Tore seamount study

Álvaro Peliz

Centro de Oceanografia, Universidade de Lisboa

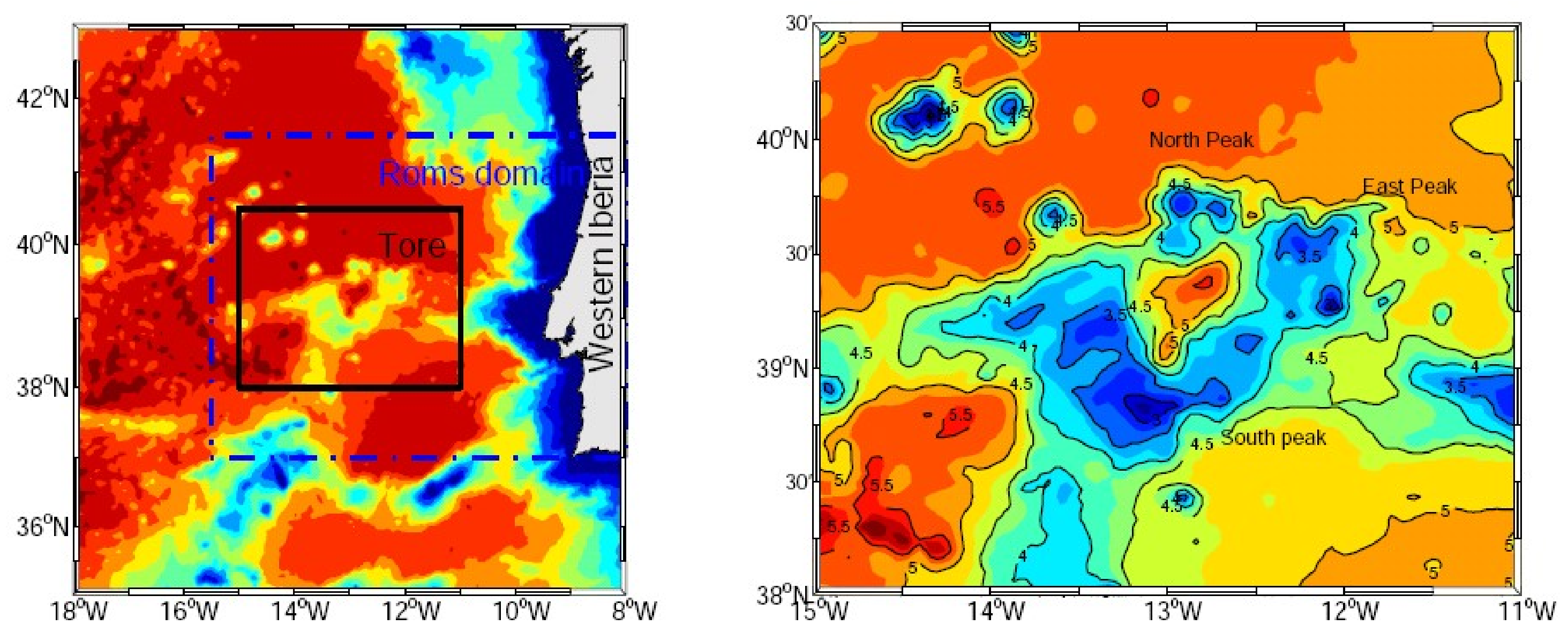
Introduction

Tore is a deep seamount system with an enclosed crater probably resulting from a meteorite impact 65 M years ago. In its deeper part, the crater is as deep as the abyssal region around the ridge (~5.5 km), and isolates a 1200 m thick water column. The crater is relatively narrow (50-60 km), and its deeper connection with the exterior is at about 4300 m. All the Tore topography is located in the deep weakly stratified ocean.

Data from a sediment core collected in the deeper part of the crater indicate that it be well ventilated rather than stagnated: ***What processes may induce the renovation of the Tore crater waters? Is the deeper part of the crater ventilated or stagnated? Which are the dynamics inside and along the edges of Tore? What processes may increase the diapycnal mixing beyond abyssal background diffusion?***

Interactions of mean and eddy flow with Tore (Meddies for example) may be significant and will be analyzed latter. Here, we will be concerned with: i) Mean flow associated with tidal rectification; ii) mixing processes forced by internal tide generation/interaction with Tore topography.

