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Revision of the current theory of unstably stratified turbulence and its potential implications for PEEX

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Turbulence in unstably stratified flows is traditionally considered as chaotic eddies generated on equal terms by the two very different mechanisms: mean velocity shears, and buoyancy forces. By this means, vertical buoyant plumes comprising “convective turbulence” are not distinguished form 3-dimensional shear-generated eddies comprising “mechanical turbulence”. The latter are dynamically unstable and, hence, break down to produce smaller eddies, thus performing direct cascade of turbulent kinetic energy (TKE) and other properties of turbulence from larger to smaller scales towards their molecular dissipation. The conventional theory does not distinguish convective plumes from mechanical eddies and, factually, postulates that plumes also perform the direct cascade.

We declare that this conventional vision is erroneous except for the trivial case of domination of dynamic instability, when mechanical eddies destroy convective plumes and violently involve them into direct cascade. In geophysical convective boundary layers (CBLs), this condition is satisfied in the thin near-surface sublayer comprising usually less than one per cent of CBL. Beyond this sublayer, dominant role belongs to convective plumes that do not break down but merge to form larger plumes, thus, performing inverse cascade culminated in the conversion of convective TKE into kinetic energy of the CBL-scale self-organised structures: cells or rolls. Therewith, weak mechanical turbulence generated by the mean-flow shears performs usual direct cascade. Hence, horizontal TKE is fully mechanical, whereas vertical TKE is almost fully convective. The key role in this unorthodox picture play the rates of conversion of TKE or another property of convective turbulence into kinetic energy or anther property of the CBL-scale self-organised structures. We define this vision of unstably stratified turbulence theoretically and prove it experimentally by the example of TKE budget in horizontally homogenous atmospheric surface-layer flow.