Contents

1 Introduction

1.1 Figures

The following pages contain analysis results of the paired radar data. Each case is described by a figure, similar to that shown below. The left hand panel presents the paired radar data. The right hand panel shows the residual of the fit as a function of the difference in the collection angles of the radars. The analysis procedure will be described elsewhere. Here is suffices to say that the curve has been obtained by stepping the angular difference from -0.4^o to 0.4^o in steps of 0.02^o. For each difference, a weighted sum of the deviations between the model and observations has been calculated. This is the residual of the fit.

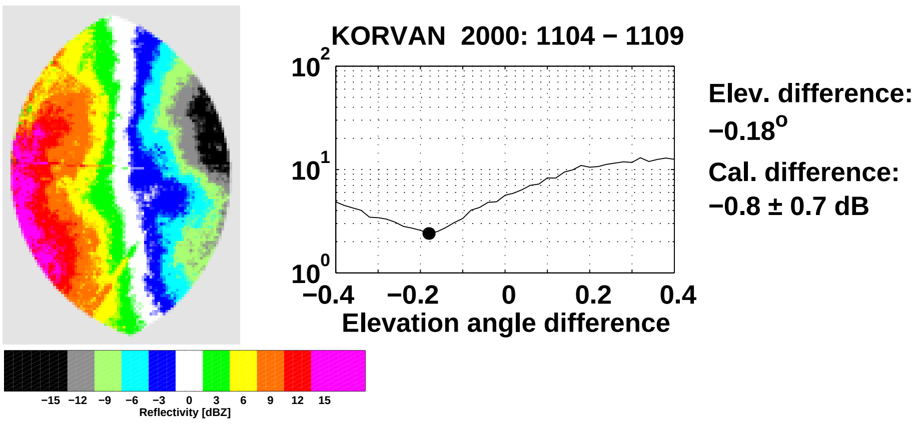


Figure 1: An example of the paired radar data with the analysis of the collection angle and calibration difference. The colour palette is seen below the figure.

One can read from the figure the most probable angle by finding the minimum of the curve. That point is also denoted by a filled circle. The numerical value of the elevation difference, as well as the calibration difference with an error estimate, is given to the right of the figure.

1.2 Fit residual

A study of the the values of the fit residual χ^2 gives us a way of checking if the model employed is valid and whether the error estimates for the basic data are estimated correctly. If the model is valid and error estimates correct, the fit residual should fluctuate around one. By looking at the results we can see that in all the cases we see that the residual at the minimum point exceeds unity.

There are two possible explanations for the values of the residual exceeding unity. The first is that the error of the difference data, i.e. the data shown on the right hand panel of Fig. 1 has been estimated incorrectly. We have assumed that the error is 0.5 dB, as the data is available in integer values only. Hence 0.5 dB is definitely the minimum value of the error, but the error may be larger. There is no easy way of find it out, because the processing leading to the difference data is complicated and includes non-linear operation.

Another possible explanation for the value of the residual is that the analysis method, i.e. the model employed, is not sufficient. The analysis method will be explained in the project report (in preparation). A short summary is found in the extended abstract for the AMS radar workshop (Asko Huuskonen: A method for monitoring the calibration and pointing accuracy of a radar network). There are known deficiencies in the method, e.g. in the treatment of the blocked sectors. This cannot, however, explain the values of the residual, as it exceeds unity also for all the Finnish radar pairs, most of which have no blocked sectors.

1.3 Error estimates

A consequence of the above is that the error estimates for the calibration difference must be regarded as preliminary.

Reliable error estimates for the angular difference are neither yet available. For the very best examples we have, e.g. for the KORVAN pair, the error can be as low as 0.02^o. This is deduced from the scatter of the results within the five periods analyzed.

Another estimate, based on the residual curve itself, indicates that the error is roughly 0.1^o for the best cases. It can be considerably larger for some other cases. There are cases in which the residual is rather constant. Then there is no way of telling what the most probable angular difference is.

1.4 Results close to edge of analysis span

The analysis span has been chosen wide enough so that the minimum should occur within it. Hence if the minimum is found at the edge of the analysis grid, it should be studies with caution. First of all, it is evident that the true minimum would be found outside the $\pm 0.4^o$ span if the analysis span would be extended. Secondly, it is highly unlikely that the true angular difference is larger than what the analysis covers. For this reason even values close to the edges, e.g. 0.38^o are highly suspicious.

1.5 Missing data

Not all radar pairs are presented, because the data appeared not to be good for various reasons. The following three cases are excluded:

1. OSUOVI: Data which was collected during year 2000 cannot be used because the coordinates of the Östersund radar were found wrong. Correct coordinates have been used since December 28, 2000 in the production of the paired radar products. It then appeared that the product generator could not produce correct data for the new area defined. The problems were solved by January 25, 2001, after which correct data has been available.

2. HUDOSU As above

3. UTALUO The product generator problems made the data useless until February 25, 2001.

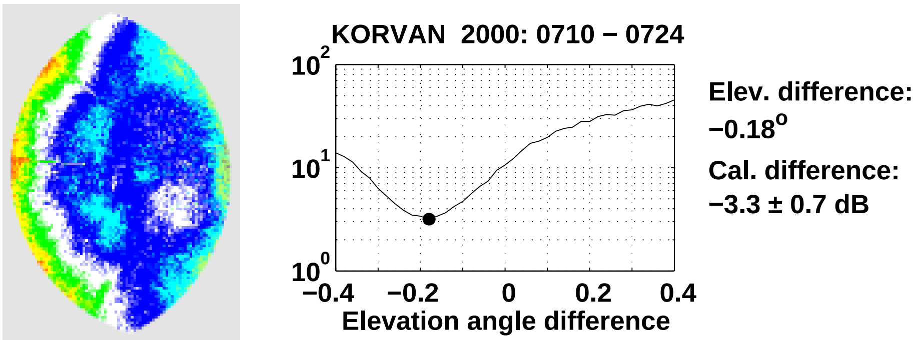
2 The paired radar data and analysis results

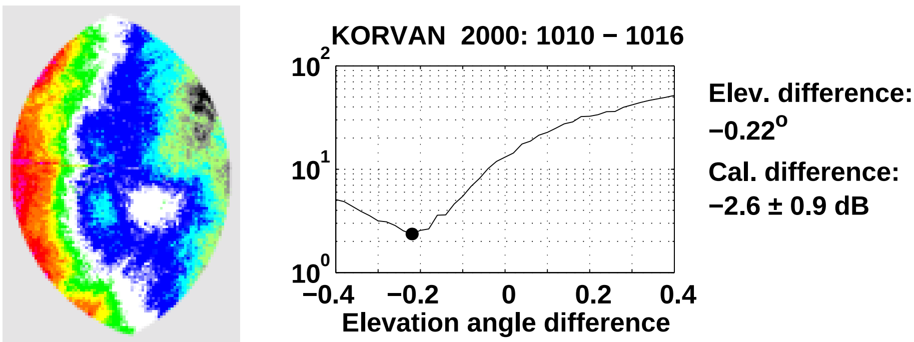
2.1 KORVAN

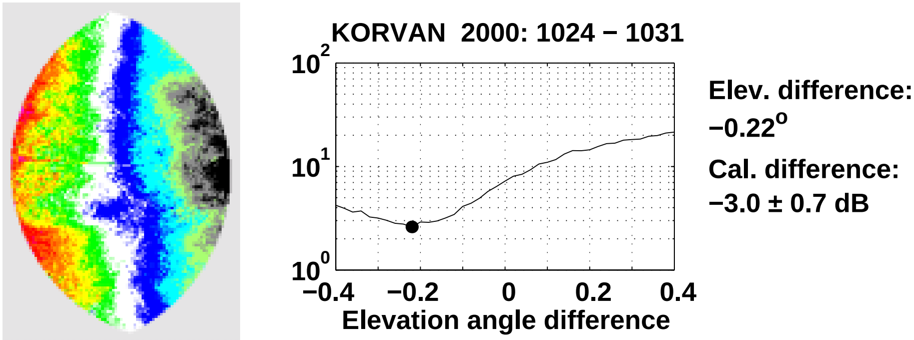
The Korpo-Vantaa pair is an excellent example of the power of the analysis system. All five cases studied give the same angular difference within ±0.02°. We may conclude that the Korpo radar measures at 0.2° lower angle than the Vantaa radar.

