

Troposphere-stratosphere response to large-scale North Atlantic Ocean variability in observations and an atmosphere/ocean coupled model

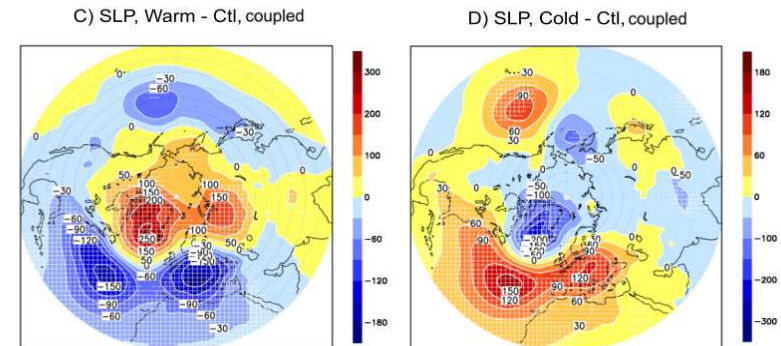
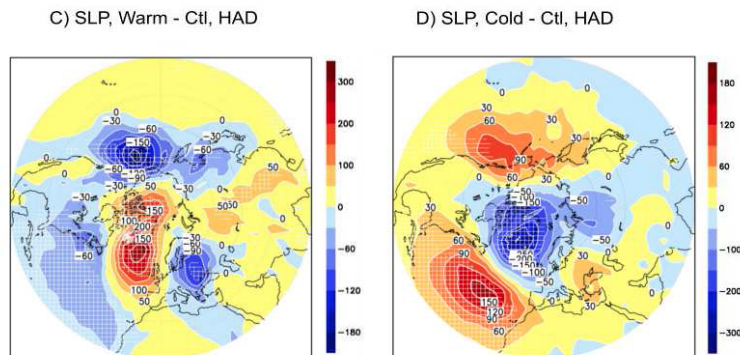
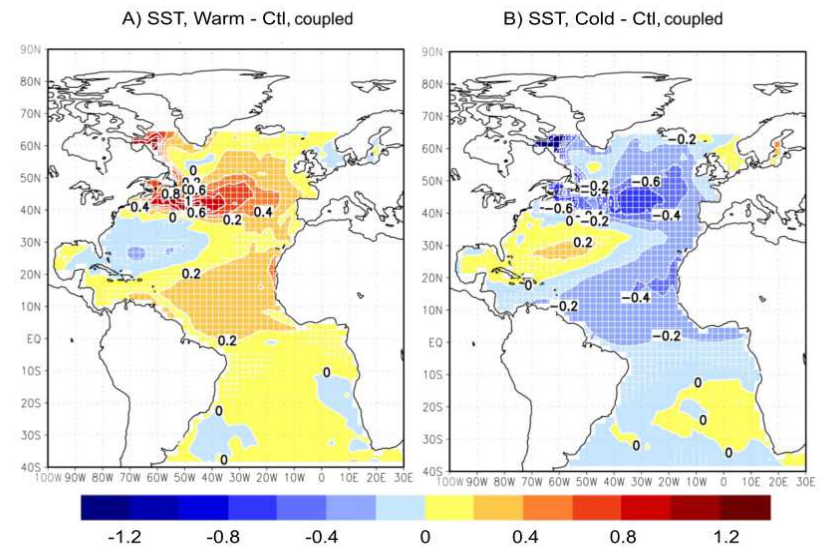
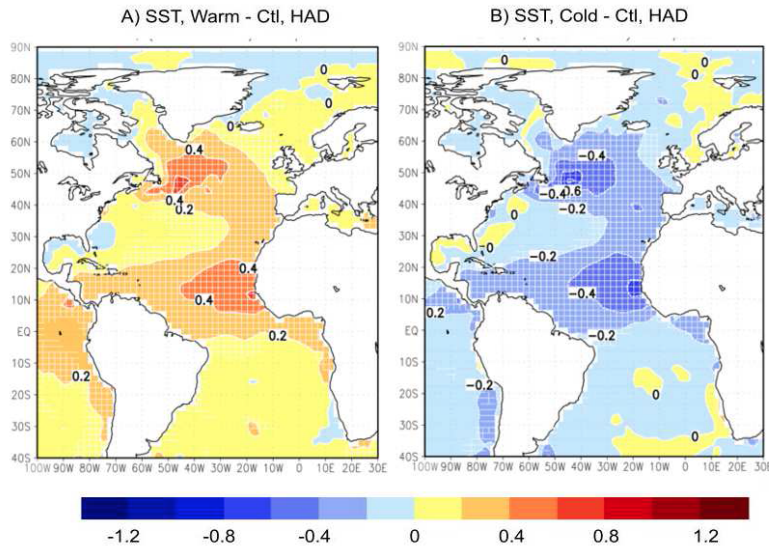
N.-E. Omrani, Jürgen Bader, N. S. Keenlyside & Elisa Manzini

- Observed AMV-NAO relationship
- Role of stratosphere
- Role of ocean/atmosphere two-way coupling

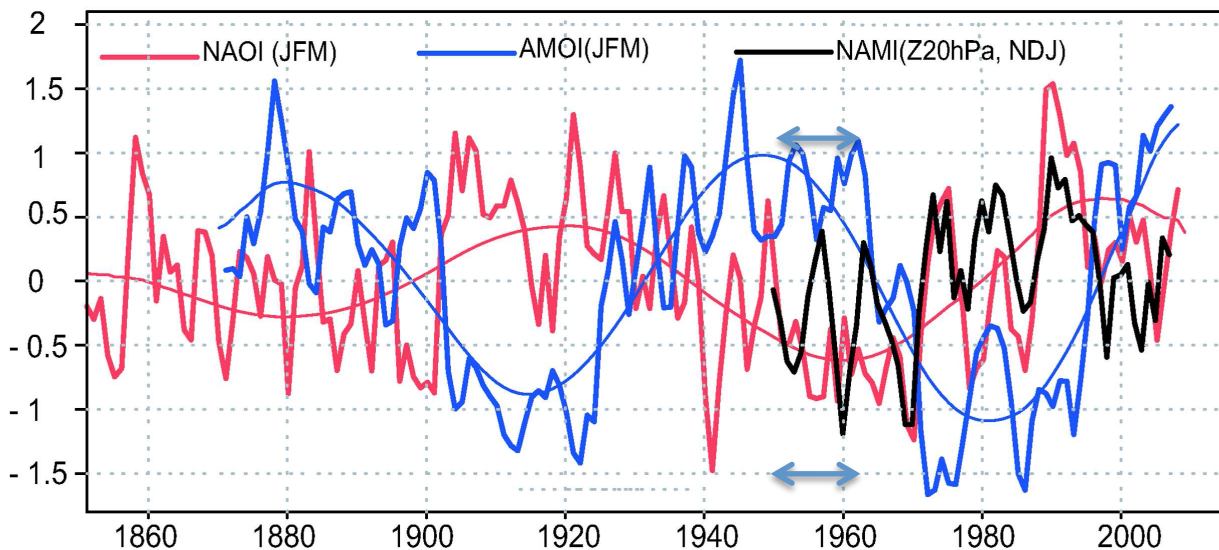
NAV/NAO coupling: 500 year control simulation using atmosphere/ocean coupled MPI-ESM model

