W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

OPAG ON STANDARDIZATION AND INTERCOMPARISONS

JOINT MEETING OF

CIMO EXPERT TEAM ON INSTRUMENT INTERCOMPARISONS
First Session

and

INTERNATIONAL ORGANIZING COMMITTEE FOR THE WMO SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT
First Session

GENEVA, SWITZERLAND

5 – 7 OCTOBER 2011

FINAL REPORT

DISCLAIMER

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

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GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the session

1.1.1 The Joint Meeting of the CIMO Expert Team on Instrument Intercomparisons (ET-II) and the International Organizing Committee for the WMO Solid Precipitation Intercomparison Experiment (IOC-SPICE) was held in Geneva, Switzerland, from 5 to 7 October 2011. The participants were welcomed by Dr Roger Atkinson, Acting Head, Instruments and Methods of Observations. The list of participants is given in Annex II.

1.1.2 Mr Sai Krishnan (member or ET-II) and Mr Bruce Baker (member of IOC-SPICE) were unable to attend. Mr Baker, as well as Dr Paul Joe (Canada, Invited Expert) participated in the afternoon sessions via teleconference communication.

1.1.3 Dr Atkinson noted that the proposed work of ET-II is at the heart of CIMO's activities, since the broad aims of both are concerned with improving data traceability and uncertainty, characterizing instruments and improving operational and maintenance procedures. He noted that this meeting falls near the beginning of the ET's work period, so it marks the beginning of the work programme, and there will be a great deal for the ET to accomplish before the next CIMO Session in 2014. He also stressed that, with such a short time allocated for this meeting, the ET matters unrelated to SPICE would need to be considered in two parallel sessions, and urged those not closely involved with SPICE to attend these sessions as far as possible.

1.1.4 Dr Atkinson went on to describe SPICE as the first and major task confronting the ET. He described SPICE as an ambitious and challenging experiment, but noted that many of the world's experts on solid precipitation measurement are involved in its planning so there is every chance of it being particularly successful. He noted that there was much planning to do over the coming three days at the meeting, and urged the meeting participants to be focused and concise in their contributions to the meeting, and to recognize that a cooperative spirit would be essential and not only the key to a successful meeting but also the key to a successful intercomparison experiment. In closing, he wished the meeting well with its endeavours.

1.2 Adoption of the agenda

1.2.1 The Joint Meeting adopted the modified Agenda Annex I for the meeting.

1.3 Working arrangements for the session

1.3.1 It was agreed that Dr Emanuele Vuerich, Chair of ET-II and Ms Rodica Nitu, Chair of IOC-SPICE would share the chairing responsibilities. For the parallel sessions on Thursday morning, Dr Vuerich would chair the ET-II session, while Ms Nitu would chair the SPICE-IOC session.

1.3.2 The working hours for the meeting were agreed upon.

2. REPORT OF THE ET-II CHAIR

2.1 The ET-II Chair reported on his activity since 2010 and on the ET-II approved workplan achievements to date. He noted the progress achieved against both higher and lower priority tasks and indicated additional progress expected by the conclusion of the ET meeting. The ET Chair recalled the role of the ET after the approval of (i) the new working structure of CIMO (CIMO-XV, Helsinki, 2-8 September 2010); (ii) the Mission/ToRs statements of the ET; and (iii) the key elements of its workplan. The ET Chair also recalled the relevant items and decisions of the

9th Session of the CIMO Management Group (CIMO MG-9, Geneva, 5-8 April 2011) concerning the ET's role and workplan.

2.2 The ET Chair described a few problems encountered so far in carrying out the ET workplan and the related risks, and made a number of recommendations for the meeting:

- enhance the Team Building approach (IOC members and other experts) which plays a crucial role for the ET/IOC decision making;
- increase the participation and support of each expert through high motivation;
- finalize decisions in due time and identify clearly future actions and deliverables and responsibilities;
- finalize the SPICE project timeline (or time chart) and identify a "Monitoring & Control process" to check the progress and to adopt corrective action in case of biases from expected outcomes;
- define a protocol for preparing/taking decisions after the meeting (through a suitable agenda of telephone conferences and powerful forms of document sharing).

2.3 The ET Chair concluded by recalling the ET's Vision 2011-2014 to indicate how the ET should try to be for a successful mission and thanked all experts for their previous work and for coming to the meeting.

3. SPICE PLANNING

3.1 Report of the IOC-SPICE Chair

3.1.1 The Chair of the International Organizing Committee (IOC) of the Solid Precipitation Intercomparison Experiment (SPICE) presented an overview of the background work leading to the proposal for the organization of the intercomparison experiment.

3.1.2 Based on a proposal from Canada, CIMO-XIV (Geneva, Switzerland, 7-14 December 2006) acknowledged the need to assess the methods of measurement and observation of solid precipitation, snowfall and snow depth at automatic unattended stations used in cold climates (polar and alpine), in consultation with CCl, Antarctic WG, WCRP-CLiC, WCP, CHy, CAgM, CBS and GCOS. As a result, in 2008, CIMO conducted a survey to document national summaries of instruments and methods of observation for solid precipitation measurement at AWSs. The results were published in 2010, as: *CIMO Survey on National Summaries of Methods and Instruments for Solid Precipitation Measurement at Automatic Weather Stations*[1]. The report provided an improved understanding of the global configuration of precipitation measurements and paved the way for a proposed WMO intercomparison of instruments measuring solid precipitation.

3.1.3 At CIMO-XV (Helsinki, Finland, 2-8 September 2010) the Commission agreed that an instrument intercomparison on solid precipitation, focusing on snowfall and snow depth measurements by automatic weather stations, was needed and decided to organize this intercomparison as a priority. It was proposed that the intercomparison would assess the impact of automation and determine the errors in measurement of snowfall, snow depth and solid precipitation in cold climate, particularly from automatic weather stations. The Commission noted that the intercomparison should be conducted in cooperation with other relevant technical commissions and the Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS). Canada indicated its commitment to take a leadership role if other Members commit to participate and share the work to ensure the results are representative and valuable for the broader community. The Commission also recognized that such an intercomparison should be carried out on different sites with various climates, and that manual observations would be needed at each site for verification. The Commission welcomed the support expressed by China, Finland,

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[1] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM 102, WMO/TD-No.1544)

New Zealand, the Russian Federation, Switzerland and the United States of America, their commitment to contribute to this intercomparison, including hosting the intercomparison.

3.1.4 The WMO Congress (Cg-XVI - Geneva, Switzerland, 16 May – 3 June 2011) commended CIMO for embarking on an Intercomparison of Solid Precipitation Measurements, in view of its high relevance to climate monitoring.

3.1.5 The membership of the IOC-SPICE was proposed by the President of CIMO and approved by WMO Secretary-General on 29 July 2011. In addition to the core membership, the IOC has benefited from the ongoing support of several other Invited Experts and that of the members of the CIMO ET-II.

3.1.6 The IOC commenced the planning process for SPICE in May 2011, and its members held eight substantial teleconferences in preparation of this first face-to-face meeting.

3.2 SPICE Project Proposal

3.2.1 Ms Nitu, the Chair of IOC-SPICE, provided a review of the current project proposal of SPICE. The proposal was developed based on the outcome of a 2010 consultation of the experts of Environment Canada. Since May 2011, the IOC-SPICE members, the Invited Experts, and the WMO Secretariat have actively contributed to further developing the proposal for this intercomparison. Dr Paul Joe and Mr Craig Smith (Canada), Mr Keijo Leminen and Mr Jani Poutiainen (Finland), and Mr John Kochendorfer (USA), although not formally members of the IOC and not present at this meeting, have been active contributors to the project. Given the complexity of the intercomparison, the engagement of other experts has been critical. The organization of the intercomparison at multiple sites will require good coordination, good communication and a strict focus on the project's objectives.

3.2.2 As encouraged by CIMO-XV, several Member countries have expressed interest in hosting intercomparison sites. To date these comprise Canada, China, Finland, Italy, New Zealand, Norway, Russian Federation, Switzerland, United States. It is expected that other Members will be joining the experiment as its objectives are better understood by the community at large. Each participating country will be asked to nominate a Project Lead, who will become an ex-officio member of IOC-SPICE, if not already a member.

3.2.3 Ms Nitu noted that with such a large project team there will, undoubtedly, be differences in preferred approaches and particular national priorities, so a spirit of willing cooperation by all will be key to a successful experiment. She also noted that some sites have pre-existing experiments underway, so it will be important for SPICE not to disturb but to add to them.

3.2.4 Ms Nitu concluded by noting that the formalization of the project objectives and deliverables at this meeting will provide the guidance needed by the IOC to shape the finer details of the experiment over the coming months.

3.3 Project Stakeholders

3.3.1 Prior to the meeting, the SPICE IOC had invited representatives of SPICE stakeholders to outline their expectations from SPICE, on behalf of the Program or the Commission they represent. Representatives of GCOS, EC-PORS, CHy, CAgM and the Remote Sensing community have provided input, emphasizing the importance of:

- identifying the minimum practical time interval for reporting measurements of solid precipitation amount using in-situ instruments;
- providing of guidance on overall measurement uncertainty;
- developing adjustments to be applied to measurements to account for known errors, and identifying the ancillary measurements required to derive these adjustments;

- the availability of metadata;
- assessing emerging technologies; and
- guidelines to assist in the transition from manual to automatic measurement of solid precipitation observing systems.

The contributions provided by individual stakeholders are provided in Annex III.

3.3.2 Dr Barry Goodison provided the meeting with a brief presentation on the key requirements for SPICE from the perspective of EC-PORS.

3.4 Review of Intercomparison Mission, Vision and Scope

3.4.1 The IOC discussed in detail the proposed SPICE mission, vision, and scope, and decided that the Intercomparison will focus on the performance of modern automated sensors measuring precipitation during the period of the year when the precipitation is expected to be solid. As a first priority, the SPICE will investigate and report on the measurement of precipitation amount as a function of precipitation phase, and of snow on the ground (snow depth). As a lower priority, it will investigate the measurement and reporting of solid and mixed precipitation intensity. The experiment is expected to formally commence in 2012, to extend over two winter seasons, and be conducted on sites in the Northern and the Southern Hemispheres.

3.4.2 The participants revised the detailed wording of the SPICE Mission, Vision, and Scope statements. The agreed text is included at Annex IV.

3.5 Review of Objectives and Deliverables

3.5.1 The participants reviewed and revised the SPICE Objectives and Deliverables. The agreed text is contained in Annex IV.

