The time-scale of mixing in the surface mixed-layer from random-walk simulations

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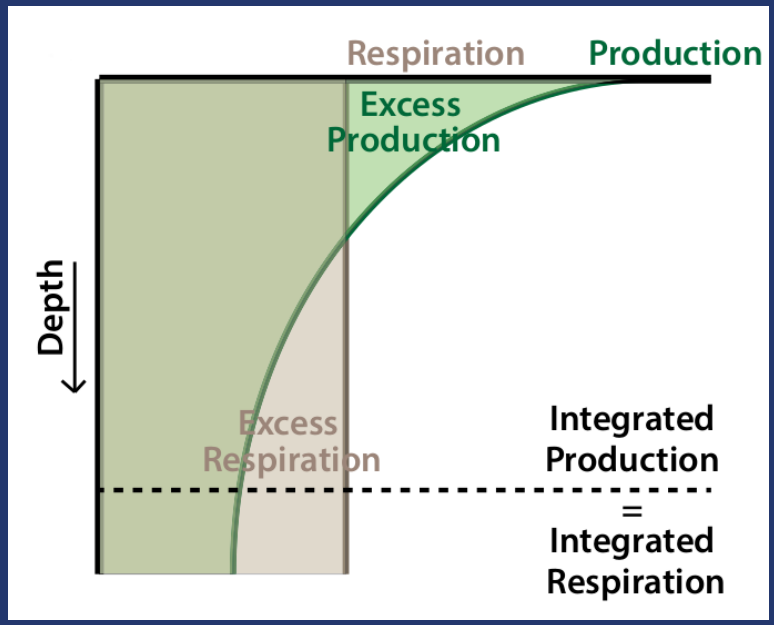
Does the *critical mixing hypothesis* (CMH) explain seasonal phytoplankton growth in the Ría de Vigo?

What is the *Critical mixing hypothesis* (CMH)?

Light controls phytoplankton growth



$$\frac{\partial P}{\partial t} = (\alpha I(z) - m_P)P$$

$$I(z) = I_0 \exp^{-kz}$$

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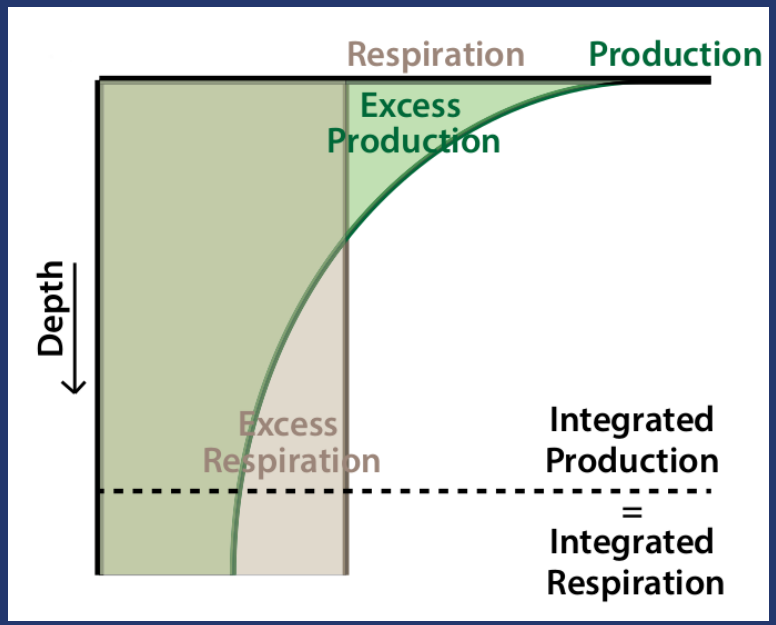