Observations, 1870-2009, HAD-SST and SLP

MPI-ESM coupled model, T63,L95



Observed NAV/NAO relationship

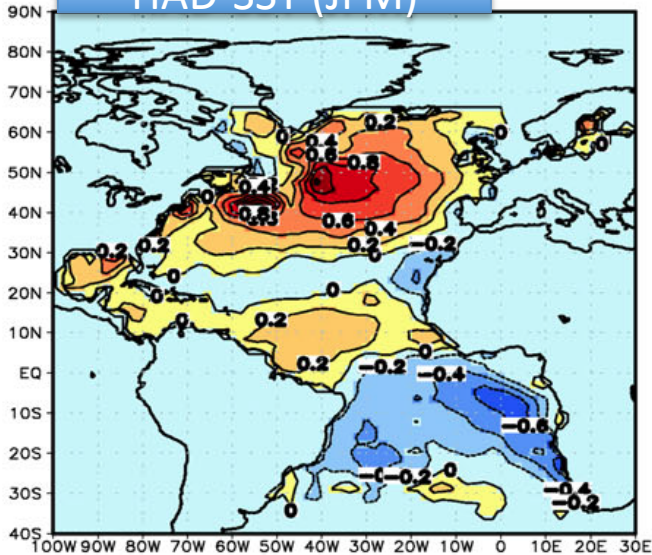


Multidecadal NAO and
SST-NAV

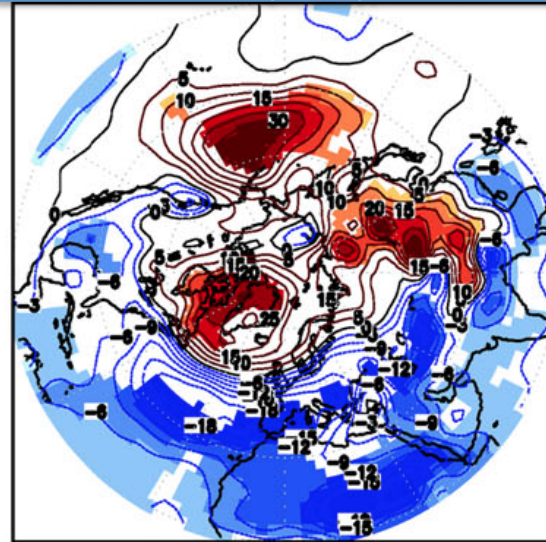
Omrani et al. 2014

Warm(1951 to 1960)-Control(1961 to 1990)

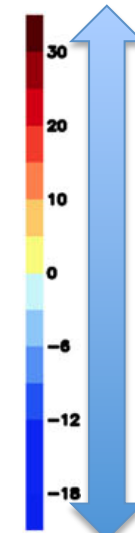
HAD-SST (JFM)



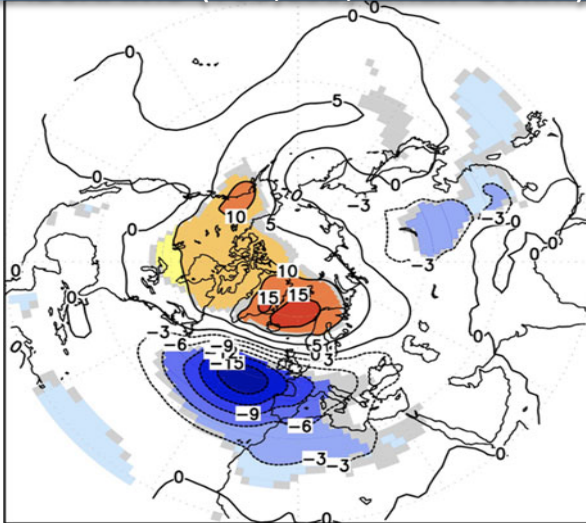
Z1000hPa (JFM), NCEP



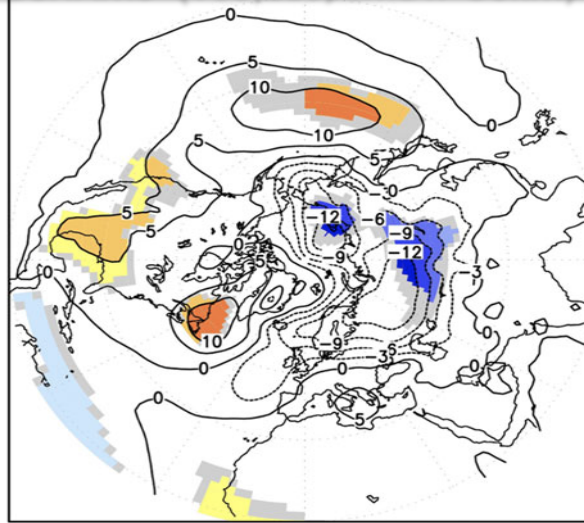
Observed warming in 1950s was associated with negative NAO



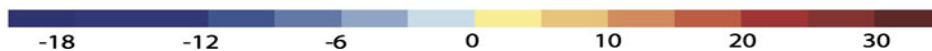
Z1000hPa (JFM), high-top model MAECHAM5 (T63,L39, zmax=80km)



Z1000hPa (JFM), low-top model ECHAM5 (T63,L19, zmax=30km)

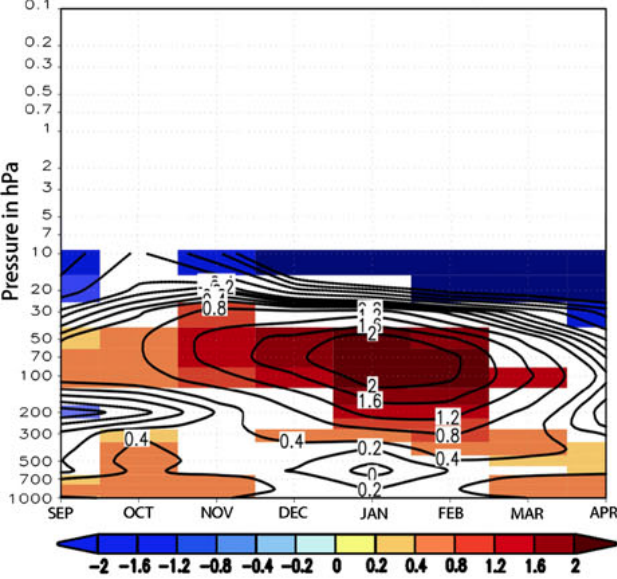


Atmospheric model driven by observed warm SST-conditions shows that negative NAO seen in 1950s can be driven by the observed warm Atlantic conditions only by resolving the stratosphere

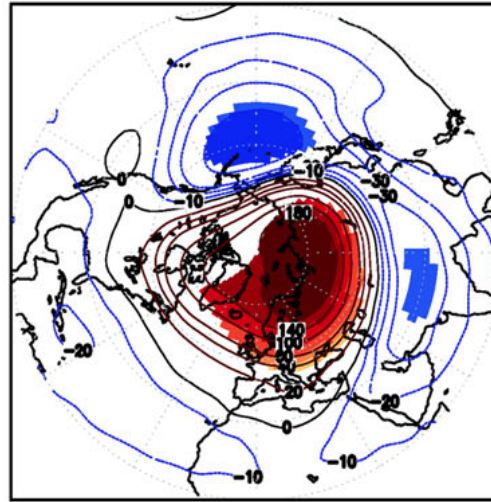


Warm(1951 to 1960)-Control(1961 to 1990): How is the stratosphere involved?

(C) Atmospheric temperature, reanalysis



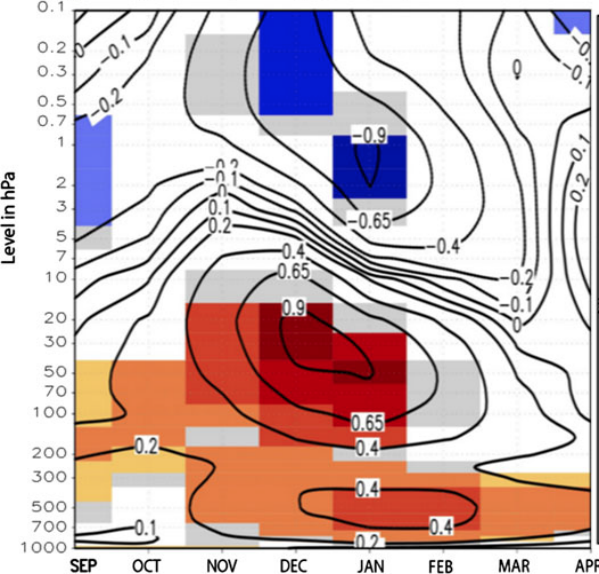
(D) 20hPa Geopotential height (NDJ)