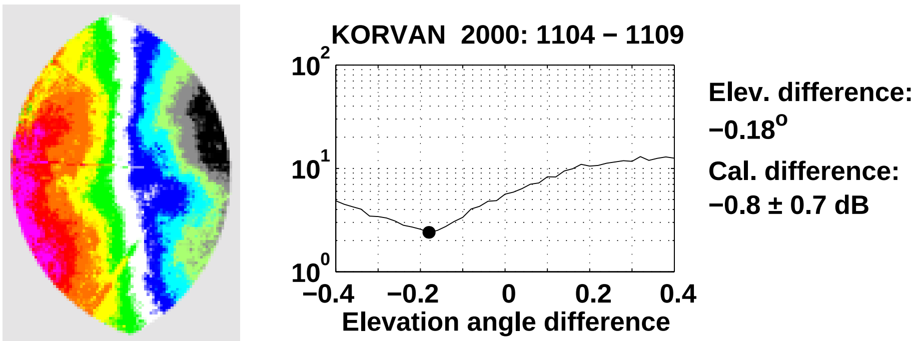
The first three periods indicate a -3 dB difference in the calibration. At that point the receiver of the Vantaa radar was recalibrated and it was found that that the receiver response curve had been incorrect for some time. After the recalibration the difference reduced to about -1 dB, as seen in the last two cases.

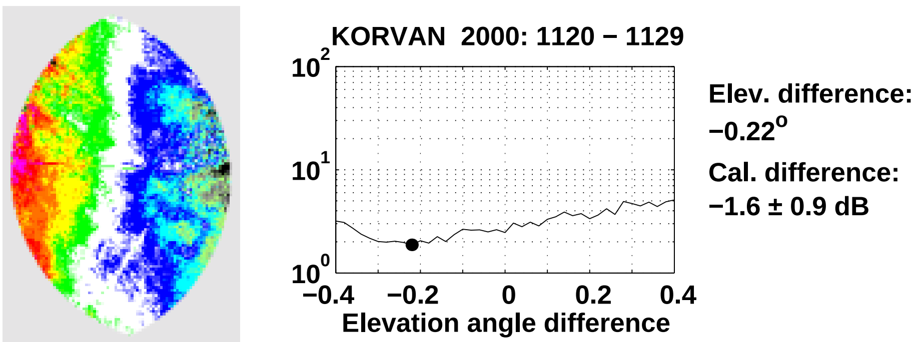
We can note from the figures that the Vantaa radar has three minor blocking sectors. It is assumed that these do not affect the results, although this has to be verified. The last two cases show a marked unsymmetry between the upper and lower halves of the figure. This indicates that the rain has not been uniform over the analysis area. Both radars are situated close to the sea, and the Southern half of the analysis are is over the sea, whereas the Northern half is situated over the mainland. This may, at least partly, explain the unsymmetry.






KORVAN 2000: 1024 − 1031
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
−0.22°
Cal. difference:
−3.0 ± 0.7 dB


KORVAN 2000: 1104 − 1109
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
−0.18°
Cal. difference:
−0.8 ± 0.7 dB


KORVAN 2000: 1120 − 1129
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
−0.22°
Cal. difference:
−1.6 ± 0.9 dB

2.2 VANANJ

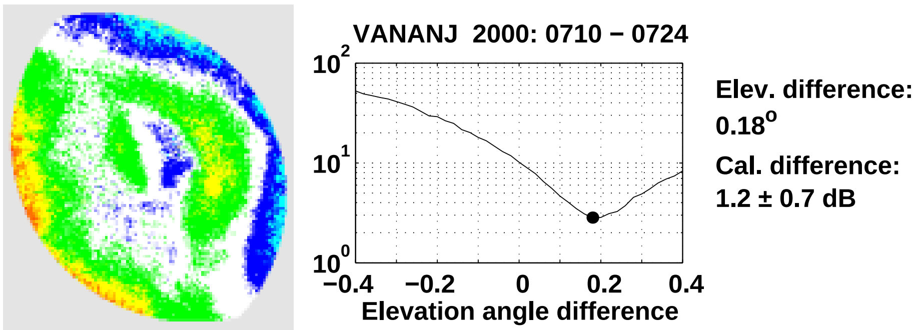
The Vantaa-Anjalankoski pair is one of the best cases studied. Four first analysis periods tell that the Vantaa radar measures at 0.2^o higher angle as the Anjalankoski radar and the last gives a 0.1^o difference.

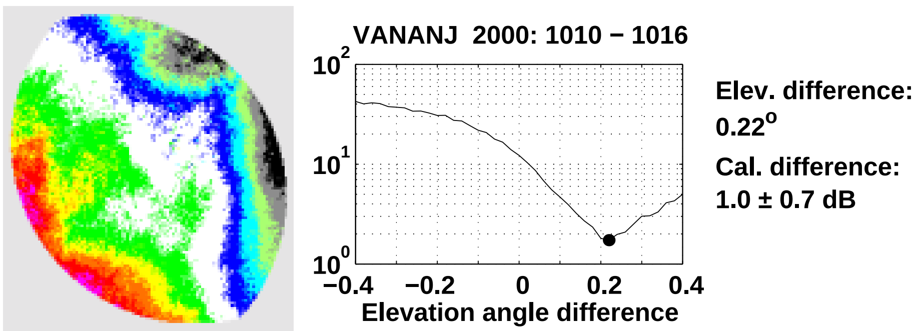
This drop is in a good agreement with changes in the nominal angles. For the Summer period, the nominal angle for Vantaa radar is 0.6^o and that of the Anjalankoski radar 0.5^o, whereas in the Winter both measure at 0.4^o. The change from the Summer angles to Winter angles happened between periods 4 and 5. Thus the nominal difference is 0.1^o for the first four periods and zero for the last. The analysis give 0.2^o and 0.1^o, respectively.

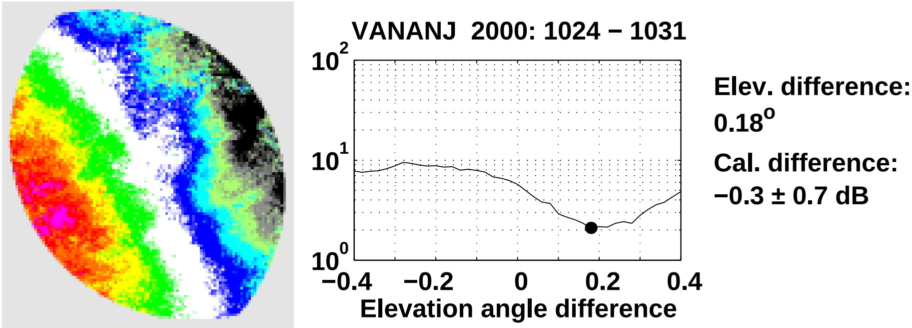
The method gives only differences in the collection angles. Thus it is not possible, just by using these results, to tell which radars have problems in the antenna pointing. However, combining Korpo-Vantaa resuls with Vantaa-Anjalankoski results, we see that Korpo and Anjalankoski collect at the same angle and the Vantaa radar at 0.2^o higher to both. This will be verified with solar pointing measurements at the three radars.

