NORTHERN HEMISPHERE SNOW COVER: RECENT VARIATIONS IN HISTORIC PERSPECTIVE

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INTRODUCTION

Snow covers approximately 46 million square kilometers of northern hemisphere lands during winter, yet decreases to less than 4 million km^2 (much of this over Greenland) during summer. Given the important role of snow cover in the radiative and hydrologic budgets at the earth's surface, it is crucial that accurate information on this highly variable component of the climate system be available. Here, we provide an update of snow coverage over northern hemisphere lands between 1972 and the present based on analyses of the weekly NOAA satellite-derived snow product. These results are then compared regionally with station observations over the United States Great Plains which extend back to 1910.

DATA

NOAA snow charts: These charts are produced by a visual inspection of visible satellite imagery by trained observers. Charts have been produced in a consistent manner using approximately one kilometer resolution imagery since 1972. Inconsistencies in the demarcation of land versus ocean grid cells used in chart digitization have been identified and corrected, and a routine to calculate monthly snow extents from the weekly charts has been developed (Robinson 1993a). The latter employs a weighting scheme to account for charts covering parts of two months.

Great Plains station observations: Daily observations of snow depth over the northern and central Great Plains are taken from the Historical Daily Climate Dataset (Robinson 1993b). The Plains study region includes North and South Dakota, Nebraska, Kansas, western Minnesota, Iowa and Missouri, and eastern Montana, Wyoming and Colorado. Some 230 stations are available, 44% with records back to 1910, and 66% back to 1920. Data run through 1988. Approximately 18% of the data are missing at an average station, with a range from 2 to 62%. Approximately 15% of the missing data (or data flagged as suspicious from a quality control interrogation) are filled (replaced) using statistically-derived algorithms (Hughes and Robinson 1993). To compensate for inhomogeneities in the spatial distribution and length of record of stations, the data are gridded using a least squares distance weighting routine. Grid size is 9000 km^2 (1° x 1° at 43°N).

NORTHERN HEMISPHERE SNOW COVER: 1972-1993

Median values of snow extent over northern hemisphere lands exceed 40 million km^2 from December to March. From April to June snow cover declines from 31.4 to 11.4 million km^2. July to September snow cover runs between 3.7 and 5.6 million km^2, 2.1 million km^2 of this covering Greenland. Snow cover increases rapidly in fall, rising to 17.5 million km^2 in October and to 32.8 million km^2 in November. Standard deviations of monthly means range from 1.0 (Aug) to 2.9 million km^2 (Oct).

Mean (and median) annual northern hemisphere snow cover is 25.3 million km^2, 14.7 million km^2 lying over Eurasia and 10.6 million km^2 over North America (including Greenland). The variability of snow cover over the Northern Hemisphere between January 1972 and September 1993 is expressed through anomalies of individual months and twelve month running means in Figure 1. Periods of above average snow extent occurred in the early and late 1970s and the mid 1980s. Somewhat below normal coverage was observed in the mid 1970s and early 1980s. However, it is since the late 1980s that the longest interval of subnormal snow cover in the past two decades has been observed. It is not surprising that running means have been below normal given the paucity of months with above normal coverage during this period.

Robinson, D.A., A. Frei, M.G. Hughes & J.J. Wright (1994)
Northern Hemisphere snow cover: recent variations in historic perspective.
Proceedings of the 18th Annual Climate Diagnostics Workshop, Boulder, CO, NOAA, 248-251.

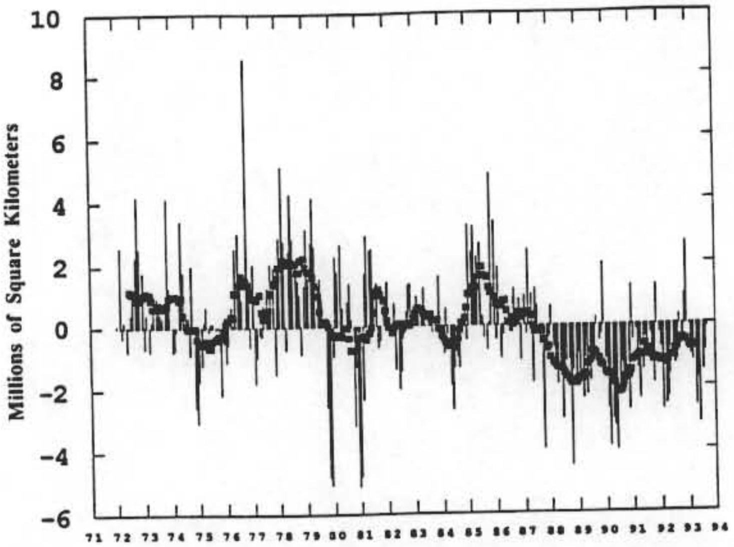

Fig. 1. Anomalies of monthly snow cover extent over northern hemisphere lands (including Greenland) between Jan 1972 and Sep 1993. Also shown are twelve-month running anomalies of hemispheric snow extent, plotted on the seventh month of a given interval.

