MODELLING THE IMPACT OF TIDAL FLOWS ON THE BIOLOGICAL PRODUCTIVITY OF THE ALBORAN SEA

José C. Sánchez Garrido, C. Naranjo, D. Macías,
J. García Lafuente, T. Oguz

Physical Oceanography Group

UNIVERSIDAD DE MÁLAGA

University of Málaga

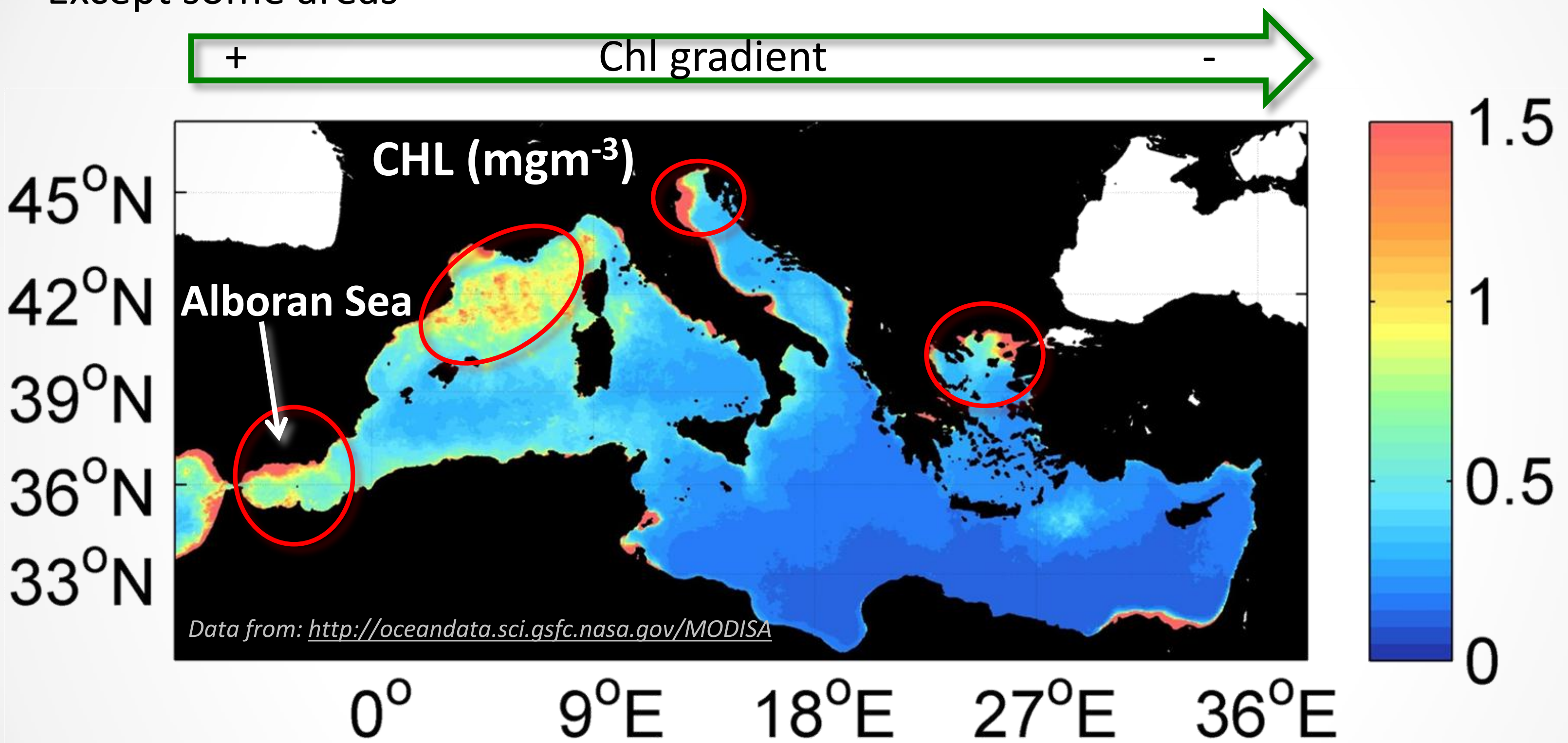
ALBOREX Meeting. Palma de Mallorca
April 12-13 2015

