Projected Future Climatic and Ecological Conditions in San Luis Obispo County

Marni E. Koopman, Richard S. Nauman, and Jessica L. Leonard
The National Center for Conservation Science and Policy

April, 2010

A collaborative effort by:

National Center for
Conservation Science & Policy

Local
Government
Commission

The MAPSS Team at the USDA Forest Service
Pacific Northwest Research Station

Acknowledgements: Ray Drapek and Ron Neilson at the USDA Forest Service Pacific Northwest Research Station provided climate projection data as well as logistical support. Stacy Vynne of the Climate Leadership Initiative and Cindy Deacon Williams of NCCSP offered assistance with wording. We also appreciate the insights on climate projections provided by Phil Mote with the Oregon Climate Change Research Institute. The photo of the Yucca flower is from Denis Kearns while the other three cover pictures were generously supplied by Jim Zimmerlin.

TABLE OF CONTENTS

INTRODUCTION

San Luis Obispo County is rich in history, culture, and biological diversity. The county extends from semi-desert in the east, across the Santa Lucia Mountains, through the rolling hills and oak woodlands and finally to the rugged coastline along the western border. Changes to this landscape due to climate change are likely to affect natural ecosystems as well as local residents and their livelihoods.

Climatic changes are already underway across the County and are likely to increase in the coming decades. Changes to the local climate are likely to include more frequent and intense storms and floods, extended drought, increased wildfire, and more heat waves. The local communities in the County will need to plan for such changes in order to prevent potentially catastrophic consequences.

This report provides community-members and decision-makers in San Luis Obispo County with local climate change projections that are presented in a way that can help them make educated long-term planning decisions. The climate change model outputs in this report were obtained from the USDA Forest Service Pacific Northwest Research Station and mapped by scientists at the National Center for Conservation Science and Policy.

Climate projection
A model-derived estimate of the future climate.

Climate prediction or forecast
A projection that is highly certain based on agreement among multiple models.

Scenario
A coherent and plausible description of a possible future state. A scenario may be developed using climate projections as the basis, but additional information, including baseline conditions and decision pathways, is needed to develop a scenario.

MODELS AND THEIR LIMITATIONS

Climate change presents us with a serious challenge as we plan for the future. Our current planning strategies at all scales (local, regional, and national) rely on historical data to anticipate future conditions. Due to climate change and its associated impacts, however, the future is no longer expected to resemble the past.

To determine what conditions we might expect in the future, climatologists created models based on physical, chemical, and biological processes that form the earth's climate system. These models vary in their level of detail and assumptions, making output and future scenarios variable. Differences among models stem from an incomplete understanding of many of Earth's processes and feedbacks. Taken as a group, however, climate models present a range of possible future conditions.

How certain are the projections?

HIGH CERTAINTY:

Higher temperatures – Greater concentrations of greenhouse gases trap more heat. Measured warming tracks model projections.

Lower snowpack – Higher temperatures cause a shift from snow to rain at lower elevations and cause earlier snow melt at higher elevations.

Shifting distributions of plants & animals – Relationships between species distributions and climate are well documented.

MEDIUM CERTAINTY:

More frequent storms – Changes to storm patterns will be regionally variable.

Changes in precipitation – Current models show wide disagreement on precipitation patterns, but the model projections converge in some locations.

LOW CERTAINTY:

Changes in vegetation – Vegetation may take decades or centuries to keep pace with changes in climate.

Changes in runoff – Current models of runoff are unsophisticated and based on historical conditions. Uncertainty in precipitation, land use, and shifting vegetation also contribute to the uncertainty in runoff patterns.

Wildfire patterns – Many uncertain components, including vegetation, tree pests and disease, and precipitation will impact fire patterns.

Most climate models are created at global scales, but are difficult to apply at local or regional scales because global model output does not reflect regional or local variation in climate. For managers and policymakers to make decisions at these finer scales, they need information about how climate change will impact the local area. The MAPSS (Mapped Atmosphere-Plant-Soil System) Team at the Pacific Northwest Research Station adjusted global model results to local and regional scales.

The Intergovernmental Panel on Climate Change (IPCC) uses numerous models to make global climate projections. The models are developed by different institutions and countries and have slightly different inputs or assumptions. From these models, the MAPSS Team chose three global climate models that represented a range of projections for temperature and other climate variables. These three models are Hadley (HADCM, from the UK), MIROC (from Japan), and CSIRO (from Australia). While the specific inputs are beyond the scope of this report, they include such variables as greenhouse gas emissions, air and ocean currents, ice and snow cover, plant growth, particulate matter, and many others (Randall et al. 2007). The three models chosen included specific variables, such as water vapor, that were needed in order to run the MC1 vegetation model.

Model outputs were converted to local scales using local data on recent temperature and precipitation patterns. The climate model output was applied to the MC1 vegetation model (Bachelet et al. 2001), which provided data on possible future vegetation types and extent of wildfire.

The utility of the model results presented in this report is to help communities picture what the conditions and landscape may look like in the future and the magnitude and direction of change. Because model outputs vary in their degree of certainty, they are considered projections rather than predictions (see box on page 2). Some model outputs, such as temperature, have greater certainty than other outputs, such as vegetation type or runoff (see box on previous page).

We urge the reader to keep in mind that these model results are presented to explore the types of changes we may see, but that actual conditions may be quite different from those depicted in this report.

Uncertainty associated with projections of future conditions should not be used as a reason for delaying action on climate change. The likelihood that future conditions will resemble historic conditions is very low, so managers and policy makers are encouraged to begin to plan for an era of change, even if the precise trajectory of such change is uncertain.

GLOBAL CLIMATE CHANGE PROJECTIONS

The IPCC (2007) and the U.S. Global Change Research Program (2009) agree that the evidence is "unequivocal" that the Earth's atmosphere and oceans are warming, and that this warming is due primarily to human activities including the emission of CO_2, methane, and other greenhouse gases, along with deforestation. Average global air temperature has already increased by 0.7° C (1.4° F) and is expected to increase by 2° - 6.4° C (11.5° F) within the next century (Figure 1).

The IPCC emission scenario used in this assessment was the "business-as-usual" trajectory that assumes that most nations fail to act to lower emissions. The current growth in emissions actually exceeds the assumed growth in this modeled

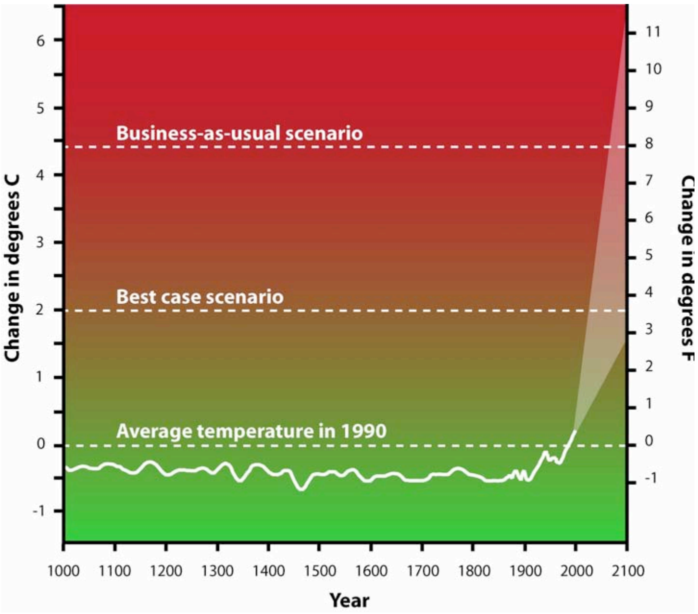


Figure 1. The last 1000 years in global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions would lead to an increase of about 2ºC by 2100 while the current trajectory will lead to an increase closer to 4.5º C and as high as 6º C (adapted from IPCC 2007).

scenario, meaning that the results presented in this report could underestimate actual impacts.

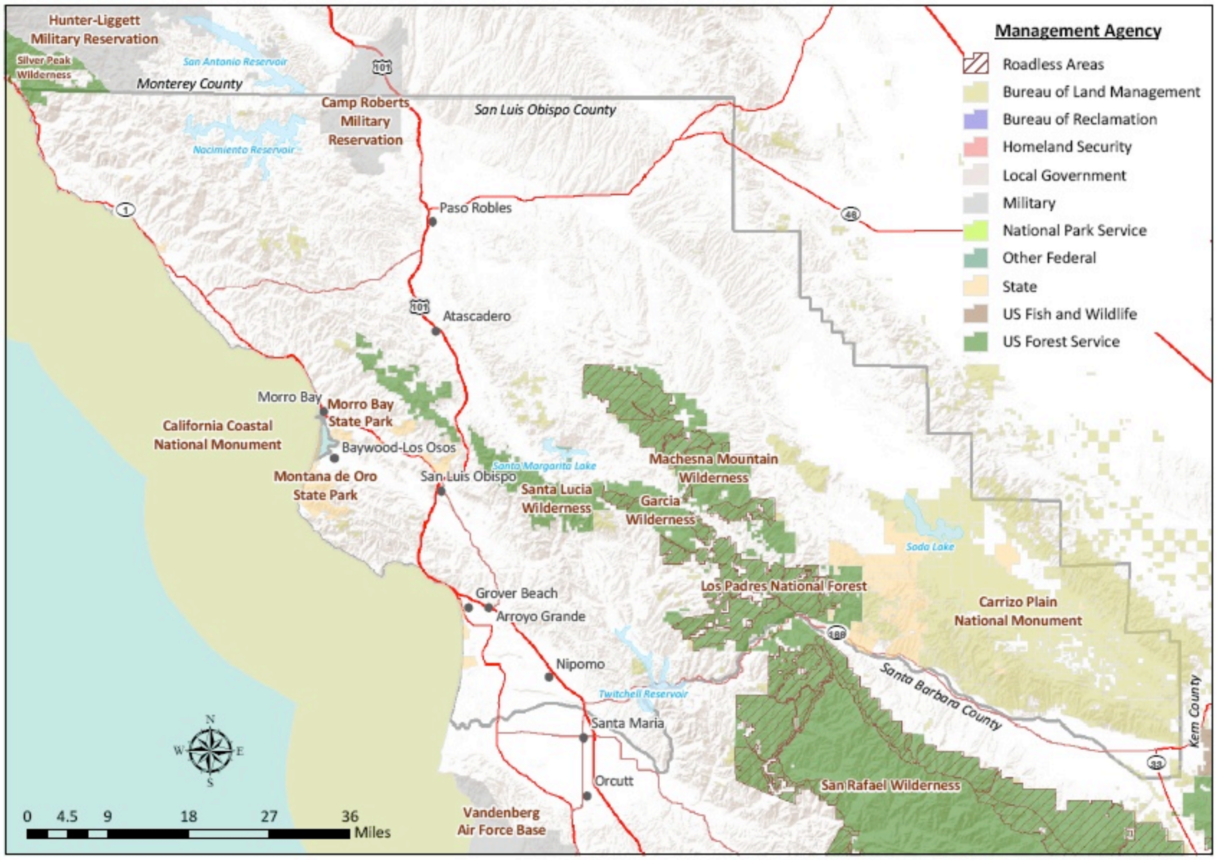
Due to climate system inertia, restabilization of atmospheric gases will take many decades even with drastic emissions reductions. Reducing emissions is vital to prevent the Earth's climate system from reaching certain tipping points that will lead to sudden and irrevocable changes. In addition to emissions reductions, planning for inevitable changes triggered by greenhouse gases already present in the atmosphere will allow residents of San Luis Obispo County to reduce the negative impacts of climate change and, hopefully, maintain their quality-of-life as climate change progresses.

SAN LUIS OBISPO COUNTY CLIMATE PROJECTIONS

Variables modeled using HADCM, CSIRO, and MIROC, and the vegetation model (MC1) include temperature, precipitation, vegetation type and distribution, and annual percent of the landscape burned. These variables were calculated based on historical data for making baseline comparisons, and were projected out to 2100. Again, these projections are uncertain, because of the different assumptions by the models, but they represent a likely range of possible future conditions in San Luis Obispo County. As climate change plays out, we are likely to gain a better understanding of interactions and the climate systems and be able to make more certain projections- however, we may also see surprises and unforeseen chains of cause-and-effect that could not have been projected.

Climate change projections are provided here in three different formats – as overall averages, as time series graphs that show change over time (averaged across the County), and as maps that show variation across the County, but averaged across years. We mapped climate and vegetation variables for the historical period (1961-1990) and for two future 11-year periods (2035-45 and 2075-85).

Figure 2. Land ownership in San Luis Obispo County.



San Luis Obispo County Land Management

Data Source: ESRI National Atlas, ESRI Data Resource Center,
Bureau of Land Management: www.blm.gov/ca/gis/

National Center for Conservation Science & Policy
Created: 09.18.2009

TEMPERATURE

The projections from all three models agree, with high certainty, on a warmer future for San Luis Obispo County (Table 1).

Table 1. Projected increase in average temperature in San Luis Obispo County, from three different global climate models, based on a historic annual average of 58.3° F (14.6° C) from 1961-1990, a historic summer average of 69.9° F (21.1° C), and a historic winter average of 47.3° F (8.5° C)

TEMPERATURE	2035-2045	2075-2085
Annual	+2.1 to +3.9° F (+1.2 to +2.2° C)	+4.1 to +7.6° F (+2.3 to +4.2° C)
Jun - Aug	+1.8 to +4.7° F (+1.0 to +2.6° C)	+4.3 to +8.9° F (+1.0 to +2.6° C)
Dec - Feb	+1.7 to +3.6° F (+1.0 to +2.0° C)	+3.4 to +7.0° F (+1.9 to +3.9° C)

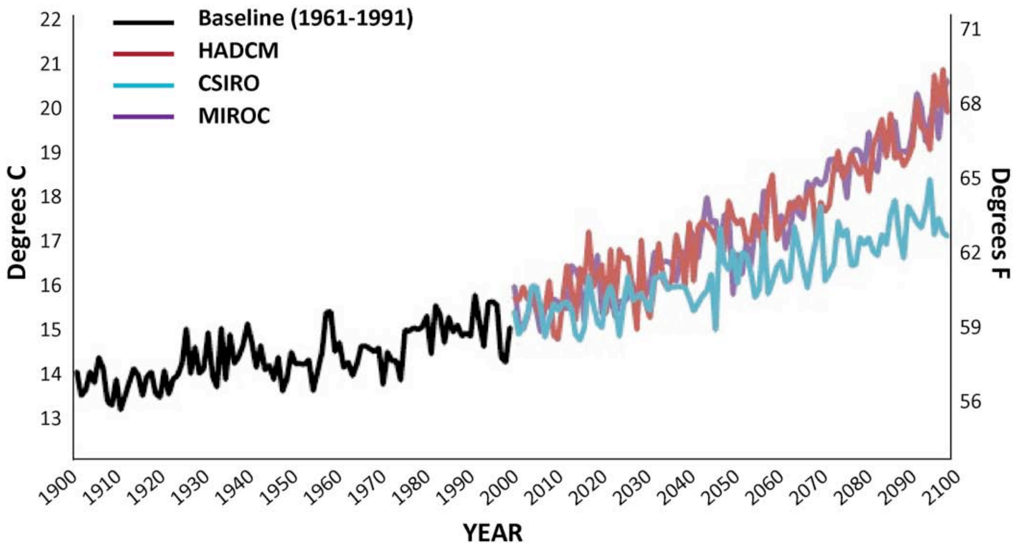


Figure 3. Average annual temperature across San Luis Obispo County from 1901 to 2000 (measured historical) and projected through 2100 using three global climate models.

