Tidal front numerical modeling

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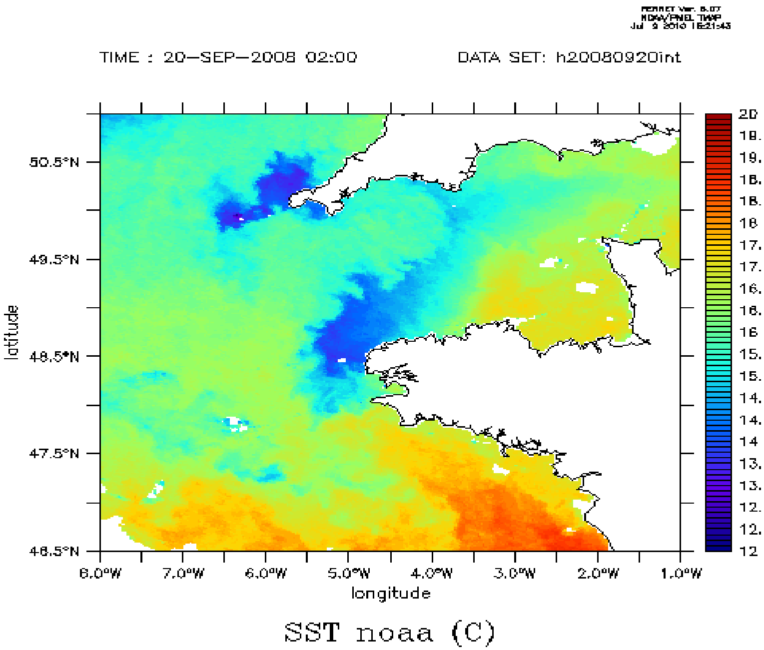
Tidal Front modeling in the Iroise Sea

Configuration parameters:
Diapycnal mixing and barotropic current
Stratification
Bottom friction
Sloping topography

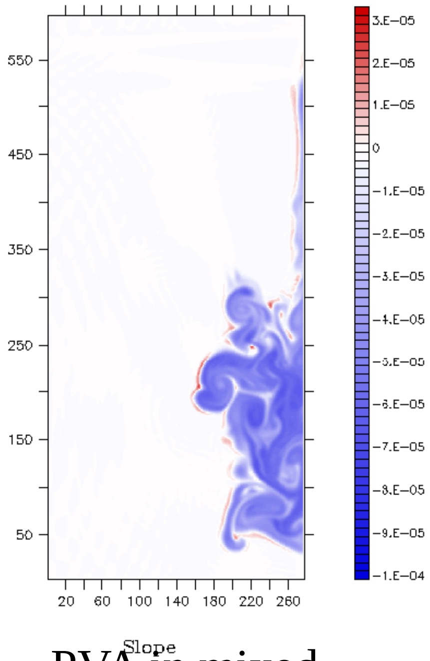
Environmental parameters:
Tides
Atmospheric flux
Topography

Understanding of front extension mechanisms with MICOM *(sensitivity studies such as in Schiller and Kourafalou, 2010)*

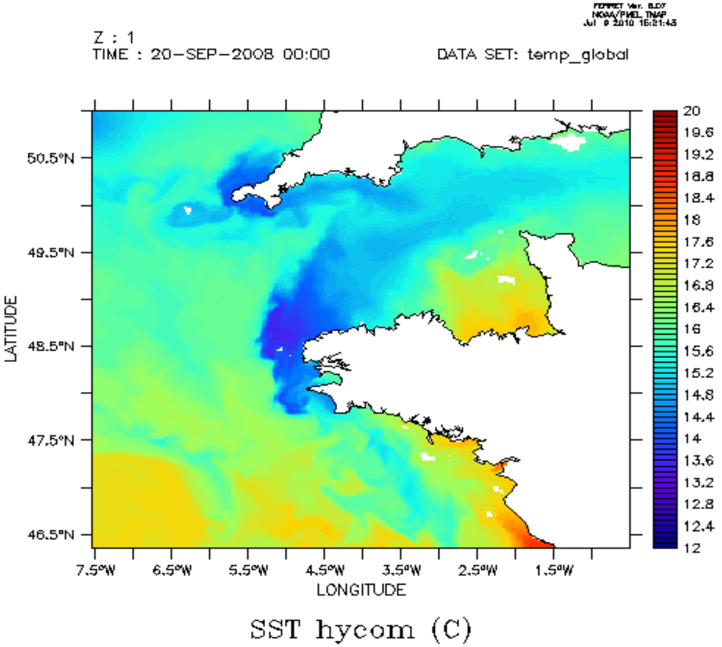
Efficiency of HYCOM to model the Ushant Front?



SST NOAA 09.20.2008



PVA in mixed water layer, MICOM

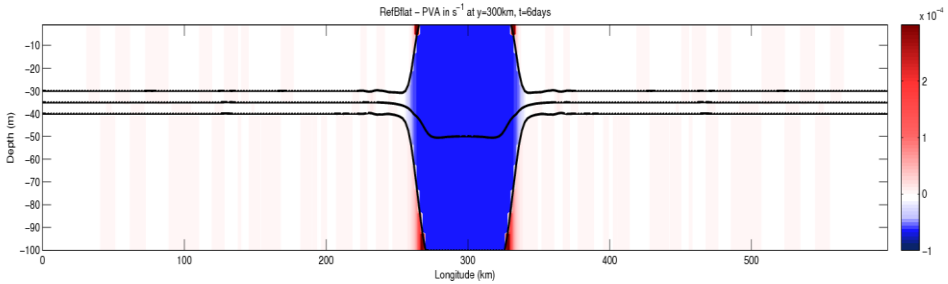


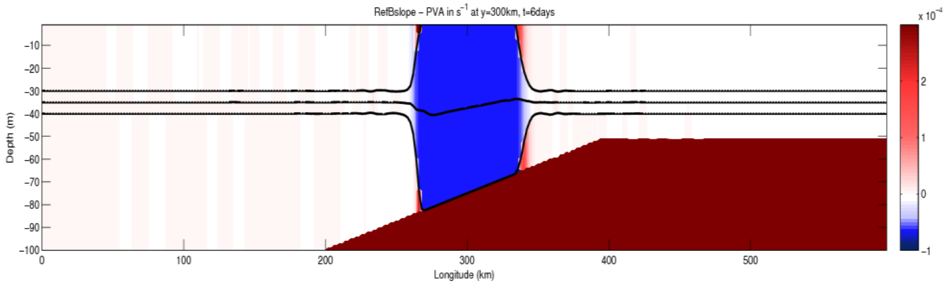
SST HYCOM 09.20.2008

Dispersion of homogenized water

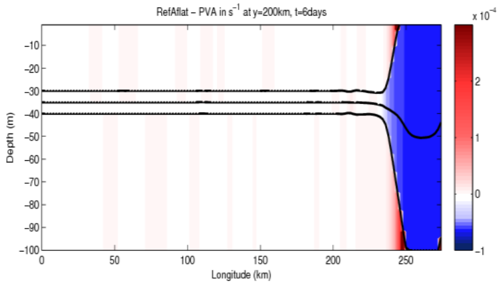
MICOM academical sensitivity studies

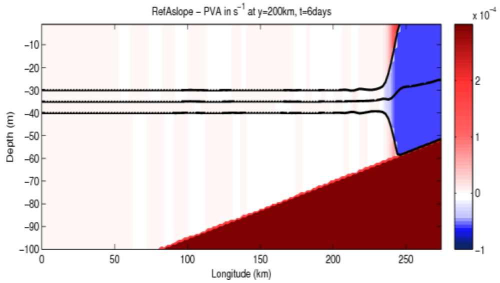
Reference experiments


RefBflat – PVA in s^{-1} at y=300km, t=6days


RefBslope – PVA in s^{-1} at y=300km, t=6days

PVA at t=6 days:
Centered conf.
(top)
Coastal conf.
(bottom)


RefAflat – PVA in s^{-1} at y=200km, t=6days


RefAslope – PVA in s^{-1} at y=200km, t=6days

Initial configuration parameters:
Diapycnal mixing: *Kv*= 0.005 m²/s
Stratification: *Δϱ* = 0.5 o/oo
No bottom friction (*Cd* =0)
Slope: *α*= 0 or 25/100000

Baroclinic instability and frontal initial configurations

PVA ↔ mass flux in 2nd and 3rd layers *(Haynes and Mac Intyre, 1987, 1990; Morel and Mac Williams, 2000)*

Baroclinic instability production and hetons emergence from the ZMP *(Charney Stern Criterion; Morel and Mac Williams, 2000)*

Dispersion of homogenized water

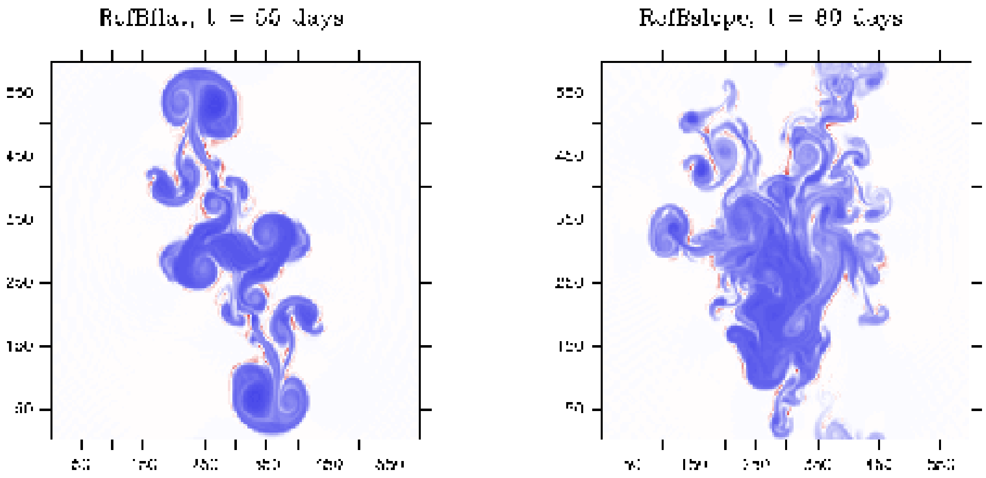
MICOM academical sensitivity studies : Mechanisms

Production rate

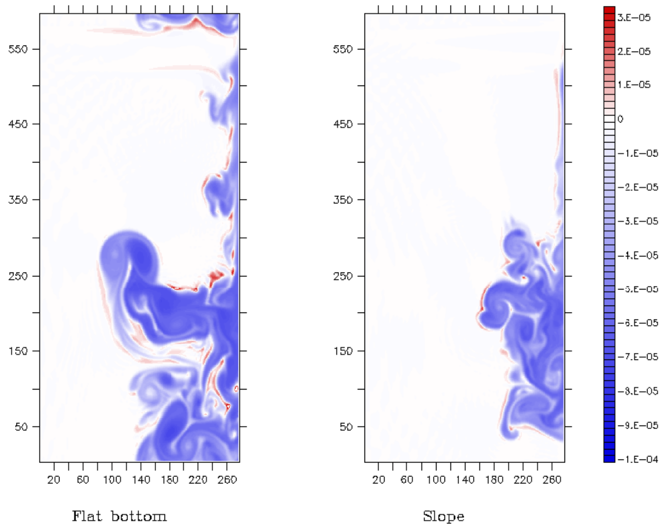
Continuous homogenization of the ZMP ruled by *Kv*
Size of structures of instabiliy depending on $\Delta\varrho$

Dispersion mechanisms

Dipolar interactions	α, $\Delta\varrho$, *Kv*, *Cd*
Mirror effects (near vertical wall)	*d (distance from wall)*
Topographic beta effects	α, $\Delta\varrho$
Kelvin waves	α



PVA in 2nd layer, centered (flat,slope)



PVA in 2nd layer, coastal (flat,slope)

