Using inexpensive temperature sensors to monitor the duration and heterogeneity of snow-covered areas in complex terrain

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Abstract

Small, self-recording temperature sensors can be deployed quickly and inexpensively to monitor spatial and temporal patterns of snow accumulation and melt in complex environments. Burying these sensors slightly below the soil surface provides a record of the presence/absence of snow cover because near-surface soil temperatures only experience diurnal temperature oscillations when they are not covered by an insulating layer of snow.

I. Introduction

Variability in snow-covered area (SCA), i.e., snow patchiness, occurs at scales ranging from one meter to many kilometers, and an accurate depiction of this spatial heterogeneity of snow covered area is necessary to accurately model land surface climatic feedbacks, particularly albedo, and the magnitude and timing of snowmelt runoff [*Essery and Pomeroy,* 2004; *Giorgi and Avissar*, 1997; *Liston,* 1999; *Liston*, 2004; *Luce et al.,* 1998; *Skaugen,* 2007]. The spatial and temporal evolution of SCA is generally monitored with satellite imagery, e.g, Landsat (30-m resolution and 16-day repeat intervals) and/or MODIS (500-m resolution and daily repeat intervals), and with sparsely-located surface measurements of snow depth, snow weight, and human observations. Fractional SCA at scales smaller than these observational scales is generally parameterized with a snow-cover depletion scheme, many of which are summarized by *Essery and Pomeroy* [2004]. To provide ground truth information about the spatial extent and timing of snowcover at these sub-grid scales requires a multitude of spatially-distributed measurements that can operate at higher resolution and frequency than satellite images, including operating during cloud cover. To achieve this, instrumentation must be robust and inexpensive, be easy to construct and install in remote regions, and need infrequent site visits.

II. Temperature-sensed snow cover

Temperature sensors placed 2-20 cm beneath the soil surface provide not only an indication of soil temperatures and frozen ground but, when distributed, also provide spatial representations of the presence-absence of snow cover. *Tyler et al.* [2008] used fiber-optic distributed temperature sensing (DTS) technology to obtain basal snow temperatures at resolutions of 1 m, 10 s, and 0.1°C in both California and Idaho. They observed uniform basal snow temperatures of 0°C and highly-varying diurnal ground temperatures in snow-free areas. While fiber-optic cable costs as little as 50-cents per meter, the entire set-up, included DTS technology, costs over $30,000. Here, we present a lower-cost alternative.

Self-recording temperature sensors, such as Maxim iButtons [*Hubbart et al*., 2005] and Onset Tidbits, Pendants, and HOBOs [*Whiteman et al*., 2000], have prices ranging from approximately $30 to $100, with an accuracy of better than ±0.5 °C and an ability to record hourly data for a duration of about a year or more. Many of these sensors are waterproof and can be submerged in lakes and streams (e.g., Onset Tidbits), while others are water resistant and must be protected from corrosion if placed in contact with water for long periods of time (e.g., Maxim iButtons, Figure 1).

Soil temperature sensors were wrapped in thin plastic (Figure 1) to prevent corrosion, buried 2 to 20 cm beneath the surface (mainly for protection from rodents), and tied to a nearby tree trunk or root with a nylon cord to aid in finding the sensor again. Sensors were buried at least 0.5 m from the tree trunk to avoid monitoring the “tree well effect,” where snow immediately adjacent to the trunk melts first in the spring, due to enhanced longwave radiation. Sensor locations were identified with GPS coordinates, photographs, and drawings, and sensors were retrieved, and data downloaded, a year later.

Snow-cover insulates the ground, so snow-covered temperature sensors record a steady near-0°C temperature. The rest of the year, soil temperatures oscillate with diurnal cycles in temperature, providing a clear record of when snow is or is not present at a site (Figure 2). A transect of ground-based temperatures situated at the base of different densities of trees along the Tioga Road in Yosemite National Park indicates that snow cover lasts 11 to 19 days longer under dense clumps of trees than under isolated trees in the Sierra (Figure 2), likely due to a combination of enhanced shading from solar radiation and deeper snow drifts. Patchy, shallow snow cover resulted in damped temperature oscillations, as observed in December under the single tree in Tuolumne Meadows and Tioga Pass (Figure 2c and 2d).