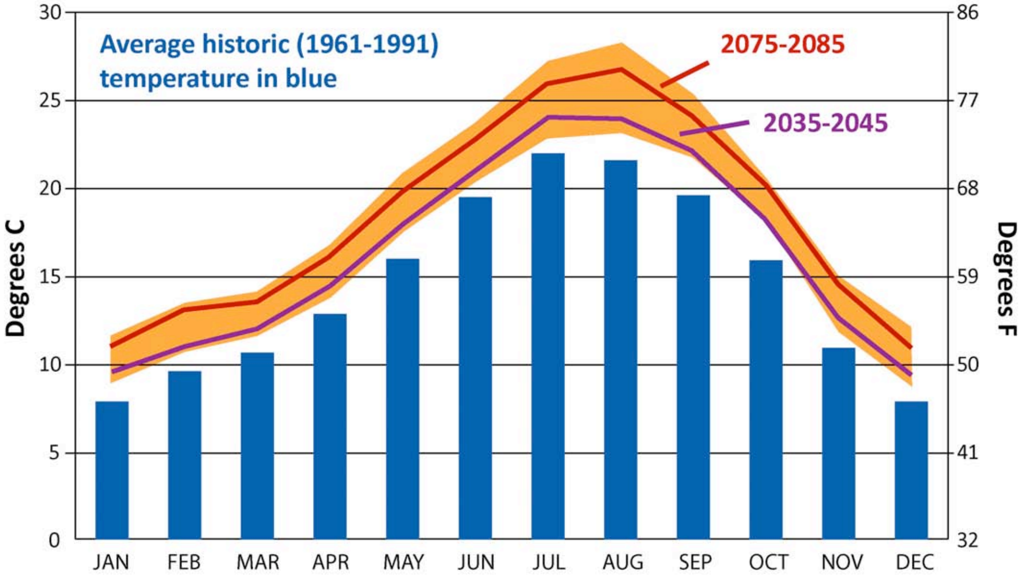


Figure 4. Average monthly temperature across San Luis Obispo County. Future projections are averaged across the three global climate models for two different time periods: 2035-45 (purple line) and 2075-85 (red line). The full range of projections from all three models is shown in orange.

Figure 5. January temperature (in degrees C) across San Luis Obispo County.

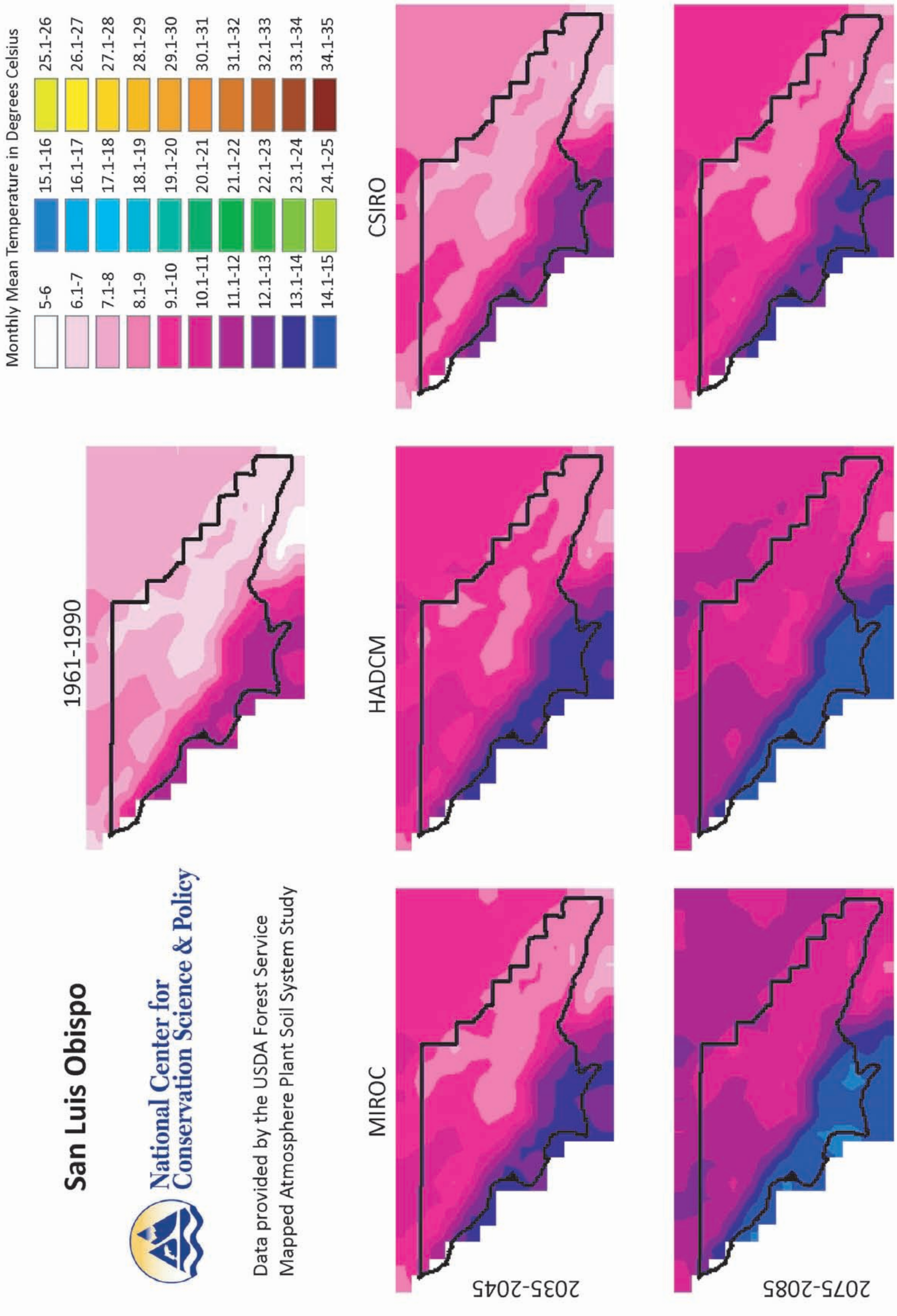


Figure 6. April temperature (in degrees C) across San Luis Obispo County.

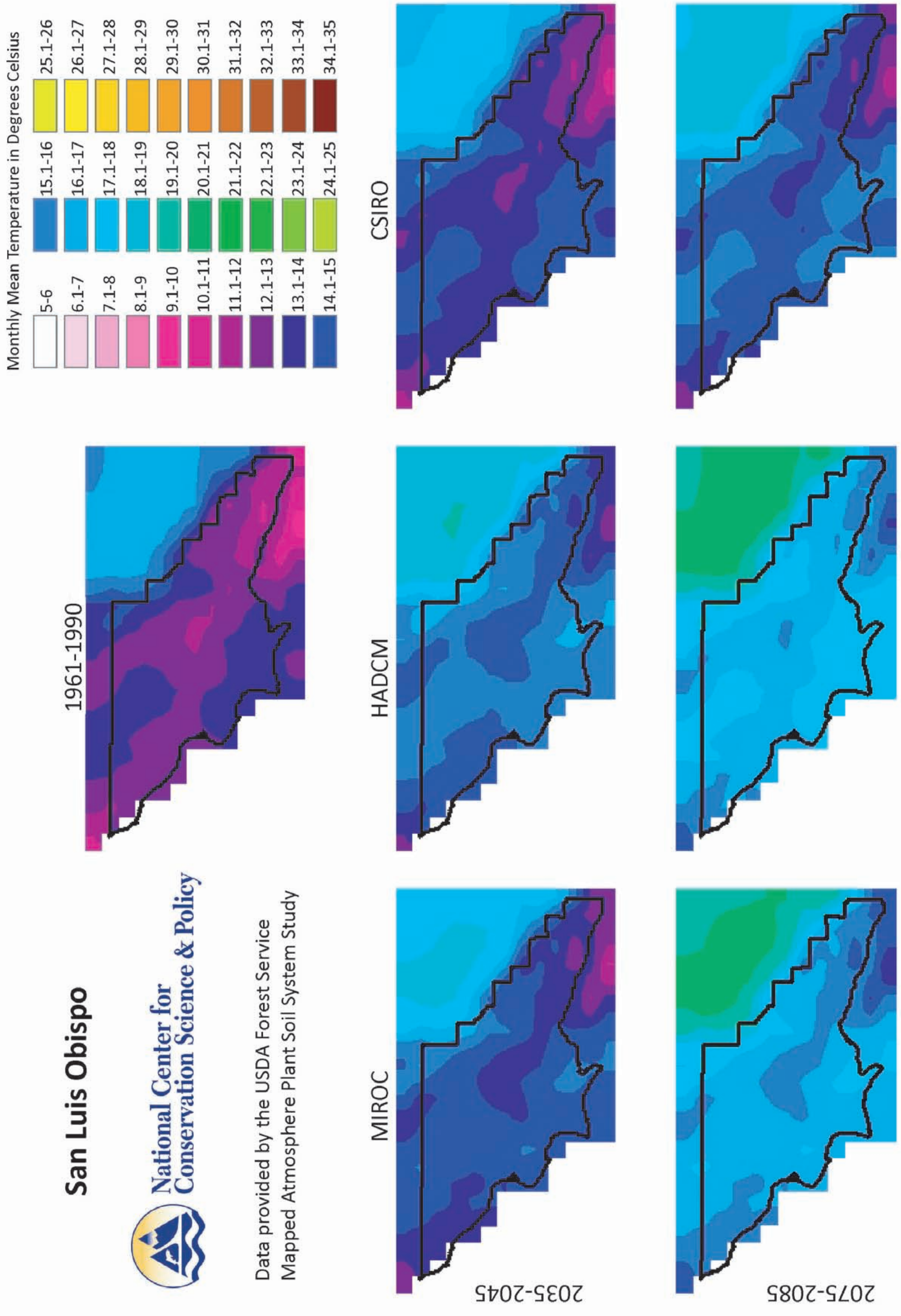


Figure 7. July temperature (in degrees C) across San Luis Obispo County.

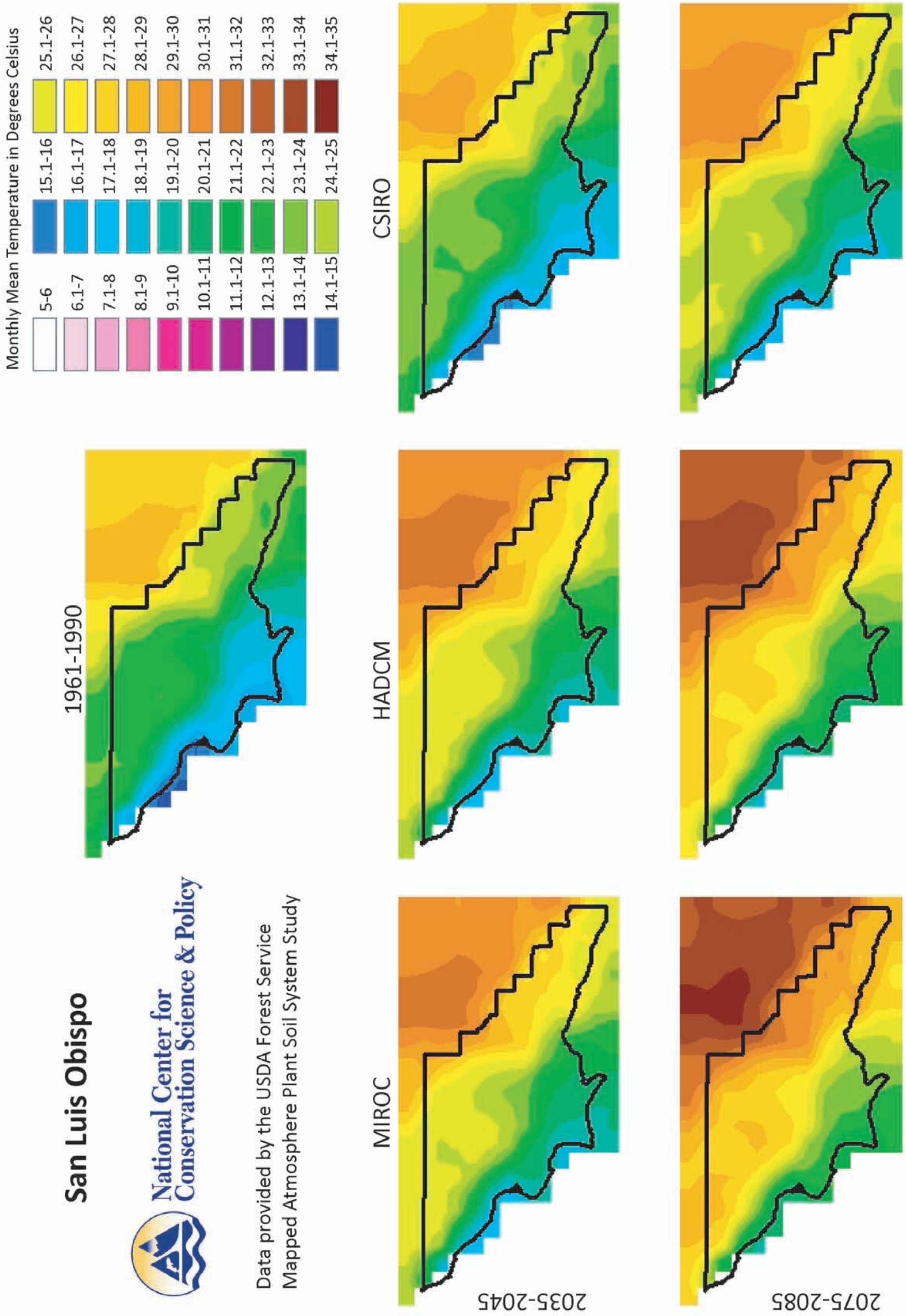
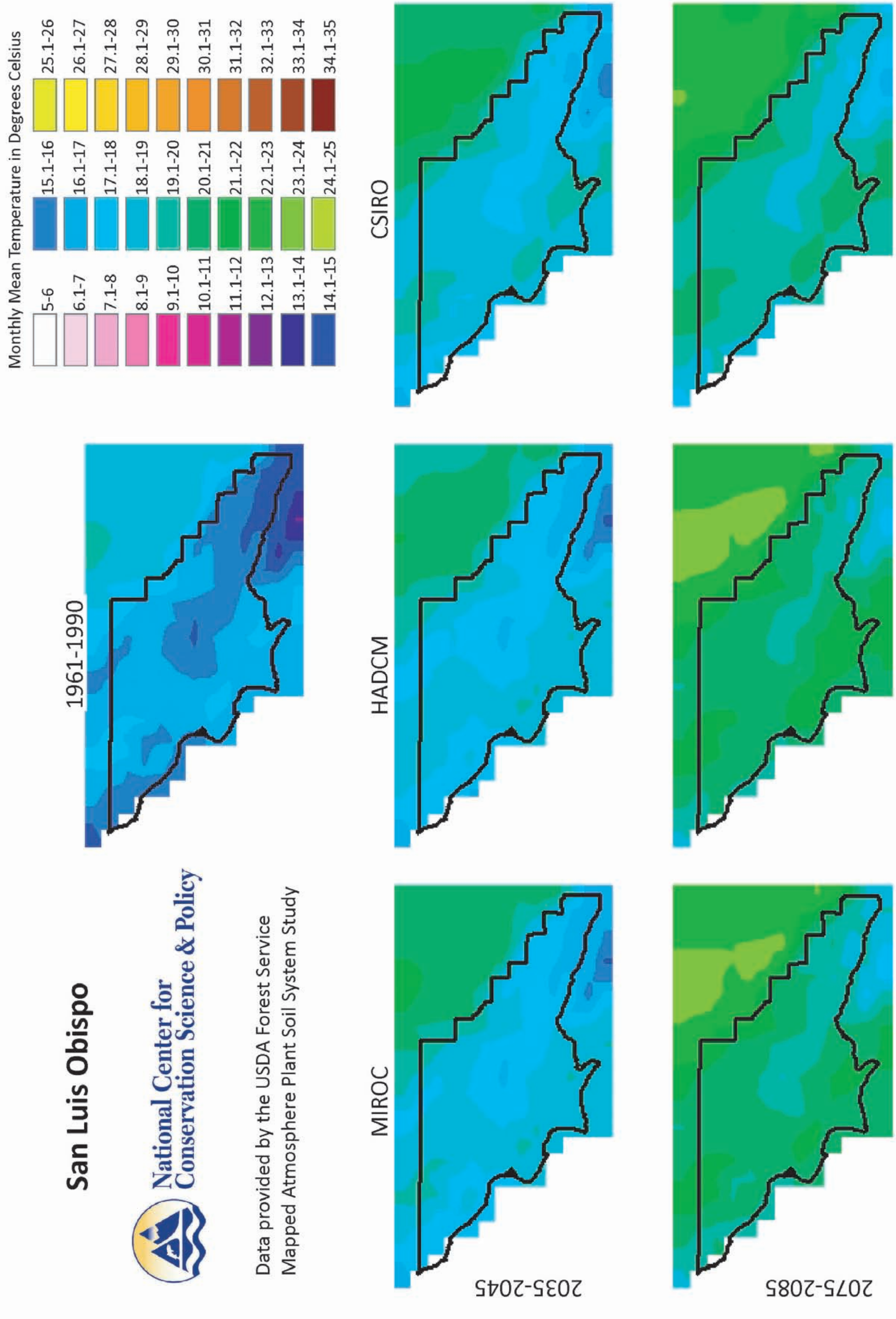


