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NORWEGIAN METEOROLOGICAL INSTITUTE
BOX 43 BLINDERN N-0313 OSLO

PHONE: +47 22 96 30 00

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TITLE

Quality Control of Meteorological Observations at the DNMI - Airport Weather Stations: The ALF/METAR Routine

AUTHOR

Petter Øgland

PROJECT CONTRACTOR

DNMI - Climatology Division / NORDKLIM

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 ALF/METAR routine, for quality control of meteorological observations from the airport weather 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 at the time of arrival (AQC1), Automatic Quality Control as the observations fill up the database (AQC2) and Human Quality Control (HQC).

KEYWORDS
1. Quality Control
2. Meteorological Observations
3. METAR
4. NORDKLIM

SIGNATURE

Petter Øgland
Research Scientist

Bjørn Aune
Head of Climatology Division

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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).

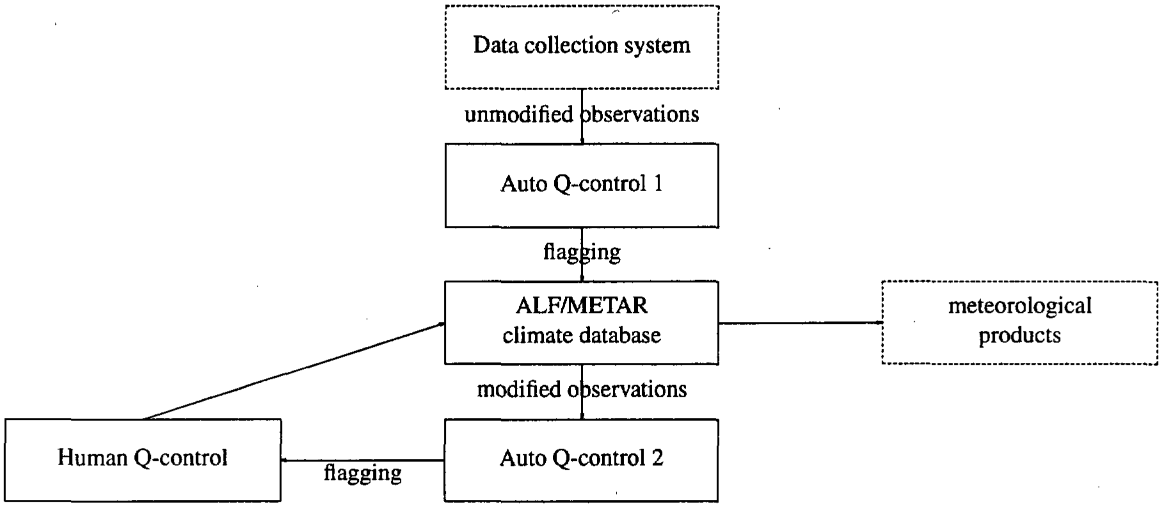
Every participating country within the NORDKLIM project is expected to write status summaries for each of the three quality control modules. DMI is responsible for collecting Nordic information on AQC1, SMHI collects information on AQC2 and DNMI collects information on HQC. Deadline for contributing information on each of the modules is on the 1st of October 1999. The joint Nordic experience with quality control will then be used as input for the second Task 1.2 group meeting in Norrköping, 21 - 22 October 1999.

This document demonstrates the quality assurance methods used with the Airport Weather Stations system (ALF/METAR system) for storing and manipulating digital meteorological observations at DNMI. The METAR observations consist of realtime data, but as the data collection system has only been running since late 1995, older observations need to be inserted into the database. The quality control is 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 ALF/METAR system. It then goes on to describe the AQC1 subsystem and how observations are initially inserted into the ALF/METAR database. The AQC2 system is then described, and finally we have a description of the HQC. An additional discussion and conclusion is left for the final section.

2. THE NORDKLIM QUALITY CONTROL MAIN STRUCTURE

The quality control system for the METAR 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 (datatables METAR and ALF), they are checked 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 observation lists and ad-hoc statistics.

On the next level, another automatic quality control, AQC2, turns into action by checking status and content for the datatables, now being able to use more advanced techniques than what could be applied to AQC1. The AQC2 system is monitored by a human quality control (HQC). Problems in the data set may cause iterated loops between AQC2 and HQC as the system grows and matures.

2.1. Automatic Quality Control 1 (AQC1)

Realtime METAR enter the KLIBAS database system by telegrams via the METARinn system (Øgland, 1995) and binary coded files with extracts from the telegrams via the META_INN system (Øgland, 1998a). The two systems are run in parallell, inserting telegrams into the METAR datatable twice a day, and inserting elements from the binary files into the ALF table every three hours. As the two systems overlap, the METARinn system is presently running as a backup system for the META_INN system, and is expected to be eliminated as the AQC1 continues to evolve.

The quality control in AQC1 consists of format checks and checks against station definitions within the KLIBAS meta-data archives. In case the observations violate format constrictions, observations have to be eliminated. Violations against meta-data definitions are logged to file for further analysis (HQC).

2.2. Automatic Quality Control 2 (AQC2)

The second level quality control module consists of two main submodules. Firstly, the program ALF2TELE (Øgland, 1998b) is responsible for inserting observations into the TELE datatable whenever such an interpolation makes sense. In order to prevent this program from breaking down, due to prohibited updates of TELE, a format check is contained, this time checking the synops generated from ALF against the constraints of the TELE datatable.

The other main submodule for the AQC2 is the program METAR_KONTR (Øgland, 1999d). The purpose of this program is to run all the METAR application statistics programs with the latest updates in ALF, and to perform an analysis of the results in order to detect errors before products are delivered to internal or external customers. This type of quality control is sometimes refered to as product quality control (Andresen, 1999).

