P4.9 **THE SEVERE THUNDERSTORM OUTBREAK IN FINLAND ON 5 JULY 2002**

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1. INTRODUCTION

On 5 July 2002 a fast propagating severe bow echo formed over Eastern Finland causing wind damage in exceptionally vast areas. The Emergency Response Centre received nearly 400 thunderstorm-related reports at different locations (Fig.1) during a 6-hour period. According to the Finnish Forest Research Institute (Lipponen and Pouttu, personal communication 2003) the total volume of fallen trees was about 1 million cubic meters. The major axis length of the wind damage area in Finland was 450 km meeting the criteria of a derecho (Johns and Hirt 1987).

The 5 July derecho developed in front of a short wave trough within a warm air mass close to a meridionally oriented frontal zone. The derecho had similarities to both progressive and serial derechos (Johns and Hirt 1987). Evans and Doswell (2001) called this kind of derecho a hybrid which forms within the warm air mass (serial type) but propagates fast near the frontal zone and whose line orientation is perpendicular to the mean flow (progressive type).

Derechos have been mainly documented in the North America, but recently also in Europe (Gatzen 2004). As far as the authors know, the 5 July 2002 case is the highest latitude derecho that has ever been documented.

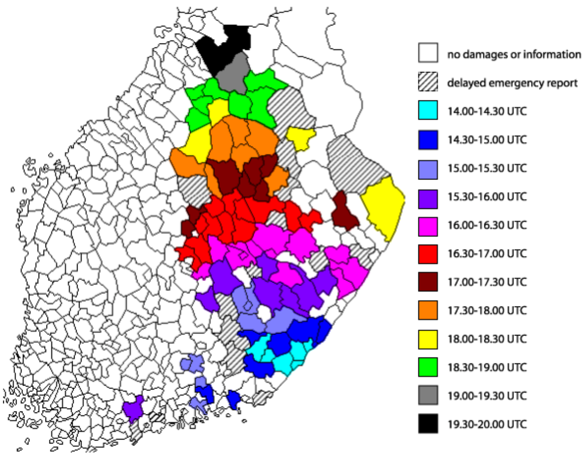

FIG. 1. Wind damage reports of fallen trees in southern half of Finland on 5 July 2002. The first report in each municipality was used in the analysis.

2. THE SYNOPTIC SETTING

On the previous day, 4 July, an upper level low was situated over the Norwegian Sea and a 300 hPa short wave through was moving from Central Europe towards the Baltic Countries. In lower troposphere the area of warm humid air mass stretched from Eastern Europe northward and low centre was moving north along the Baltic Sea. Another severe bow echo with damaging winds developed on 4 July in the warm sector and traveled from Lithuania over Estonia to Southern Finland, where it weakened. During the night the surface low continued its movement northward and a warm front with heavy precipitation propagated from southern Finland to Lapland.

During 5 July the upper trough moved from Poland to Estonia (Fig. 2) where a secondary low developed in the vicinity of the frontal boundary. The low moved slowly north and in the early afternoon some isolated thunderstorms developed in eastern Estonia close to it (Fig. 3). According to the morning surface observations, a weak pre-frontal convergence zone may have been present in the area of the first thunderstorms. The thunderstorms started to organize as a bow echo as they moved over the Gulf of Finland. The convective system moved from south-southeast to north-northwest on the eastern (warm) side of the quasi-stationary front away from the secondary low (Fig. 4).

The bow echo propagated along 850 hPa θ_e ridge with a speed that was close to the maximum wind throughout the troposphere. Thus, this speed was greater than the mean wind in the troposphere which Johns and Hirt (1987) found to be typical for warm season derechos. The southerly mid-level jet was around the 700 hPa height and it was located in the vicinity of the bow echo track (Fig. 5). According to ECMWF model (analysis) data the temperature advections throughout the troposphere were weak in the warm sector. In this case low level warm advection, that is typical for the derecho genesis region (Johns et. al. 1990), was not found. However, the accuracy of model (analysis) data could not be verified due to the coarse sounding network. It should be emphasized that in the vicinity of the frontal zone only a minor change of the wind direction could significantly affect the amount of temperature advection.

