Seasonal Predictability of Wintertime North Atlantic cyclonic activity through the NAO and the eddy-driven jet stream

Alvise Aranyossy[1], Sebastian Brune[1], Lara Hellmich[2,3], Mikhail Dobrynin[1], Daniel Krieger[4,3], and Johanna Baehr[1]

EGU22-3948

CL5.3.4 Predictions of climate from seasonal to (multi)decadal timescales (S2D) and their applications

[1]Institute of Oceanography, CEN, Universität Hamburg, Hamburg, Germany
[2]Max Planck Institute for Meteorology, Hamburg, Germany
[3]International Max Planck Research School on Earth System Modelling, Hamburg, Germany
[4]Helmholtz-Zentrum Hereon, Geesthacht, Germany

Why do we want to predict storms seasonally?

Economic and social losses

Storm Eunice: tens of thousands still without power in UK

Widespread disruption to services continuing in aftermath of worst storm in 32 years that has led to at least four deaths

Contribution relative to total precipitation

How much Northern Hemisphere precipitation is associated with extratropical cyclones?

M. K. Hawcroft,[1] L. C. Shaffrey,[2] K. I. Hodges,[3] and H. F. Dacre[1]

2 VARIABLES

Number of days every winter above the Eddy Kinetic Energy (EKE) 90th percentile.

Total amount of precipitation per winter.

The Guardian, 19/02/2022   *Hawcroft et al., 2012*

Calculating Variables

Seasonal number of days above the Eddy Kinetic Energy (EKE) 90th percentile:

1. 3-10 days bandpass filtering of *u* and *v* winds at 850hPa.
2. Calculating Eddy Kinetic Energy daily values :

$$EKE = \frac{1}{2}\left(\overline{(u')^2} + \overline{(v')^2}\right)$$

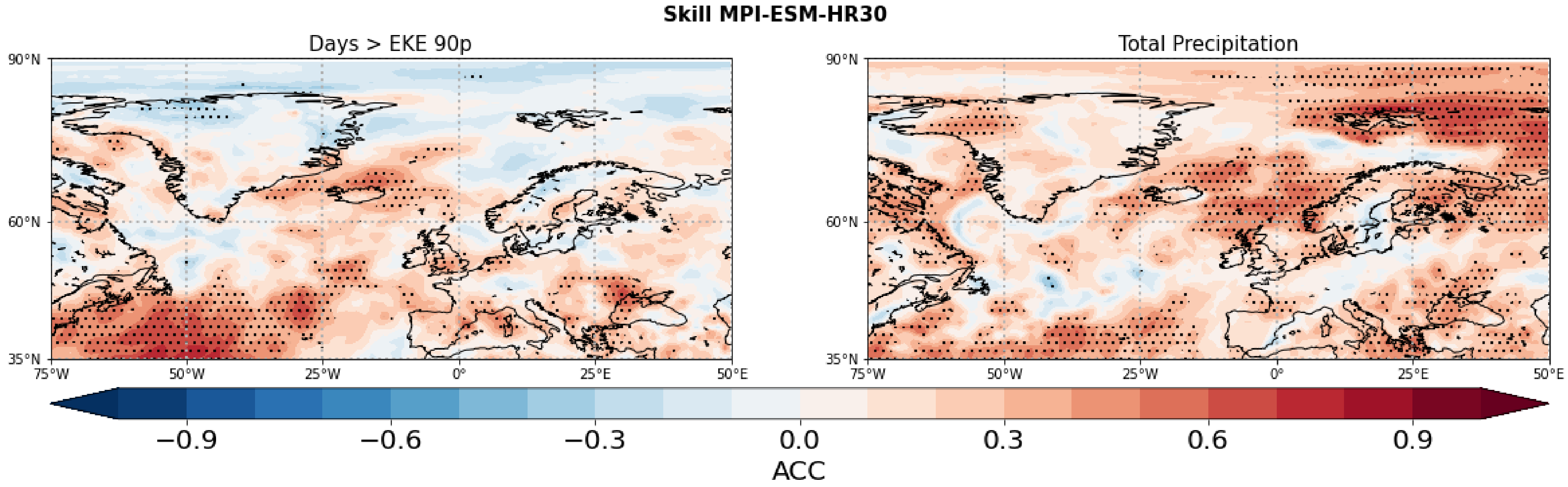
3. For every grid-point, calculating the EKE 90th percentile in the time-series distribution.
4. Selection and seasonal sum of days with an EKE above the 90th percentile.

