Climate Change Impacts in Los Angeles and Their Implications for Policymakers

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In my testimony today, I will present the results of my research group's project to predict future climate change impacts in the Los Angeles region, and I will discuss the implications of our findings for policymakers in California.

Research Overview

Our project, called Climate Change in the Los Angeles Region, is an ongoing study that began in 2010 and was funded jointly by the City and County of Los Angeles, the U.S. Department of Energy, and the U.S. National Science Foundation. We undertook this project in part because a comprehensive study of climate change impacts on a regional scale had not yet been done in the Los Angeles region. We were also motivated by the need to advance the science of regional climate modeling—in other words, to develop a rigorous and reliable method for downscaling global climate models so that we can recover projections of future climate on a fine spatial scale.

To explain what downscaling is and why it is useful, I will provide a brief overview of climate modeling. The tools that climate researchers use to project future climate are called global climate models, or general circulation models (GCMs). These are large, complex computer models that process equations representing our most up-to-date and complete understanding of the physics of the climate system. When researchers impose conditions onto a GCM (for example, given atmospheric concentrations of greenhouse gases), they can simulate how the climate system is likely to respond under those conditions. Through analysis of GCM experiments and observational studies, the Intergovernmental Panel on Climate Change (IPCC) concluded in its recently released 5th Assessment Report, of which I am a lead author, that global average surface temperature is likely to increase by 0.3 to 4.8 degrees Celsius by 2100, depending on the quantity of greenhouse gases the world emits between now and then.[1]

Of course, global average temperature gives a sense of the scale of climate change overall, but it does not tell us much about what will happen at scales relevant to policymakers and the public. Although GCMs provide the best available projections of future global climate change, they are limited in what they can tell us on smaller spatial scales because they typically produce results at a very coarse resolution. The highest-resolution global climate models produce results at about a 100-km resolution, which means they divide the area of study into 100-km-square grid boxes and treat the entire area within each grid box as though it has a uniform climate. This aspect of GCMs makes them unsuitable for understanding climate change in a region with a complex topography. As anyone familiar with California knows, its climate varies greatly from coastal areas to mountains and valleys, and a GCM cannot reproduce this variety. So rather than simply running a

[1] Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis, Summary for Policymakers, available at http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf

GCM over the LA region, we need to employ techniques to *downscale* that GCM, zooming in on the region and producing high-resolution projections that account for its topographical variations.

Another limitation of GCMs is that there are differences from model to model. Different modeling centers have different ways of constructing models to represent complex atmospheric and oceanic dynamics. Because of these differences, we cannot necessarily rely on output from a single GCM; we need instead to downscale as many GCMs as possible to adequately sample the uncertainty arising from differences in the models. However, the standard method of downscaling, called dynamical downscaling, is computationally very expensive, rendering it impractical for producing multimodel analyses.

In the Climate Change in the Los Angeles Region Project, we set out to address the above limitations of GCMs with respect to regional modeling, and the resulting studies are the first to produce future climate projections for the region at a policy-relevant scale and with robust information about most likely outcomes and uncertainty estimates.

Study Methodology

In our project, we downscaled 32 GCMs using a new hybrid dynamical–statistical technique to produce climate change projections for the Los Angeles region at a very high (2-km) resolution. The models we selected are all part of the Coupled Model Intercomparison Project Phase 5 (CMIP5) archive, the same model archive employed by the IPCC in its 5th Assessment Report. We produced projections for two future periods, 2041–2060 and 2081–2100, and two different greenhouse gas emissions scenarios, RCP8.5 and RCP2.6. These are standardized "representative concentration pathway" scenarios used by the IPCC. RCP8.5 represents a "business-as-usual" scenario in which emissions continue to rise unchecked, and RCP2.6 represents a "mitigation" scenario in which the world comes together to significantly reduce emissions over the coming decades.

We first produced a baseline climate simulation for the years 1981–2000 using a regional climate model called the Weather Research and Forecasting Model (WRF) and dynamically downscaled National Centers for Environmental Prediction North America Regional Reanalysis (NARR) weather data. Using WRF in the same configuration, we then dynamically downscaled output from five global climate models in the CMIP5 archive corresponding to the mid-century period and the RCP8.5 emissions scenario. We calculated the climate change signal by comparing the differences between the mid-century and baseline periods, and then we used that signal to develop a statistical model. With the statistical model, we produced downscaled output for the remaining GCMs for the business-as-usual emissions scenario at mid-century, and for all 32 GCMs for business-as-usual at end-century. We also produced statistically downscaled output for 24 GCMs corresponding to the mitigation scenario for both future periods.

