Influence of bottom friction and vertical diffusivity parametrization in a 3D barotropic model, comparison with observations in the Iroise sea.

Y. Soufflet and F. Lyard

Legos, OMP, Toulouse

yves.soufflet@legos.obs-mip.fr

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Outline

- The model T-UGOm

- Detiding the data from profilers

- Choice of parameters

- Response of the model to those parameters

- Conclusion

T-UGOm 2D/3D model

Finite elements/finite volumes

Continuous/discontinuous Galerkin

Semi-implicit/explicit
(multiple dynamical cores)

Time sub-cycling

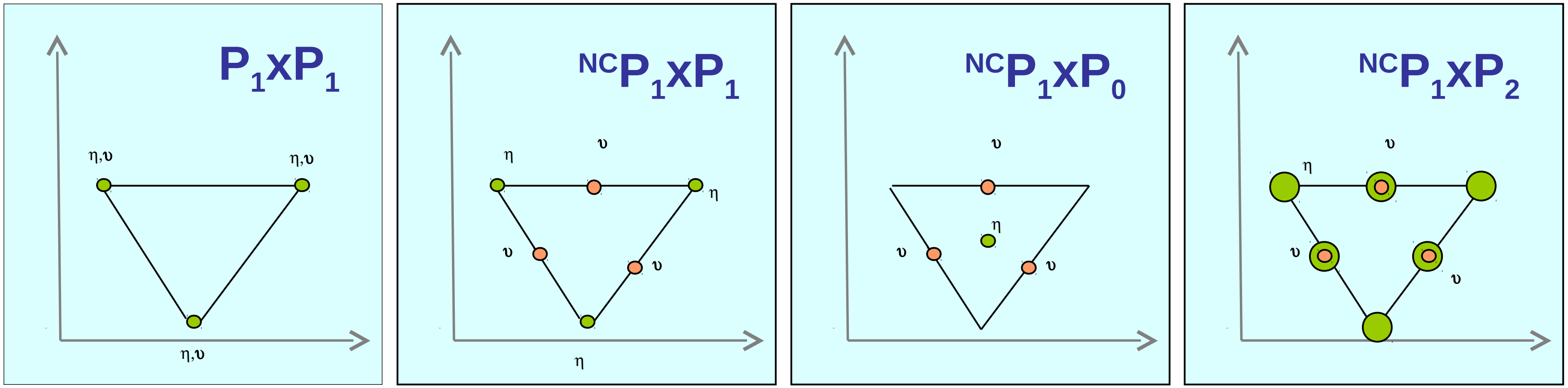
Multi-discretisation: triangle, quadrangle

Embedded spectral solver (tides)

C/C++, MPI parallelization

Operationally used for space altimetry and gravim

Optimized for tidal applications
full potential:
astronomical, loading and self attractio
online harmonic analysis
etc..



2D spectral equations

-Continuity: $$j\omega\alpha + \nabla \cdot Hu = F_{\alpha}$$

-Momentum: $$j\omega\mathbf{u} + \mathbf{f} \times \mathbf{u} = -g\nabla(\alpha + \delta) + g\nabla\Pi - \mathbf{D}\mathbf{u}$$

$$H\mathbf{u} = \mathbf{M}(\nabla\alpha - \mathbf{F}) \qquad \mathbf{M} = -\frac{gH}{\Delta}\begin{bmatrix} i\omega + r''' & f - r' \\ -f - r'' & i\omega + r \end{bmatrix}$$

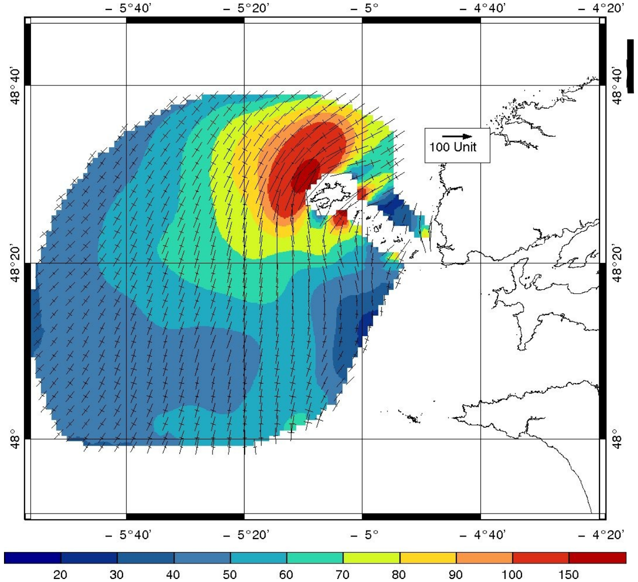
-Wave equation: $$j\omega\alpha + \nabla \cdot M\nabla\alpha = F_{\alpha} + \nabla \cdot MF_{u}$$

Solved implicitely with a complex-valued, sparse matrix solver (variational formulation)