3.5.2 Dr Roy Rasmussen raised the issue of the current operational use of visibility to determine light, moderate, and heavy snowfall intensity. This has been shown to provide a poor representation of the Snow Water Equivalent (SWE) snowfall rate, and yet many users (such as ground deicing operators) are using it in this fashion. He suggested that the WMO provide recommendations on the use of visibility for SWE rates, as well as developing a definition of light, moderate and heavy snowfall intensity based on SWE rates instead of visibility. He volunteered to lead such an effort. This effort would result in recommendation on snowfall and visibility and the definition of light, moderate, and heavy snow, to the CIMO Guide[2]. In order to achieve this objective, the visibility will need to be added as one of the ancillary measurements for SPICE.

3.6 SPICE Measurement References (requirements, proposals, definitions)

3.6.1 The IOC decided that, at the participating sites, where possible, the secondary field reference defined at the conclusion of the first WMO Solid Precipitation Intercomparison should be included in the field reference for SPICE, to ensure the traceability of the results of SPICE to previous studies. The secondary field reference consists of a Double Fence Intercomparison Reference (DFIR) surrounding a manual Tretyakov gauge with a Tretyakov shield; its configuration is presented in the report of the previous solid precipitation intercomparison: *WMO Solid Precipitation Measurement Intercomparison*[3] A protocol for conducting the manual observations will be established to ensure that measurements are completed in a traditional and consistent manner.

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[2] http://www.wmo.int/pages/prog/www/IMOP/CIMO-Guide.html
[3] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM-67, WMO/TD-No.872)

3.6.2 For meeting the objectives of SPICE, the IOC decided that a working field reference with a higher temporal resolution, using an automatic gauge, is needed. This working field reference will be configured similarly to the secondary field reference, and use an automatic weighing gauge in wide operational use, instead of the Tretyakov gauge. The specific configuration of this working field reference and the type of the weighing gauge used will be identified by the IOC after the northern hemisphere winter pre-SPICE experiment of 2011/12.

3.6.3 The IOC recognized that, in the context of the multi-site organization of SPICE, it is important to develop a flexible approach for the configuration of the field reference; selecting and using a standard configuration of a field reference for all participating sites will establish the traceability between the results obtained from the participant sites, hence greatly increasing the prospects for achieving the SPICE objectives. While highly desirable to have a DFIR with an automatic gauge on all participating sites, the IOC recognized that this is not feasible everywhere given the limitations on some of the sites; for that reason, the IOC defined alternative approaches for addressing the configuration of a field reference for the experiment.

3.6.4 The options for the configuration of intercomparison sites and the configuration of the field references for the experiment were adopted by the IOC (Annex V). The nomenclature proposed is used only for communication purposes and doesn't represent a means for classifying the participating sites.

3.6.5 The IOC recommended that, in support of the experiment, a Task Team is formed for modeling the wind flow around a DFIR. It was agreed that Dr Roy Rasmussen and Dr Eckhard Lanzinger will co lead the Task Team. This proposal was supported by the Chair of the Expert Team on Instrument Intercomparisons, and he will work with the WMO Secretariat, to form this Task Team.

3.6.6 The configuration of the field reference for the measurement of Snow on the Ground, snowfall, and snow intensity was not discussed at the meeting, due to the time constrains. The recommended field reference for the measurement of snow on the ground includes manual measurements using a snow board, complemented by the measurements from the working field reference for precipitation amount. The IOC will decide on the configuration of these references following the meeting.

3.7 Ancillary Measurements: defining minimum requirements

3.7.1 The meeting assessed which ancillary parameters must be measured at each intercomparison site, to enable comprehensive analysis and characterization of the measurement systems and their data. Only the requirements for investigating precipitation amount measurements were considered at the meeting, due to time restrictions.

3.7.2 The table in Annex VI summarizes the ancillary measurements required for precipitation amount measurements (as distinct from snow on the ground) as accepted by the IOC.

3.7.3 A similar list of requisite ancillary measurements for the snow on the ground component of SPICE awaits separate consideration by the IOC after the meeting.

3.8 Contribution and engagement of participating WMO Members

3.8.1 Following the decision of the CIMO-XV and prior to this meeting several Members have indicated interest in participating in SPICE and hosting experiments on their field test sites. These are Canada, China, Finland, Italy, Norway, Russia, Switzerland, New Zealand and USA. The representatives of these Members provided a brief description of their intended participation. A summary of the information provided is included in Annex VII. Additional participation is expected to be announced following the formal engagement of the WMO Members, and the broader distribution of information on the organization of the experiment.

3.8.2 The IOC recommended that those WMO Members who participated in the previous Solid Precipitation Intercomparison (1989 -1993) be asked whether the work which was started then is still active today, and if so, whether they may be interested in participating in SPICE. If the responses are positive, the IOC will work with those Members to engage them in the experiment.

3.8.3 A mandatory condition for all participants to SPICE will be their agreement to abide by the SPICE data protocols. All participants will be required to sign prior to the commencement of SPICE, a formal data protocol agreement, drawn up by the IOC/ET in consultation with the WMO Secretariat. (see 3.14)

3.9 Summary of results from current and recent projects relevant to the scope of the SPICE

3.9.1 The SPICE IOC seeks to complement the results of the intercomparison with a summary of the results from previous experiments related to the objectives of SPICE. A summary of these results will be prepared with input from the experts involved in these experiments. A template was developed to enable the preparation of these summaries and is available in Annex VIII.

3.9.2 The participants recommended that inquiries be made with WMO on the most effective means of obtaining past publications on topics of relevance to SPICE, including the best means of storing and sharing them amongst the IOC members. The IOC committed to prepare a summary paper of the results to date on the measurement of solid precipitation, and work with the WMO Secretariat to publish it.

3.10 Pre-SPICE 2011/12 Reference Experiment:

3.10.1 The IOC agreed that the organization of the formal intercomparison, will be preceded during the winter of 2011/12 by an experiment that will give the opportunity to assess the principles of the formal intercomparison. These would include the configuration of a working field reference using an automatic gauge, the coordination of the data acquisition and archive in the context of a multi-site experiment, the principles and the methodologies for the data quality control, and the data analysis. The report of this experiment will be issued to the SPICE IOC in June 2012.

3.10.2 The 2011/12 pre-SPICE experiment will take advantage of existing field testing capacity and activities already underway in some Member countries. For this portion of the experiment no calls for the submission of additional equipment or engagement of other parties, will be made.

3.10.3 For the purpose of the 2011/12 pre-SPICE experiment, where possible, a WMO secondary field reference will be used. In addition, one or more DFIRs surrounding an automatic precipitation gauge will be configured and assessed as a representation of a field working reference.

3.10.4 The IOC asserted that the automatic gauge used for the working field reference may need to be heated. The heater configuration and heating algorithm will be assessed during the 2011/12 pre-SPICE experiment. The decision regarding the heating configuration and algorithm for the gauges used in the working field reference will be finalized after the completion of the pre-SPICE experiment.

3.10.5 The IOC recognized the need for a standardized approach in dealing with occurrences of frozen or capped gauges. A protocol for this will be developed during the pre-SPICE experiment.

3.10.6 The IOC agreed that the results of the pre-SPICE experiment of 2011/2012 will guide the decisions regarding the organization of the formal intercomparison, and will become an integral part of the results of the intercomparison.

3.10.7 It was agreed that, as a result of the 2011/12 pre-SPICE experiment, the requirements and configuration for the ancillary measurements could change, to better support the SPICE objectives.

3.10.8 The Members who indicated potential to coordinate their national experiments with the 2011/12 pre-SPICE objectives are the USA, Switzerland, Norway, Canada and Finland.

3.10.9 The IOC decided that the laboratory calibration of the instruments considered for use as part of the working field reference is warranted, and will be performed at the Precipitation Intensity Lead Centre in Genoa (Italy). This has to include a vibration test and a temperature test, representative of the winter operating conditions. To enable the development of a representative test, the pre-SPICE experiment organized in the USA and in Canada will include monitoring of wind induced vibrations on the automatic gauges.

3.10.10 It was agreed that Canada will explore during the pre-SPICE experiment, the testing of precipitation gauges in a wind tunnel, to assess the deformation of the wind field around the gauge.

3.11 2011/12 Data requirements:

3.11.1 The meeting discussed input documents on SPICE Data Terminology and SPICE Data Analysis. The SPICE Data terminology, as approved by the SPICE IOC/ET, is available in Annex IX.

3.11.2 The meeting agreed that data at the highest reasonable temporal resolution from each instrument (defined for SPICE as level 1 data), should be stored on site. This resolution is expected to vary from one instrument to another, and in each case to correspond to the reporting time interval specific to that particular instrument.

3.11.3 The IOC also agreed to collect and transmit to a project database, the 1 minute data from all instruments (defined for SPICE as level 2 data), insofar as this is possible (see 3.13).

3.11.4 The 2011/12 pre-SPICE experiment will be used to assess the minimum useful reporting interval for each instrument, and the optimal data averaging period for the intercomparison.

3.12 Protocol for selecting and including instruments in the experiment

3.12.1 It is expected that the instruments for the intercomparison, will be proposed and provided by the WMO Members, potentially in cooperation with an instrument manufacturer, or by manufacturers who are members of HMEI.

3.12.2 The IOC will prepare a set of requirements for participation and objective criteria for the selection of instruments to be included in the intercomparison and these will be communicated in the letter of invitation distributed to potential participants. Since it is anticipated that the number of instruments proposed may exceed the available capacity at participating host sites, likely, only a subset of those will be able to participate in the experiment.

3.12.3 The procedure for selecting instruments for SPICE will include provisions to enable the inclusion of instruments with a variety of measurement principles, and in various configurations typical to their operational use. A questionnaire developed in this sense by the IOC will be distributed to all potential participants, as part of the formal invitation for participation to SPICE.

3.12.4 Given the multi-site organization of the experiment, the IOC will take into account the possibility to directly include those instruments and configurations which are already in place and are used for on-going experiments linked to SPICE.

3.13 Requirements for data acquisition system and dataset/database, data QA/QC: requirements additional to those defined for 2011/12 under Agenda Items 3.10 and 3.11

3.13.1 The IOC was pleased to accept a generous offer received from the National Centre for Atmospheric research in Boulder, Colorado, USA (NCAR) to host the SPICE database for the level 2 intercomparison data. The 2011/12 pre-SPICE experiment will be used to test the potential for using the NCAR real time data system, for storing the 1 minute data and for conducting the first level of data quality control. NCAR will provide a summary of the data requirements for the transfer and ingest of data in real time or near real time. Where the real time data transfer is not possible, the IOC and the respective host country(s) will agree on time limitations for file transfer.

