Channelling effect of the coastline and radar observed insect migration

Matti Leskinen[1], Hannu Savijärvi[2], Susanna Lautaportti[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, hannu.savijarvi@helsinki.fi*

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

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

Presenting author
Susanna Lautaportti

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Fig. 1 The Kumpula weather radar 350 km surveillance range, and weather radars in Helsinki area. The city centre is shown by the location of the first Finnish Doppler weather radar (H). The current systems operated by the University of Helsinki are in Kumpula (KUM) and Järvenpää (HYL). The Finnish Meteorological Institute operational radar is in Vantaa (VAN), and the Vaisala Ltd research system in Kerava (KER).

1. Introduction

The coast of the Gulf of Finland (Fig. 1) causes a channelling effect in easterly and south-westerly winds according to mesometeorological model simulations (Savijärvi et al. 2005). The created maximum of the flow along the coastline westwards may modify the distribution of migrated large insects, and lepidopterological observations have shown more immigrants along the coastline than far inland. Insect migrations may occur in winds from SW as well, and in these cases the migrants may cross the entire Baltic Sea, hundreds of kilometres above water (Nieminen et al. 2000). Channelling effect of the SW winds helps insects to reach more easterly locations along the Finnish coastline. On the other hand sea-breeze fronts developing during the day have strong effects on insect migrations. The front blocks the migration across the sea at the lower altitudes while the higher level migration above the sea-breeze continues (Gahmberg et al. 2010). The congregation of insects into the sea-breeze front area by the convergent lower boundary layer flow, and updrafts in the front cause several interesting modifications to the migration paths as well.

We compare the atmospheric model results to the Doppler weather radar observations of the University of Helsinki in some migration cases. The radar echoes are in fact mostly caused by the migrating insects themselves, but mostly by insects that follow the air current without much influence by their own flight speed. We discuss the modelled and observed features of the flow. Our special emphasis in this study is the channelling and other local wind features related to the Gulf of Finland, and how they affect the immigration of insects.

2. Wind field modification by the Gulf of Finland

The University of Helsinki 2D mesometeorological model, UH-2D, has been used in simulations of meteorological phenomena in the Gulf of Finland area (e.g. Savijärvi et al. 2005, and Gahmberg et al. 2010). Doppler weather radar of the University of Helsinki has been available since 1984, until 2004 in the Helsinki city centre, and since 2005 in the Kumpula Campus about 4 km north. Both of these radar locations are very near the coastline. The radar surveillance area and weather radar locations in the Helsinki area are shown in Fig. 1.

