THE EFFECT OF ATMOSPHERIC RIVERS ON WINTER ACCUMULATION RATES IN SOUTHWESTERN YUKON, CANADA ICE CORE DATA

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Introduction

Atmospheric rivers are long, narrow regions in the atmosphere, which transport significant volumes of water vapor out of the tropics. They are usually associated with extreme precipitation events in the middle and subpolar latitudes. The main goal of this study is to test the hypothesis that the winter accumulation rate measured in an ice core located in southwestern Yukon Territory, Canada varies with the magnitude and/or frequency of atmospheric rivers impacting this region.

Figure 1: Map view of the Eclipse ice core site. The black box represents the location of Figure 2.

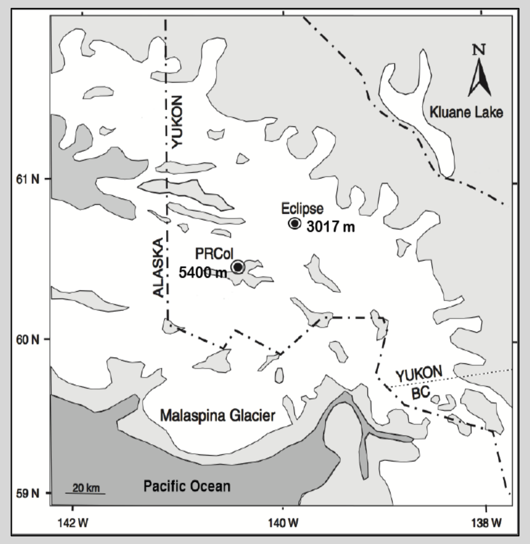

Figure 2: Plan view of the Eclipse ice core site. White represents perennial glacial ice, light gray represents land and dark gray represents ocean.

Methodology

- Winter (October-March) accumulation data is from the Eclipse ice core (60.85˚N 139.78˚W, 3017m asl; 345 long), which was extracted in 2002 and dates back to ~1000 A.D.[1]
- The 13 highest and 13 lowest accumulation winters were examined for patterns between moisture flux and accumulation. These sets of years where chosen because consistent sea-level patterns occur for these winters.[1]
- Daily mean values of moisture flux between the 850mb and 700mb levels were calculated across a lateral line from 146-134˚W along 60˚N (Figure 8) by using the daily mean meridional (north-south) wind and specific humidity data from the 20th Century Reanalysis V2 gridded dataset[1] from 1871-2010. Daily mean values of northward moisture flux into southwestern Yukon for each winter were calculated using Equation 1[2]. Moisture flux (moisture advection) is the horizontal movement of water vapor by the wind. The moisture flux data was standardized.
- Two moisture flux variables were calculated; the average southerly moisture flux and the number of ≥1σ events per October through December. The focus was on the average southerly moisture flux because of the southerly pattern of atmospheric rivers from the equatorial region of the Pacific Ocean.

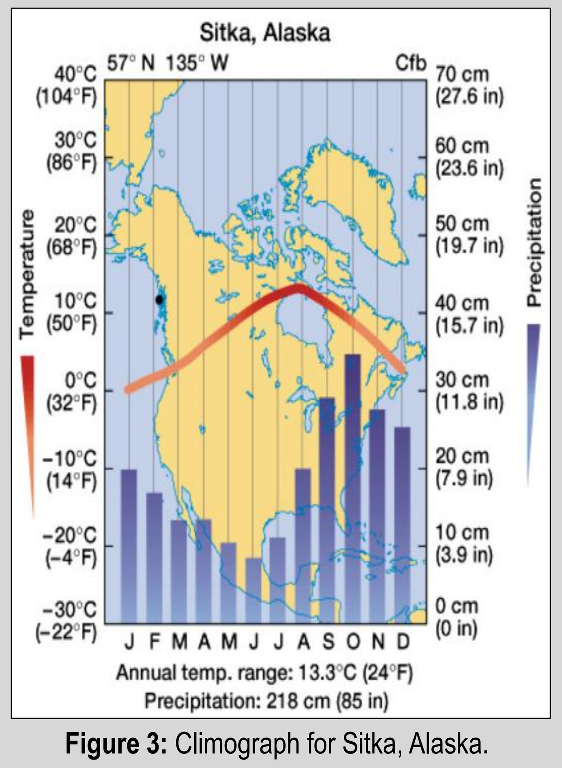

Figure 3: Climograph for Sitka, Alaska.

