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An Airborne Radar Technique for the Investigation and Control of Migrating Pest Insects

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Phil. Trans. R. Soc. Lond. B 1979 **287**, 459-465
doi: 10.1098/rstb.1979.0077

Phil. Trans. R. Soc. Lond. B **287**, 459–465 (1979)
Printed in Great Britain

An airborne radar technique for the investigation and control of migrating pest insects

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A new airborne radar technique has been developed and used during two seasons on three aircraft in Canada, to investigate the source areas, flight behaviour and areas of deposition of migrating insects. The radar measures, records and analyses more than 100 high resolution profiles of insect orientation and absolute density per second, at a spacing of less than one metre of aircraft track. During some 11000 km flown with this equipment in New Brunswick and neighbouring areas, synoptic and small-scale meteorological systems have been traversed and their effects on the flying insects (spruce budworm moths) have been measured.

1. Introduction

There is a need for an integrated approach to understanding and controlling migrant pests. Our unit has had eleven seasons of ground radar experience and two airborne seasons, giving a total of 300 nights of observation to date. Aircraft carrying nets, light traps and radar were all used as identification aids, and the last was helped by the others; a knowledge of what insects were present in the area, and therefore likely to be detected by radar, was particularly helpful. The power of radar as an entomological tool (Schaefer 1976) has now been greatly enhanced by the development of the airborne radar system.

2. The airborne radar technique

The system, based on the same low cost compact Decca marine radar transmitter/receiver used in our recent ground radars for insect detection, was installed in a Cessna 185 of the Canadian Forestry Service (C.F.S.) in 1975, and in a Piper Aztec (chartered for the purpose by C.F.S.) and a DC3† in 1976, with downward-looking conical beams of half-power width 3.5° and 2.4° in these 2 years respectively. Individual budworm could be detected down to the forest canopy from aircraft altitudes of 500 m (1975) and 750 m (1976) above ground, and moths at typical migration densities from altitudes of 1 km and 1.5 km respectively.

The detected echoes were fed to an electronic range gating and processor system. This high-speed device sampled the intensity of the insect echoes at 32 different levels below the aircraft, starting 50 m down and ending approximately at ground level.

The 1976 system was capable of measuring each 32-level height distribution in eight milliseconds (32 ms in 1975). It then averaged 16 successive measurements at each level, to produce smoothed profiles of density and orientation at 32 levels at the rate of 8 per second (1 per second

† Equipped also with Doppler radar navigation and wind-finding systems, chartered by the New Brunswick Department of Natural Resources, and already used during the 1973–5 seasons of field research (Rainey 1975, 1976).

in 1975). At the airspeed of the Aztec (85 m/s), a smoothed profile was obtained every 10 m of travel. Complete intensity profiles were stored on tape at the rate of 128 per second.

The antenna, with diameter of 61 cm (1975) or 91 cm (1976), consisted of a paraboloid fed by a rotating dipole; as with the ground-based radars, the wavelength was 3.18 cm.

Evidence on the orientation of the flying insects was provided by this airborne system. Thus it had been found in 1973 and 1974 that budworm frequently fly with a common orientation or heading (Schaefer 1976). When this happens, the intensity of the received echoes at any particular level below the aircraft will go through maxima and minima as the dipole of the antenna rotates, when the insect bodies are respectively parallel and perpendicular to this common alignment.

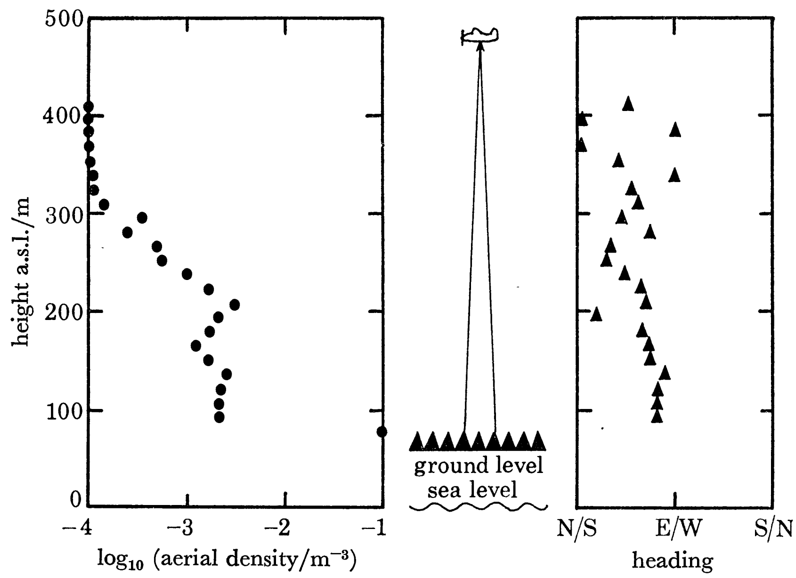

Figure 1. Spruce budworm moth height–density and height–orientation profiles: airborne radar observations stored on tape in aircraft during flight and subsequently processed by computer.

