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TITLE

Quality Control (AQC1, AQC2 & HQC) of wind observations at the DNMI - AERO stations: The VINDREG routine

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SUMMARY

This report is a part of the NORDMET project NORDKLIM *Nordic Co-Operation Within Climate Activities* and is written as a documentation of parts of the quality control documentation for project task no. 1.2 *Quality Control* following specifications from the first NORDKLIM Quality Control meeting in Helsinki, 22-23 April 1999.

The VINDREG routine, for quality control of wind observations from the AERO stations, is one of several data processing routines at DNMI. This description focuses on giving input to the three Quality Control modules defined in Helsinki, Automatic Quality Control of Realtime Data (AQC1), Automatic Quality Control of Non-Realtime Data (AQC2) and Human Quality Control (HQC).

KEYWORDS

1. Quality Control
2. Digital wind speed data
3. VINDREG
4. NORDKLIM

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1. INTRODUCTION

In the NORDMET-project NORDKLIM: *Nordic Co-Operation Within Climate Activities*, there are two main tasks. Task 1 is dealing with **Climate Data** and has four subtasks (1.1 Network design; 1.2 Quality control; 1.3 Operational precpitation correction; 1.4 Long-term datasets). At a meeting in Oslo in January 1999, the NORDKLIM Advisory Commitee decided that highest priority within Task 1 should be given to subtask *1.2 Quality Control (QC)*. All Nordic countries have an urgent need for improved systems for controlling climate data and correcting suspect values. The main aim in 1999 for Task 1.2 is according to the NORDKLIM project plans to work out a *joint report on Nordic algorithms for QC of climate data, and suggestions for QC routines on real-time data (incl. data from Automatic Weather Stations).*

As a result of the Task 1.2 group meeting in Helsinki, 22 - 23 April 1999, it was decided that work should be divided into three main activities: Real-time quality control (**QC1**), Non-realtime quality control (**QC2**) and Human quality control (**HQC**). In order to stress the non-subjective or **automatic** character of the two first modules, they are also refered to as **AQC1** and **AQC2** (Rissanen and Hellsten, 1999).

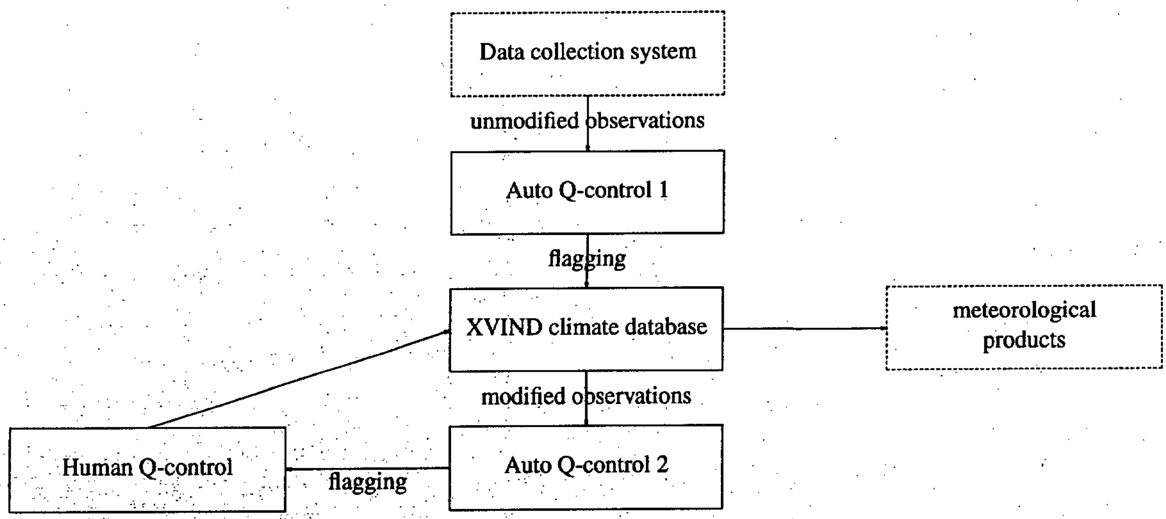
Every participating country within the NORDKLIM project is expected to write status summaries for each of the three quality control modules. DMI is responsible for collecting Nordic information on AQC1, SMHI collects information on AQC2 and DNMI collects information on HQC. Deadline for contributing information on each of the modules is 1st of October 1999.