Figure 8. October temperature (in degrees C) across San Luis Obispo County.



Data provided by the USDA Forest Service Mapped Atmosphere Plant Soil System Study

Figure 9. Temperature change (in degrees C) across San Luis Obispo County in January and April.

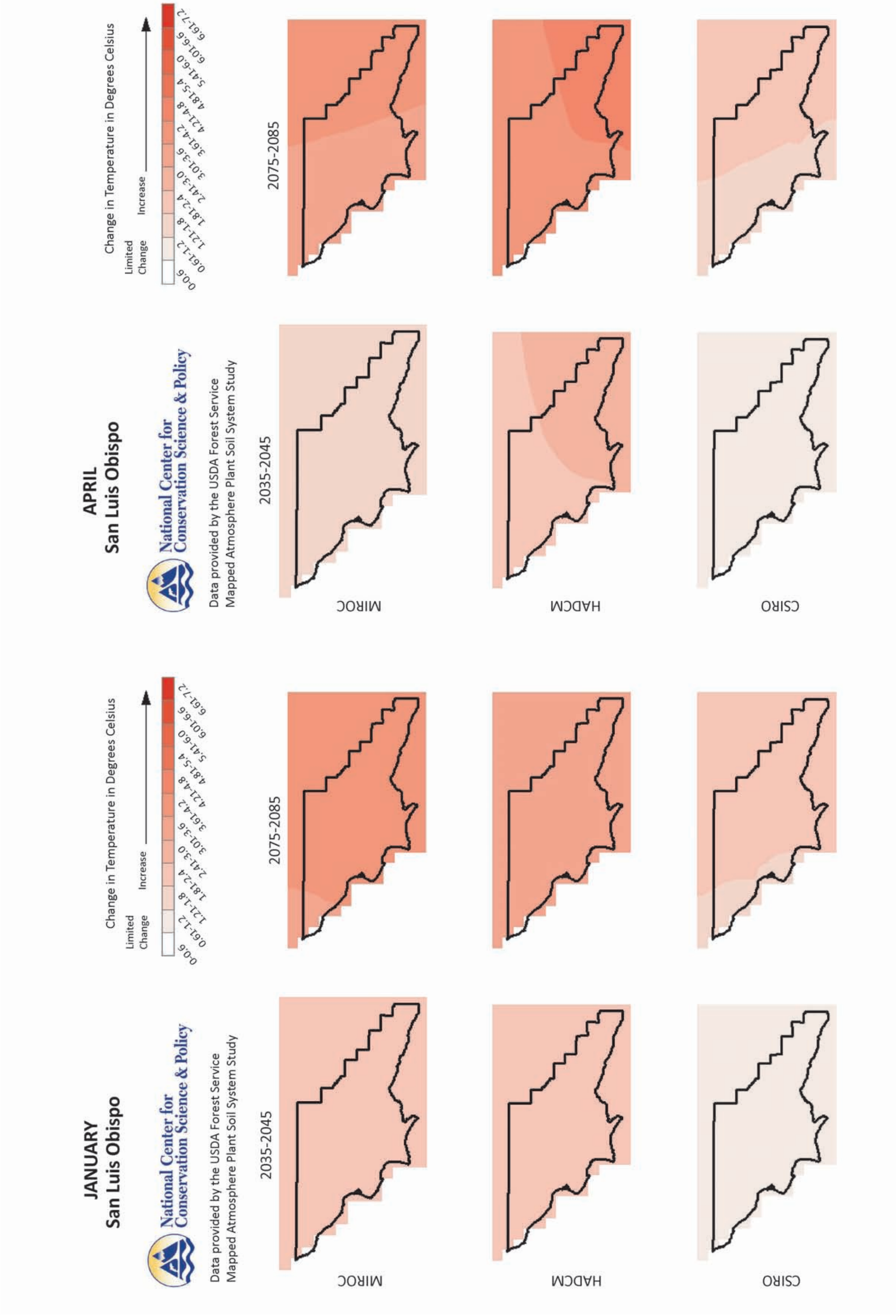
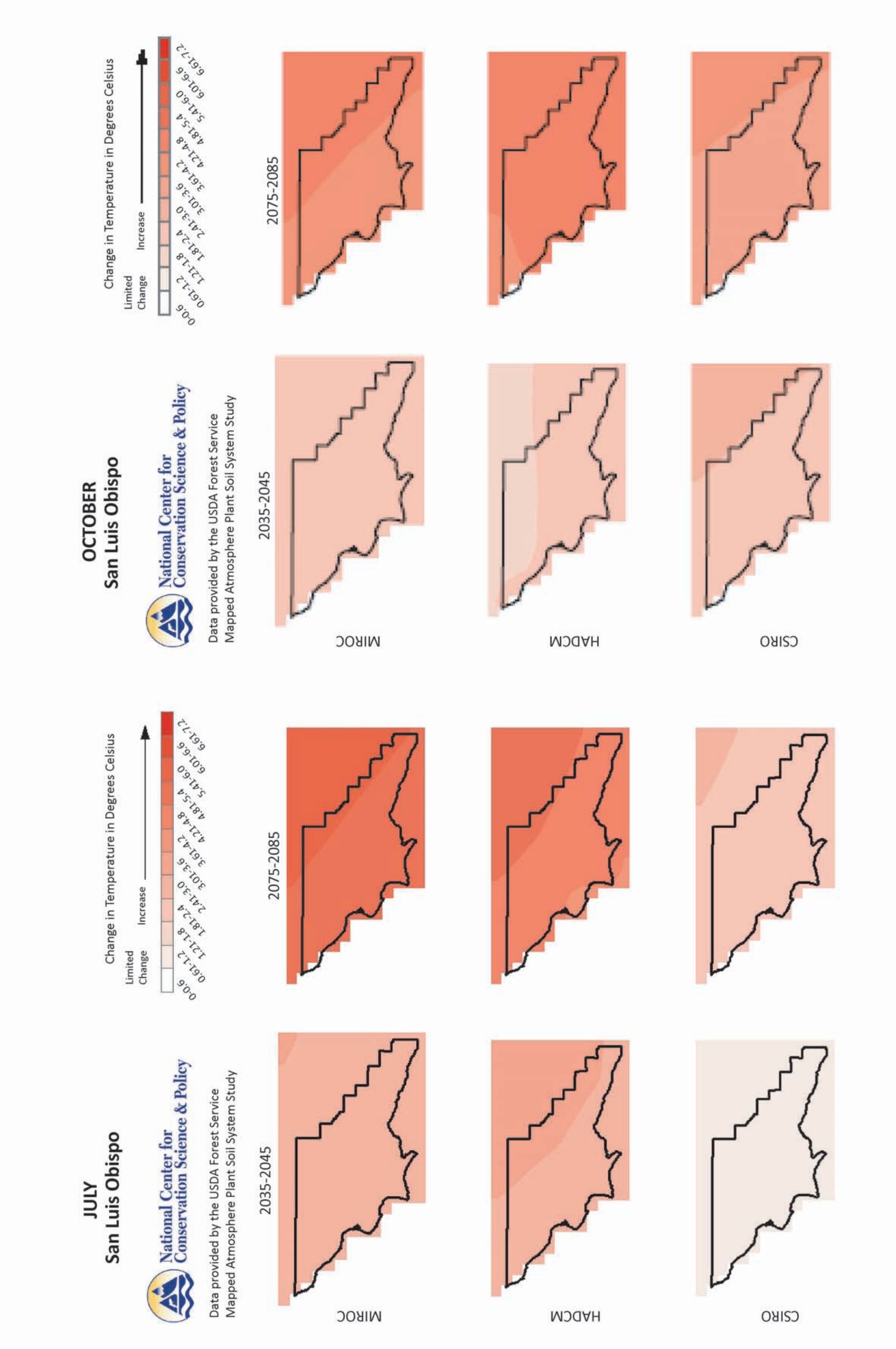


Figure 10. Temperature change (in degrees C) across San Luis Obispo County in July and October.



PRECIPITATION

Projections for future precipitation varied substantially among the three models, with MIROC generally providing drier projections than HADCM and CSIRO. In a series of reports released by the California Energy Commission, a set of six models showed consensus on a drier climate for Central California (Westerling et al. 2009). Further, even with substantial increases in precipitation, soil moisture is expected to decline due to increased temperature and evaporation.

Table 2. Projected change in precipitation in San Luis Obispo County, from three global climate models, based on a historic annual average of 395.9 mm from 1961-1990, a historic summer average of 1.4 mm per month and a historic winter average of 70.6 mm per month.

Precipitation	2035-2045	2075-2085
Annual	-106.7 to +38.6 mm (-27% to +25%)	-120.2 to +22.4 mm (-30.4% to +5.6%)
Jun- Aug	-0.4 to +0.0 mm (-26% to +2%)	-0.4 to +0.3 mm (-29% to +24%)
Dec - Feb	-14.6 to +33.5 mm (-21% to +47%)	-26.1 to +10.7 mm (-37% to +15%)

