Performance Analysis of CS725 Snow Water Equivalent Sensor

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Abstract

This poster continues the evaluation of the CS725 snow water equivalent (SWE) sensor as previously conducted by Wright et al. (2011). The CS725 was developed by Hydro Québec in collaboration with Campbell Scientific Canada Corporation and determines SWE by passively measuring the attenuation of naturally emitted terrestrial gamma radiation from the soil by the snowpack. The CS725 provides a non-contact technique for determining SWE that is effective with any type of snow or ice cover and whose performance is not affected by adverse weather conditions. Field testing of the CS725 was conducted at Sunshine Village, Alberta (2008-2011), SNOTEL Tony Grove Ranger Station, Utah (2009-2010), and Anestølen, Norway (2011-2012).

• Field testing of the CS725 was conducted at Sunshine Village, Alberta (2008-2011), SNOTEL Tony Grove Ranger Station, Utah (2009-2010), and Anestølen, Norway (2011-2012).
• Automated SWE measurements were made at the various test sites using the CS725, snow pillow, and precipitation gauge. At Sunshine Village (2008-2010) and Anestølen, Norway (2011-2012) monthly manual snow course measurements were also conducted.
• Analysis of CS725 performance was conducted by comparing the CS725 to other sensors that provide a measurement for SWE either directly or indirectly: snow pillow, precipitation gauge, snow density sensor, and manual SWE values from snow course measurements. Strong agreement is shown both qualitatively and quantitatively between all automated methods of SWE, CS725, snow pillow, and precipitation gauge. Statistically, all automated methods show strong correlations of 0.96-0.99 over the entire season and up to peak periods. Monthly snow course measurements were found to be the least reliable method for measuring SWE:

Analysis of the CS725 suggests that it provides comparable, if not better, SWE accuracy to the snow pillow and precipitation gauge, while eliminating the disadvantages associated with these measurement techniques.

Introduction

With much of Canada’s freshwater coming from snowmelt, the accurate assessment of a snowpack’s snow water equivalent (SWE) is a vital first step in any water availability forecasting (Osterhuber et al., 1998). Monitoring of SWE is vital for management of water resources for hydropeaking (Laakkanen, 2004), domestic use, and industrial extraction (Lundberg et al., 2010) and is essential for flood prediction and prevention (Laakkanen, 2004). A number of ground-based techniques have been developed for the measurement of SWE:

• Manual Snow Course Measurements, snow pillows, radioactive attenuation, and acoustic sounding.

The ideal ground-based snow measurement technique:

• Does not cause environmental harm, disturb the accumulation pattern by altering the wind field at the measurement site, or influence the exchange of solar radiation, thermal energy, and water between the snow and the atmosphere and/or ground (Lundberg et al., 2010).

• Monitors SWE on a daily basis to determine what day of the year peak SWE is reached.

The CS725

A new SWE sensor developed by Hydro Québec in collaboration with Campbell Scientific (Canada) Corp. (Chiappetta, 2008). The CS725 is a gamma monitor for snow water equivalent and soil moisture that passively measures the natural terrestrial gamma radiation emitted by the soil and their absorption by the snowpack.

The sensor element utilizes a thallium-doped sodium iodide crystal NaI(Tl) to measure naturally emitted terrestrial gamma radiation. It detects potassium and thallium gamma rays (the most abundantly naturally emitted gamma rays) and places counts of each gamma ray detected in a histogram that is used to calculate SWE.

Main Advantages:

• Non-contact
• Performance is not affected by adverse weather conditions
• Effective with any type of snow or ice
• Can cover large surface area (50-100 m²/m² when mounted 3 m above the ground)
• Can be post-calibrated if installed after the onset of snow
• Not affected by measurement errors due to bridging or wind
• The CS725 only monitors existing naturally occurring Gamma radiation (No Special licenses or precautions are required to install or operate the CS725)

Results

• There is no standard method to precisely measure SWE values of a snowpack.
• Analysis of the CS725 sensor technique must therefore be conducted by examining the errors associated with a particular technique and the scale of important errors based on the usage of the sensors. The different measurement techniques were observed at all sites over all field seasons.
• Although many researchers have tried to explain these deviations, there is no way to determine the true causes without detailed snow surveys on a daily scale, which would result in destruction of the snowpack at the survey site.
• CS725 SWE measurements demonstrated increased variability at greater snow depths (> 30 cm) for all testing sites relative to snow course (Figure 5). However, this was not observed at the Tony Grove Ranger Station (Figure 1) and Anestølen, Norway (Figure 2) likely due to the lower density of each test site.
• This increased variability in the CS725 SWE measurement may be explained by a decrease in potassium counts as the snow depth increases resulting in a greater possibility of noise (non-target sources of potassium gamma rays).
• Statistical comparisons of the three automated daily SWE measurements at all sites show strong correlations (0.98-0.99) between the CS725 and snow pillow and the CS725 and precipitation gauge (Table 1).
• Comparison of SWE measurements using a CS725 with and without a collimator in Anestølen, Norway (Figure 4) show a very strong correlation (0.99) suggesting that in open sites with a uniform snow pack and no trees present the CS725 can be used without a collimator.
• When peak snow depths were compared for the three automated techniques the difference in peak SWE was found to be small (Table 2).
• Due to this and the comparisons of the three techniques above it is difficult to determine a significant difference between the measurement techniques. Therefore, at this level of agreement it can be argued that the CS725 will perform at least as well, if not better, than the snow pillow and the precipitation gauge.
• However, the disadvantages of monthly snow course measurements, snow pillows and precipitation gauges must be also taken into account:
• Snow Course measurements are labour intensive, time consuming, expensive, negate the possibility of around the clock data collection (Pomeroy and Gray, 1995), and are prone to human error (Hulstred, 2000).
• Snow pillows must be installed prior to the first snowfall, have logistical and transport issues (Osterhuber et al., 1998), measurement can also be prone to errors in the form of bridging due to the formation of ice lenses (Hulstred, 2002; Osterhuber et al., 1998; Johnson and Schaefer 2002), and dark pillows often absorb more energy than the surrounding area delaying accumulation in the SWE.
• Precipitation gauges experience a reduction in catch efficiency of snowfall with increasing wind speeds (Rasmussen, 2010) and do not provide a peak SWE value crucial for hydrological models.
• Both the snow pillow and precipitation gauges provide an environmental hazard due to the potential leaks of antifreeze solution used by both sensors (Osterhuber et al., 2010).
• Seeding experiments (Figure 5) conducted using potassium fertilizer show potential for increasing potassium counts measured by the CS725 at sites where low counts are found. However, significant future development and testing is still required to validate these results and put this theory into practice.

Discussion/Conclusions

References


http://warnercnr.colostate.edu/~dmhultst/Lit_Review/Lit_Review2.pdf