

H33B-1386 Relationship Between Winter Snowfall and Summer Droughts in the Northern Great Plains of North America

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ABSTRACT

The relationships between snowfall/snow cover and summer drought (moisture) conditions are not, generally speaking, well understood. While numerous studies have demonstrated that Eurasian snow cover affects the strength of the Indian/Asian summer monsoon, a connection between North American snowfall/snow cover and moisture conditions during the summer has not been definitively established. The impact of fall/winter/spring snowfall on growing-season droughts were examined using a one-degree grid spanning the northern Great Plains of North America (40° to 54° N; 95° to 113° W). Based on data from 1929 to 1999, the results suggest that the relationship between snowfall and summer moisture conditions is non-linear. It appears that snowfall anomalies must exceed some minimum threshold before they have a significant impact on atmospheric circulation and precipitation during the following summer. The results also suggest that snowfall anomalies during the late winter/spring are more important for determining summer moisture conditions than snowfall anomalies during the early winter. However, snow cover extent during the late fall may also have an impact.

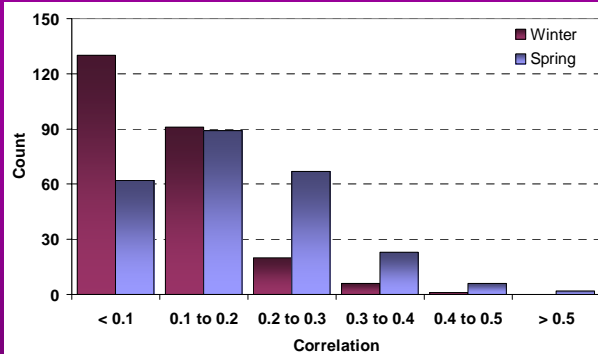


Figure 1. Linear correlations between winter (DJF) and spring (MAM) snowfall and summer (JJA) moisture conditions for each of the 249 grid cells in the study region. In winter the correlations are only statistically significant (at the 0.1 level) at 8% of the grid cells, during spring there are statistically significant correlations at 30% of the grid cells.

Lowest Snowfall Seasons		Highest Snowfall Seasons		Driest Summers		Wettest Summers	
Season	Snowfall (mm)	Season	Snowfall (mm)	Year	Moisture Anomaly	Year	Moisture Anomaly
1931	638.4	1997	1541.2	1961	-2.52	1993	4.00
1981	680.4	1979	1499.2	1936	-2.51	1944	1.95
1977	825.4	1967	1384.8	1988	-2.48	1951	1.63
1963	831.8	1986	1374.9	1934	-2.13	1965	1.62
1961	842.5	1956	1340.9	1931	-1.73	1995	1.54
1992	850.5	1950	1338.3	1933	-1.40	1947	1.52
1988	852.8	1975	1314.5	1929	-1.24	1999	1.36
1934	857.5	1970	1308.4	1940	-1.23	1942	1.33
1998	861.0	1984	1281.9	1959	-1.09	1975	1.30
1987	911.8	1974	1274.5	1937	-0.99	1968	1.28

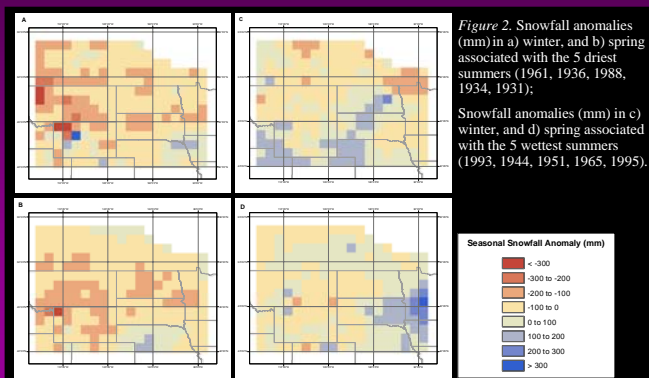


Figure 2. Snowfall anomalies (mm) in a) winter, and b) spring associated with the 5 driest summers (1961, 1936, 1988, 1934, 1931);
 Snowfall anomalies (mm) in c) winter, and d) spring associated with the 5 wettest summers (1993, 1944, 1951, 1965, 1995).

DATA & METHODS

The study region includes the north-central United States and the southern portion of the Canadian prairie provinces. It covers portions of three Canadian provinces (Manitoba, Saskatchewan, and Alberta) and 12 states (Colorado, Iowa, Idaho, Minnesota, Missouri, Montana, Nebraska, North Dakota, Nevada, South Dakota, Utah, and Wyoming). The analysis is based on monthly drought index (Palmer's Z-index) and snowfall data (1929-1999) that have been interpolated to a one-degree grid spanning 40° to 54° N; 95° to 113° W. Details on how the Canadian drought data was generated can be found in Quiring and Papyriakou (2003, 2005). The US drought data is monthly climate division data provided by the National Climatic Data Center that has been interpolated to the one-degree grid. The snowfall dataset was developed by T. Mote and collaborators at the University of Georgia. It is based on daily observations (1900-2000) from the National Weather Service cooperative station network and observations from the Meteorological Service of Canada. After quality control procedures were performed, this data was interpolated using a modified version of Shepard's algorithm.

