The use of the solar monitoring data to assess the quality and the stability of weather radar antenna systems

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Abstract

The sun is a signal source for monitoring the antenna pointing and the radar receiver chain. Recently an ”online” method has been developed, which is entirely based on the analysis of sun signals in the polar volume data produced during operational scanning of weather radars. The method is suited for routine applications and have been implemented as part of the operational quality control at several European Meteorological Services. In this paper we show how the antenna elevation and azimuth offset and width values are used in monitoring the pointing accuracy and the stability of the radar antenna system.

1. Introduction

The Finnish Meteorological Institute has developed over the years the monitoring of the antenna pointing and the calibration level of the radars. Monitoring of the antenna pointing is based on using solar hits from operational scan data. Hits over a certain period of time, usually one day, are collected and analyzed together to get estimates of the antenna elevation and azimuth biases and the power level of the solar radiation. The method has been developed since 2003 and is now used operationally.

The method is described in a series of papers by Huuskonen and Hohti (2004), Holleman and Beekhuis (2004), Huuskonen and Holleman (2007) and Holleman *et al.* (2010). In the method, elevation angles close to horizon are used, and the method thus requires that the refraction, as well as the attenuation, of the radio waves due to propagation in the atmosphere is taken into account. A detailed description on the determination of the antenna pointing bias is found in Huuskonen and Holleman (2007), and of the determination of the solar flux power in Holleman *et al.* (2010a). Recently the method has been expanded to studies of the differential reflectivity of dual polarization radars (Holleman *et al.* 2010b). Darlington *et al.* (2003) have also used operational scan data to monitor the receiver stability and the antenna pointing, but by using elevation angles where the refraction effects are negligible.

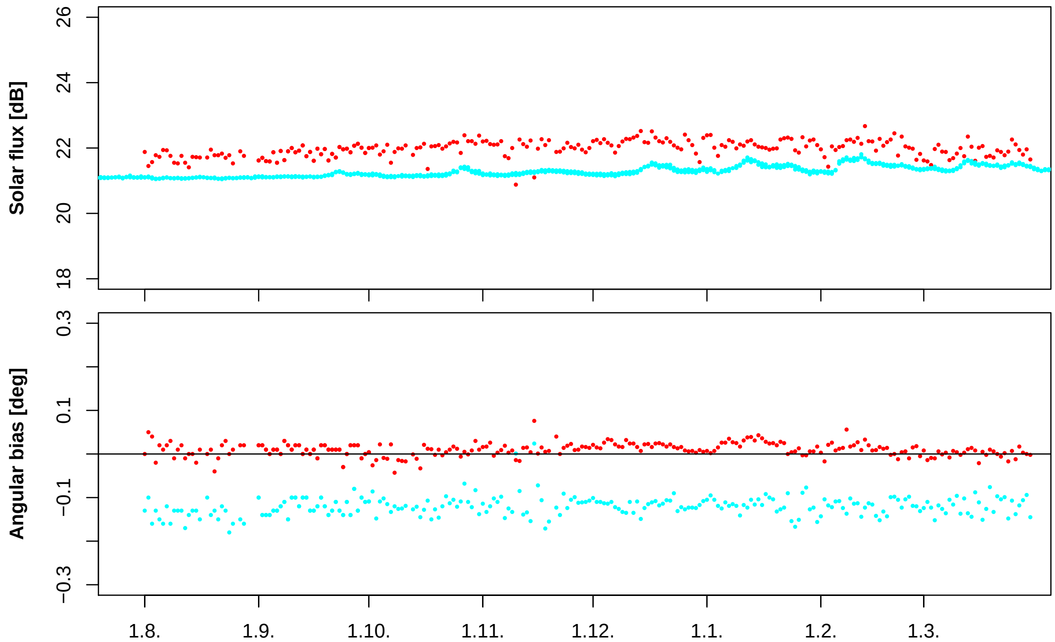

Figure 1: Solar analysis results from the Vimpeli radar from August 2009 to March 2010. In the top panel, the solar flux in sfu (solar flux units) estimated from the radar data is shown in red and the solar flux calculated from the DRAO time series in cyan. In the bottom panel, the antenna bias in elevation is shown in red and the antenna bias in azimuth in cyan.

In this paper, we will show solar monitoring results of the FMI network. We also show elevation width results and discuss their use in the monitoring of the antenna system.

2. Antenna pointing

Figure 1 shows the solar flux and antenna bias results for the Vimpeli radar as an example. The properties of the Vimpeli radar as well as those of other radars in the FMI network are described in detail by Saltikoff *et al.* (2010). Some basic information is shown in Table 1. The solar flux values in the top panel show that the solar flux estimated from the radar data is higher than the DRAO observatory value, and that the difference decreases slightly during the period. The standard deviation of the flux within the last 30 days is 0.14 dB, which is the combined effect of the system fluctuations and the method error. Either is hence below this value. The elevation bias is zero, which is clearly better than the target of 0.05°. The azimuth bias is 0.12°, which is slightly greater than the target accuracy of better than 0.1°.

