RESPONSE OF THE NORTH ATLANTIC OSCILLATION TO A FUTURE GRAND MINIMUM

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❖ Song, Lubin & Zhang, 2010: *GRL*, 37, L01703, doi:10.1029/2009GL041290
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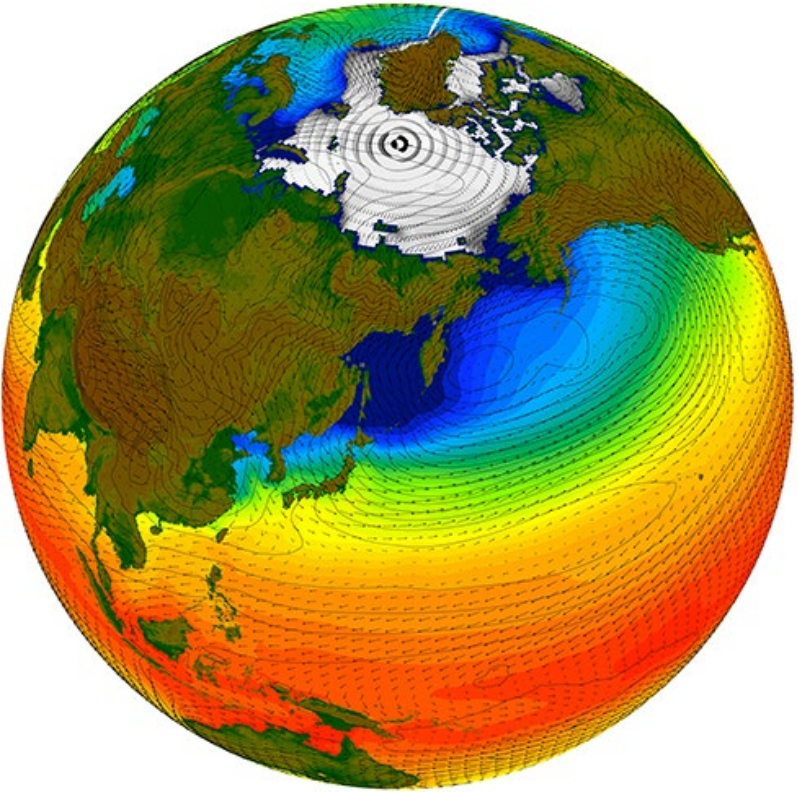
WHAT WOULD HAPPEN IF THE SUN GOES INTO A MAUNDER MINIMUM TOMORROW?

A study using the NCAR Community Atmosphere Model version 3 (CAM3)
Collins et al., *Journal of Climate*, 2006



- T42 truncation: 2.8° x 2.8° latitude x longitude.
- 26 levels from surface to 2.917 mb, about 8 levels in the stratosphere.
- Coupled to mixed-layer slab ocean model (SOM) with a thermodynamic sea ice component that is part of the Coupled Climate System Model (CCSM3).
- Equilibrium climate sensitivity of CAM coupled with SOM is is 2.47°C for doubling of CO_2.
- Conduct 50-year equilibrium simulations (they stabilize after ~25 years).

