Warming stripes spark climate conversations: from the ocean to the stratosphere

BAMS In Box

Warming Stripes Spark Climate Conversations: From the Ocean to the Stratosphere

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ABSTRACT: The "warming stripes" are an iconic climate data visualization, adopted globally as a symbol of our warming world. We discuss their origin and uses for communication, including understanding long-term changes in the climate and consequences of future emission choices. We also extend the stripes concept to explore observed temperature variations throughout the climate system, revealing coherent warming for the troposphere and upper ocean and cooling in the stratosphere, consistent with our understanding of human influences on our climate.

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1. Introduction

Earth's climate is warming: 2024 was the warmest year on record and the first to be more than 1.5°C above preindustrial levels (WMO 2025). It is likely that we are now living through the warmest period in the whole of human civilization, and climate-related risks increase with every bit of further warming (IPCC 2021). Scientists, policymakers, educators, and campaigners need a wide variety of tools to effectively communicate this scientific reality to broad audiences.

As a simple and accessible data visualization, the warming stripes (Fig. 1a) have been an effective and ubiquitous illustration used to communicate these concepts. They represent observed changes in global mean near-surface temperature, condensing more than a billion individual thermometer measurements into a set of simple colored stripes to indicate the average temperature in each year since 1850. They are colored with blues for cooler years and

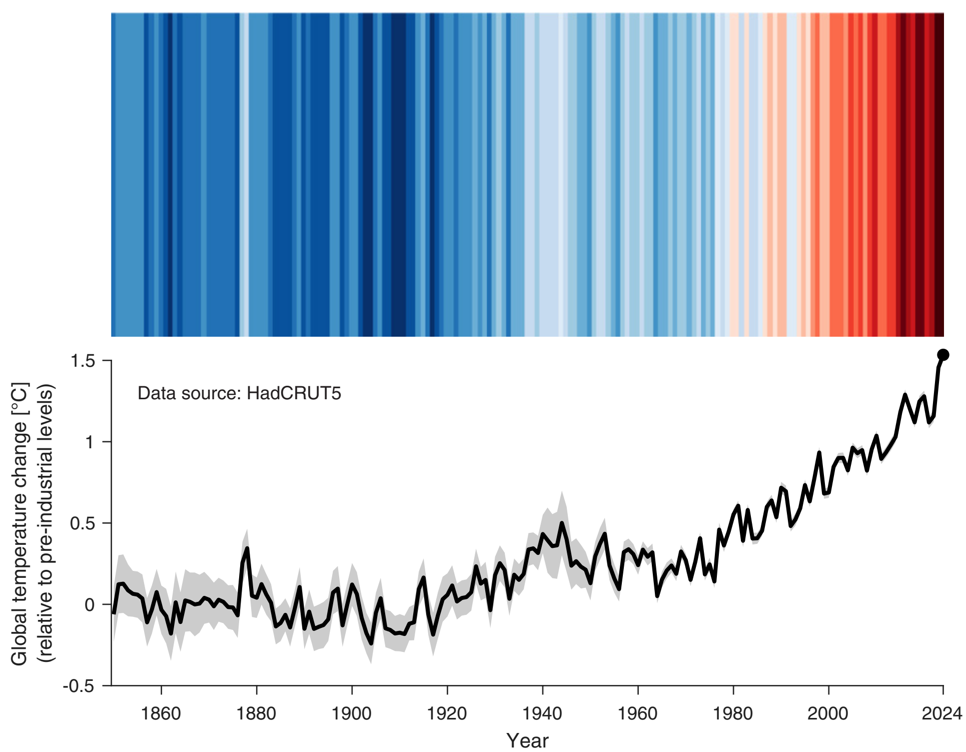

Fig. 1. The warming stripes of observed changes in global mean surface temperature from 1850 to 2024 using the HadCRUT5 dataset (Morice et al. 2021) using (top) a 1961–2010 baseline for the transition between blues and reds and (bottom) a more traditional representation of the same data showing the observed change relative to preindustrial (1850–1900) levels and the associated uncertainties.

reds for warmer years, chosen to be inclusive for those with color vision deficiencies and to intuitively represent cold and hot, aiding understanding. Typically, global average temperature is represented because of its relevance to international policymaking, but regional and city versions are also available, illustrating how climate change is already affecting everybody, wherever they live (www.ShowYourStripes.info; see in the online supplemental material). Empowering individuals to see their own local stripes enables a deeper connection with the data and the changes that they represent.