3. Results

(a) *Examples of moth height profiles*

Absolute budworm height–density and height–orientation profiles were extracted by ground computer for each $\frac{1}{8}$ second or approximately 10 m of aircraft track. A sample pair of these profiles is shown in figure 1.

(b) *Area-density of moth along a transect*

On board the aircraft, the density profile was displayed pulse-by-pulse on an A-scope, while a circuit integrated the profile to display the area density of moths per hectare on a strip chart. A 24 minute chart obtained on an Aztec transect of south New Brunswick is shown in figure 2. This trace of absolute area density for the 120 km track was condensed from 3.6 million density measurements contained in 120000 profiles of density, at peak moth take-off time. The higher densities in the first 30 km were associated with unsprayed sources in the Gagetown area just upwind (southwest) from the aircraft track over the St John river, while very few moths were flying over the river marsh area (60–75 km). The aircraft then passed over a concentration of

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moths produced by a sea breeze front (75–87 km) to be discussed below. Finally, very few moths were flying in the foothills of central New Brunswick (120 km). Computer analysis also provided ground contours, while the tape-recorded output of a *PRT*-5 radiation thermometer gave forest canopy temperatures along the tracks.

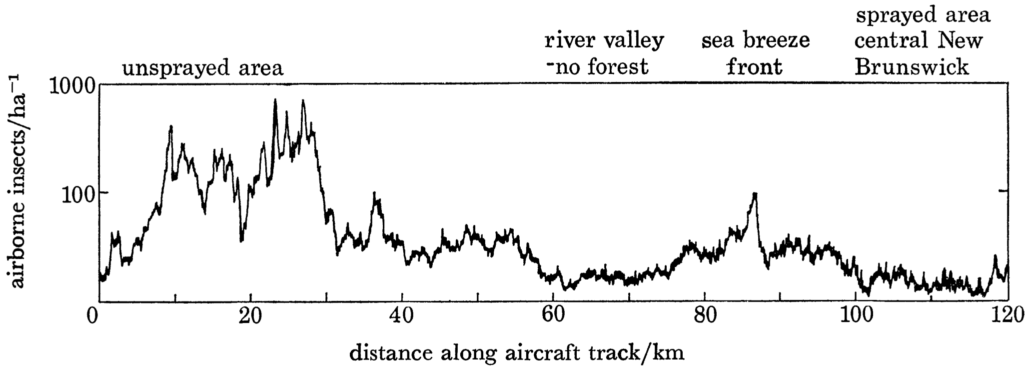

FIGURE 2. Airborne radar transect of south New Brunswick (along ACB in figure 3).

(c) *The sea breeze study of 10 July 1976*

The impressive redistribution of moths by sea-breeze and similar frontal systems (Greenbank, Schaefer & Rainey 1979) observed in 1973, 1974 and 1975 gave rise to an intensive programme to study the origins and effects of such fronts in 1976, including 12 temporary meteorological ground stations added in south New Brunswick by Atmospheric Environment Services. One such front reached as far inland as the ground radar site during the peak migration period, on 10 July 1976.

A low-altitude windfield survey of the south and east coasts of New Brunswick by the DC3 during the afternoon located the advancing sea-breeze front, indicated by a windshift at 15.28 h, from WSW to SW, as the aircraft passed south along the St John River valley (inset to figure 3). At ground level a weak discontinuity in humidity passed northwards during the afternoon and evening at Coles Island and Gagetown. At 21.58 h the ground radar at Acadia detected a weak line echo overhead, just in the process of forming from moths beginning their evening flight on this warm night. It was orientated along 263°/083° (figure 3) and moved northwards with a speed of 4.5 m/s.

At 21.58 h the DC3 began a 10 minute slow climb, from 120 m above ground level, for wind-finding and temperature, humidity and turbulence transects, passing close to the radar (figure 3). A very sharp windshift occurred within a distance of 300 m (small inset, figure 3; figure 4), at a point established by the Doppler navigation system as very closely coincident in time and place with the ground radar observations. Simultaneously, wet and dry temperatures changed abruptly and there was an abrupt onset of turbulence (figure 4).