Dispersion of homogenized water

MICOM academical sensitivity studies : Main results

Academical studies gave information on the impact of realistic environmental parameters on the Ushant Front:

A sloping topography enhances and then reduces dispersion, and shapes the dispersed water in a plume that follows slope gradients

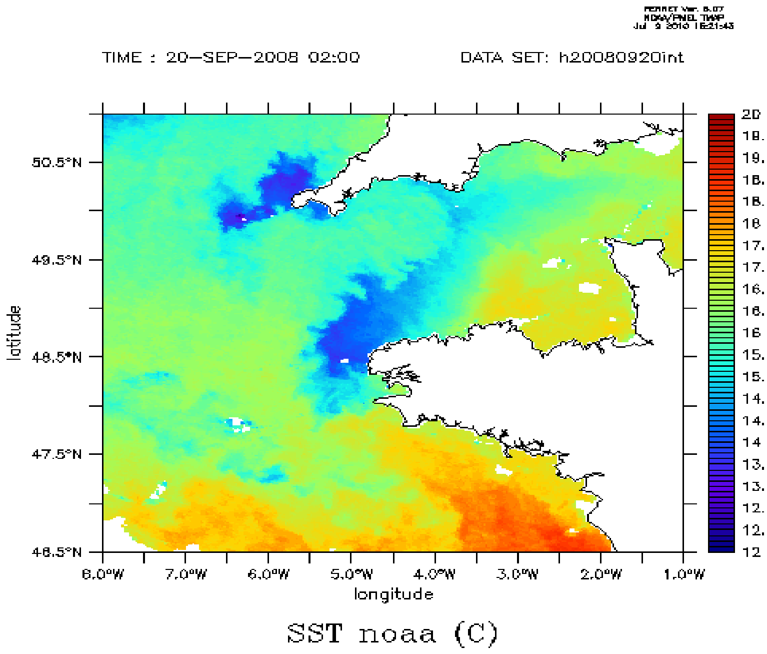
Strong tides have a limited impact on the front extension in areas where dispersive mechanisms are weak

The stratification strengthening in summer is necessary for the front to form and to develop. Production rates of homogenized water, and thus dispersion, drastically depends on this parameter.

Weak uncertainties on bottom friction parametrization can significantly impact the model efficiency to reproduce frontal dynamics. A shift between surface and bottom fronts is modeled.

Realistic Tidal Front Modeling
The Ushant front variability

Environmental parameters:
Tides
Atmospheric flux
Topography



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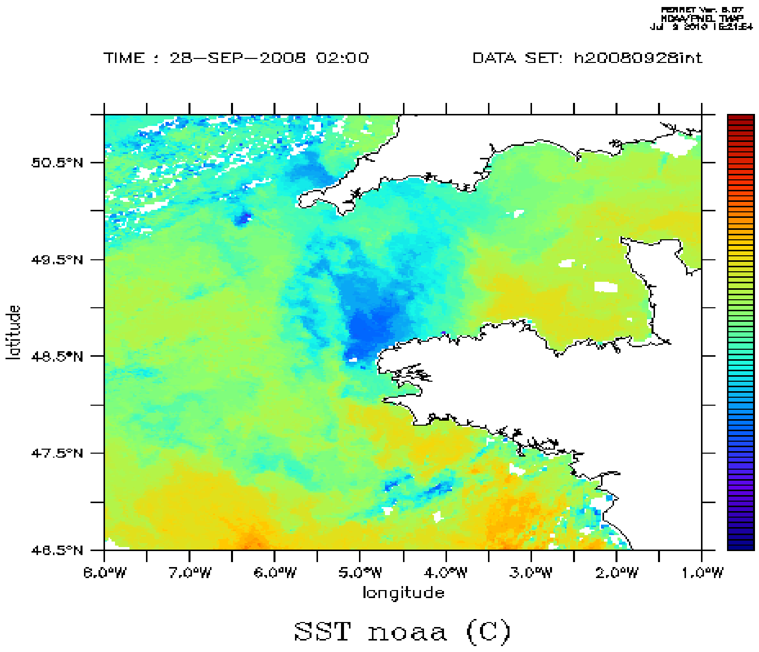
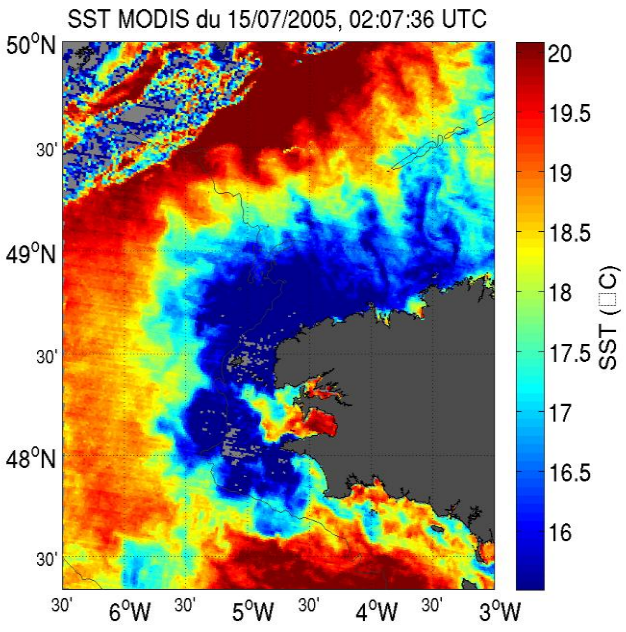
High variability in scale and time

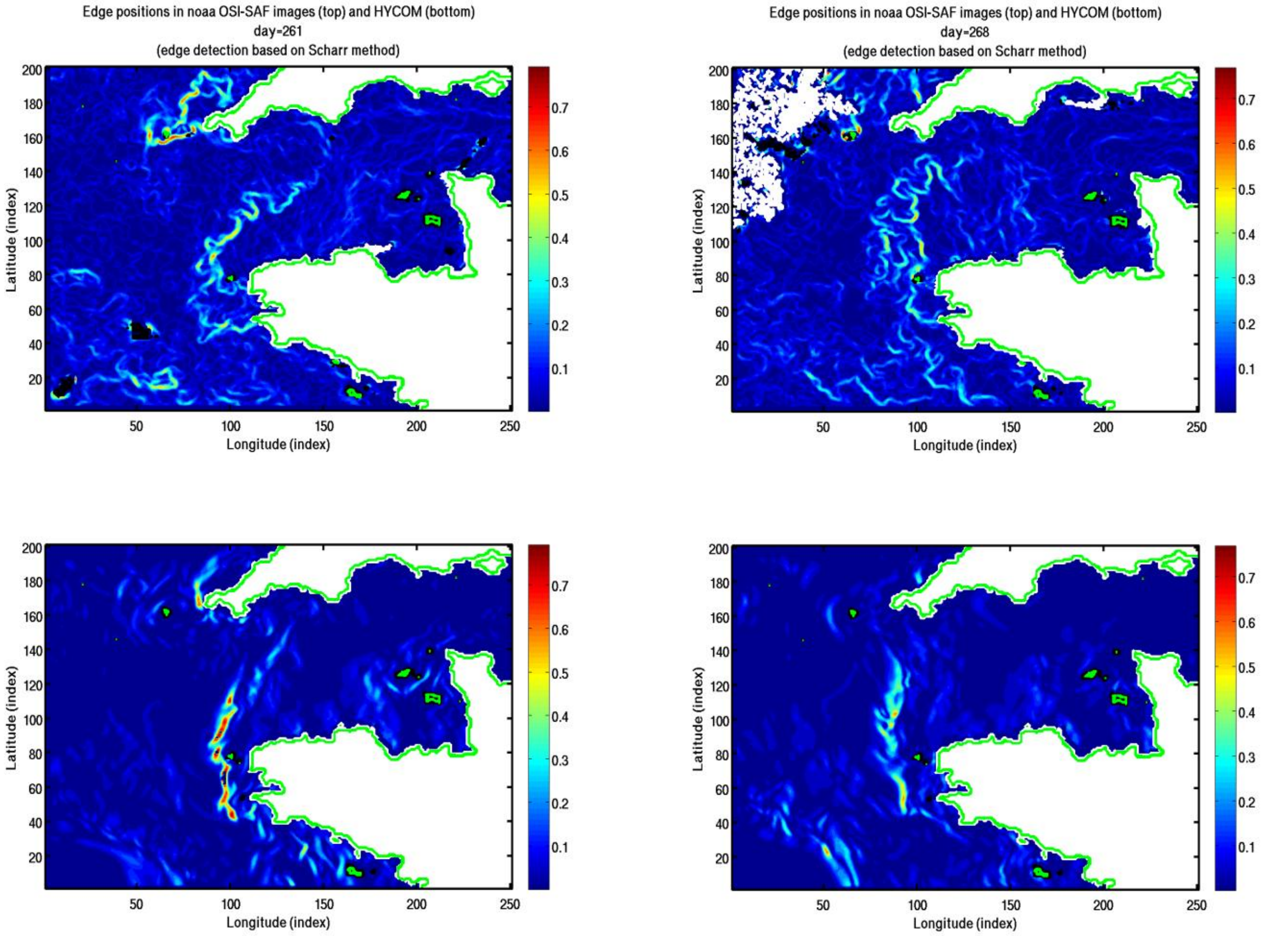


SST NOAA 09.28.2008



SST MODIS 07.15.2005 *(Szekely et al. 2010)*

Realistic Tidal Front Modeling



09.20.2008

09.28.2008

Edge detection based on a Scharr method, on satellite images (top) and Hycom outputs (bottom)

HYCOM parameters
32 layers
Grid step: 1.7 km
KPP
Atmospheric forcing CEP
Nesting Mercator

Aim

1. Correlation between environmental forcings and different front dispersion patterns using HYCOM outputs

2. Assessing the impact of configuration parameters in HYCOM on the front edges

Realistic Tidal Front Modeling

Tide filtering : Main features of a new method

Simple method

$$\forall (i,j)\ ,\ Ures_{st} = X_0(t) - \sum_f a_f \times \cos(w_f t + phi_f)$$

→ Errors up to 10% of the global signal

Minimization method *(Baraille et al. 2011)*

$$\forall (i,j)\ ,\ Ures = \underset{(\tilde{a},\, \tilde{phi},\, \tilde{c})}{Min} \int_{t\in T} \left\| X_0(t) - \underbrace{\sum_f a_f \tilde{a}_f \times \cos(w_f t + phi_f + \tilde{phi}_f)}_{\text{Tidal frequencies to filter}} - \tilde{c} \right\|$$

Tide filtered low time scale dynamics

Global initial signal

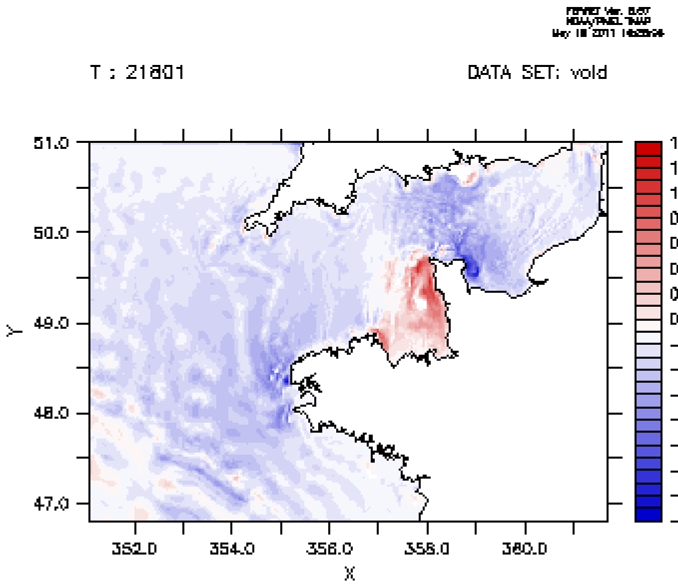
High time scale residue

→ T is a time span determining the separation between ***high and low time scales dynamics***