Findings to Date

To date, we have released our findings on two aspects of climate: temperature and snowfall. Analysis is still underway and results are forthcoming on additional aspects, including overall precipitation, surface hydrology including runoff and streamflow, Santa Ana winds, and fire risk. I will summarize the temperature and snowfall results below; for more information, visit http://c-change.la.[2]

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[2] Full reports on the temperature and snowfall studies are available at http://c-change.la/pdf/LARC-web.pdf and http://c-change.la/wp-content/uploads/2013/06/Snowfall-Final-Report.pdf.

To compute the most likely outcomes, we took the average of the results across all the GCMs in our ensemble, a value known as the ensemble-mean. We captured the range of uncertainty associated with intermodel variability by noting outcomes from the GCM showing the most change and the least change for any given variable.

Temperature
By mid-century, the most likely warming under the business-as-usual scenario is roughly 4.6 degrees Fahrenheit averaged over the LA region's land areas, with a 95% confidence that the warming lies between 1.7 and 7.5 degrees. The high resolution of the projections reveals a pronounced spatial pattern in the warming: High elevations and inland areas separated from the coast by at least one mountain complex warm 20% to 50% more than the areas near the coast or within the Los Angeles basin. See Figure 1 in the attached Appendix.

The number of extreme heat days, which we define as days in which the high temperature exceeds 95 degrees Fahrenheit, rises everywhere at mid-century under the business-as-usual scenario. The number of extreme heat days in the future follows a similar spatial pattern to that of the warming results, with inland areas seeing much higher totals than coastal areas. For example, Santa Barbara sees average annual extreme heat days rise from 5 in the baseline period to more than 12[3] at mid-century under business-as-usual. By contrast, Riverside sees an increase from 58 days to 103 days.[4] For more locations, see Figure 2.

In the mitigation scenario, we see slightly less warming at mid-century (see Fig. 1) and a less pronounced increase in extreme heat days (see Fig. 2). The warming under mitigation at mid-century is about 70% of the warming under business-as-usual. Put another way, this means 70% of the business-as-usual warming is inevitable.

Snowfall
In our snowfall study, we projected total annual snowfall in the LA region's mountain areas, including the San Gabriel, San Bernardino, San Emigdio/Tehachapi, and San Jacinto ranges, expressing results as the percentage of annual snowfall that remains in the future periods compared with the baseline period. By mid-century, the mountains in the Los Angeles region are likely to receive substantially less snowfall than in the baseline period. Under the business-as-usual scenario, 58% of baseline snowfall is likely to persist, whereas under mitigation, the likely amount remaining is somewhat higher (69%). Results are summarized in Table 1 in the Appendix.

Business-as-usual versus mitigation
As shown above, the results for temperature and snowfall do not show dramatic differences between the business-as-usual and mitigation scenarios at mid-century, indicating that substantial changes in temperature and snowfall loss are inevitable. When we look at end-century results, however, the differences between the business-as-usual and mitigation scenarios become more pronounced. As Figure 3 shows, in the business-as-usual scenario, warming sees a substantial further increase from mid-century levels. By contrast, in the mitigation scenario, warming stabilizes, remaining at about mid-century levels. A similar pattern is seen in the end-century snowfall results. In the business-as-usual scenario at end-century, most likely annual snowfall

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[3] This is the ensemble-mean, or most likely, value. The most sensitive GCM shows a mid-century business-as-usual total of 24 days a year, whereas the least sensitive GCM shows a more modest increase, to just under 7 days.

[4] This is the ensemble-mean value. The most sensitive GCM shows a mid-century business-as-usual total of 127 days a year, whereas the least sensitive GCM shows 73 days a year.

sees a substantial further reduction from mid-century levels, dropping to just one-third of baseline snowfall. This is likely to represent a complete disappearance of snowfall at lower elevations. However, in the mitigation scenario at end-century, snowfall sees only a negligible further reduction from mid-century levels. (See Table 1.)

Implications of Our Findings

As a climate scientist, I do not possess the requisite expertise to offer specific policy recommendations for addressing climate change in the Los Angeles region. However, I can offer thoughts on the policy questions our findings raise and the kinds of issues policymakers will need to consider as they weigh whether and how to act.

