

The Powered Sailplane in Meteorological Research

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Introduction

Between 1970 and 1975 glider pilots circling in thermals close to Lasham, England, were occasionally startled to see a maverick aircraft heading for them, only to fly straight through the thermal instead of joining the circle in a peaceful and orderly manner. There was sometimes a chance to explain that this was part of a scientific research programme, but not always, and this paper aims to review the work done by Reading University using a powered sailplane. A number of scientific papers have been published; the main ones are listed below. Also the prospects for a realistic programme are outlined. A similar programme might be undertaken elsewhere, but would be within a different administrative framework: this is not a negligible factor, and complications caused in the U.K. by partial support from the University and from a Research Council help to explain the rather protracted period between the flights and some of the publications. The use of a number of the aircraft is being developed methodically under Dr. M. Reinhardt at DFVLR, and this is happily within a viable size of research unit.

Aims

The stated objective of the research was to instrument a powered sailplane, and to explore its possible uses in meteorological research. A number of different experiments were therefore carried out, whereas more scientific output might have arisen from concentrating on one particular line. Possible uses were indeed explored, but the unstated aim, that the programme would lead to a semi-permanent facility, was always somewhere in mind. This did not happen, and the work is now in abeyance.

The meteorological problems which are accessible to a powered sailplane are confined to the atmospheric boundary layer, say up to 300 m at most, and to the meso-scale in the horizontal. Each person is allowed to define his own meso-scale, but here we mean

100 m to 20 km. The features must not be so large that they change while the aircraft flies from one end to the other. They must not be so small and transient that they can only be viewed statistically. Our own interests centred on meso-scale discontinuities, such as sea-breeze fronts, on the structure of individual thermals, and on the way in which a whole boundary layer full of thermals transports heat and water vapour away from the surface. A variety of other topics was discussed at various times, some more light-heartedly than others, and a number are mentioned in the later sections of this paper. The cases of most general interest to meteorologists and fluid dynamicists at large are those where the observed atmospheric phenomenon can be related to one or more models. These may be mathematical, usually involving computer calculations of considerable complexity, or they may be physical. The ability to represent a real life event in a water tank in the laboratory enables the researcher to increase his "productivity" by several orders of magnitude, if this is measured by the number of experiments carried out. The laboratory experiments are worthless, however, if atmospheric experiments do not show that there is a real life event which corresponds closely: waiting for these to happen was a large part of the powered sailplane programme.

Historical

In 1968, when applications for funds were being made, no two-seater motor sailplanes were available in Britain, and the first flying was done in a Slingsby T 53, collected in the autumn of 1969 and largely instrumented during the winter. The same data logger, described to OSTIV (Milford and Whitfield 1970) was used throughout the programme. It enabled six parameters to be measured and recorded every 1.6 s with adequate resolution and accuracy, and in principle allowed for further parameters to be measured more often. Decoding the more detailed da-

ta was impractically tedious with this system, and a 1980 version would be totally different in this respect, owing to the micro-processor revolution. The actual sensors would not have changed much, for virtually all our meteorological flights were carried out using aneroids for height and indicated airspeed, a variometer for fluctuations of vertical velocity, a series/parallel network of miniature thermistors for temperature, and a wet-bulb for humidity reference data. Rapid variations of humidity were measured with a Lyman alpha hygrometer: calibrations in flight against the wet- and dry-bulb checked absolute values. The cost was equal to that of the rest of the instrumentation hardware put together, but the very rapid response allowed humidity to be used as an indicator of relative motions down to a small scale, as in the case of the best of our sea-breeze front observations.

During 1970, 1971 and 1972 operations with the T 53 enabled us to learn the virtues of the powered sailplane the hard way. Some interesting cases were observed (Milford and Simpson 1972, Milford 1972) but systematic observations were impractical, as I believe we could have been told before we started. Some interesting flying took place in the neighbourhood of the high power radar operated by the Meteorological Research Unit at the Radar Research Establishment at Malvern. This exercise used an elderly Terrior, and for one exercise, a Scheibe Falke borrowed from the Air Cadets. The weather was unhelpful, and the exercise led to more after-dinner stories than scientific results. Increasingly, we relied on a hired Falke, installing instruments on the day of the operation.

The main results were obtained in 1973 and 1974, when a Falke was hired on a sufficiently regular basis to allow part of the instrumentation to be installed permanently. By this time the Lyman alpha hygrometer was in use, and the sea-breeze fronts reported by Simpson et al. (1974, 1977) were observed. Novel results included the detail observed at the front with the rapid humidity sensor, and the observation of the "sea air" advancing to 150 km inland by 0200 when the influx of air to the region behind the front had ceased by 1700 the previous day.

