PROJECTED FUTURE CONDITIONS IN THE MID WILLAMETTE RIVER SUBBASIN OF WESTERN OREGON:

MARION, POLK, YAMHILL, LINN & BENTON COUNTIES

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INTRODUCTION

The Willamette Basin, stretching from Cottage Grove in the south to Portland in the north, is home to 68% of Oregon's population.[1] The Cascade Range and Coast Range provide barriers on the east and west (respectively) of the Willamette Valley preventing east-west movement. Along the Interstate 5 corridor ,running north-south, major population centers have developed such as Portland, Salem and Eugene/Springfield.

Major tributaries to the Basin include the Calapooya, Clackamas, Coast Fork, Long Tom, Luckiamute, McKenzie, Mary's, Middle Fork, Molalla, Santiam, Tualatin and Yamhill Rivers. With its fertile soils, the River Basin has attracted settlers since the early 1800s. The entire Willamette Basin includes a land area of 11,500 square miles, a population of 2.5 million and about 75% of Oregon's economy.

The Mid Willamette Subbasin, defined for the purposes of this assessment as the counties of Marion, Polk, Yamhill, Linn and Benton, is rich in history, culture and biological diversity. The Mid Willamette historically was a mix of wildlife habitats, including wetlands, meandering streams, and seasonal marshes. In addition to naturally occurring wildfires, the Kalapuya Indians set fires to help maintain the grasslands. Many of the naturally occurring grasslands have been converted to farmland and growing cities, which now dominate the Valley.

Figure 1. Map of Willamette River Basin with Subbasin red-shaded (Marion, Polk, Yamhill, Linn and Benton counties).

In the Mid Willamette region of the Basin, state government and university employment are major employers in the cities of Salem and Corvallis, while agriculture is dominate throughout the Subbasin. It is well known for its fruits and berries, grass seeds, nursery stock, hops, filberts and wine grapes.

This report in intended to provide an ecological overview of the Subbasin and localized projections of the consequences of climate change in the Mid Willamette Subbasin. It is provided to support climate preparedness and adaptation, planning and policy development in the Mid Willamette. The climate

[1] Pacific Northwest Ecosystem Research Consortium Willamette River Basin Atlas. http://www.fsl.orst.edu/pnwerc/wrb/Atlas_web_compressed/PDFtoc.html

change models presented in this report were mapped by scientists at the Oregon Climate Change Research Institute. The Climate Leadership Initiative at the University of Oregon helped develop this summary of the assessment.

MODELS & LIMITATIONS

Preparing and planning for climate change is, above all, an exercise in risk management. Traditionally, future planning has been based on historical conditions and experiences. However, that approach is no longer reliable as climate change will produce never before seen changes in temperature, precipitation, streamflow, vegetation and fire patterns. To understand the possible impacts on natural, built, economic, human and cultural systems, climate models are used to project future conditions.

Understanding what actions should be taken to prepare for climate change is challenging as the Earth's climate and ocean systems are too complex to be simulated in a laboratory experiment or reactor. Therefore, climate scientists use global climate models to estimate how climate change might affect conditions in mid- and end-of-century. These climate models incorporate the physical laws and chemical interactions of the Earth. Future conditions are calculated based on different "scenarios" (or estimations) of future greenhouse gas emissions, policies and regulations that would limit emissions, technological improvements, and behavioral changes. (For the scenarios selected in this project, please see below.) In order to test the climate models, they are backcasted against observed data to see how well they "predict" the past. While each of the inputs to the models are the same, they vary in their level of detail and manner of interpretation. The results cause differences in outputs creating some uncertainty as to which future scenario is most likely to occur -- and therefore the importance of running multiple models. The difference in detail and interpretation causing this uncertainty is due to processes and feedbacks between different parts of the Earth's climate system that are not fully understood. We account for these variances by comparing groups of climate models, making it possible to project a credible range of possible future conditions.

Most climate models are created at global scales, but are difficult to downsize to local or regional scales because the more localized they become the greater the chance of errors and uncertainty. However, managers and policymakers need regional and local data that reflect how climate change will impact their region in order to plan and develop policies. In response, the Oregon Climate Change Research Institute (OCCRI) has adjusted global model

results to local and regional scales to support this effort.

The Intergovernmental Panel on Climate Change (IPCC) uses approximately 27 models to make global climate projections. While the models use the same inputs, they interpret reactions differently and therefore provide slightly different results. The models are developed by different institutions in different countries around the world and are subject to different interpretations.

OCCRI has selected the following models for use in the Mid Willamette Subbasin project based on their ability to perform well in the Northwest:

- **PCM1**: The Parallel Climate Model, developed through a collaboration of United States federal agencies.
- **CSIRO-MK3**: Developed by the Atmospheric Research Office in Australia.
- **HadCM3**: Developed by the Met Office, the national weather office for the United Kingdom.
- **MIROC**: A Japanese model used for the MC1 vegetation models (shown in results for fire and vegetation projections).

These models were selected because they use temperature and precipitation forcing agents including changes in greenhouse gas emissions, aerosols, water vapor and cloud cover, solar radiation, and changes in land use to represent possible future conditions.

To further refine these projected futures, the IPCC has developed a range of scenarios under which climate models are run. These scenarios, as described in the IPCC's Special Report on Emissions Scenarios (SRES), describe different futures for greenhouse gas emissions, land use, and agricultural practices based on global policy decision-making.[2] For this report, two scenarios were selected to model how different futures might play out:

- **A1b**: The business as usual scenario (for which current global emissions are actually exceeding) that presumes continued growth in economies, population and technology, and reliance on mixed energy sources.
- **B1**: The 'greener' emissions scenario, which suggests emissions increasing slightly in the coming decades but then falling to lower than current levels by 2100 due to deployment of low carbon energy and transportation systems.

Model outputs were converted to local scales using local data on recent temperature and precipitation patterns. The MC1 vegetation model provides information on possible future vegetation types and wildfire patterns. The utility of the model results presented in this report is to assist public and private entities with envisioning what the conditions and landscape may look like in the future as well as the potential magnitude and direction of change.

It is important to note that the scenarios described should be considered **possible outcomes** rather than definite predictions. Actual conditions may vary quite substantially from those depicted in these scenarios. Readers are

[2] For more information on SRES, visit: http://www.ipcc-data.org/ddc_envdata.html

therefore urged to focus on the **range of projections** and the trends they suggest, as opposed to relying on the outputs of a single model or on a particular number.

GLOBAL CLIMATE CHANGE PROJECTIONS

The IPCC[3] and the U.S. Global Change Research Program[4] 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 land conversion and deforestation. Average global air temperature has already increased by 0.7° C (1.4° F) over the last hundred years and is expected to increase up to 6.4° C (11.5° F) within the next century (Figure 1).

Even with immediate reductions in greenhouse gas emissions, impacts from the current build up of greenhouse gas emissions in the atmosphere will continue to be felt for decades. It may take equally as long or even centuries to restabilize the system. Reducing emissions is a vital mitigation measure to reduce further impacts on climate systems. Additionally, countries and communities must also begin to plan and prepare for the likely impacts that will be experienced as a result of the emissions already present in the atmosphere. By taking proactive steps to plan for changes, residents of the Mid Willamette will be better positioned to build resistance and resiliency within the systems they depend on for maintaining quality of life under a climate changed future.

When using projections to prepare for climate change, we must consider how to deal with the uncertainty of models and make decisions that are robust against a range of future scenarios. One approach is finding

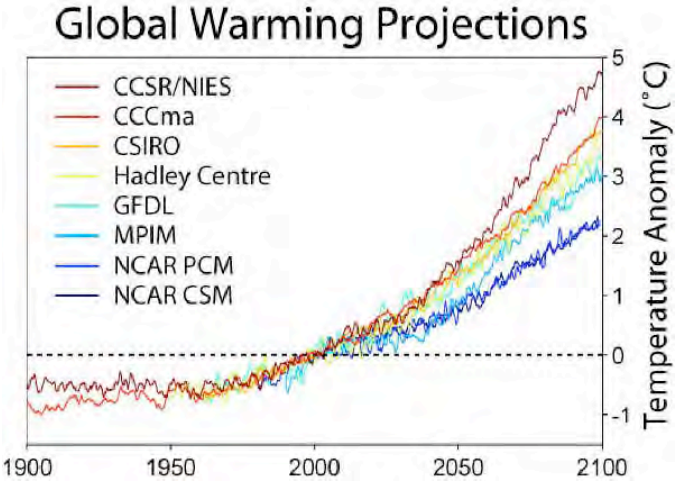


Figure 2. Projections for global temperature increase for a number of models used by the IPCC, compared with temperatures over the last one hundred years. Note that while projections for temperature increase vary by the end of the century, all models show a clear upward trend. (From IPCC 2007)

[3] 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.
[4] USGCRP 2009. Global Climate Change Impacts in the United States. T. R. Karl, J. M. Melillo, and T. C. Peterson,(eds.). Cambridge University Press.

consistency in models; another approach is finding consistency in strategies that are effective no matter what change occurs. This will most likely involve building system resilience and resistance, as well as flexibility into the planning process.

SELECT RESOURCES FOR CURRENT ENVIRONMENTAL CONDITIONS WITHIN THE MID WILLAMETTE SUBBASIN

Oregon Department of Environmental Quality. 2008 Air Annual Report. http://www.deq.state.or.us/aq/forms/2008AQreport.pdf

Department of Environmental Quality Willamette Basin Report. 2009. http://www.deq.state.or.us/about/eqc/agendas/attachments/2009oct/F-WillametteBasinAssessmentRpt.pdf

Oregon State University - Institute for Natural Resources - Oregon Explorer http://inr.oregonstate.edu/oregon_explorer.html

Oregon State University - Oregon Natural Heritage Information Center http://oregonstate.edu/ornhic/index.html

Oregon State University - Willamette Basin Explorer http://www.willametteexplorer.info/

CLIMATE PROJECTIONS FOR THE MID WILLAMETTE: YAMHILL, MARION, POLK, LINN & BENTON COUNTIES OF WESTERN OREGON

Outputs of our climate models (PCM, CSIRO, and HadCM) and the vegetation model (MC1) include projections for changes in temperature, precipitation, percent of landscape burned, suitable vegetation types and distribution, snowpack, and streamflow. A historical baseline of 1971-2000 was used in order to make comparisons of projections for the 2040s (2030-2059) and 2080s (2070-2099) (scientists use thirty year time slices, or averages, to account for interannual and interdecadel variability). Stream data is for 2020s and 2040s due to data availability. The results present a range of different possible future conditions in the Subbasin. Unforeseen circumstances such as uncertainties about chemical reactions or international policy to drastically reduce greenhouse gas emissions may result in a future different than has been projected.

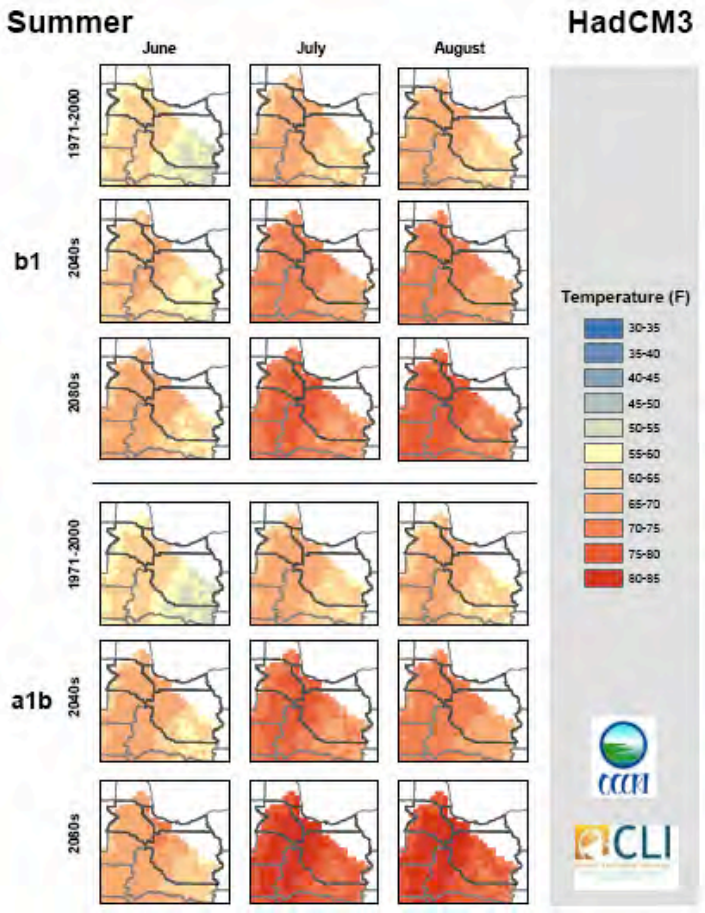


Figure 3. Summer temperature change for HadCM model under both emissions scenarios for mid and end of century.

Climate change projections are provided in this document as bar graphs, charts and spatial maps to demonstrate the results of the modeling using a variety of visualizations that may be useful for different decision-making groups. Samples for each factor are posted below: the full suite of maps, charts and graphs can be found in the appendix at the end of the document.

The projections presented below come from the global modeling results available from the IPCC Fourth Assessment Report. Implications for the Pacific Northwest and are based on the twenty global climate models analyzed by Mote and Salathé (2009). For an historical baseline, 800m PRISM 1971-2000 climate grids were used to apply to the analysis and downscale the data.

Temperature

The three models consistently show an annual average increase in

temperature for all seasons under both the B1 and A1b scenarios (5-8 degrees F). The most severe change in temperature is during the late summer months of August and September. The HadCM model shows the greatest increase in temperature of up to 10-15 degrees F in the summer months by the end of the century.

Precipitation

Modeling projections show slightly less precipitation in summer and winter for the PCM1 and HadCM models, with little change during the fall and spring months. The CSIRO model shows a slight increase in precipitation in the winter months. The decrease in precipitation for summer months in the Mid Willamette is not shown to be as severe as in other parts of the state.

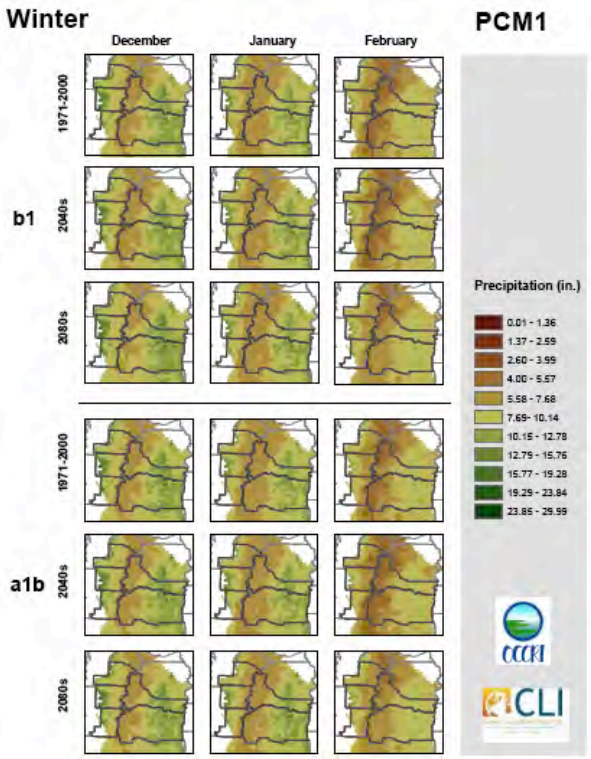


Figure 4. PCM1 projections for precipitation during winter months for both emissions scenarios and mid and end of century.

Vegetation

For Maritime Evergreen Needleleaf species, the HadCM and MIROC models project a significant decline, with near disappearance by the end of the century. CSIRO also shows a decline, but not as severe as the other models. HadCM shows a rapid increase in Temperate Evergreen Needleleaf species, replacing Maritime species. MIROC and CSIRO also project an increase in Temperate Evergreen species, but not as rapidly as HadCM. Subtropical Mixed Forest species make their appearance around 2020 and increase dramatically after mid-century under the MIROC model, but less change was apparent in the HadCM and CSIRO models (see additional maps in Appendix). The vegetation types are defined as the following:

- Subtropial Mixed Forest: This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. It often gets no frost in any year, but may on occasion. Typical species include diverse mixed pines and hardwoods, with some frost sensitive species such as madrone and evergreen oaks.
- Temperature Evergreen Needleleaf: This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. The difference between summer and winter temperatures is greater; it does freeze regularly. Douglas fir, true firs, and ponderosa pine savannahs are typical.
- Maritime Evergreen Needleleaf: This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. The difference between summer and winter temperatures is relatively small; it does freeze regularly. Coastal spruce and fir are

typical, but with earlier springs there could be an increase in deciduous trees, including oaks.

(Data provided by Ray Drapek, Pacific Northwest Research Station.)

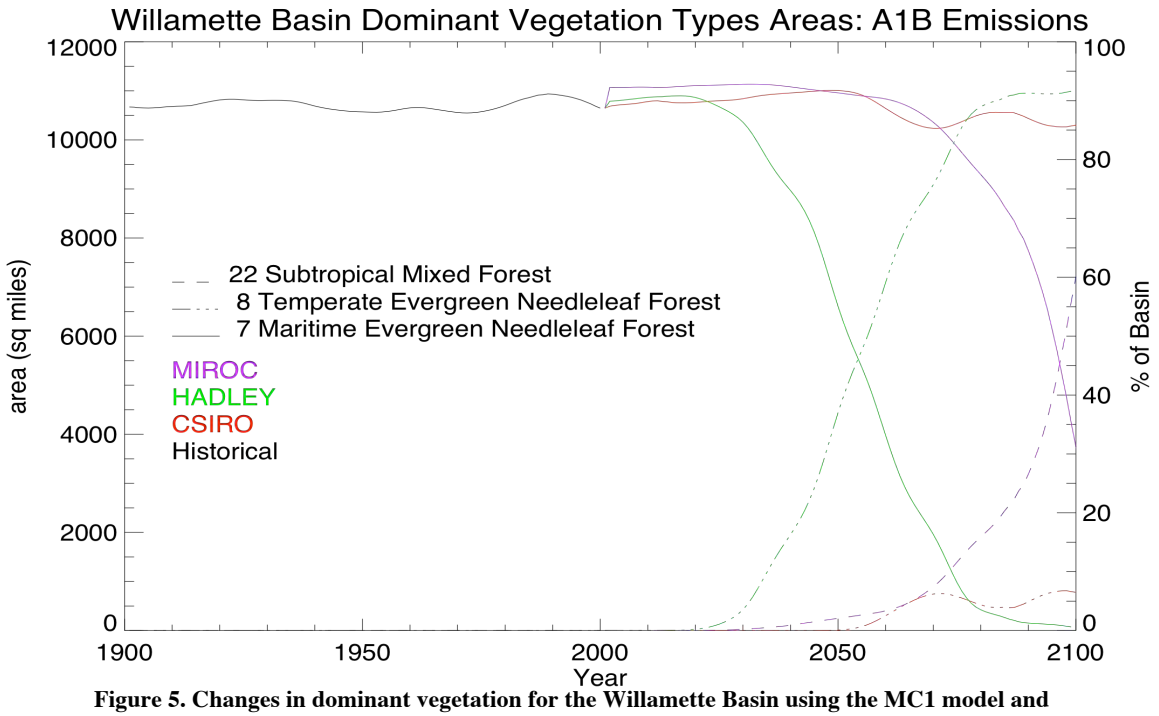


Figure 5. Changes in dominant vegetation for the Willamette Basin using the MC1 model and a1b emissions scenario.

Snow Water Equivalent

Under the A1b scenario, the model projects a severe decrease in snow water equivalent with near disappearance (greater than 80% loss) by the end of the century. (Data provided by Heejun Chang, Portland State University.)

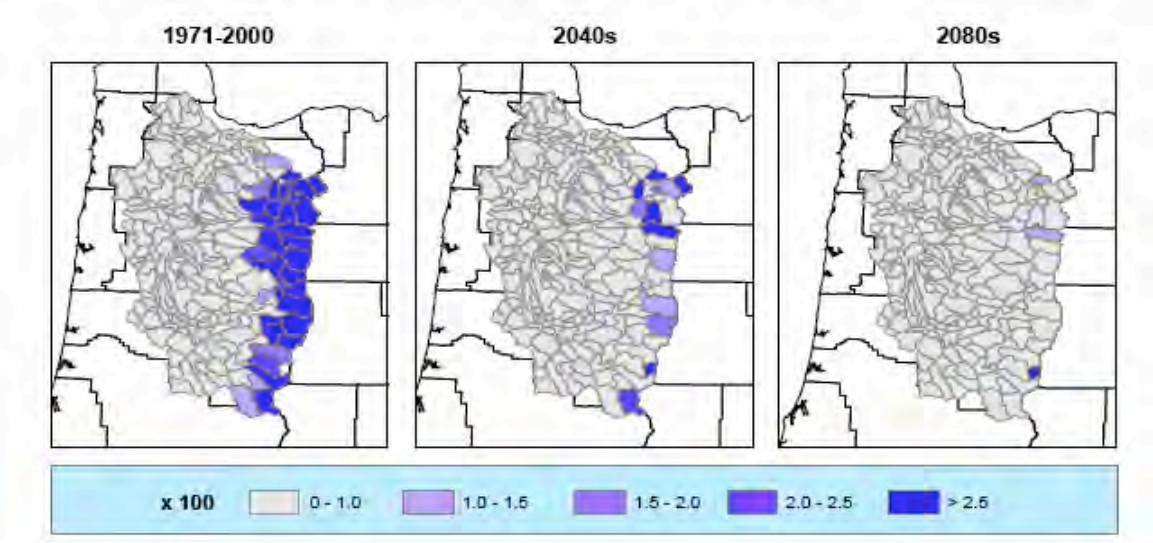


Figure 6. Percent snow water equivalent for the Willamette Valley, historical conditions and mid and end of century projections.

Streamflow

Projections show that streams are likely to become flashier in the winter and early spring– that is, higher high flows with more frequent and severe flooding in winter, and lower low flows with more streams going dry in the summer due to temperature, more precipitation falling as rain, groundwater and storm severity changes. All three models show a severe increase in winter flow, with moderate decrease in historical summer flows. Flow level is provided for the Willamette, South Yamhill and Luckiamute rivers at different city locations.

- Willamette River at Albany shows an increase in stream flow of 88% in the winter, and a decrease of over two thirds of normal summer flow. At Salem, winter stream flow for the Willamette is up 87% in winter, and down by over half in the summer.
- The South Yamhill at McMinnville increases in winter flow by 87%, with about a third lower stream flow in the summer.
- The Luckiamute stream flow at Suver increases by 87% in the winter, and decreases by a little less than half in the summer.

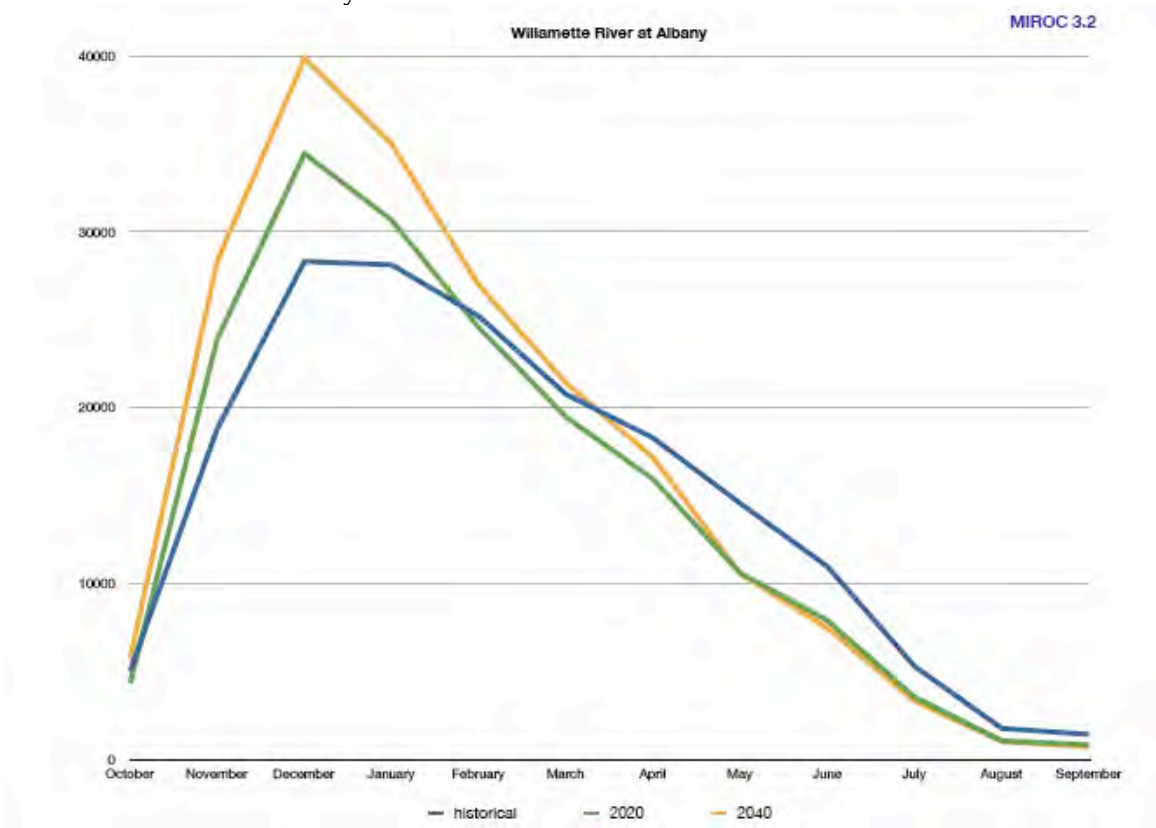


Figure 7. Monthly stream flow for Willamette River at Albany under the MIROC model for 2020 and 2040 compared to historical conditions.

Acres Burned

The data below shows the percent of area in each grid cell (8km) that is projected to be burned for the entire Willamette Basin (note, counties for the Mid-Willamette Subbasin could not be overlaid). Under both scenarios, HadCM

projects a greater proportion burned (almost 2% of each grid cell) by 2080. MIROC and HadCM show an increase in intensity of areas burned (see additional maps in Appendix), especially under the A1b scenario and for the Mid Willamette Subbasin. CSIRO shows less change in proportion burned. (Data provided by Ray Drapek, Pacific Northwest Research Station.)

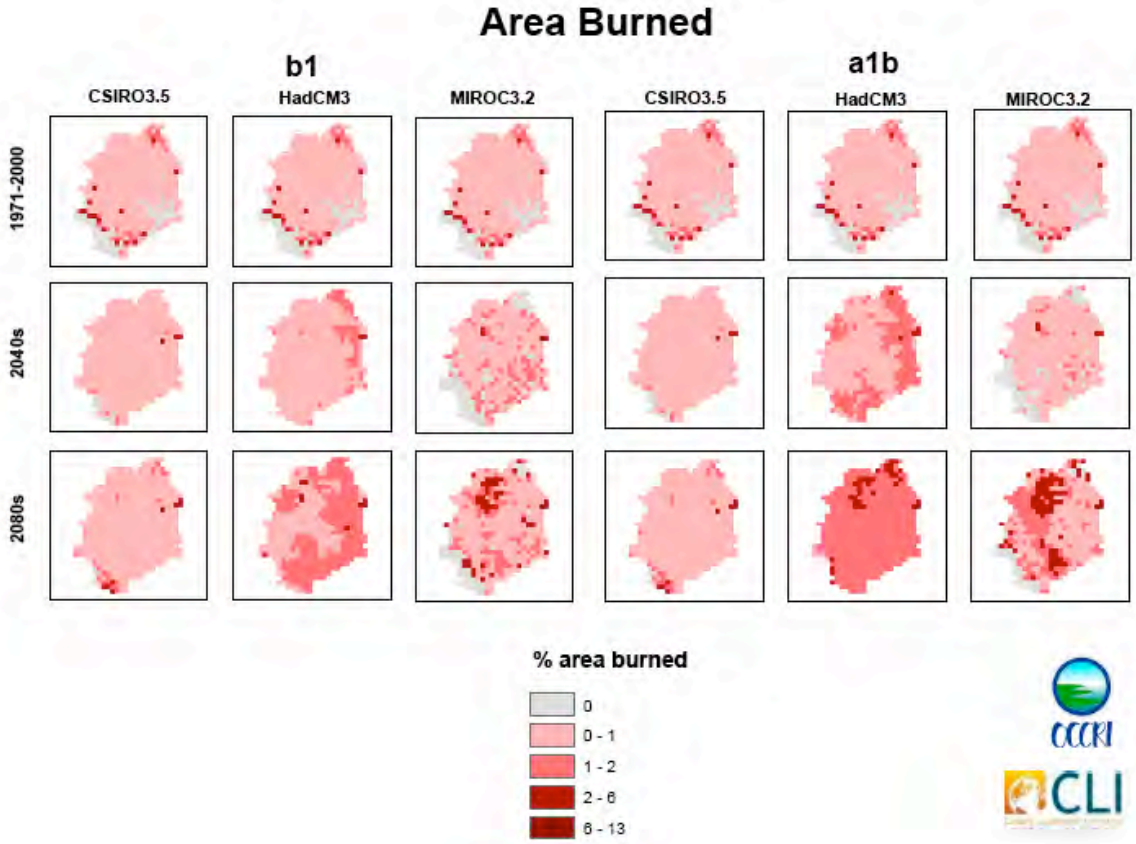


Figure 8. Percent area burned for entire Willamette Valley under both scenarios for CSIRO, HadCM and MIROC.

