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

**PROJECT TEAM AND (REDUCED) INTERNATIONAL**

**ORGANIZING COMMITTEE FOR THE WMO**

**SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT**

**Seventh Session**

**Toronto, Canada**

**11 – 15 July 2016**

**FINAL REPORT**



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**EXECUTIVE SUMMARY**

This report provides a summary of the meeting of the Project Team and (reduced) Seventh session of the International Organizing Committee (IOC) of the WMO Solid Precipitation Intercomparison Experiment (SPICE) that was held in Toronto, Canada from 11 to 15 July 2015.

The meeting reviewed the draft final report of SPICE. Break-out sessions were organized to carry out an in-depth review of specific parts of the draft final report and significant time was devoted to improve the text and draft missing sections of the text.

The meeting reviewed several draft recommendations to be later included in the SPICE Final Report.

The meeting agreed on the way forward to finalize the report prior to TECO-2016, and to share it with the instrument providers.

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**AGENDA**

1. **ORGANIZATION OF THE SESSION**
   1. Opening of the Session
   2. Adoption of the Agenda
   3. Working Arrangements for the Session
2. **REPORT OF THE CHAIRPERSON**
3. **REVIEW OF THE SPICE DRAFT FINAL REPORT AND OF SPECIFIC RESULTS**
4. **PLANNING TOWARDS THE FINALIZATION OF SPICE**
5. **DEVELOPMENT OF RECOMMENDATIONS FOR WMO MEMBERS BASED ON THE SPICE PRELIMINARY OUTCOMES**
6. **OTHER BUSINESS**
7. **CLOSURE OF THE SESSION**

# GENERAL SUMMARY

1. **ORGANIZATION OF THE SESSION**
   1. **Opening of the Session**
      1. The meeting of the Project Team and (Reduced) International Organizing Committee (IOC) for the WMO Solid Precipitation Intercomparison Experiment (SPICE), Seventh Session, was opened on Monday, 11 July 2015 at 8:30, by Ms Rodica Nitu, the IOC Chairperson and SPICE Project Leader. The list of participants is given in [Annex I](#Annex1_Participants).
      2. Mr Richard Hogue, acting Director General, Monitoring and Data Services Directorate, Environment and Climate Change Canada, welcomed the participants on behalf of Environment and Climate Change Canada (ECCC) to Toronto. He stressed the importance of finalizing the intercomparison report to enable all interested users to benefit from the outcomes of the experiment and of all the efforts invested in it. He appreciated Ms Nitu’s leadership of the project over the last years to coordinate this project that involves organizations from 15 countries, 20 test sites and instruments from 20 different instrument providers. He stressed the importance of improving the data quality for their assimilation in NWP models. He finally encouraged the team to widely publish the report of SPICE.
      3. Mr Barry Goodison, Vice-Chair of the Global Cryosphere Watch (GCW) Steering Committee, recalled that SPICE is a demonstration project of GCW and that some SPICE-related activities could be continued under the auspices of GCW, for example to demonstrate how to apply those results. In the current context of the high visibility of climate change, more attention is also given to measurements of snow, which may help in disseminating the results of SPICE and having them applied in operational network.
      4. Ms Isabelle Rüedi welcomed the participants on behalf of WMO. She expressed thanks to Canada for hosting the meeting as well as for its active involvement in SPICE throughout the project through the provision of several test sites having unique configurations and for supporting the active involvement of several ECCC staff members in the SPICE data analysis.
   2. **Adoption of the Agenda**

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

* 1. **Working Arrangements for the Session**

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

1. **REPORT OF THE CHAIRPERSON**
   1. Ms Rodica Nitu, the SPICE Project Leader and Chairperson of the IOC, presented her report on the status of the experiment.
   2. She recalled the main mission statement of SPICE:

* 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:
  + total precipitation amount in cold climates for all seasons, especially when the precipitation is solid,
  + snowfall (height of new fallen snow), and
  + 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.
  1. She recalled that the project was approved in 2010, and the progressive involvement of several organizations and manufacturers in it. She thanked all participating organizations and instrument providers for their involvement in the project.
  2. She reminded the team of the expected deliverables of the project and recognized that the team has been working towards them throughout the project. She acknowledged that the legacy of the project is not only the final report and the recommendations that it will include, but that the dataset is also an inherent part of the legacy as it will enable further data mining by various interested parties. She encouraged the team to include in the report recommendations to manufacturers toward improving instruments, so that they meet user requirements.
  3. Ms Nitu presented the objectives for the work of the meeting: reviewing the draft final report, integrating report components, refining assessments of results, drafting recommendations and conclusions and preparing for presenting the results of the experiment at TECO. In view of the limited amount of time until TECO-2016, and the change in availability to support the project from a few major contributors, she concluded that the team would have to be very pragmatic to ensure it can deliver the expected results. She also recognized that some objectives might not be reached and that they would have to be recommended as new work items for CIMO, or other interested parties. She finally expressed her plan to develop a list of lessons learned from the project with respect to the organization of intercomparisons by CIMO.
  4. Ms Nitu informed the meeting that the SPICE Special Issue had been extended until June 2017 and encouraged all to publish SPICE-related analyses in this journal special issue.
  5. Mr Morin recommended that the report includes guidance to network managers on how it is feasible to implement SPICE results in operational network (what should be done, how it should be done, and what is feasible).

1. **REVIEW OF THE SPICE DRAFT FINAL REPORT, AND OF SPECIFIC RESULTS** 
   1. The meeting organized the review of the current draft SPICE Final Report. The meeting agreed that the final report would have to be based on analyses carried out to date. When reviewing the material, the meeting would have to identify areas of analysis that are not appropriately covered, and possibly missing. It would also have to identify whether such missing areas would be nice to have, or absolutely critical to the overall understanding of the results. It was agreed that the team would currently only consider areas that are absolutely critical, and would prepare a list of areas that are less critical and which could be addressed at a later stage, by the SPICE team of other interested parties.
   2. In order to effectively review the draft final report, several break-out sessions were organized. They covered the following topics:

* Instrument performance reports, for the different types of technologies,
* Transfer functions,
* Trace precipitations,
* Capping, and how it can be minimized,
* High winds and complex terrains
* Description of the sites,
* Assessment of the feasibility of using a R3 configuraiton as a field reference,
* Weighing Gauge assessments,
* Snow on the ground assessments,
* Non-catching type instruments assessments.
  1. Several decisions were proposed by break-out sessions and agreed in plenary. These include, among others (in no specific order):
* Update chapter 2 (“Methodology”) with “Intercomparison Principles” which would include a high-level description of the references, principles for the selection of instruments and their allocation to sites, and a list of instruments allocated to the sites in an Annex. (Y.-A. Roulet)
* Include as Annexes, the questionnaires with the expression of interest for contributing sites, instruments (both for precipitation accumulation and snow on the ground), data protocol, and template for the commissioning reports, (Y.-A. Roulet)
* Clarify that the algorithms used in SPICE are not those of specific Members and that WMO Members need to decide whether or not they want to apply those algorithms, and if so, to which extent, assessing how a change of algorithm may affect/improve their time series, (Y.-A. Roulet)
* Update description of quality control and event selection methodology, (A. Reverdin)
* Include discussions on thresholds used in the main part of the report, (R. Nitu)
* Include information on calibration of gauges in the general principle part of the report, and remove it from the instrument performance reports, (Y.-A. Roulet)
* Mention use of anti-freeze and oil, and provide as an Annex, the table with the specificities of the products used at each site, (Y.-A. Roulet)
* Site descriptions should be based on, and extracted from the material provided at the beginning of the experiment by the sites (submission, as well as commissioning reports, and include a brief site description, objectives, images and site layout, but no climatological information, and no information on site data acquisition system. (F. Sabatini)
* Remove data availability from the site description, (F. Sabatini)
* The methodology used to derive the instrument performance reports will be included in the main body of the report, rather than in the individual instrument performance reports. An individual section on each type of technologies will be needed. (R. Nitu, Y.-A. Roulet)
* Ancillary measurements during the intercomparison will be provided in the instrument performance reports as they provide information on the conditions under which the evaluation were performed. (A. Reverdin, M. Earle, K. Wong)
* Specify wind-height used for the derivation of the transfer functions. (J. Kochendorfer)
* Include only a summary of G. Lee’s method for the derivation of transfer functions as a function of the precipitation intensity in the main body of the report, recognizing that the detailed analysis is about to be published in the SPICE Special Issue. (G. Lee)
* Include a reference on the paper on transfer function from John and Mareile to the summary provided in the draft final report. (J. Kochendorfer)
* Develop transfer function for the Belfort Double Alter, using CARE data, and possibly data from other sites, if available, (J. Kochendorfer)
* Coordinate contributions related to the R3 (from reference report, from current draft final report, and from J. Kochendorfer), and the fact that it did not permit to improve the transfer functions as it had originally been expected, because of the low value of the transfer function to a single Alter shield. (J. Kochendorfer)
* Clarify that “operational comparability” is the same as “RMSE”, (R. Nitu)
* For the assessment of Pluvio2 gauges as sensors under test, present results for both the Bucket RT and Accumulation NRT outputs, (K. Wong)
* Include the names of the instruments that were used for the SoG automatic reference at each site. (C. Smith)
* Provide information on the instrument performance reports on how to use the quality numbers outputed by the instruments for quality control, especially for snow on the ground instruments, (C. Smith)
* Develop a separate table of contents for snow on the ground (if time allows, put all information related to snow on the ground into a single section/part of the final report),
* Include section on Forni Glacier results as a site report, (Y.-A. Roulet)
* Move information on noise experienced at Caribou Creek to the main part of the report, rather than having it in the individual instrument performance reports, as it is linked to the site rather than to the individual instruments, (Y.-A. Roulet)
* Insert information on noise experienced with analog signals originating from heaters in lessons learned, (C. Smith)
* Include information on availability of heater, and heating algorithms provided by the manufacturers, in the instrument performance reports (J. L. Collado)
* Describe heater and heating algorithm used within SPICE, (Y.-A. Roulet)
* Add a section on blowing snow, and the difficulty to identify it with only one instrument. (M. Wolff)
* Include R2-R3 comparison in the final report, (J. Kochendorfer)
* Include R2 Pluvio vs R2 Geonor comparison in the final report, (G. Lee)
* Check availability of R2 data from Volga in NCAR (whether it was received and whether any QC was performed on it), (Y.-A. Roulet)
* Include a summary of GyuWon’s work on uncertainties, with some preliminary results, in the main part of the final report and refer to the publication that is in preparation, (G. Lee)
* Include as Annexes studies carried out on oils and anti-freeze by the team members. (Y.-A. Roulet)
  1. The meeting noted that some sites had not been able to contribute as they had originally wanted, due to changes in the support they were receiving from their funding organization. The meeting agreed to recognize those changes in involvement of some sites in the final report.
  2. Several terms specific to SPICE are used throughout the final report. The meeting decided to include a glossary of terms in the final report. Mrs Mekis and Mr Sabatini will contribute to the creation of the glossary that will be coordinated and finalized by Mr Roulet. Each team member is encouraged to send abbreviations and specific terms used in the report to Mr Roulet.
  3. The meeting recommended that the analysis of the performance of disdrometers, as a function of their shielding, that was performed at the Formigal and Weissfluhjoch sites, after the formal completion of the SPICE data collection, be included in the SPICE Final Report as a site report.
  4. The meeting also recommended including Mr Buisan’s study on hydrological applications as an Annex to the final report, as site report.
  5. For the previous WMO solid precipitation intercomparison, the bush gauge of Valdai was used as reference for the derivation of the transfer functions, because it had a very long record. However, this represented data from only one site in one climate. For SPICE, an automatic bush gauge was set up in Caribou Creek. Automatic instruments were also installed in the bush of Valdai, but the data is not yet available for comparison on the NCAR archive. The results that had been obtained with the manual Valdai bush gauge are not in full agreement with the recent results of the automatic bush gauge of Caribou Creek. In this context, it was noted that the Caribou Creek data cover only a very limited range of wind velocities. The meeting agreed that it was premature to conclude on a difference in the performances of the manual and automatic bush gauges.
  6. For SPICE, the team has access to data from several sites having R2/DFAR configuration, which represent various climates, and a range of meteorological conditions. The meeting agreed that for SPICE, the transfer functions would be derived from the DFAR, and would not be corrected to the DFIR, nor to the bush gauge. This is already mentioned in the draft final report, but it should be ensured that there are no ambiguities on this throughout the report.

