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Cosmic-Ray Moisture Probe on North Slope of Alaska Field Campaign Report

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June 2017

ARM
CLIMATE RESEARCH FACILITY

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
COSMOS	COsmic ray Soil Moisture Observing System
DOE	U.S. Department of Energy
ha	hectare
m	meter
SWE	snow water equivalent

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1.0 Summary

In September of 2014 a wide-area snow monitoring device was installed at the U.S. Department of Energy (DOE)'s Barrow, Alaska Atmospheric Radiation Measurement (ARM) Climate Research Facility site. The device is special in that it uses measurements of cosmic-ray neutrons as a proxy for snow water equivalent (SWE) depth. A unique characteristic of the technology is that it integrates over a wide area (as much as 40 ha), in contrast to conventional ground-based technologies, which essentially give point samples. Conventional point-scale technologies are problematic in the Arctic, both because extreme weather conditions are taxing on equipment, and because point measurements can fail to accurately characterize the average SWE over a larger area, even when excellent precision is obtained.

The sensor installed in Barrow is, by far, the northernmost of a constellation of sites that makeup the U.S. COsmic ray Soil Moisture Observing System (COSMOS). The sensor is used for SWE measurements in winter and soil moisture measurements in summer. The ability of this type of sensor to operate in the Arctic had not been verified until now.

The cosmic-ray sensor was installed on a tripod located approximately 150 m south of the ARM User Facility (Figure 1), and within boundaries of land managed by the ARM Facility. The sensor consists of both "bare" and "moderated" channels, where the moderated channel is the primary output used to calculate SWE. A QDL2100 data logger with pressure sensor was located inside of the User Facility, and a Campbell CS215 temperature and humidity sensor was attached to a rail on the upper deck of the User Facility, to enable near-real-time absolute humidity corrections to the data. The cosmic-ray sensors are connected to the data logger using an armored Cat5e cable that lies on top of the tundra. Data are retrieved hourly via Iridium satellite link.

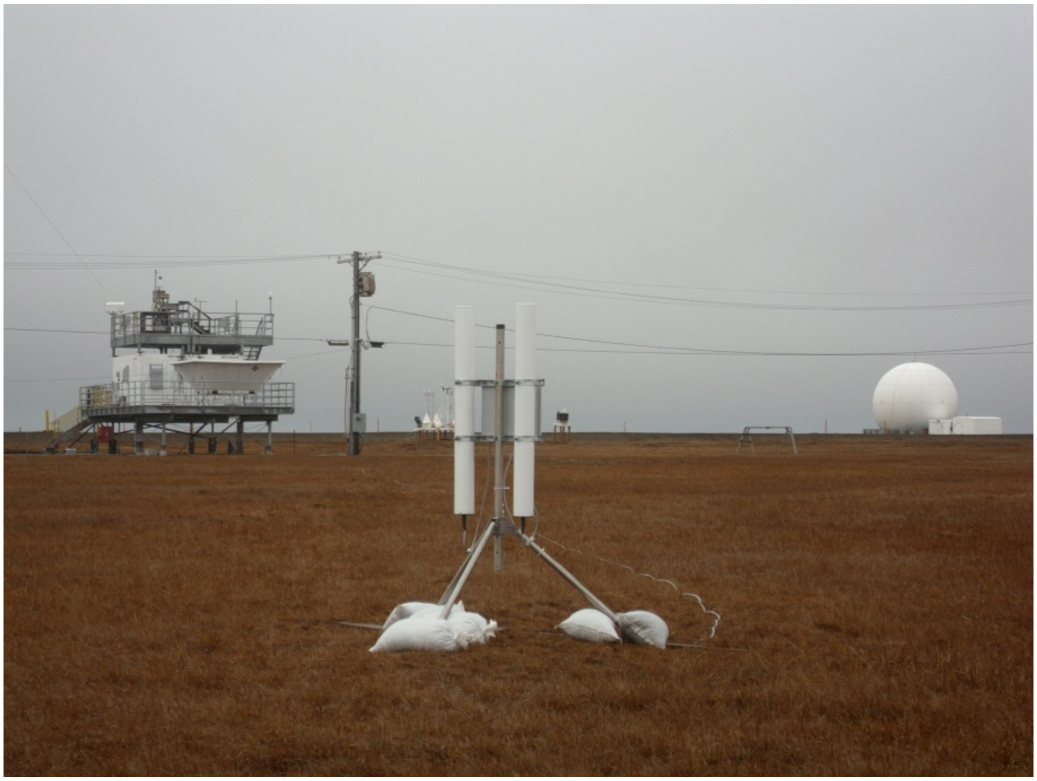

Figure 1. Cosmic-ray sensor installed during this campaign, with the ARM User Facility in the background.

2.0 Results

SWE was calculated from the cosmic-ray neutron counting rates recorded by the moderated channel. Counting rates were first corrected for variations in barometric pressure using data collected from the User Facility and for solar activity using data from the neutron monitor at Inuvik, Northwest Territory, Canada. The corrected neutron counting rates were then converted to SWE by applying a linear calibration function obtained in prior research in New Mexico.

