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Forecasting the weather
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On self-maintenance of clear-air turbulence

K. E. Haman
University of Warsaw, Faculty of Physics, Institute of Geophysics, Warsaw, Poland (khaman@igf.fuw.edu.pl, 48 22 822 23 87)

Clear-air turbulence (CAT) i. e. turbulence encountered mostly at higher altitudes (over 3000m up to tropopause) in cloudless air or inside thin cirrus clouds creates considerable problems for air traffic. It has rather complex physics and may result from various reasons. Literature on this subject is fairly extensive, but mostly refers to various observational data and empirical or statistical studies directed towards practical applications like CAT forecasting or warnings for pilots. Most of it can be found in various technical reports, conference preprints or pilot manuals rather than in regular scientific periodicals and seldom try to go deeper into theoretical aspects of this phenomenon. The most typical mechanism taken into account is vertical (sometimes also horizontal) shear instability resulting either from larger scale phenomena like jet stream or some more local processes like short gravity waves of surface origin (e.g. mountain waves) or connected with disturbances around thunderstorms. Another source of CAT may follow from deformation fields of frontogenetic processes. Atmospheric indices used as predictors for practical, statistical CAT forecasting usually include various forms of Richardson number or certain parameters of frontogenetic function equation or combination of both; their performance (mostly rather problematic) is usually empirically tested against pilot (PIREP) reports.

CAT is often observed in patches which are only few hundreds (or even tens) of meters thick and extend over several kilometers in horizontal. This patchy structure can result from small inhomogeneities in forcing or from other mechanisms which introduce intermittence to chaotic phenomena, but it seems that there may also be some internal feedbacks tending to maintain such patches when once formed. One of such feedbacks is presented in the present paper. Idea of its existence emerged from aircraft observations of cooling tower and stack plumes. Such a plume can be divided into an active part dominated by buoyant eddies and a passive one which drifts with the wind at the level of zero average buoyancy. The passive part retains fairly strong turbulence generated by decay of buoyant eddies and undergoes mixing with environmental air. It looks however, that the turbulent energy of the passive part is not merely advected from the active one but also produced at place more intensively than in the surrounding air. This suggested that the preexisting turbulence (formed by decay of buoyant eddies) may improve the conditions for generation of turbulence by other factors like e.g. external wind shear. The same mechanisms may be present in self-maintaining patches of CAT. A simple conceptual model indicates that this is in fact possible, at least in situations when Richardson number can be treated as a plausible criterion of onset and maintenance of turbulence. It shows, that thin patches of CAT of limited horizontal extent may be a self-maintaining phenomenon due to the fact, that Richardson number at the lower and upper boundary of the patch is relatively smaller than in its undisturbed environment and in plausible conditions may fall there below the critical value (remaining above it outside), triggering turbulence within the whole patch.