ALFRED-WEGENER-INSTITUT
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Making the impact of climate change more tangible through storylines

Thomas Jung, Marylou Athanase, Sebastian Beyer, Helge Goessling, Amal John, Eva Montfort, Antonio Sanchez-Benitez + more colleagues

Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research

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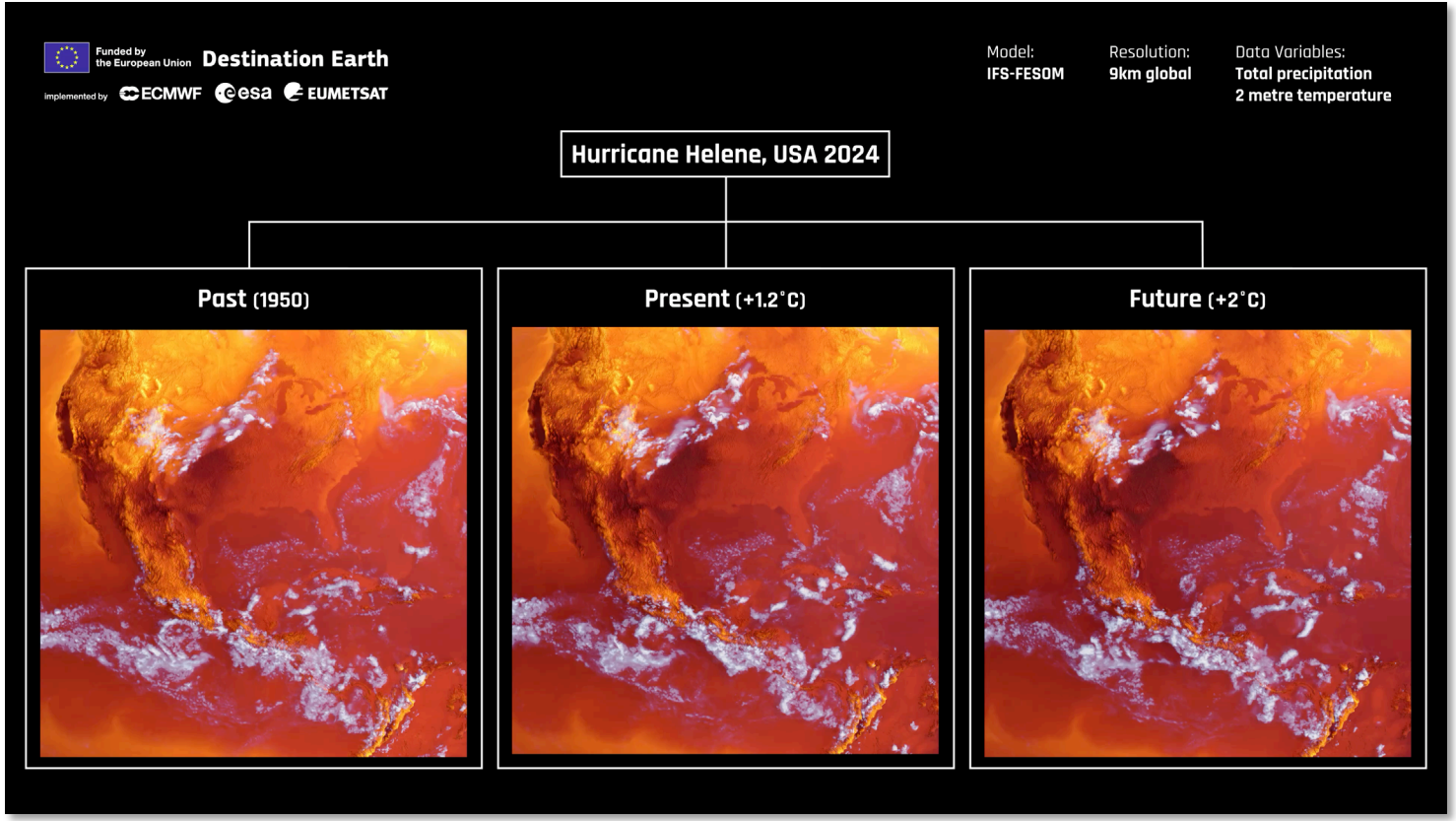
Replaying extreme events in different climates



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Related work

nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATE2450

Tales of future weather

W. Hazeleger[1,2,3*], B.J.J.M. van den Hurk[1,4], E. Min[1], G.J. van Oldenborgh[1], A.C. Petersen[4,5], D.A. Stainforth[6,9,10], E. Vasileiadou[4,8] and L.A. Smith[6,7]

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather patterns will change. The search is on for more effective methodologies to aid decision-makers both in mitigation to avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternatively, numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of high-resolution simulations of high-impact weather in a future climate. This 'tales of future weather' approach will aid in the interpretation of lower-resolution pictures of what

Forecast-based attribution of a winter heatwave within the limit of predictability

Nicholas J. Leach[a,1], Antje Weisheimer[a,b,c], Myles R. Allen[a,d], and Tim Palmer[a]

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Edited by Kerry A. Emanuel, Massachusetts Institute of Technology, Cambridge, MA, and approved October 8, 2021 (received for review July 1, 2021)

Attribution of extreme weather events has expanded rapidly as a field over the past decade. However, deficiencies in climate model representation of key dynamical drivers of extreme events have led to some concerns over the robustness of climate model–based attribution studies. It has also been suggested that the unconditioned risk-based approach to event attribution may result in false negative results due to dynamical noise overwhelming any climate change signal. The "storyline" attribution framework, in which the impact of climate change on individual drivers of an extreme event is examined, aims to mitigate these concerns. Here we propose a methodology for attribution of extreme weather events using the operational European Centre for Medium-Range Weather Forecasts (ECMWF) medium-range forecast model that successfully predicted the event. The use of a successful forecast the specific event that occurred, unlike in unconditioned climate model simulations. Finally, weather forecasts are run routinely by many different national and research centers. The models used are generally state of the art and extensively verified. We propose that the attribution community could and should take advantage of the massive amount of resources that are put into these forecasts by developing methodologies that use the same type of simulation. Ideally, the experiments required for attribution with forecast models would be able to be run with little additional effort on top of the routine weather forecasts; in this way they might provide a rapid operational attribution system. We discuss these ideas further throughout the text.

There have been several studies that propose or perform methodologies related to the forecast-based attribution demon-

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Natural Hazards and Earth System Sciences

A methodology for attributing the role of climate change in extreme events: a global spectrally nudged storyline

Linda van Garderen[1], Frauke Feser[1], and Theodore G. Shepherd[2]

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Correspondence

Received: 5 June
Revised: 25 Sept

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Earth Syst. Dynam., 11, 855–873, 2020
https://doi.org/10.5194/esd-11-855-2020
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Earth System Dynamics

Storylines of the 2018 Northern Hemisphere heatwave at pre-industrial and higher global warming levels

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Institute for Atmospheric and Climate Science, Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland

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Received: 30 December 2019 – Discussion started: 24 February 2020
Revised: 30 July 2020 – Accepted: 3 September 2020 – Published: 21 October 2020

Abstract. Extreme temperatures were experienced over a large part of the Northern Hemisphere during the 2018 boreal summer (hereafter referred to as "NH2018 event"), leading to major impacts on agriculture and society in the affected countries. Previous studies highlighted both the anomalous atmospheric circulation patterns during the event and the background warming due to human greenhouse gas emissions as main drivers of the event. In this study, we present Earth system model experiments investigating different storylines of the NH2018

