

Analyse von Extremereignissen in Europa unter Klimawandeleinfluss mittels großer Modellensembles und Deep Learning



Dr. Magdalena Mittermeier
Department für Geographie, LMU München

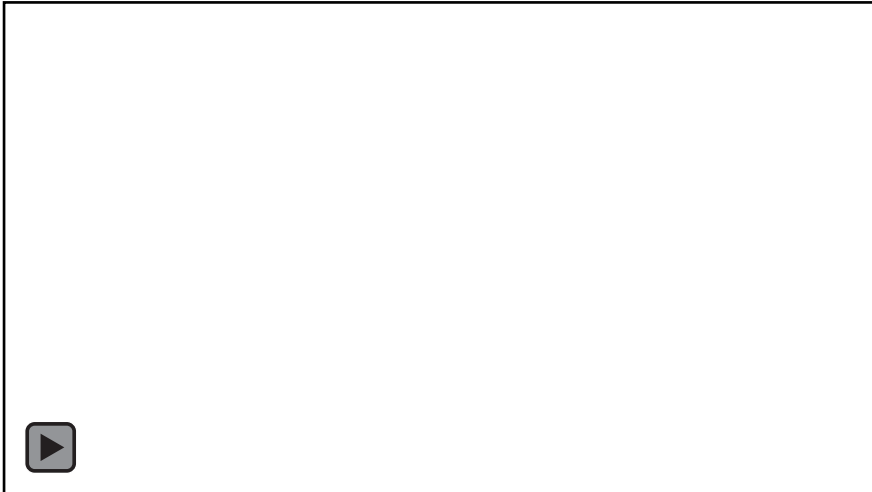
**Versicherungsmathematisches
Kolloquium der LMU München**

19.05.2025

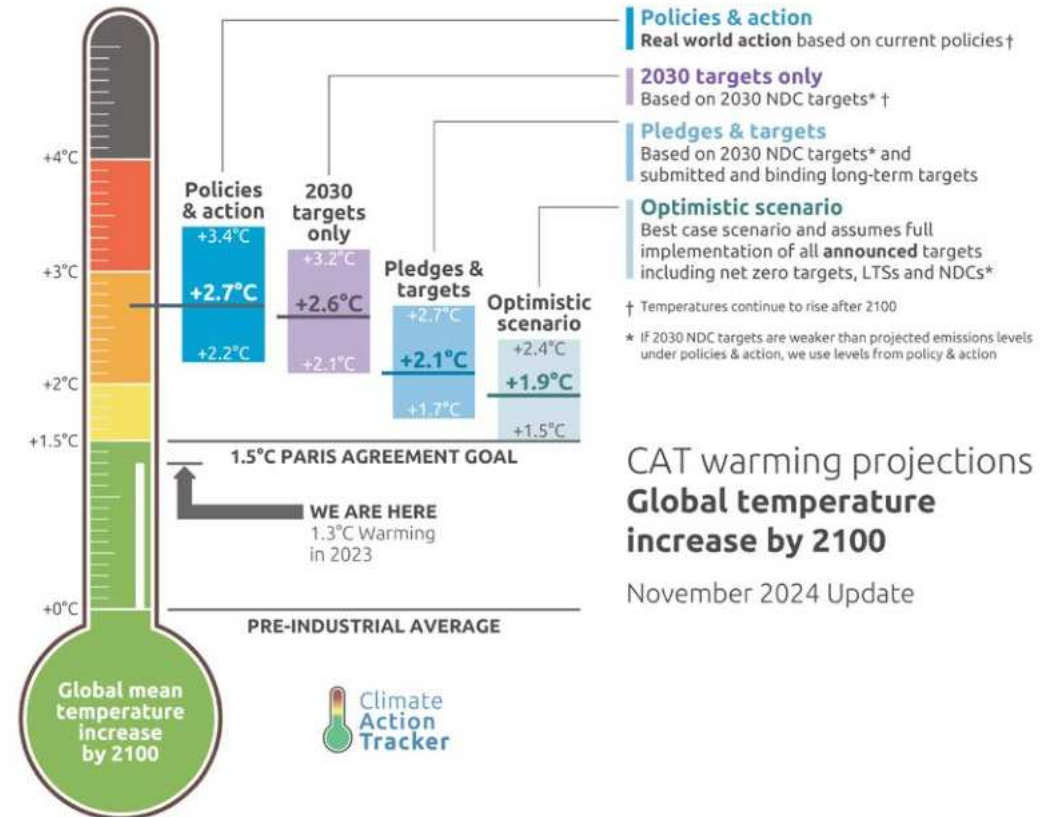


Support through climate modelling: understanding, mitigating, and adapting to climate change

Climate Model



Warming projections

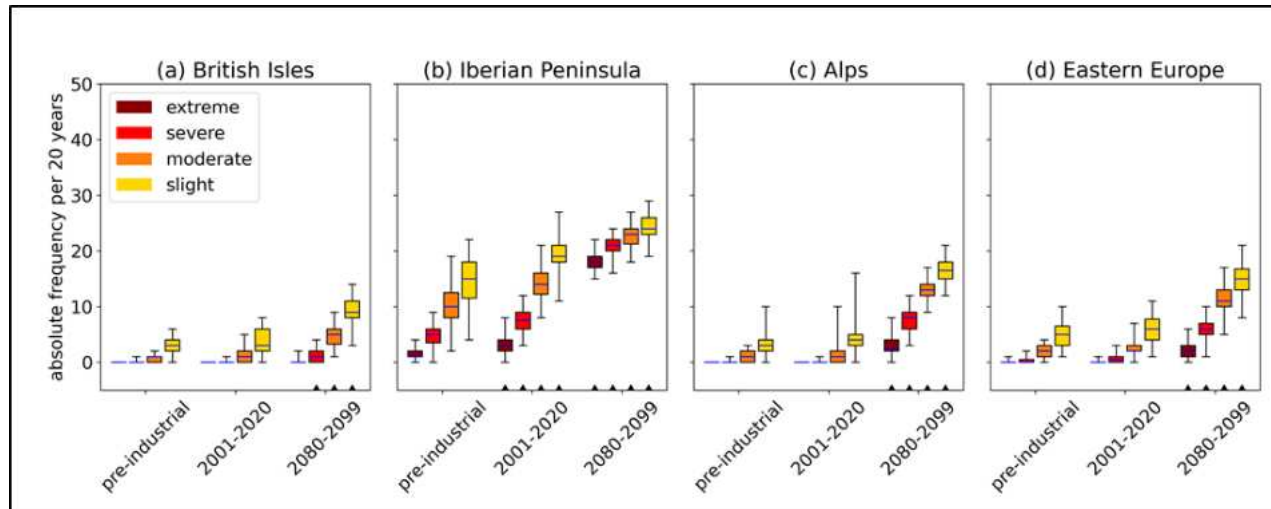


<https://climateactiontracker.org/global/cat-thermometer/>
https://climate.metoffice.cloud/current_warming.html

Support through climate modelling: understanding, mitigating, and adapting to climate change

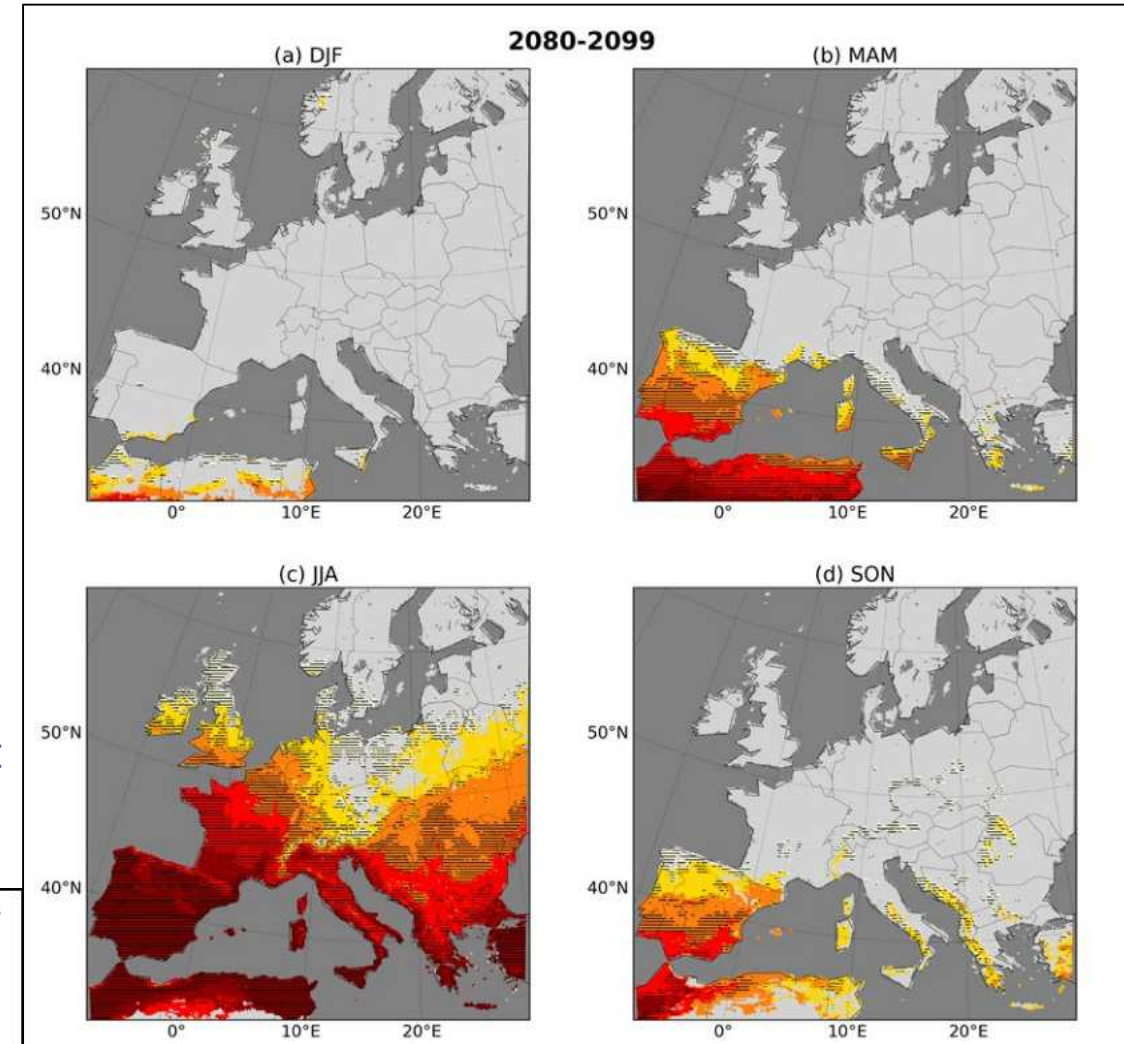
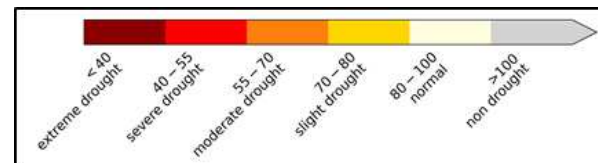
Percent of Normal Index (PNI) for selected European Regions

... in the Alps



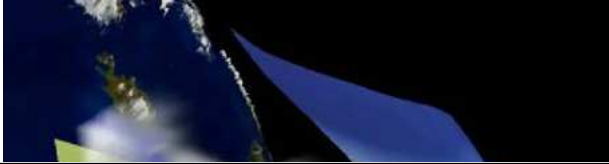
Frequency of drought events

Increase in the extreme drought risk in the Mediterranean region, but also...



