SCIENCE ADVANCES | RESEARCH ARTICLE

CLIMATOLOGY

Machine learning–based extreme event attribution

Jared T. Trok[1]*, Elizabeth A. Barnes[2], Frances V. Davenport[3], Noah S. Diffenbaugh[1,4]

1 Intensifying risk of mass human heat mortality if historical
2 weather patterns recur

3 Christopher W. Callahan[1,*], Jared Trok[1], Andrew J. Wilson[2], Carlos F. Gould[3], Sam
4 Heft-Neal[2], Noah S. Diffenbaugh[1], & Marshall Burke[1,2,4]

Geophysical Research Letters®

RESEARCH LETTER
10.1029/2024GL111832

Key Points:

- We train CNNs to predict peak global warming given the map of recent annual temperatures and total additional CO_2 emissions

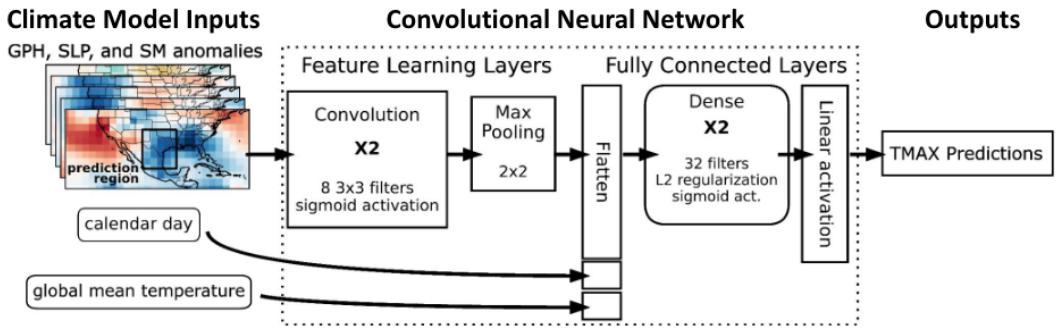
Data-Driven Predictions of Peak Warming Under Rapid Decarbonization

Noah S. Diffenbaugh[1] and Elizabeth A. Barnes[2]

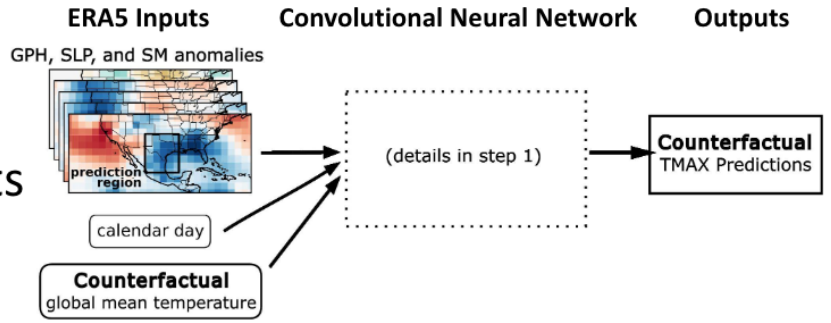
[1]Doerr School of Sustainability, Stanford University, Stanford, CA, USA, [2]Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA

Machine Learning-based extreme event attribution

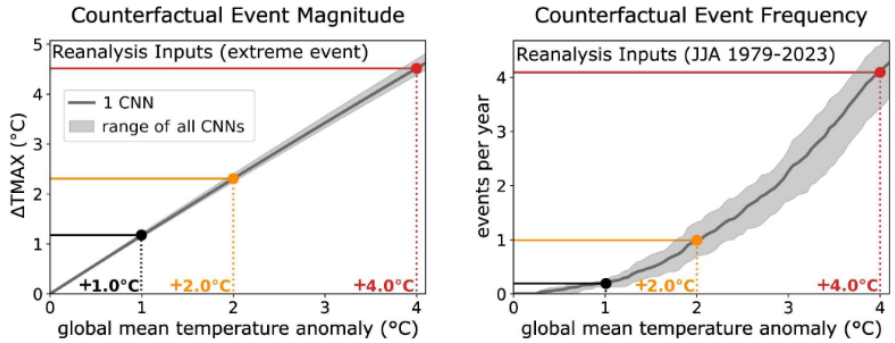
Step 1: Train neural network on existing climate model simulations