Equation 1: $\frac{1}{g}\int_{700}^{850} qv\,dp$

g = gravity = 9.8 m/s2
q = specific humidity (kg/kg)
v = meridional wind (m/s)
dp = change in pressure (mb)

- Correlations between the mean October through December moisture flux values and winter Eclipse ice core accumulation were explored. The time frame of October through December was chosen for the moisture flux values because this was the time of the year with the highest average regional precipitation (Figure 3).
- The expected result of this research is that high accumulation winters are associated with a large number of atmospheric rivers (i.e., moisture flux events), while the low accumulation winters are associated with relatively few atmospheric river events.

Results

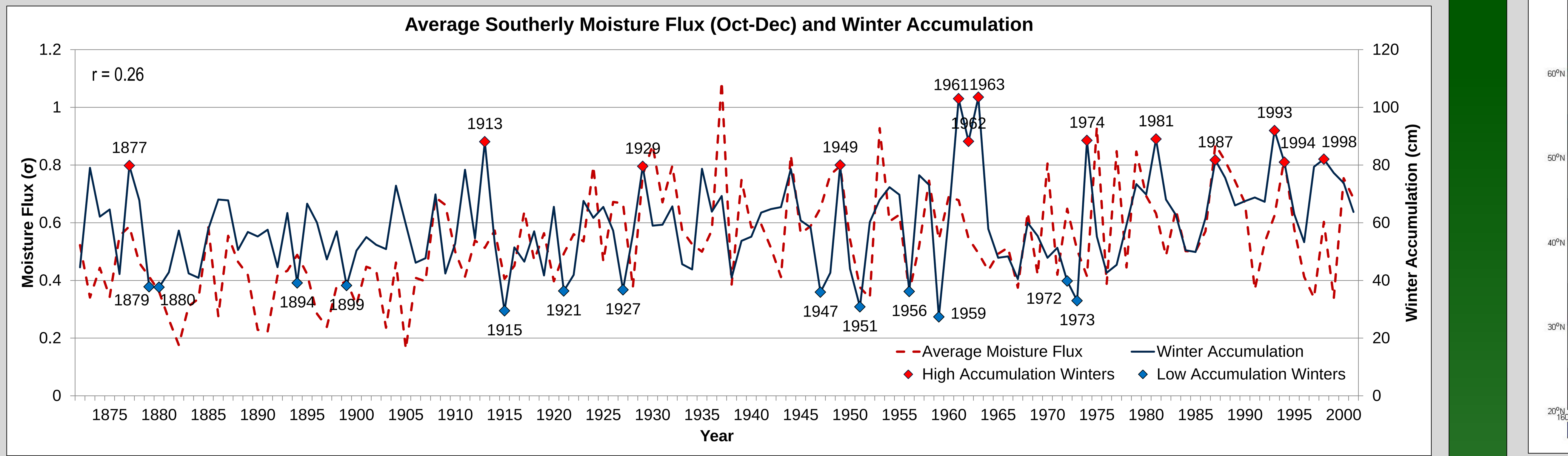

Figure 4: Standardized Average Southerly Moisture Flux (σ) is plotted in dashed red and Winter Accumulation (cm) is plotted in solid blue. The High Accumulation Winters (red diamonds) and the Low Accumulation Winters (light blue diamonds) are labeled with the year.

