Wintertime atmospheric response to Atlantic multi-decadal variability and the role of stratosphere

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Introduction

The winter North Atlantic Oscillation (NAO) changes drive a significant portion of the Atlantic Multidecadal Variability (AMV). However, it is still controversial whether ocean-atmosphere interaction or other processes internal or external to the atmosphere force the NAO changes.

Data and models

- NCEP reanalysis and HAD-SST and SLP
- Non-coupled experiment with low and high top ECHAM5
- Long-term coupled control experiments using ECHAM6/MPIOM

Fig. 1

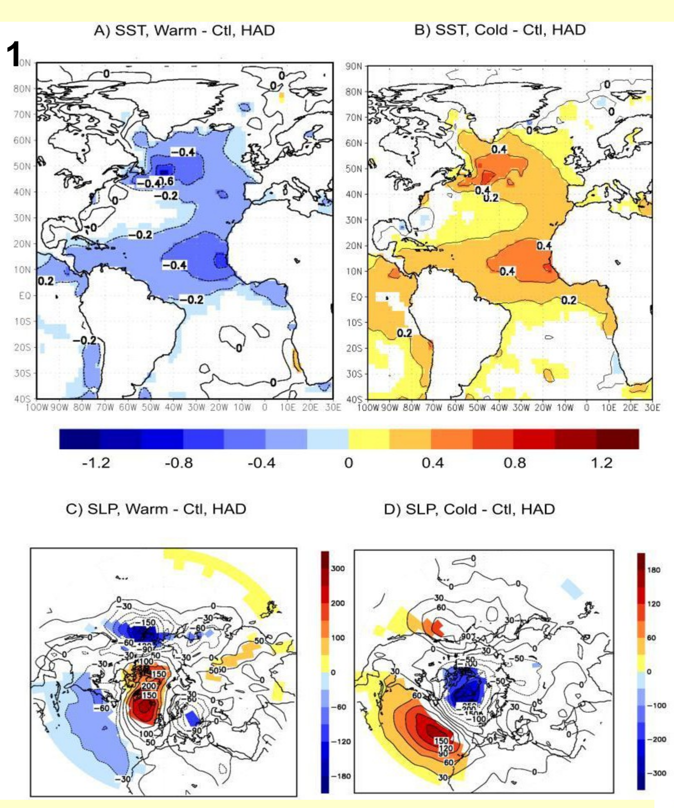
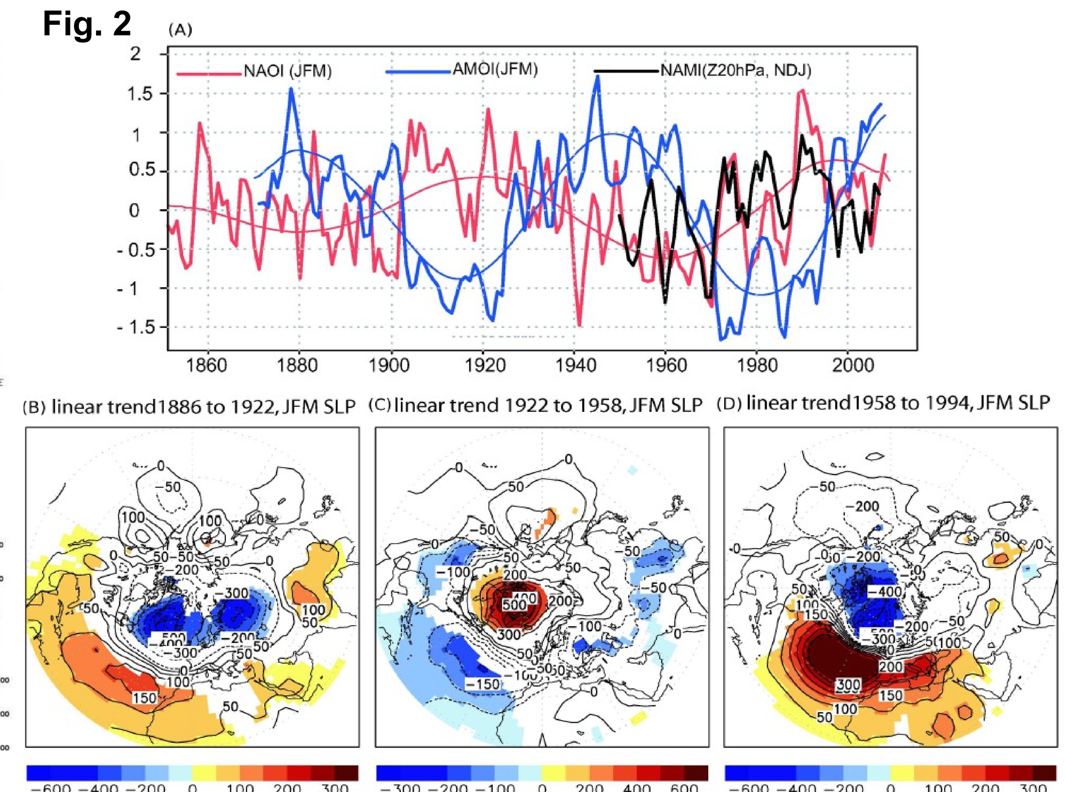