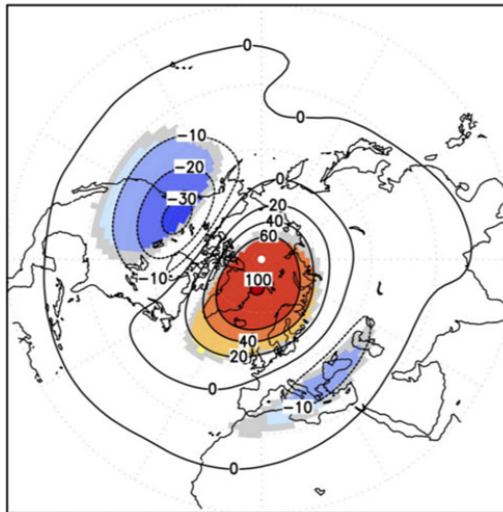
Observation

In both observation and model simulation we have precursory stratospheric warming and vortex weakening that propagate into the troposphere

(A) Atmospheric temperature, high top response



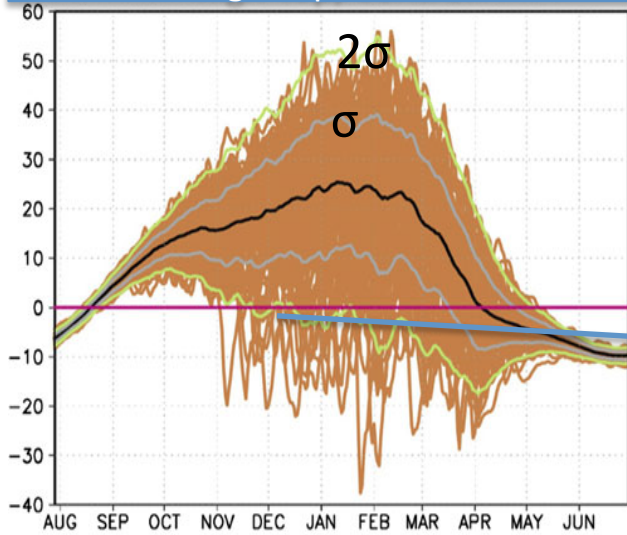
(B) High top simulated 20hPa geopotential high response



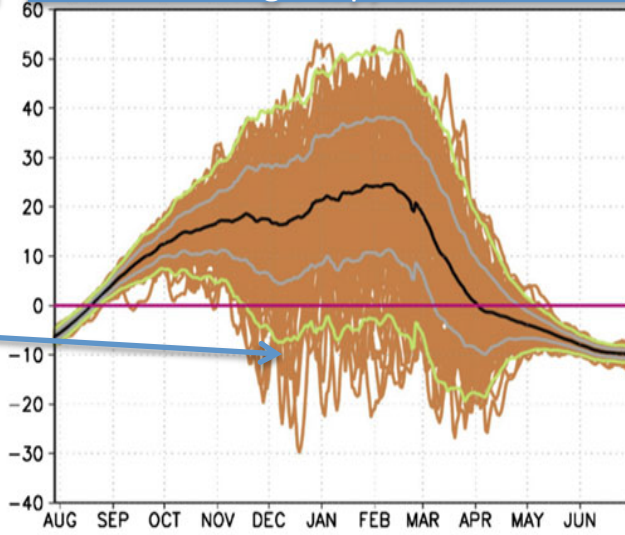
High-top stand-alone atmospheric model simulation MAECAHM5

Warm(1951 to 1960)-Control(1961 to 1990): How is the stratosphere involved?

A) Zonally averaged U (10hPa, 60°N)
high-top, Control



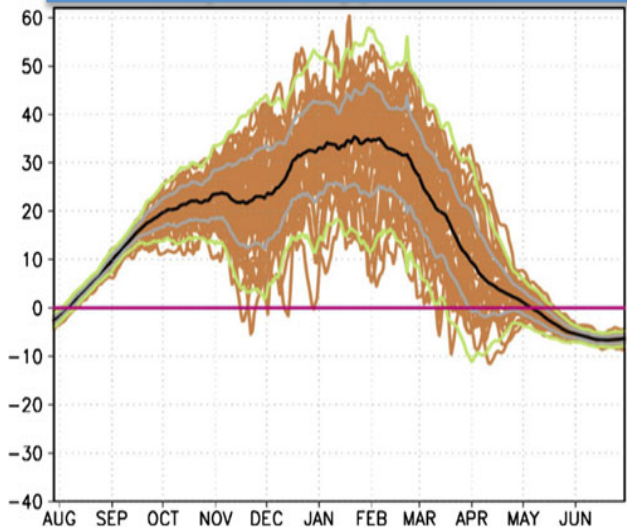
B) Zonally averaged U (10hPa, 60°N)
high-top, Warm



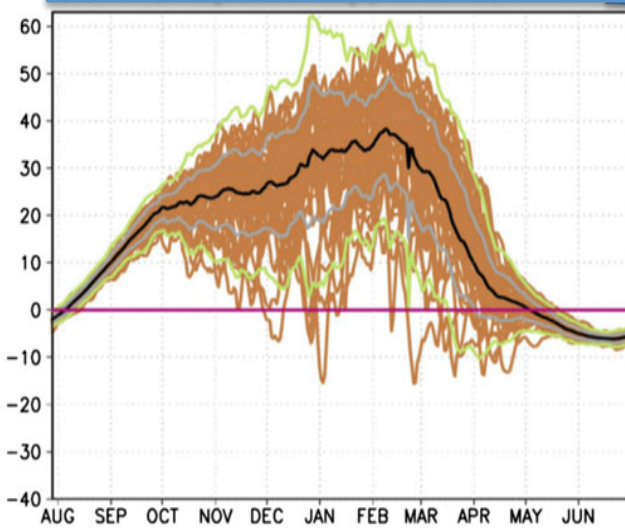
High-top

Precursory stratospheric warming and vortex weakening seen around DEC is due mainly to the shift of extreme circulation change towards more Major Stratospheric Warming (MSW), which can be simulated only in high-top configuration

