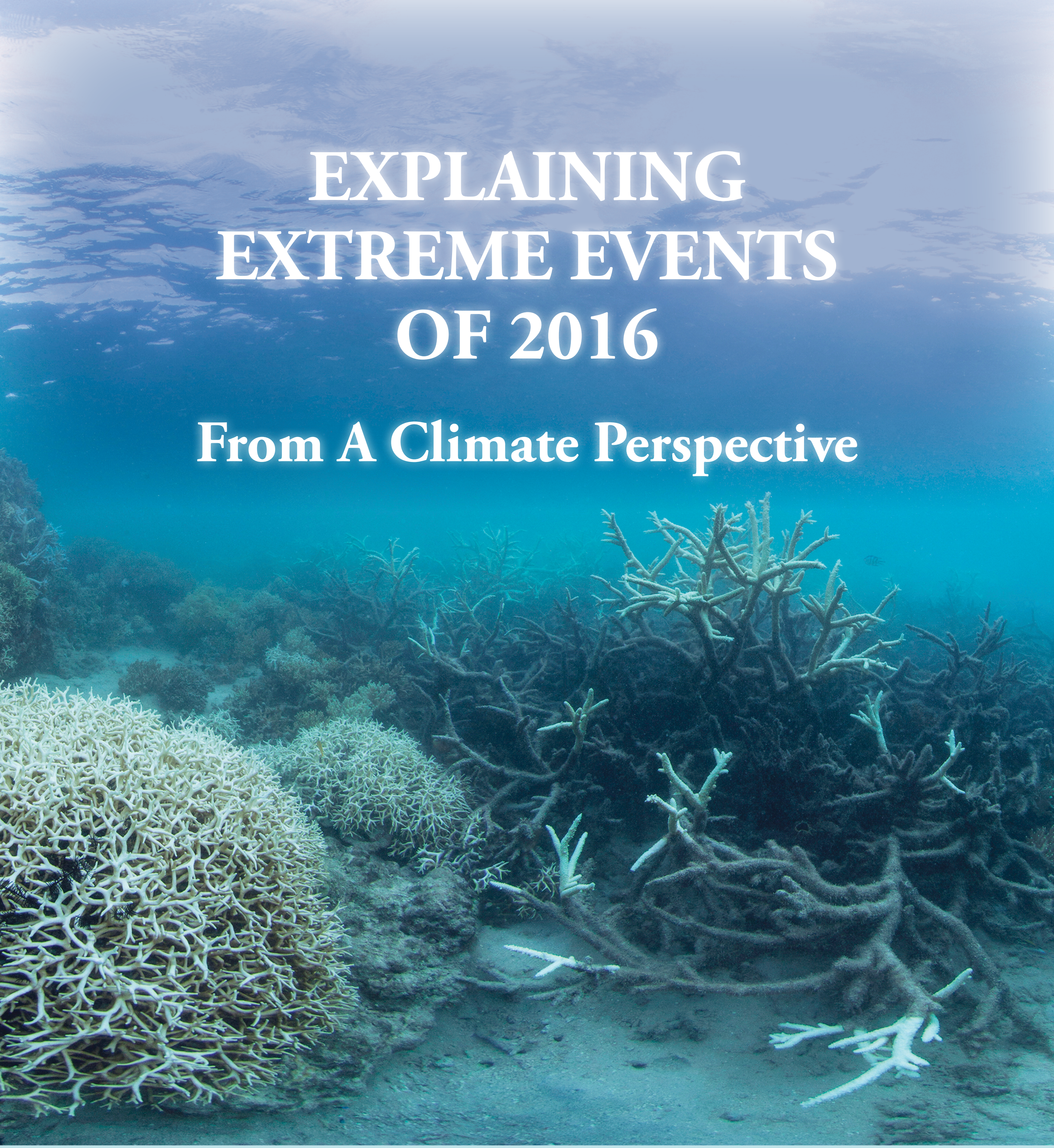
EXPLAINING EXTREME EVENTS OF 2016

From A Climate Perspective



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EXPLAINING EXTREME EVENTS OF 2016 FROM A CLIMATE PERSPECTIVE

Editors

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Carl J. Schreck III, and Peter A. Stott

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©The Ocean Agency / XL Catlin Seaview Survey / Chrisophe Bailhache—A panoramic image of coral bleaching at Lizard Island on the Great Barrier Reef, captured by The Ocean Agency / XL Catlin Seaview Survey / Christophe Bailhache in March 2016.

