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ATMOSPHERIC STRUCTURES ASSOCIATED WITH TURBULENCE
IN THE FREE ATMOSPHERE

By K. T. Spillane

Mr. K. T. Spillane of the Department of Meteorology, University of Melbourne, commenced his talk with a brief description of the technique used: telemetered flight information from pilotless aircraft was interpreted in terms of turbulence in the free atmosphere and related to vertical wind shear, Richardson number, and to the static stability as well as to its local and individual changes. The data covers several years of flights to altitudes around 65,000 ft.

The use of Jindivik target aircraft as turbulence probes was first investigated, at the suggestion of U. Radok, by C. Rider who found that the clearest indication of disturbed conditions is provided by the roll rate record. Roll rate disturbances have been classified by magnitude as light, moderate or strong turbulence, and as "transient" or "persistent" according to whether the aircraft encountered the disturbed layer during ascent or descent only, or during both ascent and descent. The supporting meteorological data consist of radiosonde temperatures and radar winds measured some tens of miles away from the aircraft. A study of the precision of these data indicates r.m.s. errors of vertical wind shear ranging from 1.5 kt/1000 ft at 20,000 ft to 4.5 kt/1000 ft at 60,000 ft; height r.m.s. errors of around 400 ft; and coincidence of temperature and wind profile data in the upper troposphere with a r.m.s. error of 300 to 500 ft.

The most significant turbulence parameter obtainable from individual wind soundings is the vertical shear, $\partial \vec{v}_H / \partial z$, whereas temperature soundings are best analysed in terms of the static stability, $s = \frac{g}{\theta} \frac{\partial \theta}{\partial z}$, where g is the acceleration of gravity and θ the potential temperature; together these two quantities determine the Richardson number, $Ri = s / (\partial \vec{v}_H / \partial z)^2$. By combining wind and temperature information, estimates may be obtained of the individual and local rates of stability change, using the thermal wind equation and assuming isentropic flow. The individual logarithmic stability change for unaccelerated flow and the same geostrophic component throughout the turbulent layer can be written

$$\frac{d \ln s}{dt} = \frac{\theta}{g} f \frac{\partial}{\partial z} \left(\frac{\vec{k} \cdot \vec{v}_H \times \frac{\partial \vec{v}_H}{\partial z}}{\frac{\partial \theta}{\partial z}} \right) * \quad \dots (1)$$

where f is the Coriolis parameter.

The ceiling height reached by the 54 target aircraft flights used in this study can be deduced from the table below.

Frequency of heights exceeded by target aircraft

Height (10^3 ft)	15	20	25	30	35	40	45	50	55	60	65
No. of flights	54	53	45	43	41	41	36	29	18	12	0

* This final form was suggested by Dr. C.H.B. Priestly in discussion.

Turbulence was concentrated around 35,000 ft, with an even more pronounced second maximum around 55,000 ft. The lower of these maxima has long been familiar from middle latitude work, but evidence for the upper has only recently been supplied by U2 flights (Reiter 1962) and is believed to arise from mesoscale disturbances extending over vertical distances of the order of 3,000 ft and horizontal distances of some hundreds of miles (Barbé 1958, Sawyer 1961).

A first test of turbulence parameters has been made for a sample of 14 flights with well-defined persistent layers, measuring 5,000 ft on the average. Although in individual cases large vertical shear values occurred at the base of turbulent layers, the average shear profile was fairly uniform. By contrast the static stability had a clear minimum near the centre of the turbulent layers where also the static stability appeared to decrease individually, due to cold air advection which is not compensated by subsidence. Individual Ri values of seven cases with strong turbulence were close to or even well below 1 near the disturbed layers.

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ROUTINE MEASUREMENT OF CROP EVAPORATION

by I. McIlroy

In introducing the speaker, the Chairman, Dr. C.H.B. Priestley, emphasized the far-reaching importance of evaporation measurement, not only for agriculture and hydrology but ultimately, on a world-wide network basis, in further development of forecasting methods.

Mr. I. C. McIlroy, of C.S.I.R.O. Division of Meteorological Physics, then discussed what he regarded as the most promising of a very limited number of approaches available for reliable routine estimation of evaporation, applicable to most natural surfaces but in particular to irrigated crops, with which it had already been very successful.

A rigorous derivation of this so-called combination method was then given. For space reasons this has had to be abbreviated here, both by the earlier introduction of certain assumptions and approximations necessary to achieve simplicity in the final working formula adopted for evaporation, and by the omission of any discussion of the errors introduced thereby.

The method combines two types of basic relationship, that of proportionality between the average rate of flow of a quantity and the associated concentration gradient and that of balance between the energy flows to and from a surface. The equations for vertical transfer through the atmosphere, of sensible heat and of the latent heat associated with evaporation respectively, can be written as:

$$H = h \Delta T \quad \dots(1)$$

$$\text{and} \quad LE = L \frac{h}{c_p} \Delta q$$

$$\approx \frac{h}{\gamma} \Delta q \quad \dots(2)$$