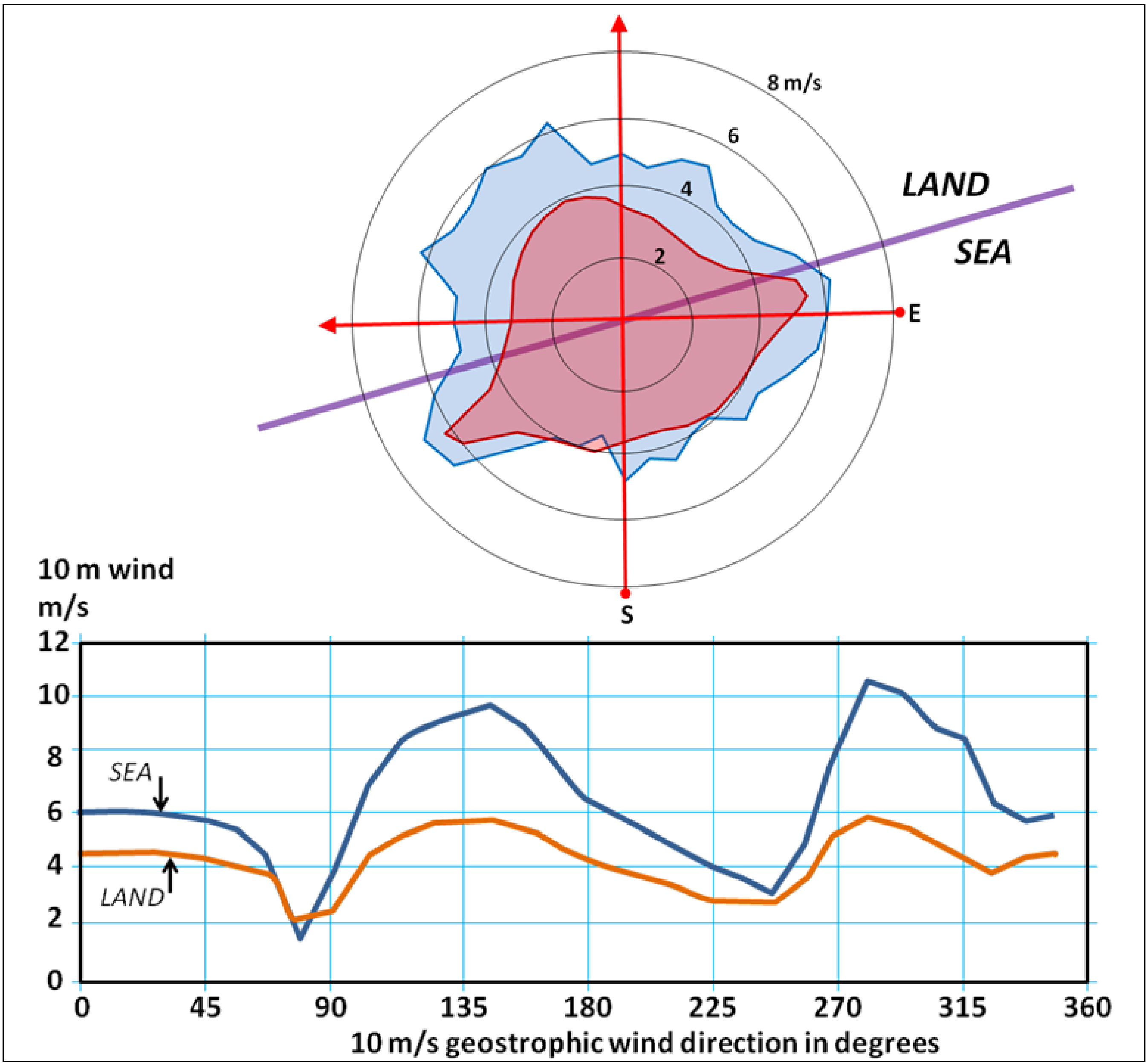

Fig. 2 Mean wind speed at Finnish coast of the Gulf of Finland and UH-2D model simulations at 15 hours local time. The top graph shows the observed mean wind at Isosaari (blue line) and the UH-2D model simulated 10 m level speed (red line). Isosaari is about 10 km to the sea from Helsinki city centre, and the model point is 3 km of the coastline to the sea in

overcast situation with 10 m/s geostrophic flow. The bottom image shows the model simulations in clear sky situation in points 3 km from the coastline on land on sea. (Savijärvi et al. 2005)

Channeling effect can be seen in surface wind observations. Figure 2 shows the surface mean wind speed for May-June 1999-2003 in Helsinki Isosaari, 10 km SSE from the city centre (Fig. 1). The simulated 10 m level wind speed by UH-2D model in test runs using various directions of the geostrophic wind speed of 10 m/s in overcast situation is shown in the same figure. The overall pattern is quite similar to the observed surface wind. The large scale orientation of the coastline is added to the figure, and the observed maxima are seen in the SW and E sectors, slightly to the south of the along the coast direction. The UH-2D model simulations in clear sky conditions with varying geostrophic wind directions for a 10 m height wind speeds 3 km off the coastline over land and over sea are seen in the lower graph of Fig. 2. In clear sky conditions the sea-breeze circulation is modifying the channelling effect compared to the overcast case.

3. Insects with westerly winds

The UH-2D model simulation of afternoon wind components is shown in Fig. 3. The maximum wind speed along the Gulf is observed over the sea, and would be near the Finnish coast in the Gulf of Finland case. The perpendicular wind component has a maximum of about 5 m/s to the left below 500 m. This would be a sea-breeze cell over Finland, and another sea-breeze cell is formed over the Estonian side.