A key finding of our work arises from the comparison of the business-as-usual and mitigation emissions scenarios. The similarities of two scenarios at mid-century and their stark differences at end-century have implications for the adaptation-versus-mitigation policy debate. At mid-century, we see that significant warming and snowfall loss are inevitable, regardless of any actions we take to curb greenhouse gas emissions. Change is coming, and we need to assess whether we are prepared for that change or need to take measures to adapt. Based on the mid-century results, it may be tempting to conclude that mitigation measures could be abandoned in favor of adaptation measures. But as our end-century results indicate, mitigation prevents significant further change. The end-century business-as-usual projections paint a picture of a future climate that is very different from the one we are used to, and policymakers and their constituents need to ask themselves whether those conditions are acceptable. If not, then mitigation is an important part of an overall strategy for dealing with climate change.

Changes in temperature and snowfall have implications for public health, urban infrastructure and the energy grid, water resources, and ecosystems. Hotter temperatures are associated with decreased air quality, and more extreme heat days can adversely affect vulnerable populations. Heat increases are also likely to put greater pressure on the energy grid, as its efficiency decreases and more energy is needed to cool buildings. Mountain snowpack acts as a natural reservoir for freshwater, and our reservoir and flood control systems were built presuming the natural reservoir would remain available. Changes to temperature and water availability are likely to have consequences for plant and animal species and have the potential to disrupt marine and terrestrial ecosystems. Measuring the specific impacts of climate change on human and natural systems was beyond the scope of our project, but our findings point to a need for further research so that planners and resource managers can better characterize likely impacts and plan accordingly.