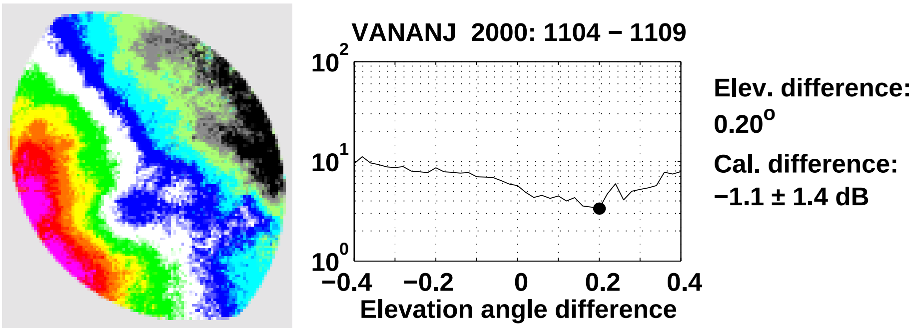
The calibration difference is 1 dB in the first two cases, and -1 dB in the last two, after the Vantaa radar recalibration. This drop by 2 dB is consistent with the 2 dB drop found in the Korpo-Vantaa pair after the Vantaa radar recalibration.

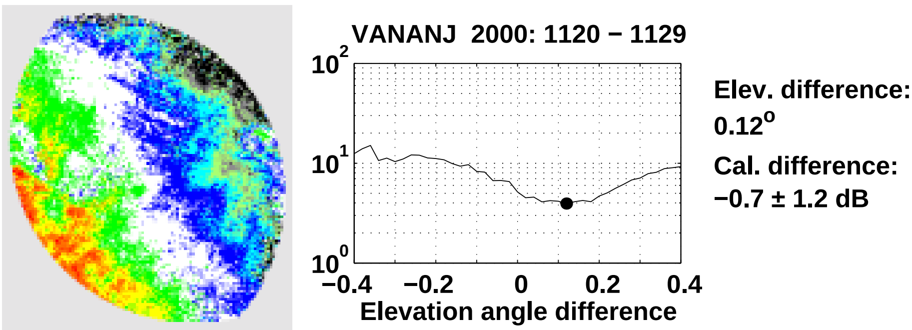
The general appearance of the data is good. The figures are symmetric with respect to the join line. The last case, which gives a different value for the collection angle difference, is noisy. Possibly the analysis period was not long enough for this pair.





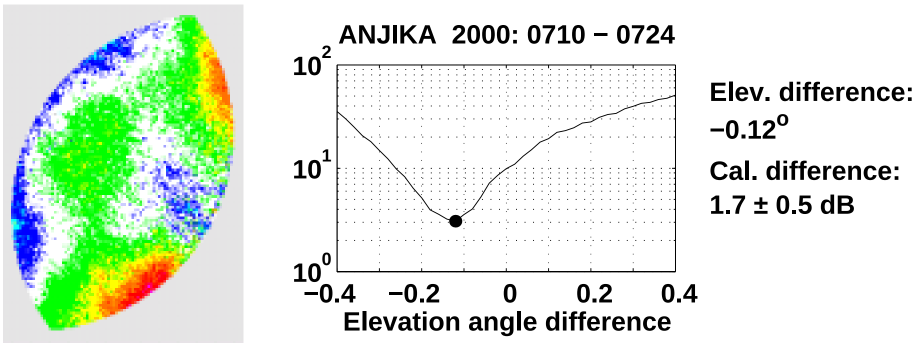

VANANJ 2000: 1024 − 1031
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
0.18°
Cal. difference:
−0.3 ± 0.7 dB

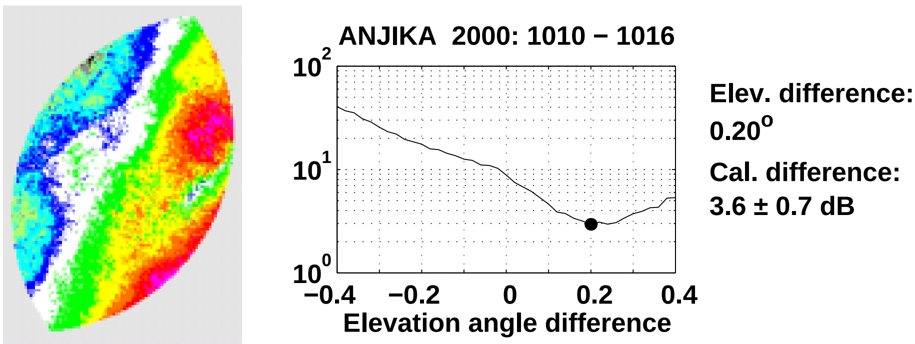

VANANJ 2000: 1104 − 1109
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
0.20°
Cal. difference:
−1.1 ± 1.4 dB

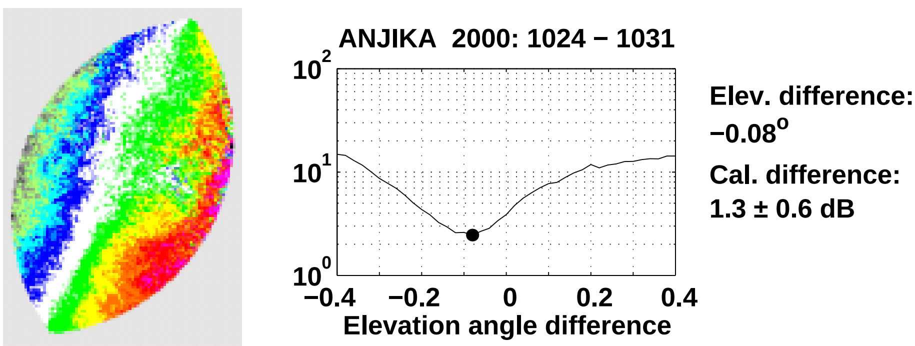

VANANJ 2000: 1120 − 1129
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
0.12°
Cal. difference:
−0.7 ± 1.2 dB

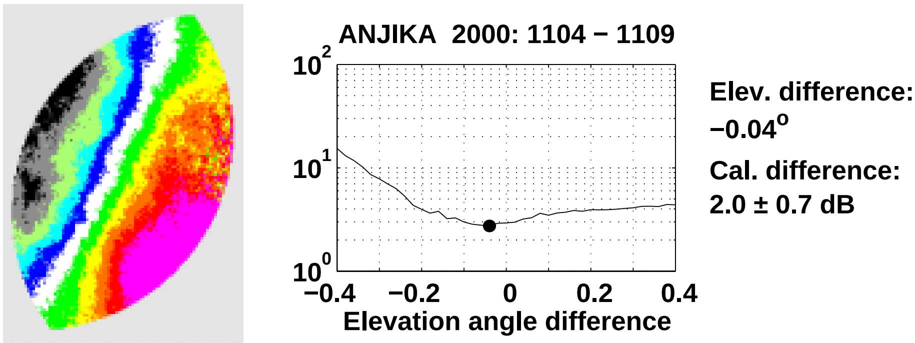
2.3 ANJIKA

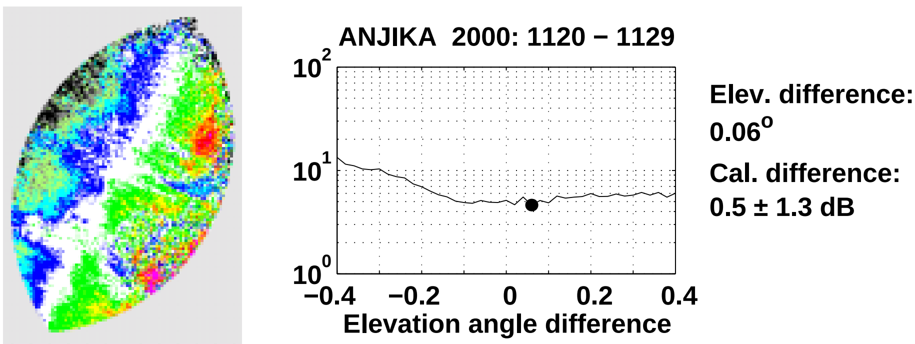
The Anjalankoski-Ikaalinen pair is puzzling. In the first three cases the minimum is rather well-defined, yet the second example gives an angular difference, which does not agree with the two others. The figure shows that in the second case the rainfall was not uniform. One can note a green 'channel' going though the high difference red area in the right hand edge of figure. The other periods indicate that the collection angles of the two radars are closely identical. The calibration difference deduced from the four periods is 1.4 dB.







