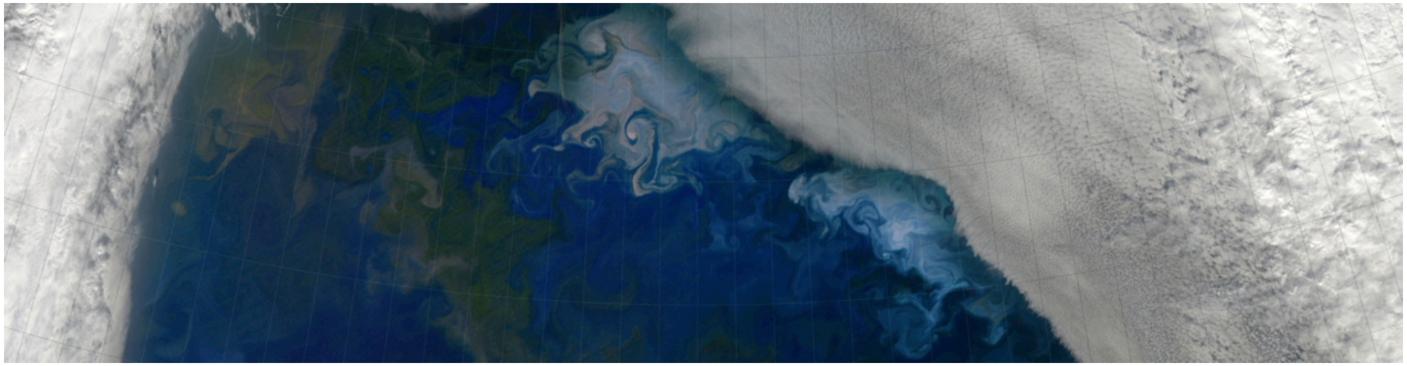
Planktonic ecosystem response to meso-submesoscale dynamics above a shelf slope

Romain Pennel[1] - Pascal Rivière[1]

Philippe Pondaven[1] - Xavier Carton[2] - Camille Mazoyer[3]



SYNBIOS Workshop 6-7-8 July 2015

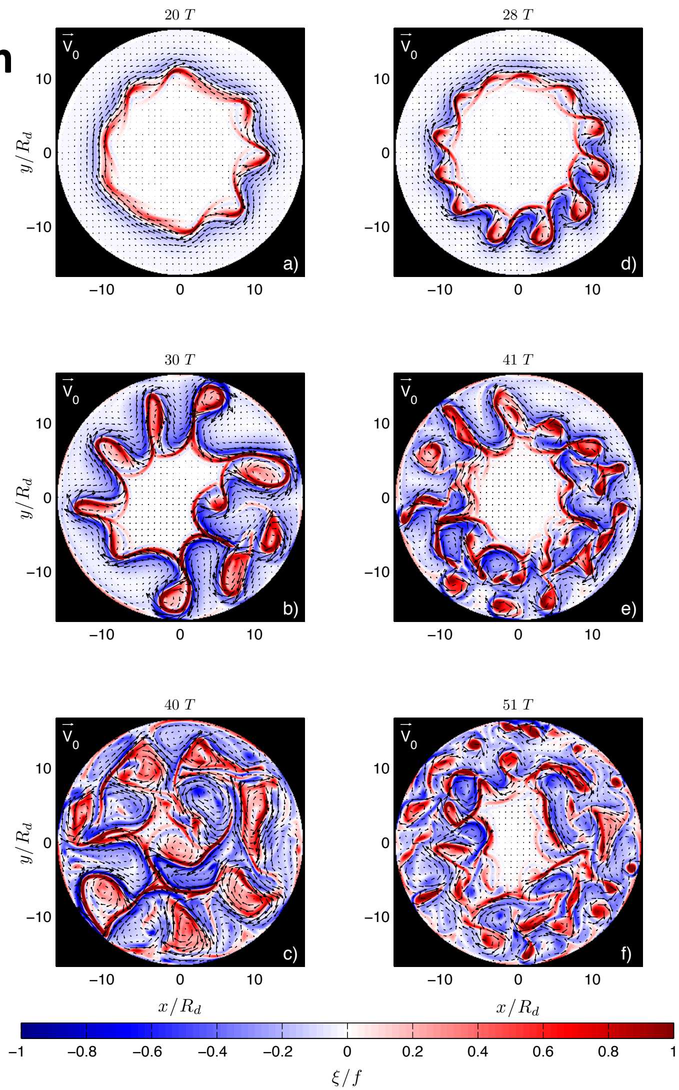
[1] Laboratoire des Sciences de l'Environnement Marin (LEMAR), Institut Universitaire Européen de la Mer (IUEM), Brest, France
[2] Laboratoire de Physique des Océans (LPO), Université de Bretagne Occidentale (UBO), Brest, France
[3] UMS 3113, OSU, Institut Universitaire Européen de la Mer (IUEM), Brest, France

IUEM – Institut Universitaire Européen de la Mer (UBO, CNRS, IRD) · LPO · LEMAR – Laboratoire des sciences de l'environnement marin (UMR CNRS/UBO/IRD/Ifremer) · UBO – université de bretagne occidentale · ueb · ANR – Agence Nationale de la Recherche

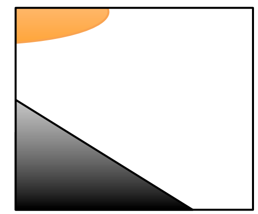
Context

- Shelf slope triggers the formation of meso- submesoscale eddies :

Flat bottom



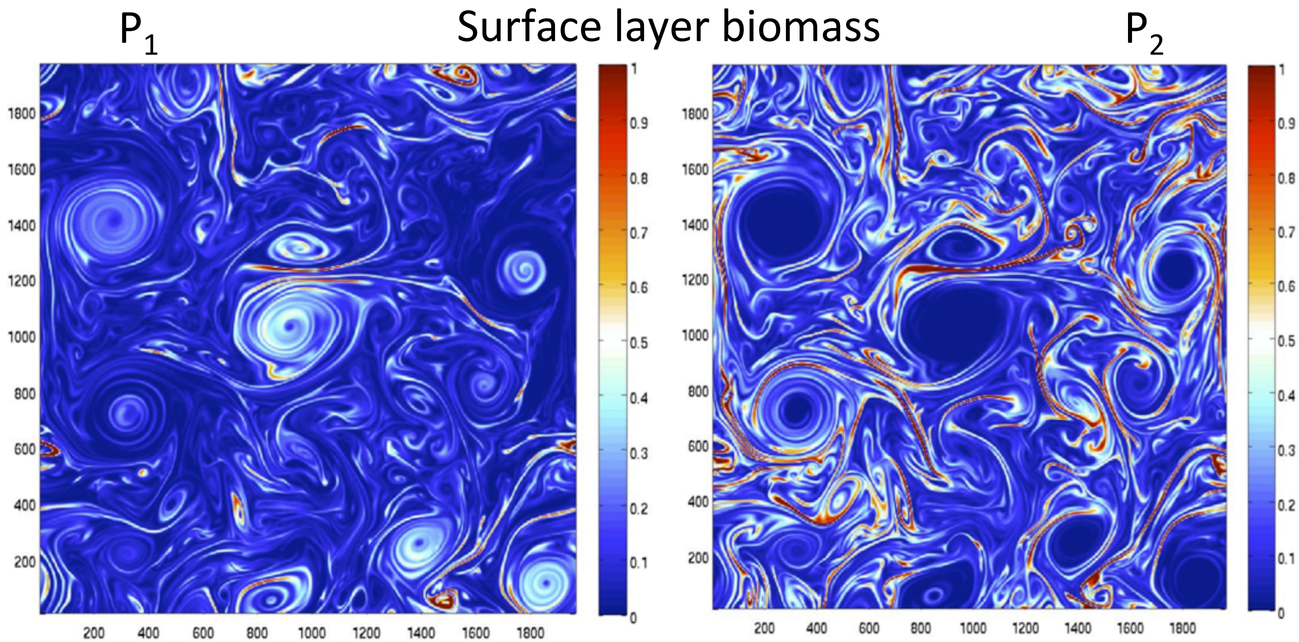
Steep slope

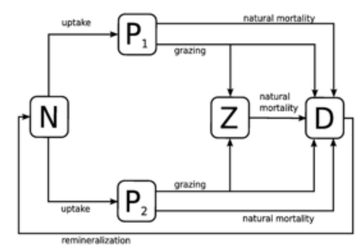


Pennel et al. 2012

Context

- Meso and Submesoscale dynamics stimulates primary production but also organizes plankton diversity
  (d'Ovidio et al. 2010, Perruche et al. 2011, Levy et al. 2012,2014)





