Dear Prof. Lucarini,

Thank you for your comment and decision on our manuscript. We have tried to be modest in our claims and deferential towards the prior literature. We understand that migration is a very complicated and multi-factored problem. We agree that simple deterministic models cannot be used to predict migration flows. Our conclusions provide quantitative support for claims made qualitatively in the past: The tropics are likely to become hot and, other things equal, this will provide a motivation for people to move to cooler climates. However, as we all know, other things are never equal and there will be a wide array of confounding dynamics. We believe our manuscript, although limited in scope, is a useful contribution to the literature in that it quantifies one piece of this big puzzle. This message is repeated several times in our paper, but in response to editorial request to consider additional prior work we have modified a key paragraph in our Introduction, so it now reads as follows:

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) with ongoing debates (Afifi, 2011; Bettini, 2013; Boas et al., 2019; Mortreux and Barnett, 2009; Piguet et al., 2011; Suhrke, 1994). For example, Milan et al., (2015) pointed out household vulnerability could impact human migration patterns in the mountain areas of the global South.

The marked-up version of the manuscript is attached for your review.

Thank you.

Ken Caldeira and Min Chen

Climate change as an incentive for future human migration

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Abstract

Human migration is both motivated and constrained by a multitude of socioeconomic and environmental factors, including climate-related factors. Climatic factors exert an influence on local and regional population density. Here, we examine implications for future motivation for humans to migrate by analyzing today's relationships between climatic factors and population density, with all other factors held constant. Such 'all other factors held constant' analyses are unlikely to make quantitatively accurate predictions but the order-of-magnitude and spatial pattern that come out of such an analysis can be useful for thinking about the influence of climate change on the possible scale and pattern of future incentives to migrate. Our results indicate that, within decades, climate change may provide to hundreds of millions of people additional incentive to migrate, largely from warm tropical and subtropical countries to cooler temperate countries, with India being the country with the greatest number of people with additional incentive to migrate. These climate-driven incentives would be among the broader constellation of incentives that influence migration decisions. Areas with the highest projected population growth rates tend to be areas that are likely to be most adversely affected by climate change.

1. 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). Climate change is expected to lead to higher temperatures and an altered hydrological cycle in the coming decades (McLeman and Hunter, 2010), and temperature and precipitation changes have been shown to influence human migration at local to regional scale (Barrios et al., 2006; Black et al., 2011; Bohra-Mishra et al., 2014; Gray and Bilsborrow, 2013; Hsiang et al., 2013; Kelley et al., 2015; Marchiori et al., 2012; Mueller et al., 2014). Hsiang and Sobel, (2016) examined consequences for migration if everyone moved to remain at the same annual global mean temperature under a climate change scenario.

We apply a simple and transparent approach to estimate the number and geographic distribution of people for whom temperature and precipitation changes may provide an additional incentive migrate. 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) with ongoing debates (Afifi, 2011; Bettini, 2013; Boas et al., 2019; Mortreux and Barnett, 2009; Piguet et al., 2011; Suhrke, 1994). For example, Milan et al., (2015) pointed out house hold vulnerability could impact

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human migration patterns in the mountain areas of the global South. Nevertheless, our goal is to identify what continuance of current relationships between climate variables and global human population density would imply for future incentives to migrate. While these relationships will not remain fixed in time, it is nonetheless useful to understand what direct application of current relationships to future climate would contribute to the set of incentives that will influence future human migration.

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2. Methods

2.1 Overview

Nordhaus (Nordhaus, 2006) applied a regression analysis on geographic and economic data to estimate the influence of climate variables on the areal density of Gross Domestic Product (GDP). Samson et al. (Samson et al., 2011) used weighted regression model to identify ideal temperature and precipitation ranges for human habitation (as measured by population density), and studied how those ideal temperature and precipitation ranges may change in the future owing to climate change. Here we apply similar methods to the same dataset, the Geographically based Economic data (G-Econ), to estimate the influence of climate variables on population density.

To estimate of the influence of climate on the attractiveness of different locations, we apply the historical relationship between climate variables and population density, along with projections (Taylor et al., 2012) of future climate change from the output of the Coupled Model Intercomparison Project Phase 5 (CMIP5) under Representative Concentration Pathways (Vuuren et al., 2011) (RCPs, including RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) scenarios, incorporating future country-scale demographic population projections from the United Nations' World

Population Prospects 2015 (United Nations, 2015). Details are in the Analysis section below, but the basic idea is that if, for example, historical relationships between population density and climate change would predict a 10% decrease in population density for a grid cell in a climate change scenario, we would estimate that there would be incentive for 10% of the future population (as estimated by the UN) to migrate from that grid cell. Of course, many other factors including family ties, linguistic barriers, lack of resources, employments relations, and so on, would be expected to influence migration decisions. 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. Thus, internal migration is not considered in our study (Rigaud et al., 2018).

2.2 Data

This research uses the Geographically based Economic data (G-Econ) dataset (Nordhaus, 2006) for the historical climate and population data. The G-Econ dataset is originally developed for analyzing global economic activities and provides gridded (1°×1°) economic (e.g. Gross Cell Product, population) and geographical (e.g., climate, location, country, distance from seacoasts, soils and vegetation cover) information covering all terrestrial regions. In total, there are 27,445 grid cells in the dataset. G-Econ's climatology data, including annual mean air temperature (T, in °C) and annual precipitation (P, in mm year^{-1}), were derived from the Climate Research Unit Average Climatology high-resolution data sets (New et al., 2002). The gridded population (N) was adapted from the Gridded Population of the World (GPW) dataset (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3). More details and the data download link is available at http://gecon.yale.edu/.

In this study, from the G-Econ dataset, we used the population density (*D*) and the geographical data, including *T*, *P,* distance to lake (*DL*, in *km*), distance to major river (*DMR*, in *km*), distance to river (*DR*, in *km*), distance to ocean (*DO*, in *km*), elevation (*E*, in *m*), and surface roughness (*Roughness*, in *m*).

To make our projections, we used *T* and *P* in historical (*i.e.*, 1960-2005) climate, and future climate scenarios (2006-2100) from the output of the Coupled Model Intercomparison Project Phase 5 (CMIP5), which produces state-of-art multi-model dataset to advance the knowledge of climate change. We collected the model projected *T* and *P* (20 model projects; see Table S1) under all Representative Concentration Pathways (RCPs, including RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) from CMIP5 dataset to represent the range of future climate projections. We regridded the CMIP5 data to a 1°×1° common grid using bilinear interpolation.

We used the historical and predicted (median-variant) country-level population data from the World Population Prospects: The 2015 Revision by the United Nations Department of Economic and Social Affairs (United Nations, 2015). We use $W_{i,y}$ to denote the population estimated by the UN for grid cell *i* in year *y*; we use $W_{c,y}$ to denote the population estimated by the UN for country *c* in year *y*.

2.3 Analysis

Year 2005 population density and within-country distribution. Areal population density for year 2005 in each grid cell i (D_i) was calculated from the population (N_i) of 2005, grid area (A_i, in km^2) and land fraction of the grid (L_i, no unit) from G-Econ dataset:

$$D_i = N_i / \left(A_i \times L_i \right) \quad (1)$$

We denote the fraction of population of country c living in grid cell i with the symbol $d_{i,c}$:

$$d_i = N_i \Big/ \sum_{i \in c} N_i \quad (2)$$

where $i \in c$ indicates that the summation is performed over all grid cells in country c. The distributional parameter, $d_{i,c}$, is considered to be constant in time.

Linear regression model. Our methods for estimating climate influence on population density parallels methods previously applied (Nordhaus, 2006) to estimate climate influence on areal density of GDP. The basic idea is to find a single set of coefficients that explain within-country relationships between population, climatic and geographic variables. For our regressions, we used data from the G-Econ dataset (Hsiang et al., 2013) and the Climate Research Unit Average Climatology high-resolution data sets(Hsiang et al., 2013) (for filling the missing data in the G-Econ dataset). To estimate logarithm of population density from both geographical (**G**) and climatic variables (**C**), we used the equation:

$$\log_{10} D = \beta_0 + \mathbf{G}\boldsymbol{\beta}_\mathbf{G} + \mathbf{C}\boldsymbol{\beta}_\mathbf{C} \quad (3)$$

where D is a vector of grid-scale population densities (i.e., D_i for grid cell i). Specifically,

$$\mathbf{G} = \left[country \quad soil \quad DL \quad DMR \quad DR \quad DO \quad E \quad roughness \right] \quad (4)$$

$$\mathbf{C} = \left[T \quad T^2 \quad T^3 \quad p \quad p^2 \quad p^3 \quad Tp \quad T^2 p \quad p^2 T \right] \quad (5)$$

where T is as defined above, and p is $\log_{10} P$. *country* and *soil* are categorical variables, $\boldsymbol{\beta}_\mathbf{G}$ and $\boldsymbol{\beta}_\mathbf{C}$ are numerical coefficients vector on geographical and climatic variables, respectively.

$$\boldsymbol{\beta}_\mathbf{G} = \text{Transpose}\left[\beta_{G,country} \quad \beta_{G,soil} \quad \beta_{G,DL} \quad \beta_{G,DMR} \quad \beta_{G,DR} \quad \beta_{G,DO} \quad \beta_{G,E} \quad \beta_{G,roughness}\right] \tag{6}$$

and

$$\boldsymbol{\beta}_\mathbf{C} = \text{Transpose}\left[\beta_{C,T} \quad \beta_{C,T^2} \quad \beta_{C,T^3} \quad \beta_{C,p} \quad \beta_{C,p^2} \quad \beta_{C,p^3} \quad \beta_{C,Tp} \quad \beta_{C,T^2p} \quad \beta_{C,p^2T}\right] \tag{7}$$

Antarctica, Greenland, and grid cells with zero precipitation were excluded from this analysis.

