How much can the frontal-induced biological production compensate adverse effects of climatic warming in an oligotrophic system?

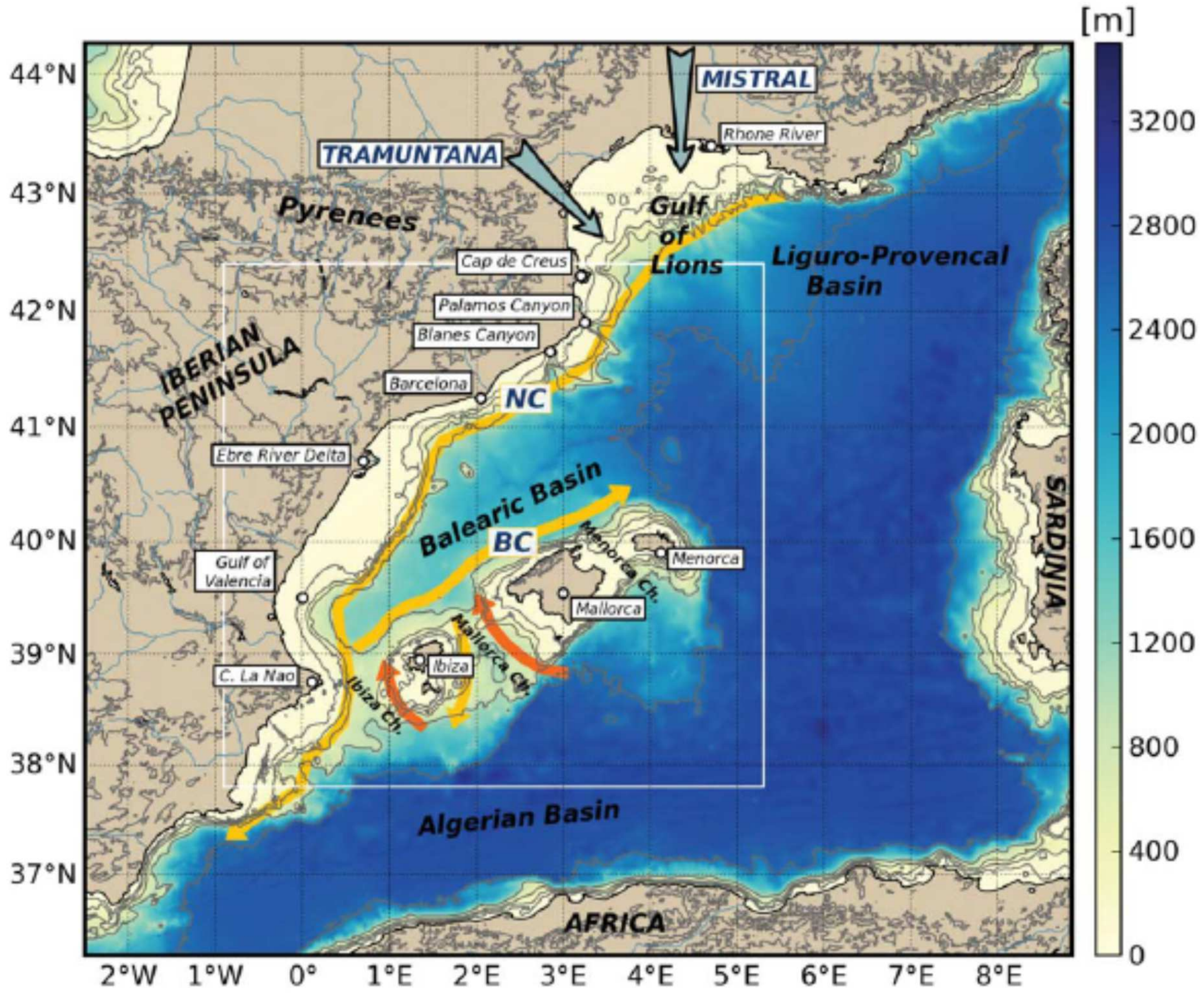
A numerical process study in the Western Mediterranean

Temel Oguz, Diego Macías, Joaquín Tintoré

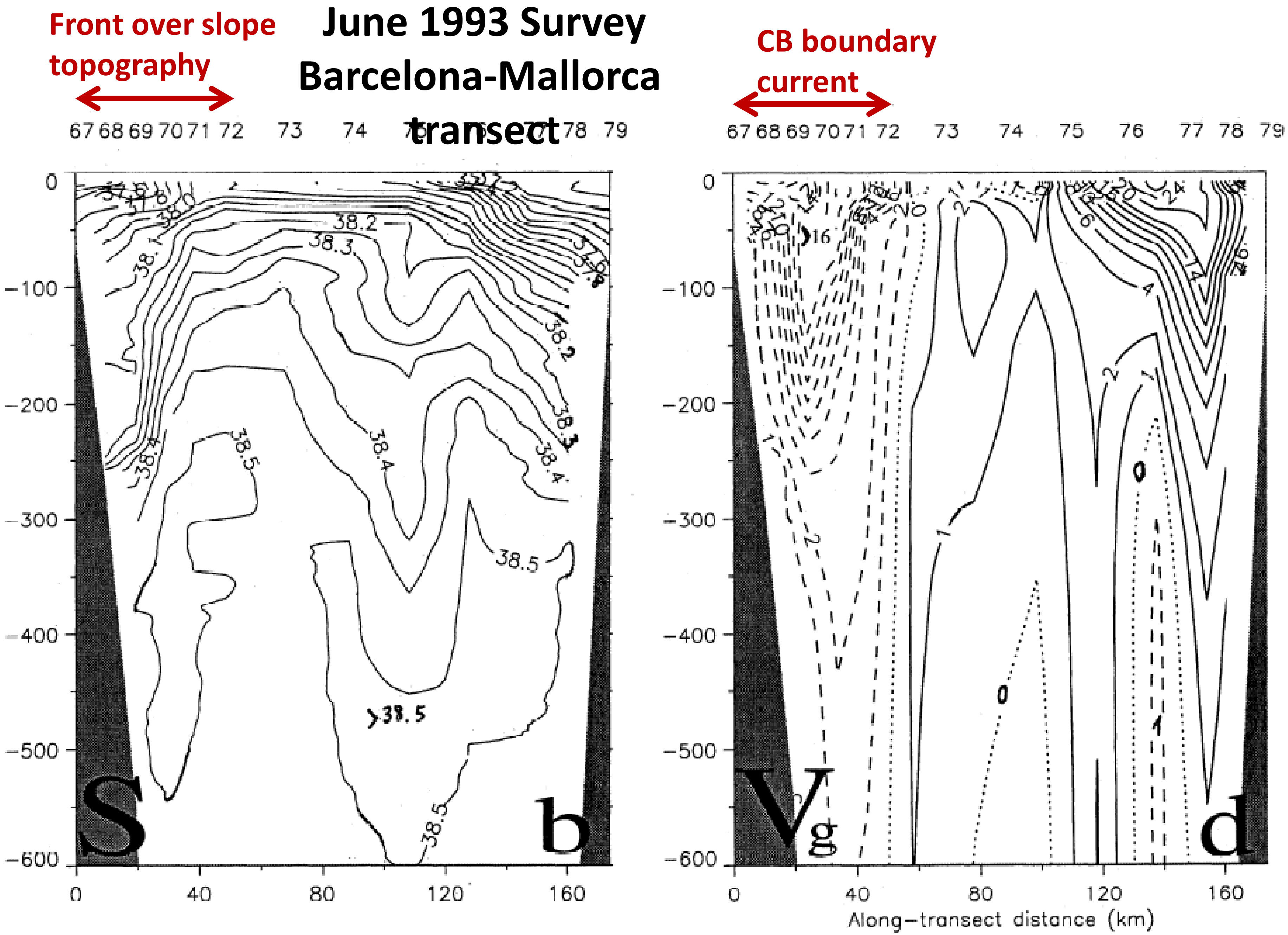
What do we know about the dynamics of frontal - induced biological production in marginal seas ?

