

Observed Differences Between Snow Extent and Snow Depth Variability at Continental Scales

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EXTENDED ABSTRACT

Snow extent and snow depth are two related characteristics of a snowpack, but they need not be mutually consistent. Different behaviors of snow depth and snow extent are readily apparent at local scales; for example, during conditions of uninterrupted snow cover, snow depth at a point can vary substantially due to snowfall events, metamorphosis and ablation. However, the behavior of snow extent vs. snow depth at regional to continental scales is understudied. Regional/continental-scale gridded datasets of snow depth and snow water equivalent (SWE), obtained from field observations and satellite data, were utilized to quantitatively evaluate the relationship between snow extent and snow depth over North America. Statistical methods were applied to assess the mutual consistency of monthly snow depth vs. snow extent. Results from all the datasets indicate the significance of snow depth variations, and that snow depth anomalies and snow extent anomalies are not necessarily consistent, especially at higher latitude. This observed lack of mutual consistency at continental scales suggests that average snowpack depth variations may be of sufficiently large magnitude, spatial scope and temporal duration to influence regional-hemispheric climate, in a manner unrelated to the more extensively studied snow extent variations.

Keywords: Snow depth, Snow extent, Continental-Scale, Consistency

Datasets

In order to study the temporal differences between snow depth and snow extent at regional to continental scales, datasets characterized by spatial coverage across North America and/or 20th century temporal duration have been acquired and utilized.

- Gridded snow depth dataset spanning North America interpolated from 349 Stations located in the United States and southern Canada for the 1915–1997 period. (Brown, 2000)
- Daily 1°x1° grid dataset covering all of North America interpolated from a comprehensive set of station snow depth observations from 1956 through 2000. (Dyer and Mote, 2006)
- SWE Maps for the Canadian Prairies derived using passive microwave data from the NASA Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave Imager (SSM/I) instruments from 1978 to 1997. (Derksen et al., 2004)

Results

The North America snow extent (i.e., spatial snow covered area) was computed by Ross Brown (Brown, 2000). The corresponding mean snow depth variable is computed as the area-weighted average snow depth over this snow covered extent. Monthly statistics are applied to assess the

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mutual consistency of snow depth vs. snow extent over North America. Results from all three of the datasets described above consistently indicate that at continental/regional scales, snow depth and snow extent anomalies are not mutually consistent.

Figure 1a shows that the monthly evolution of both mean and variability of snow depth and snow extent for North America follows different temporal patterns. Snow extent increases in the early snow season and reaches its maximum value in January, but interannual variability of monthly snow extent is small in January. On the contrary, both mean value and range of variability of monthly snow depth increases steadily through February/March. Another indication of different behavior between these two snow parameters is the monthly correlation between snow depth and snow extent, presented in Figure 1b. The interannual snow depth and snow extent timeseries are often poorly correlated, especially in winter. Figure 1c shows the coefficient of variation (i.e., ration of standard deviation to mean) for both extent and depth, and indicates that the interannual variability of snow depth comprises a larger percentage of its climatological mean state than that for snow extent, consistently across all months. Hence the magnitude of snow depth variability can be considered more substantial than the magnitude of snow extent variability. Monthly scatterplots (Figure 1d) support the correlation results, i.e., wide scatter and a lack of an apparent snow extent vs. snow depth relationship during winter, and a more noticeable but still modest relationship during autumn and spring.

