Weather radar observations of Underwing moth immigrations to Finland

Matti Leskinen[1], Laura Rojas[2], Kauri Mikkola[3]

[1]*Department of Physics University of Helsinki, P.O.Box 64, FI-00014 UNIVERSITY OF HELSINKI, Finland, matti.leskinen@helsinki.fi*

[2]*Department of Physics University of Helsinki, P.O.Box 48, FI-00014 UNIVERSITY OF HELSINKI, Finland, laura.rojas@helsinki.fi*

[3]*Finnish Museum of Natural History, P.O.Box 17, FI-00014 UNIVERSITY OF HELSINKI, Finland, kauri.mikkola@helsinki.fi*

(Dated: 3 June 2012)

Presenting author
Laura Rojas

1. Introduction

Underwing moths, *Catocala spp*., are large moths with wing spans close to 10 cm. These moths immigrate to Finland occasionally in huge numbers, usually from S-SE assisted by relatively strong warm air currents. We discuss the last two episodes of extensive immigration of these moths in 2003 and 2011, both of which happened in the end of July. On these situations, the only common local species, *Catocala fraxini*, did not yet fly. So the “swarms” of moths in the sky were exclusively long-range migrants.

We use weather radar data from Helsinki in 2003, and from Kerava and Järvenpää in 2011, to see how the moth migration proceeded according to the radar observations. All radars are C-band Doppler weather radars. The Järvenpää radar is the same EEC WSR-81C radar as in Helsinki in 2003, but operated mostly in vertical looking mode. Kerava radar is a dual-polarization Vaisala WRM200 system. Helsinki is located at the coastline, Kerava 20 km, and Järvenpää 30 km inland.

The E-SE wind was probably modified by the coastline to produce a channelling of flow along the coast towards west. This could be seen in the distribution of moths observed at the ground level during these migration episodes (Savijärvi et al. 2005).