This is totally unexlored subject !

How do Ageostrophic Frontal Processes control phytoplankton production in the Catalano-Balearic Sea (Western Mediterranean)?

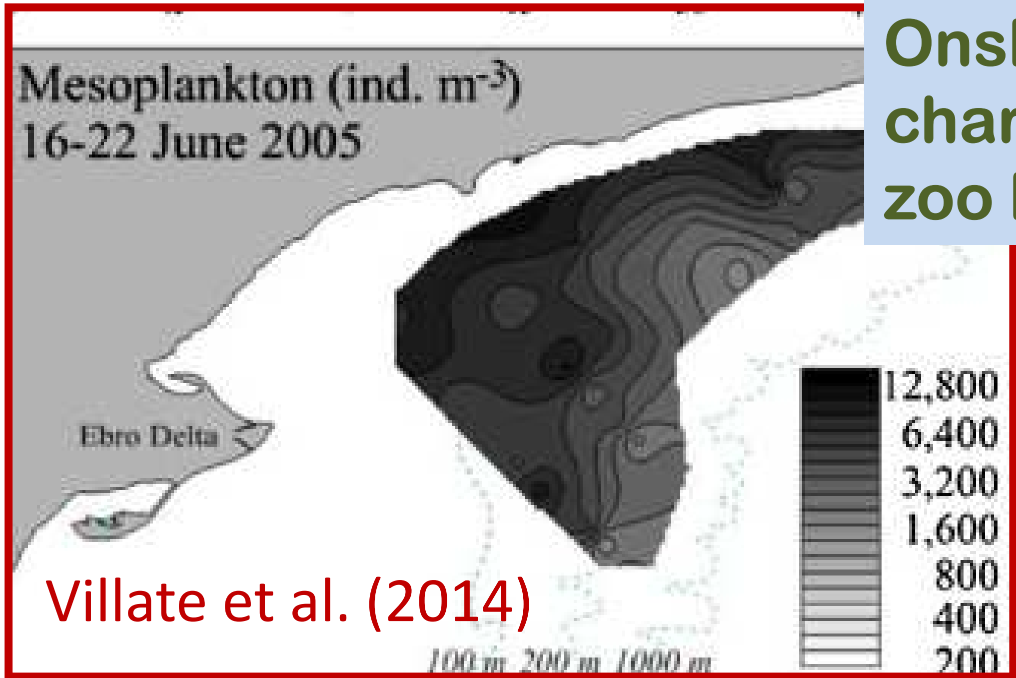

[m]
3200
2800
2400
2000
1600
1200
800
400
0
44°N
43°N
42°N
41°N
40°N
39°N
38°N
37°N
2°W
1°W
0°
1°E
2°E
3°E
4°E
5°E
6°E
7°E
8°E
MISTRAL
TRAMUNTANA
Rhone River
Pyrenees
Gulf of Lions
Liguro-Provencal Basin
Cap de Creus
Palamos Canyon
Blanes Canyon
Barcelona
IBERIAN PENINSULA
NC
Ebre River Delta
Balearic Basin
BC
Menorca Ch.
Menorca
Mallorca
Gulf of Valencia
Mallorca Ch.
Ibiza
C. La Nao
Ibiza Ch.
SARDINIA
Algerian Basin
AFRICA