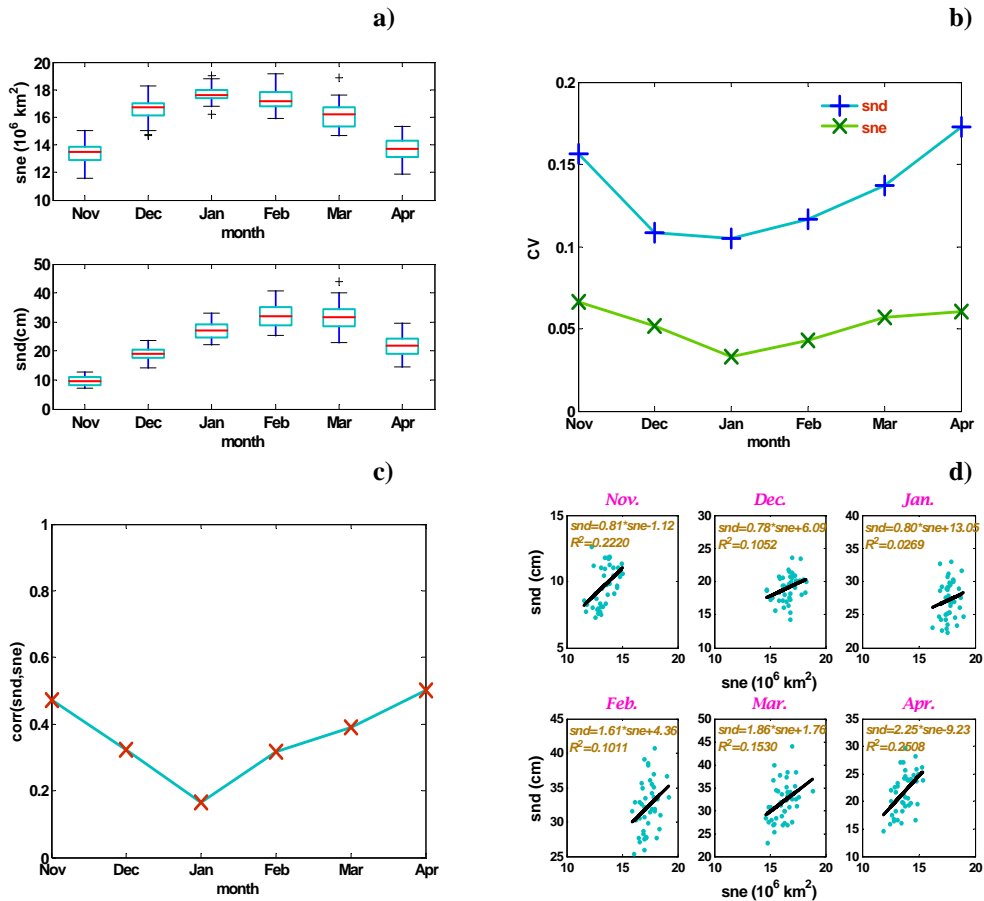


Figure 1. Nov.–Apr. timeseries of North America snow extent “sne” (Brown, 2000) and grid domain average snow-covered depth “snd” (Dyer and Mote, 2006) from 1956 to 1997. a) Monthly box plots of interannual sne and snd; b) Monthly correlations between interannual sne and snd; c) Monthly cv (std/mean) of interannual sne and snd time series; d) Monthly scatterplots of interannual sne and snd.

Figure 2 presents correlation maps between gridded snow depth (Dyer and Mote, 2006) and North America snow extent (Brown, 2000) from November to April. All the months show strong correlation near the snowline and weak correlation over virtually all points north of the snowline. Correlations drop off dramatically north of the snowline, resulting in a very large high-latitude region in which snow depth and snow extent are poorly correlated. During winter months there are even regions of negative correlation north of the snow line, which may be due to the interannual variation of northeastward mid-latitude cyclone tracks.

