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COMMISSION FOR INSTRUMENTS
AND METHODS OF OBSERVATION

INTERNATIONAL ORGANIZING COMMITTEE FOR THE WMO SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT

Second Session

Boulder, United States
11 to 15 June 2012

FINAL REPORT

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EXECUTIVE SUMMARY

This report provides a summary of the second session of the International Organizing Committee (IOC) of the WMO Solid Precipitation Intercomparison Experiment (SPICE) that was held in Boulder, USA, from 11 to 15 June 2012.

The IOC reviewed the outcomes of the informal Pre-SPICE experiment that took place during the winter of 2011/12 in the interest of assessing the principles of the formal intercomparison and to address, in particular, the configuration of a working field reference using an automatic gauge.

The IOC reviewed a number of aspects dealing with the configuration and operation of the reference and participating instruments. It also reviewed and agreed on the publication and data protocol for SPICE.

A number of proposals for potential test sites and for potential participating instruments had been received. The IOC reviewed all submissions and agreed on a list of participating sites and instruments, as well as on the distribution of the instruments to the respective sites.

The IOC agreed on actions to be followed-up in view of finalizing the procedures and set-ups to be used during SPICE as well as in preparation for the SPICE data analysis.

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GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the Session

1.1.1 The second session of the International Organizing Committee (IOC) for the WMO Solid Precipitation Intercomparison Experiment (SPICE) was opened on Monday, 11 June 2012 at 8:30, by Ms Rodica Nitu, the IOC Chairperson and SPICE Project Leader.

1.1.2 Dr Roy Rasmussen welcomed the participants to NCAR and provided an overview of NCAR's activities. The list of participants is given in Annex I.

1.2 Adoption of the Agenda

The meeting adopted the Agenda as reproduced at the beginning of this report.

1.3 Working Arrangements for the Session

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

2. REPORT OF THE CHAIRPERSON

2.1 Ms Rodica Nitu, the SPICE Project Leader and Chairperson of the IOC, presented the advances made with regards to SPICE since the first meeting of the SPICE IOC (Geneva, 5-7 Oct. 2011, SPICE-IOC-1). The work of the IOC continued through teleconferences organized, approximately, bi-weekly. The IOC and the invited experts focused on a broad range of activities related to the organization of the intercomparison. These covered the organization of the intercomparison, the invitation of the potential participants, and the refinement of the principles for the organization of the intercomparison, based on the results of the experiments underway during the winter of 2011/12.

2.2 The activities related to the organization of the intercomparison covered the preparation and distribution of the letters of invitation to the WMO members and to the Association of Hydro-Meteorological Equipment Industry (HMEI), the analysis of responses, the preparation of the Data Protocol and of the Publication protocol.

2.3 The first letter of invitation for the expressions of interest in participating in WMO-SPICE was issued by WMO on Nov 2nd, 2011. Through this letter the WMO-SPICE IOC sought indication from Members and HMEI members, on the potential for participating in SPICE. Each potential participant was requested to provide a focal point for the experiment. A total of 25 responses were received.

2.4 A second letter (2nd SPICE Letter) of invitation for participating in SPICE was issued by WMO on February 23rd, 2012. The letter was accompanied by two questionnaires, developed to allow for the gathering of detailed information on the proposed sites and on the proposed instruments, respectively. WMO Members and instrument manufacturers interested in participating in SPICE were invited to provide further details of their proposed participation by completing the relevant questionnaires. The WMO Members or their representatives were invited to express interest in hosting the experiment on a test site for SPICE or providing instrumentation for the intercomparison, while the HMEI Members were invited to submit instrumentation for the intercomparison. Those interested in participating in some other capacity were asked to provide details of this desired participation.

2.5 The 2nd SPICE Letter indicated that all participants would be required to abide by the Data Protocol for the experiment and that they would be required to sign an agreement to this effect before the commencement of their participation.

2.6 The potential participants were informed that the formal phase was expected to continue for at least two complete northern and southern winter seasons, with participation for the full duration of the experiment being expected of all participants.

2.7 It was expected that both siting capacity and the overall capacity of the experiment would be limited, so no assurance was given that all those interested in participating could be accommodated.

2.8 The responses to the 2nd SPICE Letter allowed the IOC-SPICE to evaluate the potential for participation in the experiment, based on the perceived value to SPICE of the proposed participation, on the completeness of the information provided in the questionnaires, and the capacity available for hosting the intercomparison.

2.9 In response to the 2nd SPICE Letter, fifteen WMO Members and eighteen manufacturers or their representatives indicated interest in participating in the intercomparison. Twelve WMO Members proposed contributing to SPICE by organizing the experiment on their sites, as well as contributing with instruments. Three WMO Members indicated interest in contributing with instruments, only.

2.10 The instruments proposed for the experiment by the WMO Members and the Manufacturers cover a broad range of measuring principles and are representative of the current configurations of the national monitoring networks of the Members. The following instrument types were submitted for consideration for the intercomparison: weighting type gauges, tipping bucket type gauges (heated), optical systems, snow depth sensors, snow water equivalent systems.

2.11 The selection of the sites organizing the intercomparison, and the selection of the participating instruments, and their distribution to the organizing sites is expected to be completed during this meeting.

2.12 As agreed at the SPICE-IOC-1, the formal organization of the intercomparison was preceded during the winter of 2011-12 by experiments that allowed assessment of some of the principles considered for the formal intercomparison. These included the configuration of a working field reference using an automatic gauge, the data acquisition and archival in the context of a multi-site experiment, the principles and the methodologies for the data quality control, and the data analysis. The experiments conducted during the winter of 2011/12, in preparation of the SPCIE experiment, are informally referred to as Pre-SPICE.

2.13 The 2011/12 Pre-SPICE experiments took advantage of existing infrastructure and experiments underway in Canada, Finland, Italy, Norway, Switzerland, and the USA.

2.14 The IOC and the invited experts reviewed the partial results of the 2011/12 tests during the regular teleconferences and through correspondence, which contributed to the refinement of criteria which would support the selection of the configuration of the field reference system, covering the automatic gauge used and its configuration, the type and configuration of the shield used, and the impact of the heating of the automatic gauge, on the catch efficiency of the gauge.

2.15 As part of the 2011/12 Pre-SPICE experiment, a WMO secondary field reference, using a manual Tretyakov gauge installed in a DFIR was used in Canada and Finland. In addition, one or more DFIR-fences surrounding an automatic precipitation weighing gauge were configured and assessed as a representation of a field working reference in Canada (CARE and Bratt's Lake), Finland (Jokioinen), Norway (Haukeliseter), and USA (Boulder). In Switzerland, the focus of the Pre-SPICE experiment was the assessment of the heating of a weighing gauge in alpine conditions, in the presence of large amounts of snowfall.

2.16 Following the decision of the SPICE-IOC-1, a laboratory calibration of the instruments considered for use as part of the working field reference was performed at the Precipitation Intensity Lead Centre in Genoa (Italy). This focused on the testing of the weighing gauges at temperatures representative of the winter operating conditions.

2.17 In parallel, a subgroup of the IOC and the invited experts developed the principles for the data quality control and the data analysis which will be considered in preparation of the formal phase of the experiment.

3. PREVIOUS SOLID PRECIPITATION EXPERIMENTS AND RELATED PROJECTS

Overview of Previous Solid Precipitation Experiment

3.1 Dr Barry Goodison and Dr Daqing Yang provided an overview of the first WMO Solid Precipitation Intercomparison, which attracted participation from 16 countries operating 26 experimental sites. Field studies started by some countries during the 1986/87 winter and the last official field season was 1992/93, allowing most countries to collect data during 5 winter seasons. Some sites have continued to operate until present. The goal of the intercomparison was to assess national methods of measuring solid precipitation against methods whose accuracy and reliability were known, including past and current procedures, automated systems and new methods of observation. The intercomparison succeeded in determining wind related errors in national methods of measuring solid precipitation, including consideration of wetting and evaporative losses; deriving standard methods for adjusting solid precipitation measurements; and in introducing a reference method of solid precipitation measurement for general use to calibrate any type of precipitation gauge (the Double Fence International Reference – DFIR). It was noted that the emphasis was on manual gauges / methods (the national standard methods at that time), but that automatic recording gauges were also tested.

3.2 The intercomparison determined quantitatively the systematic errors in the measurement of solid precipitation for over 20 different types of precipitation gauges and shield combinations. It confirmed that solid precipitation measurements must be adjusted for wetting loss (for volumetric measurements), evaporation loss, and for wind induced undercatch before the actual precipitation at ground level can be estimated. The results showed that wind speed was the most important environmental factor contributing to the under-measurement of solid precipitation and that shielded gauges performed better than their unshielded counterparts. Deviations from the DFIR precipitation measurement also varied according to gauge type and precipitation type (snow, mixed snow and rain, and rain). The intercomparison also identified other issues related to solid precipitation measurement which need to be considered for improved precipitation measurement, including measurement of trace precipitation, use of heated gauges, and operational problems in the use of automatic recording, weighing gauges. Examples of the results and their applications were provided to the meeting in the context of developing the current intercomparison which is focused on the impact of automation on solid precipitation and snow depth observations. The need for and importance of adjustments were demonstrated at national, regional and global scales.

3.3 The results and recommendations were summarized at the meeting. The issue of effectively communicating the results of the experiment to WMO Members, researchers, industry and others was raised for consideration in the current experiment. The Final Report of the experiment is available as WMO/TD-No. 827, 1998 (see http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html) and provides the methodology, a summary description of the sites, instruments and data archive and the results with discussion.

Investigation of the dependence of snow gauge collection efficiency and snowflake characteristics

3.4 Dr Julie Thériault presented the result of her work on the investigation of the dependence of snow gauge collection efficiency and snowflake characteristics. Systematic errors in snowfall measurements are often observed due to the gauge geometry and the associated weather conditions. Collection efficiency generally decreases with increasing wind speed. However, a large scatter in the collection efficiency is observed at a given wind speed. The deflection of the airflow in the vicinity of the gauge influences the trajectories of snowflakes. Because of that the different types of snow crystals, which fall at different terminal velocity, may interact differently with the flow around the gauge. The study aimed to investigate the impact of snowflake characteristics on snow gauge collection efficiency. To address this, field experiments and theoretical simulations were carried out. First, the observed snowflake types were correlated to the efficiency of a GEONOR placed in a single-Alter shield compared to a GENOR placed in a DFIR. Second, a theoretical study using finite element modeling (FLUENT) was used to simulate the flow around the snow gauge. Snowflake trajectories were calculated to compute theoretical collection efficiencies for the different crystal types considered (ex: dry snow and wet snow). The result shows that fast-falling snowflakes (wet snow) have higher collection efficiency than slow falling snowflakes (dry snow). The numerical simulations allowed the derivation of a correction factors for different snowflake types, which improve the correction of the measurements. Finally, the type of snowflakes observed helps explain the scatter observed in the collection efficiency for a given wind speed.

Hydro-Meteorology Equipment Industry (HMEI)

3.5 The Chair of Association of Hydro-meteorological Equipment Industry (HMEI), Mr Brian Day, shared with the SPICE IOC and the project team the perspective of the Association regarding the experiment. On behalf of the HMEI Membership, he indicated the interest of the community he represents to lend their resources and assistance to SPICE which they feel is a significant undertaking by WMO.

3.6 Mr Day recognized that the measurement of solid precipitation is one of the most difficult parameters to quantify when considering the issues independent of the instrument itself. The variability in the measurement due to the effects of siting, shielding, temperature and wind make snow a difficult parameter to quantify. Understanding the interrelationship of each of these variables will lead to a significant improvement in the measurement of solid precipitation.

3.7 From the manufacturers' perspective, one of the key outcomes of the SPICE should be that the results published in the final report will assist the WMO Members and industry alike to instruct instrument users in the proper measurement techniques of solid precipitation. HMEI would like to see the IOC of SPICE focus on the measurement system as a whole, which includes the sensors under test, shielding, data logging, and siting. It is HMEI's hope that SPICE will be conducted as an assessment of current and emerging technologies providing guidance to the Members, industry and to the measurement community. Given the global outreach of industry, the HMEI Membership interacts with instrument users, well beyond the meteorological community or WMO. The manufacturers have the opportunity to educate a broader range of organizations contributing precipitation data to the National Hydrological and Meteorological Services. HMEI encouraged the IOC of SPICE to focus their efforts on addressing the project objectives, without ranking the instruments. On behalf of HMEI, Mr. Day wished all the participants, scientists and the IOC of SPICE a successful experiment.

4. PRE-SPICE OUTCOMES

4.1 During the winter 2011/12 the informal Pre-SPICE experiment was carried out taking advantage of existing field testing capacities already underway in some Member countries. The goal of Pre-SPICE was to assess the principles of the formal intercomparison and address in particular the configuration of a working field reference using an automatic gauge. Six Member countries took part in Pre-SPICE, five of them with test sites, and one carrying out laboratory testing of potential reference gauges. The following sections provide a summary of the results achieved by each of them.

CANADA

4.1 Dr Michael Earle presented the summary of results from the Canadian contribution to Pre-SPICE. During the Pre-SPICE period, precipitation and ancillary meteorological measurements were obtained at two sites in Canada: the Centre for Atmospheric Research Experiments (CARE) in Egbert, Ontario, and Bratt's Lake in Saskatchewan. Each site was equipped with Geonor T-200B and Pluvio^2 automatic weighing gauges in various wind shields and heating configurations. At CARE, a manual Tretyakov gauge was used in the DFIR configuration recommended as the secondary field reference. Data were sampled every 6 seconds at CARE and every 15 minutes at Bratt's Lake. The analysis of weighing gauge data was organized into three key categories: accuracy, precision, and influence of heating. Consideration was also given to the simplicity of the reference system, which consists of a shield, weighing gauge, precipitation detector, data logger, data acquisition system, and supporting algorithms (quality control, filtering, corrections, etc.). It was noted that analysis was limited by the number of solid precipitation events during Pre-SPICE;

for example, there were only three events with accumulations of solid precipitation larger than 1 cm at CARE from mid-January to the end of March, 2012

4.2 Accuracy was assessed by comparing accumulated precipitation from automatic gauges (both heated and unheated) in double-Alter shields with corresponding manual observations from a Tretyakov gauge in the DFIR at CARE. Heated Geonor and Pluvio gauges both agreed well with the manual observations, with lower root mean square errors relative to unheated Geonor gauges. A similar assessment was conducted using Bratt's Lake data from 2004-2009, comparing accumulated precipitation from an unheated Geonor gauge in a DFIR-fence with a Tretyakov (manual) gauge in a second DFIR. The automatic gauge was found to catch less than the manual gauge for solid precipitation events with at least 1 mm of accumulation and air temperatures below -2 °C, particularly at higher wind speeds, however the cause of the differences was not assessed. One aspect of precision, the repeatability/consistency between gauges, was investigated by comparing 10 minute average precipitation rates from gauges with identical wind shields and heating for a wet snow case at CARE. Consistency was observed between pairs of heated Geonors, heated Pluvios, and unheated Geonors, all in double-Alter shields. Another aspect of precision, consistency within a given gauge, was explored by comparing raw precipitation amounts from the individual transducer wires of a Geonor gauge. For a non-precipitating case at CARE, the responses of individual wires were observed to vary following a temperature increase. Laboratory studies of a three-wire Geonor gauge provided an additional avenue for assessing precision, indicating that the data logger sampling strategy can influence both the magnitude and distribution of variability (noise) in measurements. Finally, the influence of heating was investigated using a series of case studies from both the CARE and Bratt's Lake sites. Heating was found to increase catch and improve gauge response to precipitation, with no apparent disadvantage.

4.3 The results demonstrated the utility of the framework of accuracy, precision, heating influence, and simplicity for the analysis of precipitation data from weighing gauges. The elements of this framework were therefore proposed as criteria for the selection of the field reference for SPICE. Acknowledging the limitations of the Pre-SPICE data set, it was proposed that reference configurations could include either Geonor or Pluvio weighing gauges, preferably heated, and that an emphasis be placed on the characterization of both gauges in pertinent configurations.

4.4 The heating configuration of gauges tested at the CARE site was as follows: Geonor in DFIR-fence was equipped with the CRN heaters and algorithm. The two heated Geonors in Double Shield were equipped with heaters provided by Geonor, and with the algorithm used for the Geonor in the DFIR-fence. The Pluvio^2 gauges were tested in the heater configuration supplied by the manufacturer with no changes. The heated Geonor tested at Bratt's Lake was configured with the CRN heaters and algorithm.

FINLAND

4.5 Mr Osmo Aulamo of the Finish Meteorological Institute (FMI) presented the Jokioinen test results from the testing that took place during the winter of 2011/12. The analysis was conducted by Jaakko Ikonen and the measurement period was 19.02.2012 – 30.04.2012. There were only few snow precipitation events during this period and the measurements were mainly during rain precipitation.

4.6 The manual measurements of the precipitation accumulation were obtained using a Tretyakov collector installed in a DFIR (secondary field reference) and were compared with the output of an automatic weighing gauge model Pluvio^2, 400 cm^2, installed in the second DFIR-fence, available on site. The manual measurements are made only once every day at 06:00 UTC. The manual measurements are made at DFIR Tretyakov gauge but also in gauge of the meteorological observation station of FMI, about 300 m away of the field with the DFIRs. The Pluvio^2-400 cm^2 measurements are also averaged to daily measurements for comparison of manual measurements.

4.7 The results presented focused on the DFIR-Pluvio^2 400 cm^2 daily precipitation accumulation vs. DFIR - manual daily precipitation accumulation, the DFIR-Pluvio^2 400 cm^2 daily precipitation accumulation vs. manual daily precipitation accumulation at the Jokioinen meteorological observation station. Additionally, the relative daily precipitation accumulation difference vs. average daily precipitation intensity was assessed. Average daily precipitation intensity calculated as average between the experimental DFIR measurement field observations and manual observations made at the Jokioinen meteorological observation station, was also assessed. The relative daily precipitation accumulation difference between DFIR-Pluvio^2 observations and daily manual precipitation observations made at the experimental measurement field plotted against time series of ancillary meteorological observations (daily average temperature, daily wind speed variation, and daily manual precipitation accumulation), were also presented, and showed good agreement between the measurements.

SWITZERLAND

4.8 During the first SPICE meeting (SPICE-IOC-1, Geneva, 5-7 October 2011), it was agreed that the contribution of the test site Davos/Weissfluhjoch to the 2011/12 Pre-SPICE campaign would be to evaluate the impact of the heating on data availability and data quality for the Pluvio^2 weighting gauge, which is a candidate to act as reference for automatic precipitation gauges within SPICE. On 21 December 2011 two 200 cm2 Pluvio^2 were installed in Davos at SLF (Swiss Institute for Snow and Avalanche Research), which will collaborate with SPICE in offering the test site for Alpine climate at Weissfluhjoch. Both gauges were installed with the rim at 2 meters above the ground level. The configuration of both gauges were identical, except that one gauge was heated, and not the other. The standard heating algorithm from the manufacturer was applied, with a threshold for the temperature at +5°C. No changes to the Pluvio^2 algorithm were made.

