CIMO Survey
on National Summaries of Methods and Instruments
for Solid Precipitation Measurement
at Automatic Weather Stations

- Preliminary results -

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Abstract

The fourteenth session of the World Meteorological Organization (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 methods of measurement and observation of solid precipitation, snowfall and snow depth, at automatic, unattended stations in cold climates (i.e., polar and alpine).

In 2008, as a first phase of this initiative, ET-SBII&CM conducted a survey to develop up-to-date national summaries of methods, instruments, and challenges of automatic solid precipitation measurements, at the National Meteorological and Hydrological Services (NMHSs) of the Member countries. The results will facilitate a better understanding of the global configuration of precipitation measurement and contribute towards the decision of CIMO on whether an intercomparison of instruments measuring solid precipitation should be organized.
The information provided by Member countries is used to develop a synopsis of the current configuration of the in-situ measurement and observation of precipitation, solid precipitation in particular, and will be published by WMO in 2009.

This paper presents the summary of the automatic instruments in use for measuring the amount of precipitation, liquid and solid, in-situ at land stations, by the NMHSs, worldwide.

Introduction

A comprehensible, optimized, sustainable and integrated Global Observing System requires that homogeneous observations be available from interoperable and compatible systems.

Precipitation is one of the most important atmospheric variables, as change in precipitation has a major impact on hydrology, climate, and ecosystems. It is also one of the key components in hydrological modeling and process studies.

Over the past decade, the transition from manual to the automatic observation of precipitation has accelerated in many countries. The migration from human to automatic observations 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.

The 2008 CIMO Questionnaire on Measurement and Observation of Solid Precipitation at Automatic Stations was distributed in July 2008. The WMO Member countries were asked to provide information on the extent of using 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, in terms of instruments, their configuration, and the derivation of additional parameters.

The meteorological and hydrological services of 53 WMO Members, covering about 46% of the global land mass, at all latitudes, except Antarctica, have provided responses to the questionnaire by December 31, 2008. Thirty four (34) 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).

From the information provided, this paper tries to address the following questions:
a) How many stations use traditional precipitation gauges either manual or recording?
b) How many stations use shields with such gauges as recommended by WMO?
If so what type of shielding?
c) How many stations use heated gauges?
d) How many stations use other type of electronic sensors to measure precipitation, e.g. distrometers, snow pillows, etc?

Given the global coverage of the information provided, the results of the 2008 CIMO survey on instruments and methods of observing solid precipitation are considered as representative at a global scale.

Background

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

The variability of principles implemented for measuring precipitation and the variability of configuration of automatic instruments pose significant challenges for the users of precipitation data at large scales, and understanding their relative performance becomes paramount.

Between 1987 and 1993, WMO organized a Solid Precipitation Measurement Intercomparison (Goodison et al 1998), which assessed national measurement methods for solid precipitation at the time, and most of them were using manual observations.

Currently, the automatic stations are 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. With the increasing percentage of automatic observations, there is a growing need for better understanding the relative performance of different measuring instruments, using different operating principles and configurations and measuring the same parameters.

Methodology

Several outcomes are expected to be addressed through this CIMO project.

Firstly, a summary of the instruments with different operating principles and their configurations measuring the same precipitation parameters will be developed. This information will be critical in deciding if an intercomparison is warranted and its scope.

Secondly, a summary of the types of wind shields and their use in conjunction with precipitation gauges will be prepared. It is recognized that the wind-induced undercatch of precipitation gauges continues to be a concern, for the measurement of snow in particular. (Stacy G White et al, 2002)

The third element of interest is related to the development and application of adjustments to precipitation data and the parameters used for that.
The final report of the 1987-1993 WMO Intercomparison (Goodison et al, 1998), recommended wind adjustments developed using observations available from sites 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, Sweden). 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 function using instantaneous or short-interval observations of both wind and precipitation is 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 the study sites, to estimate the wind at gauge height. Following the recommendations of the 1987-1993 intercomparison, currently, in many countries, the automatic stations are equipped with wind sensors installed at the level of the precipitation gauge, thus providing a better indication of the wind impacting the precipitation measurements.

