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

Sixth Session

Zaragoza, Spain
18 – 22 May 2015

FINAL REPORT

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EXECUTIVE SUMMARY

This report provides a summary of the meeting of the Project Team and (reduced) Sixth session of the International Organizing Committee (IOC) of the WMO Solid Precipitation Intercomparison Experiment (SPICE) that was held in Zaragoza, Spain, Finland from 18 to 22 May 2015.

The meeting reviewed the progress made to date in preparing the data for the overall analysis of the SPICE dataset. It considered the way for developing the final report and for deriving the individual instrument data sheet. It also proposed a list of topics to be considered to advance science related to solid precipitation measurements.

Finally, the meeting agreed on the way forward to complete the analysis and on how to share the work towards having the draft final report available by TECO-2016.

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GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the Session

1.1.1 The meeting of the Project Team and (Reduced) International Organizing Committee (IOC) for the WMO Solid Precipitation Intercomparison Experiment (SPICE), Sixth Session, was opened on Monday, 18 May 2015 at 9:00, by Ms Rodica Nitu, the IOC Chairperson and SPICE Project Leader. The list of participants is given in Annex I.

1.1.2 Mr Raphael Requena, Head of the Regional Office for Aragon, welcomed the participants to Zaragoza. He stressed the importance of accurate precipitation measurements for Spain to enable AEMET to provide accurate services for external users, recalling that two months ago, Spain suffered from the worst flooding event it experienced in 50 years.

1.1.3 Ms Isabelle Rüedi welcomed the participants on behalf of WMO. She expressed thanks to Spain for hosting the meeting as well as for its active involvement in SPICE, and for having provided the site of Aramon-Formigal. She recalled the large expectation from a number of interest parties for the results of SPICE and urged the meeting to ensure that the results will be presented in such a way that they can be easily understandable by WMO Members to enable them to improve the data quality from their observing networks, and also to enable manufacturers to further improve their instruments towards better meeting Members requirements.

1.1.4 She also urged the meeting to start thinking about the legacy of the SPICE sites and to start developing recommendations on how the unique infrastructure and experience gained through SPICE could be further used to improve other aspects of solid precipitation measurements and to consider whether it would continue requiring coordination at the international level.

1.1.5 Major Emanuele Vuerich, chair of the CIMO Expert Team on Instrument Intercomparisons addressed the meeting and stressed the importance of a very cautious approach in this critical phase of the project that is the data evaluation and the preparation of the experiment's final report. He noted that this should lead to the development of best practices, enhanced standardization of practices that are at the core of CIMO's activities and that are essential for the WMO Integrated Global Observing System (WIGOS).

1.1.6 Mr Samuel Buisan, the site manager of the Aramon-Formigal SPICE site, briefly presented the structure of AEMET and the duties of the AEMET Regional Office for Aragon.

1.2 Adoption of the Agenda

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

1.3 Working Arrangements for the Session

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

2. REPORT OF THE CHAIRPERSON

2.1 Ms Rodica Nitu, the SPICE Project Leader and Chairperson of the IOC, presented her report on the status of the experiment (see Annex II) , including key activities that took place since the last physical meeting of the project team in 2014, the current arrangements for data analysis and for data archiving and management. She also presented a tentative work plan for the coming year in order to have an advanced draft of the final report at the time of TECO-2016 that is scheduled to be held from 27 to 30 September 2016 in Madrid (Spain). She listed a number of practical perspectives to follow in preparing the experiment results and report.

2.2 Ms Nitu expressed concerns with respect to the fact that since late 2014, the communication with two of the participating sites, Hala Gasienicowa (Poland), and Tapado (Chile),

has not been possible, in spite of repeated efforts made by the Project Lead and WMO Secretariat to connect with the project teams.

2.3 A face-to-face meeting on Snow on the Ground (SoG) took place in Grenoble (France), in March 2015, in conjunction with a COST Action Meeting, to progress the SoG data analysis. That meeting proposed to consider developing a new chapter of the Guide to Meteorological Instruments and Methods of Observation (CIMO Guide, WMO-No. 8) focusing on the measurements of snow on the ground and of snow water equivalent (SWE).

2.4 Ms Nitu also presented the plans of SPICE sites to continue the experiment beyond the formal end of the SPICE experiment. Finally, she presented the stated user requirements for precipitation and snow depth as they can be extracted for the WMO Observing Systems Capabilities Analysis and Review tool (OSCAR) which results from the WMO Rolling Requirement Review process.

2.5 Ms Nitu acknowledged the tremendous work performed by the whole project team since the beginning of the project. She stressed that the significant and representative dataset that has been collected to date for instruments recording solid precipitation and snow on the ground and its associated applied quality control procedures is already a tremendous achievement of the experiment. She thanked NCAR for hosting the data archive and for implementing the quality control (QC) procedures and appreciated that a large portion of data has already been validated by the Site Managers.

2.6 Ms Nitu indicated that the meeting will have to agree on general principles for the return of the instruments to the manufacturers (see also section 5.20).

2.7 Ms Nitu stressed the importance of having dedicated resources for data analysis, which is secured only until the end of 2015. She noted that the team would now have to take a pragmatic approach toward managing the expectations, while conducting the data analysis with limited resources and towards delivering an advanced draft of the final report by Sept. 2016. The experience gained in the process of developing the reference report will be important to plan a realistic approach for the drafting and completion of the SPICE final report. Also, considerations will have to be given to ensure that the report will have the expected impact, helping WMO Members operate their network for specific applications. Therefore, the team will have to consider and make recommendations on how to obtain data for a specific purpose, rather than restricting its work to the evaluation of specific instruments.

2.8 The next months should be focusing on the preparation of the preliminary instrument datasheet towards presenting to, and discussing early results with manufacturers at the Brussels exhibition, in October 2015.

3. TOWARDS THE PUBLICATION OF THE SPICE FINAL REPORT

SPICE Reference Report

3.1 The SPICE Report on the Field Reference for Precipitation Amount (so-called SPICE Reference Report) was drafted to describe the concepts that are proposed to be used to derive the reference data. It was shared in draft form with the project team at the beginning of the year. Extensive amount of work was needed to compile it and a number of lessons were learnt from this experience which will have to be taken into account for the drafting of the SPICE final report:

- Very good for documenting the approaches, making it a valuable reference for the project team.
- Effort needed to properly document the results is significant - a pragmatic approach will need to be followed for the final report.
- Text needs to be targeted to the users/readers and include appropriate amount of details (neither too much, nor too little).
- Cross-checking of the contributions written by different contributors requires dedicated editorial skills to ensure consistency, avoid duplications, etc...

- Formatting is time consuming and requires some general guiding principles.

3.2 The meeting noted that only limited feedback had been received from within the project team on the SPICE Reference Report. It decided to invite selected experts (E. Lanzinger and C. Garcia Izquierdo) who had not been involved in its drafting to review it, so as to check and possibly improve the presentation of the content and its consistency.

From the SPICE Reference Report to the SPICE Final Report

3.3 The meeting recognized that a large amount of work would be required to carry out the editing and formatting of the final report. However, it was recognized that it is not simple to find an editor with the appropriate understanding of the subject and that funds to pay such an editor would likely not be available. The lack of such an editor will represent an additional challenge to meet the expected deadline for completion of the final report.

3.4 The meeting recommended that the Secretariat seek guidance on how IPCC is achieving consistency in publishing reports including contributions provided by many authors.

3.5 The meeting noted that the SPICE Special Issue would be able to accommodate publications on results as well as publications on methodologies. In order to limit the size of the SPICE final report and to improve the dissemination of the results with respect to earlier intercomparisons, the meeting recommended that the SPICE project members strive at publishing papers targeted at specific aspects of the intercomparisons, in the SPICE Special Issue, by end of 2015. Appropriate references and a summary of these papers would then be included in the final report instead of the full information. Should such publications not be available in time, part of the descriptions on the methodologies used would have to be included in Annexes to the SPICE final report. The meeting recalled that any such publication should remain in the frame of the SPICE data protocol.

3.6 The meeting decided that the SPICE Reference Report would not be published as stand-alone document, but that part of its content would be used for the SPICE Final Report and that part of it should be published as individual papers in the SPICE Special Issue. The main decisions were the following:

- The first chapters of the SPICE Reference Report which provide an overall descirption of the experiment will be used as introductory chapters for the SPICE Final Report.
- The chapters of the SPICE Reference Report addressing the comparisons of the different types of references (R0, R1, R2 and R3) should be published as individual papers prior to the final report, and including the data from the whole duration of the experiment. If they are not publised as individual papers before the end of 2015, then they will most likely have to be included as annexes to the SPICE Final Report.
- The main content of other chapters describing methodologies will be either published as separate papers or included as Annexes to the SPICE Final Report.