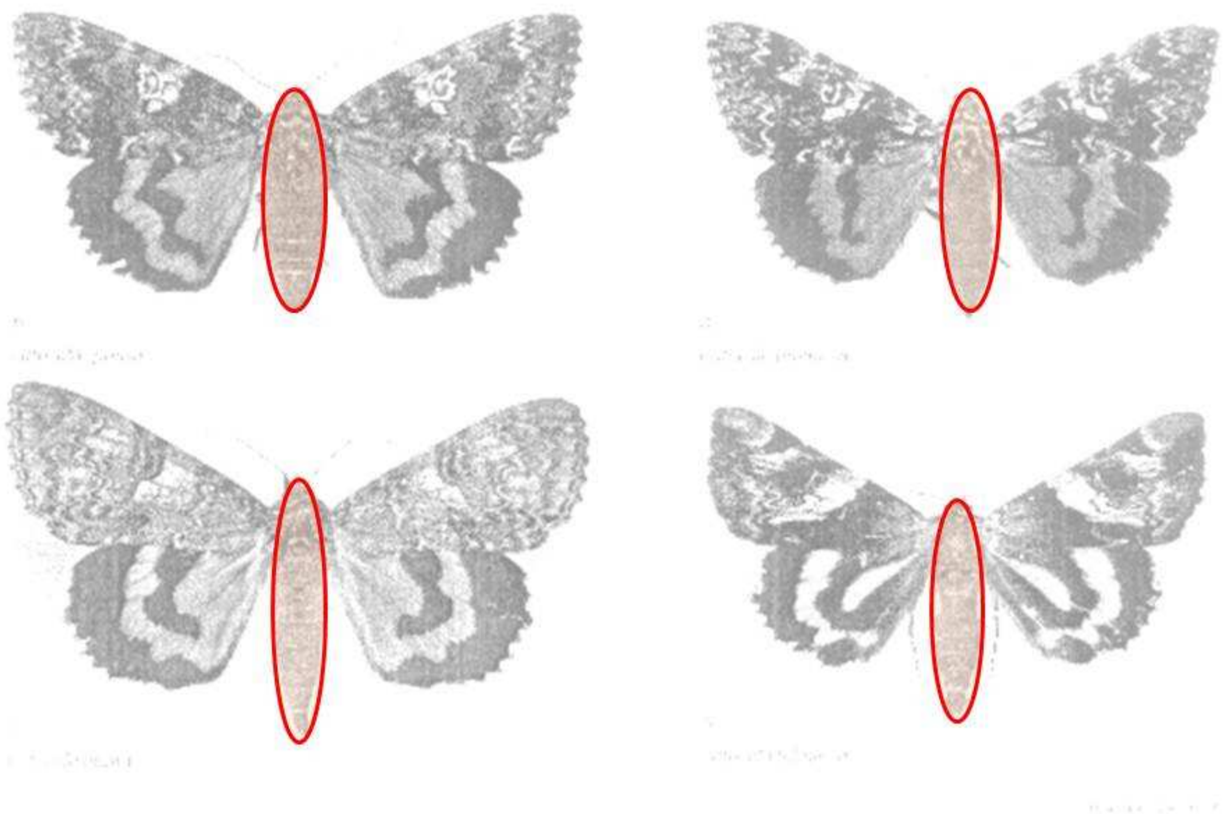

Fig. 1 Underwing moth species that immigrated in 2003(Mikkola 2004), and the approximate oval shapes for the bodies.

2. Migration in 2003

On the 30th of July, 2003, we could observe large insects by the Helsinki radar at high altitudes both during the day and night. Probably Underwing moths were detected as individual targets tens of kilometres away in their layer at 2 to 3 km height in daylight. According to the radar the orientation of insects' bodies was along SW-NE axis in, while the motion relative to the ground was towards NW in the beginning and later to WNW-W. The maximum temperature in Kumpula (Helsinki) was about 29 degrees centigrade, even though the wind was from the nearby sea. The very elongated structure of the moths' bodies (Fig. 1) and their body length being near the wavelength of the C-band weather radars that we use is reflected (really) in the observations. The targets could be detected even at about 40 km ranges, but only in NW and SE sectors, where they were oriented their sides towards the radar. There was a tendency of the moths to fly higher during the day, up to 4 km height, and near the freezing level. The actively flying moths generate heat and it is assumed that the low temperature that they prefer may be optimal for cooling. The solar heating during the day may be compensated by the moths to rise higher. It is important to point out that these insects rise to their migration level by their active flight, partly because of their nocturnal activity and partly because of their flight level being even about twice the height of the convective daytime boundary layer.