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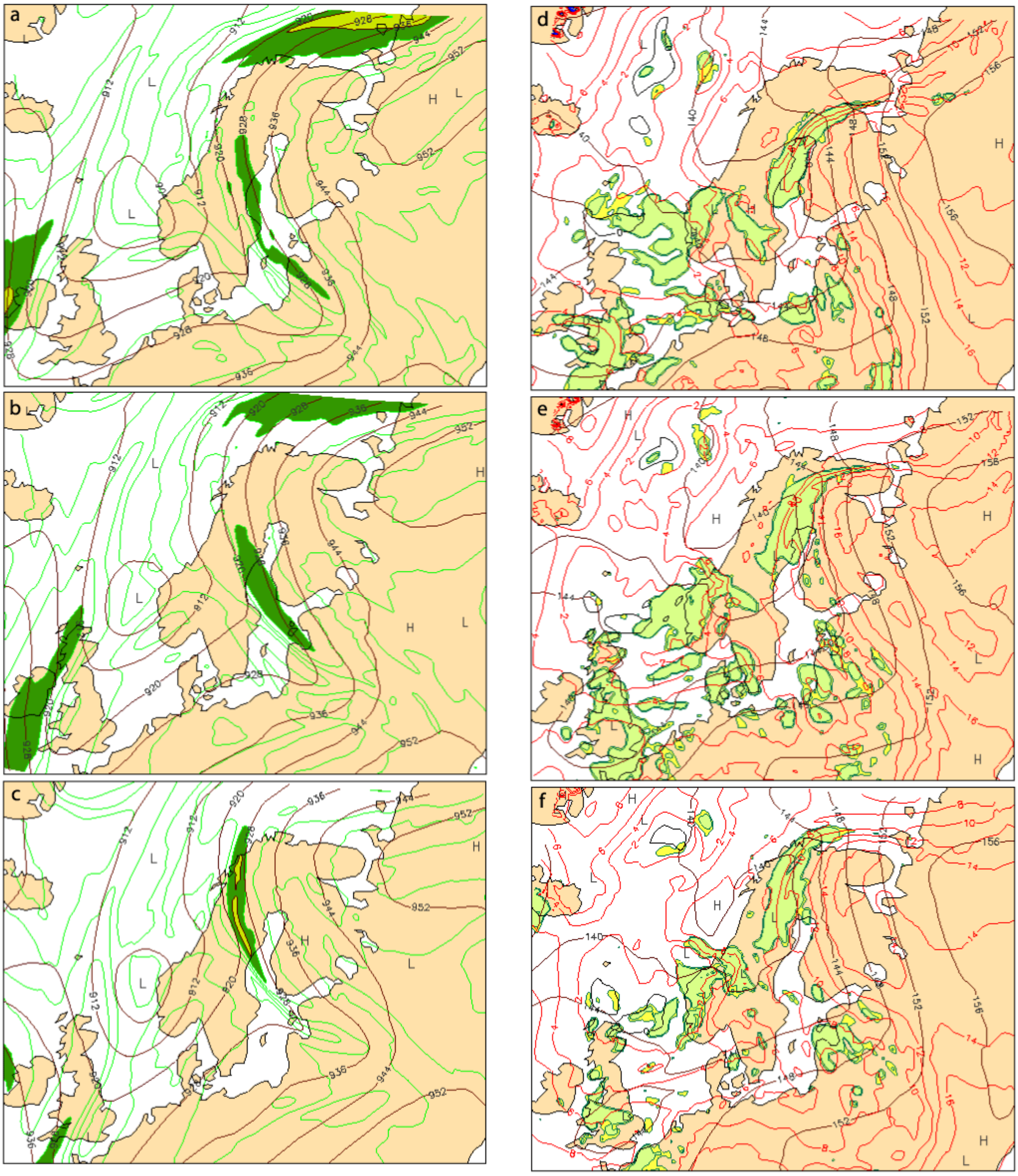

FIG. 2. HIRLAM analysis on 5 July 2002 of 300 hPa at a) 06, b) 12 and c) 18 UTC. Black lines are isohypses (dm) and green lines isotachs (m/s). 850 hPa HIRLAM analysis at d) 06, e) 12 and f) 18 UTC. Black lines are isohypses (dm), red lines isotherms (C), and the cloud water (g/kg) in green.

