Reference measurements at Weissfluhjoch (Switzerland) for the WMO/CIMO SPICE Project

Y.-A. Roulet [(1)], J.-M. Aellen [(1)], S. Brönnimann [(1)], Ch. Fierz [(2)], J. Grandjean [(1)], B. Henchoz [(1)], Ch. Marty [(2)], A. Reverdin [(1)],M. Ruesch [(2)]

[(1)] *MeteoSwiss, Ch. de l'Aérologie 1, Case postale 316, CH-1530 Payerne, Switzerland (yves-alain.roulet@meteoswiss.ch)*

[(2)] *WSL Institute for Snow and Avalanche Research SLF, Flüelastrasse 11, CH-7260 Davos Dorf (marty@slf.ch)*

ABSTRACT

SPICE (Solid Precipitation Intercomparison Experiment) is a WMO/CIMO multi-site intercomparison of instruments and systems of observation for the measurement of solid precipitation. One of the main objectives is the assessment of a wide range of instruments under various climates. For that purpose, around 20 sites worldwide are equipped and configured according to standards defined within the project, allowing to compare measurements taken at these sites. The experiment started in October 2013 and is meant to last over two winter seasons. At Weissfluhjoch (Switzerland), a SPICE site has been set up by MeteoSwiss in close collaboration with the WSL Institute for Snow and Avalanche Research SLF to provide reference measurements for the Alpine climate. Among others, a reference set of instruments consisting of three OTT Pluvio^2 weighing gauges – one placed in a DFIR (Double Fence Intercomparison Reference), one equipped with an Alter shield and one unshielded – will provide data sets for reference measurements analysis. A strong focus for SPICE Weissfluhjoch will be given on developing a methodology for precipitation phase discrimination using an optical disdrometer, and to link solid precipitation measurements with measurements of snow on the ground using various manual and automatic methods. The paper describes the site and presents the results obtained from the first winter of measurements (2013-2014).

1. Introduction

The Weissfluhjoch SPICE site (see Figure 1) is on a flat portion of an Alpine mountain, located at 2'500 m asl. No vegetation, except small amounts of grass. Various topographical obstacles (mountain ridge) to the East and West, about 500 m from the site. It is an existing site used by the Swiss Institute for Snow and Avalanche Research (SLF) based in Davos. The site was proposed in a partnership between MeteoSwiss and the SLF, which has extensive experience in measuring snow on the ground and great interest in SPICE.

Prior to SPICE, the site was already fully equipped with automatic devices measuring snow on the ground (Lysimeter, Jenoptic SHM30, Campbell SR50AT, Snowpillow, Snowscale), as well as daily or biweekly manual measurements (Snow board, Graduate stake, snow profiles). Numerous ancillary data are also provided by the SLF (e.g. air temperature, wind, pressure, humidity).

Since 2012, MeteoSwiss has been expanding the site to meet the requirements for participation in SPICE. Instruments for SPICE references or under test, as well as additional sensors for ancillary data have been installed (OTT Pluvio^2, Geonor T-200B3MD, Belfort AEPG 600, Meteoservis MR3H-FC, Thies LPM disdrometers, GPS based snow depth sensor, and Lufft WS600-UMB meteo station). A DFIR (Double Fence International Reference) has also been built, according to SPICE requirements.

Figure 1: The Weissfluhjoch (Davos) SPICE site, with the DFIR (lower left corner)

1.1. Reference configuration for snowfall measurement

The Weissfluhjoch has been approved by the SPICE IOC as a S2 site where both R2 and R3 reference types are available (as defined in SPICE IOC 2:

http://www.wmo.int/pages/prog/www/IMOP/reports/2012/IOC-SPICE-2.pdf). The precipitation gauge used for both references is a 200 cm^2 OTT $Pluvio^2$ with a 1'500 mm capacity. The configurations of the two references in Weissfluhjoch are as follow :

- **R2:** One OTT $Pluvio^2$ with a single Alter shield within a DFIR, together with a precipitation detector (Thies LPM disdrometer) that has been installed into the DFIR, perpendicular to the main wind direction, half way between inner fence and single Alter shield.
- **R3**: Two OTT $Pluvio^2$, both identically configured except that one is shielded with a single Alter shield, and the other is unshielded. Distance between the two is 6.5 m.

The three OTT $Pluvio^2$ send data via GPRS with a 1-min frequency. The R2 reference (see Figure 2) is located at approximately 40 meters from the R3 reference (see Figure 3). As the depth of the snowpack can reach 3 m, the height of the DFIR and all three instruments has been adjusted to maintain the minimum clearance from the snowpack over the entire season (DFIR outer fence at 4 m, gauge orifice at 3.5 m). A mix of 7.5 L of propylene glycol and 2.5 L of water was put into the gauges as antifreeze together with 0.4 L of linseed oil to prevent evaporation. A webcam provides high resolution hourly pictures of all SPICE instruments to enable a monitoring of the instruments, and in particular to detect any snow capping or other problems occurring on the instruments.

