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International Workshop

EXPERIENCES WITH AUTOMATIC WEATHER STATIONS IN OPERATIONAL USE WITHIN NATIONAL WEATHER SERVICES

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World Meteorological Organization (WMO)
The provision of high quality meteorological in situ surface observations remains fundamentally important for the World Weather Watch and World Climate Programmes of the World Meteorological Organization. The trend to automation of surface data acquisition systems began in the seventies of this century, accelerated in the eighties and nineties and is expected to continue world-wide in the coming decades. It is anticipated that in about thirty years, automated surface weather observing systems will be installed at most sites.

Automation of the surface observation function has the advantages of reducing operating costs, improving timeliness and eliminating the subjectivity inherent in human observations of parameters such as visibility and cloudiness. However, new generations of automatic weather stations will inevitably introduce inhomogeneities into the climatic record because of changes in sensor design, in observation techniques, in the interrogation time and data processing algorithms. This will be particularly noticeable at sites that have been converted from conventional human observations. Data based on measurements from the same site and under the same environmental conditions but by different systems usually show slight differences which can introduce inhomogeneities into the climatic record. The homogeneity of the time series of meteorological data is critical to the analysis of climate variability and the detection of climate change.

National guidelines and standards for the recording and archiving data from automatic stations vary from one country to another. This is particularly evident in the variety of sensors used in automatic stations. In the scientific analysis of time series of climatic records, one can often see the influence of the changes in measuring and averaging techniques. The papers presented in this report demonstrate the differences that exist in a variety of existing networks of automatic stations, some of which can lead the introduction of inhomogeneities in the climatic record. This information exchanged at this workshop will serve to help WMO Members in guiding the future development of sensors for automatic station and networks. It will also be helpful in the management and scientific analysis of climatic data from automatic stations.

(Dr J. Kruus)
President of the Commission for Instruments and Methods of Observation
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INTRODUCTION

This publication contains the papers which were presented at the INTERNATIONAL WORKSHOP ON EXPERIENCES WITH AUTOMATIC WEATHER STATIONS ON OPERATIONAL USE WITHIN NATIONAL WEATHER SERVICES. It summarizes the status of development in the area of automation of surface weather stations. The papers are focused on the following topics:

a) Descriptions of various automation programs, equipment used and future plans
b) Experiences and problems encountered with various automatic weather observing equipment
c) Data quality assurance and monitoring procedures

I hope that participants of the workshop and other readers of this report will find the contents useful and informative. I should like to express my gratitude to the sponsors and co-sponsors for the planning and the arrangements made for the workshop.

Ernest Rudel
Central Institute for Meteorology and Geodynamics
Vienna, Austria

OPENING ADDRESS

It is a pleasure for me to welcome all the participants of this workshop here in Vienna. The great response to the call for papers and the participation of more than 50 experts in the workshop underlines the importance of the problems which will be discussed here. Our institute has a long-standing tradition in international meetings. So I want to remember that the first international congress of meteorology was held in Vienna 1873 which lead to the foundation of the predecessor of WMO. According to the goals of WMO and with regard to rapidly changing technology this workshop should help to lead to a better knowledge of the compatibility of data from Automatic Weather Stations and to unify performance of algorithms and software used in this new devices.

Peter Steinhauser
Permanent Representative of Austria with WMO
THE ITALIAN AGROMETEOROLOGICAL NETWORK

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1. INTRODUCTION

The Italian Ministry of Agricultural, Alimentary and Forestal Resources (MRAAF) is carrying out new facilities in the field of agrometeorology in the framework of the National Agricultural Information Service (SIAN). The activities started in 1988 and were developed under the technical coordination and responsibility of the Central Office of Agrarian Ecology (UCEA), with the basic contribution of the private company FINSIEL.

The main achievements realized up to now are the following ones:

- The National Agrometeorological Data Base, gathering all the meteorological data collected by the national and local services was set up. The available informations are used to evaluate the climatic conditions regarding the agricultural areas in terms of space-time variability and anomalies of the more significant meteorological parameters.
- Climatological and meteorological models were developed in order to analyse, monitor and forecast meteorological phenomena for agricultural purposes.
- The realization of the Italian Agrometeorological Network is still in progress. All the stations are automatic and unattended. In the next future, five stations will be installed each year. All these stations integrate and increase the Air Force national network and the Regional local networks.

The management of agrometeorological stations is one of the most important items of the MRAAF activity.

2. THE ITALIAN AGROMETEOROLOGICAL NETWORK

The architecture of the Italian Agrometeorological Network (IAN) is composed of the following elements:

- DEC systems, installed at SIAN, in Rome, dedicated to network remote management, acquisition of agrometeorological information and connection of end users;
- automatic weather stations;
- telecommunication lines.

A VAX 4000 is dedicated to the Central Network Management (CNM), in order to manage the telecommunication lines and the correct running of the automatic stations. It manages telecommunication links to the Air Force's Meteorological Service, to the Regional Services and to other institutions (ENEA, ecc) connected to the Italian Agrometeorological Service.

Telecommunication links are operative between SIAN's National Agrometeorological Service and the Meteorological Service of the Air Force, the Agrometeorological Service of the Puglia Region, and ENEA.

Connections are being established with the Agrometeorological Service of Sardinia Region (Consorzio SAR), the Agrometeorological Service of Veneto Region (CSIM) and with the Genoa's University.

Through the link to the Air Force's Meteorological Service the system acquires in real-time measured and elaborated meteorological data available on GTS system (SYNOP, TEMP, GRIB messages, ecc.).

By the connection to the Regional Services the system acquires data measured by local Regional Network. All the data acquired is decoded and validated.
Meteorological data are temporarily loaded on a RDB Data Base in order to allow the following operations:

- data validation (I level and II level);
- users inquiry;
- users message switching.

Only the most recent two months of data are kept on the CNM DEC system, available for real-time inquiries and file transfers. The CNM system is linked through a SNA Gateway to an IBM/3090 system, where data are definitively archived on tapes and on the DB2 tables of the Agrometeorological National Data Base, where they are made available for on-line inquiries.

The number and the position of the National Agrometeorological weather stations was planned by means of a specific methodology, with the object to integrate the existing meteorological networks (in particular, the Air Defence Meteorological Service's network and the networks of Regional Services) and to minimize the sampling error of ground meteorological fields.

At present the IAN is composed by 26 installed weather stations. Six further stations are being installed and will be put in action in a few months; it is planned to install 5 further weather stations each year.

The standard configuration of a IAN station is composed of the following sensors:

- air temperature at 2 m, 50 cm, 5 cm (archived every hour)
- relative humidity at 2 m, 50 cm (archived every hour)
- rainfall at 2 m (archived every ten minutes)
- wind speed at 10 m, 2 m and wind direction at 10 m (archived every ten minutes)
- air pressure (archived every hour)
- solar global radiation (archived every hour)
- sunshine duration (archived every hour)
- heat soil flux (archived every hour)
- soil temperature at -10 cm, -50 cm (archived every three hours)
- evaporation (archived once a day)
- leaf wetness at 2 m (archived every hour).

3. DATA CHECK

Meteorological data, collected by the Agrometeorological Network or by other Services, are always validated at SIAN before being used. Suspect or wrong data are never corrected: they are always "flagged" by means of a specific character, so that users can decide to elaborate or not the suspect data.

Data check reports give the start to different courses of action, depending on the type of error discovered. For stations belonging to IAN, a maintenance intervention is immediately activated.

Agrometeorological data checking is realized with different algorithms at different levels, depending on the availability of control data and on the needs of the final users.

First level validation is realized with automatic algorithms on real time data which must be immediately made available to connected users. It is applied in real time during the decoding elaboration to the SYNOP, SYREP and TEMP data acquired from GTS system; every three hours it is applied to data received by the IAN agrometeorological network and to data received by other local services.

Validation of second level is realized, typically on a daily basis, with automatic algorithms which fundamentally compare hourly data with daily data (i.e.: hourly temperature versus daily minimum and maximum temperature).

First level and second level checks reports are archived on a log file, which is printed daily in order to make any problems evident and to activate maintenance actions on the stations belonging to IAN.

Data checked with first and second level validation algorithms are temporarily archived on DEC, available for remote user requests, and are transferred daily to the IBM/3090 system where they are archived on the National Agrometeorological Data Base with a temporary quality flag that gets confirmed or corrected after the third level validation which is next described.
Every month, a third level validation is applied, in order to guarantee the quality of data finally stored on the National Agrometeorological Data Base and used for different kinds of elaborations (objective analysis, hydrological balance, etc.). An operator elaborates several different graphs and looks at them in order to evidentiate significant problems (anomalous trends, etc.). Third level checks reports activate maintenance actions on the IAN stations and the quality flags of the data related to a sensor which was found not functioning properly are changed.

On a long-term basis, a fourth level statistical validation is applied to some important parameters, based on climatology, spatial and interannual variability.

4. FIRST LEVEL VALIDATION

The criteria used to implement first level checks are the following:

- first level checked data must be available as soon as possible;
- the checks applied must not be too strong, in order to avoid to flag data which might be in fact correct;
- applied checks must be completely unattended.

First level validation is mainly based on the checks hereafter described.

Range check
The whole parameters are checked against fixed or variable ranges of values. This check may evidentiate only coarse errors. For example, screen temperature is validated against ranges which vary with the month of the year, the latitude and the altitude of the station. If available, ranges are estimated using minimum and maximum measured temperature of historical time series.

Theoretical value check
Some parameters are checked against theoretical values. For example, solar global radiation is checked (hourly or daily) against theoretical solar radiation flux at the top of the atmosphere; sunshine duration is checked against sunrise and sunset time, etc.

5. SECOND LEVEL VALIDATION

Second level checks are applied every day, in order to verify the internal congruence between the data measured at different instants of the day and the summarized daily data (total, minimum, maximum, etc.). Specifically, the following checks are applied:

- Internal congruence
  The coherence of different parameters referred to the same interval of time is verified (i.e. daily minimum temperature against daily maximum temperature and hourly temperature).
- Time congruence
  The consistence of the time evolution of the measured phenomenon is checked with a control between two following measures.

Log reports of first and second level validation are examined daily, and whenever they show anomalous situations, a maintenance action is taken for the IAN stations.

6. THIRD LEVEL VALIDATION

Third level validation was implemented with the main object to control sensor trend or systematic errors and to verify the global quality of data. It is generally applied once a month, or whenever it is needed for particular situations.

This validation essentially consists in checking graphic representations of data. The graphs that are typically produced are:

- time series of one or more parameters measured by one or more stations;
- scatter diagrams, to analyse the behaviour of correlated parameters measured by the same station (i.e.: ten metres and two metres wind speed), etc.
The expert who examines the graphs may decide to produce or not some further graphs, depending on the results of previous analysis. For example, it is possible to produce graphs representing time series of:
- 5 cm, 50 cm, 2 m air temperature;
- atmospheric pressure;
- 2 m and 10 m wind speed;
- 50 cm and 2 m air relative humidity; etc.

Scatter diagrams of:
- daily sunshine duration (percentage of maximum expected value) vs daily global solar radiation (percentage of theoretical value at the top of the atmosphere);
- 10 m wind speed vs 2 m wind speed; etc.

Whenever graphs highlight anomalous situations, a maintenance action is activated for the station and the suspect data are flagged.

7. FOURTH LEVEL VALIDATION

The highest level of validation is applied to historical time series of measured parameters. It is essentially based on statistical estimate of the “climatological” behavior of the physical measures, in order to establish “normal” situations and to evidence “anomalous” situations which must be related either to extreme events or to data errors.

This validation is different from parameter to parameter, for it must take into account the statistical properties of the physical measure. Besides, some types of checks may be applied only whenever nearby stations are available.

Temperature, for example, is verified by means of three different checks applied in sequence:

a) Interannual variability check

A daily climatology $T_i$ ($i=1, \ldots, 365$) is estimated, using the following algorithm:

$$
\sum_{i=1, \ldots, 365}^{N} \sum_{y=1}^{i} \frac{t_{xy}}{N*31}
$$

where $N$ is the maximum number of available years.

A daily interannual variability $\sigma_i$ ($i=1, \ldots, 365$) is estimated, using the following algorithm:

$$
\sum_{i=1, \ldots, 365}^{N} \sum_{y=1}^{i} \frac{(t_{xy}-T_i)^2}{N*31}
$$

Each measured data $t_{xy}$ is checked in order to verify if it verifies the following:

$$
T_i - 3 \cdot \sigma_i \leq t_{xy} \leq T_i + 3 \cdot \sigma_i \quad i=1, \ldots, 365; \quad y=1, \ldots, N
$$

Data which result out of the above ranges are temporarily flagged as "suspect" and are verified with the checks with nearby stations.

b) Daily variability check

A daily climatology of the increments between one day and the following one $A_i$ ($i=1, \ldots, 365$) is estimated, using the algorithm:

$$
\sum_{i=1, \ldots, 365}^{N} \sum_{y=1}^{i} \frac{(t_{xy+1}-t_{xy})}{N*31}
$$

where $N$ is the maximum number of available years.

A daily interannual variability of the daily increments $\delta_i$ ($i=1, \ldots, 365$) is estimated, using the algorithm:

$$
\sum_{i=1, \ldots, 365}^{N} \frac{(t_{xy+1}-t_{xy}) \cdot A_i}{N*31}
$$

Data which result out of the above ranges are temporarily flagged as "suspect" and are verified with the checks with nearby stations.
Each measured data \( t_i \) is checked in order to verify the following:

\[
\Delta t - 3 \cdot \Delta t \leq t_{ij} - t_{i,j-1} \leq \Delta t + 3 \cdot \Delta t \quad i = 1, \ldots, 365; y = 1, \ldots, N
\]

Data already flagged by a previous check are not used in the algorithms nor verified. Data which result out of the above ranges are temporarily flagged as "suspect" and are verified with the checks with nearby stations.

c) Spatial variability check

A daily climatology of the differences between one station and nearby stations \( \psi_i \) \((i=1, \ldots, 365)\) is estimated, using the algorithm:

\[
\psi_i = \frac{\sum_{s=1}^{N} \sum_{j=1}^{M} (t_{ij} - t_{i,j = s})}{N \cdot M}
\]

where \( N \) is the maximum number of available years and \( M \) is the number of nearby stations, chosen in a spatial range depending on the analysed physical parameter.

A daily interannual variability of the daily differences with nearby stations \( \psi_i \) \((i=1, \ldots, 365)\) is estimated, using the algorithm:

\[
\psi_i = \frac{\sum_{s=1}^{N} \sum_{j=1}^{M} (t_{ij} - t_{i,j = s}) \cdot \psi_i}{N \cdot M}
\]

Only "suspect" data \( t_i \) already flagged by the previous controls are checked in order to verify the following:

\[
\psi_i - 3 \cdot \psi_i \leq t_{ij} - t_{i,j = s} \leq \psi_i + 3 \cdot \psi_i \quad i = 1, \ldots, 365; y = 1, \ldots, N; s = 1, \ldots, M
\]

Data which result out of the above ranges are definitively flagged as "wrong".

8. CONCLUSIONS

Only some of the checks applied in the National Agrometeorological Service have been showed in this paper. The operative experience realized during the last years in the management of the Italian Agrometeorological Network showed us that only some types of checks must be automatic and that, very often, only expert people may discriminate wrong data from correct ones. Algorithms, however, may help to underline "suspect" data, in order to screen among the hundreds and hundreds of data which daily SIAN receives.

We are aware, however, that validation is a theme that must be continuously implemented and improved in order to guarantee the best results.

FIGURES

IAN station Pietranera (Sicilia): Scatter diagram of wind values february 1995

Scatter diagram representing wind speed (measured as an average 10 minutes) at 10 m and 2 m. The values are well correlated and distributed along a line which has an angular coefficient just below 1, as expected.
IAN station San Polo d'Enza (Emilia-Romagna): Scatter diagram of wind values February 1995

Scatter diagram representing wind speed (measured as an average over 10 minutes). The values are spread along two lines with distinct angles; one of them has an angular coefficient remarkably lower than 1.

IAN station Montanaso Lombardo (Lombardia): 2 m and 5 cm air temperature September 1995

The graph shows the hourly values of air temperature at 5 cm and 2 m. In the last decade of the month it is very evident that the sensor needs calibrating.

UCEA station Venezia Seminario (Veneto): Minimum temperature 1993 compared with climatological data

Minimum temperature measured in 1993 is compared with the climatology of the station (calculated over 40 years). In particular, the bottom and top line represent respectively the climatological average of the parameter plus or minus three times the daily interannual variability.
QUALITY CONTROL OF METEOROLOGICAL AUTOMATIC MEASUREMENTS
by Philippe DE BOSSCHERE, Météo-France, SETIM/Quality Assurance

ABSTRACT
The measurement of meteorological parameters are more and more automatic. The procedures for quality inspection of automatic measurement are quite different of the procedures for the "old" classic instruments. Being electronic, the instruments are subject to drift or sudden shift which must detected. Means to detect such problems are spatial network analysis, sensor redundancy and "intelligent" sensors. Example will be given for wind sensors, barometers, temperature and humidity measurements.

The automation of measurement of meteorological parameters imposes specific constraints. Nevertheless, the rules concerning the exposure and the installation of measuring instruments remain current events for automated sites.

These rules of the art are increasingly difficult to respect. Many automated sites do not follow the quality criteria imposed for representative measurements. Some causes are an inheritance of the meteorological history:

1) rules of wind instrument setting are sometimes very difficult for obtain, by example in semaphore\(^1\) or a station situated on a cliff. Although imperfect, this wind measurement is very useful to the local forecaster as tool of assistance to the analysis. The generalized distribution or the use of this information at a higher level necessitates to take some precautions. Météo-France studies the possibility to create a system allowing to qualify sites, quantify the level of confidence to grant to each parameter in function of rules of the art.

2) the environment of sites evolves in permanence. To choose a new automated site Météo-France makes an evaluation of the different possibilities in function of the rules above, but it is particularly difficult to apprehend the development of site and therefore to insure the durability of the conformity. The human activity can be a disruptive factor to take in consideration as much as possible. For example, the new city development transforms some sites into urban sites.

The automation, relating to the environment of the site, increases implantation constraints and create new ones : access for the maintenance, installation of necessary energy, connection for transmission, sometimes dedicated building for operator control and maintenance, availability of a local supervision and maintenance.

To preserve the level of quality of our systems, we increase our quality inspections, formalize them and change our ways of working.

The philosophy retained by Météo-France is the inspection as nearly as possible to the creation of the information, that is to say at the level of the sensor and the measuring system. This axiom of basis allows us to upgrade reliability of our systems and to guarantee a level of quality known taking in account the necessity to lower the costs. Consequently, we aim our instrumental developments to self-inspected instruments.

In this optic, Météo-France has developed a protocol of exchange of information called "CIBUS". This system allows to manage a flow of data concerning:
- the state of the sensor (working, mode degraded, out of order),
- the selection or non selection of the instrument,
- defects of configuration, power supply (test of a threshold). Meteorological instruments currently supporting this protocol are barometer, wind sensors, visibilitymeter, and ceilometer.

\(^1\) semaphore : station of sea edge managed by the national Navy
A second axis of progress concerning the upgrading of the reliability is in process of evaluation. It concerns pressure sensor. Numerical barometer present a disadvantage compared to the old generations of mercury barometer. We have to take some counts the possibility of sudden drift. The use of a "pressure control equipment" that integrates several sensors and algorithms of coherence, diagnostics should enable us to get free drawbacks and make the measurement more reliable.

The elaboration of status messages for the instruments and the automatic measurement system and transmission involves an upheaval of working. Services of maintenance have to integrate new functions such as the supervision, and modify their habits: passage from a logic of curative maintenance to a preventive maintenance, one increase their reactivity, to learn management of systems working in mode degraded according to the priorities for each function and the priorities of users. The user of the primary datum becomes an intervener in maintenance. The modification of responsibilities, the new functions attributed to each are not always easy to integrate in the daily working habits. We can give as an example our cibus wind sensor and a message of alert that has not been taken in account early enough to avoid a complete unavailability of this parameter. The new wind instrument is equipped with a solar panel allowing its energy independence. The automatic station tests, in routine, the voltage of the battery associated to the solar panel. The operating staff as well as the maintenance have not taken into account the message of alert emitted by the automatic station. Ten days after the first message, the operating staff alerts the maintenance that the wind no longer appears on messages. The technician of maintenance detected on the sensor a bad connection between the solar panel and the battery.

The consequence of these developments is the installation of a second level of inspection at the location. We use coherence data controls for each point of measurement and statistical controls of probability between several stations of a homogeneous zone, zone defined by other stations with the help of the climatology and the local expertise. To to be exploitable these controls have to be made with the minimum of delay. "CDM" (Meteorological Centers) use them daily.

We can suspect and sometimes identify in some conditions, the blockage of the rain gauge, to detect anomalies, relating to space and time, of rain gauge or barometer. This technique allows by a cross-check to identify hardly detectable anomalies to the level of the sensor itself. Information are processed currently to the regional level so as to coordinate operations of maintenance and to allow the knowledge of the state of the system both the administrators and the users (ie the regional forcaster or services of climatology).

We can therefore take the third level achieved at a national scale into consideration. It consists of two parts.

• The first one is a statistical type monitoring technique. For each of analysis phase of the numerical model we compare each observation with the first-guess. Standard deviation, means and the root mean square of differences are analyzed and may allow on operation of inspections and even maintenance of the different systems.

• The second part is the check of the pertinence of the recurrence frequency of adjustment fixed by metrological service.

For example, we have observed that a selected ship indicated the force of the wind in m/s instead of knot.

