Changing atmospheric blocking; new insights with novel machine learning detection

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Introduction

Accurately detecting atmospheric blocks from climate model data is important, as it will help the study and prediction of blocking in changing climate.

- We developed a global ML-based blocking detection algorithm utilizing a ResNet-152 pre-trained model as part of our architecture.
- The ML model was trained on binary labels generated with the TempestExtremes (Ullrich et al., 202x) tracking algorithm for three separate CMIP6 models (CESM2, MPI, MIROC).
- The model was trained with daily 500 hPa geopotential height fields (Z500) from 1950-2100.

We will present results of current and future blocking climatologies across all CMIP6 data available at PCMDI for the historical and future scenario simulations (1979-2010, 2014-2100). Thus includes 36 models across the historical, SSp1-2.6, SSP2-4.5, SSP3-3.0 and SSP5-8.5 scenarios (reference).

Model Architecture

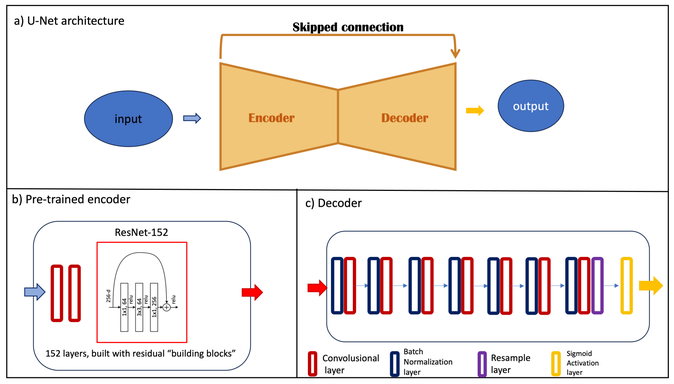

Figure 1 a) The U-Net Architecture we used for the algorithm. b) encoder part together with the pre-trained ResNet-152 model. c) Decoder part, with the different hidden layers depicted.

Model Evaluations

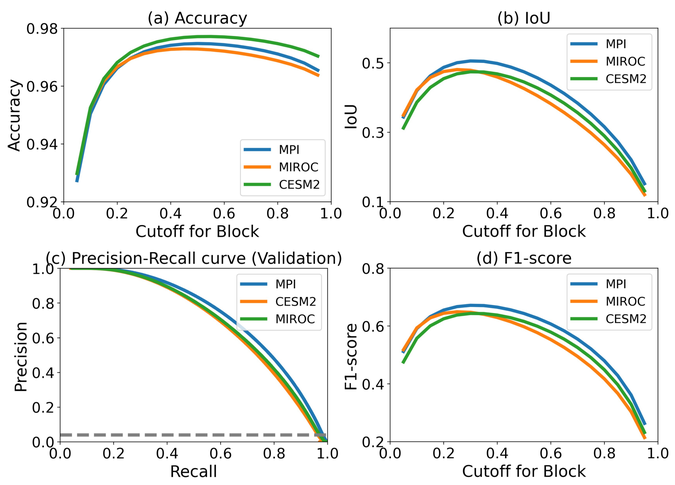

Figure 2 a) non-weighted accuracy. b) Intersection over Union for the blocking class. c) Precision-recall curve. d) F1-score that combines the presicion and recall values.

Blocking case studies and climatologies

The evolution of the detected blocks is consistent with the Z500-field evolution, and the TempestExtremes results.