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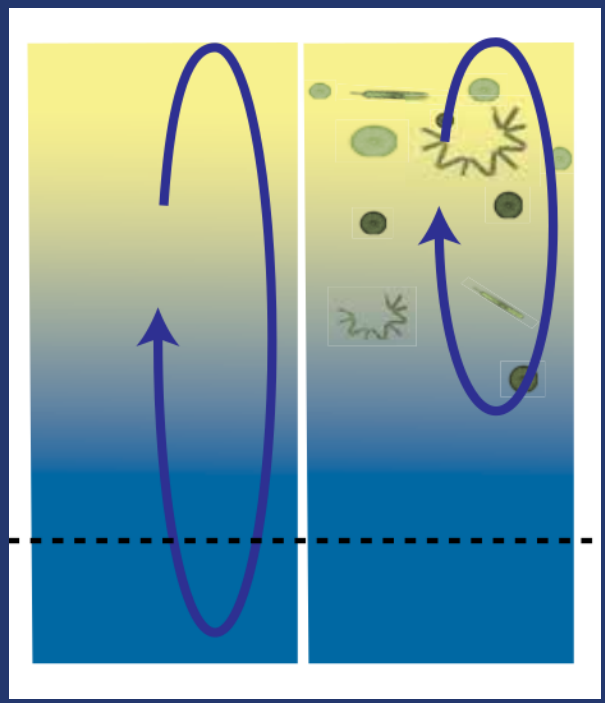
Critical depth hypothesis

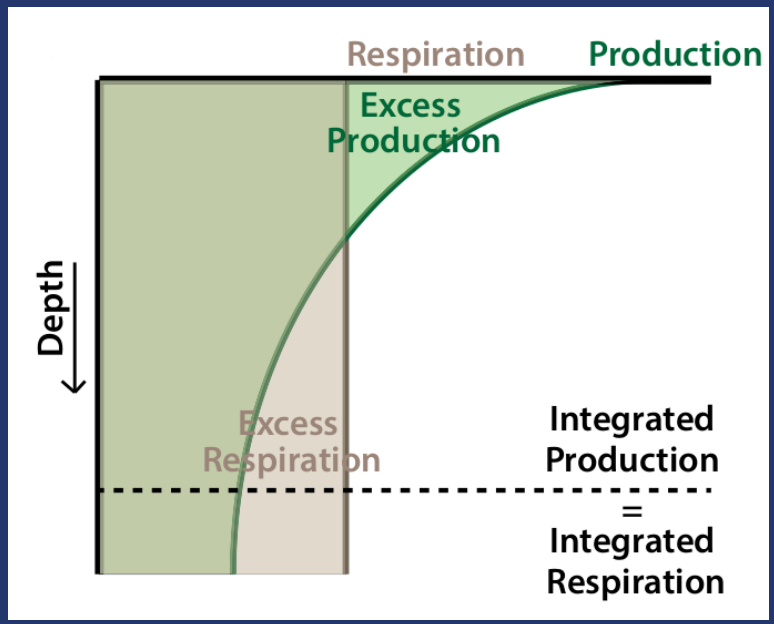
(Sverdrup 1953)



Mixed layer depth controls light availability and phytoplankton growth

What is the *Critical mixing hypothesis* (CMH)?

Light controls phytoplankton growth



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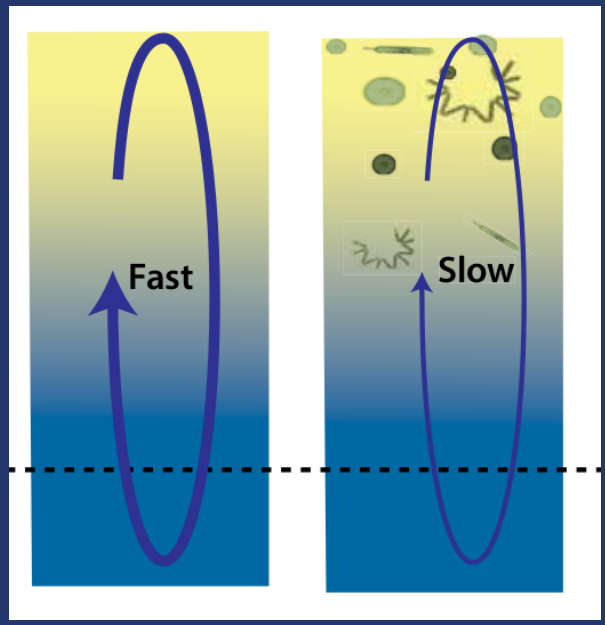
Critical mixing hypothesis