This document demonstrates the quality assurance methods used with the VINDREG system for storing and manipulating digital wind observations at DNMI. The VINDREG observations are non-realtime data, but the quality control is nevertheless structured in AQC1, AQC2 and HQC components distinguishing between two levels of automatic quality control and one level of human quality control.

The report starts with a general description of how the AQC1, AQC2 and HQC subsystems are represented within the VINDREG system. It then goes on to describe the AQC1 subsystem and how observations are initially inserted into the XVIND database. The HQC system is then described, and finally we have a description of the AQC2. An additional discussion and conclusion is left for the final section.

2. THE NORDKLIM QUALITY CONTROL MAIN STRUCTURE

The quality control system for the VINDREG observations can be viewed as to be consisting of three major quality control modules, as illustrated in the figure below. This is the NORDKLIM 1.2 design described in the report by Rissanen and Hellsten (1999).



As unmodified observations are inserted into the KLIBAS database system (XVIND), they are checked and modified by an automatic quality control (AQC1), and as soon as the observations are stored they may be used for producing various meteorological products such as wind statistics and overviews.

On the next level, another automatic quality control (AQC2) turns into action by checking and manipulating observations according to more advanced techniques. The AQC2 system is monitored by a subjective quality control (HQC). Problems in the data set may cause iterated loops between AQC2 and HQC.

2.1. Automatic Quality Control 1 (AQC1)

When floppy disks arrive at DNMI, the content of each floppy disk is copied to a direcory on the KLIBAS database computer *GALE*. A computer program VIND_REG checks this directory every hour, and if a new file is found, data is quality checked, modified and inserted into the XVIND datatable.

The program produces statistics that are used for performance monitoring and system maintenance. Certain types of data errors are reported manually by the system monitor to the QC operator. The quality control performed by the VIND_REG program is mostly format checks, filtering off values that will not fit into the XVIND datatable.

2.2. Human Quality Control (HQC)

Before the AQC1 routines turn completely automatic, some manual supervision and quality monitoring is needed, but the main effort of subjective quality control should be used for processing data at the AQC2 level.

The main task of the QC operator is to run the VINDDEK quality control program. This program has been designed for identifying missing values and extremes. Any correction of data will have to be done on the original files, which will then automatically reload into the system.

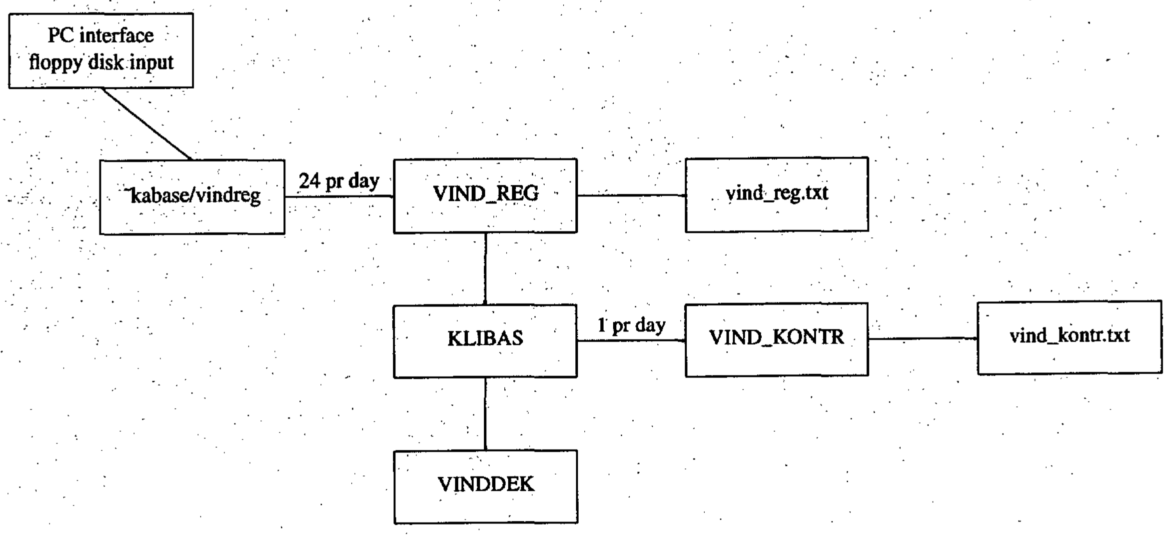
2.3. Automatic Quality Control 2 (AQC2)

