

WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

**CIMO EXPERT TEAM ON
SURFACE TECHNOLOGY AND MEASUREMENT TECHNIQUES
(ET-ST&MT)**

First Session

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13-16 October 2004

FINAL REPORT



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EXECUTIVE SUMMARY

This report provides a summary of the first session of the Expert Team on Surface Technology and Measurement Techniques (ET-ST&MT) held in Geneva, 13-16 October 2004.

The meteorological community is entering an era when a diverse collection of automatic observations will become readily available to users when and where needed. Included in national networks there will be many automatic in situ mesoscale networks, including automatic road and urban stations. Present weather, usually observed, described and reported by a human observer with a high degree of subjectivity, will be increasingly determined by automatic and unattended equipment. However the development of such complex equipment is a challenging exercise unless alternative weather information sources are found. Not only technological restrictions but also cost-effectiveness are the leading constraints when designing modern measurement systems. Guidance in terms of cost/benefit is found extremely welcome. Measurements in harsh environment near road and in urban areas are also in focus today. Determining appropriate siting and exposure is another challenge in those areas. Within this context, metadata, presented in a uniform format is an essential requirement for the interpretation of measured data. Reliable data and acceptable measurement uncertainty can only be guaranteed by appropriate quality management systems and training, issues well recognized by the surface measurements community.

The expert team initiated an action to develop standards for automated subjective observations. It was recognized that such standards would depend on available and also possible future technologies, which would provide alternative information on the present weather. As the defining or selecting standard algorithms would not be feasible because of the variety of observing techniques, it was decided to develop recommendations for further harmonization and uniformity.

In order to review the state-of-the-art of instruments and surface observing systems, it was decided to continue with updating the Instrument Development Inquiry (IDI). It was confirmed that only those developments should be covered, which are not already part of the Instrument Catalogue. Future IDIs should be accessible through CIMO/IMOP website that would providing the advantage of more frequent updating.

Special attention will be given to development of guidelines for practices in harsh environment (icing, deserts, tropics, oceans) and to further develop siting criteria and metadata standards. Because of changing requirements and developing technologies, the table on Operational Uncertainties and Instrument Performances was updated and will be published in the CIMO Guide.

Areas of special interest are observations for road and urban meteorology, because guidance material on how to perform such measurements is limited and harmonization is required. New available material will be published and the relevant chapters in the CIMO Guide updated.

The ET will also work on issues such as the Quality management and the development of training material. HMEI expressed willingness to collaborate with CIMO on these issues.

The ET agreed on the work plan with clearly defined activities, deliverables, responsibilities and deadlines.

GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the session

1.1.1 The first session of the Expert Team on Surface Technology and Measurement Techniques (ET-ST&MT) was held in Geneva, Switzerland, 13-16 October 2004. Mr Jitze van der Meulen, Chairperson of the ET-ST&MT, opened the session. The list of participants is given in [Annex I](#).

1.1.2 Following the opening of the session, Prof. Hong YAN, Deputy Secretary-General, welcomed the participants to Geneva. In his opening statement he pointed out the importance of their work and wished them a productive meeting and an enjoyable stay in Geneva.

1.2 Adoption of the agenda

1.2.1 The ET adopted the Agenda for the meeting, which is reproduced at the beginning of this report.

1.3 Working arrangements for the session

1.3.1 The working hours and tentative timetable for the meeting were agreed upon.

2. REPORT OF THE CHAIRMAN

2.1 Mr van der Meulen presented a report of ET's activities since the establishment of the ET. He provided background information on the establishment of the ET-ST&MT and referred to the new working structure of CIMO. The chairman underlined the importance of a close collaboration with the other technical commissions and the Association of Hydro-Meteorological Equipment Industry (HMEI) through their representatives.

2.2 The chairman also referred to the IMOP Programme, the WMO Sixth Long-Term Plan and decisions of constituent bodies in the planning of the ET's work plan. The IMOP Programme stipulates the need to improve the quality and reliability of instruments and the need for functional specifications and standards for automatic observing systems. He outlined key deliverables expected from CIMO in this intersessional period and also referred to the limited resources available. The results of the work of the ET will be presented in the IOM Reports, the CIMO Guide and various other documents, including reports for CIMO XIV, Executive Council and Congress.

2.3 Reference was made to the draft Work Plan that would be discussed during the meeting. The TOR and the work plan of the ET-ST&MT is on CIMO/IMOP website: <http://www.wmo.int/web/www/CIMO/cimo13-addresses-et.html>

3. STANDARDS FOR AUTOMATED VISUAL AND SUBJECTIVE OBSERVATIONS

3.1 Systems measuring present weather

3.1.1 The ET discussed the access to non-basic "ww" output from present weather sensors. Broad but not specific requests were made by members of the ET to make data available from present weather sensors in a more raw form than the "ww" code. Raw data form was not specifically defined but broadly understood to be at least the data that was used to generate the "ww" code. The reasoning behind this request was that measurements of other weather parameters, not made by the present weather sensors, might improve the integrity of the production of the final "ww" code. There are many examples of supporting information that can

improve the final output of the 'ww' code. The use of the multiple sensor outputs is not widespread but a number of NMSs had implemented multi sensor algorithms so overcome individual sensor limitations. However it should be noted that it is not clear how much the final output is improved nor whether the multi sensor algorithms are instrument specific. It was recommended that cases where algorithms had been developed to overcome individual sensor weakness be further developed and reported in an appropriate IOM report.

3.1.2 As for the restrictions of working within the "ww" code format, some concerns were expressed by NMS representatives that until we move away from endeavoring to reduce present weather down to the "ww" code for traditional synoptic coding reasons, we will be unable to use the full range of information that present weather sensors currently have the potential for measuring. Many variables are measurable by these sophisticated present weather sensors but the application to which this data can be made is limited by currently used codes, such as the SYNOP and METAR. The move away from carrying out data reduction at or before the AWS, would enable more data to be used and the state of the atmosphere observed to be better described.

3.1.3 The ET recognized that many NMSs, both developed and developing countries, do not yet have the drive towards automation of subjective observations. However, it was acknowledged that with time an increasing number of NMSs would be looking for appropriate methods for automating subjective measurement techniques. A successful migration from manual to automated present weather observations would require a move away from the constraint of the "ww" code. The training of meteorologists, predominately the forecasting staff, to accept these changes will take time as many years of experience of interpretation of "ww" codes and placing them in the context of the prevailing synoptic situation has grown up. Some of these experiences are not directly related to coherent scientific principles and so fundamental changes in approach may be needed to introduce a new data provision format. While this is not a CIMO issue the impact on the direction of measurement development is directly linked to the needs of the data users. So while "ww" codes still require algorithms to deliver the best fit set of automated "ww", codes (BUFR) will have to continue to be adjusted. The development effort for improved "ww" coded output would detract from the improvement of observational techniques.

3.1.4 The representatives of HMEI expressed some concerns that the clarity of the 'raw' data from the present weather sensors might not be as valuable as the users hoped. Many of the transformation algorithms are complex and specific to individual sensor characteristics. The sheer volume of the raw data may swamp non real time data processing systems and may result in a reduced quality of final present weather output. There was also expressed the concern that not all manufacturers would be willing to make their raw data outputs available as this may compromise the individual manufacturers competitive advantage. This was accepted as a reasonable position to take but any information that could be made available about present weather sensor transformation algorithms to the user community would be welcomed. HMEI representatives agreed to cooperate in this area more closely.

3.2 Standardization of algorithms for AWSs

3.2.1 The meeting noted that standardization of algorithms would in some cases require manufacturers, system integrators or users to divulge proprietary algorithms and this may be difficult to achieve. However these groups should be approached and their cooperation sought.

3.2.2 Due to the implementation of well-established algorithms that have been developed independently to produce the same or similar subjective observations, it may not be possible to identify a single standard algorithm. Some manufacturers and system integrators build fine-tuning into algorithms to match sensor input parameters to required outputs and this complicates the process of algorithm standardization.

3.2.3 It was decided that algorithms for individual data output parameters should be treated as separate sub tasks with the view to completing documentation for standardization of some

algorithms rather than only partially completing the documentation of standards for many algorithms. Priority should be given to sky condition followed by present weather.

3.2.4 It was also decided that where there is no clear standard algorithm either based on scientific basis, by measurement intercomparison, or by defacto standard, then methodologies should be used to define the algorithm standard and multiple implementation examples should be included in the documentation.

3.2.5 There was much discussion and concern over the realizable accuracy of automated cloud cover measurements.

3.2.6 Many algorithms used to derive cloud cover and present weather follow very similar lines but have been tuned, either deliberately or accidentally, to the environment in which the algorithm was developed. This tuning might result in inconsistent performance if the algorithm is implemented elsewhere in the world. The discussion noted that improved BUFR descriptors would allow the reporting of type of algorithm used in measurement generation and in turn this would allow users to understand the strengths and weaknesses of the measurement reports in different observational situations.

3.3 Standards for automation of manual, visual and subjective observations

3.3.1 Within this report the term "subjective observations" is used instead of "manual, visual and subjective observations". Where necessary a qualifying statement is added to indicate a specific area of discussion, for example "subjective observations (for present weather and sky condition)".

