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Energy Transfers Between Balanced and Unbalanced Motions in Geophysical Flows

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Geophysical flows such as the atmosphere and the ocean are characterized by rotation and stratification, which together give rise to two dominant motions: the slow balanced and the fast unbalanced motions. The interaction between the balanced and unbalanced motions and the energy transfers between them impact the energy and momentum cycle of the flow, and is therefore crucial to understand the underlying energetics of the atmosphere and the ocean. Balanced motions, for instance mesoscale eddies, can transfer their energy to unbalanced motions, such as internal gravity waves, by spontaneous loss of balance amongst other processes. The exact mechanism of wave generation, however, remain less understood and is hindered to an extent by the challenge of separating the flow field into balanced and unbalanced motions.

This separation is achieved using two different balancing procedures in an identical model setup and assess the differences in the obtained balanced state and the resultant energy transfer to unbalanced motions. The first procedure we implement is a non-linear initialisation procedure based on Machenhauer (1977) but extended to higher orders in Rossby number. The second procedure implemented is the optimal potential vorticity balance to achieve the balanced state. The results show that the numerics of the model affect the obtained balanced state from the two procedures, and thus the residual signal which we interpret as the unbalanced motions, i.e. internal gravity waves. A further complication is the presence of slaved modes, which appear along the unbalanced motions but are tied to the balanced motions, for which we need to extend the separation to higher orders in Rossby number. Further, we assess the energy transfers between balanced and unbalanced motions in experiments with different Rossby numbers and for different orders in Rossby number. We find that it is crucial to consider the effect of the numerics in models and make a suitable choice of the balancing procedure, as well as diagnose the unbalanced motions at higher orders to precisely detect the unbalanced wave signal.