A potential intercomparison would include the evaluation of various wind shields to determine those appropriate for unattended automatic stations, in conjunction with the development of new wind adjustment functions using wind observations at the level of the precipitation gauge, taken at shorter intervals, one hour or less.

Summary of instruments for measuring precipitation

Fifty-three (53) WMO Member countries responded to the 2008 CIMO Survey indicating that, overall, they measure precipitation, solid and liquid, at 41187 stations, which, on average, represents a spatial distribution of one station per about 1100 sq km.. Thirty-four of the respondents indicated that they measure and report solid precipitation at a total of 17242 sites, or one station per 2200 sq km. These include all stations reporting precipitation, the measurement of which is taken either manually, automatically or a combination of both.

These are conservative numbers; 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 which are managed by the Meteorological Service of Canada (MSC), extensive networks are managed and operated by other agencies (federal, provincial) and their data is not always included in the MSC database. Therefore, the density of stations measuring precipitation, may, in effect be higher than that mentioned here; however the data is not readily available from the NMSHs databases.

Automatic Instruments Measuring the Amount of Precipitation (liquid and solid)

The amount of precipitation which reaches the ground during a stated period is expressed in terms of the vertical depth of water (or water equivalent in the case of solid forms) to which it would cover a horizontal projection of the Earth's surface. (CIMO Guide #8).

The amount of precipitation is a parameter measured and reported by all stations of the NMHSs responding to the CIMO 2008 survey. Overall, manual observations continue to be the most widely used method for measuring precipitation, worldwide.

Sixty two percent (62%) of the respondents operate at least some automatic instruments for measuring the amount of precipitation (liquid and solid). Of all stations operated by all NMHSs participating in the survey, 18% are equipped with automatic instruments for measuring the amount of precipitation. We note that many of these stations operate in conjunction with a human observation program. At 82% of the stations included in the CIMO survey, the amount of precipitation is measured using manual methods.

The analysis by type of the automatic instruments used for measuring the amount of precipitation yields some notable results. Of the total of automatic instruments currently in use by the NMHSs participating in this survey, 18% are weighing type gauges (WG) and 82% are tipping bucket type gauges (TBG), which are used including for reporting snow water equivalent, where snow occurs. Relative to the total of stations where the amount of precipitation is measured, 15% use tipping bucket type gauges, while only 3% are equipped with weighing type gauges (Figure 1). In addition to those, a few countries use optical forward scatter instruments to supplement the measurement of precipitation amount; however, their number is negligible.

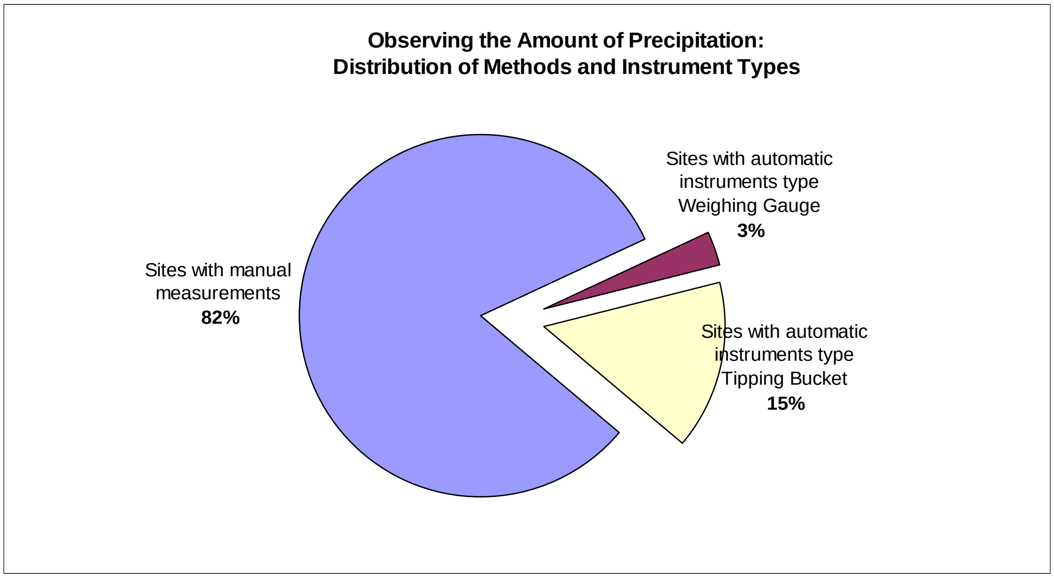

Figure 2: Amount of Precipitation: distribution of instruments and methods of observation

It should be mentioned that CIMO Guide #8, part 1, Chapter 6, Measurement of Precipitation, states that only the weighing type (gauge) is satisfactory for measuring all kinds of precipitation, the use of the tipping bucket type of precipitation gauges being for the most part limited to the measurement of rainfall.