C) Low-top, control

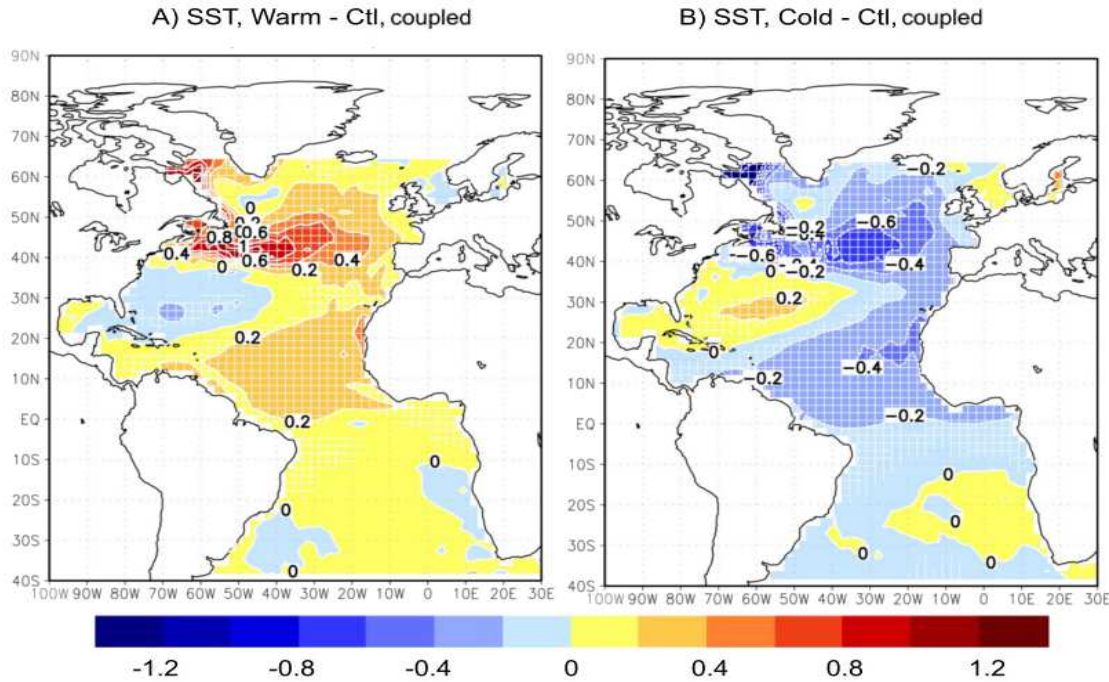


D) Low-top, Warm

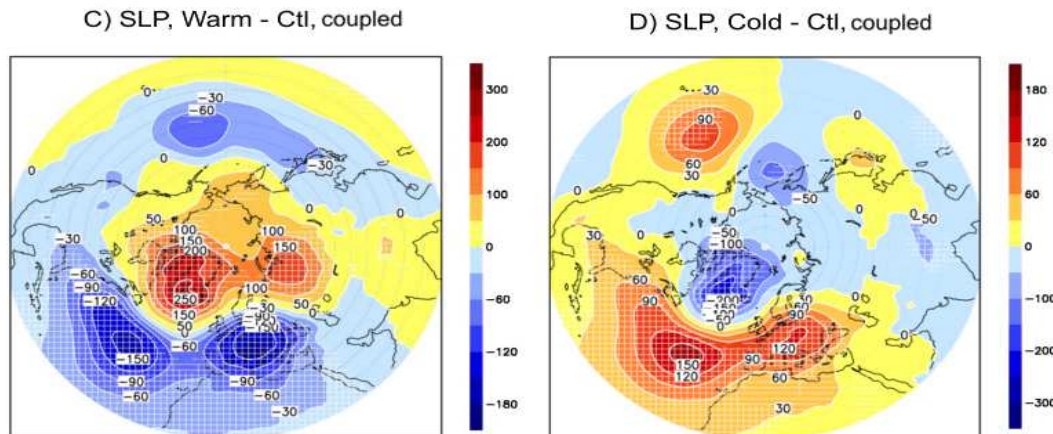


Low-top

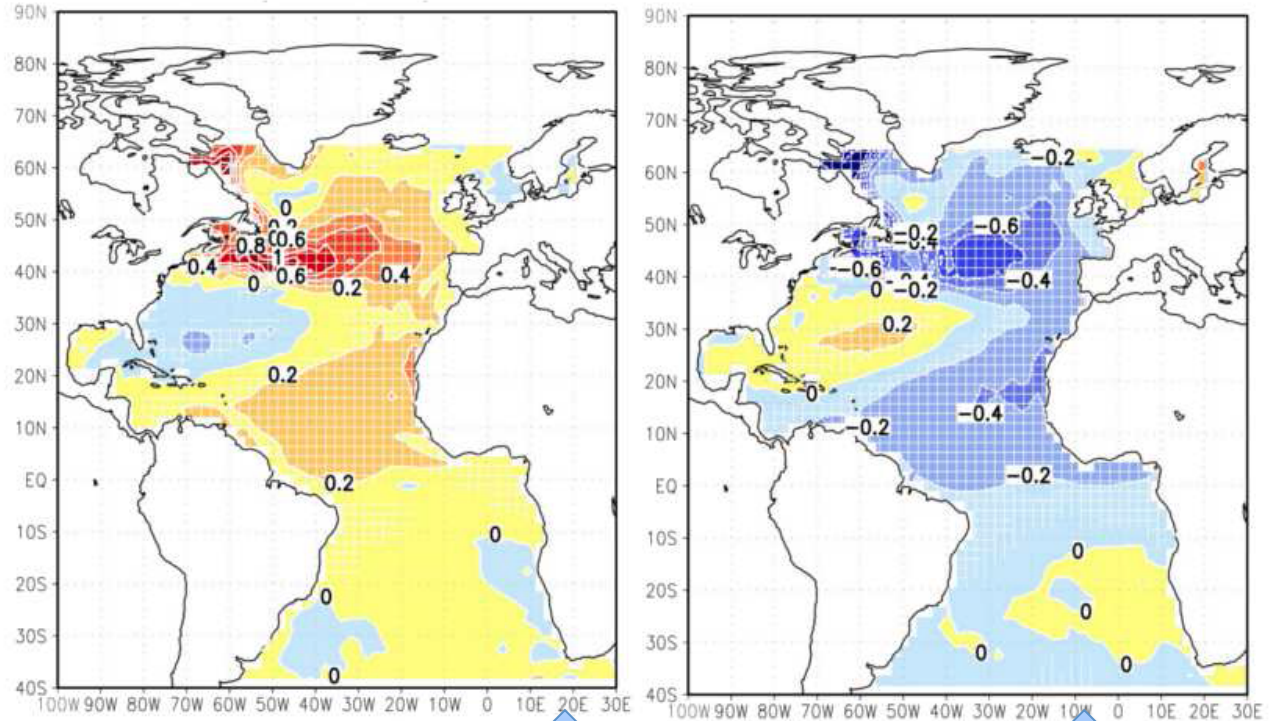
NAV/NAO coupling: 500 year control simulation using atmosphere/ocean coupled MPI-ESM model





Composite Analysis based on NAV-index from 500year model simulation (T63L95) confirms that warm/cold NAV are associated with negative/positive NAO as observed



Understanding of the role of the two-way ocean/ atmosphere coupling: Experiment set-up

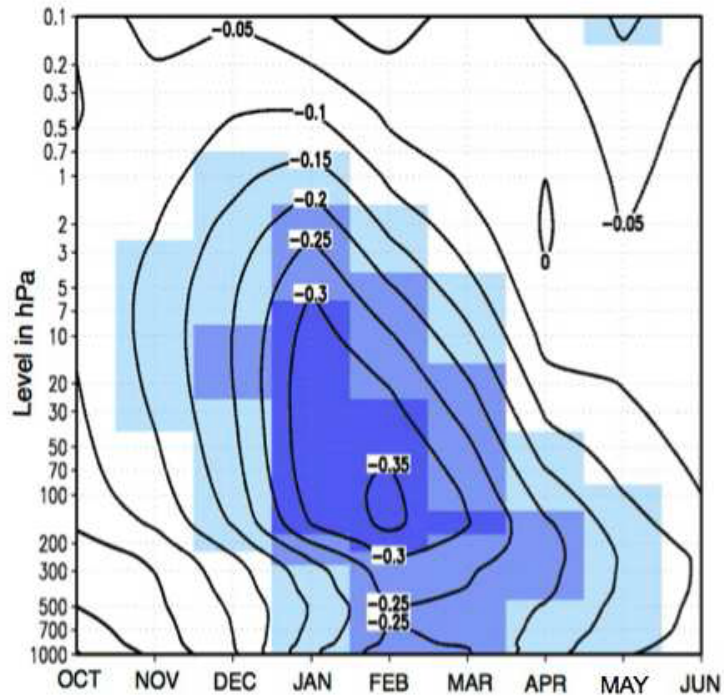


Omrani et al. submitted

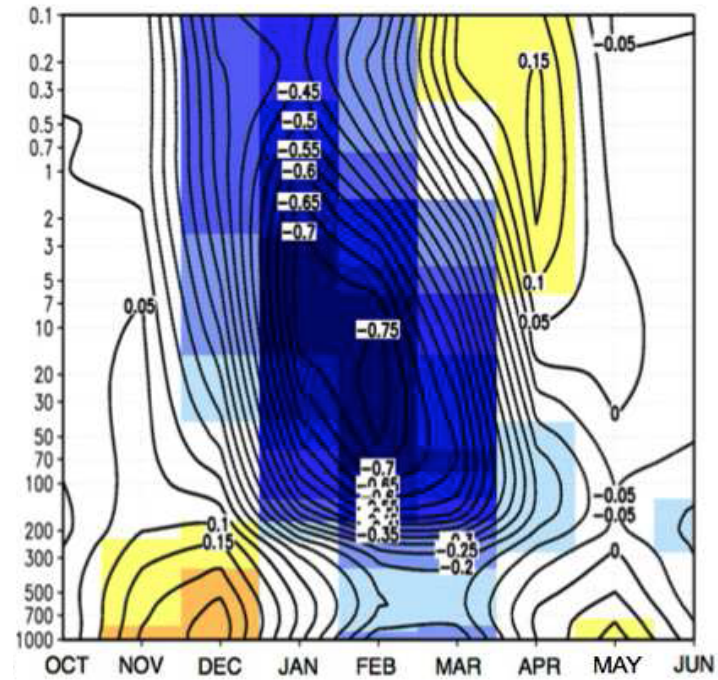
Standalone atmospheric model experiments driven by for warm  and for cold  NAV
The control experiment is driven by climatological SST from the coupled model (Model resolution: T63L95)

