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RECENT VARIATIONS IN NORTHERN HEMISPHERE SNOW COVER

David A. Robinson and Frank T. Keimig
Department of Geography, Rutgers University
New Brunswick, NJ 08903

Kenneth F. Dewey
Department of Geography, University of Nebraska
Lincoln, NE 68588

Introduction

Snow is a key variable in the global climate system, influencing the global heat budget chiefly through its effect of increasing surface albedo. Accurate information on snow cover is essential for understanding details of climate change, and such information might make snow extent a useful index for detecting and monitoring change. Currently, the best information concerning continental snow cover is provided by NOAA weekly snow charts. Here, we use this product to examine snow cover over northern hemisphere lands between December 1971 and September 1990. As will be explained, this is the first consistent analysis of cover over the nearly two decade-long period.

NOAA snow charts

NOAA weekly snow charts depict boundaries between snow-covered and snow-free land surfaces. These northern hemisphere charts are produced from a visual interpretation of photographic copies of visible satellite imagery by trained meteorologists. Snow is delimited by recognizing characteristic textured surface features and brightnesses of snow-covered lands. The charts show boundaries on the last day that the surface in a given region is seen. Since May 1982, dates when a region was last observed have been placed on the charts, and an examination of these dates shows the charts to be most representative of the fifth day of the week.

NOAA has produced northern hemisphere snow charts since 1966. However, it is recognized that in early years the snow extent was underestimated, especially during Fall. Charting improved considerably in 1972 with the deployment of the Very High Resolution Radiometer on board NOAA polar-orbiting satellites. Since 1972, charting accuracy is such that this product is considered suitable for continental-scale climate studies.

Snow charts are digitized on a weekly basis using the NMC Limited-Area Fine Mesh grid. This is an 89 x 89 cell northern hemisphere grid, with cell resolution ranging from 16,000 to 42,000 km^2. If a cell is interpreted to be fifty percent or more covered by snow it is considered to be completely covered.

A major inconsistency in NOAA monthly snow cover areas has recently been identified. Prior to 1981, continental areas were calculated from monthly summary charts, which consider a cell to be snow covered if snow is present on two or more weeks during a given month (Dewey & Heim, 1982). Since 1981, NOAA has produced monthly areas by averaging areas calculated from weekly charts. Tests comparing these two methodologies showed areas computed using the monthly approach to be from several hundred thousand to over three million square kilometers greater than those calculated using weekly areas in all months except August. The offsets were not consistent.

Also contributing to the problem are 53 cells (covering $1.8 \times 10^6 km^2$) not considered consistently in the area calculations throughout the period of record. In 1981, 26 cells were eliminated from consideration, while 27 others began to be examined. Unfortunately, to date, published time series of snow cover have used values supplied by NOAA: thus any publication with snow totals covering both the pre and post 1981 intervals contains the inconsistency, including a recent paper of ours (Robinson and Dewey, 1990).

Here, a new methodology is employed to calculate monthly areas from December 1971 through September 1990. Weekly areas are calculated from the digitized snow files and weighted according to the number of days of that week which fall in the given month. A chart week is considered to center on the fifth day of the published chart week (cf. above). No weighting was employed in the two earlier methodologies. Finally, only those cells which have consistently been considered land throughout the period are employed in the analysis.

Snow cover analyses

Through September, 1990 snow cover has been exceptionally low. Monthly minima for the nineteen years of record have occurred in every month except January (Table 1). This continues the snow drought which began in mid 1987: four of the eight monthly minima reached in 1990 have eclipsed previous 1988 or 89 lows. Only two of the past 38 months (beginning Aug 87) have had above normal hemispheric snow cover (Jan 88 & Dec 89). Thus, the recent snow drought has occurred in all seasons, as well as over both continents (Fig. 1). Spring cover has been particularly low over Eurasia in the past two years. Generally, both continents have had low monthly and seasonal cover, although frequently neither have been at record low levels.

Twelve-month running means of hemispheric snow extent have averaged 25.0 million km^2 (standard deviation: 0.9 million km^2), and ranged from 27.0 million km^2 (Jun 78-May 79) to 23.0 million km^2 (Apr 88-Mar 89) over the past 19 years (Fig. 2). Periods of above normal cover have included the late 1970s and mid 1980s, while the mid 1970s and early 80s were on the low side. Neither of the latter are close to the recent deficit on a hemispheric level, although Eurasian cover in the mid 70s and North American cover in the early 80s approached recent lows (Fig. 2).

