Oceanic internal waves internally generated in a 0.1° OGCM

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Introduction

The ocean is full of mesoscale eddies continuously generated by barotropic and baroclinic instabilities. How the eddying flows dissipate their energy is not well understood. Since mesoscale eddies tend to transfer their energy towards larger scales (Charney, 1971), processes other than quasi-geostrophic turbulence are necessary to dissipate the energy of eddying flows in an equilibrium state. Müller et al. (2005) referred to this as the ocean's route to dissipation. One way to dissipate the energy of eddying flows is to generate internal gravity waves. These internally generated waves can transfer the energy towards smaller scales via non-linear wave-wave interactions or wave breaking. Internally generated internal waves can emerge from unbalanced flows (Molemaker et al., 2010), interactions with bottom topography (Nikurashin et al., 2013) or from spontaneous imbalance. This work investigates such an energy pathway using simulations with the 0.1° Max Planck Institute Ocean Model (MPIOM). Note that externally generated internal waves, such as wind-induced near-inertial waves or internal tides, are not directly linked to eddying flows and hence may not directly participate in the dissipation of the energy of these flows.

Two simulations have been performed with the MPIOM, using a tripolar grid with a horizontal resolution of 0.1°. The simulations start from an existing multi-decadal NCEP-forced simulation (von Storch et al. 2012), in which the eddying flows are fully developed. They cover a time period of three months in 2005: June, July and August. In the first simulation (exp_6h) the ocean is driven by the fluxes derived from 6 hourly NCEP data. In the second simulation (exp_const) the ocean is driven by constant fluxes obtained by averaging the same fluxes over the three months. In both simulations, the tides are switched off. Thus, exp_const excludes all external forcing factors which otherwise would lead to externally generated internal waves. The results shown in the following are all taken from the August data.

Results

Figure 1 shows the fraction of energy in the eddying flows relative to the total kinetic energy on the left and the fraction of internal wave energy relative to the total kinetic energy on the right for exp_6h at 100 m. In figure 2 the fraction of exp_const relative to exp_6h is shown for the eddy energy on the left and the internal wave energy on the right, both also at 100 m. Energy of eddying flows/internal wave energy is defined as the variance of meridional and zonal velocity fluctuations on time scales longer/shorter than the local inertial period. On the one hand both experiments have a comparable amount of energy in the eddying flows. The ratio of eddy kinetic energy in exp_const to the one in exp_6h is around one (Fig. 2, left) in regions with strong eddy kinetic energy (Fig. 1, left). Thus the constant surface forcing does not kill the eddies. On the other hand the internal wave energy in exp_6h is much higher than in exp_const. In exp-6h, internal wave energy is strong (Fig. 1, right) in the tropical and subtropical regions outside strong currents with high eddy activities in the Gulf Stream, the Kuroshio and the Antarctic Circumpolar Current. This is consistent with the idea that the wind-induced near-inertial waves, once being generated in the storm track regions, propagate equatorward and enhance super-intertial variability there. Under constant surface forcing, the wind-induced near-inertial waves are strongly reduced.

Nevertheless, notable internal wave energy is found in tropical regions and in regions where high eddy activity is present (Fig. 2, right). In both cases the internal wave energy in exp_const is comparable to the one in exp_6h. In regions of high eddy activity the internal waves are likely spontaneously emitted by the eddying flows and then captured by the flows. The generation of the internal waves in the equatorial regions may be different from the one in high-eddy-activity regions, because there the energy of eddies is much smaller than the energy of the internal waves. Additionally the Rossby numbers in tropical regions are not as small as in the extratropical regions, thus the flow is probably not as well balanced in this region. Further research is needed to investigate the source of internal waves occurring there.

