Project: **1239**

Project title: **Collaborative Research Centre (CRC) “TRR 181” sub-project S2: Improved Parameterizations and Numerics in Climate Models**

Principal investigator: **Johann Jungclaus**

Report period: **2023-11-01 to 2024-10-31**

1. Utilization of compute time: During the last years computation period, we had to slightly adjust the resources, we were using from what we anticipated in our last years proposal. Reasons for this are delays in the hiring procedure for the new Post-Doc working in the TRR S2 project. We used roughly 14E3 node hours for the R2B6 simulations with IDEMIX (sec. 2), 36E3 node hours for running the R2B9 model to estimate the different terms of the LEC (sec. 3), and 10E3 node hours for developing the new sea-ice model and testing it in the R2B9 configuration (sec. 4). However, all the work done was directly related with the TRR project S2 which is the scientific host of this compute time project. In part our computations were used to finish work from the previous project (sec. 2) and some computations were used to study research questions which were foreseen to be answered later in the TRR S2 projection (sec. 3).

2. New mixing parameterization: During the last year, we finalized our work regarding the IDEMIX 2020 ICON and FESOM inter-comparison. The reviewer asked us to substantially expand our current simulations, which we did. Finally, our manuscript was published (Brüggemann et al., 2024). The paper discusses a new parameterization for internal wave propagation, interaction, dissipation and mixing (IDEMIX). We apply this parameterization in three different ocean models to study model independent effects.

We notice that the novel mixing scheme leads to mixing work and diffusivities which are in much better agreement with observations regarding the magnitude and spatial distribution (Fig. 1). The new mixing scheme also has consequences on the large-scale circulation by mixing the ocean stronger compared to the reference simulation. The stronger mixing typically enhanced the upper cell of the Atlantic meridional overturning circulation. Effects regarding the lower overturning cell and water mass biases were found to be model dependent and potentially related to numerical mixing. The latter will be focus for future work.

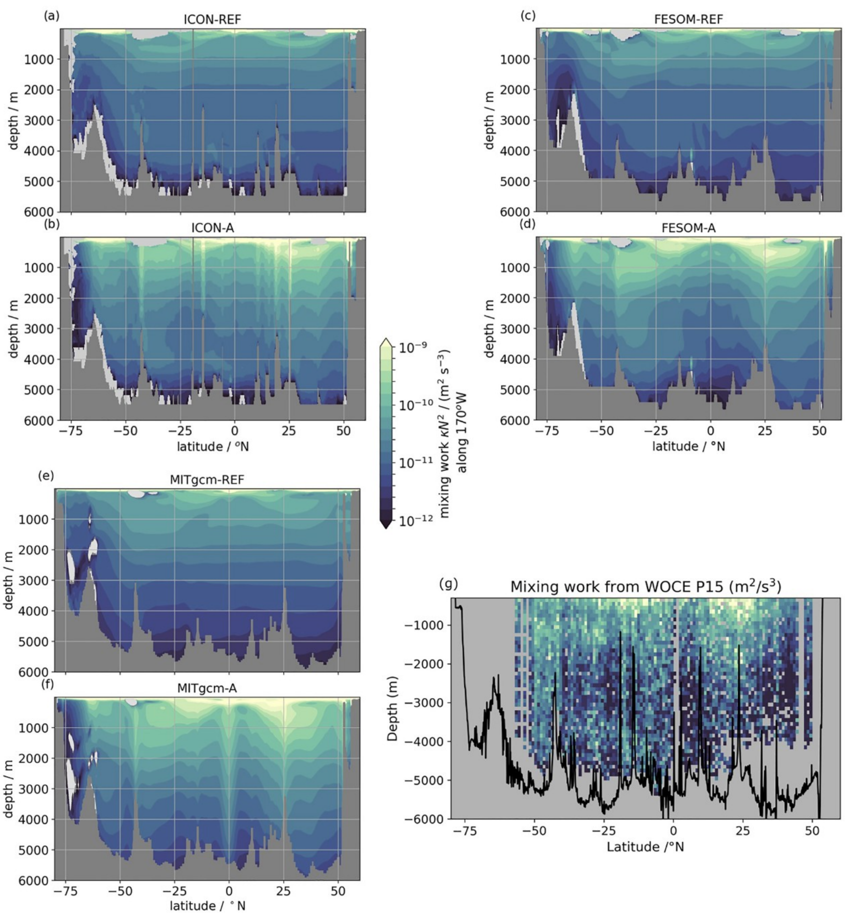

Figure 1: Mixing work along 170W for three different ocean models for. For each model, we show the reference simulation without applying IDEMIX and a simulation with IDEMIX. Finestructure observations from a WOCE section are depicted in the lower left panel.