Snow-temperature associations

The reduced extent of snow cover over northern hemisphere lands in recent years has coincided with some of the warmest surface air temperatures of the past century. An examination of the past 19 years of snow and temperature data shows a striking relationship between the two (Fig. 3). Scatter diagrams of seasonal snow and temperature departures also exhibit this association (Fig. 4), which may in part be due to a snow-albedo feedback. Such a feedback is incorporated in general circulation models, and results in an amplification of warming in model simulations which incorporate increased concentrations of greenhouse gases.

However, it is premature to infer an anthropogenic cause for the recent decrease in hemispheric snow cover. These changes may have been associated with natural variations of atmospheric circulation, temperature, precipitation, and/or other climate variables. To address adequately the natural versus anthropogenic issue, the long-term natural variability of snow cover must first be identified and relationships between snow and other climate variables more firmly established. Such a project has recently begun at Rutgers, employing lengthy (+80 year) station records from North America and Eurasia.

Conclusion

The recent discovery of an inconsistency in the NOAA monthly snow cover data set weakens one of the conclusions in Robinson and Dewey (1990): that the 1980s as a whole had less snow cover than the 1970s. Hemispheric differences of 4 to 8% in the Fall, Winter, and Spring reported in the earlier publication, actually lie between 0 and 4%. Three other major conclusions of the study remain unchanged, and with the addition of snow observations through September 1990 and temperature data for 1988-90 are strengthened. These include the overall low snow cover from mid 1987 to present, the largest negative snow anomalies of late occurring in Spring, and the inverse relationship between snow and temperature anomalies. The relative simplicity of observing hemispheric snow cover from satellites, the critical role that snow cover has in the global heat budget, and the expected role of snow feedbacks in anthropogenic climate change support the continued diligent monitoring of snow cover.

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Table 1. Monthly and annual snow cover (million km^2) over northern hemisphere lands during the period January 1972 through September 1990.

	MAXIMUM (yr)	MINIMUM (yr)	AVERAGE	STD. DEV.
Jan	48.8 (1985)	41.1 (1981)	45.7	1.8
Feb	50.1 (1978)	42.5 (1990)	45.3	1.9
Mar	43.4 (1985)	36.5 (1990)	40.5	1.8
Apr	34.8 (1979)	27.7 (1990)	31.1	1.6
May	23.7 (1974)	17.0 (1990)	20.5	1.9
Jun	15.3 (1978)	7.1 (1990)	11.3	2.1
Jul	7.8 (1978)	3.4 (1990)	5.2	1.1
Aug	5.7 (1978)	2.6 (1988,89,90)	3.8	0.9
Sep	7.5 (1972)	3.7 (1990)	5.4	1.0
Oct	25.4 (1976)	12.4 (1988)	17.2	2.9
Nov	37.4 (1985)	27.7 (1979)	32.5	2.3
Dec	45.2 (1985)	36.7 (1980)	41.6	2.3