In conclusion the automation enable us to use more formally tools of the quality from the expression of need until the withdrawal of service. We have to learn to manage a supplementary flow of technical data. Météo-France starts in a phase of important formalization : establishment of new procedure such as maintenance plans by taking into account the multiplicity of the interveners, sources of information, the feed back and processing necessity of technical facts, the traceability of the data, its pertinence and its degree of validity. In order to the emergence of a common language between the different trades that allow to elaborate, to control, to transmit, to use and file the datum, Météo-France settles indicators and synoptical tables. We have changed the humidity sensor in our national network quite recently. So as to facilitate the work of every one, to get the information that is useful to us for forecaster, climatologist, administrator of network, technician of maintenance, we have established to us a specific synoptical table. It indicates the number of defective parts, the mean time between replacement, the real mean time between calibration and so on.
REQUIREMENTS ON NEW AUTOMATIC WEATHER STATIONS
OF THE DEUTSCHER WETTERDIENST

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1. INTRODUCTION

Like other National Weather Services the Deutscher Wetterdienst (DWD) is forced to reduce manned stations without substantial loss of the number and reliability of observations. To reach this, it is necessary to introduce new sensors and algorithms for automatic weather stations to increase the number of weather parameters in the synoptic report. The FM-12 format of the synoptic message was designed having a manned station in mind. Therefore it is a complicated task to find algorithms for automatic weather stations for all groups in the SYNOP-message like cloud height for different layers, cloud forms, cloud amount, visibility, present and past weather. Beside research in new algorithms and new sensors it is also necessary to harmonize the requirements of the users with the potentiality of automatic weather stations.

2. REQUIREMENTS FOR THE AUTOMATIC WEATHER STATION (AWS)

2.1 Use of "Intelligent" sensors und algorithms

In the last few years a lot of progress was made in the development of new sensors and algorithms for automatic weather stations, which are capable to measure more parameters of a synoptic message than present AWS do. The measurements of conventional quantitative data are made at a fixed location and if necessary data are integrated in time. At manned stations the observations of other weather phenomena or subjective parameters are estimated by the observer at a fixed location by integrating in space (for example the observation of cloud amount, visibility, present weather etc.). In contrast an automatic system estimates cloud amount or present weather from measurements made at a fixed location by integrating in time. So there is a principal difference between the behavior of an observer and an automatic system by estimating these weather phenomena. The focal point in the development of new automatic weather stations is therefore not only to find new sensors but mainly to find new algorithms, which allow to calculate the spatial distribution of a parameter from point measurements.

2.2 System performance of the AWS

Measurement of quantitative data like:

- atmospheric pressure
- temperature and atmospheric humidity
- temperature of the ground
- wind velocity, wind direction, gustiness
- global and diffuse radiation
- sunshine duration
- lightning location
- precipitation amount and duration
- snow cover and water equivalent

Estimation of other weather phenomena:

- cloud height and cloud amount
- height of different cloud layers
- visibility
- present weather
- state of ground

Quality control of measured data:

- test against climatological extrem values and hourly variability in the data collection system
- remote control of the system, requesting of status information of sensors for maintenance purposes
- self-calibrating sensors

Requesting all data via communication links:

- requesting all reports, alarms and climatological data sets via public communication links

Data requests by private users:

- automatic voice generated weather information via public telephone lines
- automatic data distribution via modem line

3. SYSTEM CONCEPT

The implementation of new sensors and data processing algorithms require flexible and easy to configure data collection systems. The system has to be designed under the requirement of a fast responding and efficient maintenance service for the automatic station. For this, remote control of the system with built-in-test features of the data collection system and of the sensors is necessary. The development of new data processing algorithms and the adaptation of new sensors is a running process of the next years. The design of the AWS requires therefore flexibility and easy configuration and should be based upon system components and standards, which are used by industry. The system architecture should include a standard bus link (for example CAN-bus) between the sensor site and the data collection system. The tasks of processing weather parameters and the data communication with the responsible regional centre and other users via public communication lines should run on a PC.

4. SYSTEM ARCHITECTURE

- Sensors with standard bus link (for example CAN-bus) between the sensor site and the data collection system with the following advantages:
  - simplified sensor installation
  - standard communication protocol between sensor site and data collection system
  - safe data transmission
  - sensor test features at the sensor site
- data collection system with:
  - modular structure
  - multitasking CPU board
  - system set-up using software tools
  - radio clock

- Personal Computer for processing of the weather parameter and data communication

- data communication on the basis of open protocols like OSI-FTAM

5. OUTLOOK

From 1998 on the Deutscher Wetterdienst intends to replace the existing automatic weather stations. In addition DWD plans to replace manned stations, which have working hours between 07:00 UTC and 21:00 UTC, by the above described automatic weather station.
PROGRAM REQUIREMENTS AND ISSUES RELATED TO SURFACE WEATHER AUTOMATION IN CANADA

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ABSTRACT
This paper provides a general summary of the automatic weather observing station (AWOS) technologies in use by the Canadian government along with, information on related program requirements, issues and future activities. Although there are other federal and provincial governments operating autostations in Canada this paper will focus on those used by the Atmospheric Environment Service (AES) of Environment Canada, the Department of Transport (DOT) and the Department of National Defence (DND).

BACKGROUND
Automatic observing stations have been providing data to support climatological, public and aviation weather forecast and warning programs in Canada for over a quarter century. Initially these autostations were installed in data sparse areas where human observations were not practical; however their capabilities have improved to the extent that this equipment in now being used to replace human observations. At the present time approximately 84 percent of the Canadian hourly surface weather observations are provided by automated means.

AUTOSTATIONS IN CANADA
As of January 1995, a total of 416 autostations were being operated by AES, TC and DND and the data from these stations is being distributed over the Canadian meteorological communications network. Six basic autostation types are involved. The oldest of these is the MARS I (Meteorological Automatic Reporting Station) designed by AES in the 1960's and showcased at EXPO '67 in Montreal. AES has since developed four other generations of autostations: MARS II, MAPS I (Modular Acquisition and Processing System), MAPS II and READAC (Remote Environmental Data Acquisition Concept). The READAC AWOS is the latest and is an advanced capability system designed to meet a variety of needs including those of the aviation community. Eighty eight of this latter type have now been installed. In addition to 190 in-house designed autostations there are approximately 233 commercial systems (mostly Campbell Scientific) used to provide basic information such as temperature, humidity, atmospheric pressure, wind and precipitation. The table below lists the number of different autostations in Canada by type and region.

<table>
<thead>
<tr>
<th>Region</th>
<th>MARS I</th>
<th>MARS II</th>
<th>MAPS I</th>
<th>MAPS II</th>
<th>AWOS</th>
<th>OTHER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>11</td>
<td>10</td>
<td>47</td>
<td>74</td>
</tr>
<tr>
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<td>2</td>
<td>5</td>
<td>40</td>
<td>91</td>
<td>153</td>
</tr>
<tr>
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<td>10</td>
<td>0</td>
<td>11</td>
<td>14</td>
<td>23</td>
<td>59</td>
</tr>
<tr>
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<td>4</td>
<td>2</td>
<td>8</td>
<td>11</td>
<td>46</td>
<td>71</td>
</tr>
<tr>
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<td>11</td>
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<td>26</td>
<td>59</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5</td>
<td>39</td>
<td>4</td>
<td>47</td>
<td>88</td>
<td>233</td>
<td>416</td>
</tr>
</tbody>
</table>
FUTURE INSTALLATIONS

Additional low cost commercial autostations will be purchased to meet future basic observing needs but the main thrust over the next few years will be to procure an additional 50 to 75 AWOS's for installation primarily at airport locations where humans are now providing weather observations. It is estimated that by the end of 1997 the Canadian government will have over 500 autostations operating.

PROGRAM REQUIREMENTS

There are two main reasons why Canada is automating its weather observing networks. Cost reduction is one. On average, a 24 hour/day 7 day/week human weather observing station costs $150,000 to $200,000 per year to operate depending on the type of staff used and location. On the other hand, the amortized cost of an installed AWOS, which is expected to last a minimum of 10 years, $300,000 so that automating pays for itself within 1.5 to 2 years. There are some trade-offs but for the most part autostations can provide most of the data to meet program requirements. The other reason is program enhancement. Autostations can free up the time of Flight Service Station specialists and weather office personnel enabling them to perform other duties. In addition, autostations often provide us with data that would not normally be available; eg. during the hours when a manned station would otherwise be closed.

From a public, marine, and climatological program perspective existing AWOS and commercial autostations are more or less capable of providing all the necessary data. There are deficiencies in the areas of evaporation, total sky cover, sunshine, snow depth, rate/amount of precipitation and supplementary data such as cloud type and remarks that need to be addressed. Further development, adaptation and testing is required but in the short term we must accept some of these deficiencies or look toward human augmentation or other means to acquire the data.

Requirements for aviation are more difficult to meet as a greater degree of accuracy and consistency is essential. Many of the sensors and associated data processing algorithms are “state of the art” and some are still under development or are in the process of being tested; eg. icing and thunderstorm sensors. Safety and economic issues are also more in the limelight and must be dealt with. The fact that autostations measure things differently than humans must also be considered as cloud and visibility measurements will not always agree with what a human will report. These instruments cannot scan the horizon and they report only that cloud which has passed overhead or what the visibility is, based on a relatively small sensing volume. Similarly autostations may never be able to report cloud type, virga, showers vicinity, tornado, and other remarks which only a human could provide. On the other hand autostations are able to measure many parameters more accurately and consistently on a minute by minute basis. It is felt that autostations can meet aviation requirements, however, users must understand their limitations and performance characteristics and flight regulations must be changed.

CANADIAN EXPERIENCES WITH AWOS IMPLEMENTATION

Implementation of AWOS reached a critical point in 1994 when these systems were installed at airports which had a significantly higher level of traffic than had previously been the case. Close scrutiny by pilots, forecasters, airport employees and airline dispatchers resulted in the identification of several performance issues associated with sensors, algorithms, communications, display software, and requirements. The most serious problem was in the AWOS cloud system which had a tendency to report clear sky conditions in precipitation. Other deficiencies were identified at an AWOS requirements workshop involving government agencies and the aviation user community in February of this year and are summarized on the next page:
General:
- too many special reports
- too slow to respond to some changes
- inadequate suppression of bad data
- inadequate NOTAM procedures
- limited remarks capability
- inadequate user education
- lack of documentation
- need for a commissioning protocol

Visibility Related:
- too low in ice crystals and blowing snow
- no prevailing visibility remarks

Precipitation Related:
- false reports of precipitation
- inability to report freezing precipitation
- no reports of showers, only start and stop
- all precipitation types not reported
- no reports of mixed precipitation

Related to Cloud:
- false clear reports in snow
- ceiling inaccuracies below 3000'
- missing data
- false cloud due to inversions or ice crystals
- ceilings too low in precipitation
- thin layers reported as solid
- inconsistencies in ceiling designation

Related to Weather Phenomena:
- lack of thunderstorm detection capability
- obstructions to vision not reported

Communications Related:
- missing and out of sequence observations
- observations received late

In response to these concerns, human observations were resumed at two major airports and a moratorium was placed on the further commissioning of AWOS stations for aviation purposes. Many of the above deficiencies have been resolved but a joint AES/TC action plan was prepared to resolve outstanding ones by June 1996. The plan involves:

- a redefinition of aviation requirements for automated weather observations;
- solutions to various performance problems;
- validation of improvements by rigorous field tests and intercomparison with human observations at 6 to 8 airports across Canada;
- development of internal and external communications and information/training plans;
- a commitment to consult with aviation user groups and employee associations before commissioning any more aviation AWOS sites.

READAC AWOS OVERVIEW

The Canadian READAC AWOS is a modular multiprocessor system comprised of a relatively small mainframe containing a power supply, shelf controller (SC), communications controller (CC) and peripheral interfaces (PI's) for each sensor. In addition, a specific sensor often has a custom AES designed front end processor. The sensors send their data to their respective PI's which contain averaging and other algorithms which transform the data into user a recognizable format similar to what a human observer would report. The algorithms may also check whether readings have cross defined thresholds and if so, the PI will indicate that a “special observation” is warranted to report a significant change in the weather. Every minute, the SC assembles the individual PI reports into a complete weather observation and passes this message to the CC which sends out hourly or special reports to a central telecommunications and code conversion computer just as a human observer would. This computer does some additional computations such as calculating mean sea level pressure and climatological information using the provided data and then generates other types of messages for distribution on the meteorological communication network. Some sites are also equipped with a voice generator module which converts the alpha-numeric characters into words for transmission to pilots by radio link or telephone line.
SENSORS AND PARAMETERS REPORTED

Cloud: A Qualimetrics QL 8329A or B laser ceilometer is used to measure cloud height up to 10,000 feet. Its output is processed by an AES developed 60 minute algorithm which generates a report of cloud layer heights and amounts (CLR, SCT, BKN or OVC). The algorithm will also force the AWOS to generate a special report whenever a ceiling layer drops below or rises above any one of a number of thresholds which are relevant to aircraft operations.

Visibility is measured using a Belfort 6200/6210 forward scatter visibility meter and a 20 minute averaging scheme is used to report visibility up to 9+ miles. Decimal values are indicated when the visibility is less than 2.5 miles and special reports are generated as required.

Precipitation: Three separate sensors are used to measure and report this parameter. The AES Precipitation Occurrence Sensor System (POSS) is used to report the occurrence, type and intensity of precipitation. This is accomplished by measuring the fall velocity of hydrometeors with a small 10.525 GHZ bistatic vertically pointing Doppler radar. The fall velocity combined with temperature gives type (drizzle, rain, snow, hail or ambiguous), while precipitation intensity is deduced from the total signal power. Precipitation amount is measured using a Belfort Fischer and Porter weighing precipitation gauge and shaft encoder combined with an AES front end processor which eliminates the effects of evaporation, vibration and wind. It should soon be possible to obtain precipitation amount using precipitation rate calculated POSS's Doppler power spectrum. Freezing precipitation is detected with a Rosemount 873E3 ice detection sensor.

Station pressure and altimeter setting are recorded using a pair of Setra 270 ceramic pressure transducers. MSL pressure will be added in the near future.

Temperature is measured using a Yellow Springs International YSI linear thermistor housed in a ventilated Stevenson Screen while an AES lithium dewcel housed in the same screen is used to determine the dewpoint.

Wind speed and direction is measured using the AES designed 78D cup and vane anemometer.

FUTURE UPGRADES

Two types of lightning detectors and a electrical field mill are presently being evaluated for use with AWOS. The LLP (Lightning Location and Protection) ESID (Electrical Storm Identification Device) appears to report the presence of lightning (thunderstorms) just as reliably as human observers and this sensor will likely be added to TC AWOS stations in 1996. We have also begun to investigate artificial intelligence, neural network and other multiparameter techniques to improve the reliability and representativeness of AWOS reports. The READAC AWOS was designed with this in mind as its PI's are able to listen to one another's transfer of data to the shelf controller. AES is now evaluating some simple multisensor (cloud, visibility and precipitation occurrence) software in order to improve the quality of its AWOS cloud reports and will soon be developing some multiparameter software for precipitation. The latter will involve the use of data from the POSS, icing detector, temperature/dewpoint and possibly other sensors. For stations susceptible to extreme icing conditions, DND intends to replace the AWOS 78D anemometer with a Rosemount 1774WA1A ice resistant unit which was successfully evaluated during the last two winters at Brevvoort Island in the Eastern Arctic. An interface for this sensor is now being developed and should be available for implementation by the fall of this year.
PUBLIC RELATIONS AND TRAINING

To assist in the transition from traditional observing systems to autostations, an AWOS Support Group comprised of a meteorologist, field technician and training professional was formed to provide a local point for users and other interested parties. The Support Group monitors the AWOS reports, answers enquiries for information, deals with user complaints and is very active in user education and training. Monthly newsletters are issued and the group and has recently established an Internet web site containing a plethora of information on READAC AWOS and our automation plans. The Universal Resource Locator for the site is: http://www.dow.on.doe.ca/readac/index.html Details on the support group along with names, addresses and phone numbers are also provided on the web but for those without Internet access, Mike Crowe is the support group leader. He can be reached at 416-739-4115 (fax 416-739-4208). The group also uses an internal electronic mail system to exchange information. A READAC AWOS training video was recently developed with the support of AES Quebec Region and is available in VHS format. The video runs for about 50 minutes and gives an excellent overview of the READAC AWOS system, sensor operating principles performance characteristics, limitations and details on how to decipher the various message outputs. Work is underway to produce a 15 minute version for more general user training.

INTERNATIONAL STANDARDIZATION

A considerable amount of effort is being taken by the World Meteorological Organization in the area of sensor intercomparisons and certain member countries are also pursuing the development of international standards for meteorological measurements through the International Standards Organizations. These initiatives will help ensure the consistency and reliability of basic meteorological data which is exchanged internationally. Documentation and standardization of algorithms; however, needs to be addressed as countries are developing this software in an independent fashion. This especially applies to subjective and visual parameters such as present weather, visibility and cloud amounts. For example, the Canadian AWOS cloud report is based on a 60 minute algorithm with weighting based on cloud height and some persistence and hysteresis based on empirical results. Our software also uses a cloud layer clustering scheme which results in a maximum of 4 cloud layers being reported and which will also report more than one overcast layer when the laser ceilometer is able to penetrate layers to detect cloud above. The American ASOS (Automated Surface Observing System) cloud system is based on a different ceilometer technology and arrives at a cloud report using a totally different averaging and clustering scheme. Another example is in the case of wind where either vector or scalar averaging techniques may be applied with similar but different results.

LESSONS LEARNED

The automation of human weather observing programs should be done in an organized fashion with considerable effort taken to ensure that the needs and perceptions of the various users are taken into account. It is especially important that there be a good communications and that user training be undertaken before the AWOS is commissioned and human observations discontinued. Users will have a very strong tendency to resist change and will focus on how the autostations disagree with or cannot provide the same data that humans can. In most cases they consider human observations to be infallible, despite the fact that two observers will often disagree on things like cloud height or prevailing visibility. There are also many occasions where human observations may be very misleading, especially at night when it is very difficult to estimate cloud amount and height. Users must be made aware of the autostation sensor performance characteristics and to recognize the fact that autostation reports are more consistent. In addition, the usefulness of having minute by minute observations can enable one to detect and monitor phenomena which would otherwise not be obvious especially if one uses pictorial or graphical displays of the autostation’s minutely data. Although autostations have limitations, they can provide us with a better picture of surface weather conditions and mesoscale atmospheric processes. It is incumbent on the user; however, understand how the autostations perform and to take advantage of the opportunities they present.
Experiences with Automatic Weather Stations in Operational and Climatological Use in Finland

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Finnish Meteorological Institute

1. INTRODUCTION

The Finnish meteorological institute started to use automated weather stations (AWS) operationally in 1973. Most of the present AWSs are located in uninhabited areas like outer archipelago, lake and arctic hill areas. Some stations were set up on the places with special climatological characteristics or an unsatisfactory density of the basic network of weather stations. One important reason to implement AWSs has been the need of more frequent observations than it is possible to get from a manually operated synoptic weather station. Due to the economical reasons it is nowadays very often considered to replace a former manually operated station with an automated or semiautomated station.

Figure 1. shows how the figure of weather stations (manually operated (1), automated (2) and archived in data base (3) has been developed during the period of 1973-1994.

In the beginning data produced by automated weather stations was mostly used as a supplementary information to the real time services and there was no serious efforts to archive it for climatological purposes. Reason to this was the relative poor level of technical reliability, concerning both measuring instruments and data transfer systems, which made it almost impossible to get uninterrupted time series of observations or guarantee the quality of data over longer periods.

Since the positive progress, as well in sensor technics as in automated system of data transfer and archiving, has made the AWS data series quite competitive with those produced by traditional methods the practice in Finland has been changed so that most of the automated observational data goes through climatological quality control routines and are archived in the data base.
2. DATA TRANSFER AND ARCHIVING

In Finland the public telephone network has been used to transfer weather data from automated stations to users. The fully automated system that takes care of this job was developed by FMI and implemented during 1992. This system is running in VAXVMS computer and using a modem frame which provides 16 simultaneous calls. This capacity seems to be enough by now but the system design is made so that the resources can be easily doubled. This system takes also care of data quality control on basic level and does coding of synop messages. After these activities all data and coded messages are transferred to UMS (unified message switch) which is doing the routing to GTS, database routines and other processes that are using observations. Although the whole process is automated manual activities are possible whenever needed.

Archived synop data 1990 - 1994

![Graph showing archived synop data 1990-1994](image)

Figure 2. shows how successfully AWS data archiving has been in 1990-1994. The dramatical improvement during 1992 was partly caused by the implementation of the new data transfer system.

A relational data base is used to load also AWS-data into data base. Tables with continuously increasing data are defined so that data of each year are stored into its own table. All data retrievals are based on structural Query Language, SQL, or other ORACLE tools. All data base files are available interactively. Updating of the data base is user friendly. Use of relational data base is fast (when not rush hour) and it is easy to form and update your own tables. The relational data base have made it possible to use AWS-data also for climatological purposes more easily than before.

3. QUALITY CONTROL

Several activities are necessary to guarantee the quality of automated weather observations. In Finland the practical interval for the regular maintenance and calibration checks is twelve months. That means that every sensor used on an AWS must not only fulfill the recommendations of WMO concerning the accuracy but also it must work one year without maintenance and keep its calibration on reasonable level. These are quite hard demands and they cause a lot of work, fieldtests etc. before a new instrument can be accepted to be used on AWS.

