3ª Conferencia Internacional sobre Experiencias con Estaciones Meteorológicas Automáticas

3rd International Conference on Experiences with Automatic Weather Stations

Torremolinos (Málaga)
19, 20 y 21 de Febrero de 2003
19th, 20th and 21st February 2003

3RD INTERNATIONAL CONFERENCE ON EXPERIENCES WITH AUTOMATIC WEATHER STATIONS

PRESENTATION

The desire to know the climate in more detail, since it is a natural resource that can be optimally exploited, has led over the years to intensifying the density of terrestrial weather observation networks and, in recent years, to the gradual automation of these networks.

Using Automatic Weather Stations makes data available at a better cadence than conventional observation, no matter where the stations are installed, including difficult access areas; data transmitted on line can be readily used for weather prediction, while non-real-time transmissions can be used for climatic services and applications.

In April 2001, the task force of the Sixth Regional Association (Europe) from the World Meteorological Organisation dealing with climatic issues proposed the celebration of a Third Conference on Experiences with AWS where discussions could be carried out concerning the problems that arise in climatology when using data from these stations, as well as the potential situations of breakdowns in the uniformity of data caused by long climatic series using different observational methods, and the need to have new collection and filing systems available for this data.

In the 13th Meeting of the Regional Association, held in Geneva in May last year, the concern of the European climatologists about these issues became evident and the Spanish invitation to house the Third Edition of the International Conference on Experiences with AWS was accepted. The aim of this Conference will be of offer a meeting point to exchange knowledge between users, where manufacturers, dealers and application designers for the exploitation of these data will also be participating.

I am sure that automatic observation will gain more and more significance in weather service infrastructures and I am also convinced that after hearing the contributions from the participants, finding practical solutions to the problems mentioned above related to changes in observation systems will be much closer at hand.

In particular, I would like to mention the work that is being carried out in Spain by the AWS Regulations Task Force, that was appointed a few years ago by the General Directorate of Technological Innovation of the Ministry for Science and Technology within the AENOR[1] organisation, where the National Meteorological Institute is president and Puertos del Estado is secretary. Their work has reached its final stage: the first standard is already published, the second has completed the enquiry stage, and some two more standards are now in enquiry.

[1] AENOR: Spanish Standardization Agency

Finally, my congratulations to the Scientific and Organising Committee for the Conference, and to all the participants, for the level and number of their contributions. Also, my most sincere thanks to all the Supporting Organisations – this Conference could not have held without their collaboration.

Torremolinos, Málaga, February 19th, 2003
Enrique Martín Cabrera
Director-General of the Spanish National Meteorological Institute

PRESENTATION OF CONTRIBUTIONS AND PUBLICATIONS

PROGRAMME

WEDNESDAY, 19TH FEBRUARY 2003

MORNING

09:00 – 09:30 Attendants admission and documentation delivery. Holding of posters

09:30 – 10:00 Institutional Conference opening speeches .

10:00 – 11:00 Opening address: PROGRESS OF AUTOMATIC WEATHER STATIONS IN MEETING THE NEEDS OF CLIMATE, Neil Plummer *et al.*

11:00 – 11:30 Coffee break.

THEME 1

11:30 – 11:50 "VAISALA'S NEW-GENERATION SHIPBOARD AUTOMATIC WEATHER STATIONS", Jorma Islander .

11:50 – 12:10 "INTEGRATED METEOROLOGICAL AND HYDROLOGICAL NETWORKS – FROM SENSORS TO DATABASES", Hannu Kokko

12:10 – 12:30 "WIND SENSOR FOR AWS BASED ON NEW TECHNOLOGY", Kjell Hegg.

12:30 – 12:50 "ELECTRONIC SENSORS: DEVELOPMENT & DEPLOYMENT", Lubomir Coufal and Václáv Chalupsky.

12:50 – 13:10 "NATURAL ELECTROSTATIC FIELD MEASUREMENTS AT GROUND LEVEL: EXPERIMENTAL RESULTS AND APPLICATIONS", Joan Montanyá.

13:10 – 13:30 "TESTING, CALIBRATION AND INTERCOMPARISON OF A NEW AWS IN SHMI", Igor Zahumensky and J. Schwarz.

13:30 – 15:10 LUNCH

EVENING

THEME 1 (Continuation)

15:10 – 15:30 "SWISSMETNET: RENEWAL OF THE SWISS METEOROLOGICAL NETWORKS", A. Heimo and T. Konzelmann.

15:30 – 15:50 "COMPARISON OF VISIBILITY MEASUREMENTS WITH ROUTINE VISUAL OBSERVATIONS IN THE NETHERLANDS", Wiel M. F. Wauben.

15:50 – 16:10 "ICE-FREE WIND SENSORS", Bengt Tammelin, Alain Heimo, Michel Leroy, Aulis Peltomaa and Jacques Rast.

16:10 – 16:30 "PROBLEMATIC IN THE SUPPORT OF A NETWORK OF AUTOMATIC STATIONS IN COASTAL CLIMATIC CONDITIONS", F. J. Rodriguez.

THEME 1 POSTERS

16:30 – 16:40 "THE INTERCOMPARISON OF THE ULTRASONIC ANEMOMETERS IN REAL CONDITIONS AT THE LJUBLJANA AIRPORT", Josko Knez and Ales Borstnik.

16:40 – 16:50 "TESTING OF METEOROLOGICAL INSTRUMENTS TO BE USED AT AWS IN MARINE ENVIRONMENTS", Merete H. Larre *et al*.

16:50 – 17:00 "AN ANEMOMETER BASED ON POSITION SENSING DETECTOR", Tor Kollstad.

17:00 – 17:10 "MPS BUFR SOFTWARE FOR AWS", J. Schwarz and Igor Zahumensky

17:10 – 17:20 "METEOROLOGICAL AND SOLAR RADIATION RECORDING DATA FOR RENEWABLE ENERGIES AT C.I.B.A. LABORATORY, VALLADOLID, SPAIN", J. Bilbao, A. de Miguel, A. Ayuso and J. A. Franco.

17:20 – 17:30 "THE AGROCLIMATIC INFORMATION NETWORK OF ANDALUSIA", Juan M. de Haro, Pedro Gavilán and Rafael Fernández.

17:30 – 17:40 "ON-LINE PSYCHROMETER SUITABLE FOR CONTINUOUS OPERATION AND DATA ACQUISITION", Marina Caporaloni, Caterina Vitullo and Roberto Ambrosini.

THURSDAY, 20TH FEBRUARY 2003

MORNING

09:00 – 09:30 Invited address: "STANDARDISATION OF REGISTERS COMING FROM AUTOMATIC WEATHER STATIONS. THE NORMMA PROJECT", Andrés Guerra.

THEME 2

09:30 – 09:50 "SOME ASPECTS ON THE OPERATIVE USE OF THE AUTOMATIC STATIONS NETWORK OF THE BASQUE COUNTRY", Santiago Gaztelumendi, R. Hernández and K. Otxoa de Alda.

09:50 – 10:10 "AUTOMATIC WEATHER STATIONS NETWORK OF THE DEPARTMENT OF ENVIRONMENT OF GALICIA: DATA ACQUISITION, VALIDATION AND QUALITY CONTROL", Santiago Salsón Casado and José Antonio Souto González

10:10 – 10:30 "USE OF AWS AT METEOSWISS: EXPERIENCES AND PERSPECTIVES", Thomas Frei.

10:30 – 10:50 "AUTOMATIC WEATHER STATIONS DATA MANAGEMENT AT THE INM METEOROLOGICAL CENTER IN THE BALEARIC ISLANDS", José A. Guijarro.

10:50 – 11:10 "AN AUTOMATIC SNOW AND WEATHER STATIONS NETWORK FOR THE AVALANCHE PREDICTION IN THE CATALAN PYRENEES", Carles García, Jordi Gavaldà, José Antonio Jara and Pere Martínez.

11:10 – 11:30 "THE VALENCIA *ANCHOR STATION*, A CAL/VAL REFERENCE AREA FOR LARGE-SCALE LOW SPATIAL RESOLUTION REMOTE SENSING MISSIONS", Ernesto López-Baeza, Almudena Velázquez, Carmen Antolín, Alejandro Bodas, Jaume F. Gimeno, Kauzar Saleh, Ferran Ferrer, C. Domenech, Nuria Castell and M. Amparo Sánchez.

11:30 – 12:00 Coffee break

12:00 – 12:20 "THE XAC – AGROMETEOROLOGICAL NETWORK OF CATALONIA", Antonio Gázquez Picón, Miquel Perpinyà i Romeu and Juan Carlos Peña Rabadán.

12:12 – 12:40 "USE OF A NETWORK OF AUTOMATED WEATHER STATIONS FOR THE DETERMINATION AND DISSEMINATION OF REFERENCE EVAPOTRANSPIRATION", Pedro Gavilán, Juan M. de Haro, Rafael Fernández and D. López.

12:40 – 13:00 "THE HADA PROJECT: USE OF WEATHER STATION NETWORKS FOR DIAGNOSTICS OF INCENDENCES OF POLLUTION IN PORT AREAS", Andrés Guerra, Rafael Cano, Juan José Sánchez, Federico Torres, David Marcano, José Antonio Luaces, Rafael del Moral, Jordi Vila and Victor Rubio.

13:00 – 13:20 "THE U.S. CLIMATE REFERENCE NETWORK – VISIONS AND STATUS", Michael R. Helfert, Richard R. Heim Jr, Ray P. Hosker and Thomas R. Karl.

13:00 ***Trip to the Nerja Caves.***

FRIDAY, 21ST FEBRUARY 2003

MORNING

THEME 2 POSTERS

09:00 – 09:10 "COMPARISON BETWEEN MEASUREMENTS OBTAINED WITH A METEOROLOGICAL MAST AND A RASS SODAR", Isidro A. Pérez, M. Luisa Sánchez, M. Ángeles García and Beatriz de Torre.

09:10 – 09:20 "PROFILES OF WIND SPEED AND TEMPERATURE IN THE LOW ATMOSPHERE", Isidro A. Pérez, M. Luisa Sánchez, M. Ángeles García and M. José López.

09:20 – 09:30 "GUIDE ON METEOROLOGICAL OBSERVATIONS IN THE NETHERLANDS", Henk Benschop.

09:30 – 09:40 "COMPARISON OF DIFFERENT METHODS FOR MEASURING SOLAR IRRADIATION DATA", N. Geuder, F. Trieb, R. Meyer and V. Quaschning.

09:40 – 09:50 "AGROCLIMATIC INFORMATION SYSTEM FOR THE IRRIGATION AREAS", P. Pérez de los Cobos, J. Ignacio Carazo and F. Padilla.

THEME 3

09:50 – 10:10 "ITALIAN METEOROLOGICAL SERVICE AUTOMATIC WEATHER STATIONS NETWORK – AN AUTOMATIC SYSTEM FOR SUPERVISION AND CONTROL", Paolo Pagano, Luigi de Leonibus, Adriano Raspanti and Francesco Foti.

10:10 – 10:30 ."USE OF AUTOMATIC AND INTERACTIVE METHODS FOR FILTERING AUTOMATIC WEATHER STATIONS DATA FROM THE PORTUGUESE AWS DATA-BASE", Luis F. Nunes, Jorge Neto, Renato Carvalho, Fernanda Carvalho, Victor Prior and Diamantino Henriques.

10:30 – 10:50 "QUALITY MANAGEMENT IN THE POLISH HYDROLOGICAL AND METEOROLOGICAL SERVICE", Kazimierz Ródzdzynski.

10:50 – 11:10 "SETTING-UP AN INTEGRAL QA SYSTEM IN THE MEASURING NETWORK OF THE EARS", Josko Knez, Andrej Kobe and Silvo Zlebir.

11:10 – 11:30 "QUALITY CONTROL OF HIGH RESOLUTION DATA FROM AWS IN THE NETWORK 2000 OF THE DEUTSCHER WETTERDIENST", Reinhard Spengler.

11:30 – 11:50 "THE PROCESS OF INTEGRATION OF MANUAL AND AUTOMATIC METEOROLOGICAL NETWORKS IN THE DESIGN OF THE INFORMATION SYSTEM OF ENVIRONMENTAL CLIMATOLOGY OF ANDALUSIA (SICA). PROBLEMS ASSOCIATED WITH THE SELECTION OF VARIABLES, VALIDATION OF DATA ENTERING THE SYSTEM AND INTERPOLATION OF GAPS", Mª Fernanda Pita and Juan Mariano Camarillo.

11:50 – 12:15 Coffee break

12:15 – 12:30 Invited address: "AUTOMATIC METEOROLOGICAL NETWORK OF THE CONSEJERÍA DE MEDIO AMBIENTE DE LA JUNTA DE ANDALUCIA (ENVIRONMENT REGIONAL MINISTRY OF ANDALUSIA)", José M. Moreira.

THEME 3 POSTERS

12:30 – 12:40 "RAINFALL DATA QUALITY CONTROL USING DATA-RAINS IN THE BASQUE COUNTRY HIDROMETEOROLOGICAL NETWORK", Kepa Otxoa de Alda, Santiago Gaztelumendi and Roberto Hernández.

12:40 – 12:50 "EXPERTISE OF ERRORS IN RADIOMETRIC NETWORKS. THE CASE OF THE BASQUE SERVICE OF METEOROLOGY", Roberto Hernández, Santiago Gaztelumendi and Kepa Otxoa de Alda.

12:50 – 13:00 "LOCAL WIND CHARACTERISTICS IN ARAGÓN, LA RIOJA AND NAVARRA OBTAINED FROM DATA OF THE NETWORK OF AUTOMATIC WEATHER STATIONS", Evelio Álvarez Lamata.

13:00 – 13:10 "QUALITY ANALYSIS OF THE DATA OF THE XAC (AGROCLIMATOLOGY NETWORK OF CATALONIA) WEATHER STATIONS. TEMPERATURE AND GLOBAL RADIATION", Antonio

Gázquez Picón, Mª Carmen Llasat i Botija, Miquel Perpinyà i Romeu and Juan Carlos Peña Rabadán.

13:10 – 13:20 "AUTOMATIC VALIDATION OF DATA FROM AWS. THE EXPERIENCE OF METEOROLOGICAL BASQUE SERVICE NETWORK", M. Mercedes Maruri, Marino Navazo, Lucio Alonso, J. Antonio García, Gotzon Gangoiti, Mónica Matabuena, Jon Iza and José Antonio Aranda.

13:20 – 13:30 "DESCRIPTION AND PRELIMINARY RESULTS OF A METEOROLOGICAL NETWORK FOR HIGH ALTITUDES IN THE PEÑALARA, CUMBRE, CIRCO Y LAGUNAS NATURAL PARK", Luis Durán Montejano and Belén Rodríguez de Fonseca.

13:30 – 13:40 "DESCRIPTION OF THE CLISSA APPLICATION: CLIMATOLOGY MODULE FOR SEMI-AUTOMATIC AND AUTOMATIC SYSTEMS", Luis Fernández Sánchez and César Rodríguez Ballesteros.

13:40 – 15:30 LUNCH

EVENING

THEME 4

15:30 – 15:50 "LINKING OF TRADITIONAL AND AUTOMATIC STATIONS DATA: OPERATIONAL EXPERIENCE OF UCEA", Luigi Perini and M. C. Beltrano.

15:50 – 16:10 "CLIMATE DATA CONTINUITY USING AWS?", Ernest Rudel

16:10 – 16:30 "STUDY OF THE ERRORS OF RAINFALL RECORDED AT THE BALEARIC AWS THROUGH COMPARISON WITH TRADITIONAL RAIN GAUGES", José A. Guijarro.

16:30 – 16:50 "STATISTICAL ANALYSIS OF TIME-SERIES. GENERAL REMARKS AND APPLICATIONS LAND AIR AND SEA SURFACE TEMPERATURE. CORRECTED JOINT REDUCED VALUES AND ORIGINAL ONES", Raymond Sneyers.

THEME 4 POSTERS

16:50 – 17:00 "THE ENVIRONMENTAL CLIMATOLOGY INFORMATION SUBSYSTEM OF THE REGIONAL MINISTRY OF THE

ENVIRONMENT, JUNTA DE ANDALUCÍA". Mariano Corzo Toscano, Jesús Rodríguez Leal and José Manuel Moreira Madueño.

17:00 – 17:10 "COMPARISON ON RECORDING PRECIPITATION GAUGES: WEIGHING, TIPPING-BUCKET AND FLOAT TYPES", Mária Tekusová, Branislav Chvíla and Pavel St'astny

SATURDAY, 22ND FEBRUARY 2003

Trip to the Natural Park "Sierra de las Nieves" and the town of Ronda.

OPENING ADDRESS

PROGRESS OF AUTOMATIC WEATHER STATIONS IN MEETING THE NEEDS OF CLIMATE

Plummer, N., Collins, D. and Della-Marta, P. - Bureau of Meteorology, Australia

Allsopp, T., Durocher, Y. and Yuzyk, T. - Meteorological Service of Canada, Canada

Heim, R., and Helfert, M. - National Climatic Data Centre, USA

Heino, R. - Finnish Meteorological Institute, Finland

Rudel, E. - Central Institute of Meteorology and Geodynamics (ZAMG), Austria

Stastny, P., and Zahumensky, I. - Slovak Hydrometeorological Institute, Slovakia

Zhou, S. - China Meteorological Administration, China

Abstract

The introduction of Automatic Weather Stations (AWSs or autostations) throughout much of the globe during the 1990s resulted in unprecedented changes in surface observation systems. During a period of growing concern about climate change and the need for high quality data, many climatologists realised that they needed to be key stakeholders in the recording, collection and management of climate observations to ensure that uncertainties associated with data were minimised. This paper discusses the progress of AWSs in meeting the needs of climate data users in seven countries. The "Ten Climate Monitoring Principles" are used as a guide. While not providing an exhaustive study it does provide useful information for climate data users in framing guidelines on the climate requirements of observations from AWSs.

Key words: *AWSs, autostations, climate data, data homogeneity.*

1 INTRODUCTION

Automatic Weather Stations (AWSs or autostations) have been a significant part of surface observation networks in many countries for more than a decade. While these systems were initially developed and deployed as a means of capturing observations in regions for which they were difficult to obtain, their growth during the 1990s was accompanied by a gradual change in function. In many places they have become the primary source of surface observations.