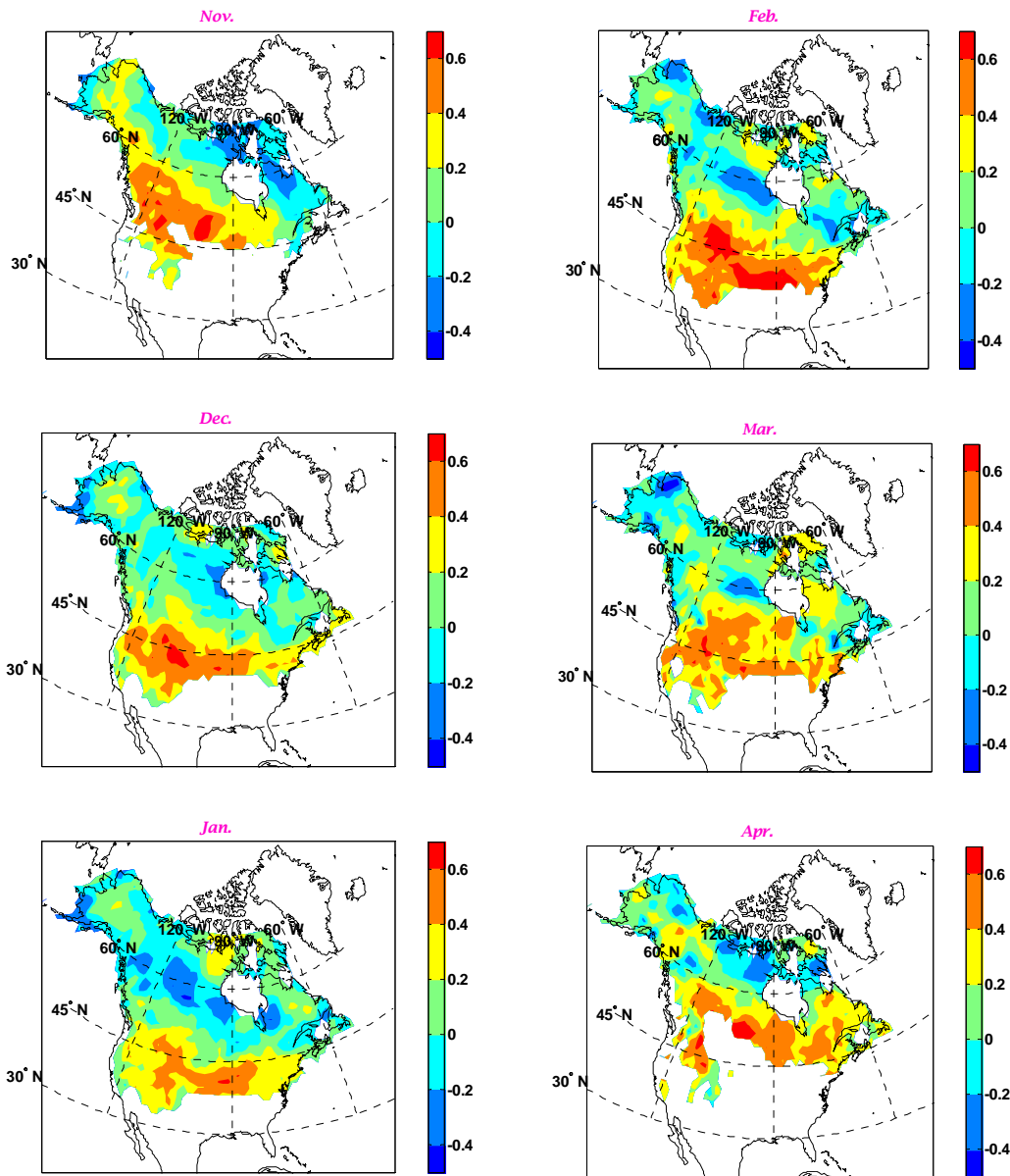


Figure 2. Correlation maps between gridded snow depth (Dyer and Mote, 2006) and North America snow extent (Brown, 2000).

Figure 3 shows the correlation maps between gridded SWE (Derksen et al., 2004) and North America snow extent (Brown, 2000). The satellite data confirms the observed inconsistency between snow depth and North America snow extent from station datasets seen in Figure 2. Correlations decline from south to north in central North America region (38N–63N) for three consecutive months (December, January and February). Regions of negative correlation also exist north of snowline during January and February.

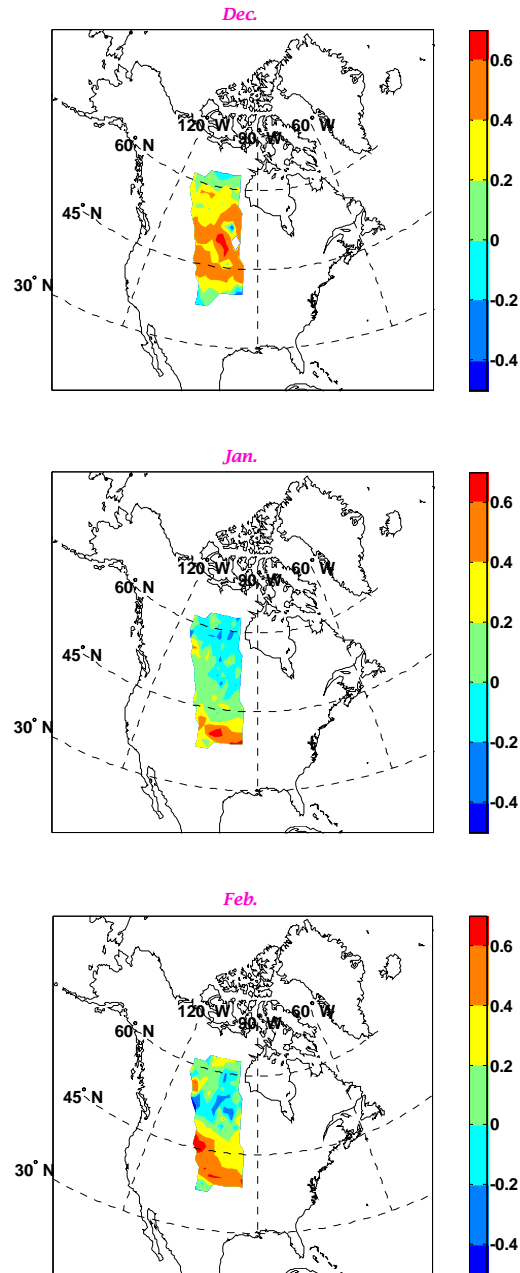


Figure 3. Correlation maps between gridded SWE (Derksen et al., 2004) and North America snow extent (Brown, 2000).

CONCLUSIONS

Three regional-continental scale snow depth datasets have been evaluated, derived from station observational data or satellite remote sensing data. All of the datasets consistently exhibit differing behavior between interannual timeseries anomalies of average snow-covered depth and North America snow extent at regional/continental scales, generally consistent with what is expected at local scales. Correlation maps of snow depth vs. snow extent show a broad, continental-scale region is maintained throughout much of the snow season in which snow depth variations are not mutually consistent with North America snow extent variations. Research also recognized that relative magnitude of snow depth anomalies is considerably larger than that for snow extent.

The observed differing behavior of the two snowpack parameters at regional/continental scales suggest that snow depth variations may be of sufficiently large magnitude, spatial scope and temporal duration to influence regional-hemispheric climate, in a manner unrelated to the more extensively studied snow extent variations. Such analysis represents the first step towards the goal of identifying explicit snow depth – climate relationships and integrating them with snow extent–climate relationships.

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