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EDITORIAL AND PRODUCTION TEAM

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ABSTRACT—Stephanie C. Herring, Nikolaos Christidi, Andrew Hoell, James P. Kossin, Carl J. Schreck III, and Peter A. Stott

This sixth edition of explaining extreme events of the previous year (2016) from a climate perspective is the first of these reports to find that some extreme events were not possible in a preindustrial climate. The events were the 2016 record global heat, the heat across Asia, as well as a marine heat wave off the coast of Alaska. While these results are novel, they were not unexpected. Climate attribution scientists have been predicting that eventually the influence of human-caused climate change would become sufficiently strong as to push events beyond the bounds of natural variability alone. It was also predicted that we would first observe this phenomenon for heat events where the climate change influence is most pronounced. Additional retrospective analysis will reveal if, in fact, these are the first events of their kind or were simply some of the first to be discovered.

Last year, the editors emphasized the need for additional papers in the area of "impacts attribution" that investigate whether climate change's influence on the extreme event can subsequently be directly tied to a change in risk of the socio-economic or environmental impacts. Several papers in this year's report address this challenge, including Great Barrier Reef bleaching, living marine resources in the Pacific, and ecosystem productivity on the Iberian Peninsula. This is an increase over the number of impact attribution papers than in the past, and are hopefully a sign that research in this area will continue to expand in the future.

Other extreme weather event types in this year's edition include ocean heat waves, forest fires, snow storms, and frost, as well as heavy precipitation, drought, and extreme heat and cold events over land. There were a number of marine heat waves examined in this year's report, and all but one found a role for climate change in increasing the severity of the events. While human-caused climate change caused China's cold winter to be less likely, it did not influence U.S. storm Jonas which hit the mid-Atlantic in winter 2016.

As in past years, the papers submitted to this report are selected prior to knowing the final results of whether human-caused climate change influenced the event. The editors have and will continue to support the publication of papers that find no role for human-caused climate change because of their scientific value in both assessing attribution methodologies and in enhancing our understanding of how climate change is, and is not, impacting extremes. In this report, twenty-one of the twenty-seven papers in this edition identified climate change as a significant driver of an event, while six did not. Of the 131 papers now examined in this report over the last six years, approximately 65% have identified a role for climate change, while about 35% have not found an appreciable effect.

Looking ahead, we hope to continue to see improvements in how we assess the influence of human-induced climate change on extremes and the continued inclusion of stakeholder needs to inform the growth of the field and how the results can be applied in decision making. While it represents a considerable challenge to provide robust results that are clearly communicated for stakeholders to use as part of their decision-making processes, these annual reports are increasingly showing their potential to help meet such growing needs.

30. FUTURE CHALLENGES IN EVENT ATTRIBUTION METHODOLOGIES

Peter A. Stott, Nikos Christidis, Stephanie C. Herring, Andrew Hoell, James P. Kossin, and Carl J. Schreck III

Since these reports began five years ago, they have played an important part in the development and remarkable advancement of the science of event attribution. At the start of this endeavor, only a few events had been studied, geographical coverage was limited, and the focus had been mainly on extreme temperature events. Now, the range of events covered includes rain storms, droughts, tropical storms, and wildfires, as well as heat waves.

The website Carbon Brief[1] has produced a graphical inventory of studies from this report along with other peer-reviewed literature. It shows a growing geographical coverage over the last five years and a developing wealth of evidence pointing to the significant effects of human-induced climate change on many extreme events. The majority of attribution studies have been published in these annual reports. This demonstrates the important role these reports have taken, thanks to the continuing engagement by the scientific community in this endeavor.

The breadth and depth of these articles demonstrate a notable developing maturity of this science. At the same time, a few important challenges still remain, and this latest report highlights three of these. They are: 1) the role of methodological choices in determining the outcome of event attribution studies; 2) the need to better assess the influence of human-induced climate change on the impacts of extreme events; and 3) the growing needs of a wider range of stakeholders to inform decision making.

First, it is becoming increasingly apparent that different methodological choices can lead to important differences in the results of event attribution studies. To take one example from this report, the study of the air pollution episode in Europe in December 2016 (Vautard et al. 2018) found different results depending on the type of climate model used. With a multimodel ensemble, a significant human-induced effect was found on the stagnant winter time conditions that prevailed over northwestern Europe during that month, but this was not found with two single-model ensembles. The record 2016 heat in Asia was found not to be possible without human-caused climate change, and the authors concluded the fraction of attributable risk (FAR) to climate change was effectively 1. This result is based on the atmospheric general circulation model (AGCM) simulations using the observed sea surface temperatures (SST). Thus, it is suggested that "the observed heat anomaly have zero probability of occurrence with the certain, observed, SST variability pattern." However, it is not clear how the FAR would be impacted if the uncertainty of the natural variability of SST were considered.

