National Climate Change Viewer Documentation

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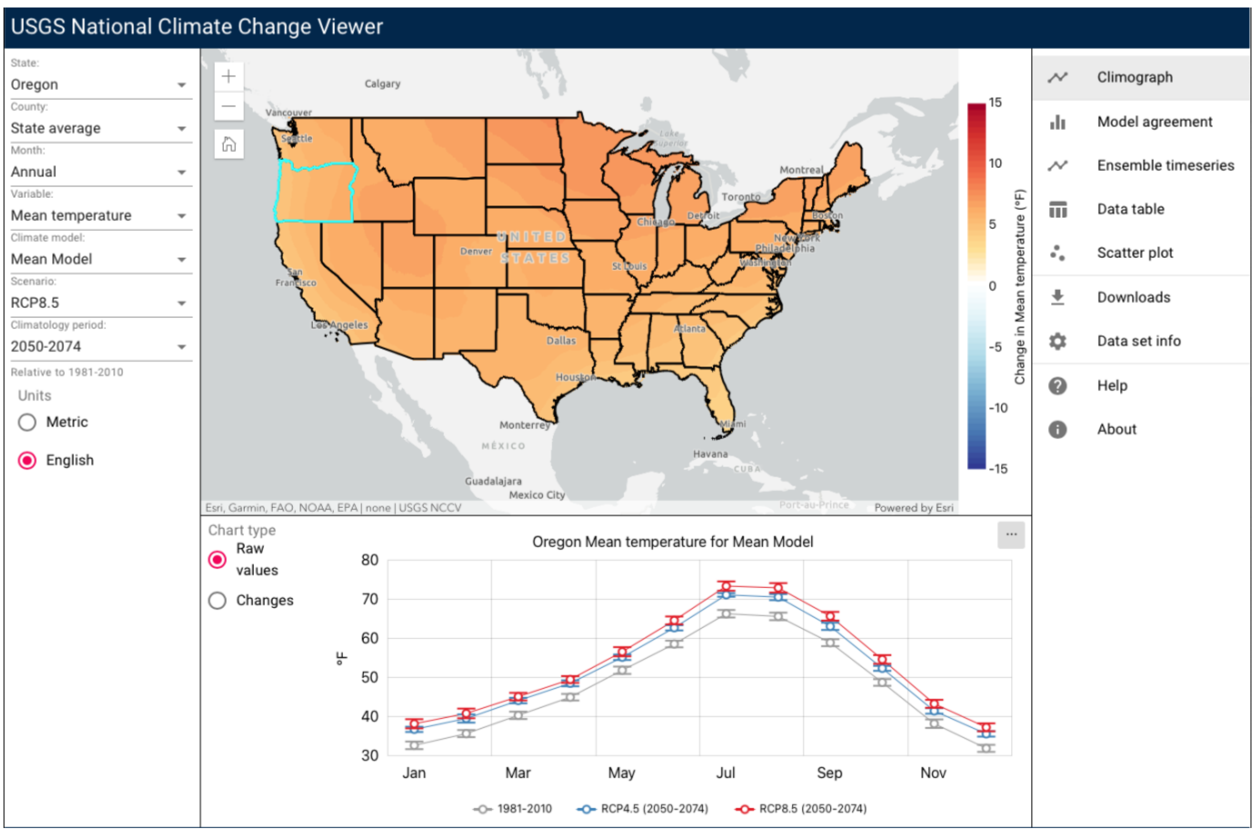


Outline

Introduction

Worldwide climate modeling centers participating in the 5th Climate Model Intercomparison Program (CMIP5) provided climate information for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The output from the CMIP5 models is typically provided on grids of ~1 to 3 degrees in latitude and longitude (roughly 80 to 230 km at 45° latitude). To derive higher resolution data for regional climate change assessments, the Multivariate Adaptive Constructed Analogs (MACA) method was applied to statistically downscaled maximum and minimum air temperature and precipitation from 20 of the CMIP5 models to produce the MACAv2-METDATA data set on a 4 km grid (**Figure 1**) over the continental United States (Abatzoglou J.T. and Brown T.J., *International Journal of Climatology*, 2012, doi:10.1002/joc.2312). The data set was bias corrected using the METDATA observational data set (Abatzoglou J. T., *International Journal of Climatology*, 2011, doi:10.1002/joc.3413).

