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NORDKLIM – Nordic co-operation within climate activities

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Recommendations for a common Nordic HQC System

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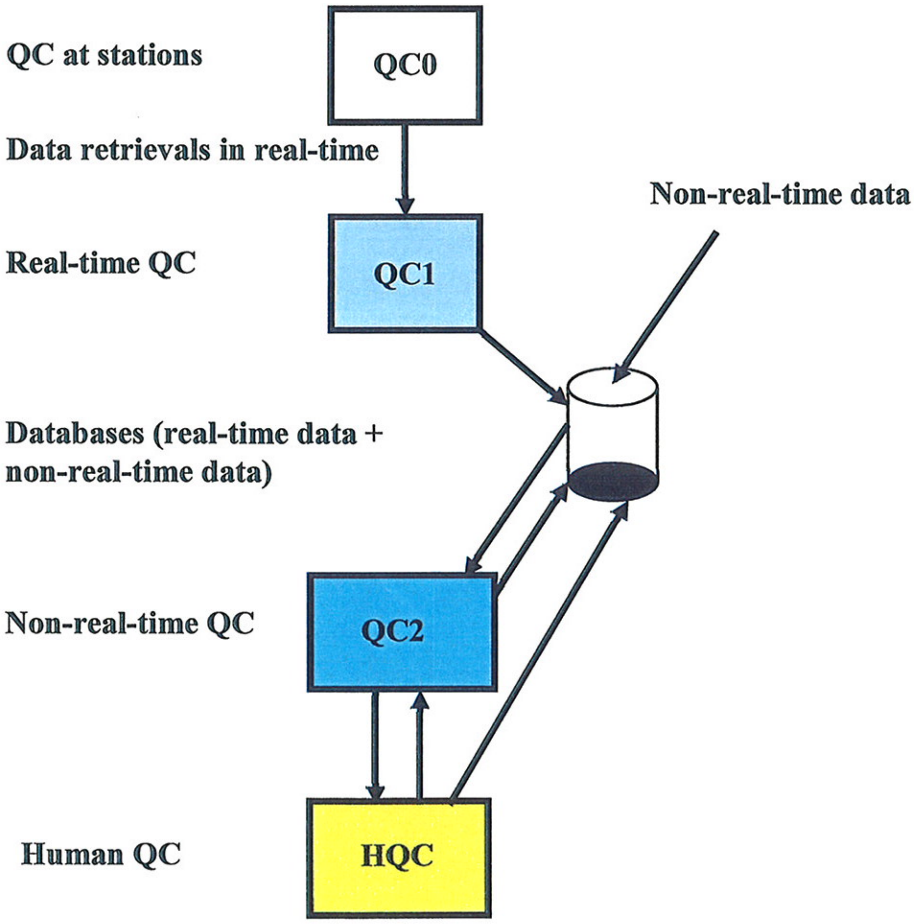
Report 9/2003



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June 2003

Leah Tracy, Veðurstofa Íslands, has corrected the orthography and improved the linguistic formulations of this document. Thank you very much!

CLIMATE REPORT

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Manual Quality Control of Meteorological Observations

Recommendations for a common Nordic HQC System

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ABSTRACT

This report is prepared under Task 1 in the Nordic NORDKLIM project: Nordic Co-Operation Within Climate Activities. The NORDKLIM project is a part of the formalised collaboration between the NORDic METeorological institutes, NORDMET.

The report describes a future manual quality control (HQC) as an integrated part of a total quality control system composed of automatic controls in real-time (QC1) and non-real-time (QC2) and a manual check and supervision of the automatic controls. In that connection the report focuses on a standard for a future manual work through different scenarios and gives general and special recommendations for a common Nordic HQC system.

KEYWORDS

Manual quality control, Meteorological observations, NORDKLIM

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Summary

The Nordic countries have their own manual control system i.e. HQC system. The different countries have reached varying stages in modernizing their manual systems, but there is general agreement that modernization and improvement of the respective HQC systems is needed for the systems to become more efficient.

The goal must be to make it possible for the persons involved in the quality control work to make quick decisions based on relevant and easy accessible information. Another goal is to carry out the manual control on a daily level close to the observation time in order to make the control as rational and effective as possible.

It is necessary to improve the automatic control methods and to automate some of the present HQC procedures. A modernized future HQC system will depend on a well designed interactive visualization tool or tools where the best and most effective methods are used during the HQC process.

Different HQC scenarios show how practical work with manual controls should be done in the future. Error lists based on the flagged observations during the automatic quality control process and the presentation of such flags are the basis for HQC.

Spatial control is a main point in the HQC, e.g. in supervising the automatic controls performed at the QC1 and QC2 phases. Furthermore, it is necessary for the inspector to know the weather analysis for the actual control hour together with different climatological information presented as topographic map, a sketch of the weather station area, exposition of the instruments, panorama, etc. Another efficient course of action for correcting data is examination of time series from the actual station and neighbouring stations. Changes of a parameter value are often comparable with the changes at representative stations in the neighbourhood.

When correcting data manually, the inspector should have the possibility to choose between different objective interpolation methods to get a suggested value before the correction is done. Whether the correction is performed automatically or manually it is favourable to have a dynamic coupling between map, graph and table to evaluate the correction in time and space.

Manual controls also contribute to the evaluation of how the automatic controls work, e.g. concerning the check values of climatological consistency controls, by means of flagging statistics. Flagging statistics may also be useful for effective planning of station visits.

In practice, HQC work is based on a user interface where inspectors can work with different tools in a single environment. For this work to be efficient, it is necessary that all tools for presentation of useful information are available. With this in mind, this report presents a description of general as well as specific recommendations for an HQC system concerning visualization, presentation, functionality and some other aspects.

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Abbreviations

ADP	Automatic Data Processing methods
DIANA	DIgital weather ANAlysis program at met.no
DMI	Danish Meteorological Institute
ECMWF	European Centre for Medium range Weather Forecasting
FMI	Finnish Meteorological Institute
GIS	Geographical Information System
HIRLAM	HIgh Resolution Limited Area Modelling
HQC	Human Quality Control
KVALOBS	QUALity assurance of OBServations at met.no
MESAN	SMHI system for MESoscale ANalysis using a first guess from Hirlam
met.no	Norwegian Meteorological Institute
NMS	National Meteorological Services
NORDKLIM	NORDic co-operation within CLIMate activities
NORDMET	Formalised collaboration between the NORDic METeorological institutes
QC	Quality Control of meteorological observations
QC0	Quality control at station site
QC1	Quality control online in real-time
QC2	Quality control in non-real-time
SMHI	Swedish Meteorological and Hydrological Institute
SYNOP	Synoptic observation from an automatic weather station, manual weather station or semi-automatic weather station
VI	The Icelandic Meteorological Office (Veðurstofa Íslands)
WMO	World Meteorological Organization

1. Introduction

The Task 1 group in the Nordic NORDKLIM project works on issues concerning the quality control of meteorological observations. Different automatic quality control methods (QC) of meteorological observations are described in Vejen et al. (2002). There is a continued need for co-operation on automatic controls, but even with the best control methods, some observations must always be checked manually (HQC). For quick decisions on handling such observations, a new and better HQC presentation system is required. The objective of developing a common HQC system is to save resources, improve data quality and make quality control more effective than it is today.

1.1. Background

A quality control system consists of two main parts: automatic quality control methods and the manual ones. Ideally it should not be necessary to correct data with manual control methods. However, experience has shown that manual controls are extremely important for many reasons:

- Single station automatic methods point at certain or possible erroneous observations but are unable to estimate the correct observation values. Moreover there are many cases where values are flagged as probably erroneous, which may turn out to be correct when spatial controls are performed later on. We need a manual system for checking this.