Although it takes less than three hours before alarms of any fatal fault in AWS comes to the maintenance personnel it can take some days before it is possible to go to the station and repair it. To avoid these blackouts as much as possible some critical sensors are doubled and so a sensor change can be done without a visit to the site.
Furthermore special care has been put on the training of persons who are making calibration checks and field calibrations because we can say by experience that a lot of harm may happen in this point. The program of AWS makes some statistical controls to every measured value and alarms or warnings are delivered if necessary. This activity is built in to find out any trouble on sensors as soon as possible.

The AWS-synop messages are loaded into data base every 3rd hour. Once a day they are preliminary checked. This routine runs on working days after the 06 TUC-synop messages have been received. The following weather variables are checked: prevailing temperature, maximum and minimum temperatures, relative humidity, dew point temperature, air pressure reduced to mean sea level and its tendense, wind direction and speed. The checking includes simple tests. The figures of the variables must be within natural variation, air pressure and its tendense, prevailing, maximum and minimum temperatures must not be in contradiction to each other. The tests are often too simple to reveal fault figures.

Every working day a list of lacking AWS-messages is also run. Lacking messages can be received by recalling to the station via a modem and look over the stored observation messages at the station.

Figure 3. shows the calibration difference of three different sensor type (relative humidity (HMP35), temperature, (PT100) and atmospheric pressure (DPA21) after one year in normal use on AWS. On the y-axis there is the number of calibration checked instruments.
An interpolation test is also run every working day using Kriging method (Henttonen, 1991): (3.1)

\[ M(x, y, h, l, s) = a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 y^2 + a_5 x y + a_6 h + a_7 s + a_8 l. \]

where

\( M \) = drift describing the broad scale features of the interpolation variable
\( x, y \) = geographical location
\( h \) = altitude above sea level
\( l \) = percentage of lakes
\( s \) = percentage of sea
\( a_0 \ldots a_8 \) = coefficients to be estimated from observed data by minimizing the difference between the estimated and observed variable values.

Manual synop observations are used to interpolate observations to the AWSs (figure 4). With this test air pressure is mainly monitored because other weather variables may differ quite a lot even within short distances when only one observation time is used. Continuous big differences may show also for other variables that there are problems with the station concerned.

**PRESSURE** 12.9.1994 at 12 UTC  
**TEMPERATURE** 12.9.1994 at 12 UTC

![Difference AWS - manual stations of air pressure and temperature after using Kringing method for 10 km x 10 km gridpoint areas.](image-url)

* manual station
* AWS
4. EXPERIENCES IN USING AWS-DATA

Duty meteorologists normally want to have as much observations as possible even observations from machine stations in their operational work.

The first trials to use observations of agro-AWSs for climatological monitoring during a growing season were not promising: mean air temperature could be calculated only for 10 pentades out of the total 18 because of bad telephone lines and some line transients, as well (Eliomaa, 1987). Nowadays some 97% of the all measured data are archived into data base and can be used also for climatological purposes (figure 2).

Changing manual observation station to machine station cannot be seen in a time series showing mean monthly air temperature difference of two off-shore stations in the Baltic sea (figure 5).

It is always quite complicated to use time series of observations when a formerly manually operated station has been replaced with an automated one. Especially problems exists with those variables which traditionally are human visual estimates, for example visibility, precipitation type, the intensity of a hydrometeor etc. In any case very careful studies are needed to fully understand all the differences caused by a new method of measuring the type and intensity of precipitation. One example is presented in figure 6, where human estimates of the precipitation intensity and measured intensity values (hourly means) measured by an AWS sensor (FD12P) at Jokioinen meteorological observatory in 1994.
Figure 6. The probability of hourly mean intensity of precipitation and classification done by a human observer (Jokioinen 1993-1994).

5. FUTURE WORK

There are plans to set up some stations of third type for places where the network of manual stations is very sparse. This kind of station will be like fully automated one but there also will be instruments for manual observation and a human observer will do daily visit to the site and do "control synop" once a day.

Also another project has just started. On one site (Jokioinen meteorological observatory, southern Finland) are two synoptic stations (manual and automated) running independently side by side. Observations from both stations are sent on real time to the users. This is done not only for the control purposes but also to show the users what really is the status of reliability of automated weather observations.

Acknowledgements
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References

AUTOMATIZATION OF THE MEASUREMENTS AT THE
PROFESSIONAL METEOROLOGICAL STATIONS
IN SLOVAKIA
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1. Introduction

Increasing demands on volume of meteorological information in real time, together with an increasing costs of manpower and also with regard to sufficient level of the construction of the automated meteorological stations led the meteorological services to decision of inevitable installation of the automated meteorological systems at the meteorological stations.

A specific feature of our meteorological institute, typical also for other meteorological services of the Central and East European countries, was the technological isolation which prevented modern technology and know-how to be imported. Our service had to focus on its own development and home production of parts and components very often of limited quality and reliability. As a result very little automation at meteorological stations within the National Observing System was done till 1991.

By the end of the 80’s, process on gradual automation, updating and restructuralizing of the National Observing Systems (NOS) started. Several projects were drafted but the initial results were affected by inexperienced staff, lack of capital investment and aggressive approach of producers able to promise anything.

2. Strategy of the automation of the NOS

The core of the strategy of the automation of National Observing System (NOS) was that observer is still the most reliable, the most intelligent, the most important and, for the time being, in some kinds of measurements, also the irreplaceable element in some duties of the meteorological station with synoptic and aviation activity programme. In addition the cost of labour was not and still it is not one of the driving forces to automation.

This basic philosophy led into creation of the so called “Automated Workplace of the Observer”. This was the name of the first project related to automation of the NOS. At this stage only some aspects of the observer’s duties were automated. It concerned mostly compilation of WMO and national messages (METAR, SYNOP, national message INTER), primary data checking and transmitting of the synoptic messages. The system was based on personal computers PC XT, AT (186, 286) with fax/modem connection to National Telecommunication
Hub (NTH). At the beginning an observer made manual input of all data and in the later stage manually observed data only.

The second project related to automation of NOS got the name: "Integrated workplace of the observer" (IPP). In this stage more complex automation of the observer’s duties is done with the stress on the automation of the measurements of meteorological parameters. In this way, an observer was put in a position to control the system with gradually less and less interventions to the process of the measurement, processing and transmitting of the meteorological data collected within the NOS.

3. Installation of the automated meteorological stations

3.1. Datalogger ESC 8800E

In 1991 dataloggers ESC 8800E (made in the USA) were chosen for automation of the NOS. These dataloggers are used in extended network for measurement of air pollution in the USA. It means, there was a guarantee that those loggers can reliably operate also in our conditions. In addition to the loggers, there were bought sensors from different well known companies like YOUNG, LAMBRECHT, PAAR, KRONEIS. Installation, configuration and connection to the existing Automated Workplace of the Observer was done by local company ECOMONITORING. That time this company as well as our staff lack enough experience which resulted in underestimation of a significance of the software for this system. Therefore merging the high quality logger with high quality sensors did not bring the same quality system.

System based on datalogger ESC 8800E measures air temperature at the height of 2 m and 5 cm above the ground surface, wind velocity and direction, soil temperatures in depths of 5, 10, 20 and 50 cm, duration of sunshine, precipitation total from heated precipitator and evaporation. The station measures the mentioned parameters with a high frequency (each 2-3 seconds). Data are further processed to get minute means and totals. In case of wind also maximum gusts are stored. Parameters, processed in such a way, are displayed on PC screen together with temperature and wind extremes for a certain period, suitable for the code procedures SYNOP and the national message INTER. (For instance, the maximum air temperature for the period 6 a.m. - 6 p.m. UTC being suitable for coding into the message SYNOP at 6 p.m. UTC). The maxima and minima of the measured parameters were chosen from one minute means of these parameters and not from the instantaneous values (with the exception of wind gust). Minute means and totals are put into an archive file according to the individual days. It is possible to scan this file on the PC (so called scanning file of minute values) and spooled on the diskette. Due to the fact, that software of the Automated Workplace of Observer operating in DOS operational system, was not constructed as multitask one, it was not possible to interconnect properly both systems. That is why the dataloggers in this system worked as intelligent distance stations with archiving of primary processed measured data. Dataloggers operating in such a way were installed at 8 professional
meteorological stations of the Slovak Hydrometeorological Institute. At present, there are 7 dataloggers of this kind in operation.

3.2. Vaisala MILOS 500

The experience with the ESC dataloggers showed little perspective therefore new international tender was called for automation of the NOS. Foreseen automated meteorological stations were supposed to be state of art technology with rigid construction complying with international and national criteria for accuracy, reliability of system and sufficient protection against disturbing effects of overvoltage and electric discharges. The winner of competition was fy Vaisala with its MILOS M500. In addition Vaisala 500 has also an advantage of operating in very rough conditions. It has “Your way” configurable operating regime with a great capacity of internal storage and it is able to operate relatively long time in fully automatic regime. In the configuration our Institute put into operation the MILOS 500 can work independently even they are installed at manned station and they are transmitting SYNOP and/or METAR messages and other data directly to the National Telecommunication Hub.

The MILOS 500 stations are configured to measure wind direction and velocity with the frequency of 2 s. Each 10 seconds, they measure air temperature in 2 m and at the ground, soil temperature in depths 5, 10, 20 and 50 cm, relative air humidity, global radiation (on the basis of which the sunshine duration is calculated), air pressure, atmospheric precipitation, precipitation indicator (yes/no). These measurements are further processed into one minute intervals and totals (in case of wind, they are vector and scalar means, maximum and minimum wind gust, corresponding direction and time of occurrence with accuracy in minutes. Instantaneous maximum and minimum of global radiation during one minute interval is also stored. All those data are channelled into the PC called Integrated workplace of the observer (IPP). MILOS 500 also stores these one minute data approximately for one week and if necessary they can be redirected into the IPP system in the case of IPP failure. Automated meteorological stations Vaisala MILOS 500 have been installed at 12 professional meteorological stations and 2 more installation are in progress. Up till now MILOS 500 are mostly used in semiautomatic mode. That means MILOS 500 supplies data into an IPP and IPP does the further compilation of messages using the manual input of observed data by observer and transmits messages to NTH. MILOS 500 is used in full automatic mode only beyond the working hours of the observer and in any case of IPP failure. Therefore MILOS 500 is connected not only to IPP but directly to ACP 10 communication computer of the X 25 SHMI data network as well. The connection is done via leased line or modem line. The first pure field installation of MILOS 500 is going to be done in September 1995 in full automatic mode only.

4. The task of automated meteorological stations in the IPP system

Both described automated meteorological stations are, on the base of defined working programme, interconnected with the IPP system. Here on the basis of the instantaneous values and minute means common data base is created for use of all
application within IPP. An integrated observer’s workplace is a complex multitasking system, created by the joint venture of Slovak Hydrometeorological Institute and local company MICROSCOPE Ltd. IPP system is supposed to satisfy the needs not only observers at synoptic and aviation stations but also other internal and external users. Hence the IPP has developed into a low cost workstation that is able to communicate with NTH, get and processed any data (including binary data like GRIBs, T4, radar and satellite images) and make presentation. It has therefore a variety of functions that can be easily started from the main menu with sufficient help. IPP is based on PC (at least 386) with QNX fully multitasking operation system which enables to use many functions at one time. For our purpose we shall deal only with some of those functions.

Data from automated meteorological station enter the so called synoptic-climatic screen page, where there are displayed the measured parameters in real time (minute means, totals). In case of wind also instantaneous wind parameters, and from the one minute means also 2 and 10 minute vector mean is computed and displayed together with the maximum wind gust for 1 and 6 hours and for 24 hours from 07 a.m. to 07 a.m. and with time of this gust. Further, there are minima, maxima and totals which can enter the SYNOP message and national message INTER for compilation. The observer can anytime scan and use them in his work.

The other screen page is called aviation display and it serves not only observer but the meteorologist and different aviation users as well. This screen page displays the measured meteorological data and processed parameter utilisable at the aviation meteorological station in messages METAR, SPECI, METREPORT and work of operator and aviation meteorologist.

Some other screen pages are so called message compilation screens for SYNOP, METAR, SPECI, METREPORT, INTER and CLIMAT, etc. The observer can check the automated input data and in the case of disagreement he can correct them using other instruments. The system then asks the observer to input other manually measured and observed parameters, checks the data compiles and transmits the message.

IPP stores two basic so called 1 minute and 10 minute archive files. One minute data are stored cca 30 days and 10 minute data 1 year.

5. Utilization of automated meteorological stations’ data in Climatology

Special sensitive and contraversive problem presents utilization of data from automated meteorological stations in Climatology. In the IPP system it was designed in such way that data measured in climatological terms at 7, 14 and 21 hour of the mean local time are offered from automated stations’ data. Observer acknowledge them only if they are in absolute agreement with manually measured ones. It means, manually measured data are of the absolute priority to data from automated meteorological stations. After finishing of the climatological day (07 a.m. to 07 a.m.) these data are transmitted in form of the national INTER message to the NTH.
Above mentioned 10 minute archive file is, because of its application in Climatology, formed in the temporal interval of the whole 10-minutes of the mean local time. This file contains data on air temperature at 2 m height and at the ground, air pressure, soil temperature in depths of 5, 10, 20 and 50 cm, mean wind velocity and direction, global radiation, total and duration of atmospheric precipitation. But the structure of this file is much more complex.

From this archive file, so called climatological message are compiled and transmitted automatically to the NTH every hour.

6. Conclusion

The aim of this article is to make others familiar with the development within the Slovak Hydrometeorological Institute in the area of automation of the National Observing System. This project of course went hand in hand with the project for upgrading the National Telecommunication Hub and with the project for Development of new Data Communication Network. The idea of the X 25 private data network and meteorological stations connected to it gives the enclosed picture.

The experience with the automation is not enough to make an official judgement. But it is clear that connection of MILOS 500 stations to our private network was successful and it was proved that both semiautomatic (using IPP computer) and fully automatic regimes are viable and both are exploited in our service.

This automation will have an implication in the way of reducing the number of observers within the NOS and expanding the network to a remote areas. At the beginning of 1996 using the experience in this part of the automation another project will be drafted. Within the NOS there are more than 600 precipitation station, more than 300 phenological stations and some 85 climatological stations. The next project will try to cope with this extended manned network if that is feasible.

References

The Swiss Automatic Networks: Aspects of Operation, Reliability and Control of Measurements

Patrick Hächler, Swiss Meteorological Institute

Summary

At the end of the seventies an automatic meteorological network covering the whole country was put up. Nowadays 115 automatic weather stations within two different networks are fully operational. They produce most of the surface data of the Swiss meteorological institute (SMI). The control of availability of these data shows very good results for the older network, called ANETZ, while the newer one, ENET, shows good results for the wind alarms.

Different actions help us to keep the quality of the data as high as possible. We also try by special campaigns to solve certain problems. For example additional measurements lead to an improvement of pressure. Also extreme weather events help to assess the reliability of the networks.

1. ANETZ Description and operation

The ANETZ (= automatic network of the SMI) was developed in the seventies and provides since 1980 meteorological measurements of 10-20 parameters over the whole country. There is a total of 72 stations, the lowest at 200m, the highest at 3600m above sea level.

Figure 1: All automatic stations of the SMI (ANETZ and ENET)
All basic parameters are measured but also evaporation, number of lightnings and radioactivity. Some data are continuously measured (wind, sunshine), others discretely. For the temperature for example we heat during 8 minutes in order to avoid rime or wetness. Then we ventilate during 2 minutes and get optimal measuring conditions. Thus we get 144 daily values and calculate minima and maxima on that base.

All stations are connected to the central computer (a PDP11) with permanent telephone lines. The computer sends each ten minutes a signal to the stations and gets the latest bulletins as answer. In this phase some tests are executed and certain values have to be converted into physical values. 8 minutes after their measurement all parameters are available for the users.

On weekdays a group of two or three people controls the correctness and completeness of the collected data. In any case of problems they have to start adequate measures, for example to start an intervention in the field. At nighttime or at weekends a part of these functions is done by the operators of the computer center.

The technical service in the field is done on the base of six groups which are placed in all parts of Switzerland. They have to be ready to repair all breakdowns usually within two days.

In addition to this service, every station is visited and controlled once a year. We also do some calibrations or exchange certain instruments. This needs about two working days for each station per year.

2. ENET Description and Operation

The ENET as the second automatic network of the SMI has become operational in the years 1991-94. It was planned for the following tasks:

- Basic network
  Wind information for continuous information and for better knowledge about the development of storms and gusts. Several other parameters at selected stations. For forecast and climatological information. 30 stations in the north and in the south of the Alps.
- Mountain stations
  Wind, snow-depth and temperature. For general weather information and specially for the Swiss avalanche institute in order to give information about snow cover development and transport of snow due to wind. 10 stations in the Alps between 1900 and 3100m.
- Boundary layer stations
  Measurement of temperature, humidity and wind on tv/radio/telecommunication towers. 3 stations on hills, totally 400-600m above the surroundings.

The cycle of measurements is 10 minutes like at the ANETZ, but the data are transmitted only each hour. All stations except the mountain stations can also produce wind alarms if the gusts reach 25 knots or more.

3. Operational availability of the ANETZ and ENET

ANETZ
real-time: percentage of available transmitted messages about 10' after measurement (relative to total possible data). Thus a single missing parameter is not considered if the message as a whole has arrived.
archive: percentage of available data after IFI-procedure and interpolation of very short gaps (IFI:= memory-card which can be sent to the SMI e.g. after interruption of the telephone-line).

ENET
real-time: hourly data correctly available 30' after measurement
archive: after second interrogation

Alarms
The median in time of the arrival of the alarms gives that time when 50% of the alarms have arrived at the users.
The long-term development of the availability at the central computer of the ten minute messages of the ANETZ is showed in the following graphic.

4. Operational control-measurements, calibrations and other measures at the ANETZ

The following table gives a general overview over the different methods in the field. They have to be seen together with the measures at the central office (presented in the paper of M. Kiene).

<table>
<thead>
<tr>
<th>parameter</th>
<th>measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>wind</td>
<td>few stations double equipped</td>
</tr>
<tr>
<td>temperature</td>
<td>mostly 2-4 instruments</td>
</tr>
<tr>
<td>humidity</td>
<td>usually 2 instruments</td>
</tr>
<tr>
<td>pressure</td>
<td>manual measurements for control</td>
</tr>
<tr>
<td></td>
<td>2-7 times a week at many places</td>
</tr>
<tr>
<td>precipitation</td>
<td>calibration on the occasion of the yearly maintenance</td>
</tr>
<tr>
<td></td>
<td>manual measurements 1-7 times a week at many places</td>
</tr>
<tr>
<td>global radiation</td>
<td>calibration on the occasion of the yearly maintenance</td>
</tr>
<tr>
<td>brightness</td>
<td>calibration on the occasion of the yearly maintenance</td>
</tr>
<tr>
<td>sunshine</td>
<td>(comparisons)</td>
</tr>
<tr>
<td>lightnings</td>
<td>--</td>
</tr>
</tbody>
</table>

5. Special comparisons of the air pressure

For several years we know the ANETZ-barometers are not absolutely stable. Typically they have a drift of about 0.1 hpa per year. We didn't correct this effect during the last years, and so some stations showed differences of 1 hpa or more from one another.

In order to find exact values and to make individual corrections we defined 1992 a campaign with the following components:
1. Comparison of our stations with 10 neighbouring foreign stations
2. Presentation of the differences between Hg and automatic barometer at several stations over years
3. Campaign with a high precision instrument at all stations

4. Analysis of yearly pressure average

5. Control of other parameters (station height, formulas)

In several cases we found more than one component contributing to the error. And we found also - which was not expected - that certain automatic stations showed an annual variation of pressure. For this reason it was not possible to make corrections on the base of just one precise measurement.

The results were the following:
1. The differences with all neighbouring countries were quite small on the average, but we found in some cases high variations.
2. The difference Hg/automatic barometer confirmed at many stations the existence of a linear trend. Hg seems to be a reliable stable base over very long periods.
3. The comparison with the high precision instruments showed no short time variations and confirmed the trend mentioned in 1.
4. Yearly averages showed clearly the stations with a big trend. But the exact pressure field is still unknown...
5. At 4 stations we found height or calibration errors.

As a consequence 15 stations could be corrected up to now. Differences of 0.3 hpa or less were not corrected.

This campaign is pursued and we hope to have correct values in the whole network by the beginning of 1996.

6. Extreme weather situations

Such situations leading to extreme values are suitable for testing our stations because they often combine different aspects, which are usually not possible to simulate in the laboratory. Some examples may illustrate this aspect:
- Strong precipitations up to 30mm in 10 minutes could be measured in several cases without problems. But after a heavy thunderstorm with hail it was observed that the samplers exit was obstructed by melting ice.
- Strong winds can destroy installations, but in most cases of damages we found that lightnings were responsible and not the strong wind. The precision of the measurements seem to decrease with extreme conditions.
- Low temperatures didn’t lead to problems, but the combination of negative temperatures, fog and wind provided in a few cases some problems even to our best instruments.
- Dew point measurement can be a problem at low temperatures and very low moisture. We found examples where it was not possible if there was ice or water on the dew point mirror. Consequently in some cases the wrong formula was used. This error was only found at mountain stations and could not yet be repaired.

As a consequence each new instrument is tested before operational use on mountain stations with hard conditions during months.

7. Outlook into the future

At this time no significant expansion of the network is planned.

We try to keep the standard we have reached at the ANETZ at the today’s level which causes more and more problems due to its age. In the next two years we test new wind sensors and plan to introduce them in the network.

The ENET still needs quite a lot of activity to get closer to the ANETZ’s standard. In the next years a few stations and additional instruments shall be installed at selected places.