1



The model

ROMS simulations were produced to investigate the flow topography interactions around Tore considering tidal forcing only on a laterally homogeneous climatological density stratification. The model was forced with single or multi-tidal constituents using TPXO global tidal model amplitudes and phases: M_2, S_2, N_2, K_2, K_1 and O_1. No surface fluxes are imposed. The domain limits may be sensible for the remotely generated baroclinic tidal energy. The option to include the shelf in the domain was motivated by the spot of internal tide generation over the promontory. Also, the shelf on the east helped to reduce the strong velocities along the eastern boundary associated with Kelvin wave propagation. The meridional and zonal dimensions of the domain were selected to allow the internal tide to propagate away of Tore. Southern, western and northern boundaries are open, and a set of radiative (orlansky) conditions for 3D momentum and tracers, Flather for 2D variables and passive/active nudging type conditions (Marchesiello) where used. The solutions along the boundaries was also complemented with a sponge layer (with a scale in the order of 60 km) on viscosity and diffusivity.

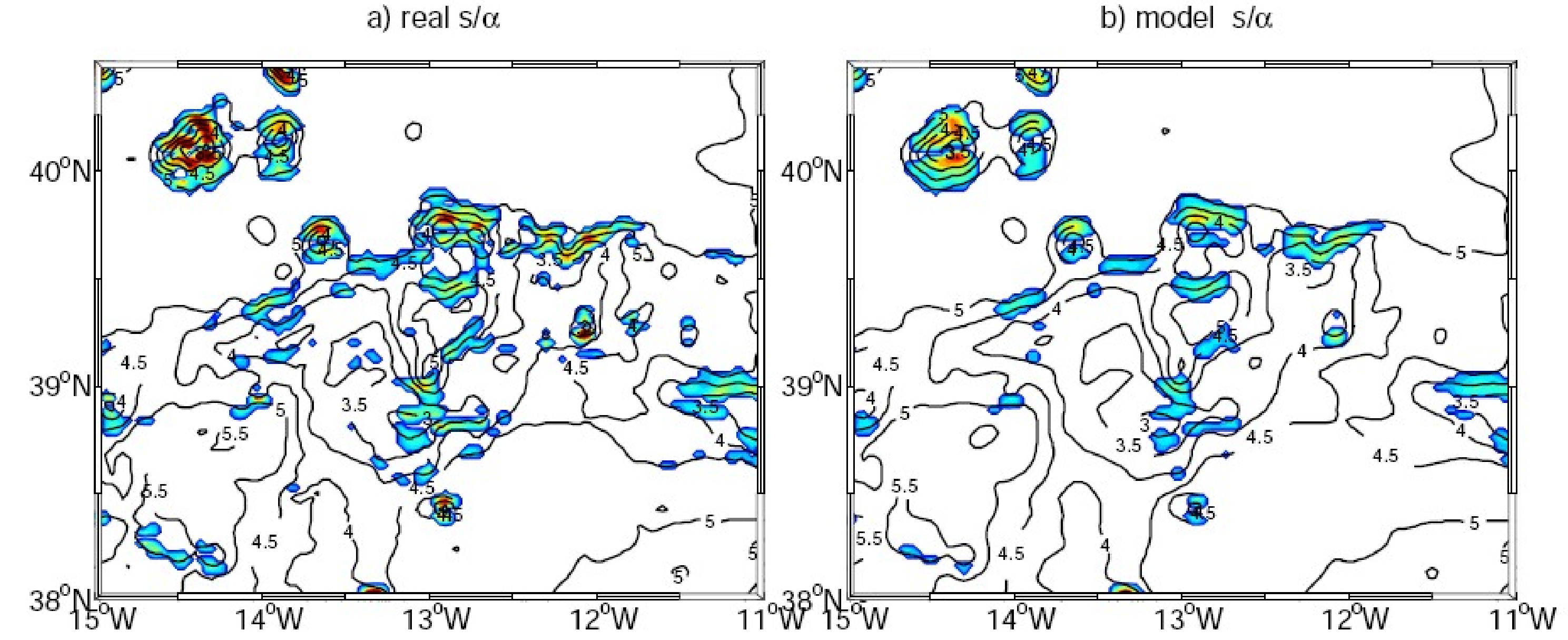
Horizontal resolution is $1/30^{o}$ (approximately 2.7 km), and 60 sigma layers with stretching factors, θs=2, θb=0. A linear bottom drag parameterization is used (C_d = 3 10^{-4} m/s). The diffusion and viscosity is applied using Laplacian operators along geopotential surfaces. Background levels of 20 m^2/s were used especially in cases forced by the K_1 only component. A surface and bottom BBL was parameterized using KPP.
Several simulations were conducted over real or idealized topography using either M_2 or K_1, or the first 6 (larger amplitude) constituents all together. The runs are between 40-60 days long, and the results were averaged either in periods of 5 or 15 days (the fortnightly period dominates in the case all components are used).

