PCIC SCIENCE BRIEF: THE PROJECTED TIMING OF CLIMATE DEPARTURE FROM RECENT VARIABILITY

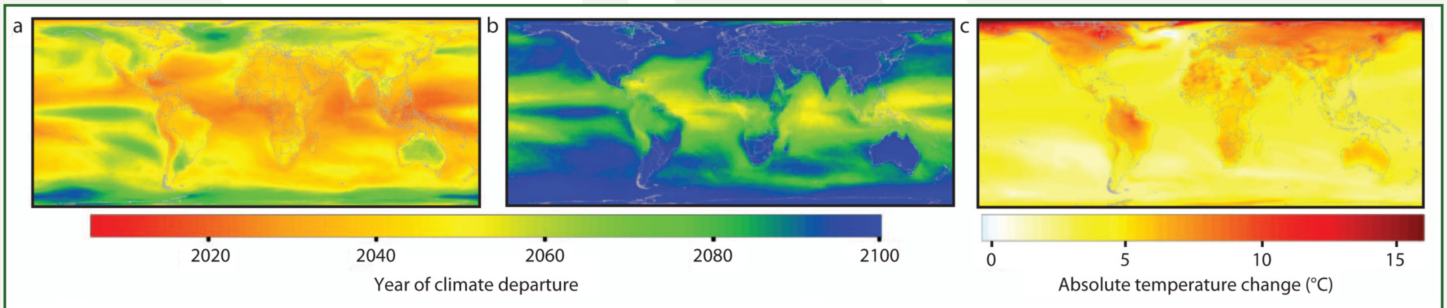

Figure 1: Projected year of climate departure and absolute temperature change, from Mora et al. (2013). The above figure shows the projected year at which the (a) annual or (b) monthly mean surface air temperature move to a state completely outside of their historical (1860-2005) variability. Panel (c) indicates the projected change in air temperature of the 2091-2100 period, relative to the 1996-2005 period average. Results shown are from 39 models from CMIP5[3], using the RCP8.5 emissions scenario.

Recent research by Mora et al. (2013), published in *Nature*, finds that the projected annual-mean global surface air temperature will move outside of historical (1861-2005) variability by about 2047 under a business-as-usual emissions scenario, and by about 2069 assuming some emissions reductions. Projected climate departures are not globally uniform. The climates of tropical and low-income countries are projected to shift first.

The degree and extent of the potential impacts that anthropogenic climate change will have depend on both the magnitude and rate of the change. The time scale over which the climate of a region shifts outside the range of its historical climate will affect the magnitude of the impacts that may result.

Climate departure is here used to mean the year past which the annual (or monthly) average value for a climate variable, such as surface temperature, moves and stays outside of the range of historical annual (or monthly) means.

To investigate the time frame of such shifts and how quickly they will occur in different areas, Mora et al. (2013) examine the output from 39 Earth System Models[1] (ESMs) contributing to the fifth phase of the Coupled Model Intercomparison Project[2] (CMIP5). The models used for this experiment made future climate projections assuming two different greenhouse gas emissions scenarios[3], a business as usual scenario leading to very high (approximately quadruple preindustrial) atmospheric greenhouse gas concentrations (RCP 8.5), and a scenario that assumed some emissions reductions, leading to substantially lower (roughly double preindustrial) concentrations in year 2100 (RCP 4.5).

The authors find that the projected distribution of annual-mean global surface temperature shifts completely outside of the distribution of historical variability by 2047 for the higher-concentration RCP 8.5 scenario and by 2069 for the lower-concentration RCP 4.5 scenario. Projected annual-mean global ocean temperatures follow suit, departing the bounds of historical variability by 2051 for RCP 8.5 and 2072 for RCP 4.5. Further, they find that, for most of the tropics, by the 2050s, not only the annual mean, but every individual monthly mean will be outside of the range of monthly surface temperature variability (see Figure 1, Panel b), making each

1. Earth System Models are numerical models, similar to physical climate models, that simulate the physical, chemical and biological aspects of the Earth system, including oceans, atmospheres, ice and vegetation.
2. For more on the fifth phase of the Coupled Model Intercomparison Project, see here: http://cmip-pcmdi.llnl.gov/cmip5/.
3. CMIP5 (Taylor et al., 2012) uses four new trajectories of atmospheric greenhouse gas concentration, known as Representative Concentration Pathways (RCP) for its Fifth Assessment Report. The four trajectories are denoted by the change to radiative forcings that would result from each concentration, e.g. RCP 4.5 would result in an increase of 4.5 Watts per square meter as compared to the preindustrial period (taken to be the year 1750). For more information on CMIP5 and the RCPs, see: van Vuuren et al., 2011: The Representative Concentration Pathways: An Overview. Climatic Change, 109 (1-2), 5-31 doi:10.1007/s10584-011-0148-z.

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month an "extreme climatic record." The projections also show the global-mean ocean acidity moving outside of historical variability by 2008, which the authors note is consistent with recent studies.

Surface temperature changes are not globally uniform in their magnitude or the date at which they depart historical variability (Figure 1). Also, the absolute change in temperature that a region experiences by the year 2100 is not tightly related to the year in which it shifts beyond the range of historical variability. For instance, tropical surface air temperatures depart from historical variability earlier in part because the region has a smaller overall variability than other regions. So, while tropical regions might not warm as quickly or as much as higher-latitude regions, the tropical climate can depart from the range of historical variability after undergoing comparatively modest changes.