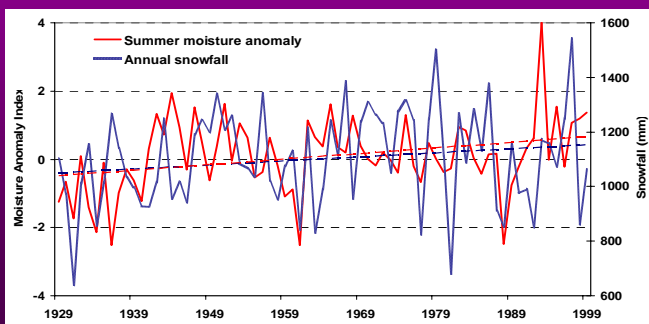


Figure 3. Summer (JJA) moisture anomalies and annual snowfall (mm) in the northern Great Plains (1929 to 1999) ($r = 0.24$). Trends for summer moisture conditions and annual snowfall are also shown. The 10 most extreme seasonal snowfall anomalies and summer moisture anomalies are shown in the tables on the left.

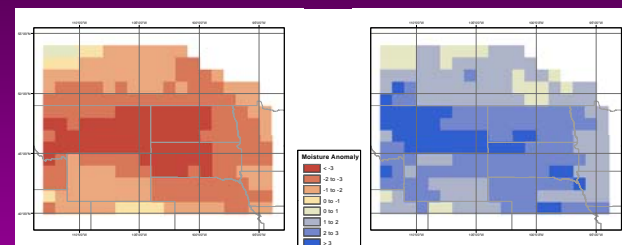


Figure 4. Summer (JJA) moisture anomalies (Palmer's Z-index) associated with the a) 5 driest (1961, 1936, 1988, 1934, 1931), and b) 5 wettest years (1993, 1944, 1951, 1965, 1995) between 1929 and 1999

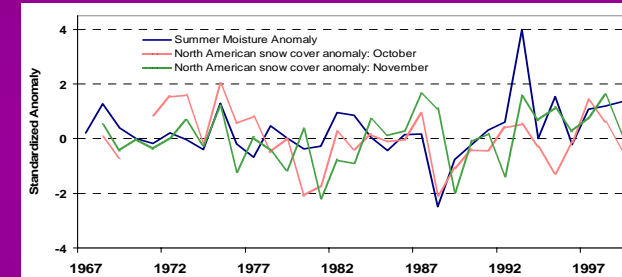


Figure 5. Summer moisture anomalies in the northern Great Plains (1967 to 1999) versus North American snow cover extent anomalies during the prior October ($r = 0.35$) and November ($r = 0.31$)

RESULTS & CONCLUSIONS

•There is only a weak linear relationship between winter/spring snowfall and summer moisture conditions in the northern Great Plains of North America (only 8% (30%) of the grid cells have a statistically significant correlation during winter (spring)).

•Based on the composite analysis, the 5 driest summers between 1929 and 1999 (1961, 1936, 1988, 1934, and 1931) are associated with:

- 1) Mean winter (spring) snowfall that is 66.7 (62.4) mm below normal
- 2) 28.5% (24.9%) of the study region has winter (spring) snowfall anomalies less than -100 mm
- 3) 2.4% (1.2%) of the study region has winter (spring) snowfall anomalies greater than +100 mm
- 4) 85% of the study region received below normal snowfall during the prior winter and spring
- 5) The 5 wettest summers between 1929 and 1999 (1993, 1944, 1951, 1965, and 1995) are associated with:

- 1) Mean winter (spring) snowfall that is 6.2 (21.6) mm above normal
- 2) 14.9% (12.1%) of the study region has winter (spring) snowfall anomalies greater than +100 mm
- 3) 7.2% (1.2%) of the study region has winter (spring) snowfall anomalies less than -100 mm
- 4) 53.4% (46.2%) of the study region received above normal snowfall during the prior winter (spring)

It appears that the below normal snowfall during the winter/spring may be associated with anomalously dry conditions during the summer. However, the relationship between above normal snowfall and anomalously wet summer conditions is quite weak. It is hypothesized that below normal snowfall is linked to summer drought via negative soil moisture anomalies in spring and early summer. More research needs to be done to explore the relationships between snowfall/snow cover extent on summer moisture conditions.