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Understanding and parameterizing sub-grid scale processes and dynamics towards improving variability and trends in Earth System Models

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The Southern Ocean plays a critical role in mitigating some of the effects of climate change through its heat and carbon uptake. Models are the most useful tool to simulate the earth system and predict the effects of climate change as observations are sparse and limited on space and time scales, yet global models have a shortcoming in their available resolution due to computational expense from having to run very long multi-century simulations (Fox-Kemper et al., 2014). However, these models fail to adequately simulate the ocean system particularly in the Southern Ocean (Kessler and Tjiputra, 2016; Mongwe et al., 2016, 2018). Our hypothesis is that the key to improving the confidence and reducing biases in future long-term model projections lies in the inclusion of the missing sub-grid scale physics. We aim to develop a suitable parameterization for these processes (~10 - 100km scale) from a Southern Ocean perspective to include their effects within global models without substantially increasing their computational cost.

Mesoscale eddies are unstable, unpredictable flows appearing as swirling deviations of the main current (Rhines, 2001), they can alter large-scale ocean dynamics through mixing, the uptake of heat and carbon through meridional transport as they possess high amounts of kinetic energy (Fox-Kemper et al., 2019). Small changes to mesoscale parameterization can exhibit large effects on the sensitivity of the ocean climate and affect climate feedbacks.

Our dataset consists of NEMO ocean models of various resolutions (1/2°, 1/12°, 1/36°) run and analysed on the CHPC. To run the BIOPERIANT12 model with physics and biogeochemistry requires 3240 CPUs and contains 223 million grid points (4322x1122x46levels). The coarser models are run over the full Southern Ocean domain whereas the 1/36° model is run only in the Sub-Antarctic zone in the Southern Atlantic. In this research we aim to focus on the mixed layer in the upper ocean which is the gateway between the atmosphere and the deeper ocean and plays a key role in the uptake of heat and carbon.

It is of critical importance to identify the physical mechanisms that drive heat and carbon flux in the Southern Ocean. The first aim of this research is to investigate the impact of mesoscale features on carbon and heat variability using the 1/12° mesoscale resolving model, identify characteristics of variability and fluxes across the air-sea boundary and within the mixed layer. A process based study will then be conducted focussing on mixing dynamics in terms of atmospheric forcing and responses to identify process differences between the models of varying resolution. These findings will then be used to develop a suitable parameterization of these sub-grid scale processes and improve their representation in global Earth Systems Models.

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