2.3. Human Quality Control (HQC)

The human quality control for the ALF/METAR may be divided into three sections. Firstly there is the monitoring of the automatic system. Statistics are collected at regular intervals and presented in terms of statistics and diagrams for daily inspection.

Secondly, if the daily inspection gives rise to a suspicion that there may be something in error with the system, maintenance or development programming is performed.

Thirdly, if the daily inspection indicates that there are missing or inconsistent data within the present ALF/METAR dataset, interpolations or corrections should be inserted. As there is no formalised routine of manual METAR-data processing at DNMI at the present, such updates have to be done in an ad-hoc manner and gradually eliminated by growing the AQC2 module.

In order to keep objective track of the development of the ALF/METAR system, the program METAR (Øgland, 1999e) has been designed for updating the KLIBAS list of work packages, using warning and error statistics from the ALF/METAR system as input.

3. DATA COLLECTION AND FIRST LEVEL AUTOMATIC Q-CONTROL

The aeronautical stations (METAR stations) are manned stations where visual observations are being made every hour or every half hour, either through out the day or during the time of day when the airport is open for trafic. Presently data from 58 aeronautical stations are inserted into the KLIBAS system (Øgland, 1999f, page 23).

A general description of the METAR stations as a part of the DNMI network of meteorological stations is given by Andresen et al. (1997).

The present AQC1 module consists of a parallell collection of METAR data through the programs METARinn and META_INN, each of the programs reading data from different sources and inserting observations into different datatables in the KLIBAS database system, giving the opportunity for different first level format controls and station definition tests.

3.1. The METARinn program

The first version of the METARinn program was released in October 1995. It was then designed as an experiment program for reading METAR telegrams (MSYS8-files) and inserting these into the METAR datatable of the KLIBAS database system.

The program was further improved and stabilised several times until the version 1.1 was released two years later (Øgland, 1997).

Apart from reading the telegrams as lines of text into the database system, a select list of meteorological elements are inserted seperately into columns. The elements fall into six groups: Wind elements (DD, FF, FG), weather code (WW,REWW), visual range (VV), air temperature (TT, TD), air pressure (QNH), and a maximum of three levels of visual cloud observations (NS1, C1, HS1, NS2, C2, HS2, NS3, C3, HS3).. A more detailed account of the acronyms may be found in the KLIBAS literature (ibidem).

The METAR datatable is defined according to the description below. The first column ('name') contains the METAR columns names, the second ('null?') specifies whether there is a restriction or not, if the METAR column will accept an empty value (NULL) or not, and the final column ('Type') shows how the METAR columns are formatted. A format of the type NUMBER(5) means that values for this column will only be accepted if they are integers of no more than five digits.

The METARinn program is constructed in such a manner that the complete set of observations for a given station and a given time will be neglected if the content of one of the elements violates the format conditions.

```
Name                            Null?    Type
------------------------------- -------- ----
STNR                            NOT NULL NUMBER(5)
AAR                             NOT NULL NUMBER(4)
MND                             NOT NULL NUMBER(2)
DAG                             NOT NULL NUMBER(2)
TIM                             NOT NULL NUMBER(2)
MIN                             NOT NULL NUMBER(2)
DD                                       NUMBER(2)
FF                                       NUMBER(2)
FG                                       NUMBER(2)
VV                                       NUMBER(4)
WW                                       NUMBER(2)
NS1                                      NUMBER(1)
C1                                       NUMBER(1)
HS1                                      NUMBER(3)
NS2                                      NUMBER(1)
C2                                       NUMBER(1)
HS2                                      NUMBER(3)
NS3                                      NUMBER(1)
C3                                       NUMBER(1)
HS3                                      NUMBER(3)
TT                                       NUMBER(2)
TD                                       NUMBER(2)
QNH                                      NUMBER(4)
TELEGRAM                                 VARCHAR2(250)
REWW                                     NUMBER(4)
```

As the METARinn program was designed as a test program for collecting METAR data, no steps have been taken so far for further automatic statistical analysis of the format errors.

At present, the rows that are rejected are being written to file, but as each new loading session will overwrite this file, there is no history of how the observations fail to load.

For the daily inspection of the METAR datatable, however, a matrix containing the number of stations reporting for each possible time of observation is updated. The matrix is mostly used as a visual verification of observations entering the database as prescribed.

Below is an example of such a matrix. This particular example was updated on the 20th of September 1999 and indicates that we have received data from the stations network up to the present day.

