Project: **1102**

Project title: **SFB-Transregio (TRR181)**

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Within this project, we are running the highest resolved ocean ICON ocean configurations which are currently available. Therewith, we reach resolutions which allow to simulate submesoscale instability, baroclinic tides, low to intermediate mode internal waves and the interactions between these processes.

During the last CRC phase, we focused on the implication of submesoscale dynamics for upper-ocean tracer transport as well as the implication of tides for the energetics. We also observed the occurrence of lee waves in one prototype simulation with a horizontal resolution of 1.25km globally. This last finding is the motivation for our main future studies and computations as we will outline in more detail in the project request.

Interaction of submesoscale dynamics for the upper-ocean tracer transport

Submesoscale eddies occurring via the process of baroclinic instability of strong upper-ocean fronts are known to overturn these fronts, thereby transporting tracer downwards and re-stratifying the upper-ocean. In our previous study, were able to diagnose this overturning at single ocean fronts (Fig. 1, left). Furthermore, we estimated the overturning by these fronts and tested them against typical parameterizations. We found that the parameterizations are able to qualitatively capture the effect of the parameterization. However, there are important discrepancies which motivate to further improve these parameterizations which will be addressed in the next phase of the TRR181 (note that these parameterizations will even be beneficial for next generation climate models of resolutions >2km).

Currently, we are assessing to which degree the re-stratification associated with submesoscale eddies is able to dampen upper-ocean turbulent mixing. We observe that a strong reduction of TKE takes place wherever submesocale eddies occur along horizontal density fronts (Fig. 2, right).

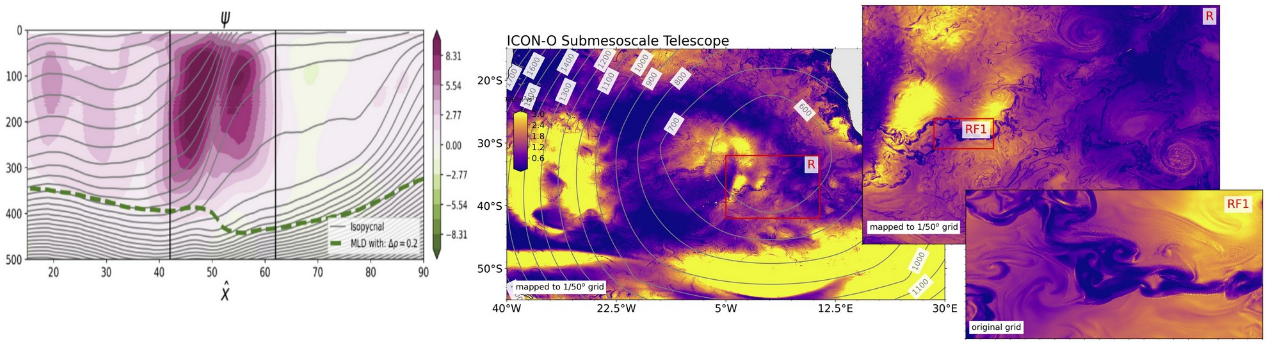

Figure 1: Left: Overturning of diagnosed submesoscale eddies at a single density front of an SMT-NATL simulation. Right: Turbulent kinetic energy within the center of the mixed layer for an SMT-WAVE simulation.

Implications of tidal forcing for ocean energetics

Tidal dynamics are an important constituent of the zoo of ocean processes interacting with each other and modifying the ocean general circulation. Here, we investigate the effect of ocean tides on ocean energetics and upper-ocean mixing in simulations which are able to resolve the first constituents of baroclinic tides. These baroclinic tides occur once the barotropic tidal flow mainly forced by the sun and moon encounter topographic obstacles. Depending on the spectrum of the surface roughness, the stratification and the latitudinal location, internal waves of different wave length and frequencies can be excited. While the highest possible modes require resolutions of several meters, only the high and intermediate modes can be resolved with SMT-WAVE. However, already these resolved modes lead to substantial changes of the ocean energy spectrum. In Fig. 2, we asses the SSH frequency spectrum for four different SMT simulations. We compare our SMT-NATL spectrum which was run without tides against a Hycomm50 configuration which has slightly less horizontal resolution. We observe that ICON has substantial more variability (note the logarithmic axes) at smaller frequencies which indicates a less strong artificial damping of the higher resolved ICON simulation. Furthermore, we estimate the spectra for our three SMT-WAVE simulations which we run mainly this year. We find that substantial more variability is on sub-inertial frequencies once tides are activated. In particular, we observe strong peaks associated with the main tidal constituents and their harmonics. However, we also observe a strong seasonal cycle in the SSH spectra which indicates that only year-long simulations are finally able to give a reasonable estimate of the tidal energy cycle.