June 1993 Survey Barcelona-Mallorca transect

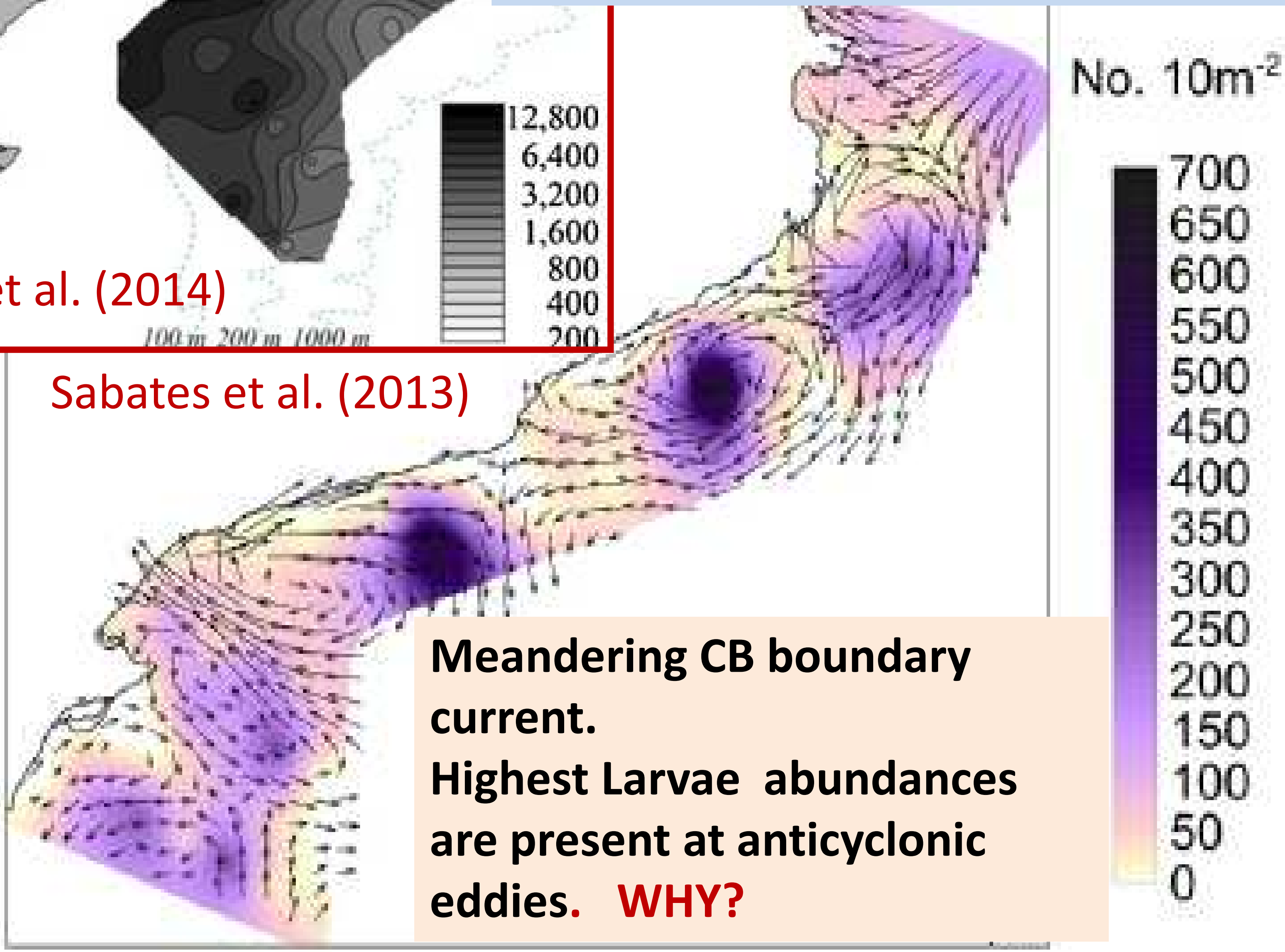


Pinot & Ganachaud (1999)

Onshore side of the CB front is characterized by high phyto and zoo biomass and fish larvae.



Villate et al. (2014)



Sabates et al. (2013)

Meandering CB boundary current.
Highest Larvae abundances are present at anticyclonic eddies. WHY?

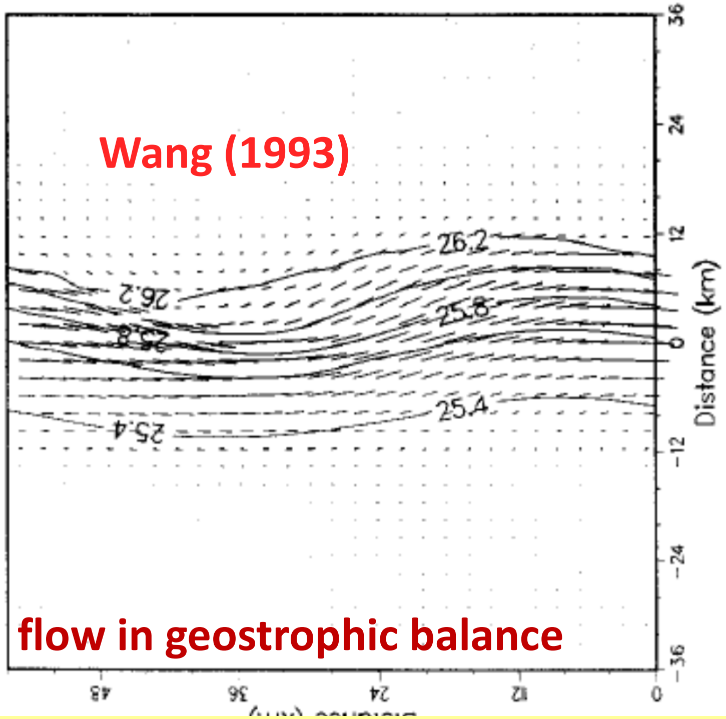
We show that

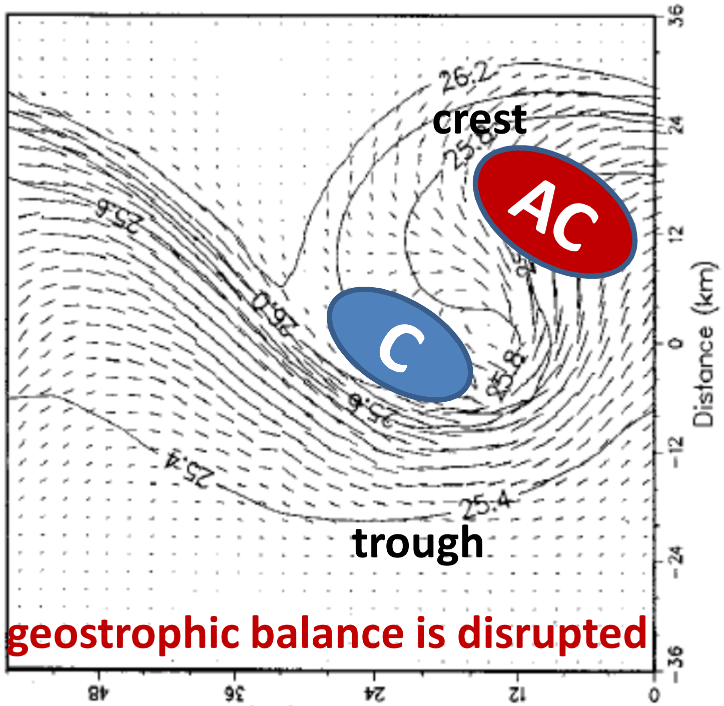
When frontal boundary current was unstable, and moderately nonlinear (i.e. beyond the quasigeostrophic regime),

• the ageostrophic cross-frontal circulation arise (due to conservation of potential vorticity).
• It provides high upwelling velocities up to 80 m d^{-1}
• to inject nutrients into the photic layer and
• to promote enhanced plankton production on the less dense, onshore side of the front within anticyclonic eddies.

Thus, ageostrophic frontal processes govern biological production characteristics in the Catalano-Balearic Sea to a large extent.

BOUNDARY CURRENT INSTABILITIES Intensify cross frontal density gradient that causes disruption of the geostrophic balance





As the disturbance starts growing, the surface jet becomes narrower, the along-channel velocity becomes stronger at wave trough than at wave crest.

The horizontal velocity shears (relative vorticities) also become larger on the cold (cyclonic) side than on the warm (anticyclonic) side.

Similarly, the density front (between 25.6 and 26.0) is much narrower and steeper in the wave trough.

The geostrophic balance is restored by the development of ageostrophic (i.e. cross-frontal) circulation.