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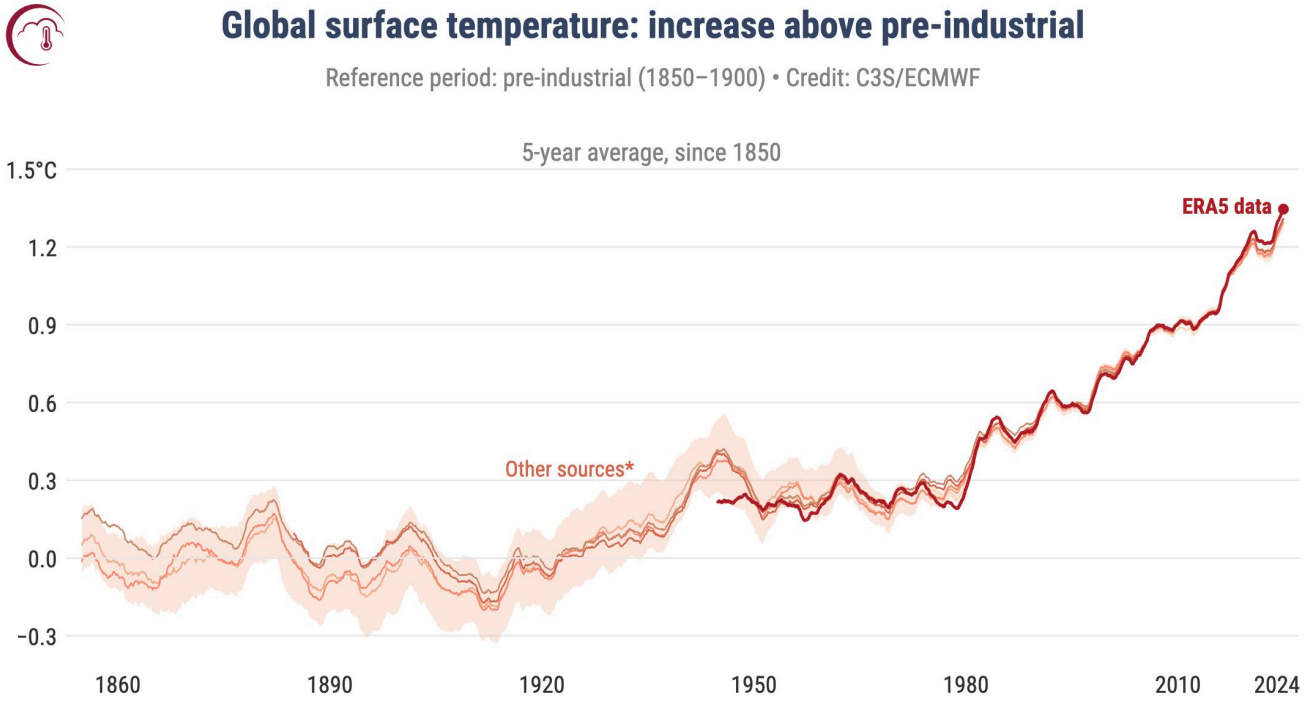
Background



***Other sources** comprise JRA-3Q, GISTEMPv4, NOAAGlobalTempv6, Berkeley Earth and the HadCRUT5 ensemble mean. Shading shows the range of the HadCRUT5 ensemble.

PROGRAMME OF THE EUROPEAN UNION
Copernicus
Climate Change Service
IMPLEMENTED BY ECMWF

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Extreme events in a warming world

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Storylines: A heatwave example

Weather forecast for 25 July 2019

How would this day have “looked like“ in pre-industrial times?

How would this day “look like“ in a +2K, +3K and +4K warmer world?

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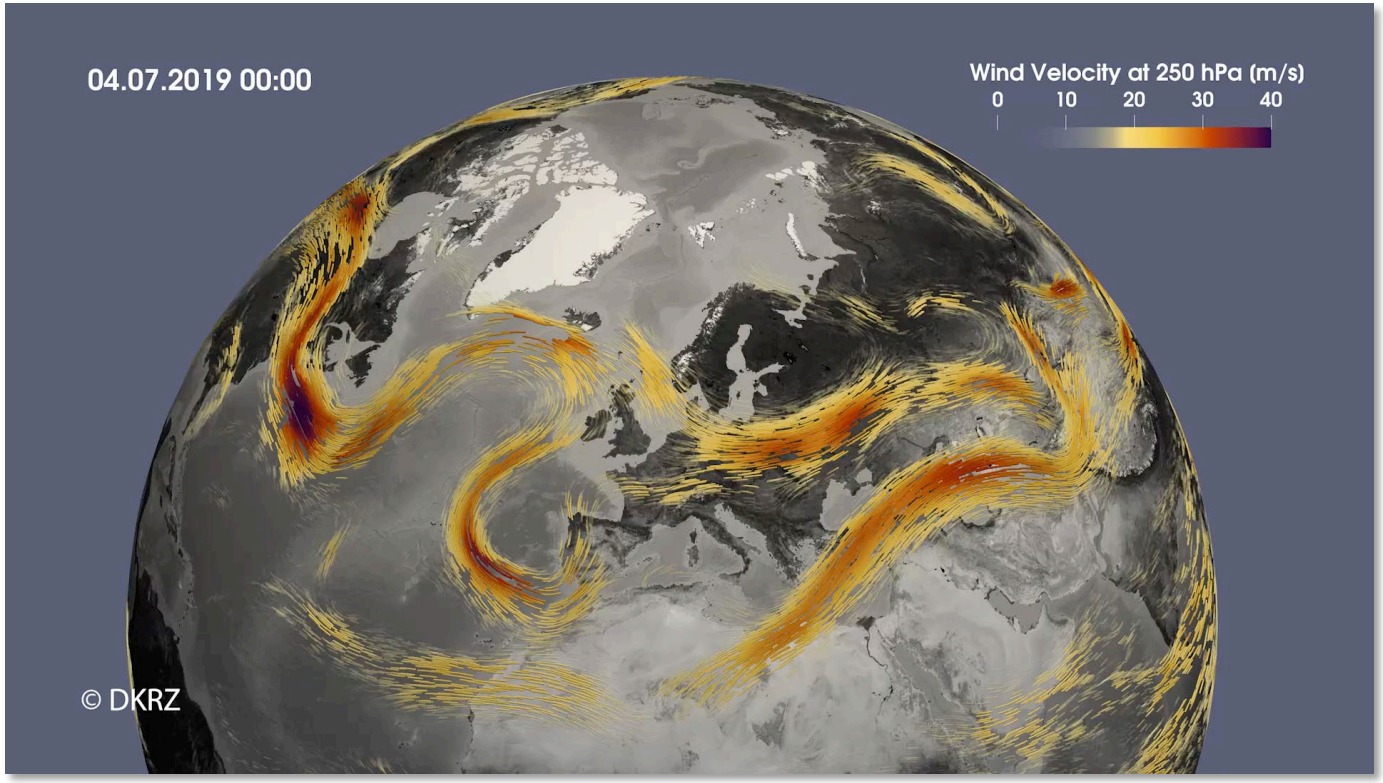
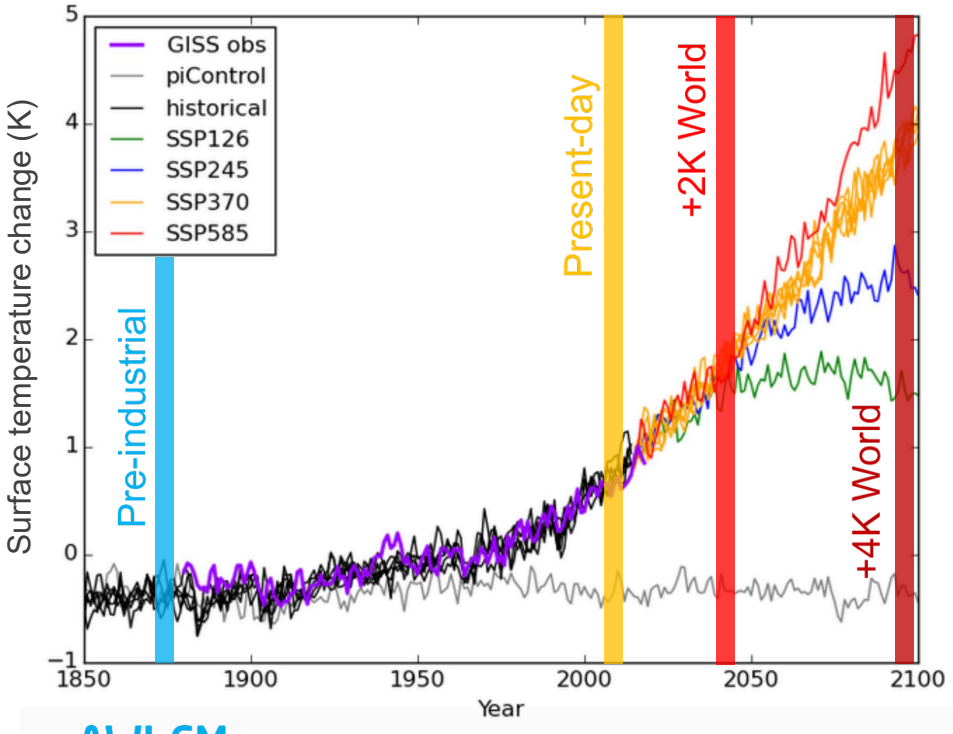
The jet stream