(Huisman 1999)



The rate of turbulent diapycnal mixing (K_ρ) controls light availability and phytoplankton production

Due to methodological limitations to quantify K_ρ, the CMH has not been ever verified in the field

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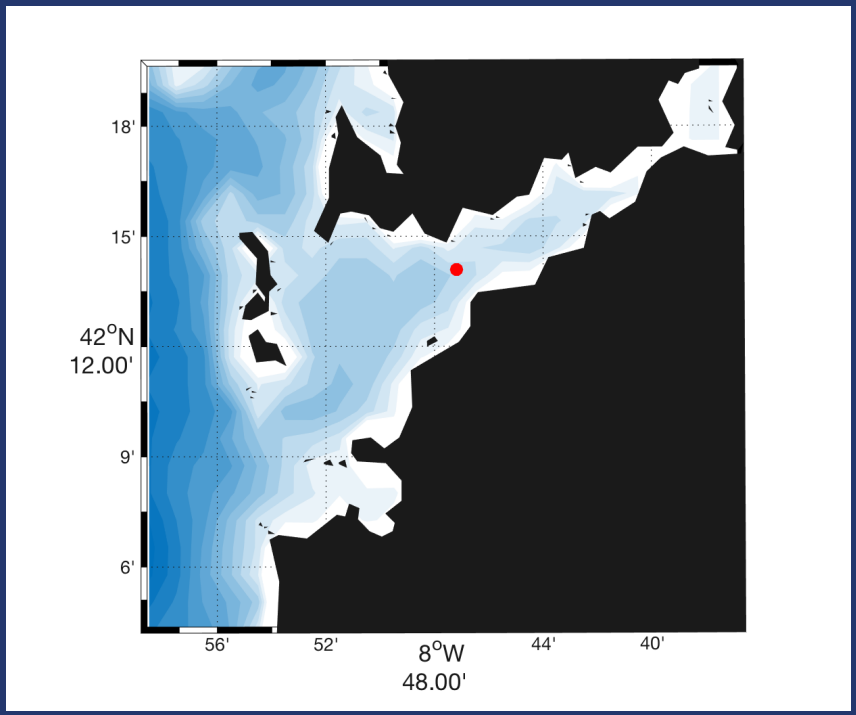
No problem, we have some...

The REMEDIOS project



52 weekly samplings

April 2017 - May 2018

Ría de Vigo

Central Station
(Depth $\sim$ 40 m)

R/V Kraken

Biological variables

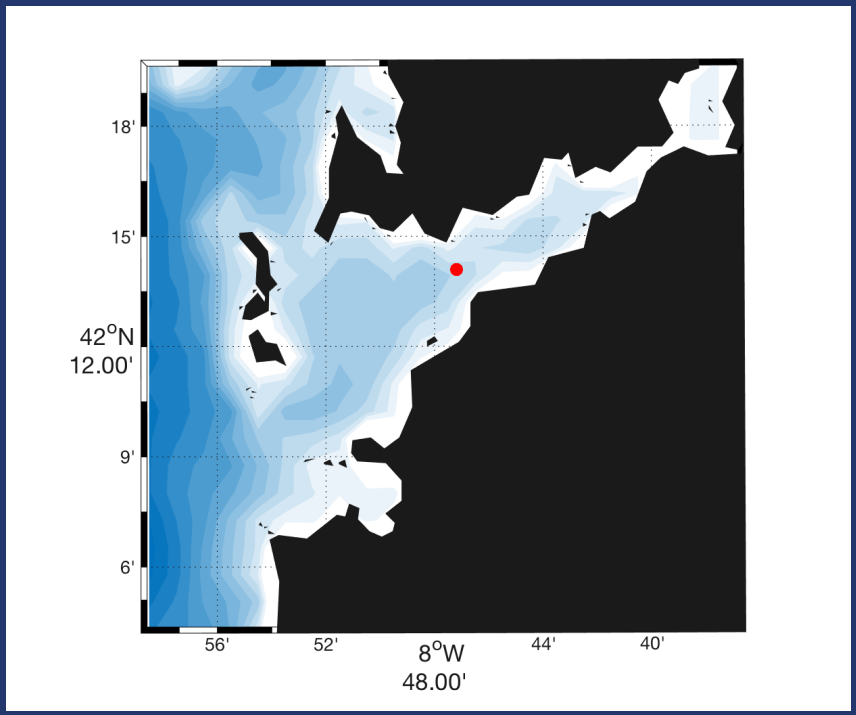
(at 10 m – 15% PAR):