4.9 The weather conditions on site during the experiment were such that the snow level rapidly reached the orifice of the gauges. Data were transmitted on a 10-minute basis via GPRS without interruption, even when the gauges and the data acquisition and transmission unit were totally covered with snow.

4.10 Pictures taken during the experiment (December to April) and the data analysis allowed to draw the following conclusions:

- The installation, which will be transferred to the test site for SPICE at Weissfluhjoch, has proven to be robust and reliable, even in harsh conditions. The data transfer experienced no interruption, even when the gauges and the logger/modem unit were completely in snow.
- For prevailing Alpine conditions, measurement is difficult with unheated gauge: snow can induce mechanical effects on the sensor, with possible formation of ice or snow bridges between the housing and the weighting elements. Heating of the ring is mandatory to ensure good quality measurement in Alpine winter conditions with high snow amount.
- Regular on-site maintenance and control of the instruments is clearly an advantage to ensure good quality of the measurements during SPICE.

ITALY

4.11 Mr Vuerich presented the results of the laboratory tests that were performed at the laboratory of the CIMO Lead Centre on Precipitation Intensity of Italy (University of Genoa). The two weighing gauges proposed for use as part of the field reference system for SPICE were tested in controlled laboratory conditions at one-minute resolution in time. Steady-state (constant reference flow) tests have been performed in a temperature chamber at three different temperatures (-5°C, 0°C, +5°C) with reference flow rates of 1 mm/h, 3 mm/h, 5 mm/h and 10 mm/h. Non steady-state or dynamic tests (time-varying reference flow rate) have been performed in laboratory at ambient temperature. The characteristics and performance of the lab reference system (software controlled pumps) were described to show the accuracy, precision and suitability of the system for the above-mentioned tests. The laboratory tests of instruments did not include vibration tests, until a better understanding of the vibration frequencies and amplitudes expected in a field environment, are better understood.

4.12 Mr Vuerich recalled the importance of laboratory tests on reference instruments as a comparative experiment to assess the relative performance of those instruments in controlled conditions. Based on the results, the following conclusions could be provided:

- Steady-state tests demonstrate that precision and accuracy (trueness) decrease (worsen) with the decrease of the precipitation intensity for both instruments. Precision, in particular, decreases with reducing the intensity, with relevant differences between the two gauges. The OTT Pluvio^2 seems to be less influenced than the Geonor T200B by ambient temperature, especially with regards to precision. The inherent intensity resolution of the instruments also affects the performance at low precipitation rates.
- The dynamic tests at ambient temperature show that both gauges are able to reproduce likely real world events with quite comparable performance.
- The results from laboratory tests open the way for possible improvements of their accuracy and precision.
- The Lead Centre is willing to consider the possibility of performing further tests.

4.13 Considering the results achieved, the IOC decided that further investigations were needed on the relative performance of the reference gauges in steady-state and dynamic conditions, proposing the following activities:

- Performing temperature tests in steady-state condition at temperatures lower than -5°C.
- Laboratory vibration tests using the available field data on the monitoring of wind induced vibrations, recently started at Marshall site (Boulder, CO, USA).
- Performing additional dynamic tests with flow rate below 10-15 mm/h and determining the response time of reference instruments.
- Considering the significant statistics of lab tests data, Geonor T200B data can be reprocessed by using the proposed SPICE algorithms in order to assess their performance in view of their implementation.

4.14 The IOC welcomed the availability of the University of Genova (Italy) of providing the work of a PhD student for performing additional tests and agreed on the proposal of working jointly with NCAR (USA) personnel involved in SPICE and spending a period at NCAR facilities in Boulder, CO (USA).

NORWAY

4.15 Dr Mareile Wolff presented the summary of results from the Norwegian contribution to Pre-SPICE. The test site Haukeliseter in Norway was established in 2010 for an ongoing (until summer 2013) national solid state precipitation study. The study is a cooperation of the Norwegian Meteorological Institute and a union of Norwegian hydro-energy companies. Its main goal is to develop a new set of adjustment functions that accounts for Norway's typical climate and that is suitable for automated measurements, by this improving the data quality of Norwegian precipitation measurements. The data and results for pre-SPICE shown at the meeting are therefore data and results from the national study at Haukeliseter.

4.16 As measurements at Haukeliseter started in early 2011, test data from two consecutive winters are available and the analysis is underway. The analysis-strategy is a two-fold approach aiming to:

- Identify and classify individual precipitation events after various aspects (windspeed, wind direction, precipitation type, intensity, temperature,..). Using these data sets to understand the physical processes which yield to differences between the measurements of gauges in the DFIR fence and the comparison gauges.

- Start from operational periods (24h, 12h, 1h) and analyse differences purely statistically.

4.17 An event identification algorithm which solely depends on a significant precipitation accumulation in the DFIR-GEONOR was tested. The algorithm was working fairly well, but often missed the less-intense onsets and endings of the of the precipitation events. Low-intensity events, some of them resulting in significant accumulation, were not detected by the algorithm. Norway encourages a discussion on a common event-identification which also uses precipitation detectors/wetness sensors or disdrometers in combination with the measured accumulation of the gauge.

4.18 The Geonor-gauge inside the DFIR-fence was measuring significantly more than the surrounding comparison gauges. Both, the individual event-analysis and preliminary statistical analysis show the expected relationship between wind speed and precipitation loss. The influence of precipitation type (indicated by temperature) could be shown. Some data suggests that wind-direction has to be taken into account to consider possible in-homogeneities.

UNITED STATES

4.19 The joint presentation of the Marshall Field site and results relevant to Pre-SPICE was given by Bruce Baker, John Kochendorfer and Roy Rasmussen. During the Pre-SPICE experiment gauge accumulations for various weighing gauges in DFIR-fences were comparable, including the small (2/3 diameter, 4-foot slats for inner and outer fence) DFIR-fence used by CRN.

4.20 The results indicate that gauge accumulation was mostly dependent on shield-type than gauge-type. A number of cases showed that the Belfort Double-Alter collects more than standard Double-Alter. More data are needed to confirm this result, however. Collection efficiencies for gauges in a single Alter drop to ~ 0.2 for wind speeds of 10 m/s. The cause of this behavior was suggested to be turbulence, but more data and model studies are required to verify this hypothesis. During a wet, heavy snow case on March 23, 2010, the OTT Pluvio1 gauges showed dumping behavior leading to anomalously high collection efficiencies. This was true for a Pluvio1 in a DFIR-fence or double Alter shield or Tretyakov shield. In this case the heating was not sufficient to eliminate capping or sidewall accumulation, leading to the dumping behavior. Dr Rasmussen emphasized the importance of heating of the gauges to prevent this type of behavior during the SPICE field program. During a winter case in December, 2011, the lack of heating of the lower tube of the GEONOR gauge led to dumping behavior. This was caused by the snow impacting the upper, heated portion of the GEONOR melting, and the drops running down the tube and re-freezing on the lower, un-heated tube. This result emphasized the need to heat the entire GEONOR tube.

5. PLANNING, SCHEDULING AND COORDINATION OF SPICE

5.1 Algorithm to derive the reference precipitation observation

5.1.1 Dr John Kochendorfer presented the principles and preliminary results from tests of a proposed precipitation algorithm to be used for the derivation of the precipitation reference observation for SPICE. The development of this algorithm has been a joint effort between NOAA, NCAR, and the Norwegian Meteorological Institute. Weighing gauges measure bucket weight and derive total precipitation depth; to obtain precipitation rates, the change in depth must be calculated as a function of time. Errors in the depth measurement can therefore affect the precipitation rate, and can be mitigated by the use of signal processing or digital filtering algorithms. The proposed algorithm also employed a capacitive precipitation detector to corroborate the presence of precipitation with weighing gauge observations. These types of algorithms are used in operational precipitation measurement networks. The results to date indicate that several good algorithms are available, but that more testing and refining are needed.

5.1.2 The NOAA Climate Reference Network precipitation algorithm was described in some detail, and is based on the calculation of the five minute depth change (referred to as a wire delta) and the delta average variance from the three wire mean for each wire over the past two hours. To account for the contribution of each wire, weights are assigned to each wire inversely proportional to average delta variance and the precipitation is calculated as the weighted average of the three wire deltas. A wetness sensor is used to validate the presence or absence of precipitation. If the wetness sensor was dry, average delta is negative (evaporation), or average delta is too large (maintenance), the precipitation output is zeroed.

5.2 Configuration and operation of the Working Field Reference Systems

Overview

5.2.1 The meeting noted that the term DFIR (Double Fence Intercomparison Reference) as defined during the previous WMO Solid Precipitation Intercomparison (1989-1993, WMO/TD-No. 872 (1998)) refers to the complete system comprising the octagonal double-fence as well as the Tretyakov gauge placed in its centre. In order to clearly differentiate the octagonal double fence from the complete system, the IOC decided to use the term DFIR-fence when referring to the octagonal double fence only. Furthermore, in order to clearly differentiate the DFIR system from a similar configuration using an automatic gauge in the centre of the octagonal double-fence, the IOC decided to refer to the latter as a Double Fence Automatic Reference (DFAR). The IOC stipulated that the DFIR-fence and DFAR shall have the dimensions as defined in the first intercomparison and summarized in Annex II.

5.2.2 SPICE-IOC-1 defined the field reference configuration for SPICE and the nomenclature for the intercomparison sites. The information is contained in Annex V of the SPICE-IOC-1 Final Report, and is reproduced in this report in Annex II for completeness. The intercomparison objectives are also reproduced in Annex IV. The first of these objectives is the recommendation of appropriate field reference system(s) for the unattended measurement of solid precipitation. This recommendation will be the result of the assessment conducted during the experiment and may be based on the configuration of the working field reference system used during the experiment.

5.2.3 The configuration of the SPICE working field reference system for the experiment was determined based on criteria refined through the experiments conducted by some Members during the winter of 2011/12 (Canada, Germany, Finland, Italy, Norway, USA), as summarised in Section 4 of this report. The criteria cover the simplicity of the configuration of the field reference system in terms of the gauge, shield(s), other sensors used, and processing algorithm. The criteria for the selection of the weighing gauge for the field reference system included satisfactory results from static and dynamic calibration in the laboratory, acceptable measurement performance in relevant field conditions and relative to a field reference, simplicity of operation and of the maintenance effort, accuracy/validity, precision/reliability, sensitivity, and resolution. The decisions of the IOC regarding the detailed setup of the Working Field Reference Systems are listed below.

5.2.4 The IOC decided that it is the responsibility of the sites to purchase their own gauges for their reference systems, as the data from the reference gauges would not be shared with the instrument manufacturers during the duration of SPICE.

Working Field Reference System type R1

5.2.5 The Working Field Reference type R1 comprises a Double Fence Intercomparison Reference (DFIR) with a manual Tretyakov gauge and a Tretyakov shield [adopted as the secondary field reference at the end of the WMO Intercomparison of Solid Precipitation 1989-1993 (WMO/TD-872 (1998,)], together with a capacitive precipitation detector. A site hosting a R1 reference is designated as a S1 type Intercomparison site.

Working Field Reference System type R2

5.2.6 An automatic weighing gauge equipped with a single Alter windshield within a DFIR-fence, together with a capacitive precipitation detector, is designated as a R2 working field reference. A site hosting a R2 reference is designated as a S2 type intercomparison site.

Working Field Reference System type R3

5.2.7 The Working Field Reference System type R3 consists of a pair of identical automatic weighing gauges heated in the same manner, one being unshielded and the second installed with a single Alter shield, together with a capacitive precipitation detector. The configuration of the Alter shield is specified by the SPICE IOC and will be posted on the WMO SPICE website. A site operating only a R3 reference is designated as a S3 type site.

5.2.8 The decision to configure the R3 reference as a combination of a gauge in a single Alter shield and an unshielded gauge is based on the fact that, globally, the operational configurations of instruments for the measurement of precipitation amount are typically either unshielded or have a single shield. These results have been documented in the WMO-CIMO survey conducted in 2008. This rationale was applied during the first WMO Solid Precipitation intercomparison.

Uniform configuration of all sites

5.2.9 The IOC agreed that transfer functions for various gauge configurations will only be determined at S1 or S2 sites. The methodology for deriving and validating the transfer functions will be established as part of the SPICE Data Analysis methodology and will be published in the Final Report.

5.2.10 The IOC further agreed that all participating sites focusing on the assessment of the measurement of precipitation amount shall have, as the minimum requirement, a R3 type reference.

5.2.11 By deriving the catch ratio of the two gauges in the R3 reference, the applicability of transfer functions for different sites and climatologies will be evaluated. Therefore, the IOC decided that a R3 reference must also be installed at all S1 and S2 sites in order to establish traceability of the R3 reference to the R2 and R1 reference systems.

5.2.12 The IOC agreed that sites at which none of the above reference configurations could be installed will be devoted to specific questions of interest, e.g. operability of gauges in certain environments.

Selection of Weighing Gauges used for the Working Field Reference System

5.2.13 At the SPICE-IOC-1 meeting, two gauges with wide operational use were considered as potential candidates to be implemented in the field reference systems for SPICE. These were the GEONOR T-200B3 gauge (with 3 transducers) and the OTT Pluvio² gauge. Laboratory and field investigations conducted during the 2011/12 winter by some Members have shown that both precipitation gauges perform similarly, and are equally suitable for use as part of the field reference system for SPICE.

5.2.14 Given the models currently in use, the IOC agreed that GEONOR T-200B3 gauges with 600 mm and 1000 mm capacities, and the OTT Pluvio² gauge with 200 cm^2 inlet opening are suitable for use as part of the field working reference system. Beyond their similar performance in 2011/2012 winter studies, these gauges have similar physical profiles, and are not expected to differ significantly in terms of air flow around the gauge.

5.2.15 These weighing gauges are to be mounted on a concrete foundation using a low vibration mast. For practical reasons, windshields are sometimes mounted on the mast, but mounting on separate foundations is preferred, if possible, to mitigate the influence of vibration in the mast.

5.2.16 The IOC recommended that special attention be paid to the grounding and levelling of the gauges, as these have significant effects on the noise level induced by the signal lines, particularly for the Geonor gauges.

Heating of the Weighing Gauge used in the Field reference System

5.2.17 Based on the results of Pre-SPICE, the IOC agreed that all gauges used as part of the field reference system shall be heated as described below.

5.2.18 Comparisons of heated and unheated GEONOR T-200B3 and OTT Pluvio² gauges have shown that the collection efficiency was not negatively affected by the heating of the gauges, e.g. by a possible chimney effect. Furthermore, the results showed that heated gauges provided a more timely response to snowfall events and are less prone to capping of gauge orifices.

5.2.19 The heating algorithm and physical configuration of heaters tested during the 2011/12 season was based on the experience gained in the Climate Reference Network (CRN) of the US National Oceanographic and Atmospheric Administration (NOAA). This algorithm maintains the temperature of the orifice rim at 2°C while the ambient temperature is between 2°C and -5°C. In addition, for temperatures below -5°C, the heaters are activated once every 24 hours.

5.2.20 A point of concern remains the value of the ambient temperature below which the heaters should be turned off. Based on previous experience, a temperature of -5°C was seen as insufficient for some sites, as capping had been observed at temperatures well below this value.

5.2.21 It was decided that for the start of the experiment during the winter of 2012/13, the heating of gauges will be configured in a similar manner to that used during Pre-SPICE; this includes the physical configuration, the algorithm, the rim temperature, and the monitoring of the state of the heaters.

5.2.22 Each Intercomparison Site will monitor and assess heating performance throughout the winter to identify any problems that occur. If changes to the heating algorithm are required at any site, the Site Manager will evaluate the issues with the IOC, assessing the need for modifying the heating algorithm based on data obtained from the site, including pictures. Any changes will have to be accepted by the IOC before implementation.

5.2.23 In parallel, laboratory tests will be carried out to evaluate the chimney effect at low temperatures.

5.2.24 The field experience of several participants with the OTT Pluvio^2 gauges showed consistent observations of snow build-up on the shoulders of the gauge housing, just below the orifice. The project team agreed to initiate the development and testing of a solution for additional heating of the Pluvio^2 gauges used as part of the field reference system. The IOC tasked E. Lanzinger and Y.-A. Roulet with developing this proposal. Before this proposal is validated and implemented with the approval of the IOC, the Site Managers of each Intercomparison Site are requested to monitor and document any snow build-up on the outside of the OTT Pluvio^2 gauge.

5.2.25 For the GEONOR gauges, several heating solutions are available. The IOC agreed that the CRN approach, with heaters on the upper and lower part of the inlet tube, will be used for Geonor gauges in field reference systems. The IOC kindly accepted the offer of USA to provide heater assemblies for GEONOR reference gauges to all sites requiring them, and to provide a detailed description of the procedure used to install the heaters.

Use of antifreeze and oil for the Weighing Gauges

5.2.26 A survey of the participating countries indicated that the current methodologies vary as a function of the local conditions (in particular, air temperature), and legislative provisions regarding the use of certain substances.

5.2.27 The IOC agreed that the local project teams have experience regarding the local conditions and requirements regarding the use of antifreeze, during the winter season, and agreed to recommend the utilization of standard national procedures for the compositions and quantities of antifreeze used for the experiment on each site. Each Site Manager is responsible for documenting the methodology used (including whether anti-freeze is also used during the summer season) and providing this information to the IOC prior to the commencement of the experiment. The IOC will review the submissions and provide additional guidance, if required. Once adopted, each site will maintain the same methodology for antifreeze throughout the experiment.

5.2.28 The IOC requested that an oil film be used for all reference gauges (also the Ott Pluvio^2) to prevent evaporation and also to mechanically minimize the hygroscopic effect of the powercool or propylene glycol/water mixture. The amount of initial water could be reduced when using oil as a top layer. Careful handling and disposing of the waste has to be mandatory! Oil used by different countries will be made available in a separate document.

5.2.29 Given the previous experience of several members, it was recommended that the Geonor gauges are never left empty, as this could lead to a measurement error. These gauges should always be filled to at least 25% capacity.

Alter Shield Configuration

5.2.30 The weighing gauges in the DFIR-fence (R2 reference system) and one of the gauges in the R3 reference system will be installed with Alter-type windshields. As various types of Alter windshields are in use, and given the fact that the windshield can have a large effect on catch efficiency, the IOC decided that the same type of Alter shield will be used in all R2 and R3 reference configurations, as well as for any other configurations included in the intercomparison where a single Alter shield is used.

