Institution: University of Reading		
Unit of Assessment: 7 - Earth Systems and Environmental Sciences		
Title of case study: Communicating climate change through spirals and stripes visualisations and engaging a diverse global audience of millions		
Period when the underpinning research was undertaken: Between 2012 and 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Ed Hawkins	**Role(s) (e.g. job title):** Professor of Climate Science	**Period(s) employed by submitting HEI:** 2005 to Present
Period when the claimed impact occurred: Between 2016 and 31 December 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Climate change is a complex issue for society to understand and, as a consequence, to respond to. If society is to avoid breaching the internationally agreed limits to climate change, more informed debate is required about the timing and scale of transformative changes required to policy and lifestyles. Engagement and dialogue are key to triggering the widespread everyday conversations that are needed to lead to this more informed debate. At the heart of this problem has been the lack of a simple means of emphatically conveying that significant and recent climate change is underway and will affect individuals, and particularly to do so in a way that does not need arguments or information that require scientific literacy. This case study describes the use of research that has inspired and achieved mass public communication and engagement using specifically designed simple visualisations about how the climate has changed. More specifically, research at Reading has examined the importance of how changes in global temperature are estimated and defined, and how those changes are experienced at the local level. This has improved understanding and communication of historical temperature changes and resulted in the development of the Climate Spiral and the Warming Stripes. These two visualisations have reached millions, becoming iconic representations of concern for climate change and now widely recognised around the world. Underpinned by the best available quantitative climate observations and research, they have been effective in raising awareness at scale, starting conversations that may lead to solutions.

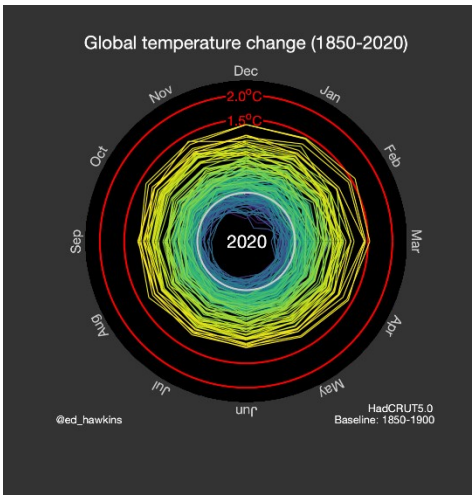
2. Underpinning research

Since 2006, Hawkins has published a wide body of highly-cited research dealing with climate change detection and quantification. This has been complemented by very active and enthusiastic communication and engagement campaigns in which Hawkins has looked for new ways of explaining the extent of recent climate change to wider audiences. This engagement has been through presentations, social media platforms, for example Twitter, his *Climate Lab Book* blog and other online publications such as *The Conversation*. Learning from these experiences has led Hawkins to increasingly focus on developing climate change visualisations as a means of effective engagement at scale. This visualisation work requires the statistical robustness of temperature records, baselines, signal detection, and attribution, which has been a focus of Hawkins' fundamental research.

On the statistical robustness of the global temperature record, in [R1] Hawkins analysed the warming 'hiatus' (which had been widely discussed and debated between 2000 and 2010), in terms of how inter-annual and decadal variations in climate can temporarily mask or enhance the changes caused by humans, and how the observations were consistent with model simulations for the same period when the variations were accounted for. In [R2], Hawkins showed that observational warming records and climate model simulations could be even more closely reconciled by accounting for the geographic bias in observational records to places where the warming is naturally slower.