The approach

- Take a coupled climate model for which climate change simulations are available (e.g. CMIP6 and DestinE)
- Rerun the model for present-day climate in which upper tropospheric winds are spectrally nudged to ERA5 (1 Jan 2017 to today), keeping everything else untouched
- Repeat for +2K World (≈ 2042)
- Repeat for +4K World (≈ 2093)
- Repeat for pre-industrial climate (≈ 1850)



AWI-CM
AWI Climate Model

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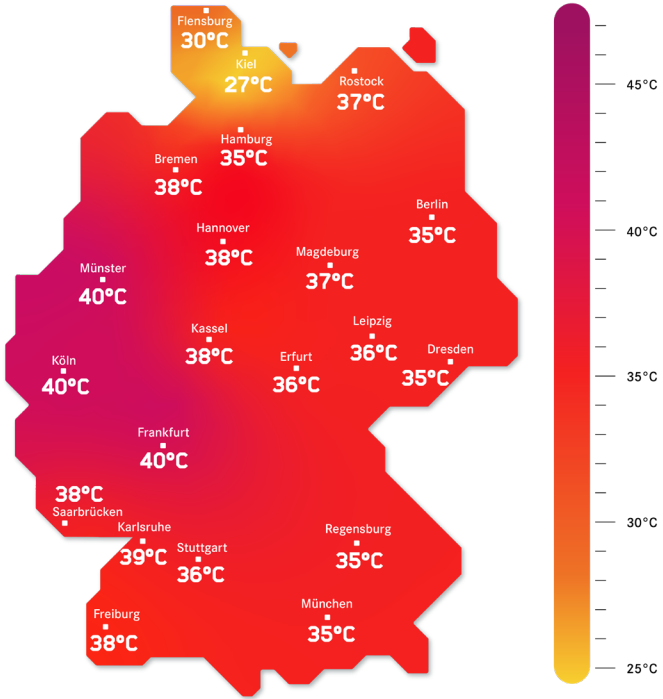
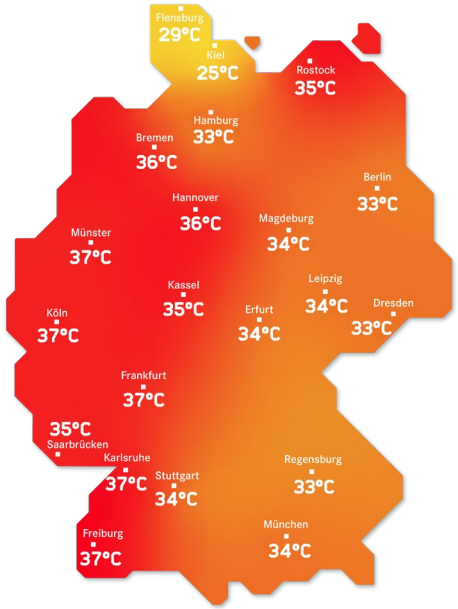
The July 2019 heatwave in different worlds

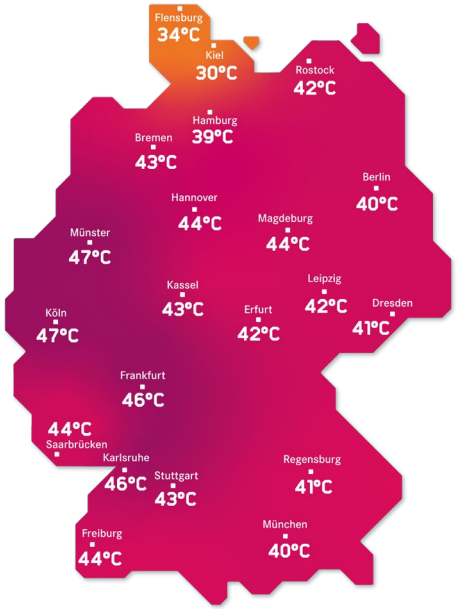
Present-day



Pre-industrial



+4K warmer world



Sanchez-Benitez et al., J. Climate (2022)

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Near-realtime storylines

ZEIT ONLINE

Hitzewelle

So viel heißer wäre die aktuelle Hitze in Zukunft

Der bislang heißeste Tag des Jahres war im Juli. Eine Simulat
die Klimakrise gewesen wäre – und wie extrem er in

13. Juli 2023, 16:22 Uhr / 229 Kommentare

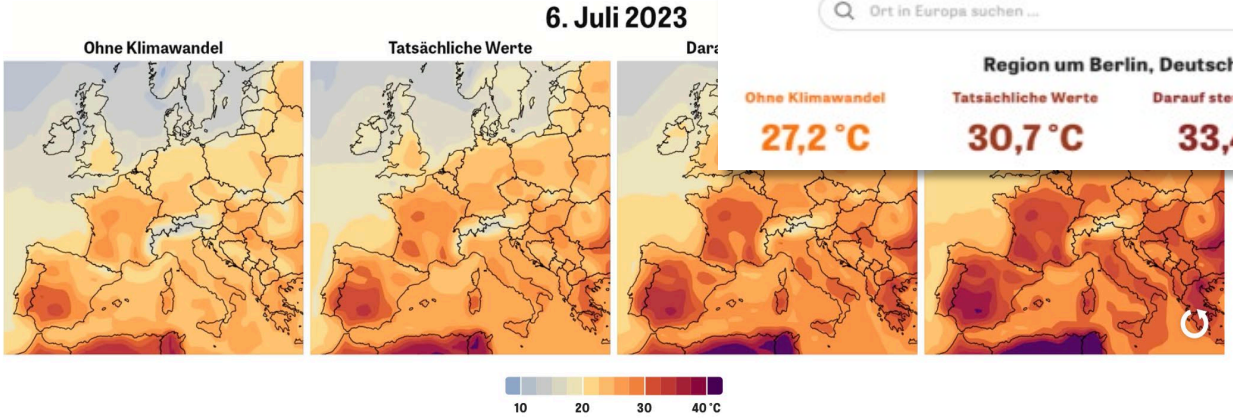
Wie viel heißer macht der Klimawandel es bei Ihnen?