- Chlorophyll-a
- ^{14}C-Primary Production

Physical variables:

- Hydrography and PAR profiles
- Microstructure turbulence

The REMEDIOS project



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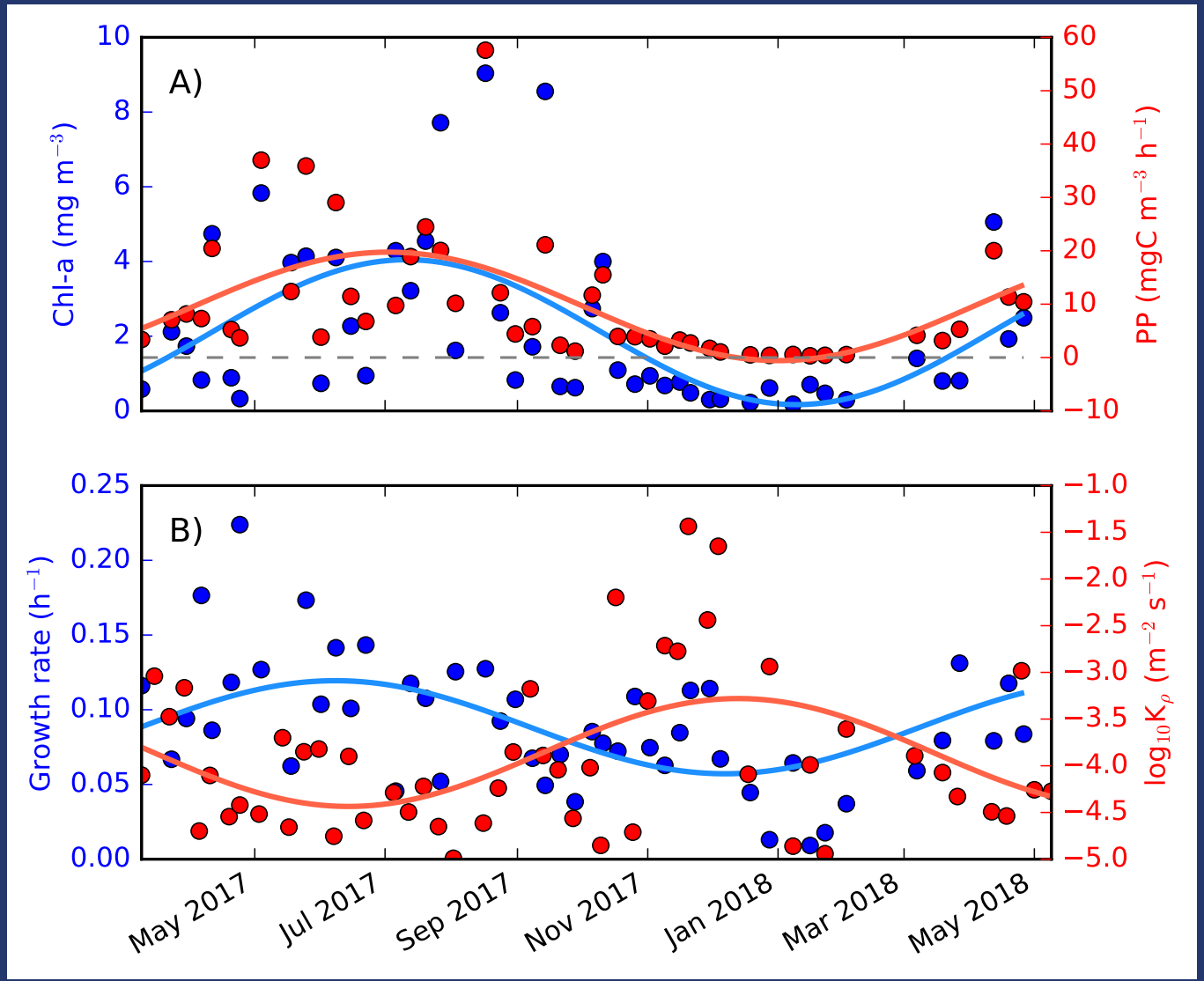
Turbulence Microstructure Profiler (MSS)