Continuing Research and Research Needs

As noted above, we are continuing our analysis of Climate Change in the Los Angeles Region Project results pertaining to precipitation, surface hydrology, Santa Ana winds, and fire risk. We have also begun preliminary work on a project to employ our hybrid dynamical–statistical downscaling technique over the rest of California, with a focus on the Sierra Nevada Mountains, so that we can better characterize climate change impacts on California's water resources and mountain ecosystems.

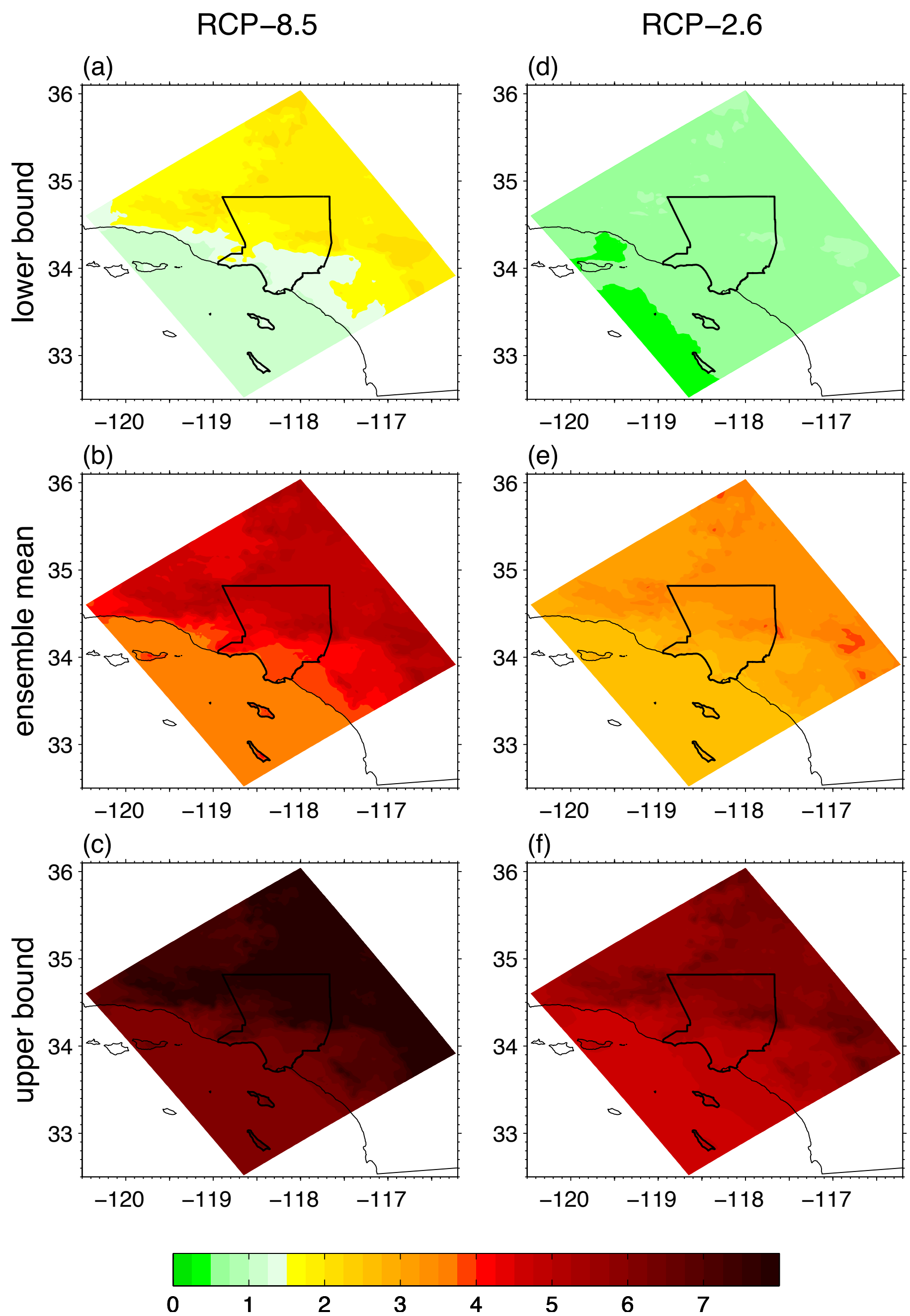
Our climate change projections have the potential to be of great use to planners and natural resource managers, and we have already received several requests for our data. For example, planners at LA Metro are using our temperature data to conduct a vulnerability analysis for the agency's area of service. Researchers from UCLA's Fielding School of Public Health are writing a manuscript on the public health implications of climate change based on our data and are conducting a series of workshops with the Los Angeles County Department of Public Health's working group on climate change planning (a group formed in response to our research) to help them plan for the future. There is great potential for detailed regional climate data to inform adaptation planning, but at present the framework does not exist for others to access our data, and our group does not have the capacity to respond to every data request we receive. To address this, we are currently seeking funding and personnel to build an online portal allowing anyone to access, visualize, and download our data for their own use.