So warm wäre es am 9. Juli in Ihrer Region ohne den Klimawandel gewesen – und wenn Klimaszenarien der Zukunft schon heute eintreten würden.

Ort in Europa suchen …

Region um Berlin, Deutschland

Ohne Klimawandel	Tatsächliche Werte	Darauf steuern wir zu	Worst-Case-Szenario
27,2 °C	30,7 °C	33,4 °C	36,1 °C



Quelle: Alfred-Wegener-Institut, eigene Berechnungen

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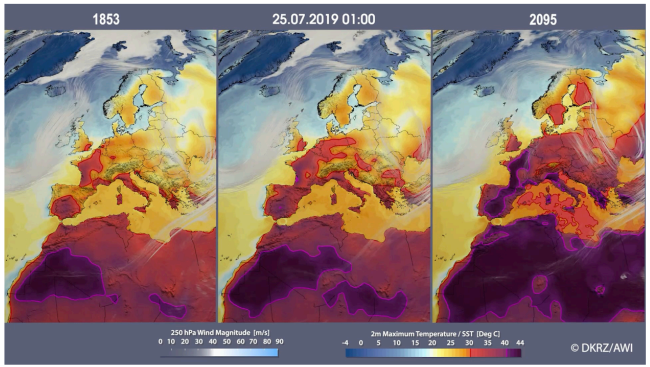
Near-realtime storylines

AWI Climate Storylines

Home | About | Data Explorer | Impressum

Climate change is not just an abstract, complex change of weather statistics. Climate change is present in the weather of every single day – and it is not the same each day!



The European heatwave in July 2019 in different climates. The visualization shows the same simulated weather sequence in the three images: on the left for the pre-industrial climate, in the middle for today's climate and on the right for a 4°C warmer world. The wind at an altitude of around 10km is shown as white stripes, the daily maximum surface temperature is shown as colors, and the sea ice concentration as white shading in and around Europe. Available as an animation on YouTube: https://www.youtube.com/watch?v=RzrSkWRytZY.

Consider a summer day somewhere in Europe with an Atlantic ocean breeze, and compare it to a day influenced by winds blowing from the continent. The latter will tend to be more strongly affected by climate change, simply because the continents warm more strongly than the oceans.

Can we be more specific? Yes! By using a climate model in a special way, where the winds are forced to follow the observed winds, we simulate the 'climate change signal of the day'. Every day and everywhere. Just a few days behind real-time. And with this tool, you can have a look and explore our storyline simulations yourself.

Our results have limitations and are not perfect. We use just one climate model, and other models will give somewhat different results. Our model is coarse, using grid boxes as wide as 100km, so a lot of detail is lost. And finally, this storyline method only extracts the 'thermodynamical' component of climate change, meaning that it necessarily ignores possible (but mostly rather uncertain) changes of wind patterns.

For these reasons, we consider our storyline simulation system a prototype. The approach has already proven to be a powerful tool for climate research, as showcased in a recent publication in the Nature journal *Communications Earth & Environment*. By making climate change very tangible, we envision climate storylines like ours to become an important piece of the future dissemination portfolio of climate change information.

Publication: Athanase, M., Sánchez-Benítez, A., Monfort, E., Jung, T., and Goessling, H. F. How climate change intensified storm Boris' extreme rainfall, revealed by near-real-time storylines. Commun Earth Environ 5, 676 (2024). https://doi.org/10.1038/s43247-024-01847-0

Athanase et al. (2024b)

https://climate-storylines.awi.de

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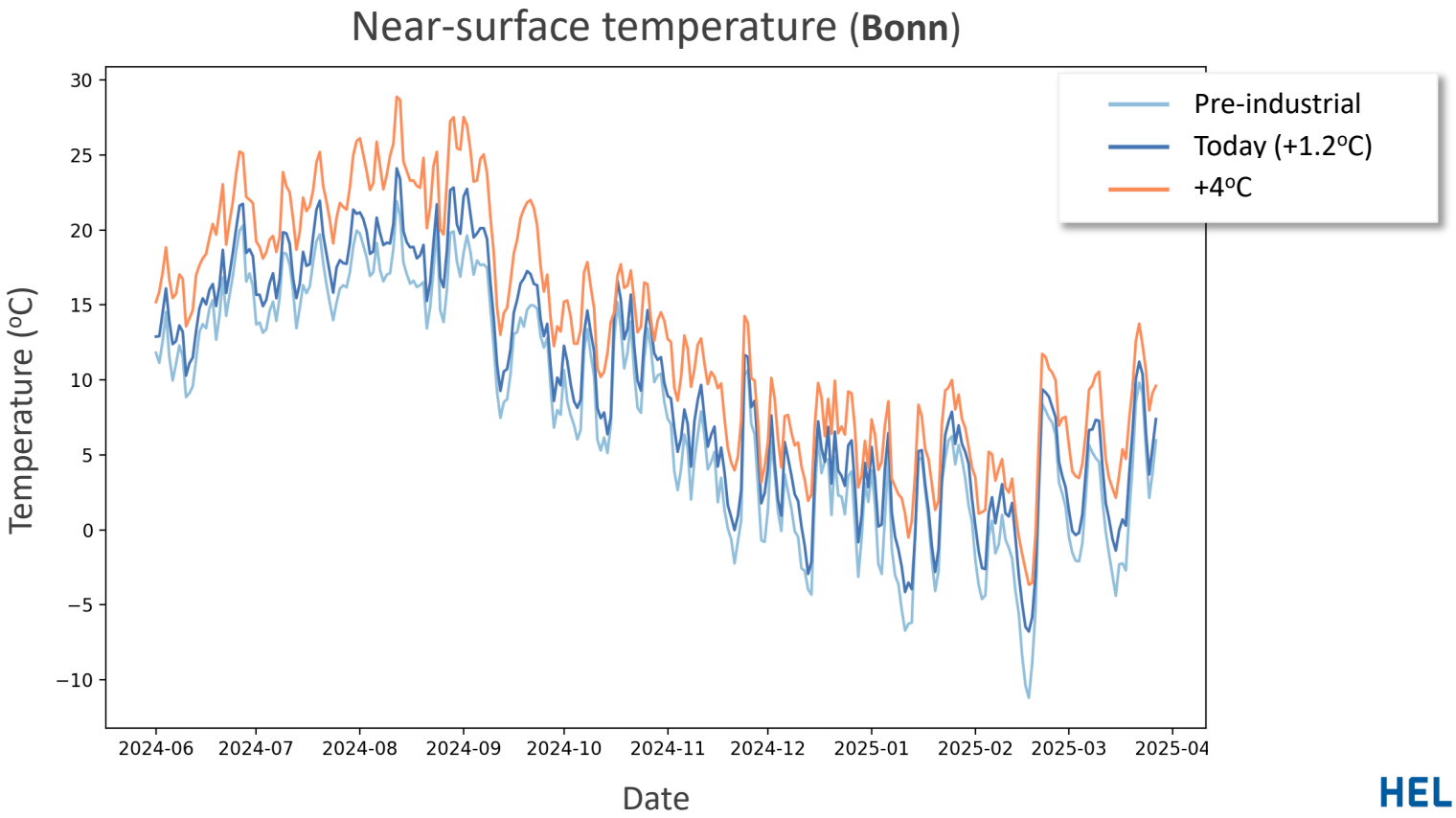
Impact of climate change in Bonn



