Research on Atmospheric Turbulence and Freezing Nuclei Transport by Means of a Sailplane

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Introduction

The characteristics of a sailplane sometimes permit it to be an effective research tool for projects which require a device to measure or detect small atmospheric motions. During the past year two meteorological research projects have been conducted with a sailplane. The first, a fundamental study of atmospheric turbulence, utilized the high lift-to drag ratio and the simple descent-vs-speed relationship of the sailplane to help separate the measurement of vertical and horizontal turbulence [1]. The second, a study of the transport and decay of the silver iodide smoke used for cloud seeding, utilized the low stalling speed and high manuverability of the sailplane to permit it to locate the thermal masses in which the smoke rises, and the lack of motor vibration added to the reliability of the measuring apparatus [2]. The advantages of the sailplane make it a unique tool for these introductory projects. Now that the validity of the measurement techniques have been established with the help of the sailplane, future work can make use of powered aircraft which are less trouble to operate.

Turbulence

The aim of the atmospheric turbulence project was to obtain accurately the power spectrum of vertical and horizontal turbulence over a broad range of eddy sizes. Continuous records of air velocity (with a fast response hot-wire anemometer) and vertical glider acceleration (with an accelerometer) were made on a magnetic tape recorder. Later analysis of the tape records permitted the accurate finding of the horizontal energy in eddies from 0.7 to 88 meters wavelength, and the vertical energies in the 25 to 50 meters wavelength range.

It was found that for the amplitude-modulated-carrier system the magnetic tape record-playback cycle would produce less than 2 % RMS error if the tape were run at a speed which lets one cycle of the carrier exceed 0.018 cm on the tape. The power spectra were measured by playing back the tape in the lab, passing the reproduced signal through a narrow adjustable band pass filter, and then finding the mean square output with a "rotating disk square integrator" (a chopper disk and photoelectric counter which integrates the square of the position of a spot on an oscilloscope screen).

Turbulence power spectra curves were analyzed for parts of flights from 200 meters to 3500 meters altitude in smooth wave conditions, turbulent wave conditions, slope soaring, and thermal soaring. In every case the entire frequency spectra curves for horizontal turbulent energy were very smooth, and were consistent with the "energy$\sim$(wavelength)$^{5/3}$ law" derived from Kolmogoroff's Similarity Hypothesis. Taking all curves together, the exponent was 1.75 ± 0.10, in good agreement with the theoretical value of 1.67. From the curves and from formulae derived from the Similarity Hypothesis it was possible to estimate the rate of viscous dissipation; the dissipation per gram varied from 51 cm^2 sec^{-3} in the wave turbulence to 0.13 cm^2 sec^{-3} in the smooth wave, and averaged 1.4 cm^2 sec^{-3} in thermals. Eddies under 6 cm produced over 90 % of the dissipation in all cases.

The power spectrum for vertical air velocity was found by 1) finding the power spectrum for vertical acceleration load, 2) treating this to yield the power spectrum for vertical sailplane velocity, and 3) correcting this by considering the aircraft response function. In the 25—50 meter range this third step can be fairly accurately followed, and in this range the turbulence energies measured reasonably isotropic. Presumably if isotropy exists at these eddy sizes, it exists for smaller eddies. The sailplane response characteristics (vertical load vs horizontal turbulence) were calculated from the data; the response characteristics agreed closely on all flights. Since vertical load depends primarily on vertical turbulence, this result showed the vertical turbulence to be uniquely related to the horizontal turbulence; the most probable relationship is that of isotropy.

On the basis of the measured turbulence and aircraft response, it was found that maximum acceleration load on the sailplane comes from 75 meter wavelength eddies (50 chord lengths) and eddies from 32 to 275 meters contribute loads over 50 % of maximum.

During the wave flight it was noted several times that the sailplane went from a "smooth wave" to a "severe turbulence" regime within 50 meters, and exited from the turbulence just as rapidly. This indicates very sharply delineated areas of turbulence, similar to the intermittency noted in wind tunnel airfoil experiments.

Nuclei Studies

A TG-3 sailplane, with a portable cold box for detecting freezing nuclei, was used as a probe for locating silver iodide smoke released from ground generators during convective conditions. Two important questions have been raised during some cloud seeding discussions: 1) do nuclei released from the ground reach the clouds in reasonable concentrations, and 2) do the nuclei resist deactivation by sunlight or warm temperatures. If high concentrations of effective nuclei can be measured entering cloudbase near ground generators, the answers to both questions must be "yes".

Silver iodide nuclei were detected, on different occasions, to a maximum distance of 15 miles and a maximum height of 4000 feet above the generators. Concentrations were in the range of 35—100/liter at these extreme distances. 200/liter was once measured at 10 miles. The weather during the tests was hot, and the upcurrents generally weak. It can be tentatively concluded that seeding from the ground in summer convective conditions is feasible within a radius of at least 15 miles of the generator with the generating equipement used in this work (string burning AgI generator, emitting 5—10^{13} nuclei/minute). If deactivation occurred, it was not of a magnitude to prevent seeding.

High natural nuclei counts sometimes masked the silver iodide plume. Presumably high natural counts would decrease the possible effect of a silver iodide generator. As an interesting sidelight, it was noticed that certain types of industrial smoke in the Los Angeles region are high in natural nuclei count.

The work is being continued with a Cessna 195 aircraft.

(Editor's note: The above is a summary of the paper presented by Dr. MacCready at the 6th OSTIV Congress. A complete report is given in "Atmospheric Turbulence Investigation by Sailplane" by P. B. MacCready, T. J. Lockhart, R. J. Diamond, T. B. Smith; Final Report under Contract No. AF 19 [604]-1107, March 31, 1956.)

[1] Contract AF 19 (604)-1107, Geophysics Research Directorate of Air Force, Cambridge Research Center, ARDC.

[2] Sponsored by the President's Advisory Committee on Weather Control.