

Downscaling climate change impacts on socio-economic parameters in a storyline-based investigation

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A

Introduction

Changing climate has various effects on society and human health. In this project we use climate storyline simulations from within the SCENIC project framework for the prediction of mortality rates in Germany under warmer climate conditions. We train an echo state network (ESN) with temperature fields from AWICM1 climate model as inputs and mortality rates in Germany as targets. Due to excess mortality during the COVID-19 pandemic we restrict our analysis to before 2020. We investigate the effects on the scale of Germany and also for several federal states in order to detect regional effects.

B

Climate storylines

Nudging of large-scale tropospheric winds towards reanalysis allow recreation of extreme events in warmer climate conditions. Without nudging the modeled state of the atmosphere diverges quickly from the observed state. By nudging the tropospheric winds the model stay close to the observed state. This allows to run a climate simulation with the same nudging and increased atmospheric forcing to see how a specific event would unfold under warmer conditions. In this approach the thermodynamic response to climate change is captured but possible dynamical changes are ignored.

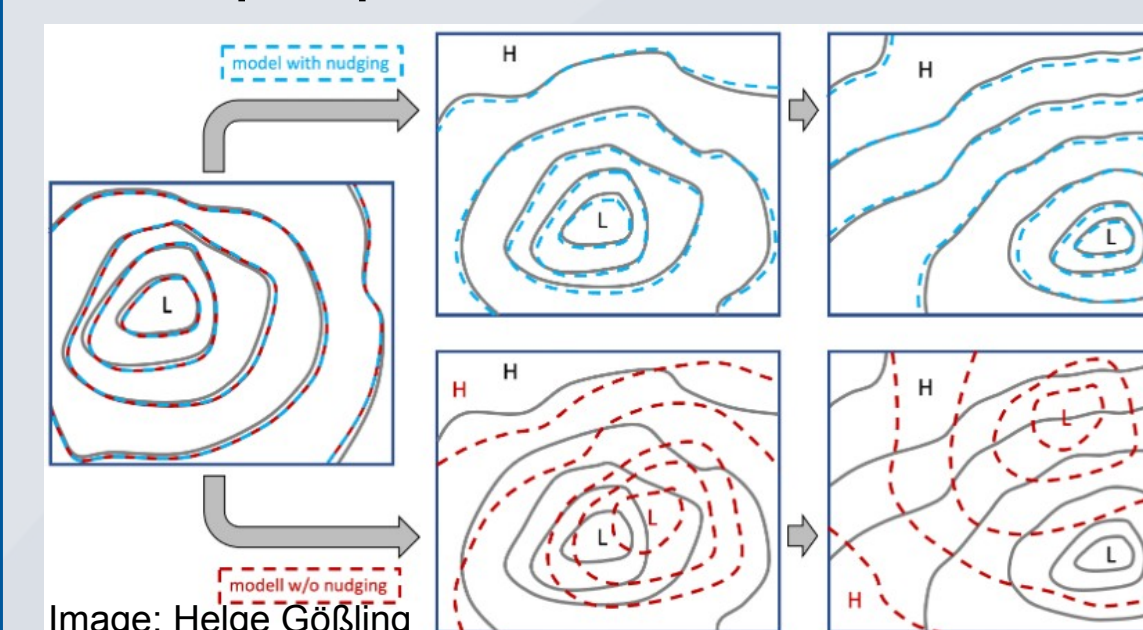


Fig. 1: Schematic of tropospheric nudging.

C

Echo state networks

ESNs contain a sparsely connected reservoir with feedback loops and recurrent connections. They are able to capture time dependent input features and have a low number of free parameters. Input layer and reservoir are initialised randomly. The reservoir weights remain unchanged during training, only the node activations are adapted. The output weights are determined by a ridge regression. ESNs are suitable for short input data.