3.13.2 Further QA/QC requirements for the intercomparison will be explored during the 2011/12 pre-SPICE experiment. The QA/QC protocols used in the previous WMO intercomparisons will be used as guidance.

3.13.3 The access to the intercomparison data, during the intercomparison, will be guided by the SPICE data protocol. Prior to the issuing of the final report, the access will be limited to the SPICE project team, subject to the agreements with each host country.

3.13.4 The configuration and operation of the data acquisition systems for each host site will be the responsibility of the host country. The configuration of the data acquisition protocol for each instrument will be established by the IOC in consultation with the representatives of the participating sites, to ensure a consistent implementation on all participating sites.

3.14 SPICE Data analysis

3.14.1 A data protocol agreement for SPICE will be developed by the IOC/ET-II, and all participants will be required to strictly adhere to it. Each participant must sign the agreement prior to the IOC approving their participation. The primary purpose of the data protocol agreement is to establish clarity regarding the intellectual property (IP) involved in the experiment and to ensure that no commercial advantage will be gained from participation in the experiment. The data protocol agreement will cover ownership of the IP, and what participants may or may not do with the data and the reports from the experiment.

3.14.2 The SPICE data analysis requirements were further discussed in a breakout session. The summary of the group's discussion is contained in Annex X.

3.15 SPICE work plan: multi-site organization of experiment

3.15.1 As guided by the CIMO-XV, the SPICE intercomparison will be coordinated as a multi-site experiment, organized on sites offered by the WMO Members. An summary of proposed sites will be developed based on the interest expressed by the Members.

3.15.2 The intercomparison is planned to take place on sites located in the Northern and the Southern Hemispheres, formally start in 2012, and continue over two winter seasons. The completion of the experiment is estimated for late 2014, at the end of the winter season in the Southern Hemisphere. A formal report will be issued based on the results of the two winter season experiment from all participating sites. The activities organized on any of the SPICE sites may continue past the formal two seasons, and will be the exclusive responsibility of the host.

3.15.3 The meeting agreed to inform the WMO Members and the HMEI about the planned intercomparison, as soon as possible. The WMO Secretariat will therefore send a letter in early November 2011 to WMO Members and to HMEI addressing a preliminary Call for Expressions of Interest in participating in the WMO Solid Precipitation Intercomparison Experiment. The initial call will include a brief description of the SPICE mission and objectives. It will indicate that all participants must cover their own cost. In response, the proponents are requested to provide a point of contact for all future correspondence. Responses will be expected by December 2011. A WMO Member could participate by providing a host site for the experiment, submitting one or more instruments for the intercomparison, or by contributing in some other way (e.g. providing expertise to assist with the data analysis). It is anticipated that manufacturers will participate by providing instruments only. The manufacturers may be invited either to install their instrument(s) at the selected site(s) or to inspect the siting of their instruments after installation.

3.15.4 The HMEI representative indicated that it strongly supports this approach.

3.15.5 The SPICE Second Letter will be issued in January 2012 to all respondents to the first letter, and will include the formal invitation to participate in SPICE. This letter will include questionnaires on each type of participation (instruments, sites, other forms).The IOC will develop standard questionnaires to gather the information from the prospective participants. For example, for the proposed sites, the questionnaire will include, but not be limited to, information on site climatology, capacity (existing, planned) and proposed ancillary measurements.

3.15.6 WMO Members could join SPICE at a later date, and will be able to continue their experiments after the formal completion of SPICE. The Members unable to actively contribute will be encouraged to participate in an observer role, in order to build capacity for future involvement in similar intercomparison experiments.

3.15.7 The siting of instruments for the intercomparison will take into account the guidelines laid out in the CIMO Guide (WMO No. 8), the recommendations of the previous solid precipitation experiment (e.g. accounting for prevailing wind) and contained in report *WMO Solid Precipitation Measurement Intercomparison*[4], the experience gained since then, and local conditions and climatology.

3.15.8 The IOC will define the selection criteria for matching the sites with the SPICE objectives, taking into account the expectations of the host country; e.g. correlate the testing of instruments in environments where it is most likely to be used.

3.15.9 The Members hosting the intercomparison will be expected to identify and include, as part of the intercomparison database, the available remotely sensed precipitation data. Although the analysis of these data is beyond the scope of this intercomparison, the participants will be encouraged to take advantage of the available remotely sensed data for the data analysis of the intercomparison. The overall dataset can later contribute to further improve the spatial and temporal estimates of precipitation.

3.16 SPICE Risk management plan

3.16.1 The IOC agreed that the official commencement of the data collection phase of the intercomparison is November 15, 2012, in the Northern Hemisphere and May 15, 2013 in the Southern Hemisphere. An early start, where possible, is encouraged. Based on the agreed schedule, the Northern Hemisphere test will run over the winter seasons of 2012/13 and 2013/14, while the Southern Hemisphere tests will run over the winter seasons of 2013 and 2014.

3.16.2 The IOC discussed the proposed timeline for SPICE, as prepared by the Chair. To enable scheduled commencement of the intercomparison in the Northern Hemisphere, the following milestones are considered critical:

- April 2012: complete the selection of host sites and identify the instruments selected for the intercomparison;
- July 2012: the participating instruments are delivered to the host sites;

[4] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM-67, WMO/TD-No.872)

- September 2012: the site configuration and the instrument installation are finalized and are followed by a pre-intercomparison testing.

3.16.3 A risk analysis and assessment will be performed by IOC-SPICE and communicated to all participants to guard against problems impacting on the timely or successful completion of the experiment.

3.16.4 The configuration of the working field reference(s), as well as aspects related to data quality control and transfer for the formal experiment is function of the results of the pre-SPICE experiment of 2011/12. For that reason, the results of the pre-SPICE experiment will be made available to the IOC in June 2012, to allow for the implementation of the recommended strategies and configurations.

3.17 Project delivery: assignment of responsibilities

3.17.1 The participants at the meeting identified the immediate activities required to advance the SPICE objectives and agreed to share the responsibility for their completion. The allocation of responsibilities is summarized in Annex XI. The IOC will closely monitor progress over the coming months, and make adjustments as required to ensure all tasks are completed on schedule.

3.17.2 The SPICE team agreed to continue working together through teleconferences, which will be coordinated through WMO, and are planned to take place twice a month (tentatively the first and the third Thursday of each month).

4 WORK PLAN OF THE EXPERT TEAM ON INSTRUMENT INTERCOMPARISONS

4.1 Follow-up of the 8th WMO Intercomparison of Radiosondes (Yangjiang, China)

4.1.1 The meeting expressed appreciation for the excellent work conducted by the IOC Upper-Air and CIMO experts and the support provided by the China Meteorological Administration (CMA) for the 8th WMO Intercomparison of High Quality Radiosondes (Yangjiang, China, 12 July - 3 August 2010). The meeting also recognized that the final report[5] of the Intercomparison represents a particularly valuable source of information on the performance of systems tested, with advice to Members and manufacturers and recommendations for future intercomparisons.

4.1.2 The meeting thanked Mr LI Wei for his role in co-authoring the report and for providing the meeting members with an overview of potential follow-up on the Yangjiang Intercomparison. The meeting also recognized the effort of Mr LI in preparing draft advice to GCOS on the most appropriate radiosondes for use in GCOS Reference Upper Air Network (GRUAN), following the outcomes of the Yangjiang Intercomparison, and provided feedback to enable him to finalize that task. The meeting recommended that further interaction take place between CIMO experts and GCOS community and requested Mr LI to continue contributing. The meeting also requested the Secretariat to facilitate such interaction by indicating the GCOS focal points/experts on upper-air measurement requirements.

4.1.3 A draft proposal for a “road map” for future global radiosonde intercomparisons was presented by Mr LI Wei to the meeting (proposal and questionnaire). Based on the lessons learned from previous intercomparisons, the draft proposal is intended to present a staged plan for preparation of the next large WMO intercomparison exercise (in approximately 5 years time) and for improving the organization of radiosonde inter-comparisons through a standard/agreed procedure. The meeting agreed on considering the proposal of the first working draft to be circulated among CIMO and GCOS experts as soon as possible for evaluation and revision, in view of a final draft to be proposed to the CIMO Management Group in 2014. The meeting requested the Secretariat to indicate the most appropriate way to accomplish such task.

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[5] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM-107, WMO/TD-No.1580)

4.2 CIMO Guide update reflecting intercomparison results

4.2.1 In accordance with the Terms of Reference of the ET, the meeting requested the Chair and Co-Chair of ET-II, in consultation with the CIMO Guide Editorial Board, to develop a proposal for updating the CIMO Guide with relevant information from recent and planned instrument intercomparisons. The CIMO MG addressed appropriate mechanisms for updating the CIMO Guide during its 9th Session in 2011 (sec. 5.1.1 Final Report 9th Session CIMO MG).

4.2.2 The meeting noted that, following the request of CIMO-XV, revision of Part I, Chapters 12 and 13 is underway, with Dr John Nash having been contracted by WMO to draft respective revised text for the CIMO Guide. This drafting work is expected to be completed by December 2012. The meeting requested Mr LI Wei to collaborate with Dr John Nash within the appropriate mechanisms addressed and report on progress. The meeting suggested that consideration should also be given to updating the CIMO Guide to take into account relevant information from the final report of the Eleventh International Pyrheliometer Comparison (IPC-XI - Davos, Switzerland, 27 September – 15 October 2010) and the amendments requested by CIMO-XV, and reported in paragraph 4.13 and Annex I of its Final Report.

4.2.3 The meeting was informed by Mr LI Wei of a potential need to update Part III, Chapter 4, Annex 4.A of the CIMO Guide: “Procedures on global and regional intercomparisons of instruments” (CIMO Guide) as recommended by the IOC-UA in the Final Report of the Yangjiang Intercomparison. The meeting agreed to this recommendation and requested Mr LI Wei to collaborate.

4.3 Eleventh International Pyrheliometer Comparison 2010 (IPC-XI)

4.3.1 The ET/IOC expressed appreciation for the excellent work conducted by the PMOD/Word Radiation Centre of Davos (Switzerland) and recognized the continuous efforts for disseminating the World Radiometric Reference (WRR) in order to ensure worldwide homogeneity of meteorological radiation measurements.

