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Downburst identification using Doppler shear in FMI radar network

E. Saltikoff, J. Koistinen, and H. Hohti

Finnish Meteorological Institute, P.O. Box 503, FIN 00101 Helsinki, Finland

Abstract. Downbursts were identified using shear of Doppler radar measurements. Shearlines were found not only near the radar at gust fronts, but also at higher altitudes, related to upper end of the downburst. A gust warning guidance product was developed for the duty forecasters. Data was compared to gust measurements at automatic weather stations, and to reports of forest damage. In 40% of the forest damage reports, a shearline had been recently nearby. Forecasters appreciate the new tool for gust warning guidance and evaluation.

1 Introduction

FMI weather radar network is designed mainly for precipitation measurement. Thus the used PRFs are small and the maximum unambigious Doppler speed is limited. The main benefit of the Doppler measurement has been the efficient clutter thresholding, and wind profiles. The wind profiles are calculated using the VVP technique, which includes necessary unfolding and provides easy-to-use output for aviation and air quality forecasting. A recent project is concentrating in assimilation of the radial winds to limited area NWP model (Lindskog et al., 2004.).

Doppler radars are often used to detect gusts and squalls at airports near the radar. Dangerous downbursts are detected by identifying the convergence areas of a gust front. An experienced user can also recognize the typical pattern in reflectivity field. Gusts fronts are shallow phenomena and thus such techniques are limited to immediate neighbourhood of the radar.

However, when the Doppler fields of FMI radars were studied, convergence lines were found in connection to verified downburst events even up to distances of 200 km from the radar where the lowest radar measurement is made at height of 4 km. At least in some cases this could be related to the upper end of a downburst, known as Mid-Altitude Radial Convergence (MARC) velocity signature (Schmocker et al., 1996).

Correspondence to: E. Saltikoff
(Elena.Saltikoff@fmi.fi)

Schmocker and his team found in Missisippi Valley, USA the maximum convergence in the mid-levels of the storm (5.0–5.5 km), and strongest magnitudes within the 4 to 7 km layer. In a small set of Finnish data from different elevations, two layers of frequent shear warnings were found: one near the surface , the other one roughly between 2 and 4 km. According to Houze et al. (1989) the ascending front-to rear flow meets the descending rear inflow near the melting layer (bright band). In Finland in summertime the bright band is located between 2 and 4 km (Pohjola, 2003). Thus, the difference to American results could be explained with climatological differences.

Houze et al. (1989) show that characteristic patterns indicating presence of mesoscale downdraft are routinely clearly evident in Doppler PPI displays. FMI's 7 radars produce a new lowest angle PPI every 5 min which makes 735 840 images a year. So one cannot expect a duty forecaster to keep steering at the Doppler displays, but a more automatic warning system is essential.

2 Methods

In this study, two algorithms by Sigmet Inc. were used: SHEAR and the shear line algorithm SLINE (Sigmet, 2003). The shear line algorithm finds either radial, azimuthal or elevational shear of radial wind. A warning was created wherever the radial shear exceeded a threshold of 2 m/s/km. The SLINE algorithm uses the calculated shear and looks for area of shear and convergence and fits there a curve. For azimuthal shear, it uses uniform wind assumption, to remove apparent shear caused by mean wind. At FMI, only radial shear of radial wind is used. In cases of strong convection the estimate of mean wind using the previous (15 min old) VVP (average wind of a 40 km cylinder, assumed to be uniform) was found not to be good enough.

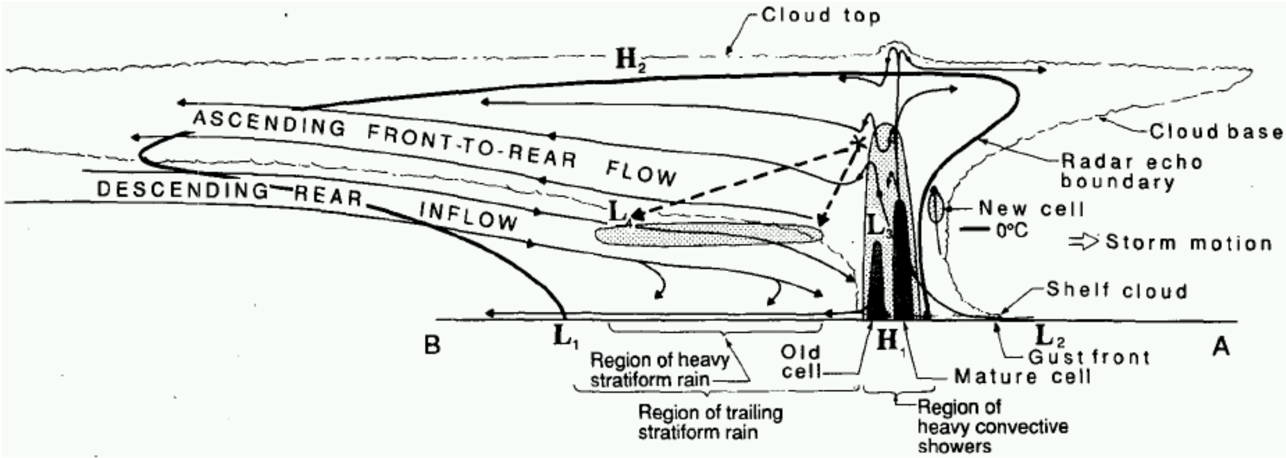

Fig. 1. Vertical cross section of conceptual model of a squall line (Houze et al., 1989). Note how the are of maximum horizontal shear (roughly above words "old cell"), heavy convection (black shading) and gust front near the surface are not at the same geographical location.

