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CIMO SURVEY ON NATIONNAL SUMMARIES OF METHODS AND INSTRUMENTS FOR SOLID PRECIPITATION MEASUREMENT AT AUTOMATIC WEATHER STATIONS

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FOREWORD

This publication reports on the results of the CIMO survey, initiated in 2008, on the current methods, instruments and challenges for the measurement of solid precipitation at automatic weather stations. The current survey is the third in its category. It was built on the two previous surveys that were conducted by CIMO 10 and 20 years ago. Since then, the automatic stations have been providing an increased percentage of precipitation data, snow water equivalent, and depth of snow on the ground. The CIMO, at its 14th session, initiated this review to assess the methods for measurement and observation of solid precipitation, snowfall and snow depth, at automatic, unattended stations in cold climate (polar and alpine). In that context, CIMO tasked the Expert Team on Surface-Based Instrument Intercomparisons and Calibration Methods (ET-SBII&CM) to conduct this work.

This IOM Report, prepared by a member of the Expert Team, Ms Rodica Nitu as Lead author, and by Ms Kai Wong, provides the result of the analysis of the survey on National summaries of methods and instruments for solid precipitation measurement at automatic weather stations that was performed in 2008 to document and review the current methods, instruments and challenges of automatic solid precipitation measurements.

The survey was prepared in a way to reflect the transition from manual to automatic observation of precipitation and to provide information on the extent of use of automation for measuring precipitation, the parameters monitored, the instruments used and their metadata, and the current development work taking place for improving the measurement of precipitation.

This publication facilitates a better understanding of the global configuration of precipitation measurement and lays the ground for a proposed WMO intercomparison of instruments measuring solid precipitation.

I wish to express my sincere gratitude and that of CIMO to the author of this report, R. Nitu and K. Wong (Canada) for their remarkable work done in analysing this survey and elaborating this report.

John Nash

(Dr. J. Nash)

President Commission
for Instruments and Methods of Observation

TABLE OF CONTENTS

Foreword

1 Summary

This publication reports on the results of the survey, initiated in 2008, on the current methods, instruments and challenges for the measurement of solid precipitation at automatic weather stations. The survey was conducted on behalf of the Expert Team on Surface-Based Instrument Intercomparisons and Calibration Methods (ET-SBII&CM) of the World Meteorological Organization (WMO) Commission for Instruments and Methods of Observation (CIMO). The weather stations are primarily those own and operated by the National Meteorological and Hydrological Services (NMHSs) of the Member countries.

The questionnaire for the survey was organized into 7 sections.

A: Network configuration
B: Measured parameters and instruments used
C: Adjustment to measurements
D: Derived measurements
E: Use of snow courses
F: Development work on improvement of solid precipitation measurements
G: Contact information

The meteorological and hydrological services of 54 WMO Members, covering about 46% of the global land mass, at all latitudes, except Antarctica, provided responses to the questionnaire.

For section A (network configuration), thirty five (35) of the countries participating in the survey, covering about 28% of the global landmass, indicated that they monitor solid precipitation (by manual and automatic means). A total of 41673 sites measuring precipitation (liquid or solid) have been reported, and among them 17561 sites, or 42%, measure solid precipitation.

The responses to Section B on measured parameters indicate that total precipitation amount is measured and reported by all 41673 stations recorded in the survey. Of the total, 18% of measurements are obtained from automatic sites, with the balance of 82% being reported from manual sites. The next most widely reported parameter is the depth of snow on the ground. The use of automatic gauges for measuring this parameter is limited to less than 7% of the sites reporting it.

The instrument types in use are tipping bucket rain gauges (TBRG), weighing gauges (WG), optical sensors and “level” gauges, with their respective percentages being 82.9%, 16.2%, 0.4% and 0.5%. About 36% of the TBRGs, and about 82% the WGs, are equipped with wind shields.

For Section C, among the 54 responding participants, 13 countries, or 24%, adjust the precipitation measurements for some known errors.

On the topic of derived parameters (Section D), among the 54 surveys there are only 7, or 13% of the surveyed countries, that currently derive any parameters from the automatic stations in their services.

The use of snow courses to survey the ground snow cover was reported by nine Member countries.

For Section F, among the 54 surveyed countries, there are 16, or about 30%, that are currently testing or developing new instruments and methods of measurement of solid precipitation parameters at their automatic weather stations.

It should be pointed out that the results of this survey are conservative; a known limitation of the assessment is the fact that in many countries the measurement of precipitation is configured and managed through several independent agencies in addition to National Meteorological and Hydrological Services. For example, in Canada, in addition to the monitoring networks measuring and reporting precipitation managed by the Meteorological Service of Canada (MSC), extensive networks are managed by other agencies (federal, provincial) and their data is not generally included in the MSC database. Therefore, the number and density of stations measuring precipitation, may, in effect be higher than that mentioned in this report.

2 Introduction

2.1 Motivation and Background

Precipitation is one of the most important atmospheric variables; changes in precipitation measurements impact on ecosystem, hydrological, climate modeling and process studies.

Over the past decade, the transition from manual to automatic observation of precipitation has accelerated in many countries. The migration has introduced new challenges with respect to the quality, consistency, compatibility, and representativeness of hydro-meteorological measurements.

Solid precipitation, although simple to be observed by humans, is one of the more complex parameters to be measured using automatic means. While solid precipitation measurements have been the subject of a multitude of studies, there has been only a limited number of coordinated assessments on the ability and reliability of automatic sensors for measuring solid precipitation accurately, as well as the homogeneity of their measurement results.

Precipitation measurements are sensitive to exposure, wind, and topography. The metadata describing the circumstances of measurements, including with respect to the instrumentation used, are important for the users of data. The consistency of precipitation data would be achievable more easily if the same or compatible gauges and siting criteria are used throughout.

Between 1987 and 1993, WMO organized a Solid Precipitation Measurement Intercomparison (Goodison et al 1998), which assessed the national measurement methods for solid precipitation used at the time, and most of them were based on manual observations. Since then, the automatic stations have been providing an increased percentage of precipitation data, snow water equivalent, and depth of snow on the ground. In some countries (e.g. Canada, Germany, USA), there are attempts to derive snowfall observations from these measurements, as an alternative for the significant decrease in the availability of manual observations.

The fourteenth session of the WMO Commission for Instruments and Methods of Observation (CIMO-XIV) has established as a priority for the Expert Team on Surface-Based Instrument Intercomparisons and Calibration Methods (ET-SBII&CM), the assessment of the methods for measurement and observation of solid precipitation, snowfall and snow depth, at automatic, unattended stations in cold climates (i.e., polar and alpine). In the first phase of this initiative, a survey was conducted to develop up-to-date national summaries of methods, instruments, and challenges of automatic solid precipitation measurements, at National Meteorological and Hydrological Services (NMHSs)

The results of the 2008 CIMO survey build on the results two previous surveys conducted by CIMO 10 and 20 years ago. The first CIMO survey had estimated a total of approximately 200,000 standards gauges being in use at that time (Sevruk and Klemm, 1989), with about one fifth being recording precipitation gauges (Sevruk, 2002). The results will facilitate a better understanding of the global configuration of precipitation measurement and lay the ground for a proposed WMO intercomparison of instruments measuring solid precipitation.

2.2 Organization

In July 2008, a questionnaire was distributed through WMO-CIMO Secretariat, to all WMO Members. Its purpose was to survey the current methods, instruments, and challenges of automatic solid precipitation measurements.

A copy of the questionnaire is provided in Appendix A.

The WMO Members were asked to provide information on the extent of using automation for measuring precipitation, the parameters monitored, the instruments used and their metadata, and current development work taking place for improving the measurement of precipitation. Most of the responses were received by January 2009, with the last response by June 2009. All the data is available in soft format on the server of the Observing Systems and Engineering section of Environment Canada. If Members are interested in obtaining the responses, they are kindly invited to contact the main author of this report:

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The following general information was requested:

A: Network Configuration: Information on whether solid precipitation is measured operationally in-situ, and on the number of sites where precipitation and solid precipitation are measured.

B: Summary of Measured Parameters and Instruments Used: This section was divided into two parts, one on the measured parameters, and the other on instruments used. For measured parameters, the number of manual and automatic sites, as well as the reporting frequencies, are sought for the following parameters:

- Total precipitation
- Type of precipitation
- Snowfall amount (depth of fresh snow)
- Snowfall water equivalent
- Depth of snow on the ground
- Snow temperature and/or snow surface temperature
- Snow on the ground water equivalent
- Snow wetness
- Rate of snow melt
- Seasonal statistics
- Other

For the instruments used and for all parameters listed above, information was sought on:

- Instrument(s) type/method(s) used
- Instrument manufacturer
- Instrument model
- Principle of operation

- Type of detection system
- Averaging interval and time
- Number of similar instrument per site
- Number of sites
- Shield used (if so, type/characteristics)

C: Adjustments to measurements: Information was sought on whether precipitation measurements are adjusted for known errors, and on the type of adjustment and the time of its application for all the parameters listed above. Furthermore, information was sought on the measurement of wind and temperature at sites where solid precipitation parameters are measured.
D: Derived measurements: Information was sought on whether parameters related to the measurement of solid precipitation are derived using measurements from automatic stations, and on some specifics of algorithms used in the derivation.
E: Use of snow courses: Information on the use of snow course was requested.
F: Development work related to solid precipitation measurements: Information on the development of new instruments and methods for measuring solid precipitation at automatic stations was sought.
G: Contact information.