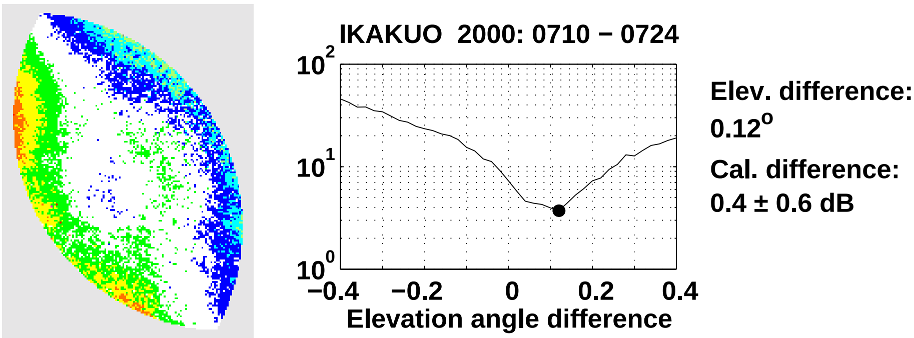

ANJIKA 2000: 1104 − 1109
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
−0.04°
Cal. difference:
2.0 ± 0.7 dB

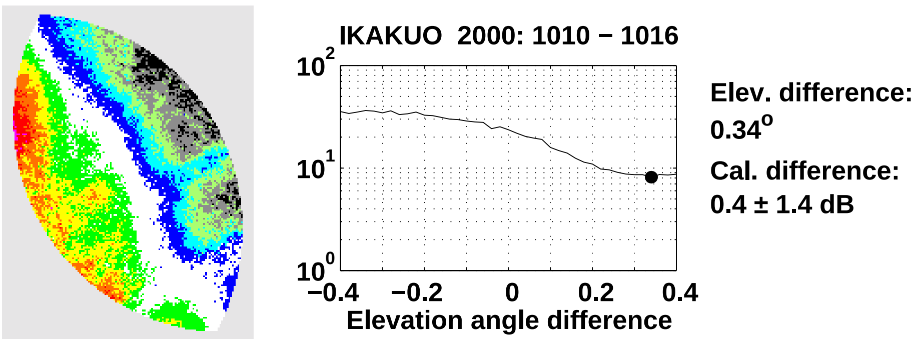

ANJIKA 2000: 1120 − 1129
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
0.06°
Cal. difference:
0.5 ± 1.3 dB

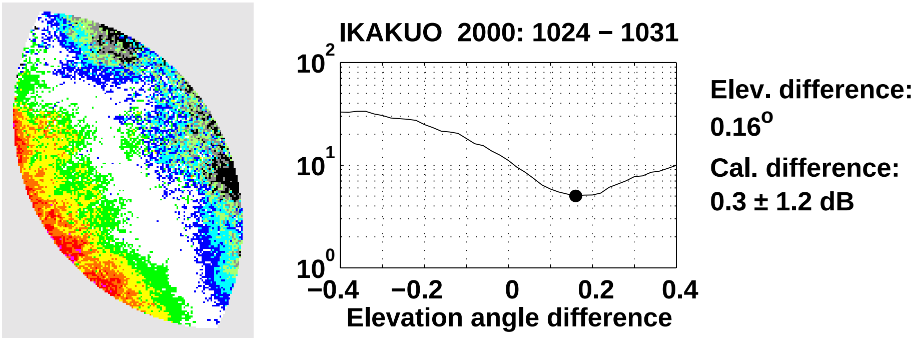
2.4 IKAKUO

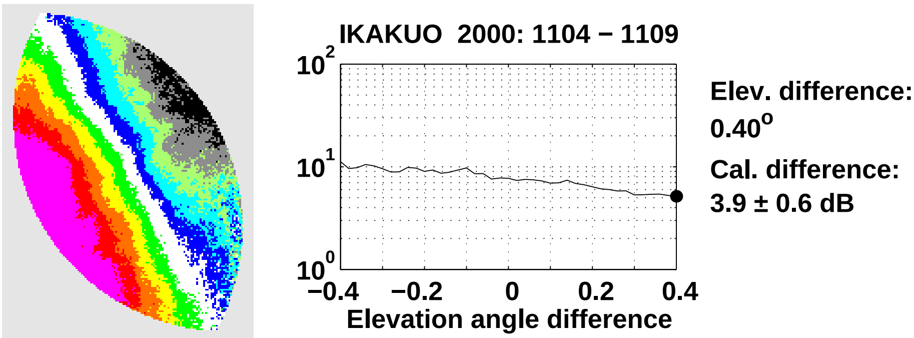
For the Ikaalinen-Kuopio pair no evident result is available. Two of the five cases indicate a $0.1 \ldots 0.2^{o}$ difference, whereas the other three point to $0.3 \ldots 0.4^{o}$. However, each of these has some peculiarities in the data. The figure for the second period is not symmetric with respect the join line, which is also true for the last period. For period 4 the residual curve is rather flat and thus the analysis is not decisive. This is most surprising, as the data itself is very much as we expect good quality paired radar data to be like.

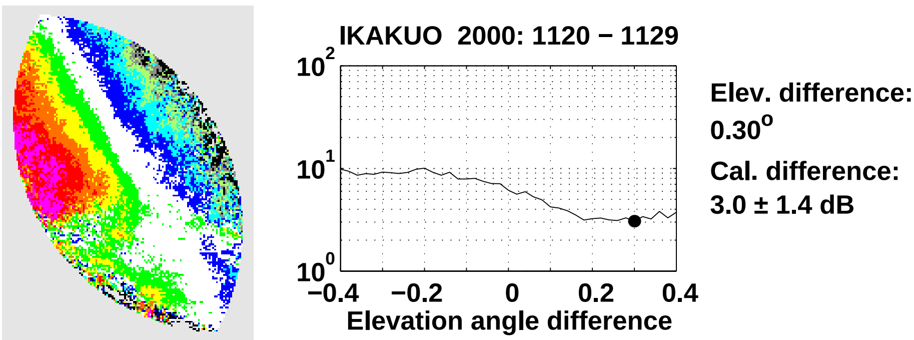
All in all, it is not possible to give fully unquestionable estimates in this case. The best we can do tells that the Ikaalinen radar collected data at a slightly higher collection angle ($\approx 0.1^{o}$) during the first three analysis periods, and that there is no calibration difference. The result of the collection angles is in agreement with the nominal angles, because the Ikaalinen radar has a nominal collection angle of 0.5^{o} during the Summer periods, whereas the Kuopio radar uses always a lowest elevation angle of 0.4^{o}.






