Alaska Decadal Average Monthly Snow-Day Fraction

Overview

Data represent the decadal average percent of wet days in a month that are snowy rather than rainy.

Gridded decadal average monthly snow-day data are supplied as geotiffs at 771m. resolution. Historical data cover the period from 1900-1909 to 2000-2009. Projected data from 2010-2019 to 2090-2099. Units are percentage.

Separate equations were used to model the relationship between decadal monthly average temperature and the fraction of wet days with snow in each of seven regions delineated in Perica et al. (2012): Arctic, western Alaska, Interior, Cook Inlet, SW Islands, SW Interior, and the Gulf of Alaska coast. In the Arctic, one equation was used for the entire year. In the other six regions, different equations were used for September through February and March through August. The equations were developed from daily Global Historical Climatology Network weather station data acquired from the National Climatic Data Center.

These equations were then applied to gridded decadal monthly average temperature data (CRU TS3.1) and projections from five climate models used in the IPCC's Fourth Assessment Report (CCCMA-CGCM3.1 t47, GFDL-CM2.1, MPI-ECHAM5, MIROC3.2 medres, and UKMO-HadCM3) driven by two different greenhouse gas forcing scenarios (A1B and A2). Data and projections were downscaled to the 1971-2000 771m PRISM climatology by SNAP.

Major caveats include local differences from the equation, uncertainty about the suitability of these equations for higher elevations, and uncertainty about the stability of the equations with climate change. Model validation demonstrated that some stations are consistently less well described by regional models than others. Very few high-quality weather stations with long records are located above 500m elevation in Alaska. It is not clear whether the relationships developed at lower elevation sites will be completely appropriate in the mountains. Finally, these equations summarize a long-term monthly relationship between temperature and precipitation type that is the result of short-term weather variability. In using these equations to make projections of future snow, as assume that these relationships remain stable over time, and we do not know how accurate that assumption is.

Detailed discussion of data set construction and validation follow.

How were the snow-day fraction data constructed?

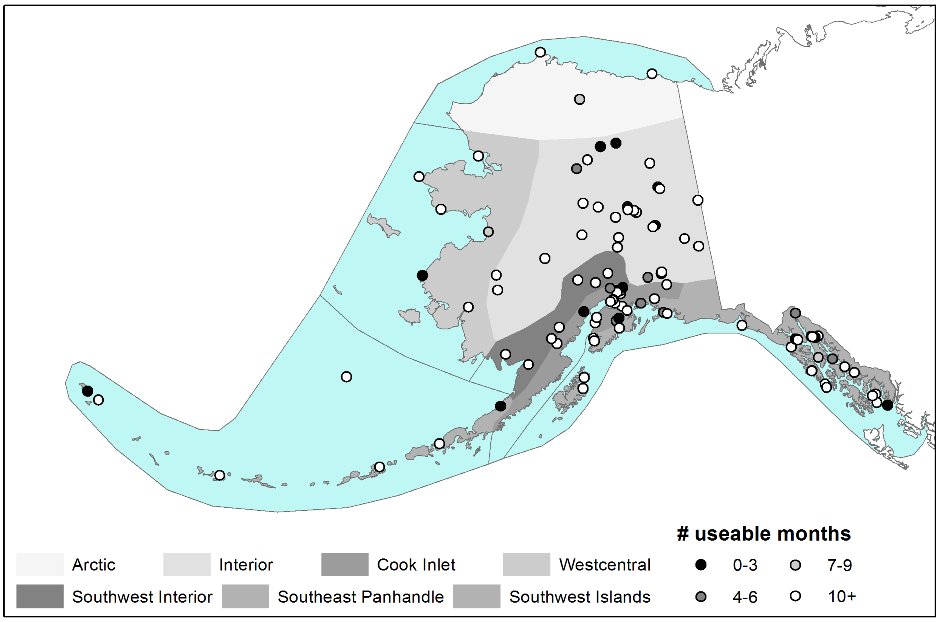
- Identify stations in the Global Historical Climatology Network database with 30+ years of >90% complete data.
  - To increase the number of usable stations we do this separately for each month .
  - The 30+ years of data did not need to be consecutive.
  - There are 104 stations that contribute data from at least one month of each year, and 68 that contribute data for all 12 months.
  - A list of stations used and how many years of data
- Calculate monthly average temperature (T) for each month and year.
- Calculate snow-day fraction for each month m and year i.

$$\boldsymbol{Fs_{m,i} = \frac{nsd_{m,i} - nmd_{m,i}}{nwd_{m,i}}}$$

  where,
  nsd is the number of days with trace or measurable snowfall.
  nwd is the number of days with trace or measurable precipitation.
  nmd is number of mixed precipitation days (snow fall >4 x gauge-measured precipitation).
- Calculate 10-year average T and Fs for each station and month, resampling to 1000 samples.
- Use 500 replicates to fit logistic curves for September – February and March – August for each region except the Arctic (only 1 algorithm).

