Atlantic multi-decadal variability and the role of stratosphere-troposphere

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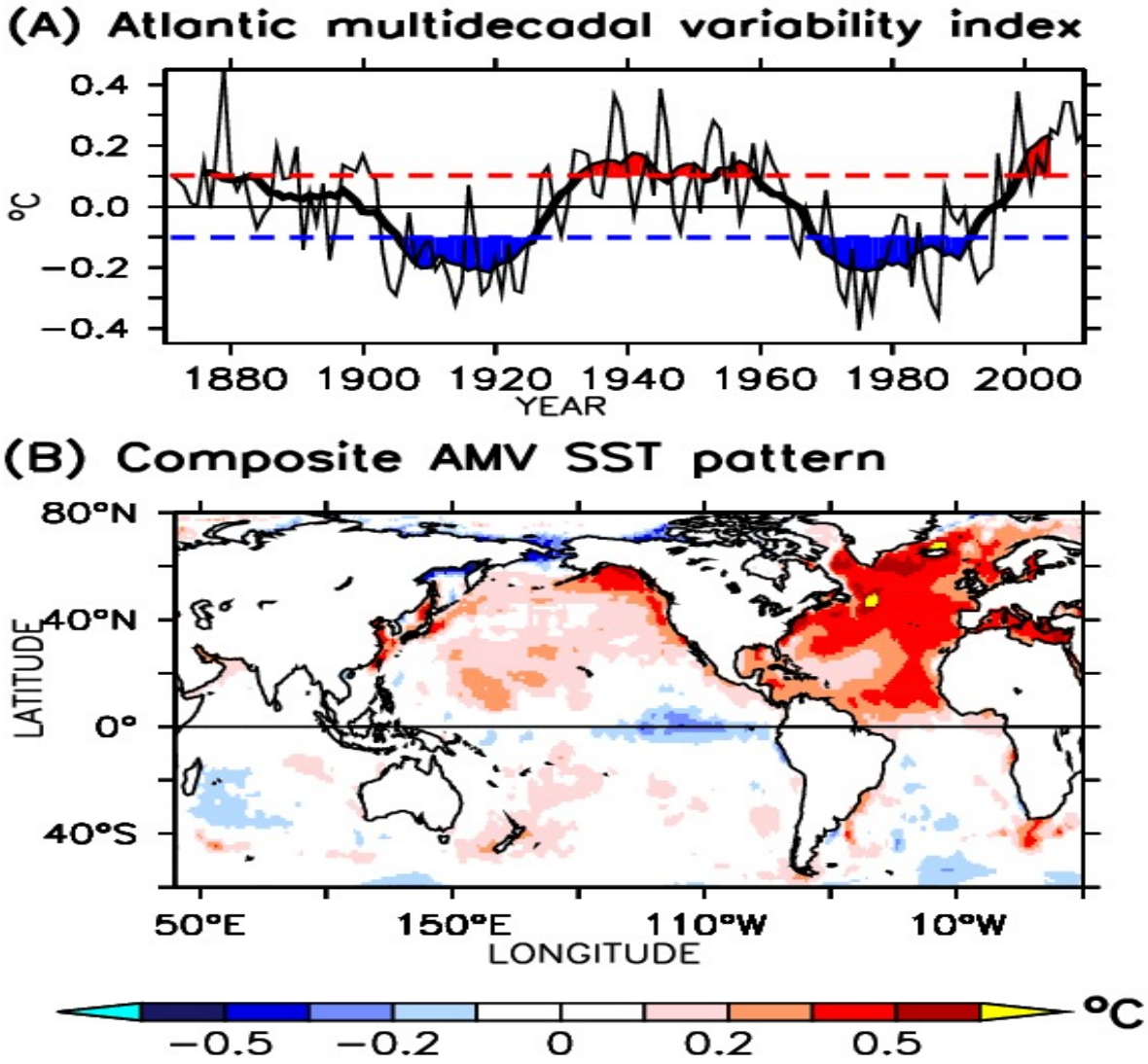
Atlantic multi-decadal variability (AMV)
Seen in instrumental and proxy data, persistence unclear



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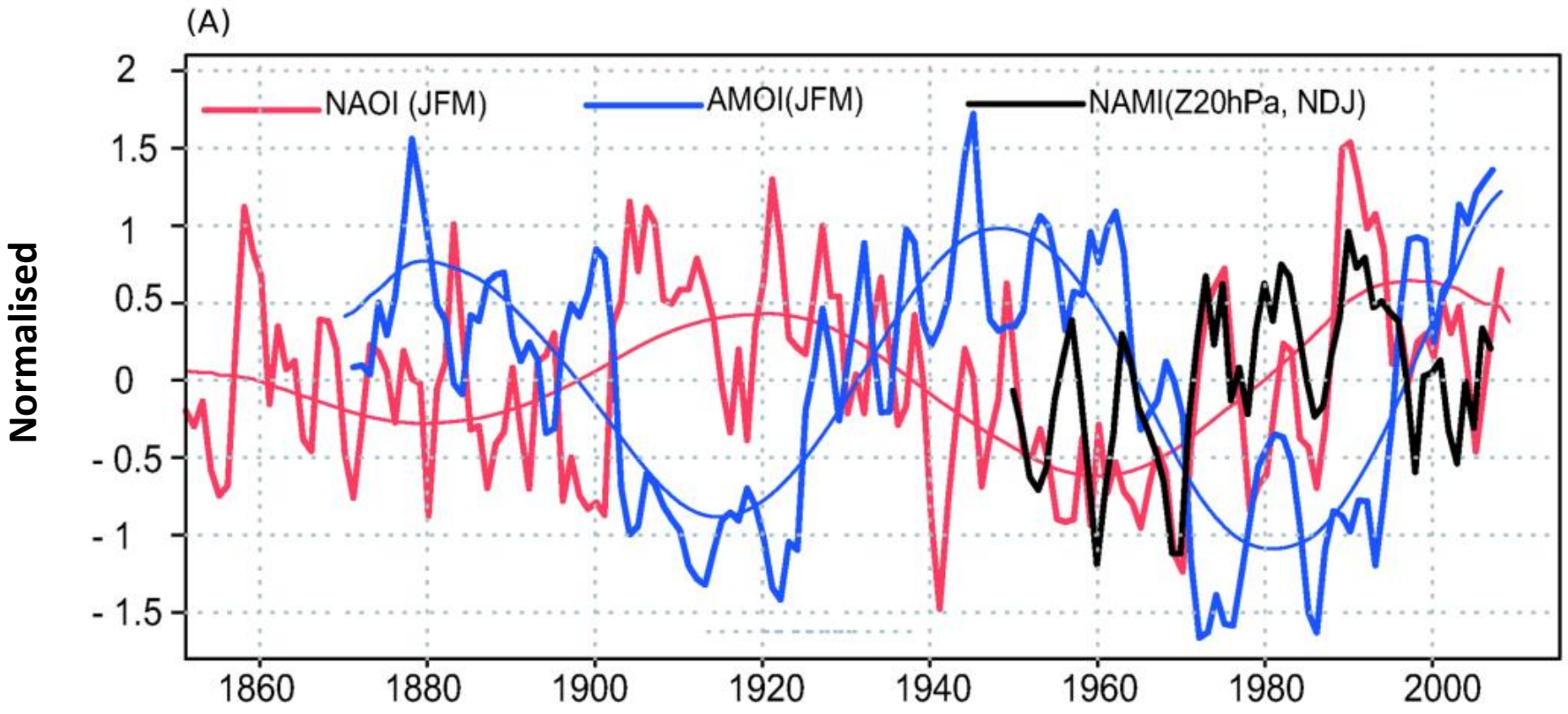
Multi-decadal fluctuations in Atlantic Sector variability: ocean-stratosphere



Multi decadal variability explains 48% of AMV index and 14% of NAO index

Omrani et al. 2014

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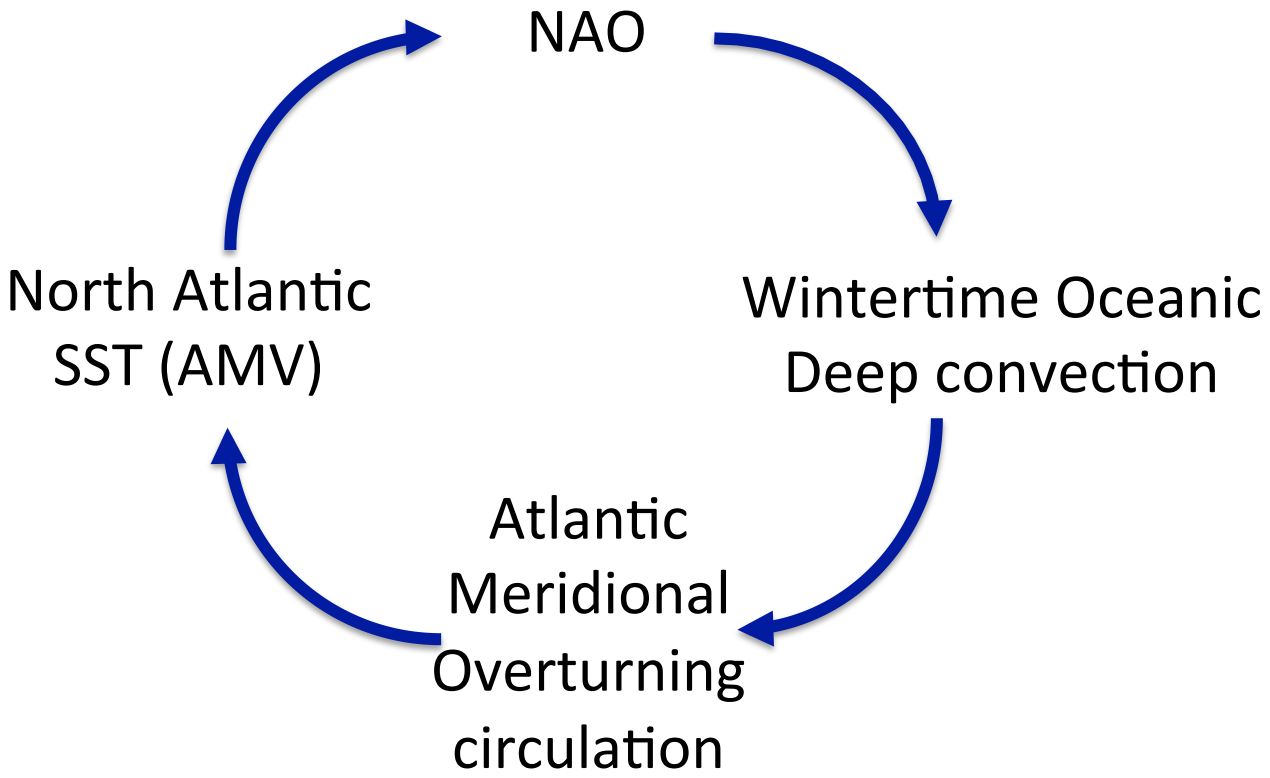
Atlantic multi-decadal variability

