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CLIMXTREME Climate Change and Extreme Events

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End-of-century heat and drought stress approaching Europe swiftly

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Suarez-Gutierrez et al., Under Review

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Extremely rare 'end-of-century' events can happen earlier than expected due to internal variability

When such extremes occur repeatedly year after year, they become even more damaging
(Zscheischler et al. 2020, Bastos et al. 2021, Raymond et al. 2022)

Europe could be especially prone to successive year-after-year extremes, due to the multi-year variability in the North Atlantic and its influence on the European climate
(Gao et al. 2019, Borchert et al. 2019, Müller et al. 2020, Lesk and Anderson 2021, Qasmi et al. 2021)

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1. How will the likelihood of successive extremes over Europe change in a warming world?

2. How early could we reach typical end-of-century extreme heat and drought stress levels?

3. How is this outcome affected by internal climate variability?

Using MPI-GE:

- Largest ensemble from a comprehensive climate model
- Offers one of the best representations of variability and forced changes in observed temperature and precipitation
- Ideal tool to precisely sample low-probability events
- Here: moderate scenario RCP4.5 (2,25C end-of-century warming)

The Max Planck Institute Grand-Ensemble:

Maher et al. 2019, JAMES

Evaluation of MPI-GE and other large ensembles:

Suarez-Gutierrez et al. 2021, Clim. Dyn.

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Impact-relevant metrics of heat and drought stress

Excess metrics = sum of every excess above threshold

- **Difference of actual reached value minus extreme threshold, accumulated for all days and grid cells**
  [Perkins-Kirkpatrick and Lewis, 2020, Nat. Comm]
- **Excess Thresholds: above 90th percentile for heat, below 10th percentile for rain deficit, for 1950-1999.**
- **Normalized by average excess over 1950-1999.**
- **End-of-century typical levels are the 50th percentile of the ensemble averaged over 2090-2099.**

Excess Heat
Maximum temp.
JJA

Main heat mortality and morbidity driver after short exposures ~ hours to days
[E.g., Guo et al, 2017, Environm. Health Perspectives]

Humid Heat
Wet Bulb temp.
JJA

High ambient humidity + high temps
Hinders evaporative cooling
Lethal to irreversible damages after short exposures ~ hours
[E.g., Sherwood and Huber, 2010. Proc. Natl. Acad. Sci.]

Night Heat
Minimum temp.
JJA

Lack of Nighttime Cooling
Impedes restorative rest, increasing mortality for unadapted people after persistent exposure ~ days
[E.g., Royé et al, 2021, Epidemiology]

Rain Deficit
Monthly Precip.
MJJASO

Reinforcing moisture-temp feedbacks
Agricultural, ecologic, and economic damages after persistent exposure ~ weeks to months
[E.g., Feller et al, 2021, . Front Environ Sci]

