Finnish Meteorological Institute
15.4.1999

Revised proposal for a NORDRAD quality-assurance project

Name of the project: NORDRAD QA project

Active project period: 1.5.1999 - 30.4.2000

Overall project leader: Robin King, FMI

Project management group: Robin King FMI, Madelene Nilsson Swedish Armed Forces, Oddbjörn Thoresen DNMI, Jan Svensson SMHI

Impetus for the project: approval by the NORDRAD Steering Group (in Oslo, 20.4.1998) of the conclusions of the Final Report of the NORDRAD Continuation Project, and in particular the Executive Summary recommendations 9.9, 9.12, 9.13 and 9.14.

Aims of the project (summary): to improve the intensity level harmonisation of C-band radars in the NORDRAD network to within +/- 2dBZ on a monthly basis by the completion of the project, and to establish workable and efficient quality assurance and maintenance practices.

Sub-projects:

SP1: Monitoring of all NORDRAD radars using the NRDTOOLS software (both single and paired-radar data being used)
SP2: Investigation of angular pointing accuracy of all NORDRAD radars and implementation of improvements to achieve an agreed level of performance
SP3: Investigation of calibration and radar parameter value accuracy at all NORDRAD radars, and implementation of improvements to achieve an agreed level of performance

Reporting:

The project leaders, supported by the contact persons, shall produce
a) an interim report covering all aspects of the QA project before 31.12.1999
b) a final report including country-specific SP2 and SP3 reports before 31.5.2000.
The reports shall be prepared for,and finally approved by, the NORDRAD Steering group or its corresponding responsible body.

The final report of the project will contain a summary of agreed calibration and other maintenance practices, based on the work done in the three sub-projects in the three countries. Sub-projects SP2 and SP3 shall provide a report on the work on a country-specific basis, including detailed documentation of methods and problem-solving. These sub-project reports, prepared by their project leaders, shall be included as an integral part of the final report of the project (i.e.1 report for SP1 and 3 reports for SP2 and SP3).

Funding:

SP1 will be carried out by the FMI on behalf of SMHI and DNMI with their cooperation. Funding will be divided proportionately between the Institutes, using an agreed division scheme (see SP1 proposal).

SP2 and SP3 will be funded by each Institute separately for work carried out in its own country. If e.g. a calibration expedition is arranged to a given country, the costs will be agreed between the participating countries on a case-by-case basis (as in e.g. the expedition to Hudiksvall in the NORDRAD Continuation Project). Contributions to the final report shall be drawn up by the individual project leaders in consultation with the participant Institutes and other involved parties.

Proposal for a NORDRAD quality-assurance project: sub-project 1

Name of sub-project: NORDRAD intensity level operational monitoring (NORDRAD QA SP1)

Project leader: R. King, Observational Services, FMI
Contact person DNMI: Oddbjörn Thoresen
Contact person SMHI: Jan Svensson

Aim of sub-project: to carry out analyses (using both single radar and paired-radar data) of the NORDRAD network using the software package NRDTOOLS, and to produce regular reports of the relative intensity levels of the participating radars to support other activities in the NORDRAD QA project (i.e. antenna angle, calibration and radar constant parameter investigations).

The single radar analyses will use the standard NORDRAD pseudo-cappi (0.5 km level) product with a range of 240 km and a resolution of 2*2 km^2. This should involve very little or no new product definition or production. In the case of the paired-radar data, the requisite areas will be defined by the project (see attached example of Finland's areas). They will contain both radars, with an extra area of about 10 km behind each. The resolution will be 2*2 km^2. Each composite area product is made at 15 minute intervals, once for each radar separately. The data from these two products are compared and combined in the analysis image. Additionally, the composite containing both radars of the pair is run monthly, or whenever elevation angles or other definitions are changed for either radar. This third product provides the NORDRAD dividing line between the radars as used in the other composites. In order to minimise the number of extra products required for the analysis, it is proposed that, as far as possible, each radar shall be compared with a maximum of only two neighbouring radars (in special cases, this may be 3). To share the burden of the production of these paired-radar "composites", each country may be asked to produce its own paired-radar data, with cross-border areas being shared. These products will then be picked up by FMI for analysis using the normal NORDRAD facilities. Even with this arrangement, the number of extra NORDRAD products is quite considerable, as can be seen from the following table:

Single radars	paired with	number of products
VAN	KOR, ANJ	2
ANJ	VAN, IKA	2
IKA	ANJ, KUO	2
KUO	IKA, UTA	2
KOR	VAN, STO	2
UTA	KUO, LUL, ROV	3
ROV	UTA	1
LUL	KIR, OVI	2
HUD	OST, LEK	2
OVI	LUL, OST	2
STO	HUD, NKP	2
NKP	STO, GOT	2
GOT	KKR, NKP	2
KKR	GOT, GBG	2
GBG	NKP, KKR, OSL	3
LEK	HUD, STO, OSL	3
	(alternatively only HUD, STO)	
KIR	LUL	1
OST	OVI, HUD	2
OSL	GBG, LEK	2
	(alternatively, only GBG)	

Total numbers of (new) products to be run in NORDRAD: Finland: 14
Sweden: 23 (22)
Norway: 2 (1)

Chains of comparison:

1) KKR->GOT->NKP->STO->LEK->HUD->OST->OVI->LUL->KIR
2) KKR->GBG->OSL
3) STO->KOR->VAN->ANJ->IKA->KUO->UTA(->ROV)
4) LUL->UTA(->KUO->IKA->ANJ->VAN->KOR)
5) OSL->LEK (may be omitted)

The chains would be much more secure if multiple-pairing could be considered. However, it is probable that the extra loading on the national nodes brought about by the production of the abovementioned extra products may be the maximum permissible. The chains are designed so that they consist of radars with good overlaps, and have a double link between Finland and Sweden (STO<->KOR and LUL<->UTA) for more robust use. The double link between Norway and Sweden may not be thought necessary, although desirable. Because the Rovaniemi radar is exceptional in the network (an X-band radar using EWIS 1 software), its comparison is only made with Utajarvi, although in principle it could be also compared with Lulea and Kiruna. During the course of the project, the Rovaniemi radar will probably be replaced by the new Luosto radar, in which case comparisons with this will replace those with the old radar.

The actual relative levels between neighbouring radars will be determined not only from the levels obtained from the paired-radar data, but also from the levels of the single-radar analysis products, both in map and graph form (see examples in the Final Report of the Continuation Project). The determination will be made subjectively using the available data analysed over approximately 2 - 3 week rainy periods. Experience from 1997 shows that typically one usable period occurs monthly. More frequent analysis will be made if weather permits.
As the wet weather will probably not affect all parts of NORDRAD simultaneously, the levels found throughout the chains will probably be an average over about a month.

The results will be placed on FMI www pages which are accessible from authorized internet addresses in SMHI and DNMI. In this way the results (including all the single and paired-radar images for all radars in NORDRAD) will be immediately available to users in the three Institutes. A mailbox will also be provided for feedback. The relative levels of the radars will be shown on a diagram which contains +/- 2dBZ warning levels on each side of the average level for the whole network. After a period of time it will also be possible to compare the average level from month to month using as a reference a radar (or several radars) which are found to be particularly stable with respect to the whole group of radars. It is to be hoped that the Institutes will, in the light of the results obtained, take prompt steps to reduce the scatter, probably by changing a parameter in the radar equation at the radar stations which are persistent outliers: the project year is in this respect also a period of working towards a model of agreed operational cooperation in this respect between the NORDRAD countries.

The analyses will be run in FMI computers. In view of the large amount of data generated, FMI will not guarantee to keep the whole year's data on-line on disk. If felt desirable, the data may be archived on CD, and distributed to the participant NORDRAD countries.