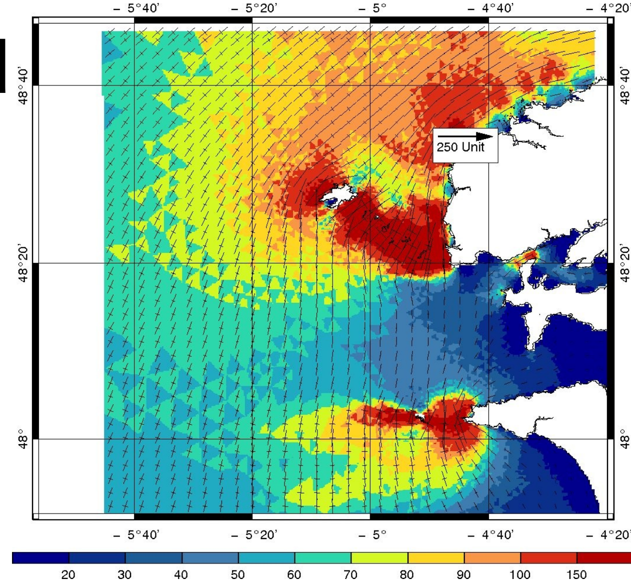
-Wave Separation

-Useful for parameter exploration, ensemble computation

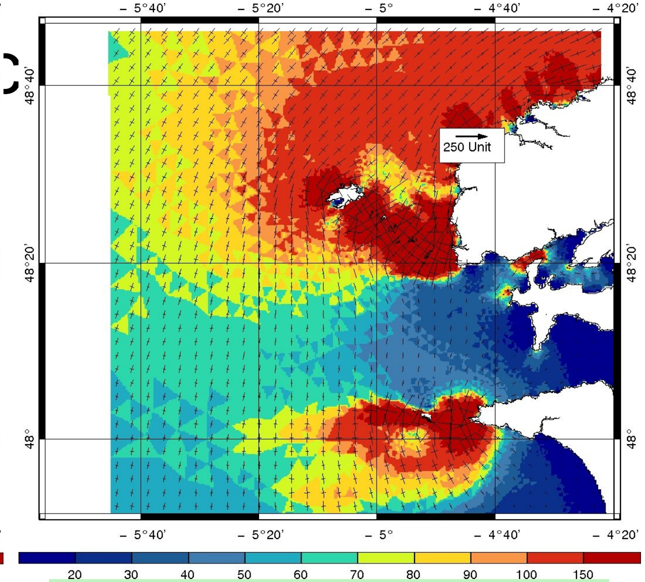
Radar, 2D and 3D spectral



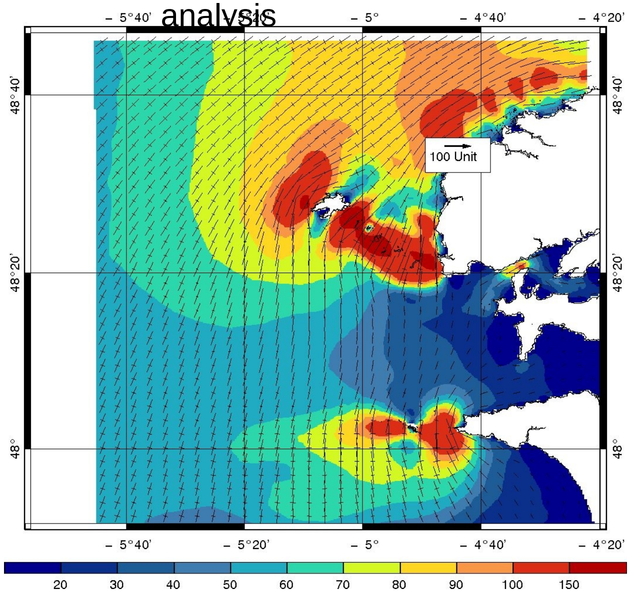
HF-Radar M_2 analysis



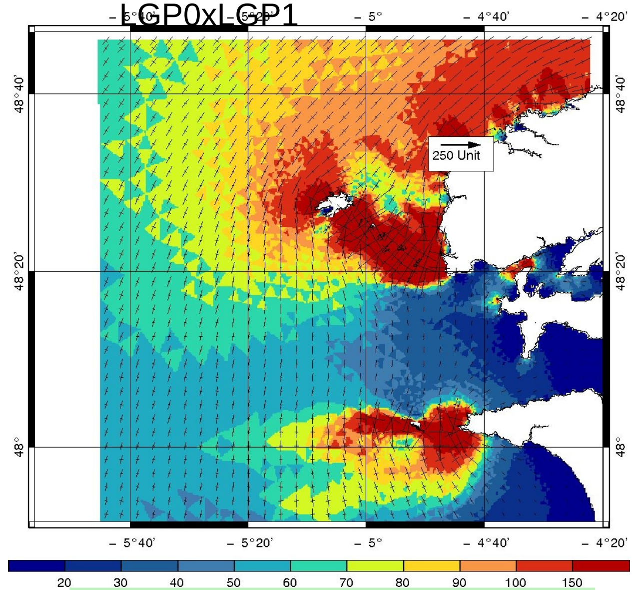
M_2 2D-spectral LGP0xLGP1



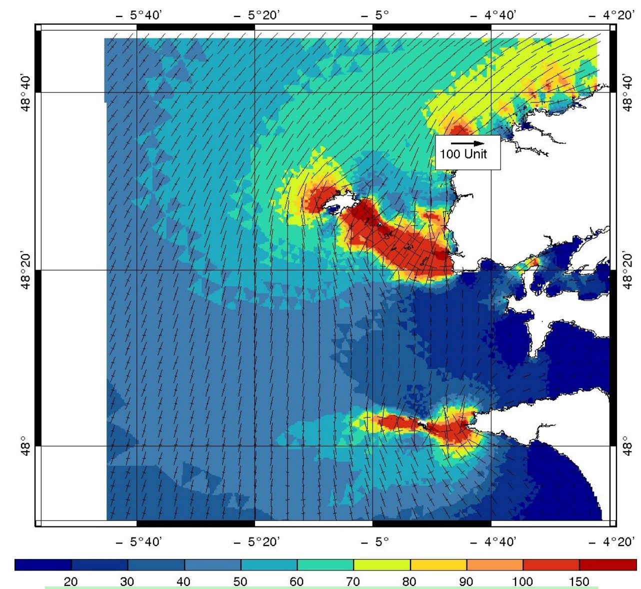
M_2 3D-spectral LGP0xLGP1, surface



M_2 2D-sequential LGP1xLGP1



Mean M_2 3D-spectral LGP0xLGP1



M_2 3D-spectral LGP0xLGP1, bottom

Parameters exploration

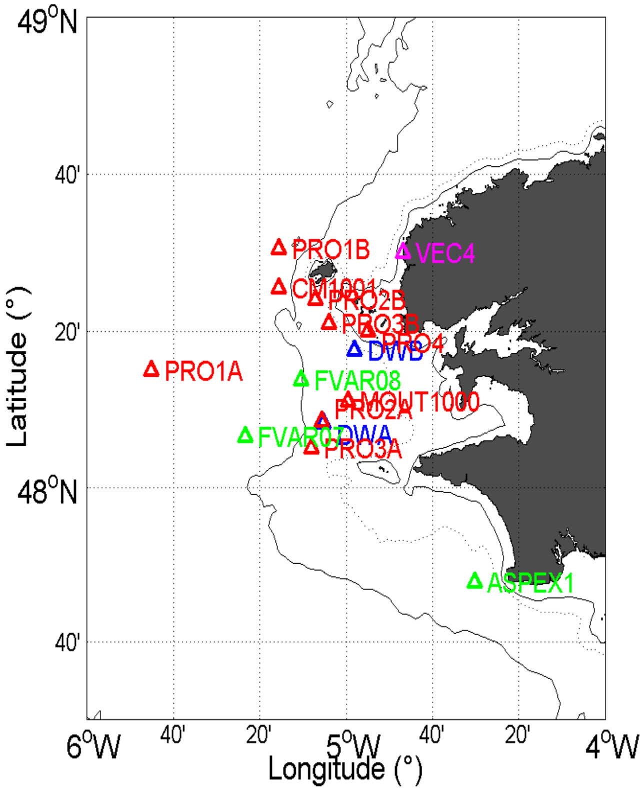
- **Objectives :** improve 3D barotropic currents for data corrections (moored or embarked ADCPs)