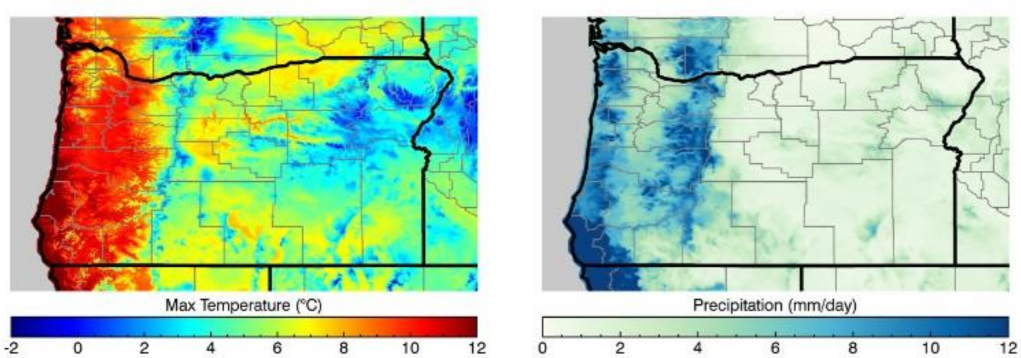


Figure 1.

The MACAv2-METDATA data set includes 20 climate models for historical and 21st century simulations for two Representative Concentration Pathways (RCP) greenhouse gas (GHG) emission scenarios developed for AR5. (Further details regarding the science behind developing and applying the RCPs are given by Moss et al., *Nature*, Volume 463, 2010, doi:10.1038/nature08823). The USGS National Climate Change Viewer (NCCV) includes the historical and future climate projections from 20 of the downscaled models for two of the RCP emission scenarios, RCP4.5 and RCP8.5. RCP4.5 is one of the possible emissions scenarios in which atmospheric GHG concentrations are stabilized so as not to exceed a radiative equivalent of 4.5 Wm^{-2} after 2100, about 650 ppm CO_2 equivalent. RCP8.5 is the most aggressive emissions scenario in which GHGs continue to rise unchecked through the end of the century leading to an equivalent radiative forcing of 8.5 Wm^{-2}, about 1370 ppm CO_2 equivalent. For perspective, the current atmospheric CO_2 level is about 416 ppm. Additionally, we have used the climate data (temperature and precipitation) to simulate changes in the contiguous United States (CONUS) water balance over the historical and future time periods (Hostetler, S.W. and Alder, J.R., Water Resources Research, 52, 2016, doi:10.1002/2016WR018665).

The NCCV allows the user to visualize projected changes in climate (mean, minimum, and maximum air temperature and precipitation) and the simulated water balance (snow water equivalent, runoff, soil water storage, and evaporative deficit) for a state or county and for USGS Hydrologic Units (HUC) HUC4 and HUC8. USGS HUCs are hierarchical units of watershed area. For example, the California-Northern Klamath-Costal HUC4, spans an area of 4.3×10^4 km^2 whereas the Upper Klamath Lake, Oregon. HUC8 subbasin within that HUC4 spans an area of 1.8×10^3 km^2. To create a manageable number of permutations in the viewer, we averaged the climate and water balance data into four climatology periods: 1981-2010, 2025-2049, 2050-2074, and 2075-2099. The 1981-2010 range represents the current climate normal period; although, the MACAv2-METDATA data set is bias corrected over the 1979-2012 period (see details here). The viewer provides many useful tools for exploring climate change such as maps, climographs (plots of monthly averages), histograms that show the distribution or spread of the model simulations, monthly time series spanning 1950-2099, the ability to view individual model spread by combinations of variables (e.g., temperature and snow water equivalent), and tables that summarize projections for each variable. The application also provides access to summary reports of climate and water balance variables in PDF format and CSV files of monthly time series. Users can also download the chart data used within the application as compressed JSON files. The gridded MACAv2-METDATA data are available in NetCDF format from the MACA web site (https://climate.northwestknowledge.net/MACA/index.php), and the water balance data are available from USGS ScienceBase (https://doi.org/10.5066/P9B2O22V).

