

Wilderness, Wildlife, and Ecological Values of the Hyalite-Porcupine-Buffalo Horn Wilderness Study Area

APPENDIX

Results for prediction of temperature changes show a steady increase in maximum average temperature and minimum average temperature even with the most optimistic scenario for the shortest time frame. This increase is fairly uniform throughout the year. (Figure 1).

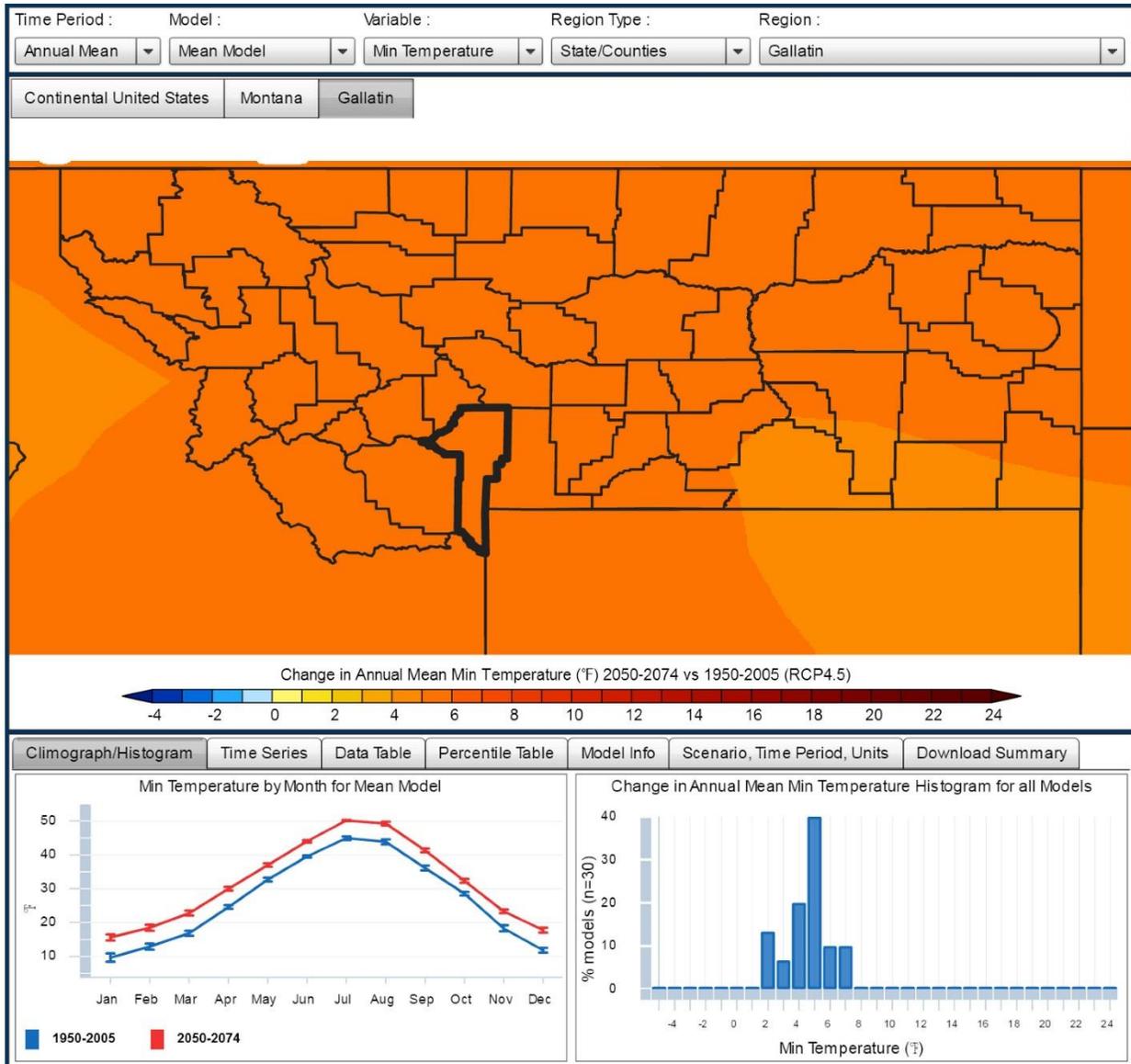


Figure 1. Historic and Future Average Monthly Minimum Temperatures through 2074.

County wide the temperature will increase by 6 – 10 degrees Fahrenheit by 2100 (Figure 2). This agrees with predictions for the northern Rockies by Westerling et al. (2011).

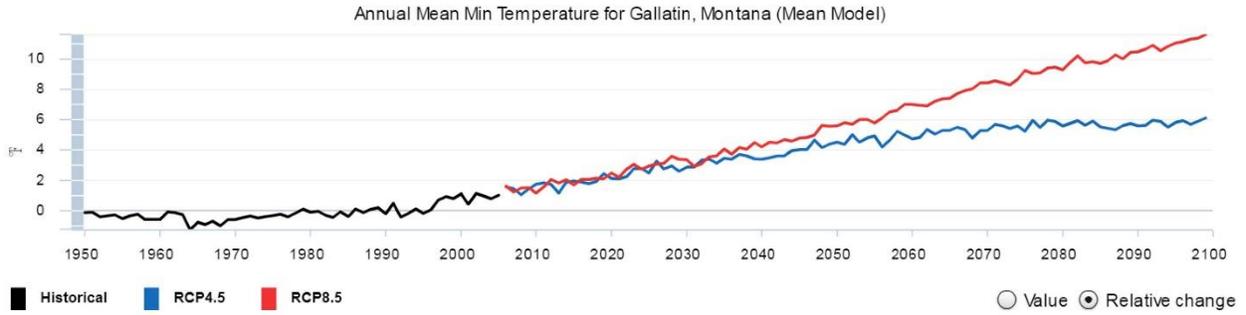


Figure 2. Historic and Future Annual Mean Minimum Temperature Change through 2074.

For Gallatin County as a whole, overall precipitation will increase slightly (Figures 3 through 5). Precipitation will fall fairly uniformly across the county as shown by the shades of blue in the map below up through 2074 (Figure 3).

