Imprint of the Pacific Decadal Oscillation on the Western Canadian Arctic climate

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Abstract

It is well established that the Arctic strongly influences the global climate through positive feedback processes, one of the most effective being the decrease in sea-ice extent (Cohen et al. 2014, Screen and Simmonds 2010). Understanding the internal mechanisms forcing the climate variability of this region is thus a prerequisite to better forecast future global climate variations. Here, sedimentological evidence from an annually laminated record highlights that the Pacific Decadal Oscillation (PDO) has been a persistent regulator of the regional climate in the Western Canadian Arctic since the past 700 years. Annual varve thickness from East Lake at Cape Bounty, Melville Island, is negatively correlated to the PDO indexes (Mantua et al. 1997, MacDonald and Case 2005, Gedalof and Smith 2001, D'Arrigo et al. 2001) throughout most of the last 700 years, suggesting drier conditions during high PDO phases, and vice-versa. This is in agreement with known regional teleconnections whereby PDO indexes are negatively and positively correlated to precipitation and mean sea level pressure, respectively. Future negative PDO phases will likely amplify the current warming.

Fig. 1 Study site Melville Island Cape Bounty East Lake

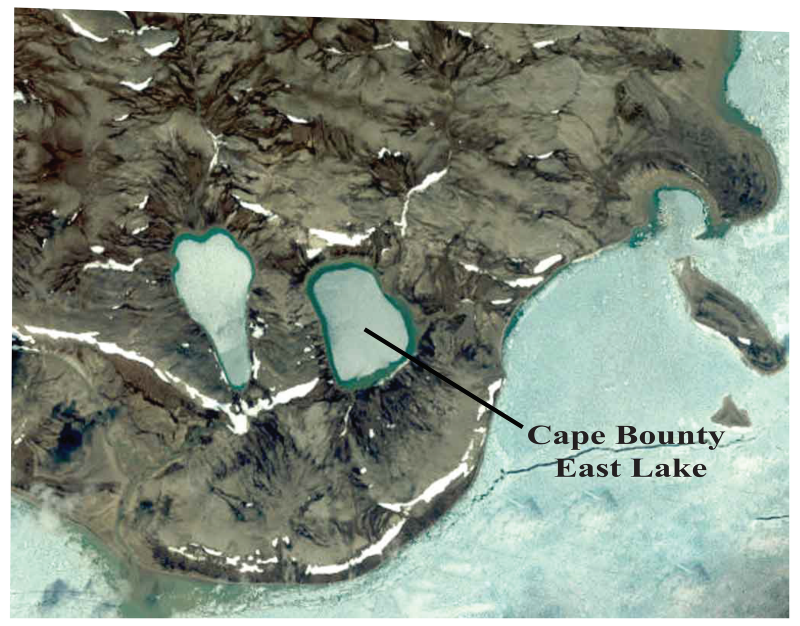
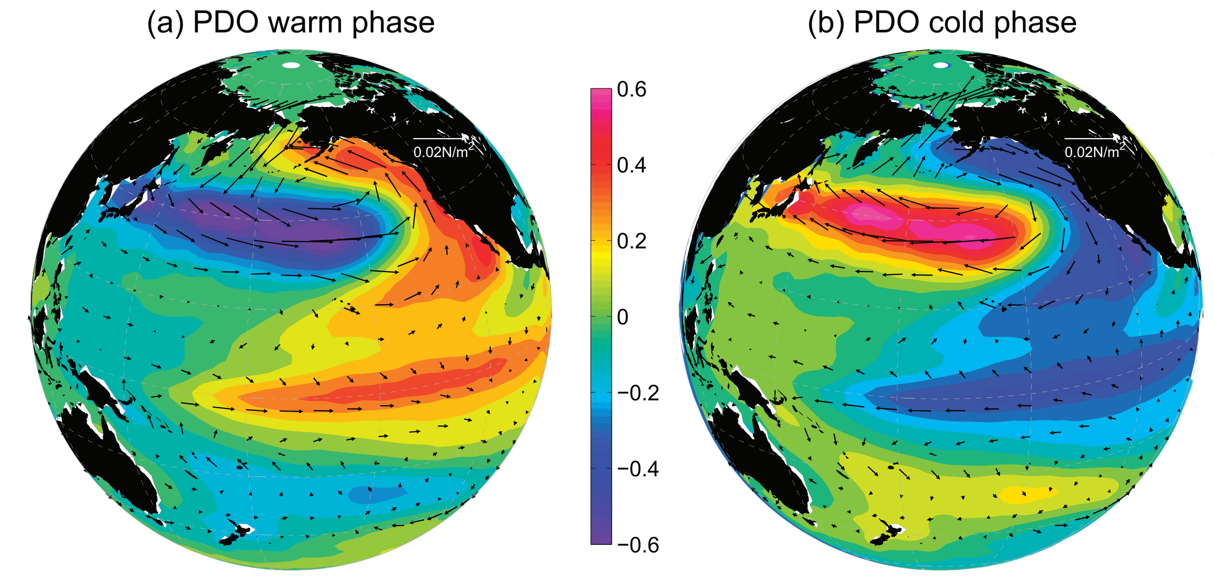