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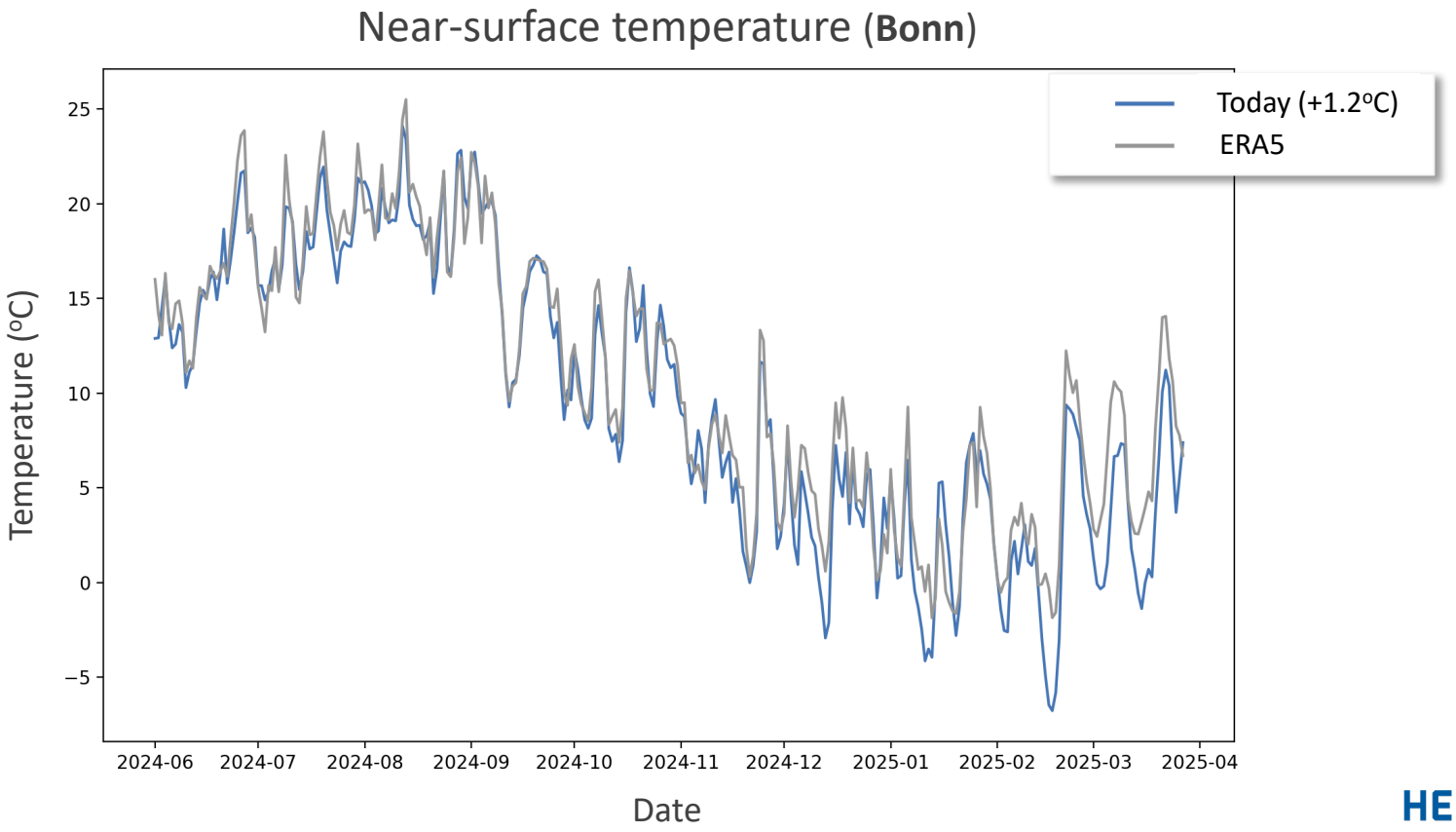
Temperature evolution in Bonn



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Marine heatwaves

communications earth & environment

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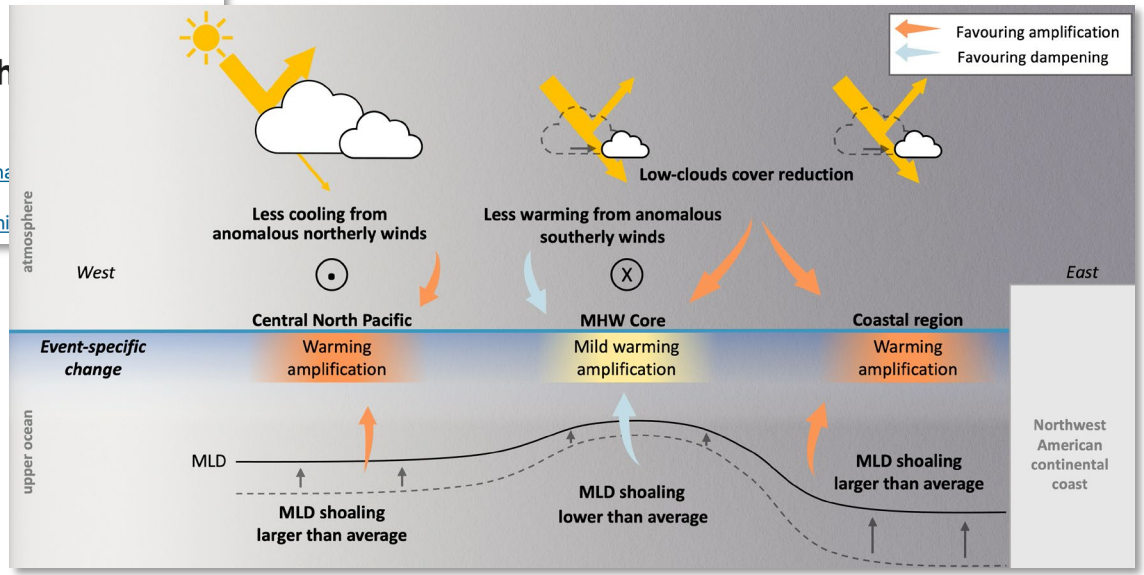
Article | Open access | Published: 26 January 2024

Projected amplification of summer marine h… a warming Northeast Pacific Ocean

Marylou Athanase ✉, Antonio Sánchez-Benítez, Helge F. Goessling, Felix Pitha…

Communications Earth & Environment **5**, Article number: 53 (2024) | Cite thi…



Athanase et al. (2024a)