A first prototype of a program VIND_KONTR, specially designed for running VINDDEK and other quality control programs as a part of an automatic system, has been constructed, but does not include any system calls yet.

3. DATA COLLECTION AND FIRST LEVEL AUTOMATIC Q-CONTROL

As floppy disks arrive in the beginning of every month they are copied to the tmp-directory ~kabase/vindreg. Every one hour this directory is checked by the VIND_REG program and any new file on the directory is loaded into the KLIBAS database tables. Status from the VIND_REG program is stored on the vind_reg.txt file.

In order to check that the data cover is under control and that the data collecting routine is working, the program VINDDEK is run manually as the observations are being stored. An automatic routine, VIND_KONTR, is also being run once a day and consists presently of an automatic run of the VINDDEK program. Results are supposed to be updated on a daily basis to a vind_kontr.txt file.



The first version of the VIND_REG program was put in operative use at DNMI on July 12th 1998. The present version 1.3 was released April 7th 1999. A technical description of the present system and how it has developed is given by Øgland (1999d).

In June 1999 the runtime for VIND_REG for the 45 available stations was 61 seconds on the average with a standard deviation of 30 seconds. The longest time of execution was 180 second. Since the program was first run in April 1998, the average has been between 4 seconds and 45 seconds with a standard deviation ranging from 9 to 90 seconds. There may be a slight tendency of the program using a little more time for each run on the average for each month as the XVIND table is growing.

VIND_REG is not an unproblematic program as it has been breaking down and has been in need of maintenance every now and then. Most of the problems have been due to format problems on the files, and the revised versions of

VIND_REG have grown more flexible as each such problem has been handled. More information technical information on VIND_REG may be found in the KLIBAS-report mentioned above.

3.1. The wind parametres

In Stenberg (1996) the definition of parametres and file format is given. The file consists of eleven columns with the following content:

DATE:	mmddhh (month/day/hour)
TIME:	mmss (minute/second)
FG:	max gust of the hour (m/s)
DG:	wind direction FG
KLFG:	time of observation for FG
FX:	max 10 min. average wind speed of the hour (m/s)
DX:	wind direction FX
KLFX:	time of observation for FX
FF:	instant 10 min. average wind speed (m/s)
DD:	wind direction FF
FG10:	max 10 min. gust of the hour (m/s)

3.2. The AERO stations

According to the HQC checklists for May 1999 there are 65 potential AERO stations reporting digital wind observations.

One of the features of the VIND_REG program is to produce an updated file of data cover for these stations for the past 6 months. The list below shows data cover for relevant months ultimo June 1999. The first May file was received on the 7th of June, the last on the 25th. The list consists of 55 measuring sites, 43 of these reporting data. There may be several observation units at a given station. The main observation site is given the code 'H', while alternative sites are coded 'R'.