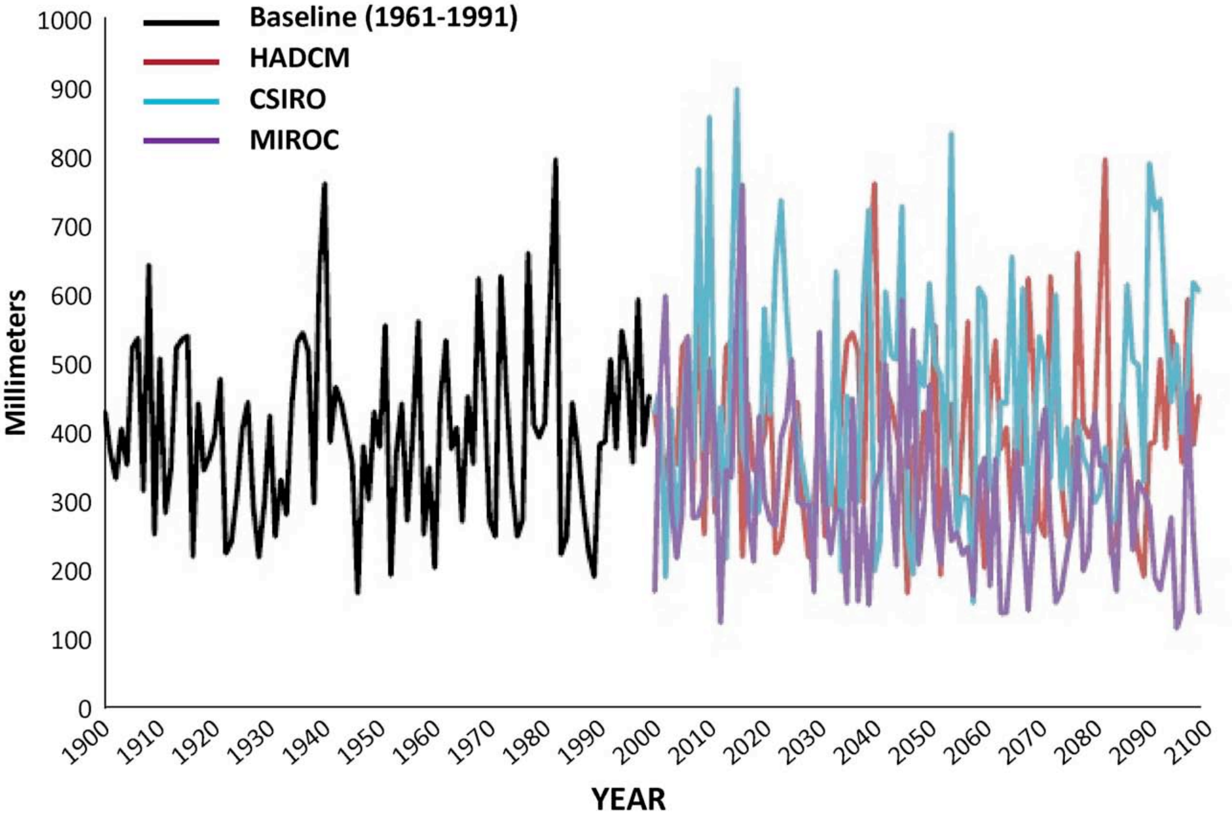
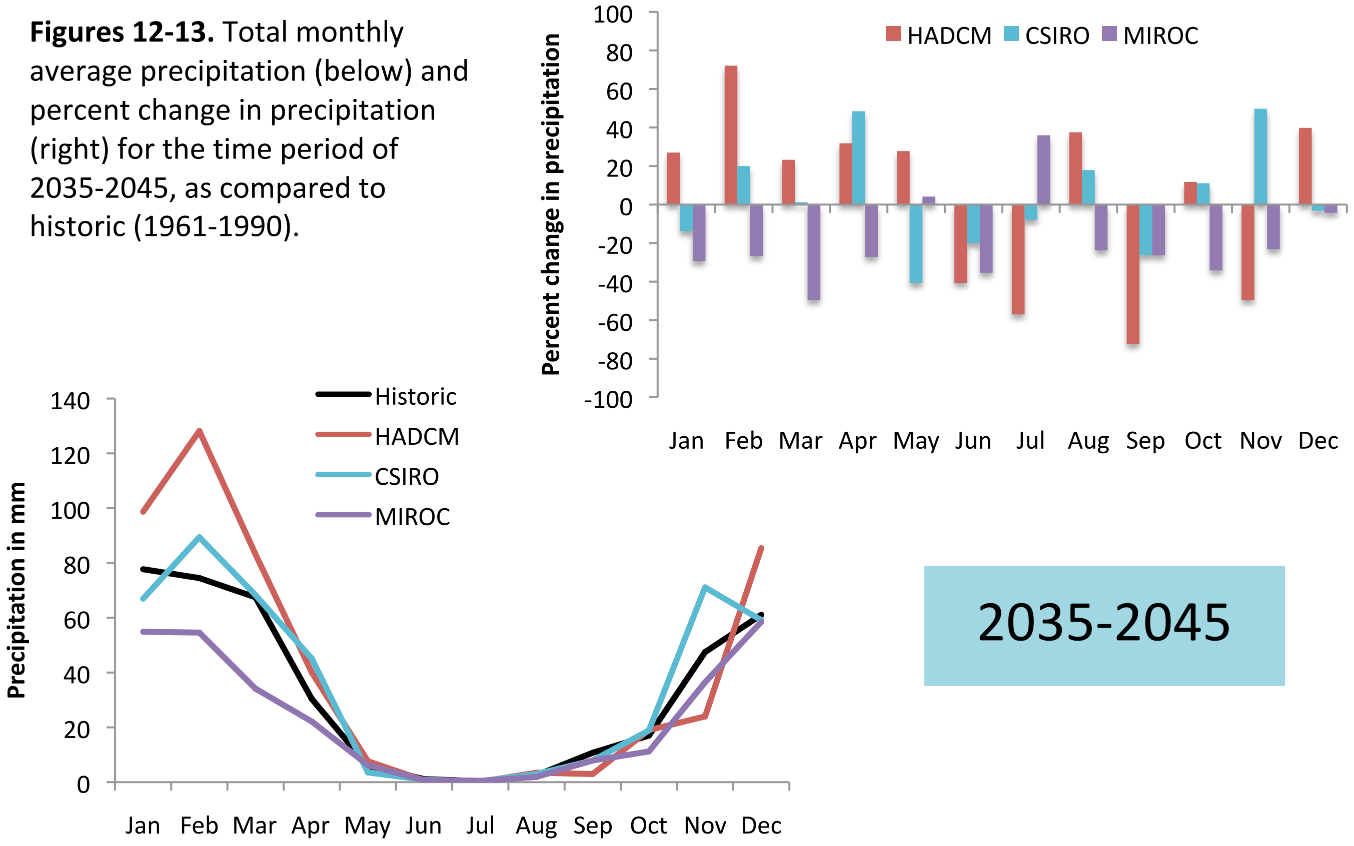


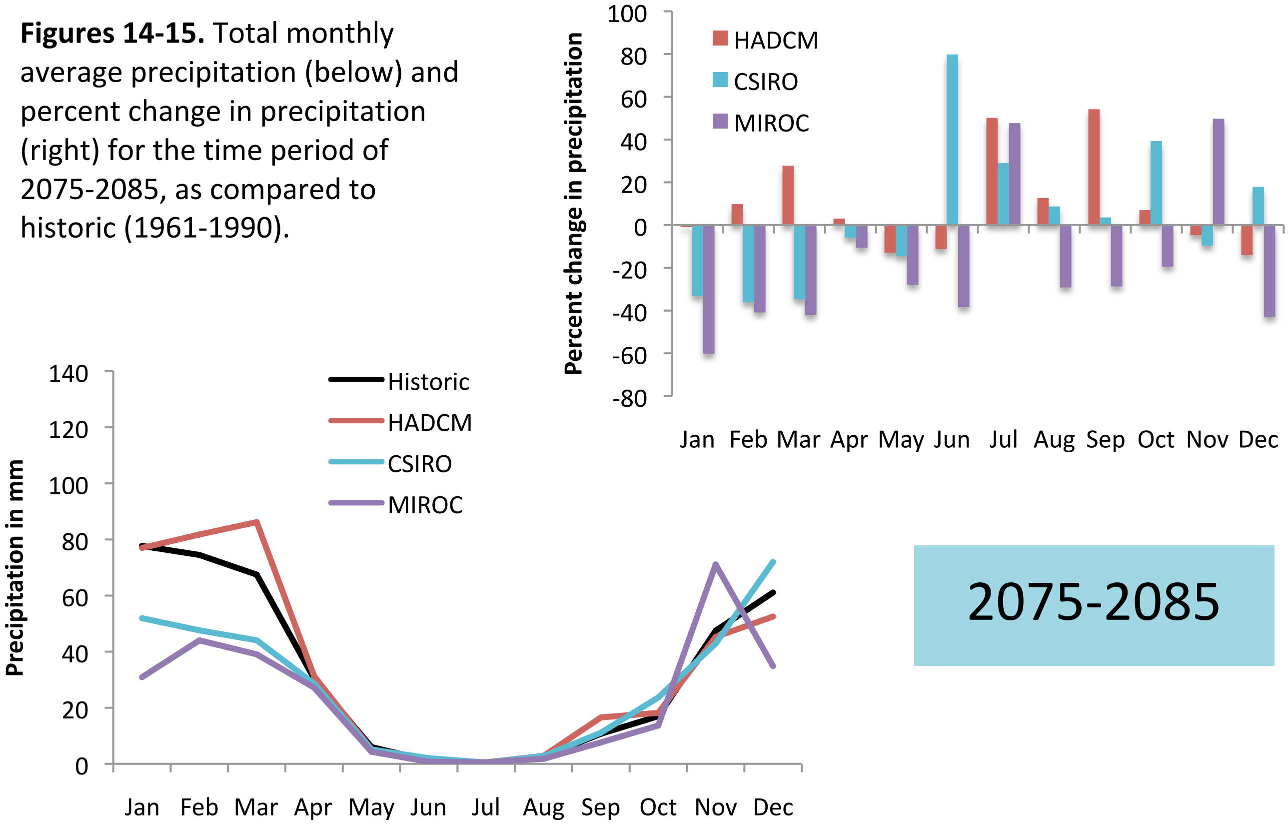
Figure 11. Average annual precipitation (mm) across San Luis Obispo County. On average, HADCM shows a slightly wetter future while MIROC and CSIRO show a drier future.

Figures 12-13. Total monthly average precipitation (below) and percent change in precipitation (right) for the time period of 2035-2045, as compared to historic (1961-1990).



2035-2045

Figures 14-15. Total monthly average precipitation (below) and percent change in precipitation (right) for the time period of 2075-2085, as compared to historic (1961-1990).



2075-2085

Figure 16. January precipitation (in millimeters) across San Luis Obispo County.

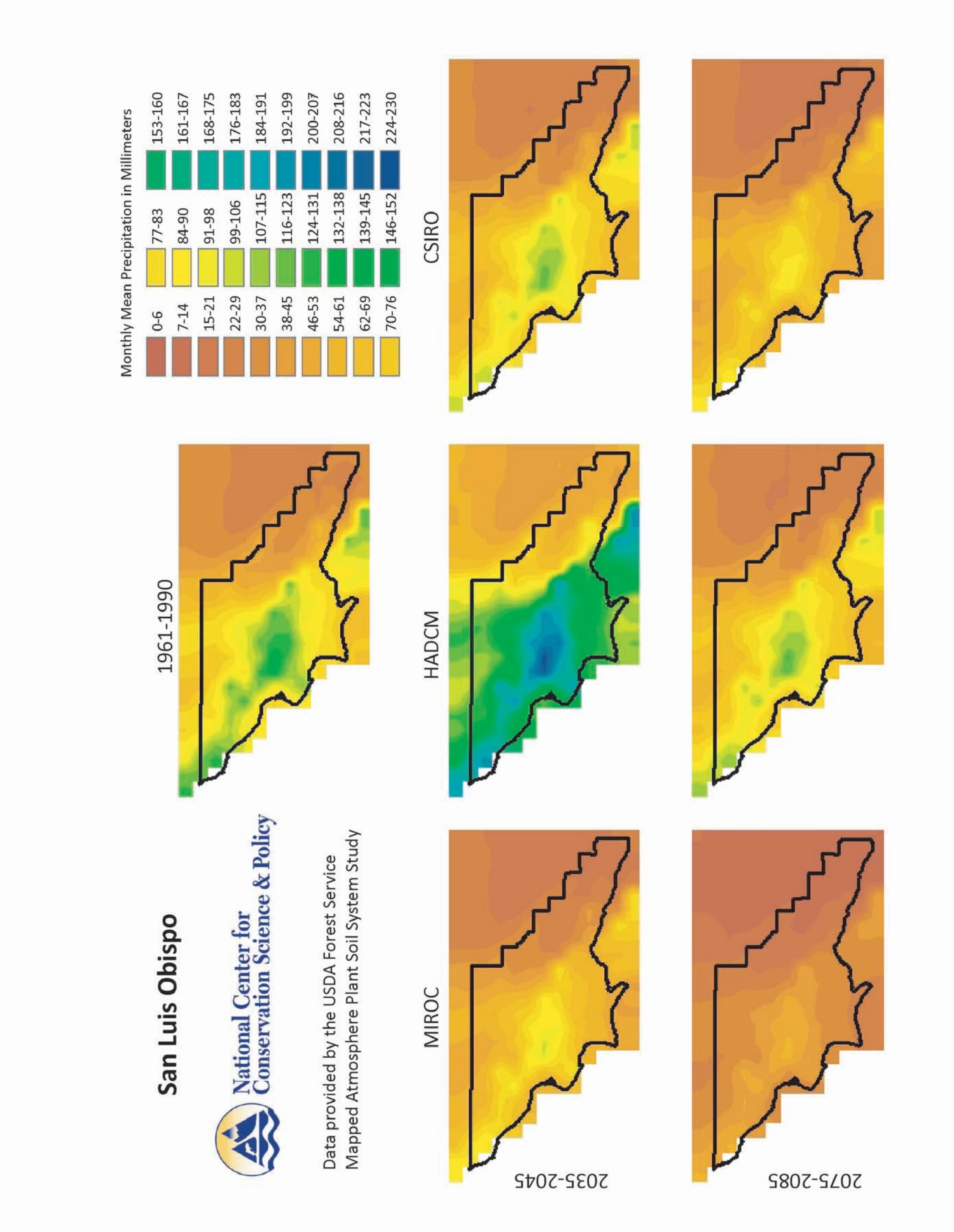
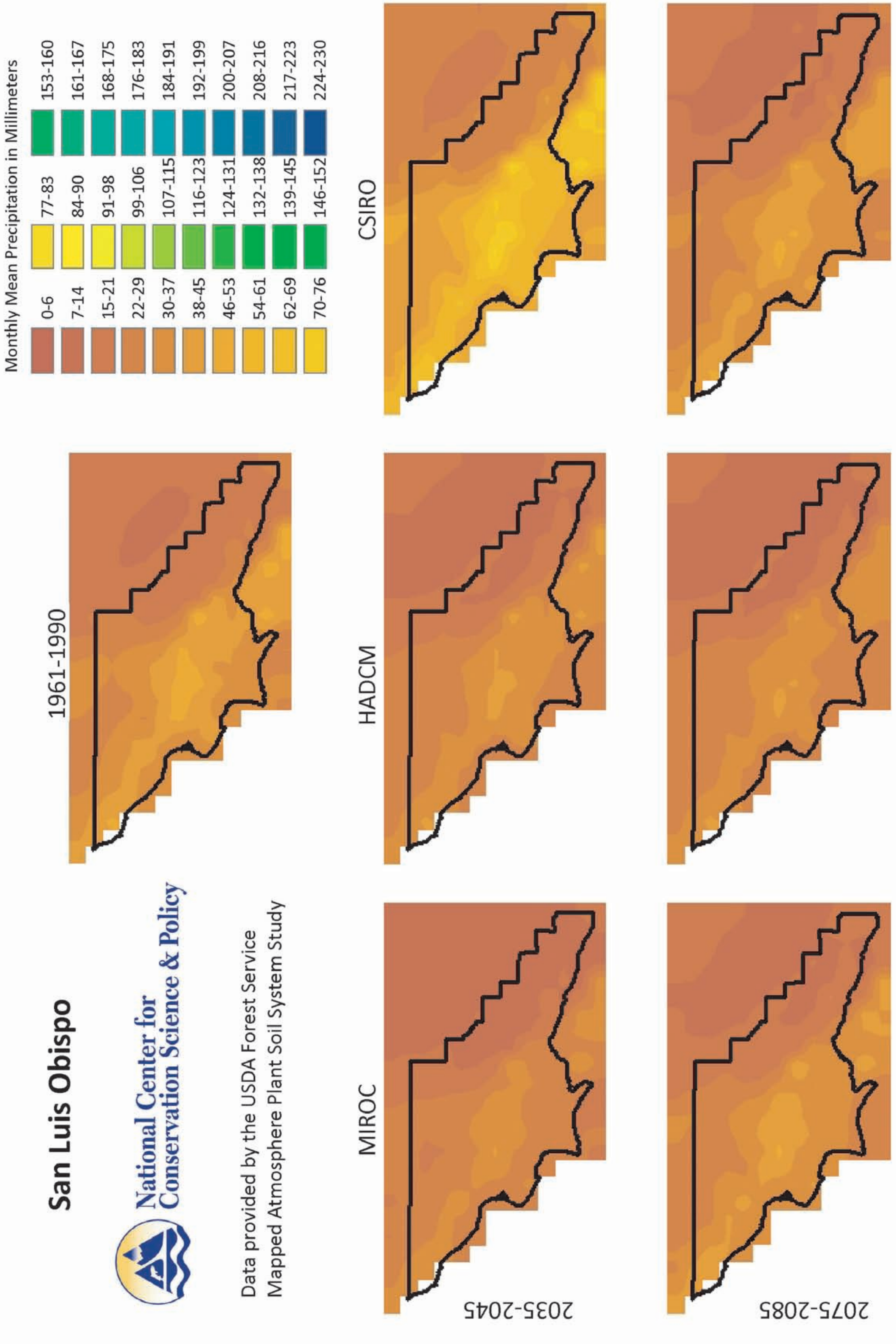


Figure 17. April precipitation (in millimeters) across San Luis Obispo County.