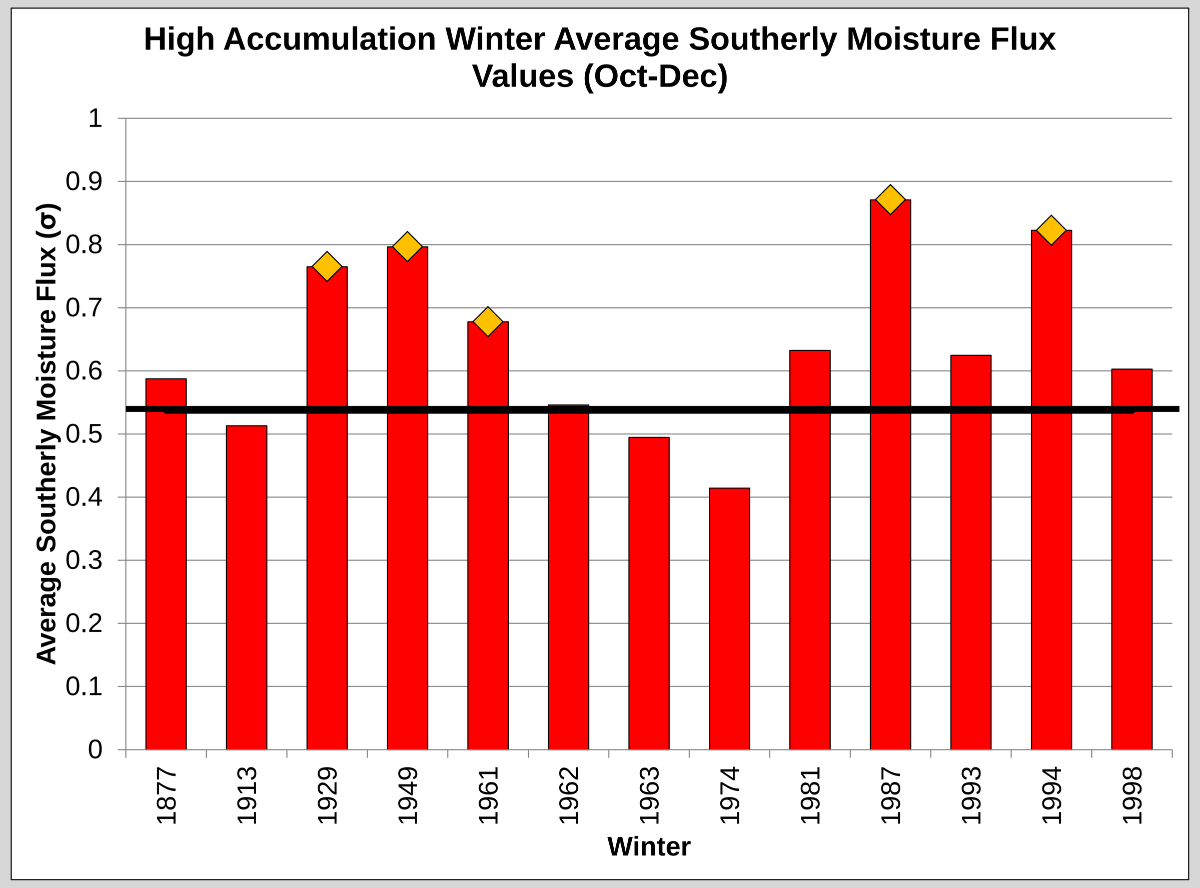

Figure 5: The Winter Moisture Flux Values are plotted for the 13 High Accumulation Winters (red bars) compared to the Mean Moisture Flux of the entire 139-year data set (black line). Marked with orange diamonds are the 5 of the 13 moisture flux values that are in the top 20%.