These findings imply that metrics of absolute change in climate variables, such as how much a region warms, do not account for aspects of climate change that may have impacts on global biodiversity. Mora and colleagues explain that the species in tropical regions are probably adapted to a narrow range in variability and more vulnerable to climate change, as is reflected in the narrower geographic sizes of the home ranges of these species, in which they live, travel and search for food. The early emergence of such unprecedented climates in the tropics is potentially made more problematic by the fact that a great deal of the world's biodiversity is concentrated in these regions. Projections for both emissions scenarios showed that, in areas which are hotspots[4] of biodiversity, novel climates will occur approximately one decade earlier than the global average.

By 2050, assuming that emissions continue in a manner consistent with RCP 4.5, the regions that will potentially depart from historical precedents will include low-income countries (Figure 2, Panel b) that are presently home to one billion people. If emissions follow RCP 8.5 the regions of departure by 2050 increase, including poorer nations home to five billion people. Mora et al. point out that this "further highlights an obvious disparity between those who benefit economically from the processes leading to climate change and those who will have to pay for most of the environmental and social costs."

For mean annual surface temperature, the authors' projections show that different areas within the BC-Yukon region would be expected to depart historical variability at different times, with lower latitude regions exceeding historical variability first. Table 1 shows projected dates of annual-mean surface temperature departure from historical variability, for Yukon and the resource regions of BC. These averages were computed at PCIC from roughly 100 km-resolution grid cells, for RCPs 4.5 and 8.5, using supplemental material from Mora et al.

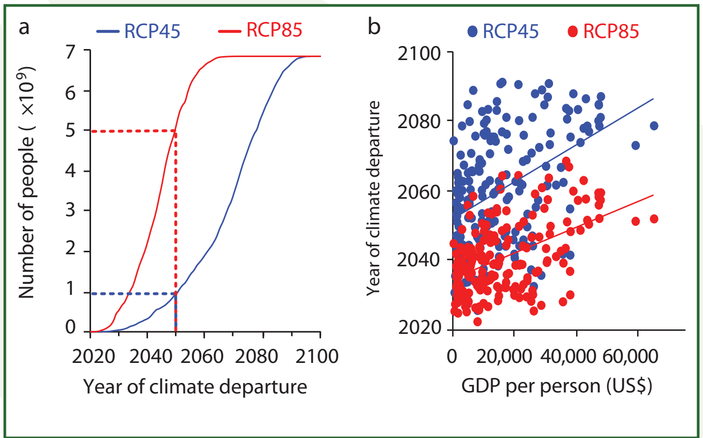

Figure 2: Number of people affected by climate departures and GDP vs. year of climate departure, from Mora et al. (2013).
Above are (a) the cumulative number of people in regions with climates that are projected to depart from historical variability plotted against the year at which the climate of their region departs from historical variability, and (b) the relation between the year of projected climate departure plotted against the GDP, per person, of the region in which climate departure occurs. (Results for both emissions scenarios, RCP 4.5 and 8.5 are shown.)

Table 1: Projected dates of climate departure of mean annual surface temperature from historical variability.

Region	RCP4.5	RCP8.5
Cariboo	2089	2061
Kootenay/Boundary	2085	2057
Northeast	2091	2066
Omineca	2091	2065
Skeena	2092	2067
South Coast	2084	2056
Thompson/Okanagan	2086	2056
West Coast	2089	2064
Yukon	2093	2067

Methodology

The authors used projections from 39 ESMs participating in CMIP5 for the following variables: near-surface air temperature, sea surface temperature, precipita-

4. Here, hot spots of biodiversity are the top 10% most species-rich areas on Earth in which a given taxonomic group—a population of organisms grouped together into a group for biological classification—or "taxon" is found.

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tion, evaporation, transpiration, surface sensible heat flux and ocean pH. All data was interpolated to a equal-spacing grid with a resolution of 100 km. The historical experiment used model output for the period of 1850 to 2005 while future projections covered the period of 2006-2100. The year of climate departure was that year after which all subsequent annual averages fell entirely outside the range of the maximum and minimum annual average values over the historical period, and similarly for the month of departure.

The authors tested the robustness of the models by comparing model output over the historical period with 20 years of air and sea surface temperature observations from the National Centres for Environmental Protection's reanalysis[5] data set.

To calculate absolute climate change values, Mora and colleagues used multimodel decadal averages, over the 2091-2100 period, relative to the 1996-2005 period. Decadal averages were chosen to minimize aliasing by inter-annual variability (i.e. to "average out" internal variability).

The authors determined the projected timing of climate departure of specific areas, such as biodiversity hotspots and populated areas, by examining the data for these areas from global map results for near-surface air temperature departure.

Using these methods, the authors arrived at the results above.

Mora, C. et al., 2013: The projected timing of climate departure from recent variability. *Nature*, **502**, 183-187, doi:10.1038/nature12540.

5. A reanalysis is a representation of the historical climate that is created from historical observations that are "assimilated" into a global weather forecast model that is run in a hindcast mode.

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