

Plankton dynamics at the mesoscale, a case study of a coastal cyclonic eddy in the California Current System

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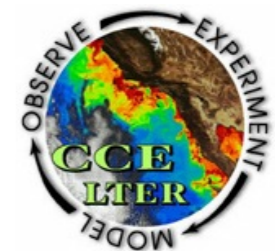
Peter J.S. Franks, SIO, San Diego CA, USA

Pascal Rivière, LEMAR, Brest, France

Xavier Capet, LOCEAN, Paris, France

Bruno Blanke, LPO, Brest, France

Nicolas Grima, LPO, Brest, France



SYNBIOS - 6-7-8 July 2015 - Paris

Outline

INTRODUCTION

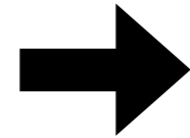
MODEL SETUP

EDDY CHARACTERIZATION

ECOLOGICAL IMPLICATIONS

CONCLUSION AND PROSPECTS

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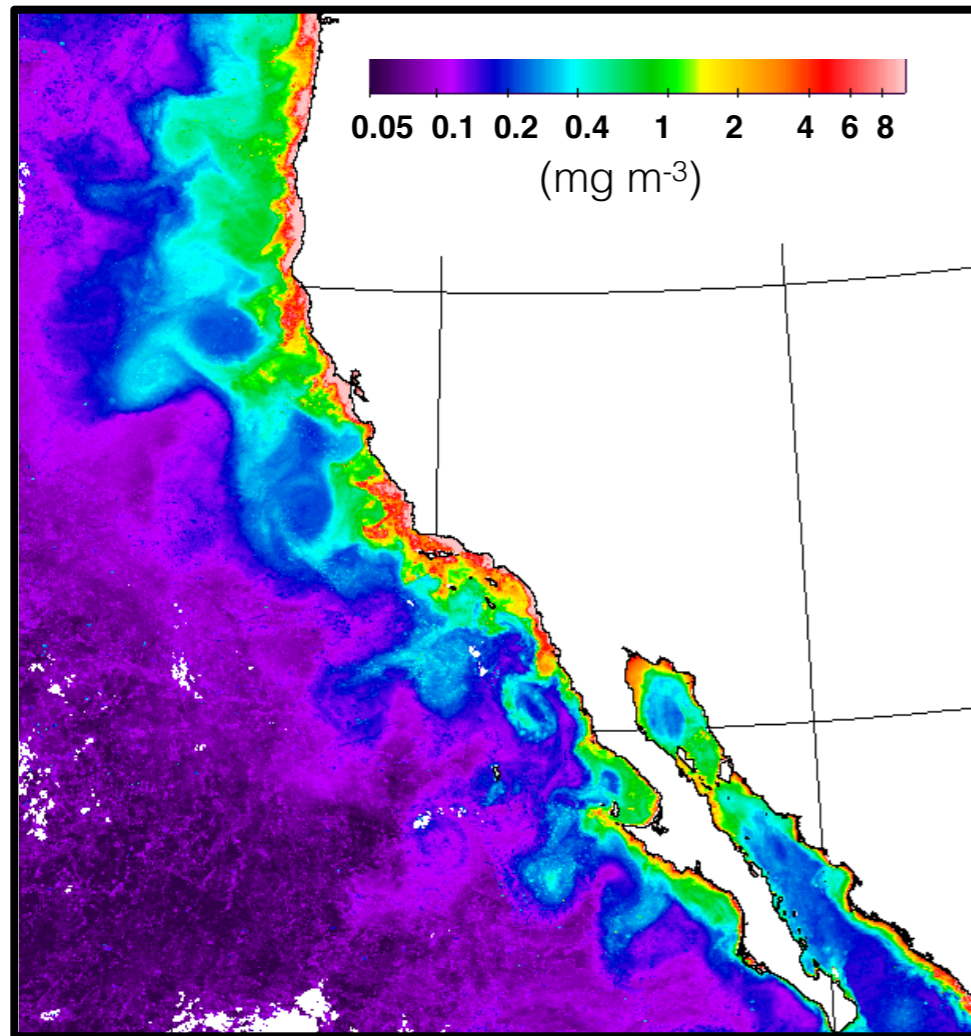
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Chl a, 15-30 Sept. 2003 (SeaWiifs)



Eddies in coastal upwelling systems:

Overall effect: mesoscale turbulence
export 13-24% of coastal material offshore and
reduces net primary production

Gruber et al. 2011

Nagai et al., 2015

In situ high subsurface production with
various ecosystem structures

Almazàn-Becerrill et al. 2012

Stramma et al. 2013

Biological role of eddies in upwelling system
is poorly documented

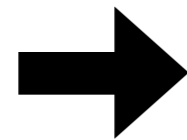
Questions:

Which mechanisms influence
the ecosystem dynamics in eddies?

What are the relative contributions of the
horizontal and vertical advection
in the biological production?

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Physical model

ROMS - Regional Ocean Modeling System

- { Eddy-resolving
- { 5 km horizontal resolution
- { 32 vertical levels (σ -coordinates)

Capet et al, 2008

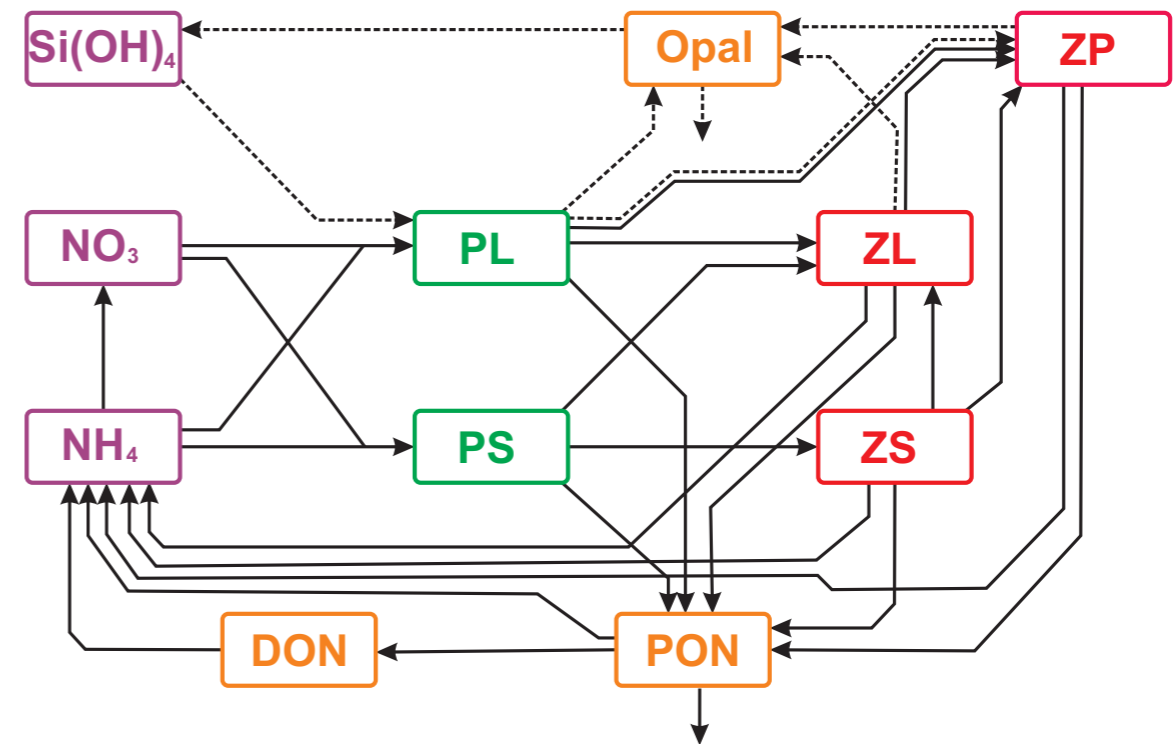
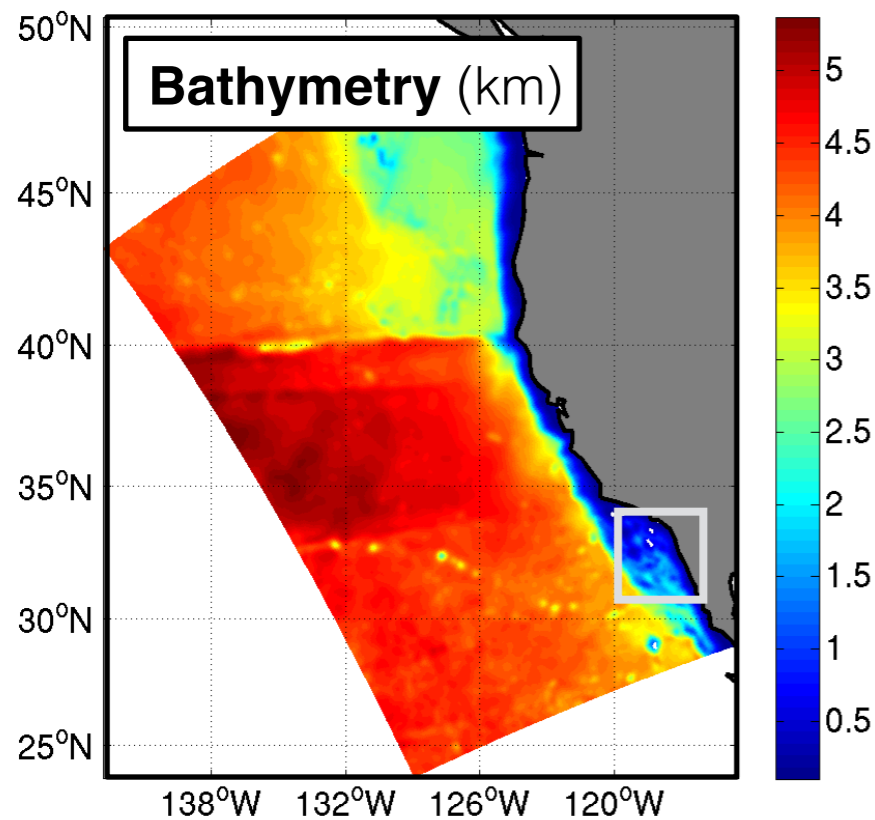
Ecosystem model

NEMURO - North Pacific Ecosystem Model for Understanding Regional Oceanography

Kishi et al, 2007

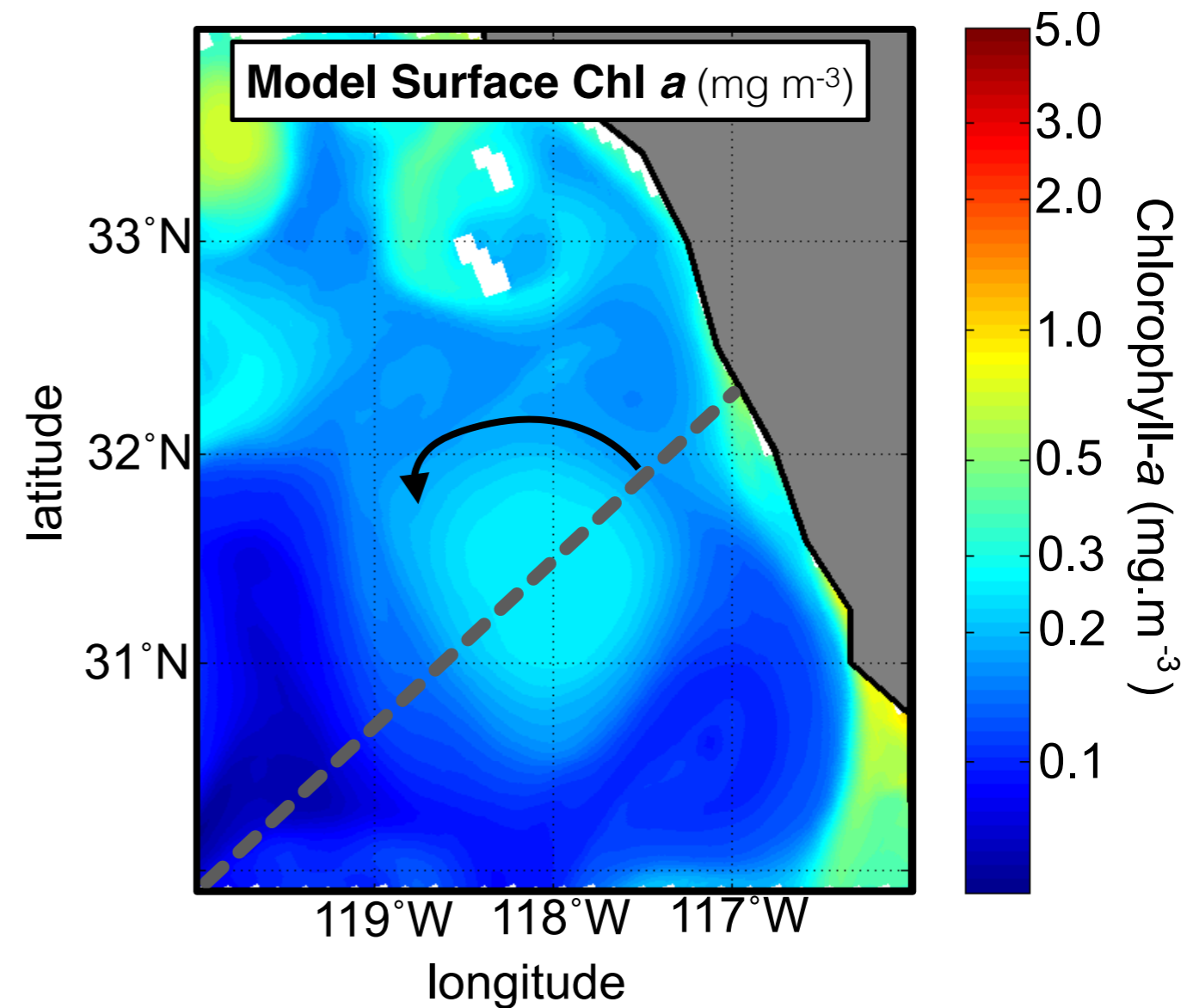
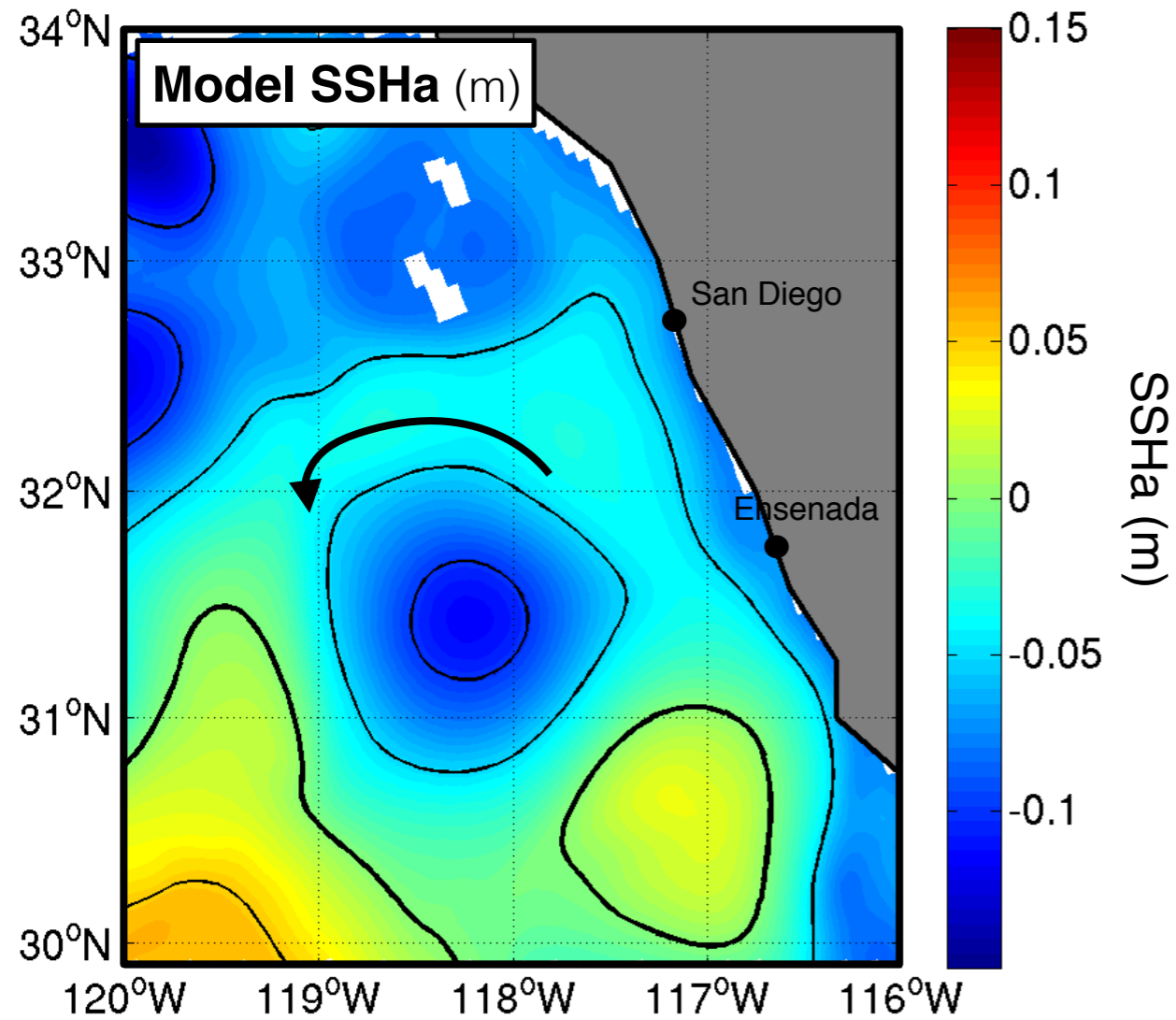
- 2 size classes for phytoplankton
- 3 size classes for zooplankton
- Nitrogen and Silicon cycles

