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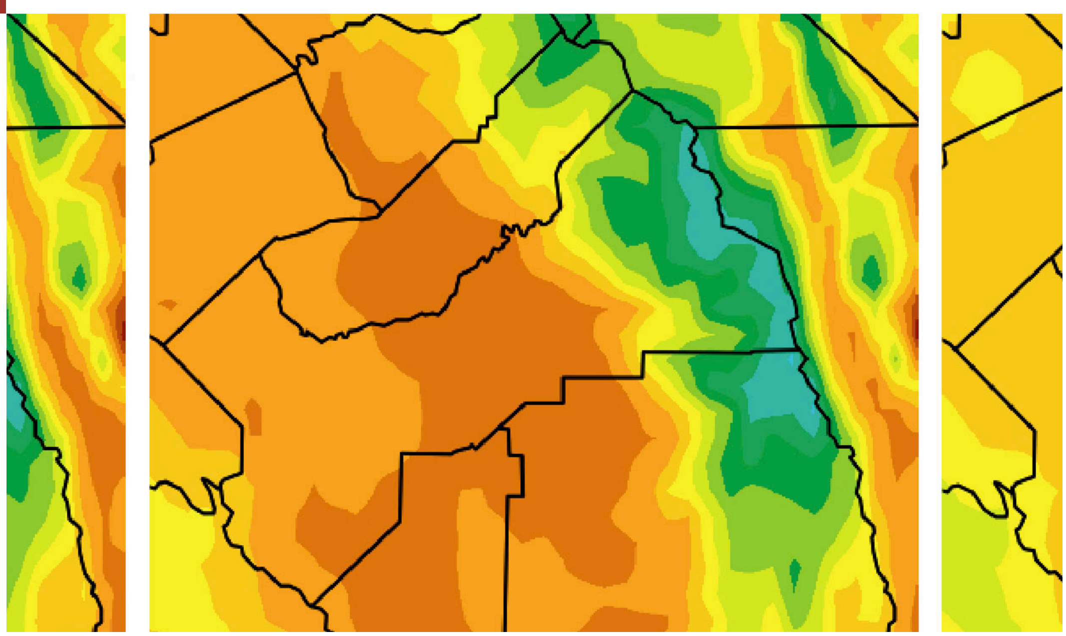
Future Climate Conditions in Fresno County and Surrounding Counties



July 2010

Future Climate Conditions in Fresno County and Surrounding Counties

Geos Institute

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INTRODUCTION

Fresno County and the surrounding counties of Madera, Kings, and Tulare are rich in history, culture, and biological diversity, in addition to being vital for the nation's food production. These counties extend from semi-desert and agricultural valley floor all the way to the crest of the Sierras. Changes to this landscape due to climate change are likely to affect local residents and the natural resources they rely on.

Climatic changes are already underway across California 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. Local communities will need to plan for such changes in order to prevent potentially catastrophic consequences.

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. **Yet due to climate change and its associated impacts, the future is no longer expected to resemble the past.**

This report provides community members and decision-makers in Fresno County and surrounding counties 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 provided by the USDA Forest Service Pacific Northwest Research Station and mapped by scientists at the National Center for Conservation Science and Policy.

The results presented in this report are complementary to an in-depth study of climate change impacts to the city of Fresno and much of the surrounding area, completed by researchers at CSU Fresno (Harmsen et al. 2008). Together, these reports and an upcoming companion report on the vulnerabilities of socio-economic systems of Fresno County to climate change provide the basis for informed planning efforts.

Many of the impacts of climate change are inevitable due to current levels of greenhouse gas emissions already in the atmosphere. Preparing for these impacts to reduce their severity is called "adaptation" (see box below). Preventing even more severe impacts by reducing future emissions is called "mitigation."

MITIGATION = Reducing emissions to prevent run-away climate change. Run-away climate change occurs when positive feedbacks kick in to such an extent that emissions reductions are no longer effective.

ADAPTATION = Planning for the inevitable impacts of climate change and reducing our vulnerability to those impacts.

MODELS AND THEIR LIMITATIONS

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 differences in current understanding of many of Earth's processes and feedbacks. Taken as a group, however, climate models present a range of likely future conditions.

Most climate models project the future climate at global scales. For managers and policymakers to make decisions, however, 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 output to local and regional scales (8km).

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

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 severe 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.

Wildfire patterns – The relationship between fire and temperature has been well documented, but other components also play a role (such as vegetation, below).

LOW CERTAINTY:

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

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 historic 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, biomass consumed by wildfire, and carbon sequestration.

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 insert). Some model outputs, such as temperature, have greater certainty than other outputs, such as vegetation type (see box on previous page).

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.

However, much uncertainty associated with model projections arises due to uncertainty in future greenhouse gas emissions. We urge the reader to keep in mind that 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 or rate 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 (A2) that assumes that most nations fail to act to lower emissions. If the U.S. and other key nations drastically and immediately cut emissions, some of the more severe impacts, like run-away climate change, can still be avoided.

Due to climate system inertia, restabilization of atmospheric gases will take many decades even with drastic emissions reductions. Reducing emissions (called "mitigation") 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 (called "adaptation) will allow residents of Fresno County and the surrounding area to reduce the negative impacts of climate change and, hopefully, maintain their quality-of-life as climate change progresses.

Throughout this report we present mid- and late-century model outputs. Mid-century projections are highly likely, due to greenhouse gases already released, but late-century projections may change, depending on future emissions.

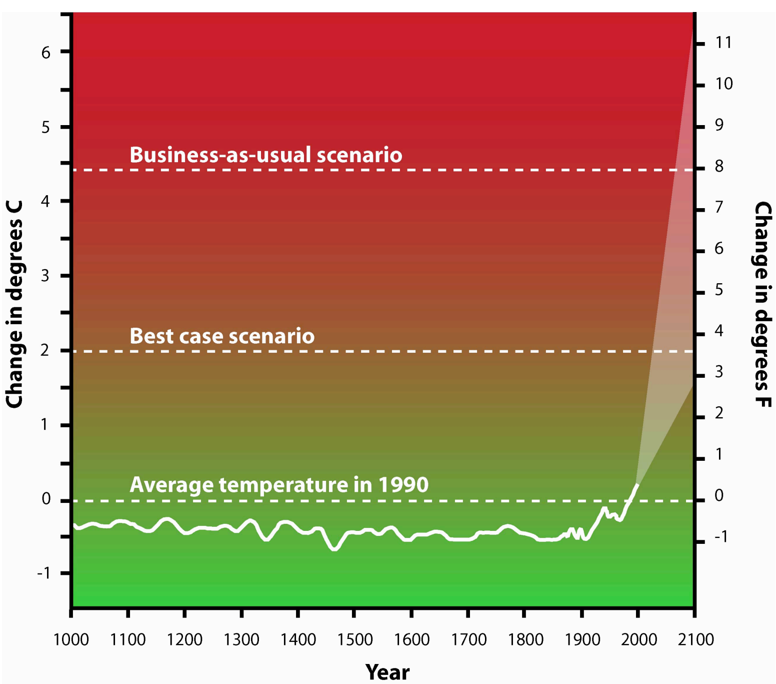


Figure 1. The last 1,000 years in global average temperatures, in comparison to projected temperatures through 2100. Drastic cuts in greenhouse gas emissions (best case scenario) would lead to an increase of about 2° C by 2100, while the current trajectory (business-as-usual) will lead to an increase closer to 4.5° C and as high as 6° C (adapted from IPCC 2007).

CLIMATE PROJECTIONS FOR FRESNO AND SURROUNDING COUNTIES

Variables modeled using HADCM, CSIRO, MIROC, and the vegetation model (MC1) include temperature, precipitation, vegetation type and distribution, wildfire, and carbon storage in biomass. These variables were calculated based on historical data for making baseline comparisons, and were projected out to 2100.

These projections represent a likely range of possible future conditions in Fresno County and the surrounding counties. As climate change plays out, we may be able to make more certain projections. We may also experience 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 graphs that show change over time, and as maps that show variation across the region, but averaged across years. We mapped climate and vegetation variables for the historical period (1961-1990) and for two future periods (2035-45 and 2075-85). Because of the difference in climate between the Sierras and the valley floor, we calculated model output for eastern areas over 1,000 feet in elevation separately from other areas (Figure 2). We label these two areas the "Upper" and "Lower" Fresno County Region.

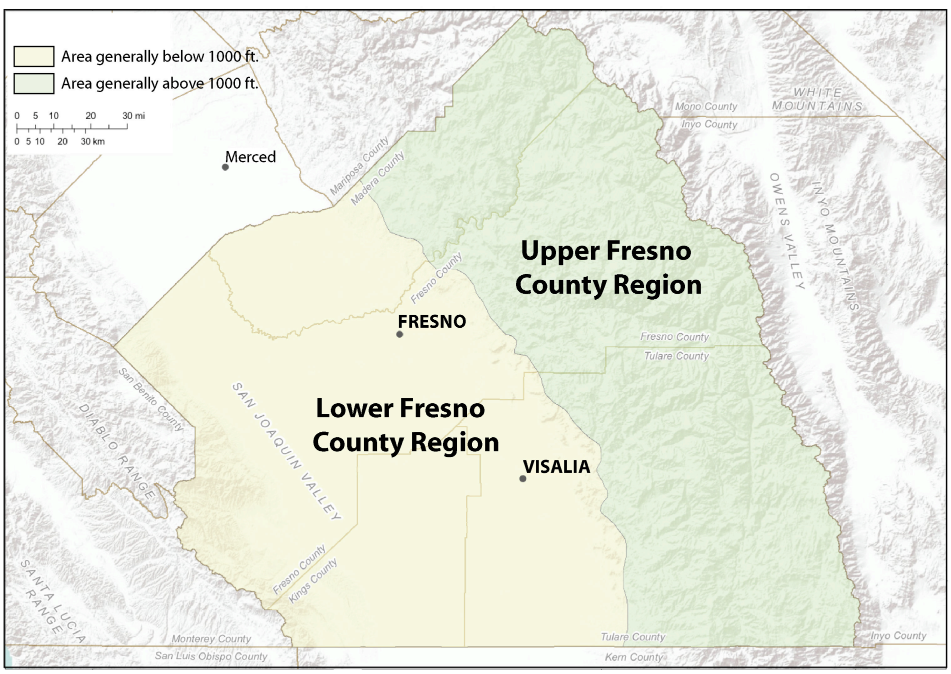
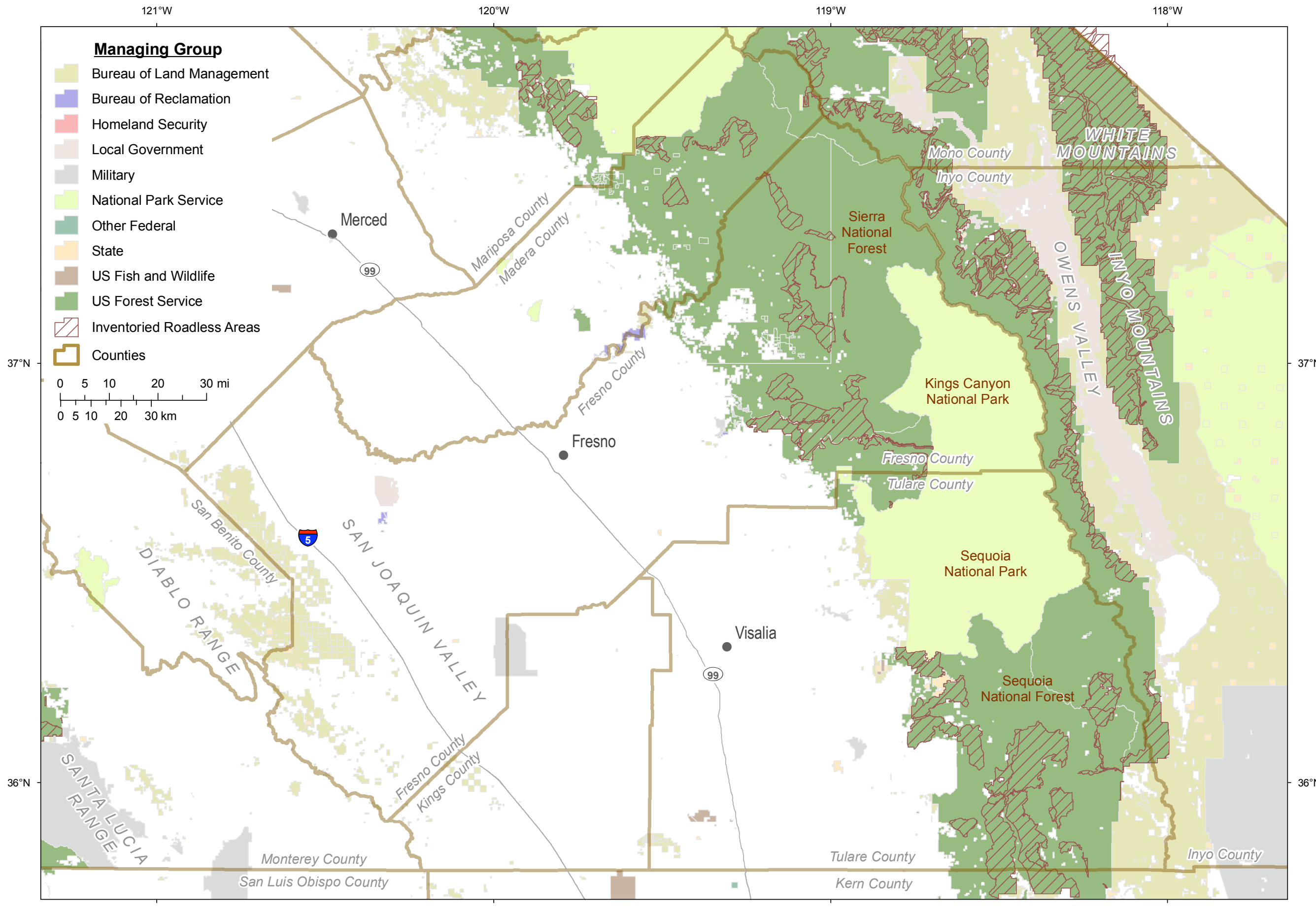


