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Isotropic turbulence, stable layers: facts or fictions?

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Using state of the art drop sonde data (from 237 sondes over the Pacific) we examine two classical and fundamental idealizations of atmospheric science showing that they are untenable in the light of the vertical structure.

The first is the notion of stable atmospheric layers. This is used for understanding atmospheric dynamics and thermodynamics, including the most advanced dynamical meteorological notions such as potential vorticity. Using the drop sonde data, we show that each apparently stable layer is actually composed of a hierarchy of unstable layers themselves with embedded stable sublayers, each with unstable sub-sub layers etc. i.e. in a Russian doll-like fractal hierarchy whose dimension we estimate. We therefore argue that the notion is untenable and must be replaced by modern scaling notions.

The second idealization we examine is the turbulence assumption of isotropy. If we include intermittency, Kolmorogov's landmark proposal that fully developed turbulence has an "inertial subrange" with isotropic energy spectrum $E(k) \approx k^{-\beta}$ with $\beta \approx$5/3 has apparently been spectacularly confirmed in both the horizontal direction and in the time domain (k is a wavenumber). For gradients over a horizontal distance Δx this implies $\Delta v \approx \Delta z^{Hh}$ (H_h=1/3 corresponds to β=5/3; "<.>" indicates ensemble averaging). Remarkably, H_v for gradients over vertical distances Δz ($\Delta v \approx \Delta z^{Hv}$) has not been seriously investigated. Using drop sonde data of horizontal wind, we find that from scales of 5 m to >10 km from the surface layer through to the top of the troposphere, H_v is close to (or larger) than the Bolgiano-Obukhov value 3/5. $H_v > H_h$

implies that a) the atmosphere becomes progressively less stratified at smaller scales although in a scaling way; b) that at most a single (roughly) isotropic “sphero-scale” exists (often in the range 1-100 cm).