Parameters adapted to CCS
Li et al, 2010



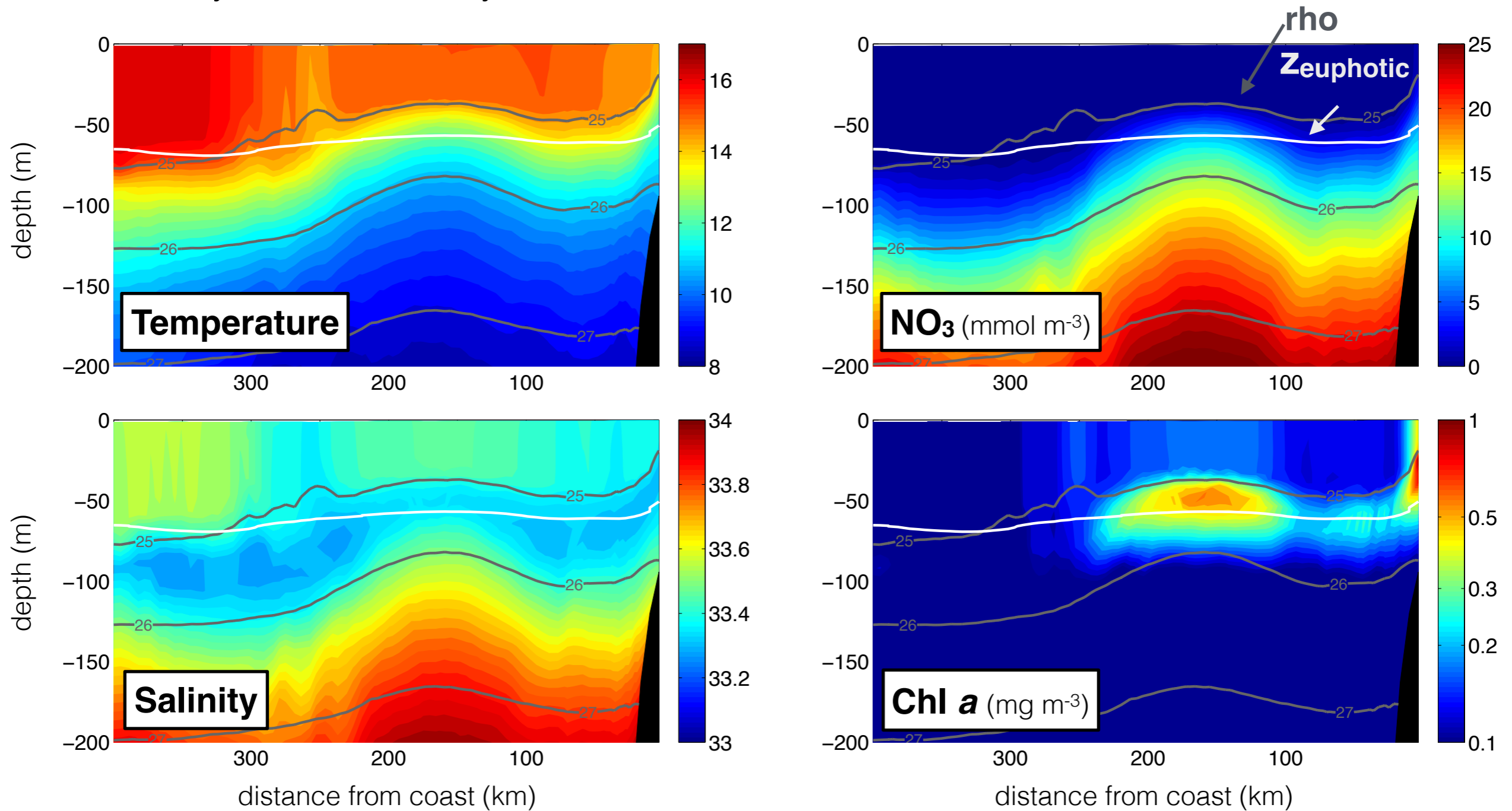
Identification of a specific eddy

- Cyclonic eddy in March, Year 2
- Similar features observed with satellite data



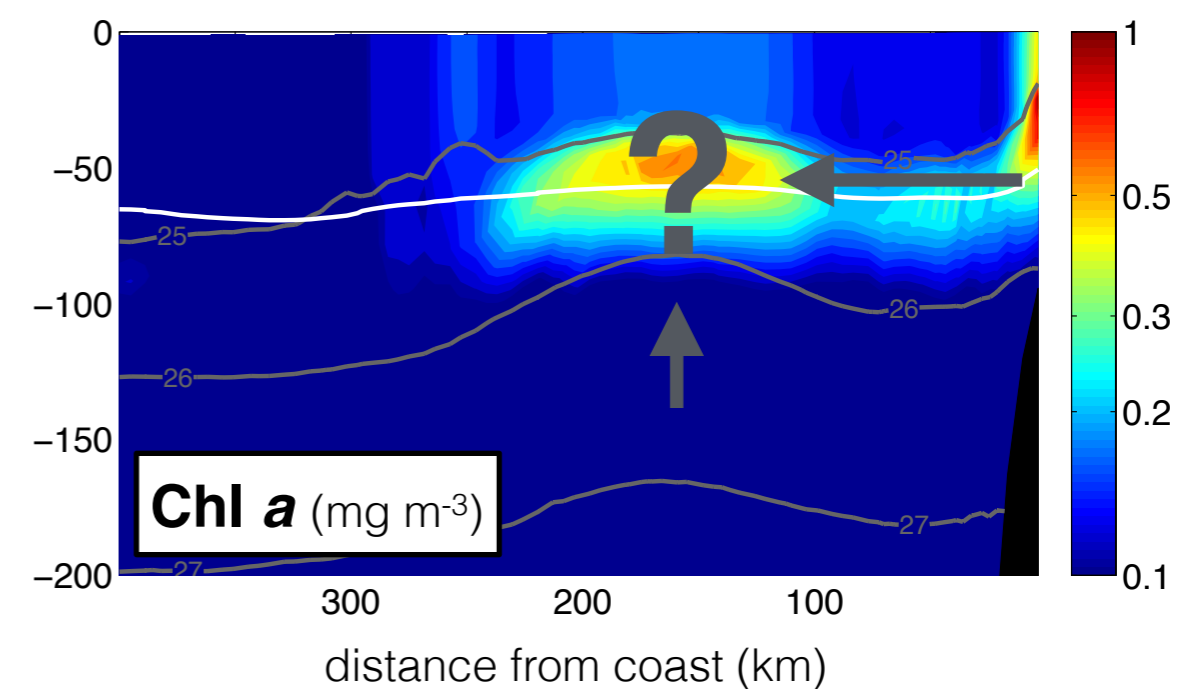
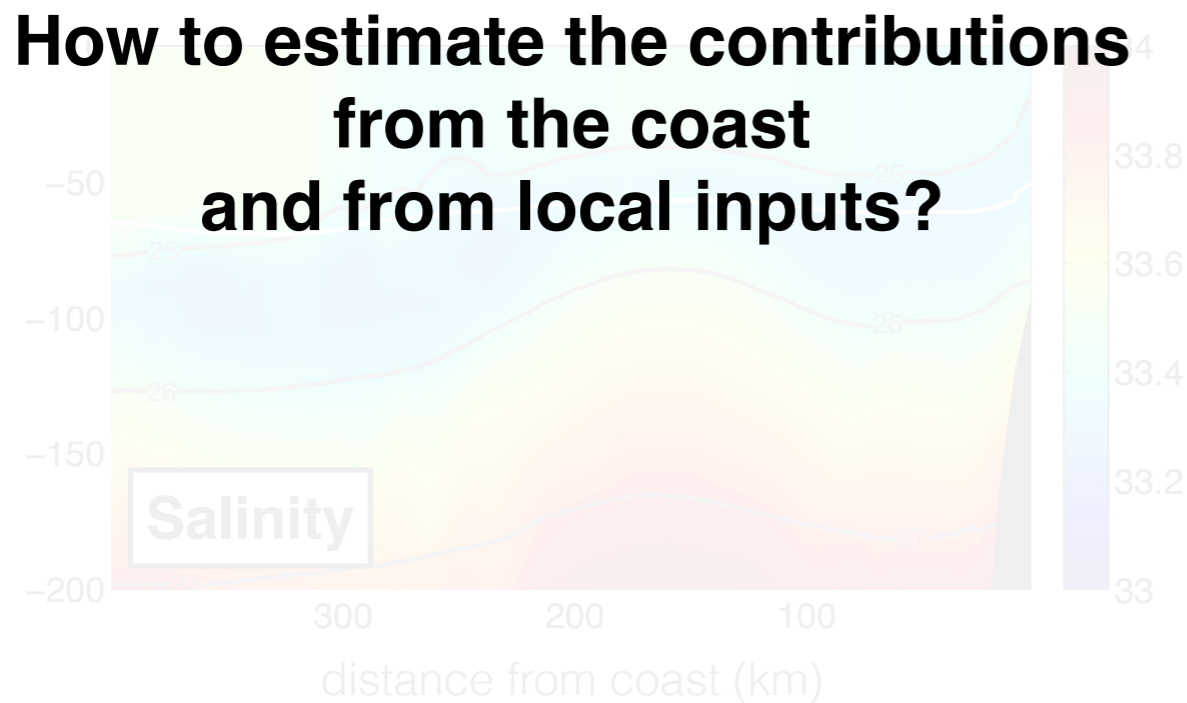
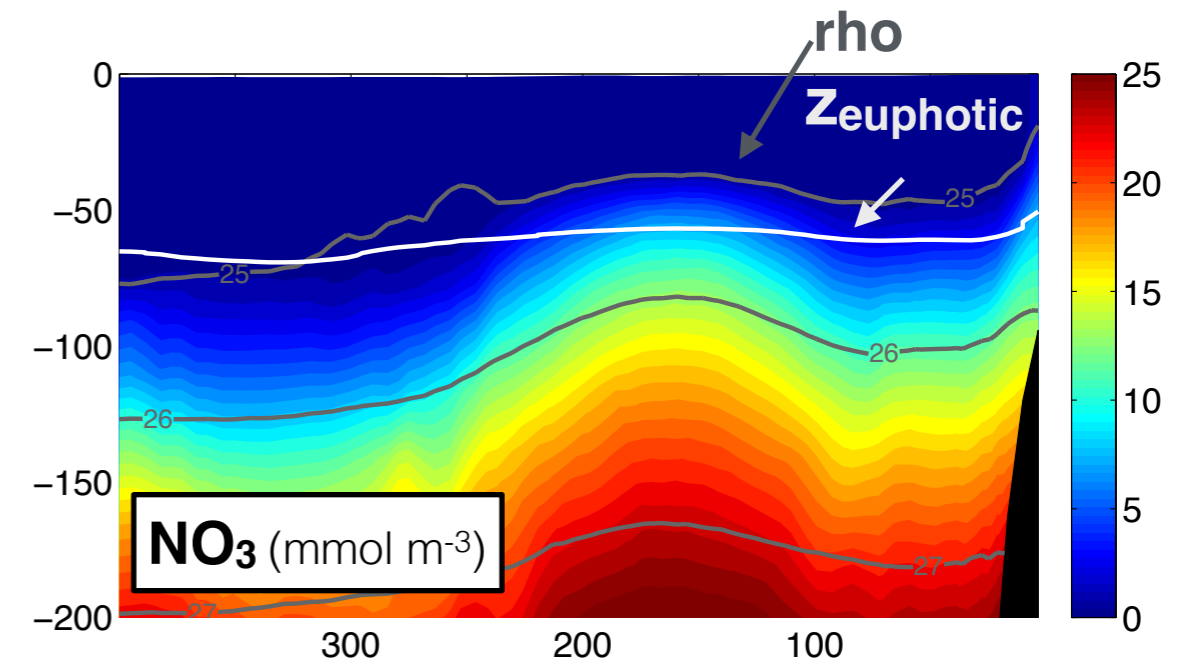
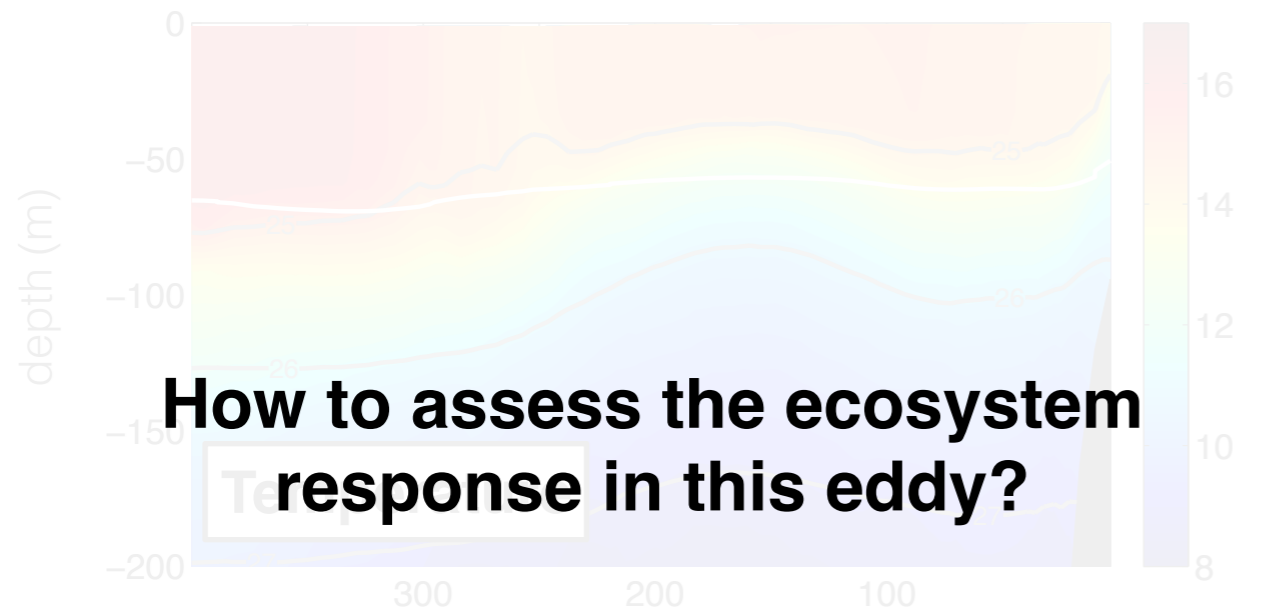
Identification of a specific eddy

- Dominging of isolines
- Eddy core: cold, salty, nutrient-rich, subsurface maximum of chl a



Identification of a specific eddy

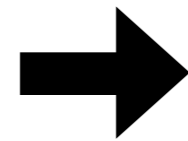
- Dominging of isolines
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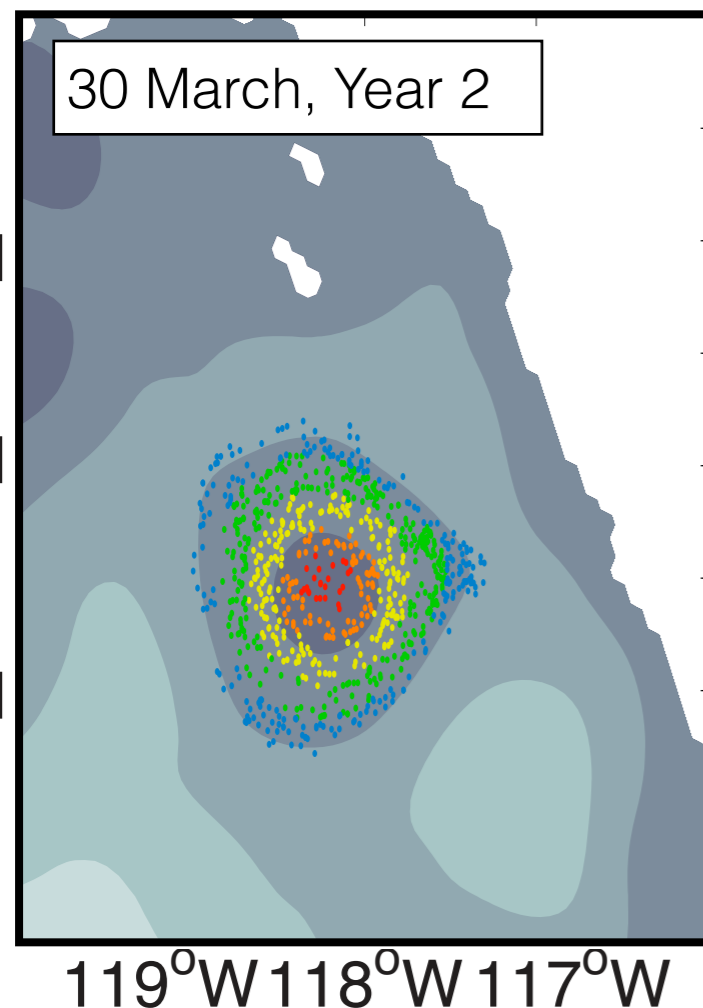
CONCLUSION AND PROSPECTS

Lagrangian experiments: Ariane

General overview:

- Compute Lagrangian trajectories (3D) using Eulerian velocity fields (offline)
- Diagnose main pathways of water masses following particles