Fig. 2 The Pacific Decadal Oscillation (PDO)

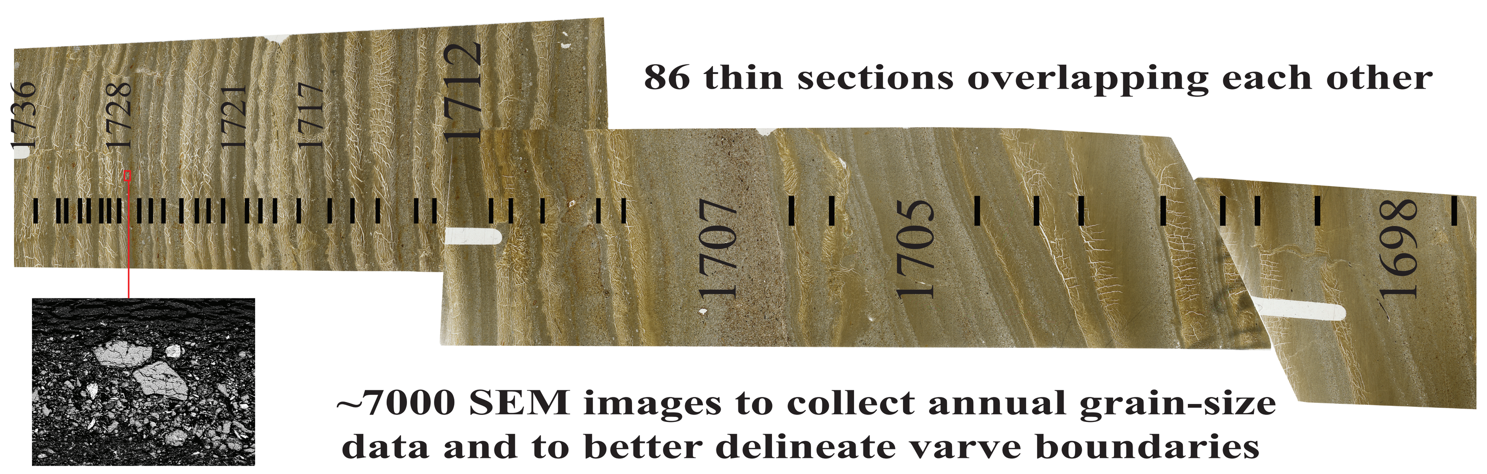


Arrows: surface winds stress

From Zhang and Delworth (2015)

PDO: a 20-30 year-cycle and a lower component at ~60 year-cycle.