3.3.2 Subjective observations were originally designed to provide a snapshot or picture of the "weather" as viewed by an observer at a particular location. Due to the way a human observes the weather the resulting observation can encompass the local site, the surrounding area, and preceding weather. The list of subjective observations is in [Annex II](#). Even though some of the identified subjective observations are capable of being performed to some extent by modern sensors, they are still, for the purpose of this document, considered to be subjective observations. These observations are natural for a human, but for an automated system to produce the same output may require the quantitative measurement of many input parameters followed by an application of the complex algorithms. For example, a present weather sensor could measure visibility, atmospheric particle characteristics and statistics, air temperature, and surface wetness, and then use a time history algorithm on all of this data to determine the type and intensity of some current precipitation.

3.3.3 Standards are used to achieve "reproducibility" or "compatibility" between measurements made by different instruments, over a wide range of ambient or dynamic conditions, with a period of validity of at least 6 months and preferably a year or more. The best way to ensure compatibility between operational instruments is to calibrate them against "standard" instruments that have a much better accuracy and are traceable to international standards.

3.3.4 To define standards for a "multi-parameter followed by algorithm" measurement system, it was discussed whether the standards would be best applied to: sensor end output "products", sensor individual input parameters and processing algorithms, some combination of the previous two options, or in the case where none of the above are achievable, the eventual replacement of the subjective observation with either appropriate quantifiable data parameters or an alternative measurement method if such exists.

3.3.5 Following are the precedents that have been set for widely implemented existing sensor systems:

- For single sensor parameters, it is the standard of the output measurement that is defined. For example, it is not important whether a solar radiation sensor provides a current or a voltage as

an electrical output. The manufacturer specifies a measurement process and supplies an algorithm to convert the electrical signal into the appropriate units, and the calibration laboratory determines a calibration constant that is one of the input parameters to the processing algorithm. Manufacturers, based on their research, provide a statement on the converted sensor output uncertainty that includes the measured data parameter uncertainty, the uncertainty in the calibration constant, and any errors introduced during application of their algorithm. Users generally perform calibration of the sensor only and use the manufacturers output accuracy statement in good faith.

- For simple multiple sensor parameters, such as QFE, QHN and dew point, where the output is calculated from an algorithm that is applied to data parameters from more than one sensor, the standards are normally defined for the input data parameters (as they are usually also used in their own right as measurements) as well as the output parameters. Standard algorithms are recommended by CIMO however this does not stop manufacturers from using their own algorithms. Manufacturers normally supply statements or tables indicating the accuracy of the derived parameters using their algorithms and usually publish these algorithms so that users can verify the algorithms ability to meet standards.

3.3.6 It was identified that implementing standards for the sensor end output "product" would require:

- A definition of the subjective observations in terms of quantitative measurements so comparisons could be made, i.e. a scoring system would be required to enable determination of how well two sensors agree. These quantitative measurements could take the forms of "probability of detection" and "false alarm rate" and these values, even though they are numeric in value, are themselves subjective in nature due to the way in which the pass and fail criteria would be defined.
- Performing of intercomparisons with a "standard" sensor over a period of time so that the full sensor output range is exercised during the intercomparison; or exposure of a sensor to controlled stimuli that demonstrate the correct operation of the full sensor output range.

3.3.7 The ET identified the following difficulties for the above option:

- The result would be an agreement or confidence level that would provide no indication of what "types" of measurement a sensor was good or bad at performing;
- Calibration of input parameter sensors would still need to be performed before the intercomparison;
- The intercomparison would not provide calibration constants for adjustment of input parameter sensors that were not performing correctly;
- A standard instrument or instruments would need to be identified and these would need to be calibrated to traceable standards. A standard instrument normally needs to have a measurement uncertainty an order of magnitude better than the instrument being calibrated and currently the instruments used for automation of subjective observations are the best in terms of measurement uncertainty.
- It may be necessary to target intercomparisons towards known areas of sensor measurement difficulties;
- If real world weather conditions were being used to provide stimuli of instruments under test, it might take considerable time for the required range of conditions to occur before a test can be completed. This would probably be impractical because the full test time might be so long that earlier parts of the tests might have started to become out of date.

- If "controlled" weather conditions were being used to provide stimuli of instruments then the combinations of input parameters and algorithm variations would lead to a large number of test points.

3.3.8 It was agreed that implementing standards for the individual input parameters and the processing algorithm would require:

- A definition of the algorithm (manufacturers and system implementers would need to divulge their algorithms and then agree to standardize on the most suitable algorithm). Alternatively a conversion table that relates quantitative input parameters to output subjective products could be created and manufacturers could implement portions of the table that are applicable (refer to EUMETNET PWS-SCI Project "Exploratory actions on automatic present weather observations" for further discussion on this);
- A definition of the uncertainty requirements of the subjective measurements and then the translation of these back through the algorithm to provide the uncertainty requirements of the individual input parameters (however this process might be more qualitative than quantitative).

3.3.9 The ET identified the following difficulties for the above option:

- Recommending generic standards for input parameters and algorithms might tend to force conformity on manufacturers and therefore stifle innovation, i.e., the way in which instrument developers (companies and instrument researchers) independently develop automated systems for making subjective observations leads to systems that are dissimilar in the way they operate. Each developed instrument may have its own strengths and weaknesses in terms of: how "correct" and "representative" its derived parameters are, how easy it is to operate and maintain, its reliability, and how often it requires routine maintenance and cleaning. It is this diversity in development that leads to innovation and this must not be stifled by enforcing standards that would cause manufacturers to significantly change their products, or in the worst case causes the orphaning of a product in the market place that although it may not conform to recommended standards, still produces useful information.
- Comments made by HMEI representatives indicated that due to the level of investment already made in developing algorithms to produce automated subjective observation codes, and in particular present weather and sky condition, they may be reluctant to release details of some algorithms. The meeting felt however that they should be approached and this issue discussed with them. Concern was also raised that due to the complexity and detailed fine tuning involved in these sensor algorithms, knowledge of their content might in some cases complicate rather than simplify the definitions of the standards for automated subjective observing systems.

3.3.10 In the cases of present weather and sky condition measurements, the method "implementing standards for the sensor end output product" would seem impossible to perform because this would require the ability to physically generate all of the weather conditions that a sensor is capable of reporting.

3.3.11 The option "Implementing standards for the individual input parameters and the processing algorithm" is more likely to be achievable but would require manufacturers to publish their algorithms and there may be some reluctance by them to do this. An alternative to publishing of algorithms was discussed that would use tables or matrices to define the relationship between input sensor data elements and output data elements. The table or matrix would include statement of the required input sensor data uncertainties that would be required to generate an "accurate" output data parameter. The aim would be to produce a generic table that could be applied to any system that produced the same output data parameter.

3.3.12 Mr Zahumenský, the representative of CBS, indicated that he had been working on tables for translation between subjective present weather data parameters and quantitative data values.

He offered to provide electronic copies of his work for review by the ET members working on this task.

3.3.13 If neither of the options (paragraphs 3.3.6 and 3.3.8) prove viable then the way forward may be to leave the operation of current subjective sensors in the status quo, i.e. as recommended by manufacturers in their equipment manuals which normally means calibrating the individual sensor measurements but does not include any algorithm performance verification. In parallel, there could be a movement towards the reporting of individual quantifiable measurement parameters that, after suitable development, documentation and training, would provide users with the same "picture of the weather" as provided by subjective observations. This may work better for some subjective observations than others, e.g., describing 30 minutes of cloud/sky condition could be done as a set of bin heights, a bit like rounding or chopping temperatures to a certain resolution.

3.3.14 Because of traditional thinking that has been ingrained for generations this method will require users, such as forecasters and aviators, to translate the new quantitative data into the equivalent subjective picture of the weather.

3.3.15 Reporting of individual data parameters have the following advantages:

- The data can be easily ingested into numerical models.
- In the case that one single sensor parameter malfunctions, the other parameter(s) would not be affected, whereas when the output is the result of a subjective data algorithm then the failure of any one input sensor may cause the output to be lost.

3.3.16 Implementing this method may require additional data elements and message code elements to be defined, and this should be investigated further.

3.3.17 In reviewing the current standards and practices and in development of recommendations for standards, the ET decided to concentrate on:

- State of the weather (present and past);
- Sky condition (cloud layers: cover/amount, height, type);
- Icing;
- State of ground;

3.3.18 To proceed further, the HMEI was requested to comment on the feasibility of defining and implementing probability of detection and false alarm rates as standards for their sensors that perform automatic subjective observations.

3.3.19 The meeting recommended that due to the difficult nature of defining and implementing standards for automated sensors that perform subjective observations, high priority should be given to further work to identify and define data parameters and codes to allow the measurement and reporting of appropriate alternative quantitative data instead of subjective data.

3.4 Possible alternative methods for replacing some traditional observations

3.4.1 Because of the lack of knowledge on current developments that are being made by research organizations and manufacturers, it was decided to first collect the required information from various sources, such as the HMEI and other experts, and to review existing documentation. A questionnaire to manufacturers and CIMO members will be used to collect information.

4. THE STATE-OF-THE-ART OF INSTRUMENTS AND AUTOMATED SURFACE OBSERVING SYSTEMS

4.1 Instrument development inquiry

4.1.1 The meeting discussed procedures of performing instrument development inquiries (IDI). It was agreed that IDI should be performed regularly, at least once in every four years, to collect information on new developments regarding meteorological instruments and measurement techniques. The meeting expressed that an interactive WMO website would facilitate entry of and access to more up-to-date information on new instrument developments.