$$K_\rho = 0.2 \frac{\varepsilon}{N^2}$$

Seasonal variability of phytoplankton growth and mixing

$$GR = \frac{PP}{chl \cdot r_{C:chl}}$$

$$r_{C:chl} = 50$$



Large growth $\Longleftrightarrow$ Weak Mixing

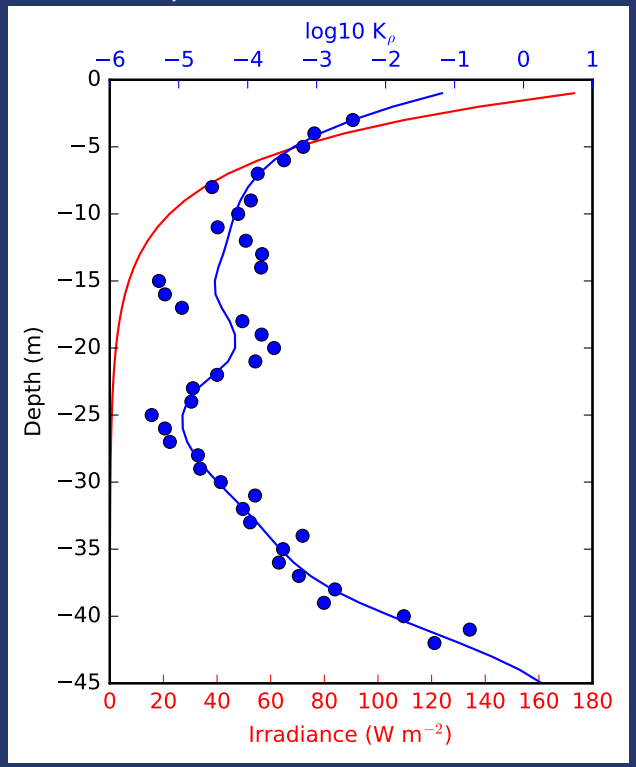
Small growth $\Longleftrightarrow$ Intense Mixing

This is consistent with the CMH, but...