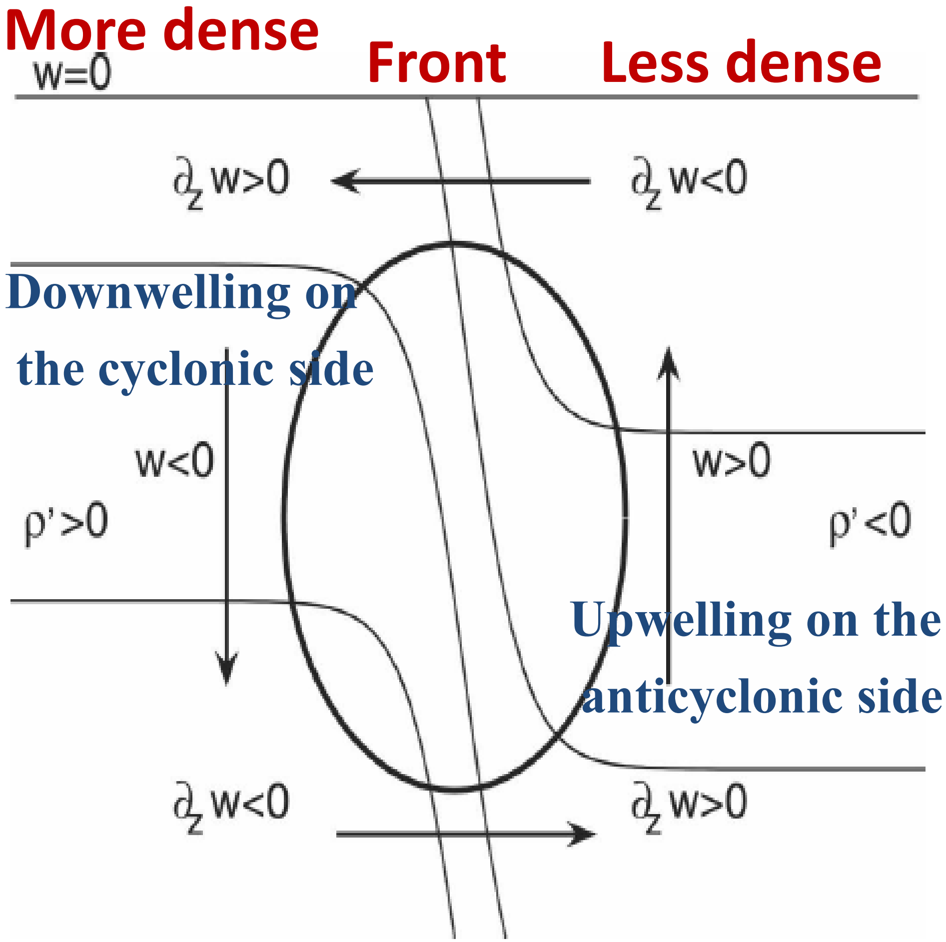
HOW?

By tilting the isopycnals towards horizontal (i.e. restratifying the water column) and thus reducing the cross-frontal density difference in the frontal zone.

HOW?

By lifting lighter fluid (upwelling) and subducting denser fluid (downwelling) so that isopycnals are flattened.

HOW ?

