Multi-decadal initialized climate predictions using the EC-Earth3 global climate model

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Motivation and experimental design:

Recent study highlighted the potential for skillful predictions of climate for up to 20 years over a few regions using MPI-ESM model (Düsterhus and Brune, 2023).

In addition, some studies suggest combining climate information from initialized prediction could be merged with those from historical simulations after the 10 years of initialized predictions (Befort et al. 2022).

Using 30 year long initialized predictions we evaluate here weather there is added value beyond the first 10 and 20 forecast years using the EC-Earth3 global climate model.

And also evaluate whether we could perform merging of climate information from initialized prediction and historical simulations.

Using EC-Earth3 model we performed multi-decadal initialized climate predictions following the same protocol as in CMIP6 DCPP-A (Boer et al., 2016)

The hindcast experiment consists of a 10-member ensemble, with predictions initialized on the first of November of every fifth year from 1960 to 2020, resulting in 13 start dates for 30-year predictions

For comparison with historical simulations we use 10 members from CMIP6 simulations performed with the same version of the EC-Earth3 model.

Skill assessment for decadal and multi-dacadal mean forecasts:

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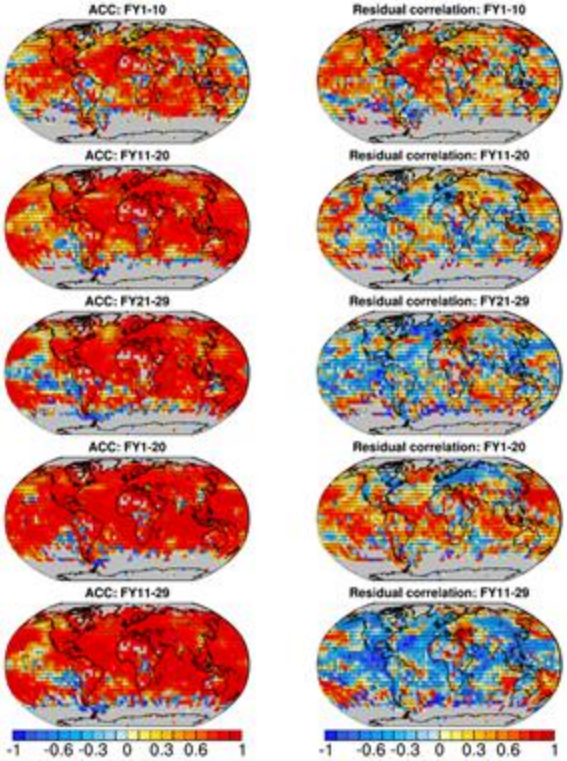
Left Panels: ACC

Right Panels: Residual correlations (Smith et al., 2019)

First three rows decadal mean forecasts, while the last two rows multi-decadal mean forecasts

=> Added skill from initialization for the first decade

=> No added skill for the second and the third decade



Time series analysis of the initialized predictions and the uninitialized projection simulations:

Panels: each panel represent time series for one start-date.

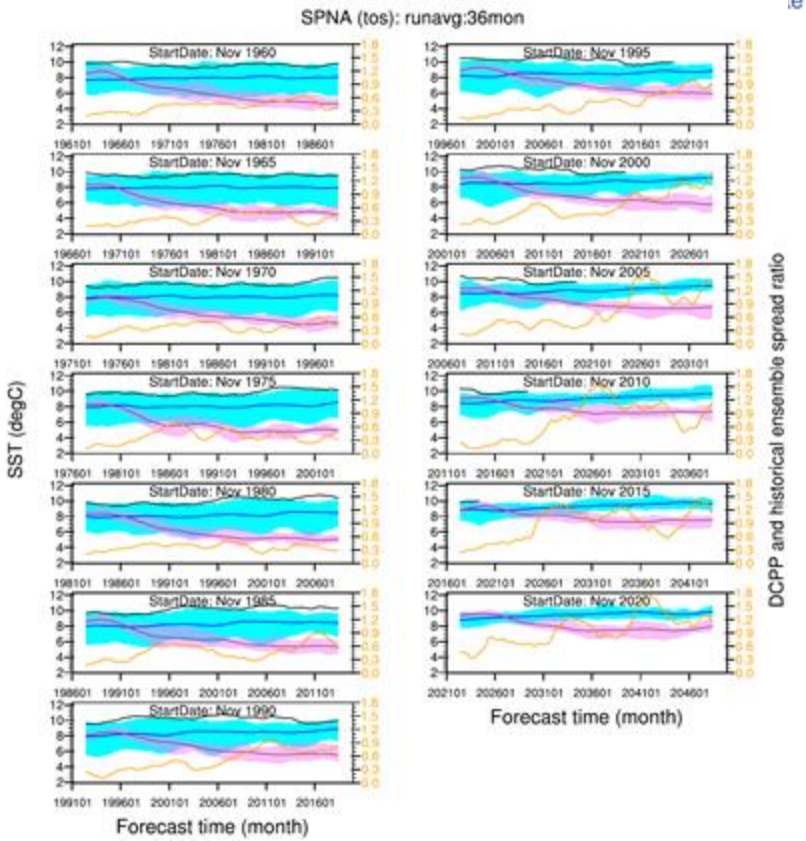
Blue: historical ensemble

Pink: initialized predictions

=> after few years of initialization the predictions drift to a different climate state than the projection simulations