Observation technology prior to the operational implementation of AWSs had remained relatively static and, aside from non-climatic factors such as urbanisation and site re-location, this situation largely benefited data homogeneity. Data inhomogeneities have been the scourge of climatologists for some time and the problem has received more attention over the last decade as focus has shifted to reducing the uncertainties of observed climate change (e.g. Peterson et al. 1998).

The purpose of this paper is to provide a qualitative assessment of the progress of AWSs in

meeting the needs of long-term climate monitoring in a number of countries across the globe. AWSs in the following seven countries are examined: Australia, Austria, Canada, China, Finland, Slovakia and the USA. This network was selected on the basis of interested experts within the World Meteorological Organization's Commission for Climatology (CCl), noting that it was not possible to include contributions from all members.

This paper does not attempt to provide a comprehensive analysis of the progress of AWSs in meeting climate needs but, by documenting progress in a number of countries, it does give some guide on progress and helps better understand what needs to be done in the short to medium term.

2 LONG-TERM CLIMATE MONITORING PRINCIPLES

The "Ten Climate Monitoring Principles" were specified by Karl et al (1995). They are not intended solely for AWSs (nor solely for surface observation systems for that matter) but most of the principles are directly relevant to AWSs. In that context, progress with AWSs (since 1990) is considered with respect to assessing the impact of new AWSs or associated sensors prior to their operational implementation; maintaining overlapping observations for changes to AWSs or their sensors; reducing missing data from AWSs; recording and managing metadata, including results of calibration, validation and results from station comparison experiments; providing network designers and observation managers with descriptions of long-term climate needs; and providing appropriate data management systems for AWS data (i.e. providing easy access, adequate quality control, etc).

3 EXPERIENCES OF AWS WITHIN SELECTED COUNTRIES

3.1 Australia

A climate perspective on AWSs in Australia was provided by Plummer et al. (2000). In 1990, 57 synoptic stations (11%) had an AWS. In 2002, this figure stands at 471 or 56% of the network. Due to this rise there has been a 55% increase in the number of surface observations routinely archived in the Australian climate database since 1990. The size of the AWS network is likely to plateau over the next few years. However, the proportion of routinely archived observations from AWSs will continue to increase due to the storage of higher temporal resolution data.

The number of “stand-alone” AWSs, with no human intervention other than routine maintenance, has increased from 46 in 1990 to 347 in 2002. This rise is cause for concern. Generally the poorest performing stations in Australia are the stand-alone AWSs, both in terms of missing data and erroneous data. Also, stand-alone AWSs do not provide visual observations such as cloud amount and type, and are currently unable to report maximum and minimum temperatures to one decimal place for the standard 24-hour to 9am time period. The majority of stand-alone AWSs are found on remote islands or airports around Australia. Consequently they are hard to maintain and it is difficult to ensure data continuity in the event of a major failure.

While stand-alone AWSs are not ideal for climatic purposes it is recognised that they are a necessary part of the modern Australian climate network. AWSs have increased the density of observations in remote, data-sparse regions where manual observations are not possible. The automation of lighthouses, and the closure or part-time staffing of rural post offices, police

stations and national parks offices, has meant that once reliable sources of co-operative observers are no longer available. Also, the transitory nature of today's society means that people are generally less interested in making a long-term commitment to observing than they were decades ago.

Several projects are underway to alleviate the long-recognised problems associated with AWS observations. Recently AWS communication protocols were reconfigured and systems developed for the routine recovery of missed messages from the AWS memory. This has improved overall collection statistics by approximately 0.5%. While this network-wide figure is small, it is not trivial, as it means greater continuity in individual records. The next generation of AWS software includes a data filter to reduce the number of erroneous "data spikes" reported. This software upgrade will also enable stand-alone AWSs to transmit daily maximum and minimum temperatures with standard precision and time intervals.

AWS performance monitoring systems have been developed to help identify calibration errors, missing data and communication problems. These systems form part of a comprehensive station metadata database that aids the quality assurance process of AWS data. Another project currently in development aims to routinely archive high-resolution one and ten-minute data from AWSs. Access to this data will also help in the quality checking of AWS data.

An important aspect of using AWS data for climate purposes is maintaining strong links between climate and observation programs. A number of cross-functional teams exist within the Bureau of Meteorology to address AWS data issues. The intention is to minimise impacts on the climate record by ensuring that those responsible for the management of observation systems are aware of climate requirements, such as overlap observations for changes in location and instrumentation.

Over the past decade many manual observation sites located within small towns have been replaced with AWSs located at nearby airports. To help preserve the homogeneity of the climate record at these locations a period of dual observations is requested between the old and new sites. In reality, manual site closures cannot always be anticipated. Consequently, some site moves in the Australian surface network have not been accompanied by overlap observations. However, special effort is given to ensuring that overlap programs are implemented for stations included in international and national climate networks. Most of these moves have been accompanied by at least two years of overlap data. To assist in the homogenisation of records considerable improvements have been made in the recording of metadata for both AWSs and manual stations, such as the development of an electronic metadata database.

Before AWSs are placed in the Australian observation network they undergo detailed instrument calibration and laboratory tests at the Bureau of Meteorology's Regional Instrument Centre (RIC). The RIC has a team of metrologists using internationally traceable standards of measurement to calibrate and test components of the AWS. A history of calibration and other important metadata for each instrument are stored in an electronic database.

3.2 Austria

Often when new systems are put into operation, climatologists do not hear about the replacement of their existing network of climate stations until after the new generation of

measurements are implemented. It can be many years before they understand the impacts of these changes on the climate record. Fortunately, this was not the case in Austria where the climate department of the Central Institute of Meteorology and Geodynamics (ZAMG) manages the whole observation network and was significantly involved in the implementation of the AWS network (Rudel 1995).

Anticipating a gradual conversion of manually-operated climate stations to AWSs, the need to maintain data homogeneity was given high priority. Parallel comparisons were undertaken at converted stations for at least one year where possible, even longer for climate parameters with high interannual variability. Also, stations with historical significance were to be maintained in their current state for as long as possible.

The introduction of AWSs in 1981 throughout the Austrian network resulted in many changes in sensor design, observation techniques, interrogation time and data processing algorithms. All of these changes could have introduced inhomogeneities into the climatic record. To preserve homogeneity, initially assessments were made of how the proposed changes to the observing systems would influence the record, particularly in respect to climate variability and change. Most of the discontinuities caused by changes in observing times and averaging methods proved to be significant compared with the magnitude of the climate signal itself. Consequently, AWS algorithms were developed to guarantee a comparison with the conventional systems (Rudel 1997).

AWS sensor specifications, observation and measurement methodologies and data preprocessing algorithms were successfully standardised. Algorithms were modified several times before acceptable comparisons were obtained. By taking into account available station metadata, discontinuities in the time series of temperature, relative humidity and pressure were avoided. Overlapping timeseries of two years or longer at major stations was also useful.

For some elements (e.g. pressure) the type of sensor was changed because the accuracy and drift of the measurements caused problems. For wind speed initial mistakes resulted in large biases. Only vector means of hourly data were calculated and stored, which can differ from arithmetic means by more than 100%. Consequently, changes were made in the AWS evaluation method to assure continuity.

For other climate parameters, such as precipitation and sunshine duration, attempts to retain continuity have not yet been successful. The majority of raingauges used in Austria are heated tipping bucket gauges. Due to evaporation, differences between the old gauges and the new systems are sometimes more than 50%. Comparisons of sunshine duration data recorded by the conventional systems and the sensors of the AWS indicate systematic differences caused by different responses to some types of cloud formation. Work is progressing to develop algorithms to compare the different timeseries.

To assess the impacts of station relocations it was intended to undertake parallel measurements for at least two consecutive years. However, due to technical and financial difficulties, it was not possible to fulfill this requirement in most cases. Sometimes the old station was closed a month before the new AWS was put into operation.

The increasing size of the Austrian AWS network is proving to be a challenge for climatologists. However, their advantages seem to outweigh their disadvantages. Before AWSs were introduced, Austria had a network of about 70 stations (grid point distance ~35km)

which generally transmitted four times a day. In 2002 there are 130 AWSs (grid point distance ~25km) in operation, reporting in real-time every ten minutes. Additionally there are 21 offline AWSs for which the data is stored locally and the data-chips are sent once a month to the regional centres. In the near future these stations will be integrated in the online-network.

Due to pronounced differences in elevation, monitoring the climate with 70 stations in Austria was nearly impossible. Also, manual observations were submitted by mail and it often took more than six weeks before data was available for the monthly climate review. These days AWSs submit electronic data with high temporal resolution, quality management is easier and the monthly review is presented via the internet on the first day of the following month. The reliability and accuracy of most data has also increased.

Other advantages of AWSs include being able to more easily locate a site in rural areas to avoid anthropogenic influences, real-time data checking using sampling and processing procedures, and the possibility of integrating remote sensing products like weather radar or satellite information. AWS data better meets the growing demands for meteorological information from new clients such as lawyers, environmental consultants and urban water planners. Also, climate modelling is well supported by AWS data in regard to spatial and temporal resolution requirements.

3.3 Canada

Early generation autostations were introduced in Canada in the early 1970s. These stations focused on weather program needs, with little attention paid to climate data needs. By 1990, 168 of the 448 Canadian hourly/synoptic stations were autostations. By 2002, as a result of increased cooperative agreements, the real time hourly network has grown to 739 stations including 264 aviation weather observation stations inspected and maintained by Meteorological Service of Canada (MSC). Of the 739 stations, 446 are autostations. All stations supporting the MSC surface weather program (public and coastal marine) are automated.

MSC and its partners operate 302 Reference Climate Stations for climate change studies, as well as other climate research. Approximately 132 of these have been automated, particularly those sites at risk of significant program change or closure. The intention is to overlap the observing programs for two years but this is not always possible for cooperative agency stations. The RCS network also includes a subset of GCOS Surface Network (GSN) stations. These stations have increased from 72 in 1998 to 96 in 2002, reflecting Canadian government initiatives to address data sparse regions in northern Canada. All new GSN stations are automated.

Since the late 1990s all sensors and systems have been tested and evaluated before operational implementation. MSC employs a formal change management process for the orderly introduction of sensors, system equipment, algorithms and related documentation. Membership of the change management board not only includes operational monitoring program representatives but also representation from climate research and archives. A national MSC Monitoring Committee provides an opportunity for network planners, operational managers and internal MSC stakeholders to discuss long term climate needs. There are also various inter-agency mechanisms and workshops to coordinate climate programs.

Canadian autostation data undergoes various quality checking procedures before being stored in a national archive. A new data management framework is being developed to govern the data flow from sensor report to archives, with appropriate real time and non-real time automatic quality checking algorithms and data access protocols. MSC is also developing better metadata entry tools for technical staff and network managers, as well as access tools for users. New or modified databases are being developed to store relevant metadata such as instrument calibrations, inspection and repair information, instrument inventory and performance.

Autostations have provided the opportunity for more meteorological elements, more frequent observations and more real time availability. In many data sparse, remote regions such as Canada's north, there are no human-based alternatives. For some elements, such as temperature, pressure and wind, autostations are more reliable and accurate than human-based stations. However, there are some measurement problems, such as false precipitation due to wind-pumping and temperature sensitivities on some all-weather weighing precipitation gauges. Data logger algorithm software is being developed to mitigate these issues.

Autostations can also be vulnerable to systematic and random problems, such as data communication outages, lightning and sensor failures. The data losses can be exacerbated by the remoteness of some of these stations. Consequently, it is necessary to have real time quality assurance procedures in place for corrective action, as well as accurate, low maintenance, affordable instrumentation that minimises the need for human intervention.

In 2003 the MSC is planning to update its autostation guidelines manual for cooperative agency programs, thus renewing the standards for automatic stations contributed by non-MSC cooperating agencies. Concurrently, MSC is planning to complete an inspection and maintenance manual for surface weather and RCS autostations to replace the previous manual intended for human-based observing programs.

3.4 China

China Meteorological Administration (CMA) has used AWSs for meteorological research and services since the 1970s, but only from 1997 for synoptic observations. There are more than 2400 meteorological stations maintained by CMA, with about 673 basic synoptic weather stations. In 2002, there are 164 AWSs installed in China, with another 1000 to be installed at synoptic weather stations over the next five years.

CMA currently holds records for 47 AWSs. Each AWS must conduct overlap observations with a manual station for two years before its records are archived as climatic data. The climatic data office is responsible for analysing the overlap observations for completeness, accuracy and differences. Analyses of the overlap records have shown that AWSs are generally operating satisfactorily, and their records are of good quality.

To preserve the homogeneity of climatic data, CMA has revised its "guidelines on surface synoptic observations" to make the requirements on observation site, equipment, records processing, etc., suitable for both AWS and manual observations. Also, CMA intend to maintain overlapping automatic and manual observations for more than 100 Climatological Reference Stations to serve as references for data quality control of the whole AWS network.

AWSs are equipped with software to enable synoptic report coding, data quality checking, and the calculation of means and extreme values. When the records from an AWS are archived as climatic data, the metadata for the AWS is archived along with the data.

3.5 Finland

There has been rapid growth in the number of AWSs in Finland during the 1990s. At the same time, the number of manual stations has diminished considerably. In 1990, AWSs represented 25% of the observation network; in 2002 it represents 85%. The widespread introduction of AWSs has resulted in an increase in the homogeneity of data across the network, better real time access to data and higher temporal resolution when needed.

Homogeneity of climate records is maintained by installing AWSs at existing observation sites and by carefully storing and maintaining metadata. Comprehensive overlap observations have only been undertaken for a few stations. However, for new instrumentation and observation methods comprehensive field tests have been undertaken before their operational use. Metadata are stored in a database and can be maintained and viewed using Intranet tools. Calibration results are stored in a similar way, and comparison results are mainly published as internal reports.

The most common reason for missing AWS data in Finland is communication problems. Data are stored automatically onsite in the memory of the AWS and missing data can be retrieved if required. Initially AWS data were treated as “raw” data without significant quality control. More sophisticated quality checking methods are now in place and data are far more reliable.

3.6 Slovakia

Slovak Hydrometeorological Institute’s (SHMI’s) National Observing System (NOS) comprises of observing systems for various purposes, reflecting the historical traditions of manual weather observations. The surface weather section of the NOS has partial observing systems for aviation (10), synoptic meteorology (13), nuclear safety (2) and climatology (85). Automation of the NOS started in 1990 and has been carried out in several overlapping stages, depending on the funds available and the implementation of individual projects.

The SHMI operates a network of 27 AWSs; three are unmanned, 20 are partially manned and four are located at fully manned meteorological stations. The tendency to increase the number of unmanned and partially manned stations at the expense of manned stations is likely to continue. The future number of AWSs is expected to be around 80-90. An intercomparison of manual and automatic data from all manned meteorological stations has been running for five years.

Each professional meteorological station is equipped with an automatic station and an Integrated Meteorological System (IMS). Both process raw data and produce standard messages which are transmitted to the Data Processing Centre. Some of the AWSs are equipped with intelligent weather sensors, depending on the importance and user requirements.

A comprehensive Quality Assurance System for AWS data has been implemented on-site, as well as at the national Data Processing Centre. Furthermore, SHMI operates a full-time

Calibration Laboratory and a field maintenance facility. The performance of sensors is assessed using traveling standards, with tests performed once per year.

3.7 USA

The Climate Reference Network (CRN) represents a long-term commitment by the United States to build a climate monitoring network capable of detecting and quantifying climate variations with high scientific confidence for at least the next 50 years. The guiding principles in the design of the U.S. Climate Reference Network (USCRN) were the "Ten Climate Monitoring Principles" specified by Karl et al (1995) and adopted by the National Research Council (1999).

The vision of the USCRN program is to deploy and operate 225 high-precision, reliable, intercalibrated, autonomous and automatic stations within the 50 States of the USA by 2007. Deployment of the first 40 USCRN stations began in August 2001. By July 2003, 40 USCRN stations will have been deployed in 27 States. Additional deployments are planned at a rate of approximately 45 per year.

The design philosophy of the USCRN emphasised the use of commercial, off-the-shelf equipment wherever possible to enhance system reliability and modularity. Station instrumentation is calibrated annually against traceable standards. Data are reported hourly using satellites. When received at the National Climatic Data Center (NCDC) the data are subjected to rigorous quality control checks, and then placed into the archive. Data are available for downloading and review via the Internet, usually about 70 minutes after each reporting period.

The two primary high-precision measurements taken by each USCRN station are air temperature and precipitation. Triply redundant sensors for temperature are being used to bolster confidence in the data, and to provide a direct measure of precision. Individual secondary instruments provide measurements of wind run and absolute velocity, global solar radiation, and ground surface temperature. Testing is underway for the possible addition of relative humidity, soil moisture, and soil temperature measurements at all stations.

The climate monitoring accuracy and capabilities of the USCRN can be enhanced through inter-instrument, inter-station, and inter-network comparisons to establish data transfer functions. Transfer functions could be determined for the US Historical Climatology Network (USHCN) and the cooperative observer network. It would also be useful to determine data transfer function values among other national climate monitoring networks. The USCRN could be deployed in other regions of the world if considered suitable. Alternatively, some international joint-use megasites could be established. Different national AWSs could be deployed in order to establish various national, regional, or even international transfer functions among such networks.

4 DISCUSSION

As discussed earlier, this report does not attempt to provide a detailed analysis of progress of AWSs in satisfying climate data users but, instead, provides an insight into those areas where there appears to be progress and those where further work is required. Since 1990 there has been substantial growth in the use of AWSs in the countries discussed here (Table I).

Table I. For the countries discussed in this report, the number of AWSs providing synoptic data and the percentage this represents of the total surface observation network, both in 1990 and 2002.

	1990		2002	
Country	**No. AWSs**	**% of AWSs in network**	**No. AWSs**	**% of AWSs in network**
Australia	57	11	471	56
Austria	31	34	130	92
Canada	168	38	446	60
China	0	0	164	24
Finland	30	25	140	85
Slovakia	0	0	27	25

Most countries have indicated some progress since 1990 in better meeting the needs of climate – most consistently in improving data collection (particularly in remote areas) and in the frequency of observations; a number of countries are now actively managing higher resolution (e.g. 1 minute and 10 minute) AWS data. Reliability and accuracy of data have also generally improved. While some countries have now established practices for managing network change, few had adequate practices in place during the early 1990s – Austria perhaps being a notable exception.

Formal management structures are now in place in a number of these countries to help ensure that climate needs are taken into account (e.g. Canada). Data homogeneity is also better managed through improved metadata and station comparisons. Countries generally aim for at least two years overlap between co-located manual stations and AWSs, but most report mixed success (although Slovakia report programs running for five years). There is more focus on recording and reporting the results of homogeneity assessments than in the early 1990s. Generally, these countries also have field testing procedures in place.