INTERPRETATIONS OF RESULTS- FEEDBACK REQUESTED

1. How will projected changes in temperature, precipitation, vegetation, streamflow, snowpack, and fire affect the condition of existing species and ecosystems?
2. What species and ecosystems of the Mid Willamette will be most vulnerable?
3. What species and ecosystems of the Mid Willamette will be most buffered?
4. What regions of the Mid Willamette will be most vulnerable to projected impacts?
5. What regions of the Mid Willamette will be most buffered from projected impacts?
6. How might the activities and behaviors of species and systems change as a result of the projections?
7. What new interactions may occur among species and among ecological communities? What are the possible consequences of those interactions?
8. What types of unexpected events or changes might occur? If they were to occur, what are the possible consequences?

RECOMMENDATIONS REQUESTED

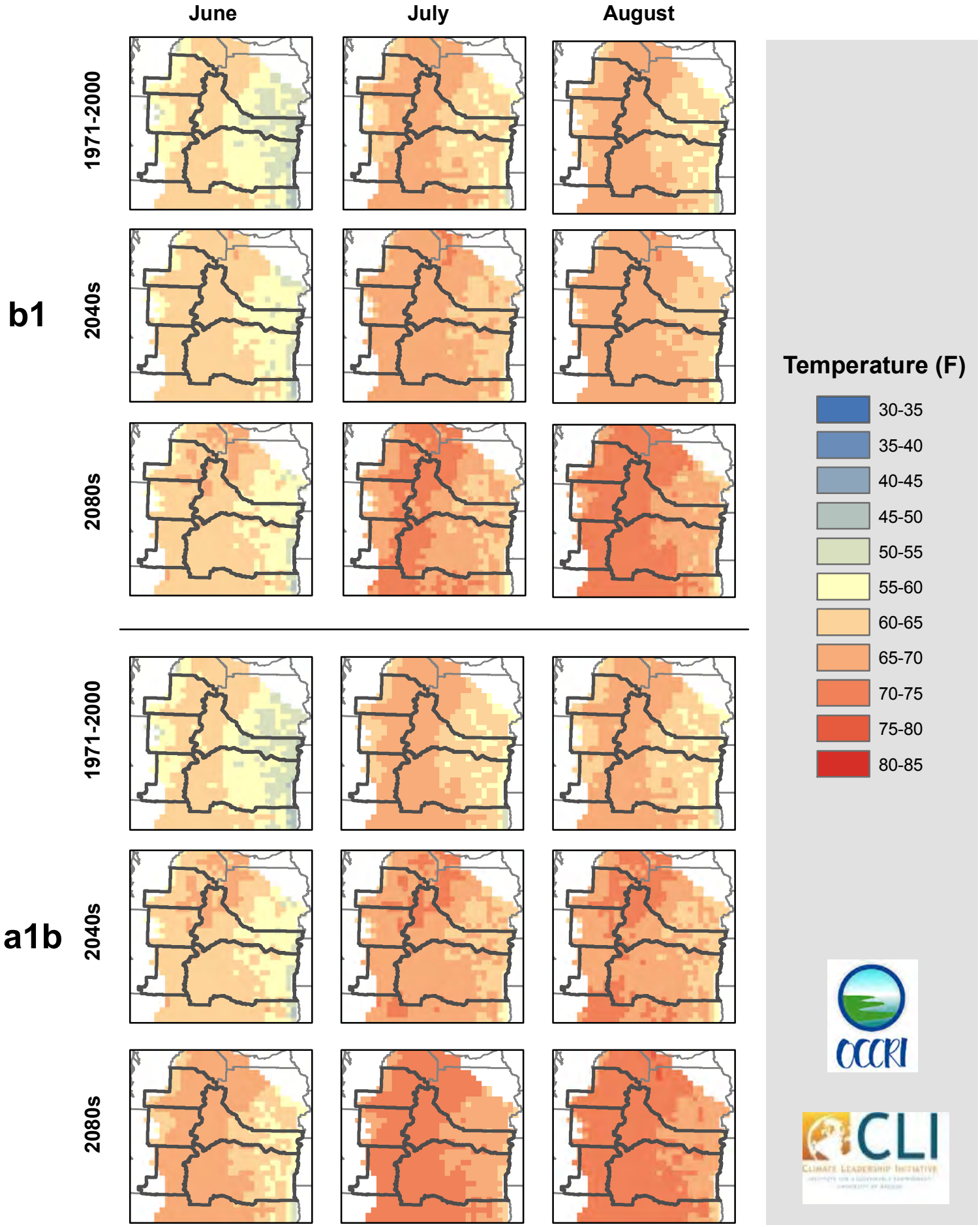
1. What near, mid and long-term actions can be taken to build resistance and resiliency among species and ecosystems?
2. What species, areas, or ecosystem types should be prioritized for management?
3. What actions should be considered urgent? Who should be responsible for taking these actions?
4. How might actions for a single species, ecosystem or region affect other species, ecosystems or resources?
5. What other types of changes might occur that produce cascading effects in other systems or species? If they were to occur, what are the possible consequences?
6. What, if any, are other consequences or impacts that should be considered?

APPENDIX ONE: SPATIAL MAPS AND GRAPHS FOR CLIMATE PROJECTIONS FOR THE MID WILLAMETTE

1. Temperature Projections (Spatial Maps and Bar Graphs)
2. Precipitation Projections (Spatial Maps and Bar Graphs)
3. Stream Flow (Graphs)
4. Vegetation Carbon Consumed by Fire (Graphs)
5. Vegetation Carbon (Graphs)
6. Vegetation Types (Graphs)

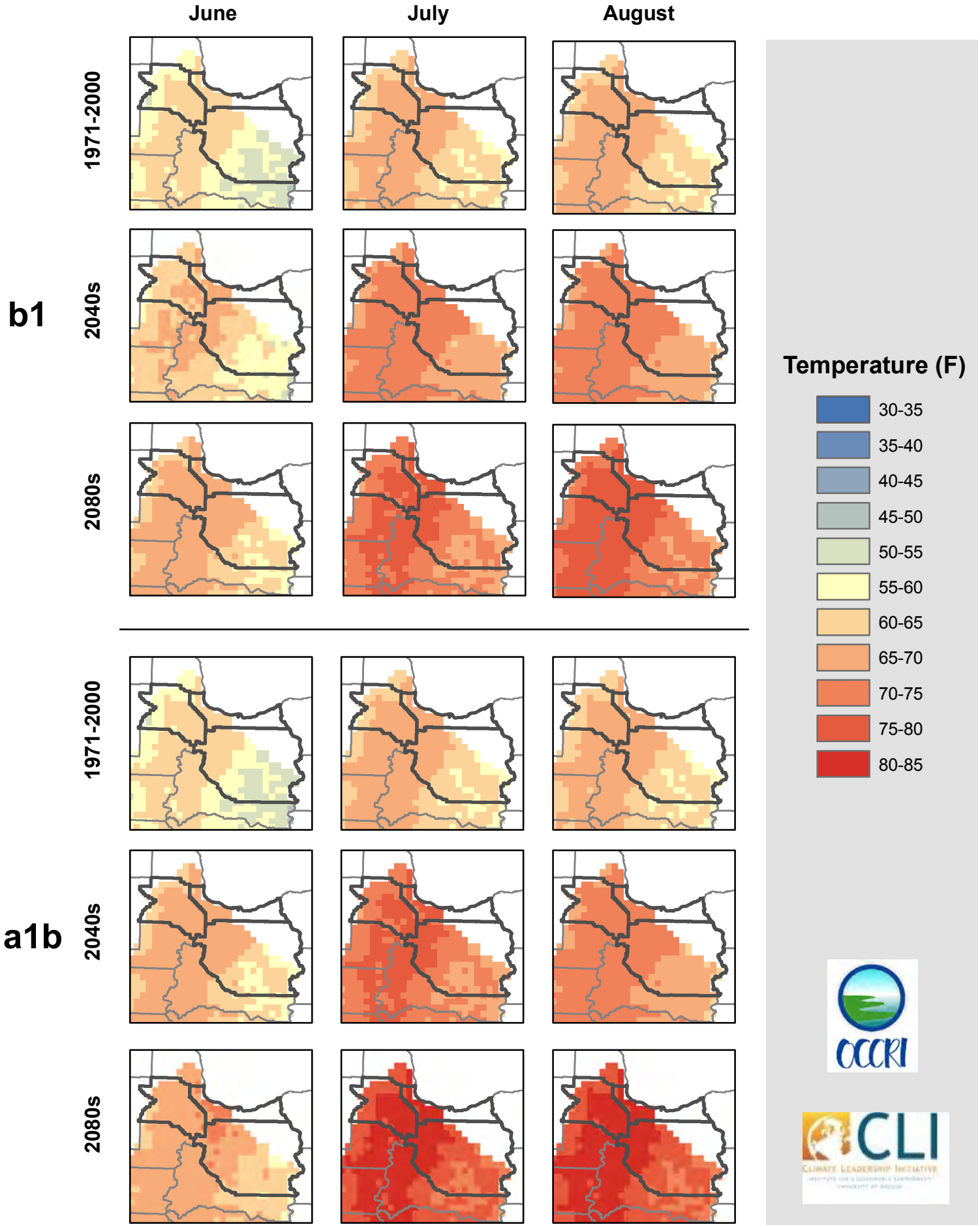
Summer

CSIRO3.5



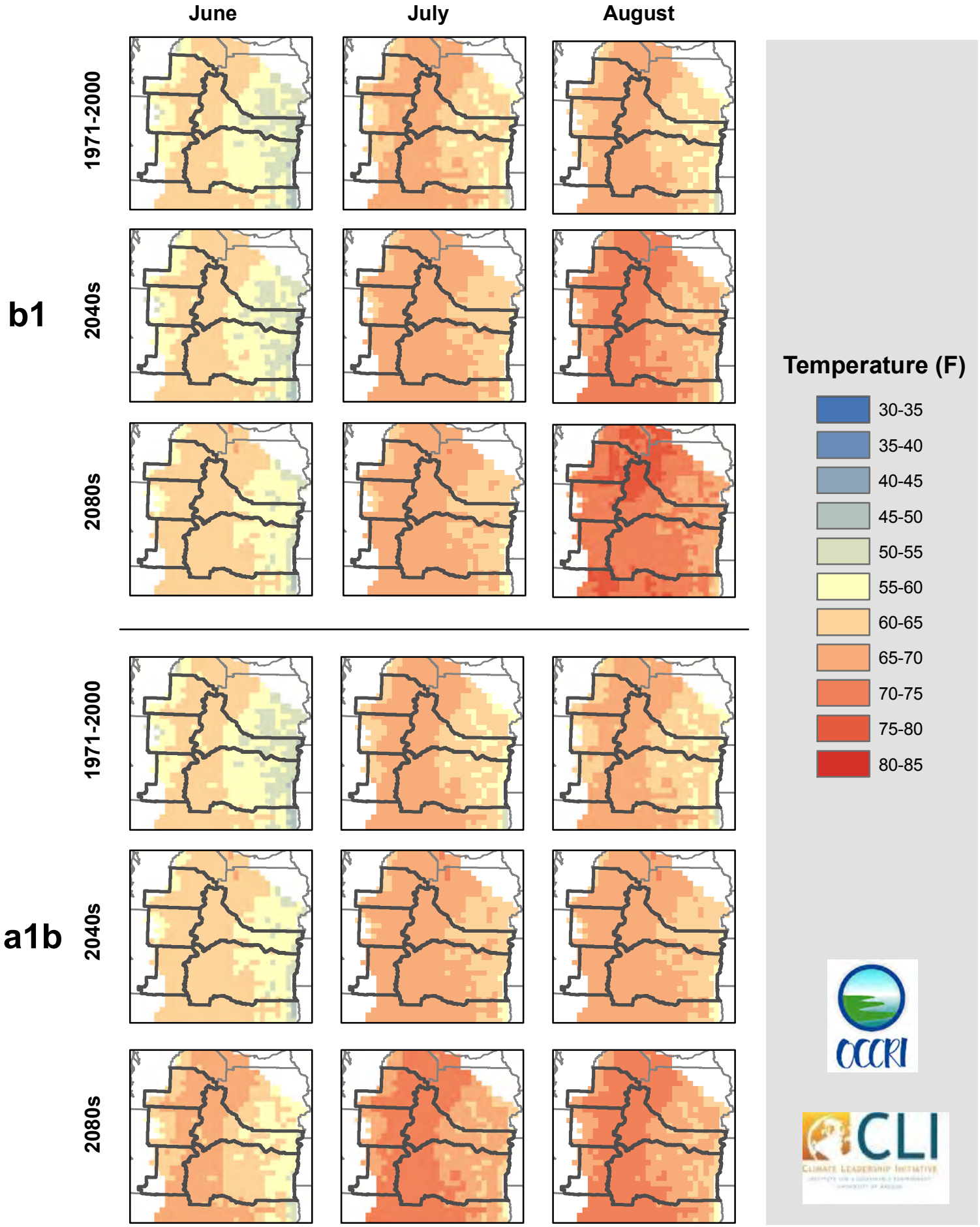
Summer

HadCM3



Summer

PCM1


June
July
August
1971-2000
2040s
2080s
b1
a1b
Temperature (F)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

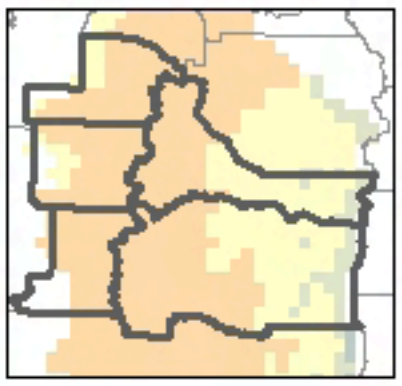
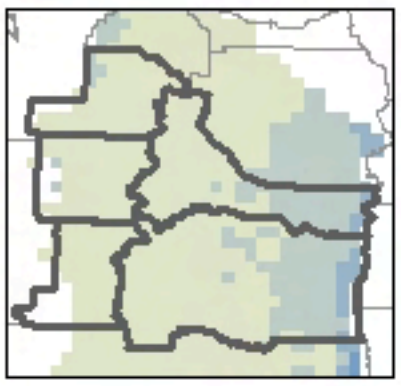
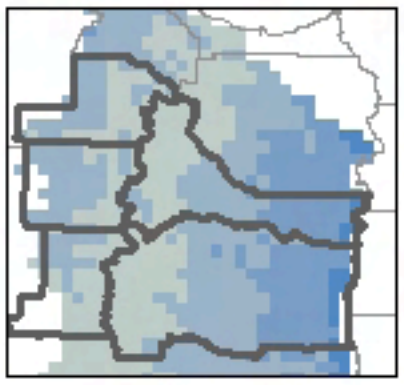
Fall

CSIRO3.5

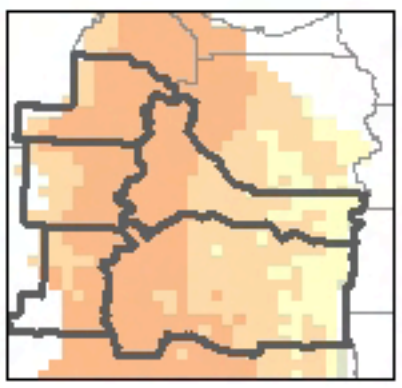
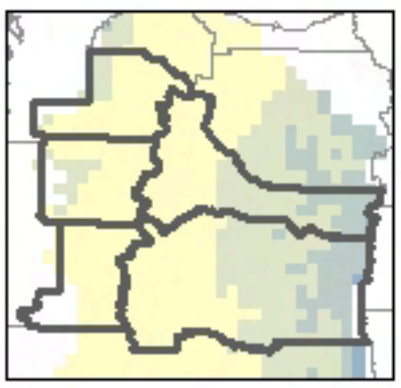
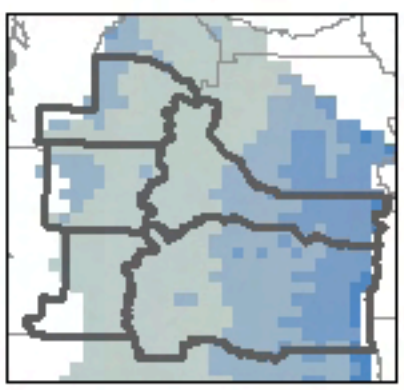
September | October | November

b1

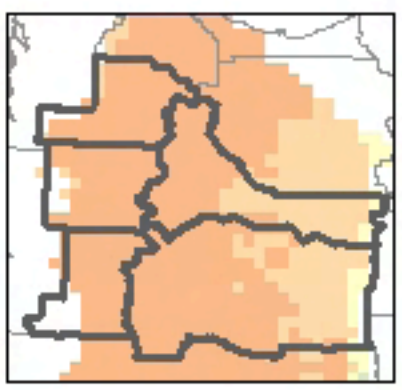
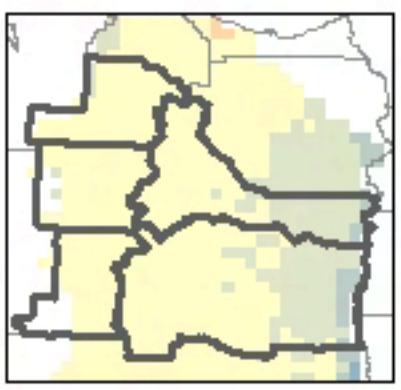
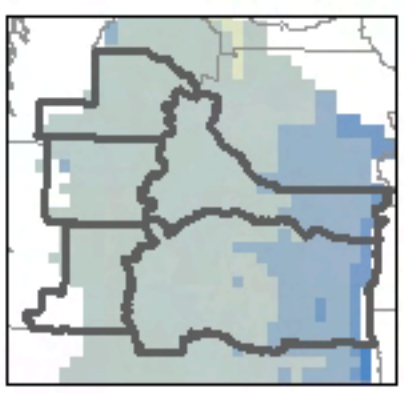
1971-2000

2040s

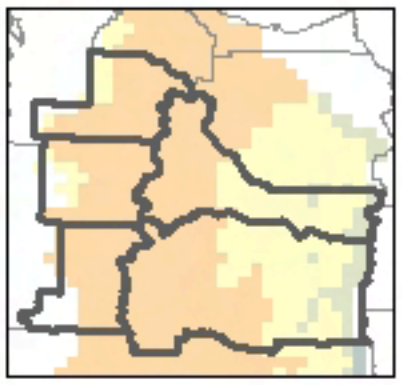
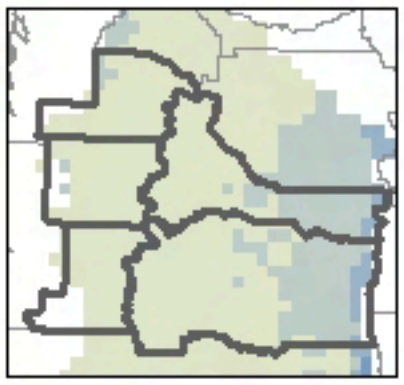
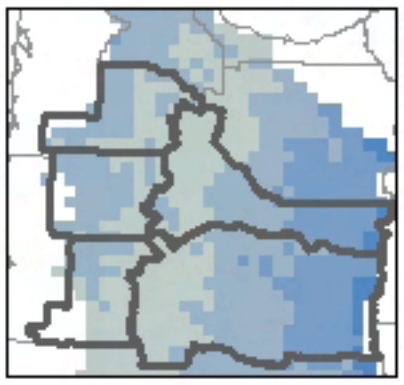




2080s

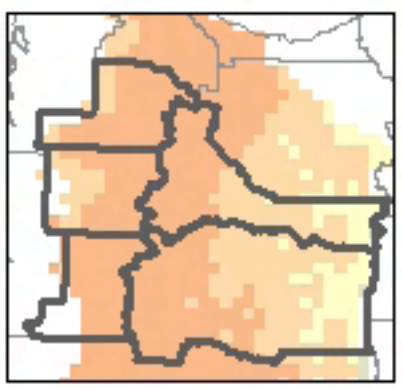
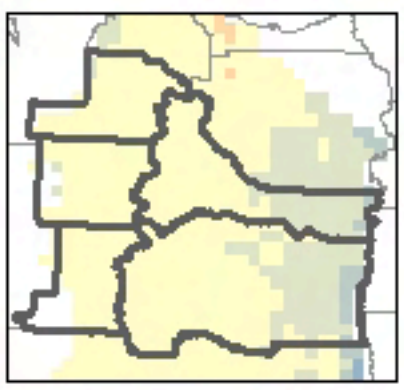
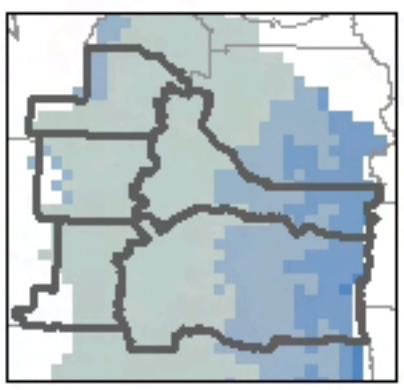




a1b

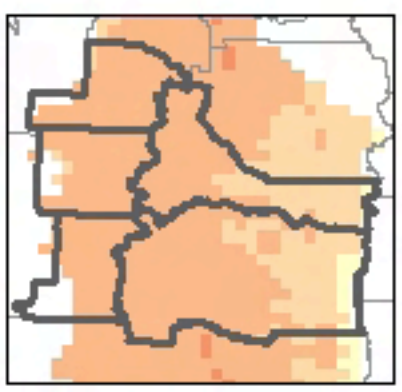
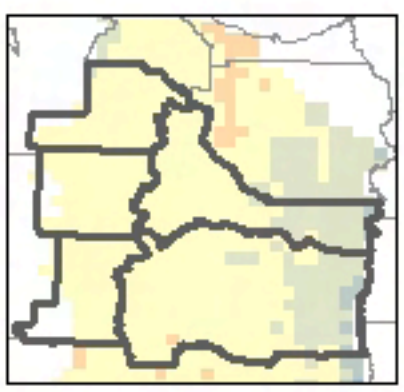
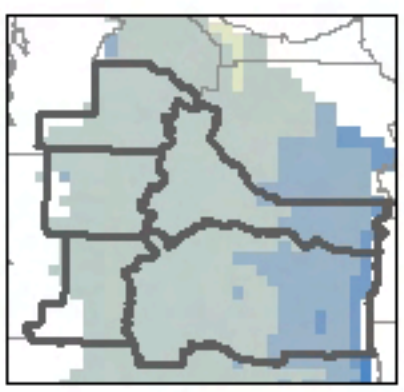
1971-2000

2040s

2080s

Temperature (F)

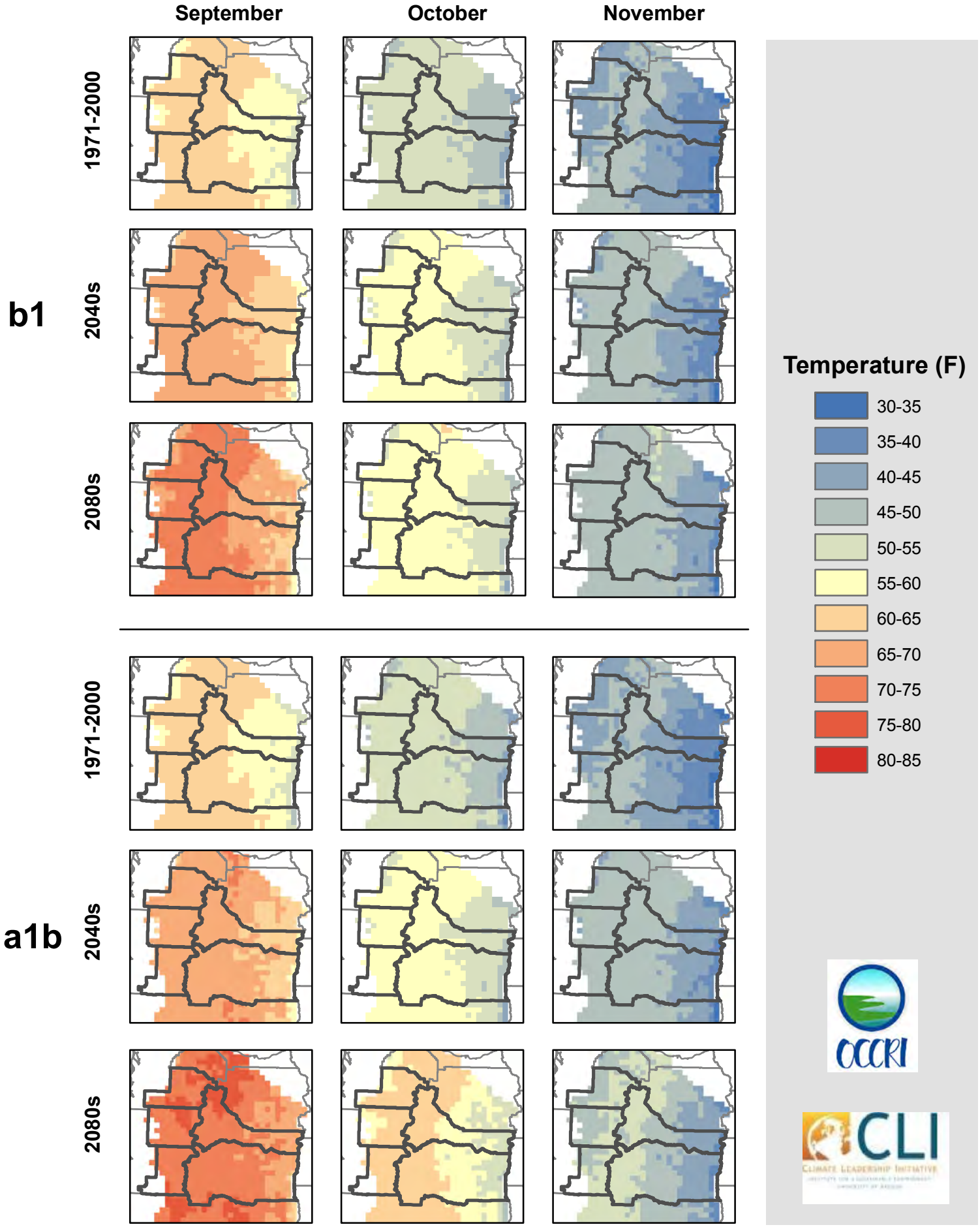
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85

CCCRI

CLI
CLIMATE LEADERSHIP INITIATIVE

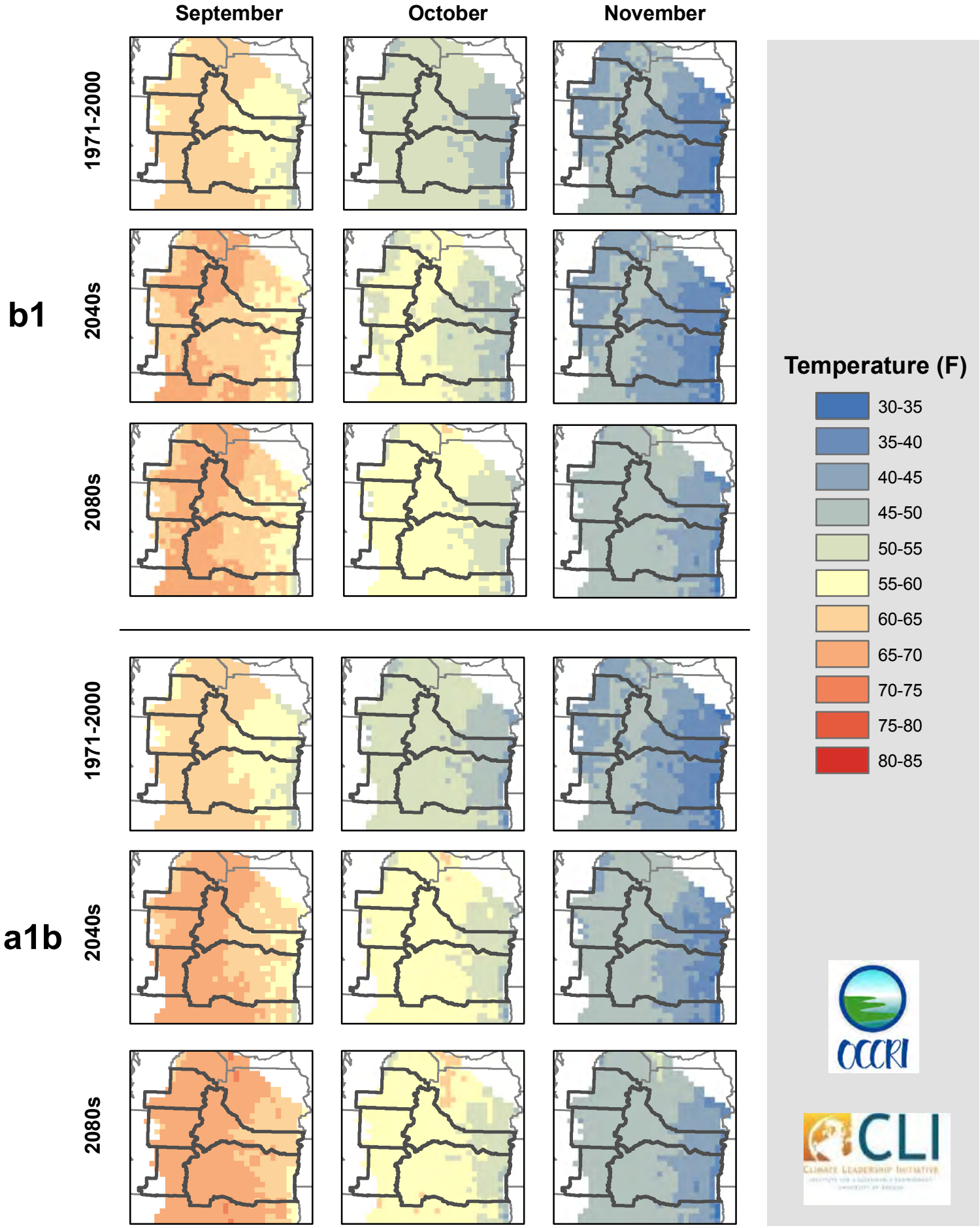
Fall

HadCM3


September
October
November
1971-2000
2040s
2080s
b1
a1b
Temperature (F)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
OCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

