Earth 2020

An Insider's Guide to a Rapidly Changing Planet

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Philippe Tortell (ed.), *Earth 2020: An Insider's Guide to a Rapidly Changing Planet*. Cambridge, UK: Open Book Publishers, 2020, https://doi.org/10.11647/OBP.0193

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ISBN Paperback: 978-1-78374-845-7
ISBN Hardback: 978-1-78374-846-4
ISBN Digital (PDF): 978-1-78374-847-1
ISBN Digital ebook (epub): 978-1-78374-848-8
ISBN Digital ebook (mobi): 978-1-78374-849-5
ISBN Digital (XML): 978-1-78374-850-1
DOI: 10.11647/OBP.0193

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Cover design: Anna Gatti

Weather

Neville Nicholls

I woke early on Sunday, 8 February 2009, in my house on the edge of Melbourne, the capital of the State of Victoria in southeast Australia. During the night, I had worked on a way to estimate the human health impact of extreme weather events, and I wanted to apply it to the heat wave that had hit southeast Australia the previous weekend, to see if the recently introduced heat wave alert system had helped save lives. I switched on my computer, and then the TV, to see the early reports of the bushfires that I knew would have occurred the previous day. For the past week, the Australian Bureau of Meteorology had been predicting that Saturday, 7 February, would be a day of very high temperatures and extreme bushfire risk. The Premier of Victoria was predicting the worst bushfire weather in the State's history.

With such dramatic predictions, and with an alert public and well-prepared emergency response crews, I expected substantial damage to properties, forests and farms, but few, if any, deaths. I was wrong. The first thing I saw on TV was the helicopter view of Marysville, a much-loved tourist town in the hills east of Melbourne. Or, more accurately, I saw a view of the charred and blackened remains of the town. I realized immediately that such destruction, caused by the combination of an unprecedented decade-long drought, record temperatures (46.4°C) and strong winds, would have led to many deaths. Indeed, more than 170 lives were lost across Victoria that day, despite the accurate predictions and warnings of an imminent public emergency.

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As bad as the devastation was on February 7, Black Saturday, even more lives had been lost the previous weekend during an unprecedented heat wave when temperatures exceeded 43°C for three consecutive days. The problem I had been grappling with was to estimate, in near real time, the death toll from such heat waves. Traditionally, scientists studying the human impacts of heat waves would have to wait many months before the death toll could be calculated, relying on government bureaucracies to compile data from hospitals and nursing homes. But by comparing the number of obituaries in newspapers in the days after a heat wave with the numbers in more typical weeks, I could estimate the extra mortality caused by the heat wave. As I watched the TV footage of the destruction from what was already being called the Black Saturday bushfires, I started calculating the excess mortality of the previous week's heat wave. I hoped that the heat wave alert system would have meant far fewer lives had been lost than in heat waves in the past, but it quickly became apparent that, despite the forecasts and heat wave alerts, as many as 500 more people had died in southeast Australia over the previous weekend than would have typically been expected for that time of year.

The deadly 2009 Australian heat wave and the fires that accompanied the heat wave were just two of the many previously unprecedented weather extremes that have been observed in recent decades. These extremes show no sign of relenting, as witnessed by the massive drought-fuelled bush fires that consumed large areas of southeast Australia in 2020. Looking back over the past half-century, the impacts of climate change on extreme weather become increasingly clear. And as our understanding of extreme weather improves, so too does our forecasting ability, providing us with tools to increase resilience in an uncertain climate future. These tools may help us avoid some of the impacts of continued global warming, if politicians are unable or unwilling to act to slow this warming.

Scientists have been warning for decades that some extreme weather events would change in frequency or intensity as the world warmed due to the burning of fossil fuels. And indeed, over the past fifty years, this has proven to be the case.[1] High temperatures, including heat waves, have become more frequent. Globally, the number of warm days (days exceeding the ninetieth percentile of historical daily maximum temperatures) has doubled since 1970, while the number of cool nights (below the tenth percentile of historical daily minimum temperatures) has halved. The extreme weather associated with severe bushfire risk has also been increasing, while heavy rainfall events appear to be becoming more frequent.