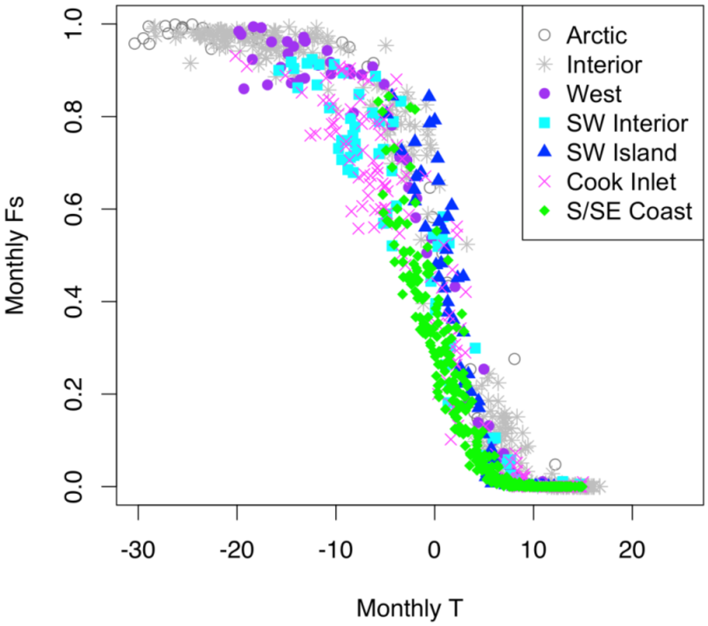
$$\boldsymbol{Fs = \frac{1}{1 + e^{-(a+bT)}}}$$

- The remaining 500 replicates were retained to evaluate the model.
- Region-specific equations are applied to gridded decadal average temperature data
  - CRU TS3.1 downscaled to the PRISM 1971-2000 771m. climatology
  - A1B and A2 projections from the CCCMA-CGCM3.1 t47, GFDL-CM2.1, MPI-ECHAM5, MIROC3.2 medres, and UKMO-HadCM3 climate models, downscaled to the PRISM 1971-2000 771m climatology.



Why were regionally and seasonally specific equations developed?

Previous studies and initial investigation confirmed that there were regional and seasonal differences in the relationship between monthly average temperature and snow-day fraction (Fs). In much of Alaska, precipitation occurs on relatively warmer days during the winter and on relatively cooler days during the summer. Differences in the type and source of storms, as well as local, often terrain-driven, climate effects can also influence the relationship between temperature and the type of precipitation (rain or snow) that falls. For example, warm storms impacting southern Alaska can bring rain or freezing rain, even on very cold days. Conversely, if the layer of warm air at the surface is thin, snow generated in cooler temperatures aloft can fall to the ground before melting complete.



Six-month models expressed seasonal variability in the relationship between temperature and snow-day fraction. While the fit was often not as good as shorter seasons, data from a six-month season generally included the full range of snow-day fraction from 0 to 1. As long as there are observations across the full range of possible snow-day fractions, temperatures that fall outside the range of observations are less of a concern.