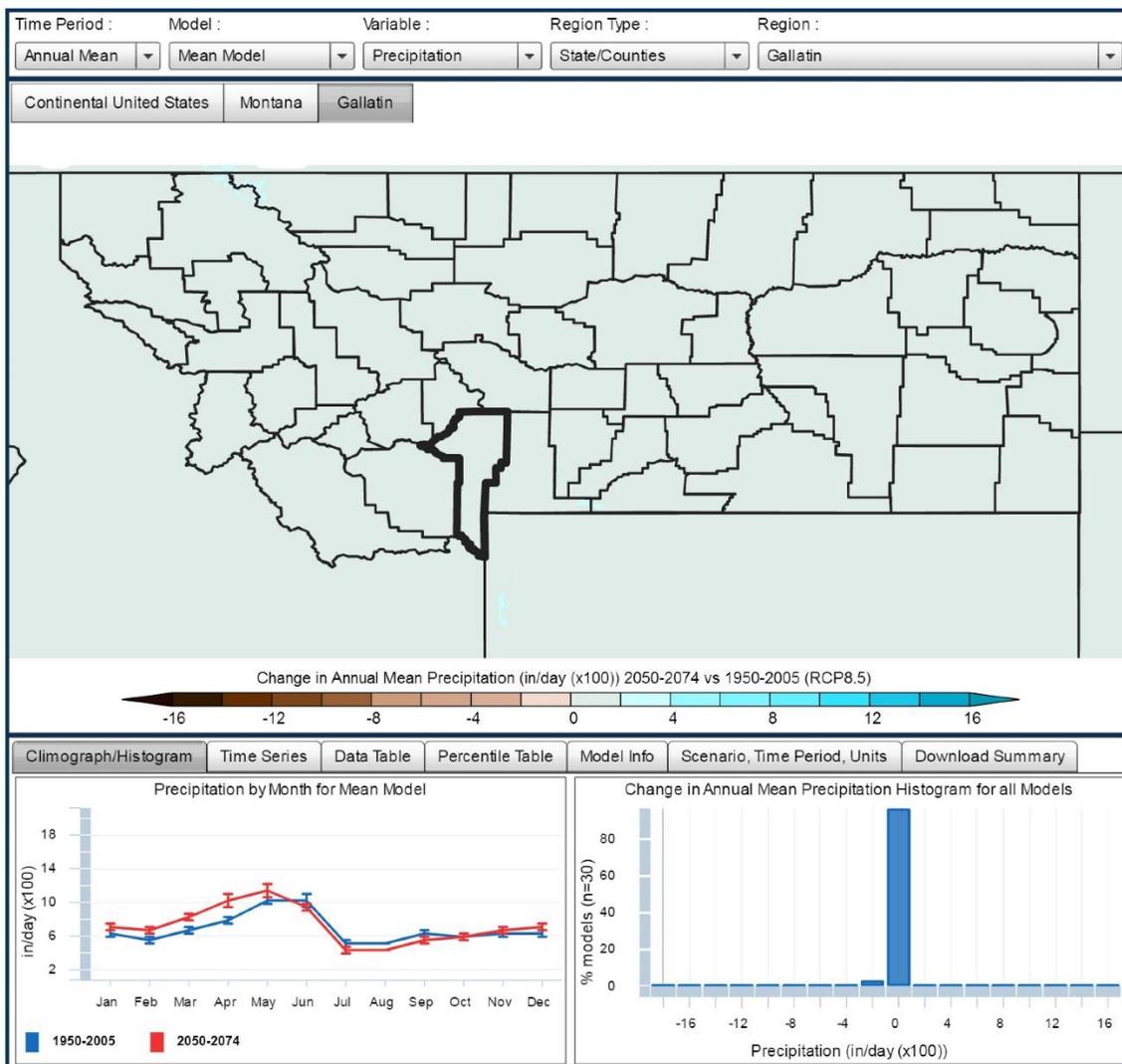


Figure 3. Historical and Future Monthly Precipitation Predictions for Gallatin County.

If the model looks farther into the future, the trend of increased precipitation will continue (Figure 4) with greater increases south of the HPBWSA in SW Yellowstone and Grand Teton Parks.

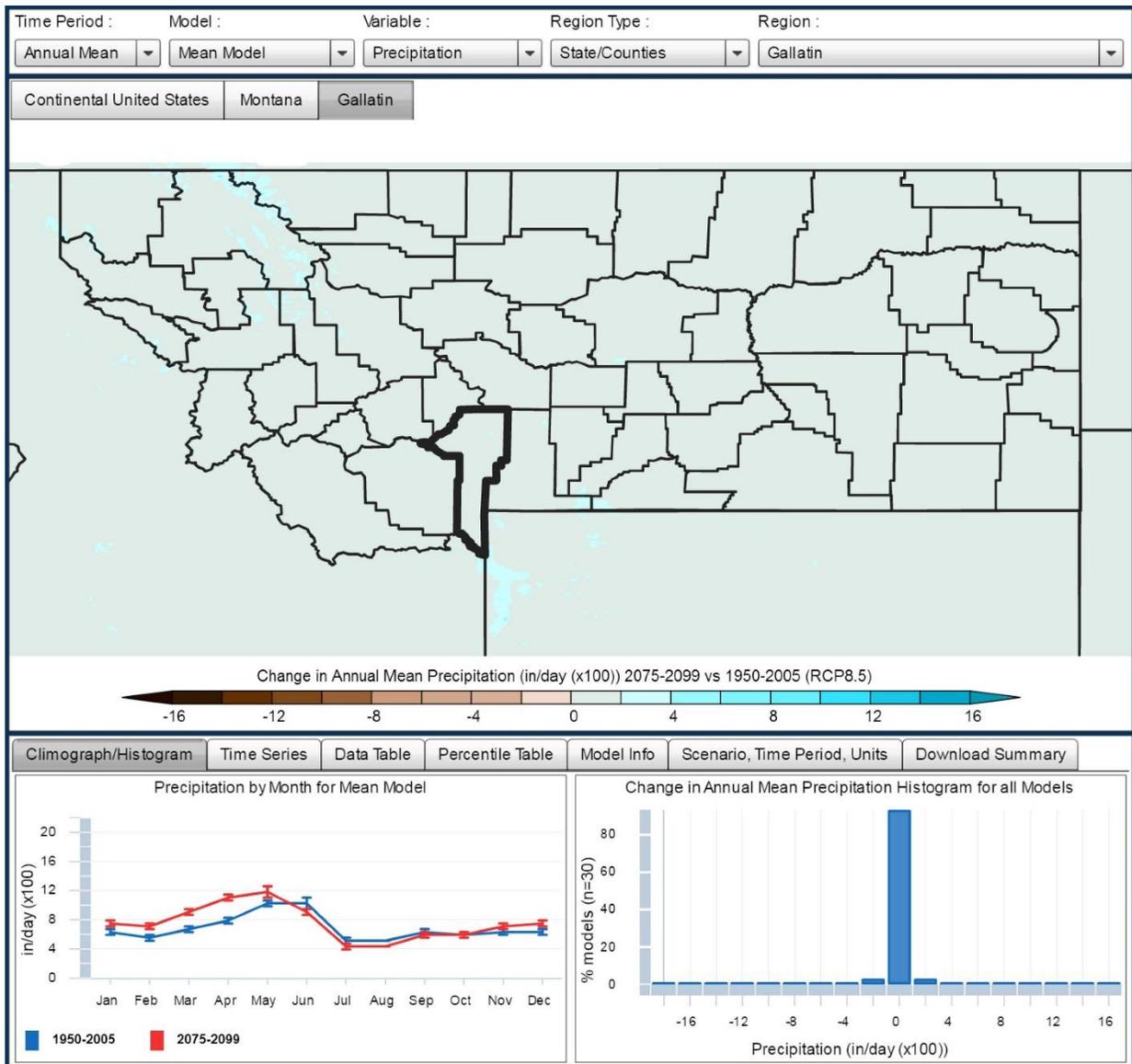


Figure 4. Historical and Future Monthly Precipitation Predictions for Gallatin County.

Average annual mean precipitation will increase slightly into the future with relatively modest increases by 2100 (Figure 5).