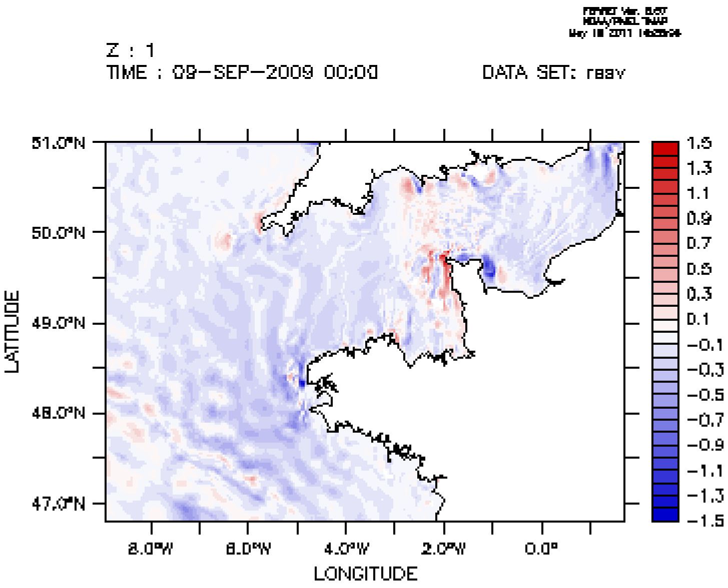
→ The minimization process brings a ***quantifiable accuracy*** to the method

Realistic Tidal Front Modeling

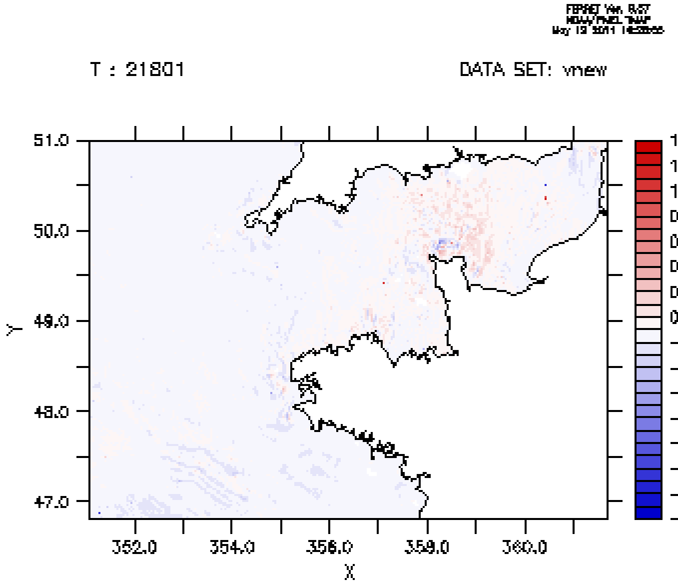
Tide filtering : Method validation (1)



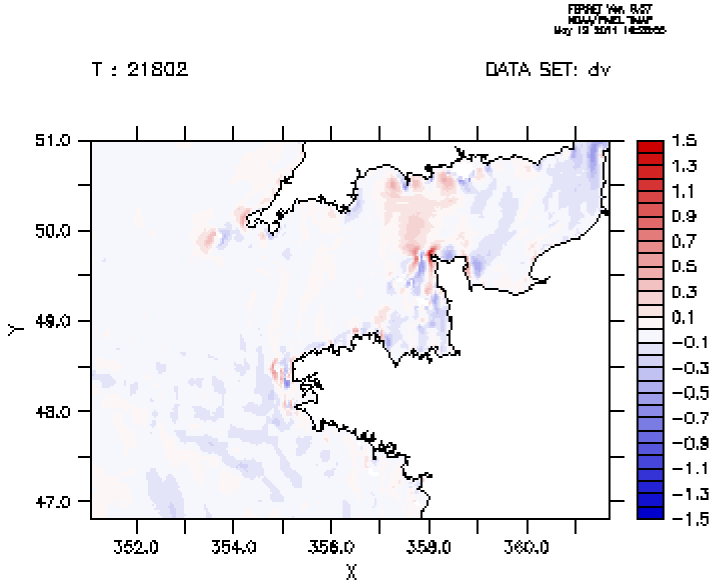
V, barotropic filter



V, barotropic+baroclinic filter



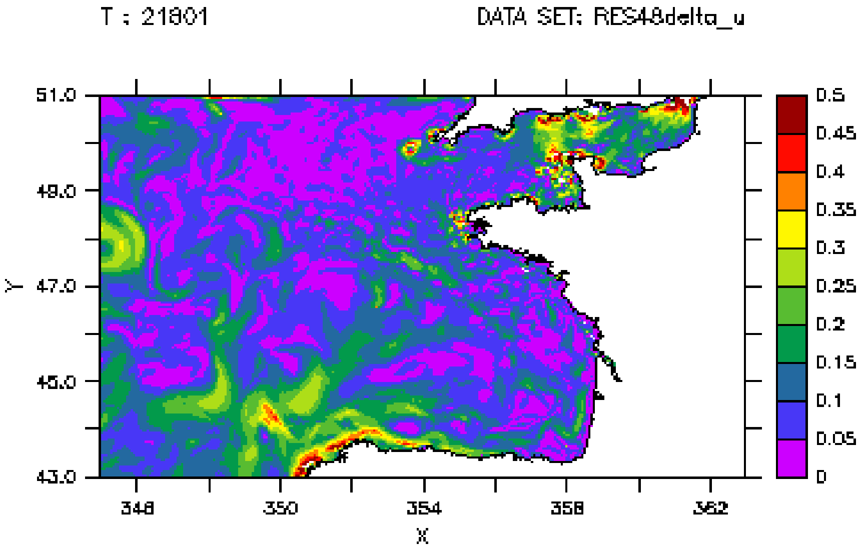
V, optimized filter



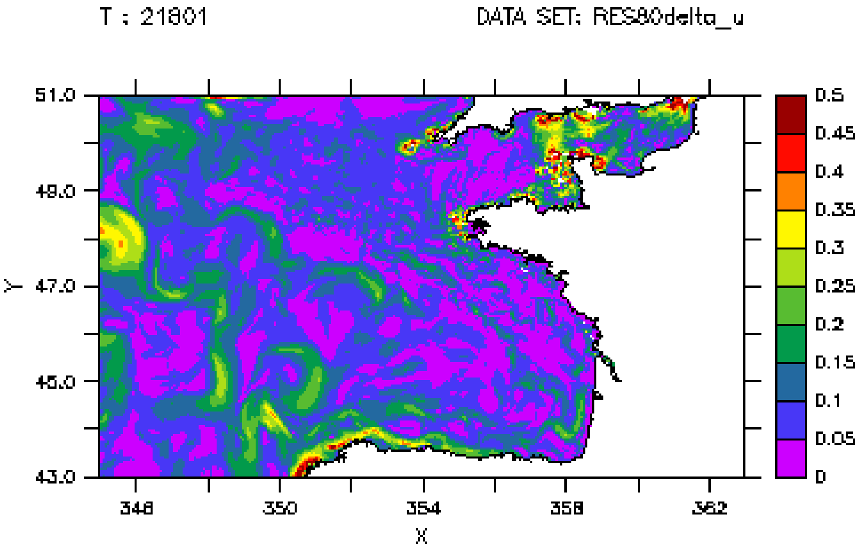
DeltaV, optimized filter

Realistic Tidal Front Modeling

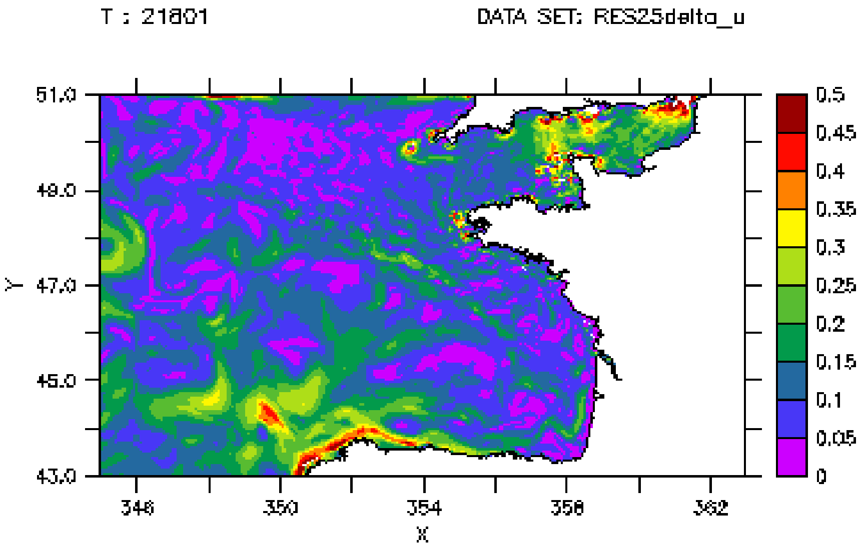
Tide filtering : Input parameters (2)



