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Case studies of gravity wave generation from cyclogenesis over the Southern Ocean

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Better understanding of the generation of gravity waves from jets and fronts is necessary in order to improve the parameterization of these waves in climate models. The way in which energy may be transferred from motions that are primarily balanced (jets and fronts) to gravity waves also constitutes a fundamental problem of geophysical fluid dynamics, with applications also in oceanography. Several mechanisms have been highlighted theoretically (Lighthill radiation, unbalanced instabilities, sheared disturbances, emission from dipole-like flows) but their relevance to real flows remains to be proven. The emission in idealized baroclinic life cycles is analogous to the emission from dipoles, but the gap between idealized simulations and real flows and observations remains to be overcome.

We present the investigation of several case studies bases on mesoscale numerical simulations and superpressure balloon observations. The simulations were carried out with the Weather Research and Forecast Model, with a horizontal resolution of $dx = 20$ km and sometimes $dx = 10$ km. They cover two months during the Vorcore campaign which took place in 2005 over Antarctica and the Southern Ocean. The overall comparison has shown that the simulations somewhat underestimate momentum fluxes, but provide a reliable description of their spatial and temporal variability. The probability distribution function from both observations and simulations, when taken in regions away from topography, is very well approximated by a lognormal distribution.

Episodes of intense momentum fluxes over the Southern Ocean, far from islands are identified for case studies, some of which include balloon observations. The emitted gravity waves appear over intense and rapid cyclogenesis events. It appears that, despite the high latitude, moist effects contribute to the emission of the gravity waves. This effect may result from the more rapid development of cyclogenesis in a moist atmosphere, but appears to also be tied to the intensification of localized updrafts ahead of the surface front. Consistent with some theoretical studies, the presence of intense shear above the fronts, and transverse to the fronts, appears to enhance significantly the emission. Sensitivity to moisture and resolution is addressed using dry simulations and double resolution simulations. Momentum fluxes are decreased typically by a factor 2 in dry simulations, and increased by a factor 2 when doubling the resolution.

Finally, the relevance of the different mechanisms that have been highlighted theoretically is discussed in the light of these case studies. The importance of moist effects, although expected and hinted at in certain studies, has been overlooked by studies which focused, for a start, on dry dynamics.