Increasing model resolution improves but does not fully rectify trends in the North Atlantic jet and its impacts

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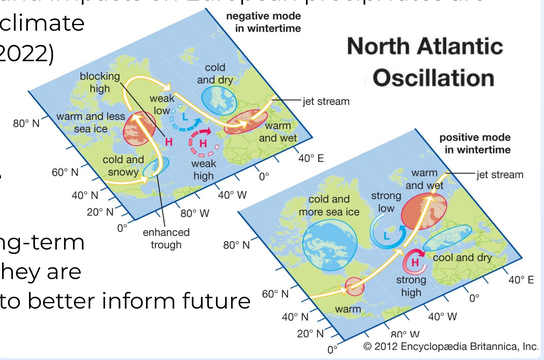
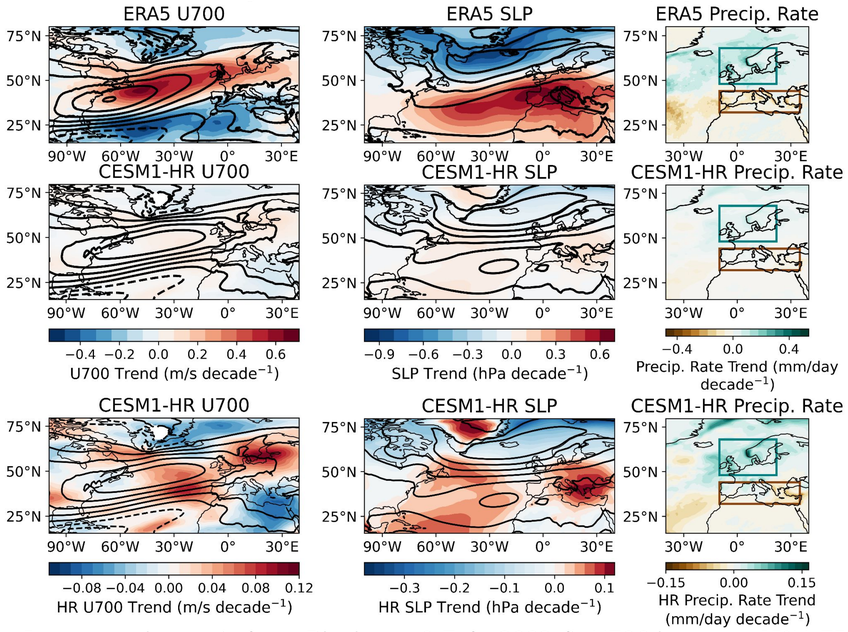
The NAO & North Atlantic jet strength

- Observed positive trends in the wintertime North Atlantic jet, North Atlantic Oscillation (NAO), and impacts on European precip. rates are underestimated by global climate models (Blackport & Fyfe, 2022)
- Large ensembles reveal a radiatively-forced component of the NAO that models underestimate (Clement et al. 2026)
- We aim to explore these long-term trends to understand why they are underestimated in models to better inform future projections



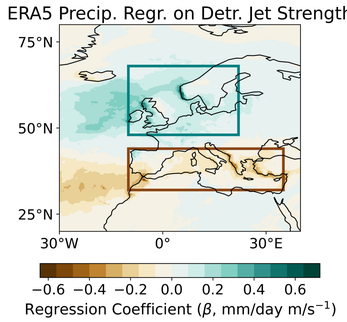
Methods: Reanalysis vs. Models

- Comparing zonal wind at 700 hPa (U700), sea-level pressure (SLP), and total precipitation rate in **ERA5** (ECMWF Reanalysis v5, 0.25° resolution), **CESM2-LE** (Community Earth System Model v2 100-member large ensemble, standard 1° resolution), **CESM1-LR** (40-member ensemble, 1° resolution), and **CESM1-HR** (10-member ensemble, 0.25° resolution) from 1950–2024 for reanalysis & models and 2025-2100 model projections