A slow-ascent radiosonde released at 22.04 h, 4 min after the passage of the front, showed cooler SSW winds below and warmer WSW winds above, with a transition zone from 200–400 m. A jet wind at 50–150 m was overtaking the front at 2.5 m/s.

The changing distribution of moths and the progress of the front were monitored by the airborne radars. The northward flight of the Aztec (AB in figure 3 inset) intercepted the front at 22.09 h (C) about 10 min after moth take-off. The moth area density along this transect is shown in figure 2, where the increased density through the sea breeze front is evident.

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On its approach to monitoring an air-to-flying moth spray trial, which was also in progress at the time, the DC3 again crossed the moth concentration at 22.37 h (figure 3). The absolute moth density across the front at this time is given in figure 4. During the spray-monitoring transects, the DC3 passed over the moth concentration again at 22.47 and 22.55 (figure 3). Finally the Aztec intercepted the concentration at 22.56 on its way back south.

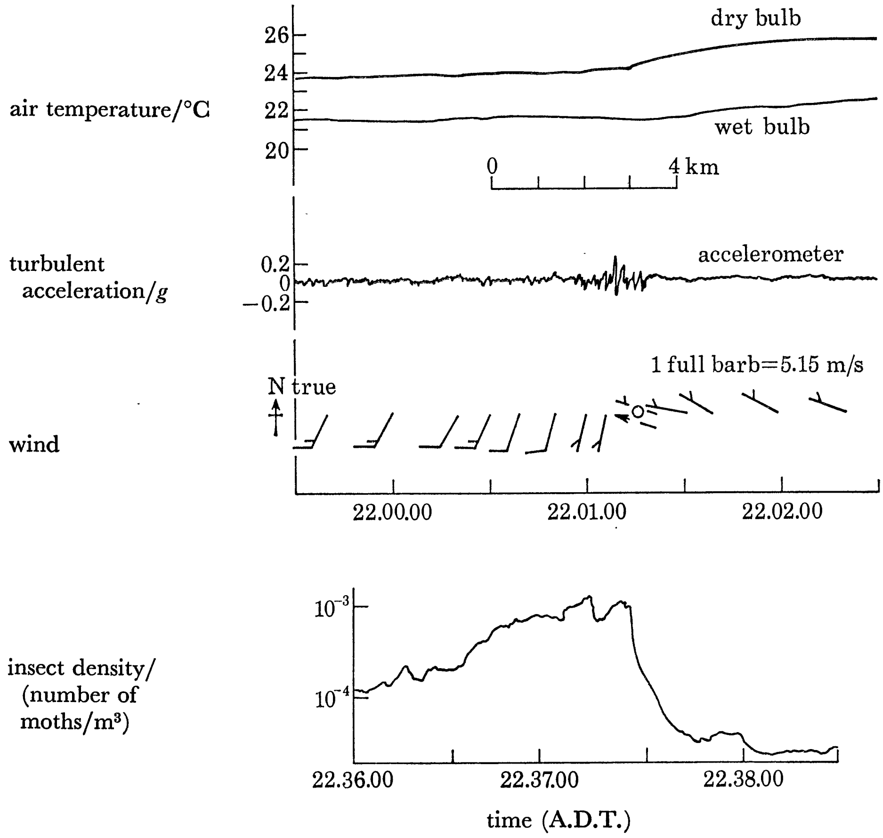

FIGURE 4. Sea-breeze front with moths, 10 July 1976. Also showing insect density on a comparable time scale.

Although the numbers of moths involved in the convergence zone were small on this occasion, the airborne radars collected much quantitative information about the micro-structure of the sea-breeze frontal circulation and the concentrating mechanism. The distribution of moth density and orientation within the convergence zone is presented in figures 5 and 6; the former from the DC3 radar at 22.37 after the front had been collecting moths for about 40 min since moth take-off; the latter from the Aztec radar at 22.09, some 10 min after moth take-off. In this preliminary analysis a low resolution grid has been used (585 m × 30 m for the former; 575 m × 60 m or 120 m for the latter), giving only 2 % of the full detail recorded. The aircraft proceeded from right to left, flying northwards. Absolute density may be obtained by comparing level 5 of figure 5 with its presentation as the bottom trace of figure 4.