Figure 2. Areas referred to in this report as "Upper" and "Lower" Fresno County region. The Upper Fresno County Region is generally above 1,000 feet in elevation and is found in the eastern portions of Fresno, Madera, and Tulare counties, while the Lower Fresno County Region is generally below 1,000 feet in elevation and encompasses western portions of Fresno, Madera, and Tulare counties as well as all of Kings County.

Figure 3. Land ownership in Fresno County and surrounding counties.



Land Management within the Fresno Region

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

National Center for Conservation Science & Policy

TEMPERATURE

The projections from all three models agree, with high certainty, on a warmer future for Fresno County and surrounding counties (Table 1). The upper Fresno County region is projected to warm slightly more than the lower Fresno County region. Other studies indicate an increase in nighttime low temperatures. Daytime highs are currently buffered by humidity from irrigation.

Table 1. Projected increase in average temperature in the upper and lower Fresno County regions (see Fig. 2 for details), from three different global climate models. Future projected temperature is shown as change in degrees Fahrenheit, as compared to historic averages (1961-1990).

	Historic		**2035-45**		**2075-85**	
Season	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Annual	46.4° F	62.3° F	+2.5-4.8° F	+2.3-4.3° F	+5.2-8.9° F	+4.7-8.2° F
Summer	61.3° F	78.0° F	+2.2-6.0° F	+2.0-5.4° F	+5.8-11.0° F	+5.2-10.0° F
Winter	33.9° F	47.0° F	+2.2-4.1° F	+2.0-3.8° F	+4.1-7.9° F	+3.7-7.4° F

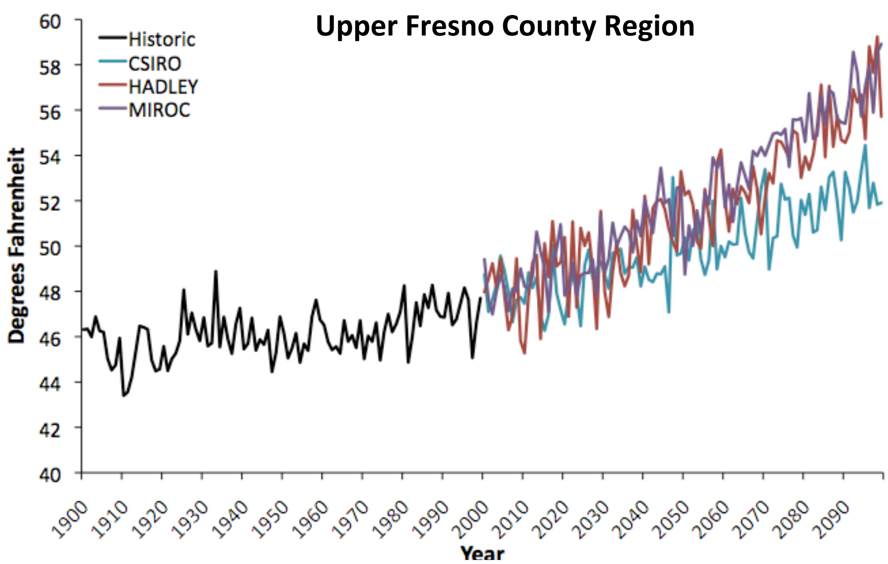


Figure 4. Average annual temperature for the upper Fresno County region, based on historic data and model projections from three global climate models.

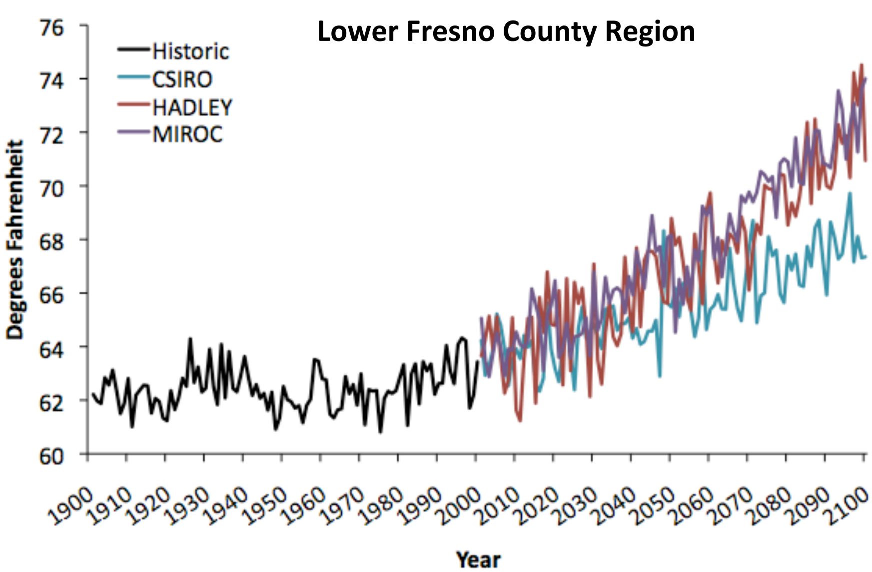
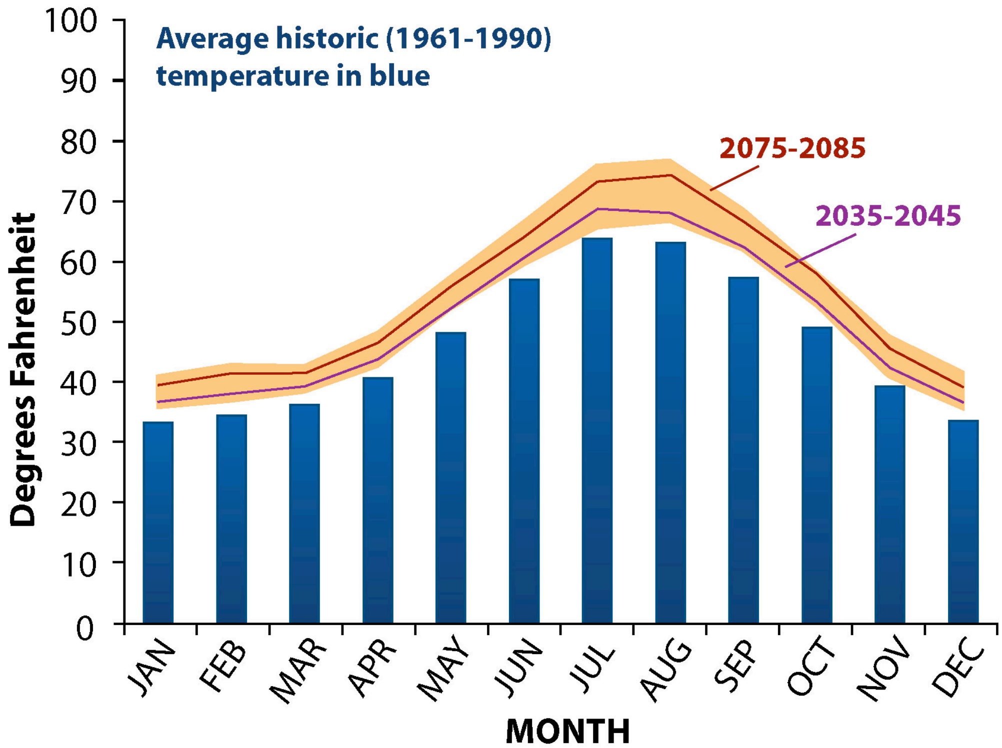


Figure 5. Average annual temperature for the lower Fresno region, based on historic data and model projections from three global climate models.

Figures 6 and 7. Average historic and future monthly temperatures in areas above 1000 feet in elevation (top) and below 1000 feet (bottom). Blue bars show historic average temperature while the orange shape represents the range of projections from the three global climate models. The average for the two future time periods is in purple (2035-45) and red (2075-85).

