⚓Assessment of the numerical efficiency of ocean circulation model : Hycom contribution to the COMODO project.

COMODO

- ***Comodo and SHOM involvement***
- ***First results of the baroclinic vortex***
- ***First results of the 2DV upwelling configuration***
- ***First results of the internal waves configuration and starting study on the sensitivity to the vertical coordinate (postdoc)***

COMODO

Comodo : COmmunity MODelling Ocean (2012-2015)
French project funded by the national agency for research
8 teams
5 OGCMs
10 academic test cases

- ***Model evaluation (benchmark)***
- ***Improving existing models and methods***
- ***Guiding future evolution of ocean models***

SHOM involvement :
- ***Implement the benchmark panel in Hycom***
- ***Study the sensitivity to the vertical coordinate***

5 OGCMs

Name	partners	use	coordinate
HYCOM	SHOM	Regional operational oceanography	Hybrid (isopycnal)
ROMS	LEGOS/IRD	Physical and environmental regional studies	sigma
NEMO	CNRS LOCEAN/LEGI	Global operational oceanography Climate Research	Z (sigma)
MARS	IFREMER	Ecosystem coastal studies	sigma
SYMPHONIE	CNRS/UPS/LA	Research	sigma

Test cases

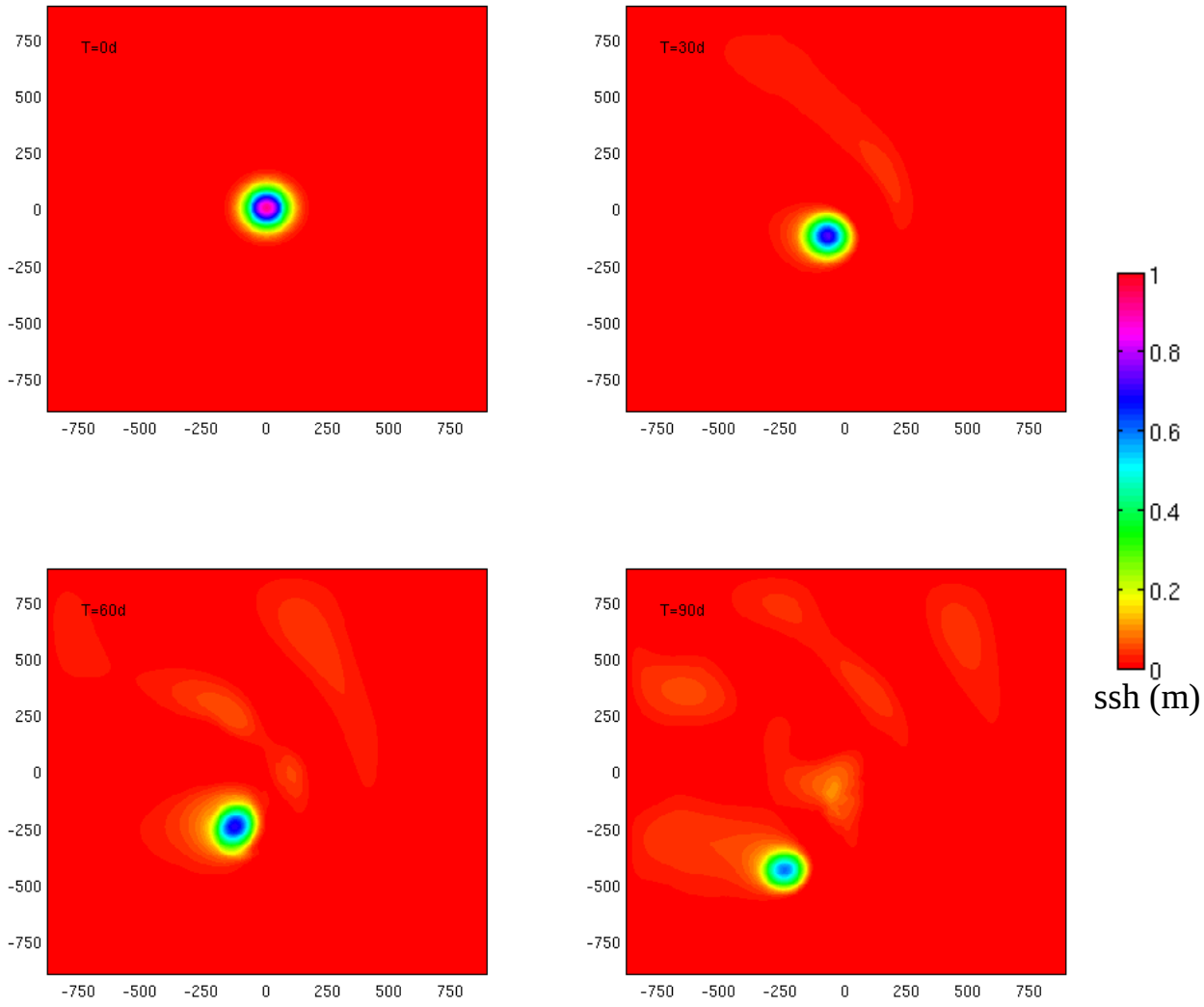
	Tested properties
Gyre de Stommel (Hecht et al., 2000)	Tracer conservation
Adapted Smolarkeiwicz	Test for terrain-following coordinate
Lock exchange	Tracer advection scheme, diapycnal mixing
Barotropic vortex	Tracer/momentum advection scheme, time stepping
Baroclinic vortex	Tracer/momentum advection-diffusion scheme, time stepping, vertical coordinate
Baroclinic jet	Effective resolution, Tracer/momentum advection-diffusion scheme, time stepping, vertical coordinate
Thacker's bowl	Wetting and drying, pressure gradient, vertical coordinate
2DV upwelling	Time stepping, vertical coordinate, bottom boundary conditions
Internal tide	Vertical coordinate, Tracer/momentum advection-diffusion scheme, pressure gradient,
Sea mount	Tracer/momentum advection-diffusion scheme, lateral boundary conditions, current/topography interactions

Hycom-Shom version

Baroclinic time scheme	Leap frog + Robert-Asselin filter
Barotropic time scheme	Leap frog + Robert-Asselin filter
Advection scheme	Centered 2th order (Sadourney 1975)
Tracer advection scheme	FCT2/FCT4
Thickness advection (continuity)	FCT2
Hybrid generator	Weno