Attribution results are potentially sensitive to methodological choices. Thus, it is important to clearly communicate the methodological choices within each study and, when possible, also to explore such methodological sensitivities in the study itself. In last year's issue, we included additional information on the methods used in the summary Table 1.1 (pages S4–S5), and this year we continue with this additional contextual information. Even so, there is an ongoing debate in the scientific community about the effects of methodological choices and optimal strategies for attribution of extreme events. For example, two recent companion pieces in *Climatic Change* took alternative viewpoints about the role of statistical paradigms in event attribution studies (Mann et al. 2017; Stott et al. 2017). Further work is needed to fully understand the effects such choices are having, as summarized by the statistics in Table 1.1 of the results in this report (p. S4).

Second, clearly much more should be done to better assess any links between the impacts of extreme

[1] www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world

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events to human-induced climate change. Traditionally, those who are part of the impacts community have focused on assessing the extent to which impacts such as changes in ecosystems can be attributed to variations in climate, howsoever caused. Ultimately, however, if we wish to make statements about links between impacts and human-induced climate change we need to differentiate possible natural climatic effects from human-induced ones. This is a challenge. We have been keen to encourage contributions to this latest report that address impacts. The submissions provide important new information but also illustrate the challenges in making such links.

Brainard et al. find that coral reef and seabird communities were disrupted by the record-setting sea surface temperatures of the central equatorial Pacific during the 2015/16 El Niño. This, by linking a particular meteorological event to impacts on marine ecosystem, is in itself an important conclusion. But this conclusion by itself would not be sufficient to be included in this issue because it does not assess the link to anthropogenic climate change. However, by making a link to a companion paper in this issue by Newman et al., which shows evidence that record warm central equatorial Pacific temperatures during the 15/16 El Niño reflect an anthropogenically forced trend, Brainard et al. are able to make an indirect two-step link to human-induced climate change. Such a two-step approach as illustrated here in Brainard et al. has been recognized by IPCC as a suitable method for attributing impacts (Hegerl et al. 2009). The value of this type of information to the marine resource management community is included as a Perspectives piece co-authored by the NOAA National Marine Fisheries chief scientist (Webb and Werner 2018). The authors describe the value of attribution results that assess the different drivers impacting living marine resources when making management decisions, in particular for considering potential future impacts to resources such as fisheries stocks.

Third, as the science matures and a mounting focus builds on possible links between extreme events and climate change, with a view to better adapting and to better partitioning the costs of climate change, there is increasing interest in applying this science. In the legal field, for example, there is an argument that attribution studies can be used to help courts determine liability for climate-related harm (Marjanan et al. 2017). In the past, beyond the scientific community, these results have primarily been used with stakeholders for whom very rapid analyses may be particularly relevant, for example those engaged in building resilience in the aftermath of an extreme event, or the media and other climate change science communicators. Today, stakeholders have expanded to include those involved in the regulatory, legal, and management frameworks who increasingly may find such approaches potentially useful.

While it represents a considerable challenge to provide robust results that are clearly communicated for stakeholders to use as part of their decision-making processes, these annual reports are increasingly showing their potential to help meet such growing needs. By taking a middle road in terms of timescale of delivery—longer than the very rapid results needed by the media but shorter than many academic contributions—and by using relatively standard approaches that have been previously peer reviewed, advances being made in these reports point the way forward toward a greater use of event attribution studies in decision-making contexts.

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Table 1.1. SUMMARY of RESULTS

	ANTHROPOGENIC INFLUENCE ON EVENT		
	INCREASE	DECREASE	NOT FOUND OR UNCERTAIN
Heat	Ch. 3: Global Ch. 7: Arctic Ch. 15: France Ch. 19: Asia		
Cold		Ch. 23: China Ch. 24: China	
Heat & Dryness	Ch. 25: Thailand		
Marine Heat	Ch. 4: Central Equatorial Pacific Ch. 5: Central Equatorial Pacific Ch. 6: Pacific Northwest Ch. 8: North Pacific Ocean/Alaska Ch. 9: North Pacific Ocean/Alaska Ch. 9: Australia		Ch. 4: Eastern Equatorial Pacific
Heavy Precipitation	Ch. 20: South China Ch. 21: China (Wuhan) Ch. 22: China (Yangtze River)		Ch. 10: California (failed rains) Ch. 26: Australia Ch. 27: Australia
Frost	Ch. 29: Australia		
Winter Storm			Ch. 11: Mid-Atlantic U.S. Storm "Jonas"
Drought	Ch. 17: Southern Africa Ch. 18: Southern Africa		Ch. 13: Brazil
Atmospheric Circulation			Ch. 15: Europe
Stagnant Air			Ch. 14: Western Europe
Wildfires	Ch. 12: Canada & Australia (Vapor Pressure Deficits)		
Coral Bleaching	Ch. 5: Central Equatorial Pacific Ch. 28: Great Barrier Reef		
Ecosystem Function		Ch. 5: Central Equatorial Pacific (Chl-***a*** and primary production, sea bird abundance, reef fish abundance) Ch. 18: Southern Africa (Crop Yields)	
El Niño	Ch. 18: Southern Africa		Ch. 4: Equatorial Pacific (Amplitude)
TOTAL	18	3	9

