Abstract

Climate change is causing the Earth to get hotter; 2015 is the hottest year ever recorded and is on course to be surpassed by 2016. Extreme heat waves are getting more common, causing untimely deaths for vulnerable populations like elderly people, as well as increased energy requirements for air conditioning and problems for natural ecosystems.

We noticed that in the months just before Central Europe experienced an especially harsh heat wave in the summer of 2015, the surface temperatures in the Northeast Atlantic Ocean were exceptionally cold. Yes, cold. Why would the ocean be extra-cold before the air over land was extra-warm? Could these unusually cool ocean surface temperatures in the North Atlantic ocean be a precursor to heat waves in Europe? If so, monitoring ocean temperatures could help us predict – and prepare for – heat waves in the future.

Introduction

In the past two years, temperatures on our planet have risen faster than they ever have before. Scientists predict that temperatures will keep trending upwards as the climate changes. That means there will be more heat waves, which are sustained periods of especially hot temperatures. Heat waves are not only uncomfortable – they can also be deadly. Elderly people, homeless people, pregnant women, outdoor workers, and people who can’t afford air conditioning are most vulnerable to suffering from excess heat.

In the summer of 2015, Central Europe sweltered under one of the worst heat waves in 65 years. Temperatures rose and stayed uncomfortably high, breaking multiple heat records, while electricity providers struggled to keep up with the demand for air conditioning and governments issued heat warnings.

Even though 2015 was an exceptionally hot year, there was one part of the globe that bucked the trend: the surface of the North Atlantic Ocean, southeast of Greenland. It was especially cold – up to 2 degrees Celsius colder than usual (Fig.1). We were curious: what caused this blob of strangely cool water? Could it be connected to the unusually warm temperatures on land?

Among scientists, there is a lot of interest in figuring out what triggers heat waves to occur so that we can accurately predict when they will strike.
Methods

We wanted to figure out three separate (though related) problems: first, we wanted to determine the origin of the blob of cold water in the North Atlantic Ocean. Second, we wanted to figure out whether there was a connection between the colder ocean blob and the heat wave in 2015. Finally, we wanted to see whether colder ocean waters in the North Atlantic historically preceded European heat waves.

To solve these problems, we brought together and analyzed monthly data for at least the past 35 years about the surface temperature of the North Atlantic Ocean, the maximum air temperature 2 meters above land in Europe, and the Jet Stream wind speed. (Fun fact: scientists use floating underwater robots to measure ocean temperatures!)

Using some cool mathematical equations that describe the origins of variations in the sea’s surface temperature, we investigated why the water in the North Atlantic Ocean was especially cold in 2015. We assessed whether the cool water temperatures were caused by changes in ocean currents, vertical movements of water in the ocean, or by loss of heat from the ocean to the atmosphere.

Next, we explored whether the cold ocean temperatures could possibly have affected the 2015 summer heat wave in Europe. Here’s how we hypothesized they might have done so: We knew that surface water temperatures in the ocean affect the atmosphere - warmer ocean waters give heat to the atmosphere, making the air “lighter” or more buoyant, and reducing the air pressure. Similarly, colder surface waters cool the air, making it denser and creating high air pressure. And when there is a stark difference between areas of high and low air pressure, it creates wind. So we investigated whether changes to ocean temperatures could potentially shift the position of the Jet Stream in such a way that it would cause hot air to stagnate over Central Europe.

Lastly, we calculated when historically the North Atlantic Ocean had been especially cold and when there were heat waves in Europe. This scientific method is called composite analysis.

Results

We had several important findings:

1. The colder temperatures in the North Atlantic Ocean in 2015 were caused primarily by loss of heat from the ocean to the air. The cold blob of water extended 700 meters (about 2,300 feet) below the surface (fig.2).

2. In 2015, the surface water temperatures in the North Atlantic coincided with the Jet Stream shifting south, which set up the conditions for the heat wave by leading to high air pressure and high temperatures in Europe.
Scientists before us knew that the ocean can affect the weather on land in different ways, but our research adds an important contribution: Atlantic Ocean temperatures are one of the potential drivers for European heat waves. That means that since we already monitor the surface temperature of the North Atlantic Ocean (using satellites), we could use this information to get a better idea when heat waves might soon hit Central Europe.

Our research didn’t allow us to say definitively whether the colder temperatures in the surface of the ocean were directly responsible for the 2015 heat wave in Europe, but we do know that the colder ocean surface temperatures preceded the heat wave. The connection between the colder ocean temperatures and the heat wave is reinforced by the fact that many major European heat waves historically have been preceded by especially cold ocean temperatures in the North Atlantic Ocean. The results of this research highlight that it is really important to understand the role of the ocean in atmospheric circulation and in the potential development of weather extremes!

Though we still don’t know exactly what triggers heat waves, we have made a striking discovery: part of the North Atlantic Ocean exhibits especially cold surface temperatures in the months before a European heat wave. Since ocean surface temperatures are already monitored everywhere in the world; we could use this information in the North Atlantic to help provide early warnings before extreme European heat waves. Doing so will allow us to help people who are more vulnerable to heat be prepared to stay cool despite the hot weather.

**Discussion**

Scientists before us knew that the ocean can affect the weather on land in different ways, but our research adds an important contribution: Atlantic Ocean temperatures are one of the potential drivers for European heat waves. That means that since we already monitor the surface temperature of the North Atlantic Ocean (using satellites), we could use this information to get a better idea when heat waves might soon hit Central Europe.

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**Conclusion**

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**Glossary of Key Terms**

**Heat wave** – An extended period of unusually hot days and nights. Multiple factors contribute to the development of heat waves. In the months before a heat wave strikes a region, a lack of rain or snow makes the soils especially dry. During the heat wave, there is an unusually long period of especially high temperatures. These persistent, unusual weather conditions are due to what we call “atmospheric blocking”, where high air pressure blocks remain in place for several days or even weeks, causing the areas affected by them to have the same kind of weather for an extended period of time. Scientists know that changes to a global air circulation pattern called the Jet Stream can set up the conditions for powerful heat waves by causing atmospheric blocking – in Central Europe’s 2015 heat wave, a shift in the Jet Stream’s position caused the air over Europe to settle and stagnate for many days at a time.
What are the different factors causing a heat wave?

This research explores one way in which the conditions in the ocean might affect life on land. Describe three other ways that the status of the ocean environment affects humans on land.

Heat waves don’t affect everyone equally. Why are heat waves more dangerous to some people than others?

Climate change means the Earth will experience more heat waves, which will be hotter and last for longer periods than those in the past. Besides finding reliable ways to predict when heat waves will occur, what are ways people in cities can prepare for the reality of more heat waves in the future?

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KEY TERMS

heat wave, ocean circulation, Jet Stream, Europe, North Atlantic Ocean, weather extremes

SCIENTIFIC METHODS

Case study, Ocean observations, composite analysis, lagged correlation