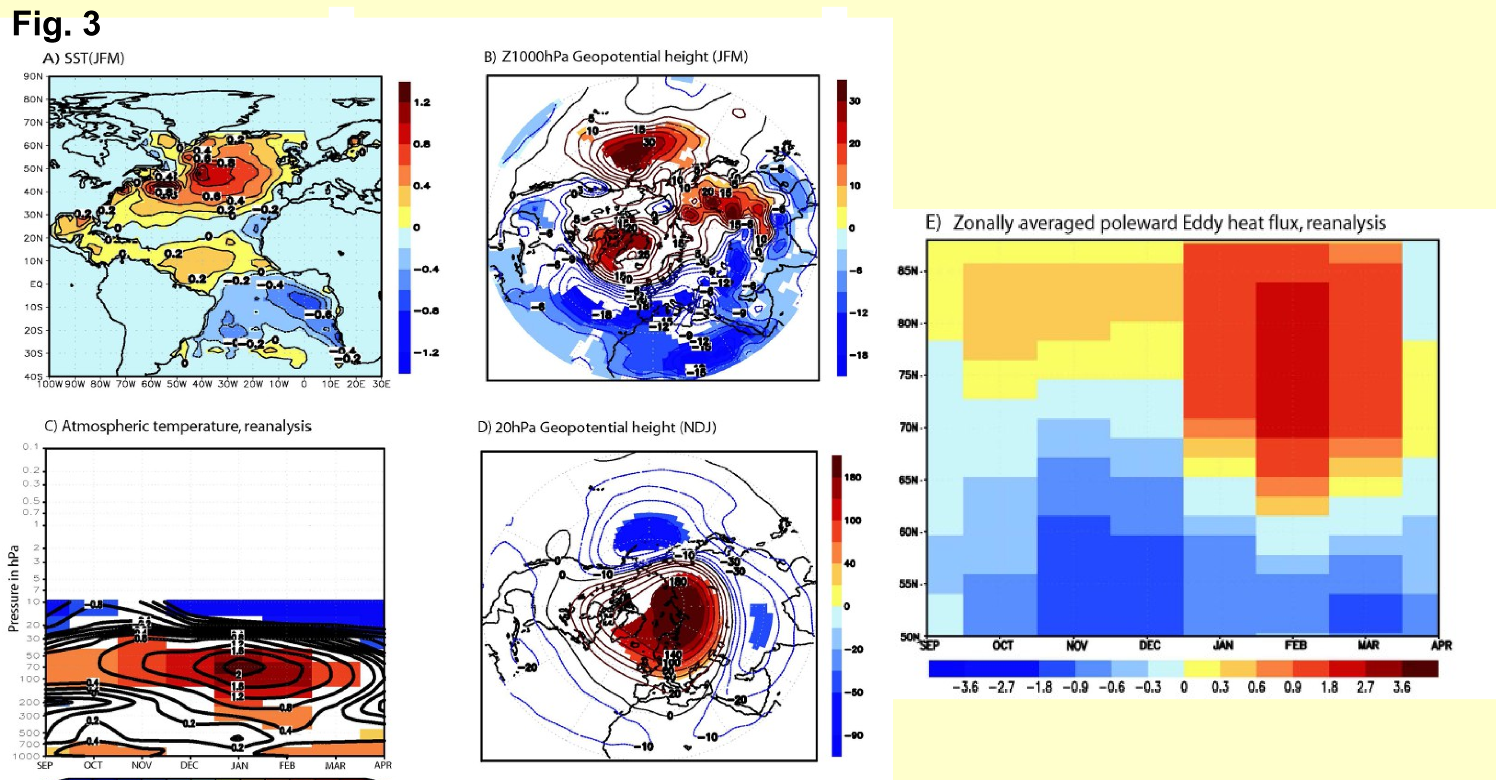
Fig. 2



- Observed warm (cold) AMV was associated with negative (positive) NAO (Fig. 1 and Fig.2 A
- Multidecadal fluctuations (Fig. 2A) constitute the first SSA-mode of both AMV and NAO variability
- The highest coherence between NAO and AMV is seen in multidecadal timescales (not shown)
- Multidecadal NAO-trend from 1958 to 1994 can be seen as part of multidecadal NAO fluctuation (Fig.2 B-C)

Warm conditions of 1950s, NCEP and observation

Fig. 3



AMV-warming in 1950s is associated with precursory stratospheric warming and vortex weakening. The stratospheric warming propagate downward and reach the troposphere in form of a negative NAO in late winter.