Overview of the USGS National Climate Change Viewer

Interpreting output from many climate models in time and space is challenging. To aid in addressing that challenge, we have designed a viewer that strikes a balance between visualizing and summarizing climate information and the complexity of navigating the site. The features of the viewer are readily discovered and learned by experimenting and interacting; however, for reference we provide the following tutorial to explain most of the details of the viewer.

Controls, map navigation, and charts

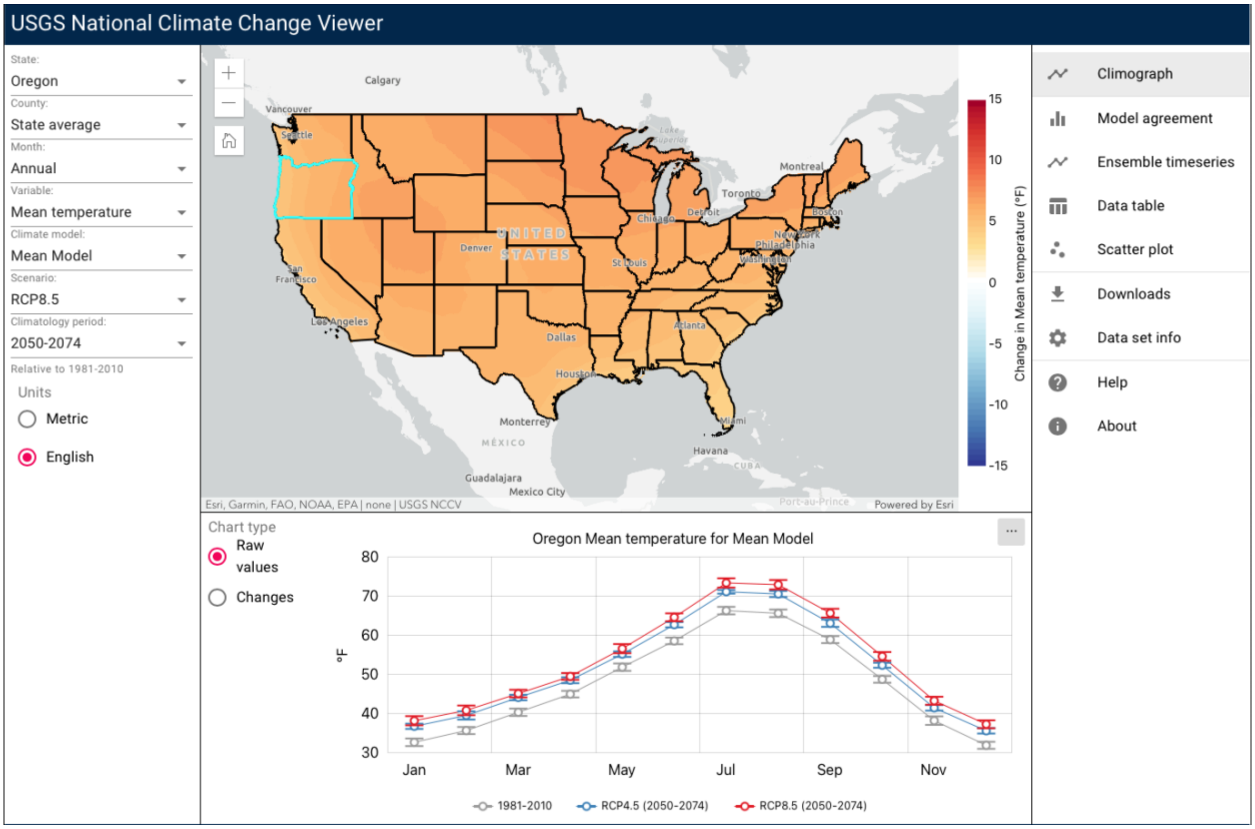


Figure 2

The main window of the NCCV (**Figure 2**) displays maps of future change (the difference between the historical period and the selected period) in a selected climate or water-balance variable and related selectable charts and tables. The maps provide the spatial variability of change across the contiguous United States, states, and counties. The dropdowns on the left-hand side of the application indicate the current selection of place, month or season, variable, climate model, emission scenario, and climatology period, which determine what is displayed in the maps and accompanying charts and tables. The application supports English or metric units throughout. Changing any of the settings updates all components of the viewer. The right-hand menu lists a series of charts in the application for visualizing climate projections for the selected place. We detail each of these charts and views in individual sections below.

