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Scaling temperature spectra near the ground in a convective boundary layer

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Half a century ago Preistley (Q. J. Roy. Meteorol. Soc., 81:139-143, 1955) showed that temperature gradients over uniform grassland are independent of Richardson Number (and so of the Monin-Obukhov stability parameter, z/L) at all heights where $-0.3 < \mathrm{Ri} < 0$. This result was confirmed and extended to other temperature statistics by Kader and Yaglom (J. Fluid Mech., 212:637-662,1990). Such behavior is usually associated with 'local free convection', but the layer where it applies extends down to levels where shear production of turbulence kinetic energy far exceeds the buoyant production. That is, the underlying dynamics is not local free convection. We propose a new model in which scalars at these heights are transported by the eddies of the outer inertial subrange impinging onto the ground. The velocity scale is then set by the observation height and the outer dissipation rate. We show that the scaling properties of temperature spectra collected over the Great Salt Desert of Western Utah are consistent with this model. A new finding is that the peaks of these spectra collapse only when wavenumbers are scaled using a mixed length scale $(z^{1/2}z_i^{1/2})$, where z_i is the depth of the convective boundary layer. That is, the lengths of the temperature plumes reflect an accommodation between local and larger-scale processes.