Data provided by the USDA Forest Service Mapped Atmosphere Plant Soil System Study

Figure 18. July precipitation (in millimeters) across San Luis Obispo County.

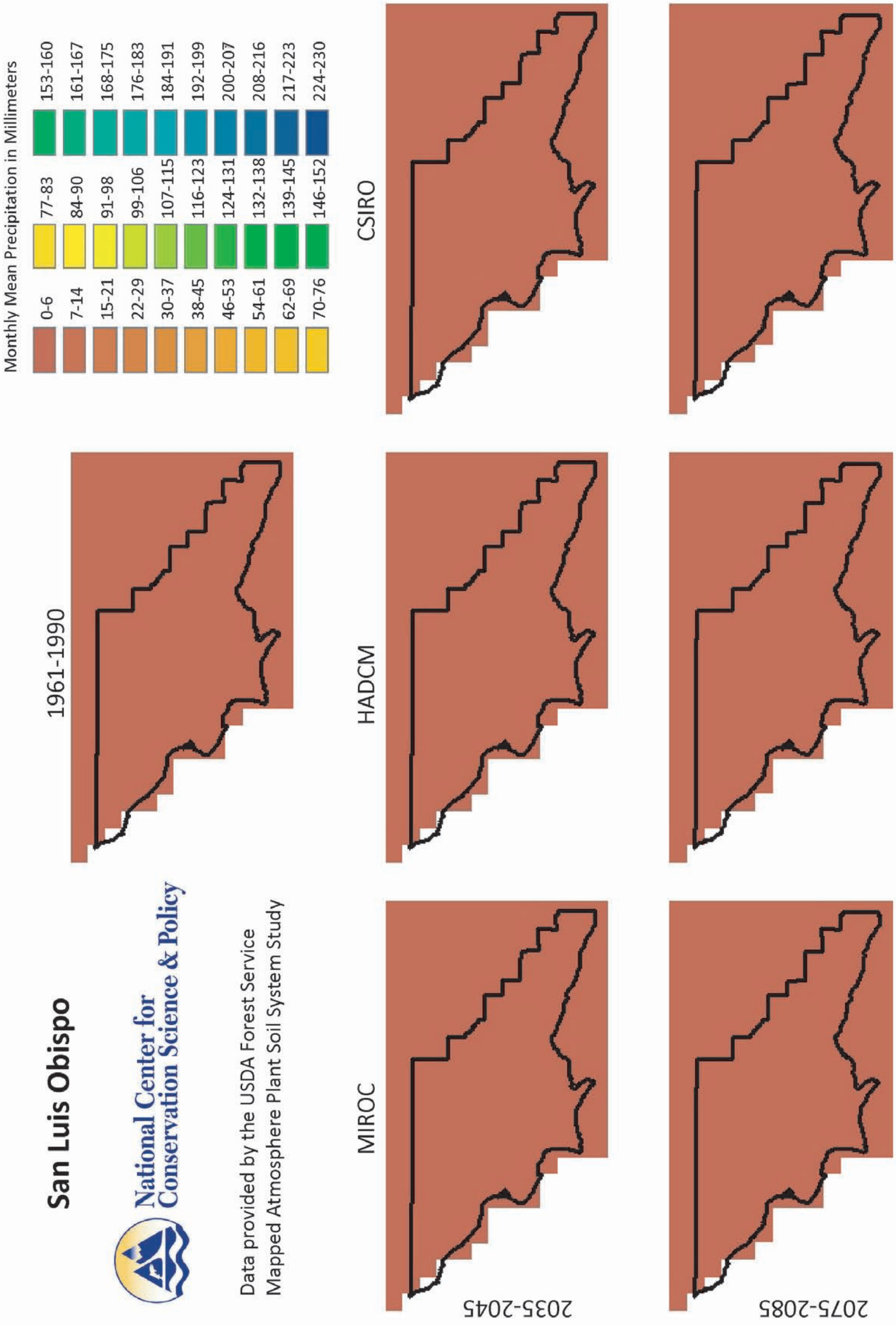


Figure 19. October precipitation (in millimeters) across San Luis Obispo County.

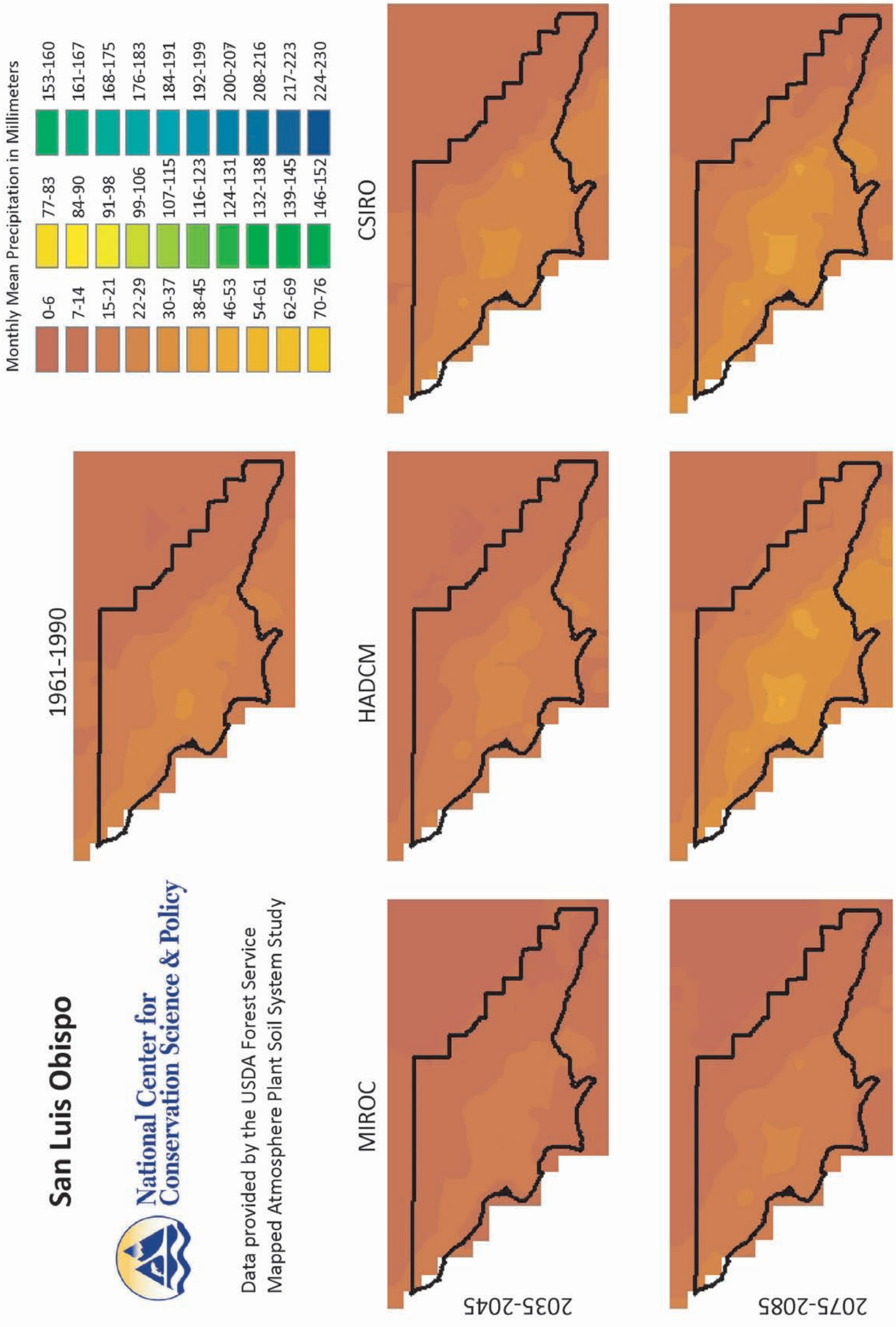


Figure 20. Precipitation change (in millimeters) across San Luis Obispo County in January and April.

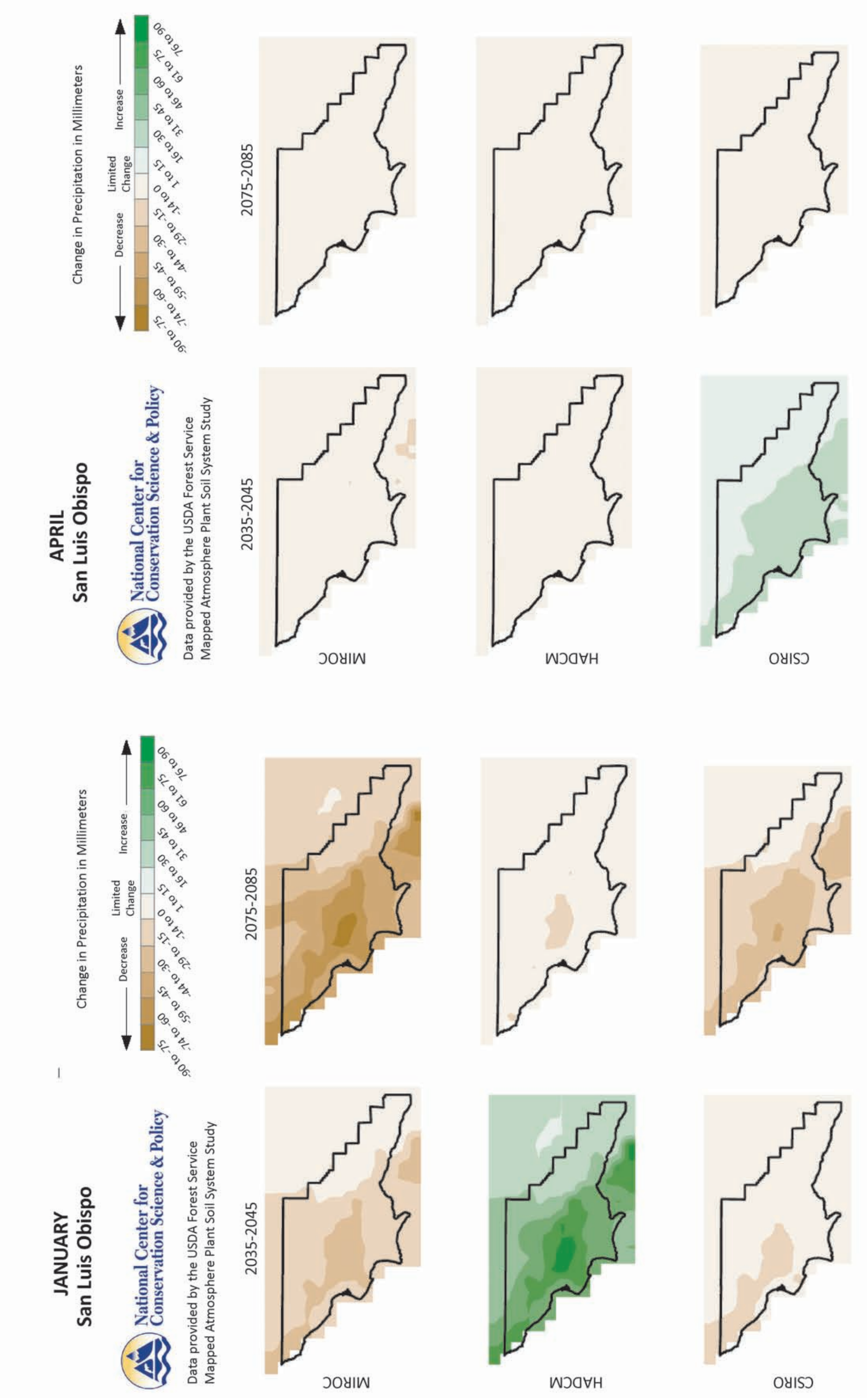
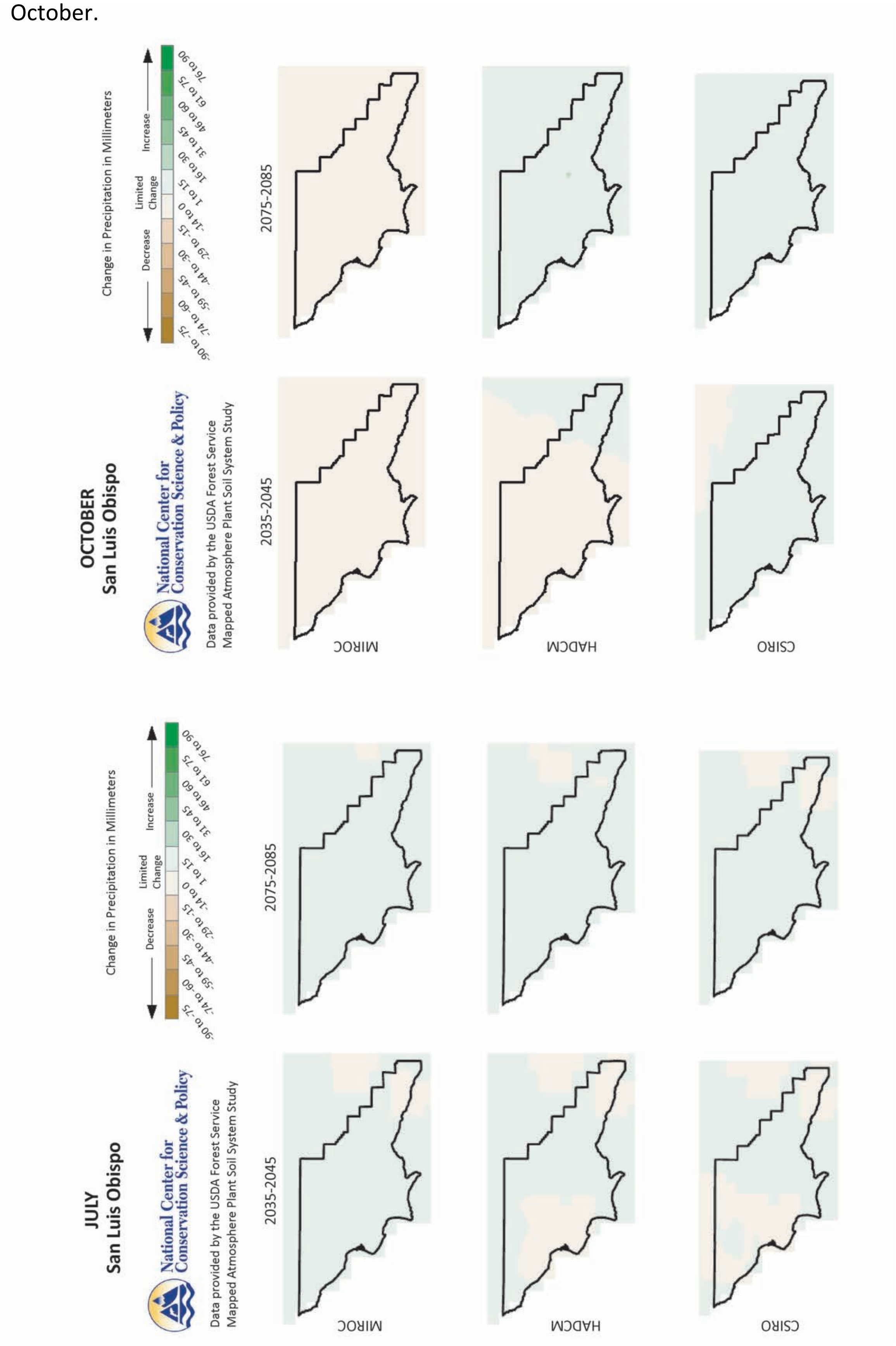


Figure 21. Precipitation change (in millimeters) across San Luis Obispo County in July and October.