Seasonal Total Precipitation:

1. Seasonal sum of daily precipitation in mm.

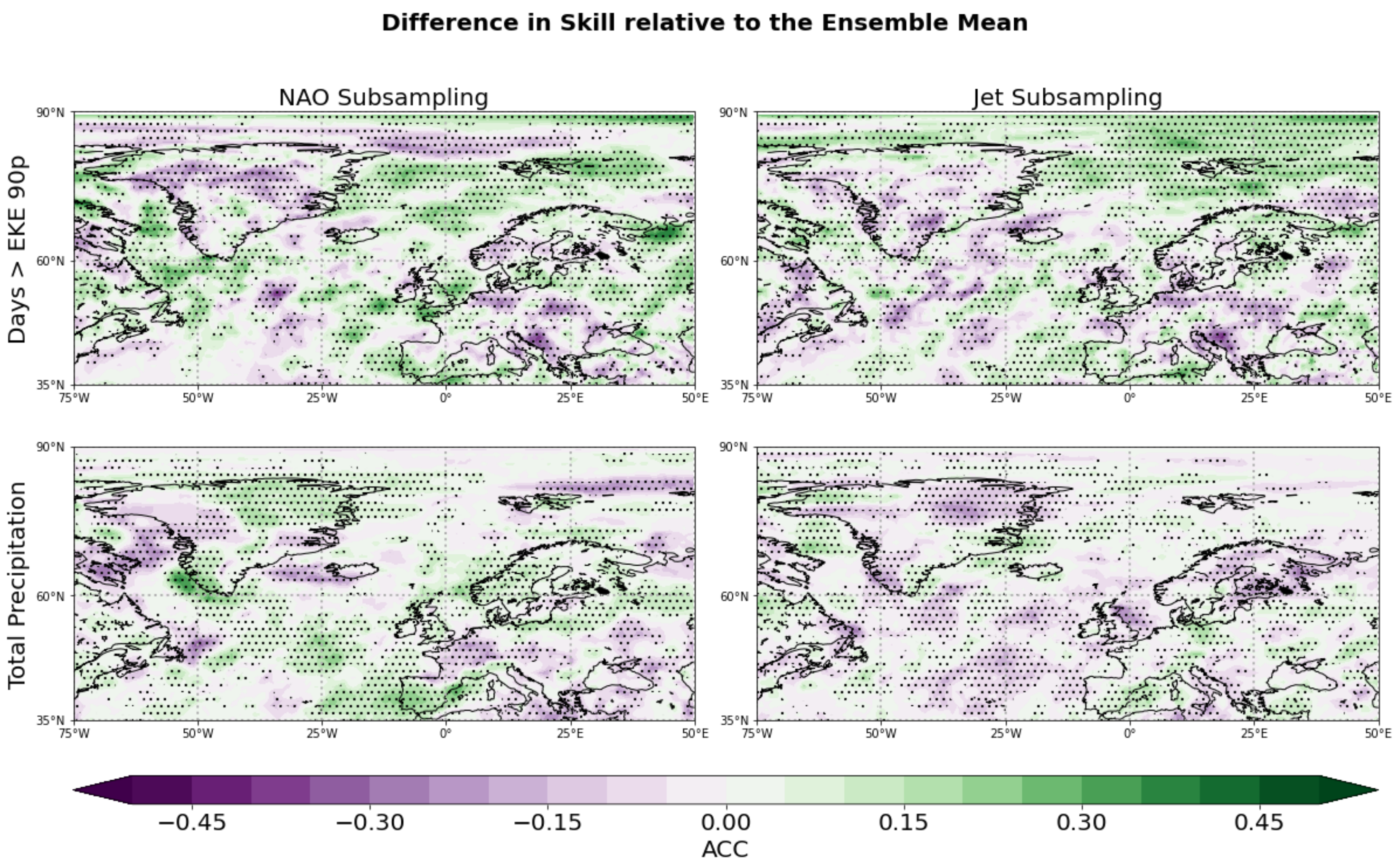
Model: MPI-ESM-HR30 *Seasonal forecast:* GCFS2.0 *Observations:* ERA5
Area of study: 75°W-50°E, 35°-90°N *Time period:* DJFM 1982-2018