-**Targeted parameters:**

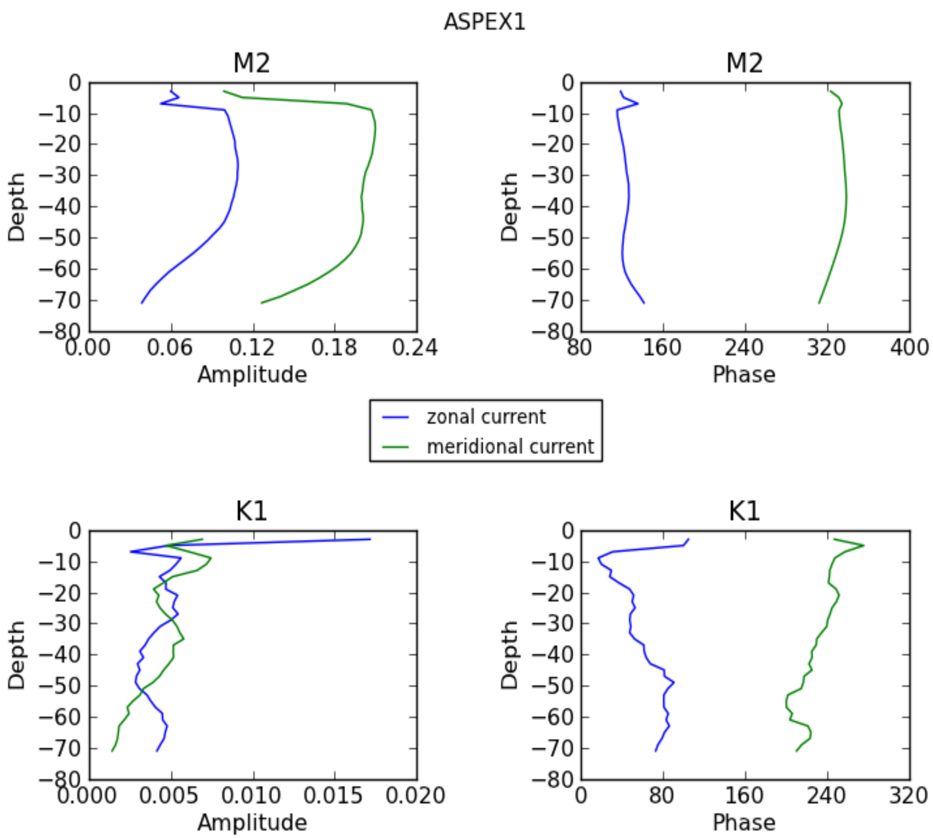
 -Roughness length
 -Kz
 -Vertical resolution

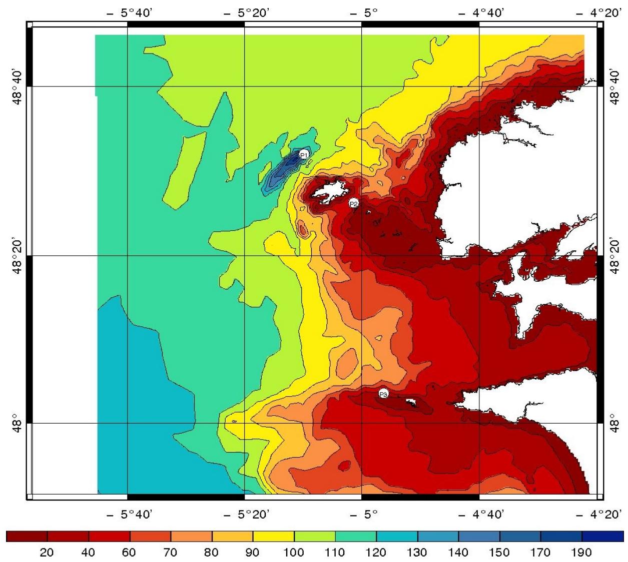
- **Experiment region:** west French Britany (Iroise Sea)
  -profilers
  -HF-radar

- Thanks to Louis Marie (IFREMER Brest) for providing the data



Detided ADCP data





- Each velocity component goes through a harmonic analysis at each bin.

Dissipation in TUGO-M

From the manual...

$K_v \frac{\partial \mathbf{u}}{\partial z} = \boldsymbol{\tau}$ it accounts for the bottom stress or wind stress

The bottom stress parameterization is given by (see Cushman-Roisin and Malacic):

$\boldsymbol{\tau}_b = \rho \left\| \mathbf{u}^* \right\| \mathbf{u}^* = \rho C_d \left\| \mathbf{u} \right\| \mathbf{u}$ where $\mathbf{u}^*$ is a friction velocity.

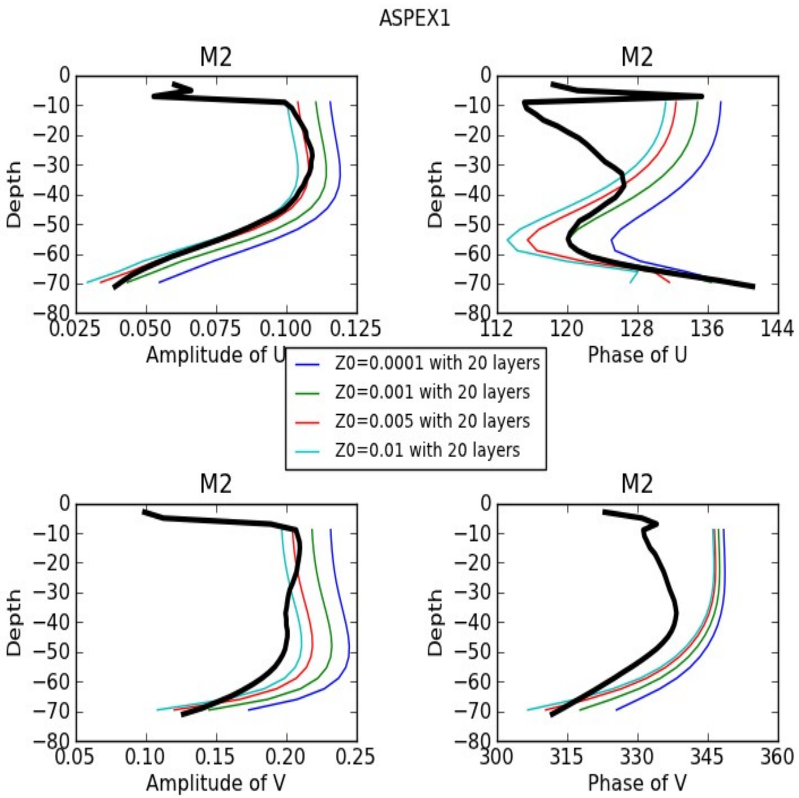
In addition, a logarithmic vertical profile is assumed for horizontal velocities:

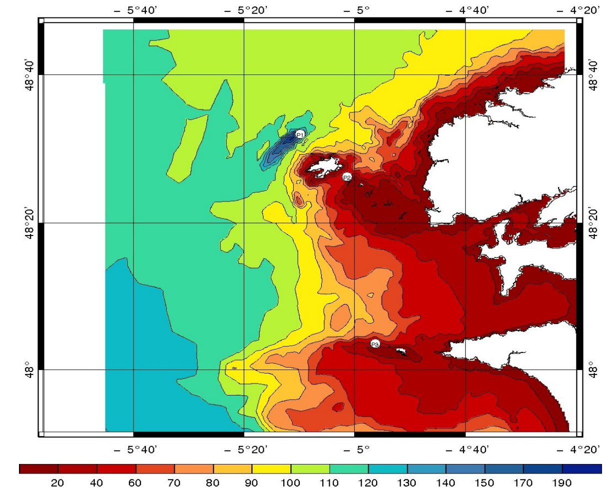
$$\mathbf{u}(z) = \frac{\mathbf{u}^*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$

In this context, we might express the bottom stress as:

$\boldsymbol{\tau}_b = \rho C_d \left\| \mathbf{u}(z) \right\| \mathbf{u}(z)$ with $C_d = \kappa^2 \ln\left(\frac{z}{z_0}\right)^{-2}$

Effect of bottom roughness



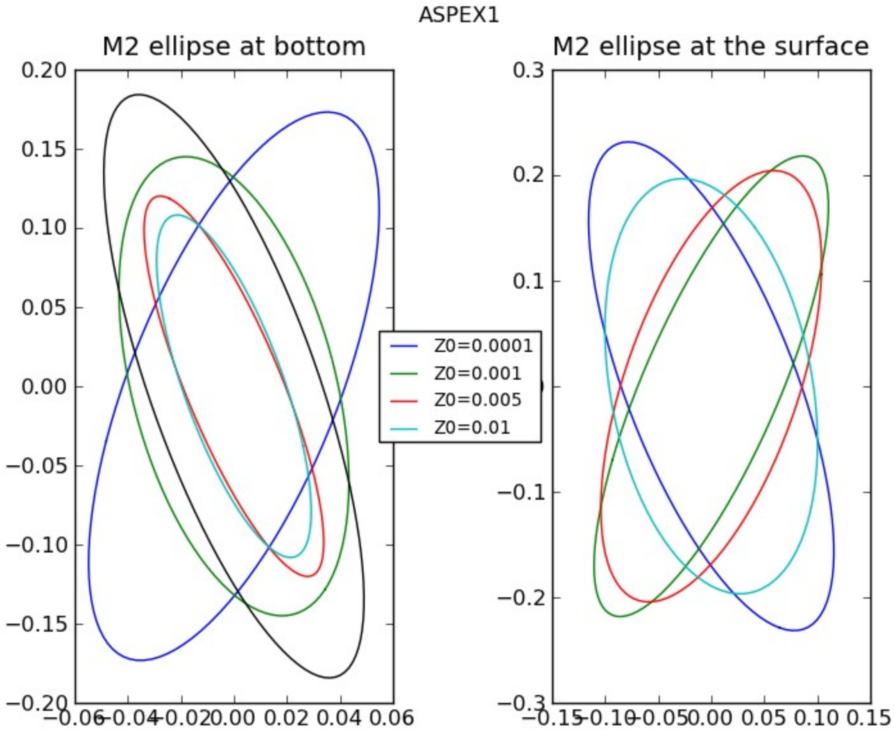


. A logarithmic vertical profile is assumed for the velocity, dependent of the bottom roughness Z0.

$$\mathbf{u}(z) = \frac{\mathbf{u}^*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$

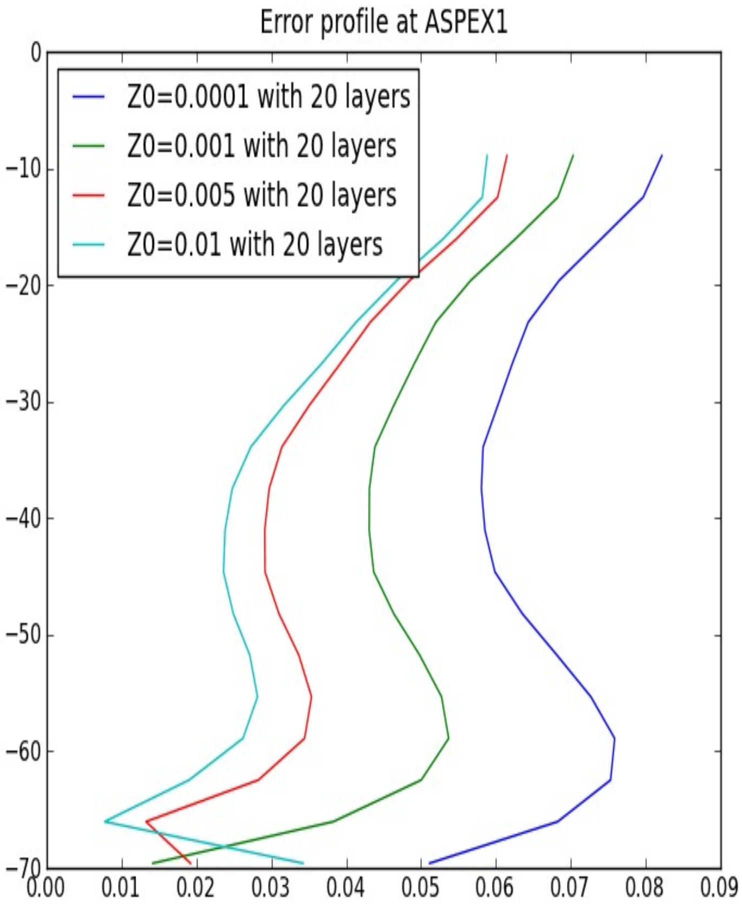
. Changes in this parameter only affect the maximum amplitude but not the depth at which that maximum occurs.

