Dispersion of homogenized water in coastal areas
Application to the Ushant Front

A. Pasquet, Y. Morel, R. Baraille

SHOM Toulouse, France

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The Ushant Front

Environmental parameters:
- Tides
- Atmospheric flux
- Topography

High variability in scale and time

SST NOAA 09.20.2008

SST NOAA 07.15.2005
The Ushant Front modeling

Environmental parameters:
- Tides
- Atmospheric flux
- Topography

Configuration parameters:
- Diapycnal mixing and barotropic current
- Stratification
- Bottom friction
- Sloping 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
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Reference experiments

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

Initial configuration parameters:
Diapycnal mixing: $K_v = 0.005 \, \text{m}^2/\text{s}$
Stratification: $\Delta \varrho = 0.5 \, \text{o} / \text{oo}$
No bottom friction ($C_d = 0$)
Slope: $\alpha = 0$ 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)
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**Production rate**

Continuous homogenization of the ZMP ruled by $K_v$  
Size of structures of instability depending on $\Delta \varrho$

**Dispersion mechanisms**

Dipolar interactions $\alpha, \Delta \varrho, K_v, C_d$  
Mirror effects (near vertical wall) $d$ (distance from wall)  
Topographic beta effects $\alpha, \Delta \varrho$  
Kelvin waves $\alpha$

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PVA in 2\(^{nd}\) layer, centered (flat,slope)  
PVA in 2\(^{nd}\) layer, coastal (flat,slope)
Dispersion assessment

Properties to consider:

- Production rate
- Dispersion rate 
  \[ r_i(t) = \frac{1}{S_{ZMP}} \partial_t (V_2 + V_3) \]
- Global rate of dispersion = time averaged \( r_i(t) \)
- Preferential direction of dispersion mechanisms

*Global dispersion rate* \( r_d \sim 0.01 \text{ – } 0.1 \text{ m/s} \)
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Global dispersion
Diapycnal mixing

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

\[ \hat{T} = \frac{T_{\text{clearing}}}{T_{\text{homogenization}}} = C_1 \frac{L K_v}{r_d} \]

Three regimes:

\( T << 1 \rightarrow \) Kv limits the dispersion rate, **sub productive regime**

\( T \sim 1 \rightarrow \) Dispersion and production equilibrate, **efficient regime**

\( T >> 1 \rightarrow \) dispersion mechanisms limits the dispersion rate, **auto restrictive regime**
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Global dispersion
Diapycnal mixing and bottom friction

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.
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Global dispersion
Stratification

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.
Dispersion of homogenized water
Application to the Ushant Front in realistic configurations

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

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

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

A sloping topography 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.

Weak uncertainties on bottom friction parametrization can drastically impact the model efficiency to reproduce frontal dynamics.