4.3.2 Upon request of the Chair of ET-II, Mr Martin Mair and Mr Yves-Alain Roulet (ET members involved with WMO Radiation Intercomparisons) had established communication with the World Radiation Center (PMOD/WRC) in Davos, Switzerland, in June 2011 (W. Finsterle, J. Gröbner) and discussed future activities. The WRC experts expressed their intention to support and actively participated in the ET’s activities in relation to Regional Pyrheliometer Comparisons (RPCs). WRC support to RPCs could comprise provision of reference instruments for RPCs, as well as support on-site, dependent on the availability of appropriate staff. The meeting expressed appreciation for this potential support and encouraged Messrs Mair and Roulet to continue liaison with WRC/PMOD regarding radiation intercomparisons.

4.3.3 WRC/PMOD experts have expressed interest in a long time intercomparison of radiation instruments (over all seasons) in order to study sensor variability under various conditions. They have stressed the importance of testing and evaluating all classes of solar instruments, in order to allow WMO Members to develop and maintain networks within available resources. In this context, the meeting was informed that an inter-comparison including low-cost sensors initiated by MeteoSwiss for a COST Action (ES-1002) has been planned to take place in Payerne (Switzerland) in Spring 2012. The meeting was also informed that the WRC is planning a UV intercomparison in 2014 as part of EURAMET, EMRP Project No. ENV-03.[6] The meeting acknowledged the importance of long-term radiation inter-comparisons, including the testing of all classes of radiation instruments, and invited Messrs Mair and Roulet to monitor progress and

[6] EURAMET: European Association of National Metrology Institutes. EMRP: European Metrology Research Programme. EMRP Joint Research Project (JRP) No. ENV-03: Traceability for Surface Spectral Solar Ultraviolet Radiation

report on the MeteoSwiss inter-comparison. The meeting also requested them to monitor activities in regard to potential UV and infrared radiation inter-comparisons in close coordination with WRC.

4.4 Radar Data Quality and Quantitative Precipitation Algorithm Intercomparison (RQQI)

4.4.1 Dr Atkinson provided a brief presentation on RQQI on behalf of the Chair of IOC-RQQI, Dr Paul Joe. Planning for the experiment is well underway. The final report of the First Session of IOC-RQQI (Exeter, United Kingdom, 14-15 April 2011), has been completed and is available on the CIMO Website[7]. It contains detailed information on the intercomparison. Invitations to participate in RQQI are soon to be issued to all WMO Members and to HMEI. RQQI is different to previous intercomparisons in that it involves intercomparison of radar software algorithms, rather than instruments per se, and will not require participants to meet face-to-face to perform the exercise. Notably, RQQI will also be the first WMO intercomparison to require all participants to sign a written Data Protocol Agreement, prior to their participation in the exercise.

4.5 WMO Regional Radiosonde Intercomparisons

4.5.1 The meeting was informed of the importance and usefulness to WMO Members of small scale pilot studies for new radiosonde types. The importance of Regional Radiosonde Intercomparisons was also highlighted. Proposals for these should be forwarded through the WMO Secretariat, to the OPAG Standardization and Intercomparison Chairs, who would make a recommendation to the CIMO Management Group on perceived priority and on the level of CIMO support that should be provided for each.

4.6 WMO Regional Pyrheliometer Intercomparisons

4.6.1 WMO RPCs are regularly organized by Regional Radiation Centres (RRCs). Mr Mair informed the meeting that two RRCs (Japan and Sweden) have announced that they will be conducting RPCs during 2012. The Chair of the ET advised the meeting of the ET's responsibility in reviewing the reports of RPCs. Therefore the meeting requested Messrs Mair and Roulet to contribute to the two planned RPCs and to report back to the ET on this participation.

4.6.2 The meeting thanked Messrs. Mair and Roulet for the report on their efforts to informally survey the RRCs regarding their plans to hold RPCs in the 2011-2015 period, and to ascertain other RRC efforts to improve measurement traceability to the WRR. The meeting noted that according to the survey, 18 out of 20 RRCs can be considered as active, having attended IPC-X and IPC-XI. As part of the survey RRCs were also asked to provide information on their plans for and ability to organize RPCs. Ten RRCs have the necessary instrumentation and personal resources required. Some have no current plans for RPCs: others expect further initiatives from WMO-CIMO to attract potential participants. One RRC has lost most of its equipment due to a natural disaster, so would require external support to reactivate it. This survey also found that in some regions, e.g. RA V and RA VI, there was little need for a RPC because most Members either participate at IPC or have their reference instruments regularly calibrated by the RRC.

4.6.3 The meeting expressed its concern at the apparent use of non-standardized procedures by some NRCs for maintaining traceability to the WRR and suggested the initiation of a more formal survey of WMO Members to ascertain the operational status of RRCs and NRCs, the traceability of their instruments and the procedures used to maintain traceability to the WRR. The survey could also enquire of Members' views on the merits of conducting infrared and/or UV inter-comparisons.

4.6.4 The meeting noted the request from CIMO MG-9 to Drs Forgan and Carlund to review the procedures in place for organizing RPCs and suggested that the aforementioned survey of WMO

[7] http://www.wmo.int/pages/prog/www/IMOP/reports.html

Members might provide an opportunity to address that task as well. Accordingly, Mr Mair was requested to prepare a draft questionnaire in consultation with Dr Forgan.

4.6.5 The meeting requested the Secretariat to advise on possible WMO resource support for RPCs, because many of the surveyed RRCs have requested this information.

4.7 Update ET Work Plan

4.7.1 The proposed draft updated Work Plan for ET-II, which reflects the progress achieved at the meeting, is included at Annex XII.

5 REVIEW OF THE DRAFT IMPLEMENTATION PLAN FOR THE EVOLUTION OF THE GOS (EGOS-IP)

5.1 Dr Atkinson advised the meeting of the development of the draft Implementation Plan for the Evolution of the GOS (EGOS-IP) and the request from CBS to CIMO to review the document. Dr Atkinson requested the Members of ET-II to provide the Secretariat with comments on the document to assist in drafting a response to ET-EGOS from the Chair of ET-II before the end of the year.

5.2 The Chair of ET-II noted the need for ET-II to contribute to the implementation of WIGOS and requested all ET members to review the WIGOS Strategy and Implementation plan and to report back to the ET before May 2012.

6 OTHER BUSINESS

6.1 Appointment of a Co-Leader of SPICE

6.1.1 The Chair of IOC-SPICE suggested to the meeting that since its initial planning, the scale and complexity of the intercomparison had grown considerably, and now involves not only the main intercomparison itself, for which planning must proceed apace, but also the pilot experiment to be conducted during the coming winter, with its own planning and coordination requirements. Accordingly, Ms Nitu proposed that a co-Lader of the SPICE project be appointed, with the specific mandate to take responsibility for planning, coordination and execution of the 2011/12 pilot project. With the appointment of a co-Leader with this responsibility, Ms Nitu would be able to focus her attention on organization of the main intercomparison to follow. IOC-SPICE agreed to the appointment of Dr Roy Rasmussen as co-Leader of SPICE.

7 DRAFT REPORT OF THE SESSION

7.1 In view of the lack of time remaining for the meeting to commence drafting of the meeting report, Dr Atkinson suggested this be done off-line after the meeting, and requested each of the attendees to send draft contributions to the WMO Secretariat describing the key points of discussion on those agenda items for which they had lead responsibility.

8 CLOSURE OF THE SESSION

8.1 The session was closed on 7 October 2011 at 15h30.

ANNEX I

AGENDA

1 ORGANIZATION OF THE SESSION

1.1 Opening of the Session
1.2 Adoption of the Agenda
1.3 Working Arrangements for the Session

2 REPORT OF THE ET-II CHAIR

3 SPICE PLANNING

3.1 Report of the IOC-SPICE Chair
3.2 SPICE Project Proposal
3.3 Project Stakeholders
3.4 Review of Intercomparison Mission, Vision, and Scope
3.5 Review of Objectives and Deliverables
3.6 SPICE Measurement References (requirements, proposals, definitions)
3.7 Ancillary Measurements: defining minimum requirements;
3.8 Contribution and Engagement of Participating WMO Members
3.9 Summary of results from current and recent projects relevant to the scope of the SPICE;
3.10 2011/12 Reference experiment:
3.11 2011/12 Data requirements:
3.12 Definition of the protocol for selecting and including instruments in the experiment
3.13 Requirements for data acquisition system and dataset/database, data QA/QC
3.14 Data analysis: data processing and method
3.15 SPICE work plan: multi-site organization of experiment
3.16 SPICE Risk management plan
3.17 Project delivery following the Oct 2011 meeting: assignment of responsibilities

4 WORK PLAN OF THE EXPERT TEAM ON INSTRUMENT INTERCOMPARISONS

4.1 Follow-up of the 8th WMO Intercomparison of Radiosondes (Yangjiang, China)
4.2 CIMO Guide update reflecting intercomparison results
4.3 Eleventh International Pyrheliometer Comparison 2010 (IPC-XI)
4.4 Radar Data Quality and Quantitative Precipitation Algorithm Intercomparison (RQQI)
4.5 WMO Regional Radiosonde Intercomparisons
4.6 WMO Regional Pyrheliometer Intercomparisons

5 REVIEW OF THE DRAFT IMPLEMENTATION PLAN FOR THE EVOLUTION OF THE GOS (EGOS-IP)

6 OTHER BUSINESS

7 DRAFT REPORT OF THE SESSION

8 CLOSURE OF THE SESSION

ANNEX II

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ANNEX III

SPICE:
STAKEHOLDER EXPECTATIONS

A. REMOTE SENSING (Input provided by Dr David Hudak, Environment Canada

A major benefit of SPICE will be the provision of high quality snowfall validation data for remote sensing applications. These data will be used to validate existing snowfall rate algorithms and contribute to the development of new algorithms.

Examples of applications:

- Quantitative precipitation estimates of snowfall based on multi-parameter dual polarization radar data;
- Snowfall rate estimates using space-based data from the dual frequency radar and microwave radiometer onboard Global Precipitation Mission (launch date December 2013)
- A refinement on the scientific requirements for future space-based missions such as the Polar Precipitation Mission.

Specific Expectations

Network Validation – to determine the algorithm bias:

- the minimum practical time interval for snowfall amount measurements using in-situ instruments in various configurations
- a definition set of ancillary measurements needed to apply corrections to the measurements.

Physical Validation – to carry out direct algorithm formulation evaluation:

- An assessment of emerging technology in determining snow rate at a 1 min time interval
- A summary of the errors in these “instantaneous” measurements
- An assessment of emerging technology at determining the nature of the snow (e.g. size, shape, particle spectra, density)

B. NOWCASTING (Input provided by Dr Paul Joe, Environment Canada)

Nowcasting and very short term forecasting are forecast techniques that cover the 0-6 hour time scales. Implicitly, nowcasts are precise in time (minutes) and space (less than a kilometer) and high accuracy are required.