Photo from ESA: http://www.esa.int/spaceinimages

Outline

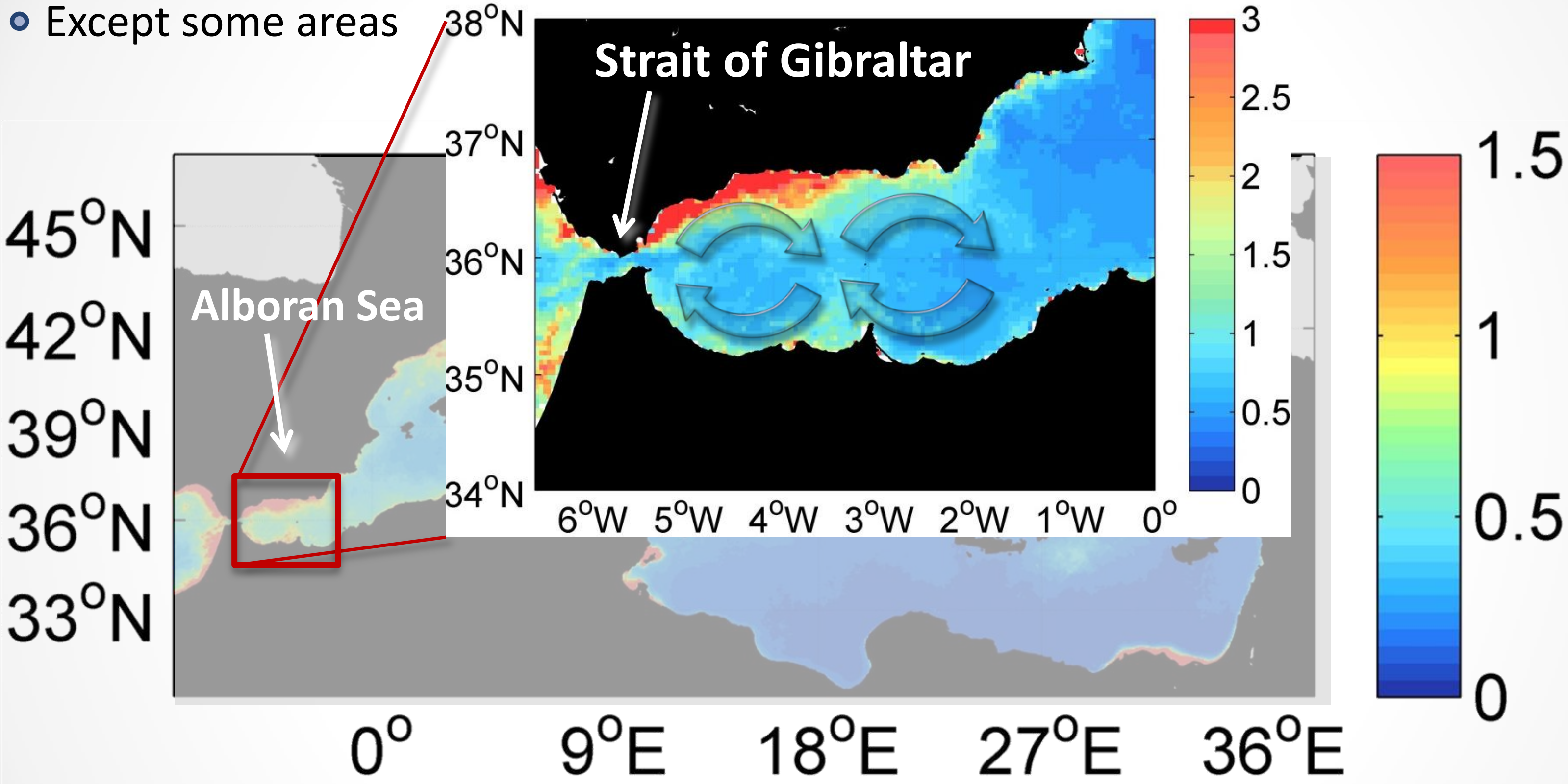
Introduction

- Mediterranean Sea generally oligotrophic
- Except some areas



Introduction

- Mediterranean Sea generally oligotrophic
- Except some areas



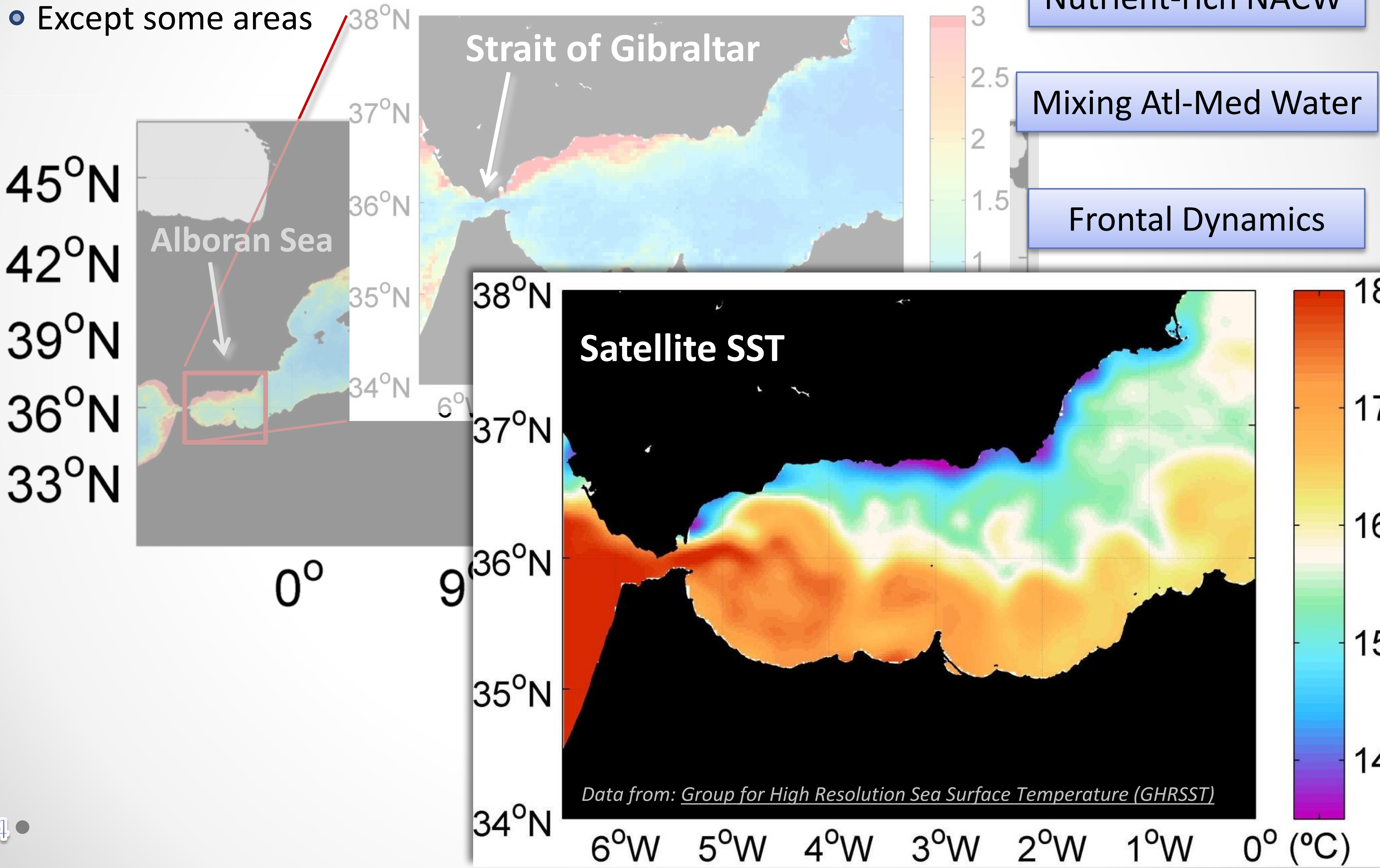
Introduction

- Mediterranean Sea generally oligotrophic
- Except some areas

Nutrient-rich NACW

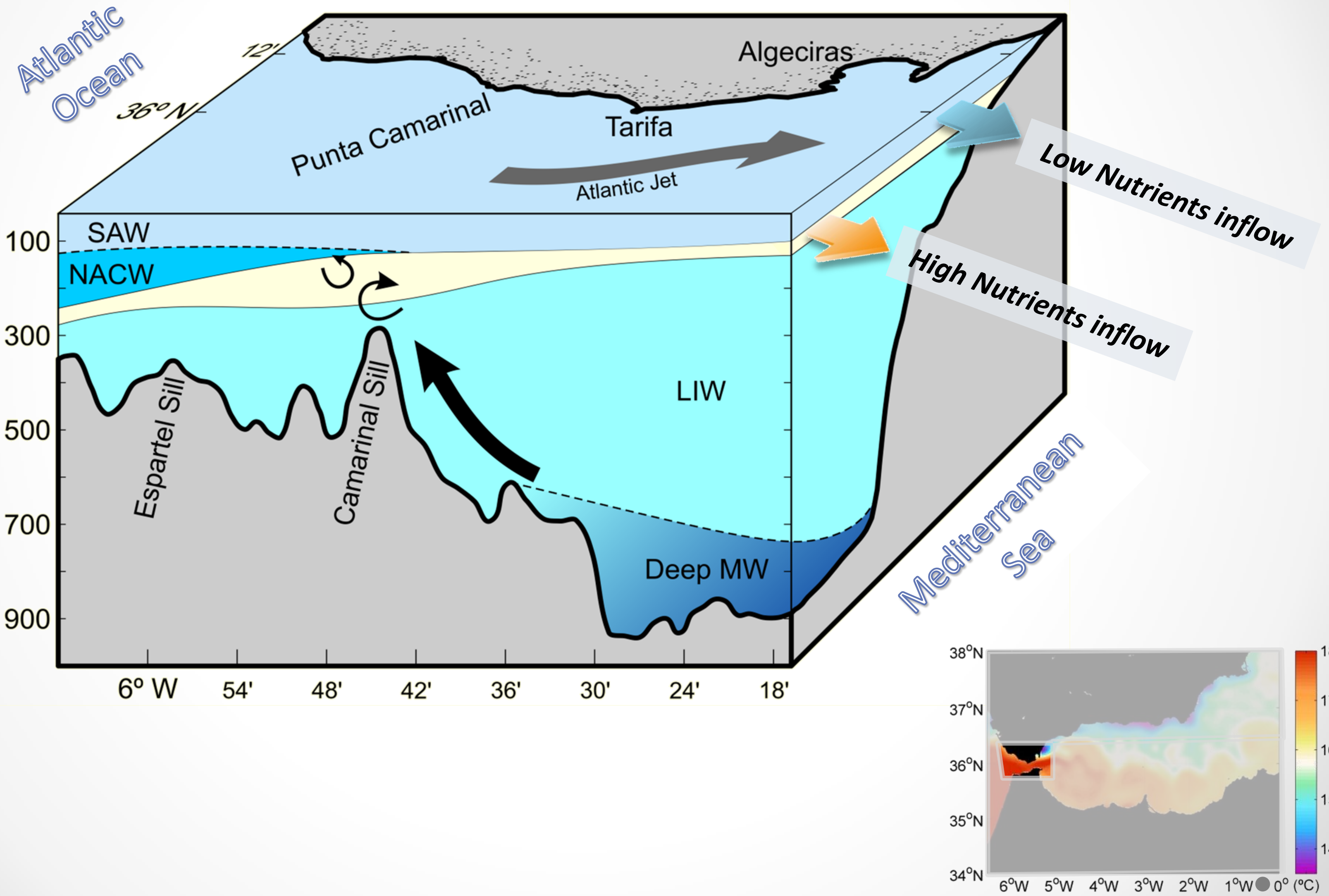
Mixing Atl-Med Water

Frontal Dynamics



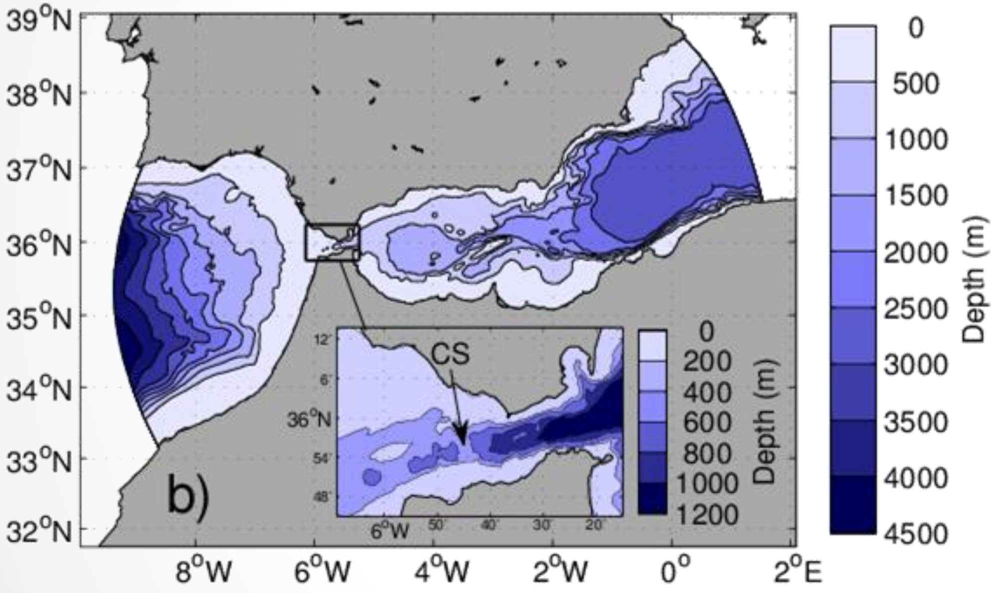
Introduction: The problem

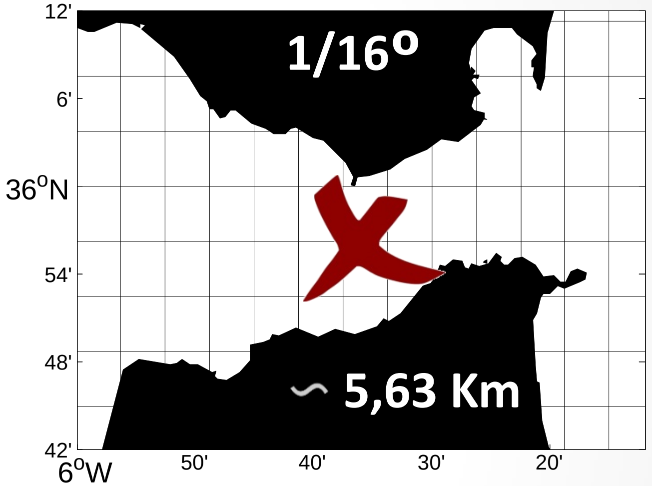
- Tidal dynamics: Mixing; internal waves; pumping …

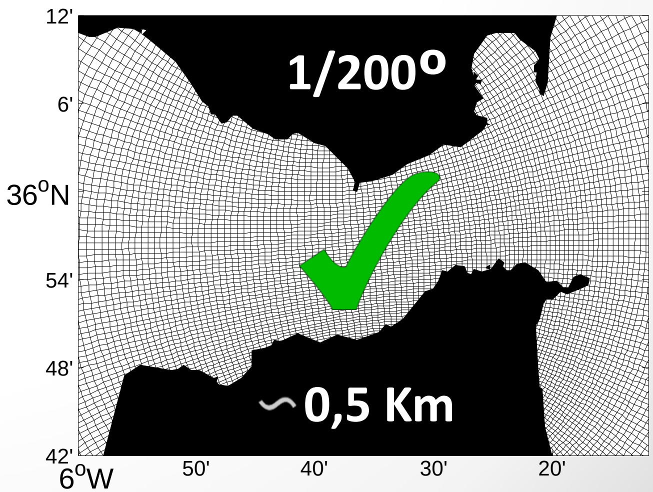


Introduction: The problem

- Tidal Flow: Small Temporal and Spatial Scale
- Regionals models: Not enough resolution to resolve Small scale processes







1. Model setup

Hydrodynamic model: MITgcm

- Tidal validation on: Sánchez-Garrido et al. 2013*[1]
- Forcings: Temperature, Salinity, Velocity (MyOcean*[2]).
  Wind stress (ASCAT*[3])
  Heat fluxes and fresh water flux (NCEP/NCAR*[4]).
  Tide: 8 main constituents

Biogeochemical coupled model (Follows et al. 2007)

- NPZD model
- Nutrients: NO_3 and PO_4
- Two-species configuration
- Initial nutrients condition: MEDAR/MEDATLAS

Two-year Non-Tidal Run

- Equilibrium state

Two-month Tidal Run

- Periodic solution

*[1] *Sánchez-Garrido, et al., What does cause the collapse of the Western Alboran Gyre? Results of an operational ocean model, Prog. in Ocean, Volume 116, 2013 .*