Corresponding ellipses



- Higher Z0 value provides more realistic tidal ellipses at the bottom

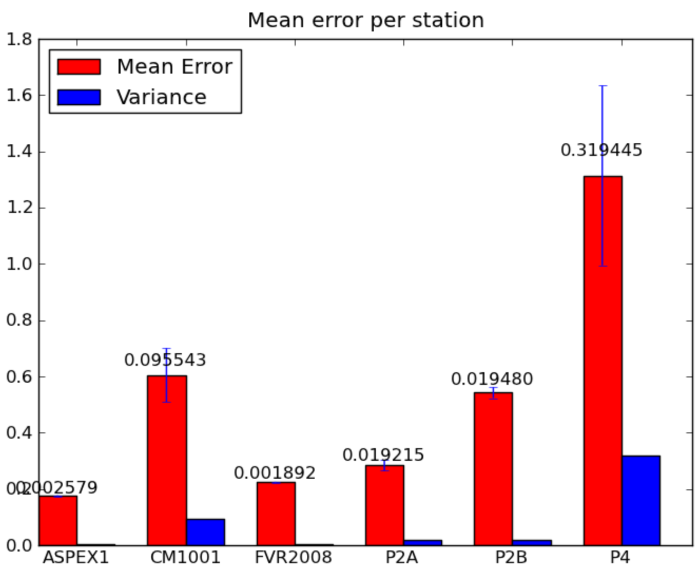
Respective error profile

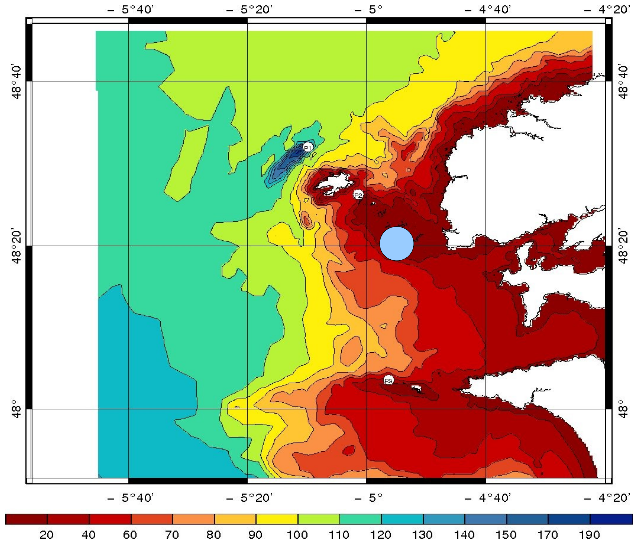


Stations	Bottom roughness				variance
	0.0001	0.001	0.005	0.01	
ASPEX1	0.234554	0.219264	0.203692	0.195312	0.000226
CM1001	0.857827	0.855556	0.849846	0.845423	0.000024
FVR2008	0.306211	0.282832	0.25978	0.244254	0.000550
P2A	0.206679	0.195286	0.190631	0.191072	0.000042
P2B	0.538324	0.487605	0.434722	0.406109	0.002565
P4	2.25315	2.34312	2.43178	2.5003	0.008647

- We can obtain maps of “best value”
- There is up to 2 order magnitude of difference in sensitivity between stations

Global error

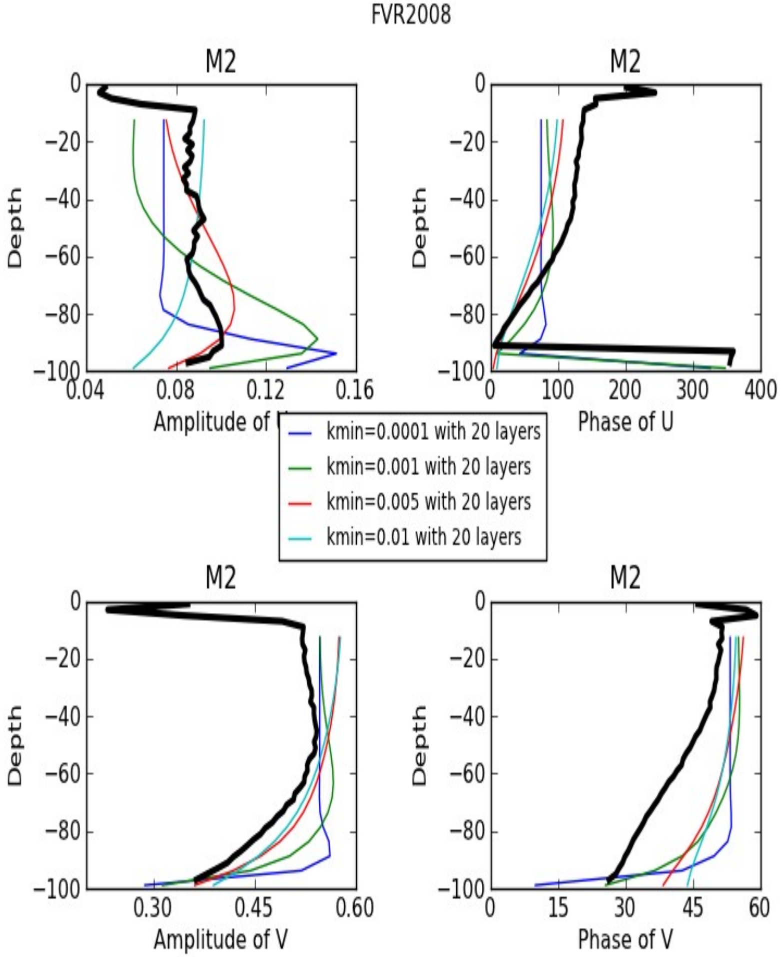




- Large difference of sensibility over the stations
- Largest error in shallow region