Blanke and Raynaud, 1997

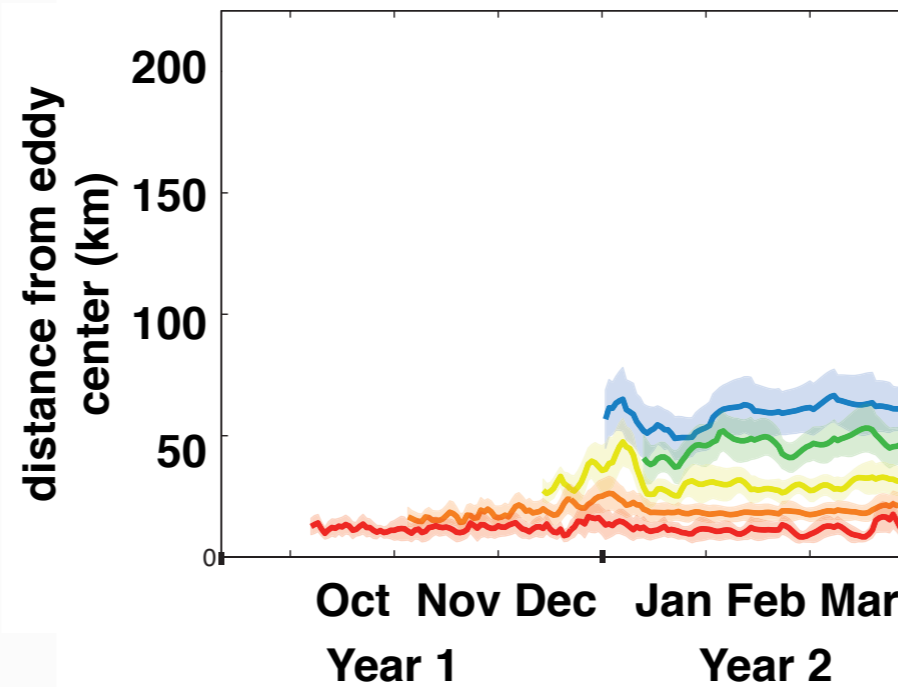
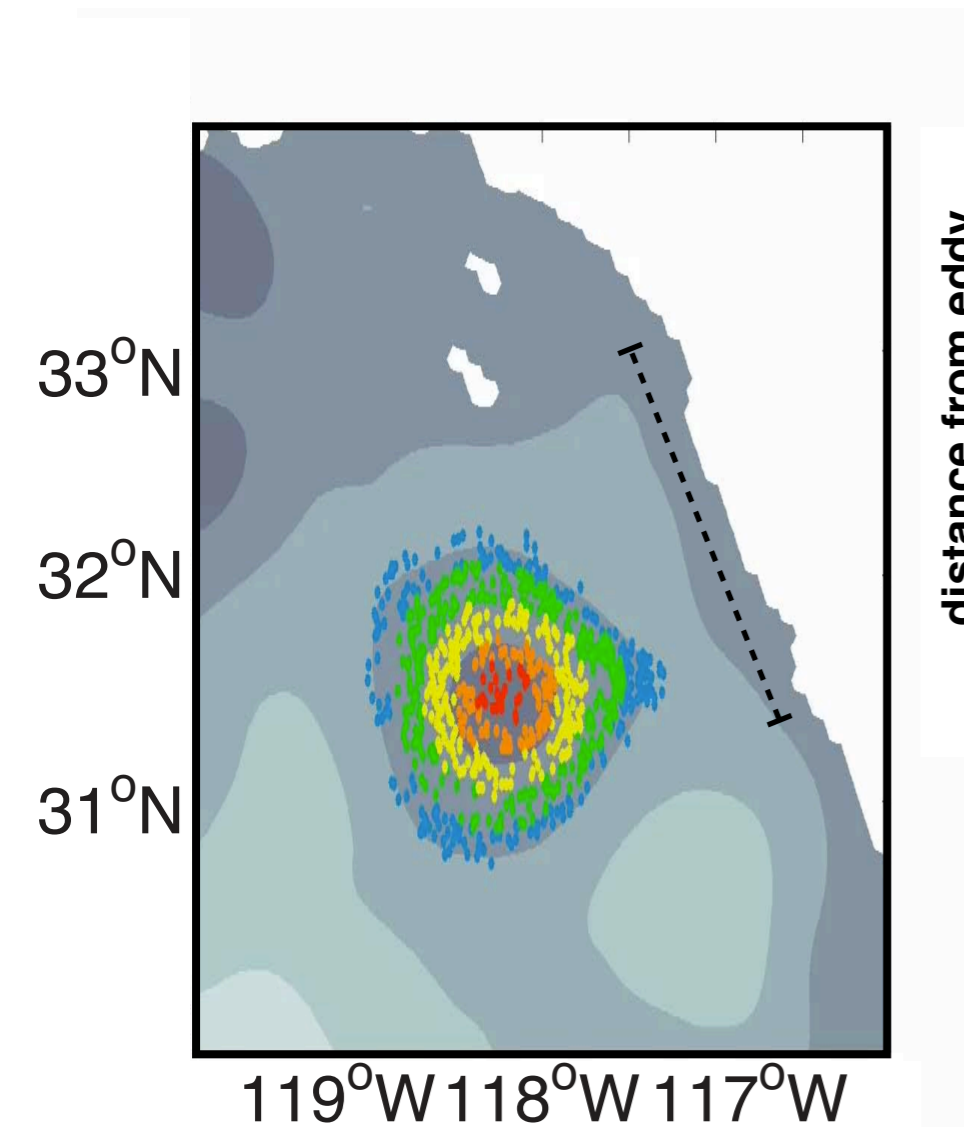


Our Approach:

- Initialization of the particles = seeding the eddy
 - Horizontally: from the core to the edge following SSH range of values
 - Vertically: from surface to 200 m depths
- Experiments:
 - Backward in time: to identify source waters
 - Forward in time: to follow the fate of this eddy
 - Both: to assess key characteristics of this eddy:
 - > average distance of each pool from eddy center

Lagrangian experiments: Ariane

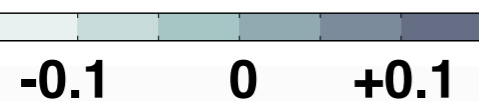
Backward Experiment:



- Distance of particle pools from the eddy center is relatively constant
- Weak lateral mixing

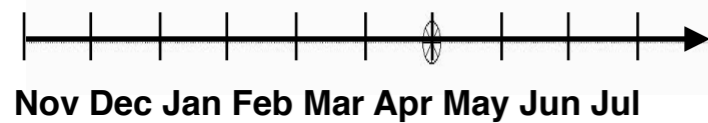
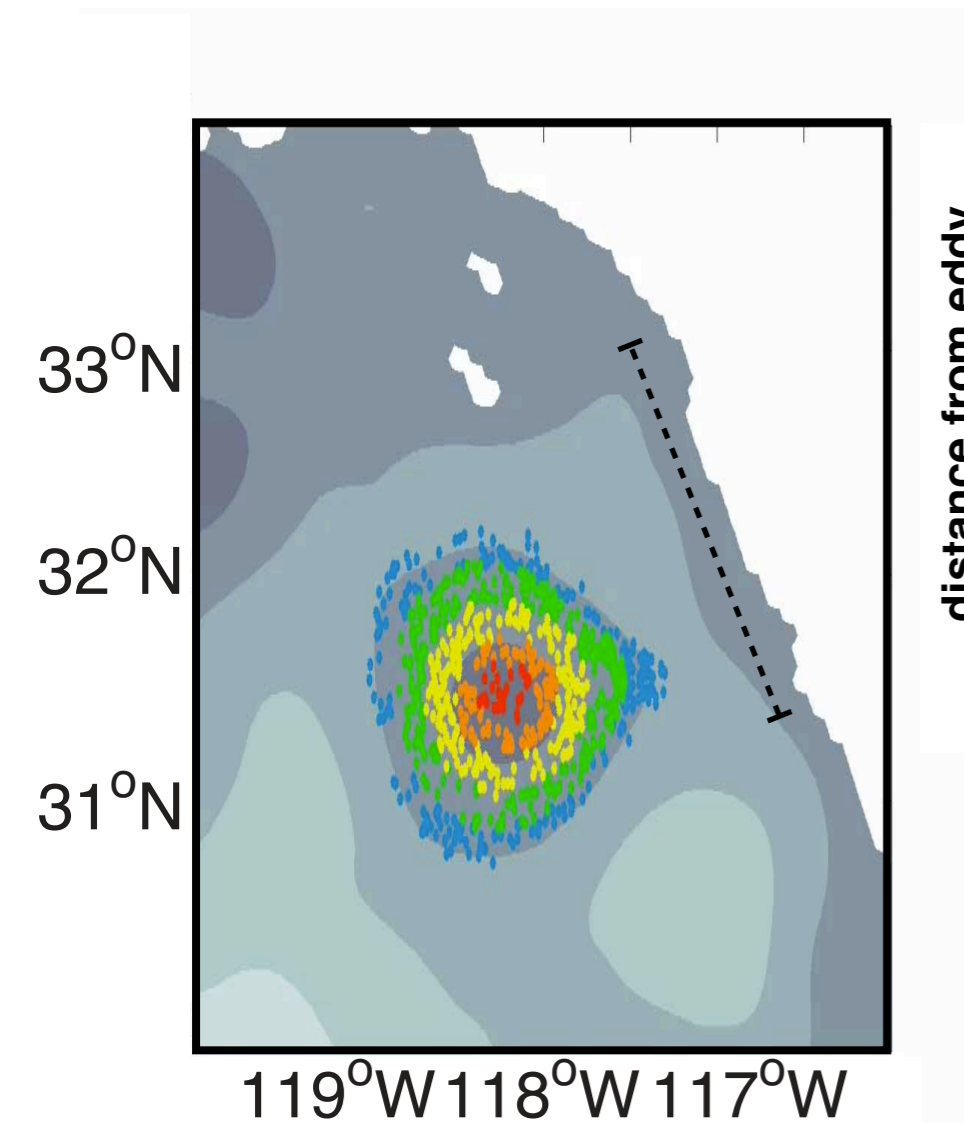


SSH (m)

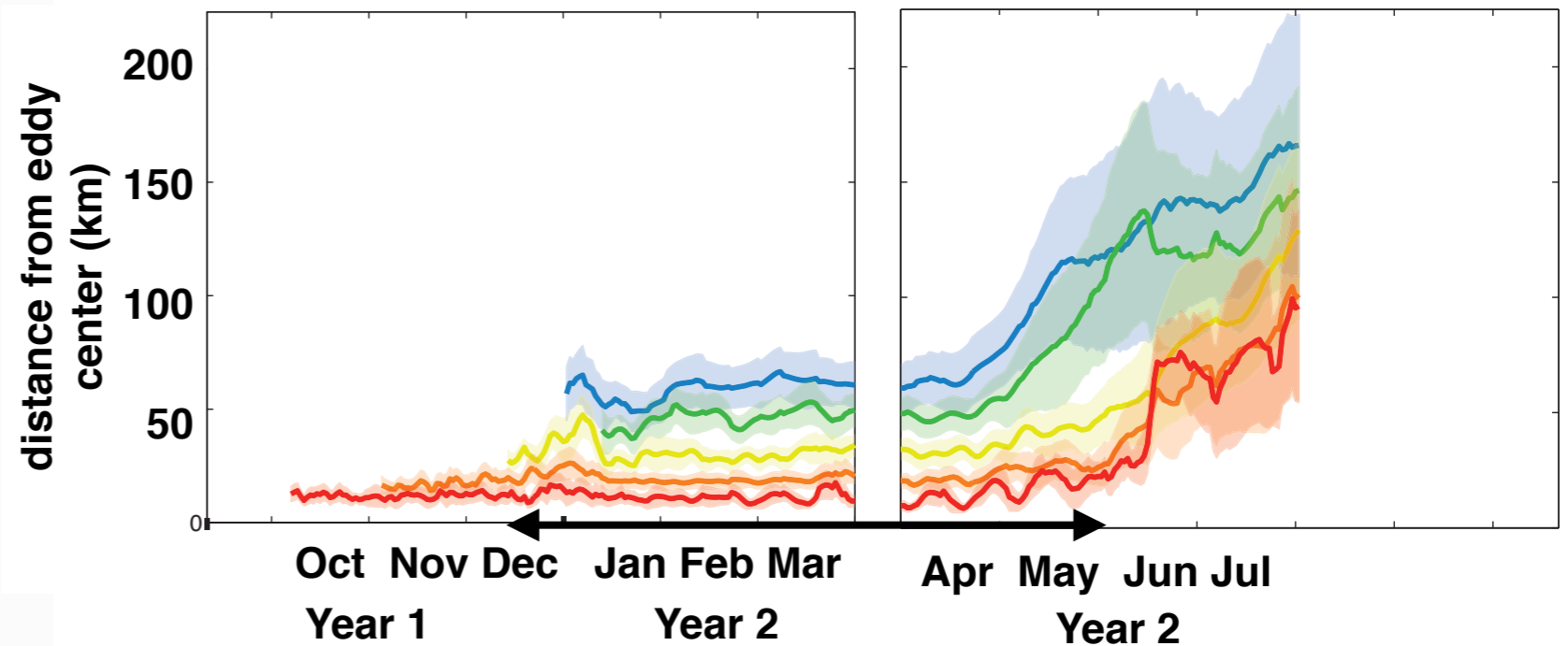
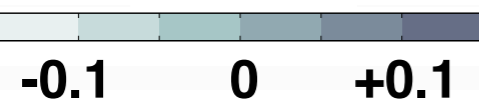


Lagrangian experiments: Ariane

Forward Experiment:



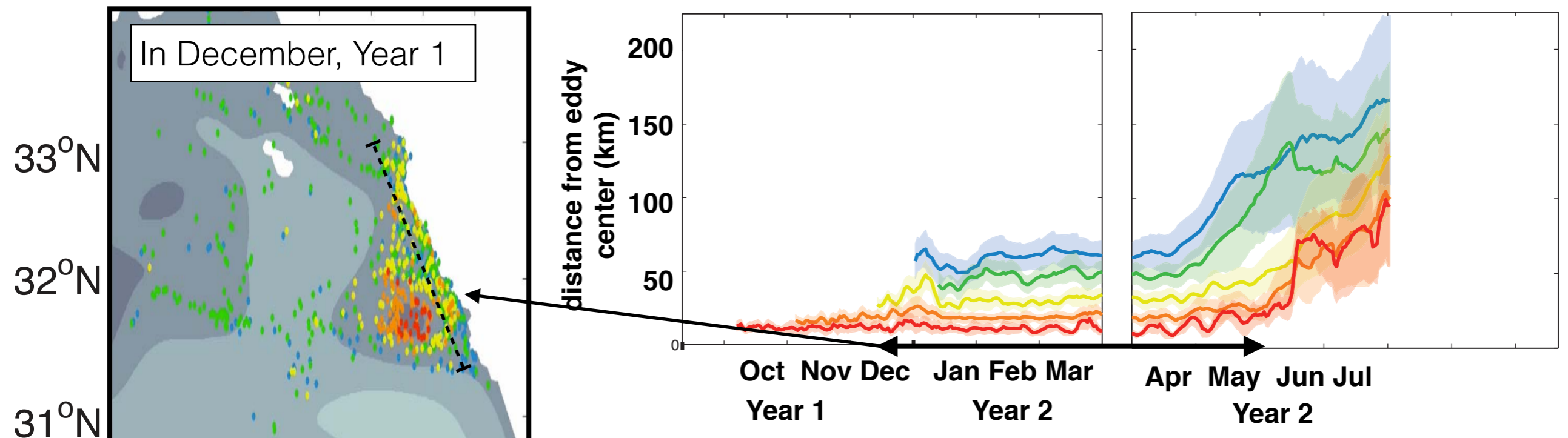
SSH (m)



- Distance of particle pools from the eddy center is relatively constant
- Weak lateral mixing
- Core is coherent for 5-6 months...

Lagrangian experiments: Ariane

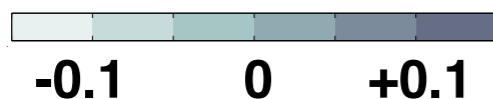
Forward Experiment:



- Distance of particle pools from the eddy center is relatively constant
- Weak lateral mixing
- Core is coherent for 5-6 months...
- ... after it detached from coast in December

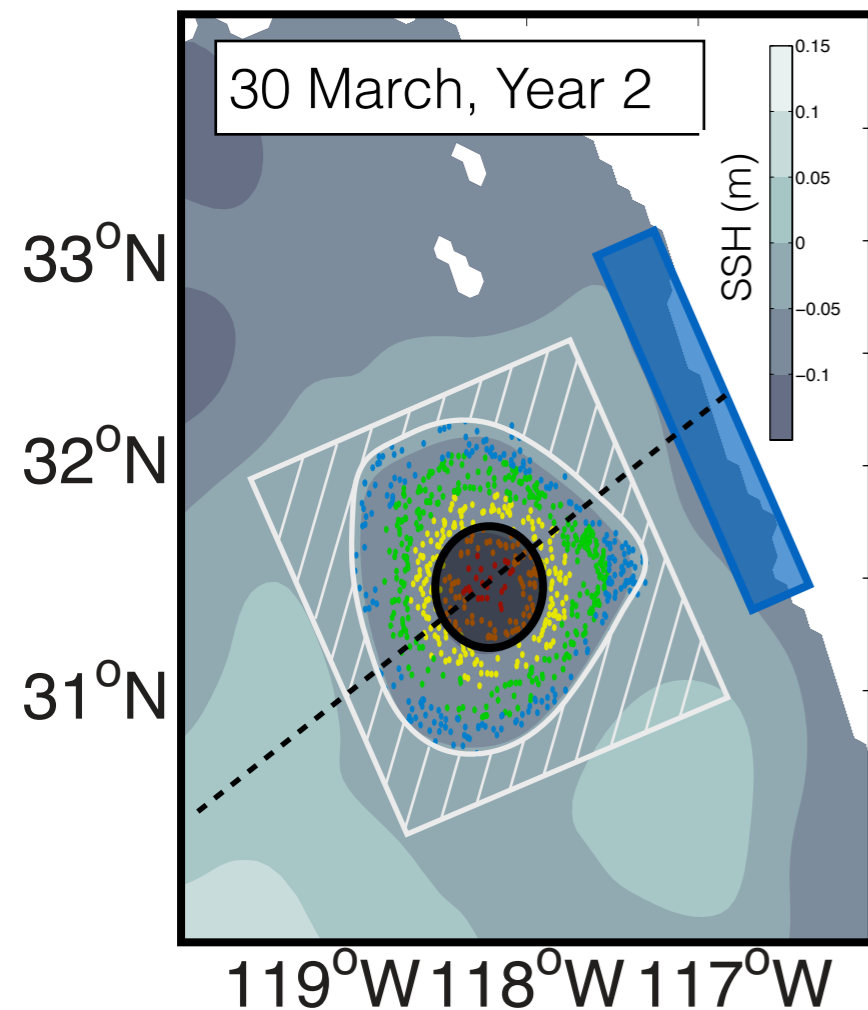


SSH (m)