Böhnisch, Mittermeier, Leduc & Ludwig, 2021, Frontiers in Water

Support through climate modelling: understanding, mitigating, and adapting to climate change



Flood: „Pfingsthochwasser“ in 1999



© Jens Weismüller.



Extreme Events – Floods and Droughts



© BBV

Major flood events in Bavaria
1999/2002/2005/2013/2016/2024



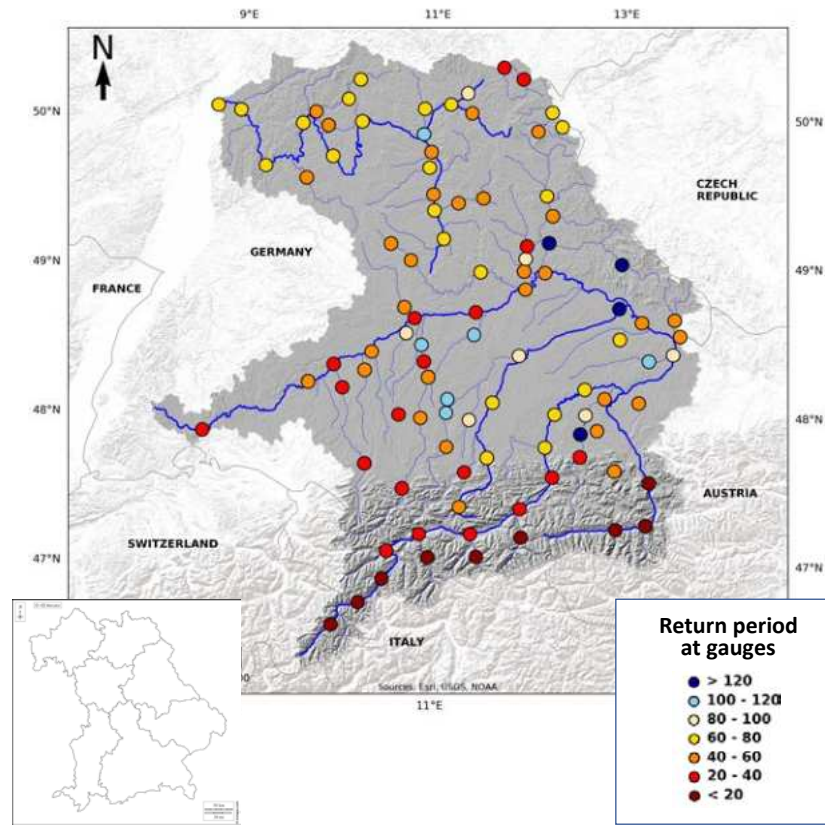
© picture-alliance/dpa

Major drought events in Bavaria
2003/2018/2019/2020/2022/2023

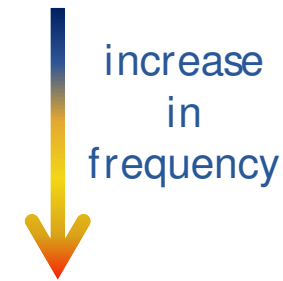
How does the occurrence of these extreme events change under global warming?

Support through climate modelling: understanding, mitigating, and adapting to climate change

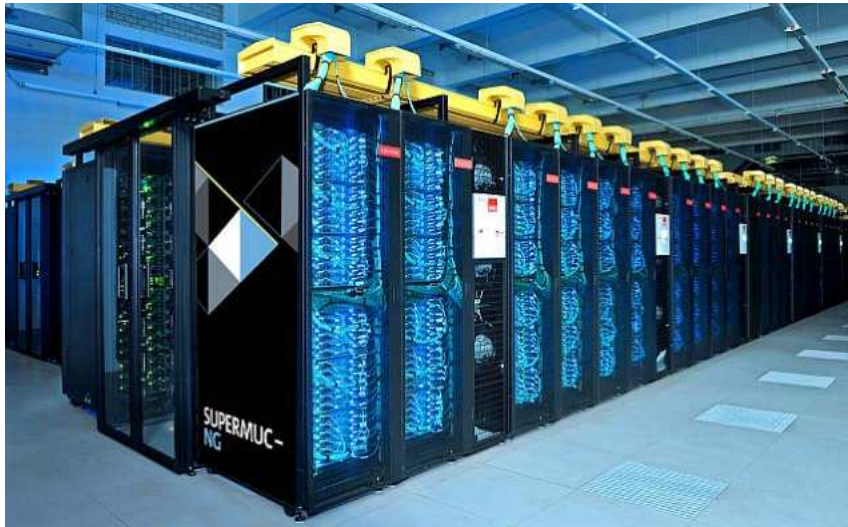
Changes in flood frequency (100-year flood)



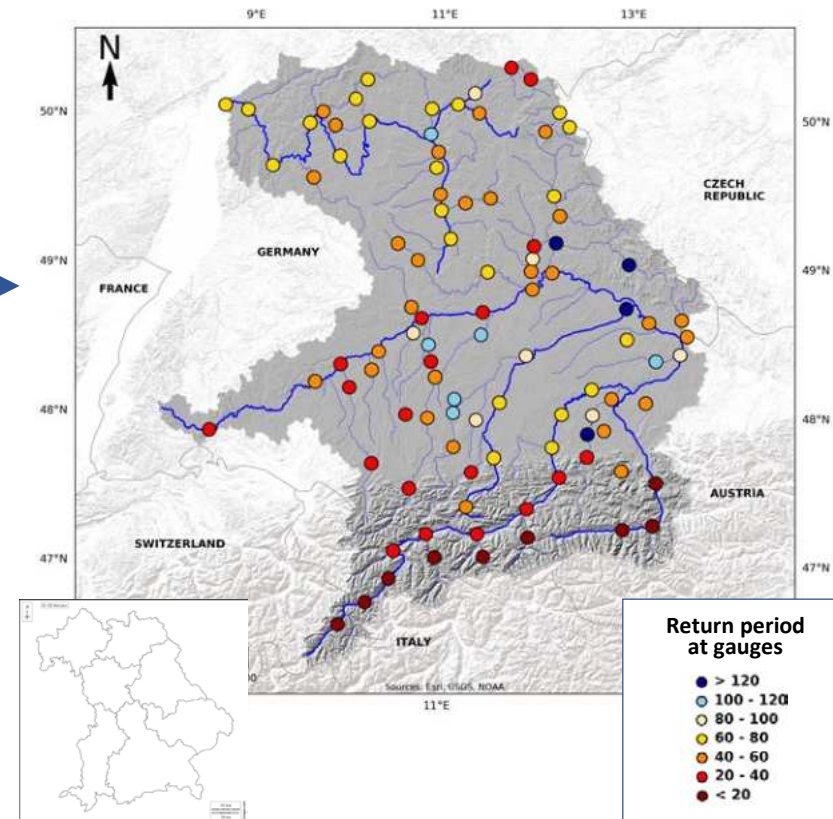
End-of-century
vs. past 30
years



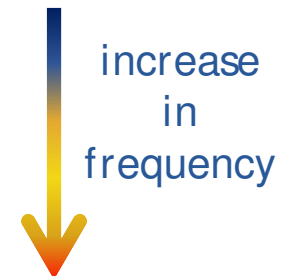
Supercomputing



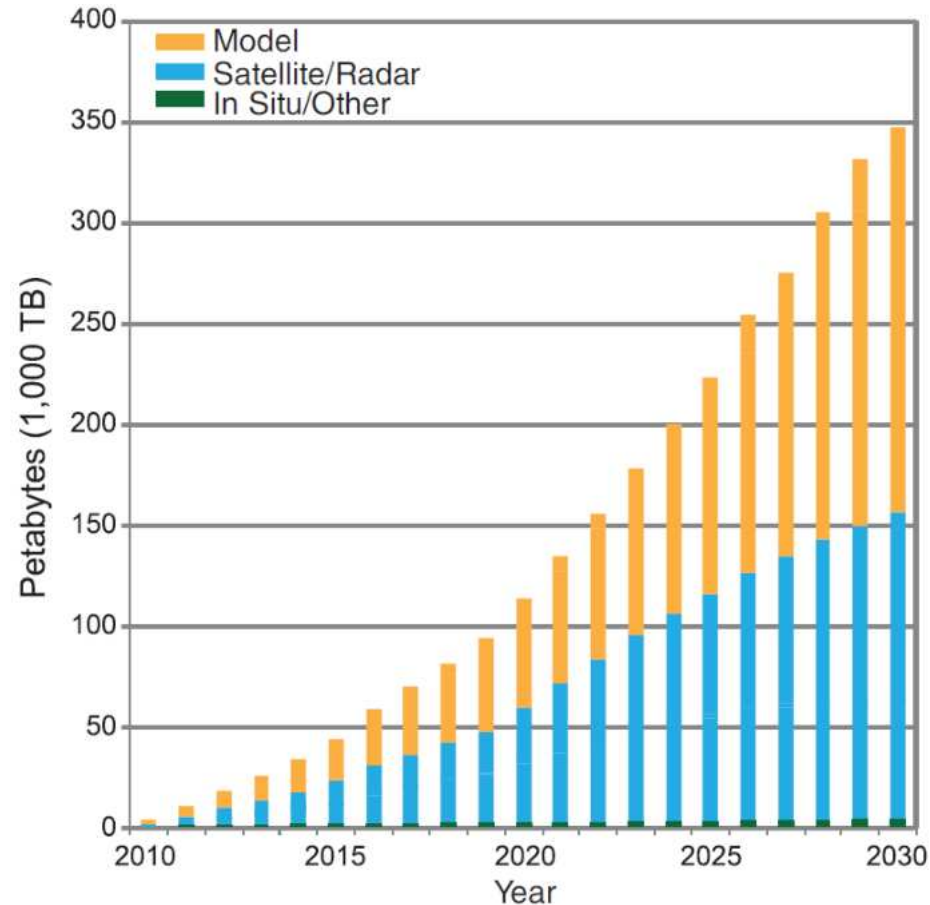
Changes in flood frequency (100-year flood)