1. **PLANNING TOWARDS THE FINALIZATION OF SPICE** 
   1. The goal of the team is to have the SPICE final report ready by TECO-2016 to ensure that the results of SPICE can be presented at TECO-2016. The meeting noted that several key contributors to SPICE would not be available anymore after September 2016, or only in a very reduced manner, and that no alternative sources for resources can be expected.
   2. The meeting did its utmost to progress as much as possible with the report writing and its critical review during the meeting itself. Several drafting session were organized to evolve the text of specific sections.
   3. It had originally been expected that instruments from smaller sites could be assessed against the R3 reference. However, the results in assessing the reliability of a R3 field reference do not support the initially planned approach, for the entire range of environmental conditions. The meeting therefore decided that the evaluation of the sensors under test would focus on those sites that have an R2 reference to ensure the consistency and the reliability of the results. Sites having no R2 would be used for site specific analysis only (apart from the Col de Porte site, used for snow on the ground analysis). This is also in agreement with the general principles that had been followed, while allocating instruments to SPICE sites, when almost all instruments had been allocated to sites having an R2.
   4. The meeting recognized the need to present the instrument performance in a manner as similar as possible for the different types of technologies, to ensure the users will have comparable information, and to reduce risks of presenting results biased towards one type of technology. The meeting therefore developed a template for the individual instrument performance reports that could be used for all technologies (weighing gauge, tipping-bucket gauges, non-catchment type instruments, and snow-on-the-ground instruments). However, there will be some differences in the reports between the different technologies, since some analysis cannot be performed the same way for different technologies (flexibility to fit the purpose must prevail).
   5. The meeting also recognized the need to share lessons learned with each type of instrument through the instrument performance reports. These should describe the reliability of the instruments and include the strengths and weaknesses of the instruments, as well as additional considerations that are not necessarily positive/negative, but that were experienced and which could be of interest to potential users of these instruments.
   6. The meeting agreed that it would be valuable if the experiences made by the technical staff that was in charge of installing the gauges could be reflected in the final report, but noted that it may not be possible to achieve this in view of the time constraint to finalize the report.
   7. The meeting agreed to proceed as follows to finalize the report:

* Finalize the instrument performance reports, and the main part of the report relating to the methodology, sites, references, transfer functions, and general results, to share them with manufacturers by mid-August.
* Finalize other sections of the main report and site reports, and perform a consistency check of all sections in later August/early September,
* Finalize the recommendations and conclusions, by end of September, or soon after.
  1. The site report of Gochang presents results on several instruments that are not available at other sites. The meeting invited the Gochang Site Manager, Youngsan Park, to ensure text would be added to this document to describe the analysis/results and provided early enough for inclusion in the mid-August release that will go to manufacturers.
  2. Responsibilities for providing the independent sections of the report were identified. All sections must be provided to Mr Roulet who continues to coordinate the integration of the various parts into the final report and to homogenize them.
  3. The instrument performance reports will be reviewed by (a subgroup of) the team before being sent to the manufacturers. Teleconferences will be organized to address specific aspects, as required.
  4. The meeting agreed to inform instrument providers, and the SPICE Project Leader will provide the draft report to the instrument providers. In the case of instruments provided to sites through bilateral collaborations, the site managers have the responsibility to inform them on the performance of their instruments, while ensuring the confidentiality of the overall experiment’s results and adherence to the SPICE Data protocol. For instruments that are owned by sites, there is no need to provide advance information to the manufacturers of these instruments.
  5. The meeting also agreed that finalizing QC for data from sites that do not have an R2 and for additional instruments provided by sites should be continued in September, after completion of the main instrument performance reports.

