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Observations of surface heat and moisture exchange in the marginal sea ice and implications for model parameterization

Andrew Elvidge[1], Ian Renfrew[1], Ian Brooks[2], Piyush Srivastava[2], Margaret Yelland[3], and John Prytherch[4]

[1]Centre for Ocean and Atmospheric Sciences, University of East Anglia, Norwich, UK (a.elvidge@uea.ac.uk)
[2]School of Earth and Environment, University of Leeds, UK
[3]National Oceanography Centre, Southampton, UK
[4]Department of Meteorology, Stockholm University, Sweden

Aircraft observations from two Arctic field campaigns are used to derive ice surface characteristics and make recommendations for the parametrisation of surface heat and moisture exchange over sea ice and the marginal ice zone (MIZ). The observations were gathered in the Barents Sea and Fram Strait as part of the Aerosol–Cloud Coupling And Climate Interactions in the Arctic (ACCACIA) project, and off the south-east coast of Greenland as part of the Iceland-Greenland Seas Project (IGP). Estimates of roughness lengths for momentum (z_0), heat (z_{0T}) and moisture (z_{0q}) are derived from turbulent wind velocity, temperature and humidity measurements; while sea ice concentration is derived from albedo measurements. The two data sets cover a range of sea ice characteristics, being much rougher in general during IGP than during ACCACIA. Large fluxes of heat and moisture were observed in the vicinity of the MIZ during both field campaigns. We show that z_{0T} and z_{0q} over 100 % sea ice (z_{0Ti} and z_{0qi}) vary as a function of a roughness Reynolds number (R*; which itself is a function of z_0 and wind stress), with a peak at the transition between the aerodynamically smooth (R*<0.135) and aerodynamically rough (R*>2.5) regimes. One of the few theory-based parameterisations available for z_{0Ti} and z_{0qi} (that of Andreas et al., 1987) reproduces these peaks, in contrast to the simple treatments currently employed in two leading numerical weather and climate prediction models – the Met Office Unified Model (MetUM) and the Integrated Forecast System (IFS) – which do not. The MetUM and IFS schemes perform adequately in smooth conditions, but greatly overestimate heat and moisture exchange in rough conditions. We develop a new parameterisation for heat and moisture exchange as a function of sea ice concentration, which blends the Andreas et al. (1987) scheme over sea ice with exchange over the ocean. This new parameterisation performs much better than the current MetUM and IFS schemes for the rough conditions observed during IGP, at least halving the bias and root-mean-square errors in sensible and latent heat fluxes; and is also marginally better for the comparatively smooth conditions observed during ACCACIA, suggesting further evaluation is warranted. However, it should be noted that representing heat and moisture exchange over sea ice is currently limited by the variability in z_0 over 100 % sea ice, which is unrepresented in weather and climate models.