Projected Future Conditions in the Klamath Basin of Southern Oregon and Northern California

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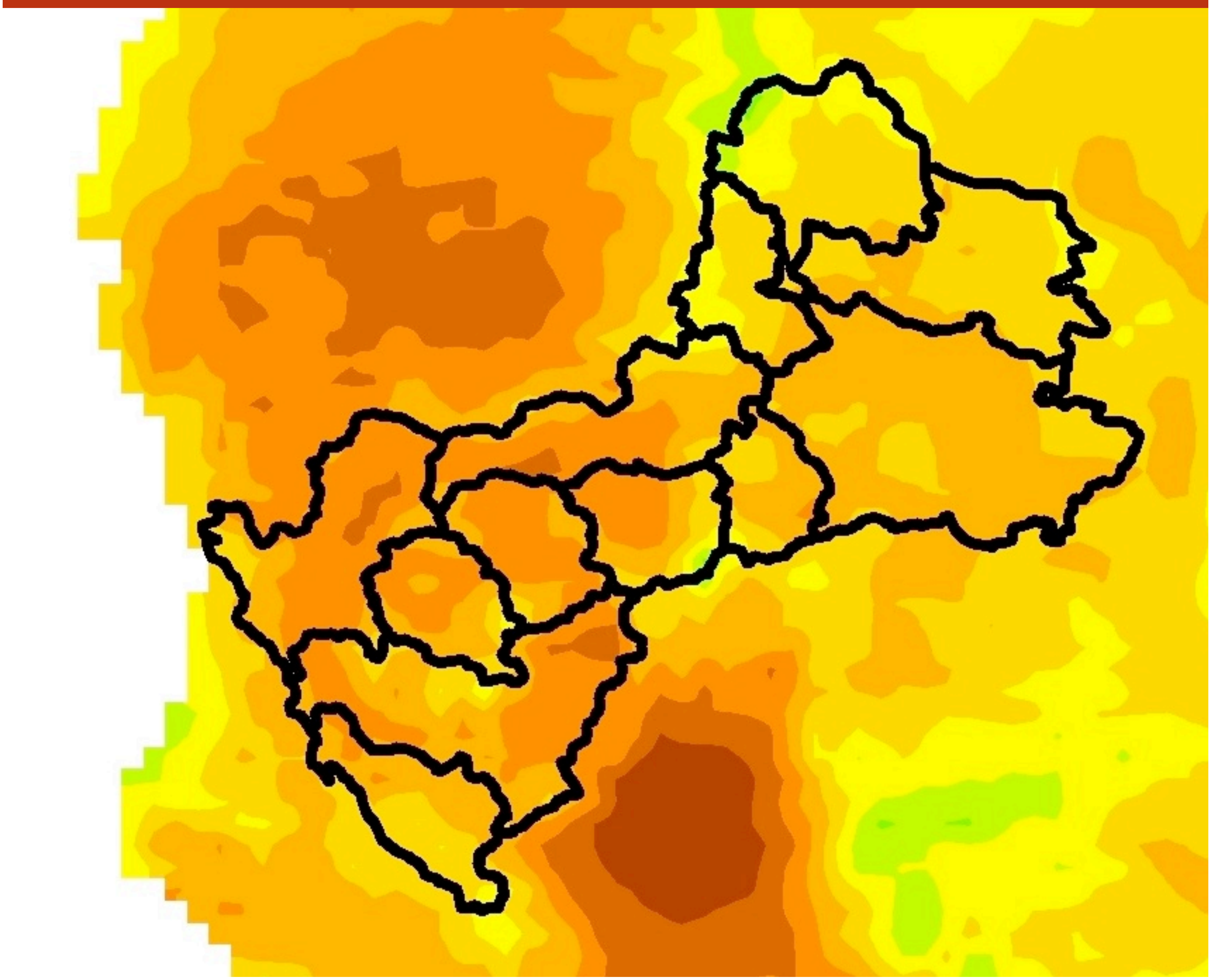
October, 2009



A collaborative effort by:

National Center for Conservation Science & Policy

CLIMATE LEADERSHIP INITIATIVE
INSTITUTE FOR A SUSTAINABLE ENVIRONMENT
UNIVERSITY OF OREGON

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. We also appreciate the insights on climate projections provided by Phil Mote with the Oregon Climate Change Research Institute.

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INTRODUCTION

The Klamath Basin is rich in history, culture, and biological diversity. Straddling the border between California and Oregon, the Basin encompasses over 15,000 square miles of temperate rainforest, other coniferous and deciduous forest, high peaks, fertile valleys, extensive wetlands, Oregon's largest lake, and the 263 mile Klamath River.

Climatic changes are already underway in the Klamath Basin and are likely to increase in the coming decades. Changes to the Basin are likely to include more frequent and intense storms and floods, extended drought, more forest fires, and more heat waves. The local communities in the Basin will need to plan for such changes in order to maintain their quality-of-life.

This report provides community-members and decision-makers in the Klamath Basin 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 unique 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.

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

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.

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).

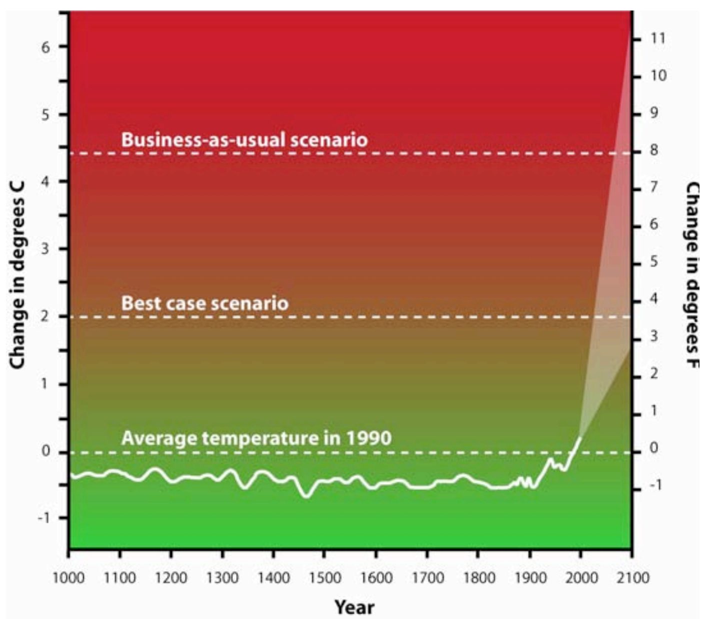


Figure 1. The last 1000 years in global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions would lead to an increase of about 2ºC by 2100 while the current trajectory will lead to an increase closer to 4.5º C and as high as 6º C (adapted from IPCC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

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 scenario, meaning that the results presented in this report could underestimate actual impacts. The three models we use in this report, however, provide some of the hotter projections for the Pacific Northwest.

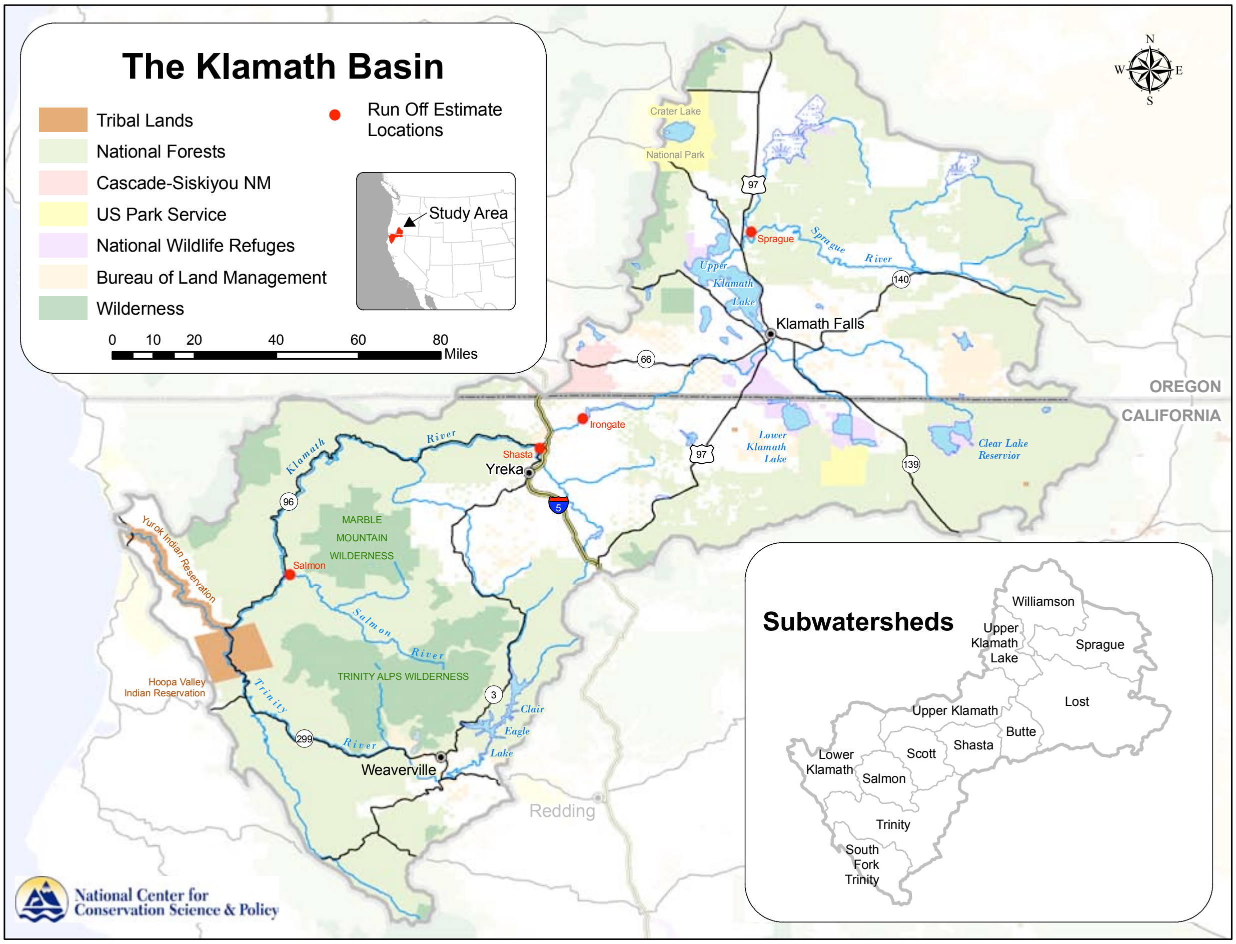
Due to climate system inertia, restabilization of atmospheric gases will take many decades even with drastic emissions reductions. Reducing emissions is vital to prevent the earth's climate system from reaching certain tipping points that will lead to sudden and irrevocable changes. In addition to emissions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

KLAMATH BASIN CLIMATE PROJECTIONS

Variables modeled using HADCM, CSIRO, and MIROC, the vegetation model (MC1), and our stream flow regression model include temperature, precipitation, vegetation type and distribution, percent of the landscape burned, and annual runoff. 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 the Klamath Basin. 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 Basin), and as maps that show variation across the Basin, 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). The historical period for comparing runoff varied depending on availability of stream gage data.