Station	Oct98	Nov98	Dec98	Jan99	Feb99	Mar99	Apr99	May99
04780 GARDERMOEN (H)	-	-	-	-	-	-	-	-
17150 RYGGE (H)	100.0%	100.0%	100.0%	100.0%	66.1%	99.9%	100.0%	100.0%
19400 FORNEBU (H)	-	-	-	-	-	-	-	-
23410 FAGERNES LUFTHAVN (H)	-	-	-	-	-	-	-	-
23420 FAGERNES (H)	99.9%	100.0%	100.0%	99.3%	99.7%	100.0%	97.5%	100.0%
27470 TORP (H)	34.0%	99.9%	99.5%	55.1%	92.4%	7.7%	-	-
30420 GEITERYGGEN (H)	90.3%	76.5%	98.7%	92.6%	92.9%	99.7%	96.5%	100.0%
39040 KJEVIK (H)	-	-	-	-	-	-	-	-
42140 LISTA FLYSTASJON (H)	-	-	-	49.7%	97.6%	100.0%	99.2%	99.2%
44560 SOLA (H)	64.0%	-	-	-	-	27.3%	100.0%	99.7%
44640 STAVANGER (H)	-	-	-	-	-	-	-	-
47260 HAUGESUND LUFTHAVN (H)	100.0%	1.4%	98.5%	100.0%	100.0%	100.0%	100.0%	100.0%
55700 SOGNDAL LUFTHAVN (H)	84.3%	100.0%	100.0%	87.5%	92.3%	99.9%	91.1%	100.0%
55701 SOGNDAL LH - STOREHAUGFJELLET (H)	100.0%	100.0%	47.2%	-	-	-	-	-
57000 FØRDE LUFTHAVN/BRINGELAND (H)	98.1%	93.3%	93.0%	65.3%	96.6%	98.0%	96.8%	31.0%
57710 FLORØ LUFTHAVN (H)	96.2%	100.0%	100.0%	100.0%	100.0%	99.7%	99.0%	100.0%
58100 SANDANE LUFTHAVN (H)	97.4%	100.0%	99.2%	99.2%	100.0%	99.1%	100.0%	100.0%
59680 ØRSTA - VOLDA LUFTHAVN (H)	95.0%	99.9%	95.0%	100.0%	100.0%	100.0%	100.0%	96.0%
59681 ØRSTA-VOLDA LUFTHAVN HELGEHORN (H)	-	-	-	-	-	-	96.8%	17.9%
60990 VIGRA (H)	95.8%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%
62270 MOLDE LUFTHAVN (H)	-	-	-	-	-	8.1%	100.0%	100.0%
62480 ONA II (H)	98.3%	97.9%	99.7%	98.5%	99.4%	100.0%	100.0%	98.1%
64330 KRISTIANSUND LUFTHAVN (H)	100.0%	100.0%	96.4%	99.7%	96.9%	100.0%	100.0%	100.0%
69100 VÆRNES (H)	99.7%	100.0%	99.9%	100.0%	99.9%	99.7%	100.0%	100.0%
71550 ØRLAND III (H)	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	94.6%
72580 NAMSOS LUFTHAVN (H)	-	38.2%	98.4%	89.0%	99.4%	97.8%	87.1%	98.7%
75220 RØRVIK LUFTHAVN (H)	100.0%	100.0%	97.8%	100.0%	22.9%	88.7%	100.0%	100.0%
76330 BRØNNØYSUND LUFTHAVN (H)	8.5%	-	-	-	-	-	-	-
76750 SANDNESSJØEN LUFTHAVN / STOKKE (H)	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	99.9%	100.0%
77230 MOSJØEN LUFTHAVN (H)	-	-	47.0%	100.0%	2.8%	-	-	-
79600 MO I RANA LUFTHAVN (H)	75.4%	98.9%	100.0%	90.2%	90.0%	89.7%	92.2%	7.7%
82290 BODØ VI (H)	99.9%	99.9%	99.1%	100.0%	99.9%	100.0%	100.0%	100.0%
84700 NARVIK LUFTHAVN (H)	100.0%	54.2%	96.2%	62.5%	93.5%	89.9%	79.2%	89.1%
85890 RØST LUFTHAVN (H)	99.9%	89.2%	100.0%	100.0%	100.0%	99.1%	96.8%	86.3%
86500 SORTLAND (H)	99.6%	100.0%	66.9%	99.5%	97.0%	100.0%	82.2%	99.9%
87110 ANDØYA (H)	99.9%	100.0%	98.8%	100.0%	100.0%	100.0%	99.7%	100.0%
89350 BARDUFOSS (H)	100.0%	99.7%	100.0%	100.0%	100.0%	99.9%	100.0%	99.9%
90450 TROMSØ (H)	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.1%
90490 TROMSØ - LANGNES (H)	100.0%	100.0%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%
90490 TROMSØ - LANGNES (R1)	-	-	-	-	-	-	-	-
90491 TROMSØ LH - STORKJØLEN (H)	100.0%	100.0%	100.0%	100.0%	100.0%	1.1%	70.8%	-
91740 SØRKJOSEN LUFTHAVN (H)	-	-	56.2%	96.8%	98.5%	98.0%	100.0%	99.5%