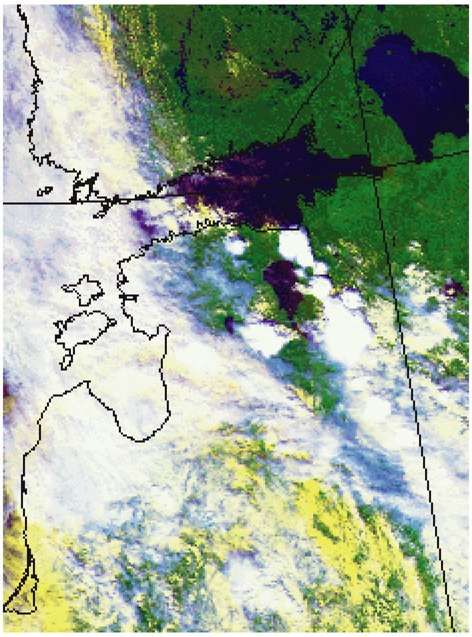

FIG. 3. NOAA satellite image (VIS-IR composite) on 5 July 2002 at 1056 UTC.

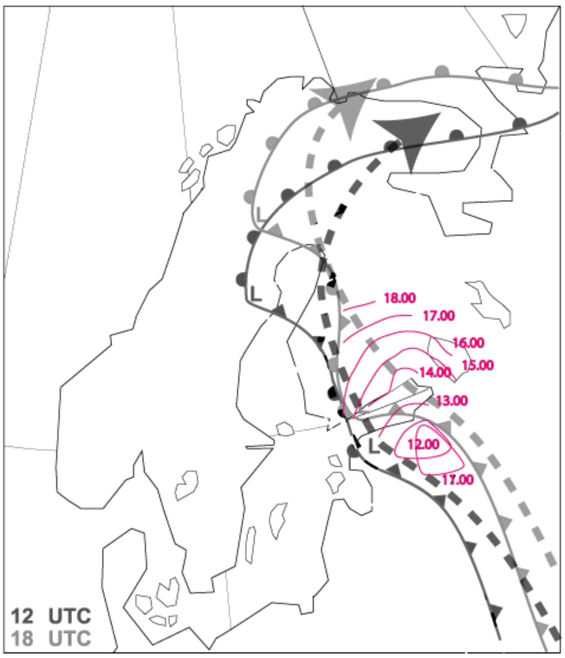

FIG. 4. Position of surface fronts and 700 hPa jet at 12 (dark grey) and 18 (grey) UTC. Position of initial thunderstorm development and leading line of the bow echo at every hour is also marked in the picture.