Improvements have been made in recent years in the areas of data management, including quality control and quality assurance. Some countries (e.g. Australia and Finland) have developed sophisticated data retrieval algorithms to ensure that data are not lost. Metadata are now generally better recorded and more accessible; China archives metadata alongside the climate data itself.

The U.S. Climate Reference Network is unique in that it represents an attempt to build a network for the primary purpose of long-term climate monitoring. Some of the key differences with this network lie with sensor redundancy and a deliberate aim to establish data transfer function across networks.

Even in these countries, which have significant experience in dealing with AWSs, there are still areas that require improvement. Early mistakes in deriving some climate variables were encountered and there are still problems in maintaining homogeneous timeseries for some variables. Concerns remain over the reliability of precipitation measurement – the key climate variable in many countries. More work is required to reduce vulnerability to problems such as data communication outages, lightning and sensor failures. Changes in observation technology will have to be carefully managed if data homogeneity is to be preserved into the future.

While the priorities of climatologists in the 1990s were rooted in preserving consistency with the past, the next decade or so will see a shift toward reinforcing these priorities, as well as

seeking opportunities for new data and indices from AWSs - e.g. for those variables approximated (mean daily temperature), indirectly estimated (evaporation) or not presently systematically recorded (sub-hourly changes).

5 CONCLUSION

AWS networks provide an opportunity for international cooperation and leveraging of resources that is unprecedented in the history of national and global climate monitoring. However, while much progress has been made in improving the capabilities of AWSs to meet the needs of climate in the seven countries discussed here, there remain areas where further improvements are needed. Information drawn from this study should be valuable for the WMO Commission for Climatology in framing guidelines on the management of AWSs to better meet the needs of climate.

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INVITED ADDRESS

VAISALA'S NEW-GENERATION SHIPBOARD AUTOMATIC WEATHER STATION

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Abstract

The importance of gathering high-quality meteorological data at sea is increasing year upon year. Although satellites can be used to collect basic data, shipboard and buoy observations are still needed. The world's land masses are increasingly being covered with automatic weather station networks which are collecting better data for weather forecasting purposes. Vaisala has been engaged in automated shipboard weather observation from the early 1980s and has gained a large body of experience from many installations. Most of the installations have been tailored to meet the customer's specific needs. When our knowledge of all the installations is pooled, it can be said that Vaisala has a profound understanding of the practical aspects of weather observation in the marine environment. Vaisala's new-generation shipboard automatic weather station is designed specifically for VOS and VOSClim applications to cover the most demanding marine weather observation requirements.

Key words: ***AWS*** *- Automatic Weather Station ,* ***VOS*** *- Voluntary Observing Ship,* ***VOSClim*** *- Voluntary Observing Ship for Climatology data*

The importance of gathering high-quality meteorological data at sea is increasing year upon year. Although satellites can be used to collect basic data, shipboard and buoy observations are still needed. The world's land masses are increasingly being covered with automatic weather station networks which are collecting better data for weather forecasting purposes. More coverage is needed over the oceans: marine meteorological data is still mainly gathered with analog instruments and the data is entered into files manually. When the data is collected afterwards from the log files it is useful only for climate models, not for forecasting. With manual observation systems, data quality is dependent on the observer: measurement accuracy can vary and the observation is based on only one reading. In comparison, automatic weather stations measure continuously 24 hours a day, and their measurement accuracy is consistent. Automatic weather stations can also use direct satellite communication links to send the meteorological data sets in coded form to the global network in real-time.

Vaisala has been engaged in automated shipboard weather observation from the early 1980s and has gained a large body of experience from many installations. The total installed base is nearing 100, and ranges from basic true wind systems to fully automatic synoptic weather stations with optical sensors and several wind sensors. Vaisala weather stations are in operation aboard cruise ships, research vessels, ice-breakers and naval vessels. Most of the installations have been tailored to meet the customer's specific needs. When our knowledge of all the installations is pooled, it can

be said that Vaisala has a profound understanding of the practical aspects of weather observation in the marine environment.

Vaisala's new-generation shipboard automatic weather station is designed specifically for **VOS** and **VOSClim** applications to cover the most demanding marine weather observation requirements. The station is a development of the field-proven Vaisala MILOS 520 automatic weather station. The MILOS 520 frame has been installed in a water-tight, non-corrosive plastic enclosure along with the mains power supply, back-up battery enclosure and other key components. High-quality connectors have been used to connect the sensor cables, mains power and communication lines. This makes installation very easy and fast. The cabling is pre-tested at the factory so the station can be put online immediately after installation.

In its basic form, the Vaisala shipboard automatic weather station's sensors are installed in a tiltable mast 6 meters in height. The high-quality Vaisala HMP45D sensor measures air temperature and humidity. It is installed in the radiation shield at a height of 2 meters. The HMP45D's sensor head is easy to remove for calibration purposes. The Vaisala WAA151 anemometer measures wind speed and direction, and the Vaisala WAV151 wind vane is installed atop the mast. The Vaisala DPA501 pressure sensor, installed in the MILOS 520 frame, measures air pressure with a static pressure head at the bottom of the enclosure.

A water temperature sensor is available as an option: its cable connector and measurement software is provided with the basic station. The water temperature sensor can be any four-wire PT100 temperature sensor or the Vaisala DTS12W water temperature sensor. Water temperature is a very important measurement parameter. Vaisala provides it as an option due to the difficulty of sensor installation below the water line. Cooperation is necessary with the shipyard and/or ship owner.

For true wind calculation, a GPS receiver can be used or an Inmarsat-C radio if one is available. In any case, GPS data alone is insufficient for calculating true wind data accurately in every circumstance. It gives speed only and the direction of speed. With this information, true wind can be calculated correctly only when the ship moves in a truly straight line. If the ship moves in reverse, which is typical for ice-breakers for example, the true wind calculation will be totally incorrect.

For accurate true wind calculation, heading information is needed. The best source of the heading information is the ship's gyro compass, which normally makes heading information available in NMEA183 format. The Vaisala shipboard automatic weather station has a compatible input for this format. Cheaper electric compasses can also provide heading information, but in order to calibrate them the ship must be turned around 360 degrees. Electric compasses are also available that do not have to be calibrated in this fashion, but they are very expensive.

Installing the system is easy. Three bolts are needed for the mast, mains power comes from the ship's power system, a little space is needed for the data entry PC on the bridge and NMEA183 data output is needed from the gyro compass.

For manual data entry, Vaisala's Yourlink PC program allows ship personnel to type in the manual observations and view the sensor data in real-time. The shipboard PC does not have to be the latest model: the Yourlink program operates with the 486 processor.

The Vaisala **AWS** software supports the FM-12 ship code and IMMT-2 code. Messages are generated every 1 to 3 hours: the interval can be selected by the user. The exact times of message generation editing can also be selected by the user. If the message is not manually edited, the **AWS** generates the complete messages automatically: they are then stored on the PC' hard disk and, if satellite communication is used, they are sent automatically by satellite.

The Vaisala shipboard **AWS** can be provided with an optional memory unit for data storage. Built-in algorithms test each measurement to ensure data quality. For each parameter, tests are carried out on the minimum, maximum and step limits as well as cross-checking between the different parameters. For manual data entry, quality checks ensure that the operator does not enter incorrect data values. A built-in testing system also runs continuously to check the hardware, reporting immediately if a fault occurs.

The basic Vaisala shipboard **AWS** supports Inmarsat-C communication but the Inmarsat-C radio itself is provided as an option. The Vaisala AWS software supports optional sensors and output messages for the YourVIEW real-time display and the Vaisala DD50, WD30 and WD50 digital displays. The Vaisala AWS software can also provide surface weather data for ASAP installations. To enable the optional output messages, another serial interface is needed along with extra cable connectors and cabling to the AWS enclosure. The optional sensors require connectors, cable sets and installation mechanics.

Water temperature sensors are another option, as well as sensors for rain duration, sunshine duration, global radiation or albedometer, long-wave radiation or precipitation amount, and optical sensors for cloud base and visibility/present weather. The data provided by optional sensors is automatically included in the report templates if the sensors have been added and activated in the software.

For wind speed and direction measurement, the zero-maintenance WAS425S ultrasonic anemometer can be chosen instead of the WAA151 and WAV151 sensors, which must be maintained periodically.

If the Vaisala **AWS** mast cannot be installed in an ideal location for the wind sensors, the wind sensors can be installed elsewhere. Their data can be fed into the system via cable or radio link. The available communication options are Meteosat GOES and GTS satellite, but other communication options such as Argos are possible as well.

The Vaisala shipboard **AWS** does not require periodical maintenance. Operational and visual checks once a year are sufficient. The sensors do require some periodical maintenance: the temperature and humidity sensor should be calibrated once a year; the pressure sensor should be checked once a year; the bearings of cup anemometer wind sensors need to be changed only once a year as well.

INTEGRATED METEOROLOGICAL AND HYDROLOGICAL NETWORKS – FROM SENSORS TO DATABASES

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***Abstract*:** Information technology, sensor technology, electronics and data communication have developed rapidly in recent years. This has made the automation of meteorological and hydrological networks more affordable and attractive to meteorological and hydrological institutes, power corporations and other authorities that need to monitor and manage water systems such as rivers, lakes, reservoirs and ground water. Operating large networks of automatic weather stations is always an economic burden. Most of the Total Life Cycle Cost (TLCC) of a network is generated by maintenance, calibration and update/upgrade costs. Meteorological and/or hydrological networks should not be built separately. In many cases, the same basic network infrastructure can serve several users and applications.

***Key words*:** Hydrology, meteorology, integrated networks, Total Life Cycle Cost.

1. Total Life Cycle Cost

The managers of meteorological and hydrological networks face a number of challenges in operating their networks[1]. These include but are not limited to:

- Operating the network efficiently with limited resources; having to cope with a reduction in personnel.
- Economic pressures lead to an increase in automation; this results in more stringent requirements for calibration and quality assurance.
- As the equipment becomes more sophisticated, the number of instrument specialists in the organization is reduced. This leads to a greater need for support from the equipment vendors and manufacturers (e.g. a need to refine subcontracting practices).
- Need to replace obsolate systems or take advantage of new technologies with frequent updates.
- Use the same capital investment to produce more data for a larger number of users.

Although some procurement officers will always favor a “lowest bidder wins” policy, the Total Life Cycle Cost (TLCC) of a network should always be considered. Cheap, poorly documented and performing systems increase TLLC, and more importantly, they have a major impact on climate records, appearing as shifts or discontinuities in the long-term time series.

The TLCC is the total cost during the expected lifetime of the meteorological and hydrological equipment. TLCC can be expressed as containing the following four basic elements:

$T = P + R + O + C$, where
P = Product Cost
R = Resource Cost
O = Operating Cost
C = Contingency Cost

An optimum selection would be a combination of a low T and good overall, long- term performance of the equipment to be purchased.

1.1 Product Cost

The Product Cost contains, in addition to the basic price quoted, the testing and documentation, packaging and transportation, taxes, import duties, and so on. Being able to share this cost with other users of the equipment provides immediate cost savings.

The ease of installation, including the manpower requirements, plays a significant role. Therefore, e.g. ready-made connectors in the cables and a meteorological mast that can be tilted by one man will have a significant positive effect on the installation cost.

1.2 Resource Cost

The Resource Cost includes site preparation work such as site purchasing, building access to the site, possible building(s), installing electrics, telecommunications and so on. Modern systems are compact, lightweight and easy to install. Frequently, they are powered by a small solar panel and communicate via wireless telemetry, thus minimizing the site preparation costs as well as improving the reliability of the systems.

1.3 Operating Cost

In the network operation of unmanned, automated equipment, the major part of the Operating Cost is generated by maintenance and telecommunication costs.

Although the quality and reliability of automatic measurements have been improved significantly and the need for maintenance has been considerably reduced in the last decade, many savings can still be realized in maintaining networks of automatic weather stations. Easily interchanged sensors, extended calibration intervals, self-diagnostics and reporting, remote maintenance (including access to intelligent sensors via data logger) and accurate METADATA records are all ways of reducing the Operating Cost.

As we all know, telecommunications technology is advancing very quickly. In days gone by, we could assume that systems would be operated continuously and uniformly for almost all their lifetime. Now, we must be prepared for changes soon after taking a new system into use. However, we can benefit from new and economically effective ways of collecting and distributing data and end products. Meanwhile, we must take telecommunications developments into consideration when planning the system design to accommodate modifications and upgrades. It can be very costly not to have done so when implementing them. Regardless of the installation

site, if the range of telemetry options is wide enough, an economical and reliable alternative for data transmission will be found.

The automatic stations should have field-proven extended Mean Time Between Failure (MTBF) rates. Also, the maintenance should be eased as much as possible by using modular, easy-to-replace modules and sensors.

Another signicant part of the Operating Cost is taken up by upgrades. When the technology advances rapidly, supporting "older technology" with spare parts and engineering may become a disproportionately large element of TLCL if it is not carefully planned and looked after. To succeed, an upgrade strategy requires support from reputable, established equipment manufacturers and compatibility with the existing system that is built into the system design.

1.4 Contingency Cost

The primary Contingency Cost covers the possible purchasing risks, such as: a defective product, late delivery, or the vendor's inability to deliver at all. It also covers the vendor's inability to support the purchase with spare parts and upgrades during the lifetime of the equipment, commonly considered to be a default of 10-15 years. Other concerns when planning future updates/upgrades include: reliability of the published performance data, compatibility of the design in the future and the availability of long-term support for spare parts, training and calibration.

2. Network Automation and Integration

"Improving reliability and accuracy" has driven automation development[2]. *"Cost-effectiveness"* is now becoming another major driver of automation. Many organizations are seeking ways to reduce the cost of operating their networks. Automation certainly offers significant savings. In many cases, network integration offers significant further savings, since the capital investment can be used to produce more data for more users. Before an integrated network can be taken into use, several matters must be considered in the network design (e.g. site selection, telemetry) and in selecting the right equipment.

2.1. Sensors

Sensors play the key roles in any measurement system. This is true not only with respect to the accuracy and long-term consistency of the data, but also in reducing the cost of calibrating and maintaining the sensors. In addition, we should not forget the effect of the sensor selection on the continuity of the long-term measurement records. Therefore, in order to extract the full benefit out of an integrated system a set of alternative sensors with documented performance should be available for any parameter. From these sets, the optimum selection can be easily made to meet the needs of all the network users.

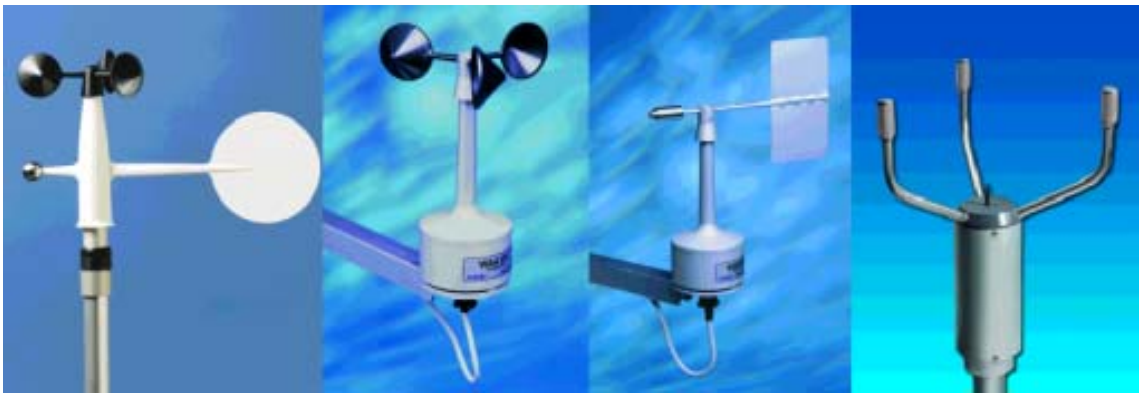

Fig 1. Different types of wind speed and wind direction sensors, also with heating for severe winter conditions

In addition, site selection for the sensors is very important in developing an integrated system. In hydrometeorological networks, it is often necessary to locate one or more sensors in a properly representative place (e.g. wind and temperature sensors need to be located far enough away from the riverbank). Therefore, options must be available for installing sensors even hundreds of meters away from the data logger.

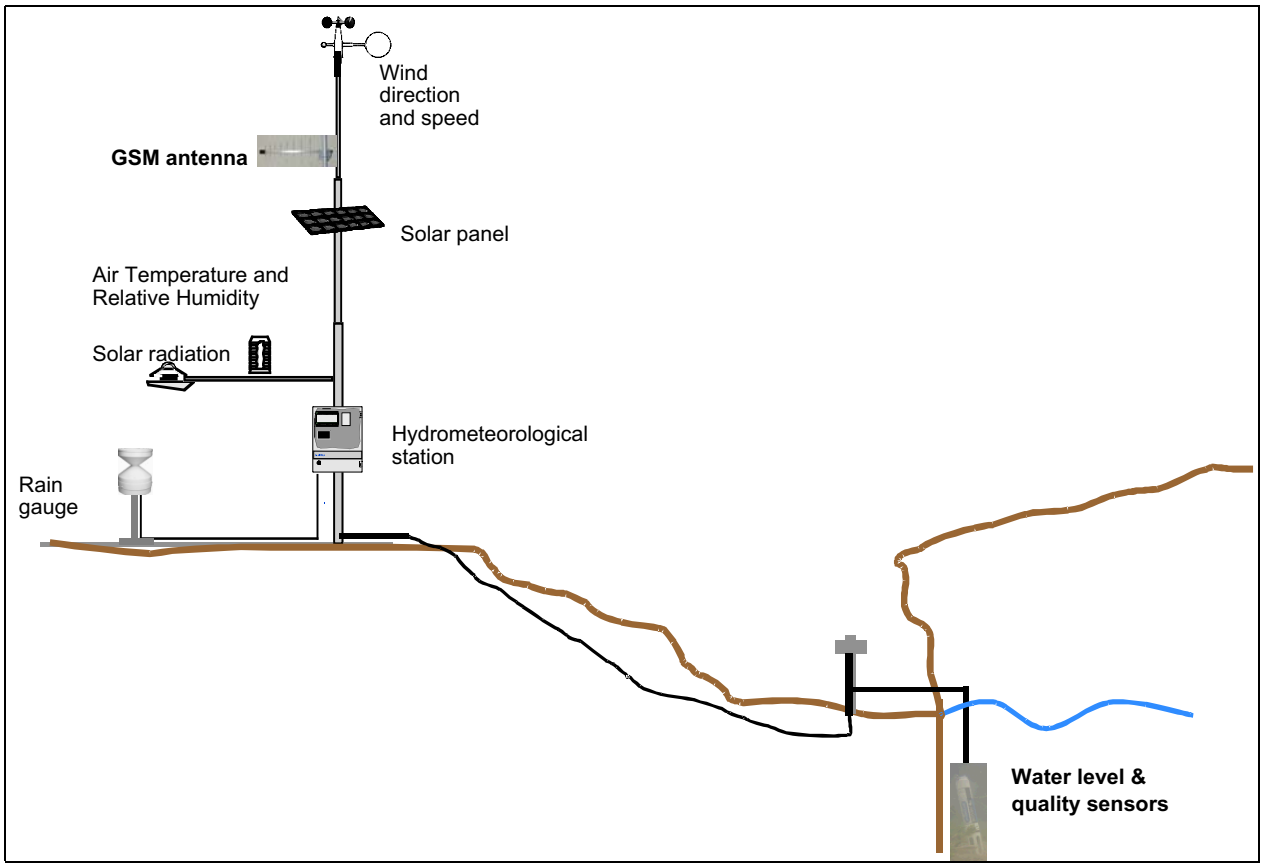

Fig. 2 Example of relocated sensors in hydrometeorological installation

2.2 Data Collection

An important part of an observation network, data loggers must provide cost-effectiveness, security, simplicity of operation and maintenance, and reliable and accurate data.