Use of Weighing Type Precipitation Gauges

Eighteen of the participating NMHSs, or 34 % of respondents, use weighing type precipitation gauges for measuring and reporting the amount of precipitation, primarily in North America, and Central and Northern Europe.

The weighing type gauges currently in use operationally, 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 country using the Belfort’s Fisher and Porter gauge, which will be phased out in the coming years.

Three different principles of measurement are implemented on the weighing gauges 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). Figure 2 depicts the relative distribution of the weighing type gauges, based on their operating principle.

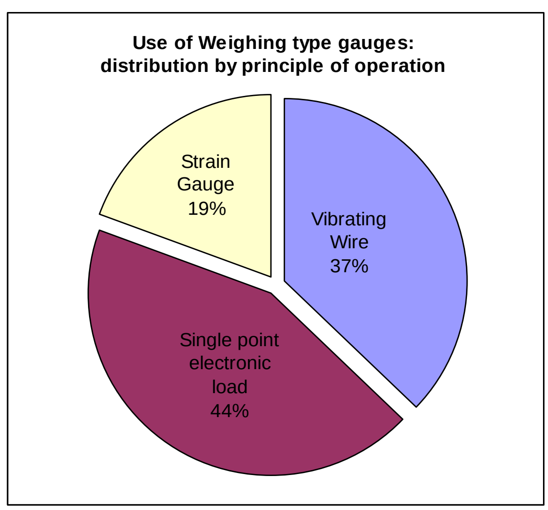

Figure 3: Operating principles of Weighing Type Precipitation Gauges

Table 1 summarizes the weighing type gauges currently in use by the NMHSs and some of their characteristics.

Table 1: Summary of the Weighing type Precipitation Gauges in use for measuring the Amount of Precipitation at NMHS sites

Manufacturer	Model	Principle of Operation	Collection Area (cm^2)	Capacity (mm)
Geonor	T200B	Vibrating wire load sensor	200	600
OTT	Pluvio	single point electronic load	200	250 and 1000
Vaisala	VRG101	single point electronic load	400	650
MPS System	TRWS 500	Strain gauge	500	240 and 750
Meteoservis	MRW500	Strain gauge	500	1000

Canada operates the largest network of weighing type precipitation gauges, 384 followed by USA (NOAA-National Weather Service) with 331 gauges, Germany with 134 gauges, Sweden with 111 gauges, Slovakia 83, and Norway 70 gauges. Other NMHSs use weighing gauges in smaller numbers.

Heating of the weighing type gauges is a feature increasingly used to deal with 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.
In Canada, for example, all weighing type gauges are used without heating, however, in the mountainous areas on the west coast, experiments are underway to assess if heating of the gauges would reduce the error of measurement due to significant snow capping.

Use of Tipping Bucket Type Precipitation Gauges

The information on the extensive use of tipping bucket type gauges for measuring the amount of precipitation, including in areas where solid precipitation occurs, is a remarkable result of this survey. When using tipping bucket type gauges, the amount of precipitation is derived by temporally integrating the bucket tip counts.

Collectively, the NMHSs participating in the CIMO survey use 28 different models of tipping bucket type precipitation gauges produced by 21 manufacturers, worldwide. Many of them are the result of joint developments between the national meteorological services and local instrument manufacturers. This has resulted in many 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, which is currently used throughout its surface networks to monitor the amount of precipitation.

Table 2 summarises the types of tipping bucket type gauges currently in use at the NMHSs participating in the CIMO survey.