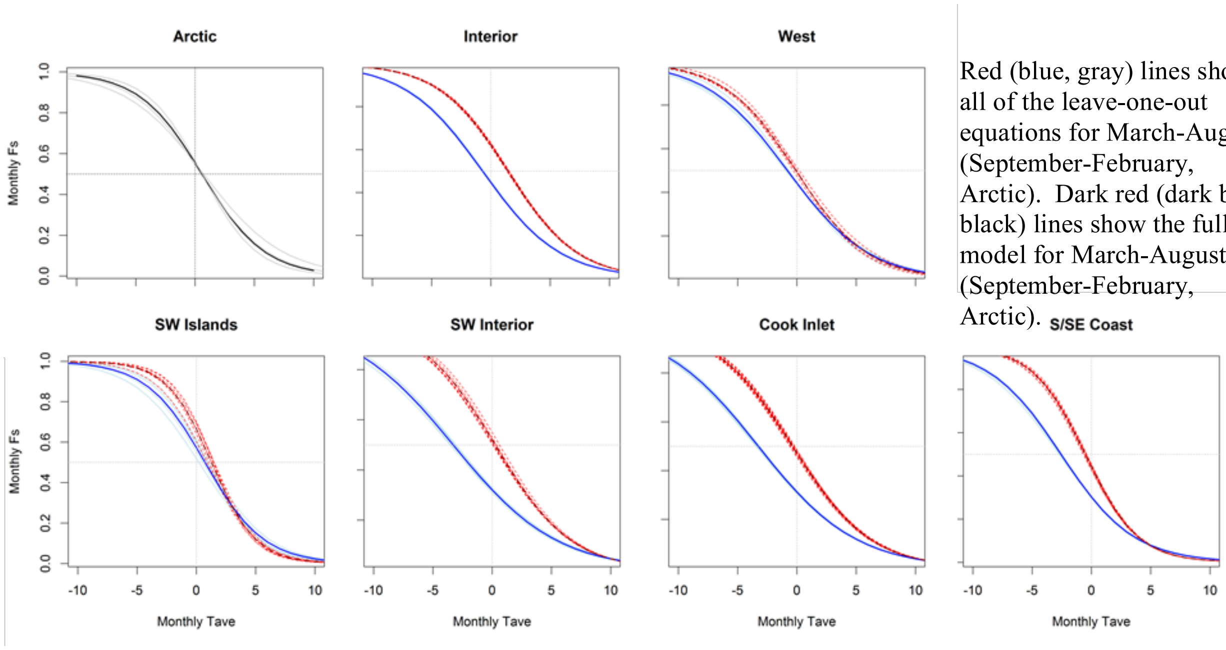
Why was snow-day fraction used instead of snow-fraction, the fraction the total precipitation contributed by snow?

Both rain and snow amounts are challenging to measure accurately, and many standard rules of thumb for estimating the amount of water in a given snowfall are known to be inaccurate. Using the occurrence of rain or snow, rather than their amount reduced the hidden uncertainty associated with those measurement errors. In addition, using rain and snow occurrence, rather than amount, increased the number of stations available for use.

Preliminary tests suggest that using snow-day fraction as a proxy for snow fraction is not unreasonable, as the two are reasonably well correlated. However, confirming the relationship between the frequencies and amounts of rain and snow for a particular area and/or season would increase confidence.

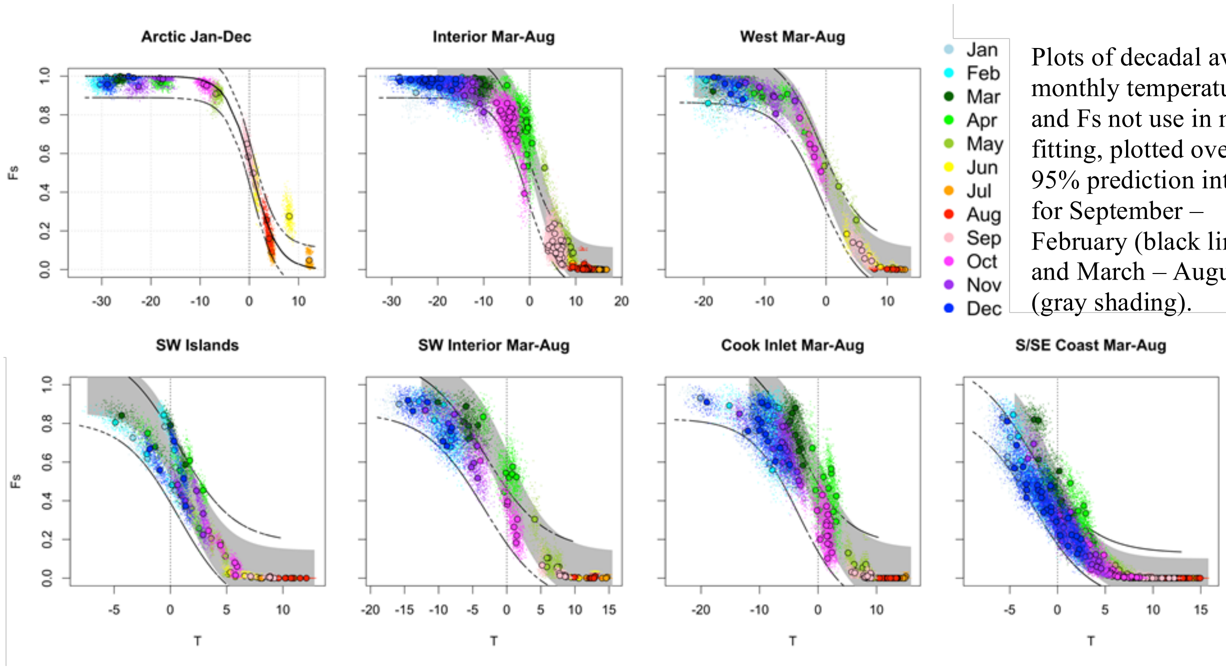
How were these data tested?