The values for the β-coefficients are determined by an area-weighted ordinary-least-squares curve fit to $\log_{10}$ D. Fitting the above linear regression model was conducted in MATLAB R2017a (http://www.mathworks.com/products/matlab/). In total, 20,503 grid cells had data for all parameters needed for the fitting procedure. Variability that is not explained by equation (3) is assumed to be the result of unknown factors which we treat as invariant with time.

Population change projections. We first calculated the ratio of population in the changed climate relative to the base-state climate (here taken to be the climate in the period preceding 2005) in region i for the climate in year y considering climate factors alone ($r_{i,y}$):

$$r_{i,y} = \frac{D_{i,y}}{D_{i,2005}} \tag{8}$$

For each grid, we calculated $r_{i,y}$ for each year from 2006 to 2100 using equation (8) and 30-year moving average of T and P projected by each CMIP5 model. (The 30-year moving average ends on the period under consideration so that decisions are made on past but not future climate states.)

In the absence of climate change, we would estimate the population in grid cell i in country c for year y ($W_{i,y}$) to be $d_{i,c} \times W_{c,y}$, where c is the country containing grid cell i. If we directly apply the population change ratio under climate change ($r_{i,y}$) to the population estimates, the population with taking climate change into account would be $r_{i,y} \times W_{i,y}$. However, this estimate must be scaled to conserve total population. Thus, the population $N_{i,y}$ of grid cell i in year y can be estimated to be:

$$N_{i,y} = r_{i,y} \times W_{i,y} \times \frac{\sum_{i \in c} d_{i,c} \times W_{c,y}}{\sum_{i \in c} r_{i,y} \times d_{i,c} \times W_{c,y}} \qquad (9)$$

By doing this adjustment, we conserve the world total population, but take climate change into account to estimate the spatial distribution of population.

We then estimate the number of people for whom climate change is projected to provide additional incentive to migrate for grid-cell i and year y (indicated by $\Delta N_{i,y}$) as:

$$\Delta N_{i,y} = N_{i,y} - W_{i,y} \qquad (10)$$

Negative values of $\Delta N_{i,}$ are interpreted as indicating areas where climate change provides additional incentive to emigrate; positive values indicate areas that are projected to increase in relative attractiveness. (Even if everyplace were to decrease in absolute attractiveness due to climate change, the places with a smaller absolute decrease would increase in relative attractiveness.)

We define $f_{i,y} = N_{i,y} / W_{i,y}$, so that $f_{i,y} - 1$ indicates the fractional change in population that would be required to offset the influence of climate change on the attractiveness of grid cell i in year y. When $f_{i,y} - 1 < 0$, that means that grid cell i has become less attractive. We integrated $N_{i,y}$ for grid cells in each country c to yield $N_{c,y}$ and define $f_{c,y} = N_{c,y} / W_{c,y}$. We calculate results independently for each of the CMIP5 models simulations (Taylor et al., 2012) and present median results. Where a range is reported, it encompasses results for 68% of the CMIP5 models.

We report results with two significant digits. The computer scripts written in Matlab R2017a used to perform our analyses are available upon request.

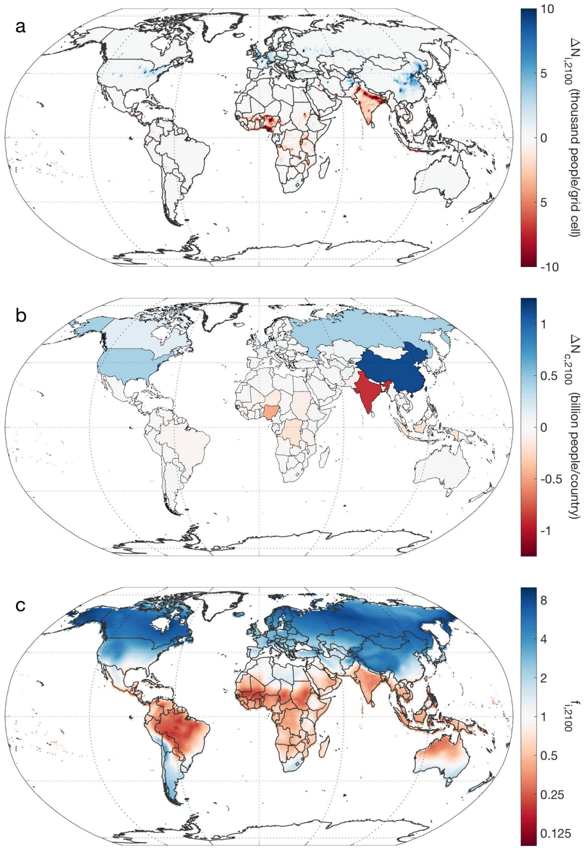

Figure 1. The number of people for whom climate change is projected to provide additional incentive to migrate under RCP 8.5 per 1° × 1° grid cell ($\Delta N_{i,2100}$, in thousand people, panel a) and per country ($\Delta N_{c,2100}$, in billion people, panel b). The fractional change in population that would be required to offset the influence of climate change on the relative attractiveness of living in a particular location for year 2100 ($f_{i,2100}$) under scenario RCP 8.5 (c). To isolate the effect of climate change on incentives to migrate, all factors are held constant, except for climate and country-level population. Of course, many other factors influence migration decisions.

Results

The regression of population density against geographic and climate variables as described above (see also Methods and Supporting Material) explains 72% of the geographic variance in the logarithm of population density. Parameter values and their uncertainties are shown in Table S2; p-values based on a Student T-test on coefficients for all temperature and precipitation related variables are <0.0005, indicating that these results are unlikely to have been obtained by chance.

Applying our regression equation to climate model and demographic projections, we find that $\Delta N_{i,y}$ is negative (i.e., indicating decreased attractiveness) in regions that are already hot and are projected to experience substantial additional warming under climate change (primarily tropical and subtropical regions), whereas we find that $\Delta N_{i,y}$ is positive (i.e., indicating increased attractiveness) in cooler regions (primarily in the temperate regions of the Northern Hemisphere; Figure 1a and S1,a,b,c).

Under RCP 8.5, India has the largest negative $\Delta N_{c,2100}$ value among countries (0.89 [0.77 to 1.10] billion; Figure 1b), followed by Nigeria (0.46 [0.38 to 0.58] billion). The other countries with the largest negative values of $\Delta N_{i,2100}$ are Democratic Republic of Congo (0.20 billion), Indonesia (0.18 billion), Niger (0.14 billion), Sudan (0.11 billion), Philippines (0.10 billion), Bangladesh (0.09 billion), Tanzania (0.09 billion) and Pakistan (0.08 billion). In contrast, China, Russia and the United States all have positive values of $\Delta N_{c,2100}$.

The metric $f_{i,2100}$ is less than 0.3 in parts of the Northern African Tropical Savanna, Tropical South America and Tropical Asia under RCP 8.5, indicating that future incentives to migrate from those areas may be substantial. The metric $f_{i,2100}$ is >5 in much of Canada, Russia and Scandinavia, and parts of the United States, and China (Figure 1c), which could indicate that in the absence of other barriers these regions could become migration destinations. Results for RCP 2.6, 4.5 and 6.0 show similar spatial patterns but at lower magnitude (Figure S1).

The countries with the largest projected population growth to year 2100 tend to be countries where the largest negative values of $\Delta N_{c,2100}$ (Fig. 2). The equation $\Delta N_{c,2100} = (1.79 \pm 0.06)\ \Delta W_{c,2100} + (0.21 \pm 0.02)$ explains 79% of the variation in population-weighted $\Delta N_{c,2100}$ (best estimate ± 1 standard error). Figure 2 shows average projected population increase from 2005 to 2100 ($\Delta W_{c,2100}$) on the horizontal axis is negatively correlated to the number of people in each country with additional incentive to emigrate ($\Delta N_{c,2100}$) on the vertical axis. About 70% of the world's projected year 2100 population lives in a country that is expected to experience population growth and for which $\Delta N_{c,2100}$ is < 0 (lower right quadrant in Fig. 2). In contrast, 14% of the global population in 2100 is projected to live in a country experiencing with a population lower than today and for which $\Delta N_{c,2100}$ is > 0 (upper left quadrant in Fig. 2). Similar patterns are found under other scenarios (Fig. S2).

Figures 3 shows values of $\Delta N_{i,y}$ integrated over all grid cells with $\Delta N_{i,y} < 0$, indicating the number of people for whom climate change for whom climate change may produce an additional incentive to migrate. Under all of the RCP scenarios, this integrated value increases over the next few decades (Figure 3), reaching 0.6 to 1.9 billion people by 2050 (depending on RCP scenario). By year 2100 under RCP 8.5, this number increases to about 3.8 [3.3 to 4.9] billion people, which is about one-third of the projected global population in 2100.

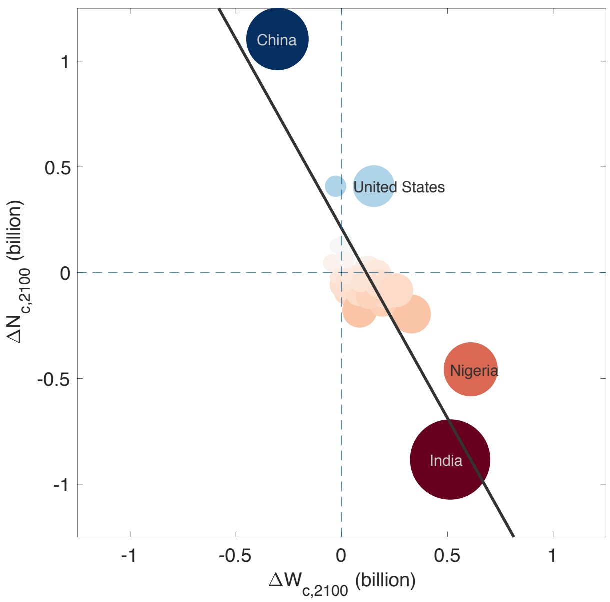

Figure 2. Country-level projections for population increase in year 2100 relative to year 2005 ($\Delta W_{c,2100}=W_{c,2100} - W_{c,2005}$, horizontal axis) and the number of people for whom climate change is projected to provide additional incentive to migrate under RCP 8.5 ($\Delta N_{c,2100}$; vertical axis). Areas of circles are proportional to year 2100 population. Color scale is as per Figure 1b. The line shows the population-weighted linear trend. Negative values on the vertical axis indicate additional incentive to emigrate; positive values indicate countries that increase in relative attractiveness. Results hold all factors constant, except for climate and country-level population. Data for producing this figure is provided in Table S3.

