Snow cover

Across the middle and high latitudes of the Northern Hemisphere, the impact of snow cover on humans and the environment is considerable. Snow lying on the ground or on ice influences hydrologic, biologic, chemical, and geologic processes. Snow exerts an impact on activities as diverse as engineering, agriculture, travel, recreation, commerce, and safety. Observational and modeling studies also show snow cover to have an influential role within the global heat budget, chiefly through the snow's effect of increasing surface reflectivity. Global models of human-induced climate change suggest enhanced warming in regions where snow cover is currently seasonal. For this reason, snow cover has been suggested as a useful index for detecting and monitoring such change.

Monitoring. Accurate information on snow cover is essential for understanding details of climate dynamics and climate change. It is also critical that snow observations be as lengthy and geographically extensive as possible. Snow data are gathered from ground sites, aircraft, or satellite platforms. Advantages and liabilities of extracting data from each of these sources are related to their accuracy and coverage. Observations of snow cover from aircraft are limited in both space and time, and they tend to be for specific investigations.

Station observations. Surface-based snow cover data are gathered mainly from observing stations on a once-per-day basis. The general practice is

Robinson, D.A. (1993)
Snow Cover. *Yearbook of Science and Technology: 1994.* McGraw-Hill, Inc., NY, 340-342.

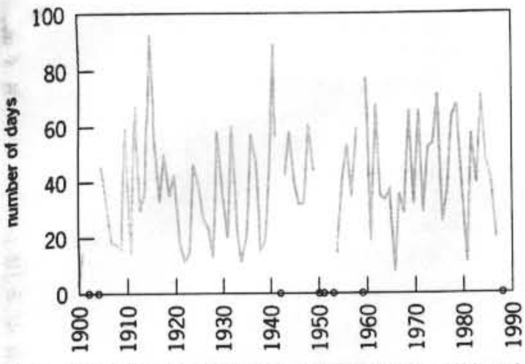

Fig. 1. Days with 7.5 cm (3 in.) or less of snow cover at Fairbury, Nebraska, during the winters (September–May) of 1899/1900 through 1986/1987. Missing years are plotted along the bottom axis. No year with data had a complete absence of snow cover days.

to record the average depth of snow lying on level open ground having a natural surface cover. Current station observations of snow cover are of a sufficient density for climatological study in the lower elevations of the middle latitudes of the Northern Hemisphere. Elsewhere, data are spotty at best.

Efforts are in progress to organize, verify, and analyze long-term station observations of snow cover. **Figure 1** is an example showing the number of days with 7.5 cm (3 in.) or less of snow on the ground between September and the following May at Fairbury, Nebraska, for the winters of 1899/1900 through 1986/1987. Only seven years during this period had insufficient data that prohibited a seasonal summation. The remaining years show considerable variability in duration of the snow cover. The 1920s and 1930s had a number of years with infrequent cover, while years in the late 1960s to middle 1980s frequently had extended cover.

Visible satellite observations. Regional and continental snow extent is gleaned from visible satellite observations of solar radiation reflected off the Earth's surface, and from microwave radiation emitted by the surface. The visible approach has the benefits of being directly interpretable by the human eye and having global imagery with a resolution of one to several kilometers available on a daily basis. Disadvantages of a visible approach include the inability to monitor surface conditions where clouds are present and where dense vegetation precludes reliable observations of the underlying surface. Low solar illumination is not a significant liability, since most high-latitude regions are snow-covered before the diminution of light and remain covered until spring.

For the past several decades the U.S. National Oceanic and Atmospheric Administration (NOAA) has mapped snow cover over Northern Hemisphere lands on a weekly basis. NOAA charts are based on a visual interpretation of photographic copies of visible imagery by trained meteorologists. Accuracy in charting is such that this product is considered suitable for continental-scale climate studies.

Mean snow extent. An analysis of the NOAA visible data since 1972 finds that, on average, some 46.5×10^6 km^2 (17.9×10^6 mi^2) of Eurasia and North America are covered with snow in January, the snowiest month of the year. February is a close second with an average of 46.0×10^6 km^2 (17.8×10^6 mi^2). August has the least cover, averaging 3.9×10^6 km^2 (1.5×10^6 mi^2), most of this being snow on top of the Greenland ice sheet. The annual mean cover is 25.5×10^6 km^2 (9.8×10^6 mi^2). The mean position of the North American snow line for four months of the year is shown in **Figure 2**. The snow season over North America and Eurasia begins in September, when snow cover becomes established over the high Arctic and on lofty mountain peaks. By January, snow over lower elevations extends southward to roughly the 40th to 45th parallels, and dips farther toward the Equator over mountainous regions. In April, the snow at the low elevations retreats across the United States–Canadian border and to about 60°N in Scandinavia and western Russia and 55°N in Siberia. By June, snow lies close to the Arctic coast and in the high mountains; and in mid-July, all lands and even the sea ice over the Arctic Ocean are essentially snow-free. Only the Greenland ice sheet maintains a year-round cover of snow in the Northern Hemisphere. Snow cover is also a permanent feature of the Antarctic ice sheet, and it occurs seasonally on the sea ice surrounding the Antarctic continent, as well as over some of the mountains and highlands of South America, Australia, and Africa.

Snow cover variability. NOAA charts indicate a great deal of the year-to-year variability in snow extent over Northern Hemisphere lands. The snowiest year of the past two decades was 1978, with a mean cover of

Fig. 2. Boundaries separating snow-covered from snow-free ground over North America in October (A), January (B), April (C), and June (D). Boundaries are defined as isolines denoting a 50% frequency of cover.