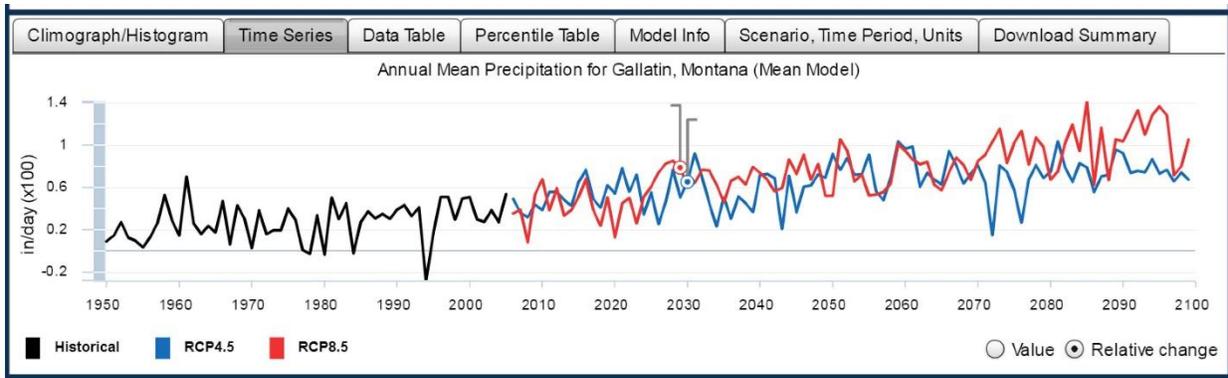


Figure 5. Historical and Future Annual Precipitation Predictions for Gallatin County.

The biggest change in precipitation will come in snowfall amounts and patterns, and snow water equivalences (Figures 6 through 8). The higher elevation areas like the HPBH WSA and Bridger Range will experience lower average snow in the future (reddish shade on the maps) while lower elevations in the NW part of the county should have just slightly lower snow (yellow shade on the maps). As these predictions look farther into the future, the snowfall will continue to diminish. Combined with the precipitation forecasts, these models predict less snow and more rain over time with some localized differences in amounts.

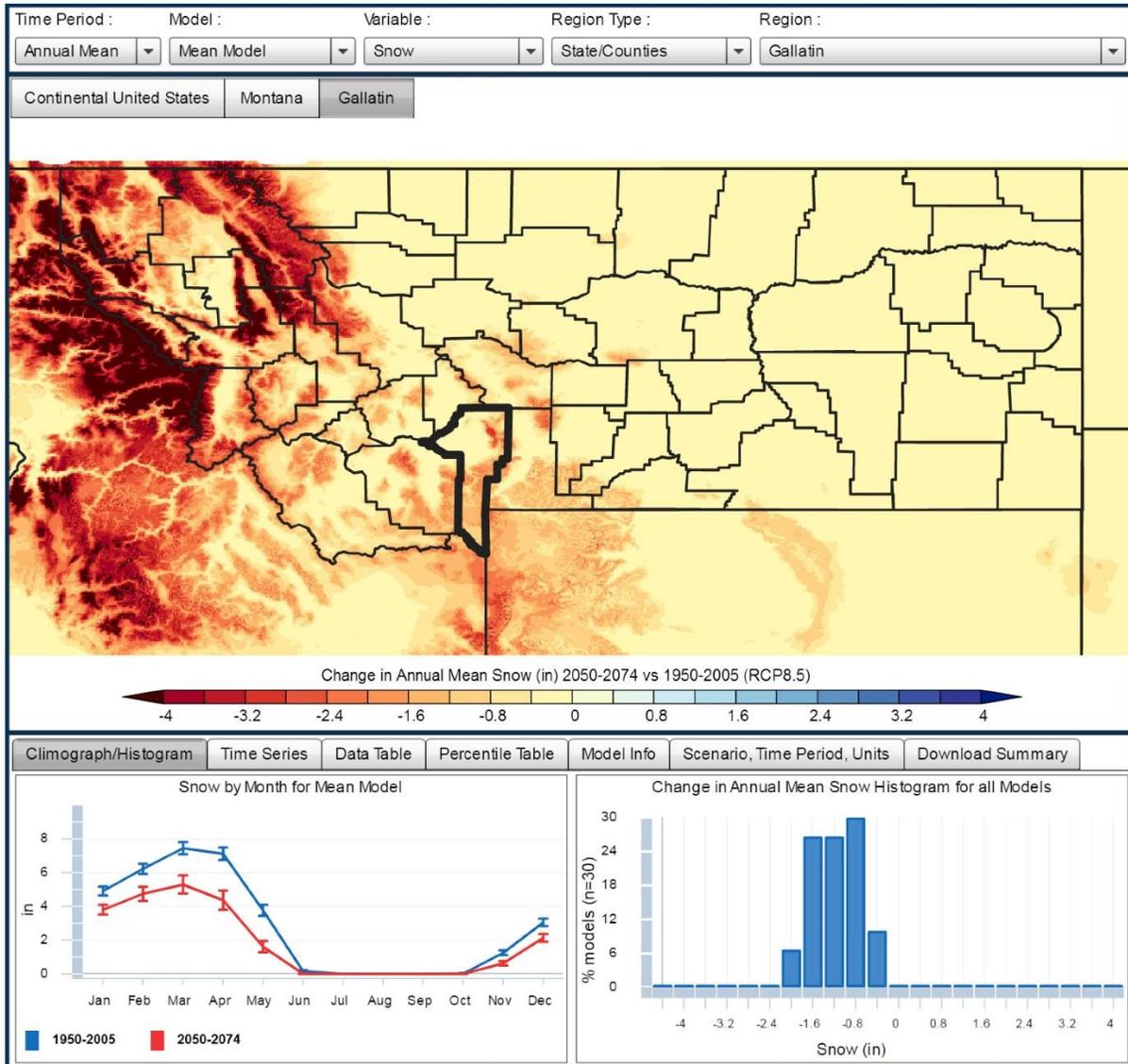


Figure 6. Historical and Future Monthly Snowfall predictions through 2074 for Gallatin County.

