Towards Appropriate Attribution for Extreme Weather and Climate Related Event

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Abstract

Extreme heat and rain are now being shaped by climate change. The level to which human activity has enhanced the risk of high-impact incidents is a focus of extensive public debate. Recent studies compared climate model experiments where the influence of an external driver can be added or artificially suppressed to ascribe specific extreme events to climate change. However, several of these findings failed to account for model imperfections when forecasting the probability of severe event occurrence. Using modern weather forecasting correction techniques, we show that appropriately correcting for model probabilities changes the risk of extreme occurrences to climate change. This study demonstrates the importance of correcting for model error in order to deliver reliable judgments of Impacts of climate change.

Keywords: Weather • Climate events • Temperature • Atmosphere

Introduction

Extreme weather and climatic phenomena are becoming more common. Today, there is abundant evidence that human activity has an impact on excessive heat and rain. This discovery is helping to raise public understanding about climate change and to make policy decisions about climate adaptation. The extent to which recent high-impact catastrophes were caused by human activity is therefore a major source of public concern. A new study discipline known as extreme event attribution is increasingly addressing this subject [1].

From a probabilistic approach, event attribution seeks to determine whether and to what extent natural and industrial drivers have favored the occurrence of a historical event. Single-extreme weather and climate incidents are one-of-a-kind-they occur only once in exactly the same way, and their likelihood is thus strictly infinitely small, preventing any attribution. Single occurrences, on the other hand, can be classified as part of a class of events, such as the locally limited excedance of a geophysical variable over a certain threshold, to which probabilities can be given (for instance the probability to exceed the extreme 2-m air temperature observed over Europe during the summer 2003) [2]. The target of many event attribution techniques based on model simulations that allow computing event probability in the presence or absence of external forcing has been to identify external factors in these probabilities. The model's capacity to correctly simulate the odds of severe occurrences and the changes in those probabilities is a weakness that affects all state-of-the-art techniques. We refer to model reliability as a statistical condition in which simulated probabilities are said to be accurate if they precisely mirror observed frequencies. For example, in all circumstances where a hot summer is simulated with a 20% probability, a hot summer should also occur in 20% of these cases in order for a model to be called realistic [3].

This concept of reliability comes from the field of weather and climate forecasting, where having reliable forecast probabilities is critical for making decisions. The goal of event attribution is to measure how an external driver has influenced the likelihood of a certain event, rather than to forecast it. As a result, model simulations used in event attribution are typically assessed for the accuracy of their mean state and different modes of variability, as well as their ability to reproduce the physical processes involved [4], which is generally thought to be sufficient for a reliable extreme event attribution. In the past, a small number of attribution studies evaluated model reliability to support or refute a claim, but they remained the exception in the present literature and usually did not go beyond a single assessment of model reliability. Climate model experiments are used to determine the role of an external element in causal extreme event attribution (such as increased levels of greenhouse gases) [5]. These studies use an ensemble approach to simulate the possible evolutions of the climate system, which entails running numerous climate simulations under the same conditions but with small beginning perturbations to generate a range of possible climate outcomes. The likelihood of a rare event occurring under specified conditions can be quantified using this ensemble approach.

In this research, we demonstrate that the current approach of not effectively accounting for reliability is not only unjustified, but also risks providing unduly strong attribution statements (for extreme events) [6]. To highlight this, we analyses how well climate variability and long-term responses to forcing are depicted in model simulations widely used for event attribution. Then, using advanced model correction strategies discovered in weather and near-term climate forecasting, we present a methodology to adjust for such flaws. Up until now, the atmosphere-only strategy has been the most popular, resulting in multiple enormous data sets dedicated to severe event attribution. Given that the radioactive and marine boundary forces (in the atmosphere-only experiments) change with time, both types of model approaches (coupled or atmosphere-only) mimic a no stationary climate. As seen in the following example, a consistent ensemble response to various forcing is critical [7].