Central European floods in September 2024

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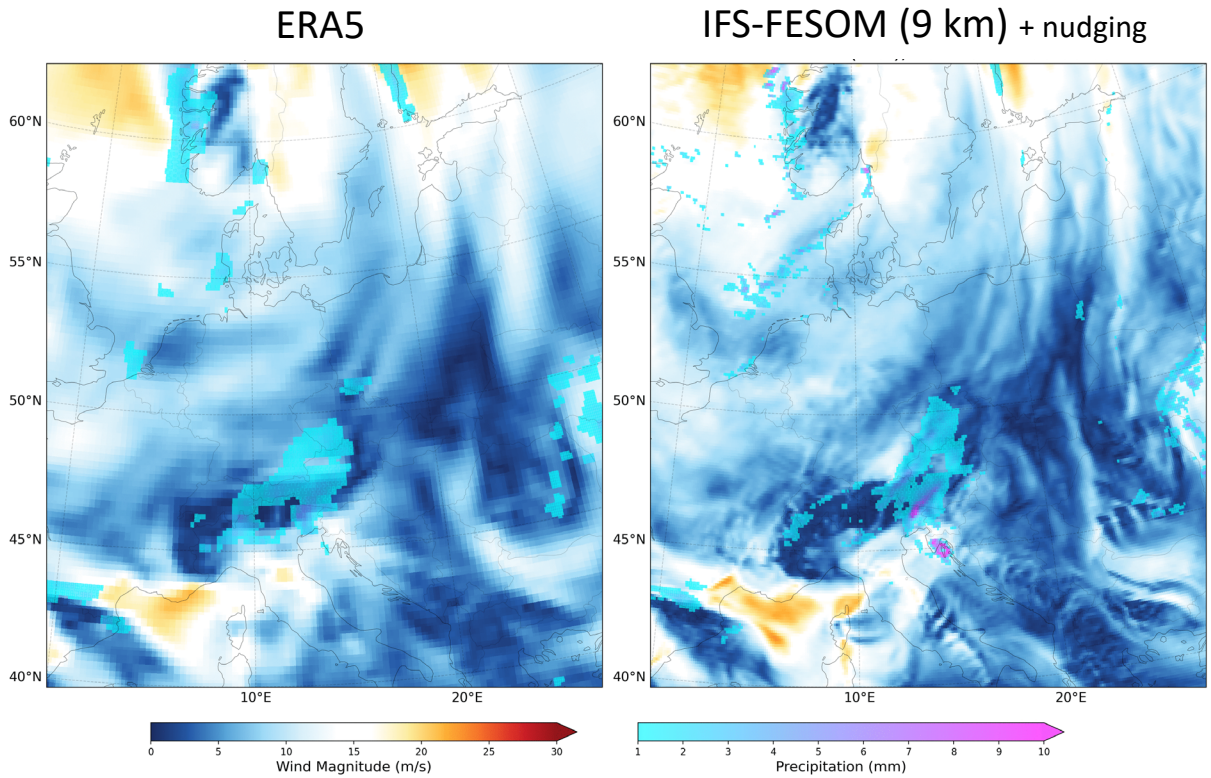
Central European floods in September 2024



John et al. (2025)

Destination Earth

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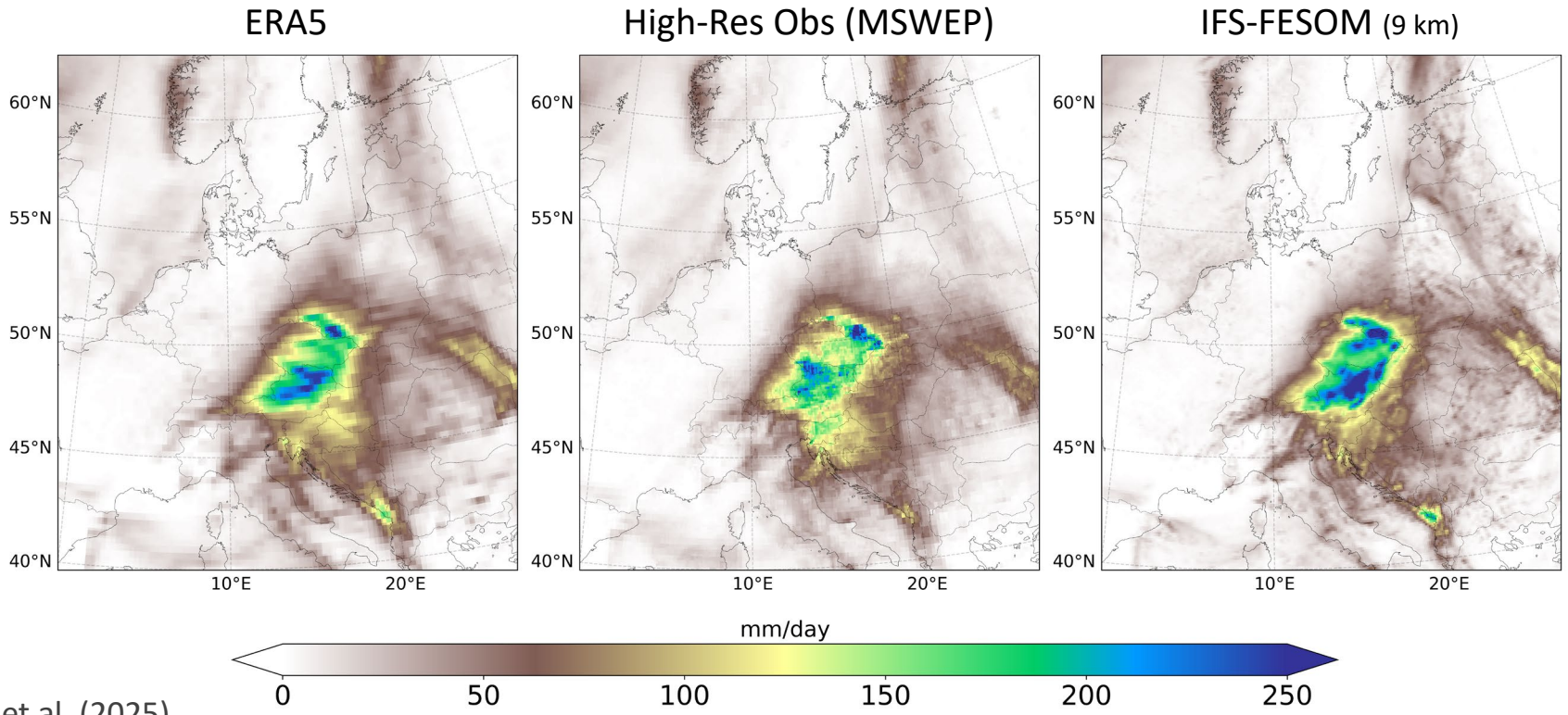
Central European floods in September 2024



Accumulated precipitation 12–16 September 2024

John et al. (2025)