The Baseline Skill



Prediction skill in the MPI-ESM-HR30 ensemble mean is mainly limited to the south-western corner of the study area, as well as a small portion of the northern North Atlantic. Over the Europe continent skill is present only irregularly in the eastern part of the continent, while no skill is found over western Europe, apart from a small area over the British Isles. This is valid for both winter days above the EKE 90th percentile and the winter total precipitations.

Using Teleconnections



The NAO Subsampling (Dobrynin et al., 2018):

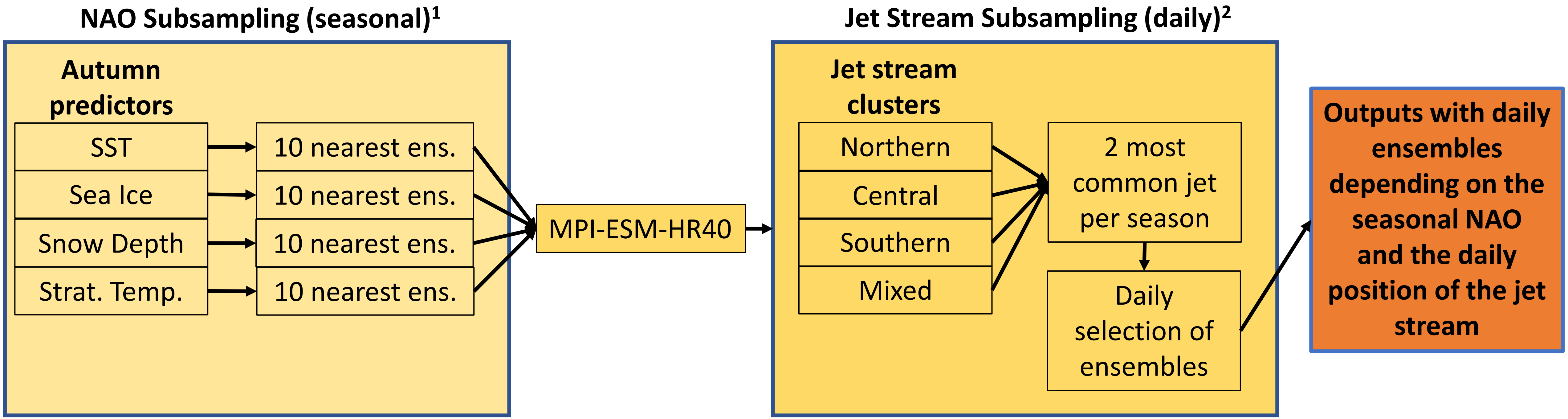
Correlation analysis is performed between 4 predictors and the upcoming NAO in historical data: North Atlantic Sea Surface Temperature, Arctic Sea Ice Volume, Eurasian Snow Depth and Stratospheric Temperature. From the weighted mean of the significant areas 4 seasonal “first guesses” are made for the upcoming NAO, one for each predictor. For each predictor, the 10 ensembles which show the nearest values to the first guess are selected. The ensembles which are picked for more than one predictor are counted only once.

The Jet Subsampling (Hellmich et al., under review):

For winds vertically averaged at 925-700 hPa, the daily position of the jet stream is calculated by retaining, for every longitude, the latitude at which the maximum u wind speed is found . The jet streams position are grouped through k-mean clustering into 4 groups: Northern, Central, Southern and Mixed. For each winter, the two most common jet groups are found. Finally, for each winter, ensembles are selected on a daily basis based on if they represent the two dominant jet groups for that winter or not.