Step 2: Use historical reanalysis data to create counterfactuals for historical extreme events



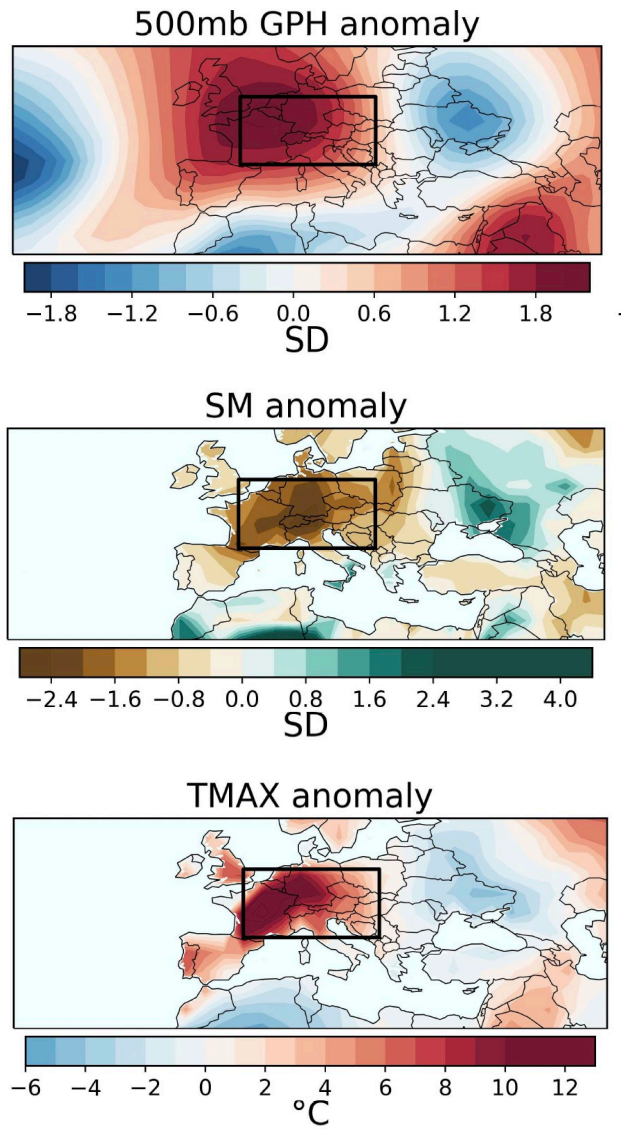
Step 3: Estimate the human contribution by comparing counterfactuals