kl/dag	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
00:20	*	2	2	2	*	2	2	2	2	2	2	2	2	2	*	2	2	2	2	1	*	*	*	*	*	*	*	*	*	*
00:50	15	16	17	18	9	16	18	18	17	16	17	11	15	19	1	15	20	19	12	19	*	*	*	*	*	*	*	*	*	*
01:20	2	2	2	2	1	2	1	2	1	2	3	2	2	2	*	2	2	2	2	2	*	*	*	*	*	*	*	*	*	*
01:50	19	18	13	16	14	17	18	17	16	18	18	11	17	20	1	17	16	20	13	20	*	*	*	*	*	*	*	*	*	*
02:20	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	2	3	*	*	*	*	*	*	*	*	*	*
02:50	26	24	24	23	14	22	26	24	21	25	22	14	23	25	25	26	24	23	15	26	*	*	*	*	*	*	*	*	*	*
03:20	9	9	10	7	3	10	9	9	10	12	8	5	8	10	10	10	10	6	6	9	*	*	*	*	*	*	*	*	*	*
03:50	35	36	36	30	13	37	36	36	38	38	26	14	36	37	38	39	38	30	15	37	*	*	*	*	*	*	*	*	*	*
04:20	20	20	20	15	12	19	19	21	20	19	14	9	19	18	18	19	19	13	12	20	*	*	*	*	*	*	*	*	*	*
04:50	47	47	46	39	20	50	46	48	49	48	36	20	48	47	46	46	48	40	20	49	*	*	*	*	*	*	*	*	*	*
05:20	20	21	21	19	13	19	18	21	20	22	18	12	20	21	19	21	19	18	12	21	*	*	*	*	*	*	*	*	*	*
05:50	51	48	55	41	22	52	52	50	53	55	43	22	54	51	50	51	49	44	21	49	*	*	*	*	*	*	*	*	*	*
06:20	22	20	21	17	12	19	19	20	22	17	16	11	20	17	19	17	20	17	12	*	*	*	*	*	*	*	*	*	*	*
06:50	53	55	56	45	24	54	54	55	52	56	44	23	54	53	54	55	56	39	25	*	*	*	*	*	*	*	*	*	*	*
07:20	21	20	21	19	15	21	18	20	22	18	16	15	21	19	22	20	22	17	13	*	*	*	*	*	*	*	*	*	*	*
07:50	54	53	55	47	29	54	53	54	54	57	46	26	54	53	54	53	57	48	28	*	*	*	*	*	*	*	*	*	*	*
08:20	19	21	21	19	17	18	19	21	22	19	18	16	21	19	19	21	22	17	18	*	*	*	*	*	*	*	*	*	*	*
08:50	55	54	54	45	34	53	52	55	56	52	44	35	54	54	52	51	54	46	34	*	*	*	*	*	*	*	*	*	*	*
09:20	20	19	20	19	19	17	19	20	21	19	15	18	22	20	19	21	21	18	20	*	*	*	*	*	*	*	*	*	*	*
09:50	55	50	54	47	39	53	54	57	53	51	46	38	54	50	54	56	54	48	37	*	*	*	*	*	*	*	*	*	*	*
10:20	19	18	18	18	19	18	21	19	19	17	18	18	17	18	19	21	22	19	18	*	*	*	*	*	*	*	*	*	*	*
10:50	54	52	56	46	41	56	52	55	55	54	46	41	57	56	57	55	54	45	41	*	*	*	*	*	*	*	*	*	*	*
11:20	20	22	18	19	19	18	20	19	18	20	17	19	20	19	20	22	21	15	14	*	*	*	*	*	*	*	*	*	*	*
11:50	56	53	55	41	42	55	50	51	53	54	41	43	55	50	54	51	51	40	44	*	*	*	*	*	*	*	*	*	*	*
12:20	21	17	20	19	19	21	20	23	19	20	18	19	19	20	18	20	19	16	18	*	*	*	*	*	*	*	*	*	*	*
12:50	52	54	54	33	46	53	53	53	52	52	37	47	54	52	56	56	53	35	47	*	*	*	*	*	*	*	*	*	*	*
13:20	18	22	19	18	19	18	19	20	19	20	16	18	18	18	19	21	20	17	17	*	*	*	*	*	*	*	*	*	*	*
13:50	53	55	55	31	49	54	51	49	51	52	35	49	50	55	56	54	54	35	50	*	*	*	*	*	*	*	*	*	*	*
14:20	19	19	20	18	19	17	20	18	20	19	16	17	18	20	21	21	21	15	17	*	*	*	*	*	*	*	*	*	*	*
14:50	51	53	55	32	51	53	53	54	55	49	31	52	49	54	54	55	54	34	50	*	*	*	*	*	*	*	*	*	*	*
15:20	18	20	18	17	19	21	18	20	19	18	18	18	19	19	20	20	19	15	17	*	*	*	*	*	*	2	*	*	*	*
15:50	52	53	52	23	48	52	52	53	54	54	22	47	51	55	54	54	52	23	49	*	*	*	*	*	*	*	*	*	*	*
16:20	17	22	18	15	17	16	16	19	14	16	14	17	17	19	18	19	18	13	18	*	*	*	*	*	*	*	*	*	*	*
16:50	53	53	51	21	51	50	51	52	51	53	20	50	51	50	52	51	53	23	49	*	*	*	*	*	*	*	*	*	*	*
17:20	16	18	16	13	15	17	17	16	16	15	11	16	15	16	15	16	17	12	15	*	*	*	*	*	*	*	*	*	*	*
17:50	50	50	50	19	46	48	47	50	46	46	21	46	48	50	51	49	48	20	46	*	*	*	*	*	*	*	*	*	*	*
18:20	14	15	14	10	15	15	14	14	14	13	9	13	13	14	13	12	13	9	13	*	*	*	*	*	*	*	*	*	*	*
18:50	47	46	46	16	44	44	44	42	43	40	18	39	44	43	44	44	44	20	45	*	*	*	*	*	*	*	*	*	*	*
19:20	13	12	14	8	13	13	11	12	12	14	8	12	12	13	11	11	12	8	11	*	*	*	*	*	*	*	*	*	*	*
19:50	38	42	39	16	35	35	38	34	38	38	15	34	36	36	36	34	38	18	33	*	*	*	*	*	*	*	*	*	*	*
20:20	11	11	12	9	11	12	11	10	11	11	8	12	11	12	10	13	12	8	11	*	*	*	*	*	*	*	*	*	*	*
20:50	30	27	31	15	31	28	29	28	29	26	15	28	28	30	29	31	30	14	30	*	*	*	*	*	*	*	*	*	*	*
21:20	8	11	9	7	11	8	10	10	10	9	7	9	10	10	9	9	8	7	11	*	*	*	*	*	*	*	*	*	*	*
21:50	22	24	23	15	25	24	23	23	22	21	14	25	25	22	23	23	24	14	27	*	*	*	*	*	*	*	*	*	*	*
22:20	4	3	4	3	4	4	5	3	4	3	3	4	4	4	3	4	3	3	3	*	*	*	*	*	*	*	*	*	*	*
22:50	17	19	20	14	13	17	18	16	18	19	13	16	19	19	19	18	20	14	19	*	*	*	*	*	*	*	*	*	*	*
23:20	2	4	2	3	3	3	3	4	2	3	3	3	3	3	3	3	3	2	3	*	*	*	*	*	*	*	*	*	*	*
23:50	19	18	21	13	20	19	19	20	19	20	14	19	21	18	20	18	21	14	19	*	*	*	*	*	*	*	*	*	*	*

The numbers in the matrix above shows the number of stations we have received data.