Destination Earth

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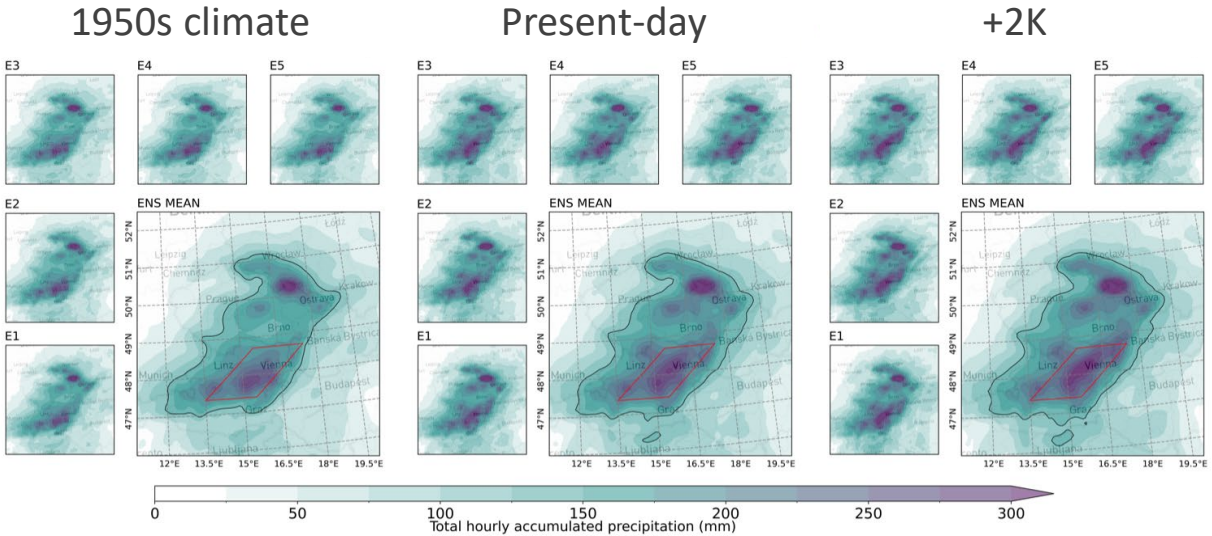
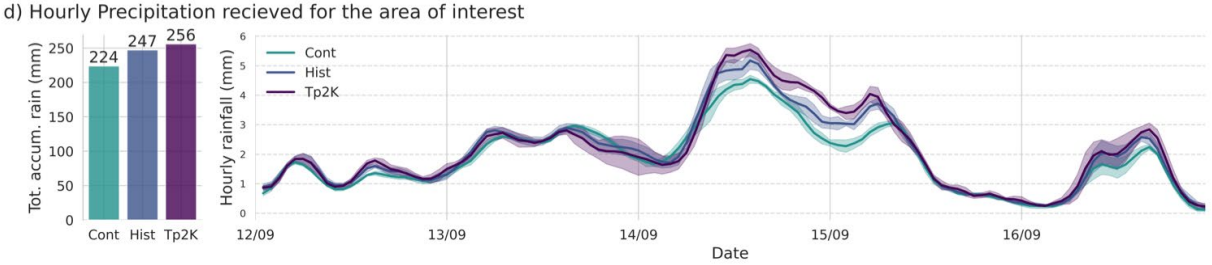
Central European floods in September 2024





John et al. (2025)

Destination Earth

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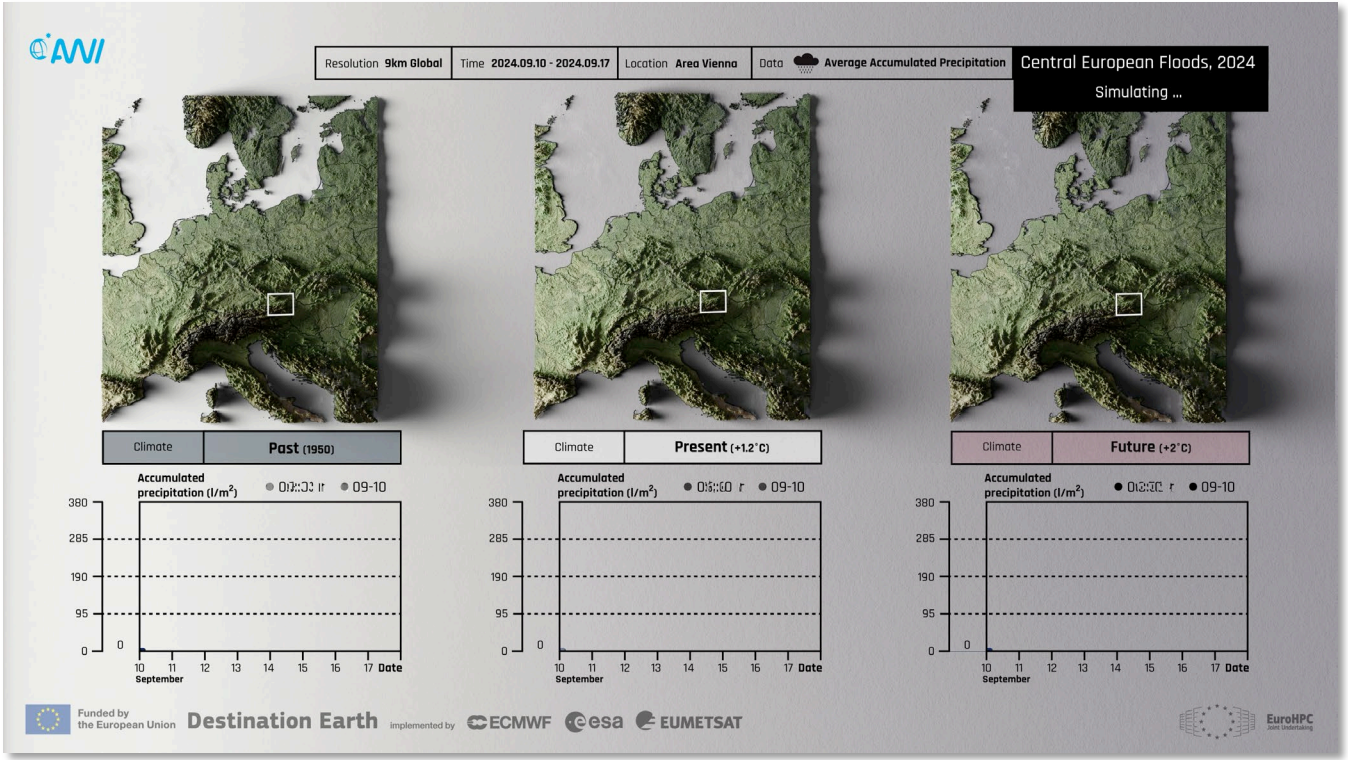
Central European floods in September 2024