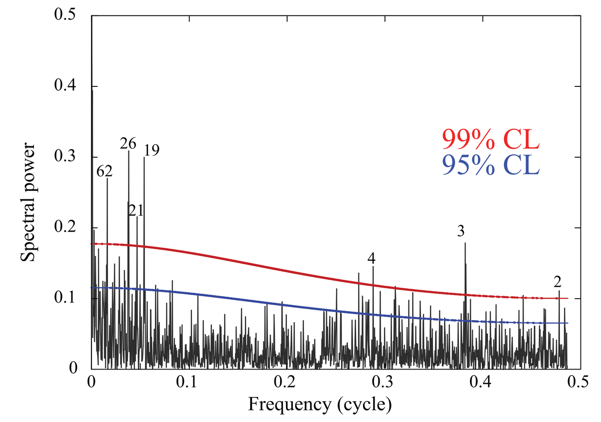
Fig.3 The varves from Cape Bounty



86 thin sections overlapping each other

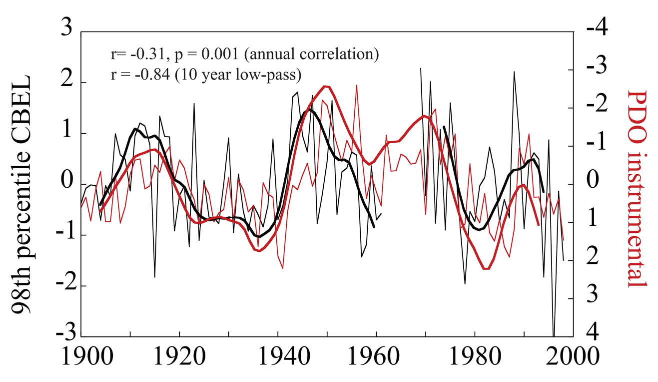
~7000 SEM images to collect annual grain-size data and to better delineate varve boundaries

Fig. 4 Spectral analysis of the 1750 years of varve thickness at Cape Bounty East Lake



20-30 yr cycle ~60 year cycle are consistent to the higher and lower range of the PDO periodicity

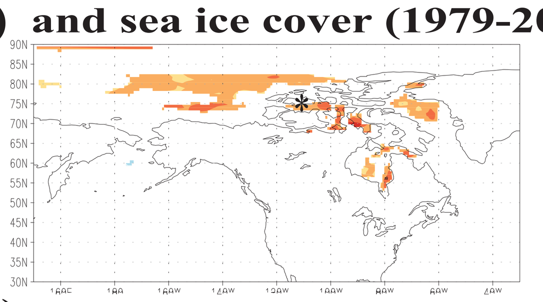
Fig. 5 Annual coarse grain size versus instrumental PDO



Thicker varves during the negative PDO phases (PDO-)

Fig. 6 Correlation between (JJA) PDO and sea ice cover (1979-2016)

a)



b) Same as a), but for Sept-Nov.

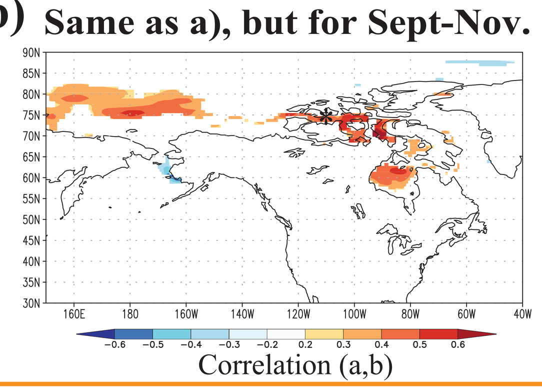
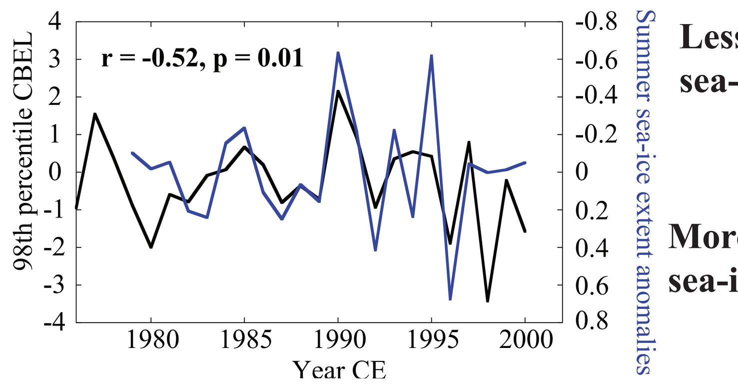


