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Enhancement of turbulent mixing over thermally heterogeneous surfaces

I. Esau (1)

Nansen Environmental and Remote Sensing Center / Bjerknes Centre for Climate Research, Thormohlensgt. 47, 5006, Bergen, Norway (igore@nersc.no, / Fax +47 55205801)

Using turbulence-resolving numerical model LESNIC, I simulated the turbulence over narrow (5-200 m, as studied in field campaigns) and wide (200-12000 m, as observed on satellite images) leads. Simulations confirmed existence of a monotonic fetch dependence for the heat exchange coefficient as it has been derived from field data. In contract, monotonic decrease of the heat flux with increase of fetch has not been confirmed. Simulations disclosed profound (by factor of $\sim$5) enhancement of the fluxes over kilometer-scale leads thus invalidating the existing surface flux schemes (adopted from homogenous turbulent mixing studies) and assumed monotonic decrease of fluxes with increasing lead width. The fluxes peak at the lead scale comparable to the corresponding scale of the coherent structures in the convective layer. Over wider leads, flux decrease to its value typical for the shear-free homogeneous convection. Onset of the flux suppression has been related to reorganization of the flow structure over leads. The flow over a narrow lead is organized in a single plume. The plume entrains the cold air horizontally, that maintains large air-water temperature difference and makes the mixing proportional to the entrainment velocity and very efficient. The flow over a wide lead is organized in multiple plumes with downdraught areas over the lead. The temperature difference is reduced and the turbulent mixing is inefficient. The wide leads comprise the major part of the open water in the Arctic, the found turbulent mixing enhancement is of significant importance and calls for the re-evaluation of the averaged surface heat balance over the Arctic Ocean. For instance, Alam and Curry model (1997) for a 2 km lead, 10K temperature difference and wind speed 3 m/s predicts the heat flux $\sim$ 60 W/sq. m., while simulations predict 110 – 150 W/sq. m.