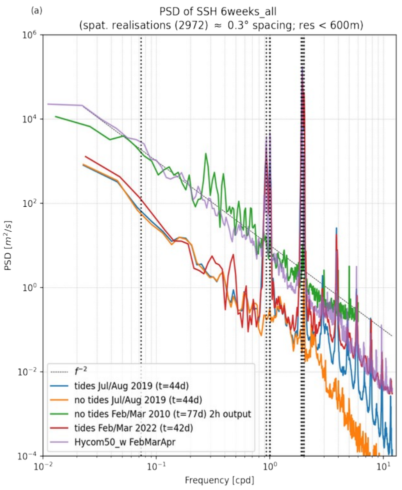

Figure 2: SSH spectra for one SMT-NATL simulation and three SMT-WAVE simulations in comparison with a Hycomm simulation from Uchida et al. (2022).

Eddy generated lee waves

How mesoscale eddies dissipate their energy is one of the remaining conundrums of physical oceanography. One hypothesis is that they transfer energy towards lee waves once these eddies encounter topographic obstacles. However, to quantify such eddy-induced lee wave emission from model simulations requires a very high spatial resolution which is why none such global quantification exists so far. We were able to observe such lee wave emissions once a mesoscale Agulhas Rings encounters the Walvis Ridge in a prototype R2B11 simulation (Fig. 3).

This finding is the motivation for our main future experiment of the next years DKRZ application cycle. Here, we aim for a quantification of these lee wave energy transfer by mesoscale eddies which requires a year-long simulation to also account for the strong seasonal cycle of mesoscale eddies.

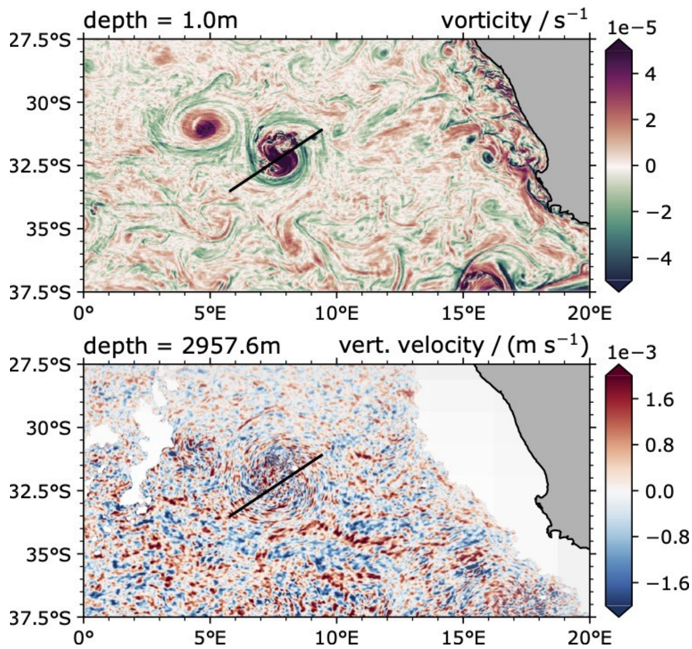

Figure 3: Upper: Surface vorticity of a prototype R2B11 simulation in the South Atlantic showing an Agulhas eddy encountering Walvis Ridge. Lower: Vertical velocitiy at 3000m depth indicating the lee waves excited by the eddy.