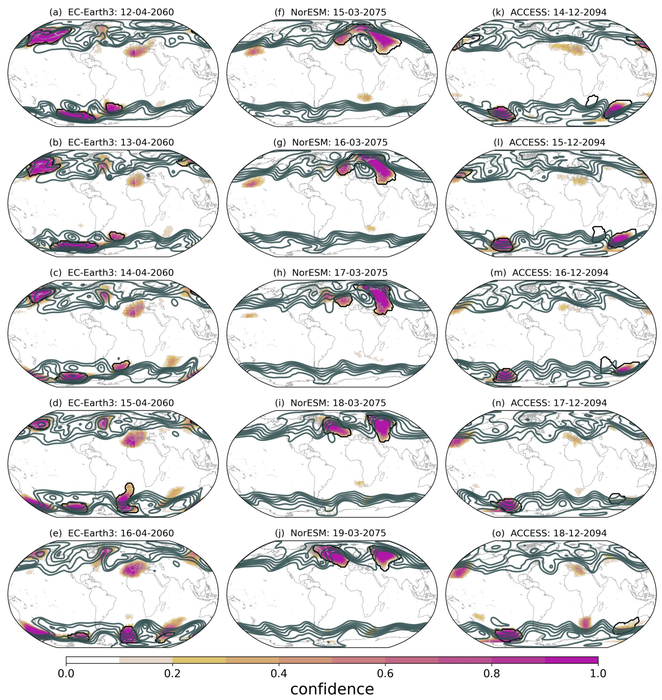

Figure 3: Randomly picked case studies, spanning 5-day time periods for EC-Earth3 (a-e), NorESM (f-j) and ACCESS (k-o). Z500-fields in grey lines, TempestExtremes blocks in black contours and the ML detection confidence in yellow to pink shading.

The ML-algorithm also catches the general blocking climatology well. In both seasonal and annual scales. With only small differences between the ML-detection (predicted) and TempestExtremes (labels).

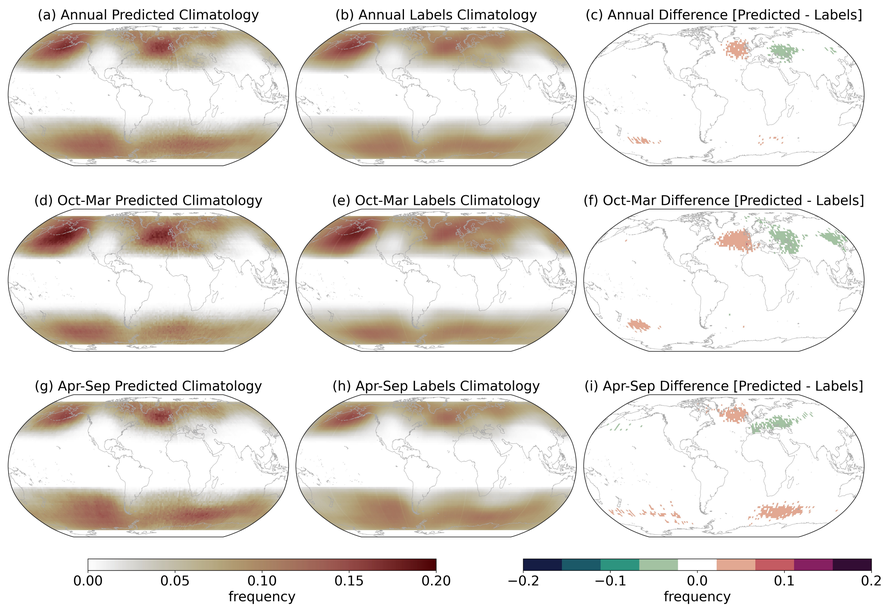

Figure 4: Annual (a-c) and seasonal (d-i) blocking frequencies. The left column shows the frequencies based on ML detected blocks, middle column TempestExtremes detected blocks and the right column the difference between the two.

Results

There is a general decrease in the future blocking frequency, but the specific spatial pattern of decrease is related to the strength of the global warming (SSP1-2.6 ->SSP5-8.5) and season (Fig. 6).

- The stronger the warming the less frequent blocking will be in the future in all seasons (SSP1-2.6 ->SSP5-8.5).

In addition:

- JJA and SON seasons display an increase in the future blocking over the south Southern Ocean.
- DJF season displays an increase in the Southern Ocean blocking in the SSP1-2.6 scenario, while in the other scenarios any increases are focused over the Alaska and Middle-East regions
- MMA displays slight increase in blocking over the xx peninsula in SSP1-2.6. In the other scenarios blocking increases over the Arctic region (SSP2-4.5 - SSP5-8.5).