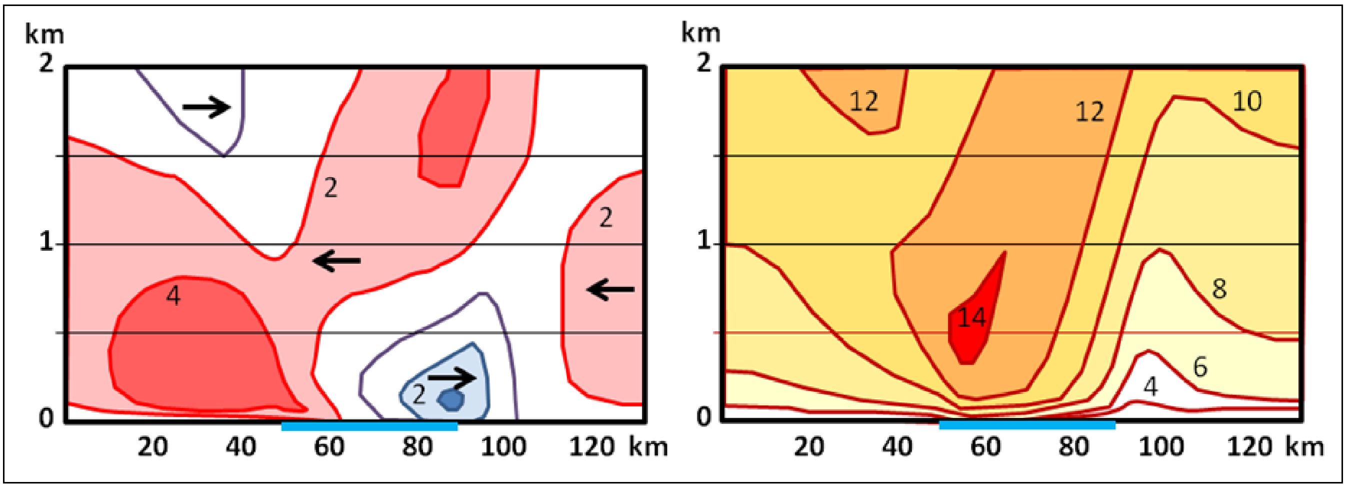

Fig. 3 The UH-2D model in clear sky situation with 10 m/s geostrophic wind towards east (along the" Gulf") at 15hours local time. The vertical cross-section of wind components in m/s, the 2D model plane parallel wind component on the left and the perpendicular component (into the figure) on the right. The sea surface position is shown by the blue bar. (Savijärvi et al. 2005)