The SWE values thus obtained are shown in Figure 2. In 2014 and 2015 the first snow events appear to have occurred in mid-September. (The first event of 2014, witnessed by the author, happened just after installing the probe on September 18, 2014). The data shown in Figure 2 run to October 20, 2016 and surprisingly there is not yet any snow cover. This anomalously slow start to winter in Barrow has been verified by local news reports.[1]

[1] https:/www.adn.com/Alaska-news/weather/2016/10/15/barrow-sets-new-record-for-latest-date-without-snow-cover/

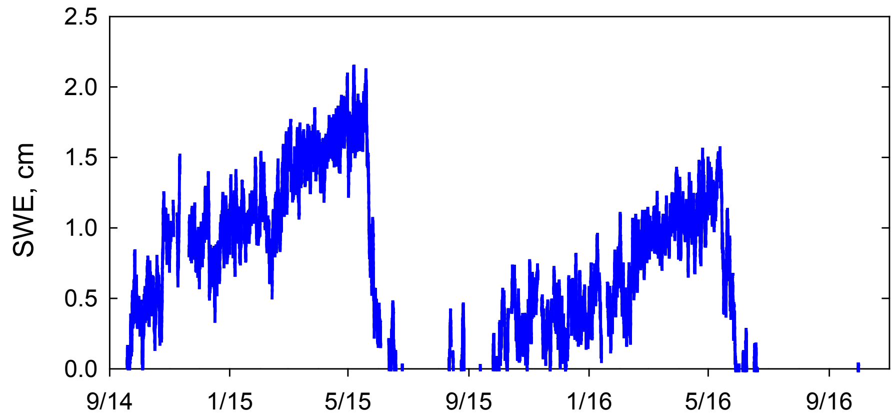

Figure 2. SWE estimated from cosmic-ray sensor at Barrow.

The corrected neutron data can also be viewed as a semi-quantitative measure of total land surface water, in which case the summer data become interesting (Figure 3). Here values above zero are interpreted as SWE, as before, and values below zero are interpreted as depletion of soil water (due to evapotranspiration or drainage) from an initial state of saturation. Here it is evident that the summer of 2016 was significantly drier than that of 2015. This could, in part, be due to lower snow pack in the 2015-16 winter. This large change in the soil moisture “baseline” could impact our SWE determinations for 2016-2017. It probably will necessitate renormalizing our counting rates each fall to the current soil moisture status. Still, the ability to observe and even quantify changes in soil water status in tundra adds an interesting new aspect to this study.

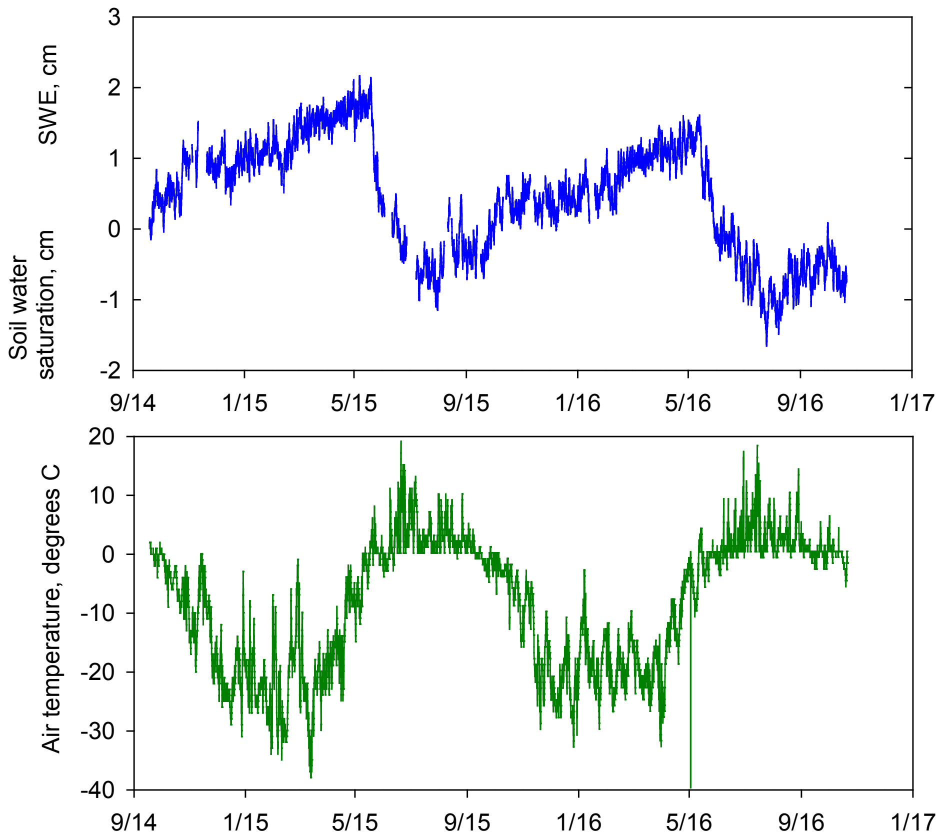

Figure 3. (A) Water availability at Barrow according to cosmic-ray sensor; (B) air temperature.

The equipment has operated almost continuously for over two years with no downtime and no maintenance. From an operations perspective, these results have exceeded expectations. Given the trends seen so far and the difficulty that would be encountered in reinstalling the equipment, it would probably be advantageous and illuminating if the equipment continued to operate.

3.0 Publications and References

Desilets, D. 2015. Arctic observations of snow water equivalent with the non-contact cosmic-ray method. AGU Fall Meeting, December, San Francisco.

Desilets, D. 2016. Cosmic rays and the cryosphere. 5th International COSMOS Workshop, August, Copenhagen.

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