IKAKUO 2000: 1024 − 1031
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
0.16°
Cal. difference:
0.3 ± 1.2 dB

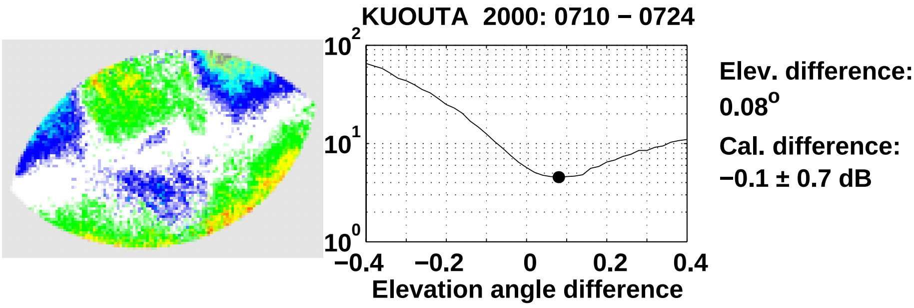

IKAKUO 2000: 1104 − 1109
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
0.40°
Cal. difference:
3.9 ± 0.6 dB

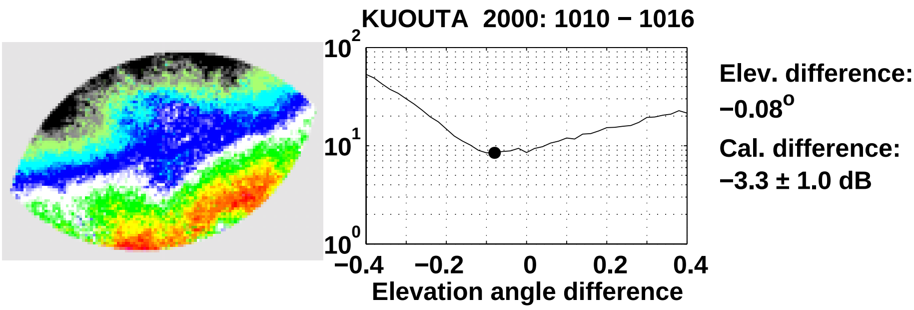

IKAKUO 2000: 1120 − 1129
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
0.30°
Cal. difference:
3.0 ± 1.4 dB

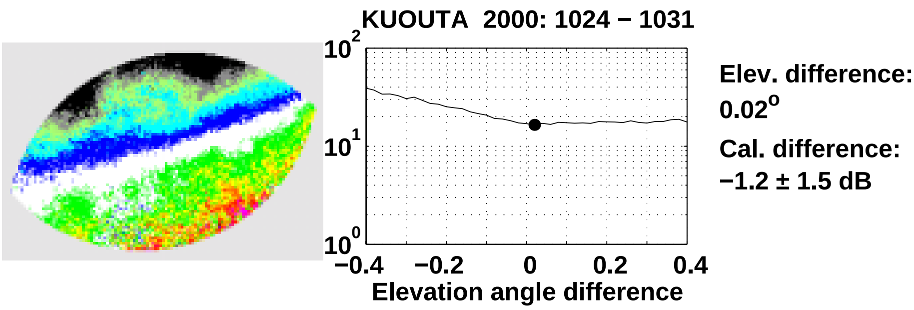
2.5 KUOUTA

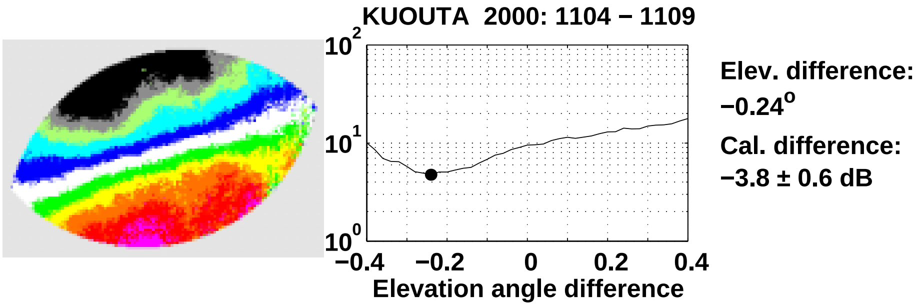
Four of the five periods studied for the Kuopio-Utajärvi pair indicate a zero difference for the collection angles. One case is very different, the angle difference is -0.24°, the data is of very good quality and the residual curve from the analysis is very good. There is no apparent reason to expect that the period 4 would not be reliable. Yet, if a single number has to be chosen, the best guess is that the radars collect data at same angles.

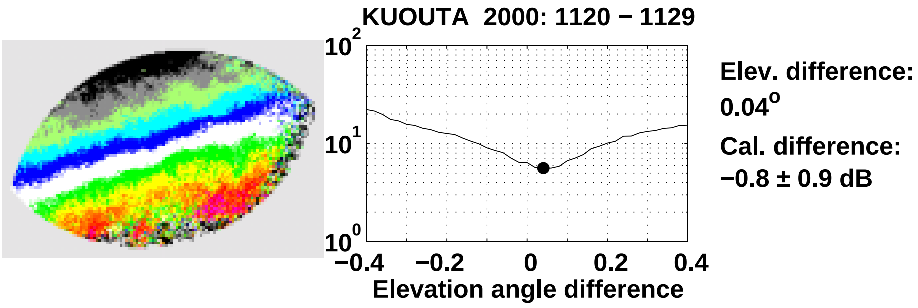
The calibration difference shows, even for the four cases with the same collection angle difference, wide variability. The may be caused by problems with the Utajärvi radar, which have been evident during the Autumn 2000.







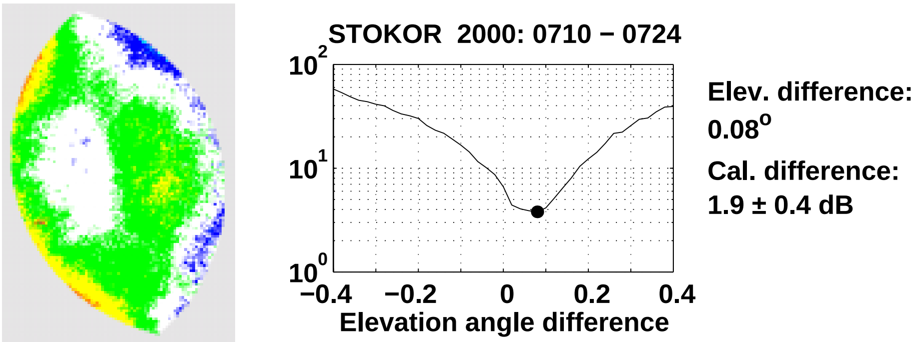

KUOUTA 2000: 1104 − 1109
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
−0.24°
Cal. difference:
−3.8 ± 0.6 dB

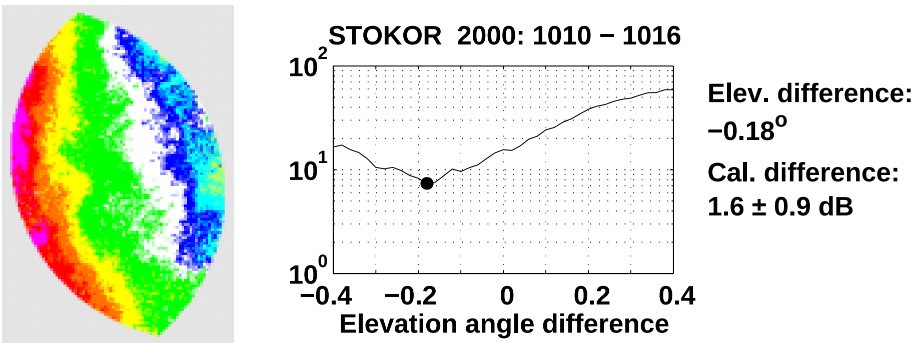

KUOUTA 2000: 1120 − 1129
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
0.04°
Cal. difference:
−0.8 ± 0.9 dB