4.1.2 The meeting also discussed the connection between IDIs, the Instrument Catalogue (IC) and the HMEI Product Catalogue (PC). The objective of the IC is to provide the meteorological community with comparable information on instruments available on the market, whereas the IDI objective is to inform on new developments. Considering the different objectives of IDIs and IC, it was noted that IDI should not contain information on instrument already presented in IC.

4.1.3 The availability of the instrument catalogue was discussed. The IC provided by China Meteorological Administration (CMA) originally on CD had also been made accessible through CMA website. At the time of the meeting, this website was not operational, but the representative of CMA expressed his belief that it would be again operational during November 2004. The ET requested that the web-based IC would be made available through a link on the CIMO/IMOP website. A concern was made of keeping the instrument catalogue up-to-date. The CMA and HMEI representatives were asked to closely collaborate in this regard. HMEI was also requested to explore the possibility of including standardized instrument information in the HMEI PC.

4.1.4 The meeting decided that IDI #8 should be based on the existing questionnaire template that should be, however, converted to a computer readable format and be available online on the CIMO/IMOP website. The questionnaire would be made available in all WMO languages, but Members should be asked to reply preferably in English only.

4.1.5 The meeting reviewed the Operational uncertainty requirements and instrument performance recently updated by the CBS ET on AWS. The reviewed proposal is presented in [Annex III](#).

4.2 Instruments for harsh climatological conditions

4.2.1 The chairman presented the historical background of this issue and informed on the different atmospheric environments, which require special attention when implementing observing systems. He referred to a number of publications on this matter and noted the recommendations to WMO in the EUMETNET Final report on severe weather sensors.

4.2.2 The need for accurate icing measurements was discussed. Mr Heimo presented the work done on the classification of stations regarding icing-induced meteorological conditions and the classification of instruments regarding their behavior during icing conditions ([see Annex IV](#)). The icing measurements also provide information that is relevant to performance of the other measurement systems. This is a strong example of where measurements are used to quantify the quality of other measurements. Another area where this is used is to inform on the quality of ceilometers outputs during precipitation and especially during drizzle and snow. The cross use of the measurement systems means that observations are not only required for data users but also to improve the quality of the data produced in the first place.

4.2.3 It was suggested that future WMO intercomparisons should be, as far as possible, planned in the harsh climatological (or environmental) conditions, such as:

- Mountainous/Arctic environments (extremely cold)
- Desert and other dusty environments (very dry)

- Tropical environment (humid and hot)
- Marine environment (extreme weather, corrosion)
- Urban environment (corrosion, contaminants)

4.2.4 WMO RICs should be more involved in the intercomparisons and their infrastructure has to be strengthened to be able to host instrument intercomparisons and testing.

4.2.5 Representative of the CHy felt that little was done regarding the intercomparison of hydrological equipment and techniques, such as current meters and flow assessment methods. Hydrology has a strong interest also in intercomparisons of precipitation and evaporation instruments and techniques. In this regard, close cooperation with CHy would be needed if the CHy-XII approves plans for intercomparison of hydrological equipment. Russian Federation has the necessary expertise and infrastructure to organize intercomparisons of hydrological or meteorological instruments.

4.3 Development of siting criteria and metadata standards

4.3.1 The ET stated clearly that siting of instruments is relevant when observations should be representative for any surrounding area. Different policies on selecting sites and the design of an AWS including sensors are applied. Sites that are easy to access are usually chosen but unfortunately often located in the neighborhood of roads, buildings, forests and settlements. Moreover the design of the weather observing equipment layout (sensors or systems) is sometimes clustered in a way that the measurements will influence each other. Sometimes it is obvious that the designer had not considered any sensing technological precautions and just placed the sensor in a way, which is easy to be connected to the data acquisition system of the AWS.

4.3.2 In practice, an ideal site with perfect exposure is seldom available, and unless the actual exposure is adequately documented the reliability of observations cannot be determined.

4.3.3 The measure of representativity of a station is of utmost relevance for the user of observational data, because these data can easily be misinterpreted due to the lack of knowledge on these siting aspects. Not only the location of a station, but also the placements of the sensors and constructions that may influence the measurements have to be considered by the user. Moreover knowledge of the state of maintenance of instruments, other equipment and the terrain itself is extremely relevant for further data interpretation and validation. All those issues (location choice, installation, up-to-date knowledge of the state-of-the-art) have to be well documented. In general such information is known as *metadata*, *i.e.* data-on-data.

4.3.4 Metadata are important for putting observations into proper perspective, for understanding the biases that might be inherent in the observations and the changes in the biases over time. Therefore, metadata should be as complete as possible, as up to date as possible, and as readily available as possible. Basic metadata should be available together with the observational data.

4.3.5 The ET agreed that the table of metadata information presented by Mr Zahumenský ([Annex V](#)) should be further updated and revised. ET members are invited to submit comments to Mr Zahumenský before the end of November 2004.

4.4 Possible means to minimize the impact on the cost of the continuous improvements of instruments

4.4.1 The chairman informed the ET of the request made by the EC to investigate possible means to reduce costs, related to improvement the performance of systems. Although such improvement might be necessary to meet the required performance targets, further costs should be minimized. The ET indicated that such improvements are usually initiated when the requirement to meet the requested specifications is endorsed. It was noted that users might not be well capable to make an appropriate and quantifiable study on the cost-benefit in case of an

upgrade/replacement of their observing technology. Such study might be limited because most of the benefits cannot be quantified and therefore are based on subjective elements. The chairman noted that the increasing level of sophistication also had an impact on the skill of maintenance personnel and therefore on the costs of maintenance as well. This sophistication factor is especially relevant for developing countries and should be taken into account when writing new training material.

4.4.2 The ET recognized the need to publish educational material on how to quantify cost-benefits in case of replacement of an observing technology. As the first step an IOM report could be published with the assistance of the HMEI.

5. PROGRESS OF URBAN AND ROAD METEOROLOGICAL MEASUREMENTS

5.1 Urban meteorological measurements

5.1.1 Mr T. Oke informed on the nature of the chapter that had already been prepared for the CIMO-Guide on the observation of meteorological elements in urban areas. The chapter stresses the need to fully appreciate the scales of urban climates (micro-, local- and meso-scale) as they impact phenomena and measurement methods. In particular, the presence of the urban canopy layer defines a micro-scale dominated layer beneath roof-level (UCL) and a layer above roof level and the roughness sub-layer (RSL) which responds to the local scale. The above roof layer represents a blended influence that brings with it questions of the rate of internal boundary layer growth and the location of the source areas ('footprints') for meteorological sensors.

5.1.2 The essential first step in selecting urban station sites is to evaluate the physical nature of the urban terrain. This will reveal areas of 'homogeneity' and conversely areas of transition and inhomogeneity. A new site classification system has been devised to describe any urban site. It is based on measures of the urban structure, land cover, building fabric and metabolism (anthropogenic heat, water and pollution), rather than land-use zones which only relate to function, which is not necessarily climatically significant. The suggested classes are called *Urban Climate Zones* (UCZ). Several UCZ comprise an urban area, hence in order to build a picture of the climate of a settlement, multiple stations are required. Sites should be selected that are likely to sample air drawn across relatively 'homogenous' urban terrain that are representative of a single UCZ. Care is necessary to ensure that microclimatic effects do not interfere with the primary objective which is to measure local scale climates that are representative of that UCZ.

5.1.3 Most of the chapter deals with the realities faced by those faced with the establishment of a climate station at an urban site where application of the CIMO Guide is often either impossible or nonsensical. The overall objective is suggested to obtain observations of those elements that are representative of the UCZ. For measurements involving a station located in the UCL the suggestion is to centre the sensors in a representative space. For measurements in the blended layer special attention is paid to the height of measurement because of the need to avoid unwanted advective influences and that the source areas are fully representative of the UCZ.

5.1.4 The chapter is subdivided according to the different elements. The instruments normally used at rural sites are mostly appropriate for use in urban areas although the harsh environmental conditions may be of concern and necessitate specific maintenance measures.

- Air temperature and humidity measurements made within the UCL can be locally representative if the site is carefully selected. However, if these variables are observed above roof-level, including above the RSL, there is no established link between them and those within the UCL.
- Wind and turbulent flux measurements should be made above the RSL but within the internal boundary layer of the selected urban climate zone. Such measurements must establish that the

surface 'footprint' contributing to the observations is representative of the climate zone. For wind, it is possible to link the flow at this level and that experienced within the canopy.

- Precipitation observations can be conducted either near ground at an unobstructed site, or above the RSL in conjunction with the wind measurements.
- With the exception of incoming solar radiation, roof top sites are to be avoided, unless instruments are exposed on a tall mast.
- Net and upwelling radiation fluxes must be made at heights sufficient to adequately sample the range of surface types and orientations typical of the terrain zone.

5.1.5 A section of the chapter is devoted to the special needs of documenting metadata in urban environments. Because the environment of urban stations change frequently as development proceeds, metadata (and their frequent update) are as important as the meteorological data gathered. Without good station descriptions it is impossible to link measurements to the surrounding terrain. This includes provision of maps and photographs relevant to the three scales of urban climates.

5.1.6 In preparation of the chapter information on the results of the Questionnaire to NMHSs were taken into account as well as the feedback received after presentations made at several conferences (in Casablanca, Morocco; Nice, France; Sydney, Australia; Ottawa, Canada; Lodz, Poland; and Albuquerque, NM, USA) and circulation to several experts in urban meteorology. The draft chapter was also made available for comment to members of the International Association for Urban Climate (IAUC) via their web site. The chapter received final editing and was approved for publication as an IOM Report. At the time the IOM report is distributed to NMHSs they will be invited to submit suggestions for modification or addition. The ET will consider these comments and incorporate changes in future revisions.