- Spatial automatic methods are able to produce parameter values (of a selection of parameters) for a station location based on observed values from the neighbouring stations. However, current calculation methods have weaknesses. They are not able to correct suspicious observations satisfactorily in all weather situations. Similarly, in weather situations, which may be of particular importance because of their rarity or severity; automatic spatial methods may change correct values into incorrect ones.

- Until now several useful automatic correction methods have been developed for some parameters, i.e. air pressure, temperature, humidity, precipitation amounts and wind. If other parameters are to be corrected or interpolated, this must be done manually.

- Most often, spatial automatic methods perform adequately for relatively plain homogenous areas, but may be unreliable in areas with rough topography. In other words, methods that may be convenient for Denmark, the southern part of Sweden and most of Finland, may be useless for the remaining part of the Nordic countries. Furthermore, even in flat terrain there are weather situations when the automatic methods do not keep up with the demands for quality.

- Manual controls contribute to the evaluation of how the automatic controls work. They can provide answers to the following questions: What is the accuracy (e.g. the hit percentage, and the miss percentage) of this control method? To what extent is the accuracy a function of weather situations? A manual well designed control system allows changes in the test values of the QC algorithms or the algorithms themselves, in order to make the controls more efficient and accurate. By evaluating which of the automatic methods are effective and which are not, it is possible to produce more realistic statistics that display the quality of the different stations to find out which stations need inspection visits, which observers need guidance, etc.

- Manual controls utilize many different data or information sources, for instance reference stations, neighbouring stations, locality and topography, oceanographic data, climatologic data, weather analyses, radar and satellite information, parameter statistics, etc. In order to reduce the burden of manual resources in routine work, we can in the future investigate the possibility of including the experience gained from the use of this information into automatic quality control procedures in a manner that still maintains acceptable quality standards.

Correcting errors is important. HQC contributes to improve this error correction. The best realistic quality information connected to the observations is another important goal for the quality control process.

It is impossible to construct a completely accurate quality control system because there will always be grey areas where misflagged values turn out to be correct. To reduce the number of misflagged observations in the database, automatically flagged observations should be controlled manually in a rational and effective way. Some times manual controls or a manual supervision of automatic controls may result in an approval of a misflagged original value or a rejection of an automatic correction. In such situations it is important that the quality information shows that the actual observation value is assessed manually by putting an OK flag to it.

<u>1.2. Need for modernization</u>

The Nordic countries each have their own manual control system i.e. HQC system. The different countries have reached varying stages in modernizing their manual system, but improvements are needed for the systems to become more efficient.

In <u>Denmark</u> several programs are used for HQC, each of them having their own functionality, which does not fulfil all the basic requirements for HQC. They must be used in combination and with some kind of swapping which sometimes makes the HQC work time consuming and difficult. Combining all functionalities into a single software platform makes manual control more efficient and effective. It also makes it easy to check observations flagged as suspicious or in error. This will make the work more rational. A new online QC1 system including more comprehensive checking and flagging procedures will be implemented in 2003. There are plans for development of spatial controls in a new QC2 system that will begin after the implementation of QC1. Not all observation types will be included in the new system, e.g. data from certain manual stations will not enter the online system but are still subject to manual procedures.

In <u>Finland</u> HQC is currently manual paper work without any sophisticated tools. QC2 gives error flags for suspicious or clearly erroneous values and these values are corrected manually to database by using ADP based correction tools. Spatial controls are only occasionally used as well as radar figures. Use of data from neighbouring stations is not on an acceptable level.

At FMI, new quality control programs QC1 and QC2 and new database structures will come into use in 2003. These programs include comprehensive flagging methods and flagging is also considered in the new database structures. These improvements in the QC programs give an excellent opportunity and platform to develop a modern HQC system. The aim is that HQC controls will work as much on daily basis as possible.

FMI needs a new HQC because of changes in database structures and new QC methods.

In Iceland HQC is performed through PC programs for automatic stations, but through summaries of station journals for the manual stations. An ongoing project aims to replace the current QC system with a new system for both automatic and manual stations. Current work focuses on QC0 and QC1. Work on QC2 and HQC system will start when QC0 and QC1 are near completion.

In Norway prognostic numeric model values are used temporarily in the control process. But most of the manual work still uses observation journals from the manual stations, e.g. in a spatial control by comparing the observations from the actual station and some neighbouring stations. By looking at station lists with parameter values or values from adequate algorithms, other parts of the spatial controls are performed. Neither weather analyses nor radar and satellite information are used in the HQC work. Climatic statistics are used only to a very modest extent. The HQC system is relatively inflexible.

The Norwegian meteorological institute has worked out specifications of a totally different HQC system in connection with the KVALOBS project. In accordance with the project timetable and the development of a new climate database, this system will be implemented during 2003. In the coming years more sophisticated QC2 methods should be developed that will be possible to run from an HQC interface.

In Sweden several methods are used in HQC, e.g. Fortran-programs run in OpenVMS, spatial control on the intranet and manual paper work. The current HQC system is somewhat effective, but would be even more so if the tools were combined into a single system. This would hopefully make it feasible to control data closer to the time of observation, which is desired by data customers. The controllers of data would like to have a graphical user interface to the HQC system; this is believed to be more attractive to future data controllers. The current platform, OpenVMS, will be replaced in the near future. The programs could then be migrated onto the new platform, but they could also be replaced by an entirely new system. A number of alternative solutions must be examined, and the most favourable should be chosen.

These short "status" descriptions show that there is a need for modernization and improvements of the respective HQC systems of the different countries.

1.3. Motivation for Nordic cooperation

It is desirable to improve the automatic control methods and to automate some of the present HQC procedures. A modernized HQC system will depend on well designed interactive visualization tools that include the best and most effective current HQC methods and allow easy integration of methods developed in the future.

The goal must be to make it possible for the persons involved in quality control work to make quick decisions based on relevant and easily accessible information. Another goal is to carry out the manual control on a daily level close to the observation time in order to make the control as rational and effective as possible.

Most of the NMSs need easily accessible meteorological information and a comprehensive tool for making decisions, concerning flagging or correction of data, adapted to the different quality control levels. The Nordic countries would benefit from co-operating on such a matter. To do otherwise would waste the resources of poorly staffed groups at the NMSs.

2. HQC scenarios

The following HQC scenarios are based on the principles of automatic control methods as they are described in Chapter 2.4 of Vejen et al. (2002). HQC involves the supervision of the automatic control methods. It is reasonable to use spatial maps for controlling the results of range checks, consistency checks and different spatial checks. Time series are mostly used for controlling step checks, both from one single station and from neighbouring stations.

The scenarios below describe practical work with the manual controls as it should be done in the future. Necessary types of information for a modernized manual control work, different tools for the presentation of such information and procedures for this future work, will be described in Chapter 3.

Scenario 1. Flagged observations and error list

Different parameters of all meteorological observations go through an automatic quality control process. During this process the parameters are flagged at each control, and the flags follow the parameter values to the end of the automatic process. The flags mark whether the controls have found the parameter value OK, suspicious, inconsistent or otherwise erroneous, or if the actual value is corrected automatically, if the observation value is the result of an accumulation (e.g. precipitation amount), if the observation is performed at an unacceptable observation hour, and so on.

Based on these flags, it is decided which parameter values are going to be manually controlled. The result is an error list and the inspector uses the flags from this list in his HQC work (see also Ch.3.1).

<u>2.1. Error list</u>
The inspector uses an error list (See figure 1) that shows suspicious values from QC1 and QC2 checks. From this list, the inspector can easily see which station is suspicious, which check has hit and hence what type of error occurred.