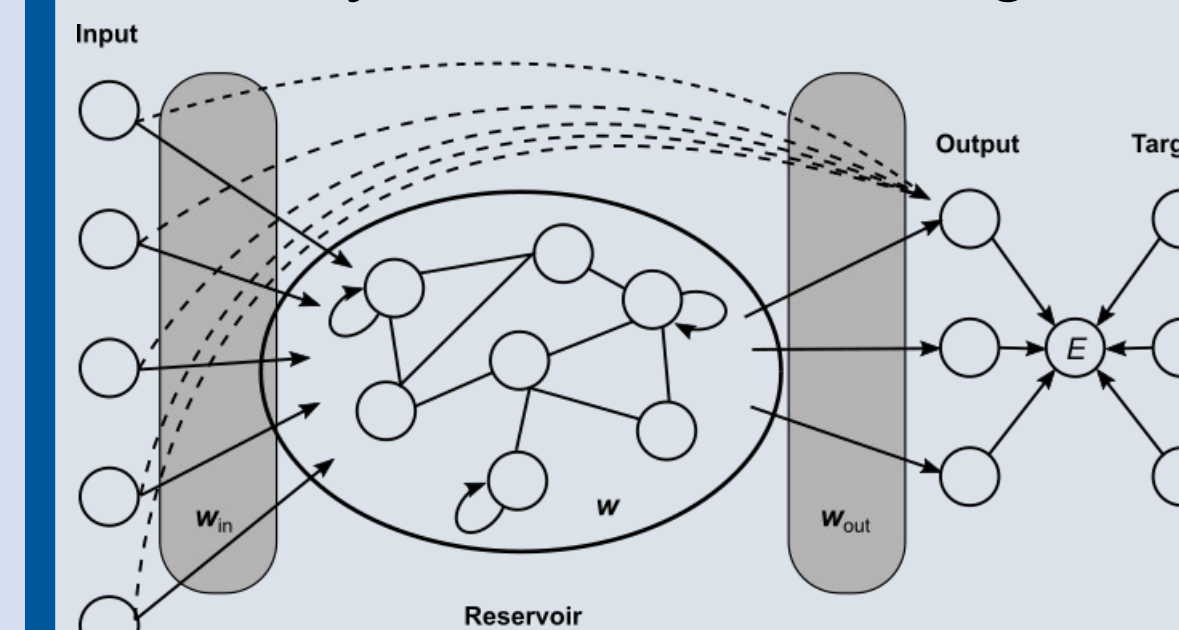


Fig. 2: Schematic of an echo state network

D

Data and network training

Input data for the ESN are monthly maximum 2m temperatures from 2015 to 2019 in the region shown in Fig. 3. Figure 4 shows the target data in black and test predictions for the network training in red. The RMS error is $\approx 2.5\%$.

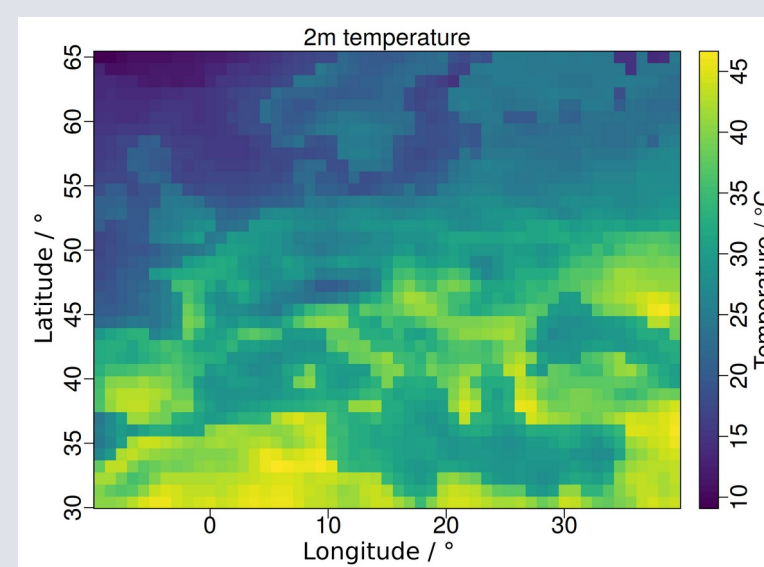


Fig. 3: Input data for the ESN – monthly maximum values of 2m temperatures.