Traditionally, nowcasts are based on the diagnosis of precipitation derived from radar observations since radar have high temporal and spatial resolution.

Emerging are nowcasts based on other surface measurements and remote sensing instrument. An example related to solid precipitation is the nowcast of airport terminal conditions for the deicing of aircrafts. Deicing fluids have effective times as short as 10 or 20 minutes as long as 40 minutes. The selection of the deicing fluid type (cost is commensurate with effectiveness time) is highly dependent on the nowcast of precipitation type and intensity from application of the fluid at the deicing bay to take off which may be a few kilometers away.

Accurate high temporal measurements or estimates of precipitation type and intensity are required from in-situ sensors. These measurements are used in combination with radar derived estimates to provide the necessary spatial estimates.

Visibility is also dependent on precipitation and accurate estimates of precipitation and particle size are needed. In mountainous terrain, accurate knowledge of the freezing levels is critical to the rain-snow transition and this translates in spatial resolutions of hundreds of meters. The adiabatic effects of snow melting to rain are critical to the wind patterns and also mid-mountain cloud formation. The measurements of rain, snow and intensity are needed to validate the physics in high resolution models.

C. HYDROLOGY (Input provided by Bruce Stewart, for CHy)

The results of the intercomparison of methods and instruments for the measurement and observation of solid precipitation will support and advance the applications in the areas of snow that accumulates in a drainage basin that is a natural storage reservoir from which a major part of some basin's water supply is derived. The results will be of importance for:

- Water balance studies,
- Water availability analyses,
- Water resources management (including extended hydrological prediction),
- Flood forecasting and warning – contributions from snow melt.

The Scope and Definition of the SPICE objectives are in line with the requirements of CHy.

An important requirement from the hydrological community is the level of uncertainty in the measurements, both in terms of accuracy of the observation and analysis of the data through adjustment/correction procedures.

The activity will provide important reference material to support other WMO publications such as the Guide to Hydrological Practices, in particular Chapter 3:
http://www.whycos.org/hwrp/guide/chapters/english/original/WMO168_Ed2008_Vol_I_Ch3_Up2008_en.pdf

D. AGRICULTURE (Input provided by Francesco Sabatini, for CAgM)

References:

1. AA. VV. Guide to Agricultural Meteorological Practices (GAMP), Draft 3rd Edition (WMO-No.134)
2. Hubbard G. K., Sivakumar M.V.K. Automated Weather Stations for applications in Agriculture and water resources management: Current use and perspectives. Proceedings of international workshop 6-10 March 2000, Lincoln, Nebraska, USA.
3. ET-AWS-6 Geneva 2010 Final Report
4. Usman Qamar. Revised Technical Specifications for rehabilitation of Meteorological network-Afghanistan, March 2009.
5. F. Sabatini, 2010, Recommendations for the design of a system for acquisition, transmission and storage of Hydro-Meteorological data on the Kailash Sacred Landscape in Nepal.

SNOWFALL OBSERVATION NETWORKS REQUIREMENTS AND CONSTRAINTS

Installation/Rehabilitation Projects of Automatic Snowfall networks

The establishment / rehabilitation projects for observation networks normally focus on the reconstruction of the weather stations towards automatic devices. The network is normally designed for permanent operation and for general purpose data collection. Data are needed for a variety of tasks including water resources assessment of the country/region/project and strategic planning, project planning and design, operational water management system (river basin management, reservoir operation, drought mitigation measures, flood protection, trans-boundary water management), monitoring of climatic trends, hydrological modeling, water availability study, flood estimation and forecasting. The observation of snow cover (water equivalent of the accumulated snow) and precipitation, as well as the collection, compilation and analysis of parameters that are relevant for the snowmelt process (temperature, relative humidity, wind, solar radiation), should provide the basis for sound decisions in water management, in particular on water abstractions for irrigation purposes.

These projects often include the installation of Automatic Snow Survey stations to be installed at elevations of more than 2000/2500 meters. Snow storage is a crucial factor for water resources availability and snow monitoring provides excellent possibilities of water availability forecasting.

Guidance on Snowfall Network Setup

The hydro-meteorological staff that had been operating the historical networks could be recruited again and made available for the implementation of the projects, because they are familiar with conventional measuring techniques and equipment installation requirements.

However, the numbers of experienced staff are insufficient and knowledge of modern hydrometric/snowfall equipment or observation techniques is normally not available. The historical networks are based on classical technology, with manual snow level measurements. Data processing is manual. Some junior staff with good computer skills could be recruited but in general the enhancement of capacity for managing an electronic data acquisition, database and telemetry system need to be built during the course of the projects.

Constraints and common problems

Key constraint for the technical concept is often the prevailing security situation in the developing countries. In many regions, site visits by international staff or contractors are not possible and implementation will have to rely on Local Authorities staff and local contractors. Both Meteorological stations and snow stations could be installed in uninhabited areas where the security constraints are most critical and mainly determined by accessibility criteria. Highly visible and vulnerable equipment should be avoided, as far as possible, in order to reduce the risks of vandalism and theft. Uninterrupted data recording must be guaranteed for long periods during which regular maintenance visits may not be possible.

EXPECTATIONS

Upon the consideration reported above, the SPICE results may provide great benefits in order to:

- assess snowfall automatic devices in order to facilitate future selection of instruments for specific conditions (i.e. type of climate, power availability, complexity of the sensor, etc.);
- evaluate the power drain by the automatic system because we often rely on solar panel / wind powered remote stations;

- characterize the instrumentation with respect to manual observations and other reference sensors
- evaluate the accuracy and the performance of snowfall devices under different climate conditions
- evaluate the robustness of the instrumentation (i.e. gap analysis, number of malfunction reports)
- increase the effectiveness of observed data interpretation by improving post processing methodologies to reduce/correct under catchment errors
- provide practical examples of snowfall data correction upon the results obtained by the intercomparison
- address guidelines to assist in the transition from manual to automatic snowfall observing systems (ref. ET-AWS 6 2010)

CALIBRATION AND GROUND TRUTH OF SPACE-BASED OBSERVATIONS

A very useful source of information comes from the joint use and integration between snowgauges/raingauges data and other weather observing systems like radar, polar and geostationary multi-spectral satellites. All these sources of data are complementary and providing information on different atmosphere stratus level, thus providing detailed information for the reconstruction of weather systems.

It should be useful to address the integration into networks of heterogeneous and innovative tools for measuring precipitation: e.g. Laser Precipitation Monitor (LPM), last generation instruments with state of the art technology that can measure the amount of precipitation, the size and the type of falling particles.

ANNEX IV

WMO-Solid Precipitation Intercomparison Experiment (WMO-SPICE)

MISSION STATEMENT AND OBJECTIVES

1. 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.

2. 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.

An important aspect of this project will be to ensure that all available remotely sensed precipitation data is collected and included as part of the intercomparison data base. However, analysis of these data is beyond the scope of this intercomparison. The results of this intercomparison can later contribute to improved spatial and temporal estimates of precipitation.

3. Background

Solid precipitation is one of the more complex parameters to be observed and measured by automatic sensors and systems. The measurement of precipitation has been the subject of a multitude of studies, but there have been limited coordinated assessments of the ability and reliability of automatic sensors to accurately measure solid precipitation. The WMO Solid Precipitation Measurement Inter-comparison (1998)[8] focused on the instruments in use in national networks at the time of the intercomparison, primarily manual methods of observation. The

[8] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM No. 67, WMO/TD-No. 872)

assessment of automatic sensors/systems for snow depth and snowfall measurement was not a central part of the study, and no intercomparison stations were included in the Arctic or Antarctic.

Since then, an increasing percentage of precipitation data used in a variety of applications have been obtained using automatic instruments and stations, including the measurement of snow depth, and many new applications (e.g., climate change, nowcasting, water supply, complex terrain, avalanche warnings, etc) have emerged. At the same time, many of the new techniques used for the measurement of solid precipitation are of non-catchment type, e.g. light scattering, microwave backscatter, mass and heat transfer, etc.

Additionally, during the development of proposals for satellite sensors to measure solid precipitation, the issue of validation and calibration of such products using *in-situ* measurements (network or reference stations) identified the availability of reliable measurements of solid precipitation at automatic stations as a key input in assessing measurements in cold climates.

The modern data processing capabilities, data management and data assimilation techniques provide the means for better assessment and error analysis.

4. 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 (e.g., radar- and/or satellite-based snowfall estimation). 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.

6. Potential Candidate list of Instruments and Configurations

The experiment may include many instrument types, models and configurations identified as currently operational, as summarized in WMO CIMO Publication IOM No. 102, *Survey on National Summaries of Methods and Instruments for Solid Precipitation Measurement at Automatic Weather Stations*[9].

In addition, known emerging technologies may be included, based on the recommendations of WMO Members.

[9] http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html (IOM 102, WMO/TD-No.1544)

The following is a list of instrument types and configurations, as identified in IOM 102, following the 2008 CIMO Survey:

- Weighing Gauges, Tipping Buckets, other storage gauges;
- Instruments employing emerging technologies e.g. laser, particle disdrometers, hot plate, spinning arm, vertically pointing radar, optical gauges, acoustic, precipitation video imaging, video camera;
- Wind shields: type: (e.g. Alter, Nipher, Tretyakov, Wyoming, Belfort, wood), and configurations (single, double, mixed type, small DFIR);
- Gauges equipped with heating in various configurations;
- Emerging trends: low-cost sensors, with (potential for) wide use.

7. Duration of the Intercomparison

Each intercomparison site will be operated for a minimum of two winter seasons.

ANNEX V

Proposed Configuration of Intercomparison Sites and of the Field References

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 to 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 2011/12 pre-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: An automatic weighing gauge in a windshield 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.

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ANNEX VI

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
RH	X	X	X
2D winds at the orifice of the gauges	X	X	X
Snow depth auto	X	X	X
Precipitation detector (absence / presence)	X	X	X
Site wind (10m)		X	X
Net Radiation		X	X
Visibility		X	X
Web / video / still		X	X
Micro physical (any method e.g. Auto or manual)		X	X
SWE observations (either manual or automatic)		X[*2]	X[*2]
Manual observations of selected parameters: precipitation type, snow course, snow depth, assessment of snow drift, blowing snow, etc:			X

[*1] Site type as per the proposed structure in Annex V of this report.