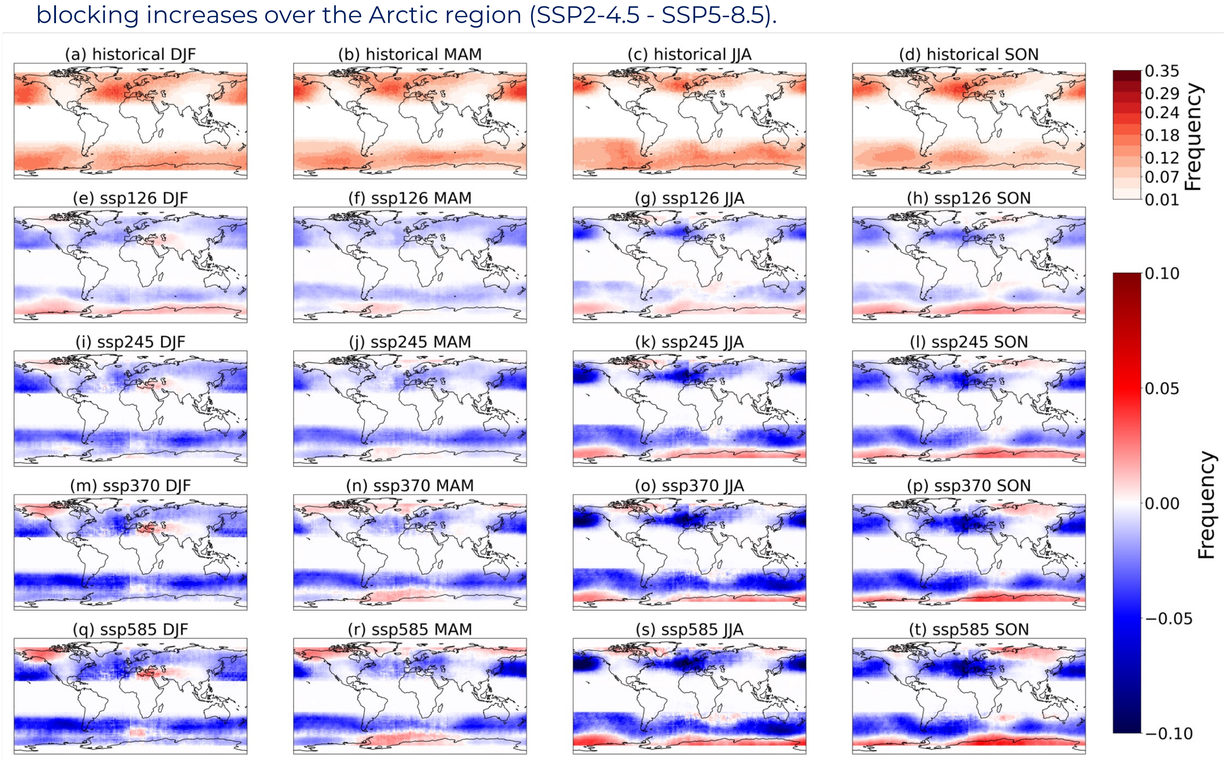

Figure 5 a-d) Seasonal multi-model mean blocking frequencies for the historical scenario (1979-2010). e-t) The difference between the multi-model mean blocking in the different scenarios (2014-2100) and the historical scenario.

Conclusions

- Blocking frequencies are predicted to decrease in the future, but the decrease is not homogeneous and depends on the warming scenario and season.
- The detection algorithm is being used to implement a blocking metric to the PCMDI Metrics Package to help evaluate CMIP7 models, see poster by Lee et al. **"Preparation of a more systematic evaluation of blockings and extremes for the upcoming CMIP7 via the PCMDI Metrics Package"**

References

- Ullrich et al.: Tempestextremes v2.1: a community framework for feature detection, tracking, and analysis in large datasets. Geosci. Model Dev. 14, 5023–5048 (2021) https://doi.org/10.5194/gmd-14-5023-2021
- Lee et al., 2023: Objective Evaluation of Earth System Models: PCMDI Metrics Package (PMP) version 3. Geoscientific Model Development (submitted), EGUsphere [preprint], doi: 10.5194/egusphere-2023-2720

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