3.7 In order to ensure consistency of terminology between the various publications related to SPICE and awareness of the whole team to the work being carried out (papers that could be referenced in other publications), the meeting requested that all SPICE publications be shared with the SPICE project team and with the WMO Secretariat prior to their submission to journals/publications.

3.8 The meeting recognized the importance of having a good executive summary of the report and the interest of developing a summary of the report for decision-makers upon publication of the final report.

3.9 The meeting decided that selected chapters of the draft SPICE Reference Report would be shared with manufacturers together with the first version of the datasheet relevant to their instruments.

3.10 Yves-Alain Roulet informed the meeting that he was considering to apply for a sabbatical to support the drafting of the SPICE Final Report. The meeting welcomed this proposal and agreed

to make every effort to ensure that individual contributions to the final report would be ready by Q1 2016, so that he could integrate them and write missing parts in Q2 2016.

4. REVIEW OF PROGRESS MADE TO DATE

Snow on the Ground

4.1 The meeting reviewed the progress made with respect to the analysis of the snow-on-ground (SoG) observations. Discussions focussed on the derivation of the reference data set, results and methodologies, and risks to data quality. A SoG breakout session was organized and targeted the layout and content of the preliminary data sheets that will be delivered to the manufacturers in October 2015.

Derivation of reference dataset

4.2 The manual reference measurements for SoG are described in detail in the SPICE reference report. It is clear that the manual measurements at each of the participating SoG site differ substantially and these differences are due to variations in infrastructure, resources, and national observations procedures. Mr Craig Smith provided an overview of these measurements. Even though there are substantial differences in the manual observations, this data will be very useful as a benchmark for the automated instruments. Differences in the reference measurements combined with intra-site spatial variability in snow depth and SWE will make inter-site comparisons difficult but can be linked via the uncertainty analysis presented by Mr GyuWon Lee.

4.3 The options for references for SoG-Snow depth are as follows:

1) Individual instruments vs the daily manual (photographed or visual) snow stake measurements:
   a) snow stake closest to sensor,
   b) average of all manual measurements at each pedestal (such as at CARE),
   c) average of all manual measurements at the site.
2) Individual instrument vs an average of all automated instruments:
   a) at the site,
   b) at the pedestal (such as at CARE).

4.4 Mr Smith provided examples of instrument intercomparisons with theses references. As an example, Sodankyla is using photographs of the 4 stakes distributed in the measurement field and not co-located with the individual instruments. It is therefore difficult to assess whether the errors seen in the intercomparison are due to the instruments or rather due to spatial variability, differential melt, etc. CARE has 3 targets per pedestal with daily manual measurements at each corner of the targets. At CARE, comparisons with manual measurements are less good than at Sodankyla due to larger spatial variability in snow depth. There is probably a depression in the middle of the target due to the presence of the snow stakes at the corners. When looking at the automatic intercomparison at Sodankyla using an average of 6 sensors (allows 1 min data), the relationship tends to be a bimodal fit for some sensors which is indicative of differential melt from the instrument target. This bimodal behaviour is not present in the CARE data.

4.5 The meeting agreed that the data would have to be analysed using both methods for the computation of the reference: 1) using the manual measurements (regardless of how they are derived), as well as with 2) the average of the automated instruments. The instrument under test should be used in the average for the reference as it is part of the reference “configuration”. The first set of intercomparisons using the automated reference will be done at 1-minute resolution. Then other time scales (5 min, 30 min, 60 min, etc) should be considered to enable bridging the data to standard reporting times. Other things that should be examined include the question of spatial variability.

Uncertainties and Methodology

4.6 Mr GyuWon Lee presented an uncertainty analysis for the SoG data based on data from the Sodankyla and CARE sites. The Uncertainty in snow depth measurement is quantified for manual and automatic observations from both sites. Various methodologies were tried to quantify the uncertainty: standard statistical measures and propagation of errors. The error propagation equation was solved by the least squared fitting for different pairs of observation. Significant bias exists within a site: 4 cm at the Sodankyla site and 8 cm at the CARE site. This bias represents the natural variability of snow depth for the specific site. In addition, the random uncertainty reaches 1.4 cm in manual measurement. Bias of automatic sensors are even larger than the manual measurement: 9 cm at the Sodankyla site and 16 cm at the CARE sites. This bias is in particular linked with the environment of the site such as sloping, nearby obstacle, etc. The random error is about 2.8~3.1cm and no site specific variation is found.

4.7 Gyuwon Lee agreed to extend his uncertainty analysis to all the sites where this analysis is possible.

4.8 The result from this analysis will be included in the SoG data sheets as a way to frame the interpretation of the intercomparison with the reference.

4.9 Ms Rodica Nitu presented results from the work carried out by Michael Earle on the impacts of QC and data processing frequency on data quality. It is not completely understood as to how to interpret these results to make decisions on frequency of reporting snow depth. This involves employing the outputted quality numbers to improve the reported values. Other questions were raised about the integration of various sensors (snow depth + accumulating gauge + temperature, etc) to produce the final numbers. The ability to detect first snow was raised and this may be accomplished by looking at albedo step jumps (as done on Forni glacier) or by using the return signal strength from an optical sensor which tends to increase as snow collects under the instrument.

Risks to data quality

4.10 Mr Smith showed some results and raised some questions on target performance. He showed that the melting from the 1.25x1.25m grey plastic targets at Caribou Creek was representative of the surrounding area. The target did not melt out first or last in the measurement compound so it is deemed to be relatively representative. Unfortunately, no data is available during snow inception. In Sodankyla, the targets are approximately the same size as Caribou Creek but they consist of green artificial turf or indoor/outdoor carpet. The snow appears to melt faster on targets than in the surrounding compound. This may not be a concern for Sodankyla because of the relatively deep and persistent snow packs but it might be a concern for sites with more ephemeral snow. Mr Smith agreed to collect any previous reports on target analysis (Colorado State, MSC/CARE, Lanzinger et al.) and to compile this information for inclusion in the final report. As it stands now, SPICE probably does not have enough information to make a complete recommendation on targets.

4.11 Mr Smith showed an analysis of target shifting for the Sodankyla and CARE sites for the 2013/2014 season. This analysis was completed by calculating an average season start and season end zero snow depth value and determining the difference between the two values. The difference was less than 2cm for CARE suggesting some settling of the target in the first season after installation. Settling at Sodankyla was negligible. This will be checked again for the 2014/2015 season. No recommendations were made about correcting for potential target shift which is likely unnecessary for SPICE if the changes continue to be small. This becomes another source of uncertainty.

4.12 FMI is examining the potential impacts of snow collecting on the sensor cone of the USH-8 on data quality at Sodankyla. Falling snow collects on the instrument cone and support infrastructure which eventually falls to the target surface. Some evidence suggests that this falling snow can have an impact (either positive or negative) on the depth measurement after the snow drops to the surface. The magnitude of this is being investigated.

4.13 A KNMI report suggests that the heating process of the SHM30 has an impact on the return signal strength of the sensor and has a potential impact on data quality. Using data from the SPICE SoG sites, this phenomena will be investigated to determine if this impact is discernible. This can potentially happen to the SR50ATH instrument as well.

4.14 Anna Kontu and Craig Smith have reported on the intercomparison of the CS725 at Caribou Creek and Sodankyla. Mr Smith has been collecting soil moisture and temperature data under the CS725 at Caribou Creek and will explore whether this data can be used to assess the issues with the CS725 and/or improve the data product. FMI will investigate the source of the annual failure of the SSG1000 at Sodankyla. Russia has some experience on CS725 that can be shared. There is also and intercomparison as part of Canadian-SPICE in the Rockies.