Because the insulating effect of snow cover is so great, the sensors used to detect the location and duration of snow cover don’t need to be particularly precise or accurate, e.g. a flat line at 1°C through the winter could be interpreted to be snow cover over a sensor biased 1°C too warm, thus keeping costs low. These soil temperature sensors could be distributed in any configuration to test a multitude of hypotheses, ranging from the timing of snow cover in zones receiving both solid and liquid winter precipitation, to spatial patterns of snow-vegetation feedbacks, such as seedling growth and development.

III. Acknowledgements

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IV. References

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V. Figure Captions

Figure 1 iButton (Maxim DS1922L) wrapped in plastic wrap (or press-n-seal) ready to be buried in the ground below a tree,

Figure 2 Hourly temperature data from sensors deployed 5 cm below the soil surface at (a) Hodgedon Meadow, 1500 m elevation, (b) Porcupine Flat, 2500 m, (c) Tuolumne Meadows, 2600 m, and (d) Tioga Pass, 3000 m, below a single tree and a dense group of trees for water year 2005-2006. Note: The temperature record from the single tree at each site has been shifted up by 20°C to more clearly illustrate when the diurnal temperature fluctuations start and stop at each location.

VI. Figures

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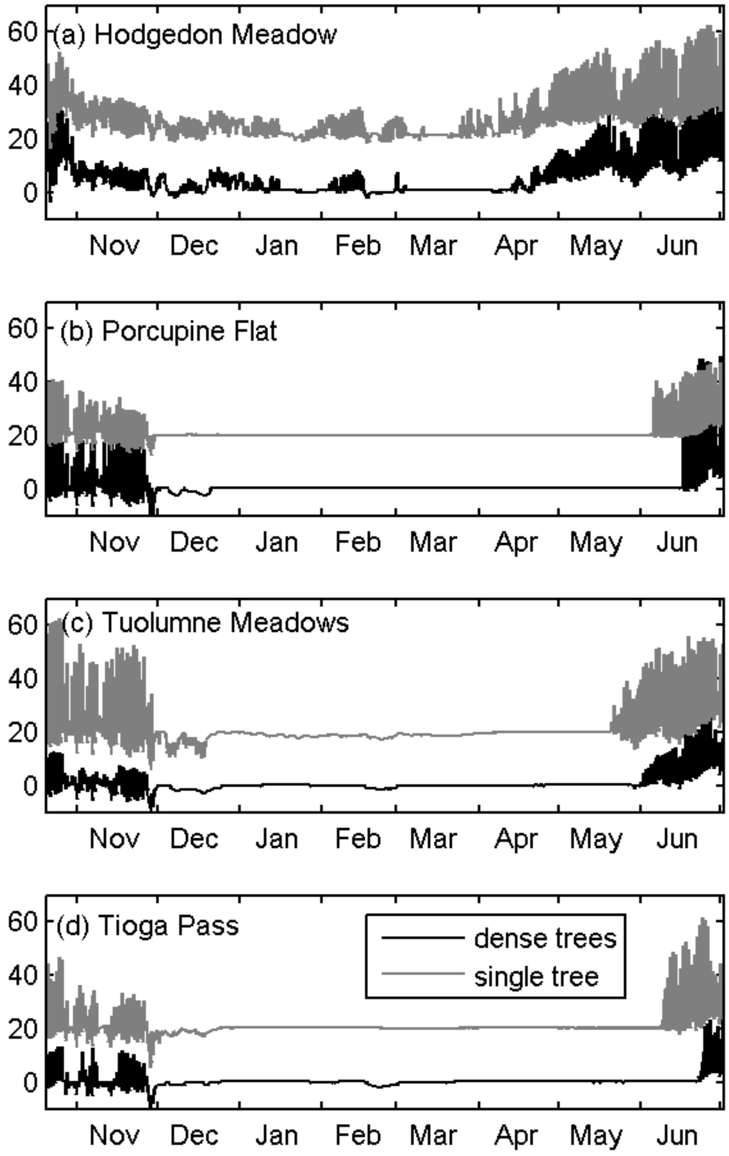

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