Warm conditions of 1950s model simulations

Fig. 4

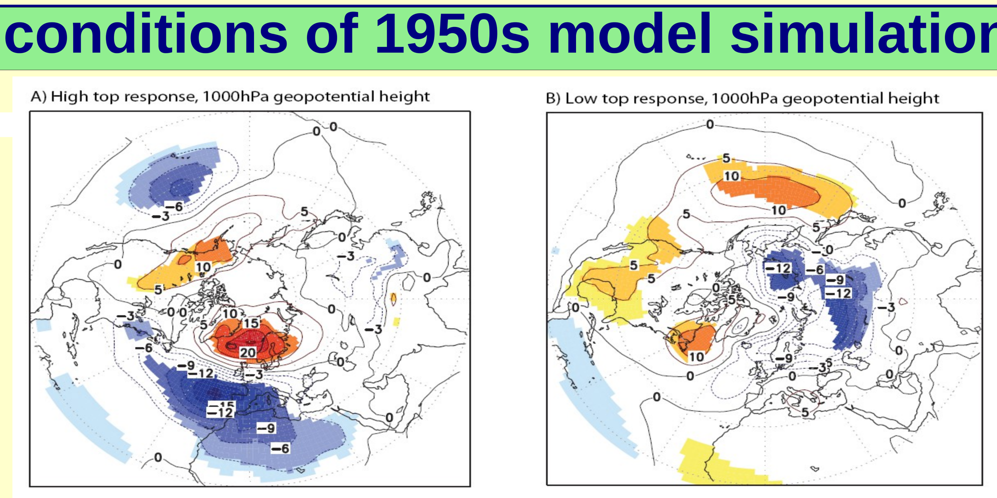
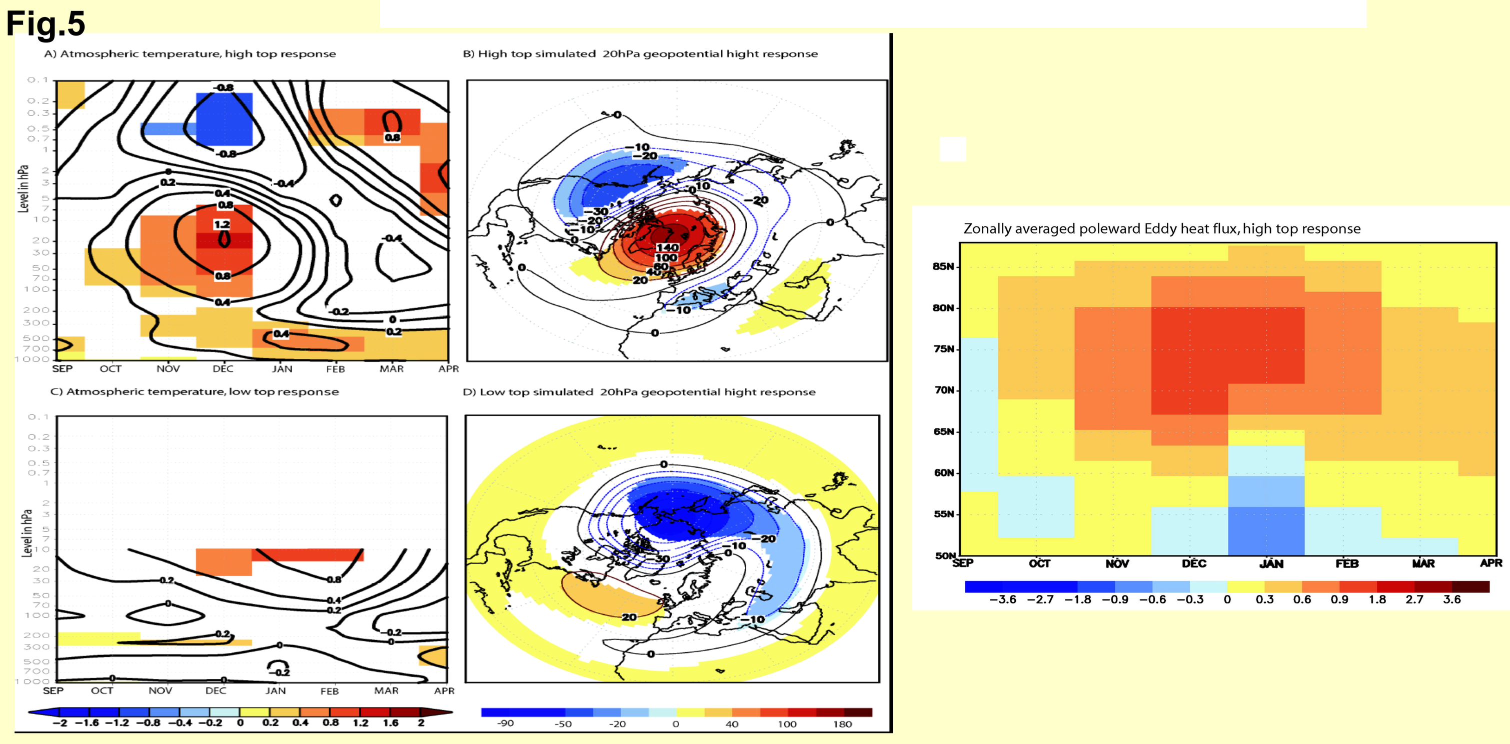