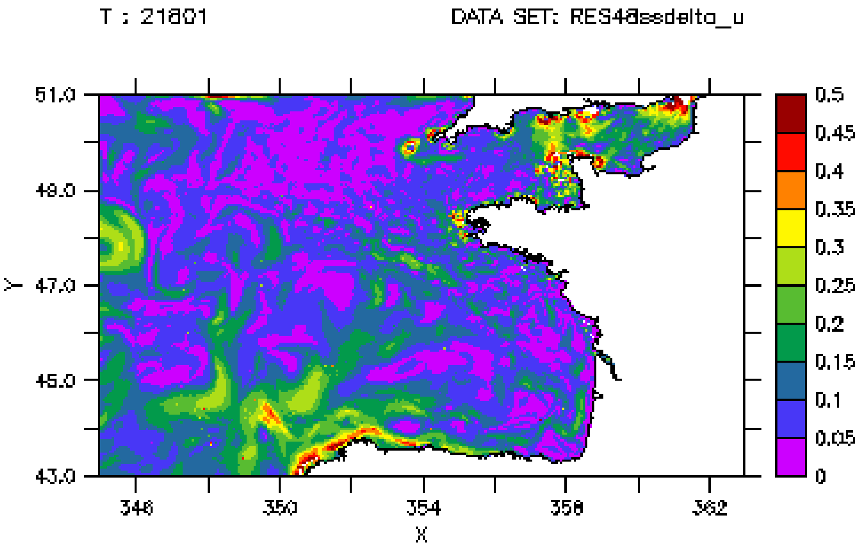
48 hrs time span



80 hrs time span



25 hrs time span

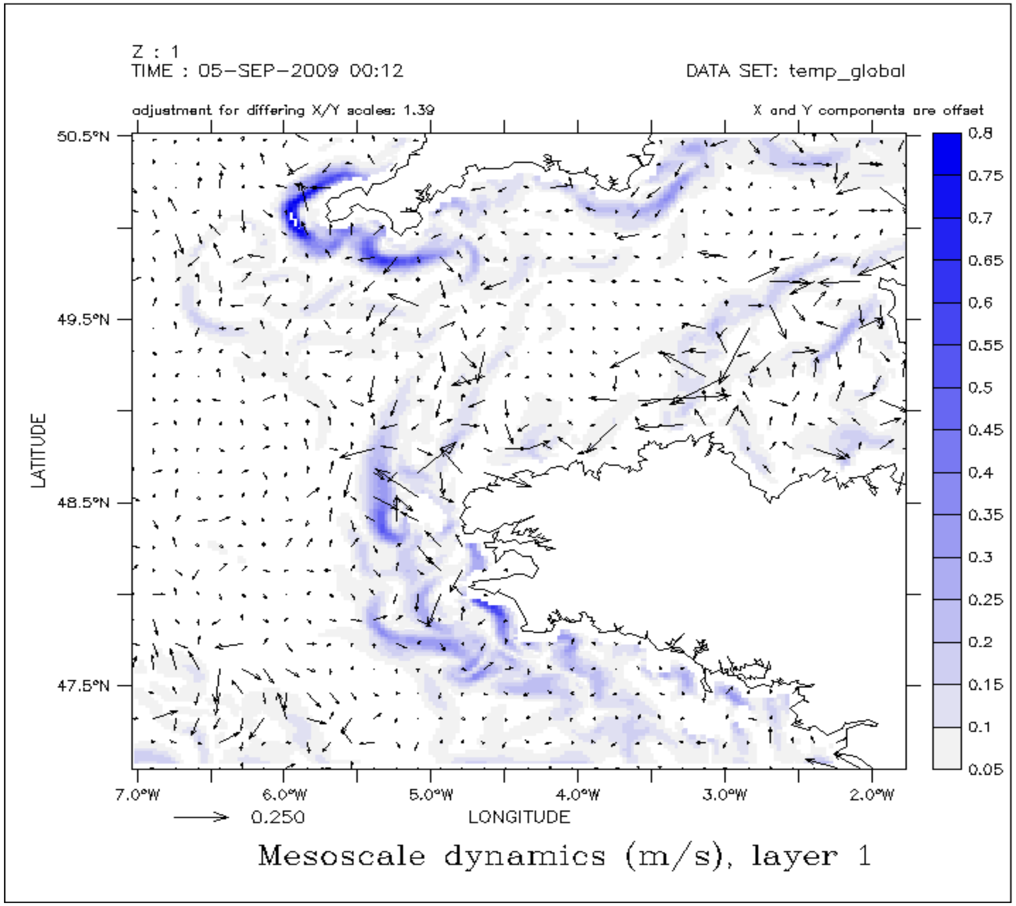


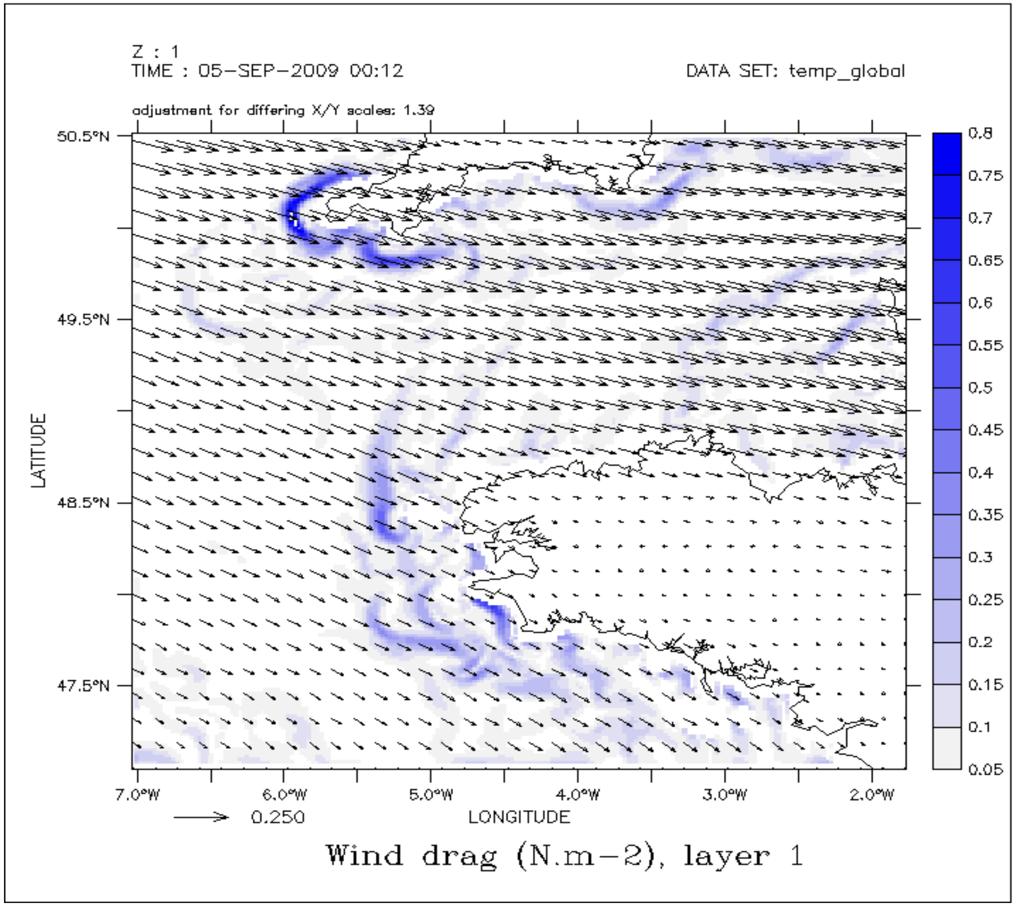
48 hrs time span, no diagnostics

Realistic Tidal Front Modeling

Wind stress impact on the front edges, september 2009

iroise_delta
iroise_res
iroise_atm





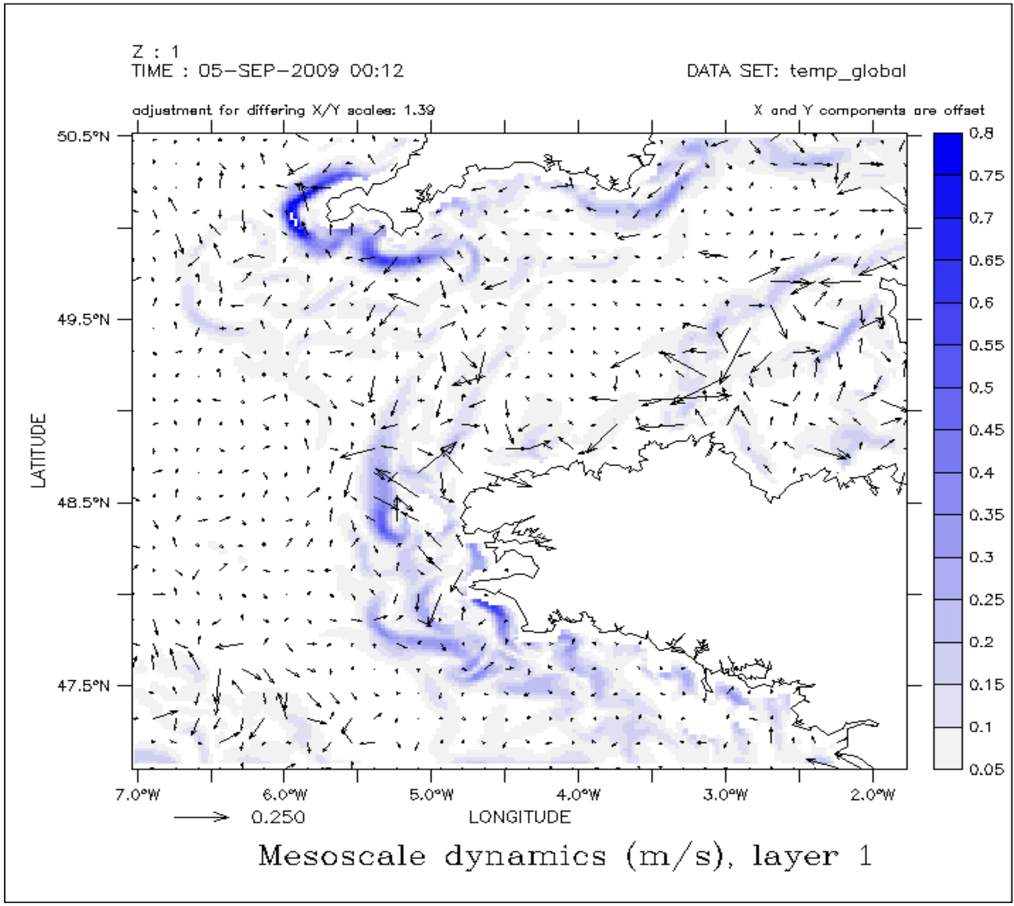
At the sea surface, a long lasting wind stress induces a quasi permanent westward surfacce current covering the Iroise area.
The circulation along the temperature gradients is retrieved in the low frequency residue.

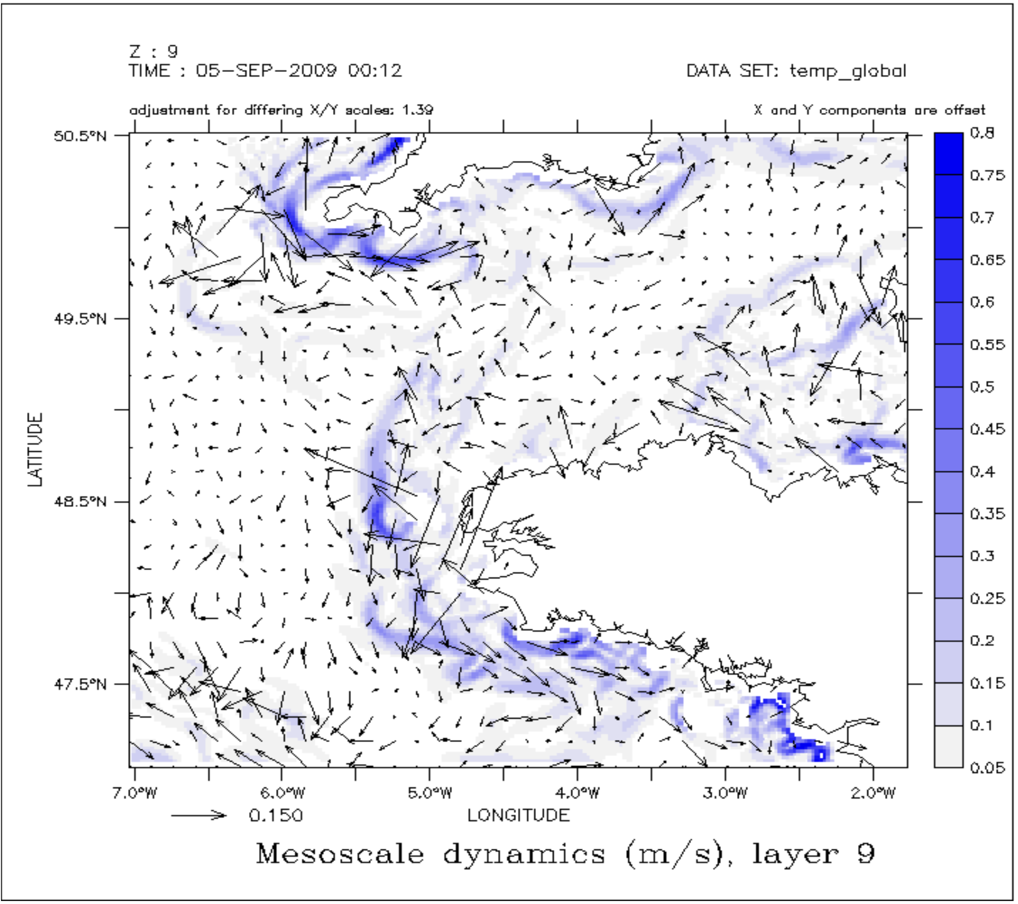
scilly_delta
scilly_res
front_delta
front_res