Upper Fresno County Region



Lower Fresno County Region

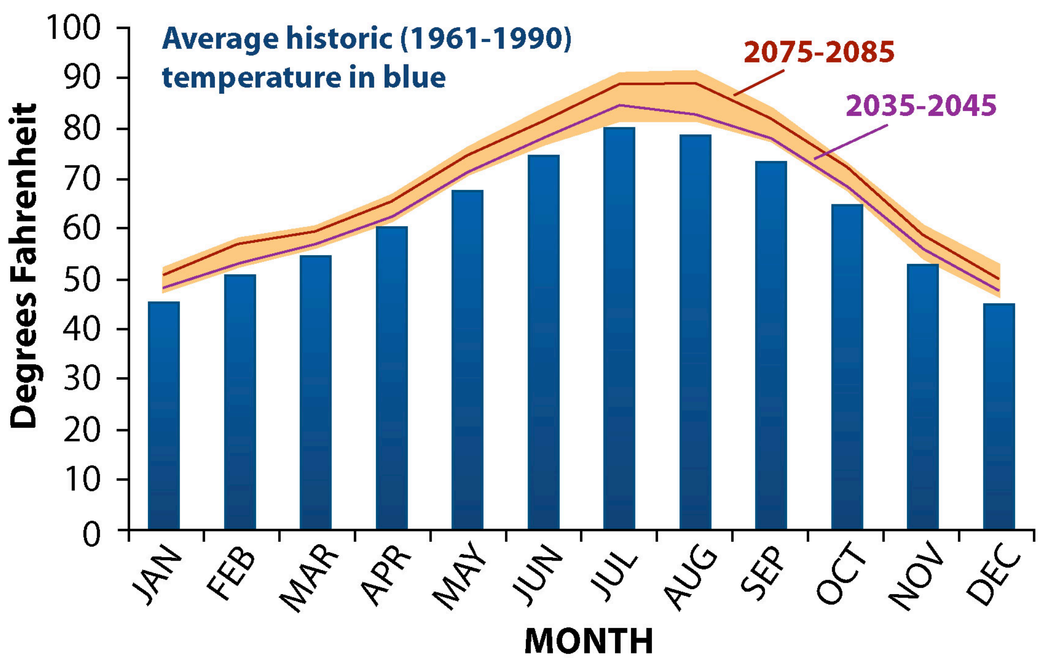
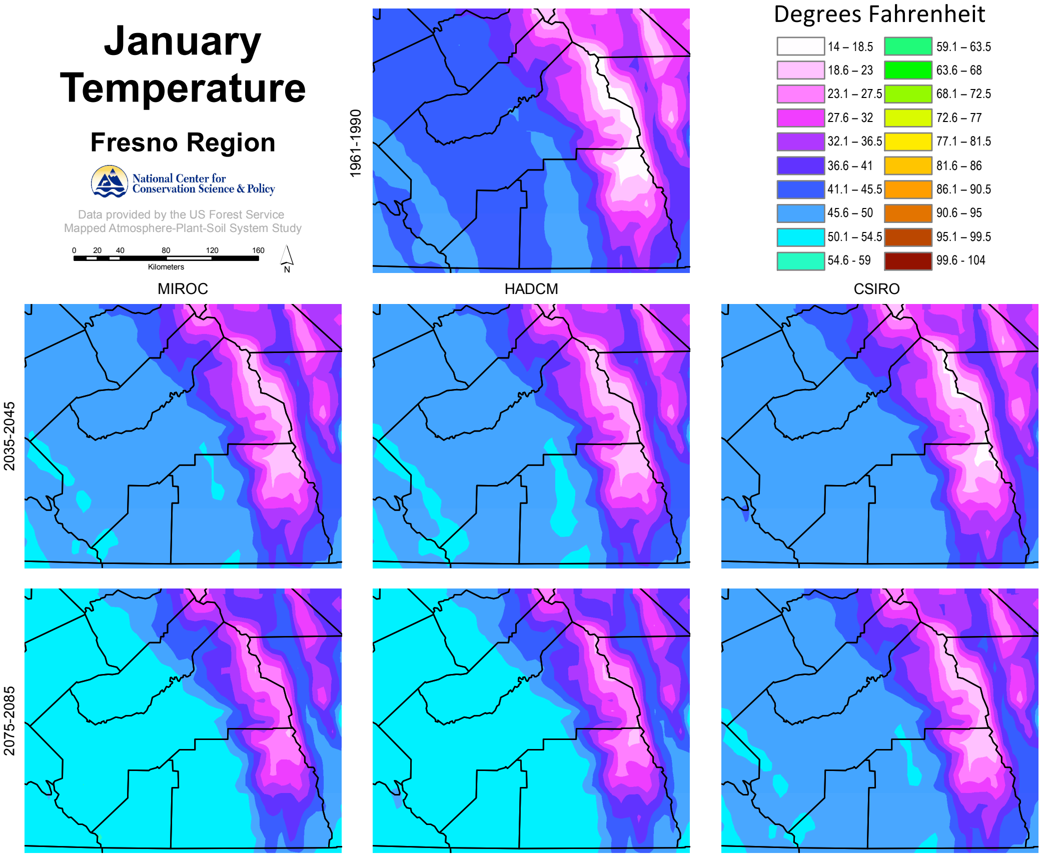


Figure 8. January temperature (top) and change in temperature (bottom), in degrees F.



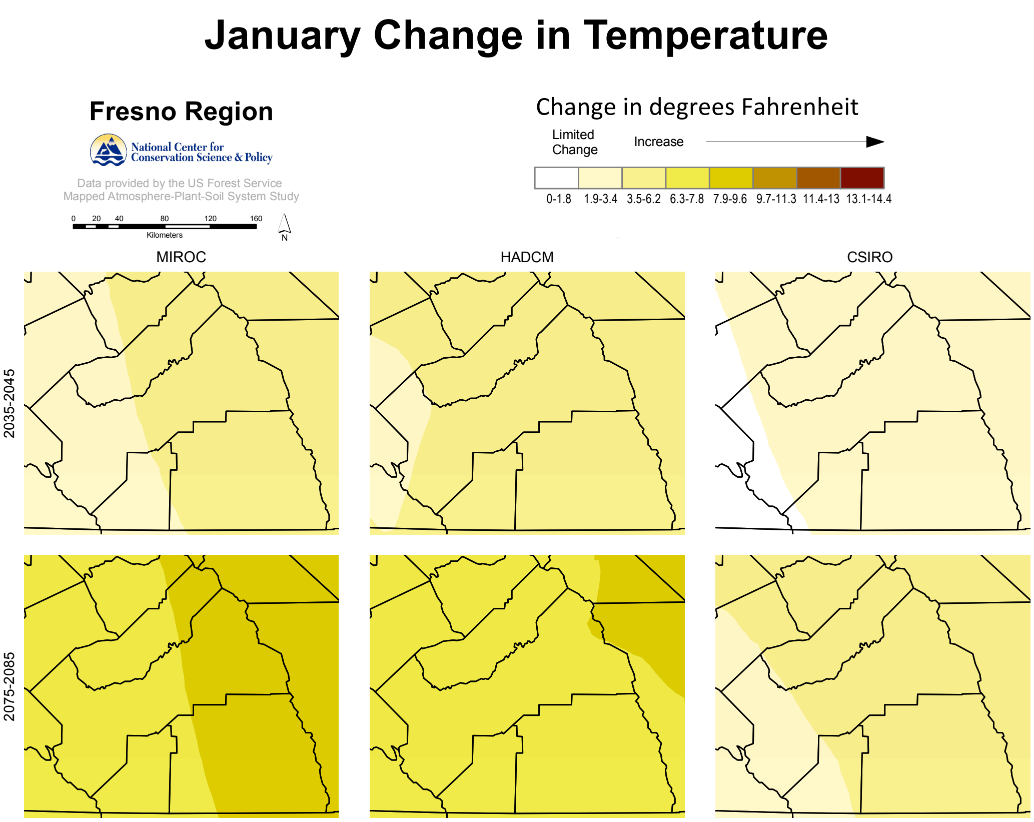
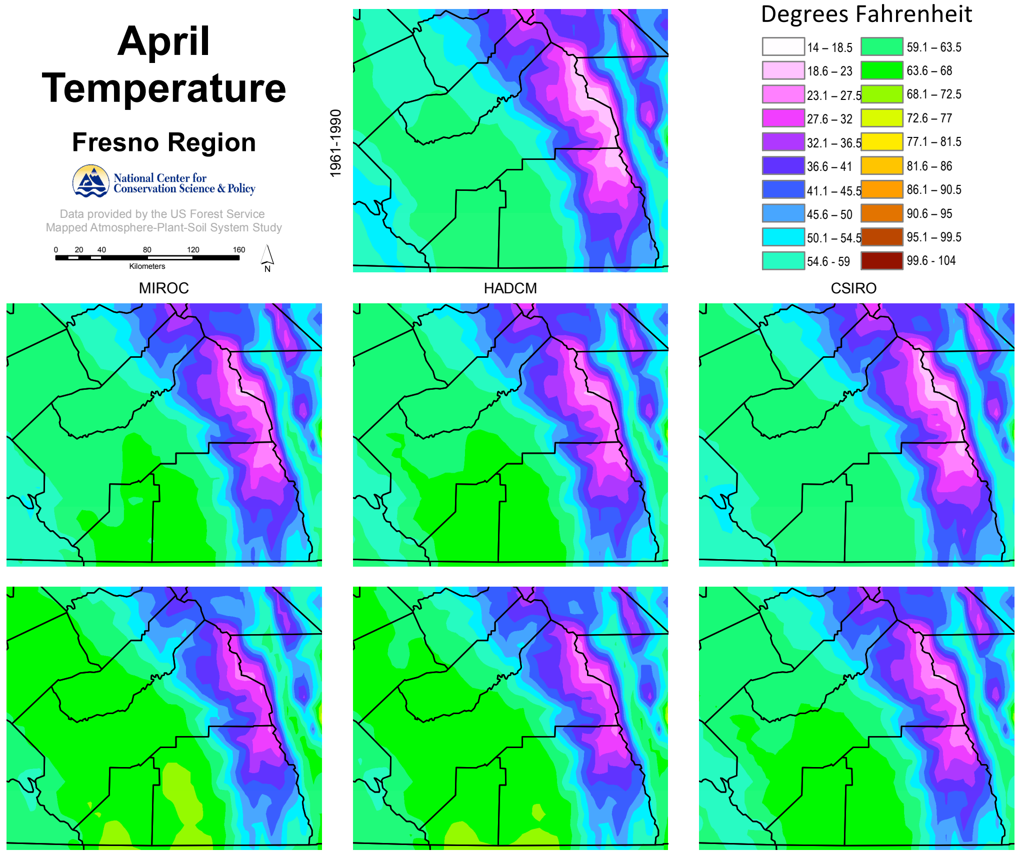


Figure 9. April temperature (top) and change in temperature (bottom), in degrees F.



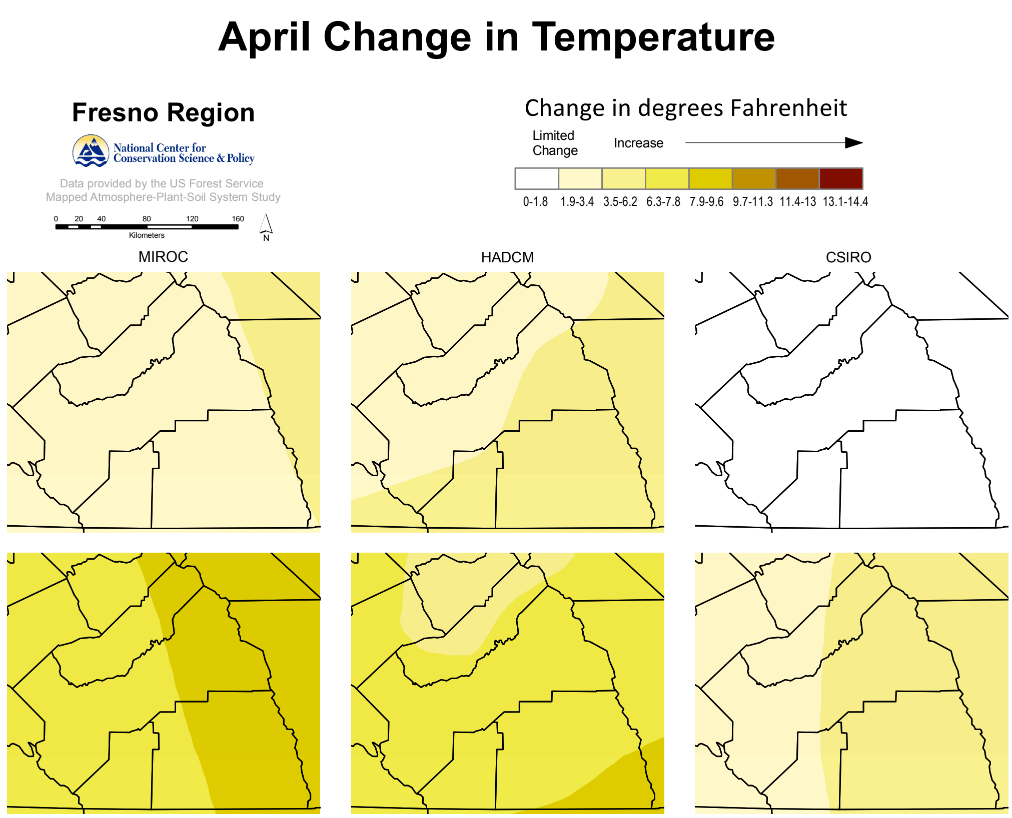


Figure 10. July temperature (top) and change in temperature (bottom), in degrees F.