Figure 2: The R2 SPICE reference with a $Pluvio^2$ in a Single Alter shield surrounded by a DFIR (Double Fence International Reference)

Figure 3: The R3 SPICE reference with one Pluvio^2 unshielded (right) and one with a Single Alter shield (left)

1.2. Reference for snow on the ground measurement

The Weissfluhjoch site provides numerous measurements of snow on the ground parameters (snow depth, snow water equivalent (SWE), fresh snow height, fresh SWE, snow profiles) using automatic or manual methods (see Figure 4).

Automatic measurements at a frequency of 5 to 30 minutes :

- Lysimeter
- Jenoptic SHM30 (snow depth)
- Campbell SR50AT (snow depth)
- Snowpillow (SWE)
- Snowscale (SWE)

Manual measurements :

- Once per day
  - Snow board (new snow height, new SWE),
  - Graduate stake (snow depth)
- Twice a month
  - Snow profiles, snow height and SWE

Figure 4: The snow on the ground measurements at Weissfluhjoch SPICE site.

2. Results

The first winter of measurements has been completed (2013-2014), and first data analysis are currently being performed. The accumulation for the different instruments running on site from February 3 to April 14 2014 is shown in Figure 5. A large spread can be seen, with accumulation varying from 100 to 200 mm, the tipping bucket (Meteoservis) and the Thies LPM disdrometer measuring the lowest quantity and the weighing gauges (OTT Pluvio^2, Belfort, Geonor) measuring the most. For the three OTT Pluvio^2 gauges, the parameter "Bucket Content RT" is used here. The results obtained between the three gauges are consistent with the shielding configuration: the gauge in the DFIR shows larger accumulation (190 mm) than the gauge shielded with the Single Alter (155 mm), and finally the unshielded gauge (125 mm).

Looking at the agreement between snow on the ground (SWE) and snowfall measurements, the SWE measured manually (biweekly) and automatically with the snow pillow show similar evolution than the snowfall measurements using gauges during the entire period of observation. The snow scale seems to underestimate the SWE, probably due to ice bridges with the surrounding snowpack.

The signal from all five weighing gauges (3 OTT Pluvio^2, 1 Belfort and 1 Geonor) shows diurnal variation during non-precipitation days (e.g. 7 to 14 March 2014, see Figure 5). These fluctuations occur during days with strong temperature gradients, and are probably due to temperature effect on the measuring device (load cell, transducers). This will need further investigation.

Despite oil layer in equal quantity in five weighing gauges, evaporation has been unequally observed. The week from 7 to 14 March 2014 was dry and sunny, with daily maximum temperature reaching up to 15 °C. Evaporation is clearly observed for the OTT Pluvio^2 in the DFIR and for the Geonor (about 10 mm in 7 days), whereas the other three weighing gauges show practically no evaporation. This behavior is still under investigation. Among others, laboratory tests are being performed in order to assess the ability for linseed oil to act as a layer preventing from evaporation. For the difference between the three OTT Pluvio^2, one assumption is that natural ventilation is larger for the unshielded gauge and for the gauge with the Single Alter, whereas impact of solar radiation for evaporation is likely to be larger for the gauge in the DFIR, where wind is generally lower.