DATE – OBSERVATION HOUR – DISTRICT

STNO	PARA	CONT	FLAG	MESSAGE	ORIG	OK	CORR ?
19480	TA	FR	= 4	25.4 > 24.8	Y	Y	
19480	PR	FNUM	= 6	MISSING, INTERPOLATED 1008.4	N	N	Y

Figure 1. An example of a possible error list. The columns to the left show station number, parameter, control type, flag number and reason for flag number. The columns to the right are meant for HQC flagging. This is an example of an interactive connection to the database. If the original value is OK, there is no reason for any correction. If the original value is not OK or interpolated automatically, there may be a reason for a correction.

When the suspicious values are evaluated and checked out manually, HQC flags are set automatically. But it should be possible to change the flags manually if it is necessary. E.g. if a missing value is interpolated and the correct value is found in the journal later on, the original value will be inserted and then the flag has to be changed in accordance with this.

2.2. Presentation of observations and control flags (in HQC program)

Observations are presented in different ways (optionally): Either all the observation parameters, a few or only one parameter. Stations with traditional synop information may be presented like "mets", i.e. the information from a station is presented around the station circle (filled in with the symbol of cloud amount), where all the parameters have a fixed position. It is possible to select one or more parameters in this way. It is also possible to have the parameters (or a selection of parameters) presented as a list close to the station circle.

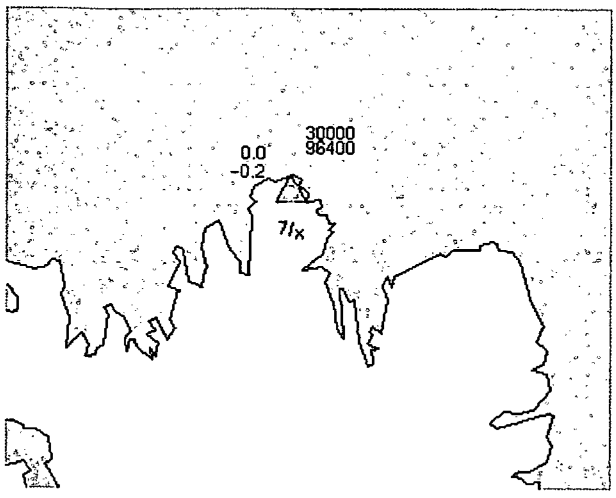


Figure 2. Signal flag (yellow) and flag code (30000, see explanation below) of air temperature (-0.2) of station 96400.

The flags are presented in a suitable way, e.g. like a number code (simplified if that is preferred) close to the station circle (See figure 2). The code, which is connected to the chosen parameter, displays the result of different automatic controls during the process. The flag code can be individually defined for each country. In Figure 2, the digit 3 means climatologic questionable value, the digit 0 means not checked. For this purpose the station circle is filled in with colours: green for OK, yellow for suspicious and red for erroneous; the colour must correspond to the flag code mentioned above. In this way the inspector will easily see which stations need an HQC inspection by looking at the details from the flag code, and by comparing the chosen parameter values of all the stations at the chosen observation hour. Like other types of information, the flag information should be turned on/off optionally.

It is then possible to see what type of weather station has delivered the actual observation. Or in other words, there are defined station type symbols to identify the different stations.

Scenario 2. Spatial control

Manual control is intended to correct suspicious or erroneous values, to approve or disapprove automatically interpolated values or to interpolate missing values that the automatic control system has not been able to handle. Through this process, the values under control get an appropriate HQC flag. A great part of the manual decision making is based on a spatial control, either together with some type of weather analyses (See "Weather analysis"), short time prognostic parameter values (See "Numeric model"), climatologic/local site calculations/ considerations (See "Climatologic information"), different kinds of statistics (See "Statistics"), or time series presentations (See "Time series"). The idea is that the inspector should have all relevant information for the decision about the actual observation parameter, and thereby be able to do a good correction or evaluation very quickly. A spatial control is based on comparisons (of weather, local climate, diurnal changes in parameter values, parameter statistics, etc) with neighbouring stations where the inspector expects to find conditions similar to those at the actual station.

2.3. Weather analysis

In the HQC work, it is necessary to know which air masses are dominant in the areas to be controlled and to know the stability of the air masses. The inspector uses much of the information that is found in computerized versions of traditional weather maps (See figure 3). It is possible to combine information from the weather analysis with satellite picture and radar pictures (See figure 4) or other digital information. Automatic analyses based on ground based observations, model calculations, radar and satellite pictures are also useful (See figure 5).

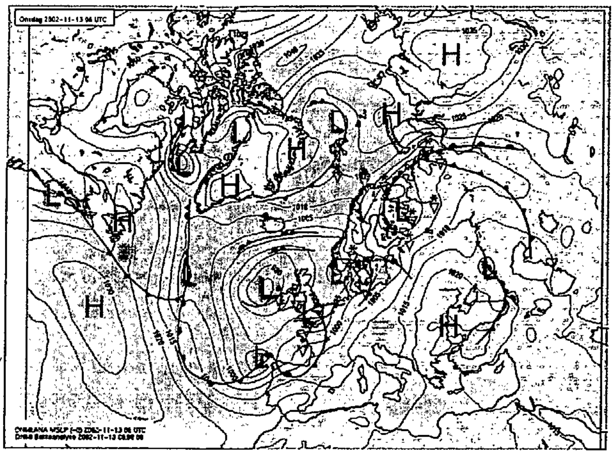


Figure 3. Digital analysis (DIANA).

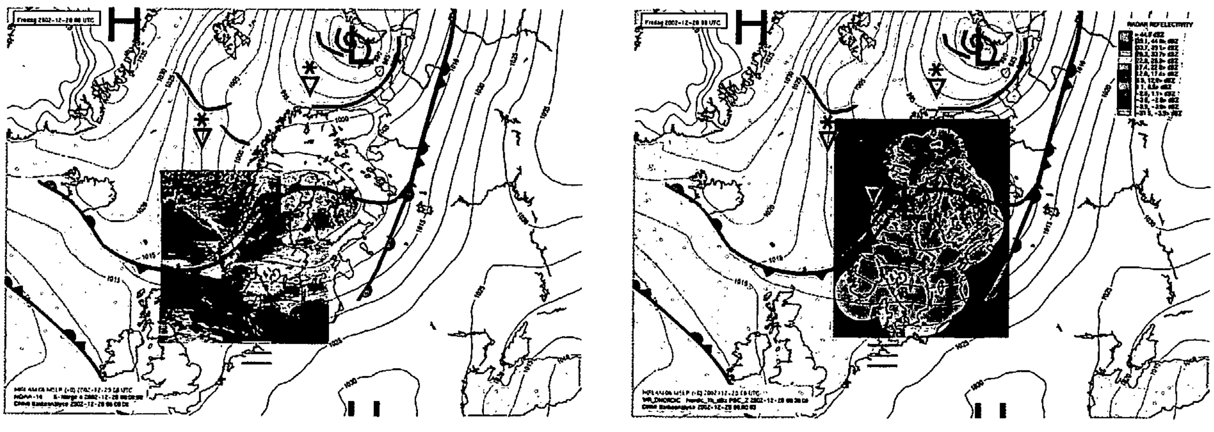


Figure 4. Weather analysis from DIANA in combination with satellite image (left) and radar image (right). It is possible to take off the black and grey colours in the radar image.