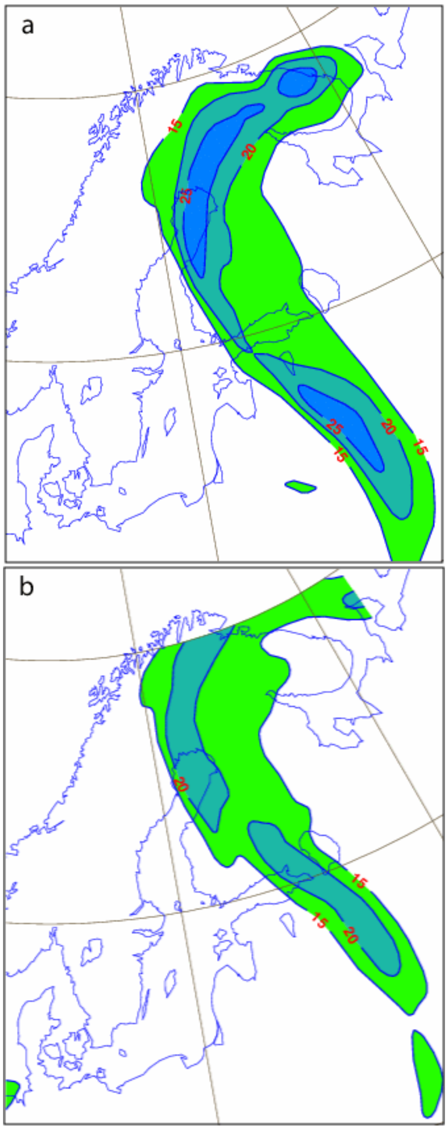

FIG. 5. ECMWF 700 hPa isotachs (m/s) at a) 12 and b) 18 UTC.

This case appeared to have some similarities to Berlin derecho, on 10 July 2002, studied by Gatzen (2004). Both occurred close to an intense upper level short wave trough, developed in the warm sector in the area of high θ_e and during the early stage were associated with prefrontal convergence zone. The deep layer flow in Finland was southerly with the strongest shear in the lowest 300 hPa above ground level (AGL), whereas in Germany the winds varied from southeasterly in lower troposphere to southwesterly at upper levels. In contrast to the Berlin case, in Finland the bow echo did not move along a thermal boundary, but on the eastern side of it. Also the position and strength of upper level jet streaks were different. In the Berlin case the left exit region of the jet streak probably affected the formation of the derecho (Gatzen 2004).

Interestingly, in this case the orientation of the frontal zones and the upper level trough axis has backed counterclockwise 90° compared to the typical warm season derecho-producing synoptic pattern observed in the United States (Johns and Hirt 1987).

3. MESOSCALE STRUCTURE AND FORCING MECHANISMS

The mesoscale convective system (MCS) was initiated as a cluster of thunderstorms in Estonia over the area of surface convergence. On the Gulf of Finland the cluster started to get a linear structure and at 15 UTC over southeastern Finland the bow shape of the leading convective line was evident (Fig. 6). During the evening the bow echo proceeded further north-northwest and the leading convective line was followed by a region of stratiform precipitation (Fig. 6).

The leading edge had a strong reflectivity gradient and some isolated thunderstorms merged into it (Fig. 6). These kinds of cell mergers were also observed in the Berlin derecho (Gatzen 2004). The meridionally oriented convective line north of the derecho was associated with the frontal zone. During the evening, the derecho and the frontal rain band merged partly resulting in an L-shaped convective line.

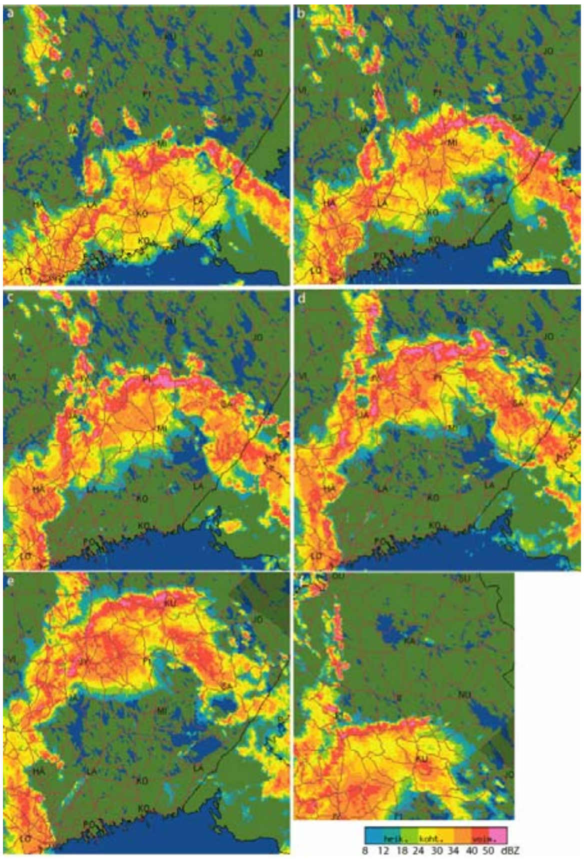

FIG. 6. CAPPI composite reflectivity images in eastern Finland at a) 1500, b) 1530, c) 1600, d) 1630, e) 1700 and f) 1730 UTC.

