Decadal Predictability of German Bight Storm Activity

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1) Motivation

Decadal forecasts of storm activity may greatly aid coastal protection efforts in the German Bight. Historical records of German Bight storm activity (GBSA), however, do not show a significant climate signal, and the confidence in the response of GBSA to climate change is low. Thus, climate projections may not be suited to provide robust decadal forecasts of GBSA. Decadal prediction systems (DPS) on the other hand show only limited forecast skill for certain variables related to storms, such as the mean sea-level pressure (MSLP) or cyclone tracks (Kruschke et al., 2014, Moemken et al., 2020). We therefore focus on a different proxy for GBSA that is based on MSLP gradients and the resulting geostrophic winds. We employ a DPS based on the Max-Planck-Institute Earth System Model in low resolution mode (MPI-ESM-LR) (Mauritsen et al., 2019) to explore the predictability of this proxy on a decadal scale.

2) Methods

Model: We use a 64-member ensemble of initialized decadal hindcasts, starting yearly from 1960-2018, based on the MPI-ESM-LR. We analyze all possible combinations of start and end lead years within the decadal predictions.

Data: Storm activity is defined identically in the model and observations, namely as the standardized annual 95th percentiles of geostrophic winds, calculated from triplets of three-hourly MSLP. We compare GBSA in the model against observed GBSA from Krieger et al. (2020). We also compare winter mean (DJF) MSLP in the model against winter mean MSLP in the ERA5 reanalysis (Hersbach et al., 2020).

Skill Metrics: We evaluate the deterministic and probabilistic prediction skill of the DPS. The deterministic skill is quantified by Pearson's correlation coefficient between time series of predicted (ensemble mean) and observed (observations & reanalysis) quantities. The probabilistic skill is expressed via the Brier Skill Score (BSS). We use a 5 year persistence-based forecast as a reference, and set the detection threshold to 1. The threshold allows for an evaluation of the model's skill for periods of high storm activity.

