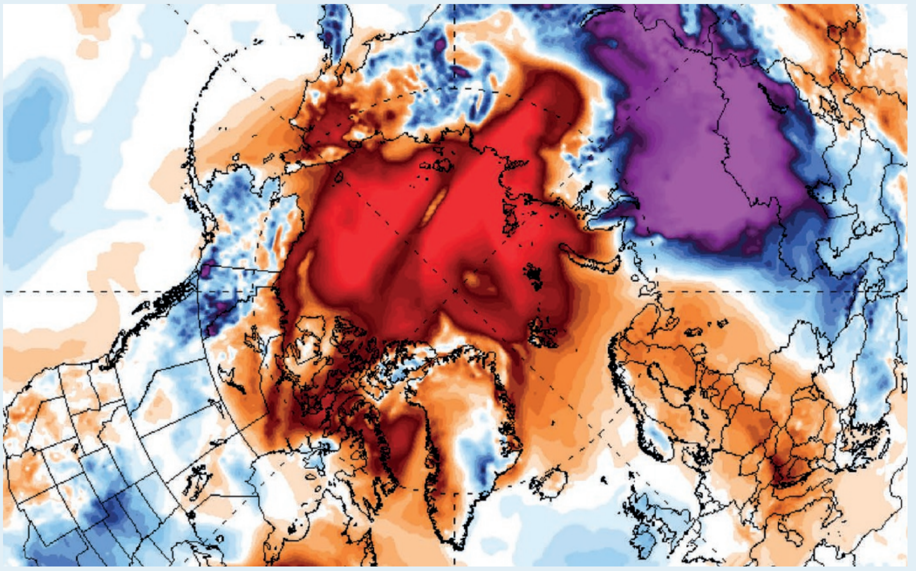
SNAPSHOT

Extreme Arctic heat



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2016 will be remembered for many things, one of them being the heat. Globally, it was the hottest year since instrumental records began, but Arctic temperatures during 2016 were truly exceptional. As the year drew to a close, the high-latitude Arctic was blistered with extended periods of record-breaking heat. Surface temperatures during October–December were, on average, ~5 °C above expected in an area spanning the Arctic Ocean, from Greenland across the North Pole to far eastern Russia. Even more astounding were the daily anomalies, which exceeded +16 °C in many locations. With temperatures nearing the melting point, sea ice exhibited a sluggish wintertime expansion during a time when rapid growth is the norm. In fact, for a brief period during November, Arctic sea ice growth actually stopped and reversed. As a result of the extreme heat, monthly sea ice extents from October–December 2016 were the lowest ever recorded for that time of year.

The cause of these extreme Arctic conditions is multifaceted. James Overland, Research Oceanographer for the National Oceanic and Atmospheric Administration, USA, explains that these record-breaking events can be attributed to large-scale wind patterns, namely "the advection of warm air by strong mid-latitude weather systems located in the Bering Sea and North Atlantic". While northward wind trajectories blasted the Arctic with heat from multiple positions, they also carried significant moisture: "moist air encourages cloud formation which traps the extra heat in the lower atmosphere — this is key to explaining the observed temperature changes" adds Jennifer Francis, Research Professor at Rutgers University, USA.

Acting alone, however, both Francis and Overland agree that these winds would not have had quite the same impact; sea ice, or rather an absence thereof, played a pivotal role. Prior to autumn 2016, Arctic sea ice extent and volume were already anomalously low, particularly in the locations over which the weather systems drove warm air — the Barents–Kara and Beaufort–Chukchi seas. "Crossing open water helped to maintain the heat, allowing the warm air trajectory to reach near to the North Pole", notes Overland. This would have driven further sea-ice melt, amplifying temperature increases. Had the warm air flowed over an area of more extensive sea ice, the heat would have dissipated, the result being that, as Francis comments, "the observed heat wave would not have been half as bad".

Although natural variability inevitably plays a strong role in driving extreme Arctic heat, early work by the World Weather Attribution group, led by Climate Central, concludes that the North Pole heat waves of November and December 2016 are "extremely unlikely to occur in the absence of human-induced climate change" (http://go.nature.com/2inFfie).

Indeed, periods of Arctic heat were once extremely rare, but in 2016, they were a common occurrence. The first two months of 2016 saw very similar conditions, with surface temperatures ~6 °C higher than normal — exceeding the differences observed in more recent months. "At the time, we thought that [the January–February heat] was a random event", says Overland, "yet here it is again". Given that 2016 has witnessed two such periods of extreme Arctic heat, can we expect to see them more frequently in the future? The various factors governing Arctic climate make this difficult to predict, but according to Francis "the deck is not stacked in its favour". Arctic heat wave events arise due to the co-occurrence of both strong weather systems and sea-ice loss. There has been a marked decline in Arctic sea ice since 1979, satellite observations reveal, and models project that this loss will continue with increasing greenhouse gas concentrations (J. Overland & M. Wang *Geophys. Res. Lett.* **40,** 2097–2101; 2013). As Overland states, "in the past we didn't have the sea-ice loss, but now [and in the future], we only need the right random weather pattern to reoccur", indicating that Arctic heat extremes may well become more commonplace.

An increase in extreme Arctic warmth, and resulting low sea-ice coverage, will likely have vast ecological consequences. Sea ice loss, for example, is linked to a decline in the habitat of polar bears and ringed seals, as well as shifts in phytoplankton structure and bloom timing (E. Post *et al. Science* **341,** 519–524; 2013). Additional connections to coastal erosion (I. Overeem *et al. Geophys. Res. Lett.* **38,** L17503; 2011), carbon cycling through permafrost degradation (C. Koven *et al. Proc. Natl Acad. Sci. USA* **108,** 14769–14774; 2011), and mid-latitude atmospheric circulation (J. Cohen *et al. Nat. Geosci.* **7,** 627–637; 2014) to name but a few, all emphasise the importance of understanding such Arctic heat events and their possible change under further anthropogenic warming.

For now, however, Francis states that "the crazy winter will likely continue", and with that, the future of the Arctic doesn't look too bright. Nevertheless, she puts a positive spin on recent events by remarking that "the Arctic is a tool for the public... the observed changes are so huge that they can be used to educate and inform about climate change".

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