When the United Nations Framework Convention on Climate Change (UNFCCC) 2015 Paris Agreement agreed to limit global temperature rise to "well below 2°C above pre-industrial levels", Hawkins noted that it did not specifically define the meaning of 'pre-industrial' or discuss the sensitivities to the choice of a pre-industrial baseline which leads to ambiguity in the meaning of the temperature limits. Around this time Hawkins started experimenting with visualisations of climate change, leading to the development of the Climate Spiral, a dynamic animated graphic which grows from the 1850 to 1900 average towards the present day, matching the

Intergovernmental Panel on Climate Change (IPCC) 2013 5th Assessment Report (AR5), which used 1850 to 1900 from which to measure changes in temperature. A commentary of how the Climate Spiral was developed and used was published, building on Hawkins' research into how global temperatures have changed over time. The culmination of the research into defining the meaning of 'pre-industrial' separately from a 'temperature change baseline', appeared in [R3], a paper led by Hawkins with an international group of co-authors. This provided a detailed examination of possible definitions of 'pre-industrial periods', recommending 1720 to 1800 as a more justifiable choice; it also recommended that temperature targets, such as those specified in Paris, be defined around more recent, better observed, 'temperature baseline' time periods.



In May 2018, Hawkins was invited to speak to a broad audience about climate change at the Hay-on-Wye Literary Festival. Hawkins wanted to create a simpler visualisation focused on regional climate change and developed the 'Warming Stripes' for the town of Hay, showing how temperatures had changed there in the previous 100 years (Figure 2). The Warming Stripes are a series of vertical stripes, one for each year, coloured by the average temperature in that year (blue = colder, red = hotter). Figure 3 depicts the annual changes in global temperature from 1850 to 2019, with change from mainly blue (colder) to mainly red (warmer) through time, with much less interannual variability than the local Hay stripes, showing a compelling and simple story about recent warming temperatures.

***Figure 1**: Spiral shows the average global temperature for each month, from 1850 to 2020, relative to the 1850 to 1900 baseline period, shown as a white inner circle. As the viewer moves outwards from the baseline circle (0°C), the temperature increases. See: http://www.climate-lab-book.ac.uk/spirals/*

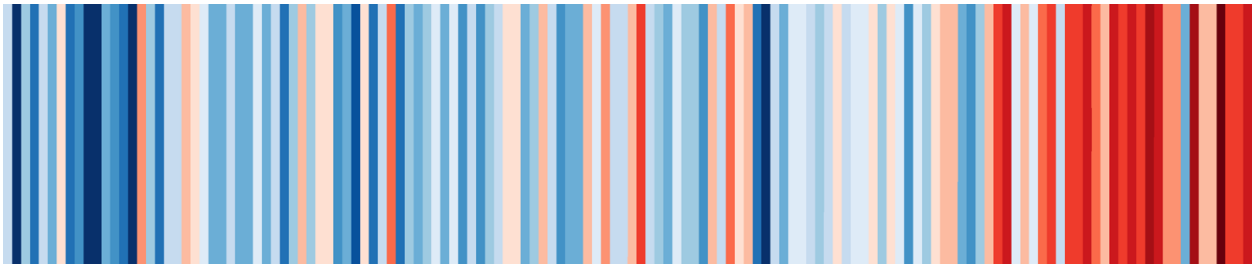


***Figure 2:** Warming stripes for the town of Hay from 1884 to 2017, as shown at the Festival 2018.*

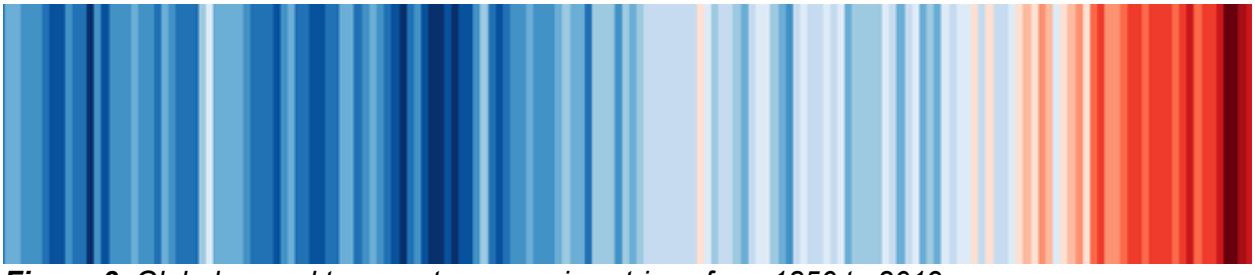


***Figure 3**: Global annual temperature warming stripes from 1850 to 2019.*

Hawkins quickly realised that to make this image more useful and comparable for different regions, a signal-to-noise scaling was needed (dividing the temperature anomaly in each year by the amplitude of the natural variability in the region). This allows the very different temperature variations found in different regions to be displayed with the same colour scale. These scaling ideas were first developed in [R4] for determining the robustness of climate change signals in different model simulations, and were subsequently used in IPCC AR5 Chapter 11 "*Near-term Climate Change: Projections and Predictability.*" In [R5], these scaling ideas were extended to determine the relationships between global and regional temperature change signals.

