Using a nested single-model large ensemble to assess the internal variability of the North Atlantic Oscillation and its climatic implications for Central Europe

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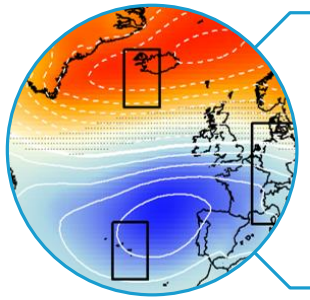
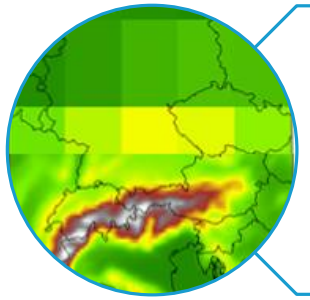
Introduction & Research Questions



This study investigates an important climate mode with known impacts in **central Europe** in a global climate model **(GCM)**: the North Atlantic Oscillation (**NAO**; e.g. Hurrell & Deser 2009)

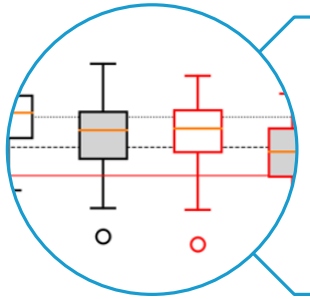
- quantified as a **pressure dipole over the North Atlantic** with strong control on the North Atlantic westerlies
- and therefore influences on northern hemisphere weather and climate



However, when interested in regional responses to the NAO, the spatial resolution of the GCM may be too coarse:

⇨ use a regional climate model (**RCM**)

The **GCM** used in this study is the Canadian Earth System Model, version 2 (**CanESM2**), with a **2.8°** spatial resolution. The **RCM** used in this study is the Canadian Regional Climate Model, version 5 (**CRCM5**), with a **0.11°** spatial resolution.



A single realization of GCM/RCM may be subject to considerable internal variability. To robustly assess NAO patterns and responses:

⇨ use a **single-model initial condition large ensemble (LE)**

We used the CRCM5-LE of the ClimEx project (Leduc et al. 2019), obtained by downscaling the **50-member** CanESM2-LE (Fyfe et al. 2017).

Research Questions:

1) How does global circulation (the NAO in this case) affect **local climate characteristics** when downscaled using a RCM?
2) Is the range of internal variability (**expressed as inter-member spread**) represented consistently between the driving data and the RCM data?

Key topics:

a) **Nesting approach**: Does the RCM produce realistic NAO response patterns in a central European domain during winters of 1981-2010?

b) **Internal variability**: What is the range of these possible NAO responses (within the large ensemble)?

Results and Conclusions

Key Topics:

a) Nesting approach: Does the RCM produce realistic NAO response patterns during winters of 1981-2010?

- *responses of winter mean temperature (**tas**)/precipitation sums (**pr**) to NAO unit index change expressed by slope of a linear regression line*
- **realistic** (i.e., comparable to reanalyses) **responses** in both the GCM and the RCM ensemble (**spatial pattern & change magnitudes**)
- **strongest tas** responses in **eastern central Europe**
- **opposite** change directions **north/south of the Alps**, with **highest** values in **mountainous regions** for **pr**

b) Internal variability: What is the range of possible NAO responses (within the large ensemble)?

- internal variability regarding **strength of NAO responses**: when comparing the **GCM and RCM large ensembles**, we found **no change in** the amplitude of the inter-member **spread** of NAO/response correlations in spatially aggregated regions, but a shift towards a significantly **stronger NAO-response** relationship in the **RCM**
- internal variability regarding **change induced by NAO**: **similar** values of **inter-member standard deviation** in GCM and RCM, and spatial distribution similar to response patterns

Research Questions:

1. How does global circulation (the NAO in this case) affect local climate characteristics when downscaled using a RCM?

   As can be derived from the results, regional responses to the NAO, which evolves outside the RCM (the CRCM5) domain, are reproduced inside the RCM domain. This finding holds for the spatial pattern of tas/pr responses, but also for the change magnitudes. However, RCM responses are found to be stronger compared to the GCM responses.

2. Is the range of internal variability represented consistently between the driving data and the RCM data?

   In general, it can be stated that **the spread of internal variability propagates correctly from the GCM to the RCM** in this GCM-RCM combination.

Further details, future changes and supporting figures: Böhnisch, A., Ludwig, R., and Leduc, M.: Using a nested single-model large ensemble to assess the internal variability of the North Atlantic Oscillation and its climatic implications for Central Europe, Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2019-58, in review, 2019.

References

Böhnisch, A., Ludwig, R., and Leduc, M. (2019): Using a nested single-model large ensemble to assess the internal variability of the North Atlantic Oscillation and its climatic implications for Central Europe, Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2019-58, in review.

Fyfe, J., Derksen, C., Mudryk, L., Flato, G., Santer, B., Swart, N., Molotch, N., Zhang, X., Wan, H., Arora, V., Scinocca, J., Jiao, Y. (2017): Large near-term projected snow pack loss over the western United States, Nature communications, 8, 1–7, https://doi.org/10.1038/ncomms14996.

Hurrell, J. W., Deser, C. (2009): North Atlantic climate variability: The role of the North Atlantic Oscillation, Journal of Marine Systems, 78, 28–41, https://doi.org/10.1016/j.jmarsys.2009.11.002.

Leduc, M., Mailhot, A., Frigon, A., Martel, J.-L., Ludwig, R., Brietzke, G., Giguère, M., Brissette, F., Turcotte, R., Braun, M., Scinocca, J. (2019): The ClimEx Project: A 50-Member Ensemble of Climate Change Projections at 12-km Resolution over Europe and Northeastern North America with the Canadian Regional Climate Model (CRCM5), Journal of Applied Meteorology and Climatology, 58, 663–693, https://doi.org/10.1175/JAMC-D-18-0021.1.

The ClimEx project and selected CRCM5-LE data: https://www.climex-project.org/

The CanESM2-LE data set: http://crd-data-donnees-rdc.ec.gc.ca/CCCMA/products/CanSISE/output/CCCma/CanESM2/