[*2] Not mandatory, but highly desirable

ANNEX VII

Overview of the planned contribution and engagement of WMO Members, as identified prior to the IOC-SPICE meeting, Oct. 5th to 7th, 2011

1. Canada:

Canada plans to host SPICE on one of its sites, in Egbert – Ontario; this site participated in the 1989-1993 WMO Solid Precipitation Intercomparison and will participate in the 2011/12 pre-SPICE experiment. The site is located at 44°13'N, 79°47W, with an elevation of 252 m, with easy access year around, about 80 Km north of Toronto. The site will have two full size DFIRs.

During the winter of 2011/12, the site will host the GPM Cold Season Precipitation Experiment (GCPex), organized by NASA and Environment Canada. The GPM Science Plan for GCPEx can be found at : http://trmm-fc.gsfc.nasa.gov/Field_Campaigns/GCPEX/ .

For the winter of 2011/12, an additional site located at the Bratt's Lake Observatory, (50° 9′ 44″ N, 104° 40′ 44″ W), 23 km south of Regina, Saskatchewan will host an experiment on the working field reference. The site has had two DFIR for the last decade, and the data was used for a number of comparative studies of manual and automatic measurements of solid precipitation.

A third component of Canada's participation in SPICE, currently under consideration, is the assessment of the primary reference, the bush gauge. Studies are underway on the potential location and the associated logistics.

2. China:

CMA intends to host SPICE on one of its intercomparison sites. CMA has built 3 sites in North China for solid precipitation tests, according to different climate between wind and solid precipitation amount. The first site is for heavy snow measurement with low wind speed, the second is for light snow with high speed, and the third is for heavy snow with high wind.

Every site has one DFIR, several type AWGs and manual solid Precipitation measurement. The Tretyakov shield is the only one used into national operational Solid Precipitation measurement, but different shields can be mounted for the intercomparison.

CMA is planning the expansion of these sites with additional infrastructure, potentially a second DFIR, to support SPICE site(s) in China.

3. Finland:

Finland intends to participate in the experiment with the FMI Sodankylä observatory in North Finland called also FMI Arctic Research Centre (FMI-ARC). This is also a site which is applied as WMO-CIMO-testbed, http://fmiarc.fmi.fi/. FMI plans to build one or two full DFIRs at the site, planned for completion in 2012.

FMI has two DFIRs also in Jokioinen observatory in South Finland. This site is also a candidate for SPICE, including in the 11/12 pre-SPICE experiment; it was one of the participating sites in the WMO-Solid Precipitation Intercomparison of 1989-1993.

4. Italy:

Italy may offer two potential forms of participation:

Lead Centre on precipitation intensity "B. Castelli" (Laboratory + Mountain Site + Field Site/ Vigna di Valle). *Nature of participation:* experience's support on intensity, laboratory dynamical calibrations of gauges (all catching types), dynamical characteristics of gauges (all catching type), field dynamical calibrations by portable devices (A proposal for SPICE is being under development, soon available - see also agenda item 4).

Mountain Apennine Site 1850 mt a.s.l. (mixture of oceanic and continental circulations; cold-humid air). *Nature of participation*: intercomparison site for SPICE phase 2 (from 2012 or 2013). The site will be equipped by a DFIR, a SDFIR + other combinations.

5. New Zealand

New Zealand (NIWA) has recently installed a number of new high elevation snow monitoring stations, which are part of the newly developed national snow and ice monitoring network: http://www.niwa.co.nz/news/niwas-national-snow-ice-monitoring-network.

Some of these locations could be used for SPICE, as they are well situated and have new infrastructure.

Due to site limitations (i.e. that they are all alpine in nature and on Crown Corporation land, including in World Heritage areas), building DFIRs is not feasible, or permitted.

These sites could make a great contribution to the objectives of SPICE as many are at one end of the maritime/continental snow continuum. They represent challenging locations that experience large amounts of snow, strong winds, and regular rime ice build-up. As these sites are located in the Southern Hemisphere, they fill an important gap at global level.

These sites are located in remote areas, and operate solely on solar and battery power. They offer an excellent opportunity for testing of gauges in remote locations, where the human intervention is minimal, and significant power restrictions, apply. The testing of instruments in these environments would result in the identification of instruments and configurations which could be deployed in any environment across the snow continuum, and with a wide range of power supply options.

NIWA conducted a small intercomparison in New Zealand during the winter of 2010 with three different gauges, which could serve as a baseline for the SPICE configuration.

Norway:

Norway has established a testsite at Haukeliseter (59°48.71'N, 7°12.86'E, 991m a.s.l.), a mountain plateau in Southern Norway. The site has been in use since the winter 2010/2011. Currently, a national intercomparison of solid precipitation measurements is ongoing for the course of 3 winters (2011-2013). Haukeliseter is located directly at European Road E134, AC power and broadband internet are available. The station is unmanned. Two lakes provide a relatively flat area around the testsite, especially during the winter months. Distances to the surrounding mountaintops (1200m - 1500m altitude) are generally 2-4 km, the closest is located in north east direction in ca. 1km distance.

Some average climate data:

- Average Annual Temperature: 0.4°C (normal period 1961-1990, note: only 10 years winter observations (1984-1995: average: -4.5°C) available)
- Average Annual Precipitation: 840 mm (normal period 1961-1990, note: only 10 years winter observations (1984-1995: 350-470mm) available)
- Percent of precipitation that falls as snow: 60-65%
- Daily Average 10m Wind Speed: 5 m/s (based on winter observations 1984-1995) main wind directions are WNW and ESE.

The site has one DFIR surrounding an AWG (Geonor with 3 transducers & Alter windshield) at 4.5m height, as well as two AWGs (Geonor w 3 transducers & Alter windshield) beside. The unusual height was chosen to secure sufficient clearing under the DFIR until the end of the snow season and to minimize events where drifting snow can reach the orifice. The height of the instruments cannot be changed until at least summer 2013 due to the needs of the ongoing study.

All AWGs are equipped with wind sensors at approximately orifice height. Additional instruments are present weather sensors, disdrometer, camera, precipitation indicators, snow depth sensors, as well as sensors for the usual meteorological parameters (temp, hum, wind) at a nearby mast. 3D wind measurements are to be installed before the winter 2011/2012.

The site is limited in its horizontal extent and therefore does not bear the possibility to establish another DFIR.

Norway is interested in participating with the current test site (mainly as is) in the early experiment and the 2012/14 field campaign. Necessary major changes, which are not jeopardizing the ongoing study, need individual financial approval.

7. Russia:

Precipitation station at Valdai branch of the SHI is currently operational. There is a reference precipitation measuring unit adopted by WMO as the primary standard, two Tretyakov gauges in DFIR adopted as secondary standard, 6 Tretyakov gauges, a pit gauge, a П-2 rain gauge, and automatic rain gauges RG-50.

In October 2011, the OTT Pluvio 2 and Pluvio 4 will also be installed, with a possibility to install other instruments supplied by WMO in the project framework.

8. Switzerland:

Two test sites are proposed for SPICE: the test facilities at high Alpine elevation (Weissfluhjoch, 2500 m asl) and in the lower Alpine conditions (Davos, 1500 m asl). The combination of both will be very valuable for meeting the SPICE objectives.

Weiifluhjoch test facilities are already equipped with various heated and non heated gauges (TGRB), optical sensors, snow pillow and camera. The Davos site is equipped with TGRBs. Manual observations could be performed extensively during the SPICE campaign.

For winter 2011-2012, it is plan to start measurement with the existing set-up (possible addition of a Pluvio2 at Weissfluhjoch).

Additional installation for SPICE could be made in Spring/Summer 2012 (DFIR, additional gauges). Ancillary measurements are available on both sites.

9 USA

The proposed site is in Marshall, CO (39.949°, -105.195°, at 1750 m asl).

Three DFIRs are available at the site, and will be used to develop transfer functions between planned manual measurements using a Tretyakov gauge, a Geonor T-200B within a full size wooden double fence and a single Alter, and an OTT Pluvio2 gauge shielded in a full size wooden double fence and a single Alter.

Auxiliary sensors include a disdrometers, several types of anemometers installed at several heights (including a 3D sonic anemometer recording turbulence data at 10 Hz), air temperature, wetness sensors, and several snow depth sensors.

For the 11/12 pre-SPICE experiment, the Marshall test site will investigate the configuration of the field working reference using various weighing gauges in several configurations. A forth DFIR will be made available before the end of 2011.

A second component of the USA contribution consists in using the Niwot Ridge site for the snowfall and snow on the ground component of SPICE, by taking advantage of numerous instruments and projects already underway on site.

ANNEX VIII

Summary of Previous Intercomparison Projects Focused on the Measurement and Observation of Solid Precipitation

(Template for Completion)

This document is intended to summarize solid precipitation measurement intercomparison projects that have either been completed or are in progress at the time of the start of the WMO Solid Precipitation Intercomparison, WMO-SPICE, in 2011.

The information provided by participants will be used to catalogue intercomparison results, reduce redundant research effort, and complement the SPICE objectives. If the information requested is not available, please indicate such under the category heading.

Send the completed documents to:

Mr Craig Smith (craig.smith@ec.gc.ca) or

Ms Rodica Nitu (rodica.nitu@ec.gc.ca).

1. Project title:
2. Project objective:
3. Project location (Intercomparison Site Name and Country):
4. Site Coordinates (lat/lon/elevation):
5. Brief Site Description:
6. Study Duration (Start Date/End Date):
7. Climate Summary:
    a. average annual temperature (deg C):
    b. average annual precipitation (mm):
    c. percent of precipitation that falls as snow:
    d. daily average 10m wind speed:
8. Solid Precipitation Measurement Reference(s):

9. Instrument Intercomparisons (10 most significant):

Indicate instrument name, manufacturer and model, wind shield configuration (if applicable), instrument intercomparison start date and end date, measurement resolution, and whether or not data can be shared with SPICE collaborators.

Instrument (Manufacturer & Model)	**Wind Shield Configuration**	**Start Date yyyy/mm**	**End Date yyyy/mm**	**Measurement Resolution**	**Data Share (y/n/?)**

10. Ancillary Measurements

Parameter	**Instrument (Manufacturer, Model)**	**Measurement Height**	**Measurement Resolution**	**Remarks**

11. Indicate in 300 words or less how these intercomparison results/data/experiences links to the goals and objectives of SPICE. Any notes on lessons learned and limitations experienced during the intercomparison exercise would be valuable and appreciated.

12. Publications and Reports

13. General Comments

ANNEX IX

SPICE Raw Data Terminology

(Prepared by Dr Paul Joe, Environment Canada)

Introduction

The term "raw data" means different things to different people. This is a common problem. NASA, NWS NOAA NEXRAD and others have adopted terminology which may prove to be useful for the SPICE project.