94280 HAMMERFEST LUFTHAVN (H)	33.9%	98.1%	96.9%	90.3%	88.1%	98.0%	81.8%	100.0%
94281 HAMMERFEST LH - BOAZUVARRI (H)	32.8%	2.2%	93.8%	89.9%	99.7%	94.1%	99.4%	97.8%
94500 FRUHOLMEN FYR (H)	6.7%	96.5%	99.7%	96.9%	100.0%	99.9%	2.5%	100.0%
95350 BANAK (H)	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	99.9%	100.0%
96310 MEHAMN LUFTHAVN (H)	97.8%	97.9%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%
98090 BERLEVÅG LUFTHAVN (H)	99.7%	95.4%	56.9%	-	66.4%	96.2%	97.5%	78.4%
98580 VARDØ LUFTHAVN (H)	-	65.0%	100.0%	17.6%	-	-	-	-
98790 VADSØ LUFTHAVN (H)	95.8%	82.5%	91.8%	79.7%	94.3%	99.1%	95.3%	50.0%
99370 KIRKENES LUFTHAVN (H)	95.0%	95.0%	99.1%	99.7%	99.0%	99.1%	95.1%	-
99760 SVEAGRUVA (H)	95.4%	100.0%	100.0%	29.7%	-	-	-	-
99840 SVALBARD LUFTHAVN (H)	100.0%	100.0%	95.4%	53.2%	99.7%	99.9%	99.6%	100.0%
99841 SVALBARD LH - PLATÅBERGET (H)	99.9%	100.0%	95.3%	91.4%	92.3%	99.7%	90.4%	98.5%
99999 TESTSTASJON (H)	-	-	-	-	-	-	-	-

3.3. Automatic checks and datamanipulations

In the VIND_REG program there are two main sets of modifications done in order to prepare the data set. The first set of modifications are the corrections that were a part of the original specifications for the program (Andresen, 1997). The second set of modifications are the format checks that are needed in order to insert data into the XVIND data table (Vidal, 1998).

3.3.1. Quality flags

The XVIND table contains two quality flags, FLBRUDD indicating different types of fractures in the time series and FLRETT indicating if the observations are modified or not and the type of modification.

A fracture is an incoming observation that is reported at a non-full hour. A datastructure similar to the tables below is used for temporary storage of time of incoming data in order to flag observations on a later stage. The observations are to be flagged.

FLBRUDD	═	0	Measure taken by one hour interval as expected.
	═	1	One and only one fracture during last sixty minutes.
	═	2	Two or more fractures during last sixty minutes.
	═	3	More than one hour since last 00:00 UTC registration.
	═	4	No registration at this hour, observation construced from previous observations during last sixty minutes.