End-of-century
vs. past 30
years



increase
in
frequency



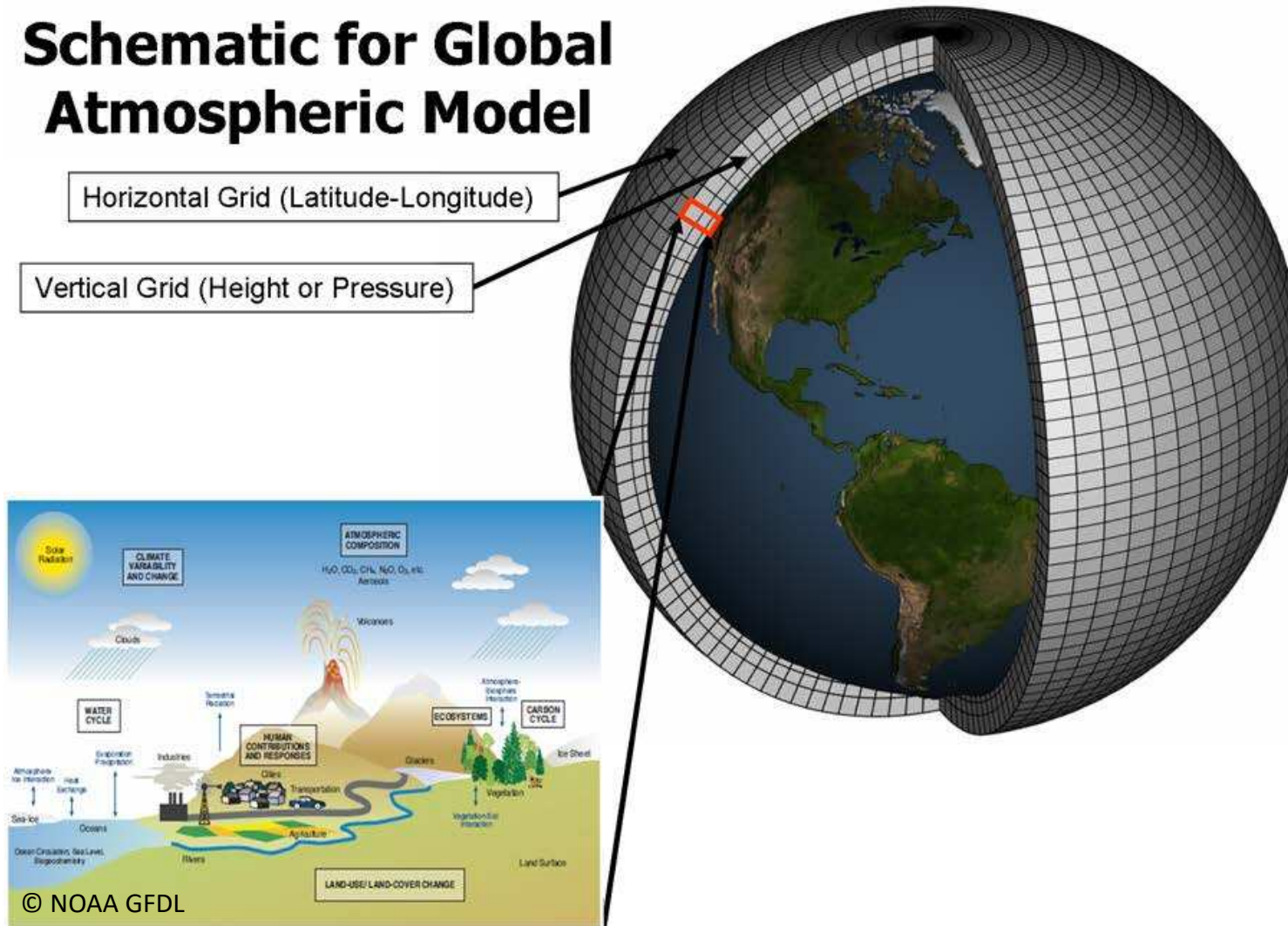
- *Explosion* in available climate data
- further increase in complexity, velocity and volume of climate data is to be expected

- **Climate Models:**
 - Resolution (spatial)
 - Ensemble techniques

Single Model Initial-Condition
Large Ensemble (SMILE)

Overpeck, Jonathan T.; Meehl, Gerald A.; Bony, Sandrine; Easterling, David R. (2011): Climate data challenges in the 21st century. In *Science (New York, N.Y.)* 331 (6018), pp. 700–702. DOI: 10.1126/science.1197869.

Schematic for Global Atmospheric Model



- Climate modeling is an extension of weather forecasting focusing on changes over decades
- Climate models use equations to represent the processes and interactions that drive Earth's climate
- Components: atmosphere, ocean, land surface, ice, carbon cycle etc.

A short history of climate models

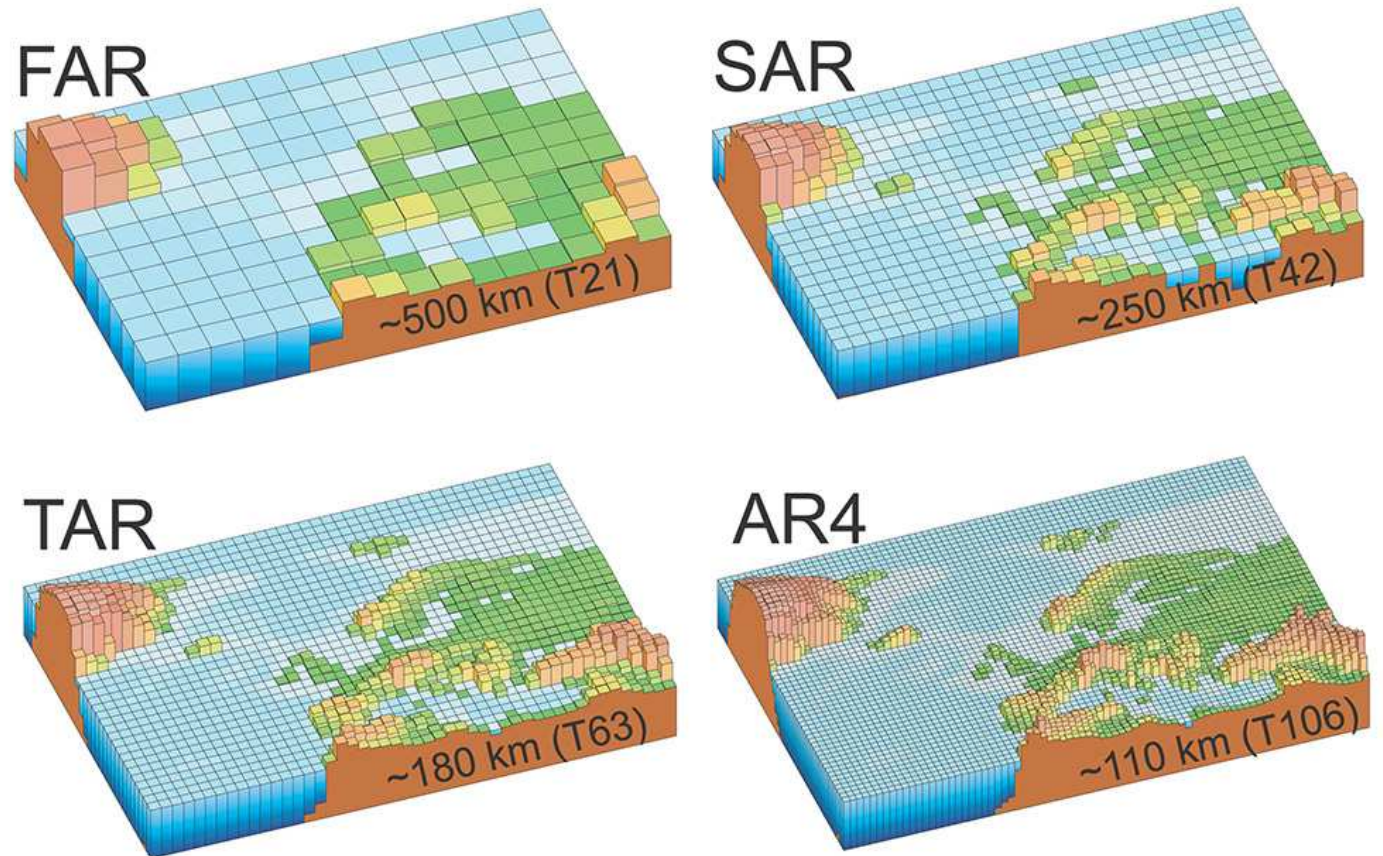
Complexity:

The World in Global Climate Models



© IPCC AR4, Fig. 1.2

Resolution:

