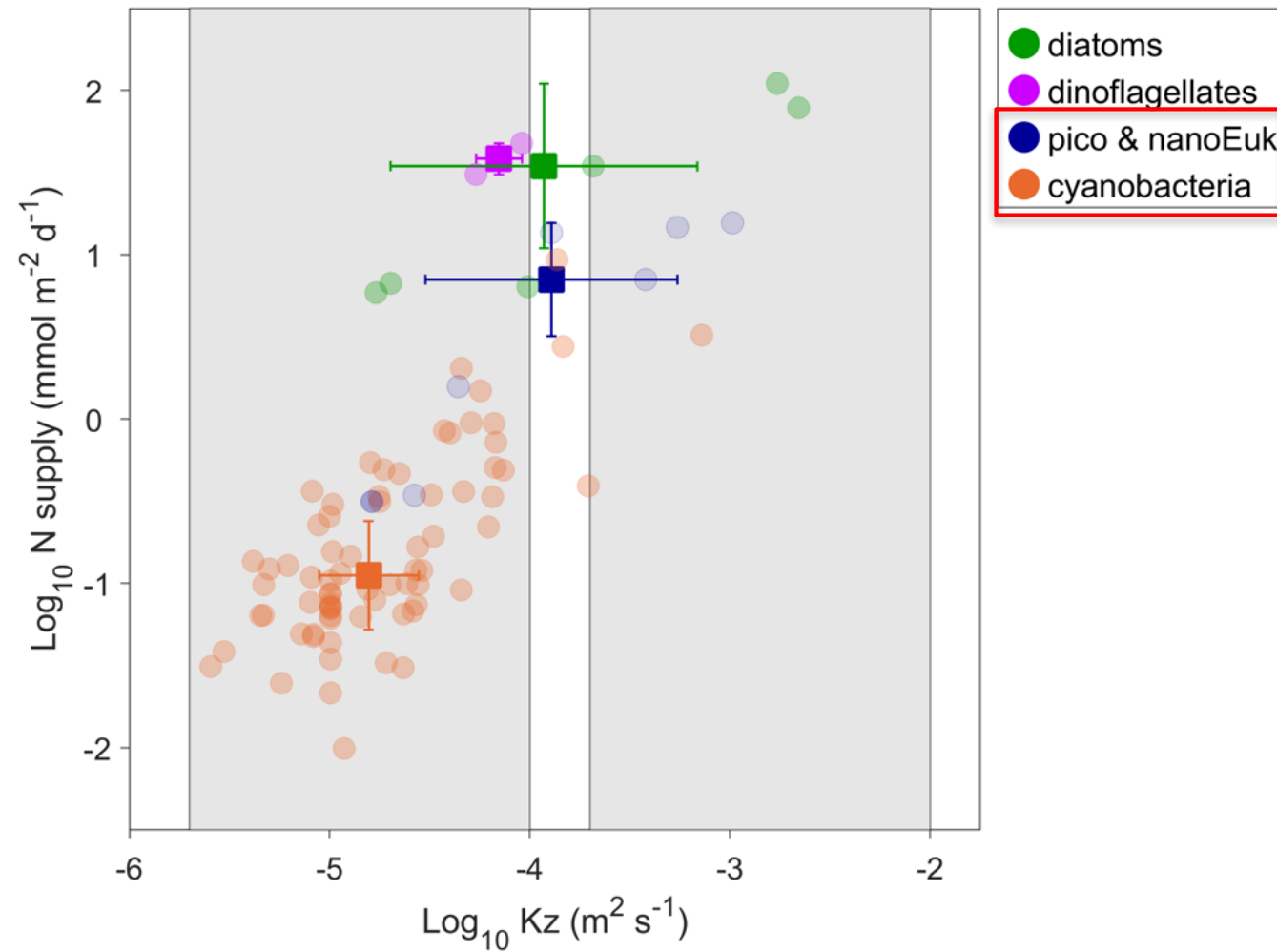
Thin layers of phytoplankton observed in the Galician Rias



(Villamaña et al., under rev in Progr. Oceanogr.)