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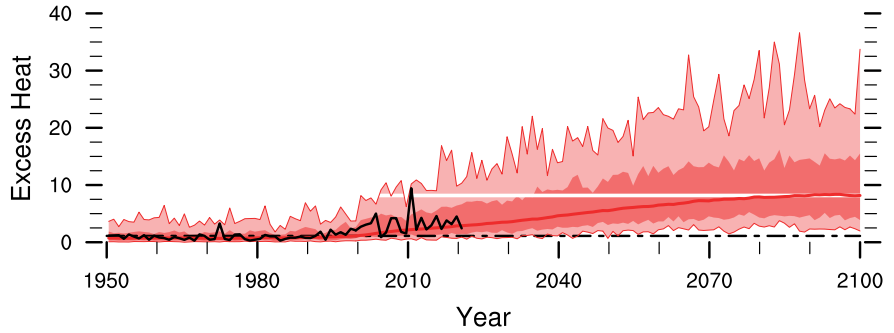
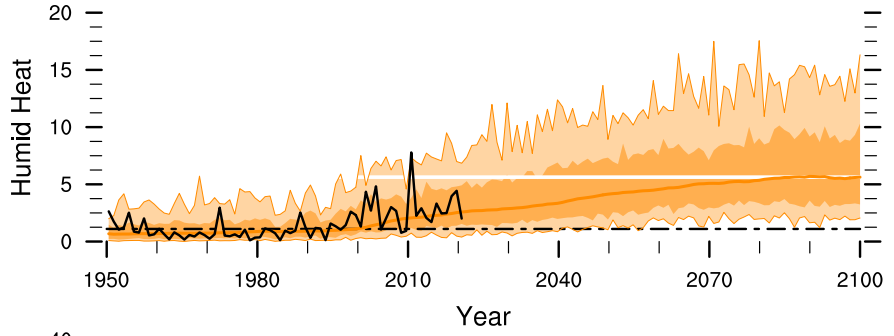
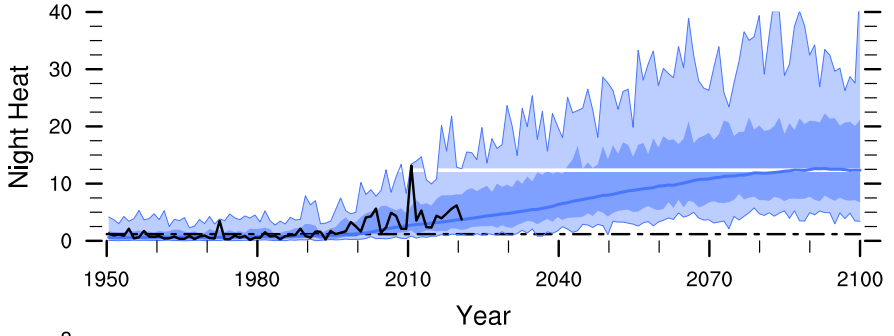
Excess Heat
Maximum temp.
JJA



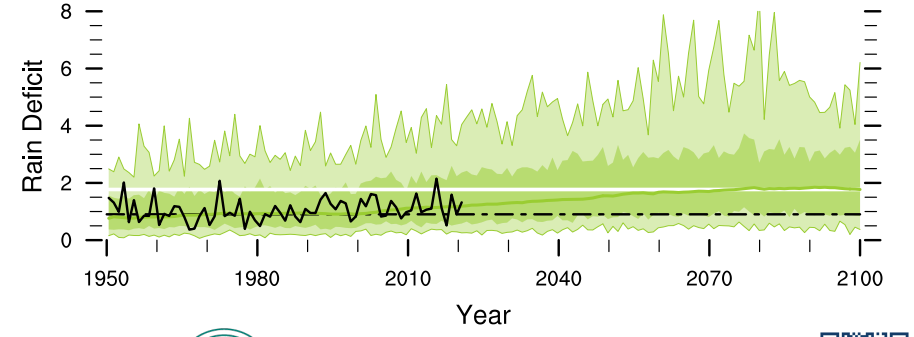
Humid Heat
Wet Bulb temp.
JJA



Night Heat
Minimum temp.
JJA



Rain Deficit
Monthly Precip.
MJJASO



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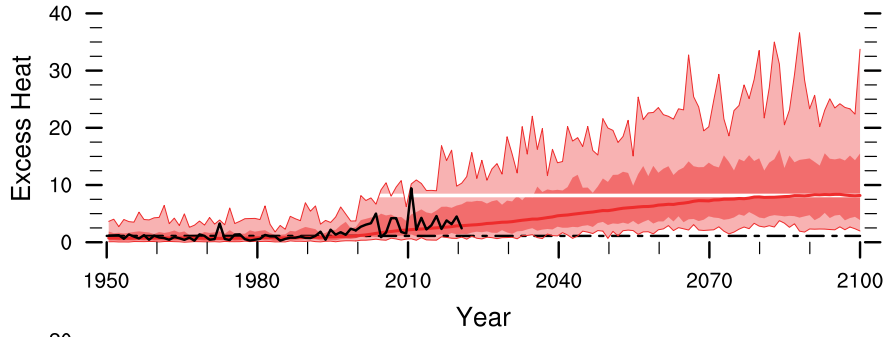
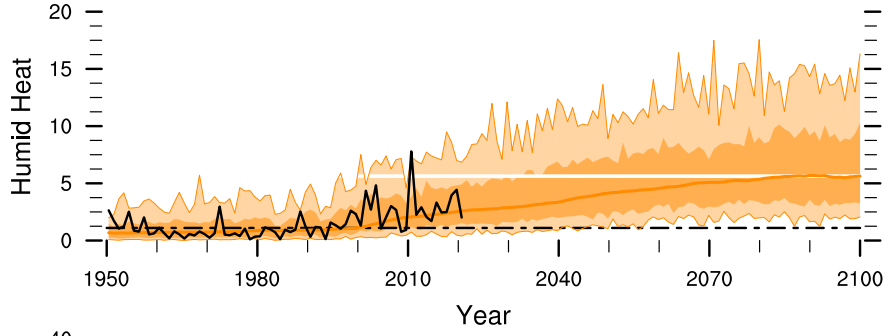
Typical end-of-century extreme heat, virtually impossible 20 years ago, reaches 1-in-10 likelihood already in 2030-2039.