Seasonal plots of hemispheric snow extent (Fig. 2) show the below normal snow cover of the past six years to be most pronounced in spring. Cover has been close to average in three of the past six falls and below average in the others, and close to normal in winter. Summer coverage, while below normal in recent years, is generally not extensive. A time-longitude plot of mid spring (Apr) to early summer (Jun) snow anomalies illustrates spatial relationships of snow cover over both continents (Fig. 3). Standardized snow anomalies are calculated in 5° longitudinal increments for all swaths with at least a 40° latitudinal coverage of land. A general hemisphere-wide signal is seen during the recent spring snow deficit as well as during the late 1970s to early 1980s maximum. Deficits over Eurasia primarily account for the occasional lower hemispheric values in the early and mid 1970s. Subnormal values over North America are more pronounced than in Eurasia during the first half of the 1980s. In Eurasia, meridional variations of spring snow anomalies are evident in the early and mid 1970s and the mid 1980s. Longitudinal differences over North America tend not to be as striking as over Eurasia. It is also interesting to note that in a general sense since the late 1970s, shifts in spring anomaly patterns appear first over North America, followed a year or so later in Eurasia.

GREAT PLAINS SNOW COVER: 1910-1993

Snow cover has exhibited considerable year-to-year fluctuations in duration over the northern and central Plains this century (Fig. 4). At no time was this more evident than in the late 1970s and early 1980s; three fold variations in annual snow cover duration occurred during this interval. Decadal to multi-decadal tendencies in snow cover duration are also apparent. The ground was snow covered less frequent during the first half of the period than in the past 40 years, particularly in the mid 1920s to mid 1930s. The 1970s to mid 1980s was a period of generally extensive cover. Following six low years from 1987 to 1992, the winter of 1993 stood out as one of the snowiest this century.

Durations for the past five years are based on an analysis of data from the NOAA snow charts, as data from the HDCD end in 1988. Justification for merging the station and satellite records is provided by the results of a comparative study covering 1972-1988, when data from both sources are available. Satellite durations are on average three days greater than station results, most likely due to the recognition of snow cover of less than 2.54 cm in visible imagery over this thinly vegetated region. The satellite-derived values in Fig. 4 are adjusted by three days to account for this difference.

DISCUSSION

The lengthy regional analysis suggests that care must be exercised when evaluating the significance of year-to-year, and especially multi-year, variations in snow cover derived from satellite or station

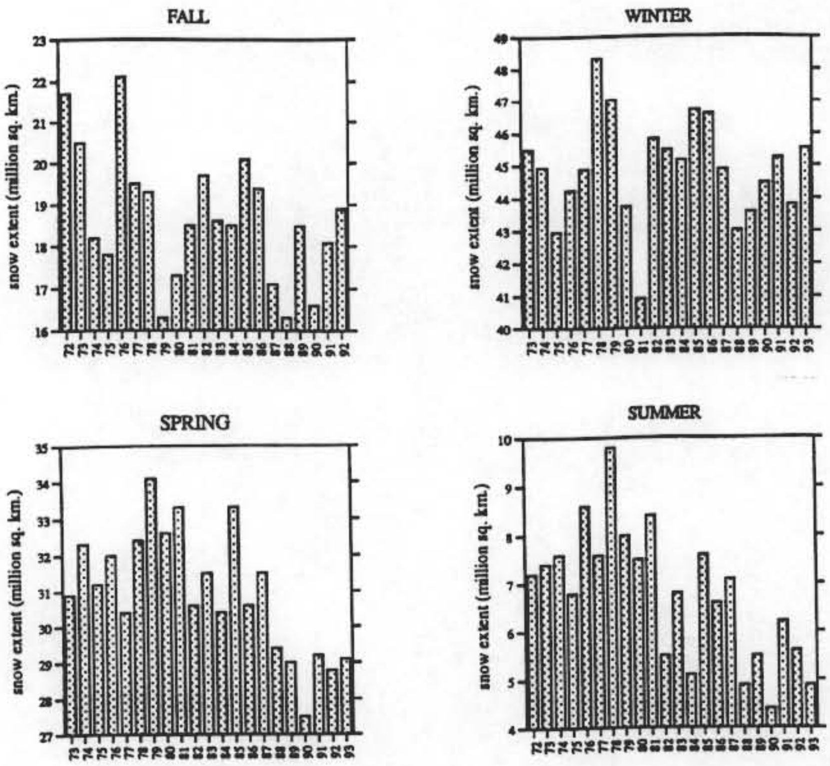

Fig. 2. Seasonal snow cover extent over northern hemisphere lands (including Greenland) between spring (Mar-May) 1972 and summer (Jun-Aug) 1993. The winter (Dec-Feb) is plotted using the year in which January falls.