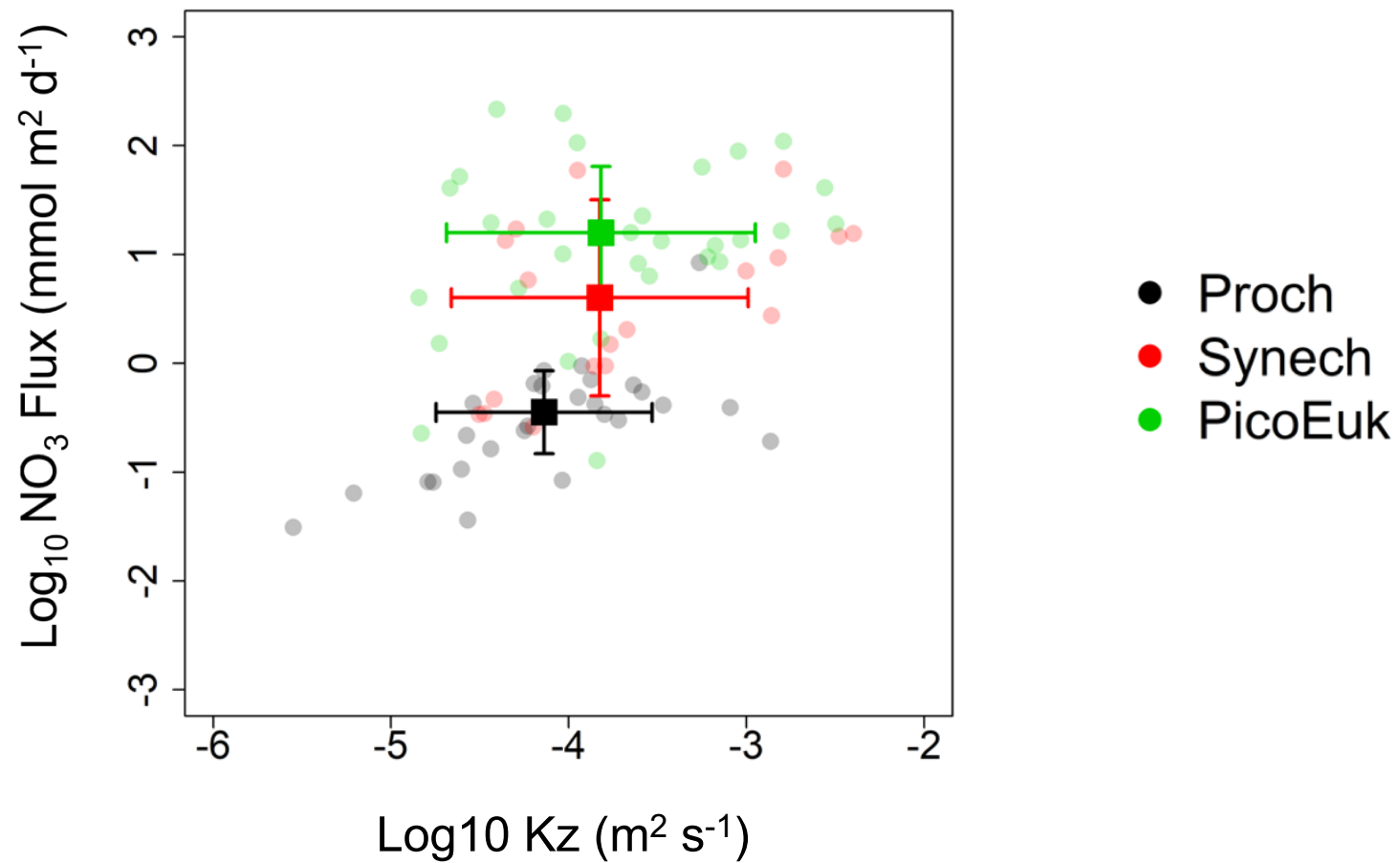
Diatoms also dominated in low mixing conditions