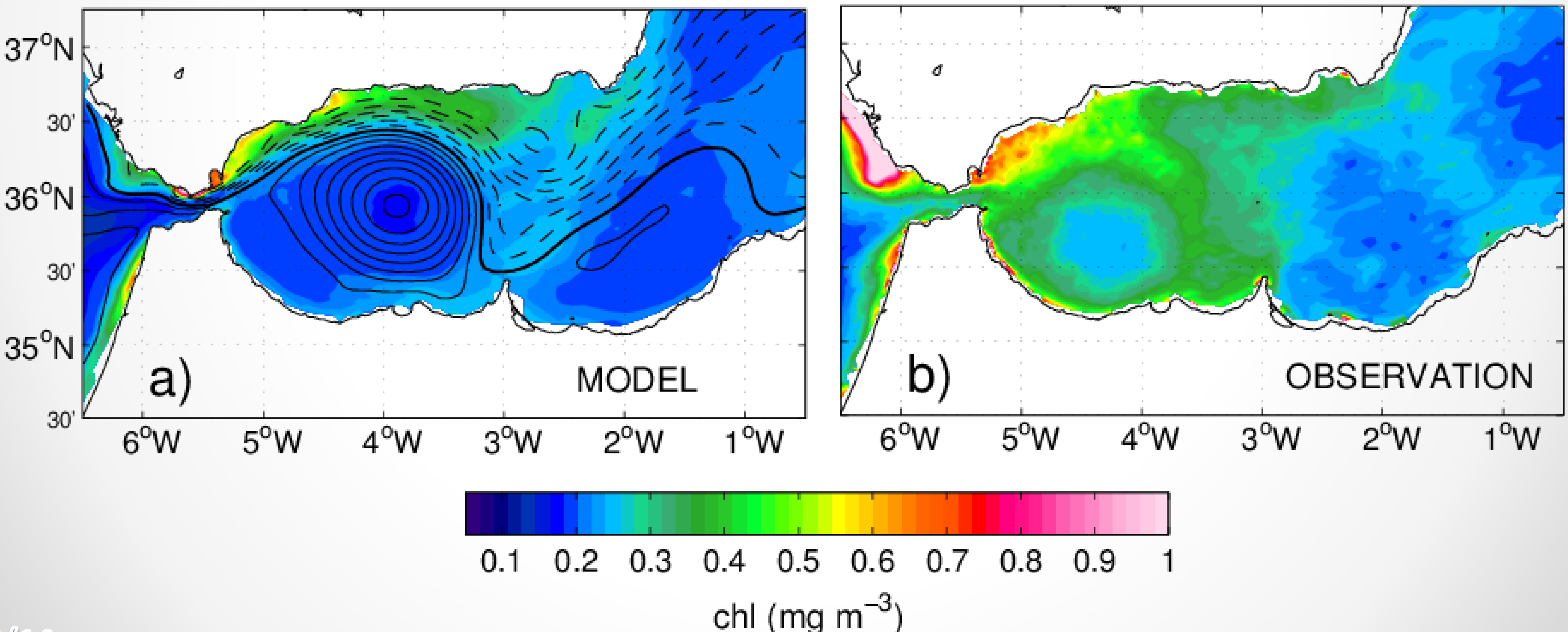
*[2] *Re-analysis products from MyOcean: http://myocean.met.no/.*

*[3] *ASCAT from CERSAT: ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/MWF/L3/ASCAT/Daily/*

*[4] *NCEP Reanalysis data provided by the NOAA/OAR/ESRL: http://www.esrl.noaa.gov/psd/*

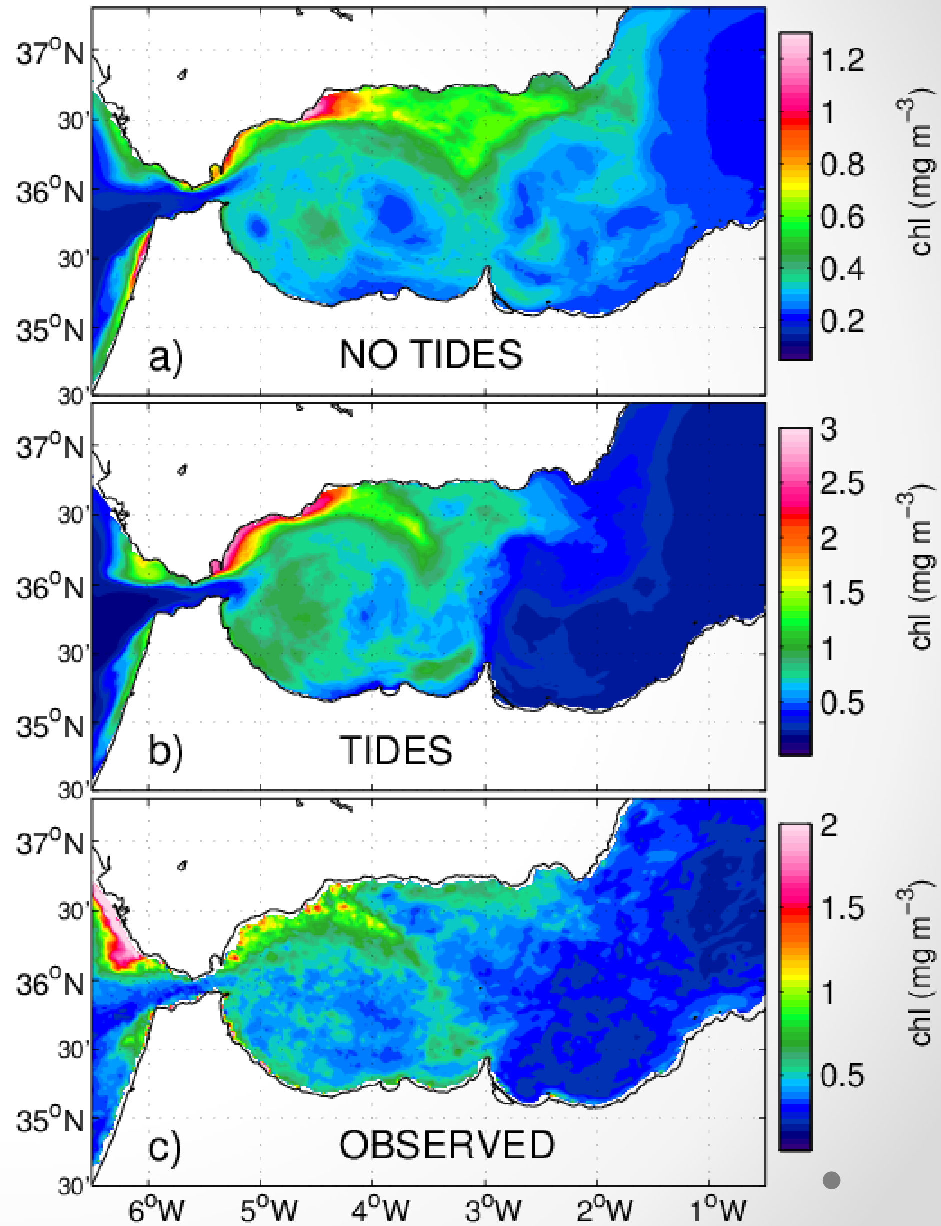
2. Non-Tidal, Two-year Run

- Mean model chl maps captures the MAIN PATTERNS of Satellite data
- WAG, EAG and central gyre oligotrophy ✓
- High Chl concentration in northwestern coast ✓
- West-East gradient NOT PRESENT in the model ✗



3. Tidal Run

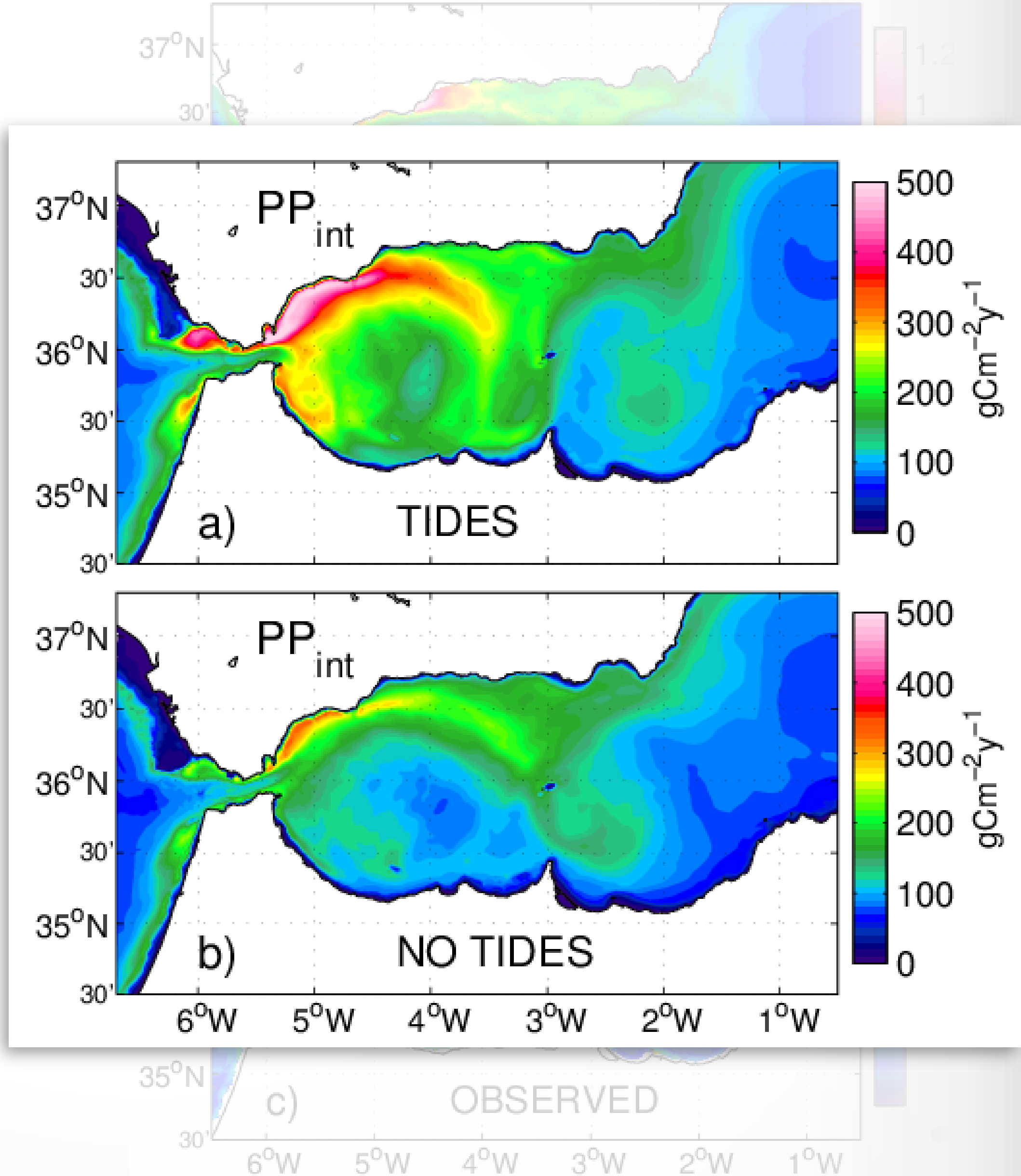
- Surface PATTERNS better reproduced by the Tidal Run
- Marked West-East gradient



3. Tidal Run

- Surface PATTERNS better reproduced by the Tidal Run
- Marked West-East gradient
- Vertically Integrated Primary Productivity

