Impact of mesoscale variability on spatial and temporal patterns of phytoplankton communities in the Iroise Sea (N-E Atlantic)

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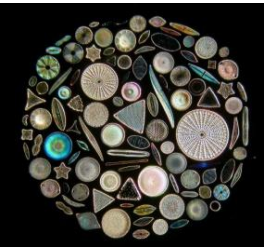
Journée de rencontre des utilisateurs CAPARMOR
PLOUZANE, 13 mars 2015

BACKGROUND

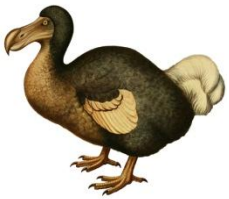
Definitions




Biodiversity = Number and relative abundance of different species that occupy a specific location

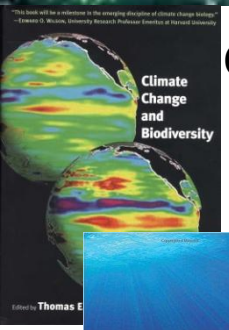



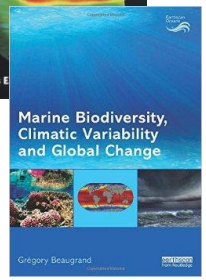




BACKGROUND

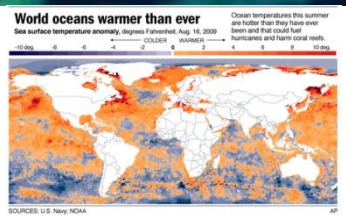
Definitions





Climate change ?

Ocean Warming ?



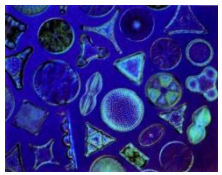
Acidification ?

Biodiversity = Number and relative abundance of different species that occupy a specific location

Marine resources ?

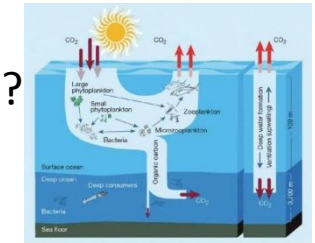
Air-sea CO_2 fluxes ?

Ecosystem stability and resilience ?



Carbon export ?

Primary production ?



Species shifts ?

Carbon cycle ?

Trophic transfer efficiency ?

Ecosystem functioning ?

BACKGROUND

Plankton biodiversity

Phytoplankton communities are very diverse :
-Size / shape
- Nutrient acquisition
- photo-acclimation
- predation avoidance
- biogeochemical function
- etc.

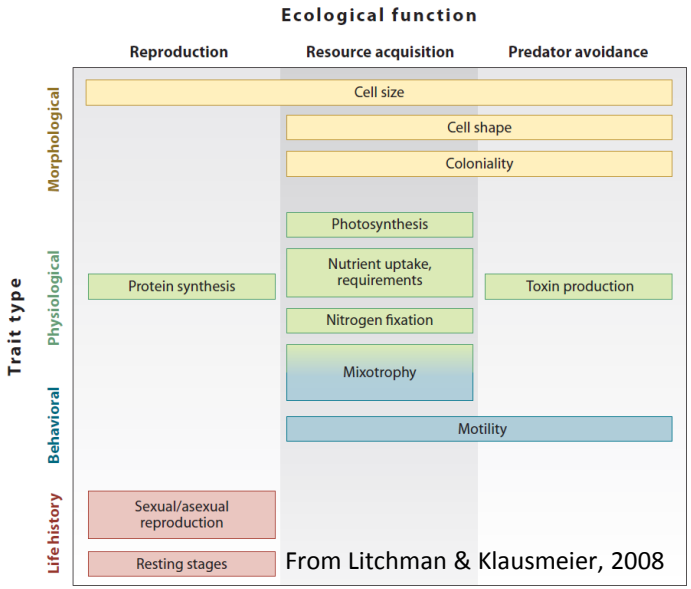
Ecological/physiological **traits** selection driven by Environmental conditions

➢ Abiotic factors

- Water column dynamic : stratification/MLD/ turbulence
- Light/nutrients availability

➢ Biotic interactions

-Resource competition
- Grazing



From Litchman & Klausmeier, 2008

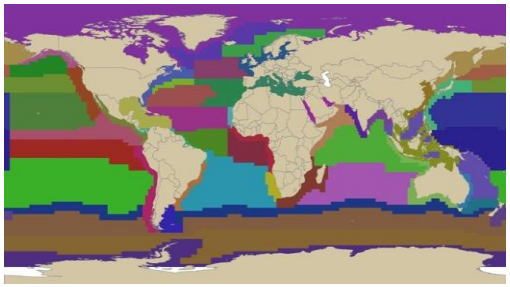
Assemblage composition
Ecosystem functioning

=> BIOREGIONALISATION

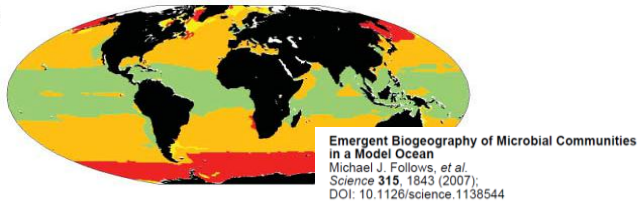
Phytoplankton biogeography :

From global scale ….

WELL – KNOWN



Longhurst Biogeographical Provinces (1995)



Diatoms – other large –
Prochlorococcus – other small

… to regional (coastal) scale

LESS STUDIED

Temperate coastal systems dynamic is complex :

- seasonal variations
- spatial heterogeneity

→ mesoscale structures
- fronts
- filaments/jets

Light/nutrients gradients

↓

Ecological niches

Understanding of small scale phytoplankton functional diversity distribution is relevant for :

- Biogeochemical budgets (production, export)
- Trophic interactions (fisheries)
- Conservation and management (MPA)

CENTRAL QUESTIONS

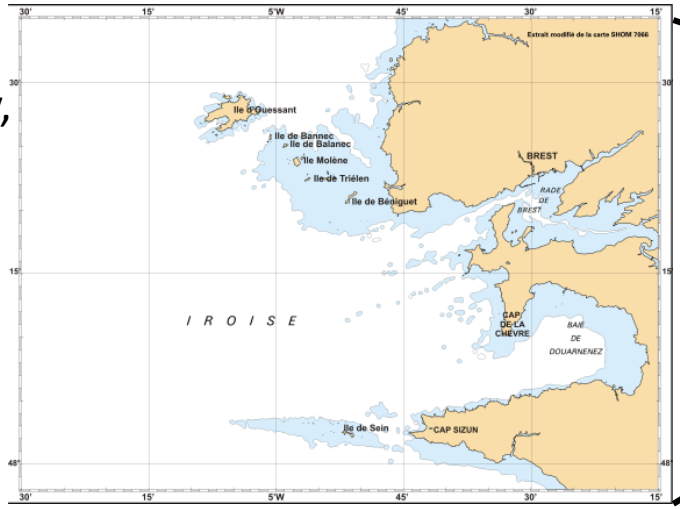
How to explain the spatial and temporal changes in phytoplankton communities based on environmental gradients (frontal dynamics ,mixed layer depth, nutrients, etc.) in the Iroise Sea coastal ecosystem ?