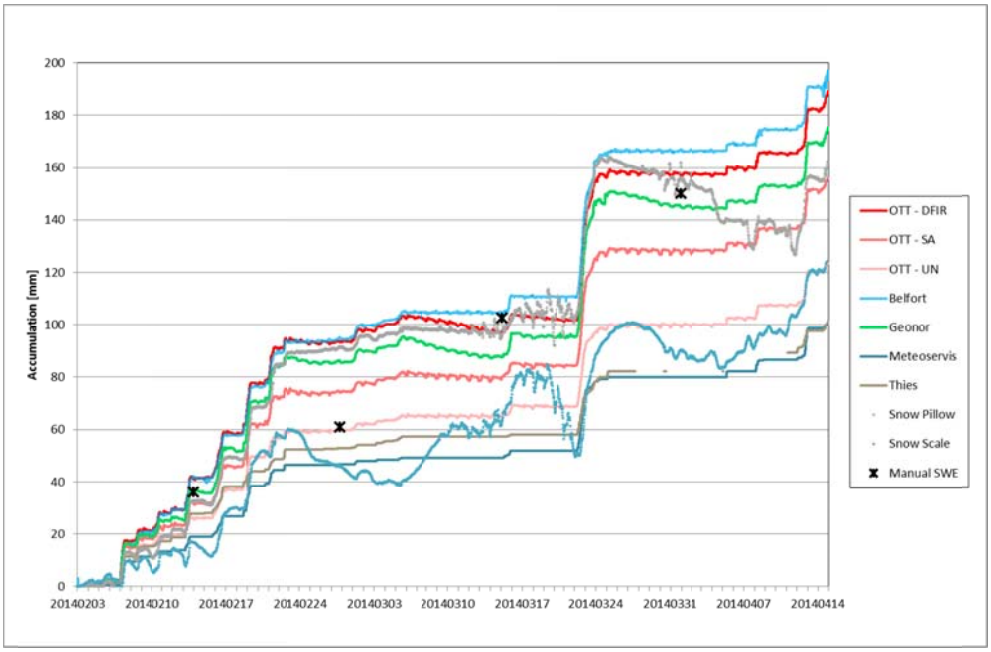

Figure 5: Snow accumulation from several rainfall gauges, with the SPICE references R2 (OTT – DFIR: Pluvio^2 in the DFIR), and R3 (OTT – SA: Pluvio^2 with a Single Alter shield, OTT – UN: Pluvio^2 unshielded) and comparison with snow on the ground measurements (Snow Pillow, Snow Scale and Manual SWE) from February 3 to April 14 2014.

Another ongoing study is focusing on the interpretation of particles size and fall velocity distribution measured by a Thies LPM disdrometer. The main goal is to derive information on precipitation type and transition between liquid and solid phases using this particles distribution. According to Löffler-Mang & Joss (1999), the precipitation type can be defined as a function of drop size and fall velocity (see Figure 6). The disdrometer particles distribution from the Thies LPM placed in the DFIR shown in Figure 7 illustrates an example of transition phase from liquid to solid during one single event on February 7 2014. The sensor delivers the full binned data (22 classes for size and 20 classes for fall velocity) every minute, so that the evolution of the distribution within one event can be characterized with high time resolution. Further events will be analyzed, the objective being to determine

transition phase during an event, and to follow the evolution of particles size and fall velocity distribution in time.

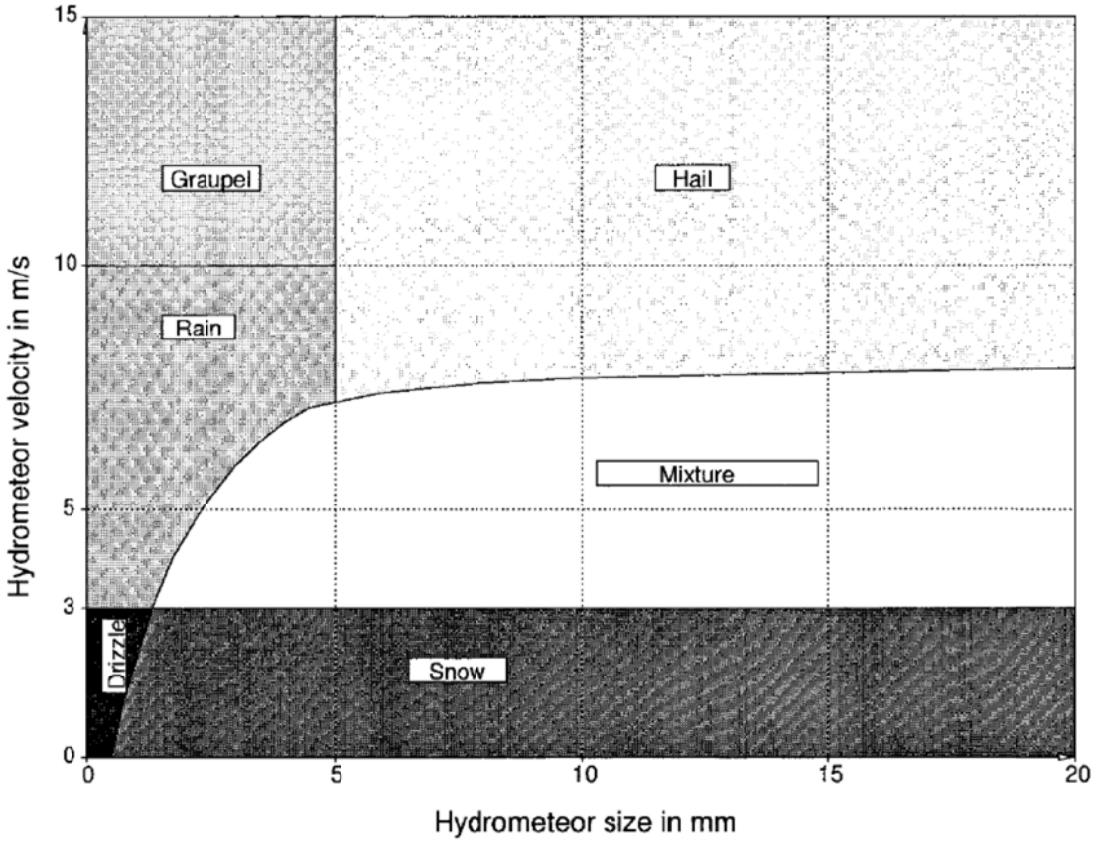

Figure 6: Schematic concept for using velocity and size information to detect the different type of hydrometeors.