3. The quasi geostrophic Lorenz Energy cycle: Another important aspect of our last years work was studying dissipation of mesoscale eddies as part of the Lorenz Energy Cycle (LEC). Eddy dissipation is important since it can generate additional mixing and provide sources for water mass transformations that potentially require to be represented in ocean models (e.g. it might be necessary to connect eddy dissipation with internal-wave-driven mixing in the parametric framework of ocean models). During the past year, we analysed three different components of eddy dissipation as simulated by an eddy resolving ICON simualtion. Those three components are bottom friction, vertical friction and horizontal friction. We found that a large part of the dissipation of high-frequent motions was related to time varying Ekman currents. To filter those dynamics, we applied a five day time filter prior to calculating the LEC. With this filtered fields, we find that (a) wind forcing of eddy kinetic energy (EKE) is largely reduced, (b) dissipation of EKE by vertical friction is reduce by a similar amount, and (c) that buoyancy production also reduces. All other terms of the LEC are rather unaffected (Fig. 2).

To further also filter ageostrophic Ekman velocities and other ageostrophic currents, we are also applying a Quasi-Geostrophic (QG) filter, where we are using a five day time filter to approximate the QG pressure. From this pressure, we derive all other relevant terms of the momentum equation. This expanded filter even shows that the wind forcing of EKE becomes very small and negative (no wind forcing of eddies anymore, however, dissipation of eddies by friction with the atmosphere remains, the so-called eddy killing).

Furthermore, we also recognized a spatial mismatch between production and dissipation of EKE which means that energy transfers are important as well. Currently, we are carrying out dedicated sensitivity experiments with altered friction operators to investigate if those changes have an effect on the spatial eddy fluxes and to quantify the effect on eddy dissipation.

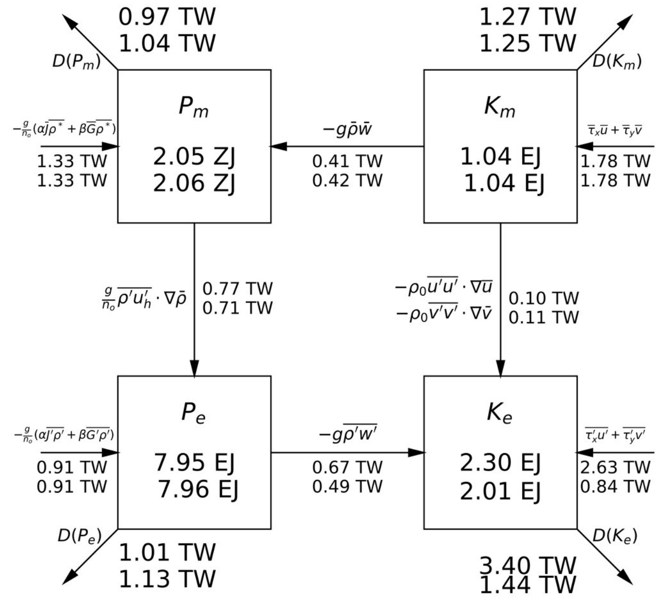

Figure 2: LEC of an eddy resolving R2B9 (5km hor. resolution) ocean-only ICON simulation. Upper numbers indicate values befor time filtering, lower numbers indicate values after time filtering. Largest effect can be seen for transfers regarding EKE (K_e in the figure).

4. New sea-ice model: We continued to participated in the development of ICON-o's new sea ice dynamics. Here, we performed several sensitivity simulations with various parameter tests of the mEVP rheology in ocean-only configurations of 5km horizontal resolution. We established several diagnostics to more accurately check the convergence of the mEVP algorithm.

References:

Brüggemann, N., and Coauthors, 2024: Parameterized Internal Wave Mixing in Three Ocean General Circulation Models. *Journal of Advances in Modeling Earth Systems*, **16**, e2023MS003768, https://doi.org/10.1029/2023MS003768.