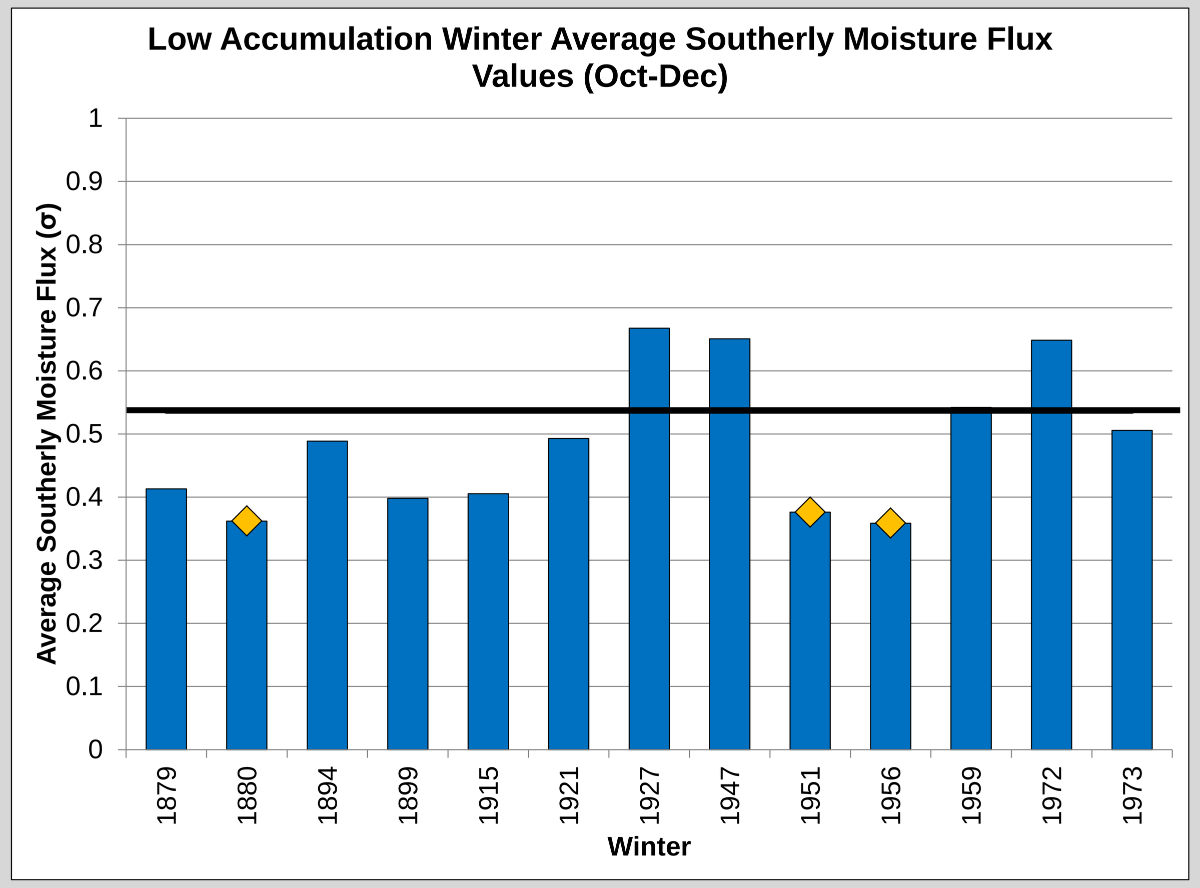

Figure 6: The Winter Moisture Flux Values are plotted for the 13 Low Accumulation Winters (light blue bars) compared to the Mean Moisture Flux of the entire 139-year data set (black line). Marked with orange diamonds are the 3 of the 13 moisture flux values that are in the bottom 20%.

- For the 13 highest accumulation winters, 77% (10/13) of the October through December southerly moisture flux values are above the mean moisture flux (Figure 5). For the 13 lowest accumulation winters, 69% (9/13) of the moisture flux values are below the mean moisture flux (Figure 6).
- Of the 13 high accumulation years, 5 were in the top 20% of the moisture flux dataset (Figure 5). Similarly, 3 of the 13 low accumulation winters were in the bottom 20% (Figure 6).
- The winter accumulation and the number of ≥1σ events that occurred between October and December has an r-value of 0.21 (Figure 7).
- The event depicted in Figure 8 is a ≥1σ event from the 1994 winter season. This season was the 10th highest accumulation winter overall with the second highest October through December average southerly moisture flux out of the selected 13 high accumulation years, but was 9th overall out of the 139-year dataset.