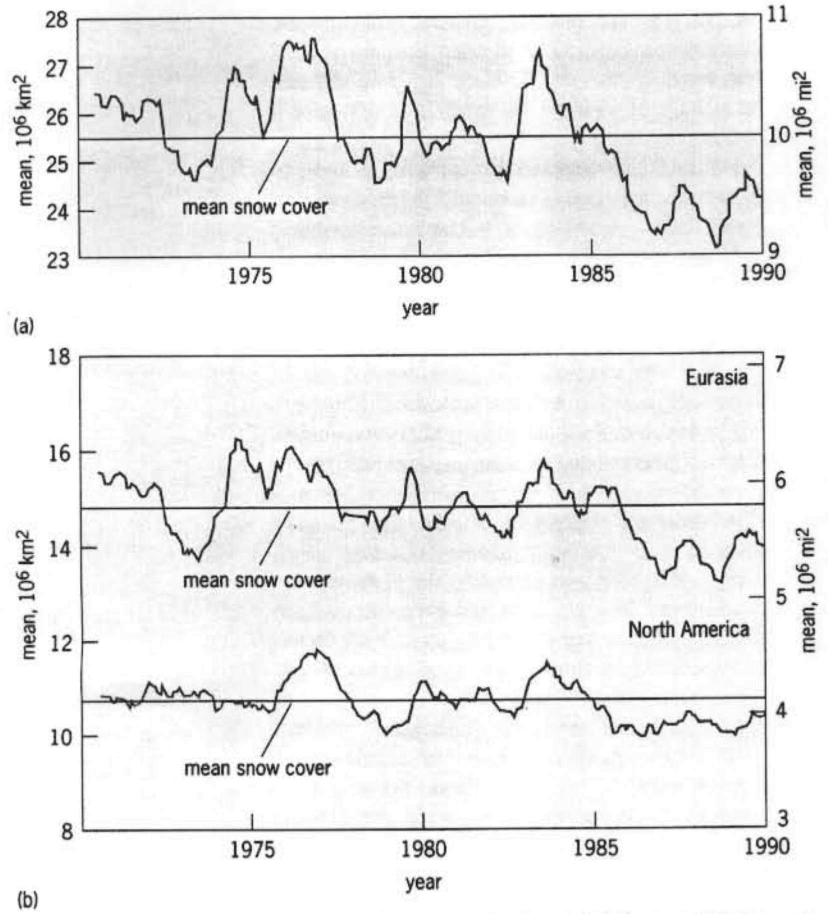

Fig. 3. Twelve-month running means of snow cover for the period January 1972 through May 1992. (*a*) Over Northern Hemisphere lands. (*b*) Over Eurasia and North America (including Greenland).

27.4×10^6 km^2 (10.8×10^6 mi^2); 1990 was the least snowy at 23.2×10^6 km^2 (9.0×10^6 mi^2). Twelve-month running means of continental snow extent best illustrate the periods of above-normal cover that occurred in the late 1970s and mid-1980s (**Fig. 3**). Intervals with lower snow extents include the mid-1970s and early 1980s; however, neither interval approaches the deficit of snow cover observed in recent years. Of the 58 months between August 1987 and May 1992, only five had above-normal snow cover. Spring cover showed pronounced deficits during 1988–1992 in Eurasia and during 1987–1992 in North America; snow extents in these spring seasons were at or below lows established prior to this period. During the same interval, both continents had low seasonal cover in the fall and summer, although frequently neither continent was at or approached record low levels. Winter cover was close to average during 1987–1992.

Microwave satellite observations. Microwave radiation penetrates winter clouds, permitting an unobstructed signal from the Earth's surface to reach a satellite. The discrimination of snow cover is possible mainly because of differences in emissivity between snow-covered and snow-free surfaces. Estimates of the spatial extent as well as the depth or water equivalent of the snowpack are made by using multiple-channel microwave data. Spatial resolution is on the order of several tens of kilometers, making a detailed delineation of snow extent difficult, particularly where snow is patchy. It is also difficult to identify shallow or wet snow by using microwaves, and recognition of snow is a problem where vegetation masks the surface. Microwave-derived snow data are available since the late 1970s, although the data are still considered to be experimental in nature. The lack of sufficient ground truth data (data gathered at the surface) on snow depth makes an adequate assessment of the reliability of such microwave estimates uncertain. The focus of research into the microwave monitoring of snow cover remains on the extent of snow. Comparing a hemispheric time series derived from microwave data with NOAA visible observations suggests that microwave estimates of snow extent are between 80 and 90% of the more reliable visible areas in winter and spring and at times as much as 50% lower than visible values in the summer and fall.

Prospects. The critical role that snow cover plays in the global heat budget and the expected impacts of snow feedbacks in human-induced climate change support the continued diligent monitoring of snow cover over continents and sea ice. With the availability and better understanding of data from a variety of satellite and ground sources, and the ability to integrate and examine these data by using geographic information techniques, more accurate and extensive knowledge of snow cover across the globe is within reach. This information, along with expanded retrospective analyses using historical station data, is solidifying the position of snow as one of the key indicators of future change in the climate system.

For background information *SEE CLIMATIC CHANGE; SNOW; SNOW LINE; SNOW SURVEYING* in the McGraw-Hill Encyclopedia of Science & Technology.

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