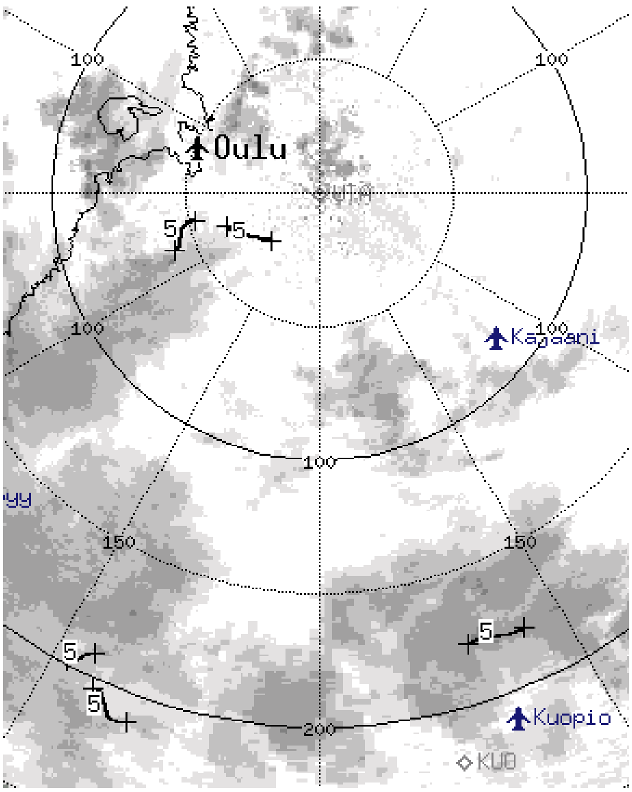

Fig. 2. Example of the SLINE product (line marked with 5) superimposed with reflectivity PPI elevation 0.3 degrees (grey shades from 0 to 60 dBZ) Utajrvi radar 28 June 2004 12:30 UTC. The rings indicate distance from radar in km.

3 Application

Two gust warning guidance products were made for the forecasters at the FMI. The warnings are shown superimposed to standard CAPPI or PPI products. Examples of the SLINE product are shown in Figs. 2 and 3. Near the radar, as seen in Fig. 2, the shearline matches nicely with the narrow reflectivity band, typical for gust fronts. The product does not find the entire gust front, because for geometrical reasons the radial component of the shear is too small in the part of the gust front almost parallel to radar beam. Further away from radar (Fig. 3), the SLINE warnings are located inside of the precipitating areas. Some lines are found up to 220 km from antenna, where the beam at 0.3 degree elevation is at height of 4.4 km.

Because the detection depends so strongly on geometry, the forecasters are shown not only single radar products but also a composite of FMI's 7 radars. Figure 4 is an example of a national composite of SHEAR warnings. Ovals indicate areas of shear greater than 2 m/s/km. A occasional single oval can be neglected, but a persistent crowding of ovals usually indicates and area of interest, and guides the forecaster to have a closer look at more detailed images.

4 Evaluation

Strong squall cases were first identified using data from automatic weather stations for some case studies. Violent storms damage AWS stations or their power and communication lines, and thus AWS data can be even sparser than normally. Typically, when a shearline went over an weather station, an increase in the gust level was observed.

Another source for evaluation data was emergency reports of trees falling to roads and power lines. From May and June 2003, 307 such reports were compared to shearline radar products within the nearest half an hour. A case was taken as hit, if the shearline was less than 50 km from the damage location. Of the 307 emergency reports of "storm damage", 125 cases (40%) were hits. The 50 km threshold is known to be coarse. But as the convective systems are slanted, the gusts on surface do not happen at the same place

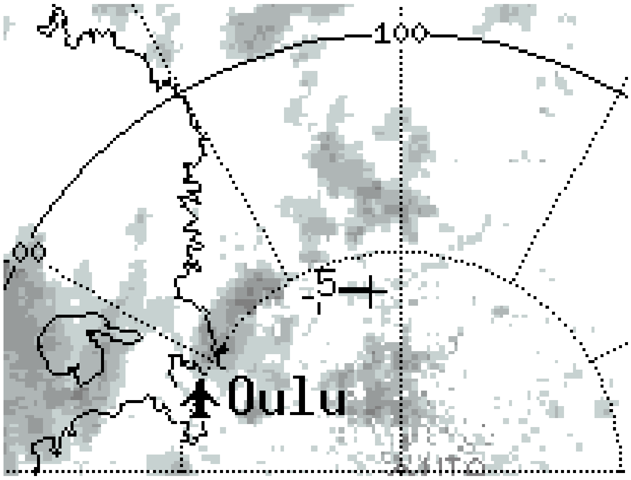

Fig. 3. Another example of the SLINE product 28 June 2004 12:45 UTC. Arrows indicate the gust front, visible in the reflectivity field. Other symbols as in Fig. 2.

as the convergence at upper levels. Also, when forest damages occur in sparsely populated areas, the alarm may happen several hours or even days after the event. The broadminded attitude in location tries to compensate the vagueness of timing.