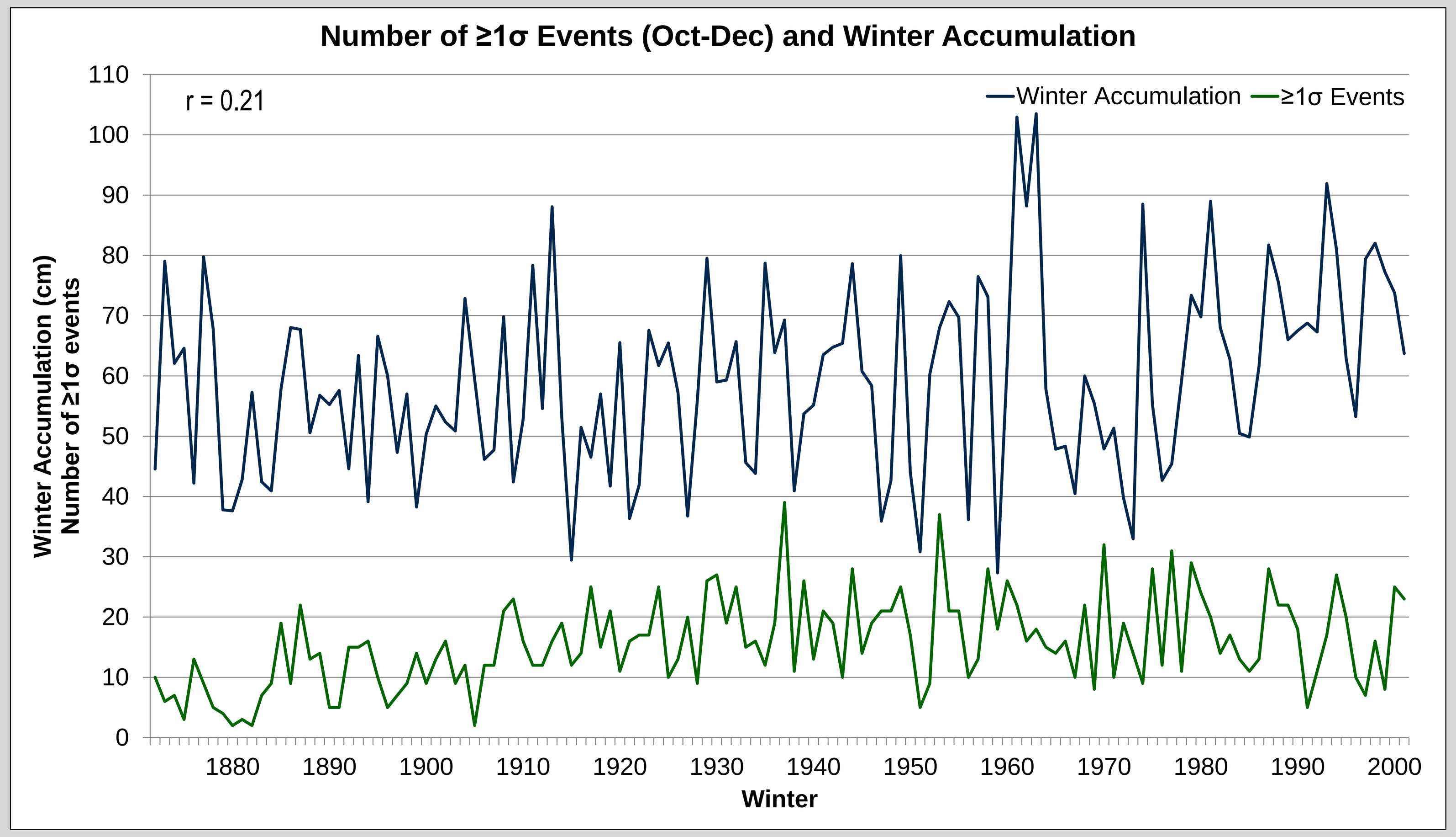

Figure 7: The number of ≥1σ events (plotted in solid green) with the winter accumulation in cm (plotted in dark blue).