1. Understanding of ocean-atmosphere interaction

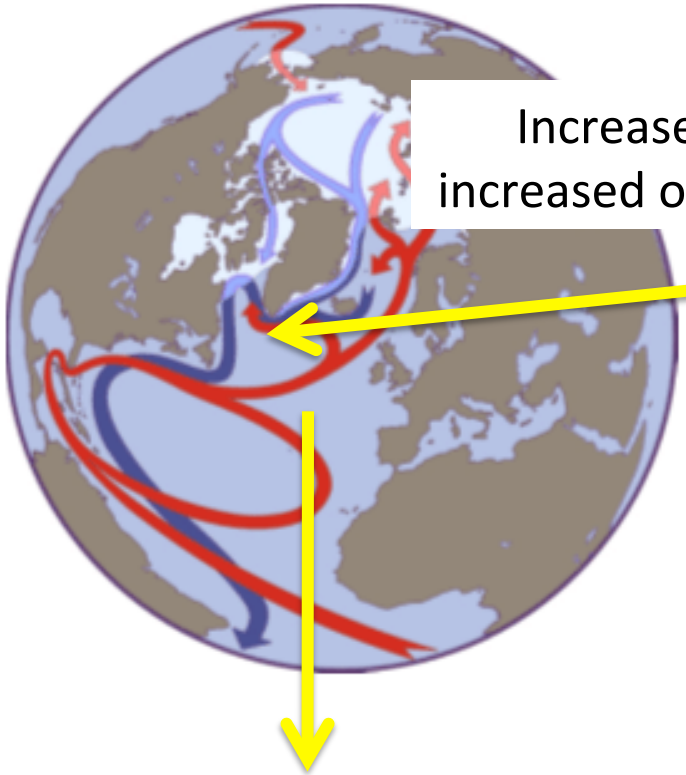


2. Ideas for future directions

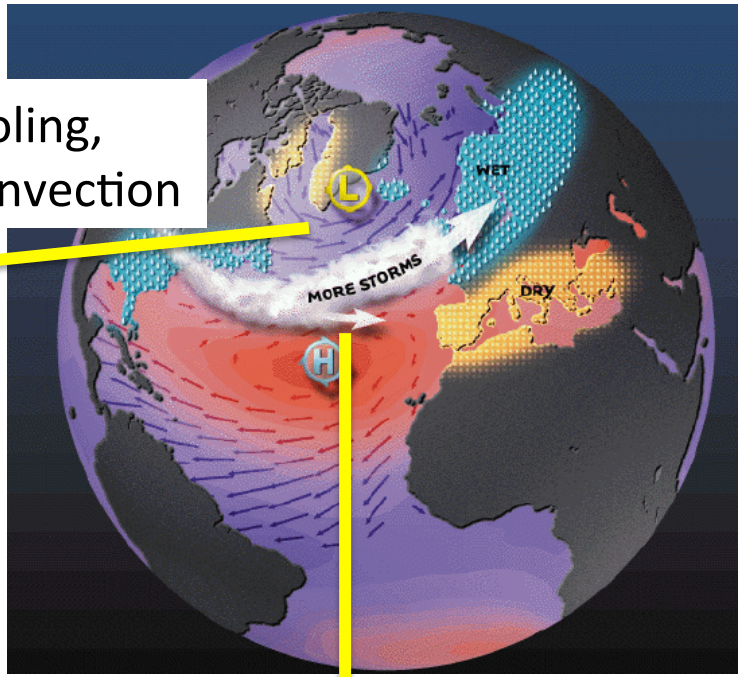
Dynamical and thermodynamical considerations

Atlantic Meridional overturning circulation (AMOC)

North Atlantic Oscillation (Positive phase)



Increase heat flux cooling, increased ocean deep convection



Heat transport drives an SST monopole

-> Heat flux to atmosphere

Heat fluxes drive an SST tripole

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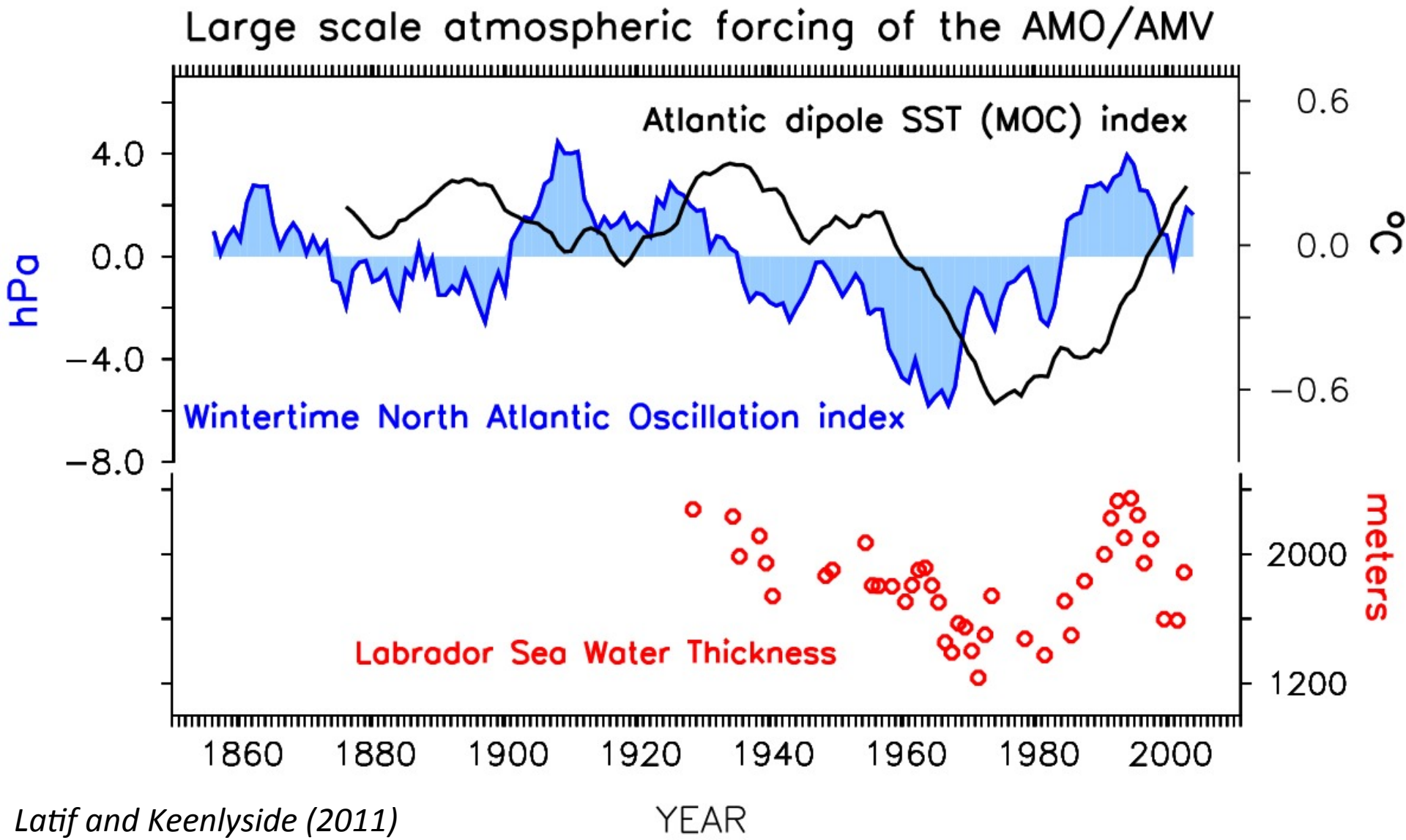
Observed NAO, ocean convection, AMOC/SST relation