Both subsampling methods show areas of weaknesses and strengths compared to the skill of the MPI-ESM-HR30 ensemble mean. However, the NAO and the jet stream do not act independently. The goal of this study is to combine the strength of both subsampling methods by taking into account these two phenomena in one single method.

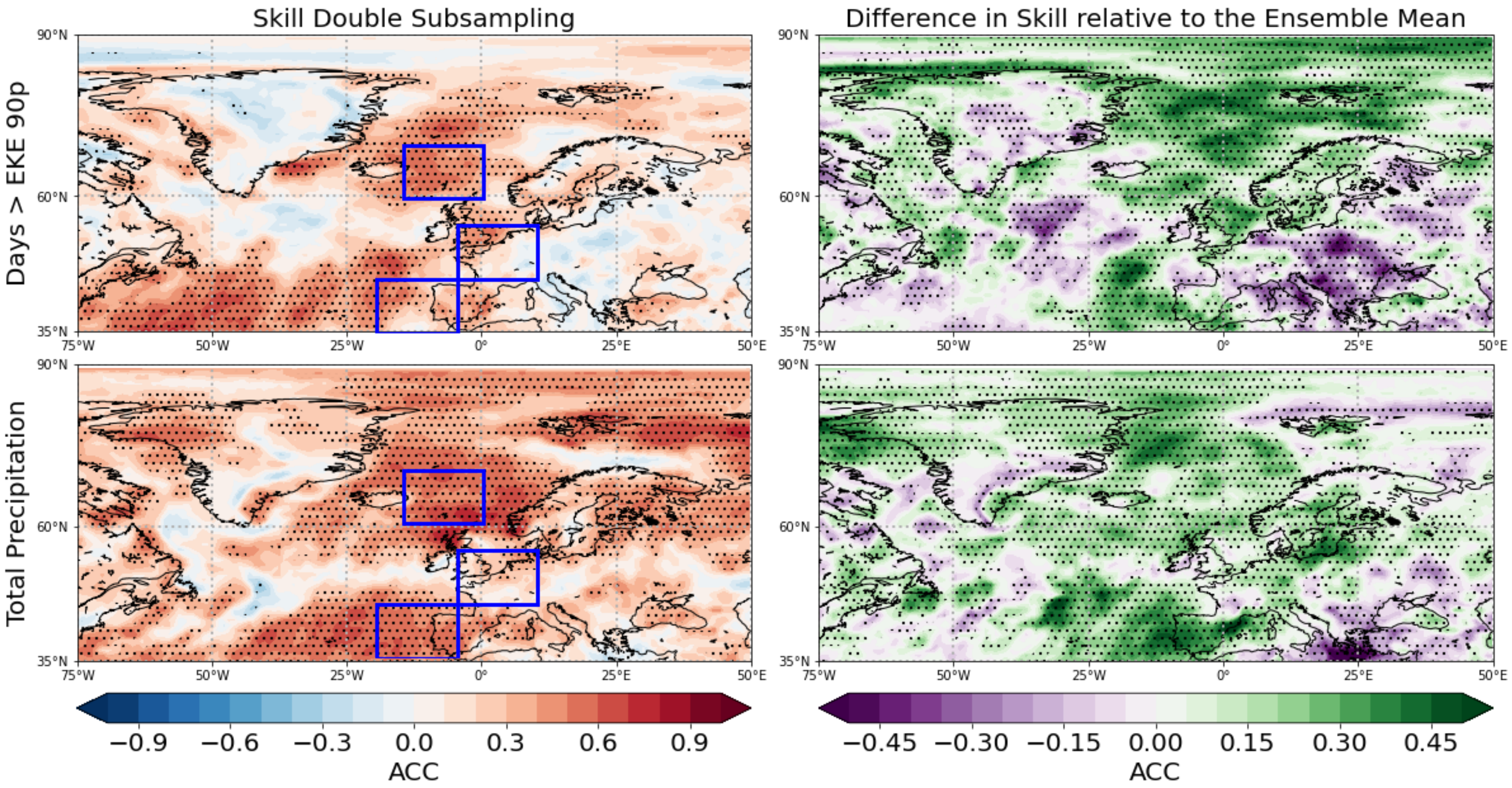
The Double Subsampling Method



In the Double Subsampling method, we use the ensembles which have been selected in the NAO subsampling (MPI-ESM-HR40) as the starting point for the jet stream subsampling. In this method, if an ensemble is selected for more than one predictor is kept. As a result we have a total of 40 ensemble members for each winter. As a final result, the choice of the seasonal most common jet stream clusters will be influenced by the seasonal NAO of that year.