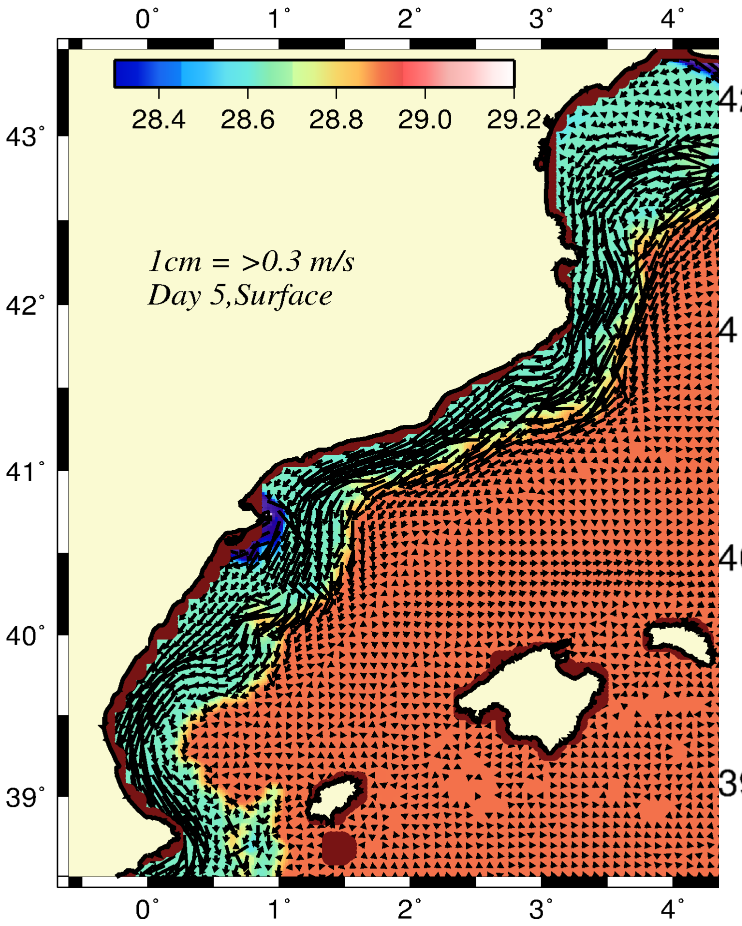


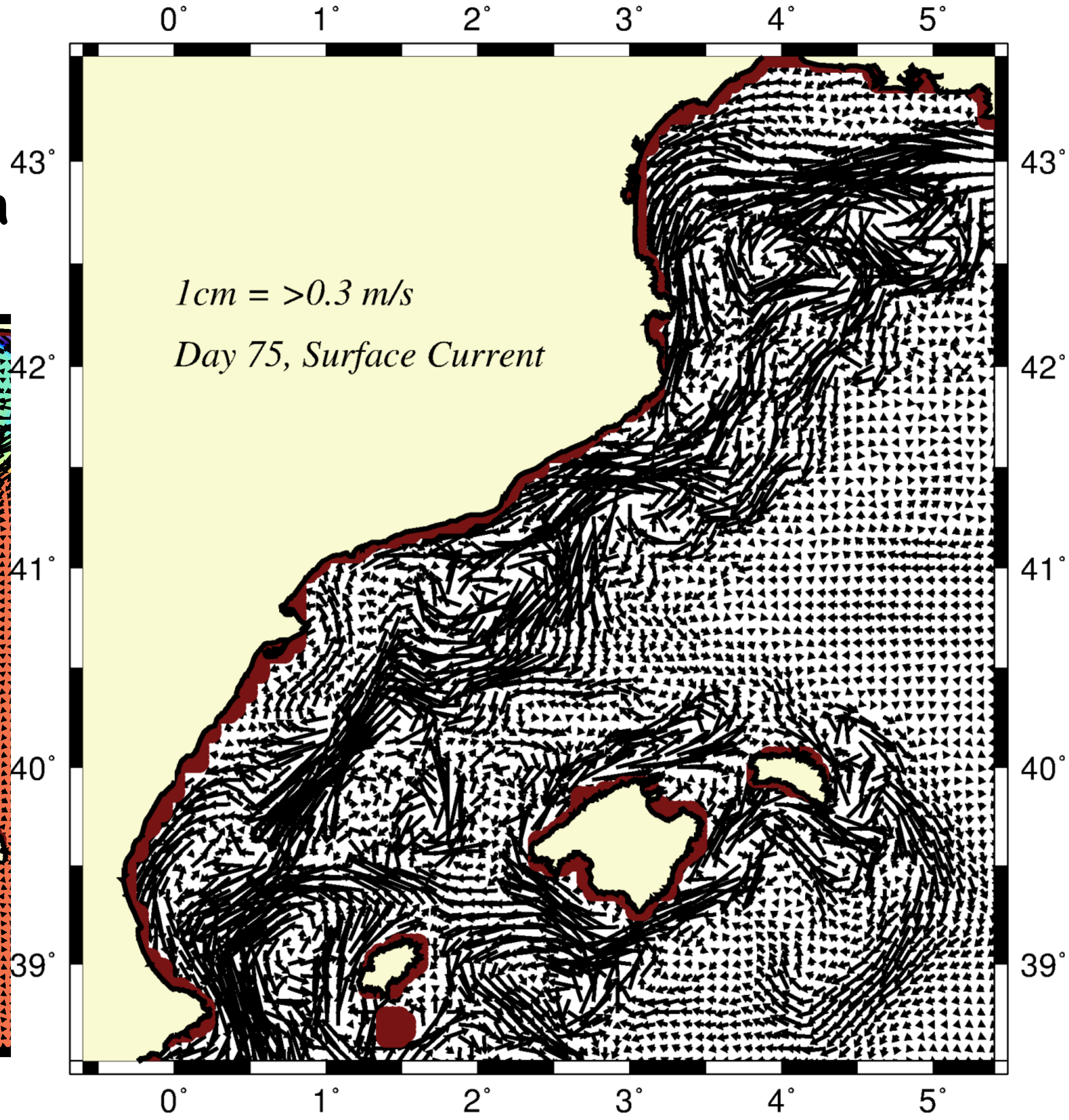
An idealized coupled physical-biological model study

- ~3km grid size (eddy resolving), 29 sigma levels in the vertical.
- POM hydrodynamical model + NPZD biological model.
- Simplified initial Winter conditions (representing the most productive season): horizontally uniform T, S, nitrate over the basin.
- Front is located initially along the topographic slope at 800-1400m isobaths. More fresh but colder waters on the onshore side of the front at the upper 250 m layer.