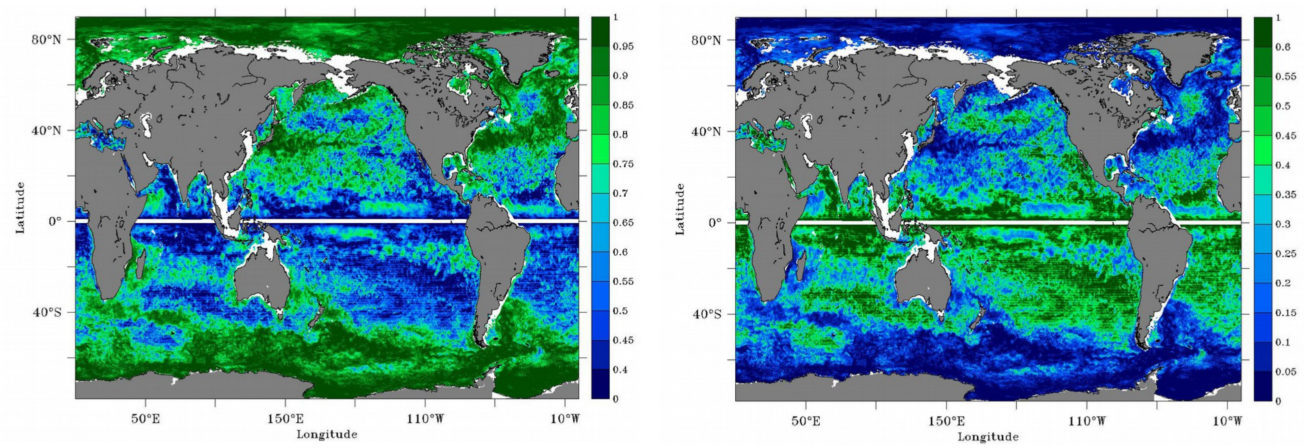

Figure 1: Fraction of energy relative to the total kinetic energy for exp_6h (left: eddy, right: internal wave)

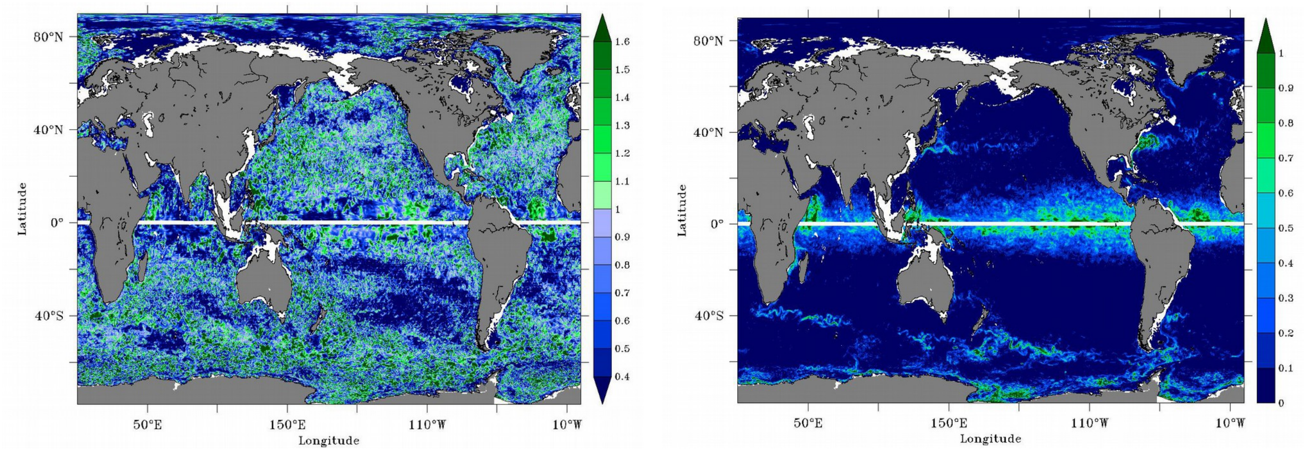

Figure 2: Fraction of energies in exp_const relative to the energies in exp_6h (left: energy of eddying flows, right: internal wave energy)

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