3.2. The META_INN program

When the META_INN program was introduced in September 1998, the purpose of the program was to replace the METARinn system with a program that was more reliable, easier to maintain and which collected a more complete set of observations.

The program has been officially revised twice (Øgland, 1998a; 1999c), although a number of minor adjustments have been made as problems have surfaced. Unlike the METARinn system, if there is a format error for one of the elements in a set of observations for a given station and a given time, only this particular element will be neglected by the META_INN program, not the complete set.

Observations are stored on a datatable ALF, as indicated in the description below. An explanation of the elements and column names can be found in the version 1.2 documentation of the META_INN program (ibidem).

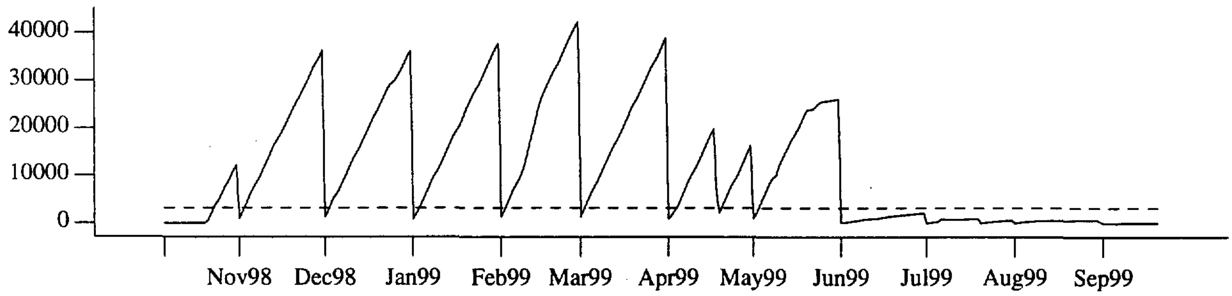
```
Name                            Null?    Type
------------------------------- -------- ----
EN_KODE                         NOT NULL VARCHAR2(4)
STNR                            NOT NULL NUMBER(5)
AAR                             NOT NULL NUMBER(4)
MND                             NOT NULL NUMBER(2)
DAG                             NOT NULL NUMBER(2)
TIM                             NOT NULL NUMBER(2)
MIN                             NOT NULL NUMBER(2)
P                                        NUMBER(4)
QNH                                      NUMBER(4)
DD                                       NUMBER(3)
FF                                       NUMBER(3)
TT                                       NUMBER(2)
TD                                       NUMBER(2)
CAVOK                                    NUMBER(1)
FM                                       NUMBER(3)
DN                                       NUMBER(3)
DX                                       NUMBER(3)
VV                                       NUMBER(4)
NS1                                      VARCHAR2(3)
HS1                                      NUMBER(3)
CB1                                      VARCHAR2(3)
NS2                                      VARCHAR2(3)
HS2                                      NUMBER(3)
CB2                                      VARCHAR2(3)
NS3                                      VARCHAR2(3)
HS3                                      NUMBER(3)
CB3                                      VARCHAR2(3)
NS4                                      VARCHAR2(3)
HS4                                      NUMBER(3)
CB4                                      VARCHAR2(3)
WMWM                                     VARCHAR2(9)
WMWM2                                    VARCHAR2(9)
WMWM3                                    VARCHAR2(9)
WMWMRE                                   VARCHAR2(9)
DV                                       NUMBER(1)
```

```
VVX                                         NUMBER(4)
DVX                                         NUMBER(1)
DR                                          NUMBER(3)
DRC1                                        VARCHAR2(2)
DRC2                                        VARCHAR2(2)
DRPM                                        VARCHAR2(1)
VR1                                         NUMBER(4)
VR1PM                                       VARCHAR2(1)
VR2                                         NUMBER(4)
VR2UDN                                      VARCHAR2(1)
```

Unlike the METAR datatable, the complete telegram is not stored here, but all essential elements of that telegram should be contained within the select list of weather elements.

Problems recorded by the program, both format errors and conflicts between station definitions in the ALF_PARA datatable and the ALF table, are logged to file and used as basis for statistical quality control in terms of a Shewhart diagram and a top ten list.

The plot below shows the day by day count of defects according to quality control performed by the program. These types of plots are sometimes refered to as Shewhart diagrams or Shewhart control charts (Ross, 1997).



Day by day counting of defects according to interal quality control in META_INN.

There are some striking features in the plot. First of all it appears to describe a process that behaves very differently before and after the first of June 1999. The first phase of the process, from the initial start of the statistical process control medio November 1998 until the middle of May 1999, problems for the current month are accumulated as more and more observations are filling up for the month, and there is no sign of any improvement as the same behaviour repeats itself month after month. The heart of the problem during this phase was that the definitions in the ALF_PARA datatable were not yet properly initialised.

During the next phase, from the beginning of June 1999 and onwards, the behavior is quite different. As the ALF_PARA table has now been updated and is actually updated automatically by the META_INN program itself, when there is sufficient evidence for a change in the observation program for a certain station, the daily count of problems is much smaller than before.