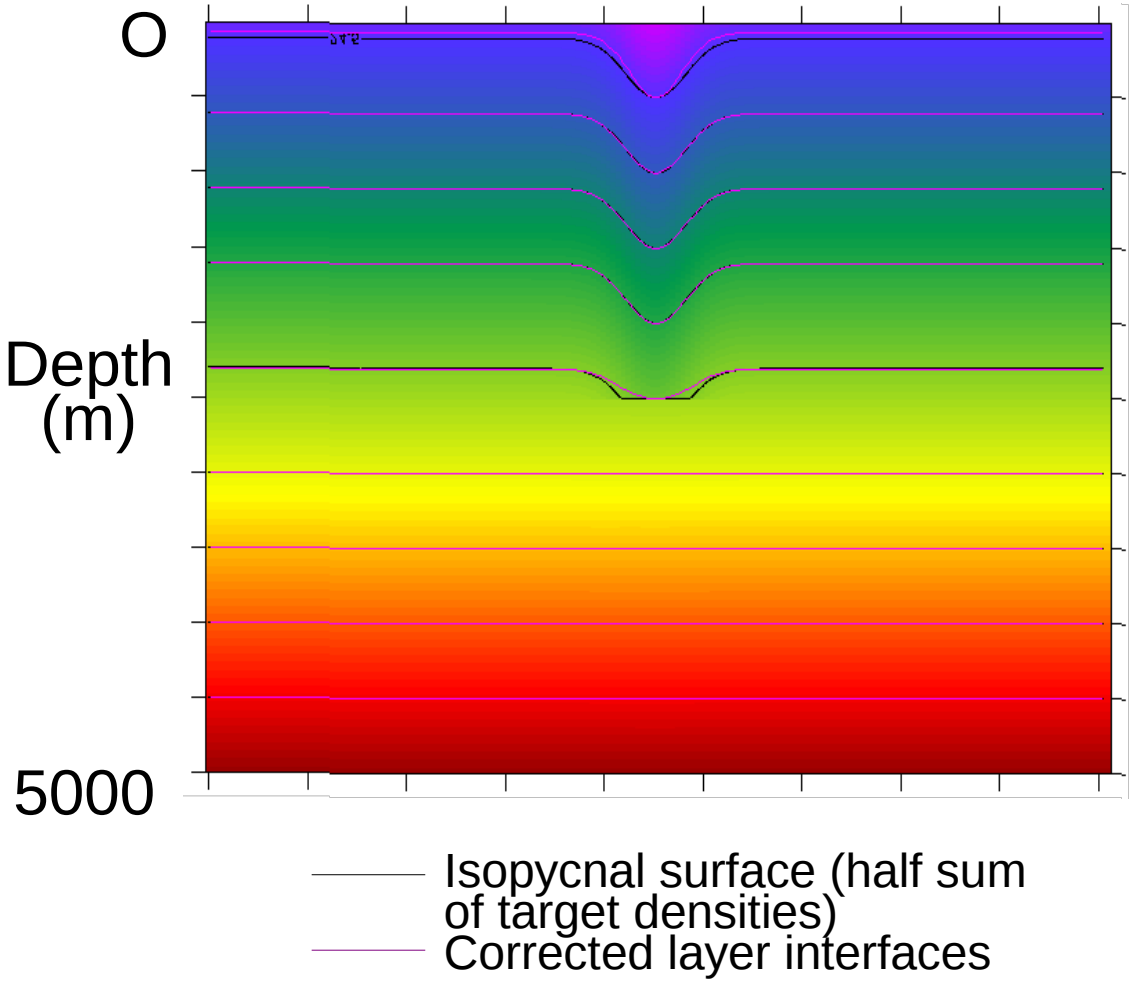
Baroclinic vortex

- *Density anomaly between surface and 2500m*
- *Bottom depth 5000m (uniform)*
- *Beta plane*
- *SSH at the vortex center at t=0 : 1m*
- *Vortex size scale : 60km*
- *Boundary condition : wall*
- *10 layers*
- *4 horizontal resolutions : 30km, 20km, 10km, 5km*



Isopycnal case

Need to compute some corrections on the interfaces to initialize an ocean at rest below 2500m



Sensitivity

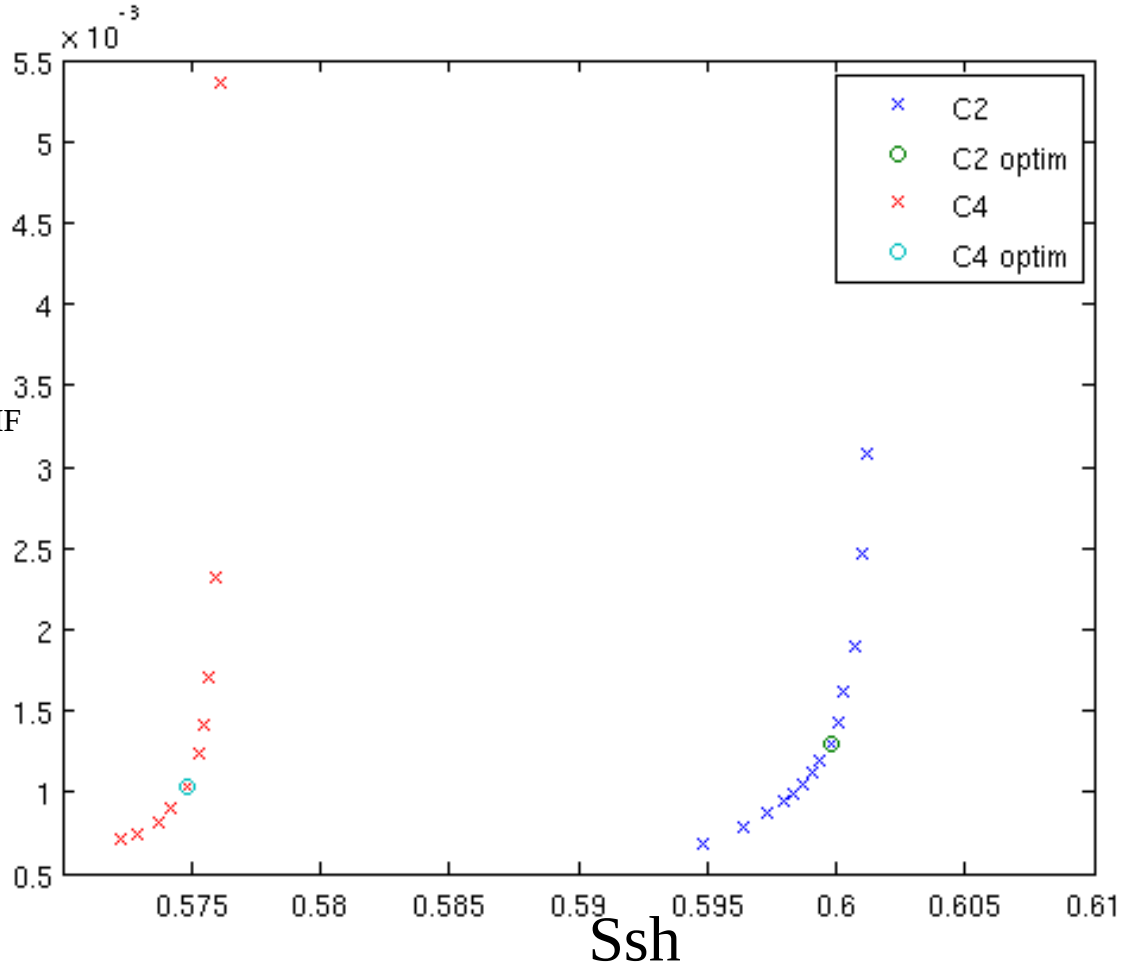
	Vertical coordinate	Momentum advection scheme	Thickness advection scheme	Tracer advection scheme	Hybgen scheme	viscosity	diffusion	Asselin
1	z	EC-C2	FCT2	FCT2	weno	Bilap 0,05 m/s	0.	0,125/ 0,250
2		EC-C2		FCT4		Bilap 0,05 m/s		
3		EC-C2		FCT4		Smag. 0,05		
4	isopycnal	EC-C2		-	-	Smag. 0,05		
5		EC-C2				Bilap 0,05 m/s		
6		C4				Smag. 0,03		

