How extreme was the 2023 September global heat?

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Global temperature anomaly in September 2023

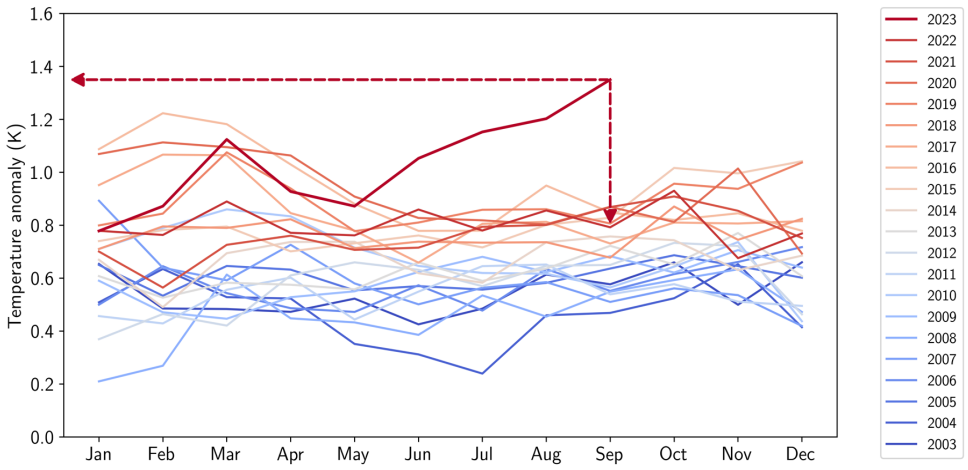

Fig. 1: Monthly observed global mean surface temperature (GMST) anomalies 2003 – 2023 with respect to 1961 – 90.

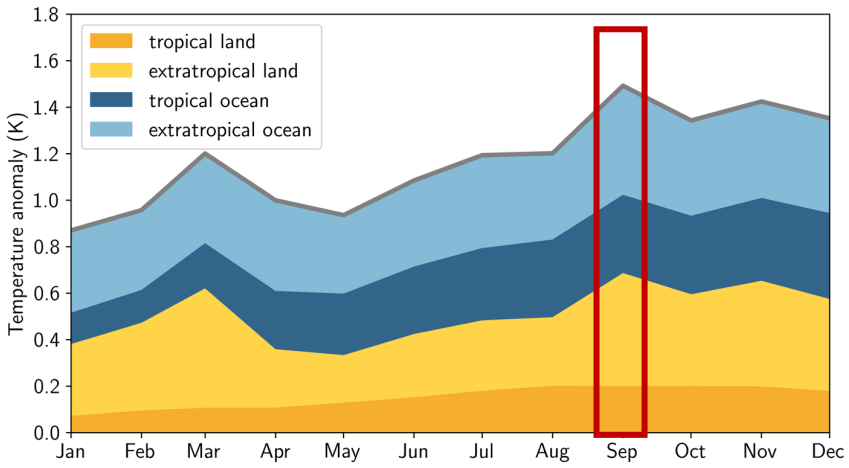

Fig. 2: Contribution of different regions to GMST anomalies in 2023; each regional timeseries is weighted by its share of the Earth's surface.

September 2023 broke the previous record by an exceptional margin of 0.5 °C.

Are we soon expected to witness similar or even more extreme temperature anomalies?

Attribution methodology

World Weather Attribution approach:

$N(\mu, \sigma)$ for global anomalies

$GEV(\mu, \sigma, \xi)$ for regional anomalies

$\mu = \beta_0 + \beta_1 * GMST + \beta_2 * NINO3.4$

Interannual variability in CMIP6 models

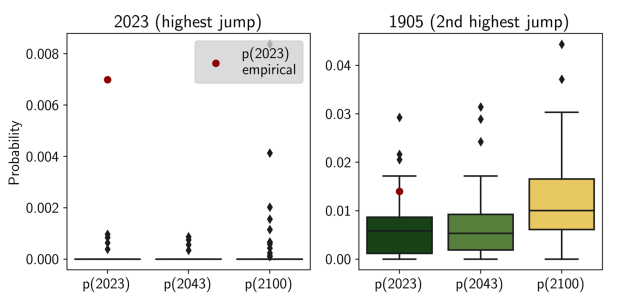

Fig. 6: Estimated probabilities for observed Sept. GMST differences between subsequent years ('jumps') in CMIP6 models based on data until 2023 (p_2023), 2043 (p_2043) or 2100 (p_2100). 2023 is the year where each model reaches the global warming level (GWL) observed in 2023, with subsequent years incremented accordingly.

The GMST difference between Sept. 2022 and Sept. 2023 is not reproduced by CMIP6 models, but previous jumps are well captured.