The total count of problems during the present day, the right hand side of the curve in the Shewhart diagram, is distributed among the stations in order to put focus on the stations causing the most problems. The present day list of the top ten looks like this:

```
10380 RØROS FLYPLASS, 5 problems.
98580 VARDØ LUFTHAVN, 4 problems.
98090 BERLEVÅG LUFTHAVN, 3 problems.
47260 HAUGESUND LUFTHAVN, 3 problems.
98350 BÅTSFJORD LUFTHAVN, 3 problems.
57710 FLORØ LUFTHAVN, 3 problems.
85890 RØST LUFTHAVN, 3 problems.
48120 STORD LUFTHAVN, 2 problems.
85450 SVOLVÆR LUFTHAVN, 2 problems.
60990 VIGRA, 2 problems.
```

In order to facilitate the problem search even more, the program automatically makes an ordered list of the problems associated with the station heading the top ten list. In this case we have 10380 RØROS FLYPLASS on top with the following list of problems:

```
10380: 1 case having an observation at 17:20 in ALF not defined in ALF_PARA.
10380: 1 case having an observation at 16:50 in ALF not defined in ALF_PARA.
10380: 1 case having an observation at 16:20 in ALF not defined in ALF_PARA.
10380: 1 case having an observation at 17:50 in ALF not defined in ALF_PARA.
10380: 1 case having an observation at 18:20 in ALF not defined in ALF_PARA.
```

Apart from the format checks in META_INN, defined by the ALF table describtion in the beginning of this section, the quality check performed by the program consists only of checking the time stamp for each observation handled by the program with the time definition in ALF_PARA.

If the program records an observation that does not correspond with the definitions in ALF_PARA, as the five cases for 10380 RØROS FLYPLASS, these instances are logged to file. If, however, there are seven instances of this particular irregularity repeating itself for a given station during a month, the program assumes that the observation programme at the station has been changed and makes an automatic change in the ALF_PARA definition table in order to accomodate this change and prevent the program from producing more warnings of this case, preventing more interesting information to surface.

A similar type of control/update is being planned for each of the most important weather elements, such as temperature, wind, visibility and so on, but at the moment the station definition test only contains a check of the time stamps.

In addition to these tests, the program also updates a file containing the total number of observations of the month distributed among each of the stations defined in ALF_PARA for visual inspection. Here we have the current update on the distribution of observations in ALF for September 1999:

Stnr	Sign	Name	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Sum
04780	ENGM	GARDERMOEN	31	34	38	37	36	37	36	38	37	36	37	37	37	36	37	36	37	37	35	37	38	37	38	36	875
76920	ENEK	EKOFISK	33	33	40	38	38	35	35	36	36	34	34	33	36	36	35	36	33	36	35	38	35	38	37	37	857
44560	ENZV	SOLA	18	18	19	36	37	37	36	38	37	36	37	37	37	37	37	36	37	37	37	38	36	37	38	36	829
82290	ENBO	BODØ VI	18	17	38	39	39	37	36	38	38	36	37	37	37	37	37	37	37	37	37	38	38	38	19	19	821
69100	ENVA	VÆRNES	19	18	20	35	36	37	36	38	37	36	37	36	37	37	37	37	37	37	37	38	38	38	19	19	796
50500	ENBR	FLESLAND	19	18	20	19	39	37	36	38	38	36	37	37	37	37	37	37	37	37	37	38	38	38	19	19	785
90490	ENTC	TROMSØ - L	19	18	18	31	36	35	34	38	35	34	37	36	36	37	37	37	36	36	37	38	38	35	19	19	776
71550	ENOL	ØRLAND III	19	19	20	18	34	37	36	38	37	36	36	37	34	35	35	36	37	36	37	19	19	19	17	19	710
87110	ENAN	ANDØYA	15	16	22	34	36	34	34	34	37	36	36	37	37	35	35	35	32	31	18	18	19	19	17	19	686
89350	ENDU	BARDUFOSS	16	15	17	33	39	37	36	38	37	36	37	37	37	37	36	37	36	18	15	16	16	16	16	16	674
17150	ENRY	RYGGE			20	17	35	37	36	38	37	36	37	36	37	37	37	37	37	37	20	18	19	19	14	19	660
39040	ENCN	KJEVIK					37	37	35	38	36	36	37	36	37	37	37	37	36	37	37	38	35	32			655
47260	ENHD	HAUGESUND					27	31	30	37	33	35	35	37	37	36	36	36	33	33	31	31	32	9	2		581
64330	ENKB	KRISTIANSU			2	16	28	30	30	33	36	32	36	36	35	35	34	36	31	29	28	26	15	7	5	2	562
57710	ENFL	FLORØ LUFT				28	31	24	27	24	32	34	33	32	29	29	30	27	25	30	27	28	24	23	7	2	546
62270	ENML	MOLDE LUFT					31	31	31	34	34	31	32	29	35	34	29	34	29	29	29	30	29	5			536
57000	ENBL	FØRDE LUFT			1	28	26	25	23	27	30	30	30	25	29	33	32	28	24	26	20	19	2				458
60990	ENAL	VIGRA				1	30	32	29	31	30	28	24	27	31	31	31	27	28	29	17	16	11	3			456
99840	ENSB	SVALBARD L	20	20	20	18	19	18	17	17	18	17	17	18	18	18	18	18	18	18	17	18	19	19	18	19	437
93140	ENAT	ALTA LUFTH	18	18	16	18	19	18	17	18	18	16	18	18	18	17	18	18	18	19	17	19	19	17	18	17	427
95350	ENNA	BANAK	14	14	16	15	16	18	16	18	17	17	18	17	17	18	17	18	17	18	17	19	18	16	15	14	400
76923	ENGC	GULLFAKS C	18	18	19	19	17	17	16	18	17	16	17	15	16	13	15	14	16	17	18	14	18	17	14	18	397
99370	ENKR	KIRKENES L	7	12	15	16	17	16	17	18	18	17	18	18	18	18	18	17	18	18	17	20	19	14	13	13	392
76750	ENST	SANDNESSJØ	12	15	17	15	15	15	15	19	16	17	17	17	18	18	18	15	15	15	15	16	15	15	9	16	375
79600	ENRA	MO I RANA	13	14	16	16	16	15	14	17	18	17	17	18	16	17	18	15	14	14	14	16	17	15	10	15	372
94280	ENHF	HAMMERFEST	15	15	15	15	13	14	14	16	15	15	17	18	18	15	16	15	16	16	17	16	15	16	15	15	372
76928	ENHE	HEIDRUN			1			29	27	34	30	28	34	29	30	26	31	29	31								359
76927	ENOA	OSEBERG A	3	5	5	7	22	24	23	27	26	22	23	21	25	24	25	29	22	8	8	7				1	357
76330	ENBN	BRØNNØYSUN	10	13	13	17	16	12	13	15	18	14	17	17	17	17	16	15	15	15	15	16	15	13	13	12	354
27470	ENTO	TORP					36	25	23	29	25	22	23	23	20	18	18	12	17	16	15	15	10	1			348
84970	ENEV	EVENES LUF	3	3	2	16	19	18	17	17	17	17	18	18	16	18	18	15	15	15	13	15	16	15	3	3	327
77230	ENMS	MOSJØEN LU			17	17	16	13	14	15	16	17	17	18	16	18	18	15	15	15	15	16	16				304
98790	ENVD	VADSØ LUFT		1	15	16	15	13	14	15	17	12	15	16	16	16	14	15	14	14	15	16	14	15			298
10380	ENRO	RØROS FLYP							31	28	31	32	32	30	33	31	29	10	4	4	2						297
85450	ENSH	SVOLVÆR LU			15	16	11	14	13	16	16	15	17	18	15	15	15	14	14	14	15	13	1	1			268
72580	ENNM	NAMSOS LUF				16	16	15	13	14	17	17	18	18	18	18	15	15	15	14	14	11	1				265
86600	ENSK	STOKMARKNE			17	16	15	14	12	15	14	15	18	16	15	15	15	15	15	14	14	3				2	260
94680	ENHV	HONNINGSVÅ				16	16	14	11	15	14	13	15	11	12	12	12	12	15	16	15	16	3	3			241
75220	ENRM	RØRVIK LUF				14	15	14	14	15	14	13	12	14	15	14	14	15	15	14	15	14					241
85560	ENLK	LEKNES LUF				15	16	13	13	13	15	15	18	18	12	16	12	12	15	14	15	4	2	1	1		240
59680	ENOV	ØRSTA - VO				3	14	11	13	15	16	17	14	11	15	10	14	15	15	15	14	16	9				237
84700	ENNK	NARVIK LUF				16	16	10	12	11	12	11	18	18	14	15	15	15	15	15	15	3	2	1			234
58100	ENSD	SANDANE LU				13	15	15	13	15	18	16	13	12	15	17	18	15	15	11	10	1					232
55700	ENSG	SOGNDAL LU				13	15	15	13	14	17	12	13	13	18	16	13	12	14	13	7						218
91740	ENSR	SØRKJOSEN					15	15	14	15	15	12	15	13	12	14	15	15	15	15	14						214
30420	ENSN	GEITERYGGE				1	12	11	12	12	11	13	14	15	16	16	17	16	15	13	9						203
98090	ENBV	BERLEVÅG L		1	1			27	14	12	14	14	13	12	14	15	14	10	12	10	12	7	1				203
96310	ENMH	MEHAMN LUF			15	15	15	13	10	6	8	9	13	11	8	6	8	10	13	13	9	10	1				193
48120	ENSO	STORD LUFT				3	15	14	10	13	10	11	13	15	14	15	16	13	15	12	3						192
76921	ENFR	FRIGG					13	15	13	16	16	14	13	14	13	16	14	14	5	1							177
23410	ENFG	FAGERNES L						13	12	12	12	14	15	14	13	13	13	13	10	10							164
98580	ENSS	VARDØ LUFT	1			1	1	8	13	13	9	10	12	10	11	7	12	15	9	11	13	6	1				163
85890	ENRS	RØST LUFTH					10	14	12	14	10	7	9	10	10	11	9	16	12	11	1	1	1				158
92750	ENHK	HASVIK LUF			3	7	12	13	5	10	8	8	10	5	13	12	13	11	7		1	1					139
30650	ENNO	NOTODDEN F					2	13	11	12	12	11	12	10	12	12	13	5	3	1							129
98350	ENBS	BÅTSFJORD				1	1	1	3	2	7	12	13	13	1	1	9	14	12	11	9						110
42140	ENLI	LISTA FLYS					4	6	6	5	6	4	6	5	5	5	8	15	15	13	3						106
29720	ENDI	DAGALI LUF							11	11	11	11	13	13	14	15	6										105
99710	ENBJ	BJØRNØYA												1													1