Response of stand-alone atmosphere model to warm NA-conditions taken from the coupled model

A) Projection on the NAM, coupled



B) Projection on the NAM, uncoupled

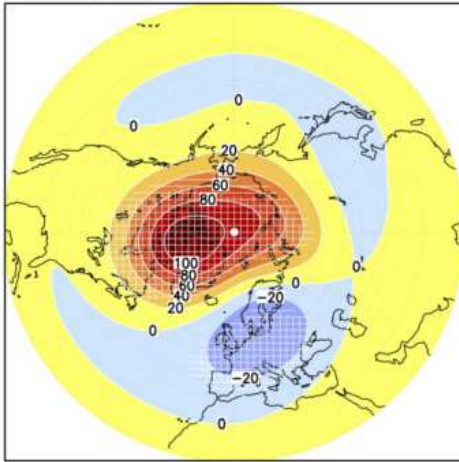


Two-way ocean atmosphere interaction:

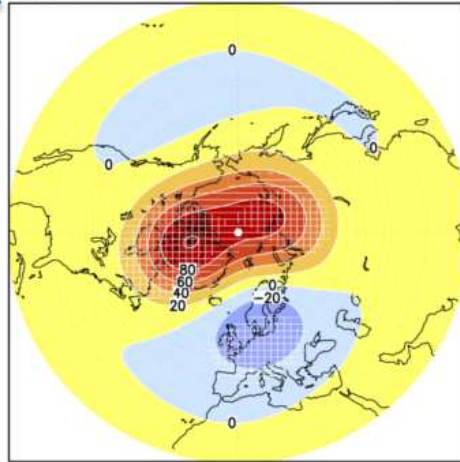
- 1) increases the strength and seasonal persistence of the tropospheric response
- 2) but strongly decreases the stratospheric response to the warm North Atlantic Conditions.

Stratospheric response of stand-alone atmospheric model to warm NA-conditions taken from the coupled model

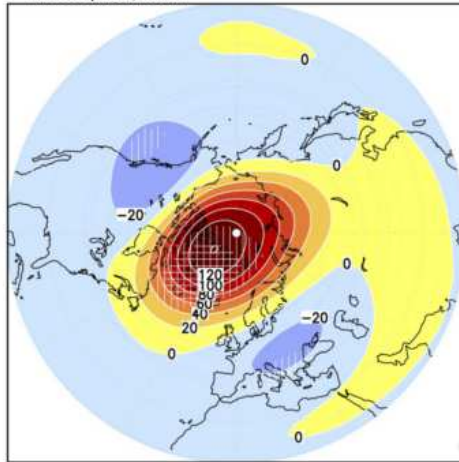
A) Warm composite of 30hPa geopotential height, coupled, JAN



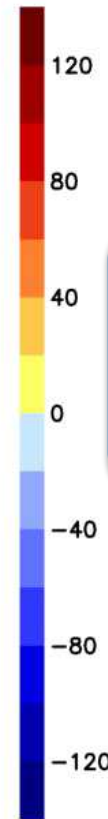
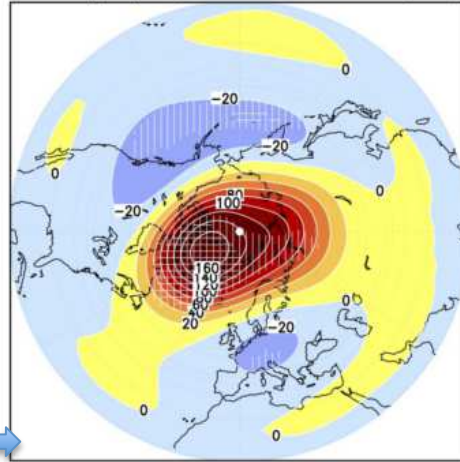
B) Warm composite of 30hPa geopotential height, coupled, FEB



C) Response of 30hPa geopotential height, uncoupled, JAN



D) Response of 30hPa geopotential height, uncoupled, FEB

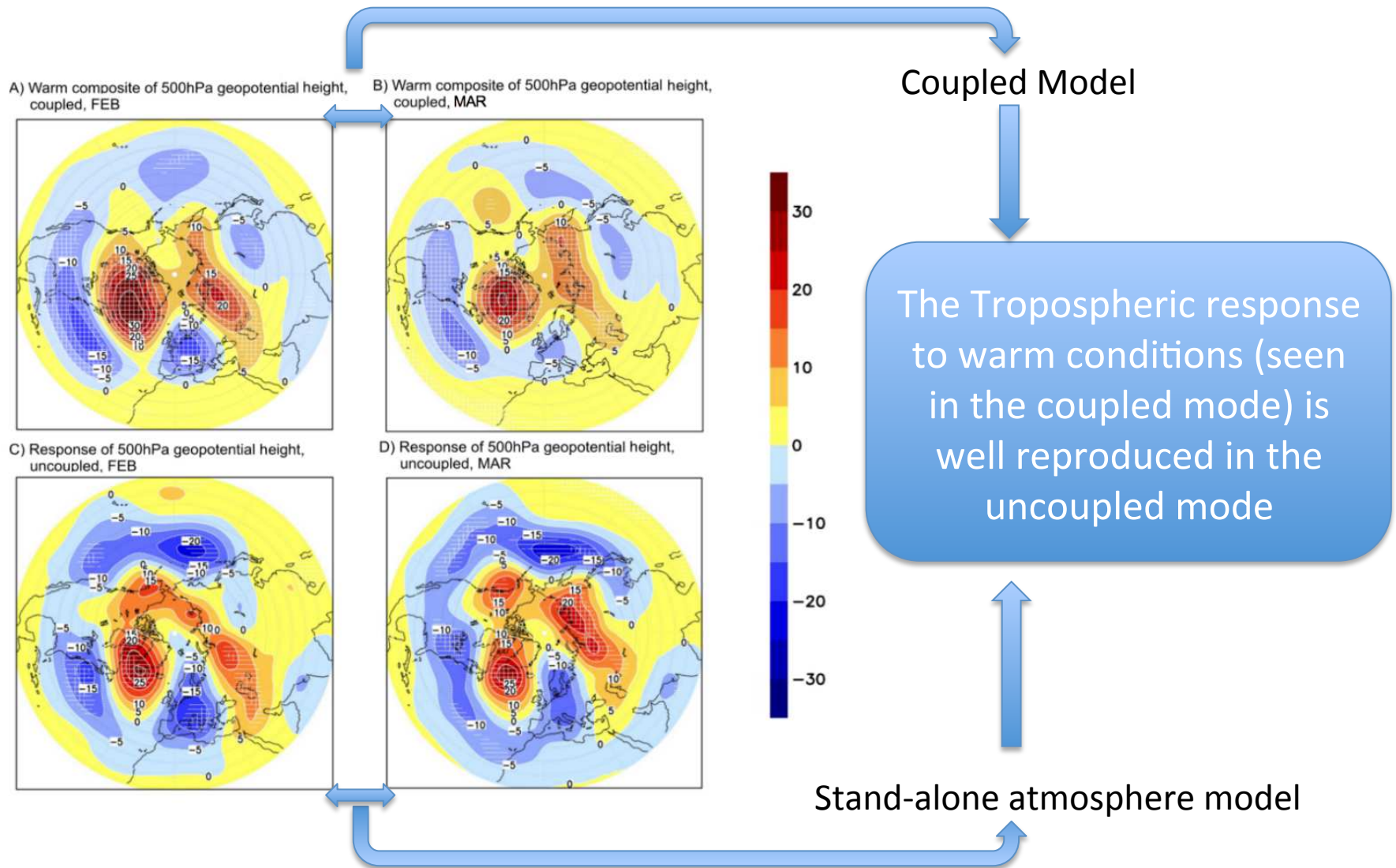


Coupled Model

Stratospheric response is much stronger in the coupled than in the uncoupled mode

Stand-alone atmosphere model

Stratospheric response of stand-alone atmospheric model to warm NA-conditions taken from the coupled model