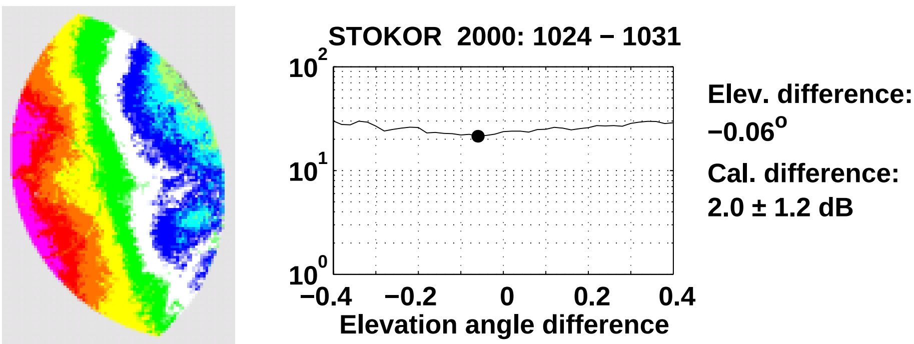
2.6 STOKOR

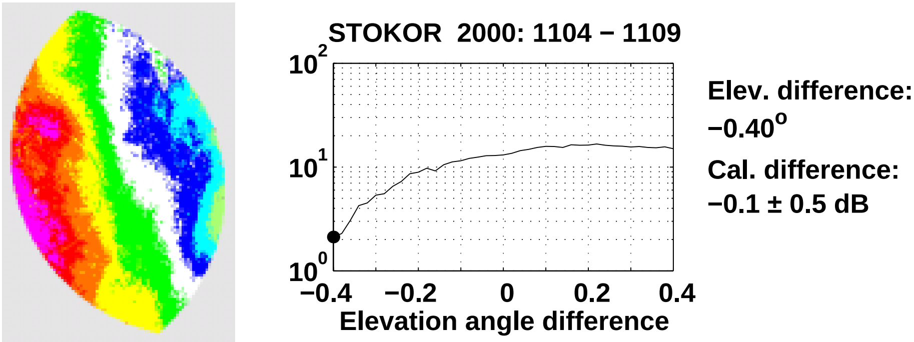
The collection angle difference for the Stockholm-Korpo pair range from -0.4° to 0.4° for the five periods analyzed. Two of the five have very flat residual curves, and thus these results are not very valuable. It is difficult to draw any conclusive result from the remaining three cases.

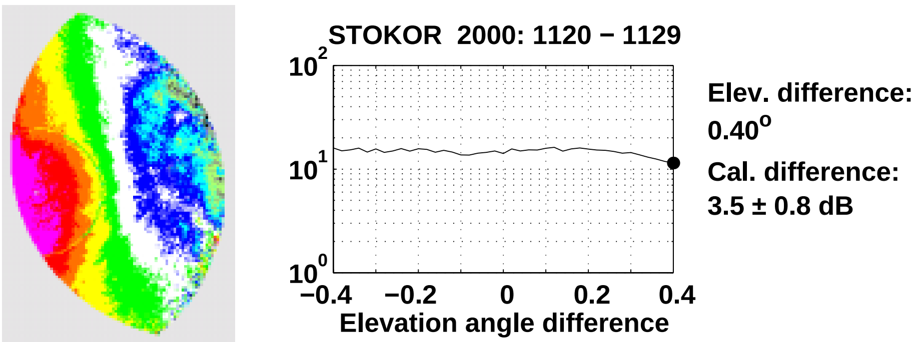
The data is of good quality and does not give any reason for the high variability of the results. An easy explanation is that this is caused by the rain attenuation correction. There is, however, no proof that this is the case. This can be tested be restricting the analysis to closer range, i.e. to the are between the radars.







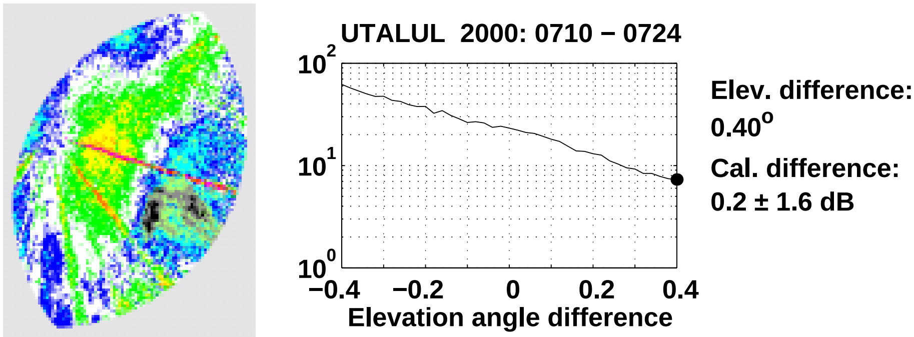

STOKOR 2000: 1104 − 1109
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
−0.40°
Cal. difference:
−0.1 ± 0.5 dB

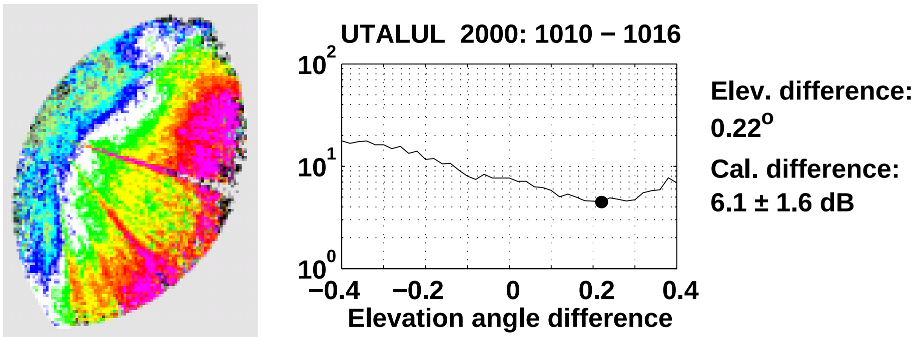

STOKOR 2000: 1120 − 1129
10^2
10^1
10^0
−0.4
−0.2
0
0.2
0.4
Elevation angle difference
Elev. difference:
0.40°
Cal. difference:
3.5 ± 0.8 dB

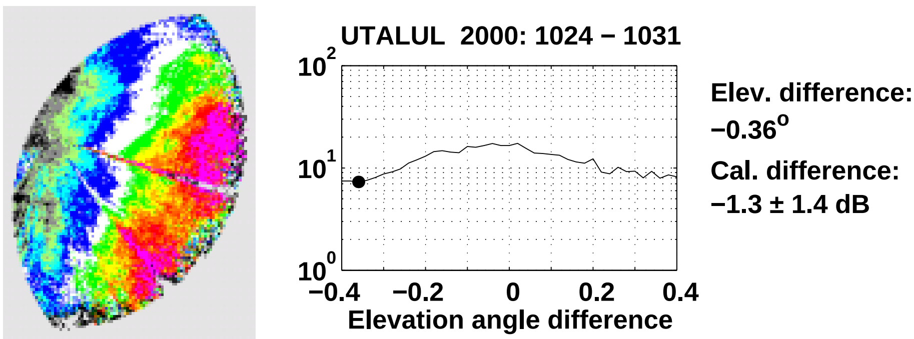
2.7 UTALUL

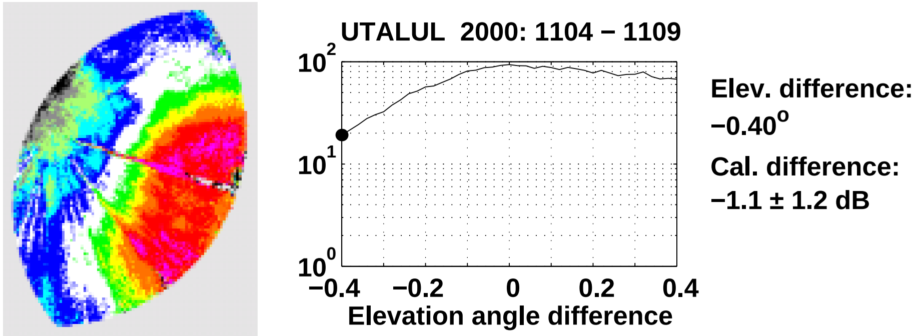
The Utajärvi-Luleå pair suffers heavily from the blocking sectors of the Luleå radar. The collection angle results cover the full range of differences that has been used in the study. In the last two examples the effect of the rain attenuation correction is well seen. As it is applied to the Luleå radar data and is not applied to the Utajärvi radar data, the lines of the constant diffrence turn towards the Utajärvi radar near the peaks of the ogee.

