Exploring future European cold spells within a combined storyline-statistical framework

In light of accelerating global warming, the question of how extreme weather events will change is coming increasingly into focus. Due to the virtually certain changes in mean temperature, heat waves are projected to increase in frequency and intensity, whereas cold spells are thought to become less frequent in the future. However, across the mid-latitudes, winter-time temperatures exhibit a particularly high variability, and cold extremes with considerable impact might still occur, even in a much warmer climate.

In this master thesis, a novel approach will be used to study how recently observed European cold spells (e.g. late February 2018) would change in a future warmer climate – both in terms of their intensity and occurrence probability. To this end, so-called storylines of three recently occurred European cold spells will be explored. This technique is based on model simulations, in which the weather patterns are forced to closely follow those of recently observed events while the thermodynamical background is changed according to expected future warming. Thereby the global warming-related thermodynamic contribution to changes in extreme event can be accurately isolated. However, storylines alone cannot provide any insight into the future probability of such events. Therefore the storyline simulations are extended by a statistical approach using so-called „dynamical analogues“. Within projections of a large climate model ensemble (MPI-GE), weather situations similar to those of the recently occurred cold spells are being searched for. Due to the high number of simulated within a 50-member ensemble, hundreds of similar events will be found, allowing a robust statistical assessment of projected changes to both the event characteristics and the probability of such cold spells.

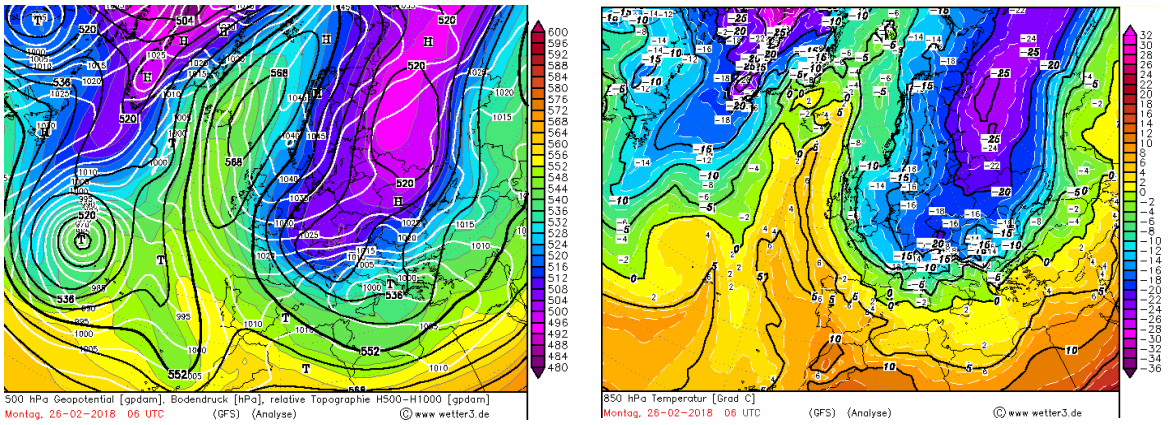

Figure: Example of a recent impactful cold spell affecting large regions of Europe. The left panel shows the 500hPa geopotential whereas the right panel shows the temperatures in 850hPa.

Related publications

de Vries, H., Haarsma, R. J., & Hazeleger, W. (2012). Western European cold spells in current and future climate. *Geophysical Research Letters*
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2011GL050665

The combined storyline-statistical approach applied to the 2018 heatwave:

León-FonFay, D., Lemburg, A., Fink, A. H., Pinto, J. G., & Feser, F. (2026). A combined storyline-statistical approach for conditional extreme event attribution. *Weather and Climate Dynamics*
https://wcd.copernicus.org/articles/7/597/2026/

Storyline simulations for the 2019 heatwave:

Klimiuk, T., Ludwig, P., Sanchez-Benitez, A., Goessling, H. F., Braesicke, P., and Pinto, J. G. (2025) The European summer heatwave of 2019 – a regional storyline perspective, Earth Syst. Dynam https://esd.copernicus.org/articles/16/239/2025/