Project: **1102**
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In the past year of this project, we aimed to assess which processes contribute to which degree to high-frequent ocean variability. In the ocean, this variability is usually caused by internal waves and submesoscale motions. The latter is forced by mesoscale fronts that become unstable with regard to baroclinic instability. The resulting eddies have time scales from days to weeks and they are therefore closely larger than the inertial period. Internal waves in contrast, have time scales smaller than the inertial period. These waves are usually caused by high-frequent winds and tidal motions.

Our main tool, for investigating the high-frequent dynamics was the ICON ocean model in its SubMesoscale Telescoping (SMT) configuration. In this configuration, the grid resolution is refined up to 530m within the focus area which we chose to be in the South Atlantic. Due to its high-resolution, this configuration is ideally suited to study submesoscale and intermediate-scale internal wave dynamics which operate on scales of one to ten kilometres. Since these scales are embedded and interacting with larger-scale dynamical features like mesoscale eddies or originate from topographic ridges and propagate some distances before interacting, a large domain size was required likewise to the high spatial resolution. The ICON ocean SMT configuration perfectly fulfils both requirements.

One central part of the past computation project was to assess the frequency energy spectra and to investigate which dynamics are responsible for the high-frequent motions. To accurately assess this high-frequent variability, it was essential to store hourly snapshots for a period of one year. The one-year-long time period was essential to capture enough occurrence of Agulhas eddies (which pass through the study area roughly every two month). These eddies have tremendous effects on the energy spectrum (see last years report) and only if a large-enough time period is applied, we obtain a significant temporal representation.

Few studies have had the opportunity to directly compare submesoscale-resolving simulations with in situ observations. In this study, we are in the unique position to perform such a comparison using multiple observational datasets (PIES, moorings, CTDs, etc.) collected during two cruises of the collaborative TRR181 project. Figure 1a shows the comparison of kinetic energy spectra from the SMT configuration and several 5 km configurations against moored observations. The agreement in energy levels between the SMT configurations and the observations at low and intermediate frequencies is remarkable and unprecedented. In contrast, the year-long R2B9 (5 km) reference run (green line) exhibits clear discrepancies, emphasizing the importance of employing such a fine grid resolution.

To further disentangle the contributions of different dynamical processes, such as tides, high-frequency wind forcing, and fully developed eddy fields, additional R2B9 configurations were simulated over the same period (see Figure 1b). This allows us to quantitatively assess their respective impacts on the spectral energy levels. These results will be discussed in detail in a forthcoming manuscript (Epke and Brüggemann, 2025b).

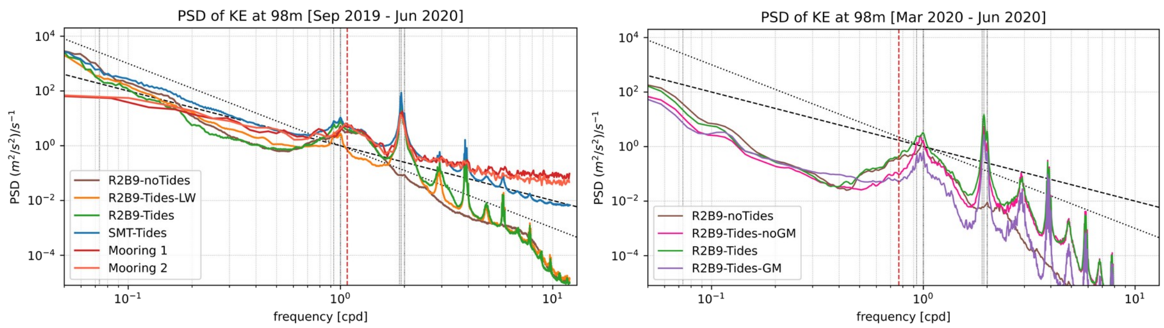

Figure 1a shows the frequency spectra of the horizontal kinetic energy at 98m depth that we obtained within the study area from various model configurations and two moorings (part of TRR181 collaboration). Figure 1b shows the frequency spectra in configurations where the mesoscale eddy field is supressed by employing the GM parameterization as well as a configuration where GM is disabled after the destruction of the eddy field. The Coriolis frequency is represented by a red dashed line, while the first tidal constituents are shown as grey dotted lines. Additionally, the spectral slopes of -2 (dashed) and -3 (dotted) are included.