Even though the percentage of detection seemed subjectively good, many cases which most probably were false alarms occured. Some of the false alarms were identified to non-precipitation echoes such as birds and ships. However, verification of the false alarms is even more demanding than verification of the hits: how can you be sure there was no gust? For an example, on 30 June 2004, a mesoscale storm destroyed probably hundreds of hectars of forest in Northern Finland. Kuusamo fire chief Heikki Levon said in interview of newspaper Kaleva (2 July) that 'nobody knows how big are the damages in the roadless areas until someone flies there with a helicopter or the forest owners visit the area' (probably next winter by snowmobiles).

The forecasters at FMI have had access to the gust warning guidance products operationally in 2004, and in test use during the summer 2003. Feedback has been positive. The forecasters underline, that even though they have been asked to issue warnings of severe gusts assosiated with thunderstorms, they have had hardly any tool to verify their forecast or to learn, how do those dangerous weather situations look like in reality. Automated warning for end users would be useful, but most users do not want an observation (which can be made only when the phenomena has already occurred), but would prefer an early warning method.

5 Conclusions and future work

Use of shear calculated from Doppler measurements seems to be rather an useful too for downburst identification, even

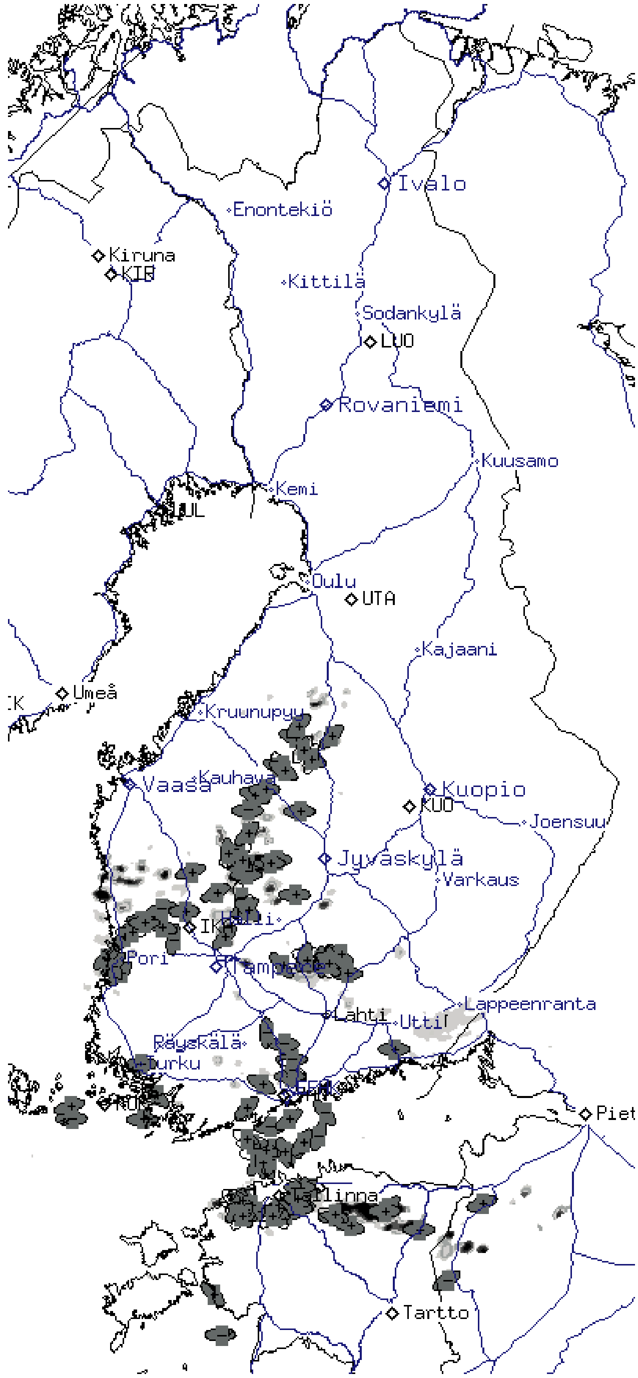

Fig. 4. Example of the national composite of SHEAR WARNING product (radial shear greater than 2 m/s/km indicated with an oval). Composite of 7 FMI radars, 15 July 2003 15:45 UTC.

at areas where the radar beam overshoots gust front. For such a relatively rare phenomena, duty forecasters need a simple warning guidance tool.

The next stage is to combine the shear data to reflectivity data in order to decrease the false alarm rate. Even this is somewhat demanding, as typically the maximum reflectivity is at different geographical location than the maximum convergence.

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