Dynamical setting

ω< f_0

The slope of the internal tidal beams, $\alpha=((\omega^{2}- f^2)/(N^{2} - \omega^{2}))^{1/2}$;where *f* is the coriolis parameter, N^2 the buoyancy frequency, and the tidal frequency ω=2π/*T* (*T* being the tidal period) is used to determine the steepness parameter, *s*/α (*s* being the topographic slope). If larger than unit, the baroclinic response to barotropic tidal forcing is in the supercritical regime, and higher baroclinic modes will probably generate. For subcritical regimes, low modes are generated which are not efficient in generating enough shear for mixing dissipation. Although some interaction and energy transfer between modes is possible, the time scale for this spectral interaction is larger than the one associated with the group velocity which propagates the energy away from the generation point. Unless supercritical conditions are met, a transfer of barotropic tidal energy to small scale turbulence is not expected. High values of *s*/α including near critical and supercritical conditions are present on the summit of the individual seamounts, especially along the northern flank of Tore. Inside the crater, the estimates are below critical.

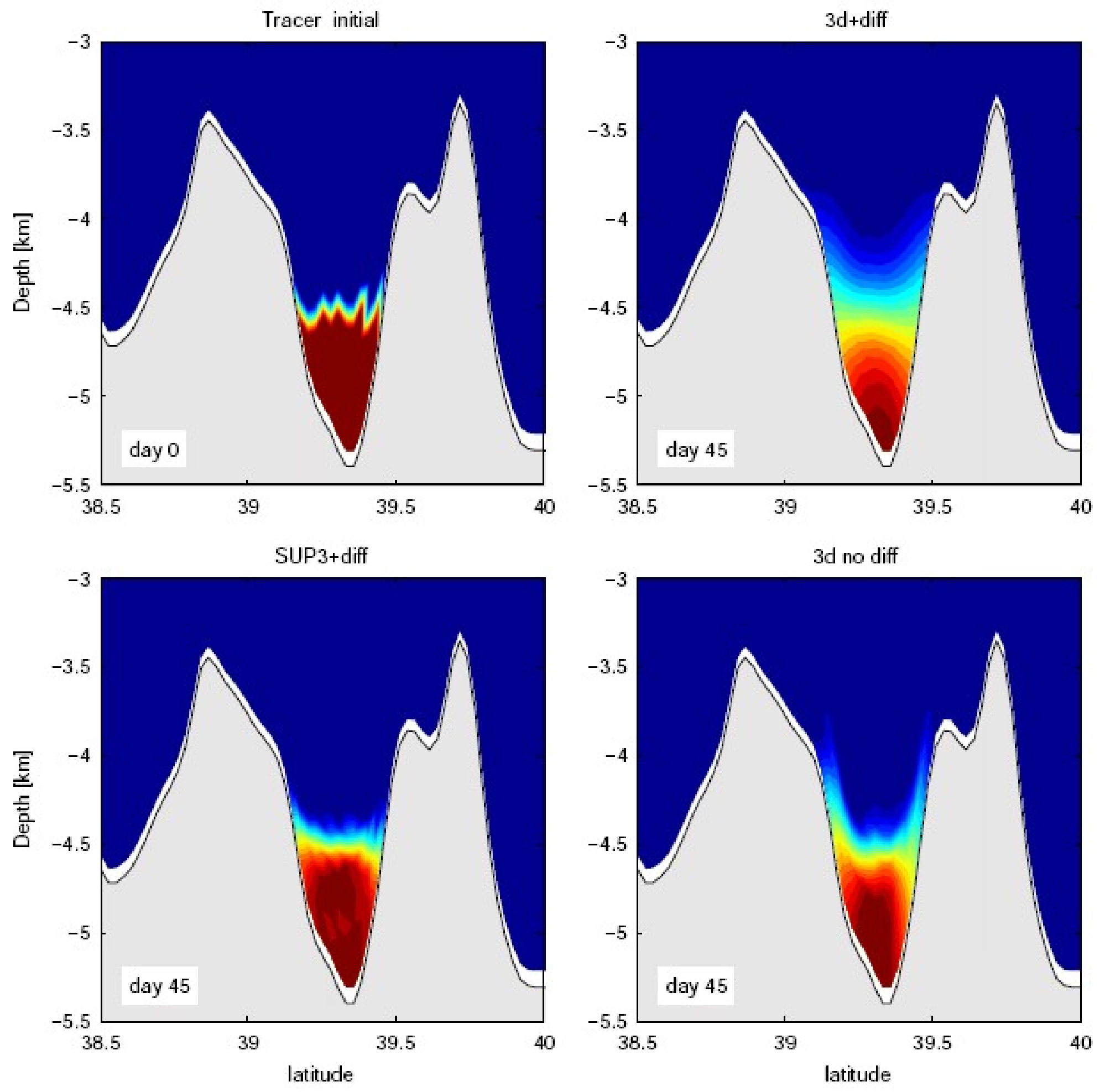
Other topographic features are located in the vicinity of Tore at distances not exceeding 1-3 mode 1 M_2 baroclinic wave length (λi estimated to be in the order of 150 km). Which means that remotely generated baroclinic tides may interact with Tore. The scattering of internal waves is a much more efficient process of energy transfer between modes. Scattering over steep topography, especially in convex slopes, always produces a flattening of the internal wave spectra with a flux of energy towards higher modes. The smaller seamounts around Tore, and the shelf system of the Iberian margin will most likely play an important role in this context.



