Imprint of the Pacific Decadal Oscillation on the Western canadian Arctic

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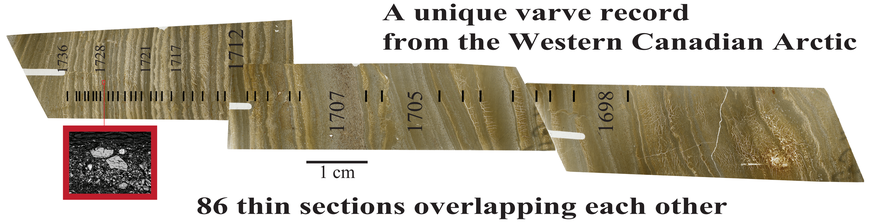
Abstract

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 pre cipitation and mean sea level pressure, respectively. These climate anomalies projecting onto the PDO- (NPI+) phase are key factors in enhancing evaporation and subsequent precipitation in this region. As projected sea-ice loss will contribute to enhanced future warming in the Arctic, future negative phases of the PDO (or NPI+) will likely ast as amplifiers of this positive feedback.

Study site : Cape Bounty East Lake

Varves from Cape Bounty, A unique varve record from the Western Canadian Arctic

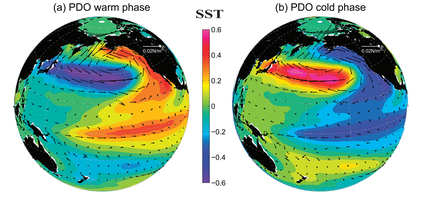


86 thin sections overlapping each other

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

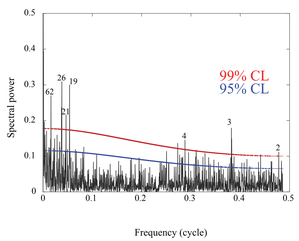
Pacific Decadal Oscillation (PDO)

Arrows: surface winds stress



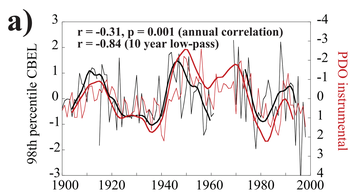
PDO: Recurrent pattern of SST change in the North Pacific with a 20-30 year-cycle and a lower component at ~60 year-cycle. White asterisk denotes Cape Bounty East Lake.

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

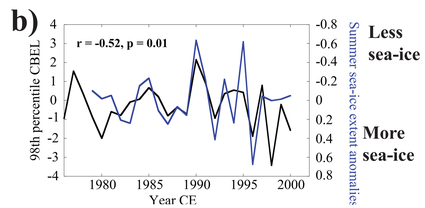


20-30 yr cycle ~60 year cycle are consistent to the higher and lower range of the PDO periodicity

Instrumental PDO (a) and sea-ice extent (b) compared to coarse grain-size



Coarser sediments during the negative PDO phases (PDO-)



84°- 67°N, - 100° W - 170° E
(Data from the National Snow and Ice Center)

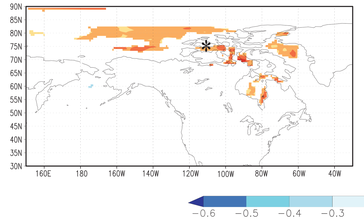
Highlights

Coarse deposits during the negative PDO phases

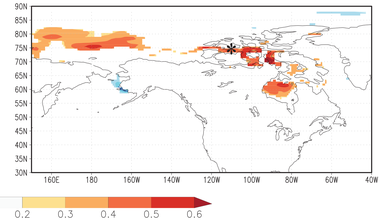
Coarse grain-size appears to increase during low sea-ice extent

Less sea-ice cover during negative PDO phases.

a) Correlation between (July-Aug.) PDO and sea ice cover (1979-2016)



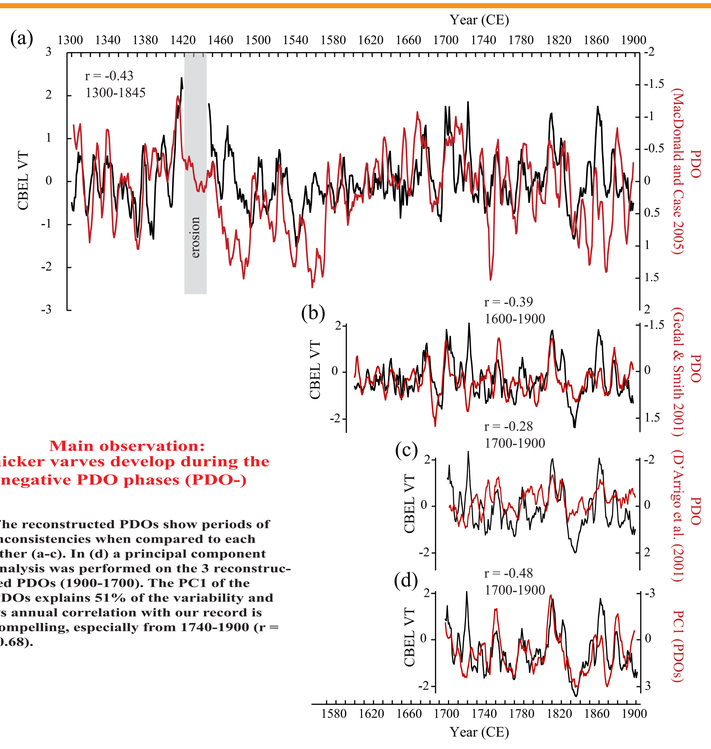
b) Same as a), but for Sept-Nov.