5.2.31 The IOC established a task team lead by J. Kochendorfer and C. Smith that will provide the exact specifications, including material, length and shape of shield slats, and schematics of the shield assembly. Once approved by the IOC, these specifications will be distributed to all site managers.

5.2.32 For the R3 field reference system, a minimum height above ground of 2 m (depending on the expected amount of snow) was adopted. It is expected that the gauge orifice will be located 1.5 m above the height of the maximum snow pack, as identified from 30 year climate normals. The upper rim of the Alter shield shall be 2 cm above the gauge orifice.

DFIR-Fence configuration

5.2.33 For R1 and R2 reference configurations, DFIR-fences will be used. The IOC decided that the standard configuration of the DFIR-fence shall be that recommended by the first WMO Solid Precipitation Intercomparison, report WMO/TD 872/1998 (see Annex II). The clearance below the outer fence should be about 1.5 m above the the maximum snow pack, as identified from 30 year normals. Additional installation considerations will be summarized and shared amongst the team members to provide assistance for new DFIR installations.

Data sampling for gauges used as part of the Field Reference System

5.2.34 The IOC agreed that the frequency measurements of GEONOR gauges should use the period time averaging method instead of the pulse counting method, because the former provides better temporal resolution.

5.2.35 For all reference gauges, it is recommended to sample data at 6 s time intervals. In case of limitations of the data acquisition system, 10 s or 60 s sample intervals can be used, alternatively.

5.2.36 For the purpose of the intercomparison, the 6 s data should be collected for the gauges under test, where possible. This will allow for gaining deeper insight into the reasons for observed differences between gauges, as well as for any observed errors.

5.2.37 The OTT Pluvio^2 gauge uses a proprietary algorithm to collect and process the gauge measurements. In order to derive the SPICE reference observation, the IOC agreed to use the 6 second Bucket RT output from the Pluvio^2. To enable full understanding of the data used as part of the reference, the IOC decided to ask OTT for information regarding the derivation of the Bucket RT data from the individual load cell measurements.

5.2.38 Each Site Manager is requested provide information on the sampling strategy and frequency for the gauges used as part of the field reference system to the IOC prior to the start of the intercomparison.

Calibration of gauges used as part of the Field Reference System

5.2.39 The IOC agreed that gauges used as part of the reference system shall be calibrated at the beginning and at the end of the intercomparison. The calibration of the weighing gauges involves the use of a traceable weight, which could be a calibrated weight (traceable to national standards) or water. If using weights, provisions have to be made to ensure that they are placed centrically at the bottom of the bucket of the weighing gauge. The CIMO Lead in Italy will perform a laboratory dynamic calibration of two reference instruments (one Geonor and one OTT Pluvio^2) and determine their response times and the related performance, in particular for flow rates below 10-15 mm/h. No corrections or adjustments of calibration coefficients of reference gauges will be applied for it.

5.2.40 For the GEONOR gauge with three transducers, NOAA will document and provide the CRN calibration procedure. The IOC decided to review this procedure and adopt it during future teleconferences.

5.2.41 For the OTT Pluvio² gauge, a special set of weights is available from the manufacturer that fits exactly onto the weighing plate. Configuration software is also provided to guide the user through the calibration and adjustment process.

5.2.42 Each participant has the responsibility to complete the calibration of the gauges prior to the start of the experiment, which is recommended to take place in a sheltered room close to the site.

5.2.43 The calibration coefficients obtained through the pre-test calibration process will be collected and assessed during the data analysis phase of the intercomparison.

5.2.44 As part of the installation procedure, it is recommended that the users of GEONOR gauges pay particular attention to the levelling of gauges, as this is critical to the data quality.

Use of Precipitation Detectors as part of the Field Working Reference System

5.2.45 The IOC agreed that to increase the reliability of the reference observation derived from the field working reference system, the binary output (Yes/No) of a precipitation detector will be integrated into the algorithm for deriving the reference observation.

5.2.46 A capacitive precipitation detector shall be used in a threshold capacity, in order to avoid false reports by the reference gauges for precipitation amount when no precipitation is present.

5.2.47 Optical precipitation detectors are more sensitive by one or two orders of magnitude, and should additionally be installed at every S1 and S2 site to indicate the total duration of precipitation, including times with intensities that are below the sensitivity threshold of precipitation gauges and capacitive precipitation detectors. The IOC recommended that the precipitation detectors are installed outside the DFIR or gauge windshield, depending on the specific configuration employed.

Site Commissioning

5.2.48 Each Site Manager is responsible for the configuration of the experiment on their particular site. Prior to the official start of the experiment, it is required that the site configuration is commissioned following a procedure developed and approved by the SPICE IOC. The commissioning report will be reviewed by the IOC, and the formal acceptance of the report will signal the commencement of the experiment. The IOC recalled the importance of verifying the proper levelling of the gauges during the site commissioning.

5.2.49 For every field intercomparison, an initial phase is needed to ensure that all instruments and equipment are working correctly. To shorten this phase, it was agreed that the data of each site has to be monitored carefully by experts of the SPICE project team. The local site managers will be supported to identify possible errors or malfunctions of instruments and equipment as early as possible.

5.2.50 If opportunities arise, members of the IOC or their designates could visit participating sites to review the site configuration and provide additional guidance, if required.

5.3 Configuration and operation of the participating instruments

5.3.1 The configuration of the instruments included in the intercomparison will be implemented according to the manufacturers' recommendations and in accordance with the WMO Site Classification Guidelines.

5.3.2 As mentioned above, the 6 s data should be collected for the gauges under test, where possible.

5.4 Ancillary Measurements

5.4.1 The list of requisite ancillary sensors adopted during the SPICE-IOC-1 meeting has been expanded to include additional sensors which would provide complementary measurements to be used as input or evaluation parameters for numerical flow simulations. It was recognized that the following additional parameters are needed: vertical particle velocity, precipitation type, snow density, turbulence, temperature at the 700 hPa level, and wet bulb temperature. Their implementation will help with the identification of differences in the amount of precipitation using different types of weighing gauges.

5.4.2 The IOC accepted the recommendation to add sensors for the measurement of the above parameters at both S1 sites (Marshall and CARE), at minimum. Three-dimensional sonic anemometers should be installed upstream and inside of windshields to measure and compare turbulence values predicted by models. Present weather sensors should be used to identify precipitation type if human observations are not available, and small X-band RADAR systems should be installed to measure vertical particle velocities. Upper air temperatures at 700 hPa should be taken from model reanalysis. Snow densities determined using a snow model and wet bulb temperatures derived from humidity measurements should be correlated with gauge catch efficiency.

5.4.3 Measurements of these additional parameters are intended to improve flow models for windshields and precipitation gauges. It was acknowledged that these parameters are not available at most operational sites, but that they are needed for a deeper understanding of the physical phenomena.

5.4.4 The IOC acceptance of the recommendation to monitor wind direction, in addition to wind speed, is of significant value to the experiment, both to allow for understanding of the potential interactions between collocated structures and for data quality control. Accordingly, measurements of wind direction must be part of the standard set of ancillary measurements (10 m and at the height of the gauge). The availability of wind direction measurements will enable the preparation of wind roses during the precipitation events, relative to the site layout.

5.4.5 The precipitation detectors have to be installed at gauge height or above to avoid measuring blowing snow.

5.4.6 The updated list of ancillary measurements is provided in Annex III.

6. REVIEW AND SELECTION OF PROPOSED PARTICIPATING SITES

6.1 Overview

6.1.1 Following the Second Letter of Invitation issued by WMO to all Member countries, 12 Members indicated interest in participating in the experiment with at least one site. A total of 17 sites have been proposed as potential hosts for the SPICE experiment in both the Northern and Southern Hemispheres.

6.1.2 The IOC reviewed the site submissions and decided to accept the participation of 15 sites. The following sections outline the IOC assessment and decision for each site. Additional information on each site, including the motivation for participation relative to the project objectives, is provided in the Annexes to this report.

6.1.3 The site proposals included information on the configuration of the references for the measurement of precipitation amount and snow on the ground, which would support the organization of the experiment. Additionally, the site proponents included in their submissions instruments proposed for inclusion in the intercomparison as instruments under test. These instruments and their configurations either reflect current national standards for the measurement of solid precipitation, or are of specific interest for the proponent. Given the interest in increasing understanding of the national methods of measurement, the IOC acceptance of a site for participation in SPICE is implicitly an acceptance of the proposed configurations and instruments for inclusion in the experiment. These instruments are owned and/or operated by the site proponents, and their configuration is entirely the responsibility of the proponents.

6.1.4 The list of instruments to be included in SPICE that were proposed by the site proponents will be finalised prior to the commencement of the experiment in November 2012. The IOC requested all approved sites to provide an updated list of instruments by 1 October 2012.

6.1.5 The IOC agreed that additional site submissions made following the official start of the experiment will be reviewed in a similar manner, and that additional sites could join the experiment throughout its duration; however, the issuing of the final report will follow the original schedule.

6.2 **Australia**

Site Overview

6.2.1 Snowy Hydro Limited of Australia has proposed to participate in SPICE by hosting the experiment at Guthega Dam weather station, Kosciuszko National Park, New South Wales, Australia. The proposal is endorsed by the Bureau of Meteorology of Australia. A description of the site is provided in Annex V of this report.

Decision Regarding the Site Selection

6.2.2 The IOC accepted the participation of the Guthega Dam Weather Station in the WMO SPICE Intercomparison as a S3 site. The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

6.2.3 The gauge used at the Guthega Dam site is the ETI NOAH II. The Marshall site will install a similar gauge, to enable a comparison of the performance of this gauge against R1 and R2 references.

Site Manager

6.2.4 The Site representative for the Guthega Dam weather station is Shane Bilish, of Snowy Hydro Limited, who becomes an ex-officio member of the SPICE IOC.

6.3 **Canada**

Site Overview

6.3.1 Environment Canada proposed to participate in SPICE with three of its experimental sites: the Centre for Atmospheric Research and Experiments (CARE), Egbert, Ontario; Bratt's Lake, Saskatchewan; and Caribou Creek (Smeaton), Saskatchewan. Descriptions of these sites are provided in Annex VI of this report.

Decision Regarding the Sites Selection

6.3.2 The IOC accepted the participation of the three sites proposed by Environment Canada, as follows:

- CARE: as a S1 type site, based on the availability of a DFIR with manual measurement and a second DFIR-fence with an automatic gauge.
- Bratt's Lake: as a S2 type site, as a result of the availability of two DFIR-fences with automatic gauges.
- Caribou Creek: as a S2 type site, as a result of the availability of a DFIR-fence with an automatic gauge. In addition, this site will operate automatic gauges installed in an area with recent jack pine growth maintained at the height of the gauges for the duration of the experiment. This would be a representation of the primary field reference (i.e. the bush gauge) as implemented in Valdai, Russian Federation, but using an automatic gauge instead of a manual gauge.

6.3.3 All three sites are requested to install a R3 type field reference, to enable the linking of their results with the results from all other participating sites.

Site Manager

6.3.4 The site managers for the three Canadian sites are: Rodica Nitu (CARE), Craig Smith (Bratt's Lake), and Daqing Yang (Caribou Creek). If confirmed by their organization, they would become ex-officio members of the SPICE IOC. Ms Nitu is already a member of the IOC.

6.4 Chile

Site Overview

6.4.1 Centro de Estudios Avanzados en Zonas Áridas of Chile proposed the site Tapado AWS, Valle de Elqui, Región de Coquimbo, Chile, for participation in SPICE. The site is located in the Andes at an elevation of 4518 m, and is primarily used as part of a glacier research programme. The site is located in a remote area with difficult access. A description of the site is provided in Annex VII of this report.

6.4.2 At 4500 m elevation, the terminal velocity of precipitation particles is much larger than at sea level, and the transfer functions are expected to be very different from those determined at lower altitudes.

Decision Regarding the Site Selection

6.4.3 The SPICE IOC agreed to the participation of the Tapado AWS site in the SPICE experiment, with a focus on testing instruments in remote locations, at high elevations. While the IOC recognizes the difficulty in configuring weighing gauges on sites as remote as Tapado, it still encourages the proponent to explore the potential for configuring a R3 reference. The IOC also recommends that, to the extent feasible, a Chile national standard gauge is installed on the Tapado AWS site.

Site Manager:

6.4.4 Shelley MacDonell, who is responsible for the configuration and operation of the site, is the SPICE Site Manager, and in this capacity, once confirmed by the proponent organization, she would become an ex-officio member of the IOC.

6.5 Finland

Site Overview

6.5.1 The Finnish Meteorological Institute (FMI) proposed a new test site at the Sodankylä Arctic Research Centre (ARC) for participation in SPICE.

6.5.2 Sodankylä is located above the Arctic Circle, and is a supersite for satellite data calibration-validation activities, with several on-going programs. It also contributes to the Global Atmospheric Watch (GAW). These programs involve the remote sensing of snow, soil moisture, permafrost and atmospheric constituents. The description of the site is provided in Annex VIII of this report.

6.5.3 During the winter of 2011/12, Finland organized experiments at the Jokioinen site, which will remain operational during SPICE, but not as an officially participating site.

Decision Regarding the Site Selection

6.5.4 Given the availability of a DFIR-fence with an automatic gauge, the IOC accepted the participation of the Sodankylä ARC site in SPICE, as a S2 type site.

6.5.5 In addition, based on the presence of manual observations of snow depth and a suite of other snow research activities, the site is recommended as an ideal location for the testing of additional instruments for the measurement of snow on the ground and snow water equivalent.

6.5.6 The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

6.5.7 The site has an antenna dish which is 12 m in height, about the same level as the trees surrounding the site. The IOC recommended that during the site configuration, appropriate distances are maintained between the antenna and the instruments to avoid erroneous measurements, due to snow blowing off the antenna, or due to the antenna as an obstruction.

Site Manager

6.5.8 The Sodankylä site representative is Osmo Aulamo, who becomes the SPICE Site Manager and an ex-officio member of the SPICE IOC.

6.5.9 For the configuration of the intercomparison site, the FMI has designated a second contact, Timo Laine, from the Helsinki office of the FMI.

6.6 Japan

Sites Overview

6.6.1 Two sites have been proposed by two different organizations in Japan:

- Joetsu, proposed by the National Agriculture and Food Research Organization (NARO), Agricultural Research Center; and
- Rikubetu, Ashorogun, Hokkaido, proposed by the National Institute of Polar Research (NIPR), 10-3, Midoricho, Tachikawa, Tokyo.

A detailed description of the sites is provided in Annex IX of this report.

6.6.2 The Joetsu site operates a DFIR-fence, and is known for its extreme snowfall events, with the total average annual snowfall reaching 635 cm.

6.6.3 The proponent of the Rikubetu site considers the current site as an option for SPICE, while also investigating the possibility for configuring a new site in the proximity of the existing site, which would allow for the installation of a DFIR-fence.

6.6.4 Both sites will be ready for participation in the SPICE experiment for the winter of 2013/14.

Decision Regarding the Site Selection

6.6.5 The IOC approved the participation in the SPICE experiment of the Joetsu site, recognizing the contribution that could be made to the project objectives, given the site climatology.

6.6.6 The IOC agreed in principle to the participation of the Rikubetu site; however, additional information is required regarding the final plans for the site.

6.6.7 The site proponents are requested to install a R3 type field reference on each site, to enable the linking of the results from these sites with the results from all other participating sites.

Site Manager

6.6.8 The representatives of the proponents for the two sites are Sento Nakai (Joetsu) and Naohiko Hirasawa (Rikubetu), and if confirmed as the Site Managers, they would become ex-officio members of the SPICE IOC.

6.7 New Zealand

Site Overview

6.7.1 The National Institute of Water and Atmospheric Research Ltd of New Zealand proposed the Mueller Hut Electronic Weather Station site, which is part of the National Climate Network, for participation in SPICE. The site is located in a remote location at an elevation of 1818 m, above the tree line.

6.7.2 Their participation is motivated by interest to enhance knowledge regarding the operation of precipitation gauges in remote locations, as well as the testing of new and emerging technologies. The description of this site is provided in Annex X of this report.

Decision Regarding the Site Selection

6.7.3 The IOC agreed to the participation of the Mueller Hut Weather station site in the SPICE experiment, with a focus on testing of instruments in remote locations.

6.7.4 The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

6.7.5 The IOC acknowledged that the instruments will have to be removed from the field during the summer season.

Site Manager

6.7.6 The Mueller Hut site representative is Christian Zammit, and when confirmed by his organization, he would become the SPICE Site Manager and an ex-officio member of the SPICE IOC.

6.8 Norway

Site Overview

6.8.1 The Norwegian Meteorological Institute proposed hosting SPICE on the site Haukeliseter, Vinjeveien, Telemark, Norway. This site currently hosts two major national projects: National project on wind correction of precipitation (2010-2013) and the site is an avalanche warning site (as part of a larger avalanche warning network) since 2012. All instruments at the site are financed by the national project for wind-correction of precipitation. Energi Norge is the official owner of the site for the course of the study. Afterwards, a formal transfer to the Norwegian Meteorological Institute is planned.

6.8.2 The site currently houses a DFIR-fence equipped with a Geonor T200B3, with 1000 mm capacity, and heated using standard Geonor heaters on the upper portion of the gauge funnel. The height of the gauge and of the DFIR-fence is 4.5 m above ground, due to the height of the snow pack, over a winter season.

6.8.3 The site has limited capacity for expansion in 2012, due to the commitments made for the currently running projects. Additional capacity may become available in 2013. The description of this site is provided in Annex XI of this report.

Decision Regarding the Site Selection

6.8.4 Given the availability of a DFIR-fence with an automatic gauge, the IOC accepted the participation of the Haukeliseter site in SPICE, as a S2 type site.

6.8.5 The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

Site Manager

6.8.6 The Haukeliseter site representative is Mareile Wolff, who becomes the SPICE Site Manager and in this quality she becomes an ex-officio member of the SPICE IOC.

6.9 Poland

Site Overview

6.9.1 The Institute of Meteorology and Water management, National Research Institute of Poland, proposed two operational synoptic stations for participation in SPICE, Hala Grasienicowa and Zakopane. The two sites are located close together, but at different elevations.

6.9.2 The Hala Gasienicowa site typically receives large amounts of snow, and operates a program for the manual measurement of snowfall.

6.9.3 The Zakopane site is located at a lower elevation in a more sheltered location.

6.9.4 The description of each site is provided in Annex XII of this report.

Decision Regarding the Site Selection

6.9.5 Given the local conditions at the Hala Gasienicowa site, and the presence of a well established manual observation program, the IOC accepted the participation of this site in SPICE, with a primary focus on the measurement of snow on the ground and its relation to snowfall.

6.9.6 The site proponent is encouraged, to the extent possible, to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

6.9.7 The IOC agreed to postpone the decision regarding the Zakopane site, to allow for a better understanding of the potential contribution that this site could make towards meeting the SPICE objectives.