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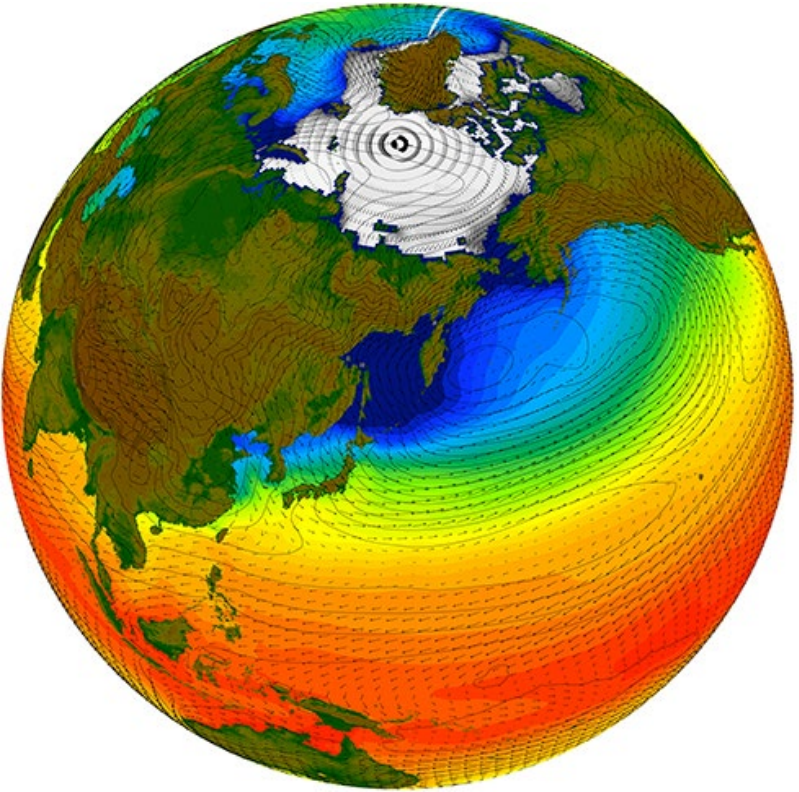


Experiment 1: Preindustrial CO_2 concentration 288 ppm.

- Preindustrial Control (PICTL) and Maunder Minimum (PIMM)

Experiment 2: Human industrial activity increases CO_2 concentration to 550 ppm (IPCC B1 Scenario), also increase ozone, methane, and add CFC11 and CFC12.

- B1 Control (B1CTL) and B1 Maunder Minimum(B1MM)

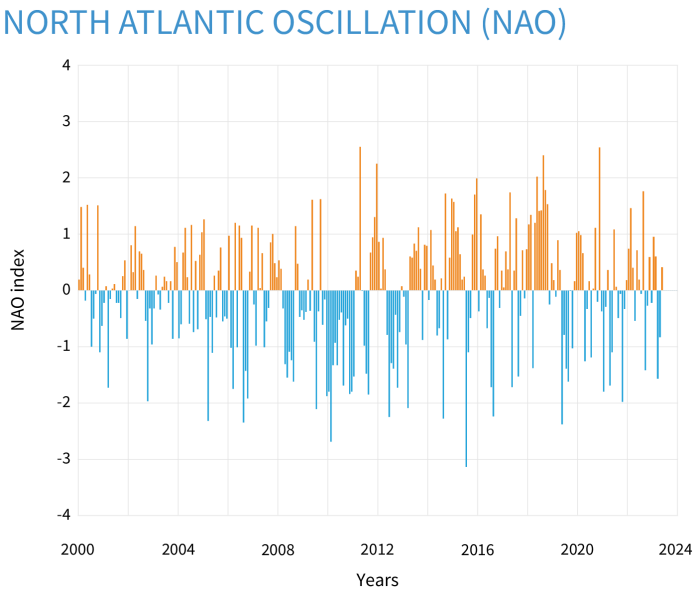
In Both Experiments:

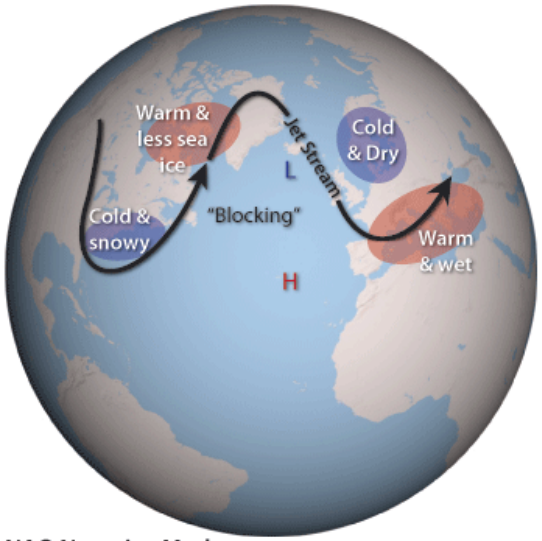
1. Do a global climate simulation with climatological mean total solar irradiance (TSI).
2. Run a second climate simulation with total solar irradiance reduced by 0.2% or 2.7 Watts per square meter, a ***large*** estimate for the Maunder Minimum TSI reduction (Lean et al., *GRL*, 2000).
3. Analyze the global and regional differences in temperature and atmospheric circulation.