The density distribution shows a sharply defined dense nose near ground level, a dense head sloping southward and extending up to 500 m, and a shallow dense layer below 100 m extending well to the south, with the majority of the insects concentrated into a width of 4 km and a height of 350 m. Moth orientation at the lower levels to the north and to the south of the front was

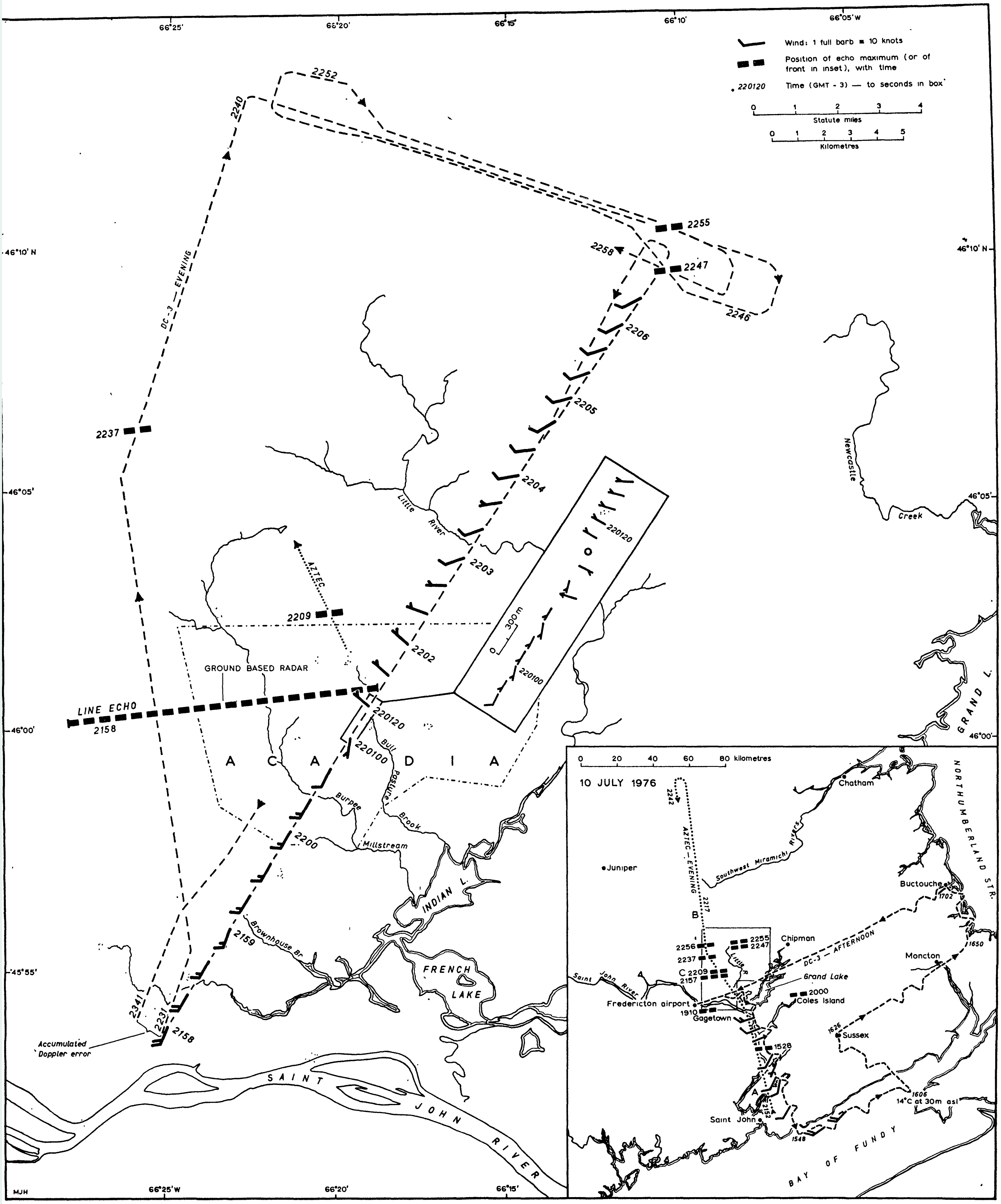

FIGURE 3. Exploration of sea-breeze front and moth concentrations, by aircraft and radar (ground and airborne).

downwind as usual; this was confirmed by reference to the Acadia meteorological tower, the pilot balloon at 22.04 and the DC3 winds at 22.01 (figure 3). The low level dense layer to the south was overtaking the front at 2.5 m/s, meeting with the insects from the northwest at a relative speed of 6.5 m/s. The mixing process can be observed by comparing orientations, densities and head shape in the mixing zone between 0 and 6 km. It is evident that the northward moving insects when overtaking the front surged upwards at the nose and again a few kilometres to the south, at points where the highest densities reached the highest altitudes.