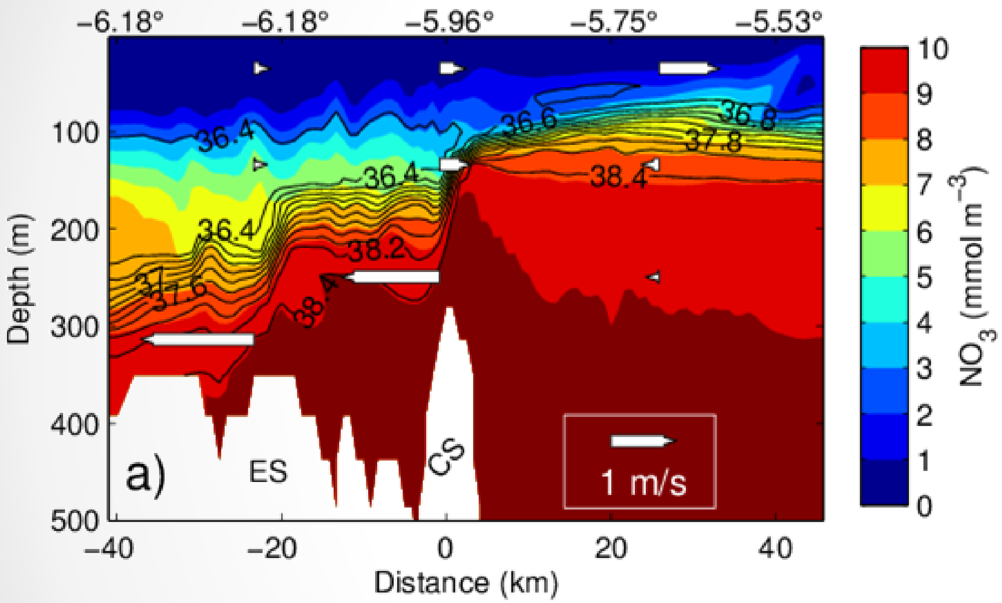
$$\int_{-100}^{0} PP.dz$$

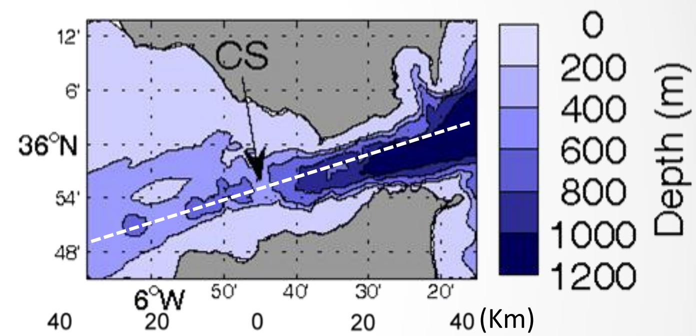


3. Tidal Run

3.1. Tidal simulation: *differences with respect to Non-Tidal run*

Non-Tidal run

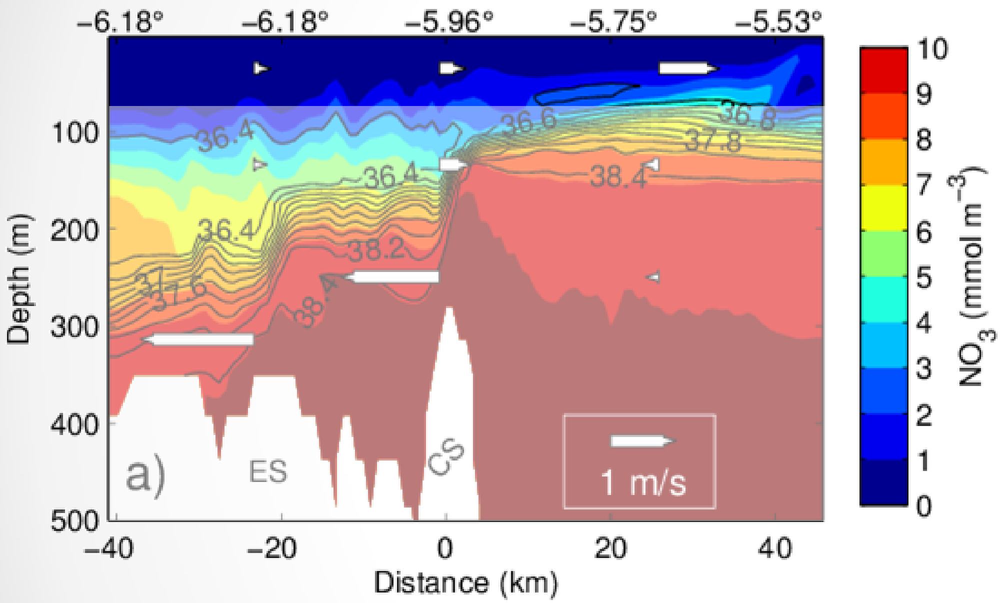


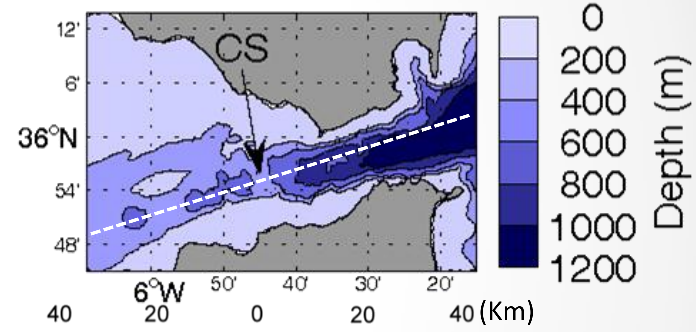


3. Tidal Run

4.1. Tidal simulation: *differences with respect to Non-Tidal run*

Non-Tidal run



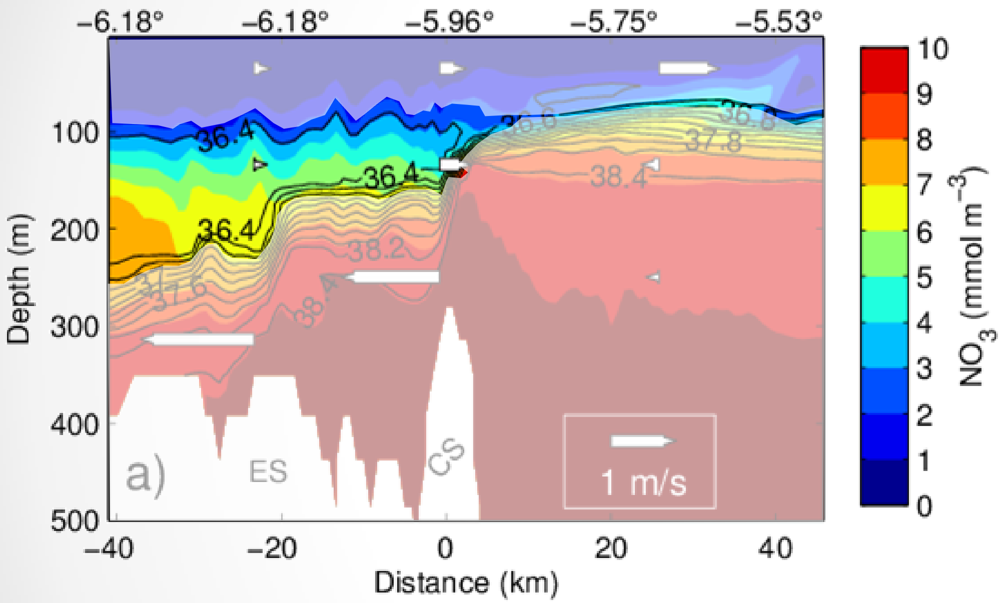


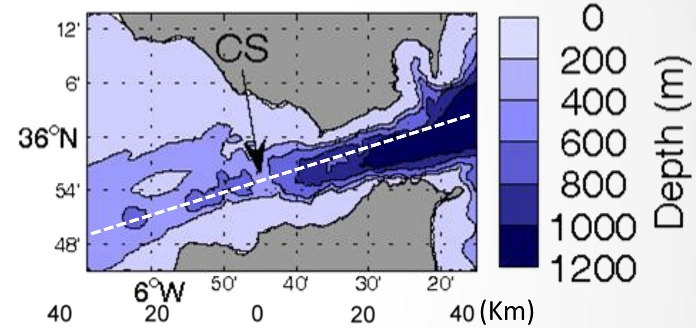
SAW (S>36,6) poor in nutrient

3. Tidal Run

4.1. Tidal simulation: *differences with respect to Non-Tidal run*

Non-Tidal run





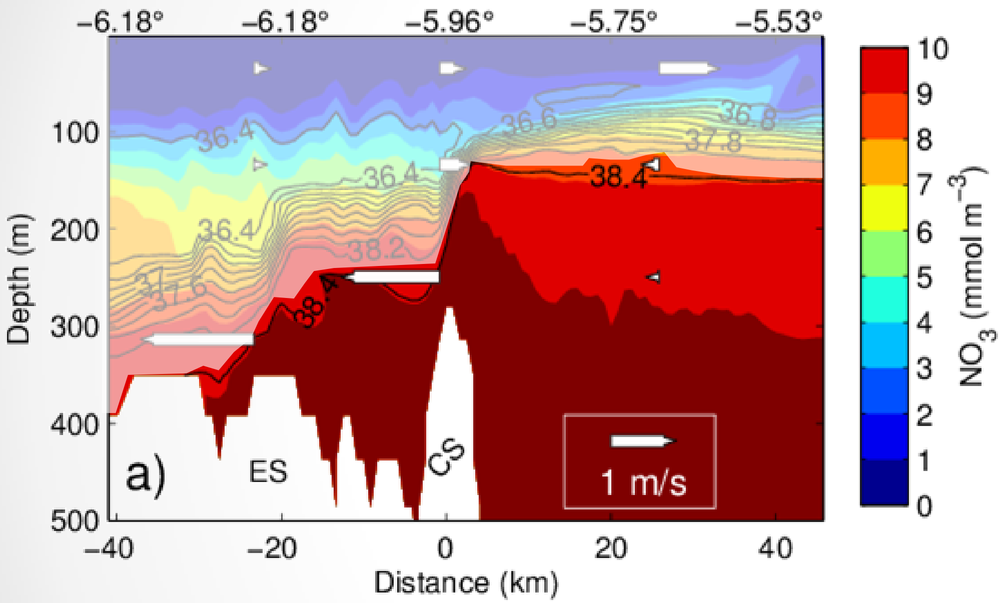
SAW (S>36,6) poor in nutrient

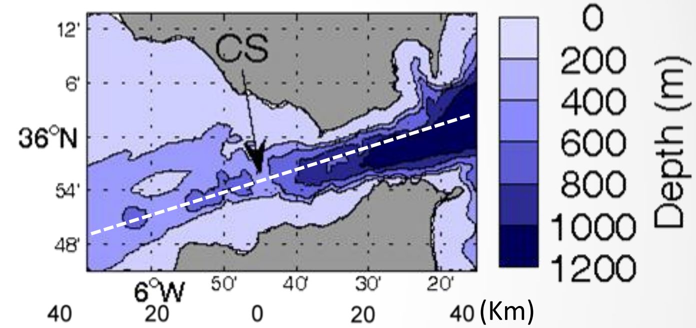
Nutrient-rich NACW (S < 36,2)