These graphics, and different versions of the concept, have been used by weather forecasters, rock bands, fashion designers, sports teams, authors, artists, community groups, and many others to start conversations about climate change across the world (see supplemental material). In contrast to traditional styles of graphic (Fig. 1b), the simplicity and clarity of the warming stripes means they are easy to share and adapt. This visualization can naturally solicit engagement and initiate conversations about their meaning which, importantly, often happen in places and communities where climate change is not typically discussed. Their design also effectively communicates how the long-term trend relates to the usual year-to-year variations in temperature in each location.

The warming stripes break many conventions for scientific graphics. For example, they do not include any axes or scales to indicate the timing or magnitude of change. Uncertainty is not represented. However, this simplicity helps explain the stripes' popularity: You do not need to be able to read a scientific graph to understand their underlying message. They have even been considered as "art" (Kahn 2018), a communication form that can create emotive connections with the image (Lesen et al. 2016; Pope et al. 2024). Indeed, the stripes will be part of an exhibition highlighting design as an agent of change at New York's Museum of Modern Art during 2025.

The origin of these highly successful graphics is also atypical. In 2017, Professor Ellie Highwood, a climate scientist at the University of Reading, crocheted a colorful striped blanket using observed changes in global temperature to define the colors of each stripe (Highwood, https://elliehighwood.com/2017/06/12/climatechangecrochet-the-global-warming-blanket/). This physical representation of climate change, designed as a gift for a colleague, was one of the inspirations for the subsequent creation and development of the warming stripe graphics by a colleague, Professor Ed Hawkins. Ellie's blanket was itself partly inspired by many knitters who make annual weather blankets using measured temperatures each day in their location.

The first versions of the graphics were published online and used at a public event at the Hay-on-Wye Literary Festival (United Kingdom) in 2018. From initial reactions, it was immediately obvious that the images had the potential to influence a much wider audience than typical scientific graphics (Kahn 2018; Kintisch, https://www.science.org/content/article/new-climate-stripes-reveal-how-much-hotter-your-hometown-has-gotten-past-century). Later in 2018, the U.S. TV Meteorologist Jeff Berardelli collaborated with *Climate Central* on an international campaign to encourage broadcast weather presenters to use the graphics during their usual TV segments. Hundreds of presenters in more than 40 countries have used the graphics live on air and in various social media feeds.

Now, 21 June is an annual #ShowYourStripes day, when people are encouraged to share the warming stripes graphics, exposing millions of people to climate change information on 1 day. To spark more climate conversations, the design has been added to clothing, painted on buildings, used in books and films, and projected onto iconic landmarks, including the Tower of London and the White Cliffs of Dover in the United Kingdom and Times Square in New York, among other global locations.

While the warming stripes showing changes in surface air temperature have had globally popular appeal and acclaim, they have also inspired others to communicate in a similar way about other critical global issues, such as biodiversity loss (Richardson 2023), ocean acidification (Gruber and Gregor, https://www.OceanAcidificationStripes.info), the loss of languages (Richardson 2024), and air quality (Pringle et al. 2025). Here, we extend the warming stripes concept to explore and communicate other aspects of climate change, including other climate indicators, longer time scales, and framing choices about future greenhouse gas emissions. These figures are potentially useful communication tools, and so we provide some more technical explanations.

We first examine how and why temperatures are changing for the rest of the atmosphere and the ocean with the aim to explore how representative the surface warming is and to highlight the differences in trends across different parts of the climate system (Fig. 2).

The warming stripes over the troposphere (typically the lowest 10–15 km of the atmosphere) have very similar characteristics to the warming stripes of the surface with the warmest years predominantly occurring over the last two decades. The 2024 was the warmest year on record for all tropospheric levels too. Note that this dataset draws upon satellite data and is independent from observations contained in the surface temperature datasets, providing additional confidence in the observed long-term trends.