Choice of viscosity parameter

dx=10km
C2 : Visco4 = 0.05
C4 : Visco4 = 0.03

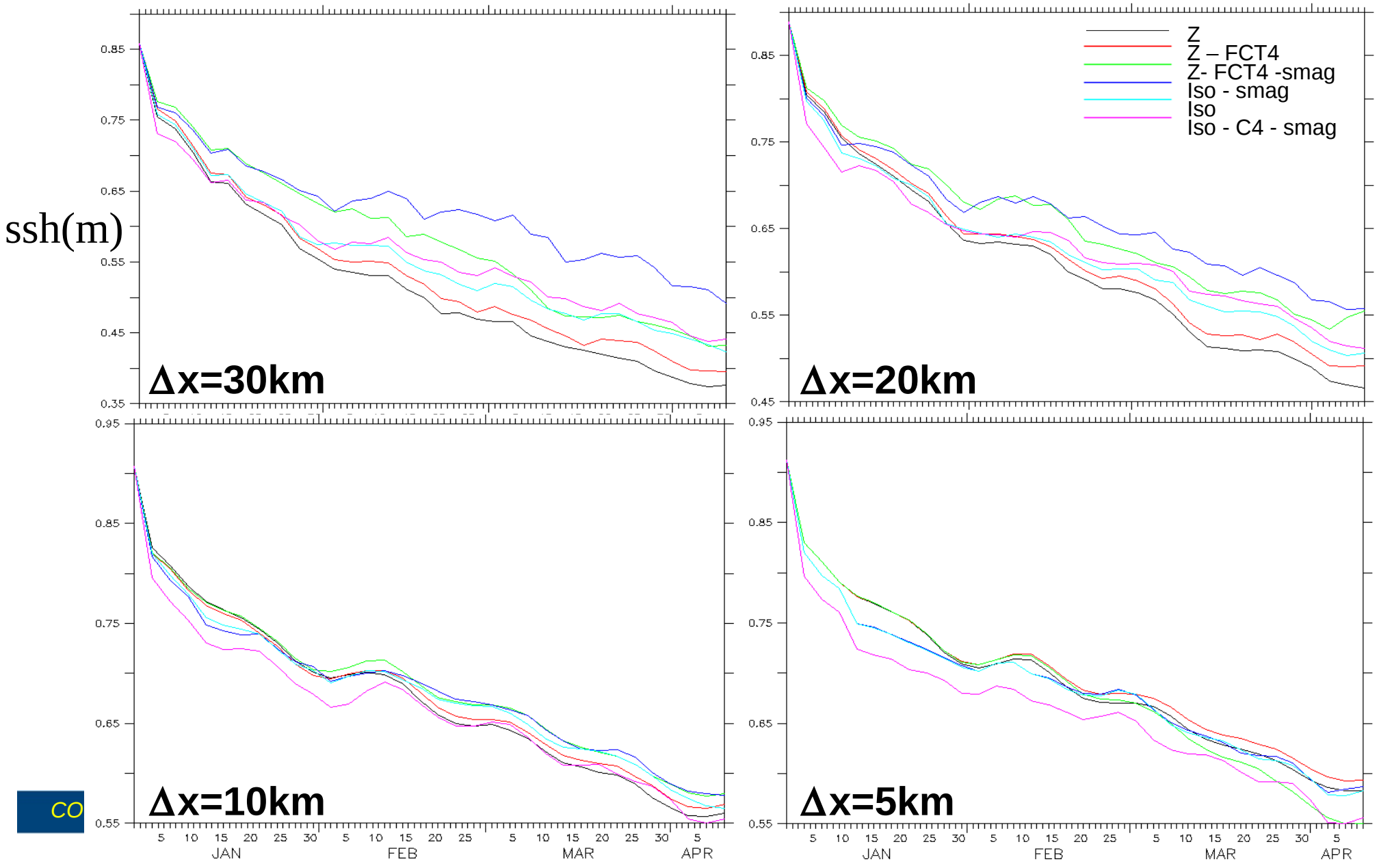
U_{HF} =high-pass filtered velocity (Hanning filter 3 points)