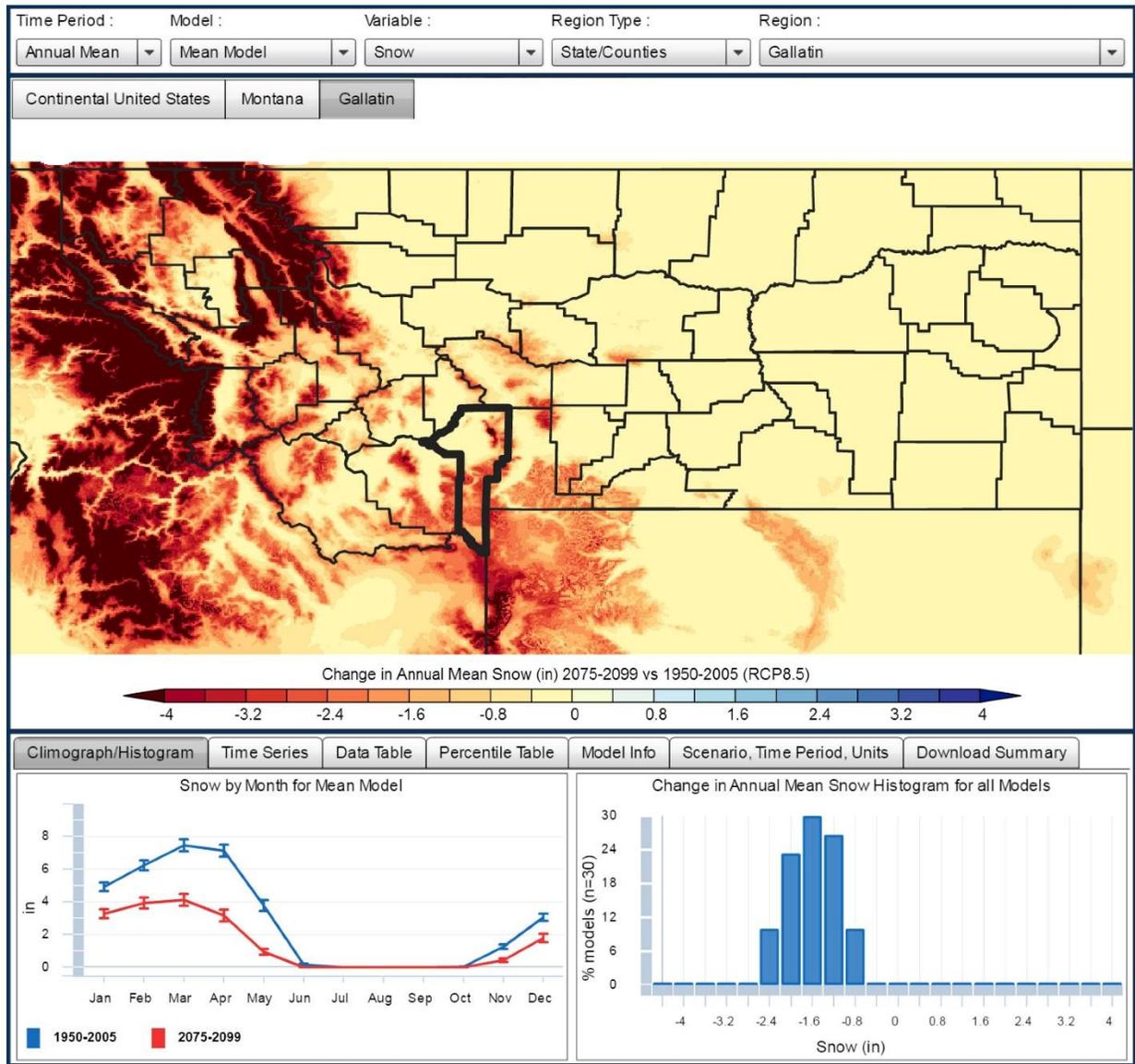


Figure 7. Historical and Future Monthly Snowfall predictions through 2099 for Gallatin County.

By 2100, under scenario 8.5 there will be an average change of about 1-2 inches in snowfall.

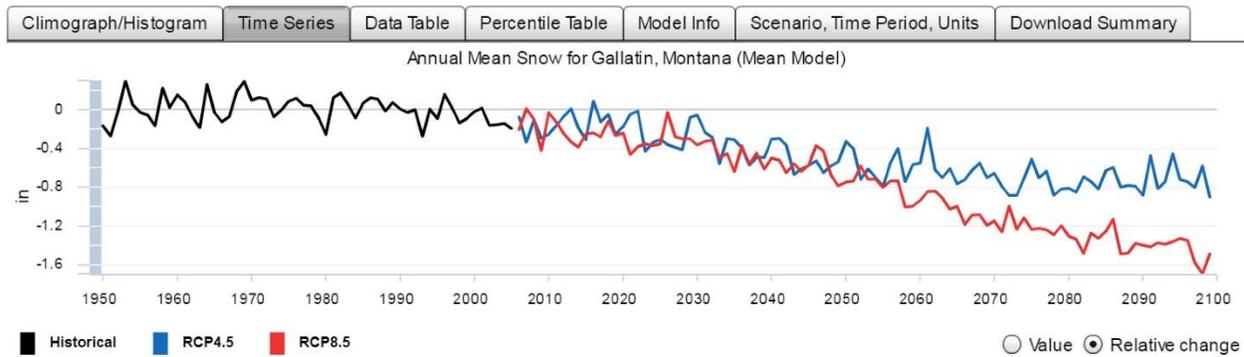


Figure 8. Historical and Future Monthly Snowfall Predictions for Gallatin County.

Runoff in the future will follow a similar pattern to precipitation with increases in late winter and spring, and decreasing after June (Figure 9). The higher elevation areas like the HPBH WSA will experience lower total runoff in the future (yellow shade on the map) while lower elevations in the NW part of the county should have higher runoff (blue shade on the map).