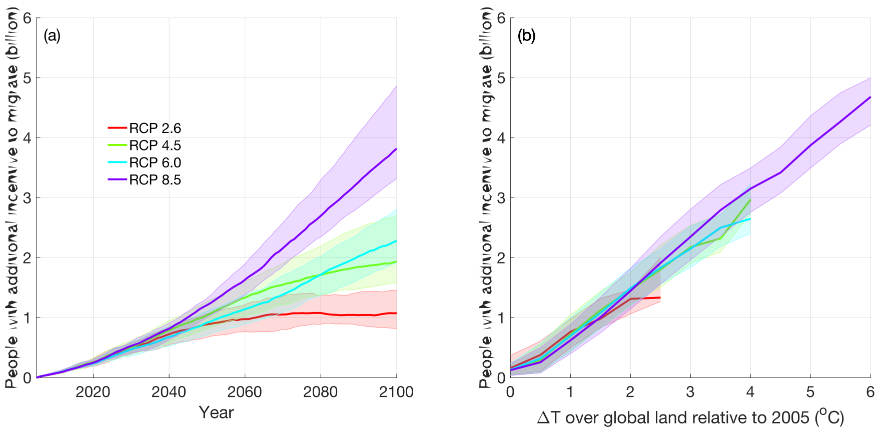

Figure 3. Number of people projected to experience additional climate-related incentive to emigrate under four Representative Concentration Pathways against years (a) and change of 30-year moving mean temperature over global land relative to 2005 (b) . The lines show the median value across CMIP5 models with results from 66 % of the models falling within the shaded area. Results hold all factors constant, except for climate and country-level population.

Discussion and Conclusions

In this section, we discuss some of the relevance of the results of our calculations for the real world. We intend our quantitative results to indicate possible orders-of-magnitude and global-scale spatial patterns of people with changed incentives; we do not intend our results to be interpreted as quantitative predictions of future climate-induced human migration.

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). Our calculations take into account changes in temperature and precipitation only, under the artificial assumption that all other factors remain constant. Further, our calculation treats the relationship between climate and incentive to move 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.

Our highly idealized calculations are intended to indicate the scale and geographic distribution of people for whom climate change might provide an additional incentive to migrate. Our calculations also indicate which regions climate change might make more attractive to potential migrants. Clearly, migration decisions are influenced by a wide range of factors (Fussell et al., 2014; McLeman and Hunter, 2010). Further, there is often a substantial incentive to avoid migration entirely, so additional incentive to migrate does not imply an overall positive net incentive to migrate. The number of people who will have positive net incentive to migrate as a result of climate change is thus less than the number of people for whom climate change will provide an additional incentive to migrate. Migration is one of many possible adaptive responses to climate change. For example, people might choose to cool interior spaces with air conditioners (Barreca et al., 2016). Another response could be to shift from agricultural work in rural environments to industrial or service-sector jobs in more urbanized environments (Jiang and O'Neill, 2017; Neill et al., 2010), and thus migration flows can be influenced by differences in types of development and not only climatic factors.

Our results indicate that India may be the country that will contain the largest number of people to whom climate change may provide an additional incentive to emigrate. West Africa, and in particular, Nigeria, may be the second most important area in this regard (Figure 1a,b). This is largely a consequence of high population densities in areas that are already warm and projected to get warmer. Our results indicate that many people living in the Amazon region would have additional incentive to emigrate, but population density is generally low. More generally, climate change may provide additional incentive to emigrate to many people living in the tropics (Figure 1c). In contrast, our regression equations indicate that, from a purely climatic perspective, climate change may increase the attractiveness of northern countries, such as China, Russia, Canada, Norway, Sweden and Finland, relative to most other parts of the world.

There is a country-level correlation between projected population increase and the degree to which climate change is projected to provide an additional incentive to emigrate. This correlation suggests that population increases have the potential for exacerbating negative effects of climate change in much of the world. Over two-thirds of the world's year 2100 population is projected to live in a country with greater population than today and for which climate change may provide additional incentive to emigrate. In contrast, about one out of seven people are projected to live in a country with a lower population and where climate change may cause to become relatively more attractive. China is the largest country that is expected to both experience a decrease in population and an increase in climate-related relative attractiveness. Moreover, our calculations suggest that India could be the largest potential source of climate emigrants, and that China could potentially be the largest potential destination for climate immigrants (Figure 1b). However, immigration in China is currently very limited (Abel and Sander, 2014). Thus, barriers to migration in southeast Asia could potentially become an important source of future climate-related conflict (Hsiang et al., 2013).

Climate change may provide additional incentive to migrate to hundreds of millions of people within the next decades and potentially billions of people by the end of this century (Figure 3). Approximately 0.8 billion people have additional incentive to migrate per 1 °C increase of air temperature over global land (Figure 3b). The number of people projected to have additional incentive to migrate by year 2100 under RCP 4.5 or 6.0 is about half that projected under RCP 8.5, and the number project under RCP 2.6 is about half that projected under RCP 4.5 or 6.0. This result points to the important role that emissions reductions may play in reducing climate-related incentives to migrate. Successful local adaptation measures could greatly reduce incentives to migrate (Adger et al., 2014).

Climate change is likely to induce a complex web of dynamical interactions at a range of spatial and temporal scales, and these interactions are not well represented by our model. A more complete treatment of migration, and not simply an examination of one possible set of incentives as we have done here, would require embedding our results in the broader context of incentives that could influence migration decisions (Piguet et al., 2011). For example, considerations of language, work, and family ties can provide strong incentive not to migrate. Projections of how climate change might affect migration are therefore fraught with uncertainty. Nevertheless, the results of our calculations may indicate areas that climate change can be expected provide large numbers of people, primarily in the tropics, an additional incentive to migrate, primarily to the middle and high latitudes of the Northern Hemisphere. This change in climate-driven incentives to migrate is one factor among many that need to be included in a comprehensive understanding of possible future migration flows.

Code/Data availability

All the data used in this study is publicly available. The CMIP5 climate projections are available at https://cmip.llnl.gov/cmip5/data_portal.html. The G-Econ dataset is available at http://gecon.yale.edu/. The WPP2015 (World Population Prospects: The 2015 Revision by the United Nations Department of Economic and Social Affairs) data is available at http://esa.un.org/unpd/wpp/Download/Standard/Population/.

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Author Contributions

M. C. and K. C. conceived and designed the project and performed the computational analysis. M.C. wrote the first draft of the manuscript with later development from K. C.

Competing interests

The author(s) declare no competing interests.

Supporting Material for

Climate change as a driver of future human migration

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Figure S1. The number of people for whom climate change is projected to provide additional incentive to migrate under RCP 2.6, 4.5 and 6.0 per 1° × 1° grid cell ($\Delta N_{i,2100}$, in thousand people) and per country ($\Delta N_{c,2100}$, in billion people). The fractional change in population that would be required to offset the influence of climate change on the relative attractiveness of living in a particular location for year 2100 ($f_{i,2100}$) under the scenarios. The three rows presents $\Delta N_{i,2100,}$ $\Delta N_{c,2100}$ and $f_{i,2100}$ under RCP 2.6, 4.5 and 6.0 (columns), respectively. Color schemes are the same as in Fig. 1. Results hold all factors constant, except for climate and country-level population.

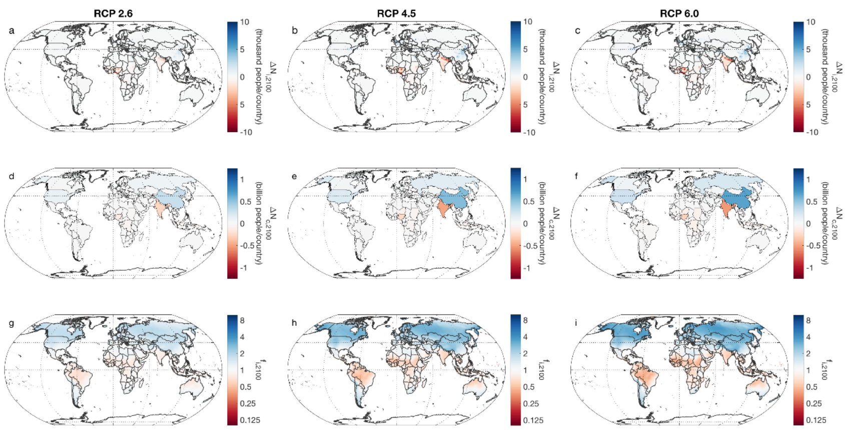

Figure S2. Country-level projections for population increase in year 2100 relative to year 2005 ($\Delta W_{c,2100}=W_{c,2100} - W_{c,2005}$, horizontal axis) and the number of people for whom climate change is projected to provide additional incentive to migrate under RCP 2.6, 4.5 and 6.0 ($\Delta N_{c,2100}$; vertical axis). Areas of circles are proportional to year 2100 population. Color scale is as per Figure 2. The line shows the population-weighted linear trend by fitting $\Delta N_{c,2100}=a\Delta W_{c,2100}+b$, where a and b are parameters. For RCP 2.6, a=-0.49±0.06, b=0.06±0.02 (best estimate ± 1 standard error), and R^2=0.80; for RCP 4.5, a=-0.92±0.06, b=0.10±0.02, and R^2=0.79; for RCP 6.0, a=-1.08±0.06, b=0.13±0.02, and R^2=0.79. Negative values on the vertical axis indicate additional incentive to emigrate; positive values indicate countries that increase in relative attractiveness. Results hold all factors constant, except for climate and country-level population. Data for producing this figure is provided in Table S3.