Quite often squall lines tend to turn perpendicular to the low-level wind shear. Also in this case, the leading edge of the bow echo was oriented perpendicular to the low-level southerly wind shear.

Often a rear inflow jet is observed in strong mesoscale convective systems (Smull and Houze 1987). In this case, at the most intense stage, the rear inflow notch was visible both in radar (Fig. 6) and satellite (Fig. 7) pictures. The track of the rear inflow notch was closely associated with the location of the most severe damage. In Southern Finland the development of a line-end vortex at the western flank of the bow echo was evident in a radar loop. However, that probably did not have a significant influence on the rear inflow jet owing to the large distance between the vortex and the apex of the bow echo. The severe thunderstorm radar signatures of the case have been discussed by Teittinen and Punkka (2004).

The bow echo produced a strong cold pool mesohigh (Johnson and Hamilton 1988), which could easily be seen on the surface chart (Fig. 8). The cold pool progression speed was calculated to be 23 m/s near the area of the worst damage in Central Finland.

Clear skies in front of the bow echo may have resulted in steep low-level lapse rates. Also evaporation from vegetation may have significantly increased boundary layer moisture due to the previous night's precipitation over Eastern Finland. In the afternoon 2 meter temperatures were around +30C and dew points nearly +20C just before the bow echo passage.

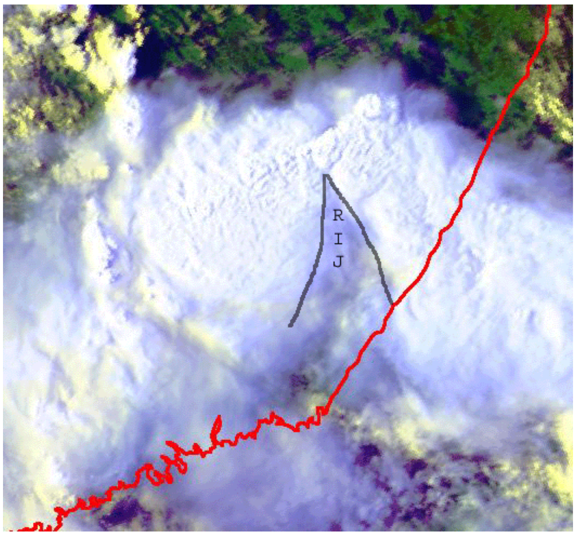

FIG. 7. NOAA satellite image (VIS-IR composite) on 5 July 2002 at 1535 UTC.

