Some Suggestions for Experimental Studies of Atmospheric Turbulence[1]

Summary

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The atmosphere is the largest facility available for basic studies of turbulent motion. Nowhere can we find a larger spread between the size of the energy-carrying eddies and the size of the dissipating eddies (Kolmogoroff's length). One of the fundamental aspects of the problem has to do with the rate of growth of the mean square vorticity. This nonlinear process is measured by the following nondimensional factor

$$S = \frac{\overline{(\partial u/\partial t)^3}}{(\overline{(\partial u/\partial t)^2})^{3/2}}$$

where $u(t)$ is the velocity fluctuation parallel to the mean flow [*Batchelor,* 1953]. Observations in grid flows and in channel flows indicate that S amounts to about 0.4 and that it is only during short intervals of time that the function $\partial u/\partial t$ really contributes to the mean cube.

It would be important to repeat these experiments in atmospheric turbulence where the eddy Reynolds number is quite large. Furthermore, the geometry associated with the positive pulses of $\partial u/\partial t$ should be studied. For this purpose, we could use electronic gates giving a signal $+1$ whenever the function $\partial u/\partial t$ exceeds a certain limit, say twice its root-mean-square value. The gate gives a signal zero when the function does not exceed the limit.

With several hot-wire anemometers, each followed by an electronic gate, rates of coincidence could easily be measured. For example, we suggest the following set-up: three hot wires respond to the u component at the summits of an equilateral triangle. The triangle is normal to the direction of mean flow. As the size of the triangle is increased, the rate of coincidence should decrease, indicating the size of the regions where $\partial u/\partial t$ assumes large values simultaneously. With a fourth hot-wire traveling along the normal to the center of the triangle, we should be able to measure the thickness of this region.

If this thickness is of the order of the length of Kolmogoroff, it would indicate that the spikes of $\partial u/\partial t$ are produced by head-on collisions between chunks of fluids [*Betchov,* 1956].

In general, this technique would lead to a better understanding of the basic structure of turbulence, since multiple coincidences are easier to measure than, say, quadruple correlations.

The atmospheric vagaries of the mean flow and of quantities such as $(\overline{\partial u/\partial t^2})$ could be eliminated by mounting the instruments on a sort of weather vane, by using constant resistance anemometers and normalizing amplifiers.

Although there are no theories dealing with turbulent rates of coincidence, it is likely that such a study would increase our understanding of the basic mechanisms of turbulent flows. In particular, it may point out the weakness of the theories based on the assumptions of quasi-Gaussian quadruple correlations [*Proudman and Reid,* 1954; *Tatsumi,* 1960].

Studies of this type should also bring some clarification of the turbulent processes. We know [*Betchov,* 1956] that a positive value of S is indicative of concentration of vorticity and of squashing of the fluid particles. These two processes are not mutually exclusive. For example, in a collision between two fluid blobs, the rate of deformation tensor indicates squash-

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ing along one axis (axis of collision), and stretching, at a slower rate, along two other axes. The plane of these two axes is perpendicular to the axis of collision. Any component of the vorticity lying in this plane will be stretched. By studying the size and shape of the regions where $\partial u/\partial t$ takes significantly high values, we should clear up this subject. In particular, it will be interesting to know the Reynolds number characteristic for those spikes of $\partial u/\partial t$ that contribute to, say, half the value of S. Indeed, the size and the length of the pulses are sufficient to build a Reynolds number.

References

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