Re-calculating for each region and season repeatedly, leaving out one station each time and plotting the equations over a standard temperature interval to determine how stable they are. In most regions, leaving out one station had very little influence on the equation. Differences are most notable for the Arctic, where there are only three stations, and in the SW Islands and western regions. These regions also have relatively low station numbers. There is also some indication that these regions may not be ideal: stations in the eastern and western Aleutians display slightly different relationships between temperature and snow-day fraction. There may also be differences between stations in the northern and southern part of the western region.



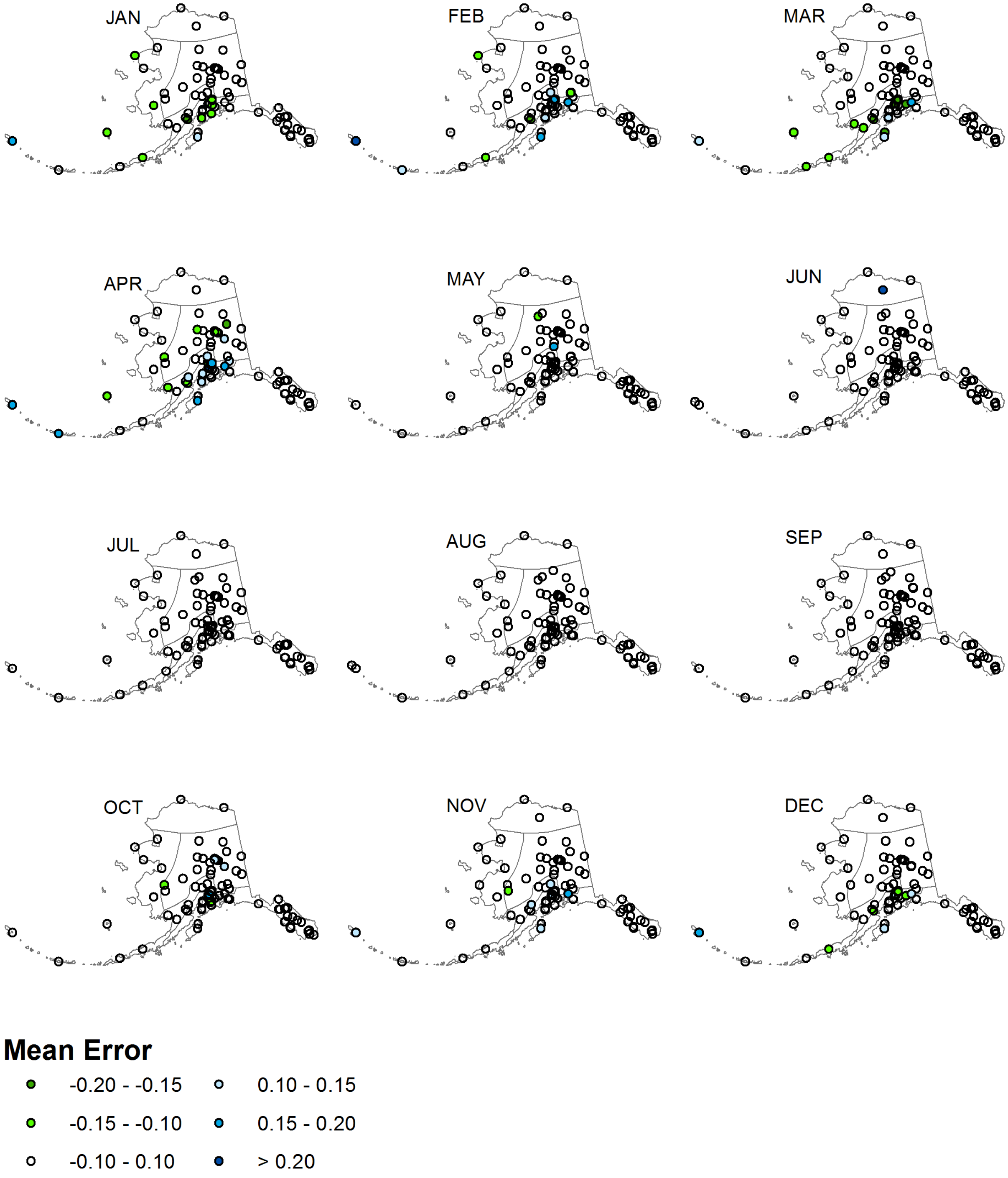
Red (blue, gray) lines show all of the leave-one-out equations for March-August (September-February, Arctic). Dark red (dark blue, black) lines show the full model for March-August (September-February, Arctic).