Mechanisms proposed for the response of NAO to high latitude Atlantic warming

High latitude SST-warming

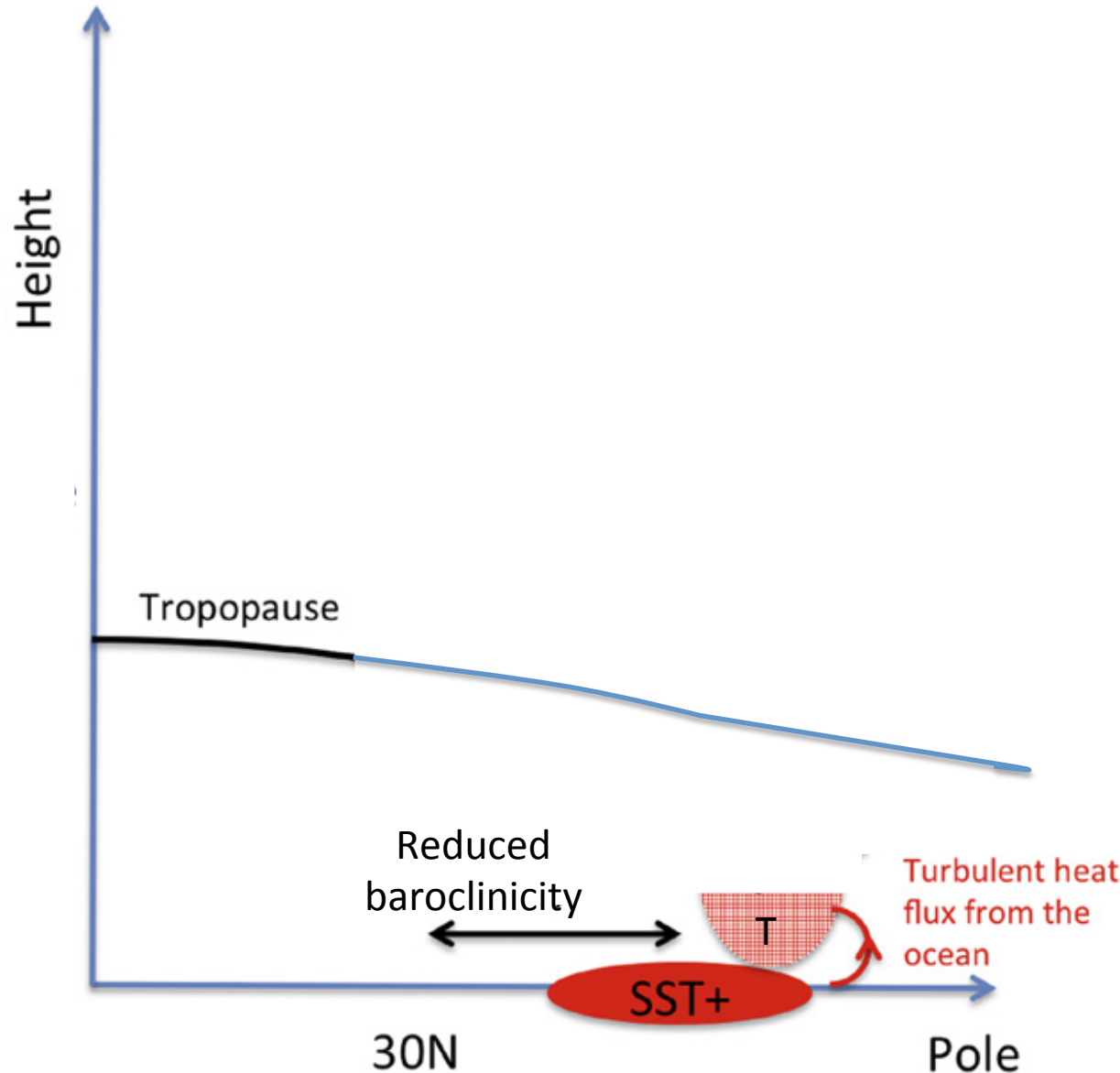


Turbulent heat flux in to the lower troposphere



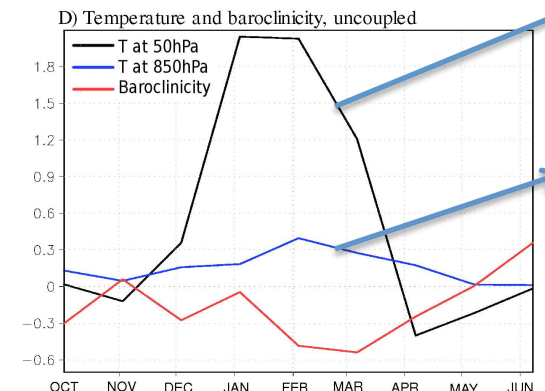
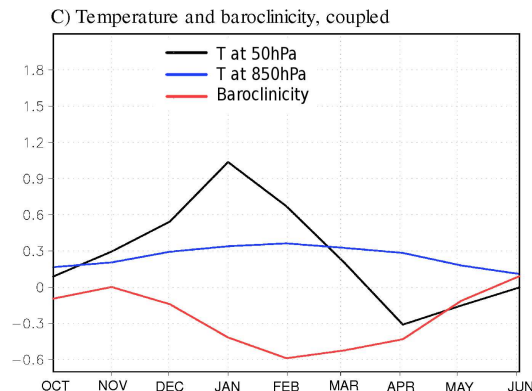
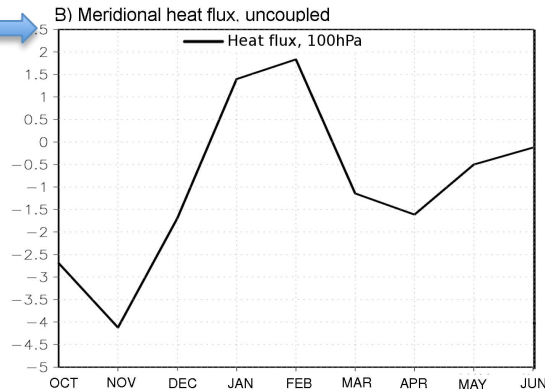
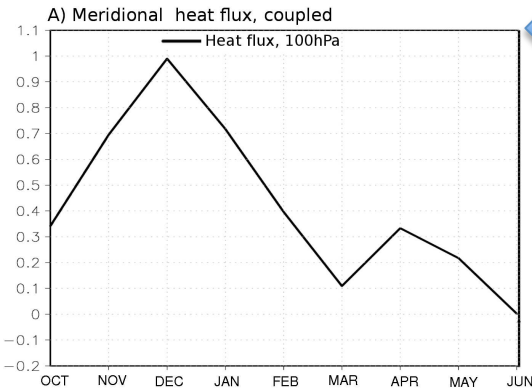
Reduction of baroclinicity
Explaining the negative NAO

This mechanism is not able to explain our response, since our low-top model can not respond to the NAO



Dynamics of the response to warm conditions

Why?
Still unclear



Upward wave propagation

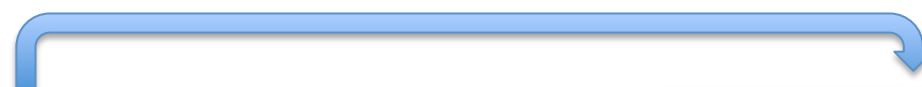
High latitude stratospheric warming and vortex weakening






