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Turbulence closure for stably stratified flows: Local and non-local formulations

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In this paper we further advance the physical background and summarise our vision of turbulence closures based on the budget equations for the key second moments (turbulent kinetic and potential energies, TKE and TPE, and vertical turbulent fluxes of momentum and buoyancy) developed in a series of our paters since 2007. In particular, we employ a new formulation of the turbulent dissipation length and time scales. The model is designed for any geophysical sheared flows from neutral to very stable, including both boundary-layer flows and free flows, and grants the existence of turbulence at any gradient Richardson number, Ri. In accordance with experimental evidence, the model distinguishes between the two principally different regimes: “strong turbulence” at Ri « 1 typical of boundary layers and characterised by the turbulent Prandtl numbers of order unity, and “weak turbulence” at Ri > 1 typical of the free atmosphere or deep ocean. In the latter regime, the turbulent Prandtl number asymptotically linearly increases with increasing Ri. For different applications we propose a hierarchy of closure models including the local (algebraic) model, the comparatively simple eddy-viscosity / eddy-conductivity model based on the total turbulent energy (TTE) budget equation, the model based on separate prognostic equations for TKE and TPE, and the “non-gradient transport model” based on prognostic equations for all five statistical moments under consideration.