NASA focuses on Earth Observations from space which has point, vertical profile and swath type data. NWS NOAA NEXRAD deals with ground base radar data which is in polar coordinates around radar location and three dimensional. These data are highly processed and often in separate stages and in separate computers. So these data are different from data typically collected from precipitation sensors. In precipitation sensors, the processing happens in front end processors (hardware and firmware) and in data loggers (a computer).

There is even some diversity within the NASA community and each project defines these levels (and sub-levels) for clarity of system design and discussion.

Attached are links to some relevant web sites.

http://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products/

Some Implementations (showing diversity of implementation to meet specific requirements):

http://irina.eas.gatech.edu/EAS_Fall2008/NASA-EOS-data-products-terminology.pdf

http://ilrs.gsfc.nasa.gov/reports/ilrs_reports/9809_attach7a.html

http://smap.jpl.nasa.gov/science/dataproducts/datalevels/

The Processing Chain and Raw Data Definitions

The core issue of the raw data discussion is the difference between "signal", "noise" and data for various end users. What is garbage or noise for one user may be gold or signal for another user. In the NASA and radar world, signal and data processing are conveniently separable. In the SPICE world, this separation is not clear as they tend to be stand-alone units in the field, where signal ("front end processor") and data processing ("data logger") have relatively low computational requirements and everything is packaged as a "black box" and things can be done in different places.

The discussions of data recording for the SPICE project leads to a discussion of where in the processing chain the data is collected and at what frequency. There are suggestions to get at the "rawest data" and this may mean:

- After the sensor but before the transducer
- After the transducer but before the front end processor
- After the front end processor
- After the data logger

Hence the term is ambiguous.

There are also suggestions of collecting the data at the "highest temporal resolution". In this sense, the sensor technology is a determining factor. Optical sensors may be able to report sensible data at high frequency (say 60 Hz or better) but catchment systems need to accumulate mass before it can report a change in their output (0.05 mm for example) and reporting times of several minutes may be the best that can reasonably be expected. Some designs rely on the signal and data processing system to remove artifacts such as wind pumping and so require substantial time series of data to remove. In this latter case, the data processing system is an integral part of the sensor concept. Each system may have a minimal (best) reporting frequency below which the sensor is reporting signal and noise and not just signal.

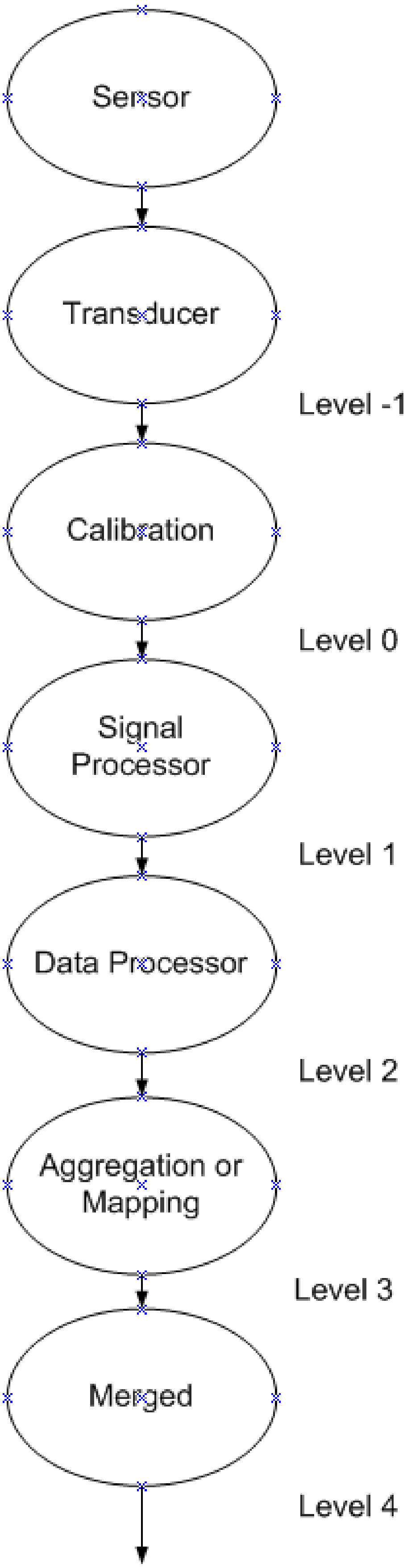
The attached figure is a summary of terminology used by NASA, NEXRAD radar and with some comments linking it to SPICE, and is proposed as data nomenclature for SPICE. All the "levels" described "raw data".

NASA also has a concept of data maturity which may be useful for subsequent discussions.
http://science.nasa.gov/earth-science/earth-science-data/data-maturity-levels/

Discussion

It seems that improvements by the manufacturers in the algorithm processing have apparently removed some artifacts such as wind pumping. Wind pumping probably still occurs, as this is physical effect of the shield and the sensor, but the effect in the data (high frequency positive and negative fluctuations in the reported amounts) has probably been removed by the signal or data processing either in a "front end" processor or in the "data logger". In order to evaluate this, one needs to record into Level 0 or Level 1 data but this is not always readily available or it may require adding specialized external signal and data recording systems, however this is not the intention of the project.

In order to compare instruments, a common reporting frequency is highly desirable. This may not be always achieved as the reporting frequency is highly dependent on the instrument and intercomparison concept. For example, it is not reasonable to collect 1 minute data from the Secondary Field Reference (as an extreme) since it is manual measurement. Manufactures may have determined that 1 minute data is not feasible for a "catchment" type sensor and only 1 hour or 10 minute data should be reported and treated as robust and reliable data whereas other, particularly non-catchment systems, are able to report at 1 minute. This is also a core issue for SPICE, as one of the objectives is to determine what the minimum reporting interval is and what to recommend for each sensor, shield and data processing combination. The reporting interval for Level 2 data may be configurable and the SPICE team will determine how best to resolve this in the experimental design.



Ref: http://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products/
Comment: One is free and should define the various levels as there are differences in usage. NASA has a standard terminology of Earth Observation data. A similar terminology but slightly different is used by NOAA NEXRAD Radar. This may need tailoring for surface observations.

Sensor may be the bucket or the tin can, the collection cone in a TBRG, laser sampling area, or radar antenna.

This might be a spring, a balance or frequency of wires. Anything to convert the physical signal to a electrical signal or voltage. The sensor and transducer are often thought to be one component . But, there are physical measuring principles that might permit extraction of information from the same sensor by different means. This level is not always defined but can be convenient.

This is the adjustment of the output of the transducer to make it "absolutely" correct. For example, this may be done by a off-line procedure. In the case of weather radars, an off-line receiver calibration that determines the relationship from the sampled voltage to reported voltage is often done and then this is applied. This may convert "tips" to "millimeters". This may be done with a "quantization calibration" or some other empirical procedure. Note - this step may occur later. In weather radar, this is often called "raw data" or the time series data or the IQ data (In-phase, Quadrature data).

This takes the fluctuating signal and applies some processing to separate "signal from noise". Often, this is done by averaging and thresholding but it can be quite sophisticated and it is up to the instrument design and concept to separate the signal from noise and what to do with it. Artifacts may or may not be removed here (wind pumping, spurious echoes). After this step, the "data" may be "end user units" eg (mm/h or mm). In the case of gauges, one may consider this to be "raw data" as it may still have the "wind pumping" effect in the data as this may be removed in the "data processing" step. It depends on the processing system design. Interestingly, in weather radar, this is not called "raw data".

The data processor collates the "data", adds meta data and quality information and applies navigation and time information (eg. Range, azimuth information in the case of radar). Note that signal and data processing is not always separate steps as some QC is done in the signal phase and some in the data processing phase. In the world of EO and radar, the important issue is that this is in the spatial resolution of the Level 1 data and has not been degraded. This is often called the "raw data" or "moment data" in weather radar. There is some QC applied at the instrument and data parameter level. In the world of automatic precipitation gauges, this is often the available data that is reported every minute, ten's of minutes or hourly. For wind data, some processing is done to produce max wind, max gust and it is often not clear what this is and at what resolution the calculations are done. The signal/data processing is often proprietary.

The terminology diverges here. Often the data is now released to users and it is up to the user to accumulate/aggregate the data (e.g. daily from hourly or minutely data or seasonal accumulations from daily data). This is an optional step for some applications or it may be part of the data logger output in the case of precipitation gauges and may be a running total. In weather radar, these are accumulation maps and they may be at degraded resolution (1kmx1deg becomes 4kmx4km maps) or quantization level. They could also be images. In some definitions (EO), this may be where the data is mapped to a uniform grid. For gauge applications, this may be considered maps.

Again there are differences in terminology. In general, the commonality is that this is where data from different sensors are merged into a map. In weather radar, they are mosaiced maps of individual radars. However, in EO and probably in maps,, they could be from different sensors.

Conclusions:

- The SPICE IOC/ET decided to adopt a standard terminology for discussion and communication purposes, as outlined in the chart below.
- The IOC/ET will determine the best reporting interval for each sensor included in the intercomparison. This takes into account the manufacturer recommendations and the project objectives.
- SPICE will collect Level 0 or Level 1, whenever possible, to meet the “understanding of sources of error” goal. It is recognized that this may require a more complex data collection, management, and analysis procedure.

ANNEX X

BREAKOUT DISCUSSION ON DATA ANALYSIS

Present: Eckhard Lanzinger, Luca Lanza, Daqing Yang, Roy Rasmussen

1. What is the fundamental measurement?

a. One minute weight for weighing gauges.

b. If possible, record the higher frequency data for this winter to see if useful for future analysis.

c. Present Weather information users focus on rate not accumulation. Climate users focus on accumulation, but also need rate. Accumulation and rate both important.

- Issue of what the rate is at the onset of precipitation: The first exceedance of a threshold amount does not tell you when the event started. Propose some analysis to filter the noise better and get lower rates.

2. Evaluate the different algorithms to produce the level 2 data:

Comment: The way the algorithm works can define the response time of the instrument.

a. Need to document the different algorithms used on the weighing gauge one minute weight data.

b. Should apply various algorithms to the one minute and higher resolution data and compare performance.

c. Define or derive a common algorithm for processing the one minute and higher resolution weighing data (level 0 and 1 to level 2 data). Call the WMO algorithm?

d. Decide with this winter's data whether to archive the higher than one minute data or not based on the performance of the algorithms.

e. Processed data should be available to the WMO users, not the level 0 or 1 data.

f. Transmit the level 1 data to a central location where it will be archived (not necessarily in real-time, e.g. daily, zipped file).

g. The data policy (protocol) should allow us to record and transmit the level 0 and 1 data from all manufacturer gauges.