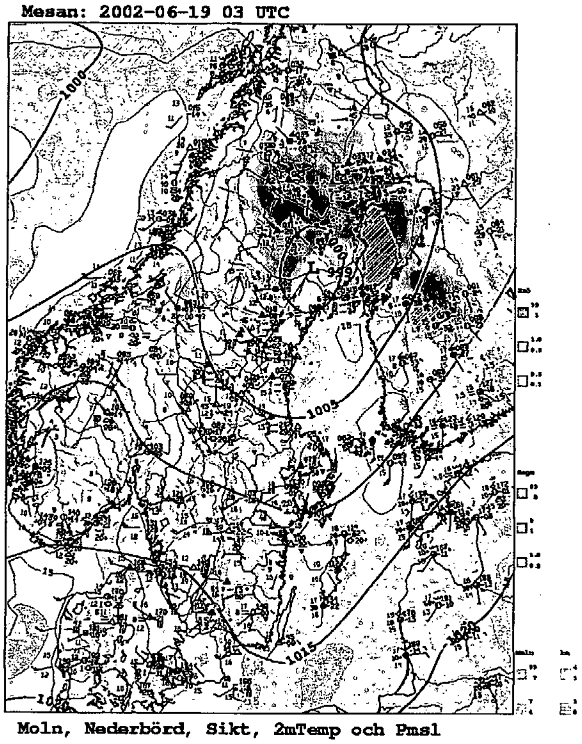
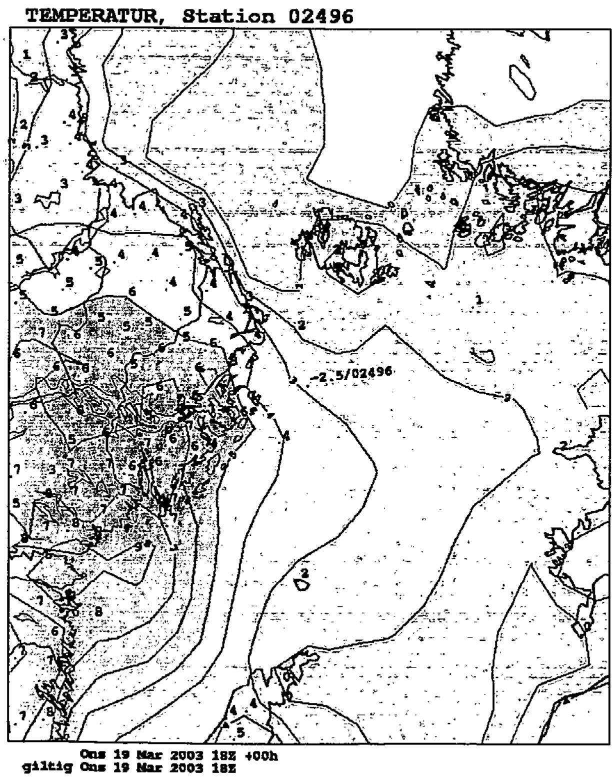


Figure 5. Mesoscale analysis (MESAN).

2.4. Numeric model

Short time prognostic parameter values for the control time in question may also be useful at the HQC stage. The inspector may choose to have the differences between observed and calculated values presented. Then it will be possible to evaluate whether the numeric model is reliable or not in the actual weather situation for the area in question. This may be very helpful if missing values are to be interpolated manually by the inspector.



Another use of numeric models is described in Vejen et al. (2002, Ch.4.6). When the model values for the actual weather situation are reliable, single observations that are obvious wrong are corrected in accordance with the model calculations (See figure 6 and 7). The observed temperature for a site called Svenska Högarna (station 02496) shows –2.5°C instead of +2.5°C. The comparison, made by the mesoscale analysis MESAN, shows the error distinctly.

Figure 6. Temperature analysis, 19 March 2003 28 UTC, calculated from MESAN. The station 02496 does not fit in.

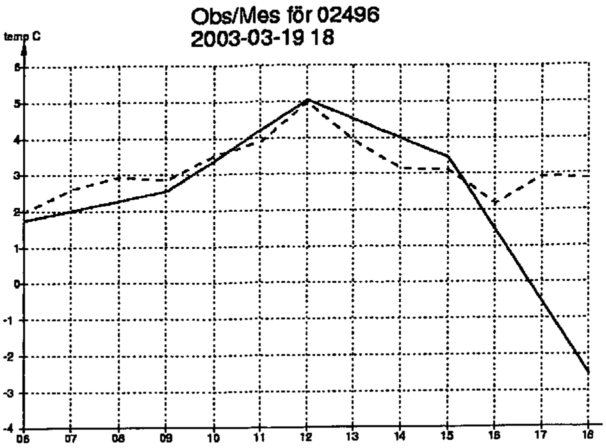


Figure 7. Temperature time series 19 March 2003 for the station 02496, compared with the corresponding MESAN values. At 18 UTC there is an obvious mismatch between observation and model calculation.

Correspondingly systematic errors may be found by comparing observations and model calculations statistically. Errors may be found either at the actual site or in the model. Statistics for March 2003 shows that the observation station Tarfala is drier than what MESAN suggests (See table 1). Tarfala is a site, which is known to be a little bit warmer than the surroundings. That influences the humidity to be drier.

Table 1. Statistics for differences between humidity observations and MESAN calculations during March 2003 at standard observation hours. DU is the difference OBS – MESAN.

Name	Synnr	DU <=-40	-40< DU <=-20	-20< DU <=-10	-10< DU <10	10<= DU <20	20<= DU <40	DU >=40
RITSEM_A	02013	0	0	2	227	0	0	0
KATTERJÅKK	02020	0	0	2	227	0	0	0
STORA_SJÖ-FALLET_A	02024	0	0	1	193	24	7	0
TARFALA_A	02029	1	6	31	190	0	0	0
RENSJÖN_A	02031	0	0	1	218	10	0	0
NIKKALUOKTA_A	02036	0	1	48	169	11	0	0
LATNIVAARA_A	02038	0	0	3	224	2	0	0
KIRUNA_ FLYGPLATS	02044	0	4	33	163	2	0	0
GÄLLIVARE_A	02049	0	0	2	225			

2.5. Climatological information

It has been described above how observation parameters are presented in relation to a comprehensive weather analysis. It is also necessary to have available climatological and local site information for manual controls. In future HQC work, it will be convenient to receive results from different interpolation methods from the HQC system, where climatology and/or local meteorology is incorporated into the methods. Considering the actual weather situation and the topography of the area surrounding the stations involved in the spatial control, the inspector chooses a method that has empirically proved to be the best to use on the actual parameter.

With one click at the station the inspector finds pictures showing the exposition of the instruments (See figure 8), panorama (See figure 9), sketch and map of the station area (See figure 10) and other relevant station information.