FLRETT	═	NULL	No manipulation / original observation.
	═	1	Observation corrected.
	═	2	Observation interpolated.

3.3.2. Algorithms for datamanipulation

1. If observations are arriving regularily by the hour, FLBRUDD is assigned the value '0'. FLRETT is left unassigned.
2. If an observation arrives between two regular hours, the following procedure is used: The greatest of FX and FG during the last hour, with corresponding DG, DX, KLG and KLX replace the value of relevant hour. FLBRUDD is assigned the value '1' or '2'.
3. If consecutive hourly values are missing, the following procedure is used: Maximum of FX and FG since the last full hour, with corresponding DG, DX,

FLFG and FLFX are used for replacement. FF, DD are kept intact. FLBRUDD is assigned the value '3'.

4. If the full hour value is missing, but registrations of other observations within the same hour are present, the full hour value is constructed. The last ten minutes value is blanked out. FLBRUDD is assigned the value '4'.
5. If there are two full hour observations with equal date and time, the last one on file is used.
6. If the last observation on file is not a full hour observation, this row is used as the first row on the next file unless the next file overlaps.

3.3.3. Format check

The list below is the complete list of constraints used for defining the XVIND table. The violation of the rules F.9 to F.15 will result in the variable being removed and thus allowing for the rest of the row to be inserted into the table. If a value is removed, the FLRETT flag is assigned the value '1'. The tests below are strict format tests, accepting wind speeds far beyond what would be normally considered reasonable in most situations.

$$stnr \in ST\_INFO \tag{F.1}$$

$$1900 \leq aar \leq 2100 \tag{F.2}$$

$$1 \leq mnd \leq 12 \tag{F.3}$$

$$1 \leq dag \leq 31 \tag{F.4}$$

$$0 \leq tim \leq 23 \tag{F.5}$$

$$1 \leq minutt \leq 60 \tag{F.6}$$

$$rhtype = 'H' \text{ or } rhtype = 'R' \tag{F.7}$$

$$1 \leq rhnr \leq 5 \tag{F.8}$$

$$-1 \leq dd \leq 360 \tag{F.9}$$

$$-1 \leq dx \leq 360 \tag{F.10}$$

$$-1 \leq dg \leq 360 \tag{F.11}$$

$$0 \leq ff \leq 200 \tag{F.12}$$

$$0 \leq fx \leq 200 \tag{F.13}$$

$$0 \leq fg \leq 200 \tag{F.14}$$

$$0 \leq fg10 \leq 200 \tag{F.15}$$

$$0 \leq \mathit{flbrudd} \leq 4 \tag{F.16}$$

$$1 \leq \mathit{flrett} \leq 2 \tag{F.17}$$

4. HUMAN QUALITY CONTROL

4.1. The VINDREG processing routine

The non-automatic part of the VINDREG data processing routine is given in Kjensli (1998). This document contains a four-step procedure for storing data in the KLIBAS database, checking the quality of the input, and directives in case the quality is not acceptable. There are presently no guidelines for manual correction or interpolation of observations.

1. The Personal Computer is prepared in order to copy content of the floppy disk to the KLIBAS database server.
2. The files on the database server are to be given names according to certain rules which will then make it possible for the VIND_REG program to identify the correct observation sites and dates.
3. The datafile is copied.
4. Quality control by use of the computer program VINDDEK is performed. If a massive amount of data is missing, the AERO station is contacted and a new floppy disk is ordered if possible.

The sequence 1-4 should be completed for all AERO stations before the 6th of every month. Old floppy disks are stored in a fire proof container.

4.2. The VINDDEK quality control

The program has been constructed in order to focus on three types of problems as it is run for each station one month at a time (Øgland, 1998).