The county, state, or watershed of interested can be selected either by the dropdown menus in the left control panel or by clicking on the map, which highlights the area of interest in cyan color. The map can be panned and zoomed using the mouse, scroll wheel, + and – buttons in top left of map (**Figure 3**) or by using the keyboard (up, down, left, right keys to pan and + and – keys to zoom). The map needs to be selected for keyboard navigation (often the tab key or shift+tab keys are used to navigate web pages without the use of a mouse). The home icon in top left of map returns the map to view full CONUS.

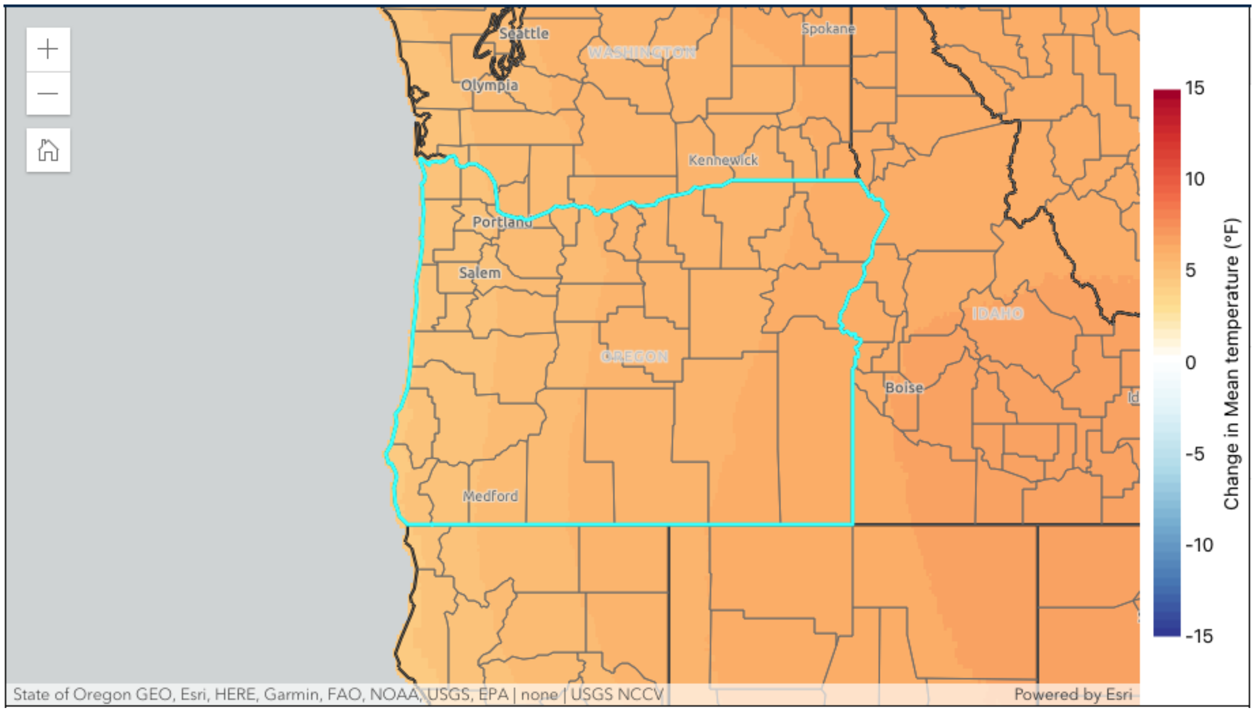


Figure 3

Climate projections can be viewed for each of the twelve months, seasonal averages (i.e., Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Fall: September, October, November), and annual average. The Climograph chart will only display the twelve calendar months. The application currently displays nine variables: mean temperature (the average of min and max temperature), maximum temperature, minimum temperature, precipitation, vapor pressure deficit, surface runoff, snow water equivalent (SWE), soil storage, and the evaporative deficit, which is the difference between potential evapotranspiration and actual evapotranspiration and is a measure of aridity. Individual climate models or the average of all the models (Mean Model) can be selected in the dropdown box. The scenario and climatology period menus (Figure 2) allows the user to select either the RCP4.5 or the RCP8.5 scenario and one of three time periods of interest: 2025-2049, 2050-2074, or 2075-2099. Changes are all relative to the 1981-2010 historical period. The maps always display anomalies (future minus historical differences), but the Climograph and Ensemble time series charts can display either raw values or anomalies.