Figure 2. Land ownership in the Klamath Basin.



TEMPERATURE

The projections from all three models agree, with high certainty, on a warmer future for the Klamath Basin (Table 1).

Table 1. Future temperature in the Klamath Basin, based on projections from three different global climate models.

TEMPERATURE	2035-2045	2075-2085
Annual	+2.1 to +3.6° F (+1.1 to +2.0° C)	+4.6 to +7.2° F (+2.5 to +4.6° C)
Jun - Aug	+2.2 to +4.8° F (+1.2 to +2.7° C)	+5.8 to +11.8° F (+3.2 to +6.6° C)
Dec - Feb	+1.7 to +3.6° F (+1.0 to +2.0° C)	+3.8 to +6.5° F (+2.1 to +3.6° C)

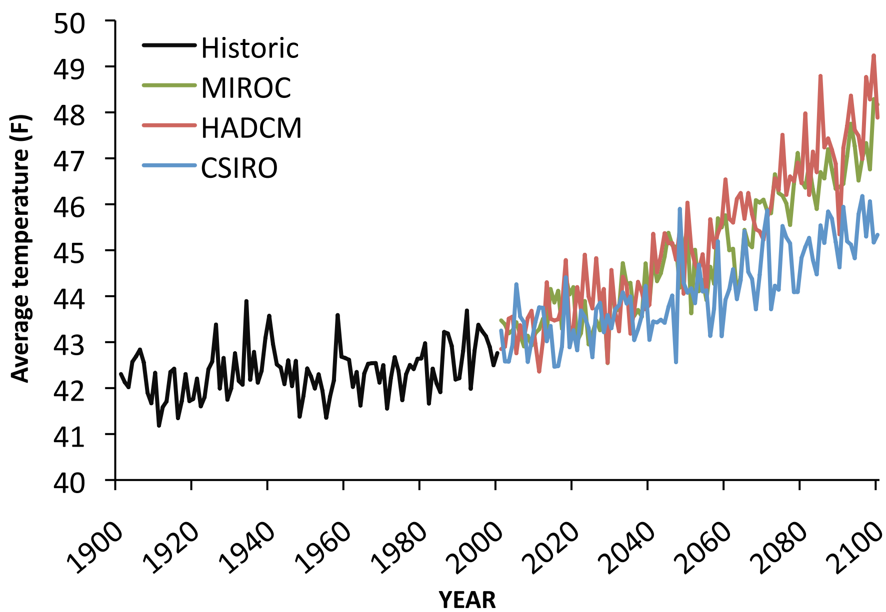


Figure 3. Mean annual temperature (°F) across the Klamath Basin from 1901 to 2000 (measured historical) and projected through 2100 using three global climate models.

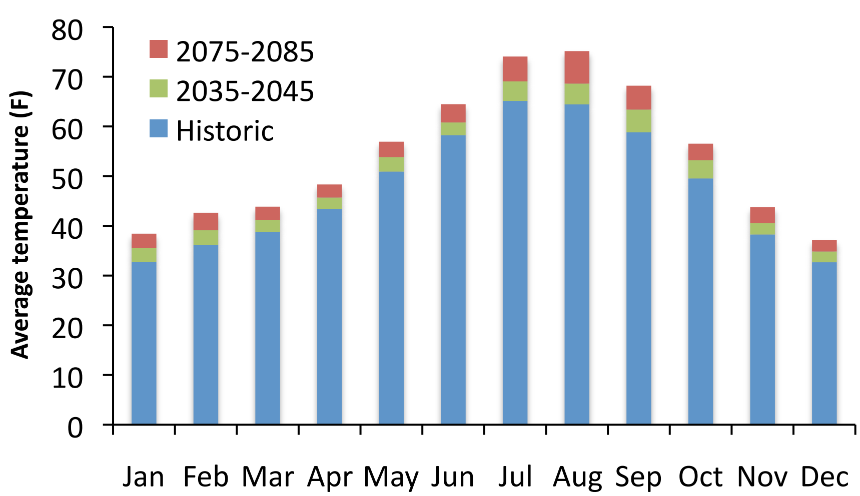
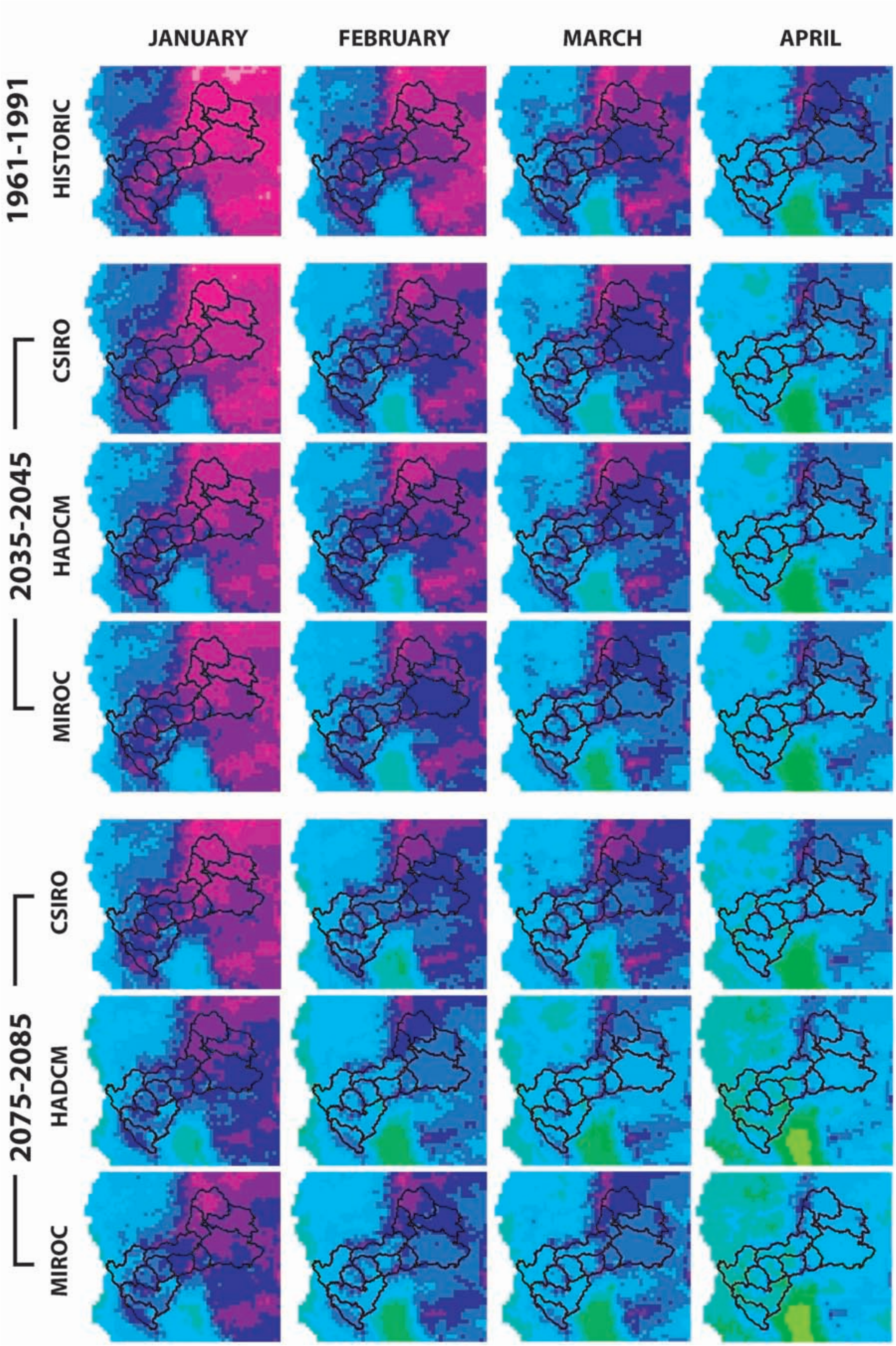


Figure 4. Monthly increases in temperature (°F), based on an 11-year average with a midpoint in 2040 (green) and in 2080 (red), as compared to historic (blue). All three models showed greater warming in the summer than the winter, so all three were averaged for this graph.

Mean Temperature in Degrees Celsius

Figure 5 (continues on the following 3 pages). Average monthly temperature across the Klamath Basin for three time periods: historical (1961-1991), 2035-45, and 2075-85, based on projections from three global climate models (CSIRO HADCM, and MIROC). The color ramp on this page shows the temperature, in degrees Celsius, whereas the following three pages show regional variation in average monthly temperature for each month of the year.