Minimum diffusivity coefficient and vertical resolution

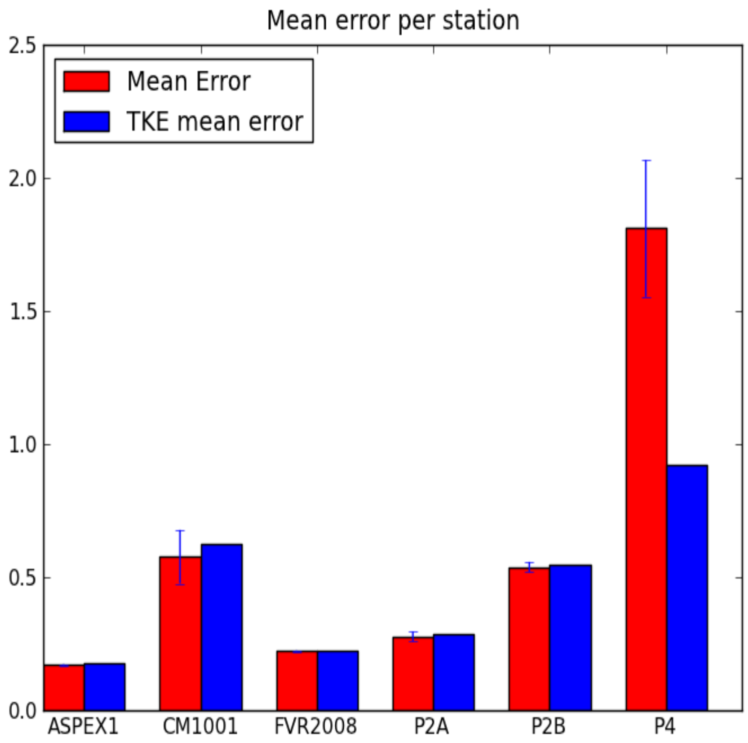
Stations	Minimum diffusivity 0.0001	0.001	0.005	0.01	variance
ASPEX1	0.194159	0.194971	0.195227	0.194538	0.000000
CM1001	0.837197	0.840627	0.842704	0.839526	0.000004
FVR2008	0.202223	0.174141	0.170229	0.169256	0.000184
P2A	0.463126	0.466383	0.461082	0.457226	0.000011
P2B	0.704374	0.707775	0.710081	0.709588	0.000005
P4	1.28139	2.32092	2.17189	1.65755	0.171370



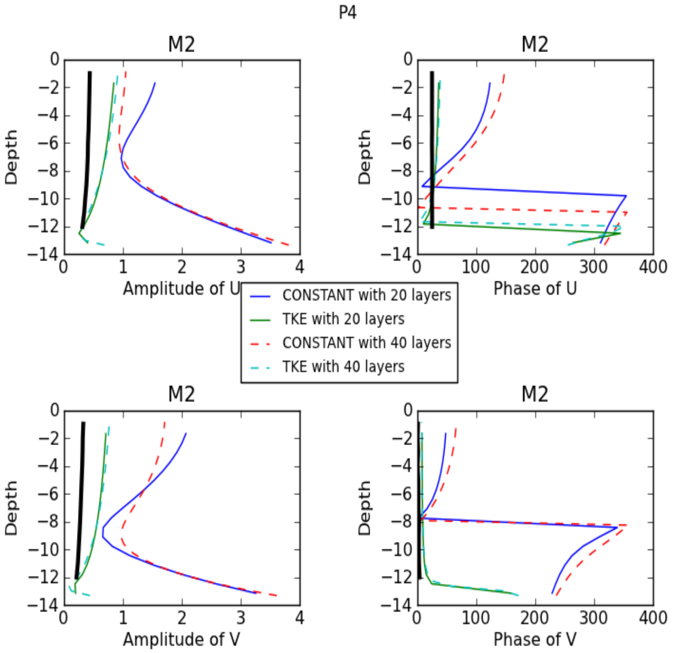
Stations	Minimum diffusivity 0.0001	0.001	0.005	0.01	variance
ASPEX1	0.19533	0.195312	0.194392	0.193453	0.000001
CM1001	0.844146	0.845423	0.841509	0.834216	0.000019
FVR2008	0.286584	0.244254	0.243387	0.240903	0.000360
P2A	0.231963	0.191072	0.175642	0.179898	0.000496
P2B	0.516784	0.406109	0.408874	0.403111	0.002304
P4	1.67442	2.5003	1.66452	1.14373	0.235865

- Best Kmin at different resolution: 20 (bottom) and 40 layers (top)