IN PARTICULAR: LOOK FOR THE RESPONSE OF THE NORTH ATLANTIC OSCILLATION (NAO)

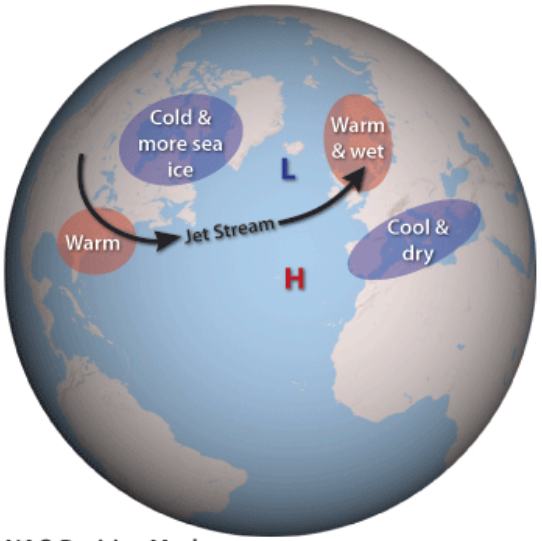
NAO Index represents the fluctuating difference in sea level pressure between the Azores High and the Icelandic Low.

- Positive (Negative) Index signifies larger (smaller) pressure differential.





