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Human-induced rainfall changes

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Climate change ***[Subject strapline]***
Human-induced rainfall changes ***[Titles must fit within one line, in practice about 32 chars (including spaces).]***

Southwestern Australia has become drier and drier over the past century. Simulations with a high-resolution global climate model show that this trend is linked to greenhouse gas emissions and ozone depletion -- and that it is likely to continue. ***[Okay? Standfirsts should fall between 150 and 250 chars, and generate interest in the piece. Please feel free to modify as necessary.]***

David J. Karoly

Reliable water resources are vital to human society. However, long-term changes in rainfall can severely affect water resources. Australia is the driest continent on the planet, apart from Antarctica, with the most variable rainfall. On top of this naturally parched state, in the south-west corner of Australia, a pronounced drying trend has evolved over the past forty years. Writing in *Nature Geoscience*, Delworth and Zeng[1] conclude from simulations with a high-resolution global climate model that human influences associated with increasing greenhouse gases in the atmosphere and stratospheric ozone depletion are the best explanation of the observed rainfall decline in the south-west of Australia. The study is one of the very few instances that regional rainfall changes have been linked to human-caused climate change. ***[Okay? We try to keep the first paragraph brief, below 150 words, to make it as inviting as possible. I have moved the specifics about Perth water resources further down.]***

Referring to global mean conditions and temperature change, the Intergovernmental Panel on Climate Change in 2013 concluded that "It is extremely likely that human influence has been the dominant cause of the observed global warming since the mid-20th century"[2], a very high-confidence conclusion. In contrast, for observed rainfall changes over the past decades, it is much harder to distinguish possible human influences from natural factors in most regions around the world. Reasons include the very high variability of rainfall at all space and time scales; difficulties in reliably simulating this high variability of rainfall in climate models; and differences between different climate models in projected rainfall changes in response to human influences. Hence, in most regions, there is no clear signal of rainfall changes as a result of global warming and there is very large natural variability.

The south-west of Australia has a Mediterranean climate. The bulk of its annual rainfall falls in winter, associated with the passage of cold fronts that bring moist air from over the Southern Ocean. In the 21st century, average streamflow into the reservoirs that supply the water resources of the city of Perth and its 1.9 million inhabitants has been less than a quarter of the average streamflow[3] during 1911-1974 (Fig. 1). This rainfall decline has been associated with a reduction in the number of the winter weather systems affecting the region, as the winter storm track has shifted southwards over the Southern Ocean[3].

For the winter season, the large-scale changes in the winds and pressure patterns over the Southern Ocean have been linked to increasing atmospheric greenhouse gas concentrations, whereas changes in austral summer have been linked to Antarctic ozone depletion[4,5]. However, it has not been possible to formally attribute the observed rainfall decline to human influences. Most climate models have a spatial resolution that is too coarse to represent the topography of the Australian south-west. As a result, they generally underestimate its mean rainfall as well as the variability of precipitation.

Simulations with the higher-resolution climate model of Delworth and Zeng[1] capture quite well the mean rainfall in the south-west of Australia and its year-to-year and decadal variability over the past hundred years. Using multiple simulations with different forcing factors, Delworth and Zeng were able to show that the observed rainfall decline cannot be explained by natural climate variability or human-caused emissions of aerosols in their model. Instead, simulations that include increasing atmospheric greenhouse gas concentrations and stratospheric ozone depletion agree best with the observed rainfall.

Nevertheless, even the best-performing sets of simulations still underestimate the rainfall decline. Natural variability of rainfall could therefore still be a substantial contributor to the observed rainfall decline. In addition, although stratospheric ozone depletion has been identified as a key factor in observed Southern Hemisphere climate change in summer[6,7], it is unlikely to be an important factor in atmospheric circulation and rainfall changes in austral winter. Additional support from other high-resolution climate models is needed.

In addition, this case study of southwestern Australia should not be taken to suggest that rainfall changes in other regions have a substantial contribution from human-caused climate change. Instead, the Australian Southwest is a special region with highly seasonal rainfall, where the changes in winds and weather systems in response to climate change have already affected precipitation.

The success of the model used by Delworth and Zeng[1] in simulating the pattern of the observed decline in rainfall not only over the south-west of Australia but also over south-east Australia is encouraging, even though the amplitude does not entirely match. This agreement gives greater confidence in model projections that show continuing reductions into the future in winter rainfall across southern Australia, a prospect that poses increasing risks to sustainable water resources.

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[We would suggest to complement the streamflow graph that you included with a pretty picture, to make the piece more visually attractive. Would something like http://www.alamy.com/image-details-popup.asp?pv=1&stamp=2&imageid={A80BDA05-4FAF-45A3-AA02-F631958580FD} be okay? If so, we can obtain this image.]

Figure 1. Drought in southwest Australia. Estimated annual streamflow (in gigalitres) into dams supplying Perth, Australia, has declined over the past century (left), leading to low water levels in reservoirs in the region (right) ***[this would be the suggested picture]***. Delworth and Zeng link the drying trend to human-induced greenhouse gas emissions and stratospheric ozone depletion. Data obtained from the Water Corporation of Western Australia[1].

References:

1 Delworth, T. L., and F. Zeng (2014) Regional rainfall decline in Australia attributed to anthropogenic greenhouse gases and ozone levels. *Nat Geosci.*, this issue.

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3 https://www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams/streamflow/streamflowhistorical, cited 9/6/2014.

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7 Thompson, D.W.J., S. Solomon, P. Kushner, M. H. England, K.M. Grise and D.J. Karoly (2011) Signatures of the Antarctic ozone hole in Southern Hemisphere surface climate change. *Nat. Geosci.,* **4**, 741-749.