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Turbulent kinetic energy generation in the convective boundary layer derived from thermodynamics

Aljoša Slameršak (1), Maik Renner (1), Laurens Ganzeveld (2), Oscar Hartogensis (2), Olaf Kolle (1), and Axel Kleidon (1)

(1) Max-Planck-Institute for Biogeochemistry, Jena, Germany , (2) Wageningen University & Research Centre, Wageningen, The Netherlands

Turbulent heat fluxes facilitate the bulk of heat transfer between the surface and lower atmosphere, which results in the diurnal growth of convective boundary layer (CBL) and turbulent kinetic energy generation (TKE). Here we postulate the hypothesis that TKE generation in the CBL occurs as a result of heat transfer in a "Carnot-like" heat engine with temporal changes in the internal energy of the boundary layer. We used the Tennekes energy-balance model of CBL and extended it with the analysis of the entropy balance to derive the estimates of TKE generation in the CBL. These TKE generation estimates were compared to the turbulent dissipation from a simple dissipation model from Moeng and Sullivan, to test the validity of our heat engine hypothesis. In addition, to evaluate the performance of the dissipation model, this was independently validated by a comparison of its estimates with the turbulent dissipation calculations based on spectral analysis of eddy covariance wind measurements at a German field station. Our analysis demonstrates how a consistent application of thermodynamics can be used to obtain an independent physical constraint on the diurnal boundary layer evolution. Furthermore, our analysis suggests that the CBL operates at the thermodynamic limit, thus imposing a thermodynamic constraint on surface-atmosphere exchange.