$U_{RMS\ HF}$

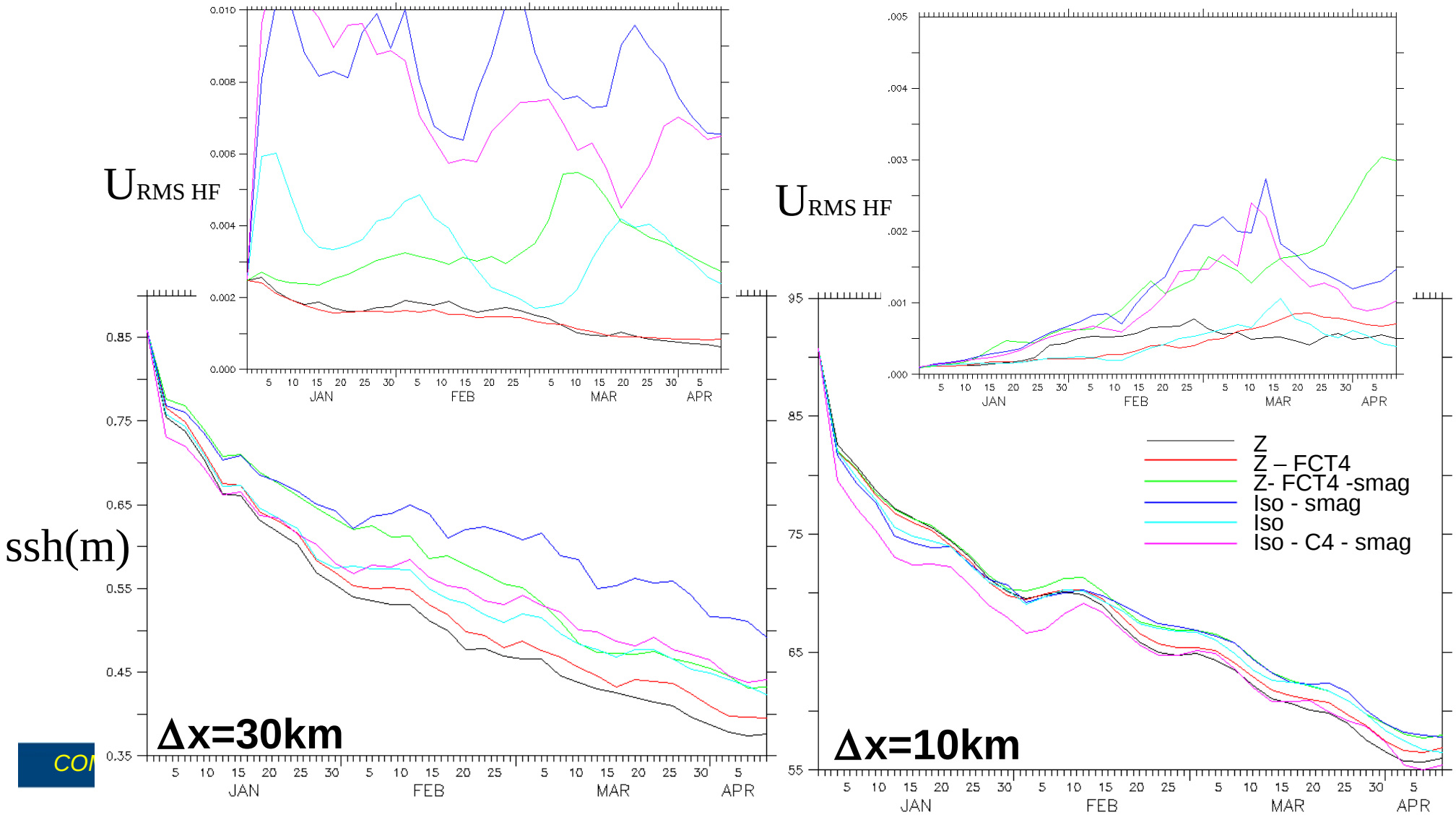


Is it sufficient to prevent dispersion errors ?