Towards the end of the 1-year period the situation will be reviewed: FMI may be asked (but may also refuse) to continue the analyses on behalf of the other NORDRAD countries. In either case the software extensions that FMI has made to carry out the analyses and their visualization will be available for use in the other NORDRAD countries free of charge, although FMI will not install or guarantee the use of such software on other systems than its own.

Estimate of required resources at FMI

In the initial stages of the sub-project, the following tasks will be carried out:

- definition of paired radar areas
- setting up of www pages for results
- automatising of data selection and processing (mainly Perl scripts)
- standardizing of data output image format (Perl and PV-Wave graphics)
- writing of output chain comparison graphics program
- testing and trial runs

It is estimated that this phase will require 14 working days at senior research scientist

level.

In the operational phase of the sub-project, it is estimated that somewhat more than one rainy period per calendar month will be used (14 occasions for the year of the project), and that each occasion will require 2 working days of analysis covering the 19 single radar analysis results and the 39 (or minimum 37, see above) paired radar comparisons. The year's total for the operational phase is therefore estimated as 28 working days at senior research scientist level.

The total personnel resources are therefore estimated as 28 + 14 = 42 working days for the year of the project. Costs are estimated using the standard FMI rate for the staff grade concerned, including infrastructure costs that cover the use of computer resources as required. This cost is 291 FIM/hour, or 2110 FIM for a 7.25 hour working day. Total costs for this sub-project are therefore 88620 FIM.

If we use the same principle to divide these costs that we use with e.g. the AU maintenance costs then they would be split between FMI, SMHI and DNMI according to the number of operational radars, i.e. 7, 11, 1 respectively. To these figures is added a standard "1 radar" overhead for each institute. The above sum would therefore be divided in the ratios 8/22, 12/22 and 2/22, respectively. Final cost allocation would be as follows:

FMI uses staff resources to the sum of 32226 FIM SMHI disemburses FMI to the sum of 48338 FIM DNMI disemburses FMI to the sum of 8056 FIM

Total costs: 88620 FIM

If data from the new Norwegian radar, planned to be brought on line in the summer of 1999, is included in SP1, then the division of costs may be changed to reflect this.

Proposal for a NORDRAD quality-assurance project: sub-project 2

Name of sub-project: investigation of angular pointing accuracy of NORDRAD radars (NORDRAD QA SP2)

Project leader in Finland: R. King, Observational Services, FMI.
Project manager Sweden: Madelene Nilsson
Contact person DNMI: Oddbjörn Thoresen

This sub-project aims at investigating the azimuth and elevation angle pointing accuracy achieved operationally by radars in the NORDRAD network, and implementing improvements to achieve an agreed level of accuracy. The continuation project coupled with operational experience of the radars has shown that in particular the variation of the true elevation angles achieved by the radars plays a significant role in producing visible differences between the data of neighbouring radars in a composite image. Additionally, such inaccuracies obviously cause errors in products using height determinations, such as CAPPI and ECHO TOP. Although small azimuth errors may be less visible, nevertheless a quality assurance system should also include regular checking of azimuth angles, too.

Because of the differences between the Ericsson and Gematronik radars and their associated radar data and control systems, it will not be possible to carry out identical project programmes in Finland on the one hand, and in Sweden and Norway on the other. The overall aims of the sub-project in each country are, however, the same:

1) To carry out on several occasions throughout the project period at each radar an investigation of the azimuth and elevation pointing angle accuracy, repeatability, resolution and control linearity using primarily the sun and also other aids, such as echoes from masts and in-situ mechanical measurements of antenna position.

2) To devise suitable operational versions of these measurements for routine use.

3) To propose acceptable levels of variation of achieved antenna behaviour within NORDRAD, with action limits leading to servicing/overhaul.

4) To analyse the causes of inaccuracy and variability and make recommendations for structural and/or electrical modifications. These analyses shall also lead to the proposal of a (radar-specific) code of practice including diagnostic methods and documentation.

