Abstract

The structure of the instantaneous flow fields and turbulence statistics in oceanic convection affected by wind-induced shear are analysed using a large-eddy simulation (LES) data set. LES is a method in which the large energy-containing eddies are represented on the numerical grid while the smaller more universal eddies have to be modeled by a subgrid-scale (SGS) model.

Three distinct convective flows driven by surface cooling are generated. One is the convectively mixed layer with neglegible surface shear corresponding to calm wind conditions. The other two are convectively mixed layers affected by enlarged wind-generated shear stresses correspoding to a wind speed of 7 and 14 m/s, respectively. The heat flux was held constant in order to provide equal thermal forcing. Instantaneous flow fields reveal the ability of the mean shear to order temperature fluctuations into convective roll-like structures rather than the well-known cells from Rayleigh-Bénard convection.

A modified SGS model has been developed in order to overcome known deficiencies of the Smagorinsky SGS model in near-wall flows. The SGS model has been formulated as a second-order moment approach. In the present formulation this corresponds to a non-linear SGS eddy viscosity formulation. It is shown that some of recently proposed modifications of Smagorinsky SGS modeling can be recovered from the present approach as special cases.

In free convection the well-known non-local effects due to turbulent and pressure transport of turbulent kinetic energy from the surface to the bulk of the convectively mixed layer are confirmed. The convective flow exposed to a wind speed of 14 m/s under consideration shows hybrid characteristics. In the near-surface region, it exhibits typical shear flow characteristics, since shear is by far the dominant mechanism. The flow exposed to the moderate wind is more closely to the calm wind case than to the case with intense wind mixing. In the bulk of the mixed layer all of the flows exhibit typical bouyant flow characteristics, especially large-scale coherent structures either in form of convective cells or in form of convective rolls . The unstable stratification significantly lowers the Ekman volume transport compared to near-neutral stratified flows. This behaviour is dedicated to the coherent structures typical for convective flows which effectively distribute momentum throughout the mixed layer. However, the details of the Ekman transports strongly depend on the amount of the wind. The results suggest that the role of Earth's rotation cannot be neglected. This is in strong opposite to conditions in the atmosphere. It is demonstrated that scaling laws derived for atmospheric convection do not apply in the ocean.

Mixed layer bulk modeling was used to set up the numerical grid which is shown to be a remarkably good estimation.