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A Mid-Century Shift in AMV Impacts

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Background

We examined the impact of two North Atlantic modes of climate variability, the Atlantic Multidecadal Variability (AMV) and the North Atlantic Oscillation (NAO), on observed surface temperature, pressure, and rainfall across the globe. In the pre-industrial era, changes in the phase of the NAO had similar global impacts on temperature as a phase change in the AMV. However, the increase in anthropogenic greenhouse gases since roughly 1950 has raised questions as to how the AMV and NAO are responding.

Our research addresses:

1. **How has the AMV changed in comparison to the NAO after 1950 and what is driving these changes?**
2. **What are the impacts of these changes, particularly in terms of surface temperature and precipitation?**

Methods

Observation Data:

- **SST:**
  - ERSSTv5
- **2m Surface Temperature:**
  - HadCRUT5
  - 20th Century Reanalysis v3
  - NCEP Reanalysis v1
- **Surface Air Pressure:**
  - 20th Century Reanalysis v3
  - NCEP Reanalysis v1
- **Precipitation:**
  - GPCC
  - 20th Century Reanalysis v3

Calculations:

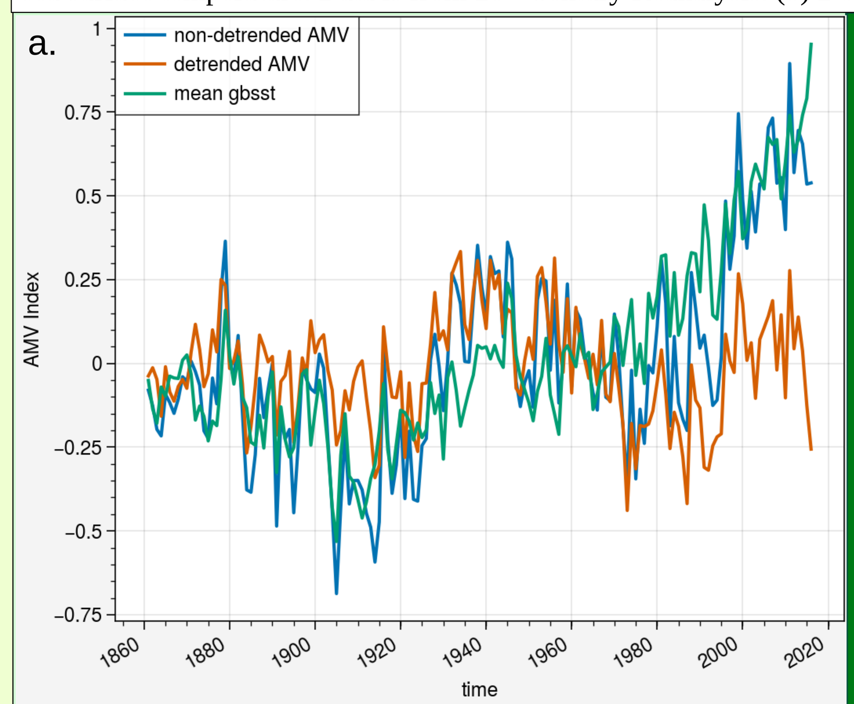
- **AMV:** average SSTs over the North Atlantic Basin
  - (0° to 60°N, 80°W to 0°)
- **NAO:** Pressure difference between the Azores high (36 ° to 40°N, -28°W to -20°) and the Icelandic low (63° to 70°N, -25°W to -16°)

Code:

- Data was tested both not detrended and detrended, meaning the anthropogenic forced component was removed.
- Data was also tested unfiltered and then with a 10-year low-pass filter which removes the high-frequency signals and leaves only the decadal low-frequencies.

Results

Fig. 1: Example of calculating the AMV and NAO indexes (a) Time series from 1860-2015 of the detrended and not detrended AMV index compared to the mean global sea surface temperature. Data is from 20th Century Reanalysis. (b) Detrended and not detrended NAO index from 1860-2015 using 20th Century Reanalysis.



- The NAO displays no change in variability when not detrended.
- **Pre-1950:**
  - the AMV was in a lagged relationship with the NAO and was driven by changes in wind over the North Atlantic.
  - During AMV+/NAO-, we observe lower pressure over southern Europe and the Azores and higher pressure over northern Europe and Iceland. Also, cooler surface air temperatures over the US and northern Europe while southern Europe is warmer.

