A Shearline Investigation with an Instrumented Glider

J. R. Milford and J. E. Simpson
Department of Geophysics, University of Reading

Presented at the 13th OSTIV Congress, Vršac, Yugoslavia (1972)

Summary

A line of low level wind shear was investigated in an instrumented T 53 glider during the afternoon of 11th September 1971, near Lasham, in southern England.

The shearline, between a light easterly wind and a light southerly one, was clearly marked by haze in the southerly flow, and appeared to be continuous with a sea-breeze front lying along part of the south coast.

This surface discontinuity appears to have been caused by differential heating, in much the same way as a normal sea-breeze front. On this day, although the temperature had risen by as much as 12° C in some places inland, in the south-west continuous cloud and heavy rain had kept the land temperature about the same as that of the surrounding sea.

A marked frontal convergence developed, with a slope of about 30° and a line of ascending air with a mean vertical velocity of more than 1 m s^{-1} was measured over a 10 km run.

Synoptic Analysis

A vigorous trough associated with a European low had brought thundery type rain to south-west England on 10th September. On the 11th, frontal troughs approaching from the Atlantic had become stationary on a line from Western Ireland to Brest, while a ridge of high pressure, extending from an anticyclone centred over Greenland, dominated the weather over the east and north of the British Isles.

The distribution of cloud on the 10th and 11th was static, as the map (fig. 1) prepared from Essa 8 photographs on the two days shows. Fig. 2, taken at midday on the 11th, shows continuous cloud in the south-west with a few oktas of fair-weather cumulus over the rest of the country. On the morning of the 11th there had been heavy rain in Cornwall (20 mm at Culdrose), but only traces fell north-east of a line drawn from the Isle of Wight to South Wales. The temperature charts at 1200 and 1500 GMT (Fig. 3a and b) show that in the southwest counties the temperatures were lower than the mean sea temperature for September, and a line of maximum temperature gradient existed from the Isle of Wight to the Bristol Channel. A corresponding pattern appeared in the pressure map (fig. 4).

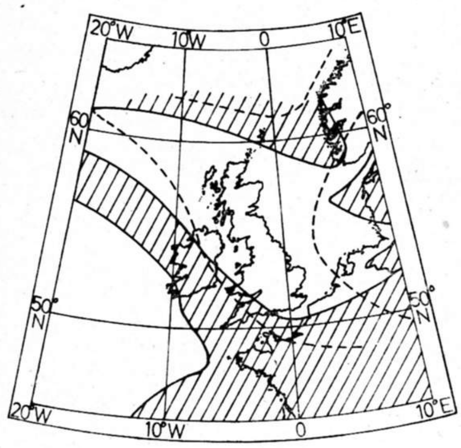

Fig. 1. Cloud cover from Essa 8 photographs. Full line on 11th September, dotted line on 10th September 1971.

Local Conditions

At Lasham on the 11th, a bright morning with a light north easterly wind promised good soaring. After midday, however, the fair-weather cumulus diminished from a maximum of three oktas, showing that an inversion was limiting the convection. By 1500 there was little lift around Lasham airfield, and by 1630 none at all.

On this day, the Red Queen, a Slingsby T 53 glider used for meteorological research by Reading University and owned by the Natural Environment Research Council, was being used to investigate individual thermals. For the afternoon flight another pilot, Rika Harwood, soaring in a Skylark 3, had agreed to mark thermals for the Red Queen to make passes through. The Red Queen, piloted by Paul Loewenstein, was aero-towed from Lasham at 1453 GMT. After release near the airfield the Red Queen struggled to reach 1000 m (all heights quoted are referred to mean sea level), and then flew across to join the Skylark, which was circling about five miles to the west in a thermal marked by smoke from a stubble fire. Fig. 5 is a sketch map of the whole flight path, and the reference numbers mark salient points on the flight.