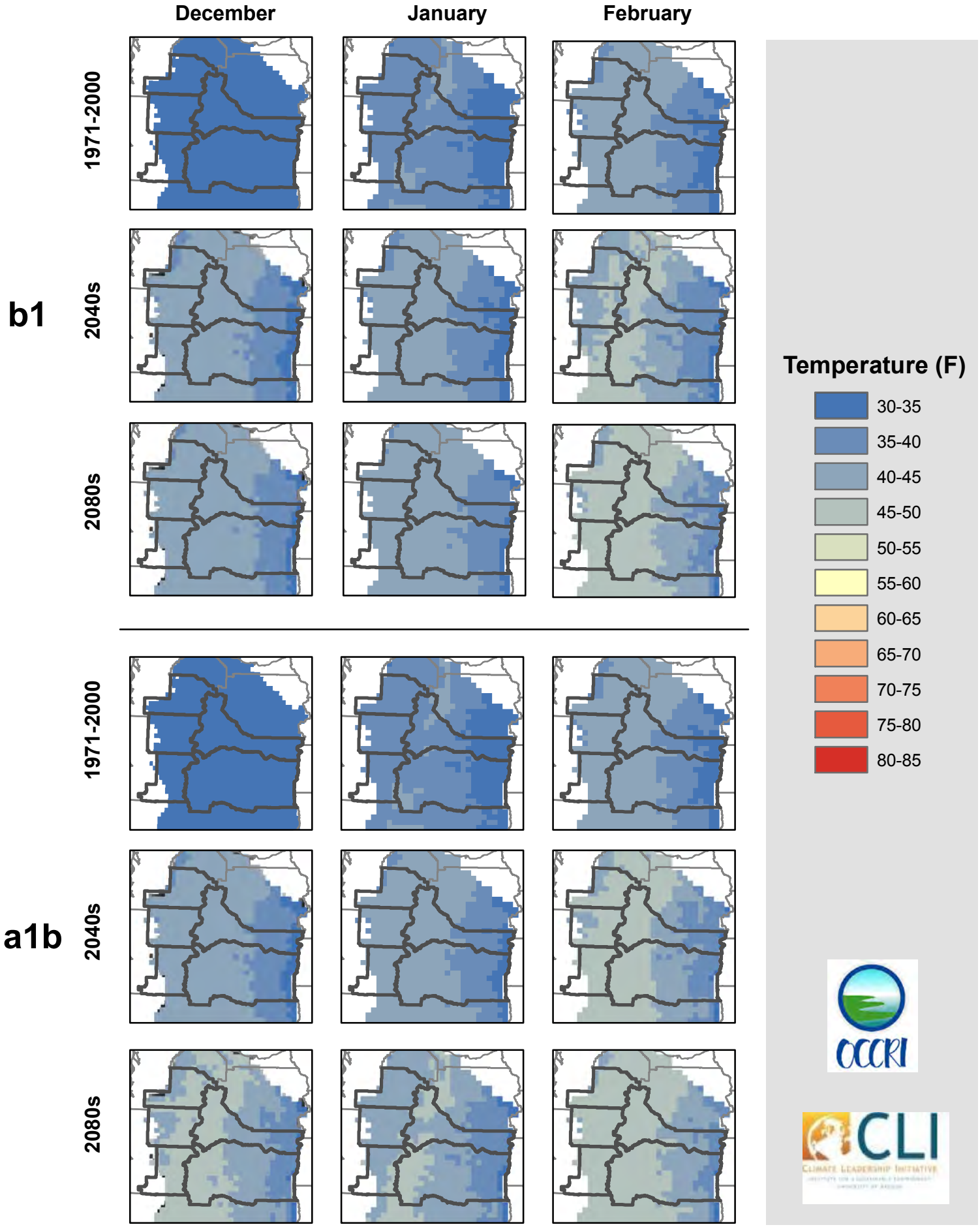
Fall

PCM1


September
October
November
1971-2000
2040s
2080s
b1
a1b
Temperature (F)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
OCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

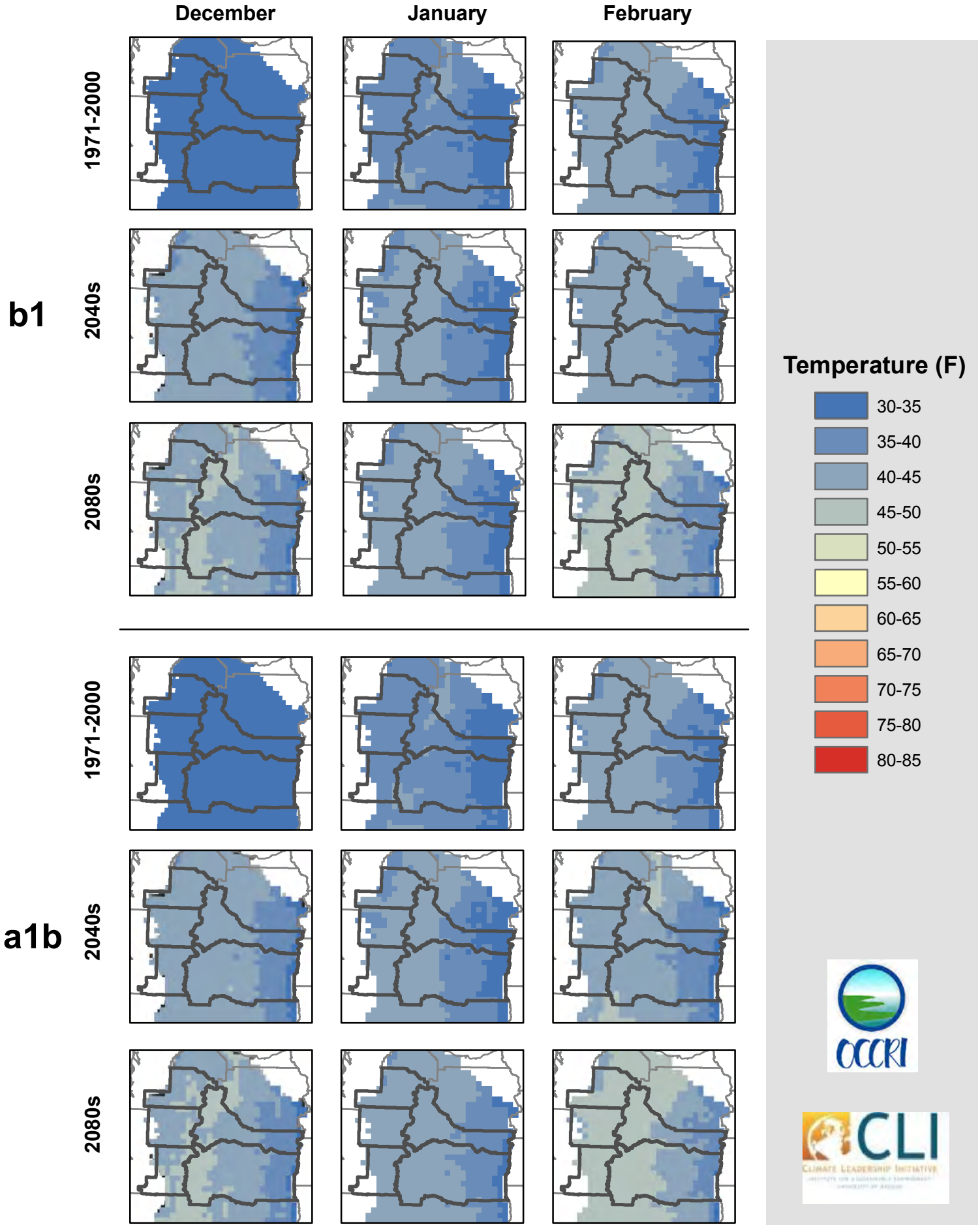
Winter

CSIRO3.5



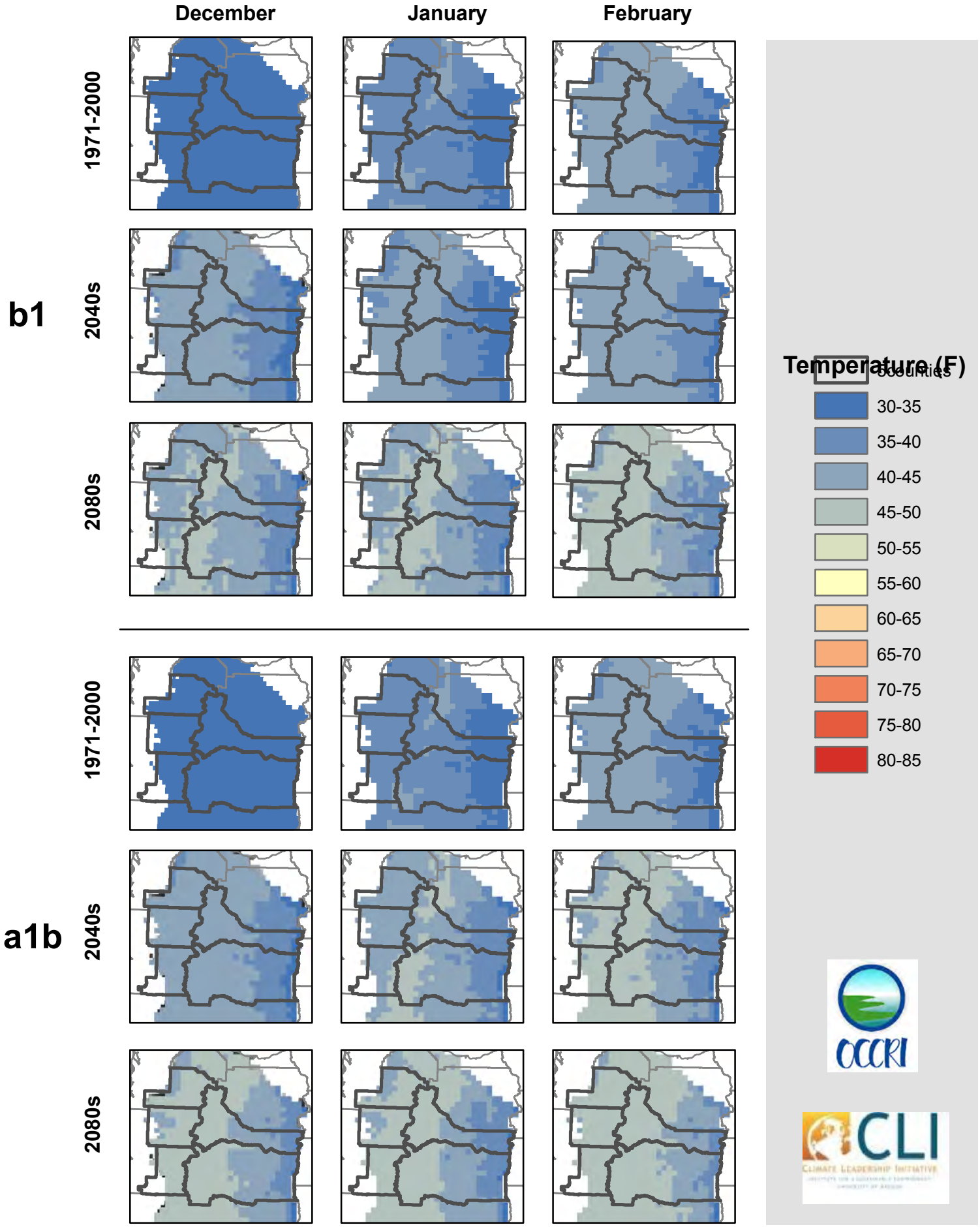
Winter

HadCM3



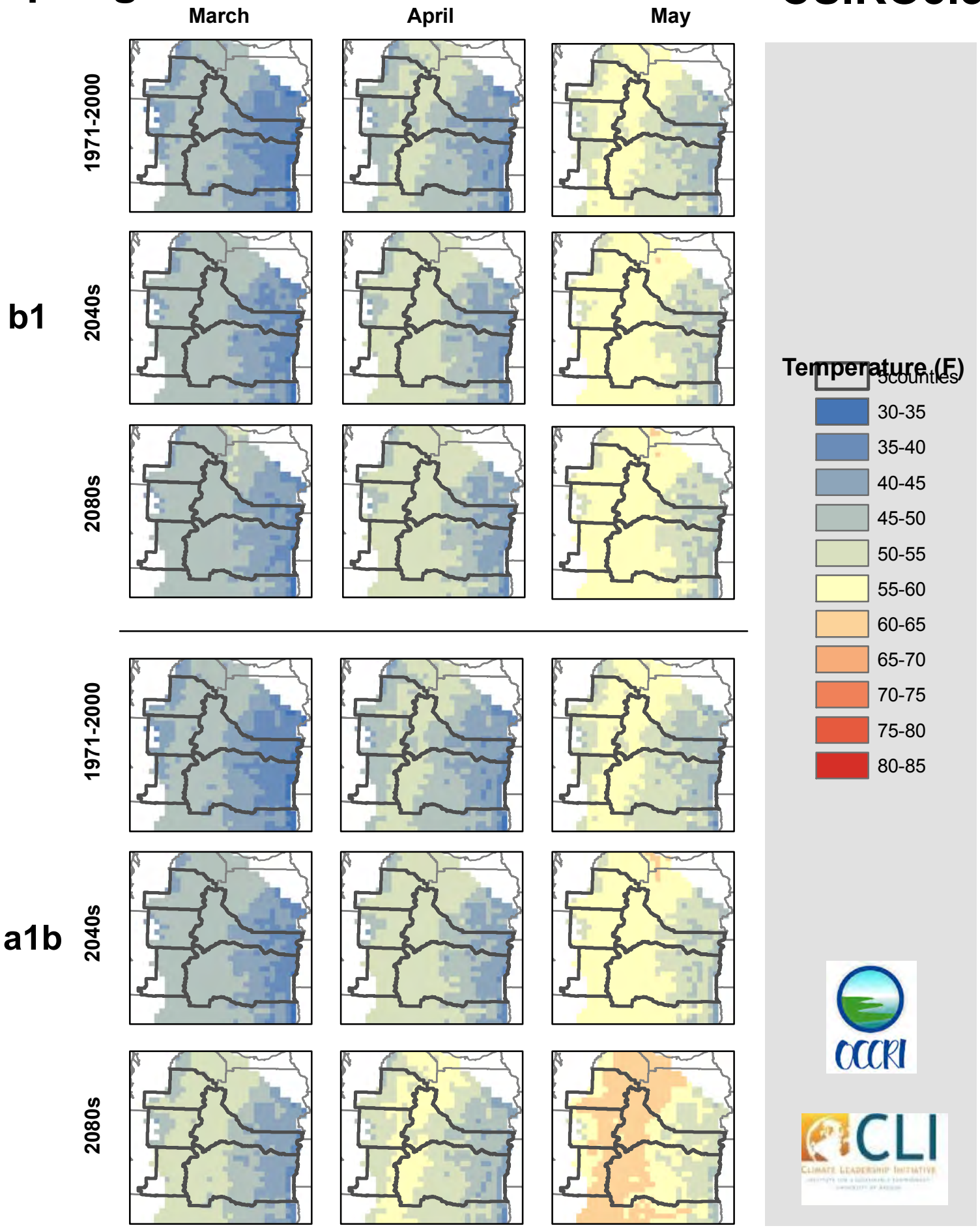
Winter

PCM1


December
January
February
1971-2000
2040s
2080s
b1
a1b
Temperature (F)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
OCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

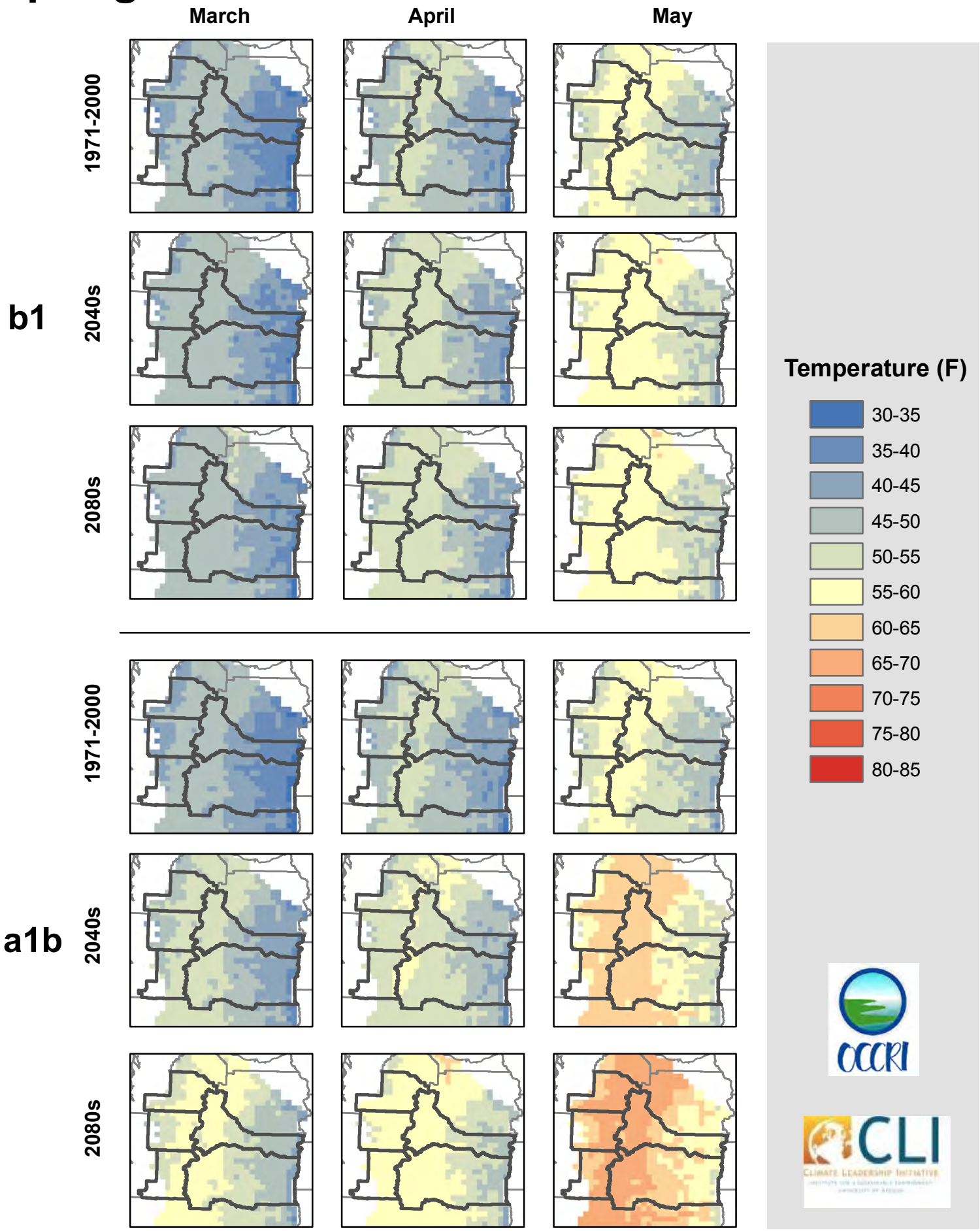
Spring

CSIRO3.5



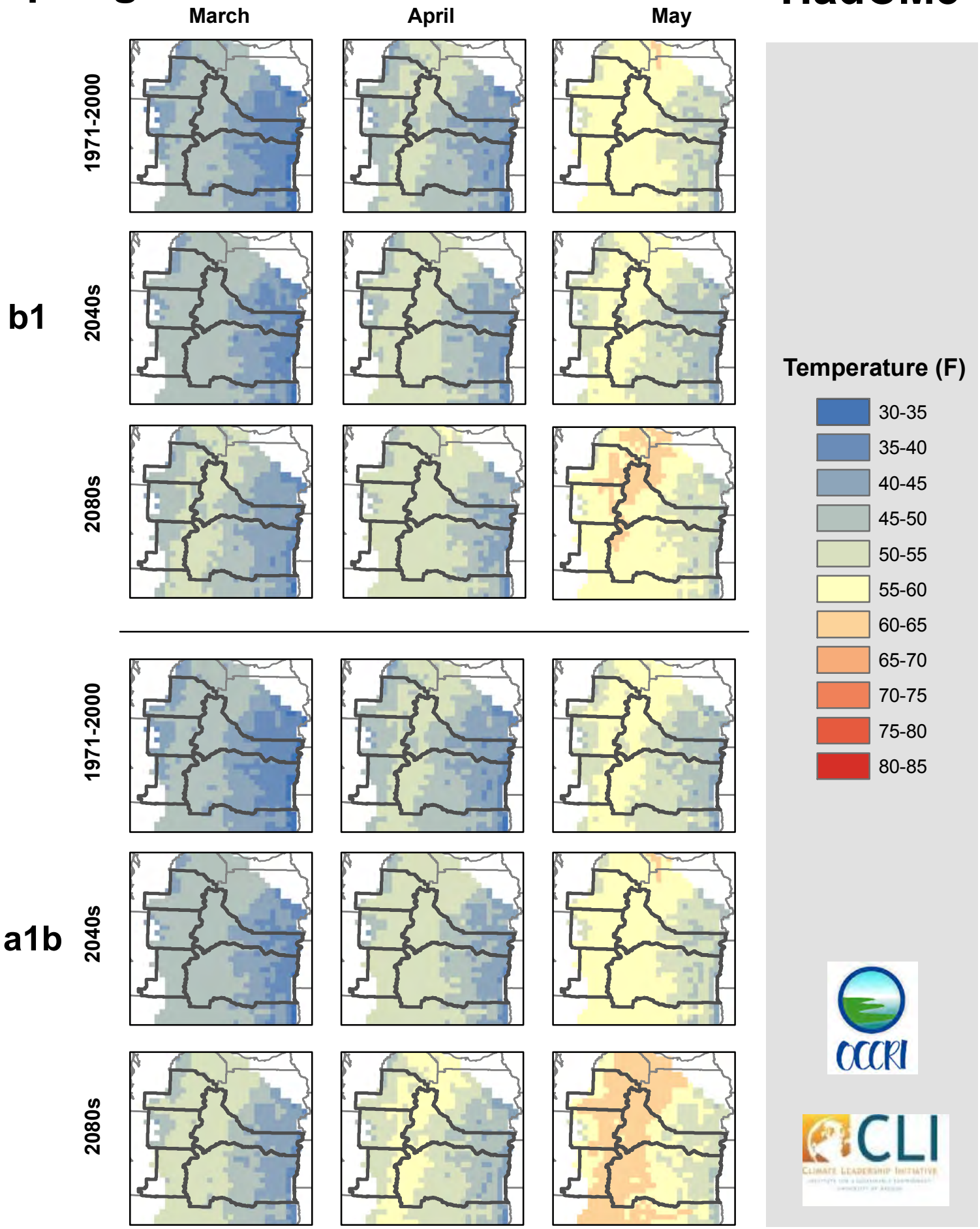
Spring

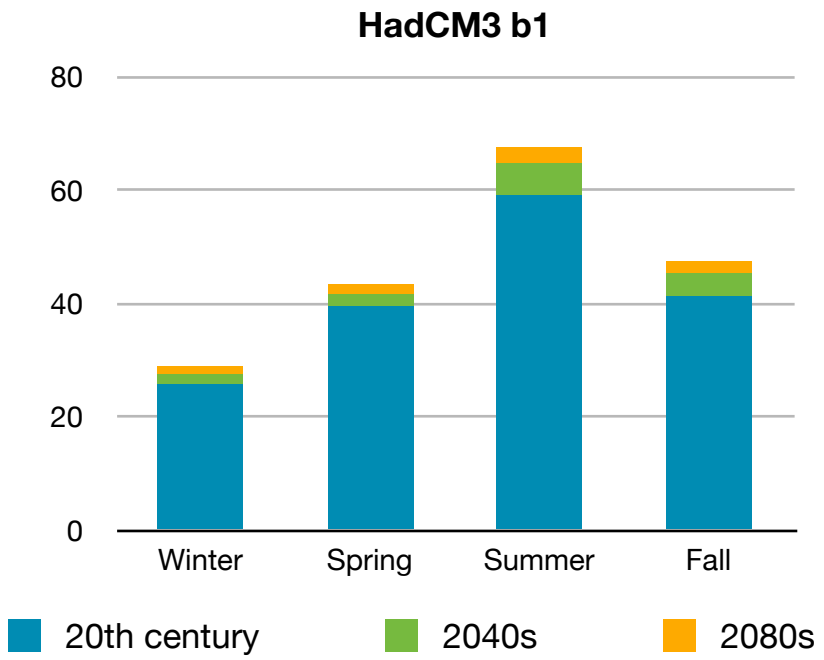
PCM1

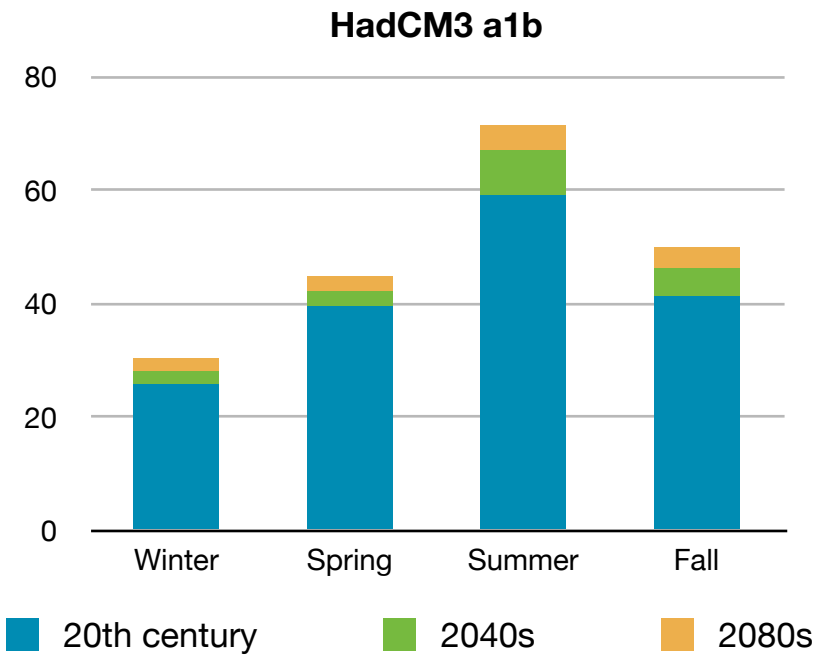

March
April
May
1971-2000
2040s
2080s
b1
1971-2000
2040s
2080s
a1b
Temperature (F)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

