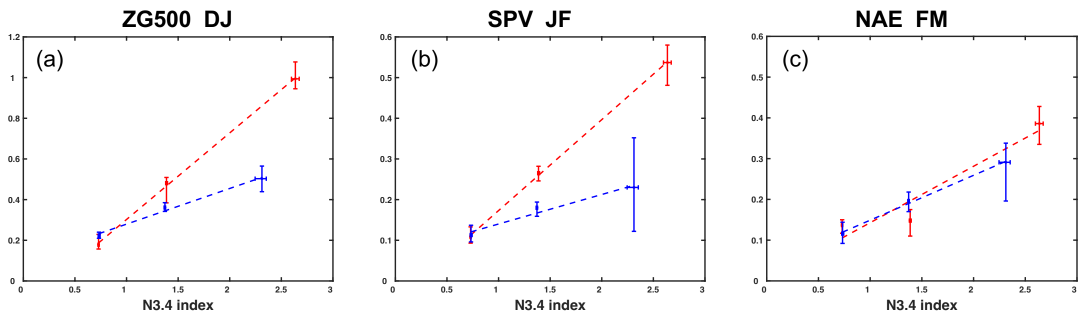
Project: 1190
Project title: JPI Oceans / JPI Climate project ROADMAP (extended until 31.10.2024)
Principal investigator: Dr. Daniela Matei
Allocation period: 2025-01-01 to 2025-12-31

Achievements in 2024

<u>Nonlinearity and asymmetry of the ENSO Stratospheric Pathway</u>

Nonlinearities and asymmetries of El Niño Southern Oscillation (ENSO) stratospheric pathway to the North Atlantic and Europe have been examined in large ensembles conducted with fully coupled climate models during wintertime. The analysis was centered on historical experiments of the Max Planck Institute Grand Ensemble and expanded to six other ensembles of more limited size. Within the ENSO stratospheric pathway, the link between sea surface temperature anomalies in the Equatorial Pacific to climate variability of the North Atlantic - European regions is mediated by the stratospheric polar vortex because the latter is sensitive to the anomalies in planetary waves triggered by ENSO over the North Pacific region. We assess the sensitivity of the ENSO stratospheric pathway as the magnitude of the sea surface temperature anomalies increases, for each ENSO phase. To this end, ENSO events are grouped in three intensity categories (weak, moderate and strong) according to the magnitude of SSTAs. We have found linear relationships for either El Niño or La Niña key diagnostics that characterize the ENSO pathway. However, these relationships are generally weaker for the cold La Niña than for the warm El Niño so that asymmetries between them develop as the events intensify. Specifically, for strong events, the extra-tropical North Pacific and stratospheric responses are asymmetric, with substantially larger responses for El Niño events. The reason of this asymmetry in the stratospheric response is due to the patterns of the geopotential height anomalies associated with El Niño and La Niña in the North Pacific, which are different for strong events. The stratospheric asymmetry in strong events may thereafter contribute to the asymmetry in strong events in the North Atlantic - Europe response in the troposphere in late winter.

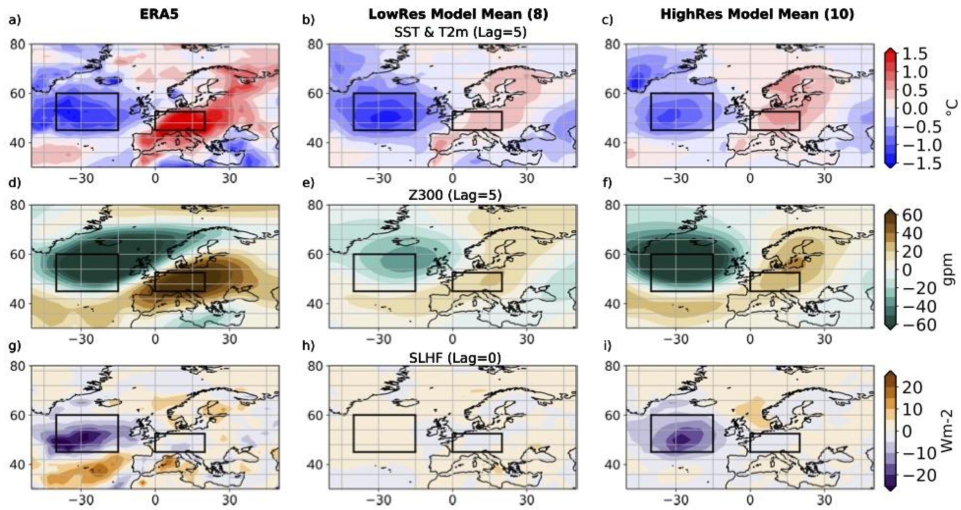


Intra-phase linear fits in function of Niño3.4 SSTA magnitude, for the magnitudes of the (a) DJ geopotential 500 hPa index; (b) JF stratospheric polar vortex index; and (c) FM sea level pressure difference between Atlantic-Europe midlatitudes and Arctic. The fits are calculated over the three medians of the distributions of the composites by category, El Niño (red) and La Niña (blue).