Strategy to study the biology

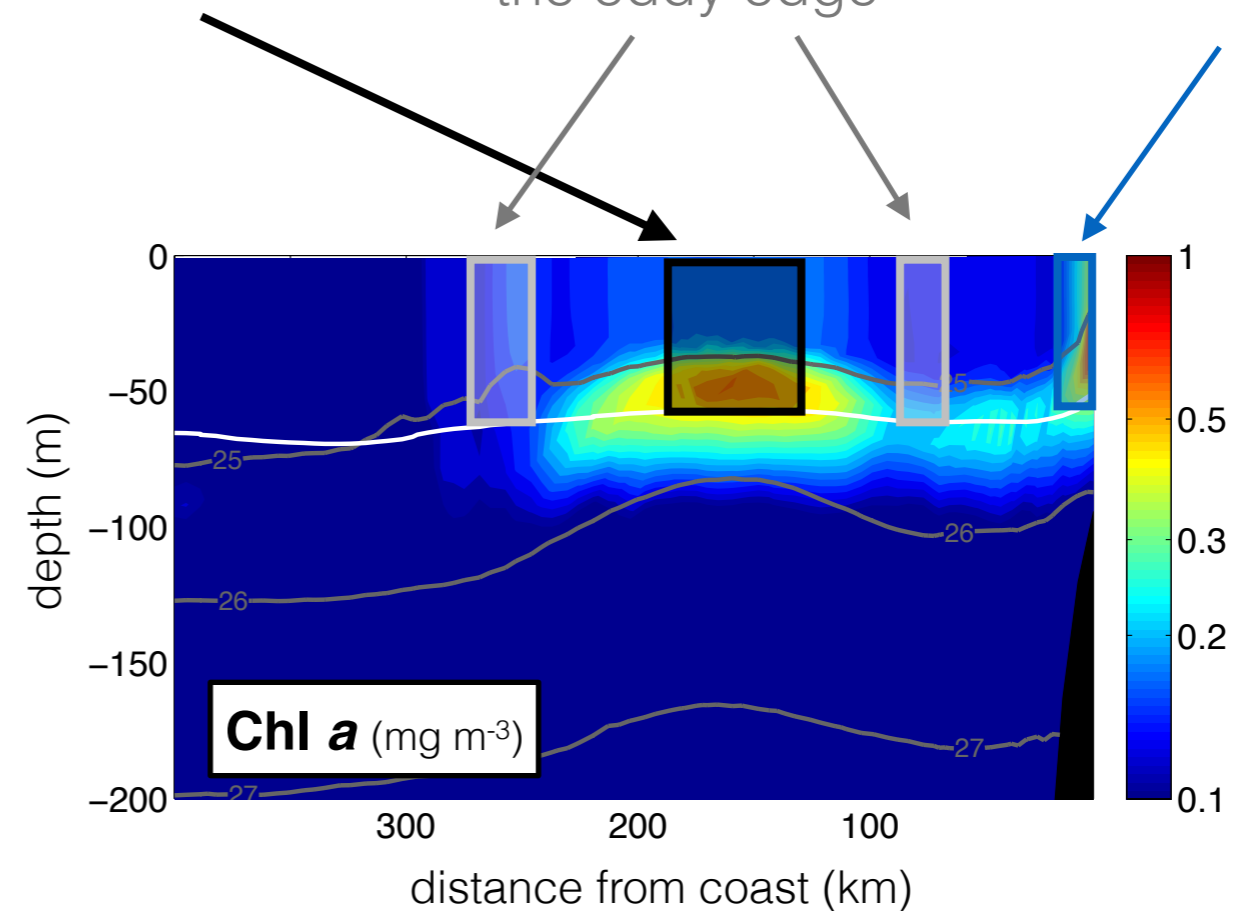
Definition of different regions



Eddy core:
particles inside the core

Eddy exterior:
region surrounding
the eddy edge

Coastal area:
Upwelling region
where the particles
come from



**How does the eddy ecosystem differ from other key regions?
Which mechanisms explain the production in the eddy core?**

Outline

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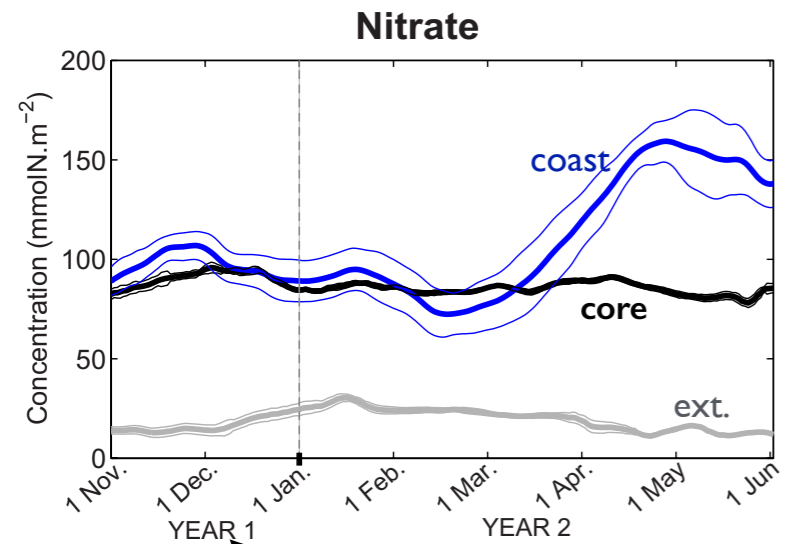
MODEL SETUP

EDDY CHARACTERIZATION

 **ECOLOGICAL IMPLICATIONS**

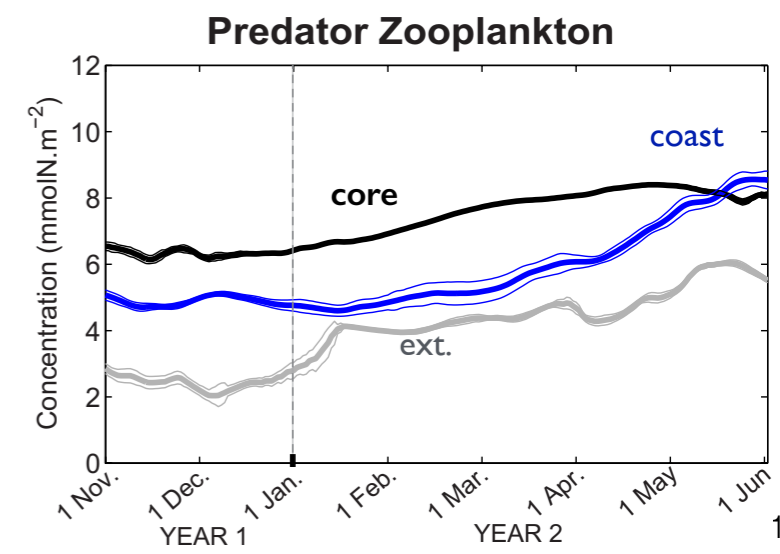
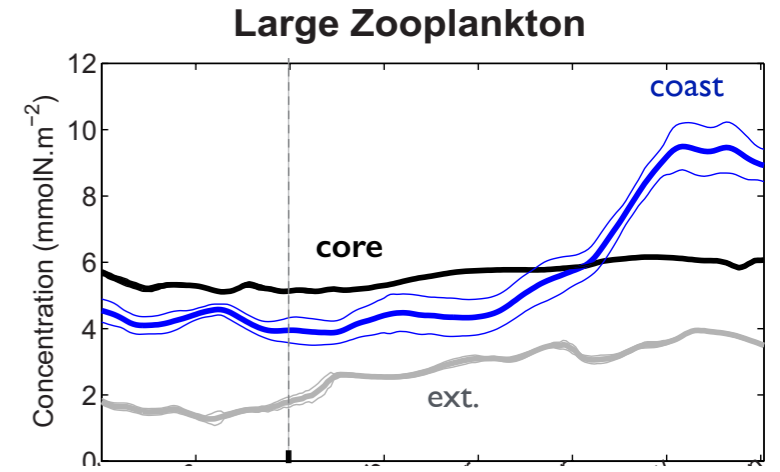
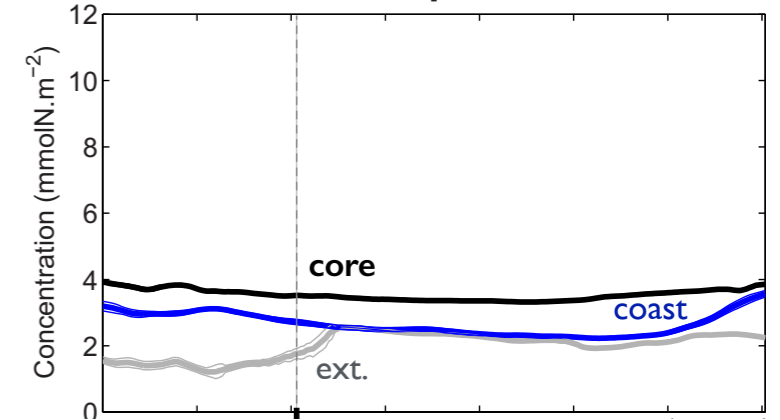
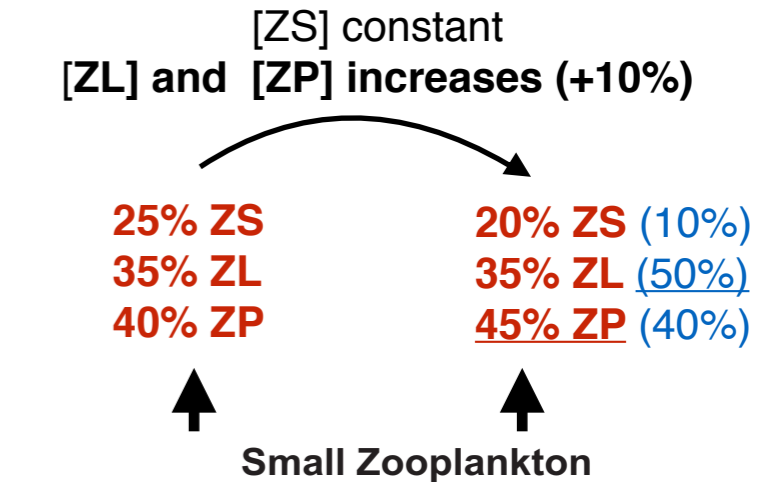
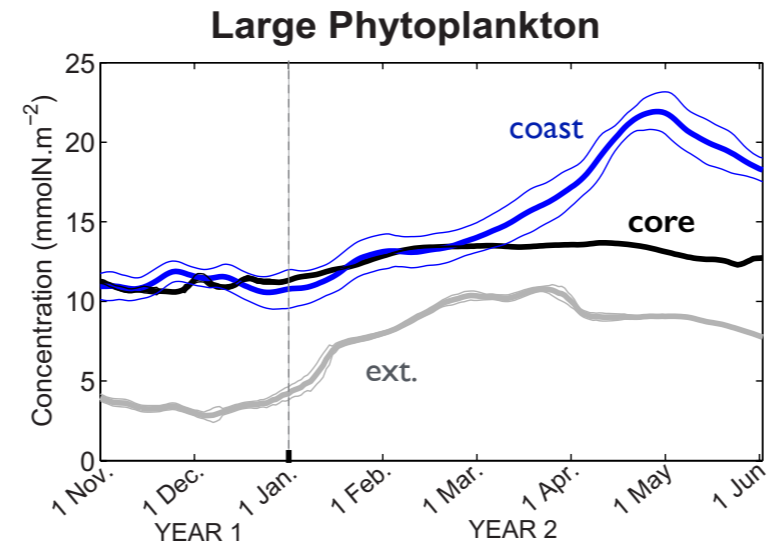
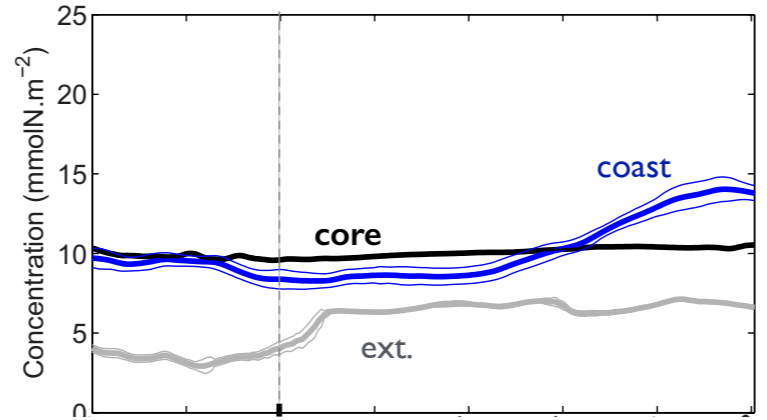
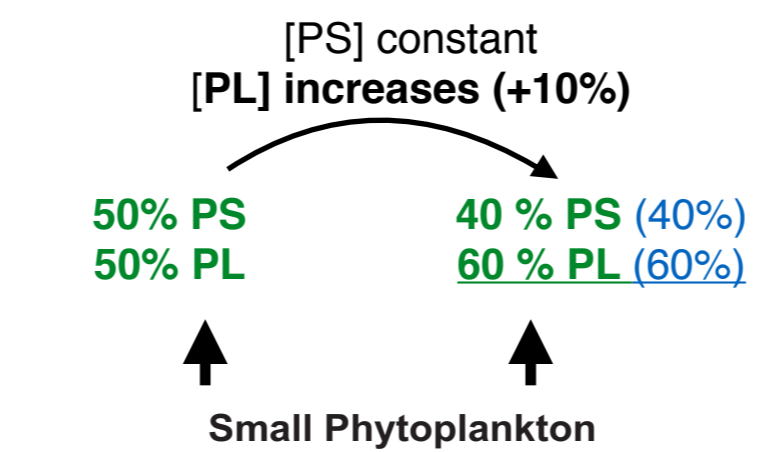
CONCLUSION AND PROSPECTS

How does the eddy core ecosystem differ from other key regions?



core detached from coast

- Eddy Core = Coastal upwelling system when the core detached from coast
- Eddy Core: NO₃ relatively constant
- Eddy Core > Eddy exterior



How does the eddy core ecosystem differ from other key regions?

[PS] constant
[PL] increases (+10%)

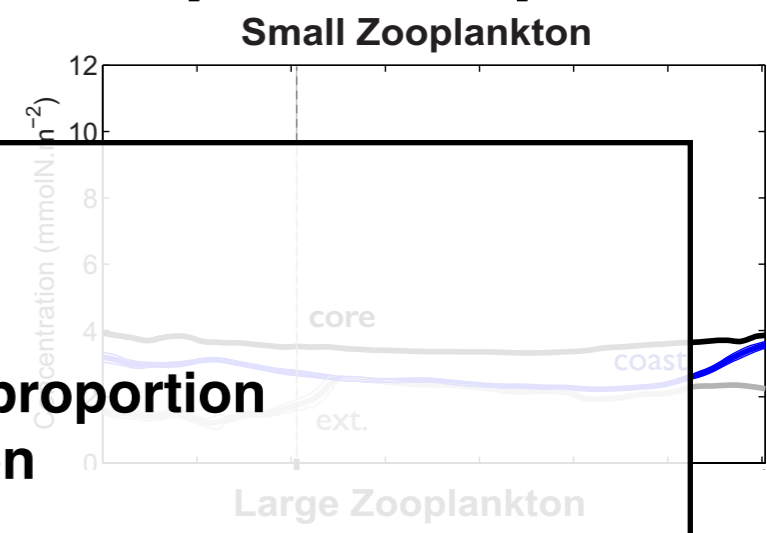
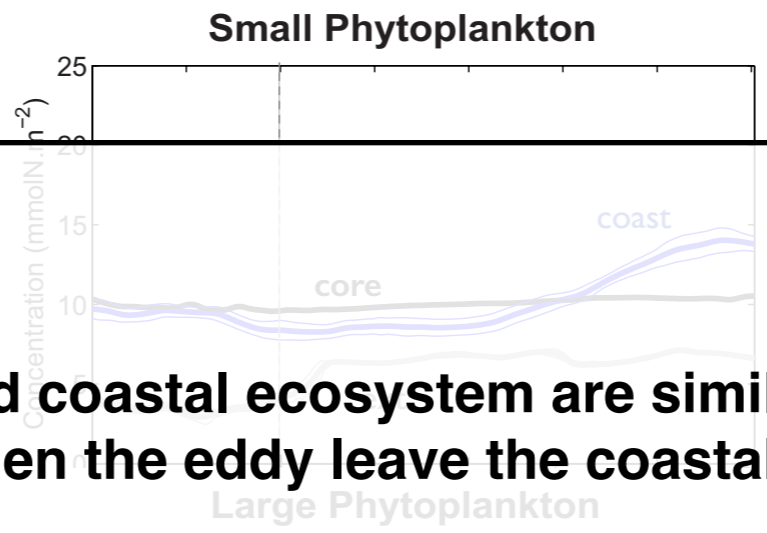
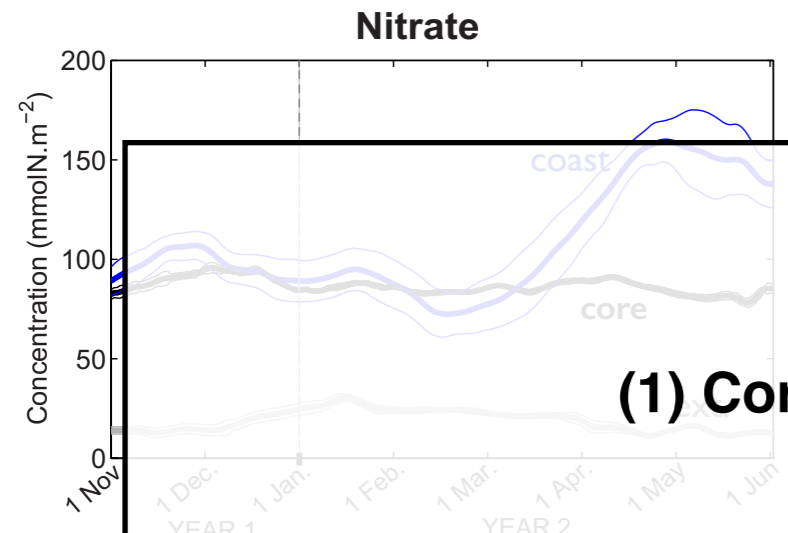
50% PS
50% PL

40% PS (40%)
60% PL (60%)

[ZS] constant
[ZL] and [ZP] increases (+10%)

25% ZS
35% ZL
40% ZP

20% ZS (10%)
35% ZL (50%)
45% ZP (40%)