Realistic Tidal Front Modeling

Wind stress impact on the front edges... in a deeper layer

iroise_atm_l9
iroise_delta_l9
iroise_res_l9



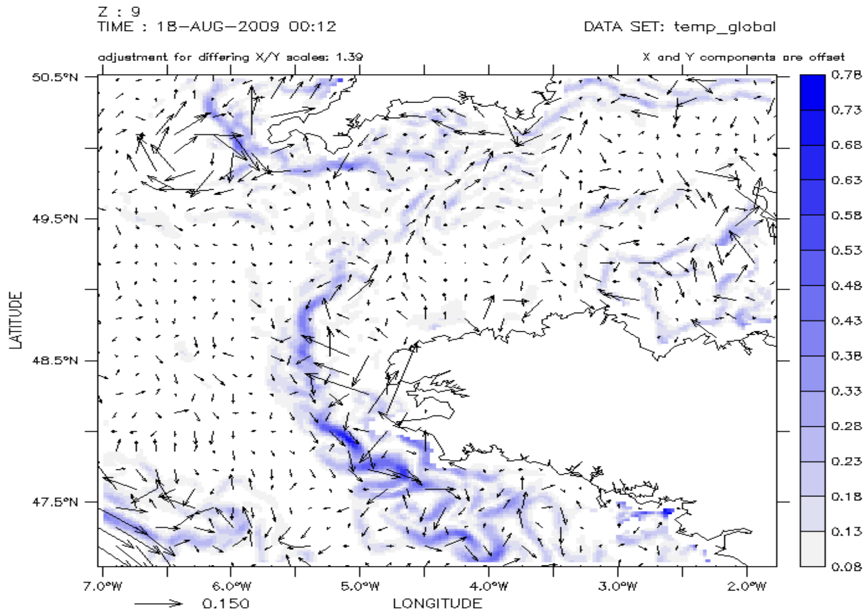


scilly_delta_l9
scilly_res_l9
front_delta_l9
front_res_l9

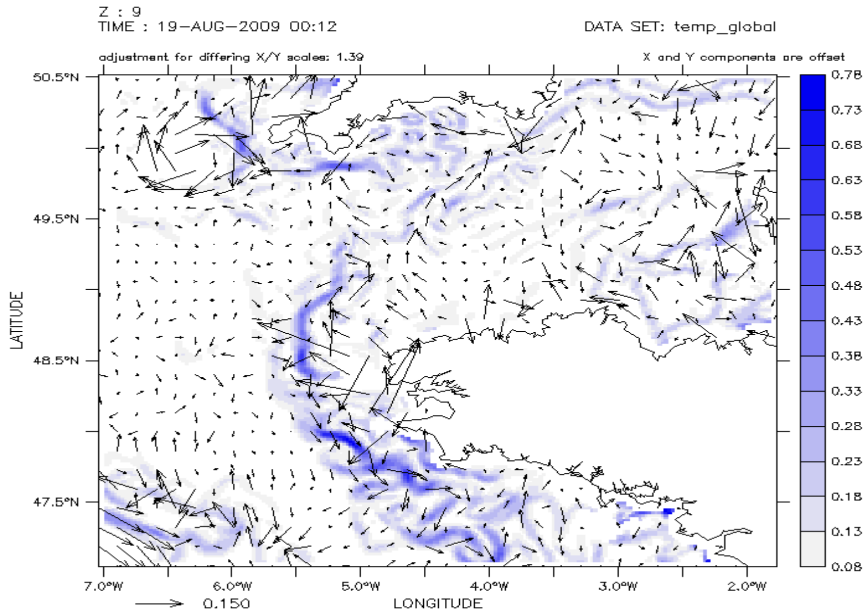
At ~20 m depth, the residue is weaker and deviated from the surface current in large areas.

Realistic Tidal Front Modeling

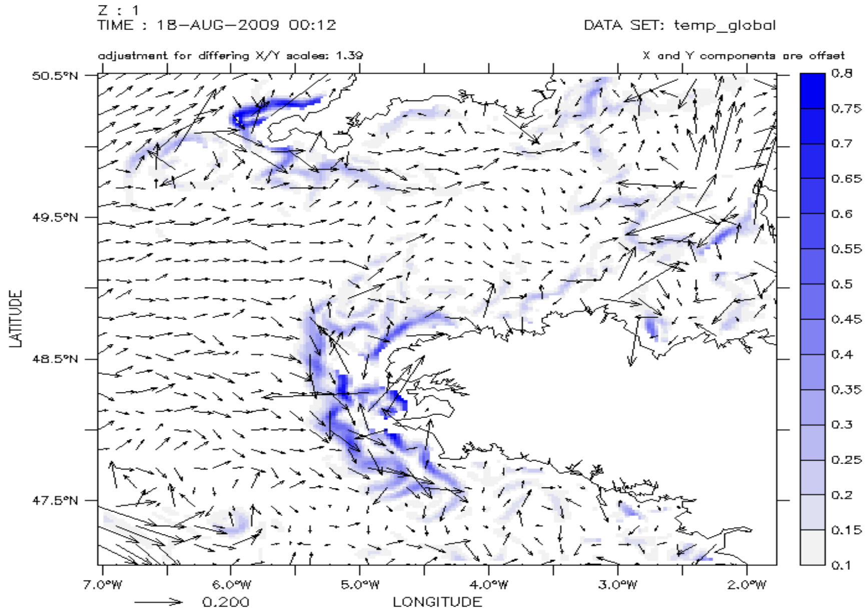
Other peculiar dynamics of the front in 2009



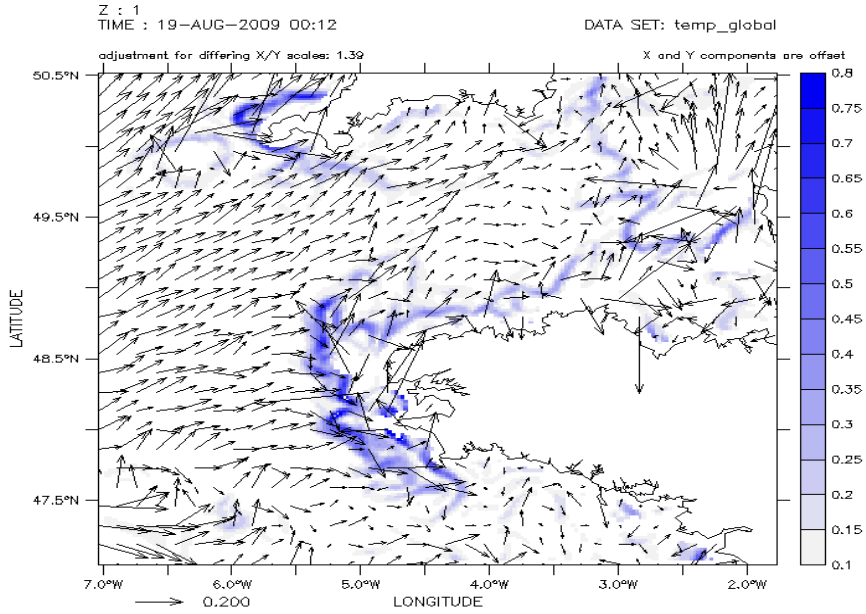
Mesoscale dynamics (m/s), layer 9



Mesoscale dynamics (m/s), layer 9



Mesoscale dynamics (m/s), layer 1



Mesoscale dynamics (m/s), layer 1

Conclusions and perspectives

Academical studies informed on the theoretical effect of realistic environmental parameters on the fronts such as ***slope gradients, stratification, residual tidal currents and bottom friction.***

The ***front edge detection*** method and ***an accurate frequency filtering tool*** ,separating tidal and high frequencies induced dynamics from lower frequencies mechanisms, are operational. They are used to ***determine different time scales parameters impact on the front extension***. In particular :

- The plume of the Ushant front has a ***northern variability*** that can cautiously be related to ***long lasting wind stress events***.

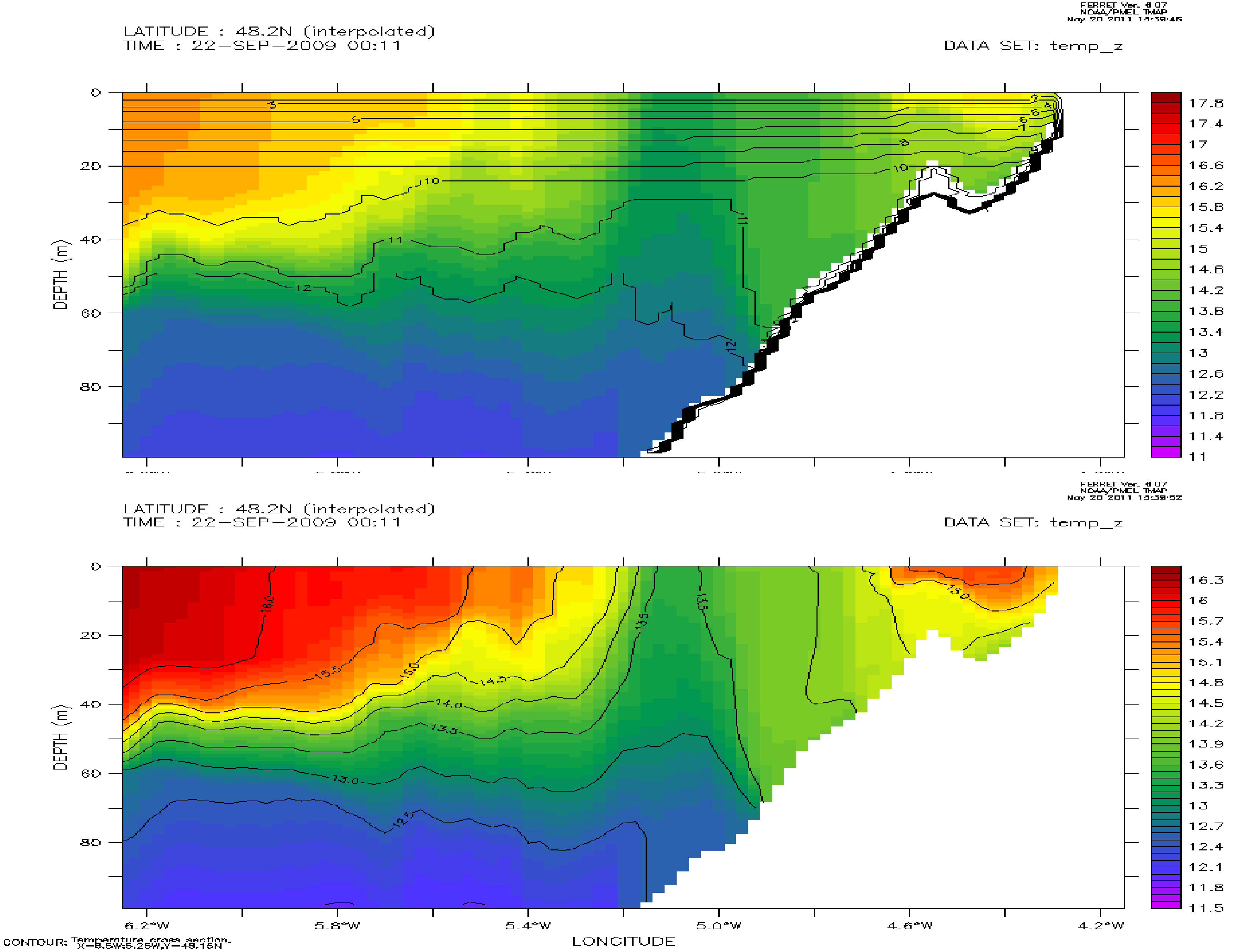
- Other mechanisms impacting the ***initial extension*** of the front, ***observed extensions southward***, or any peculiar event, are currently investigated.

- Sensitivity studies to the ***bottom friction parameterization*** are now considered...