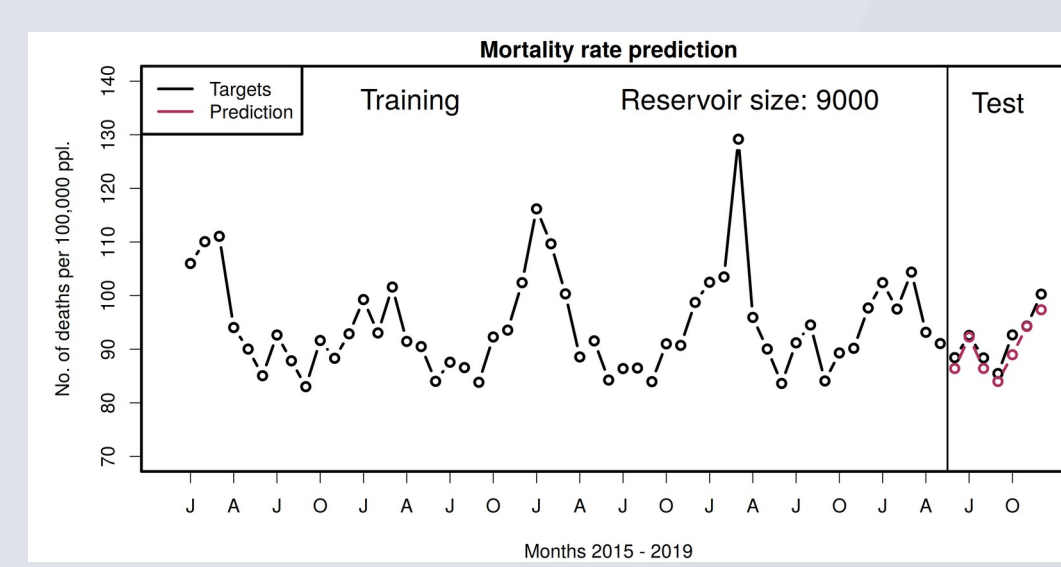


Fig. 4: Target data for the ESN training – monthly mortality per 100,000 ppl in Germany (black). In