2.3 Responses

The meteorological and hydrological services of 54 WMO Members, covering about 46% of the global land mass, at all latitudes, except Antarctica, provided responses to the questionnaire. A list of the countries that replied to the questionnaire is provided in Table 7, Appendix B.

3 Survey Results

The results of the analysis of the responses to the survey are given below, and are organized according to the seven sections in the questionnaire.

3.1 Network Configuration

In response to Section A of the survey, thirty five (35) of the countries participating in the survey, covering about 28% of the global landmass, indicated that they monitor solid precipitation (by manual and automatic means). They reported a total of 41673 sites measuring precipitation (liquid or solid), and among them 17561 sites, or 42%, measuring solid precipitation.

3.2 Summary of Measured Parameters and Instruments Used

3.2.1 Summary of Measured Parameters

In response to Section B1 of the survey, the summaries of sites with manual or automatic observations were reported on 11 categories, along the lines of parameters measured. These categories are: (1) Total precipitation amount (solid and liquid); (2) Type of precipitation; (3) Snowfall amount (depth of fresh snow); (4) Snowfall water equivalent; (5) Depth of snow on the ground; (6) Snow temperature and/or snow surface temperature; (7)

Snow on the ground water equivalent; (8) Snow wetness; (9) Rate of snow melt; (10) Seasonal statistics (for any of the above parameters); (11) Other (name).

The summary of the survey results are given in Appendix C.

3.2.1.1 Numbers of Manual and Automatic Sites

Of the total number of stations measuring total precipitation amount, 18% of measurements are obtained from automatic sites, with the balance of 82% being reported from manual sites.

The next most widely reported parameter is the depth of snow on the ground. The use of automatic gauges for measuring this parameter is limited to less than 7% of the sites reporting it.

The other parameters reported are the type of precipitation, the snowfall amount (as depth of fresh snow), snowfall water equivalent, snow temperature/snow surface temperature, snow on the ground water equivalent.

Among the surveyed countries, none perform measurements on snow wetness and rate of snow melt. On the “Other” category, Belgium has 5 automatic sites measuring freezing point temperature, and the Netherlands has 318 manual sites measuring the percentage of snow coverage.

The details are provided in Table 8 and Table 9, Appendix C.

3.2.1.2 Reporting frequencies

The participants have also provided information on the reporting frequency for each of the precipitation parameters indicated as measured, in their respective networks.

3.2.1.2.1 Total precipitation Amount

Most of the manned sites report the total precipitation amount once per day; however it could be as infrequent as once per month. For automatic sites, the reporting frequency ranges from once per day to once per minute, most sites reporting once per hour followed closely by once per minute.

The summary of responses on this category are given in Table 10 and Table 11, Appendix C, for manned and automatics sites respectively.

3.2.1.2.2 Type of Precipitation

For this parameter, the reported frequency of reporting used by most manned sites is once per day. This has been interpreted to be the frequency relative to climate and other non real-time purposes. For automatic sites, the frequency used by most sites is once per hour. For manned stations, the “at any time” reporting frequency comes from Japan Meteorological Agency which has 87 sites. This is interpreted to mean that reporting is done when “at any time” a new precipitation type is identified.

Table 12 and Table 13 in Appendix C provide summaries of the reporting frequencies for manned and automatic sites respectively.

3.2.1.2.3 Snowfall Amount (Depth of Fresh Snow)

The reporting frequencies used by most manned and automatic sites are once per day and once per hour, respectively. The details are given in Table 14 and Table 15 in Appendix C.

3.2.1.2.4 Snowfall Water Equivalent

The results on the reporting frequency of data for manned and automatic sites are given in Appendix C, Table 16 and Table 17 respectively.

3.2.1.2.5 Depth of Snow on the Ground

The reporting frequencies used by most manned and automatic sites are once per day and once per hour respectively. The frequencies for manned and automatic sites are summarized in Appendix C, Table 18 and Table 19 respectively.

3.2.1.2.6 Snow Temperature and/or Snow Surface Temperature

The results on the reporting frequency for this parameter are given in Table 20 and Table 21, of Appendix C for manned and automatic sites respectively. The frequency "occasionally" comes from France.

3.2.1.2.7 Snow on the Ground Water Equivalent

The results are given in Table 22 and Table 23, of Appendix C.

3.2.1.2.8 Seasonal Statistics

The results are given in Table 24 and Table 25, of Appendix C.

3.2.1.2.9 Other

The percentage snow coverage measurement is conducted by the meteorological service in The Netherlands at 318 stations, with a frequency of one report per day. The freezing temperature (dew point) is measured by the Belgium service at 5 sites with a frequency of reporting of once every 10 minutes.

3.2.2 Summary on the Topic of Instruments and their Configuration

This section summarizes the responses to the questions in Section B2 of the survey, on the topic of instruments and configurations used for the measurement of eleven parameters: (1) Total precipitation amount (solid and liquid); (2) Type of precipitation; (3) Snowfall amount (depth of fresh snow); (4) Snowfall water equivalent; (5) Depth of snow on the ground; (6) Snow temperature and/or snow surface temperature; (7) Snow on the ground water equivalent; (8) Snow wetness; (9) Rate of snow melt; (10) Seasonal statistics (for any of the above parameters); (11) Other (name). For each category, the details of the instruments and/or the methods used are sought.

The total number of automatic sites, based on the information provided in Section B1, is 7538. Due to some discrepancies between the numbers of sites given by some countries in Section B1 and B2, the total count of gauges reported as operational is 7502, and this is the number used as reference for the analysis that follows.

3.2.2.1 Measurement of Total Precipitation Amount (Solid and Liquid)

There are essentially four types of automatic instruments used in the measurement of total precipitation amount. They are: tipping bucker rain gauge (TBRG), weighing gauge (WG), optical sensor, and "level" gauge.

The TBRG measures the amount of liquid precipitation by recording the number of tips which correspond to a fixed amount of precipitation, which is the nominal value of each of the two tipping buckets. The TBRGs in use vary in size and shape and can be heated or non-heated. Additional information on the TBRGs is provided in section 3.2.2.1.1, below.

The WG weighs the precipitation collected in a large bucket, and calculates the precipitation amounts based on the detected mass or load. A WG may or may not have rim heating. Additional information on the WGs is provided in section 3.2.2.1.2, below.

An optical sensor uses the scattering or obscuration by hydrometeors, in some cases together with information gathered by other sensors such as rain sensor and temperature, to determine the type of precipitation and to estimate its intensity and accumulation. Additional information on the TBRGs is provided in section 3.2.2.2, below.

A "level" gauge captures and stores the precipitation in a buffer tank, and measures any increase in the amount using a floater. This device was developed and is currently used by the Royal Netherlands Meteorological Institute, KNMI.

Almost all the sites have one instrument per site. The exceptions are Ukraine which has one site with two WGs, and Poland, which reported that it has two instruments per site, most likely two TBRGs. The use of instruments in the surveyed countries, by type, is given in Table 1, below.

	Number of Instruments	**Percentage (%)**
TBRG	6218	82.9
WG	1218	16.2
Optical Sensor	31	0.4
"Level" Gauge	35	0.5
Total	7502	100

*Table 1 - **Use of instruments for total precipitation measurement***

The manufacturers and some technical specifications of the TBRGs, WGs, optical sensors and level gauge used by the countries surveyed are listed in Appendix D.

3.2.2.1.1 On the use of Tipping Bucket Rain Gauges

A remarkable result of the survey is the extent of use and the variety of TBRGs for measuring precipitation accumulation, including in countries where solid precipitation is a frequent occurrence.

Collectively, the NMHSs responding to the CIMO survey currently use 28 different models of TBRGs produced by 22 manufacturers, worldwide. Many of these are the result of joint developments between the national meteorological services and local instrument manufacturers. This has resulted in several country specific gauges. For example, Japan Meteorological Administration (JMA) has developed in cooperation with three Japanese manufacturers, Ogasawara Keiki Seisakusho Co. Ltd., Koshin Denki Co. Ltd., and Yokogawa Denshikiki Co. Ltd., precipitation gauges to meet JMA specific requirements. Similarly, the UK Met Service has developed the MK5 gauge, currently used throughout its surface networks.

All the TBRGs operate on the principle of pulse count, where pulses are generated by magnetic reed switches. There is significant variability in terms of gauge sensitivity, this being determined by the size of the bucket, which ranges from 0.1 mm to 0.5 mm of precipitation, and their collecting area varies from 200 cm^2 to 1000 cm^2.

3.2.2.1.2 On the use of Weighing Type Gauges

The WGs currently in use are from six manufacturers, Geonor (model T200B), OTT (Pluvio), Vaisala (VRG101), Belfort (Fisher and Porter), MPS System (TRwS500), and Meteoservis v.o.s. (MRW500). Canada is the only NMHS continuing to use the Belfort's Fisher and Porter gauge, which will be phased out in the coming years. The collecting capacity of the WGs in use varies from 240 mm to 1000 mm, while the collecting area is between 200 cm^2 and 1000 cm^2.

Three different principles of measurement are implemented on the WGs currently in use; these are the vibrating wire load (Geonor), the single point electronic load (Vaisala, OTT), the strain gauge (MPS System, Meteoservis, and Belfort).

Heating of the WGs is a feature increasingly in use to address the ice buildup and snow capping. The extent to which heating is implemented operationally has not been included in the CIMO survey. The MPS System and Meteoservis gauges are configured by default with heating capabilities, while the others offer heating as an option.