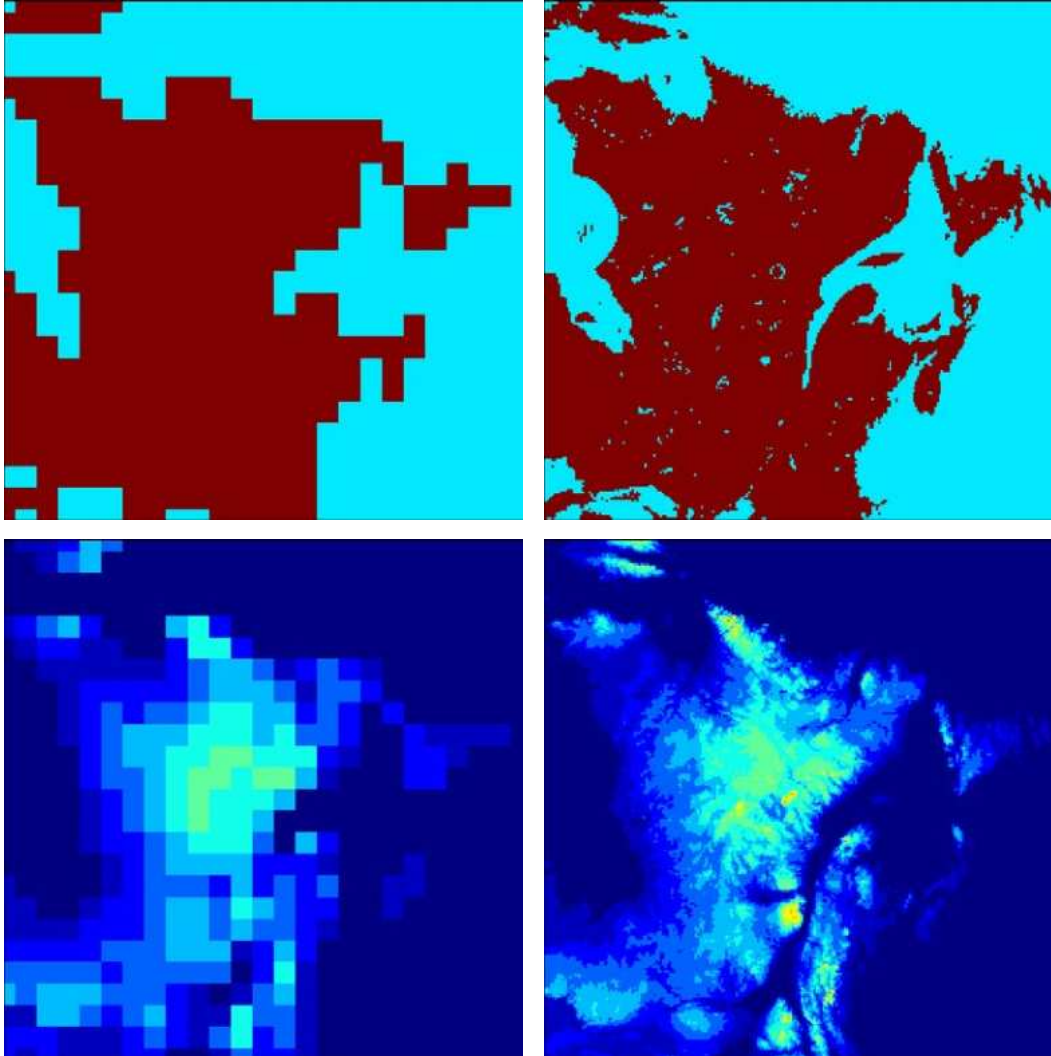


© IPCC AR4, Fig. 1.2

Effect of spatial resolution

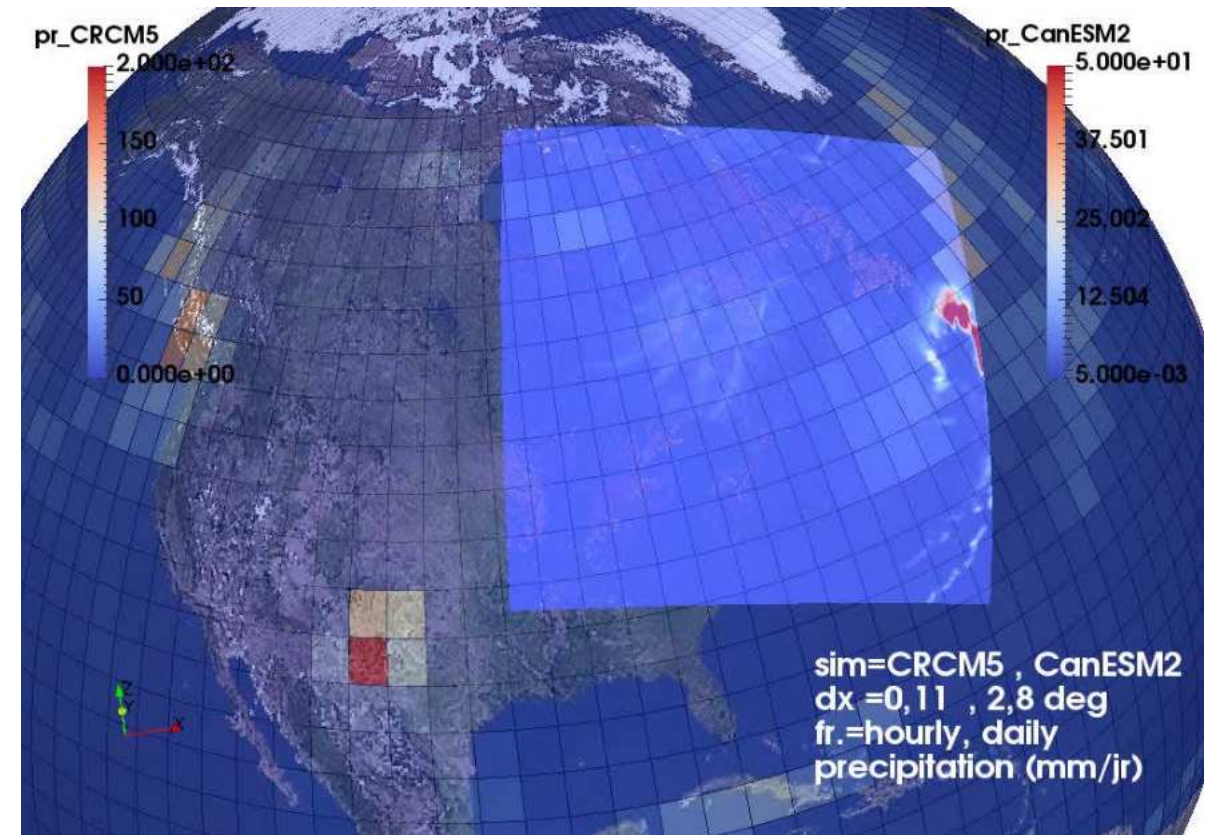
100 km

10 km

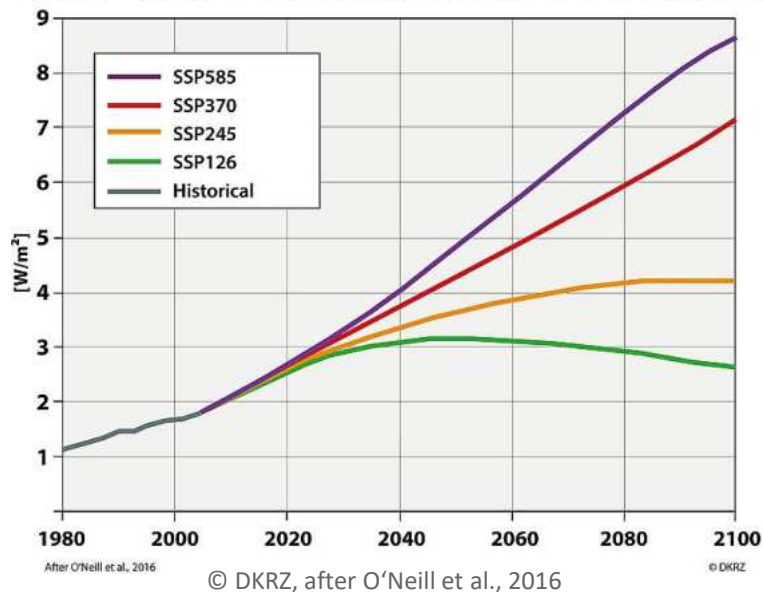


A regional climate model (~12 km) nested within
a global climate model (~112 km)

ClimEx



CMIP6 Scenarios - Anthropogenic Radiative Forcing [W/m^2]



Climate projections:
multi-model ensembles of
several different climate
models under different
scenarios of greenhouse
gas concentrations

1. External Forcing
(Scenario)

2. Model Response

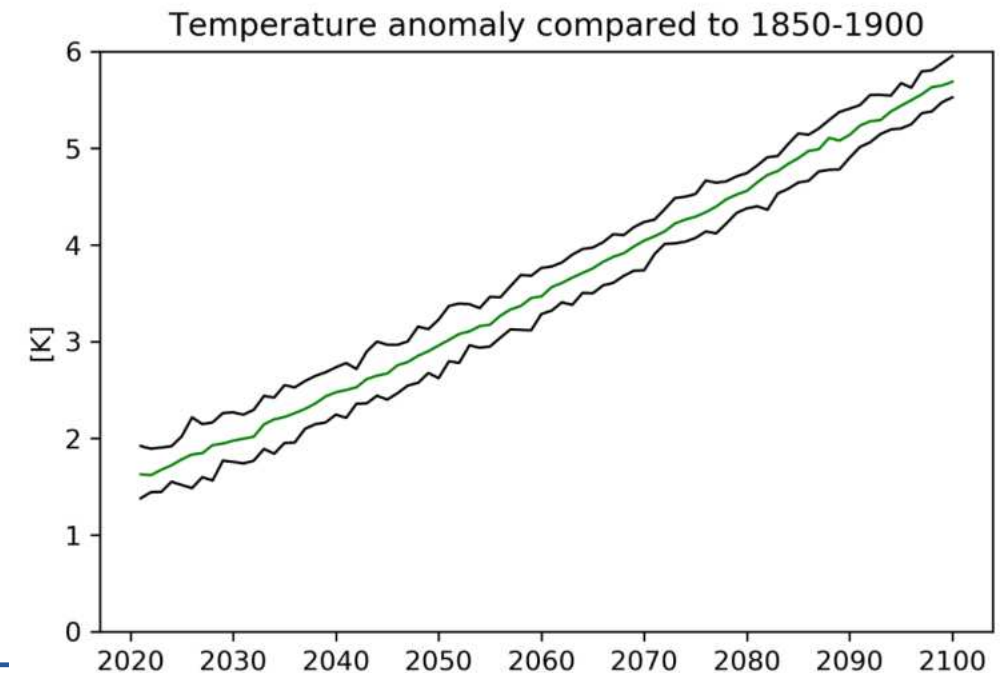
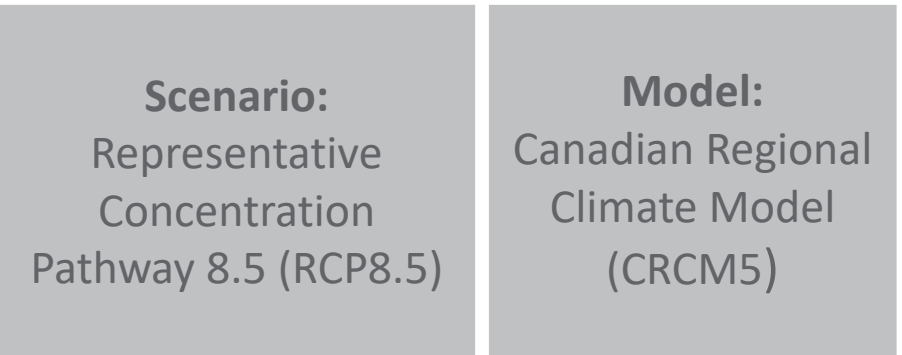
Single-Model Initial-Condition Large Ensembles (SMILEs)

- Same forcing and climate model
- Different initial conditions → fluctuations of natural climate variability

- Especially relevant for **extreme events**
- Large database of rare events (50 simulations, 1950-2100 → 7500 years of modelled climate)



