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Turbulent surface fluxes in Arctic fjords in Svalbard

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The atmospheric boundary layer (ABL) over Arctic fjords is poorly understood and many processes occur on spatial scales that cannot be resolved by climate and weather prediction models. The meteorological conditions over a fjord are largely affected by surrounding complex topography, sea ice cover and oceanographic phenomena. This study addresses the turbulent surface fluxes in Arctic fjords in Svalbard. First, the applicability of the Monin-Obukhov (MO) similarity theory, which is widely applied in atmospheric models, was investigated based on tower measurements. Second, the spatial variability of the turbulent surface fluxes was studied based on mesoscale model simulations.

The tower measurements with the flux footprint over an ice-free fjord in Svalbard were taken in January-June 2008. The measurements indicated that the turbulent exchange in this fjord differed from the exchange taking place over the open ocean mainly due to topographic effects. The total stress vector was often found to lie between the mean wind direction and the direction of the fjord axis. When the flow was along the fjord with moderate or high wind speeds, the MO similarity theory was applicable even if the fjord environment does not fulfil the basic assumption of horizontal homogeneity made in the theory.

The spatial variability of the turbulent surface fluxes was investigated in three Arctic fjords in Svalbard, which have different size, shape and orientation, applying the mesoscale model WRF (Weather Research and Forecasting). Ten real cases from winter and spring 2009, representing the most common large-scale flow directions, were simulated at high-resolution for 36 h each. The same cases were also simulated without any topography over Svalbard, and the results of these two simulation types were compared. Due to the topographic effects and strong stability of the flows, several air masses of different origin were often found over a single fjord. The topography increased the spatial variability of the turbulent surface fluxes within a fjord and also had an effect on the mean values. Furthermore, the spatial variability was influenced by the large-scale flow direction, which represented different synoptic conditions, but also different topography in relation to the fjord orientation. The degree of spatial variability often reached levels comparable to the temporal variability. Comparison of the horizontal resolutions in the model clearly indicated that a high resolution of order of 1 km is needed to capture the complex small-scale processes which have an important role in the air-ice-sea interactions taking place in Arctic fjords.