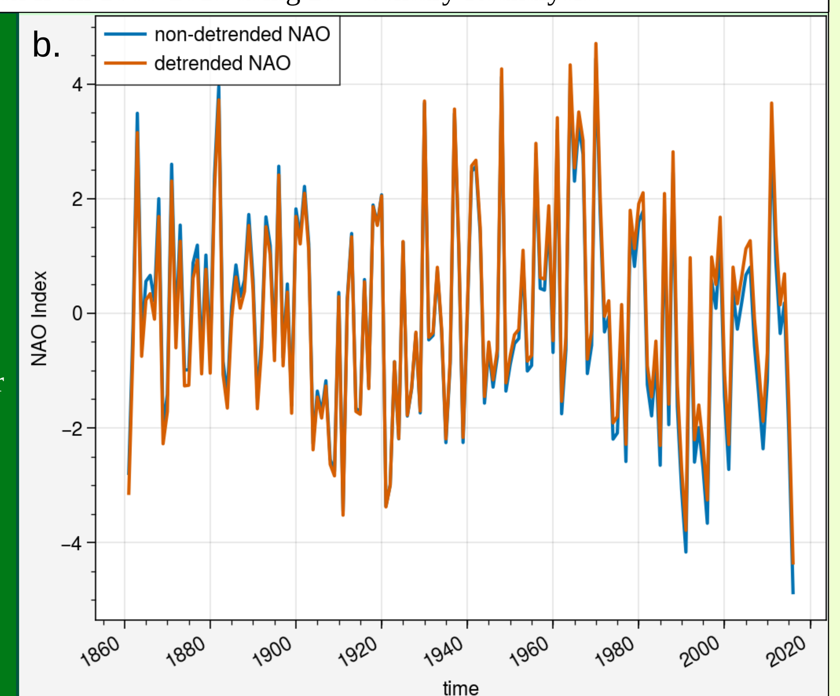


Fig. 2: Removing the anthropogenic factor to visualize the natural trend. (a-d) Regression maps of the detrended NAO index (a, c) and detrended AMV index (b, d) on surface temperature and sea-level pressure for the periods 1870 – 1950 (a, b) and 1951 – 2019 (c, d).