Different
initial
conditions

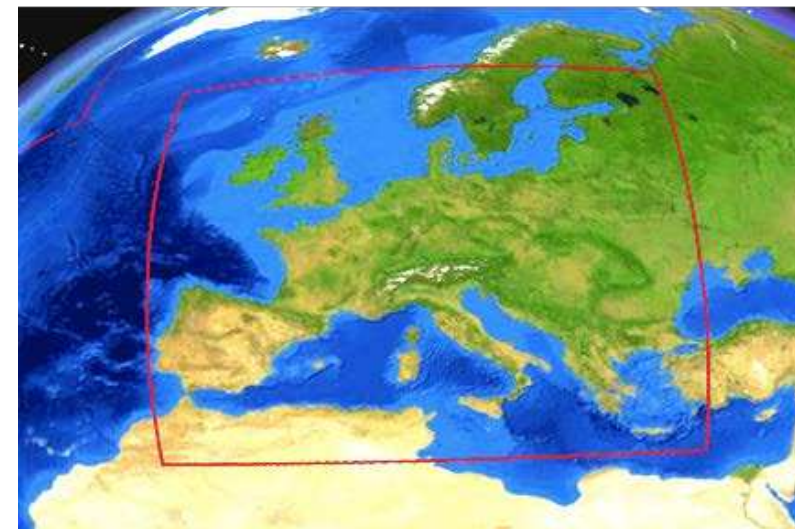


Challenge: Large Data Volumes

- Challenge: handling large volumes of climate data
- Example ClimEx-ensemble: 50 simulations, over two domains with 12 km resolution; total: ~ 500 TB



**Research
Question:**
Can deep neural
networks facilitate?



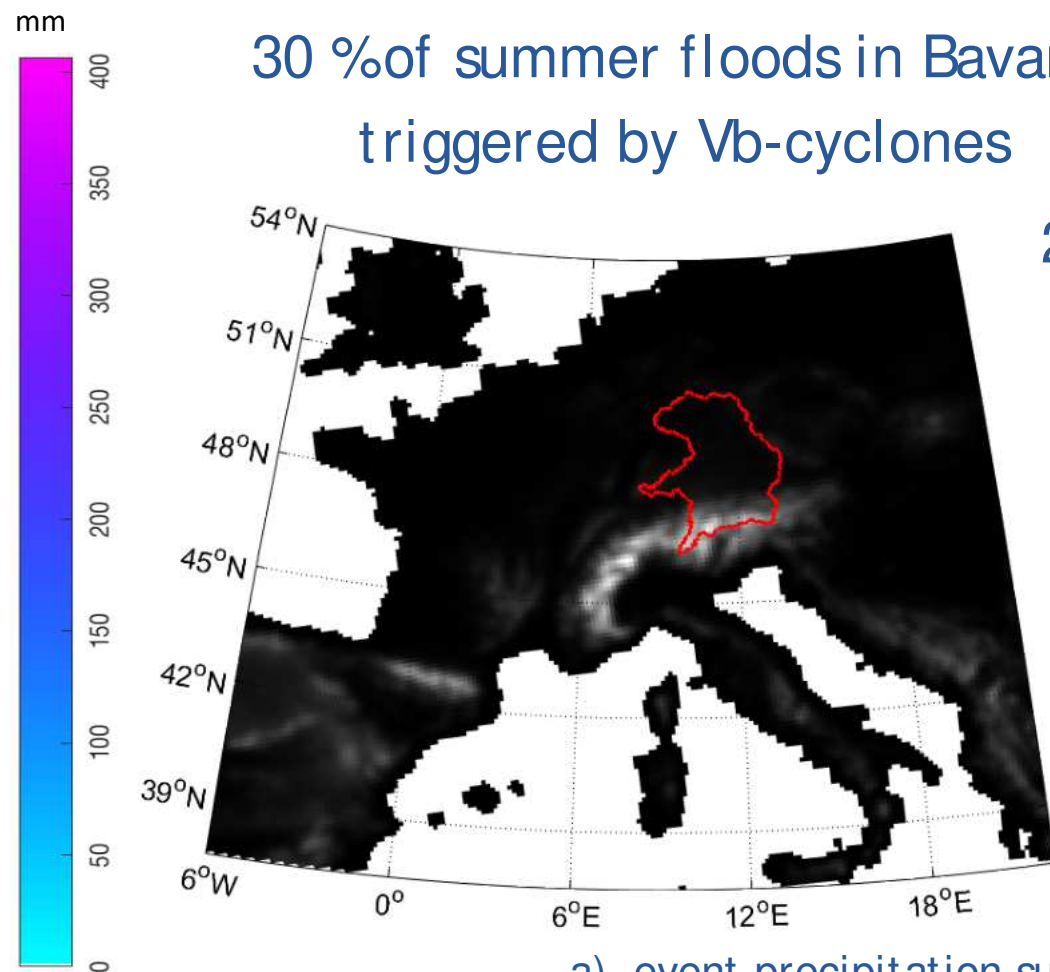
© ClimEx project



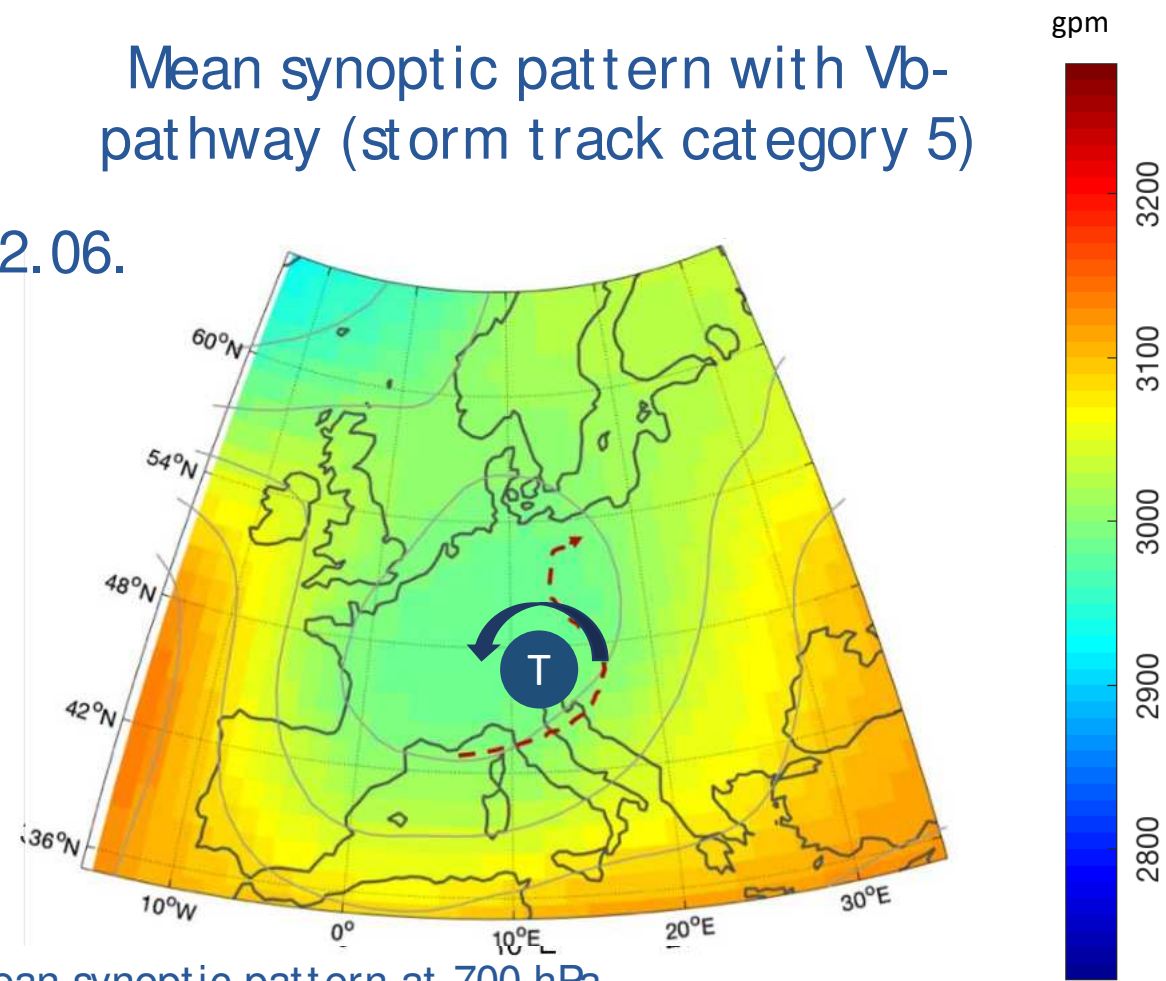
Typical Bavarian summer flood: Vb-Cyclones

30 % of summer floods in Bavaria triggered by Vb-cyclones

Mean synoptic pattern with Vb-pathway (storm track category 5)

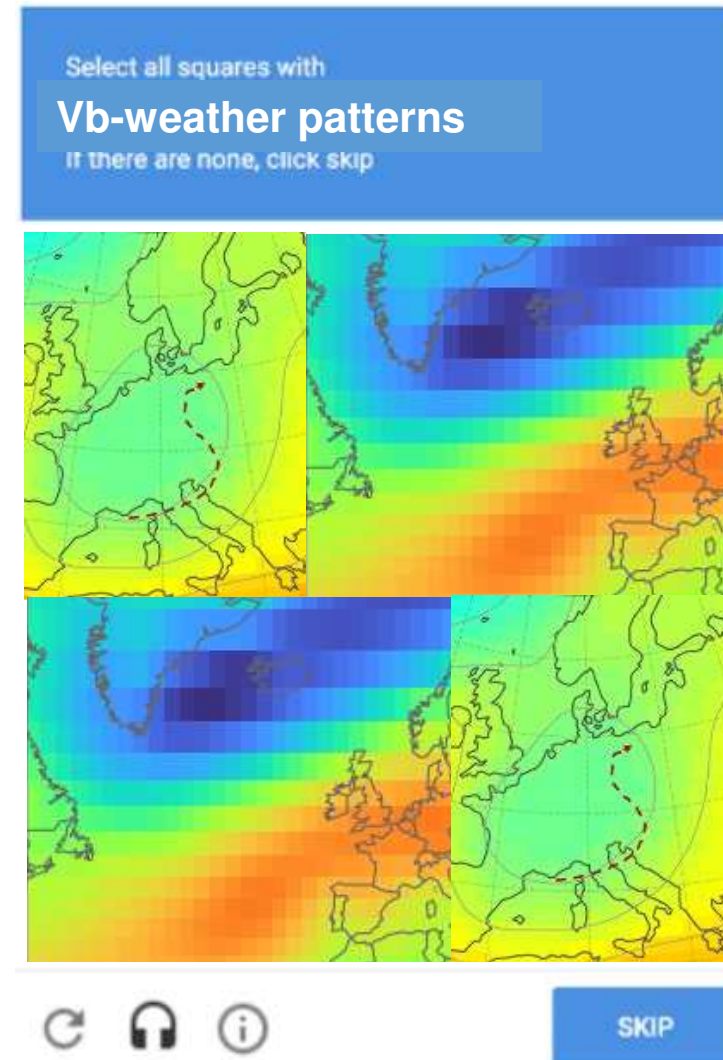
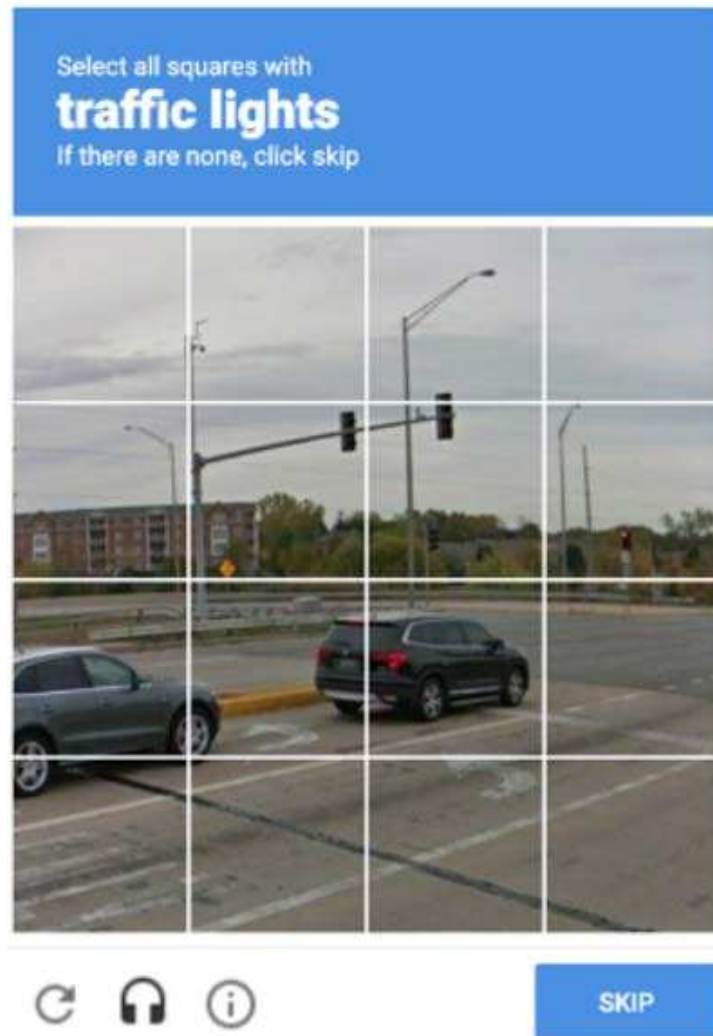