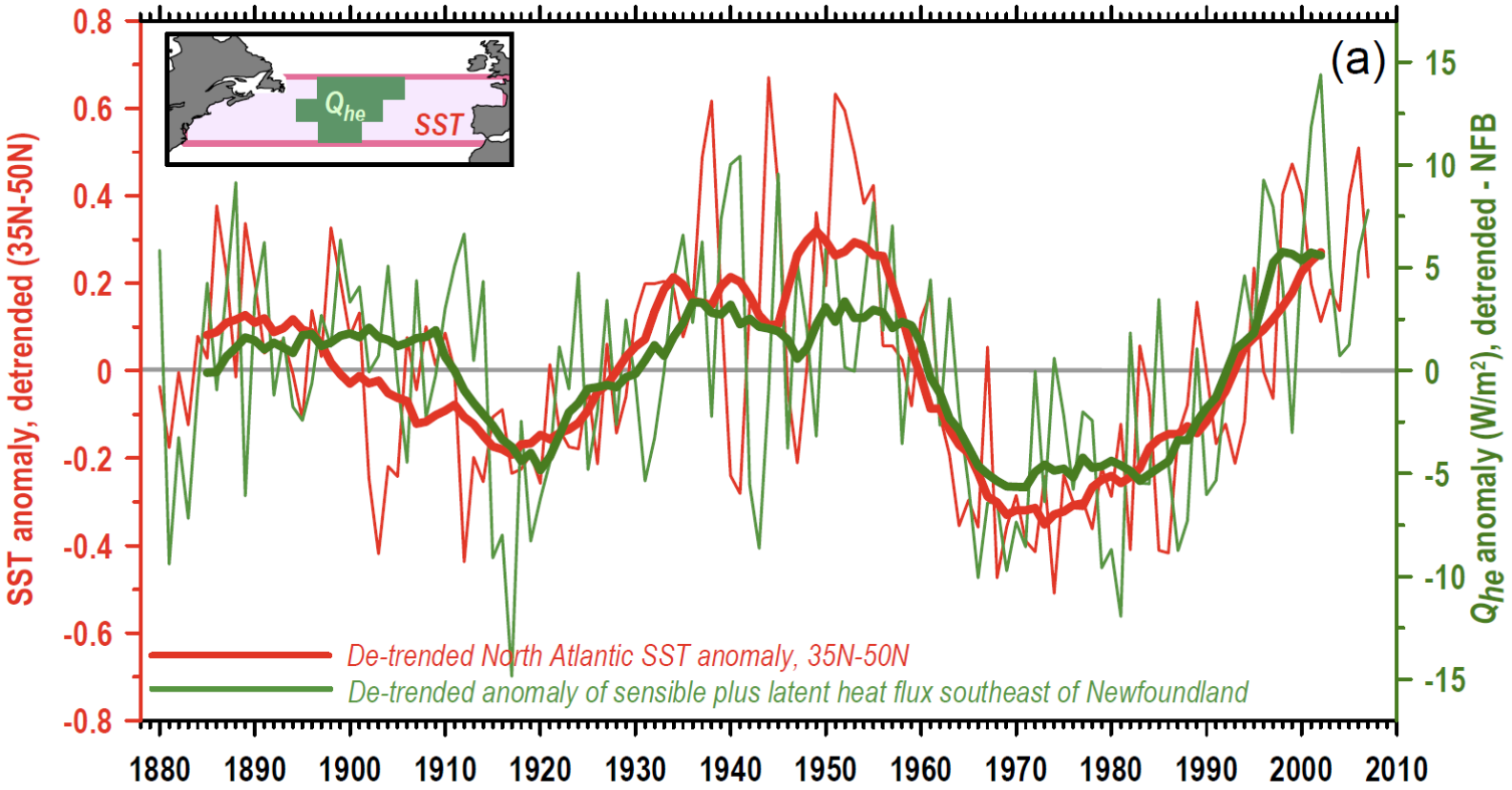


Latif and Keenlyside (2011)

Reconstructed turbulent fluxes support ocean role on decadal timescales (i.e., Bjerknes Conjecture)

Annual mean indices:

Atlantic multi-decadal variations SST and turbulent heat flux



Gulev et al. (2013)

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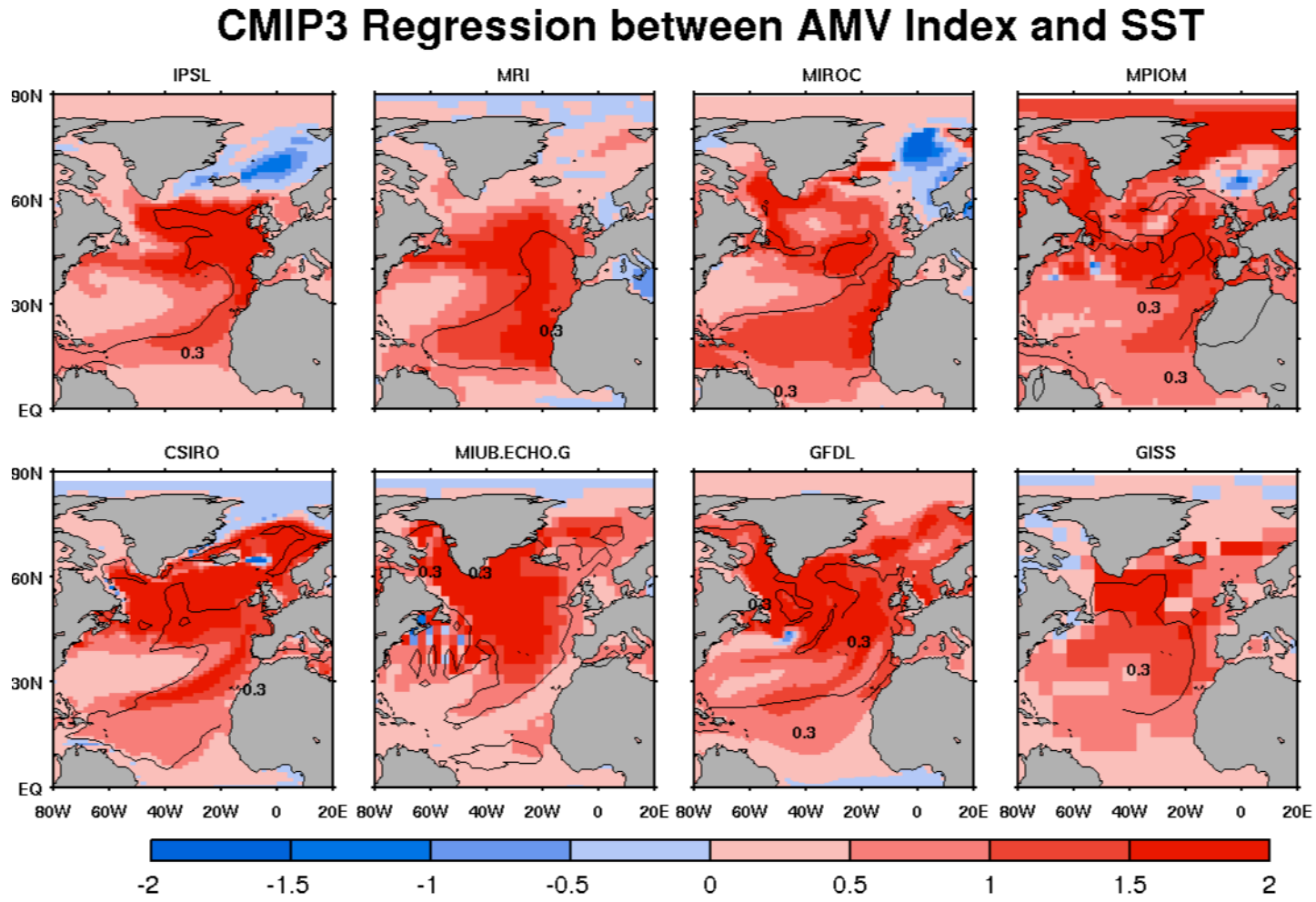
Climate models

- Capture some basic features of AMV
- Do not show much evidence for a coupled NAO-AMV mode
- Models may follow the stochastic null hypothesis for AMV

Models simulate Atlantic multidecadal variability with similarities to observations



Keenlyside et al. 2014, Peings et al. 2015, and many others

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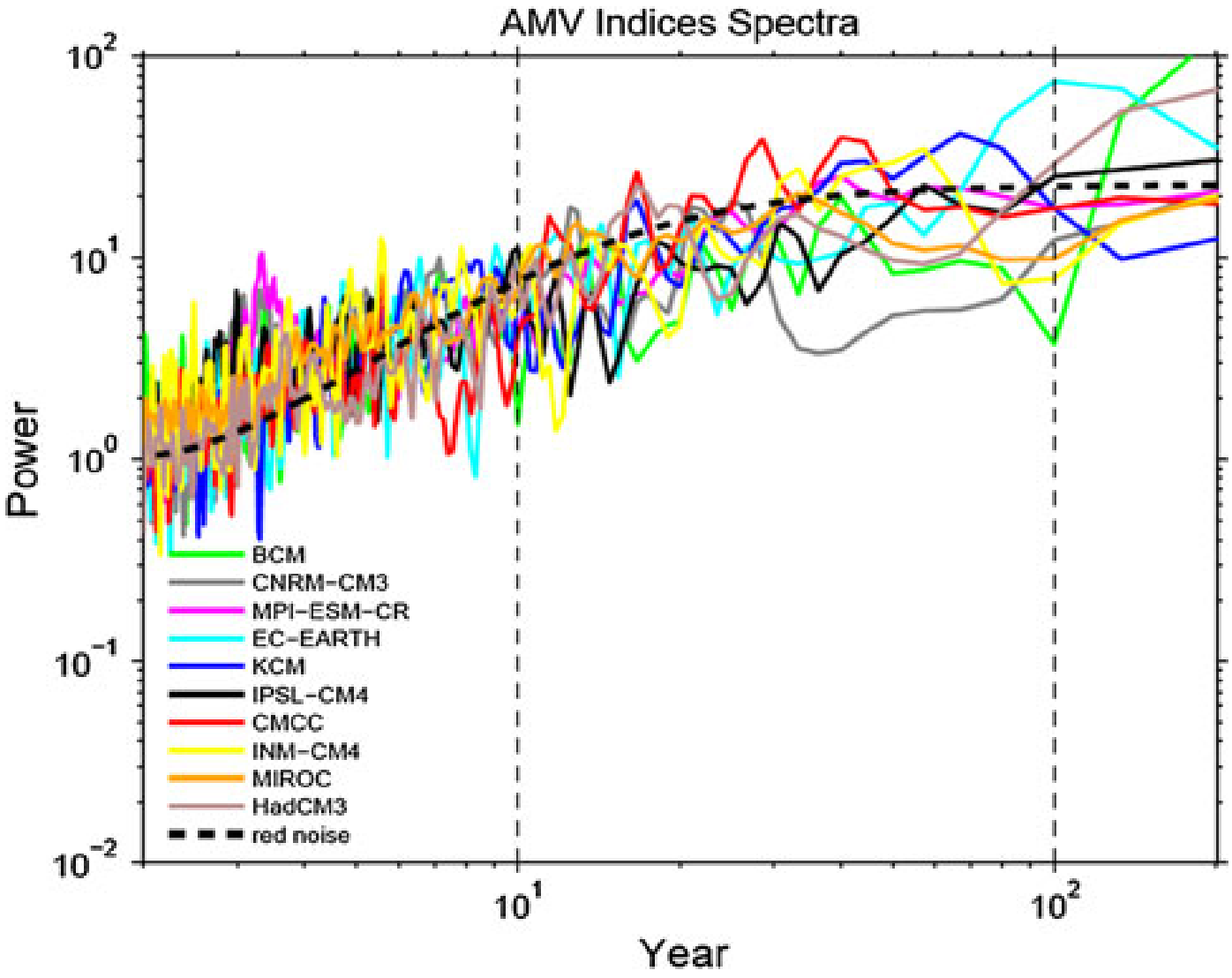
Simulated Atlantic multidecadal variability rather consistent with “red noise”