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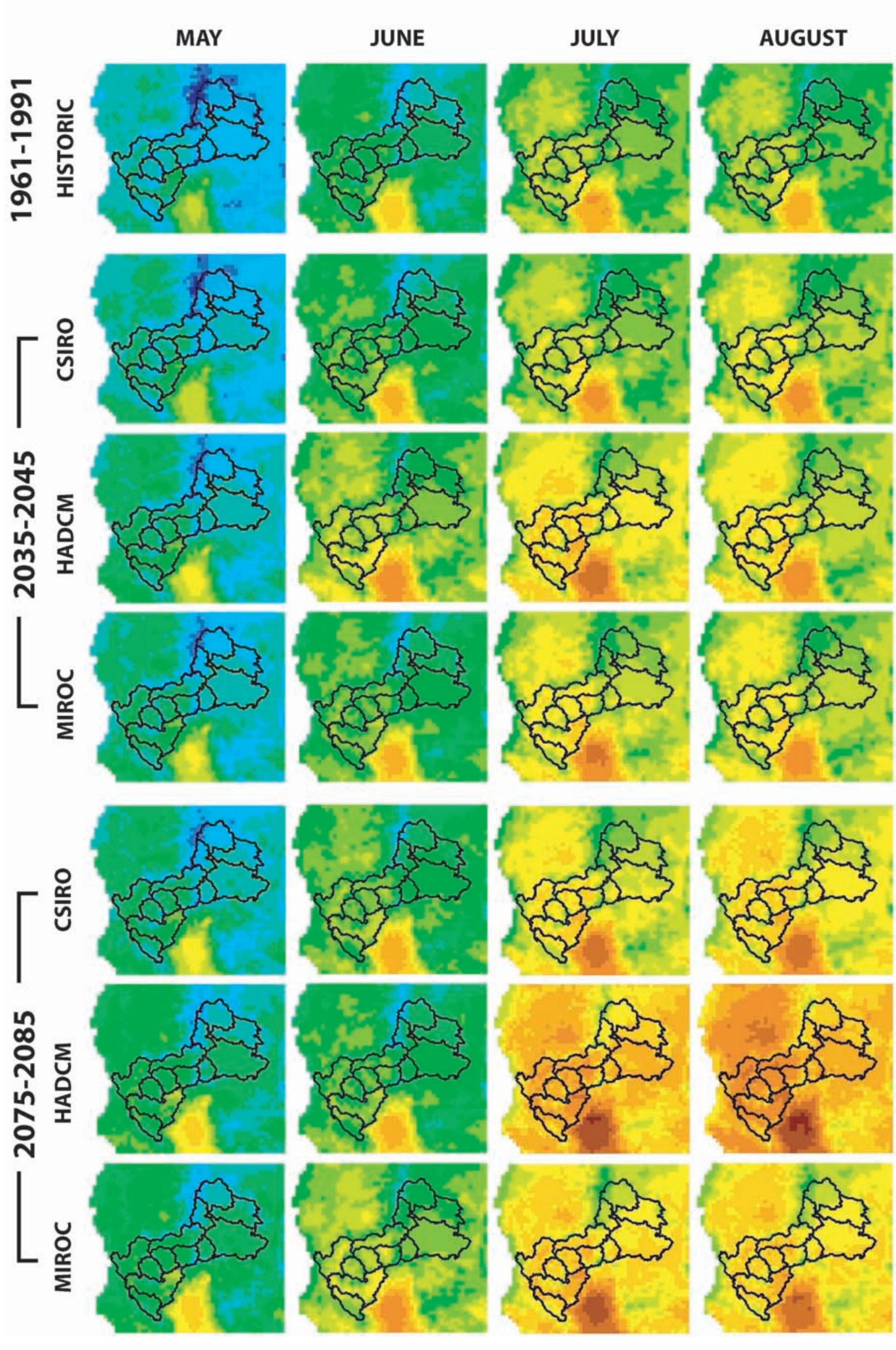
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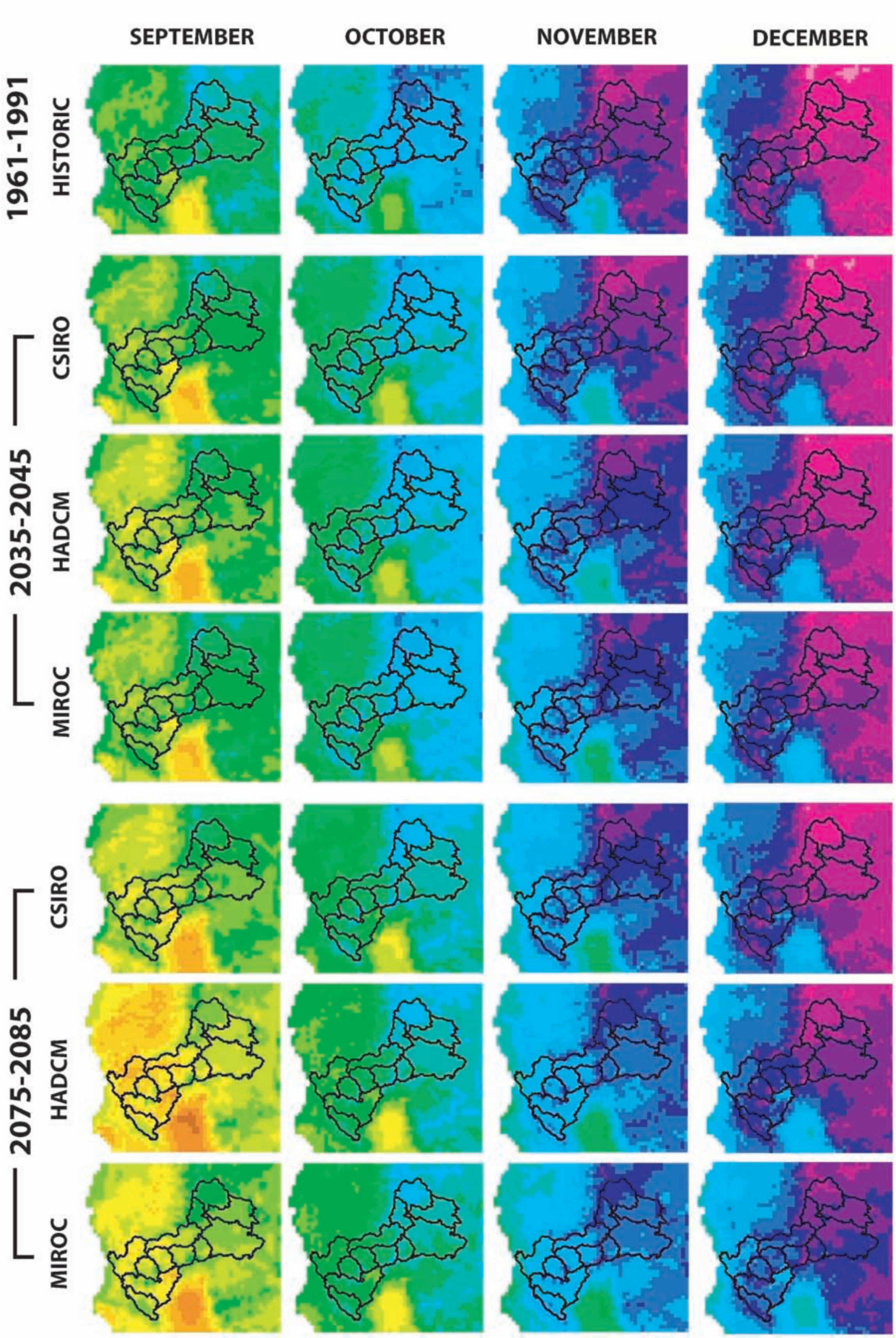
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MIROC
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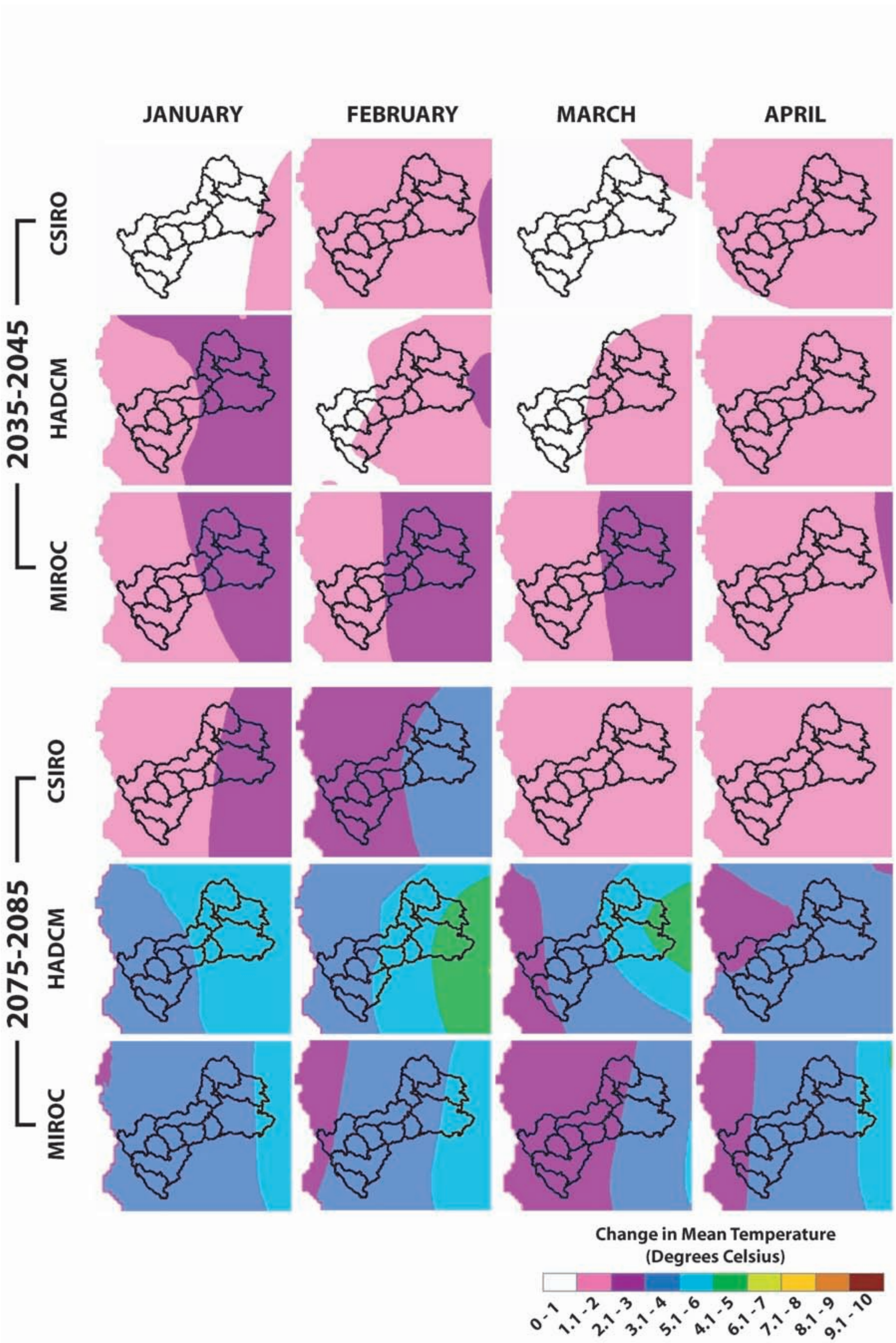
CSIRO
HADCM
MIROC