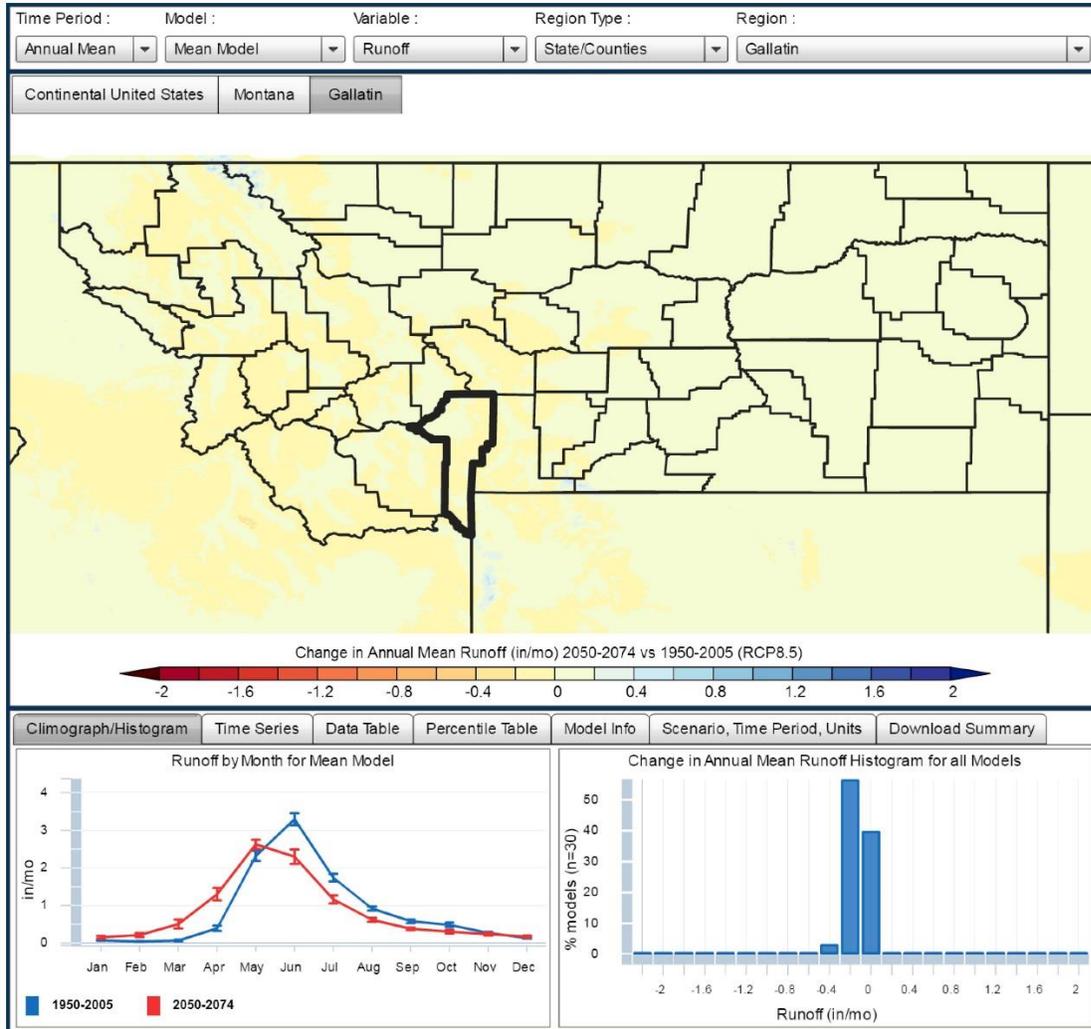


Figure 9. Monthly Runoff predictions for Gallatin County.

An average change of 2-4 inches doesn't seem like much of a change in precipitation, but the timing of events will have significant effects on plants and animals in the HPBH WSA. Runoff will start earlier in the year and drop off during the summer months. A comparison of the various model outputs shows broad agreement in this respect with differences in magnitude depending on the model (Figure 10).

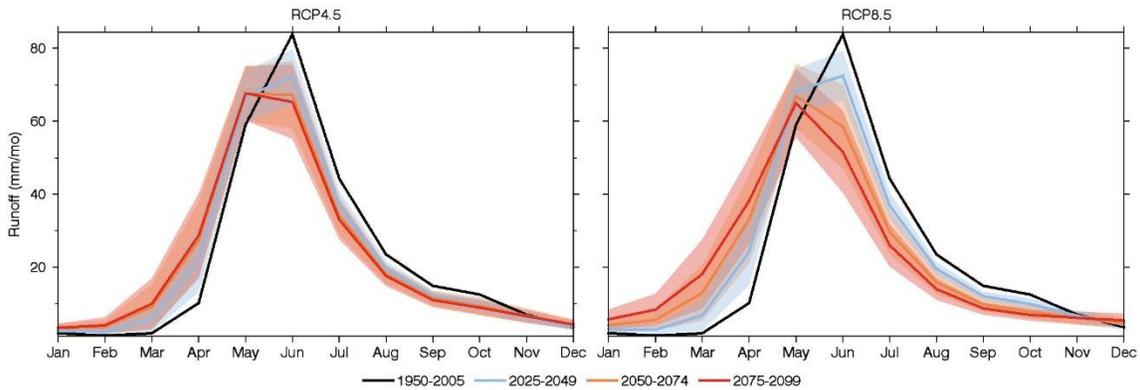


Figure 10: Monthly averages of runoff for four time periods for the RCP4.5 (left) and RCP8.5 (right) simulations. The average of 30 CMIP5 models is indicated by the solid lines and their standard deviations are indicated by the respective shaded envelopes.

Figure 10. Monthly Averages of Runoff Model Variation.

The website for the National Climate Change Viewer (NCCV, http://www.usgs.gov/climate_landuse/clu_rd/nex-dcp30.asp) allows a wide variety of simulations to be run for all regions of the country. Regardless of the models used, there is a consensus that total runoff will not change greatly in the future (Figure 11), but the timing of runoff will.

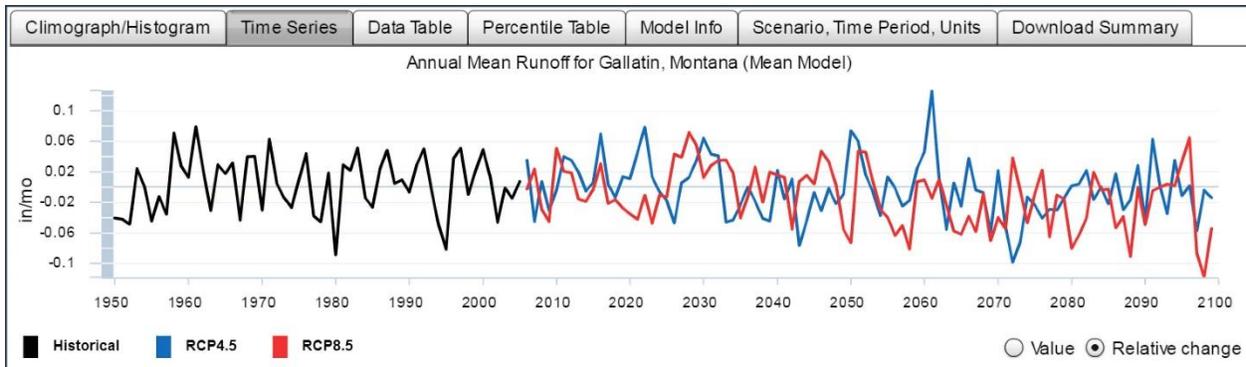


Figure 11. Historic and Future Average Annual Mean Runoff for Gallatin County.

Another way to look at the effects of climate change is to analyze what changes in plant and animal communities these differences in temperature and precipitation will have. A team of researchers from the Klamath Center for Conservation Research, the University of Washington, and the University of Alberta have developed a climate change database (AdaptWest) to help planning for climate adaption. As the climate warms, most regions will shift from their current climates by 2050. This toolkit was developed in response to Executive Order 13653: “Preparing the United States for the Impacts of Climate Change” was issued in November 2013. To implement actions, the Executive Order established an interagency Council on Climate Preparedness and Resilience, chaired by the White House and composed of more than 25

agencies. Actions include developing actionable climate science, launching a climate data initiative, and providing a toolkit for climate resilience.

To enhance the role of science in helping manage climate impacts, strengthen the climate resilience of watersheds, natural resources and ecosystems, and enhance adaptive capacity (the ability of a system to adjust to climate change, moderated potential damages, and/or cope with the consequences), AdaptWest is designed to provide spatial data on the location of potential refugia (areas with a high contribution to a landscape's adaptive capacity), and estimates on the relative intensity of climate-related threats to ecosystem services.

AdaptWest can be used to help land management agencies and other organizations implement strategies that promote resilience, protect biodiversity, and conserve natural resources in the face of a changing climate. It uses a wide range of spatial data to provide regional analyses and provides a bridge between climate and ecological data. The datasets used are open, well-documented, and reliable.

It is especially useful in identifying future refugia which are key to promoting climate change resilience. A method of accomplishing this is to calculate the climate velocity of a given area: velocity is the rate at which species must move to shift to areas of similar climate as their current area changes. Climate velocity analyses can highlight areas with high adaptive capacity that may serve as refugia, and also areas with high levels of threat to ecosystem services. In areas with low velocity of climate change, species can adapt if they can disperse faster than the velocity of climate change.

Climate velocity data for all of North America at 1km resolution are available at:

<http://adaptwest.databasin.org/pages/adaptwest-velocitywna> . Among other results, it can identify areas where current climates will disappear: be pushed off mountaintops and continents.