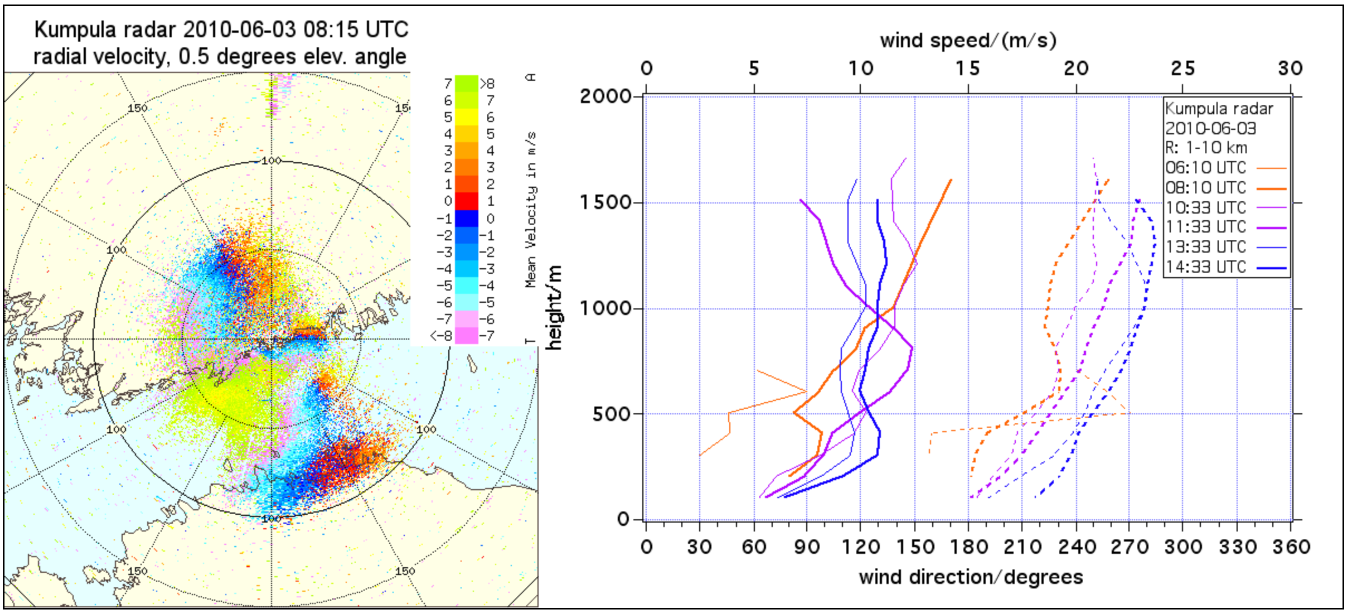

Fig. 4 Insect migration 2010-06-03 in westerly winds. Kumpula radar radial velocity PPI 08:15 UTC and wind soundings (VVP) using data from 1 to 10 km range, solid lines for speed and dashed lines for direction.

On the 3rd of June, 2010, significant amount of insects were migrating in flows from SSW-W. Figure 4 shows Kumpula radar wind soundings. The first measurement at 06 UTC did not have much insects, but still some remains of probably nocturnal migrants over the sea and reluctant to land in the cooler air below. After the morning take-off period the number of insects increased rapidly over the land areas, and insects started to arrive from SSW-SW over the sea as well. The insects are seen to move over the Gulf of Finland from Estonia towards ENE, but the radial velocity structure over the sea show a more NW directed flow, presumably height difference and sea-breeze onset may be affecting. The vertical cross-sections are shown in Figure 5 at around 11:25 UTC, already at this stage the upper wind direction starts to be from the land side.

