Attribution of the high March temperatures in Tucson

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Whenever there is extreme weather the question is raised whether it was due to external influences such as greenhouse gases or variations of solar activity. Local influences such as irrigation, urban effects and the decreasing snow cover in the mountains in March can also play a role. There are now methods to answer the scientific version of this question: "has the probability of an event like this or worse changed due to these factors?" Extreme weather always has a large element of chance due to the random weather, but the external factors may have shifted the odds. Let's try to find out how much the odds have shifted, and why.

The standard method of 'extreme event attribution' has two steps.

- Analyse the observations of similar events to determine how rare it was and whether there was a trend before the event occurred.
- In climate models that simulate the event well, vary individual factors and see how the probabilities change.

This quick look at the Tucson temperatures is based on the Tucson International Airport series, the same that is used by the NWS. I am afraid I do everything in degrees centigrade, the USA is almost alone in using Fahrenheit (the others are the Bahamas, Belize, and the Cayman Islands).

The heat from 8 to 22 March 2017 is certainly impressive.

Because it covered such a large part of the month, I propose to look at the March monthly mean maximum temperature as our variable of interest. This should have very little influence from urban heat island (UHI) effects, which are more visible in the minimum temperature in arid regions. Irrigation cooling effects (ICE) can affect maximum temperatures strongly.

The March 2017 is record high, but even before that there was a clear upward trend in March temperatures starting in the mid-1970s.
The trend is much faster than global warming, with temperatures rising by about 4 ºC since 1950. This raises the suspicion that other factors also play a large role at the airport station.

To investigate this we also consider another station in the area, Willcox, AZ has data from 1903 to 2017 with only a few gaps. It also had the March heat wave, though not as extreme, and March 2017 was not record warm there. The trend over 1948-2016 was 3.4 times global mean warming, but there is very little warming trend from 1900 to 1950, so that the overall trend over the whole century is a bit lower, about 2.82.5. Casa Grande, AZ, was also not record warm, and has a trend of about 2.1 times global mean temperature since 1948 (and again a bit lower when taking the data before 1948 into

account). The whole region seems to be warming in March, but the rate of warming varies quite a bit from station to station with the airport heating up most rapidly, and was much lower before 1948. This can be due to decadal variability or local forcings, I cannot establish that in a quick look like this.

The next step is to determine the trend in climate models, where we can vary the anthropogenic emissions of CO2 and other greenhouse gases, plus aerosols, or keep them constant.One model that was runs specifically for these attribution studies is the UK Met Office model HadGEM3-A at a resolution of about 60km. This model has been used to simulate two world: the real one with all factors included, and a counter-factual one in which there were no anthropogenic emissions. It is an atmosphere-only model in which the sea surface temperatures have been prescribed from observations.

In the historical runs, including all large-scale forcings (but not changes in irrigation and urban effects), the trend at the grid point closest to Tucson, AZ, is about 2.5 time faster than global mean temperature. Without anthropogenic forcings there is no trend: solar and volcanic forcings cannot explain the warming in Tucson, not can the observed decedal variability from the ocean.

Curiously, the ensemble of coupled climate models used of rth latest IPCC assessment, CMIP5, shows on average less warming at the location of Tucson, only just a bit more than the global mean temperature, but with a large uncertainty due to natural variability. *The vertical bars give the trend in Tmax at this location in the CRU TS and Berkeley gridded datasets.

Finally I looked at other influences. There is one obvious factor: the aftermath of the 2016/17 La Niña certainly helped to bring some extra warmth to Tucson.

To sum it up: the maximum temperature at the Tucson airport station has risen very fast in March since 1948 when observations started there, with almost four degrees Celsius. This is has increased the probability of observing heat waves like the one observed a few weeks back. Other stations in the area show lower trends, so I suspect there are local factors that contributed to the trend, the underlying trend is about three degrees Celsius, maybe a bit less.

A high-resolution climate model shows that most of this is due to climate change. However, the coarse-resolution models used for the latest IPCC report only show half this trend on average with a large spread due to natural variability. For the arid region of Arizona I trust the high-resolution model more, so my working hypothesis is that the IPCC models underestimate the trend in maximum temperature there because thy do not represent the feedbacks operating there correctly. However, it could be that the high-resolution model has too high a trend and at the same time the observations are influenced by a non-climate change factor. I have not yet done the analysis to figure this out.

So, definitely partly due to climate change, probably mostly due to climate change, but also partly due to something else.