Analyses can be done in two directions. Future climate velocity predicts where current species will go to (how fast will they need to move); Backward climate velocity predicts where species will come from (how distant are source populations). Climate velocity analyses can inform questions about the 1) Ability of resident species to persist locally or regionally, 2) Which areas can best facilitate such persistence, and 3) Likely degree of community turnover.

Analyses of climate velocity were run for the HPBH WSA and neighboring region. These show the predicted climate velocity for two time frames, 1995-2055 and 1995-2085, under two climate change scenarios: RCP 4.5 and RCP 8.5 (Figures 12-15). These two scenarios represent the extremes of most climate predictions; from the most optimistic (4.5) to the most unfavorable (8.5). Given the slow response of most nations to reduce CO₂ emissions, the more unfavorable scenarios may in fact be the most realistic. Under any scenario, in general, many refugia are mid-slope montane areas, especially on north-south trending mountain ranges such as the HPBH WSA.

Figure 12 shows predictions for a shorter time frame and assuming great efforts are made right now in reducing greenhouse gas emissions (RCP 4.5). In this scenario the HPBH WSA fares quite well and the current species do not have to move fast or far to find a similar climatic niche (plant and animal communities will not change precipitously).

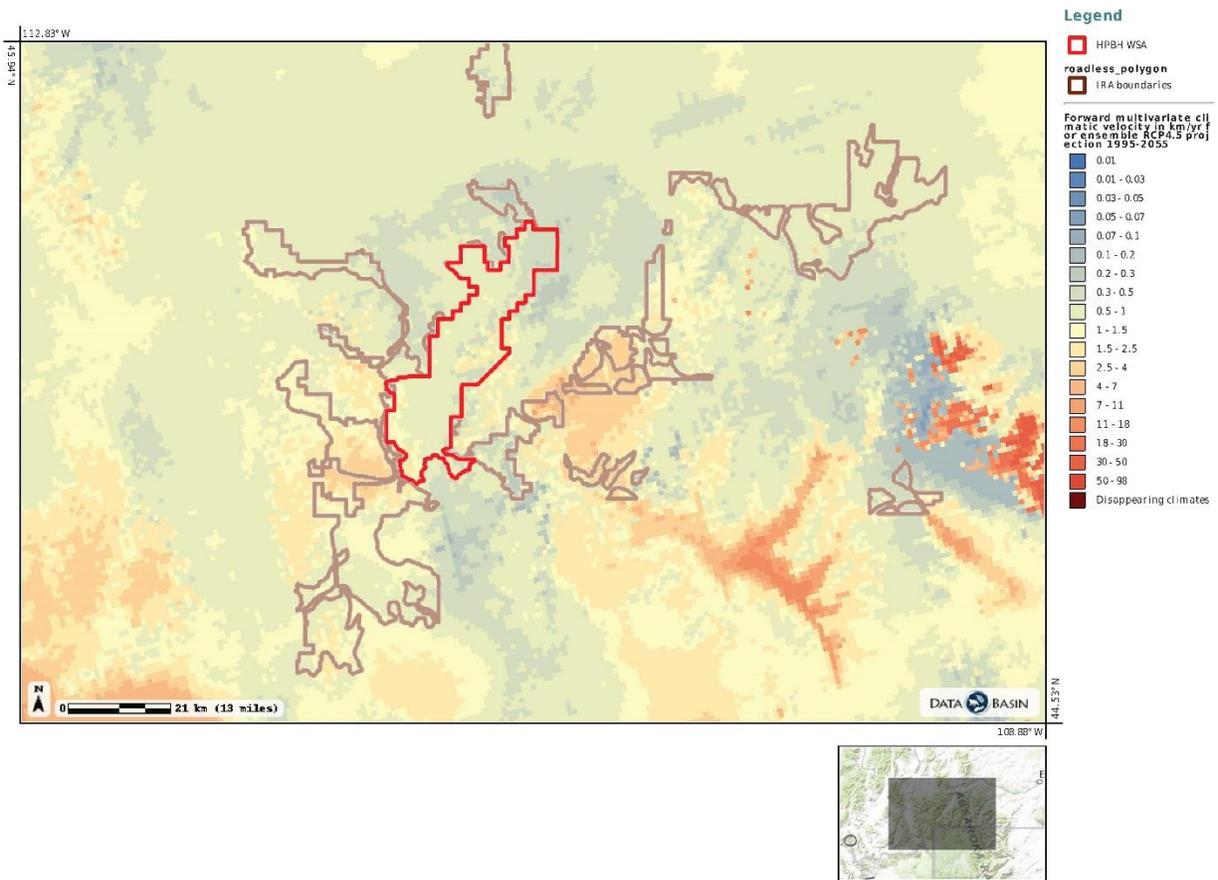


Figure 12. Forward climate velocity 1995-2055 - Scenario 4.5.

Figure 13 shows predictions for a longer time frame and assuming great efforts are made right now in reducing greenhouse gas emissions (RCP 4.5). In this scenario the HPBH WSA also fares quite well and species do not have to move fast or far to find a similar climatic niche (plant and animal communities will not change precipitously).

