Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
42nd NOAA Annual Climate Diagnostics and Prediction Workshop
Norman, OK, 23-26 October 2017

Investigating the Potential for Seasonal Snowfall Forecasts at CPC

Stephen Baxter

Climate Prediction Center, NCEP/NWS/NOAA, College Park, MD

1. Introduction

CPC currently issues probabilistic temperature and precipitation forecasts for 3-month overlapping seasons for the upcoming 13 seasons. Seasonal snowfall forecasts are not explicitly issued, though CPC's website contains seasonal snowfall composites based on the phase of ENSO for overlapping 3-month seasons. Seasonal snowfall accumulation is an important variable over much of the CONUS; in the western U.S. snowfall is closely monitored due to its hydrological importance as well as impacts on winter tourism. Farther east there is interest in the broader impact of seasonal snowfall on economic productivity and related issues. A seasonal snowfall outlook by CPC could satisfy forecast needs for stakeholders ranging from water managers and agricultural interests to industry and the general public. A recently published data set (Kluver *et al.* 2016) provides gridded daily snowfall accumulation data from 1900 to 2009. Using the data from 1950-2009, we investigate whether seasonal snowfall accumulation might be predictable over the U.S.

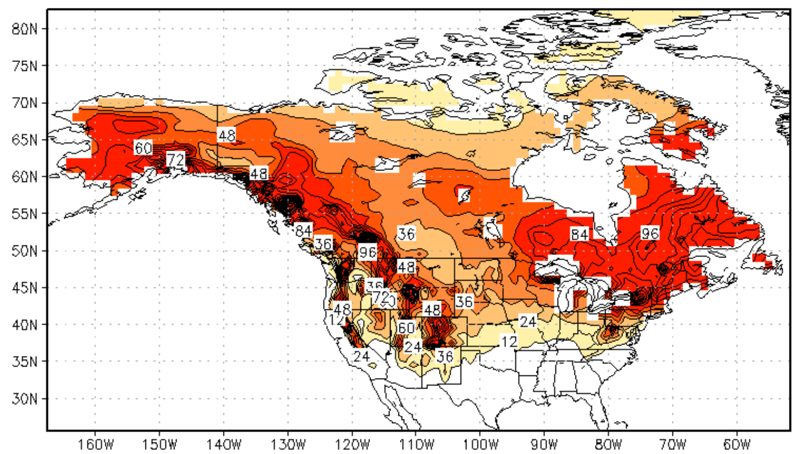

Fig. 1 Snowfall climatology (Oct-Apr) over North America from the winter of 1950-51 to 2008-09. Contour and shading interval is 12 inches, starting at 12 inches.

2. Methods

Kluver *et al.* (2016) details a new gridded daily snowfall data set. We use this data at 1° x 1° resolution for the extended cold season spanning from October through April. (The analysis presented here was repeated using the peak winter months of December-February with little change in the results.) The October-April seasonal snowfall data is subject to a square-root correction to bring it closer to a normal distribution prior to analysis. For temperature and precipitation data we use the GHCN+CAMS data set and the gridded CPC precipitation reconstruction data set, respectively, each at the same 1° x 1° resolution. Sea surface temperature (SST) data is taken from the ERSSTv4 data set at 2° x 2° resolution.

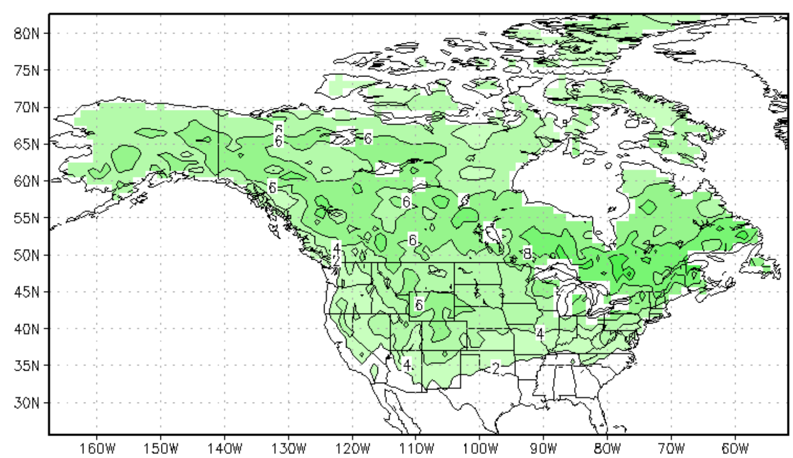

Fig. 2 Ratio of the mean to standard deviation (Oct-Apr) in the square-root adjusted data. Contour and shading interval is 2, starting at 2. Areas where this ratio is less than 2 are masked out in subsequent figures.