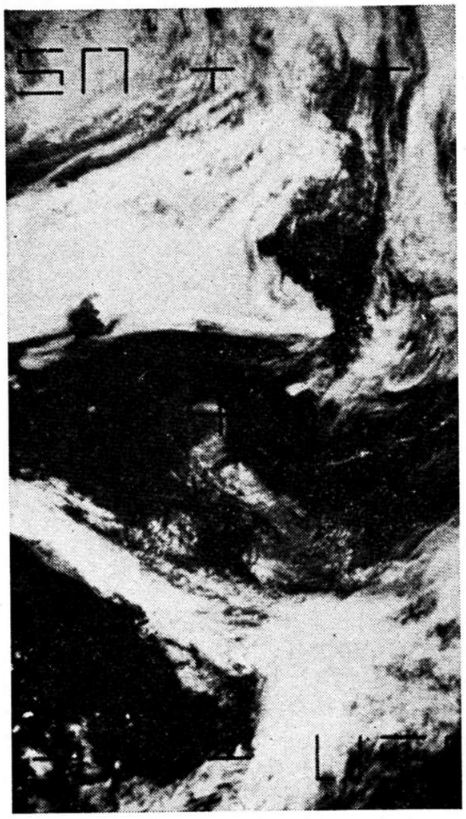

Fig. 2. Essa 8 photograph midday, 11th September 1971.

The smoky thermal provided good lift, and after climbing 700 m in eight minutes the Red Queen was near cloud-base at 1600 m. The other glider was then 1.5 km away and a straight run was made in the direction of the wind as shown by the original smoke plume, crossing above the Skylark. Four peaks of lift were found in this 3 km run (8 to 10 in fig. 5), separated by slow descent. In the return run, (10–13) four cells were again detectable. Within such runs, vertical velocity correlates with temperature changes, but with humidity less well.

At the end of a third run, a little further to the west (pt. 14) the glider became involved in some lower cloud and turned to regain clear air. The flight continued in an easterly direction, passing above the smoke plume, which had changed direction. Analysis of cine-photographs taken overhead shows a new wind direction from 080°.

At this point the crew began to suspect that they were in a seabreeze front, but the orientation of it seemed rather improbable. At any rate it was not an isolated thermal which was being investigated, but one associated with a line marked by increased convection, and by a sharp change in visibility. Three minutes later a glider pilot called up on the radio to say that he could see a

sea-breeze front near Inkpen, 30 km to the north-west. There was thick haze beyond it, and he could not see down to the ground in the south-westerly direction. Our analysis shows that the use of the term «sea-breeze front» here, although descriptively useful, is scientifically misleading.
The rest of the flight (pts 19 onwards) consisted of runs close to the front of the haze-line at heights of 1000 m to 1250 m. This height was easily maintained without circling for a distance of 6 km to the northwest. On the return run, (pts 23–25) height was again maintained without circling for a distance of 11 km. The line of haze and cumulus extended as could be seen in both directions.
At a point near Alresford (25, fig. 5) at 1600 GMT the investigation had to be discontinued because there was no lift on the route back to the airfield, and because the Red Queen is not equipped for cloud flying.

The data

In addition to the descriptive observations, the instrument system in the Red Queen was recording pressure height, airspeed, rate of climb, air temperature and wet-bulb depression every 1.6 seconds, or about every 40 m along the flight path (Milford and Whitfield, 1970).