- Inflow from the northeastern corner (over topographic slope zone along the French coast within the upper 250m.
- Weak (background) down-front (northeasterly) wind stress. with magnitude of $0.2*10^{-4}$ m^2/s^2 .
- Weak (background) cooling (50 watts/m^2) .
- Instabilities are excited by perturbing the initial front and atmospheric forcing.
- River discharge and nutrient supply are switched off.
- No nutrient supply from sediment within the shelf.

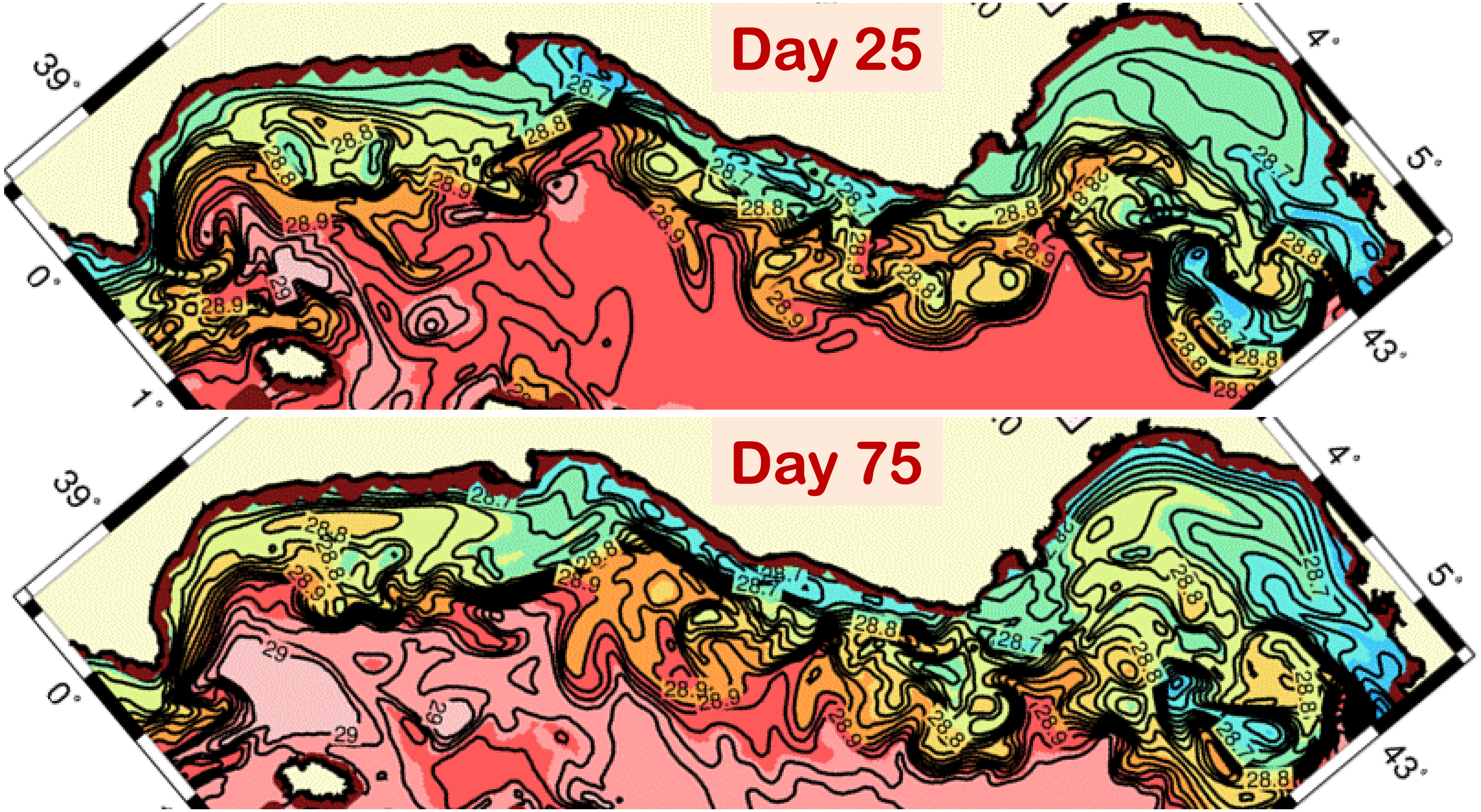
Topographically-controlled meandering current system

