Evolution of Arctic Oscillation in the Past 21,000 Years: A Modeling Study

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1 Introduction

Arctic oscillation (AO) is one of the most influential mode linked to mid-latitude wintertime weather and climate in the Northern Hemisphere. The long-term variability of AO's mean state and its amplitude in the past 21,000 years, due to lack of observations, still remains unknown.

Here, we investigate the AO's behavior and features in a set of long-term transient simulations covering the last 21,000 years using NCAR CCSM3, suggesting that: **(1)** Two AO modes, glacial mode and inter-glacial mode, can be precisely identified in our preliminary results. AO's mean state and its interannual amplitude in the glacial mode are distinctly weaker than those in the interglacial mode. **(2)** AO's inter-annual amplitude is proportional to its mean state of south-to-north pressure gradient throughout the last 22,000 years. **(3)** The changes of land ice sheets over North America and Scandinavia play a key role in modulating mid-latitude atmospheric circulation and AO's variability through upward propagating Eliassen-Palm fluxes and thermal wind relations.

2 Model and Simulations

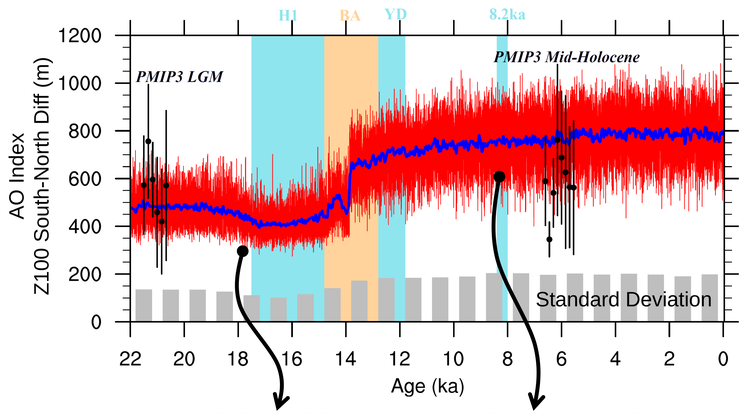
Model:	NCAR CCSM3 with T31
Simulation Length:	22,000 years (22ka to pres.) transient simulations
All Forcing Run:	Forcing = ORB + CO2 + MWF + ICE
Sensitivity Run 1:	Forcing = ORB
Sensitivity Run 2:	Forcing = CO2
Sensitivity Run 3:	Forcing = MWF
Sensitivity Run 4:	Forcing = ICE
9 PMIP3 Models:	For comparison

Forcing Details:

ORB: Solar insolation with 22ka-through-present realistic orbital parameters
CO2: Greenhouse gases (CO2, CH4, and N2O) concentrations from ice cores
MWF: North Atlantic and Southern Ocean melting water input
ICE: Land ice sheets from ICE-5G dataset
Others: Modifications of coastlines due to sea level changes

3 Arctic Oscillation

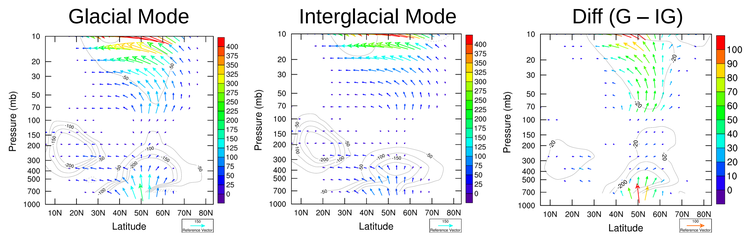
3.1 AO Variability in the Past 21,000 Years



	AO Glacial Mode	AO Interglacial Mode
Mean State	WEAK South-North Gradient	STRONG South-North Gradient
Amplitude	SMALL Interannual Variance	LARGE Interannual Variance

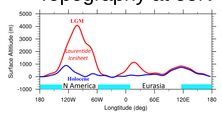
Note: AO's glacial and interglacial modes CANNOT be identified in slice simulations like PMIP3

3.2 E-P Fluxes for Glacial & Interglacial Modes



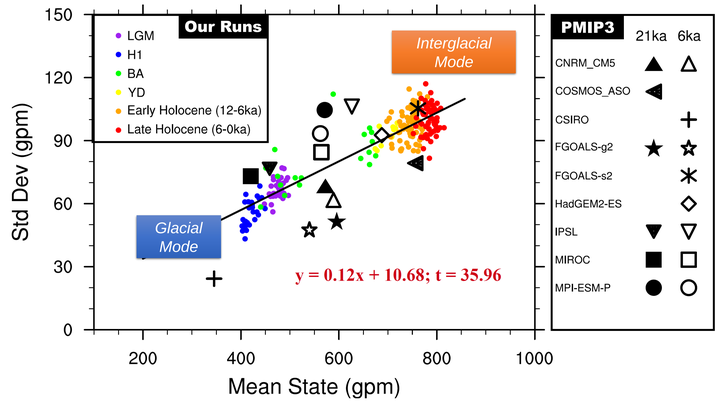
Stronger upward propagating E-P fluxes due to steep terrain around North Atlantic favor a weaker AO mean state and variance at LGM

Topography at 55N

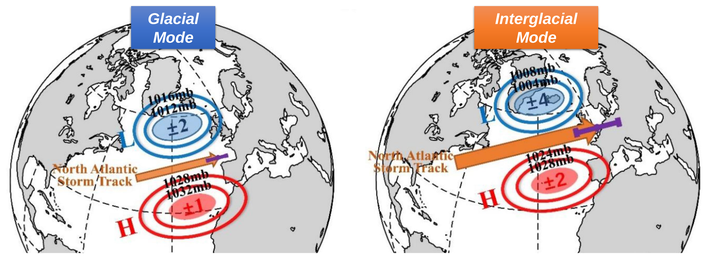


4 Schematic Diagram

4.1 Two AO Modes in MeanState-Variance Space



4.2 Two Typical AO Modes



5 Summary

Our results show the diversity nature of AO on up to orbital timescale. In the past 21,000 years, AO behaves in two major modes, the glacial mode and the interglacial mode. The former has weaker mean state and variance than the latter one. The present results significantly improve our understanding of AO's evolution since LGM, and provide the community a potential modeling evidence for reconciling various paleoclimate proxies.

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