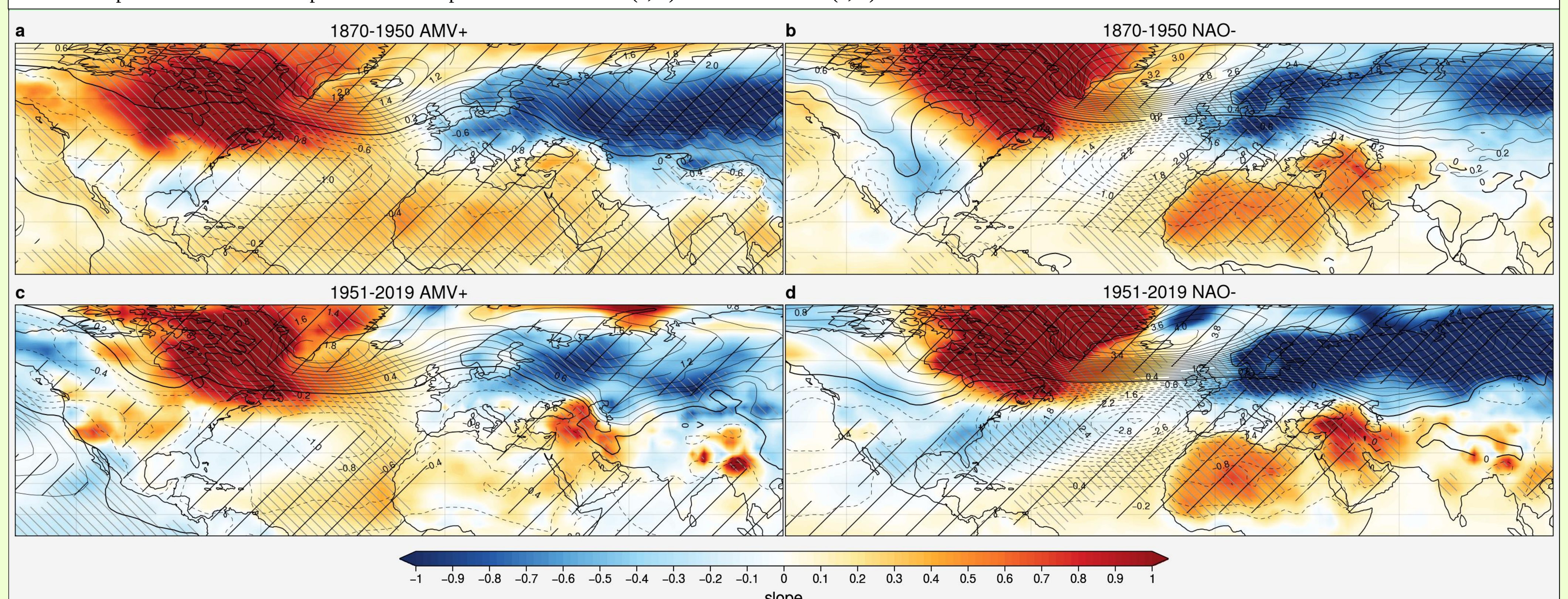
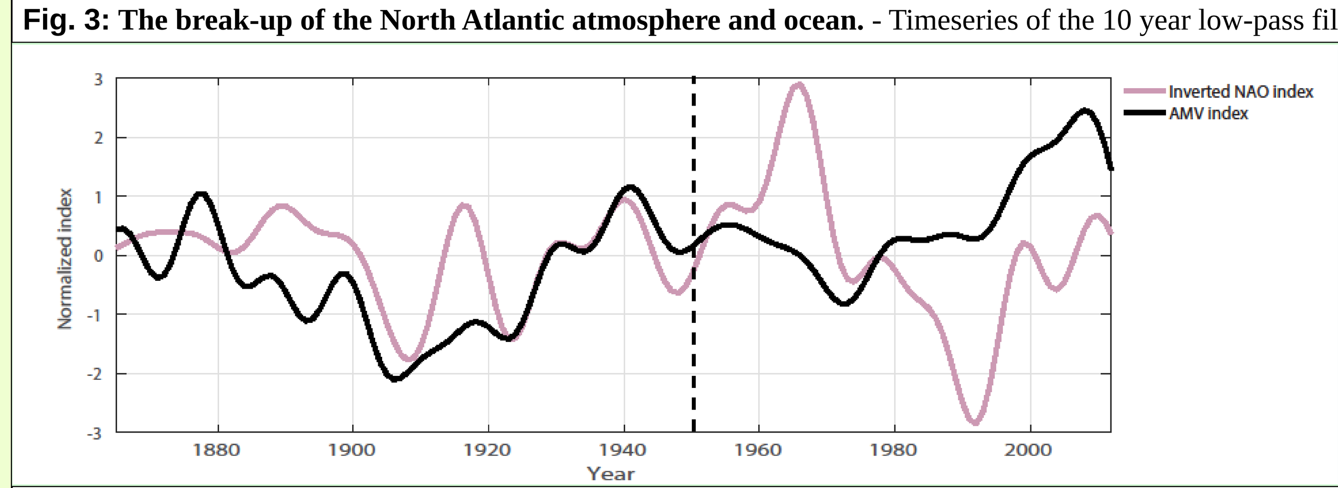


Fig. 3: The break-up of the North Atlantic atmosphere and ocean. - Timeseries of the 10 year low-pass filtered AMV Index (black) and inverted NAO index (red).



- Figure 3 shows a strong correlation between the AMV and NAO under internally driven conditions.
- **Anthropogenic forcing causes a breakup in the correlation of the AMV and NAO**
- The state of the AMV and NAO have veered away from the natural pattern of variability seen before the middle of the 20th century.

Fig. 4: The break-up of the North Atlantic atmosphere and ocean. (a - d) Unfiltered and not detrended regression maps for NAO- (b, d) and AMV+ (a, c) on surface temperature and sea-level pressure for the periods 1870 – 1950 (a, b) and 1951 – 2019 (c, d). The small gray hatching represents the 95% confidence interval for the surface temperature. The larger black hatching is for the pressure.