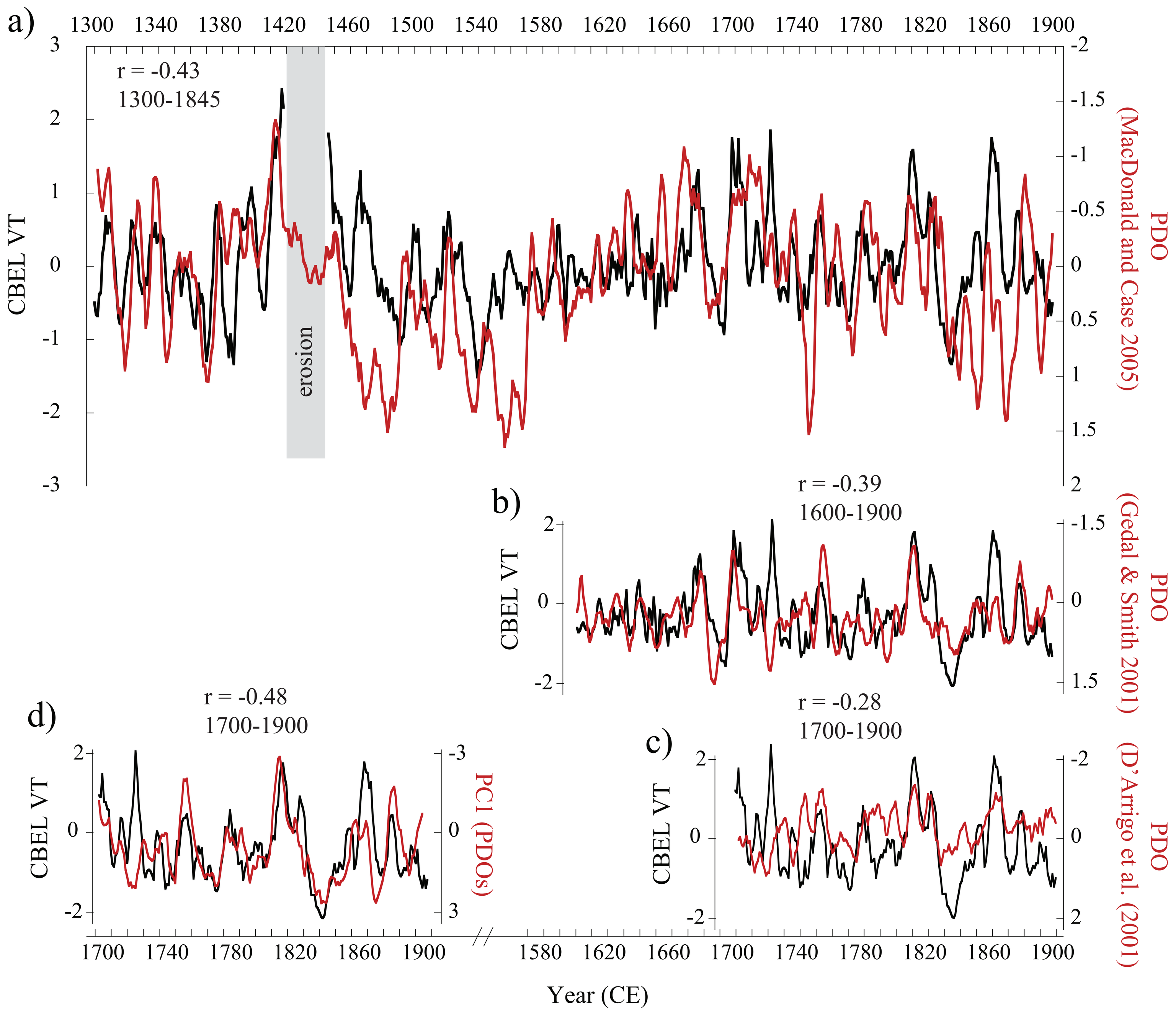
Fig. 7 Coarse grain-size versus instrumental sea-ice extent 84°- 67°N, - 100° W - 170° E

