Robust attribution and projection of extreme heat events to human influence on the climate

Nicholas J. Leach

St. Cross College
University of Oxford

A thesis submitted for the degree of
Doctor of Philosophy

Trinity 2022

Abstract

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Institutional

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Contents

List of Figures

List of Abbreviations

SST . . . . . Sea surface temperatures.

Quote

— author

1 Introduction

In this chapter I introduce the problem of attribution of individual extreme weather events to anthropogenic climate change. I review the current methodologies and frameworks that address this problem, in particular the contrasting storyline and probabilistic approaches to attribution. Although these frameworks are gaining acceptance and maturity, I suggest that a weather forecast-based approach could further increase the trustworthiness of attribution studies. Finally, I provide a conceptual sketch of these various attribution frameworks within a simple non-linear dynamical system.

Author contributions: This chapter is based on the the following publication *

Surname, I1. I2., Surname, I1. I2. (year). **Title**. *Journal*, **vol**(issue), pages. DOI

Contents

*with the author contributing as follows.

1.1 Section

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Quote

— author

2

Conventional probabilistic attribution

Here I present a probabilistic extreme event attribution of the 2018 European heatwave. Whilst demonstrating the methodologies behind this framework, I examine how one particular aspect of probablistic event attribution – the definition of the event – projects strongly onto the quantitative results. In the closing remarks, I reflect on potential issues with the approach taken within the chapter, and suggest ways in which these could be overcome.

Author contributions: This chapter is based on the the following publication [*]

Leach, N. J., Li, S., Sparrow, S., van Oldenborgh, G. J., Lott, F. C., Weisheimer, A., & Allen, M. R. (2020). **Anthropogenic Influence on the 2018 Summer Warm Spell in Europe: The Impact of Different Spatio-Temporal Scales**. *Bulletin of the American Meteorological Society*, **101**(1), S41-S46. https://doi.org/10.1175/BAMS-D-19-0201.1

Contents

[*]with the author contributing as follows. Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Resources, Visualisation and Writing – original draft.

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Quote

— author

3 Attribution and projection

In this chapter, I explore the close links between attribution of extreme weather events and their projection with climate change. I study a novel set of large-ensemble atmosphere-only model experiments to show that such large-ensembles are necessary to generate samples of the most extreme weather events, an understanding of which is crucial for climate change adaptation. In the closing discussion, I consider how forecast-based attribution could be leveraged to provide similar samples of specific future extreme weather events.

Author contributions: This chapter is based on the the following publication *

Leach, N. J., Watson, P. A. G., Sparrow, S. N., Wallom, D. C. H., & Sexton, D. M. H. (2022). **Generating samples of extreme winters to support climate adaptation**. *Weather and Climate Extremes*, **36**(), 100419. https://doi.org/10.1016/j.wace.2022.100419

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Quote

— author

4

Partial forecast-based attribution

This chapter contains much of the conceptual description of, and motivation for, forecast-based attribution. Using the well-predicted February 2019 heatwave as a case study, I carry out forecasts with the operational medium-range ECMWF model in which I have instantaneously perturbed the CO_2 concentration at initialisation. These perturbed forecasts allow me to estimate the direct contribution of diabatic heating due to CO_2 to the heatwave. This partial attribution provides a proof-of-concept of the forecast-based approach, and I close with a discussussion of how I could perform a more complete estimate of anthropogenic influence on a specific extreme event in following work.

Author contributions: This chapter is based on the the following publication *

Leach, N. J., Weisheimer, A., Allen, M. R., & Palmer, T. (2021). **Forecast-based attribution of a winter heatwave within the limit of predictability**. *Proceedings of the National Academy of Sciences*, **118**(49), . https://doi.org/10.1073/pnas.2112087118

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Quote

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5 Forecast-based attribution

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Quote

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6 Discussion

Chapter description.

Contents

6.1 Section

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6.2 Concluding remarks

Appendices

The first kind of intellectual and artistic personality belongs to the hedgehogs, the second to the foxes . . .

— Sir Isaiah Berlin [1]

References

[1] Isaiah Berlin. *The Hedgehog and the Fox: An Essay on Tolstoy's View of History*. English. Ed. by Henry Hardy. 2nd. Princeton University Press, June 2013.