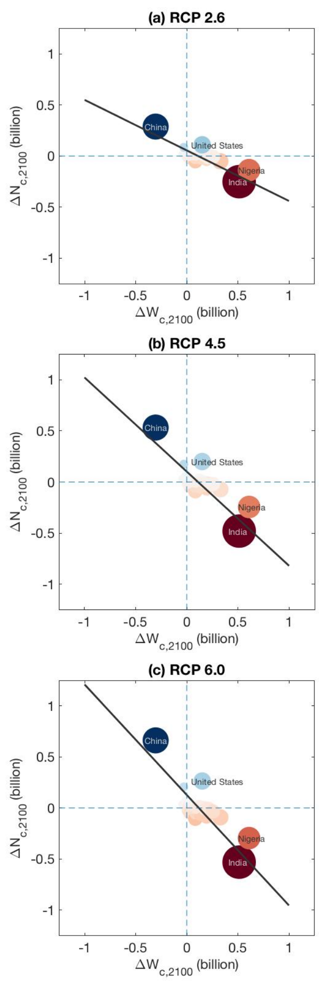

Table S1. CMIP5 models used in this study.

Model	Country and Research Center	Resolution (Latitude, Longitude)
CCSM4	United States, NCAR	(0.9424, 1.25)
CESM1-CAM5	United States, NCAR	(0.9424, 1.25)
CSIRO-Mk3.6.0	Australia, CSIRO	(1.8653, 1.875)
FIO-ESM	China, The First Institute of Oceanography, SOA	(2.8125, 2.8125)
GFDL-CM3	United States, NOAA/GFDL	(2, 2.5)
GFDL-ESM2G	United States, NOAA/GFDL	(2.0225, 2)
GFDL-ESM2M	United States, NOAA/GFDL	(2.0225, 2.5)
GISS-E2-H	United States, NASA GISS	(2, 2.5)
GISS-E2-R	United States, NASA GISS	(2, 2.5)
HadGEM2-AO	United Kingdom, MOHC	(1.25, 1.875)
IPSL-CM5A-LR	France, IPSL	(1.8947, 3.75)
IPSL-CM5A-MR	France, IPSL	(1.2676, 2.5)
MIROC-ESM	Japan, JAMSTEC; Atmosphere and Ocean Research Institute (AORI); National Institute for Environmental Studies (NIES)	(2.7906, 2.8125)
MIROC-ESM-CHEM	Japan, JAMSTEC; AORI; NIES	(2.7906, 2.8125)
MIROC5	Japan, JAMSTEC; AORI; NIES	(1.4008, 1.40625)
MRI-CGCM3	Japan, MRI	(1.12148, 1.125)
NorESM1-M	Norway, Norwegian Climate Centre	(1.8947, 2.5)
NorESM1-ME	Norway, Norwegian Climate Centre	(1.8947, 2.5)
BCC-CSM1.1	China, BCC	(2.8125, 2.8125)
BCC-CSM1.1-M	China, BCC	(1.125, 1.125)

478 Table S2. Coefficients and their statistics of the linear model used in this study.

	β - *e*stimate	SE	tStat	pValue
Intercept (β_0)	-0.82004	0.291	-2.8179	0.0048379
Country_Brazil	0.054015	0.26167	0.20642	0.83646
Country_Cameroon	0.27116	0.28968	0.93608	0.34924
Country_Canada	-2.0539	0.25889	-7.9334	2.24E-15
Country_Central_African_Republic	-0.0073257	0.28708	-0.025518	0.97964
Country_Chad	0.37767	0.27666	1.3651	0.17223
Country_Chile	-0.075873	0.27075	-0.28023	0.7793
Country_China	1.0506	0.25918	4.0537	5.06E-05
Country_Egypt	0.31233	0.28154	1.1094	0.26728
Country_Federated_State_of_Micronesia	1.4972	0.35412	4.228	2.37E-05
Country_Finland	-0.12924	0.27827	-0.46444	0.64233
Country_France	0.45474	0.27542	1.6511	0.098734
Country_Japan	0.89189	0.2734	3.2622	0.0011073
Country_Kiribati	-2.631	0.30061	-8.7522	2.25E-18
Country_Madagascar	0.56175	0.28628	1.9623	0.049747
Country_Mali	0.46656	0.27798	1.6784	0.093284
Country_Mauritania	0.11439	0.28137	0.40653	0.68436
Country_Mexico	0.41965	0.26585	1.5785	0.11446
Country_Namibia	-0.22503	0.27955	-0.80497	0.42085
Country_Nigeria	1.0808	0.28032	3.8555	0.00011583
Country_Norway	-0.04153	0.27382	-0.15167	0.87945
Country_Pakistan	1.0611	0.27669	3.8352	0.00012586
Country_Peru	0.22118	0.27156	0.81448	0.41538
Country_Russia	0.19449	0.25894	0.75109	0.45261
Country_Saudi_Arabia	1.0125	0.27021	3.7472	0.00017929
Country_United_States	-0.31607	0.25823	-1.224	0.22097
Country_Mozambique	0.11655	0.27868	0.41823	0.67578
Country_Niger	0.5135	0.27887	1.8413	0.065586

Country_Zambia	0.32284	0.28177	1.1457	0.25191
Country_Kyrgyzstan	1.1234	0.31068	3.6161	0.00029981
Country_Bolivia	-0.3021	0.27416	-1.1019	0.27053
Country_Ethiopia	0.78187	0.27681	2.8245	0.0047395
Country_Ecuador	0.18874	0.30052	0.62807	0.52997
Country_Argentina	-0.31947	0.26284	-1.2154	0.22421
Country_Papua_New_Guinea	1.0409	0.28674	3.6303	0.00028379
Country_Sudan	0.7487	0.2705	2.7678	0.0056484
Country_Philippines	1.8121	0.28303	6.4022	1.56E-10
Country_Fiji	1.1483	0.33344	3.4439	0.00057463
Country_Cambodia	0.90276	0.3187	2.8326	0.004621
Country_Suriname	-0.86616	0.33684	-2.5715	0.010134
Country_Venezuela	-0.26962	0.27742	-0.97189	0.33112
Country_Botswana	-0.43587	0.2903	-1.5015	0.13325
Country_Indonesia	1.6201	0.26703	6.0671	1.33E-09
Country_Algeria	0.58076	0.2699	2.1518	0.031425
Country_New_Zealand	-0.44577	0.30894	-1.4429	0.14906
Country_Belize	0.28789	0.40293	0.71449	0.47493
Country_Australia	-1.6405	0.2686	-6.1077	1.03E-09
Country_Nicaragua	0.29798	0.33371	0.89293	0.37191
Country_Solomon_Islands	1.2243	0.32488	3.7685	0.00016469
Country_Georgia	0.51667	0.35712	1.4468	0.14798
Country_Greece	0.3789	0.2927	1.2945	0.19551
Country_Kenya	0.50217	0.28922	1.7363	0.082531
Country_Mongolia	0.58845	0.26755	2.1994	0.02786
Country_Denmark	0.72447	0.33383	2.1702	0.030003
Country_Sweden	0.06815	0.27494	0.24787	0.80423
Country_Lesotho	0.45029	0.42984	1.0476	0.29485
Country_Senegal	0.81041	0.3247	2.4959	0.012573
Country_Ireland	0.094257	0.33073	0.28499	0.77565

Country_Malawi	1.01	0.34276	2.9467	0.0032156
Country_Estonia	0.14562	0.34077	0.42732	0.66915
Country_Guyana	-0.54643	0.32003	-1.7074	0.087755
Country_Guinea	0.66098	0.31288	2.1126	0.034649
Country_Panama	0.45172	0.34989	1.291	0.19671
Country_South_Africa	0.10451	0.27254	0.38346	0.70138
Country_Libya	0.44555	0.27462	1.6224	0.10472
Country_Tajikistan	0.96066	0.31753	3.0255	0.0024857
Country_Morocco	0.60245	0.28091	2.1446	0.031995
Country_Democratic_Republic_of_Congo	0.51953	0.26886	1.9324	0.05333
Country_Cote_dIvoire	0.72778	0.30729	2.3684	0.017876
Country_Angola	-0.10325	0.27256	-0.3788	0.70484
Country_Eritrea	0.84228	0.33261	2.5323	0.011339
Country_Croatia	0.28673	0.3332	0.86054	0.3895
Country_Yemen	1.0474	0.29189	3.5882	0.00033379
Country_Guinea_Bissau	0.53134	0.41681	1.2748	0.2024
Country_Colombia	0.117	0.2749	0.42561	0.6704
Country_Swaziland	0.17974	0.46615	0.38558	0.69981
Country_Ghana	1.0778	0.31349	3.4379	0.00058751
Country_Burkina_Faso	1.0021	0.31034	3.2289	0.0012445
Country_Sierra_Leone	1.1884	0.3868	3.0724	0.0021265
Country_Paraguay	-0.76484	0.29417	-2.6	0.0093296
Country_Portugal	0.63332	0.31946	1.9824	0.047443
Country_Laos	0.48923	0.30677	1.5948	0.11077
Country_United_Kingdom	0.4896	0.28293	1.7305	0.083558
Country_Turkmenistan	0.41639	0.28429	1.4647	0.14303
Country_Tanzania	0.49139	0.279	1.7612	0.078216
Country_Congo	-0.16071	0.29857	-0.53826	0.5904
Country_Latvia	0.23659	0.34168	0.69242	0.48868
Country_Oman	0.20327	0.30182	0.67349	0.50065

