ATMOSPHERIC TURBULENCE

by L. P. Harrison of the U. S. Weather Bureau

WHEN a mass of air travels along the ground, every obstruction creates a disturbance in the flow pattern. Generally speaking, the disturbances take the form of eddies which roll along the ground. The eddies are of different size, depending largely upon the prevailing lapse rate, the wind shear in the vertical, the roughness of the terrain, and the presence of clouds and fronts.

Consider, first, the situation just before dawn on an occasion when a steep inversion exists in the layer of atmosphere from the surface to a height of, say 1,500 feet. The surface wind then flows very smoothly for convection is prevented by the stable temperature distribution with height. Tiny eddies are formed in the immediate vicinity of the ground by friction, but these are hampered from rising far off the surface by the stabilizing influence of the inversion and dissipate quickly. Surface gustiness is then practically nil. At higher levels in the inversion layer the wind flow is likewise very smooth. The wind velocity increases rapidly with elevation in this layer. Obstacles in the path of the surface wind form some eddies with vertical axes around the sides and with horizontal axes along level upper structures. These eddies continually reform in more or less the same locations, while previously formed eddies are carried away by the wind. The latter eddies rapidly decay so that the smooth flow is quite widespread.

Consider next, the situation a few hours after sunrise when the surface has warmed up somewhat, and the lapse rate is, say, 0.25°F. per 100 ft., which is moderately less than adiabatic in the layer of atmosphere from the ground to 1,500 feet. The layer is still stable but much less stable than when the inversion existed. Eddies are formed as in the previous case but they persist for longer times and are carried up to slightly higher elevations. Surface wind gustiness is only slight, but the wind velocity does not increase with elevation so rapidly as before. Since the surface wind is slowed up by friction at the ground, eddies propelled upward by obstacles possess less forward velocity than the surrounding horizontally moving air. The eddies thus tend to slow down the air aloft, thereby using up momentum and dissipating the energy as heat. At the same time, eddies formed by turbulence aloft are brought down to the surface in replacement of the eddies transported upward. The downward moving eddies have greater forward motion than the surface air and hence tend to speed it up. This adds momentum. A slight gust is experienced as an eddy from aloft strikes the observer, while a slight lull is felt as the slower main body of surface air slowed by friction passes by. In addition, a slight to moderate amount of bumpiness may be met with above the surface in the layer being studied.

Consider, now, the situation when a super-adiabatic lapse rate exists in a thin surface stratum of air and an adiabatic lapse rate exists for 1,500 to 3,000 feet above, say in midafternoon when maximum surface temperatures prevail. Eddies then formed at the ground are transported upward by convection possibly to the top of the layer characterized by the adiabatic lapse rate, and generally somewhat higher until a stable lapse rate is encountered and temperature equality achieved. These eddies rise in the form of "bubbles" from the surfaces like pavements, plowed fields, etc., which because of their excellent absorptive power for solar radiation are hotter than surrounding surfaces like ponds, lakes, woods, etc., which are poor absorbers of radiation. The descending counterparts of the ascending eddies are usually found to replace them quickly at the surface. But, as previously explained, when the wind velocity increases with height, the sinking eddies have greater horizontal velocities than the surface air impeded by friction. Consequently, the wind velocity at the ground varies rapidly as the gusts from higher levels alternate with the lulls.

Aloft, the pilot will experience rough air as his airplane glides through a succession of upward- and downward-moving bodies of air undergoing convection to and from the surface.

If clouds form within the rising column of air due to expansional cooling, convective activity increases to a marked degree. An upward draft is created by the convection within the cumuliform clouds, this being reflected in stronger ascent of air from the surface. In association with the chimney-like action of the clouds,