(Data from the National Snow and Ice Center)



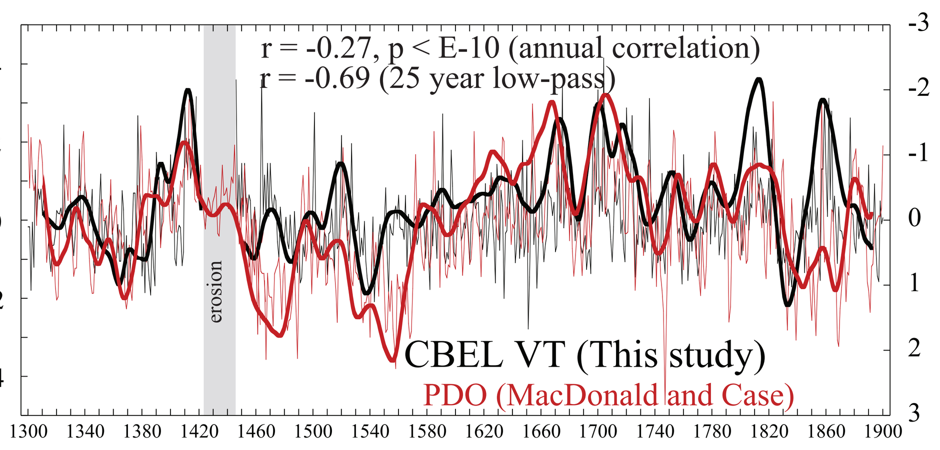
Increase (decrease) sea-ice cover during PDO+ (PDO-) during summer-autumn

Fig. 8 Comparison between CBEL varve thickness with reconstructed PDOs from tree-rings.



Data are filtered by a 5-year running-mean to remove higher frequencies. All correlations are significant at $p < 0.0001$