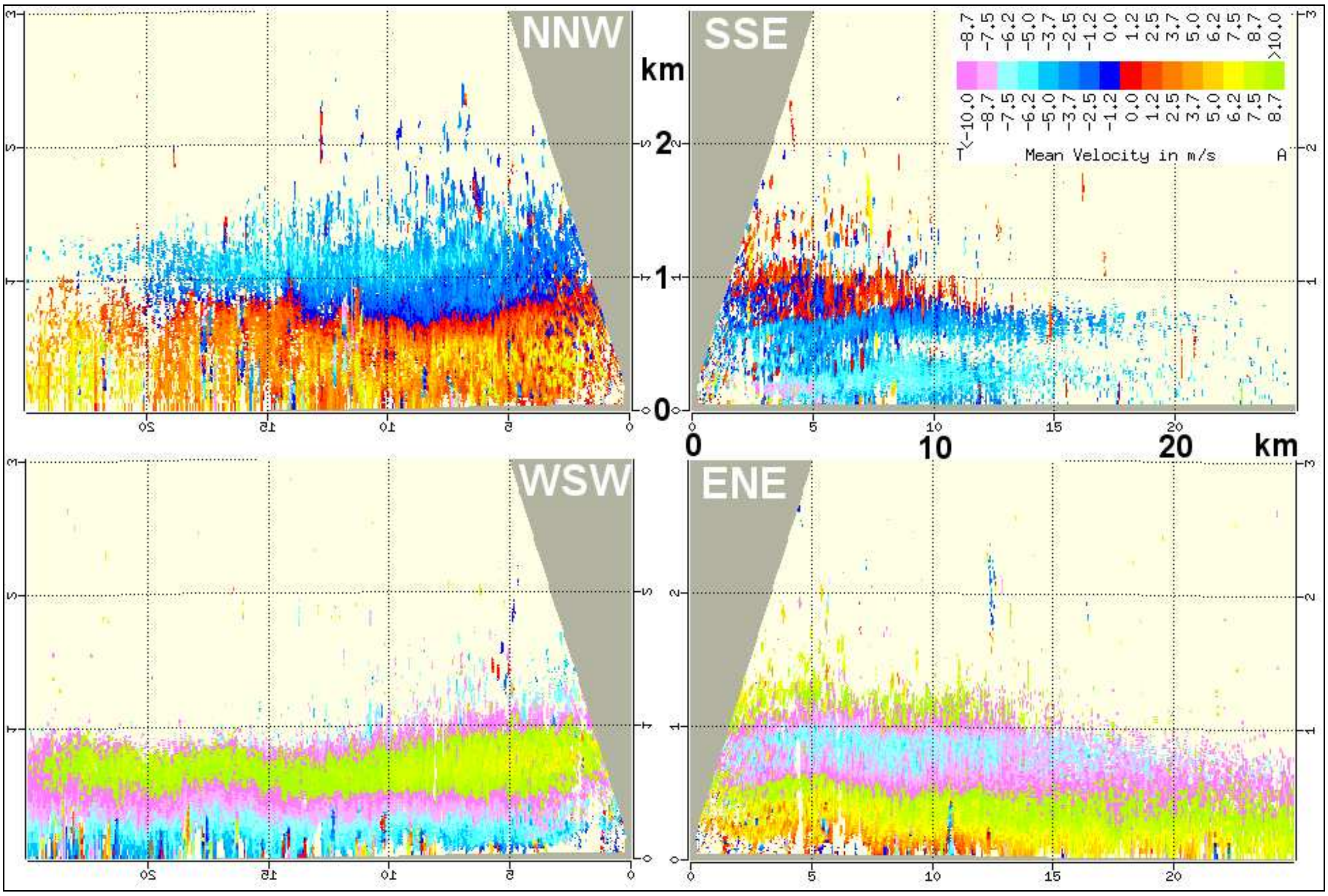

Fig. 5 Insect migration 2010-06-03 in westerly winds, Kumpula radar RHI images 11:25 UTC. Radial velocity perpendicular to and along the coastline, notice aliasing in WSW and ENE maxima 0.5-1.2 km height (about 13 m/s).

4. Insect migrations from SE sector

Cases are of interest to very many entomologists. Mikkola had collected many cases where moths or butterflies migrated into Finland during 1994-2003, and classified some of the episodes further to predominantly along the coast immigrations. Marja-Liisa Ahtiainen made her M.Sc. thesis in 2006 studying the observed immigrations and channelling of the winds by the Gulf of Finland, utilizing surface weather stations, and reports of Helsinki radar observed insect migrations by Leskinen (available in the web since 1997). In her study the channelling of SE flow was seen in most of the cases were the insects were found predominantly in the coastal region, but many cases had winds from east or SW, not the desired source direction in her study. However, as pointed out already, the SW flow migrants have travelled long distances above the water and may eagerly come down when they reach the Finnish coastline. On the other hand easterly flow at the surface is related to strong channelling of the upper SE-ESE wind in the Gulf of Finland region. Therefore both of these cases are logical situations for insects to be found at the coast rather than far inland.

One of the Mikkola's original periods for a coastal immigration was 1997-08-29. This case was studied by Savijärvi et al. (2005) using the HIRLAM, limited area numerical weather prediction model. The migration case by radar observations was already reported near real-time by Leskinen in the web, including Helsinki radar wind soundings of this episode. Figure 6 shows HIRLAM model cross-section perpendicular to the coastline at Helsinki at 12 UTC, and the radar wind soundings, a few hours earlier. The radar winds show a maximum below 1 km level, and the absolute value is not much different from the model along the coast component. Already in 2003 the operational higher resolution numerical weather prediction models could quite correctly get channelling features forecasted, but at the time of the migration in 1997 the operational forecast model was still underestimating wind speeds in these situations, which was verified by Ahtiainen's study.