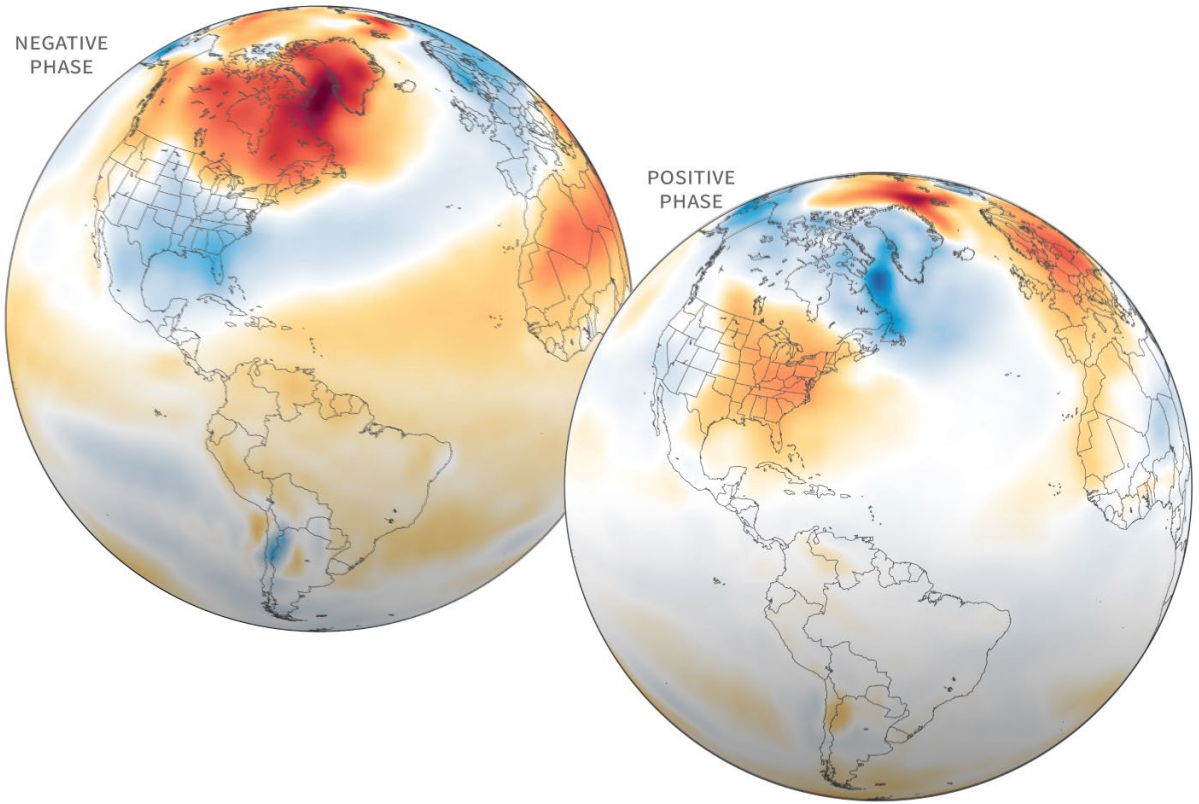
NAO Negative Mode



NAO Positive Mode

Figures from *climate.gov*

NAO TEMPERATURE PATTERNS



Jan-Mar 2010 (left)
Jan-Mar 1990 (right)

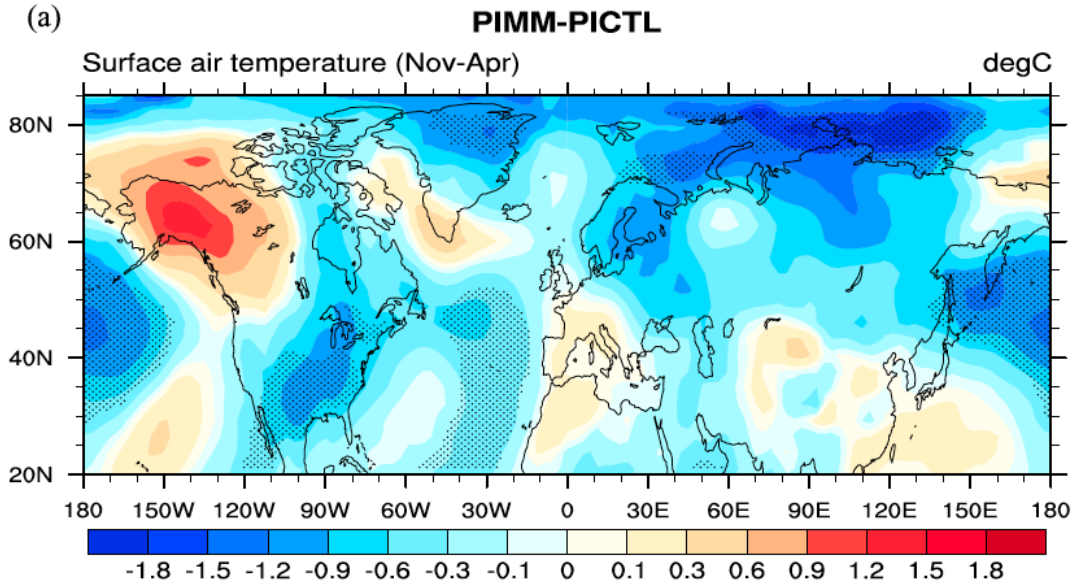
Difference from average temperature (°C)