[1]Dobrynin et al. (2018) [2]Hellmich et al. (under review)

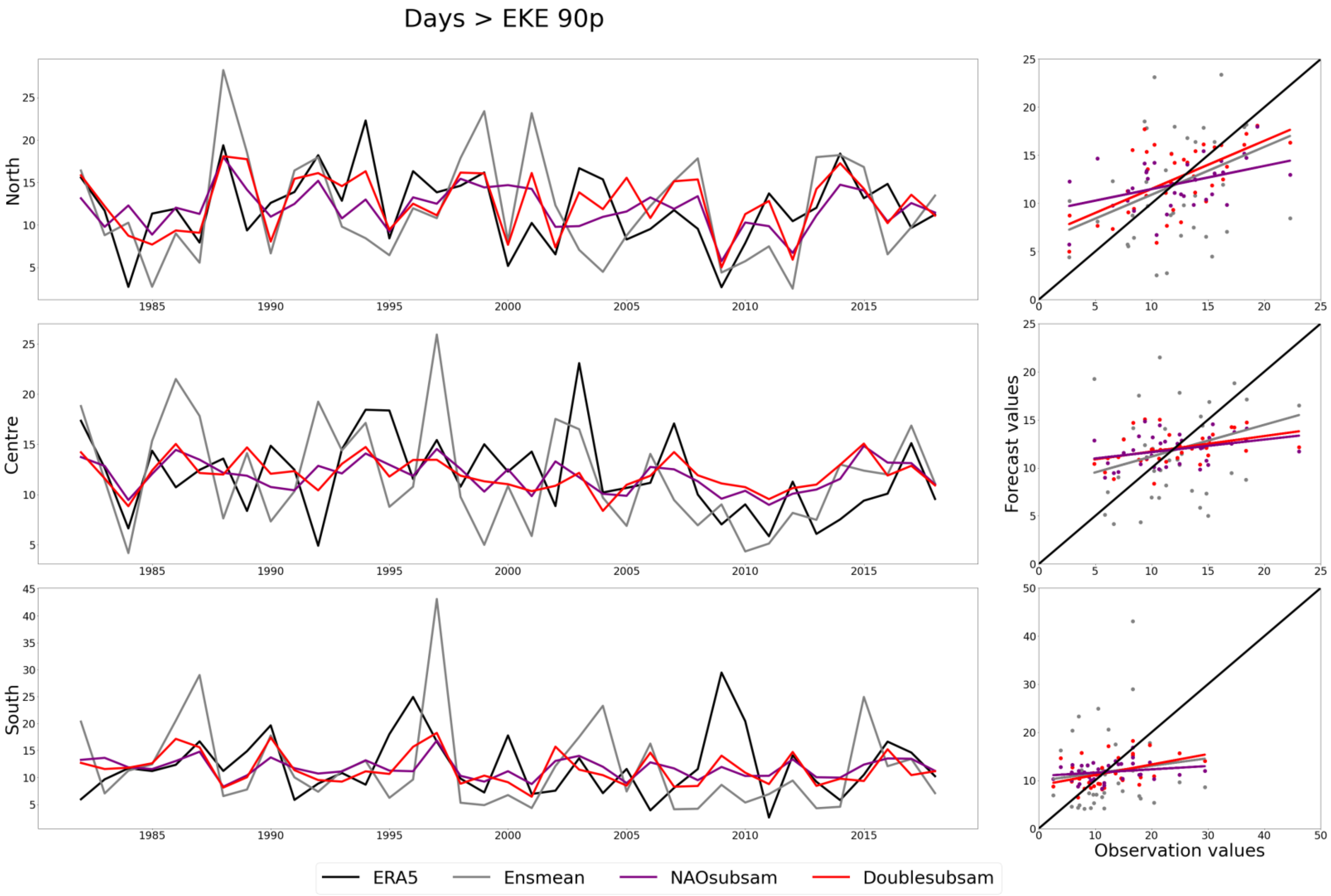
Skill of the Double Subsampling



.