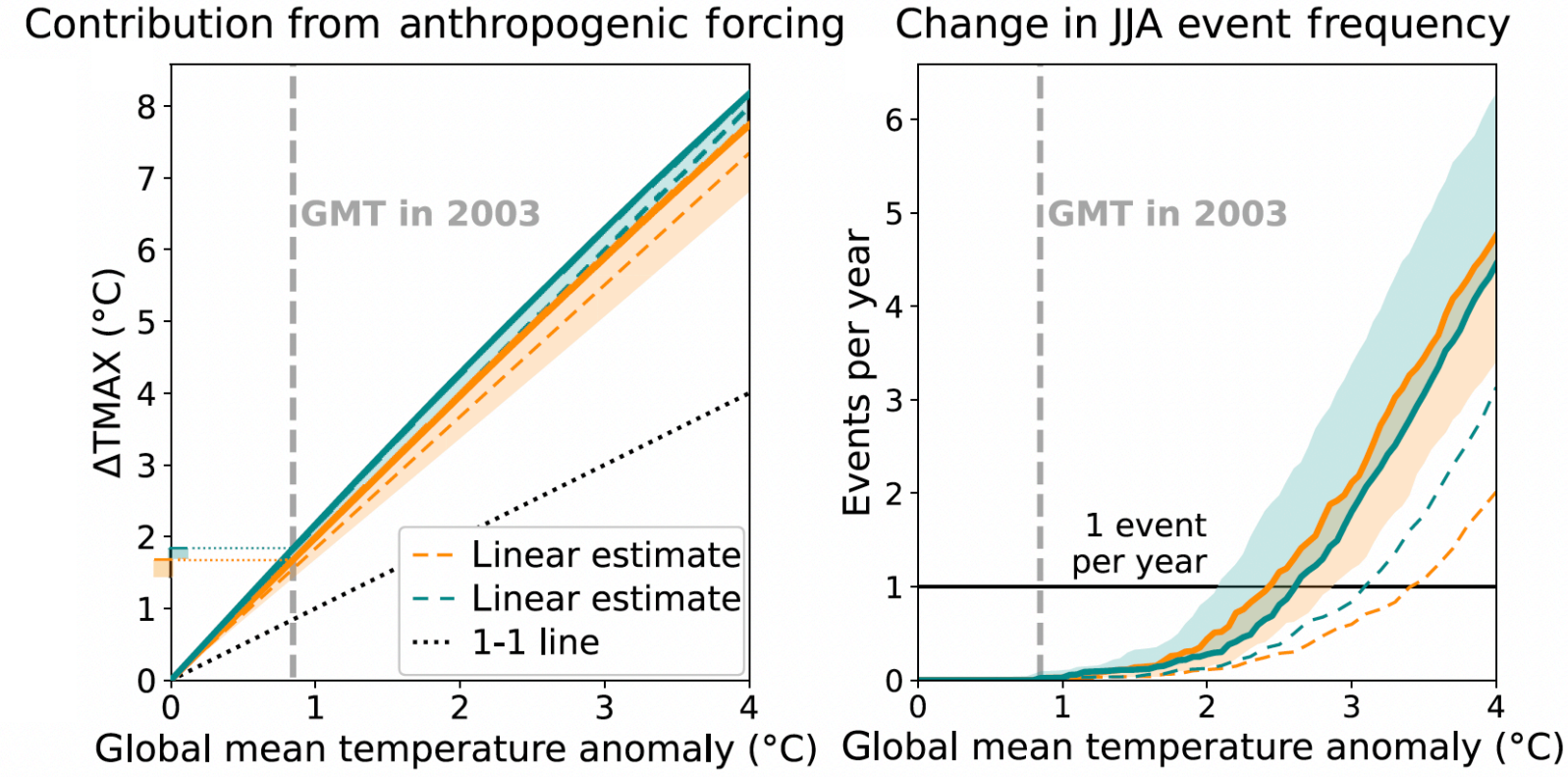
Stanford | Doerr
School of Sustainability

