IMAGE MOSAICS FROM SWEDISH WEATHER RADARS

Tage Andersson
Swedish Meteorological and Hydrological Institute

1. Introduction

This paper describes the principles for merging data from the Swedish digital weather radars into one image. The main principle is that data as close to the ground as possible should be displayed. That is, if a pixel (horizontal size 2*2 or 1*1 square km) is depicted by two or more radars, the information from the radar having the lowest lower border of the beam is selected. This demands a knowledge of the elevation angles to obstacles for each radar.

2. Measuring the elevation angles to obstacles

The obstacles can be divided into 'large-scale' and 'small-scale' ones. The large-scale ones are terrain features, as hills and ridges, and do not change with time. The small-scale ones are buildings and trees close to the antenna which may change with time.

The elevation angles to the large-scale obstacles were computed with an automatic routine. A topographic map with a resolution of 0.5 km was used, and a '4/3 earth radius' was assumed.

To measure the angles from the small-scale obstacles a camera was mounted on a tripode at the position of the center of the antenna. This procedure has to be made before the antenna installation, or when the antenna and the radome are removed. (If there is no radome, a camera may be fixed on the antenna). Pictures were taken 'round the horizon'. From these pictures elevation angles to nearby buildings and trees were measured. As 'fix points' were used buildings with known heights and elevation angles to large-scale obstacles.

If it was not possible to perform the photo procedure described, i e the antenna and radome were already installed, the elevation angles to nearby obstacles were estimated visually. Furthermore, the effect of close buildings etc were checked by inspection of reflectivity data in polar form. With a vast precipitation area above the antenna, those obstacles cast 'shadows', which are easily recognized.

3. Finding boundaries between areas of coverage

In a network of radars a pixel may be depicted by two or more radars. The question is then which information to display. The by far most used radar information by forecasters is a PPI with the lowest elevation angle or a CAPPI for the lowest possible altitude. Therefore it is reasonable to select the information from the radar with the lowest altitude of the beam, Fig 1. Due to the curvature of the earth and the beamwidth this altitude is dependent upon the distance to the antenna. Furthermore it is determined by obstacles to the beam. A similar principle is used for the UK network, though they used the central axis of the radar beam instead of its lower boundary and made the assessments subjectively (Larke and Collier, 1981).

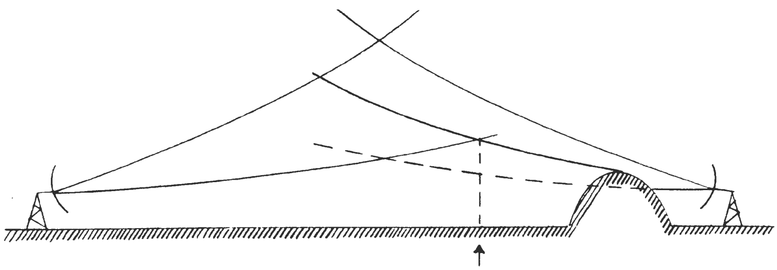

Fig 1. How to find the border between the coverage areas of two radars. Applies to lowest-angle PPI and pseudo-CAPPI.

Other principles for selecting the information where there is overlapping from two or more radars are of course possible (Durand, 1990). One might compute and display the arithmetic mean, the median or the maximum value. The disadvantage of those quantities is that they are dependent upon the altitude, which the operator does not know. A PPI or pseudo-CAPPI is in itself a mapping of echos at different altitudes, the altitude increasing with range from the antenna. In a composite image this altitude mixing is in itself complex. If the image shows the coverage areas the operator can handle this, i e he/she knows, at least qualitatively, the altitudes of the echos. If, on the other hand, the coverage areas are not fixed, but for instance the maximum value is presented the operator does not know from which altitude (radar) they originate. For instance, it is quite common that Altostratus give fairly strong echoes at altitudes above say 3 km, but no echoes below this altitude. If there is such an echo above a radar, this radar does not see it when scanning at the lowest elevation (about 0.5). Another radar at a range of say 200 km may detect this echo when scanning at the lowest elevation. If the maximum reflectivity from the two radars were displayed, an echo would appear over the first-mentioned one, though this radar actually does not detect any low-level echoes. At SMHI the maximum reflectivity principle was earlier used for image mosaics. Several forecasters found the described situation very annoying and misleading.

We must also remember that different precipitation systems reach different altitudes. Systems giving drizzle or snow frequently reach less than 2 km altitude, while heavy showers from convective systems may reach above 10 km. The so-called effective range of a weather radar, i e the range up to which correct detection of precipitation can be expected (Wessels, 1990), thus depends upon the weather type (and the season).

We have considered the beam as a cone, with a clearcut lower border at an angle of the beamwidth/2 from the central axis. An obstacle cuts away a part of the beam. The boundary between the coverage areas of two radars occurs where the lower borders of their beams intersect, see Fig 1. We have developed a routine that selects those points.

As an example of a radar horizon with much obstacles, Fig 2 gives that for the Norrköping radar. Especially to the east there are several small-scale obstacles (buildings) protruding as peaks. Those gives very uneven boundaries. Therefore, the elevation angles were smoothed by forming (13-point) running means. The coverage areas were then computed with a resolution of 0.05 in latitude and 0.1 in longitude. Within each area, data are used from one radar only. There is no blending of data from different radars across these boundaries. There are several possible data sets and boundaries depending upon data availability and how the coverage areas overlap. For instance, with a network of 5 radars there are 31 possible data sets. If the coverage areas do not overlap there is no boundary, if only two coverage areas overlap there is one boundary. Fig 3 shows the borders between the areas of coverage for the case when 5 radars are operating.