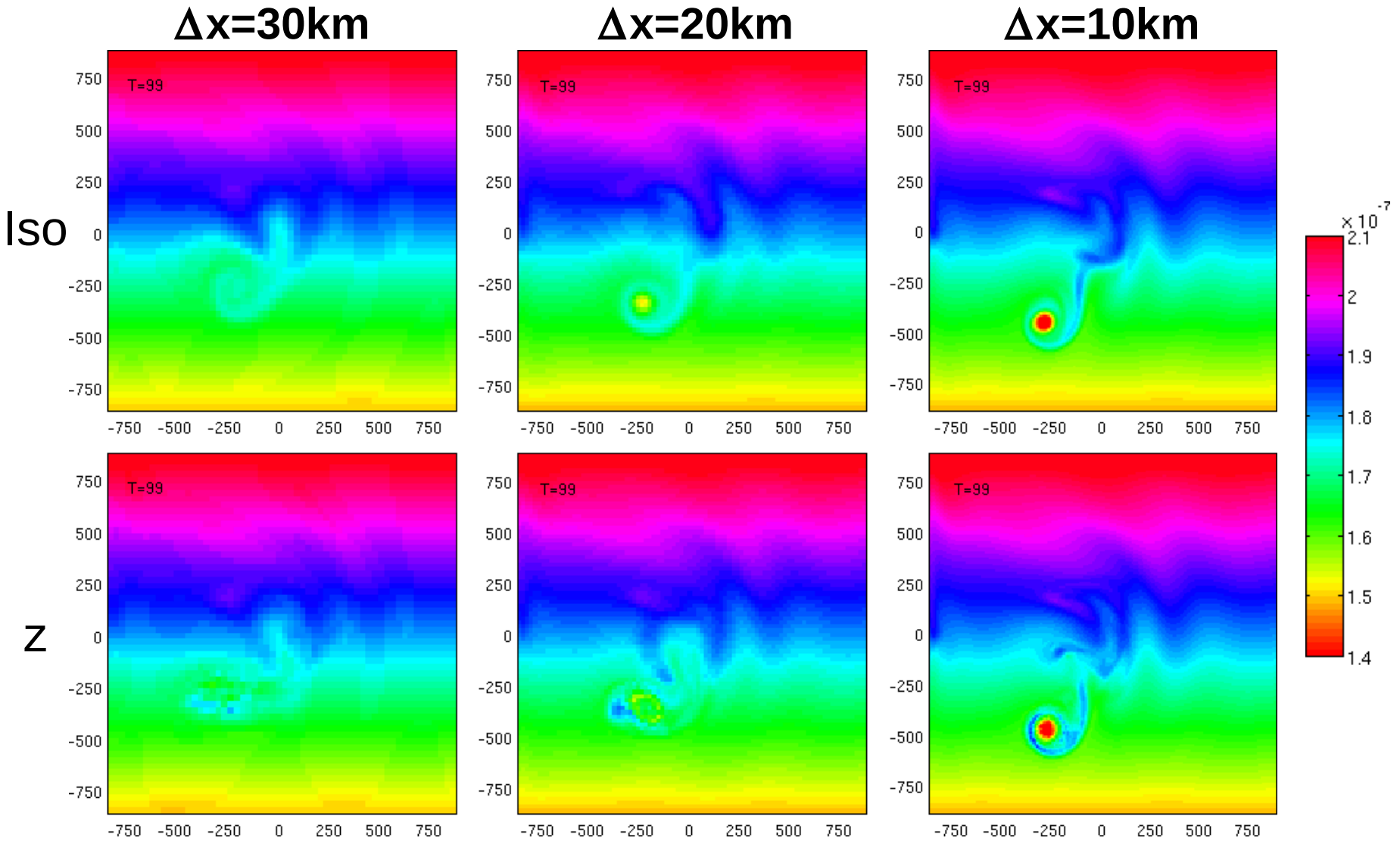
Vortex sea level evolution



Grid point velocity gradients



PV analysis (third layer ~1000-1500m)

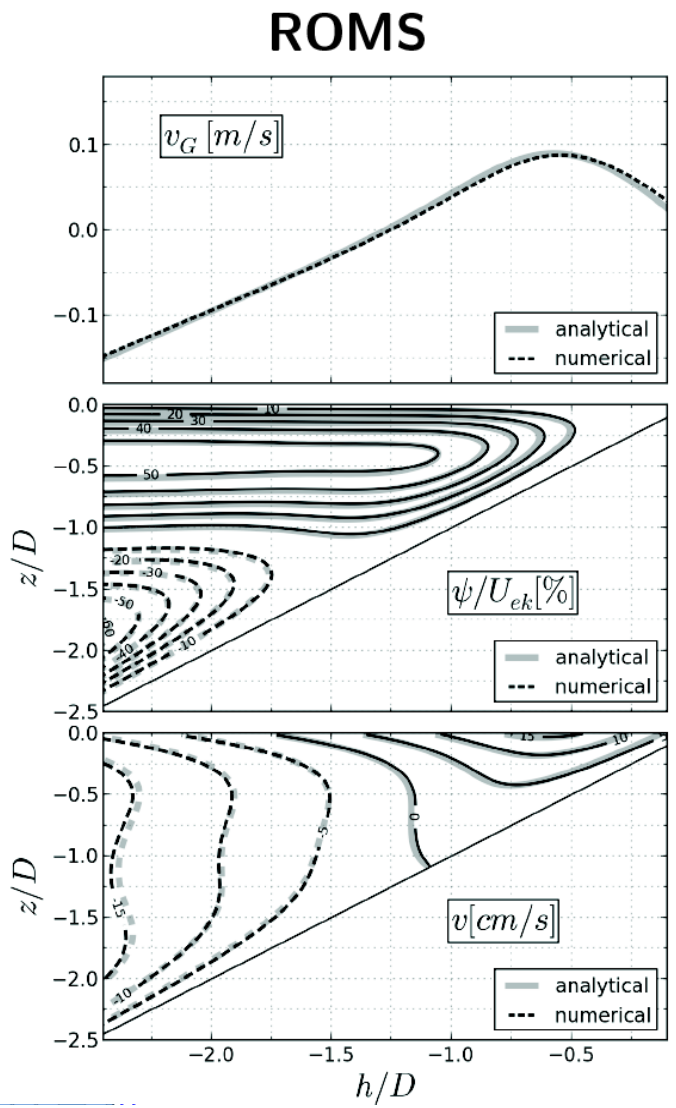


baroclinic vortex : conclusion remarks

- ***The implemented baroclinic vortex is sensitive to the vertical coordinate***
- ***The vortex is more preserved using isopycnal coordinate at low resolution***
- ***The high-order momentum scheme C4 do not give good results in this case***
  - **C4 may be not compatible with leap frog**
  - **LF-C2 works well when close to CFL condition**
- ***The better results are obtained using low viscosity***
  - **May be lower than the viscosity which is necessary to avoid dispersion errors**
  - **There is no frontogenesis neither forcing.**

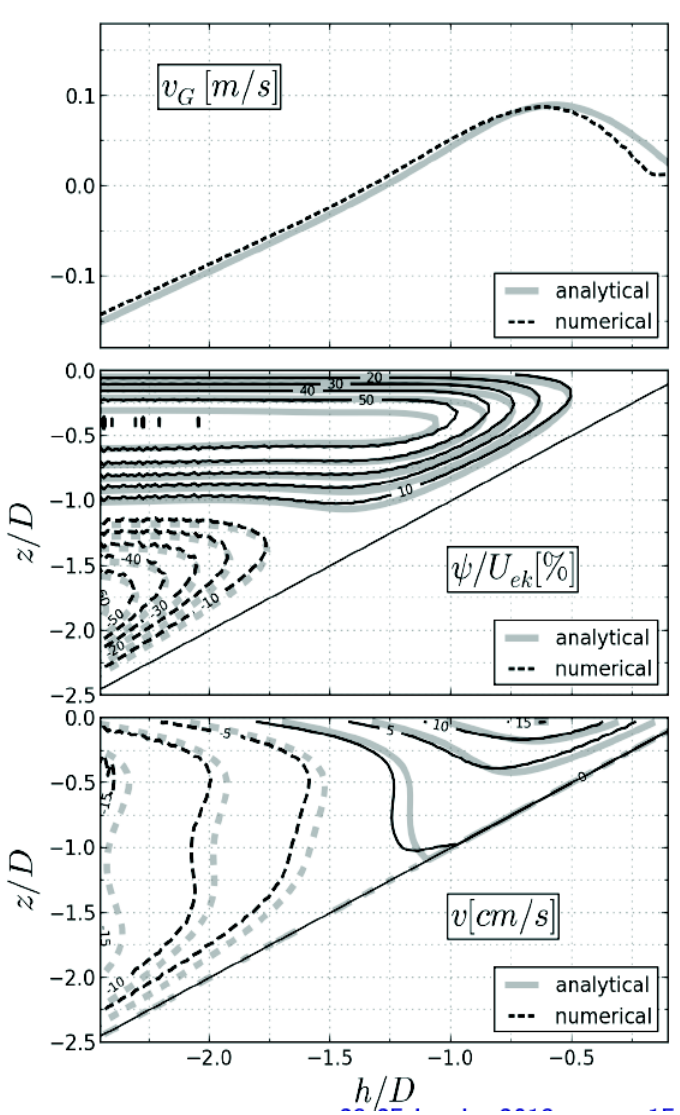
2DV upwelling

- ***Hard-coded alongshore pressure gradient driving an onshore current of 2cm/s***
- ***Strong linear bottom friction***
- ***No advection***
- ***Constant vertical mixing Kz=0.01 m²/s***
- ***Comparsion with an analytical solution (using no slip bottom condition)***