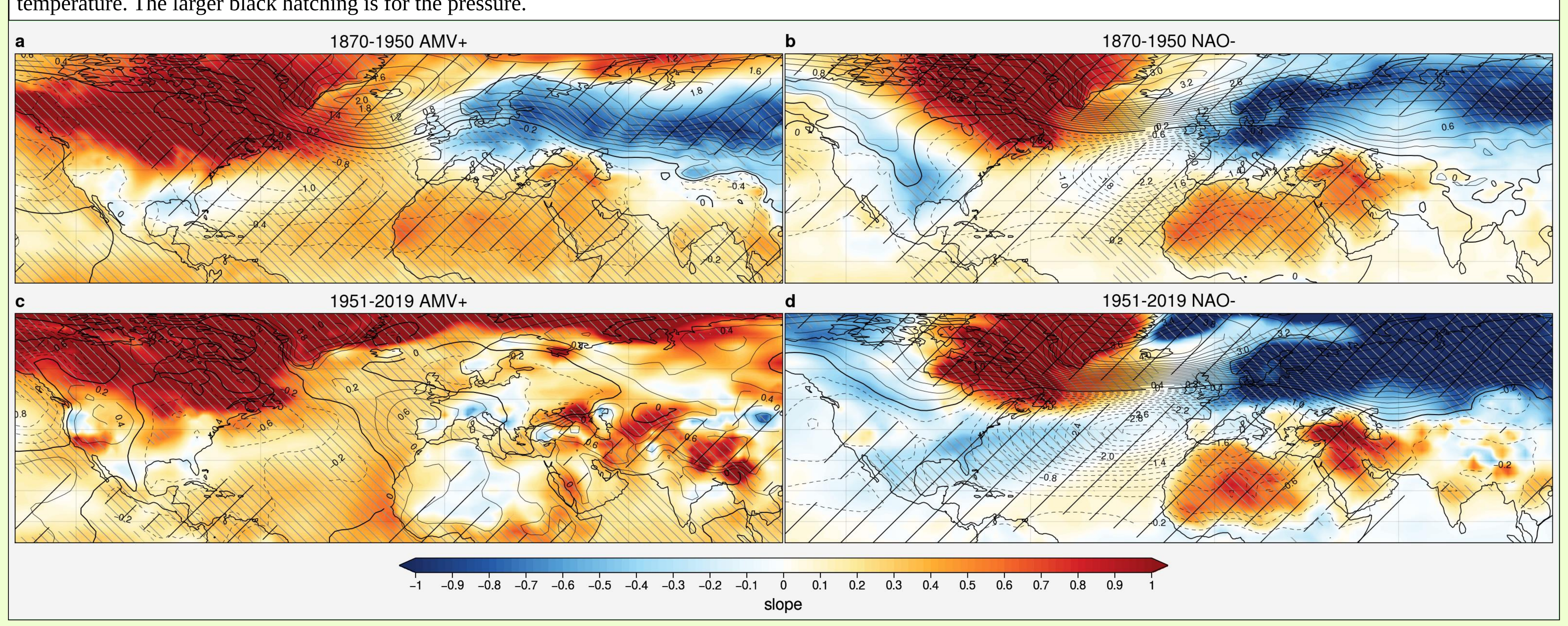


Fig. 5: Summer precipitation patterns - Detrended and filtered regression maps for NAO- (b, d) and AMV+ (a, c) on precipitation using GPCC data