INITIAL FIELD (surfa

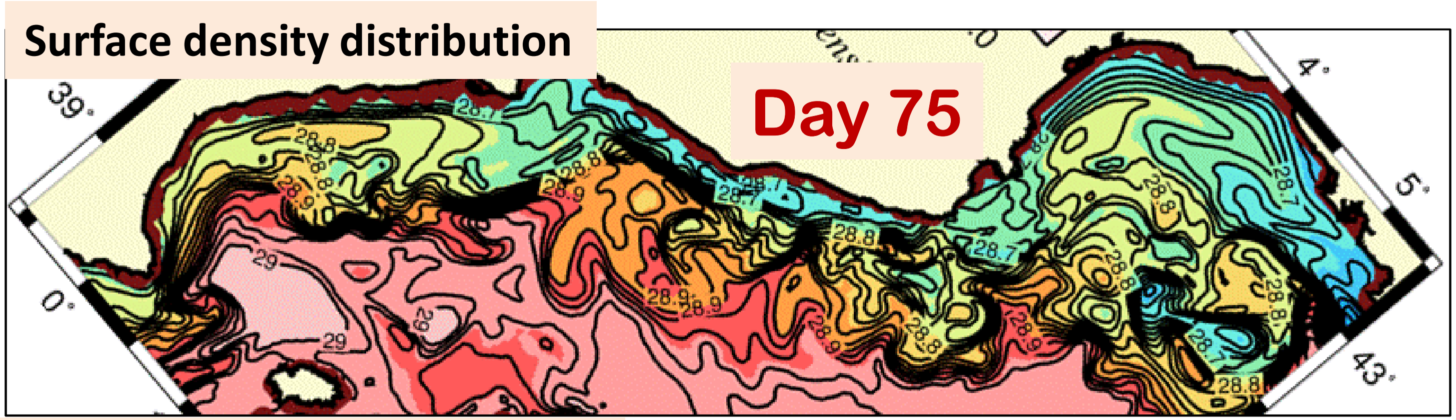


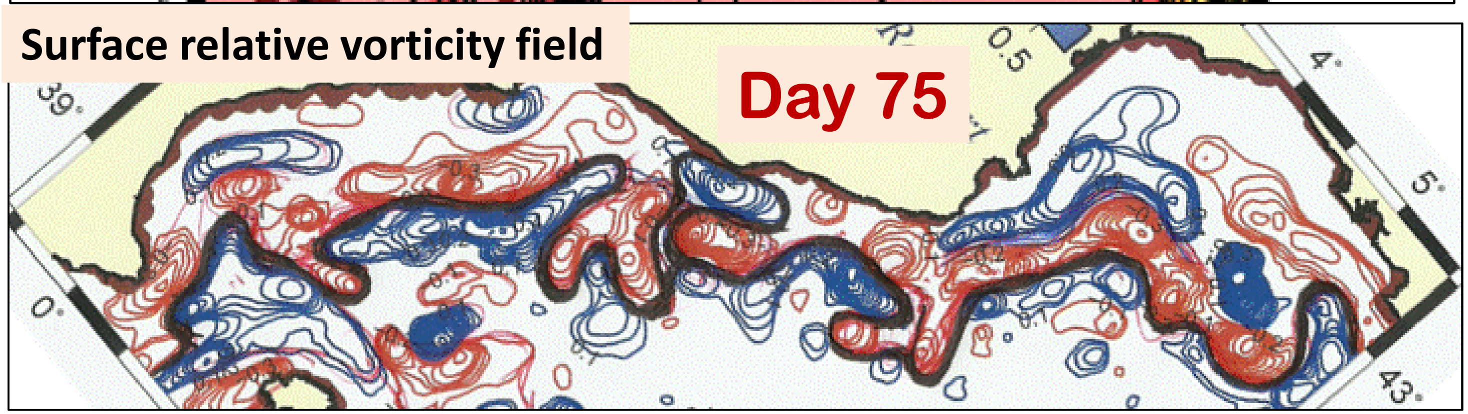


Surface density distributions

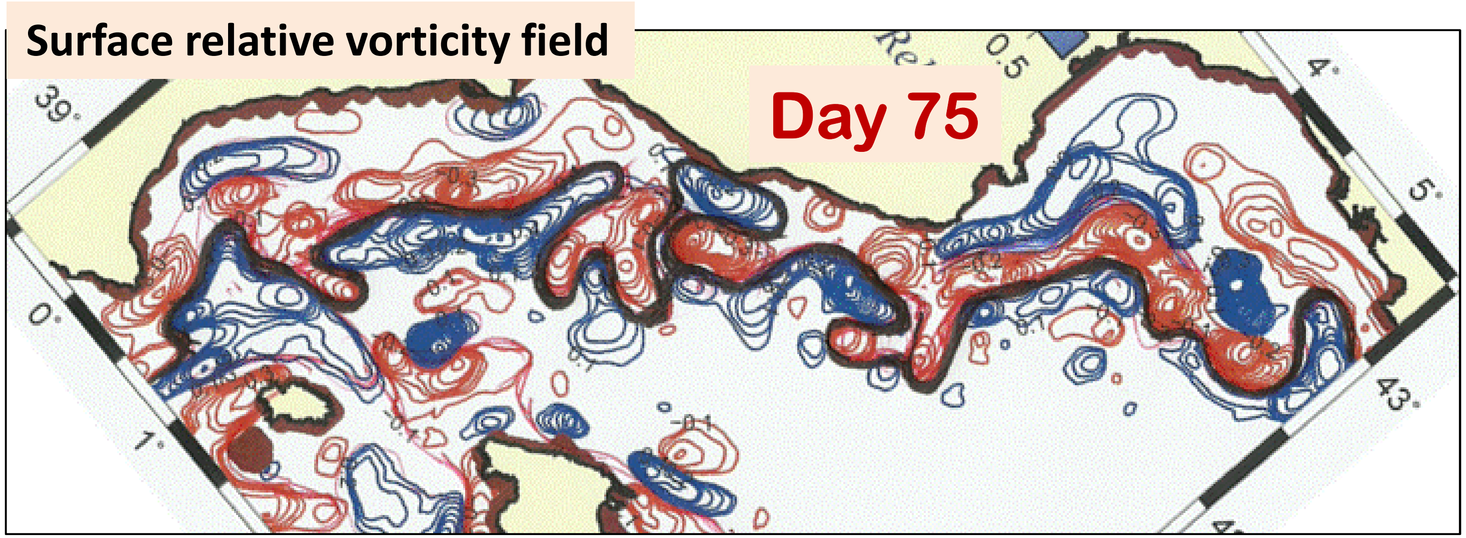


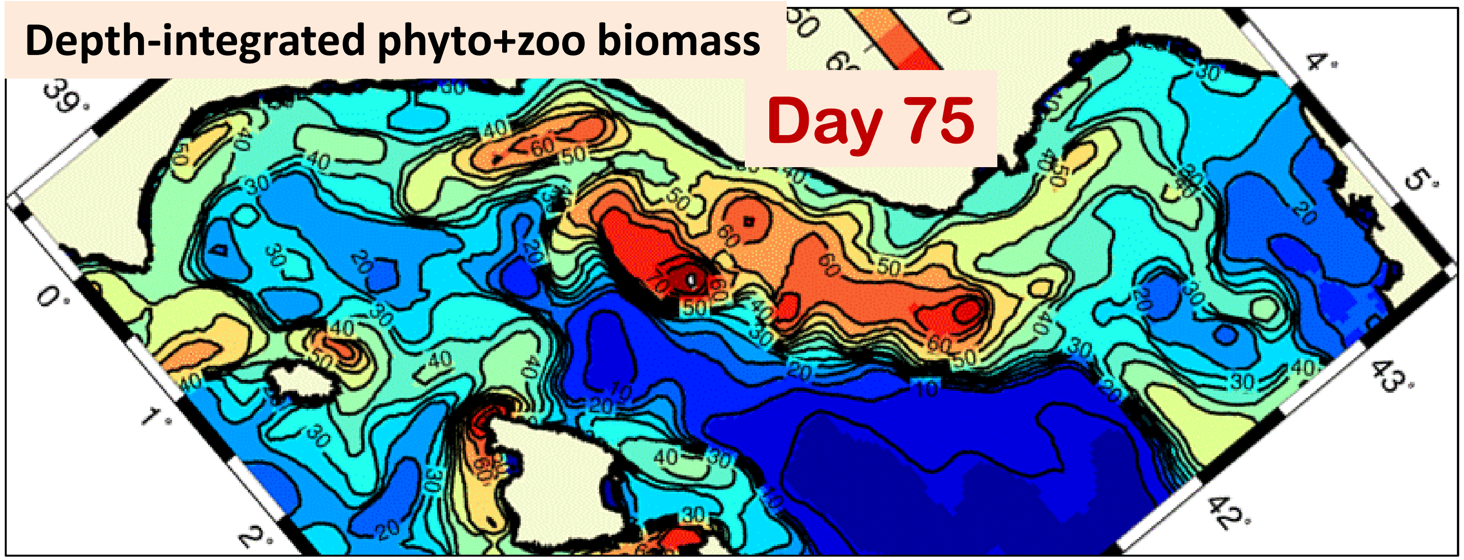
Instabilities were quickly developed to deform the frontal structure. Water column harizontally and vertically stratified by the instabilities.
Double front system; over the shelfbreak and further offshore along the margin topography.