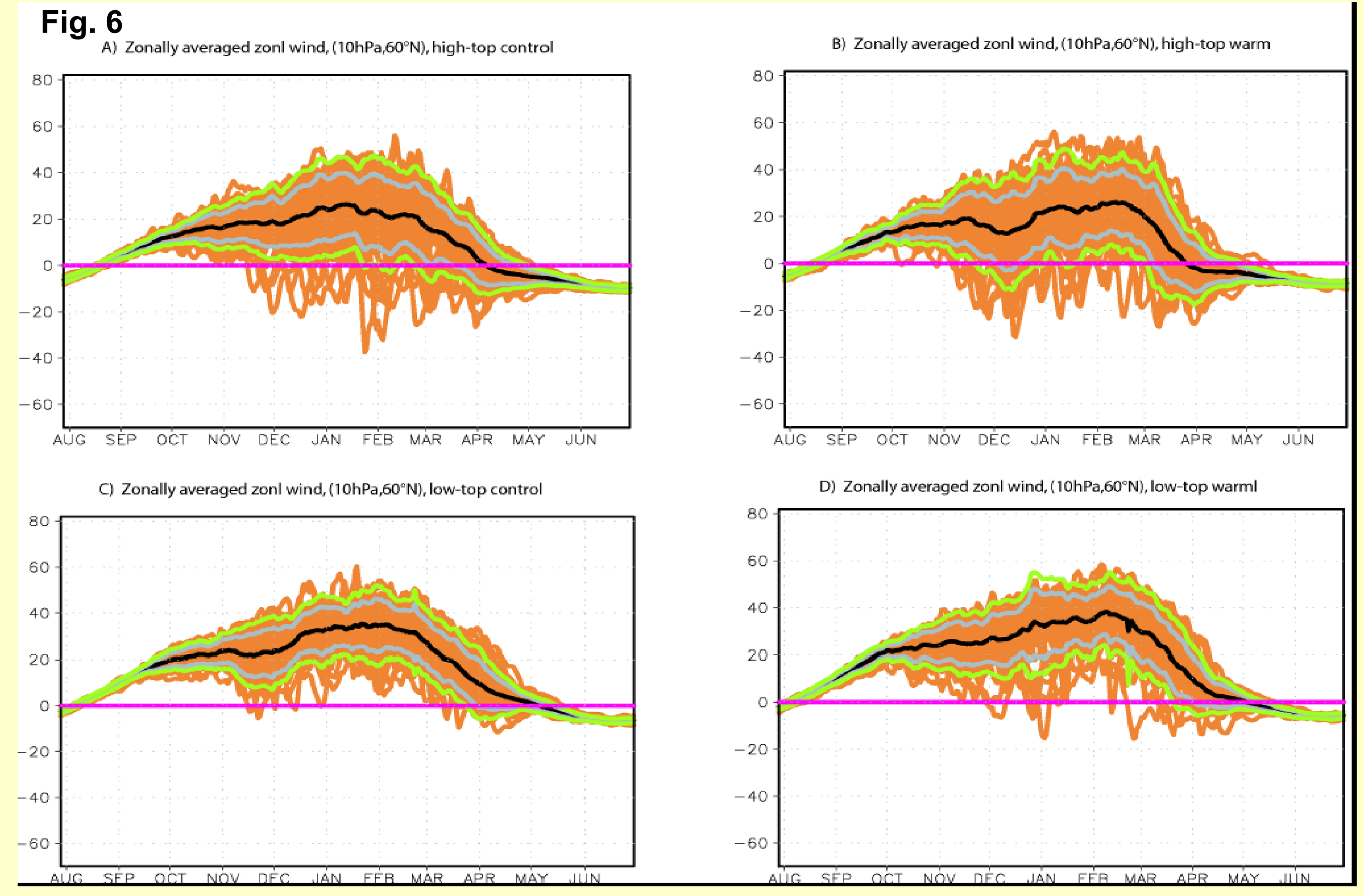
Fig.5



The negative NAO caused by AMV, the associated precursory change in the stratosphere and the downward propagation of stratospheric warming can be simulated only by stratosphere-resolving models.

Simulated variability and major stratospheric warming

Fig. 6



- The precursory weakening of the stratospheric vortex seen in the high-top warm simulation is due mainly to the shifting of the daily extreme stratospheric changes toward more major warmings
- The low-top model is not able to simulate such shifting
- The low top simulate also smaller variability, which can inhibit the wave propagation and the associated stratospheric warming