VEGETATION and WILDFIRE

The MAPSS team vegetation model (MC1) provided projections for predominant vegetation types (Figure 22) and proportion of the area burned annually by wildfire (Figure 23). Projections for changes in vegetation types include a loss of needleleaf forest at higher elevations, a loss of temperate shrubland in eastern portions of the County, and expansion of subtropical grasslands. (The model does not reflect the dominance of non-native grasses in the area.) Despite changed growing conditions, vegetation can take decades or centuries to adjust. Mechanisms for vegetation change are likely to be drought, fire, invasive species, insects and disease.

According to MC1 output, the annual percentage of the County burned by wildfire is expected to increase from a historical average of 3.7% to 6.8-7.3% by 2035-45 and 8.1-8.5% by 2075-85. This translates to up to 311 mi^2 burned, on average, per year (Figure 23). Similarly, Westerling et al. (2009) also projected substantial increases in area burned by wildfire, with much of San Luis Obispo County expected to experience 200-350% increase in acreage burned by 2085 as compared to the historic (1961-1990) amount.

Figure 22. Suitable growing conditions for dominant types of vegetation.

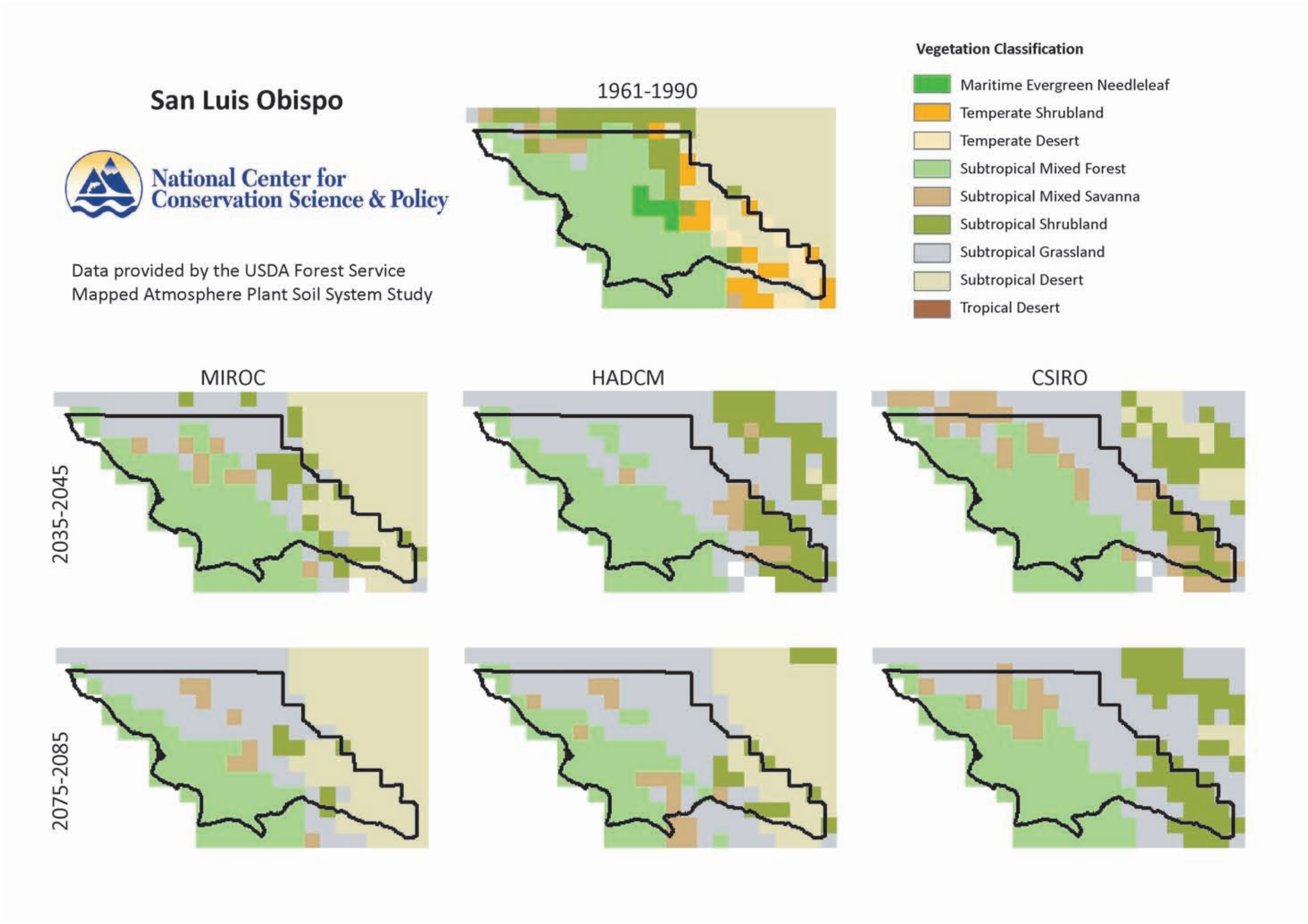
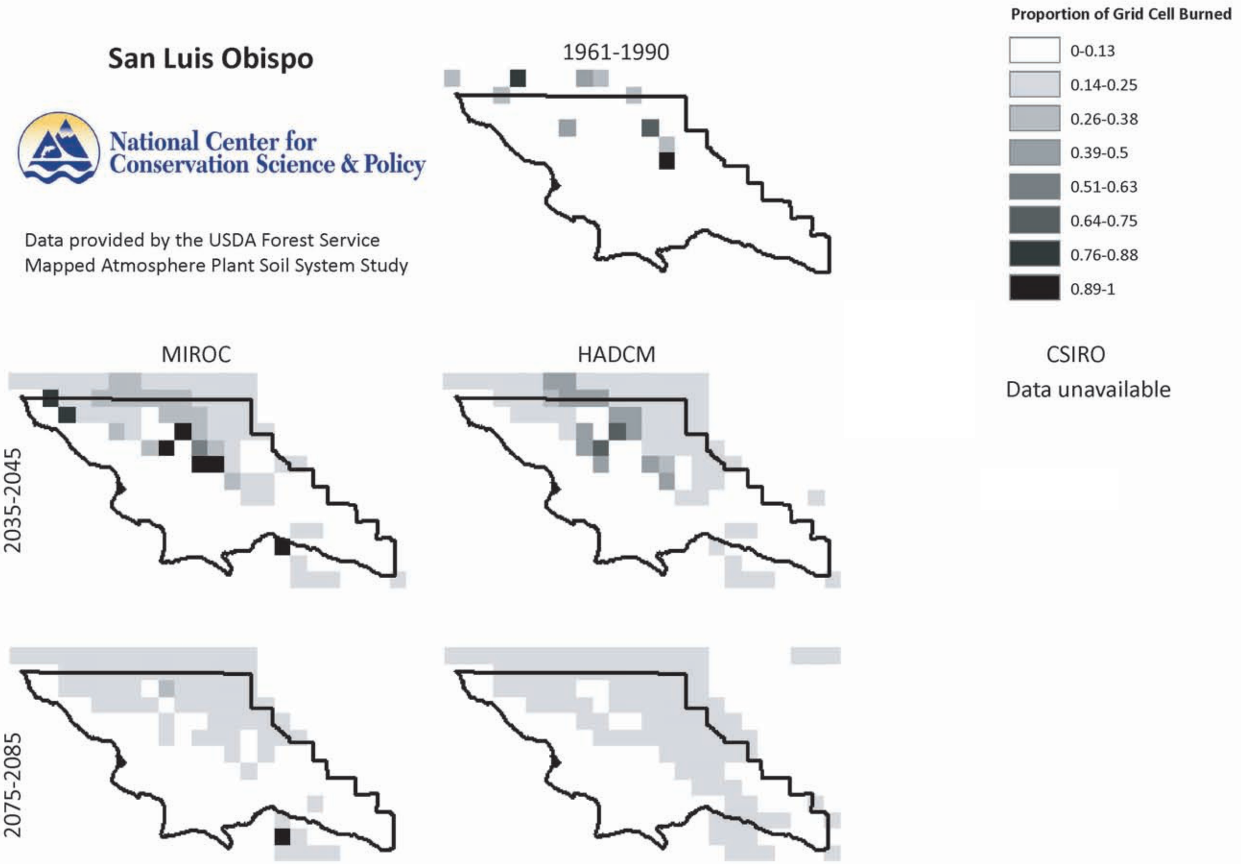


Figure 23. Average proportion of each grid cell (8km x 8km) burned annually in San Luis Obispo County, shown for the historical period (1961-1990) and projected for two future periods (2035-45 and 2075-85), using two global climate models (MIROC and HADCM; results from CSIRO were unavailable).



SEA LEVEL RISE

Sea level has risen nearly eight inches along the California coast over the past century. Climate models project further increases of 3.3 – 4.6 feet (1.0 – 1.4 meters) by the year 2100[1] (Cayan et al. 2009). The primary threats associated with sea level rise include flooding, erosion, and loss of valuable coastal land and unique habitats.

Heberger et al. (2009) conducted a rough GIS exercise that identified some areas of potential high risk from sea level rise along the entire California coast. Based on this analysis, which has not been ground-truthed, San Luis Obispo County supports 6.1 mi^2 of existing coastal wetlands. As sea level rises, these wetlands are expected to migrate inland, potentially covering 1.1 mi^2 of new terrain. The Pacific Institute mapped the area where wetlands are expected to migrate, and determined that 69% is viable for migrating wetlands and should be protected to allow for such shifts. An additional 7% of the area where wetlands might migrate is viable but will experience loss of other functions, such as pasture, parks, or open space. The remaining 24% of the area has infrastructure making it unfeasible for wetlands to migrate.

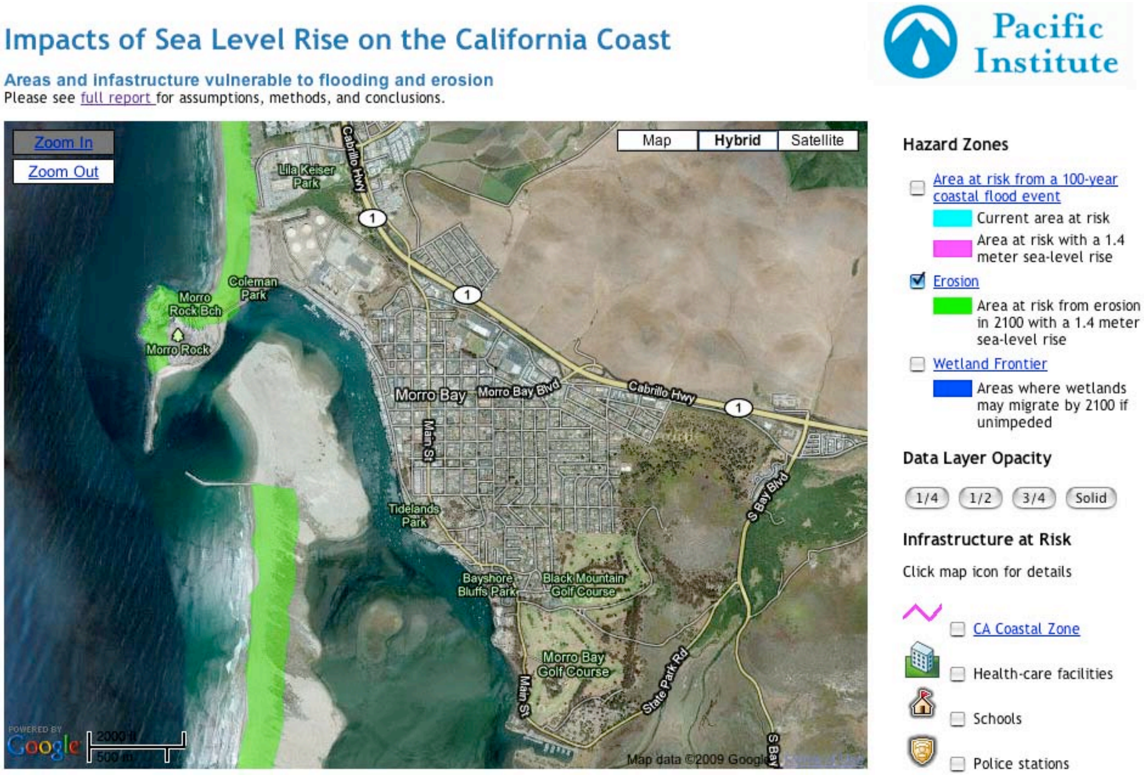
The Pacific Institute mapped areas of potential flooding, erosion, and wetland migration along the entire coast of California. These maps can be found on their website (http://www.pacinst.org/reports/sea_level_rise/maps/index.htm). Substantial areas of the coast are at risk of erosion, including Morro Rock Beach (Figure 24) and Avila Beach (Figure 25).

The GIS assessment of sea level rise is a valuable first step towards identifying areas at risk along the coast. More detailed spatial analyses that include actual wetland area and type data are needed to better identify areas and resources at risk. Better projections of sea level rise are also needed, as sea level rise model output is highly variable.

---

[1] Mean sea level may actually be much higher, as most climate models fail to incorporate Greenland and Antarctic ice sheet melt into their projections.