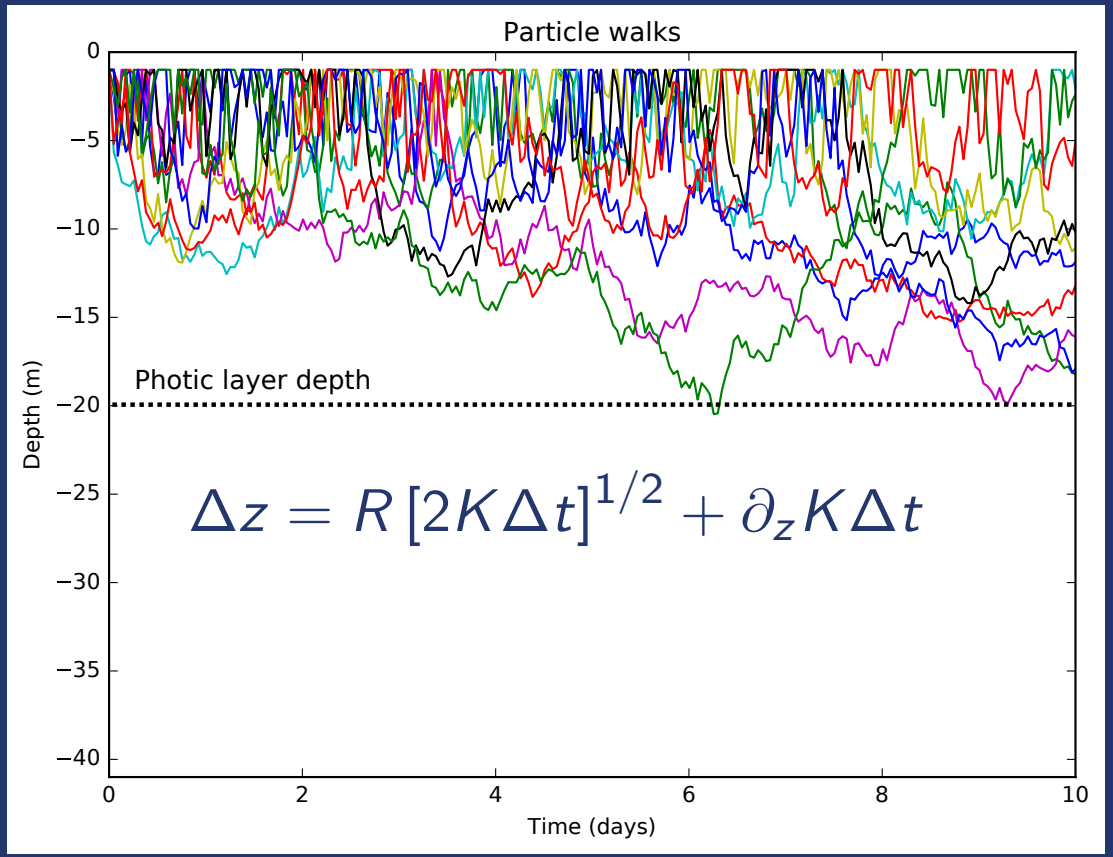
Is phytoplankton growth variability driven by changes in light availability due to turbulent mixing?