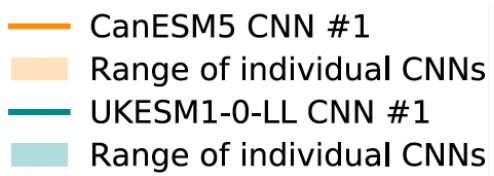
Trok et al., 2024

Extreme event attribution for 2003 Europe heatwave



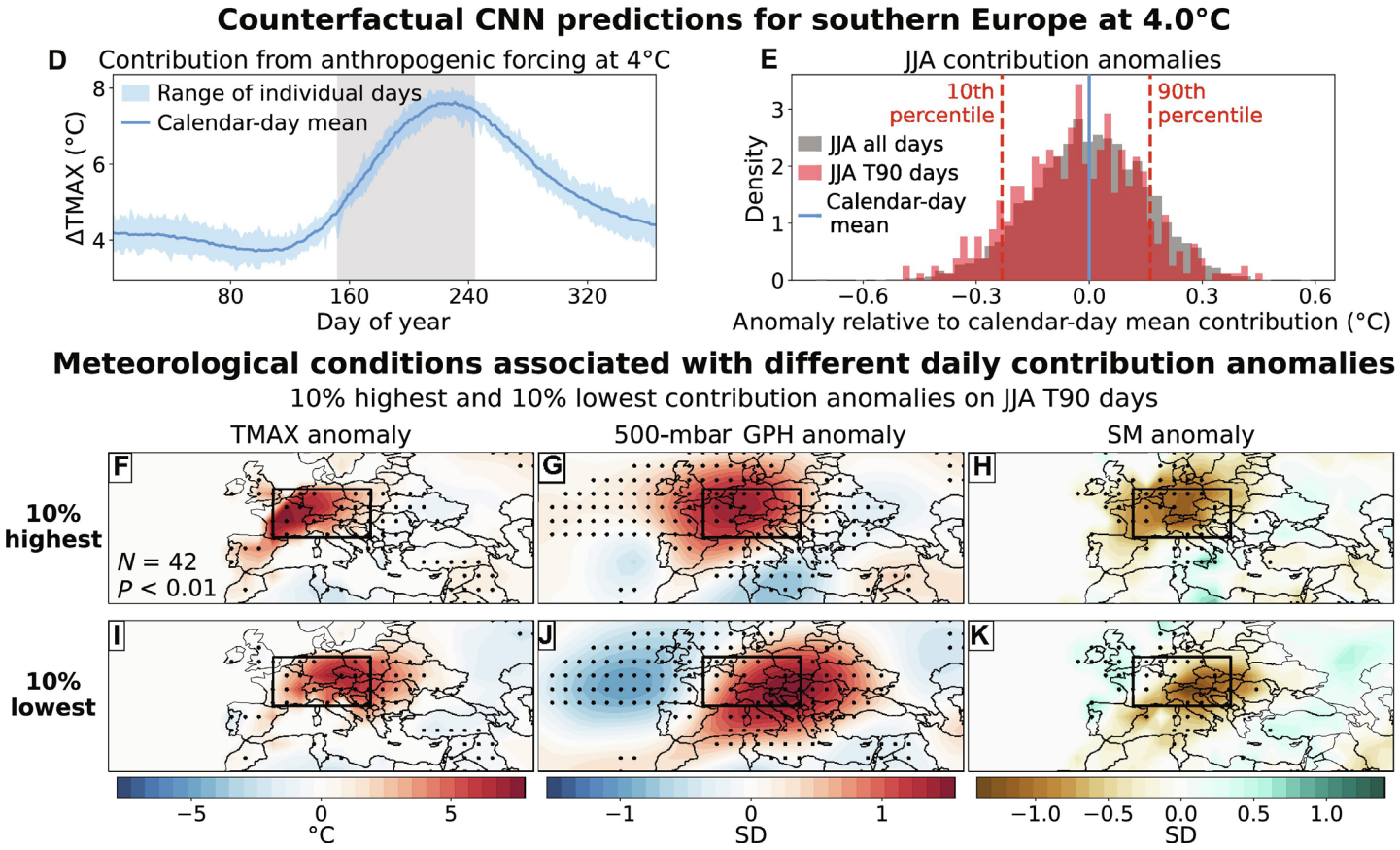
Europe 2003





Trok et al., 2024

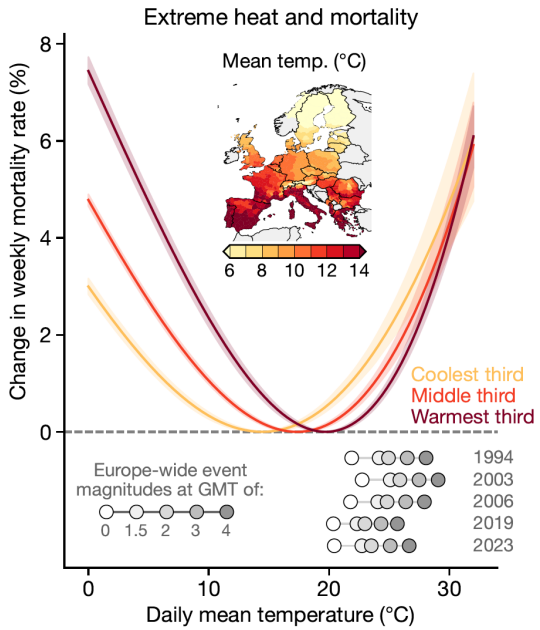
Extreme event attribution for 2003 Europe heatwave