Visual storytelling

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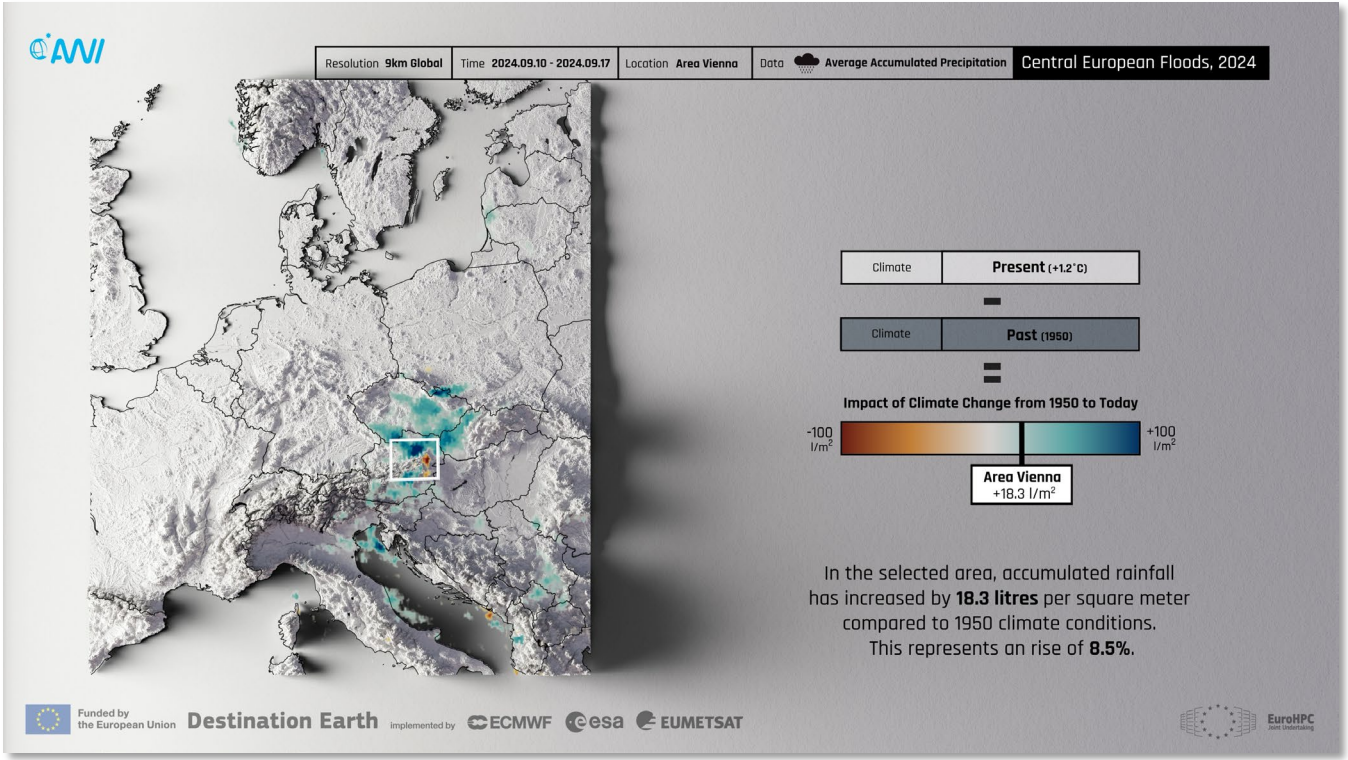
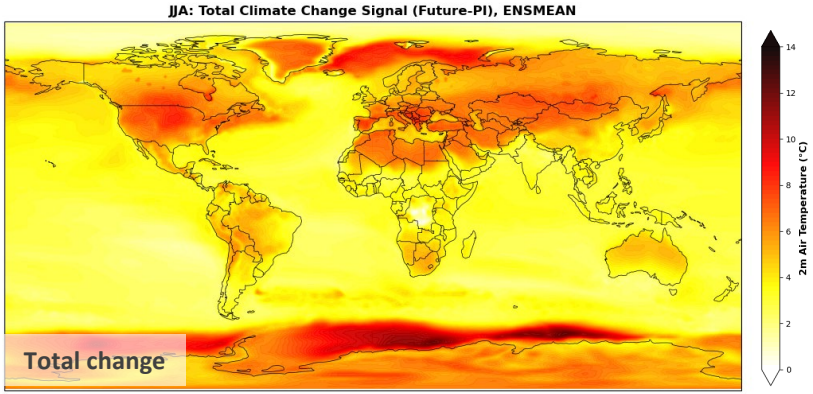
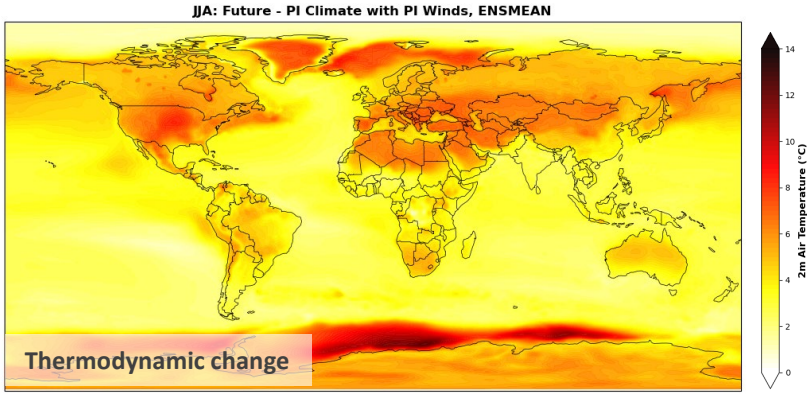
Central European floods in September 2024

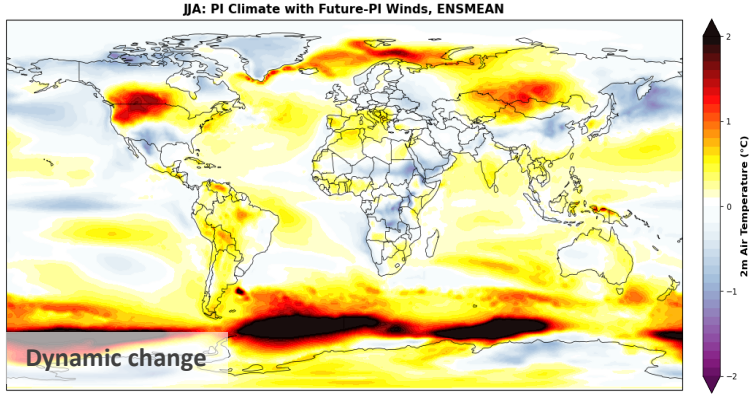


Visual storytelling

But is the jet stream not changing?







Average over 150-years of data

Montfort et al., in preparation

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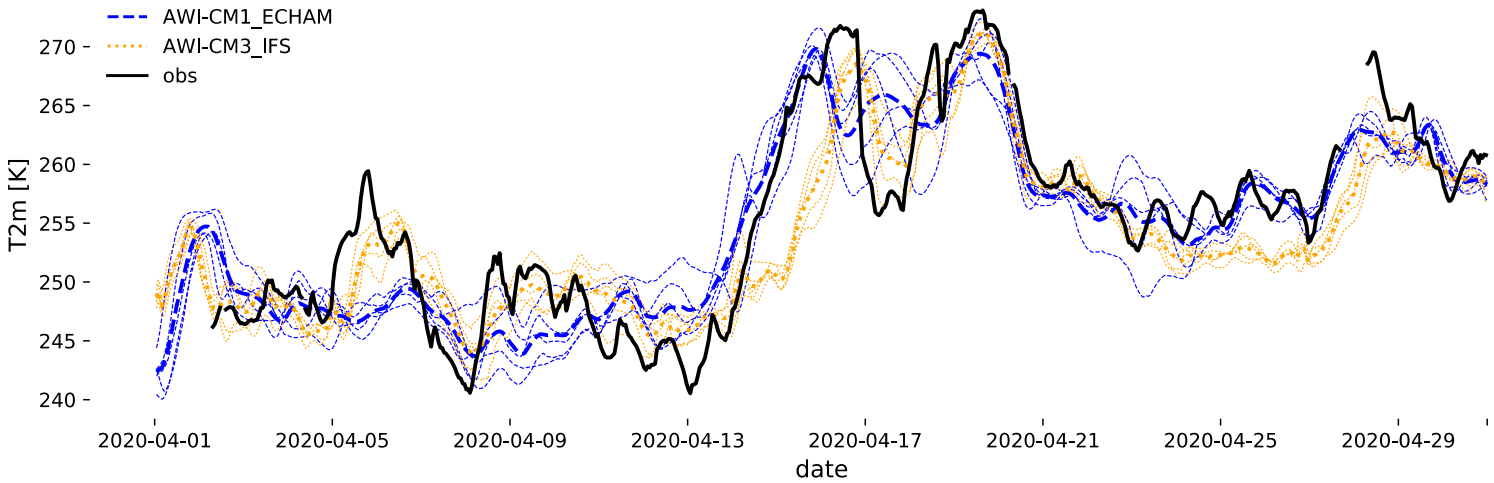
Other applications: Model error diagnosis

T2m at MOSAiC during a warm air intrusion in April 2020 (target observing period)



Pithan et al. (2023)

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Key points

- **Storylines provide a promising** (additional) **way of looking into the future**
  - Excellent analogues in space and time (”replaying works”)
  - Make climate change and its impact more tangible (“pictures of the future)
  - Separate thermodynamic from dynamic uncertainties
- **Other interesting applications**
  - Facilitates coupled climate model evaluation (field campaigns)
  - Understand the physics of climate change (e.g., marine heatwaves)
- **Some exciting ongoing developments** (Destination Earth)
  - Operationalisation, including realtime capabilities
  - Km-scale global configurations
  - End-to-end with impact models
  - AI-based versions