3.2.2.1.3 On the use of shields on precipitation gauges

The participants in the CIMO 2008 survey indicated that, overall, 72% of the automatic instruments (WGs and TBRGs) are not configured with wind shields. Of the automatic gauges that have wind shields, the WGs are used in a much larger proportion with shields. Specifically, 82% of the total of WGs, or 10% of the total automatic instruments, are configured using single wind shields. The wind shields in use are Alter, Nipher, Tretyakov, or of a special design (e.g. JMA) type.

The National Weather Service (NWS)of the United States of America is the only Service in process of adopting double shields, installing starting with 2009 a second shield, type Alter, around all its 331 weighing type gauges, in addition to the Tretyakov shield currently in use. It is also known that in the Climate Reference Network (CRN) of NOAA of the USA, the WGs are equipped with a double fence, similar to the WMO recommended Double Fence Intercomparison Reference, DFIR, however, with a smaller footprint and of lower height.

In some participating Services only some of their TBRGs are equipped with shields. However, their exact numbers of gauges with and without shields are not given. These countries are Australia (among its 968 gauges, only the TBRGs at alpine sites are equipped with shields), Norway (most of its 20 TBRGs have no shield), and Switzerland (some of its 72 TBRG are equipped with shields).

Excluding these instruments, the results indicate that 36% of the total number of TBRGs operated by the rest of the NMHSs, are configured with wind shields. It's worth noting that these are used primarily by two weather services, the JMA, 9% of the 36%, and the NWS of the USA, 21% of the 36%. Aside from JMA and NWS, only a very small percentage of the TBRGs operated by the other services are configured with shields.

The JMA uses a specially designed shield, in the shape of a cylinder with the diameter twice that of the rain gauge orifice and the height equal to half the height of the rain gauge. National Weather Service of USA uses Alter shields for all its TBRGs.

The report on the 1987-1993 Precipitation Intercomparison (Goodison et al, 1998) indicated that the Nipher shield was the most effective in minimizing the wind undercatch. For shielded gauges the wind-induced loss for snow can be reduced to one-half of its value for unshielded gauges and to 70 % for mixed precipitation (Goodison et al., 1998). However, windshields that are typically good for human observations are responsible for other issues with snow measurements at automatic stations, such as the snow capping. Although Nipher shields reduce wind effectively, the snow capping could result in a larger error of measured precipitation, both as amount and timing of the observation. While there is some evidence that a double fence, similar to that accepted as secondary reference during the 1987-1993 intercomparison, works well for automatic stations, its very large footprint translates into a large real-estate requirement at the instrument site, which is not always affordable.

3.2.2.2 Type of Precipitation

Based on the information given in Section B1, the total number of automatic sites for determining the precipitation types is 1515.

Broadly speaking, there are two classes of instruments used by the surveyed countries for precipitation typing. One determines typing using Doppler radar measurement (6%), while the other uses optical measurement.

Within the optical instruments, there are three types of technologies: One operates on the principle that a partially coherent infrared or visible light beam, when passed through an irregular medium, will have its frequency altered. The phenomenon is called scintillation. When precipitation falls through an infrared beam it introduces frequencies in the beam that are a function of the size and fall speed of the particles. The sensor measures and analyzes the frequency composition of the beam after it has passed through precipitation, and deduces the type, amount, and intensity of the precipitation. We label this technology as optical scintillation based on its principle of operation.

In the second type of technology, the sensor measures the extinction caused by the hydrometeor falling through a thin light sheet, and it determines the size and velocity of the hydrometeor from the amplitude and duration of the light extinction. The precipitation type, amount, and intensity are deduced from the size and velocity information. We label this technology as optical extinction.

The third technology measures the forward optical scattering by the particles and the water content of the precipitation using a rain sensor. The precipitation intensities estimated from forward optical scattering and from the rain sensor measurement together with an air temperature measurement allow for the identification of precipitation types, amount, and intensity. We label this technology as optical scattering.

All the sites have one instrument per site. The relative use of instruments with different operating principles, in the surveyed countries, is given in Table 2, below.

Technology	Number of Instruments	Percentage (%)
Doppler radar	85	5.9
Optical scintillation	883	60.8
Optical Extinction	145	10.0
Optical Scattering	338	23.3

Table 2 - ***Use of instruments for determining the precipitation type***

The Doppler radar measuring systems have been used in Canada, however, they are going to be phased out, over the next few years.

The manufacturers and some technical specifications of the present weather sensors used by the surveyed countries are listed in Appendix E.

3.2.2.3 Depth of Snow on the Ground and Snowfall Amount (Depth of Fresh Snow)

The survey results indicate that there are a total of 823 automatic sites in 11 countries for the depth of snow on the ground, and a total of 689 automatic sites in 7 countries for the snowfall amount parameter, which is obtained mostly on the basis of snow depth measurements. In Slovenia, this parameter is obtained using forward scattering type of present weather sensors.

The majority of the instruments that measures snow depth are of the ultrasonic type, also known as sonic ranging depth sensors. Other snow depth instruments operate on the principle of phase variation of visible laser when it bounces off the snow surface. All the countries except Canada have one snow depth sensor per site, and Canada has one or three instruments per site. The sonic ranging sensors measure the elapsed time between emission and return of an ultrasonic pulse sent vertically down to the snow covered ground surface. The most widely used sonic ranging sensors are manufactured by Campbell Scientific, models SR-50 and SR-50A. Several other sensors in use are Sommer Ultrasonic snow depth sensor USH-8 (Austria), MPS System SwS-3 (Slovakia), ultrasonic snow level meters model JMA-95-1, from Ogasawara Keiki Seisakusho, and JMA-89, JMA-93, JMA-04-1 from Ultrasonic Kaijo Sonic Corp (Japan).

Several new snow sensors are currently under test. Meteo France is planning to install in 2009 Solia 300, an optical and capacitive snow detector sensor manufactured by Degréane.

The manufacturers and some technical specifications of the sensors used by the surveyed countries for depth of snow on the ground and snowfall amount are listed in Appendix F.

3.2.2.4 Snowfall Water Equivalent

Nine of the participating NMHSs indicated that they collectively operate a total of 1411 automatic sites for measuring and reporting precipitation as snowfall water equivalent. There are four types of instruments used for measuring this parameter: the WGs, representing 23.5% of the total number of sites, the heated tipping bucket rain gauge (HTBRG), 74.3%, the optical sensor, 1.9%, and the “weight” sensor, representing 0.3% of the total number of sites. The optical sensors used are, essentially, the present weather sensor, operating on either the extinction principle or forward scattering principle (see above).

The so called weight sensors are snow pillows which determine the snow water equivalent by measuring the weight of the snow over a specific area. The working principle of the sensor is based on the detection of the hydrostatic pressure caused by the layer of snow on top of the pillow. The snow pillows use four tensiometric sensors, situated under each corner of the steel frame on which the plate is mounted. Data on the weight of the overlying snow is combined with the snow depth measured with an ultrasonic snow sensor, to derive the snow water equivalent. The standard dimensions of a snow pillow are 3 x 3m or 4 x 4m.

Czech Republic Meteorological Service is the only participant in the CIMO survey that reported using snow pillows. Four such systems are in use; two are model LEC 3010 (manufactured by LEC, Cz) and operating in conjunction with an ultrasonic sensor type Vegason61, for continuous level measurement. The other two snow pillow systems are type SOMMER, manufactured by Sommer GmbH & Co KG (Austria) and are operated in conjunction with a USH-8 ultrasonic snow depth sensor.

3.2.2.5 Snow Temperature and/or Snow Surface Temperature

Seven NMHSs reported measuring snow temperature or snow surface temperature, at a total of 111 automatic sites. Some sites are equipped with more than one instrument; thus, a total of 131 instruments. All the temperature sensors are PT100 platinum resistance thermometers. The manufacturers and some technical specifications of the sensors used by the surveyed countries for snow temperature and/or snow surface temperature measurement are listed in Appendix G.

3.2.2.6 Other parameters

There are only two countries that provide information in this category. They are Belgium and Norway. For Belgium, the freezing point temperature is measured at 5 sites with 2 to 4 instruments at each site. Norway uses an optical detector to determine precipitation duration at 20 sites with one instrument at each site. The information is used for in situ control and correction of Geonor WG data.

3.3 Adjustment to Measurements

The CIMO questionnaire sought to determine whether NMHSs monitor specific parameters which could be used for deriving adjustments to be applied to precipitation data, and which adjustments are normally applied.

Among the 54 responding participants, 13 countries, or 24%, adjust the precipitation measurements for some known errors. The number of countries that apply adjustments by parameter is given in Table 3, below. The list of adjustments and the manner in which they are applied are given in Appendix H, and are organised by the parameter surveyed.

Parameter	Number of Countries	Percentage (%)
Total precipitation amount (solid and liquid)	10	18.5
Type of precipitation	6	11
Snowfall amount	4	7
Snowfall water equivalent	3	5.6
Depth of snow on the ground	5	9.3
Snow on the ground water equivalent	2	3.7
Snow temperature and/or snow surface temperature	1	1.9
Snow wetness	1	1.9
Rate of snow melt	1	1.9
Seasonal statistics (for any of the above parameters)	2	3.7
Other (name)	0	0

Table 3 - ***Number of Countries that Apply Adjustments to Each Parameter***

The second part of this section concerns with information on the measurement of wind and temperature at sites where solid precipitation is monitored. The information is gathered through six questions. A summary of the questions and the responses received is given in Table 4, below.