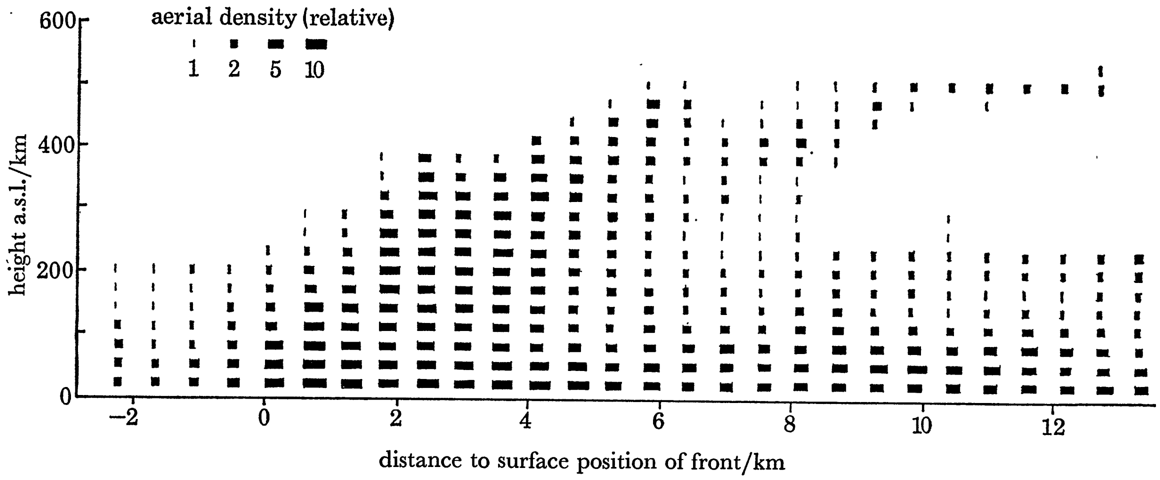

FIGURE 5. Airborne radar traverse of spruce budworm moth density at sea-breeze front, 22.37 h, 10 July 1976.

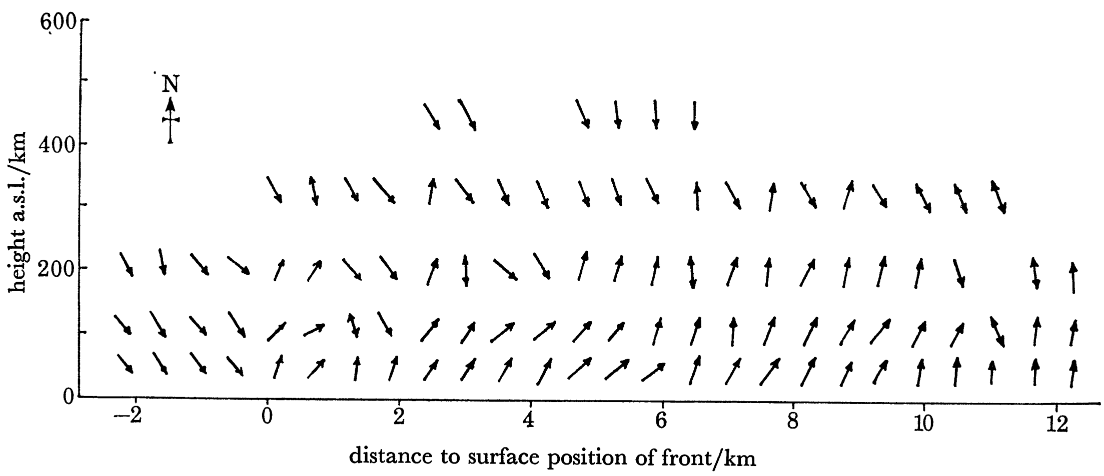

FIGURE 6. Spruce budworm moth orientation in sea-breeze front, 22.09 h, 10 July 1976.

These upsurges were inter-leaved by downward surges of 'northwest' orientation. The shape of the nose and the wave-like form of the top of the head closely resembles the form of density currents in laboratory tanks (Simpson 1969).

An estimation of the absolute flux of moths into the convergence zone from the north and south over the 40 min period accounts for the bulk of the moths present in the 4 km concentration of figure 5. Thus the moths had allowed themselves to be retained, without re-settling, in the turbulent head and transported northwards; with their high teminal velocity they would

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have had opportunities of dropping out of this moderately active system. Moth orientation in the head at 22.37 was nearly random; by then the moths would have circulated around the head several times.

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