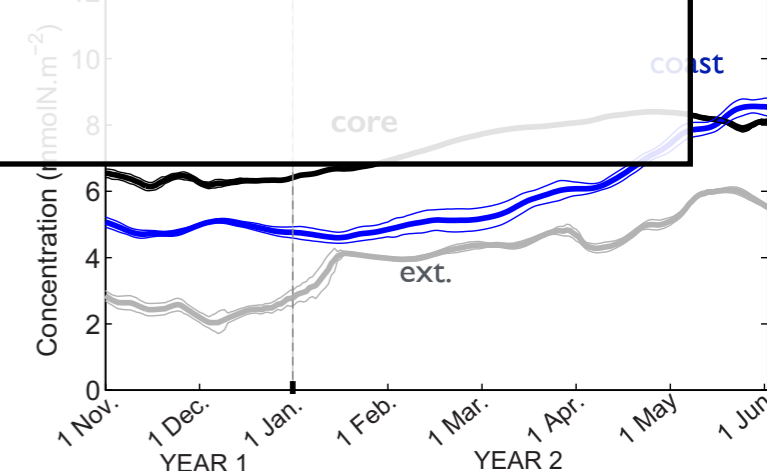
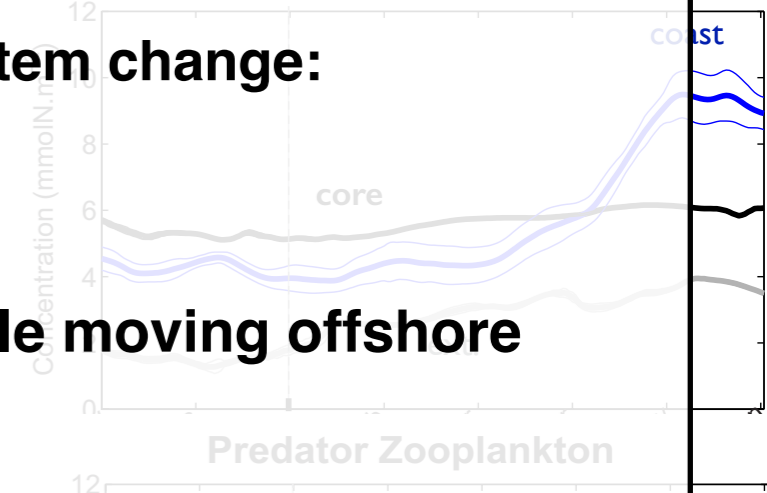
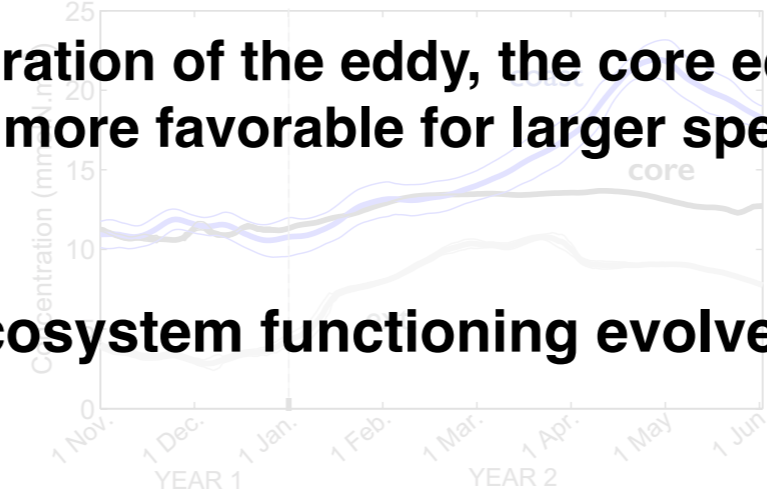


(1) Core and coastal ecosystem are similar in proportion when the eddy leave the coastal region

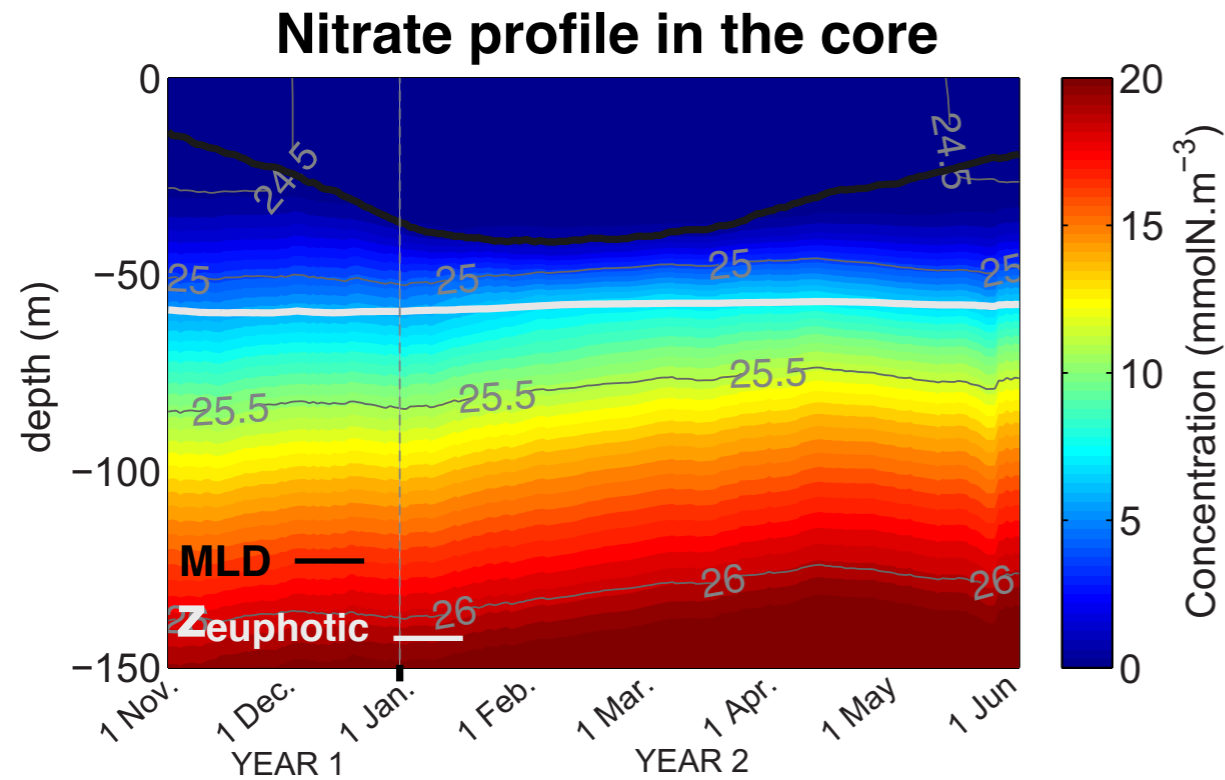
(2) After maturation of the eddy, the core ecosystem change: more favorable for larger species

The eddy core ecosystem functioning evolves while moving offshore

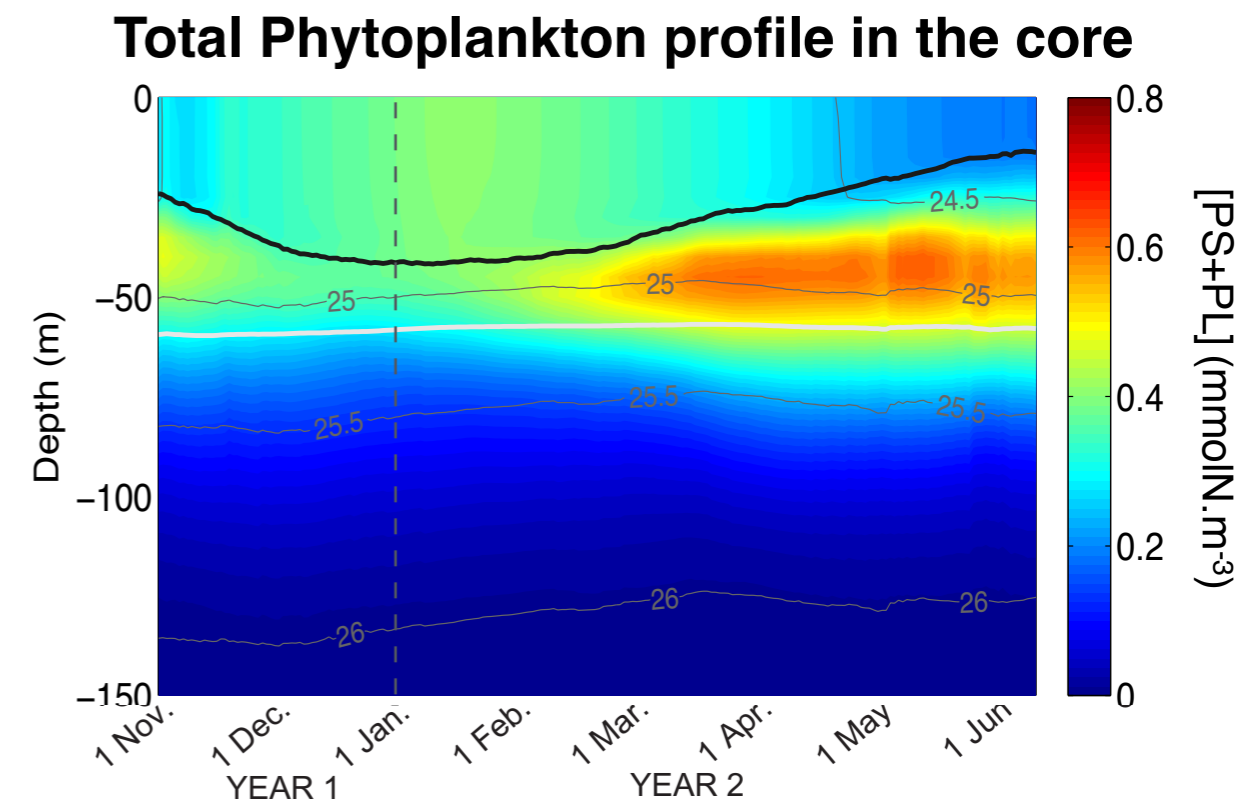
- Eddy Core = Coastal upwelling system when the core detached from coast
- Eddy Core > Eddy exterior
- Eddy Core > Eddy exterior



The eddy core ecosystem functioning evolves while moving offshore: why?



- Low surface concentrations
- Upward shoaling of nitracline into the euphotic layer (~20 m in 6 months)



- Mixed Layer:

- production based on recycling
- signal decreases over time

▀ Surface signature fits with seawifs data : decrease of chl *a* with eddy age (cyclonic)

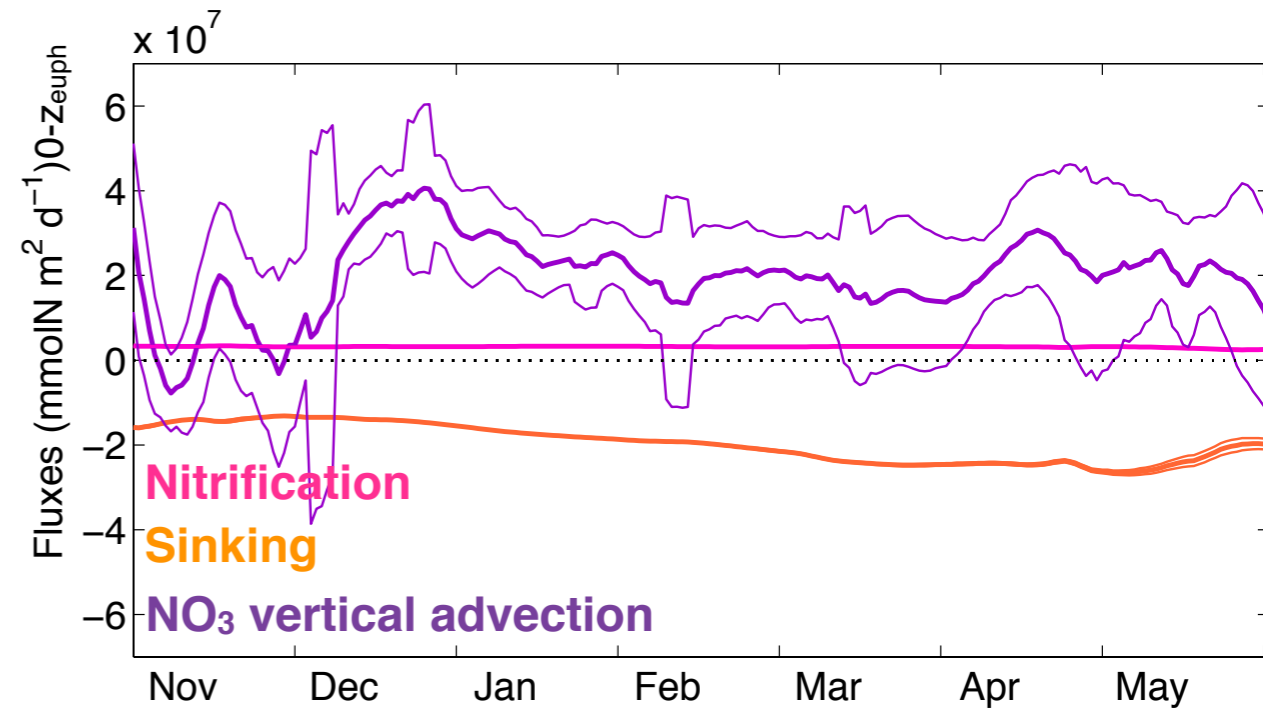
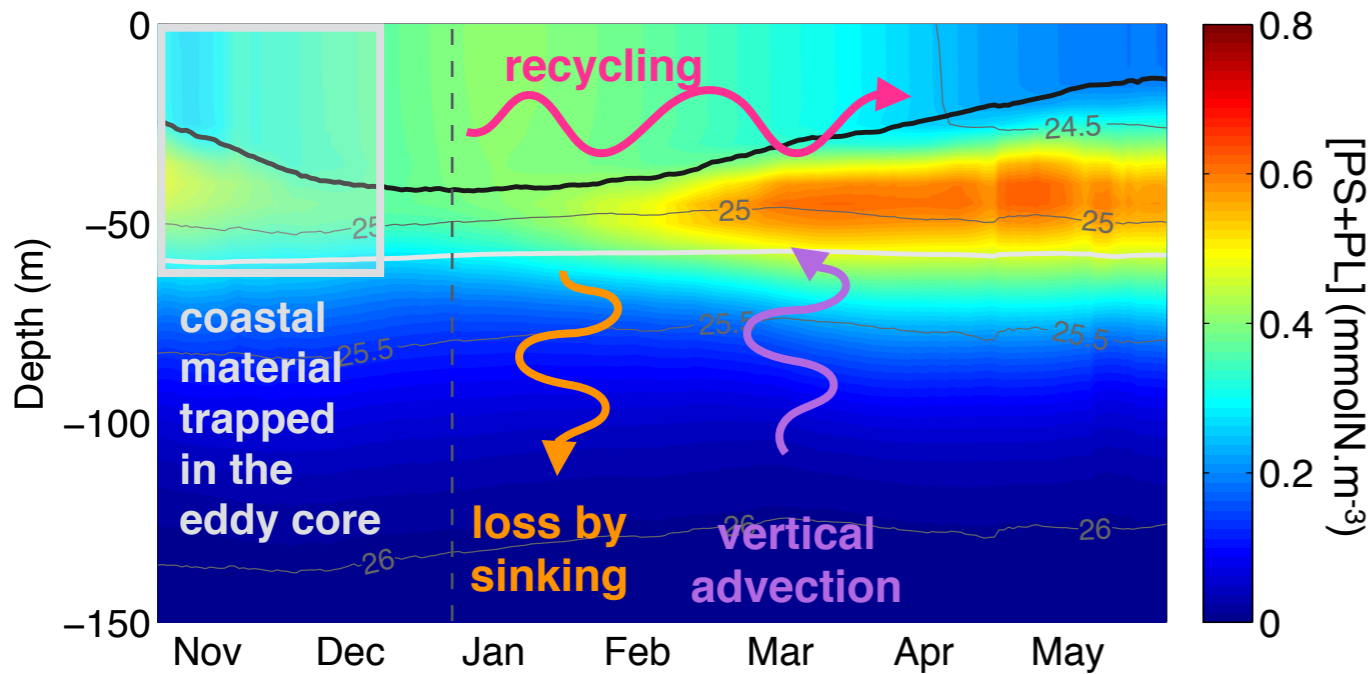
(Mati Kahru, pers. comm.)

- Deep Chlorophyll *a* Max:

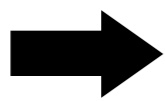
- strong signal decoupled from surface
- high biomass based on new production

Which mechanisms explain the production in the eddy core?