Country_Syria	1.0244	0.31248	3.2782	0.0010466
Country_Tonga	1.5336	0.4161	3.6856	0.00022876
Country_Liberia	0.65014	0.3566	1.8231	0.068296
Country_Vanuatu	-0.5573	0.37179	-1.4989	0.1339
Country_Austria	0.50166	0.32793	1.5298	0.12608
Country_Uganda	1.0701	0.31892	3.3554	0.00079398
Country_Cape_Verde	0.92242	0.41689	2.2126	0.026935
Country_Iceland	-0.37392	0.30322	-1.2331	0.21754
Country_Thailand	1.3239	0.28589	4.6309	3.66E-06
Country_India	1.5667	0.2646	5.9209	3.25E-09
Country_Uzbekistan	0.78449	0.28509	2.7517	0.0059339
Country_Italy	0.90838	0.28091	3.2337	0.001224
Country_Ukraine	0.18756	0.27558	0.68058	0.49615
Country_Turkey	0.7291	0.27391	2.6618	0.0077779
Country_Belarus	0.23115	0.30098	0.76798	0.44251
Country_Bulgaria	0.24623	0.32824	0.75015	0.45317
Country_Macedonia	0.65063	0.42679	1.5244	0.12741
Country_Azerbaijan	1.1076	0.33732	3.2835	0.0010271
Country_Jordan	0.83516	0.35977	2.3214	0.020277
Country_Nepal	1.0544	0.32383	3.2561	0.0011315
Country_Spain	0.60454	0.27696	2.1827	0.029067
Country_Antigua_and_Barbuda	0.76365	0.76941	0.99252	0.32096
Country_Grenada	1.6808	0.76829	2.1877	0.0287
Country_Equatorial_Guinea	0.48824	0.40289	1.2118	0.22559
Country_Djibouti	0.6703	0.46675	1.4361	0.15099
Country_St._Lucia	1.7858	0.57319	3.1155	0.0018388
Country_Gabon	-0.35629	0.30861	-1.1545	0.24831
Country_Vietnam	1.2933	0.29063	4.4501	8.63E-06
Country_Benin	0.64242	0.35266	1.8217	0.068522
Country_Romania	0.38968	0.29693	1.3123	0.18942

Country_Uruguay	-0.70171	0.32499	-2.1592	0.030849
Country_Togo	0.94793	0.38677	2.4509	0.014258
Country_Lithuania	0.32159	0.34919	0.92094	0.35709
Country_Malaysia	1.2708	0.29615	4.291	1.79E-05
Country_Bhutan	0.0689	0.38518	0.17888	0.85803
Country_Honduras	0.72943	0.34225	2.1313	0.033076
Country_Dominican_Republic	1.3677	0.42757	3.1988	0.001382
Country_Hungary	0.37842	0.3379	1.1199	0.26276
Country_Maldives	3.7061	0.37102	9.9889	1.93E-23
Country_Moldova	0.60217	0.41488	1.4514	0.14668
Country_Guatemala	1.0096	0.35439	2.8488	0.0043928
Country_Germany	0.98754	0.28406	3.4765	0.00050906
Country_Albania	0.58426	0.42667	1.3694	0.1709
Country_Iran	0.83813	0.26856	3.1208	0.0018059
Country_Czech_Republic	0.71234	0.34011	2.0945	0.036231
Country_Costa_Rica	0.77503	0.40353	1.9206	0.054793
Country_Tunisia	0.95827	0.31945	2.9998	0.0027053
Country_Slovakia	0.56175	0.36852	1.5243	0.12744
Country_Haiti	1.5987	0.44451	3.5966	0.0003232
Country_Burundi	1.4094	0.49262	2.861	0.004227
Country_Comoros	1.4577	0.5766	2.5281	0.011477
Country_Mauritius	2.748	0.64673	4.2491	2.16E-05
Country_Poland	0.72687	0.28994	2.507	0.012183
Country_Samoa	2.5367	0.65479	3.8741	0.00010734
Country_Gambia	1.018	0.57689	1.7647	0.077635
Country_Armenia	0.98773	0.41365	2.3879	0.016956
Country_Cyprus	-0.25011	0.49074	-0.50966	0.61029
Country_Trinidad_and_Tobago	1.3077	0.645	2.0275	0.042624
Country_Switzerland	0.74948	0.38276	1.9581	0.050231
Country_Bangladesh	1.8892	0.32605	5.7944	6.96E-09

Country_St._Vincent_and_the_Grenadines	1.6581	0.7686	2.1573	0.03099
Country_Kuwait	1.5242	0.4669	3.2646	0.0010981
Country_Israel	1.3332	0.4286	3.1107	0.0018693
Country_Rwanda	1.5003	0.52788	2.8422	0.0044855
Country_El_Salvador	1.7571	0.49214	3.5703	0.00035737
Country_Belgium	0.8982	0.40127	2.2384	0.025206
Country_Brunei	1.5873	0.57459	2.7625	0.0057413
Country_South_Korea	1.1503	0.34765	3.3089	0.00093819
Country_Netherlands	1.1674	0.37521	3.1112	0.0018659
Country_Luxembourg	0.63188	0.57266	1.1034	0.26986
Country_Sri_Lanka	2.4363	0.39383	6.1863	6.28E-10
Country_Malta	2.0795	0.76799	2.7077	0.0067805
Country_St._Kitts_and_Nevis	1.7476	1.056	1.6548	0.097974
Country_Lebanon	0.9647	0.57313	1.6832	0.092349
Country_Slovenia	0.18594	0.46384	0.40086	0.68853
Country_Jamaica	1.7548	0.52567	3.3383	0.00084452
Country_Seychelles	2.5197	1.0563	2.3855	0.017066
Country_Bahrain	2.7657	0.77	3.5918	0.0003292
Country_Barbados	2.1958	1.0553	2.0807	0.037477
Country_Singapore	3.6019	0.76976	4.6793	2.90E-06
Country_Hong_Kong	2.9842	0.76929	3.8792	0.00010513
Country_Afghanistan	0.67027	0.27953	2.3978	0.016503
Country_American_Samoa	-0.79909	0.57448	-1.391	0.16424
Country_Andorra	0.92949	1.0551	0.88092	0.37837
Country_Anguilla	1.5217	0.76826	1.9808	0.04763
Country_Aruba	2.2667	0.76931	2.9464	0.0032181
Country_Bahamas	-0.011416	0.32535	-0.035089	0.97201
Country_Bailiwick_of_Guernsey	1.5257	1.0549	1.4463	0.14812
Country_Bailiwick_of_Jersey	1.183	1.0549	1.1214	0.26213
Country_Baker_and_Howland_Island	-2.9064	1.0602	-2.7413	0.0061254

Country_Bermuda	2.7749	1.0554	2.6292	0.0085641
Country_Bouvet_I.	-4.5437	1.0586	-4.2924	1.78E-05
Country_British_Indian_Ocean_Territory	2.7432	1.0573	2.5946	0.0094769
Country_British_Virgin_Is.	1.4856	1.0559	1.407	0.15945
Country_Cayman_Is.	0.8128	0.64523	1.2597	0.20779
Country_Christmas_I.	1.3325	1.0558	1.2622	0.20691
Country_Cocos_Is.	2.0668	1.056	1.9571	0.050345
Country_Cook_Is.	0.57887	0.38106	1.5191	0.12875
Country_Cuba	1.0668	0.31374	3.4003	0.00067433
Country_Dominica	1.1962	1.056	1.1327	0.25735
Country_Falkland_Is.	-0.91864	0.42787	-2.147	0.031805
Country_Faroe_Is.	0.84833	0.6444	1.3165	0.18803
Country_French_Guiana	-0.80395	0.37846	-2.1242	0.033662
Country_French_Polynesia	-0.7766	0.2854	-2.7211	0.0065124
Country_French_Southern___Antarctic_Lands	0.37874	0.47339	0.80005	0.42369
Country_Gibraltar	1.6034	1.0551	1.5197	0.1286
Country_Guadeloupe	1.2415	0.52612	2.3596	0.018302
Country_Guam	2.717	0.76912	3.5327	0.00041231
Country_Heard_I.___McDonald_Is.	-4.7244	0.77437	-6.1011	1.07E-09
Country_Iraq	1.0298	0.29129	3.5351	0.00040848
Country_Isle_of_Man	0.48467	1.055	0.4594	0.64595
Country_Jan_Mayen	-0.32849	0.57306	-0.57322	0.5665
Country_Jarvis_I.	-2.8804	1.0604	-2.7162	0.0066084
Country_Johnston_Atoll	-3.9549	1.0586	-3.7358	0.00018761
Country_Kazakhstan	0.23392	0.26429	0.88507	0.37613
Country_Liechtenstein	1.7341	1.0557	1.6426	0.10048
Country_Macau	3.8402	1.0561	3.6362	0.00027739
Country_Marshall_Islands	-0.048242	0.31549	-0.15291	0.87847
Country_Martinique	1.893	0.76838	2.4635	0.013765
Country_Mayotte	-0.21446	0.76872	-0.27899	0.78026

Country_Midway_Is.	-4.5231	1.057	-4.2791	1.89E-05
Country_Monaco	2.4057	1.0554	2.2794	0.022653
Country_Montserrat	1.2743	1.0554	1.2074	0.22728
Country_Myanmar	0.56878	0.27979	2.0329	0.042077
Country_Nauru	3.784	1.0592	3.5725	0.00035443
Country_Netherlands_Antilles	0.067537	0.52568	0.12848	0.89777
Country_New_Caledonia	0.56364	0.38367	1.469	0.14184
Country_Niue	1.2425	0.77711	1.5989	0.10985
Country_Norfolk_I.	1.3083	1.06	1.2343	0.21711
Country_North_Korea	1.124	0.33353	3.3701	0.00075287
Country_Northern_Mariana_Is.	-1.4264	0.42855	-3.3286	0.00087449
Country_Palau	-1.3925	0.46562	-2.9905	0.0027882
Country_Pitcairn_Is.	2.0099	1.0603	1.8955	0.058037
Country_Puerto_Rico	2.0694	0.491	4.2146	2.51E-05
Country_Qatar	1.3723	0.49427	2.7765	0.0055001
Country_Reunion	2.135	0.76957	2.7742	0.005538
Country_Saint_Helena	0.40919	0.57321	0.71386	0.47532
Country_San_Marino	1.3377	1.055	1.268	0.2048
Country_Sao_Tome_and_Principe	1.0597	0.76931	1.3775	0.16837
Country_Serbia_and_Montenegro	0.41968	0.33653	1.2471	0.21238
Country_Somalia	0.80866	0.28534	2.8341	0.0046007
Country_South_Georgia___the_South_Sandwich_Is.	-5.6298	0.49267	-11.427	3.79E-30
Country_St._Pierre___Miquelon	0.38142	0.76789	0.49672	0.6194
Country_Svalbard	-2.9429	0.28745	-10.238	1.54E-24
Country_Taiwan	1.3282	0.40168	3.3067	0.00094582
Country_Timor_Leste	1.9158	0.46734	4.0994	4.16E-05
Country_Tokelau	1.5255	0.77089	1.9789	0.047844
Country_Turks___Caicos_Is.	0.77263	0.76831	1.0056	0.31461
Country_Tuvalu	1.853	0.44876	4.1291	3.66E-05
Country_United_Arab_Emirates	1.8366	0.34885	5.2646	1.42E-07

