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OPINION

Operational extreme weather event attribution can quantify climate change loss and damages

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Abstract

"It is now well established that the influence of anthropogenic climate change on certain individual extreme weather events can be quantified by event attribution techniques. It is time that these activities move from the research community to the operational centers. Such routine evaluation of the human influence on extreme weather increases our scientific understanding and informs the public of climate change impacts. Furthermore, quantification of the human influence on extreme weather can be used to fairly evaluate climate change induced loss and damages".

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The recent Conference of Parties (COP26) decision in Glasgow, known as the Glasgow Climate Pact, "*acknowledges* that climate change has already caused and will increasingly cause loss and damage and that, as temperatures rise, impacts from climate and weather extremes, well as slow onset events, will pose an ever-greater social, economic and environmental threat." The Glasgow Climate Pact further "*urges* developed country Parties, . . . to provide enhanced and additional support for activities addressing loss and damage associated with the adverse effects of climate change" [1].

The increased risk and severity of certain types of extreme weather due to global warming are thus formally recognized to be immediate, dramatic, and substantial. Indeed, a recent report of the World Meteorological Organization finds that the impacts of extreme weather over the last 50 years are unevenly distributed across the world [2]. While the most financially expensive weather events have been hurricanes in the United States, the deadliest events have been droughts and floods in developing nations.

Extreme weather event attribution, the science of quantifying the influence of anthropogenic climate change on specific individual events has matured to point to be able to play a significant role in quantifying loss and damage [3].

Since this pioneering study, the field has expanded both in the range of weather events analyzed as well as the number of participating scientists. Confidence in a substantial human influence on any recent heat wave is now very high [4]. Quantifying the human influence on

extreme precipitation events is a more difficult question but for many storms, including tropical cyclones and hurricanes, climate change has significantly aggravated damages [5]. The human influence on meteorological drought is less well established, but the human influence on agricultural drought is clear due to increased evapotranspiration caused by higher temperatures [4]. New methods and data continue to expand the types of extreme weather events subject to attribution analyses.

Human influence, if any, on specific weather and climate events is usually expressed as either a change in the occurrence frequency or probability of an event of the observed magnitude and/or the change in the magnitude of an event at a fixed estimate of the observed probability [6]. This characterization about the weather event itself can then be applied to assess the change in magnitude of the impact [7]. For instance, an estimate of the increased precipitation caused by anthropogenic global warming has been used to calculate the change in flooding due to climate change during Hurricane Harvey across the Houston, Texas region, permitting estimates of the total financial costs attributable to climate change, as well as the disparity of these impacts across poor and rich neighborhoods [8]. Climate change induced increases in extreme weather damages are not limited to just money. Vicedo-Cabrera et al. found that 37% of the heat wave deaths across 43 countries from 1991–2018 were attributable to human induced climate change with larger attributable increases in Central and South America than in Asia, Europe, and North America [9].

Confidence in extreme weather event attribution statements is enhanced when similar conclusions can be drawn from multiple techniques and data sets [10]. Long-term, high quality observational records, generalized extreme value statistical methods, large ensembles of climate model simulations, shorter conditional hindcast "storyline" simulations, and concepts from causal inference theory can all play a role in understanding the magnitude of current loss and damages from climate change.

While there has been much discussion about operationalizing extreme weather event attribution [11], none such exists today. Rather attribution statements are performed by a myriad of academic-minded groups, mostly as research projects. The most prolific of these groups, the World Weather Attribution (WWA) project has developed methods that could be adopted by the operational weather prediction centers to provide timely event attribution statements [12]. Indeed, the model and data expertise of the forecast services would add great value to the science of event attribution.

After many extreme weather events, there usually is a demand from journalists for a climate change statement. This demand reflects a desire from the general public to understand how climate change has affected them through that event [13]. But in addition to this public outreach service, extreme weather event attribution across a wide variety of similar events can lead to increased understanding of how climate change affects that class of events. For instance, attribution studies of hurricanes and other storms has led to increased understanding that extreme precipitation can increase at rates greater than that from thermodynamic considerations alone [14]. Operationalizing extreme weather event attribution could expand the number of events studied and remove the selection bias of studying just the most interesting or damaging events [15].

But the COP26 decisions up the ante for extreme weather event attribution. The climate change loss and damages from extreme weather is large and increasingly obvious. By careful application of attribution findings, quantifying these loss and damages can be made in a rigorous and defensible manner. The Glasgow Climate Pact urges the developed nations to provide support addressing loss and damage associated with climate change impacts that can be partially fulfilled by operationalizing extreme weather event and impact attribution. It is in all parties' interest to make the best estimate economic impacts resulting from climate change in

order to ensure that funds from any international loss and damage financial mechanism are equitably distributed.

The credibility of extreme weather event attribution statements has been demonstrated for a wide variety of impactful events. The observational, computational, and statistical tools are well developed and readily available. Thus, we call on the funding agencies of the developed nations to direct resources to their weather forecast services to begin to operationalize extreme weather event and impact attribution before next year's Conference of Parties in Egypt.

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