# *Interactive comment on* "Climate change as a driver of future human migration" *by* Min Chen and Ken Caldeira

**Min Chen and Ken Caldeira**

kcaldeira@carnegiescience.edu

A formatted version of this response is attached as a supplement.

Referee responses:

RC1: 'Review', Anonymous Referee #1, 03 May 2020

Review comments were very positive, which we appreciate. The main suggestion was to include some additional references and discussion.

They are obviously aware of the controversial nature of projections of migration related to climate change, but it would be good if this insight could be strengthened by a few references to the broader social science literature on migration and climate change,

which emphasis the lack of certainty of projections, for instance the recent letter from a number of researcher printed in Nature Climate Change (Boas, I., Farbotko, C., Adams, H. et al. Climate migration myths. Nat. Clim. Chang. 9, 901–903 (2019).)

This paper is now cited in the very first sentence of our Introduction:

Human migration is a complex socioeconomic phenomena driven by mixture of historical, political, cultural, economic and geographical factors (Black et al., 2011; Boas et al., 2019; Foresight: Migration and Global Environmental Change, 2011; Greenwood, 1985), often by the need to adapt to environmental stressors (Adger et al., 2014) including those caused by climate change (Missirian and Schlenker, 2017; Myers, 1993; Núñez et al., 2002; Stapleton et al., 2017).

It is also cited in another two sentences in our Introduction:

Of course, people are subject to a wide range of incentives and constraints; therefore, actual future migration will depend on a much broader set of factors (Adger et al., 2014; Boas et al., 2019; Greenwood, 1985). Ideally, projections of future human migration patterns would involve consideration of a wide range difficult-to-quantify factors (e.g., future wealth, efficacy of adaptive response, cultural factors, and non-linear interactions between climate change and population growth) (Boas et al., 2019; Holobinko, 2012; Suweis, 2018).

I also recommend adding a bit more on why the authors think that the correlation between grid cell population density and climate variables is not by coincidence. They reference a bit of literature on this, but some substantial arguments would be appreciated. A brief discussion of the mechanisms at work would also help the reader to be more aware of which of the factors held constant in the authors' analysis would like be of major importance in shaping the future relationship between population densities and climate variables.

We now write in our Discussion section:

Parameter values and their uncertainties are shown in Table S2; p-values on coefficients for all temperature and precipitation related variables based on a Student T-test are <0.0005, indicating that these results are unlikely to have been obtained by chance.

Based on observations of maps like the following, we have also added the following text:

It is clear that population distributions are related to climate variables. Population densities tend be very low both in very hot areas (e.g., Death Valley) and in very cold areas (e.g., Alaska), and relatively high in areas with intermediate temperatures (e.g., New York City). Similarly, population densities tend to be low in very dry areas (e.g., central Australia) and very wet areas (e.g., northern Australia) and relatively high where there is an intermediate amount of precipitation (e.g., Sydney, Australia).</b>

This might also lead the authors to reconsider their title, which, while not wrong, might lead to the misunderstanding that they are making predictions, when they are clear in the text that they do not.

Following the referee's suggestion, we have changed the title from

Climate change as a driver of future human migration

To

Climate change as an incentive for future human migration

The authors need to juggle between grid cell and country level data, because of data availability. It would be useful if they briefly discussed the implications and potential problems of this. If I understand correctly, the authors need to keep the within-country distribution of population constant both for the projection periods, implying that all migration is international, while, in reality, some of the incentive for migration may be internal.</i> All of our analysis is at grid cell level, except for future population projections, which are country level data, downscaled to grid level under current population distributed. Further, when we report country-level incentives to migrate, we integrate

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over all grid cells in a country, so if one grid cell would be +100 and another -100 within a grid cell, we would report zero incentive to migrate from this country. We have now added the following text to the end of our Introduction:

When we report country-level results, we integrate across all grid cells within a country and report the net value, so our methodology would not predict incentive to migrate from a country that had some grid cells indicating incentives for out-migration but with other grid cells indicating even greater incentive for in-migration.</b>

It would be good to know about which of the variables had what importance etc. I missed a table with results for the regression between population density and climate variables.</i> We are sorry. For some reason our supporting material was not included in our original submission. This information is now in Table S2.

I have a hunch that the relationship between population density and climate variables is not constant over time but trending. This would require some adjustment in estimation as well as influence projection. Related to this: the time period for estimating the relationship is considerably shorter than that for the projection. Potential implications should at least tbe mentioned.

We have now added the following text to the Discussion section.

Further, our calculation treats the relationship between climate and incentive to migrate as constant in time. However, factors such as availability of indoor work in air-conditioned environments would surely modify these relationships. This study isolates a narrow range of factors under ceteris paribus assumptions. We hope our study motivates efforts to quantitatively address the panoply of factors that can influence migration decisions.

Please also note the supplement to this comment:
https://esd.copernicus.org/preprints/esd-2019-79/esd-2019-79-AC3-supplement.pdf

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