Same as Fig. 8a, but using a 25 year-low pass filter on the series

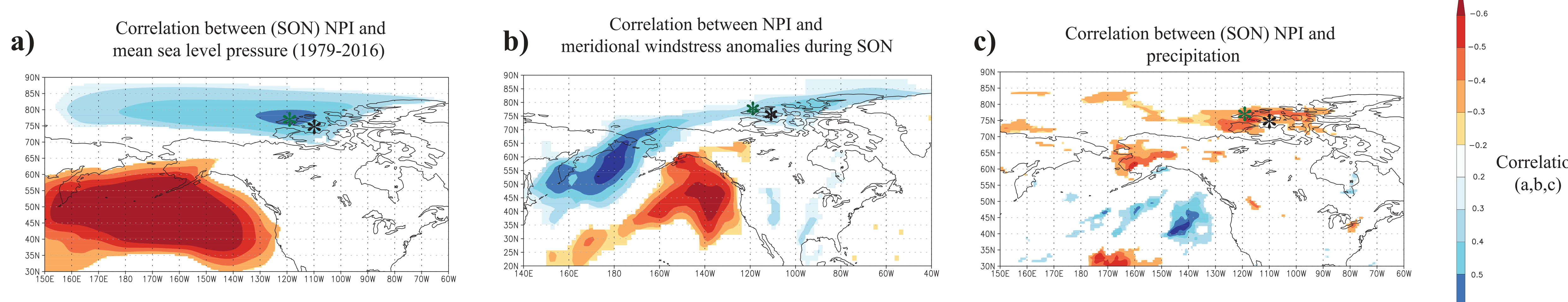


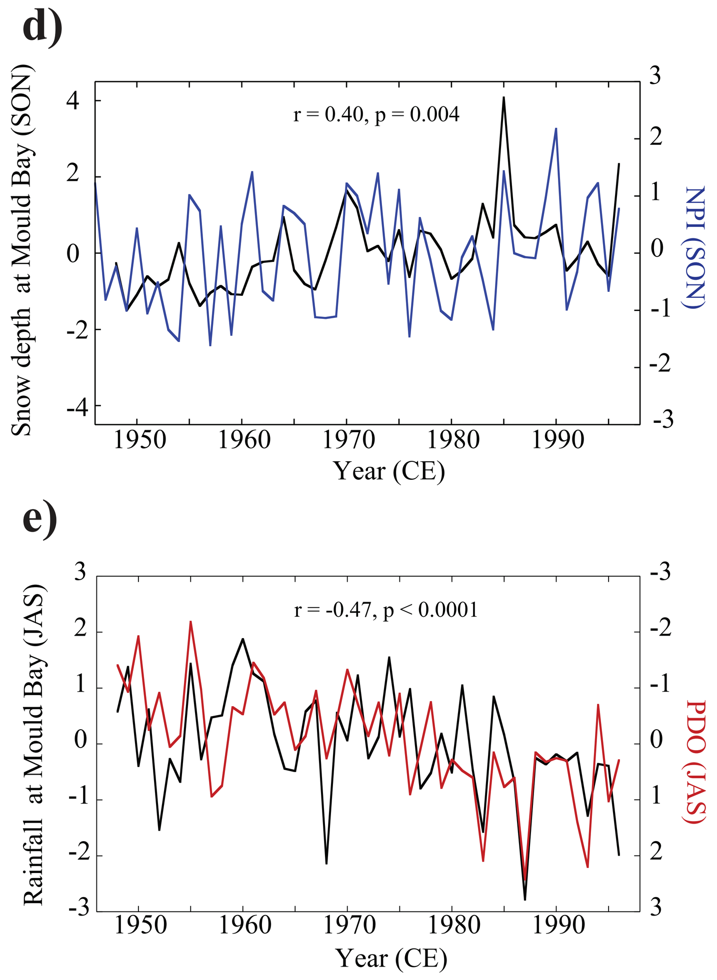
Main observation: Thicker varves develop during the negative PDO phases (PDO-)

The reconstructed PDOs show periods of inconsistencies when compared to each other. In Fig. 8d a principal component analysis was performed on the3 reconstructed PDOs (1900-1700). The PC1 of the PDOs explains 51% of the variability and its annual correlation with our record is compelling, especially from 1740-1900 ($r = -0.68$).

Fig. 9a,b,c,d,e Mechanisms linking our record to the PDO: the North Pacific index a more direct measure of the strenght of the Aleutian Low (NPI:Trenberth and Hurrell, 1994),

Mould Bay weather station (Green asterisk) Cape Bounty East Lake (Black asterisk)





a) A weakened Aleutian Low (increased SLP) is seen in the Pacific during times of positive NPI (NPI+), as is the case during PDO-. Meanwhile, an anomalous low-pressure system is observed over the Western Canadian Arctic (WCA), consistent with an increased likelihood of precipitation (c,d,e). In (b), Sustained southerly wind anomalies are observed in the northernmost part of the Pacific during PDO- (NPI+) (also in Fig. 2), increasing heat and moisture transport into the WCA region. All these features likely explain thicker varves encountered during negative PDO phases (NPI+) as seen in Figs 5 & 8.

Conclusion

For the first time we provided evidence of a significant impact of the PDO (NPI) in the Western Canadian Arctic (WCA) over the past 700 years. The existence of a reduced sea-ice extent during PDO- (NPI+) combined with sustained southerly moisture-laden winds from the North Pacific over the WCA likely increase precipitations in the region during summer-autumn. As the sea-ice extent will continue to decrease in the following decades, precipitation should increase in the WCA, especially under a warmer Arctic; a pattern which will likely be amplified during the PDO- (NPI+) (Screen and Francis 2016).

References

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