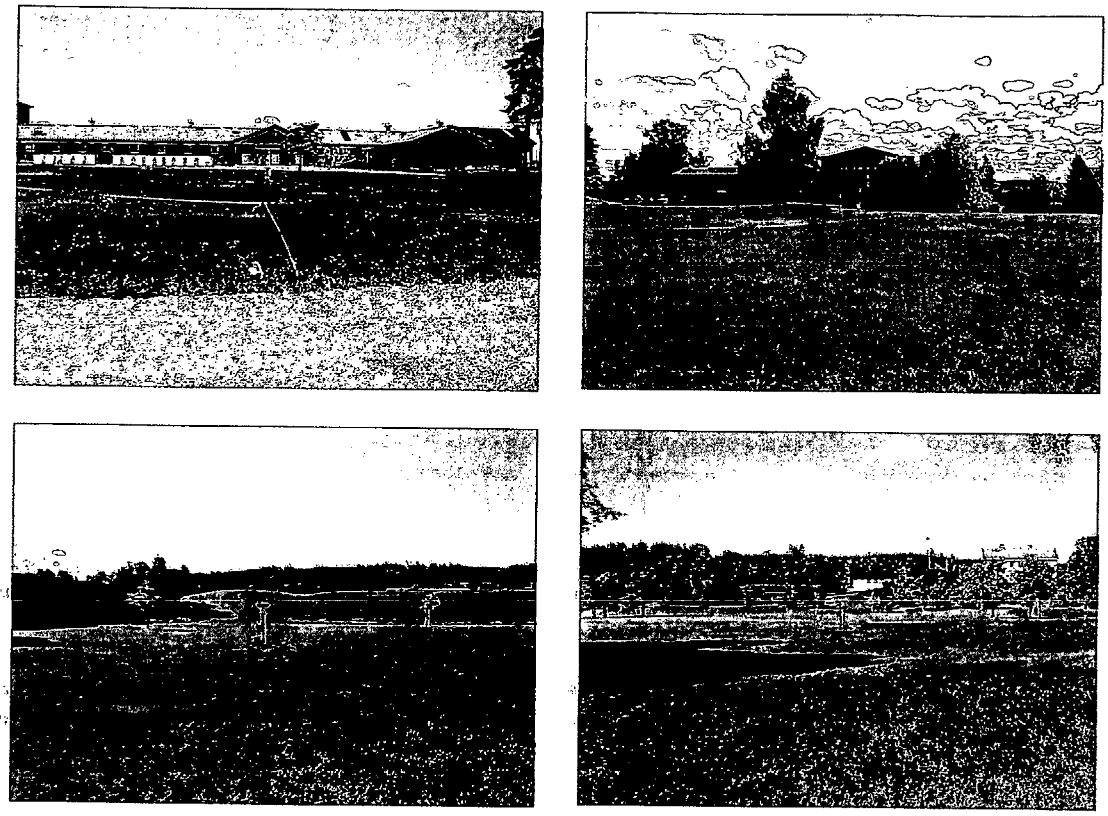


Figure 8. Exposition of instruments towards 4 main compass directions (north, east, south and west). The pictures show a Norwegian precipitation station (manual). The automatic station near by the rain gauge is private.

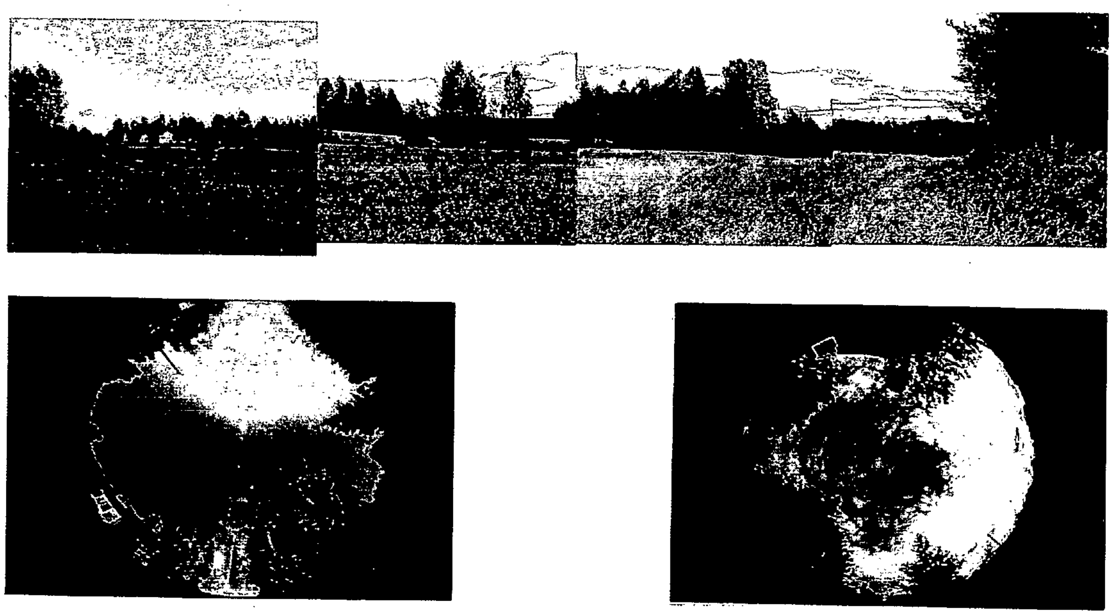


Figure 9. Top: Traditional horizontal panorama from a weather station (northerly sector). Bottom: Fish eye panorama from two different weather stations.

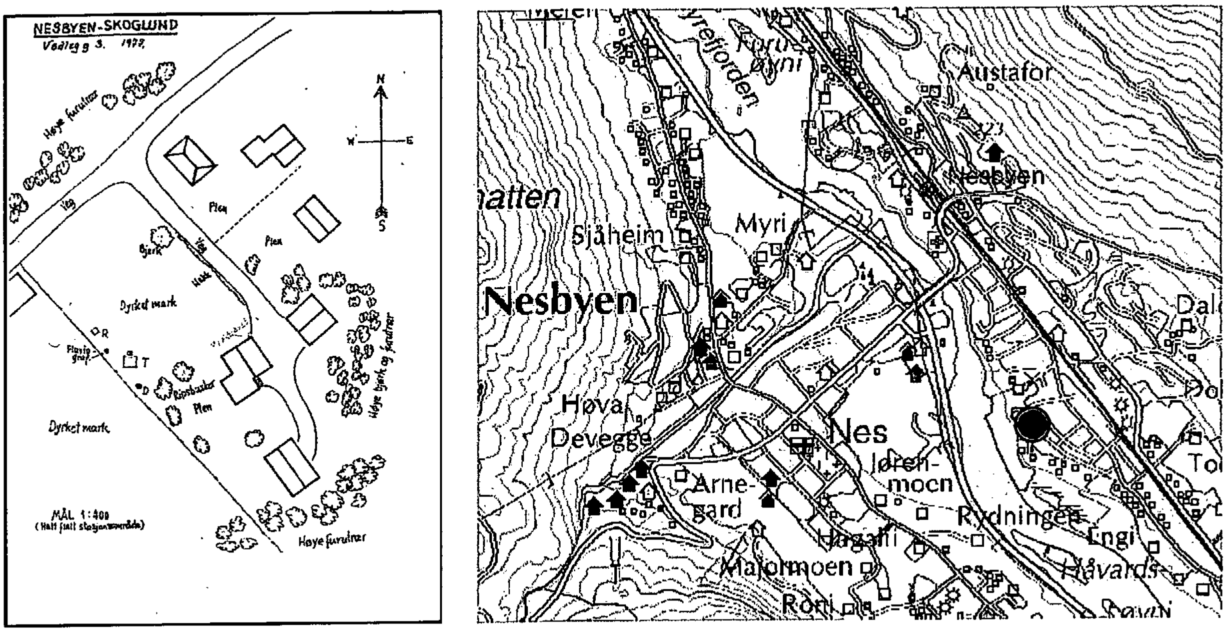


Figure 10. Sketch and map of a weather station area.

2.6. Statistics

Systematic parameter errors from a station can be difficult to discover. However, changes in statistics based on some period of time (month, last 30 days or year) can be mapped spatially and may help pinpoint problematic stations. An example of statistics that could be used for such checks are the deviation of monthly mean from a 30-year normal value, a standard deviation of a parameter value or some more complicated algorithmic value (See figure 11).