	METHOD USED	Total Events
Heat	Ch. 3: CMIP5 multimodel coupled model assessment with piCont, historicalNat, and historical forcings Ch. 7: CMIP5 multimodel coupled model assessment with piCont, historicalNat, and historical forcings Ch. 15: Flow analogues conditional on circulation types Ch. 19: MIROC-AGCM atmosphere only model conditioned on SST patterns	
Cold	Ch. 23: HadGEM3-A (GA6) atmosphere only model conditioned on SST and SIC for 2016 and data fitted to GEV distribution Ch. 24: CMIP5 multimodel coupled model assessment	
Heat & Dryness	Ch. 25: HadGEM3-A N216 Atmosphere only model conditioned on SST patterns	
Marine Heat	Ch. 4: SST observations; SGS and GEV distributions; modeling with LIM and CGCMs (NCAR CESM-LE and GFDL FLOR-FA) Ch. 5: Observational extrapolation (OISST, HadISST, ERSST v4) Ch. 6: Observational extrapolation; CMIP5 multimodel coupled model assessment Ch. 8: Observational extrapolation; CMIP5 multimodel coupled model assessment Ch. 9: Observational extrapolation; CMIP5 multimodel coupled model assessment	
Heavy Precipitation	Ch. 10: CAM5 AMIP atmosphere only model conditioned on SST patterns and CESM1 CMIP single coupled model assessment Ch. 20: Observational extrapolation; CMIP5 and CESM multimodel coupled model assessment; auto-regressive models Ch. 21: Observational extrapolation; HadGEM3-A atmosphere only model conditioned on SST patterns; CMIP5 multimodel coupled model assessment with ROF Ch. 22: Observational extrapolation, CMIP5 multimodel coupled model assessment Ch. 26: BoM seasonal forecast attribution system and seasonal forecasts Ch. 27: CMIP5 multimodel coupled model assessment	
Frost	Ch. 29: *weather@home* multimodel atmosphere only models conditioned on SST patterns; BoM seasonal forecast attribution system	
Winter Storm	Ch. 11: ECHAM5 atmosphere only model conditioned on SST patterns	
Drought	Ch. 13: Observational extrapolation; weather@home multimodel atmosphere only models conditioned on SST patterns; HadGEM3-A and CMIP5 multimodel coupled model assessent; hydrological modeling Ch. 17: Observational extrapolation; CMIP5 multimodel coupled model assessment; VIC land surface hdyrological model, optimal fingerprint method Ch. 18: Observational extrapolation; *weather@home* multimodel atmosphere only models conditioned on SSTs, CMIP5 multimodel coupled model assessment	
Atmospheric Circulation	Ch. 15: Flow analogues distances analysis conditioned on circulation types	
Stagnant Air	Ch. 14: Observational extrapolation; Multimodel atmosphere only models conditioned on SST patterns including: HadGEM3-A model; EURO-CORDEX ensemble; EC-EARTH+RACMO ensemble	
Wildfires	Ch. 12: HadAM3 atmospere only model conditioned on SSTs and SIC for 2015/16	
Coral Bleaching	Ch. 5: Observations from NOAA Pacific Reef Assessment and Monitoring Program surveys Ch. 28: CMIP5 multimodel coupled model assessment; Observations of climatic and environmental conditions (NASA GES DISC, HadCRUT4, NOAA OISSTV2)	
Ecosystem Function	Ch. 5: Observations of reef fish from NOAA Pacific Reef Assessment and Monitoring Program surveys; visual observations of seabirds from USFWS surveys. Ch. 18: Empirical yield/rainfall model	
El Niño	Ch. 4: SST observations; SGS and GEV distributions; modeling with LIM and CGCMs (NCAR CESM-LE and GFDL FLOR-FA) Ch. 18: Observational extrapolation; *weather@home* multimodel atmosphere only models conditioned on SSTs, CMIP5 multimodel coupled model assessment	
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