Perruche et al. 2011

Context

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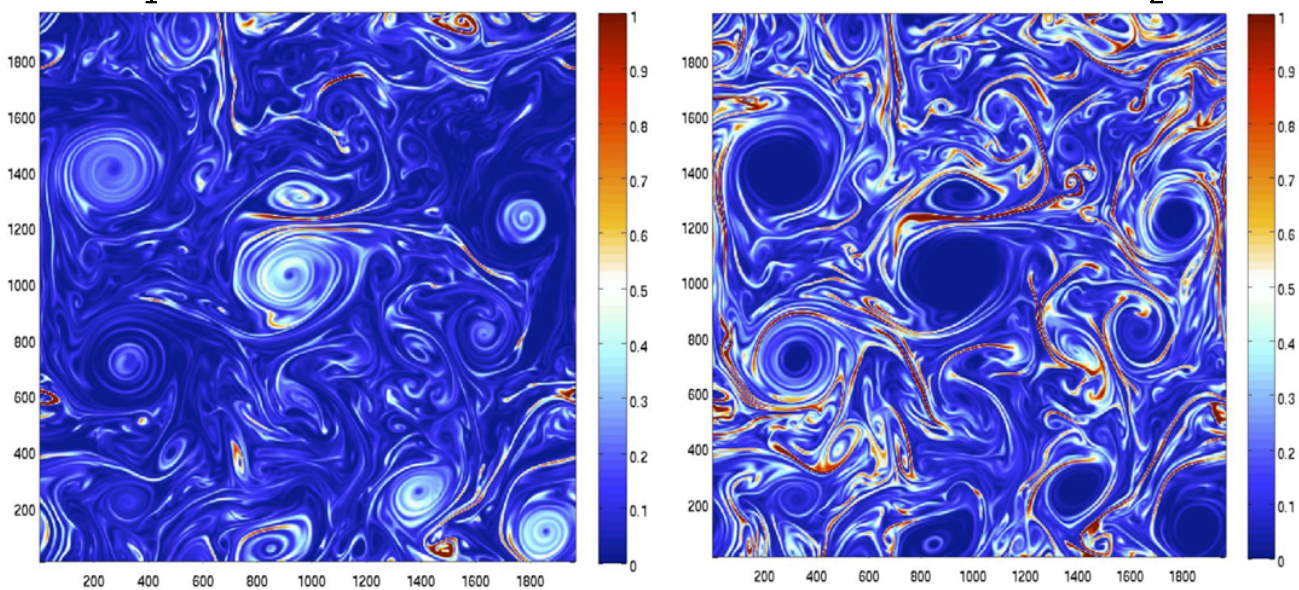
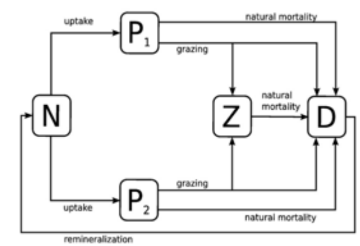
P_1 Surface layer biomass P_2





Perruche et al. 2011

- Lastly regional horizontal density gradient and vertical mixing new source of submesoscale turbulence in the surface layer
  (Boccaletti et al. 2007, Fox-Kemper et al. 2008)

Questions :

- Impact of a shelf slope on the dynamics of a coastal jet in presence of a mixed layer : Focus on the position of the jet.

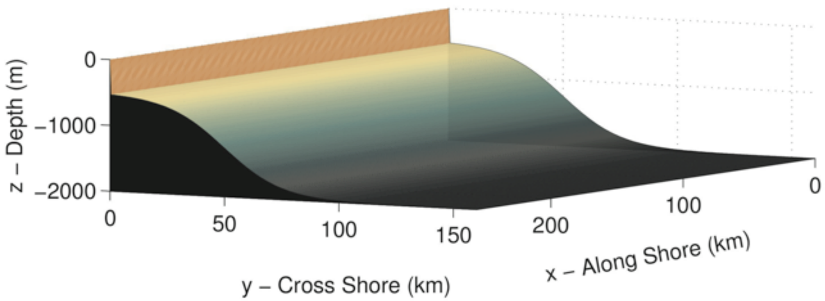
- Consequences on a planktonic ecosystem.

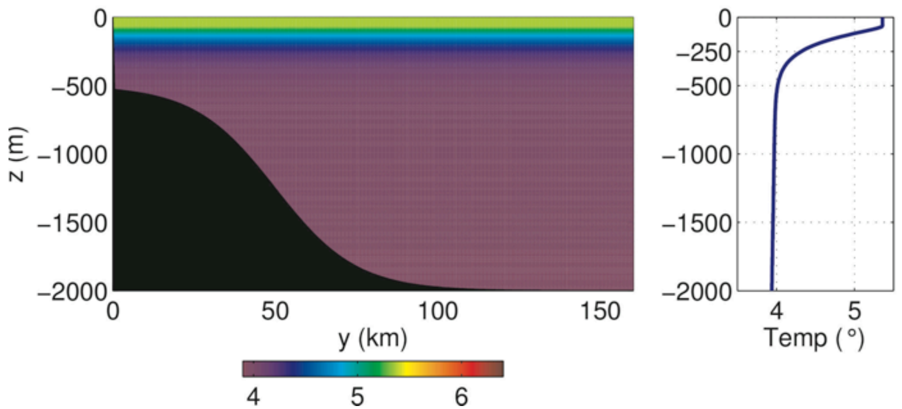
Numerical process study :

1. Idealized coastal model: Physical and Biological
2. Results:
   - Dynamical evolution
   - Planktonic ecosystem response
3. Conclusions

Idealized Coastal Model

Physical Configuration





Primitive Equations (ROMS)

Re-entrant channel
250km x 160km
600 m resolution / 60 vertical levels

tanh shelf bathymetry (3%)
Background stratification + Mixed Layer
First deformation radius ~ 7km
Mixed layer : constant short wave radiation, no net surface heat flux, KPP

Idealized Coastal Model

Physical Configuration

Initial condition:

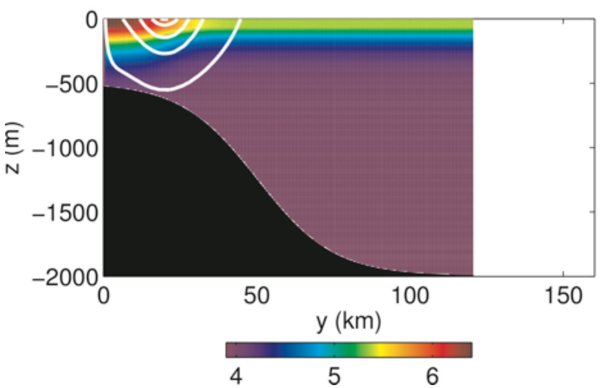
Temperature Anomaly

Geostrophic Balance

Vertical aspect ratio: $\delta = \frac{H_1}{H}$

Topographic Parameter: $To = \frac{s}{\alpha}$

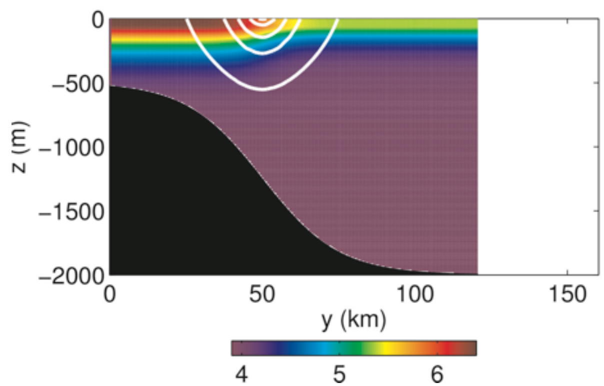
JET COAST



$\delta \approx 0.4 \qquad To \approx -0.5$

More unstable and at smaller scales

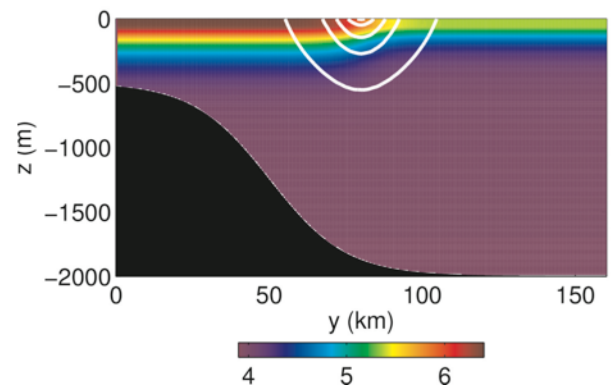
JET SLOPE



$\delta \approx 0.2 \qquad To \approx -3$

Less unstable and at smaller scales

JET SEA



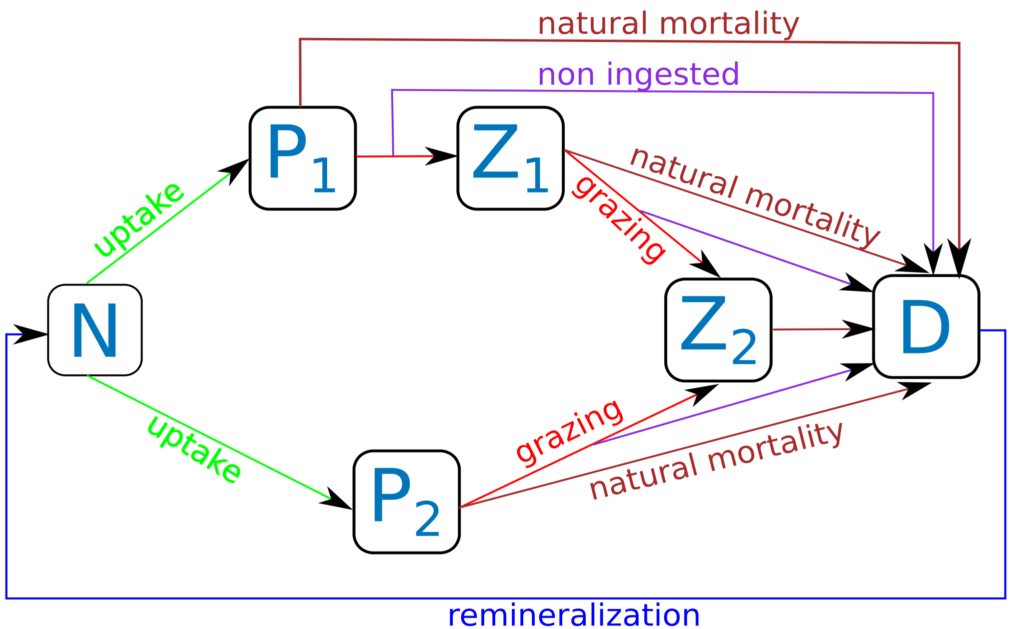
$\delta \approx 0.1 \qquad To \approx -0.5$

Open ocean like with low effect of the slope

Idealized Coastal Model

Biological Configuration

Same as Perruche et al. 2011, but grazing by 2 Zooplanktons



Small species: (P_1 , Z_1)
Large species: (P_2 , Z_2)

<u>Phytoplankton</u>

P_1 : Light limited

P_2 : Nutrient limited

<u>Zooplankton</u>

Z_1 : Specialist

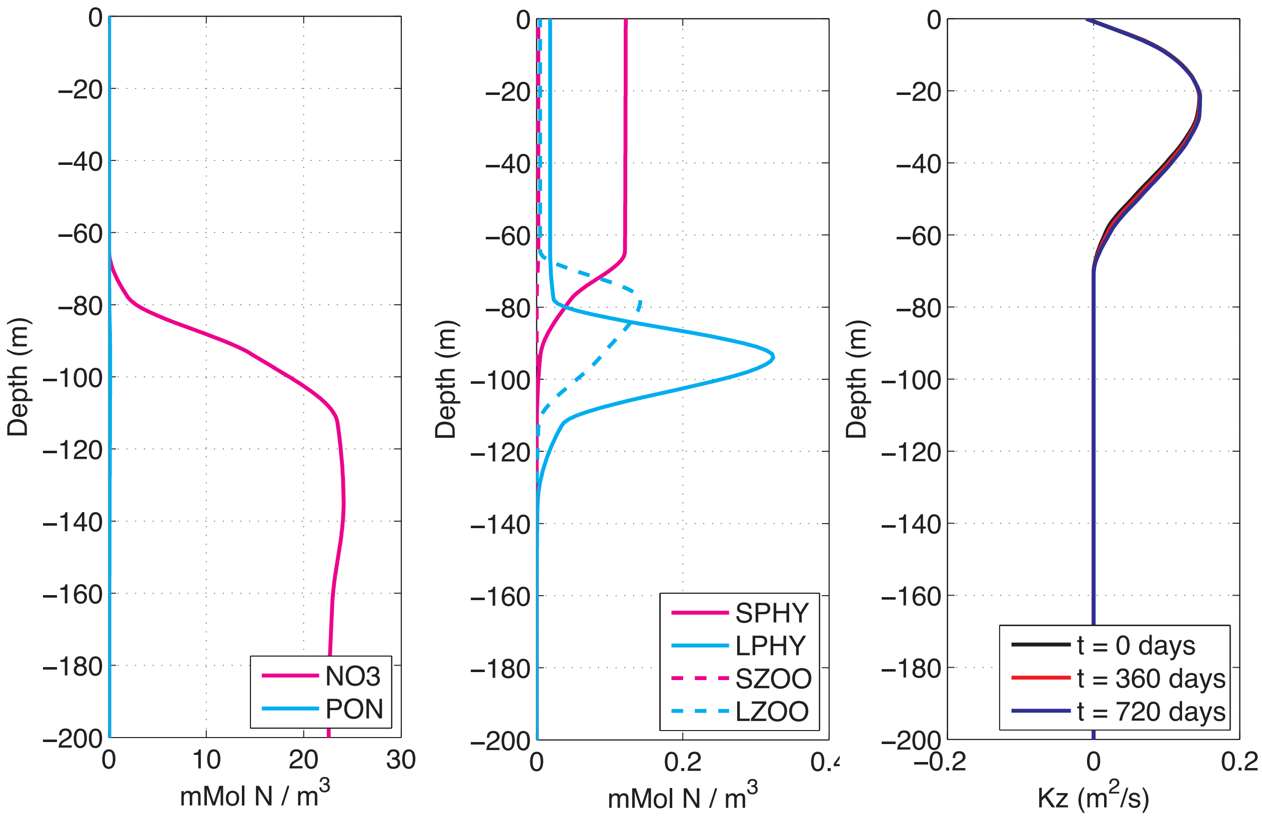
Z_2 : Generalist

Idealized Coastal Model

Biological Configuration

Biological initial conditions :

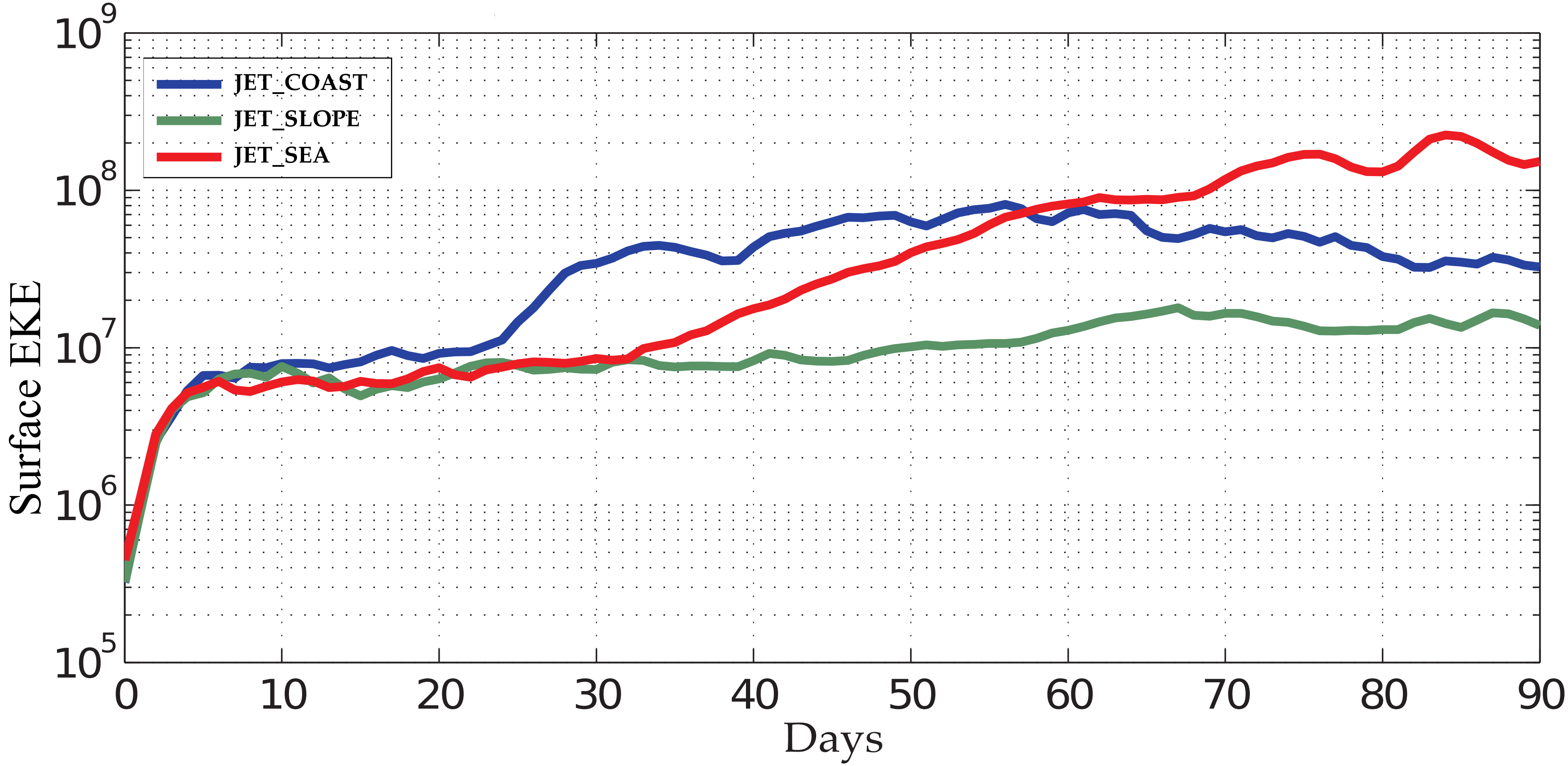
- Vertical mixing + Sedimentation (without3D dynamics)
- Equilibrium condition : oligotrophic system