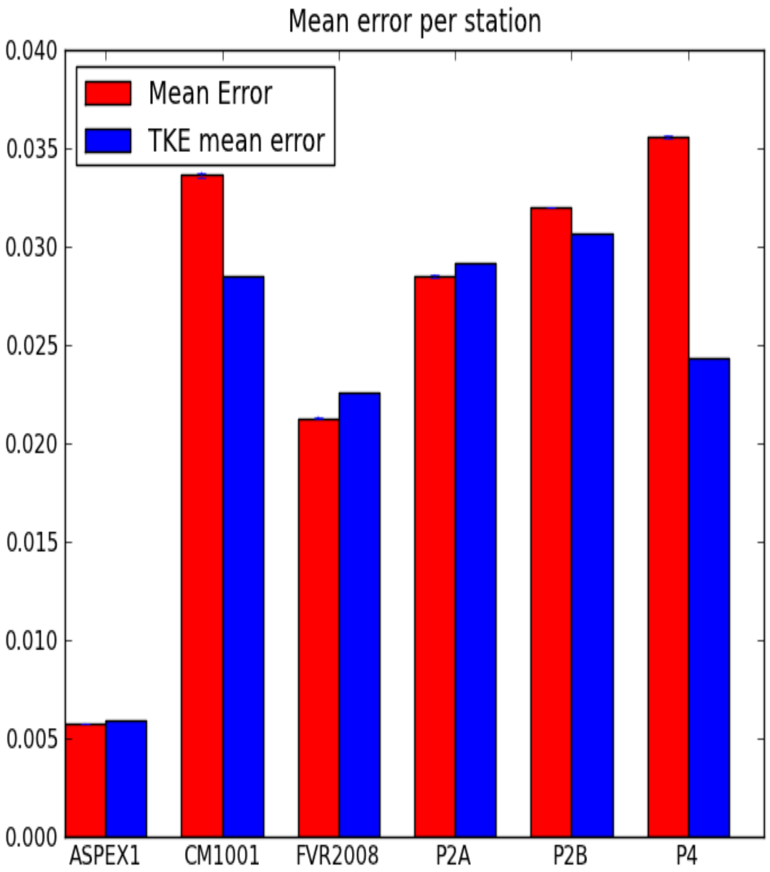
Effect of the turbulent closure scheme



- In shallow region the benefits of the turbulent scheme is obvious



What about other constituent



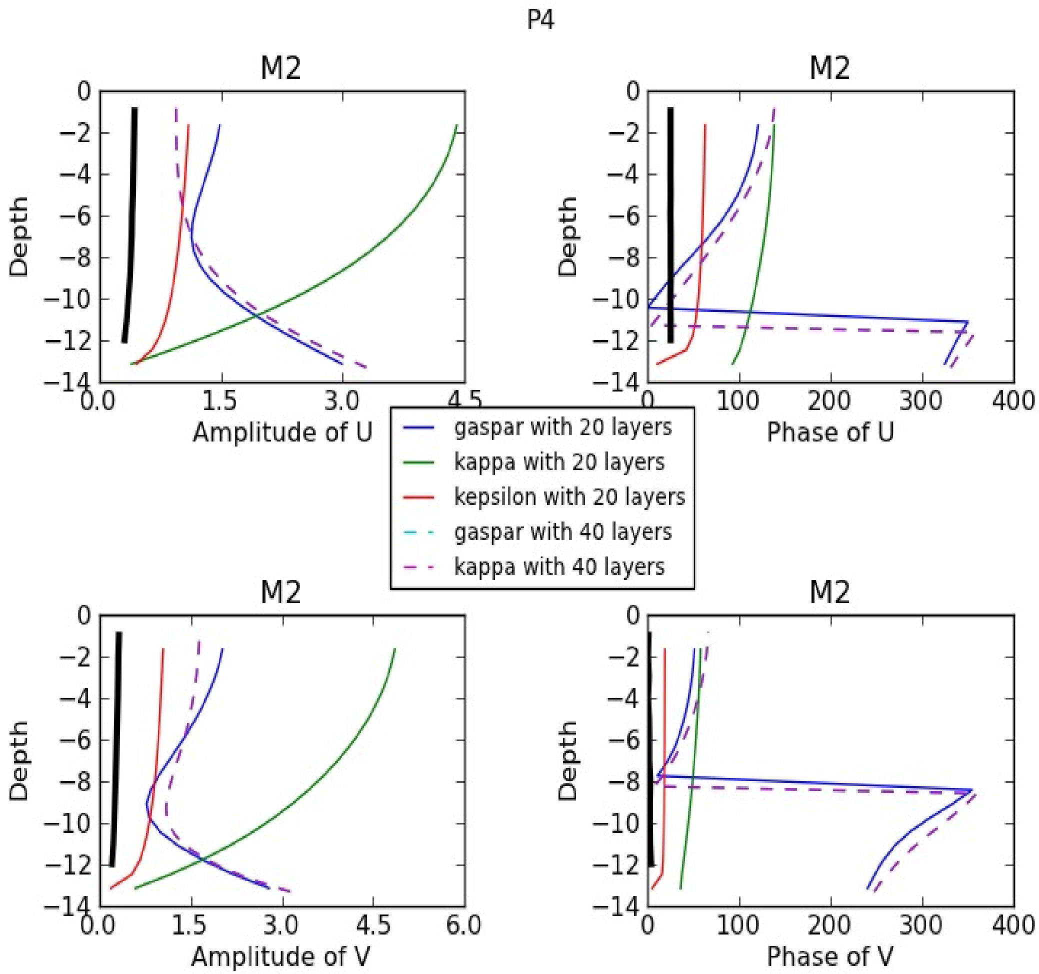
Stations	Bottom roughness 0.0001	0.001	0.005	0.01	variance
ASPEX1	0.00798935	0.00730354	0.00677942	0.00654293	0.000000
CM1001	0.0272377	0.0281832	0.0273724	0.0264164	0.000000
FVR2008	0.019618	0.02012	0.0205539	0.0207712	0.000000
P2A	0.0389803	0.0397348	0.0404641	0.0408541	0.000001
P2B	0.0323598	0.0324985	0.0323027	0.0321689	0.000000
P4	0.0324228	0.0256904	0.0216382	0.0201523	0.000023

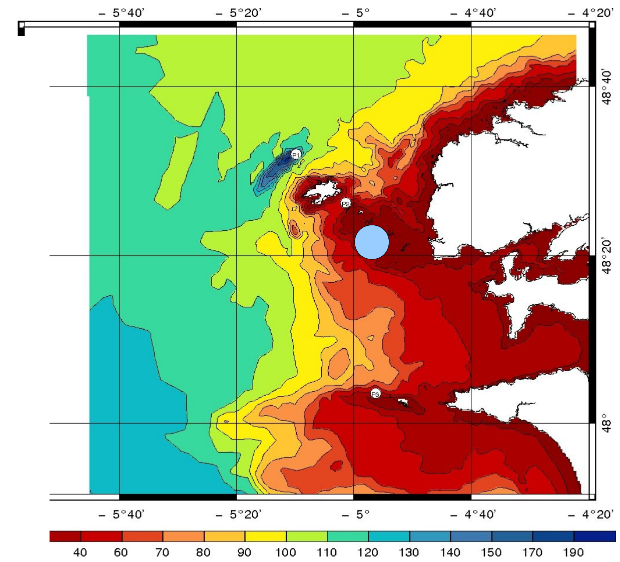
- K1 currents are much smaller in amplitude
- They seem to have very little sensibility to the dissipation parametrization

Conclusion

- The spectral approach allow quick sensitivity test to build map of parameters with “best value” (and range of values)
- Role of parameters is quickly assessed
- Zone of high error can be identified
- The turbulent scheme kepsilon seems to be of great advantage in shallow region its sensibility to initial conditions can and need to be assessed.
- Need to feedback the 2D model with CD calculated from 3D and check for improvements.