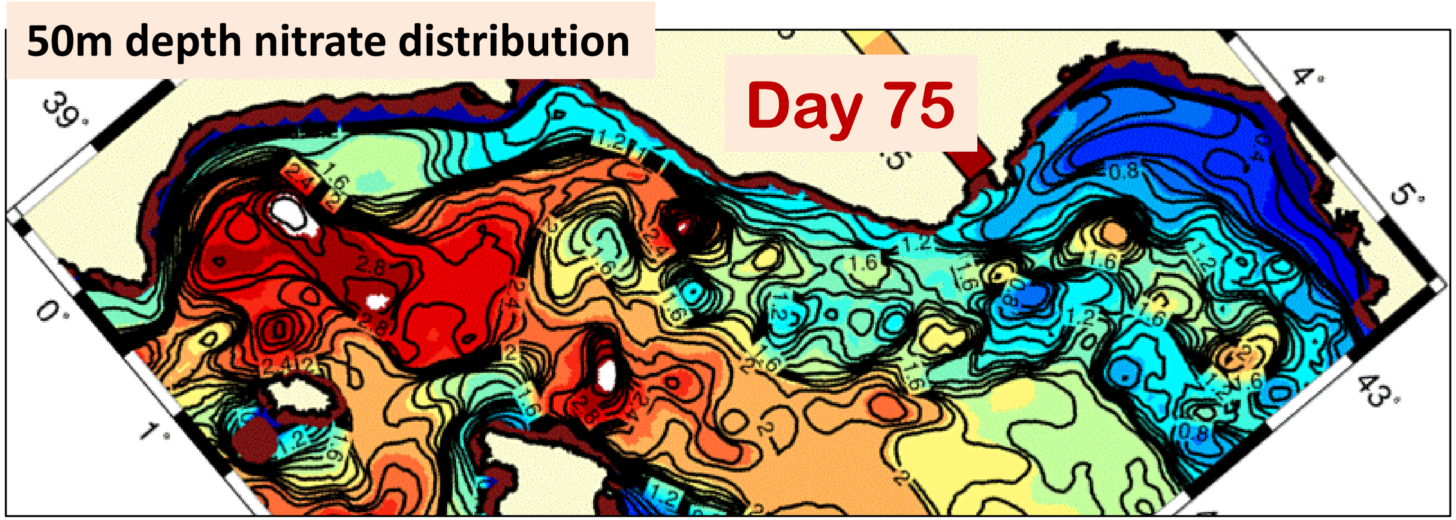


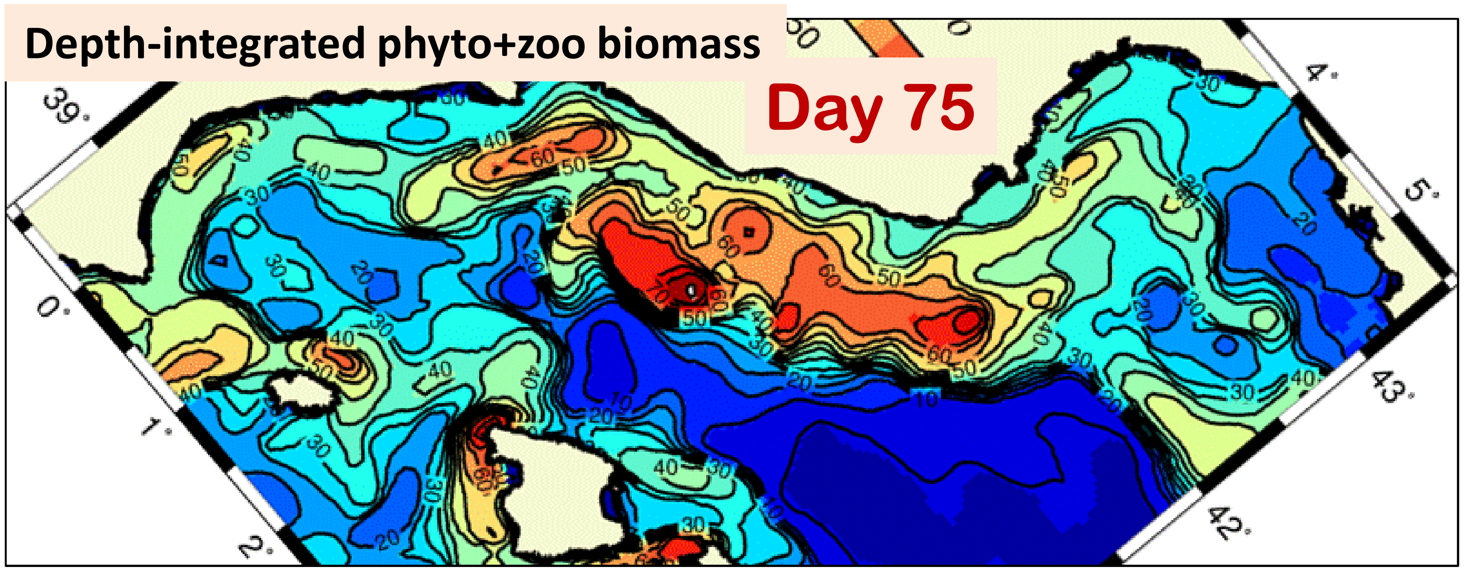
- ❑ **Strong vorticity centers with ζ/f close to unity (highly nonlinear).**
- ❑ **Large vorticity gradients across the front.**
- ❑ **Cyclonic (anticyclonic) centers are located offshore (onshore) side of the front.**
- ❑ **Catalan shelf is characterized by cyclonic rel. vort.**
- ❑ **Highly meandering frontal structure**



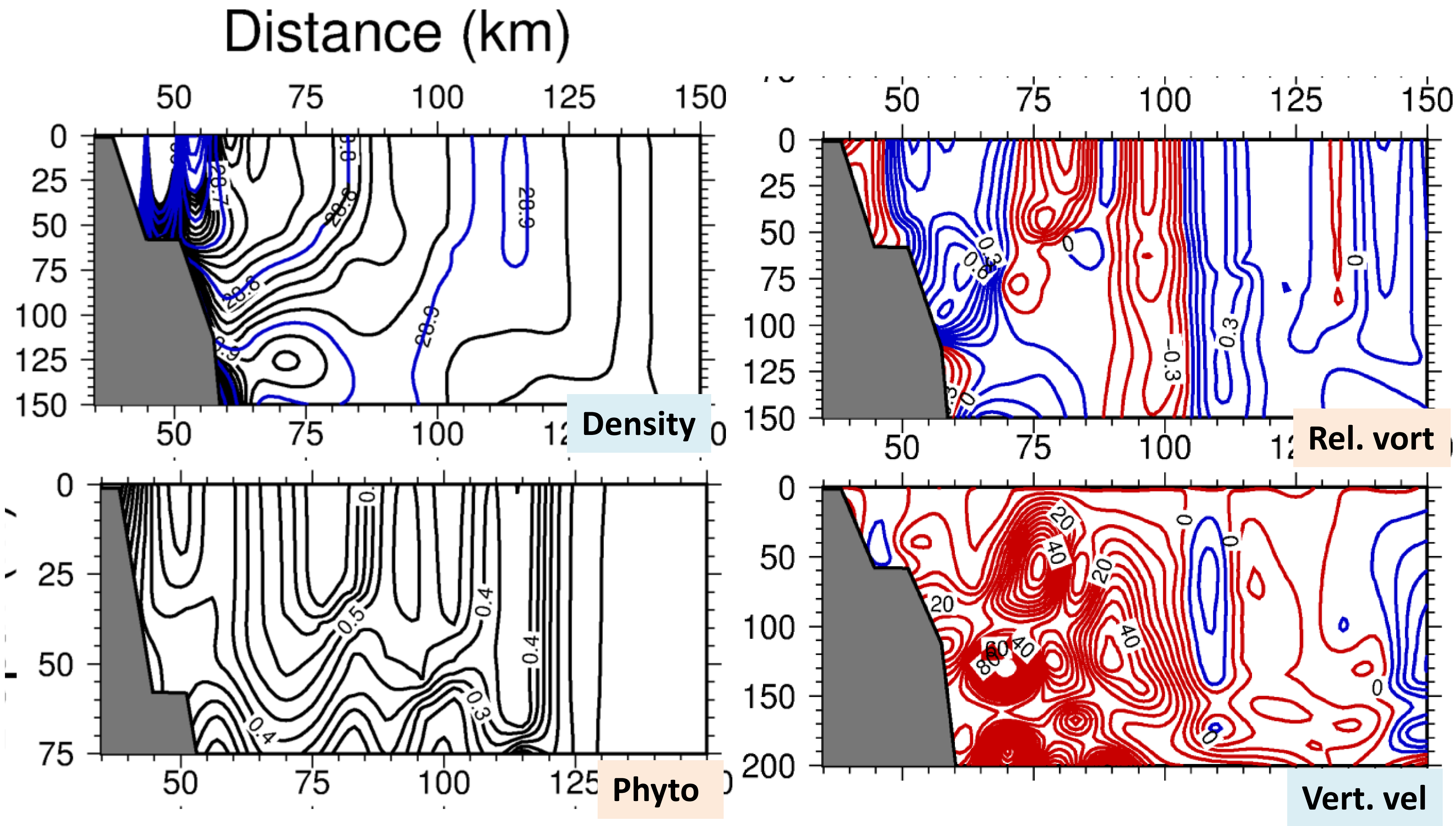


- ❑ **High Plankton biomass corresponds to anticyclonic eddies; mostly in the Catalan Sea.**
- ❑ **Relatively low but more patchy biomass in the Balearic Sea**





- ❑ **High Plankton biomass corresponds to less nitrate concentration**
- ❑ **Considerable nitrate is accumulated within 50 m depth that may be used later in spring for production in the Balearic Sea**



Distance (km)
Density
Rel. vort
Phyto
Vert. vel

CONCLUSIONS

When frontal boundary current is unstable, and moderately nonlinear (i.e. beyond the quasigeostrophic regime), the ageostrophic cross-frontal circulation with high upwelling velocities up to 80 m d^{-1} develops and inject nutrients into the photic layer and promote enhanced plankton production on the less dense, onshore side of the front within anticyclonic eddies.

This may be a major process controlling production characteristics in marginal seas.