5.1.7 Several techniques are not yet covered in the chapter and should be assigned to appropriate experts for future updates to the CIMO chapter. These include: atmospheric composition, satellite observations, radar, vertical profiling via remote sensing, and upper air observations.

5.2 Road meteorological measurements

5.2.1 Over the last several years, a large number of meteorological stations have been established for the dedicated use of highway and roadway users. These applications have been described in WMO Instrument and Observing Methods No. 66 and No. 71.

5.2.2 The ET agreed on the need to review the use of Roadway Environmental Stations (R-ESS), to establish the range and quality of existing road observations, and to provide a comparison, between R-ESS and standard synoptic meteorological stations. This should result in recommendations on specifications and site criteria to aid the roadway users in providing uniform data quality. While cost and other constraints may limit the implementation of such recommendations, the desire is to move R-ESS data to a quality level that could be used to greatly extend the geographic coverage of meteorological networks. A special attention should be paid to examine differences between the existing and proposed R-ESS standards to the WMO standards with respect to site layout and sensor specifications and configurations.

6. QUALITY MANAGEMENT SYSTEMS PROCEDURES FOR INSTRUMENTS AND METHODS OF OBSERVATION

6.1 Performance measures to demonstrate continuous improvement in the quality of observations

6.1.1 The meeting discussed the ways to develop performance measures to demonstrate continuous improvement in the quality of observations. In this special regard the experts discussed basic procedures for quality control of observations, instrument maintenance, calibration and operational practices. The experts considered also the overall concept of a quality management system and took note of the WMO assessment on quality management systems and a study of quality management implications on the instrumentation side.

6.1.2 The Director of the World Weather Watch gave some background information on the WMO Quality Management Framework (QMF). At Congress Cg-XIV in May 2003, Members supported the Executive Council proposal that WMO should work towards its own QMF. Congress Cg-XIV agreed that the WMO QMF constitutes the following three elements:

- WMO technical standards;
- Quality management system(s) including quality control; and
- Certification procedure(s).

6.1.3 The invited expert Dr Richter gave a short introduction of the study of quality management implications on the instrumentation side. She made clear that a quality management system is a business management system and a dynamic process that brings resources, activities and behaviors together and focuses on the achievement of objectives. Quality control procedures are simply a tool which maintain quality standards and are an element of the overall quality management concept. She referred to a study prepared for WMO that proposes general recommendations on the certification and accreditation process and on the review of documents. The ET recommended updating the Part III of the CIMO Guide following the proposal of the study before the EC in June 2005.

6.1.4 The ET considered the proposal for the quality monitoring procedures for data from Automatic Weather Station developed by Mr Zahumenský, CBS representative, (See [Annex VI](#)) and agreed that this proposal should be revised based on comments from the ET.

6.1.5 The CBS representative also presented the proposal for the Guidelines on Quality Control (QC) Procedures for Data from Automatic Weather Station, reviewed and updated during the session of the ET AWS (Geneva, 28 June - 2 July 2004). Météo-Swiss offered generic and specific information to this document as they are currently implementing a new AWS network across the entire country and are also implementing a new QMS for this observing network. Members presented several comments on the guidelines that would be further discussed by correspondence and the final proposal for the Guidelines would be also submitted to the CBS ET on AWS for consideration. The ET members are invited to submit comments to Mr Zahumenský before the end of December 2004.

7. TRAINING ACTIVITIES AND TRAINING MATERIAL

7.1 Mr E. Bazira, the OPAG-CB co-chairperson and chairman of the ET on Training Activities and Training Materials, summarized CIMO training activities since the CIMO-XIII. Unlike training in upper-air observations, no training was done so far in the area of surface technology and measurement techniques.

7.2 ET discussed the possibilities of preparing training materials in classical form or in computer aided learning. It was noted that many meteorological services are not in a position to assist in the development of training material as they no more provide specialized instrument training to their own staff. It was suggested that CIMO Web Portal be more used to link different site for available training material including those of manufacturers. HMEI representatives were asked to provide such links.

7.3 The ET noted that:

- Meteorological Instruments are continuously changing due to improvements in technology. Therefore, training of trainers or operational managers would enhance the knowledge and skills of the technical personnel to ensure effective operation and maintenance of the equipment as well as the quality of the observations.
- Simple manuals and maintenance procedures would assist the operational personnel to maintain equipment in good working condition.
- Manuals provided by manufacturers as well as documents like CIMO Guide could assist the operational and technical personnel to improve their knowledge and skills in equipment maintenance. Therefore CIMO Guide should be regularly updated.
- Workshops would further enhance the confidence of the technical personnel through practical training.
- WMO Compendium on meteorological instruments should be significantly updated or rewritten. Members of ET are requested to identify potential resource persons for this task.
- Contract for procurement of new equipment should include technical training in order to ensure effective operational use and maintenance of the equipment.
- Outsourcing for instrument maintenance is one of the options used in some of the Meteorological Services in order to provide equipment maintenance.
- Dr Richter (DWD) offered to provide training materials available in DWD and Mr Goldstraw (UK Met Office) offered to update the training material on Basic radar by mid 2005.
- Other members were requested to consider linking with training institutions within their respective countries and forward any training materials to WMO Secretariat as they become available.

8. WORK PLAN

8.1 The outcome of the discussion on the above agenda items were recast into a detailed Work Plan that specifies actions and deliverables for all tasks that were put forward to the team by CIMO-XIII and CIMO-MG. The Work Plan is in [Annex VII](#).

9. AOB

No proposals were made in this agenda item.

10. DRAFT REPORT OF THE SESSION

10.1 The members of expert team prepared their inputs for the final report, a draft of which was subsequently prepared by the Secretariat. Final report will be posted on the CIMO/IMOP website: <http://www.wmo.int/web/www/reports.html>.

11. CLOSURE OF THE SESSION

11.1 The session was closed on 16 October 2004 at 14h30.

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The list of current subjective observations

Observation	Manual Observation Method	Current Sensor Technology
State of the Weather (present and past)	Spatial detection from a single point with human averaging (opinion) of the current and recent state of the weather. e.g. Thunderstorm - lightning and location, Hail, Virga, Volcanic ash, Tower visibility, Freezing drizzle/rain, Ice pellets, Snow depth and snow increasing rapidly, significant weather not at the station, variable sky conditions, widespread dust and sand, other obscurations etc.	Intelligent multi-parameter sensor e.g. Vaisala FD12P, Optical Scientific Inc. LEDWI. Precipitation detector Lightning detector
Sky Condition (Cloud layers: cover/amount, height, type)	Visual observation. Possibly use height markers or get additional information from pilots. Cloud search light.	Ceilometer and algorithm - not spatial, algorithm over time Cloud tops and coverage from satellite imagery Web Cam with height markers CB and TCU cloud type detection image sensor
Runway Visual Range (RVR)	Visual observation against range markers.	Transmissometer (one direction, limited distance, time average) Web Cam with land and light markers
Visibility/Meteorological Optical Range (MOR)	Visual observation against range markers.	Forward scatter meter (spatial spot measurement, time average) Web Cam with land and light markers
State of Ground	Visual observation of surface condition.	Reflection and/or scattering sensor Ultrasonic snow/ice depth gauge
State of Road Surface	Visual observation of surface condition.	In ground sensor for temperature, water/ice thickness, conductivity Reflection and scattering sensor
State of Sea (Wave and swell: height, period and direction, roughness. Ice coverage)	Spatial detection from a single point with human averaging (opinion) of the current sea state (spectra of wave heights and periods).	Submerged pressure sensors Satellite stereoscopic imagery Sea state radar Web Cam
Sunshine Duration	Interpretation of cards.	Electronic combined global/diffuse sensor Sun tracking Normal Incidence Pyrheliometer Global solar radiation, site lat and long, and an algorithm
Wind Chill	Using the current temperature and wind speed with look up tables.	Algorithm using the Screen measured air temperature and the wind speed. The algorithm is still based on opinion.
Sun Burn	Amount of reddening of the skin at some time after the exposure. Very dependent on skin type.	UV solar radiation and erythemal action spectrum Algorithm to determine sunburn index

Operational Uncertainty Accuracy¹ Requirements and Typical² Instrument Performance

Present values [from the Guide to Meteorological Instruments and Methods of Observations, 6th edition (WMO No. 8, 1996)] are given by "**(old:...)**". Further explanation and remarks to the data by ET/AWS are given as footnotes at the bottom of each page. The endnotes are part of the table and are as published in WMO-No. 8.