Ba et al. 2012

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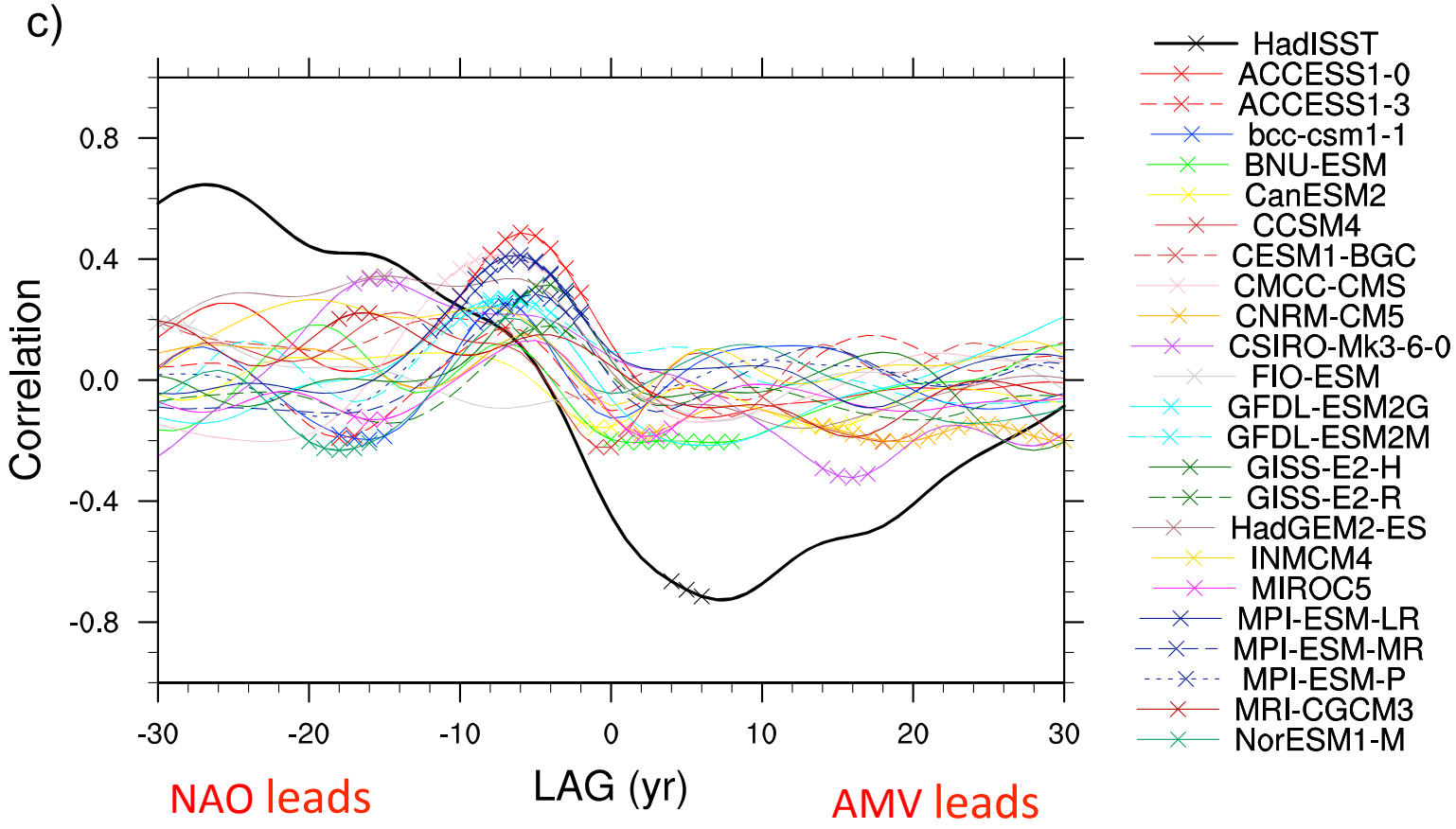
Climate modes do not capture the two way NAO – AMV relation

Lead-lag correlation NAO (DJFM) and AMV (DJFM) indices

CMIP5 Preindustrial controls



Peings et al. 2015, Ba et al. 2014

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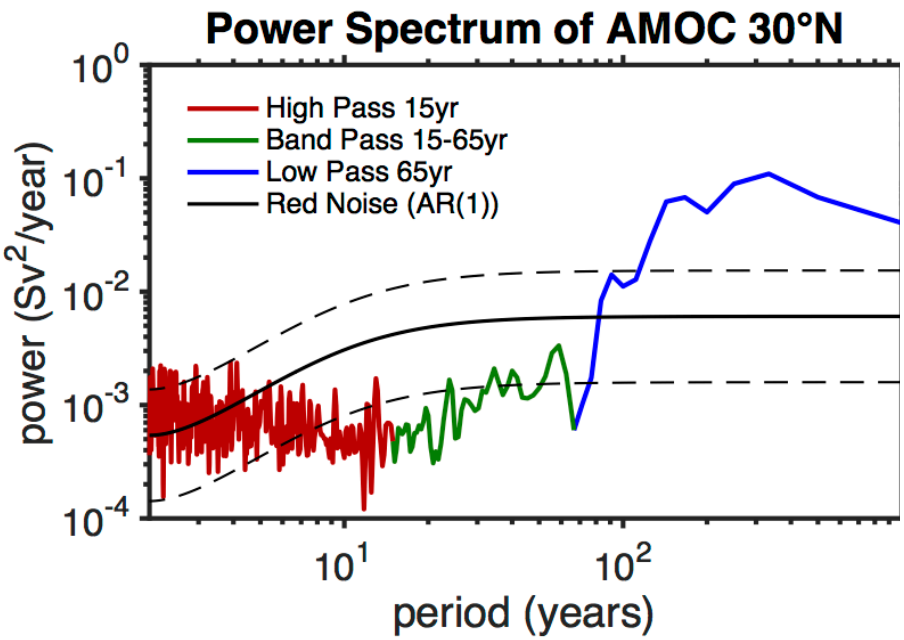
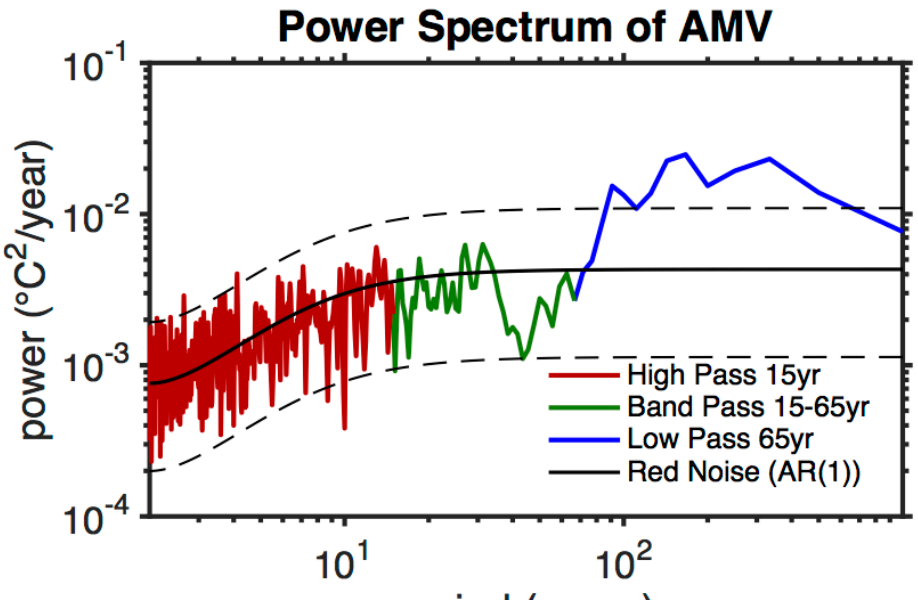
Ocean model response to stochastic NAO forcing, red, but not AR-1

Results from 2000 year simulation with NEMO, ORCA05





Delworth and Greatbatch 2001 Mecking et al. 2013, 2015

New evidence suggesting AMV does force of atmospheric variability

- Role of stratosphere-troposphere interaction

(Omrani et al. 2014, 2015, Gastineau et al. 2016)

- Some low-top models also reproduced NAO response

(Peings and Magnusdottir, 2014, Gastineau & Frankignoul 2015)

- AMOC driven SST patterns, not exactly AMV

(Gastineau et al. 2014, 2016, Frankignoul et al. 2015)

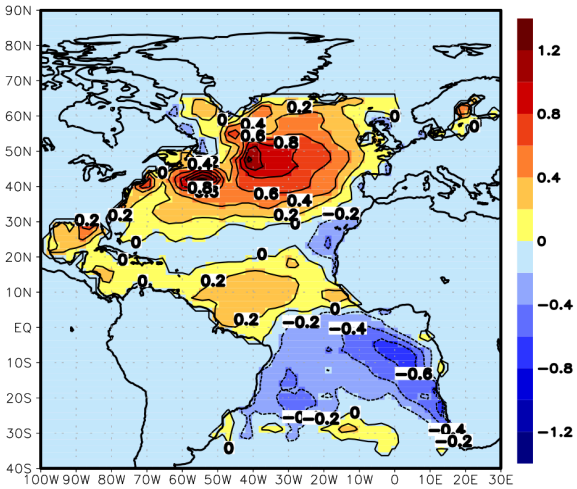
- Tropical versus extra-tropical Atlantic SST forcing

(Davini et al. 2015)

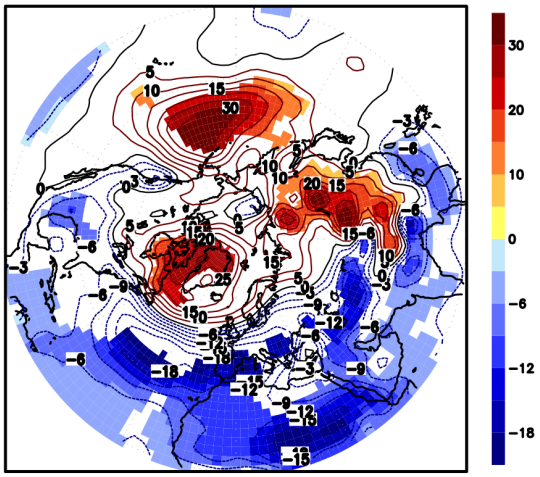
Stratospheric resolving model captures response to warm AMV conditions (1951-1960)

Observed SST anomalies

(A) Obs. SST anomaly (1951-1960)