3. Tidal Run

4.1. Tidal simulation: *differences with respect to Non-Tidal run*

Non-Tidal run





SAW (S>36,6) poor in nutrient

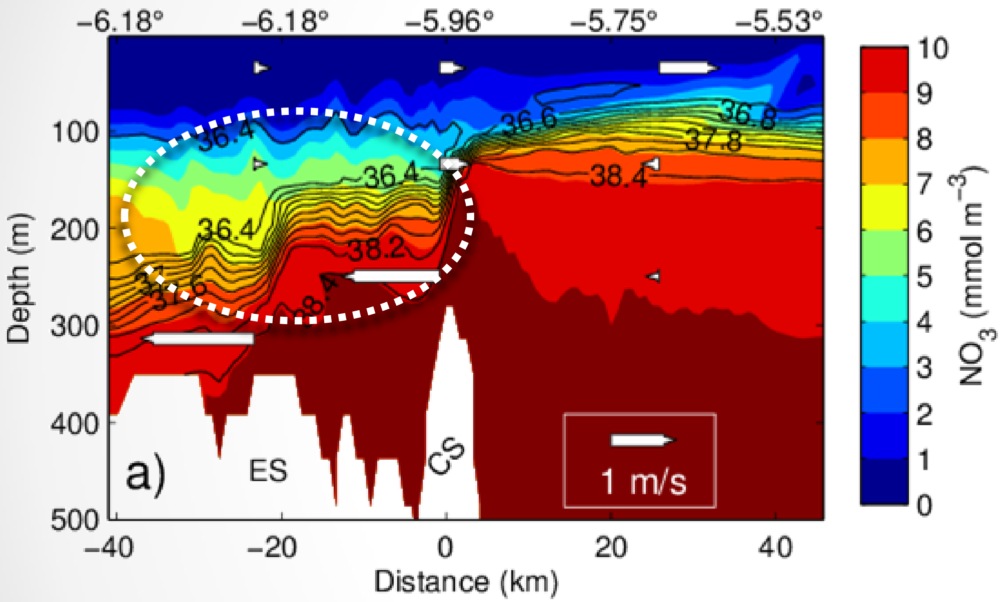
Nutrient-rich MW (S > 38,4)

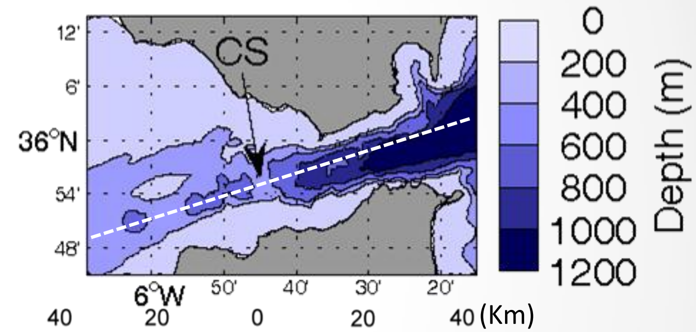
Nutrient-rich NACW (S < 36,2)

3. Tidal Run

4.1. Tidal simulation: *differences with respect to Non-Tidal run*

Non-Tidal run





SAW (S>36,6) poor in nutrient

Nutrient-rich NACW (S < 36,2)

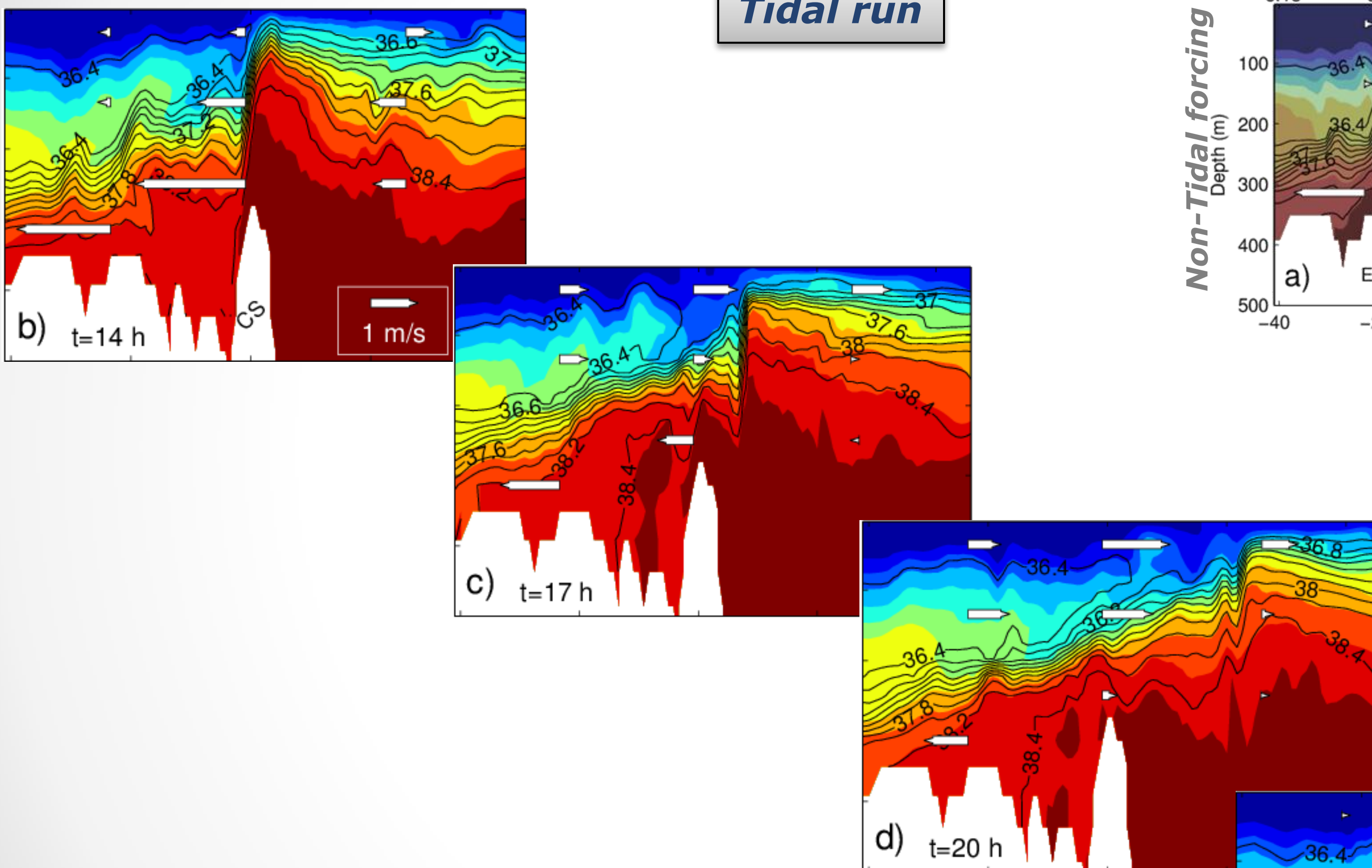
Nutrient-rich MedWat (S > 38,4)

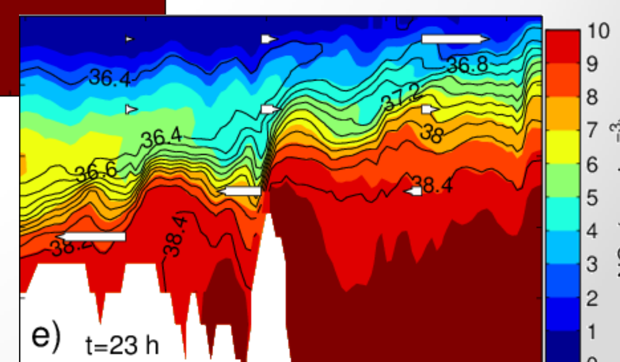
Nutrient-rich water west of CS does not contribute to the inflow

3. Tidal Run

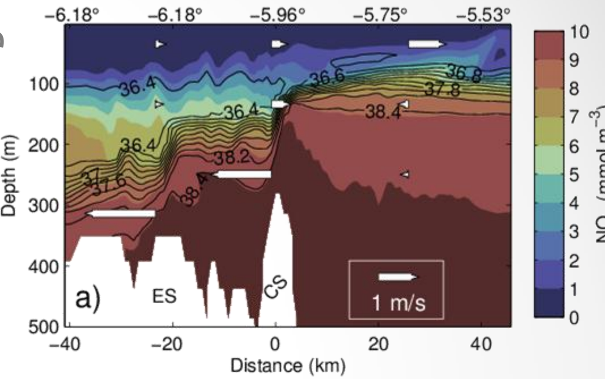
3.1. Tidal simulation: *differences with respect to Non-Tidal run*