Figure 6 (on the following 3 pages). Average monthly CHANGE in temperature, in degrees Celsius, across the Klamath Basin, as compared to the historical average (1961-1991), for each of two time periods (2035-45 and 2075-85) and each of three climate models (CSIRO, HADCM, and MIROC). The following three pages show geographic variation in temperature change for each month of the year.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Change in Mean Temperature
(Degrees Celsius)
0 - 1
1.1 - 2
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7.1 - 8
8.1 - 9
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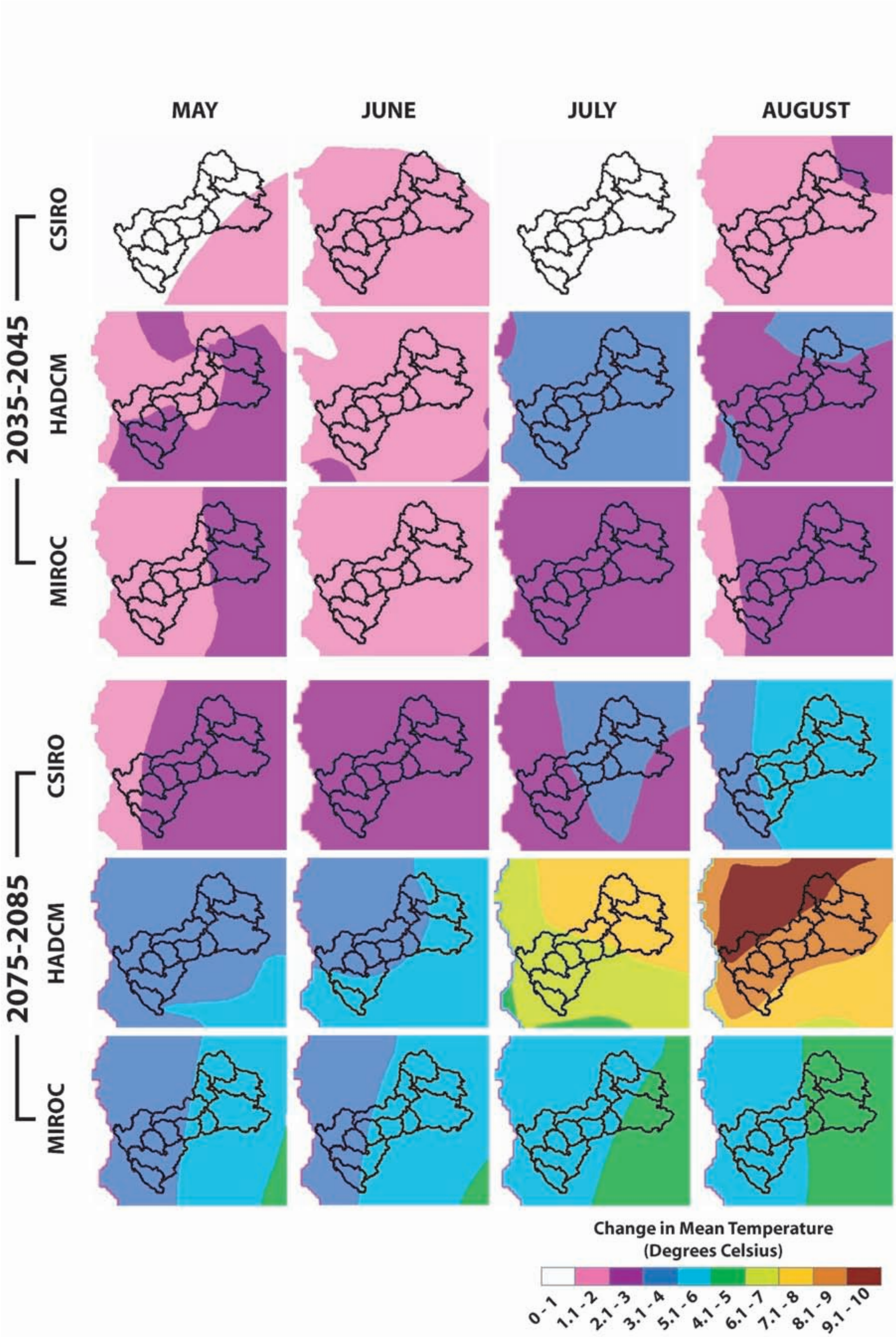
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Change in Mean Temperature
(Degrees Celsius)
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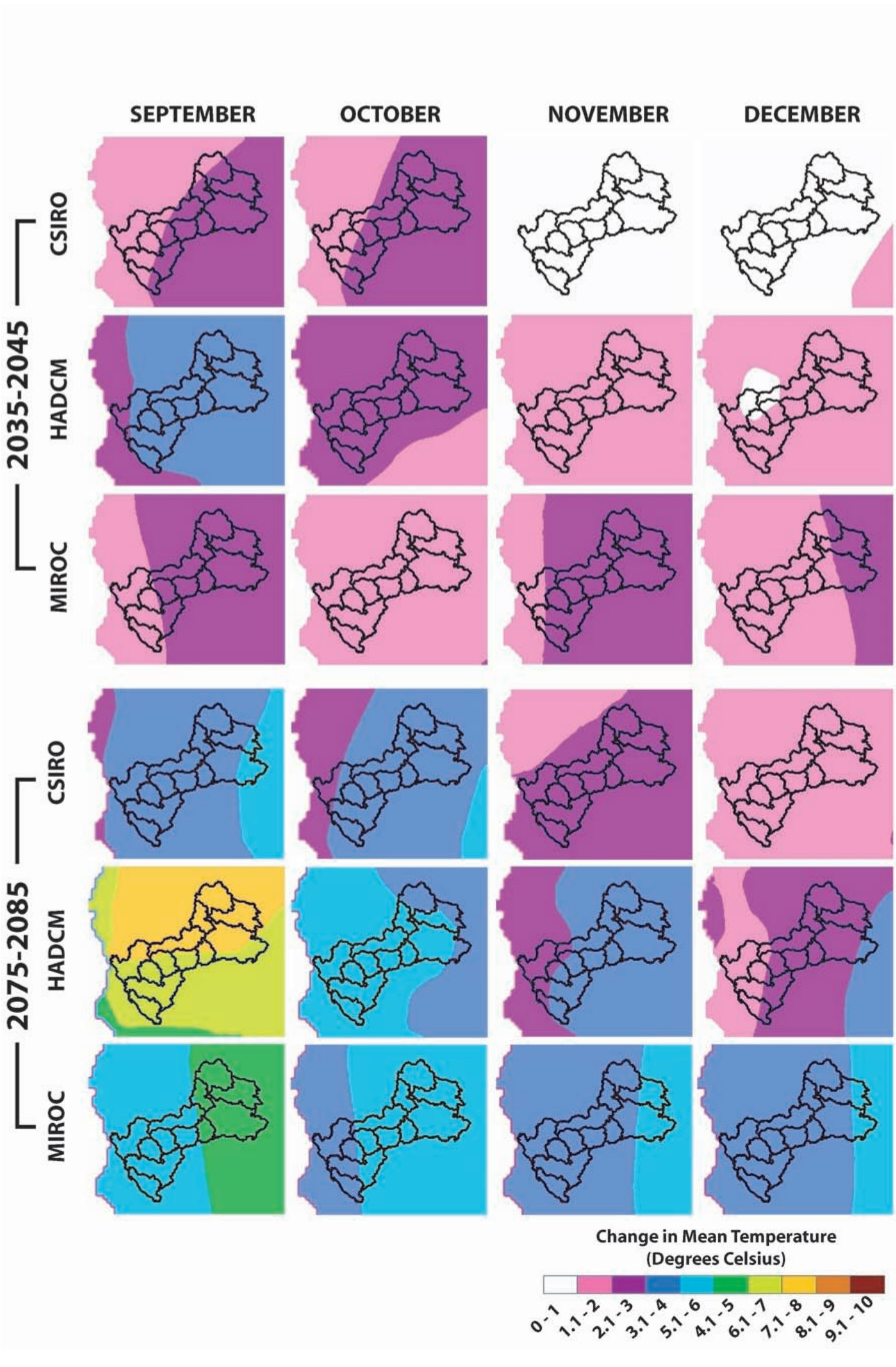

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3.1 - 4
5.1 - 6
4.1 - 5
6.1 - 7
7.1 - 8
8.1 - 9
9.1 - 10

PRECIPITATION

The three models agree that summers will be drier, but winter precipitation projections are widely variable.

Table 2. Future precipitation in the Klamath Basin, based on projections from three global climate models (CSIRO, HADCM, and MIROC). Results are presented as the full range of projections provided by all three models.