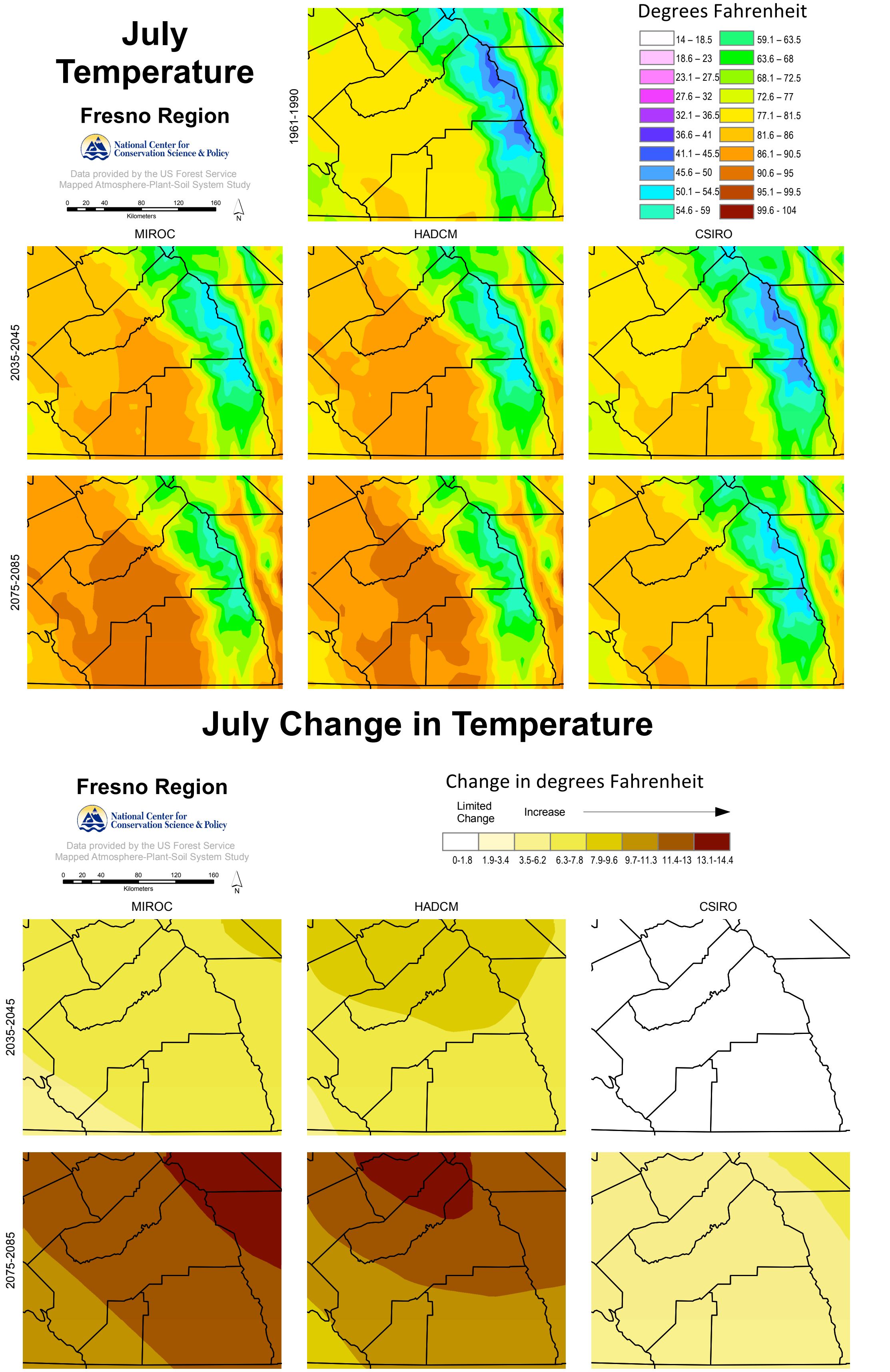
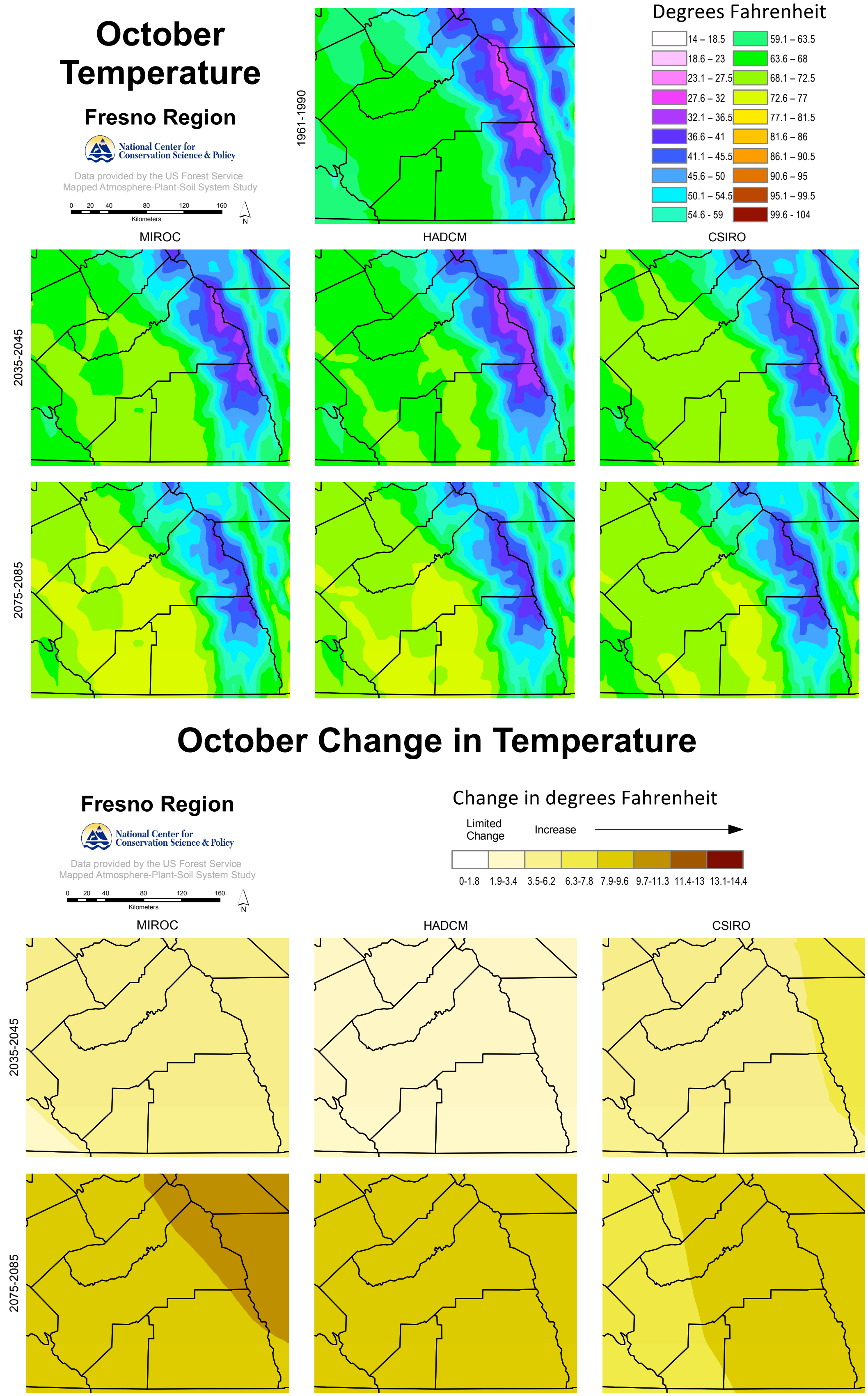


Figure 11. October temperature (top) and change in temperature (bottom) in degrees F.



PRECIPITATION

Projections for future precipitation varied among the three models (Fig. 13-14), but all three models agreed on drier conditions, on average, by late century, especially in the spring (Fig. 15-16). 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 air temperature and evaporation, effectively causing increased drought conditions.

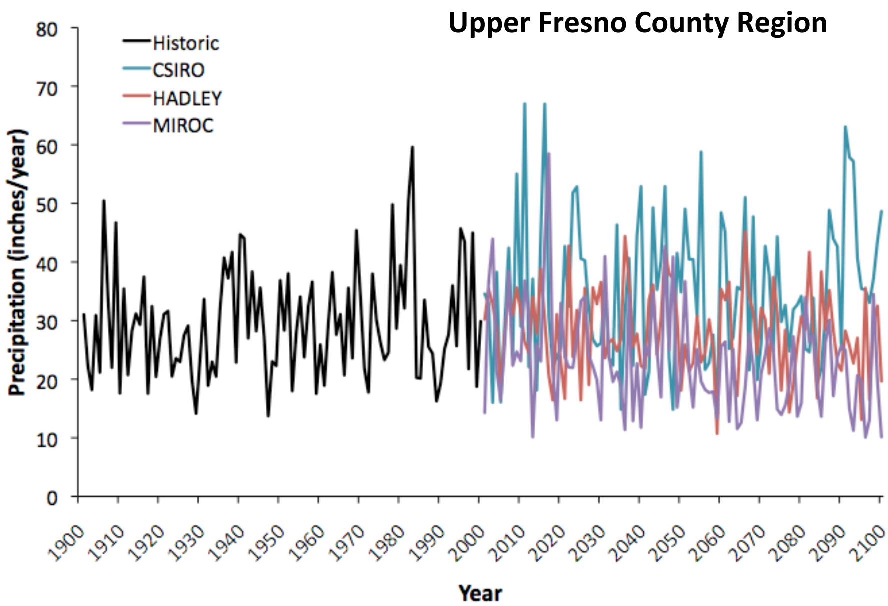


Figure 13. Average annual precipitation across the upper Fresno region (above 1000 feet), based on historical data (black line) and three global climate models projected out to 2100 (averages are found on the next page).

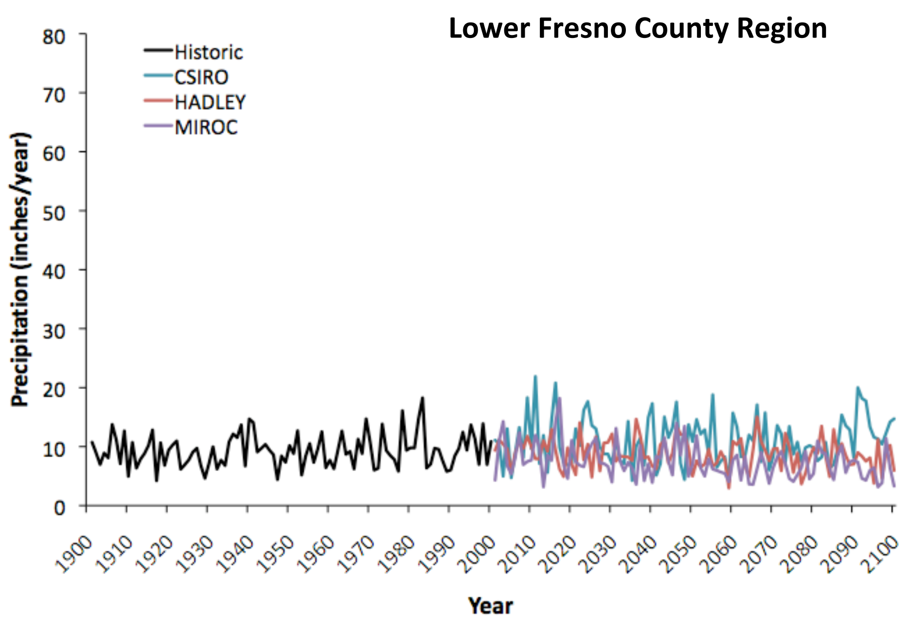


Figure 14. Average annual precipitation across the lower Fresno region (below 1000 feet), based on historical data (black line) and three global climate models projected out to 2100 (averages are found on the next page).