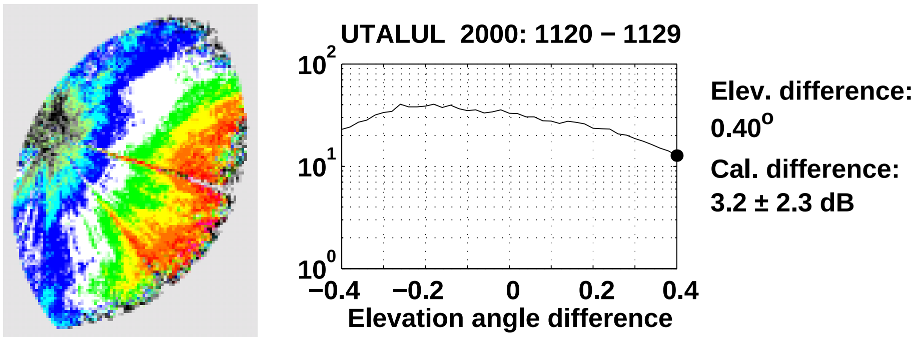
No result for the collection angle difference can be given.





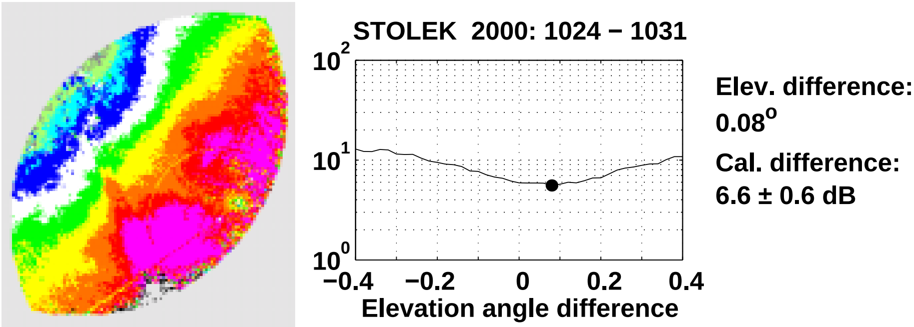


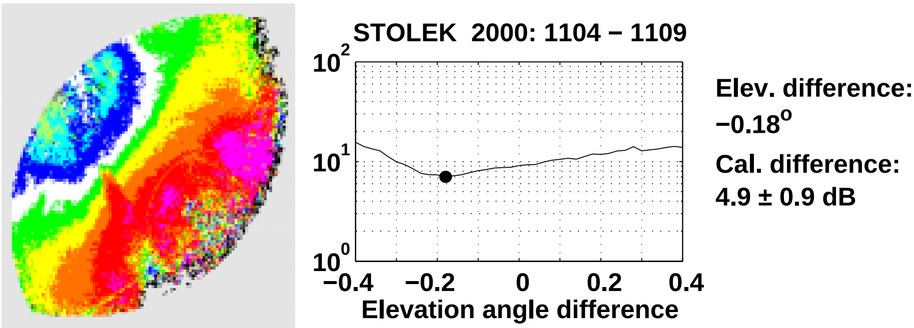

UTALUL 2000: 1104 − 1109
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
−0.40°
Cal. difference:
−1.1 ± 1.2 dB

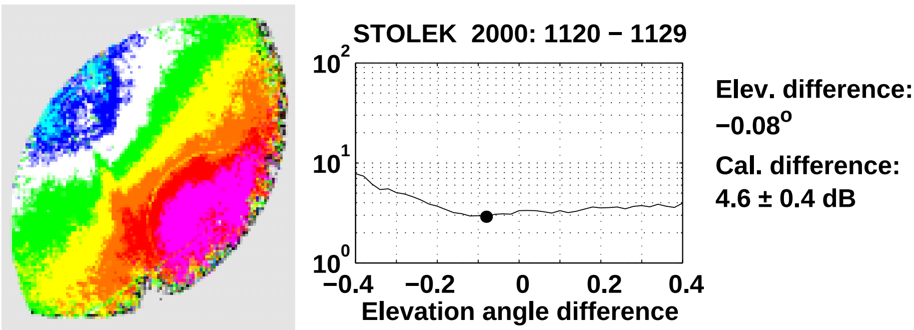

UTALUL 2000: 1120 − 1129
10^2
10^1
10^0
−0.4 −0.2 0 0.2 0.4
Elevation angle difference
Elev. difference:
0.40°
Cal. difference:
3.2 ± 2.3 dB

2.8 STOLEK

The Stockholm-Leksand pair produces good quality data, although there is one blocking sector of the Leksand radar visible. The collection angle difference varies, but the data supports a slightly lower collection angle for Stockholm. A calibration difference of about 5 dB is evident.