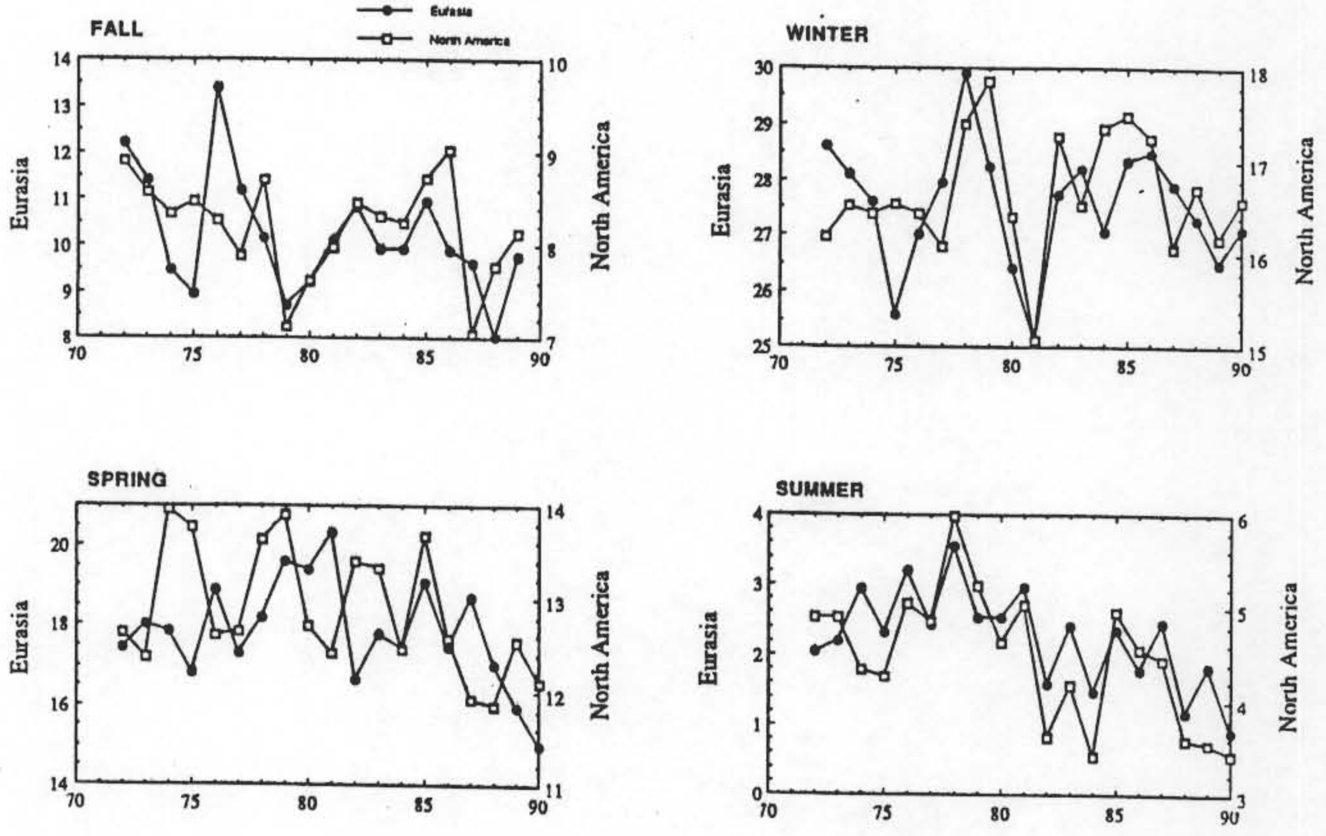

Fig. 1. Seasonal snow cover (million km^2) over Eurasia and North America from Winter 1971/72 to Summer 1989. Note the different scale for each continent.