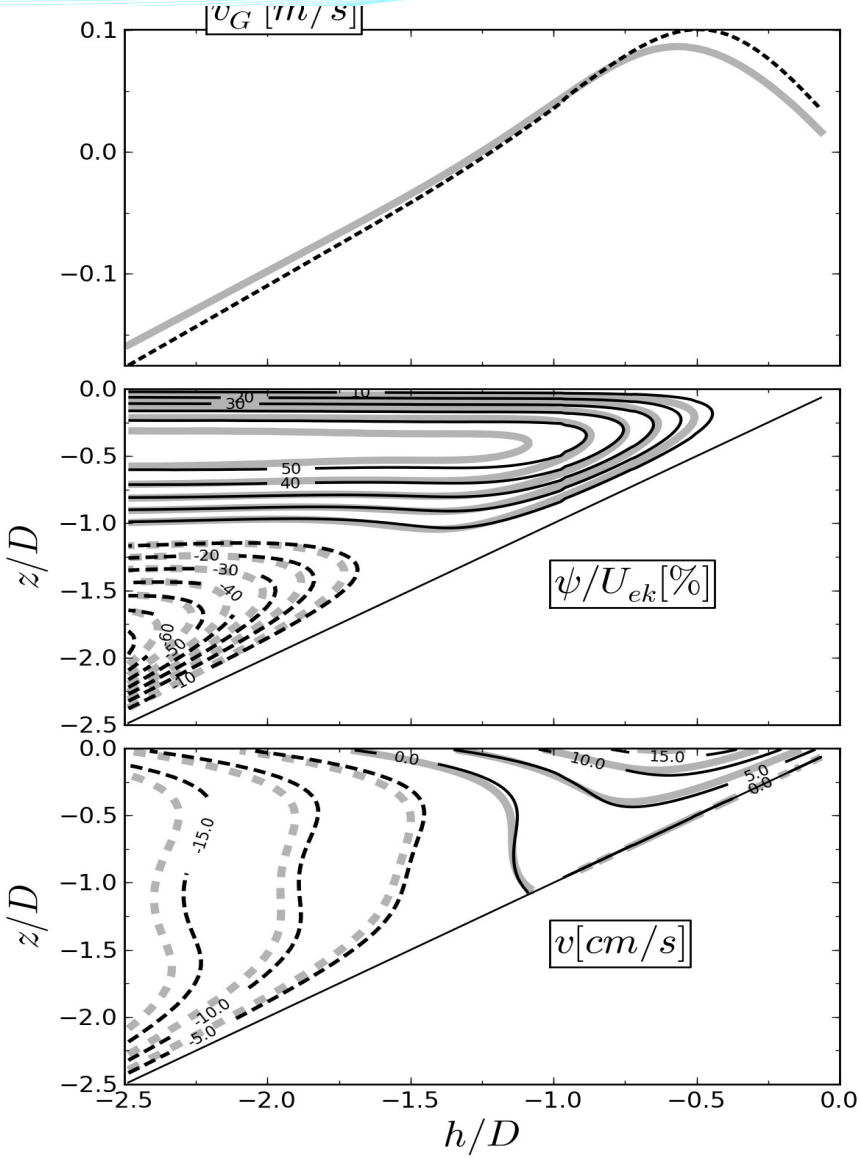


First implementation using Hycom...