Finally, it would be highly beneficial to conduct multimodel downscaling studies in other regions of California. The Los Angeles region has a unique climate, and therefore the results of our study may not be generally applicable to other areas of the state.

Thank you for considering this testimony. I look forward to answering any questions you may have.

Appendix: Figures and Table

Fig 1. The ensemble-mean, annual-mean surface air temperature change (mid-century minus baseline), and its uncertainty, unit: °F. Results from the RCP8.5 emissions scenario ("business-as-usual") for 2041–2060 are shown in the left panels, while those from the RCP2.6 emissions scenario ("mitigation") are shown in the right panels. Panels (b) and (e) (the middle row) show the ensemble-mean, annual-mean surface air temperature change (future minus baseline) of all GCMs for the two emissions scenarios. The top row shows the lower bound of the 95% confidence interval of annual-mean surface air temperature change for all GCMS for RCP8.5 (a) and RCP2.6 (d), while the bottom row shows the upper bound of the 95% confidence interval of annual-mean surface air temperature change for all GCMS for RCP8.5 (c) and RCP2.6 (f).



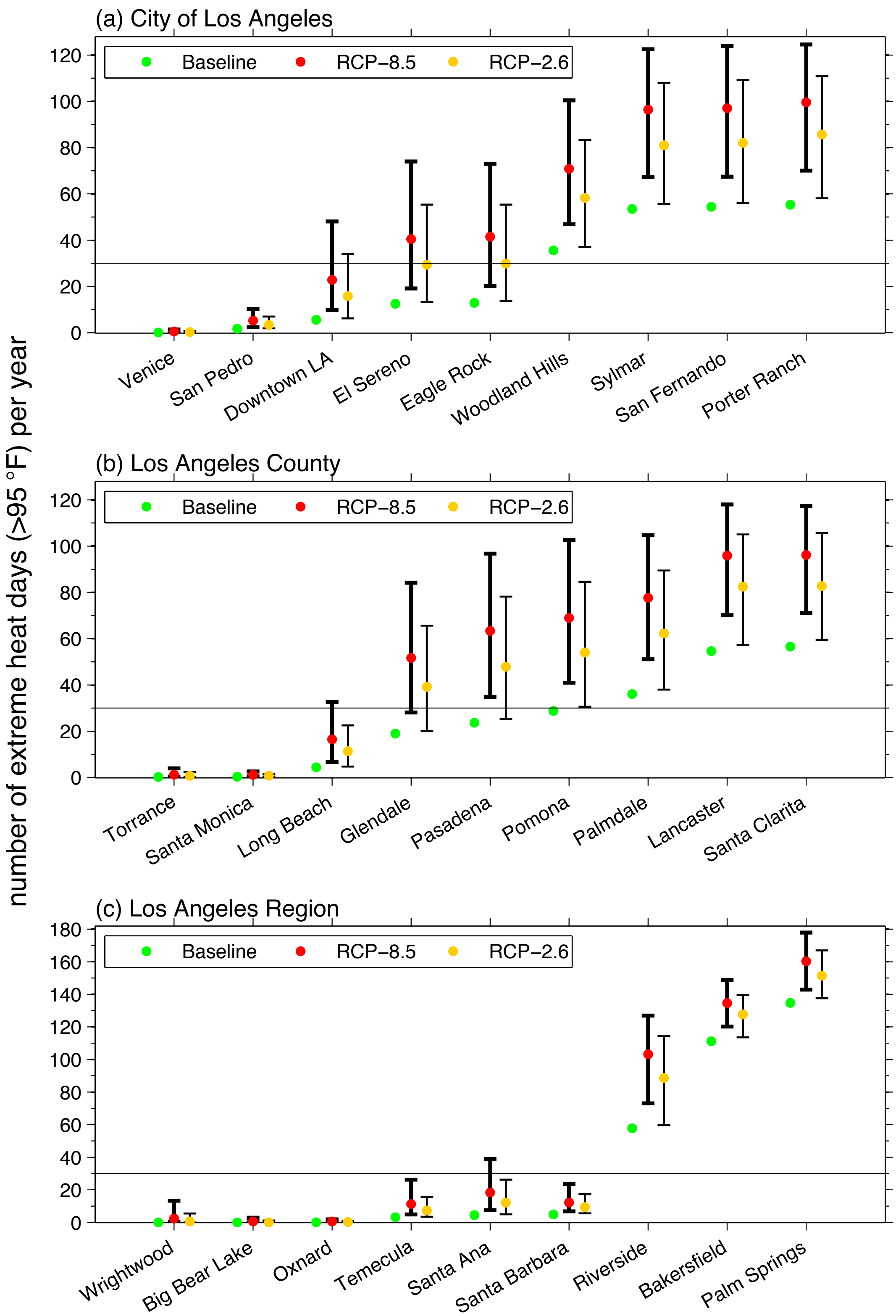


Fig 2. The ensemble-mean annual-mean expected number of extremely hot days in the mid-century (2041–2060) period and its uncertainty, for various locations. The number of extremely hot days at baseline is shown with a green dot. An extremely hot day is defined as one where the maximum temperature is greater than 95°F. Panel (a) shows districts within the city of Los Angeles, panel (b) shows other cities within Los Angeles County, and panel (c) shows cities within in our study domain but outside of Los Angeles County. Red and yellow dots represent the ensemble-mean for RCP8.5 and RCP2.6 emissions scenarios, respectively. Whiskers represent the approximate 95% confidence interval for the projection, based on the spread seen in the regionalization of every available GCM. To aid the reader, a horizontal line corresponding to 30 days per year has been drawn on each panel.