Excess Heat
Maximum temp.
JJA



Humid Heat
Wet Bulb temp.
JJA



Night Heat
Minimum temp.
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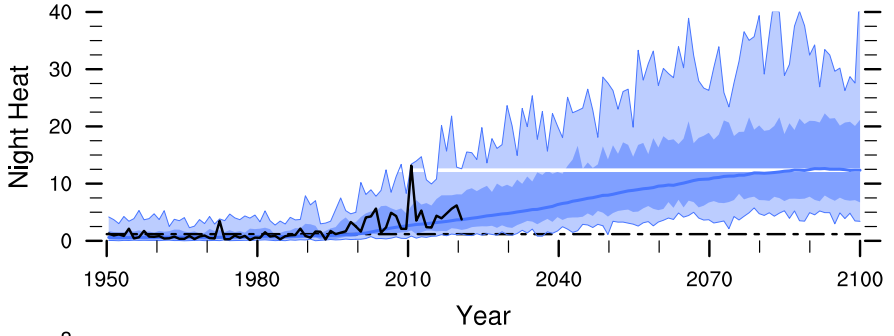

Rain Deficit
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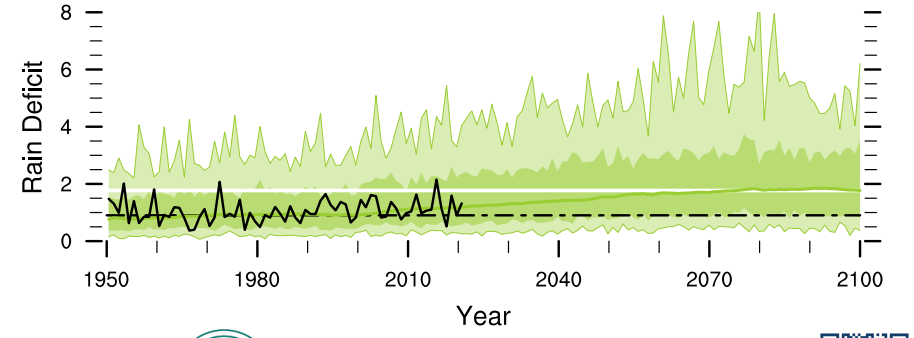

Excess Metrics for MPI-GE against E-OBS (black), for the full ensemble spread (light shading) and the 10-90th percentile range (dark shading), and the 10-year average of the 50th percentile of the ensemble (colored lines).

End of the 20th and 21st century typical decades are shown as 50th percentile of the ensemble averaged over 1990-1999 (black dashed line) and over 2090-2099 (white line).

Region [35–63N, 10W–55E].