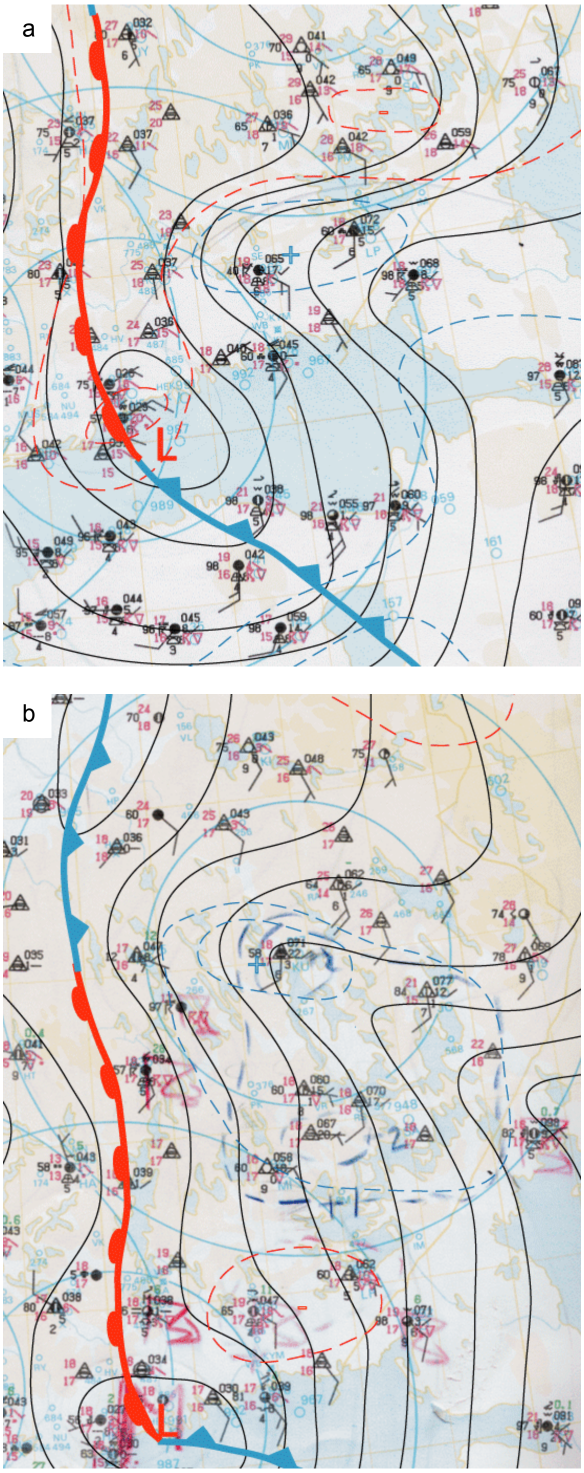

FIG. 8. Observations and (subjective) surface analysis on 5 July with fronts, isobars (solid lines) and isallobars (hatched lines) a) at 15 UTC b) at 18 UTC.

4. ANALYSIS OF SOUNDINGS

The morning sounding in Central Finland (Fig. 9a) showed strong low-level shear, close to unidirectional wind shear and a mid-level jet at 600-700 hPa. It has been suggested that strong wind shear in the lowest 2.5 km and constant unidirectional winds above that are favorable for bow echo maintenance (Johns 1993). The morning sounding also revealed two upper inversions that may have blocked the deep convection before the arrival of the squall line. The lower one of these two was probably the consequence of nocturnal inversion and warm air advection associated with the passage of warm front. Also the St. Petersburg 1200 UTC sounding (Fig. 9b) showed stable layer at around 900 hPa height. The mean layer convective available potential energy was 550 J/kg and lifted index -2.5C. According to Przybylinski (1995) the behaviour of derechos that develop over the areas of strong low-level shear and marginal CAPE is not well known.

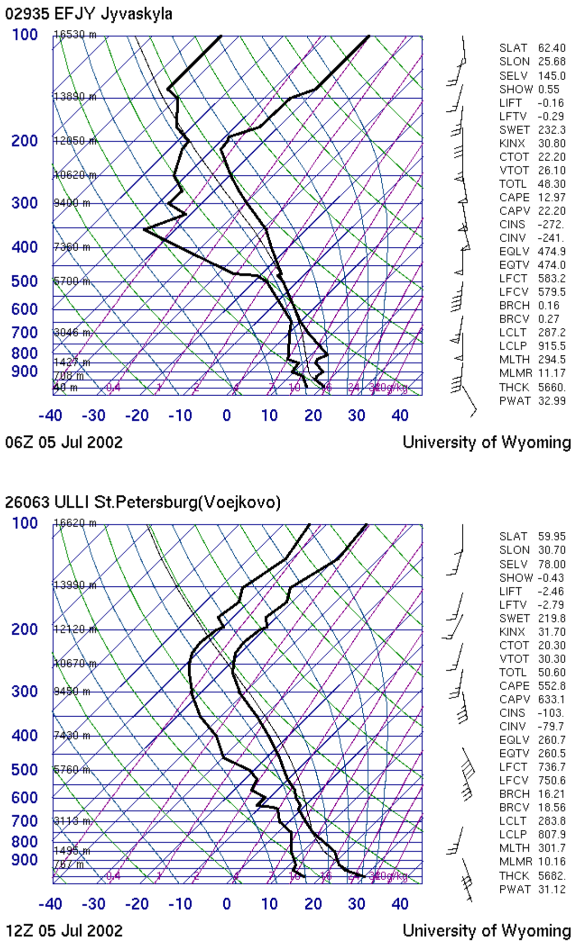

FIG. 9. Soundings on 5 July 2002 a) from Jyväskylä at 06 UTC and b) St. Petersburg 12 UTC.