Compared to both the subsampling methods the double subsampling shows an increase in skill in both significant area covered and magnitude. The increase in prediction skill, relative to the MPI-ESM-HR30 ensemble mean, is especially concentrated in the northern and the southern sector of the study area. On the other hand, the central sector, as well as part of the European continent, show no increase or even a worsening of the skill. This could be connected to the fact that in that area the NAO has little influence, and other patterns, such as the East Atlantic Oscillation, are more dominant. In order to investigate this possible relationship, we select a North box (15°W-0°,60°-70°N), a Central box (10°W-5°E, 45°-55°N) and a Southern box (20°-5°W, 35°-45°N). The Northern (Southern) box represents an area with a strong relationship with the positive (negative) phase of the NAO, while in the Central box the NAO signal is weak. A spatial averaged is applied on the variables and the boxes are represented through time series and scatterplots.

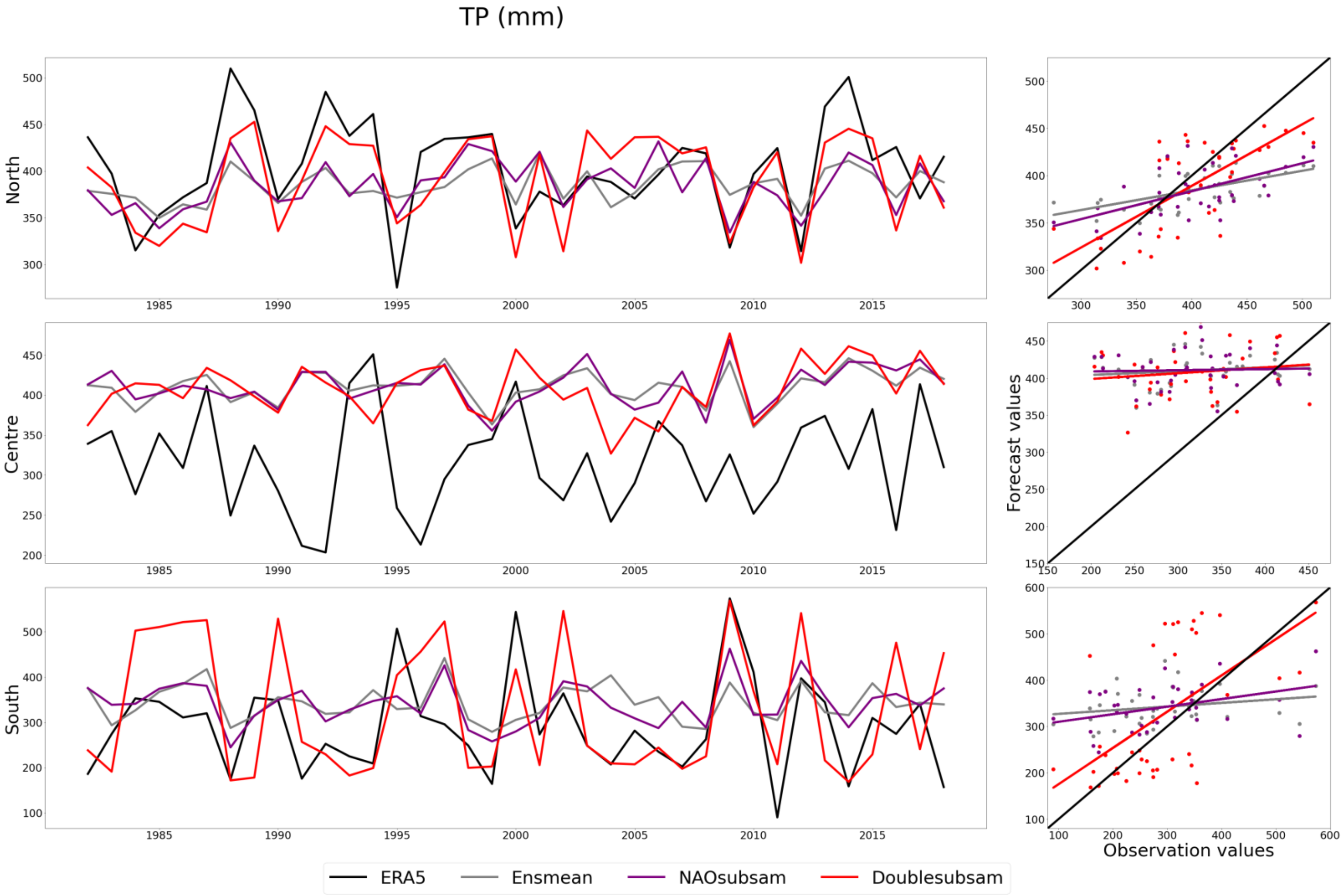
Where does the skill comes from? (i)