The warming stripes over the stratosphere (typically from 10 to 50 km) reveal a cooling trend, with the warmest years around 1980 and the coolest years over the past decade. This cooling trend is due to two reasons. First, increased levels of carbon dioxide enhance the

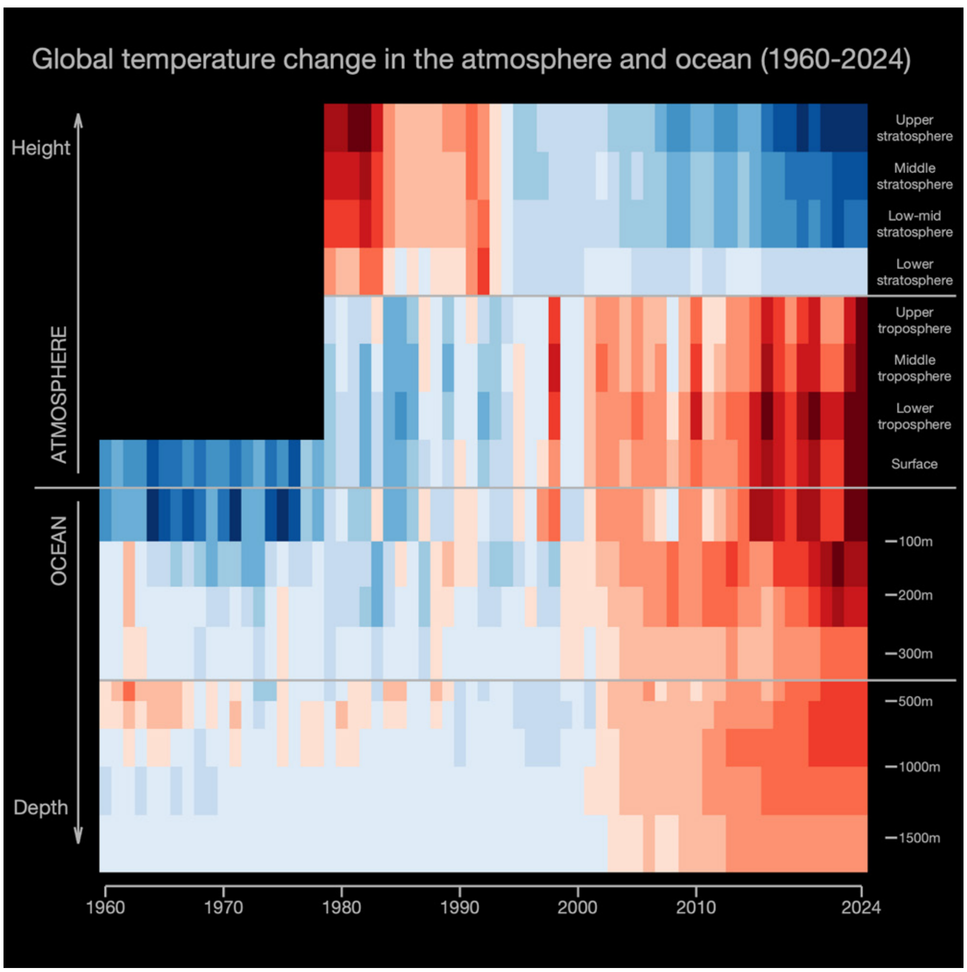

Fig. 2. Warming stripes for the surface and ocean depths (1960–2024) and for different layers of the atmosphere (1979–2024). Anomalies relative to the 1981–2010 period are shown, with different color scales for the atmosphere, upper ocean, and deeper ocean, with these layers separated by the gray horizontal lines. The global surface temperature data are from HadCRUT5. Global average temperatures for tropospheric layers are from RSS, with stratospheric layer global temperatures updated from Steiner et al. (2020). Ocean data are from Met Office Statistical Ocean Reanalysis (MOSORA) (Smith and Murphy 2007), globally averaged for different depth levels.

emission of infrared radiation, an effect that strengthens with altitude. Second, there is decreased absorption of solar radiation due to the depletion of stratospheric ozone by human activity, which peaked in the mid-1990s. This effect is strongest in the lower stratosphere and is expected to diminish as global ozone levels recover (WMO 2022).