Table 2. Average historical (1961-1990) precipitation, in inches, and changes in projected precipitation for two time periods (2035-45 and 2075-85) based on projections from three global climate models.

Time period	Average precipitation (% change from historic)	
	Lower Fresno region	Upper Fresno region
Historic	9.4 in.	29.9 in.
2035-45	6.9 - 10.6 in. (-27% to +13%)	21.7 – 33.6 in. (-28% to +12%)
2075-85	6.8 - 8.8 in. (-28% to -7%)	20.5 – 28.2 in. (-32% to -6%)

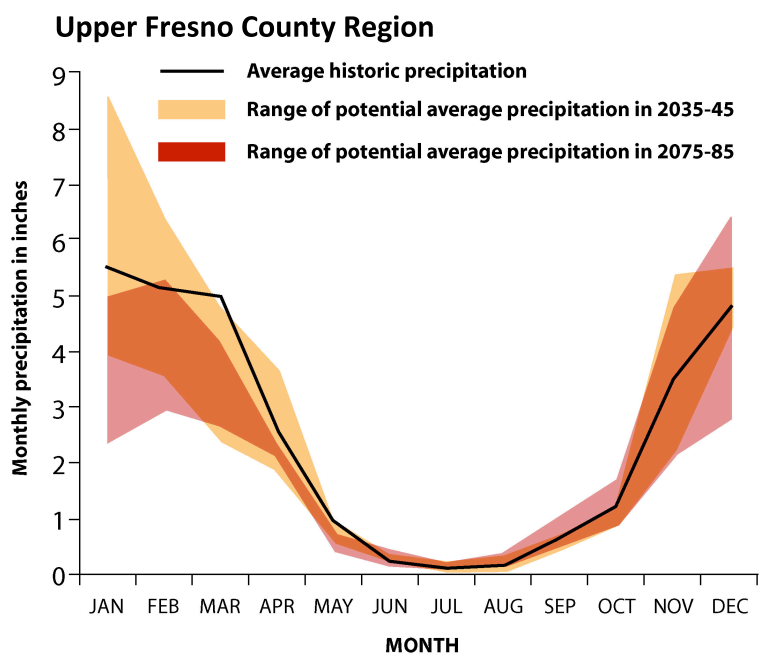


Figure 15. Monthly historic (1960-1991) and future precipitation in the upper Fresno County region (above 1000 feet), for two time periods (2035-45 and 2075-85). Average future precipitation was derived from three global climate models, and is expected to fall within the orange and red areas.

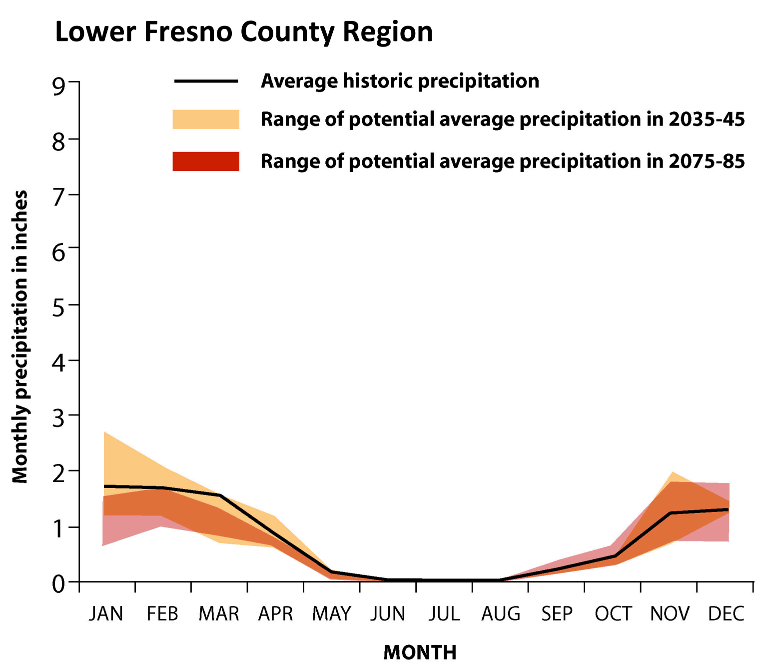


Figure 16. Monthly historic (1960-1991) and future precipitation in the lower Fresno County region (below 1000 feet), for two time periods (2035-45 and 2075-85). Average future precipitation was derived from three global climate models, and is expected to fall within the orange and red areas.

Figure 17. January precipitation (top) and change in precipitation (bottom), in mm.

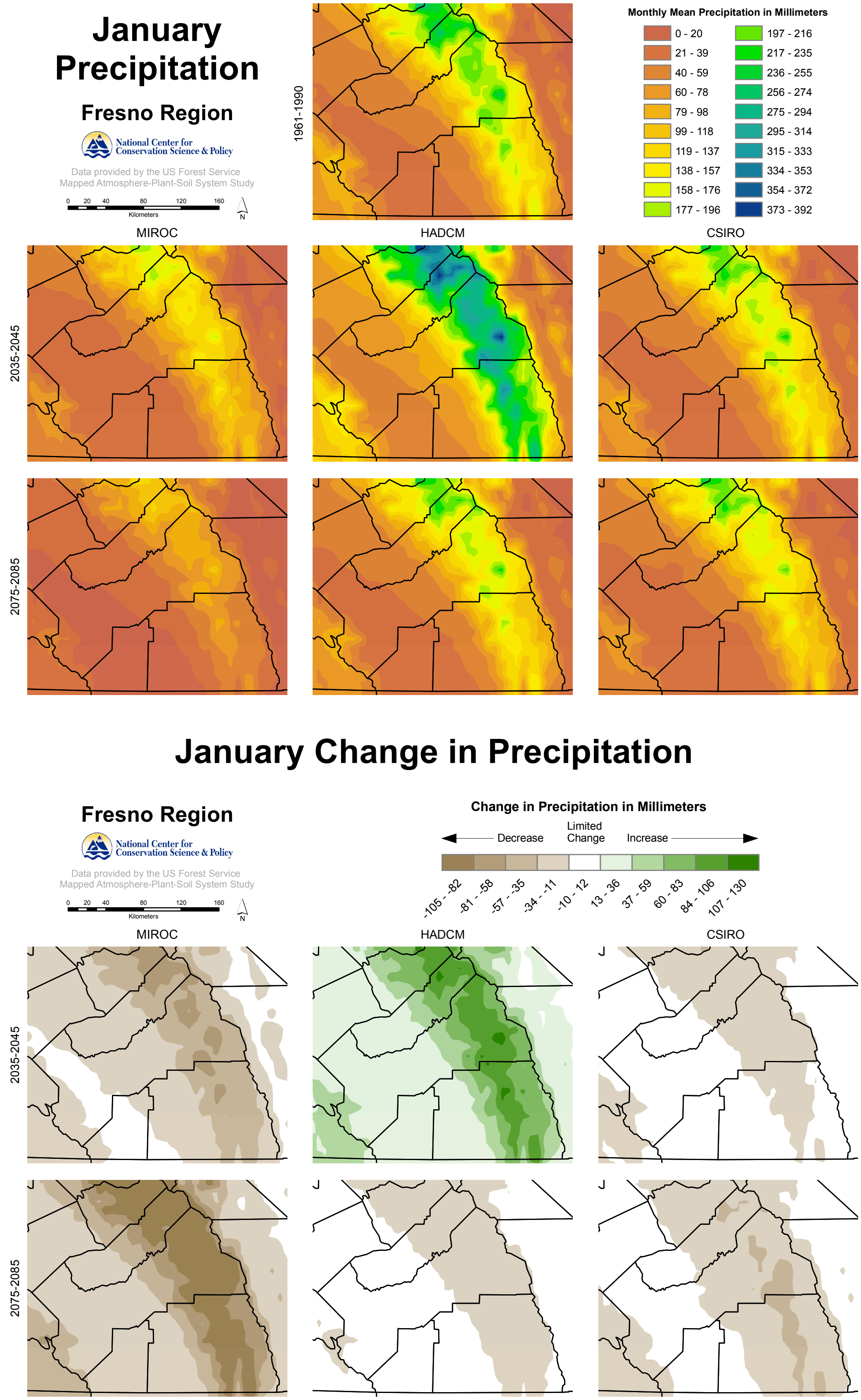


Figure 18. April precipitation (top) and change in precipitation (bottom), in mm.