Total Phytoplankton profile in the core

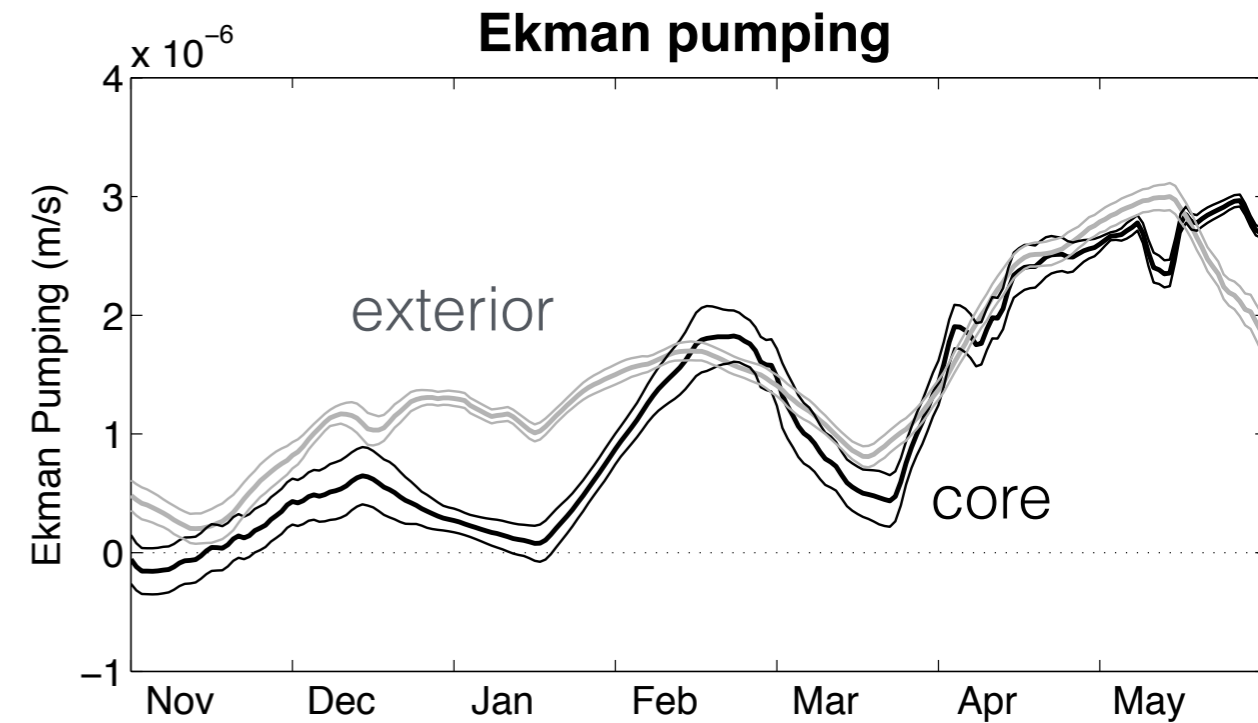
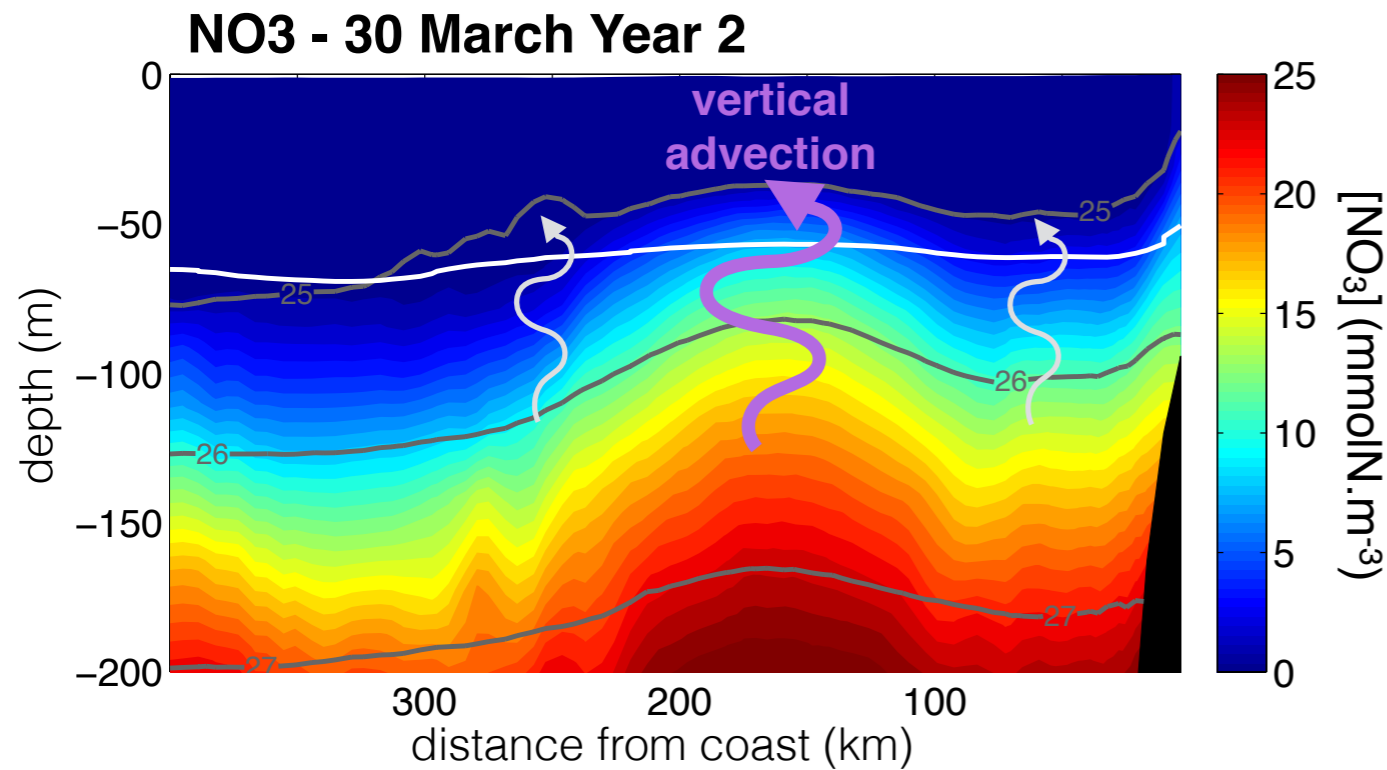


- Comparison of biological fluxes can't explain the biological production in the eddy



Local physics help to enhance biological production:
Vertical advection explains 1/3 of nitrogen stock

Local input of NO₃ : driven by wind-stress curl (Ekman pumping)?



~50 m shoaling of the nutricline
 NO₃ vertical advection:
 Eddy Core > Eddy Outer Region

Ekman pumping in the core:
 ~20 m in 6 months

➔ Ekman pumping lifts up the domed isopycnals

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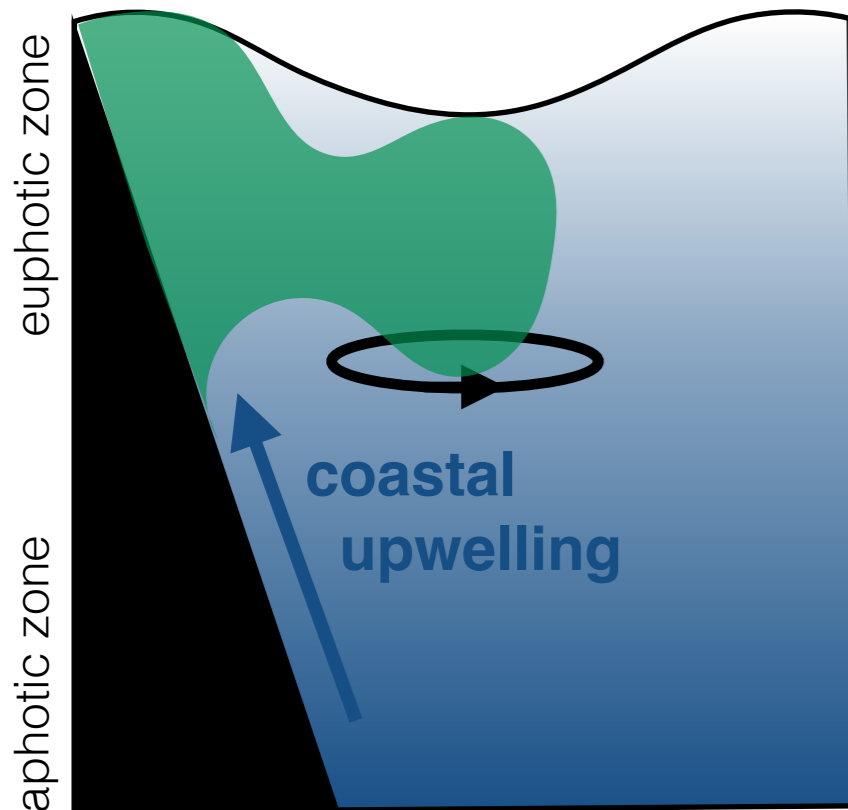
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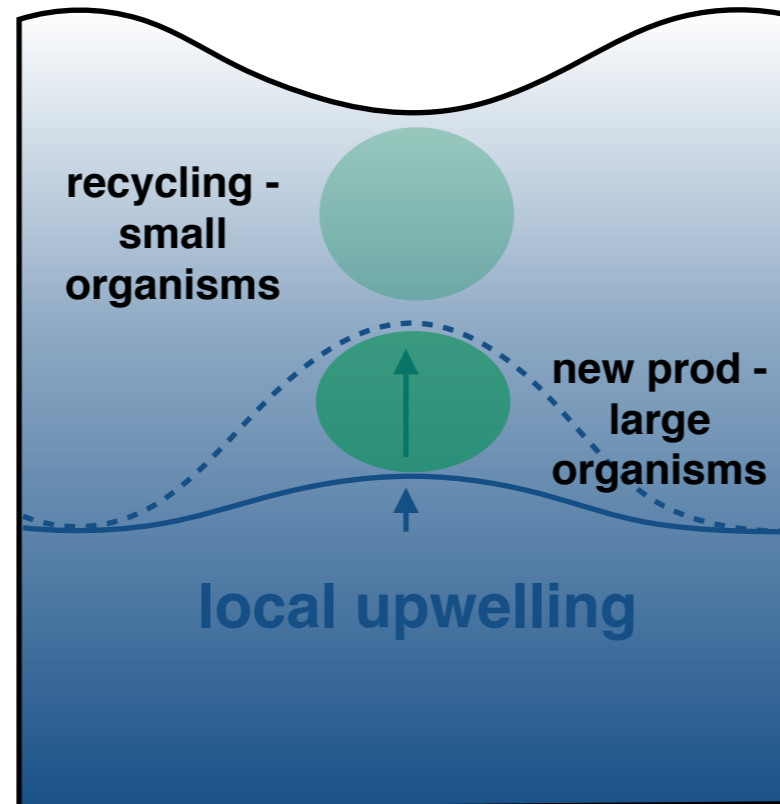
 **CONCLUSION AND PROSPECTS**

Take home messages:

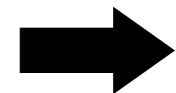
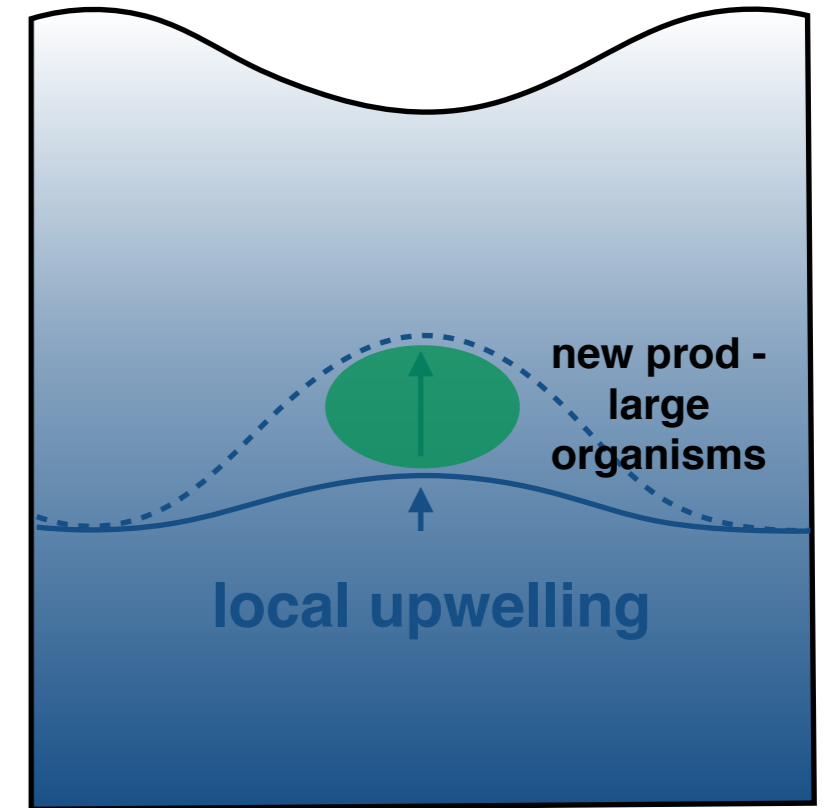
1/ Nearshore formation of the cyclonic eddy and trapping of coastal ecosystem



2/ Maturation of the eddy while it moves offshore and vertical segregation



3/ Shift of the ecosystem structure in response to physical forcings



Eddy ecosystem structure and functioning depends on its age

- Young Eddy : upwelling-like ecosystem due to eddy trapping process
- Old Eddy : surface recycling-based ecosystem with decreasing productivity

versus

high subsurface max biomass based on new production



Biological production in old eddies results in a combination of dynamical processes

- ~ 2/3 horizontal (eddy trapping process + low lateral mixing)
- ~ 1/3 vertical (Ekman pumping + nitracline doming)

Important implications:

Role of eddies for the evaluation of the carbon pump :

Gruber & al. 2011: "Eddies of the CCS are able to transport nutrient-rich waters offshore and reduce coastal productivity"... but not only! Important local/offshore productivity and spatial redistribution of material

Role of background nutrient availability (= coastal concentration) ?

Biological properties in the eddy are a function of: the time in the year & the site of the formation

Same stories in all eddies?

Eddies differ from:

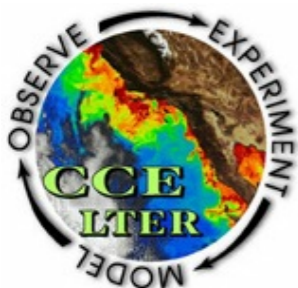
- nature (surface/subsurface)
- intensity (strength)
- persistence (age)
- depth of mixed layer within them
- degree of interaction with other features

Work in progress:

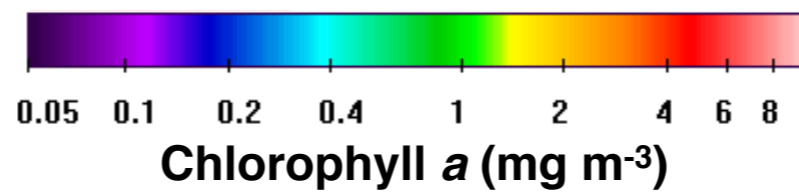
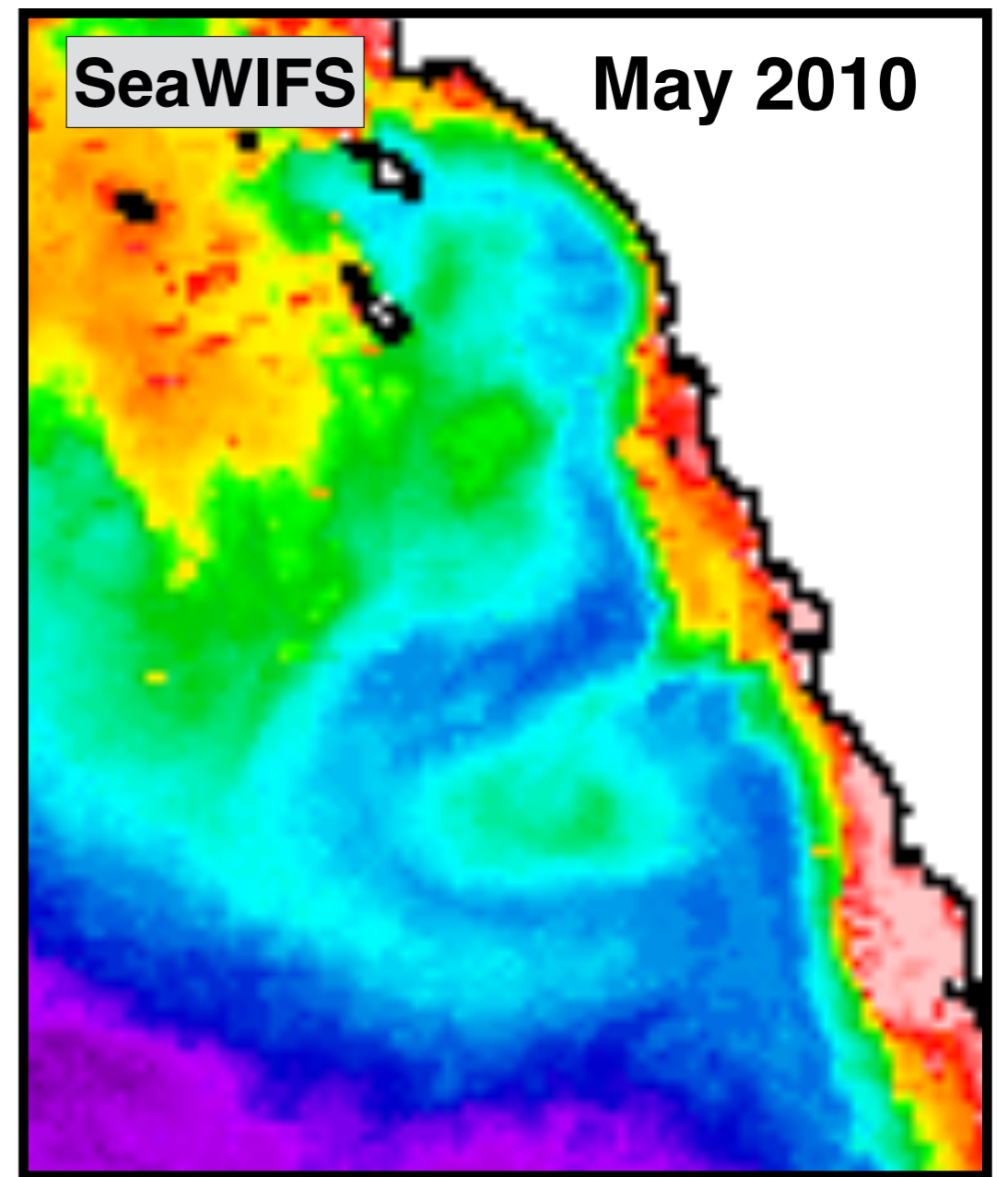
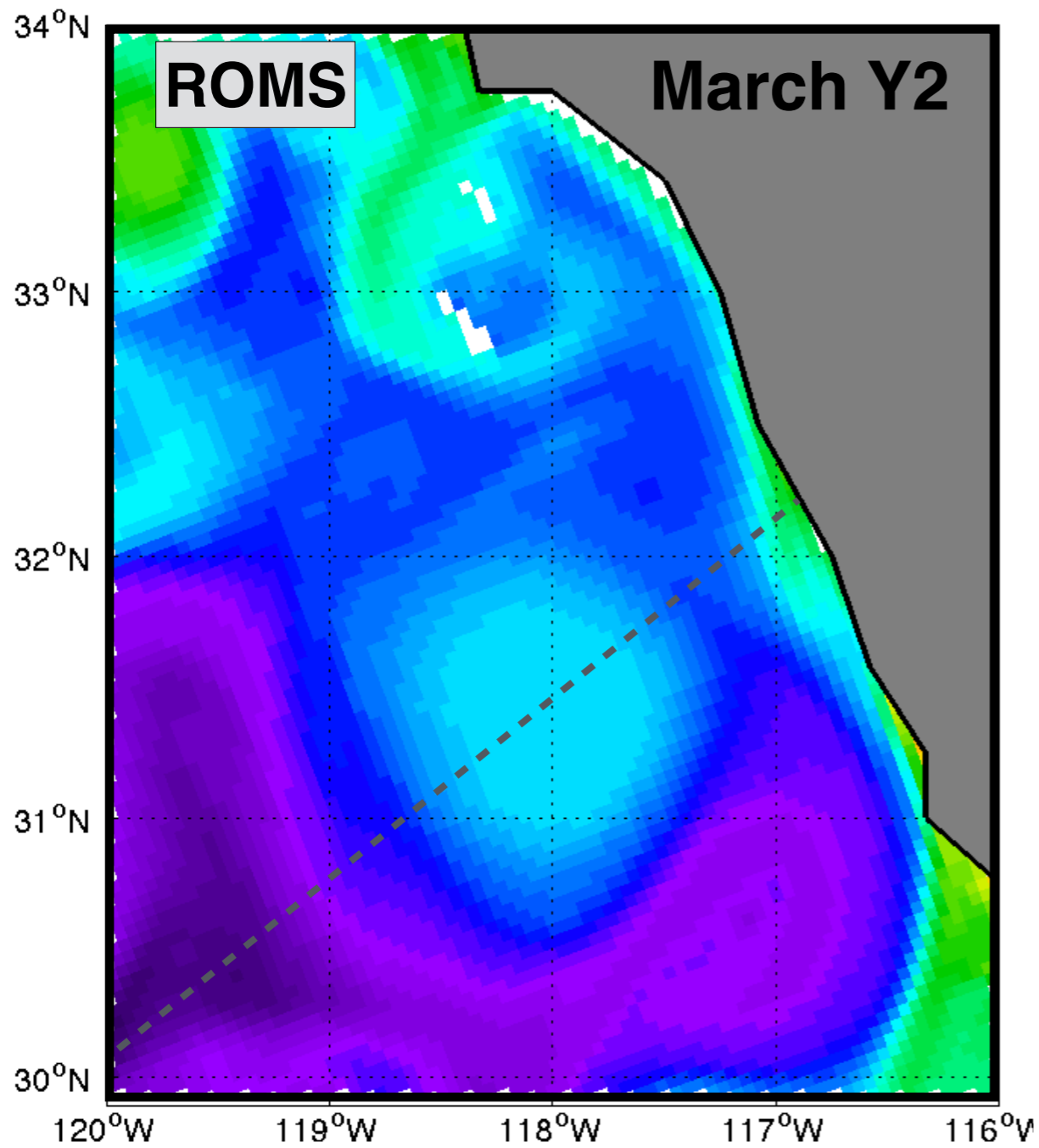
Composite analysis of biological properties of eddies in the CCS (asymmetry between biogeochemical role of cyclones and anticyclones), with *Vincent Combes, OSU*.