Time series (first column) show the seasonal and spatial averages of the total number of days per winter above the EKE 90th percentile for each of the three boxes. The scatterplots (second column) show instead the forecast values (y-axis) compared to observation's values (x-axis) for the same winter. Grey, purple and red lines represent the regression slopes for the MPI-ESM-HR30 ensemble mean, the NAO subsampling and the Double Subsampling respectively. The black line represents the "perfect forecast line".

The Northern and Southern boxes show a higher interannual variability compared to the central box. This variability is connected to the NAO as it can be seen that the Double Subsampling method performs similarly to the NAO subsampling in the various areas. However from the scatterplots it can be seen that this doesn't bring an improvement in the forecast, with the regression slope of the Double Subsampling being very close to the one of MPI-ESM-HR30 ensemble mean. The only difference that can be perceived is that the single seasonal values (dots) are less dispersed compared to the original model. This is to be attributed to the subsampling of the ensemble members. An explanation of the little improvement could be the few amount of days present in each winter, which leads to a loss in forecast skill even in the event of a little deviation from the observations.

Where does the skill comes from? (ii)



Same as in the previous figure, just for seasonal total precipitation.

For Total Precipitation, the difference between the areas, and the consequent connection with the NAO signal, becomes more evident. All the methods appear to perform poorly in the Central area, systematically overestimating the amount of total precipitation. On the other hand, the Northern and Southern areas show a significant improvement of the Double Subsampling compared to the other two prediction methods. The NAO subsampling shows a good general variability, which in turns brings the regression slope slightly nearer to the perfect forecast line, compared to the MPI-ESM-HR30 ensemble mean. The Double Subsampling method however shows a high interannual variability, which is in agreement with the variations from ERA5 observations. This improvement shows the effective contribution of picking the ensembles based on the jet stream position and on a daily basis.

Preliminary conclusions

EGU General Assembly 2022

1. Regarding on the general skill, the Double subsampling method brings improvements in both wind-based and precipitation-based parameters. The improvement in the skill is even bigger than both the NAO and Jet stream subsampling combined. However, Both the NAO and the Jet stream subsampling play a key role in this improvement.
2. Apparently, the ensembles selected from the NAO subsampling determine where this enhancements take place, with a regions strongly influenced by the NAO signal showing strong improvements. On the other hand, in regions where the NAO signal is weak, the skill of the Double Subsampling appears to be the same or worse than the MPI-ESM-HR30 ensemble mean. This could be due to the fact that in those areas other climate patters play a more dominant role.
3. The Jet stream subsampling, when fed with the ensembles from the NAO, is capable to enhance the sensitivity of the model to the interannual variations of the two different parameters, enabling the Double Subsampling method to detect even the more significant variations.
4. Days > EKE 90 percentile show a slight but not significant improvement with the others method. The overall values in the scatterplots are however less dispersed, which suggests that even if the subsampling is able to reduce part of the noise, the sensitivity could not be increased. Regarding total precipitation, in the areas where the NAO signal is strong the sensitivity of the model is substantially increased.