In two years we plan to start the analysis for the replacement of the main components of the ANETZ. At that time it seems to be possible to create additional stations and also to make operational new sensors.
AUTOMATED METEOROLOGICAL STATIONS
IN THE NETWORK OF THE SLOVAK
HYDROMETEOROLOGICAL INSTITUTE
(D. Jakubik, J. Danč, M. Ondráš)
Slovak Hydrometeorological Institute, Bratislava

1. Introduction

The very first fully automated measuring system within the Slovak Hydrometeorological Institute's (SHMI) Observing System was established at the meteorological station Jaslovske Bohunice. Its aim was to provide meteorological information for nearby nuclear power plant and was put into operation in 1974. At present, at this workplace, there is at disposal an effective measuring and monitoring system for gradient measurements on 200 m high meteorological mast. System provides not only measured data but derived and forecasted meteorological information as well for the operation of nuclear power plant.

An automated measuring system for continuous sunshine radiation measurement was developed at the SHMI in 1980. Few such systems were put into operation within the National Observing System. They were based upon the modified automated hydrological stations and were aimed for experimental purposes only. Very good reliability and accuracy of these systems are the reason why they are still in operation.

At the same time with the help of fy MARCONI the main international airport Bratislava was equipped with the Automated Weather Observing System (AWOS). Design of the system and the complete analysis were done by our specialists while hardware was brought by the foreign company. One of the little known feature of that system was it could compute automatically vertical and horizontal wind shear and localise low inversion layers. This was done by means of automated station installed at the nearby hill and sophisticated software prepared locally as well. Two other international airports (Poprad and Košice) were equipped with the VAISALA AWOS systems in 1992 and both together with the Bratislava airport are at present rebuilding and upgrading to a very sophisticated ones build upon the VAISALA MIDAS 600.

Simultaneously, with development of the measuring systems our specialists work on the fully automated process of collecting, checking, pre-processing, coding, distribution and final processing of data of the national observing network. This project was called APP (Automated Workplace of Observer). In between 1990 and 1993 APP was installed at 22 professional meteorological stations that are the backbone of the National Observing System. APP was build upon the PC/AT within its DOS environment. Right at the end of the APP project new one called IPP (Integrated Workplace of Observer) has started taking into account all the experience with the development and operation of the older one. In 1995 IPP was installed at all professional meteorological stations (23 at present). IPP is build upon the PC/AT but within the multitasking QNX Operating System. An integral part of the IPP is the
automated data measurement system, either USA datalogger ESC 8800E or VAISALA MILOS 500. Up till now 19 from 23 professional meteorological stations are equipped with the automated data measurement systems. At the end of 1995 IPP will work in the full configuration at 22 professional meteorological stations and at two unmanned field stations (Malý Javorník and Donovaly). Among those 22, there are 3 mountain stations. See figure 1 for the National Observing System.

2. Architecture of automated meteorological station originally operating in APP

This automated meteorological station was built up from datalogger ESC 8800E (made in USA). Logger performs measurement and data processing. It also has a special program for mathematical and statistical processing of the measured parameters. Data from datalogger are transmitted into a PC at the observer’s workplace via serial line RS 232. Air pressure sensor (Vaisala PA 11) is connected to a PC by a serial line, too. Datalogger has 16 differential analogue programmable inputs, 8 digital inputs, input for precipitator, 32kB RAM, 64 ROM and battery backup for internal clock and RAM.

The following sensors of meteorological parameters are connected to datalogger:

- air temperature, soil temperature - linearized thermistor NTC YSI, range of measurement is from -40 °C to 60 °C, accuracy is 0.1 °C,
- relative air humidity - capacity sensor Rotronic MP100F, range of measurement is from 0% to 100%, accuracy is 2 %,
- atmospheric precipitation - tipping bucket raingauge PAAR AP23, size of orifice is 500 cm², heated, resolution is 0.1 mm,
- wind direction and velocity - Young 05103, range of measurement is from 0 to 60 ms⁻¹, sensitivity threshold is 0.6 ms⁻¹,
- sunshine duration - sensor with rotating optical waveguide Lambrecht 1622, heated, sensitivity is 120 Wm⁻²,
- evaporation measurement - Lambrecht 6844-A, resolution is 0.3 mm, range is up to 142 mm,
- atmospheric pressure - Vaisala PA 11A, range is from 500 to 1060 hPa, resolution is 0.1 hPa, accuracy is 0.3 hPa/year

Period of measurement (sampling) is 2 s, data are scalar averaged, wind parameters by vector. Into RAM there are loaded 1 min averages and totals.

Data are transmitted into a PC at the observer’s workplace where they are checked, derived parameters computed and pre-stored. Upon them and with the help of manually inputted observed data regular messages like SYNOP, METAR, SPECI and national message INTER are compiled and transmitted to the National Telecommunication Hub (NTH) and to local users. Many other jobs mostly for climatological purposes are done upon the same database.
3. Architecture of automated meteorological station operating in IPP

IPP is built upon the VAISALA MILS 500, model DMF 50, but for the time being on some meteorological stations still dataloggers ESC 8800E are used. The configuration of it is as follows:

- Mother Board DMB 51
- Central Processing Unit DMC 50A
- DC/DC Converter DPS 50
- Sensor Interface Unit DMI 50
- Analogue Interface Unit DMA 50
- Memory Unit 2 Mb DMM 55B
- Pressure Transducer DPA 21

CPU is presented by 16 bit 80C188EB processor. Multitasking operational system AMX, configurable user software "Your Way" allows to change program of measurement, processing and message generation.

MILOS 500 in the configuration used up till now, within the SHMI's Observing Network, allows to measure meteorological parameters as follows:

- air temperature - Pt 100, DTS 12, range of measurement is from -60 °C to +80 °C, accuracy is 0.1 °C,
- relative humidity - capacity sensor type HMP 35D, range is from 0 % to 100 %, accuracy is 3 %,
- soil temperature - Pt 100, DTS12G, range of measurement is from -60 °C to +80 °C, accuracy is 0.1 °C,
- atmospheric precipitation - tipping bucket raingauge Lambrecht, orifice 200 cm², accuracy is 0.1 mm, heated,
- precipitation detector - type RGD 11A, capacity type,
- wind direction and velocity - Vaisala WAA 15A, WAV 15A, range of measurement is from 0.4 to 75 ms⁻¹, sensitivity threshold 0.4 ms⁻¹, accuracy is 2 %, wind direction uses 6 bit Gray code, sensitivity threshold is 0.3 m/s, resolution is 5.63 degree, accuracy is 2.8 degree,
- solar radiation - global radiation, sensor Kipp and Zonnen CM 11, spectral range 305 to 2800 nm, sensitivity 4 to 6 uW·m⁻²·M⁻¹,
- sunshine duration - calculated from global radiation according to WMO recommendations,
- atmospheric pressure - type DPA 21, range is from 600 to 1060 hPa, resolution is 0.1 hPa, accuracy is 0.3 hPa/year (in range 800 - 1060 hPa) and 0.5 hPa/year (in range 600 - 1060 hPa).

Period of measurement (sampling) is 2 s for wind parameters and 10 s for other parameters. Data are scalar averaged and wind parameters by vector. Into RAM there are loaded 1 min averages and totals.

Data from MILOS 500 are transmitted into a PC at the observer's workplace by serial line RS 485 and via the ACP 10 there are fed into the telecommunication system as well. MILOS 500 simultaneously work in 2 modes. The first one is as an integral part of IPP into which it provides collected data. In this mode IPP generates,
with the help of manually inputted observational data, regular messages like SYNOP, METAR, SPECI, CLIMAT and national message INTER, as well as hourly climatological messages. The latter mode uses a bypass via communication computer ACP 10 directly to our X 25 communication network and to the main communication computer STRATUS in the NTH. In some stations modem connection to the nearest ACP 10 is used. This second mode was developed for the pure field operation and as a emergency backup if the main IPP computer fails. In the case of the fault of IPP computer, STRATUS retrieves only messages from MILOS 500 and channels them to the users so that there is no gap in providing information mainly for the operation of the Central Forecasting Office. In this mode MILOS transmits regular meteorological messages, without the manually collected meteorological parameters, in pre-specified time scale and whole range of measured parameters in a special format once in an hour.

4. Data transmission and processing

In 1993 many development projects started within the SHMI. All projects were interconnected and had the main objective, which was the Strengthening of the Slovak Hydrometeorological Institute. All those projects, including the development of IPP and implementation of Automatic Meteorological Stations, were closely related to the main project. The name of the main project was development of new data communication network and rebuilding the National Telecommunication Hub. The success in this project was the basement for the operation of all the others. It needs to mention in order to understand how the whole system works.

Telecommunication network of the SHMI (see figure 2) is determined for the national and international data and information exchange. It is designed as a private X 25 data network of the packet transmission of data with communication processors ACP (SmartNET) in nodes. Connection between the main nodes of the backbone network is realised by leased four-wire land lines. Star-interconnections between main nodes and professional meteorological stations have been realised by land and switched communication lines. Routing and re-routing of data within the backbone is done automatically upon the current status of the operation and traffic on the lines. The maximum data throughput is 19.2 and 24 kbit/s depending on the line respectively. Integral part of the communication network is the Wide Area Network composed, up till now, of 6 LANs interconnected via Netbuilders.

Telecommunication computer STRATUS at the National Telecommunication Centre in Bratislava mediate connection to GTS WMO (Global Telecommunication System), being equipped with specialised MSS (Message Switching System) software, with own database system and with special meteorological software for display of synoptic charts, radar and satellite data, for generating charts using GRIB and BUFR codes, for coding and decoding charts into T4 format, and so on.
5. Conclusion:

At present there are in full operation 7 automated meteorological stations equipped with datalogger ESC 8800 and 12 automated stations VAISALA MILOS 500. Three more are going to be installed. In mid 1996, upon the results of the present system, project for continuation will be prepared. New project will be aimed mostly for automation of climatological and agrometeorological network. At the same time special networks are likely to be build for special customers like road maintenance. For this purpose easy, low-cost system are supposed to be implemented.

Sensors of temperature and relative air humidity are exposed in classical wooden Stevenson screen at 2 m height. Sensors of the ground temperature are at 5 cm height, in a standard VAISALA radiation shelter. Soil temperatures are measured in depths 5, 10, 20, 50 cm. Wind sensors are installed on 10 m flap mast in the meteorological enclosure. Dataloggers ESC 8800 and barometers PA 11 (Vaisala) are installed inside, at the operator's workplace, automated stations MILOS 500 are installed outside, in the meteorological enclosure.

Experiences with operation of an older type of the automated meteorological stations (measurement systems) are as follows:

- Datalogger ESC 8800E was not tailored to the SHMI's needs due to the wrong producer and distributor's policy contrary to excellent VAISALA tailoring and policy.
- System based on datalogger ESC 8800E had many initial faults but afterwards became a standard reliable equipment.
- From the maintenance point of view, 7 ESC operated systems need after three years of operation approximately one new complete system (as a spare parts) to keep them in the operation.
- Only one destruction of ESC 8800E was recorded in case of a direct stroke by lightning.
- Some problems occurred with soil temperature sensors due to infiltration of the soil humidity into sensors.
- Sensors of relative humidity Rotronic were of a lower reliability and shorter service life as it was given by producer.
- Automated measurement of evaporation was proved to be unreliable.
- Automated stations MILOS 500 are still in a warranty. Control test before and after the installation demonstrated that stations fit the parameters given by producer.
- Maintenance of the MILOS 500 is done by the local VAISALA contractor and even the short experience shows VAISALA equipment are very reliable.

References:

Network of meteorological stations on the territory of Slovakia
Central Data Processing and Quality Control Procedures for Automatic Stations at the Swiss Meteorological Institute (SMI)

Martin Kiene
Swiss Meteorological Institute, Data Branch

Abstract

The quality control of meteorological data at the Swiss Meteorological Institute (SMI) with the purpose to detect faulty instruments and incorrect data has different levels. Every 10 minutes a network monitor gives first hints about suspicious data. The current system is rather time consuming. The use of today's better computers with advanced graphic tools will allow a reduction of the manpower needed for data control while increasing its quality and efficiency.

1. Introduction

The purposes of the quality control of meteorological data at the SMI are the following:

- detection of faulty instruments
- elimination of data errors and correction of wrong values in order to improve the data quality
- interpolation of missing data

The SMI runs different types of station networks that measure meteorological data:

<table>
<thead>
<tr>
<th>Type of Station Network</th>
<th>Number (1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic stations (ANET since 1981, ENET since 1994)</td>
<td>72 + 43</td>
</tr>
<tr>
<td>Conventional stations</td>
<td>49</td>
</tr>
<tr>
<td>Precipitation stations</td>
<td>350</td>
</tr>
<tr>
<td>Flight weather stations (METAR and AERO)</td>
<td>29</td>
</tr>
<tr>
<td>Storm wind stations</td>
<td>24</td>
</tr>
<tr>
<td>Biometeorological stations</td>
<td>218</td>
</tr>
</tbody>
</table>

This paper will handle only the problems of automatic stations. But it should be noted that the quality control of meteorological data transmitted from different station networks to different central data processing units can cause major problems. In particular, the equal treatment of a parameter measured by different networks is extremely difficult.

2. Data Processing and Quality Control Procedures

Two automatic networks collect meteorological data via telephone lines and send them to the central computers:

- ANET: Automatic network consisting of 72 stations spread over Switzerland, since 1981 (some stations earlier, some later).
  This net has a quite good quality control system.
ENET: Automatic network consisting of 43 stations spread over Switzerland, since 1994. This net is a so-called complementary network with the main aim of measuring wind but also other parameters, especially in the mountain regions. The quality control of this net is still quite rudimentary. The reasons for this are:
- the net is new
- the computer that polls and processes the data is different from the ANET computer and therefore it is not possible to use the programs of ANET for the quality control.
- ANET polls every 10 minutes, ENET only once an hour for the 10-minutes values

The ENET isn't discussed here any further. There are plans to combine the data processing and quality control of these two nets (and others) in the future. (See chapter 4).

3. Data Processing and Quality Control Procedures

A graphic overlook shows the main parts of the whole process:

Graphic 1: Flowchart of the data processing and quality control procedures

a) Station 1  Station 2  Station 3  Station 4  Station 5  Station 6  Station 7

b) Central Computer, collecting the data; rough quality control

c) Monitor, demanding action

d) Computer with database and quality control programs

e) Call for instrument repair team

- Manual data correction
- Other databases with corrected values
- Homogenization
The description of the different parts of the data processing and quality control system shown in the above scheme is as follows:

a) A first check of some instruments is made automatically at the stations. This information is coded in parameters that come from the stations.

b) The central computer polls the station every 10 minutes to collect the data of the last 10 minutes interval. The information about the status of some instruments is decoded and sent to the console, monitoring unusual appearance of values. The central computer also runs various tests:

- test for completeness of the data
- test for limits (Are the values inside defined intervals?)
- test for internal consistency (e.g.: Are rain and sunshine recorded within the same time interval? Is lightning detected but no rain?)
- test for variability (Is the sequence of the values of a parameter logical?)
  e.g.: check for icing on the wind measuring instruments

If any of these tests responds, a message will be sent to the monitor indicating suspicious behaviour of the instruments. The data in this computer is stored for about 5 days.

c) The network monitor shows a table with all stations and with information about the status of instruments and data.

Graphic 2: Network monitor indicating suspicious instruments and data

<table>
<thead>
<tr>
<th>Sxn</th>
<th>Sx0</th>
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An operator has to analyse the messages sent to this monitor. He notifies the repair team or takes other action. After the problem is solved he enters some commands and the message disappears.

d) The data is sent to a mainframe computer with the main database. This happens independently from the network monitor and the actions taken there. In the early morning the previous day's data is run through other plausibility check programs. A paper output with all resulting messages is produced. Operators look through this report and decide whether the values are correct or not. This gives other hints about faulty instruments. The wrong or incomplete data is corrected or completed and then stored in the database.
e) Inconsistency and inhomogeneity in the data due to instrument changes or relocation of the station can not be detected or corrected with the tools described in c) and d). The task of homogenizing the data of some parameters from 1961 to 1990 is presently being carried out by a project group called CLIMATE90. The project will be finished by the end of 1995. This work is done half automatically but needs human decisions in every case. Many tests have been programmed to indicate inhomogeneity graphically. The discussions about the warming up of the earth's atmosphere make the importance of homogeneous data quite obvious.

Graphic 3: Example of an output of a homogeneity test showing an inhomogeneity at the beginning of 1979, when the station Altdorf changed from conventional to automatic.


accumulated differences of the 3 daily temperature observations between Altdorf and reference series, 1971-1983

graphics created by Andreas Roesch
The first time series of graphic 3 shows that the change of the instrument for temperature measurement caused a change of the average difference between the temperature at the station examined and a reference time series of temperatures.

4. Plans for the Future

As it can be imagined the quality control procedures as described above are quite time consuming and require a lot of manpower. So the main goals for the next generation of data processing and quality control programs at the SMI are not only to reduce the manpower needed but also to improve the data quality and to shorten the time used to obtain homogeneous data. This aim will be achieved with the following improvements:

- combining the different station networks and using the same programs for all stations
- automatic regional variability checks (comparison with surrounding stations) to reduce the number of error messages
- graphic utilities for the correction of data with the mouse instead of the keyboard
- the programs will give the operator a choice of different possibilities to correct or interpolate data
- shorter intervals for homogenization by using the programs developed for the CLIMATE 90 project (homogenization every 10 years or less)

5. Summary

A serious quality control is essential for a quick repair or replacement of faulty instruments and to obtain comparable data from different stations over a longer period. Different station networks can complicate the issue. Using the facilities of today's computers with clever programs can keep the manpower for this purpose within acceptable limits.
AUTOMATIC STATIONS IN THE METEO-FRANCE NETWORKS

Michel LEROY, Météo-France

ABSTRACT

The different types of network using automatic station are described. Such equipments are now widely used by Météo-France which operates more than 1000 automatic stations. The different categories of networks leads to different constraints and quality level.

Automatization brings more uniform measurements, a higher density of observations available in real time and more work at a central level for installation, maintenance and quality control.

INTRODUCTION

Météo-France has used its first automatic stations more than 25 years ago, in isolate islands. This first generation used hundreds of kilogramms of battery and radio transmission.

Automatic stations really began to be used on a large scale 15 years ago on two main types of stations : in completely isolate location and as an aid to human observer. Today, about 1000 automatic stations are in operation in various networks in France (and overseas territories). With these networks, the quality control procedures have evolved (and still have to evolved).

Let's examine now the different categories of network and their particularity on the point of vue of quality.

AUTOMATIC STATIONS WITH HUMAN OBSERVERS

Météo-France has a network of about 200 sites using both automatized measurements and human observation. In these sites, an automatic station is used to make the acquisition and first level data management of "classic" measurements : wind, amount of precipitation, temperatures, humidity, solar radiation, pressure, visibility and cloud base level on airports. This automatic station is associated to a PC computer, making the interface with the human observers who can input their own observation and supervise the system. Coding of the messages is made either automatic or on request of the observer. Therefore, when the observer is present, the system is an aid to observation. All the repetitive tasks are automated. When the observer is absent, the system is fully automatic, Synop messages (and other messages) are issued (but, today, the Metar and Speci messages are still transmitted after human input and validation).

The basic network of professional observing stations of Météo-France has been equipped the last 10 years, at the origin mainly to allow staff economy during night or week-end. One problem is the lack of "present weather" observations during night. An advantage is the uniformity of the measurements, a much higher measuring rate and the saving of time for the meteorologist. This saving of time is essential, the number of sites where a meteorologist is dedicated to observation during 100 % of time, is getting lower and lower (the meteorologist is more and more in contact with users and has to take care of climatology, forecast, specific studies). This versatility, partly allowed by the automatization, leads to a perverse effect, which can affect the quality of observations : many meteorologists have less motivation for instruments (it's automatic). They are no longer obliged to go to the instrument park several times a day. Therefore, the sensors have to be more and more reliable (what they are), sometimes redundant. A specific effort has to be conducted to inform the meteorologist on the instruments and associated uncertainly, and to avoid a neglect of the instruments.
Today, all the observing sites with human observer of Météo-France, are equipped with an automatic station. Different configurations are based on the same equipment and software, from large airports with several runways to small stations in France and some "exotic" places such as French Guyana or Antarctica. Based on commercial products, developed in France, the systems are partly assembled and installed by Météo-France. The software has been developed by Météo-France.

Météo-France has in charge both the synoptic and the aeronautic observation. One third of the stations are located on an airport. Synoptic and aeronautic measurements are made by the same equipment ; the PC computer, named CAOBS, for "calculateur d'observation", has to manage the two types of data with an online archive of one month of one minute data. CAOBS is also handling the synoptic data to compute daily climatologic data, sent to a specific climatologic computer. When automated, the management of synoptic data is much more complicated than the management of real time aeronautic data.

To ensure good transmission with the fewer constraints on cables, specifically on airports, a numeric field bus has been developped by Météo-France and a French manufacturer, Degreane. This bus, called CIBUS, allows numeric transmissions on long distance (up to 10 km), with an electric isolation against overvoltage. It is used for sensors with long distance connections, such as wind sensors, transmissometers, ceilometers.

FULLY AUTOMATIC STATIONS

These sites are using the same family of automatic stations than above.

Météo-France has two types of networks with fully automatic stations : a national network and several "regional" networks.

The national network is dedicated to synoptic observation, in places where manned stations are impossible or too expensive. Météo-France operates such stations in mountainous area and overseas territories (The Alps, French Polynesia, islands near New Caledonia, islands in Indian Ocean,...). The stations use solar energy and various transmission peripheries, depending on the site : satellite transmissions to Meteosat or GMS, radio link, Inmarsat Standard C terminal.

In these sites, the reliability of the station and the sensors is of primary concern. Maintenance duty is often an expedition with high delays and costs. For example, some isolate islands near New Caledonia require 4 days of navigation with a French Navy ship, specially chartered.