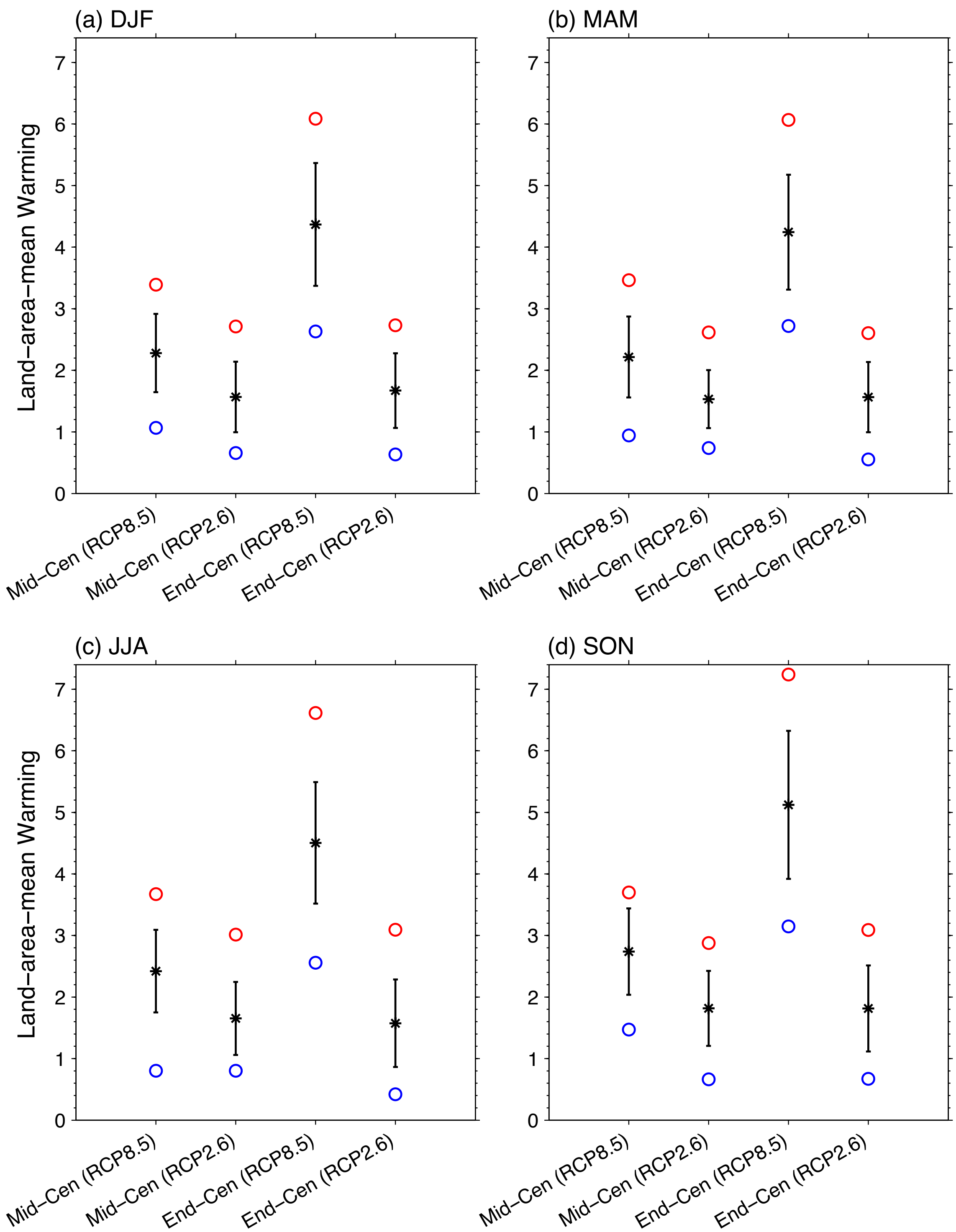


Fig. 3: Statistically downscaled surface warming (unit: °C), averaged over the region's land areas, for (a) winter, (b) spring, (c) summer and (d) autumn. Averages at mid-century and end-of-century, for both the RCP8.5 and RCP2.6 scenarios, are shown. The asterisks denote the ensemble-mean, the error bars denote one standard deviation, and the red and blue circles denote maximum and minimum warming across all GCMs.

Table 1: Inches per year of baseline snowfall and most likely (ensemble-mean across GCMs) future snowfall averaged over domain and its percentage (in parentheses) to the baseline. Due to significant differences in climate change outcomes across the global models, these numbers are associated with uncertainty, in the range of 15–30 percentage points.

	Entire domain	San Emigdio/ Tehachapi	San Gabriel	San Bernardino	San Jacinto
Baseline	42.8	39.9	49.7	65.4	68.4
RCP8.5 Mid-century	24.7 (58%)	22.3 (56%)	29.4 (59%)	40.5 (62%)	41.2 (61%)
RCP8.5 End-of-century	14.3 (33%)	12.5 (31%)	17.2 (35%)	25.3 (39%)	25.8 (38%)
RCP2.6 Mid-century	29.7 (69%)	27.1 (68%)	35.1 (71%)	47.7 (73%)	49.3 (72%)
RCP2.6 End-of-century	28.6 (67%)	26.1 (65%)	33.9 (68%)	46.3 (71%)	47.8 (70%)