29.05. – 02.06.
2013



a) event precipitation sum and b) mean synoptic pattern at 700 hPa during the 2013 flood (JRA-55 reanalysis data)

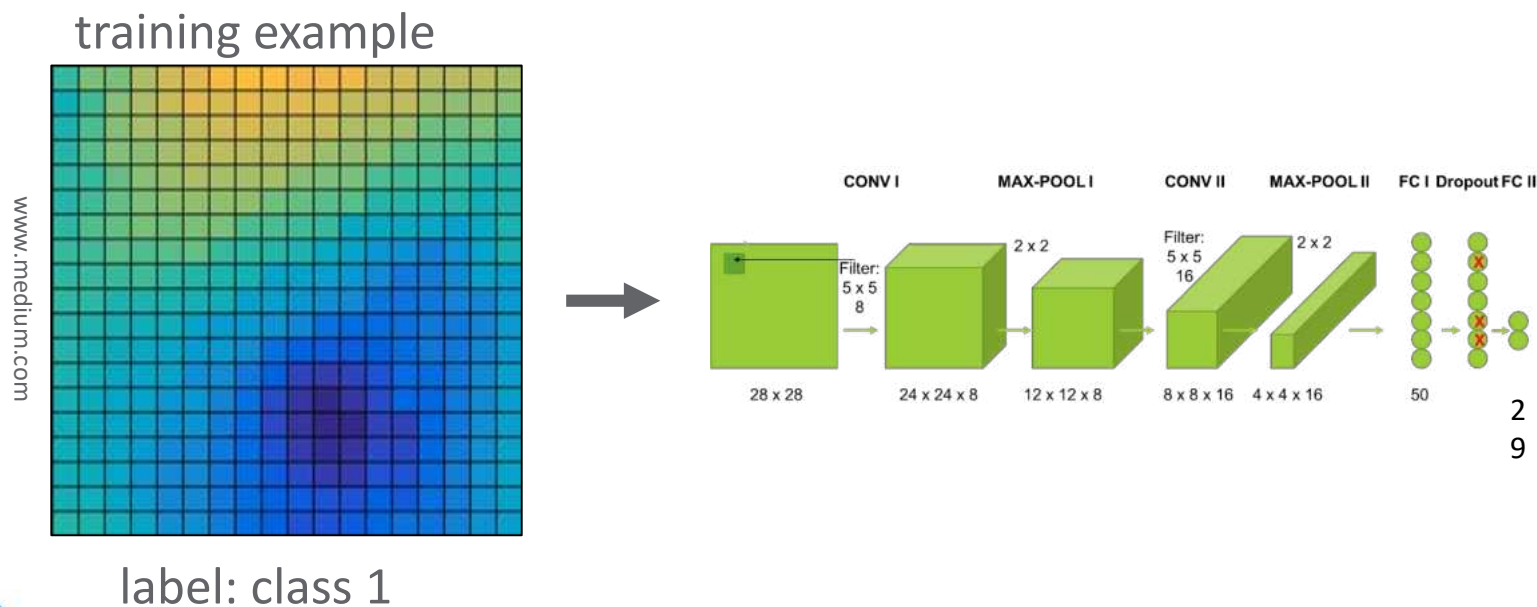
Deep Learning for weather pattern recognition



Deep Learning for weather pattern recognition

Neural Networks

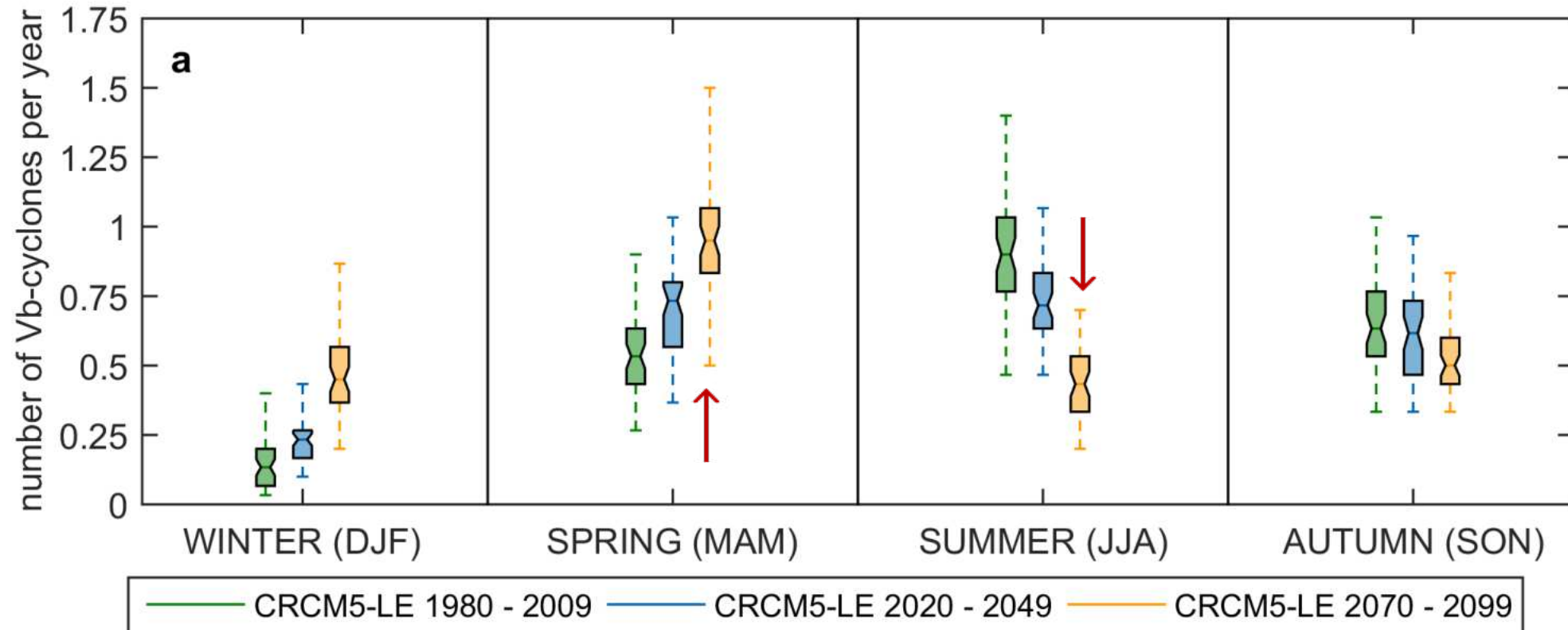
- Detection and classification of atmospheric circulation patterns
- Training set: historic events in reanalysis data + catalog of storm tracks (labels)



Research Concept:

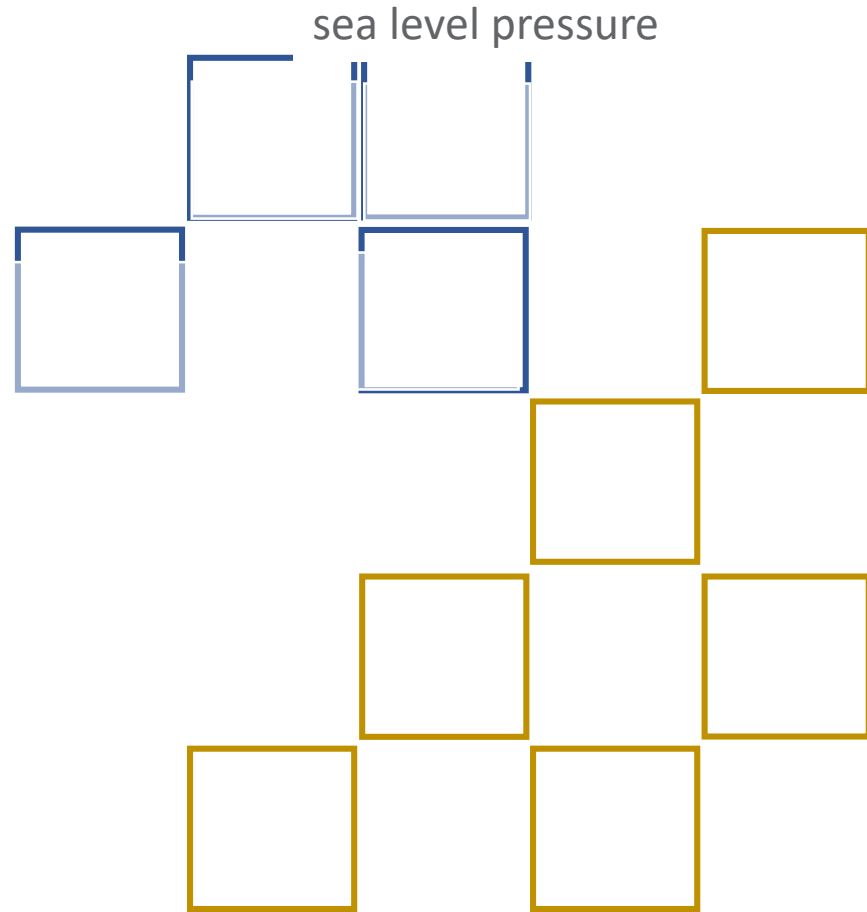
1. Training a neural network on the classification of atmospheric drivers of extreme events
2. Applying the trained network to climate model data
3. Efficiently analyzing large data volumes
→ climate change study