Flexibility and adaptability are central to the design philosophy: the data logger should be usable with many types of sensors, telemetry devices and across a wide range of technical and environmental settings. In addition, sensor requirements differ from country to country and organizations will often have particularly stringent performance requirements for sensors, which will need to be accommodated, too. New modern sensors will be extensively exploiting the microprocessor technology providing instant and statistical data via serial line or fieldbus. If this is not accounted for in the data logger design, the cost of updating a system with new sensors can be prohibitive.

The development of new end products such as numerical weather prediction models (NWP's) will require data to flow in more frequently (e.g. every 10 minutes or "as required"). Data from alternative meteorological parameters will also be needed in the future. The ability to remote configure the automatic stations is therefore a basic requirement. Data must be made constantly available, not only by autosending or polling at preset intervals, but also whenever real-time data is requested.

In addition to the measurement tasks, it may occasionally be necessary in carrying out hydrological projects to interface the observation station with other automated systems and environmentally friendly equipment such as aerating turbines and fish bypass devices.

2.3 Telemetry

Telecommunications costs frequently account for the largest portion of the annual operating budget. Since data flow will have to become more continuous in future, telemetry will often be the most critical area of network design from the operating cost point of view. During the network design stage, therefore, the widest possible range of telemetry options should be specified so the most economical telemetry solution can be found for each monitoring site. This also greatly reduces the odds of making a costly misstep when the network is updated in future.

As already mentioned, telemetry solutions are developing fast. Where today we may have a remote station that can only be reached for data transmission with an expensive satellite link, tomorrow the coverage of the local GSM network may be extended over this site. If the station hardware already has built-in GSM communication capability, the upgrade will be easy and economical to accomplish without additional hardware module(s) or software redesign.

One way to reduce telecommunication costs is to use one or several of the stations in the network as *main station(s)* with primary telemetry (e.g. GSM or satellite). These main stations can have *Substations* that send data to the main station via radio modem, for example, which has practically no extra operating cost.

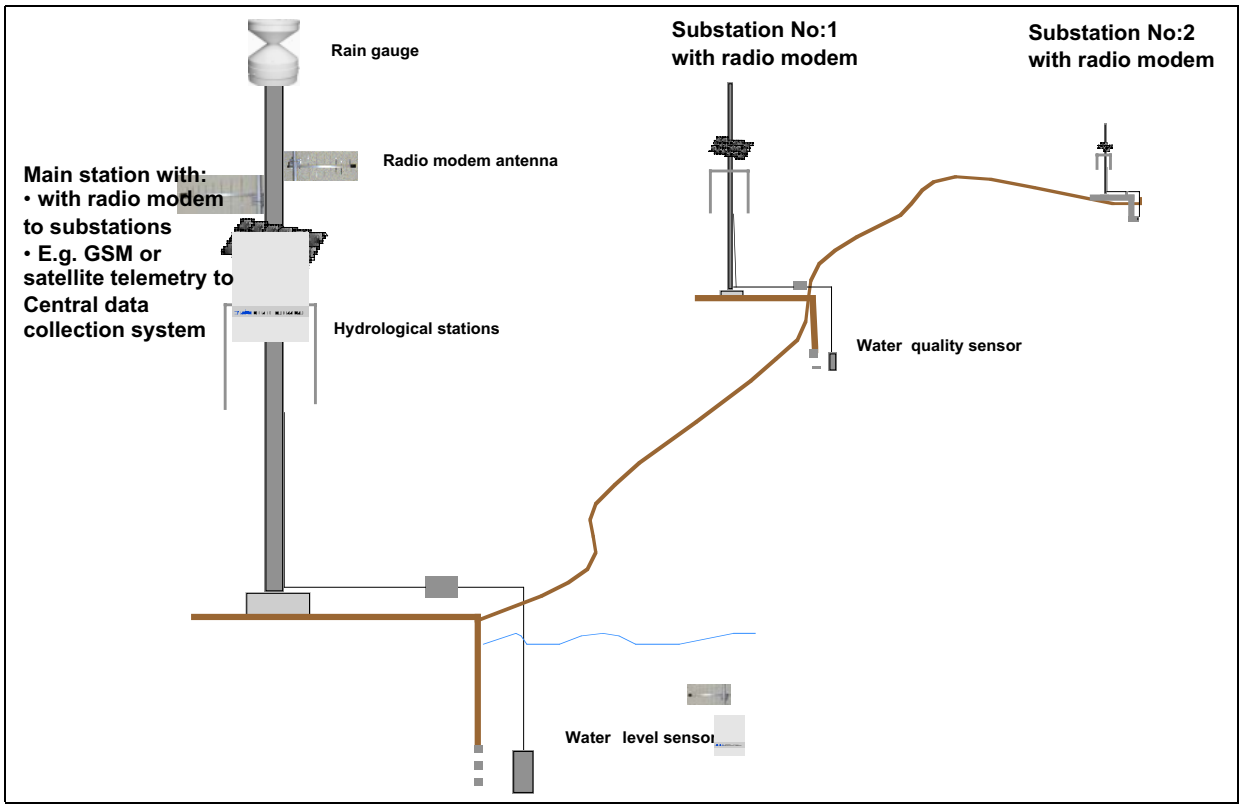

Fig. 3 Main stations with substation using radio modem for telemetry

2.4 Central Data Collection & Database

In addition to the routine data collection schedules, which will become more frequent in future, there will be also a requirement for "on-request" data. "On-request" data will make it possible to respond promptly and appropriately in an emergency situation such as a flood, approaching thunderstorm or other real-time situation that requires decisions to be made immediately.

Increasing automation requires the establishment of sound quality management procedures. In addition to scheduled field inspections, comprehensive and accurate METADATA records should be kept for the sensors, site maps and the equipment itself. A modern central data collection (CDC) system should offer this facility, and also allow it to be used and updated remotely e.g. during field inspections.

In addition to conventional meteorological and hydrological forecasting, demand will grow for interfacing with systems that aid decision-making in the short-term and long-term: e.g. flood or hazardous weather warnings, or optimizing the generation of hydroelectric power.

With the goal of reducing the total operating costs of the network, the CDC system must include integrated functions that perform remote maintenance and checking of the network.

When a large database system is installed, dedicated and professional personnel are needed to look after it, and support and guide its users. Therefore, considerable savings can be achieved by using a common database system, even for a countrywide network.

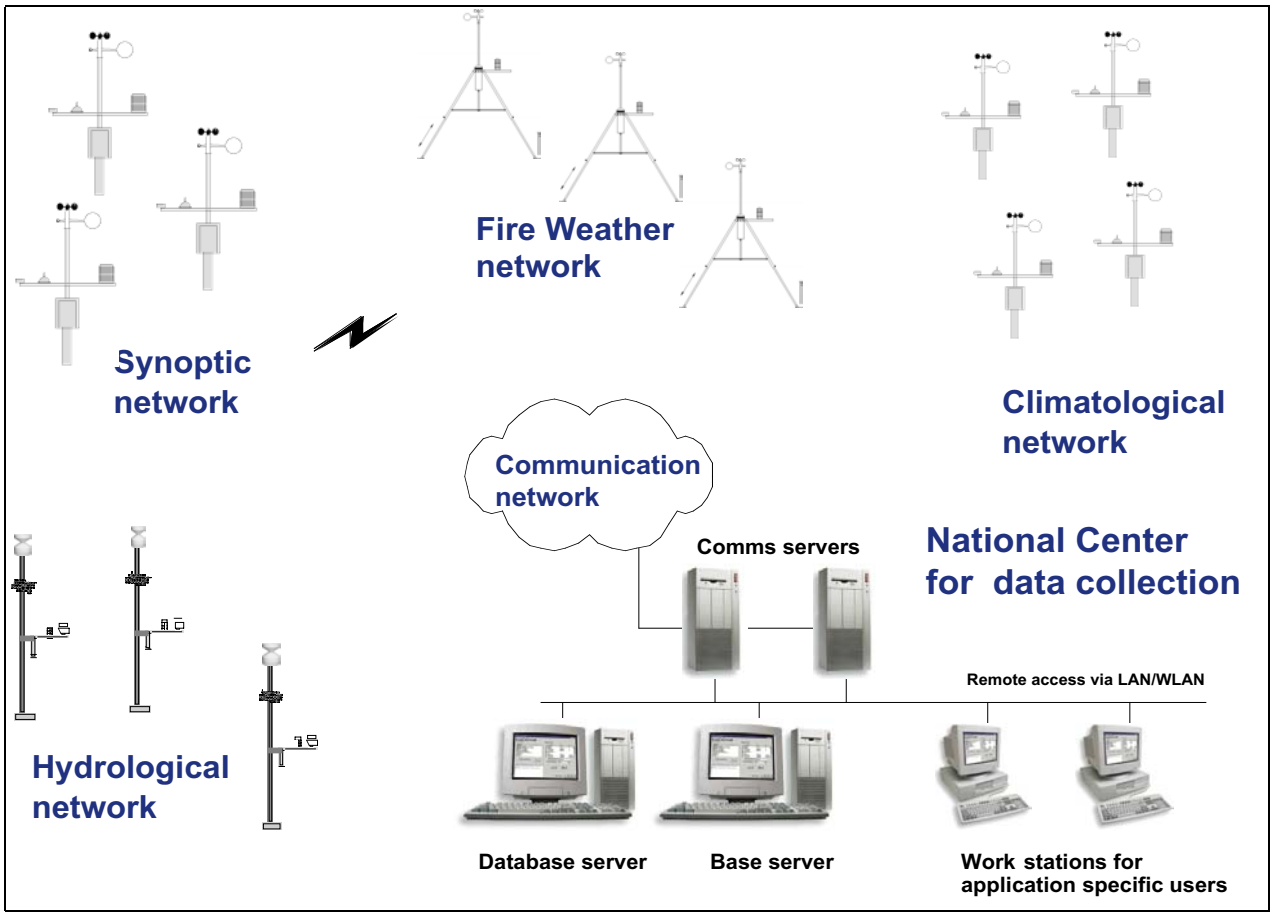

Fig.4 Example of a large Central Data Collection System with many users

Requirements for real-time applications such as forecasts ("nowcasts"), warnings, control and commercial services, will increase significantly. Therefore, a special attention must be paid to selecting a database, which can support all these functions and increased number of users also in the future. Selecting right commercially available tools, the updates are easily and economically available, too.

3. Building on Existing Technology

Most of the sensing technology – such as meteorological sensors, water level sensors and water quality sensors – has been in use for many years. However, enhancements to these technologies are on the horizon: sensors will become more intelligent and will be combined together with more sophisticated and fast-evolving telecommunications, data management, decision-making support and real-time systems. New opportunities will appear for integrating environmental monitoring with the goal of generating more accurate data while operating the network more efficiently and economically throughout its lifecycle.

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WIND SENSOR FOR AWS BASED ON NEW TECHNOLOGY

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***Abstract**: A prototype of a new design wind sensor is shortly described. The short description contained in this paper is as given by the manufacturer. Some results from the manufacturer's laboratory and field testing of the prototype sensor is also presented. The sensor is small with a design and measuring principle that looks promising with respect to low maintenance costs, as well as the possibilities to keep the sensor ice-free without having to apply a lot of power. The Norwegian Meteorological Institute will be involved in operational field testing of the sensor at our maritime test site at Stavernsodden light house off the coast of south-eastern Norway during the winter 2002 /2003.*

INTRODUCTION

Traditionally designed wind sensors, cup anemometers and ultrasonic sensors, calls for frequent maintenance work or problems with reliable measurements in severe weather conditions. Especially at remote stations, both maritime stations at unmanned light-houses off the coast of Norway and mountain stations where heavy wind and precipitation conditions can be expected, the amount of work and expenses connected with ensuring reliable wind measurements is extensive. A promising new wind sensor, developed by TMI (Trondheim Maritime Instrumentation) will be tested at a maritime test station off the coast of southern Norway during the winter 2002/2003. The content in this paper are based on information and test results supplied by the manufacturer.

MEASURING PRINCIPLE

The new wind sensor makes use of a Position Sensing Detector (PSD), an opto-electronic device which converts an incident light spot into continuous position data (x, y). An illustration of the measuring principle is given in figure 1. The wind induced drag force tilts the stick slightly (in the order of 5° during hurricanes), and the x, y – position of the light spot emitted from the laser diode mounted on the lower end of the stick is detected by the PSD. The x, y – values is detected as analog signals (voltages). The signal conditioning electronics together with the micro processor is housed inside the unit, and the output is a calculated wind speed and direction together raw data and some housekeeping parameters. According to manufacturer, additional sensors for measuring atmospheric pressure and humidity will also be implemented in future versions.

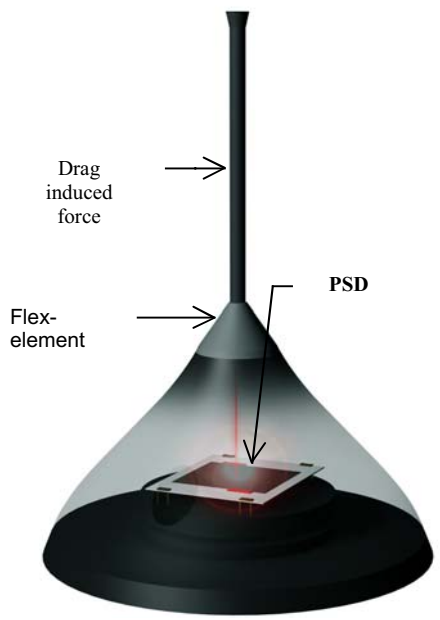


Figure 1.

The anemometer is based on the drag induced force principle. A cylinder (stick) which is exposed to a

relative wind V_r, experience a drag force F_D according the following formula: F_D = _ * _V_r^2*A_s*C_D (1)

Where V_r is the relative velocity _ = density of air
A_s = cross sectional area of cylinder C_D = the drag coefficient in air

The drag coefficient C_D is not constant. If the flow is laminar, the drag coefficient is inversely proportional to the velocity. This means that the drag force then is only proportional to the body's velocity. When the flow is turbulent, the drag coefficient C_D is approximately constant, resulting in a drag force that is dependent on the square of the velocity. In the design of the anemometer the manufacturer has strived for a constant C_D coefficient in order to simplify the calibration routines in the production.

LABORATORY TEST

The response of the sensor with various spring/damping constants and shapes of the flex-element was investigated thoroughly in the laboratory. The first tests revealed a critical damping with a time constant of approximately 0.06-sec. (63%). See figure 2.

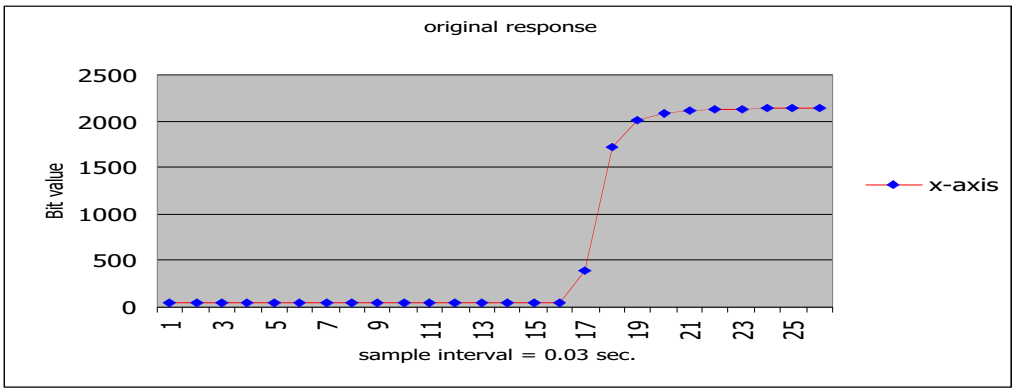


Figure 2. Response with critical damping.

Modifications on the signal conditioning electronics gave a shorter time constant (0.017 sec.), but a small overshoot (approximately 10%). The modified response as presented in figure 3 was chosen for the first field measurements.

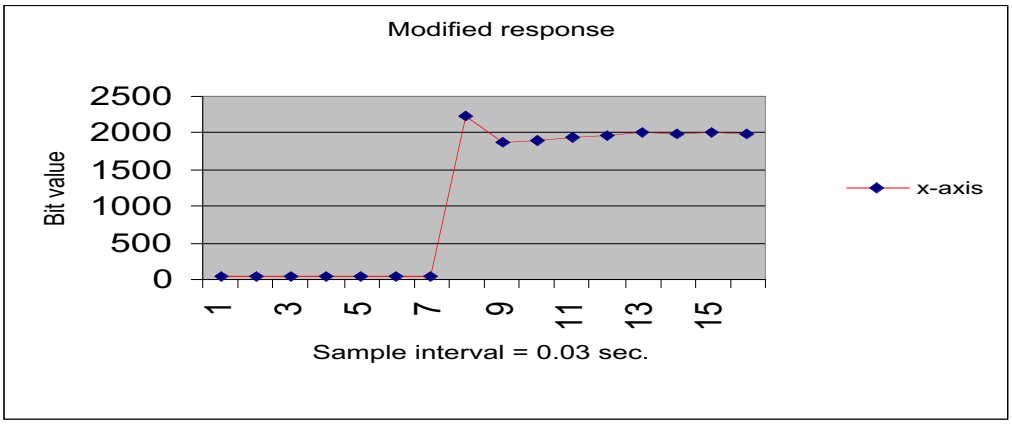


Figure 3. Noncritical damped response.