These insights were key to enabling the creation of a worldwide array of regional Warming Stripes using a consistent algorithm, allowing their launch on the *#ShowYourStripes* website (www.showyourstripes.info). This allows anyone from around the world to find and freely download their country's Warming Stripes to see how their temperatures have changed. Users can also download the global changes, or changes in other regions, inviting greater appreciation of how change is occurring. The regional climate stripes visual comparisons also stimulated Hawkins' further research, leading to [R6], that highlights in which regions, and for which climate indicators, the effects of climate change can already be confidently claimed.

This visualisation work has therefore drawn on, and sometimes stimulated, Hawkins fundamental research related to statistical robustness of temperature records, baselines, signal detection, and change attribution through modelling.

3. References to the research

Research Quality Statement: All references were published in the peer-reviewed literature and meet or exceed the two-star quality criteria ("provides useful knowledge and influences the field"; "involves incremental advances"). Evidence of influence is indicated by Web of Science Citations in square brackets, as at December 2020.

[R1] **Hawkins, E.**, Edwards, T. and McNeall, D. (2014) 'Pause for thought'. *Nature Climate Change*, **4** (3). 154-156. doi: https://doi.org/10.1038/nclimate2150 [30]

[R2] Richardson, M., Cowtan, K., **Hawkins, E.** and Stolpe, M. B. (2016). 'Reconciled climate response estimates from climate models and the energy budget of Earth'. *Nature Climate Change*, **6** (10). 931-935. doi: https://doi.org/10.1038/nclimate3066 [73]

[R3] **Hawkins, E.**, Ortega, P., Suckling, E., Schurer, A., Hegerl, G., Jones, P., Joshi, M., Osborn, T. J., Masson-Delmotte, V., Mignot, J., Thorne, P. and van Oldenborgh, G. J. (2017). 'Estimating change in global temperature since the pre-industrial period'. *Bulletin of the American Meteorological Society*, **98** (9).1841-1856. doi: https://doi.org/10.1175/BAMS-D-16-0007.1 [91]

[R4] **Hawkins, E.** and Sutton, R. (2012). 'Time of emergence of climate signals'. *Geophysical Research Letters*, **39** (1). L01702. doi: https://doi.org/10.1029/2011GL050087 [220]

[R5] Sutton R, Suckling E & **Hawkins E**., (2015). 'What does global temperature tell us about local climate?', *Phil. Trans. A*, **373**, 20140426 doi: https://doi.org/10.1098/rsta.2014.0426 [37]

[R6] **Hawkins, E**., Frame, D., Harrington, L., Joshi, M., King, A., Rojas, M. and Sutton, R. (2020), 'Observed emergence of the climate change signal: from the familiar to the unknown'. *Geophysical Research Letters*, **47** (6). e2019GL086259. doi: https://doi.org/10.1029/2019GL086259 [3]

4. Details of the impact

The Climate Spiral and the Warming Stripes have become iconic representations of concern for climate change, widely recognised around the world. Underpinned by science, and freely available to download, they have been effective in raising awareness at scale and inspiring creative proliferation in surprising ways. They remind people, including policymakers, of the recent abrupt warming, while also containing scientific content and being adaptable to highlight specific regional concerns.