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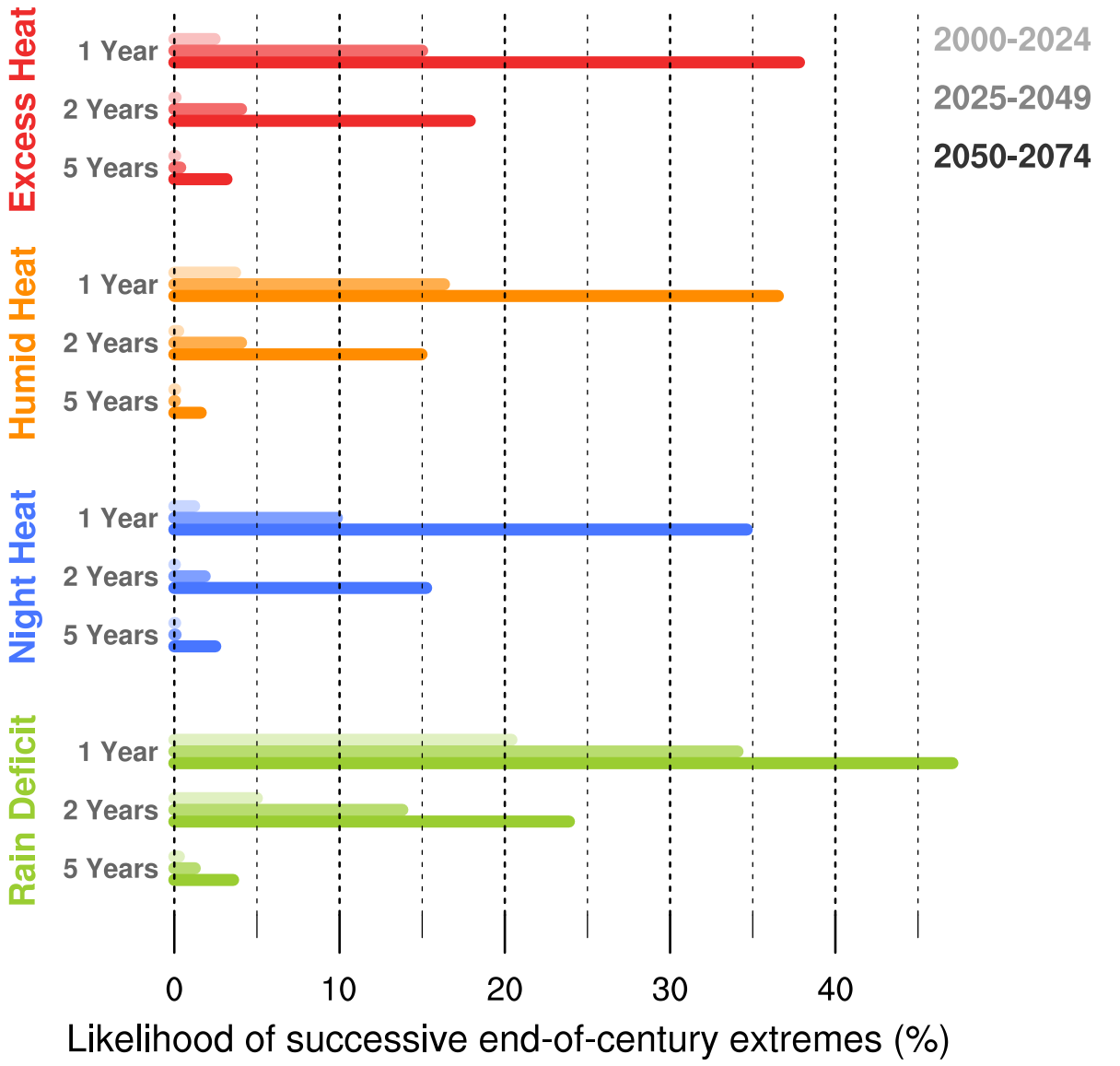
Successive years of end-of-century drought stress almost triple in likelihood in the next 25 years.

By 2050-2075, unprecedent 5-year long Europe-wide megadroughts become plausible.



Likelihood of year-after-year succeeding extremes. Extreme years are defined as those equal or larger than the end-of-century average extreme.