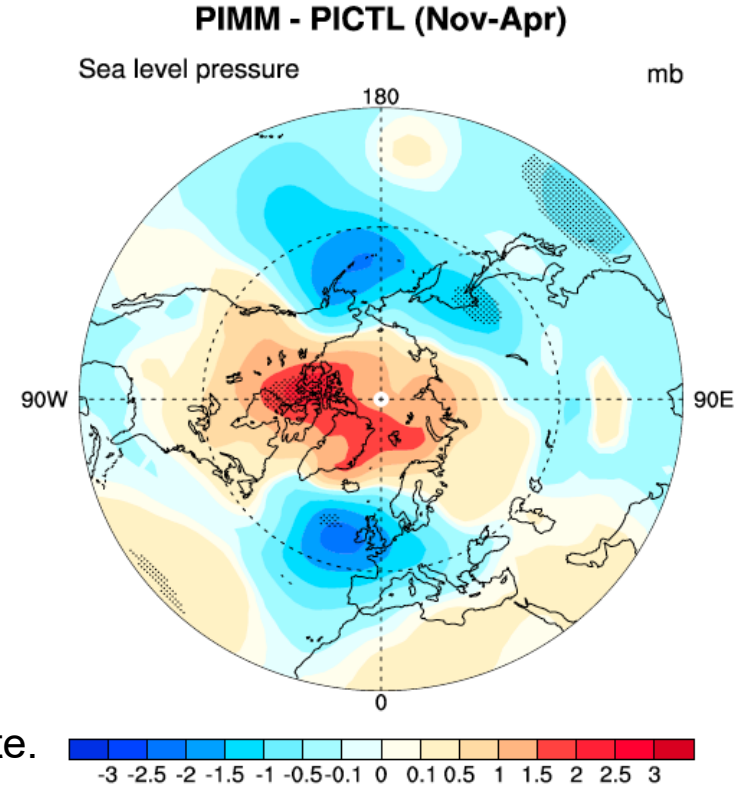
-10 0 10

NOAA Climate.gov
Data: NCEP/NCAR

HISTORICAL MAUNDER MINIMUM

- Cooling over northern Eurasian and warming over Greenland are up to 2.1°C and 0.6°C respectively.
- Global averaged surface air temperature (SAT) simulated by PIMM is 0.347°C cooler than PICTL.





- TSI reduction shifts NAO to more negative state.

HISTORICAL MAUNDER MINIMUM

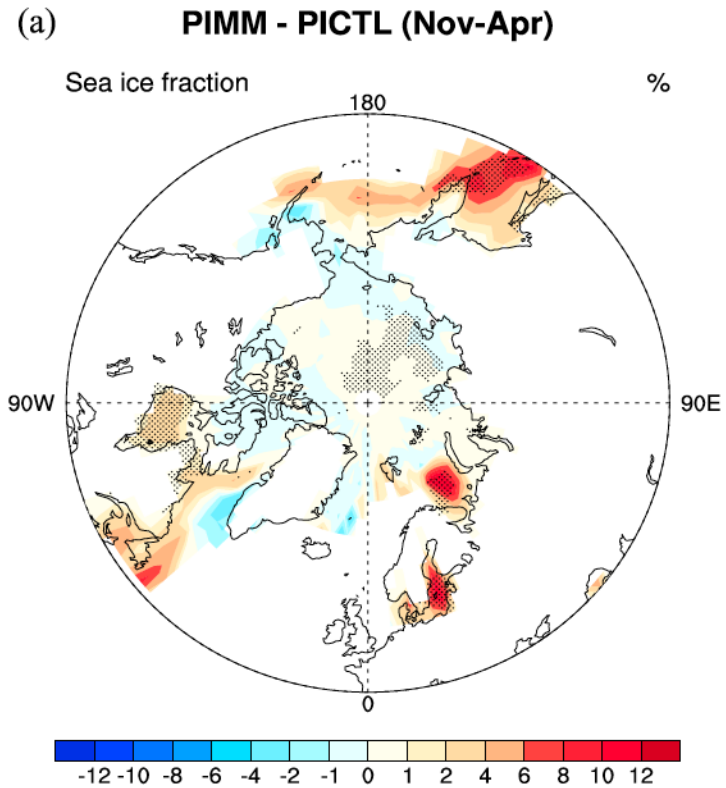
- The frequent negative NAO index condition also produced much more frequent easterlies in the North Sea after 1662 (Degroot, *Environment and History*, 2014).
- This gave the Dutch Navy significant operational and tactical advantages during the 2nd and 3rd Anglo-Dutch wars; the Netherlands then rivaled England as a global maritime and economic power.