Dominance of phytoplankton groups vs mixing and N supply



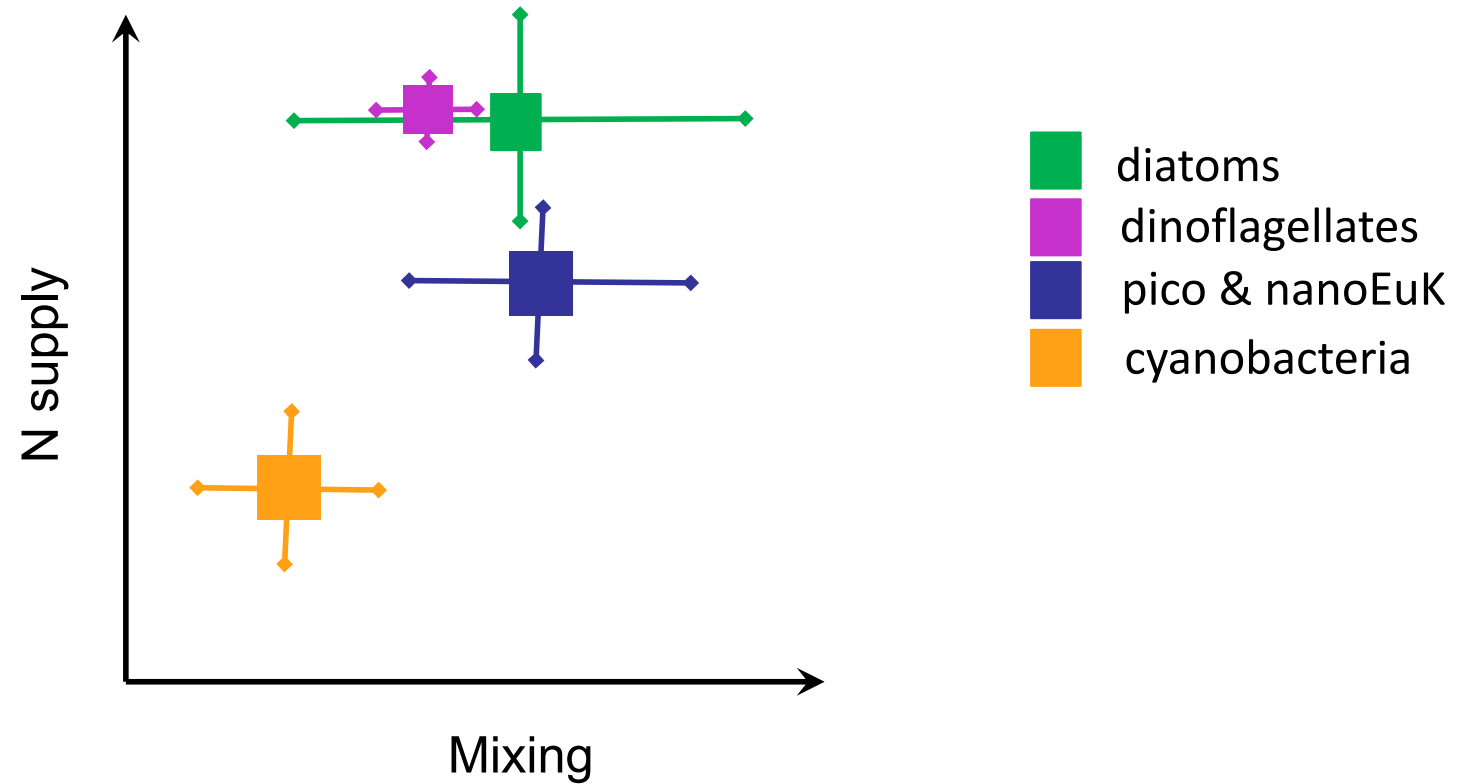
(Villamaña et al., under rev in Progr. Oceanogr.)

