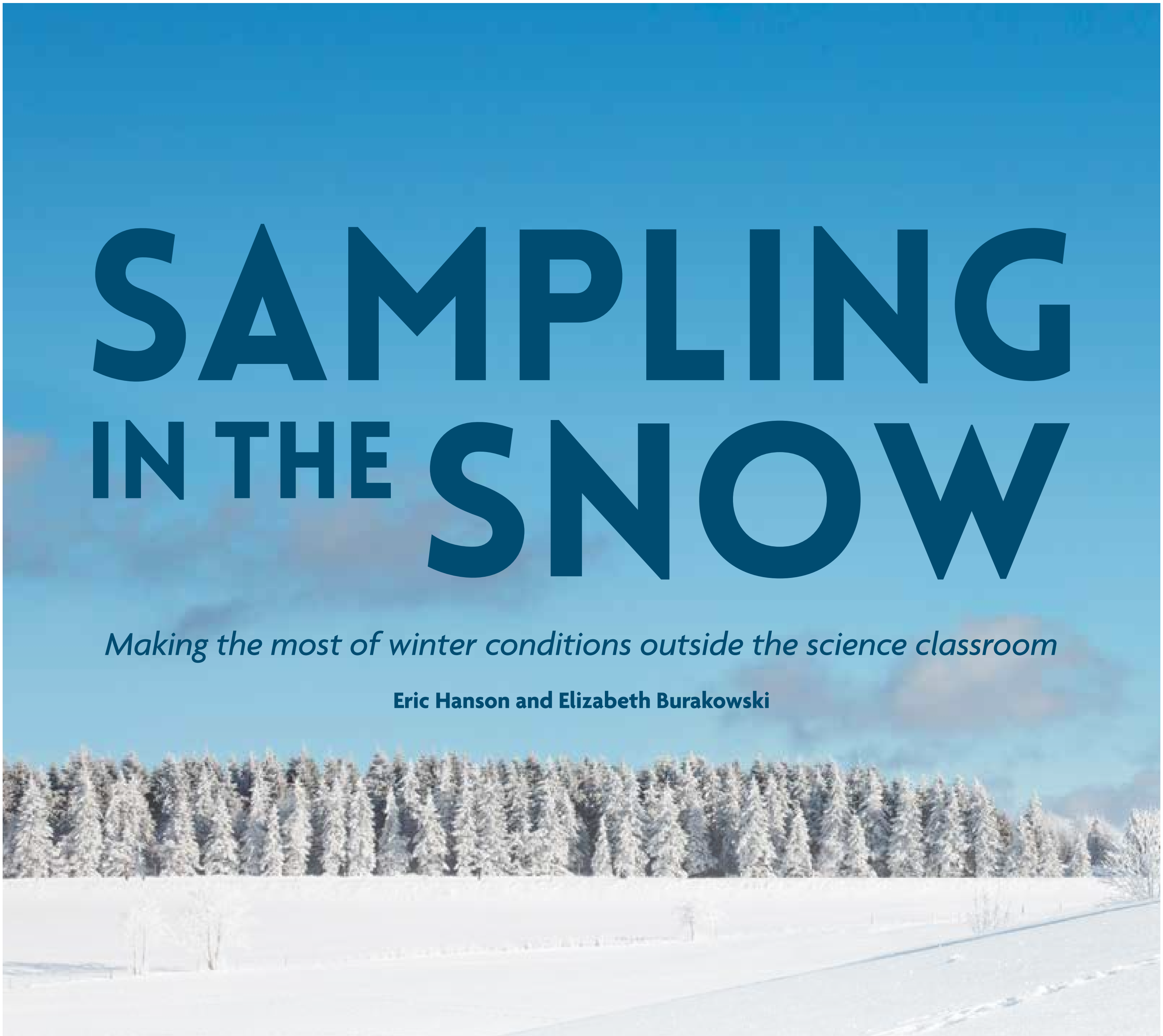


SAMPLING IN THE SNOW

Making the most of winter conditions outside the science classroom

Eric Hanson and Elizabeth Burakowski

For much of the northern United States, the months surrounding the winter solstice are a time of increased darkness, low temperatures, and frozen landscapes. Each year, the ubiquitous white ice crystals that blanket regions of the north go uninvestigated.