2

ω> f_0 and rectification

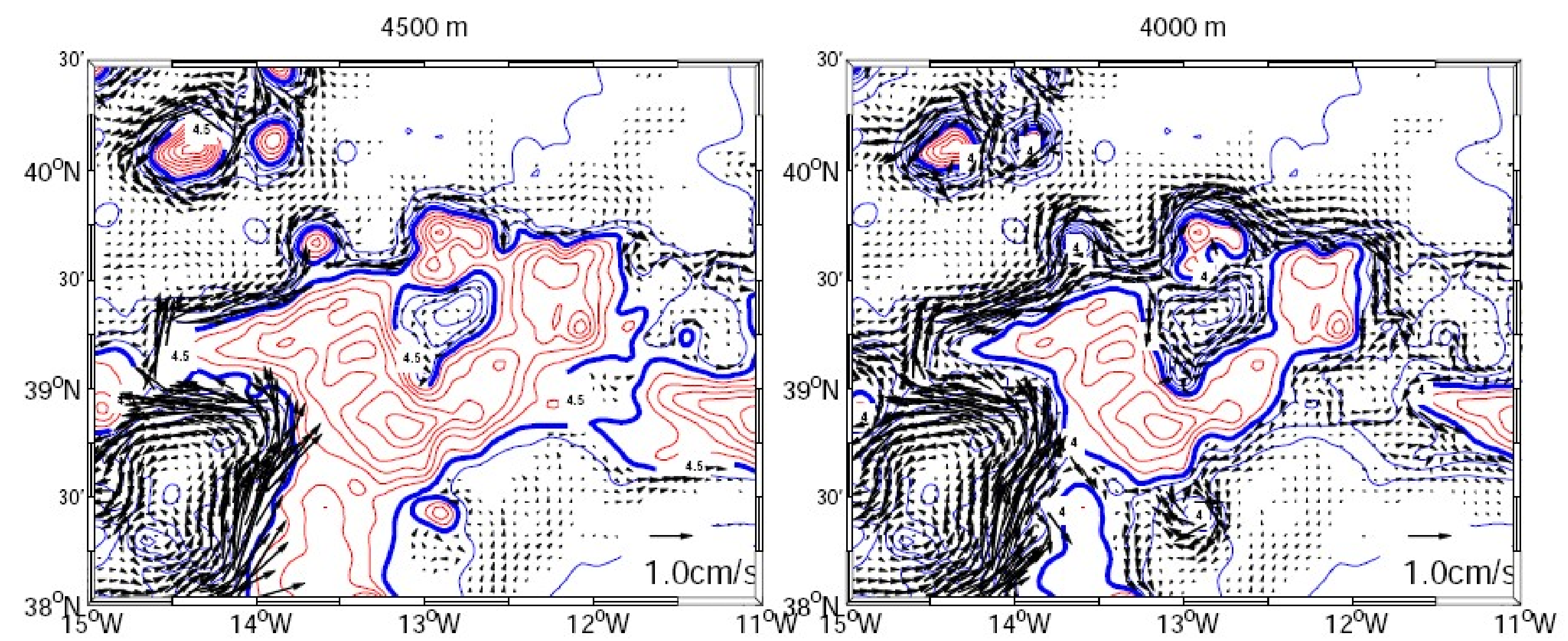
At Tore latitude, the inertial period, T_f = 2π /*f* is around 18.8 hr, meaning that diurnal tidal forcing may generate freely propagating trapped waves around the seamounts. However, as referred above the amplitude of diurnal tides over Tore is rather small (below 0.1 m). The Burger number, *S* = *NH/fL*, and the Rossby number, *Ro=U/Lf*, together with the fractional seamount height $\delta=h_{max}/H$ are used to classify and predict the tendency of isolated topographic features for the development of coherent time-mean flow structures like trapped waves or Taylor caps. Using the climatological stratification data, and taking certain intervals for h_{max} and *L* (considering an external scale of whole seamount 100 km, and an internal bound relative to the small topographic features like the small seamounts over the Tore ~ 20 km), we estimate some intervals for these adimensional dynamical scales: *S*=[0.3 - 2.3]; δ=0.62; *Ro*=[0.5 \ 10^{-3} - 0.01]. Tore is a candidate for the production of resonantly generated trapped waves and trapped Taylor columns. Finally, both semidiurnal and diurnal tides may produce time-mean flows over topography by nonlinear rectification



Tracer advection/diffusion

Apparently, a potential for significant mixing and crater water renovation is predicted by the model. However, it may be unphysical or overestimated, and it is strongly sensitive the advection/diffusion schemes/levels. It will be necessary to analyze and isolate the effects of diapycnal mixing associated with tidal activity from other advection processes associated with rectification.