Questions	Number of Positive Answers	Percentage (%)
Is the precipitation measurement adjusted for wind effects?	7	13
Is wind speed measured at the gauge location?	24	44
Is the wind speed measured at the height of the gauge measuring solid precipitation?	2	3.7
If wind speed is not measured at the sensor level, is wind speed reduced to the height of the precipitation gauge?	5	9.3
Is the air temperature measured at the site?	26	48
Are the snow pack and/or subsurface temperature measured?	9	16.7

Table 4 - ***Summary of responses on measurements to support deriving adjustments to precipitation***

3.4 Derived Measurements

The questions posed in the CIMO questionnaire on derived measurements are as follows.

The first question was: Are any parameters related to the measurement of solid precipitation, derived using measurements from automatic stations in your Service? Three parameters were listed: Depth of freshly fallen snow, Snow derived density, and Precipitation type. All other parameters are put under the heading of “other”. For each parameter, answers are sought regarding whether the parameter is derived in real-time or in post-processing, and the frequency with which is reported.

The second part concerned with how the parameter is derived: single-sensor or multiple-sensor algorithm, and the list of parameters used.

The third and final question on the topic was: Are the current derivation algorithms documented? If so, their accessibility either through the web or in other forms is asked.

The responses to the first question are as follows. Among the 54 surveys, there are only seven countries, or 13% of the surveyed countries, that currently derive some precipitation parameters from automatic stations in their services, using measurements available from that site. These countries are: Austria, Canada (derivation applied to some sites), Denmark, Finland, France, Germany and The Netherlands. There is one country (Switzerland) that is planning to implement derived measurements in its service in the future.

The derived parameters are depth of freshly fallen snow (Austria, Canada, Finland and France), precipitation type (Finland, France, Germany and The Netherlands), and other (snow amount) (Denmark). Table 43, Table 44 and Table 45, Appendix I, give a view of how these parameters are derived.

Availability and accessibility of documentations of the derivation algorithms are summarized in Table 46, Appendix J.

3.5 Use of Snow Courses

Nine participants in this survey provided information on their programs of manual survey of the snow pack. These are Belarus, Estonia, Finland (30 stations), France (150 stations), Island (14 stations), Latvia, Slovenia, Ukraine, and Uzbekistan (453 stations).

The use of snow courses was assessed through three questions: how often the snow survey is conducted, the equipment is used, and how many data points are used.

The responses at the question on the frequency of the snow survey indicate that, in general, there is a dependency on the location of the course, i.e. open field versus forest or wooded areas, and the timing of the survey, i.e. less frequent in the earlier parts of the snow season, and more frequent during the periods of snowmelt. A survey every ten days is conducted in Belarus from October to January, in Estonia for all stations situated in open fields, at all courses in Latvia, and at about of half of the stations in Uzbekistan.

A frequency of survey of 5 days was reported by Belarus and Estonia, as taking place during snowmelt (February to April), by Finland and Ukraine for all their stations in this category, and by Uzbekistan as the highest survey frequency. France and Island operate snow courses in the mountainous areas, and the survey frequency is about once every 7 days. Slovenia reported conducting snow survey every 12 hours, while Uzbekistan reported conducting surveys at 210 of its stations on a monthly basis.

Where implemented differently, the frequency of survey in open field is generally higher than that for forested areas.

The participants indicated that the equipment used for conducting snow surveys consists of snow stakes or rules and snow scales or snow weighing cylinders. In addition to those, Island reports using crystal cards, magnifying glass, and density kits.

On the topic of the number of points used in the snow course, the responses vary largely. Belarus indicated using 50 points for snow depth measurement and 10 points for the measurement of snow density, Estonia uses 50 points throughout. Finland uses 5 points, France one point, Slovenia three points, Ukraine 100 points, and Uzbekistan 5-125 points. Latvia reports using for snow depth measurement 100 point in open field and 50 points in wooded areas, while for the measurement of snow density uses 10 points in open field and 5 points in wooded areas.

3.6 Development of New Instruments and Methods

On this topic, the question posed in the questionnaire was: Is your Service currently testing or developing new instruments and methods of measurement of precipitation at Automatic Weather Stations? If the answer is “yes”, the list of new instruments and methods was sought.

Among the 54 surveys, 18 Members, or about a third of the respondents, indicated that they are currently testing/developing new instruments and methods of measurement of solid precipitation parameters at Automatic Weather Stations. These countries are Austria, Republic of Belarus, Canada, Denmark, Germany, France, Lithuania, Morocco, The Netherlands, New Zealand, Norway, Portugal, Slovakia, Sweden, Switzerland, Ukraine, United Kingdom and United States of America. The instruments and methods being tested/developed in these countries are listed in Table 5, below.

Country	Instruments and Methods
Austria	Field test of sensors for automatic snow depth measurement from various manufacturers and various principles of measurement;
Republic of Belarus	(No specific information provided)
Canada	Field testing of weighing gauges and TBRGs, heated and non heated, and in various shield configurations, present weather sensors; testing of SR-50A single vs. triple configuration. Evaluation of Jenoptik snow depth sensor. Development of algorithm to derive snowfall. Development of sensor and configuration specific adjustment curves.
Denmark	Pluvio II, Vaisala VRG101
Germany	Improvement of the "ground plate" to be used as zero level for ultrasonic snow depth measurements. Currently a wooden plate is used and should be replaced by a material/method that is representative for the natural ground with respect to snow accumulation and melting. (2) testing a simple "microphone based" hail sensor. (3) improved the real-time algorithms to improve PWS. (4) might test an optical snow depth sensor (by JENOPTIK, Germany) in the near future.
France	The Solia 300 sensor will be installed in 2009. A comparison was done between SR50A and Solia 300 measurements (Clotilde Augros, Fabrice Zanghi "Snow depth measurement at Meteo-France" TECO 2008) Research are also done: (1) snow fall amount corrections by using wind and air temperature information on the Col de Porte site (French Alps), (2) remote sensing of the snow pack in order to derive snow surface characteristics from photos or satellite data.
Lithuania	Testing VRG101, comparison with manned Tretyakov rain gauge. In 2009 planning network upgrade with 25 instruments VRG101 type, 1 instrument measuring snow height
Morocco	The National Meteorological Service of Morocco (DMN) is installing its own network measuring type of precipitations and depth of snow on the ground. For the first parameter (type of precipitation) the DMN is testing 03 Laser Optical Distrometers (manufacturer: OTT Parsivel) implemented in the area of middle Atlas Mountains. Furthermore, the DMN will install, by the beginning of the year 2009, 03 ultrasonic sensors measuring depth of snow on the ground.
The Netherlands	work together with Eumetnet WgINS to find an appropriate and reliable work around
New Zealand	Deploy snow depth using a commercially available ultrasonic ranging sensor.
Norway	Plan to establish a new high mountain test field, particularly to achieve better correction formula for wind effects for different gauges and shields.
Portugal	The Meteorological Institute of Portugal is implementing a network of "present weather sensors" to be installed at sites of existing meteorological stations

	(manned and automatic) with the aim of automatic identification and measurement of different precipitation types. There are 6 of these systems installed and under tests. In 2009 they will start to operate, together with 12 more PWS systems to be installed.
Slovakia	Intercomparison measurements using different types of rain gauges with new technologies like weighing gauge TRwS (MPS system) and distrometers Parsivel (OTT)
Sweden	Heating equipment and algorithm for Geonor is implemented with good experiences, Operational test of ultrasonic instruments for snow depth measurements.
Switzerland	Testing of different surfaces under the ultrasonic snow depth sensor. Testing optical method (distrometers).
Ukraine	The Department of Meteorology for two years tested the sample of tipping-bucket rain gauges without shield, with shield and with warming in various wind conditions.
United Kingdom	Currently testing Thies Distrometers, OTT Parsivel Distrometers and Campbell Scientific PWS100 present weather sensors at Eskdalemuir.
United States of America	NOAA National Weather Service has been working with Colorado State University to develop and assess a sonic snow depth sensor at several northern CONUS Weather Forecast Offices. Tests indicated that with proper siting of the sensor, reasonable results could be obtained from the sensor. NWS is investigating how these sensors could be implemented in an operational environment.

Table 5 - ***Developments of new instruments and methods***

In summary, the development work on new instruments and methods of observation of precipitation, solid precipitation, in particular, could be organized in four themes: the evaluation of snow depth sensors, the evaluation of target surfaces for the snow depth sensors, the evaluation of precipitation gauges and present weather sensors, and the derivation of gauge specific adjustment curves. Table 6, below, lists the Member countries working on the different types of instruments. The testing and development efforts include the comparison of instruments from different manufacturers, and improvement of sensor outputs with the use of other measurements.

Snow Depth Sensor	Surface for Snow Depth Sensor	Precipitation Gauge	Present Weather Sensor
Austria Canada Germany France Morocco New Zealand Sweden United States of America	Canada Denmark Lithuania Slovakia Sweden Ukraine United States of America	Canada Germany Switzerland United States of America	Canada Germany Morocco Portugal Slovakia Switzerland United Kingdom

Table 6 - ***Instrument types being tested by the countries***

4 Conclusions

The results of the 2008/09 CIMO survey on the instruments and methods for measuring solid precipitation indicate that manual observations are still the primary method for measuring precipitation. In general, worldwide, this is the case at about 82% of all stations. In particular, to measure snowfall or snow on the ground, only a small fraction of the stations (about 7%) use automatic instruments.