Climograph

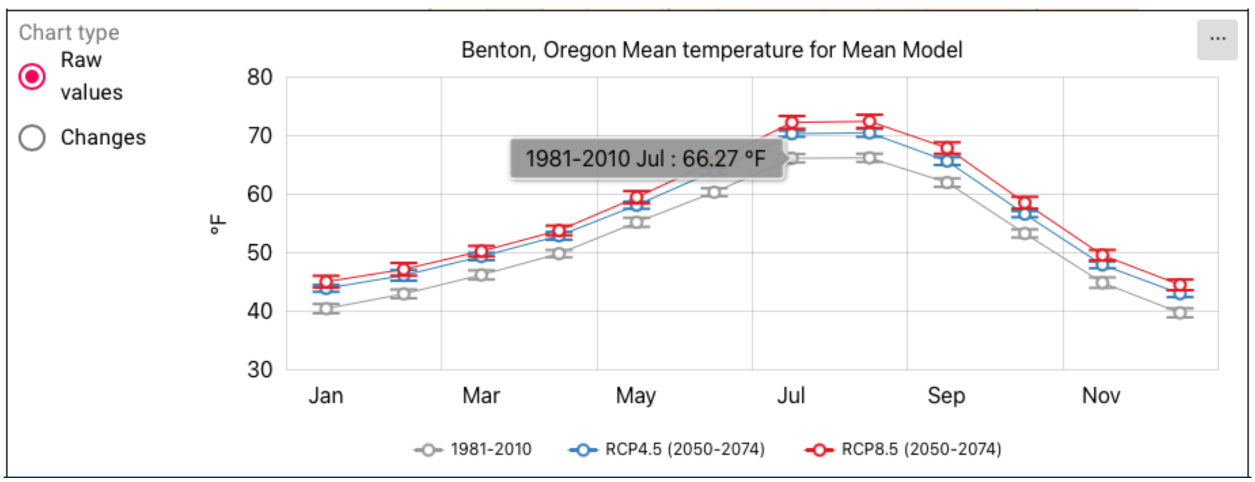


Figure 4

The Climograph chart displays the seasonal cycle for the selected location and climate variable comparing the historical period (1981-2010) to a future period for the RCP4.5 and RCP8.5 scenarios (**Figure 4**). The error bars represent ± 1 standard deviation within the climatology period (ie 2050-2074), a measure of temporal variability. The mouse can be used to hover over the month circle symbols to display the numeric values. Clicking the circle symbols changes the selected scenario, month, and updates the map display. Individual series can be shown or hidden by clicking on the legend.