(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement observation	(5) Required Uncertainty accuracy ³	(6) Sensor time constant ⁴	(7) Output averaging time	(8) Achievable ⁵ operational uncertainty accuracy	(9) Remarks
1. Temperature								
1.1 Air temperature	-80 – +60 °C (old: -60 – +60 °C)	0.1 K	I	0.3 K for ≤ -40°C 0.1 K for > -40°C and ≤ +40°C 0.3 K for > +40°C (old: 0.1 K)	20 s	1 min	0.2 K	Achievable uncertainty accuracy and effective time constant may be affected by the design of thermometer solar radiation screen.
1.2 Extremes of air temperature	-80 – +60 °C (old: -60 – +60 °C)	0.1 K	I	0.5 K for ≤ -40°C 0.3 K for > -40 °C and ≤ +40°C 0.5 K for > +40°C (old: 0.5 K)	20 s	1 min	0.2 K	
1.3 Sea-surface temperature	-2 – +40 °C	0.1 K	I	0.1 K	20 s	1 min	0.2 K	

¹ The term *accuracy* is replaced by *uncertainty* to be in accordance with ISO standards on *uncertainty of measurements*

² To be removed

³ ± signs were originally used with accuracy, those have been removed to be in accordance with ISO standards on *uncertainty of measurements*

⁴ n/a = not applicable

⁵ Uncertainty normally achieved in operational practice

2. Humidity ⁶	2.1 Dew point temperature	-80 – +35 °C (old: -60 – +35 °C) ⁷	0.1 K	I	0.1 K (old: 0.5 K)	20 s	1 min	0.5 K	If measured directly. Tending to 0.1 K when relative humidity ⁸ nears saturation.
						<p style="text-align: center;">Wet-bulb temperature</p> <p>Large errors are possible due to aspiration and cleanliness problems.</p> <p>If measured directly. Tending to 1% when relative humidity⁸ nears saturation.</p> <p style="text-align: center;">Solid state and others</p> <p>Solid-state sensors may show significant temperature and humidity dependence.</p>			
	2.2 Relative humidity	0 – 100 %	1 %	I	1 % (old: 3%)	40 s	1 min	3 % (old 2 – 5 %)	

⁶ Note that dew point temperature, relative humidity and air-temperature are linked, and thus their uncertainties are linked

⁷ Primary standards for dew point available for t-dew > -60°C

⁸ The string "relative humidity" can be removed

3. Atmospheric pressure 3.1 Pressure ⁹ 3.2 Tendency	500 – 1080 hPa (old: 920 -1080 hPa) Not specified	0.1 hPa 0.1 hPa	I I	0.1 hPa 0.2 hPa	20 s 	1 min 	0.3 hPa 0.2 hPa	Range to sea level¹⁰ . Uncertainty Accuracy seriously affected by dynamic pressure due to wind and temperature coefficient of transducer. Differences between instantaneous values.
4. Clouds 4.1 Cloud amount 4.2 Height of cloud base 4.3 Height of cloud top ¹¹	0 – 8/8 0 m – 30 km (old: 30 m - 30 km) not available ¹²	1/8 10 m (old: 30 m)	I I	1/8 10 m for ≤ 100 m 10 % for > 100 m	n/a ¹³ n/a		2/8 (old 1/8) ≈ 10 m repeatability*	Period (30s) clustering algorithms may be used to estimate low cloud amount automatically. * Uncertainty Accuracy difficult to determine since no definitions exists for instrumentally measured cloud base height.

⁹ Both station pressure and MSL pressure

¹⁰ To be removed (also station pressure involved)

¹¹ New variable

¹² To be determined

¹³ To be determined for instrument measurements

5. Wind								
5.1 Speed	0 – 75 m s ⁻¹	0.1 m s ⁻¹	A	0.5 m s ⁻¹ for ≤ 5 m s ⁻¹ 10 % for > 5 m s ⁻¹	Dist. cont. ¹⁴ 2–5 m	2 and/or 10 min	0.5 m s^{-1} for $\leq 5 \text{ m s}^{-1}$ 10 % for $> 5 \text{ m s}^{-1}$ (old 5 m s⁻¹) 5° 0.5 m s^{-1} for $\leq 5 \text{ m s}^{-1}$ 10 % for $> 5 \text{ m s}^{-1}$ (old 0.5 m s⁻¹)	Average over 2 and/or 10 minutes. Non-linear devices. Care needed in design of averaging process. Highest 3s average should be recorded.
5.2 Direction	0 – 360°	1°	A	5°		2 and/or 10 min		
5.3 Gust	0.1 – 150 m s ⁻¹ (old: 5 - 75 m/s)	0.1 m s ⁻¹ (old: 0.5 m/s)	A	10 %		3 s		
6. Precipitation								
6.1 Amount (daily ¹⁵)	0 – 500 mm (old: 0 - > 400 mm)	0.1 mm	T	0.1 mm for ≤ 5 mm 2 % for > 5 mm	n/a ¹⁷	n/a	The larger of 5 % or 0.1 mm (old 5%)	Uncertainty Accuracy depends on aerodynamic collection efficiency of gauges and evaporation losses in heated gauges. Average depth over an area representative of the observing site Uncertainty Accuracy seriously affected by wind. Sensors may show significant non linear behavior
6.2 Depth of snow	0 – 25 m (old: 0 – 10 m)	1 cm	A	1 cm for ≤ 20 cm 5 % for > 20 cm				
6.3 Thickness of ice accretion	Not specified	1 cm	I	1 cm for ≤ 10 cm 10 % for > 10 cm				
6.4 Precipitation intensity ¹⁶	0.02 mm/h - 2000 mm/h to be implemented	0.1 mm/h to be implemented	I	0.02 - 0.2 mm/h (trace): n/a 0.2 - 2 mm/h: 0.1 mm/h > 2 mm/h: 5% to be implemented		1 min (to be implemented)		

¹⁴ Distant constant; for anemometers: *response length*

¹⁵ Refined

¹⁶ New variable, specified for rainfall intensity by the expert team on rainfall intensity measurements (Bratislava, Slovakia, 23 to 25 April 2001)

¹⁷ Not applicable for reading of totals

7. Radiation								
7.1 Sunshine duration (daily) ¹⁸	0 – 24 h	60 s (old: 0.1 h)	T	0.1 h	20 s	n/a	The larger of 0.1 h or 2 % (old 2 %)	
7.2 Net radiation – radiant exposure (daily) ¹⁹	Not specified	1 J m ⁻² (old: 1 MJ m⁻² d⁻¹)	T	0.4 MJ m ⁻² for ≤ 8 MJ m ⁻² 5 % for > 8 MJ m ⁻² (old: 0.4 MJ m⁻² d⁻¹ for ≤ 8 MJ m⁻² d⁻¹ ; 5 % for > 8 MJ m⁻² d⁻¹)	20 s	n/a	0.4 MJ m ⁻² for ≤ 8 MJ m ⁻² 5 % for > 8 MJ m ⁻² (old 5 %)	
8. Visibility								
8.1 MOR	10 m – 100 km (old: <50 m-70 km)	1 m (old: 50 m)	I, A ²⁰	50 m for ≤ 600 m ²¹ 10 % for > 600 – ≤ 1500 m 20% for > 1500 m (old: 50 m for ≤ 500 m 10 % for > 500 m)		1 and 10 min (old: 3 min)	The larger of 20 m or 20% (old 10 - 20 %)	Achievable instrumental uncertainty accuracy may depend on the cause of obscuration.
8.2 RVR	10 m – 1 500 m (old: 50 m-1500 m)	1 m (old: 50 m)	A	10 m for ≤ 400 m ²¹ 25 m for > 400 - ≤ 800 m 10 % m for > 800 m (old: 25 m for ≤ 150 m 50 m for >150 – ≤ 500 m 100 m for >500 – ≤ 1000 m 200 m for > 1000 m)		1 and 10 min		²¹

¹⁸ Refined¹⁹ Refined. According to the Guide to Instruments and Methods of Observation (WMO No. 8), Vol. I, Ch. 7, "Measurement of Radiation" to be *Radiant exposure*", symbol *H*, to be used for daily sums of (net) radiation. In Annex 7.A of this Guide, the unit for *H* is J m⁻² and not W m⁻². Although it is common practice to regard radiation as an *intensity* variable like *irradiance* in W m⁻² or J m⁻² d⁻¹, daily amounts of radiation, expressed in J m⁻² are in use as well.²⁰ A: For 10 min intervals, averaging over logarithmic values is advised.²¹ In accordance with WMO Technical Regulations (WMO No. 49) - Vol. II, Attachment B

9. Waves								
9.1 Significant wave height	0 – 50 m (old: 0 – 30 m)	0.1 m	A	0.5 m for ≤ 5 m 10 % for > 5 m	0.5 s	20 min	0.5 m for ≤ 5m 10 % for > 5 m (old 10%)	Average over 20 minutes for instrumental measurements.
9.2 Wave period	0 – 100 s	1 s	A	0.5 s	0.5 s	20 min		Average over 20 minutes for instrumental measurements.
9.3 Wave direction	0 – 360°	1° (old: 10°)	A	10°	0.5 s	20 min	0.5 s 20°	Average over 20 minutes for instrumental measurements.
10. Evaporation								
10.1 Amount of pan evaporation	0 – 100 mm (old: 0 – 10 mm)	0.1 mm	T	0.1 mm for ≤ 5 mm 2 % for 5 mm				

NOTES:

- Column 1 gives the basic variable.
- Column 2 gives the common range for most variables; limits depend on local climatological conditions.
- Column 3 gives the most stringent resolution as determined by the *Manual on Codes (WMO-No. 306)*
- In column 4:
I: Instantaneous. In order to exclude natural small-scale variability and noise, an average value over a period of one minute is considered as a minimum and most suitable; averages over periods of up to 10 minutes are acceptable.
A: Averaging. Average values over a fixed time period, as specified by the users' requirements.
T: Totals. Totals over a fixed time period(s), as specified by the users' requirements.
- Column 5 gives the recommended uncertainty accuracy requirement for general operational use. Individual applications may have less stringent requirements. The stated value of required uncertainty accuracy represents the uncertainty of the reported value with respect to the true value and indicates the interval in which the true value lies with a stated probability. The recommended probability level is 95 %, which corresponds to the 2σ -level for a normal (Gaussian) distribution of the variable. The assumption that all known corrections are taken into account implies that the errors in reported values will have a mean value (or bias) close to zero. Any residual bias should be small compared with the stated uncertainty accuracy requirement. The true value is that value which, under operational conditions, perfectly characterizes the variable to be measured/observed over the representative time interval, area and/or volume required, taking into account siting and exposure.
- Columns 2 to 5 refer to the requirements stated by the Meeting of CBS Expert Team on Requirements of Data from Automatic Weather Station, July 2004, and confirmed by the presidents of technical commissions.
- Columns 6 to 8 refer to the typical operational performance stated by the CIMO Expert Team on Surface Technology and Measurement Techniques, October 2004.