The results of the survey indicate that a large variety of automatic precipitation gauges is currently used for the measurements of precipitation amount and solid precipitation, worldwide, including in the same country. Also there is a wide range of parameters reported, measured or derived, which could create difficulties for the users accessing the precipitation data bases. The gauges vary in terms of their measuring system, orifice area, capacity, sensitivity, and configuration. This variety exceeds by far the variety of manual standard precipitation gauges (Goodison et. al, 1998).

It is widely known that the extensive use of a wide range of instruments and configuration significantly impacts the ability to derive representative results at large scale and has serious consequences for the measurement accuracy and consistency of local and global precipitation time series. Because of the non-consistent data sets, it is difficult to compile the global or large-scale climatology of solid precipitation.

The report on the 1987-1993 Precipitation Intercomparison (Goodison et al, 1998) indicated that the Nipher shield was the most effective in minimizing the wind undercatch. However, windshields that are typically good for human observations are responsible for other issues with snow measurements at automatic stations, such as the snow capping. Therefore, alterative shield configurations have to be considered for gauges operating at automatic stations, in particular those unattended.

The gauge undercatch in windy conditions has to be compensated with better wind adjustments. The final report of the 1987-1993 intercomparison (Goodison et al, 1998) indicates that the wind adjustments recommended were developed using observations available at the time, mainly daily precipitation and synoptic observations, taken 6 hrs apart. Today's automatic stations provide precipitation values hourly, and in many cases, at 15-minute (e.g. Canada) or 5-minute (USA, NOAA- Climate reference Network –CRN-) intervals. At this time scale, the dynamic and climatology of precipitation is different. Goodison et al (1998) indicated that the wind during precipitation events is usually less intense than following the event, when it often picks up in intensity. Therefore, the wind adjustment functions using instantaneous or short-interval observations of both wind and precipitation are significantly different from the wind adjustment using daily precipitation and wind data.

Furthermore, the 1987-1993 (Goodison et al, 1998) intercomparison results used 10m winds available at the time at most study sites, to estimate the wind at gauge height. This report shows that following the recommendations of the 1987-1993 WMO precipitation intercomparison, in some countries, the automatic stations have been equipped with wind sensors installed at the level of the precipitation gauge, thus providing a better indication of the wind impacting the precipitation measurements. However, there is no evidence that new adjustment curves have been developed to take advantage of the higher resolution measurements.

The development work conducted by the Member countries is conditioned by the ability to realize a reliable precipitation reference in field conditions. The 1987-1993 WMO intercomparison recommended the use of a Double Fence Intercomparison Reference (DRIF) with manual Tretyakov gauge as a secondary field reference standard (Goodison et all, 1998). Since then, in many applications, the manual gauge in the DFIR has been replaced with automatic gauges as a result of various limitations, e.g. unavailability of local human observers, remote locations, etc. The instrument experts have identified the re-evaluation of the DFIR using automated gauges, as a priority.

5 Recommendations

The need for increasing the accuracy and the consistency of local and global precipitation time series and the effective support of applications relying on the ground observation of precipitation (e.g. satellite measurement validation), requires that an up-to-date body of knowledge on the performance of measurement of the gauges in use, and their relativity, in all climate conditions, is made available.

Given the information obtained through this survey, and the requirement for addressing the widely documented needs of the user community, it is recommended that WMO leads the organization of a field intercomparison of automatic precipitation gauges and their configurations, in various climate conditions, building on the significant efforts currently underway in many countries. The intercomparison should be aimed at understanding and improving the ability to reliably measure solid precipitation using automatic gauges.

The following objectives are proposed for a WMO lead intercomparison of methods and instruments for automatic snowfall/snow depth/precipitation measurements:

- evaluate and report on the performance of instruments and methods of observation for solid precipitation, in field conditions;
- evaluate and provide guidance on the operational configuration of automatic gauges (e.g. use of heating, use of windshields, height of installation, use of redundancy)
- assess the feasibility of developing multi-parameter algorithms to improve the quality of precipitation data reported from an Automatic Weather Station.
- provide datasets to support improving the homogeneity of long-term records of precipitation with special consideration given to solid precipitation;
- enable the development of adjustment procedures of systematic errors related to precipitation measurements
- establish the WMO field reference standard using recording precipitation gauges;
- provide feedback to manufacturers in support of the development of recording precipitation gauges, addressing known limitations.
- draft recommendations for consideration by CIMO.

Acknowledgements

The authors would like to thank the Member countries and their representatives who responded to the CIMO questionnaire and provided the information used to develop these results.

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A very special thanks to Barry Goodison, one of the most ardent promoters of the increase in accuracy and availability of the solid precipitation data series, who has been the key initiator and strongest supporter of this initiative.

References:

B.E. Goodison et al, The WMO Solid Precipitation Measurement Intercomparison" - Final Report, (WMO/TD - No. 872, IOM 67), 1998

CIMO Guide WMO#8, CHAPTER 6, Measurement of Precipitation

B. Sevruk, WMO Questionnaire On Recording Precipitation Gauges State-Of-The-Art, Water Science and Technology, 45(02), 139-145, 2002

Sevruk, B. and Klemm S. (1989). Catalogue of national standard precipitation gauges. WMO, *Instruments and Observing Methods Rep.,* WMO/TD-No. 313, 50 pp., 1989.

APPENDIX A: Questionnaire

Measurement And Observation Of Solid Precipitation At Automatic Stations

The migration from human to automatic observations has introduced new challenges with respect to the quality, consistency, compatibility, and representativeness of hydro-meteorological measurements. The measurement of precipitation (rain, mixed, freezing rain, snow grains, snow, ice crystals, ice pallets, hail, etc) at auto stations has unique challenges that significantly affect the ability to acquire accurate measurements over the expected range of conditions and timescales.

Although precipitation measurement, in general, has been the subject of a multitude of studies, there has been limited coordinated assessment of the ability and reliability of automatic sensors to accurately measure solid precipitation.

The previous WMO Solid Precipitation Measurement Intercomparison that took place between 1986 and 1993, "The WMO Solid Precipitation Measurement Intercomparison" - Final Report B.E. Goodison (Canada), P.Y.T. Louie (Canada) and D. Yang (China), (WMO/TD - No. 872, IOM 67), 1998, (www.wmo.int/pages/prog/www/IMOP/publications/IOM-67-solid-precip/WMOtd872.pdf) focused on the national measurement methods during the study period, mostly manual methods of observation.

Additionally, during the development of proposals for measuring solid precipitation using satellite sensors, the need for validation and calibration using *in-situ* measurements has identified the limitations of measurement of solid precipitation at surface automatic stations as a very serious problem in assessing measurements, in cold climates in particular.

With the objective of determining the nature and extent of automation of solid precipitation measurements, the fourteenth session of the WMO Commission for Instruments and Methods of Observation (CIMO-XIV), has tasked its Expert Team on Surface-Based Instrument Intercomparisons and Calibration Methods (CIMO/OPAG-SURFACE ET-SBII&CM), to assess the needs and methods of measurement and observation of solid precipitation at automatic stations.

The proposed work, under the leadership of the CIMO ET-SBII&CM and in consultation with Antarctic WG, WCRP-CliC; WCP-CCl and CAgM, CHy, CBS and GCOS[1], will include:

- Preparing national summaries of methods, issues and challenges of automatic precipitation measurement;
- Updating and making accessible all metadata related to precipitation measurement instrumentation at all NMHS AWS, and especially for those countries participating in IPY[2];

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[1]

Antarctic WG: Antarctic Working Group

WCRP-CliC: World Climate Research Program – Climate and Cryosphere Project

WCP: World Climate Program

CCl: Commission for Climatology

CAgM: WMO Commission for Agriculture Meteorology

CHy: WMO Commission for Hydrology (Hydrology and Water Resources Program)

CBS: WMO Commission for Basic Systems

GCOS: Global Climate Observing System

- Documenting the needs of WMO Technical Commissions and Programs;
- Compiling, updating and, if required, ensuring compatibility of measurement standards and requirements of WMO Technical Commissions, in particular for cold climate precipitation measurement;
- Assessing the need for an intercomparison of methods and equipment for automatic snowfall/snow depth/precipitation measurements, and develop an intercomparison plan) during the IPY period.

Using the information expected to be provided by member countries, the first phase of the project aims at developing global summaries of methods, instruments and associated metadata, issues, and challenges of the measurement of precipitation, solid precipitation in particular, using automatic means. The second phase will focus on compiling and documenting the precipitation measurement needs of WMO Technical Commissions and Programs, with emphasis on solid precipitation measurement.

Based on the results, CIMO will assess the opportunity of conducting an intercomparison of measuring technology and methods of observation of solid precipitation at automatic stations.

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[2] International Polar Year

Questionnaire On Measurement And Observation Of Solid Precipitation

At Automatic Stations

This questionnaire aims at identifying the current configuration of the in-situ observation of precipitation, solid precipitation in particular, in terms of data and metadata. The results will be compiled and they are expected to facilitate a better understanding of the global configuration of precipitation measurement and lead to concrete steps to identifying and addressing gaps.

Please complete this questionnaire, adding all the information relevant to each question and representative for your country.

WMO Member Country: ....

A: Network Configuration

- Is **solid precipitation** measured operationally in-situ in your Service: Yes/ No
- The total number of sites where precipitation (liquid or solid) is measured is: _______
- The total number of sites where solid (non-liquid) precipitation is measured is: _____

If no measurement related to solid precipitation is made, questions of B to F can be skipped.