Overall, we see that the surface warming stripes are representative of variations throughout the troposphere, while there are opposite trends in the stratosphere. This signature is consistent with our understanding of the consequences of an enhanced greenhouse effect and reductions in stratospheric ozone levels and is the expected fingerprint of human activities on the climate system (Manabe and Wetherald 1967; Santer et al. 2023).

Warming stripes for different depth levels in the ocean are shown for 1960–2024 (Fig. 2), which are based on a combination of ship-based measurements and profiling float data from the Argo program (Smith and Murphy 2007). There are insufficient data to reliably reconstruct the warming trends over the global ocean at depths greater than 2000 m (due to the limited Argo coverage). These ocean warming stripes reveal a broadly similar warming trend as at the surface, with the warmest years occurring over the past decade, emphasizing the strong connections between the thermal responses of the atmosphere and upper ocean. Hence, the surface warming stripes are also representative for communicating temperature trends for the upper ocean.

The ocean warming stripes are important to show how additional heat is stored in the climate system: The global ocean accounts for around 90% of the extra heat stored by the planet (von Schuckmann et al. 2023). The warming stripes for the upper ocean may be equivalently viewed in terms of global ocean "heat stripes," highlighting that the greatest additional storage occurred over the last decade (Cheng et al. 2021), although there are some variations between ocean basins (see supplemental material).

Longer-term climate proxy datasets clearly demonstrate the unprecedented nature of recent warming in the context of the last 2000 years (Fig. 3; Neukom et al. 2019). The dominant cause of this warming is from human emissions of greenhouse gases, mainly from burning fossil fuels. This stripes-inspired visualization also highlights that natural climate factors were slowly cooling the climate before the advent of the industrial revolution. Importantly, the physics of why an increase in carbon dioxide should warm the climate was understood before the warming was observed (see Chen et al. 2021).

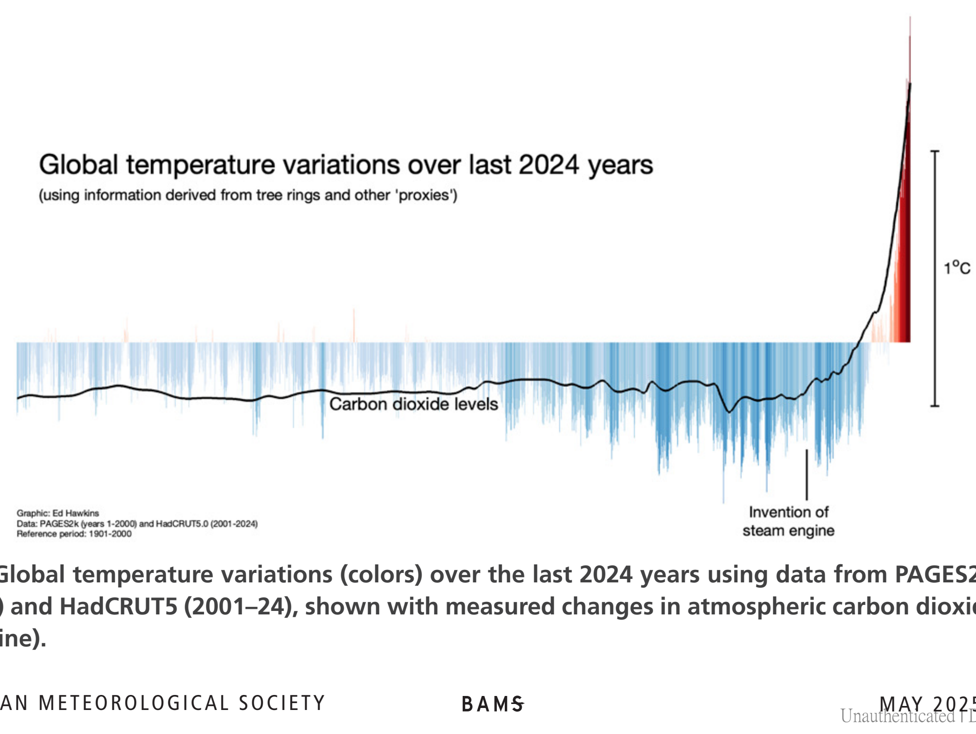

Fig. 3. Global temperature variations (colors) over the last 2024 years using data from PAGES2k (years 1–2000) and HadCRUT5 (2001–24), shown with measured changes in atmospheric carbon dioxide levels (black line).