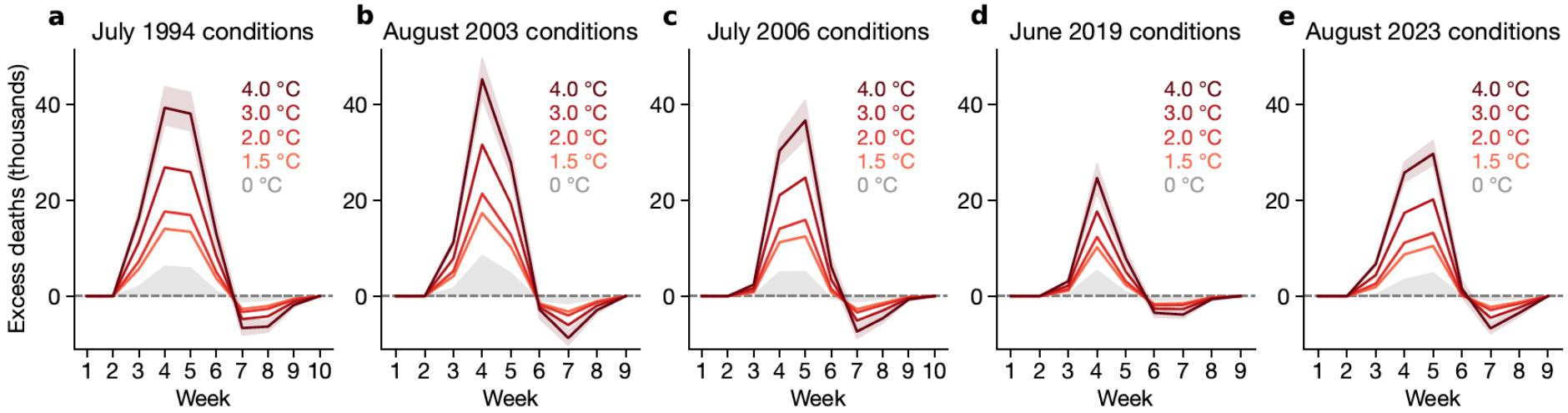
Much of the attribution is driven by the calendar-day warming, but network learns different contributions of global warming for different meteorological patterns