3) Prediction Skill: Storm Activity

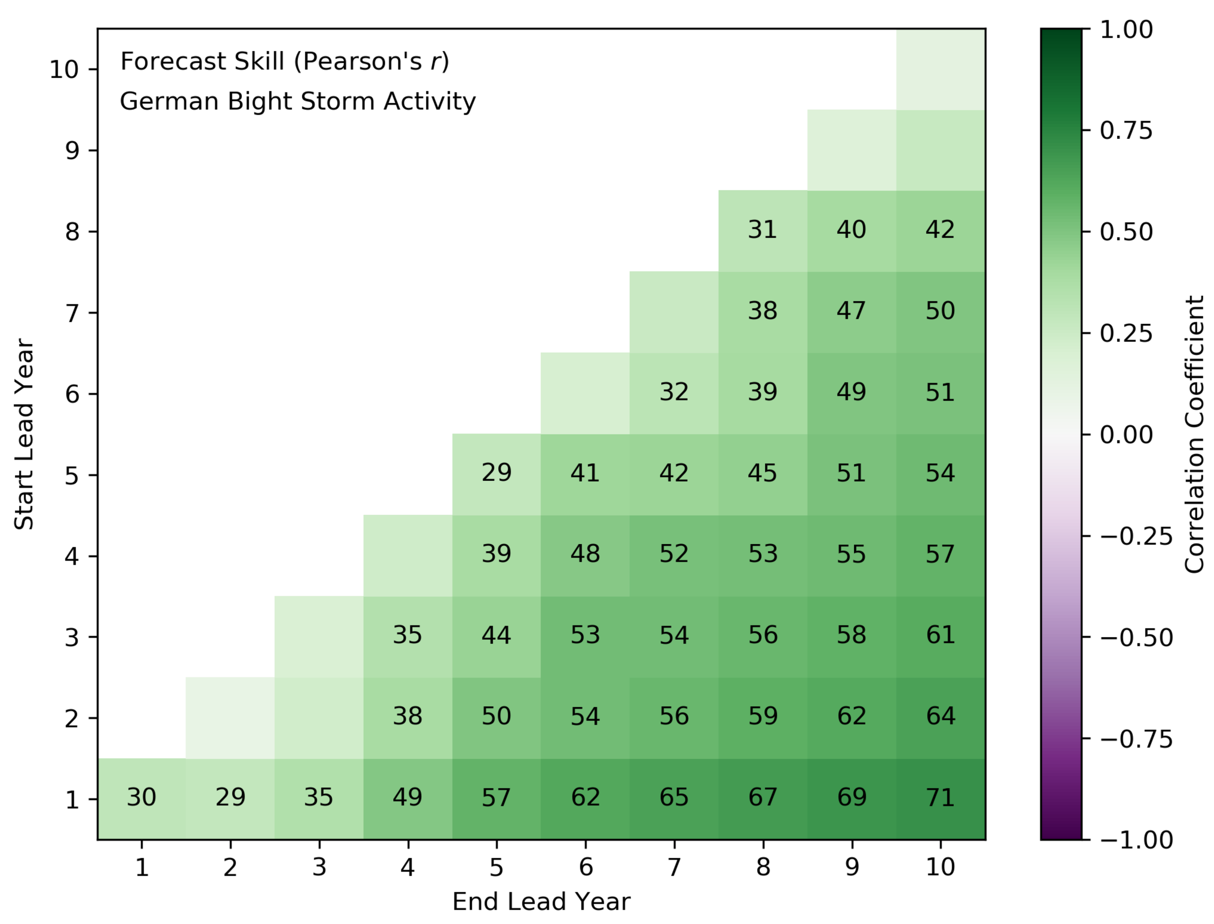

Fig. 1: Prediction skill of DPS for German Bight storm activity for all combinations of start (y-axis) and end lead years (x-axis). Numbers in boxes indicate the respective correlation coefficients (expressed as rounded percentages, i.e. "65" equates to r=0.65). Boxes without numbers show lead year ranges with insignificant prediction skill (p >= 0.05).