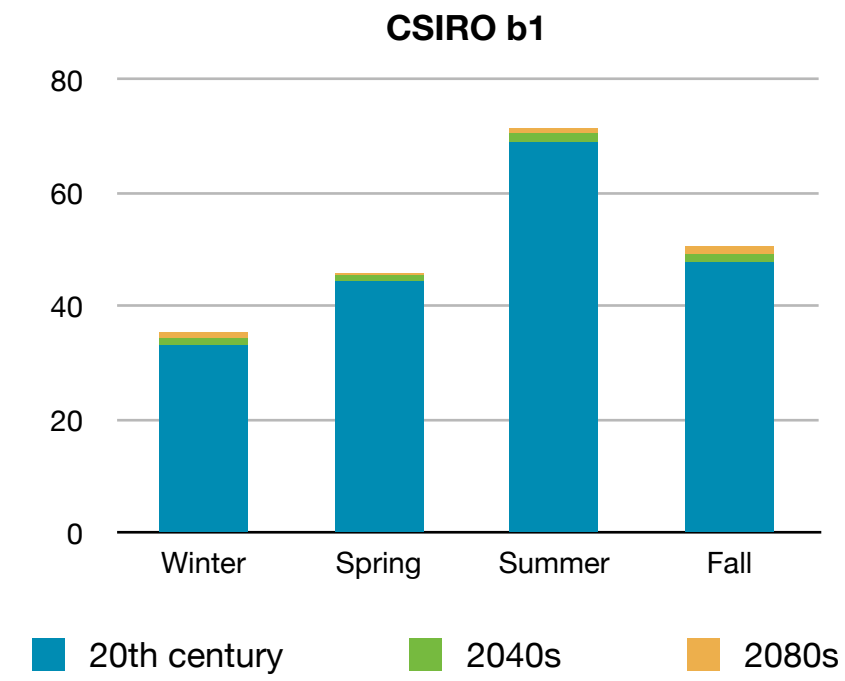
Spring

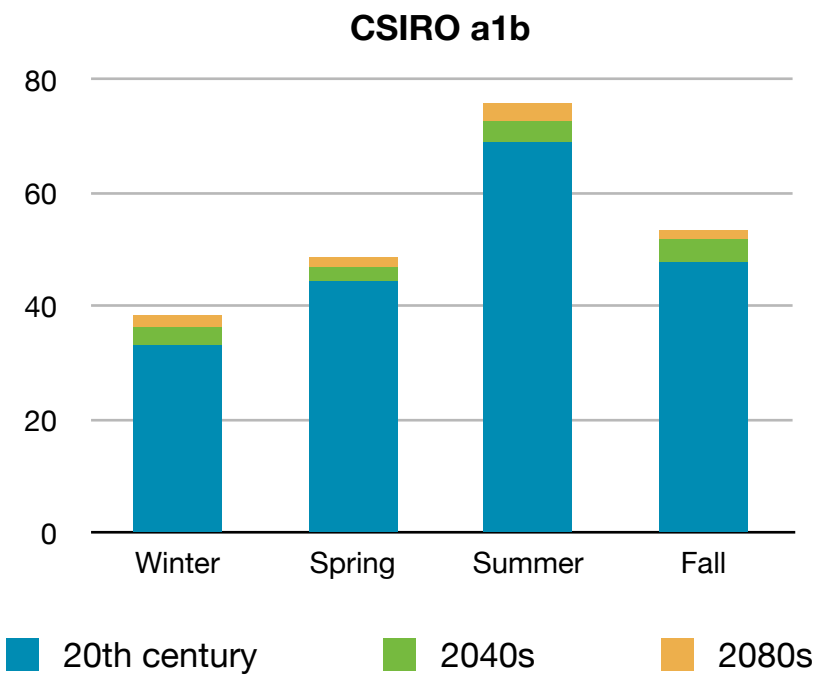
HadCM3

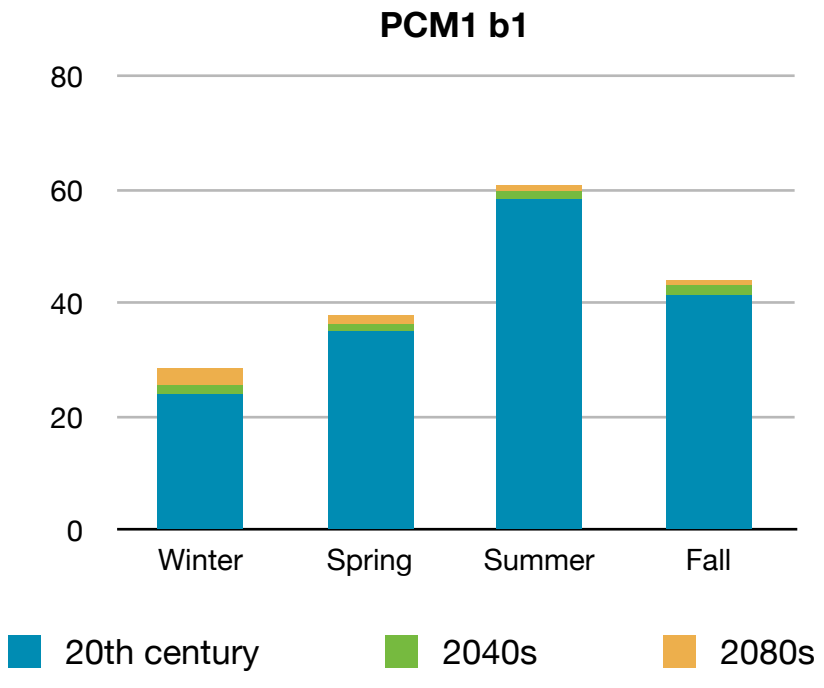


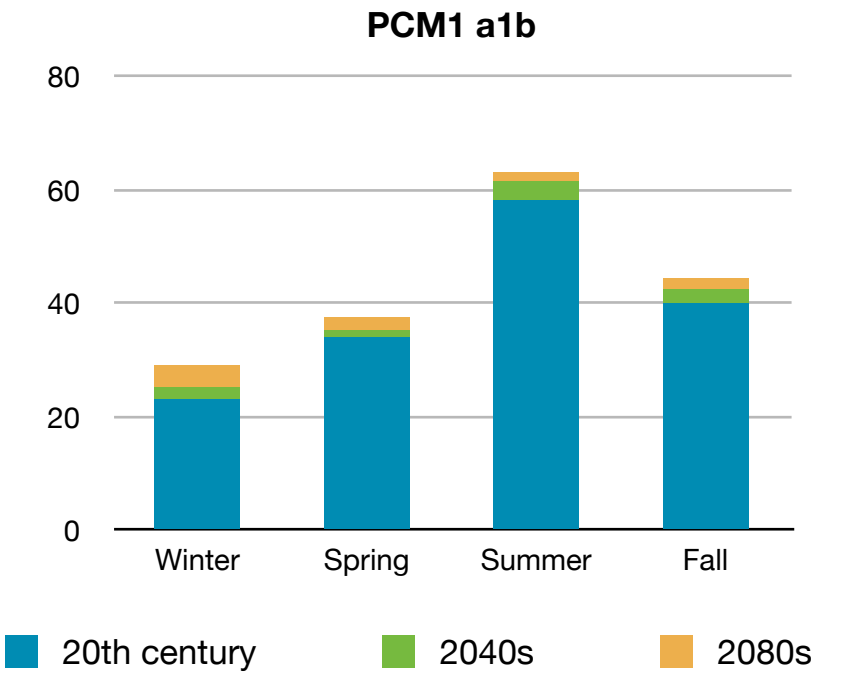

HadCM3 b1
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s


HadCM3 a1b
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s


CSIRO b1
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s

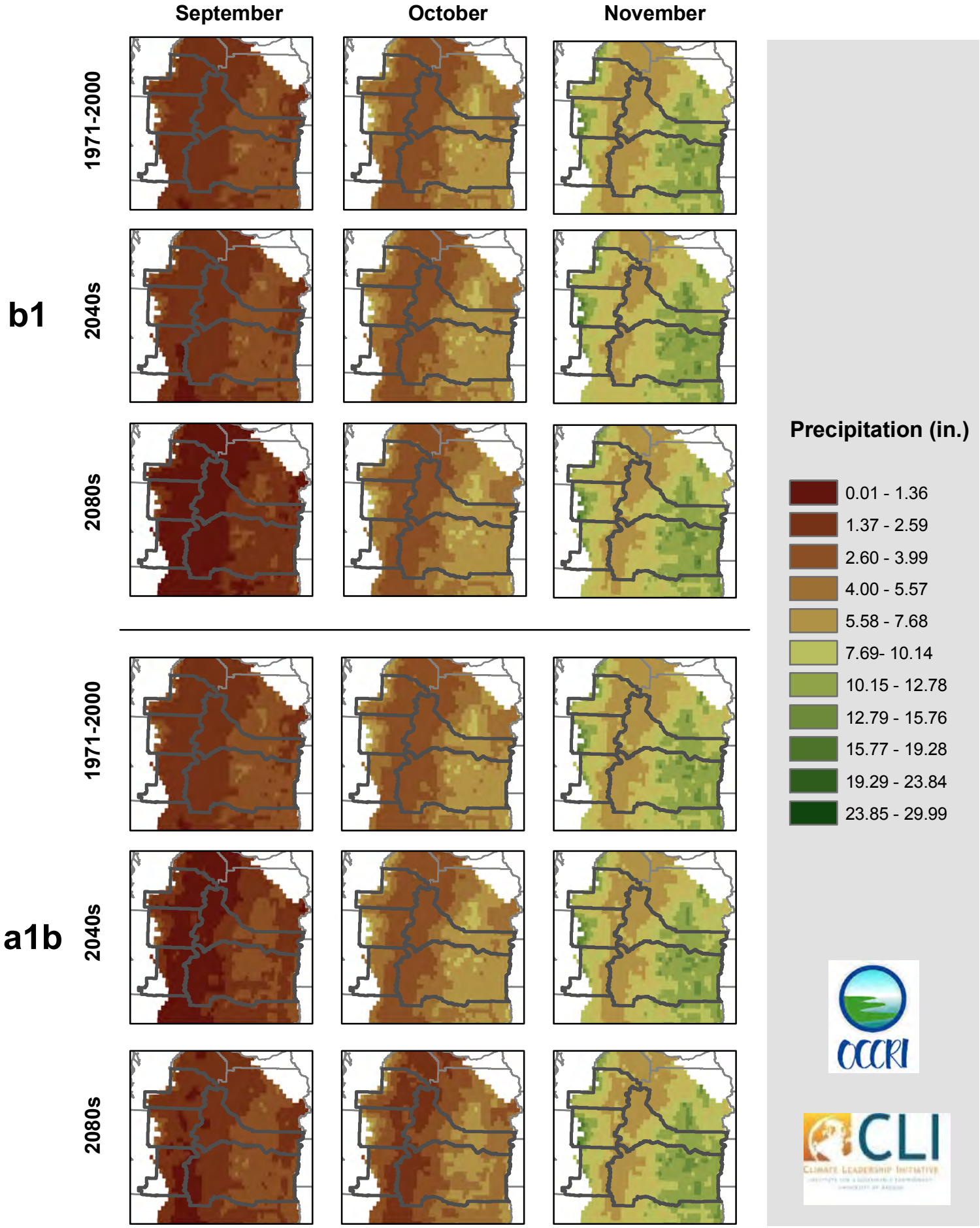

CSIRO a1b
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s


PCM1 b1
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s


PCM1 a1b
80
60
40
20
0
Winter
Spring
Summer
Fall
20th century
2040s
2080s

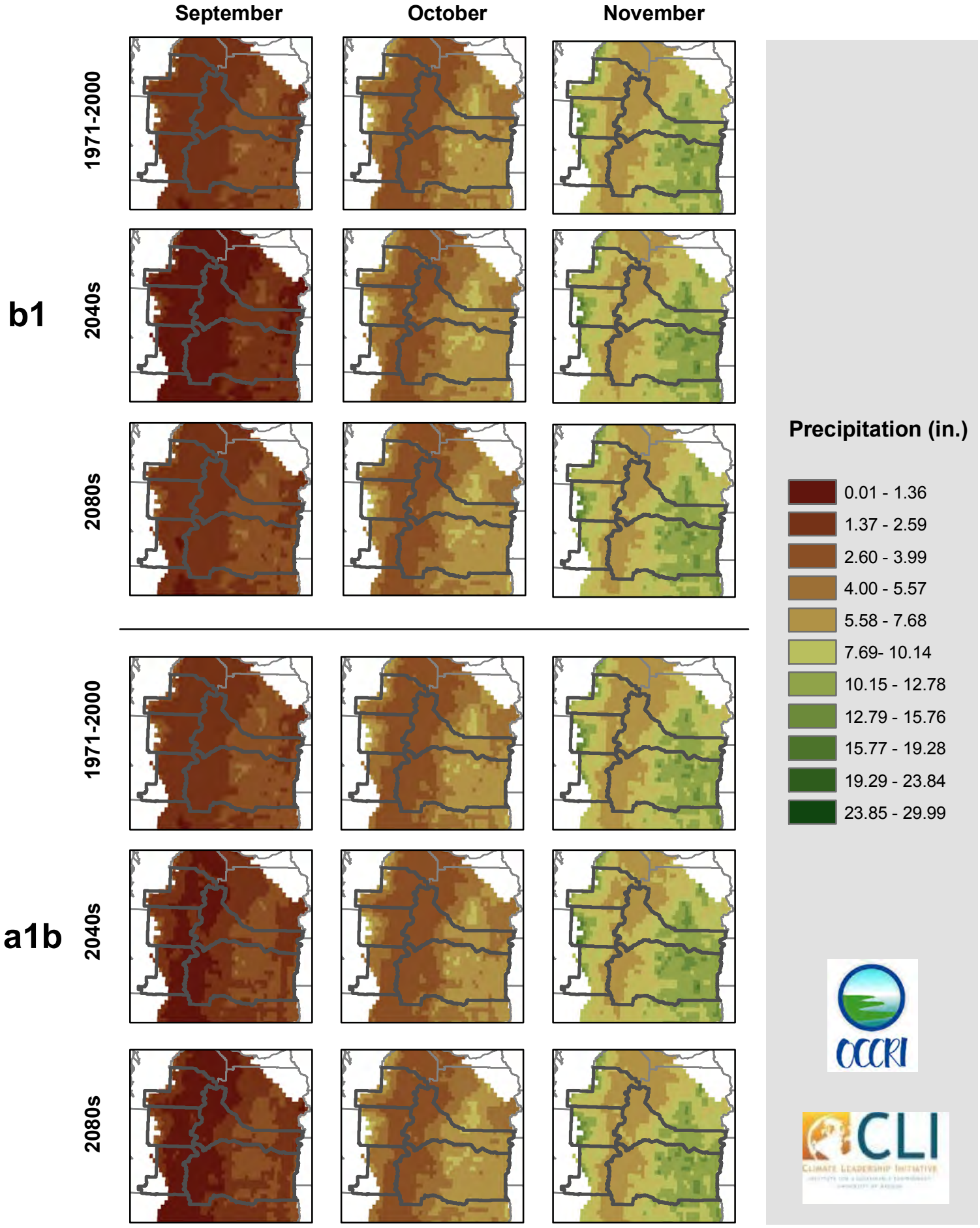
Fall

CSIRO3.5



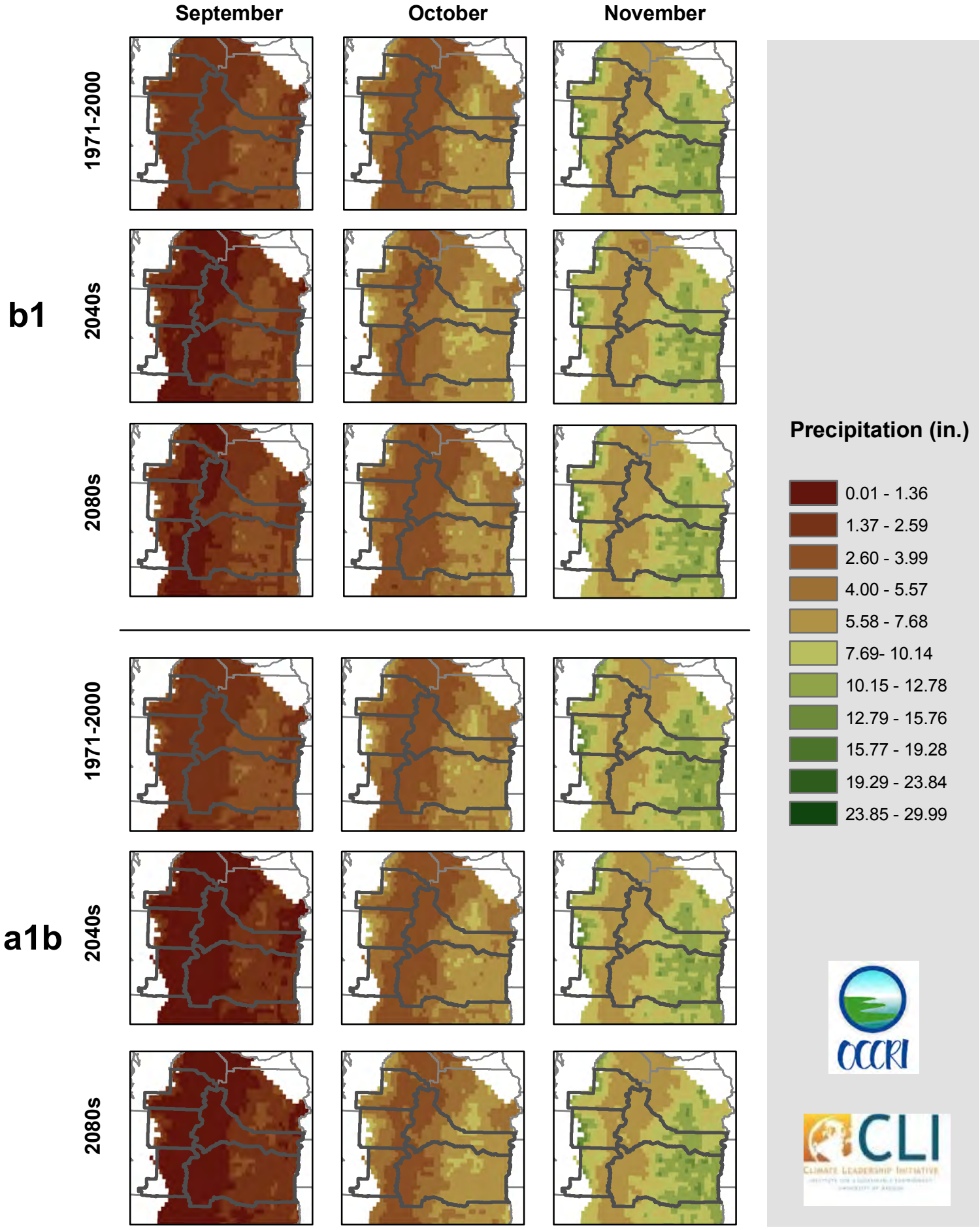
Fall

HadCM3


September
October
November
1971-2000
2040s
2080s
b1
a1b
Precipitation (in.)
0.01 - 1.36
1.37 - 2.59
2.60 - 3.99
4.00 - 5.57
5.58 - 7.68
7.69- 10.14
10.15 - 12.78
12.79 - 15.76
15.77 - 19.28
19.29 - 23.84
23.85 - 29.99
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

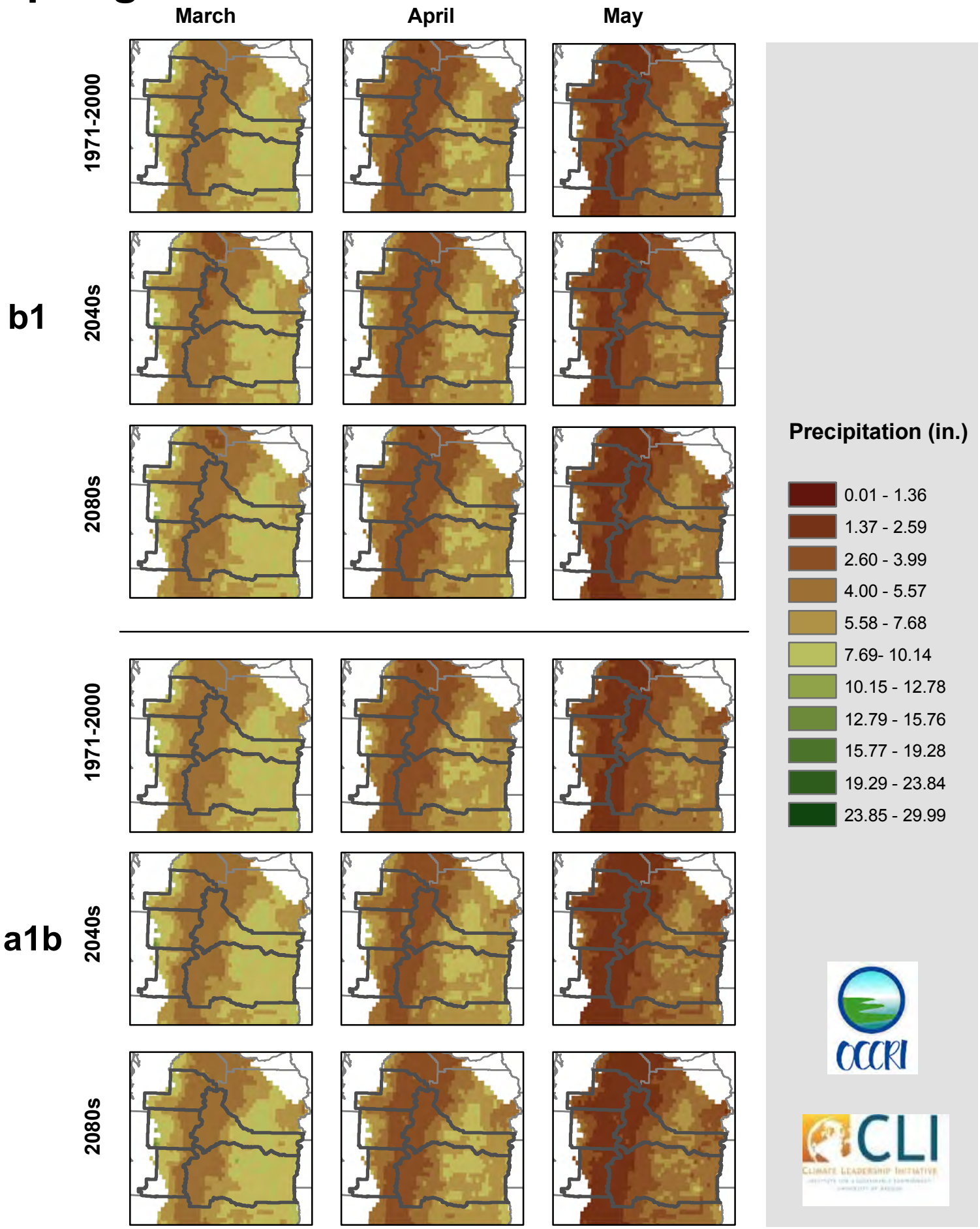
Fall

PCM1


September
October
November
1971-2000
2040s
2080s
b1
a1b
Precipitation (in.)
0.01 - 1.36
1.37 - 2.59
2.60 - 3.99
4.00 - 5.57
5.58 - 7.68
7.69- 10.14
10.15 - 12.78
12.79 - 15.76
15.77 - 19.28
19.29 - 23.84
23.85 - 29.99
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

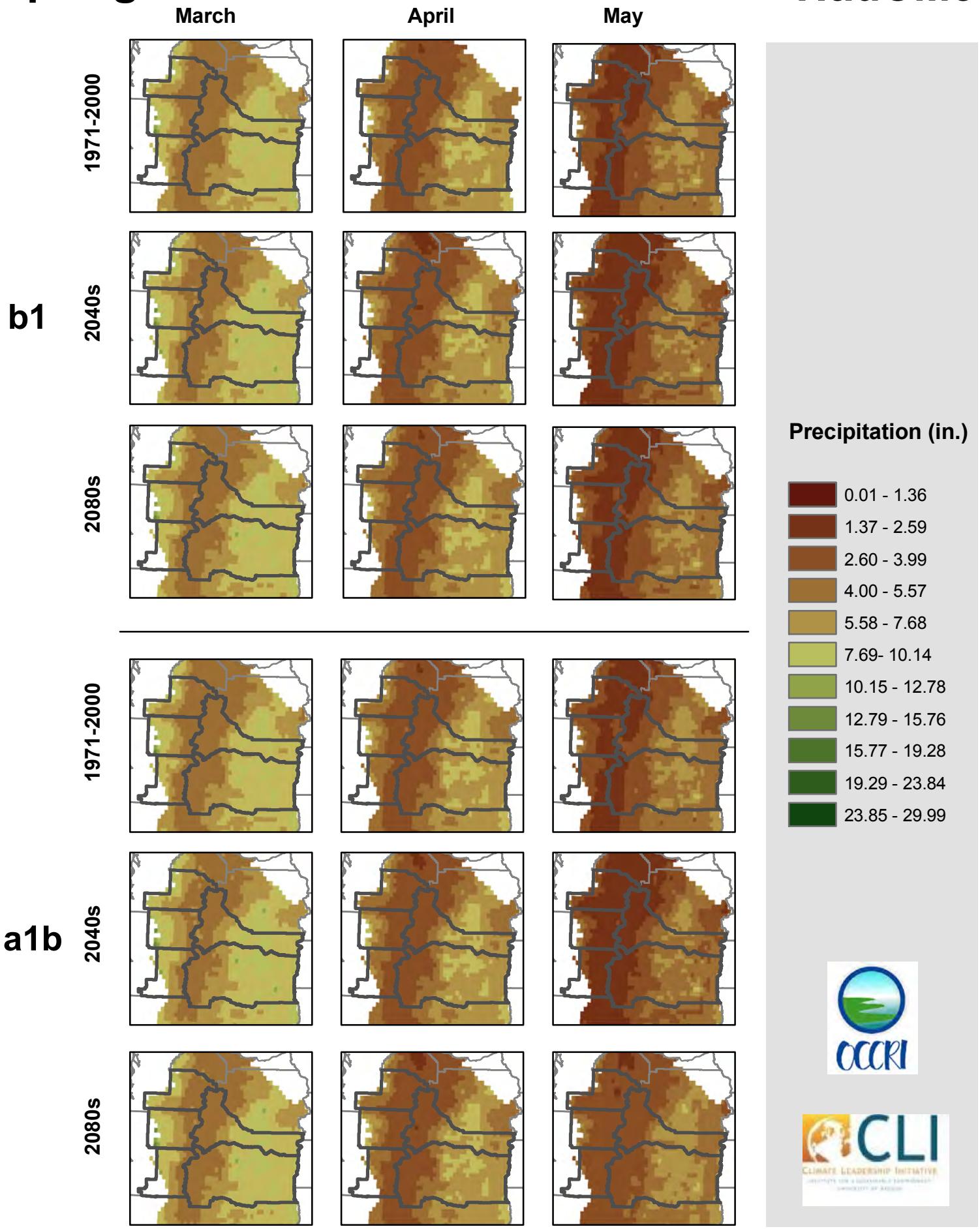
Spring

CSIRO3.5



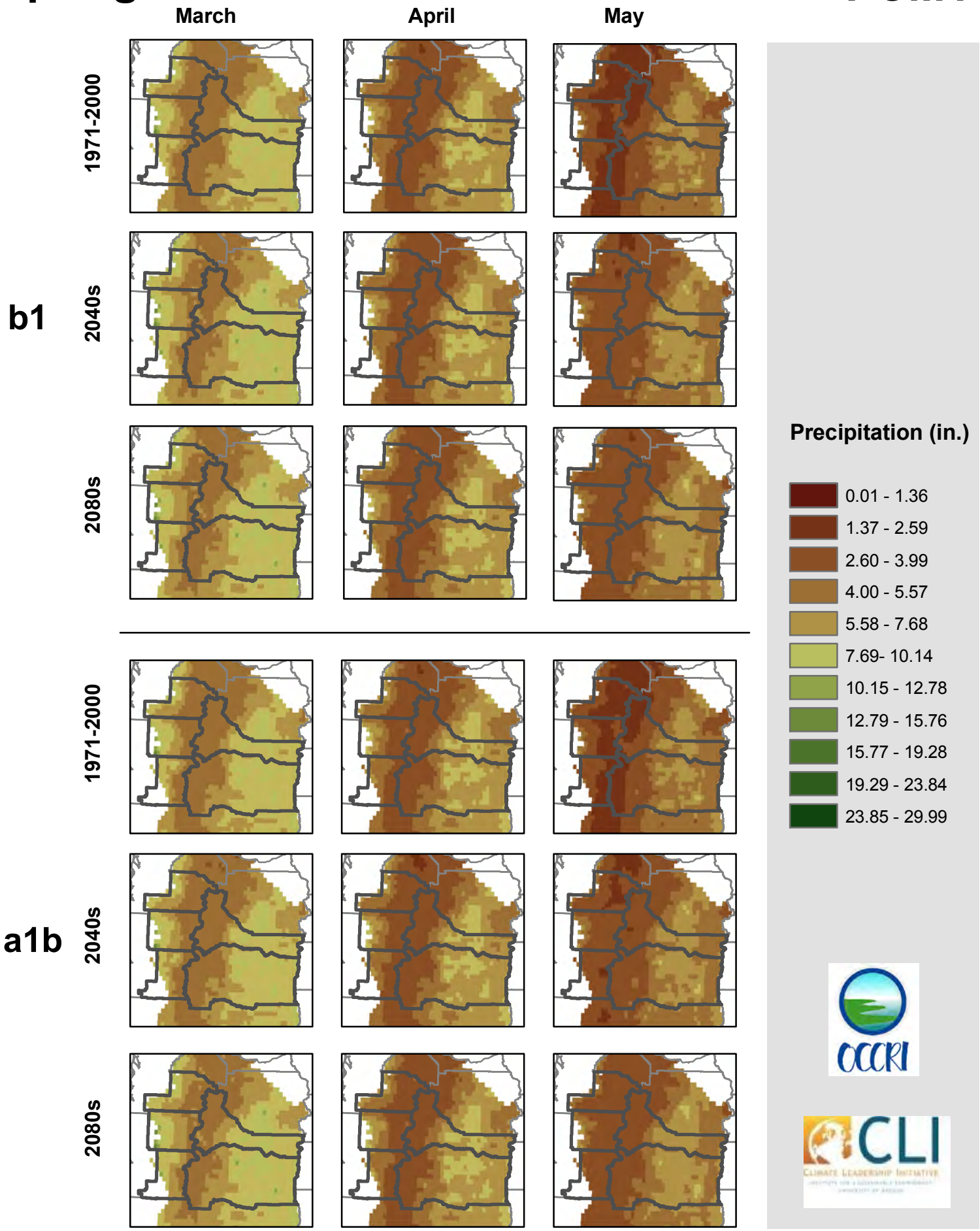
Spring

HadCM3



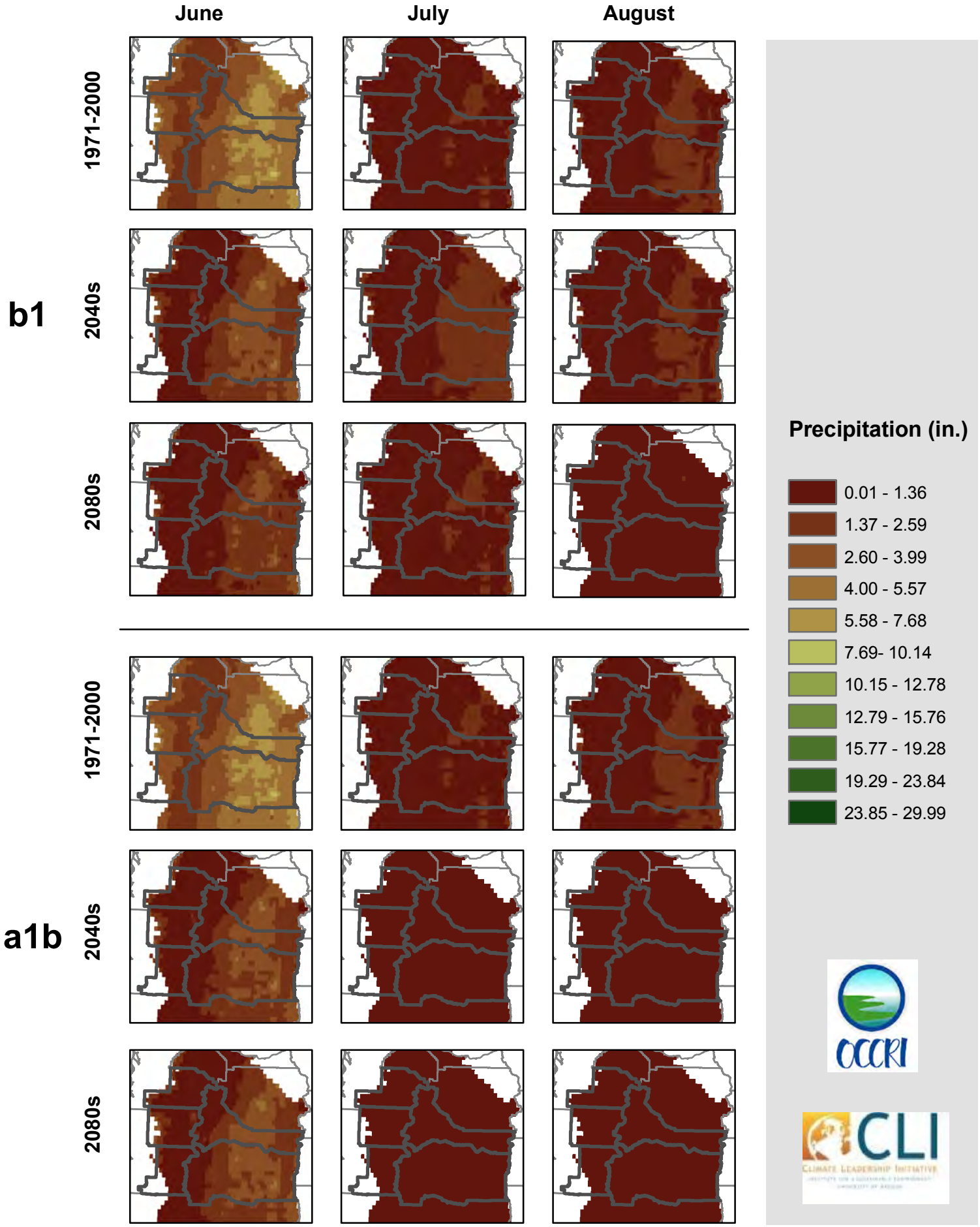
Spring

PCM1


March
April
May
1971-2000
2040s
2080s
b1
1971-2000
2040s
2080s
a1b
Precipitation (in.)
0.01 - 1.36
1.37 - 2.59
2.60 - 3.99
4.00 - 5.57
5.58 - 7.68
7.69- 10.14
10.15 - 12.78
12.79 - 15.76
15.77 - 19.28
19.29 - 23.84
23.85 - 29.99
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

