Project: **1102**

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

Principal investigator: **Nils Brüggemann**

Report period: **2024-11-01 to 2025-10-31**

In the past year of this project, we aimed to assess how geostrophically balanced eddies dissipate their energy. To this end, we applied an eddy-resolving ICON ocean simulation with 5km horizontal grid spacing (R2B9 grid). This simulation allows to resolve the dominant parts of the mesoscale eddy energy generation. However, regarding dissipation of mesoscale eddy energy, it relies on unphysical parameterizations like biharmonic momentum mixing and bottom friction. In reality one would expect that the inverse energy cascade inherent to geostrophic turbulence transfers the energy towards larger scales, at the same time the rotational effects of the earth force the eddying motions to propagate westward. Geostrophic turbulence suggests that during the inverse cascade, also a barotropization of the eddies takes place. Thus eddy energy is likely to be dissipated either at the ocean floor or close to western boundaries. In the former case, bottom friction or lee wave generation might be the dominant dissipation process and in the latter case, loss of balance or like-wise bathymetry related dissipation processes might be responsible for the energy dissipation. In both cases, small-scale processes like internal waves, ageostrophic and small-scale turbulence which are not resolved within a 5km ocean model are most likely responsible for the energy dissipation.

Although the exact dissipation processes cannot be resolved directly with our ICON ocean model with 5km horizontal resolution, we apply this configuration to assess eddy dissipation in an indirect way. The processes of eddy dissipation as simulated in the model might be unrealistic but if the processes that are responsible for eddy generation and eddy energy transports are resolved in such model configurations, the location and magnitude of eddy dissipation in such configurations might still be relatively accurate despite that the processes that are in the end leading to dissipation of mesoscale energy are not directly resolved. Therefore, we can learn from this configuration how eddy dissipation is achieved in this type of modern eddy-resolving ocean model configurations of next generation climate models.

The determination of geostrophic eddy dissipation is complicated since the geostrophic turbulent motion is not easily excluded from other oceanic motions like ageostrophic Ekman-driven transports or internal-wave dynamics. To achieve a separation of theses dynamics, we apply the following filtering mechanism: First, we determine Ekman driven currents by solving the differential equations that originates from the balance of the Coriolis term and the vertically viscous term of momentum. The remaining velocity is further filtered by assessing the geostrophic velocity from a five-day time average

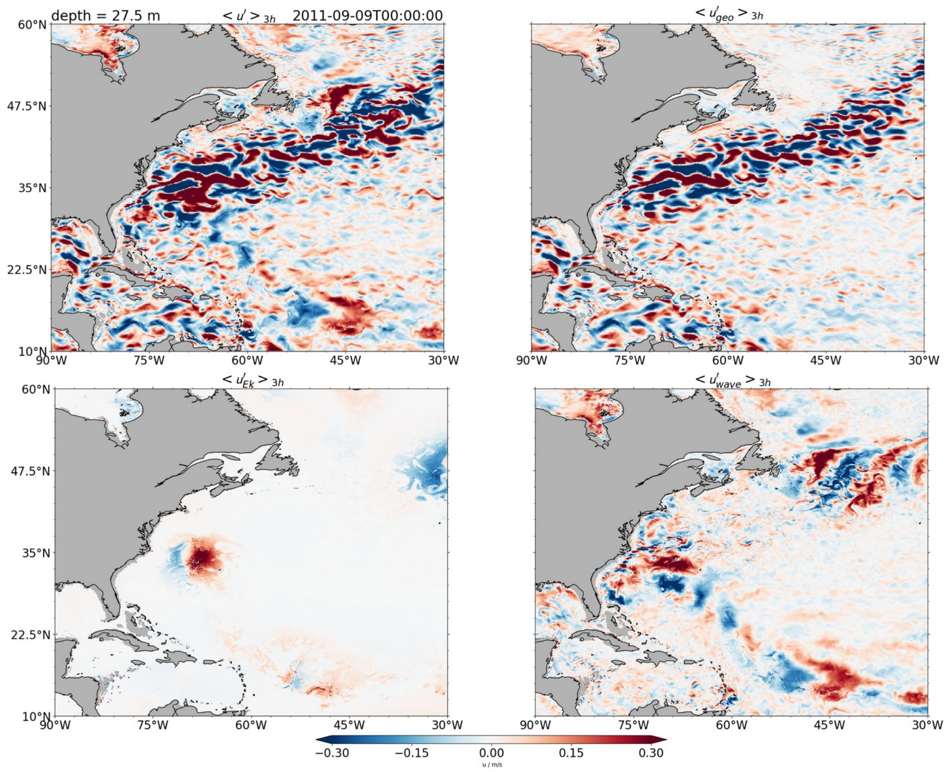

Figure 1: Full horizontal zonal velocity field (a) and the decomposition into geostrophic component (b), Ekman component (c) and the residual wave component (d).

of the pressure field. The residuum of the full velocity and the Ekman and geostrophic velocities will be associated with internal wave dynamics. In Fig. 1, we show the decomposition of the full velocity field. We can identify mesoscale eddies in the North Atlantic from the geostrophic velocity field (Fig. 1b), the Ekman flow that resembles wind-driven larger-scale fast-fluctuating currents (here a Hurricane in Fig. 1c) and the residual component that is associated with internal and mainly near-inertial waves (Fig. 1d).

From the

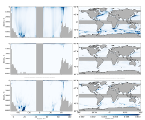

Figure 2: Dissipation of geostrophic eddy energy. For zonal intergrals (a, c, and e) and vertical integrals (b, d, and f) for horizontal dissipation (a, b), vertical dissipation (c, d) and bottom friction (e, f).

geostrophic part of this velocity decomposition, we asses the dissipation of geostrophic eddies (Fig. 2). We find that mesoscale eddy energy is dissipated predominantly along western boundaries and within the Southern Ocean. An integration of the energy dissipation for regions that are within 200km of the next lateral boundary indicates that most of the dissipation occurs within western boundaries often close to the ocean floor.

It is remarkable that the energy dissipation is so much enhanced within the proximity of ocean boundaries. To assess further the reason for this behaviour, we analyse the spatial energy fluxes that we determine as the residuum of energy dissipation and energy generation (not shown). Here we find that strong zonal westward and vertical energy fluxes are responsible for the energy transfers towards lateral boundaries. These findings are in general agreement with theoretical consideration after which the eddies become more barotropic and thus transfer energy towards the bottom and that those eddies predominantly propagate west-ward due to the rotation of the earth.

Overall, this our project could identify key processes of eddy dissipation and their spatial location. To this end, we provide a fundamental contribution towards the goals of the research project TRR181. In future studies, we will asses other quantities of eddy-resolving simulations in particular the imprint of vertical momentum and tracer mixing and how it impacts key quantities of the oceanic circulation like the depth of the upper-ocean mixed layer but also consequences of eddy parameterizations in coarser coupled configurations as they are typically applied in classical CMIP models.