B: Summary Of Measured Parameters And Instruments Used:

The definition of the parameters included below could be found in the following references:

1) International Meteorological Vocabulary, WMO-No. 182 (http://meteoterm.wmo.int/meteoterm/)
2) Guide to meteorological Instruments and methods of Observation (WMO-No. 8)
3) Glossary of meteorology (AMS, http://amsglossary.allenpress.com/glossary)

B1: Summary of Measured Parameters

Parameter measured	**Number of sites where the measurement is done:**		**Frequency of reporting**	
	Manually	Using automatic means	Manned sites	Automatic sites
Total precipitation amount (solid and liquid)[1]				
Type of Precipitation				
Snowfall amount (depth of fresh snow)				
Snowfall Water Equivalent				
Depth of Snow on the ground				
Snow temperature and/or snow surface temperature				
Snow on the ground Water Equivalent				
Snow Wetness [2]				
Rate of Snow Melt[3]				
Seasonal Statistics (for any of the above parameters)[4]				
Other (name)				

Note 1: If total precipitation monitored, are rain and snow totals separated for reporting and archiving?

Note 2: Snow wetness refers to percentage of the snow pack that is in liquid form.

Note 3: Rate of Snow Melt refers to the measurement of snowmelt runoff.

Note 4: These statistics may include maximum or average seasonal values, for example.

B2: Summary of Instruments and Configuration used:

This section focuses on gathering information on instruments used at automatic weather stations for the measurement of precipitation, with focus on solid precipitation.

For each parameter listed, indicate if the parameter is monitored at automatic stations, by circling as appropriate: directly measured, derived, or not available.

If a parameter is directly measured, please provide details on the instrument(s) used operationally, e.g. type, model, manufacturer, if a shield is used, etc. Add any additional information that may apply.

If a parameter is derived, please indicate the measurements used to derive the respective parameter. For example, the snowfall amount may be derived from two or more Depth of Snow measurements.

If several types of instruments/methods are used for a given parameter, depending on site, please repeat the description for each instrument/method.

Total Precipitation (solid and liquid): *Directly Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ___________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Type of Precipitation: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ___________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Snowfall amount (depth of fresh snow): *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ___________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Snowfall Water Equivalent: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ______________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:____________________________

Depth of Snow on the Ground: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ______________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:____________________________

Snow on the Ground Water Equivalent: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: ______________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Snow temperature and/or snow surface temperature: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:_____________________________________

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: __________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Snow Wetness: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:_____________________________________

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: __________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Rate of Snow Melt: *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: _____________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

Seasonal Statistics (for any of the above parameters): *Measured/ Derived/ Not Available*

____

Other (name): _____________________________________ *Measured/ Derived/ Not Available*

Instrument(s) type/method(s) used:____

Instrument manufacturer: ____

Instrument model: ____

Principle of Operation: ____

Type of detection system: ____

Averaging Interval and Time: ____

Number of similar instruments per site: _____________________________________

Number of sites: ____

Shield used: Yes/No

If shield is used, indicate shield type/characteristics:___________________________

C: Adjustments To Measurements:

C1: Are the precipitation measurements adjusted for known errors? Yes/ No

(E.g. wind, temperature, etc…)

If yes, please provide the following:

Measured Parameter	**Adjustments applied** **(list all that apply)**	**When the correction is applied (i.e. Real time or archived data)**
Total precipitation amount (solid and liquid)		
Type of Precipitation		
Snowfall amount		
Snowfall Water Equivalent		
Depth of Snow on the ground		
Snow on the Ground Water Equivalent		
Snow temperature and/or snow surface temperature		
Snow Wetness		
Rate of Snow Melt		
Seasonal Statistics (for any of the above parameters)		
Other (name)		

C2: Information on the measurement of wind and temperature at sites where solid precipitation parameters are measured:

Is the precipitation measurement adjusted for wind effects?	Yes/No
Is wind speed measured at the gauge location?	Yes/No
Is wind speed measured at the height of the gauge measuring solid precipitation?	Yes/No
If wind speed is not measured at the sensor level, is wind speed reduced to the height of the precipitation gauge?	Yes/No
Is the air temperature measured at the site?	Yes/No
Are the snow pack and/or subsurface temperatures measured?	Yes/No

D: Derived Measurements:

D1: Are any parameters related to the measurement of solid precipitation, derived using measurements from automatic stations in your Service?

For example, the depth of freshly fallen snow may be derived from Depth of Snow measurements, potentially in conjunction with precipitation amount, etc.

For any derived parameter, indicate in the table below, those parameters used for the derivation and reporting interval.

Derived parameters	**Real-time vs. post processing derivation**	**Reporting interval**
Depth of freshly fallen snow		
Snow derived density		
Precipitation type		
Other (name)		

D2: Indicate whether for deriving the above parameters *"single-sensor algorithms"* or *"multi-sensor algorithms"* are used:

Derived parameters	**Derivation algorithm:** **Single-sensor (S)/ Multi-sensor (M)**	**Parameters used for derivation (list all that apply)**
Depth of freshly fallen snow		
Snow derived density		
Precipitation type		
Other (name)		

D3: Are the current derivation algorithms documented? **Yes/ No**

If algorithms are documented, is documentation available on the World Wide Web?

If available, please list Web site(s): ....

If algorithms are documented but not available on a Web site, indicate below how they can be accessed:

....

E: Use Of Snow Courses:

Are snow courses operated to measure snow depth and snow water equivalent?

- How often are they conducted?
- What equipment is used?
- How many data points used in the snow course?

Note: For definitions and additional information, please refer to the Snow Survey report from Meteorological Service of Canada at http://www.socc.ca/nsisw/atlas/woo.pdf

F: Development Work Related To Improving The Measurement Of Solid Precipitation Parameters At Automatic Weather Stations

The information provided in this section should reflect the initiatives of different services towards improving the ability to measure and report precipitation at automatic weather stations, with focus on solid precipitation.

Is your Service currently testing/developing new instruments and methods of measurement of solid precipitation parameters at Automatic Weather Stations?
Yes/No

Please list all that apply, including any relevant additional information.

…………………………………………………………………………………………

G: Personal Data Of The Expert Nominated As Focal Person For Further Contacts:

Prof., Dr, Ms, Mrs, Mr .... ,

Institution: ....

Position: ....

Address:...

....

Telephone: .... E-mail: ....

Fax: ……………............................... URL/HTTP: ………………...

Date: ....   Signature: ....

(Permanent Representative or designated expert)

Please, return the completed form at your earliest convenience, but **not later than 15 September, 2008** to the following address:

Dr I. Rüedi

World Meteorological Organization
Observing and Information Systems Department
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Switzerland
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E-mail: IRuedi@wmo.int

APPENDIX B: List Of Countries Replying To The Survey

The table below lists the countries that responded to the survey.

	WMO Members responding to the Survey on Solid Precipitation	Is Solid Precipitation measured? (Yes/No)
1	Argentina	No
2	Armenia	No
3	Australia	Yes
4	Austria	Yes
5	Belarus	Yes
6	Belgium	Yes
7	Bosnia Herzegovina	No
8	Cameron	No
9	Canada	Yes
10	Colombia	Yes
11	Croatia	Yes
12	Cyprus	Yes
13	Czech Republic	Yes
14	Denmark	Yes
15	Ecuador	No
16	Estonia	Yes
17	Finland	Yes
18	France	Yes
19	Germany	Yes
20	Hong Kong, China	No
21	Iceland	Yes
22	Iran	Yes
23	Israel	Yes
24	Italy	No
25	Japan	Yes
26	Jordan	No
27	Kyrgyzstan	No
28	Latvia	Yes

29	Lithuania	Yes
30	Macao, China	No
31	Malaysia	No
32	Malta	No
33	Mauritius	No
34	Morocco	No
35	New Zealand	Yes
36	Niger	No
37	Norway	Yes
38	Philippines	No
39	Poland	Yes
40	Portugal	Yes
41	Russian Federation	Yes
42	Senegal	No
43	Slovakia	Yes
44	Slovenia	Yes
45	Sweden	Yes
46	Switzerland	Yes
47	Thailand	No
48	The Netherlands	Yes
49	Ukraine	Yes
50	United Kingdom	Yes
51	United States of America	Yes
52	Uruguay	Yes
53	Uzbekistan	Yes
54	Vietnam	No

Table 7 – ***WMO Members that responded to the survey***

APPENDIX C: Summary Of Measured Parameters

	Number of Manual Sites	Number of Automatic Sites	Ratio of Manual to Automatic
Total Precipitation Amount (Liquid and Solid)	35249	7538	4.7
Type of Precipitation	8319	1515	5.5
Snowfall Amount (Depth of Fresh Snow)	8424	648	13
Snowfall Water Equivalent	9879	1781	5.5
Depth of Snow on the Ground	14987	1027	14.6
Snow Temperature and/or Snow Surface Temperature	560	104	5.4
Snow on the Ground Water Equivalent	4313	134	32.2
Snow Wetness			
Rate of Snow Melt			
Seasonal Statistics	11677	3572	3.3
Other			

Table 8 - ***Numbers of manual and automatics sites***

	Number of Countries Perform the measurement	Number of Countries with			
		All Manual Sites	More Manual than Automatic Sites	More Automatic than Manual Sites	All Automatic Sites
Total Precipitation Amount (Liquid and Solid)	37	4	23	4	6
Type of Precipitation	23	6	14	2	1
Snowfall Amount	16	13	2	0	1

