EGU24-17759, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-17759
EGU General Assembly 2024

A daily ensemble of Past and Future Weather for rapid attribution and future perspectives

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Europe faced many extreme events in the year 2023; storms, heatwaves, intense precipitation, widespread flooding, to mention a few. Long-standing records were broken, and re-broken again. The events invariably received a lot of attention by the media and triggered many questions from journalists, eager to report about them. These questions are typically about the frequency or 'extremeness' of the event, whether or how already occurred climate change has impacted this frequency, and what the future perspectives are: Would a similar event in future or past climate have (had) a larger or smaller impact?

It is a challenge for scientists to answer such (attribution) questions *rapidly*, i.e., before or on the day of the event, or in the immediate aftermath. Weather attribution teams like WWA (World Weather Attribution) now apply standardised procedures based on combining observations and climate modelling, to produce such analyses within weeks.

Here we discuss an approach that may augment the set of already existing tools and frameworks for rapid attribution analysis. The approach is based on regional downscaling in combination with pseudo global warming (PGW). Each day a small downscaled ensemble is created using as initial and boundary conditions the ECMWF analysis and forecasts. In addition to this 'present-day' ensemble, also a 'past' and 'future' ensemble are created using PGW. Due to the synchronicity of the time-evolution of the past, current and future ensembles, the signal-to-noise ratio is high, allowing an immediate estimate of how (thermodynamic) changes could have contributed to the event, and how a similar event in a future climate could look. Inherent limitation of PGW is that it cannot, or only in a limited way, address the frequency-change aspect.

We illustrate the PGW-ensemble with a number of events that occurred during 2023 such as storm Hans (August), the December snowfall, and the unprecedented yearly rainfall amount in the Netherlands.