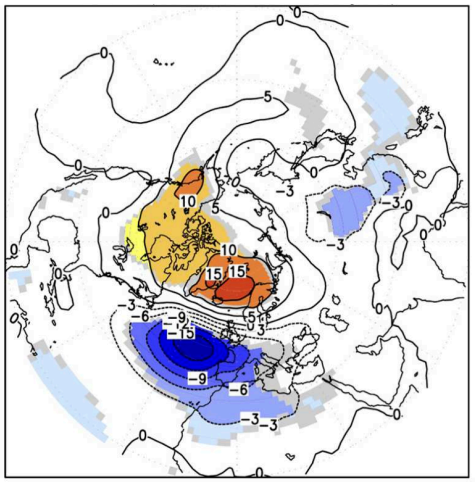
(B) NCEP 1000 hPa GPH



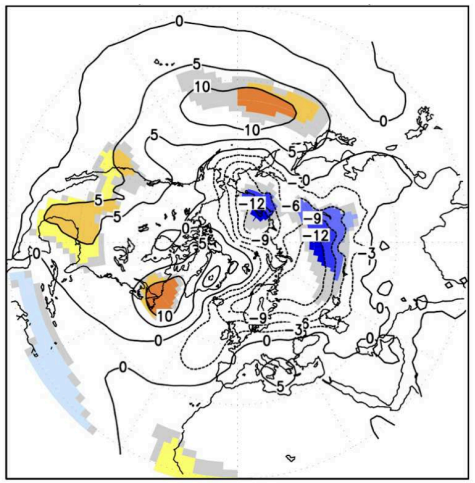
NCEP/NCAR Geopot. height anomalies

High-top simulated response (MAECHAM5)

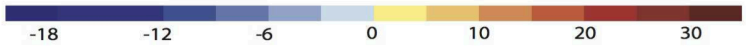
(C) High-top response, 1000 hPa GPH



(D) Low-top response, 1000 hPa GPH



Low-top simulated response (MAECHAM5)



Omrani et al. 2014

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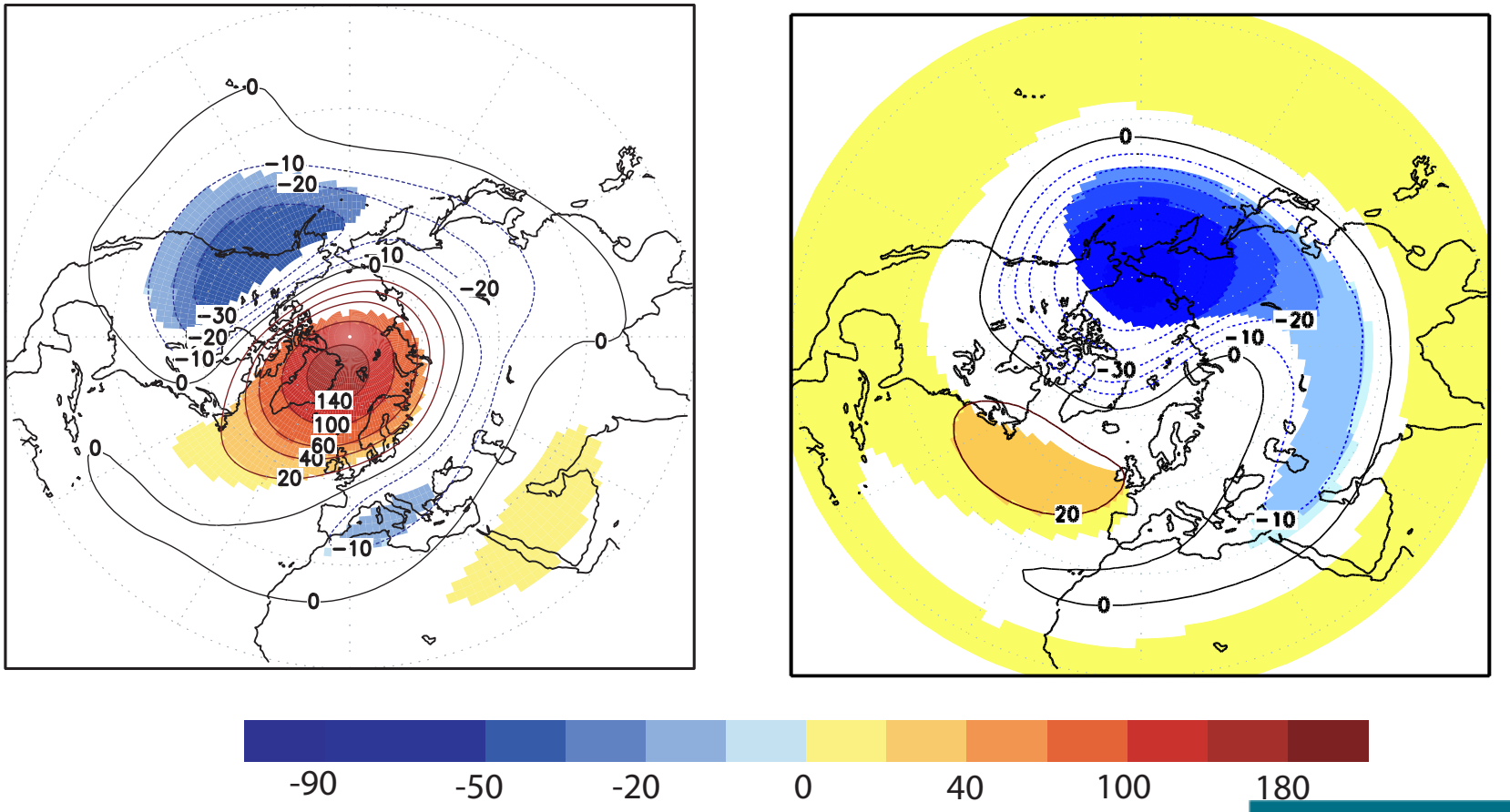
Simulated and observed weakening of early winter stratospheric polar vortex

20 hPa geopotential height (NDJ) for the 1950-60s warm period

High-top

Low-top model



Omrani et al. 2014

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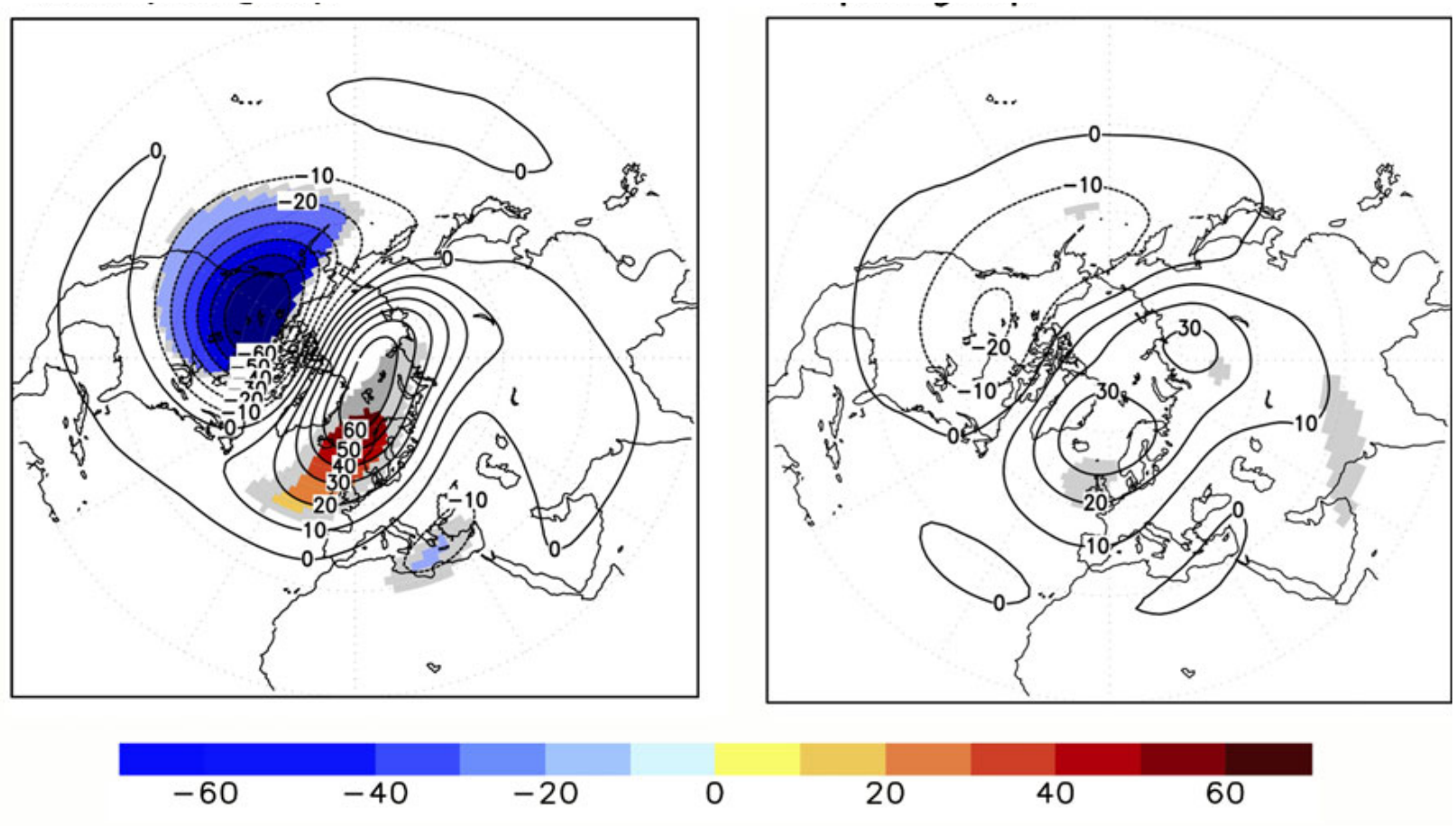
Extra-tropical SST forcing key to stratospheric and tropospheric NAO response