In the absence of decisive political action to mitigate the global warming trend and its effects on extreme weather, bureaucrats and scientists around the world have begun developing and implementing new alert systems for extreme weather events, especially heat waves. This work has taken on an increased sense of urgency after the 2003 European heat wave that led to the death of as many as 70,000 people. By 2009, a heat event alert system had been established for Melbourne, based on the observation that mortality in the city increased substantially when the daily average temperature exceeded 30°C. An alert was initiated when forecasts by the Bureau of Meteorology indicated that this threshold would be crossed. Without this early warning system, even more people would likely have died in the 2009 Australian heat wave.

The development of early warning systems for extreme weather events has become possible in recent years because of improved weather forecasting capabilities. Today, in 2020, national weather services can forecast temperatures 5–6 days in advance more accurately than their predecessors in the early 1970s could forecast a single day in advance. These improvements have come from increased computing power, which has allowed ever more complex and realistic mathematical simulation of the atmosphere, and the increased availability of satellite observations to drive and refine model predictions. Thanks to these greatly improved weather forecasts, bureaucrats, politicians, the media, medical and emergency services and the public now have several days to implement strategies to minimize deaths from high temperatures and other extreme weather events. As global warming increases the frequency and intensity of heat waves, these alert systems can reduce some of the likely human cost of climate change.

Increased monitoring and forecasting skills allow us to observe the occurrence of a wide variety of weather extremes in addition to heat waves, and to predict their future trajectories. Extreme cold events also cause many deaths and illness in many parts of the world. Cold events have been decreasing in frequency and intensity in countries around the world, as another consequence of global warming. Nonetheless, cold events still occur, but these events can now be predicted days in advance, allowing us to reduce their health impacts. The combined effect of global warming, which reduces the frequency of cold events, and the improved forecasting of these events, will continue to reduce their deleterious effect on the human population.

Although the changing frequency of hot and cold extremes is very clear over the past fifty years, patterns in other extreme weather events are more difficult to identify. In some cases, this may reflect the absence of any real change in frequency of these events. But in other cases, it may be that changes in the way we observe particular weather phenomena are obscuring any real underlying change in their frequency or intensity. For instance, the increased availability of satellite observations since the 1970s has greatly improved our ability to detect tropical cyclones. Apparent increases in tropical cyclone activity may thus simply reflect better observations, rather than any real change in the frequency of cyclones.

Irrespective of any long-term trends, improved forecasting of tropical cyclones and other extreme weather, including storms, droughts and floods, has lessened their human impacts. Prior to the forecasting revolution of the last half-century, tropical cyclones were much more deadly. A single tropical cyclone in 1970, for instance, is believed to have caused more than 300,000 deaths in Bangladesh. Since that time, the mortality associated with tropical cyclones, even in countries with limited financial resources, has declined. For example, during Cyclone Fani in 2019, authorities in India and Bangladesh relied on improved monitoring and forecasting of the cyclone to move at least a million people out of the storm path, thereby drastically reducing the potential death toll. This reduction in the menace of tropical cyclones stems from improved satellite monitoring of these systems, and more accurate prediction of their trajectories, as well as the creation of improved alert systems and infrastructure to notify people of imminent danger and enable rapid evacuation. Looking to the future, cyclones, although still deadly, should not cause the enormous mortality seen half a century ago, even if their intensity increases on a warming planet.

Droughts are also changing as a result of global warming. Global warming has meant that droughts today are accompanied by higher temperatures than they would have been fifty years ago, and this trend towards warmer droughts will continue into the future. In some areas, there is also evidence that droughts have become more frequent (although this is not universal). Whether droughts in the future will be drier or longer-lasting will depend on the regional impacts of global warming on atmospheric circulation, which we cannot currently predict with confidence. It is even harder to predict how floods will change in the future, because of the complex factors at play. Over the past several decades, there has been an increase in intense precipitation events associated with global warming, and we can expect such changes to continue into the future. But the extent to which this increased rainfall will lead to flooding will depend, among other things, on alterations in the land surface (such as increasing road surfaces) and changes in riverbanks and drainage systems. Once again, our improved ability to monitor heavy rainfall events, using radar and satellites, has improved our ability to provide more timely forecasts of flooding. As these observing systems continue to evolve, they should help us avoid some of the greatest damage and threats posed by flooding, even if flooding events become more frequent.