Figure 2 shows the antenna bias curves for all radars in the network. First of all, it is seen that the antenna elevation is correct to 0.05° for all radars, and correct to better than 0.02°

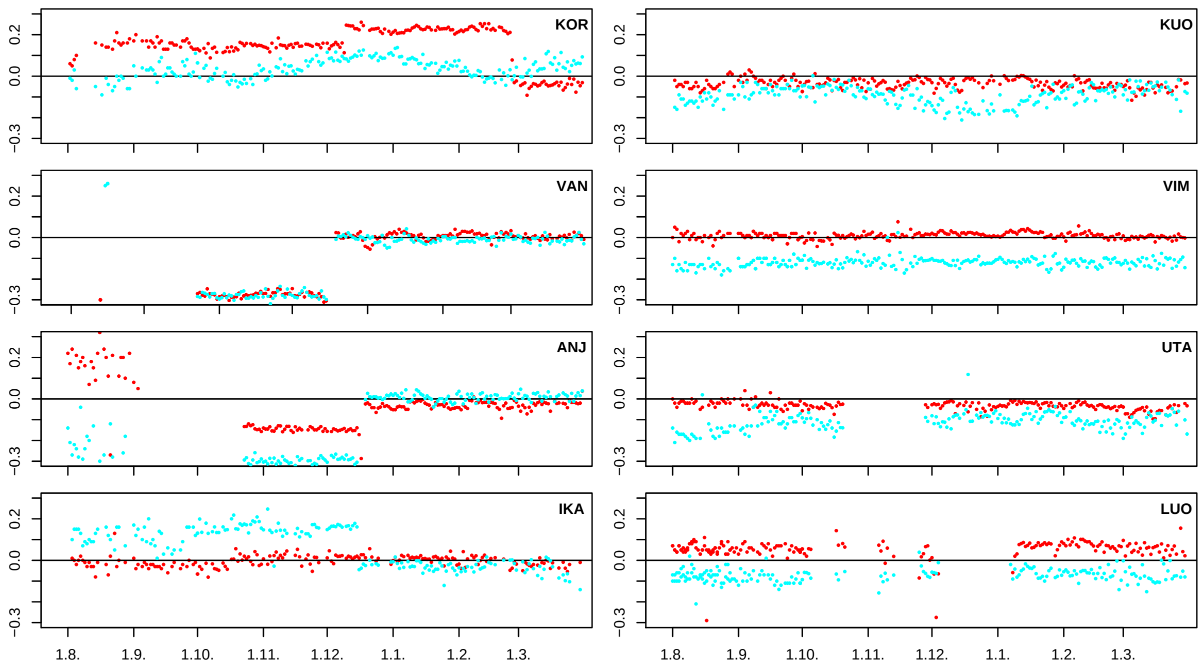

Figure 2: Antenna bias of FMI radars from August 2009 to March 2010. The elevation bias in degrees is denoted by red and the azimuth bias in degrees by cyan.

for several in March, but that there are periods of greater deviation earlier. It is seen that the radar systems appear to be stable. This is most evident for Anjalankoski, Vantaa and Vimpeli, which are also the newest radars in the network. The standard deviation of the bias is below 0.01° in elevation and less than 0.02° in azimuth for these radars. For other radars typical values are 0.015° and 0.03° for elevation and azimuth, respectively.The bias values of the old Anjalankoski radar (August 2009) show a much larger scatter of points than any other radars. The old Anjalankoski antenna system was well known to have problems of stability, which are demonstrated here. Please note that the gaps in the time series do not indicate that the radar was not operational at the time. Some of the gaps in the Luosto series are due to winter solstice, around which the sun in not visible at Luosto.

3. Use of the azimuth and elevation widths

As described by Huuskonen and Holleman (2007), the solar analysis uses a five parameter model, in which the distribution of the solar hits is modeled by a two-dimensional Gaussian distribution in azimuth and elevation. When using logarithmic powers the model appears as a two-dimensional polynomial of degree two, in which the cross terms are zero. Huuskonen and Holleman (2007) recommended that the width in elevation and azimuth is fixed for operational use of the method, which improves the stability of the fits.

Table 1: FMI radar network. The radar name, three letter acronym, hardware manufacturer and model and the year of installation.

Radar	code	Manufacturer and model	Year
Korpo	KOR	Selex Meteor 360	1997
Vantaa	VAN	Selex Meteor 360	1994
		Vaisala WRM 200	2009
Anjalankoski	ANJ	Selex Meteor 360	1994
		Vaisala WRM 200	2009
Ikaalinen	IKA	Selex Meteor 360	1994
Kuopio	KUO	Selex Meteor 360	1995
Vimpeli	VIM	Selex Meteor 500	2005
Utajärvi	UTA	Selex Meteor 360	1997
Luosto	LUO	Selex Meteor 500	2000

If a full five parameter is made, additional insight into the data is obtained. The experience gained at FMI has shown that it is possible to use a five parameter fit operationally, and meaningful results of the widths are obtained in daily fits. We show examples of such results in Figure 3, which shows monthly medians of seven radars of the FMI network during 2009-2010. The Luosto radar is not included into the plot, because of its larger antenna.