Tidal run



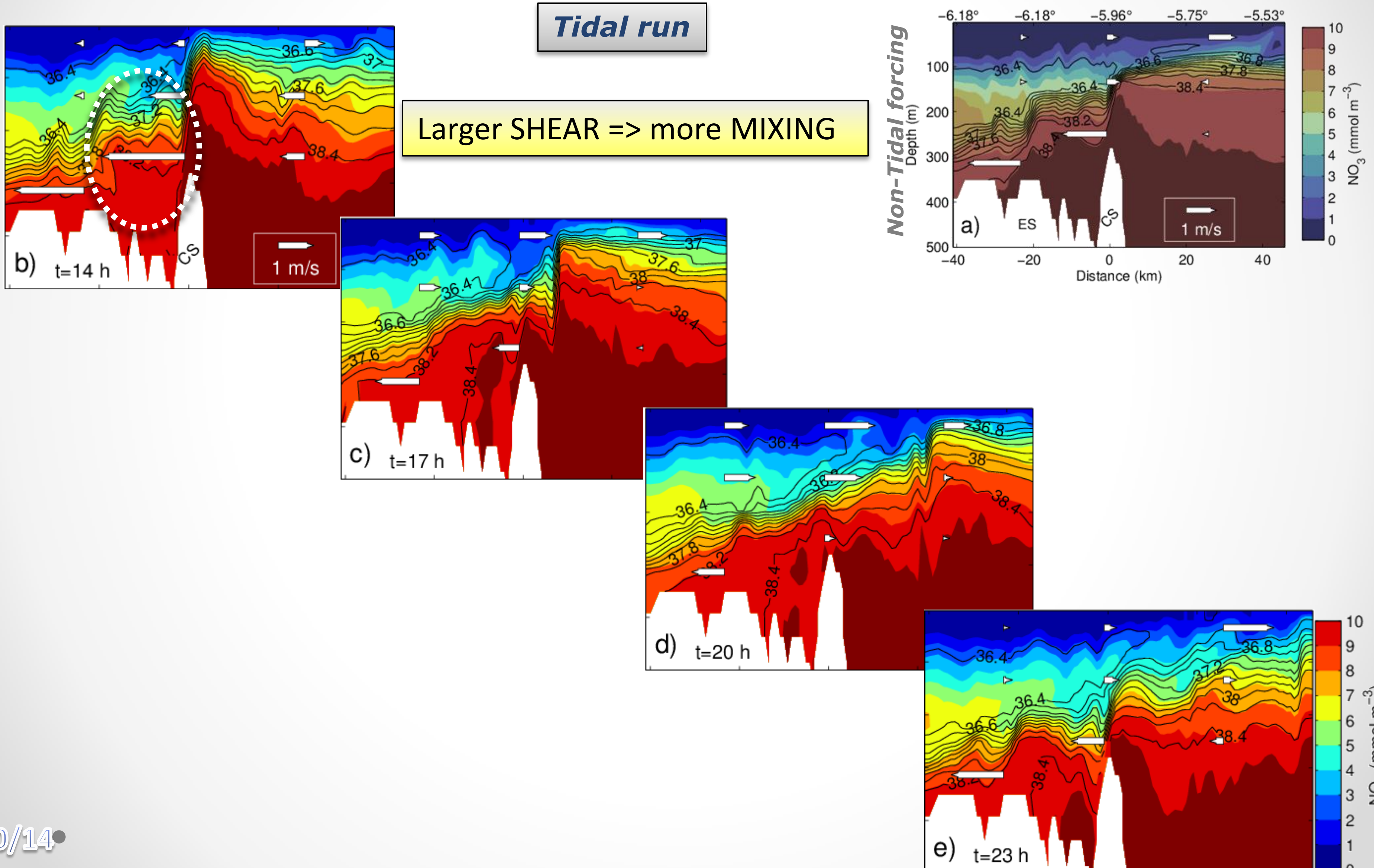


Non-Tidal forcing



3. Tidal Run

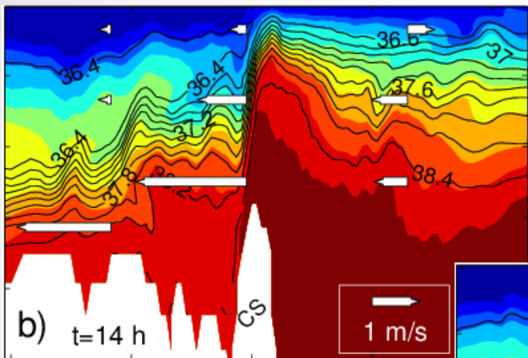
3.1. Tidal simulation: *differences with respect to Non-Tidal run*



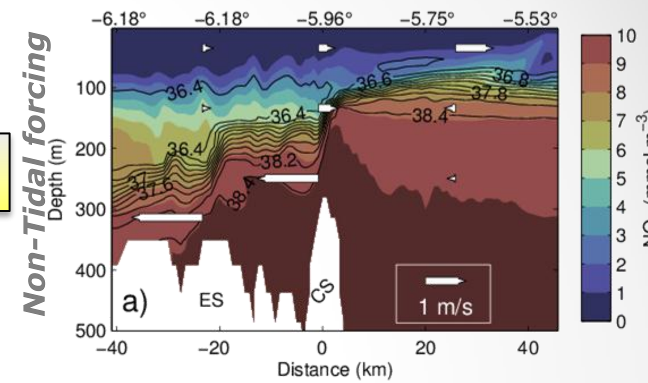
3. Tidal Run

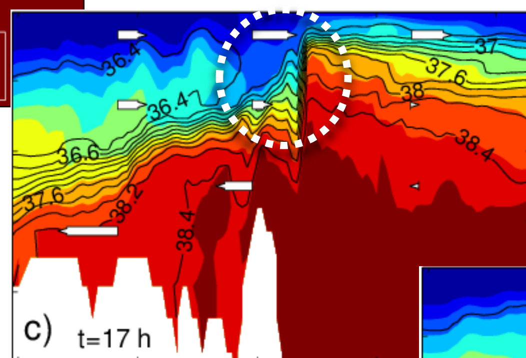
3.1. Tidal simulation: *differences with respect to Non-Tidal run*

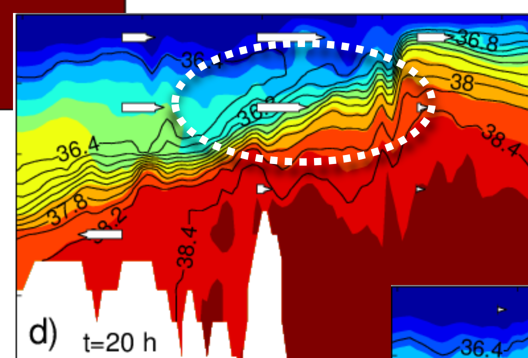
Tidal run



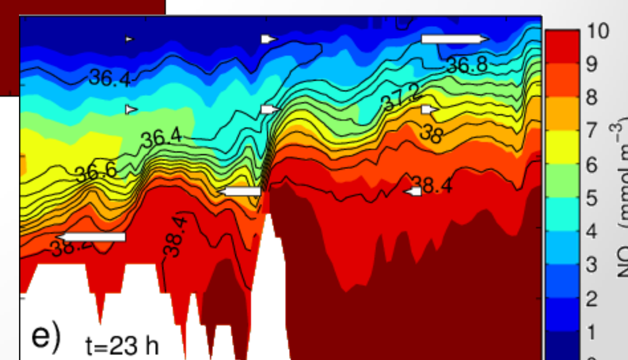
Larger SHEAR = more MIXING







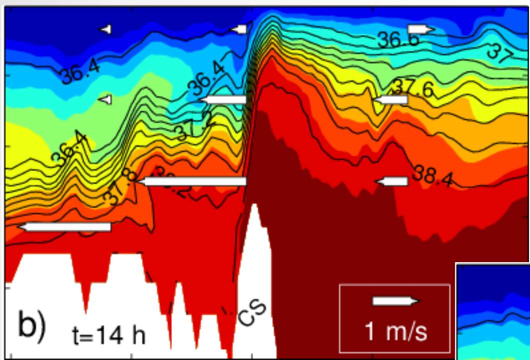
Nutrient-rich **NACW** flows **Eastward**



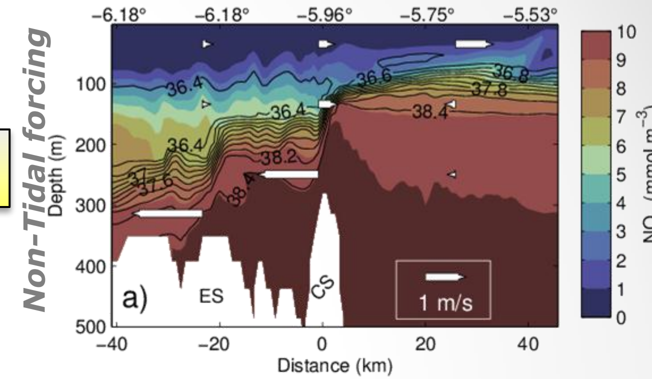
3. Tidal Run

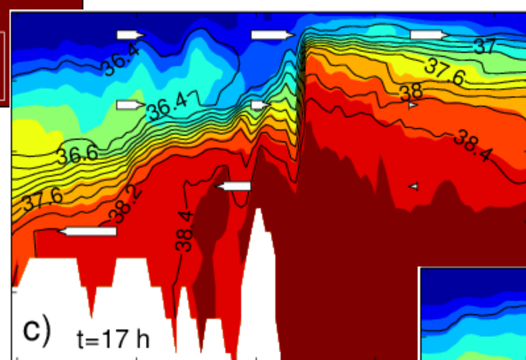
3.1. Tidal simulation: *differences with respect to Non-Tidal run*

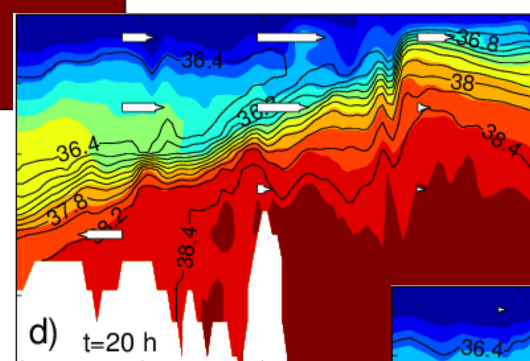
Tidal run



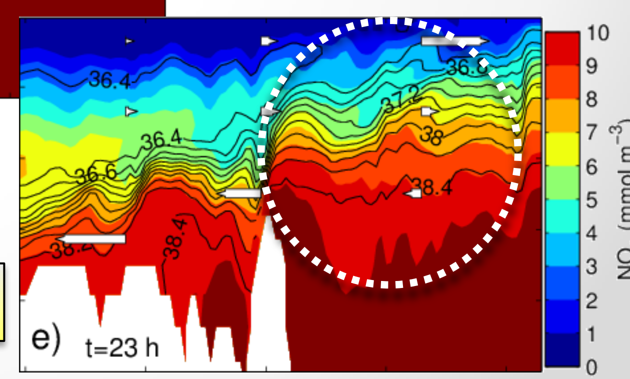
Larger SHEAR = more MIXING







Nutrient-Rich **NACW flows Eastward**



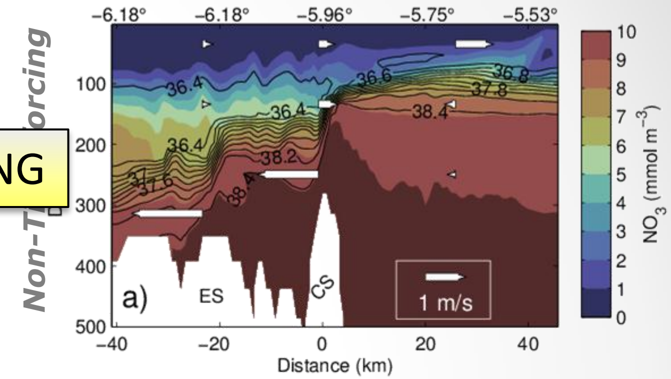
Nutrient-Rich **mixed water overpass the Sill**

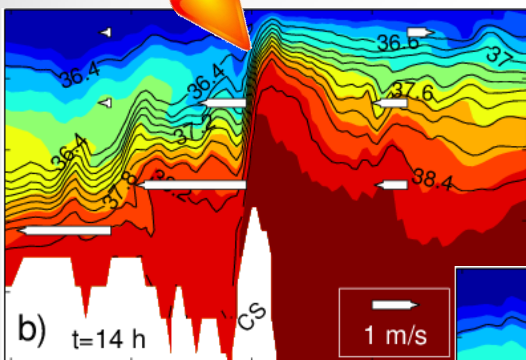
Mixed & Nutrient-Rich water fertilizes the **surface layer**