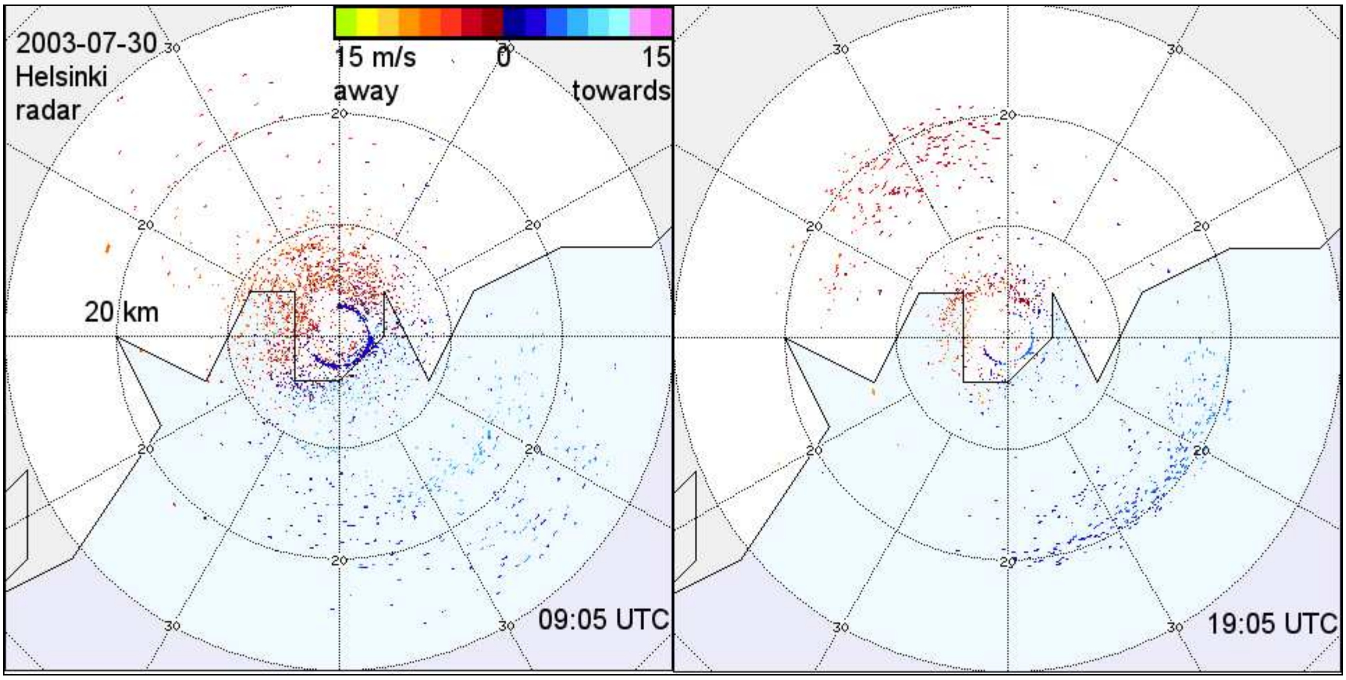

Fig. 2 Helsinki Doppler weather radar PPI scan 2003-07-30 09:05 and 19:05UTC. Radial velocity at 8 degrees elevation angle, at 20 km distance the height of the beam is 2.8 km. Large insects with obvious common orientation along SW-NE axis are found during the day at 2-4 km and during the night at 2-3 km altitude moving towards WNW about 10 m/s.

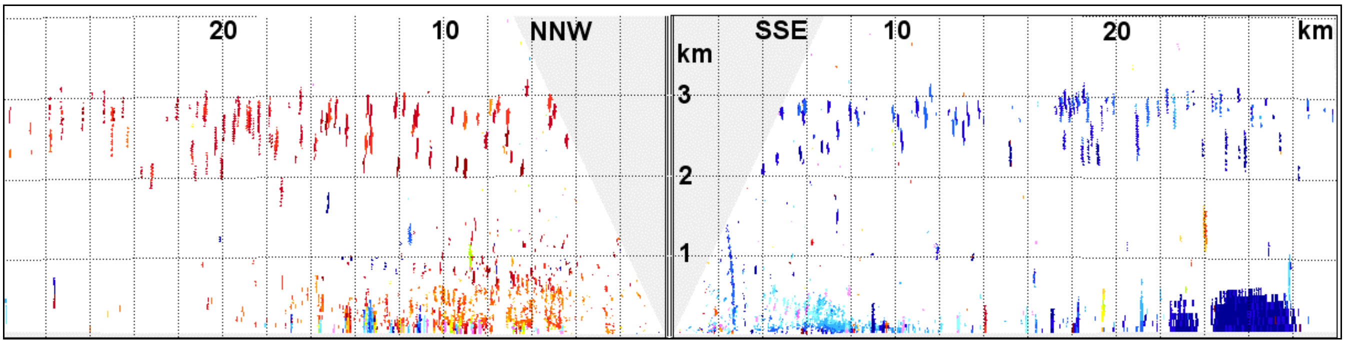

Fig. 3 Helsinki Doppler weather radar RHI scans 2003-07-30 19 UTC. Radial velocity: red colours away from and blue colours towards the radar. Really large insects at 2 to 3km altitudes, smaller ones below 1.5 km but more over the land side (NNW), sea-clutter near the surface 22 to 26 km in SSE.

3. Migration in 2011

Lepidopterological observations set the main immigration period of the moths in 2011 from the 22nd to 23rd of July. The surface temperature in Järvenpää reached 31 degrees centigrade on the 22nd, and in Kumpula 28 degrees. The radars showed mass migrations of insects from E-SE, and early in the morning on the 23rd large insects were observed up to 3 km height. The migration was towards WNW-NW with maximum speed of around 20 m/s before heavy rain in the afternoon on the 23rd. The migration continued in the evening from SE-SSE, until the wind direction gradually turned to westerly during the next night.