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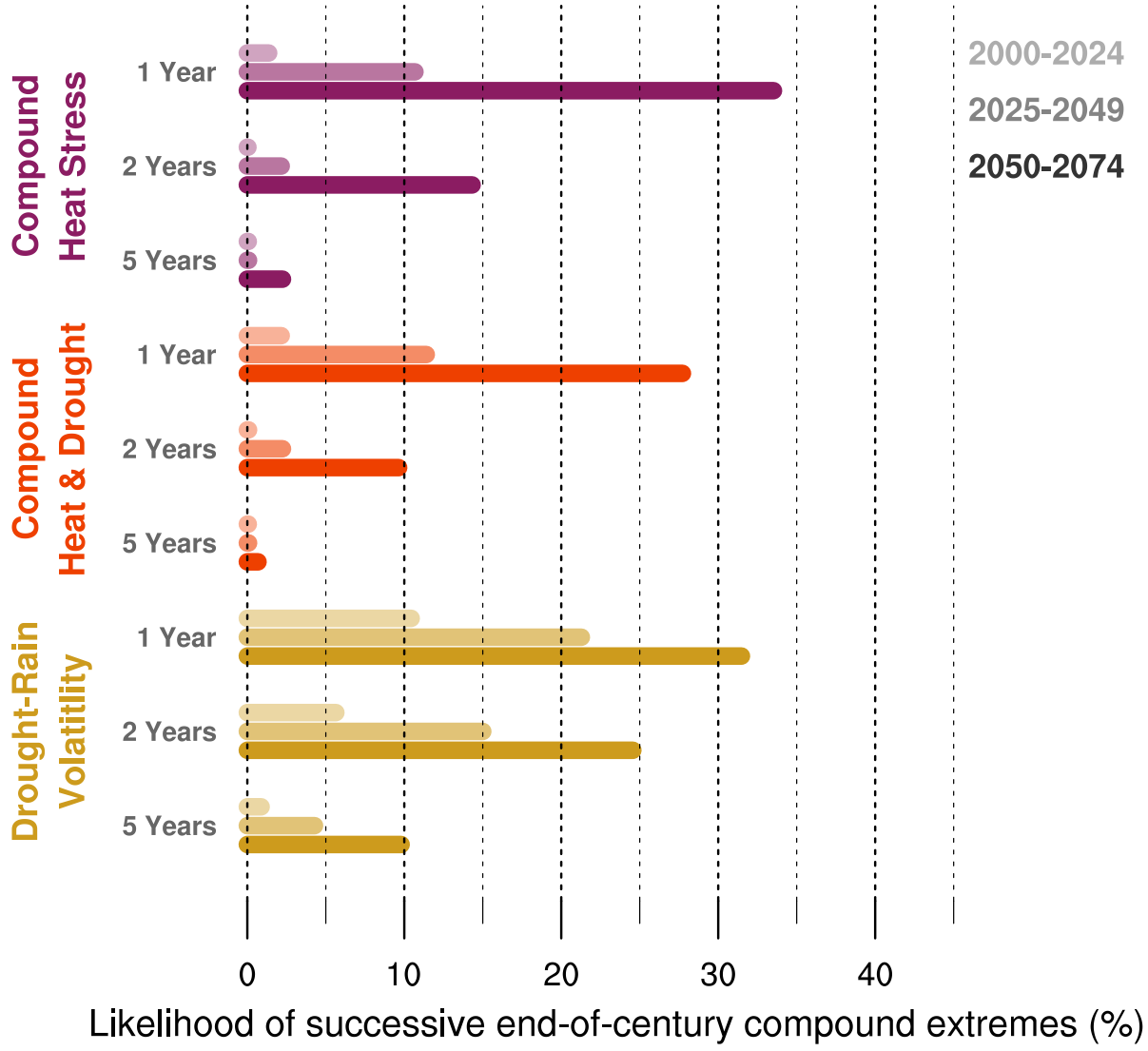
End-of-century Compound Heat Stress or Heat & Drought reach in 1-in-10 likelihood in the next 25 years for a single summer, and by 2050-2075 for two consecutive summers.



Likelihood of year-after-year succeeding compound extremes. Extreme years are defined as those equal or larger than the end-of-century average.

Compound Heat Stress = extreme Excess Heat, Night Heat and Humid Heat.
Compound Heat & Drought = extreme Excess Heat and Rain Deficit.
Drought-Rain Volatility = extreme Rain Deficit and extreme Excess Rain the year before and/or the year after.