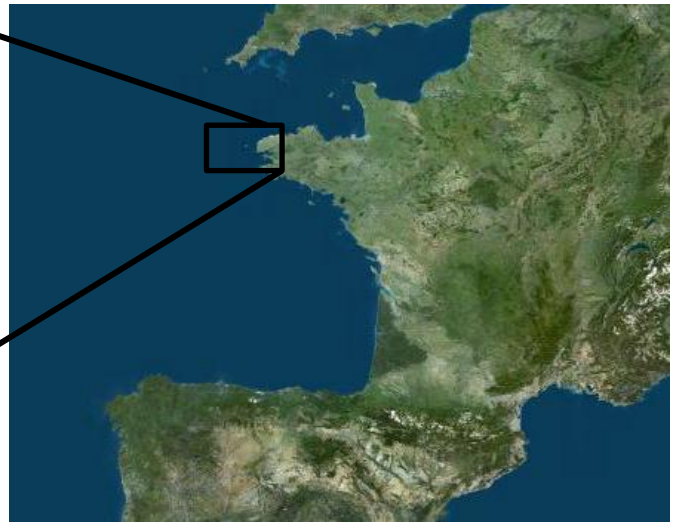
What are the main drivers of simulated patterns of biomass and diversity ?

STUDY AREA

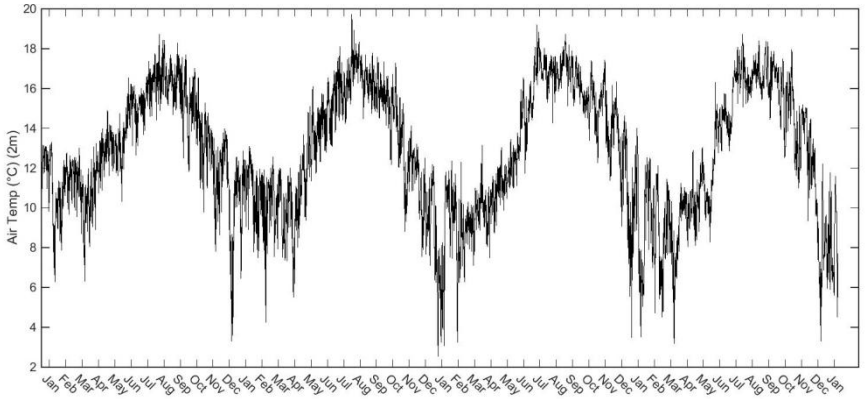
Iroise Sea

West Brittany, France

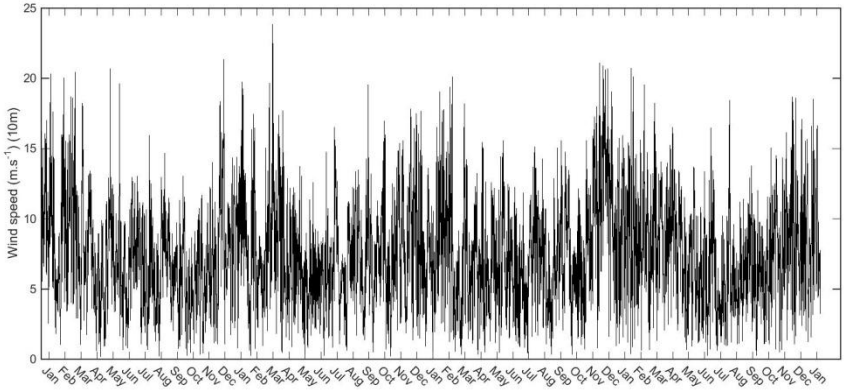




Air temperature (°C)

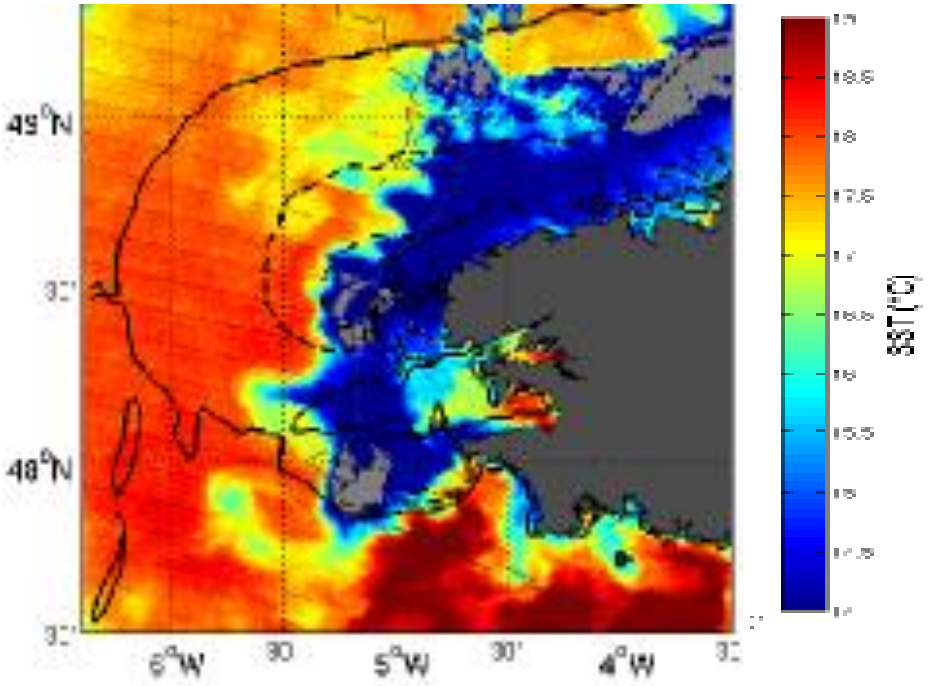


Wind speed ($m.s^{-1}$)