Some sensors are not still well adapted to such harsh conditions, for example rain gauges subject to blocking. Sensors requiring calibration are systematically replaced each year, such as barometers and hygrometers. Sometimes, the wind sensors are protected against birds by placing them (the sensors) in a cage. We did not found a solution for the rain gauge against the birds and this measurement has often a very short life time.

"Regional" networks are located in more accessible places and are often meso-scale networks. Météo-France operated about 700 automatic stations of this type, with classic sensors : wind, rain gauge, temperature and humidity sensors, global solar radiation and sometimes moistening detectors. The particularity of these network is that Météo-France has succeeded to prescribe the same transmission protocol, called Patac. Patac is using the public telephone network and has been implemented on stations of at least 4 different manufacturers. The transmission of data is made on request of concentrators located both in the departmental and regional centers. Blocks of 30 minutes data are transmitted. The transmission is not made in real time but on request. The frequency of the concentration of data is depending on the locations, the networks and the meteorological conditions, and can range from 1 to 8 (or more) per day. Differents types of automatic stations from different manufacturers can be mixed in the network with no influence on the concentration technology.

Initially, the first regional networks have been set for "real time" climatology (with 24 h delay). They are now used both for climatology and sub-synoptic observation. The observations are added to synoptic data and are also used by forecasters.

Now, what about the quality ? With so much stations, it is not perfect.
When the first networks were erected in 1984, the main objectives of the users (the regional centers) were first to get as much data as possible; the quantity was considered before the quality. The concern on quality arrived several years later, sometimes leading to minor or major changes in the stations. For example, all the temperature screens of one of the first network (60 stations) had to be changed, due to poor performance. The original screens were chosen for their low price (I think that this problem of screen is potential in many automated networks).

So the homogeneity of these regional networks is not so good that the national network. One reason is that they are directly managed, from their design to their exploitation, by regional centers who sometimes are happy to be independant of the national service, for these networks. Another reason is that the funding of the network didn't came from Météo-France but from departmental or regional administrative authorities. Therefore the aspect of cost became sometimes more important that the technical and quality aspects. Moreover the funding covered the initial setting of the networks and much more infrequently the maintenance. Hopefully, the organization of Météo-France allows a minimum of maintenance with quite large human ressources allocated to maintenance tasks.

The location of the stations do not always follow the state of the art rules, especially for wind sensors location. The sensors are installed at top of 10 meters masts. The rules of clearing of ten times the height of neighbouring obstacles are quite difficult to respect, especially when the sites are chosen with the following constraints :
- availability of a protected site, with some confidence of timelessness.
- availability of a local human supervision for first level maintenance (again against the blockage of rain gauge).

Therefore the vicinity of the automatic stations is a compromise between representativity and logistics.

The high number of automatic stations leads also to maintenance problems, essentially coming from the sensors. Spare parts and available time have to be shared between the national and regional networks. Officially, the priority is the national network. In the reality, the higher priority of the national network is not so clear, when the regional centers are at the direct origin of the setting of "their" regional network and therefore are sometimes more motivated for this network. Clarification is necessary and is in progress, by taking officially in account the regional networks, including them in the national network.

BASIC CLIMATOLOGIC AUTOMATIC STATIONS

Météo-France operates a basic climatologic network of about 3000 points, measuring daily amount of precipitation. About 700 of these sites also measure daily extreme of temperature. The measurements are made with very basic instruments by quasi-volunteer human observers. Finding such daily available observers is getting more and more difficult and the quality and density of the network is decreasing.

Météo-France has in project a fully automatisation of this network by replacing the manned observations by small automatic stations measuring precipitations and temperature. The aimed number of stations is 1500.

Before setting such a dense network, an experimental network will be installed in 4 administrative departments in the South of France. The objective is to test the reliability of the stations and rain-gauges, the quality of automatic measurements compared to the classic ones and especially the maintenance constraints generated by such a dense network. For the test, 2 models of automatic stations and 4 models of rain gauges will be tested this year. The test will begin in May 95 for a one year period.

All the stations will record hourly data and any detected precipitation event on PCMCIA memory cards. Additionally, one third of the stations will be interrogated daily using the public telephone network.

The stations include correction functions for rain gauges to take in account the influence of the intensity of precipitation on the response of tipping buckets sensors. Maintenance and control operations (mainly on the rain gauge by pouring a fixed quantity of water) will be also recorded in a log file. A new model of a weighting rain gauge will be tested (HYETOCAP). The advantages of this sensor are the facility of calibration, it's stability in time due to no mechanical parts and a low risk of obstruction.

The evaluation of this experimental network is necessary before taking the decision to set a dense network on the whole territory.
TOWARDS FURTHER AUTOMATION

As mentioned earlier, one disadvantage of the automatization is the lack of "present weather" observations with such systems. Present weather sensors now begin to be available on the market. A WMO international inter-comparison is currently been held both in Canada and France. Therefore a technical solution to the problem is possible.

Météo-France is testing a complete automatic system, including a present weather sensor, a visibilitymeter, a state of the ground sensor and a lightening detector. An additional software combine all the data, taking in account the redundancy between some sensors and output a Synop code.

Météo-France has in project the setting of a first network of about 30 systems in the next 3 years.

Such configurations could lead at the end to disappearing of the human observers. This would reinforce the problem of first level maintenance of the sensors. The need for less maintenance sensors will be greater, with probably the development of on-line diagnostic techniques.

CONCLUSION

The organization of the quality control of the different automated networks becomes a real specific job.

Météo-France has still to improved it, to get a known level of quality in each network.

Additional methods, not described in this paper, are used such as:

- monitoring with the first guess of numerical models,
- space and time controls,
- regular calibration of sensors,
- auto-calibration of the automatic stations,
- control of conformity of the equipment before installation.
AUTOMATIC WEATHER STATIONS and INFRASTRUCTURE

A.N. Mazee
Royal Netherlands Meteorological Institute
De Bilt, The Netherlands

1 INTRODUCTION

During the last ten years the whole network of Synoptic and Climatic stations in the Netherlands has been replaced by (semi)Automatic Weather Stations (AWS). The modular setup was developed by the KNMI. With the developed modules it is possible to build manned and unmanned stations. The manned stations can also be used at (small) airports. At the bigger airports for instance Schiphol a more complicated system is used, this will not be discussed here. At these airports the same sensors and interfaces are used.

2 SENSORS and INTERFACES

2.1 Sensors

It is the policy of the KNMI to use digital sensors instead of analogue. The KNMI developed its own digital sensor for windspeed, winddirection and precipitation. Other sensors used are e.g. HSS-Present Weather sensor, Vaisalla Ceilometer and Paro Scientific digital barometer.

2.2 Sensor Interfaces

All sensors are connected via our interface, the Sensor Intelligent Adaption Module (SIAM) to the Local Data Acquisition System (LDAS). This interface is situated near the sensor. For every sensor or group of related sensors a different SIAM is developed. E.g. the SIAM for global radiation is a SIAM for a single sensor. An other combines 10 cm temperature, ambient temperature (150 cm), relative Humidity and dewpoint. Windspeed and winddirection are combined in one SIAM.

1 SIAM: Sensor Interface

The SIAM is a small autonomous micro computer system and is of a modular setup too. It is a microcomputer unit existing of three or four printed circuits. Only the software and if present the analog sensor interface, is sensor dependent. The format of the outputmessage of the different SIAMs is standardized, only the sensor identification

1 Royal Netherlands Meteorological Institute
is different.

The SIAM units are mains powered. Transmission of the data by radio, in combination with a low power system and solar cells will be realised this year for some locations.

The use of the SIAM has the following advantages:

- The signal of the sensor is digitized near the sensor, so the output signal is relatively insensitive to interference.
- Because all sensors for one physical entity are the same, no sensor dependent calibration factors are incorporated in the SIAM.
- The input signal is converted to physical values, so replacing the sensor and the associated SIAM will not affect the Local Data Acquisition System.
- Preliminary calculations over a ten-minute period are incorporated in the SIAM.
- Data validation is done in the SIAM.
- Output message is standardized.
- The SIAM generates status signals incorporated in the output message.

These status signals inform the user of the data about:

* the SIAM itself
* the sensor
* the incoming signal

2.3 Calculations in the SIAM

Every 12 seconds all calculations are done over the last 10 minutes. These are a one minute average, a ten minute average, a ten minute maximum and a ten minute minimum are calculated. Also conversions are made. For instance relative humidity and temperature are converted to dewpoint. If for this measurement a dewpoint system should be used, the relative humidity can be calculated. Because the layout of the output message of the SIAM is not changing this will have no consequences for the Local Data Acquisition System (LDAS).

All calculations will meet the requirements of the WMO.

2.4 Validation

The validation process is done in the SIAM. This process is a part of all checks that are done by the microprocessor.

Three types of checks are done:

a The circuit itself.

b The sensor.

c The behaviour of the sensor signal, e.g. steps and physical impossibilities.

An example is given when a temperature is measured (with a Pt resistor):
ad. a  Resistors with a known value are connected to the system prior to the measurement. If the deviations are to big no values will be measured and an error state is reported.

ad. b  If one of the four terminal leads is broken a measurement is impossible. And an error state is reported.

ad. c  Because a temperature above 41 degree Centigrade is not realistic in the Netherlands, the signal will be rejected, an error state is reported.
A temperature sample that differs more than +0.3 C or more than -0.5 C from the previous is rejected. And an error state is reported.

It depends on the sensor and its physical qualities what kind of tests are incorporated.

Every time a sample is rejected the 12 s sample is replaced by four slashes. If no calculations can be made anymore all fields are filled with slashes.
The percentage of rejected samples over the ten minute period is important for the further processing in the LDAS. When more than 2 samples (4 %) of the samples in a 10 minute period are rejected, the LDAS will not process the data.

2.5 Output message

Every 12s a measurement is done and an output signal is generated.
The output message consists of a single sample, a one minute average, a ten minute maximum, a ten minute minimum, a ten minute average, a ten minute standard deviation and at the end of the record a percentage of rejected samples is added.
The output message of the SIAM is a 1200 Baud RS-422 serial signal in readable ASCII, that can be transmitted over a longer distance (some kilometres).

Below an example of the output of a SIAM for Barometric pressure (Pressure at Station level) is given:

X38 PSOA PS 0 1 0169 0169 0171 0167 0169 0001 00

The pressure is in hPa, the 1000 digit (if present) is omitted.
In this example the pressure has not been stable over the last ten minutes.
A maximum of 1017.1 and a minimum of 1016.7 is reported.

3  Local Data Acquisition System (LDAS)

The Local Data Acquisition System (LDAS) can be used as a standalone unit. In that case the LDAS will generate a SYNOP and a CLIM, both will be stored in the memory.
Every hour the last SYNOPs and the last CLIMs of seventeen AWSes are collected by a mainframe computer using the Public Switched Telephone Network (PSTN).

There is one special LDAS that generates an automatic METAR, SYNOP and CLIM. This LDAS is deployed on the oil platform F03, located about 250 km north from the Netherlands at the North Sea. Its data is used for helicopter operations and briefings.
Because it was not possible to use the PSTN an other solution is found by using a Data Collection Platform (DCP) of Dornier and an uplink to the METEOSAT satellite. The data is received, every half hour, in De Bilt, the Netherlands.
An other feature of the LDAS is a build-in ten minute database with a storage capacity of at least one week. This database is mainly used for maintenance purposes.
3.1 Status information

Every hour all status information collected in the memory of the LDAS is converted into a status report that is stored in the cyclic memory for about three weeks. Every day the status reports of all AWSes are collected automatically and the data is reduced to a small record that is printed. When the service technicians arrive in the morning they can see, at one glance, what is going on. Problems are evaluated and reported to the maintenance department. Most locations in the Netherlands can be reached within one day for repair.

2 An LDAS and connections

4 Interactive Data Acquisition System

On those sites where visual observations are required an LDAS alone cannot be used. For these location a second computer, the Interactive Data Acquisition System (IDAS) is added. With this IDAS all automatic measurements are presented to the observer and the visual observations can be added to form a complete report.

When the IDAS is used at an airport METARS and SPECIALS are generated. For this purpose ICAO requirements for the METAR and SPECIAL are met. The observer is warned automatically by the system when SPECIAL thresholds are reached. The LDAS will send the raw data (in general 1 minute averages), to the IDAS. All the other functions LDAS will be the same.

For the IDASes the data is not collected by means of the PSTN. Because it is not known when the human observer has completed the data, the data cannot be collected by means of the PSTN. The data is sent to the KNMI using a leased line. On eight locations this IDAS is used.

4.1 The Air Force

At nine basis the Air Force is using the LDAS with the same sensors and SIAMs. The maintenance is done in cooperation with the maintenance department of the KNMI. In just the same way as we use the IDAS, the Air Force developed an alphanumeric and graphical system using the same raw data. The meteorological reports of the Air Force are sent by leased lines to a central location. There the data is compiled to a bulletin which is sent to the KNMI at de Bilt.

4.2 Display units
For local use the KNMI developed a PC display program. This display shows all actual values to the local user. This display is used at small airports, harbours and locks. The data for this display unit is the same as used for the IDAS.

Within the Ministry of Transport and Public Works other ten minute databases are used. They are using the same protocol as the LDASes and data can be collected using the PSTN. In order to display the data from these ten minute databases an other department of our ministry developed a Multi Functional Display Program. This program is also used by technicians and for maintenance purposes.

5 Evaluation

The system using the PSTN for data collection appears to be very reliable. Our first goal was a reliability of 95%. A percentage of about 98% is reached, which is extremely high for automatic weather stations.
1. INTRODUCTION

The Automated Surface Observing System (ASOS) has been designed and developed primarily to satisfy the meteorological needs of the aviation community. As ASOS sites are commissioned, the official observations will shift from manually-generated reports to automatically-generated reports. ASOS observations are generated by processing weather sensor information through a complex set of algorithms. Representative reports of parameters such as sky condition, visibility and present weather phenomena can be derived using single-sensor algorithms at most ASOS sites. Multi-sensor algorithms have been developed to provide information about meteorological discontinuities in sky condition and visibility at locations that have special, localized conditions. For example, San Francisco International airport will need a ceilometer a few miles away to detect the low stratus coming in from the Pacific. The meteorological discontinuity algorithm will provide a remark indicating the existence of the low stratus northwest of the airfield. Multi-sensor algorithms have also been designed to provide redundancy (at major airports) in the event that the primary ceilometer or visibility sensor should fail. This is to prevent any disruption in airport operations.

2. SINGLE-SENSOR ALGORITHMS

2.1 Sky Condition

The single-sensor sky condition algorithm in ASOS uses a Vaisala CT-12K laser ceilometer. The ceilometer detects the presence of clouds by firing laser pulses into the atmosphere directly above the sensor (See Figure 1). Once every 30 seconds, the sensor firmware analyzes the amount of reflected energy received from each pulse. The analysis will result in classifying the sample as a cloud "hit", vertical visibility, or "no hit", depending on the signature of the reflected energy. If a cloud is detected, the height of the cloud is assigned to one of the 252 50-foot increments from the surface to 12,600 feet, the upper design limit of the sensor. If no cloud is detected, the sample is designated as "no hit".

To update the sky condition report each minute, the algorithm processes the 30-second samples from the past 30 minutes. Each of the 60 samples is examined for a cloud height or "no hit". Cloud heights between the surface and 5000 feet are rounded to the nearest 100 feet. Cloud heights between 5000 and 10000 feet are rounded to the nearest 200 feet. Cloud heights above 10000 feet are rounded to the nearest 500 feet. Sensor data gathered during the most recent 10 minutes are double weighted to accelerate the detection of rapidly changing sky conditions.

Once each minute, the cloud heights from the past 30 minutes are examined to find the least-squares distance between adjacent bins, using the equation:
\[ D(j,k)^2 = \frac{\text{NO}(j)xN(k)x(H(j) - H(k))^2}{N(j) + N(k)} \]

where \( j \) and \( k \) are designators for the lower and upper cloud height bins, \( N \) is the population of the bins, and \( H \) is the height of the bins. Once all adjacent cloud height bins have been examined, the two bins having the smallest least-squares distance are combined into a single cloud cluster. The height of the combined cluster, \( H(L) \), is determined by the equation:

\[ H(L) = \frac{\text{NO}(j)xH(j) + (N(k)xH(k))}{N(j) + N(k)} \]

where \( j, k, H, \) and \( N \) are defined above. This approach continues grouping the data until only five clusters remain.

These clusters are then examined to see if they can be combined further to form reportable cloud layers that are meteorologically sound (See Table 1). Once all combining is complete, the cloud layer heights are rounded to the nearest reportable value. The algorithm uses the summation principle in computing the cloud amount for a given layer. The cloud amount of a layer is the ratio of the cumulative population of cloud hits up to and including that layer to the total possible number of hits possible. If a layer has less than 6% cloud amount, that layer is discarded and not used in the summation of cloud amounts for higher layers. The computed cloud amount for a layer is converted to a reporting category (scattered, broken, overcast) in order to emulate the manual observation. The algorithm then selects up to 3 layers to report in the observation, depending on the computed cloud amount for each layer. When the visibility is less than or equal to 1 mile and the majority of the ceilometer samples are classified as vertical visibilities rather than cloud hits, ASOS generates an automated report of a total obscuration, "Wx\( a \)", where "\( a \)" is the height of the obscuration.

Cloud remarks describing amount variability are generated when the cloud amount of the ceiling layer approaches the boundary between two reporting categories. Remarks describing ceiling height variability are generated by examining the standard deviation of cloud hits comprising the ceiling layer.

Finally, ASOS will generate a sky condition special observation if the ceiling layer of the automated sky condition report crosses established thresholds. Standard thresholds are set at 3000, 1500, 1000, and 500 feet. A special observation will also be generated if a new layer forms below 1000 feet since the transmission of the previous hourly observation.

### Table 1 - Cluster Combining Criteria

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<tr>
<td>( H &gt; 8000 ) Feet</td>
<td>( \leq 1600 ) Feet</td>
</tr>
</tbody>
</table>


2.2 Visibility

The baseline ASOS visibility algorithm uses the output from a single Belfort Model 6220 forward-scatter sensor. Once each minute, the sensor provides a one-minute average extinction coefficient. A collocated photometer supplies an indication of either day or night conditions.

If the photometer indicates "day", ASOS then transforms the extinction coefficient into a one-minute average visibility using Koschmeider's Law:

\[ V = \frac{\text{Ec}}{Ec} \]

where Ec is the extinction coefficient. If the photometer indicates "night", ASOS uses Allard's Law to calculate the one-minute average visibility:
where \( e = 2.718 \). Once the one-minute visibility values are calculated, they are rounded to the nearest 0.01 mile. One-minute visibility values below 0.1 mile are set to 0.1 mile, while values above 10 miles are set to 10 miles.

In order to smooth the naturally occurring variability of the one-minute visibility values, ASOS calculates a running 10-minute average visibility value. A harmonic mean is used since it responds more rapidly to sudden changes in prevailing visibility. The mean is computed using the equation:

\[
\frac{1}{V_{10}} = \frac{1}{N} \sum_{i=1}^{n} \frac{1}{V_i}
\]

where \( V_{10} \) is the 10-minute harmonic mean visibility, \( N \) is the number of valid one-minute visibility values during the past 10 minutes and \( V_i \) are the individual one-minute average visibility values.

Once the 10-minute mean visibility is determined, it is rounded to the nearest reportable visibility value. Reportable visibilities (in miles) are <1/4, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 1 3/4, 2, 2 1/2, 3, 3 1/2, 4, 5, 7 and 10+ (OFCM, 1994). When \( V_{10} \) lies halfway between reportable values, it is rounded to the next lower reportable value. Values of \( V_{10} \) below 0.2 miles are reported as "<1/4"; values between 0.2 and 0.375 are reported as "1/4". The 10-minute mean visibility is updated each minute and is reported in the body of the observation as an approximation of the prevailing visibility.

After the 10-minute mean is calculated, the algorithm reviews the variability of the individual one-minute average visibilities. If there have been sufficient changes in the visibility, a variable visibility remark of the form "VSBY minVmax" will be generated.

Once each minute, the algorithm will compare the latest 10-minute mean visibility with that of the previous minute. If the current value has crossed standard threshold values, a special observation is generated.

### 2.3 Precipitation Identification

The ASOS precipitation identification algorithm uses the output from a Light Emitting Diode Weather Identifier (LEDWI) developed and manufactured by Scientific Technology Incorporated. The LEDWI discerns the type and intensity of precipitation by monitoring the particle-induced scintillation in a coherent beam of infrared light with a path length of approximately 0.8 meters.

Once each minute, the LEDWI automatically identifies the occurrence (yes/no), type (rain/snow), and intensity of precipitation (light, moderate, heavy). Sensor output is limited to the types shown in Table 2, in ascending priority. Once each minute, the algorithm examines the valid sensor output generated during the past 10 minutes. When two or more of the one-minute sensor readings indicate precipitation, ASOS will begin to generate a report of precipitation occurrence. The precipitation event will be continued until less than two samples in the past 10 minutes indicate precipitation.

If only two samples in the past ten minutes indicate precipitation, ASOS will report the higher priority precipitation type of the two samples as shown in table 2. If three or more samples in the past 10 minutes indicate precipitation, ASOS will report the highest priority precipitation type represented by at least 2 sensor samples. If no precipitation type is represented by two or more samples, ASOS will report the highest priority precipitation type observed in the samples.