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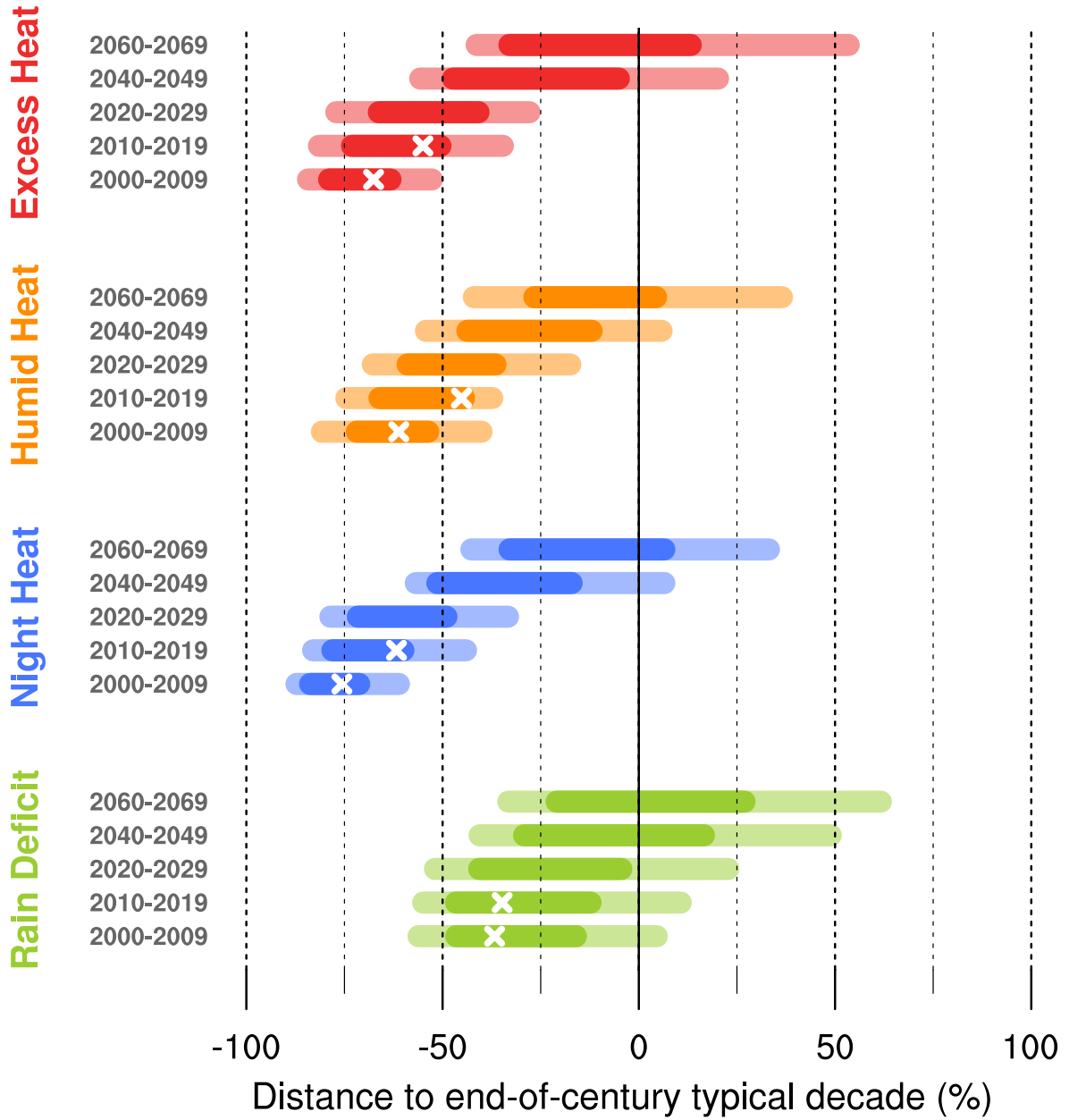
Accumulated over whole decades, the variability in heat and drought stress increases drastically.

Decades of end-of-century extreme heat could start already by 2040, by 2020 for drought stress.