Precipitation	2035-2045	2075-2085
Annual	-7.0 to +1.7 mm (-9 to +2%)	-8.4 to +18.9 mm (-11 to +24%)
Jun- Aug	-4.1 to -2.7 mm (-15 to -23%)	-6.5 to -0.3 mm (-37 to -3%)
Dec - Feb	+1.5 to +14.4 mm (+1 to +10%)	-7.2 to +40.4 mm (-5 to +27%)

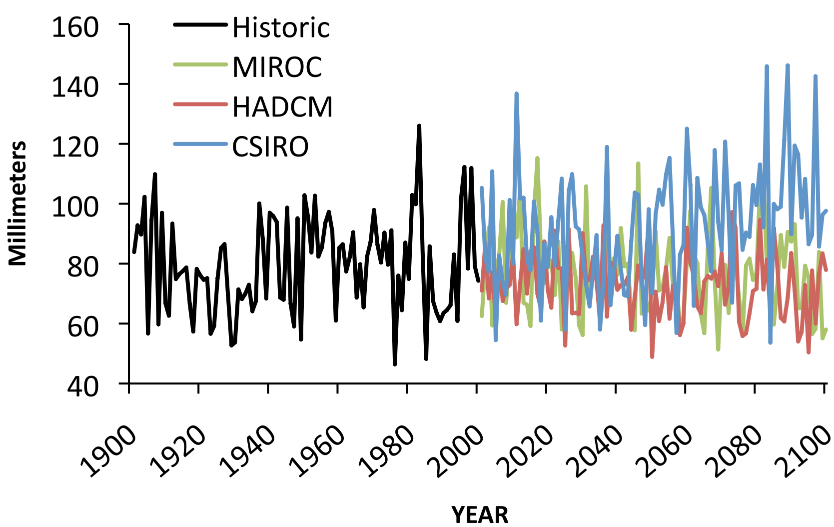


Figure 7. Average annual precipitation (mm) averaged across the Klamath Basin. On average, CSIRO shows a wetter future while MIROC and HADCM show a slightly drier future.

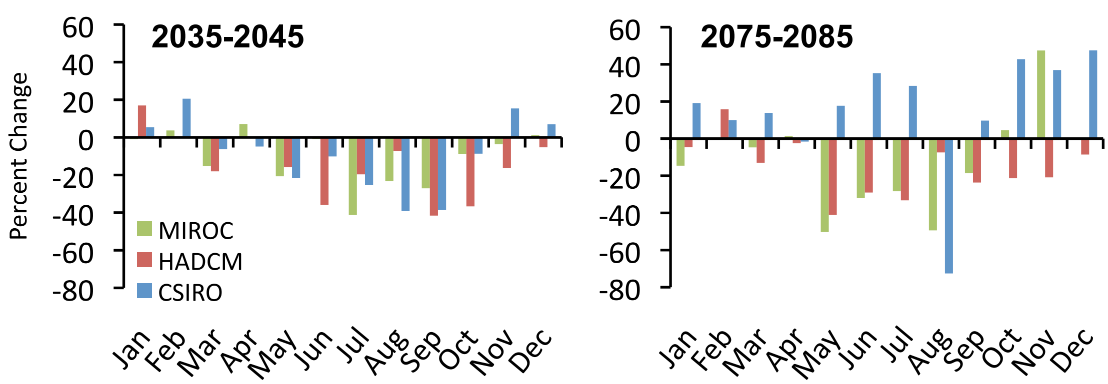


Figure 8. Monthly percent change in precipitation in the Klamath Basin, as compared to historic (1961-1991) levels, for two different time periods: 2035-45 (left) and 2075-85 (right). All models project drier summers in the short term. In the long term, HADCM and MIROC project drier conditions while CSIRO projects wetter conditions.

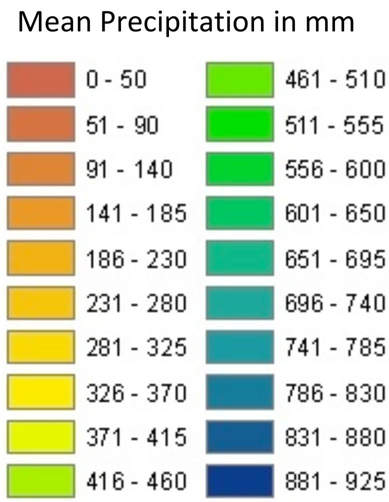
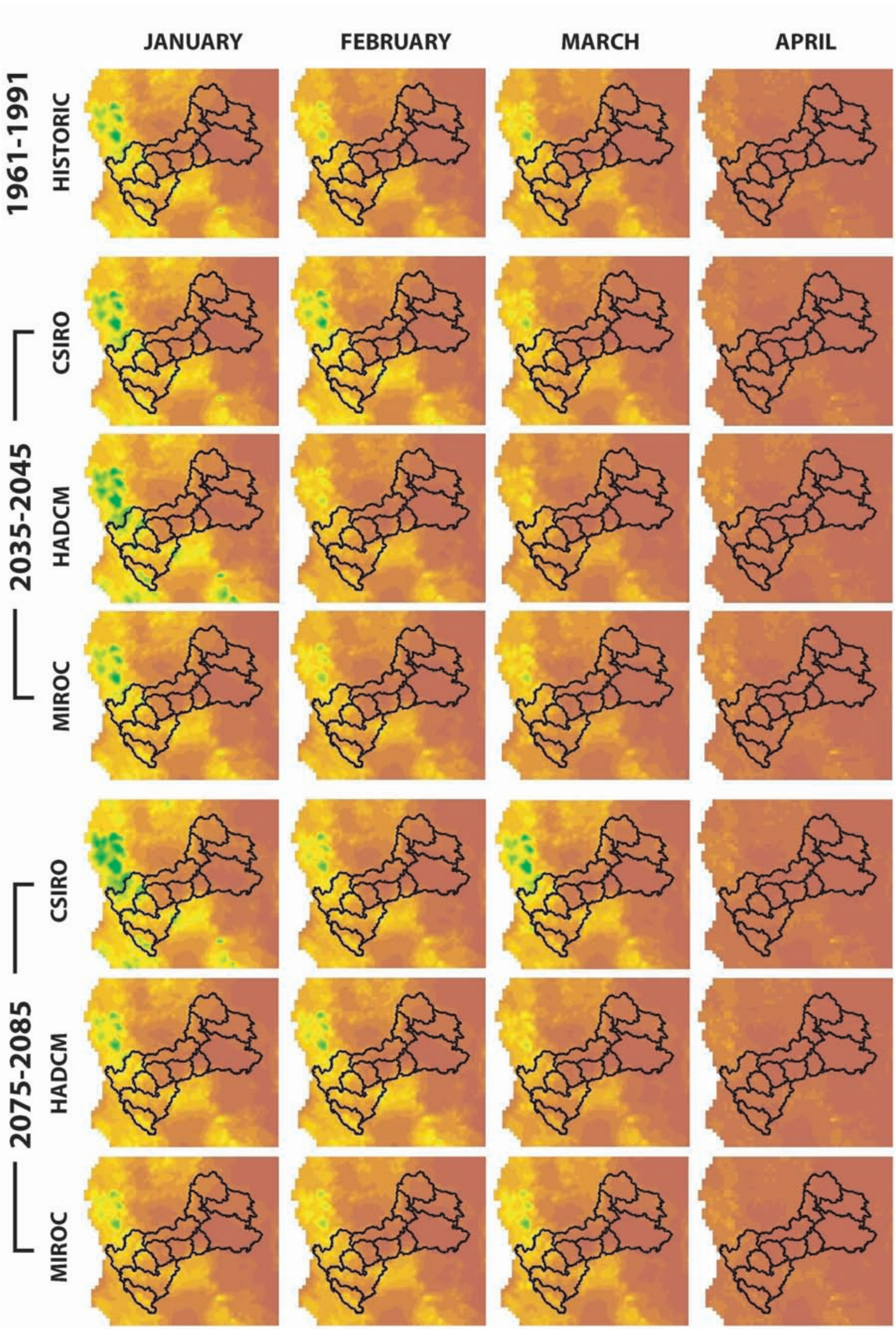