- Mixed layer (ML): 60 m deep
- Small species inside ML
- Large species bellow ML
- Nitracline depth 100m

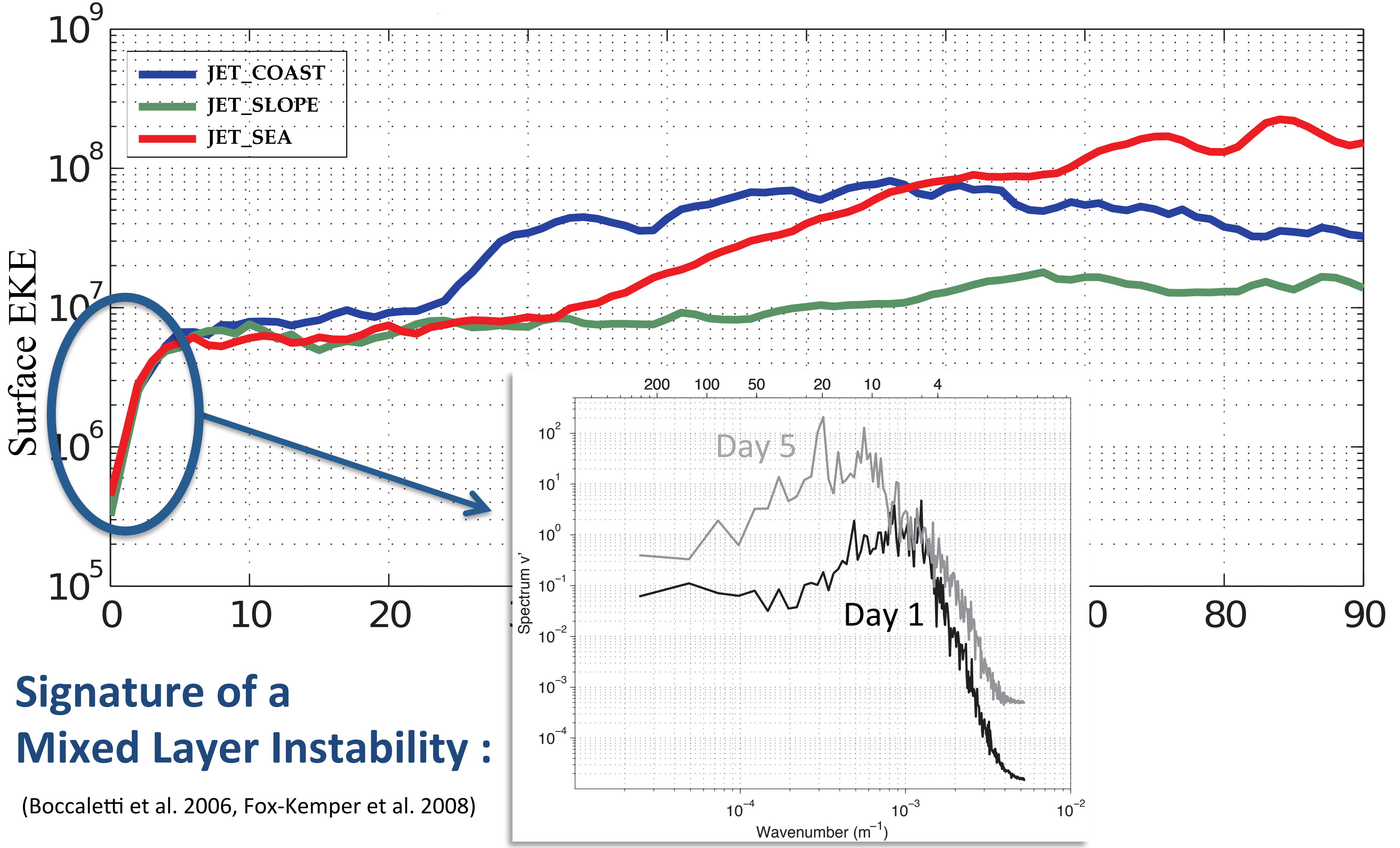
Results

Dynamical Evolution



Results

Dynamical Evolution

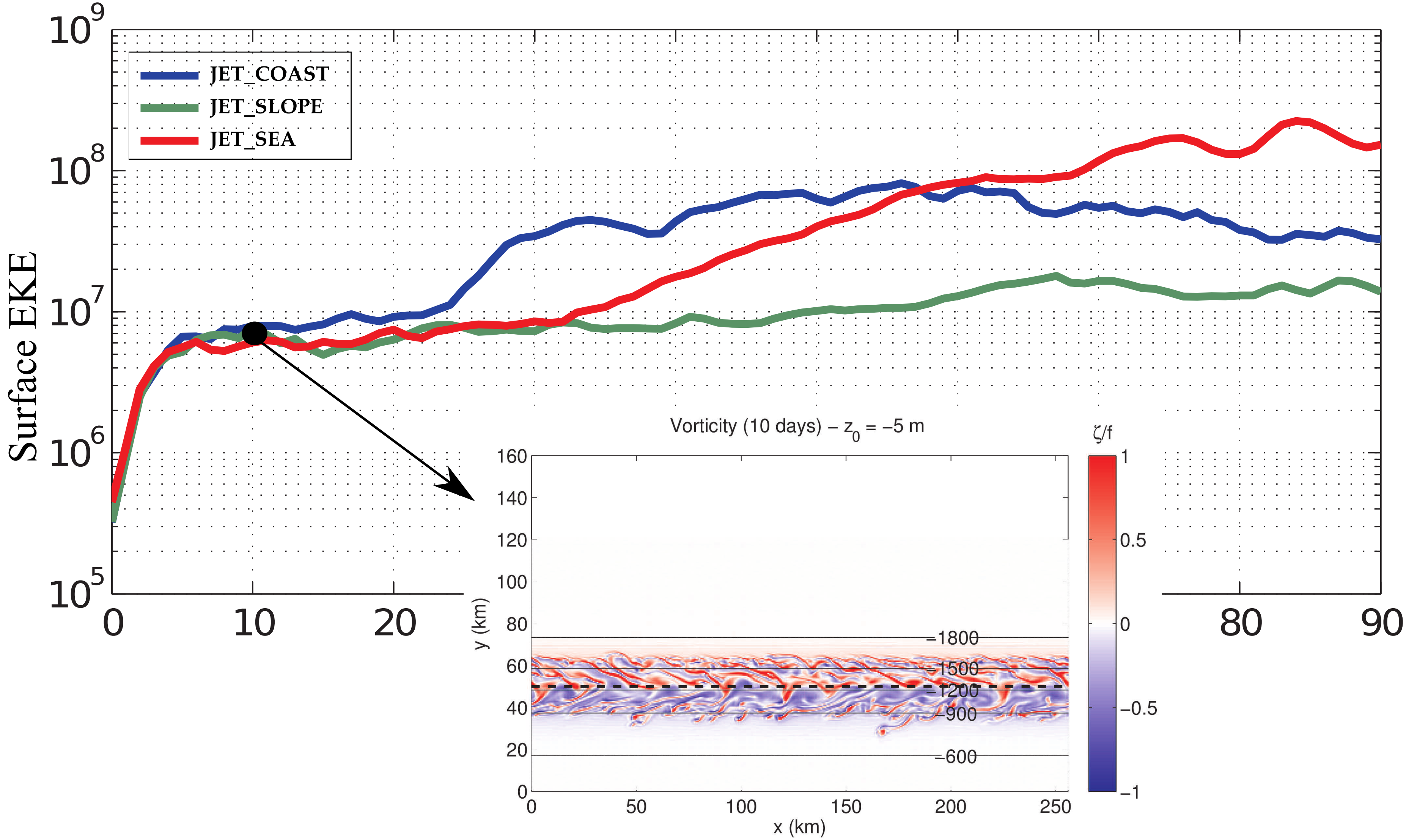


Signature of a Mixed Layer Instability :