We further demonstrate that the SMT model captures a substantially larger fraction of the internal wave field, as shown in Figure 2. The comparison with the first few baroclinic modes of the dispersion relation reveals enhanced energy levels along these modes, indicating the presence of a strong internal wave field. Unlike ICON-R2B9, ICON-SMT is capable of resolving the first three baroclinic modes and additionally captures intermediate-frequency waves with frequencies higher than 2M2.

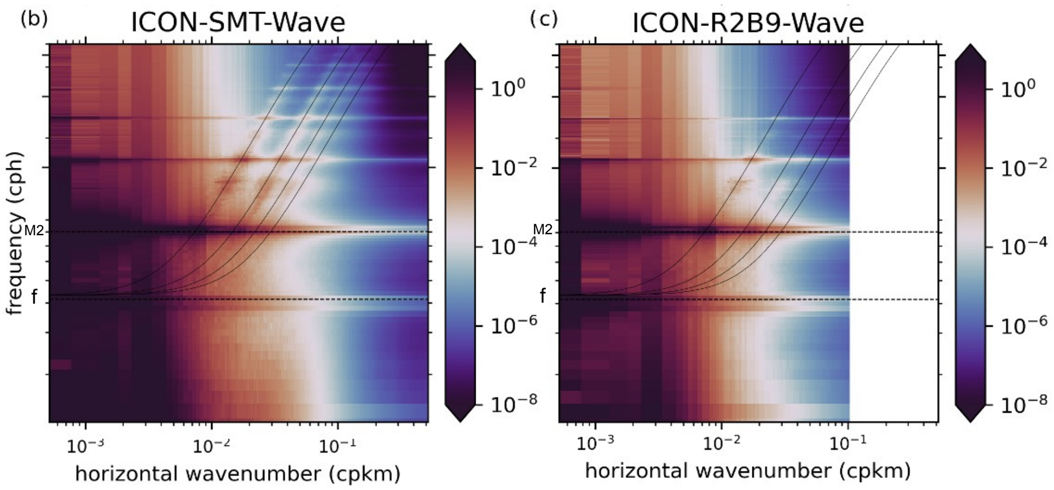

Figure 2 shows the frequency-wavenumber omega-k spectra of the SSH obtained from a 20°x20° region in our study area and three week time series in August (local winter) for all model configurations (left) and the difference between the model configurations (right). The Coriolis frequency and the semi-diurnal frequency are denoted by black dashed lines. Theoretical expectations of the first three wave modes are shown by thin black lines. The Brunt Väisäla frequency is estimated with N=1.6e^(-3) [1/s].

Publications based on SMT simulations:

1. **Epke, M., L. Linardakis, P. Korn, and N. Brüggemann**, 2025a: Overturning of mixed layer eddies in a submesoscale resolving simulation of the North Atlantic. Journal of Physical Oceanography, 1-66, https://doi.org/10.1175/JPO-D-25-0015.1

2. **Epke, M**. (2025). Kilometer-scale ocean turbulence and waves in the North and South Atlantic. PhD Thesis. doi:10.17617/2.3658361.

3. **Leimann I., Griesel A., Walter M., Epke M., Brüggemann N., Linardakis L., Korn P.** (2025): "Diagnosing kinetic energy scaling in different dynamical regimes of the North Atlantic using Lagrangian and Eulerian metrics", submitted to Journal of Geophysical Research.

4. **Kourkouraidou Z**. (2025). Uncovering the Effects of Agulhas Eddies on Low and High Internal Tide Modes and Their Energetics in High-Resolution ICON

5. **Epke M., Brüggemann N. (2025b)**: "Impact of tides and eddies on ocean energy spectra in a submesoscale resolving simulations of the South Atlantic", currently in preparation for submission.