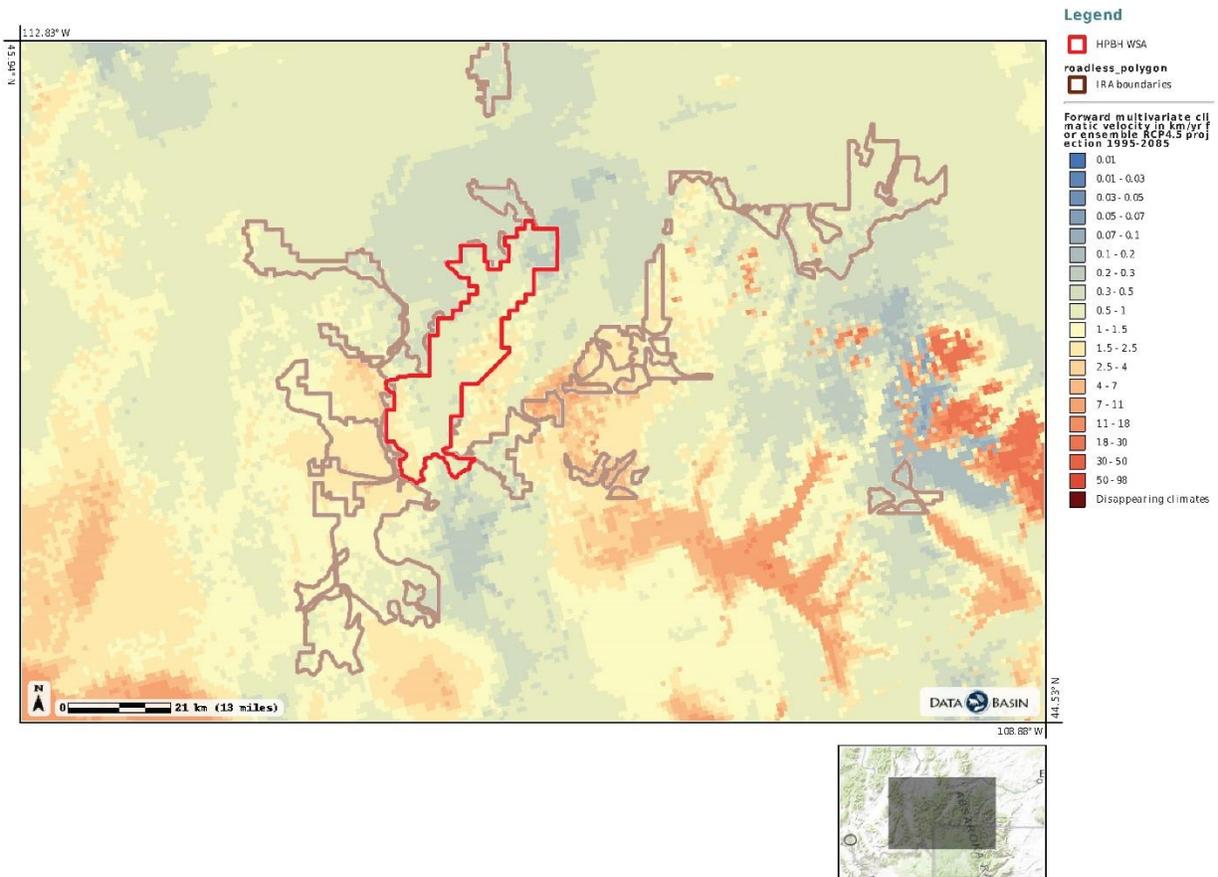


Figure 13. Forward climate velocity 1995-2085 - Scenario 4.5.

Figure 14 shows predictions for a longer time frame and assuming few efforts are made right now in reducing greenhouse gas emissions (RCP 8.5). In this scenario the HPBH WSA fares moderately well and species have to move moderately fast or far to find a similar climatic niche (plant and animal communities will change less than regions to the south, but more than regions to the north).

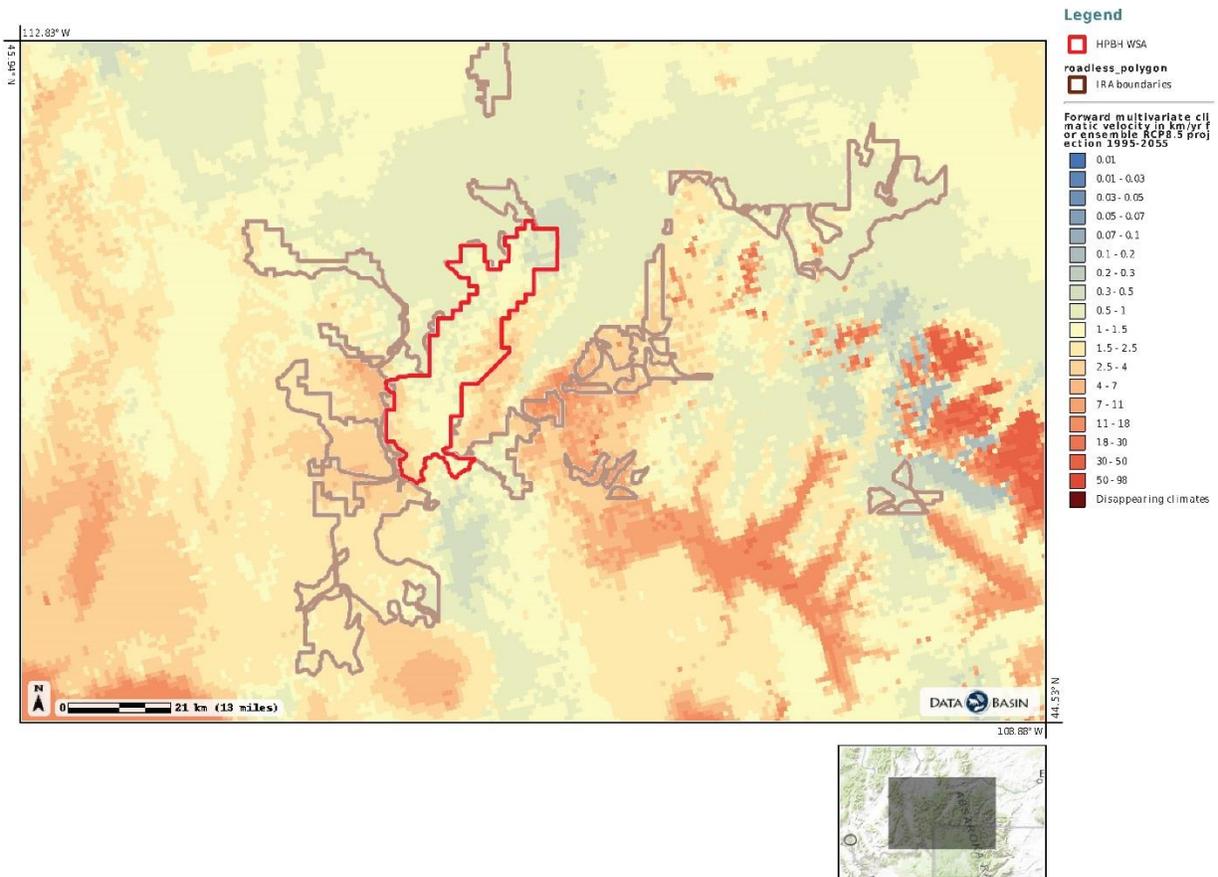


Figure 14. Forward climate velocity 1995-2055-8.5

Figure 15 shows predictions for a longer time frame and assuming no significant efforts are made right now in reducing greenhouse gas emissions (RCP 8.5). In this scenario the HPBH WSA fares poorly and species have to move very fast or far to find a similar climatic niche (plant and animal communities throughout the region will change greatly). The climate on south-facing slopes north of Gardiner, Montana, (dark red dots in lower center of map) will disappear as they become even drier and hotter. Potential refugia will move north from the HPBH WSA and may be found in the Bridger and Bangtail mountain ranges. This highlights the need for maintaining intact habitat for connectivity northward from the HPBH WSA so that many species can adapt by moving north.

In general, the highest mountains such as the Absarokas and Taylor-Hilgards, and the lowest basins such as the Green River basin in Wyoming, are the most threatened ecosystems.