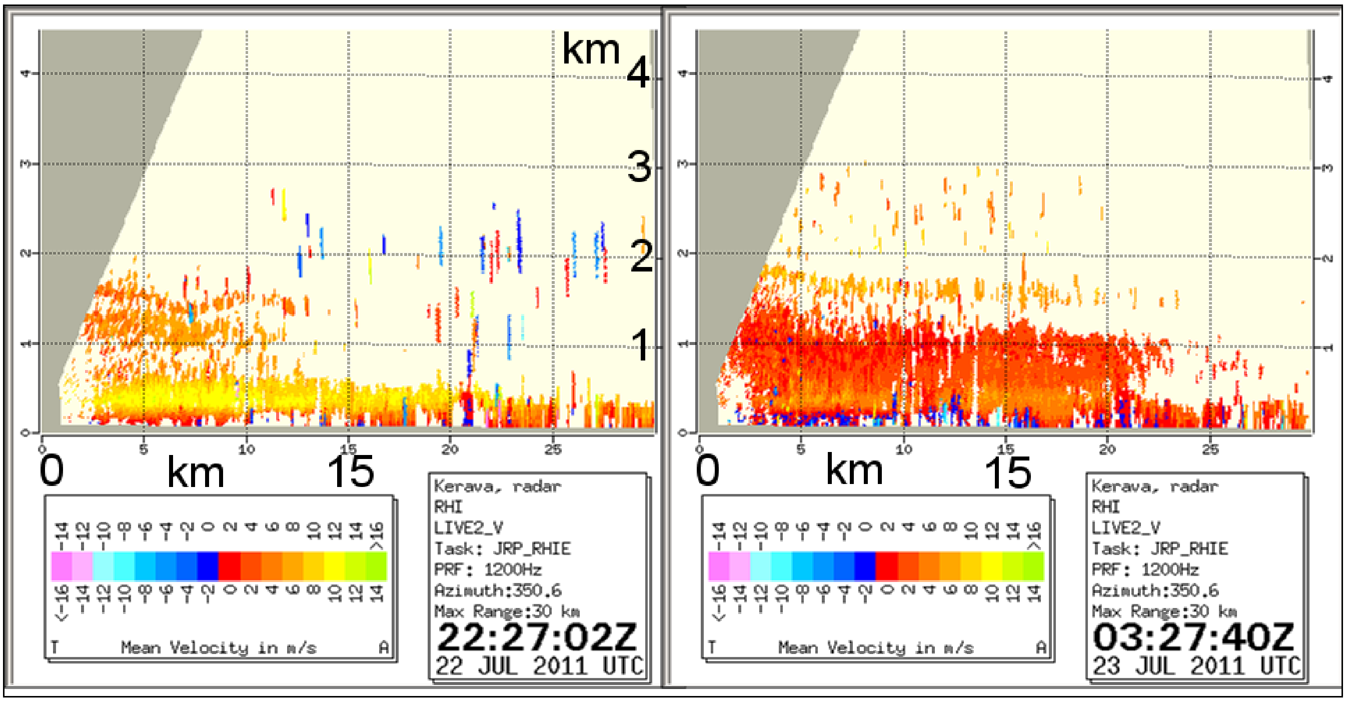

Fig. 4 Kerava radar RHI scans 2011-07-22 22:27 UTC (at midnight) and 2011-07-23 03:27 UTC.