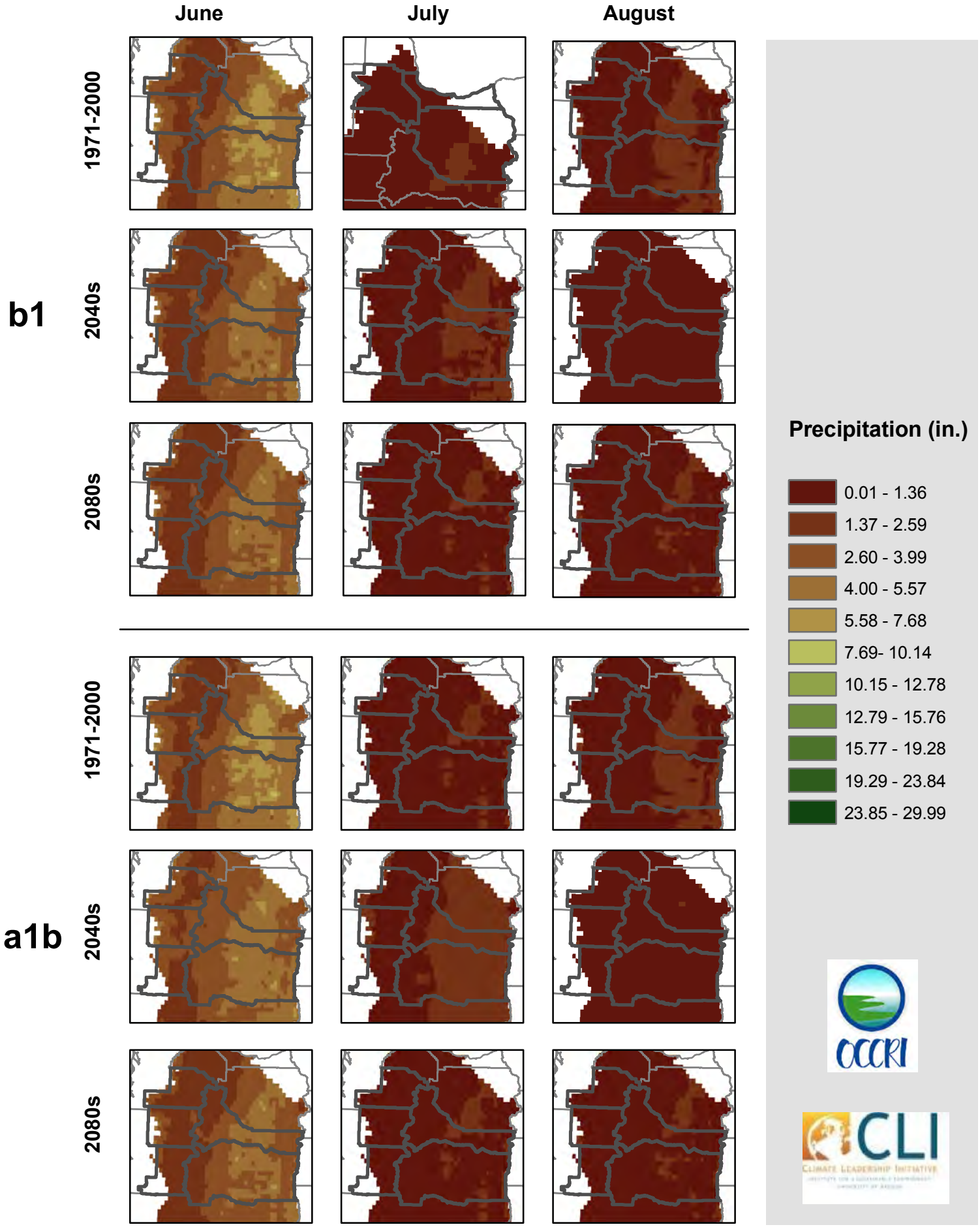
Summer

HadCM3



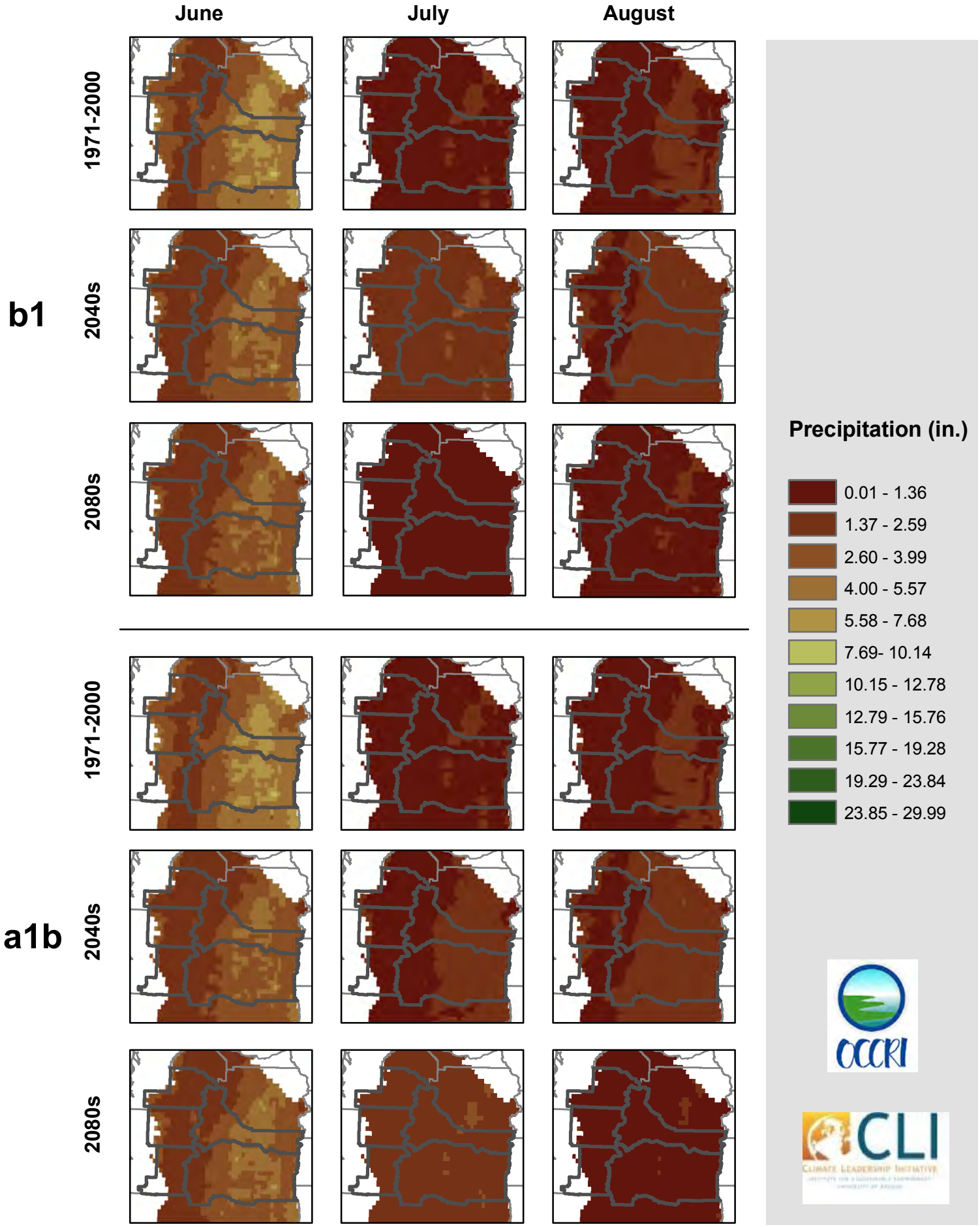
Summer

PCM1


June
July
August
1971-2000
2040s
2080s
b1
a1b
Precipitation (in.)
0.01 - 1.36
1.37 - 2.59
2.60 - 3.99
4.00 - 5.57
5.58 - 7.68
7.69- 10.14
10.15 - 12.78
12.79 - 15.76
15.77 - 19.28
19.29 - 23.84
23.85 - 29.99
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

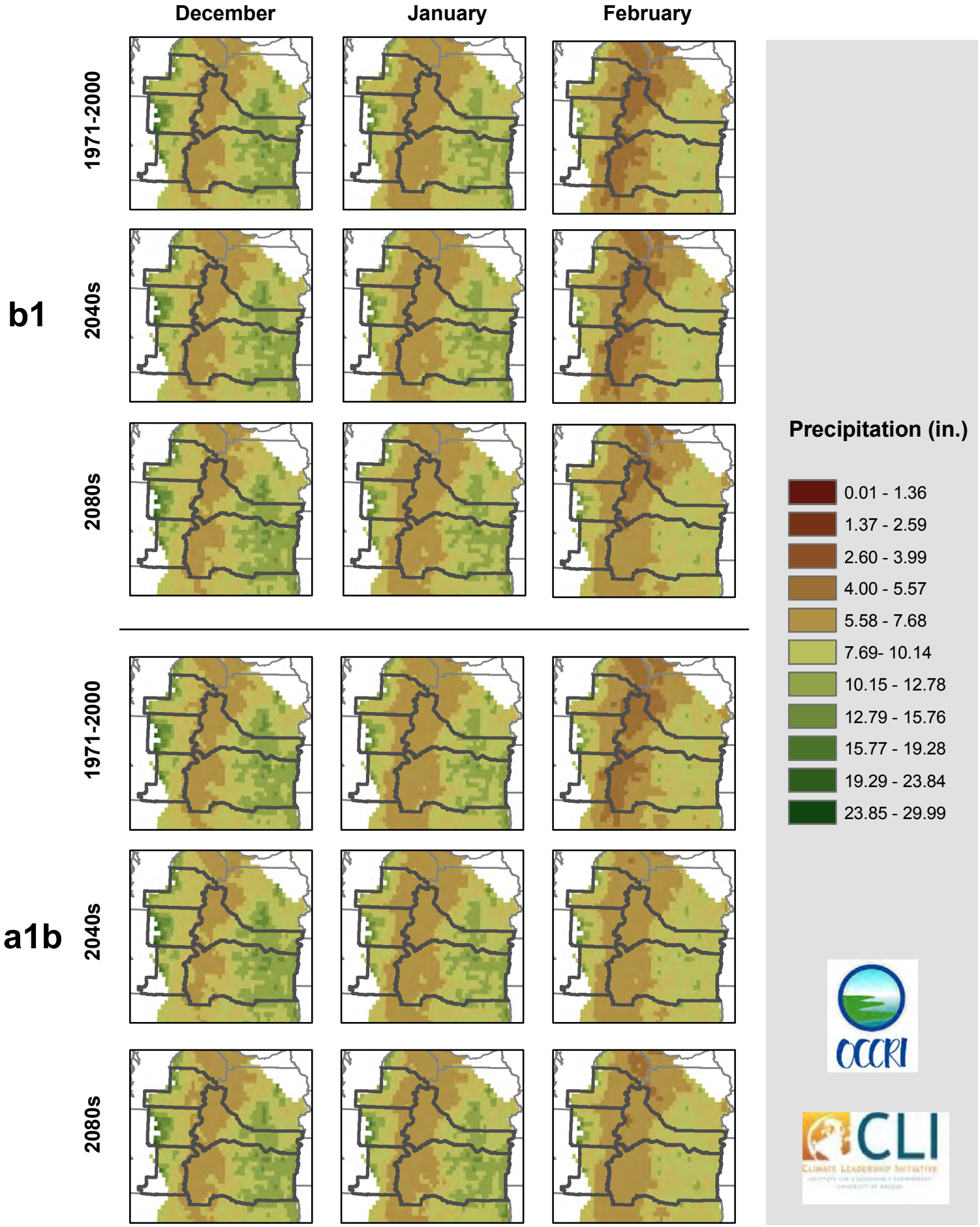
Summer

CSIRO3.5



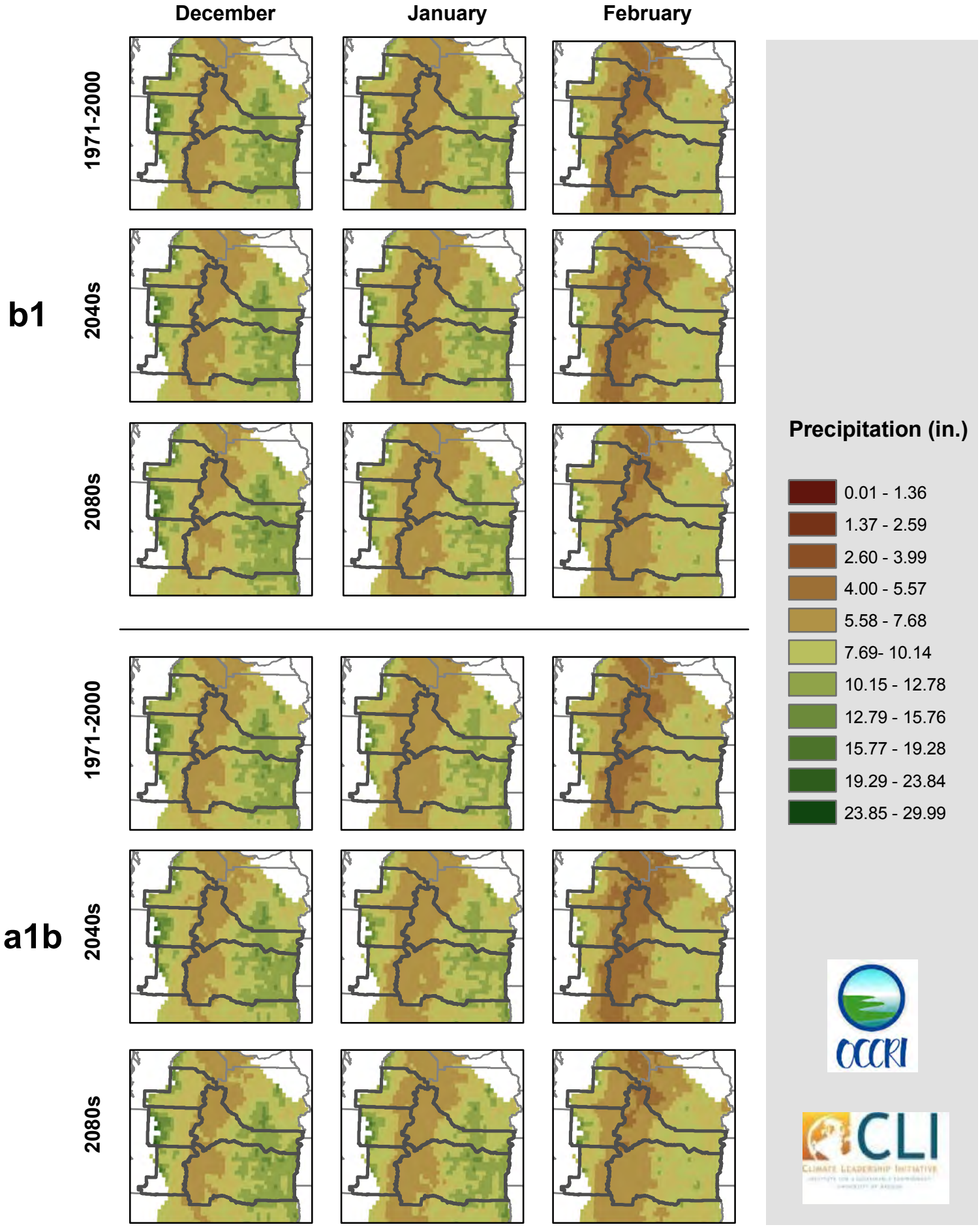
Winter

HadCM3



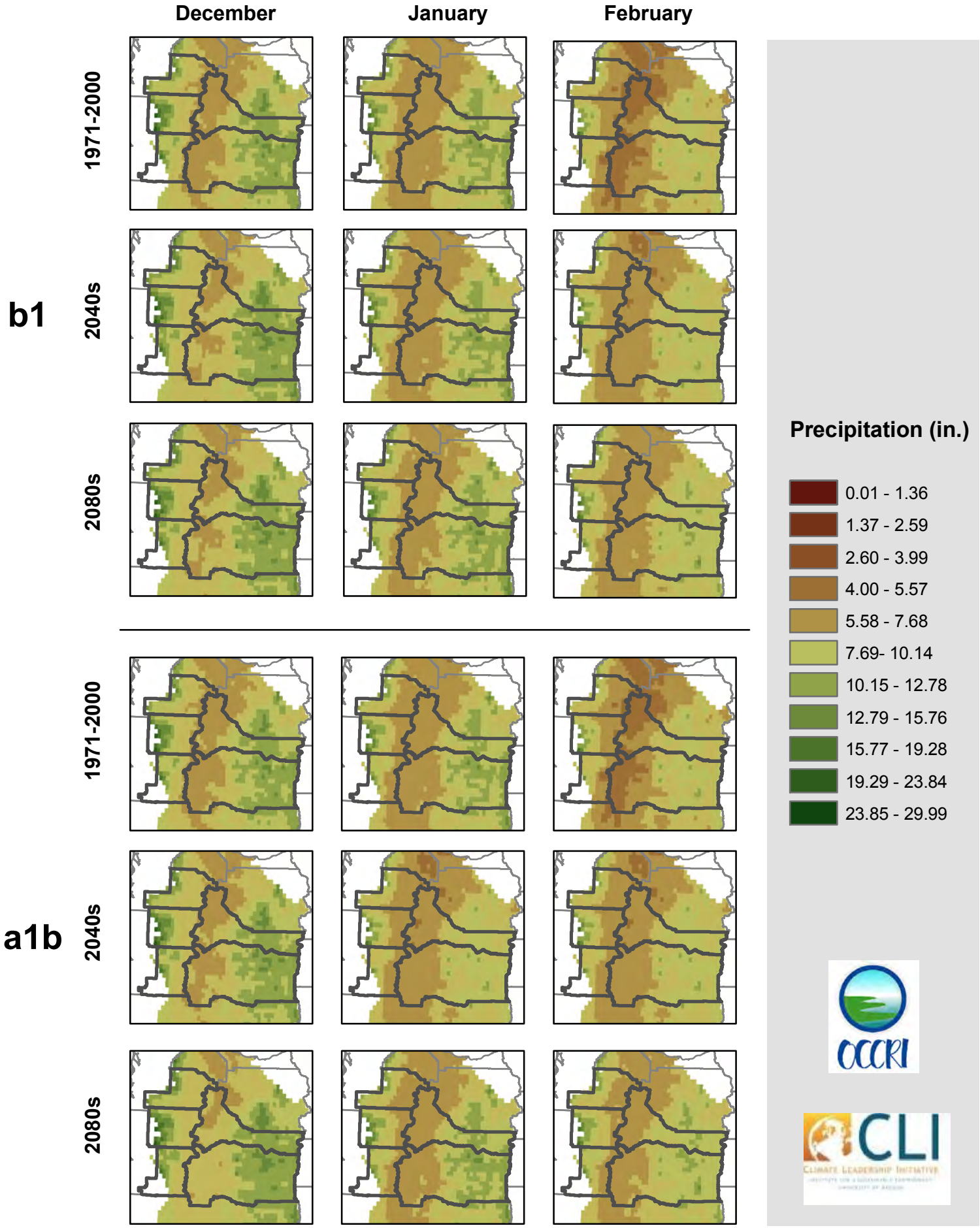
Winter

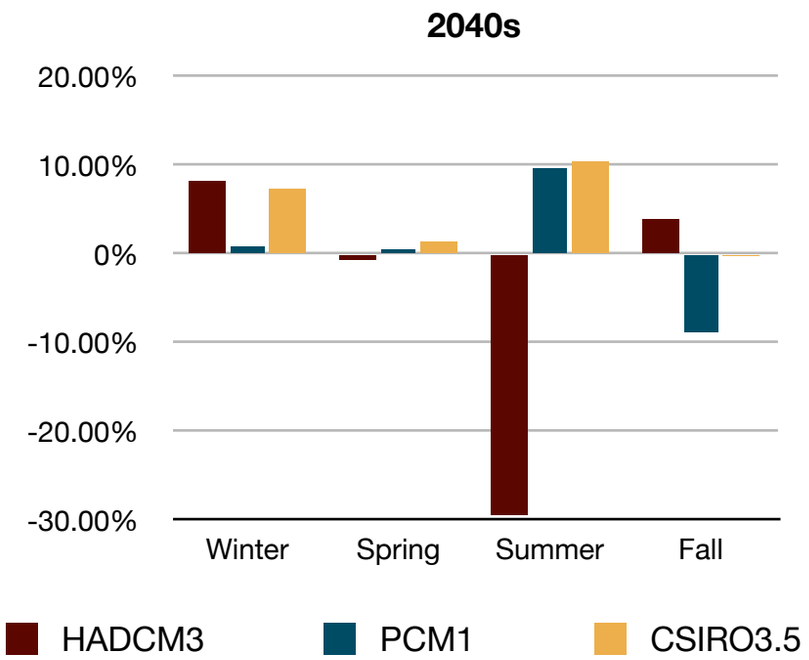
PCM1

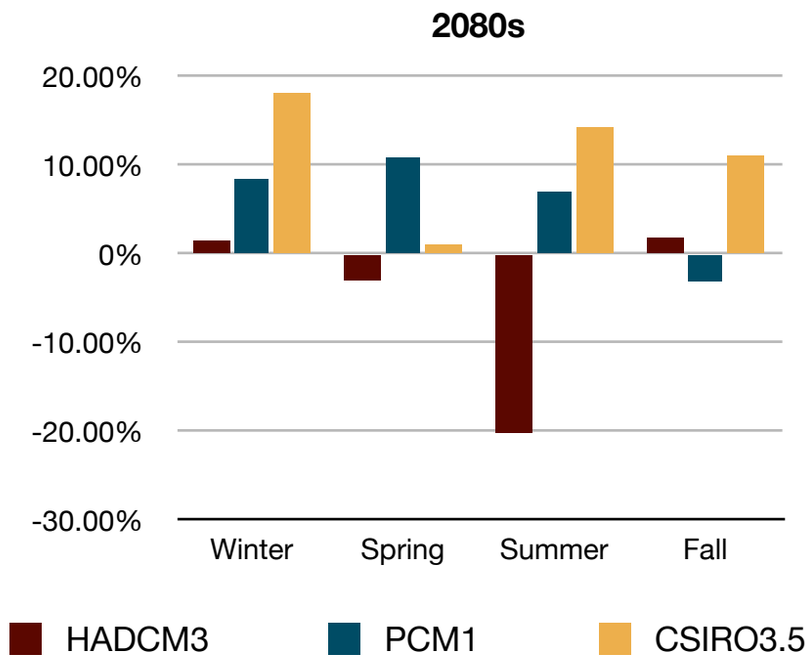

December
January
February
1971-2000
2040s
2080s
b1
1971-2000
2040s
2080s
a1b
Precipitation (in.)
0.01 - 1.36
1.37 - 2.59
2.60 - 3.99
4.00 - 5.57
5.58 - 7.68
7.69- 10.14
10.15 - 12.78
12.79 - 15.76
15.77 - 19.28
19.29 - 23.84
23.85 - 29.99
CCCRI
CLI
CLIMATE LEADERSHIP INITIATIVE

Winter

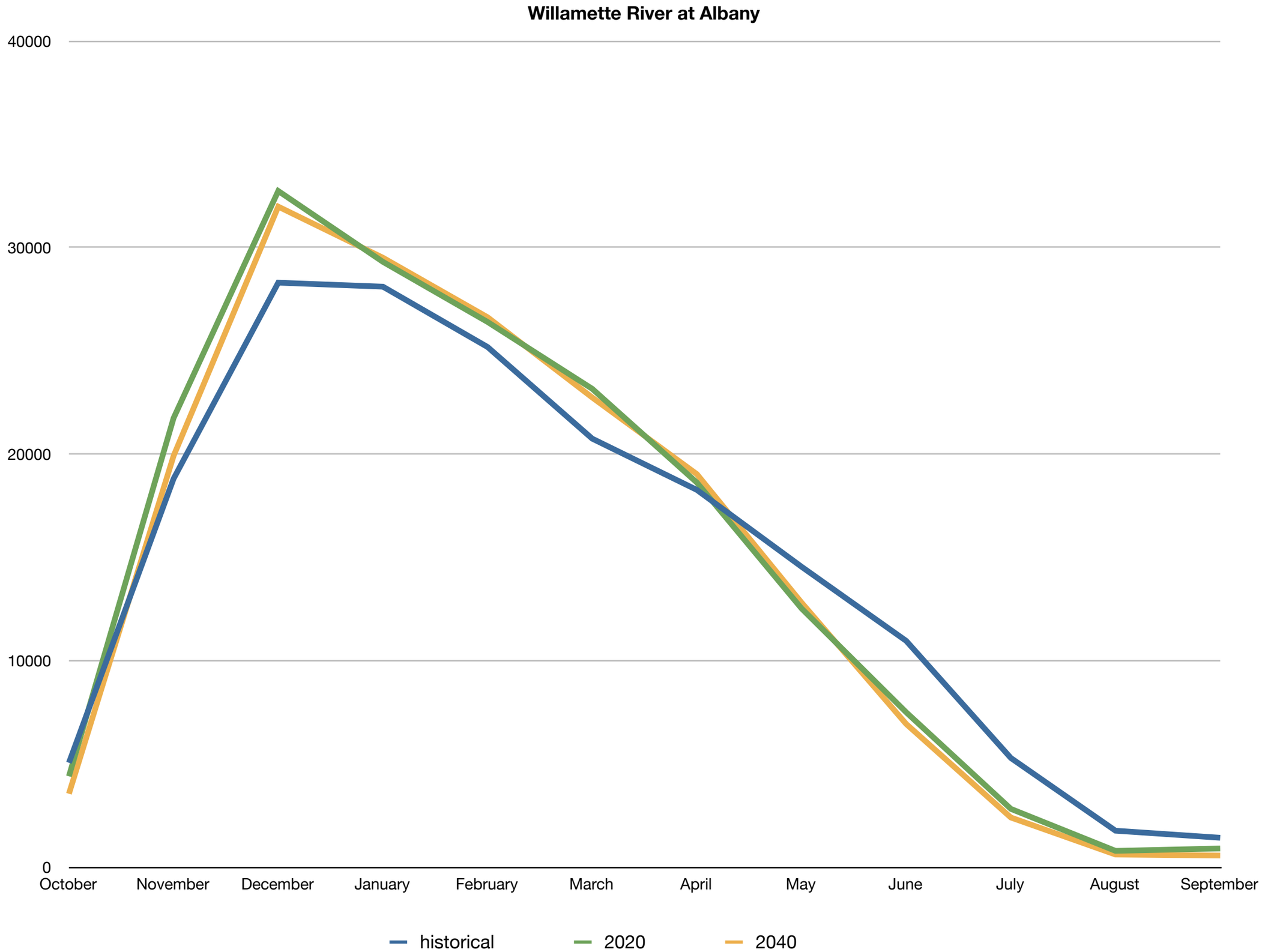
CSIRO3.5



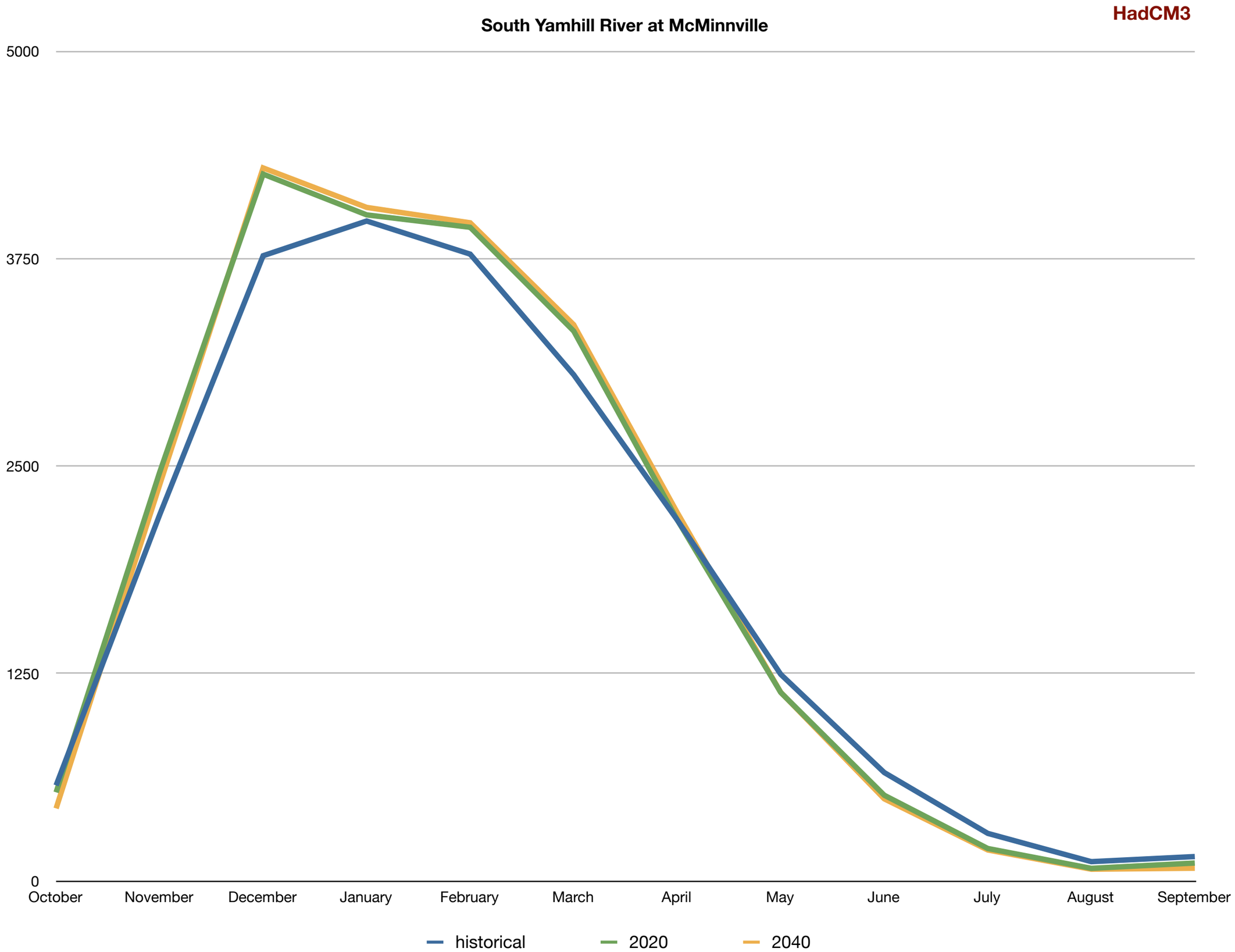

2040s
20.00%
10.00%
0%
-10.00%
-20.00%
-30.00%
Winter
Spring
Summer
Fall
HADCM3
PCM1
CSIRO3.5