Still controversial

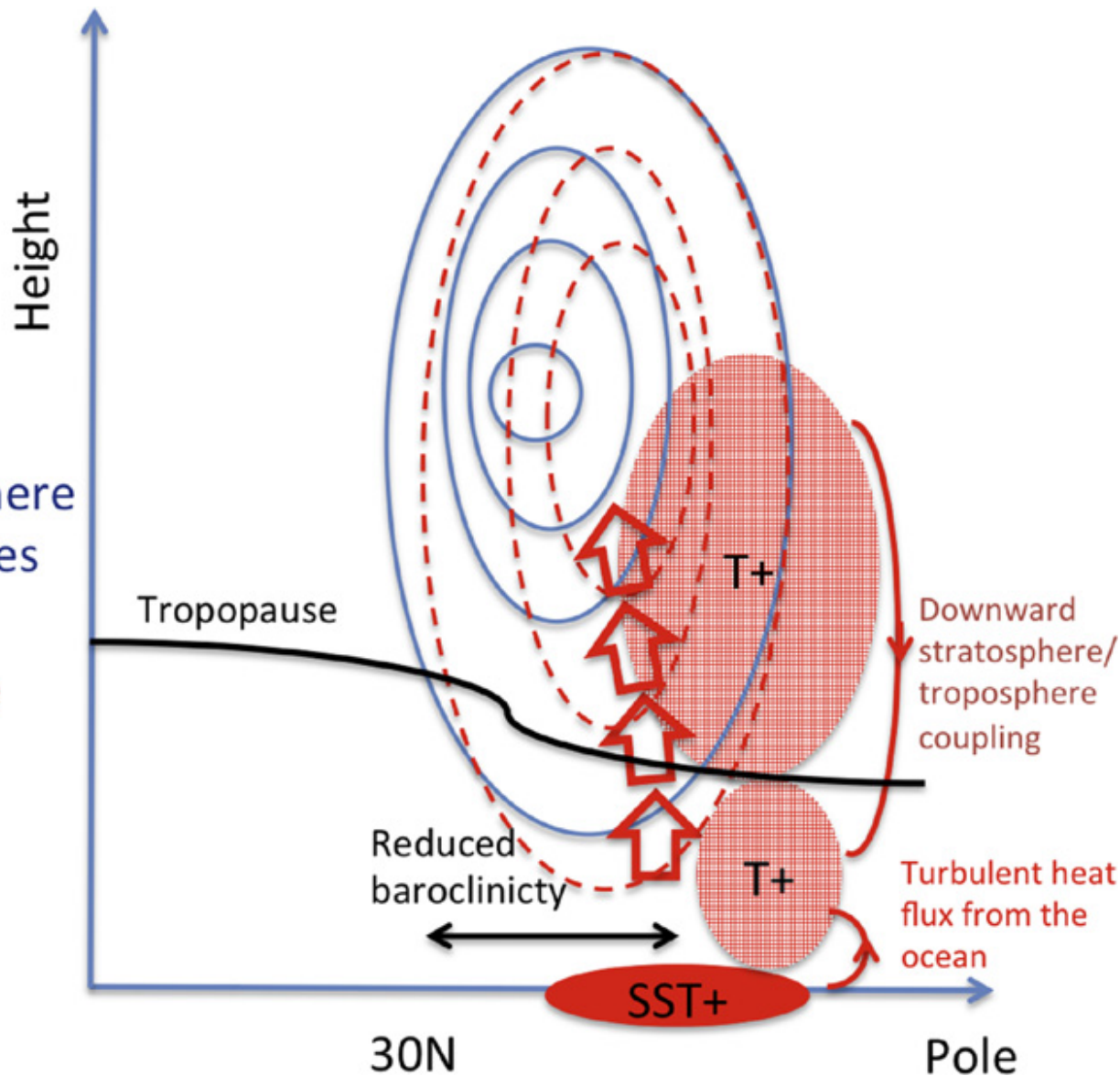
Warming in the high latitude North Atlantic regions

Reduction of the lower tropospheric baroclinicity

This will contribute to negative NAO in addition to the reduction of the baroclinicity due to the turbulent heat flux from the ocean

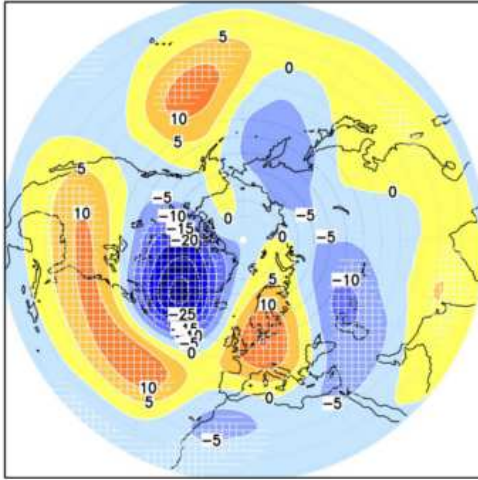


-  Upward wave flux
-  Weaker westerlies
-  Climatological stratosphere & high-latitude westerlies
-  Warming in atmosphere
-  Warming in the Ocean

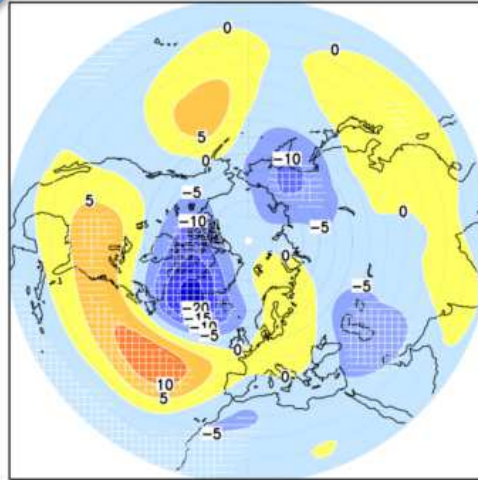


Response to the cold phase, troposphere

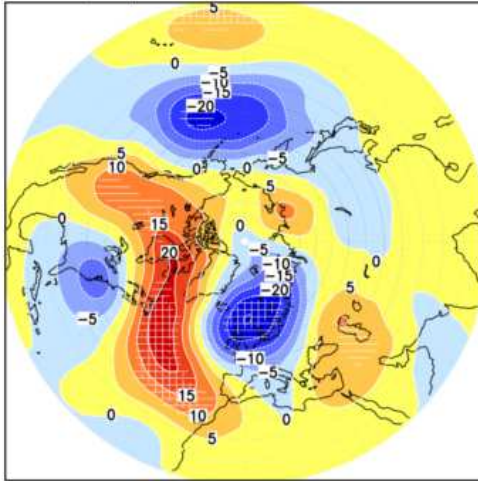
A) Cold composite of 500hPa geopotential height, coupled, FEB



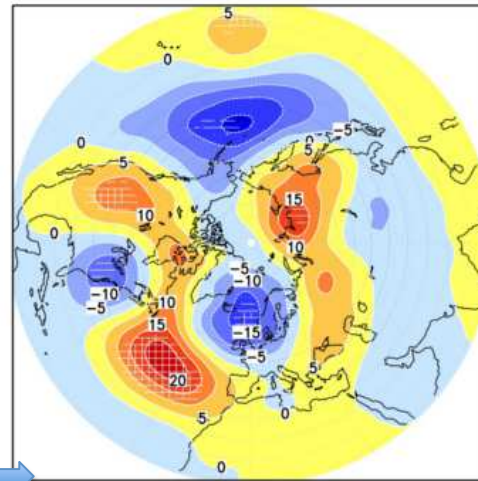
B) Cold composite of 500hPa geopotential height, coupled, MAR



C) Response of 500hPa geopotential height, uncoupled, FEB

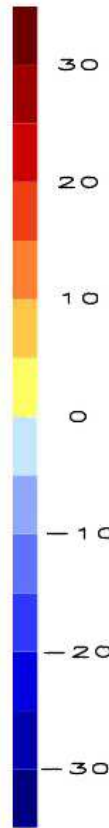


D) Response of 500hPa geopotential height, uncoupled, MAR



Coupled Model

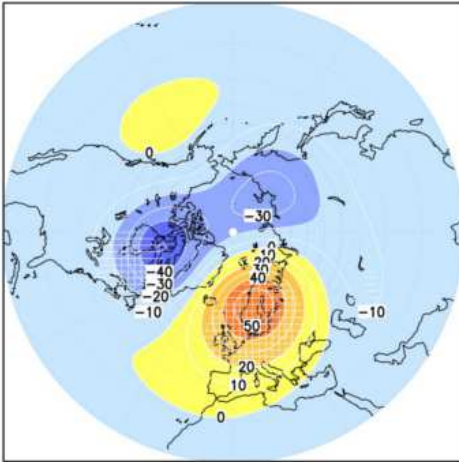
The Tropospheric response to Cold conditions (seen in the coupled mode) is not well reproduced in the uncoupled mode



