

## **Witchcraft, Wizardry, and Water: The Intersection of Physics, Electrical Engineering, and Snow Monitoring**

PAUL W. NUGENT<sup>1</sup>, COOPER P. MCCANN<sup>1</sup>, AND AUSTIN W. BEARD<sup>1</sup>

### **ABSTRACT**

NWB Sensors, Inc. has been developing prototype technology for measuring snow water equivalent (SWE), snow liquid water content (LWC), snow depth, and snow density by observing the changes in GNSS signals that have transmitted through the snowpack. Snomonstor<sup>TM</sup>, is a fully electronic fluidless snowpack measurement technology targeting the replacement of antifreeze filled snow-pillows in snowpack measurement. By creating a smaller, accurate, easy-to-maintain, and more economical snow measurement system, a larger number of snow measurement stations to be installed in locations where no snowpack data is currently available. This will allow water-hydrologists to have a higher spatial sampling of snow measurement permitting improved watershed forecasts and water management in order to help meet human water needs.

NWB Sensors built prototype snow sensors and over the past three winters deployed it at two USDA operated Snow Telemetry (SNOTEL) sites, and last winter at three Montana Climate Office operated Montana Mesonet sites. Data collected has been used to develop algorithms that derive snow parameters. Agreement with an adjacent snow pillow was within  $\pm 7$  mm of SWE during both accumulation and ablation (well below the error of the snow pillow itself). Derived LWC data showed daily melt-freeze cycles as expected.

LWC data has compared reasonably to published studies. However, published literature values for mapping between snow density and LWC and complex index of refraction do not necessarily match with the way in which GPS signals propagate through the snow and semi-empirical models are necessary to obtain good agreement with preexisting methods.

---

<sup>1</sup> NWB Sensors, Inc., Bozeman, MT, USA