4

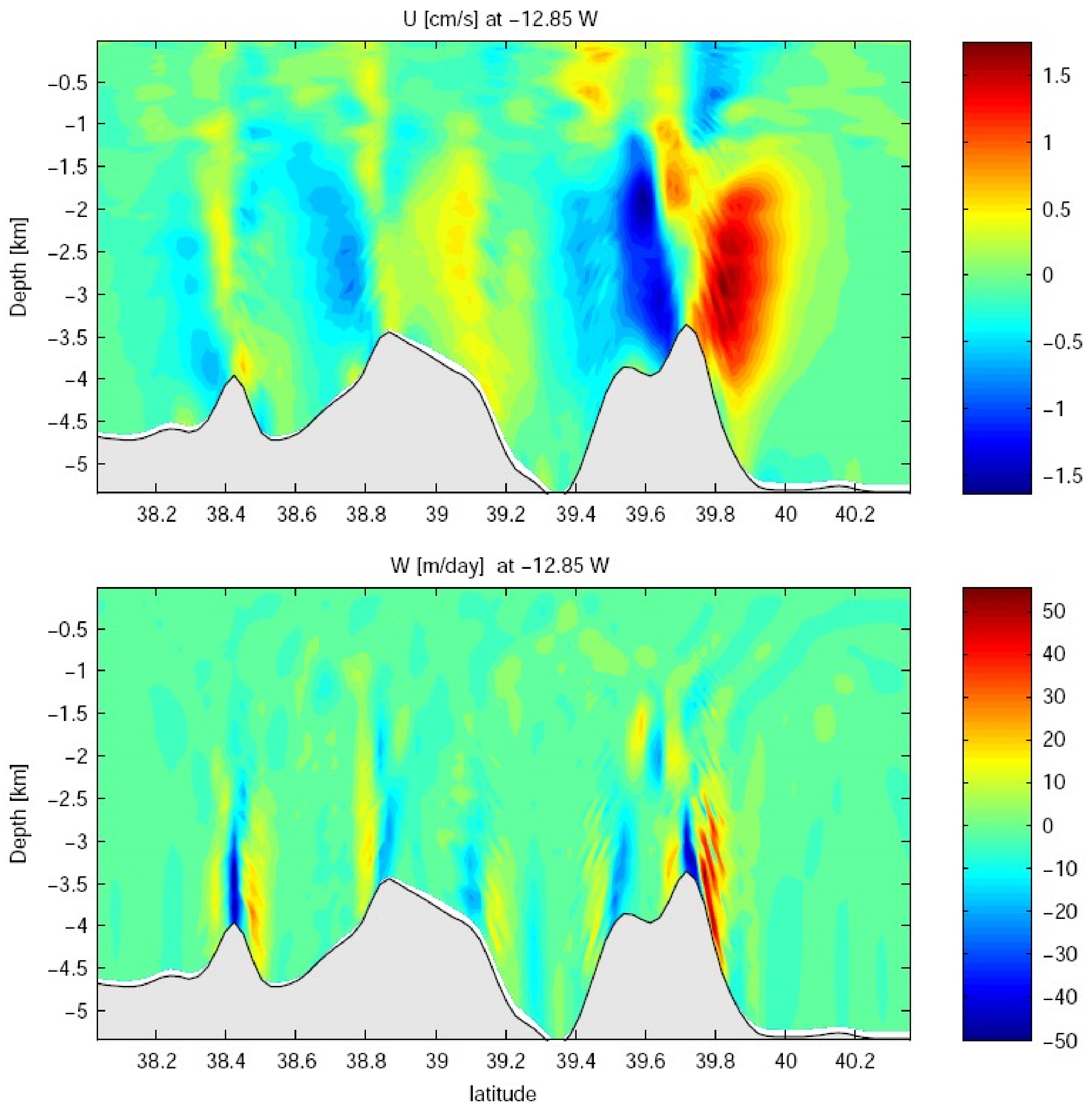


Rectified flow

The residual flow is around 2-3 cm/s (maximum is located to the southwest of the ridge). The horizontal vector fields at several depths reveal a coherent across-ridge current contouring clockwise all the Tore system. This rectified flow is clear in the 4500 m depth horizontal field, and still noticeable by the 2000 m depth level. It is depth intensified, and about 2000 m thick. The circulation inside the bay, is slower and mostly cyclonic. Along the Tore ridge, the small seamounts are also able to trap their own smaller caps, and 4-5 anticyclones are clearly seen at 3000 and 2000 m levels. Particularly intense is the flow above the northern peak. The rectified flow structures over Tore have a large vertical extent (order of 1 km) and velocities in the order of 0.5-2 cm/s. It is also observed a tendency for the establishment counter-rotating (slower circulation) features above the pycnocline. The vertical component of the rectified flow is always more significant over sharper topography attaining a few tens of m/day on the borders of Tore. Inside the bay they are smaller but appreciable in the context of abyssal circulation.