Instruments for harsh meteorological conditions

It is recognized that a number of Members are confronted to the consequences of icing on instruments installed at Automatic Weather Stations located in harsh environment.

The following topics should be discussed:

- classification of stations regarding icing-induced meteorological conditions
- classification of instruments regarding their behavior as function of the previous stations' icing classification

As a result, the user should be able to select the right instrument for the prevailing environmental conditions regarding the icing issue.

REVIEW OF THE STATE OF THE ART FOR MEASUREMENTS UNDER HARSH CONDITIONS

Basis:

WMO/CIMO Wind Instrument Intercomparison, Mont Aigoual, France, 1992-1993

A documented experiment has been conducted at the Mt. Aigoual station, France (within a joint venture between France and Switzerland) in order to analyze the performances of a number of ice-free anemometers under extreme meteorological conditions.

Reference:

WMO Wind Instrument Intercomparison, Mont Aigoual, France
1992-1993 : final report by P. Gregoire and G. Oualid.
Instruments and observing methods report; no. 62
Technical document (WMO); no. 859

EUMETNET/SWS II Experiment (2000-2002):

A documented experiment has been conducted at three sites in Finland, France and Switzerland in the period 2000-2002 in order to analyze the performances of ice-free instruments under extreme meteorological conditions.

Reference:

Improvement of Severe Weather Measurements and Sensors – EUMETNET SWS II Project
B. Tammelin and al.
FMI reports 2004:3

Definitions

Meteorological icing: meteorological event or perturbation which causes icing.

Meteorological icing can be characterized by:

- 1) the total amount of ice accreted during the icing event, and/or
- 2) the duration of the icing event, and/or
- 3) the maximum accretion rate, and
- 4) the meteorological conditions (simultaneous and following)

Automatic sensors are lacking for the determination of items 1) and 3), while the items 2) and 4) can be more or less achieved with presently available technology.

Instrumental icing: technical perturbation of the instrument due to icing.

Instrumental icing can be defined as the effect of icing on the quality of the measurements. It can be characterized by

- 1) analyses of video recordings, and/or
- 2) regular visual observation

The classification of instrumental icing CII during a meteorological icing event can be defined in the following way:

Class	State of instrument	Availability Factor AV
0	Remains free of ice	0
1	Light ice accretion, without obvious effect on the measurement	0
2	Moderate ice accretion, with probable influence on the measurements	1
3	Strong ice accretion, preventing the instrument to deliver data	1

An instrument remaining in classes 0 and 1 is considered as available (Availability Factor AV=0). For higher values of CII, the instrument's results are most probably erroneous and the sensor is considered as unavailable (AV=1).

The Availability Ratio

$$AR = \frac{\text{Instrumental} - \text{icing}}{\text{Meteorological} - \text{icing}}$$

can be used for the selection of the instrument as function of the station's classification and can be combined with the above instrumental icing classification. A value of AR smaller or equal to 1 reflects a good behaviour of the instrument in terms of icing (e.g. good heating). Values of AR higher than 1 indicate a sensor which is sensitive to icing (e.g. poor heating) for a time period (much) longer than the meteorological icing.

The performance index PI of an instrument is defined by:

$$PI = AV \times AR$$

An instrument which is not sensitive to icing has a PI value equal to zero. On the contrary, high values of PI reflect a poor behaviour in terms of icing sensitivity.

Further definitions:

- **Incubation time:** delay between the beginning of the meteorological icing and of the instrumental icing.
- **Recovery time:** delay between the end of the meteorological icing and the full recovery of the performance of the instrument

RECOMMENDATIONS

Considering that:

1. Meteorological icing is different than instrumental icing, the latter being the consequence of the former, but with different effects depending on the characteristics of the meteorological conditions and of the instrumental design (instrumental icing can be smaller, equal or longer than meteorological icing due to the sometimes very long recovery time, especially in northern countries with low solar irradiance in winter).
2. Despite relative high human and financial investments, it was recognized that the defined goals of the above mentioned intercomparisons were not completely reached due to the lack of market available adequate instruments for the measurement and characterization of icing accretion.
3. Not only the heating power, but also the design of the instrument and of the heating geometry is of particular importance.

Noting that:

1. The WMO Guide defines meteorological requirements and characteristics for sensors. However, the WMO Guide does not separately consider severe weather conditions like icing, even if low temperature is specified in the requirements. In the same way, manufacturers specify their instruments' performances in severe weather conditions in terms of low temperatures (e.g. operating temperature range), but not icing.
2. There is an increasing demand for accurate meteorological measurements and measurement of icing in cold climate and mountainous regions to improve the information provided by meteorological networks, to produce reliable data for icing forecasting, to produce valuable information for numerous human activities, (esp. energy production) and finally to design structures withstanding such harsh environment.

It is proposed that:

A. *The WMO/CIMO Guide is extended in order to include recommendations for the definition of the siting characteristics of the AWS in terms of local icing conditions.*

A classification of AWS is introduced indicating the degree of severity of local icing conditions. The following table describes tentatively the frame of such a classification.

Table 1: Classification of sites according to severity of icing. It is assumed that the sensors operate at the given accuracy (WMO or manufacturer) minimum 95% of the time per month.

Site class	Icing days / year	Duration of icing events %/year	Max. load per day g/100 cm ² (95%)	Intensity of icing g/100 cm ² /h (95%)	Icing type
S5	> 60	> 20	> 100	> 50	Heavy
S4	31-60	10-20	50	25	Strong
S3	10-30	5-10	35	10	Moderate
S2	3-10	< 5	20	5	Light
S1	0-2	0-0.5	0-10	0-5	Occasional

B. The WMO/CIMO Guide is extended in order to include recommendations for the definition of the requirements for measurements in severe icing conditions:

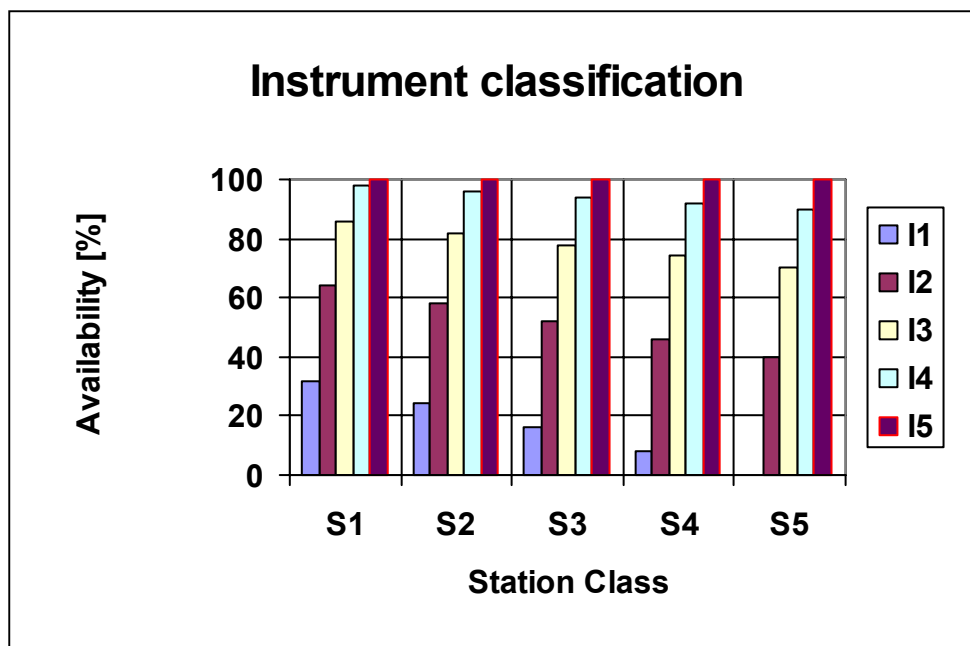
A classification for meteorological sensors taking into account accuracy and required reliability of data combined with climatic conditions is difficult to achieve. A good indicator may be given by **In**, the mean availability index of the instrument against the different site classes S1 to S5 (see below).

The range of this classification extends from I5 (PI = 0; availability = 100 % → perfect icing non-sensitive instruments) to I1 (PI = very high values; availability ≤40 % → instruments which could remain frozen for a very long period after the meteorological icing period, e.g. long recovery time for high latitude stations without sun during whole seasons). The classification of the instrument could therefore look like:

Table 2: Classification of instruments in terms of mean performance depending on the station's classification (*the availability values displayed in italic are purely hypothetical*)

Mean Availability Index	PI for S1 → S5	Mean availability in % for S1 → S5	Remarks
I5	0	<i>100 %</i>	Excellent instrument not sensitive to icing
I4	0 → 1	<i>99 → 90 %</i>	Good instrument, little sensitivity to icing
I3	1 → 5	<i>89 → 70 %</i>	Good instrument but during icing events
I2	5 → 20	<i>69 → 40 %</i>	Instrument to be used only with separate icing detection
I1	20 → ∞	<i>39 → 0 %</i>	Instrument not recommended for such applications

This index **In** is strongly dependant on the station's class ($S_n, n=1-5$). Furthermore, the effect of icing on the results' quality (see AV definition above) is taken into account. This leads to the possible following graphical representation where the user can select the class of instruments needed to fulfill his requirements depending on the location (e.g. classification) of his station.



