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Statistically impossible temperatures.

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The 2021 heatwave in the Pacific Northwest of the United States and Canada was unusual in many regards. In particular, not only was the event deemed impossible prior to the human interference in the climate system, standard out-of-sample non-stationary generalized extreme value (GEV) analyses revealed it to be statistically impossible in 2021 as many observed temperatures were above the upper bound of the upper bound of fitted GEV distributions. Obviously, as the event actually occurred, these statistical models are not fit for the purpose of estimating the influence of climate change on the event's probability.

By expanding the number of physical covariates beyond just greenhouse gas concentrations and by incorporating spatial statistical techniques in a Bayesian hierarchal framework, we are able to construct a statistical model where observed temperatures during this heatwave were not "impossible" and thus estimate the change in their probabilities leading to Granger-type causal inference attribution statements.

We further extend this statistical framework to all quality daily GHCN station measurements and find that while many physically plausible outlier temperatures are impossible in the simple non-stationary GEV framework, they can be explained using our more complicated non-stationary Bayesian spatial statistical model embedded in a deep learning machinery.