Site Manager

6.9.8 Mr Lucasz Mrozinski is the designated representative for the Hala Gasienicowa site, and once confirmed as the Site Manager he would become an ex-officio member of the SPICE IOC.

6.10 **Switzerland**

Site Overview

6.10.1 MeteoSwiss proposed the site Weissfluhjoch (Davos) for participation in SPICE. The site is proposed in a partnership between MeteoSwiss and the Swiss Institute for Snow and Avalanche Research (who owns the site), which has extensive experience measuring solid precipitation and great interest in SPICE.

6.10.2 The site will be expanded in 2012 to meet for the requirements for participation in SPICE.

6.10.3 Construction of a DFIR-fence is planned for the summer of 2012. An OTT Pluvio^2 weighing gauge with 200 cm2 orifice area and 1500 mm capacity will be used in the DFIR-fence, as this is the gauge being deployed in the national network. As the depth of the snowpack could reach 3 m, the height of the DFIR-fence and of all other instruments will be adjusted to maintain the minimum clearance from the snowpack over the entire season (see Section 5.9).

6.10.4 Additional reference gauges, as recommended by the SPICE IOC, will also be installed during the summer of 2012.

6.10.5 Manual measurement of snow depth will be available for the experiment, once per day, complemented by the use of a video camera. The description of this site is provided in Annex XIII of this report.

Decision Regarding the Site Selection

6.10.6 The IOC approved the participation of Weissfluhjoch (Davos) as a S2 site.

6.10.7 The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

Site Manager

6.10.8 The Weissfluhjoch Site Manager is Yves-Alain Roulet, who is a member of the SPICE IOC.

6.11 **Russian Federation**

Sites Overview

6.11.1 Roshydromet proposed two sites for participation in the SPICE intercomparison: Valdai, State Hydrological Institute, Valdai Branch, and Voljskaya Hydro Meteorological Observatory, Gorodec, Nijny Novgorod Reg., Russia.

6.11.2 The Valdai site participated the WMO Intercomparison for solid precipitation, 1987-1993. This site hosts the only bush gauge, which represents the primary field reference for the measurement of solid precipitation. Additionally, the site has a DFIR with a manual Tretyakov collector and a Tretyakov shield. This has been operational between 1970 - 1976 and 1988 – 2010.

6.11.3 The site has six Tretyakov precipitation gauges (orifice area: 200 cm^2) with standard shields, three bush–sheltered Tretyakov gauges, and one Nipher precipitation gauge (500 cm^2).

6.11.4 No DFIR-fence with an automatic gauge is currently available on site, and at present, there is no indication of the potential for installing one. If the proponent configures a DFIR-fence with an automatic gauge, the Valdai site has the potential to become a S1 site. The proponent is willing to configure a field reference on site, based on the recommendation of the IOC.

6.11.5 The site Voljskaya Hydro Meteorological Observatory has a DFIR with a manual Tretyakov collector and a Tretyakov shield. This has been operational since 1957.

6.11.6 No DFIR-fence with an automatic gauge is currently available on site, although there are indications that one may be installed in the near future. The proponent is willing to configure a field reference on site, based on the recommendation of the IOC.

6.11.7 At this site, manual measurements of snow on the ground are completed every three hours using a metric mast. In addition, a video camera is available on site. The site has a focus on the measurement of snow on the ground and could contribute to SPICE from this perspective.

6.11.8 The description of each site is provided in Annex XIV of this report.

Decision Regarding the Sites Selection

6.11.9 The IOC accepted the two sites proposed by Roshydromet, Valdai and Voljskaya, for participation in SPICE. Additional clarification is required from the proponent with respect to the configuration of DFIR-fences and the proposed instruments on both sites.

6.11.10 The site proponent is requested to install a R3 type field reference on each site, to enable the linking of the results from these sites with the results from all other participating sites.

Site Manager

6.11.11 Dr Anton Timofeev is the designated representative for the Valdai site and Dr Arkadi Koldaev is the designated representative for the Voljskaya site. Once confirmed as Site Managers, they would become ex-officio members of the SPICE IOC.

6.12 **United States of America**

Site Overview

6.12.1 The National Oceanographic and Atmospheric Administration (NOAA)/Atmospheric Turbulence and Diffusion Division proposed for its participation in SPICE the NOAA/FAA/NCAR Winter Precipitation Testbed (Marshall) site in Boulder, CO.

6.12.2 During the summer of 2012, the proponent will install a standard DFIR gauge (Tretyakov gauge and Tretyakov shield), for conducting regular manual observations in support of SPICE.

6.12.3 A DFIR-fence of standard height and diameter is in the process of being installed on site, which will serve as a field working reference with an automatic gauge. The gauge used is a GEONOR T-200B3 gauge with three vibrating wires, equipped with an Alter shield, and heated using a configuration specific to the Climate Reference Network of NOAA.

6.12.4 In addition, the site has several DFIR-fences of standard diameter and gauge height of 2 m AGL. The weighing gauge used in these DFIR-fences is either a Geonor T-200B3 or OTT Pluvio[2], equipped with an Alter shield.

6.12.5 The proponent plans to install a SPICE recommended field reference to meet the SPICE objectives.

6.12.6 For the measurement of snow on the ground, the site runs a manual measurement program, conducting one measurement per storm using a snow stake.

6.12.7 The description of this site is provided in Annex XV of this report

Decision Regarding the Site Selection

6.12.8 The IOC approved the participation of the Marshall site (Boulder) as a S1 site.

6.12.9 The site proponent is requested to install a R3 type field reference, to enable the linking of the results from this site with the results from all other participating sites.

Site Manager

6.12.10 Dr Roy Rasmussen, who is the alternate representative of the site proponent, is the Site Manager for the Marshall site, and he becomes an ex-officio member of the SPICE IOC.

6.13 Uzbekistan

Site Overview

6.13.1 The Scientific-Research Hydrometeorological Institute of Uzhydromet proposed the site located at the Mountain Kumbel, hole Beldersay, Bostalik district, Tashkent region, Republic of Uzbekistan, for participation in SPICE. The site presently hosts a weather radar. A follow up conversation between the site proponent, the IOC Chair, and the WMO Secretariat allowed for a better understanding of the site conditions. The site currently has no automatic instruments or infrastructure for hosting instruments, and no experience with any automatic measurements.

6.13.2 The site is at 2300 m elevation, in an area with significant snowfall, and significant snow redistribution due to high winds. The access to the site is very difficult (helicopter, horses, cableways; no roads). Any construction effort (cables, pipes, plates, equipment, human resources) will require significant costs and logistics. Given the amount of snow, instruments need to be installed at increased heights. Due to the high winds and open exposure, the measurement of snow on the ground (SoG) is not possible, nor reliable.

Decision Regarding the Site Selection

6.13.3 The IOC recognized that installing a SPICE site at this location would require major construction work, time and significant costs. It also noted that WMO would not be in a position to provide financial support for this infrastructure. Based on the assessment of the site conditions, the IOC recommended that the proponent cooperates with the proponent from the Russian Federation and enable capacity building in the Scientific-Research Hydrometeorological Institute of Uzhydromet regarding the measurement of solid precipitation and the use of automatic instruments. The recommendation is based on the sharing of a common language, and the proximity of the sites. The IOC also welcomed the proposal of Switzerland to liaise with the site proponent in view of sharing expertise with them on the construction, installation and operation of such facilities, and on the possibilities to consider other funding strategies.

6.14 China

6.14.1 Mr Haihe Liang reiterated the interest of the China Meteorological Administration (CMA) to actively participate in SPICE. In preparation of the submission expected to be made by the CMA, he provided an overview of the facilities currently in place which will support the participation in SPICE.

7. REVIEW AND SELECTION OF PROPOSED INSTRUMENTS

7.1 In response to the second letter of invitation issued by WMO for participation in SPICE, three Members and 19 manufacturers have indicated interest in providing instruments for inclusion in the experiment. Once included in the experiment, these instruments will complement the suite of instruments proposed by the site hosts and already available for the intercomparison. In the following, a WMO Member (who is not hosting a SPICE intercomparison site) or a manufacturer proposing instruments for inclusion in the intercomparison is generically recognized as an *Instrument Provider*.

7.2 The Instrument Providers proposed a wide range of instruments for the measurement of precipitation amount, snow on the ground and snow water equivalent, covering the operating principles currently used for operational and scientific applications. Of the instruments provided, the following breakdown by operating principle was noted: weighing gauges (7 models), tipping bucket type gauges with heating (9 models), optical sensors (5 models), snow depth measurement sensors (6 models), snow water equivalent systems (2 models) and GPS reflection sensor (1 model).

7.3 The IOC reviewed the list of instruments proposed by the Instrument Providers and decided on their allocation to the SPICE sites as provided in Annex XVI (organized by instrument model and by site). The IOC decided to allocate instruments principally to S1 and S2 sites to ensure fairness for the proponents and ensure the results are most relevant as the transfer functions would be derived from those sites. Given the available capacity of the sites and the interest to test the instruments in a variety of climatological conditions, the IOC contacted the Instrument Providers that proposed more than one instrument of the same model, seeking their agreement for installing all the instruments proposed at the start of the intercomparison, without keeping any spares. In addition, the IOC sought the Instrument Providers' cooperation in dealing with instrument failures, when and if needed over the course of the experiment. Most of the Instrument Providers agreed with the installation of the proposed instruments at the beginning of the experiment, as proposed by the IOC.

7.4 The IOC assessed the submissions made by the Instrument Providers and all instruments proposed have been accepted for participation in SPICE, with the exception of one prototype instrument which would be difficult to accommodate as part of the experiment. The allocation of instruments to the participating sites took into account the site capacity, the project objectives, the site climatology, and the site objectives stated in each submission.

7.5 The IOC decided that the primary focus of the Marshall Site (USA) would be the assessment of instruments measuring the precipitation amount. For that reason, at least one unit of each of the proposed models of weighing gauges will be installed and tested on this site. Additionally, based on the site capacity, one unit of most of the tipping bucket type gauges selected has also been assigned to this site. The second unit of the available weighing gauges and the balance of the tipping bucket type gauges were distributed between the following sites: CARE and Bratt's Lake (Canada), Sodankylä (Finland), Haukeliseter (Norway), Weissfluhjoch (Switzerland), Guthega Dam (Australia), and Mueller Hut (New Zealand).

7.6 For the assessment of the snow depth/snow on the ground instruments and snow water equivalent, the sites Sodankylä (Finland) and Hala Gasienicowa (Poland) have been designated as primary sites, and the instruments proposed by manufacturers for these types of measurements were allocated to these two sites. Additionally, tests for the assessment of snow depth measurements and their relationship to snowfall are organized on most of the participating sites, using instruments owned and operated by the site proponents.

7.7 The optical sensors proposed by the Instrument Providers were distributed to several sites, taking advantage of their range of climatological conditions and complementing the availability of similar sensors proposed by the site proponents. Most of the submitted optical sensors are represented at the Marshall site, to allow for their assessment alongside the represented weighing type gauges and tipping buckets, in the context of the focus on the measurement of precipitation amount.

7.8 The configuration of the instruments provided by the Instrument Providers will be the responsibility of the Site Manager, working in conjunction with the Instrument Providers. The Instrument Providers are responsible for the delivery of their instruments to the intercomparison site and for supporting the site managers in verifying their proper configuration/functioning before and during SPICE.

7.9 The Site managers are responsible to provide information to the Instrument Providers regarding the customs procedures for the temporary import of instruments by 15 Aug 2012. Site managers are encouraged to find solutions for having customs taxed waived for the temporary importation of the instruments.

7.10 A late submission was received from Surfasense proposing an instrument currently under development (S1 revA) that estimates snow depth using the GPS reflection off the ground surface. It has a wide field of view, requiring an unobstructed view of at least 50 m. The IOC recognized that this instrument was a very interesting new development, but was concerned about the footprint required for this instrument to ensure no interferences between it and other participating instruments and to ensure it would be fairly placed. The IOC noted that none of the participating sites have indicated availability of space to accommodate this instrument. The IOC also recalled that the SPICE objectives were to assess and characterize automatic systems used in operational applications for the measurement of solid precipitation. The IOC was therefore of the opinion that it would not be appropriate to include this instrument in SPICE, but recommended that the manufacturer collaborate with some SPICE test sites in view of further testing this sensor so that it could be commercialized. The IOC encouraged in particular the USA and Canadian sites to consider testing this instrument on their facilities in collaboration with SPICE.

7.11 Following the communication with the instrument providers regarding the allocation of instruments to the intercomparison sites, two instruments have been withdrawn from the experiment by their proponents: these are the Electrical Rain Gauge submitted by the KNMI (The Netherlands) and the Snow Melt Analyser submitted by the Hydrological Services America, and manufactured by Sommer Mess-Systemtechnik.

7.12 Following discussion with the site representatives, the representative of Australia indicated that they would not be able to install the proposed Geonor 1500 mm gauge in addition to the new R3 reference.

7.13 Following the original submission, Campbell Scientific Canada has notified the SPICE IOC that, based on internal decisions, the name of the Snow Water Equivalent gauge identified as GMON3 has been changed in their product line to CS725. The Instrument Provider requested that the change in name be reflected in the project documentation, and indicated that no changes to the instrument characteristics and performance have been made. An official submission with the new instrument name has been made. Taking into account the recommendation of Campbell Scientific Canada, the SPICE IOC has adopted the new name of the instrument, CS725.

8. SPICE DATA PROTOCOL

8.1 The SPICE Data Protocol was developed to guide the participants in the experiment. Its purpose is to define the protocol governing access to, use of, and publication of information regarding the intercomparison sites and instrumentation, the algorithms employed by the instruments, the algorithms used in analysis of the data, the intercomparison data and the results to ensure that all SPICE participants are treated in a fair manner, and to ensure the timely dissemination / publication of SPICE results.

8.2 The SPICE Data Protocol was approved by the IOC and is included in this report in Annex XVII. The Data Protocol must be signed by all participants in the experiment, including IOC members, sites and instrument providers, as a condition of their participation in the experiment.

9. SPICE WORK PLAN

9.1 Additional clarification of the project objectives

9.1.1 The IOC agreed that as a deliverable of the project, the Final Report will include recommendations on the reporting of the specifications of instruments for the measurement of solid precipitation parameters. The goal is to allow for consistency across the market and provide sufficient detail regarding the performance of an instrument to effectively inform the instrument users. This will include reference to the use of wind shields.

9.1.2 The IOC acknowledged the recommendation that an outcome of the project should be the development of a WMO algorithm for the derivation of the precipitation amount from the raw data over various time scales, independent of the gauge(s) used for the measurement, and committed to include it as a SPICE deliverable. This would not include the wind adjustment.

9.1.3 The use of heated gauges and instruments in a remote location was recognized as a challenge. The representatives of participating sites agreed to configure during the experiment, on the S1 or S2 sites, gauges powered by alternative means (e.g. solar panels) and assess performance against the site reference. Additionally, all participants are encouraged to actively share their expertise related to powering and operating instrumentation in remote locations.

9.1.4 At the recommendation of the meeting participants, the IOC amended the Objective # VI of the experiment, by removing the reference to making available the remote sensing observations. The revised project objective # VI, states that the project will "*Configure and collect a comprehensive data set for further data mining or for specific applications. Enable additional studies on the homogenization of automatic/manual observations and the traceability of automated measurements to manual measurements.*" (see Annex IV of this report)

9.2 Interaction with Instrument Providers

9.2.1 The IOC strongly encouraged that the Site Managers and the Instrument Providers interact continuously during the course of the intercomparison, to ensure the optimal performance of instruments under investigation. This could include site visits by the Instrument Providers. Also, the Site Managers are requested to liaise with Instrument Providers when they notice that an instrument in not functioning as expected.

9.2.2 Each Instrument Provider will be given access to unprocessed output from its own instrument(s), and a minimum set of corresponding ancillary data consisting of air temperature, relative humidity, and wind speed. These data are provided only for ensuring the proper functioning of the instruments, and it is expected that the Instrument Providers shall neither report nor publish them prior to publication of the SPICE Final Report.

9.3 2012/2013 work plan

9.3.1 The IOC, in cooperation with the WMO Secretariat, will send to the representatives of sites and the Instrument Providers the decisions regarding their participation in SPICE together with a copy of the SPICE Data protocol by August 15, 2012. The Instrument Providers are responsible for the delivery of their instruments to the intercomparison sites, for supporting the site managers in verifying their proper configuration/functioning before and during SPICE, and for the return of the instruments at the end of the experiment.

9.3.2 The participants acknowledged that the Final Report of the WMO Field Intercomparison of Rain Intensity Gauges, IOM 99, recommends that (Recommendation 14) *"…for future intercomparisons, a test period be held before the official start of the intercomparison. After this test period a meeting with all participants could be organized to confirm and verify the setting of the instruments and data acquisition. If the data analysis procedure is already known at this time, it could also be presented to the participants for comments."*

9.3.3 The IOC requested that all Site Mangers provide the site layouts, including the proposed positioning of all instruments under test, references and ancillary instruments, and the prevailing wind direction during precipitation events, by 31 Aug. 2012. These will be reviewed by the IOC at the planned meeting on October 15, 2012, for approval prior to the final site acceptance.

9.3.4 The IOC will ensure that the start of the intercomparison is preceded by a testing phase which will allow confirmation of the “end-to-end” intercomparison data flow for all instruments (those under test and those providing ancillary measurements), and will be conducted as part of the commissioning protocol. The IOC will work with each Site Manager to confirm the success of the test period prior to the start of the formal intercomparison.

9.3.5 The IOC recognized that there is a fundamental difference between SPICE and most other intercomparisons, as SPICE is distributed over several sites. The data sampled on the different sites will not be collected simultaneously because of the different meteorological conditions prevailing at each site. Therefore, the IOC recognized that the exact start date for the intercomparison will depend on the specific site conditions.

9.3.6 The IOC urged the Site Managers to install the instruments and configure the SPICE sites to allow for commencing the experiment on November 15, 2012. The IOC recognized the risk that some sites may not be fully operational at that time and asked the Site Managers to give the highest priority to the configuration and operation of the field reference systems prior to November 15, 2012. Depending on the site conditions, the field reference systems may require additional fine tuning (e.g. heating), which may require a focused attention over the following winter season. In parallel, the site teams are encouraged to make every effort to install all instruments under test and perform end-to-end tests for the commissioning of the SPICE configuration.

9.3.7 To maintain an active engagement during the configuration phase, the project team will hold weekly teleconferences to assess progress and adjust plans, as required. These are scheduled to take place, in principle, every Thursday at 13:00 UTC. The IOC decided to approve additional procedures for SPICE during these teleconferences, or by correspondence. These procedures would be provided to the Site Managers and would be posted on the WMO website, if appropriate.