This availability is dependant on the instrument type (anemometer, thermometer, etc.), design (e.g. rotating parts), heating (power, design/geometry), but also on the meteorological conditions prevailing at the selected site (AWS classification). However, it should be determined independently of the site's meteorological characteristics, e.g. under laboratory conditions and/or at selected regional centers (RICs) representative of the stations' classification.

The goal is that the user can determine approximately if the selected instruments fulfils the required specifications for his station.

Example: A potential user is located at a station with classification S4. He intends to perform wind measurements of high quality. But, due to financial restrictions, he will choose an instrument of class I3, which guarantees that his measurements will be performing correctly 74% of the time for a station of class S4. However, when installing the same instrument at a station of type S2, the mean availability of the instrument would increase to 82%.

Requirements:

1. The development of reliable sensors to measure the duration and loads of icing is sponsored by WMO. This information is necessary to determine the above mentioned meteorological icing periods.
2. Test sites for ice-free sensors are promoted by WMO (e.g. RICs for S1 to S5), equipped for the determination of the meteorological icing periods as well as for the characterization of the instrumental icing.

CONCLUSIONS:

With this new WMO/CIMO recommendation for measurements performed under icing conditions:

- 1) The user knows in a unique way how the acquired instrument will perform at his station.
- 2) The manufacturer has a unique definition to characterize the performance of his product (ISO certification)

Proposed set of basic metadata elements

2.1 Station information

There is a great deal of information related to a station's location, local topography and others. Basic station metadata include:

Type of metadata	Explanation	Examples
Station name	Official name of the station	Prievidza
Station index number(s)	Number used by the National Meteorological Service to identify a station	11867
Geographical co-ordinates	Latitude and longitude of the station reference point	18.7697 18.5939
Elevation above mean sea level	Vertical distance of a reference point of the station measured from mean sea level	260.25 m
Types of soil, physical constants and profile of soil	Description of soil type below the station, its characteristics	clay
Types of vegetation and condition	Description of the station's environment land	natural; grass
Local topography description	Description of the station's surroundings, with emphasis on topographic features that may influence the weather at the station	valley station
Type of AWS, manufacturer, model, serial number	Basic information on the AWS installed	MILOS 500, Vaisala, DMF50, S14507
Observing programme of the station:	Information on types of observation made, variables measured	1-hour synoptic obs.
▪ parameters measured	List of variables measured	T, P, U, DF, ...
▪ reference time	Reference time of observations	UTC
▪ times at which observations are made	Actual time of observations	50.-59.min.
The datum level to which atmospheric pressure data of the station refer	MSL or geopotential of the datum level to which the atmospheric pressure is reduced	MSL; 925 hPa; 850 hPa;

2.2 Individual instrument information

Relevant metadata should be:

Type of metadata	Explanation	Examples
Sensor type:	Technical information on the sensor used for the measurement of the variable	Temperature; humidity; pressure ...
▪ manufacturer		Vaisala, Campbell, ...
▪ model		HMP45C, PTU-2000
▪ serial number		12345...

Type of metadata	Explanation	Examples
Principle of operation:	Description of method or system used	
▪ method of measurement / observation	Type of operation principle describing method of measurement/observation used	constant current principle, polymer capacitance
▪ type of detection system	Complete set of measuring instruments and other equipment assembled to carry out specified measurements	optical scatter system combined with precipitation occurrence sensing system
Performance characteristics	Operating range of sensors	-50 - +60 °C, 0 - 100 %
Unit of measurement	SI unit in which the variable is measured	K, Pa, m s ⁻¹
Measuring range	Interval between upper and lower value limits for which a variable is reported	-50 - +60 °C, 0 – 75 m s ⁻¹
Resolution	The smallest change in a physical variable which will cause a variation in the response of a measurement system.	0.01 K,
Uncertainty	Variable associated with the result of a measurement that characterizes the dispersion of the values that could be reasonably attributed to the measurand; the interval in which the “the value” of the variable at the time of measurement is expected to lie.	±0.1 K
Time constant	Time required for an instrument to indicate a given percentage (63.2 %) of the final reading resulting from an input signal	20 s;
Time resolution	Frequency of sampling	3 s, 10 s
Output averaging time	Time period used for the purpose of determining of reported value	1 min.; 2 min; 10min.
Siting and exposure:		
▪ location		screen, mast, tower
▪ shielding		screen, naturally aspirated
▪ height above ground (or level of depth)		1.75 m, -0.1 m
Data acquisition:		
▪ sampling interval	Time between successive observations	3 s, 10s, 30s
▪ averaging interval	Time interval from which samples are used	1, 2, 10, 30 minutes
▪ type of averaging	Method used for the calculation of the average	arithmetic; exponential; harmonic

Type of metadata	Explanation	Examples
Correction procedures	Corrections applied to the data	for temperature, for gravity, for wind speed
Calibration data		
▪ correction	Value to be added to or subtracted from the reading of an instrument to obtain the correct value	$C = R (1+0.6R)$
▪ time of calibration	Date when the last calibration was made	12/12/2003
Preventive and corrective maintenance:		
▪ recommended / scheduled maintenance	Frequency of preventive maintenance	one per 3 months
▪ calibration procedures	Type of method/procedure used	static/dynamic calibration
▪ calibration frequency	Recommended frequency	12 months
▪ procedure description		
Results of comparison with traveling standard	Result of the field tests of the sensor	98%

2.3 Data processing information

For each individual meteorological parameter, metadata related to processing procedures should include:

Type of metadata	Explanation	Example
Measuring / observing programme:		
▪ time of observation		10 th , ..., 60 th min.
▪ reporting frequency		10 min.
▪ data output	Quantity that is delivered by an instrument or system	2-min. average value
▪ processing interval	Time interval from which the samples are taken	2, 10 min. (wind)
▪ reported resolution	Resolution of variable reported	0.1 ms ⁻¹
Data-processing method, procedure, algorithm	Method used	running 10-min. average
Formula to calculate the element		$VIS=N/(1/V_1+1/V_2+ \dots +1/V_n)$
Mode of observation / measurement	Type of data being reported	instantaneous, total, mean value, variability,
Input source (instrument, element, etc.)	Measured or derived variable	WAA 151
Constants and parameter values	Constants, parameters used in computation of derived parameter	$g=9.806 65ms^{-2}$

2.4 Data handling information

Metadata elements of interest include:

Type of metadata	Explanation	Example
Quality control procedures, algorithms	Type of QC procedures	plausible value check; time consistency check, internal consistency check
QC flags definition	Description of QC flags	1 good, 2 inconsistent, 3 doubtful 4 erroneous, 5 not checked, 6 changed
Processing and storage procedures	Different procedures used in the process of data reduction and data conversion	computation of visibility from extinction coefficient
Constants and parameter values		

2.5 Data transmission information

The transmission-related metadata of interest are:

Type of metadata	Explanation	Example
Method of transmission	Means of transmission	GSM/GPRS, OrbComm; radio
Data format	Type of message used for data transmission	BUFR; SYNOP
Transmission time	Time of regular transmission of data	11 th minute; 60 th minute
Transmission frequency	Frequency of data transmission	10 minute; 1 hour

Quality monitoring procedures for data from AWS

I. Background

Quality control is the best known component of quality management systems. It consists of examination of data at stations and at data centres to detect errors so that data may be either corrected or deleted. A quality control system should include procedures for returning to the source of data to verify them and to prevent recurrence of the errors. Data quality control has to be applied as real time quality control performed at the station and at data processing centre. In addition, it has to be performed as near real time and non real time control at data processing centre.

Quality monitoring or performance monitoring is both real time and non-real time activity in which the performance of the network or observation system is examined for trends and systematic deficiencies. It is typically performed by the office which manages and takes responsibility for the network or system, and which can prescribe changes to equipment or procedures.

Besides instrument installation, maintenance and calibration, quality of data depends also on the real-time quality control procedures applied during data acquisition and processing, in order to eliminate the main sources of errors. These procedures are specific for each type of measurement but generally include plausible value checks, time consistency checks and internal consistency checks. In AWSs, special built-in test equipment can allow detection of specific hardware errors. Application of these procedures is most important because some errors introduced during the measuring process cannot be eliminated later.

As real-time quality control procedures have their limitations and some errors can go undetected, such as sensor drift or bias, as well as errors in data transmission, performance monitoring at the network level is required at meteorological data processing centers and by network managers.

A critical component of rigorous QC is the accurate and appropriate flagging of data. All AWS data should be flagged using appropriate QC flags. At basic QC level performed at AWS five data QC categories are enough:

- good (accurate; data with errors less than or equal to a specified value);
- inconsistent (one or more parameters are inconsistent);
- doubtful (suspect);
- erroneous (wrong; data with errors exceeding a specified value);
- missing data.

It is essential that data quality is known and demonstrable; data has to pass all checks in the framework of basic QC. In case of inconsistent, doubtful and erroneous data, additional information should be transmitted; in case of missing data the reason of missing should be transmitted.