4. SECOND LEVEL AUTOMATIC QUALITY CONTROL

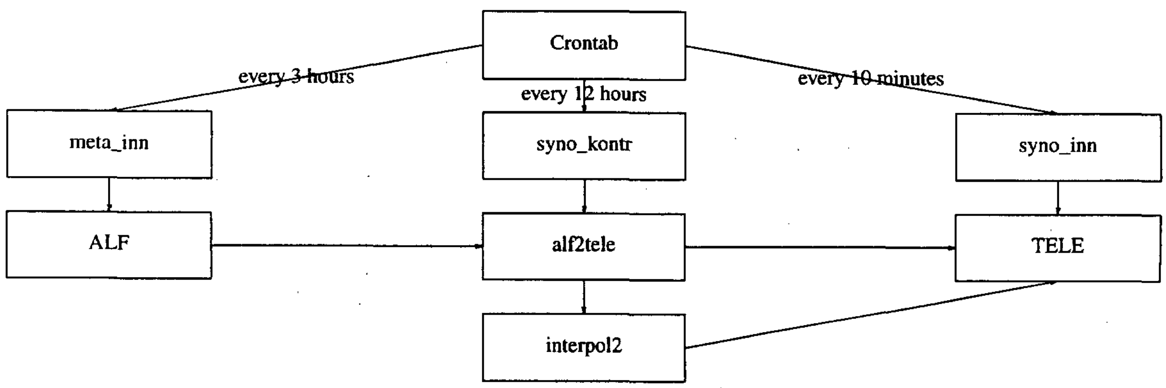
There are two modes in which the ALF/METAR observations are being used at DNMI. Firstly, they are being used for interpolation in the TELE data processing routine, a task managed by the ALF2TELE program (Øgland, 1998), and, secondly, a number of METAR climate products are produced, or at least there are several prototype programs under construction specifically designed for generating ALF/METAR climate products.

While the ALF2TELE injection into the TELE database system is monitored by itself, a program METAR_KONTR (Øgland, 1999e) has been designed for running each of the climate statistics programs and to evaluate and quality check the output for each such program.

4.1. The ALF2TELE program

The purpose of the program ALF2TELE is to update the datatable TELE with METAR values found in the datatable ALF in cases where either the whole row in TELE is missing or a particular observation from a single weather element is not registered.

The program is run in a regular fashion by system call from the SYNO_KONTR program (Øgland, 1999h), making sure that METAR observations are inserted into TELE before attempting to interpolate with statistical methods or other means. The diagram below illustrates the relationship between datatables and relevant programs.



The TELE table is filled with observations from the synoXX-files every ten minutes. Dataflow, control and interpolation programs such as ALF2TELE and INTERPOL2 are driven by the SYNO_KONTR program.

If no update in the datatable TELE results from running ALF2TELE, missing values may be interpolated by statistical methods by programs such as INTERPOL2, INTERPOL3 or HIRLAM, programs that are part of the SYNO_KONTR package and used filling in for missing values by various methods.

The current prototype version of ALF2TELE updates only temperature from ALF to TELE, and the only test performed by the program is a format check with respect to TELE in the case of air temperature TT.

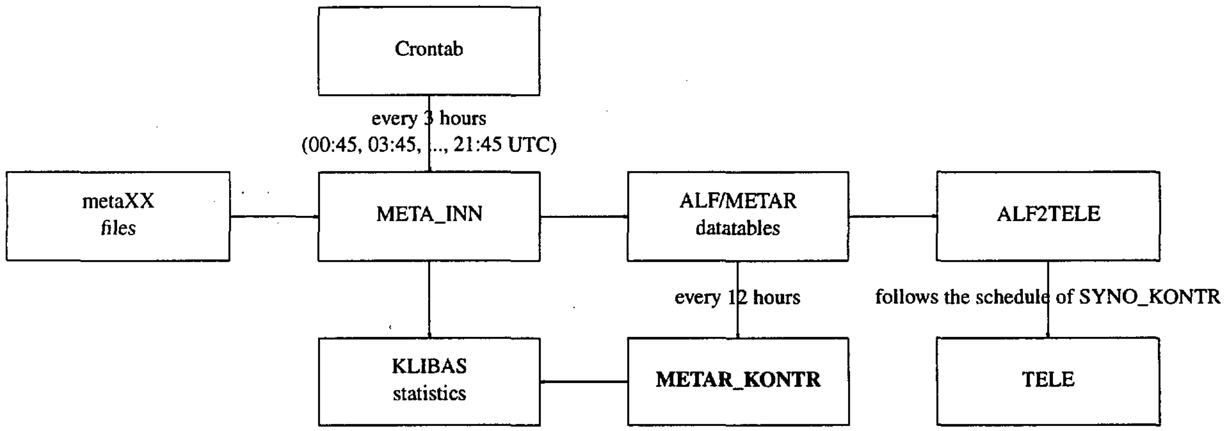
$$-60.0 \leq TT \leq 60.0 \tag{4.1}$$

The program updates a process control chart (Shewhart control chart) based on this test for daily statistical process control of the system.

Whenever an update in TELE for TT is made by this program, a quality flag '6' is indicated in the column FLTT.

4.2. The METAR_KONTR process monitor

The prototype version of the METAR_KONTR system, the operative version of the system, uses a consistency check between ALF and ALF_PARA as the main quality check. The program also makes system calls to the METAR climate statistics programs, and, according to plans, output from these programs will be analysed on a daily basis by METAR_KONTR.



As the system develops, the purpose of the program METAR_KONTR is to produce statistics of the same kind as SYNO_KONTR, that is statistics that 1) presents the daily level of quality in order to easily visualise any improvement or deterioration in the quality level, and 2) produce sorted lists of stations according to the number of problems they have associated with them, and which climate controls or other quality control programs where most problems are found.

Below each of these climate statistics programs are discussed, with comments on how the programs may be a part of the general quality control for the ALF/METAR system.

4.2.1. The BRODOY program

The purpose of the program BRODOY is to provide data cover statistics for METAR observations and is intended to work as a module in the METAR quality control system.

The presentation of data cover statistics are designed in order to fit specifications for a data cover analysis performed at VNN during at Bodø in February 1999. As a part of the METAR_KONTR process, however, the program should be used for keeping track of changes in the level of missing data for the METAR stations.