Instead of hunkering down indoors with their classes, however, teachers can take advantage of a plethora of learning opportunities outdoors. We (a high school science teacher and a snow scientist) developed multiple activities to engage students in the scientific process of collecting, analyzing, and interpreting snow data. This article describes two outdoor activities in which students learn about the insulative properties of snow cover and participate in a citizen-science network to collect scientific data on snow reflectivity *(albedo)*.

Addressing the standards

The Thermal Index of Snow and Measuring Snow Reflectivity in a Citizen Science Network investigations integrate scientific practices, crosscutting concepts, and disciplinary core ideas as described in the *Next Generation Science Standards* (NGSS Lead States 2013).

Students engage in the scientific practice of Analyzing and Interpreting Data and explore the crosscutting concepts of Patterns and Cause and Effect. Disciplinary core ideas addressed include ESS2.C: the roles of water in Earth's surface processes and ESS2.D: weather and climate. The creation and analysis of bar graphs and *xy* scatterplots also directly address the *Common Core State Standards* (NGAC and CCSSO 2010) as well (see "On the web").

Activity I: Calculating the thermal index of snow

Introduction

Snow is a good thermal insulator for the plants and animals that live in snow-covered regions (Marchand 1982). Shrews, voles, moles, mice, and ruffed grouse, a common bird species in northern latitudes, rely on snow for protection from predators and insulation from the cold. Snow also insulates and protects dormant plants and shrubs (e.g., wild blueberries) from mid-winter frost that would otherwise damage stems and root rhizomes when temperatures are lower than -25°C (Barney 1999).

The lower the thermal conductivity of a material, the slower heat transfers through it and the greater its insulative value or thermal index (Marchand 1982). Snow is an excellent thermal insulator because of its relatively low thermal conductivity value. Snow depth and density drive variations in snow conductivity, so snow's thermal index varies. In general, deeper snowpacks provide better insulation than shallower ones; however, snowpack density is another important factor. High-density snowpacks have more snow crystals per unit volume, promoting contact between individual ice grains and increasing the snowpack's ability to transfer heat energy, thus decreasing its insulative value.

Using data gathered from snow sampling activities, students can assess and interpret the insulative quality of snowpack and predict temperature fluctuation at the ground-snow interface (Marchand 1982). This activity spans a few class periods and is a great introduction to the second activity that investigates albedo. *Life in the Cold: An Introduction to Winter Ecology* (Marchand 1996) is an excellent reference and invaluable resource for teachers investigating the snow.

Snow kits

Building snow kits is relatively simple and inexpensive. Each student group will need:

- a clipboard,
- data sheets,
- 0.6 m (2 ft.) sections of 5 cm (2 in.) PVC pipe with end caps,
- a high-precision scale (to 0.001 kg), and
- a measuring stick.

The kit costs about $35, not counting the scale, which many school labs already have. (For a complete materials list, see "On the web").

Collecting data

Students love excuses to play in the snow and learn about it. It's easy to sample and provides a great opportunity for hands-on, outdoor inquiry (Figure 1). Equipped with their snow sampling kits and data sheets, students venture outdoors to measure snow depth and density and report snow surface conditions (Figure 2). Students should select a wide variety of sample sites with regard to exposure, aspect, and tree cover to provide for a greater range of data values. Sampling in numerous sites of varying conditions leads to richer discussion and interpretation of the data. (Note: More information on the sampling methodology is available online [see "On the web"].)

(**Safety note:** Successful snow data collection is largely reliant on appropriately dressed, well-prepared student scientists. Teachers should use their discretion with respect to temperature, environmental conditions, and level of student preparedness before taking students outdoors. Providing less-prepared students with access to additional clothing and footwear can help ensure a safe and successful outdoor lab experience. Before embarking on field data collection, teachers can demonstrate appropriate sampling techniques indoors to improve the quality of students' collected data.)

FIGURE 1

Students collect snow albedo, depth, temperature, and density data on campus.

FIGURE 2

Students work together to record data as they collect snow depth and density measurements.