By comparing the 5 July 12 UTC St Petersburg sounding θ_e vertical profile (Fig. 10) to the cold pool θ_e (method used by Duke and Rogash 1992), the origin of the downdraft air was approximated to be around 4 km ASL. At that height the relative humidity was less than 50 %. The mixing of dry air with the downdraft air increases the evaporative cooling, strengthens the downdraft and may lead to an intense, fast propagating cold pool. A layer of dry air at 3-7 km above ground layer has been observed to be a common characteristic in most derecho cases (Johns 1993).

The storm relative winds derived from proximity soundings (Fig. 11) showed some evidence of the existence of the rear inflow jet. The St Petersburg 12 UTC sounding, which was in front of the MCS, had the front-to-rear storm relative winds throughout the troposphere. In contrast, the Jyväskylä 18 UTC sounding behind the MCS showed storm relative rear-to-front flow above the 850 hPa height.

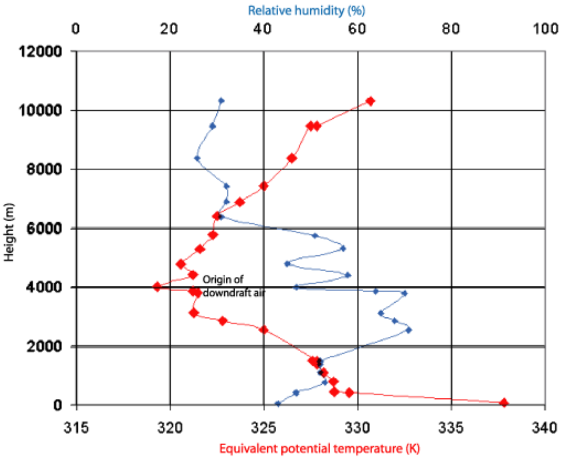

FIG. 10. Equivalent potential temperature and relative humidity vertical profiles from St. Petersburg sounding 5 July 2002 at 1200 UTC.

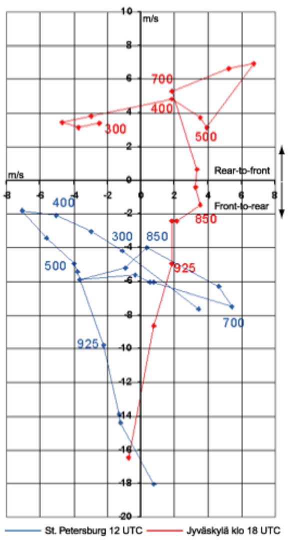

FIG. 11. Storm relative winds calculated from St. Petersburg 1200 UTC and Jyväskylä 1800 UTC soundings.

5. SUMMARY

On 5 July 2002 a bowing fast-propagating mesoscale convective system (MCS) caused straight-line wind damage over extensive areas of Eastern Finland. The total length of the damage path exceeded 450 km meeting the definition of a derecho. As far as the authors know the 5 July 2002 derecho is the highest latitude derecho that has ever been documented.

The derecho formed within the 850 hPa equivalent potential temperature ridge in front of an upper level short wave trough. It propagated north-northwest at the speed of over 20 m/s which was greater than the mean wind in the troposphere. The leading convective line of the system was oriented perpendicular to the low-level wind shear and it had very sharp radar reflectivity gradient at the leading edge. Also merging cells in front of leading line and a well-defined rear inflow notch were clearly evident in the radar imagery.

The analysis of proximity soundings showed that deep convection was blocked by two upper inversions in the area ahead of the MCS. It was also observed that storm relative winds in the mid- and upper troposphere behind the bow echo were from rear to front indicating the presence of a rear inflow jet. The origin of downdraft air was approximated to be around 4 km (ASL) where the relative humidity of surrounding air was under 50%. Consequently, the downdrafts and cold pool strength were enhanced by evaporative cooling.

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