9.3.8 The IOC agreed that the complexity of the experiment requires a dedicated focus regarding the organization and delivery of the data analysis towards meeting the project objectives. For that reason, a dedicated Data Analysis Team will be assembled and Dr E. Lanzinger kindly agreed to lead it. The team will bring together experts from the participating countries and will commence its activity in September 2012. The initial composition of the Data Analysis team includes Dr M. Wolff, Dr Y.-A. Roulet, Dr R. Rasmussen, Dr D. Yang, Dr P. Joe, Dr M. Earle, Dr B. Baker, Dr J. Kochendorfer, and Dr J. Hendrikx.

9.3.9 The IOC agreed that annual reports on the progress of SPICE for informing the WMO, the participants, and the community of users are highly desirable and will work with the project team towards preparing them.

10. MEASUREMENT OF SNOW ON THE GROUND

10.1 As defined in the project objectives, SPICE will also focus on the performance of modern automated sensors for measuring and reporting snow on the ground (snow depth); as snow depth measurements are closely tied to snowfall measurements, the intercomparison will address the linkages between them.

10.2 The participants acknowledged that the definition of references for the measurement of snow on the ground would benefit from articulating, with increased clarity, the objectives of the intercomparison regarding the measurement of snow on the ground. The IOC tasked Dr B. Goodison with leading a team of experts to summarise the issues to be addressed in that aspect of SPICE. The team would subsequently work on defining the reference to be used for the measurements of snow on the ground and on the methodology for analysing these data.

11. OTHER BUSINESS

11.1 The name of SPICE has created some confusion. In order to differentiate the current project from others bearing the same or similar names, the IOC recommended using the acronym WMO-SPICE for the Solid Precipitation Intercomparison Experiment, recognizing that it is a WMO project.

Planning of publications and presentations on SPICE

11.2 The IOC and the project team acknowledge the importance of actively reaching the target audience of instruments and data users to inform them of progress and the results of the experiment. Following the publication of the Final Report of the previous WMO Solid Precipitation Intercomparison, approximately 30 papers were published, in various languages.

11.3 Given its global reach, the IOC strongly encouraged that papers and publications are made both prior to and following the final report of SPICE, to enable the dissemination of the experiment results, and stimulate discussion within the community on topics related to the measurement of solid precipitation. It is expected that continued discussion will lead to effective improvements in the quality of the global precipitation data set, and the building of capacity for acquiring measurements of known quality at the global level. It was recognized that the project is organized in countries where the official language is other than English, and papers and publications are encouraged to be published in those languages, as well.

11.4 Three presentations on SPICE are planned at the TECO-2012 conference, one of which will be a keynote address on the results of the 2011/12 Pre-Spice experiment. The other two presentations will cover the organization of the experiment and the results from the laboratory tests conducted at the Precipitation Lead Centre at the University of Genoa (Italy). An abstract for an oral presentation has also been accepted for the UrbanRain12 Workshop taking place in San Moritz in December 2012. Additional presentations are planned at the American Meteorological Society conference in Atlanta (Jan 2012) and a planned session on Solid Precipitation measurement organized at the Congress of the Canadian Meteorological and Oceanographic Society (CMOS), in June 2013.

11.5 All project team members are strongly encouraged to actively promote the SPICE objectives, activities, and results, within the context of the SPICE Data Protocol

SPICE Project Team Co-Lead

11.6 The IOC agreed to establish a SPICE Project Team which will include representatives of the IOC, representatives of the Intercomparison Sites, and other nominated experts who, together, will deliver on the SPICE objectives. The SPICE Project Team reports to the IOC. The project Team is lead by the Project Lead and a project Co-Lead. As decided at the First Meeting of the SPICE IOC, Ms Rodica Nitu is the Project Lead. Dr Roy Rasmussen, who was named as the Project Co-Lead for the pre-SPICE will continue in this role during the formal phase of SPICE.

Next meeting

11.7 The next meeting of the IOC is planned for October 15, 2012, in the context of the WMO-CIMO TECO-2012 conference taking place in Brussels, Belgium. This venue was chosen to take advantage of the presence of a number of IOC members and manufacturers at TECO-2012, which is organized in conjunction with the Meteorological Technology World Expo. The representatives of the participating manufacturers will be invited to participate at this meeting. The WMO Secretariat will make arrangements with the conference organizers to reserve space for the meeting.

11.8 A SPICE website is hosted by WMO, and will be used to distribute public documents related to the project organization and delivery. The site address is http://www.wmo.int/pages/prog/www/IMOP/intercomparisons/SPICE/SPICE.html

12. DRAFT REPORT OF THE SESSION

The meeting decided to finalize some decisions by teleconference in the weeks following the meeting and agreed to review and approve the report of the session, including relevant outcomes of teleconferences, by correspondence.

13. CLOSURE OF THE SESSION

The session closed on Friday, 15 June 2012 at 15:10 hours.

ANNEX I

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ANNEX II

PROPOSED CONFIGURATION OF INTERCOMPARISON SITES AND OF THE FIELD REFERENCES (Reproduced from SPICE-IOC-1 Final Report)

Field Reference for the Measurement of Precipitation Amount

For the Solid Precipitation Intercomparison (1989-1993), the IOC designated the following method as the reference for the Intercomparison and named it as the _Double Fence Intercomparison Reference (DFIR)_:

> *"The octagonal vertical double-fence inscribed into circles 12 m and 4 m in diameter, with the outer fence 3.5 m high and the inner fence 3.0 m high surrounding a Tretyakov precipitation gauge mounted at a height of 3.0 m. In the outer fence there is a gap of 2.0 m and in the inner fence of 1.5 m between the ground and the bottom of the fences." (*WMO/TD-872/1998, section 2.2.2)

At the conclusion of the intercomparison, it was recommended that "*The Double Fence Intercomparison Reference (DFIR) should be accepted as a secondary reference for the (manual) measurement of solid precipitation*;" (section 6.1.2 of WMO/TD-872/1998)

For the purposes of SPICE, the IOC decided that a working field reference with a higher temporal resolution and using an automatic gauge is needed. The IOC decided that the working field reference for this experiment has to be configured similarly to the secondary field reference. The proposed definition of this working field reference is:

> *The octagonal vertical double-fence inscribed into circles 12 m and 4 m in diameter, with the outer fence preferably 3.5 m high, and the inner fence preferably 3.0 m high, (DFIR) surrounding an automatic weighing precipitation gauge mounted at a height of, preferably, 3.0 m. The automatic weighing gauge will be installed with a typical shield".*

The exact height of each of the fences and of the gauge may have to be adjusted to account for the local climate conditions (increased amount of snow on the ground, high winds, etc).

The automatic gauge used for reference is a weighing gauge with a wide operational use and sufficient history and characterization to give confidence in its performance. The CIMO Survey conducted in 2008 (published in WMO IOM 102/2010) indicate that weighing gauges from the following manufacturers were in use operationally, at that time: Geonor 37%; OTT Pluvio 40%) MPS Systems 7%, Meteoservis 2%, Vaisala VRG101 4%.

Based on these results, most likely candidates are Geonor T-200 (with three transducers) or Pluvio-2 from OTT.

The model and the configuration of the weighing gauge will be identified by the IOC at the end of the Pre-SPICE experiment of 2011/12. Rational on the selection made will be provided as part of the decision.

The IOC recommended that the automatic gauge used for the field reference may require heating. If warranted, the heater configuration and the heating algorithm will be developed and accepted by the IOC based on the current practice implemented operationally in various countries and the results of the 2011/12Ppre-SPICE experiment.

Configurations of Field References

In the context of the multi-site organization of SPICE, the IOC recognized the need to develop a flexible approach for the configuration of the field references. This would allow to link the results of SPICE with those from the previous intercomparison, provide a working field reference with an increased time resolution, and ensure the transferability of the results from the participating sites, while recognizing the physical limitations on some of the sites.

Taking into account these expectations, the following three configurations of the SPICE field reference are endorsed:

- R1: DFIR + Tretyakov gauge (manual measurements)+Tretyakov shield, designated in the 1989-1993 intercomparison as secondary field reference WMO/TD-872/1998);
- R2: DFIR + automatic weighing gauge (AWG) + shield; the model and the configuration of the AWG and its shield will be determined at the end of the 11/12 pre-SPICE experiment.
- R3: A combination of automatic weighing gauge(s) and windshields with sufficient characterization and history, to have a degree of confidence for the purpose of meeting specific objectives, as agreed between the host country and the IOC. The characterization of R3 must be done in relation to the R1 and R2, and could be done as part of SPICE. This is a pragmatic approach for sites contributing to meeting the SPICE objectives (e.g. complex terrain with heavy wet snow), but where the installation of a DFIR is not feasible.

In addition to the typical accumulation gauge, other instruments may be considered important in better characterizing the reference for the measurement; e.g. disdrometers, video cameras, etc.

Intercomparison Site Configuration

Given the proposed configurations of the SPICE field reference, defined above, the following configurations of the intercomparison sites, are possible:

- S1: those sites where references type R1, R2 and R3 are available; the presence of R3(s) will allow its characterization against the R1 and R2;
- S2: those sites where references type R2 and R3 are available (no manual measurements, being made); the presence of R3(s) will allow its characterization against the R2;
- S3: those sites where, due to the site limitations only field references type R3 are feasible.

The presence of R3 on sites type S1 and S2, will enable the transferability of results between the participating sites, by enabling the characterization of R3 as a function of the R1 and R2.

The site and reference nomenclature has been introduced to allow an easy differentiation between different configurations, and is not intended as a classification mechanism.

The configuration of the instruments evaluated on each site will depend on the site capacity, local conditions, the experiment objectives attributed to the site, the availability of the instruments, the national objectives, and the desired contribution.

Each or some of the intercomparison sites may have specific measurement objectives, as agreed between the hosting country and the SPICE IOC, for example:

- Sites with a predominance of precipitation climates – dry, wet, light, heavy, mixed or blowing
- Sites with peculiar weather regimes – Arctic, Mountain, Ocean, etc

The intercomparison sites will be configured with instruments under test and auxiliary measurements, which will allow meeting the agreed site specific measurement objectives. Some examples of potential site specific objectives are:

- measurement and reporting of snowfall and snow on the ground;

- assessing different shield configurations (e.g. one gauge type in multiple configurations on a site with a wide range of wind regimes);
- assessing heating solutions for gauges;
- assessing emerging technologies (non-catching type).

Field Reference for the Snow on the Ground
Recommended reference: snowboard measurements (manual measurements) supported by an array of ancillary measurements.

Field reference for the observation of precipitation Intensity/Rate

Precipitation intensity is defined as the 1 minute sum in units of [mm/h].
At the minimum, the recommended reference is the AWG in a DFIR fence.

ANNEX III

Requisite Ancillary Parameters (by Site Type[*1]) for Amount of Precipitation ONLY

Parameter	**S3 (Basic site)**	**S2 (Reference Auto)**	**S1 (Reference incl. manual)**
Temperature	X	X	X
Relative humidity	X	X	X
2D winds at the orifice of the gauges (speed; direction)	X	X	X
Snow depth auto (different from the SD sensors under test)	X	X	X
Capacitive Precipitation detector (absence / presence)	X	X	X
Site wind (10m) speed and direction	X[*2]	X	X
Net Radiation	desirable	X	X
Visibility (to establish the relationship to snowfall – assess the practice of use to estimate the snowfall; assess sources of errors (detect fog and its impact on measurement)	desirable	X	X
Cameras Web / video / still	X[*2]	X	X
Micro physical (any method e.g. Auto or manual) vertical particle velocity, precipitation type; Manual obs of precip type;		X	X
SWE observations (either manual or automatic): this is the water equivalent of the entire snow pack on the ground at the time of the measurement.		X[*2]	X[*2]
Wet bulb temperature: derived	x	x	x
Manual observations of selected parameters: precipitation type, snow course, snow depth, assessment of snow drift, blowing snow, etc:			X
Optical Precipitation detector (absence / presence)		X	X

[*1] Site type as per the proposed structure in Annex II of this report.
[*2] Not mandatory, but highly desirable

ANNEX IV

Intercomparison Objectives

WMO-SPICE will focus on the following key objectives:

I. Recommend appropriate automated field reference system(s) for the unattended measurement of solid precipitation. Define and validate one or more field references using automatic instruments for each parameter being investigated, over a range of temporal resolutions (e.g. from daily to minutes).

II. Assess/characterize automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as “black boxes”):

   a. Assess the ability of operational automatic systems to robustly perform over a range of operating conditions;
   b. Derive adjustments to be applied to measurements from operational automatic systems, as a function of variables available at an operational site: e.g., wind, temp, RH;
   c. Make recommendations on the required ancillary data to enable the derivation of adjustments to be applied to data from operational sites on a regular basis, potentially, in real-time or near real-time;
   d. Assess operational data processing and data quality management techniques;
   e. Assess the minimum practicable temporal resolution for reporting a valid solid precipitation measurement (amount, snowfall, and snow depth on the ground);
   f. Evaluate the ability to detect and measure trace to light precipitation.

III. Provide recommendations on best practices and configurations for measurement systems in operational environments:

   a. On the exposure and siting specific to various types of instruments;
   b. On the optimal gauge and shield combination for each type of measurement, for different collection conditions/climates (e.g., arctic, prairie, coastal snows, windy, mixed conditions);
   c. On instrument specific operational aspects, specific to cold conditions: use of heating, use of antifreeze (evaluation based on its hygroscopic properties and composition to meet operational requirements);
   d. On instruments and their power management requirements needed to provide valid measurements in harsh environments;
   e. on the use of visibility to estimate snowfall intensity
   f. On appropriate target(s) under snow depth measuring sensors;
   g. Consideration will be given to the needs of remote locations, in particular those with power and/or communications limitations.

IV. Assess the achievable uncertainty of the measurement systems evaluated during SPICE and their ability to effectively accurately report solid precipitation.

   a. Assess the sensitivity, uncertainty, bias, repeatability, and response time of operational and emerging automatic systems;
   b. Assess and report on the sources and magnitude of errors including instrument (sensor), exposure (shielding), environment (temperature, wind, microphysics, snow particle and snow fall density), data collection and associated processing algorithms with respect to sampling, averaging, filtering, and reporting.

V. Evaluate new and emerging technology for the measurement of solid precipitation (e.g. non-catchment type), and their potential for use in operational applications.

VI. Configure and collect a comprehensive data set for further data mining or for specific applications. Enable additional studies on the homogenization of automatic/manual observations and the traceability of automated measurements to manual measurements.

5. Deliverables

WMO-SPICE will provide reports on the intermediate and final results of the experiment covering the following aspects;

a. Recommendations of automatic field references systems, for the unattended measurement of the parameters evaluated;
b. Characterization of the performance of existing, new, and emerging technologies measuring solid precipitation, and their configurations, addressing the objectives of the intercomparison.;
c. A comprehensive data set for legacy use, for further data mining.
d. Update of relevant chapters of the CIMO Guide (WMO No 8) and potential publications of WMO/ISO standards (under the WMO-ISO agreement, 2009).
e. Guidance to Members on transition to automation from manual observations of solid precipitation measurements;
f. Recommendations made to manufacturers on instrument requirements and improvements.

ANNEX V

AUSTRALIA

Site Name: Guthega Dam weather station, Kosciuszko National Park, New South Wales
Proponent: Snowy Hydro Limited

Site Location

Latitude: 36.3773°; Longitude: S 148.3706°; Elevation: 1586 m

Site Climatology

Most of the year's snow is received between May and September, although snow may fall year-round. The majority of significant wintertime precipitation events occur during the passage of westerly frontal systems.

Data from this site are used in the Snowy Precipitation Enhancement Research Project (SPERP). See Manton et al (2011) (DOI: 10.1175/2011JAMC2659.1)

Site References

- Field Reference: DFIR operational since 2006; Gauge: ETI NOAH II with Alter shield, orifice at 3 m above ground
- Other field reference currently on site: Half DFIR (6 m diameter) using a ETI NOAH II, Gauge orifice 3 m above ground with an Alter shield;
- ETI NOAH II, Gauge orifice 3 m above ground with an Alter shield;
- Reference for the measurement of snow depth: NO.

Motivation

Three areas of particular interest:

- 1) potential use of adjustments for operational data (SPICE objective II a-d);
- 2) gauge siting and exposure (SPICE III a-f);
- 3) instrument and measurement error (SPICE IV).

In addition to the specific interests listed above, Snowy Hydro is interested in contributing to, and learning from, any other aspect of SPICE where appropriate.

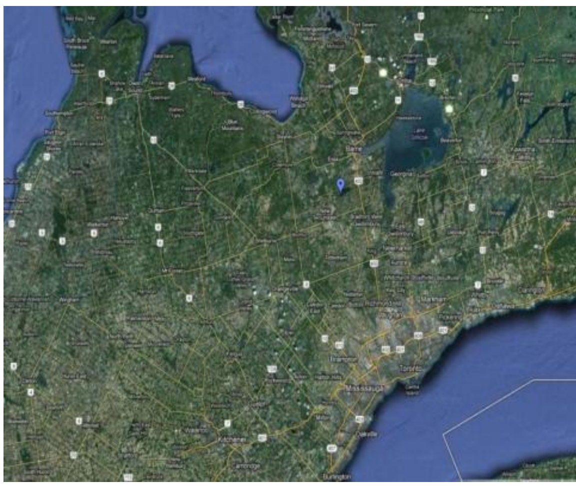
ANNEX VI

CANADA

Centre for Atmospheric Research and Experiments (CARE), Egbert, ON

The facility is a test site to evaluate new instruments and measurement methods for national weather monitoring programs. The Centre is a base for monitoring networks (Reference Climate Station).
The site hosted the GCPEX study in 2012 and participated in the 1st WMO intercomparison of solid precipitation.

Site Location
Latitude : 44° 14' 00.000" N, Longitude : 79° 47' 00.000" W, Elevation: 251 m



Site Climatology
The climate is classified as humid continental.
Daily mean wind speed (Nov-April): 3.5 m/s to 4 m/s.
Total average Snowfall, annual: 157 cm
Daily average temperature: -8.2 °C (Jan); 1.9 °C (Nov)

Site References
The CARE test site has the following references for the measurement of precipitation amount:

- A DFIR (Double Fence Intercomparison Reference) with a manual Tretyakov gauge and Tretyakov shield, 3 meters off the ground.
- A DFIR with a GEONOR T-200B series precipitation gauge with a US-CRN model heated rim, 600 mm capacity and three vibrating wire transducers. The height of the sensor is 3 m. The Geonor is surrounded by an Alter shield, built according to the Geonor shield specifications.