2080s
20.00%
10.00%
0%
-10.00%
-20.00%
-30.00%
Winter
Spring
Summer
Fall
HADCM3
PCM1
CSIRO3.5

HadCM3

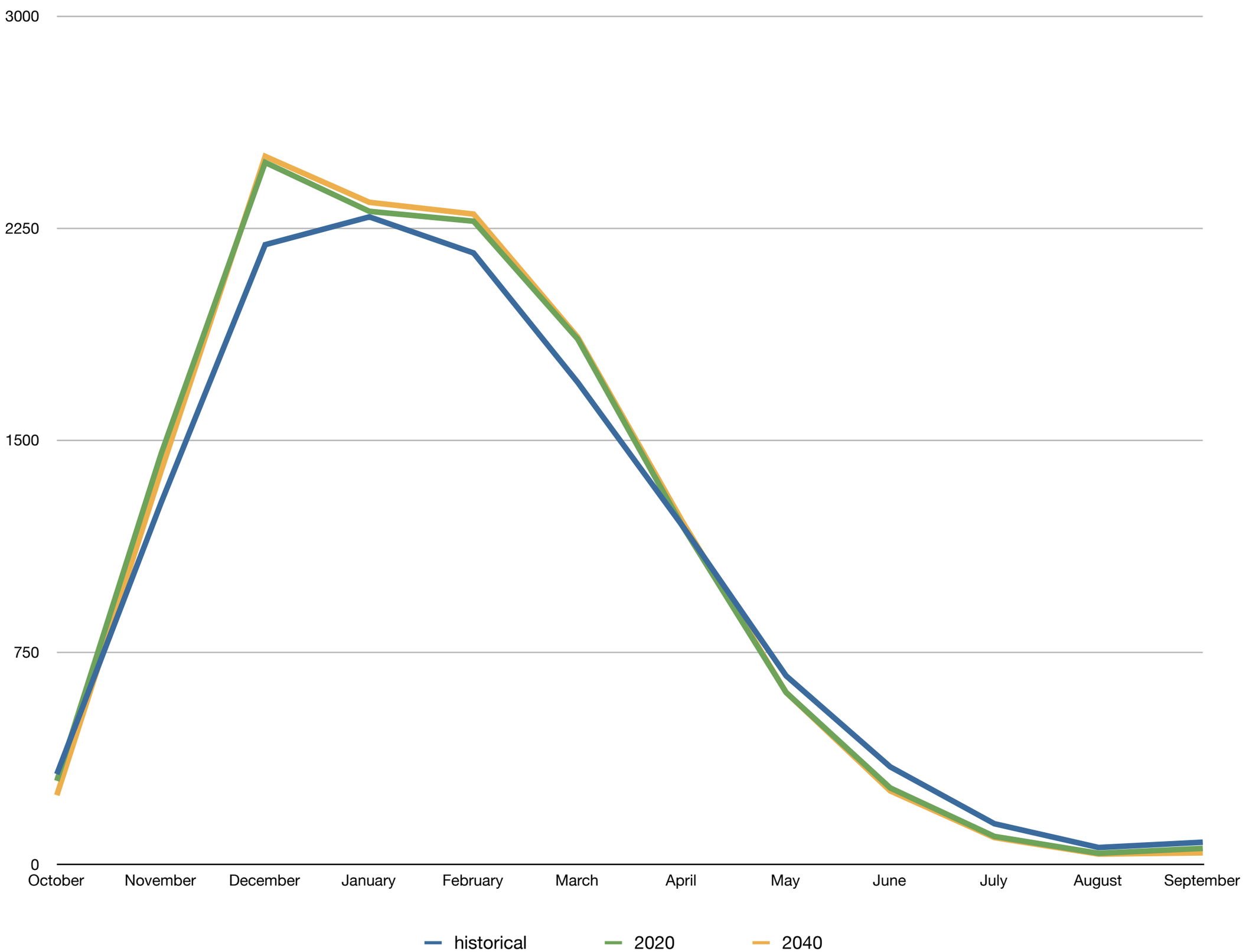

Willamette River at Albany
40000
30000
20000
10000
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

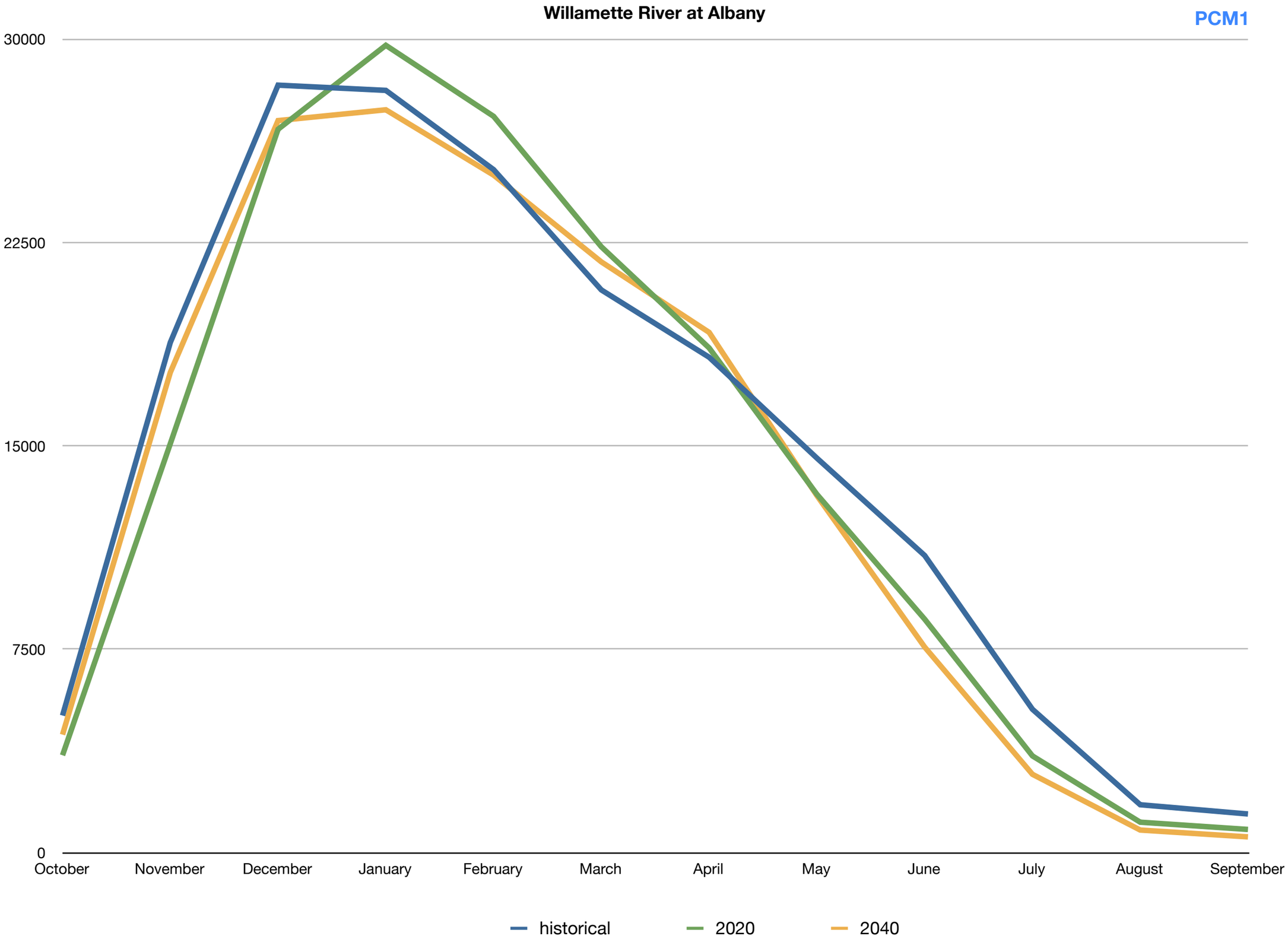
HadCM3

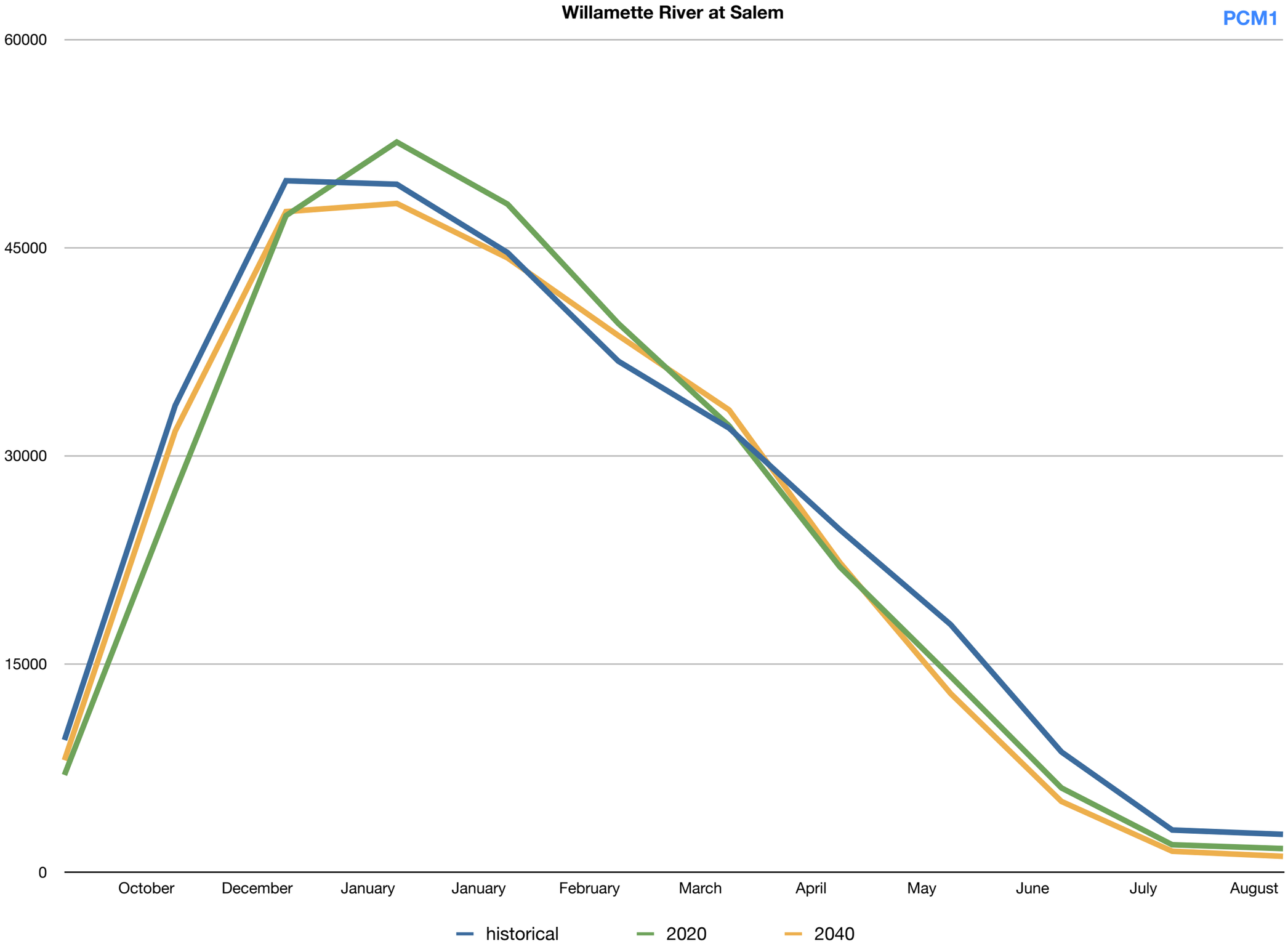

South Yamhill River at McMinnville
5000
3750
2500
1250
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

HadCM3

Luckiamute River near Suver

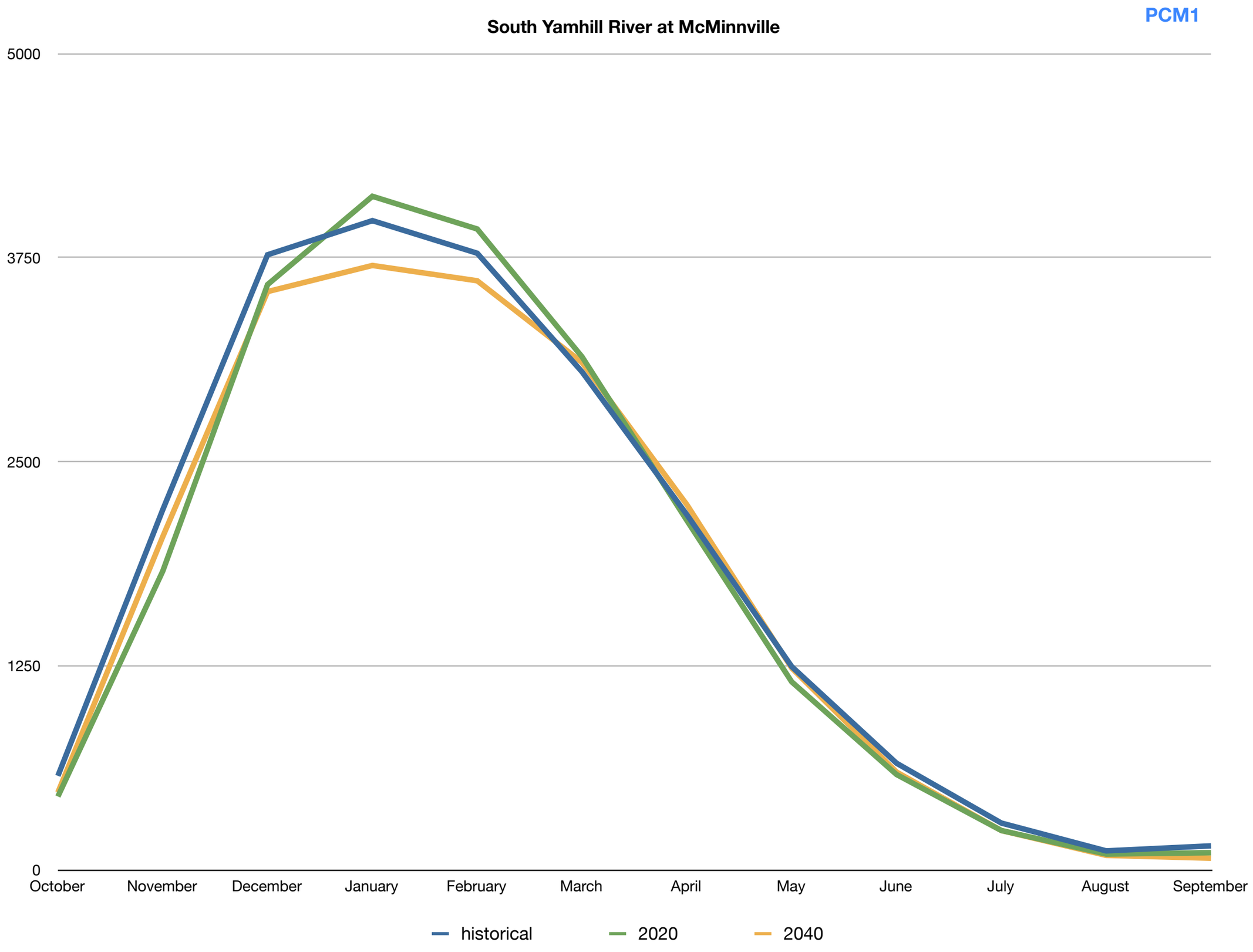


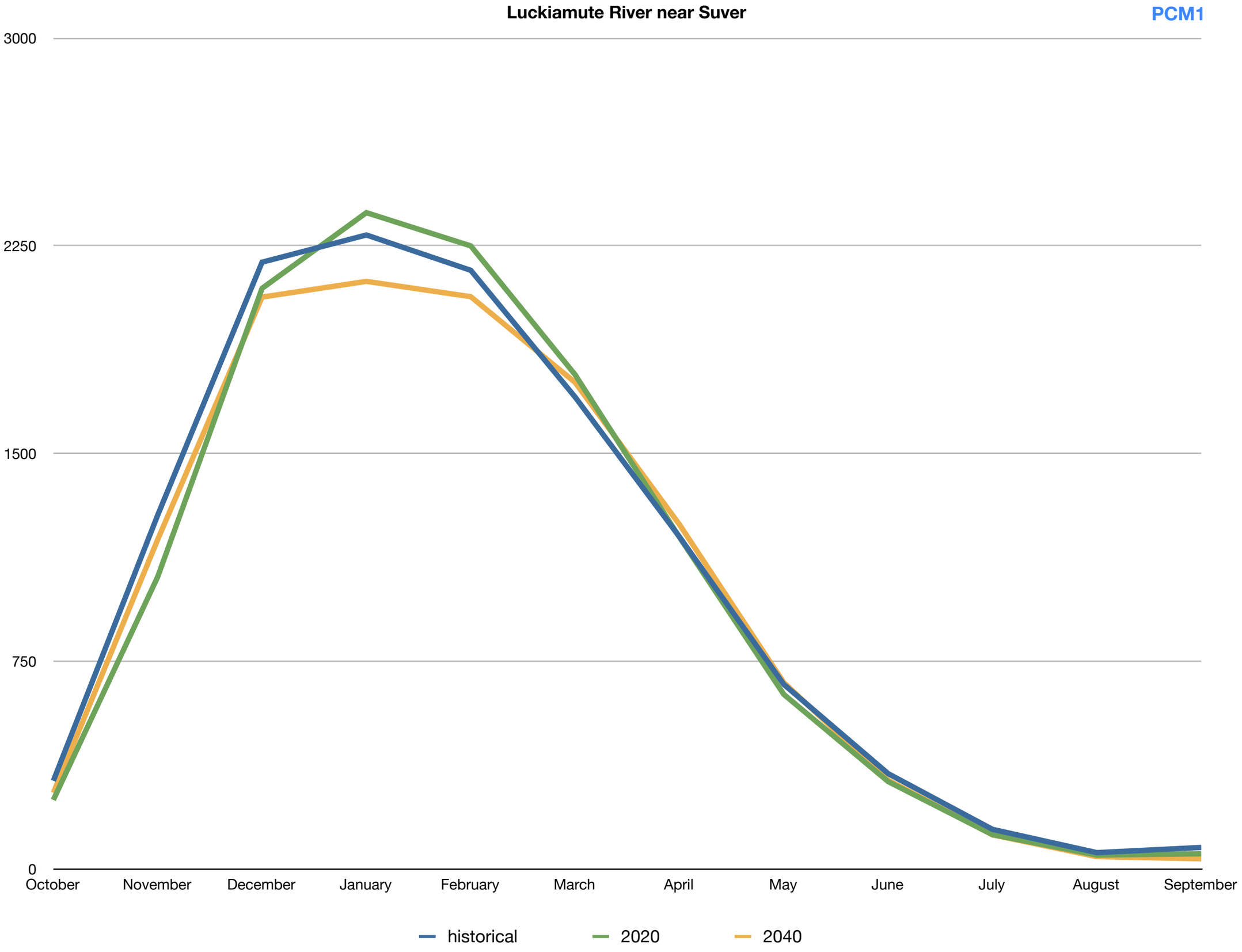

Willamette River at Albany
PCM1
30000
22500
15000
7500
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040



Willamette River at Salem
PCM1
60000
45000
30000
15000
0
October
December
January
January
February
March
April
May
June
July
August
historical
2020
2040

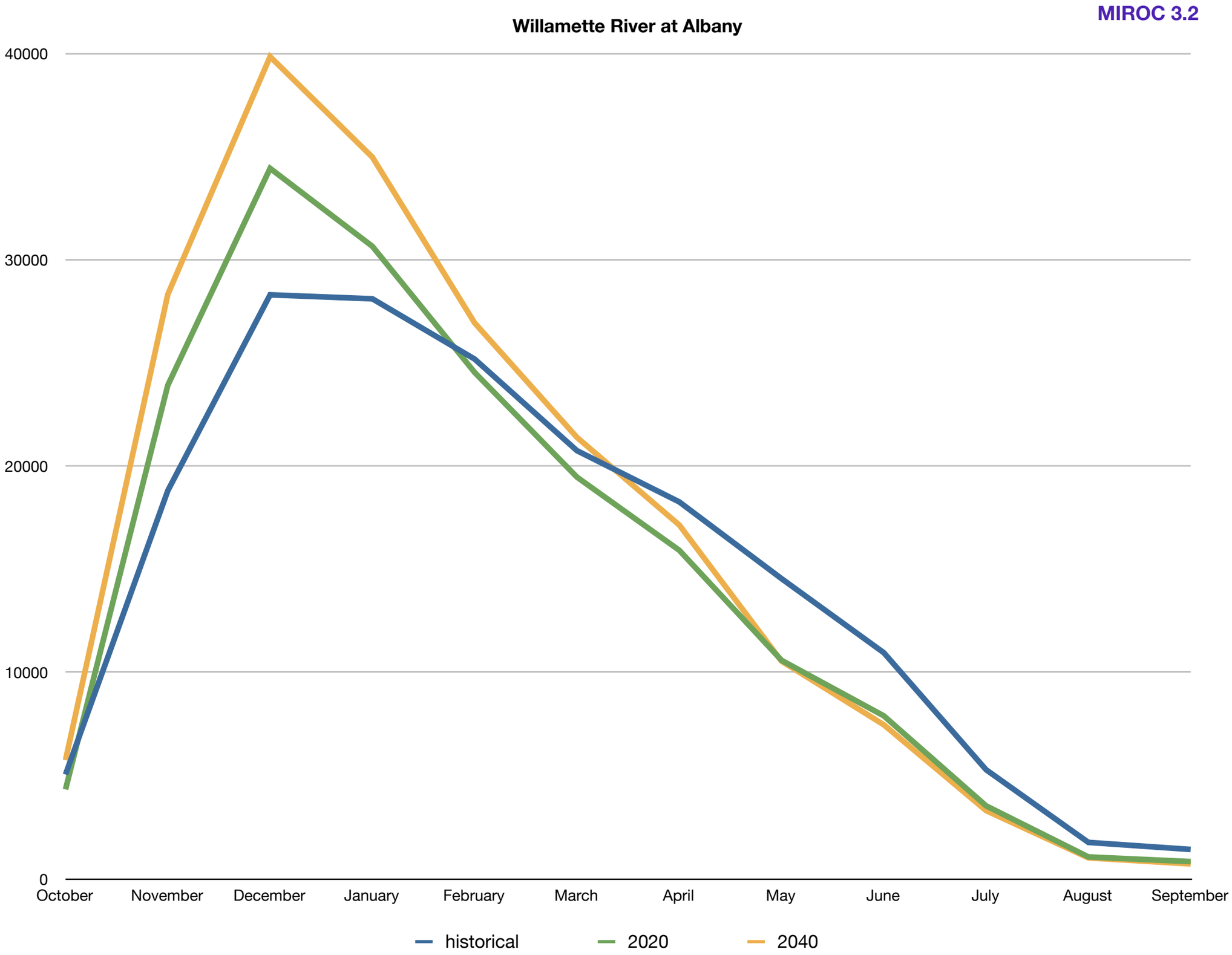
PCM1


South Yamhill River at McMinnville
5000
3750
2500
1250
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

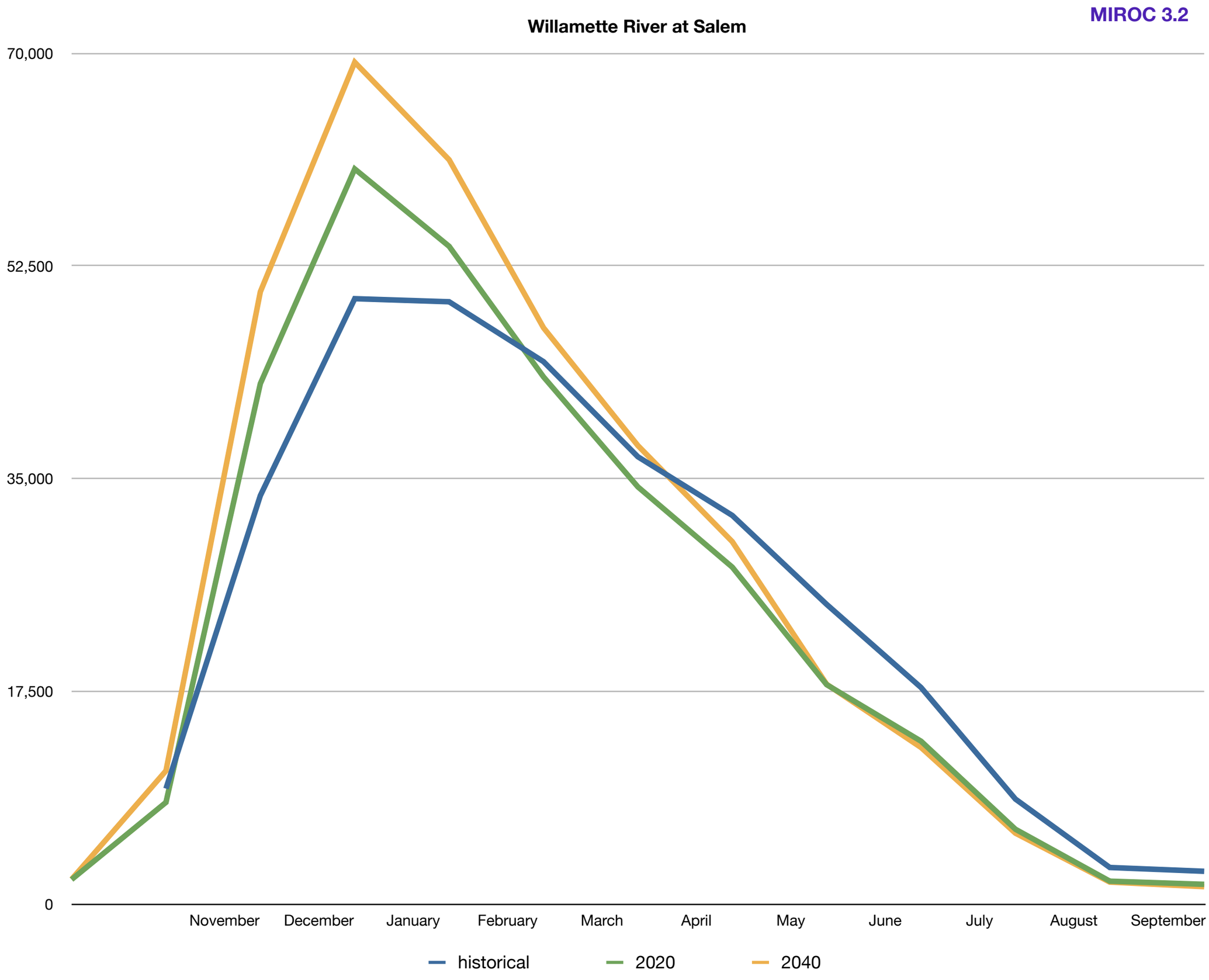


Luckiamute River near Suver
PCM1
3000
2250
1500
750
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