Manzini, E., Ayarzagüena, B., Calvo, N., & Matei, D. (2024). Nonlinearity and asymmetry of the ENSO stratospheric pathway to North Atlantic and Europe, revisited. Journal of Geophysical Research: Atmospheres, 129, e2023JD039992. https://doi. org/10.1029/2023JD039992.

<u>Improved European heat event simulation by resolving oceanic mesoscale eddies</u> [in collaboration with GEOMAR]

Owing to the rapid increase of European heat event occurrences over the past decades, the understanding of their physical drivers has become increasingly important for the scientific community. Recently, it has been shown that cold North Atlantic sea surface temperatures (SSTs) are strongly linked to European heat events such as in summer 2015 and 2018. Thereby, an accurate representation of this connection in climate models is crucial for a more realistic European heat event simulation. Here, we investigate the connection by employing seven global coupled climate models, from which six models are embedded in the High Resolution Model Intercomparison Project (HighResMIP). High-resolution versions of these models capture mesoscale eddies, thus enabling to study their impact on the North Atlantic SST - European summer temperature extremes connection. Our results show that high-resolution model versions better capture the North Atlantic trough and the downstream ridge anomalies over central Europe, although still underestimated in intensity and duration compared to observations. Improvements in high-resolution configurations are due to the increased ocean model resolution, which reduces the North Atlantic surface biases and improves air-sea interactions, thus having implications for the prediction and projection of climate extremes in the North Atlantic - European region.

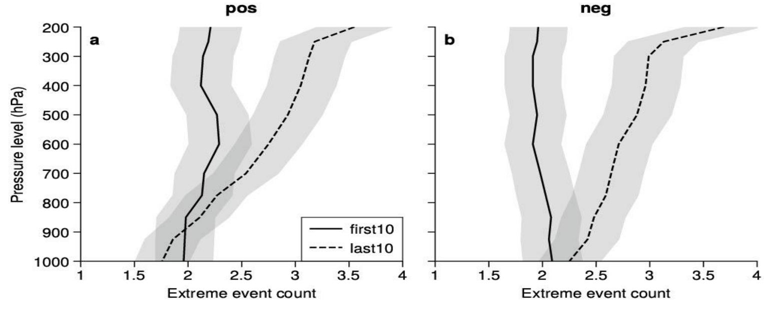


Composite-mean anomalies of 2-meter air temperature (upper panels), 300 hPa geopotential height (middle panels) and downward surface latent heat flux (lower panels) for the identified European heat events in atmospheric reanalysis as well as low-resolution and high-resolution HighResMIP control-1950 simulations.

Krüger, J., J. Kjellsson, K. Lohmann, D. Matei and R.P. Kedzierski: Improved European heat event simulation by resolving oceanic mesoscale eddies. Submitted to Nature Communication

<u>More extreme summertime North Atlantic Oscillation under climate change</u>

Extreme states of the NAO in summer can lead to severe weather events such as heatwaves and floods in Europe. But how the summer NAO extremes evolve in response to climate change remains unexplored. Here we show that the statistical distribution of summer NAO index grows wider with increasing global warming in the MPI-M Grand Ensemble of climate change simulations as well as in reanalysis data. The amplified internal variability by global warming leads to a higher probability of internally generated summer NAO extremes - for both positive and negative phases - accompanied by an amplification of their impacts on surface temperature over northwestern Europe (Figure MPIM_2). This study highlights that global warming may degrade the predictive skill for the summer NAO by amplifying its internal variability, and thus exacerbate risks of the associated severe weather events in Europe.



Profile of positive and negative summer NAO extremes in the first and last 10 years of the MPI-M Grand Ensemble 1% CO_2 simulations.

Q. Liu, J. Bader, J. Jungclaus, D. Matei, 2024: More extreme summertime North Atlantic Oscillation under climate change. In preparation.