Reference for the measurement of snow on the ground:

- Manual measurement program, using 30 MSC Wooden Snow Stakes, marked, with a reporting resolution of 0.5 cm.
- Video camera

Site Capacity
Total site capacity: 49 instrument pads with power and data communication
Pads available for additional instruments selected for the intercomparison: up to 10

Motivation

- Define appropriate automated field reference system(s) for the unattended measurement of solid precipitation.
- Assess/characterize automatic systems (both the hardware and the associated processing) used in operational applications, as well as new and emerging technologies.
- Assess/characterize best practices and configurations for measurement systems in operational environments.
- Derive adjustment curves to account for gauge undercatch.
- Focus on snow depth measurement and the derivation of snow fall.
- Other projects planned to take place on site: assessment for procurement of precipitation sensors for the national networks.

Bratt's Lake, Saskatchewan, Canada

Site Location
Latitude : 50.2005°N, Longitude : 104.7113°W, Elevation: 585 m

The Bratt's Lake precipitation intercomparison facility is located 36 km south of Regina, Saskatchewan, Canada. The site is in an agricultural landscape with surrounding vegetation typically less than 1m in height. The topographical relief is small, with elevation changing less than 1 m per km.

Site Climatology
With low vegetation and large fetch, the wind speeds at the site are relatively high, with 10 m daily average wind speeds exceeding 5 m/s. Average annual snowfall is approximately 106 cm, with an average annual temperature of 2 °C.

Site References
The intercomparison facility has been operating since 2004 and hosts two DFIR wind fences. Historically, the objective of intercomparisons at the site were to develop wind speed - catch efficiency relationships for snowfall measured with the Geonor T-200B precipitation gauges in various wind shield configurations.

Site Capacity
The Bratt's Lake precipitation intercomparison facility has capacity for about 20 precipitation instruments with, 13 pedestals available for additional instrumentation. The site also hosts a Canadian Reference Climate Station (RCS).

Oblique photo of Bratt's Lake Intercomparison Facility

Caribou Creek, Saskatchewan, Canada
Site Location: 53.9447°N, 104.6493°W

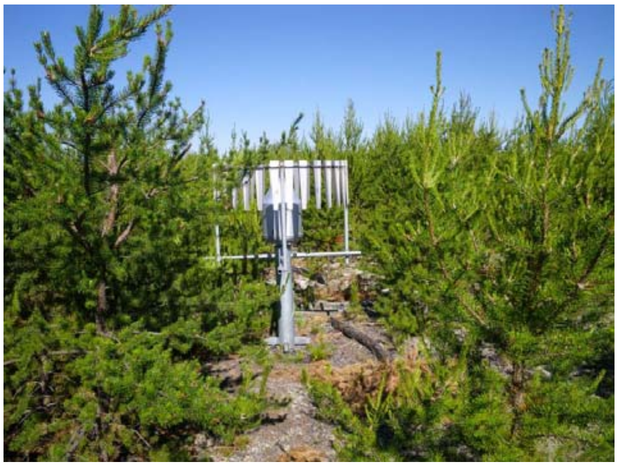
The planned Caribou Creek intercomparison facility will be located at an Environment Canada research site in the southern boreal forest, approximately 280 km north-east of Saskatoon, Saskatchewan. Predominate vegetation in this region is mature Jack Pine. However, this site was situated in the centre of an area harvested in 2002 with naturally regenerating growth now approaching heights of 2.5 m.

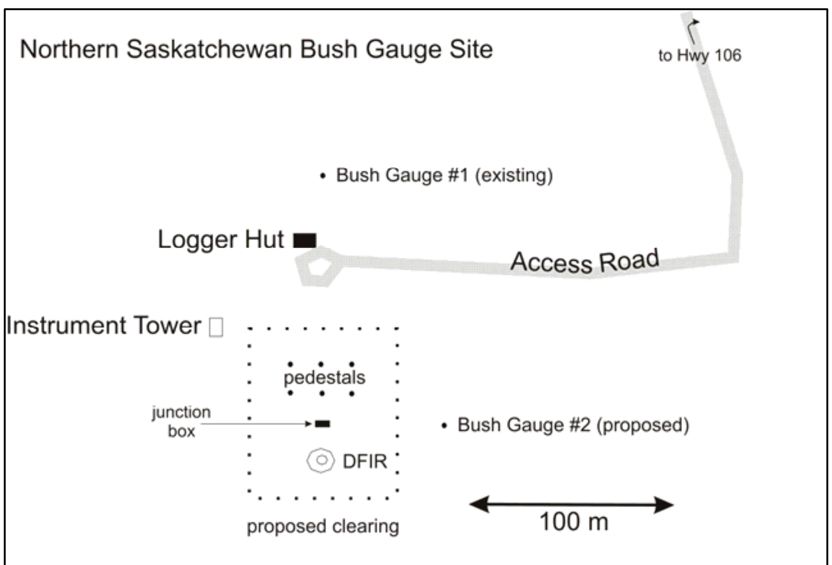
Site Climatology

The average annual temperature at the Caribou Creek site is 0.7 °C and it receives approximately 130 cm of snowfall per year, with persistent snow pack from November through April.

Site References

This planned intercomparison facility is unique in that the post-harvest vegetation has grown to the level of 2 to 2.5 m, which is the typical height of a precipitation gauge orifice. The height of the vegetation and the vegetation density make this an ideal site for intercomparisons with a bush shielded gauge. The planned facility will include two bush shielded gauges and a clear-cut area that will accommodate a DFIR shielded gauge, as well as up to six additional instruments for intercomparison.





Caribou Creek: site layout

ANNEX VII

CHILE

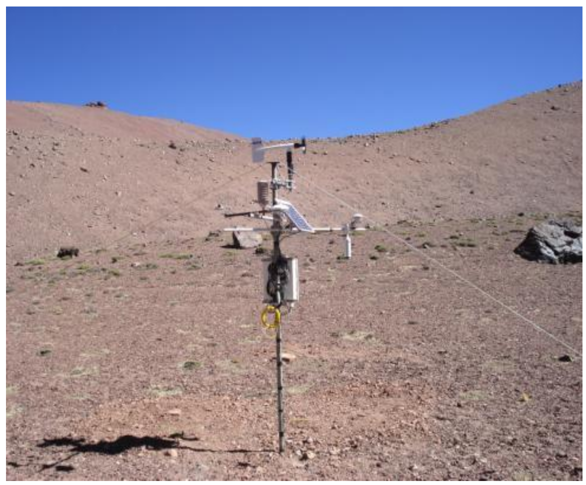
Tapado AWS, Valle de Elqui, Región de Coquimbo, Chile
Proponent : Centro de Estudios Avanzados en Zonas Áridas

The site is primarily used as part of a glacier research programme. The location offers the ability to understand snow processes in a high elevation, semi-arid region, where snow contributes the bulk of the water available in the wider catchment.
Two projects are currently in progress at this site:

- Modelling glacier meltwater production in the dry Andes (PI: Dr. Shelley MacDonell; funded by the Fondo Nacional de Desarrollo Científico y Tecnólogico (FONDECyT 3110053))
- Caracterización y monitoreo de glaciares rocosos en la cuenca del Río Elqui, y balance de masa del Glaciar Tapado [*Characterization and monitoring of rock glaciers in the Elqui River catchment, and mass balance of the Tapado Glacier*] (PI: Dr. Christophe Kinnard; funded by the Dirrección General de Aguas)

Site Location

Latitude: 30º 9' 30"S; Longitude: 69º 54' 30"W; Elevation: 4318 m ASL



Site Climatology

Winter snow is associated with the passage of low pressure troughs from higher latitudes, with few events per winter (five expected). In the summer, snowfall is associated with the Altiplano winter and convective events from the eastern side of the Andes.
Daily average temperature, May to Sept: -9.1 °C (July); -3.0 °C (May)
Total average snowfall: 94.6 cm (July); 32.4 cm (Sept)

References on Site

The site is situated in a remote location and is an operational station for research purposes. Due to the rugged terrain, the instruments are installed on a mast.
The measurement of Snow on the Ground takes place at the end of winter using avalanche probes. One camera is situated approximately 200 m away from the station and takes daily photos of the glacier catchment, which can be used to assess snow coverage. There is potential to attach another camera to take photos from the station.

Motivation

Interested in SPICE objective IIf
SPICE Objectives of primary interest: I, IIa, IIb, IIf

ANNEX VIII

FINLAND

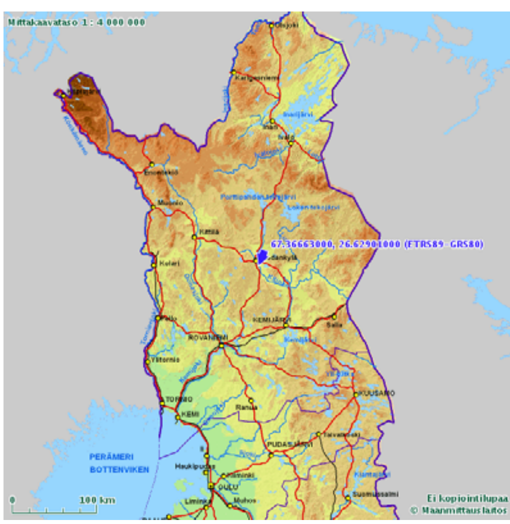
Site Proposed: FMI/Sodankylä Arctic Research Centre (ARC)
Proponent: Finnish Meteorological Institute

Sodankylä is a supersite for satellite data calibration-validation activities and has several on-going satellite cal-val programs (WMO GAW - Global Atmospheric Watch). The programs are involved with remote sensing of snow, soil moisture, permafrost and atmospheric constituents.

Also on site is the EU SNAPS - Snow, Ice and Avalanche Applications project which will focus on snow and avalanche services for transport infrastructure. Near-real time snow cover maps will be produced and further developed to become an input to snowdrift and avalanche forecasts aimed at e.g. transport authorities.

The Academy of Finland ClimWater Project on site focuses on development of methodology using remote sensing for water circulation in a Boreal region. In Boreal regions, precipitation (water/snow), temperature, ice coverage of the lakes, wind, frost, soil humidity and flood reserves are the key factors that affect water circulation.

Site Location
Latitude : 67° 21' 59.87", Longitude : 26° 37' 44.44", Elevation : 179 m



The site is in the middle of the Boreal forest (pine); an open space with a diameter of 80 m; the forest around the site is about 15 -18 meters high.

Site Climatology
Daily mean temperature Nov to April: -13.5 °C (Jan); -1.3 °C (April)
Total average snowfall: 33 cm (Jan); 16 cm (April)
Daily mean wind speed (Nov to April): 2.6 to 2.9 m/s

Site References
The site will have with a DFIR and an automatic weighing gauge, surrounded by an Alter shield.
For the measurement of snow on the ground, the site will run a manual measurement program.
The site hosting the SPICE experiment will be developed during 2012, and will include a DFIR equipped with a Pluvio^2 automatic weighing gauge. The 400 cm^2 Pluvio^2 is currently deployed in the national networks of the FMI, as opposed to the 200 cm^2 model recommended for the R2 reference configuration in Section 5.2.5.

Site capacity

The site will be configured during the summer of 2012 and will have sufficient capacity to meet the needs of SPICE.

Motivation

All the documented Spice objectives are valid and important for FMI, but the most important are:

II. Assess/characterize automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as "black boxes"):

a. Assess the ability of operational automatic systems to robustly perform over a range of operating conditions;

d. Assess operational data processing and data quality management techniques;

e. Assess the minimum practicable temporal resolution for reporting a valid solid precipitation measurement (amount, snowfall, and snow depth on the ground);

IV. Assess the achievable uncertainty of the measurement systems included in SPICE and the ability to effectively report solid precipitation:

a. Assess the sensitivity, uncertainty, bias, repeatability, and response time of operational and emerging automatic systems;

V. Evaluate new and emerging technology for the measurement of solid precipitation (e.g. non-catchment type), and their potential for use in operational applications.

Primary focus desired:

Research and development of satellite data calibration and validation methods and instrumentation. Sodankylä ARC has a strong background in the field of snow research in a harsh arctic environment. Sodankylä ARC's first priority is snow and hydrology research and their climatological impact.

ANNEX IX

JAPAN

Site 1: Joetsu
Proponent: National Agriculture and Food Research Organization (NARO), Agricultural Research Center

Site Location
Latitude: 37 08' 45"; Longitude: 138 16' 31"; Elevation: 11 m

The terrain is the paddy field zone of a plain.
Current programs on site:

- Operating observation field of a research centre
- Routine detailed meteorological and snowpack observations
- Operational Station of the Japan Meteorological Agency (JMA).

Site Climatology
The climate in the area is snowy and cloudy almost all days throughout the winter, with very frequent continuous snowfall. Dry snow, wet snow, rimed snowflakes, graupel, sleet, and rain are observed.
Daily mean temperature (Dec-March): 2.4 °C (Jan, Feb); 5.3 °C (Dec)
Total average snow fall: 247 cm (Jan); 635 cm (annually)
Total amount of precipitation: 423.1 mm (Dec), 419 mm (Jan)
Daily mean wind speed: 2.6 m/s (Dec, Jan)

Site Reference
The site has a DFIR with a Tretyakov gauge combined with automatic weighing gauge (Meisei electoric QW-90S). The gauge is equipped with a Tretyakov shield.
The site has manual measurements of snow depth using snow depth stakes and snow boards. The measurements are conducted daily, at 00 UTC.
No cameras are available on site.
The proponent could add a field reference, as recommended by SPICE IOC, as long as the facility does not affect other meteorological and snowpack observations.

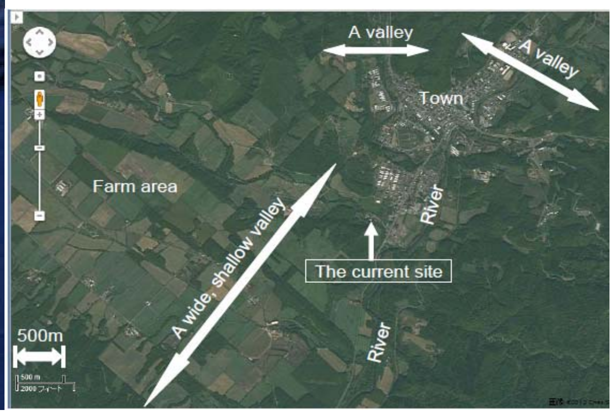
Motivation
The objective of primary interest is assess/characterize automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as "black boxes")

Interested in contributing to the assessment of automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as “black boxes”).

Site 2: Rikubetu, Ashorogun, Hokkaido
Proponent: National Institute of Polar Research (NIPR), 10-3, Midoricho, Tachikawa, Tokyo.

Current activities on site consist of routine meteorological and snowpack observations, including a station operated by JMA near the site.

Site location
Latitude: 43 28' 00"; Longitude: 143 44' 12"; Elevation: 200 m



The site is on the bottom basin of a valley with a width of about 5-6 km, mainly occupied by farms. It is currently only a candidate site, with the potential for another site in this area with almost the same conditions. The height of the watershed surrounding the basin is approximately several hundred metres.

This site is currently operated as part of an ongoing project.
In parallel, the proponent is investigating the feasibility for an alternate site near the existing one, in order to extend the set of observations available, as well as to allow for installing a DFIR.
The site is accessible by car.

Site Climatology
One of the coldest areas in Japan. The winter temperature often goes down below -20 °C in early morning. The snowfall amount is not significant, with a maximal snow depth around 50 cm throughout winter. Winds are not overly strong, and are often calm at night. The weather is rather stable, but moderate storms can occur about 10 times during winter, which contribute a large component of the annual snowfall amount.

Daily average temperature (Dec-March): -11.4 °C (Jan); -3.7 °C (March)
Daily mean wind speed: 1.2 m/s (Dec); 1.8 m/s (March)
Total average snowfall, per month (Dec to March): 86 cm (March); 106 cm (Jan)
Total average precipitation (annually): 799.8 mm

Site Reference
The proponent plans to install a field reference with an automatic weighing gauge, but the details have not yet been decided

The proponent intends to install a field reference recommended by the SPICE IOC, based on its feasibility.

No snow depth measurements are available at this site.

Motivation

The proponent is interested in participating in SPICE, and contribute to the assessment and characterization of automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as “black boxes”)

ANNEX X

NEW ZEALAND

Proponent: National Institute of Water and Atmospheric Research Ltd
Site: Mueller Hut Electronic Weather Station (Part of National Climate Network)

Site Location
Above tree line; Latitude: -43.72154 (S), Longitude: 170.06493, Elevation: 1818m

Site Climatology
Terrain: Rock, snow covered during winter and spring. Typically late melt (November/December).

Site References
Because of the remoteness of the site and the lack of access, a DFIR is not feasible on this site. For the measurement of precipitation on site, an OTA tipping bucket rain gauge is used – the oifice is at 3.5m above bare ground. A SR50A sonic ranger is positioned 3m above ground and directly above a 12 ft Hypalon Pillow with a Druck pressure sensor.
Manual measurement of snow depth is done only sporadically.

Motivation
All SPICE objectives are of interest, however, 1,5 and 6 would be priorities for NIWA.
The site will continue to operate during SPICE as part of a suitable high altitude network of climate stations.

ANNEX XI

NORWAY

Proponent: Norwegian Meteorological Institute (met.no)
Proposed site: Haukeliseter, E134, Vinjeveien, Telemark, Norway

Current projects
During the SPICE experiment, the existing projects (National Project on Wind Correction of Precipitation and Avalanche Warning Site) will continue.

Site Location
The site is located on a relative plateau in the mountains, well above the tree line. The overall size of the site is 4500 square meter, flattened area.
Latitude: 59 48.72; Longitude: 7 12.81; Elevation: 990m

Site Climatology
The estimated mean annual air temperature (MAAT, 1961-1990) for the site is 0.6 °C. Mean monthly temperatures are below 0 °C for the period November to April, with an estimated mean air temperature (1961-1990) of -5.4 °C. The estimated uncorrected annual precipitation (1961-1990) is approximately 800 mm, of which more than 50% is solid precipitation. In a normal winter, the average snow depth reaches approx. 1.5 – 2 m. The daily average 10m wind speed is 5 m/s (based on winter observations 1984-1995).

Site References
The site has a DFIR-shield with a GEONOR T-200BM (1000mm, 3 transducers). The orifice height is at 4.55m.
The reference-gauge is surrounded by an Alter shield, of standard Geonor configuration.
An additional R3 reference will be installed.
No manual measurements of precipitation amount or snow on the ground are available on site.
An ACTI CAM 6630 videocamera is planned to take hourly pictures from chosen locations.