STUDY AREA

Iroise Sea



Strong tidal currents+ seasonal atmospheric forcing

=

- Ushant tidal front (June to October)
- Baroclinic instabilities (density gradients)

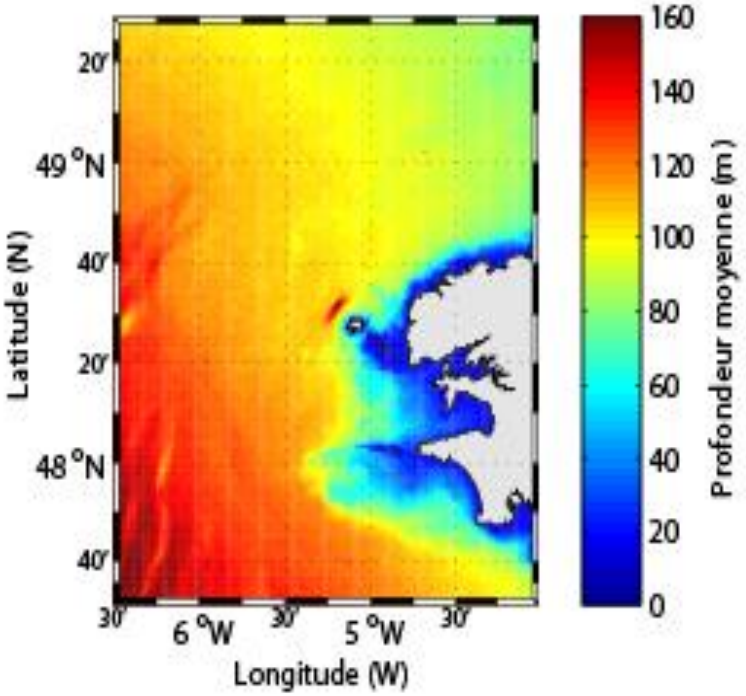
→ **Nutrient supply**

→ **Enhanced primary production**

METHOD

modelling design

ROMS AGRIF 3D (V3)



- **Horizontal resolution : 1.5 km (120 x 143)**
- **Vertical resolution : 30 sigma levels**

- **Atmospheric forcings (T° Air, humidity, precipitations, wind speed, short- longwaves radiations) : ALADIN atmospheric system (CNRM) (3h)**

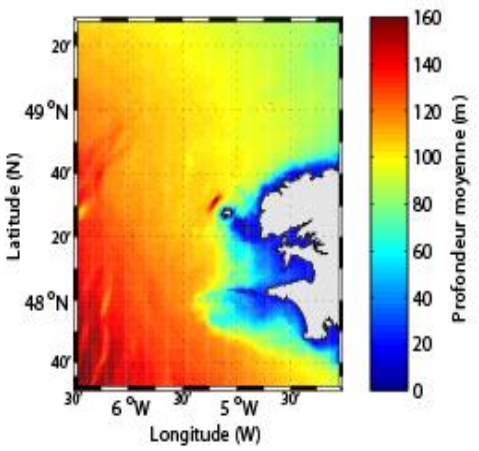
- **Boundaries Conditions (T°, S , velocities, NO_3, PO_4, SiO_2) : NEMO PISCES North Atlantic Model (0.25 °) - 5 days**

- **Tidal cycle : COMAPI (Coastal Modeling for Altimetry Product Improvement)**

- **Rivers (Q, T°, S, NO_3, PO_4, SiO_2) : Agence de l'eau Loire Bretagne et réseau ECOFLUX (Monthly climatology)**
  Aulne, Elorne

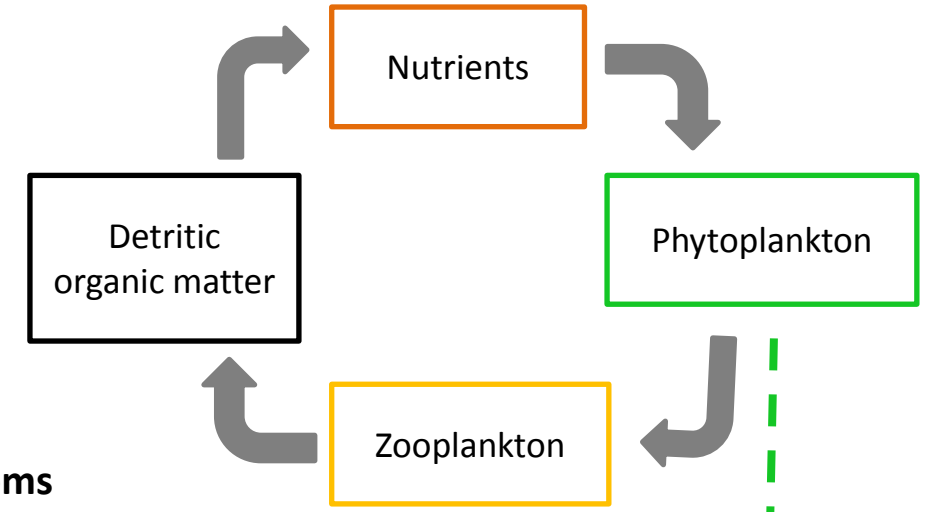
modelling design

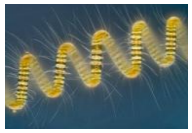
ROMS AGRIF V3 (1.5 km resolution)



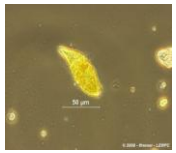
+

'DARWIN' plankton diversity model (Follows *et al.*, 2007)

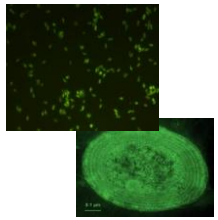




Diatoms
(Si, high μ, high ksat)



Nanoeukaryotes
(high μ, high ksat)



Picoplankton (Euk. + Prok.)
(low μ, low ksat)

Prochlorococcus
(use $NH_4 - NO_2$)

Functional diversity

Specific diversity
30 'species' per PFT

Technical Aspects

-120 phytoplankton types run
=
-144 3D advected tracers
- 167 3D diagnostics variables

-Time step = 100 sec

- MPI : 96 CPUs (queue parallel256)