SoG Breakout Session

4.15 The SoG Breakout session focussed on the content and format of the SoG data sheets. The following was discussed:

- Fine tuning of the information tables, renaming of columns, more site specific photos of installations, more information on the targets.
- Add information in the “Data Output” table to reflect Data Output from manufacturer and Data Output from sites.
- Add hyperlink to the instrument manual.
- Add information on data processing/corrections (from the SoG data catalogue).
- Diagram of sensor footprint and how it changes with snow depth.
- Reference Intercomparison: show both a comparison with the manual and automated reference “system”:
    - Add disclaimers about what this intercomparison is actually telling us.
    - Start with 1-minute data for auto reference and get feedback from the manufacturers.
    - Need to include a note about the uncertainty by site in both the manual and automated reference measurements.
- Move the data QC metrics in the documents to appear before the reference plots.
- Instrument performance measures:
    - Does distance to the snow pack change the noise?
    - Quality of temperature measurement.
    - Impact of new precipitation on quality numbers/signal strength output (where available).
    - Impact of wind and temperature on quality numbers.
    - POD/FAR: identifying thresholds for new snow on the target (This becomes a significant analysis task and will not be ready for phase 1).
    - Repeatability and drift: separate natural variability from the noise.
    - Bias is addressed via Gyuwon’s uncertainty analysis .

Non-Catchment Type Instruments

4.16 Mr Yves-Alain Roulet presented the progress on the analysis of the non-catchment type instruments. The plan for further analysis is to focus first on the accumulation and intensity and then to also consider the information provided by the raw data (matrice of drop size and fall velocity distribution). He mentioned that WMO Members are interested in having transfer functions for non-catchment type instruments. Non-catchment type instruments have totally different sources of errors than catchment-type instruments, because of the different working principles and designs of these instruments (incl: slashing, superposition of droplets, ….). As a result, they show totally different patterns in dependence of the catch ratio on wind than those observed for catchment-type instruments. The precipitation type outputted by the instrument seems to be in agreement with the theory (rh, T distribution). However, there is no information from the manufacturers on the

principles used in the instruments. For low intensities, they demonstrate very low catch ratios which suggests they are not suitable for low intensities.

4.17 Mr GuyWon Lee presented an evaluation of snow related information from non-catchment type instruments. SPICE provides abundant information from the non-catchment type snow sensors such as snowfall rate, snow size distributions, their related moments (reflectivity, velocity, spectral width, etc), and precipitation types. The information is commonly collected in high temporal resolution (ex: 1 min). This information, in particular snowfall rate, was evaluated by comparing it with an R2 reference and mode fall velocity of snow particles was used to constrain the catch efficiency. The mode of catch efficiency decreases from single alter to no shields. However, snowfall estimator with power information is less dependent on wind speed and temperature and dependent on snowfall intensity. The laser type instrument shows significant underestimate which may be linked with density assumption in the algorithm. Intensity dependence of catchment type instruments was also shown.

4.18 The dependence of catch ratio to mode fall velocity of snow particles was also shown in particular at larger fall velocity. This dependence was added into the Bayesian modelling of transfer function. This new approach significantly improved the modeling and reduced the residual in correction. This new modelling can also be applied to overall precipitation types without any classification.

4.19 Mareile Wolff presented a comparison of all disdrometers and present weather detectors at Haukeliseter. Analysis and results were taken from a recently finished master thesis. The following instruments were evaluated: Thies LPM (anxillary instrument), Thies LPM (inside DFIR, anxillary instrument), Ott Parsivel (anxillary instrument), Vaisala PWD 22 (anxillary instrument), Vaisala PWD 21 (anxillary instrument), Campbell PWS 100 (SPICE instrument under test from provider). Observed precipitation type (minute data) from all sensors were compared with the help of contingency tables and skill scores. Since no absolute reference was existing, the Vaisala PWD was chosen to act as a reference, being aware that its results might not represent the truth in all cases. Skill scores were computed for the complete dataset (3 winters) and for various selections, representing different weather conditions (light/heavy winds, high intensity precipitation, low/high visibility). An additional comparison was performed between the two Thies LPM to check for impacts of the installation differences (in- and outside DFIR). For most sensors, a relatively good agreement was found for the detection of precipitation/no precipitation. Less agreement was found for the individual precipitation types. Rain and snow detection scores were on average between 40 and 60%. Even less agreement was found in the other solid precipitation classes. Solid precipitation scores improved when all classes of solid precipitation (snow, snow grains, ice pellets, etc.) were merged. The impact of the DFIR on Thies LPM did not seem to be very high. A better analysis could be performed when comparing longer time intervals. For the distrometers, a direct analysis of the distributions of particle sizes and fall velocities instead of the derived precipitation classes would allow an assessment of differences due to differences in the sensors' internal algorithms.

4.20 Mr Samuel Buisan presented results of non-catchment type instruments from two snowfall episodes in Formigal.

4.21 Ms Audrey Reverdin and Ms Floortje Heuvel presented a proposal for the data sheet of non-catchment-type instruments. It was agreed that a large number of plots could be kept in these datasheets for a start, while recognizing that some of those plots would most likely be removed at a later stage to constrain the size of each datasheet. The datasheet will be shared with the respective manufacturers, which would be invited to comment on the datasheet and their suggestions, if any, will be taken into account for the finalization of the data-sheet model. The meeting agreed that the review of the datasheet by the site managers was crucial, as they are the ones who know how the instruments were used and could detect potential problems in the datasheets.

Catchment Type Instruments (Tipping buckets and weighing gauges)

4.22 Ms Audrey Reverdin and Ms Floortje Heuvel presented a proposal for the data sheet of weighing gauges and Mr Mike Earle presented a proposal for the data sheet of tipping-bucket gauges.

4.23 The meeting performed a thorough review of the proposed datasheets. An agreed list of plots and tables, and relevant text was agreed, which will be used to produce the first version of the datasheets that will be shared with the instrument providers, prior to the 2015 Brussels Meteorological Technology World Expo. The main changes for the weighing gauges/eremging technology instruments are.

- 2) Add operating temperature range from manuals for each temperature and real experienced temperature range during SPICE from dataset.
- 4.1 a) 3 Time series (each one to three days) showing test instrument and R2-reference under snow, rain and non-precipitation conditions, include temperature and wind speed. Separate plots for each instrument/instrument configuration. Try to find "representative" plots, not necessarily the worst case plots. Significant, but intermittent problems (i.e. phantom accumulation) should get an extra plot and more explanation (possibly at end of data sheet under performance limitations).
- No Intensity plot at this point, these plots needs to be developed and reviewed (what's their information content). Emanuele Vuerich is working on that topic for the final report, and developing plots that could eventually be included in second generation data sheets.
- 4.1 b) Accumulation Scatter plots: Test instrument vs. R2-reference, with temperature ranges, one-to-on line, linear regression(s) and a grid.
- 4.1) Calculate RMSE for precipitation events (A. Reverdin, M. Earle), Calculate RMSE for non-precipitation events for WG (**A. Reverdin to calculate SNEDS for WG; J. Kochendorfer to calculate RMSE for both 30 min and 1 min data**).
- 4.2) Catch efficiency plots, combine same instrument configuration from different sites, three plots for each configuration (T>+2,-2 - +2, <-2) against wind speed (WG).
- 4.2) For Non catchment: additional CE-plots against intensity.
- 4.3) Provide explanations of used POD&FAR, include CSI (**definition to be sent by M. Wolff**). Use two thresholds for precipitation: >0.25 mm and >0.1 mm in reference. Test instruments "need" accumulation > 0 for precipitation. Histograms vs wind speeds and temperature.
- 5.1)Diagnostic data: No baseline-change detection; **Sitemanagers to send start/end data of data acquisition for each instrument (each season) plus site logs until 1st of June**.
- 5.2) Performance limitations: **Description of problems and solutions from site managers required until 15th of June, C. Smith's student will send individual email to site managers and instrument champions.**
- 5.3 General operating experience (new header instead of Maintenance). **Input required from site managers by 15th of June. C. Smith's student will writes email to all site managers, and attach an example text from A. Reverdin about Belfort.** Add link to manual under technical specifications; if not available store at WMO-page. Add this link and comment that manual is not available.
- 6. Recommendations: Can we give recommendations at this point? To be checked in review phase.
- No calculation of sensitivity, biases, repeatability and response time as we have no method to calculate according to their original definitions.
- No report of minimum temporal resolution for reporting a valid solid precipitation at this point. Method is not available. **Connected data analysis activity by E. Vuerich, M. Collio, L. Lanza.**

- No assessment of the ability to detect and measure light precipitation, no method exists. **Connected analysis activity on trace precipitation by E. Mekis and others.**

4.24 The meeting agreed that the datasheet would be addressing individual instrument models, but not individual configurations.