MIROC 3.2

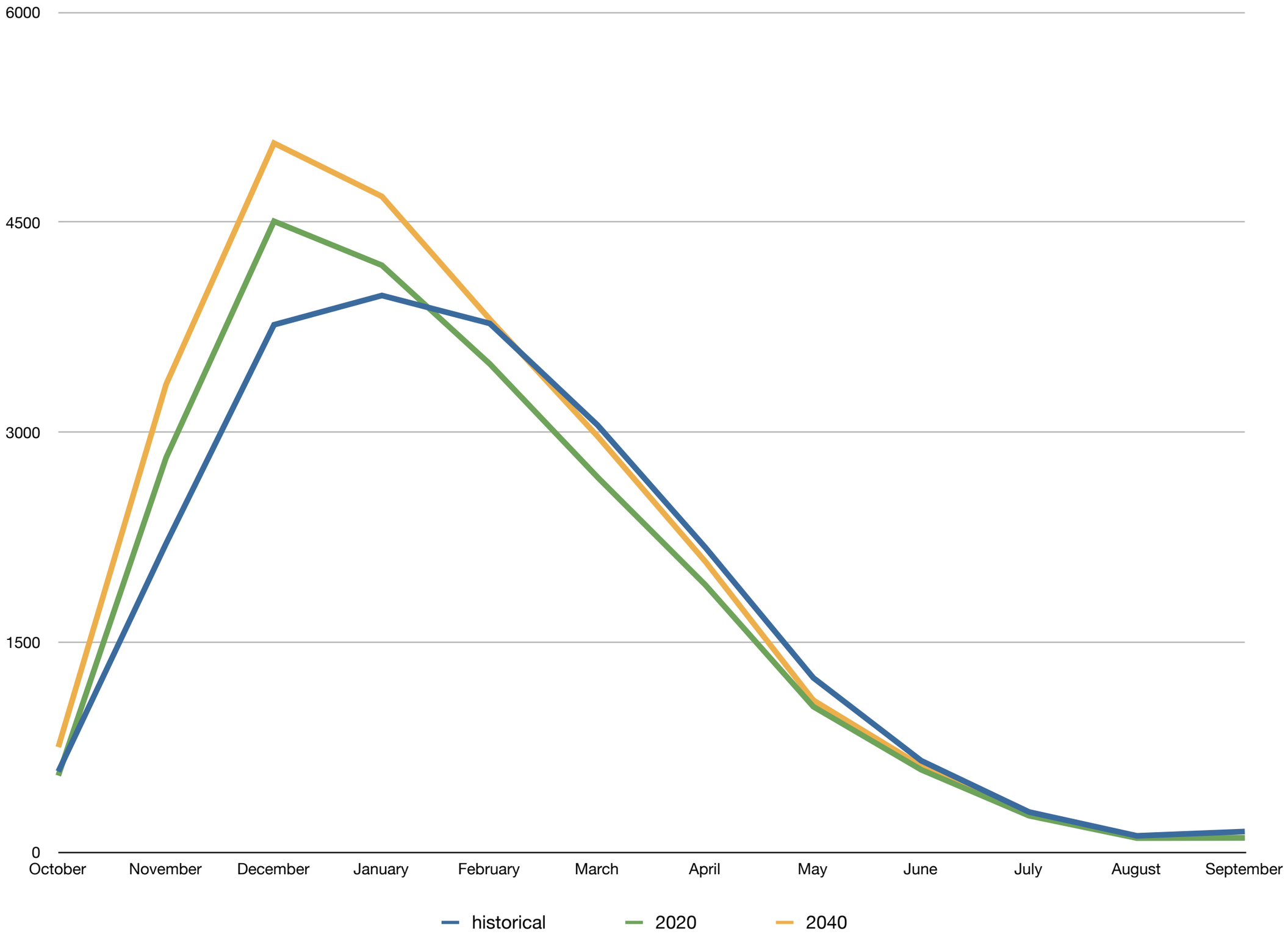

Willamette River at Albany
40000
30000
20000
10000
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

MIROC 3.2

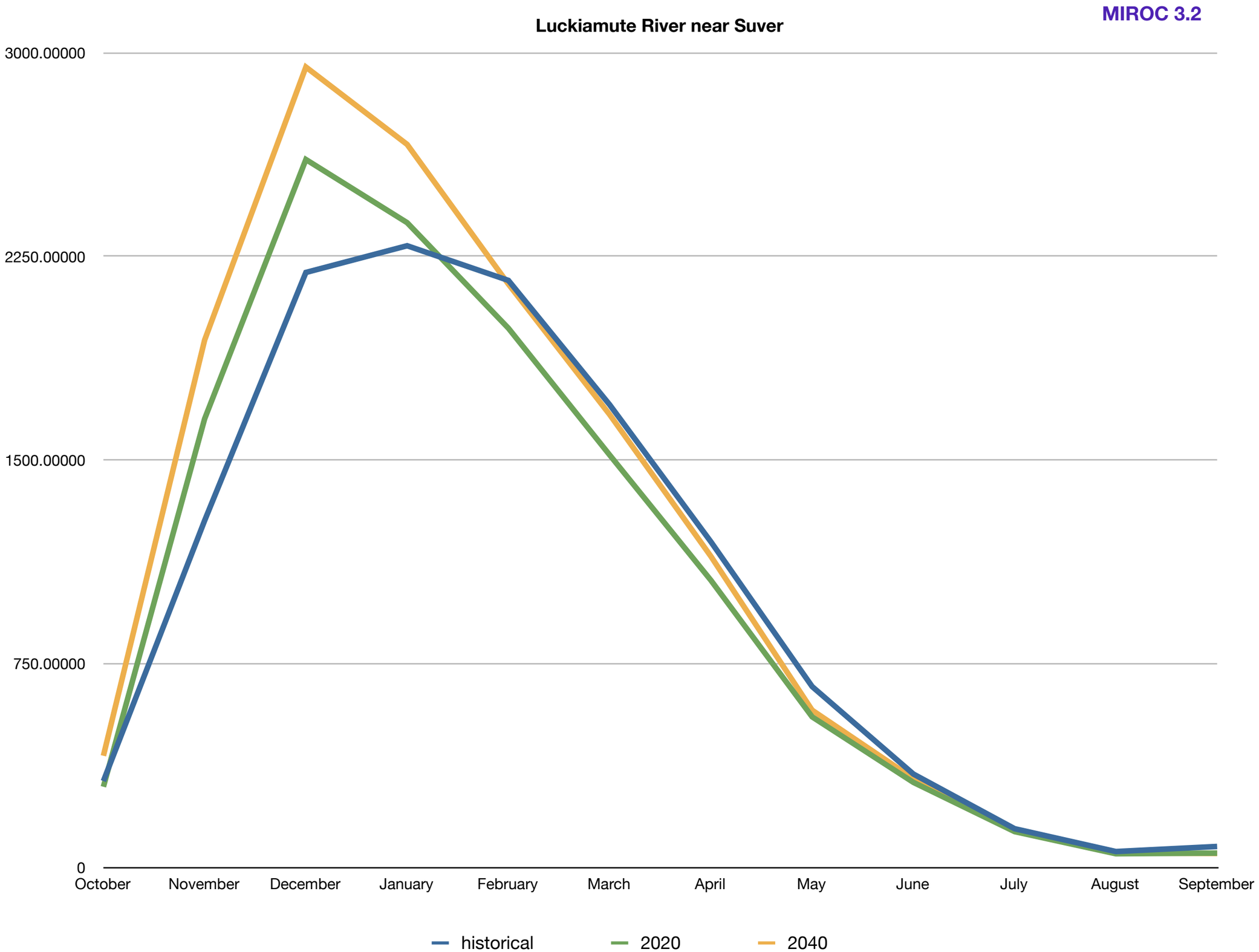

Willamette River at Salem
70,000
52,500
35,000
17,500
0
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

MIROC 3.2

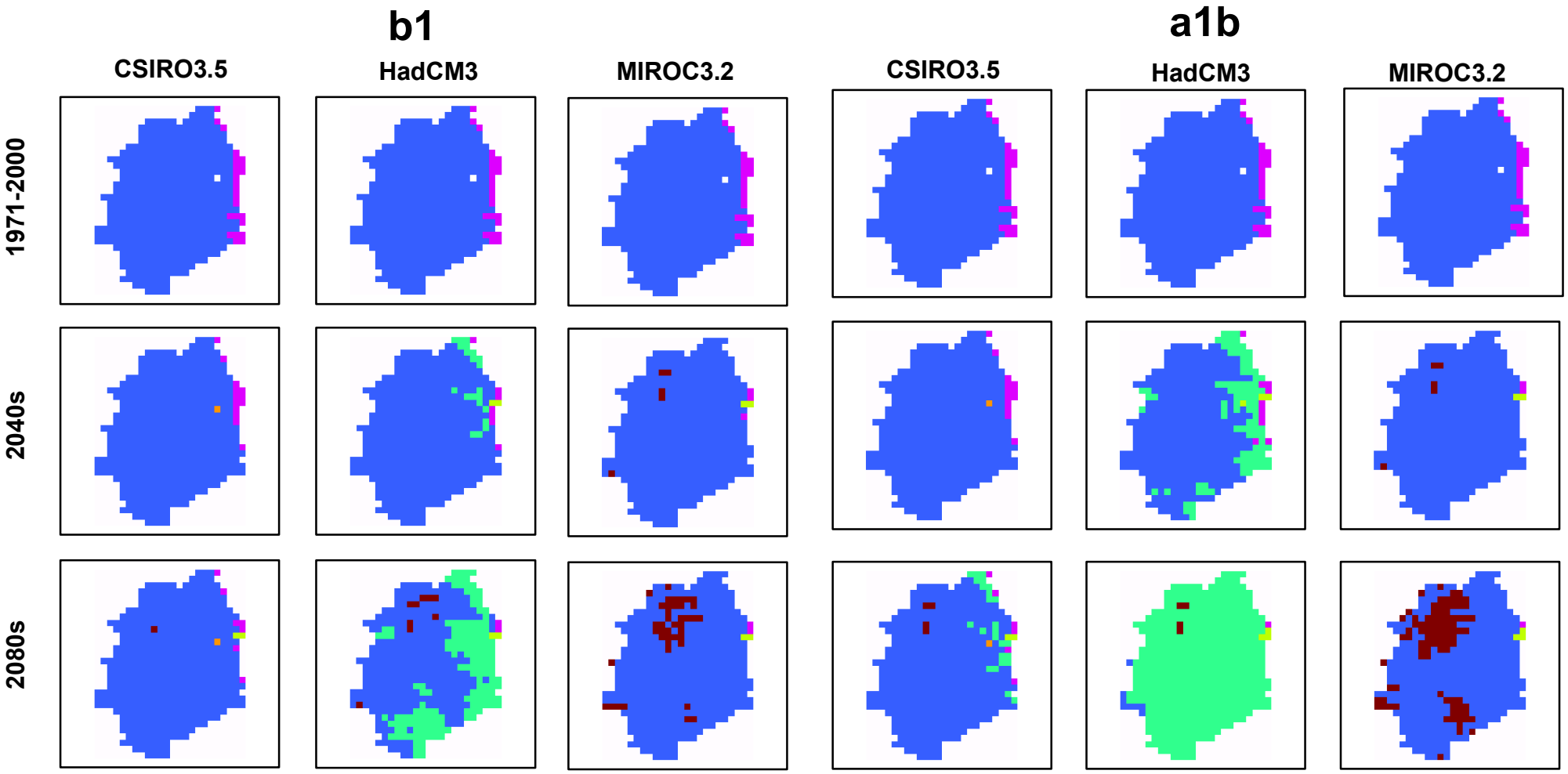
South Yamhill River at McMinnville



MIROC 3.2


Luckiamute River near Suver
3000.00000
2250.00000
1500.00000
750.00000
0
October
November
December
January
February
March
April
May
June
July
August
September
historical
2020
2040

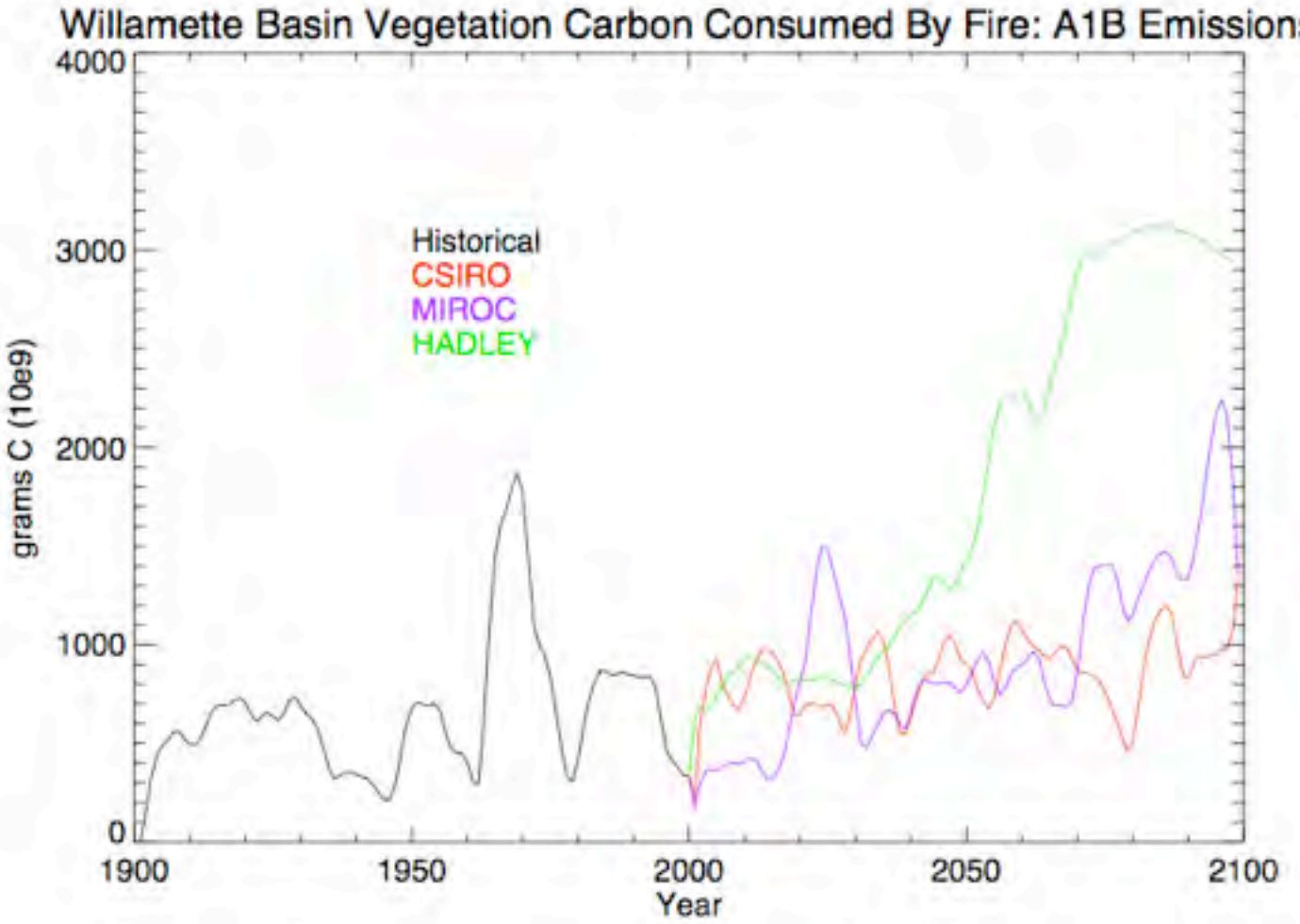
Predominant Vegetation Type

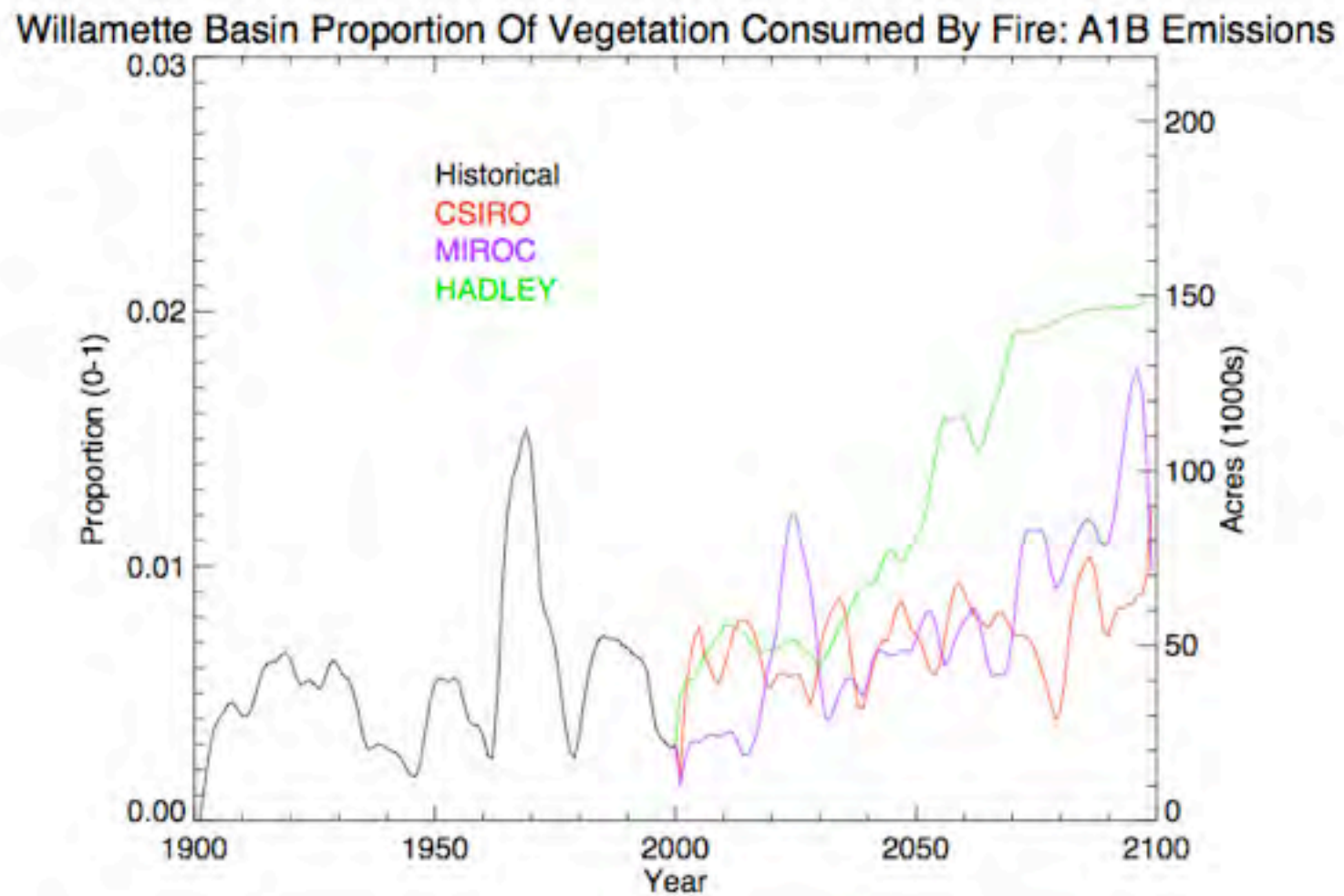


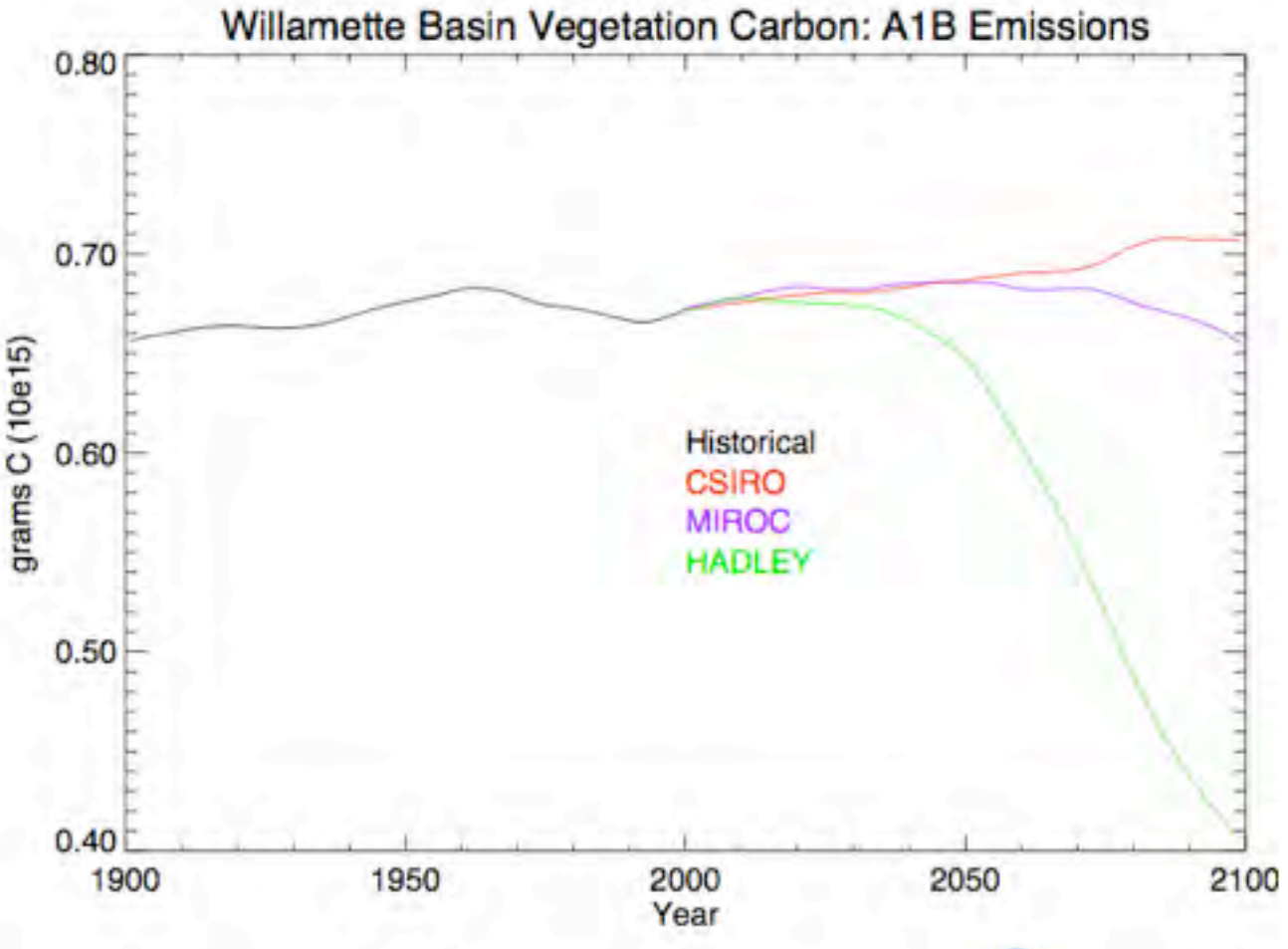
- Subalpine Forest
- Maritime Evergreen Needleleaf Forest
- Temperate Evergreen Needleleaf Forest
- Temperate Evergreen Needleleaf Woodland
- Temperate Grassland
- Subtropical Mixed Forest