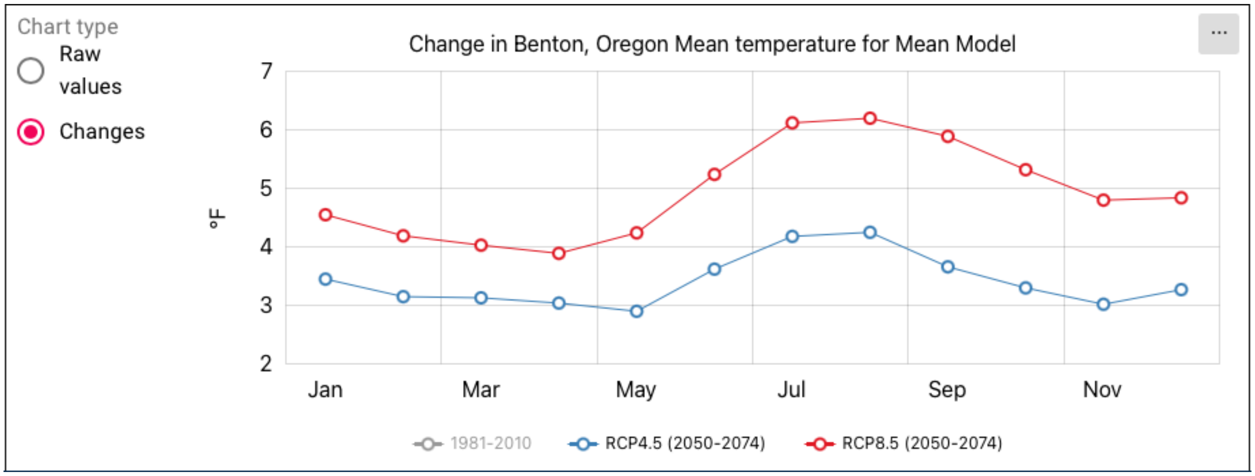


Figure 5

The chart can also display changes in the seasonal cycle which highlights the magnitude of monthly change projected at this location (**Figure 5**).

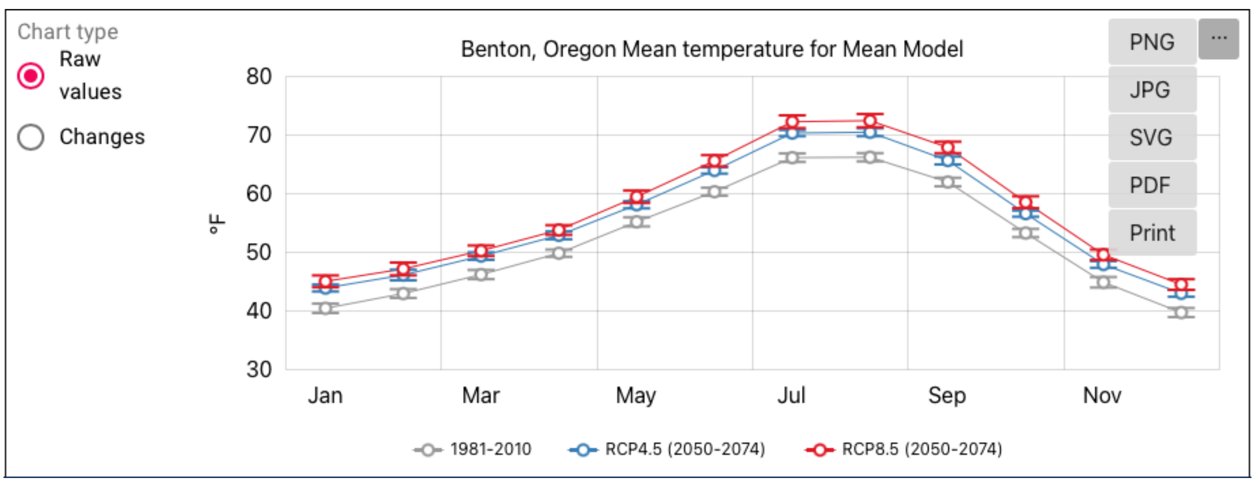


Figure 6

All charts within the application can be exported for download in various image formats by clicking the […] menu in the top right of each graphic (**Figure 6**).