4.25 For the tipping-bucket gauges, the meeting expressed concerns about the possibility/appropriateness of deriving transfer functions for such instruments. It agreed that the data would be analyzed over different time intervals to assess the difference in performance, when considering longer time intervals Different temperature intervals will also be considered, analyzing some data in the range -2 °C to +2 °C to possibly catch some freezing rain events that are most relevant and challenging for some Members that chose tipping-bucket gauges precisely for catching such events.

4.26 The meeting agreed with the proposal to develop plots on snowfall intensity to evaluate the performance of gauges with respect to this parameter. Scatter plots of all 1minute QC-ed intensity data will be realized to show general results and the performance of gauges against the reference. Emanuele Vuerich agreed to develop such plots. The team will then be invited to review them and to decide whether they are suitable for inclusion in the datasheets, or whether they should be included as a section of the final report body. The temporal interval (for now limited to 1 minute) could possibly be extended to find the optimal one in parallel to the derivation of transfer functions on several temporal resolutions. Luca Lanza and Matteo Colli agreed to work on application of transfer function for different time scales (scientific approach), while Mareille Wolff and Matteo Colli agreed to work on the application of that work on operational network/situations which could be included as part of the final report body.

Data Availability and Quality Control

4.27 Francesco Sabatini presented an analysis of the current data availability and data quality checks performed on the data available at the NCAR ftp (see Annex III). Some problems were encountered, but they were fixed. The data will be checked again to ensure no remaining errors occur in the data ingestion and quality control.

Capping

4.28 Samuel Buisan presented an analysis of some capping events from Formigal, Sodankyla and Weissfluhjoch and a summary of the main weather conditions favouring capping and the solutions adopted to solve this issue. Mr Buisan will ask the other site managers for additional inputs/events in order to summarize all the information on capping events for the final report. Other examples from capping events experienced in operational networks would be welcome as well and all participants were invited to search for such events and provide them to Mr Buisan.

SPICE Dataset

4.29 The meeting recognized that the SPICE dataset is already an invaluable achievement. As the same configurations were used on all sites, and the same quality control and event selection procedures were applied to the whole dataset, it enables studies that could not be performed at a single site. By combining the data from all sites, transfer functions could be derived, from the DFIR to single alter shield, and from DFAR to unshielded configuration that cover a much wider spectrum of wind speeds, temperature, precipitation intensity than if derived from a single site. The function derived from this dataset could then be applied to any site.

5. STRATEGY AND PLANS TO ACHIEVE THE PROJECT OBJECTIVES

5.1 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. In view of the short time remaining until this date, it is necessary that the team agrees on the expected content of the final report to avoid spending too much time in the coming months on topics that are not expected to be included in it.

5.2 It was recognized that there are strong expectations for the delivery of the project. However, the project will only be successful, if its findings are implemented by Members, which is not straightforward, as has been seen after other intercomparisons. The meeting recommended that some implementation challenges be shown and explained in the final report (like capping, implementation of transfer functions), so that Members understand them and implement them in their networks and operational practices.

5.3 The meeting agreed that all data, from all sites, had to be transferred to NCAR data archive by 30 June 2015 at the latest. Beyond this date, there will be no guarantee that the data will be ingested in the database and quality-controlled.

5.4 The meeting was informed that Audrey Reverdin and Mike Earle would be working together during three weeks towards producing early versions the datasheets. In order to enable the analysis of all the data, sufficient confidence in the data is needed. Therefore, the meeting requested all site managers to check the quality of the quality-controlled data from their site available on the NCAR ftp and to confirm to Audrey Reverdin by 8th June 2015 that the data is fit for analysis and compete.

Datasheets

5.5 The meeting recognized that the instrument data sheet would have to be developed in several iterations.

5.6 The meeting agreed on the way forward to review the first versions of the datasheets in July/August 2015. A first review would be done in July by the site managers and identified issues would be discussed during a teleconference in July, in a small group. The datasheet would then be shared in August with the whole team. An August teleconference would be organized to start reducing the size of the datahseets, which would be shared with instrument providers prior to the Brussels Expo 2015.

5.7 The meeting recommended that a small group be present at the Brussels Expo and conducts discussions with each manufacturer that will be present there and review the datasheet with them. Feedback and recommendations from instrument providers would be used to develop the next iteration of the datasheets.

Data Analysis

5.8 The meeting agreed to share responsibilities for the data analysis and development of relevant publications/contributions to the SPICE final report. A tentative plan for the data analysis and development of science results is provided in Annex IV. Although it would be desirable to include the results of all these analyses in the final report, the meeting recognized that some of them (like application studies) were less urgent than others and could be treated with a lower priority. The meeting reiterated its encouragement to all to strive at publishing parts of these results in the SPICE Special Issue, ideally by end of 2015, so that the SPICE final report could build on them, rather than having to include all results into the final report.

5.9 The meeting noted that for one instrument, the manufacturer is analyzing the data. The meeting recognized that this was an exception and that the results of this instrument needed to be treated and reported with appropriate care in the final report. As this instrument is not a commercially available instrument (only 4 such instruments world-wide) and as it had been included in the project to assess the potential of some emerging technologies, this would be acceptable.

5.10 The meeting made recommendations related to the data analysis that are summarized below.

5.11 The meeting recommended that Daqing Yang approaches Anton Timofeev and Youri Melnichuk to involve them in the R0-R1 analysis, making also use of the recent SPICE data from Valdai.

5.12 The meeting recommended that a comparative analysis of R2 Geonor and R2 Pluvio be carried out using the data from Bratt's Lake, Care, Marshall and Gochang. The meeting invited Kai Wong to consider performing this analysis.

5.13 It was noted that in the R2-R3 comparison, care should be taken to include also the dependence on the shield type, as some sites have the Ott shield instead of the single alter shield.

5.14 The meeting recognized that several team members are working on uncertainty analysis of the transfer functions and that results are similar. The meeting agreed that papers on these different approaches could be published.

5.15 The meeting agreed that the decision on whether to derive transfer functions for tipping bucket would be deferred to later, when better understanding of the tipping-bucket performances will be available.

5.16 The meeting welcomed the proposal of Mr Roulet and Buisan to perform an analysis of the performance of disdrometers as a function of their location (inside/outside the DFIR) that could possibly be performed based on data from Formigal and Weissfluhjoch to be gathered during the winter 2015/16 and published as a national case study, as an Annex to the final report.

Presentation and publication of results

5.17 The meeting encouraged all team members to present the results from their analysis during forthcoming teleconferences to inform the team of their results and enable better cross-referencing them and better taking all results into account in the drafting of the final report.

5.18 The meeting encouraged all site managers and site teams to publish results from their own site and to inform the project leader as soon as possible on their plans. The meeting also recalled that some sites had been accepted into the project because of some special contributions they were expected to provide to the project, and that it was now time to liaise with them to coordinate their contributions to the final report.

5.19 The meeting agreed that some publications on the application of the results could/should be published after the publication of the final report and build on the large amount of knowledge gathered by the team during the whole project.

Return of instruments to instrument providers

5.20 The data collection phase for the northern hemisphere sites is now completed. Some of the customs arrangements for the temporary import of instruments are coming to an end. The meeting therefore requested all the site managers to review the customs arrangements they have for each instruments and to make appropriate arrangements to return the instruments to the manufacturers and avoid customs/import costs. The meeting recognized that in case of common interest to continue the experiment, sites could make bilateral arrangements with manufacturers to keep/purchase the instruments they had on loan. Such arrangements would be depending on the national priorities and plans of the sites to continue the experiment in the coming years.

5.21 The meeting agreed that the SPICE Project leader would write to all instrument providers to inform them that the data-collection phase of the experiment is completed and that they should liaise with the sites to arrange the return of their instruments, or to establish bilateral arrangements with the site managers in case of common interest to continue the testing of their instruments.

Liaison with site managers

5.22 The meeting requested the project leader to contact all site managers to:

a. ensure there are no customs issues for the instrument from their site,
b. make them aware of the need to provide all data to NCAR by 30 June 2015 at the latest,
c. invite them to prepare reports on the specific results from their site, and to inform the project leader how they plan to report them.

5.23 The meeting also requested the project leader to contact Chile, to clarify which gauge they have on their site.

NCAR Data Archive

5.24 The meeting agreed that the highest priority for NCAR was to ingest the data from all the sites.

5.25 The meeting decided that the final analysis will be conducted on manually QC'd data, taking into consideration the site logs and the input from site managers. The manually QC'd data will be made available to all those conducting data analysis for the report, and will be stored for future use, together with the other project datasets, appropriately labeled.