It is important to establish effective liaison procedures between those responsible for monitoring and for maintenance and calibration, to facilitate rapid response to fault or failure reports from the monitoring system.

II. Proposal

Successful real time QC monitoring has to include checks of the following items:

- ✓ Completeness of observations at the meteorological station;
- ✓ Quality of data;
- ✓ Completeness and timeliness of the collection of observational data at the centre concerned.

QC monitoring is intended to identify deficiencies and errors, monitor them and activate appropriate remedial procedures. Some assessment can be and should be performed in real time, whereas other evaluations can only be accomplished after gathering of sufficient data over a longer period.

QC monitoring requires the preparation of summaries and various statistics. Therefore, it is necessary to built up QC Monitoring System which has to collect different statistics on observational errors of individual meteorological variables, through a series of flags indicating the results of each check, and at least generate hourly, daily, weekly, monthly and yearly summaries of:

- The total number of observations scheduled and available for each variable (completeness of data);
- The total number of observations which failed the QC checks for each variable (quality of data) in case of:
 - Plausible value check,
 - Time consistency check,
 - Check on a maximum allowed variability of an instantaneous value,
 - Check on a minimum required variability of instantaneous values,
 - Internal consistency check;
- The percentage of failed observations (quality of data);
- The error and threshold values for each failed observation (reason of failure).

Stations with large percentages of failed observations are most likely experiencing hardware or software failures.

QC Monitoring System has to keep station monitoring statistics on the frequency and magnitude of observation errors encountered at each station. The statistics provide information for the purpose of:

- ✓ Monitoring quality of station performance,
- ✓ Locating persistent biases or failures in observations,
- ✓ Evaluating improvement of quality of observation data, performance and maintenance of station/network.

WORK PLAN
Expert Team on Surface Technology and Measurement Techniques
(2003-2006)

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
1	In cooperation with HMEI, report and recommend standards for automated visual and subjective observations					
1 a)	Systems measuring present weather (including clouds, icing, state of the ground, lightning and thunderstorms)	Stuart GOLDSTRAW	1. Review the past recommendations	Mar. 05	• Report on reviewed past recommendations	May. 05
		Jitze van der MEULEN	2. Review the current guidance material and practices	Mar. 05	• IOM report on current standards and practices	Sep. 05
		Hannu KOKKO	3. Develop recommendations for standards	Aug. 05	• Update CIMO Guide • Report to CIMO-XIV	Dec. 05 May. 06
1 b)	Standardization of algorithms for AWSs (including algorithms for the automatic assessment of cloud base height and cloud amount)	Bruce HARTLEY	1. Review the available algorithms, presented in IOM 78	Feb. 05	• IOM Report on methods used by current systems, including recommendations for standards	Feb. 06
		Jitze van der MEULEN	2. Study the references from this review	Jun. 05		
		Mike EDWARDS	3. Develop recommendations for standards	Oct. 05	• Report to EC and other TC's • Report to CIMO-XIV	Nov. 05 May. 06
1 c)	Standards for automation of manual, visual and subjective observations	Bruce HARTLEY	1. Review the current standards and practices	Jun. 05	• IOM Report on methods used by current systems, including recommendations for standards	Feb. 06
		Hannu KOKKO	2. Develop recommendations for standards	Sep. 05	• Report to CIMO-XIV	May. 06

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
1 d)	Explore alternative methods for replacing those subjective observations that are currently not able to be automated in the foreseeable future	Stuart GOLDSTRAW	<ol style="list-style-type: none"> 1. Identify those subjective visual observations that are not able to be automated in the foreseeable future 2. Explore alternative methods for replacing those subjective observations identified above 	<p>Jun. 05</p> <p>Dec. 05</p>	<ul style="list-style-type: none"> • IOM Report on possible alternative methods for replacing some traditional observations • Report to CIMO-XIV 	<p>Feb. 06</p> <p>May. 06</p>
2	Report to Members on the state-of-the-art of Instruments and Automated Surface Observing Systems (ASOS)					
2 a)	Review and report on development of instruments and ASOS	Kjell HEGG Jitze van der MEULEN Hannu KOKKO	<ol style="list-style-type: none"> 1. Instrument Development Inquiry No. 8 (IDI8) 2. Analyze replies from members and HMEI on ID 	<p>Jan. 05</p> <p>Sep. 05</p>	<ul style="list-style-type: none"> • IOM Report on Instrument Development • Report to CIMO-XIV 	<p>Dec. 05</p> <p>May.06</p>
2 b)	Provide guidance on implementation in harsh climatological conditions, on siting and on metadata standards, and update WMO regulations	Yu Feng HU Jitze van der MEULEN + Alain HEIMO (severe weather, arctic) Jacob MISHAELY (severe weather, deserts) Jon WIERINGA (metadata and siting) Ernest RUDEL (metadata and siting) Tim OKE (metadata and siting-urban obs)	<ol style="list-style-type: none"> 1. Review available guidance and practices related to implementation in harsh climatological conditions 2. Review available guidance and practices related to siting 3. Review available guidance and practices related to metadata 4. Recommend standards on the above (1-3) 	<p>Jun. 05</p> <p>Jun. 05</p> <p>Jun. 05</p> <p>Dec. 05</p>	<ul style="list-style-type: none"> • Updated relevant IOM Reports • Updated CIMO Guide • Proposals for consistency of CIMO Guide with Guide of CCI, CHy and AgM, Manual on GOS, and Technical Regulations • Report to CIMO-XIV 	<p>Jan. 06</p> <p>Mar. 06</p> <p>Mar. 06</p> <p>May. 06</p>

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
2 c)	Consider possible means to minimize the impact on the cost of the continuous improvements of instruments	Yu Feng HU Jitze van der MEULEN Jacob MISHAELY	1. Study the cost/benefit impact of the continuous improvements of instruments 2. Propose possible means to minimize the impact on the cost	Feb. 05 Apr. 05	<ul style="list-style-type: none"> • IOM Report of the cost impact • Report CIMO-XIV 	June. 05 May. 06
3	Report on progress of urban and road meteorological measurements					
3 a)	Monitor the emerging requirements for measurements for road meteorological measurements	Larry SENN Anna BRATOEVA Hannu KOKKO	1. Review current uses and applications for Roadway Environmental Sensor Stations (R-ESS) including typical sensor specifications, sensor mounting configurations and siting criteria 2. Contacting a sample of R-ESS users representing a cross-section of users to obtain typical specifications, sensor mounting, site criteria and specific applications 3. Review findings of WMO "Instruments and Observing Methods" reports 77 and 61 to identify any changes 4. Provide a draft report of findings in 1 and 2 above 5. Develop recommended draft sensor specification and mounting configurations and site criteria	Feb.05 Feb.05 May.05 Feb.05 May.05	<ul style="list-style-type: none"> • IOM Report on R-ESS uses, typical sensor configurations and site criteria • Report to CIMO-XIV 	Nov.05 May.06

3 b)	Explore further difference in perception of WMO standards for synoptic stations at road meteorological observing stations , especially in the light of the requirements of modern road monitoring and traffic management systems	Larry SENN Anna BRATOEVA Hannu KOKKO	1. Study the perception of WMO standards as they related to Roadway Environmental Sensor Stations (R-ESS) 2. Develop recommendations for standards and practices	Sep. 05 Nov. 05	<ul style="list-style-type: none"> • Recommendations for standards and practices on road meteorological measurements, such as sensor specifications and mounting configurations, site criteria for R-ESS. • Suggestions on practices for Quality Control (maintenance) networking for data collection and data archiving, site metadata including obstructions and shading and possible links to GIS systems • Updated CIMO Guide • Report to CIMO-XIV 	Dec. 05 Nov.05 Feb. 06 May.06
3 c)	Monitor the emerging requirements for measurements for urban meteorological measurements	Tim OKE Anna BRATOEVA Jon WIERINGA (siting)	1. In cooperation with the user community monitor the requirements 2. Develop recommendations for standards and practices	Jun. 05 Sep. 05	<ul style="list-style-type: none"> • Recommendations for standards and practices on urban meteorological measurements • Updated CIMO Guide 	Nov. 05 Feb. 06

4	Provide advice on <i>Quality Management Systems</i> procedures for instruments and methods of observation (based on the CIMO Guide) and implement links with relevant international organization active on this area					
4 a)	Develop performance measures to demonstrate continuous improvement in the quality of observations	Stuart GOLDSTRAW Alain HEIMO Gerhard PEVNY	1. In collaboration with ET C.2, develop basic procedures for quality management of observations, instrument maintenance, calibration and operational practices	Jul. 05	<ul style="list-style-type: none"> IOM Report on Basic procedures for quality management of observations, instrument maintenance, calibration and operational practices 	Dec. 05
4 b)	Contribute to the review and update of WMO Technical Regulations, Guides and other material related to Quality Management and standardization of observations	Kjell HEGG Jitze van der MEULEN Stuart GOLDSTRAW Igor ZAHUMENSKÝ	<p>1. In collaboration with ET C.2, prepare proposals for relevant updates of CIMO Guide</p> <p>2. In collaboration with ET C.2, prepare proposals for update of WMO Technical Regulations and Guides</p>	<p>Jun. 05</p> <p>Jun. 05</p>	<ul style="list-style-type: none"> Update CIMO Guide Report to CIMO-XIV 	<p>Dec. 05</p> <p>May. 06</p>