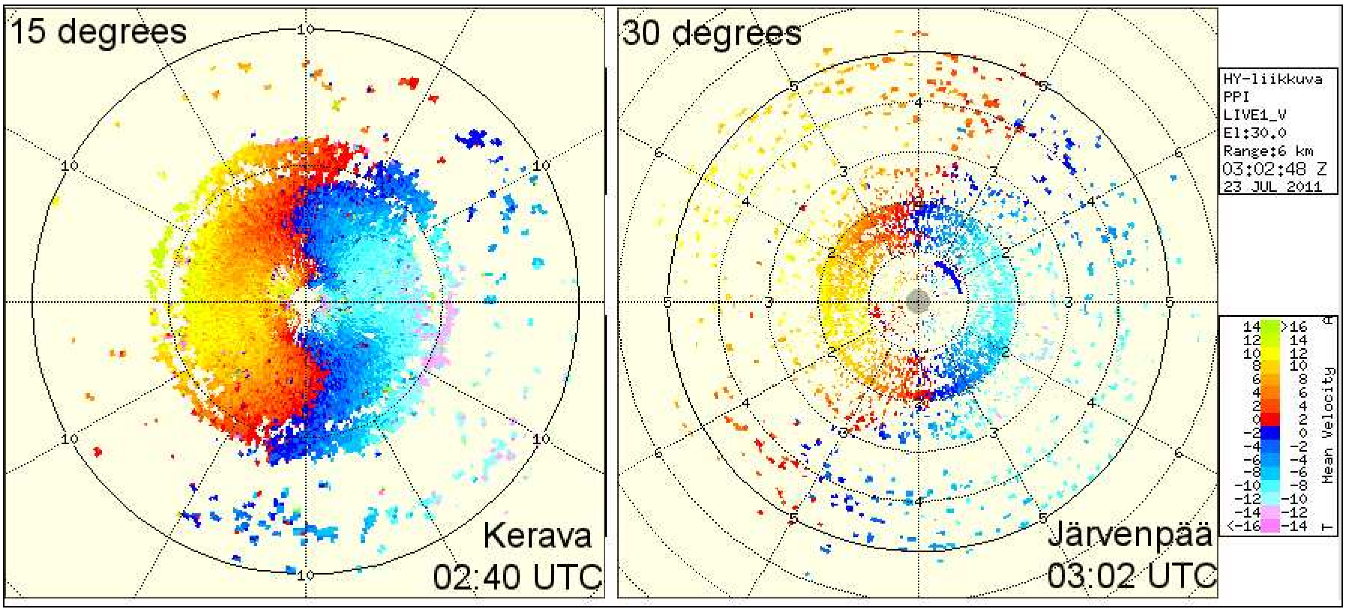

Fig. 5 Kerava and Järvenpää radar radial velocity PPI scans at high elevation angles 2011-07-23 around 03 UTC. Distance rings 5 and 10 km in Kerava and 1 to 6 km in Järvenpää.

The maximum detection range of the targets 03:27 UTC at 2-3 km height is about 20 km. The sensitivity of Kerava radar may be about the same that Helsinki radar in 2003, even though the dual-polarimetric Kerava system used simultaneous transmitter mode in these scans, causing an extra 3 dB reduction in transmitted pulse level. The targets may not be as optimally oriented as in Fig. 3. At 22:27 UTC the strongest targets are birds, probably swifts that get to the high level layers during the night to rest.

The high elevation PPI scans made both by Kerava and Järvenpää radars have quite short ranges, and individual insects can be seen. The velocity scale is the same in the images. The Kerava radar measurement is in fact a dual-PRT mode scan, and that may reduce the number of single targets in the output. Both radars show the low layer of insects below about 1 km in westward movement. The single large insects are seen in the PPI in Järvenpää quite well between 2 and 3 km altitude, and in the middle layer large insects are detected as single scatterers as well. The large insects in the high layer are moving towards WNW-NW 15-17 m/s.

Usually the Järvenpää radar is used in vertical looking mode. Very short time of this is dedicated to high temporal resolution measurements of the echoes. In practice 8 pulse samples with 1100 Hz pulse repetition frequency is used and the sampling time span makes it possible to record wing beat related variations of echoes caused by birds and large insects. An example of the echo signature of probably a large insect is seen in Fig. 6. As a comparison a similar track of a bird, most probably a swift is shown in Fig. 7. The relative altitude in these figures is calculated according to the measured vertical speed.