3. Analysis approach of the level 2 data one minute data:

a. Compare all instruments against the reference and each other:

   i. Investigate different accumulation periods from one minute to daily.

   ii. Update the DFIR versus Bush gauge analysis of uncertainty using data from Valdai (past and future).

   iii. Set up a Bush gauge in Canada, during the summer of 2012.

   iv. Estimate uncertainty of the DFIR/auto reference by running two systems side by side.

   v. Perform numerical simulations of the airflow/snowflake trajectory around a DFIR to help estimate the uncertainty of an automated gauge in a DFIR (reference).

vi. Measure the airflow around the DFIR under different wind regimes to help validate numerical simulations (ask if any wind tunnel analysis of the DFIR shield and documentation of the flow around the shield).

vii. Create a numerical simulation task team led by Eckhard and Roy.

viii. Write a short plan.

ix. Simulate two different gauge/shield simulations and compare to the field results (ratio of the standard deviations).

b. Create a precipitation/snowfall event dataset from the various site data (characterized by certain environmental conditions) and non-event false alarms.

c. Derive transfer functions for the various gauge/shield systems using different accumulation periods (including one hour as the main period to daily).

d. In addition to the transfer function, also derive equations for the standard deviation of gauge catch as a function of wind speed:

   i. Standard deviation for single Alter GEONOR = fct (windspeed).

4. Data acquisition and synchronization:

a. Need to make sure that the data acquisition system collects data that allows for the analysis we want to do.

b. Synchronization: Should do at one site if possible.

ANNEX XI

ASSIGNMENT OF RESPONSIBILITIES

Task	Assignment	Due Date
Develop Data Protocol	R. Atkinson, E, Vuerich, Y.-A. Roulet, D. Yang, L. Lanza, H. Liang, R. Nitu, V. Vuglinskiy	20 Dec. 2011
Questionnaire on the proposed intercomparison sites	R. Nitu, M. Wolff, J. Hendrikx, Y.-A. Roulet, B. Goodison, H. Liang, B. Goodison, F. Sabatini	20 Dec. 2011
Questionnaire on the selection of instruments	E. Lanzinger, E. Vuerich, IOC	20 Dec. 2011
Finalise the organization for the pre-SPICE experiment and coordinate the activities (2011/12);	R. Nitu, R. Rasmussen, B. Baker, Y.-A. Roulet, M. Wolff, B. Goodison, J. Kochendorfer	01 Dec. 2011
Develop the data analysis procedure	R. Rasmussen, E. Lanzinger, D. Yang, L. Lanza, J. Hendrikx, P. Joe, J. Kochendorfer, H. Liang	January 2012
Acquire gauge vibration information to support the development of the dynamic laboratory test	R. Rasmussen, R. Nitu	June 2012
Develop the laboratory test of gauges to include the vibration and temperature cycling tests	L. Lanza, E. Vuerich, E. Lanzinger, R. Rasmussen, R. Nitu	June 2012
Develop glossary of terms specific to SPICE	IOC	Ongoing
Prepare and distribute first letter of information to be distributed to WMO Members and HMEI	R. Atkinson, R. Nitu, R. Rasmussen, B. Goodison	31 Oct. 2011
Summarize response to the First SPICE Letter	IOC	January 2012
Prepare and distribute the Second SPICE Letter of invitation for the intercomparison	R. Atkinson, R. Nitu	January 2012
Summarize the responses to the second SPICE letter of invitation	IOC, R. Atkinson	31 March 2012
Select the Instrument participating in the Intercomparison	IOC	15 April 2012
Agreement between the IOC and the host countries on the objectives and configuration of the experiment on the selected sites	IOC, Project Leads, WMO	15 April 2012
Issue third letter of invitation specific to instruments and sites selected for participation	IOC, WMO	30 April 2012
Report on the results of the 2011/12 pre-SPICE intercomparison	R. Rasmussen, D. Yang, M. Wolff, Y.-A. Roulet, R. Nitu, J. Kochendorfer, B. Baker	June 2012
Agreement on the configuration of the field reference for the experiment	IOC	July 2012
Assess opportunity for a Task Team for modeling the wind flow in a DFIR; develop plan	E. Lanzinger, R. Rasmussen, P. Joe, E. Vuerich,	2012

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ANNEX XII

CIMO Expert Team on Instrument Intercomparisons (ET-II)

UPDATED WORKPLAN 2011-2014

No.	Task description	Person responsible	Action/Milestone	Deliverables	Deadline for delivery	Status	Comments
Higher priority							
1.	**WMO Solid Precipitation Inter-Comparison Experiment (SPICE)**	**Ms Nitu (Project Leader)** Mr Vuerich Mr Lanzinger Mr Roulet	**a.** Concept, objectives, references and instruments, duration and organization, possible intercomparison sites, proposals for the establishment of IOC (International Organizing Committee) and of TT (Task Team), initiate SPICE. **b.** Invitation and questionnaires circulated **c.** Monitor progress of SPICE	**a.** Report to CIMO-MG **b**. Report to CIMO-MG & ET **c**. Report to CIMO-MG	**a.** Dec 2011 **b.** Dec 2011 **c.** CIMO-MG-10 Dec 2012 and every 12 months	80% 50% 0%	**a.1** Spice pilot/reference phase: Dec 2011 – Jun 2012 **a.2** Spice will commence in November 2012. **b.1** Information letter to Members+HMEI: Nov '11 **b.2** Invitation letter + questionnaires for instruments and sites + data protocol: Mid Jan 2012
2.	**8th WMO High Quality Radiosonde Intercomparison (Yangjiang, China) (Program, par. 7.2)**	**Mr Li** (with IOC-UA) Mr Vuerich Mr Li	**a.** Assist in finalization of the final report **b.** Incorporate relevant outcomes from Yangjiang radiosonde intercomparison into the CIMO Guide **c.** Advice GCOS on most appropriate radiosondes for use in GRUAN (relevant outcomes of Yangjiang radiosonde intercomparison about traceability) **d.** Participate in defining the road map for next global radiosonde intercomparisons (5 years intervals) – see also 5.a.	**a**. Publication of Final Report as IOM Report **b.** If applicable provide document to CIMO Guide Editorial Board based on Final Report **c.** Document to GCOS contact point based on Final Report **d.** Document to CIMO-MG before CIMO-XVI	**a.** July 2011 **b**. Oct 2011 (Dec 2012) **c**. Oct 2011 (April 2012) **d.** March 2014	100% 0% 10% 20%	**Task 2b**. Dr Nash contracted by WMO for the task. Revision expected in Dec 2012. Mr Li collaborates. Advise: ANNEX 4.A, Part III Chap.4 CIMO Guide will not updated. **Task2c**. Activity initiated, deadline to be extended (April 2012) **Task2d**. Activity initiated, draft document annexed to ET's 1st Session Final Report (Oct 2011).

No.	Task description	Person responsible	Action/Milestone	Deliverables	Deadline for delivery	Status	Comments
3.	**Liaison with other ETs and communities (BSRN, GAW, WCRP, etc.) to update CIMO Guide following results of intercomparisons**	**Mr Vuerich**	**a.** Liaise with other CIMO ETs members and communities on plans/on-going/completed instruments intercomparisons **b.** Coordinate updates of relevant CIMO Guide chapters related to inter-comparisons with these groups and CIMO Guide Editorial Board as required.	**a(1).**Report to CIMO-MG **a(2).** Report to OPAG-A Chairs if updates of standards required. **b**. Update of relevant CIMO Guide Chapters, if required	**a(1)** CIMO-MG-10 Dec 2012 **a(2)** as required **b**. as required	10%	Activated Liaisons: 1) GAW-NDACC, 2) CEN-ISO TC 318 and TC113, 3) EUMETNET WG Ins, 4) ET-A2 (for standards)
4.	**Contribute to the implementation of WIGOS and provide relevant advice and support to the CIMO-MG**	**All experts**	**a.** Address relevant items of WIGOS Implementation Strategy approved by Cg-XVI and subsequent WIGOS IP	**a.** Report to CIMO-MG	**a**. TBD	0%	As emerged from CIMO MG-9 ,2011. **ET chair needs assistance by OPAG Co-Chairs**
Lower priority							
5.	**WMO Radiation Intercomparisons**	**Mr Roulet** Mr Mair Mr Mair Mr Mair Mr Roulet	**a.** Initiate a survey to determine if Regional Radiation Centres are holding a regional comparison in 2011-2015, or alternative forms of traceability to WRR **b.** Investigate and report on the potential for adding an infrared international inter-comparison to list of CIMO approved comparisons **c.** Investigate and report on the outcomes of IPC-XI and suggest modifications to future IPCs **d.** If applicable assist in coordination of a regional radiation comparison	**a.** Report on survey results **b.** Report to CIMO-MG **c.** Report to CIMO-MG **d.** Report to CIMO-MG	**a(1)** Initiation in April 2011 **a(2)** Report July 2012 **b.** CIMO MG-10 Dec 2012 **c**. June 2014 **d.** on-going	50% 0% 5% 5% 25%	**a**. An INFORMAL survey was conducted. An official survey was requested through Secretariat. In close collaboration with B. Forgan. **b**. Investigation through the survey in (a) **c.** Initiated **d.** RPCs announced by Japan and Sweden for 2012. Contacts were established and coordination was started.

No.	Task description	Person responsible	Action/Milestone	Deliverables	Deadline for delivery	Status	Comments
6.	**WMO Regional radiosonde Intercomparisons**	**Mr Krishnan** Mr Krishnan Mr Vuerich, Mr Krishnan	**a.** Develop a strategy for further radiosonde intercomparison based on recommendations of the WMO Radiosonde Intercomparison in China to be considered for the regional intercomparison **b.** Investigation on **availability of hosting country** for organizing the regional Intercomparison (Indian Meteorological Department, India) **c.** If applicable assist in coordination of radiosonde intercomparison	**a.** Report to CIMO-MG **b.** Report to ET **c.** Report to CIMO-MG	**a**.CIMO MG-10 Dec 2012 **b**. Dec 2011 **c.** As required	0% 0% 0%	**a**. Activity in close coordination with task 2d. **b**. No updates
7.	**Contribute to the implementation of WIGOS and provide relevant advice and support to the CIMO-MG**	**All experts**	**a.** Address relevant items of WIGOS Implementation Strategy approved by Cg-XVI and subsequent WIGOS IP	**a**. Report to CIMO-MG	**a**. TBD	0%	As emerged from CIMO MG-9 ,2011. **ET chair needs assistance by OPAG Co-Chairs**