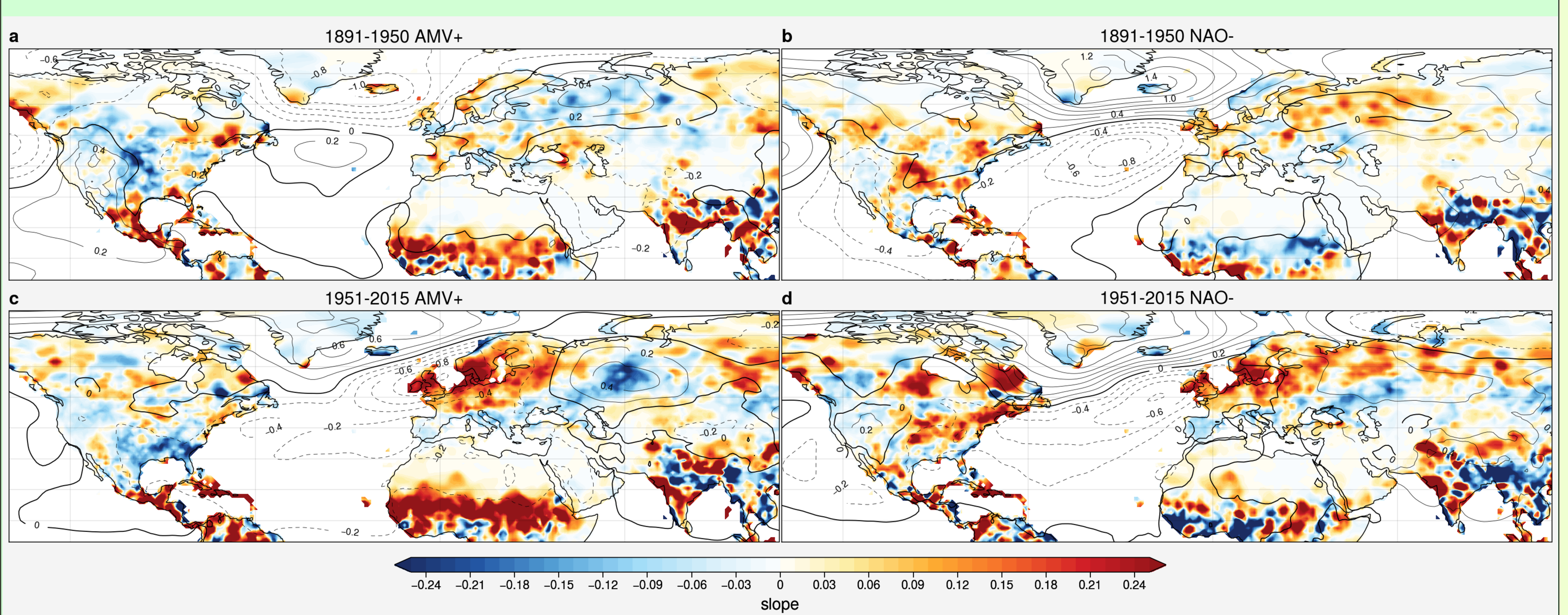


Fig. 6: Winter precipitation patterns - Detrended and filtered regression maps for NAO- (b, d) and AMV+ (a, c) on precipitation using GPCC data

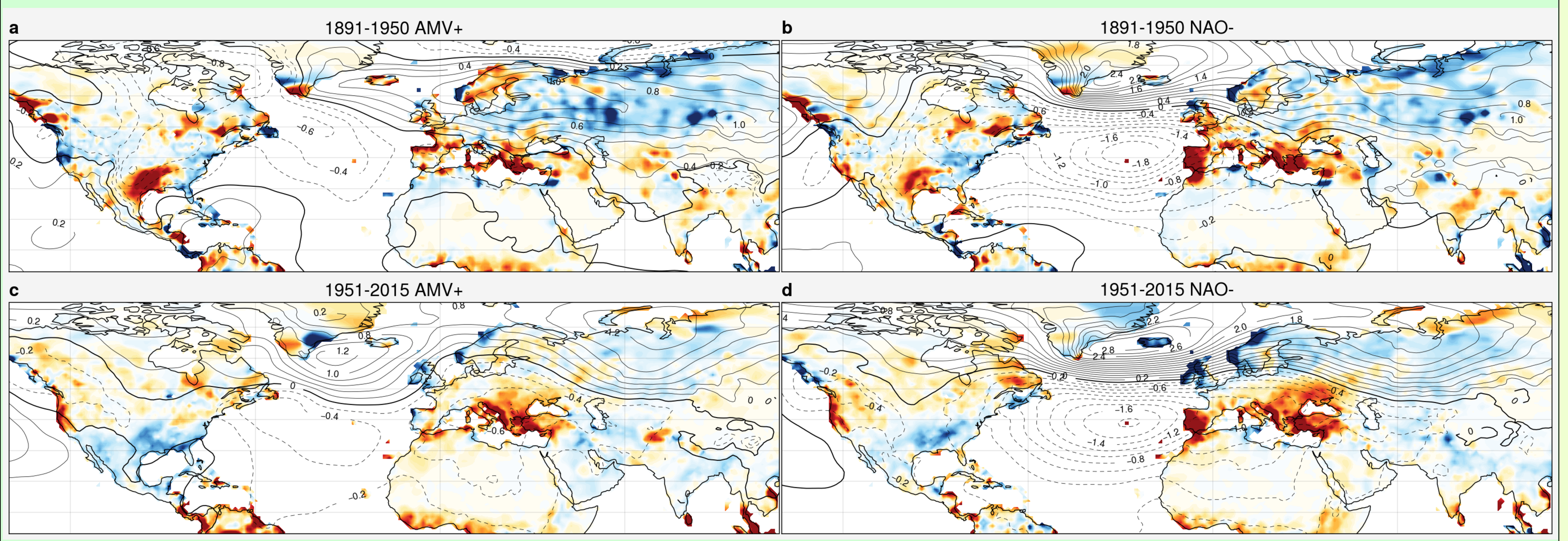
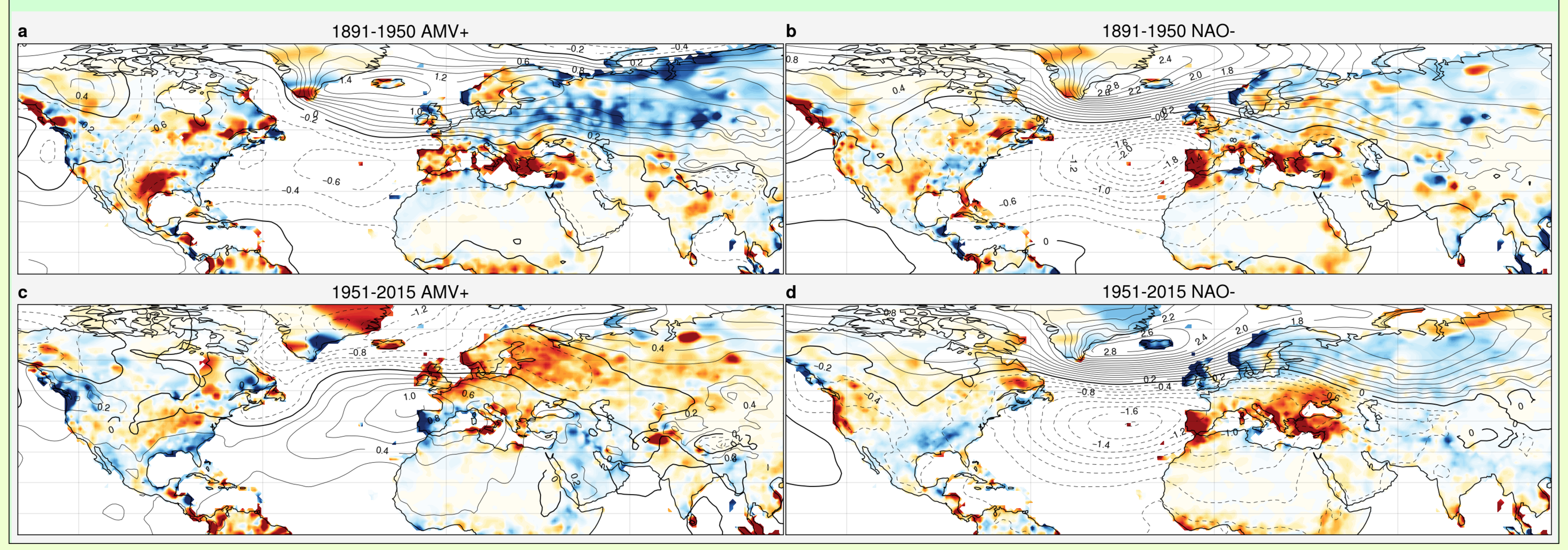