3. Tidal Run

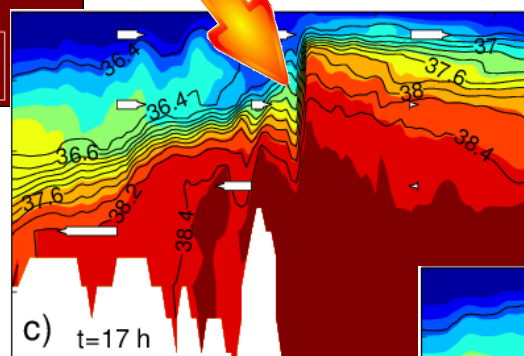
3.1. Tidal simulation: *differences with respect to Non-Tidal run*

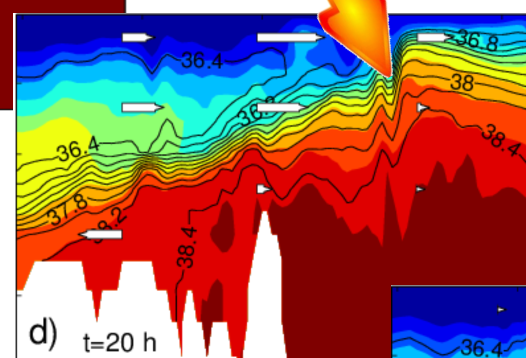
Tidal run





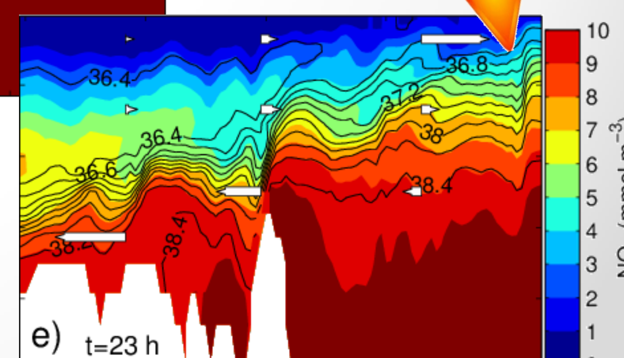
Larger SHEAR = enhanced MIXING





Internal bore
eastward
propagation

Nutrient Rich **NACW** flows **Eastward**



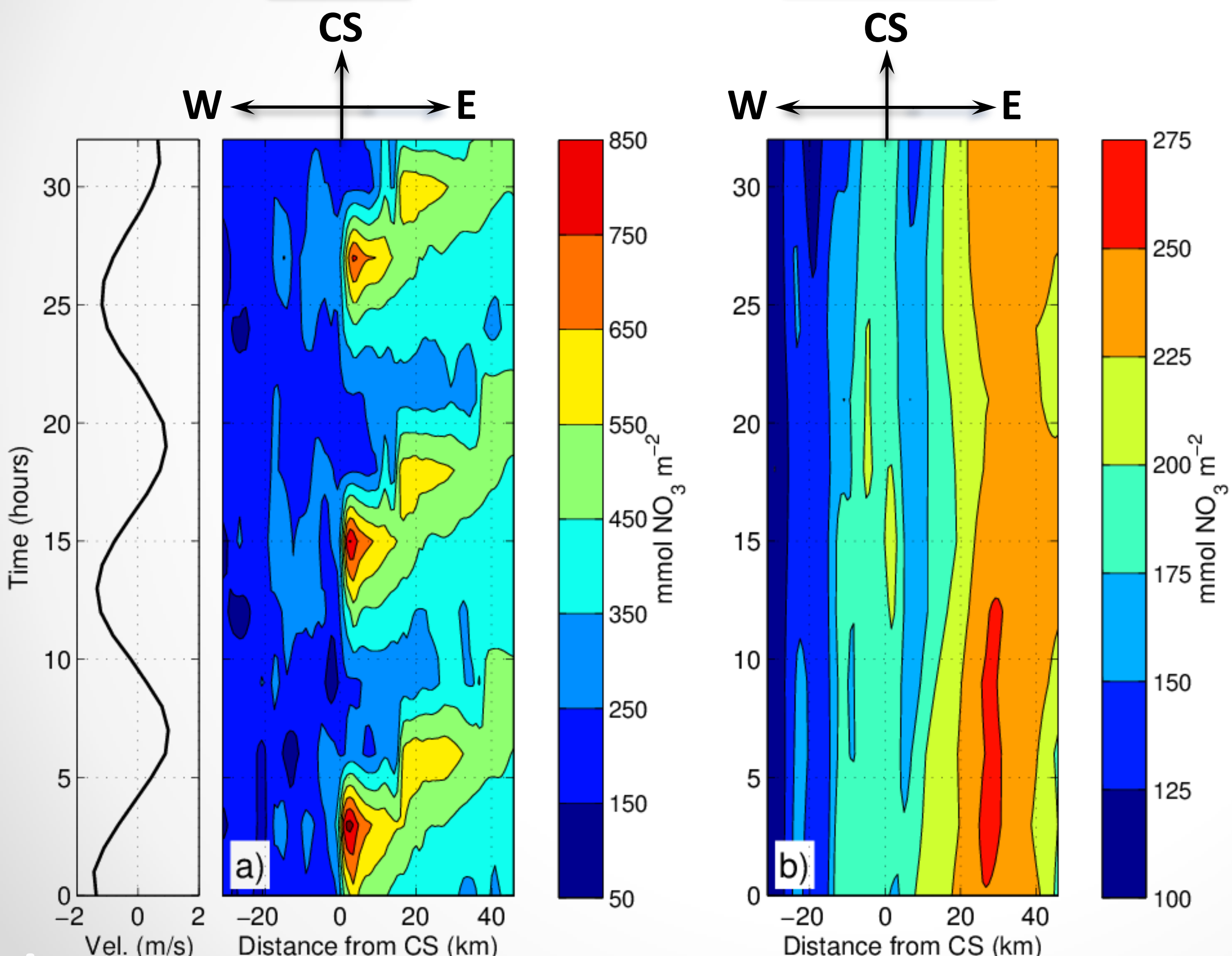
Nutrient-Rich **mixed water overpass the Sill**

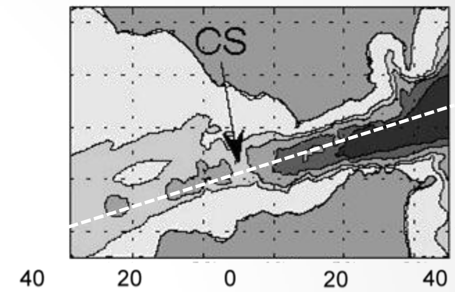
Mixed & Nutrient-Rich water floods the **surface layer**

3. Tidal Run

3.1. Tidal simulation: *differences with respect to Non-Tidal run*

Tides | **No-Tides**





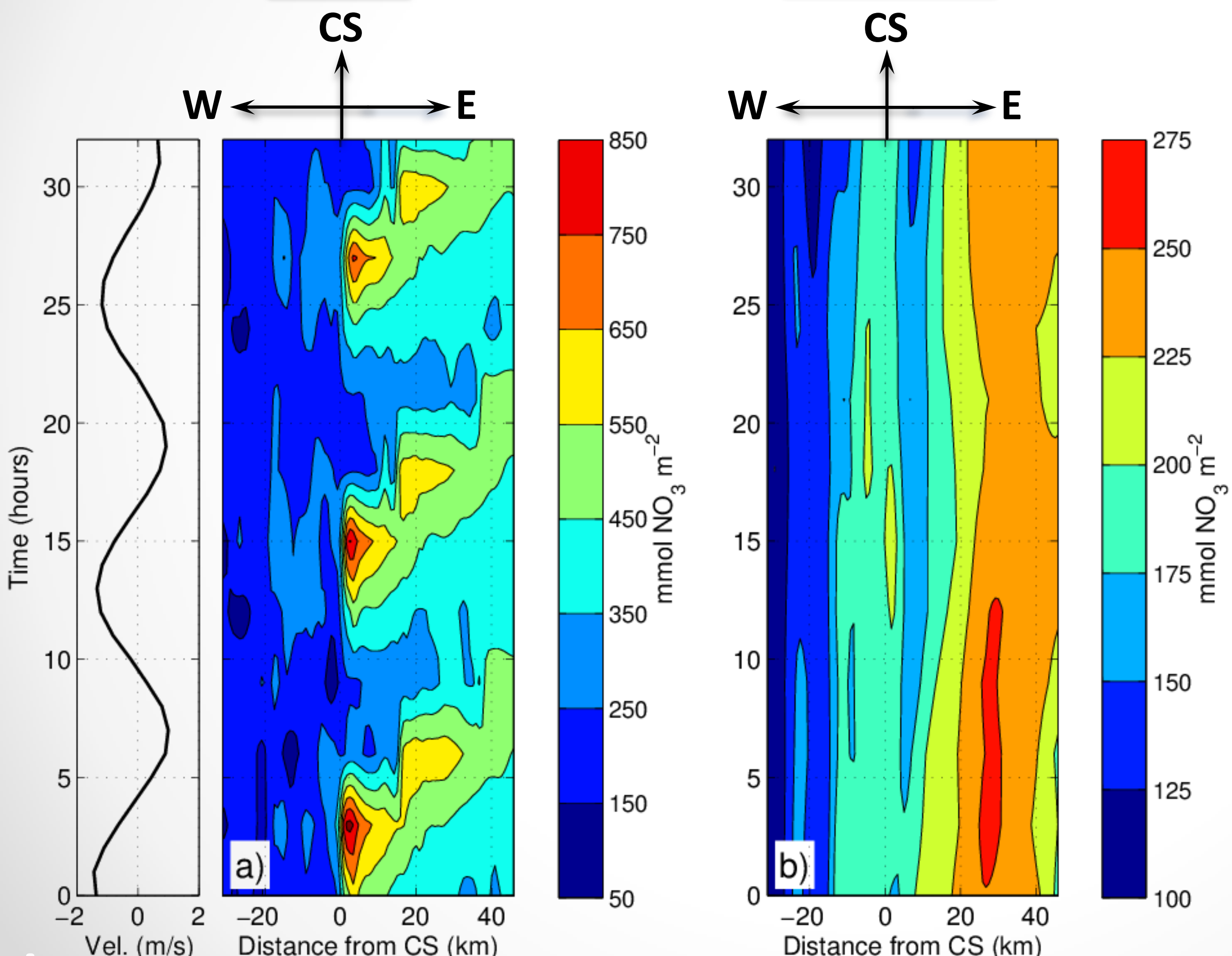
$$\int_{-100}^{0} NO_3 dz$$

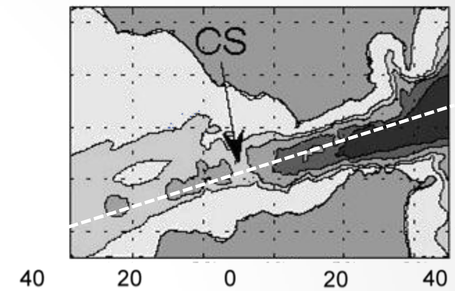
(Note the different color scale !)