Figures 24 and 25. Examples of areas at risk of erosion (green) from 4.6 ft. (1.4 m) sea level rise (Heberger et al. 2009).



Impacts of Sea Level Rise on the California Coast

Areas and infastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☐ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise

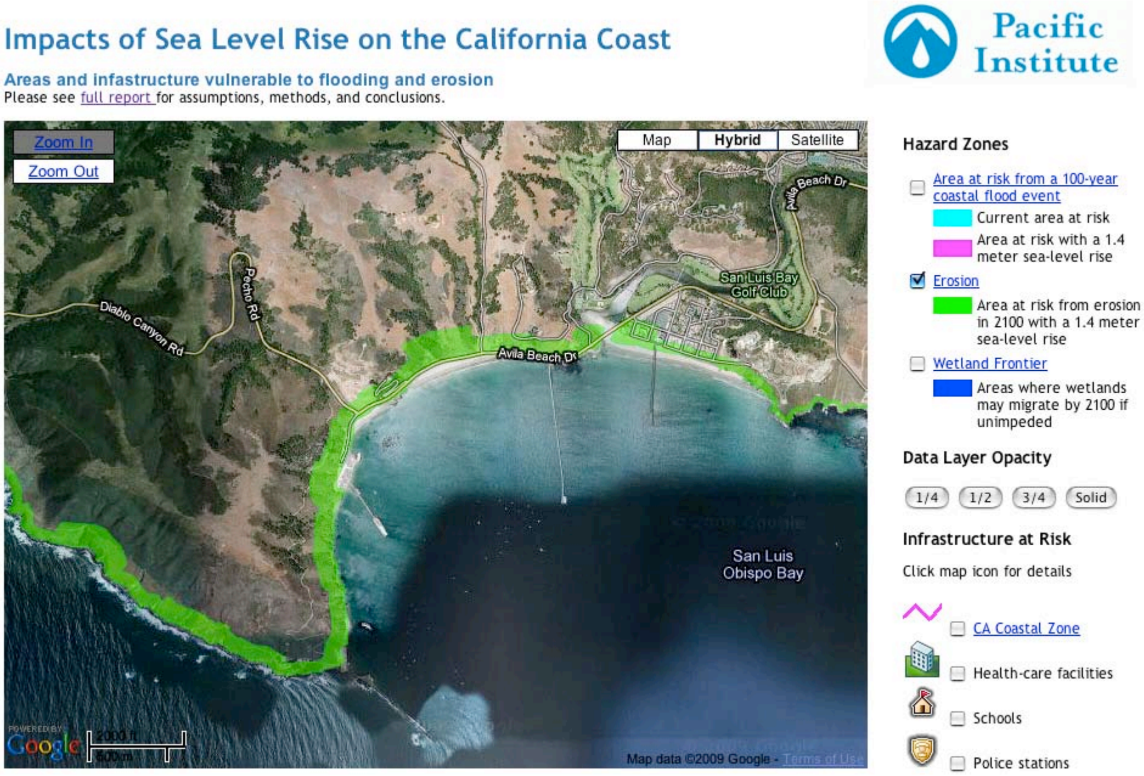
☑ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise

☐ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

Data Layer Opacity

Infrastructure at Risk
Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations



Impacts of Sea Level Rise on the California Coast

Areas and infastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☐ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise

☑ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise

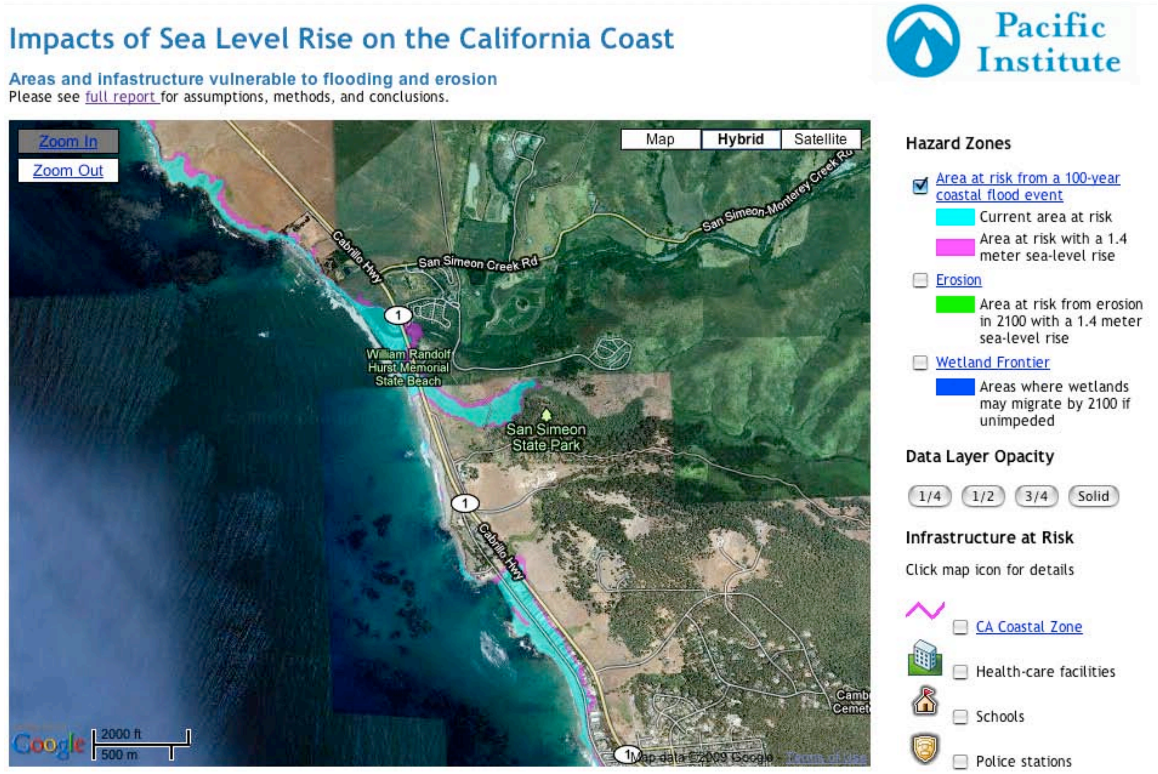
☐ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

Data Layer Opacity

Infrastructure at Risk
Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations

Figures 26 and 27. Examples of areas at risk of flooding currently (light blue) and with 4.6 ft. (1.4 m) sea level rise (magenta) (Heberger et al. 2009).



Impacts of Sea Level Rise on the California Coast

Areas and infrastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☑ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise
☐ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise
☐ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

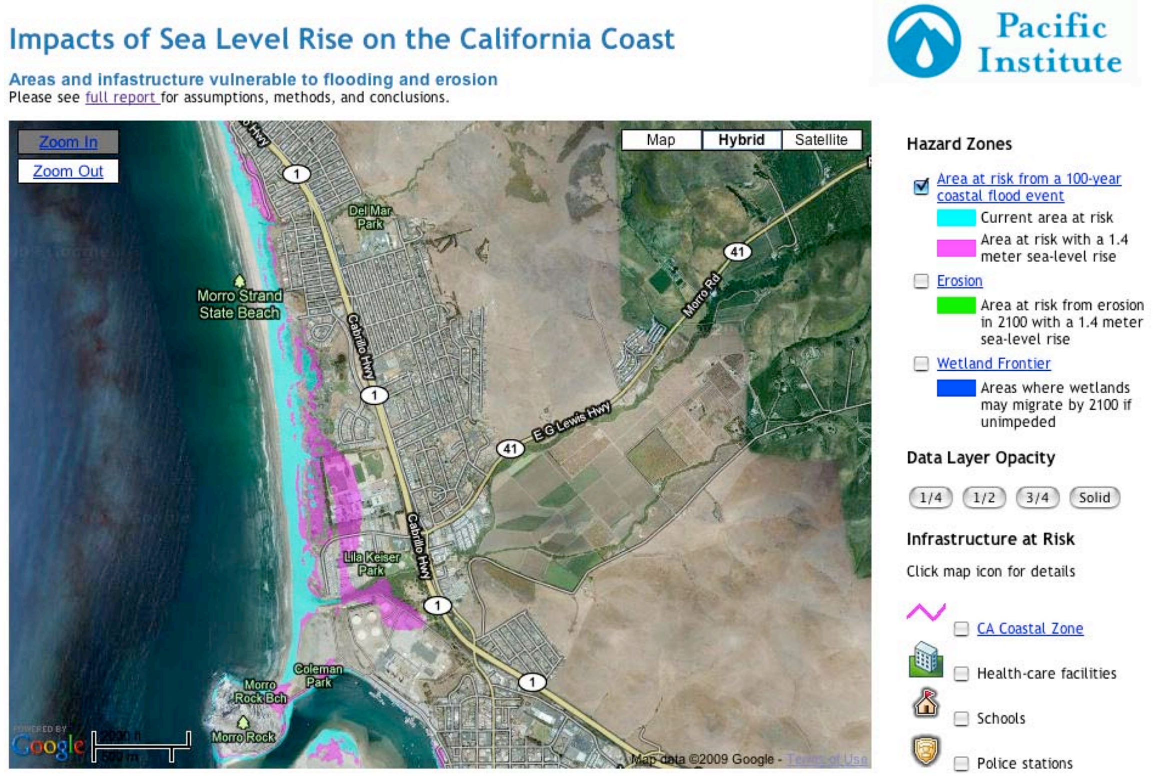
Data Layer Opacity

1/4 1/2 3/4 Solid

Infrastructure at Risk

Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations



Impacts of Sea Level Rise on the California Coast

Areas and infrastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☑ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise
☐ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise
☐ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

Data Layer Opacity

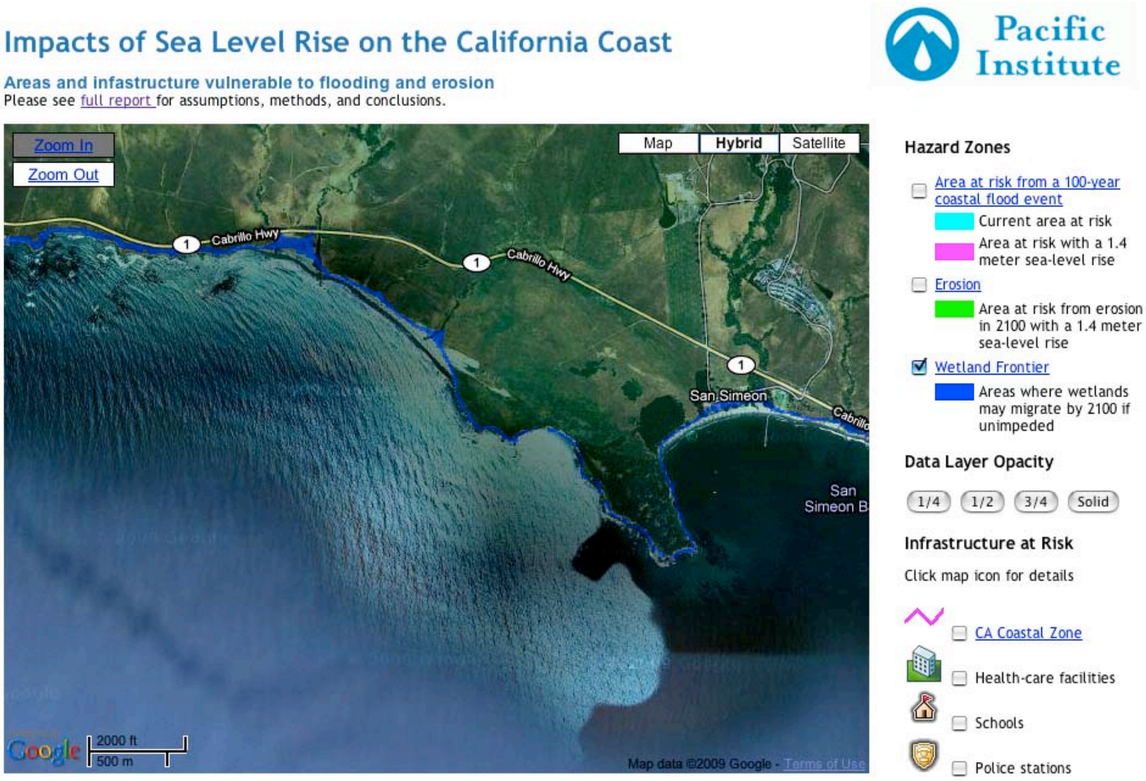
1/4 1/2 3/4 Solid

Infrastructure at Risk

Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations

Figures 28 and 29. Examples of areas where wetlands may migrate (blue) with 4.6 ft. (1.4 m) sea level rise (Heberger et al. 2009).



Impacts of Sea Level Rise on the California Coast

Areas and infrastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☐ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise
☐ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise
☑ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

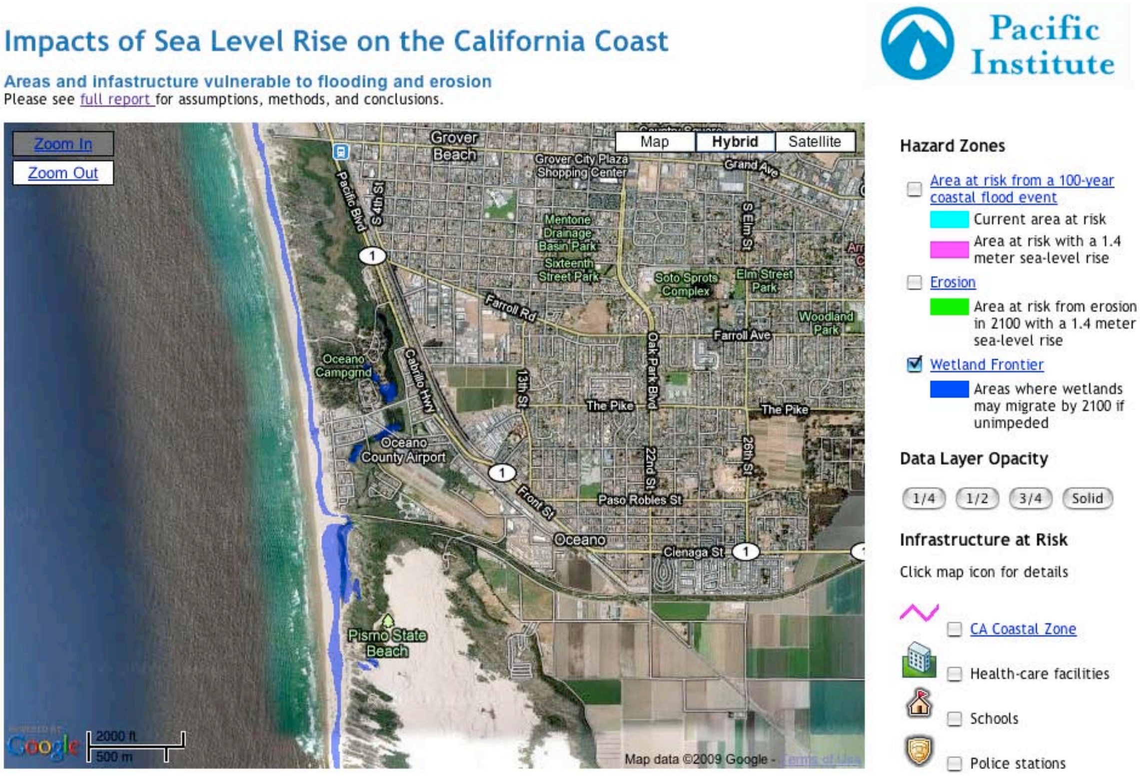
Data Layer Opacity

1/4 1/2 3/4 Solid

Infrastructure at Risk

Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations



Impacts of Sea Level Rise on the California Coast

Areas and infrastructure vulnerable to flooding and erosion
Please see full report for assumptions, methods, and conclusions.