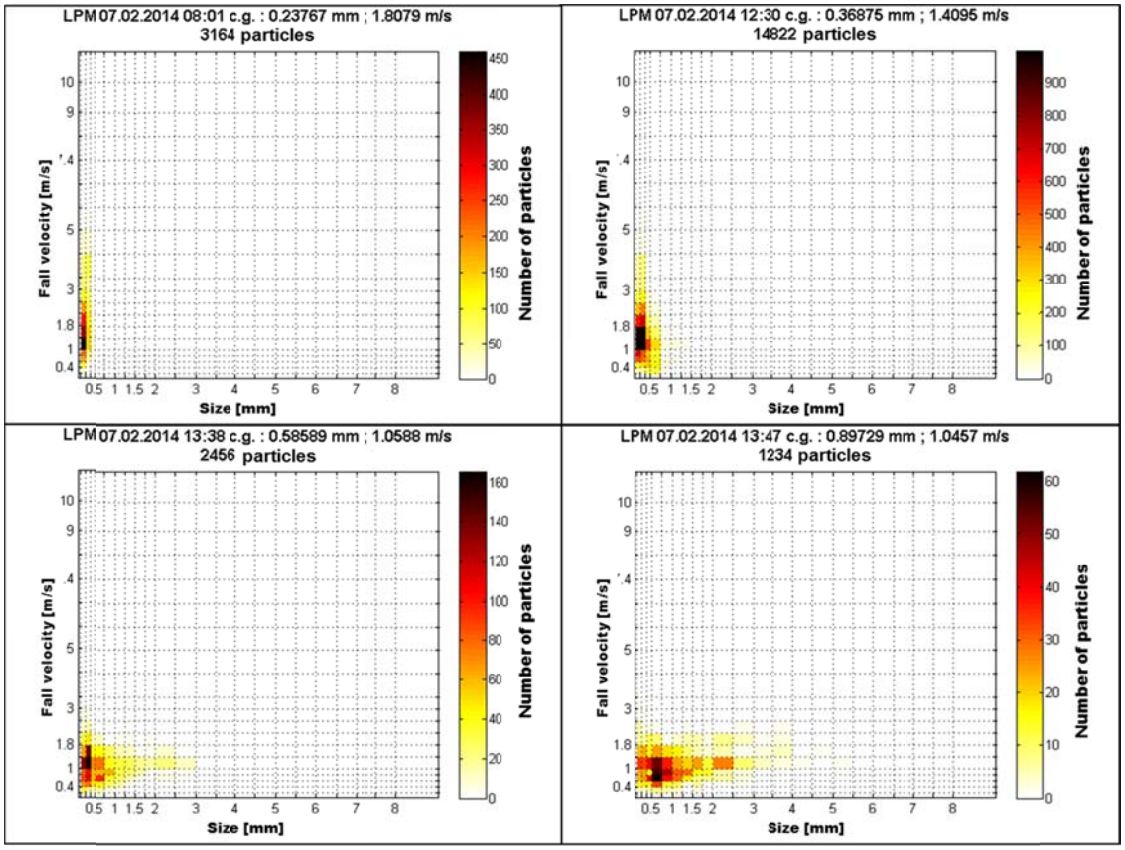

Figure 7: Particles size and fall velocity distribution measured by the Thies LPM disdrometer located in the DFIR in 1 min resolution during one snow event on February 7 2014 (snapshot at 08:01, 12:30, 13:38 and 13:47)

3. Conclusion and Outlook

Data from the first winter of measurement within SPICE (2013-2014) are currently being analyzed. The SPICE Data Analysis Team (DAT) will also work with data from several sites, the objective being to define transfer function between the references (e.g. between a R2 and a R3 reference).

The second winter will complete the existing data set and will allow for comparison of the two winter seasons. At Weissfluhjoch, the focus will be given on further analysis of the existing set of instruments. A collaboration with another scientific program working with radar (mobile X-band radar) and 2D videodisdrometer (2DVD) will also be developed, allowing further investigations of precipitation type assessment and study of other methods for rainfall measurement. The SPICE Weissfluhjoch site and its numerous instruments and methods of observation, for snowfall and snow on the ground measurements, offers a great opportunity to link with radar activities, combining in-situ measurements and remote sensing technology.

References

Löffler-Mang M., Joss J., 2000: An Optical Disdrometer for Measuring Size and Velocity of Hydrometeors, Journal of Atmospheric and Oceanic Technology, Vol. 17, 130-139.