Figure 9 (continues on the following three pages). Average monthly precipitation across the Klamath Basin for three time periods: historical (1961-1991), 2035-45, and 2075-85, based on projections from three global climate models (CSIRO, HADCM, and MIROC). The color ramp on this page shows the precipitation, in mm, whereas the following three pages show regional variation in average monthly precipitation for each month of the year.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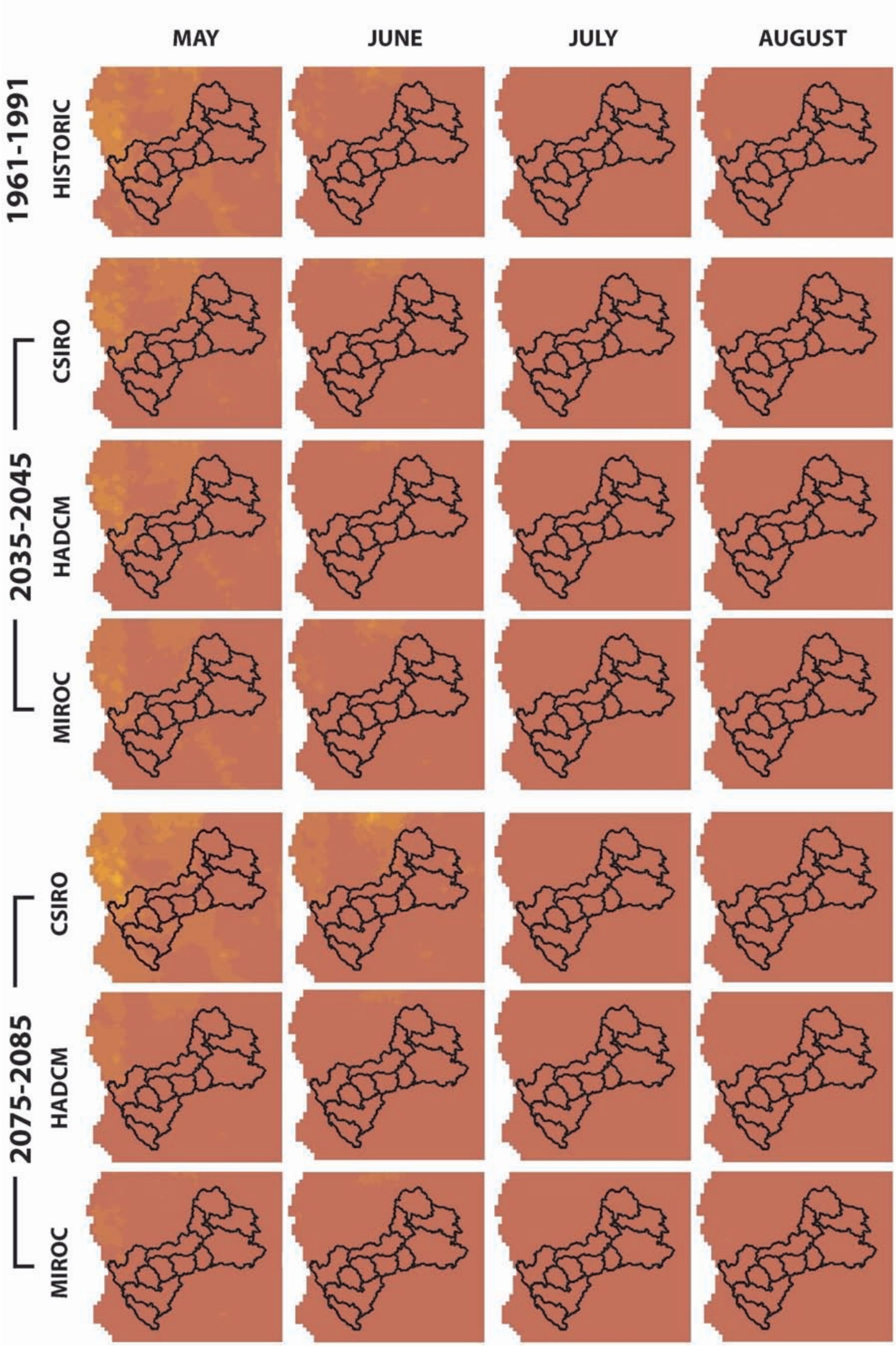
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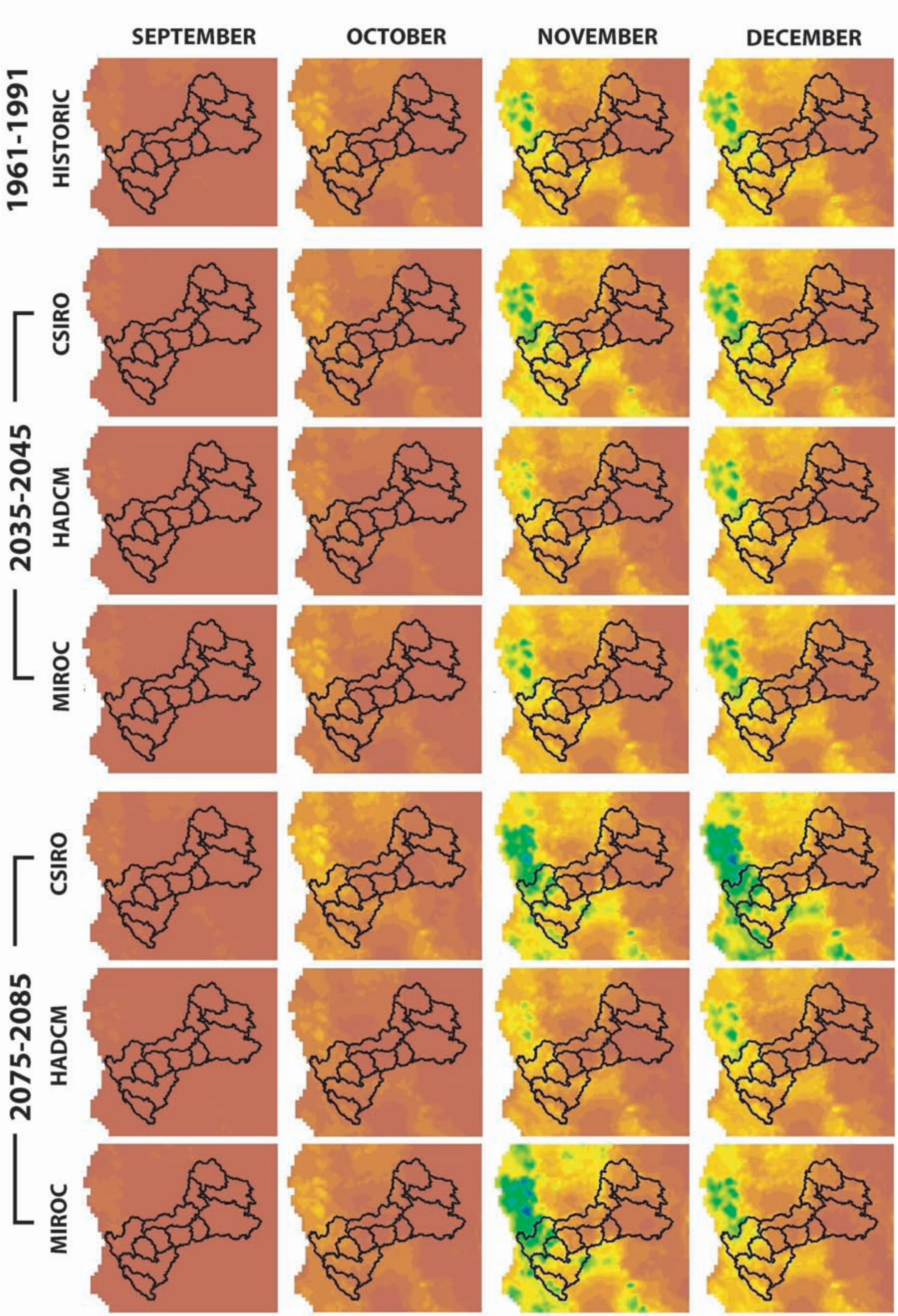
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HADCM
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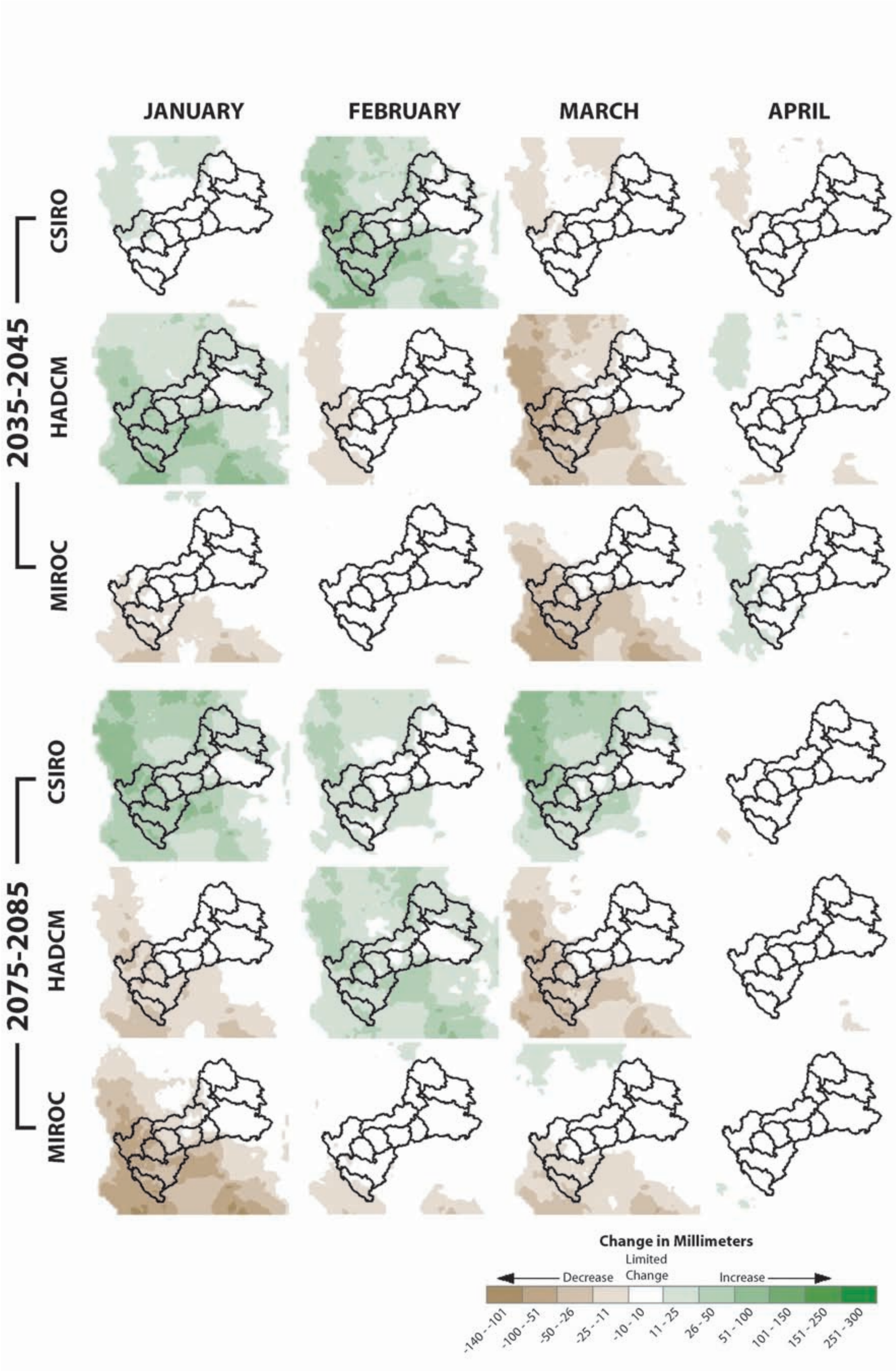
Figure 10 (continues on the following three pages). Average monthly CHANGE in precipitation, in millimeters, across the Klamath Basin, as compared to the historical average (1961-1991), for each of two time periods (2035-45 and 2075-85) and each of three climate models (CSIRO, HADCM, and MIROC). The following three pages show geographic variation in precipitation change for each month of the year.