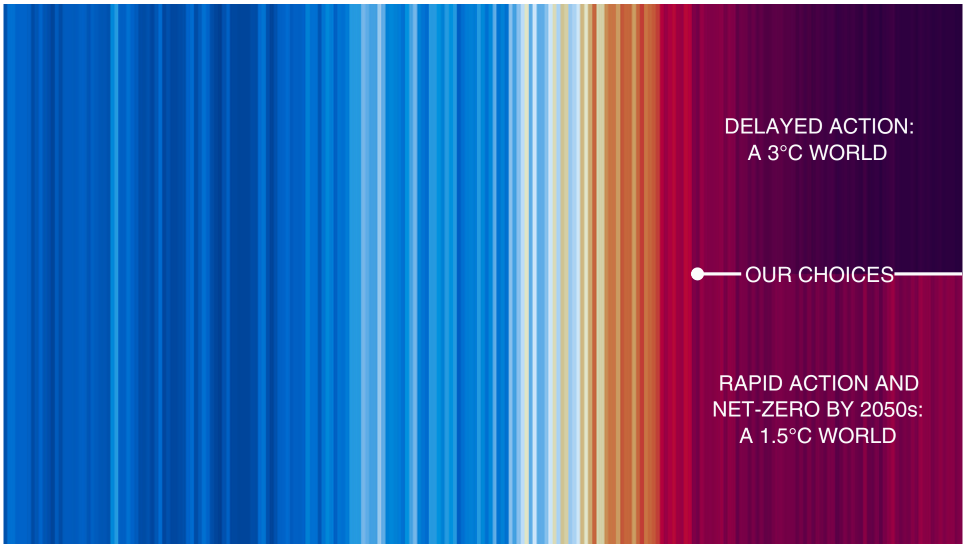

Fig. 4. Warning stripes, including observations of global average temperature (1850–2024) and two different future emission scenario choices for the next several decades (2025–90). Assessed future projections taken from IPCC (2021) using SSP1–1.9 and SSP2–4.5, with added random noise to generate stripes. Color scale developed by Alex Radtke to span a wider range of temperatures.

The warming stripes concept can also be used to communicate possible climate futures with different carbon emission choices: the warning stripes (Fig. 4). Rapid action to reduce global carbon emissions aimed at reaching net zero by the 2050s would likely result in relatively limited future warming (with stripes remaining similar shades of red). Delayed action in reducing carbon emissions leads to temperature records being significantly exceeded over the next century (with warming stripes moving into much darker shades of red), so that 2024—the warmest year to date—would eventually be viewed as a cold year. This concept of highlighting future choices was first suggested by Twitter user Alex Radtke in 2019 and was used by the IPCC in its Sixth Assessment Report (Chen et al. 2021; IPCC 2023) and has since been built into an interactive tool by NASA (2024).

The warming stripes have inspired many people to think creatively about communicating climate change because they are simple, striking, and have been made freely available. Although the warming stripes are not suitable for every communication purpose, these qualities have proved them to be an invaluable tool for raising awareness, creating deeper and different engagements with climate science, and sparking vital climate conversations. Our advice is to consider adopting creative ways to communicate complex, socially relevant topics (Hawkins et al. 2019), and being open to inspiration from a wide range of sources and perspectives.

Acknowledgments. There are simply too many examples of creative ways that the stripes have been used worldwide to include an exhaustive list in this paper. We gratefully acknowledge everyone who has used the warming stripes to start climate conversations but especially the TV weather forecasting community who first recognized the potential to communicate climate change to millions of people with a simple colored graphic. We are also grateful to Jon Starr from the National Center for Atmospheric Research and Leon Hermanson from the Met Office for updating the stratospheric and ocean temperature data used in Fig. 2. We thank the two reviewers whose comments significantly improved the paper. Figures 3 and 4 are part of the Climate Visuals collection (https://ed-hawkins.github.io/climate-visuals/).

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