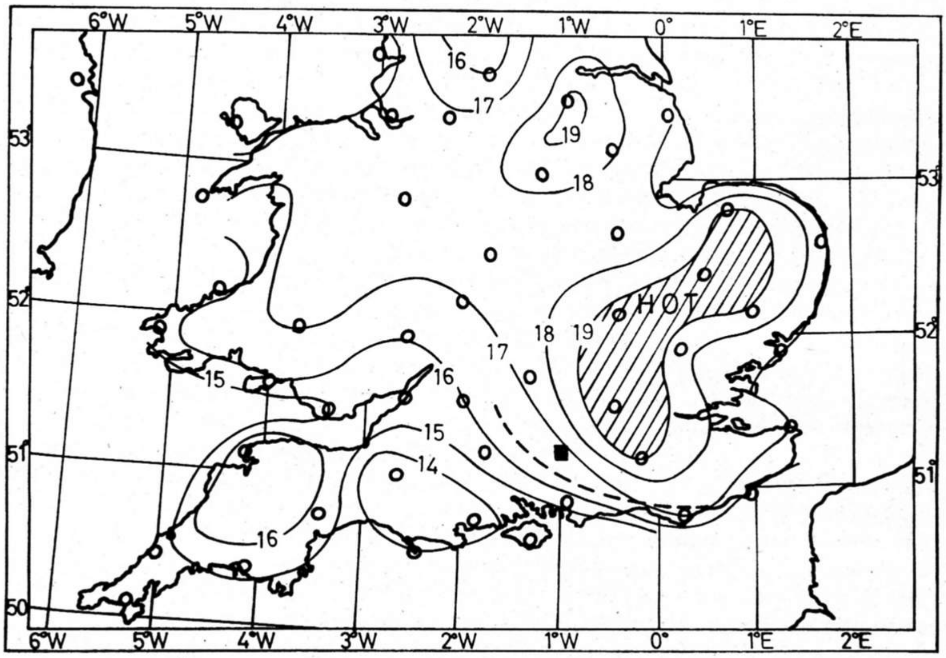

Fig. 3a. Temperatures at 1200 GMT, 11th September 1971. Lasham airfield.

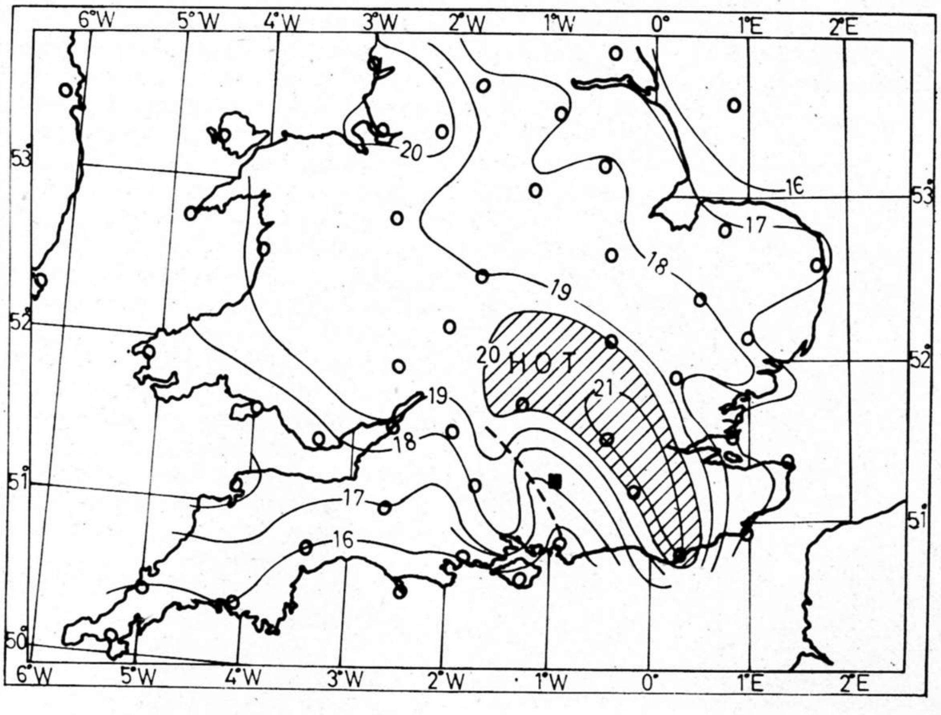

Fig. 3b. Temperatures at 1500 GMT, 11th September 1971, Lasham airfield.

During part of this flight, photographs were also taken automatically every 6.5 seconds by a cine camera fixed in the aircraft and viewing vertically downwards. This enables ground speed to be deduced in straight flight, and the mean drift over the period of several circles while circling in a thermal. Vertical air motions were deduced from changes in aircraft height, assuming it to sink in still air with a velocity of 1 ± 0.2 m s^{-1}.

Wind near the shearline

From the cine photographs taken during the initial straight run towards the smoky thermal (5 to 7, fig. 5) we can calculate a following wind at 900 m of about 2.5 m s^{-1}. Surface wind at the airfield was also from about 090°, but at the end of the run the drift of the smoke near the ground was from 165° (pt.7 at 1514 GMT). From the cine photographs taken during the climb (7 to 8, fig. 5) the mean drift during the climb was measured as 4.2 m s^{-1} from 080°.