The Four Days Battle, June 1666. Painting by Pieter Cornelizs van Soest.

Michiel de Ruyter
Dutch Jedi Admiral

SEA ICE RESPONSE

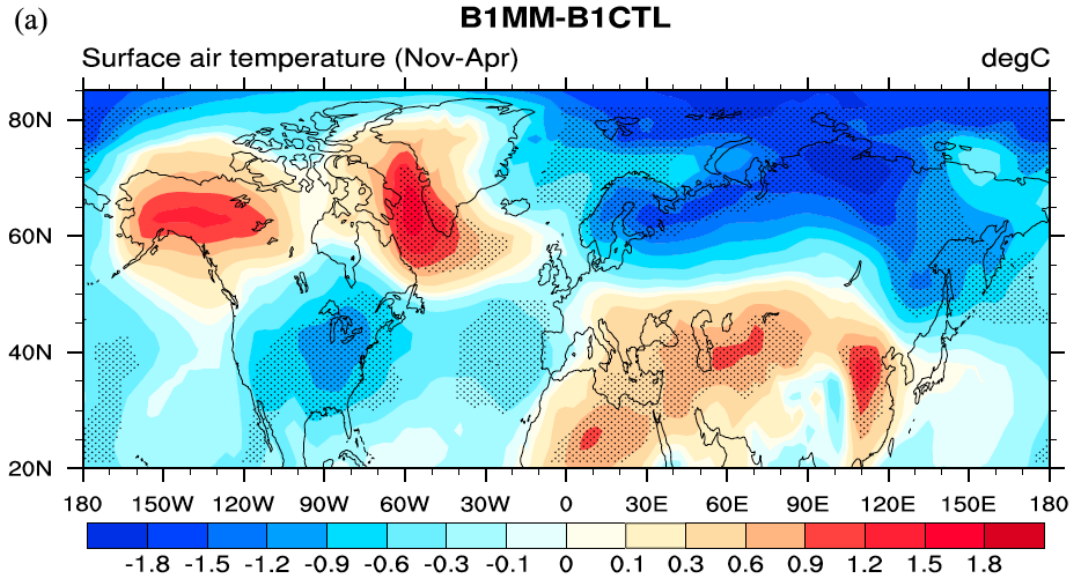
- PIMM sea ice response in the Baltic is consistent with historical records and historical events.

