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Interactive comment on "Point observations of liquid water content in natural snow – investigating methodical, spatial and temporal aspects" *by* F. Techel and C. Pielmeier

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The paper presents and discusses a comprehensive set of field observations of liquid water in snow. The data are valuable and important for helping understand the response of snow to infiltration and for managing water resources.

Considerable editing is needed to help sharpen the focus of the manuscript.

Additional specific questions/comments include: P1970 L3: I was surprised that there is no consideration of infiltration caused by rain-on-snow. Does your data set exclude such events? If so, it would be important to comment on that point.

P1971 L25 and following: Discussion of the theory and operation of the dielectric devices is hard to follow. For example I do not think that parameter B is the 3dB bandwidth. Do you really need to state the empirical relationships used to calculate the water content since they are given in the cited papers. Instead you might consider stating something like:

. . .. . . Liquid water content has also been estimated by measuring the real and imaginary parts of the permittivity of snow. This measurement is diagnostic of liquid water because the permittivity of water (εâĂši $\approx$ 86) is much higher than those of air (εâĂši $\approx$ 1), and ice (εâĂši $\approx$ 3.15) (Frolov and Macharet, 1999). In this study, we compare "hand" measurements with measurements made with a "Finnish Snow Fork" (SnF, Sihvola and Tiuri, 1986; Toikka, 2009) and also with a Denoth meter (Dn, Denoth, 1994).

The Snow Fork is a two-pronged wave-guide that operates at $\sim$1GHz and calculates both the real and the imaginary parts of the permittivity simultaneously by measuring changes in the resonance curve between air and snow. Insertion of the Snow Fork compresses the surrounding snow, which has a small effect on the estimate of the real part of the permittivity (Sihvola and Tiuri, 1986). The snow fork that we used provided an estimate of water content on samples of area 7.5x2 cm2. [IS THIS CORRECT]?? The SnF has been used in a variety of studies including measuring the spatial wetness distribution (Williams et al., 1999), snow characteristics in Antarctica (Karkas et al., 2005), and the wetness of snow in ski tracks (Moldestad, 2005).

The Denoth meter is a capacitance probe that operates at 27 MHz providing a measure of the permittivity of snow of area 13x13.5 cm2. A separate measurement of density is required to resolve for the real and imaginary parts of the permittivity (Denoth, 1994), necessary to estimate liquid water content. The Denoth meter has also been used in field studies to monitor changes in snowpack wetness during the melt period (Martinec, 1991a; Kattelmann and Dozier, 1999), and to validate models (Mitterer et al., 2010).

The accuracy of measurements made by dielectric methods is $\sim \pm$0.5 vol.% (Sihvola and Tiuri, 1986; Fierz and Fo ÌĹhn, 1994). Additional uncertainty can arise if sensors near the surface are affected by solar radiation (Lundberg et al., 2008). These methods are destructive to the snow sample and also require the excavation of a snow-pit, which can cause local disturbances to water flow (Fig. 2). To overcome this problem, upward-looking radars installed at the snow-ground interface have been used to measure wetness in snowpacks (Heilig et al., 2009). In addition, multispectral imaging from satellites has been used successfully to map regions of dry and wet snow surfaces (e.g. Gupta et al., 2005).

P1978 L14: "These results imply that Snow Fork and Denoth instrument will generally provide similar measures of liquid water content." I do not follow this – it seems that previously you state (on the basis of the regression) that the Finnish Snow Fork generally yields higher estimates than the Denoth meter (at least up to values of 10%. Also, do you know how acidity of the snow might affect the measurements of permittivity? Also, how might the volume of snow sampled by each device affect the measurement?

P1979 L25: Comparisons with snow fork; again, you mention that snow fork is not calibrated above 10%, so perhaps that is why the agreement with hand tests falls off at high moisture content

P1980 L21: I do not follow the sentence: "The results indicate that in particular grain shape (and size) and layer hardness may unconscientiously influence even experienced observers when estimating the liquid water content." From the earlier discussion I understood that when wetted, the hardness of mf layers decreased, and the same happened when TG grains were wetted.

P1983 L1: Although this may be true, I suspect that liquid water content above ice or capillary barriers can be much higher, and these boundaries could well exert strong control on the mechanical response of snowpacks during infiltration.

P1986: I agree with your idea that including some sort of qualitative estimate of the spatial distribution of water in snow would be a useful addition to the traditional point

estimates of moisture content.

P1989 L3: Earlier you seem to be thinking that the Finnish Snow Fork is a good substitute for the hand test. I must be missing something here?

P1989 L9: Note that in several locations in the US and NZ forecasters are measuring outflow (using lysimeters), snow surface temperature (using IR sensors) and snow temperature profiles (using thermistors or thermocouples) in real time.

P1968 L12: You seem to think that the dielectric devices yield quantitative results. I would think that to prove this statement you would need to test them against calorimetry measurements.

Interactive comment on The Cryosphere Discuss., 4, 1967, 2010.