Country_Vatican_City	1.5108	1.0551	1.4318	0.15221
Country_Virgin_Is.	1.5021	0.64501	2.3288	0.019882
Country_Wake_I.	-4.3664	1.0572	-4.1301	3.64E-05
Country_Wallis_and_Futuna	1.5572	0.64912	2.3989	0.016453
Country_West_Bank_and_Gaza	1.9202	0.57361	3.3476	0.00081656
Country_Zimbabwe	0.041646	0.29476	0.14129	0.88765
soilG_1	-0.08548	0.04338	-1.9705	0.048799
soilG_2	0.14156	0.032052	4.4166	1.01E-05
soilG_3	0.82392	0.062164	13.254	6.28E-40
soilG_4	0.33996	0.058386	5.8226	5.88E-09
soilG_5	-0.22181	0.047077	-4.7115	2.47E-06
soilG_6	0.17949	0.039289	4.5684	4.94E-06
soilG_7	0.43548	0.081028	5.3744	7.77E-08
soilG_8	0.34388	0.06047	5.6868	1.31E-08
soilG_9	0.16491	0.048229	3.4192	0.00062928
soilG_10	0.46339	0.037577	12.332	8.16E-35
soilG_11	1.357	0.16722	8.1154	5.12E-16
soilG_12	0.11692	0.076302	1.5323	0.12546
soilG_13	0.25922	0.058664	4.4188	9.98E-06
soilG_14	0.29749	0.043966	6.7664	1.36E-11
soilG_15	-0.10014	0.047052	-2.1284	0.033319
soilG_16	-0.78281	0.038685	-20.236	3.72E-90
soilG_17	0.071928	0.097623	0.7368	0.46126
soilG_18	0.13503	0.092667	1.4572	0.14508
soilG_19	0.091908	0.06443	1.4265	0.15374
soilG_20	0.20184	0.084774	2.381	0.017277
soilG_21	-0.14081	0.049703	-2.833	0.0046152
soilG_22	-0.21691	0.038285	-5.6657	1.48E-08
soilG_23	-0.1309	0.090673	-1.4437	0.14885
soilG_25	0.23548	0.091834	2.5642	0.010349

T	-0.068128	0.013415	-5.0784	3.84E-07
T^2	0.0055026	0.00037946	14.501	2.06E-47
T^3	-0.0001098	5.43E-06	-20.244	3.15E-90
P	-0.24403	0.069994	-3.4864	0.00049062
P^2	0.50102	0.029582	16.937	6.67E-64
P^3	-0.091919	0.0070132	-13.106	4.37E-39
T*P	0.075841	0.0068578	11.059	2.39E-28
T^2*P	-0.0019909	0.00016115	-12.355	6.14E-35
P^2*T	-0.0058814	0.00099014	-5.9399	2.90E-09
DL	-1.56E-07	1.93E-08	-8.1139	5.18E-16
DMR	6.05E-08	1.46E-08	4.1464	3.39E-05
DR	-3.57E-07	2.01E-08	-17.772	4.01E-70
DO	-3.27E-07	1.86E-08	-17.622	5.45E-69
E	-0.000117	1.52E-05	-7.6993	1.43E-14
roughness	0.49991	0.062695	7.9737	1.62E-15

Root Mean Squared Error: 1.02

R-squared: 0.721, Adjusted R-Squared: 0.717

F-statistic vs. constant model: 185, p-value = 0

484 Table S3. Data used in Figure 2 and Figure S2.

Country	$\Delta W_{c,2100}$ (billion)	$\Delta N_{c,2100}$ (billion)			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
'India'	5.15E-01	-2.54E-01	-4.83E-01	-5.34E-01	-8.86E-01
'China'	-3.01E-01	2.85E-01	5.30E-01	6.59E-01	1.10E+00
'Nigeria'	6.13E-01	-1.41E-01	-2.47E-01	-2.98E-01	-4.59E-01
'United States'	1.54E-01	1.07E-01	1.97E-01	2.61E-01	4.07E-01
'Democratic Republic of Congo'	3.33E-01	-5.40E-02	-7.42E-02	-9.52E-02	-1.98E-01
'Pakistan'	2.11E-01	-5.67E-03	-2.61E-02	-1.80E-02	-8.43E-02
'Indonesia'	8.74E-02	-5.27E-02	-9.25E-02	-1.07E-01	-1.80E-01
'Tanzania'	2.60E-01	-1.04E-02	-2.27E-02	-3.76E-02	-8.59E-02
'Ethiopia'	1.66E-01	7.14E-03	1.87E-03	5.09E-03	-1.25E-02
'Niger'	1.96E-01	-4.38E-02	-7.72E-02	-9.92E-02	-1.43E-01
'Uganda'	1.75E-01	-4.59E-03	-1.13E-02	-1.71E-02	-5.32E-02
'Egypt'	1.26E-01	1.50E-02	2.48E-02	1.82E-02	1.26E-02
'Brazil'	1.18E-02	-1.29E-02	-2.32E-02	-2.97E-02	-5.87E-02
'Bangladesh'	2.66E-02	-3.05E-02	-5.55E-02	-6.05E-02	-9.42E-02
'Sudan'	1.29E-01	-3.16E-02	-6.26E-02	-7.57E-02	-1.13E-01
'Philippines'	8.25E-02	-2.87E-02	-5.29E-02	-6.24E-02	-9.95E-02
'Iraq'	1.37E-01	8.80E-03	-1.11E-03	-8.94E-03	-3.87E-02
'Kenya'	1.22E-01	2.32E-03	-1.70E-04	1.80E-04	-1.84E-02
'Mexico'	3.87E-02	2.86E-03	8.20E-04	-7.49E-04	-2.16E-02
'Angola'	1.21E-01	-1.17E-02	-2.22E-02	-3.06E-02	-5.85E-02
'Mozambique'	1.07E-01	-9.72E-03	-2.52E-02	-2.92E-02	-5.14E-02
'Russia'	-2.62E-02	8.22E-02	1.72E-01	2.03E-01	4.06E-01
'Madagascar'	8.72E-02	-1.29E-03	-4.29E-03	-9.08E-03	-2.43E-02
'Vietnam'	2.09E-02	-1.28E-02	-2.36E-02	-2.54E-02	-4.38E-02
'Zambia'	9.28E-02	-5.67E-03	-1.74E-02	-2.18E-02	-4.64E-02
'Cote dIvoire'	8.30E-02	-1.73E-02	-2.99E-02	-3.42E-02	-5.76E-02
'Mali'	8.01E-02	-2.16E-02	-3.82E-02	-4.67E-02	-6.75E-02
'Turkey'	2.01E-02	2.12E-02	3.51E-02	4.28E-02	6.20E-02
'Malawi'	7.43E-02	-5.53E-03	-1.70E-02	-2.09E-02	-3.98E-02
'Japan'	-4.38E-02	1.37E-02	2.75E-02	3.14E-02	4.41E-02
'Cameroon'	6.43E-02	-1.34E-02	-2.21E-02	-2.73E-02	-4.24E-02
'United Kingdom'	2.22E-02	2.82E-02	5.71E-02	6.92E-02	1.20E-01
'Burkina Faso'	6.76E-02	-1.97E-02	-3.60E-02	-4.24E-02	-6.06E-02
'France'	1.48E-02	2.37E-02	4.69E-02	5.78E-02	9.01E-02
'Senegal'	6.38E-02	-9.67E-03	-1.89E-02	-2.38E-02	-4.00E-02