Motivation
The Norwegian Meteorological Institute is interested in the following SPICE objectives:
I. Recommend appropriate automated field reference system for the unattended measurement of solid precipitation;

IIb. Derive adjustments to be applied to measurements from operational automatic systems, as a function of variables available at an operational site;
IId. Assess operational data processing and data quality management techniques;
IIe. Assess the minimum practicable temporal resolution for reporting a valid solid precipitation measurement;
IIIb. Provide recommendations on best practices and configurations on the optimal gauges and shield combination for each type of measurement for different collection conditions/climates.
IIIc. Provide recommendations on best practices and configurations on instrument specific operational aspects, specific to cold condtions: use of heating, use of antifreeze
IIIf. Provide recommendations on best practices and configurations on appropriate target(s) under snow depth measuring sensors.
IV Assess the achievable uncertainty of the measurement systems included in SPICE and the ability to effectively report solid precipitation.

ANNEX XII

POLAND

Proponent: Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB)
Proposed Site 1: Hala Gasienicowa station
Proposed Site 2: Zakopane station

Site 1: Hala Gasienicowa station

This is an existing synoptic station, staffed 24h, situates in a natural environment, uncluttered, mountainous area.

Site location

Latitude: N 49, 14, 39; Longitude: E 20, 00, 21; Elevation: 1520 m ASL

Site Climatology

The site is located in a mountain valley, subalpine zone, with a cool climate

- average daily temperature (Dec to April): -5.3 °C to 1.3 °C
- Total average precipitation (Dec to April): 68.6 mm to 114.3 mm
- Extreme Snowfall (Dec to April): 124 cm to 221 cm.

Site References

The site does not have a DFIR. Currently, the measurement of precipitation is achieved using an ASTER TPG-037-H24 rain-gauge. Additionally, precipitation amount is measured using a Hellmann rain gauge, three times per day.

For the measurement of snow on the ground, the site runs daily manual measurements, once per day, using snow stakes, as part of the operational program. No cameras are available on site.

Site 2: Zakopane station

The site is at an existing synoptic station, staffed 24h.

Site location

Latitude: N 49, 17, 38; Longitude: E 19, 57, 37; Elevation: 845 m ASL

The site is located in an urban area, in the foothills, with a forested area 2 km away.

Site Climatology
The climate at the site is moderately cool climate

Site References
The site does not have a DFIR. Currently, the measurement of precipitation is achieved using an ASTER TPG-037-H24 rain-gauge. Additionally, precipitation amount is measured using a Hellmann rain gauge, three times per day.

For the measurement of snow on the ground, the site runs daily manual measurements, once per day, using snow stakes, as part of the operational program. No cameras are available on site.

Motivation
Participation in the project will allow examining the structure and distribution of liquid and solid precipitation. It will also help to determine the impact of local conditions on the amount of rainfall and its effect.
The program implementation will also help to identify differences in the amount of rainfall using different types of rain gauges.

ANNEX XIII

RUSSIAN FEDERATION

Proponent: Roshydromet

Proposed Sites:
Site 1: Valdai, State Hydrological Institute, Valdai Branch.
Site 2: Voljskaya Hydro Meteorological Observatory, Gorodec, Nijny Novgorod Reg., Russia

Site 1: Valdai, State Hydrological Institute, Valdai Branch.
The site hosted the WMO Intercomparison for solid precipitation 1987-1993. Also on the site is the only bush gauge, which represents the primary field reference for the measurement of solid precipitation.
Currently on site, a project assessing the possibility of using the OTT Pluvio^2 gauge in the natural settings of the Russian Federation for scientific and practical purposes, is conducted.

Site Location
Latitude: 57º 59', Longitude: 33º 15'; Elevation: 194 m above sea level

The research district where the precipitation station is located lies on the north-western part of the Eastern European plain, in the Valdai hills.

Site Climatology
Semi-continental, fairly humid. The coldest month is January (average monthly temperature: -9,1 °C). A steady snow cover is usually observed from the last ten days of November until mid-April. The deepest snow cover occurs towards the end of the first ten days in March and measures 71cm.. The annual average wind speed is 3.4 m/s. The highest wind speed in winter is on average 4.0-4.5 m/s.

Site References
The site has manual gauges installed in an area with shrubs maintained at the gauge level, which constitute the primary field reference for the measurement of solid precipitation.
Additionally, the site has a DFIR with a manual Tretyakov collector and a Tretyakov shield. This has been operational 1970 - 1976, 1988 – 2010.
The site has 6 Tretyakov precipitation gauges (orifice area: 200 cm^2) with standard shield,
3 bush–sheltered Tretyakov gauges, and 1 Nipher precipitation gauge (500 cm^2).
No DFIR with an automatic gauge is currently available on site. There is no indication of the potential for installing one at this time.
The proponent is willing to configure a field reference on site, based on the recommendation of the SPICE IOC.

Site 2: Voljskaya Hydro Meteorological Observatory, Gorodec, Nijny Novgorod Reg., Russia
Activities on site:

- Routine meteorological and hydrological measurements (7 days a week,)
- Intercomparisons of liquid precipitation sensors.
- Atmospheric electricity research (joint program with Russian Academy of Science)

Site Location
Latitude: 56 º 41'; Longitude: 43º 26'; Elevation: 101m

The observatory is located on the high and steep right bank of the Volga River (Gorky Reservoir). It is a wooded area of mixed forest, but the regional forest cover is only 15%. In the area where the site is located, the vegetation consists of deciduous trees up to 20 m high and bushes, which surround the site on three sides.

Site Climatology
The climate is moderately continental, humid, with relatively warm summer months and relatively cold and snowy winter. Cyclonic activity is prevalent most of the year. The air temperature fluctuates between -45 °C and 38 °C. The coldest month is January. A steady snow cover is usually observed from mid-November to the first ten days of April. The maximum depth of the snow cover occurs around mid-March and reaches 89 cm. Annual mean wind speed: 2.1 m/s. Maximum wind speed in winter: 2.6-2.7 m/s. Recurrence of windless days: 8%.

Site References
The site has a DFIR with a manual Tretyakov collector and a Tretyakov shield, operational since 1957.
No DFIR with an automatic gauge is currently available on site, although there is an indication that the proponent will be able to install one in the near future.
The proponent is willing to configure a field reference on site, based on the recommendation of the SPICE IOC.

On the site, manual measurements of snow on the ground are completed ever 3 hours, using a metric mast. In addition, a video camera is available on site.

Motivation:
SPICE Objectives of primary interest for the proponent: Intercomparison of different types of sensors with different physical principles of measurement with the aim of improving the national observational network.

Topic of primary interest for the proponent: Automatic measurements of snow depth

Other activities organised in parallel with SPICE: Microwave remote measurements of snow water equivalent from mobile snow platform.

ANNEX XIV

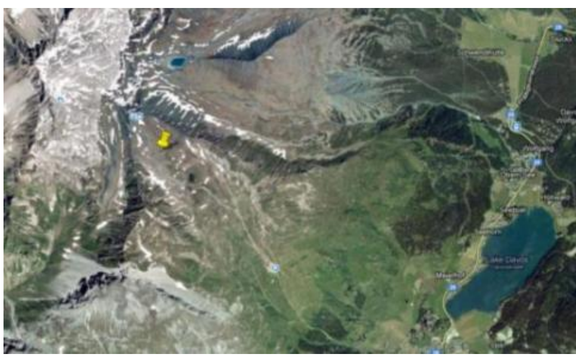
SWITZERLAND

Proponent: MeteoSwiss
Site Proposed: Weissfluhjoch (Davos)

Existing site used by the Swiss Institute for Snow and Avalanche Research (SLF), fully equipped for other projects The site is proposed in a partnership between MeteoSwiss and the Swiss Institute for Snow and Avalanche Research, which has extensive experience in measuring solid precipitation and great interest in SPICE.
The site will be expanded in 2012 to add the required configuration for a SPICE host site.
Planned site capacity for hosting SPICE provided sensors: up to six instrument pads.

Site Location
Latitude: 46°49’46 N; Longitude: 9°48’33 E; Elevation: 2500 m asl

The site is on a flat part of the mountain. No vegetation, except small amounts of grass.
Various topographical obstacles (mountain ridge) to the East and West, about 500m from the site.
The site is located a few kilometers above Davos, and is reachable by train and ski lift.



Site Climatology
Alpine climate, usually large amounts of snow in this part of the Alps

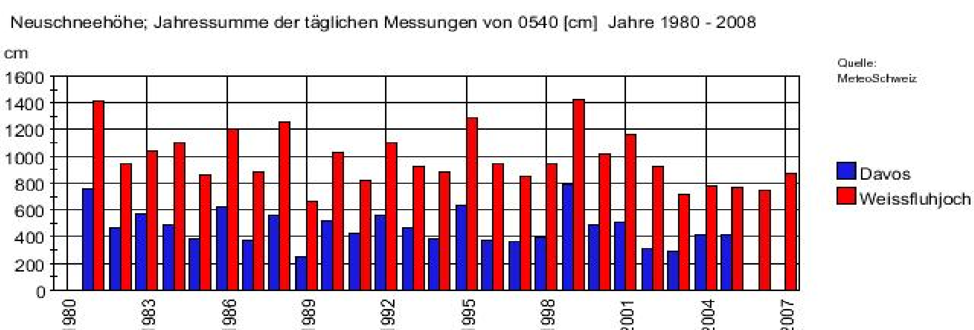


Figure 1: Yearly snow accumulation

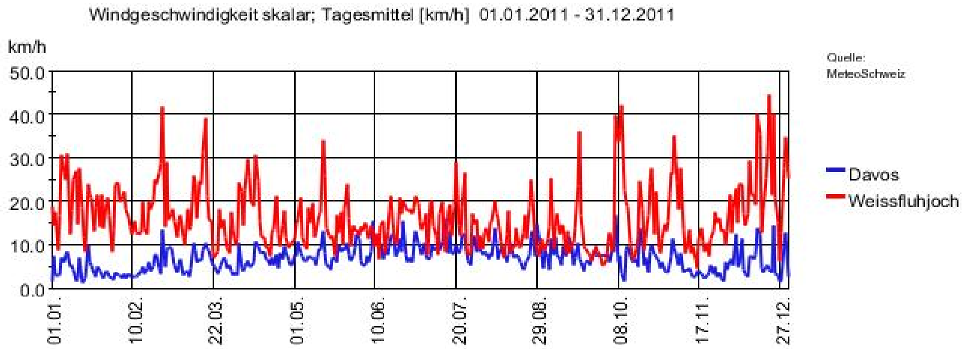


Figure 2: Daily mean wind speed

Site Reference

Construction of a DFIR is planned for Summer 2012 and will be used together with a weighing gauge type OTT Pluvio², 200 cm², 1500 mm capacity.

Additional references, as recommended by the SPICE IOC will also be installed during the summer of 2012.

Manual measurements of snow depth will be available for the experiment, once per day, using the Pegel. This will be complemented by the use of a video camera type AXIS 215 PTZ Network Camera.

Motivation

SLF has a long history of projects dealing with research in snow topics, and is specialized in snow measurements and analysis. The collaboration between SLF-MeteoSwiss in SPICE offers an existing test site that has expandable possibilities with personnel on-site.

Both institutes are very interested in the general objectives of SPICE. The test site is already equipped, but can host additional equipment during SPICE

A C-band radar for research purposes might be installed in the vicinity of the test field next winter.

ANNEX XV

UNITED STATES OF AMERICA

Proponent: National Oceanographic and Atmospheric Administration (NOAA)/Atmospheric Turbulence and Diffusion Division
Site Proposed: The NOAA/FAA/NCAR Winter Precipitation Testbed (Marshall Site), Boulder, CO

The NCAR (National Centre for Atmospheric Research) Marshall site was established in the early 1990's by the Research Applications Laboratory and has been used to study winter precipitation since its inception. Data has consistently been collected at the site using primarily GEONOR precipitation gauges and a DFIR at 2 m height with aand single Alter shield have been used for measurements consistently over the years.

Other programs running on site:
GPS snow depth measurements sponsored by the University of Colorado
Testing of various instruments by NCAR
Ozone sonde launches once a month by NOAA

Site location
Latitude: 39.949; Longitude: -105.195; Elevation: 1740 m

Type of terrain: Flat grassland

Site Climatology
Cold and semi-arid
Total average Snowfall (cm): 201.7 cm (yearly)

Site references
During the summer of 2012, the proponent will install on the site a standard DFIR, with a Tretyakov gauge and Tretyakov shield, for conducting regular manual observations in support of SPICE.
A 3.5 m DFIR is installed on site, which will serve as field working reference with an automatic gauge. The gauge used is a GEONOR T-200B gauge with 3 vibrating wires, equipped with an Alter shield, and heated using the configuration of the Climate Reference Network of the NOAA.
In addition, the site has several DFIRs with the standard diameter and gauge height at 2 m AGL. The gauge used in these DFIRs is either a Geonor T-200B3 or OTT Pluvio^2, equipped with an Alter shield.
The site has plans to install a SPICE recommended field reference, as required, to meet the SPICE objectives.

For the measurement of snow on the ground, the site runs a manual measurement program, conducting one measurement per storm, using a snow stake.

Specifically, 5 snow stakes are installed, and photos are taken of each of them every hour during daylight hours.

Motivation
Quantify solid precipitation errors, define standard measurement and analysis methods, develop transfer functions between different types of measurement systems.

Projects underway
NOAA Climate Reference Network precipitation gauge testing.

ANNEX XVI

Allocation of SPICE Instruments Proposed by Instrument Providers

Summary by Instruments

Instrument Provider	Country	Number proposed	Manufacturer	Instrument Name	SPICE site(s) where allocated and number of instruments allocated
Weighing Type Gauges					
Belfort	USA	1	Belfort Instrument Company	All environment Precipitation Gauge, model 36000-1DDH	• Weissfluhjoch (Switzerland): 1
Geonor As	Norway	7	Geonor AS	WG model T-200B3/T-200BM3, 1500 mm	• Bratt's Lake (Canada): 1 • Caribou Creek (Canada): 1 • Guthega Dam (Australia): 1 • Marshall (USA): 2 • Mueller Hut (New Zealand): 1 • Weissfluhjoch (Switzerland): 1
Meteoservis	Czech Rep	2 sets	Meteoservis v.o.s.	Weighing Rain Gauge model MRW500	• Bratt's Lake (Canada): 1+1spare • Marshall (USA): 1+1spare
MPS System	Slovakia	2	MPS System	Total Rain Weighing sensor, model TRwS 204	• Haukeliseter (Norway): 1 • Marshall (USA): 1
OTT Hydromet GmbH	Germany	2	OTT Hydromet GmbH	OTT Pluvio model 200_RH	• Marshall (USA): 1 • Sodankyla (Finland): 1
NIMH Bulgaria	Bulgaria	1	Sutron (USA)	TPG model TPG-0001-1	• Marshall (USA): 1
Optical Instruments					
Adolf Thies GmbH&Co KG	Germany	2	Adolf Thies GmbH&Co KG	Laser precipitation monitor model 5.4110.01.200	• Marshall (USA): 1 • Weissfluhjoch Switzerland): 1
Campbell Scientific Ltd	UK	3	Campbell Scientific Ltd	Present Weather Sensor model PWS100	• Haukeliseter (Norway): 1 • Marshall USA): 1 • Tapado (Chile): 1
Droplet Measurement Technologies	USA	2	Droplet Measurement Technologies	Meteorological particle sensor	• CARE (Canada): 1 • Marshall (USA): 1
OTT Hydromet GmbH	Germany	2	OTT Hydromet GmbH	OTT Parsivel	• Caribou Creek (Canada): 1 • Sodankyla (Finland): 1

Tipping Bucket type gauges					
Adolf Thies GmbH&Co KG	Germany	2	Adolf Thies GmbH&Co KG	Precipitation transmitter, model 5.4032.35.008	• Marshall (USA): 1+1spare
CAE S.p.A.	Italy	2	CAE S.p.A.	Tipping Bucket (heated) model PMB25R	• CARE (Canada): 1 • Marshall (USA): 1
Environment Meas. Limited	UK	2	Environment Meas. Limited	Universal Precipitation Gauge UPG1000	• Marshall (USA): 1 • Sodankyla (Finland): 1
E.T.G. srl	Italy	2	E.T.G.srl	Heated Rain Gauge, model R102R	• CARE (Canada): 1 • Marshall (USA): 1
Hydrological Services America	USA	3	Hydrlogical Services Pty. Ltd	Heated Tipping Bucket , model TBH/TBH-LP	• CARE (Canada): 1 • Marshall (USA): 1+1 spare
Meteoservis	Czech Rep	5 sets	Meteoservis v.o.s.	MR3H-FC Rain Gauge, model AH-01 with heating	• CARE (Canada): 1+1 spare • Marshall (USA): 1+1 spare • Sodankyla (Finland): 1+1 spare
MTX s.r.l.	Italy	2	MTX s.r.l.	TB Precipitation sensor , model FAK015AA	• Marshall (USA): 1+1 spare
ZAMG	Austria	2	Meteoservis (Czech Rep)	TB MR3H-FC ZAMG-version	• CARE (Canada): 1 • Weissfluhjoch (Switzerland): 1
KNMI	Netherlands	1, plus spare	KNMI	Electrical Rain Gauge (KNMI)	WITHDRAWN
Snow Water Equivalent Instruments					
Campbell Sci. Canada	Canada	1	Campbell Scientific	CS725 Gamma Ray Snow Water Equivalent Sensor (previously known as GMON3)	• Sodankyla (Finland): 1
Hydrological Services America	Austria	2	System Mess-Systemtechnik	Snow Melt Analyser, model SPA	WITHDRAWN
Snow Depth Sensors					
Campbell Sci. Canada	Canada	4, plus spares	Campbell Scientific	Snow depth sensors model SR50ATH-316SS	• Sodankyla (Finland) : 2 • Hala Gasienicowa (Poland) : 2
ESW GmbH	Germany	2	ESW GmbH	Snow Depth Sensor SHM30/012840-642-22	• Sodankyla (Finland) : 2
E.T.G. srl	Italy	2	E.T.G srl	Snow Depth Sensor, model SENULSNIV	• Sodankyla (Finland) : 2
Felix Technology Inc.	Canada	2	Felix Technology Inc.	Snow Depth Sensor, model SL300	• Sodankyla (Finland) : 2
Sommer GmbH & Co KG	Austria	2	Sommer	Snow Depth Sensor, model USH-8	• Sodankyla (Finland) : 2