The response of the y –axis was the same as for the x-axis. The initial laboratory tests comprised calibrations with respect to input force, threshold level (sensitivity), stability and repeatability.

MANUFACTURERS FIELD TEST

To do field tests of the TMI wind sensor, the manufacturer mounted the sensor on the roof of Pirsenteret, a building located seaside in Trondheim. For reference the manufacturer used a cup anemometer (Aanderaa) mounted at the same site. At this site the sensor was tested for 7 months. During the test period the sensor was exposed to strong winds as well as heavy precipitation. The analogue output from the TMI-anemometer was digitized with a sampling frequency of 1 Hz, and all data were stored on PC for later analysis and comparison with the reference data. The reference cup anemometer gave 1 minute averaged wind speed together with maximum 3-second wind speed gust during the last minute. A wind vane gave the wind direction as an instant value at the end of the averaging period. Totally 250 million samples of wind data from the prototype were collected during the first field-test. During the test period the reference sensor had to be replaced twice due to malfunction, while the TMI-Sensor worked satisfactory through all 7 months.

The response of the sensor was tested prior to and after the field measurements. Any degrading (aging) effects of the material in the flex-element were not found. In general it can be concluded that the both speed and direction correlated very good with the reference data during the manufacturer's test period. In the following some characteristic samples from the recorded data are presented. The results from the prototype anemometer are not calibrated values. The results are only used for a quality assessment of the sensor during different weather conditions. However, the non-calibrated values give a good indication of the performance with respect to sensitivity, dynamic range and repeatability.

Data collected during periods with heavy precipitation

Representative time series from a period with heavy precipitation is shown in figure 4 (below). A moving average with a window of 1 minute is applied on the data from the prototype. The averaged data correlate very good with the data from the reference station.

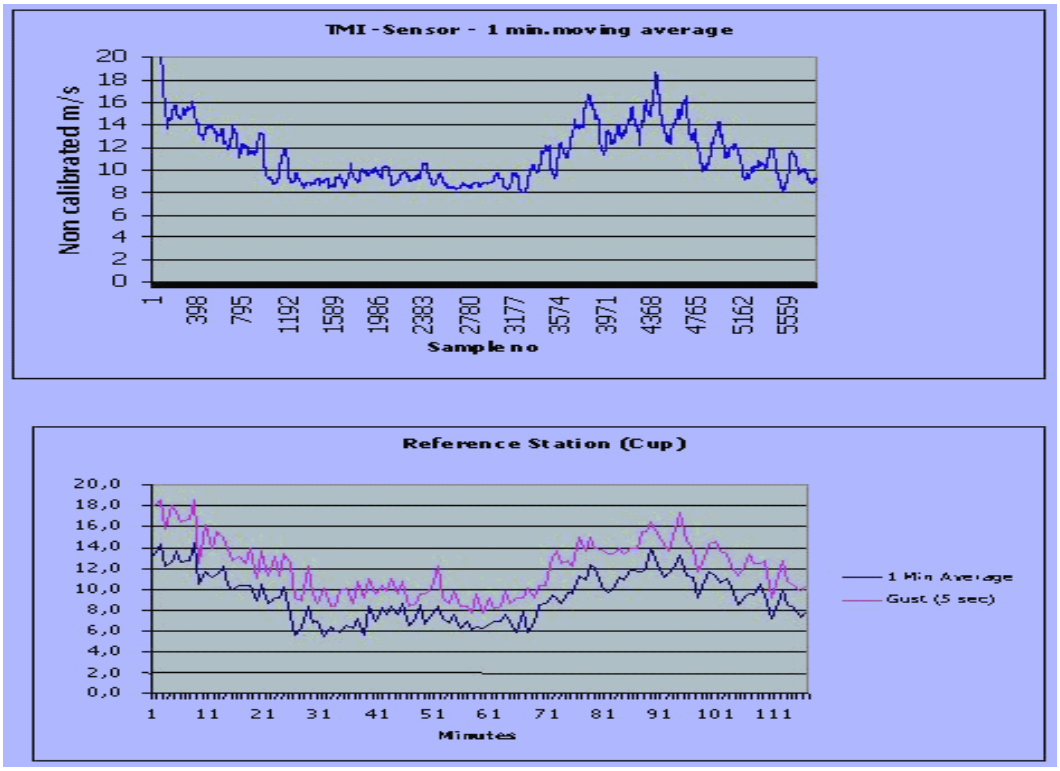


Figure 4. Heavy precipitation. Comparison with reference station.

The preliminary results from the prototype indicate that the instrument performs satisfactory during conditions with heavy snow fall/rain, and no sign of degrading effects were seen during such conditions.

Comparison of wind direction data with reference station

Wind direction is calculated by using unit vector summation. i.e. independent of wind speed. While the direction from the reference wind vane is a momentary value at the end of the averaging period (1 minute), the direction obtained from the prototype instrument is a 1-minute smoothed value. Therefore it is not worthwhile to make any detailed correlation analysis, but the directional data are presented to give an impression of the stability of the x- and y-components measured by the prototype.

Periods with strong wind have been chosen for presentation. The length of the timeseries presented in figure 5 (below) is approximately 10 hours.

The prototype tested measures the x- and y-component of the wind vector, and the direction is calculated later from the recorded components.

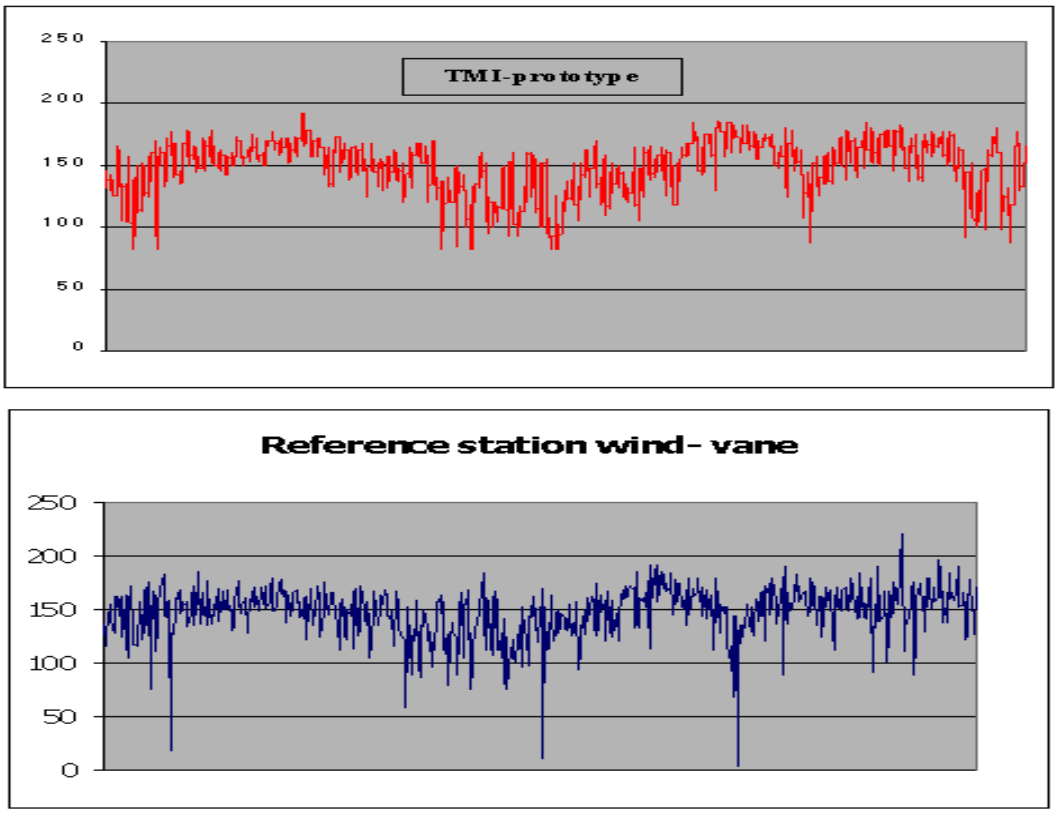


Figure 5. Comparison of measured wind directions.

Sensitivity and stability of sensor

An evaluation of the sensitivity and stability of the sensor was the main purpose with the first field tests. The prototype was designed to measure wind speeds up to 100 m/s and still be able to resolve speeds as low as 0.1 m/s. The averaged data presented in figure 6 confirm that the prototype is able to give reliable and stable data within the aimed limits. As can be seen from the graphs, the sensor output is appr. 40 bits when wind reference speed is 4 m/s. This indicate that the sensor is accurate and stable in the lower end of the measuring range.

Further laboratory tests (wind tunnel) are required to establish the correct and final resolution, but it is reasons to conclude that the sensor satisfies the specifications that were set in the design phase of the development project.

The manufacturer is aiming at being able to measure wind speed as high as 100 m/s. However, due to for instance the limited area of the PSD and also the squaring effect, the maximum speed might be down to 90 m/s.

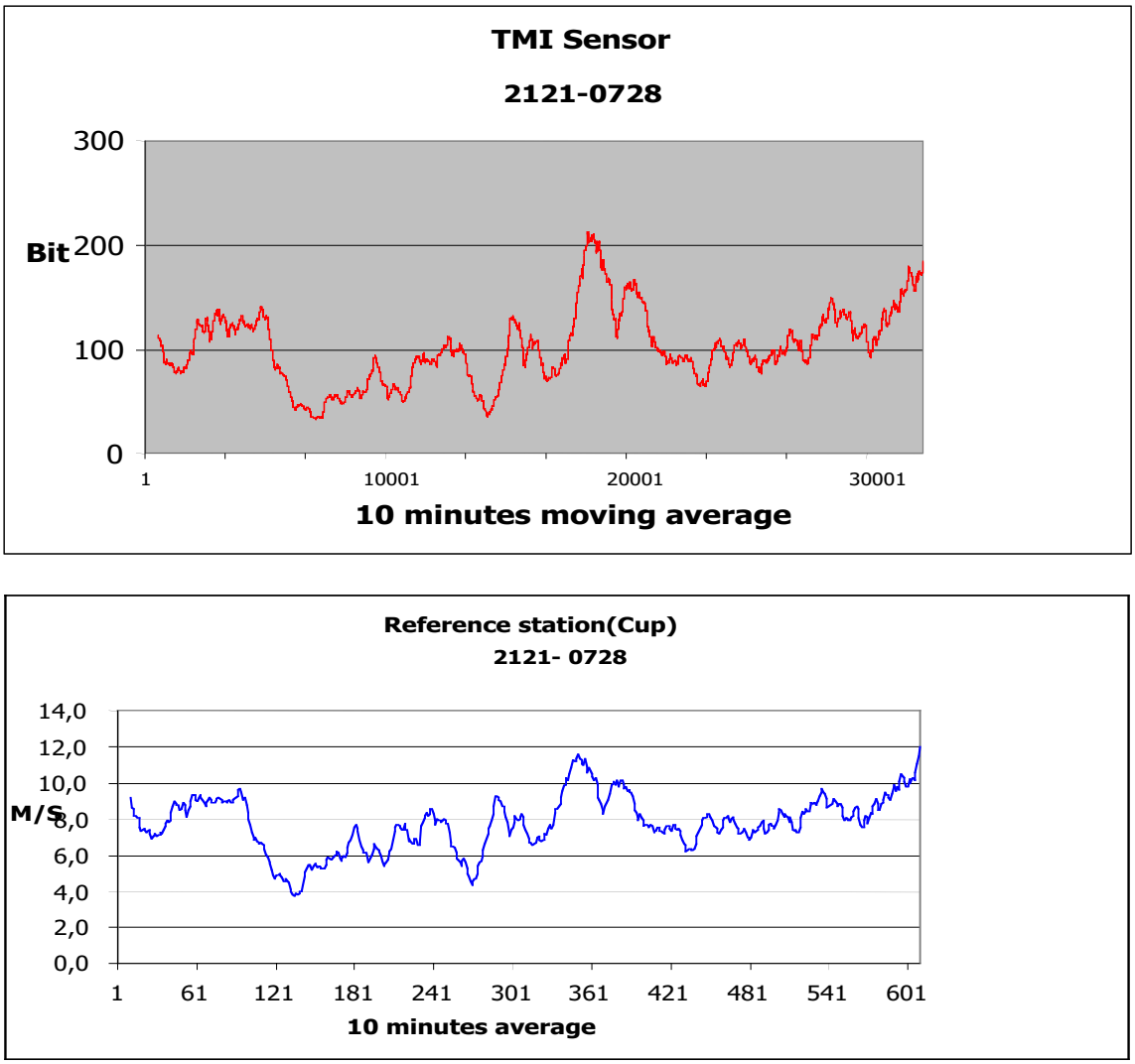


Figure 6. Comparison of 10 minutes averaged wind speed.

Due to the squaring effect, the higher wind speeds are amplified, and apparently the prototype seems to have lower resolution at lower wind speeds.

THE NORWEGIAN METEOROLOGICAL INSTITUTES FIELD TEST

At the Stavernsodden test site the new wind sensor will be mounted at the top of a 6 m high wind tower. For comparison the wind tower is also equipped with two different cup anemometers (Vaisala and Vector) and two ultrasonic wind sensors from Gill. The tests of the TMI sensor have been delayed and will start as soon as a calibrated version of the new sensor is installed at the site. Results from this field tests will be presented at the conference in February 2003.

ELECTRONIC SENSORS: DEVELOPMENT & DEPLOYMENT

Lubomír Coufal (CHMI, Prague), Václav Chalupsky (METEOSERVIS, Vodyany)

Abstract

The paper describes the development of electronic sensors and the problems that surfaced and were identified after deploying the sensors in the network. Attention is paid to the SD4 electronic sunshine recorder and its heating, and to the upgrading of the quality of measurements and calibration in laboratory conditions. The paper also offers a preliminary comparison of its readings with those of the Campbell-Stokes sunshine recorder. The development of the weighing rain gauge addressed two basic aspects: to improve measurements in the winter season and to make the operation easier while maintaining all the measured precipitation in the liquid state. The last instrument discussed in the paper is a floating evaporimeter that takes readings on a free water table. The paper looks at the influence of water waves and problems with deployment in a unusual environment.

Key words

Automatic station, electronic sensors, sunshine recorder, weighing rain gauge, evaporimeter.

At the last meeting, we spoke about the principles of installing automated meteorological stations in the volunteer-operated climate network of the Czech Hydrometeorological Institute. In the course of automating the station network – both the professional and volunteer-operated sites – the need arose to further increase the number of electronic sensors to meet the requirements for the quality of measurements and to take into account the climatic conditions. The efforts for gradual improvements in the quality of observations are resulting in an increasing number of sensors, which fit, among other things, the climatic conditions that prevail in central Europe. This contribution deals with the problems accompanying the development and deployment of new sensors.

NEW SENSORS

SD4 sunshine recorder

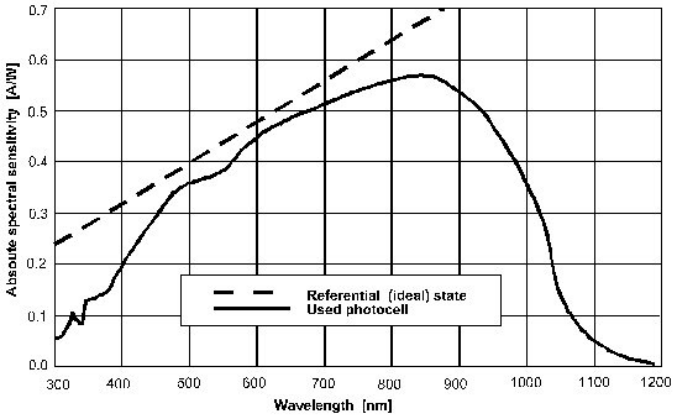
The SD4 sunshine recorder is an electronic detector; it has been developed to replace the currently used system of the Cambell-Stokes detector, to eliminate the subjective evaluation of the burnt trace on the system's tape and to become directly part of a higher-level automated measuring system.

The principle is to create a picture of the sky, on a well-arranged array of discrete photosensitive elements, from which the presence of direct solar radiation can be detected from different intensities of the illumination of these elements, using suitable software. This single sentence describes the principle of measurement in a simple way, but the path leading to this goal took several years to travel. Although this sensor is now being deployed in the Institute's network, its development has not been finalised and work is under way on improving its parameters.

The sensor is composed of a glass cupola through which the sky's radiation passes, and an optical system with suitable irises, which passes the radiation over to a layer of discrete photosensitive elements. These are silicon plates commonly used in solar cells. The body of the sensor, made of a Dural alloy, hides evaluation electronic circuitry, including a control processor. The sensor is fitted with powerful heating for winter, and air humidity under the copula is absorbed by Silicagel in a replaceable cartridge. The output from the sensor is two-state information – direct solar radiation has been detected or not. The sensor

detects direct solar radiation from a level of incident power of 120 $W.m^{-2}$. It is also fitted with self-calibration adjusted to this level.

The development path of each of the sensor's parts is strewn with a number of both failures and victories. For example, there were several other options how to set up the array of photosensitive elements. One of them was to create an array from photodiodes, another option was to use industrial CCD chips. It is technologically more challenging to assemble an array from solar cell silicon plates, but this approach has its rewards – a broader spectral sensitivity of the sensor in the range of photo radiation. The following graph indicates the spectral sensitivity of this material.



Graph 1. Spectral sensitivity of materials

Another problem was the sensor's ability to work under extreme conditions, for dew or frost on the copula would certainly render any measurement useless. The lessons learned from several failures have resulted in the current version of a really powerful and reliable heating system for the sensor's internal space.

However, the most challenging aspect of the sensor's design, which we continue to improve, is the sensor's ability to correctly detect direct solar radiation. This means to be able to detect, using a suitable optical system and evaluation software and absolutely accurately and repeatedly, direct solar radiation even when the sun is low over the horizon, for instance at the time of sunrise and sunset, or to be able to reliably distinguish the disturbing background of bright skies. Although the current version of the sensor yields satisfactory results, many more improvements can certainly be achieved in this respect. One of the approaches is to adjust the evaluation software, another way forward would be several new ideas – changes in the sensor's optical system and hardware.