'Ghana'	5.16E-02	-1.30E-02	-2.37E-02	-2.83E-02	-4.24E-02
'Iran'	-4.85E-04	1.51E-02	2.58E-02	2.77E-02	4.09E-02
'Chad'	5.89E-02	-1.66E-02	-2.85E-02	-3.15E-02	-4.67E-02
'South Africa'	1.73E-02	8.23E-03	1.58E-02	1.83E-02	1.96E-02
'Germany'	-1.80E-02	2.79E-02	6.00E-02	7.16E-02	1.24E-01
'Burundi'	5.47E-02	-2.39E-03	-5.19E-03	-8.07E-03	-1.97E-02
'Algeria'	2.78E-02	6.50E-03	9.88E-03	1.05E-02	7.64E-03
'Argentina'	1.94E-02	1.09E-02	1.91E-02	2.23E-02	3.29E-02
'Somalia'	4.98E-02	-7.07E-03	-1.37E-02	-1.60E-02	-2.73E-02
'Afghanistan'	3.32E-02	2.30E-02	4.09E-02	4.75E-02	8.72E-02
'Myanmar'	6.04E-03	-8.69E-03	-1.42E-02	-1.54E-02	-2.73E-02
'Yemen'	3.03E-02	-3.83E-03	-8.90E-03	-1.09E-02	-2.15E-02
'Canada'	1.74E-02	3.07E-02	6.34E-02	7.67E-02	1.55E-01
'Italy'	-9.01E-03	1.13E-02	1.98E-02	2.32E-02	3.21E-02
'Guinea'	3.94E-02	-9.12E-03	-1.40E-02	-1.75E-02	-2.83E-02
'Saudi Arabia'	2.28E-02	-2.97E-03	-6.52E-03	-9.77E-03	-1.73E-02
'Colombia'	2.04E-03	-4.66E-03	-7.90E-03	-1.02E-02	-1.82E-02
'Australia'	2.21E-02	5.24E-03	1.02E-02	1.18E-02	1.80E-02
'Morocco'	1.11E-02	2.77E-03	3.26E-03	4.44E-03	-2.42E-03
'Venezuela'	1.52E-02	-7.24E-03	-1.29E-02	-1.50E-02	-2.18E-02
'Thailand'	-2.43E-02	-7.51E-03	-1.17E-02	-1.37E-02	-2.20E-02
'Peru'	1.39E-02	1.01E-03	4.37E-03	6.07E-03	7.30E-03
'Malaysia'	1.50E-02	-6.98E-03	-1.26E-02	-1.44E-02	-2.38E-02
'Zimbabwe'	2.73E-02	-4.10E-04	-3.21E-03	-5.02E-03	-1.31E-02
'South Korea'	-9.10E-03	1.15E-02	2.12E-02	2.57E-02	4.34E-02
'Spain'	-5.52E-03	7.82E-03	1.18E-02	1.39E-02	1.72E-02
'Syria'	2.00E-02	4.18E-03	5.37E-03	5.33E-03	2.60E-03
'Benin'	2.74E-02	-6.71E-03	-1.08E-02	-1.36E-02	-2.15E-02
'Guatemala'	2.16E-02	-4.94E-03	-9.72E-03	-1.11E-02	-1.89E-02
'Uzbekistan'	6.15E-03	1.44E-02	2.95E-02	3.59E-02	6.59E-02
'Nepal'	4.17E-03	-1.85E-03	-3.37E-03	-3.46E-03	-7.27E-03
'Togo'	2.23E-02	-5.42E-03	-8.82E-03	-1.11E-02	-1.71E-02
'Ukraine'	-2.04E-02	1.11E-02	2.16E-02	2.49E-02	4.06E-02
'Rwanda'	1.67E-02	-5.52E-04	-6.41E-04	-1.89E-03	-6.92E-03
'North Korea'	1.03E-03	1.23E-02	2.17E-02	2.67E-02	4.88E-02
'Kazakhstan'	9.26E-03	1.72E-02	3.16E-02	3.92E-02	7.25E-02
'Ecuador'	1.08E-02	-2.38E-03	-4.40E-03	-5.10E-03	-9.81E-03
'Cambodia'	1.06E-02	-4.75E-03	-7.72E-03	-8.73E-03	-1.37E-02
'Poland'	-1.62E-02	1.04E-02	2.29E-02	2.66E-02	4.69E-02

'Congo'	1.85E-02	-3.64E-03	-4.79E-03	-6.66E-03	-1.17E-02
'Chile'	3.65E-03	5.01E-03	9.03E-03	1.02E-02	1.88E-02
'Tajikistan'	1.18E-02	9.84E-03	1.88E-02	2.43E-02	4.52E-02
'Bolivia'	8.99E-03	3.65E-03	7.65E-03	9.18E-03	1.58E-02
'Papua New Guinea'	1.19E-02	-2.29E-03	-4.04E-03	-4.98E-03	-8.70E-03
'Israel'	1.07E-02	9.65E-04	8.90E-04	9.19E-04	-1.56E-03
'Netherlands'	8.88E-04	6.60E-03	1.38E-02	1.61E-02	2.69E-02
'Liberia'	1.27E-02	-3.08E-03	-4.39E-03	-5.56E-03	-8.73E-03
'Eritrea'	1.14E-02	-2.05E-03	-3.74E-03	-4.70E-03	-7.91E-03
'State of Palestine'	1.19E-02	9.30E-04	8.19E-04	7.19E-04	-1.19E-03
'Sri Lanka'	-4.67E-03	-3.02E-03	-5.15E-03	-5.78E-03	-8.92E-03
'Sierra Leone'	9.42E-03	-2.89E-03	-4.39E-03	-5.26E-03	-8.23E-03
'Sweden'	5.44E-03	8.35E-03	1.70E-02	2.02E-02	3.66E-02
'Jordan'	8.81E-03	9.58E-04	9.78E-04	8.70E-04	-5.49E-04
'Haiti'	4.28E-03	-1.22E-03	-2.20E-03	-2.64E-03	-5.00E-03
'United Arab Emirates'	8.91E-03	-1.21E-03	-2.97E-03	-4.16E-03	-6.96E-03
'Belgium'	2.65E-03	4.97E-03	1.04E-02	1.22E-02	2.01E-02
'Other non specified areas'	-1.01E-02	4.20E-03	7.74E-03	8.86E-03	1.51E-02
'Mauritania'	9.90E-03	-2.12E-03	-3.98E-03	-5.11E-03	-7.76E-03
'Central African Republic'	8.46E-03	-2.26E-03	-3.71E-03	-4.20E-03	-7.37E-03
'Tunisia'	2.39E-03	1.12E-03	1.52E-03	1.54E-03	2.15E-04
'Dominican Republic'	2.79E-03	-9.06E-04	-1.66E-03	-2.02E-03	-4.04E-03
'Switzerland'	3.84E-03	5.40E-03	1.06E-02	1.26E-02	2.32E-02
'Romania'	-1.07E-02	4.04E-03	7.35E-03	8.89E-03	1.37E-02
'Honduras'	3.77E-03	-1.22E-03	-2.57E-03	-2.89E-03	-4.85E-03
'Laos'	4.67E-03	-1.13E-03	-1.99E-03	-1.96E-03	-3.99E-03
'Azerbaijan'	1.07E-03	2.89E-03	5.43E-03	6.49E-03	1.07E-02
'Kyrgyzstan'	3.93E-03	6.09E-03	1.29E-02	1.73E-02	3.64E-02
'Gambia'	7.46E-03	-1.36E-03	-2.75E-03	-3.19E-03	-4.97E-03
'Czech Republic'	-1.46E-03	4.26E-03	8.21E-03	9.97E-03	1.77E-02
'Paraguay'	2.87E-03	-6.24E-04	-9.03E-04	-1.86E-03	-3.52E-03
'Austria'	1.00E-04	3.71E-03	7.36E-03	8.96E-03	1.51E-02
'Libya'	2.34E-03	8.60E-04	9.48E-04	1.14E-03	9.62E-04
'Hong Kong'	1.08E-03	-7.07E-04	-1.31E-03	-1.27E-03	-2.92E-03
'Norway'	3.22E-03	4.55E-03	9.84E-03	1.15E-02	2.21E-02
'Portugal'	-3.07E-03	1.06E-03	1.62E-03	1.82E-03	2.05E-03
'Greece'	-3.68E-03	1.02E-03	1.61E-03	1.79E-03	1.38E-03
'Cuba'	-4.16E-03	-8.48E-04	-1.27E-03	-1.59E-03	-2.58E-03
'Nicaragua'	1.62E-03	-9.26E-04	-1.84E-03	-2.15E-03	-3.49E-03

'Belarus'	-2.72E-03	3.61E-03	8.17E-03	9.45E-03	1.72E-02
'Denmark'	1.42E-03	3.12E-03	6.46E-03	7.55E-03	1.32E-02
'Hungary'	-3.59E-03	2.79E-03	5.06E-03	5.94E-03	9.26E-03
'Kuwait'	4.22E-03	-2.18E-04	-7.29E-04	-1.19E-03	-2.10E-03
'Ireland'	2.17E-03	1.99E-03	4.14E-03	4.85E-03	8.59E-03
'New Zealand'	1.96E-03	1.38E-03	3.01E-03	3.63E-03	5.41E-03
'Panama'	2.69E-03	-1.27E-03	-1.85E-03	-2.16E-03	-3.33E-03
'Finland'	6.11E-04	4.36E-03	9.29E-03	1.12E-02	2.15E-02
'Serbia and Montenegro'	-4.03E-03	1.93E-03	3.39E-03	4.11E-03	6.35E-03
'Oman'	3.24E-03	-3.04E-04	-9.60E-04	-1.10E-03	-1.94E-03
'Namibia'	3.70E-03	-2.70E-04	-7.06E-04	-1.09E-03	-2.28E-03
'Turkmenistan'	8.58E-04	1.59E-03	2.30E-03	2.81E-03	3.42E-03
'Singapore'	1.10E-03	-1.04E-03	-1.87E-03	-2.06E-03	-3.38E-03
'Guinea Bissau'	4.03E-03	-9.44E-04	-1.81E-03	-2.18E-03	-3.23E-03
'Costa Rica'	7.45E-04	-9.11E-04	-1.36E-03	-1.59E-03	-2.60E-03
'Lebanon'	7.54E-04	4.65E-04	3.47E-04	4.68E-04	-3.66E-05
'Mongolia'	1.96E-03	2.98E-03	6.90E-03	8.53E-03	1.98E-02
'Gabon'	3.09E-03	-7.36E-04	-1.16E-03	-1.43E-03	-2.41E-03
'El Salvador'	-1.53E-03	-6.36E-04	-1.27E-03	-1.44E-03	-2.42E-03
'Slovakia'	-1.65E-03	1.76E-03	3.25E-03	3.90E-03	6.03E-03
'Botswana'	1.82E-03	5.68E-05	2.97E-06	-1.61E-04	-7.43E-04
'Lesotho'	1.62E-03	7.74E-04	1.45E-03	1.71E-03	2.35E-03
'Bulgaria'	-4.28E-03	8.92E-04	1.61E-03	1.88E-03	2.68E-03
'Uruguay'	-6.76E-05	5.37E-04	1.06E-03	1.17E-03	1.75E-03
'Timor Leste'	2.24E-03	-5.08E-04	-9.50E-04	-1.12E-03	-1.83E-03
'Qatar'	2.33E-03	-2.02E-04	-4.99E-04	-7.86E-04	-1.46E-03
'Equatorial Guinea'	2.36E-03	-5.56E-04	-7.87E-04	-9.73E-04	-1.64E-03
'Croatia'	-1.76E-03	8.59E-04	1.62E-03	1.92E-03	2.82E-03
'Georgia'	-2.04E-03	1.13E-03	2.22E-03	2.68E-03	5.07E-03
'Comoros'	1.69E-03	-2.76E-04	-4.53E-04	-5.90E-04	-1.01E-03
'Puerto Rico'	-1.55E-03	-1.51E-04	-2.24E-04	-2.92E-04	-6.21E-04
'Swaziland'	9.77E-04	1.32E-04	2.48E-04	2.47E-04	1.24E-04
'Lithuania'	-1.33E-03	1.06E-03	2.41E-03	2.72E-03	5.03E-03
'Bosnia Herzegovina'	-1.91E-03	5.69E-04	9.97E-04	1.14E-03	1.72E-03
'Moldova'	-2.30E-03	6.79E-04	1.32E-03	1.49E-03	2.37E-03
'Armenia'	-1.22E-03	8.18E-04	1.61E-03	1.96E-03	3.87E-03
'Albania'	-1.33E-03	3.46E-04	5.95E-04	6.84E-04	7.42E-04
'Jamaica'	-9.74E-04	-1.56E-04	-2.65E-04	-3.21E-04	-5.64E-04
'Slovenia'	-3.04E-04	6.06E-04	1.17E-03	1.44E-03	2.14E-03