Table 2: Summary of Tipping Bucket type Precipitation gauges in use for measuring the amount of precipitation at NMHS sites

Manufacturer	Model	Sensitivity (mm of precip/tip)	Collection area (cm^2)	Heating
Rimco	RIM 7499 andRIM 8020,	0.2	323	In some configurations
Ogasawara Keiki Seisakusho Co., Japan,	RT-1	0.5	N/A[1]	N/A
Koshin Denki Co, Japan,	RT-3	0.5	N/A	N/A
Yokogawa Denshikiki Co,Japan	TR-4	0.5	N/A	N/A
PAAR (Austria)	AP23	0.1	500	yes
Meteoservis v.o.s. (CZ),	MR3H, MR2H MR3H-FC (electronic linearization)	0.1	500	yes
Vaisala	RG13H, RG13, QMR102	0.2	400	Only for RG13H
Precis Mecanique	3030 or 3070	0.2	1000	yes
Degreane	3060	0.2	1000	yes
Lambrecht	1518H3, L15188H, 15188	0.1	200	Yes, except 15188
Teodor Fiedrichs	7051	N/A	N/A	N/A
THIES Clima	54032	0.1	200	N/A
Campbell	ARG100	N/A	N/A	N/A
SIAP	UM7525	0.2	1000	no
OTA	15180	0.2	N/A	no
SEBA	RG50	0.2	200	yes
MET ONE	60030	N/A	N/A	N/A
RM YOUNG	52202	0.1	200	yes
UK Met Office	MK5	0.2	N/A	N/A
AMES	DDE93A	0.1	500	yes
Frise Engineering Company of Baltimore (USA)	HTB	0.25	N/A	yes

[1] N/A: where information was not provided by the Member country or was not readily available from previous information provided by the Member country.

All the tipping bucket type gauges 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. The use of tipping bucket type gauges function of their sensitivity is presented in figure 3.

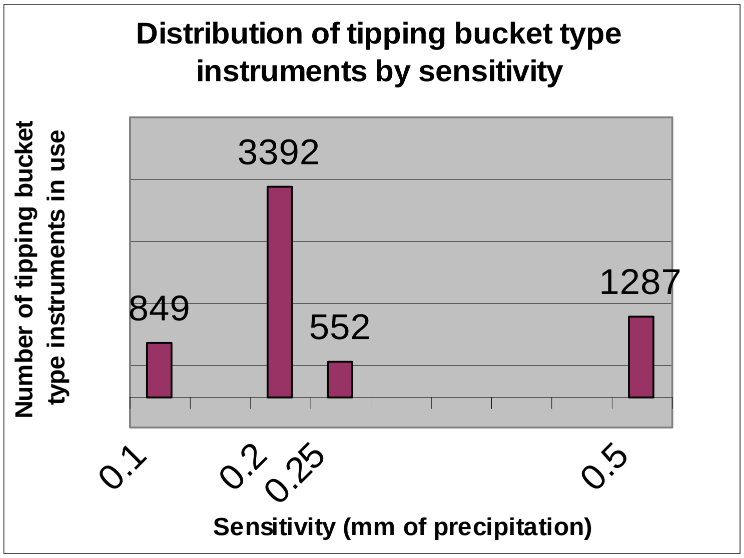

Figure 4: Distribution of tipping bucket type precipitation gauges by sensitivity

Most of the tipping bucket gauges used for measuring the amount of precipitation have heating circuits. While heating the funnel is the most widely used method, additional heating of the collecting ring is available on some models, increasing their operating range to as low as -35deg Celsius.

As the questionnaire had not asked for information on the field installation of gauges, there is no information available regarding the height at which the tipping bucket gauges are installed, especially where snow occurs.

Many of the tipping bucket gauges used for measuring the amount of precipitation have been included in the 2005 WMO Intercomparison on rainfall intensity instruments (L. Lanza et al, 2005).

Use of shields on precipitation gauges

The participants in the CIMO 2008 survey have indicated that, overall, 72% of the automatic instruments (weighing gauges and tipping bucket gauges) used for measuring the amount of precipitation are not configured with wind shields. Of the automatic gauges that have wind shields, the weighing type gauges are used in a much larger proportion in this configuration. Specifically 78% of the total of weighing type gauges, or 10% of the total automatic instruments, are configured using single wind shields. The wind shields in use are either Alter, Nipher or Tretyakov type.