(Boccaletti et al. 2006, Fox-Kemper et al. 2008)

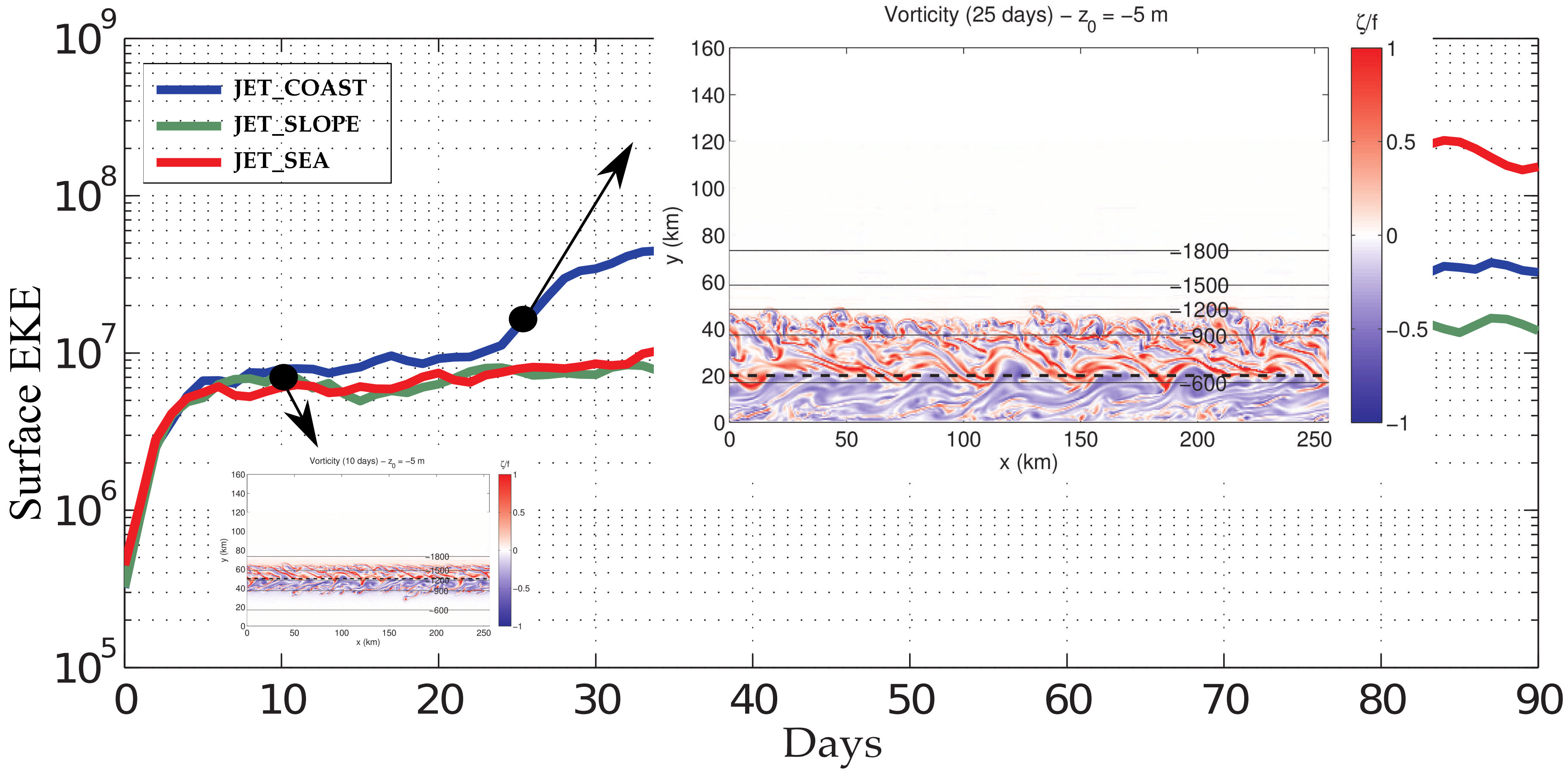
Results

Dynamical Evolution



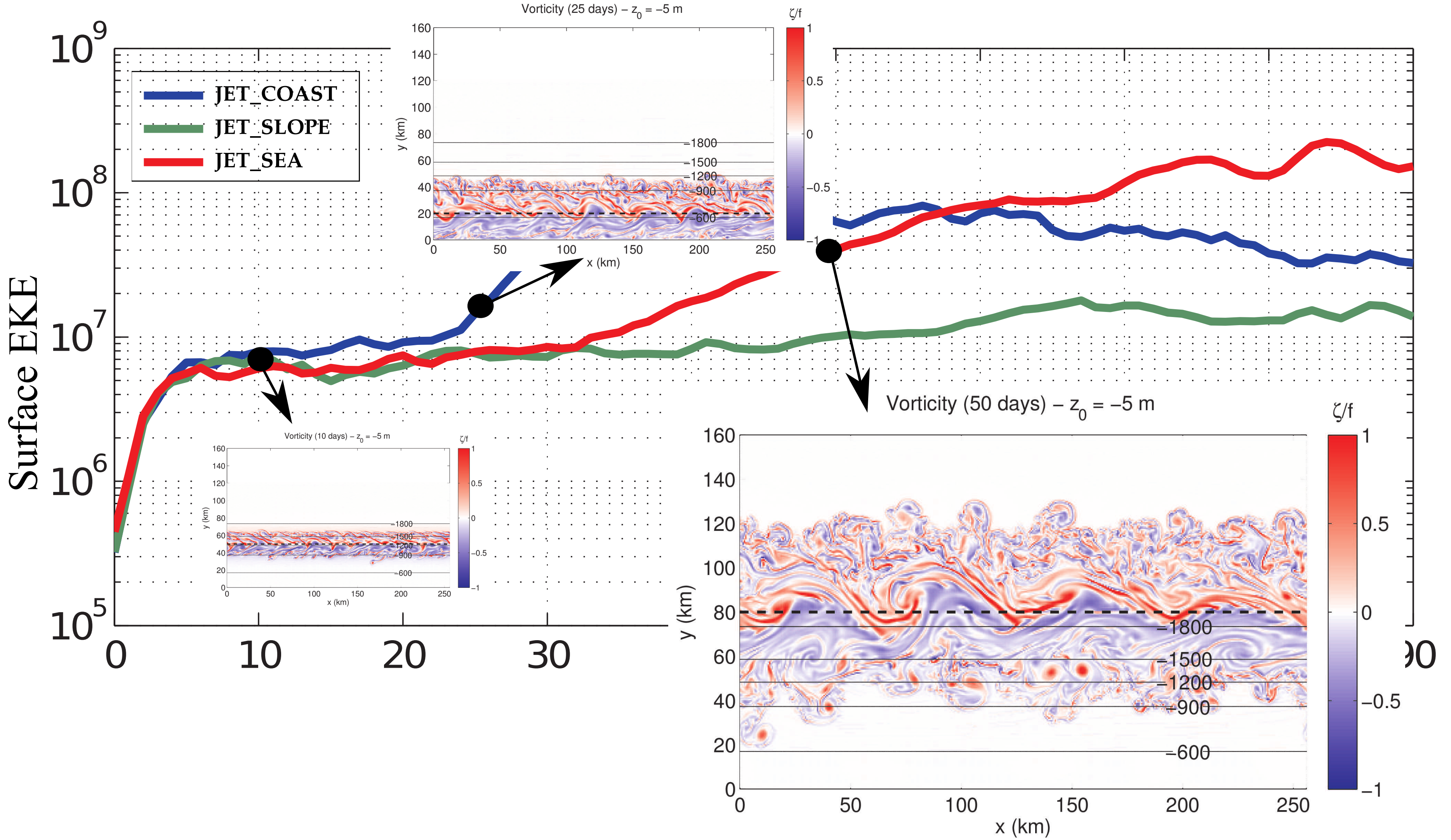
Results

Dynamical Evolution



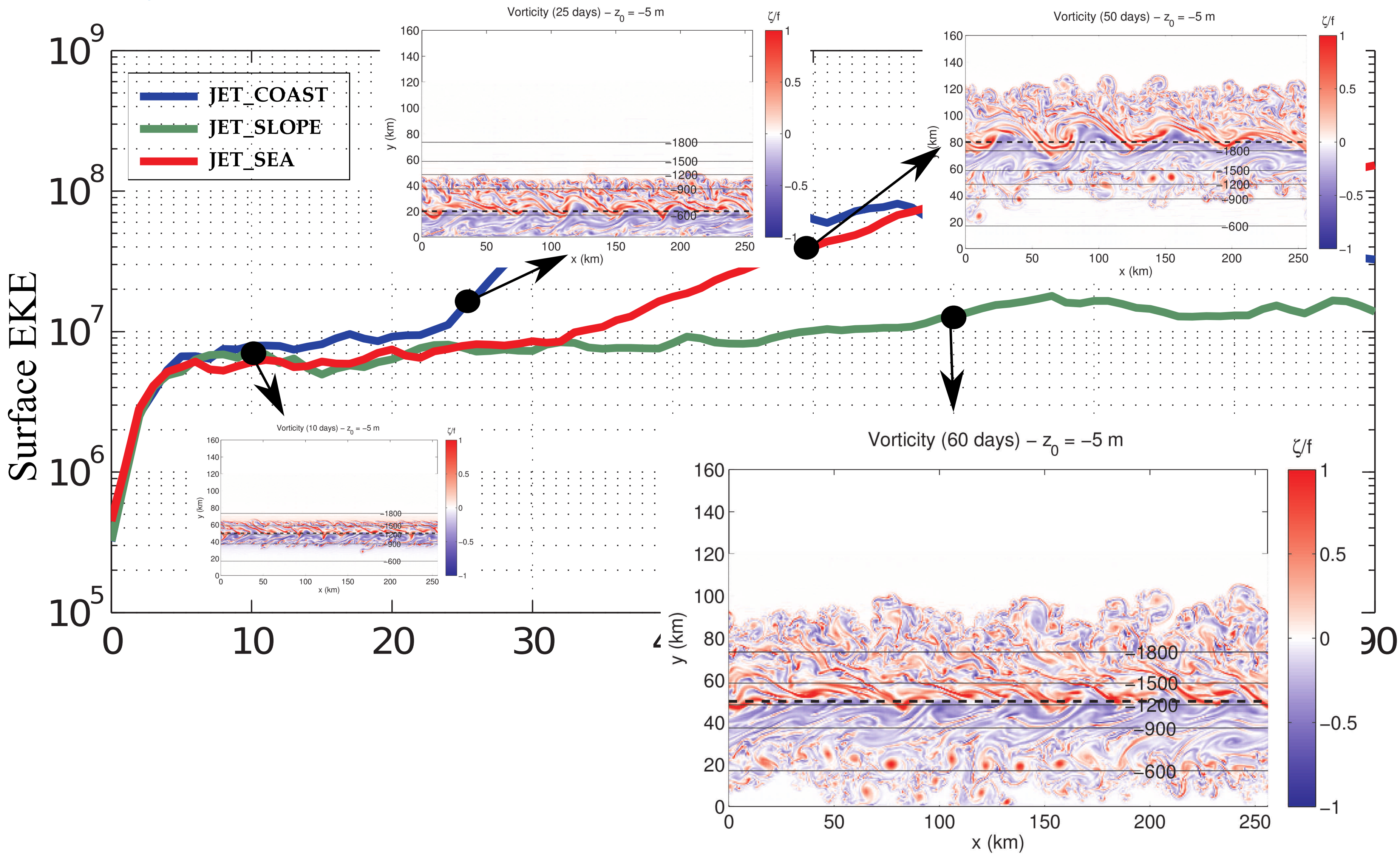
Results

Dynamical Evolution



Results

Dynamical Evolution



Results