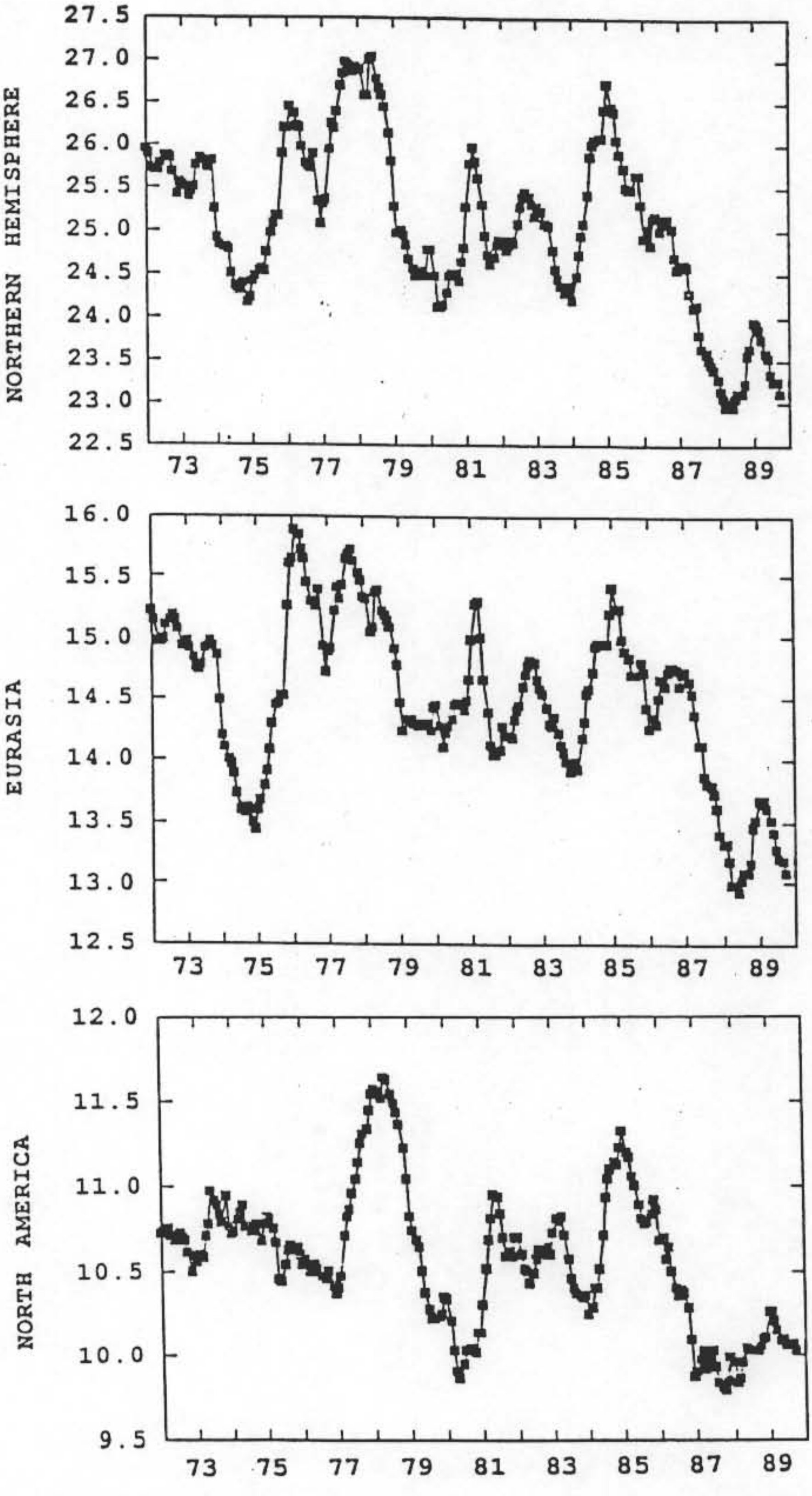

Fig. 2. Twelve-month running means of snow cover (million km^2) over northern hemisphere lands for the period January 1972 through September 1990. Also partitioned for Eurasia and North America.