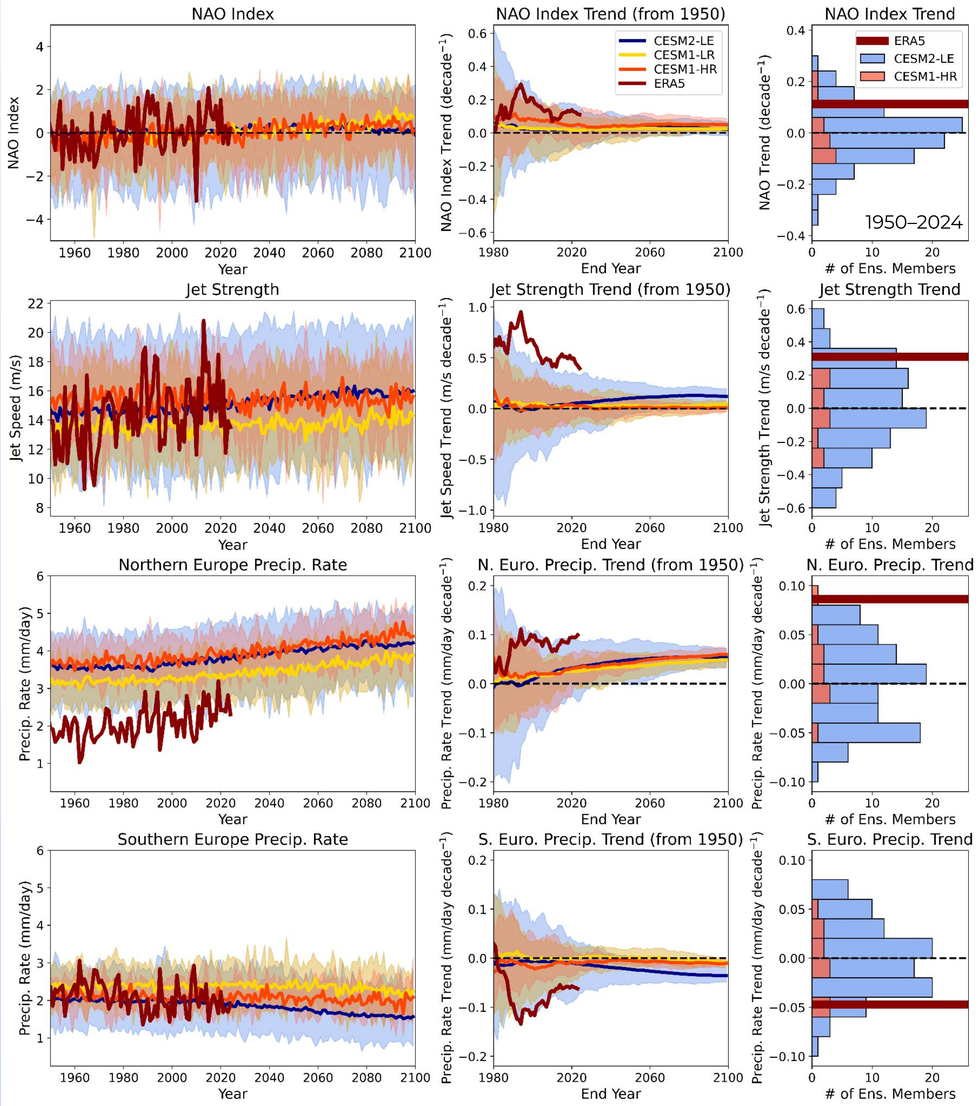


- Jet strength metric from Blackport & Fyfe, 2022: fit U700 between 15°N–75° N to a parabola at each longitude from 60°W–0° and zonally average the maximas of the resulting functions
- Signal-to-noise statistics from Scaife & Smith, 2018: estimating correlations of a sample ensemble mean vs. ensemble members & vs. reanalysis
  - Indices are standardized, padded, and 10-year Lanczos low-pass filtered for models & reanalysis, then bootstrapped 10,000 times

Models underestimate observed trends

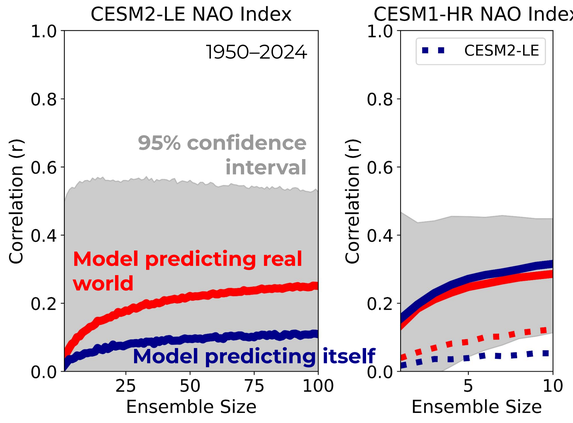


- European precip. rates are driven interannually by jet strength and long-term trends resemble the regression pattern (left) as the jet strengthens
- The ERA5 1950–2024 NAO trend falls on the upper end of model ensemble spread & the jet strength trend is almost entirely outside of the spread
- CESM2-LE projects a positive jet strength trend through 2100 while CESM1-LR & -HR project near-zero trends, and all three models project weak positive trends in the NAO
- Models weakly capture the positive ERA5 precip. rate trend in N. Europe and negative trend in S. Europe which reflect the jet strengthening pattern, and project ongoing strengthening trends of the same signs



HR improves signal-to-noise

- Global climate models underestimate the forced signal-to-internally generated noise ratio (Scaife & Smith, 2018; Clement et al. 2026)
- For the NAO index, CESM1-HR's ensemble mean has a higher correlation with ERA5 & with its individual ensemble members compared to CESM2-LE, improving the signal-to-noise ratio



Key Points

- Global climate models (large ensemble & high-res.) do not capture the magnitude of winter trends in the NAO, North Atlantic jet strength, and European precip. rates
- Increasing model resolution helps to improve the signal-to-noise ratio of the NAO index
- A clearer forced signal in the high-res. model and the emergence of trends in future model projections help to build confidence in the future positive trajectory of the NAO, North Atlantic jet, and impacts

Sources & Acknowledgements

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