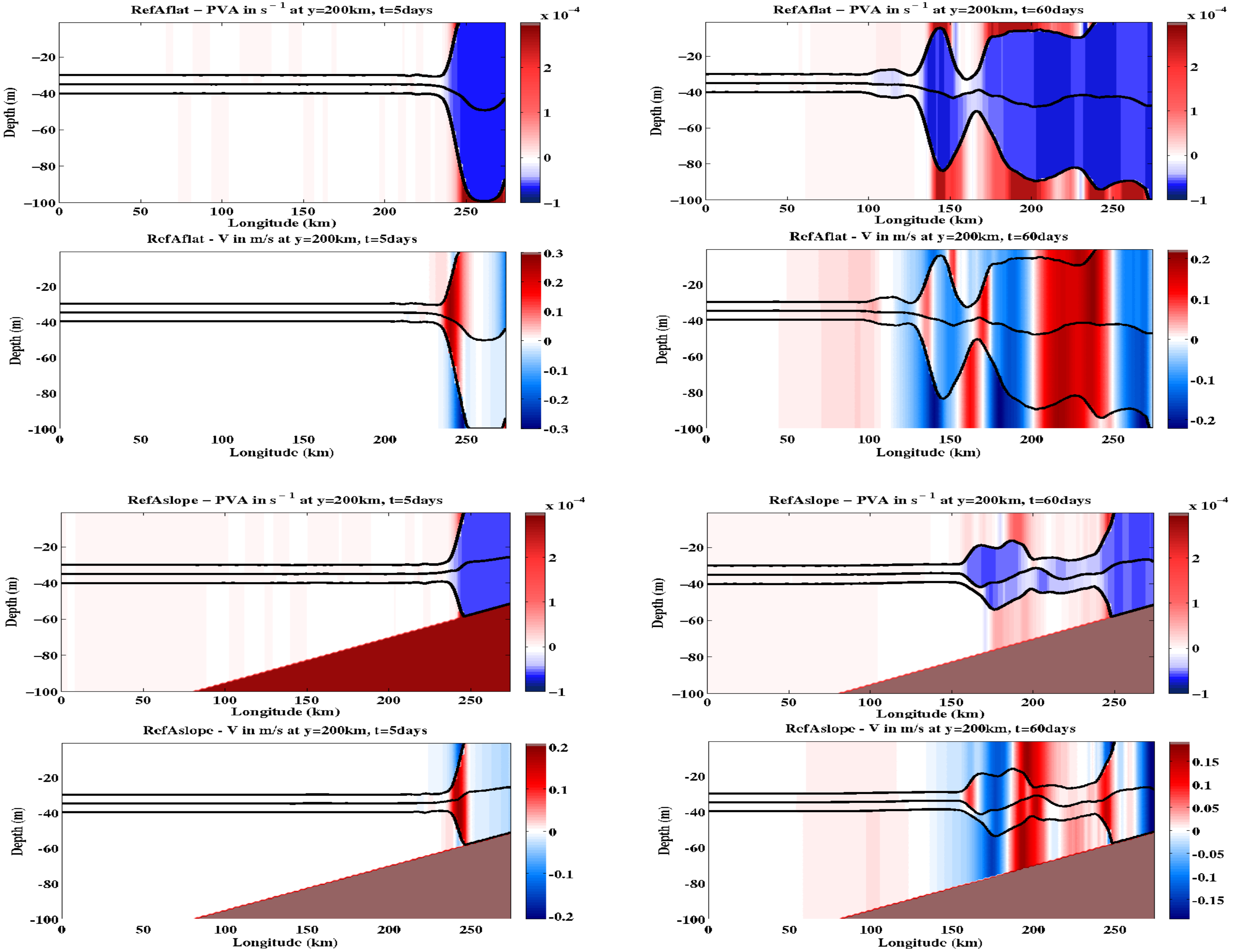
The filtering tool could also be used to highlight and better understand the interrelation between the global circulation and the tidal signal via the bottom friction.

Thank you for your attention

Any question ?


FERRET Ver. 6.07
NOAA/PMEL TMAP
May 20 2011 15:39:46
LATITUDE : 48.2N (interpolated)
TIME : 22-SEP-2009 00:11
DATA SET: temp_z
DEPTH (m)
0
20
40
60
80
3
5
7
4
6
8
10
11
12
17.8
17.4
17
16.6
16.2
15.8
15.4
15
14.6
14.2
13.8
13.4
13
12.6
12.2
11.8
11.4
11
FERRET Ver. 6.07
NOAA/PMEL TMAP
May 20 2011 15:39:52
LATITUDE : 48.2N (interpolated)
TIME : 22-SEP-2009 00:11
DATA SET: temp_z
DEPTH (m)
0
20
40
60
80
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
13.5
15.0
16.3
16
15.7
15.4
15.1
14.8
14.5
14.2
13.9
13.6
13.3
13
12.7
12.4
12.1
11.8
11.5
6.2°W
5.8°W
5.4°W
5.0°W
4.6°W
4.2°W
LONGITUDE
CONTOUR: Temperature cross section, X=6.5W:5.25W,Y=48.15N

TEMP_Z


RefAflat – PVA in s^{-1} at y=200km, t=5days

RefAflat – PVA in s^{-1} at y=200km, t=60days

RefAflat - V in m/s at y=200km, t=5days

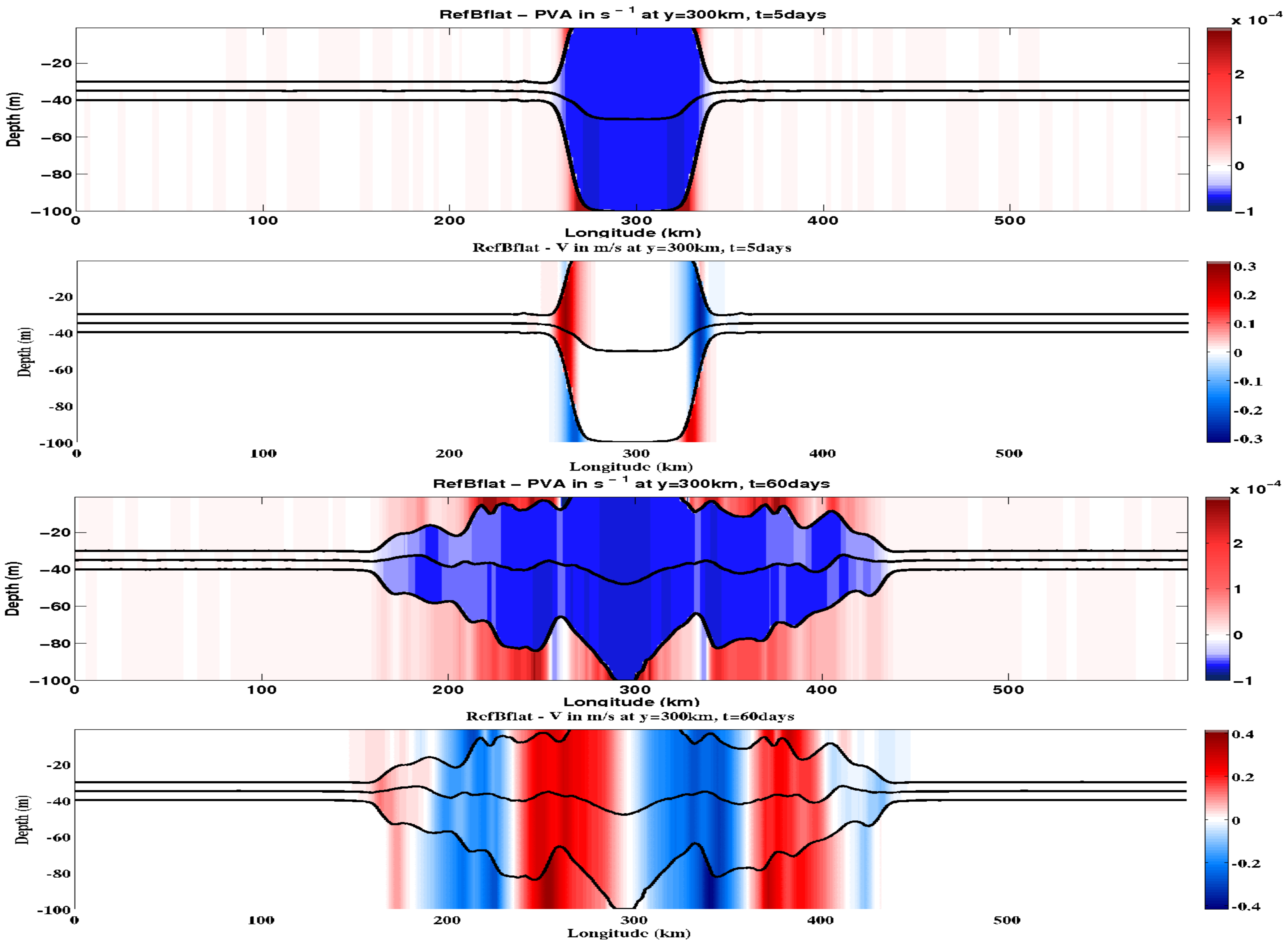
RefAflat - V in m/s at y=200km, t=60days

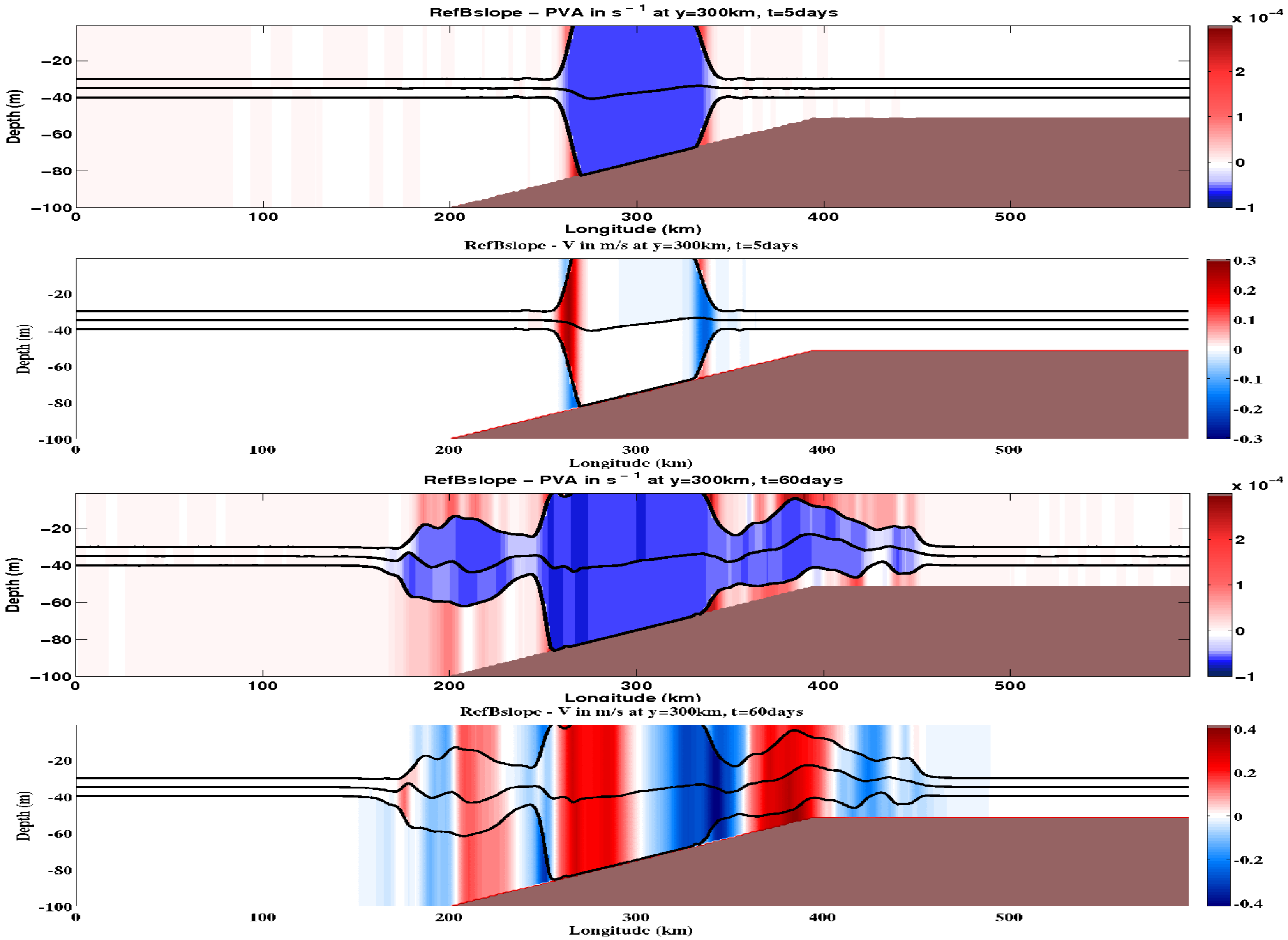
RefAslope – PVA in s^{-1} at y=200km, t=5days