Temperature and humidity

The main changes in both temperature (expressed as potential temperature, Θ) and humidity (expressed as humidity mixing ratio, r) can be identified with movements from one part of the flow pattern to the other. The changes are all small, but r shows more systematic variation than Θ. For instance, at points 20 and 24 (fig. 5) the aircraft was to the east of the main region of lift, and met air sinking at 0.2 to 0.3 m s^{-1}. The humidity mixing ratio fell by 0.4 g kg^{-1} and recovered as the pilot moved back into the lift. Under the clear area (25 to 26) sink of the same magnitude and similar humidities (5.1 to 6.1 g kg^{-1}), were found. The driest air found anywhere at this height was midway between points 24 and 25: this was in a localised downdraught, less than 1000 m across, and in the centre r was down to 5.5 g kg^{-1}, Θ was reduced by 0.3 deg C, and the sink was 2 m s^{-1}. The main regions of lift, after the initial climbs, all had humidities between 6.3 and 6.6 g kg^{-1}, and there appear to have been two air masses with little change in potential temperature, but a humidity difference of about 0.5 g kg^{-1} between them. Between points 20 and 21 (fig. 5), the only place where the flight crossed the interface perpendicularly, the humidity jump occurred within 750 m (and a height of 15 m).

Slope of the front

The time of the wind shift at the ground shown by the smoke is known within four minutes. We can also assume that the Red Queen passed through the frontal zone shortly after point 14 before entering cloud. This indicates a slope of the front of about 1200 m in a horizontal distance of about 2000 m, or

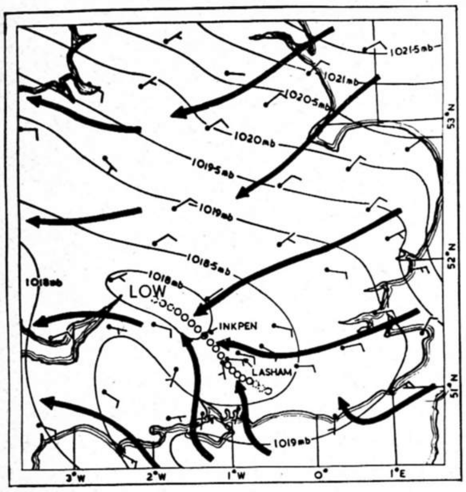

Fig. 4. Surface pressure and winds at 1500 GMT, 11th September 1971. The line of circles marks the convergence zone. The heavy black lines are streamlines.

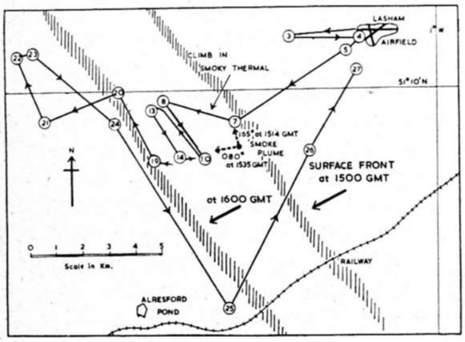

Fig. 5. Sketch map of flight path. The numbers are reference points from the flight log, some of which are referred to in the text.

an angle around 30°. A photograph taken from the air shows a similar slope marked by haze.

Upward motions

If we subtract the measured movement of the front (about 1 m s^{-1}) from the measured drift of the glider when circling above it we obtain a wind relative to it of 3.2 m s^{-1}, and this, blowing up a slope of 30°, would give a vertical velocity of 1.8 m s^{-1}.

Typical thermal velocities to the east of the shearline were not more than 2 m s^{-1} by this time of day, and the greater velocity in the smoky thermal (up to 3.5. m s^{-1}) is attributed to the combination of thermal lift with that due to convergence at the line. The contribution of the thermals would explain the cellular structure found here, whereas the upcurrent found on the longer runs was much smoother. On these runs, the mean vertical velocity of the air was 1.0 m s^{-1} over 11 km.

By the time the run back to the airfield was made (25 to 27, fig. 5), thermals had died. The sink was small but steady, and some return flow feeding it and completing the circulation in a plane perpendicular to the front was shown by the tops of the cumulus at the southeast end of the line which were sheared well to the northeast (fig. 6).

Another shearline

Another shearline with some rather similar features was investigated by several pilots on 16th May 1971, but only a broad outline of it can be given. A cold front had lain for 24 hours almost stationary from Biscay through the Low Countries to South Sweden. A wave depression had developed on this front early on 16th, maintaining cloudy weather over extreme south-west England. Further to the west a ridge extended from high pressure in the Atlantic.