For higher-levels CAPPI the significance of the obstacles decreases since higher antenna elevations are used more and more for the CAPPIs. Therefore one, or perhaps more, set of borders should be computed. For some picture types, as echo top maps, we have not yet discussed what principles should be applied.

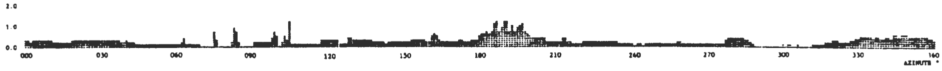

Fig 2. The horizon of the Norrköping weather radar.

4. Selecting lowest antenna elevation angles

The 3-dB beamwidth of the radars in our network is 0.9°. Then, if the elevation angle to the horizon is 0.00° and the antenna elevation 0.45°, we consider this beam as not obstructed, though actually some energy is intercepted. We thus consider an antenna elevation of half the beamwidth above the obstacles as the optimum one for the lowest scan. Since the elevation angles to the obstacles are not constant for any of our radars, but we have to use a constant lowest antenna elevation angle for each one, (not necessarily a common one) some compromise is necessary. To analyse the situation we have computed frequencies of different elevation angles to obstacles for each one of our radars as well as their arithmetic means, see Table 1.

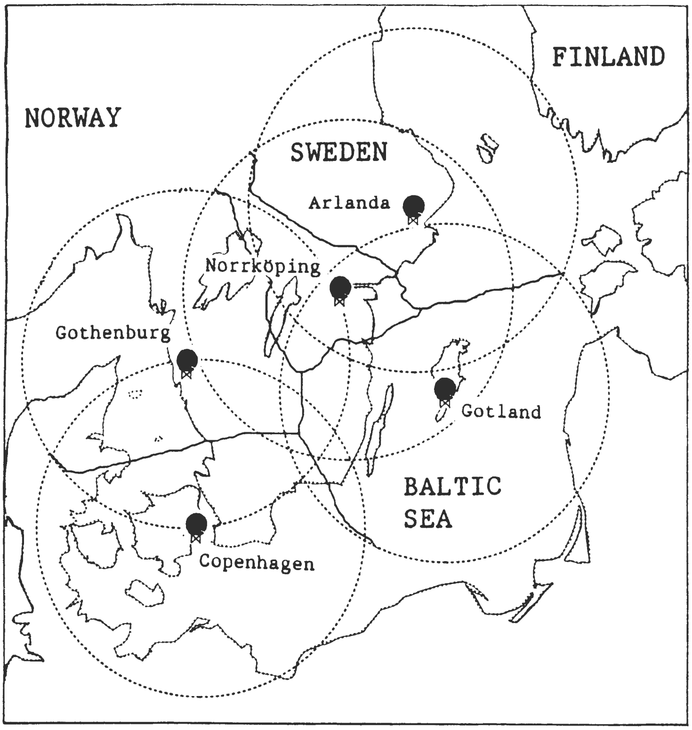

Fig 3. Boundaries between coverage areas (solid heavy lines) when data from the five radars shown are available. For lowest-angle PPI and pseudo_CAPPI. The radius of the circles is 240 km.

TABLE 1. FREQUENCIES OF ANGLES (UNIT 0.1°) TO OBSTACLES AND THEIR ARITHMETIC MEAN (UNIT °). NEARBY OBSTACLES ARE ONLY SIGNIFICANT FOR NORRKÖPING.

	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	MEAN
NORRKÖPING	0	0	0	91	67	81	47	31	17	6	9	0	3	2	2	4	0.252
ARLANDA	0	0	305	55	0	0	0	0	0	0	0	0	0	0	0	0	-0.126
GOTHENBURG	62	87	80	125	6	0	0	0	0	0	0	0	0	0	0	0	-0.152
GOTLAND	0	90	160	63	47	0	0	0	0	0	0	0	0	0	0	0	-0.108

Evidently, the Norrköping radar suffers from much more obstructions than the other ones. As a consequence, its effective area of coverage is smaller than the others'. Let us formulate two criteria:

1. The lower border of the beam (elevation angle = antenna elevation angle - beamwidth/2) shall pass just above most of the obstacles
2. Only few obstacles shall intercept more than 1 dB (1 dB loss corresponds to an angle of 0.2° above the lower border of the beam).

If we select as lowest antenna elevation (mean + beamwidth/2) these criteria are met by Arlanda, Jonsered and Hemse. The situation is worse for Norrköping. We then get the lowest antenna elevations in Table 2.

TABLE 2. SUGGESTED LOWEST ANTENNA ELEVATION ANGLES, °.

NORRKÖPING	0.70
ARLANDA	0.32
GOTHENBURG	0.30
GOTLAND	0.34

As to the elevation angles of obstacles, a consequence is that obstacles reaching less than (antenna elevation angle - beamwidth/2) should be considered to reach just this angle when computing the boundaries between areas of coverage, cf Fig 1.

References

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