Distance to the average end-of-century decades, as the full MPI-GE spread (pale colors) and the 10-90th percentiles (bright colors), compared to observed decadal excess in E-OBS (white crosses).

Decadal excess metrics = 10-year sum of annual excess metrics.

End-of-century typical decade = 50th ensemble percentile decadal excess in 2090-2099. Distance shown as the normalized difference between each decadal metric minus end-of-century average.



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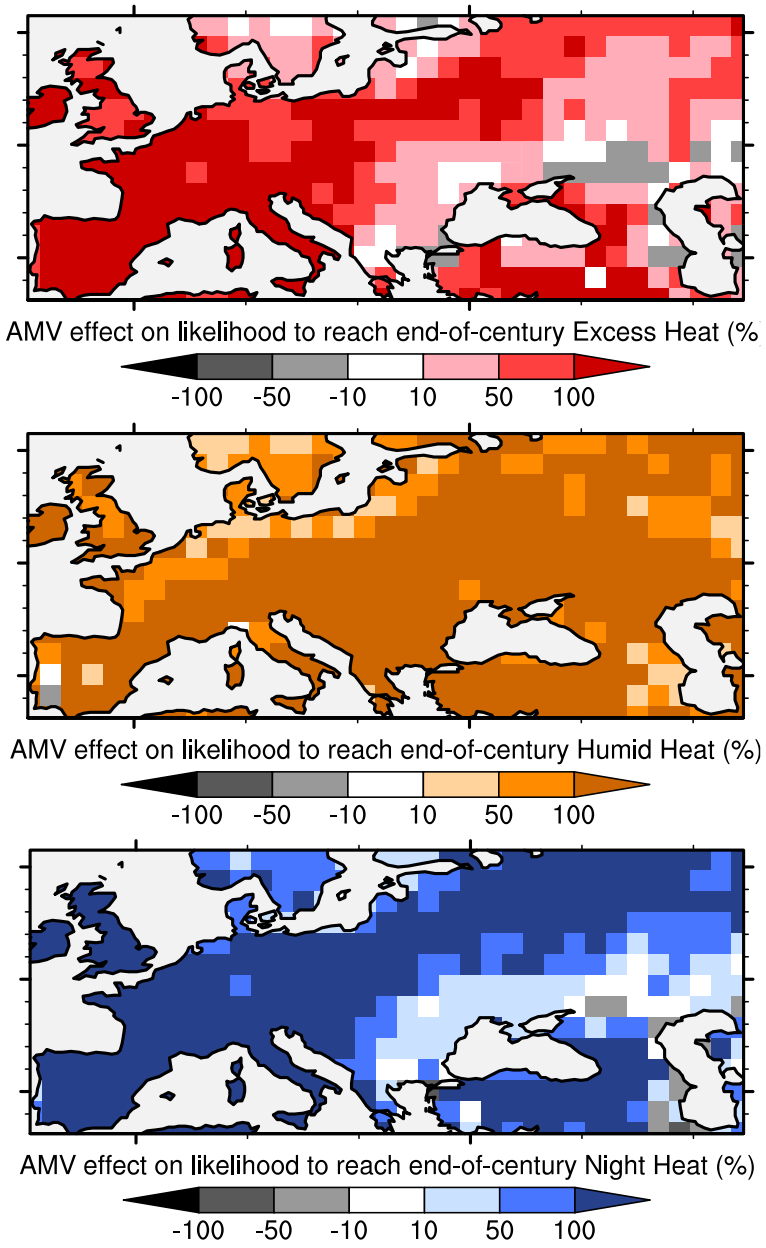
A warmer than normal North Atlantic makes whole decades of end-of-century excess heat starting in 2030 twice as likely



Difference in likelihood of decadal excess metrics starting in 2030-2049 exceeding end-of-century typical levels under different concurrent AMV phases, as likelihood during AMV+ minus during AMV-, weighted by likelihood during AMV-, in percentage.

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The end-of-century climate is not a distant reality, it can reach Europe swiftly and repeatedly year after year.

With a warmer than normal North Atlantic, whole decades of end-of-century excess heat starting as early as 2030 become twice as likely.

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