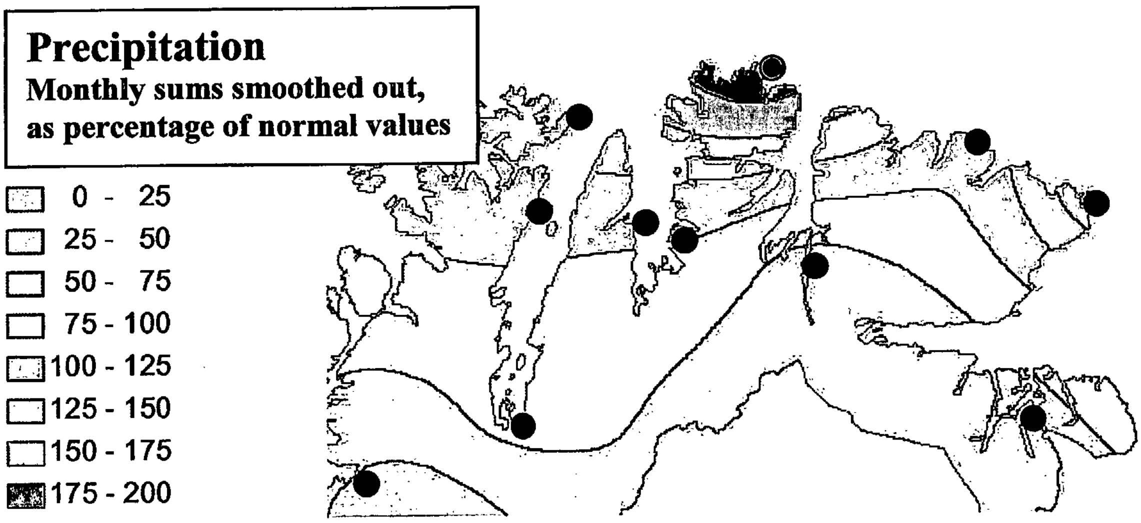


Figure 11. Check of monthly amount of precipitation for February 2003 for the northernmost part of Norway. All the stations conform well with the analysis except one station (marked with red colour), which showed a percentage of 373. The reason for this proved to be a decimal error leading to a 10 times magnification of some daily values during a five day period (e.g. 6.4 mm became 64 mm).

2.7. Time series

A spatial control is an efficient course of action for correcting data. Examining time series from the actual station and neighbouring stations will ensure that the changes of the parameter value during the day are reasonable and in accordance with the corresponding changes at representative stations in the neighbourhood (See figure 12).

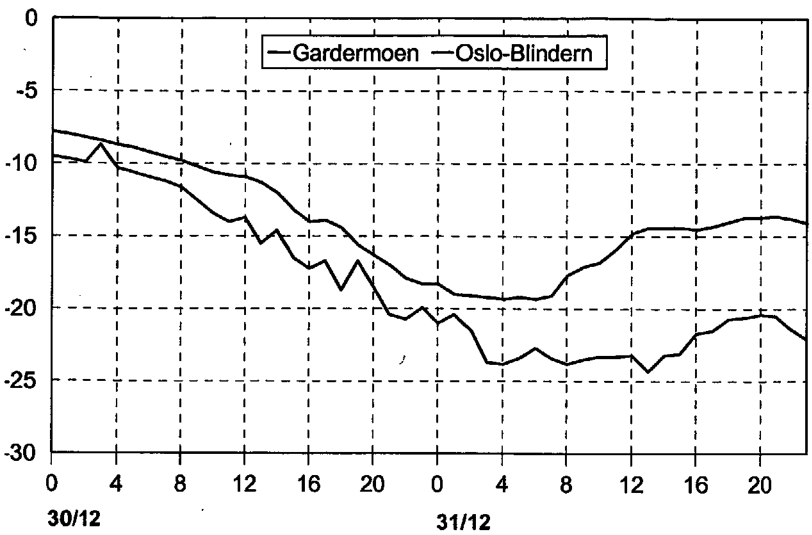


Figure 12. Temperature conditions of the weather stations Oslo-Blindern and Gardermoen on the two last days of the year 2002.

A time series from a single station provides information about occasional outlier values or if there are so called "frozen values". An alternative idea is to compare the actual parameter time series with a numeric model time series calculated for the same geographical position. This may be an efficient way of checking out how the numeric model values fit in with the observed values of the actual area to be controlled.

Scenario 3. Dynamic coupling between map, graph and table

When the inspector has considered a suspicious or erroneous observation value it is needed to either accept or correct the value. The inspector can then proceed in different ways. A mouse click on the parameter value on the map activates the table at the actual observation date and hour and the numbers can be typed in the column for corrected values of that special station or the approval of the observation is made visible by an HQC flag. Suppose the inspector is looking at the time series of the actual station. Again a mouse click on the parameter value on the graph activates the table at the actual observation date and hour where the new numbers can be typed. In both cases the corrected value appears immediately on the map and the graph adjusts itself to the corrected value. This is called a dynamic coupling between map, graph and table (See figure 13).

		TA (°C)	
St.no.	Obs.date	Original	Corrected
18950	19.02.03 12:00	9.4	9.4
18950	19.02.03 13:00	8.8	8.8
18950	19.02.03 14:00	8.7	8.7
18950	19.02.03 15:00	8.1	8.1
18950	19.02.03 16:00	6.1	6.1
18950	19.02.03 17:00	6.3	6.3
18950	19.02.03 18:00	-3.3	6.6
18950	19.02.03 19:00	6.9	6.9
18950	19.02.03 20:00	5.7	5.7
18950	19.02.03 21:00	6.0	6.0
18950	19.02.03 22:00	6.6	6.6
18950	19.02.03 23:00	4.1	4.1
18950	20.02.03 00:00	4.4	4.4

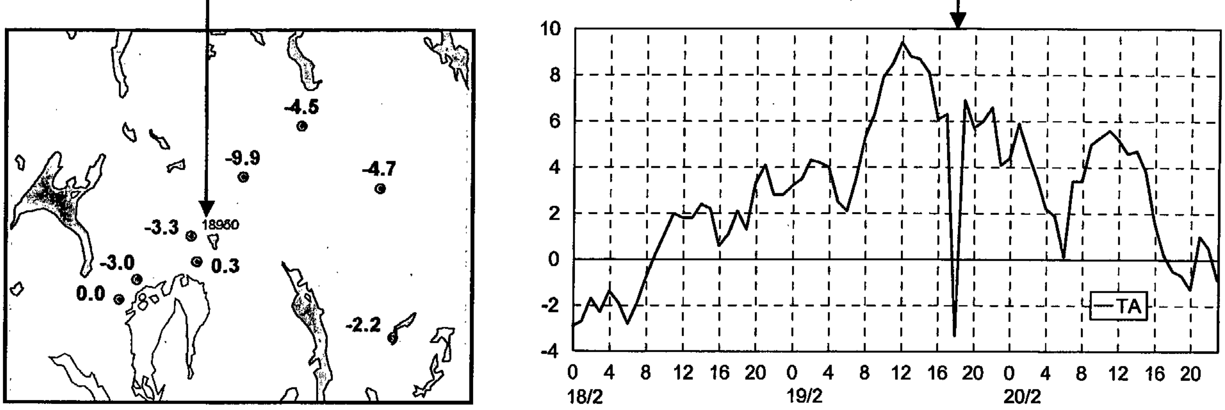


Figure 13. Dynamic coupling between table, map and graph. When actual temperature value from station no.18950 (514 m a.s.l.) is corrected in the table, changes will appear in the map and the graph as well. The weather situation of 19 January for Southeast-Norway: High air pressure, weak winds, almost no clouds and a strong temperature inversion. The spatial analysis gives no reason for suspicion because of the low temperatures of the lowland stations; therefore the graph is needed.

As previously mentioned, the control flags from the automatic quality control procedure are the basis for the development of an error list. The dynamic coupling also functions in the opposite direction. A mouse click on a parameter on the list opens a map with the corresponding parameter values of all interesting stations presented. The time series of the parameter for the actual station and some neighbouring stations also appear. It is then possible to get the analysed weather map and actual satellite and radar pictures. Detailed flag information is presented.

In a web based program dynamic coupling is harder to realise than many of the other features of a future HQC system. But it is possible to have a one way coupling, from table to map and from table to graph.

Scenario 4. Manual handling of automatic controls

The result of the automatic controls contributes to the error list. Although some or most of the automatic controls are run in a routine, there will also be a need for running automatic controls manually.

Suppose an inspector is ready to correct a parameter value based on inspection (of a map or time series), but would prefer to have an objective proposal before the correction is done. Then the inspector can choose between different interpolation methods to see which parameter values are calculated. It should be possible to run such QC2 programmes (and QC1 algorithms as well) from the HQC interface.