−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6

Increased (decreased) sea-ice cover during the positive (negative) PDO phases

Comparison between Cape Bounty East Lake varve thickness and reconstructed PDOs from tree-rings

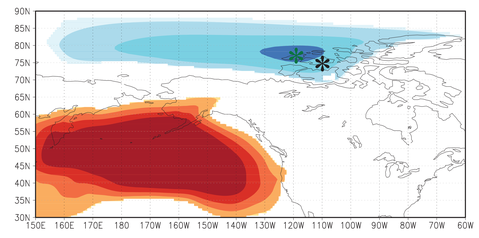


Main observation: Thicker varves develop during the negative PDO phases (PDO-)

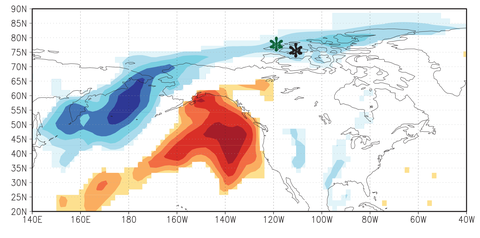
The reconstructed PDOs show periods of inconsistencies when compared to each other (a-c). In (d) a principal component analysis was performed on the 3 reconstructed PDOs (1900-1700). The PC1 of the PDOs explains 51% of the variability and its annual correlation with our record is compelling, especially from 1740-1900 (r = -0.68).

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).

a) Correlation between (SON) NPI and mean sea level pressure (1979-2016)

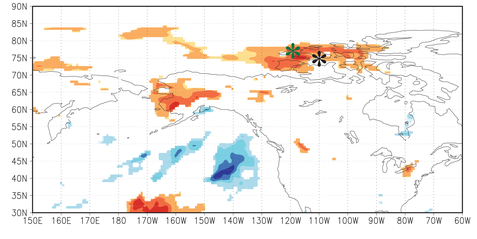


b) Correlation between NPI and meridional windstress anomalies during SON



−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6

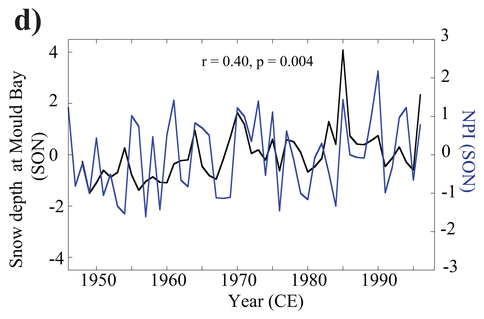
c) Correlation between (SON) NPI and precipitation



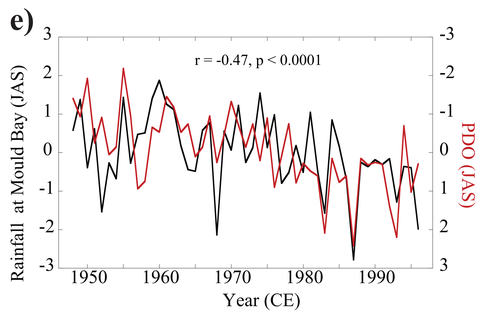
a) Weakened Aleutian Low in times of positive NPI
b) Low-level southerly winds from Pacific reach our site
c) Increased precipitation is seen during autumn
d) More increase snowfall during positive phase of NPI
e) More rainfall during negative PDO phases

Instrumental NPI (d) and PDO (e) compared to precipitations from nearby weather station (green asterisk shown in a) and b)).

d)



e)



Note that Mould Bay weather station stopped operating in 1996 CE

Conclusion

For the first time we provided evidence that the PDO – Western Canadian Arctic relationship has persisted at least for the past ~700 years as revealed by the strong coherence between the CBEL varve record and multiple PDO reconstructions, suggesting some potential for decadal-scale climate prediction. These climate anomalies during the negative phases of the PDO will likely continue to impact not only the Western Canadian Arctic, but also the whole Arctic (Screen and Francis 2016). Future warming is projected to further decrease mslp and increase precipitation in Arctic regions (Screen et al., 2015). As the sea-ice extent will continue to decrease in the following decades, precipitation might increase in the Western Canadian Arctic, especially under a warmer Arctic in times of PDO- (NPI+).

References

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Acknowledgements

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