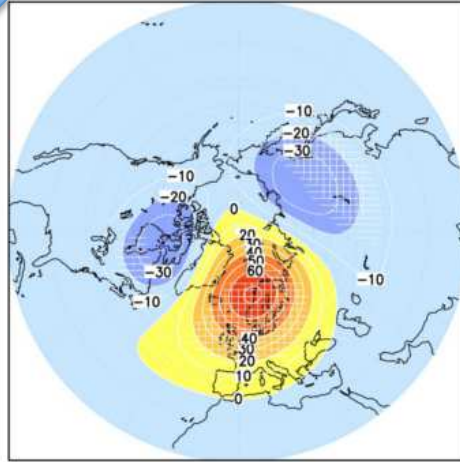
Stand-alone atmosphere model

Response to the cold phase, stratosphere

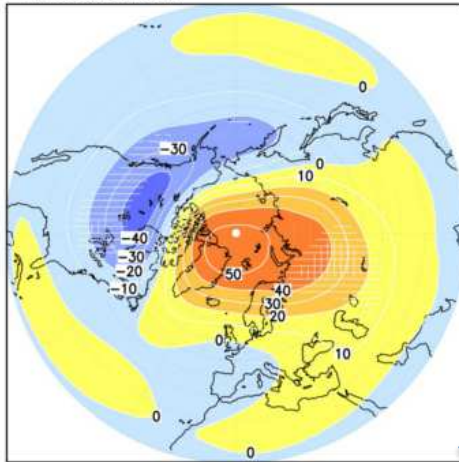
A) Cold composite of 30hPa geopotential height, coupled, JAN



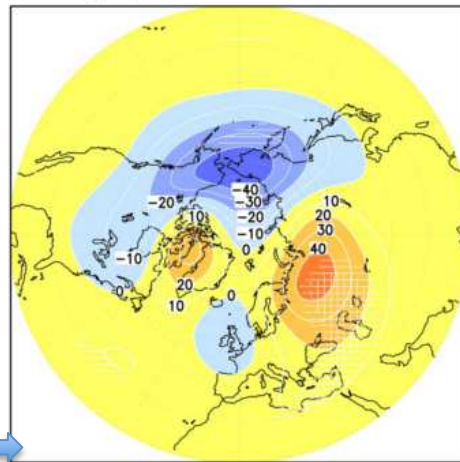
B) Cold composite of 30hPa geopotential height, coupled, FEB



C) Response of 30hPa geopotential height, uncoupled, JAN

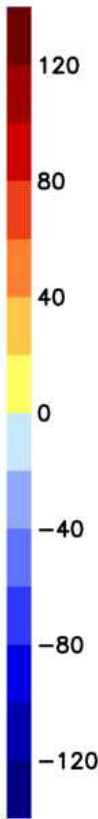


D) Response of 30hPa geopotential height, uncoupled, FEB



Coupled Model

Stratospheric changes in the coupled mode is much weaker in the cold phase and can not be reproduced by the uncoupled mode

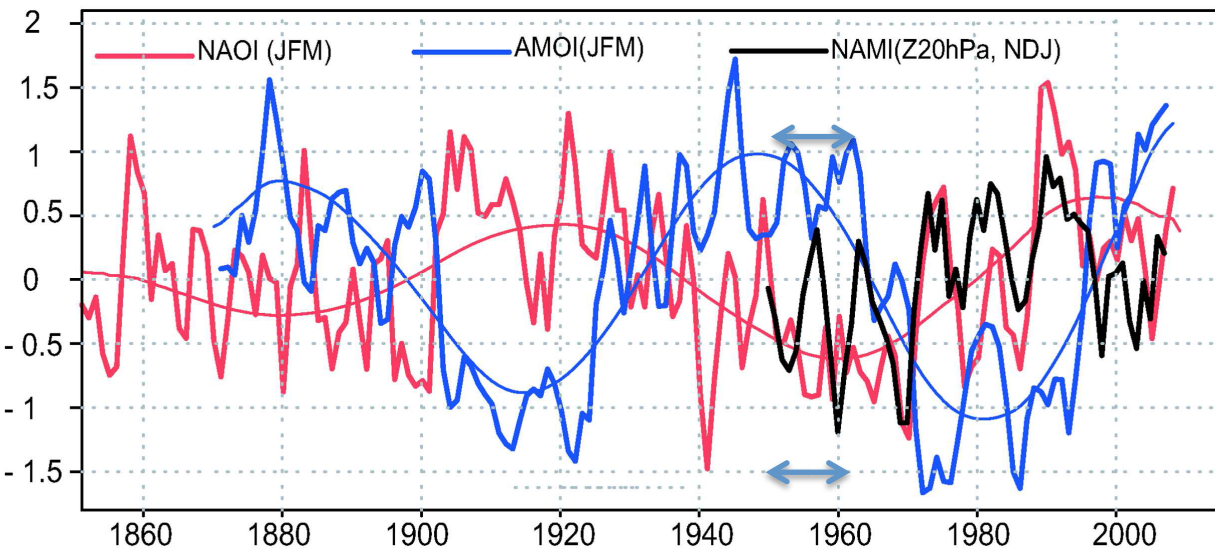


Stand-alone atmosphere model

Conclusions

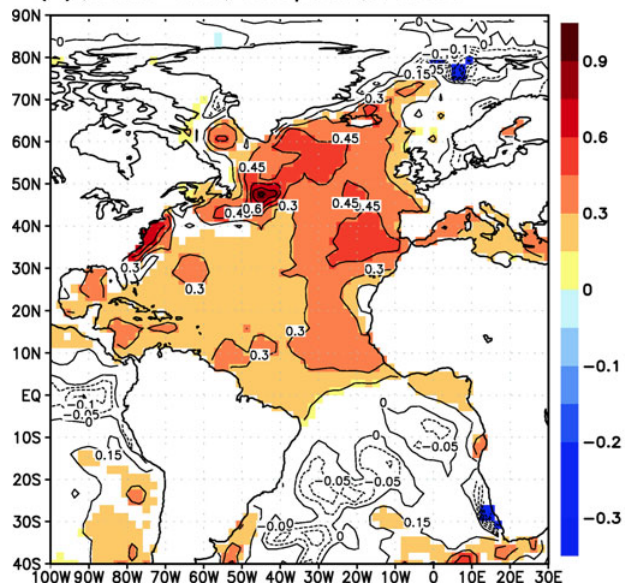
- Both NAO and stratosphere respond to Warm NAV conditions
- Only our high-top model configuration is able to simulate the tropospheric response to the large-scale NAV-warming
- Stratosphere/troposphere downward coupling can provide the troposphere with additional warming and changes in the baroclinicity and contribute to the NAO-changes
- The changes in the atmosphere seen in the cold NAV-phase of the coupled model are not well reproduced by the stand-alone atmosphere model configuration
- Active two-way ocean-atmosphere interaction plays an important role in shaping and modulating the structure and strength of the atmospheric response to the NAV

Observed NAV/NAO relationship

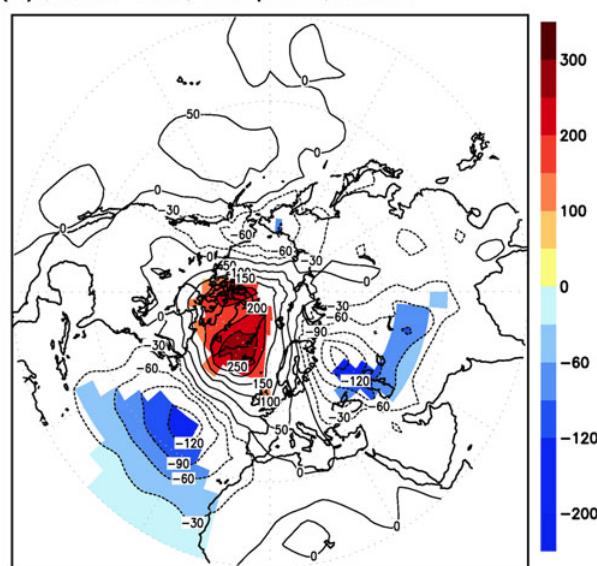


Multidecadal NAO and SST-NAV

(A) (Warm - Cold)-Composite, JFM SST



(B) (Warm - Cold)-Composite, JFM SLP



Warm/cold NAV are associated with negative/positive NAO