Dominance of picoplankton groups vs mixing and NO_3 Flux



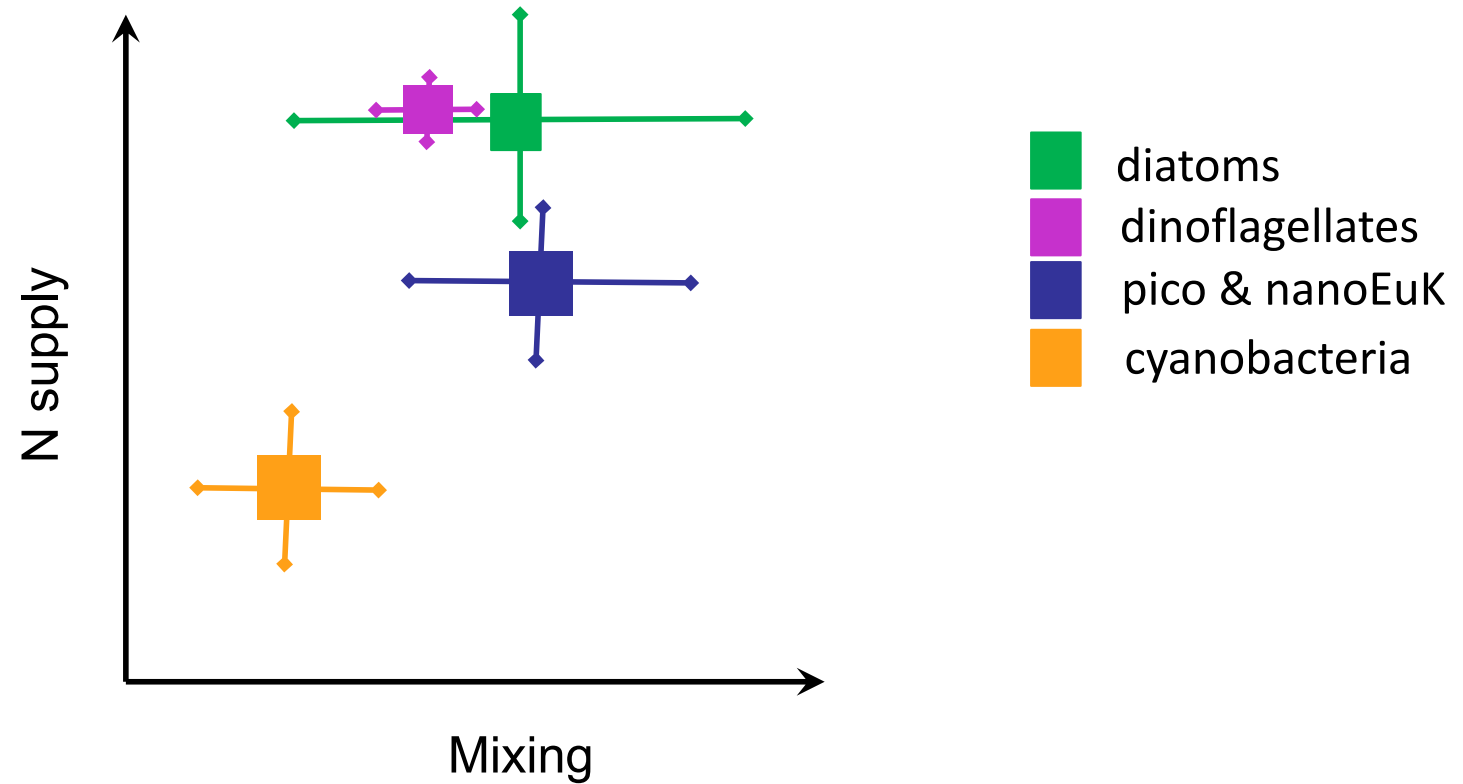
(Otero-Ferrer et al., in prep.)

Conclusions



1. Margalef's mandala is validated for the whole phytoplankton community

Conclusions



2. Nutrient supply should be used as an indicator of nutrient availability

Thanks to...

- REN2003-09532-C03-01 to Ramiro Varela Benvenuto (Spanish government)
- CTM2004-05174-C02 to Emilio Marañón (Spanish government)
- CSD2008-00077 to Carlos Duarte (Spanish government)
- CTM2008-0626I-C03-01 to Mikel Latasa (Spanish government)
- FP7 SPACE.2010.1.1- 01 261860 to Manuel Ruiz Villareal (European Commission)
- CTM2011- 25035 to Pedro Cermeño (Spanish government)
- Grant CTM2012-30680 to B. Mouriño-Carballido (Spanish government)
- EM2013/021 to Beatriz Mouriño (Galician government)
- CTM2016-75451-779 C2-1-R to B. Mouriño-Carballido (Spanish government)
- 09MMA027604PR to Manuel Ruiz Villareal (Galician government)
- RADIALES project coordinated by Antonio Bode (IEO)