High-top model response for 1950-60s warming for **20 hPa GPH**

Driven by SST **south** of 30N

Driven by SST **north** of 30N



Omrani et al. 2014

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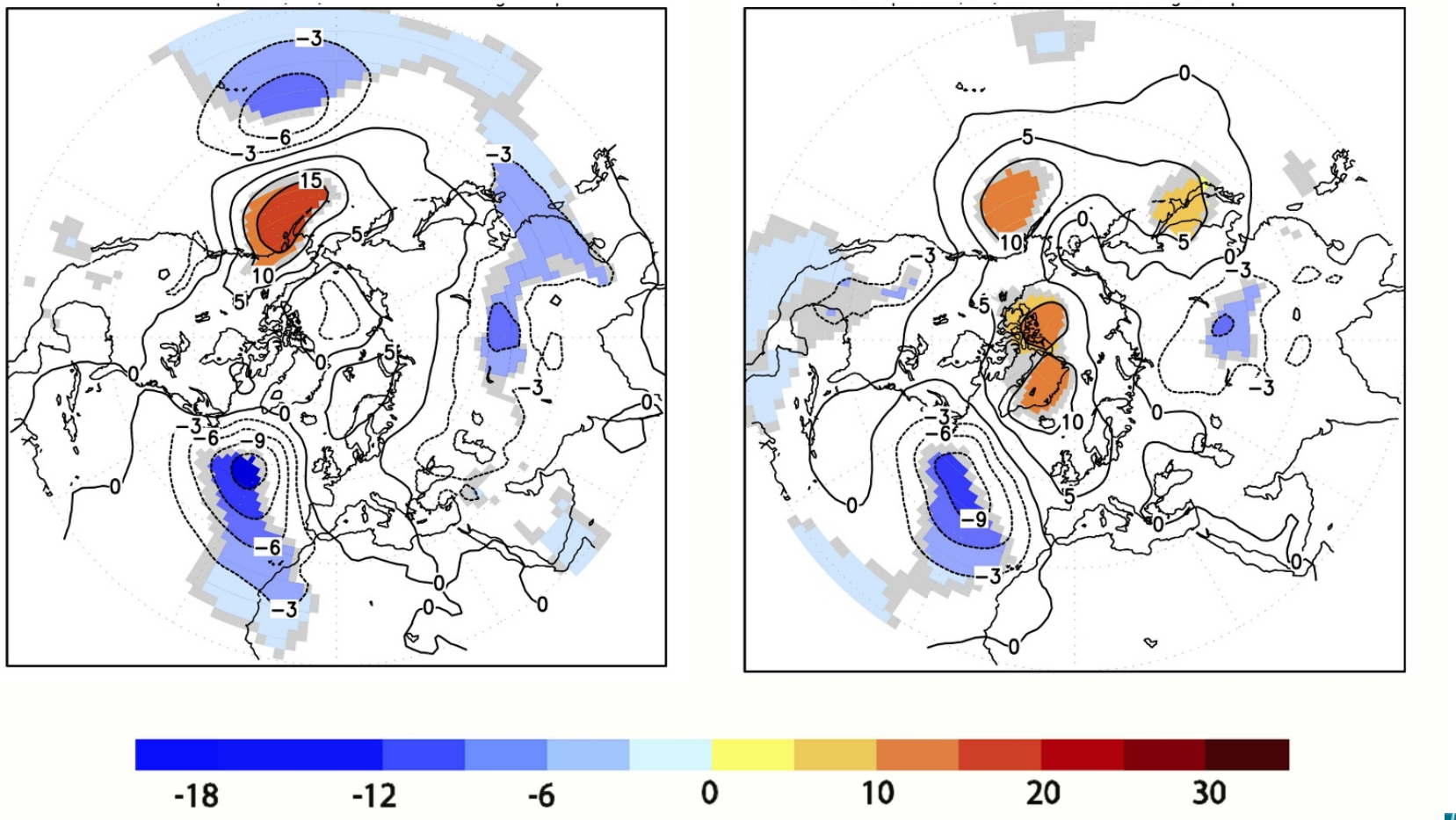
Extra-tropical SST forcing key to stratospheric and tropospheric NAO response

High-top model response for 1950-60s warming for 1000 hPa GPH

Driven by SST **south** of 30N

Driven by SST **north** of 30N



Omrani et al. 2014

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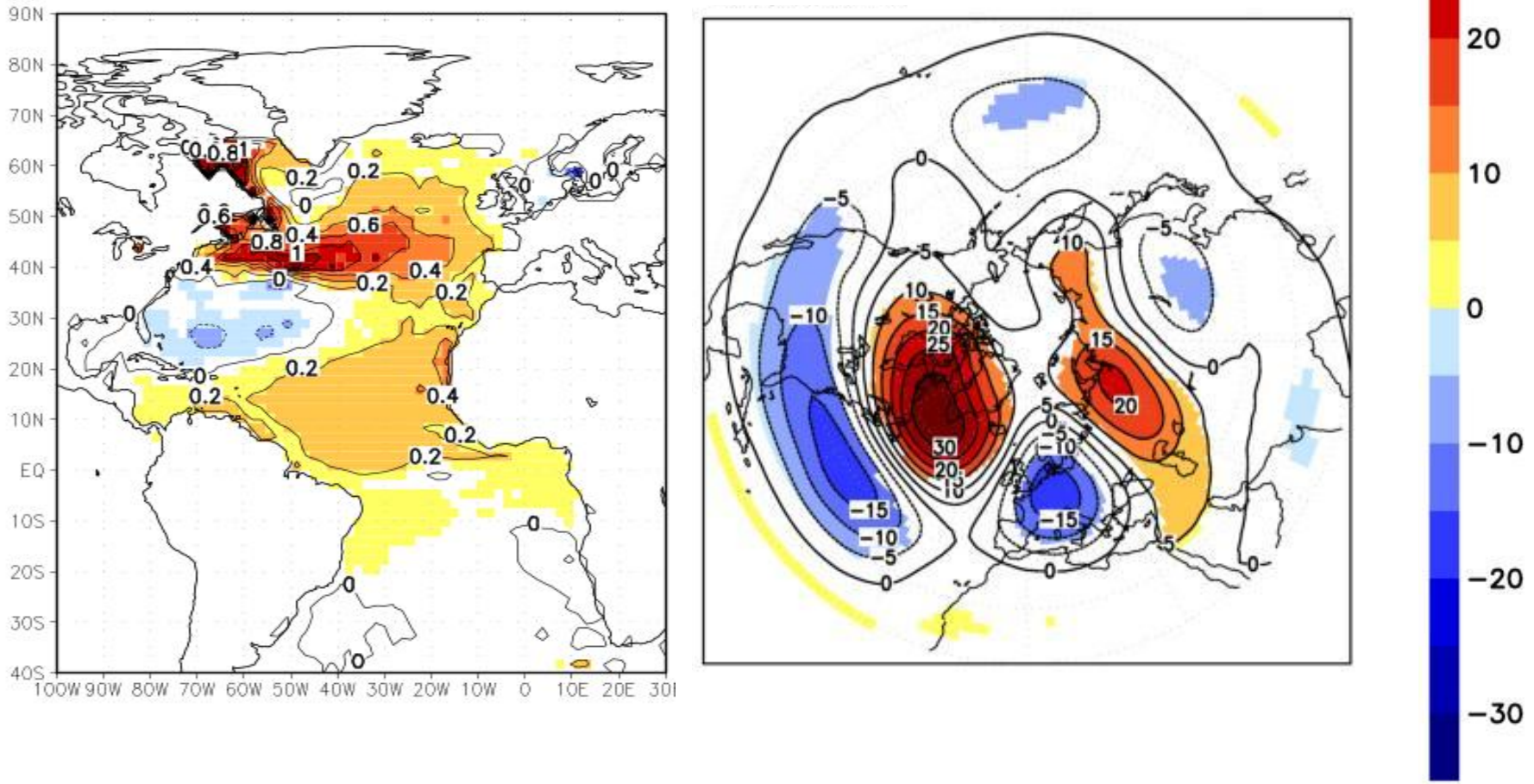
ECHAM6/MPIOM stratosphere Resolving model reproduces warm phase – negative NAO relation

Winter (JFM) composite analysis of unfiltered AMV-index

SST

500 hPa GPH



Omrani et al. 2015

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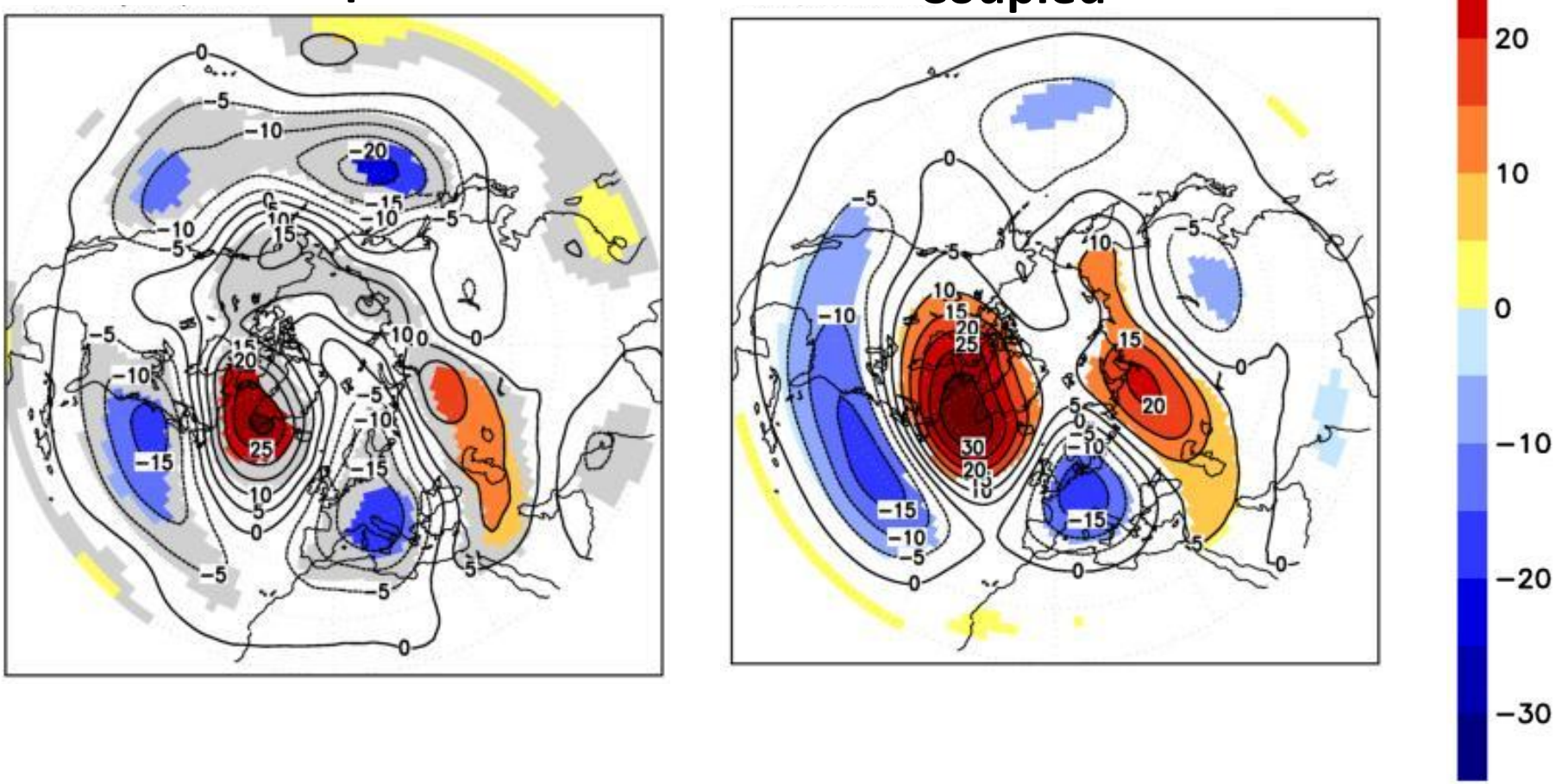
Warm phase – Atmospheric pattern largely driven by North Atlantic SST