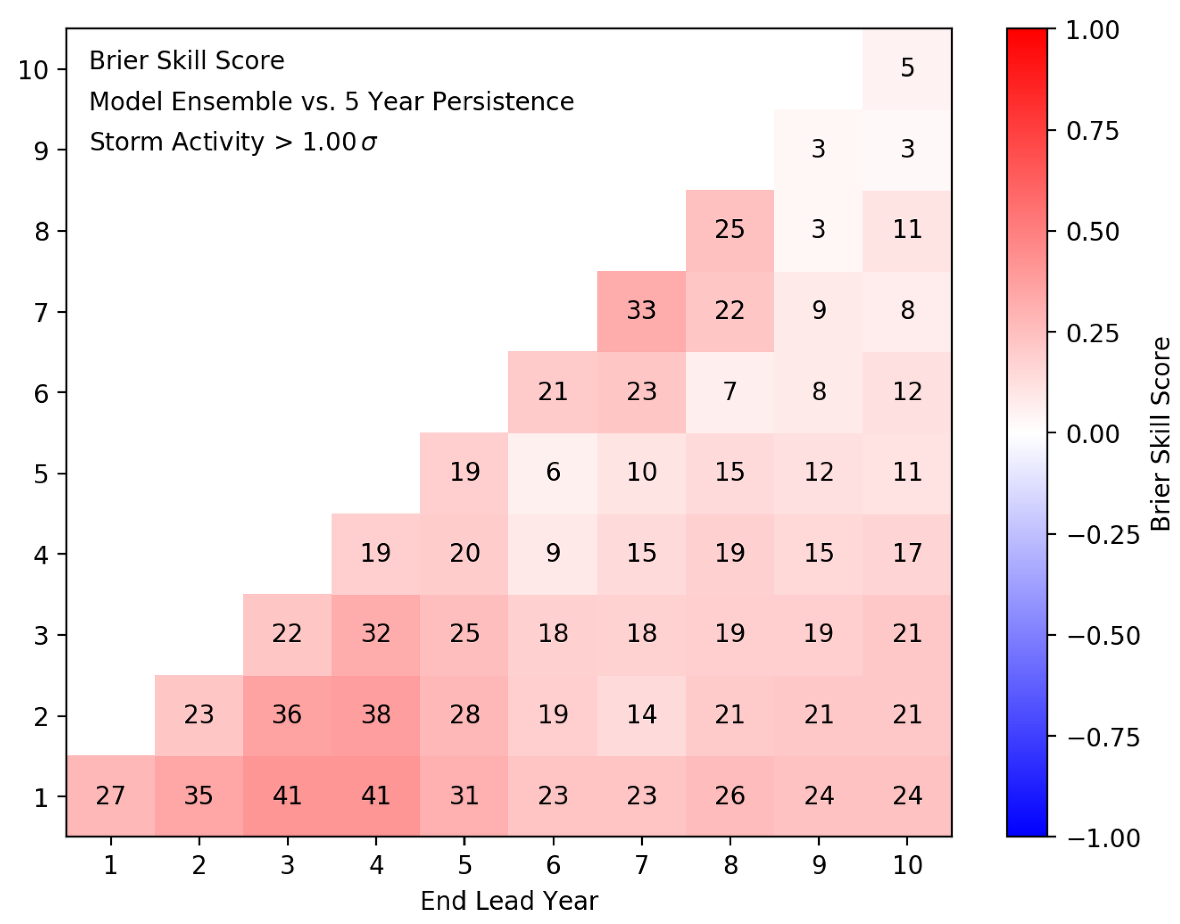

Fig. 2: Brier Skill Score (BSS) of the 64-member ensemble versus 5-year persistence for a probabilistic prediction of high storm activity, shown for all combinations of start (y-axis) and end lead years (x-axis). Numbers in boxes indicate the respective BSS (expressed as rounded percentages, i.e. "25" equates to BSS=0.25).

4) Prediction Skill: Mean Sea-Level Pressure

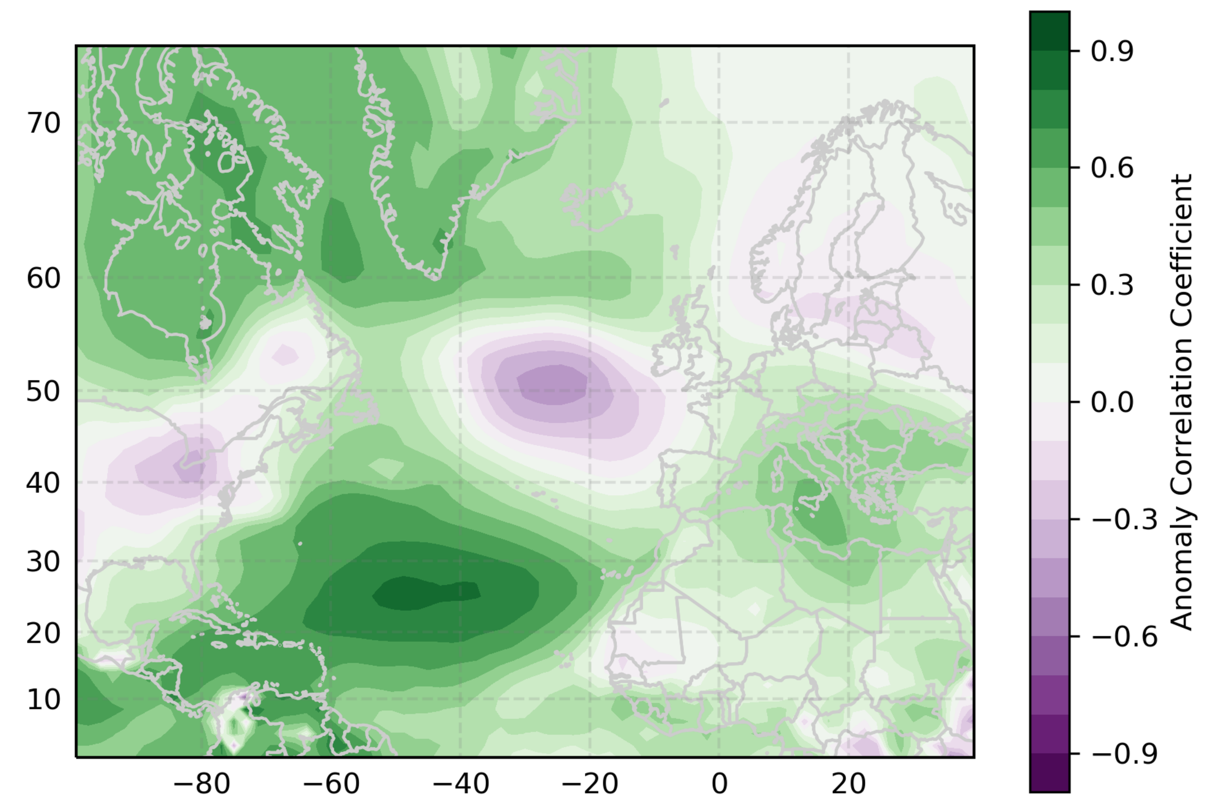

Fig. 3: Prediction skill of the DPS for wintertime (DJF) MSLP, averaged over lead years 4-10 (exemplary). Skill is expressed as the anomaly correlation coefficient (ACC) between the DPS ensemble mean and ERA5.