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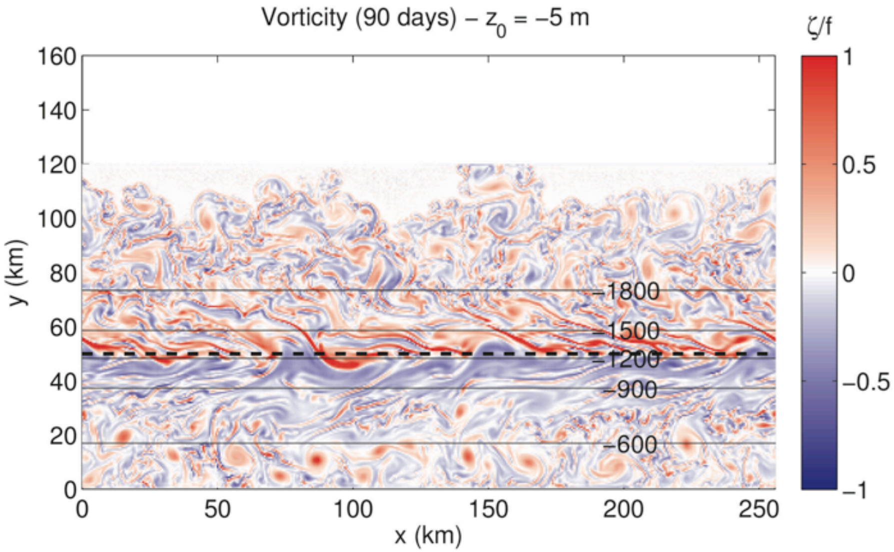
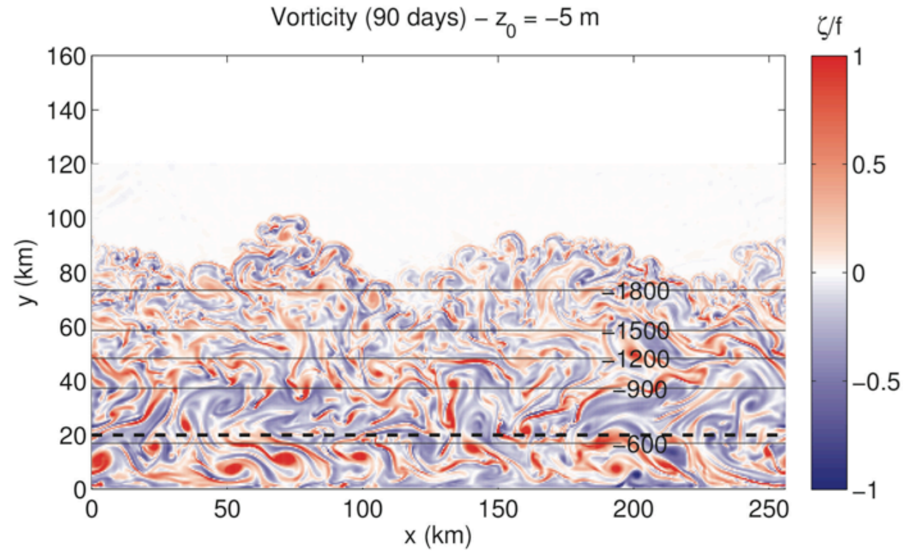
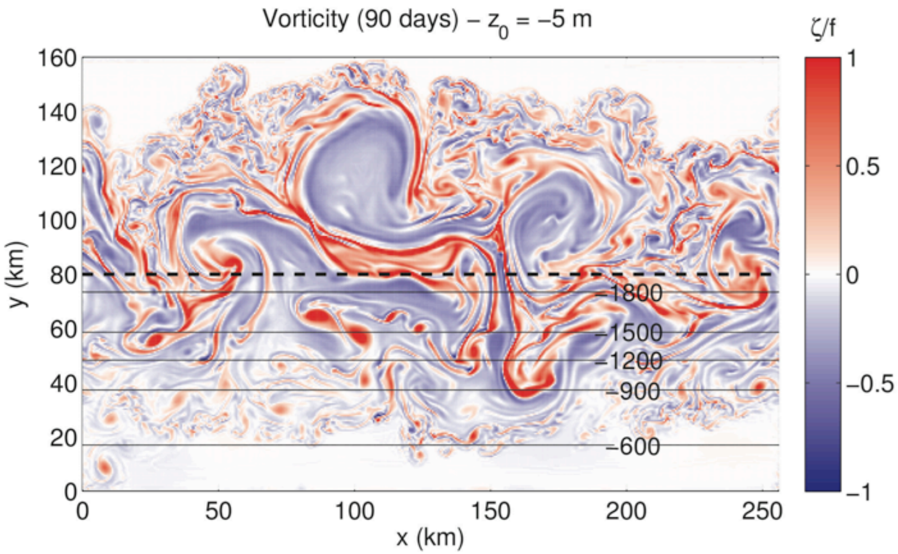




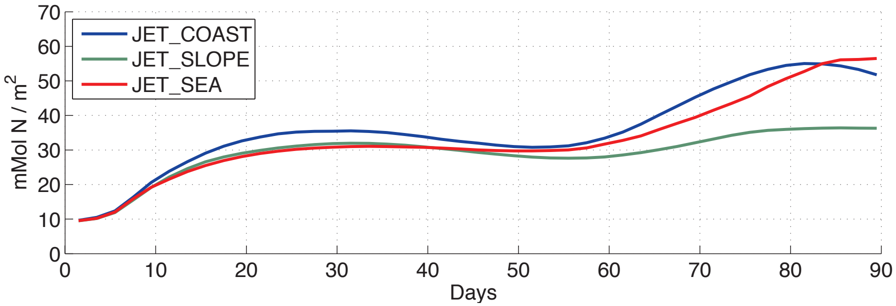


Shelf slope drives the balance between
- Small scales from Mixed Layer Instability
- Meso- Submesoscale from jet instability