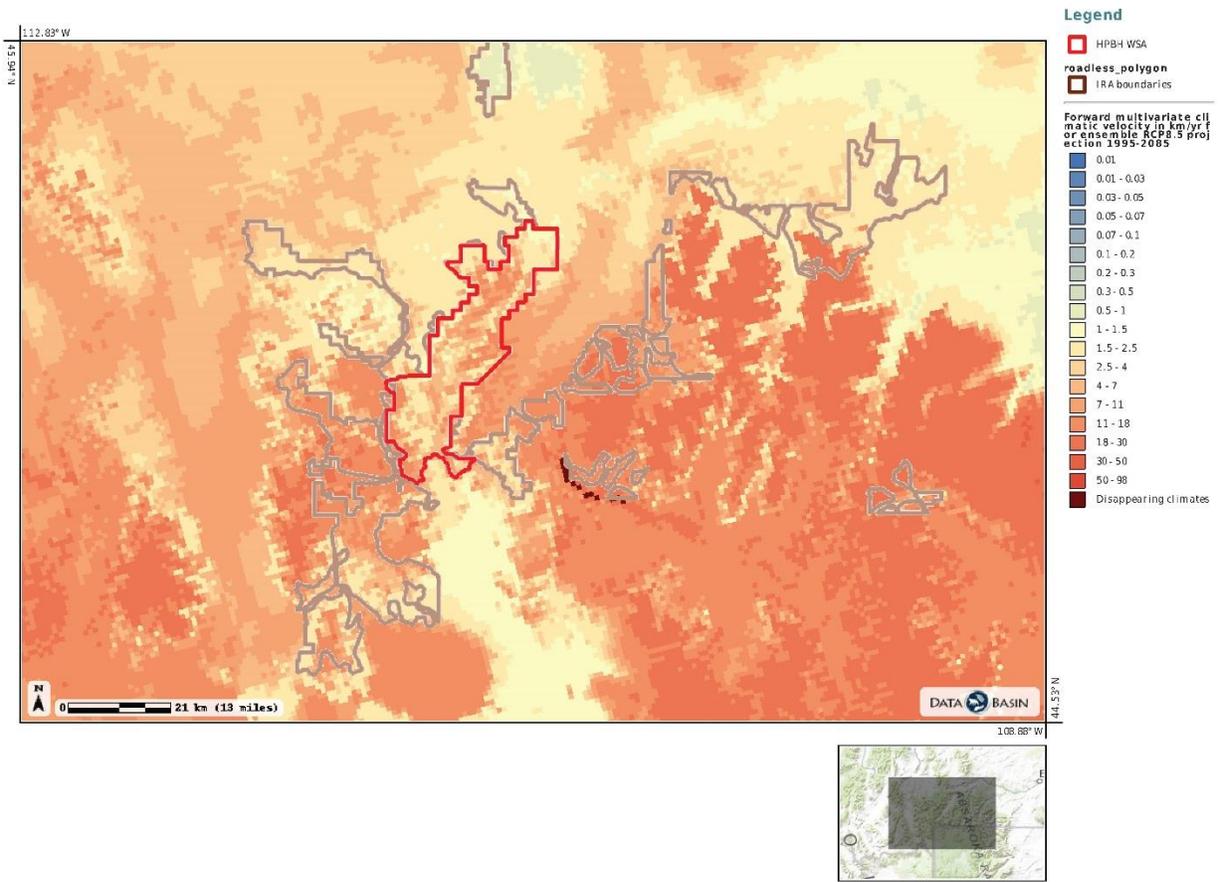


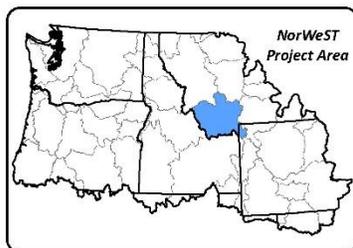
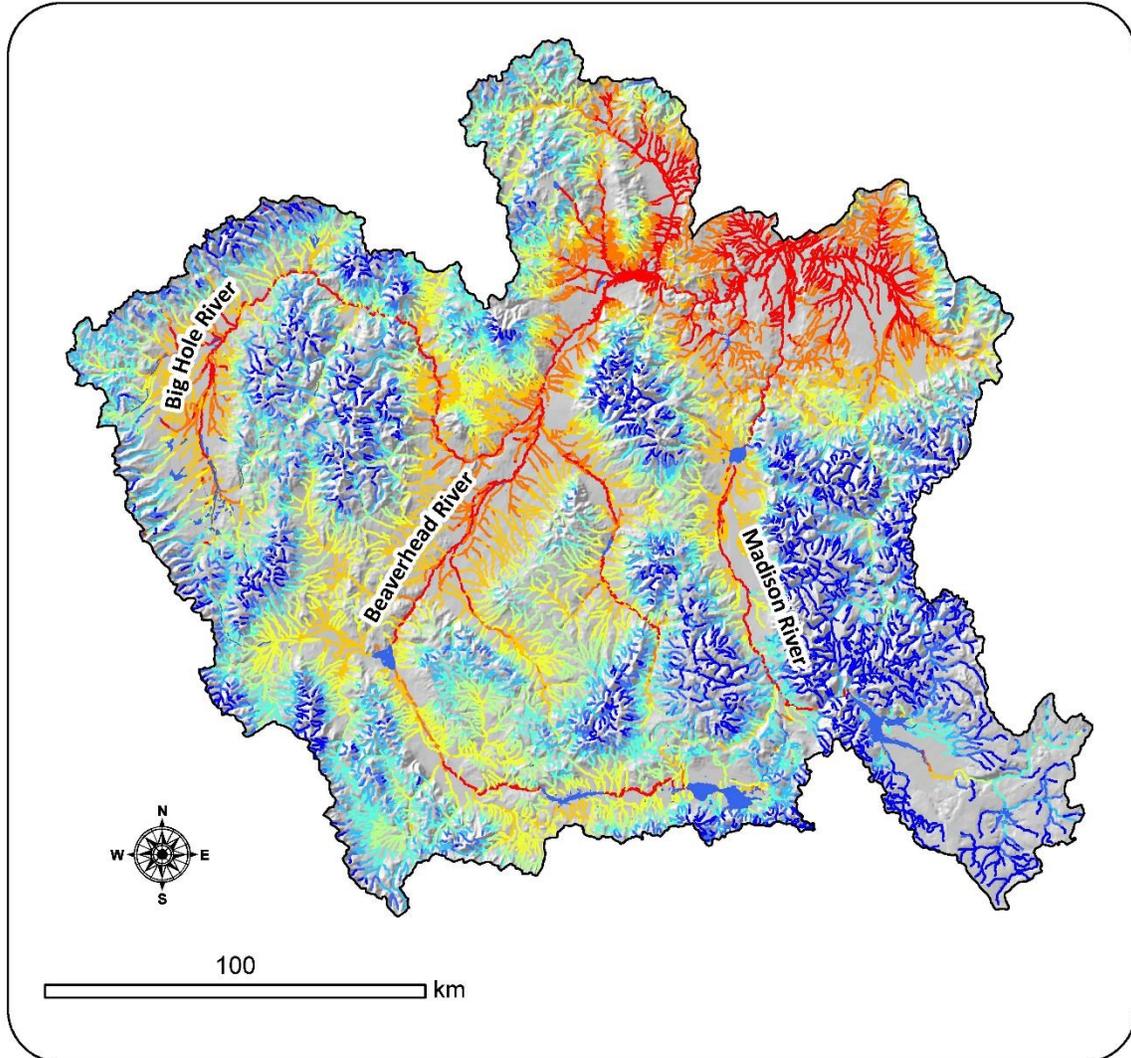
Figure 15. Forward climate velocity 1995-2085-8.5

NorWeST Stream Temperature

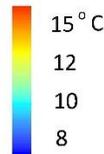
Modeled Mean August Stream
Temperature

Missouri Headwaters
Unit

Hydrologic Unit Code
100200



Scenario 1:
Mean August
Stream Temperature
1993-2011



<http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html>

NorWeST
Stream Temp



Figure 16. Modeled Mean August Stream Temperatures, 1993-2011.