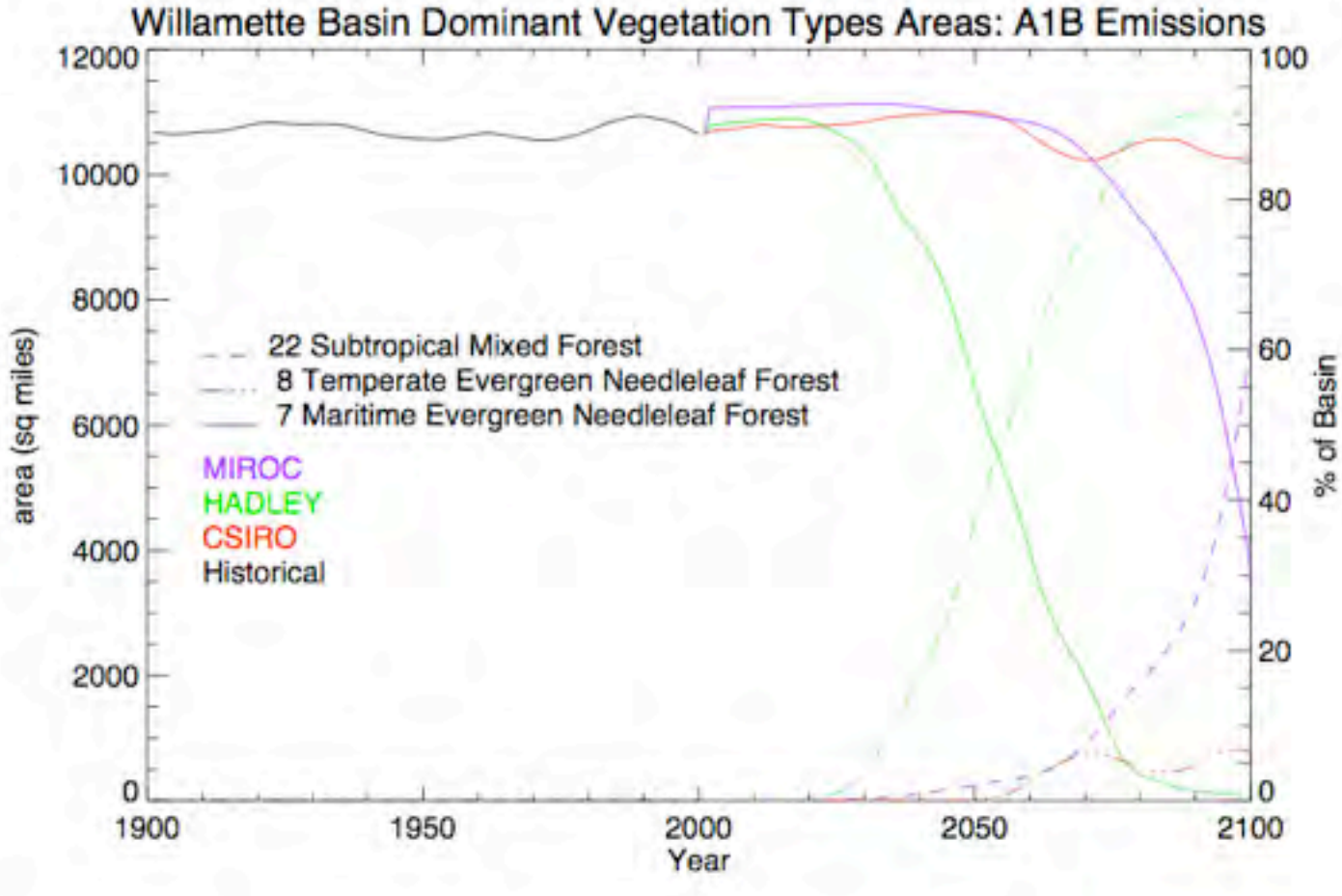
PCIC

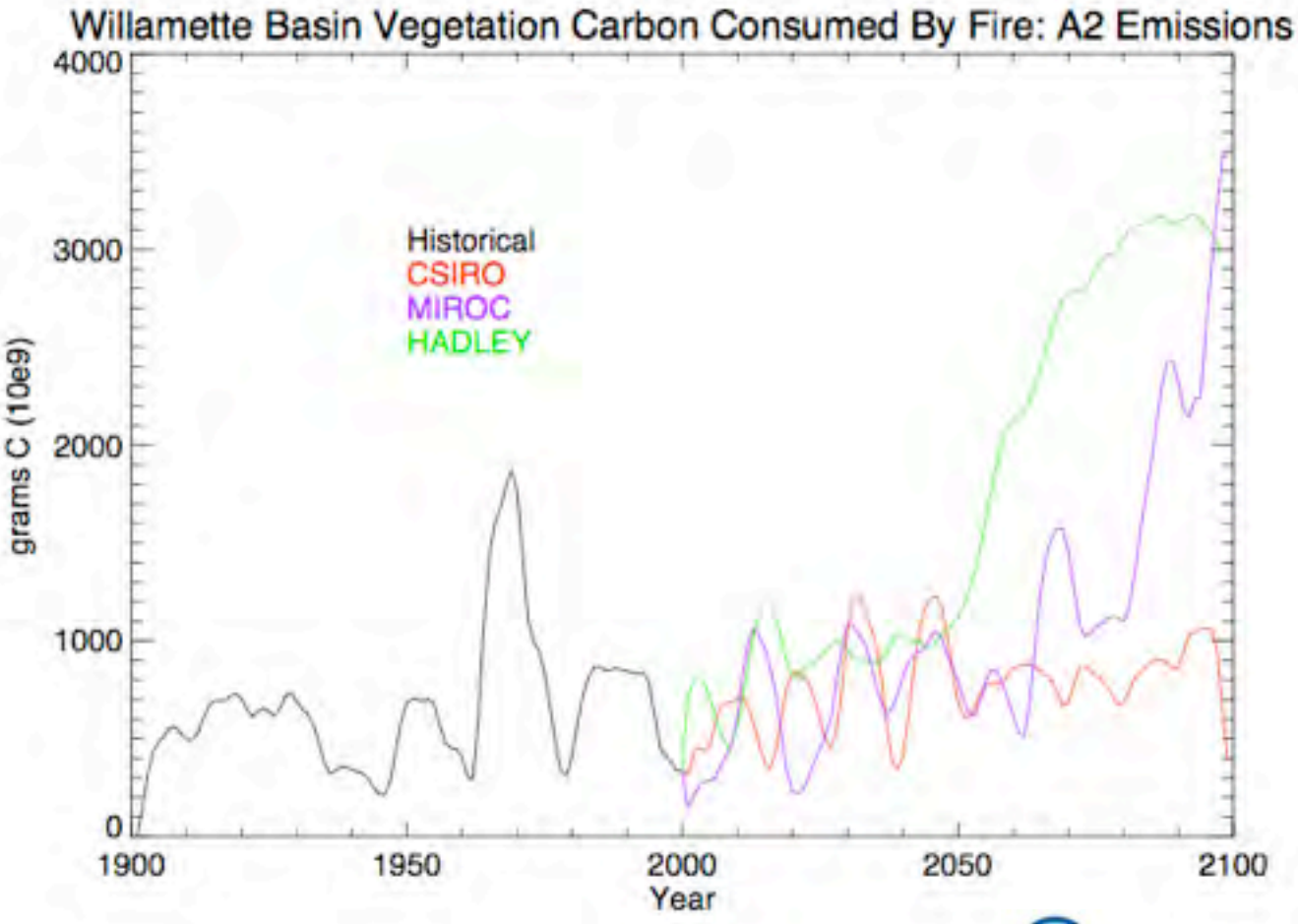
CLI
CLIMATE LEADERSHIP INITIATIVE

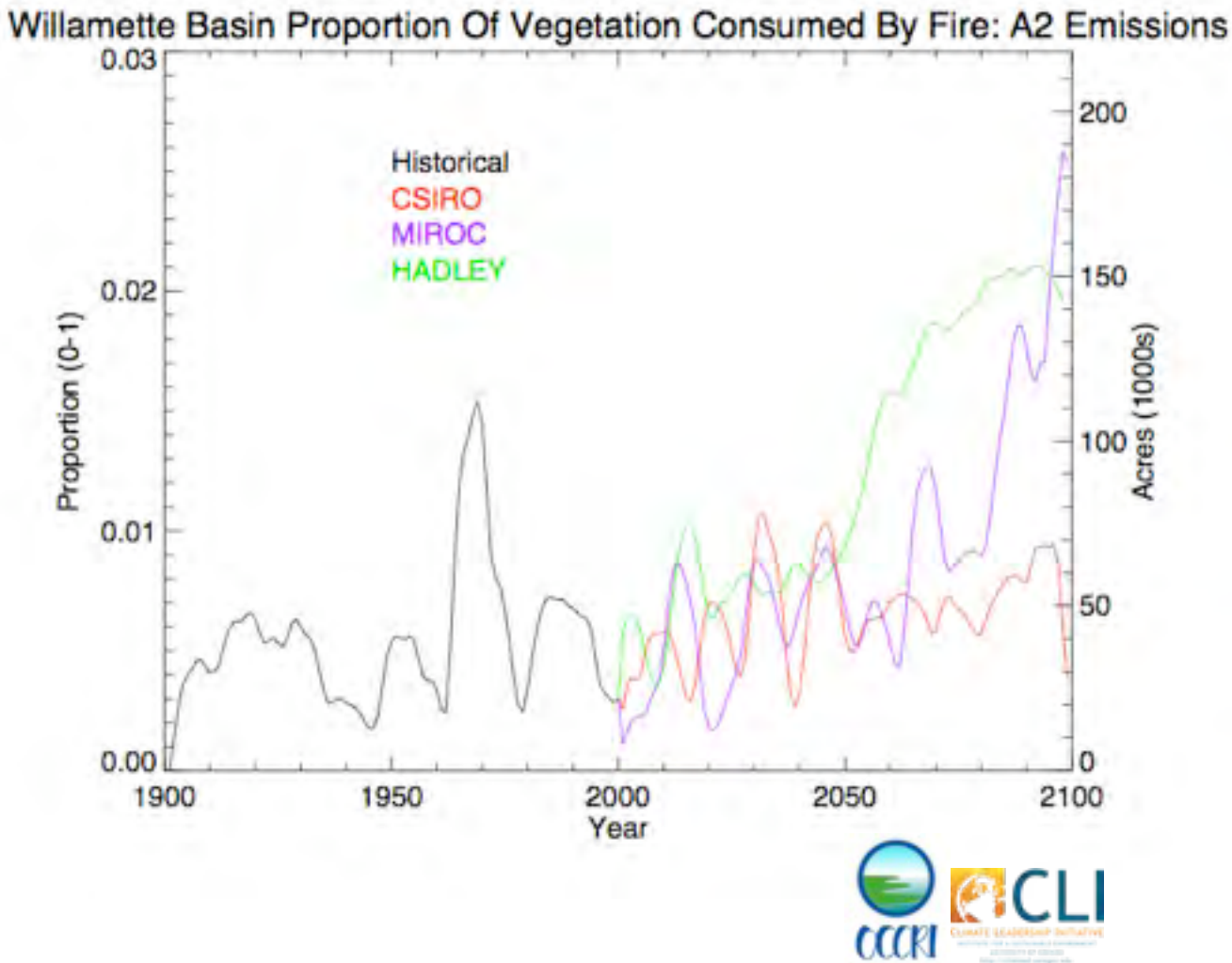

Willamette Basin Vegetation Carbon Consumed By Fire: A1B Emissions
grams C (10e9)
4000
3000
2000
1000
0
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY

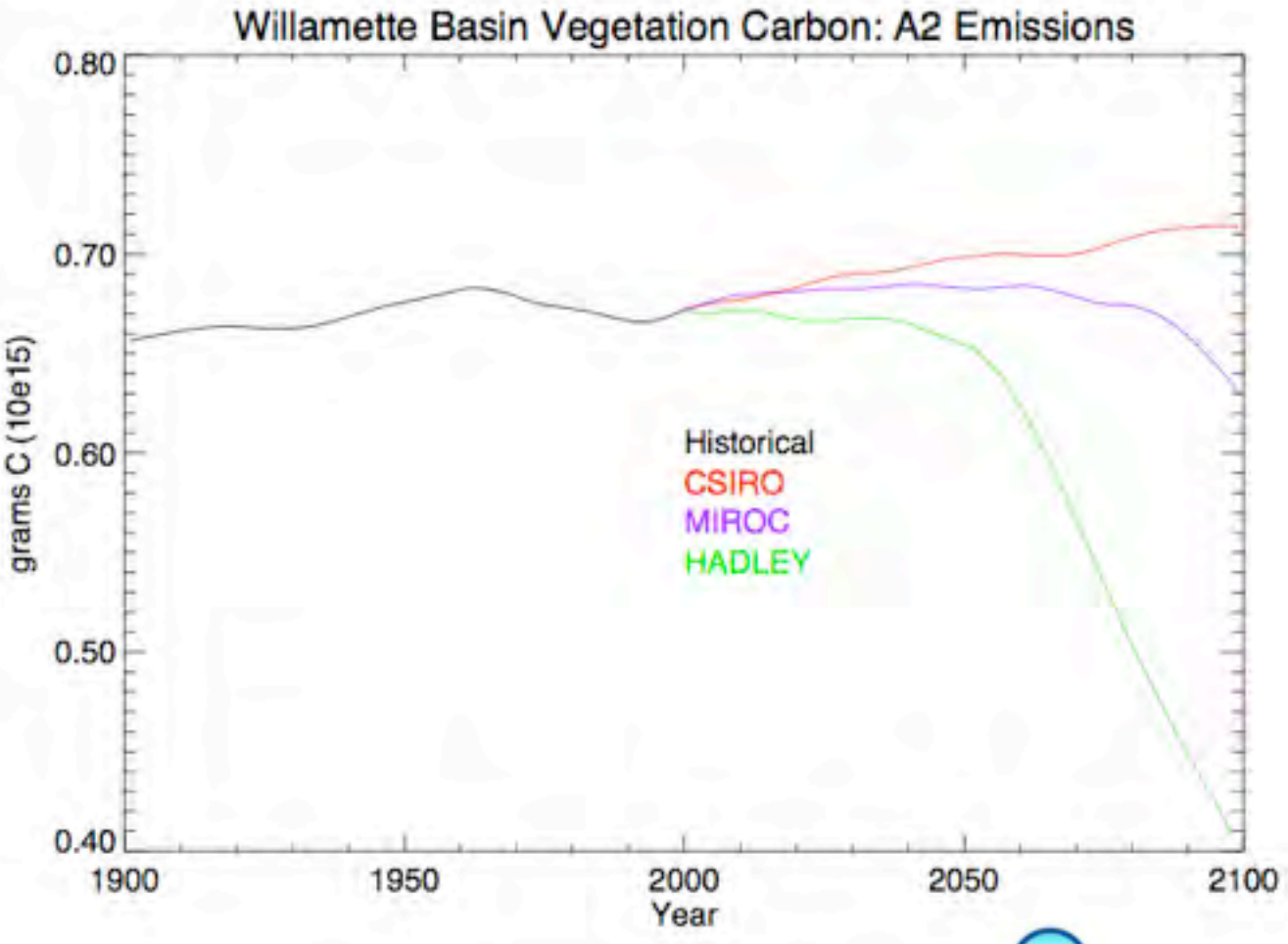

Willamette Basin Proportion Of Vegetation Consumed By Fire: A1B Emissions
Historical
CSIRO
MIROC
HADLEY
Proportion (0-1)
Acres (1000s)
Year
0.03
0.02
0.01
0.00
200
150
100
50
0
1900
1950
2000
2050
2100

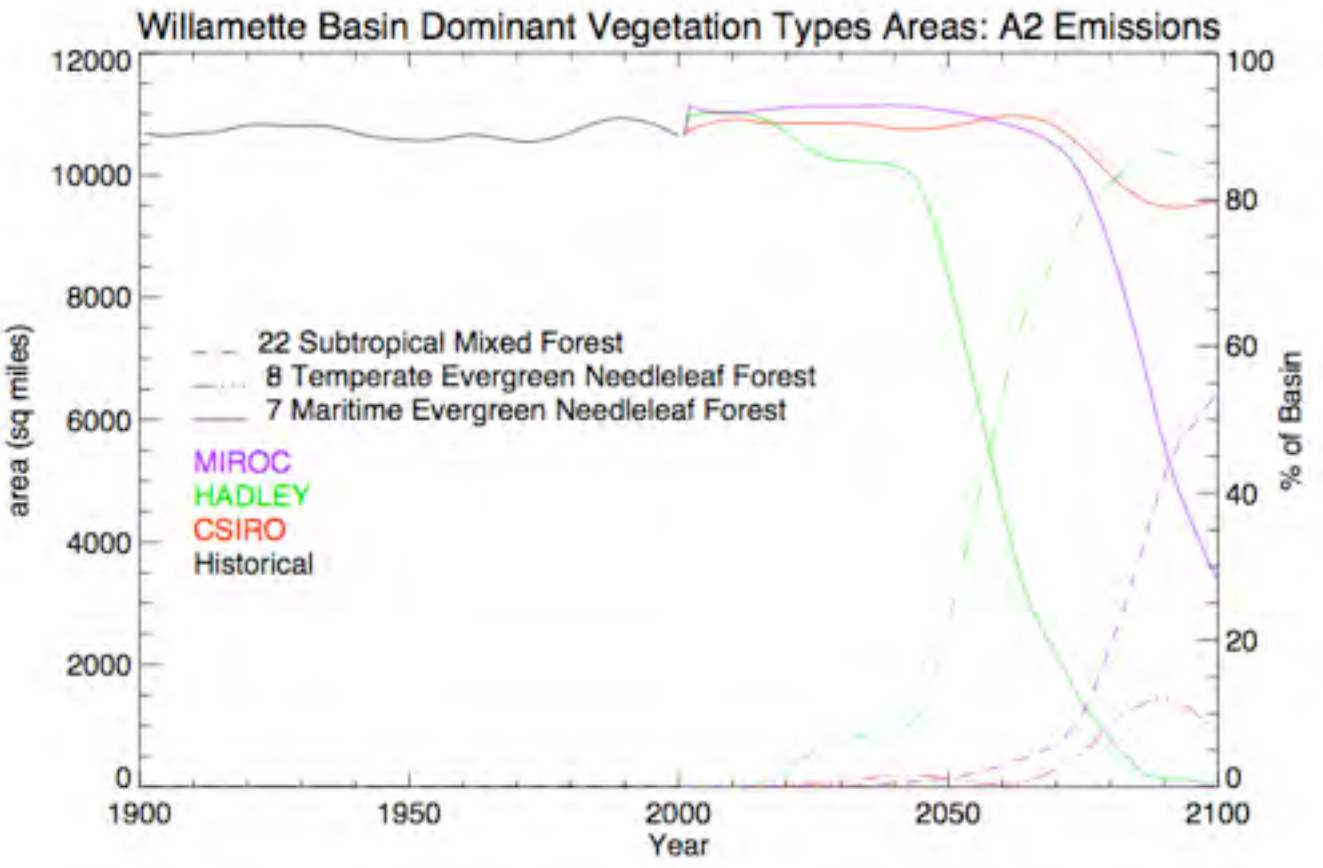

Willamette Basin Vegetation Carbon: A1B Emissions
0.80
0.70
0.60
0.50
0.40
grams C (10e15)
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY

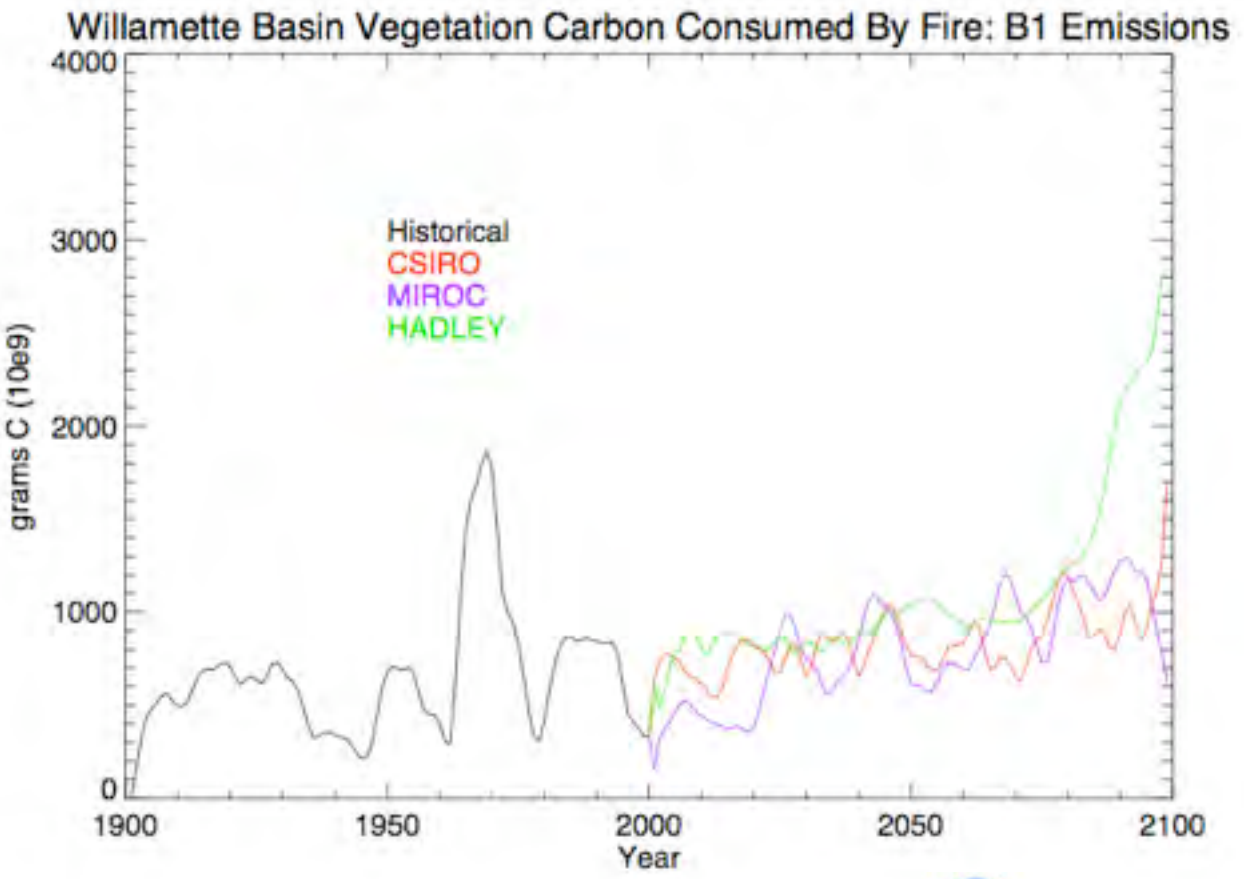

Willamette Basin Dominant Vegetation Types Areas: A1B Emissions
area (sq miles)
% of Basin
Year
12000
10000
8000
6000
4000
2000
0
100
80
60
40
20
0
1900
1950
2000
2050
2100
22 Subtropical Mixed Forest
8 Temperate Evergreen Needleleaf Forest
7 Maritime Evergreen Needleleaf Forest
MIROC
HADLEY
CSIRO
Historical

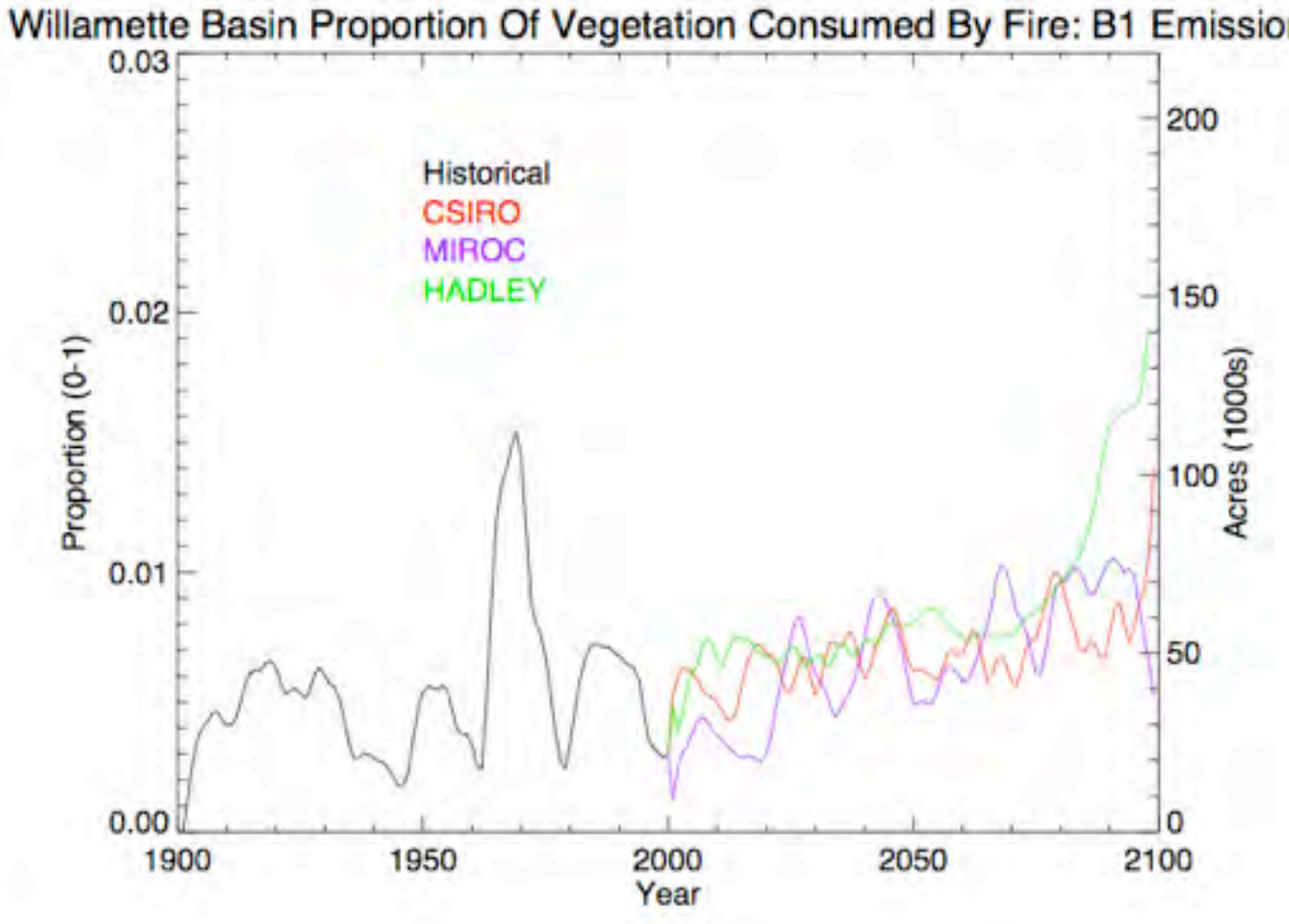

Willamette Basin Vegetation Carbon Consumed By Fire: A2 Emissions
grams C (10e9)
4000
3000
2000
1000
0
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY

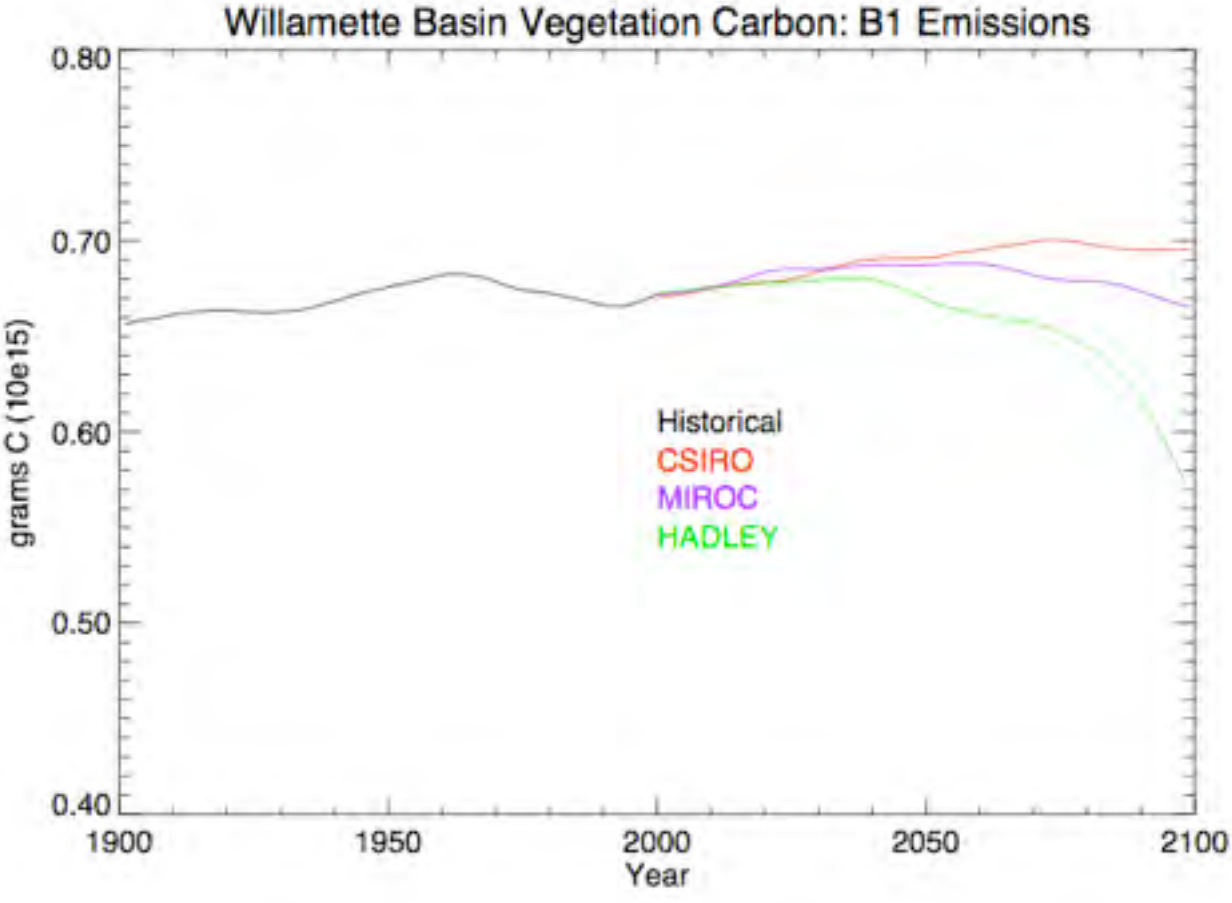

Willamette Basin Proportion Of Vegetation Consumed By Fire: A2 Emissions
Historical
CSIRO
MIROC
HADLEY
Proportion (0-1)
0.03
0.02
0.01
0.00
Acres (1000s)
200
150
100
50
0
1900
1950
2000
2050
2100
Year
CCCRI
CLI

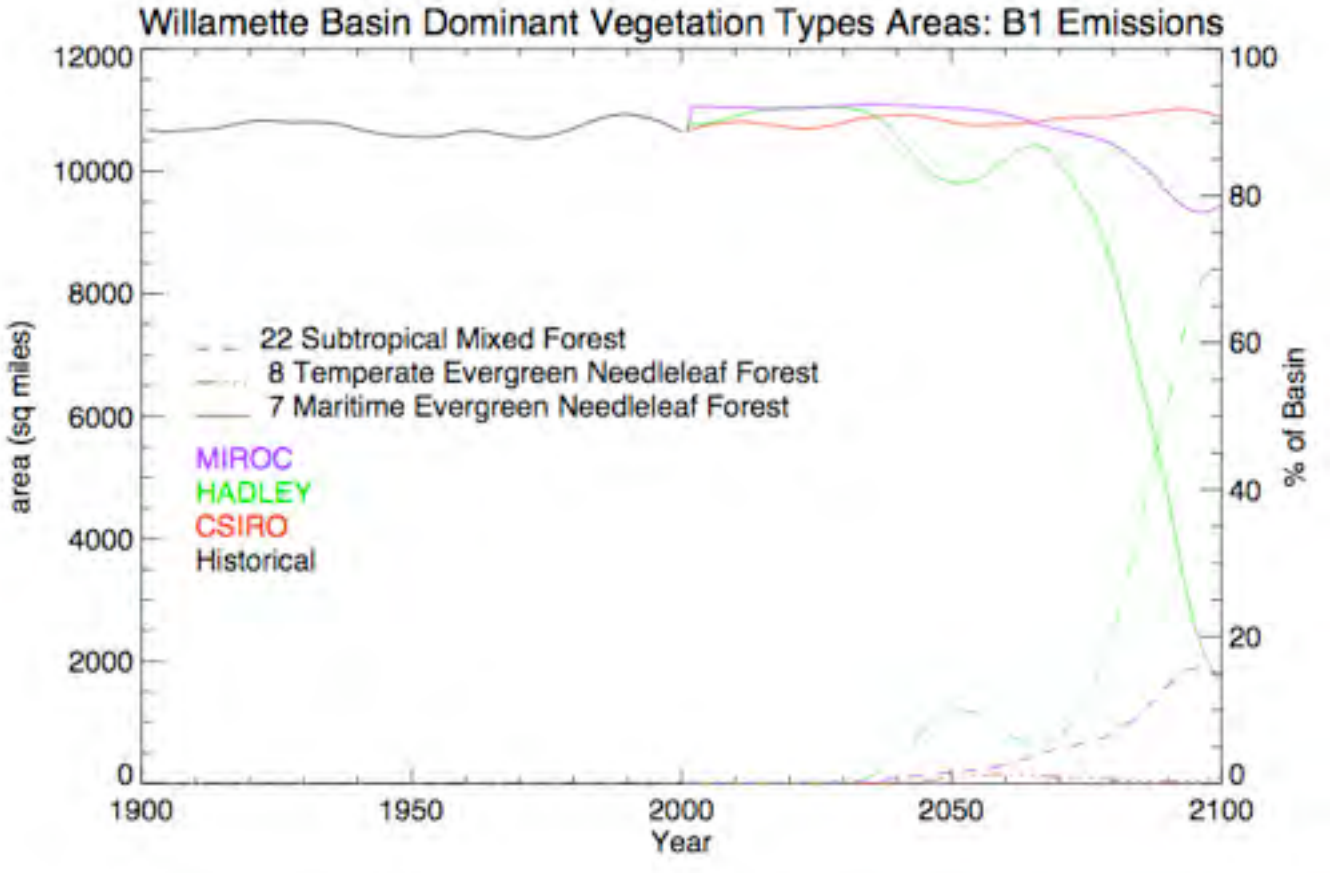

Willamette Basin Vegetation Carbon: A2 Emissions
0.80
0.70
0.60
0.50
0.40
grams C (10e15)
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY


Willamette Basin Dominant Vegetation Types Areas: A2 Emissions
area (sq miles)
% of Basin
Year
12000
10000
8000
6000
4000
2000
0
100
80
60
40
20
0
1900
1950
2000
2050
2100
22 Subtropical Mixed Forest
8 Temperate Evergreen Needleleaf Forest
7 Maritime Evergreen Needleleaf Forest
MIROC
HADLEY
CSIRO
Historical


Willamette Basin Vegetation Carbon Consumed By Fire: B1 Emissions
grams C (10e9)
4000
3000
2000
1000
0
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY


Willamette Basin Proportion Of Vegetation Consumed By Fire: B1 Emissions
Historical
CSIRO
MIROC
HADLEY
Proportion (0-1)
Acres (1000s)
Year
0.03
0.02
0.01
0.00
200
150
100
50
0
1900
1950
2000
2050
2100


Willamette Basin Vegetation Carbon: B1 Emissions
0.80
0.70
0.60
0.50
0.40
grams C (10e15)
1900
1950
2000
2050
2100
Year
Historical
CSIRO
MIROC
HADLEY


Willamette Basin Dominant Vegetation Types Areas: B1 Emissions
area (sq miles)
% of Basin
Year
12000
10000
8000
6000
4000
2000
0
100
80
60
40
20
0
1900
1950
2000
2050
2100
22 Subtropical Mixed Forest
8 Temperate Evergreen Needleleaf Forest
7 Maritime Evergreen Needleleaf Forest
MIROC
HADLEY
CSIRO
Historical