Chenillat F, PJS. Franks, P Rivière, X Capet, B Blanke and N Grima (2015) Plankton dynamics in a cyclonic eddy in the Southern California Current System. JGR Ocean, In review

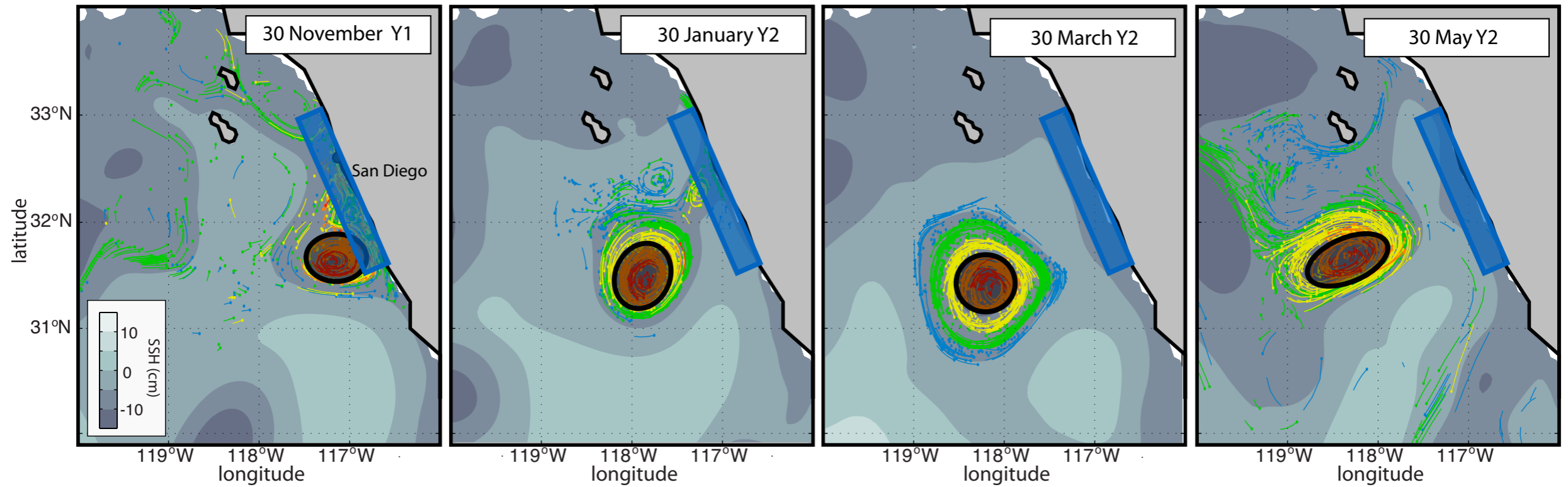
Chenillat F, B Blanke, N Grima, PJS Franks, X Capet and P Rivière (2015) Quantifying tracer dynamics in moving fluids: a combined Eulerian-Lagrangian approach. Front. Environ. Sci. 3:43. doi: 10.3389/fenvs.2015.00043



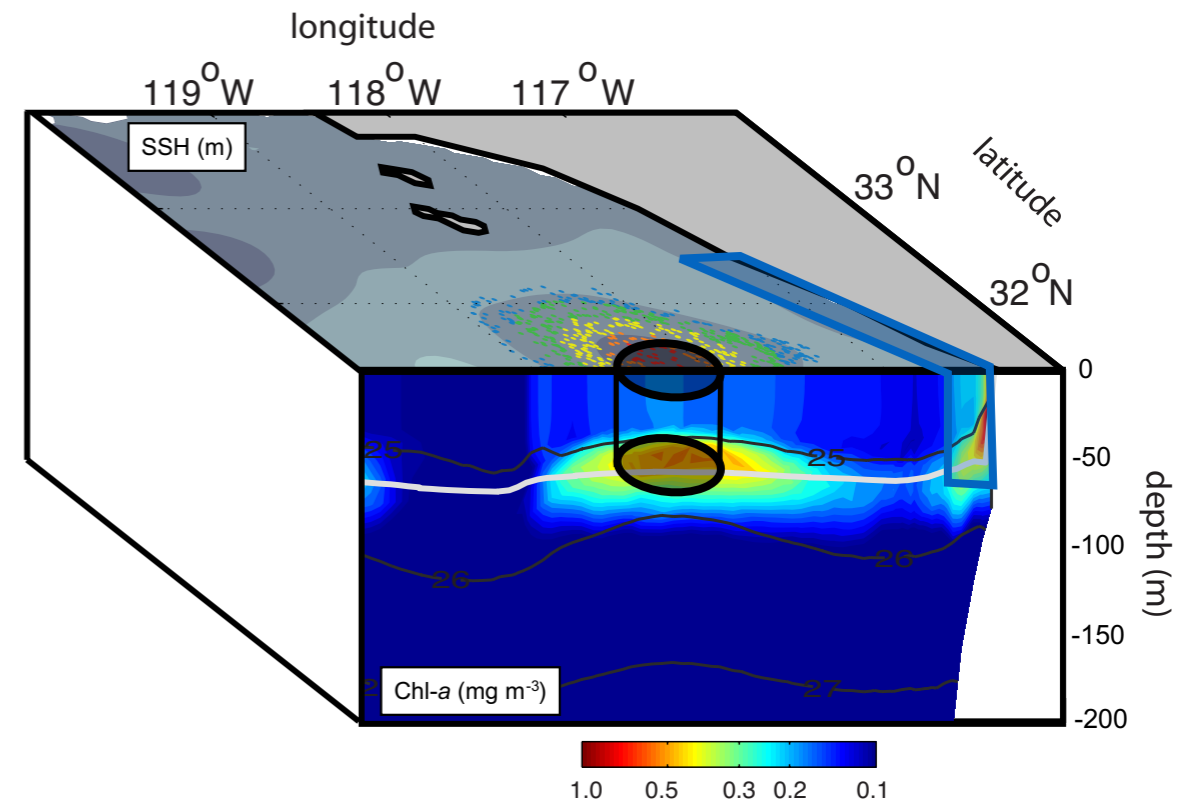
Thanks to my co-authors, Peter Franks'lab,
Vincent Combes, Camille Mazoyer and Mark Ohman.
Work supported by the CCE-LTER program.



Lagrangian experiments (Ariane)

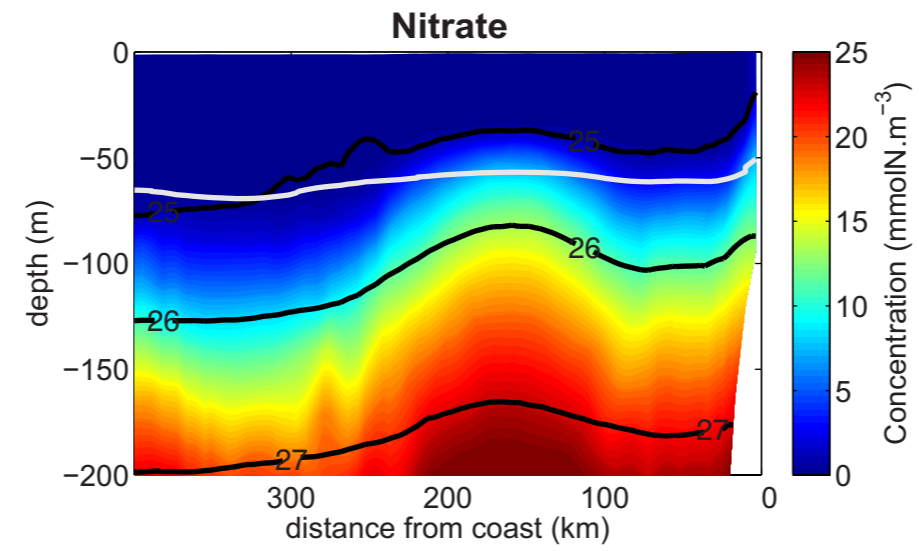


- Distance of particle pools from the eddy center is relatively constant
- Weak lateral mixing
- Core is coherent for 5-6 months after it detached from coast in December

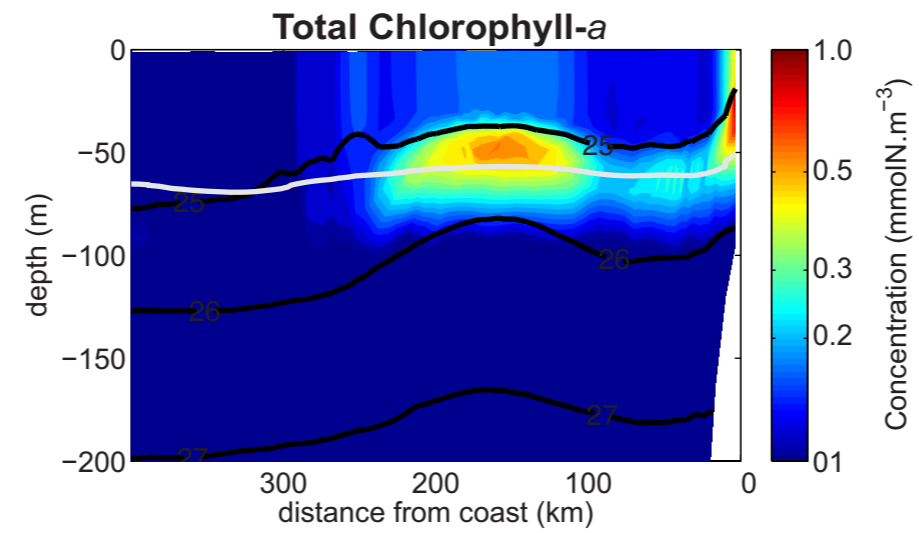


ADDITIONAL SLIDES

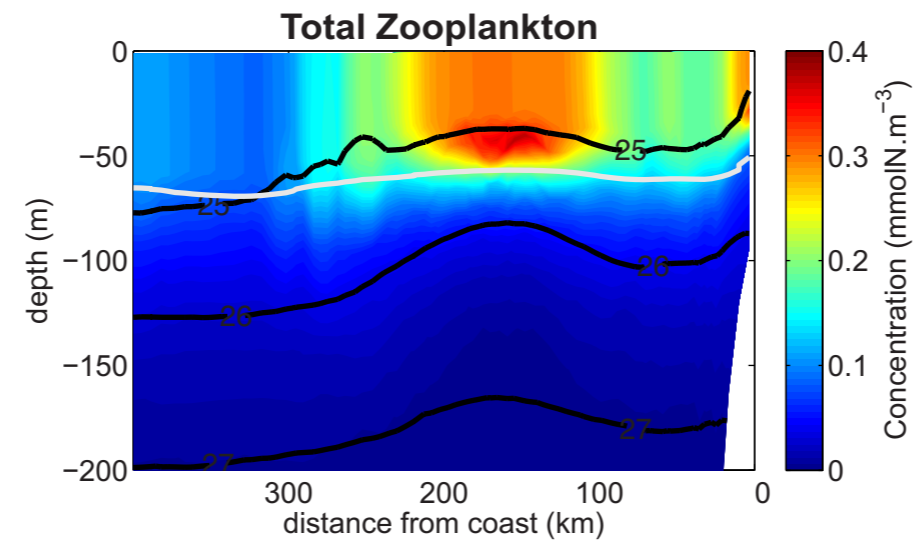
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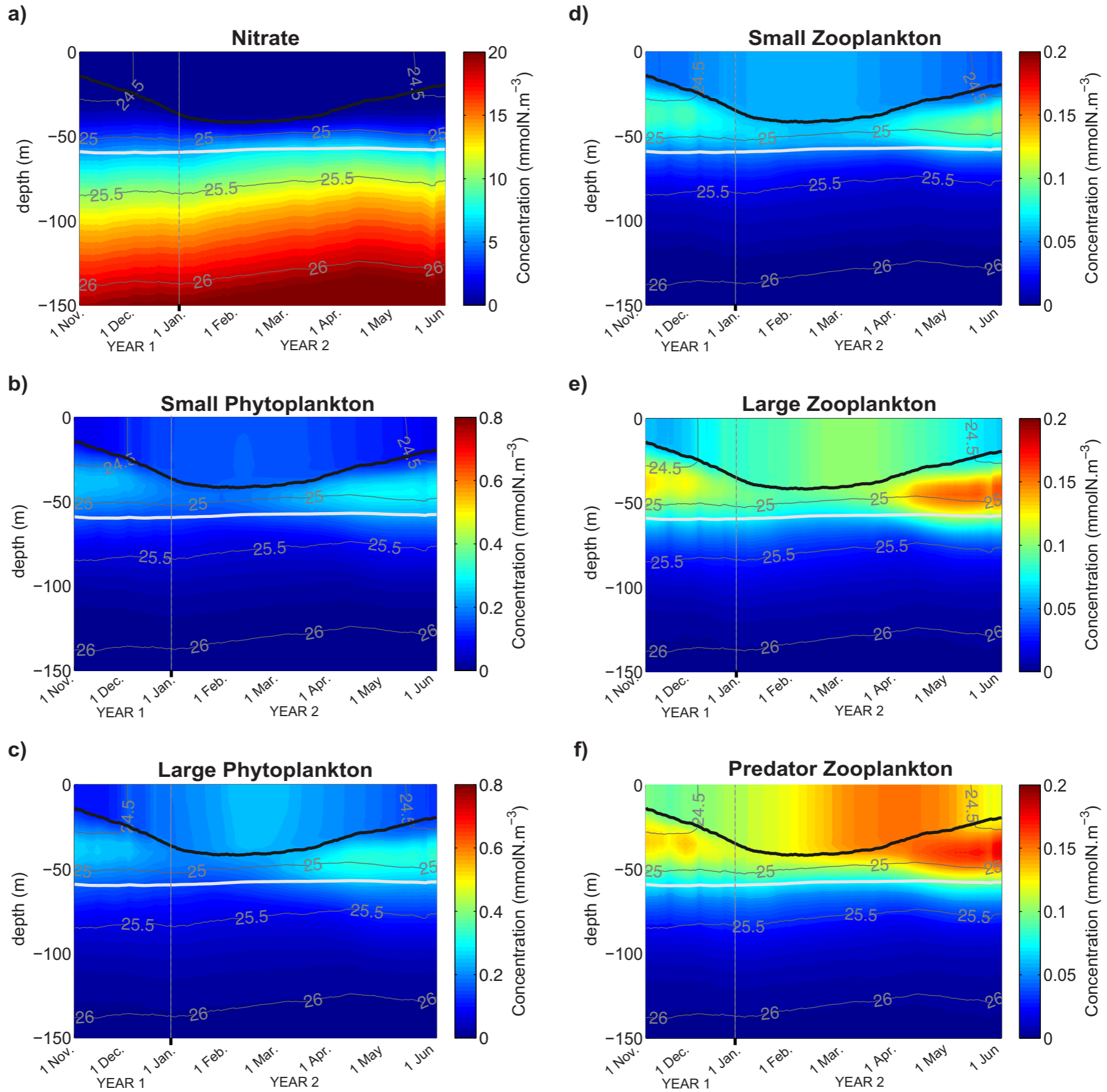
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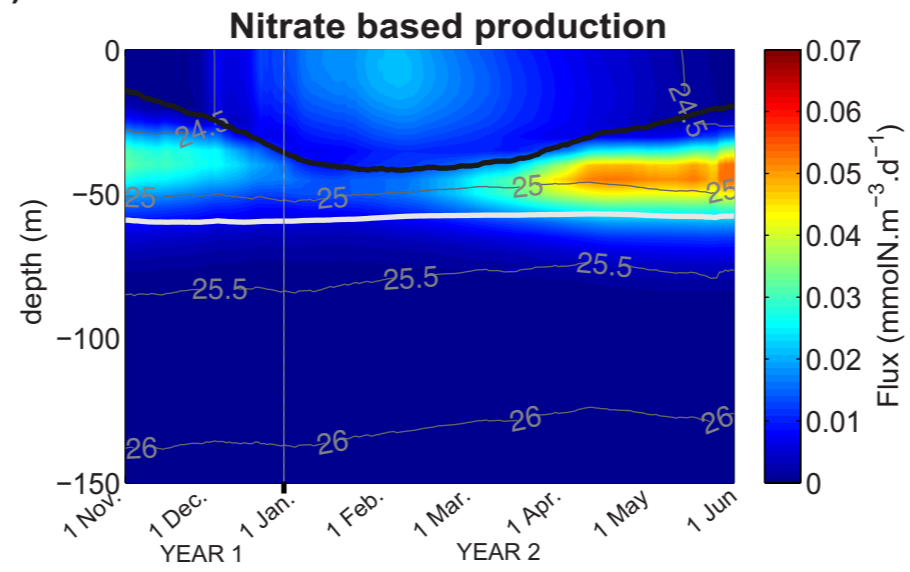
c)