red the test predictions of ESN training.

E

Results

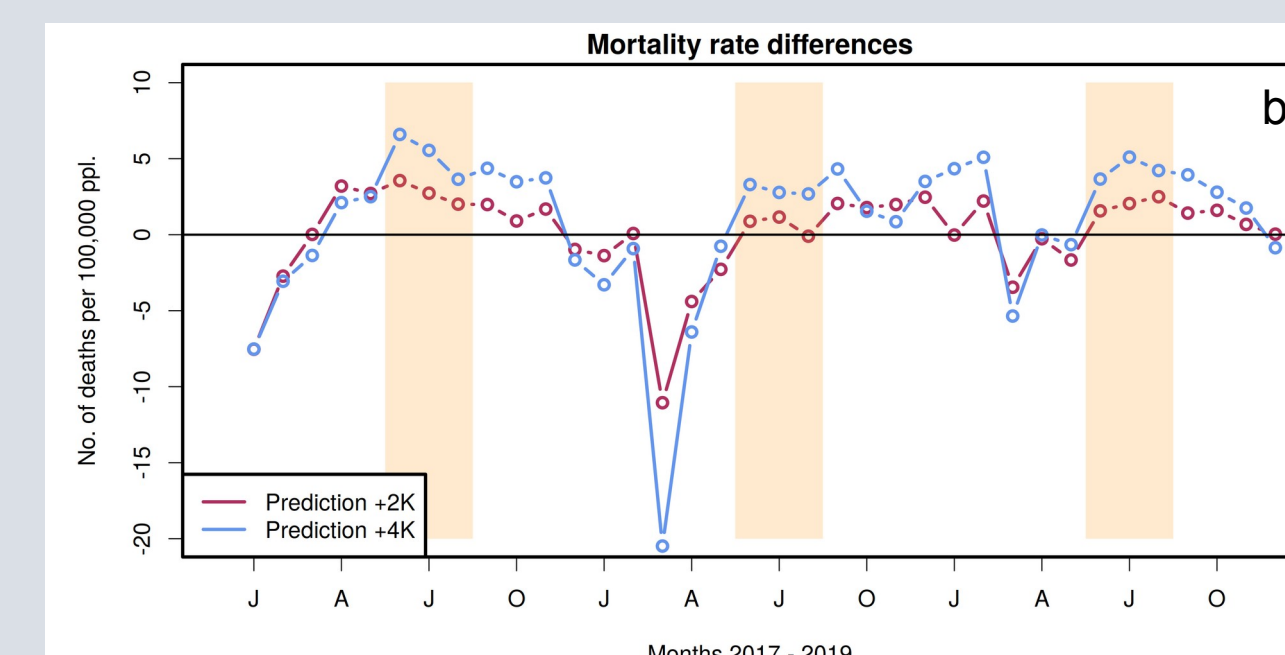
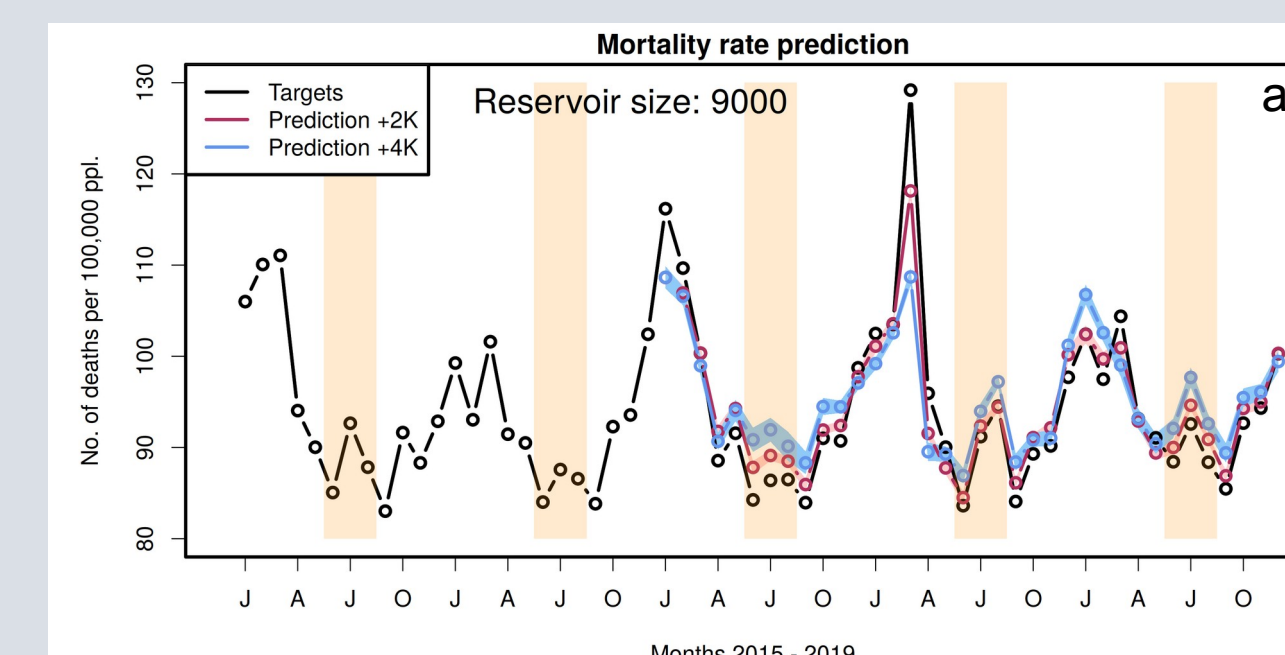