5) To carry out such electrical/mechanical repairs, overhauls or modifications as suggested by the results of the investigation.

During the active period of the project (one year), the member countries will intensify cooperation in exchanging information on methods used and experiences gained, and will document their work thoroughly for future reference.

The working methods of FMI to be used with its Gematronik/SIGMET radar systems which may be considered include, for example, the following:

1) Determination of the elevation and azimuth angle accuracy using the sun at as many angles as necessary for each radar using the IRIS ascope utility.

2) Determination of the elevation movement accuracy with a direct mechanical angle measurement with respect to the vertical using a sensitive angle-measurement instrument (goniometer) affixed to the antenna.

3) Checking of the beam for true direction and pattern at certain radars where this is possible (e.g. Vantaa) using the IRIS beam facility, which constructs the beam pattern from a 3D sector scan of an external signal generator and horn radiator. This will also provide a check on the beam widths and on-axis gain figure employed in the radar equation (see also sub-project 3).

Proposal for a NORDRAD quality-assurance project: sub-project 3

Name of sub-project: Investigation of calibration and radar parameter accuracy (NORDRAD QA SP3)

Project leader in Finland: R. King, Observational Services, FMI
Project manager Sweden: Madelene Nilsson
Contact person DNMI: Oddbjörn Thoresen

This sub-project is a follow-up of the work done by the balloon group in the NORDRAD continuation project. It builds on the experiences of that group and extends the scope of checks to other related areas.

The resources required to carry out a standard-reflector check on all radars in the network would be prohibitively large. The main remaining difficulty in reflector measurements is the accurate sampling in space, i.e. how to get the reflector in the middle of the contributing volume sampled by the radar. It seems reasonable to wait until the operational radar software and signal processors are capable of performing very dense spatial sampling in a sector volume scan before applying this method further. This kind of enhancement would make the actual measurements much easier than was the case during the winter 1997-98. It is strongly recommended that the radar systems should be enhanced to allow such measurements in the future.

The reference feed horn measurements, however, showed a very good accuracy and repeatability in the calibration of the receiver chain. There is also good evidence that measurements of the microwave emission of the sun could provide a fast quality check of the receiver calibration. Discussions at the QA Workshop in March 1999 confirmed that all NORDRAD countries are actively interested in devising operational methods of performance checking using solar microwave emissions. Both feed horn and sun measurements are quite easy and quick to perform in the field. These measurements should be made at all NORDRAD radars, at least at those radars which are outliers in the analysis carried out in sub-project 1.

In addition to the calibration procedures above, it was found during the NORDRAD calibration tests that the actual parameters (e.g. various losses) used in determining the radar constant should be carefully and critically checked and documented on-site at each radar. This re-checking will be carried out in all three NORDRAD countries throughout the project period.

A workshop was held in Finland (March 1999) for technicians and experts from all three countries, in which the emphasis was on exchange of experiences and hands-on comparison of techniques in the fields of calibration (SP3) and antenna control (SP2), also using data collected and analysed in SP1. The workshop provided additional information to help all NORDRAD countries in specifying in detail their own corresponding SP2 and SP3 projects. In addition, Sweden presented a preliminary phase report, giving details of investigations in SP2 and SP3 already carried out.

Work contents of SP3:

1. Workshop on calibration methodology prior to the actual field measurements (already held)

2. Re-checking and documentation of the radar parameters determining the radar constant and parameters affecting the measured dBZ values in the processing chain (including calibration constants) at all NORDRAD radars.

3. Feasibility study as to how the radar systems could be improved in order to achieve good sampling density in standard-reflector measurements.

4. Performance of identical reference feed horn measurements at all NORDRAD radar systems, at least at those systems which exhibit the largest inhomegeneities in sub-project 1.

5. Performance of identical and simultaneous sun measurements at overlapping radar pairs (NOR - SWE, SWE - FIN). Comparison of results to simultaneous reference feed horn measurements. Again such radar pairs have the largest priority, which show anomalies in sub-project 1.