3. Tidal Run

3.1. Tidal simulation: *differences with respect to Non-Tidal run*

Tides **No-Tides**





Tides

Pulsating inflow

Pumping of Nutrients into the photic layer

Subsequent Advection

No-Tides

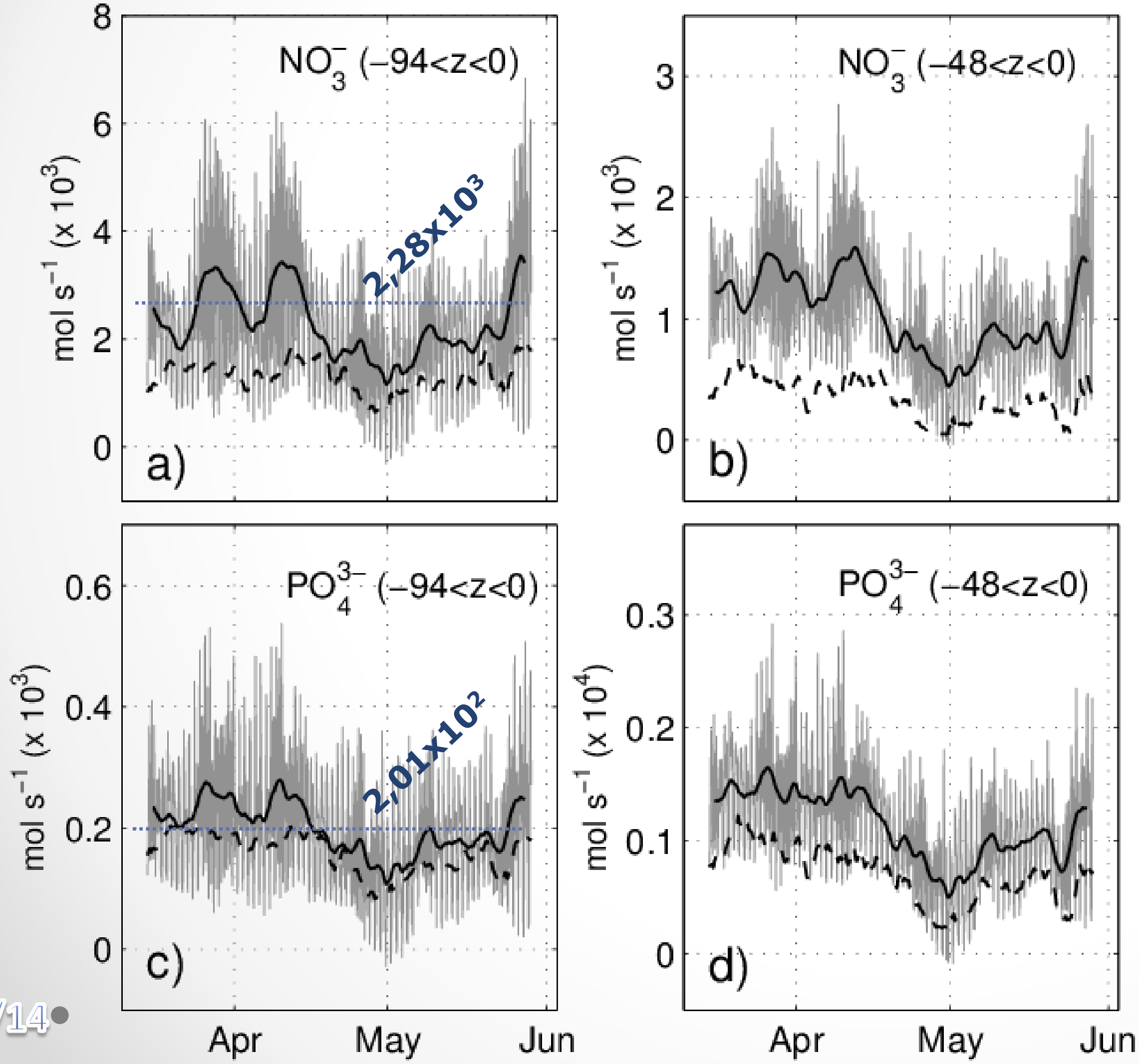
Weak Mixing

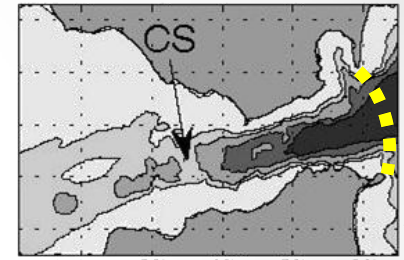
Low Nutrient [ ]

3. Tidal Run

3.1. Tidal simulation: *differences with respect to Non-Tidal run*

Nutrients Transport





Greater transports with tides

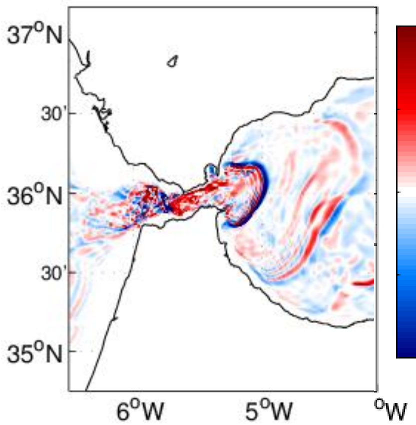
Fortnightly signal

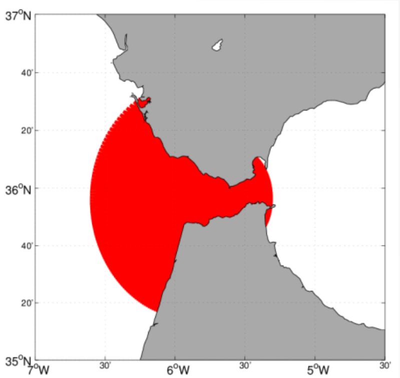
Larger differences in the shallowmost layer

Huertas et al. (2009):
$2,59x10^3 molNO_3 s^{-1}$
$2,16x10^2 molPO_4 s^{-1}$

4. Relaxation Experiment

- Could propagating internal waves play a role on PP increase ?





Relax. Time $\tau \approx 2h$

Tracer in Tidal Simulation

$$\frac{\partial BT}{\partial t} = \underbrace{-\vec{u}\cdot\nabla BT + \frac{\partial}{\partial z}\left(k_z\frac{\partial BT}{\partial z}\right)}_{\text{NON-TIDAL Dynamics}} + Bio. \underbrace{-\frac{1}{\tau}(BT - BT_{tid})}_{\text{Relaxation term}}$$

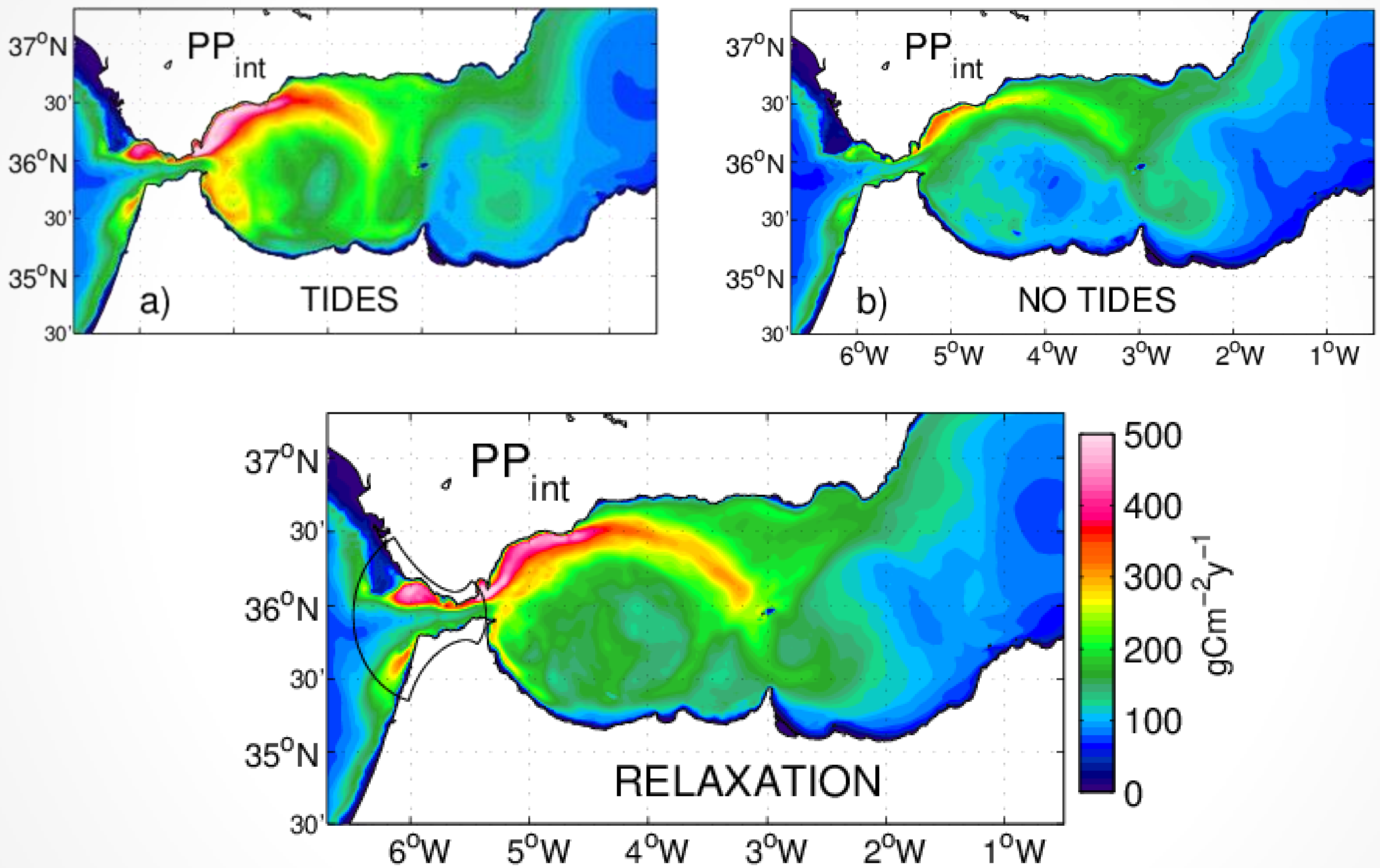
NON-TIDAL Dynamics

IWs and other tidal effects are inhibited

Relaxation term

Nutrient transports as in the Tidal Simulation

4. Relaxation Experiment



PP Tides≈PP Relaxation → Tidal dynamics in the Strait causes PP increase.

5. Conclusions

- The Tidal dynamics of the Strait of Gibraltar gives rise to a more nutrient-rich Atlantic inflow

- With tides the PP of the Alboran Sea is 40% greater than without tides (126 to 176 $gCm^{-2}y^{-1}$). Differences are greater in the western half of the basin (+60%; 141 to 226 gCm-2y-1), and less relevant in the eastern half (+11%; 111 to 124 gCm-2y-1).

- Other tidally-driven processes occurring outside the Strait of Gibraltar (propagating Internal waves) have minor effects on the biology of the Alboran Sea.