Shifting seasonality with climate change



Mittermeier, et al. (2019), *Geophysical Research Letters*

Drought and flood relevant weather patterns



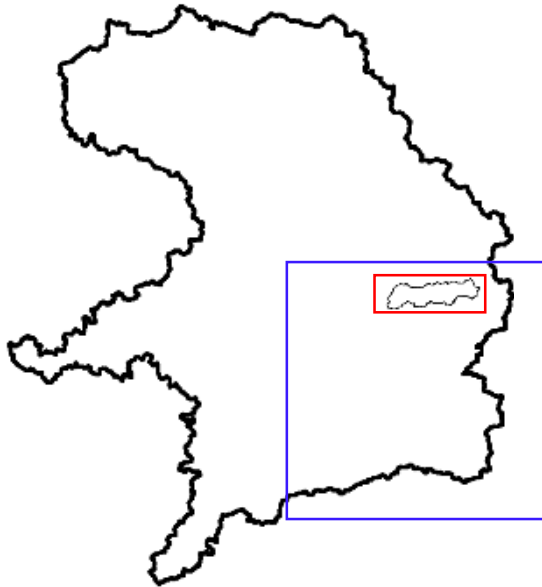
- 29 circulation types over Europe called „Großwetterlagen“
- One of the most established classification schemes in Europe (manual/subjective)
- Studies on the relationship between atmospheric circulation and extreme events (atmospheric driver)

- Favoring conditions for heat and drought in Central Europe
- Conditions associated with winter floods in Germany

Automatization for application to climate models ensembles

Welche Prozesse können zu Extremhochwasser führen? – compound events

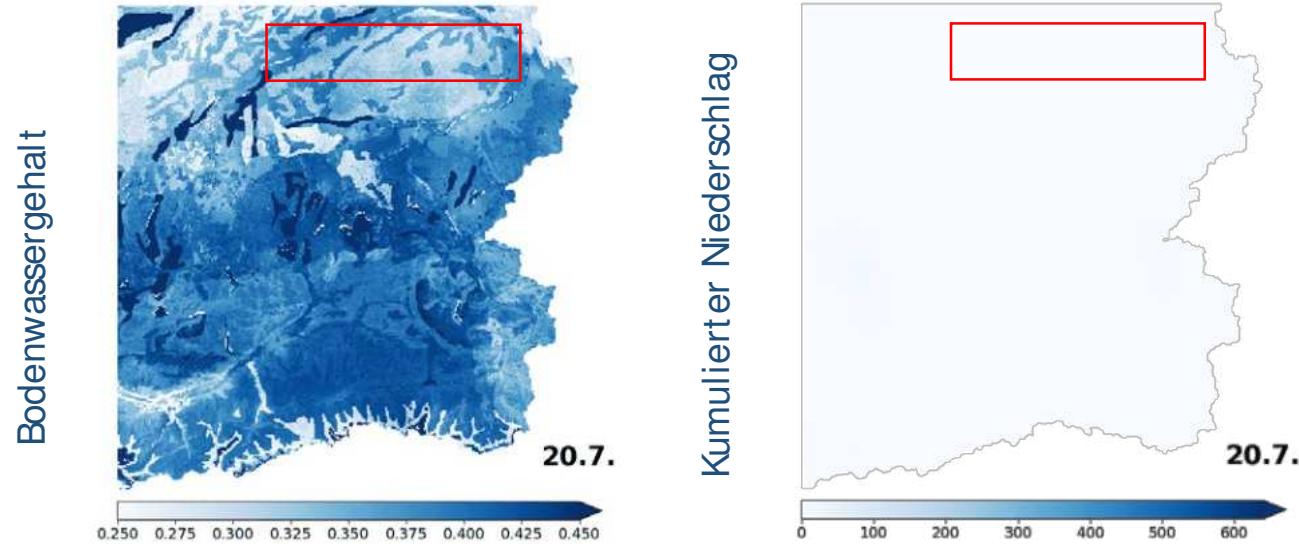
Beispiel für ein
“Compound event”



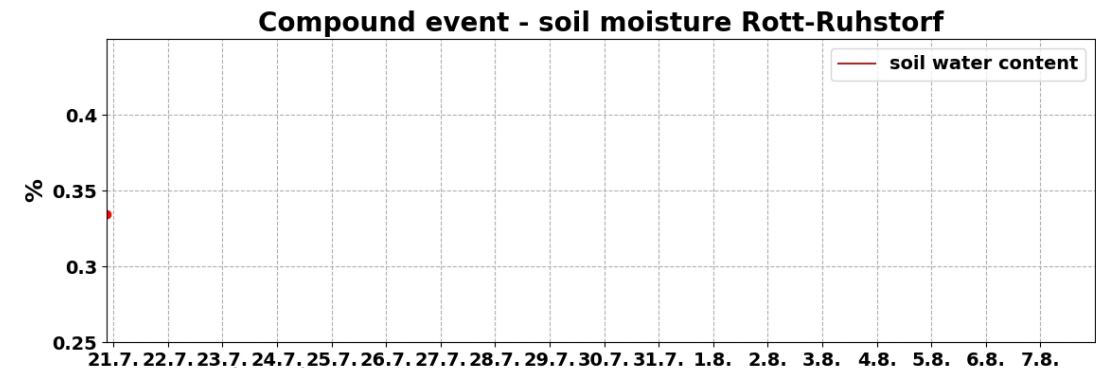
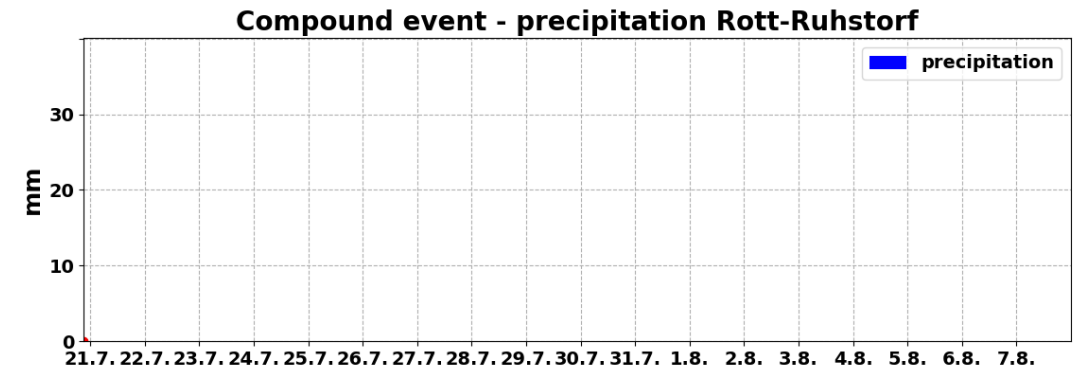
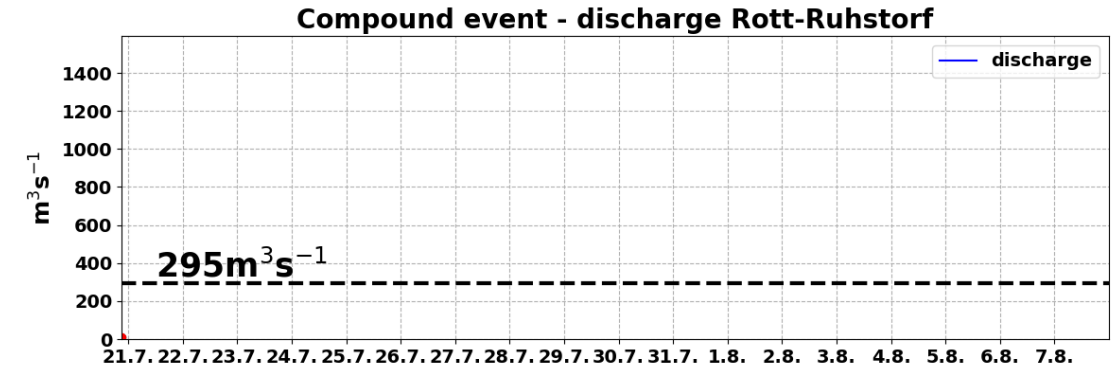
Einzugsgebiet
Rott - Ruhstorf

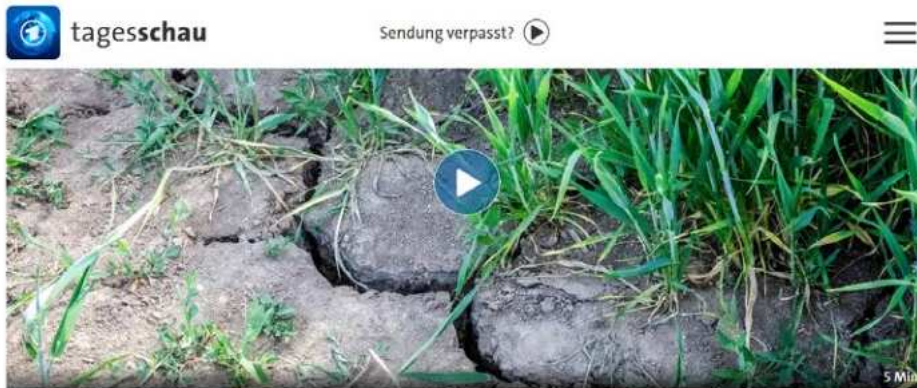
Compound Extremes

Welche Prozesse können zu Extremhochwasser führen? – compound events



Willkofer, F., Wood, R. R., & Ludwig, R. (2024). Assessing the impact of climate change on high return levels of peak flows in Bavaria applying the CRCM5 large ensemble. *Hydrology and Earth System Sciences*, 28(13), 2969-2989.





Aktuelle Großwetterlage

Warum es gerade so wenig regnet

Stand: 17.05.2025 10:47 Uhr

Das Frühjahr war bislang zu trocken. Das liegt unter anderem an der aktuellen Großwetterlage. Und die wird sich auch in den kommenden Tagen wenig verändern. Eine Vorhersage für den Sommer ist aber kaum möglich.