The National Weather Service of United States of America is the only Service adopting double shields, so far, planning to install in 2009 a second shield, type Alter, around all its 331 weighing type gauges, in addition to the Tretyakov shield currently in use.

The tipping bucket gauges are used in a much smaller percentage with shields. Only thirty one percent (31%) of the total of tipping buckets measuring the amount of precipitation, equivalent to 18% of the total of automatic instruments, are configured with wind shields. Of these, those used by JMA, representing 21% of the total of tipping bucket type gauges included in this survey, use a specially designed shield. This is 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 tipping bucket type gauges, which represent 9% of the total reported tipping bucket type gauges.

Aside from the tipping bucket gauges from Japan and USA, configured with wind shields, the percentage of use of shields is less than 1%.

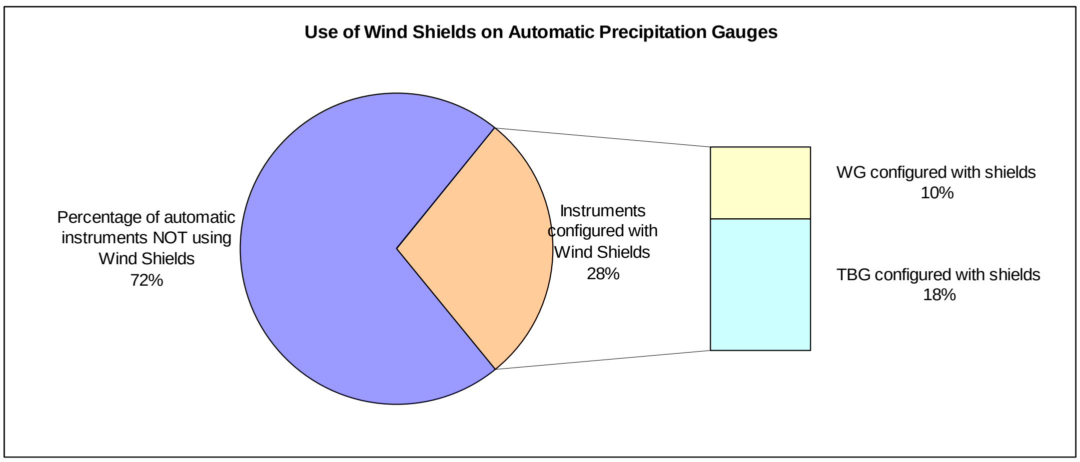

Figure 5: The use of wind shields on instruments measuring the amount of precipitation (liquid and solid)

The report on the 1987-1993 WMO Intercomparison (Goodison et al, 1998) indicates that the Nipher shield was the most effective in minimizing the effect of wind (undercatch). However, windshields that are typically good for human observations are responsible for other issues with snow measurements at automatic stations, such as snow capping. Although Nipher shields reduce wind effectively, the snow capping could result in a larger error of measured precipitation, both, amount and timing of the observation. Alterative shield configurations may have to be considered for gauges operating at automatic stations, in particular those unattended. While there is evidence that a double fence similar to that accepted as secondary reference during the 1987-1993 intercomparison (DFIR), works well, its very large footprint translates into a large real-estate requirement at the instrument site, which is rarely affordable or feasible. Using wind shields of configuration similar to a DFIR, but with a smaller footprint may be more feasible, while improving the catchment in windy conditions.

Automatic instruments for measuring solid precipitation

The CIMO Survey results indicate that thirty four (34) of the participants monitor and report solid precipitation. Overall, at 93% of the stations operated by these 34 NMHSs, the depth of snow on the ground and snowfall amount are measured using manual methods. Only 7% of the snow observations are obtained using automatic instruments, including at sites where a human observation program may be present. The results of the survey also indicate that 30 Member countries monitor and report the depth of snow on the ground, 15 report snowfall amount, and 7 NMHSs monitor and report the snow temperature or snow surface temperature. In many cases the participants report the amount of precipitation measured with automatic gauges during solid precipitation events, when they occur, as snow water equivalent.