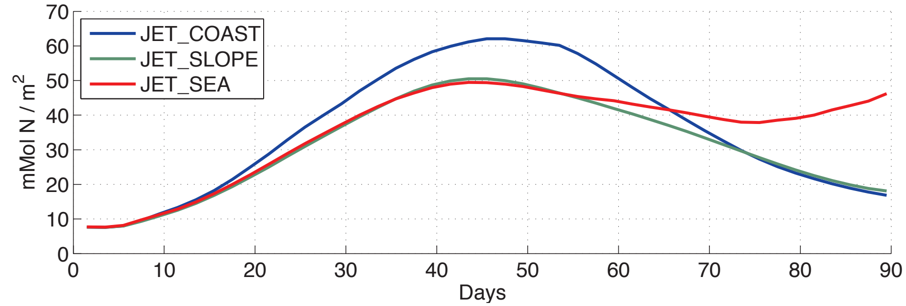
Results

Planktonic ecosystem response

Small Phyto
Biomass (P_1)



Large Phyto
Biomass (P_2)

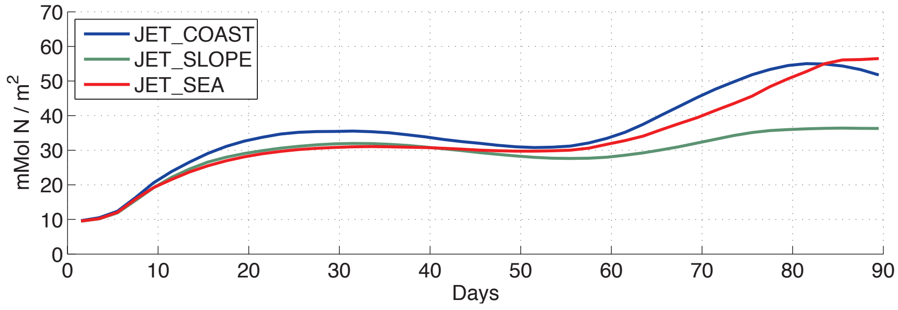


- Meso- Submesoscale triggers a first bloom dominated by large Phyto and a second one dominated by small Phyto.
- This is observed even on the slope.
- Larger and longer bloom in jet at coast
- Weaker bloom in jet at sea but sustained biomass during the second stage.

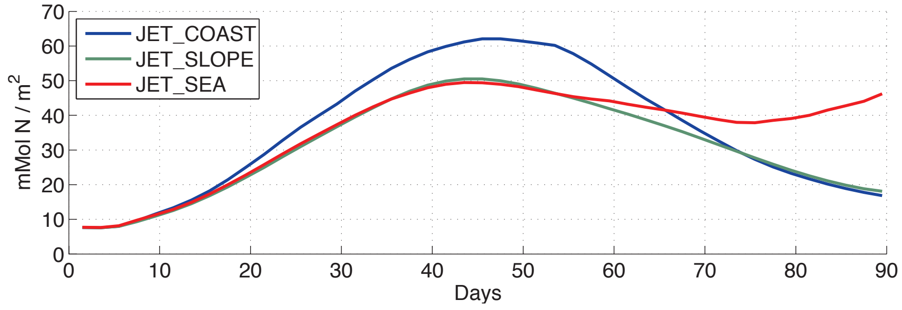
Results

Planktonic ecosystem response

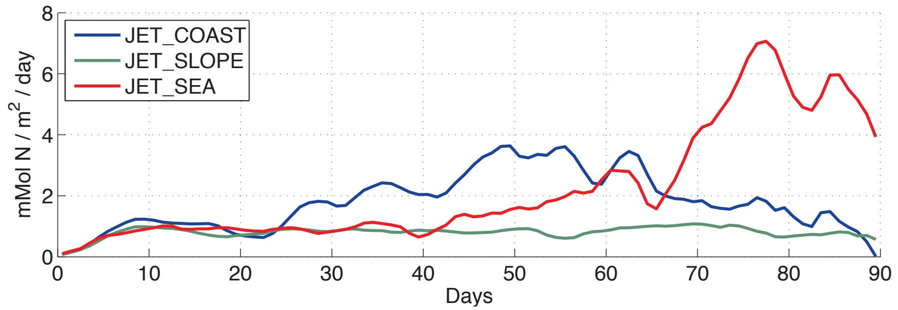
Small Phyto Biomass (P_1)



Large Phyto Biomass (P_2)



Vertical Nitrate flux at 100m (w.N)



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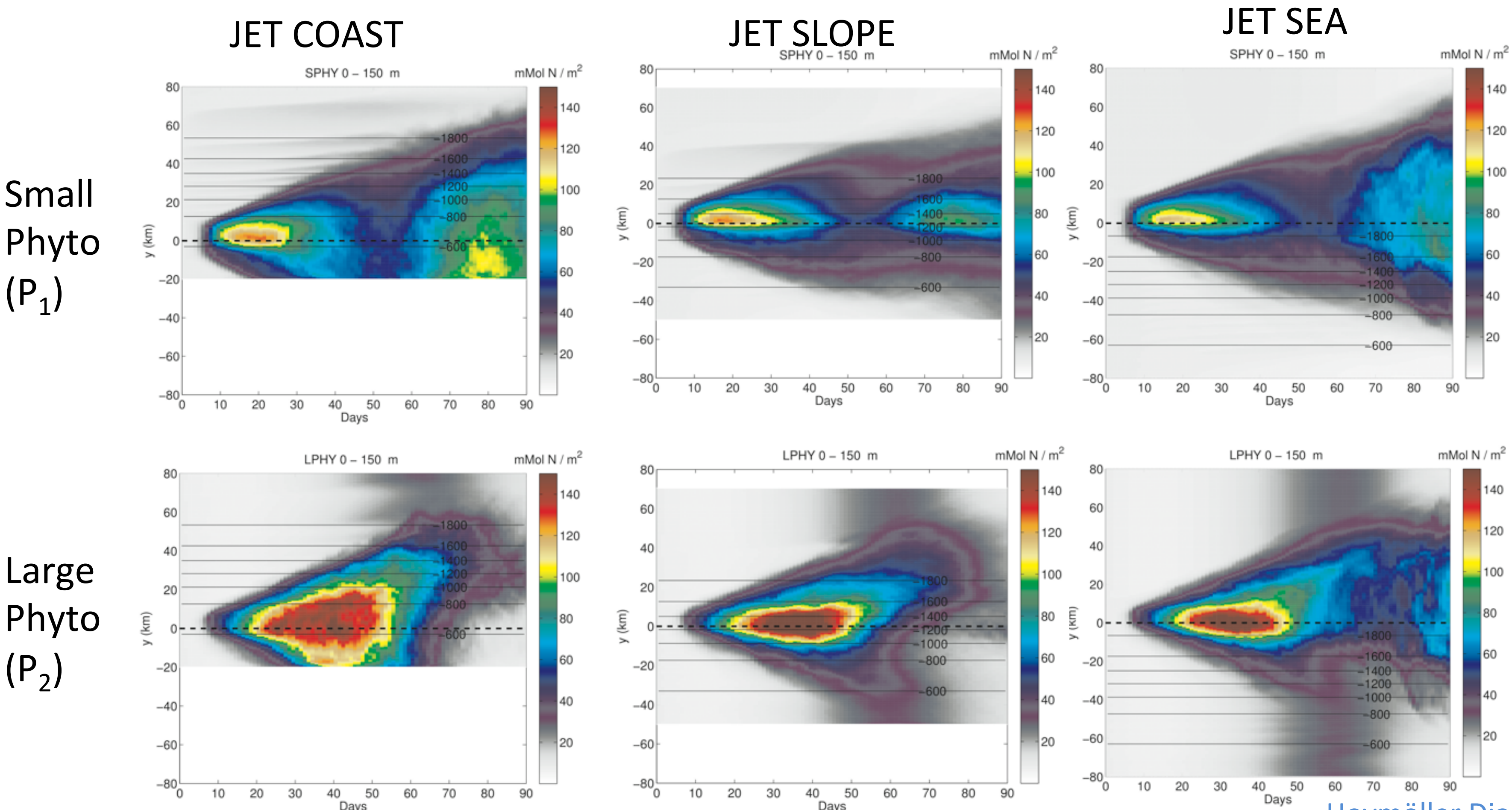
- Biomass evolution strongly in phase with vertical nitrate fluxes