The formulae to calculate the theoretical width of the image of the sun are presented in Holleman *et al.* (2010a). As the image is a convolution of the antenna beam pattern with the sun disc, the width ought to be slightly larger then the antenna width. This puts the theoretical lower limit to about 0.95° with the antennas in use. Some the present systems have widths close to this value.

Looking at the data we see that after October 2009 the widths do not show much change. The newest radars are the best ones, and the width determined is very close to the antenna half power width, or even less. This is an indication of a very stable antenna systems and that all assumptions used in the analysis are very closely correct. The widths for the other radars is larger, and the width increases with the increasing age of the hardware. For several radars, the elevation width is significantly higher during the first half of 2009. The cases are very different. The Vantaa and Anjalankoski radars were replaced by new radars during the summer, and the new antenna systems perform significantly better than the old ones. The reason for the high width values of the Korpo was a torn out elevation drive belt, with which the antenna system could not keep the elevation angle stable. For the Kuopio and Ikaalinen radars, the improvement in the Autumn 2009 is connected to a maintenance action.

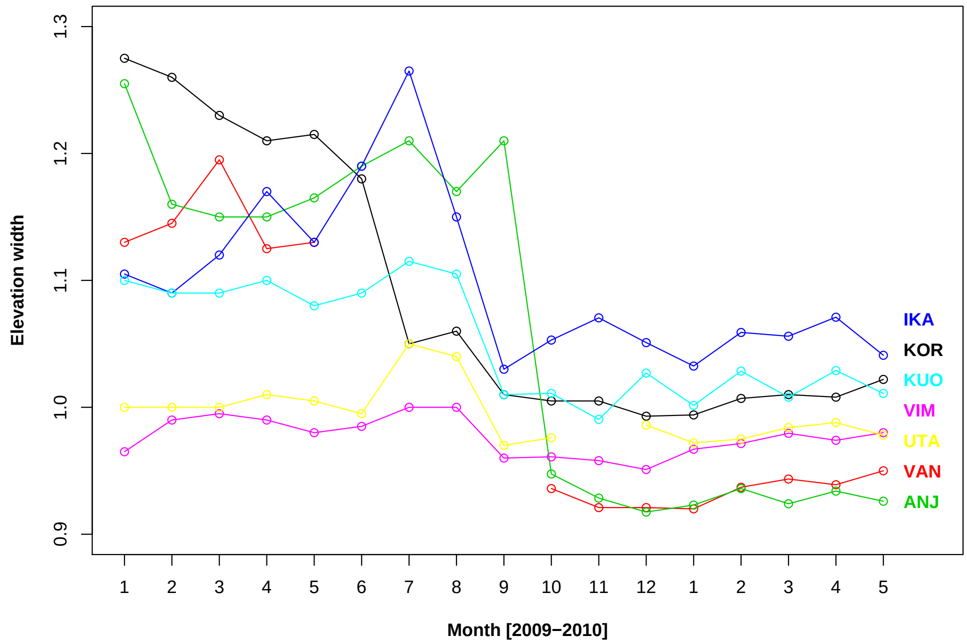

Figure 3: Monthly median of the image width in elevation.

4. Discussion

The analysis of the solar hits gives valuable information, which is useful in the monitoring of the radar systems. Firstly, the antenna elevation and azimuth analysis gives bias values, by which to correct the antenna pointing. With this is is possible to make the pointing correct to 0.05^o. An advantage of the online method is that it allows us to determine the elevation at those angles which are most important for precipitation estimation. If, instead, the antenna pointing is determined at a higher elevation (the "off-line method"), an elevation bias may be introduced when the antenna is moved close to horizontal. The off-line method is certainly good for the determination of the azimuth pointing.

The scatter of the bias values around the mean is an indication of the quality of the radar antenna system. For the best systems the standard deviation is clearly less than 0.01^o, which is a measure of the quality of the antenna system and also a measure of the maximum error produced by the analysis method itself. A larger scatter is a symptom of problems with the antenna. An example is the old Anjalankoski antenna shown in Figure 2. This type of information is only available from the on-line method. In the off-line methods the antenna is stopped or is moved in small steps, and hence the problems connected to the dynamics of the moving antenna are not revealed.

The width of the sun image gives additional information on the antenna system. There are several factors which can make the apparent width larger. Data of several elevations are used, and any error in the elevation values increases the image width. Also, any problems of the antenna system, e.g. oscillation around the nominal elevation, inability to set exactly at the wanted elevation, will increase the apparent width. And, finally, variations of the refraction have their effect. We have found that the newer antennas are better than the older ones in the network. Ageing may have some role in this, but most probably this an indication of the technical development of the radar hardware over the years.

Acknowledgements

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