Evaluating CMIP6 Model Fidelity at Simulating Non-Gaussian Temperature Distribution Tails

Arielle J. Catalano (Portland State University), Paul C. Loikith (Portland State University), J. David Neelin (UCLA)

**Introduction**

Changes in extreme temperature exceedances will be manifested in more complex ways in locations with non-Gaussian temperature distribution tails than if the distribution were Gaussian.

To boost confidence in projections of future changes in extremes, it is therefore critical that climate models realistically simulate observed non-Gaussianity in temperature distribution tails.

**Methods**

We use 2-m temperature data from the historical simulation of the recently released CMIP6 multi-model ensemble and NASA’s MERRA-2 reanalysis.

Datasets are regridded to a 1°x1° horizontal resolution. Temperature anomalies are computed by subtracting the climatological mean and detrending linearly.

Temperature anomalies are analyzed over the period 1980–2014 for the seasons comprised of June, July, and August (JJA), and December, January, and February (DJF).

To determine CMIP6 model skill in simulating tail shape, **shift ratios** are computed as follows:

1. Shift the underlying daily temperature anomaly distribution uniformly by 0.5σ.
2. Tabulate the frequency of days that exceed a fixed threshold — warm-side threshold is the 95th percentile and cold-side is the 5th percentile.
3. Divide those threshold exceedances by the expected number of exceedances from shifting a Gaussian distribution.

**Results**

**Cold Side**

- CMIP6 ensemble mean shift ratios broadly capture the principal spatial patterns of both shorter- and longer-than-Gaussian tails in MERRA-2.
- There is robust (≥ 85%) model agreement over coherent non-Gaussian areas in all sub-regions.
- Nearly all models adequately simulate broad sections of significantly shorter-than-Gaussian warm tails during DJF.
- Most models mischaracterize tail shape over areas in Russia (NAS), South America (SAM), and South Africa (SAF), implying potential biases in the large-scale circulation producing temperature extremes.

**Warm Side**

**Conclusions**

- The CMIP6 ensemble captures the principal coherent spatial regions of non-Gaussian 2-m temperature distribution tails.
- Individual models exhibit high skill in global shift ratio patterns compared with MERRA-2, indicating models simulate extreme temperatures for plausible physical and dynamical reasons.
- Understanding regional differences in model skill requires further research.

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References

*This work is part of the Model Diagnostics Task Force framework. For more information, visit: http://www.cesm.ucar.edu/working_groups/Atmosphere/mdtf/diagnostics-package/

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