

THE FACTS

1. Climate scientists say that it is virtually certain that the heat wave that stretched across much of Europe in early July was more likely to happen now than in the past due to climate change.

THE HEAT

2. Madrid (central Madrid) set a July record high on Monday, July 6th, hitting 39.9 degrees Celsius -- 103.8 degrees Fahrenheit, exceeding the previous July record from July 24, 1995 (39.5C). The city also set a June record high last Monday, reaching 39.7 degrees Celsius -- 103.5 degrees Fahrenheit.
3. Germany's all-time heat record was broken on Sunday, July 5th in Kitzingen, topping out at 40.3 degrees Celsius (104.5 degrees Fahrenheit), according to Germany's National Meteorological Service (DWD). This exceeds the previous German all-time high of 40.2C (104.4F) from August 2003 and July 1983. Many stations in German cities set all-time heat records this past weekend, including Berlin (Dahlem) hitting 37.9C (100.2F) on Saturday, July 4th and Frankfurt reaching 39C (102.2F) on Sunday, July 5th.
4. Several monthly and all-time records were either tied or broken during the July 4th weekend in France, according to Météo-France.

THE ANALYSIS

5. It is widely accepted that climate change will increase the overall frequency, intensity and duration of heat waves (Meehl and Tebaldi, 2004; IPCC 2014).
6. In 2004, a paper published in Nature (Stott et. al., 2004) showed that climate change had at least doubled the risk of the record-breaking 2003 European summer heat wave that resulted in the deaths of tens of thousands of people. The elderly were among the most vulnerable.
7. What role did global warming play in this year's heat wave? A significant one, according to new research conducted in real-time, while the heat wave was still ongoing, by an international team of climate scientists. Observational data records show a clear warming trend and climate models show a temperature increase due to increased greenhouse gases in the atmosphere and higher sea surface temperatures.
8. There are many different definitions of heat waves. In this analysis, the annual maximum of the 3-day average of maximum temperature was used. This definition is more directly related to negative health impacts than simply using the hottest day of the year. However, this definition does not capture the fact that the heat wave was unusually early in the summer. Early summer heat waves are often associated with large negative impacts.

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9. A team of climate scientists from the Royal Netherlands Meteorological Institute (KNMI) and the University of Oxford, with data and other support from regional partners at CNRS (France), DWD (Germany), and MeteoSwiss, looked at the likely influence of global warming, using two independent methods.
10. KNMI looked at 5 European cities that experienced intense heat: De Bilt in the Netherlands, Madrid (at the airport), Mannheim in Germany, Beauvais (80km north of Paris), and Zürich. They performed a two-phased analysis. As the event began, they used a combination of observed and forecast data to compute the annual maximum of 3-day maximum temperature (observations up to July 1, forecasts up to July 5). This allowed them to provide an initial analysis in real-time, while the event was still unfolding.
11. Subsequently, the scientists re-computed the analysis using only observational data up to July 6th, 2015. They performed a statistical analysis of observational records (using the KNMI Climate Explorer) to compare this summer's heat with summers about 100 years ago, before global warming played a significant role in our climate. Due to the low number of extreme events, the return times have large uncertainties and can be 2 to 3 times smaller or larger than the best estimate. It is important to note that this statistical method only detects trends and cannot attribute the trends to specific causes. For this reason, models are an important additional attribution tool.
12. Using a different independent method based on regional climate model simulations computed under a project called [weather@home](#), Oxford performed the same two-phased analysis (a preliminary one using observational and forecast data through July 5, and then an update using observational data up to July 6) in the same 5 cities. They simulated possible weather in the world as we observe it today with global warming and compared it to the likelihood that such high temperatures would occur in a climate without anthropogenic changes in the atmosphere. In the model, possible weather can be simulated again and again under the same climate conditions, allowing for robust statistics of extreme events. And while no observations of a world without climate change exist, such a world can be modelled and provide an independent analysis.
13. The results were:
 - In De Bilt, the trend analysis of the observational data shows that a 3-day period as hot as experienced over this past week is now roughly 7 times more likely to occur than it was around 1900 (and at least 4 times more likely at the 90% confidence interval). The return time is now roughly every 3 years (with a 95% uncertainty margin between 2.2 to 5 years), whereas it was roughly every 20 years around 1900 (13 to 55 years). Using the weather@home model, scientists estimate the observed heat wave to be 1-in-4 year event now compared with a 1-in-7 year event in the world without climate change, so the likelihood increased by a factor of about 2. The difference between the two methods is likely due to that fact that the model shows a somewhat slower warming rate than the observational record. That said, this discrepancy is well documented but the cause has not yet been determined.

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- In Madrid (Barajas Airport station), the trend analysis of the observational data shows that a 3-day period as hot as experienced over this past week is now roughly 4 times more likely to occur than it was around 1950 (and at least 2 times more likely at the 90% confidence interval). The return time is now roughly every 5 years (with a 95% uncertainty margin between 3 and 10 years), whereas it was roughly every 20 years around 1950 (8 to 90 years). Using the weather@home model, scientists estimate the observed heat wave to be a 1-in-20 year event now compared with a 1-in-100 year event in the world without climate change. Although the model estimates that this is a more rare event than the observations indicate, the increase in occurrence of heat waves agrees well between the observations and the model. (Note we used Barajas station at the Madrid Airport for the updated analysis rather than Retiro station used in the preliminary analysis, given Retiro is located in a city park, where local changes, e.g., in building density and lawn watering, may have caused part of the temperature trend.)
- In Mannheim, the trend analysis of the observational data shows that the heat wave was a rare event even in the current climate. A 3-day period as hot as experienced over the past week is now roughly 8 times more likely than it was in the 1930s (and at least 4 times more likely at the 90% confidence interval). The return time is now roughly every 30 years (with a 95% uncertainty margin between 13 and 400 years), whereas it was roughly every 240 years around 1930 (more than 70 years). Using the weather@home model, scientists estimate the observed heat wave to be a 1-in-36 year event now compared with a 1-in-130 year event in the world without climate change. Although the observed trend is again stronger than the modeled one, these results agree within the uncertainty ranges.
- In Beauvais-Tille (a town 80 km north of Paris, far beyond the suburbs with a good series of observations without urban effects), the trend analysis of the observational data shows that a 3-day period as hot as experienced over this past week is now roughly 4 times more likely than it was around 1950 (and at least 2.4 times more likely at the 90% confidence interval). The return time is now roughly every 3 years (with a 95% uncertainty margin between 2 and 5 years), whereas it was roughly every 10 years around 1950 (7 to 26 years). The weather@home model computes the observed heat wave to be a 1-in-2.6 year event now compared with a 1-in- 3.5 year event in the world without climate change. The estimates of how rare the event was are in good agreement, but in this region the temperature of hottest days has increased more in the observations than in the model, even though it is not an urban area.

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- In Zürich, we used the homogenized daily time series of MeteoSwiss. The trend analysis shows that a 3-day period as hot as experienced over the past week is now roughly 8 times more likely than it was around 1900 (and at least 2.5 times more likely at the 90% confidence interval). The return time is now roughly every 13 years (with a 95% uncertainty margin between 7 and 45 years), whereas it was roughly every 100 years around 1900 (33 to 800 years). Using the weather@home model, scientists estimate the observed heat wave to be a 1-in-15 year event now compared with a 1-in-40 year event in the world without climate change, which agrees with the observational analysis within the uncertainty margins.

14. *NOTE: These results reflect an updated analysis using observational data only. An initial analysis using observed and forecast data was released last Thursday, July 2nd.*

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