Light availability: a Lagrangian approach

K_ρ from MSS



Random Walk Simulations

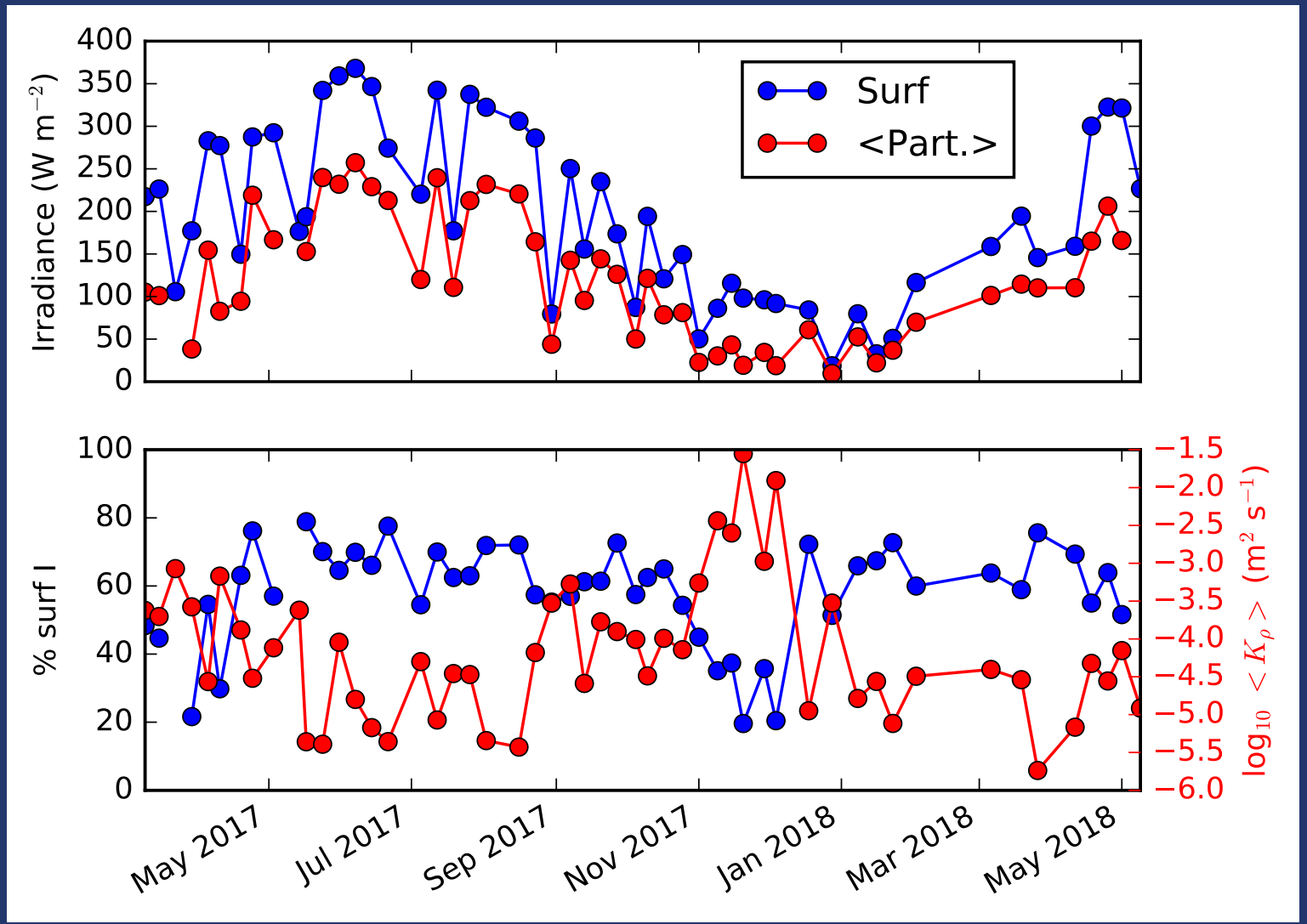


LA: $\langle I \rangle$ mean light along particle 24 h paths where $I = I_0 \exp^{-kz}$

I_0: surface irradiance from `www.meteogalicia.gal`

k: light attenuation coefficient from PAR profiles

Light availability: a Lagrangian approach



LA reduction due to turbulent mixing:

$\sim 70\%$: Summer - Spring

$20 - 40\%$: Fall - Early Winter

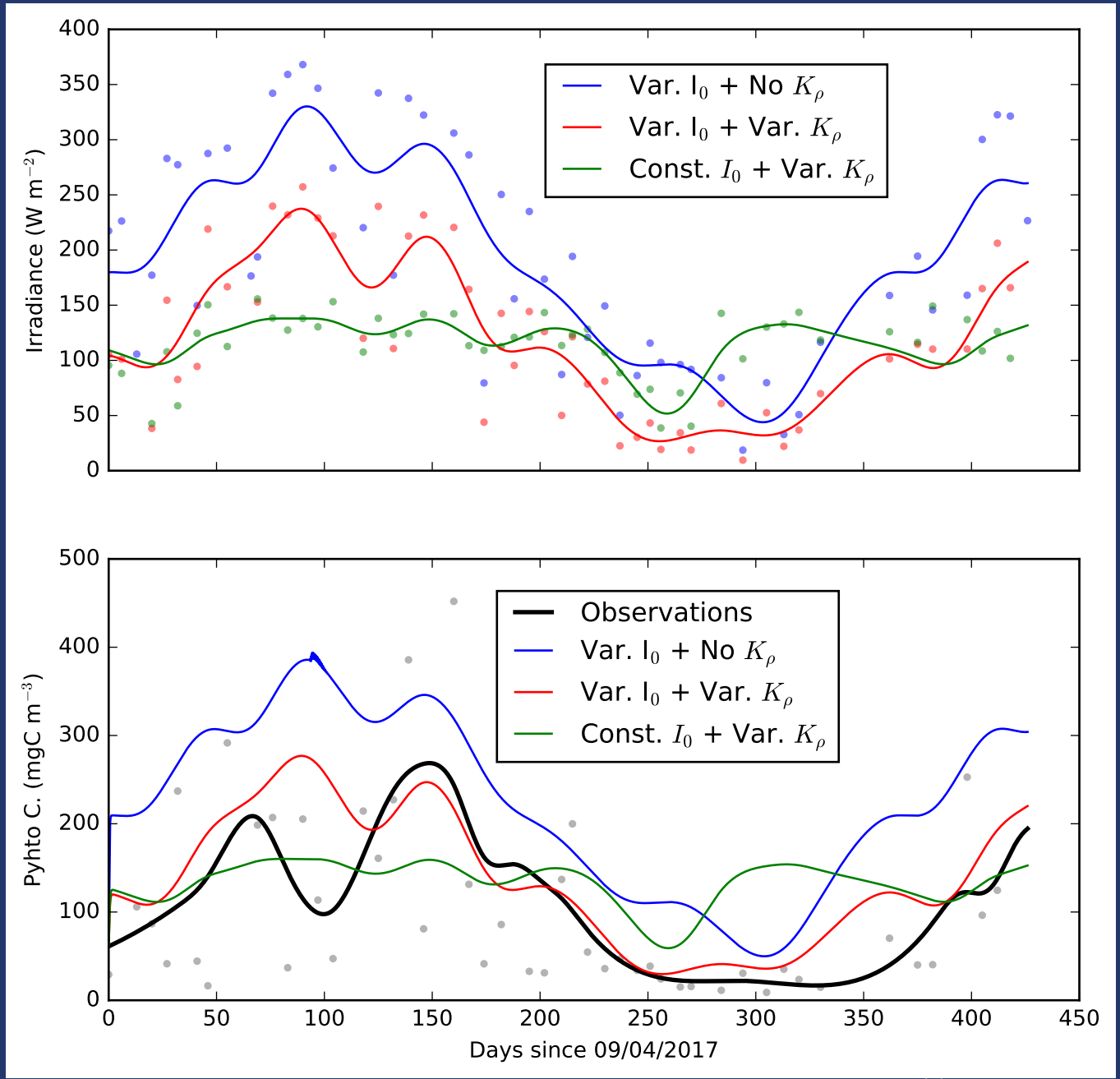
Which is the effect of LA reduction driven by mixing on phytoplankton growth?

Which is the effect of LA reduction driven by mixing on phytoplankton growth?

0D Phyto-Zoo plankton model (Lévy, 2014) with 3 light forcings:

- Variable I_0 + No K_ρ
- Variable I_0 + variable K_ρ
- Constant I_0 + variable K_ρ

LA and phytoplankton growth



Conclusions

Turbulent mixing reduces light availability, particularly during fall and early winter

Seasonal variability in phytoplankton growth is mainly driven by surface irradiance

Does the *critical mixing hypothesis* (CMH) explain seasonal phytoplankton growth in the Ría de Vigo?

Does the *critical mixing hypothesis* (CMH) explain seasonal phytoplankton growth in the Ría de Vigo?

No ...

Thanks for your attention!

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The 0D plankton model

Phytoplankton: $\frac{\partial P}{\partial t} = P \cdot [\alpha I - m_p - g_z Z]$

Zooplankton: $\frac{\partial Z}{\partial t} = Z \cdot [g_z P - \tau_z - m_z Z - (1 - a_z) g_z P]$

Parameters

Phytop. growth rate	α	3.66×10^{-7} (s^{-1} W^{-1} m^2)
Phytop. mortality rate	m_p	5.8×10^{-7} (s^{-1})
Zoop. max. grazing rate	g_z	9.26^{-6} (s^{-1})
Zoop. excretion rate	τ_z	5.80×10^{-7} (s^{-1})
Zoop. mortality rate	m_z	2.31×10^{-6} (s^{-1} $mmol^{-1}$ m^3)
Assimilated food fraction	a_z	0.7