<table>
<thead>
<tr>
<th>PRECIPITATION</th>
<th>SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Precipitation</td>
<td>Blank or NP</td>
</tr>
<tr>
<td>Undetermined Type</td>
<td>P</td>
</tr>
<tr>
<td>Light Rain</td>
<td>R-</td>
</tr>
<tr>
<td>Moderate Rain</td>
<td>R</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>R+</td>
</tr>
<tr>
<td>Light Snow</td>
<td>S-</td>
</tr>
<tr>
<td>Moderate Snow</td>
<td>S</td>
</tr>
<tr>
<td>Heavy Snow</td>
<td>S+</td>
</tr>
<tr>
<td>NOAA (1990), Page C-A-I-6-6.</td>
<td></td>
</tr>
</tbody>
</table>
To determine intensity, the algorithm examines the one-minute samples taken during the past five minutes. If the precipitation type is undetermined ("P"), ASOS will report the intensity as light. If less than two samples in the past five minutes are the same type as the reported precipitation type, ASOS will also report the intensity as light. If only two samples are of the same type as the reported precipitation type, ASOS will report the lower of the two intensities associated with these samples. If three or more samples in the past five minutes are of the same type as the reported precipitation type, ASOS will report the intensity as the highest common intensity reported by three or more samples.

If the reported precipitation type is snow, the reported intensity is then checked against the 10-minute average visibility to ensure that it complies with accepted reporting guidelines (OFCM, 1988, 1994). The reported intensity will be modified, as required, to bring it into compliance with these reporting practices (OFCM, 1988, 1994).

3. MULTI-SENSOR ALGORITHMS

3.1 Backup Sky Condition and Visibility

The backup sky condition algorithm requires the use of two ceilometers. The ceilometers must be sited so that they both view portions of the celestial dome that are representative of the station as a whole. Typically, these two sensors will be collocated.

Both the primary and backup ceilometer generate an independent sky condition report that is updated each minute. The report generated by the primary sensor is used in all official observations. Should the primary sensor become inoperative for any reason, the backup sky condition report is used in subsequent official observations until the primary sensor is restored to service.

The backup visibility algorithm requires the use of two visibility sensors that are sited so that the output from either sensor is representative of the station as a whole.

Both the primary and backup sensor generate independent visibility reports that are updated each minute. The report generated by the primary sensor is controlling and is used in all official observations. If the primary sensor becomes inoperative for any reason, the backup visibility report is used in all subsequent observations until the primary sensor is restored to service.

3.2 Meteorological Discontinuity Sky Condition

The meteorological discontinuity sky condition algorithm also requires the use of two ceilometers. The primary sensor is sited to provide a sky condition report that is representative of the airport. The meteorological discontinuity sensor is sited to detect operationally significant discontinuities in cloud cover conditions, similar to those described in the introduction.

Both the primary and meteorological discontinuity ceilometers generate independent sky condition reports that are updated each minute. The report generated by the primary sensor is the controlling observation provided in the body (as opposed to the remarks) of the observation.

Once the sky condition reports are generated, the ceiling layers of each report are compared for significant differences in height (See Table 3). If the ceiling height reported by the meteorological discontinuity sensor is lower than that of the primary and exceeds the criteria, a remark of the format "CIG VALUE LOC" is generated, where "VALUE" and "LOC" are the height of the ceiling and nominal location of the meteorological discontinuity sensor.
Table 3 - Cloud Remark Criteria

<table>
<thead>
<tr>
<th>LOWEST CEILING LAYER HEIGHT</th>
<th>DIFFERENCE LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H ≤ 1000 Feet</td>
<td>&gt; 300 Feet</td>
</tr>
<tr>
<td>1000 &lt; H ≤ 3000 Feet</td>
<td>&gt; 400 Feet</td>
</tr>
<tr>
<td>3000 &lt; H ≤ 5000 Feet</td>
<td>&gt; 600 Feet</td>
</tr>
<tr>
<td>5000 &lt; H ≤ 8000 Feet</td>
<td>&gt; 1000 Feet</td>
</tr>
<tr>
<td>H &gt; 8000 Feet</td>
<td>&gt; 1600 Feet</td>
</tr>
</tbody>
</table>

If no ceiling remark is generated, the lowest layer reported by each of the sensors is then compared using the same criteria (See Table 3). If the lowest layer reported by the meteorological discontinuity is lower than that of the primary sensor and the criteria are exceeded, a remark of the format "CLDS LWR LOC" is generated, where "LOC" is the nominal location of the meteorological discontinuity ceilometer.

3.3 Meteorological Discontinuity Visibility

The meteorological discontinuity visibility algorithm also assumes the use of two Belfort visibility sensors. The primary sensor is sited to provide a visibility report that is representative of the airport. The meteorological discontinuity sensor is sited to detect operationally significant discontinuities in visibility.

Both the primary and meteorological discontinuity sensors generate an independent visibility report that is updated each minute. The report generated by the primary sensor is used in the body of all official observations.

Once the visibility reports are generated, the reports are compared for significant differences (See Table 4). If the visibility reported by the meteorological discontinuity sensor differs from that of the primary sensor and exceeds the criteria, a remark of the format "VSBY VALUE LOC" is generated, where "VALUE" and "LOC" are the visibility report and nominal location of the meteorological discontinuity sensor.

Table 4 - Visibility Remark Criteria

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>ISSUE REMARK WHEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological discontinuity</td>
<td>Primary minus</td>
</tr>
<tr>
<td>visibility less than 3 miles</td>
<td>meteorological discontinuity visibility greater than 0.5 miles</td>
</tr>
<tr>
<td>Primary visibility less than 3 miles</td>
<td>Meteorological discontinuity minus primary visibility greater than 1.0 miles</td>
</tr>
</tbody>
</table>

4. CONCLUSION

Questions are often asked such as, "how can a single laser ceilometer pointing vertically upward provide a representative cloud observation?" The logic described in this paper was originally developed in the early 1970's using rotating beam ceilometers. Studies were conducted using three ceilometers and three visibility sensors to determine if reports could be generated using one of each sensor. The results of two studies proved that one single sensor with proper averaging techniques would suffice in most areas unless of course there was some localized phenomena that might impact the sensor. Since the mid 80s, systems have been successfully deployed in the U.S. for evaluation purposes as well as operational use based on the principles described above and automation of surface observations is an integral, key element in the modernization of weather services in the U.S. today.
5. REFERENCES


Operational Experiences with the Automated Surface Observing System - ASOS

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1. Introduction

In the mid 1980s, an agreement was made between the National Weather Service, Federal Aviation Administration, and Department of the Navy for the development and production of automated surface observing systems. The procurement contract, under the management of the Department of Commerce's National Weather Service entailed the development, design, test, installation and acceptance of about 800 systems.

The first production system was delivered and installed in Topeka, Kansas in August, 1991. For nearly three years, the ASOS contractor has continued to install systems throughout the U.S. to support the needs of the three federal agencies. In fact, more recently the Air Force has joined the interagency contract to procure several systems for installation in the 1994-1995 time period. To date, there are about 500 systems installed throughout the United States. The remaining systems will be installed over the next three years.

2. System Description

The Automated Surface Observing System (ASOS) is a microprocessor-based system using an array of sensors and sophisticated algorithms to process the data and provide a surface aviation observation at airports. The sensors are typically located at the touchdown zone of the primary designated runway on a given airfield.

Data is collected through a data collection package and sent back to the main processing and control unit, usually located in a building or shelter somewhere else on the airport. The main processor, referred to as the Acquisition Control Unit, contains all of the software necessary to process the data and output the observation to various external devices and communications lines. Each element of the observation is updated every minute, with the exception of wind speed/direction and gusts which are updated every five seconds.

Data are available for display in the air traffic control tower, the weather office or the airport operations office. In addition, there is ground-to-air radio capability for direct broadcast to the pilot and the voice output is available by phone line. For long-line transmission off the airport, the data are formatted in the standard surface aviation observation (SAO) code. (It should be noted that on January 1, 1996, ASOS begins the direct output of the METAR code rather than the SAO code.) These observations are transmitted at least hourly but more often if conditions warrant special observations.

ASOS provides the following elements: cloud height and amount to 12,000 feet, visibility up to 10 statute miles, present weather information including the occurrence and intensity of rain or snow, the occurrence of freezing rain, fog, haze, wind speed and direction plus gusts, ambient and dewpoint temperatures, sea level pressure, density altitude, pressure altitude, altimeter, and liquid precipitation amount.
3. UNITED STATES EXPERIENCES

While there can be many challenges associated with a national program of this magnitude and complexity, several warrant detailed discussion. One very critical issue is the users understanding of the system. The ASOS or any other automated system does not provide exactly the same information as a manually-generated observation. While automated observations offer great benefits to any national service, including economic, their value and acceptability depend heavily on the users. Some of those users include weather forecasters, general aviation pilots, air traffic controllers, airlines, climatologists, research scientists and television broadcasters.

The second very critical issue that will be addressed is the proper siting of sensors on the airport. For the ASOS to accurately portray the weather each minute, the siting must be in an area not prone to localized phenomena, such as ground fog.

3.1 User Understanding - Manual Versus Automated Observations

One major advantage of this system is the observation consistency. Experience shows that there is variability between human observers and differences in the way two observers might view the atmosphere, particularly evident in observations of sky and visibility. It is also recognized that the observer has difficulty observing at night as the visual elements can often be difficult to discern. An automated system using identical sensors and algorithms at all sites provides a consistent observation, site-to-site and day-to-night. Because of the inherent differences between automated systems and manual systems (i.e., the human observer), an understanding of the automated system and how it works is crucial to the success of its implementation and operational use.

The design and development of ASOS centered around the need to provide an automated observation that was similar to the manual observation and that could be used at airports in lieu of an observation that was generated by a human observer. The sky and visibility observations were the most difficult to automate and the most difficult for the users to comprehend. Experiences over the past three or four years show that as users become more familiar with exactly how the system works, their acceptance level improves. Unfortunately, the level of understanding necessary to satisfy the users and gain the required acceptability of the system was underestimated.

With more than 500 systems installed today, less than 50 have been commissioned for operational use as the official observation for a given airport. Part of this problem lies with the unwillingness to accept a "new" observation which is largely due to inadequate training or education.

Various publications and presentations have promoted a broader understanding of how single sensors can provide the sky and visibility observations without the aid of the human observer. It is now evident that education is an ongoing process that should really precede the first system installation. Unfortunately, time and resources do not always allow for much in the way of advance education. It is recognized that the educational process is nearly as important as the system development and testing. All users of the observation must be considered and must be fully informed as to how the system actually works. During 1994, special forums were established within the U.S. as well as outreach programs (with dedicated staff) to better educate the many users on ASOS, how it works and its value.

3.2 Siting of Sensors

Proper siting of sensors to provide an automated observation is extremely critical. The United States has adopted a standard for siting at airports that takes several important issues into account. A site survey has been conducted at each planned ASOS location in which the federal standards for siting are considered as well as the government regulations governing the placement of equipment on airports. The federal siting standard for meteorological instrumentation addresses the proper spacing.
to avoid any interference among sensors as well as the environs surrounding the sensors. Of course, meteorological considerations must be applied to any site. Sensors installed in an area that is frequently prone to ground fog would result in unrepresentative observations for the airport some percentage of the time. This, of course, will affect airport operations and forecasting. A few ASOS sites must be relocated now due to conditions such as those mentioned above which were not recognized during the original site survey.

In the U.S. every attempt is made to locate the ASOS sensors in the touchdown zone of the primary runway. One underlying premise of ASOS is that the observation can give the pilot the weather report that is needed the most during approach and landing. Unfortunately, there are sometimes restrictions (that is, Federal Aviation Administration (FAA) regulations governing placement of equipment on airports) at an airport that prohibit ideal siting. Siting should be recognized as a most critical aspect of implementing any automated observing system. Poor siting will affect the system's performance and therefore acceptance by the user community.

4. SUMMARY

In summarizing, there is much to be learned from the experiences in the U.S. with wide-scale deployment of hundreds of automated systems. The goal with automation is to provide a timely, representative observation and free up staff to perform other duties. A complete and basic understanding of the system will promote acceptability of the automation of surface observations. Siting standards must be followed closely to minimize the problems that may later impact a service's ability to totally automate. Both issues are critical to the success of the ASOS program and activities are ongoing to provide a properly sited system and to provide sufficient education and training so that users will understand and accept the new observation.

5. REFERENCES

FIRST EXPERIENCES WITH THE INTERCOMPARISON OF METEOROLOGICAL DATA MEASURED BY TRADITIONAL INSTRUMENTS AND SENSORS OF AWS IN HUNGARY

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1. Introduction

In the previous lecture an overview was given by dr. Práger on the modernisation and RTD activities which are in progress at the Division of Atmospheric Observations of the Hungarian Meteorological Service. One of the important parts of the modernisation is the equipping of the surface synoptic stations with Automatic Weather Station units.

The pioneering MILOS-500 AWS’s started their operation already in 1993. In 1994 seven more stations were put into operation. Presently the installation and test operation of several more stations is in progress and in the future additional ones will come into operation - according to our plan altogether 30-32. In connection with such a change in the instrumentation of observations numerous questions arise. One can study the automation of observations from the following aspects:

1. Financial aspects, such as cost of investments, cost of operation, etc.
2. Technical background of operation, such as frequency of failures, maintenance, calibration, etc.
3. Arrangement of work (e.g. unmanned automatic operation at nighttime, automatic operation completed by visual observations at daytime, etc.)
4. A very important aspect is to study the homogeneity of time series of data during and after the change of instrumentation.

In my presentation I would like to talk only about the last problem. In my opinion this is the most important question for the future. In my belief next generations will be interested only in the quality of the data, collected by us, and they will not be interested, for example, in our financial difficulties.

The automation of measurements means the change of sensors for almost all of the meteorological parameters. The basic question is whether the automation causes any change in the time series, or not, and if it does, how large this change is.

The new and the traditional sensors can be compared in laboratory and at field conditions as well. We preferred the field-comparison. After the installation of the first 5 automatic weather stations, during the last one year we carried out a field comparison. In Fig.1 the sites of synoptic stations participating in the comparison can be seen. Comparison was performed with only four stations, because at the fifth synoptic station equipped with AWS earlier than 1994, traditional measurements were immediately stopped.
2. Organisation of the instrument comparisons

Let us see now what kind of sensors has been compared. (Fig.2.)

<table>
<thead>
<tr>
<th>List of Sensors Compared</th>
<th>Sensors of MILOS 500 AWS</th>
<th>Traditional Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>WAA15A</td>
<td>FUESS</td>
</tr>
<tr>
<td>Pressure</td>
<td>DPA21</td>
<td>mercury barometer</td>
</tr>
<tr>
<td>Humidity</td>
<td>HUMICAP</td>
<td>psychrometer</td>
</tr>
<tr>
<td>Temperature</td>
<td>Pt 100</td>
<td>trad. thermometer</td>
</tr>
</tbody>
</table>

The WAA15A wind sensor is a 3-cup optoelectronic anemometer, manufactured by VÄISÄLÄ. It measures the wind-speed with high time resolution, so it is suitable to detect both the mean wind and the wind gust. Its data have been compared to readings of the traditional FUESS anemograph, earlier used as the standard instrument of the synoptic network. The FUESS instrument contains a 3-cup anemometer to measure the mean wind-speed and it also contains a Pitot-tube to observe the wind gust. Both the mean wind-speed and wind gust have been compared.

The DPA21 pressure transducer is also manufactured by VÄISÄLÄ. It is equipped with three independent aneroid capsule and the output signal is generated capacitively. It has been compared to traditional mercury barometers.

The VÄISÄLÄ produced relative humidity sensor HMP35D, frequently called Humicap, has been compared to psychrometers.

Finally, the PT100's (100 ohm resistance platinum thermometers) have been compared to the traditional (mercury) station thermometers.

Of course, all MILOS-500 AWS's have been equipped also with other type of sensors, such as: wind vane, pyranometer, soil thermometers, and so on. However, these sensors were not included in the present intercomparison.

The comparison was carried out separately for each station on monthly basis. We calculated the monthly means and standard deviations concerning every month. The monthly basis was necessary in order to study the temporal stability of differences.

The duration of parallel measurements was actually shorter than one year because in the beginning numerous data deficiency was found in the time series of the automatic stations. Nevertheless, the quantity of data obtained was sufficient for the comparison.
3. Evaluation of the results

Let us see the results now. We have got many results concerning different stations and different months. It is not so easy to overview them. In the following I will show you some typical figures and some interesting exceptions.

Our first parameter is the **hourly mean wind speed**. In Fig.3, one can see the distribution of monthly average differences between the data of the VÄISÄLÄ sensor and the FUESS instrument, mapped against windspeed, for an arbitrarily chosen site and month. The vertical lines show the respective standard deviations. The difference between the outputs of the two anemometers depends on the wind-speed. Above 2 m/s velocities VÄISÄLÄ values are less than FUESS values. The difference increases with the wind-speed. The relative differences (in percents of the wind-speed) are stable in time, but several different values were found for it stationwise. At some places they reached 10%.

In the above concern it is worth to mention an interesting fact. Recently, some of our VÄISÄLÄ anemometers were tested in wind tunnel by the courtesy of the Slovakian Hydrometeorological Service. In one of the tests we compared the performance of brand new sensors, and such ones which were operational outdoor for about one year. The results shown that the outputs of anemometers agreed within 2%.

Coming back to the VÄISÄLÄ - FUESS comparison we probably can conclude that the spatial variability of relative differences is due to the variability of FUESS instruments.

Let us see now the comparison of **wind gust**. Results can be divided into two groups, depending on the maintenance condition of FUESS instruments. Into the first group we have put the FUESS instruments, which were in good condition. - we can call it “after maintenance group”. The anemographs, which were found in poor condition formed the second group, we can call it “before maintenance group.” (The frequency of regular maintenances is 1 year.)

![Figure 3: Hourly mean wind speed](image)

In Fig.4, you can see an example for a FUESS in good condition. In the range above 10 m/s the VÄISÄLÄ anemometer gives smaller values of wind gust and in that range the difference is independent of wind gust.

In Fig.5, we can see an example for a FUESS in bad condition. There are large differences which are increasing with wind gust. This Figure shows the most extreme result of the whole comparison. After maintenance the deviation has changed dramatically. Our conclusion is the following: the replacement of the FUESS instruments with electronic anemometers is necessary, as soon as possible.
Let us go on to the analysis of the pressure data. For the comparison we used the station level data instead of sea level data in order to avoid the consequences of different calculation methods for sea level reduction and thermal correction, as well. In Fig. 6, one can see the results. These are summarized data concerning the whole campaign. The differences obtained were very stable month by month and in the range of 980 - 1050 hPa, in which we practically could study them, they were independent of pressure values. In synoptic site Keszthely it is probably useful to check the VAISALA barometer (mercury barometers are well-maintained and yearly calibrated). We can conclude that, in general, VAISALA pressure sensors give higher values than the traditional mercury barometers. The differences are about 0.5 hPa and their standard deviations are pleasingly low. They are about 0.3 hPa. It can be supposed, that systematic differences are due to the difference of reference instruments. It seems, that the reference used for factory calibration gives values higher than our national reference. The detected systematic difference does not cause big problems because the pressure sensors can properly be adjusted.

The next is the study of relative humidity data. In the case of relative humidity comparison the results show poor consistency (meaning similarity to each other). The pattern in Fig. 7 can be considered somewhat typical. We can find good agreement in the range of higher humidities, but in the range of low humidities the VAISALA sensor measures less values than the psychrometer. In extremely dry air conditions the difference exceeds 10% in relative humidity. In Fig. 8, we present another comparison diagram of humidity data obtained at the Baja station. The difference is positive for whole measuring range. We feel that quite big uncertainty in interpreting humidity comparison results remained for study in future.
The last parameter in our comparison is the **temperature**. Unexpected results were nowhere found: for every station the monthly differences fluctuated between 0 and 0,2 C.

It is necessary to tell some words about the circumstances of comparison. VÄISÄLÄ sells the temperature and humidity sensor with a radiation shield. According to our former experiences the radiation shields can considerably modify the result of temperature measurements comparing with values of thermometers placed in standard thermometer screens. For our comparison we placed both thermometers into the same thermometer screen in this case no considerably differences were found, according to the above.

On this basis we have decided to operate the VAISALA temperature and humidity sensors in thermometer screens. It seems to us, with this choice the homogenity of the temperature data is guaranteed.

**4. Conclusions**

Finally I would like to summarize the results of the comparison.

1. For hourly wind speed slight systematic differences were found, reaching 10 % for some station. The values obtained by VÄISÄLÄ anemometers are lower.

2. Differences in wind gust are in strong relationship with the maintenance condition of the FUESS instruments. In case of FUESS anemographs in good condition the systematic differences do not exceed 1 m/s. The FUESS gives the higher values.

3. In concern to the pressure sensors VÄISÄLÄ transducers give higher values in about 0,5 hPa than our mercury barometers. The difference is very stable in time.

4. There is some inconsistency in the results obtained by the comparison of humidity sensors. Further efforts must he taken in order to clear up the reason of inconsistency.

5. In the case of the thermometers compared no significant differences were found. Both sensors were placed in the same thermometer screen.


AUTOMATIC BOARD WEATHER STATION ABWST OPERATED ONBOARD CONTAINER AND MERCHANT SHIPS AS WELL AS ONBOARD RESEARCH AND FISHERY PROTECTING VESSELS

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1. INTRODUCTION

Due to the continuous decrease of navigational staff and the removal of the wireless operator there is no capacity left to carry out and transmit the meteorological surface observations onboard merchant ships. Therefore, the Deutsche Wetterdienst decided to equip a certain number of marine platforms with an ABWST using the global positioning system to localize the system.

Nevertheless, there is an option to place a PC or a Laptop on the captain’s bridge to add every hour eye observations like the state of the sea, actual weather and visibility. Out of the preparation of the hourly messages all meteorological parameters are displayed on the screen in an uncoded format.