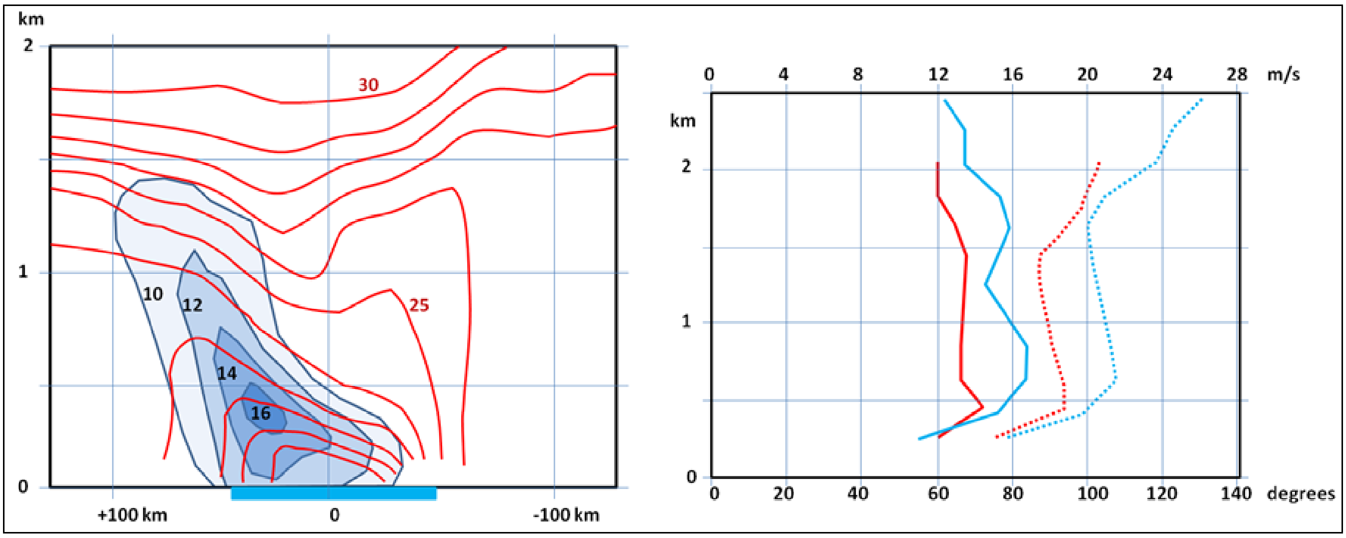

Fig. 6 Insect migrations in easterly winds 1997-08-29: HIRLAM model 12 hour forecast at 12 UTC on the left and Helsinki Doppler weather radar wind soundings on the right. HIRLAM vertical cross-section close to Helsinki perpendicular to the Gulf of Finland coastline, coast parallel wind speed in m/s in blue (to WSW, out of the figure) and potential temperature in degrees in red (Savijärvi et al. 2005). Radar winds: red curves at 05:55 and blue curves at 08:25 UTC, speed with solid and direction with dashed curves.