5.26 The meeting recognized that it would be valuable if the NCAR archive would allow to continue ingesting data beyond the formal end of SPCIE. Roy Rasmussen indicated that it would depend on the availability of funding for supporting the NCAR data manager.

5.27 The meeting recommended that NCAR continue maintaining the database beyond completion of SPICE to enable further data mining by the team and other interested researchers. The dataset collected during SPICE is unique in many ways, but particularly because the same configurations were used on all sites, and because the same quality control procedures and event selection procedures were applied to the whole dataset.

5.28 The meeting recognized that the ability to perform manual flagging on the NCAR data archive would be valuable to have, but that it was not the highest priority on the use of the time of the NCAR data manager. The meeting agreed that after 30 June 2015, the project would have to decide whether the manual QC tool for the data archive would be needed, or whether site logs would be sufficient to perform the quality control. The meeting requested Roy Rasmussen to advise the team by then, on whether the NCAR data manager would have any time left to perform this development, or whether that could not be envisaged at all.

6. OTHER BUSINESS

6.1 A visit of the Aramon-Formigal site took place on Wednesday 20 May 2015. The meeting welcomed this opportunity to visit a SPICE testsite. The meeting was impressed by the facilities set up at this site since the beginning of the SPICE Project. Following this visit, the meeting made recommendations to improve the configuration of the site and possible tests to carry out (height of the shields and size of the shields in particular).

6.2 The meeting thanked Floortje Heuvel for her contribution to the project and wished her success for the PhD she will be starting soon in a related field.

SPICE Special Issue

6.3 The meeting thanked Samuel Morin for organizing a Journal Special Issue on SPICE, which is now ready to accommodate submission of SPICE and SPICE-related publications. The Special issue jointly organized between Atmospheric Measurement Techniques, Earth System Science Data, Hydrology and Earth System Sciences, and The Cryosphere and has for title "*The World Meteorological Organization Solid Precipitation InterComparison Experiment (WMO-SPICE) and its applications".* Editor(s): M. E. Earle, S. Morin, R. M. Rasmussen, M. A. Wolff, and D. Yang available ***at*** http://www.earth-syst-sci-data.net/special_issue400_78.html .

6.4 The meeting encouraged all the team members to publish SPICE-related results in the SPICE Special Issue, and to do so preferably by end of 2015.

CIMO Guide

6.5 Only little material is available in the CIMO Guide addressing the measurements of snow on the ground. Recommendations for the measurement of snow on the surface is currently a sub-chapter of the Chapter on Precipitation. Considering that snow on the ground cannot be viewed intrinsically as precipitation, because its evolution is driven by many more processes than precipitation (melt, thermal interactions with the ground, wind drift etc.) and that its monitoring serves more purposes than inferring precipitation (monitoring of snow conditions, natural hazard, land surface data assimilation etc.), the meeting recommended to produce a specific chapter of the

CIMO guide dedicated to the measurement of the properties of snow on the surface (primarily snow depth and snow water equivalent). This chapter would address manual and automated measurements methods drawing from the conclusions of the WMO-SPICE project but also a larger body of scientific and technical literature and provide recommendations for operational monitoring of snow on the surface of the Earth.

6.6 The meeting noted that some information related to the measurements of snow on the ground may be available in the WMO Guide to Hydrological Practices and that the development of the CIMO Guide chapter would have to be coordinated with the hydrological community, as well as with the Global Cryosphere Watch community.

Capacity Development

6.7 Arkady Koldaev recalled that SPICE has also an important capacity development aspect, and that SPICE had already had positive impacts on his country. Arkadi Koldaev informed the meeting that in the context of the SPICE activities, the Valday experimental site (Russian Federation) had been upgraded to a unique level: since recently it has all four SPICE defined references from R0 up to R3 which is unique in the world. As the Valday experimental site has a historical meaning, being the reference for all previous snow precipitation intercomparisons, it is now ready to continue gathering climatic observation records with a qualitatively higher level providing 1 minute data automatically.

6.8 The other Russian experimental site at Volga River was reconstructed completely for SPICE. The reconstruction was made on the base of specially developed and approved building construction documentation. A new two floor building and a modern meteorological site were constructed nearby. The ideas for this precipitation measurement experimental site were inspired by the WMO intercomparisons in Vigna de Valle (Italy). The experimental site has R1 and R3 SPICE references and 5 instruments under test. So, this most important region for the Russian economy - the Volga River basin - has now a modern precipitation measurements experimental site due to SPICE project. The Volga river site is ready for continuous 24 hour operation during all seasons. It will be used by Roshydromet for National Water Resources Program (2012-2020) and for World Bank project “Roshydromet-2”.

Relevance of the project to the Global Cryosphere Watch

6.9 Barry Goodison informed the meeting of the continued interest of the Global Cryosphere Watch (GCW) community for SPICE and its interest in its continuation after the formal end of SPICE. GCW is collecting national guidelines, among others related to precipitation. It is not only related to instrumentation, but also to applications. If desired, the GCW may provide a forum to pursue the SPICE activities in the future.

7. DRAFT REPORT OF THE SESSION

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

8. CLOSURE OF THE SESSION

The session closed on Friday, 22 May 2015 at 17:15 hours.

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ANNEX I

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ANNEX II

REPORT OF THE CHAIR
Solid Precipitation Intercomparison Experiment
WMO SPICE

(Prepared by: Rodica Nitu, Chair, IOC SPICE)

Contents

Report Objective

1. Provide a status report of the WMO SPICE intercomparison.
2. Provide high level work planning for the second half of 2015 and 2016.

Overview

The IOC of the WMO SPICE commenced its work in May 2011, and the formal experiments started in December 2012.
The intercomparison has been organized on 20 different sites in 16 countries, and with contributions of teams from 15 countries.
The field experiments are scheduled to end by April 2015 in the Northern Hemisphere, and by Oct 2015, in the Southern Hemisphere.
Over 30 different instrument models in multiple configurations have been tested, covering all major measurement principles for the point measurement of solid precipitation and snow on the ground (current and emerging). These have been provided by the host organizations, reflecting their national interest, and by eighteen manufacturers. The instruments provided by manufacturers are being tested on ten of the participating sites.
The project has been managed through five face to face meetings (Oct 5-7, 2011, in Geneva; June 11-15, 2012, in Boulder, CO, USA; Oct 15, 2012, in Brussels, June 17-21, in Davos, Switzerland; May 19-23, 2014 in Sodankylä, Finland), and weekly frequent teleconferences facilitated by WMO. The use of WebEx contributed significantly to increasing the effectiveness of the teleconferences.
The 6th meeting is scheduled for May 18th-22nd, in Zaragoza, Spain. This meeting will formally close the field experiments, and will advance the development of the analysis methodology.

2014-15 Key Activities

Following the SPICE-5 meeting, increased focus on data analysis, with three streams:

- Documenting the configuration and methodology for the derivation of the reference data (aka SPICE Reference Report);
- Development of transfer functions to enable the adjustment of measured precipitation relative to the reference;
- Document the performance of instruments under test, relative to the reference;

Meeting on Snow on Ground (Grenoble, March 2015)

A face to face meeting on Snow on Ground (Grenoble, March 2015), which addressed;

- several SoG/SWE specific analysis topics:
    - reporting units for Sog (cm) and SWE (mm),
    - addressing the shift in the zero baseline between the beginning and the end of the season,
    - use of sensor diagnostics for data QC and advanced QC
    - incomplete temperature compensation, impacts of radiation errors on unventilated temperature sensors used for signal adjustment;
    - proposal to prepare a new CIMO Guide Chapter on SoG and SWE,
    - Snow-on-the-ground be changed to Snow-on-the-surface in consideration of glacial measurements;
    - Reference data for SoG : manual measurements (daily or hourly resolution), or a composite of instruments under test (+ cameras) for increased temporal resolution

- overall SPICE topics;

- stars based rating of instrument performance were used in previous intercomparisons : avoid this; focus on impact on data quality (in given circumstances).
- site reports : should focus on general meteorological conditions + remarkable conditions. Not duplicating the Commissioning report.
- Recommend not to compare different instrument models at the same sites (except than with the reference) on the same graph (see first point, above)
- in the final report, one datasheet to be produced for an instrument model, whenever the instrument was provided by manufacturers, or a host organization; global evaluation of performance.
- Only instruments that appear in the Commissioning report are eligible to appear in the Final report (but not compulsory except those provided by the manufacturers).