Discussion

Climate model research is used to determine the role of an external element in causal extreme event attribution (such as increased levels of greenhouse gases). These studies use an ensemble approach to simulate the possible evolutions of the climate system, which entails running numerous climate simulations under the same conditions but with small beginning perturbations to generate a range of possible climate outcomes [8]. The likelihood of a rare event occurring under specified conditions can be quantified using this ensemble approach. The ensembles are generated using coupled (ocean-atmosphere) climate models or atmosphere-only models, both of which are driven by observed SST and sea–ice concentrations. Up until now, the atmosphere-only strategy has been the most popular, resulting in multiple enormous data sets dedicated to severe event attribution. Given that the radioactive and marine boundary forces (in the atmosphere-only experiments) change with time, both types of model approaches (coupled or atmosphere-only) mimic a non - stationary climate. As seen in the following example, a dependable ensemble response to various forcing is critical [9].

Low ensemble simulation accuracy is a major topic in weather and climate forecasting. To address this problem, a set of techniques known as ensemble calibration has been developed. As we will explain in the following, these techniques are promising instruments for the development of reliable event attribution assertions. As a consequence of the model's ability to replicate the reaction to these conditions, ensemble calibration corrects the model's response to prevailing conditions, such as inter-annual climatic variability (technically as a function of the reliability) [10]. This involves a widening of the ensemble spread (though sometimes a narrowing is required) as well as a correction of the strength of the ensemble mean signal that deviates from the climatological state. It is critical in the context of event attribution that the model response to the external driver, to which we are attempting to establish a causal link, is preserved after calibration. Because the ensemble is concurrently calibrated for short-term and long-term variability's, this is a worry in traditional techniques. In this paper, we offer a forecast calibration technique that can handle this challenge. The method is based on ensemble inflation (see Methods) and corrects the ensemble independently for near-term variability (for example, inter annual SST variations or volcanic eruptions) and long-term trends (see Methods) (forced for instance by greenhouse gas concentration changes). It's worth noting that all of the climate simulations examined here employs observed SST as ocean surface boundary conditions, implying that low-frequency variability is required in the model simulations [11].

In the existing process of event attribution studies, the limitations of climate models in properly simulating incidence are neglected. Simulated probability can be confronted with data, and their reliability is an issue in simulations aimed for event attribution. We were able to improve the attribution of extreme events by taking into account the reliability of the systems utilized by utilizing and refining methodologies developed in weather and climate forecasting. These techniques can be improved to account for various kinds of unreliability, but it is obvious that the attribution community can make significant progress if it collaborates closely with other groups concerned with model error [12]. Differences in trend over a 50-year period would thus be attributed to various reactions to anthropogenic forcing rather than climate variability. However, in a coupled-model setting or in the face of highly nonlinear temporal variations in response to anthropogenic forcing, other more comprehensive techniques would be useful. Because no measurements for a world without climate change are available, the long-term trend is only corrected for the ensemble incorporating human forcing. While the additional analysis backs up the study's findings, it does not promise to be thorough, and more applications may be required to evaluate the method for different types of events. When compared to quintile-specific calibration procedures, the current proposed method is generic because it corrects the entire model distribution [13-15]. However, the method may not be appropriate for correcting a highly non-linear response to anthropogenic forcing or excessively skewed native model distributions, in which case non-parametric alternatives may be more appropriate. Furthermore, physical flaws in general circulation models, such as the right location of storm tracks, are unlikely to be remedied by this method, therefore calibration should always be accompanied with an assessment of the model's ability to simulate physical processes that enable them.

Conclusion

From a wider approach, this research shows how experience in weather and climate forecasting might help with extreme event attribution. A greater understanding of the models' ability to capture the mechanisms that contribute to the occurrence of climate extremes could be gained by bridging the prediction and event attribution communities. For example, it has long been standard practice in forecasting to separate causes of a given high-impact event by employing approaches that allow for the prescription of observable atmospheric conditions that prevailed during or prior to the occurrence. The difficulty of current techniques to capture past extreme occurrences can provide additional insight on which kind of events we can confidently conduct event attribution studies for. Because of the rising public interest in and trust in the scientific community in creating rigorous attribution assessments, it is now more important than ever for the scientific community to correctly address model limitations in event attribution research. Adopting this practice will lead to a more robust assessment of the human role in past extreme events for the Intergovernmental Panel on Climate Change (IPCC upcoming)'s assessment report, as well as for the growing demand from the media and international organizations such as the United Nations Framework Convention on Climate Change (UNFCCC) and the International Federation of the Red Cross (IFRC).

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