1. **DEVELOPMENT OF RECOMMENDATIONS FOR WMO MEMBERS BASED ON THE SPICE PRELIMINARY OUTCOMES** 
   1. The meeting discussed the type of recommendations that should be included in the concluding section of the SPICE Final Report. It recognized that they should not only encompass recommendations related to the implementation of the SPICE results in operational networks, but also provide recommendations for further work, by CIMO, or other interested parties, as well as recommendations to manufacturers related to the requirements of users for cost-effective instruments and their cost-effective operation.
   2. The meeting recommended to order and structure the recommendations to different user groups (instrument manufacturers, network managers, ….).
   3. The meeting reviewed several proposals for recommendations to be included at the end of the SPICE Final Report. It agreed that these proposals would be further reviewed and finalized once all the results for the final report would be available.
   4. Independent sections of the final report will already contain some recommendations, like those related to capping, heating, high winds, … The meeting agreed that those recommendations would have to be summarized and included in the “recommendation section” of the SPICE Final Report, with appropriate reference to the section in which they are addressed in more details.
   5. The recommendations should clearly identify what is doable and sensible to implement in operational networks (e.g. avoid giving the impression that wind speed must be recorded and archived at 1-minute resolution). The recommendations could be stratified into quick-wins and recommendations requiring more effort to be properly implemented. Recommendations on the metadata that must be collected in order to be able to apply transfer functions to a precipitation time series must also be included.
   6. The meeting invited each team member to take the results of SPICE and demonstrate to the operational division of their respective institutions how, encouraging their application at national level.
   7. CIMO, Regional Association VI (Europe) and GCW plan to collaborate in organizing a workshop on observations at mountain stations in early 2017. The meeting recommended that the organizing committee considers devoting a session of this workshop on how to apply SPICE results to operational networks.
2. **OTHER BUSINESS** 
   1. A visit of the CARE site took place on Wednesday 13 July 2016. The participants welcomed this opportunity to visit a SPICE testsite.

***Interaction with instrument providers***

* 1. The meeting decided to share an advanced draft version of the SPICE final report with instrument providers well before TECO-2016. This would enable the instrument providers to review it and convey to the team any concern they may have on the presentation of the results sufficiently in advance of TECO, so that these comments could be taken into account by the team, as appropriate, in preparing the TECO contributions that will present the intercomparison results, as well as for preparing the final version of the report. It was agreed that the dispatch of the advanced draft would take place in the second half of August.
  2. In view of the fact, that the feedback from the instrument providers would be needed by mid-September at the latest, and of the potential absence of some of them due to the vacation period, the meeting requested the Project Leader to inform them as soon as possible of this plan.

***TECO-2016***

* 1. Approximately 20 SPICE publications were submitted to TECO-2016. Several were granted an oral presentation, while the rest will be presented as posters. In view of the timing for the finalization of the SPICE final report and the consultation with instrument providers, the meeting recognized that it would be difficult for several authors to provide their contributions for the TECO-2016 proceedings by mid-August, as requested by the TECO-2016 organizers. The meeting recommended to the Secretariat to seek an extension of this deadline for SPICE contributions.
  2. Roy Rasmussen informed the meeting that AMS is not producing extended abstracts/proceedings of its conferences anymore and invited CIMO to consider whether it wants to maintain this practice for future TECOs.
  3. Several members of the SPICE project team will be attending TECO-2016. The meeting agreed to organize meetings of opportunity of the team during TECO-2016 in Madrid prior and/or after the SPICE TECO-2016 session. These meetings would be used mainly to review comments from instrument providers, have individual discussions with instrument providers if needed, and to review the conclusions and recommendations to be included in the SPICE Final Report. The meeting agreed to consider revisiting this plan and to organize a full-day meeting in case of numerous comments received by instrument providers.

***SPICE Special Issue***

* 1. The meeting was informed that the SPICE Special Issue had been extended until June 2017. To date, approximately 10 papers were submitted to the Special Issue.
  2. The meeting encouraged all the project team members to continue publishing SPICE results in the Special Issue, even if they were already included to some extent in the SPICE final report. The meeting recognized this would not be a break in copyright as the final report will be published as an IOM report, which does not have the same status as publications in peer-reviewed journals. Also, all publications would refer to SPICE (using the general disclaimer) as agreed through the SPICE data protocol.
  3. The meeting reiterated that publishing results of SPICE in the scientific literature is the only way to properly disseminate them.

***Draft Report of the Session***

* 1. It was agreed that the meeting report would be finalized and approved by correspondence.

1. **CLOSURE OF THE SESSION**

The session closed on Friday, 15 July 2016 at 16:00 hours.

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# ANNEX I

# LIST OF PARTICIPANTS

|  |  |
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