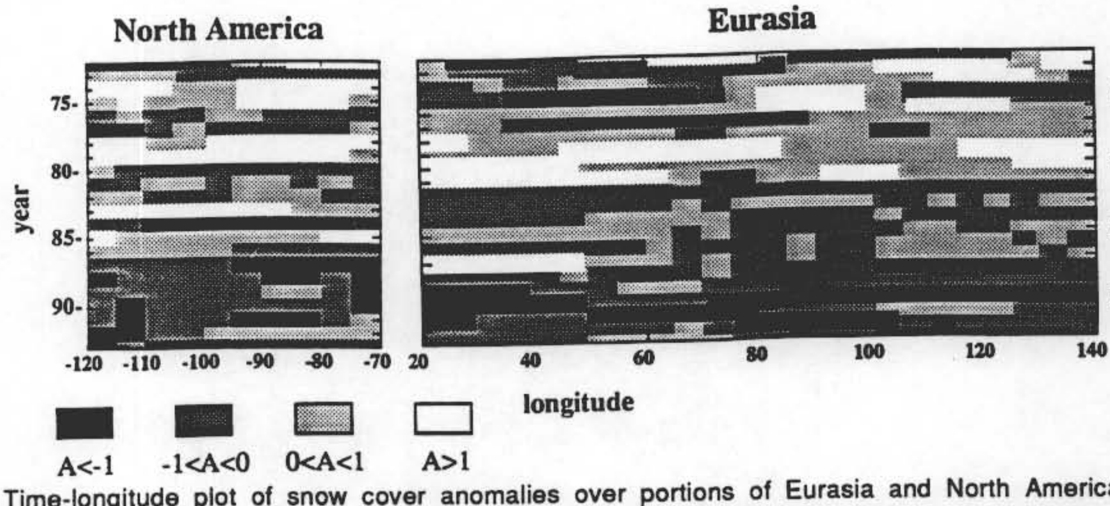

Fig. 3. Time-longitude plot of snow cover anomalies over portions of Eurasia and North America for the mid spring (Apr) to early summer (Jun) 1972 through 1993. Standardized anomalies (A) are calculated by subtracting the seasonal mean from a given season's area and dividing this value by the seasonal standard deviation.

analyses with regard to climate change. For instance, while snow durations over the Great Plains during the six years from 1987 to 1992 were low, particularly in comparison with the previous decade, they were far from unprecedented. In fact, coverage during this interval was quite typical of conditions experienced in the Plains during much of the first half of this century.

Another outcome of this investigation is the confidence that may be ascribed to both satellite and

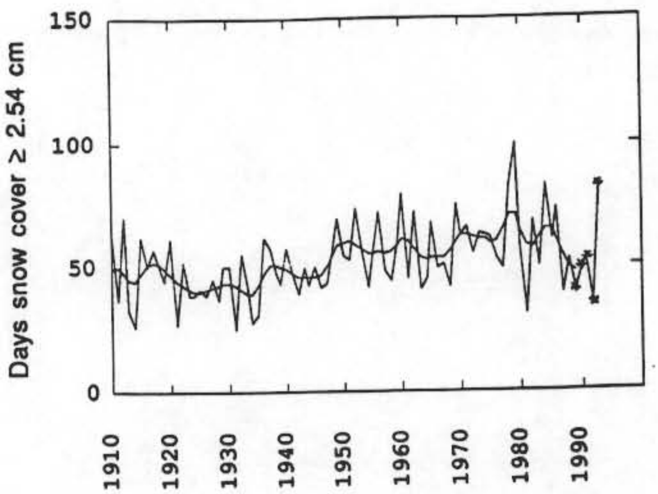

Fig. 4. Number of days in which an average grid cell over the Great Plains study region was covered with ≥ 2.54 cm of snow between the snow seasons of 1909/10 and 1992/93. Values are derived from station observations, with the exception of the starred values which are calculated using satellite data. The results are also plotted using a nine-point binomial filter.

station snow charting techniques. That both agree so closely suggests that each approach accurately depicts regional snow conditions over the Great Plains. However, it is important to note that the accuracy of either technique will vary over other terrain and biomes.

CONCLUSION

Hemispheric snow extent remains close to a two-decade low. Despite a suggestion at the end of 1992 that the below normal conditions which had persisted since 1988 might be on the way out, by spring 1993 snow cover was once again well below normal. Then again, as suggested in the regional analysis, it is uncertain whether recent cover is below normal. Rather, snow coverage during a large portion of the previous 15 years may have been above long-term means. Lengthy regional analyses are being expanded over the whole of the United States, as well as Canada and the former Soviet Union to continue addressing this possibility. Also, detailed comparisons of snow extent and surface air temperature are underway. Previous analyses suggested an inverse relationship between these two variables on a broad hemispheric level (Robinson et al., 1991). An improved understanding of snow cover and its role in the climate system will prove beneficial in the realms of climate modeling and climate change detection.

Acknowledgments

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