500 hPa GPH (JFM)

Uncoupled

Coupled

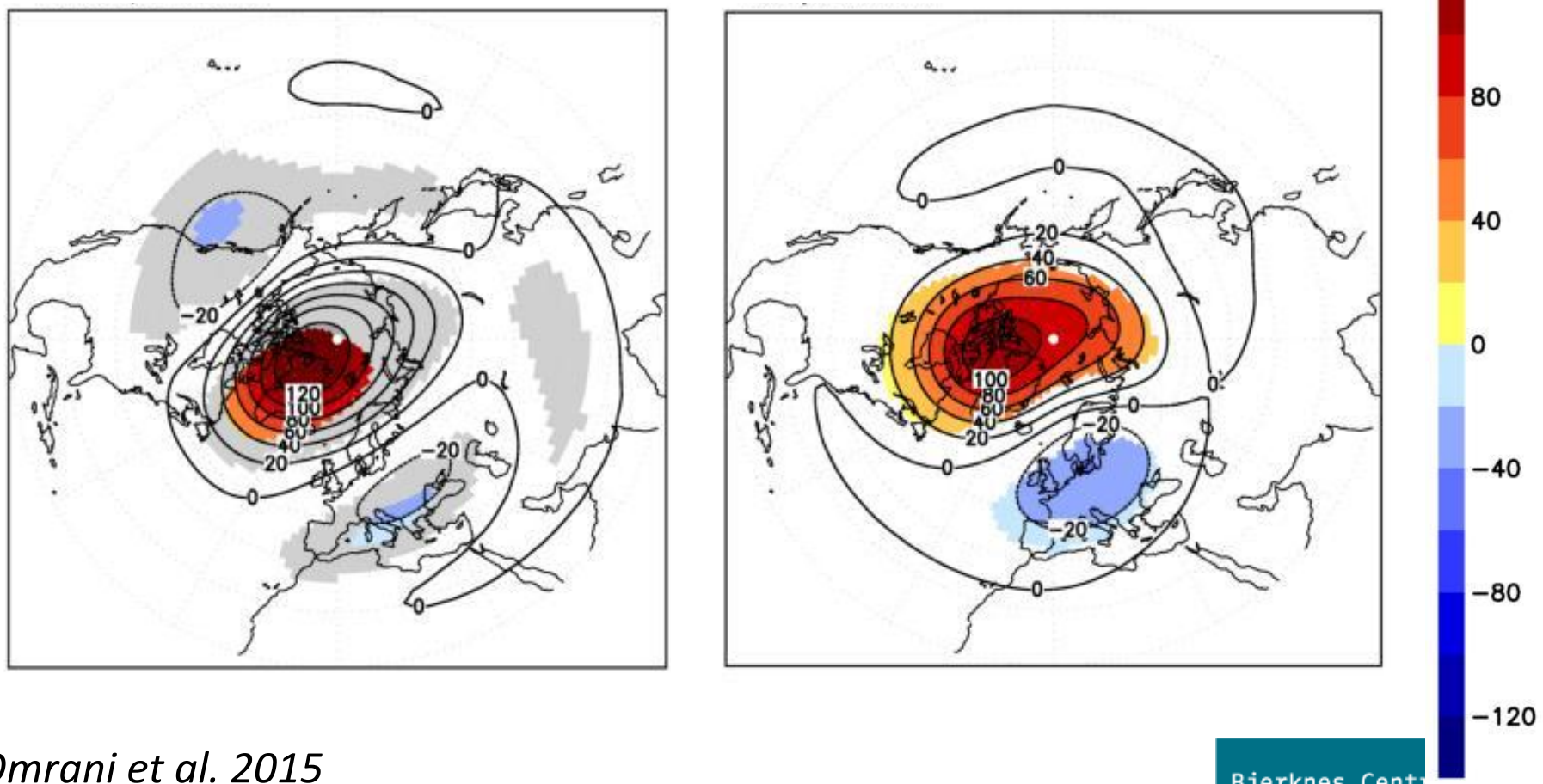


Omrani et al. 2015

Warm phase – Stratospheric polar vortex weakening largely driven by North Atlantic SST

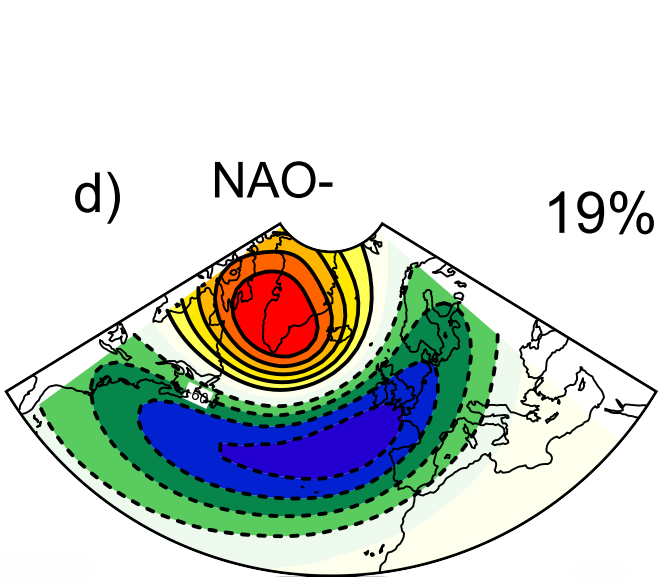
30 hPa GPH (DJF)

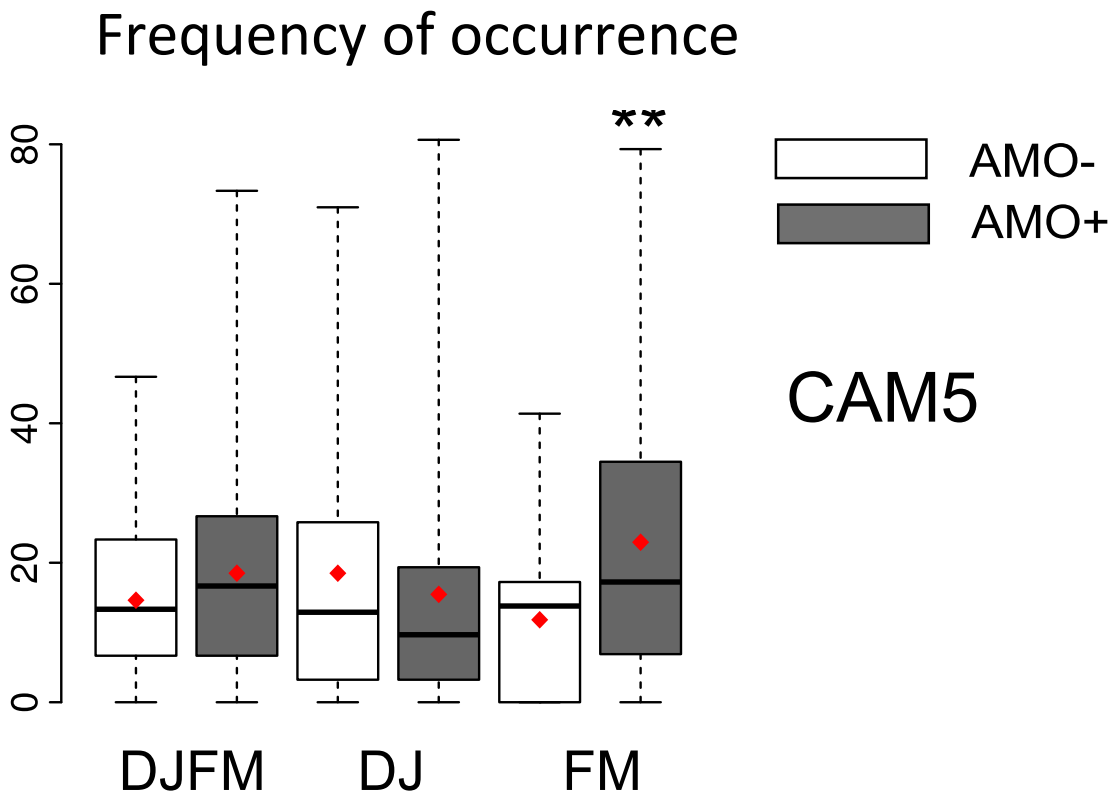
Uncoupled **Coupled**



Omrani et al. 2015

Weather regime analysis and low-top model results also show negative NAO warm AMV response