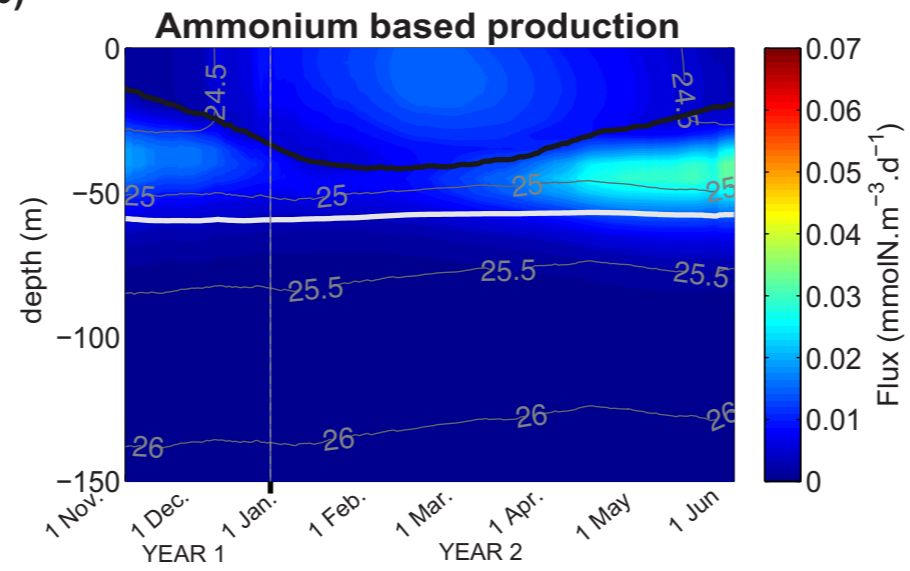
ADDITIONAL SLIDES



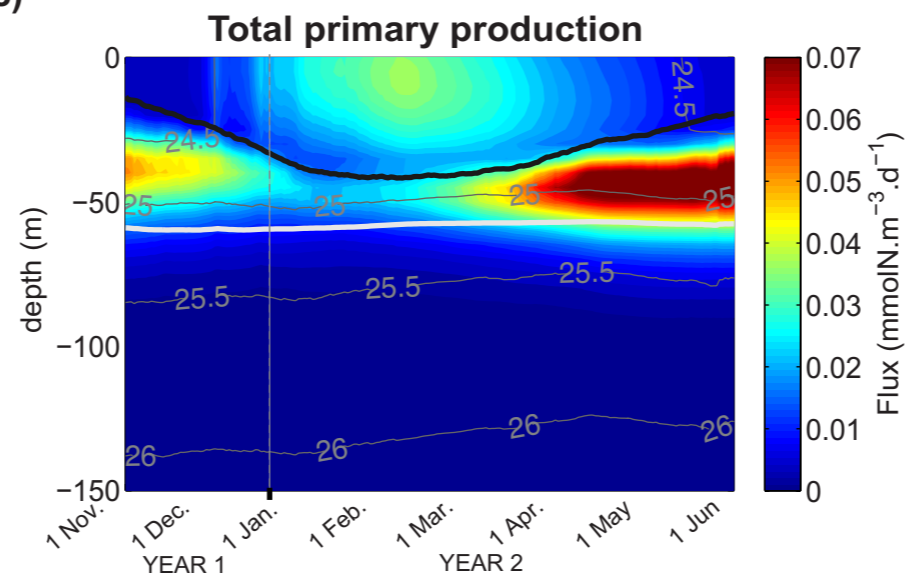
a)

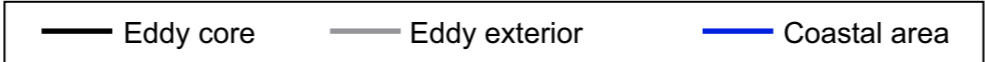
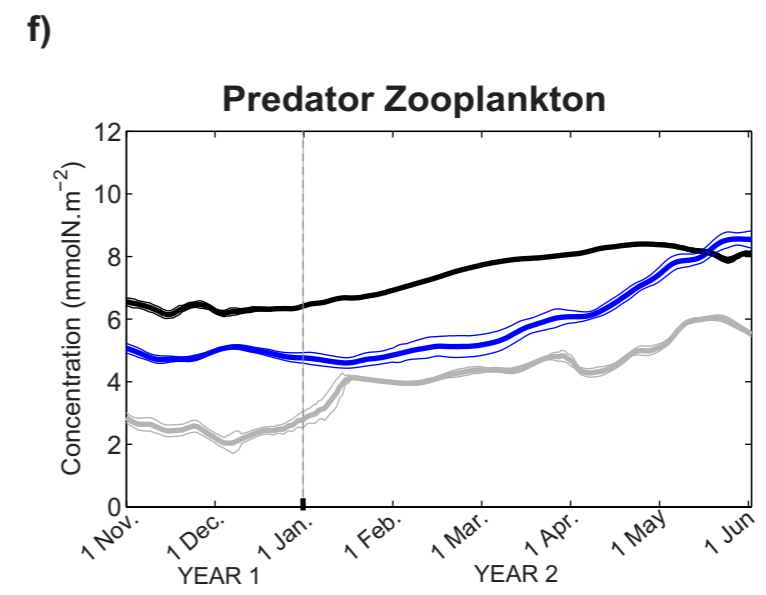
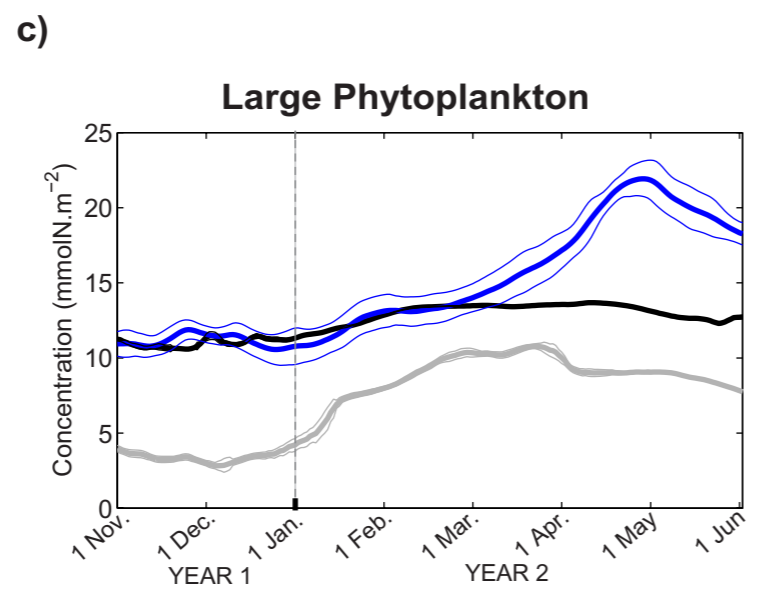
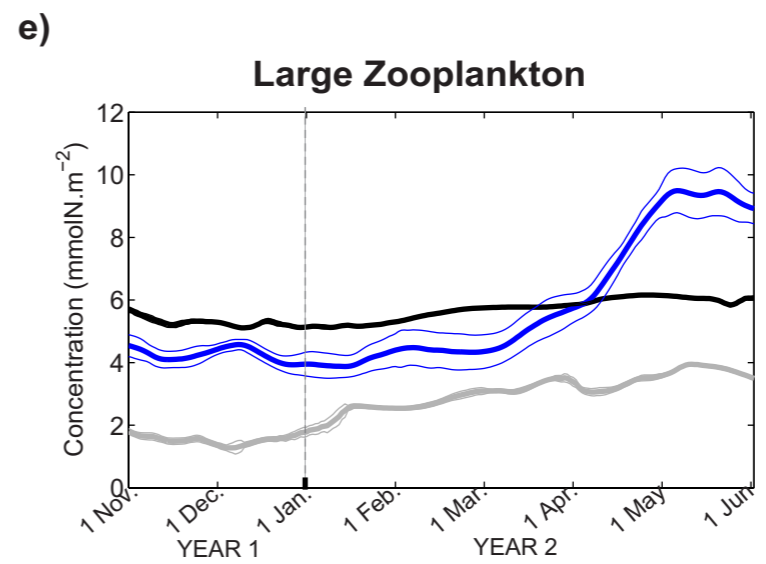
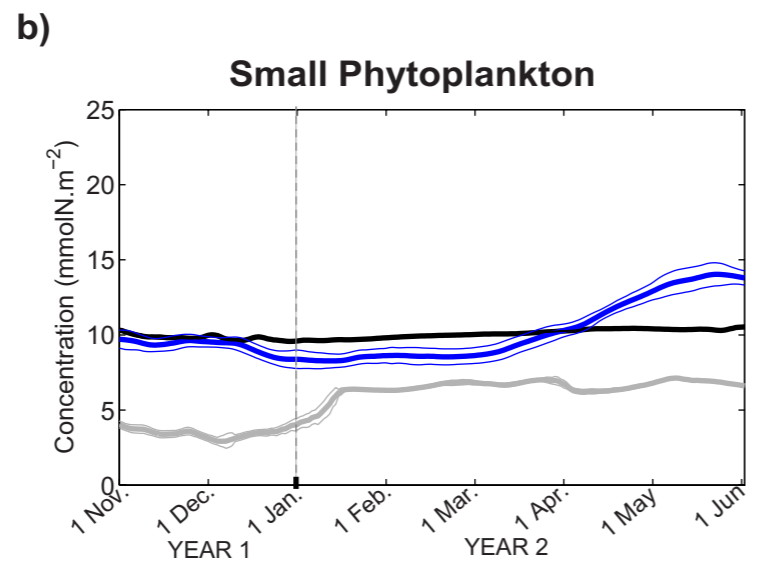
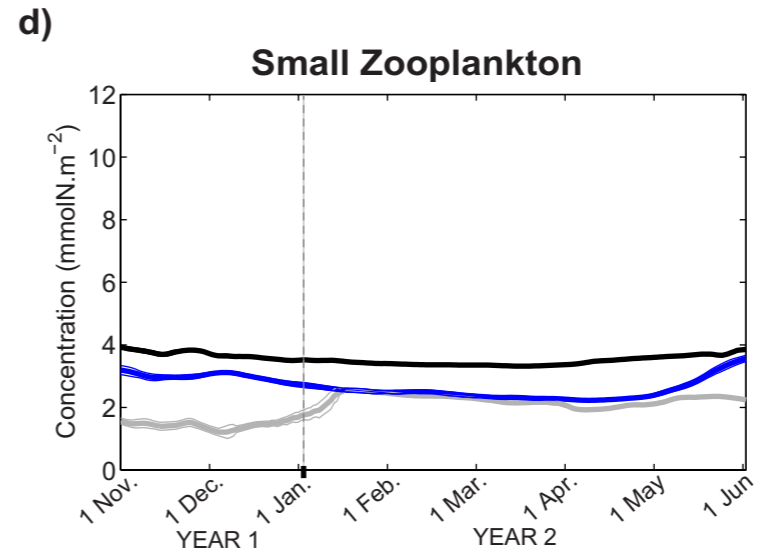
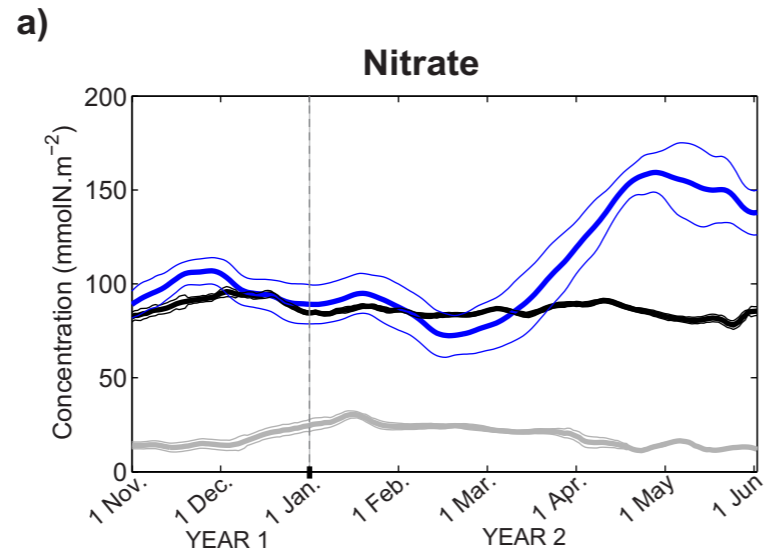


b)

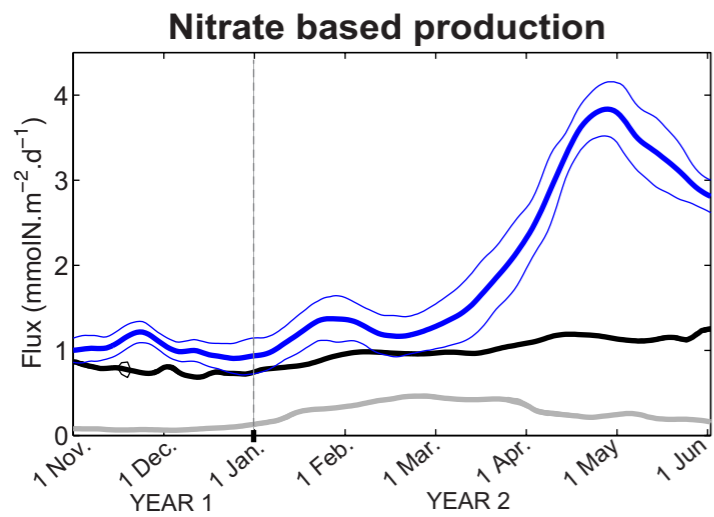


c)

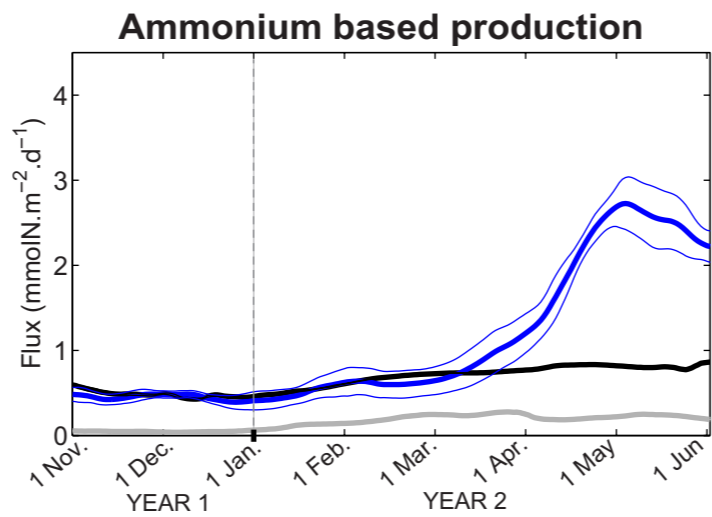




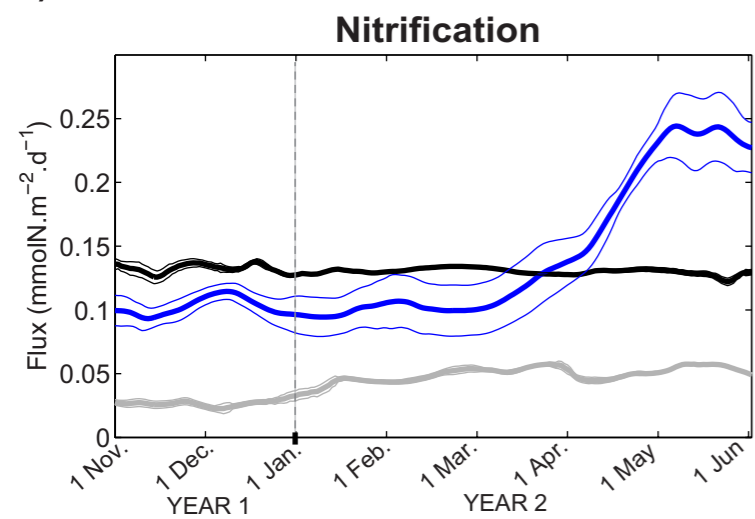
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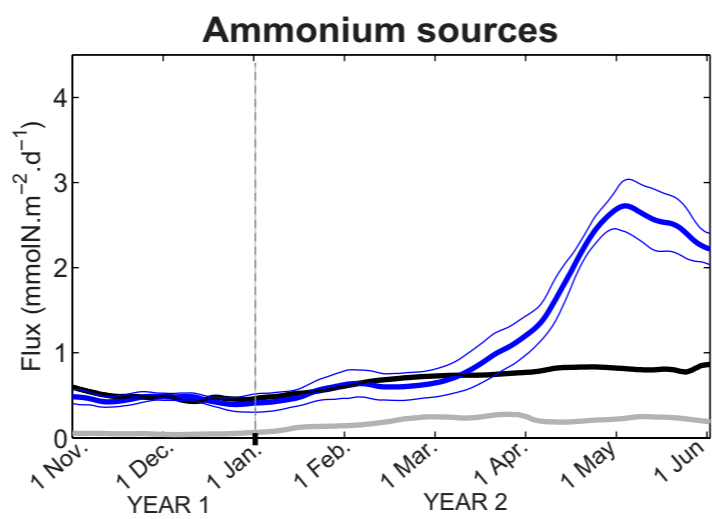
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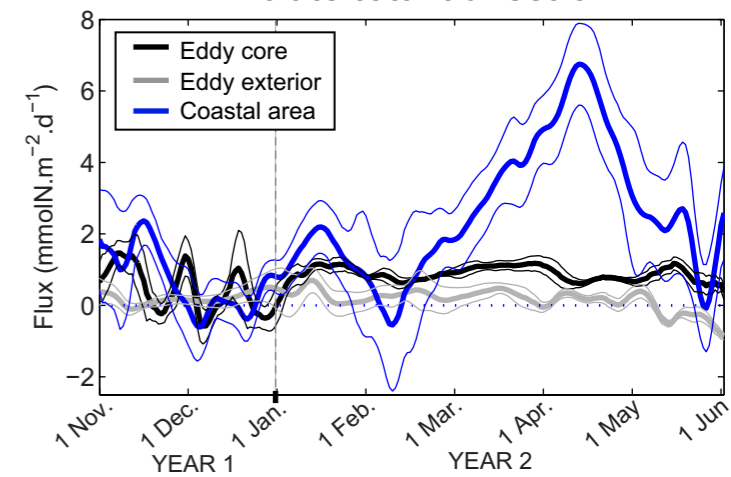
b)



e)



Nitrate total advection



c)