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Change in Millimeters
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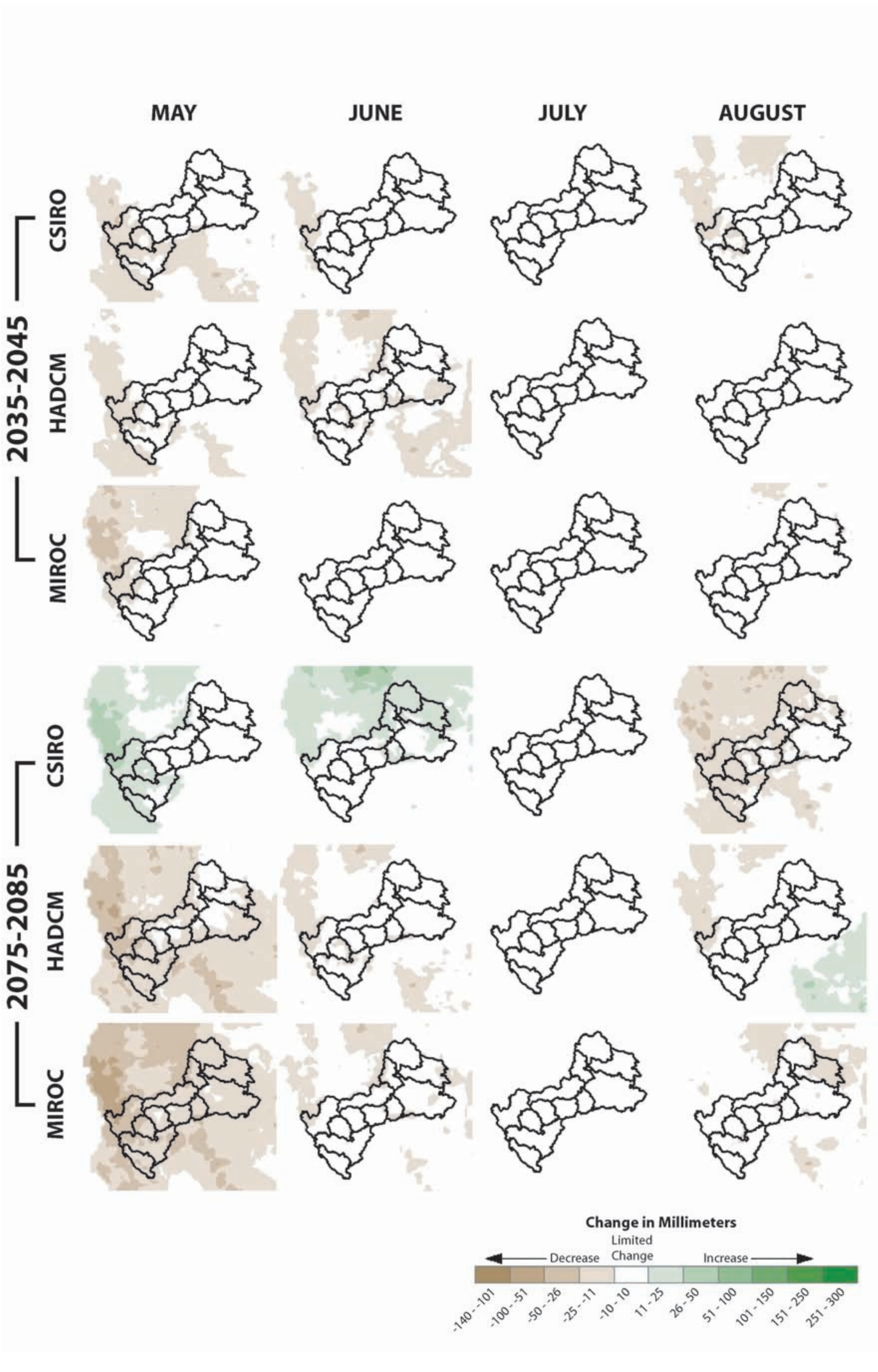
101 - 150
151 - 250
251 - 300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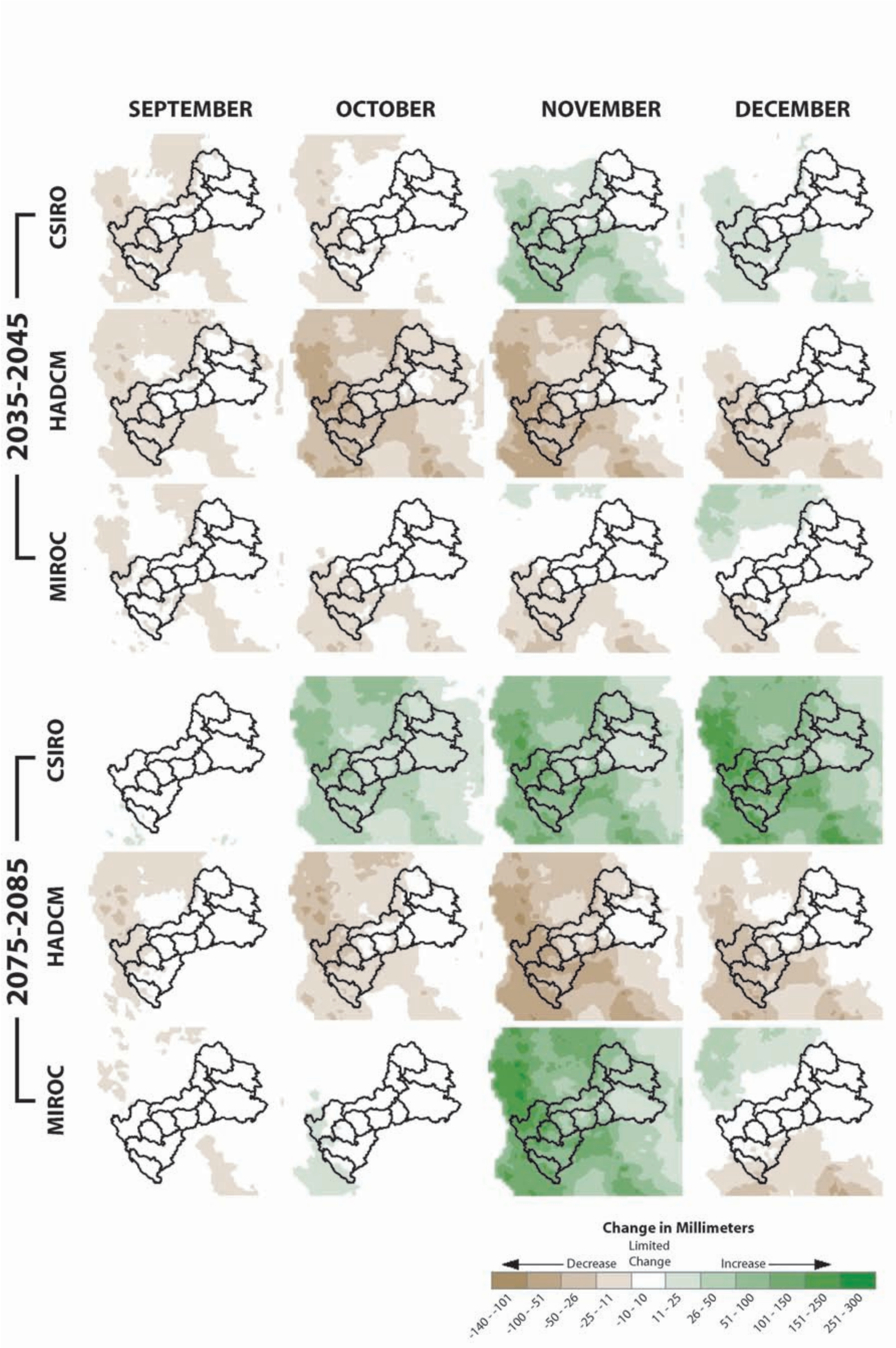
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-50 - -26
-25 - -11
-10 - 10
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151 - 250
251 - 300

VEGETATION and WILDFIRE

The MAPSS team vegetation model (MC1) provided projections for predominant vegetation types and proportion of the area burned annually by wildfire. A decline in conditions suitable for maritime conifer forest (redwood, Douglas fir, and Sitka spruce) and an expansion of conditions for oaks and madrone is projected, particularly in the Lower Basin (Figure 11). In the Upper Basin, areas currently suitable for sagebrush and piñon/juniper may shift to grasslands. Despite changed growing conditions, vegetation can take decades or centuries to adjust. Mechanisms for vegetation change are likely to be fire, logging, insects and disease. The percentage of the Basin burned by wildfire is expected to increase by 2075-85, from 2.7% to 3.0-3.3% per year (an increase of 11-22% compared to historical average), resulting in up to 330,000 acres (145,200 ha) burned, on average, each year (Figure 12).

Figure 11. Suitable growing conditions for dominant types of vegetation.

