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Upper limit of applicability of the local similarity theory in the stable atmospheric boundary layer

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The applicability of the classical Monin-Obukhov similarity theory (1954) has been limited by constant flux assumption, which is valid in a narrow range z/L < 0.1 in the stable boundary layer (SBL). Nieuwstadt (1984) extended the range of applicability of the original theory using the local scaling (height-dependent) in place of the surface scaling, but the limits of applicability of the local similarity theory in the SBL have been blurred. Measurements of atmospheric turbulence made over the Arctic pack ice during the Surface Heat Budget of the Arctic Ocean experiment (SHEBA) are used to clarify this issue. Based on spectral analysis of wind velocity and temperature fluctuations, it is shown that when both gradient Richardson number, Ri, and flux Richardson number, Rf, exceed a "critical value" about 0.2-0.25, inertial subrange associated with a Kolmogorov cascade dies out and vertical turbulent fluxes become small. Some small-scale turbulence survives even in the supercritical regime but this is non-Kolmogorov turbulence and it decays rapidly with further increasing stability. The similarity theory is based on the turbulent fluxes in the high frequency part of the spectra associated with energy-containing/flux-carrying eddies. Spectral densities in this high-frequency band collapse along with the Kolmogorov energy cascade. Therefore, applicability of the local Monin-Obukhov similarity theory in the SBL is limited by inequalities Ri < Ri_cr and Rf < Rf_cr (however, Rf_cr = 0.2-0.25 is a primary threshold). Application of this prerequisite shows that both the flux-profile and flux-variances relationships follow to the classical Monin-Obukhov local z-less predictions after the irrelevant cases have been filtered out.