'Bahrain'	7.35E-04	-6.68E-05	-1.75E-04	-3.19E-04	-6.39E-04
'Macedonia'	-5.56E-04	3.74E-04	6.72E-04	8.31E-04	1.12E-03
'Cyprus'	3.53E-04	9.67E-05	1.24E-04	1.26E-04	5.49E-05
'Solomon Islands'	8.85E-04	-2.56E-04	-4.60E-04	-5.23E-04	-7.85E-04
'Latvia'	-9.50E-04	7.30E-04	1.63E-03	1.90E-03	3.48E-03
'Djibouti'	3.48E-04	-1.03E-04	-2.24E-04	-3.00E-04	-4.98E-04
'Luxembourg'	5.72E-04	4.28E-04	8.60E-04	1.07E-03	1.75E-03
'Macau'	5.55E-04	-8.43E-05	-1.55E-04	-1.49E-04	-3.64E-04
'Trinidad and Tobago'	-3.13E-04	-1.39E-04	-2.40E-04	-2.86E-04	-4.34E-04
'Mauritius'	-2.70E-04	-4.23E-06	-5.21E-05	-6.16E-05	-1.44E-04
'Estonia'	-4.52E-04	5.96E-04	1.29E-03	1.56E-03	2.89E-03
'French Guiana'	6.88E-04	-1.41E-04	-2.50E-04	-2.74E-04	-4.72E-04
'Reunion'	7.84E-05	-5.25E-06	-5.55E-05	-6.27E-05	-1.29E-04
'Bhutan'	1.42E-04	5.93E-05	4.26E-05	8.81E-05	6.22E-05
'Mayotte'	5.74E-04	-9.49E-05	-1.63E-04	-2.02E-04	-3.30E-04
'Fiji'	-1.26E-04	-2.38E-05	-8.70E-05	-9.53E-05	-2.25E-04
'Cape Verde'	2.06E-04	4.81E-06	2.75E-05	1.22E-05	-7.46E-05
'Belize'	3.94E-04	-7.66E-05	-1.43E-04	-1.78E-04	-3.22E-04
'Vanuatu'	4.68E-04	-3.46E-05	-1.03E-04	-1.23E-04	-2.30E-04
'Guyana'	-1.48E-04	-1.12E-04	-1.89E-04	-2.19E-04	-3.42E-04
'Suriname'	5.60E-05	-1.17E-04	-1.85E-04	-2.10E-04	-3.37E-04
'Sao Tome and Principe'	3.85E-04	-8.51E-05	-1.48E-04	-1.89E-04	-2.96E-04
'Bahamas'	1.69E-04	-4.82E-05	-6.80E-05	-8.31E-05	-1.47E-04
'Brunei'	1.27E-04	-6.81E-05	-1.29E-04	-1.47E-04	-2.63E-04
'Maldives'	1.33E-04	-9.50E-05	-1.55E-04	-1.78E-04	-2.63E-04
'Guadeloupe'	-1.38E-05	-2.84E-05	-4.75E-05	-6.05E-05	-1.21E-04
'New Caledonia'	1.90E-04	6.11E-08	-7.91E-06	-1.35E-05	-5.42E-05
'Iceland'	8.73E-05	1.88E-04	3.28E-04	4.29E-04	7.76E-04
'Malta'	-4.91E-05	2.53E-05	3.29E-05	3.47E-05	2.48E-05
'French Polynesia'	4.21E-05	-1.62E-05	-2.01E-05	-3.40E-05	-6.95E-05
'Martinique'	-1.08E-04	-2.62E-05	-4.08E-05	-5.09E-05	-9.47E-05
'Samoa'	8.21E-05	-3.55E-05	-6.13E-05	-6.75E-05	-1.18E-04
'Barbados'	-1.50E-05	-2.64E-05	-4.04E-05	-4.82E-05	-8.59E-05
'Kiribati'	1.52E-04	-4.75E-05	-8.04E-05	-9.26E-05	-1.49E-04
'Guam'	8.36E-05	-4.43E-05	-7.60E-05	-8.52E-05	-1.41E-04
'St. Lucia'	2.59E-06	-1.73E-05	-2.72E-05	-3.16E-05	-5.81E-05
'Tonga'	5.81E-05	1.54E-06	-5.21E-06	-8.68E-06	-2.45E-05
'Federated State of Micronesia'	9.80E-06	-2.53E-05	-4.15E-05	-4.81E-05	-7.31E-05
'Antigua and Barbuda'	3.14E-05	-6.42E-06	-1.06E-05	-1.34E-05	-3.12E-05

'Isle of Man'	3.37E-05	4.13E-05	8.54E-05	1.04E-04	1.88E-04
'Cayman Is.'	5.04E-05	-1.11E-05	-1.66E-05	-2.10E-05	-3.54E-05
'Aruba'	-1.60E-05	-6.78E-06	-1.51E-05	-1.93E-05	-3.03E-05
'Seychelles'	-7.75E-06	-1.72E-05	-2.84E-05	-3.12E-05	-5.03E-05
'St. Vincent and the Grenadines'	-3.18E-05	-8.13E-06	-1.30E-05	-1.53E-05	-2.71E-05
'Marshall Islands'	2.29E-05	-1.64E-05	-2.62E-05	-3.06E-05	-4.60E-05
'Grenada'	-3.10E-05	-7.55E-06	-1.25E-05	-1.49E-05	-2.62E-05
'United States Virgin Islands'	-3.88E-05	-4.39E-06	-7.05E-06	-9.08E-06	-1.88E-05
'St. Kitts and Nevis'	1.39E-05	-3.79E-06	-6.15E-06	-8.09E-06	-1.69E-05
'Andorra'	-2.12E-05	1.52E-05	2.37E-05	2.67E-05	3.42E-05
'Monaco'	2.12E-05	1.10E-05	1.87E-05	2.21E-05	2.89E-05
'Dominica'	-1.85E-05	-4.25E-06	-6.79E-06	-8.19E-06	-1.57E-05
'Turks Caicos Is.'	2.56E-05	-3.99E-06	-7.04E-06	-8.26E-06	-1.53E-05
'Liechtenstein'	1.22E-05	2.40E-05	4.67E-05	5.70E-05	1.09E-04
'Bermuda'	-2.31E-05	-1.86E-06	-1.44E-06	-2.29E-06	-8.00E-06
'American Samoa'	-1.91E-05	-4.92E-06	-8.51E-06	-9.56E-06	-1.68E-05
'British Virgin Is.'	1.28E-05	-2.28E-06	-3.26E-06	-4.38E-06	-9.61E-06
'Caribbean Netherlands'	1.76E-05	-2.24E-06	-4.31E-06	-5.15E-06	-1.08E-05
'San Marino'	7.60E-07	7.06E-06	1.21E-05	1.35E-05	1.87E-05
'Northern Mariana Is.'	-3.54E-05	-4.58E-06	-8.09E-06	-9.51E-06	-1.59E-05
'Palau'	9.09E-06	-5.84E-06	-1.07E-05	-1.28E-05	-1.89E-05
'Gibraltar'	-1.08E-06	1.56E-06	6.82E-07	1.57E-06	-2.10E-06
'Cook Is.'	1.60E-06	-3.14E-07	-4.92E-07	-1.28E-06	-3.11E-06
'Wallis and Futuna'	-2.25E-06	-1.62E-06	-3.01E-06	-3.30E-06	-5.51E-06
'Anguilla'	-1.64E-06	-6.57E-07	-9.57E-07	-1.20E-06	-2.91E-06
'Tuvalu'	1.31E-06	-2.29E-06	-3.53E-06	-4.44E-06	-6.47E-06
'Nauru'	-1.12E-06	-2.07E-06	-3.06E-06	-3.69E-06	-5.84E-06
'St. Pierre Miquelon'	7.40E-07	3.33E-06	6.28E-06	7.40E-06	1.40E-05
'Montserrat'	2.20E-07	-3.52E-07	-6.00E-07	-7.21E-07	-1.44E-06
'Falkland Is.'	6.00E-08	1.10E-06	2.14E-06	2.50E-06	4.41E-06
'Saint Helena'	-1.27E-06	2.59E-07	4.69E-07	5.26E-07	6.79E-07
'Niue'	3.10E-07	-4.03E-08	-1.02E-07	-1.99E-07	-4.66E-07
'Tokelau'	7.90E-07	-3.20E-07	-5.78E-07	-7.30E-07	-1.12E-06