Status of Experiments

For the seasons 2013/14 and 2014/15 most of the participating sites have run complete experiments, which have led to the availability of a comprehensive dataset, to enable the derivation of planned results.

- The sites running experiments, as planned are
  - Northern Hemisphere:
    - Bratt's Lake (Canada);
    - CARE(Canada);
    - Caribou Creek (Canada);
    - Sodankylä (Finland);
    - Haukeliseter (Norway);
    - Weissfluhjoch (Switzerland);
    - Marshall (USA);
    - Col de Porte (France)
    - ARAMON – Formigal (AEMET – Spain)
    - Gochang Observatory (Republic of Korea)
    - *Forni Glacier/Upper Valtellina/Italy,* EVK2CNR – UNIMI, University of Milan
    - *Pyramid International Laboratory Observatory/ Lobuche /Solu Khumbu/Nepal,* EVK2CNR – UNIMI, University of Milan

  - Southern Hemisphere:
    - Guthega Dam (Australia);
    - Mueller Hut (New Zealand);
    - Tapado (Chile).

  Reduced engagements have taken place with the experiments organized on the following sites:
    - Valdai (Russian Federation);
    - Voljskaya (Russian Federation)
    - Joetsu and Rikubetsu (Japan)

  Since late 2014, the communication with two of the participating sites, Hala Gasienicowa (Poland), and Tapado (Chile), has not been possible, although efforts have been made by the Project Lead and WMO Secretariat to connect with the project teams.

A summary on the status of testing of instruments provided by Instrument Providers is provided in the Annex to this document.

Data Analysis

In addition to the data analysis conducted by the members of the individual site teams, dedicated resources for data analysis and data management have been made available through WMO funding, starting Nov 2014 (Audrey Reverdin). The current agreement with MeteoSwiss runs until Nov 2015.
Significant advancements on methodologies and data analysis have been made as a result of the availability of these resources. Significantly more effort is required to carry out to completion the planned analysis.
About 400 instruments are included in the experiment, resulting on an estimated 50,000 daily data files for each year of the experiment. The participating teams have different levels of expertize. Many participating teams are dedicating resources to the data analysis, but these are not sufficient to analyze all the data and prepare reports by 2016. While the project team includes a number of well-known international experts, their availability is limited.
It is recommended that efforts are made to secure the continuation of dedicated resources through WMO funding, to enable the completion of the data analysis and the preparation of the final report.
It is estimated that the equivalent of one person year is needed to finalize the data analysis, and report writing
If the funding for the additional required resources is not available, it would impact the ability to deliver on the SPICE results on time and within the defined scope, resulting in a final report that would take additional years for completion and including results on fewer objectives, than defined. Given the broad interest from the scientific community in timely and comprehensive SPICE results, as identified above, neither the delay in issuing the Final Report, nor reducing scope of the report are satisfactory, nor desirable.

DATA ARCHIVING and MANAGEMENT

The SPICE Data Archive is being hosted by the National Centre for Atmospheric Research (NCAR), USA; this is a significant contribution, which facilitates the archival and quality control of SPICE data in a consistent manner, making it available for analysis.

- The SPICE Archive from NCAR is being mirrored by Environment Canada.
- At NCAR the SPICE data is QC'd, and made available to participants on the NCAR ftp.
- Event Selection Datasets, SEDS, are generated off line by the participating scientists.
- NCAR (Andy Gaydos) in collaboration with DAT have developed and implemented QC procedures;
- (event datasets) based on the methodology documented in the Reference Report.

Based on the May 2015 reports from site managers:

- Data transfer at 90% or more: Bratt's Lake, CARE, Caribou Creek, Col de Porte, Formigal, Gochang, Sodankylä, Marshall, Weissfluhjoch, (Valdai): and Haukeliseter: 70% (2014/15) and)% for 2013/14;
- Rikubetsu: had no tests in 2012/13; 2013/14: Almost all data were edited in their own original time step. The data need to be edited along the required format in SPICE.; 2014/15: to be prepared.
- Joetsu: all data manually reviewed and QC'd but not transferred to NCAR.
- Data QC validation: underway as an effort of site representatives, Audrey Reverdin and Francesco Sabatini. Some bugs identified and fixed recently. Limited validated datasets are available, right now, hence limited analysis.

Availability of Site Logs

Site logs have been maintained by most of the participating sites to document site and instruments maintenance, interventions to address instrument problems, specific conditions relevant tot eh data analysis. Although these are not consistent among all sites, their availability is critical to accurately identifying the sources of errors noted in the data and accurately represent the instrument performance in the final report.

- Bratt's Lake, Caribou Creek: not currently available, but in progress. Experts available to provide support
- CARE: available; additional support available through project team
- Sodankylä: site log available; support from Antti Poikonen and Timo Laine, for further informaiton
- Formigal: have under control the main events affecting the performance of the instruments (mainly capping events) and haven't uploaded to NCAR any wrong data.
- Gochang: Yes, we have the site log written in Korean. We plan to make it available in file formats.
- Weissfluhjoch; Site log has been recorded and is available for the Data Analysis under Excel format. It records mainly the maintenance events, but not the special weather conditions that may appear during season. Yves-Alain and team in Payernne could provide additional info.
- Haukeliseter: Internal site logs are existing since February 2014; language mostly English, some Norwegian, need to be slightly edited before uploading to NCAR; Before February 2014 only more informal site logs in different formats (maintained by different people), which needs to be merged into new format and edited. Not all capping events are recorded. Hourly pictures available which can confirm eventual capping. For complete recording of all capping events, manual check of all pictures necessary.
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2015-16 High Level Work Plan

- 2015, June- September:
    - priority 1: development of instrument data sheets, for the instruments provided by Instrument Providers.
        - June: advance the production of graphs for data sheets, as per Zaragoza meeting decisions;
        - July/August: prepare datasheets; look for gaps, inconsistencies and address; write text, where needed.
    - priority 2: advanced science topics to address project objectives.
- 15th Sept 2015: Share Instrument Data Sheets with Providers, for their review and feedback.
- 15th-17th Oct 2015: meet the Instrument Providers to review Instrument Datasheets, in the context of the Meteorological Technology World Expo
- Sept –Oct, 2015:
    - refining the derivation of the reference dataset;
    - identify key new/innovative advanced science results
- Nov-Dec, 2015: integrate the Expo feedback, generate second generation Instrument Data Sheets, and include all instruments tested, regardless he provider.
- Jan-Sept, 2016: advance data analysis, write report.
- Advanced Draft of Report planned for TECO 2016.

Site Specific Plans for 2015/16 (following formal end of SPICE experiments)

Weissfluhjoch: Measurements will continue if agreement with SLF. DFIR is already confirmed for one more year at least.

Bratt's Lake: intend to keep the site running indefinitely. All SPICE instruments that do not have to be returned to the manufacturer can continue to be tested for additional years.

Caribou Creek: intend to keep the site running indefinitely. All SPICE instruments that do not have to be returned to the manufacturer can continue to be tested for additional years. We prefer not to return the instruments to the manufacturer at this time.

CARE: will continue the experiments to support national projects, along the lines of SPICE. Not all data currently collected may be available over the long term.

Gochang: intend to continue experiments as currently configured

Formigal: Our intention is to maintain the infrastructure continuing in these working lines:

1. To provide high quality data for Global Cryosphere Watching Programme from WMO
2. To test the performance of disdrometers inside and outside of DFIR (conversations with Swiss team)
3. To test our operational tipping bucket with shield or other instruments
4. To install UV radiometers
5. Open to new ideas and projects in common

Guthega Dam:
Interested in contributing to SoG (spatial representativeness of point measurements) as part of PhD work, potentially working with non-SPICE Australian data and SPICE data from other countries. Specific research question not yet defined.
Since the site was only fully commissioned in 2014, we would be interested in continuing data collection beyond 2015. Approval from the National Parks & Wildlife Service to install the R3 gauges at Guthega Dam was linked to the SPICE project; at least an informal agreement with other organisation(s) would be needed to demonstrate that collaborative research is continuing.

Rikubetsu (Japan): will continue field experiment with almost same instruments for season 15/16 and the following winters.