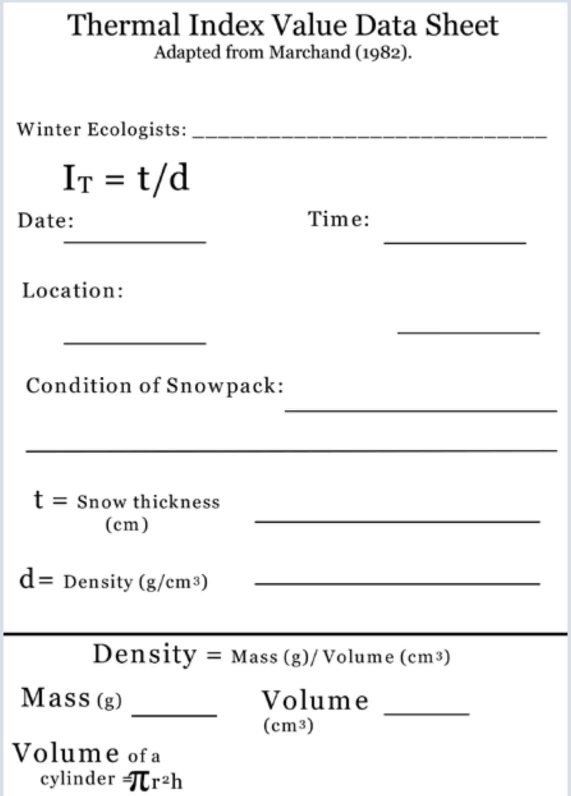
Graphing, analysis, and interpretation

Student groups return to the classroom with their snow data and calculate the thermal index (I_t) of snow at each sample site using the simplified formula $(I_t) = t/d$, where t is snow thickness (cm), and d is snow density (g/cm^3) (Figure 3; Marchand 1982). Groups upload each sample site's data to a class spreadsheet on Google Drive to facilitate further data analysis and interpretation (see "On the web").

Each student group then creates a bar graph to compare individual and mean thermal index values at various sampling sites (Figure 4). These graphs allow students to see how their individual site data vary from the class average and allow them to perform significance testing. This variability provides a great opportunity to discuss sampling error and the benefits of having numerous measurements from the same sample site.

FIGURE 3

Thermal index value data sheet.


Thermal Index Value Data Sheet
Adapted from Marchand (1982).

Winter Ecologists: ______________________________

$I_T = t/d$

Date: ____________ Time: ____________

Location: ____________ ____________

Condition of Snowpack: ______________________
____

t = Snow thickness (cm) ______________________

d = Density (g/cm³) ______________________

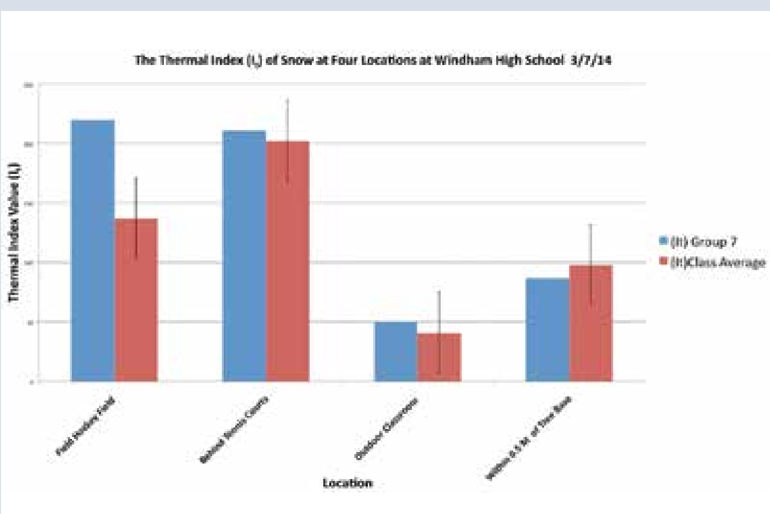
Density = Mass (g)/ Volume (cm³)

Mass (g) ______ Volume (cm³) ______

Volume of a cylinder = $\pi r^2 h$

FIGURE 4

Students create a group bar chart comparing individual and mean thermal index values at various sampling sites.



Students also discuss the thermal index values that they calculated at each of the sampling sites. Using these I_t values, they can describe and model temperature variation occurring at the ground-snow interface and determine whether the snow is providing adequate insulation for the plants and animals living below its surface. (**Note:** Formative and summative assessment exemplars are available online [see "On the web"].)