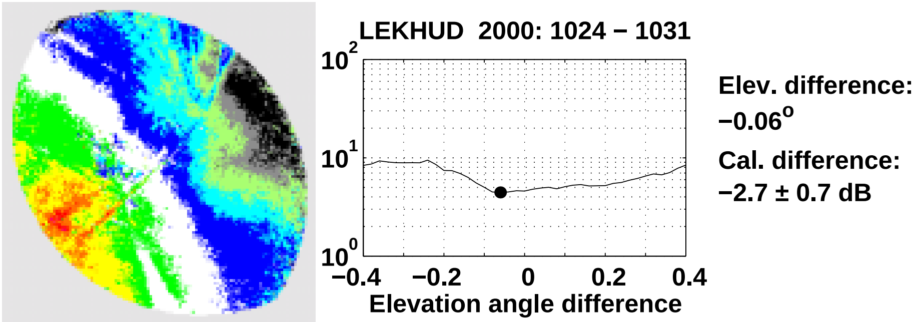


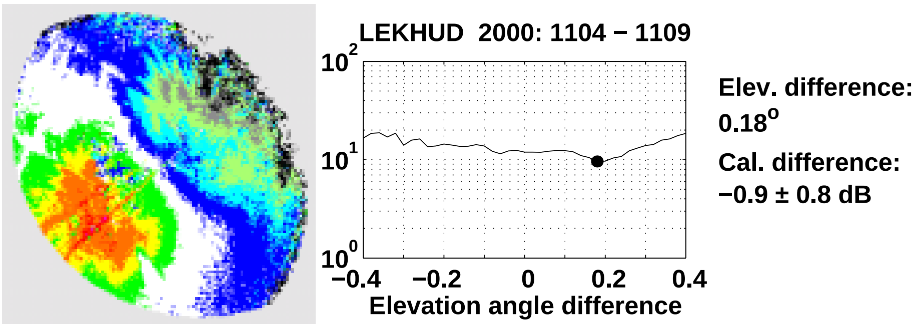


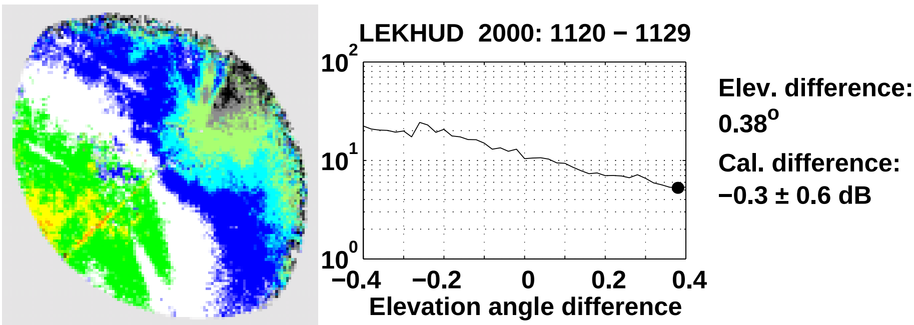


2.9 LEKHUD

The general appearance of the Leksand-Hudiksvall data is good. The three periods under study gives differing results for the angle, and thus no result is given. It is probable that better results are obtained after more periods have been analyzed.

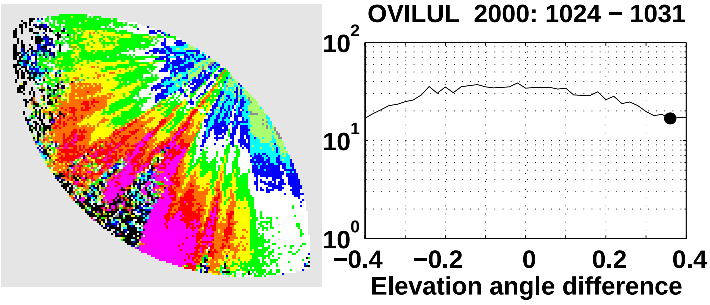




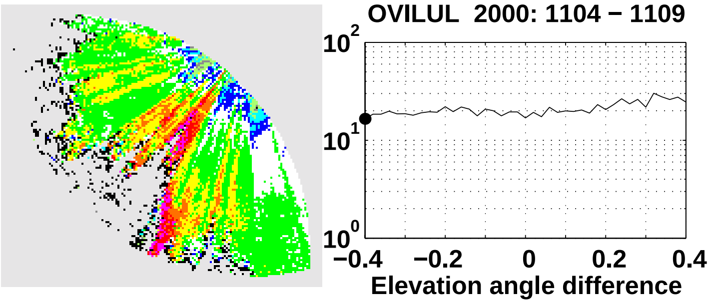


2.10 OVILUL

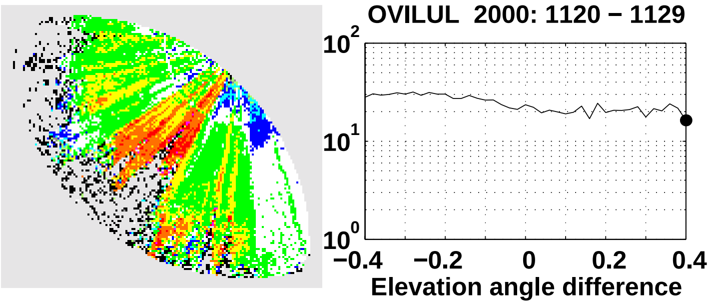
The Örnsköldsvik-Luleå pair data is useless, because of the blocking sectors of the Luleå radar.



Elev. difference:
0.36°
Cal. difference:
8.3 ± 4.0 dB



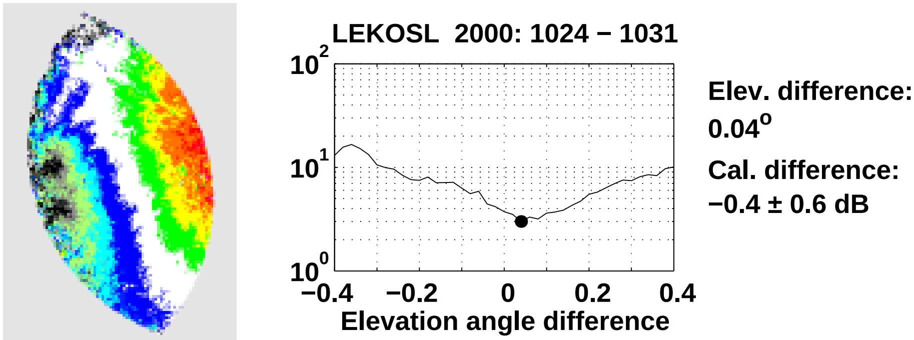
Elev. difference:
−0.40°
Cal. difference:
3.3 ± 2.0 dB

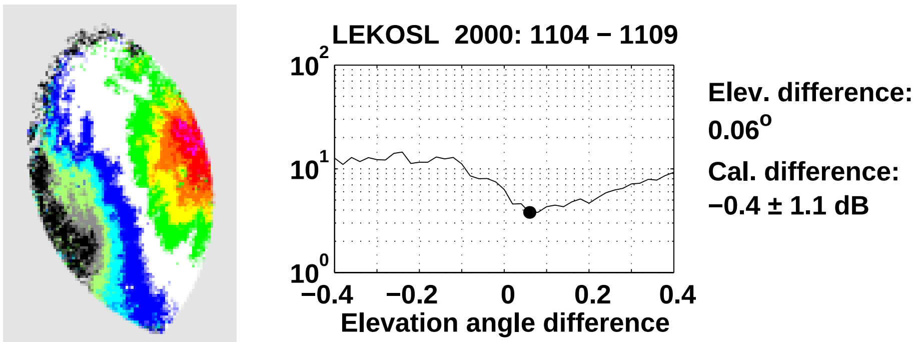


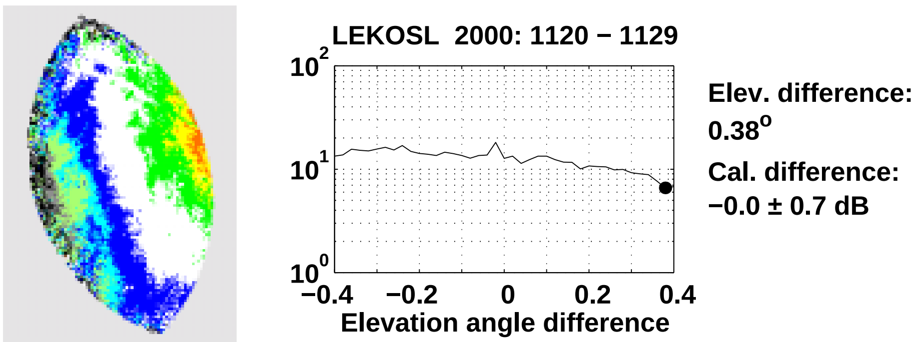
Elev. difference:
0.40°
Cal. difference:
3.4 ± 3.9 dB

2.11 LEKOSL

The Leksand-Oslo pair produces good data. Two of the three periods studied indicate the the collection angles are the same and that there is no difference in the calibration. The third case gives a very different result for the collection angle difference. However, the residual curve is rather flat. More data will probably solve the problem.







2.12 OSLHGB

The Oslo-Hægebostad pair is problematic, because the Hægebostad radar has considerable blocked sectors in the North. The results obtained so far are not decisive. The whole Northern half of the analysis area should most probably be excluded from the analysis. No such analyses have yet been done.

The present analysis indicates that the Hægebostad radar gives somewhat higher reflectivities. It was indeed found in December 2000 that there was a 5 dB error in the Hægebostad radar parameters. This is in a good agreement with the calibration difference of the last two study periods.