![Components of the ABWS]

Figure 1: The components of the Automatic Board Weather Station

The ABWST receives and processes the signals of the air temperature, water temperature, humidity, pressure and wind sensor, adds the course, speed and position of the ship from the satellite navigator and transmits the coded message to the Data Collection Platform DCP from where the messages are transmitted via METEOSAT every hour.
2. SYSTEM CONCEPTION

The system is designed under the basic requirement that installation and maintenance are to be carried out in a very short time due to the short port lay-days of container ships - 8 to 12 hours. Further on experience in a pilot project showed that it is important to be independent from the ship's equipment because of insurance problems which may arise by electrical or electronical defects released by the system.

3. SYSTEM DESCRIPTION

The Automatic Board Weather Station ABWST essentially consists of the four main components:

3.1 Sensors

The meteorological sensors for wind, humidity and temperature are installed on a mast together with a hose coupling for the pressure sensor and the antennas for the DCP (Data Collection Platform) data transmission and the satellite navigator (GPS = Global Positioning System). The sensor for measuring the water temperature is fixed by a magnetic holding device inside the ship’s wall immediately below the water line.

3.2 Data Processing

The processing unit is incorporated into a weatherproof high-grade steel housing which is installed near the sensors. The steel box contains all assembly groups which are essential for the operation of the station. Therefore, these components are installed in such a manner that they and even the whole housing can easily withdrawn by a few grips.

- The heart of the station is the micro-processor-system MILOS 500 which handles the recording, processing, computation and coding of the meteorological and navigational data. The result is a synoptic message transmitted hourly in a WMO FM-13 SHIP format.
- The position of the ship and its course and speed are calculated by the satellite navigator which uses the Global Positioning System GPS.
- The transmission of the synoptic message is carried out by the Data Collection Platform DCP which is linked to the MILOS.
- The pressure sensor in the steel box is combined with the hose coupling on the mast by a plastic pipe in order to compensate for pressure deviations.
- Last not least the housing contains the power pack and the junction devices for the connection cables.

3.3 Power Supply

The power supply and the cabling onboard the ship are prepared by a shipyard by order and for account of the Deutscher Wetterdienst.

3.4 Option

In most cases a personal computer or a laptop is installed on the captain's bridge in order to display the automatically recorded data and to add eye observations like the state of sea, actual weather and visibility; for this purpose a complete coding software is provided to the navigational staff. Before the synoptic message is transmitted to the DCP the MILOS 500 looks if there is any additional input from the bridge, otherwise, only the automatically recorded data are transfered in the coded format to the DCP for transmission via METEOSAT.
4. DATA TRANSMISSION

The prepared synoptic messages are transmitted hourly via METEOSAT to the satellite ground station. This station transfers the messages to the regional data center for input into the global telecommunication links. Additional the messages are retransmitted to the satellite and received in the WEFAX-Channel by users which operate a satellite receiving station. The Instrumentenamt Hamburg has installed such a receiving facility; therefore, the retransmitted messages can be received for monitoring the meteorological observing systems on marine platforms. The information is used to decide on maintenance and repair actions.

5. OUTLOOK

The Deutscher Wetterdienst intends to install about twenty systems onboard ships operating in the Baltic and North Sea and sailing for North America and the Gulf States. These units will provide the metservices with 14400 messages in one month when transmitting hourly. Compared to the traditional observing system which provides the metservices on an average with six synoptic messages per ship and day, that means, 80 ships are needed to collect the above number of messages. The synoptic data from sea are used for the synoptic analysis, data from ports are needed for port climatologies.
DEVELOPMENTS IN THE AUTOMATION OF THE SYNOPTIC AND CLIMATOLOGICAL NETWORKS OF THE HUNGARIAN METEOROLOGICAL SERVICE

T. PRÁGER

METEOROLOGICAL SERVICE OF THE REPUBLIC OF HUNGARY, BUDAPEST

1. DEVELOPMENTS IN THE PAST

Regular meteorological observations have began very early in the countries of the Austrian Empire in the organization of the "Zentralanstalt für den Meteorologischen und Magnetischen Dienst" founded among the first such institutions in Europe, in 1851.

It is not surprising then, that the weather observation network of the Royal Hungarian Institute for Meteorology and Earth Magnetism was born together with the institution itself in 1870. The foundation act of the state meteorological institution meticulously prescribed the countrywide organization of regular meteorological measurements and observations. During the 126 years history of the Meteorological Institute and later, the Meteorological Service the significance of meteorological measurements and observations never decreased. It was always realised that observations are the primary source of information for all kinds of meteorologist's work.

The traditional weather observation network which was based on voluntary observers was completed with synoptic stations employing professional observers from the 1950s. The network of synoptic stations made it possible - in accordance with the growing needs of the society for meteorological information - to observe and measure the meteorological parameters 24 hours a day. More perfect instrumentation and more frequent observations led to better meteorological data both qualitatively and quantitatively, and the synoptic stations, located mainly in county towns, could serve also as regional centres of meteorological information.

From that time the structure of the network of surface meteorological observations in Hungary remained practically unchanged. It consists of three different type of stations: synoptic stations, reporting climatological stations and non-reporting climatological stations. The latter two are serviced by voluntary observers.

2. PRESENT CONDITIONS: THE TRIGGER FOR AUTOMATION

Almost simultaneously with the change of the political system in our country in 1990 the Meteorological Service of Hungary survived a critical period. The culmination of difficulties was triggered by the professional and financial failure of the missile based hail-prevention system, which was considered for a long time the "success-profile" of the Meteorological Service. The new management of the Service tried to retain the integrity of the institution through radical reorganizations involving significant cut-back of the staff. In the new
organisational structure all kinds of atmospheric measurements and observations (surface meteorological observations, radiosounding, meteorological radars, measurements of the atmospheric environment, instrument maintenance and calibration) earlier belonging to the profiles of several different departments of three different institutes were put together in one unit, the Division for Atmospheric Observations. The integration of the whole observation profile in one unit has been proved to be a reasonable decision, the efficiency of work increased, informal connections between people became wider.

The very fast economic changes of the 1990s raised several problems and challenges facing the Meteorological Service and the observation unit, in particular. The most serious challenges were probably the following:

- the traditional COMECON sources of meteorological instruments and professional material (consumables) terminated their activities or became not affordable for us both from professional and financial reasons,

- maintenance and operation costs of the very extended or perhaps oversized network of meteorological stations and observatories reached an unreasonable level.

In this situation the only way was the constant adaptation to the new circumstances both from professional and economical point of view. Adoption of this policy helped to keep the observation network in operation in the past four years without significant reduction of its profile reducing meanwhile the total cost of its operation to 70% of the 1990 value.

The most important strategic ideas and achievements in the "survival process" have been and are:

a) the realisation of the need for reconstruction and modernisation through automation,

b) better and wider knowledge about the world market of meteorological instruments,

c) better international relations, more information about practices of meteorological services worldwide,

d) the adaptation of project-oriented way of thinking.

The realisation of the need for automation in the HMS has resulted from a significant change in our experts' views. Earlier in our service, like in other eastern European services concerning instrumental matters, the principles of "autarchy" or "do it yourself" were the dominating. The limited COMECON market, the difficulties to provide "hard currency" for purchasing new instrumentation led to the common opinion, that new instruments either have to be bought from the very limited collection of inside COMECON manufacturers, or have to be produced by ourselves in the specialized workshops of the meteorological service. After 1990 these options soon became expensive and inefficient.

Gathering insight into the world market of meteorological instruments we were surprised to understand, that the market is wider in magnitude as we earlier knew. It was soon realised that for efficiently providing the supply of meteorological instruments and consumables we have to have a thorough knowledge on the most important manufacturers, and also have to be skilled in market and commercial transactions (tendering, requesting references, determining the conditions of payment and warranty, etc.)

Intensified international relations, and relations with the countries of Western Europe in particular, were good aid in providing us orientation on the instrument market, in the field of meteorological networks and instrumentation the traditional cooperation with the
Austrian Zentralanstalt and later cooperation with the Regional Instrument Centre of RA/VI in Trappes were extremely useful. Beside the informations on the Instrument market we learned from our partners three important things:
- although the automation of observations is very costly, on long range it will lead to the decrease of Instrument maintenance and replacement costs, because with the time the modern electronic equipment becomes cheaper than the mechanical instruments the manufacturing of which needs a great amount of handiwork,
- automation is the only way to radically decrease network maintenance costs by reducing the number of manned observation stations,
- the automation at manned stations makes it possible to deliberate the human staff (observers) from mechanical work and to redirect their capabilities to higher quality meteorologist’s work.

The recognition of these facts led us to the decision not to seek new suppliers of traditional manually operated Instruments, but instead begin the replacement of them with modern electronic telemetric devices. We determined as final aim of the modernisation the installation of AWS equipped with electronic sensors instead of mechanical measuring instruments and the parallel development of a telemetric network via X.25/modem PC-connections instead of the presently used VHF (audio) radio connection, telexes and postal services. An important condition was that modernisation should not lead to data reduction except the loss of information induced by

The estimated cost of modernisation for the total profile of surface meteorological observations is about 2 million US dollars taking into consideration the 25 synoptic and 100 climatic stations we operate now. To raise funds for this aim in our circumstances needs the project-oriented way of thinking. Logical connections and priorities were determined between the various parts of the total project task, in order to divide it into sub-project tasks and apply for funding for partial development aims at organizations supporting that particular aim.

3. STATUS OF MODERNISATION PROJECTS

In the following we would like to give an overview of all modernisation and RTD projects which are presently in progress within the Division for Atmospheric Monitoring of the HMS. Many of them are directly connected with the installation of AWS, some of them a little more loosely. Together they will reveal the structure of modernisation.

3.1. The automation of synoptic stations.

This was one of the firstly initiated development projects and it has reached its mature phase for today. Financial support was seeked at the Ministry of Environment and Regional Policy (MERP) and at the National Committee for Technical Development (NCTD).

Resulting from a rather long decision-making process in December 1992 we have chosen the MILOS-500 automatic weather station of the well-known Finnish company VÄISÄLÄ as basic instrument of our automated synoptic stations. Presently 12 stations are operational and the import of AWS for all synoptic stations belonging to our network is in progress. It is realistic to forecast the total re-equipping of all synoptic stations which are operated by us autonomously (18) before 30 June 1995. Seven more synoptic stations which are operated jointly with the Hungarian Army (4), the Paks Nuclear Power Plant, the Pannon Agrarian University and the Eger Pedagogical Institute will also be equipped with MILOS-500
before the end of this year. Taking into consideration the unmanned operation of many of these stations and the possible breakdowns MILOS-500 AWS will be installed at three more sites (now operated as reporting climatological stations). These stations will serve as the reserve of the automated synoptic network, consisting this way altogether out of 30 AWS. The sensors are also manufactured by Vaisala with the exception of the tipping bucket raingauge, which is a product of Lambrecht and the pyranometer which is from Kipp & Zonen.

3.2. The reconstruction of the telecommunication system of the synoptic stations.

Together with the developments of the previous project the telecommunication system of the synoptic stations was also to be reconstructed. Instead of classic means of information transmission as the VHF network and public telex lines (the use of which have already been or will soon be terminated) PC-PC connections through modems and X.25 lines will serve as means of regular data transfer from the stations to the telecommunication centre (both for telemetered and observed data, SYNOP, SPECI, METAR messages). Data transfer in the opposite direction (forecasts, warnings, etc.) and communications between arbitrary nodes of the network (E-mail, circulars, etc.) are also foreseen. This development is now before completion. The work was done partly by us, partly by a Hungarian entrepreneur, the Köszöf Ltd., well-known and highly evaluated by us by their previous work on the automation of the weather radar network. The planned time for full implementation of the new telecommunication system is 30 June 1995.

The project was sponsored by the NCTD and the National Command of the Civil Defense (NCCD). Meanwhile the Meteorological Service of the Hungarian Army has also modernised its telecommunication system, so together with the system of AWS, the telecommunication will also be integrated.

3.3. Automation and telemetering in the network of climatic stations.

At the present time there are almost 100 climatic stations in Hungary operated by voluntary observers and among them almost 60 are daily reporting (until recently by postal telegrams, now by phone). Amortisation of their instrument park is high and replacement of retired observers is almost impossible. These facts implicate the need for automating these stations just after the synoptic stations. It will be a future project extending to the end of the 20. century. The tender for the first phase of this development (the automation of the first 25 stations) is now opened, the supplier will be determined before June 30, and the planned time for implementation of the automated network is 31 March 1996. Cheaper and less high performance AWS's are planned to be implemented than those at the synoptic stations. The telecommunication for the reporting stations is to be solved together with the automation, with the same hardware and software as for the synoptic stations. Reporting stations will be connected into a star-like network, with the synoptic stations as message collectors. Non real-time climatic data collection is planned to be solved via memory cards.

Support was obtained from the MERP.


This was the very first technical development project initiated by us. Practically all goals of the project has been achieved before the end of 1994. At the three radar stations of the National Meteorological Radar Network PC-LAN's performing automatic radar control, production of digital images and data transmission are installed. The two provincial stations are sending digital pictures in operative regime to the telecommunication centre of HMS and also to local users. In the telecommunication centre a composite radar image of Hungary is produced
and sent to local and remote users, those who wish to receive it. The Budapest station, where two channel parallel digitization has been implemented (both on the 3 and 10 cm channels of the MRL-5 radar) became fully operational only from the beginning of May, connected with the recent relocation of the station. Partial tasks to be solved are intercalibration of the radars and implementation of comprehensive image improving and processing algorithms, like ground cluster filtering, correction for attenuation in various precipitating objects, real-time adjustment to rain-gauge data, etc.

The project was supported by the NCTD, Water Management Authorities, Road Maintenance Authorities, and in a little part, by the Authority for Maintenance of Airports and Air Traffic. The contractor for supplying the total system was the mentioned Köszöfa Ltd.

3.5. The reconstruction of the atmospheric radioactivity monitoring and early warning system of the HMS

Our Service is operating the firstly established atmospheric radioactivity monitoring and early warning system in Hungary. It is located at the synoptic stations and consists of gamma dose-rate sensors and aerosol/fallout/precipitation total beta activity analyzing minilabs. The readings of the dose-rate sensors were taken and transmitted by the observers, and the laboratories were and are also served manually. In the first stage we wanted to convert the dose-rate sensors into fully automatic telemetric devices, which are attached to the MILOS-500 stations. BITI proportional counters for 10 stations are purchased and their interfacing to the AWS’s is solved. The network becomes operational together with the AWS’s and will constitute a part of the unified early warning network of Hungary operated jointly by the Army, the Civil Defense and the HMS.

The support for this project came from the Civil Defense and the Ministry of Interior (MI), its supervising agency.


The decrease of stratospheric ozone amount in the past three years over the Northern Hemisphere drew the attention of the Hungarian society to the establishment of a national system of monitoring the UV-B radiation and early warning of dangerous events. Sponsored by the MERP, the HMS became the basis of the system. During 1994 three ROBERTSON-BERGER UV-B photometers were installed in Budapest, Balaton and Kékestető, the touristically most important areas of the country. Their data are transmitted also via the MILOS AWS’s to the telecommunication centre. Method of evaluation and forecast of dangerous events are under development. Details of this project will be the subject of the presentation of Mr. Zoltán Nagy.

3.7. Laboratory for calibrating electronic meteorological sensors.

The laboratory of the HMS for calibrating traditional meteorological instruments, i.e. barometers, thermometers, baro-, thermo- and higrographs is totally outdated, many of its devices has been broken down beyond repair. The aim of this project is to install a new laboratory which is suitable for calibrating both traditional and electronic sensors complying with the requirements of ISO 9001. Funds for the first stage of development have been raised from the NCTD, purchase of the first part of new calibration devices is under way.

3.8. Reconstruction of the Szeged radiosounding station

The measurement profile of our second radiosounding station at Szeged was strongly reduced in 1992, because there was no more supply of MARZ sounds from Russia. From that
time only corner reflectors have been lifted by the balloons and upper-air wind measurements have been performed via sound-tracking radar. Recently, a VÄISÄLÄ PC-CORA radiosounding unit suitable to replace the outdated Soviet system, has been donated to us (as the reimbursement for participation in a Japanese sponsored environmental project). MERP was a good partner in sponsoring the purchase of the necessary consumables the (very expensive) RS-80 sounds. From May 1 the Szeged station is operational again, with 1 sounding/day at 00 UTC.

The die is cast. Successful completion of the above projects will lead to the renewal of the most important parts of our atmospheric observing system and will provide the domestic meteorology the way to proper operation. Failure of subprojects will unavoidably narrow down the scope of all meteorological activities in Hungary, and may lead to long-term stagnation.
MORE THAN 10 YEARS OF EXPERIENCE WITH THE AUTOMATIC METEOROLOGICAL OBSERVATION NETWORK IN AUSTRIA

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1. INTRODUCTION

This paper shows the point of view of users of the output of automatic stations like e.g. climatologists. Automatic meteorological observation is not an idea of our century, although the first practically used systems were installed in the 1960ies. Already in the 1870ies the Dutch instrument designer Olland developed on the suggestion of Buys-Ballot a so called telemeteograph with which meteorological measurements could be sent via telegrapher to meteorological centers. At the same time a similar principle was developed in Belgium. The whole system was not very successful because of the high costs for installation and service [5].

But the demand for automation was increasing with the interlink of economy with weather. Long distances to the registration instruments, installed appropriately from a meteorological point of view, can considerably deteriorate the quality of the data. Furthermore, the hourly evaluation of the generally analogous registrations of different meteorological parameters, is increasingly necessary for the diverse purposes of technical meteorology and climatology of health-resorts. This, however, entails great expense of personal and costs.

In the 1960ies and 70ies the considerable progress of micro processing techniques caused the development of low-priced automatic systems for the recording of meteorological and climatological data. Without going into details we have to distinguish four generations and the real step forward was that most of the tasks of these systems is executed by the software and not only by the hardware.

In Austria the beginning of automation of meteorological observation was at the end of the seventies with the development of the algorithms for data processing and recording and we could divide it in two steps [6, 9]:

1981 the Central Institute started to replace some conventional climatological stations by so called partial-automatic climatological stations (TAKLIS). They are working autonomously, only with local storing and the data on tapes is sent by mail every month to our central or local offices

1982 the first test stations of a partial automatic weather station network (TAWES) were put into operation. On this network the data are collected nearly real-time (every 10 minutes a telegram is sent via leased telephone lines to regional centers) and the data are used for forecasts as well as for climatology [7].

Because of its pronounced vertical structure, Austria possesses a relatively dense net of about 260 meteorological stations. About 80 are synoptic and climatological the rest is only climatological. All stations should produce values, mainly in the mountainous regions, which are also representative for the further regions and which are not directly influenced by the local micro-climate. To fulfill these
conditions perfectly is often difficult, because the choice for the location of the instruments frequently depends on the person eligible for observing tasks. Weather observations in Austria are generally not made by professional observers but by volunteers. Today it is nearly impossible to find persons who take care of all instruments [10].

2. SYSTEM CONFIGURATION

![System components diagram]

Figure 1: System components

The air temperature and the humidity are measured inside an aspirated ordinary stevenson screen so as to avoid the alteration of the measuring methods of conventional stations.

The task of the observer is reduced to the recording of the elements not measured by the sensors but necessary for a climatological service for example: cloudiness (amount and density), visibility, difference between liquid and solid precipitation, atmospheric phenomena like dew, hoarfrost, ripe etc.

3. DATA PROCESSING AND TRANSMISSION TO THE USERS

To make possible a comparison with the conventional registrations and evaluations of meteorological data, special programs were developed for the interrogating and processing cycle.
Figure 2: Example of Data - and Progam scheme of Temperature
The tape is sent every month to the Central or to our branch-offices.

The hardcopy stays at the stations, and the 10 minutes telegram is stored in some computers before splitting it into the different data banks.

4. DEVELOPMENT OF THE NETWORK

Till 1991 over 130 TAKLIS (including over 100 TAWES) have been put into operation with 6 up to 33 sensors connected with the system. The distance between the sensors and the central processing unit is varying depending on the observation site, but could go up till 500m.

A vital step in ensuring that data from an automatic station are satisfactory is to place the station on a site where the exposure of all sensors is acceptable and will not be compromised by the development of vegetation or buildings in the surrounding area. On this point we were not very successful in Austria we had to learn the hard way. We found that without thoroughly searching an optimal site and simultaneously looking for an observer and caretaker of the auto-station it is impossible to install the station. In some cases we have been looking several years to find all the conditions in a region [11].

5. EXPERIENCES WITH FAULTS

When running automatic weather stations observation loss caused by technical problems is inevitable.
Figure 5: Percentage of Observation Loss

Hardware or software problems at the autostations, damages of the sensors were the other reasons for observation loss.

The figure 4 does not show the failure of data caused by communication line faults, because these data are lost for the synoptic use only. The local storage of data on tapes helps to fill very easily the gaps caused by communication line faults.

These gaps in the data series can be closed by interpolation in space and time by means of the registration of neighbouring stations. The algorithms for these interpolations have been worked out and tested before the network of auto-stations was installed. With the increasing number of auto-stations this task became more and more difficult. Until now we only can fill gaps on a base of monthly and daily values. Sometimes if the gap is small also hourly data could be interpolated. Meanwhile we hope to implement a new software package in 1995 with which the correction of the data and the closing of the gaps will become much easier. This is the only way to keep up with the additional work in the climate services that comes together with the automation.

