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Influence of stability on the turbulent Prandtl number in the stable atmospheric boundary layer

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The turbulent Prandtl number, Pr_t, is an important characteristic of momentum and heat flux mixing in calibration of turbulence models and other applications. In spite of progress in the understanding of the stable boundary layer (SBL) physics, a unified picture on the stability dependence of Pr_t does not exist. Measurements of atmospheric turbulence made during the Surface Heat Budget of the Arctic Ocean Experiment (SHEBA) are used to examine Pr_t in the stably stratified boundary layer over the Arctic pack ice. Turbulent fluxes and mean meteorological data were continuously measured and reported hourly at five levels on a 20-m main tower for 11 months during 1997-1998. The comprehensive data set collected during SHEBA allows studying Pr_t in detail, including the very stable case. It is found that Pr_t increases with increasing stability if Pr_t is plotted versus gradient Richardson number, Ri but at the same time Pr_t decreases with increasing stability if Pr_t is plotted versus flux Richardson number, Rf, or versus z/L. This paradoxical behaviour of the turbulent Prandtl number in the SBL derives from the fact that plots of Pr_t versus Ri (as well as versus Rf and z/L) for individual 1-hr observations and conventional bin-averaged values of the individual quantities have built-in correlation (or self-correlation) because of the shared variables. For independent estimates of how Pr_t behaves in very stable stratification, Pr_t is best plotted against the *bulk* Richardson number. Plots of Pr_t versus the bulk Richardson number (which have no built-in correlation) for the SHEBA data show that on average Pr_t decreases with increasing stability and $\mathrm{Pr}_t < 1$ in the very stable cases.