Von Tim Staeger, ARD-Wetterkompetenzzentrum

Frankfurter Rundschau

Startseite > Panorama

Brenzliges Wetterphänomen über Deutschland – aktuelle Lage ist laut Meteorologe „besonders kritisch“

05.04.2025, 04:41 Uhr

Von: [Dominik Jung](#)



Wetter in Europa steht still! Meteorologe erklärt besondere Lage

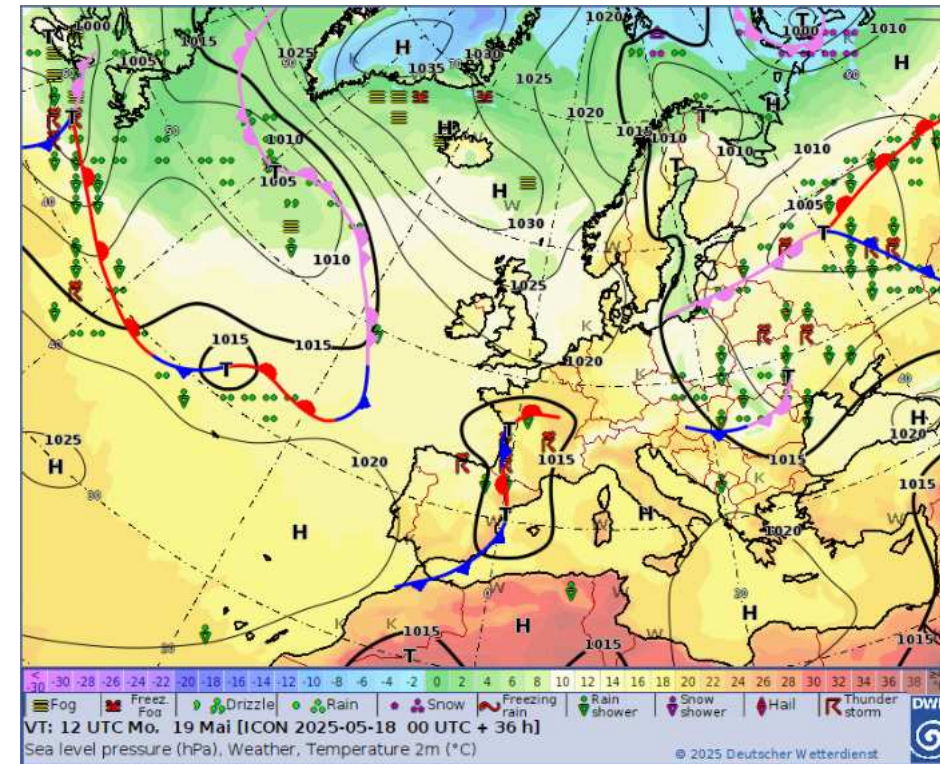
Während in Deutschland extreme Trockenheit herrscht, kämpfen die typischen Urlaubsregionen am Mittelmeer mit heftigen Regenfällen. Untypische Wetterverteilung in Europa oder die neue Normalität? Der Klimawandel und der Jetstream spielen dabei eine große Rolle. Warum die Wetterlage in Europa im Frühjahr 2025 so festgefahren ist, erfährst du im Video von unserem Meteorologen Gernot Schütz.

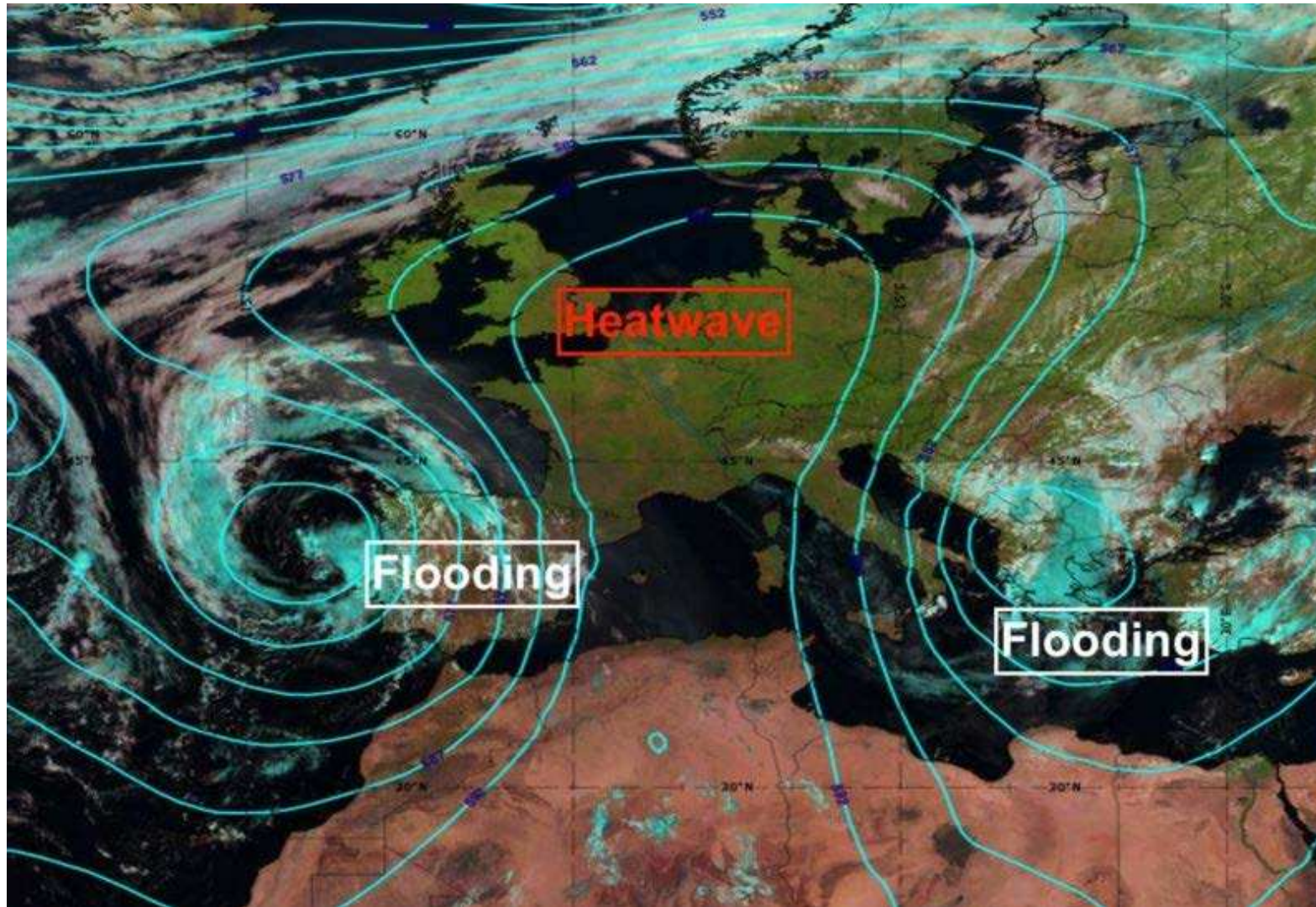
Veröffentlicht: Mi 14.05.2025 | Laufzeit: 02:17 min



- Seit März durchschnittlich ca. 60 mm Niederschlag (statt ca. 200 mm)
- Grund: blockierende Wetterlage

19.05.2025 | VBZ Offenbach

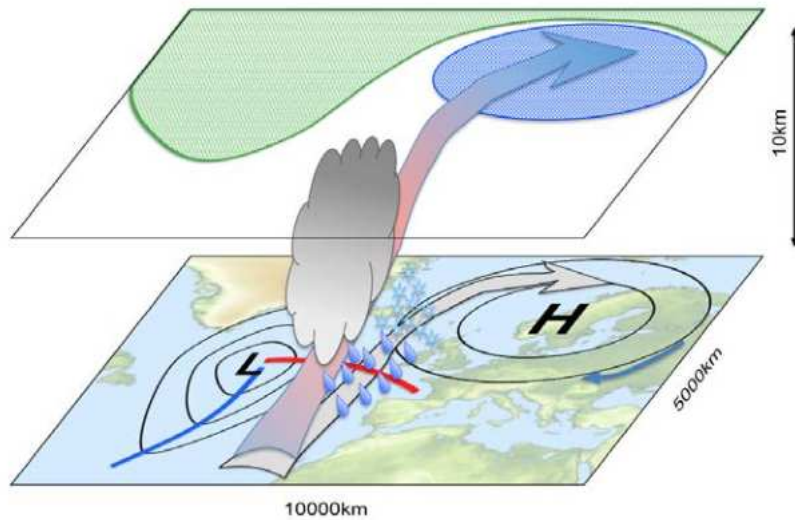




© Mika Ratanen

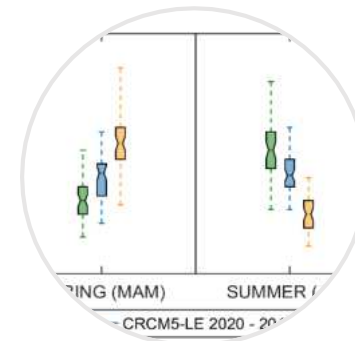
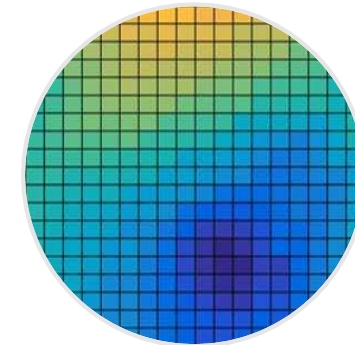
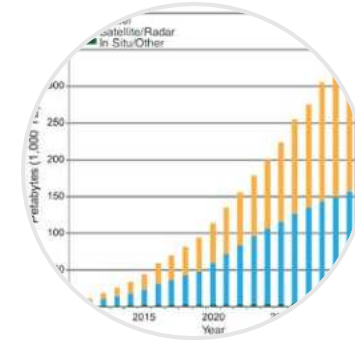
- Blockierende Wetterlage mit dem Muster des griechischen Buchstaben Ω
- Räumlich kombinierte Wetterextreme („spatially compound extremes“) über Europa
- Werden extreme Wetterereignisse mit dem Klimawandel nicht nur häufiger, sondern treten sie auch häufiger kombiniert auf? Verstärken sie sich gegenseitig?

Theory for formation of blocking high pressure systems



© DWD, Christian Grams (KIT)

- Big data in climate sciences: high-volume mainly through high resolution and large ensembles of climate model simulations
- Deep neural networks for weather pattern recognition: atmospheric drivers of extreme events
- Climate change studies: how does anthropogenic climate change influence the frequency and seasonality of event occurrence? Shift in seasonality of Vb-cyclones



Ergebnisse für **München** · [Region auswählen](#) ⋮

 **21** °C | °F
Niederschlag: 0%
Luftfeuchte: 28%
Wind: 10 km/h

Wetter
Montag, 16:00
Sonnig

Temperatur | Niederschlag | Wind



[Wetterdaten](#) · [Feedback](#)