Fig. 5: mortality rate predictions for +2K and +4 K storylines for Germany (panel a). Differences to present day values (panel b).

The predictions of mortality rates with input data from the +2K and +4K storylines are shown in Fig. 5a. We computed an ensemble of network trainings and predictions to test the variability of the results due to the random input layer and reservoir initialisation. The shaded areas are the 1 σ deviations from the mean values. The standard deviation is almost everywhere well below 1% of the mean showing the robustness of the method. Figure 5b shows the differences between the predicted and present day mortality rates. In the summer months (indicated by the orange background) the mortality is increased by 4-6 fatalities per 100,000 people, resulting in

4-5 thousand additional deaths per month. Predictions of winter values are less reliable due to additional factors influencing mortality such as severity of influenza wave or vaccination rate.

Figure 6 shows the analysis for some federal states in Germany. The increase of mortality rate is larger in the north-west than in the south reaching values of more than 12 in Brandenburg (panel a) for 2015. This corresponds to almost 300 additional fatalities per month in Brandenburg.

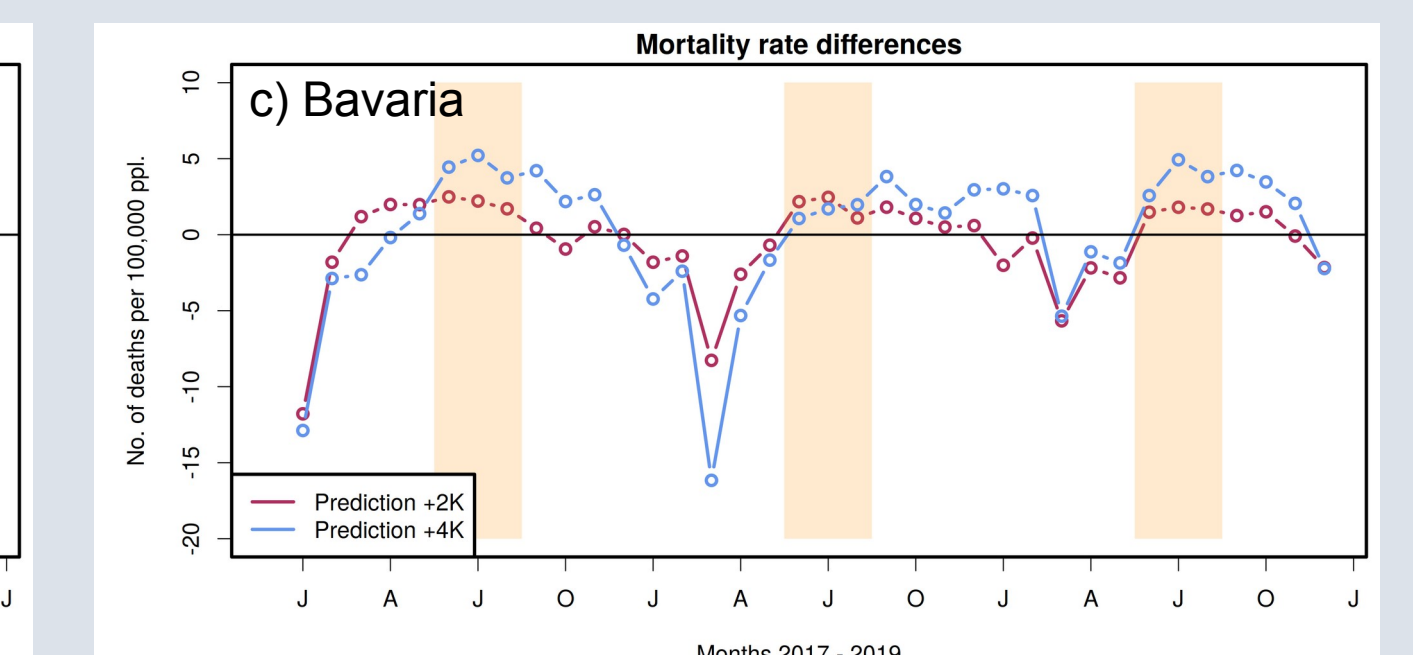