Calibration

Each new instrument deployed in network measurements must obviously be calibrated in advance. This applies all the more so to an instrument that has been newly developed, such as the SD4 solar detector. In our case, we had to find out whether the condition was met that the instrument would only indicate sunshine when 120 $W.m^{-2}$ falls on the plane perpendicular to the direction of sunrays.

The most accurate determination of sunshine duration would obviously have been using a pyrheliometer with a solar tracker. Absence of moving parts, as well as eliminating the influence of diffuse radiation, is (in connection with electronic sunshine recorders) a necessary precondition.

Solar detectors were calibrated at the Institute's Solar and Ozone Observatory in Hradec Králové. Since the observatory does not have facilities for permanent measurements of direct solar radiation (H), this radiation was calculated from standard measurements of global (G) and diffuse (D) radiation using the formula $H = (G - D)/\sin h_s$, where h_s is the Sun's elevation angle.

For measuring direct solar radiation, the reference pyrheliometer was a Linke-Feusner (LF), CM1 actinometer made by Kipp-Zonen. Global radiation is measured by a Kipp-Zonen CM11 pyranometer, the same CM11 sensor fitted with a CM121 screening ring gives values of diffuse radiation. Both CM11 instruments are used as operating instruments and the values measured are stored at one-minute intervals. The following graph documents a comparison of

the results of calculated and measured direct solar radiation in a typical one-day situation. The graph indicates that at the time of sunrise and sunset, the error of the calculation is considerable, up to tens of $W.m^{-2}$. The value of the sin h_s in the denominator suggests that for instance for the Sun's elevation angle $h_s = 1°$, each watt in the difference between the global and the diffuse radiation is multiplied by about 57. This is the reason we have not plotted in the graph values calculated for $h_s < 1°$. This error appears for both clear and overcast days, and to minimise it levelling of the offset of both sensors, or rather the measuring channels, global and diffuse, will be crucial.

Additional errors in the calculation can be observed during the day, usually when the intensity of incident radiation is higher. Assuming correctly calibrated sensors, we will discover another weakness of the calculation – the measurement proper and calculation of diffusion. The diffusion sensor, which should scan the picture of the whole sky except the sun disc, should be screened by a stop having an angular size derived from the solar disc's angular size. In our case, however, it is screened by the CM121 screening ring. This arrangement does not have any complex (and expensive) moving parts, only an adjustable ring, but screens off a much larger belt of the sky. This error is corrected by one seasonal multiplication constant, which, however, assumes an isotropy sky.

Another factor deteriorating the accuracy of the calculation is the misalignment of the two sensors' parameters; the sensitivity of the global and diffuse radiation sensors is not quite constant during the day. It exhibits a slight dependence on temperature and also changes somewhat with the intensity of the incident radiation. The result may be misalignment of the radiation intensities determined, by as much as 2%. In weather with a large proportion of diffuse radiation (up to 300 $W.m^{-2}$) this represents a deviation of 6 $W.m^{-2}$. When calculating H, this value is also multiplied by the factor 1/sin h_s, thereby contributing as much as about ±20 $W.m^{-2}$ to the error in the calculation of direct solar radiation. To assess solar recorders, results around the threshold value of 120 $W.m^{-2}$ are important, where the observed deviations of calculated H from direct measurement using an LF actinometer usually lie in the interval from -25 to + 40 $W.m^{-2}$.

To indicate the time error caused by inaccurate determination of radiation intensity we can say that the intensity of direct solar radiation increases on a bright day during dawn by 6 to 10 $W.m^{-2}$ per minute. This suggests that a solar recorder with an error in the setting of the threshold value amounting to for example +30 $W.m^{-2}$ will register sunrise, the sky being bright, by about 0.1 hour later. The variations in sunshine during the day, caused by cloud movement, usually mean much faster changes of intensity, and the error in the adjustment of the threshold level will not be reflect in the time error for all practical purposes. On the other hand, there are situations when stratiform clouds keeps the direct solar radiation intensity around the threshold value for a long time, and also high-quality detectors may easily make a considerable time error.

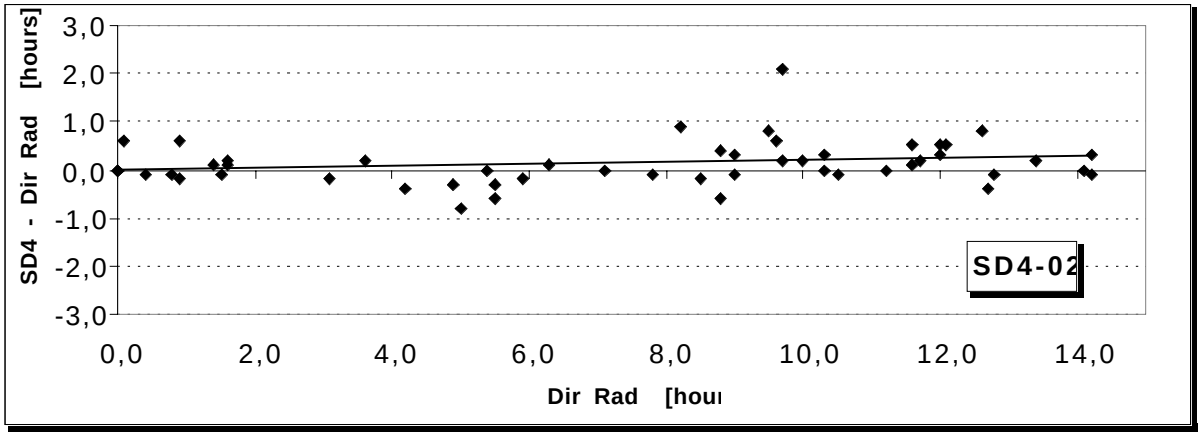
We need to note that under real-life ambient conditions solar radiation intensity usually changes too fast to allow adjustment to be made and checked for different directions of the incident radiation. Stable sunshine needs to be modelled in laboratories, with the help of a lamp. The calibration method (unit) also developed gradually.

The first solar recorder prototypes were made available for testing in December 1999. At first, a developmental model labelled SD3, in June 2000 a new piece designated SD4. The SD4 solar detectors do not have even spectral characteristics. When adjusting and checking their sensitivity in laboratory it is to be remembered that a lamp's radiation spectrum does not equal solar spectrum (the colour temperature of the Sun is about 6,000 K while the lamp has about 2,800 K). An SD4 sensor will not feel the Sun's radiation intensity of 120 W/m^2 the same as the same intensity of lamp radiation. We therefore need to find experimentally the optimum sensitivity value for a typical sensor specimen. The sensor with optimised sensitivity

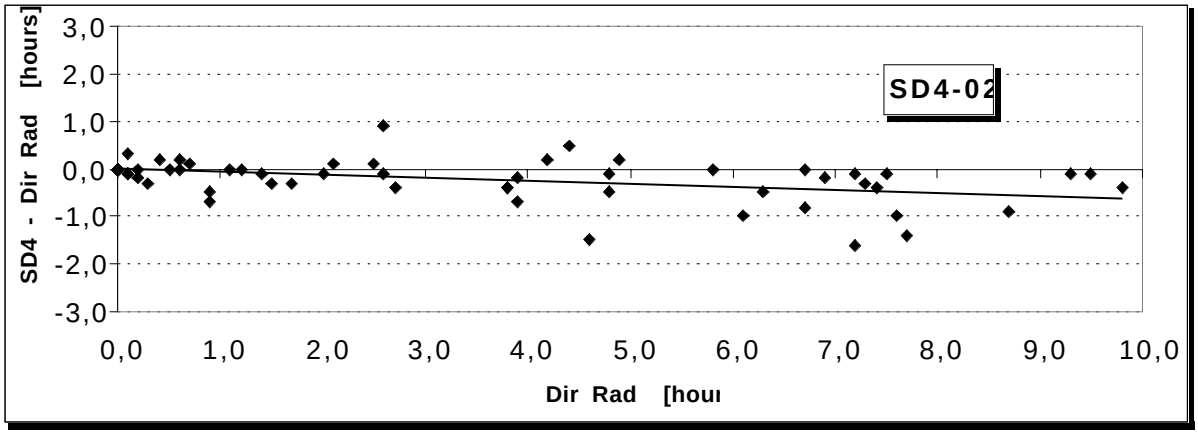
will then be used as a reference in the laboratory calibration unit for adjusting the sensitivity of other sensors of the same type.

Three new SD4 sensors were therefore tested outdoors from the spring of 2001. The first was left with the original factory-set sensitivity, while the other sensors' sensitivity was increased in several steps in spring and summer 2001. The criterion for changing the sensitivity was to minimise the differences between daily totals of sunshine duration and the reference values determined on the basis of calculating direct solar radiation intensity.

The following graphs show the typical behaviour of well-adjusted SD4 solar detectors in summer and winter. The graphs show daily sums of sunshine determined by calculating direct solar radiation, and differences from daily sums of the readings made by the SD4 sensors.



Graph 2. Daily sums of sunshine determined on direct solar radiation calculation (Dir Rad) and differences from daily sums of the readings made by an SD4-022 sensor. Data for summer (July to August 2001)



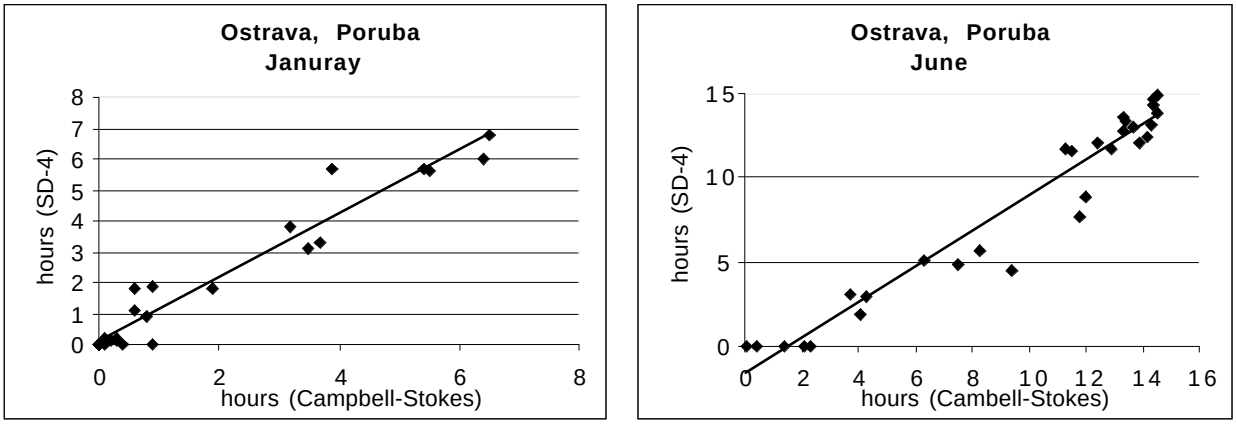
Graph 3. Daily sums of sunshine determined on direct solar radiation calculation (Dir Rad) and differences from daily sums of the readings made by an SD4-029 sensor. Data for winter (December 2001 to February 2002)

Summarising calibration results we can observe that the calibrations have not only contributed to the further development of the sensors but also highlighted the fact that in winter, when the Sun is low, the readings are slightly undervalued. The error in the determination of daily sums of sunshine ranged from +2 to -7% in comparison with the calculated reference value. All solar detectors must be calibrated before deployment in a network.

Our experience

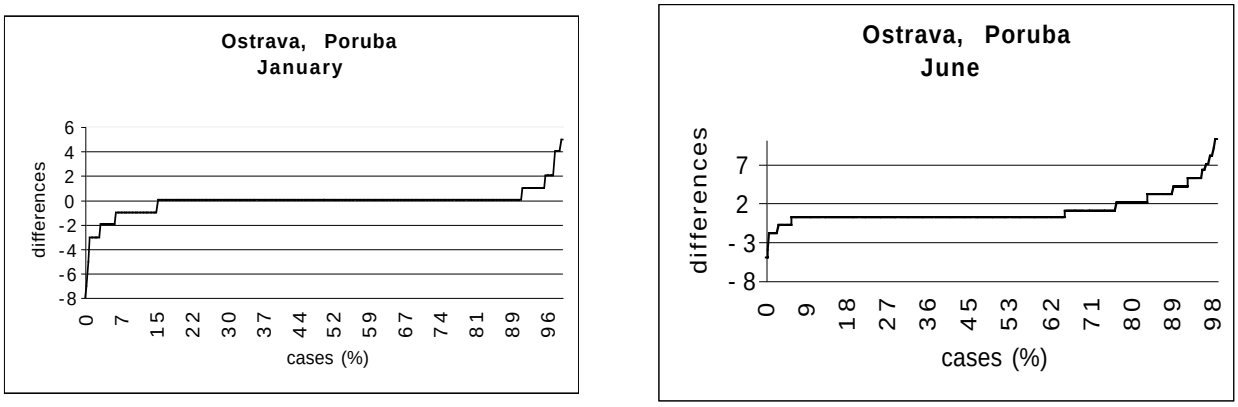
The solar detectors have not been working in our network long enough, and the conclusion is therefore to be taken as tentative information. Based on parallel measurements

at the Ostrava station, the following two graphs show the differences found between values read from the SD4 solar detector and a heated Campbell-Stokes solar recorder. When analysing the following information we need to recognise that the first traces on the tape



Graph 4. The comparisons of daily sums of the sunshine duration

(depending on the type of solar recorder and type of tape) can be detected at an intensity of as little as 100 W/m^2. The comparison covers daily sums as well as the differences of hourly sums that, naturally, must be influenced even more by the different physical principle of measurement.



Graph 5. The differences of hourly sums of the sunshine duration.

Obviously, similar simultaneous measurements must be run for a longer time for us to be able to determine the degree to which the homogeneity of the series has been impaired. The required solutions cannot be drawn from the measurements carried out so far.

MRW500 weighing gauge

The shortcomings of the tipping-bucket gauges used in the CHMI network are generally well known. There are two main factors at play. First, when measuring solid precipitation, the captured precipitation must melt to be registered in the liquid state. This time lag may last for several hours when the weather is bad. During the lag, the already captured snow may be blown out of the funnel. Secondly, when rain is intensive, the gauge's accuracy deteriorates considerably. The water "sprinkles out" when the bucket tips, which causes losses of the precipitation to be measured.

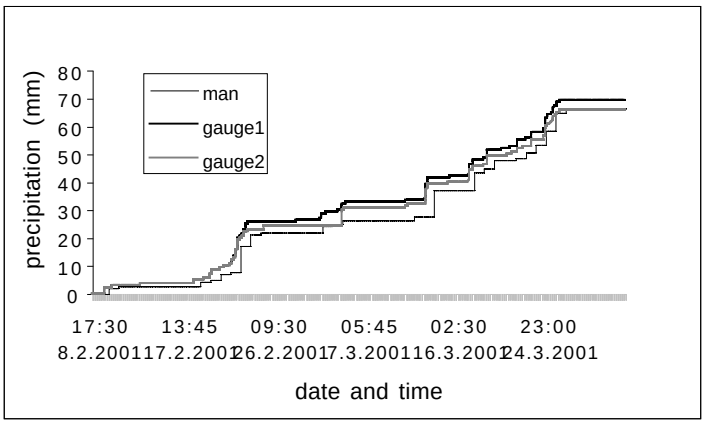
Weighing gauges capture also solid precipitation (including hail) immediately, and increasing intensity of rain does not influence the accuracy of measurement. For this gauge's parameters to follow up the existing gauges, the square area of the inlet opening is 500 cm^2.

The basis of the MRW500 weighing gauge is strain gauge scales. When under load, the strain gauge changes its electric resistance, and this change is read by the electronic circuitry that evaluates the changes. Both solid and liquid precipitation is captured in a vessel with an anti-freeze solution, which is continuously weighed. The increments in weight will then indicate the amount of precipitation. In the vessel, a thin oil film lays on the surface of the liquid, which prevents evaporation of captured precipitation. When the threshold weight is exceeded, the liquid is automatically pumped out of the weighing vessel and passed into a second, recovery vessel, while the anti-freeze solution flows from the other side of the recovery vessel into the weighing vessel. Water evaporates from the recovery vessel naturally. This processes is supported by the design of the gauge. The water/anti-freeze solution grows thicker, and may be used for the next cycle in the weighing vessel.

The preceding paragraph describes the working of the gauge in a few short sentences; however, the development of this equipment was not so short or simple. To test the gauge, a CHMI facility in Ostrava was chosen, and the first prototypes were installed there.

Two gauges were installed. One in the customary way, i.e. the inlet opening was at a level of one metre above the ground. The other was sunk in a hole in the ground, and the inlet opening was flush with the ground surface. Around it, at the surface level again, a grill with sharp edges was installed, allowing access to the gauge while minimising the bouncing of raindrops off the surrounding soil back into the gauge, and in turn their influence on the values read. At the same time, precipitation was also measured on that same site by a heated tipping-bucket gauge, and also using the classical manual method.

This experiment was designed to obtain information about the differences in precipitation amounts between the differently located gauges based on different measurement principles. This was test operation only, intended to reveal shortcomings in the design of the weighing gauge. The aim was reached. However, we made quite a few changes to the design and therefore the series of readings were distorted to a degree that partially renders them unusable for comparing the gauges. We will therefore go on making the comparisons. In spite of that, for the sake of illustration, graph shows the precipitation profiles as measured for about two months in winter/spring. The graph shows manual measurement (man), readings on the weighing gauge mounted above ground (gauge2) and readings on the weighing gauge sunk in ground (gauge1).



Graph 6. Gauges comparison

The profile clearly indicates what is quite well known: the gauge whose inlet opening is flush with the ground surface captures the largest amount of precipitation. The amounts of precipitation gauged using the weighing gauge in the standard position and manually are almost the same at the end of the period under review, and a certain lag in manual measurement is caused by the time of the reading. For the sake of interest, the first larger increase in precipitation on the graph, between 21 and 25 February 2001, reflects snowfall.

Snowfall also indicates the need to change the shape of the gauge's top so that snow is not intercepted above the opening; this snow partly bars additional precipitation from entering the gauge, and reduces the gauge's effective capturing area. The shape has been changed in the current model, and the gauge also has a "shock heating" system whereby for a short

predefined period of time (about 15 - 20 minutes), once a day under a specified temperature, the upper part of the gauge, including the capturing ring is heated intensively. This helps to melt the snow caught around the gauge's mouth and it flows away from the gauge.

