WMO Solid Precipitation Intercomparison Experiment (SPICE)
Mission Statement and Objectives

1. Mission Statement

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

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

2. Scope and Definition

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

With highest priority:

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

With lower priority:

(c) Solid and mixed precipitation intensity.

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

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

3. Background

Solid precipitation is one of the more complex parameters to be observed and measured by automatic sensors. The measurement of precipitation has been the subject of a multitude of studies, but there have been limited coordinated assessments of the ability and reliability of automatic sensors to accurately measure solid precipitation. The WMO Solid Precipitation

Measurement Intercomparison[1] focused on the instruments in use in national networks at the time of the intercomparison, primarily manual methods of observation. The assessment of automatic sensors/systems for snow depth and snowfall measurement was not a central part of the study, and no intercomparison stations were included in the Arctic or Antarctic.

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

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

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

4. Intercomparison Objectives

SPICE will report on the following key objectives:

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

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

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

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

   a. On the exposure and siting specific to various types of instruments;
   b. On the optimal gauge and shield combination for each type of measurement, for different collection conditions/climates (e.g., arctic, prairie, coastal snows, windy, mixed conditions);

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[1] WMO CIMO IOM Report No. 67, WMO/TD-No. 872, 1998:
http://www.wmo.int/pages/prog/www/IMOP/publications/IOM-67-solid-precip/WMOtd872.pdf

c. On instrument specific operational aspects, specific to cold conditions: use of heating, use of antifreeze (evaluation based on its hygroscopic properties and composition to meet operational requirements);
d. On instruments and their power management requirements needed to provide valid measurements in harsh environments;
e. On appropriate target(s) under snow depth measuring sensors;
f. Consideration will be given to the needs of remote locations, in particular those with power and/or communications limitations.

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

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

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

VI. Configure and collect a comprehensive data set for further data mining or for specific applications (e.g., radar- and/or satellite-based snowfall estimation). Enable additional studies on the homogenization of automatic/manual observations and the traceability of automated measurements to manual measurements.

5. Deliverables

SPICE will provide reports on the intermediate and final results of the experiment covering the following aspects:

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

6. Instruments and Configurations to be considered

The experiment may include many instrument types, models and configurations identified as currently operational; as summarized in WMO CIMO IOM 102, Survey on National Summaries of Methods and Instruments for Solid Precipitation Measurement at Automatic Weather Stations, http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html. In addition, known emerging technologies may be included, based on the recommendations of WMO Members, specifically:

✓ Weighing Gauges, Tipping Buckets, other storage gauges;
✓ Instruments employing emerging technologies e.g. laser, particle disdrometers, hot plate, spinning arm, vertically pointing radar, optical gauges, acoustic, precipitation video imaging, video camera;

- ✓ Wind shields: (type: e.g. Alter, Nipher, Tretyakov, Wyoming, Belford, wood), and configurations (single, double, small DFIR);
- ✓ Gauges equipped with heating in various configurations;
- ✓ Emerging trends: low-cost sensors, with (potential for) wide use.

7. Duration of the Intercomparison

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