1974 was not a good summer from the viewpoint of the scientific experimenter. This led to difficulties with our main experiment, to compare our measurements of heat and water va-

pour transfers through the boundary layer with those of other groups. The results were published in a paper by Moores et al. (1979). The flights undertaken for this part of the programme showed some interesting features incidentally, and some aspects are included in a companion paper to this (Milford 1980). Other features, of more interest to the meteorologists, are discussed by Milford et al. (1979).

The flying programme came to an end in 1975, when a proposal to use a powered glider on a full time basis was rejected, and the two full time research workers on the project moved away from Reading. A revised version of the proposal is summarised below and is still open to support from a friendly politician or millionaire.

A powered sailplane programme

The main feature of the powered sailplane which makes it unique remains that originally pointed out by MacCready, (and quantified for the Falke during our programme): the low wing loading enables it to follow vertical air motions on scales down to less than 100 m. If it is flown steadily at constant attitude vertical air motions are measured to 0.2 m s^{-1} , which is otherwise only attainable with an inertial platform at 100 times the cost. For many other purposes, like making detailed vertical soundings, a conventional powered aircraft will serve as well, but glider pilots have a unique feel for the scale of atmospheric motion we have been interested in. The flexibility of operation in flight, and in flight planning are needed for many of the small events we look at, while the ease and informality with which an instrument can be hung onto a sailplane would astonish an artificer working on more conventional aircraft, but is invaluable to an experimental scientist. We can always make the point that the Falke uses 10 litres of petrol per hour when cruising, and therefore undercuts the giants such as the C-130 used by the Meteorological Research Flight in the U.K. However, the main cost of the experiment is not that of the flying, but of the organisation of it, and the analysis after the event. The cost ratio between Falke and C-130 becomes less dramatic when this is taken into account.

The proposal made for a powered sailplane facility in the U.K. supposed that there were enough different research groups who were interested in meso-scale phenomena of one kind or another. The cost was calculated on

the basis of four experiments per year. For each experiment, the aircraft would be dedicated for two months – one for the actual field work, and one for installation and testing of special equipment, calibration, and some data processing. Two pilot-technicians would work full-time, one as pilot/technician and one to provide ground support. Even in 1980 the cost per experiment in round figures is only £15,000. For this the experimenter would get printed data for as many flying hours as he could use in one month, and experience shows that this will occupy him back in his office for the rest of the year at least.

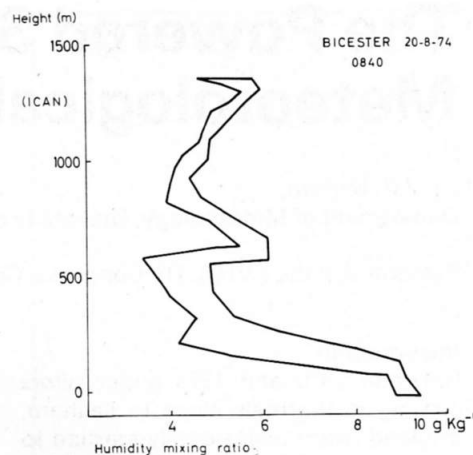
Scientific aims

Observations using the instrumented powered sailplane could help materially towards the solution of a number of meteorological problems of topical interest. Some of these unfortunately require night flying, while others call for cloud flying so both capabilities should be included if possible.

We may instance all three main aspects of our own programme which call for more observations. We want details of more sea-breeze fronts in different areas, and of heat and vapour fluxes over different regions. The actual structure and development of individual thermals is as important a problem as any, and our progress on these was regrettably small. The biggest problem is to find and observe them when they are young and close to the ground; almost as difficult is to mark them unambiguously so that several passes can be made through the same thermal.

Water vapour can be used as a tracer in other situations, for instance in following an industrial plume. Contrasts in the humidity are not always present when a tracer is needed, however, as in the case of thermals in the afternoon (Milford 1972). One interesting problem is how the boundary layer, which is well mixed by the end of one day becomes inhomogeneous during the night. Fig. 1 shows an early morning ascent by the Falke in which the driest air corresponds to air 120 mb higher on the radiosonde ascents the previous day, and vertical motion of this size penetrating into the boundary layer on a quiet night seems unlikely. Extremely dry air has also been found just above an inversion and again a straight-forward trajectory from the nearest source seems improbable.

Other problems, for example of heat islands over cities, need to be made



Morning humidity profile: extreme values for each minute during spiral ascent are drawn.

three dimensional and a variety of problems remain in cloud physics and in atmospheric electricity. In each field the powered sailplane is ideal so one may conclude that the work is still there for such a vehicle to do. Perhaps the very fact that it appeals to small and independent groups means that the degree of coordination required to make the device economic can never be achieved.

Acknowledgement

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