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Gradient-based z-less similarity in the stable atmospheric boundary layer (the SHEBA data)

A. Grachev (1,2), E. Andreas (3), **C. Fairall** (2), P. Guest (4), and O. Persson (1,2)

(1) Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder CO, USA, (2) NOAA Earth System Research Laboratory, Boulder CO, USA, (3) NorthWest Research Associates, Inc. (Seattle Division), Lebanon, NH, USA, (4) Naval Postgraduate School, Monterey CA, USA (Contact Andrey.Grachev@noaa.gov)

Traditionally, the non-dimensional gradients of wind-speed and temperature are plotted versus z/L, where L is the Obukhov length and z is the measurement height. However, as the gradient Richardson number, Ri, approaches its critical value, turbulence decays and vertical fluxes vanish. This leads to difficulties for the implementation of the above approach because the Obukhov length contains both momentum and buoyancy fluxes and therefore values of z/L are unreliable in a very stable regime. To overcome this problem, it has been recently proposed to replace the stability parameter z/L by the gradient Richardson number (the gradient-based scaling). Unlike the fluxes, the gradients of wind speed, temperature, and humidity have finite values even in very stable conditions, and Ri may be a more appropriate scaling parameter in this case. Measurements of atmospheric turbulence made during the Surface Heat Budget of the Arctic Ocean Experiment (SHEBA) made over the Arctic pack ice are used to study some aspects of the Ri-based approach. Turbulent fluxes and mean meteorological data were continuously measured and reported hourly at five levels on a 20-m main tower for 11 months. The gradient-based scaling has been recently discussed by Klipp and Mahrt (2004, 2006), Sorbjan (2006, 2007, 2008), Baas et al. (2006), and Mauritsen and Svensson (2007). Based on the SHEBA data, it is shown that a formal replacement of z/L by Ri for the phi-functions in the framework of the Monin-Obukhov theory is unsuitable. Klipp and Mahrt (2004) and Sorbjan (2006, 2007, 2008) proposed two different gradient-based scaling schemes for the strongly stable case. According to the

SHEBA data, plots in the framework of these two schemes show a dramatic reduction in scatter of data and data points collapse fairly well to a single curve in the very stable case. Furthermore, the SHEBA data demonstrate that all non-dimensional variables should not include z (generalized z-less concept) as a scaling parameter in the limit of very strong stability (e.g., Klipp and Mahrt 2004).