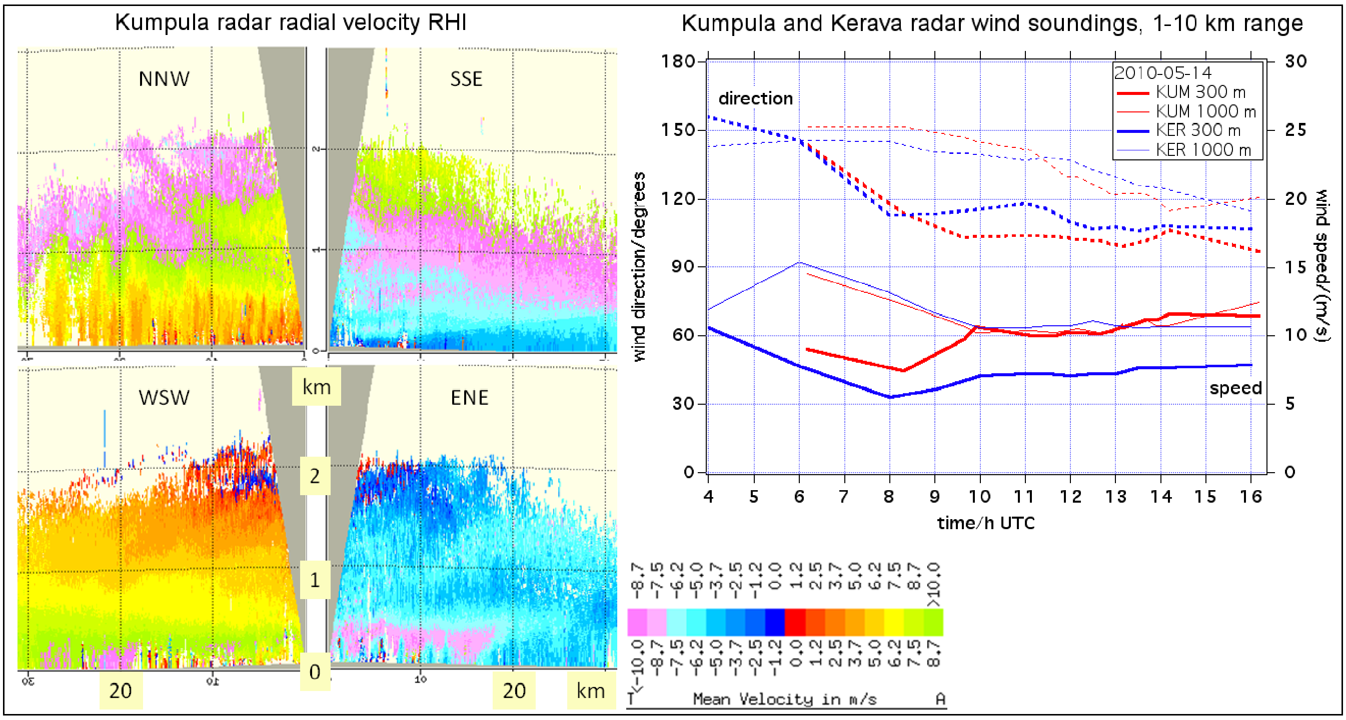

Fig. 7 Insect migration 2010-05-14. Kumpula radar vertical cross-sections of radial velocity 12:20 UTC approximately perpendicular to the coastline (NNW and SSE) and along the coastline (WSW and ENE),(NNW and WSW mirrored) on the left, and on the right Kumpula and Kerava radar determined winds at 300 and 1000 m height using 1 to 10 km ranges. Radial velocity aliasing (above 10 m/s) in NNW and SSE at higher levels, and in WSW and ENE close to the surface.

Another case of mass migration of insects from SE sector is shown by radar measurements in Figure 7. Kumpula radar vertical cross-sections of radial velocity were made approximately perpendicular to and along the coastline, and the along the coastline low level maximum is seen in the radial velocity even below 300 m height. There is also a big difference in boundary layer circulation between land and sea, the RHI to NNW has a lot of convective rolls that modify the velocity field. Figure 7 shows further on the right time evolution of radar determined wind by Kumpula radar near the coast and by Kerava radar about 20 km inland. Thick lines show the 300 m and thin lines 1000 m height wind soundings based on multiple elevation angle PPI scans of the echoes between 1 and 10 km range from the radars. In Kumpula the lower level winds equals the upper level wind after midday, while in Kerava the lower level wind speed remains slower. The wind direction in Kumpula gets more easterly at the same time, and the radar is showing the typical features of channelling.

5. Discussion

The channelling of wind in the Gulf of Finland area is a phenomenon that affects insect migrations. We have shown that Doppler radar observations verify the modelling results. Modern high resolution numerical weather prediction models can have realistic channelling effect in their output, and in addition to the meteorologists the model outputs could be used by entomologists as well. A more detailed modelling of insect migrations by an atmospheric dispersion model (Leskinen et al. 2011) may become a standard procedure at some point, but more knowledge on the actual migration habits of insects is needed for really accurate forecasts. Radar observations of insects migrations can provide nowcasting in these cases, but their main impact at the moment seems to be in improving our understanding in both the meteorology and biology of the long-range migrations.

Acknowledgment

Marja-Liisa Ahtiainen made the first analysis of the cases.

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