Joetsu (Japan): will continue experiments over a longer term, in the future. Site specific results to be derived for the Final Report.

Expectations of SPICE Results:

AEMET (Spain):

- Transfer function between references and specially with operational tipping buckets in order to be implemented in operational national networks. This way we could assess the losses in accumulation for climatology, nowcasting and forecasting purposes.
- Performance of new emerging technologies against traditional technologies. Recommendations to national weather services regarding the installation and supervision of weighing gauges, different shield configurations, etc
- Demonstration of the importance of international cooperation. Preparation of new projects in common based on the experience acquired.

MeteoSwiss (Switzerland)

For MeteoSwiss this would be (among others):

- Recommendations on how to operate a weighing gauge (and the Pluvio2 in particular) regarding wind shield, oil and antifreeze.
- Correction factor from wind induced error that should be applied when performing the measurement without any wind shield.
- Potential for disdrometer to be used operationally for measuring solid precipitation quantity.

Meteorological Service of Canada – Canada

- use of multiple technologies to derive improved precipitation and snow on the ground data, including the integration of these two parameters: in-situ station configuration of the future;
- Address gauge capping and characterize the measurement of light precipitation (relevant for arctic precipitation);
- Understand the sources of errors and define means to reduce: adjustments, integration of measurements from different sensors;
- Derivation of snowfall (hourly, 3h, etc)

Norwegian Meteorological Institute:

- Continuation as Norway’s reference precipitation station;
- Evaluating possibilities to become GCOS-site
- Connection to Research department in MET.Norway established for engaging researchers in precipitation related studies (radar-assimilation in models; roadweather forecasting)

WMO SPICE Project Results: Practical Perspective

The SPICE Final Report should provide guidance to WMO Members for the operation of their networks within the WWW and WIGOS context, i.e. operational networks (continuous operations, stations distributed over a large area).
Data from the instruments and system operated as part of national, regional and local networks and stations support:

- Impact based forecasting (weather and water)
- Risk based warnings (weather and water)
- Long term climate studies, etc

WMO expects that the SPICE Final Report will include information that will support its Members with:

- Guidance on best practices to follow for obtaining solid precipitation measurements of known quality, at all their stations.
- Relevant information on the participating instruments and tested configurations, to support the configuration of operational networks in all Member jurisdictions, as well as improving the operation and update of their systems
- Information on performance which would help Members procure new instruments/systems

  Important note of consideration: not all Members have staff with expertise in instrumentation or in the measurement of solid precipitation; as a result, the results of the intercomparison should be formulated such that they could be understood and used by people with a broader range of skills.

It is important of engaging manufacturers in the preparation of the final report and evaluation of results. Failing to engage manufacturers early enough could delay the publication of the report

- The SPICE Project is a **partnership with manufacturers**, who have enabled the work in SPICE.
- The results could impact the business lines of the participating manufacturers
- Presentation of results needs to be impartial and fair. Differentiate issues coming from the instruments and possible issues coming from the site management/setup.
- The report must include recommendations on how manufacturers could improve their systems to better meet the requirements of WMO Members based on experience gained during the intercomparison.

Contribution to the update of the CIMO Guide he results reported by SPICE in its Final Report need to prepare the ground for the update of the chapters of the CIMO Guide relevant to the measurement of falling precipitation, especially when the precipitation is solid, as well as for snow on ground, snow water equivalent, etc.

WMO Observations User Requirements on Precipitation and Snow Depth

http://www.wmo-sat.info/oscar/observingrequirements

SPICE needs to provide results that will enable WMO Members and the community of meteorological data producers, to using instruments to obtain the data expected.
The Observing Systems Capabilities Analysis and Review tool (OSCAR) is a resource developed by WMO in support of Earth Observation applications, studies and global coordination.
It contains quantitative user-defined requirements for observation of physical variables in application areas of WMO (i.e. related to weather, water and climate), as resulting from the so-called Rolling Requirements Review process.

The surface- and space-based capabilities components of the OSCAR are intended to record observing platform/station metadata according to the WIGOS metadata standard described in the *Manual on WIGOS*. Given the priority of WIGOS, SPICE needs to contribute with factual results to informing whether the requirements established in OSCAR are feasible and under which conditions.
As Members are transitioning to newer systems, the results of SPICE need to inform them of the limitations of certain technologies for the measurement of solid precipitation, and equip htem with information that could be used for investments at different scales.

Definitions
Requirements are expressed for geophysical variables in terms of 6 criteria: **uncertainty**, **horizontal resolution, vertical resolution, observing cycle, timeliness,** and **stability** (where appropriate).
For each of these criteria the table indicates 3 values determined by experts:

- The **"threshold"** is the minimum requirement to be met to ensure that data are useful
- The **"goal"** is an ideal requirement above which further improvements are not necessary
- The **"breakthrough"** is an intermediate level between "threshold" and "goal" which, if achieved, would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view, when planning or designing observing systems.

The "uncertainty" characterizes the estimated range of observation errors on the given variable, with a 68% confidence interval (1 σ).

There are several documented variable requirements in OSCAR, on precipitation (near surface) and snow (at surface), as follows:

Accumulated precipitation (over 24 h):

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm)	2.0; 5.0; 10.0	1.0; 1.3; 2.0; 5.0	0.5; 1.0; 2.0	GEWEX; Global NWP, High Resolution NWP; Agriculture Meteorology; Climate Monitoring – Atmospheric Domain (AOPC)
Observing Cycle	6h; 12h; 24h; 3d	2h; 3h; 16h; 36h	30 m; 60m; 12h; 24h	
Timeliness	24 h to 60 d	9h to 45d	6h to 30d	

The Global Energy and Water Cycle Experiment (GEWEX) is a core project in the World Climate Research Programme (WCRP) concerned with the dynamics and thermodynamics of the atmosphere and interactions with the Earth's surface. ***

Precipitation intensity at surface (liquid or solid):

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm/h)	1.0; 2.0	0.2; 0.3; 0.5	0.1	**Used in Application Areas:**
Observing Cycle	1h; 2h; 3h; 6h; 12h	10m; 12m; 30m; 60m; 3h; 4h;	5m; 8m; 60m; 3h	Agricultural Meteorology Climate-AOPC Global NWP High Res NWP Nowcasting / VSRF Ocean Applications Aeronautical Meteorology
Timeliness (m: minutes; h: hours)	30m; 2h; 6h; 12h	9m; 10m; 30m; 6h	5m; 6m; 15m; 3h;	

Precipitation type at the surface:

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm/h)	-	-	-	**Used in Application Areas:**
Observing Cycle	3h	60m	15m	High Resolution NWP
Timeliness	2h	30m	15m	

Snow depth:

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm/h)	2 cm	0.5 cm	0.1 cm	**Used in Application Areas::**
Observing Cycle	24h	60m	10m	Nowcasting / VSRF
Timeliness	24h	60m	10m	

Snow water equivalent:

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm/h)	10mm; 20 mm; 500mm	6.5 mm; 8mm;; 10mm; 23.2mm	2mm; 5mm	**Used in Application Areas:**
Observing Cycle	6h; 5d; 7d; 30d	3h to 11d	60m to 7 d	CLIC Agricultural Meteorology Climate-AOPC GEWEX Global NWP High Res NWP Hydrology SIA
Timeliness	24h to 90 d	24 h to 11 d	3h to 30 d	

Snow cover

Criteria	Threshold	Breakthrough	Goal	Applications
Uncertainty(mm/h)	10% to 50%	7% to 20%	2% to 10%	**Used in Application Areas:**
Observing Cycle	12h to 30d	3h to 6d	1h to 5d	CLIC Agricultural Meteorology Climate-AOPC GEWEX Global NWP High Res NWP Hydrology Nowcasting / VSRF Climate-TOPC
Timeliness	12h to 90d	2h to 45d	1h to 7d	