Prediction of the seasonal snowfall can be approached in two ways: using snowfall explicitly as the predictand in

Correspondence to: Stephen Baxter, Climate Prediction Center, NCEP/NWS/NOAA, 5830 University Research Court, College Park, MD 20740-3818; E-mail: stephen.baxter@noaa.gov

an empirical (or dynamical) forecast tool or statistically specifying seasonal snowfall using the forecast seasonal temperature and precipitation fields. Ultimately, a combination of these approaches might be pursued. In the case of the former, trends and ENSO are two predictors that we can use to explicitly predict seasonal snowfall. For trends we use a linear least-squares fit, and for ENSO we use a Niño 3.4 index calculated from the ERSST data over the 1950-2009 period. For seasonal specification, we use the temperature and precipitation data at seasonal resolution to construct point-by-point correlation maps related seasonal snowfall to temperature and precipitation, respectively.

Finally, EOF analysis of the North American seasonal snowfall anomalies is performed. The goal here is to see if the leading patterns of seasonal snowfall variability are related to known climate drivers. This will be assessed by regression the leading principal components onto time-lagged SST anomaly fields.

3. Results

Figure 1 shows the October-April climatology. The extended cold season mean snowfall values look very reasonable across North America from the gridded data set. Across parts of the West Coast and southern tier of the CONUS, the climatology is small. Using the square-root adjusted data, the ratio of the mean to the standard deviation is plotted (Fig. 2). A threshold of 2 is used here to identify areas where there is enough seasonal snowfall relative to the variance to yield a well-behaved distribution. In subsequent figures this value is used as mask to eliminate areas where seasonal snowfall forecasts may be ill-posed. This threshold, however, may be changed based on stakeholder feedback.

ENSO relationships (shown in Fig. 3) are strongest in the western U.S., with El

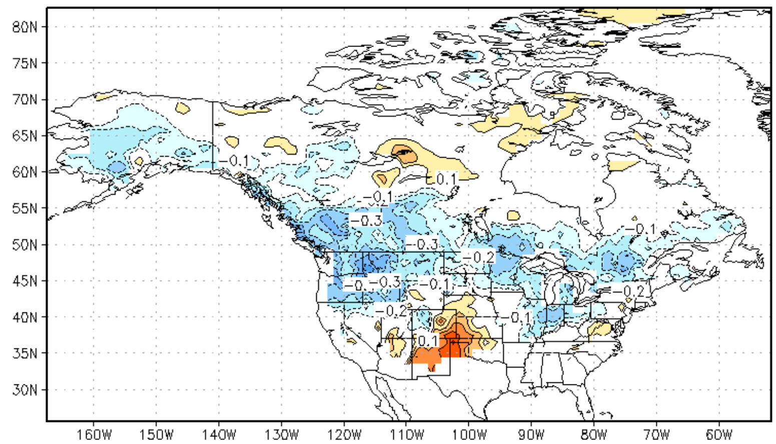

Fig. 3 Linear correlation coefficient between Niño 3.4 (calculated from the ERSSTv4 dataset) and seasonal snowfall (1950-2008). Contour/shading interval is 0.1 with the zero line omitted.

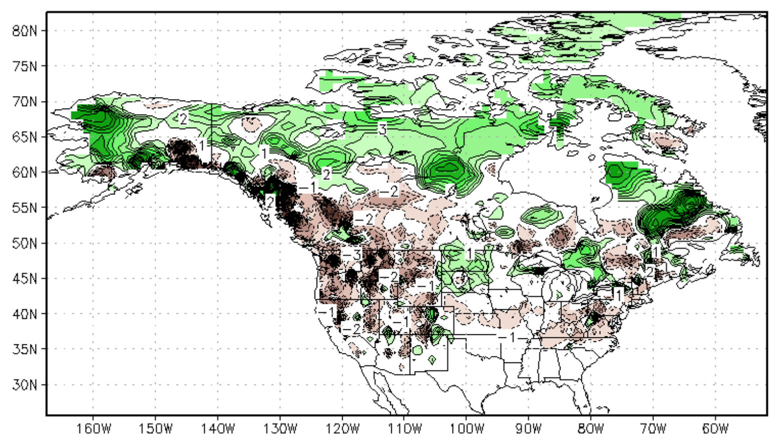

Fig. 4 Linear trend of seasonal snowfall in inches per decade (1950-2008). Contour/shading interval is 1 in/dec with the zero line omitted.