The results to date indicate that thirteen (13) of the participating Member countries operate automatic instruments to measure the depth of snow on the ground, and three, Canada, Germany, and Japan, use automatic instruments to derive the snowfall.

For the measurement of snow on the ground, two types of automatic instruments are used operationally; these are the sonic ranging sensors, and optical forward scatter sensors.
All 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 sensor is manufactured by Campbell Scientific, model SR-50, including some updated versions. Several other sensors are also in use; these 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).

Two 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. Also, German Weather Service is investigating the optical snow depth sensor manufactured by Jenoptik.

Optical forward scatter sensors are used in seven NMHSs, at some of their weather stations, primarily to derive the snowfall water equivalent. Given the reduced number, it is reasonable to assert that the use is very limited.

Norway uses optical forward scatter sensors on 28% of the sites as an indicator of the start and end of precipitation, to correct the Geonor data.

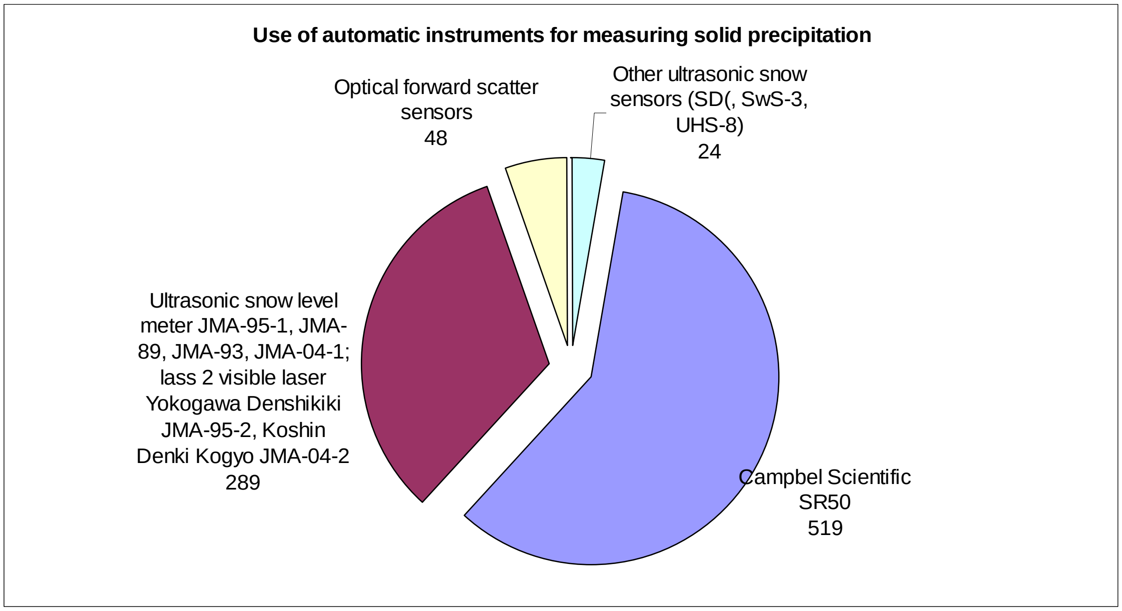

Figure 6: Summary of automatic instruments used for measuring solid precipitation

A particular category of automatic snow detectors are the automatic snow pillows used for determining the snow water equivalent. 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 which has reporting using snow pillows. Four such systems are in use; two are model LEC 3010 (manufactured by LEC, Cz) and operating in conjunction with a ultrasonic sensor for continuous level measurement, type Vegason61. 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.

Conclusions

The preliminary results of the 2008 CIMO survey on the instruments and methods for measuring solid precipitation indicate that manual observations are still the primary method for measuring precipitation. The automatic instruments used for measuring the amount of precipitation are tipping bucket type gauges and weighing type gauges. The majority of the tipping buckets are equipped with heating circuits, which enable them to operate below freezing temperatures. Most of them however are used without any shields and there is no information on how the wind induced gauge undercatch is compensated for.
Weighing type gauges are in general configured with a single shield.
For solid precipitation, only a small fraction of the stations (about 7%) use automatic instruments to measure snowfall or snow on the ground.

The complete results of the CIMO survey on instruments and methods for observing solid precipitation will be published by WMO in 2009.

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