Attribution results

Regional

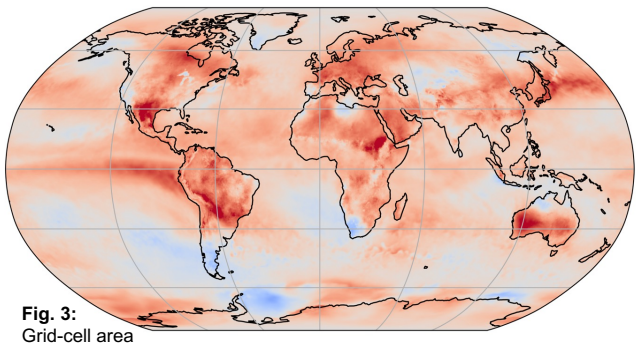

Fig. 3: Grid-cell area adjusted temperature anomalies in Sept. 2023.

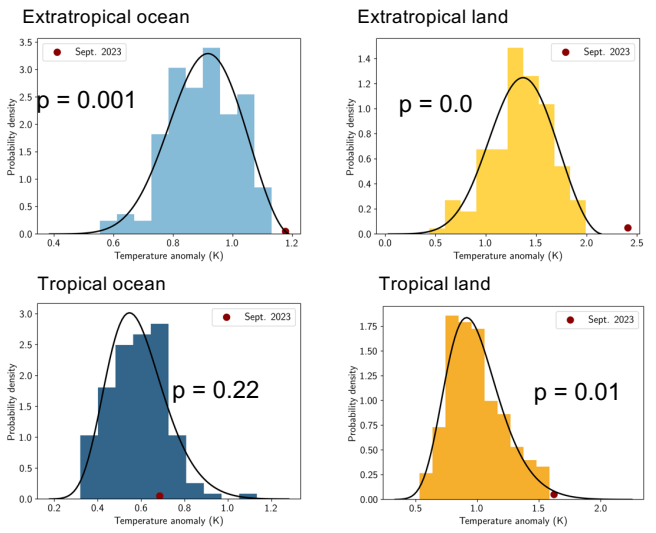

Fig. 4: Histograms of regional surface temperature anomalies 1880 – 2022 and attribution results for Sept. 2023 based on GISTEMP observations.

Global

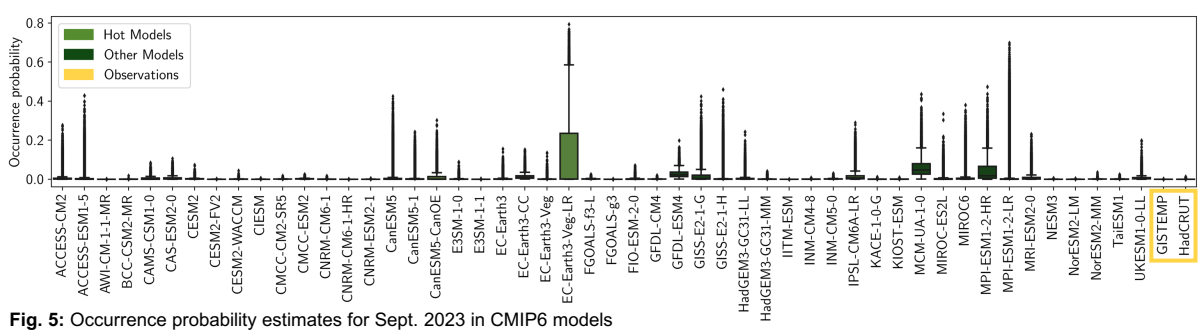

Fig. 5: Occurrence probability estimates for Sept. 2023 in CMIP6 models

On the global scale, September 2023 was extremely unlikely ($p \approx 10^{-5}$), based on extreme event attribution with observations and CMIP6 models.

The extratropics contributed most to the development of this extraordinary heat.

Future occurrences

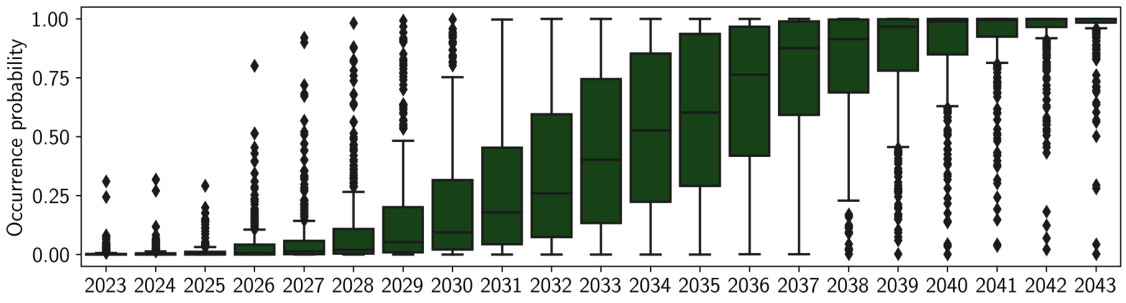

Fig. 7: Occurrence probability estimates for Sept. 23 in CMIP6 models in different years; years are GWL-based as described in Fig. 7.

Within a few years, occurrence probabilities for September 2023 rise sharply.

Conclusions

- September 2023 was highly unlikely at global and regional scales, even with the current level of anthropogenic warming.
- This is consistent for both observations and CMIP6 models.
- However, within only a few years, this event would no longer be considered extreme. The reason for the higher occurrence probability is the higher level of background warming, not increased year-to-year variability.

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