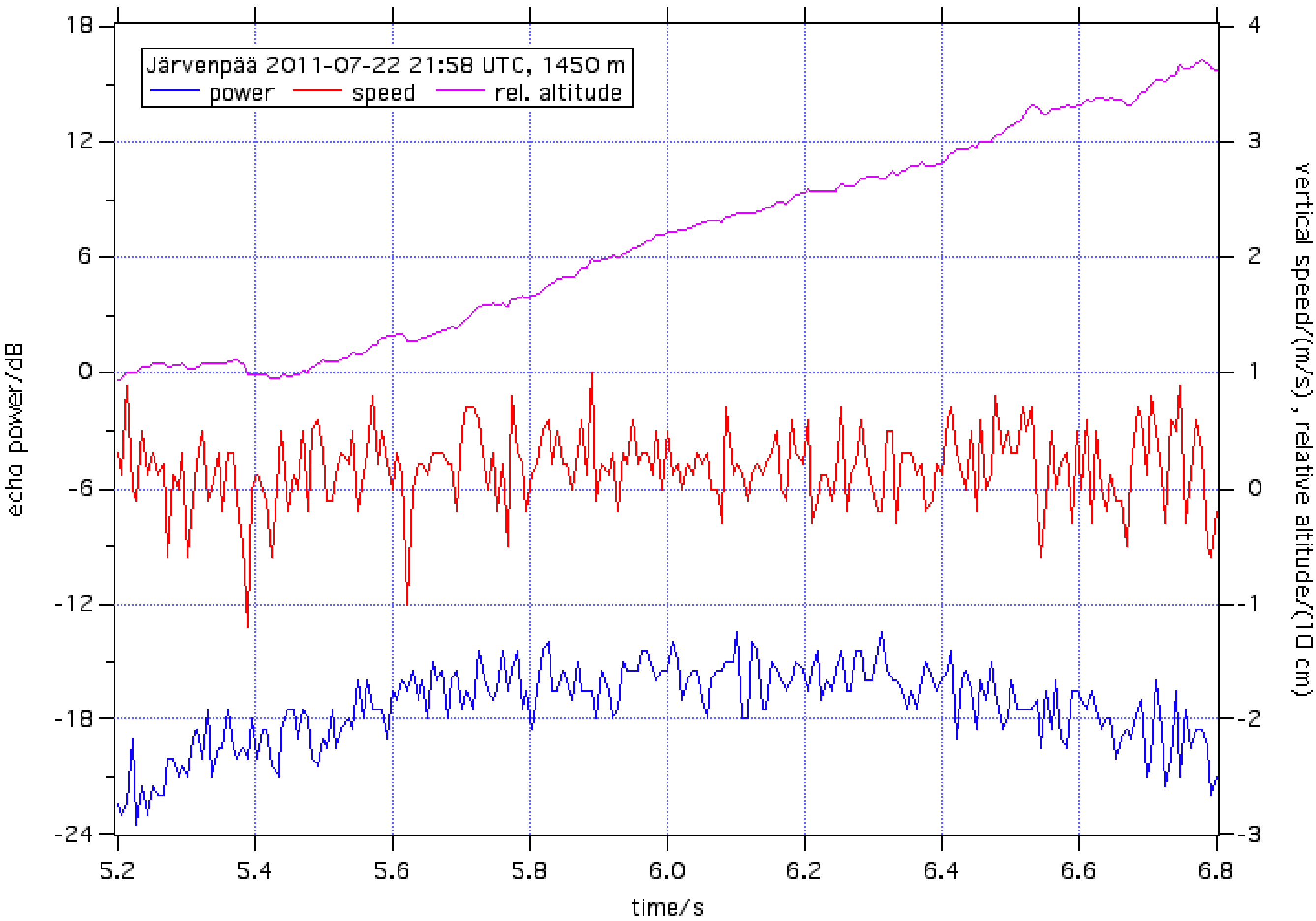

Fig. 6 Järvenpää vertical looking Doppler weather radar echo signature 2011-07-22 21:58 UTC (at midnight) at 1450 m altitude. Probably a large insect, the variation in echo power and vertical speed may show the wing beat rate, a climb of 35 cm is observed in 1.4 second of the recording