Another significant improvement in our ability to cope with Earth's changing weather has been the development of seasonal climate forecasting. In some parts of the world, specifically those areas where the El Niño–Southern Oscillation (ENSO) dominates the inter-annual climate variability, the last fifty years have seen the development of scientific methods for forecasting seasonal droughts and extended heavy rain periods. Such seasonal forecasting of weather extremes was considered impossible in the 1970s, even by meteorologists and climate scientists. But by the mid-1980s, methods for seasonal forecasting of droughts had been developed, at least for some parts of the world. These seasonal forecasts, although lacking the skill achievable in near-term forecasting, provide hope that we might avoid some of the consequences of droughts and other inter-annual weather variability through adaptive crop and stock management, or the more timely provision of food relief. For example, if we can predict El Niño-related droughts across Pacific rim countries, we can ensure that drought relief arrives in a timely fashion, thereby avoiding famine in, say, the highlands of New Guinea, an area where droughts caused by the El Niño have led to severe famines in the past.

What about the smaller scale weather extremes, such as hailstorms and tornadoes? These short-term events are notoriously difficult to monitor, with historical records of such extremes relying heavily on subjective reports from observers. Such reports are, in turn, dependent on population density, amongst other factors. Thus, an increasing population in an area, for example, might lead to increased reports of hailstorms, even if the actual frequency is not changing. Disentangling such reporting biases from any real climate-forced change in these small-scale extremes is beyond our capabilities at present. We are thus left with little confidence in any apparent trends in these extremes, even over recent decades. Nevertheless, improved systems for detecting these small-scale extreme weather events, and our increased ability to issue and distribute short-term forecasts of their movement, have begun to allow populations to avoid some of the associated damages. Continued improvements in these monitoring and forecasting systems should help to further reduce the associated damage of short-lived extreme weather events, even if global warming increases their frequency or severity.

The past half-century has seen substantial changes in the frequency and intensity of some extreme weather events. But these fifty years have also seen advances in our ability to monitor and predict these extreme weather events (and others), thereby reducing the associated human impacts. In particular, meteorologists have vastly improved their ability to predict extreme hot and cold days, storms, bushfire weather and cyclones several days in advance. These improvements have led to the development of alert systems that have reduced the loss of life previously caused by such extremes. More can be done to improve these forecasts, and their public dissemination and use in communities. At the same time, seasonal climate forecasting has developed from a pie in the sky idea into a well-developed science, at least in some parts of the world and for some seasons. With this new tool, we can now predict some droughts and seasonal tropical cyclone activity, well in advance, providing opportunities for longer-term planning and disaster-reduction strategies.

The 2019–2020 Australian bushfire season provides a case in point. The economic damage of the fires will, no doubt, be huge, especially since the fires destroyed large areas where tourism is a major industry. But the human cost has been much lower than might have been the case if the fires had occurred twenty years ago. The long-range forecasts of a very severe fire season meant that the fires services were well prepared, and the shorter-range weather forecasts have helped them to fight the fires with greater effectiveness. Similarly, recent heat waves have led to fewer deaths than the 2009 heat wave, at least partly because of improved weather forecasts and heat wave alerts.

Looking forward, increasingly accurate weather forecasts, from days to months ahead, will allow us to reduce the damage — both economic and societal — that has been caused by weather extremes throughout human history, even as human actions lead to increases in the severity of some of these extremes. In the absence of concerted political action to slow the rate of global warming,[2] improved weather forecasting is perhaps the most important, immediate tool we have to offset some of the deleterious effects of human-caused climate change now and into the future.

Endnotes

1. J. Blunden, D. S. Arndt and G. Hartfield, 'State of the climate in 2017', *Bulletin of the American Meteorological Society*, 2018, 99, Si-S310, https://doi.org/10.1175/2018bamsstateoftheclimate.1; IPCC, 'Climate change 2013: The physical science basis', in *Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley, Cambridge, UK: Cambridge University Press, 2013, 383–464, https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf; IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*, ed. C. B. Field et al., Cambridge, UK: Cambridge University Press, 2012, https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf
2. See also 'Politics and Law' by Elizabeth May in this volume.