6. INHOMOGENEITIES

Inhomogeneities of climatological time series are another problem caused either by the change from conventional to automatic systems or by new measuring units, a new technology of sensors or by new processing algorithms. Data measured on the same place and with the same environmental conditions but by different systems usually show slight discrepancies. The deviations can be divided into systematic and stochastic ones. If the systematic differences are not corrected inhomogeneities in the climatological series are the consequence. Intercomparisons of different systems over a long period of time on some representative locations covering different weather conditions are necessary to test the compatibility and to find out correction algorithms.

Intercomparison results of temperature have shown that using our automatic network in Austria there are no systematic differences in monthly means [2].

Humidity: Satisfying results with the results of the Pernix sensor we find only in the areas under 1500 m. The new developed dew point sensor shows good results, if it is well maintained [8].

Air-Pressure: Good results with the METEOLABOR sensor that is very expensive. Cheaper sensors had heavy electronic drifts and are therefore useless.

Precipitation: Using the tipping bucket the measurements in high alpine regions show a poor performance in accuracy and reliability. In the last years better results have been achieved with a new system based on a weighing system [1, 5].

An analysis of the faults shows that most of the data was lost because of power failure at the stations. Although every station has a battery backup for minimum of two hours and an auto restart after power failure up to 30 days nearly 40% of the lost data was caused by this reason. Lightning may cause that the fuses blow in the building where the central unit is situated. The caretaker or observer should detect this within the next two hours to prevent data loss. This often does not work fast enough and the lost of data is inevitable.
Wind Speed: At the beginning we made a big mistake: only the vector means of the wind speed over one hour were stored. Specially in the inneralpine valleys we have orographic wind systems and the vector means over the hour may differ from the arithmetic mean more than 100%.

The TAWES has as output the arithmetic wind velocity means over 10 minutes and sends it over the communication lines to our computers, but the local storing on an hourly base is still missing.

Sunshine Duration: The results of the intercomparison regarding sunshine duration data recorded by the conventional systems with CAMPELL-STOKES sunshine recorder and the HAENNI-SOLAR sensor at the autostations point out two systematic differences that are caused by the different technical features that have different response to some types of cloud formation. During periods of rapidly changing cloud conditions the conventional recorder indicates more sunshine than the autostation sensor. Due to lower time resolution of CAMPELL-STOKES sunshine duration seem to be overestimated by the classical instrument. In situation of small sun elevation the higher sensitivity of the HAENNI causes more sunshine in respect with the conventional type. In average HAENNI measures 1% to 4% more sunshine at low-land stations, but 5% less at the mountain areas [3].

7. CONCLUSIONS

13 years of experience with meteorological autostations in Austria show many improvements. Nowadays is nearly impossible to do up to date meteorological measurement and observation without the automatic systems. The quantity of the data is enormous and so that modern climatology has made a big step forward.

To assure that data from a network of auto-stations are of satisfactory quality and are delivered in a timely and dependable fashion requires considerable effort from staff with a wide variety of skills.

8. REFERENCES


AUTOMATION OF OBSERVATIONS IN THE NETHERLANDS

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1. INTRODUCTION

A network of manned and unmanned Synoptic and Climatic stations and a great number of observing sites with one or several sensors and auxiliary observers at the main land and the islands has been replaced by a network of (semi)automatic observing stations (AWS). This replacement was done by the KNMI. Also the observing stations at the airports of the Royal Air Force and the Royal Navy were modified according to the standards of the KNMI and became a part of the network.

The increasing amount of helicopter operations at the North Sea ask for more weather information available for flight planning, briefing and flight support. Also information about wind, waves, tidal movement etc. is required for the support of big oil tankers, the Coast Guard, the maintenance of the sand coast and projects in the tidal zone. At several existing platforms at the North Sea and at some piles in the tidal zone (semi)automatic weather stations are deployed. In the long term planning more automatic weather stations will be installed on new oil platforms. The existing weather stations at the above mentioned constructions, which are owned by Oil Companies, the Water Management Division of the Government and the KNMI, will be integrated in the network. In fig.1 the observing network is shown.

![Observing Network anno 1995](image)

Although in the entire network the standards as developed by the KNMI are used, there is an exception to the data acquisition, processing and storage of data at the main civil airports. Because of the requirements for additional or modified data generated by the human observer, the necessity to make different products as the Special or Aerodrome Warnings and the connection with other ATC-systems a different system has been developed. The most recent part of it is the Graphical Presentation System for the measured data.

Two Synoptic stations of the KNMI and the stations at the military airports will be kept manned for the time being. To make it possible to insert visual observations into the automatic weather stations an interactive part of the AWS is developed.

2. THE NETWORK

2.1 General

The development of a new network concept and the realization of this was forced by the in- and external demand of decreasing the costs of observations. The new intelligent sensors, data acquisition technology and automatic calculation, validation and presentation processes together with the remote

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"KNMI: Royal Netherlands Meteorological Institute"
maintenance technology made it possible to meet this demand. The KNMI developed standards for the observing sites (sensor type and layout of the sites), data communication, processing and presentation. At the civil airports the processing is the most complicated. In the Data Acquisition System at the Synoptic/Climatic stations only a part of this complicated process is implemented.

2.2 Concept Synoptic/Climatic network

The design specifications of the network for Synoptic and Climatic stations were:

a. implementation of an interface, called the Sensor Intelligent Adaption Module (SIAM), between the sensor and the Local Data Acquisition System. This SIAM is a small autonomous micro computer system. The advantages of such an interface are:

- the replacement of an sensor does not influence the software of the Data Acquisition System;
- preliminary calculations and data validation are done in the interface;
- standard messages are used, through which the data communication and data processing is done more simply and is standardized;
- status data are added into the standard message;
- it allows technicians to monitor its status and that of the connected sensor(s) using fixed telephone lines or the public network.

![Diagram](image)

b. a Local Data Acquisition System which:

- produces Synoptic and Climatic messages according to the WMO-definitions;
- stores the data from the interface and the messages for several days in a local 10-minute data base;
- send the data and/or messages to a Central Data Acquisition System on request;
- send messages to authorised users on request;
- allows technicians to perform remote maintenance.

c. a Central Data Acquisition and Message Switch System which automatically gathers the messages and send them to:

- the GTS;
- the users such as meteorologists;
- connected systems as the Plotprocessor for weather charts, Client Information System, etc.;
- Central Database for observations.

Figure 2: Concept Synoptic/Climatic network.

The configuration of the automated Synoptic/Climatic station in the observing network is shown in fig.2.

2.3 Concept aviation system at the civil airports

The concept of the automation of the observing sites at the civil airports is the same as for the Synoptic/Climatic observing sites. The Data Acquisition System, called AMIS (Aeronautical Information System), is different, namely:

- it produces Synoptic and Climatic messages according to the WMO definitions;
- it produces standard reports as Metar, Special, Sigmet, etc.;
- it automatic disseminates the reports to the connected systems and to the Central Data Acquisition System at De Bilt (KNMI-Headquarters);
- the Data Acquisition System is connected to systems as ATIS, an Alpha-numerical Database, a Graphical Database, Airport and ATC Television Circuits, etc.;
- allows remote maintenance by technicians;
- the different Data Acquisition Systems at the civil airports are connected in order to make it possible for observers/meteorologists at one airport to look at the data at another airport.

The whole system from sensor to presentation/dissemination as it is in use at Schiphol Airport is shown in fig. 3.

Figure 3: Observing System at Schiphol Airport.

The standard reports such as Actual, Metar, Special, Synop and Clim are made automatically by the AMIS. The observer can add visual observations and disseminate the reports. But if he doesn't do this the reports are disseminated automatically. The observer is only allowed to change the values of the measured data when it is quite clear that the data presented are wrong. Free text pages are available for the Trend, Taf, Aerodrome Warnings etc.

The data/reports of the civil and military airports are stored at two databases:

a. an Alpha-numerical Database. This database is connected to the ATIS, MOTNE/AFTN, other Databases and users.
   For briefing and consultation three modes are available, namely:
   - the Station Mode, in which the data are available at station level;
   - the Bulletin Mode, in which the reports are available in the same bulletin form as in MOTNE;
   - the Flight Mode, in which the data are stored flight oriented. This means that by typing the code of the destination all the data of the stations needed for that particular flight are presented.

   The database is available for briefing and flight planning to pilots and airlines. Historical information is available for up to 72 days earlier.

b. a Graphical Database. In this database the 1-minute average values of the observations (sensors and visual) of the four main civil airports are stored. Historical information is available for up to 30 days earlier.

   The data are presented on colour screens. Using window techniques the graphs of the sensor data of every possible combination of the four main civil airports can be presented at every workstation of meteorologists, observers or technicians. It is also possible to choose the vertical scale and the time scale of the graphs if wanted. No paper recorders are used any more.

In fig. 4 two examples of screen dumps are shown:

a. actual measured wind, visibility (MOR or RvR), and cloudbase data at Schiphol Airport and observing sites around it.

b. the MOR calculated from transmissometers measurements along runways, wind and temperature/humidity data at Schiphol Airport at different time periods.
Figure 4a: Screendump Graphical Presentation Meteorological Data Schiphol Airport

Figure 4b: Screendump Graphical Presentation Meteorological Data Schiphol Airport
2.4 Concept platforms and piles

At the moment the Automatic Weather Stations at several platforms at the North Sea will be modified by the Water Management Division in consultation with the KNMI.

At the platform F3 the KNMI have installed a new AWS. The METAR and Synop are transmitted by satellite communication. Remote maintenance is possible using a satellite telephone link. For the landing operation of the helicopters the data are presented to the operator at the platform as well. Special attention is given to location of the sensors at the platform. Due to the possibilities at the platform and the requirements for an undisturbed measurement the location of the sensors will be a compromise always.

In order to realize the same concept at the piles in the tidal zone a low power SIAM and transmitter under development.

3. FUTURE DEVELOPMENTS

3.1 Manned stations

Within a few years the manned observing stations at the military airports will be closed during the hours at which they are not operational (at night). In the long term, 10-15 years, this will also be the case for the civil airports except Schiphol Airport. The complete automation of the manned Synoptic stations will be much sooner. The costs involved to maintain a manned station are to high.

It is to be expected this will create resistance from the people involved in meteorology. So this loss has to be compensated by new observation, presentation and production technics and in some cases more observing stations. Although this process sounds somewhat revolutionary one must be aware that at this very moment, due to the automation of observations, the role of the observers is already changing into that of a process controller and the "meteorological knowledge" is disappearing rapidly. The recent development in the accuracy of sensors makes the reliability of the automatically measured data better and more uniform than the visual observations of different observers. The problem with the measurement of phenomena as cloud coverage, cloud type and weather type will be solved within the coming decade.

3.2 Synop

Synop and Clim reports will not be produced anymore at the observing sites. The data will be stored in a Central database in basic numerical form and redistributed as an input for analyses, nowcasting models etc. and in the Synop format for international data exchange.

3.3 Presentation

Graphical display of data at special presentation systems for the observers, meteorologists and technicians at will be continued. Due to the fact that these data have to be watched continuously the presentation will not be implemented in the meteorologic workstations.

4. CLOSING REMARK

External and internal forces demanding efficiency and low cost systems will continue to affect the field of the automation of the observations. This will be a continual source of conflict with the meteorologists who want more information from more locations, the technicians with new costly measurement techniques and the climatologists who will prefer established methods and regard the new developments with suspicion.
FINAL GENERAL DISCUSSION

The workshop was finished by a general table discussion where the following questions were discussed by several participants and finally there was reached nearly unanimous agreement.

1) *Should WMO take the leadership to establish guidelines for creating standards of surface autostations?*

Yes. CIMO should lead but must coordinate with other commissions. Some recommendations already exist but are not precise enough. They should be extended using written proposals such as the document on algorithms of ASOS. A Working Group for surface measurements has to be established, similar the WG for upper air measurements.

WMO must coordinate with ISO.

2) *Is there a necessity to review and prepare techniques for guidance material on data processing and quality control procedures involved in the conversion of conventionally-operated stations to automatically-operated stations?*

Yes. A summary of the various techniques and procedures used by the meteorological services is required and should be published.

3) *Is there a necessity to recommend new criteria for the quality control and management of data from automatic stations?*

Needs to be a means of identifying (flagging) instruments used and when changes introduced in the data acquisition networks.

4) *Should there be established guidelines and proposed standards for the implementation and archiving of data from automatic meteorological stations, including averaging techniques and temporal and spatial resolutions?*

Yes. Especially in regard to algorithms for subjective/visual observations. The recommendations of CIMO are not precise enough.
A NEW LOW-COST AWS FOR CLIMATOLOGICAL AND ENVIRONMENTAL MONITORING

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SUMMARY

A new low-cost AWS has been introduced in the National Network of the NIMH. The operational features, the data processing techniques and the quality control, storage and transmission capabilities of the AWS are discussed in the paper.

1. INTRODUCTION

In the latest few years more than a dozen modern AWS by Vaisala, W.Lambrecht and other producers have been installed in Bulgaria, out of the national meteorological network. Several automatic systems designed in Bulgaria have been used in the National Institute of Meteorology and Hydrology (NIMH) for experimental purposes in Hydrology and Environmental studies. The main barrier to introducing good foreign made AWS in the national network of NIMH is their high price. At present, in the conditions of the "economy in transition", the price of such one AWS is comparable with the labour costs budget for the full staff of one conventionally operated meteorological station for several years.

To solve this problem a new low-cost AWS has been developed. The design and the specialized software for data processing is accomplished in accordance with the requirements and observing practice of the NIMH and WMO. The total price of one AWS is several times lower than the price of the compatible models of foreign made AWS.

Based on the operational experiences in the national conventional network of the NIMH, the AWS has been designed to carry out observations both:
- in climatological and environmental monitoring stations with relatively long-time local storage of data,
- in synoptic and climatological stations with currently transmitting of the observed data

2. ARCHITECTURE OF THE AWS

The schematic diagram of the AWS is shown in Figure 1. All the sensors are combined with a transducer having current loop output, which provides the exposure of the sensors at long distances (up to 200 m.) from the registration device - METEOCON. At present the following sensors are already available and put into observations:

- wind speed - optoelectronic cup anemometer with frequency output, range: 0.5-50 m/s,
- wind direction - optoelectronic wind vane, 6-bit parallel Gray code output, range: 0 - 360°,
- air temperature - two-element "linear thermistor", range: -30 - +60 °C,
- soil temperature - two-element "linear thermistor", range: -30 - +60 °C,
- air humidity - thin film capacitor with frequency output, range: 0 - 100% RH
- atm. pressure - piezoresistive transducer, temp. compensated, with frequency output, range: 800-1100 hPa.
Additional sensors for environmental control and radiation monitoring (GM counters, proportional counters etc.) can be connected to the AWS. An other group of sensors are in advanced development and they will be put into measurements in the next months:

- precipitation - tipping bucket raingage, heated, orifice 200 cm², resolution 0.1 mm,
- evaporation - height of water level in evaporators, span: 0 - 150 mm, resolution 0.1 mm,
- height of water level in rivers and water pools span: 0 - 20 m, resolution 0.05 m.

All the sensors are connected to the METEOCON - a microprocessor-based specialized data acquisition and processing controller, which executes the METEOSOFT real-time operating package. METEOCON scans the counter registers clocked by the incoming frequency signals from the sensors and processes the data, according to the METEOSOFT program. The controller has 12 counter (16-bit) and 3 digit inputs, 6-bit Gray code input (all inputs opto-isolated), 8-bit CPU (6805 core), 8(16) kB of local battery back-upped RAM, 8(16) kB EPROM, 16(32) kB address space, battery backed-up Real-Time Clock with AC/DC power monitoring, switch on/off and watch-dog functions, two serial RS-232 ports.

The sensors and the METEOCON are powered by METEOPOWER - a microprocessor-controlled highly efficient switch-mode power supply unit with rechargeable battery back-up.

An integrated terminal - METEOTERM with specialized keyboard, LCD/LED display and built-in 24-(40)-column dot-matrix printer can be connected to the METEOCON. METEOTERM communicates with METEOCON either through a short-distance open-collector interface or through a long-distance (up to 200 m) optoisolated current loop interface. The latter allows the in-door installment of the of the terminal away from the controller.
3. OPERATIONAL FEATURES

The AWS was designed for fulfillment of the following main requirements, typical for the present conditions and the practice in the national meteorological network of the NIMH:

- Automatic collection of the meteorological data with accuracy, required by WMO [1];
- Possibilities for expanding in real time of the observations with data from manual measurements and therefore to complete the observed data, required for meteorological reports SYNOP, CLIMAT etc.;
- Possibilities for low-cost current local visualization of the processed data from all observed parameters even in case of absence of PC in the site of observations;
- Transmitting in real-time of the processed data via radio/telephone modem or storage in a data logger. Possibilities for low-cost, relatively longtime local storage of data, in case of absence of data logger and/or transmitting capabilities in the site of observations;
- Alarm threshold level adjustments for each measured parameter and alarm condition mode operation of the AWS;
- Significant lower price of the AWS in comparison with the wide known models of foreign made AWS.

METECON scans all the counter registers of the sensors four times a second and process the data to produce instant, average, minimum and maximum values of the parameters, measured for various time intervals, according to the METEOSOFT program. These values are stored in a 24-hour buffer in a battery backed-up CMOS RAM, and are send every 10 minutes to the communication ports. At 00:00:00 each day METECON outputs also the whole 24-hour buffer with the instant, average, minimum and maximum values of each parameter.

The current instant, average, minimum and maximum values of each parameter can be displayed on operator's request on the METEOTERM LCD/LED display. METECON scans the keyboard of METEOTERM and allows the operator: to change the displayed information and parameters; to enter manually data for parameters that are not measured automatically; to change sensor calibration constants; to set alarm limits for parameters (including two different real-time alarms); to change the printed parameters list. Either all the acquired, or an operator specified list of parameters data, or only those parameters that have exceeded predefined margins (alarm condition) can be sent to the printer in the METEOTERM.

When one of the measured current values exceeds the predefined margins for the corresponding parameter, the AWS switches in alarm-mode operation with emitting of the alarm signals.

The METECON also monitors permanently the AC mains line and in case of AC failure records this event to output it to the printer and communication ports. In case of mains line failure the METEOPOWER supply unit switches immediately to battery back-up mode, thus giving non-interruptable power to the sensors and processing electronics. The METECON constantly checks the maintenance-free rechargeable battery to prevent its full discharge. In this case METECON switches off the power supply from the sensors and other processing electronics and remains in stand-by mode while retaining with a small battery the accumulated data in RAM and the real-time clock.

4. DATA PROCESSING AND QUALITY CONTROL

Sampling.

All the counter registers of the sensors are scanned and read under a constant sequence four times a second (after every 250 ms) but different sampling intervals for the different parameter's processing are executed according to the METEOSOFT program and to comply with the requirements for AWS [1,2,3]. For the instant values processing the frequency output signals are measured over the following intervals:

- wind speed - 3 seconds period, with overlapping by 0.25 s;
- wind direction - subsequently processed every 0.25 s values, on the basis of a exponential sampling;
- air and soil temperature - 3 seconds period;
- air humidity - 10 seconds period;
- atm. pressure - 3 seconds period;
- precipitation (intensity) - sum for 10 min. period;
- evaporation - 3 seconds period;
- height of water level - 3 seconds period.

**Averaging.**

Different averaging periods and methods of averaging (arithmetical and exponential) are employed in the METEOSOFT program [2], as follows:
- 1-minute period - MEAN VALUES - arithmetical averaging: air and soil temperature, air humidity, atm. pressure;
- 10-minute period - MEAN VALUES - arithmetical averaging: wind speed (at every 10 s sub-sequence), precipitation (intensity);
- 10-minute period - MEAN VALUES - exponential averaging: wind direction (at every 10 s sub-sequence).

**Extreme values.**

Minimum and maximum extreme values for each measured parameter and for each 10-minute period are fixed in the AWS. Additional fixing for 1- (3-, 6-, or 12-) hour period of these values can be executed in accordance with the employment of the AWS.

**Quality control.**

For first level quality control two main types of checks of the input and processed data are carried out in the METEOSOFT program: range check - to reject 'impossible' values and rate of change check - to remove noise values:
- the range check limits are introduced basically in accordance with the operating ranges of the sensors, connected to the AWS;
- the rate of change check limits are determined on the basis of some WMO recommendations [2] and some estimations, based upon time responds of the sensors and meteorological practice.

Inter-sensor data quality control and additional control are envisaged to be carried out in the Regional Telecommunication Centers (RTC) before the transmitting of the data to the National TC.

**Data transmitting.**

The data transmitted from the communication ports of the AWS to the RTC (or directly to the NTC) are two types:
- data from the all automatically measured parameters. They are transmitted in sensible units (e.g. deg Celsius) and
- data for the manually observed parameters, entered in the local AWS. They are put into AWS and transmitted from it in specialized FM-IX SYNOP code digits.

The full information from both measured by and entered into the AWS data is adequately enough for preparation of a standard meteorological report SYNOP (or CLIMAT) conformed to the international guidelines. It is envisaged that this procedure has to be carried out on standard PC's in the RTC.
AAXX 15614
14:00-29.04.1995

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Legend:
- AAXX: Code of the message
- 15614: ID of the station
- Time: HH:MM
- Date: DD:MM:YYYY
- Parameter Name
- Instant Value
- Average Value
- Minimum Value
- Maximum Value
- Units

Fault!
Pwr Dn-13:43:05-29.04.95
Pwr Up-13:47:53-29.04.95

Figure 2 - Sample from the printer message

5. FIRST OBSERVATION TESTS

The first comparisons between the data from this AWS and standard manual measurements have shown a good quality of the automatically obtained data. A short sample from the printer message, obtained in the period of the first observation test of the AWS in Sofia is shown in Figure 2.

REFERENCES:

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