-1 month ≈ 8h - 1 restart/month
-1 yr ≈ 7 days

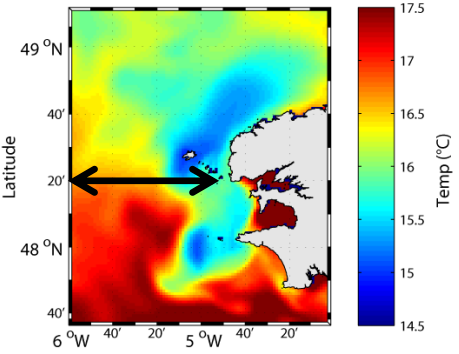
5 days average outputs :
Stockage ≈ 6 G /month (72 Go /year) (/temp)

Post-processing : matlab on service8

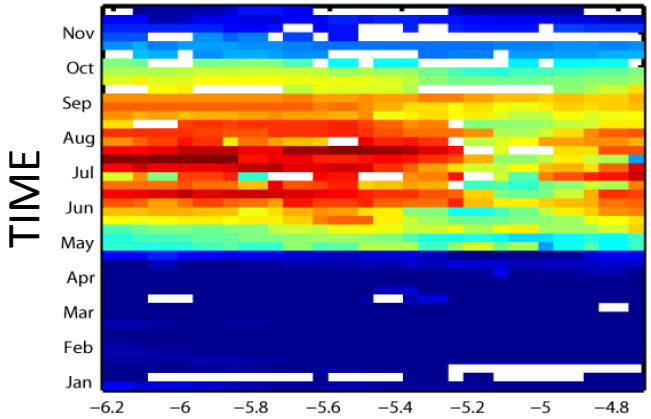
RESULTS

model outputs

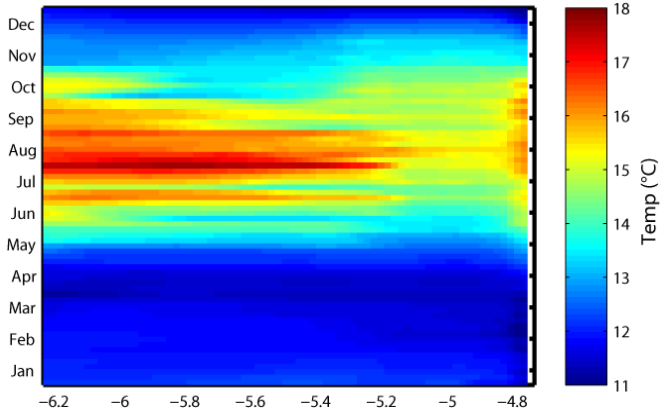
SST



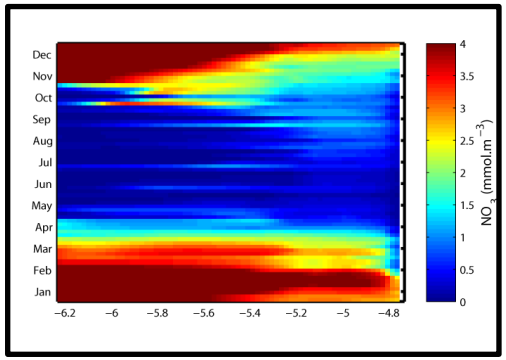
SATELLITE
MODIS



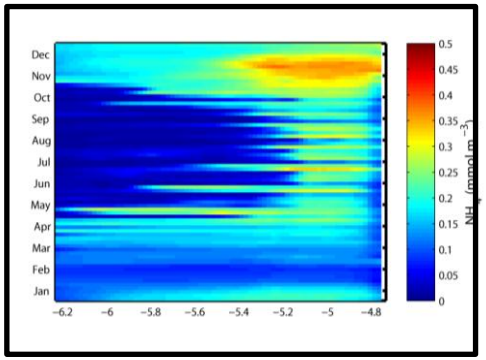
MODEL
ROMS -DARWIN



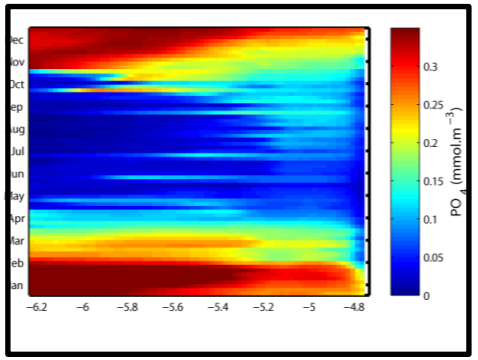
NO_3



NH_4



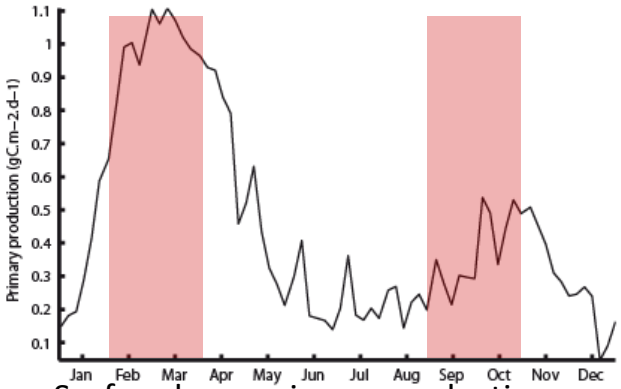
PO_4



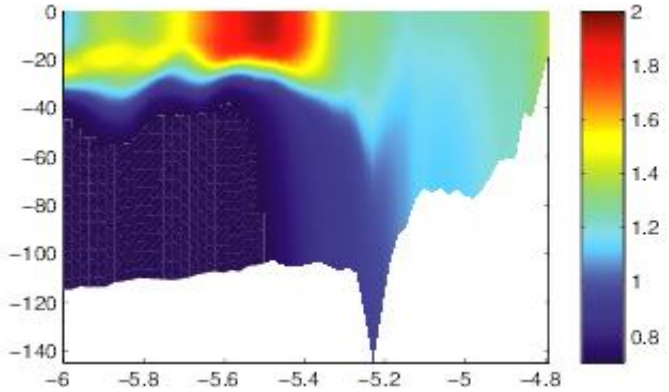
RESULTS

model validation

ANNUAL PRIMARY PRODUCTION



Surface layer primary production over the whole domain



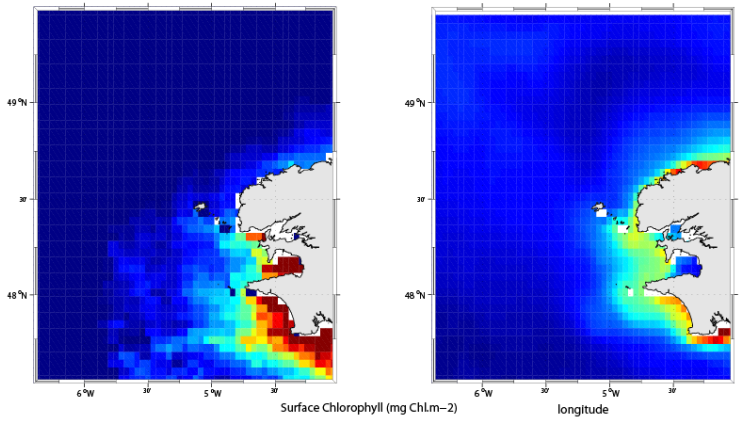
Vertical chlorophyll distribution (2008 September 25th)