4.2.2. The AARSREKKERAMME program

The AARSREKKERAMME statistics is a type of statistics defined by Andresen et al. (1994). The purpose of the program is to produce statistics, such as average temperature, for a given sequence of years, presenting the statistic (average) for each month of that year together with the annual statistic (average). For other weather elements, such as precipitation, the statistic may be a sum, i.e. monthly and annual precipitation sums.

If the program is unable to produce the given statistics for a given year and given month, this is indicated on the output, either by presenting a symbol indicating that it was impossible to produce the given value or a value may be given with an indicator showing that the month was not complete.

A preliminary version of this program has been running since January 1998, but at present there is no operative version of this program that actually produces the kind of statistics that are specified.

4.2.3. The DOGNEKSTREMRAMME program

The DOGNEKSTREMRAMME program is another climate statististics program specifed also by Andresen et al. The purpose of this program is to produce lists of extreme values, such as the highest og lowest daily air temperatures for a given station during a given interval of years. The statistics are to be presented in lists of extremes for each month and a list of daily extremes regardless of month.

As a part of the quality control package METAR_KONTR, the extremes produced by this program should be checked against the KLIBAS database of extreme values, and should also be checked against limits of what would be reasonable extremes according to relevant statistical extreme distributions.

Just like the program above, this has been running in a preliminary version since January 1998, but is not yet in operative use as it does not yet produce the statistics specified.

4.2.4. The 2-PARAMETERRAMME program

The 2-PARAMETERRAMME program is another climate statististics program specifed by Andresen et al. The type of statistics this time is a double frequency plot for a pair of meteorological elements, wind speed and wind direction for example, and the program will then decide relevant scales and produce frequency or relative frequency plots for these.

Within a quality control context, elements such as wind speed and wind direction are particulary may be investigated in order to find out whether there are problems with the wind direction in particular.

Just like the programs above, this has been running in a preliminary version since January 1998, but is not yet in operative use as it does not yet produce the statistics specified.

4.2.5. The AARSRAMME program

The AARSRAMME program is another climate statististics program specifed by Andresen et al. The purpose of the program is to produce daily averages or daily sums for a given meteorological element, a given station and a given year.

From a quality control perspective, the relevanse consists first of checking data cover and then to decide whether the distribution of values over the month looks fairly reasonable.

Just like the programs above, this has been running in a preliminary version since January 1998, but is not yet in operative use as it does not yet produce the statistics specified.

5. PROSPECTS OF A HUMAN QUALITY CONTROL

At the moment there are no formal human interaction in the ALF/METAR data processing routine except the monitoring of the data collecting system. As the METAR observations grow to become a more important part of the reference data for other weather data processing routines and METAR climate products become available, corrections and maintenance of the actual observations have to be done, and human interaction with the ALF/METAR databases have to be formalised.

5.1. Monitoring the system

Even though the system is completely automatic, some kind of monitor system must be constantly running in order to produce warnings and errors if the system should break down. The monitoring could in principle be almost as automatic as the data processing in itself, but if something goes wrong, e-mail warning messages, web page reports or whatever method one should prefer to use, should make contact with a qualified human operator who may be able to analyse and eliminate the problem.

Currently system statistics are produced on regular intervals and investigated manually on a daily basis by use of statistical methods. The results from this type of statistical process control are also used for finding out how to improve the system, control and improvement being totally integrated in the current approach.

5.2. Human interaction and subjective corrections

Even though some experience of automatic interpolation and data correction may be used from the TELE data processing system, in the METAR observation set there are types of observations that are not represented in the TELE/SYNOP system, and in order to make sure that these observations are handled properly, some human surveilance is needed.

When proper METAR climate products are defined and made part of the ALF/METAR data management process, the quality of these final products will be the natural norm for evaluating and improving the process.

If naive interpolation and correction schemes are sufficient for producing products that satisfy the internal and external customers (users) quality requirements or expectations, then this will be sufficient. The important part, however, is that customer satisfaction is in some way reported back to the ALF/METAR routine so problems may be identified and eliminated.

5.3. Making the historical database up to date

In addition to controlling and improving the system for inserting the current flow of fresh observations into the database system, there is a large amount of historical METAR observations that have not yet been digitalised or are currently in the state of being digitalised.

At present there is no routine at DNMI for inserting these into the KLIBAS database system, but there have been plans to develop a system similar to the VIND-REG system (Øgland, 1999d), which may semi-automatically insert datafiles as they are written to a properly defined computer directory.

This method may be further automated in the future if one decides to communicate these datafiles by e-mail or other electronic means. Before such developments occur, however, a manual routine at DNMI have to be constructed in order to handle floppy disks.

5.4. HQC interface with other QC routines

Presently the METAR observations serve mostly as input for the SYNOP/TELE data processing routine, i.e. processing of weather data (Øgland, 1998d). A documentation of how this routine is currently operating, including its interface with other routines such as the METAR routine, has been defined as an internal project at the Climatology Division (Aune, 1999), description and specification currently under elaboration (Andresen, 1999).

As quality control of the METAR stations may be integrated with real-time data and climate data at large, areal checks may become central parts of the quality control system.

6. DISCUSSION AND CONCLUSION

All the NORDKLIM QC components, AQC1, AQC2 and HQC are present in the ALF/METAR routine, although both AQC2 and HQC are still very much in a preliminary state.

The most natural way for further development of the system then, seems to consist of first performing an analysis of what kind improvements are needed in the HQC and the AQC2. These modules should then be designed, implemented and tested, and as the HQC and AQC2 become more and more formalised with less and less variation, they should merge as far as possible, keeping the HQC at a minimum.

As a driving force for improving the system, climatolocial products made from the ALF/METAR routine and input to other data processing routines should be in focus. At present there are other types of weather observations that are being used more frequently than the METAR observations, and thus we do expect the development of the ALF/METAR routine to take some time.

From a 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 ALF/METAR 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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