Annex: Status of Instruments Under Test from Instrument Providers

	Instrument	2012/13	13/14	14/15	Ready for return to Provider
Weissfluhjoch	GPS snowdepth sensor	Not installed	No data communicated by instrument provider	No data communicated by instrument provider	Possible continuation of the measurements
	Belfort	Not installed	Available (with some quality issues due to bad calibration)	Complete availability	Possible continuation of the measurements
	Geonor	Not installed	Complete	Complete	Possible continuation of the measurements
	Meteoservis	Not installed	Complete	Complete	Possible continuation of the measurements
	Thies	Not installed	Partially available (installed on December 2013)	Complete	Possible continuation of the measurements
CARE	Meteoservis MR3H-FC	100%	100%	100%	ready to return (some data concerns season 1 and 2)
	ZAMG MR3H-FC	100%	100%	100%	ready to return (some data concerns season 1 and 2)
	CAE SPA – PMB25R	100%	100%	100%	ready to return
	Hyd Serv America TBH/TBH-LP	100%	100%	100%	ready to return
Bratt's Lake	MRW500 (x2)	Not installed	Good	Good	Ready to return, could be tested an additional year
	Geonor 1500mm	Good	Good	Good	Ready for return, July 2015
	Hotplate	Not installed	Not installed	Poor (only data from Jan-March, 2015)	Manufacturer requires return May 2015
Caribou Creek	Geonor 1500mm	Not available	Good	Good	Ready for return, July

					2015
	CS725	Not available	Good	Good	Ready for return July 2015 but could be tested another season

Sodankyla	OTT Parsivel 2	yes	yes	yes	
	Environmental Meas Ltd Universal Precip Gauge UPG1000	yes	yes	yes	
	Meteoservis MR3H-FC, model AH-01 with heating	yes	yes	yes	
	CS725 Gamma Ray Snow Water Equivalent Sensor (GMON3)	yes	yes	yes	must be returned in September 2015
	Campbell Scientific Canada Snow depth sensors model SR50ATH-316SS	yes 2 pcs	yes 2 pcs	yes 2 pcs	must be returned in September 2015
	Felix Technology Snow Depth Sensor, model SL300	yes	yes	yes	
	Sommer Snow Depth Sensor, model USH-8	yes 2 pcs	yes 2 pcs	yes 2 pcs	
	Lufft Snow Depth Sensor SHM30/012840-642-22	yes	yes	yes	
	Vaisala PWD 53/PWD33	yes but not for SPICE	yes	yes	
	Vaisala PWD 52	yes but not for SPICE	yes	yes	
	YES Hot Plate TPS3100	yes	yes	yes	
	Vaisala FS11P	yes but not for SPICE	yes	yes	

Haukeliseter	Instrument	12/13	13/14	14/15	Ready for return to Provider
	TRWS 405	In operation since 19.1.2013	Ok, some problems after power outages, did not resume without help	Ok, some problems after power outages, did not resume without help	De-installation planned for late June 2015
	Campbell PWS100	In operation since 19.1.2013	ok	Longer periods without data – in contact with provider, no solution, seems to “come and go” arbitrarily	De-installation planned for late June 2015
	Hotplate	Not installed	Not installed	Installed in autumn 2014, data collection since end of 2014	De-installation planned for late June 2015 (requested back by provider)

ANNEX III

PRELIMINARY QC DATA ASSESSMENT

Francesco Sabatini

Quality Control (QC) of data is a fundamental component of quality management systems and is important for the examination of data to detect errors and take follow-up actions.

The QC procedures have been implemented before the intercomparison so that validated data are provided to the Data Manager and tools for the control of the functioning of instruments are available to the Site Manager.

Site raw data from gauges in field working references, systems under test, and ancillary gauges were downloaded from NCAR archive

Quality control (QC) processing was then applied to both 1 min and 6 s datasets; the latter will be used to generate 1 min datasets, so all quality controlled datasets will have 1440 minutely records per day

QC flags will be generated to inform subsequent data analysis, according to the following codes:

Flag code	Data classification	Data characterization
1	'Good'	No issues detected
2	'Inconsistent'	One or more parameters are inconsistent (e.g. wind direction ≠ 0 when wind speed = 0)
3	'Suspect '	Gauge diagnostic parameters indicate potential data issue Values exceed 'suspect' threshold for point-to-point variation
4	'Erroneous'	Gauge diagnostic parameters indicate gauge or data error Value(s) outside of gauge operational range, as defined by max/min values and max variation from point to point (plausible value check)
5	'Missing'	Missing data point (1 min datasets). Insufficient number of samples used to compute minutely value (6 s datasets)
6	'Site'	Data points flagged by site managers to reflect maintenance, malfunction, power outage, etc.

Since the first meeting and teleconferences it was decided to organize a unique FTP data server in order to consolidate the SPICE dataset from the participating sites.

Within the members and experts of the SPICE team a specific QC group was created in order to deal with QC data: Audrey Reverdin and Floortje Heuvel (Meteoswiss), Michael Earle (Environment Canada).

The IT expert, Andrew Gaydos, provides the data management at NCAR, Boulder, Colorado (USA).

Up to now the WMO SPICE operational sites are listed in the table below (in gray background the sites data available up to now at NCAR):

SITE	COUNTRY
ARAMON-Formigal	SPAIN
BrattsLake	CANADA
CARE	CANADA
Caribou Creek	CANADA
Col de Port	FRANCE
Forni Glacier	ITALY
Gochang	KOREA
Guthega_Dam	AUSTRALIA
Hala Gasienicowa (*)	POLAND
Haukeliseter	NORWAY
Marshall	USA
Mueller Hut	NEW ZEALAND
Pyramid	NEPAL
Rikubetsu	JAPAN
Sodankyla	FINLAND
Valday	RUSSIA
Volga	RUSSIA
Weissfluhjoch	SWITZERLAND

(*) Commissioning report still under construction

The first manual check was conducted at the beginning of May 2015, by downloading data from FTP NCAR server: ftp://spicedl@ftp.rap.ucar.edu

For each site four folders for each year were created (2012, 2013, 2014, 2015). For every year two or more .DAT ASCII format -1 minute data files-, for each sensors category, are present:

Geonors, Pluvios, Other Accum, Other Rain, Met (ancillary data). I.e. for Bratt's Lake site, for the year 2013 the following files are available:
Canada_BrattsL_geonors_qc_2013.dat, (Geonors WG precipitation gauges)
Canada_BrattsL_met_qc_2013.dat, (ancillary data)
Canada_BrattsL_other_accum_qc_2013.dat,
Canada_BrattsL_other_int_qc_2013.dat,
Canada_BrattsL_other_rain_qc_2013.dat

The aim of this preliminary action was, a) check the consistency of QC data files content against sensors included in the commissioning report and, b) check the time series consistency (QC data available vs SECTION 4 of commissioning report - Instrument Data Validation table, says the sensors readiness).

After checking the content of some QC files, we found a bug in the process of data files creation, which was causing the site-swapping in the QC files (filename not matching the file content). It was easy and quick to rerun the ASCII file generation scripts after debugging, so data files have been generated again on the NCAR ftp site and made available by the date of 13 May 2015.

The manual quality check will then continue on these new files up to the first week of June 2015, in order to be completed on time for the QC team meeting, that will be held in Canada during the month of June.

ANNEX IV

TENTATIVE DATA ANALYSIS PLAN

- R0-R1/R0-R2: Daqing, Craig, Kai – try to receive input/contributions from Valdai (Yuri, Anton)
- R1-R2/R1-R3, R2 Geonor vs R2 Pluvio: Kai, Craig, Daqing
- R2-R3: Roy
    - w/John: R3-TF, R3-ratio as a extra dependency, R3-simulation
    - w/Guywon: minute data TF (uncertainty), fall velocity
    - Roy: R3 Pluvio vs R3 Geonor
- WG TF: John
- Uncertainty: Guywon, presented method and minute data TF-derivation
- Impact of using TF on different timescales: Scientific analysis by Luca/Matteo
- Application of Transfer functions for operational uses (1 hour, 12/24 hours and longer time series (monthly, season): Operation aspects by Mareile/Matteo
- Tipping Bucket Analysis: Mike
- Intensity: Emanuele
- Application of DFIR for NWP: Samuel B.
- Applicaton of DFIR for extreme weather events: Samuel B.
- Trace precipitation : Eva, Mike – detection with Emerging Technologies (ET): Yves-Alain, John, Audrey
- POD/FAR Emerging Technologies: Yves-Alain, John, Audrey
- Analyse variables that affect performance of ET: Yves-Alain, John, Audrey
- Numerical simulation of ET-sensors: Matteo?
- Transfer Functions for ET-sensors: Yves-Alain, John, Audrey
- Lab experiment of ET in Grenoble: Thomas
- Reprocess actual data from ET/according to lab study(Grenoble, Marshall/Switzerland)
- Precipitation type Intercomparison (Yves-Alain and student)
- Capping/Heating Samuel B.