Z-coordinate
thkbot=10m

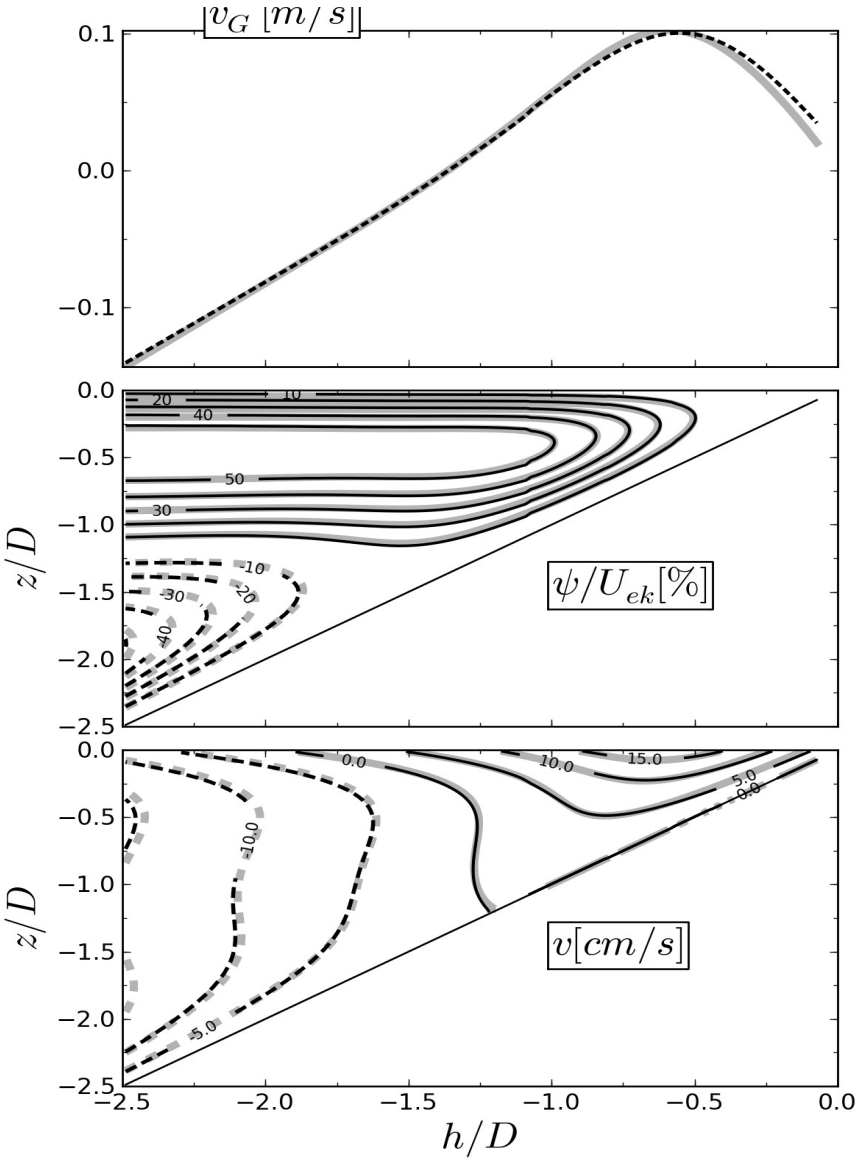


After correction of thkbot



An apparent viscosity of 0.008

Comparison with the analytical solution using a Kz of 0.008 instead of 0.01

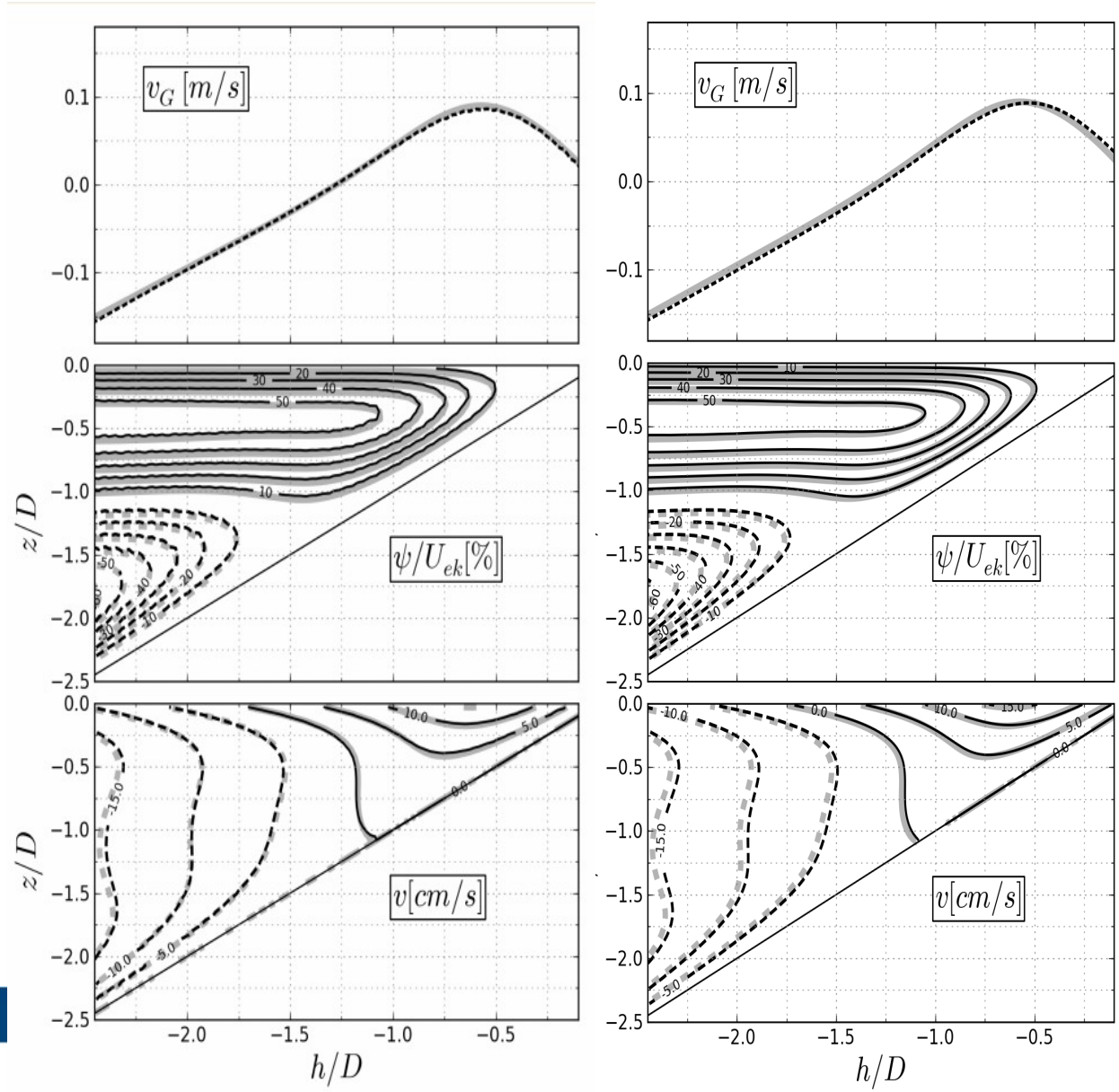


Last versions

Z:
Dp00=3.5
Ds00=3.5
Thkbot=3.5

Terrain-following coordinate :
Dp00=3.5
Ds00=1.0
Thkbot=3.5

Momentum Asselin filter moved at the end of the time step



Upwelling 2DV : conclusion remarks

Hard test case for Hycom :