Plotting the withheld bootstrapped decadal average monthly temperatures and snow-day fractions against the 95% prediction interval of the logistic regressions. Most, but not all of the points fell within the prediction interval.

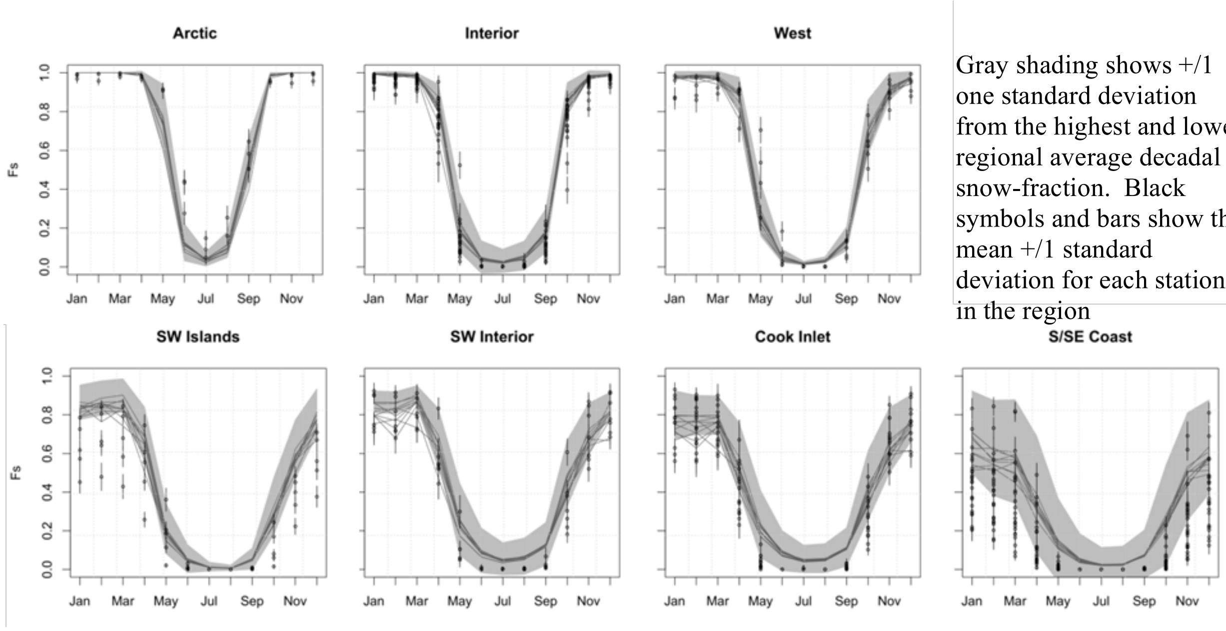


Plots of decadal average monthly temperature and Fs not use in model fitting, plotted over the 95% prediction intervals for September – February (black lines) and March – August (gray shading).

Applying the models to the withheld portion of the bootstrapped decadal average temperature and mapping the average residuals. Most residuals fall between -0.15 and +0.15. Most of the residuals that exceed 0.15 occur in the Cook Inlet region during the spring, where complicated topography can drive a great deal of variability in precipitation type over small distances.



Comparing average observed snow-fraction from the sites in a region with the average regional snow-fraction in the gridded product. Because the stations are not uniformly distributed throughout the region, regional averages from the stations and the gridded product are not expected to match in terms of absolute snow-fraction, but should show similar seasonal patterns.



Gray shading shows +/1 one standard deviation from the highest and lowest regional average decadal snow-fraction. Black symbols and bars show the mean +/1 standard deviation for each station in the region