SURFACE CHLOROPHYLL

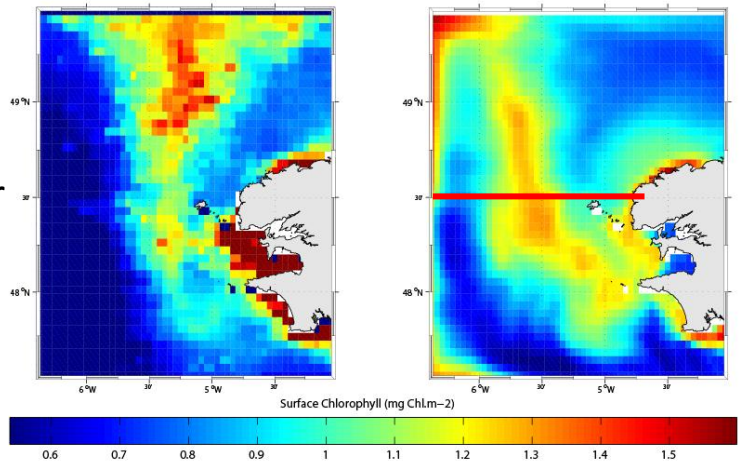
SATELLITE MODIS

MODEL ROMS -DARWIN

Spring



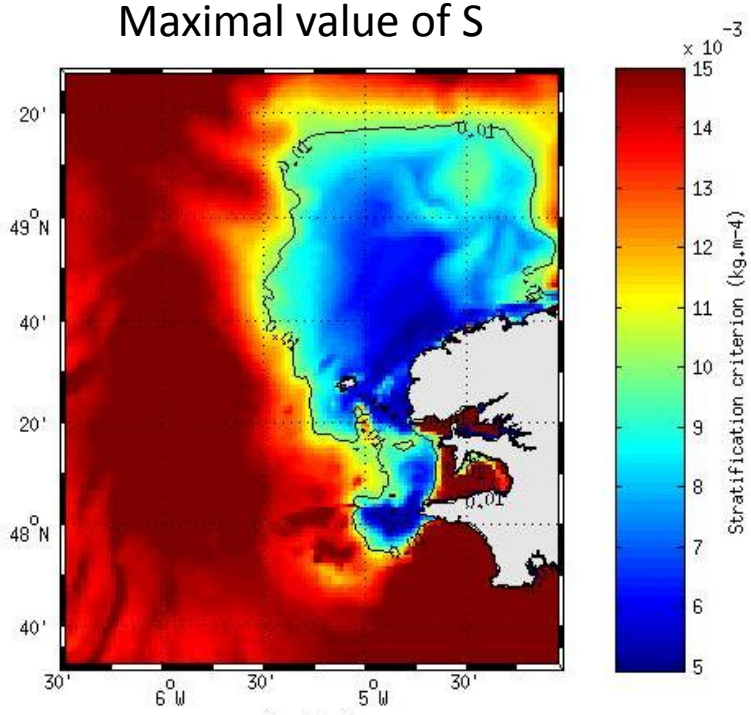
Late summer

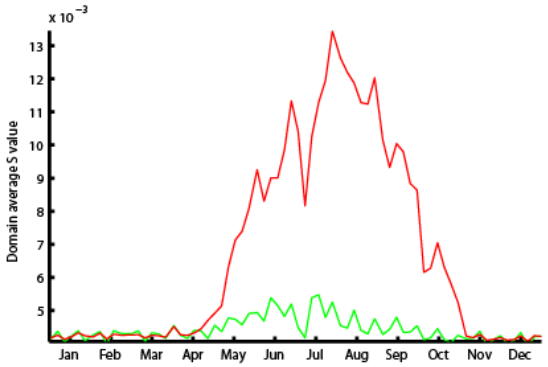


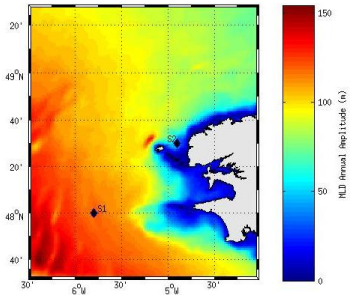
Stratification index : vertical density gradient S

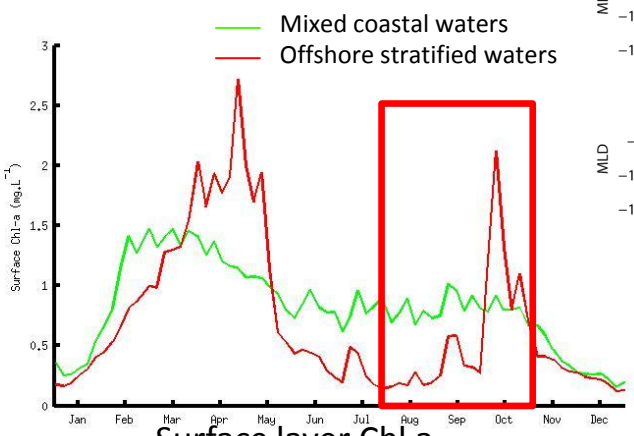
$$S = \frac{|\rho fond - \rho surf|}{h}$$