It should be possible to present the calculated values together with the original observations, e.g. near the station circle on the map. It should also be simple to decide if the suggestions can be accepted or not, and consequently easy to store eventual corrected observations.

When changes are done in the HQC stage an HQC flag should be set automatically (or semi-automatically), which completes the row of flags of the quality control procedure.

When corrections are done or bad observations are skipped, it should be possible to repeat the QC controls to see if other parameter values will be affected by the corrections, or to see if other station observations turn out to be suspicious. See also Ch.3.7.

Scenario 5. Statistical reports for evaluation of QC system and weather stations

Consider the following situation: The results of the automatic QC are kept in error lists and some of the elements are being evaluated during HQC processes. In most cases the flags are set correctly and will remain unchanged during the HQC inspection, but regardless of how sophisticated the automatic part of the QC system is, there will be times when the system cannot decide whether an observation is correct or in error. For example, it may occur in extreme weather situations that error flags are set on correct observations. Only a subsequent HQC evaluation of the error flags can reveal if the observations are correct or not. If automatic QC procedures are evaluated purely on basis of flags that have not been subject to manual inspection, there is a large risk that the evaluation comes up with misleading conclusions on the data quality as well as on the station and QC system performance.

It is therefore important to estimate flagging statistics in order to evaluate the whole QC system and the station performance: (i) which algorithms were able to identify errors and suspicious values and what is the flagging frequency for each algorithm, (ii) which stations and what parameters have been flagged and what are the flagging frequency.

First, such flagging information may be useful for effective planning of service of observation stations. Flagging for suspicious values may give a false impression of equipment problems, thus a part of the work is to check the flagged values by HQC inspection in order to prevent unnecessary station service. Often, even if the flagging statistics are solely based on automatic QC methods, there might be no doubt that the observations from a station are erroneous. Otherwise, error flags can be explained by local conditions or the weather situation. Reports on station performance should be produced regularly or by request, and the reports should contain statistics on the number of different kinds of flags, error frequency analyses, plots of the spatial distribution of flags, time sequence plots of flags, etc.

Secondly, flagging statistics can be valuable for evaluation of the performance of QC algorithms, maintenance of the QC system and implementation of improvements. QC probability estimates, checking limit values and checking methods can be currently evaluated and improved, which is very important because the automatic QC system is solely dependent on effective and optimised algorithms. These algorithms should be tuned for maximum accuracy, so that the number of situations with too many false error flags, or a too many missed errors can be as low as possible. It is likely that there will be special weather situations in which the automatic QC system will produce too many flagging mistakes.

Realization of the scenarios

The next chapter focuses on the Nordic needs concerning manual quality control and recommendations concerning visualization, functionality, types of information, error list, corrections, platforms etc.

3. Recommendations on Nordic HQC needs

This chapter will focus on common Nordic interests on HQC. A general view of these needs is presented in Appendix: Nordic needs concerning manual quality control.

A control system is needed that can make it easier: (1) to check whether an observation is correct or not, (2) to evaluate and improve the performance of algorithms and procedures in QC1 and QC2, and (3) to check and monitor the performance of stations and equipment that support the maintenance of weather stations. To summarize, an HQC system is an essential tool to ensure storage of high quality data in climate databases.

Aspects concerning HQC programs and tools

Control and correction of observations should be performed against a permanent or a temporary archive database. A common Nordic HQC system must respect individual practises, such as how the HQC system accesses databases for writing and reading of observations, or if the system should have access to a control database with a direct link to the climate database.

It should be possible to set up the system to evaluate certain QC algorithms or QC schemes and procedures by assessing observations, flags and statistical calculations done by the HQC system or some other programs running in the background.

It may be valuable to assess the performance and hit rate of algorithms in order to see if they are working satisfactorily or if improvements are needed, e.g. if too many errors are missed in certain weather situations. It would be a good idea if the system can collect stored statistics and HQC results for preparation of weekly or monthly HQC reports.

It should be possible to communicate the control results in a simple way to other persons who need the information, e.g. for planning service at weather stations. The HQC system should enable preparation of, for example, weekly and monthly statistical reports on flags and error frequencies. It is of crucial importance that these statistics are based on correct and manually inspected flags because wrongly set flags can result in needless station visits.

The system should be designed in a way that makes it easy to improve and maintain the controls in the automatic system when needed. That means e.g. to add algorithms, change or delete them or change test values of climatic controls.

The error list (described in the next section) should lead the inspector to the data that needs to be checked manually. Occasionally it should be possible to correct observations automatically.

3.1. Flags and error list

The system must take care of individual procedures of flagging. The flags are the basis for the error list, which should be able to tune according to the suitability of the different algorithms.

An error list could simply be the error log (all parameter values with flags different from OK), but an error log could be long and unpractical, and would probably contain a lot of correct observations. It would then be better to reduce the error log to a more realistic error list by comparing flags from different checks and by comparing flags from one station with flags from neighbouring stations.

The format of the list should be designed so that the inspector can see which check has hit and why, e.g. that the list contains general messages or algorithms.

An error list does not prevent a general HQC control with use of the tools described in this report. There will be errors that automatic checks have not discovered. When the inspector discovers such errors, they will be corrected as necessary.

When an observation is corrected the flag status must be updated as well.

The flags must be displayed in a way that makes it easy to inspect and evaluate the results from the automatic QC1 and QC2 procedures. The aim is to improve data quality, and to make it easier to identify certain observation errors and bad equipment at the stations.

3.2. Visualization

It should be possible to visualize all kinds of data in tables, geographically on maps and graphically in time series. Tables are useful when it is necessary to see various parameters at the same time for consecutive observation hours. Maps are useful to display the parameter values in relation to topography and distances to neighbouring stations. It should be possible to choose different background maps and isolines for selected parameters to be presented in different graphical layers. Time series are useful to see how the parameter values are changing e.g. during the day. It may be suitable that air pressure, temperature and humidity are shown as lines or curves, that precipitation are shown as bars and wind as arrows. See also Westman et al. (2001).

3.3. Types of data to be visualized

All kinds of observations and flags are to be visualized: original data, corrected data, model data like e.g. parameter and station height, metadata and geographical data e.g. station height and local topography.

3.4. Presentation and functionality

It should be possible to compare different data types, e.g. cloud information from synop and metar stations, cloud cover from visual and automatic stations, etc. It is important that the presentation tools have functionality for evaluating suspicious observations, by use of ordinary weather station data, flags, digital data from weather radars and satellites, grid data and products from numeric models like HIRLAM and ECMWF.

It may be difficult to examine all observations if too many data types are presented by the HQC system at the same time, thus it should be possible to make individual set up of the system.

Animation of weather analysis, lightning recordings and satellite and radar pictures should be possible, either as single information or as combined information. It should be possible to present different digital data from satellites (e.g. cloud temperature, radiation values), radars (precipitation intensity) and lightning recordings.

It should also be possible to present selected parameter values on maps from all types of weather stations at one observation hour, and monthly parameter values as well. In selected graphs, consecutive values of one parameter for a chosen period of time can be presented. Tables will present different kinds of data like observations selected by parameter and time period, flagged data selected by flag value, flag history, error list, original data, corrected data, model data, etc.

It should be possible that chosen information (tables, maps, graphs, pictures, etc) are presented in windows. Ordinary handling of the windows is essential (moving, changing of size, zooming, etc.). A time scroll function in each window is presupposed, and changed observation period in one window must lead to corresponding changes of the other windows presented. The system must be able to present tables and time series for more stations simultaneously, and to present different parameters simultaneously or in different windows as table, map or time series. If one parameter value is corrected, the same change should be visible in all the windows (dynamic coupling).

The tool should have an undo-functionality.