Summary of Instrument Allocation by Site

Site	**Instruments**
Marshall (USA)	• Geonor WG model T-200B3/T-200BM3, 1500 mm: 2 • MeteoServis Weighing Rain Gauge model MRW500: 1+1 spare • MPS Systems Total Rain Weighing sensor, model TRwS 204: 1 • OTT Pluvio model 200_RH: 1 • Sutron TPG model TPG-0001-1(provided by NIMH Bulgaria): 1 • Thies Laser precipitation monitor model 5.4110.01.200: 1 • Campbell Scientific Present Weather Sensor model PWS100: 1 • Droplet Measurement technologies: Meteorological particle sensor: 1 • Thies Precipitation transmitter, model 5.4032.35.008: 1+1 spare • CAE Tipping Bucket (heated) model PMB25R: 1 • Environmental Meas Limited Universal Precipitation Gauge UPG1000: 1 • ETG Heated Rain Gauge, model R102R: 1 • Hydrological Services Heated Tipping Bucket , model TBH/TBH-LP: 1+1 spare • Meteoservis MR3H-FC Rain Gauge, model AH-01 with heating: 1+1 spare • MTX TB Precipitation sensor, model FAK015AA: 1+1 spare
CARE (Canada)	• Droplet Measurement technologies: Meteorological particle sensor: 1 • CAE Tipping Bucket (heated) model PMB25R: 1 • ETG Heated Rain Gauge, model R102R: 1 • Hydrological Services Heated Tipping Bucket , model TBH/TBH-LP: 1+1 spare • Meteoservis MR3H-FC Rain Gauge, model AH-01 with heating: 1 • TB MR3H-FC ZAMG-version (Withdrawn)
Bratt's Lake (Canada)	• Geonor WG model T-200B3/T-200BM3, 1500 mm: 1 • MeteoServis Weighing Rain Gauge model MRW500: 1+1 spare
Caribou Creek (Canada)	• Geonor WG model T-200B3/T-200BM3, 1500 mm: 1 • OTT Parsivel: 1
Weissfluhjoch (Switzerland)	• Belfort All environment Precipitation Gauge, model 36000-1DDH: 1 • Geonor WG model T-200B3/T-200BM3, 1500 mm: 1 • Thies Laser precipitation monitor model 5.4110.01.200: 1 • TB MR3H-FC ZAMG-version: 1
Haukeliseter (Norway)	• MPS Systems Total Rain Weighing sensor, model TRwS 204: 1 • Campbell Scientific Present Weather Sensor model PWS100: 1
Hala Gasienicowa (Poland)	• Campbell Scientific Canada Snow depth sensors model SR50ATH-316SS: 1
Tapado (Chile)	• Campbell Scientific Present Weather Sensor model PWS100: 1

Guthega Dam (Australia)	• Geonor WG model T-200B3/T-200BM3, 1500 mm: 1
Mueller Hut (New Zealand)	• Geonor WG model T-200B3/T-200BM3, 1500 mm: 1
Sodankyla (Finland)	• OTT Pluvio model 200_RH (TBD): 1 • • OTT Parsivel: 1 • Environmental Meas Limited Universal Precipitation Gauge UPG1000: 1 • Meteoservis MR3H-FC Rain Gauge, model AH-01 with heating: 1+1 spare • CS725 Gamma Ray Snow Water Equivalent Sensor (previously known as GMON3): 1 • Campbell Scientific Canada Snow depth sensors model SR50ATH-316SS: 2 • ESW Snow Depth Sensor SHM30/012840-642-22: 2 • ETG Snow Depth Sensor, model SENULSNIV: 2 • Felix Technology Snow Depth Sensor, model SL300: 2 • Sommer Snow Depth Sensor, model USH-8: 2

ANNEX XVII

ACCEPTANCE OF SPICE DATA PROTOCOL

I, ... ……………………………………………...................... (insert your name), ……..……………………………………………….(insert your title/function) hereby declare that I and the organization/company, ……………………………………………………………………........ (insert your org/co name), shall abide by the SPICE Data Protocol as set out below.

Signature: ....
(initials of the person are put on each page of the document)

Date: ……………… … Place: ………………………

SPICE DATA PROTOCOL

1. Introduction

1.1 The World Meteorological Organization (WMO) Solid Precipitation Intercomparison Experiment (SPICE) is an international intercomparison project being conducted as part of the work programme of the WMO Commission for Instruments and Methods of Observation (CIMO). A description of SPICE and its objectives is provided at Annex A.

1.2 Achieving the objectives of SPICE will involve the participation of numerous observing sites, and continuous and frequent observations of precipitation, snow depth and ancillary variables over a long period of time, sampled by a number of instruments of different makes supplied by different providers.

1.3 The purpose of this document is to define the protocol governing access to, use of and publication of information regarding the intercomparison sites and instrumentation, the algorithms employed by the instruments, the algorithms used in analysis of the data, the intercomparison data and the results to ensure that all SPICE participants are treated in a fair manner, and to ensure the timely dissemination/publication of SPICE results.

1.4 For clarity, all terms written in bold type in this document are defined in the Glossary provided at Annex B.

2. Project Governance

2.1 Overall project governance is the responsibility of an International Organizing Committee (IOC). The initial membership of the IOC was nominated by the President of CIMO and approved by the Secretary-General of WMO. The IOC membership also includes, as ex-officio members, the Site Manager of each SPICE intercomparison site.

2.2 The IOC is responsible for project governance, organization, overall planning and selection of participants (see Sect. 3.1), including:

- setting of project terms of reference,
- goals and objectives,
- ensuring the scientific integrity of the project,
- taking pragmatic steps to promote the project,
- approval of the project conclusions and output recommendations,

- reviewing the draft Final Report, and
- approving the SPICE Final Report.

2.3 The IOC reports, through its Chair, to CIMO. The IOC is also responsible for the establishment of a SPICE Project Team.

2.4 The SPICE Project Team is responsible for advising the IOC as regard to the detailed technical requirements for SPICE, including data analysis algorithms and methodology to be employed. The Project Team is also responsible for analysis and intercomparison of the data from the different SPICE intercomparison sites, and for drafting the SPICE Final Report.

3. SPICE Participation

3.1 SPICE involves participation in several different roles:

- IOC members;
- Project Team members;
- Intercomparison Sites (represented by Site Managers and their respective Site Teams);
- **Instrument Providers** (instrument manufacturers or WMO Members, and their representatives),
- Other participants, such as experts, computing facilities providers, data analysis contributors, and capacity building observers.

3.2 All SPICE participants (as listed in Sect. 3.1) are selected by the IOC.

3.3 All SPICE participants, and others who are provided future access to SPICE data and information, shall abide by this SPICE Data Protocol.

4. SPICE Project Execution

4.1 Each Intercomparison Site shall nominate a Site Manager and a Site Team. As noted in 2.1, Site Managers will represent their site as ex-officio members of the IOC. Each Site Manager must ensure that all members of their Site Team abide by the SPICE data protocol.

4.2 The IOC will establish guidelines to be followed by each Intercomparison Site for the conduct of SPICE. These will include:

- The configuration (layout) of the Intercomparison Site,
- The configuration, installation, operation and maintenance of instruments (which will be developed in consultation with **Instrument Providers**),
- The data collection setup, data archival and data quality control.

4.3 Each Site Manager, assisted by the respective Site Team, will be responsible for:

- compliance of the site with all intercomparison guidelines established by the IOC,
- securing the data collected from the Intercomparison Site,
- documentation of a site data protocol which is consistent with the SPICE Data Protocol and which governs access to the **SPICE Site Dataset** by the Site Team and others (such as staff of the site's host organization and staff of **Instrument Providers**),
- liaising with the **Instrument Providers**,
- documentation of the system implemented for managing the **SPICE Site Dataset**,
- preparation of the **SPICE Site Dataset**, and
- preparation of a final intercomparison report for that site (the **SPICE Site Final Report)**,

4.4 **Instrument Providers** are responsible for the delivery of their instruments to the intercomparison site, and for supporting the site managers in verifying their proper configuration/functioning before and during SPICE.

5 SPICE Documentation/Information

5.1 Pre-existing analysis methodologies and/or instrument algorithms provided by a SPICE participant will remain the property of that participant and may only be used or published with the prior written permission of the owner.

5.2 New analysis methodologies and/or instrument algorithms provided by a SPICE participant will remain the property of that participant, but will be freely available.

5.3 Intercomparison Sites give permission to WMO to use and publish Site Documentation detailing various aspects of the site, including its instrumentation and data handling system.

5.4 **Instrument Providers** give permission to WMO to use and publish **Instrument Documentation** provided throughout SPICE that describes the instrument(s) proposed, in terms of performance specifications, principle of operation, data format, internal data processing, installation requirement, interfaces and synchronization, unless provided in confidence.

6. SPICE Data, Datasets

6.1 Each Site Team shall collect and prepare its own **SPICE Site Dataset** that shall include both the data from the instruments under test and the ancillary measurements. These data shall be collected, processed and stored according to guidelines adopted by the IOC.

6.2 Each Intercomparison Site shall retain its **SPICE Site Dataset**, its **Site Documentation** and the **Instrument Documentation** from the participating instruments at that site.

6.3 Each **Instrument Provider** will be given access to unprocessed output from its own instrument(s), and a minimum set of corresponding ancillary data consisting of air temperature, relative humidity, and wind speed. These data are provided only for ensuring the proper functioning of the instruments, and shall neither be reported nor published prior to publication of the **SPICE Final Report.**

6.4 Each **SPICE Site Dataset** will be made available by the respective Site Team to the Project Team.

6.5 The Project Team will take all **SPICE Site Datasets** and use them to perform the overall SPICE intercomparison analysis and assessment, to produce the **SPICE Intercomparison Dataset.**

6.6 At the conclusion of SPICE, the Project Team will derive **The SPICE Dataset**.

6.7 After publication of the **SPICE Final Report**, WMO will keep a copy of **The SPICE Dataset** and make it available to whoever may request it, subject to their agreement in writing to abide by this SPICE Data Protocol.

7 Publications and Presentations

In the following, the word "publication" is used for publications as well as for presentations made at conferences (national and international)

7.1 WMO may publish in the **SPICE Final Report** part or all of **The SPICE Dataset.**

7.2 The IOC may develop and approve a set of slides that will be made available to the IOC, the Project Team and Site Teams for general use in presentations on SPICE.

7.3 All reports, presentations and publications using part or all of **The SPICE Dataset**, either before or after the publication of the **SPICE Final Report**, shall acknowledge SPICE as the source of the data. They should also include the general disclaimer: "

> Results presented in this work were obtained as part of the Solid Precipitation Inter-Comparison Experiment (SPICE), conducted on behalf of the World Meteorological Organization (WMO) Commission for Instruments and Methods of Observation (CIMO). The analysis and views described herein are those of the author(s) at this time, and do not necessarily represent the official outcome of WMO SPICE. Mention of commercial companies or products is solely for the purposes of information and assessment within the scope of the present work, and does not constitute an endorsement by the author(s) or WMO.

7.4 Site Team(s) are free to publish results from single- or multiple-site experiments that were underway prior to the commencement of SPICE.

7.5 Site Teams, with the permission of their Site Manager, may analyse their **SPICE Site Datasets** and publish this work**,** prior to the publication of the **SPICE Final Report**, addressing instruments that they own.

7.6 Site Teams, with the permission of their Site Manager, may also publish results of instruments provided to them in the context of SPICE by **Instrument Providers.** However, these **Instrument Providers** shall be invited, through the relevant Site Manager, to provide comments on the planned publication(s) and be given a reasonable time to reply to ensure that the results are fairly reported and correspond to the proper use of the instruments. Site Teams shall consider those comments in finalizing their publication(s).

7.7 Site Teams are encouraged to follow the guidelines provided in Annex C and to share their draft publications with the Project Team.

7.8 Site Managers shall notify the IOC of all reports, presentations and publications made using part or all of **The SPICE Dataset**, to ensure their appropriate inclusion, consideration, and citation in the **SPICE Final Report**.

7.9 Each **Instrument Provider** will be provided with an opportunity to review the analysis and assessment results presented in the draft final report for the instrument(s) it provided, and each will be given a reasonable time to provide comments on the draft final report. Any feedback shall be included in the **SPICE Final Report**.

7.10 All SPICE participants and those subsequently accessing the SPICE Dataset agree to use the data, Final Report and related publications based on SPICE data solely for the purpose of scientific research and development and not in order to make comparative statements to gain commercial advantage.

ANNEX A

SPICE AND ITS OBJECTIVES

Mission statement

To recommend appropriate automated field reference system(s) for the unattended measurement of solid precipitation in a range of cold climates and seasons, and to provide guidance on the performance of modern automated systems for measuring: (i) total precipitation amount in cold climates for all seasons, especially when the precipitation is solid, (ii) snowfall (height of new fallen snow), and (iii) snow depth.

To understand and document the differences between an automatic field reference system and different automatic systems, and between automatic and manual measurements of solid precipitation using equally exposed/shielded gauges, including their siting and configuration.

Scope and Definition

Building on the results and recommendations of previous intercomparisons, the WMO Solid Precipitation Intercomparison Experiment (SPICE) will focus on the performance of modern automated sensors measuring solid precipitation. SPICE will investigate and report the measurement and reporting of the following parameters:

With highest priority:

a. Precipitation amount, over various time periods (minutes, hours, days, season), as a function of precipitation phase (liquid, solid, mixed);
b. Snow on the ground (snow depth); as snow depth measurements are closely tied to snowfall measurements, the intercomparison will address the linkages between them.

With lower priority:

c. Solid and mixed precipitation intensity.

As a key outcome, recommendations will be made to WMO Members, WMO programmes, manufacturers and the scientific community, on the ability to accurately measure solid precipitation, on the use of automatic instruments, and the improvements possible. The results of the experiment will inform those Members that wish to automate their manual observations.

Intercomparison Objectives

WMO-SPICE will focus on the following key objectives:

I. Recommend appropriate automated field reference system(s) for the unattended measurement of solid precipitation. Define and validate one or more field references using automatic instruments for each parameter being investigated, over a range of temporal resolutions (e.g. from daily to minutes).

II. Assess/characterize automatic systems (both the hardware and the associated processing) used in operational applications for the measurement of Solid Precipitation (i.e. gauges as “black boxes”):

   a. Assess the ability of operational automatic systems to robustly perform over a range of operating conditions;
   b. Derive adjustments to be applied to measurements from operational automatic systems, as a function of variables available at an operational site: e.g., wind, temp, RH;
   c. Make recommendations on the required ancillary data to enable the derivation of adjustments to be applied to data from operational sites on a regular basis, potentially, in real-time or near real-time;
   d. Assess operational data processing and data quality management techniques;

e. Assess the minimum practicable temporal resolution for reporting a valid solid precipitation measurement (amount, snowfall, and snow depth on the ground);
f. Evaluate the ability to detect and measure trace to light precipitation.

III. Provide recommendations on best practices and configurations for measurement systems in operational environments:

a. On the exposure and siting specific to various types of instruments;
b. On the optimal gauge and shield combination for each type of measurement, for different collection conditions/climates (e.g., arctic, prairie, coastal snows, windy, mixed conditions);
c. On instrument specific operational aspects, specific to cold conditions: use of heating, use of antifreeze (evaluation based on its hygroscopic properties and composition to meet operational requirements);
d. On instruments and their power management requirements needed to provide valid measurements in harsh environments;
e. on the use of visibility to estimate snowfall intensity
f. On appropriate target(s) under snow depth measuring sensors;
g. Consideration will be given to the needs of remote locations, in particular those with power and/or communications limitations.

IV. Assess the achievable uncertainty of the measurement systems evaluated during SPICE and their ability to effectively accurately report solid precipitation.

a. Assess the sensitivity, uncertainty, bias, repeatability, and response time of operational and emerging automatic systems;
b. Assess and report on the sources and magnitude of errors including instrument (sensor), exposure (shielding), environment (temperature, wind, microphysics, snow particle and snow fall density), data collection and associated processing algorithms with respect to sampling, averaging, filtering, and reporting.

V. Evaluate new and emerging technology for the measurement of solid precipitation (e.g. non-catchment type), and their potential for use in operational applications.

VI. Configure and collect a comprehensive data set for further data mining or for specific applications. Enable additional studies on the homogenization of automatic/manual observations and the traceability of automated measurements to manual measurements.

Annex B

GLOSSARY OF TERMS

Datasets:

SPICE Site Dataset: A dataset comprising all level datasets from that Intercomparison Site.

SPICE Intercomparison Dataset: this is the dataset that combines the data from all SPICE intercomparison sites and from all instruments. The **Project Team** will develop the **SPICE Intercomparison Dataset** using the datasets from each **Intercomparison Site** and performing additional analysis on them**.**

The SPICE Dataset: The total **SPICE** dataset including all **SPICE Site Datasets**, **Site Documentation** and **Instrument Documentation** for all participating sites and instruments, the **SPICE Intercomparison Dataset,** and all SPICE analysis and assessment documentation.

SPICE Site Final Report: The final report for SPICE from an Intercomparison Site, derived from all relevant data and information from that site.

SPICE Final Report: The Final Report on SPICE, derived from **The SPICE Dataset.**

Documentation:

Instrument Documentation: Documentation prepared and provided to the IOC by an Instrument Provider, which includes a description of the instrument proposed in terms of performance, principle of operation, data format, installation requirements, interfaces and synchronization.

Instrument Providers: Manufacturers or WMO Members that provide instruments for SPICE but who will not be hosting a SPICE Intercomparison Site(s).

Site Documentation: Documentation prepared and provided to the IOC by an Intercomparison Site, which includes a description of the proposed host site, its location, capacity, the data acquisition system, data acquisition protocol, data archive and data quality control system available to support SPICE.

Annex C

Guidelines for publications:

- All publications shall include the disclaimer provided in the main part of the SPICE Data Protocol.

- Site teams are encouraged to analyse and publish preliminary and partial results of their sites in advance of the Final Report, thus preparing the ground for the SPICE cross-sites analysis.

- Co-authorship of publications is highly encouraged and could include all contributors

- All publications prepared using SPICE data sets, partially of entirely, should include a section describing the configuration of the experiment, the results of which are included in the publication, indicating:
    - Instruments used, whether part of SPICE , and the instrument ownership;
    - The field configuration of instruments in the experiment (siting, windshield, heating, data logger used)
    - Processing of the instrument output into data used for the work presented.
    - Any information, specific to the experiment, and relevant to the work presented.
    - Any exceptions from the recommended practices regarding the use and configuration of the instruments.
    - This information should be reflective of the site participation in SPICE.

- If reference is made to an instrument make and model, the author(s) should:
    - Identify how the instruments is used for meeting the objectives of work presented in the publication;
    - avoid any comparative and generalized statements, as well as broad qualifiers which would be perceived as ranking instruments (e.g. better, worse.);

- o When comparative assessments are required as part of the results presented, the author(s) will indicate the context in which these assessments are made; e.g. a specific application for national purposes, outside the scope of SPICE, studies of a specific feature relevant to the scope of work (heating, shielding, siting, etc), preliminary studies on a SPICE topic, presented from a site only, etc.;
- o Reflect as far as possible the comments of the involved parties in the subproject.

- Authors should avoid making statements that would imply acceptance or rejection of instruments or inferring any conclusions for the Final Report.