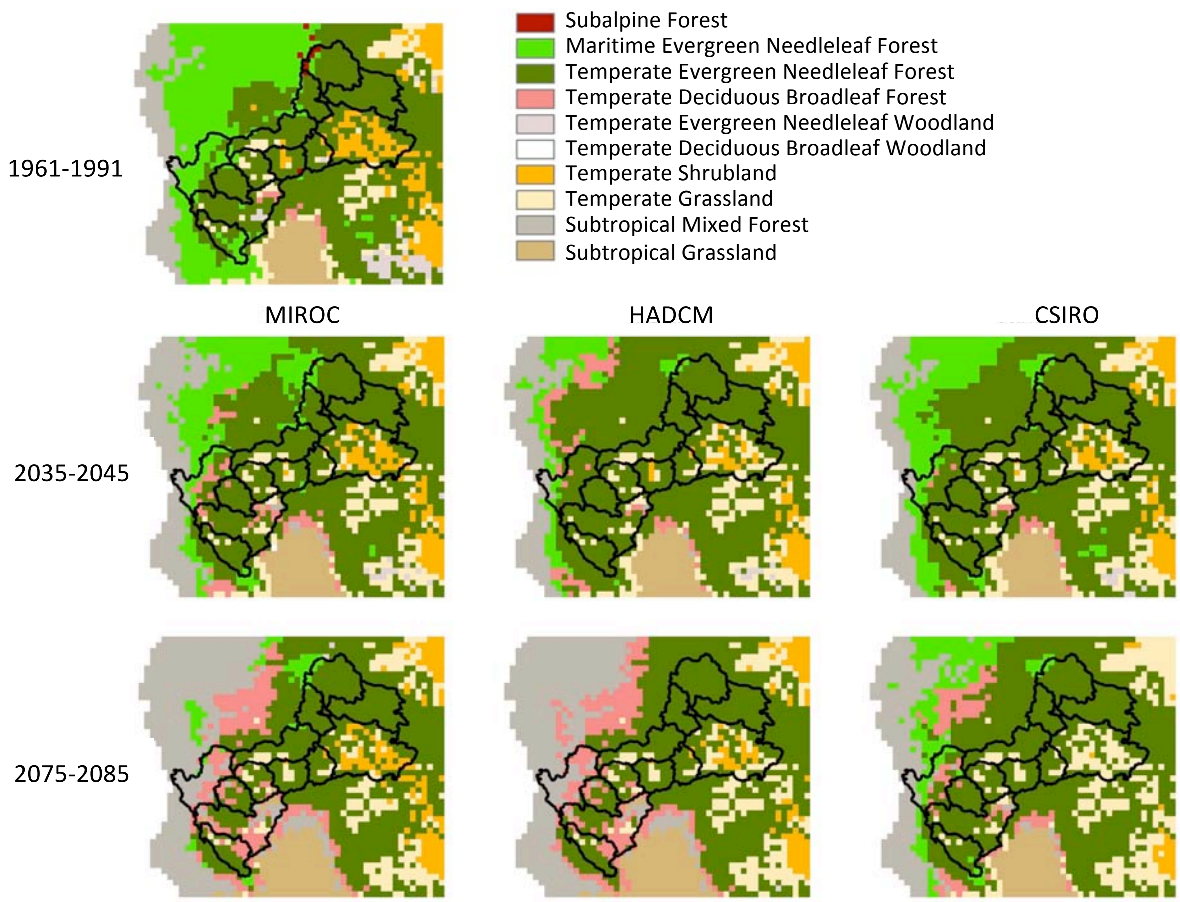
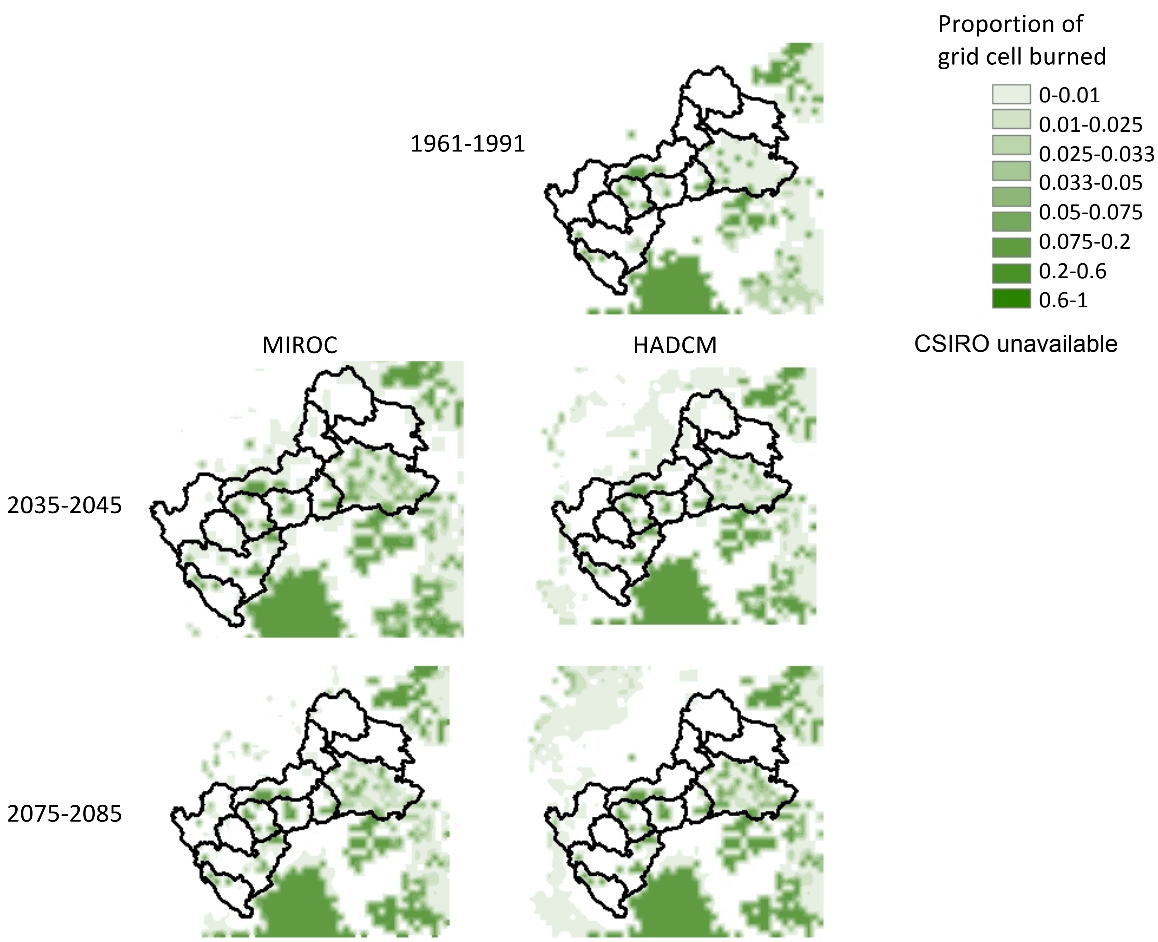


Figure 12. Average proportion of each grid cell (8km x 8km) burned annually in the Klamath Basin, shown for the historical period (1961-1991) and projected for two future periods (2035-45 and 2075-85), using two global climate models (MIROC and HADCM; results from CSIRO were unavailable) .



ANNUAL RUNOFF

Future annual stream flow was calculated based on the relationship between model derived runoff estimates and actual stream gage measurements at four gaging stations in the Basin (Klamath River at Iron Gate, Sprague River, Shasta River, and Salmon River). Projected annual stream flows at each station were more variable than past records. Two models project slightly lower annual stream flows while the other model projects slightly higher flows (Figure 13).

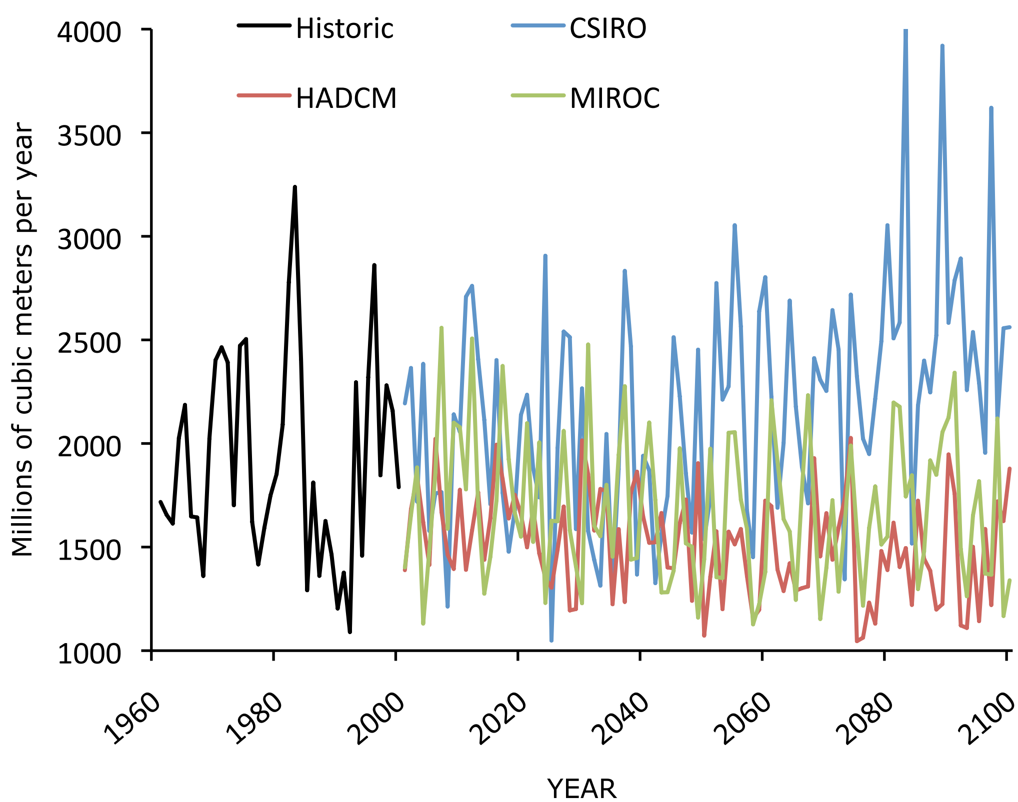


Figure 13. Mean annual runoff at the Iron Gate gaging station, in millions of m^3/year. Runoff for three other Klamath Basin gaging stations had similar projections but are not presented in this report; they are available on our website (www.nccsp.org).

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