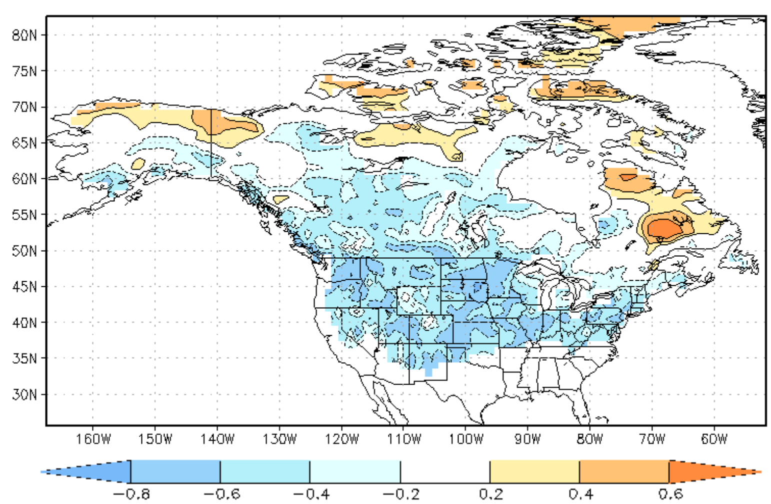

Fig. 5 The grid-by-grid correlation between Oct-Apr seasonal snowfall and temperature (1950-2008). Contour/shading interval is 0.2 with the zero contour omitted.

Niño (La Niña) associated with below-normal (above-normal) over the interior Northwest and above-normal (below-normal) snowfall over the southern High Plains. A smaller but expected relationship is also found in the Great Lakes region, where Niño 3.4 is negatively correlated with seasonal snowfall. Somewhat unexpectedly, the relationship over the Mid-Atlantic and coastal Northeast is weak in this linear framework. Long-term, linear trends are notable across North America (Fig. 4). Negative trends are strongest over parts of the mountainous West, and to less extent parts of the Mid-Atlantic and Northeast. Positive trends are seen over much of norther tier of the continent, likely associated with increased moisture availability as a result of long-term changes in the winter climate.

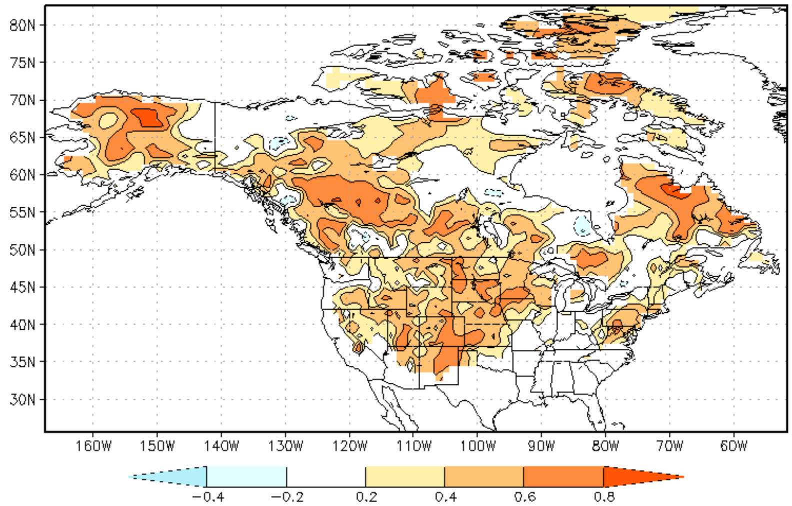

Fig. 6 Same as Fig. 5, except for precipitation.

The temperature and precipitation correlations are quite robust, especially over the CONUS. Positive (negative) correlations exist across much of the CONUS between precipitation (temperature) and snowfall (Figs. 5 and 6). Here is it important to note that in some regions, especially the High Plains, seasonal temperature and precipitation are quite highly correlated, so these cannot be thought of as independent predictors. Nonetheless, a wetter seasonal climate is one in which there are more opportunities for snowfall accumulation; this is especially intuitive in relatively cold climates. Colder-than-average seasonal temperatures can be thought to increase the ratio of frozen to liquid precipitation by lowering the average