1. *Missing values.* The total number of observations registered pr day is printed, together with the total number of DD and FF. Normally we would expect 24 observations each day.
2. *Extremes.* The maximum and minimum of the day for DD and FF are printed columnswise.
3. *Tolerance levels.* The number of DD less than 0 during month is printed, along with the number of DD greater than 360, the number of FF less than 0.0 m/s and the number of FF greater than 30.0 m/s.

The person in charge of quality control is expected to make a subjective evaluation of each station for each month and report to the observation sites if severe errors are found, as commented at the end of the final point of the VINDREG procedure in section 4.1.

4.3. HQC interface with other QC routines

Presently the VINDREG data (XVIND) serve mostly as input for the ALV data processing routine, i.e. processing of weather data (Øgland et al, 1993). A documentation of how this routine is currently operating, including its interface with other routines such as the VINDREG routine, has been defined as an interal project at the Climatology Division (Aune, 1999), description and specification currently under elaboration (Andresen, 1999).

As quality control of the AERO stations may be integrated with climate data at large, areal checks and computation of geostrophical wind may become central parts of the quality control system.

5. SECOND LEVEL AUTOMATIC QUALITY CONTROL

In this section the NORDKLIM concept of AQC2 is given a slightly broader meaning within the VINDREG routine in order to link aspects of quality control with quality management, as will be explained below.

5.1. The VIND_KONTR process monitor

A program called VIND_KONTR has been constructed in order to run all the AQC2 programs defined for the VINDREG routine. The program was defined in October 1998 and has been running continuously since then with the aim of producing process statistics (SPC) of the kind that is used for monitoring the TELE and ALV routines (Øgland, 1999b; 1999c). There are still vital algorithms lacking in the program, however, before this is achieved.

The current purpose of the VIND_KONTR program is to run the VINDDEK program for each station for the last month were HQC is expected to be completed, i.e. checking all stations of the previous month on the 6th of the current month and onwards.

By doing this, problems such as floppy disks arriving late or disks containing bad data will be subject to objective analysis in terms of problems being identified and counted on a daily basis. The sum of problems may then be plotted against a time axis and if the number of problems per station is kept in track, stations may be sorted according to this metric.

A sorting of stations based on empirical data like this has proved very useful for other types of data within the KLIBAS system. In fact the development of the KLIBAS system in itself is managed by a similar count of problems associated with each computer program, defining the order in which they should be maintained and corrected (Øgland, 1999d).

5.2. Total Quality Management

Completing the VIND_KONTR program must be considered essential for putting the VINDREG routine under statistical control and a prequisite for developing more advanced types of AQC2 in order to automatically alter observations in the XVIND data table.

More than being a part of the quality control, the priciple of VIND_KONTR is based on the DNMI interpretation of Total Quality Management (Haglund, 1996) in the sense that the purpose of the program is to identify problems in the current state of the VINDREG routine and give an objective decision aid on how to improve the process.

6. DISCUSSION AND CONCLUSION

All the NORDKLIM QC components, AQC1, AQC2 and HQC are present in the VINDREG routine, but the system is presently only on the stage of a preliminary prototype system. Especially the AQC2 and HQC components leave a lot to be desired.

The most natural way for further development of the system seems to consist of first performing an analysis of what kind improvements are needed in the HQC. These should then be designed, implemented and tested, and as the HQC becomes more and more formalised with less and less variation, parts of the HQC should be left to the AQC2.

From a more practical point of view, what should be done is to identify the parts of the routine that is causing the greatest problems today in the context of the total weather data processing at DNMI/Klima and then adjust the VINDREG routine in order to accomodate lack of features and current faults. In this way the routine should improve stepwise over time into a fully automated and selfcontained system.

The main conclusions in respect of the NORDKLIM project are the three sections respectively devoted to the modules AQC1, AQC2 and HQC. These are written as input to the NORDKLIM Task 1.2 activities that are supposed to give a complete Nordic survey for each of the tasks which will finally add up to a total description of the Nordic quality control systems.

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