Maximal value of S

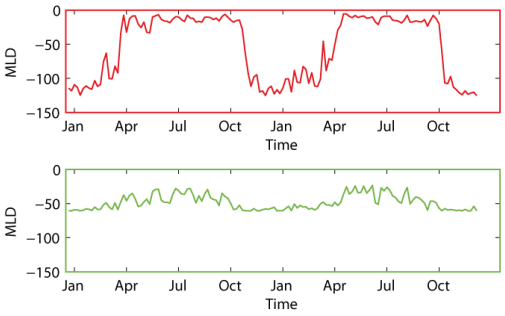








Surface layer Chl a

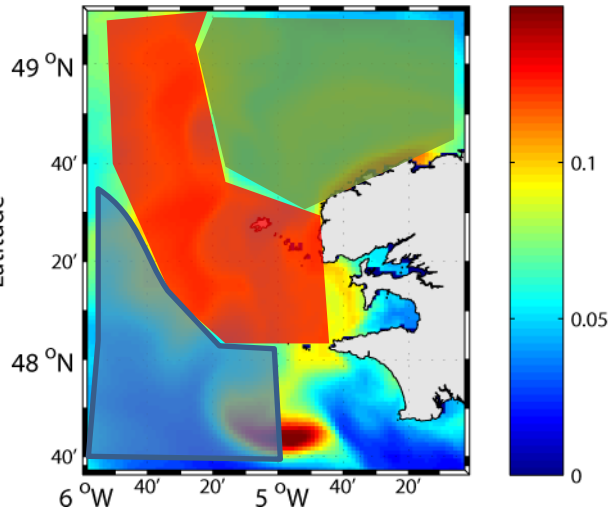


RESULTS

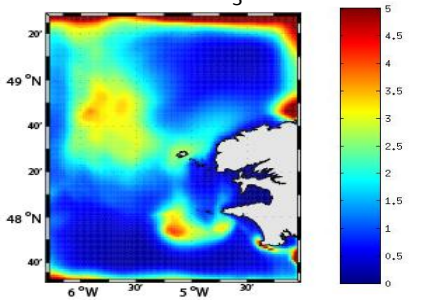
spatial heterogeneity

PHYTOPLANKTON

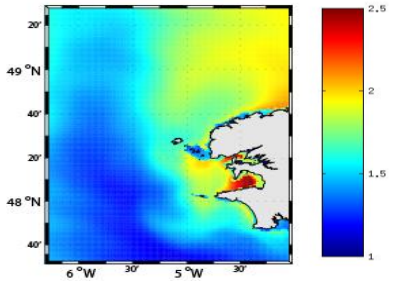
($g\ C.m^{-3}$)



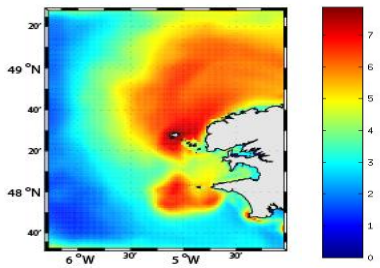
NO_3 (mmol $N.m^{-2}$)



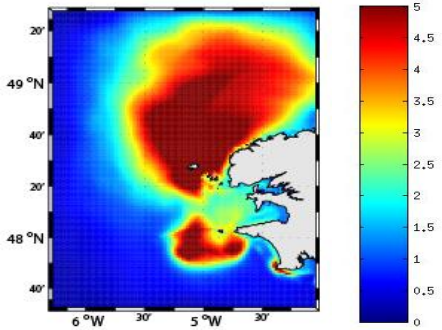
ZOOPLANKTON ($g\ C.m^{-2}$)



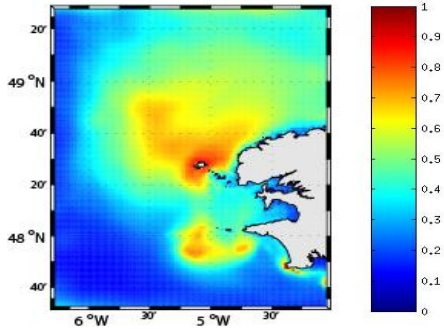
NET PRIMARY PRODUCTIVITY d^{-1}



$NO_2 + NH_4$ (mmol $N.m^{-2}$)



PO_4 (mmol $P.m^{-2}$)

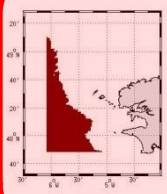


-Well-mixed area : nutrient recycling, low-NO_3/high NH_4 NO_2 - remineralization – high productivity levels

-Frontal region : low zooplankton biomass/ high phytoplankton biomass

- Offshore poor-nutrients waters : low biomass

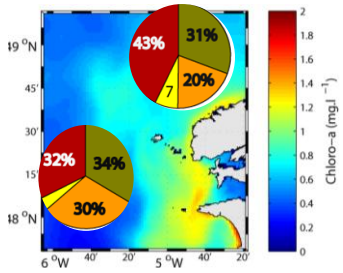
RESULTS community composition

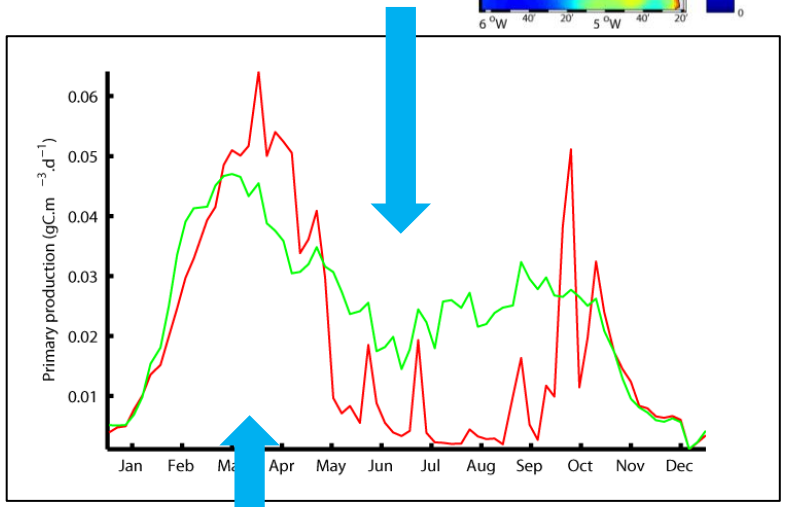


Offshore stratified Waters

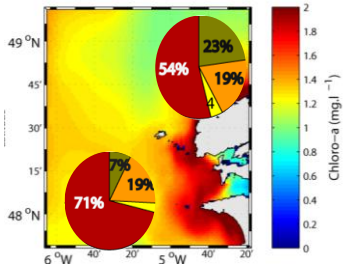
Coastal Mixed Waters

Surface distribution

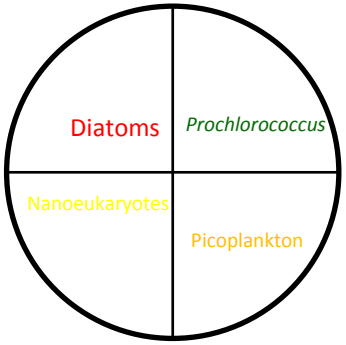




Surface distribution



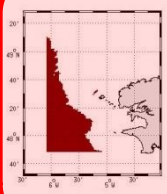
Relative contribution (%)