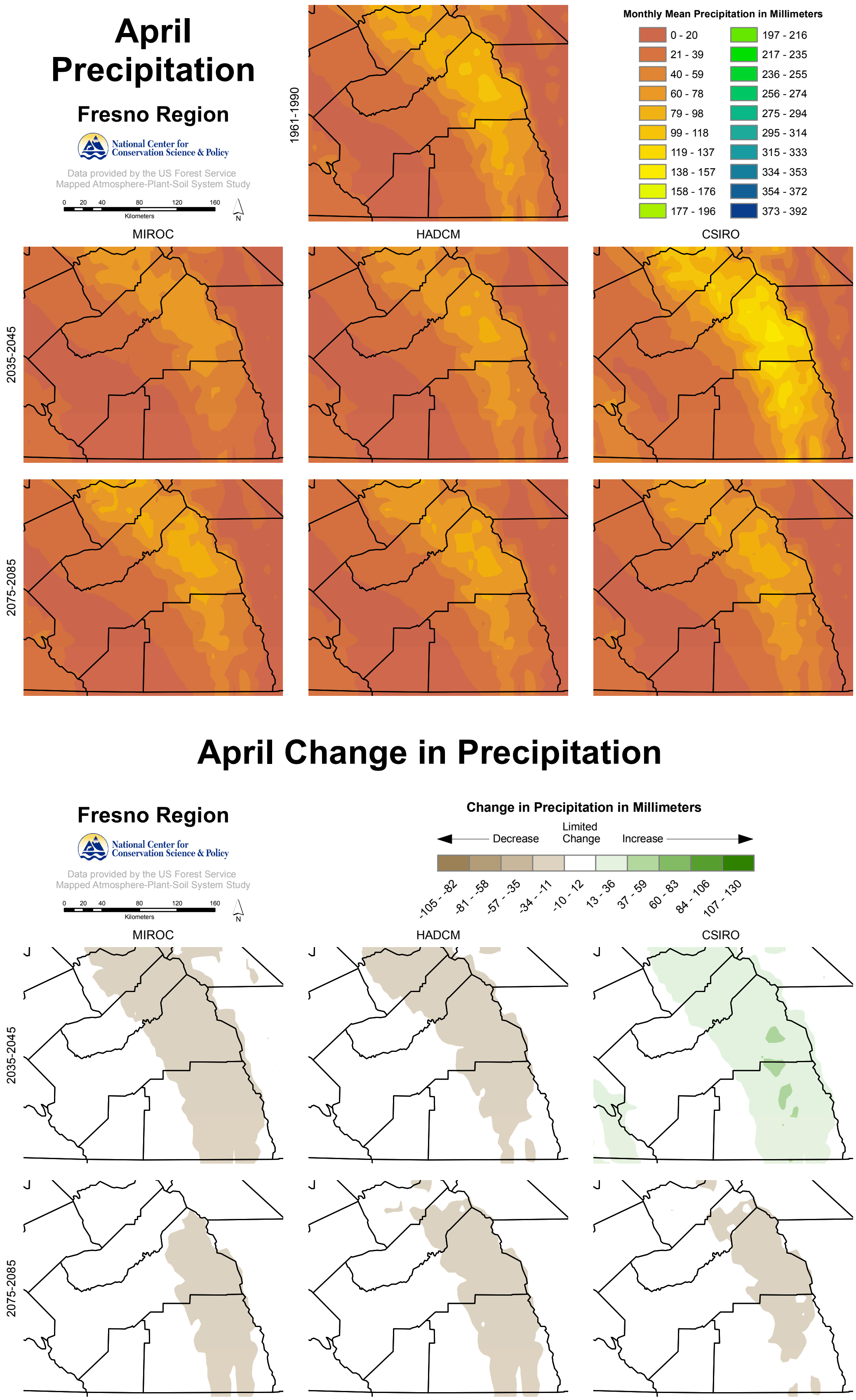
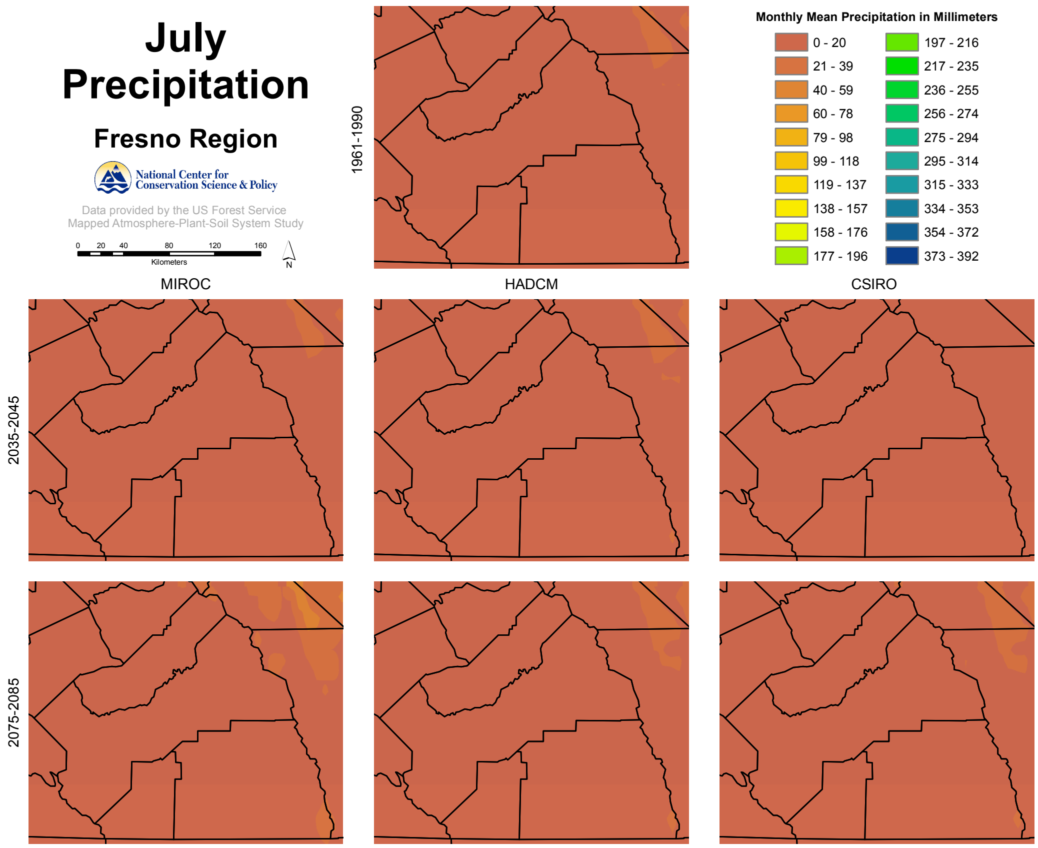


Figure 19. July precipitation (top) and change in precipitation (bottom), in mm.



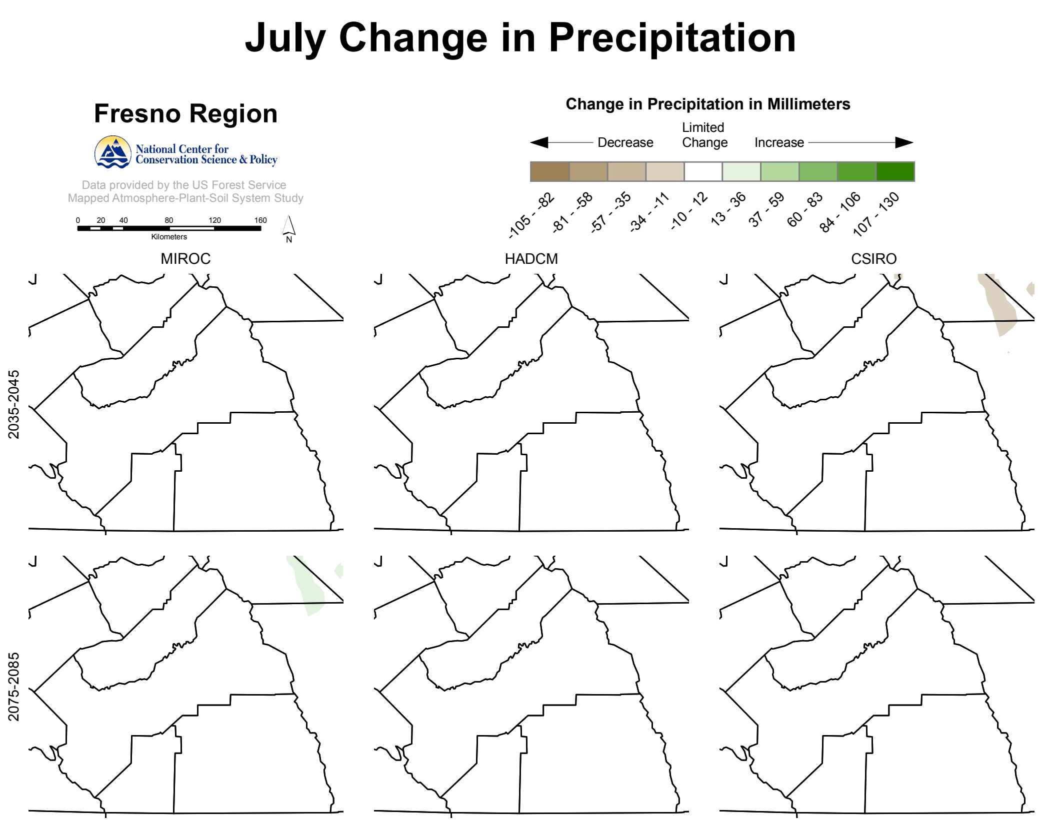
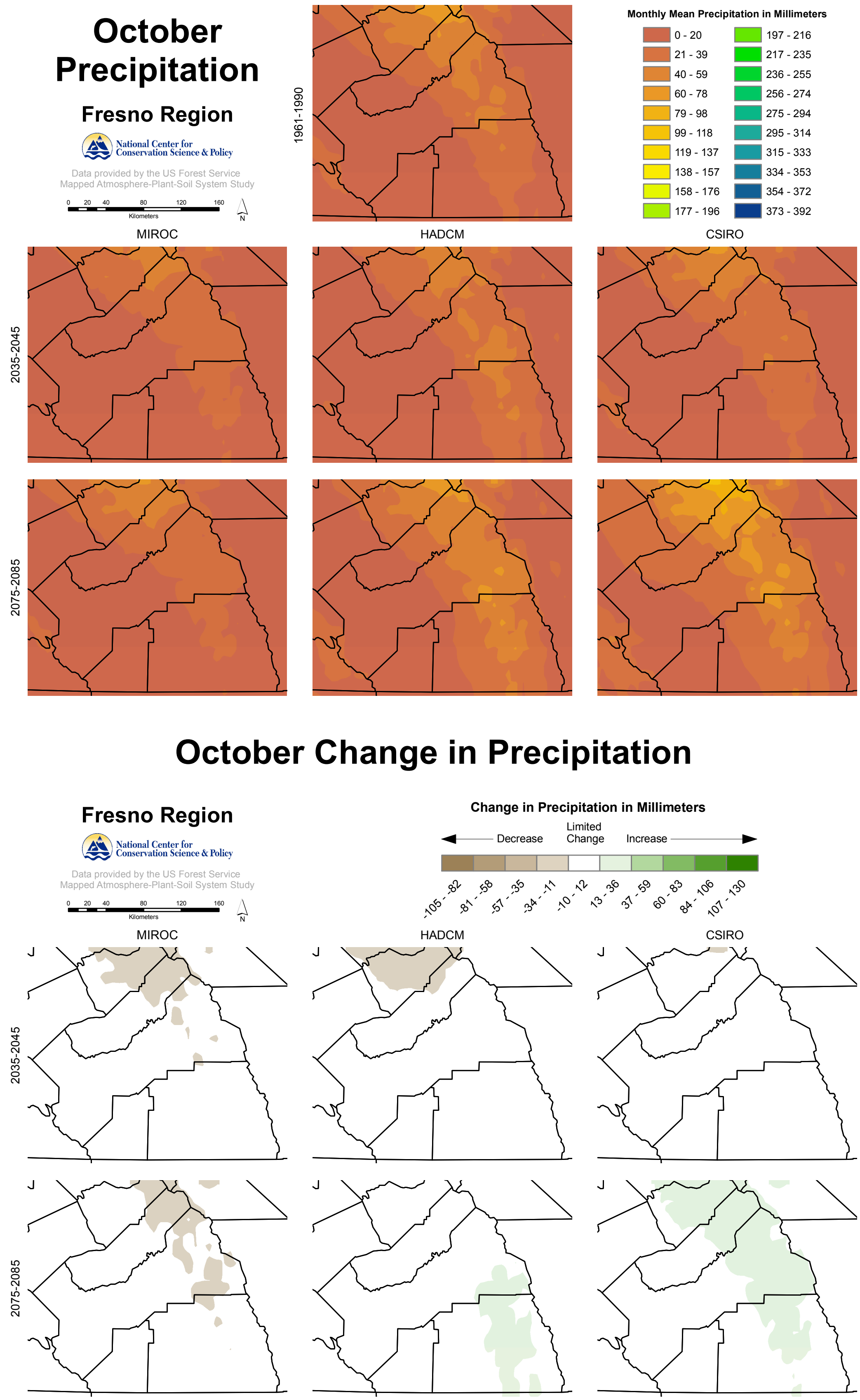


Figure 20. October precipitation (top) and change in precipitation (bottom), in mm.



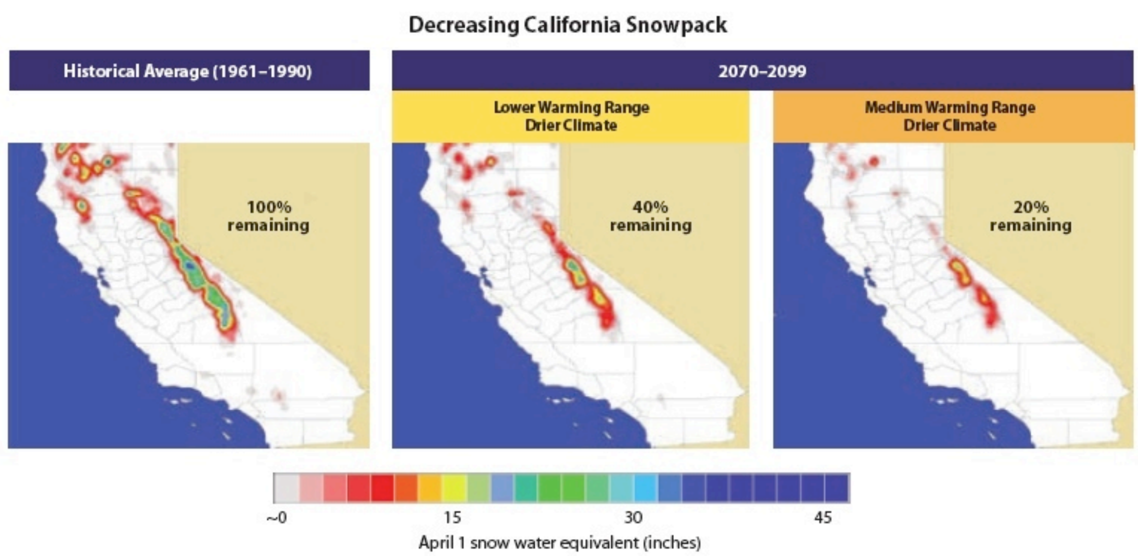
Snowpack and Water Availability

As temperatures warm, precipitation is expected to increasingly fall as rain instead of snow. In addition, snowmelt is expected to occur earlier (Hayhoe et al. 2004). Historical data indicates that peak snow mass occurs five days earlier than it did prior to 1930, and that spring temperatures are 1.2° F warmer than prior to 1948 (Kapnick and Hall 2009). Projections for future snowpack throughout the Sierra Nevada range indicate a potential loss of 80% of snowpack by the end of the century (Fig. 21) under a moderate warming scenario. Snowpack is expected to be even lower under a high warming scenario (the current trajectory).