The Climate Spiral: In May 2016, Hawkins posted the Climate Spiral (see Figure 1) on his Twitter account (@ed_hawkins) and it 'went viral' – reaching more than 4 million people and stimulating dialogue about the effects of climate change [S1(i)]. On 6 August 2016, the opening ceremony of the Rio Olympics was watched by over 1bn people. The ceremony included a segment on climate change [S1(ii)] and featured an animated spiral graphic representation of rising global temperatures. Paulo Artaxo, the science advisor to the Rio ceremony, confirmed that the animation used in the ceremony was a redrawn version of Reading's original design [S1(iii)]. In addition to the Olympics, policymakers in the UK and overseas have also engaged with the Climate Spiral. For example, the graphic description was presented in Spanish [S2], and other languages, by ShareAmerica, the U.S. Department of State's platform for communicating American foreign policy worldwide.

The Warming Stripes: Following the success of the animated spiral, Hawkins designed the Warming Stripes to be as simple as possible, to start conversations about our warming world and the risks of climate change with the widest audience, on social media and beyond, without the pre-requisite of scientific knowledge. Engagement with the Warming Stripes began at the Hay Festival but swiftly moved into social media, television and print media, physical objects, and politics.

In May 2018, after Hay, Hawkins launched the Warming Stripes on social media and their publicity began to spread through mainstream media. The results were extensive and creative. The Warming Stripes were picked up by the BBC and used on programmes such as *Weather World* and *Click*, and by ITV on the *Evening News* [S3] as an illustration of climate change. Television weather forecasters around the world launched their own campaign based on the Warming Stripes, entitled *#MetsUnite* (started by meteorologist Jeff Berardelli in Florida, USA who was inspired by the compelling data visualisation). On 21 June (the summer solstice) in 2018 and 2019, and 18 June 2020, the now annual *#MetsUnite* campaign has resulted in live broadcast coverage of the Warming Stripes by up to 120 TV weather forecasters in 30 countries, with ensuing discussions about climate change on air. Many forecasters wore Warming-Stripe-patterned clothing such as ties, scarves or earrings. Posts from the 2018 event can be found on the AGU blog and in ecointerviews.com [S4].

In Spring 2019, the international movement *School Strikes for Climate* started to proliferate globally, and Hawkins decided to support it by making the Warming Stripes widely available at a regional level. Thus, in May 2019, the University of Reading Department of Meteorology collaborated with the Institute of Environmental Analytics (also based at the University of Reading) and launched the *#ShowYourStripes* campaign. The Warming Stripes became public and freely available, with at least one set of Stripes created for every country around the world; this allowed anyone to see and further communicate how climate is warming in their region. In the first week of the *#ShowYourStripes* initiative, there were 1 million downloads from 180,000 unique visitors in over 150 different countries. The campaign asked people to adopt the Warming Stripes for their social media profiles and share the graphics for their own country, enabling anyone to join the conversation. The #ShowYourStripes website was still receiving approximately 20,000 unique visitors and downloads per month in December 2020.

In Summer 2019, rock band *Enter Shikari* used the Warming Stripes as a backdrop during their music tour gigs, including at Reading and Leeds Festivals, prominently displaying the graphic to tens of thousands of music fans [S5]. The lead singer discussed the meaning of the Warming Stripes on stage during each performance, providing a new and non-traditional forum for engagement about the realities of climate change. As a result, a full A4 print of the Warming Stripes was included in *Kerrang*, a leading UK rock music magazine with international distribution. More magazine and newspaper articles followed [S6].

In September 2019 *The Economist* magazine used the Warming Stripes as the front cover of their 'Climate Issue' which reached 1.5 million readers. Several national newspapers subsequently used the Warming Stripes on their front pages, extending its reach to millions more, including: *The Guardian* (UK) (readership: 35.6 million per month), *FAZ* (Germany; 830,000 readers per issue in 2019), *Wiener Zeitung* (Austria; readership 61,000 per week in 2020), *Internazionale* (Italy), *Publico* (Portugal; 7,592,279 unique online visitors each month), *Folha* (Brazil; monthly readership: 328,438) and *Helsingin Sanomat* (Finland; 2019 readership 339,437). Other online articles discussing the graphics have since appeared in *Design Week* (readership: 11,000 per week), *Washington Post*, *Vox*, *Fast Company* (circulation: 757,858, June 2012) and *Forbes* (readership: 140 million per month). A montage of most of the print media front pages can be seen in the Climate Stripes Scrapbook [S6].