- Lowest contribution of diatoms to total *chl a* offshore, during the summer season

RESULTS

diversity



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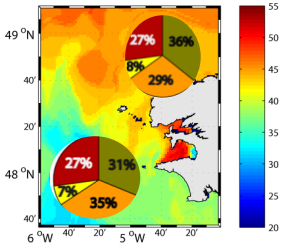
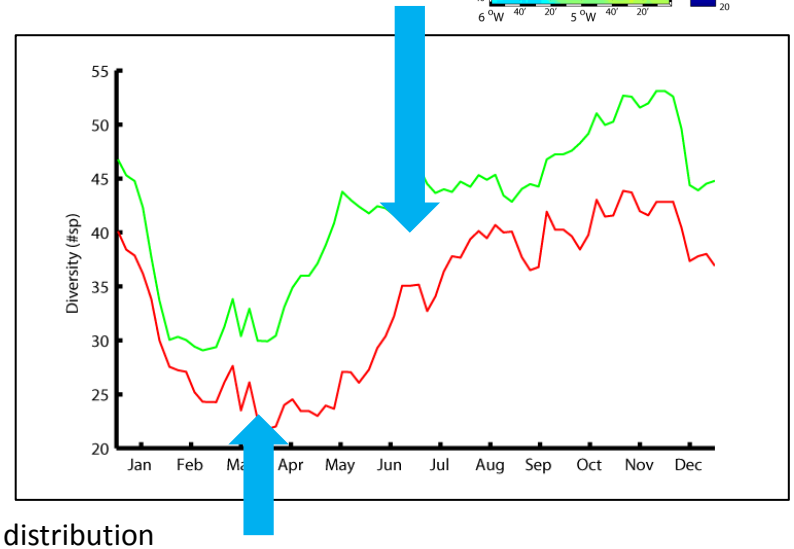
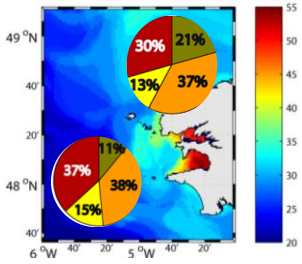
Surface distribution





Surface distribution

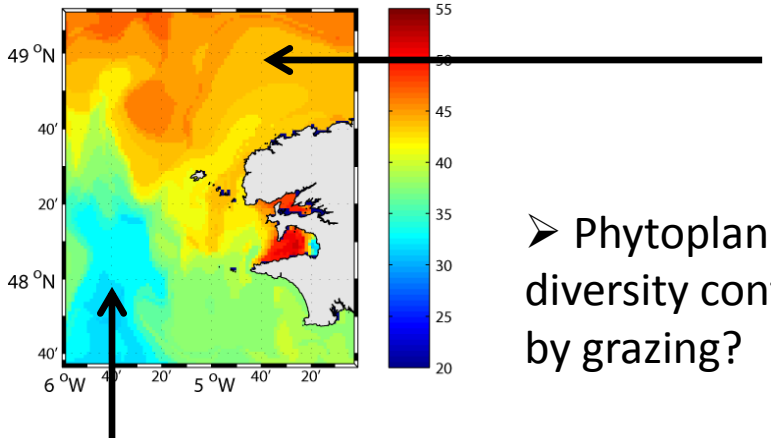


- Low diversity associated to spring phytoplankton peak
- Highest diversity observed in the well-mixed area
- Very low spatial variability in relative contribution of each PFT to total species richness

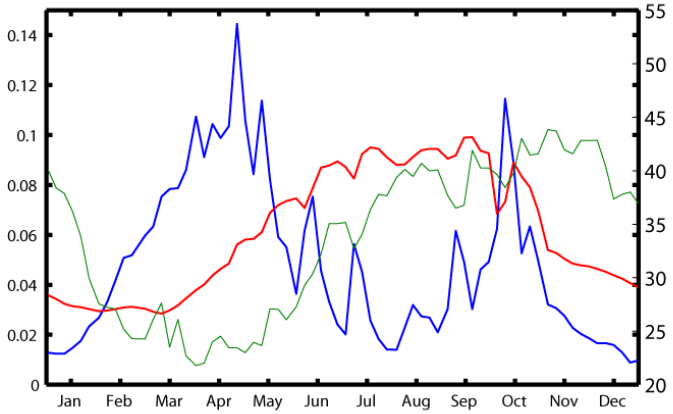
RESULTS

productivity- diversity relationship

Surface Diversity in september



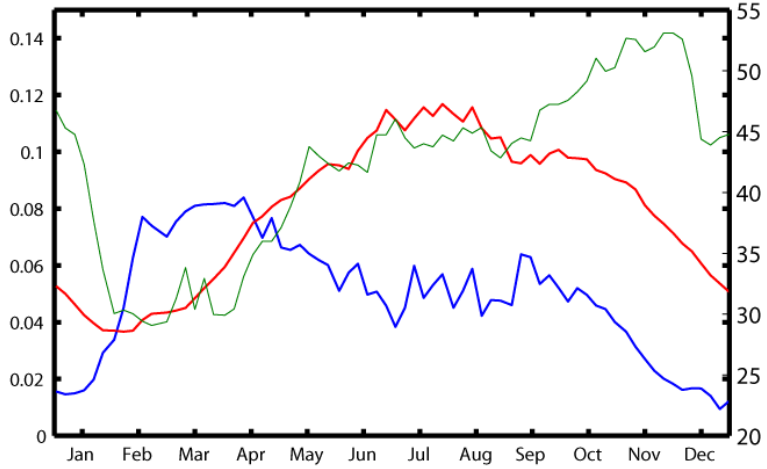
➢ Phytoplankton diversity controlled by grazing?