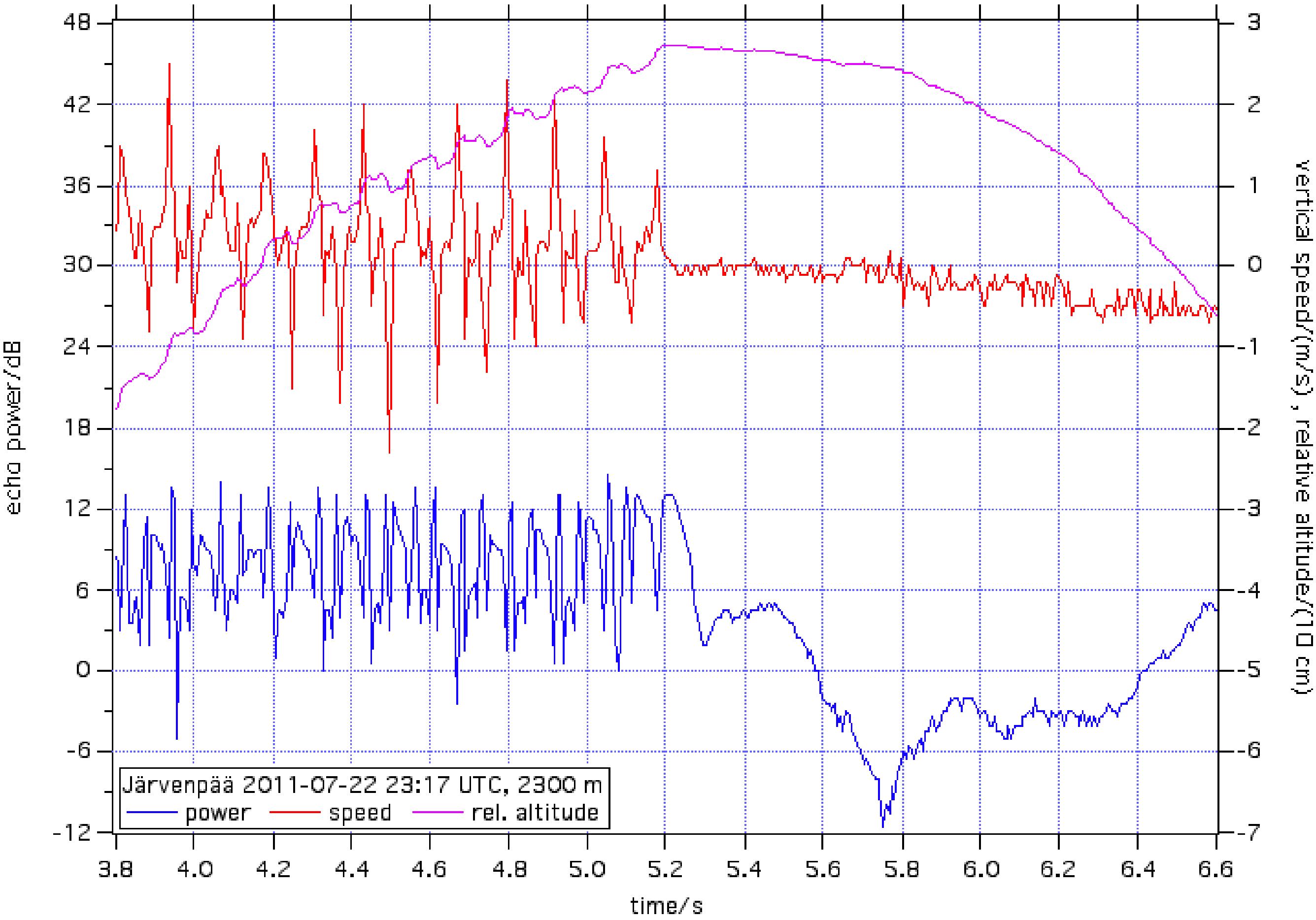

Fig. 7 Järvenpää vertical looking Doppler weather radar echo signature 2011-07-22 23:17 UTC. Probably a swift (Apus apus) first in flapping flight rising 45 cm, and then changing its course.

3. Conclusions

There are no problems for the weather radars to detect Underwing moths in the air. In our cases the moths seemed to fly above 2 km, not in a very dense cloud but forming a rather uniform layer anyway. The nocturnal nature of the insects in their take-off for migration means that they get to the migration height by their own flight, and even during the day they may fly above the atmospheric boundary layer. In 2003 the layer top was higher during the day, which may be related to the moth's need for cooling its body temperature in sunshine. Polarimetric quantities of the echo signals together with signal variations may be used to some form of identification of the moths by radar.

References

Mikkola, K., 2004: Sää ja hyönteisten vaellukset 2003 (abstract in English: The weather and insect migrations in Finland in 2003). Baptria, 1/2004, 22-27.

Savijärvi H., Niemelä S., Tisler P., 2005: Coastal winds and low level jets: Simulations for sea gulfs. *Quarterly Journal of the Royal Meteorological Society*, **131**, 625-637.