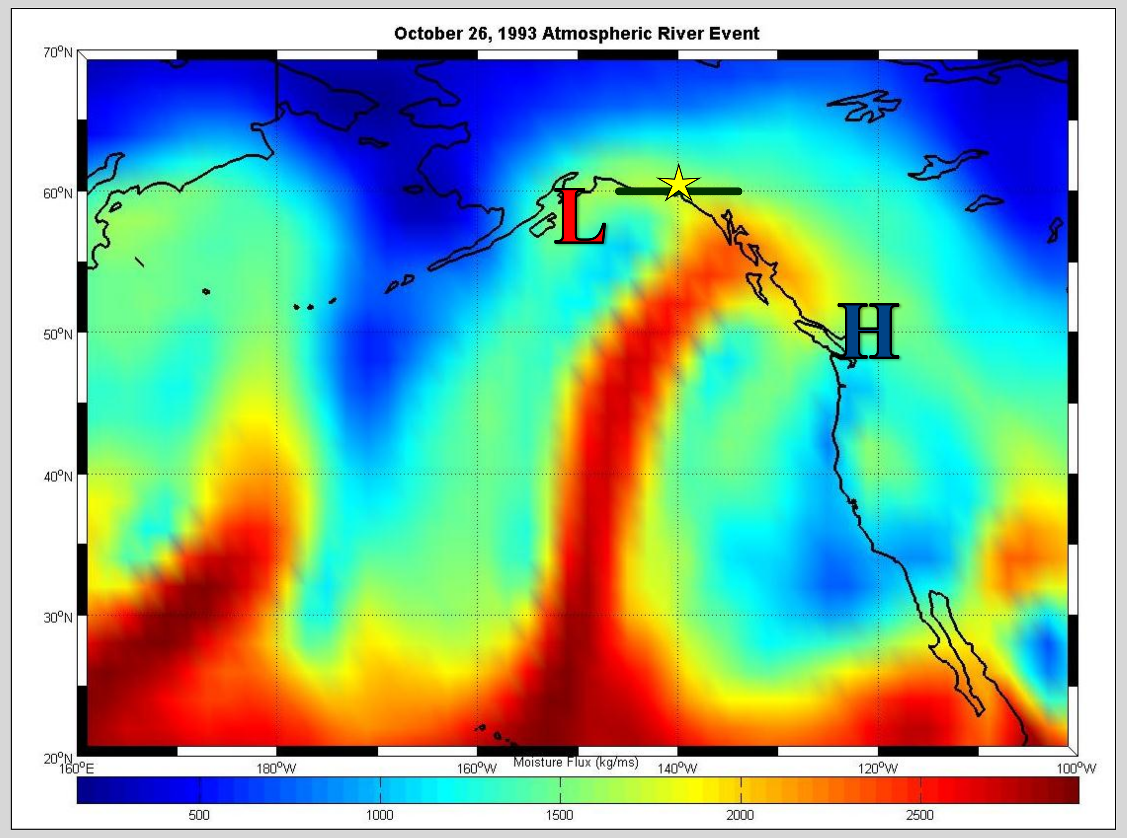

Figure 8: Moisture flux chart for October 26, 1993. The star is the location of the Eclipse ice core site and the dark green line is the region through which the moisture flux was calculated.

Conclusions

- 77% of the high accumulation winters were above the southerly moisture flux mean for October through December, suggesting that the majority of highest accumulation winters will have above average moisture flux values during those months. Similarly, 69% of the low accumulation winters were below the mean, the majority of the low accumulation winters will have below average moisture flux values. Of the high accumulation winters, 38% had a moisture flux in the top 20% of the data (Figure 5), and 23% of the low accumulation winters had a moisture flux in the bottom 20% (Figure 6).
- An r-value of 0.21, shows that the correlation between the number of ≥1σ moisture flux events (October-December) and the winter accumulation does not represent a direct relationship. These results suggest that the relationship between accumulation and moisture flux is not simply explained through either magnitude or frequency, but instead by an irregular combination of the two.
- Possible reasons for high and low accumulation winters that are not explained well by the moisture flux data include the following: 1. There may be flaws in the dating method for what is considered a winter season in the ice core. 2. The 20th Century Reanalysis V2 data has significant changes in variance throughout the dataset due to a significant increase in observations in the 1930s.

Further Research

- Identify the types of atmospheric patterns that are responsible for the atmospheric rivers that impact the Eclipse ice field.
- Evaluate the moisture flux through different pressure levels in the atmosphere.
- Apply this method to ice cores taken at different locations along the northern Pacific.
- Apply different restrictions to how a "winter season" is defined, by expanding or contracting the sequence of months included in a season.

Acknowledgements

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The 20th Century Reanalysis V2 gridded dataset is provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/.[3]

References

[1] Kelsey, E., C. Wake, E. Osterberg, and K. Kreutz. A Surprise in the North Pacific: Results from Applying a New Nonlinear Method for Calibrating Ice Cores. Poster session presented at: American Meteorological Society 93rd Annual Meeting, 2013 Jan 6-10; Austin, TX.
[2] Dominguez, F., and P. Kumar, 2004. Dominant Modes of Moisture Flux Anomalies over North America. *Journal of Hydrometeorology,* 6, 194-209.
[3] Compo, G.P., J.S. Whitaker, P.D. Sardeshmukh, N. Matsui, R.J. Allan, X. Yin, B.E. Gleason, R.S. Vose, G. Rutledge, P. Bessemoulin, S. Brönnimann, M. Brunet, R.I. Crouthamel, A.N. Grant, P.Y. Groisman, P.D. Jones, M. Kruk, A.C. Kruger, G.J. Marshall, M. Maugeri, H.Y. Mok, Ø. Nordli, T.F. Ross, R.M. Trigo, X.L. Wang, S.D. Woodruff, and S.J. Worley, 2011: The Twentieth Century Reanalysis Project. *Quarterly J. Roy. Meteorol. Soc.*, 137, 1-28.