As increasing temperatures lead to shifts from snow to rain, higher, but earlier, peak runoff is expected. Combined with the likelihood of more intense precipitation events and increasing rain-on-snow events, scientists predict more intense runoff and flooding (CA Natural Resources Agency 2009; He et al. In review).

The California water system is especially vulnerable to global warming due to its dependence on mountain snow accumulation and the snowmelt process (Vicuna and Dracup 2007). Projections show lower stream flow, lower reservoir storage, and decreased water supply deliveries and reliability, expected to be especially pronounced later in the 21st Century (Vicuna et al. 2007). Groundwater is also expected to decline due to increased demand and lowered recharge. Earlier peak run-off, more intense storms that quickly wash through the system, and lower snowpack levels all contribute to declining groundwater recharge.

Figure 21. Current (left) and future (right) snowpack for California on April 1 (from Hayhoe et al. 2004). Reductions in snowpack are a function of declining precipitation, greater proportion of precipitation as rain instead of snow, and earlier spring snowmelt.



VEGETATION and WILDFIRE

The vegetation model (MC1) provided projections for predominant vegetation types (Figure 22) and average annual biomass consumed by wildfire (Figure 23). **The MC1 vegetation model only makes projections for native vegetation types and does not account for land use change (i.e. agriculture and development) or introduced species (i.e. non-native grasses).** Projections for changes in vegetation types include a shift from temperate grassland to subtropical grassland at lower elevations. Because the valley floor is dominated by non-native grasses, this shift may not be realized. A loss of temperate shrubland on the valley floor by mid-century is also projected, although much of this vegetation type has already been lost to agriculture and development.

At higher elevations, vegetation change is apparent in areas that are currently dominated by sequoia and mixed conifer (currently sugar pine, white fir, incense cedar, etc.). Lower elevation conifers, such as gray pine, may spread to higher elevations, while high elevation species could be lost. Despite changed growing conditions, vegetation can take decades or centuries to adjust, especially at higher elevations where conditions will become more hospitable to forest but soil will take decades or centuries to develop. Mechanisms for vegetation change at lower elevations are likely to be drought, fire, invasive species, insects and disease.

Westerling et al. (2009) projected substantial increases in total average area burned by wildfire, with the eastern portions of Fresno, Tulare, and Madera Counties expected to experience 300-400% greater acreage burned by 2085 as compared to the historic (1961-1990) amount (Figure 24). Similarly, the MC1 model projects 2-4 times greater biomass consumed by wildfire (Figure 23) at higher elevations by the end of the century.

Figure 22. The MC1 model shows suitable growing conditions for native types of vegetation, but not actual vegetation or non-native vegetation. Land-use changes, such as agriculture or housing, are also not reflected in this output. Actual vegetation in the future will depend not only on climate conditions, but also on land use, non-native species, and response time needed for changes from one type to another (new forest types do not occur overnight, for example, as they may need decades or centuries to become established).

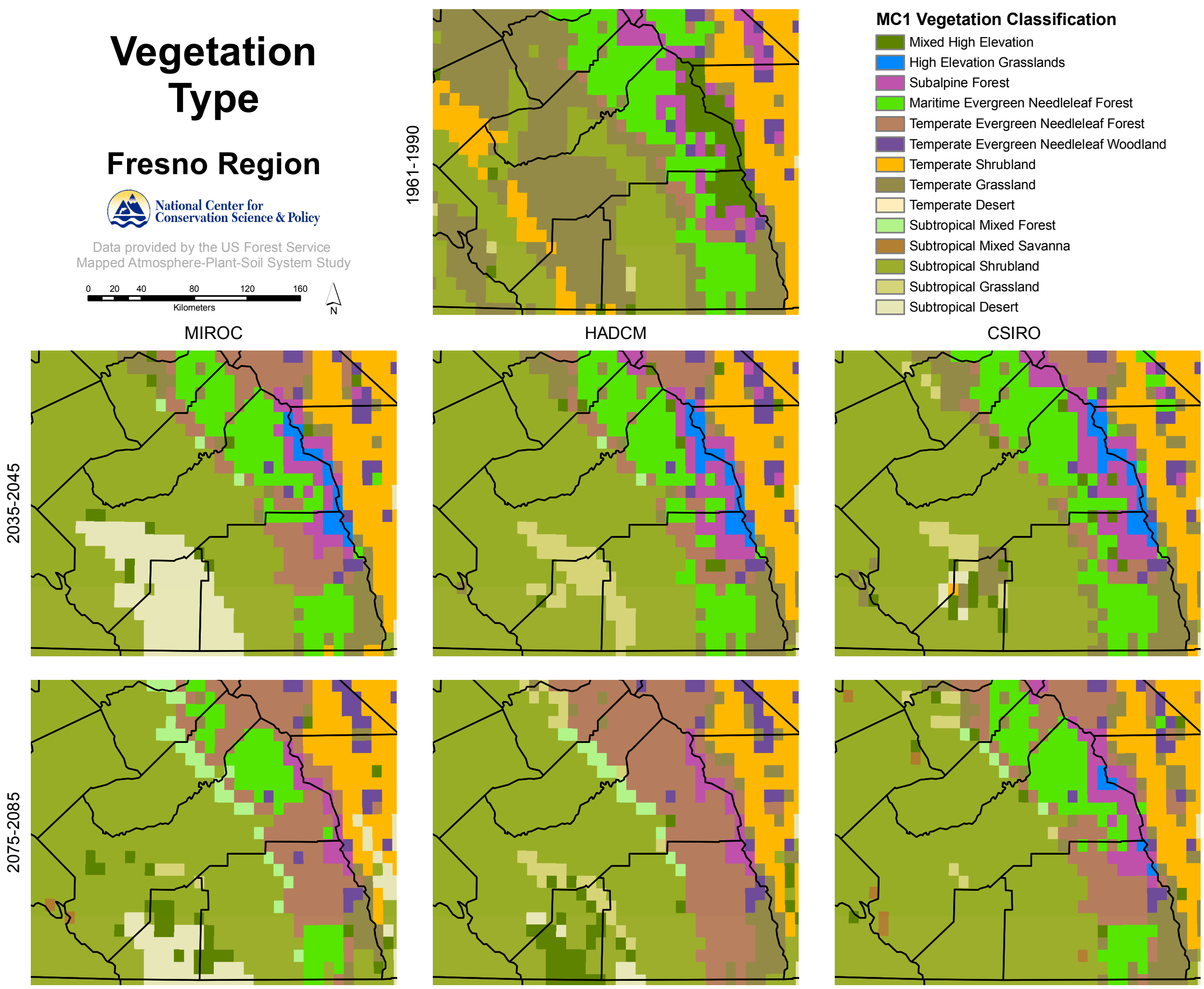


Figure 23. Average annual biomass consumed by wildfire in Fresno County and surrounding counties, shown for the historical period (1960-1991) and projected for two future periods (2035-45 and 2075-85), using three global climate models.

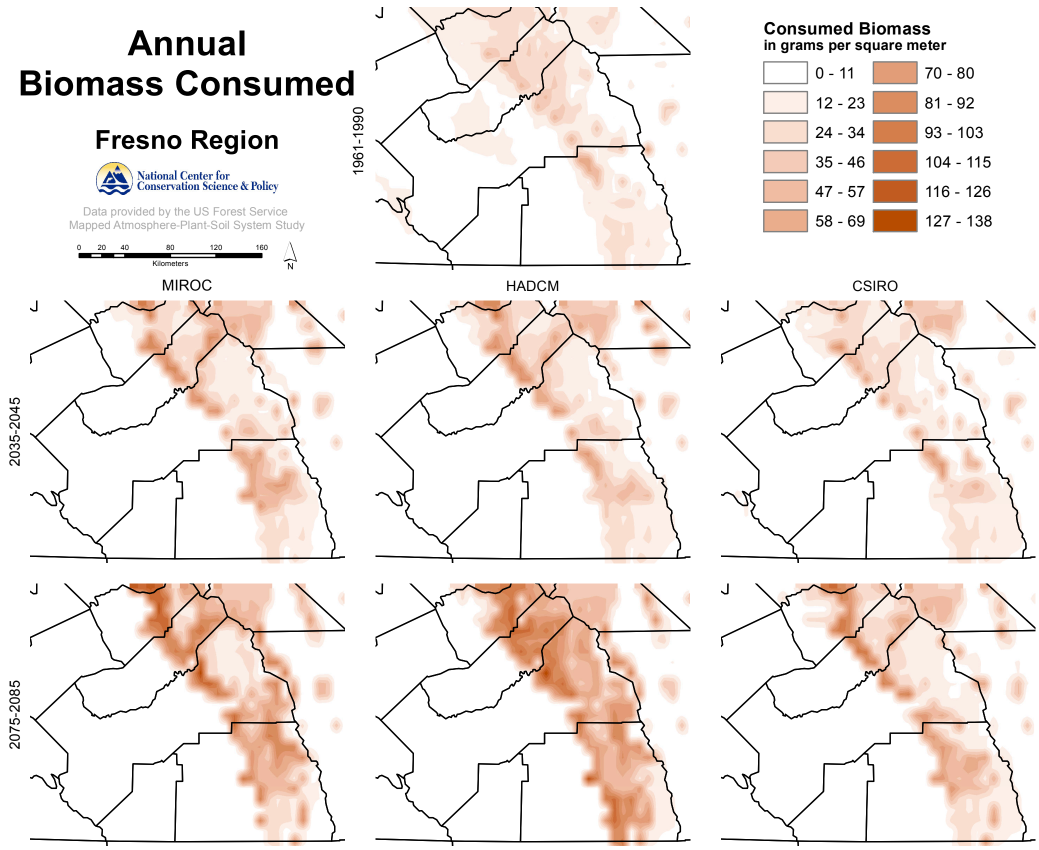
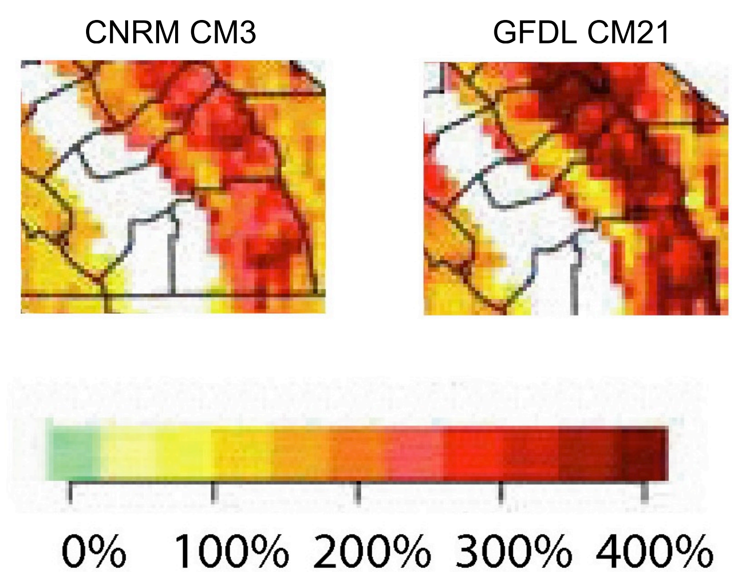