Trok et al., 2024

“Impacts attribution” for historical meteorological conditions

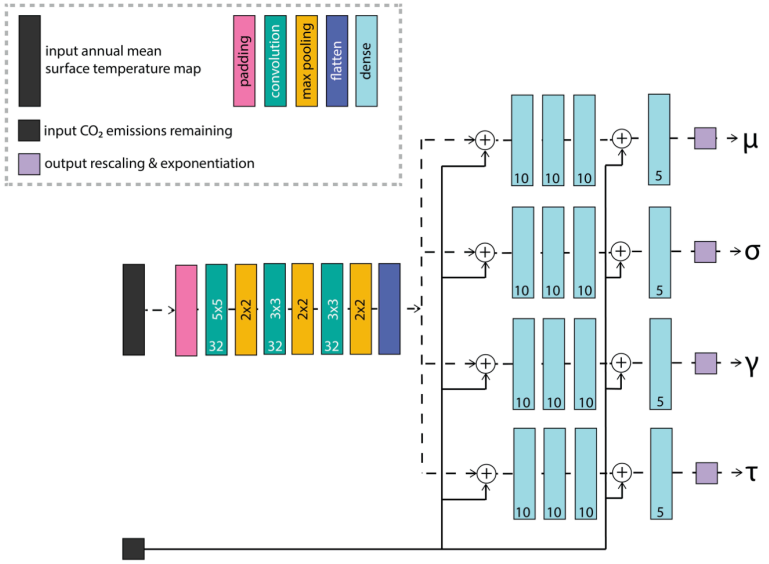


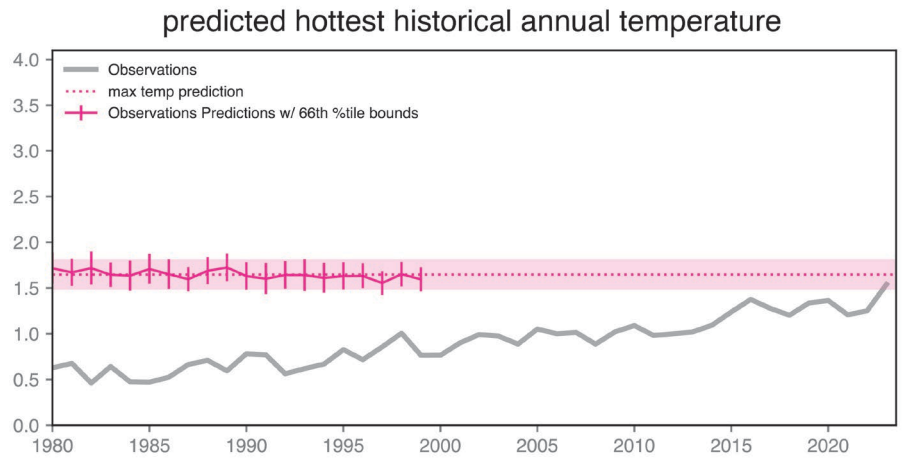
We can use machine learning combined with panel regression to predict mortality for historical meteorological conditions at different annual global temperature anomalies (including pre-industrial and the year of the actual event)

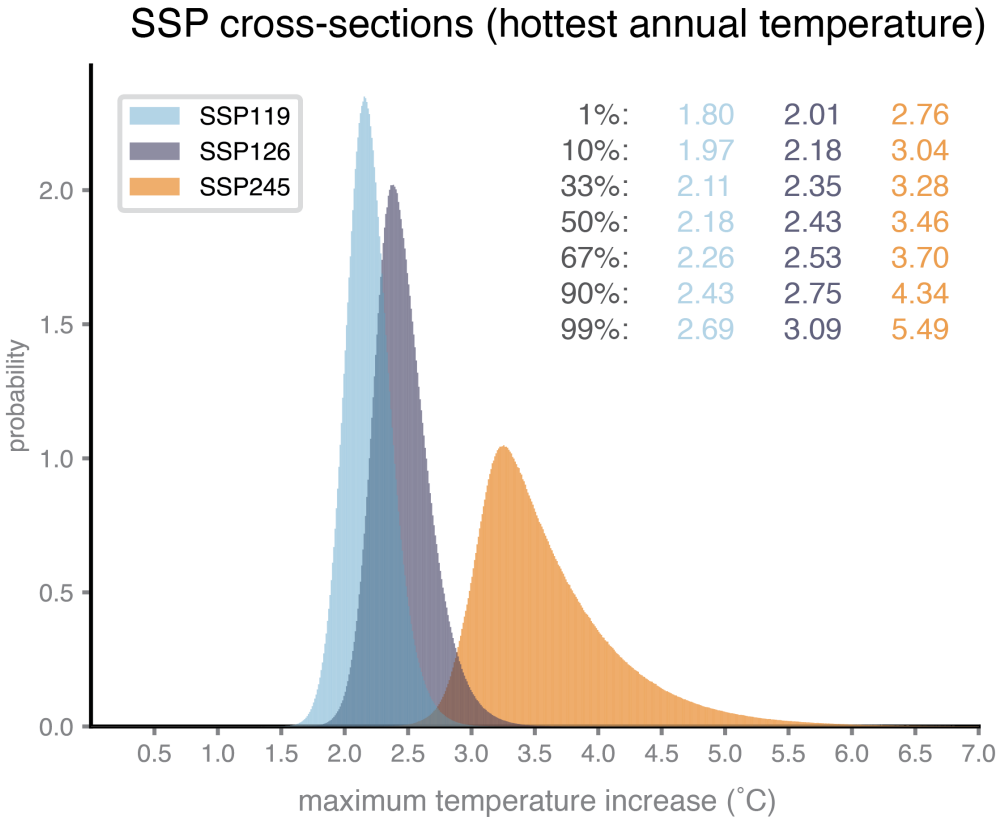


Callahan et al., EarthArXiv

Prediction of peak annual global temperature from cumulative emissions







Diffenbaugh and Barnes, 2024

Key Messages

• Machine learning is already a powerful tool to quantify the contribution of global warming to the *magnitude* of individual extreme events.

• ML can be combined with causal inference methods to quantify the contribution of global warming to the *impacts* of individual extreme events.

• It is critical that ML methods are *carefully and critically evaluated* for accuracy and fidelity with the physical world before being used for extreme event attribution.

• Further development will soon refine ML capabilities for *localized predictions over broad geographic areas*, and for quantifying the contribution of global warming to the *probability* of extreme meteorological conditions.