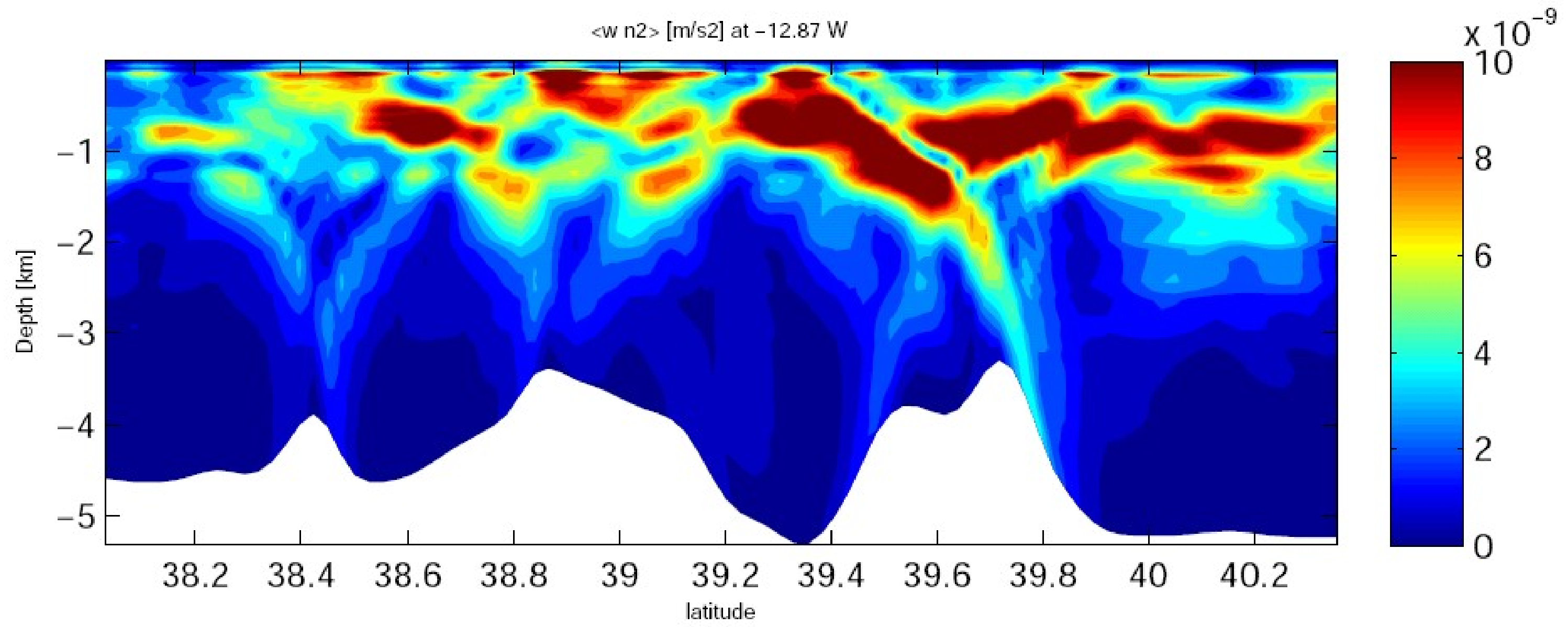
.

3



Barotropic-baroclinic conversion

A crude estimate of available baroclinic energy (an average over the fortnightly tidal cycle of w'N2), indicates that a substantial part of barotropic energy is converted to baroclinic higher modes which produce significant interaction with the sharp topography even at the very deep levels. Although the bulk of the energy is concentrated around the pycnocline some of it propagates downward along internal tide rays as expected. However, ROMS does not necessarily responds to this energy flux in terms of mixing. It remains to be studied if the model is reproducing the correct spectra of internal tide energy (Garrett-Munk), and how the mixing associated with internal tides may represented. Also it need to be clarified if our representation of BBL is the most appropriate for this type of studies.



Conclusion Modeling abyssal circulation over complex deep topography is a challenging new topic. Abyssal flow is generally weak and a low signal/noise ratio is obtained. Some of the critical factors are:

- A realistic conversion of barotropic to baroclinic energy.
- Is the baroclinic energy correctly propagated (especially into the abyss)?
- Are the turbulent parameterizations effective in transforming part of this energy into mixing?
- Details of the abyssal BBLs.

5

Acknowledgments: Discussions with Dale Haidvogel, Silvia Nave and Patrick Marchisiello were very helpful to start this work. Support from FCT was provided in the frame of AGuCA (PTDC/MAR/64902/2006).