RefAslope – PVA in s^{-1} at y=200km, t=60days

RefAslope - V in m/s at y=200km, t=5days

RefAslope - V in m/s at y=200km, t=60days



 RefBslope – PVA in s^{-1} at y=300km, t=5days

RefBslope - V in m/s at y=300km, t=5days

RefBslope – PVA in s^{-1} at y=300km, t=60days

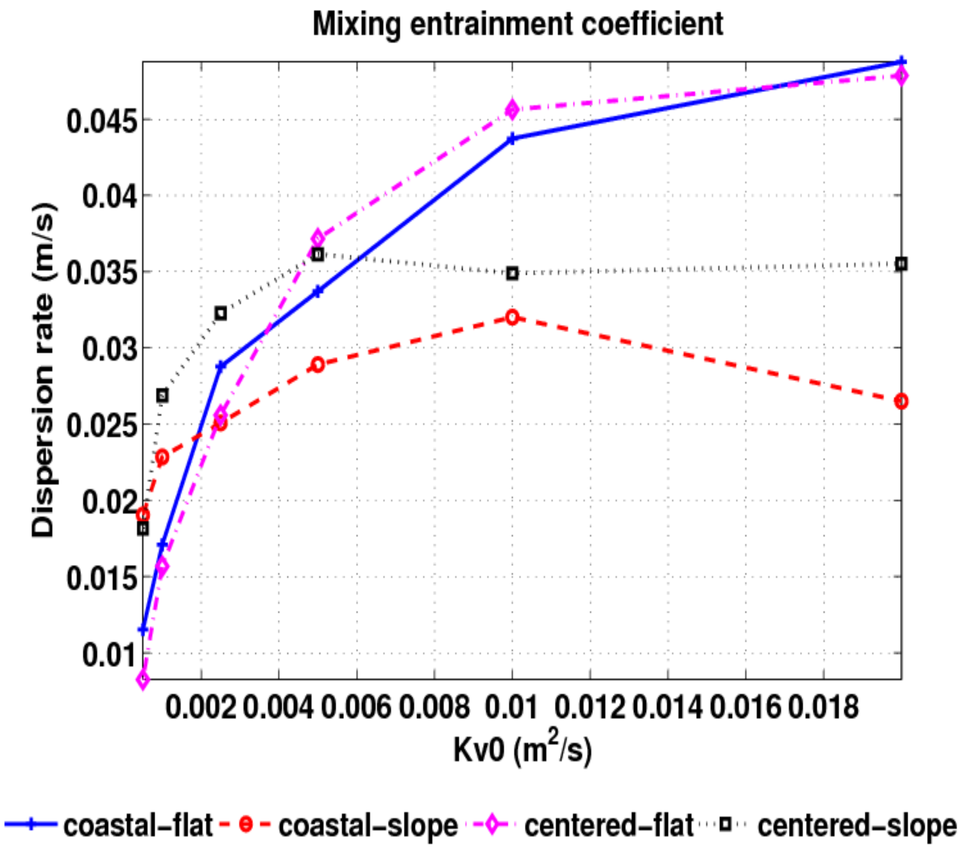
RefBslope - V in m/s at y=300km, t=60days

Dispersion of homogenized water

MICOM academical sensitivity studies

Global dispersion

Diapycnal mixing



$$T = \frac{T_{clearing}}{T_{homogenization}} = C_1 \frac{LKv}{r_d}$$

Three regimes:

T << 1 → Kv limits the dispersion rate, ***sub productive regime***

T ~ 1 → Dispersion and production equilibrate, ***efficient regime***

T >> 1 → dispersion mechanisms limits the dispersion rate, ***auto restrictive regime***

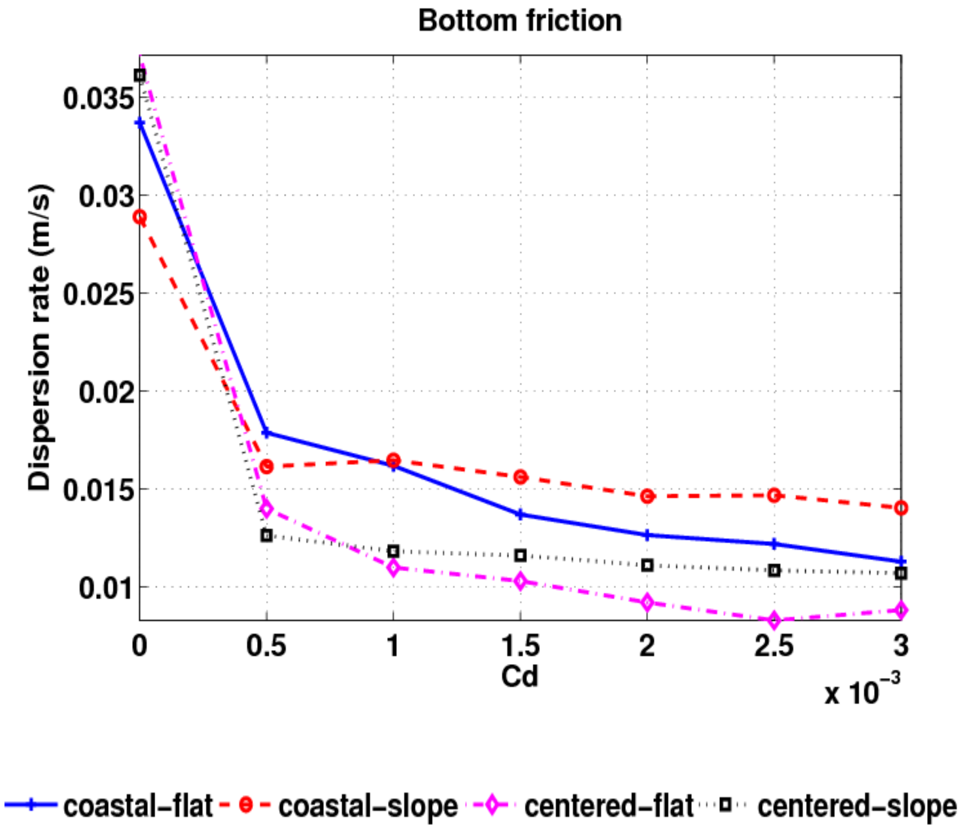
The diapycnal mixing impact on dispersion is limited by dispersive mechanisms ability to clear the ZMP from mixed water.

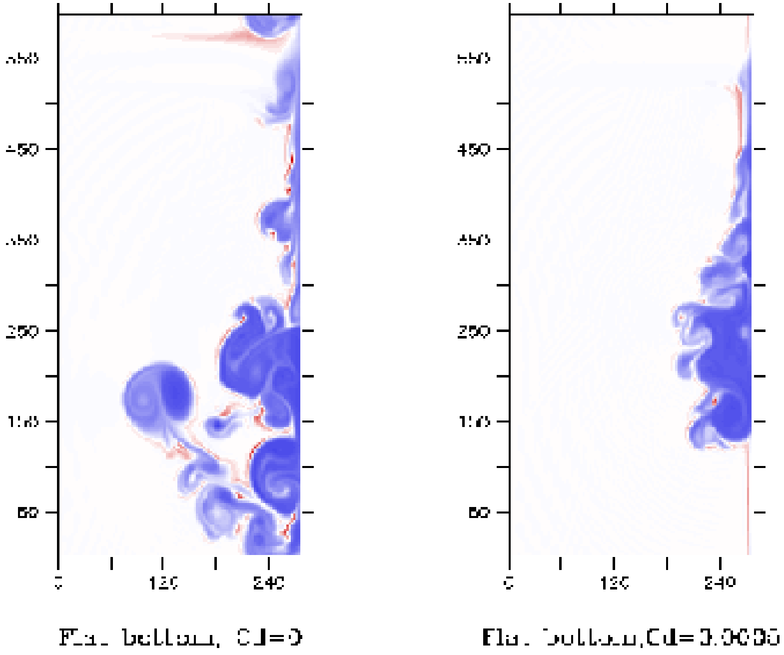
Dispersion of homogenized water

MICOM academical sensitivity studies

Global dispersion

Diapycnal mixing and bottom friction





Flat bottom, Cd=0

Flat bottom,Cd=0.0005

PVA in the 2nd layer above a flat bottom cd=0 (left), cd=0.0005 (right)

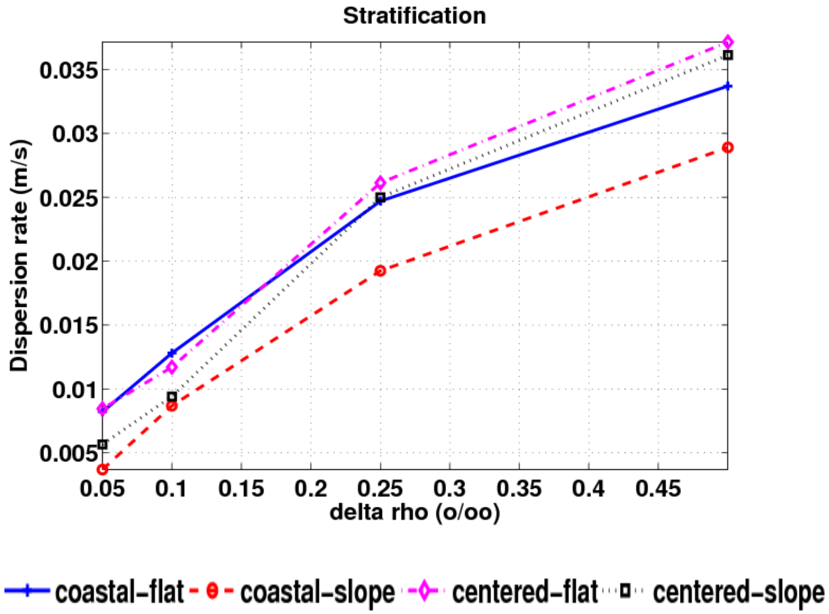
Most of the friction effect is reached for cd=0.0005, with half of the dispersion rate damped.

