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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Extreme heat in India and anthropogenic climate change" *by* Geert Jan van Oldenborgh et al.

A. Gershunov (Referee)

sasha@ucsd.edu

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SUMMARY

This is a stimulating discussion paper by a very competent international/interdisciplinary team that is somewhat biased towards physical climate science while health science is lightly represented. Health impacts motivate this paper focused on analyzing Indian heat waves in various observational/reanalysis products as well as climate models including CMIP5 and targeted model experiments. It is found that the anthropogenic climate change signal is not so far detectable in the observed data on Indian heat waves. Evidence and reasoning are presented that suggest a global climate change trend masked by regional anthropogenic impacts, e.g. pollution

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Discussion paper

and irrigation. This suggestion is expressed in a somewhat speculative manner. The article is timely and the results are quite nuanced, but not as comprehensive as they possibly should be. In particular, the main definition of heat wave activity (hottest temperature of the year) is possibly not the most relevant definition for the tasks at hand and does not facilitate the fairest comparison between models and observations. Below I make specific comments and suggestions in the hope that they are useful in making the paper more comprehensive and making the results possibly more robust.

SPECIFIC COMMENTS

1. In addition to the daily maximum temperature (Tmax), the authors could examine the daily minimum temperature (Tmin). Tmin have been increasing more than Tmax over most regions around the globe. Pollution may be directly depressing Tmax trends via solar dimming in a region such as India while increased water vapor may be bolstering the Tmin trends. Tmin is also of very high relevance for heat wave impacts as inefficient nighttime cooling makes heat waves more difficult to weather and the elevated humidity responsible for it makes the Tmax expressions of heat waves more impactful on health. The latter signal may be partially accounted for by wet bulb temperature, though it is not clear how closely the two are correlated. Anyways, other regions have experienced the largest rise in heat wave activity via the Tmin expressions of heat waves, e.g. Gershunov et al. 2009.

Gershunov, A., D. Cayan and S. Iacobellis, 2009: The great 2006 heat wave over California and Nevada: Signal of an increasing trend. Journal of Climate, 22, 6181–6203.

2. The highest daily maximum (and minimum for that matter) temperature of the year is expected to vary a lot due to small sample size. If heat waves are becoming longer-lasting or more frequent, that may not be well reflected in the annual maxima. A peaks-over-threshold approach (Gershunov et al. 2009, Gershunov and Guirguis 2012) to quantify heat wave “activity”, rather than its maximum day/year expression, would pro-

vide a larger sample size and would be more likely to show anthropogenic trends in both the Tmax and Tmin expressions of heat waves.

Gershunov A. and K. Guirguis, 2012: California heat waves in the present and future. Geophysical Research Letters, 39, L18710, doi:10.1029/2012GL052979.

3. Figure 3 shows the clearly increasing SST trend in the Northern Indian Ocean. This SST trend could be expected to relate to stronger heat wave activity, and particularly to more humid heat waves that would be expected to express more strongly in Tmin.

4. Reference to Alfaro et al. (2006) may be useful in the discussion on lines 24-31 on page 10. The relative contributions of SST and local soil moisture to summertime Tmin and Tmax are discussed quantified over a large part of North America.

Alfaro, E., A. Gershunov and D.R. Cayan, 2006: Prediction of summer maximum and minimum temperature over the Central and Western United States: The role of soil moisture and sea surface temperature. Journal of Climate. 19, 1407-1421.

5. The short section 4 that appears at the top of page 11 could benefit from a figure showing the average summertime Tmax (and Tmin). Since it is mentioned elsewhere in the text that these trends exist, it would be useful to see these time series at the stations used here.

6. The last paragraph on page 12 raises the question: Does the AOD trend reduce average summertime Tmax by the same factor as it reduces the extreme heat events' Tmax expression?

7. Section 6 at the top of page 13 could benefit from reference to Alfaro et al. (2006), who expressly quantify the impact of soil moisture on summertime Tmax over a large part of North America.

8. Section 6, last sentence: "...increased humidity also makes some impacts of heat waves more severe" and/as it tends to keep them hotter at night (Gershunov et al. 2009).

9. Discussion section, first paragraph. While it may be true that “the record heat on 19 May 2016 . . . cannot simply be attributed to global warming”, I wonder if the fact that “we find only limited evidence for positive trends in the highest temperature of the year in India in observations and the ERA-interim reanalysis” is enough to claim that there is no evidence of historical heat wave trends. As suggested above, a peaks-over-threshold approach may well lead to a clearer identification of historical trends (e.g. Gershunov et al. 2009).

10. The last sentence of the same paragraph states: “One expects a heat wave with such a return period almost every year somewhere in India”. I wonder what is the basis for this statement? Does this argument hinge on the scale of heat waves relative tot hat of the Indian Subcontinent? A clarification would be useful here.

11. Page 17, lines 14-16. The increase in irrigation “and higher SST will give an increase in humidity, leading to higher heat wave impacts” also from elevated nighttime (Tmin) temperature (e.g. Gershunov et al. 2009).

12. At the bottom of page 17, the authors describe and try to explain the disconnect between models and observations particularly with respect to the hottest temperature of the year. On line 1 of page 19, the authors suggest this may not be the most relevant definition. I think this definition is making it difficult to detect a trend in observations, even if a trend in heat wave activity exists. It also makes it harder for the models to simulate the observed trend. Defining heat wave activity as temperature excesses over a high percentile (relative to local, observed and modeled climatology) threshold, would probably lead to a more relevant comparison that would also be fairer to the models. And it certainly makes it hard (without considering Tmin) to detect temperature trends related to changes in humidity, which, as the authors state, are so important for health impacts.

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