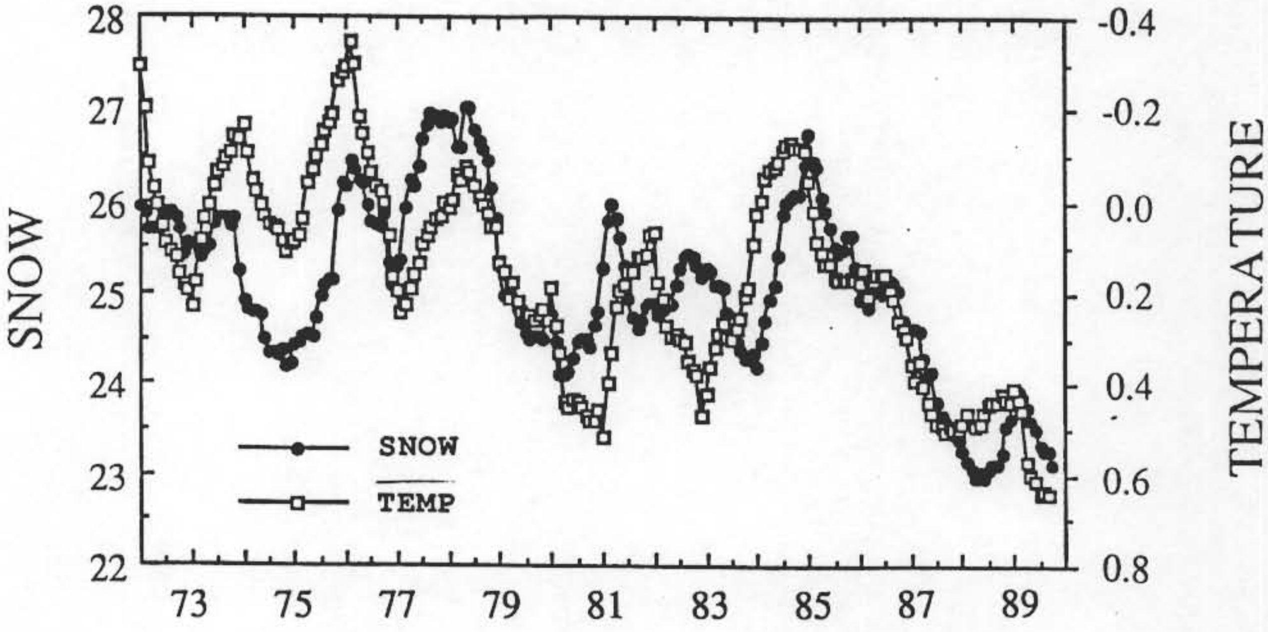

Fig. 3. Twelve-month running means of snow cover (million km^2) and surface air temperature (^oC) over northern hemisphere lands for January 1972 through August 1990. Temperatures expressed as departures from the reference period 1951-70. Temperature data from Jones et al. (1986), Jones (1988), and Jones (per. commun.).

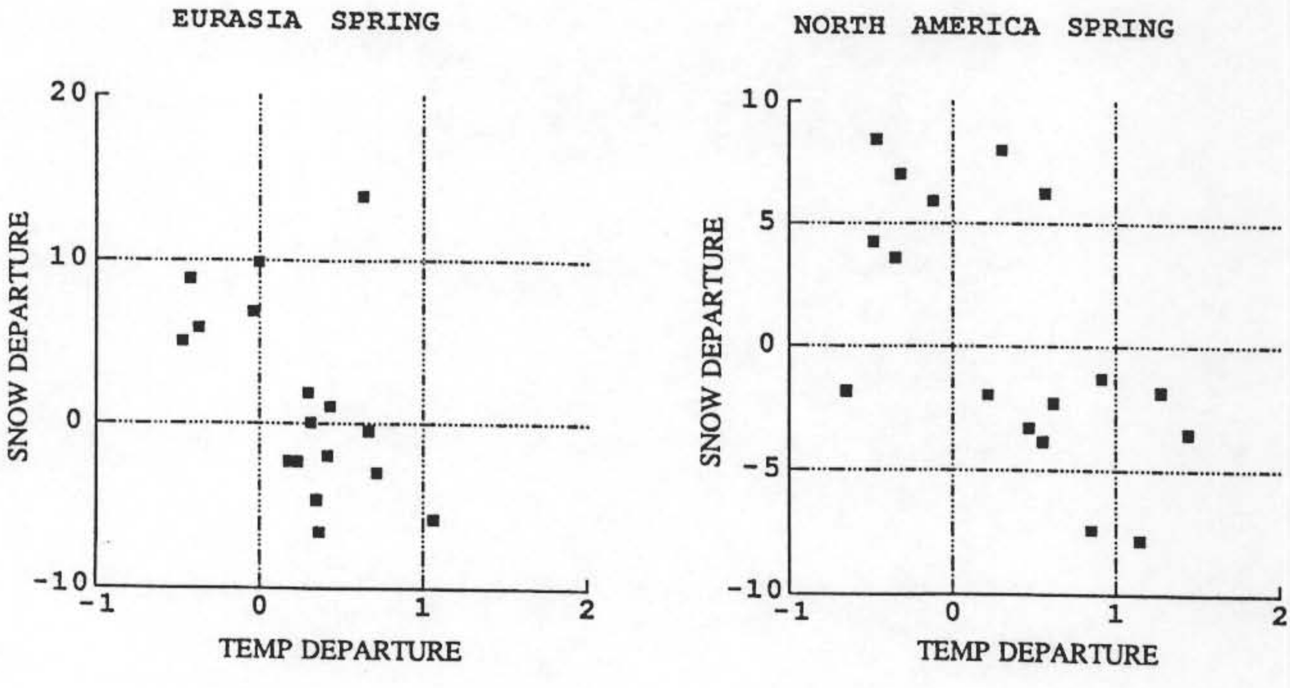

Fig. 4. Departures of Spring snow cover and surface air temperature over Eurasia and North America from 1972-1990. Snow departures are expressed as percentage of the 1972-90 mean, temperature as in Fig. 3.