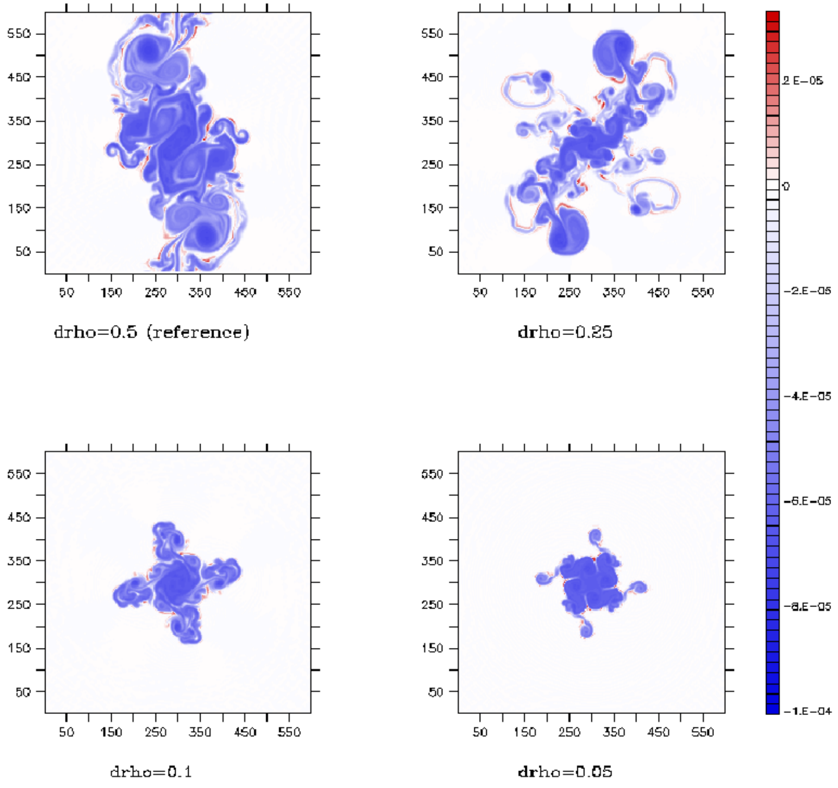
Dispersion of homogenized water

MICOM academical sensitivity studies

Global dispersion

Stratification





drho=0.5 (reference)

drho=0.25

drho=0.1

drho=0.05

2nd layer PVA, centered flat experiment

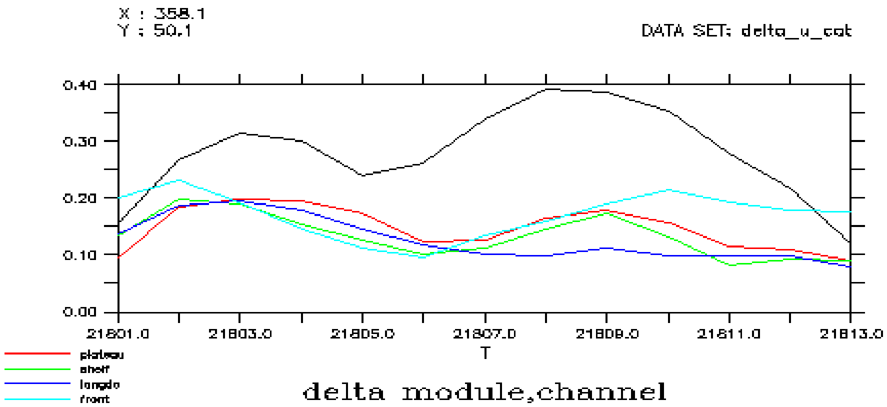
Increasing the stratification :

1. Enhances the production rate and the size of structures
2. Weakens the coupling between layers

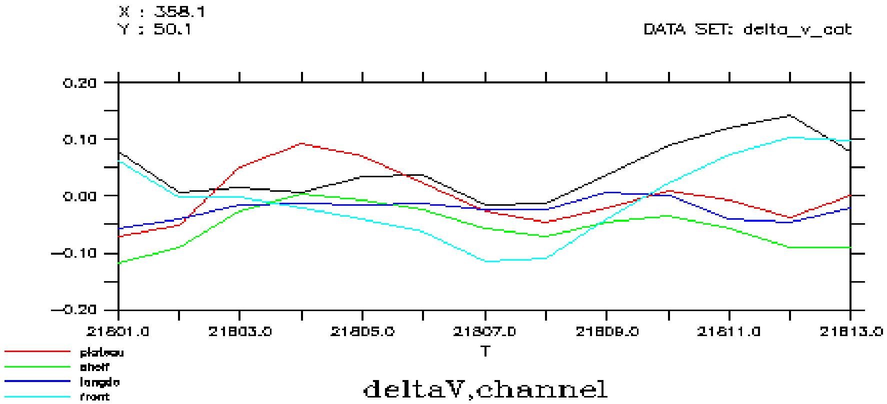
A stronger stratification favors dispersion mixed water.

Realistic Tidal Front Modeling

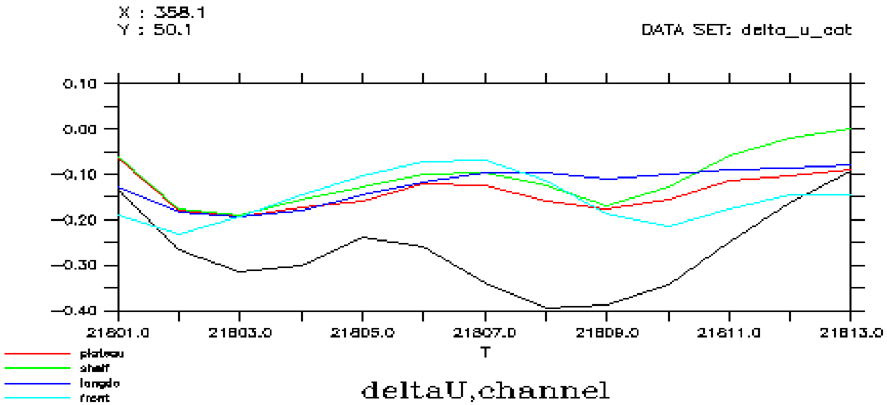
Wind stress impact on the front edges, specific points high time scale current



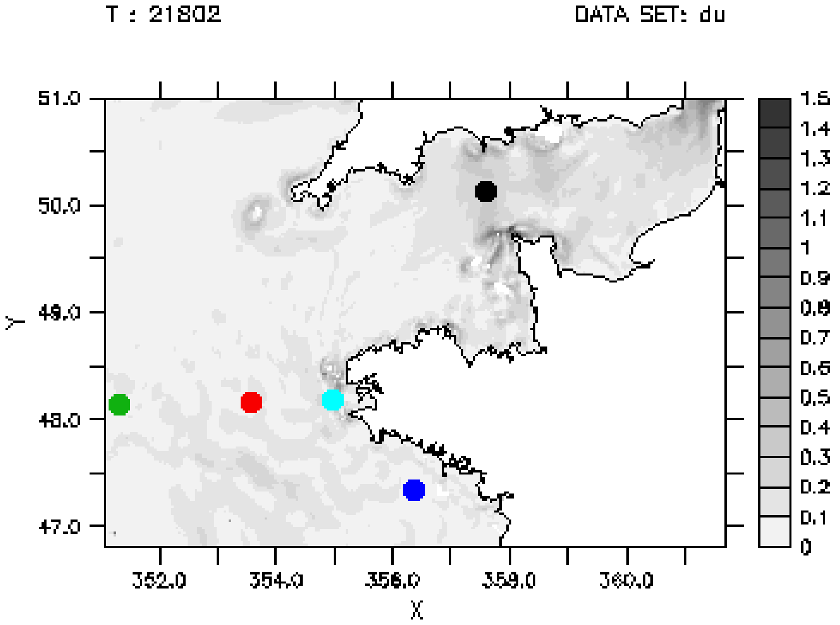
delta module,channel



deltaV,channel



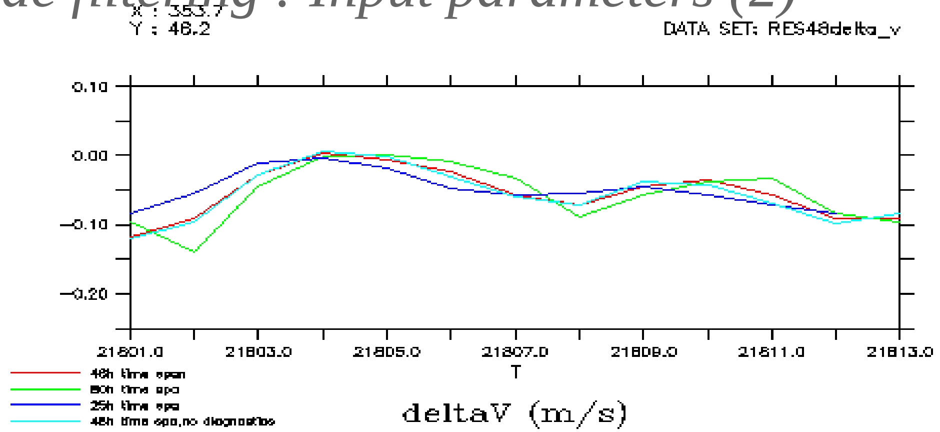
deltaU,channel



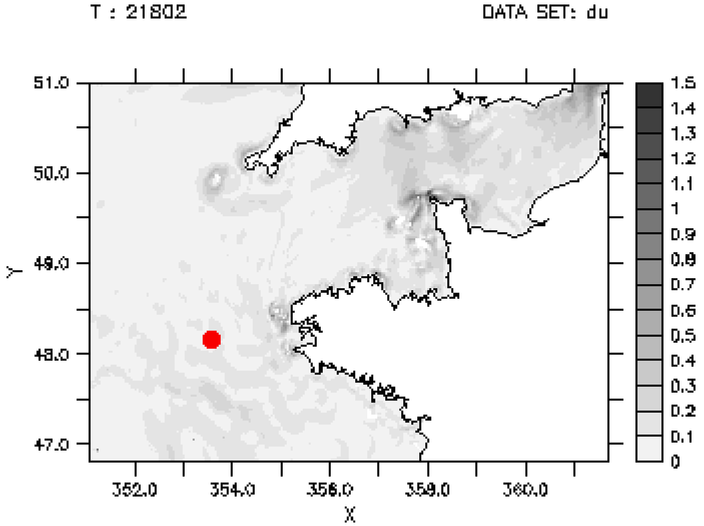
module(DeltaU), optimized filter

Realistic Tidal Front Modeling

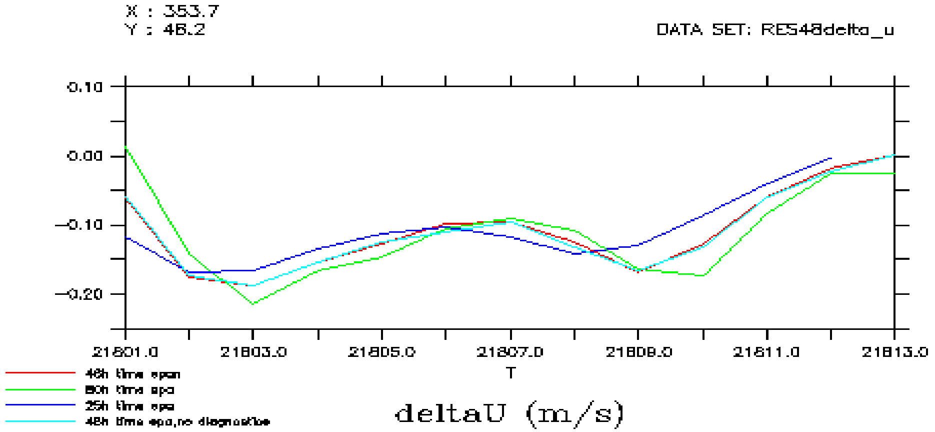
Tide filtering : Input parameters (2)



deltaV (m/s)



module(DeltaU), optimized filter



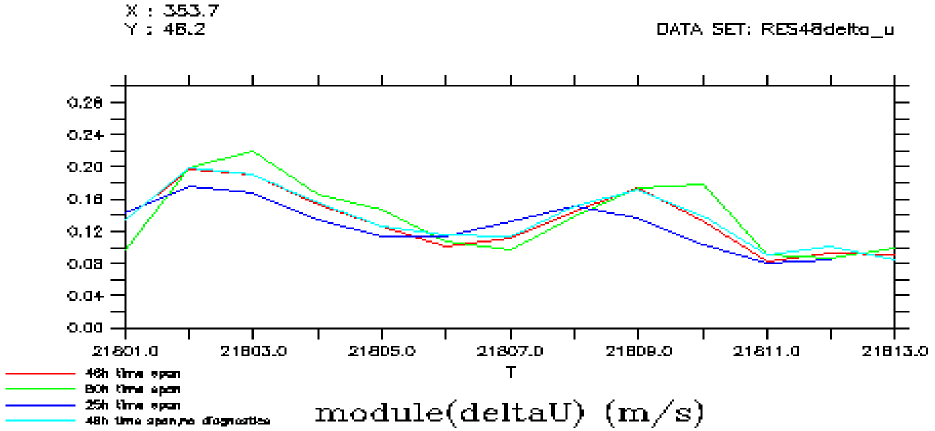
deltaU (m/s)

48h

80h

25h

48h – no preliminary tidal diagnostics



module(deltaU) (m/s)

→ 48h span chosen to separate 2 different time scales :
T1 < ~2 days < T2