(Depth of Fresh Snow)					
Snowfall Water Equivalent	14	3	6	1	4
Depth of Snow on the Ground	29	16	11	2	0
Snow Temperature and/or **Snow Surface Temperature**	10	3	2	0	5
Snow on the Ground Water Equivalent	13	12	1	0	0
Snow Wetness	17	6	5	2	4
Rate of Snow Melt					
Seasonal Statistics					
Other					

Table 9 - ***Distributions of numbers of countries with different combinations of manual and automatic sites***

Summary of reporting frequencies for sites reporting total precipitation (liquid and solid)

Reporting Frequency for Manned Sites where Total Precipitation Amount is Measured	
Frequency	**Number of Sites**
1 / day	28019
2 / day	874
3 / day	20
4 / day	2169
8 / day	37
1 / month	3628

Table 10 – ***Reporting frequency for manned sites for total precipitation amount***

Reporting Frequency for Automatic Sites where Total Precipitation Amount is Measured	
Frequency	**Number of Sites**
1 / minute	2227
1 / 10 minute	366
1 / 12 minute	34
1 / 15 minute	111
1 / 30 minute	59
1 / hour	3422
1 / 3 hour	968
1 / day	295

Table 11 ***- Reporting frequency for automatic sites for total precipitation amount***

Summary of reporting frequencies for sites reporting type of precipitation

Reporting Frequency for Manned Sites where Type of Precipitation is Measured	
Frequency	**Number of Sites**
At any time	87
1 / 30 minute	5
1 / hour	434
1 / 3 hour	160
1 / day	5472
2 / day	685
3 / day	60
4 / day	3581
1 / month	953

Table 12 - ***Reporting frequency for manned sites for type of precipitation***

Reporting Frequency for Automatic Sites where Type of Precipitation is Measured	
Frequency	**Number of Sites**
1 / minute	79
1 / 10 minute	108
1 / 12 minute	32
1 / 30 minute	7
1 / hour	1212
1 / 6 hour	287

Table 13 - ***Reporting frequency for automatic sites for type of precipitation***

Reporting frequency for Snowfall amount.

Reporting Frequency for Manned Sites where Snowfall Amount is Measured	
Frequency	**Number of Sites**
1 / hour	170
1 / day	3585
2 / day	3117
4 / day	587
1 / 10 day	57
1 / month	908

Table 14 - ***Reporting frequency for manned sites for snowfall amount***

Reporting Frequency for Automatic Sites where Snowfall Amount is Measured	
Frequency	**Number of Sites**
1 / hour	289
1 / 6 hour	225
1 / 12 hour	134

Table 15 - ***Reporting frequency for automatic sites for snowfall amount***

Reporting Frequency for Manned Sites where Snowfall Water Equivalent is Measured	
Frequency	**Number of Sites**
1 / day	2628
2 / day	619
3 / day	20
4 / day	3757
1 / 5 day	38
1 / month	2817

Table 16 - ***Reporting frequency for manned sites for snowfall water equivalent***

Reporting Frequency for Automatic Sites where Snowfall Water Equivalent is Measured	
Frequency	**Number of Sites**
1 / hour	1192
1 / 3 hour	6
1 / 6 hour	287
1 / minute	289
1 / 30 minute	5

Table 17 - ***Reporting frequency for automatic sites for snowfall water equivalent***

Reporting Frequency for Manned Sites where Depth of Snow on the Ground is Measured	
Frequency	**Number of Sites**
1 / day	8862
2 / day	2326
4 / day	587
1 / hour	17
1 / 3 hour	34
1 / 10 day	243
1 / month	1808

Table 18 - ***Reporting frequency for manned sites for depth of snow on the ground***

Reporting Frequency for Automatic Sites where Depth of Snow on the Ground is Measured	
Frequency	**Number of Sites**
1 / minute	289
1 / 10 minute	84
1 / hour	329
1 / day	177
2 / day	134

Table 19 - ***Reporting frequency for automatic sites for depth of snow on the ground***

Reporting Frequency for Manned Sites where Snow Temperature is Measured	
Frequency	**Number of Sites**
1 / 3 hour	184
1 / day	97
2 / day	79
8 / day	50
Occasionally	150

Table 20 ***- Reporting frequency for manned sites for snow temperature***

Reporting Frequency for Automatic Sites where Snow Temperature is Measured	
Frequency	**Number of Sites**
1 / minute	4
1 / 10 minute	77
1 / hour	23

Table 21 - ***Reporting frequency for automatic sites for snow temperature***

Reporting Frequency for Manned Sites where Snow on the Ground Water Equivalent is Measured	
Frequency	**Number of Sites**
1 / day	2242
2 / day	205
1 / 5 day	469
1 / 10 day	67
1 / 5-10 day	181
1 / month	8

Table 22 - ***Reporting frequency for manned sites for snow on the ground water equivalent***

Reporting Frequency for Automatic Sites where Snow on the Ground Water Equivalent is Measured	
Frequency	**Number of Sites**
1 / day	134

Table 23 - ***Reporting frequency for automatic sites for snow on the ground water equivalent***

Reporting Frequency for Manned Sites where Seasonal Statistics is Measured	
Frequency	**Number of Sites**
1 / month	820
1 / season	646
1 / year	1095

Table 24 - ***Reporting frequency for manned sites for seasonal statistics***

Reporting Frequency for Automatic Sites where Seasonal Statistics is Measured	
Frequency	**Number of Sites**
1 / month	1538
1 / season	1471
1 / year	2413

Table 25 - ***Reporting frequency for automatic sites for seasonal statistics***

APPENDIX D: Summary Of Instruments And Configuration Used

Manufacturers and some technical specifications of the instruments used for measuring total precipitation accumulation are given in this appendix.

Manufacturer	Instrument Model	Bucket Capacity (mm)	Collecting Area (cm^2)	Heating
Rimco	7499 and 8020	0.2	324.9	Optional
Frise Engineering Company of Baltimore, MD	HTB	0.254	729.7	Heated
Meteoservis v.o.s.	MR3H-FC	0.1	500	Heated
PAAR (Austria)	AP23	0.1	500	Heated
Vaisala	RG13	0.2	400	No heating
Vaisala	RG13H	0.2	400	Heated
Vaisala	QMR102	0.2	500	No heating
Precis-Mecanique	Precis-Mecanique 3030 or 3070	0.2	1000	Heated
Degreane	Degreane 3060	0.2	1000	Heated
Lambrecht	1518H3	0.1	200	
Lambrecht	15188H	0.1	200	Heated
Teodor Feidrichs	7051	0.1	200	Heated
Thies	54032	0.1		
Microstep	MR2H	0.2	200	Heated
Campbell Scientific	Campbell ARG100	0.2	506.7	No heating
SIAP	SIAP UM7525	0.2	1000	No heating
Ogasawara	RT-1	0.5		No heating
Ogasawara	RT-3	0.5		Heated
Yokogawa	RT-4	0.5		Heated
R. M. Young	52203	0.1	200	No heating
OTA	OTA 15180	0.2	314.2	No heating
SEBA	RG-50	0.1 or 0.2	200 (400 optional)	Heating (optional)
MET One	60030 (380-385)	0.1	730.6	Heated
AMES	DDE93A	0.1	500	Heated
UK Met Office	Mk 5	0.2	750	No heating
Texas Electronics Inc. USA	TE525 MM	0.1	471.4	No heating

Table 26 – ***Manufacturers and specifications of the TBRG***

Manufacturer	Instrument Model	Measurement Technology	Collecting Area (cm^2)	Capacity (mm)	Heating
OTT Hydrometry of Kempton, Germany	AWPAG/Pluvio	Strain gauge	200	1000 And 250	Rim and internal heating
Meteoservis v.o.s.	MRW500	Tensiometric sensor	500	1000	Rim heating
Geonor	T200B	Vibrating wire load sensor	200	600	No rim heating
Belfort	Fisher and Porter	Strain gauge	324	600	No rim heating
MPS-System	TRW 503	Strain gauge	500	240	Rim heating
Vaisala	VRG101	Single point load cell	400	650	Rim heating

Table 27 – ***Manufacturers and specification of the weighing gauges***

Optical Sensor - Manufacturers and Some Instrument Specifications			
Manufacturer	**Instrument Model**	**Measurement Technology**	**Sample Area or volume**
Vaisala	PWD12, PWD22, FD12P	Optical forward sensor, scattering, capacitive rain sensor and temperature sensor	100 cm^3
Thies Clima	Laser Precipitation Monitor / Disdrometer	Extinction measurement	46 cm^2

Table 28 – ***Manufacturers and specifications of the optical sensors***

Manufacturer	Instrument Model	Measurement Technology	Collecting Area (cm^2)	Capacity (mm)	Heating
Royal Netherlands Meteorological Institute (KNMI)	KNMI electrical digital rain gauge	Floater measures the increases of the amount of water	400		Rim heating

Table 29 – ***Manufacturer and specification of level gauge***

APPENDIX E: Manufacturers And Specifications Of Sensors Monitoring Precipitation Types