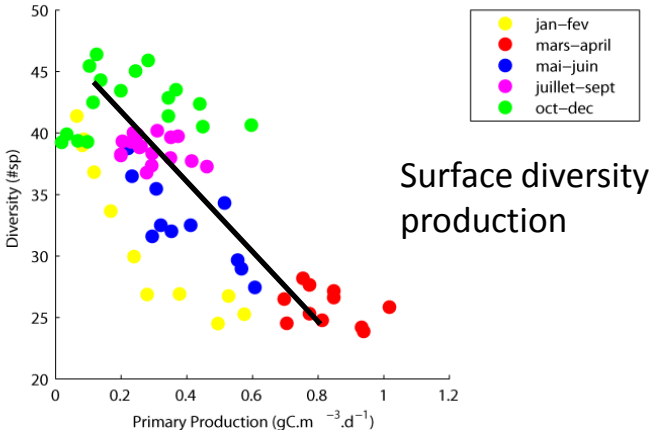


Zooplankton (g C.m^{-2})

Phytoplankton (g C.m^{-2})

Total diversity (#sp)



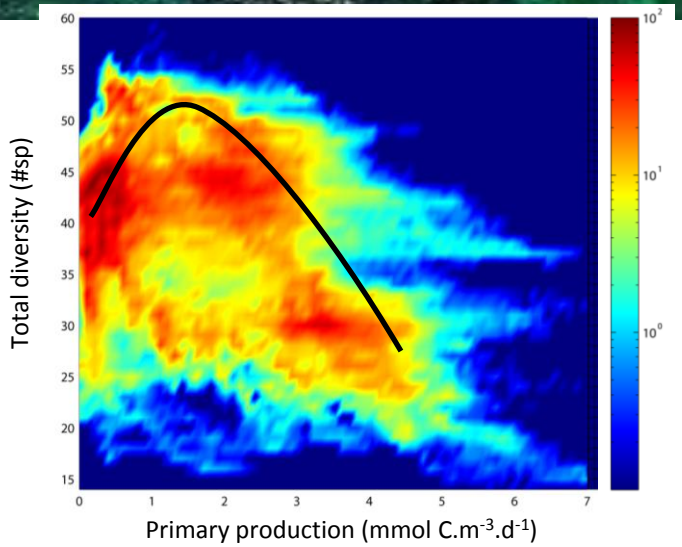


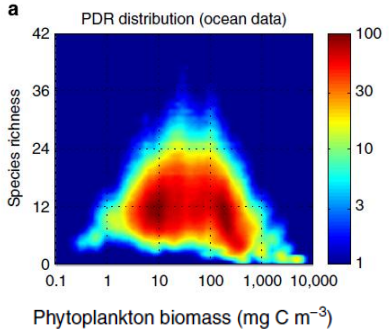
Surface diversity vs. production

➢ Spring phytoplankton peak is associated to low diversity

RESULTS

productivity- diversity relationship



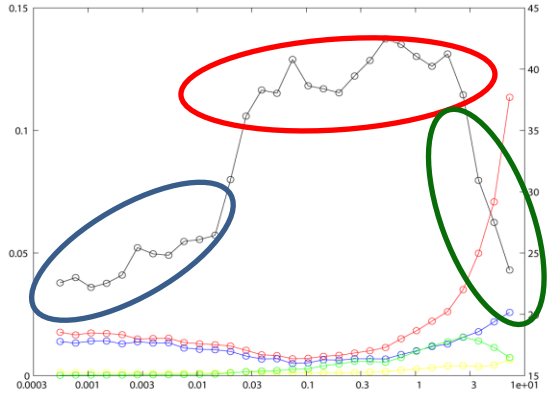


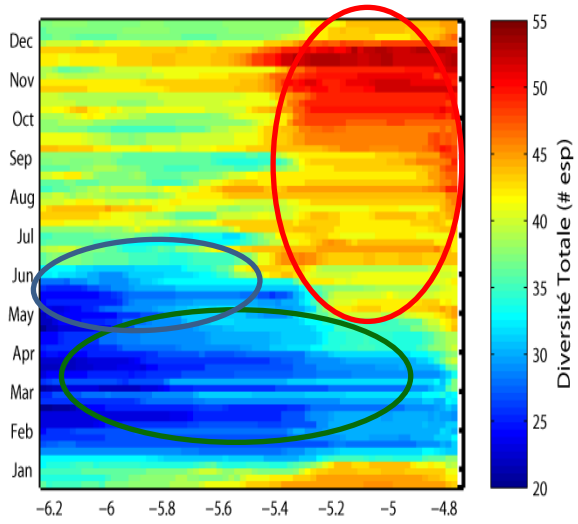
Vallina *et al., Nat. Comm.*, 2014

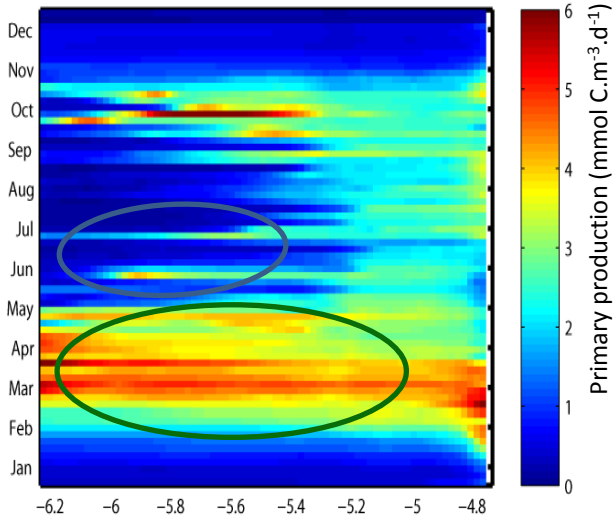
- Transient systems(opportunists)
- Oligotrophic - low diversity offshore waters (April – May)
- Stable – grazers-controlled stationary systems (summer)

Diatoms *Prochlorococcus*
Nanoeukaryotes Picoplankton
(gC.m-3)

Total diversity (#sp)







SUMMARY

Main conclusions :

- 3 sub-regions :
  - coastal homogeneous and low seasonal variations
  - high biomass, highly dynamic Ushant Front
  - low biomass – nutrients depleted offshore surface waters

- Spring bloom generally characterized by low diversity

- Strong apparent control of phytoplankton diversity by zooplankton biomass

- Unimodal productivity-diversity relationship

Outlook :

- Impact of functional and trait diversity on ecosystem's emergent properties

- Comparison with a PFT classic model (PISCES model)

- Model confrontation to observations (taxonomic dataset from *in situ* sampling)


THANK YOU FOR YOUR
ATTENTION