In the evening, north of Reading, there was a convergence zone at least 50 km long. Ron Wright, soaring a glider near Andover, extensively explored a line of strong lift marked by cloud. Further north, Anne Burns soared along the line from Benson to south of Newbury, where she landed at 1800 GMT (Fig. 7), and the line of cloud extended further south-west. Photographs taken at Reading at 1640 GMT show a very distinctive line of cloud, with droopy curtains hanging below. The line at this point was seen to be moving very slowly north-west.

The only evidence for a meso-front at the surface came from Reading, with windshift, temperature and humidity jumps coinciding at 1600 GMT. As on September 11th, the front was not apparent on three sets of autographic records between Reading and the south coast.

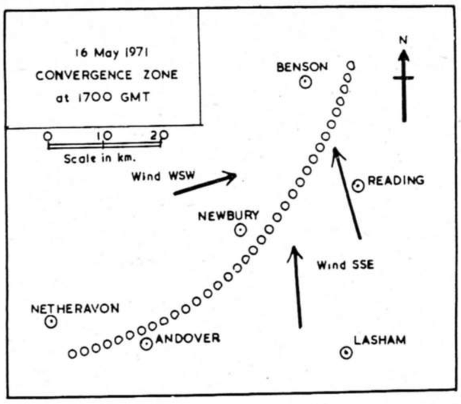

Fig. 7. Position of convergence line (line of circles) at 1700 GMT on 16th May 1971.

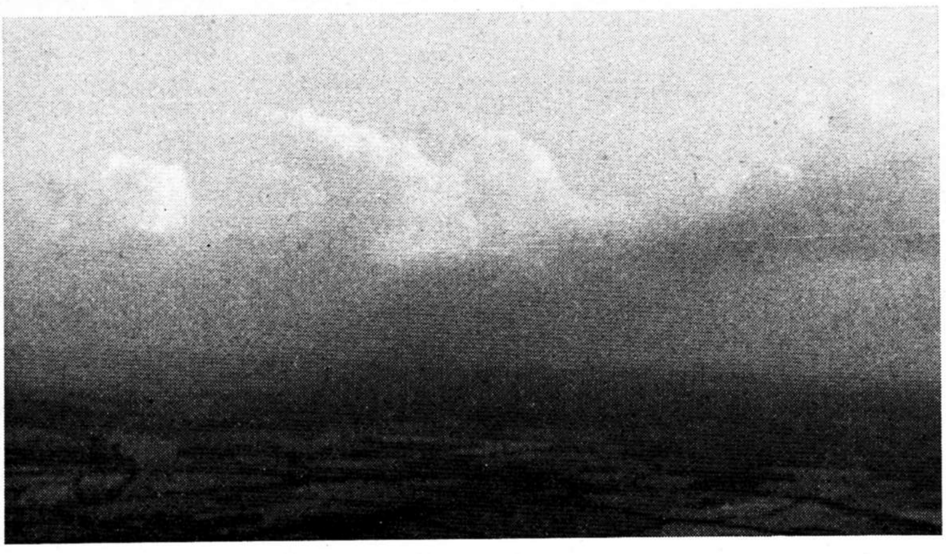

Fig. 6. Photograph showing sheared tops of cumulus at southeast end of the line.

Discussion

The origin of the local discontinuity in winds on 11 September, and possibly that on 16 May seems to have been differential surface heating on a large scale. At least on 11 September the shearline appeared to build up 'in situ'. This has a close parallel to a sea-breeze front forming near the coast, but failing to make any progress inland.

We may expect meso-fronts to form near the edge of persistent cloud cover with strong insolation in an adjacent area, and to have general properties similar to those of sea-breeze fronts, whose orientation and movement are fairly well documented. Although they are mainly of local interest, they are important to glider pilots and others interested in the detection of preferred areas of strong convection. They can also be significant advectors of pollution, and important in localising shower formation.

Significant changes in thermohygrograph traces may or may not be observed at the passage of a meso front (Milford and Simpson, 1972) and indicators of a front may involve lines of lift or cloud above surface convergence, and temperature, humidity or visibility jumps. To keep the language simple we feel it fair to use the term 'meso-front' where any two of these are observed.

References

Milford, J. R. and Whitfield, G. R.: 1970, An instrumented glider for meteorological research. 12th OSTIV Congress, Alpine, Texas.

Milford, J. R. and Simpson, J. E.: 1972, A shearline investigation with an instrumented glider. Weather, 27, 462–473.