Hawkins' warming visualisations have also been widely adopted in government and by politicians. The Met Office now use both the Spiral and Stripes graphics in their *What is Climate Change?* webpage [S7]. The Warming Stripes were used as a prominent backdrop, as well as appearing in individual exhibits, at the 25th UNFCCC Conference of the Parties (COP25) event in Madrid in

December 2019. During the February 2020 US State of the Union address, several Senators and Representatives wore badges with the Warming Stripes to show their support for more action on climate change [S8]. The US House Committee on the Climate Crisis also adopted the Warming Stripes as part of their logo for the 2020 session of Congress, crediting the University of Reading [S9]. All of the aforementioned images/logos can be found in the Climate Stripes Scrapbook [S6].

Many different creative and innovate uses for the Warming Stripes continue to appear, keeping climate change in the public eye. For example, the graphics have been painted on a tram in Freiburg (Germany) and on a Tesla car (Minnesota, USA), recreated out of stained glass, painted on walls in Spain, New York and Jersey, and used during light shows in Denmark and Berlin. Various groups of knitters, including the Women's Institute have also recreated them, and many commercially available products such as dresses, t-shirts, neck buffs and face masks incorporate the graphics. Protest groups at the recent global climate strikes in multiple locations from Oxford to The Hague, and from Nigeria to Kuala Lumpur have used them, and museums have adopted the graphics to educate the public. Many of these uses are also captured in the Climate Stripes Scrapbook [S6].

The Climate Spiral was shortlisted for data insight and consulting company Kantar's *Information is Beautiful* award in 2016. The Climate Stripes won the University of Applied Sciences Potsdam's *Vis for Future* award in 2019, as reported by ITV, and was runner up in *The Guardian*'s Marketing and Communications Campaign Awards 2020. In January 2020, Hawkins was awarded an MBE for services to climate science and science communication in the New Year's honours list [S10].

Summary: Engagement and dialogue are key to initiating the everyday conversations about climate change which lead on to demand for more informed debate and action. Hawkins' graphics have been tremendously successful in promoting these conversations and debates on a worldwide scale. By intentionally making the graphics free and easy to download, use, adapt and personalise, Hawkins has removed barriers to their adoption by the public. Consequently, they have been used by a diverse public audience across the globe– from those who are not used to seeing scientific graphics, to non-governmental organisations, and from TV weather presenters to artists. The simplicity of the graphics has enabled their use in many different ways, starting conversations amongst groups who may not normally talk about climate change. The Climate Spiral and Warming Stripes have now found a place in the global public imagination and in doing so have become important symbols to engage the wider population in discussions about climate change and society's response to it.

5. Sources to corroborate the impact

[S1] (i) May 2016 original spiral tweet on Twitter @ed_hawkins
(ii) 2016 Rio Olympics Opening Ceremony Clip – see climate change content @ 53:50
(iii) Choosing of the Climate Spiral for the Rio Olympics, August 2016

[S2] Spanish version of Climate Spiral on Share America Government Website

[S3] ITV News in reference to Extreme events in summer 2018

[S4] Blog Reporting of annual #MetsUnite campaign in June 2018, 2019 and 2020
BBC article coinciding with #MetsUnite June 2019 #MetsUnite reporting 2018

[S5] The Conversation article about Reading Festival Stage 2019

[S6] Climate Stripes in use - Scrapbook: this site is a collection of images of the Climate stripes in use around the world

[S7] Met Office "What is Climate Change?" webpage

[S8] BBC video from State of the Union, February 2020

[S9] US House Committee on the Climate Crisis 2020 session webpage: https://climatecrisis.house.gov/about

[S10] (i) Stripes win the 2019 "Vis for future" Award, Twitter discussion by Laura Tobin on Good Morning Britain
(ii) Stripes are the runners-up in 2020 Guardian Marketing and Communications Award
(iii) Hawkins awarded MBE in 2020 New Year Honours