When running the tests proper, in natural conditions, we had to change considerably our initial ideas of the design of this device. Let us mention a few examples.

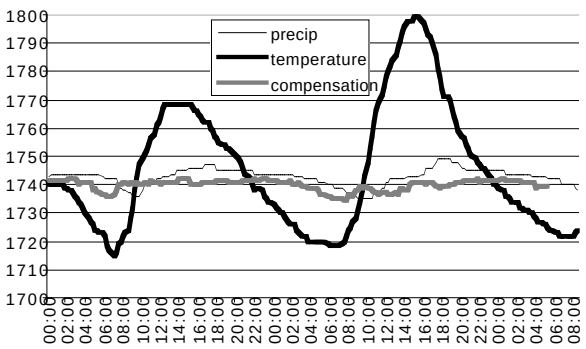
At below-zero temperatures, the anti-freeze liquid in the weighing vessel tended to form a heavier gel that separated from the precipitation water; this prevented the necessary contact between solid precipitation and the anti-freeze and in turn quick melting. This had no effect at the time of the weighing itself, but already weighed snow could be blown out and, naturally, evaporation occurred. We had to deal with this by installing a pump to stir the contents of the weighing vessel at regular intervals.

Mentioning pumps – selecting suitable models was a problem. Having tested several types of equipment and a few pumping principles we found a suitable model able to work with soiled liquid under extreme temperatures. To make it easier for the pumps to work, we placed a sieve in the weighing vessel above the maximum level of the liquid. The sieve is weighed together with the vessel. Outside the winter season, the sieve prevents insect and other impurities from falling into the vessel. When hail falls, the liquid with the oil does not sprinkle out of the gauge while the hail is immediately weighed. The sieve must be removed for the winter.

The MRW500 gauge involves a system of a partial natural "recovery" of the anti-freeze/precipitation water solution, through evaporation. This process takes place in the bottom vessel of the gauge, and is supported by the gauge's design, including a darker colour of this part. The purpose of this technical solution is to extend the time between the dates of necessary maintenance, which also requires replacing or adding the anti-freeze and pumping out accumulated precipitation.

However, the most serious problem we had to tackle is the design of the measuring (weighing) system itself, which determines the accuracy of the measurements and differentiates the amounts of precipitation. Again, there are two major factors at play here, which determine the success and validity of the measurement. First, there is the strain gauge itself, and secondly, the A/D converter used.

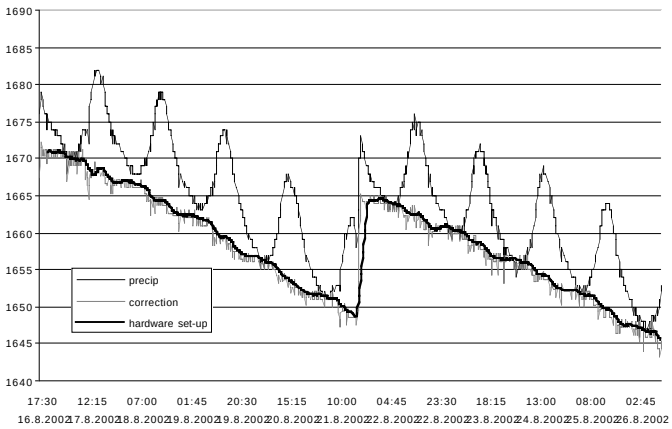
The electric resistance obtained from any strain gauge is affected by its deformation caused by weighing – this we want to measure, and also by its thermal expansivity, which is undesirable in measurements. Manufacturers usually deal with this using conventional thermal compensation, which, however, has several shortcomings. For example, it takes long for the compensation to stabilise, up to three-quarters of an hour. This makes possible fast dynamic measurements, for example one-off weighing of vehicles and weighing of goods in shops, but for our purposes this nature of thermal compensation may be felt when temperatures change quickly. In our case, thermal compensation is in fact a nuisance. The following graph shows variations of temperature around the strain gauge, and the related variations in the thermally compensated digital output value. The graph indicates that the maximums and minimums of the compensated output temperature lag



Graph 7. Dependence temperature ÷ compensation

behind the maximums and minimums of temperatures by a certain, quite significant, length of time.

Our approach to this problem consists in fine-tuning the hardware of the strain gauge without any thermal compensation, and subsequent further treatment of this signal. This means fine-tuning the analogue signal prior to its treatment in the A/D converter. The result can be seen in the graph as the dark line. The output value's maximums and minimums now coincide with the temperature maximums and minimums, and also the profile is "flatter", i.e. temperature changes are not felt so much in the output value. Further modifications will help to improve this even more. The next graph's curve depicts the output digital value compensated using conventional thermal compensation while the dark curve is the result after our tuning of the strain gauge's hardware. A marked difference can be seen here – the extremes on the white curve match diurnal temperature changes (day - night). The white curve can also be smoothed out in the data processing software. It is to be recognised that each such intervention distorts the data to a certain degree, simplifies the data and assumes that something takes place in a certain way, thereby moving away from reality. It is also for this reason that we preferred hardware fine-tuning over software modifications.



Graph 8. The example of the hardware tuning

Graph 7 was obtained under laboratory conditions, and the values for graph 8 were measured in ambient conditions. The step in the graph represents the moment of vessel filling, the output value shows a downward trend because for this demonstration experiment the oil film was missing in the weighing vessel, and evaporation therefore was not prevented. Also, in the period of time shown, the profile is not affected by measured precipitation. The fine oscillation of the value is caused by effect that already cannot be compensated, produced by both the material and the surroundings – wind blows, etc. However, this oscillation is below the required level of accuracy, and can be removed in the software.

As mentioned earlier, selecting a suitable A/D converter was difficult. We currently use a 12-bit A/D converter. Converters featuring even higher resolution are available on the market (for example 16-bit converters) but for the purposes of our application, when considering the required volume of the gauge's weighing vessel, the resolution offered by these converters is so fine that it is below the threshold of other factors' effects, which cannot be screened out. Another disadvantage of these converters is their thermal instability. At this point we have to emphasise, like in the preceding paragraphs, that the measurements must be thermally stable and repeatable over the long term throughout the whole range of ambient temperatures.

For us, it is therefore critical that the instrument has sufficient accuracy of measurements over the entire range of operating temperatures. Over the whole temperature range, these measurements must be repeatable over the long haul, producing the same results. In our case, the accuracy of the MRW500 gauge is ± 0.1 mm of precipitation, and this accuracy is guaranteed over the entire range of operating temperatures, i.e. from -40 to + 60 °C.

FLOATING EVAPORIMETER

The floating evaporimeter is a unique, fully automated measuring system intended for direct measurement of evaporation from the water table of large natural and artificial reservoirs. It is in operation at the Nové Ml_ny reservoir where large losses of water were observed which did not match the calculation methods for determining evaporation from water table. The purpose of installing it was to find the actual evaporation and verify the calculation methods in that locality. We say it is a unique system because similar systems on other sites are usually hand-operated.

All the measuring systems of the evaporimeter are borne by a structure of a pontoon raft having the shape of an isosceles triangle with sides 12 x 12 x 8 metres. At the vertex of the equal sides, the raft is fastened to a "fixed point" anchored to the reservoir's bottom. The raft can circle around this point, thereby positioning itself at all times with the vortex against the waves. This, together with the breakwaters installed, guarantees that the measuring systems placed at the base of the triangular raft are influenced by waves as little as possible. When mentioning the "fixed point" around which the raft circles, it really is in quotation marks because this point is actually part of the raft, and floats, too. Its design allows also horizontal movement of the raft when the water level in the lake changes, by up to several metres.

The following sensors are mounted on the raft:

- evaporimeter, evaporating surface 3,000 cm^2
- rain gauge, capturing area 3,000 cm^2
- wind speed sensor
- air temperature sensors at two meters and at 20 cm above the water table
- sensor of temperature on the water table
- sensor of temperature in the evaporimeter vessel
- sensors of water temperature at depths of 10, 20, and 50 cm
- sensors of relative air humidity at 2 metres and 20 cm above the water table
- sensor of global solar radiation and albedo.

All sensors are connected to an automatic data collection centre that stores the readings. Upon the operator's request, or automatically at pre-selected intervals, the data is transmitted to a higher-level computer over a cable laid on the lake's bottom and fastened to the "fixed point" around which the floating raft circles. Spare conductor pairs in the same cable power-feed the whole system.

The floating evaporimeter is an illustrative example of new system development where the intended procedures and solutions need to be substantially changed based on operating experience, which we can demonstrate on the device itself. The evaporimeter is comprised of a cylindrical vessel with a height of 60 cm and a base area (evaporating surface) of 3,000 cm^2. The vessel is filled with lake water, and is immersed in the lake so that its upper rim juts out 7 cm over the surrounding water table. There is an automatic system for pumping water in and out of the vessel.

The very first installation revealed that due to the lake being quite shallow, its depth is only 3 to 4 m, the moving waves can move the raft not only horizontally but also vertically, due to bounce off the bottom. This is why when the waves were larger, despite the water table being relatively calm around the raft thanks to its triangular shape, the vertical movement of waves would throw the vessel up. The evaporimeter vessel was therefore placed in another, larger immersed vessel, firmly fastened to the raft, which prevented the waves from hitting the evaporimeter bottom when they bounced off the lake bottom. This protective vessel was

fitted with many holes so that the surrounding water could flow towards the evaporimeter vessel.

The above reveals that the evaporimeter's vessel was not firmly fastened to the raft, but was left buoyant on the water. Originally, with a view to the maximum resolution of the measured evaporation, the mass principle of measuring the quantity of the water in the evaporimeter vessel was chosen. In this way, the vessel was weighed with the water contained in it, and fastened on movable arms, the load on which was transmitted to a strain gauge scale.

Unfortunately, this solution turned out to be unusable in practical operation, and for an interesting reason at that. We found out that the readings change during the day in an unexpected fashion – first of all, the evaporimeter's weight increased despite there being no rain. The changes evidently matched changes in various weather conditions, mainly increases in temperature together with the intensity of sunshine. No steady relationship for software compensation of the readings was observed, or was not usable. Many tests later, after many days spent on the raft to apply various measures (for example installing permanent venting of the floating pontoons because we suspected that the air inside them was warmed up by the ambient temperature, which caused the whole raft to emerge from water) we arrived at the conclusion that algae was the cause of the trouble: algae stick to the whole raft and also the evaporimeter vessel, and behave differently under changing climatic conditions (for example, the well-known bonding of oxygen, thereby making the raft more buoyant, thereby causing vertical movements of the raft and the vessel). This effect, changing diurnally and seasonally, cannot be compensated for in any way, naturally.

The only approach to tackling this effect was to change the principle of measurement. The evaporimeter vessel was firmly fastened to the structure of the raft, and instead of weighing the whole vessel, we immersed a pressure sensor in it – since then, the information about evaporation has been obtained through measurement of changes in hydrostatic pressure. We added $CuSO_4$ to the vessel to suppress algae proliferating in it. Since then, the readings have been good and usable.

However, Mother Nature is unpredictable indeed, and had some more complications for us in store. The relatively shallow lake is the home for masses of flying insects; these, naturally, attract hordes of their natural predators, for instance spiders. A spider colony that gradually developed on the raft was so strong that it tripped some sensors out of operation. The only way out of this situation was to have operators visit the raft once a week to remove the webs.

Another interesting circumstance was the behaviour of the rain gauge with its intercepting area of 3,000 cm^2. At certain moments, when the waves lashed in a certain manner, resonance occurred between the entire structure of the raft and the water table in the rain gauge (weight principle) so that the water level's movement in the gauge thwarted all measurements. We dealt with this by placing breakwaters inside the rain gauge, which prevented the undesirable movement of the water table.

The description of the design, structure and location of the raft makes it obvious that under extreme weather conditions when weaves rise high (up to 1,5 m on that lake), the values read at certain moments cannot be usable (the evaporimeter is flooded, or water spills out of it). Once the inclement conditions are over the automatic system pumps out the water, records this action in the database, and the measurement is ready to go on. The operation of the floating evaporimeter on the Nové Ml_ny reservoir, which is notorious for its frequent extreme waves, has shown that more than 90% of all the data obtained over a season is fully usable.

CONCLUSION

It will suffice to note that automating meteorological measurements is not easy at all, that there are many pitfalls on the road, and that Murphy's laws apply here without any exceptions whatsoever.

NATURAL ELECTROSTATIC FIELD MEASUREMENTS AT GROUND LEVEL: BASIS AND EXPERIMENTAL RESULTS

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Abstract: *Earth carries a net negative charge amount 10^5 C that produces a downwardy electrostatic field measured at ground level around 120 V/m in fine weather conditions. Several effects produce field variations like pollution, sea spry, mists etc... The natural earth electric field is disturbed when a thundercloud is present reaching values over 15 kV/m. The different orography and nearby objects disturb the natural electric field .*

Key words: *electric field, lightning and field mill.*

1. INTRODUCTION

Under fine-weather conditions natural electric field reaches typical average values around 100 to 200 V/m caused by the ionosphere potential and it's maintained by the global electric circuit. In presence of a electrified cloud the electric field is altered reaching values up to 10 kV/m.

The main problem is the particular evolution of the electric field due to the point of measurement, local geographic situation, nearby objects, storm behaviours and possible sources of perturbations as power systems.

This paper presents an introduction and results of the measurement system for lightning detection. Other jobs as Montanya et al. [2002] present data processing methods and data correlation in aim to have other criteria to make decisions of protection.

2. MEASURING AT GROUND LEVEL

Several studies as Livingston and E. P. Krider et al. [1978], measured the electric field at ground level and concluded that is not a full representative of the cloud electrification. It was demonstrated by instrumented planes and balloons.

As the storm becomes electrified, an inversion of polarity of the fine weather electric field is done, S.Chauzy and S. Soula et al. [1987], so, the initial electrification is developing. This electrification can develop in order of ten minutes and it's ended when the first lightning discharge appears. At this moment, the called active stage is beginning with typical duration between few minutes to an hour or more depending of the characteristics of the storm. During this stage each lightning suddenly reverses the polarity of the field at the moment of the discharge. Sign reversal denotes the presence of corona charge (usually positive) above the point of measurement, and limits the maximum values of the electric field at ground level

acting as an envelop. Then corona charge resides in relative low altitude from the ground surface. Another characteristic is the field excursions produced by precipitation and downdrafts. At the end, the presence of the called End of Storm Oscillation, indicates the dissipating stage; were no lightning are present and finally the fine weather conditions are recovered.

The description above denotes several consequences that have to take into account:

- Local storm behaviour: for the storm duration and severity.
- Nearby objects: for point effect and corona charge produced.

Besides, the complexity is increased when the storm is formed by multiple cells and its displacements.

3 THE MEASUREMENT SYSTEM

A "field mill", Malan et al. [1963], sensor has been employed to measure the natural earth electric field, which gives real time values. Time constant of the natural electric field is about 120 seconds; therefore, three samples per second are sufficient for measurement.

The sensor is based on the electrostatic induction principle. It's composed by two electrodes where one is in rotating movement in aim to modulate a signal proportional to the field by screening the measurement electrode**.** Fig 1. shows a simplified electrostatic field transducer when the lower electrode is exposed to the field.

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Fig.1 Measuring transducer.

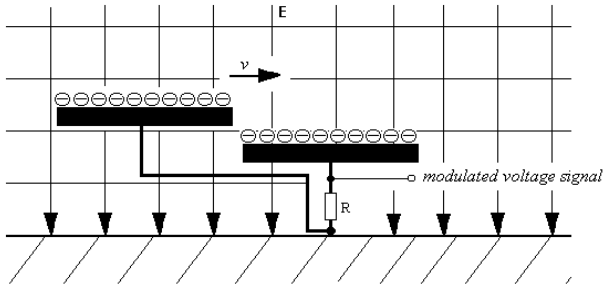
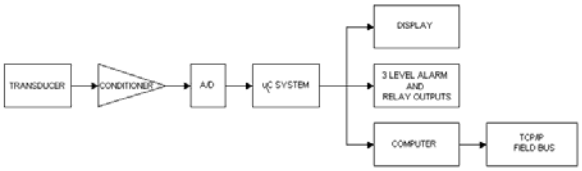


Fig. 2 shows the block diagram of the measurement system.

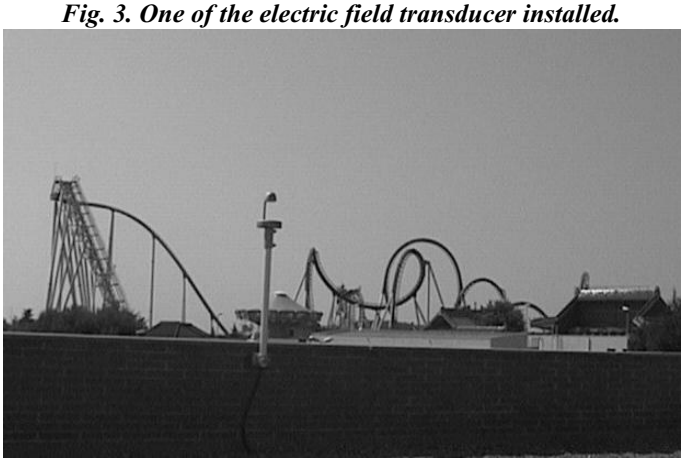
Fig.2. Block diagram of the "field mill" employed.



The measurement system is composed of an electrostatic field transducer showed in Fig. 1, signal conditioner and analog to digital converter unit to the microcontroller. The microcontroller provides data in a console with LCD display and programmable alarms associated to several electric field levels. There also exist real time communication with the computer which stores and shows the samples acquired.

Fig. 3 shows a field mill placed in a leisure park where is employed as a lightning hazard warning system.

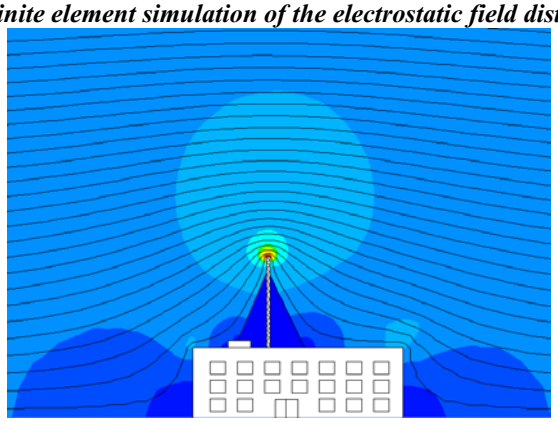
Fig. 3. One of the electric field transducer installed.