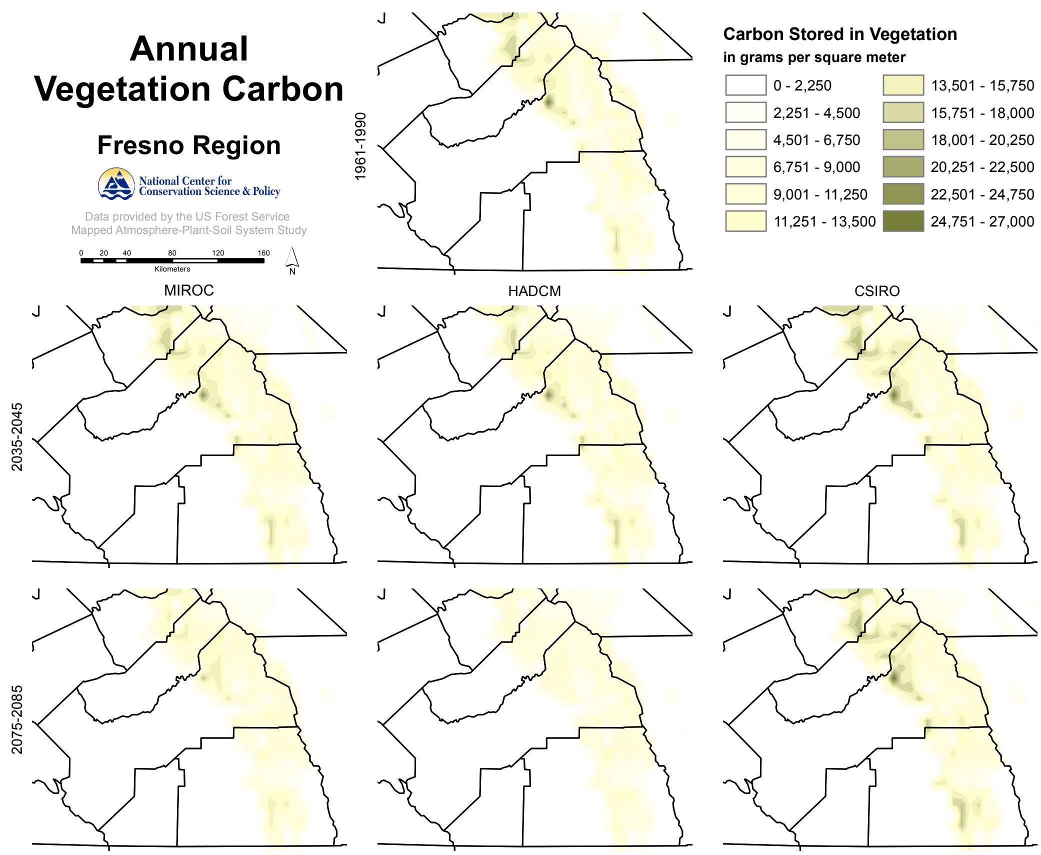
Figure 24. Predicted change in burned area in 2085 compared to historical period. A value of 100% indicates no change while a value of 400% indicates a 4-fold increase. Results are shown from two global climate models. Figure adapted from Westerling et al. (2009).



CARBON STORAGE

All three global climate models indicate a loss of carbon storage by late-century (2075-85), primarily in the Sierra Nevada range. A loss of carbon storage results from vegetation die-back or wildfire. This indicates that portions of the Sierra Nevada range could become a carbon source, rather than sink, within the next century. This result is supported by a USDA Forest Service study on forest management strategies for maintaining carbon stores on national forest lands in this region (USDA 2009).

Figure 25. Average annual carbon storage in vegetation in Fresno County and surrounding counties, shown for the historical period (1960-1991) and projected for two future periods (2035-45 and 2075-85), using three global climate models.



SUPPORTING STUDIES

The California Energy Commission (CEC) 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. These models were different than the three used in this report, which were chosen by researchers at the Pacific NW Research Station to represent a range of future conditions. Even with different models, however, the results from many CEC reports agree with or complement the results in this report, providing greater confidence in the results presented here.

Using the same vegetation model (MC1) but different climate models than ours, Shaw et al. (2009) also projects a decline in coniferous forest in the eastern portions of Fresno, Madera, and Tulare counties, with expansion of hardwood forest. Shrublands are also expected to expand, at the expense of grasslands. In addition, their study projected steep declines in forage production in the foothills of the Sierras in the same three counties (Figure 25).

In another study, 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. Species diversity is expected to remain higher at higher elevations and along the coast.

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). Both oaks experienced range contractions in the Fresno region by 2080-2099, according to the models, but the geographic complexity of the area may result in range expansion as well.

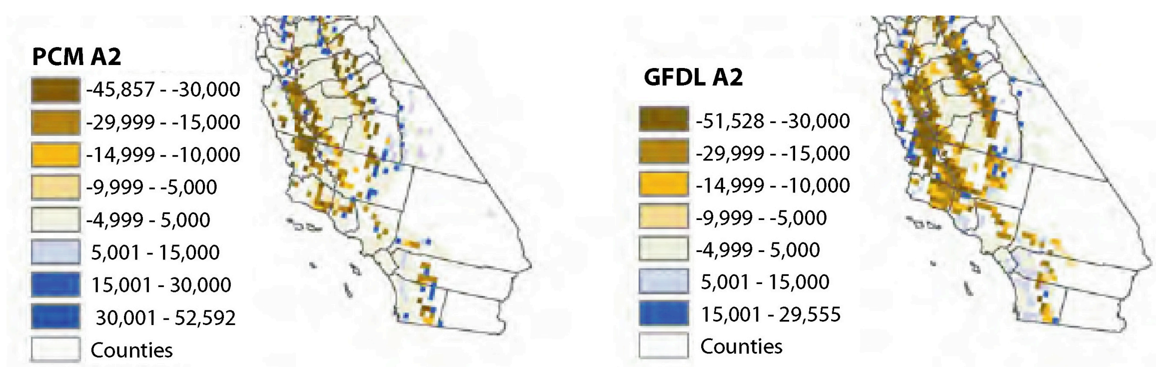


Figure 25. Net change in forage production by 2070-2099, based on two climate models under the A2 emissions scenario. Orange or brown represent a decline in forage production, while blue represents an increase in forage production. (Figure from Shaw et al. 2009)

CONNECTIVITY

As the climate changes, animals and plants are expected to respond in various ways. Most species will need to move to new areas where the climate is suitable. Some species are only able to move short distances due to natural limitations such as low dispersal rates, inhospitable terrain, or a lack of dispersal agents. Other species may be limited by development, road placement, or loss of habitat in new areas. In contrast, weedy or invasive species are expected to easily move in response to the changing climate and could increase in abundance and range.

In order to minimize the decline and potential extirpation of many of California's native species, three primary approaches to the dispersal problem (outlined above) have been recommended. **By far the most important approach is to maintain and increase habitat connectivity and corridors across counties, regions, states, and even the entire western U.S.** This approach requires a level of collaboration and communication across land ownership that is currently non-existent. Areas of Fresno County and the surrounding counties have been identified as especially important for long-term movement of animals and plants among natural areas (Figure 26).

Facilitated dispersal (translocation) is recommended for species with limited abilities and opportunities for natural dispersal. Facilitated dispersal will need to be carefully considered and planned, as there are many potentially undesirable consequences. In addition, cost and failure rate are often high.

Finally, aggressive control of undesirable invasive and weedy species will be needed to allow more desirable native species the opportunity to disperse and become established in new areas.

Figure 26. Areas important for habitat connectivity in the Fresno region. Green areas are largely natural areas while yellow and red areas are important connectors that would be more costly to conserve (adapted from Spencer et al. 2010).

CONCLUSIONS

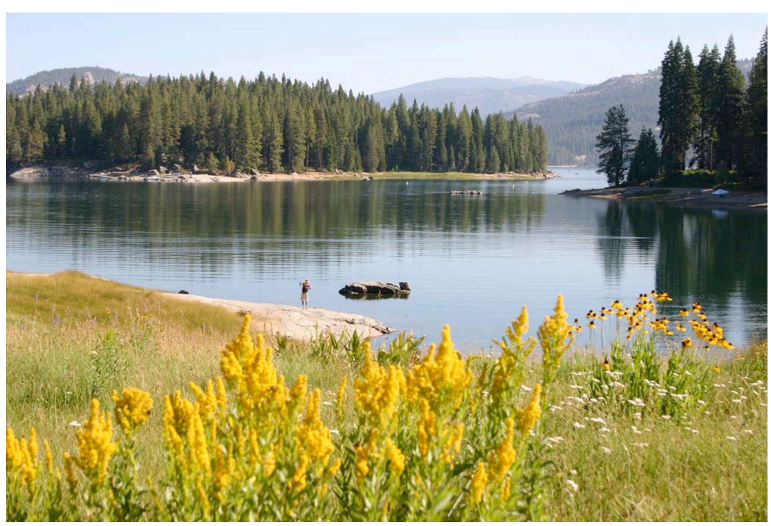
The purpose of this report is to provide up-to-date climate projections for Fresno, Madera, Kings, and Tulare Counties at a scale that can be used in community planning efforts. By providing the information that local managers, decision-makers and community members need to make day-to-day decisions and long-term plans, we hope to spur proactive climate change adaptation 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, 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 city, county, and regional 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 in a cohesive manner. This process will take place in a series of workshops involving experts in the following sectors: natural ecosystems (terrestrial and aquatic), built (infrastructure, culverts, etc.), human (health, emergency response, etc.), economic (agriculture, business, etc.) and cultural (Native American tribal customs and rights, immigrant communities and customs, etc.).

The ClimateWise® program is structured to begin the planning process in local communities, and 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 collaborating with lawmakers.

Please contact Marni Koopman at the National Center for Conservation Science and Policy for more information or to become involved in this process (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.

Harmsen, F., D. Hunsaker, P. Van de Water, and Y. V. Luo. 2008. Mitigation and Adpatation Strategies for Climate Change in Fresno, California. Institute of Climate Change Oceans and Atmosphere, College of Science and Mathematics, CSU Fresno.

Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff, E. P. Maurer, N. L. Miller, S. C. Moser, S. H. Schneider, K. N. Cahill, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, C. K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. Emissions Pathways, Climate Change, and Impacts on California. Proceedings of the National Academy of Sciences of the United States of America 101: 12422–27.

He, Z., Z. Wang, C. J. Suen, and X. Ma. In review. Climate change impacts on water availability in the Upper San Joaquin River watershed, California.

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.

Kapnick, S. and A. Hall. 2009. Observed changes in the Sierra Nevada snowpack: Potential causes and concerns. California Climate Change Center. CEC-500-2009-016-F.

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.

Spencer, W. D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California. Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration. Accessed: http://www.dfg.ca.gov/habcon/ connectivity/

CA Natural Resources Agency. 2009. California Water Plan Update 2009: Integrated Water Management. Dept. of Water Resources. Accessed 07/27/2010 at http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

USDA. 2009. National Forest Carbon Inventory Scenarios for the Pacific Southwest Region (California). Goines, B. and M. Nechodom, Eds.

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

Vicuna, S., and J. A. Dracup. 2007. The evolution of climate change impact studies on hydrology and water resources in California. Climatic Change 82:327–350.

Vicuna, S., E. P. Maurer, B. Joyce, J. A. Dracup, and D. Purkey. 2007. The Sensitivity of California Water Resources to Climate Change Scenarios. Journal of the American Water Resources Association 43: 482 – 498.

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.