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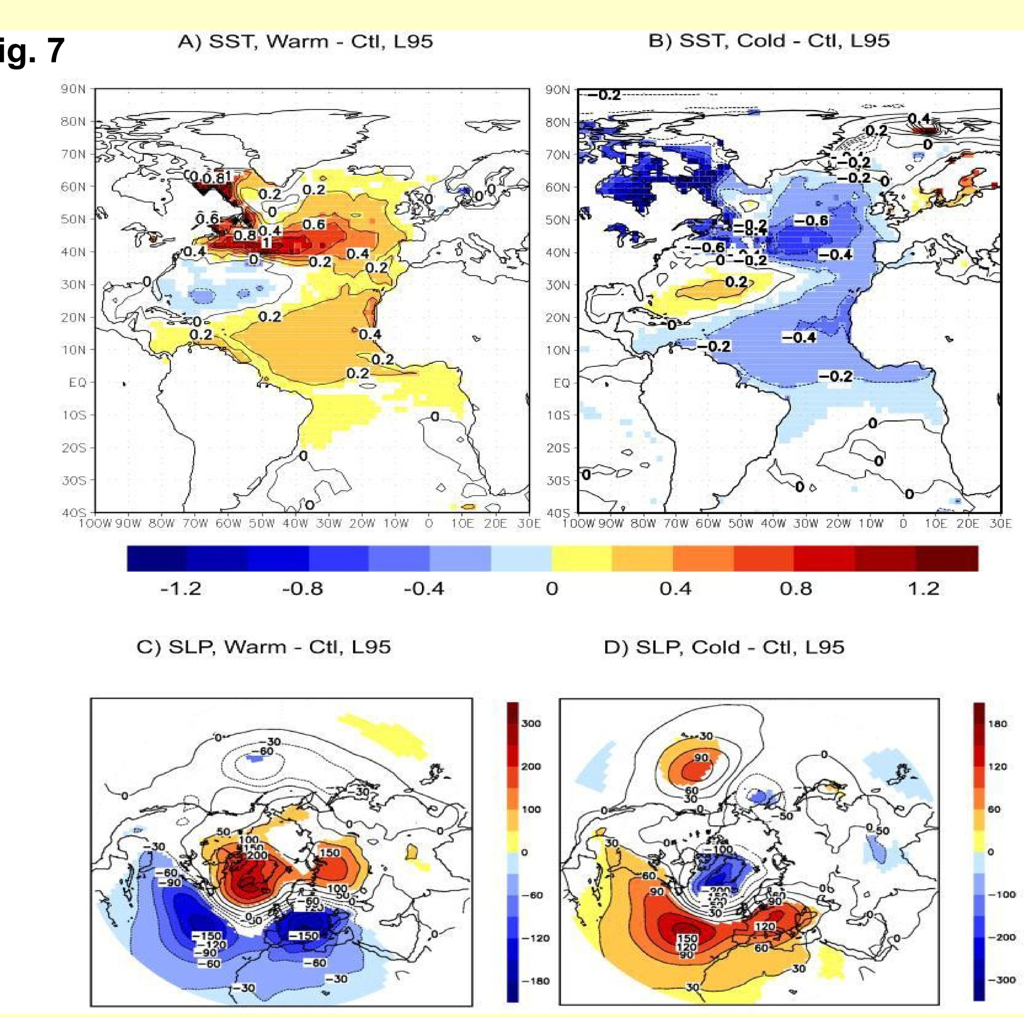
AMV/NAO coupling in stratosphere-resolving atmosphere/ocean coupled models

ECHAM6/MPIOM, L95

Fig. 7



- The observed AMV/NAO relationship can also be captured in long-term simulations using the ECHAM6/MPIOM

Conclusions

- Observed warm (cold) AMV conditions was associated with negative (positive) NAO
- The NAO responds to the AMV warm conditions with the stratosphere acting like atmospheric glasses to see and therefore feel the large-scale Atlantic warming
- The mechanisms of NAO-rsponse to Atlantic warming involve the wave-induced stratospheric/troposphere coupling, in which the AMV-induced stratospheric warming propagates into the high-latitude troposphere decreasing the meridional temperature gradient and thus low level baroclinicity
- Since it is widely accepted that the AMV is, to a large extent, the delayed NAO-response, the response of NAO to AMV support a self-maintained oscillatory behavior between AMV and NAO
- The observed AMV/NAO relationship can be captured in ECHAM6/MPIOM long-term simulation