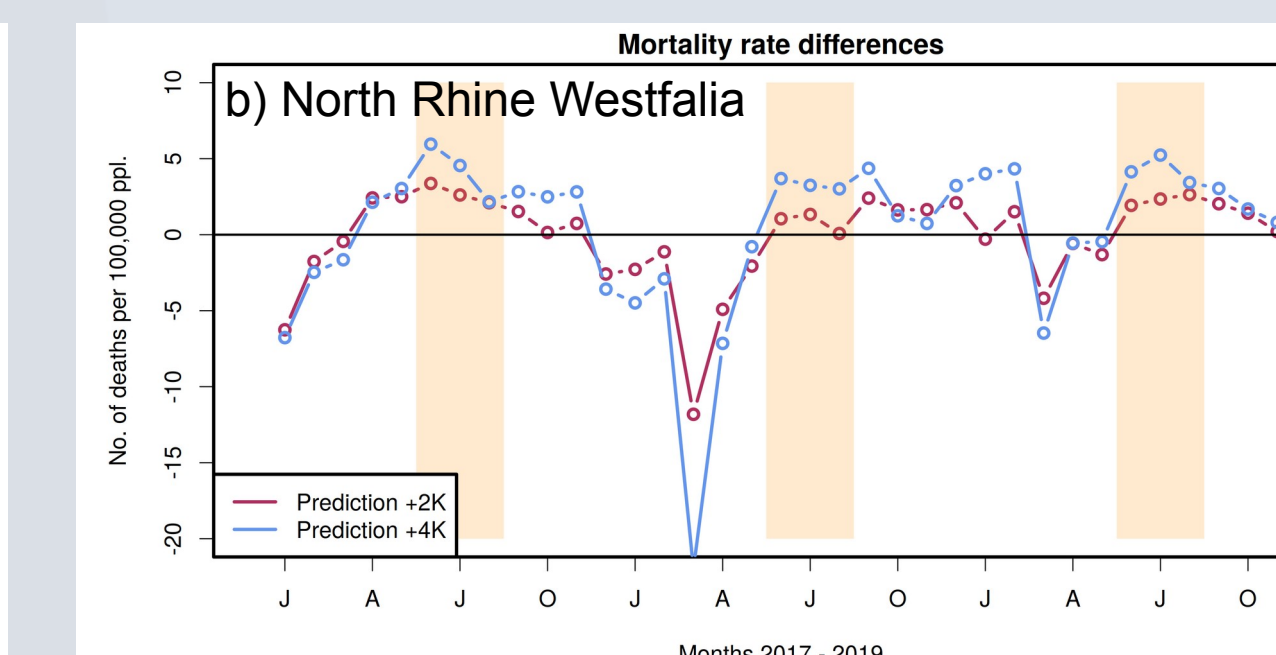
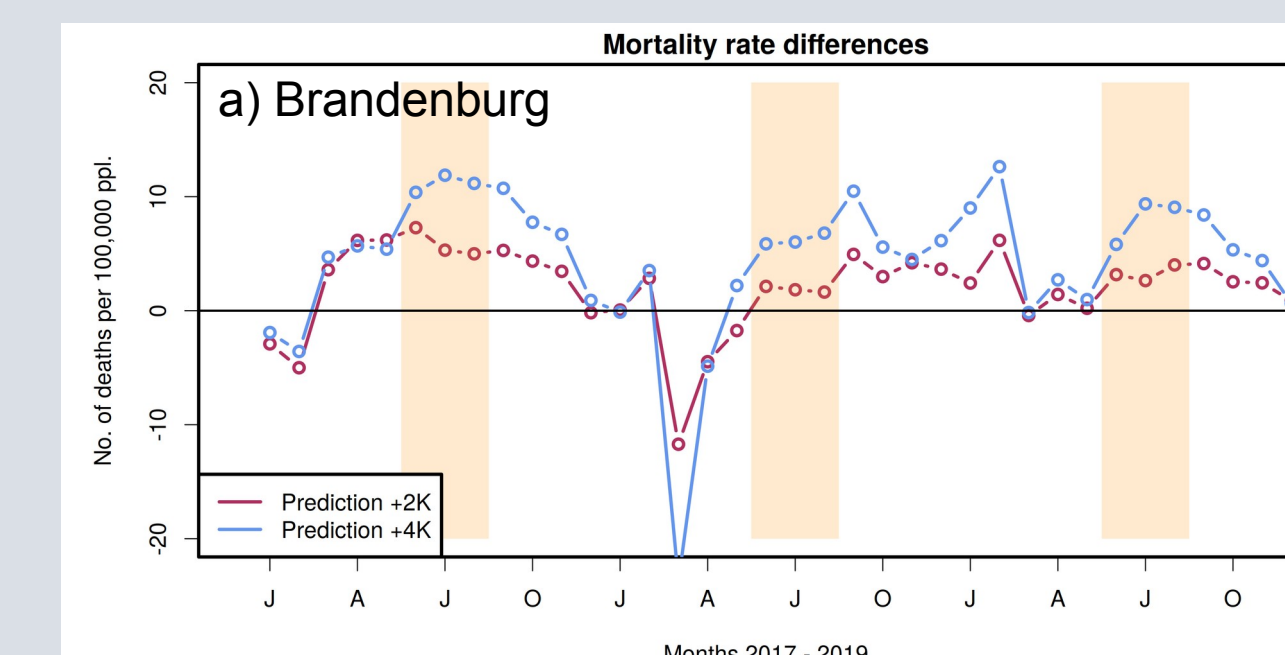


Fig. 6: Differences between mortality rates predicted for the +2K and +4K storylines and present day values for three regional predictions. The increase is higher in the Brandenburg region than in the south-west of Germany.

F

Conclusions

- We successfully trained an echo state network with climate storyline model output and mortality target data for Germany in the period 2015-2019
- The training is robust and yields RMS errors on test data of approx. 2.5%
- Predictions for the warmer world scenarios of the storylines are plausible, showing increased mortality during hotter summers and decreased values during milder winters
- We can make predictions on the regional scale allowing to identify differences between regions in the north-east and south / south-west

References

- H. Jaeger. The “echo state” approach to analysing and training recurrent neural networks-with an erratum note. Technical Report 34, German National Research Center for Information Technology GMD, Bonn, Germany, 2001
- A. Sánchez-Benítez, H. Goessling, F. Pithan, T. Semmler, and T. Jung. The July 2019 European Heat Wave in a Warmer Climate: Storyline Scenarios with a Coupled Model Using Spectral Nudging. J. Clim., 35(8):2373–2390, 2022, doi: 10.1175/JCLI-D-21-0573.1