Turbulent scheme vs constant Kv



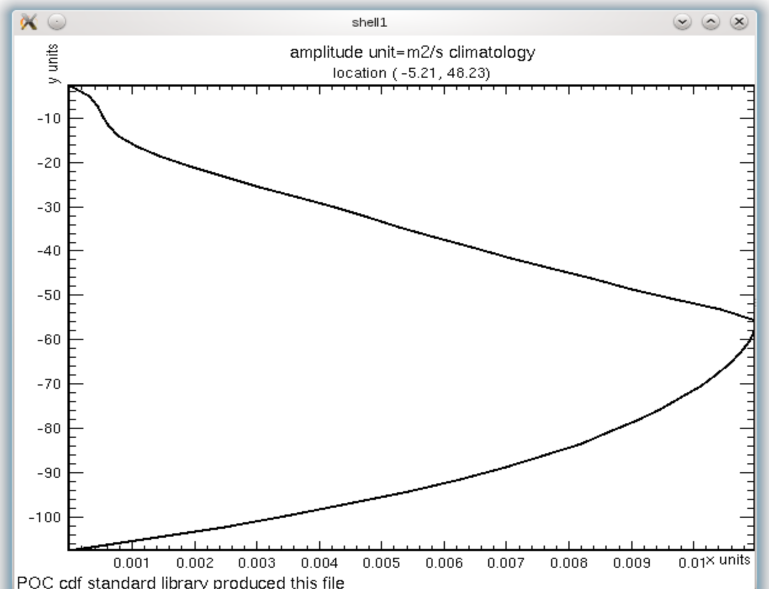


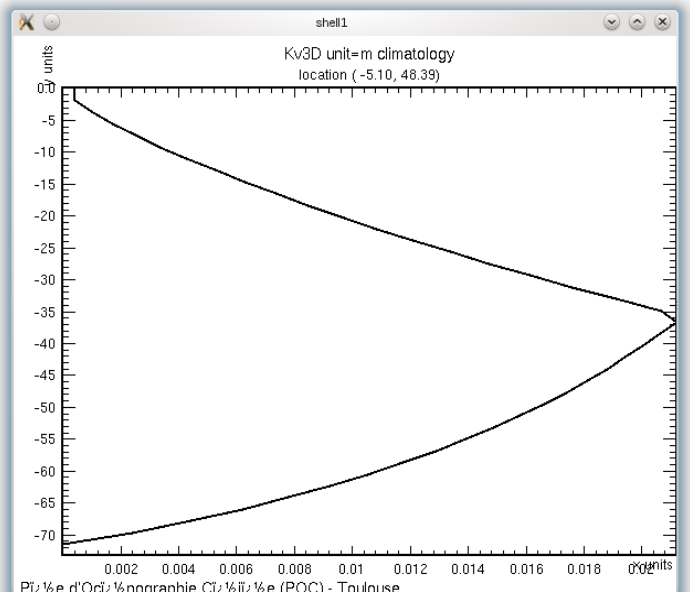
Turbulence closure scheme

- Scheme from Gaspar et al (ref):

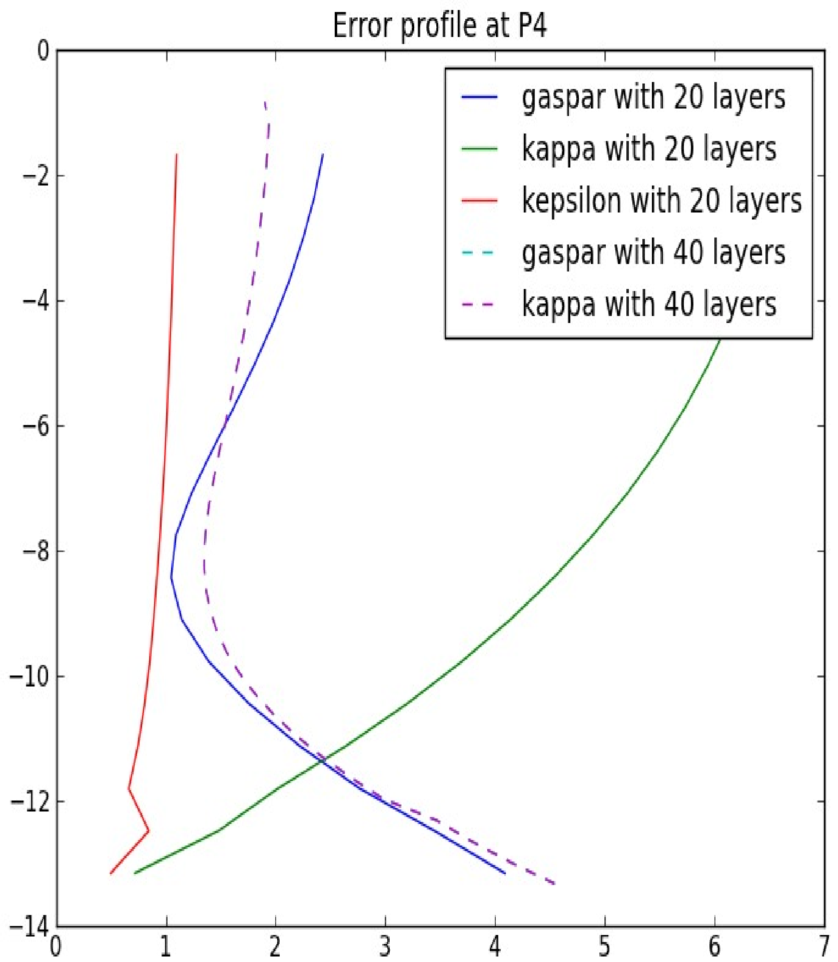
formule

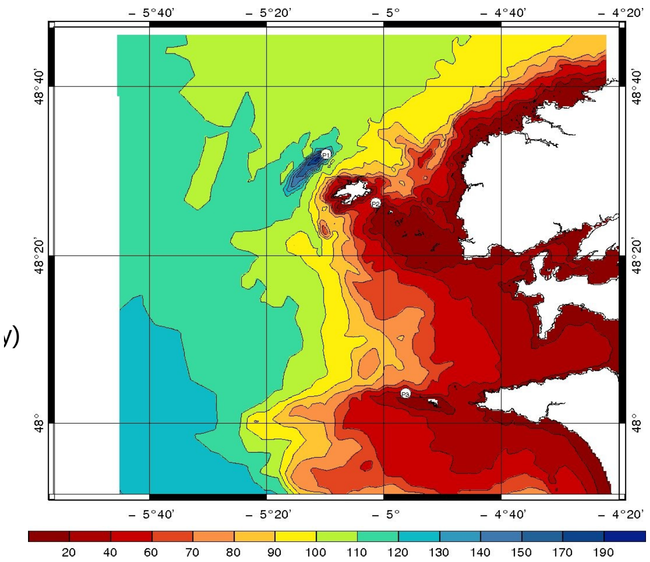
-Comparison of Kz profile between Symphonie (left) and TUGO-M (right)





Error profile at P4





.effect of closure scheme

. impact of vertical resolution