Activity II: Measuring snow reflectivity (albedo) in a citizen science network

Introducing students to snow albedo

In addition to its insulative properties, snow plays an important role in surface climate because it helps to regulate surface energy exchange at the snowpack-air interface. Albedo is a measure of surface reflectivity and is calculated as the ratio of outgoing (i.e., reflected) solar radiation (watts per square meter) to incoming solar radiation:

albedo = outgoing (W/m^2)/incoming (W/m^2)

To illustrate the effect of albedo on surface climate, teachers can ask students what color t-shirt they would wear on a hot summer day. Most will choose white because it reflects the Sun's energy (high albedo). Similarly, snow is one of nature's best reflectors of the Sun's energy, playing an important role in local and global climate patterns. A blanket of fresh snow may have an albedo of 0.9, reflecting up to 90% of incoming solar energy (Barlage et al. 2005). Snow-free surfaces (albedo 0.2–0.3) reflect only 20–30% of the Sun's energy. Future climate projections indicate that snowy regions of the United States (e.g., the Northeast) may lose up to half of their snow-covered days by 2100 (Frumhoff et al. 2007), resulting in much warmer winter temperatures as surface albedo decreases.

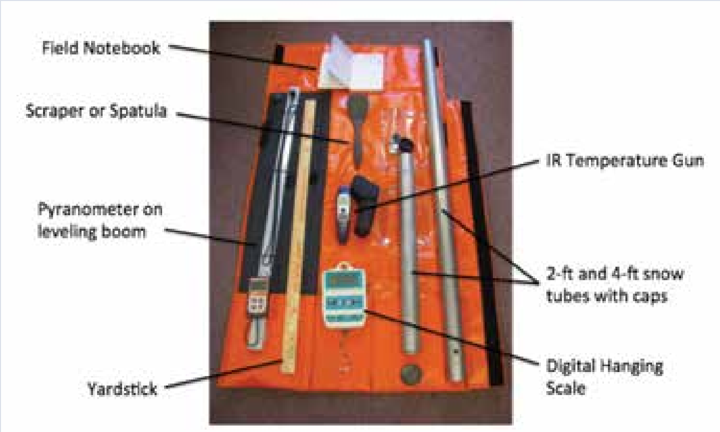
Teachers can expand upon albedo's effect on global climate using the supplemental materials online (see "On the web"). This lesson includes two short videos (see "On the web") that provide a great starting point for student-led discussions on climate change and easily transition into discussions about the significance of snow cover and sea ice on global climate (ESS2.C The roles of water in Earth's surface processes and ESS2.D weather and climate; NGSS Lead States 2013).

Participating in a citizen science network

The National Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network started in Colorado in 1998 as a com-

FIGURE 5

The CoCoRAHS Albedo snow sampling kit is provided on loan to participating classrooms.



munity-based network of precipitation observer volunteers. Today, this organization is the single largest provider of daily precipitation observations in the United States. In 2011, a team of climate scientists established a pilot project of the National CoCoRAHS Network to collect detailed snow and albedo data to investigate snow's role in local and global climate patterns.

The CoCoRAHS Albedo Pilot Project (see "On the web") embraces the network's mission "to use low-cost measurement tools, provide training and education, and utilize an interactive website" to collect high-quality snow albedo, depth, and density data for research and education applications. Students can participate as volunteers to contribute to climate research and directly engage in the scientific process. Student access to the national database of snow measurements directly connects with *A Framework for K–12 Science Education* and the *Next Generation Science Standards*. It offers students "opportunities to analyze large data sets and identify correlations" and "such data sets extend the range of students' experiences and help to illustrate this important practice of analyzing and interpreting data" (NRC 2012, p. 62). The snow data contribute to a much-needed body of observational data against which research scientists validate climate and land-surface models (Burakowski 2013; Burakowski et al. 2013).

When teachers commit their class to daily winter snow depth, density, and albedo sampling (supplemental materials available online; see "On the web") the CoCoRAHS Albedo program provides an $850 snow sampling kit (Figure 5), hands-on training, and lesson plans to instruct students on the importance of snow in the Earth's climate system. Classrooms contribute snow density, depth, and albedo data from their field site to an online, publically accessible database that contains daily data for over 20 sampling stations.