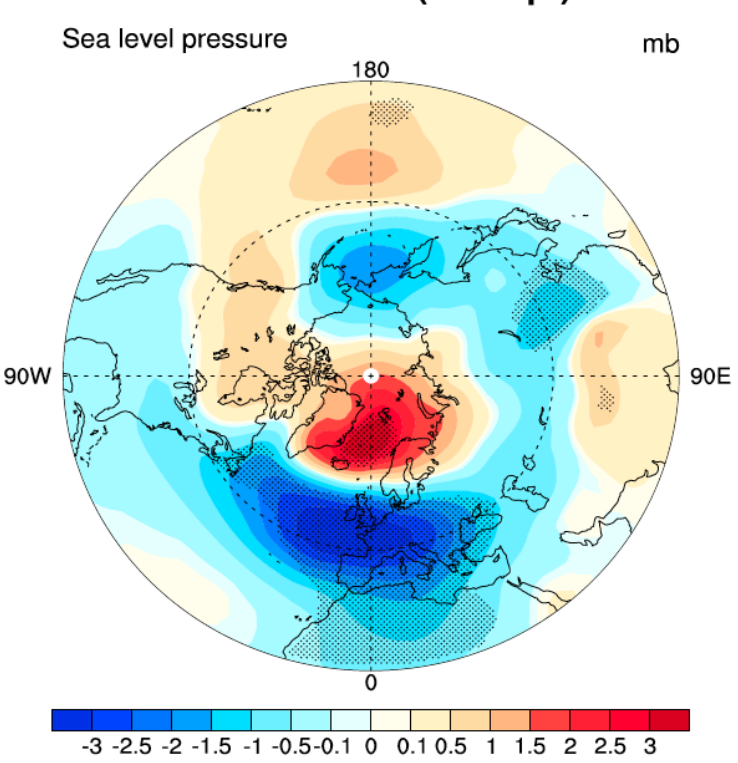


”March Across the Belts” in winter 1658.

FUTURE GRAND MINIMUM

- Global averaged surface air temperature (SAT) simulated by B1IMM is 0.254°C cooler than B1CTL, smaller than PIMM, partly due to increased GHG warming.
- Stronger response over Greenland.

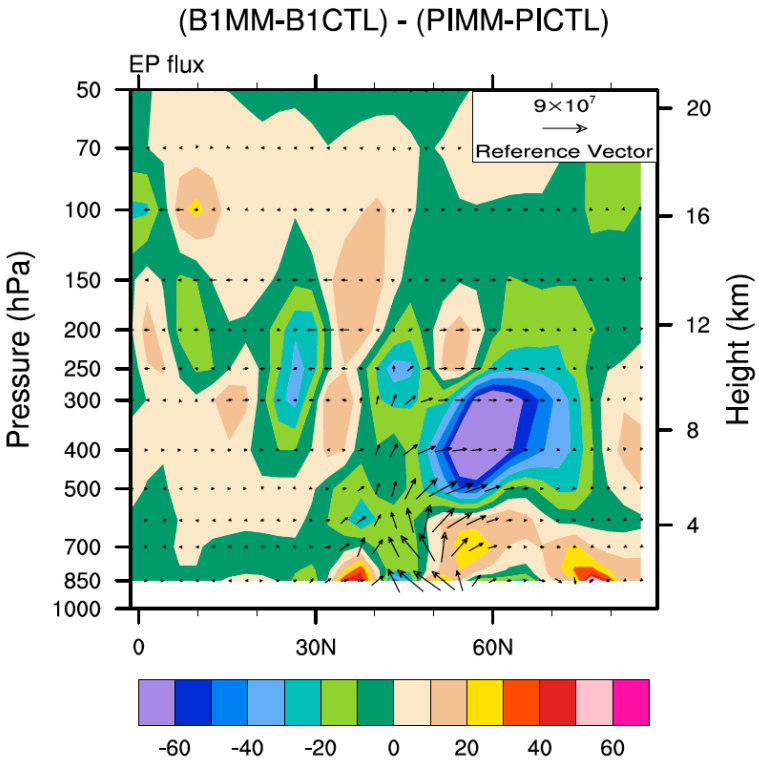




- TSI reduction shifts NAO to even more negative state.

CONCLUSION

- A future grand minimum doesn't offset GHG-induced climate warming.
- NAO shifts could be volatile and unpredictable, even possibly enhancing cryosphere mass loss sea level rise.



- Difference between the two experiments:
  - Wintertime Eliassen-Palm (EP) flux, also known as "wave activity flux" (arrows)
  - EP flux divergence (shading)

- Under the B1 scenario, the TSI reduction produces:
  - Stronger upward wave energy flux at midlatitudes,
  - relatively stronger poleward refraction of EP flux,
  - leading to EP flux convergence in the middle and upper troposphere near 60°N,
  - generating a residual circulation with subsidence at higher northern latitudes and rising motion to the south,
  - resulting in SLP changes corresponding to a more negative NAO phase.