Hazard Zones

☐ Area at risk from a 100-year coastal flood event
🟦 Current area at risk
🟪 Area at risk with a 1.4 meter sea-level rise
☐ Erosion
🟩 Area at risk from erosion in 2100 with a 1.4 meter sea-level rise
☑ Wetland Frontier
🟦 Areas where wetlands may migrate by 2100 if unimpeded

Data Layer Opacity

1/4 1/2 3/4 Solid

Infrastructure at Risk

Click map icon for details

☐ CA Coastal Zone
☐ Health-care facilities
☐ Schools
☐ Police stations

SUPPORTING STUDIES

The California Energy Commission sponsored a large body of research into the potential impacts of climate change across the state. Many of the reports from this effort were released in 2009. For consistency, authors of these reports all used the same set of global climate models for making their projections, but these models were different than the three that we used earlier in this report. Even with different models, however, the results from many of these reports agree with or complement our results, giving us even greater confidence in the projections.

Using the same vegetation model (MC1) but different climate models than ours, Shaw et al. (2009) also projects a decline in coniferous forest in San Luis Obispo County. In addition, their study projected steep declines in forage production in the northeastern and eastern portion of the county (Figure 30).

In another study, independent of the CEC reports, Loarie et al. (2008) modeled potential range shifts of endemic plant species throughout California. The modeling exercise revealed that up to 1/3 of all species will be extirpated if they are unable to move to new areas, but that the coastal ranges of Central California, including substantial areas of SLO County, are expected to be important refuges for numerous species (Figure 31).

Kueppers et al. (2005) modeled shifts in range for two species of oak: blue oak and valley oak, throughout the state, using two different climate models (one regional and one global). Their results indicated that valley oak has a higher likelihood of persistence than blue oak (Figure 32). Both oaks experienced range contractions in San Luis Obispo County by 2080-2099, according to the models, with valley oak experiencing almost complete decline in one of the two model scenarios.

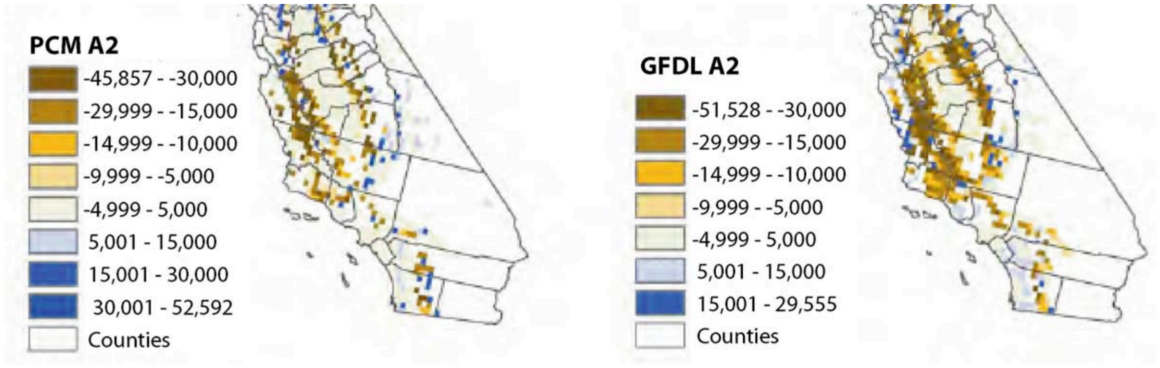


Figure 30. Net change in forage production by 2070-2099, based on two climate models under the A2 emissions scenario. Orange or brown represent a decline in forage production while blue represents and increase in forage production. (Figure from Shaw et al. 2009)

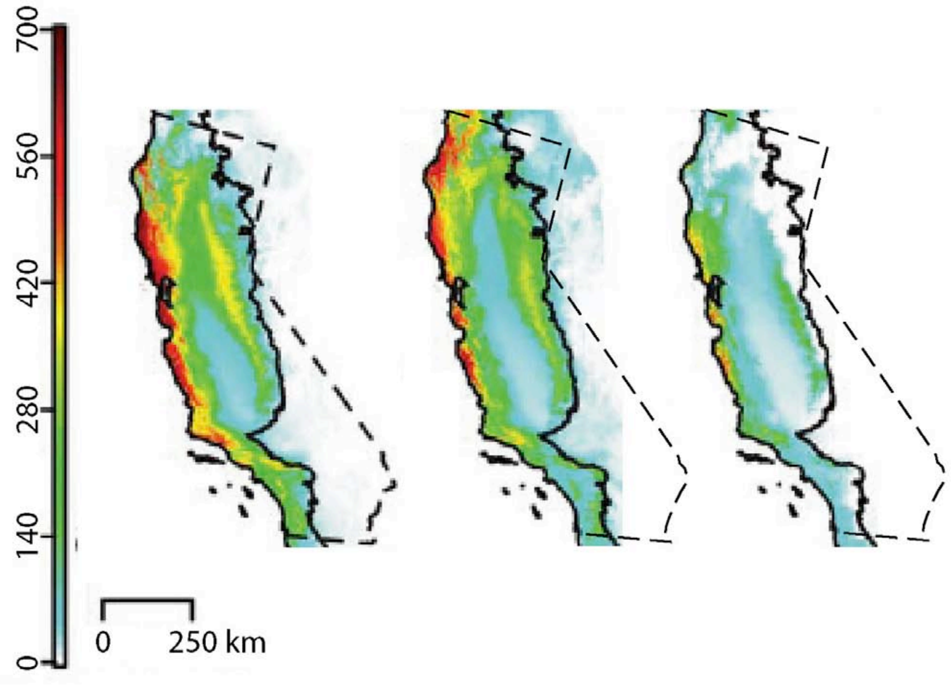


Figure 31. Projected present plant diversity (left) and plant diversity 80 years from now based on two climate models (PCM – middle and HADCM3 – right) using the A1F1 emissions scenario and assuming that plants will be able to disperse to new areas. Coastal areas, such as those in SLO County, may be especially important for harboring diversity. (Figure from Loarie et al. 2008)

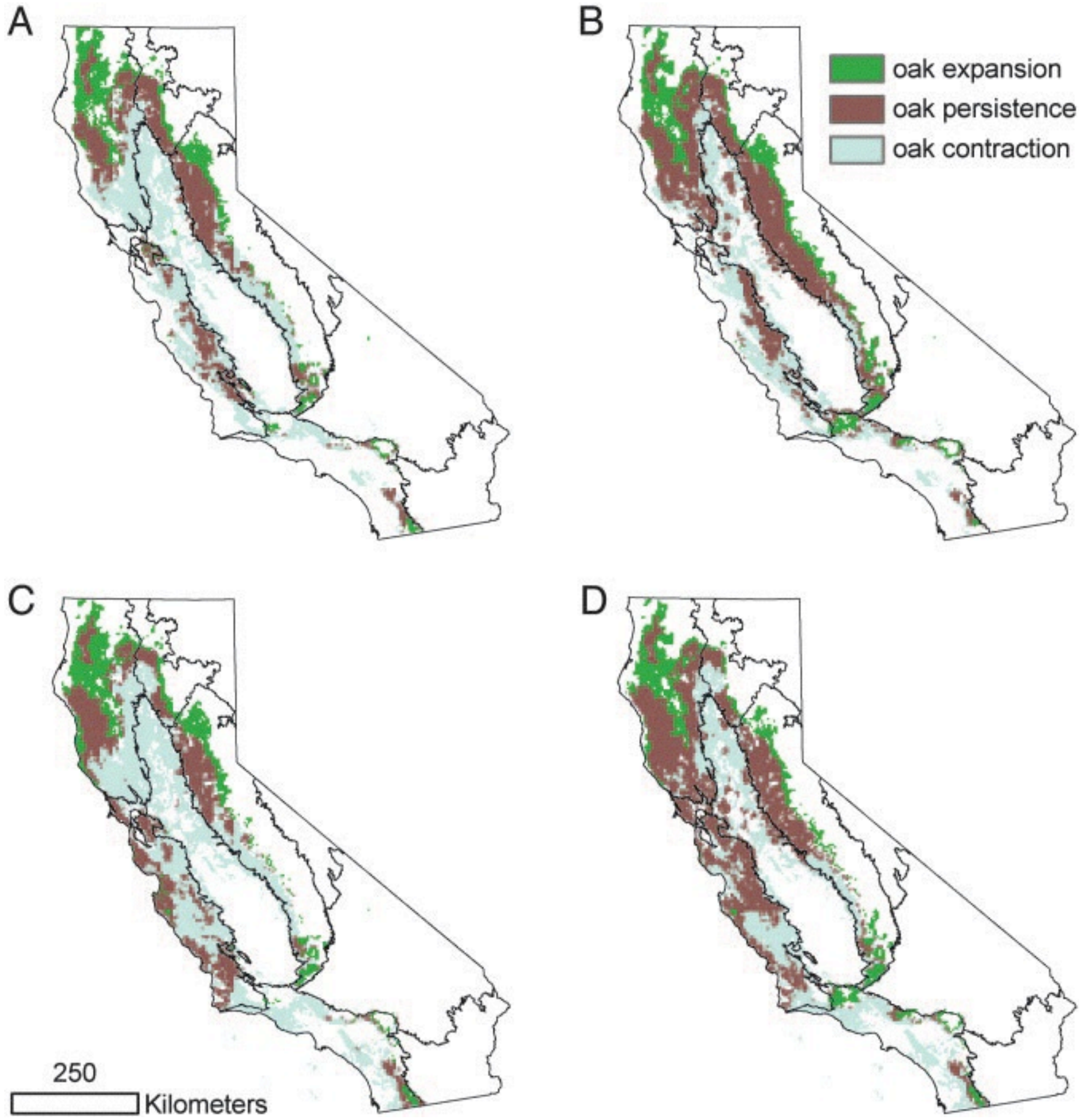


Figure 32. Shifts in distribution for two species of oak in California: valley oak and blue oak. Blue oak (A and B) is expected to decline throughout San Luis Obispo County, according to both models, with steeper declines with the Climate System Model (CSM) GCM (B) as compared to the regional model RegCM2.5 (A). Valley oak (C and D) is expected to contract in San Luis Obispo but still persist across much of its current range according to both the regional (C) and global (D) models. Figure from Kueppers et al. (2005).

CONCLUSIONS

The purpose of this report is to provide up-to-date climate projections for San Luis Obispo County at a scale that can be used in community planning efforts. By providing the information that local managers, decision-makers and community members need to make day-to-day decisions and long-term plans, we hope to spur proactive climate change preparation planning.

Many of the impacts of climate change are already progressing and will continue to accelerate throughout the next few decades, regardless of future emissions. For instance, our projections for the time period of 2035-2045 are highly likely to become reality. Whether we limit climate change to this level or continue to progress towards the level projected for 2075-2085, and beyond, will depend on whether the U.S. and other key nations choose to lower emissions drastically and immediately.

The projections provided in this report are intended to form the foundation for San Luis Obispo County adaptation planning for climate change. Our program, called the *ClimateWise* program, strives to build co-beneficial planning strategies that are science-based, are developed by local community members, and increase the resilience of both human and natural communities to climate change in a cohesive manner. This process will take place in a series of workshops involving experts in the following sectors: natural ecosystems (both terrestrial and aquatic), built (infrastructure, culverts, etc.), human (health, emergency response, etc.), economic (agriculture, business, etc.) and cultural (Native American tribal customs and rights, other culturally distinct local communities).

The *ClimateWise* program is structured to begin the planning process in local communities, but then to "scale up" management strategies to the state and federal level by identifying needed changes in policy and governance structure. During the local planning process, experts from different sectors will identify barriers to sound management, allowing us to address these limiting factors by educating lawmakers and influencing policy decisions.

Please contact Marni Koopman at the National Center for Conservation Science and Policy for more information (marni@nccsp.org; 541-482-4459 x303).

LITERATURE CITED

Bachelet, D., J. M. Lenihan, C. Daly, R. P. Neilson, D. S. Ojima, and W. J. Parton. 2001. MC1: A dynamic vegetation model for estimating the distribution of vegetation and associated carbon, nutrients, and water- a technical documentation. Version 1.0. GTR-508. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and Sea Level Rise Estimates for California 2008 Climate Change Scenarios Assessment. California Climate Change Center. CEC- 500-2009-014-F.

Heberger, M., H. Cooley, P. Herrera, P. H. Gleick, and E. Moore. 2009. The Impacts of Sea Level Rise on the California Coast. California Climate Change Center. CEC-500-2009-024-F.

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Kueppers, L. M., M. A. Snyder, L. C. Sloan, E. S. Zavaleta, and B. Fulfrost. 2005. Modeled regional climate change and California endemic oak ranges. PNAs 102:18281-18286.

Loarie, S. R., B. E. Carter, K. Hayhoe, S. McMahon, R. Moe, C. A. Knight, and D. D. Ackerly. 2008. Climate change and the future of California's endemic flora. PloS ONE 3:1-10.

Randall, D. A., R. A. Wood, S. Bony, et al. 2007. Climate Models and Their Evaluation. *In* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, et al., Eds. Cambridge University Press.

Shaw, M. R., L. Pendleton, D. Cameron, B. Morris, G. Bratman, D. Bachelet, K. Klausmeyer, J. MacKenzie, D. Conklin, J. Lenihan, E. Haunreiter, and C. Daly. 2009. The Impact of Climate Change on California's Ecosystem Services. California Climate Change Center. CEC-500-2009-025-F.

USGCRP. 2009. Global Climate Change Impacts in the United States. T. R. Karl, J. M. Melillo, and T. C. Peterson, Eds. Cambridge University Press.

Westerling, A. L., B. P. Bryant, H. K. Preisler, T. P. Holmes, H. G. Hidalgo, T. Das, and S. R. Shrestha. 2009. Climate Change, Growth, and California Wildfire. California Climate Change Center. CEC-500-2009-046-F.