Manufacturer	Instrument Model	Measurement Technology	Sample Area or volume	Precipitation Type Identified
Vaisala	PWD12	Optical forward sensor, scattering, capacitive rain sensor and temperature sensor	100 cm^3	(Unknown type) Precipitation, Drizzle, Rain, Snow, Sleet
Vaisala	PWD22	Optical forward sensor, scattering, capacitive rain sensor and temperature sensor	100 cm^3	(Unknown type) Precipitation, Drizzle, Rain, Snow, Sleet, Freezing Drizzle, Freezing Rain
Vaisala	FD12P	Optical forward sensor, scattering, capacitive rain sensor and temperature sensor	100 cm^3	(Unknown type) Precipitation, Drizzle, Rain, Snow, Ice pellets, Sleet, Hail, Ice crystals, Snow grains, Snow Pellets, Freezing drizzle, Freezing rain
Thies Clima	Laser Precipitation Monitor / Disdrometer	Extinction measurement	46 cm^2	Drizzle, Rain, Hail, Snow, Snow grains, Graupel (small hail.snow pellets), Ice pellets
Qualimetrics/ AWI	POSS (Precipitation Occurrence Sensor System)	10 GHz Doppler by-static Radar	Of the order of a cubic meter depending on particle size	Drizzle, Rain, Snow, Hail, (Unidentified) Precipitation
Optical Scientific	Light Emitting Diode Weather Identifier (LEDWI)	Light beam interference scintillation pattern		Rain, Snow (Light unknown precipitation)
Lufft	R2S	24 GHz-Doppler radar		Drizzle, Rain, Snow, Hail

Table 30 – ***Manufacturers and specifications of present weather sensors***

Chapter 2 APPENDIX F: Manufacturers And Some Specifications Of Sensors For Snow Depth On The Ground And Snowfall Amount

Manufacturer	**Instrument Model**	**Measurement Technology**	**Frequency**
Sommer	USH-8	Ultrasonic sensor	50 kHz
Campbell	SR-50, SR-50A	Ultrasonic sensor	50 kHz
Ogasawara Keiki Seisakusho Co. Ltd. Japan	JMA-95-1	Ultrasonic sensor	
Kaijo Sonic Corporation, Japan	JMA-89, JMA-93,JMA-04-1	Ultrasonic sensor	
Yokogawa Denshikiki Co., Ltd., Japan	JMA-95-2	Class 2 visible laser	
Koshin Denki Kogyo Co. Ltd., Japan	JMA-04-2	Class 2 visible laser	
MPS System	SwS-3 Snow Depth Sensor		
Vegason	Vegason 61	Ultrasonic sensor	
Mircrostep	SD9	Ultrasonic sensor	
Vaisala	FD12P	Forward scattering, and rain and temperature sensor	
Boschung	SHM100	Photo diode	

Table 31 – ***Manufacturers and specifications of snow depth sensors***

Chapter 3 APPENDIX G: Manufacturers And Some Specifications Of Snow Temperature And/Or Snow Surface Temperature Sensors

Manufacturer	Instrument Model	Measurement Technology
Mierij Meteo	812	PT100
Aerotech Telub	Frensor MKII	PT100
Malling (DK) or Friederick		PT100
Vaisala	DTS12G	PT100
Vaisala	QMT103	PT100
Markasub		PT100
Ukrainian Research Hydrometeorological Institute	AMS-METEO	PT100

Table 32 – ***Manufacturers and specifications of temperature sensors***

APPENDIX H: Summary Of Survey Responses Regarding The Adjustments Applied To Precipitation Measurements

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Austria	spatial and altitudinal correction	Archived data and only monthly totals
Canada	Wind adjustments	Archived data, as needed by users
Denmark	Yes	Archived on request
France	Intensity correction (loss of water during a tip)	Real time
Latvia	Evaporation, temperature, wetting, wind	Real time
Republic of Belarus	Correction on pail wetting	During the measurement
Slovakia	faulty data and gaps using the regional analysis	archived data
Sweden	Noise are avoided with help of a PW	Real time
United States of America	Evaporation, Wind pumping, Pressure gradient, Metal expansion coefficients	Real time
Uzbekistan	Adjustment for water lost by device wetting is brought in to measured the totalized precipitation in accordance with their type (+0.1 mm for liquid; +0.2 mm for solid) when measurements are manually provided.	The data are corrected just before their transmitting

*Table 33 – **Adjustments for total precipitation amount***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Austria	spatial and altitudinal correction	Archived data and only monthly totals
France	Sensor corrected by coherency criteria applied in the acquisition system	Real time
Germany	Several plausibility checks	Real time
Slovakia	faulty data and gaps using the regional analysis	archived data
United Kingdom	Present weather (an arbiter using the output from temperature, visibility and precipitation sensors is used to improve the accuracy of the present weather sensor)	Real time
Uzbekistan	Visual control	The data are corrected just before their transmitting

Table 34 - ***Adjustments for type of precipitation***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Austria	spatial and altitudinal correction	Archived data and only monthly totals
Germany	Air temperature at 2m	Real time
Slovakia	faulty data and gaps using the regional analysis	archived data
Uzbekistan	Preliminary critical control is based upon logical conclusion with the following pre and processing control	The data are corrected just before their transmitting

Table 35 – ***Adjustments for snowfall amount (depth of fresh snow)***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
France	Intensity correction (loss of water during a tip)	Real time
Norway	Wind correction	Archived data
Uzbekistan	Preliminary critical control is based upon logical conclusion with the following pre and processing control	The data are corrected just before their transmitting

Table 36 – ***Adjustments for snowfall water equivalent.***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Austria	Temperature compensation of measurement signal	Real time in the sensor system
Canada	Adjustment applied to snow ruler measurement using a snow water equivalent adjustment factor (SWEAF)	archived data, as needed by users
Germany	Zero correction when drift is observed. Temperature compensation for speed of sound	Real time
Slovakia	faulty data and gaps using the regional analysis	archived data
Uzbekistan	Preliminary critical control is based upon logical conclusion with the following pre and processing control	The data are corrected just before their transmitting

Table 37 – ***Adjustments for depth of snow on the ground***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Slovakia	faulty data and gaps using the regional analysis	archived data
Uzbekistan	Preliminary critical control is based upon logical conclusion with the following pre and processing control	The data are corrected just before their transmitting

Table 38 – ***Adjustments for snow on the ground water equivalent***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Uzbekistan	The amendments are added to measured data by calibration list if required	The data are corrected just before their transmitting

*Table 39 – **Adjustments for snow temperature and/or snow surface temperature***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Uzbekistan	The calculated models outputs are corrected on basis the statistical analysis and expert's assessments	The data are corrected at the end of each cycle of calculations

*Table 40 – **Adjustments for snow wetness***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Uzbekistan	The calculated models outputs are corrected on basis the statistical analysis and expert's assessments	The data are corrected at the end of each cycle of calculations

*Table 41 – **Adjustments for rate of snow melt***

Country	Adjustments applied (list all that apply)	When the correction is applied (i.e. Real time or archived data)
Austria	spatial and altitudinal correction	Archived data
Uzbekistan	Pre and processing control	The data are corrected at the end of each cycle of calculations

*Table 42 – **Adjustments for seasonal statistics***

APPENDIX I: Summary On The Derived Parameters

Country	Real-Time vs. Post-Processing	Reporting Interval	Single-Sensor vs. Multi-Sensor	Parameters Used
Austria	Post processing only check	Daily	Post processing	
Canada	Real-time	6 hours	Current: Single sensor Planned: Multi-sensor	Data from three collocated snow depth sensors and one total precipitation sensor
Finland	Real-time	10 minutes	Single-sensor	Depth of snow
France	Snow depth	1 minute	Single-sensor	Total snow depth
Switzerland (planned)	Planned	10 minutes	Multiple-sensor	Complex snow model

Table 43 – ***Derived parameter: depth of freshly fallen snow***

Country	Real-Time vs. Post-Processing	Reporting Interval	Single-Sensor vs. Multi-Sensor	Parameters Used
Finland	Real-time	10 minutes	Single-sensor	FD12P present weather sensor
France	Real-time	1 hour	Multi-sensor	Heated and non-heated rain gauges
Germany	Real-time	1 minute	Multi-sensor	Present weather sensor output and air temperature
The Netherlands	Real-time	12, 1 and 10 minutes	Multi-sensor	Present weather sensor output and air temperature
Switzerland (planned)	Planned	10 minutes	Single-sensor	Psychrometric temperature

Table 44 – ***Derived parameter: precipitation type***

Country	Real-Time vs. Post-Processing	Reporting Interval	Single-Sensor vs. Multi-Sensor	Parameters Used
Denmark	Snow amount	Daily on request	Single-sensor	Precipitation type

Table 45 – ***Derived parameter: other (snow amount)***

APPENDIX J: Summary Of The Documentation Of Algorithms For The Derived Parameters

Country	Document (Y/N)	Available on Web (Y/N)	How to access
Austria			
Canada	Yes	No	The algorithm is documented internally and under review.
Denmark	Yes	www.dmi.dk	Allerup, Madsen & Vejen, 1997: A comprehensive model for correcting rain and precipitation: Nordic Hydr., 28, 1997, 1-28. WMO 1998 : WMO Solid Precip. Intercomparison Final report. WMO/TD - No. 872 (ed. Goodison, Louie, Lang) Anex 5D.
Finland			
France	Yes	No	
Germany	Yes	No	Write to Deutscher Wtterdienst, Frankfurter Strabe 135 D-63067 Offenbach, Germany
The Netherlands	Yes	http://www.knmi.nl/samenw/geoss/avw/RIS-doc.pdf (in Dutch)	
Switzerland (planned)	Yes		Internal Documentation

*Table 46 – **Documentation and accessibility***