Results

Planktonic ecosystem response



Hovmöller Diagram of the zonal mean integrated over the euphotic layer

Cross-shore extension of the bloom increases as jet gets closer to the coast

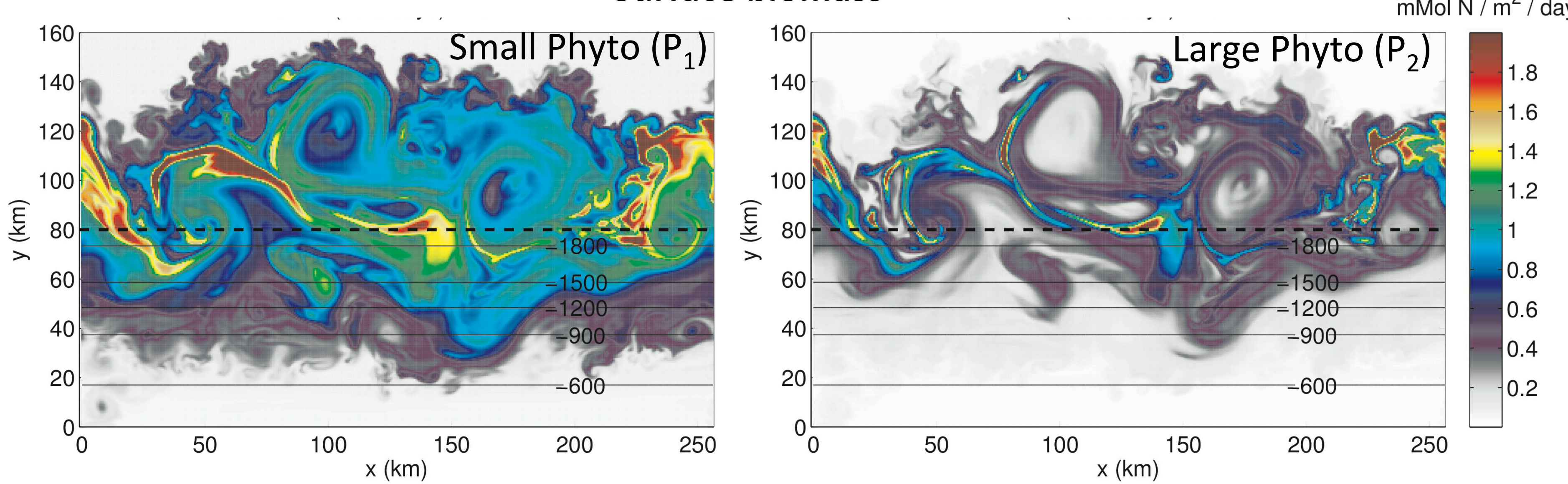
- Stimulation of Large Phyto in the jet at coast
- Significant propagationto the open-ocean after 3 months 0.9 to 0.6 km/d

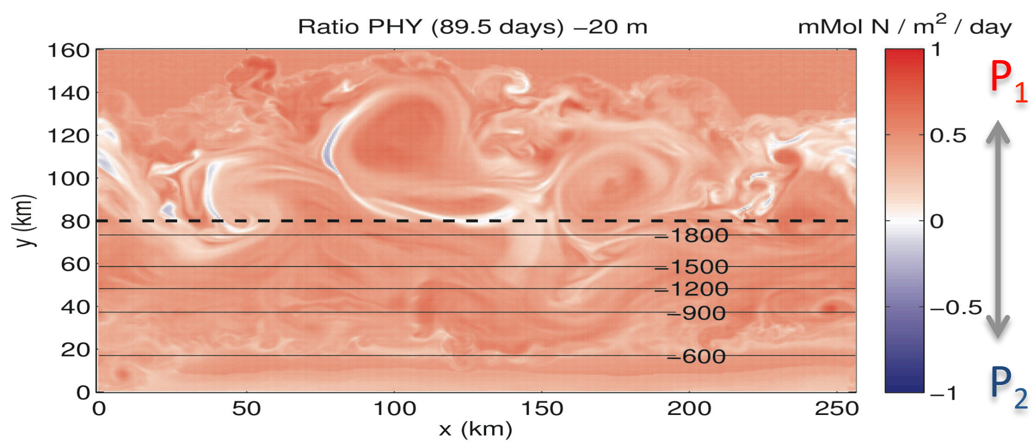
Results

Structure of the Planktonic ecosystem

JET SEA   Day 90

Surface biomass





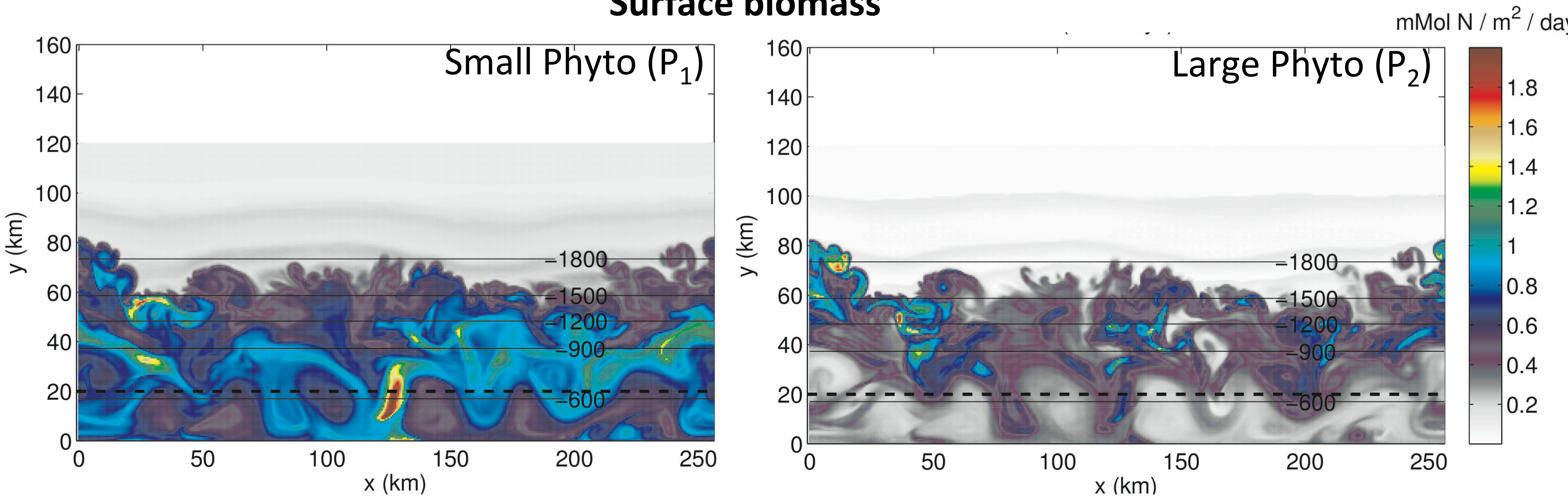
Relative dominance index $\frac{P_1 - P_2}{P_1 + P_2}$

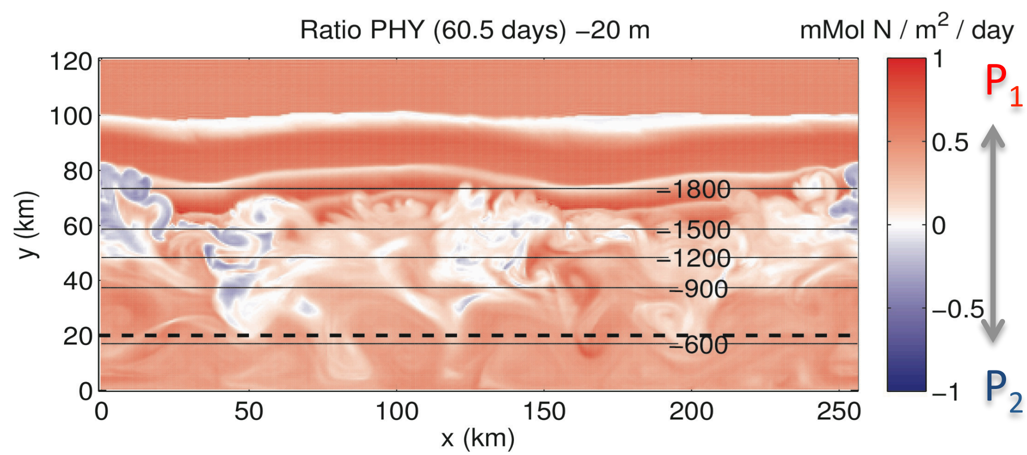
Results

Structure of the Planktonic ecosystem

JET COAST Day 60

Surface biomass





Relative dominance index

$$\frac{P_1 - P_2}{P_1 + P_2}$$

Conclusions

Dynamics

- Mixed Layer instabilities are not affected by the bathymetry
- Shef slope (δ and To) drives the balance between meso-submescale structures arising from mixed layer and coastal current instabilities.

Biology

- Even though the baroclinic instability is limited over the shelf slope, the ecosystem is stimulated by submesoscale eddies and filaments.
- The position of the jet has a significant role on the primary production level.
- For the jet at coast, the ecosystem is strongly active in small scale structures and spreads over large area.
- This dynamics affects the competition between the phytoplankton species.