4 FIELD MILL INSTALATION

The estimated value of the natural electric field in fine weather conditions is around 120 V/m in flat and extensive regions. In real situations where is difficult to have installations without nearby objects, simulations of the electric field distributions are a useful information point to resolve where the point is to measure with minimal disturbance. The finite element method provides a helpful tool to make field simulations of the electrostatic distributions.

Fig. 4. Finite element simulation of the electrostatic field distribution.

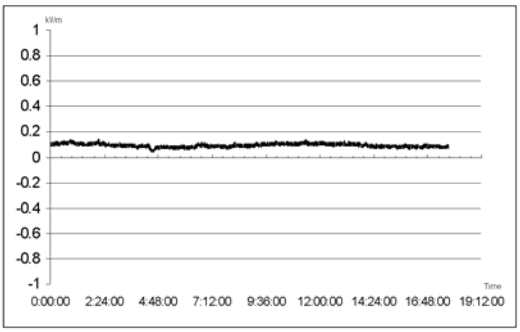


A simulation of a building with an antenna is showed in Fig 4., with this simple simulation a first idea of the field intensification zones are done. Also finite element simulations and ground level measurements provide a tool for cloud charge estimation.

5 EXPERIMENTAL MEASUREMENTS

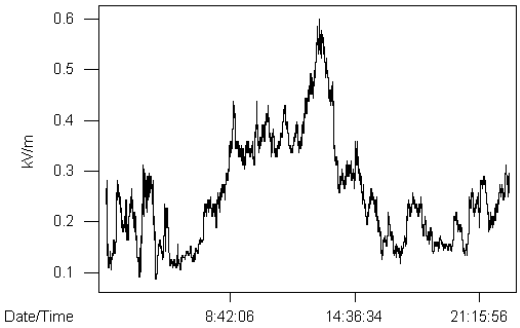
A typical result of the electrostatic field in fine weather is showed in Fig. 5, where the field remains at a values around 150 V/m.

Fig. 5. Electrostatic field during fine weather conditions.



Another possible behaviour is presented in Fig 6, where the electrostatic field is influenced by sea spry during particular hours of the day.

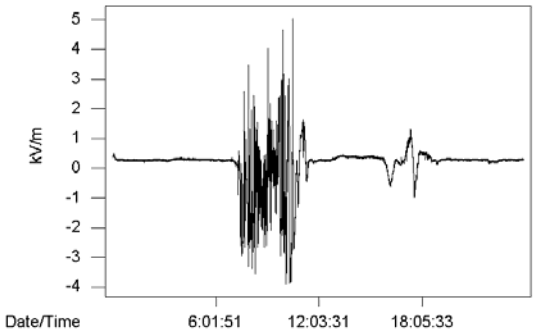
Fig. 6. Fine weather situation with sea spry effect.



At the moment the identification of risk of lightning is based on the electrostatic field value, a value of 1 kV/m is usual for first alarm suggesting the presence of electrical charge in the atmosphere, but in situations as Fig. 6 are necessary to take into account the effect of the field increasing due to sea spry or other local effects.

Fig. 7 presents a day with two storms.

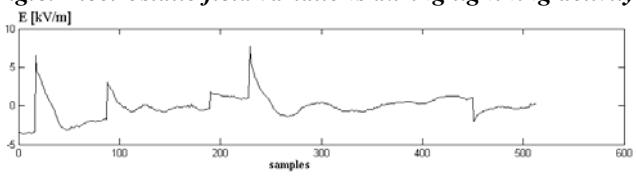
Fig. 7. Day with two storms.



Note that, in Fig. 7, the electric field before the storm activity remains at low values. When a storm is approaching or developing is usual, if the thundercloud is sufficient near, an exponential increment of the field with polarity reversal relate to fine weather. Then, is observable field changes due to lightning and field excursions due to rain periods.

Fig. 8. presents a frame of the field variation during the lightning stage.

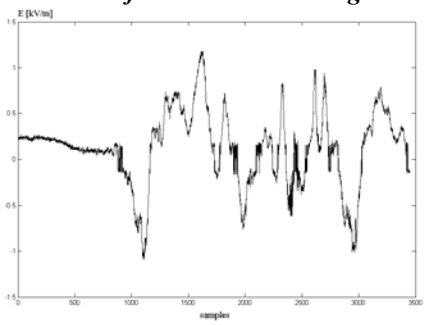
Fig.8. Electrostatic field variations during lightning activity.



Such as discussed before, sudden changes of field denotes lightning discharges. If a full change of the field is done the lightning has been stroke nearly.

The lightning activity is concluded when the end of storm oscillation is initiated, Despiau et al, [1992]. This is a low frequency oscillation and during this period no lightning are present and let us criteria to establish again the normal situation in a protection system application. This oscillation can be observable in Fig. 7 at the end of the storm activity, just before 12:00 h.

Fig 9. Electrostatic field evolution during a rain period.



During a period of rain without any lightning, the electrostatic field suffers variations due to the charge motions caused by the rain and charges generated by corona, if the field reaches a value enough high. Fig 9 shows the field evolution during a rain period.

6 CONCLUSIONS

The electrostatic field is not common variable in weather analysis but it gives a valuable information about charge concentrations as storms, lightning studies and of course in applications as a lightning hazard warning systems.

Due to the particular behaviour, data processing and data correlation with other weather variables result interesting.

No data of electrostatic field measurements are available in majority of the countries, so our work resides in data collection, analysis, correlation with lightning location systems and the application as a part of lightning protection system.

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TESTING, CALIBRATION AND INTERCOMPARISON OF A NEW AWS IN SHMI

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1. Introduction

The Slovak Hydrometeorological Institute (SHMI) operates 27 automatic weather stations (AWS) on continuous basis for the synoptic, aviation, climatological and partly hydrologic purposes: twenty three of them are VAISALA MILOS 500 AWSs and four are MPS04 AWSs. The additional MPS04 AWS was installed at the professional meteorological station equipped by MILOS 500 AWS for testing and comparison purposes.

Laboratory calibration and testing, on-site intercomparison, quality control (QC) procedures running at AWS compose the essential part of Quality Assurance (QA) system that has been implemented step by step in SHMI. Automated real-time QC running in observer's PC as well as at the National Data-Processing Centre (DPC) completes this QA system.

2. Calibration and testing

SHMI operates a full-time Calibration Laboratory and the field maintenance facility, staffed by instrument specialists and engineering technicians. The laboratory provides a facility where the institute can verify the manufacture's calibration of sensors and compare instrument performance to the other reference instrument as well as test the overall performance of the station. Every sensor installed in the surface-observing network must pass a calibration process.

Calibration and tests utilize the commercial high quality reference instruments (e.g.: SPRT Rosemount 162CE, General Eastern, DH Instruments PPC2+). They are used to verify that all sensors are within the established specific inaccuracy limits for each sensor. Calibration coefficients, which are determined in the laboratory, are applied to corresponding AWS data.

As the signal conditioning and data acquisition modules form a part of the measuring chain their stability and correct operation have also to be controlled or calibrated periodically. The whole calibration procedure consists of the calibration of the individual sensors, the signal conditioning and data acquisition modules, followed by the implementation of calibration curves, and final control of the whole measurement chain.

The performance of sensors is controlled with the travelling standards at the station. SHMI's technicians perform field tests yearly. Thanks to this control the systematic errors can be detected.

3. Quality Control Procedures

Automatic data validity checking (basic quality control procedures) are applied at all automatic weather stations to monitor the quality of sensors' data prior to their use in computation of weather parameter values. This basic QC is designed to remove the erroneous sensor information while retaining valid sensor data. The range of QC strongly depends on the type of AWS and a level of its sophistication. The outputs of QC would be included inside every AWS message.

The types of QC procedures are as follows:

Automatic QC of raw data (intended primarily to indicate any sensor malfunction, instability, interference in order to reduce potential corruption of the processed data):

a) ***The monitoring of measurement range*** (gross error check). Measurement ranges of different parameters depend on the climatological conditions of an AWS' site. Limit values for surface wind speed, air temperature, dew-point temperature and station pressure are listed in the WMO Guide on GDPS, WMO-No. 305. In addition, there are possibilities to define limit values for other measured parameters, e.g. ground and soil temperatures, amount of precipitation, radiation parameters etc. An example of the measurement ranges implemented in the Slovak Hydrometeorological Institute (SHMI) is given below. The limit values are used for checking both signal measurement data (samples) and 1-minute average, in case of wind

2- and 10-minute averages.

Measurement ranges implemented at AWS in SHMI

- dry-bulb temperature: -45 °C ... +45 °C;
- ground temperature: -50 °C ... +65 °C;
- relative humidity: 1 ... 100 %;
- pressure:
  870 - 1040 hPa (AWS between 0 – 1000 m above MSL),
  750 - 1000 hPa (AWS between 1000 – 2000 m above MSL),
  650 - 950 hPa (AWS between 2000 – 3000 m above MSL);
- wind speed:
- 0 - 30 $m.s^{-1}$ (10-minute average) (AWS between 0 – 1000 m above MSL),
  0 - 50 $m.s^{-1}$ (2-minute average) (AWS between 0 – 1000 m above MSL),
  0 - 50 $m.s^{-1}$ (10-minute average) (AWS between 1000 – 3000 m above MSL),
  0 - 75 $m.s^{-1}$ (2-minute average) (AWS between 1000 – 3000 m above MSL);
- soil temperature: -20 °C ... +45 °C;
- global radiation: 0 ... 1600 Wm^{-2};
- precipitation intensity 3 mm/minute.

b) ***The time variance of the signal*** (temporal consistency of measured values). The samples are checked every 3 seconds in case of wind speed and direction and every 10 seconds in case of temperature, humidity, pressure and global radiation. After each signal measurement the current (actual) sample is compared to the previous one. If the difference of these two samples is more then the specified limit then the current

sample is identified as suspected and not used for the computation of an average. However, it is still used for checking of the temporal consistency of the samples. It means that a new sample is still checked with the suspected one. The result of this procedure is that in case of a large noise one or two successive samples are not used for the computation of an average. The limits of the time variance of the samples implemented in SHMI are as follows:

- dry-bulb temperature: 2 °C;
- ground and soil temperature: 2 °C;
- relative humidity: 5 %;
- pressure: 0.3 hPa;
- wind speed: 20 ms^{-1};
- global radiation: 800 Wm^{-2}.

There must be at least 4 from 6 samples available in order to compute the 1-minute average in case of temperature, humidity, pressure, or sum in case of global radiation and at least 75 % of the samples to compute a 2- or 10-minute average in case of wind direction and speed.

Automatic QC of processed data (intended to identify erroneous or anomalous data):

Internal consistency of data. The range of this control depends on the capacity of AWS' processing unit and on the sensors used. The basic algorithms used for internal consistency of data are based on the relation of two or more parameters (the following conditions should be true):

(a) dew-point temperature ≤ dry bulb temperature;
(b) wind speed = 00 and wind direction = 00;
wind speed ≠ 00 and wind direction ≠ 00;
wind gust speed ≥ wind speed;
(c) both elements are suspected[1] in case of "clear (sky condition)" and "total precipitation > 0";
both elements are suspected[1] in case of "overcast (sky condition)" and "sunshine duration > 0";
(d) both elements are suspected[1] if "total precipitation > 0" and "duration of precipitation = 0";
(e) both elements are suspected[1] if "duration of precipitation > 0" and "weather phenomenon is different from precipitation";
(f) both elements are suspected[1] if "visibility < 10 000 m" and "weather phenomenon is missing".
(1:For data from a period not longer then 10 minutes)

The calculation of a ***standard deviation*** of some basic variables such as temperature, pressure, humidity, wind etc. will be implemented in near future (using BUFR for transmission). The standard deviation will not be calculated in case of a small number of the samples (less then 10). In combination with the control of time variance of the signal the standard deviation will be a very good tool for the detection of a "jammed" sensor as well as long-term drift of the sensor measurement.

The technical monitoring of all crucial parts of AWS including all sensors is unthinkable part of the QA system. Most of manufactures already provide technical monitoring for the

intelligent sensors, however the results of the monitoring are not distributed to users. The technical monitoring provides the information on quality of data through the technical status of the instrument and the information on the internal measurement status. Corresponding information will be disseminated to the users in the near future in case of BUFR transmission of data.

4. Intercomparison

The field testing of MPS04 and intercomparison with MILOS 500 have been running since October 2000 at the Meteorological Station Prievidza. The tailored software package METView for MS Windows (W2000, NT) is used for data collection, archiving and processing. Data can be viewed either in real-time or non-real time in different forms and formats, such as tables or graphs. The main emphasis has been put on data from the temperature sensor PT100 and the humidity sensor HMP35C. All sensors from both automatic stations are exposed in the non-ventilated wooden Stevenson screen, at 2 m height, next to each other.

The aim of the intercomparisons is to analyse the performance of the compared sensors as well as the whole measurement systems and estimate the accuracy, reliability and long-term stability. The following statistical parameters have been used in the data analysis:

The bias b: $b = \frac{1}{N}\sum_{i=1}^{N}(X_{ai} - X_{bi})$

The operational comparability C: $C = \pm\sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_{ai} - X_{bi})^2}$

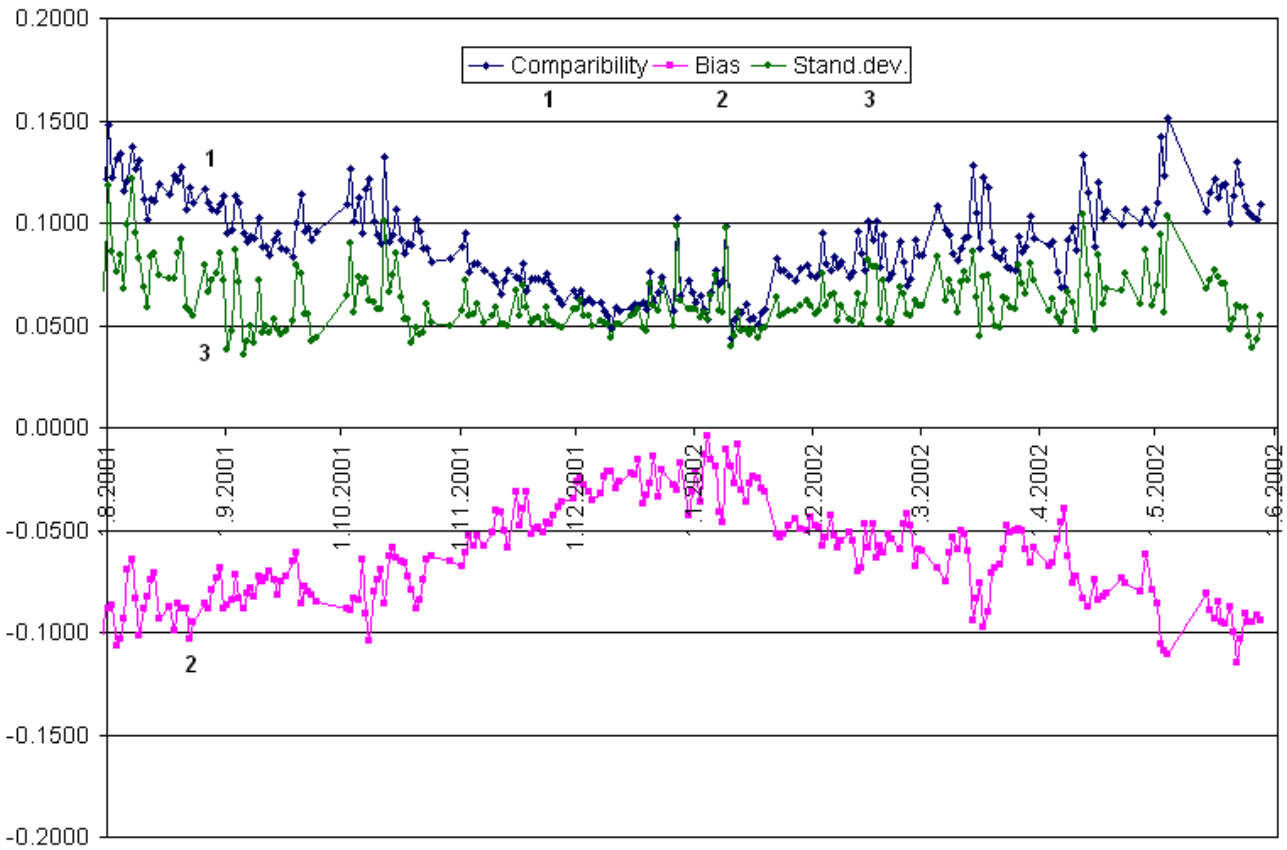
The standard deviation s: $s = \pm\sqrt{(C^2 - b^2)}$

where: N - number of the samples used, X_{ai} - ith measurements made by one system, X_{bi}- ith simultaneous measurements made by another system.

The database from the August 2001 up to May 2002 was used for the data analysis. About 80% of data were available in the final database for the statistical analysis. The intercomparison was done on the level of one-minute data. The temperature range during the whole period was from -22 °C to +34 °C. For each day the above-mentioned statistical parameters were calculated. The results of the intercomparison of the temperature and humidity data are shown in the following table:

	Temperature			**Humidity**		
	Bias (b)	***Operational Comparability (C)***	***Standard Deviation (s)***	***Bias (b)***	***Operational comparability (C)***	***Standard deviation (s)***
Average	0.063	0.090	0.062	0.940	1.219	0.700
Maximum	0.115	0.151	0.121	2.497	2.601	1.439
Minimum	0.004	0.044	0.035	0.017	0.451	0.188

The results of the statistical analysis for temperature data are presented in the following graph. The influence of the winter period can be seen clearly:



The results of intercomparison show a very good agreement of the measured data from the compared systems where QA were implemented.

5. Conclusion

The standardization and the Quality Assurance system of Automatic Weather Station data are becoming more important with the introduction of new more sophisticated sensors and processing algorithms. There is a strong need to develop and implement the basic guidelines for a quality management. The real-time quality control of data from AWS should be performed at both AWS site and at the Data Processing (Data Management) Centres.

The SHMI's QA system represents a compilation of the processes that range from the simple testing to the sophisticated analysis. The system utilises multiple techniques of data and the instrument analysis. Further improvements are planned in connection with the transition to the table driven code forms.

References

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