Unexpected point : Asselin filter

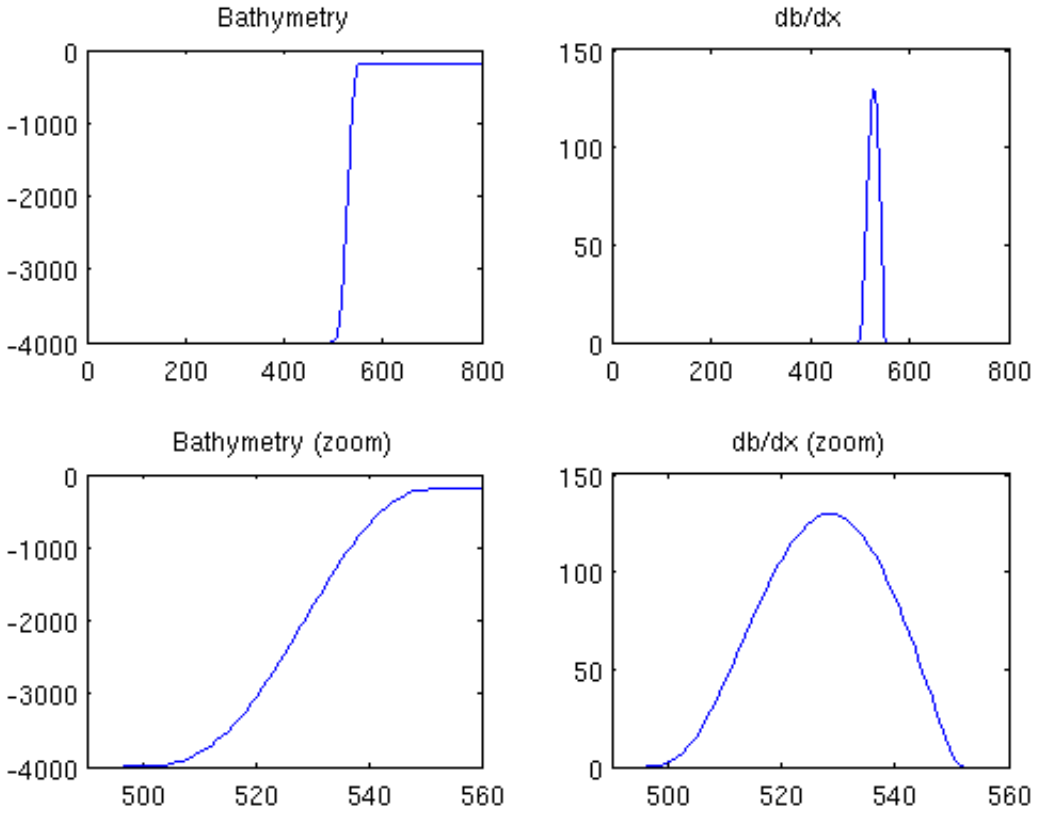
- **Make a tempory Asselin filter to compute KPP terms using a filtered velocity field and make a definitive Asselin filter at the end of the time step.**
- **Offer the possibility to use another time stepping scheme ?**

Expected points : sensitivity to numerical choices near the bottom

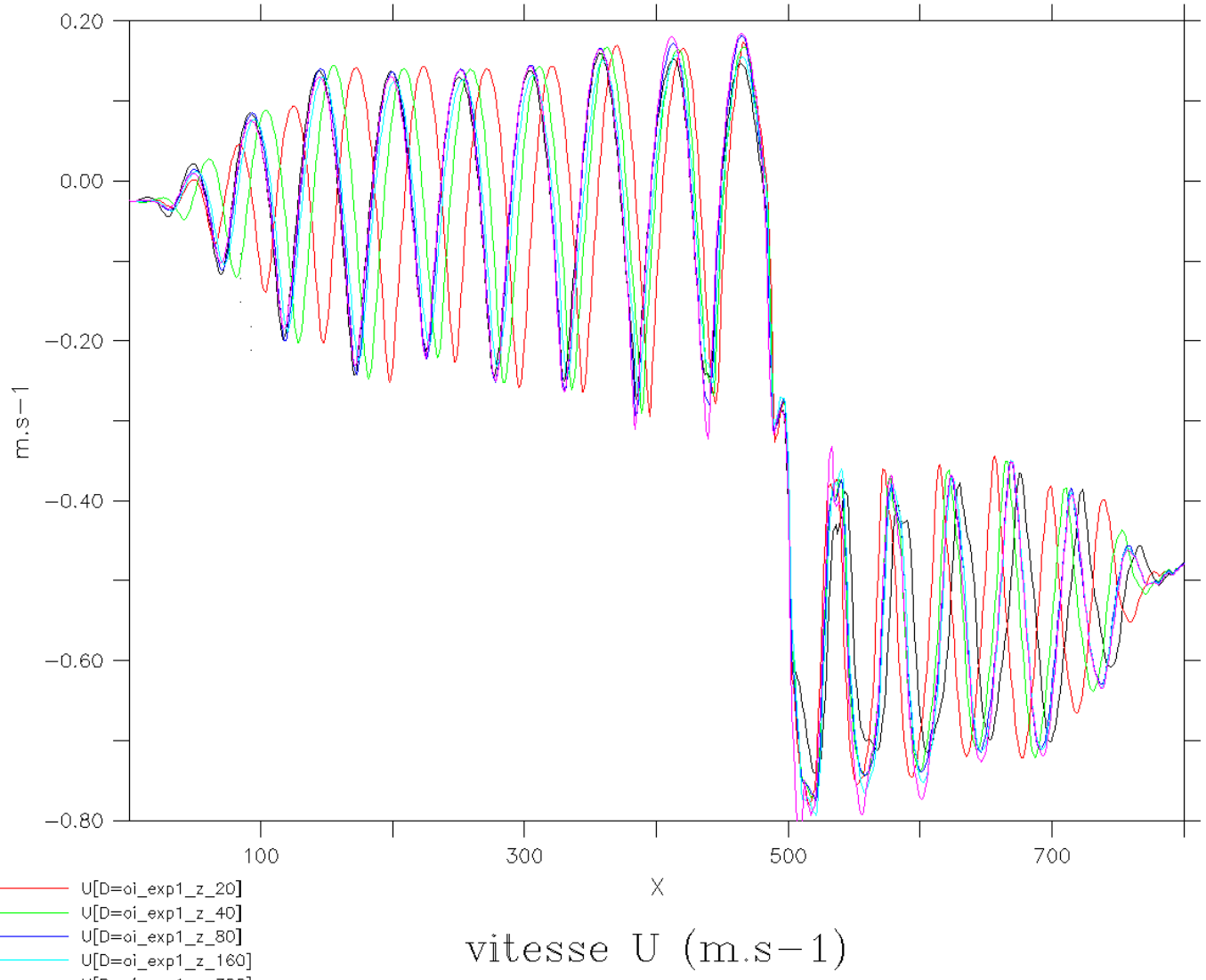
- **Offer the possibility to include the bottom friction in KPP (implicit scheme) instead of an explicit scheme in momtum.F ?**
- **Study the impact of small layers and the choice of dpu/dpv**
- **Improve the formulation of terrain-following coordinates**

Internal waves

- *2DV setup*
- *No friction*
- *open boundary conditions using very high resolution barotropic solutions*
- *Various applications*
- *Sensitivity of vertical coordinate*
- *Test of various hybrid/ALE approach*
- *Test of time stepping and advection schemes*
- *Diapycnal mixing*



Two-layer vs z simulations



Perpectives

Build a benchmark

Initiate a brainstorming on the numerical schemes and their limits

Guide the optimization of model parameters