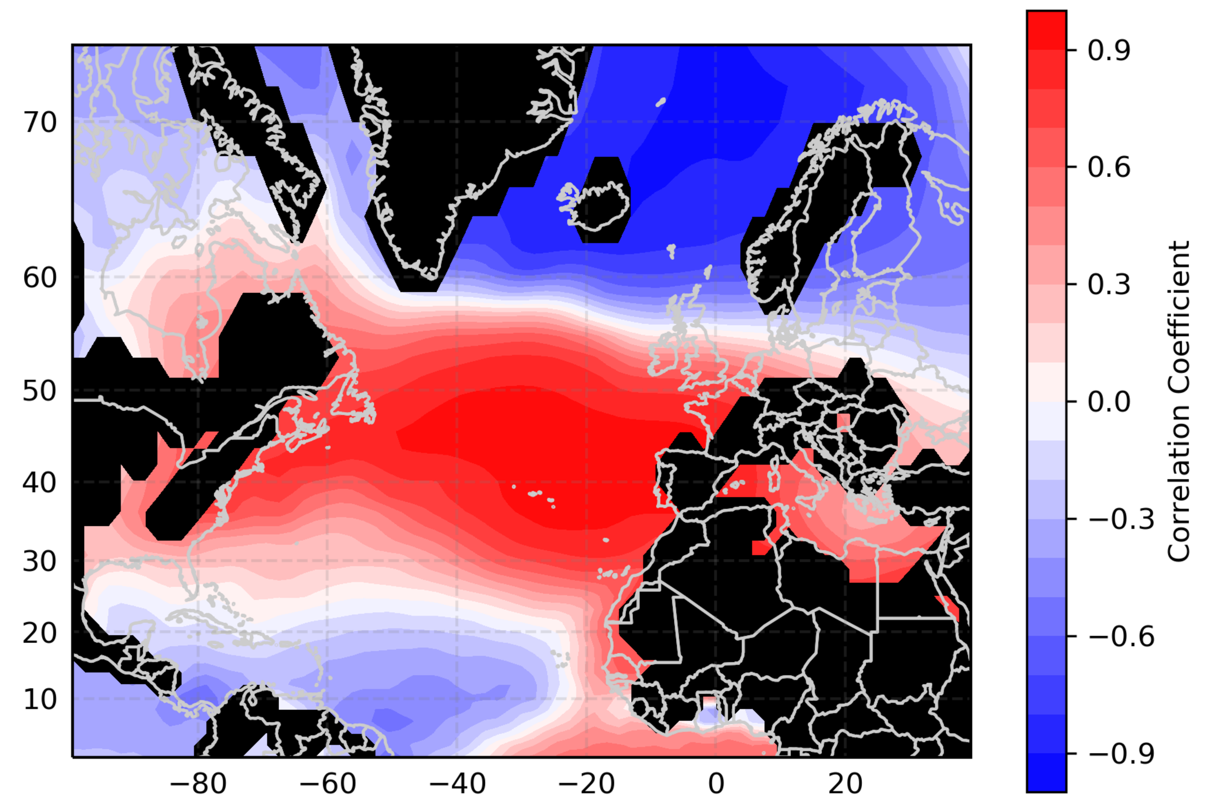

Fig. 4: First empirical orthogonal function (EOF1) of wintertime (DJF) MSLP in the model, averaged over lead years 4-10 (exemplary), and expressed as the correlation coefficient with the time series of the first principle component (PC1). Grid points over 250m elevation were masked before the calculations. Variance explained by EOF1: 51%; correlation of PC1 with observed GBSA: 0.59.

5) Conclusions

The model…

- shows expectedly little prediction skill for MSLP in the German Bight.
- can however represent the large-scale pattern of MSLP in the North Atlantic Ocean, which is connected to GBSA.
- shows significant skill for GBSA for longer multi-year averages.
- demonstrates probabilistic prediction skill for periods of high storm activity that significantly outperforms that of persistence-based forecasts.

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Hersbach, H. et al., 2020. *Q. J. R. Meteorol. Soc.*, 146, 1999–2049. doi: 10.1002/qj.3803
Krieger, D. et al., 2020. *Int J Climatol.*, 41 (Suppl. 1), E2159– E2177. doi: 10.1002/joc.6837
Kruschke, T. et al., 2014. *Tellus A: Dynamic Meteorology and Oceanography*, 66 (1) doi: 10.3402/tellusa.v66.22830
Mauritsen, T. et al., 2019. *Journal of Advances in Modeling Earth Systems*, 11, 998– 1038. doi: 10.1029/2018MS001400
Moemken, J. et al., 2020. *Int J Climatol.*, 27 (17), doi: 10.1002/joc.6824

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