=> ensemble spreads are different b/w predictions and projections

=> the ensemble spreads b/w the two ensembles vary over time



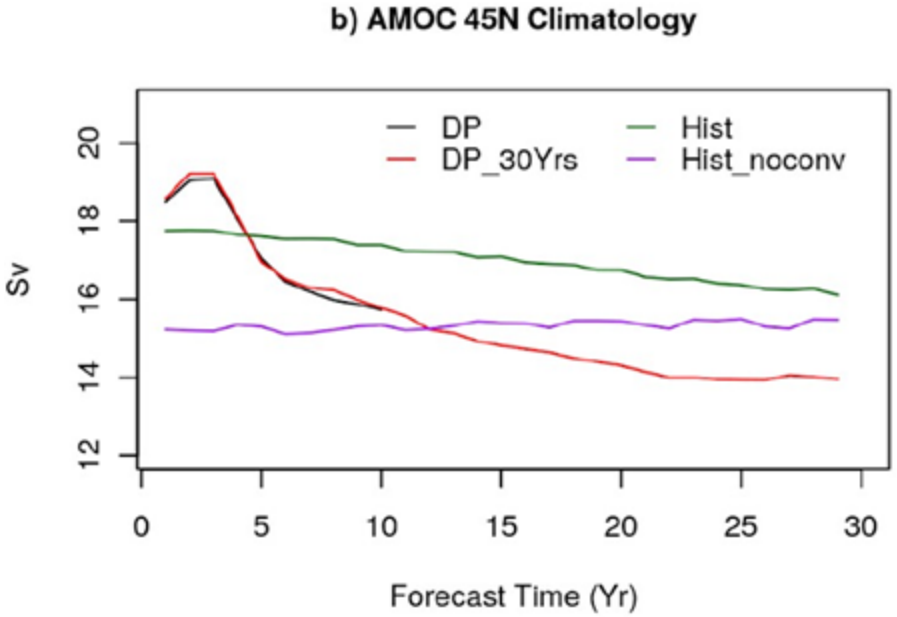
AMOC:

Red: 30 Year predictions

=> Strong AMOC drift in initialized predictions

=> AMOC drift continues until around 22nd year of predictions and then tends to stabilize at ~14 Sv.

=> AMOC in initialized predictions does not converge to AMOC in historical simulations

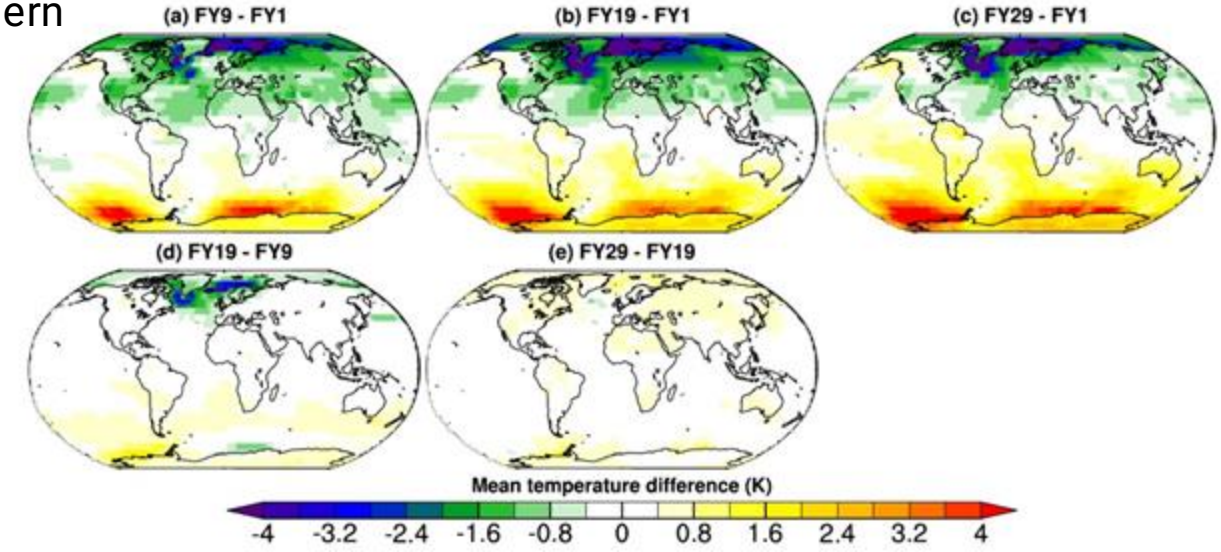


Drift in annual mean surface air temperature:

=> Strong AMOC drift in initialized predictions results in temperature asymmetries between the northern and the southern hemispheres

=> Temperature asymmetries between the two hemispheres disappear when the AMOC stabilizes

=> These artificial hemispheric asymmetries could have unrealistic influence on global circulation and regional climate



Summary:

For the 10 year average hindcasts, we find that there is limited added value from initialization beyond the first decade over a few regions.

The ensemble spread in the initialized predictions grows larger with the forecast time, however, the initialized predictions do not necessarily converge towards the uninitialized climate projections within a few years and even decades after initialization.

There is in particular a long-term weakening of the Atlantic Meridional Overturning Circulation (AMOC) after initialization that does not recover within the 30 years of the simulations, remaining substantially lower compared to the AMOC in the uninitialized historical simulations.

The lower AMOC mean conditions also result in different surface temperature anomalies over northern and southern high latitude regions with cooler temperature in the northern hemisphere and warmer in the southern hemisphere in the later forecast years as compared to the first forecast year.

These multi-decadal predictions therefore highlight important issues with current prediction systems, resulting in long-term drift into climate states inconsistent with the climate simulated by the historical simulations.

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Thank you for listening!

More details:

Mahmood, R., Donat, M. G., Bilbao, R., Ortega, P., Lapin, V., Tourigny, E., and Doblas-Reyes, F.: *Multi-decadal initialized climate predictions using the EC-Earth3 global climate model,* EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-1208, 2025.