Analysis shows consistent stratospheric, but weak response

Peings and Magnusdottir, 2014

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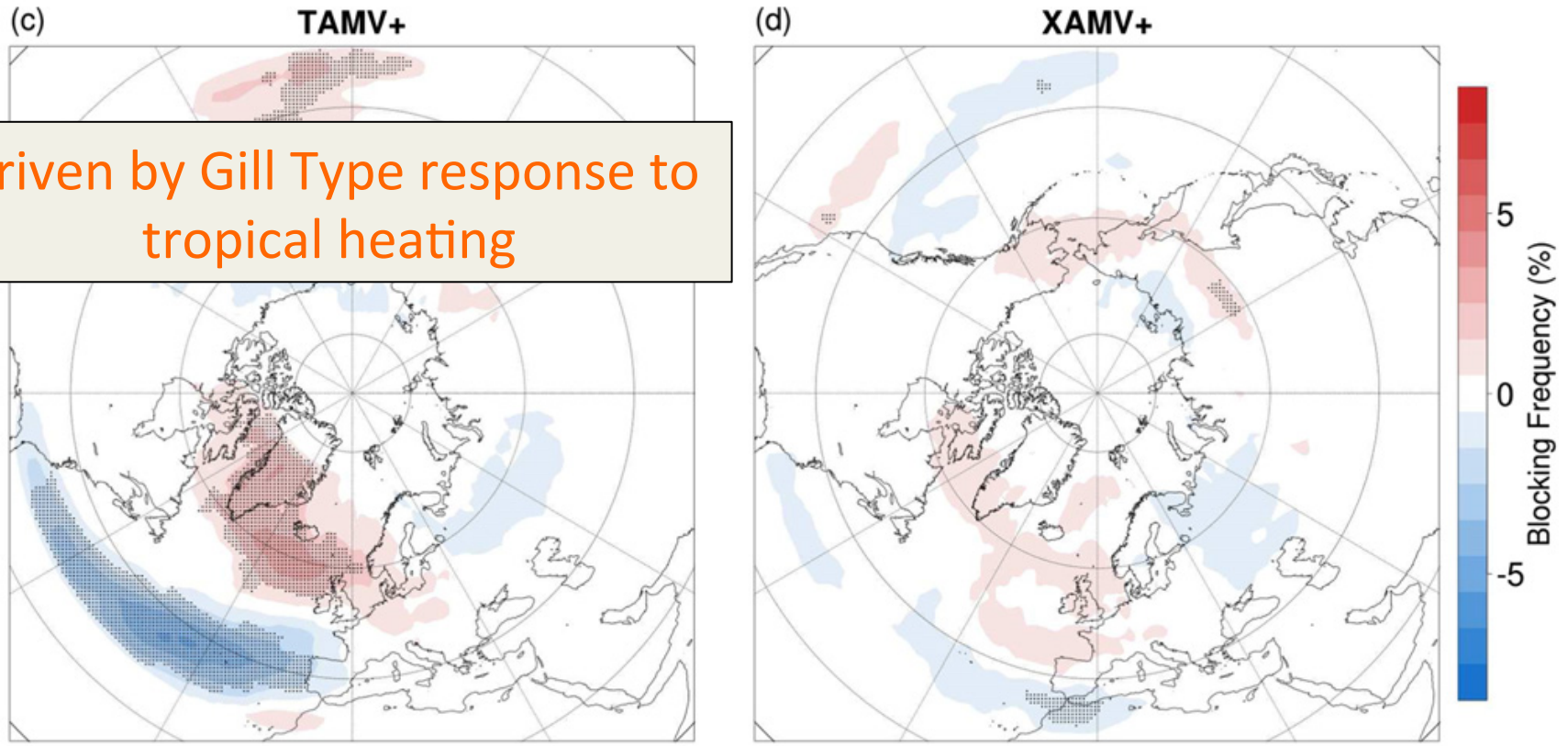
EC-EARTH reproduce NAO response using only tropical AMV SST and stratospheric response limited

Blocking frequency response

Driven by SST **tropics**

Driven by SST **extratropics**



Driven by Gill Type response to tropical heating

Davini et al. 2015

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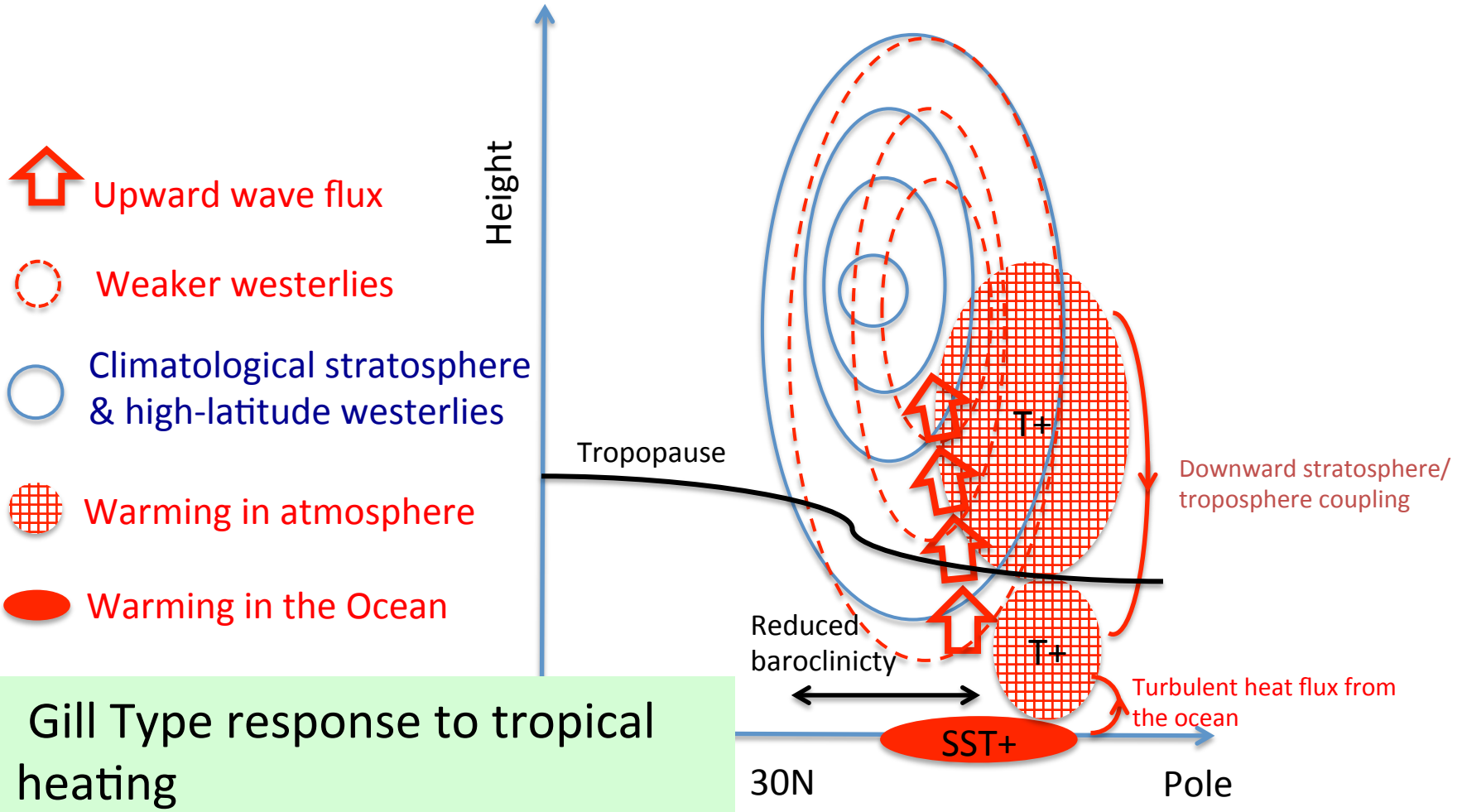
Schematic of the atmospheric response to extra-tropical North Atlantic SST



- Gill Type response to tropical heating
- Coupled models tend to capture the subtropical SLP response

Keenlyside et al., ERL, 2014

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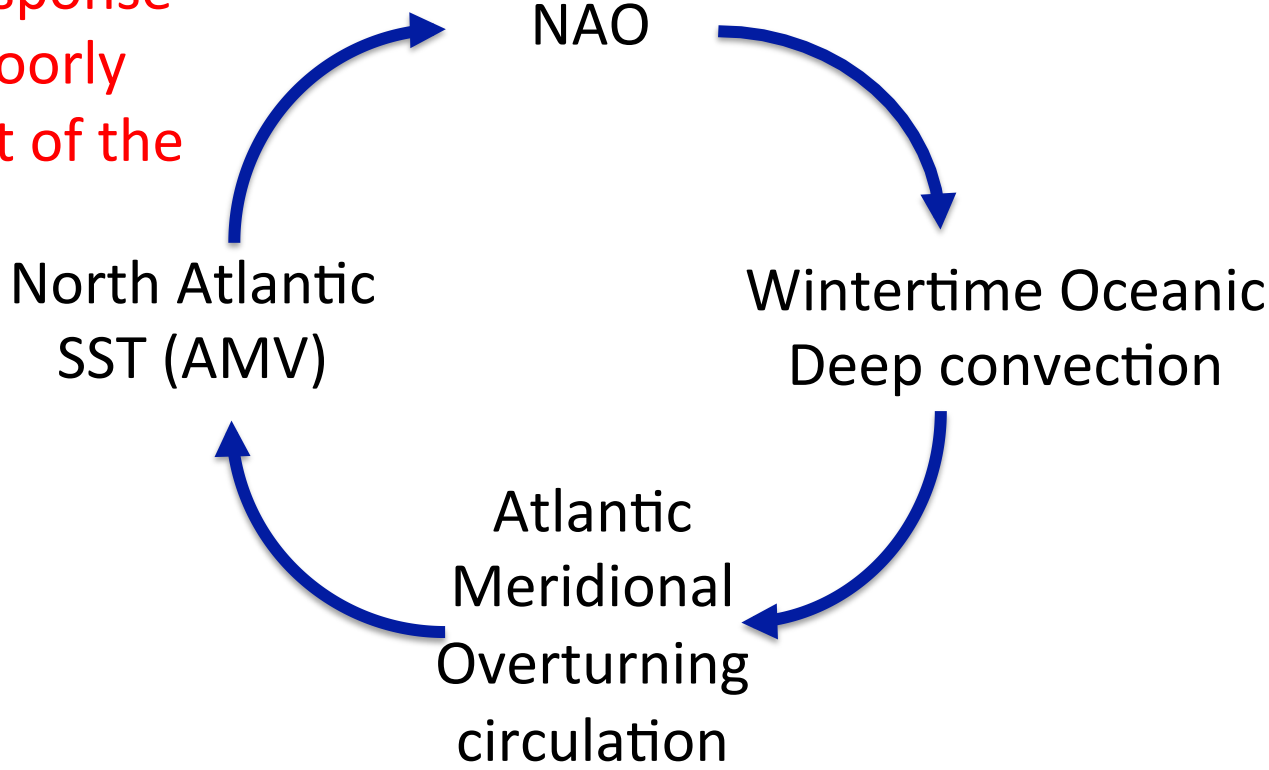
Atlantic multi-decadal variability

1. Understanding of ocean-atmosphere interaction

Atmospheric response remains most poorly understood part of the loop



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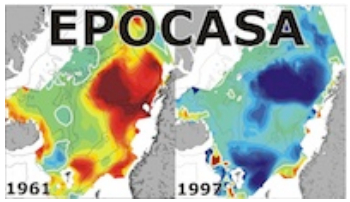
Some future directions

- Recent prediction studies suggest atmospheric models might underestimate mid-latitude response (e.g., Scaife et al 2014)
- Higher horizontal resolution, sharp SST fronts, high-frequency SST data (e.g., Minobe et al. 2008, Nakamura et al. 2004, Taguchi et al. 2012, Zhou et al. 2015)
- Understanding the role of model biases, idealised experiments to understand impact of zonal mean and stationary wave components

GREENICE



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