Fig. 7: Observed change in winter precipitation patterns - Not detrended but filtered regression maps for NAO- (b, d) and AMV+ (a, c) on precipitation using GPCC data



Discussion/Conclusions

- The new relationship between the AMV and NAO can be largely explained by external forcing, meaning **future projections of external forcing can be used to predict the AMV and NAO**.
- Post 1950:
  - The AMV pattern becomes undefined and contributes to warming in most regions. Precipitation patterns change with significant increases over Europe except the Iberian peninsula.
  - The NAO patterns remain similar.
- What happens in the future?

References

- Bellomo, K., Murphy, L. N., Cane, M. A., Clement, A. C., & Polvani, L. M. (2017). Historical forcings as main drivers of the Atlantic multidecadal variability in the CESM large ensemble. *Climate Dynamics*, 1–12. https://doi.org/10.1007/s00382-017-3834-3
- Clement, A., Bellomo, K., Murphy, L. N., Cane, M. A., Mauritsen, T., Rädel, G., & Stevens, B. (2015). The Atlantic Multidecadal Oscillation without a role for ocean circulation. *Science*, *350*(6258), 320–324. https://doi.org/10.1126/science.aab3980
- Klavans, J.M., Cane, M.A., Clement, A.C. *et al.* NAO predictability from external forcing in the late 20th century. *npj Clim Atmos Sci* **4**, 22 (2021). https://doi.org/10.1038/s41612-021-00177-8
- Murphy, L. N., Klavans, J. M., Clement, A. C., & Cane, M. A. (2021). Investigating the Roles of External Forcing and Ocean Circulation on the Atlantic Multidecadal SST Variability in a Large Ensemble Climate Model Hierarchy. *Journal of Climate*, *1*(aop), 1–51. https://doi.org/10.1175/JCLI-D-20-0167.1