Graphing, analysis, and interpretation

Regardless of whether classes participate in the CoCORAHS albedo snow sampling program, teachers and their students can leverage the graphing, analysis, and interpretation opportunities available in the publicly accessible CoCoRaHS Albedo data set (see "On the web"). Students can select one of the more than 20 stations in the data set to investigate and plot a time series of snow density and albedo (Figure 6a). By analyzing their graphs, students can develop hypotheses about the relationship between albedo and snow density. Several factors—including the increase in grain size as a snow pack compacts and melts, trapping more incoming solar radiation—explain the inverse relationship between snow albedo and snow density. (Fresh snow has small grains with very few bonds connecting the snow grains together. As the snowpack ages, melts, and compacts, bonds sinter [partly fuse] small grains together to form larger grains.) The increase in snow density also typically coincides with a concentration of impurities such as dirt, dust, and debris in the snowpack, darkening the snow and lowering albedo as the snowpack ages. Students can check their hypotheses by plotting snow density and albedo in an *x*-*y* scatterplot with snow density on the *x*-axis and albedo on the *y*-axis and analyzing the linear regression coefficient (Figure 6b). Detailed instructions for plotting the double *y*-axis time series and the *x*-*y* scatterplot, discussion questions, and ideas on assessment are outlined in the supplemental materials (see "On the web").

Conclusion

Throughout these activities, students describe their outdoor learning experience as "more interesting," "authentic," and "hands-on" than indoor classes. Students also emphasize that learning outdoors is essential in their understanding of underlying content and concepts because they "learn through actual experience." Sampling snow to integrate the practice of analyzing and interpreting data dovetails with *NGSS* disciplinary core ideas and is an excellent example of how "the actual doing of science… can also pique students' curiosity, capture their interest, and motivate their continued study" (NRC 2012, p. 42). ■

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FIGURE 6A

Students plot a double *y*-axis time series of snow density and albedo to investigate relationships between the two variables.

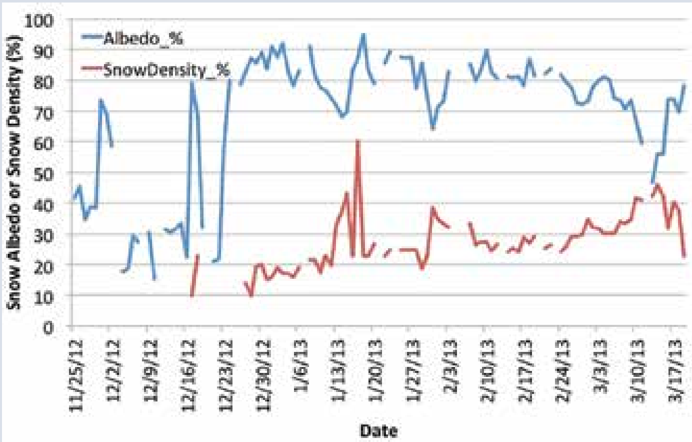
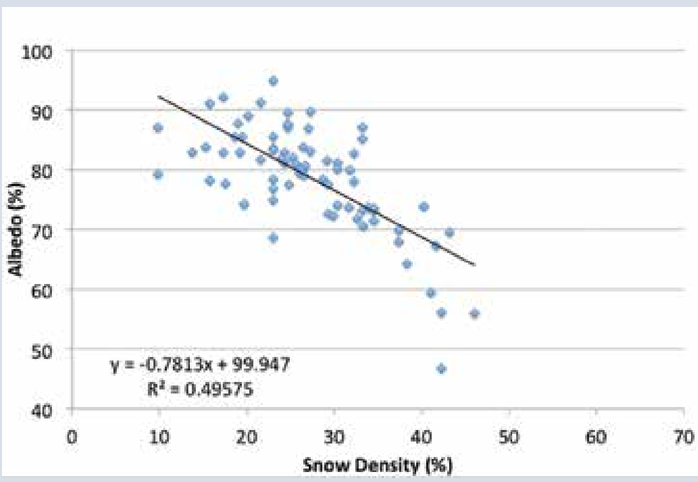


FIGURE 6B

Students plot an *x*-*y* scatterplot to investigate the inverse relationship between snow density and albedo.



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On the web

Climate change videos: *http://svs.gsfc.nasa.gov*

CoCoRAHS Albedo Pilot Project: *www.cocorahs-albedo.org*

Connections to the *Next Generation Science Standards* and *Common Core State Standards: www.nsta.org/highschool/connections.aspx*

Measuring snow reflectivity (albedo) in a citizen science network: *www.nsta.org/highschool/connections.aspx*

The Thermal Index of Snow supplemental materials: *www.nsta.org/highschool/connections.aspx*

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