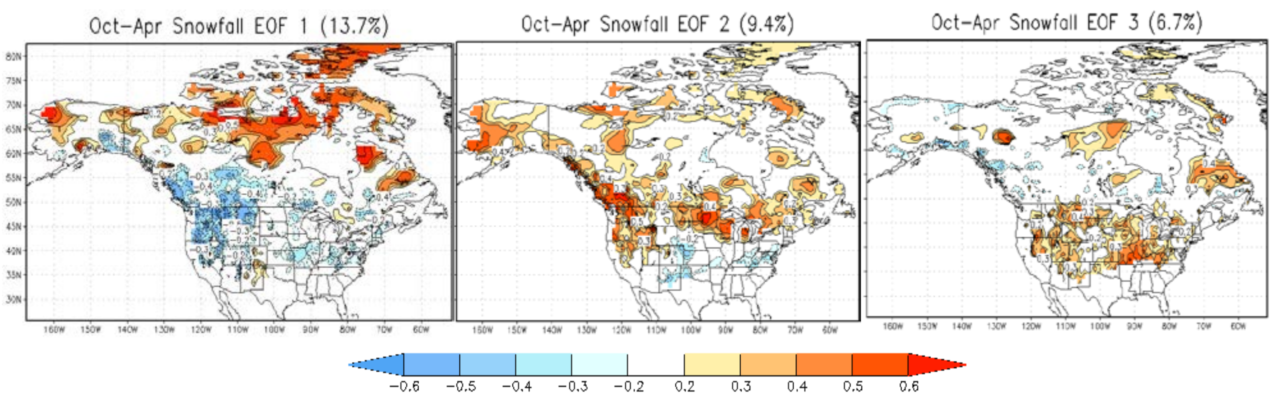

Fig. 7 Linear correlations between the leading principal components and seasonal snowfall anomalies. Contour/shading interval is 0.1 starting at +/- 0.2.

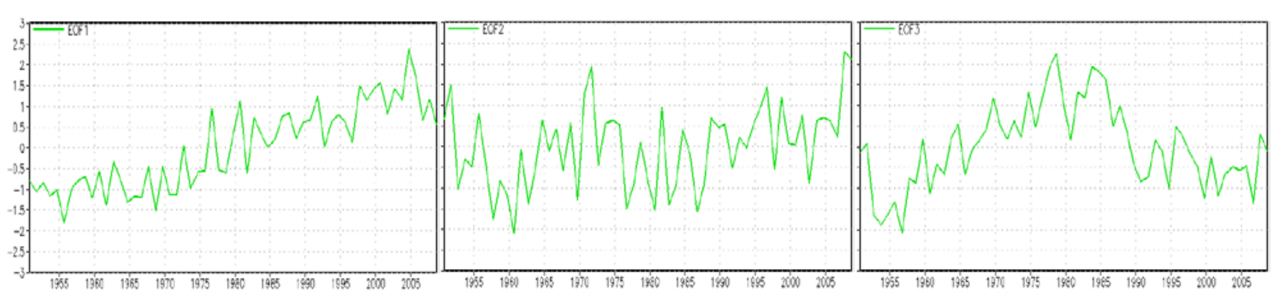

Fig. 8 Time series of three leading principal components of seasonal snowfall variability. PCs 1, 2, and 3 most closely represent trend, ENSO, and decadal variability, respectively.

freezing level in the overlying atmospheric column. To be sure, a portion of this relationship between temperature and snowfall is based on snow cover feedbacks affecting the local radiative balance. This underscores the importance of incorporating upper-level height analysis at some point; this will allow for a clearer understanding of cause and effect between seasonal temperature, precipitation, and snowfall.

The EOF analysis reveals coherent patterns with associated time series that are consistent with known patterns of interannual to decadal variability (Figs. 7 and 8). The first three principal components are associated with long-term trends, ENSO, and decadal variability, respectively. These relationships are confirmed by regressing these time series onto the time-lagged seasonal SST anomalies (not shown here). Interestingly, PC 3 peaks in the late 1970s, a break point often seen in climate analysis from which time the modern period of climate warming has continued.

4. Conclusions

Seasonal forecasts of snowfall accumulation are likely feasible based on the state of ENSO and long-term trends, statistical specification based on forecast temperature and precipitation, or both. The leading principal components of seasonal snowfall anomalies are associated with known, coherent patterns of SST variability, suggesting predictability similar to temperature and precipitation, at least in some regions. Next steps include an independent hindcast experiment to approximate prediction skill using empirical methods informed by these results, followed by assessment of dynamical model seasonal snowfall forecasts.

References

Kluver, D., and Coauthors, 2016: Creation and validation of a comprehensive 1° by 1° daily gridded North American dataset for 1900–2009 snowfall. *J Atmos Ocean Technol.*, **33**, 857–871. https://doi.org/10.1175/JTECH-D-15-0027.1