3.5. Types of information

Weather analysis should contain pressure distribution, wind field, front positions, precipitation areas, etc. Through such an analysis the inspector may be able to decide what type of air masses are predominant in the actual areas to control. Satellite pictures will supplement the analysis and e.g. show the cloud area in front of precipitation areas. Radar pictures will supplement precipitation information and radar data may present wind information as well. Lightning recording will supplement information about air mass stability.

Relevant model information is valuable. It should be possible to present model height or rather the difference between geographical and model height on maps.

Climatic information is important. Information about local topography, where the different weather stations are positioned is necessary concerning evaluation of representation of stations. Climate charts (e.g. based on different circulation patterns) may help the inspector to evaluate whether the parameter value distribution is climatically probable or not, and similar climate statistics are valuable for the manual work as well.

Values derived from algorithmic expressions should be presented on maps. It may be the difference between observed and modelled parameter value, or the difference between observed precipitation amount and corresponding radar data, etc. This will be helpful to understand the strength and weakness of different components of the control tool. When the difference between monthly values and normal values is presented on maps, it may be possible to find eventual systematic changes in parameter values at stations.

All the described information should be presented by one user-friendly control tool.

Each country must specify what type of information is intended to be quality controlled and what type of information is considered to be auxiliary. It is possible to quality control most surface observations from weather stations with consideration of weather analysis, graphs, satellite and radar images, numeric model values, statistics, etc. as auxiliary information. But it is of course possible to assess auxiliary information as well (e.g. radar images).

3.6. Statistics

QC1 and QC2 cannot identify small systematic errors that are caused by slowly degrading equipment. There is a need for implementation of statistical tools in the HQC system for analyses of e.g. frequency distributions to discover when test parameters of a distribution, like quantiles or other statistical parameters, exceed a predetermined acceptable difference, compared to long time data from the station itself or compared to a reference station.

It must be possible to present statistics for the number of interpolations, corrections and missing data from each station. It should also be possible to evaluate check limits that are being used in the automatic QC, by using accuracy estimates from interpolation methods.

3.7. Calculations

If errors have been identified and corrected, or excluded, from the dataset of that observation time, it may often be valuable to run a recalculation, especially of the spatial quality control in QC2 to see if the exclusion of bad values has an effect on the flagging of other observations at neighbour stations (See also Scenario 4). Through such experiments the investigator can gain experience that can be valuable for improving and further developing existing procedures and programmes.

Some stations may come up with error flags either because they are defect but have not yet been visited by service persons, or because of a very special station site compared to neighbouring stations. Therefore, it should be possible to exclude or blacklist such stations from the analyses, either on station or parameter level, and a note should be written in the HQC report to make clear what is going on. .

It should be possible to calculate simple algorithmic expressions like 1) the difference between observed value and model value or 2) a height reduction of a parameter to try to eliminate the height variation of the parameter, etc (See Ch.3.5). Such values should be possible to calculate by command and to present near the station circle on a map.

It should be possible to perform relevant controls on chosen observations and to present the results in a special window. Even if some values are flagged by the QC controls, it should be possible to calculate new values (from other methods) to facilitate the evaluation of suspicious values.

It should also be possible to interpolate missing data of selected parameters automatically. It would be wise to show calculated/interpolated values with a confidence range.

Interpolation methods require data from representative, often neighbouring stations. When observations are missing, it must be possible to replace chosen stations with others, either manually or from file for a selected period.

It should be possible to utilize digital satellite and radar data in calculations. Key words are: Raw data, cloud classification, accumulated "radar precipitation", CAPPI layers, and much more.

3.8. Corrections and data storage

There is an agreement that original data should be kept unchanged. Original data means data received from the observer. Corrections mean changing original data into corrected values in a separate data table (or part of such table) in the archive database or editing directly in a graph or a map. It should be possible for observer to permit observations to be corrected both automatically and manually and transmit the changes directly to the archive database as original data. Dynamic links between maps, graphs and database tables will ensure that the inspector easily may accept suspicious values or change values that are considered erroneous. Updated flags are stored automatically or semi automatically. It should be easy to insert non-real-time values later on.

4. Conclusion

The main objective of this report has been to give recommendations for a common Nordic HQC system. When manual quality control of meteorological observations is performed as the last step of the control process (QC0 – QC1 – QC2 – HQC), it is important that the inspectors are given the opportunity to 1)make the quickest possible decisions in order to save time and resources and to 2) maintain the highest desirable quality of data. This is possible by presenting all relevant information in one environment, by using different tools for visualization and calculations.

To actively pursue a joint Nordic HQC system according to the recommendations presented in this report, it is necessary to define a platform where each country (or most countries) has a chance to participate from a basis of existing or planned resources. A Nordklim work group is writing a technical report on that matter later this year. We recommend starting the practical work by first developing a simplified system, where the different countries make their own individual interfaces between the proposed HQC user interface and their own institute database. The system design can then continue, step by step.

5. References

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Appendix. Nordic needs concerning manual quality control

(X: Needed, O: Optional)

MAIN OBJECTIVES FOR HQC

	SMHI	NMI	DMI	VI	FMI
More effective QC	X	X	X	X	X
User friendly interfaces	X	X	X	X	X
All types of data (manual, semi-automatic, automatic)	X	X	X	X	X
All parameters	X	X	O	X	X
Historical data as well as real-time data	X	X	X	X	O
Appropriate quality of data	X	X	X	X	X
Closer to real-time	X	X	X	X	X

RECOMMENDATIONS

	SMHI	NMI	DMI	VI	FMI
Type of data to be visualized					
a) All kinds of observations and flags	X	X	O	X	X
b) Original data	X	X	X	X	X
c) Corrected data	X	X	X	X	X
d) Model / analysed data	X	X	X	X	X
e) Metadata	O	X	X	X	X
f) Geographical data	X	X	X	X	X
Visualization					
a) Tables	X	X	X	X	X
b) Graphical presentations	X	X	X	X	X
c) Map presentations (GIS)	X	X	X	O	X
Presentation and functionality					
a) Easy options (of stations, time period, windows of visualization)	X	X	X	X	X
b) Optional information from neighbouring stations	X	X	X	X	X
c) Optional information from tables	X	X	X	X	X
d) Optional on/off (points, lines/curves, tables, windows, etc)	X	X	X	X	X
e) Animation	O	X	X	O	X
f) Moving and zooming of windows	X	X	X	X	X
g) Dynamical connections between maps, graphs and tables	X	X	X	O	X
Types of information					
a) Weather analysis	X	X	O	X	X
b) Satellite pictures	X	X	X		X
c) Radar pictures	X	X	X		X
d) Selected parameters from all stations at one observation hour	X	X	X	X	X
e) Consecutive observations within an optional time series	X	X	X	X	X
f) Station information (e.g. height a.s.l., valley bottom, etc.)	O	X	X	X	X
g) Model information (e.g. model height, etc.)	X	X	X	O	O
h) Climatology information (maps, distributions, statistics, etc.)	X	X	X	X	X
i) Values from algorithmic expressions	X	X	X	O	X
Flagging history	X	X	X	X	X
Error lists	X	X	X	X	X

RECOMMENDATIONS (continuation)

Corrections	SMHI	NMI	DMI	VI	FMI
a) QC2 proposals / accept, reject	X	X	X	X	X
b) Editing in Visualization a), b) and c)	X	X	X	X	X
c) Interactive recalculations *	X	X	X	X	X
d) Instant correction check	X	X	X	X	X
e) Warning of insufficient corrections	O	O	O	O	O

Calculations	SMHI	NMI	DMI	VI	FMI
a) Warning of incomplete data **	X	X	X	X	X
b) Statistical calculations (black listing, etc)	X	X	X	X	X

* Run QC1 & 2 programs

** Monthly / daily means and sums missing