Model agreement

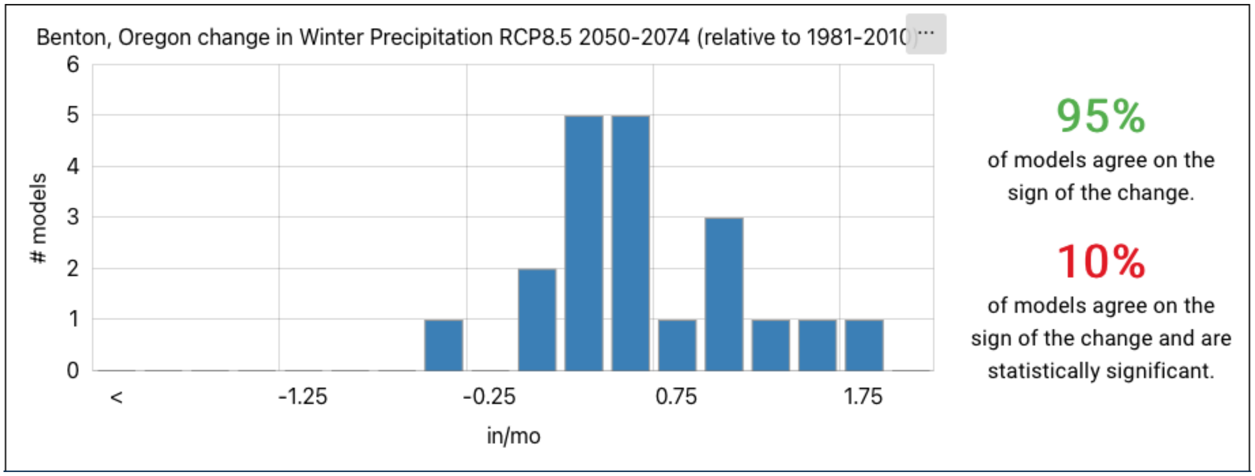


Figure 7

The Model agreement chart displays a histogram of the future changes simulated by each climate model (**Figure 7**). This graphic is a useful way to quickly determine if the climate models are simulating changes of similar sign and magnitude and gives a summary of the model spread. In the example above, 19 out of 20 climate models simulate increased winter precipitation in Benton County, Oregon in 2050-2074 under the RCP8.5 scenario. However, there is lack of agreement on the magnitude of the increase, with most models simulating a modest 0.25 – 0.75 in/mo increase. Hovering the mouse over the histogram columns displays the individual models in each bin. Clicking on the histogram column will cycle through the models within each bin.

To the right of the histogram chart are two additional metrics for model agreement and statistical significance of the simulated changes. The top number indicates the percent of the 20-models that share the same sign as the ensemble median. The text is color coded into three categories: low (red, <60% agreement), medium (orange: 60 ≤ 80% agreement), high (green > 80% agreement). The lower number indicates the percent of the models that share the both sign as the ensemble median and are statistically significant based on a Mann-Whitney rank test ($p < 0.05$). In the example above (**Figure 7**), a majority (95%, 19/20 models) of the models simulate an increased winter precipitation in Benton County, Oregon, but only 10% (2/20 models) of the model changes are positive and statistically significant. This can be corroborated in the Data table view.

Ensemble timeseries

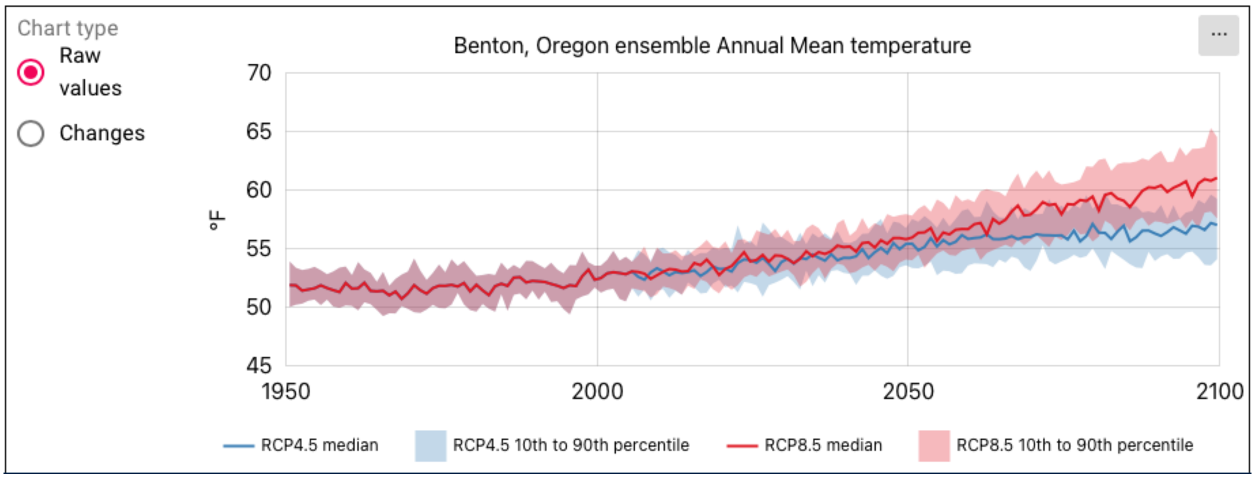


Figure 8

The Ensemble timeseries chart displays the year-by-year climate projections for the ensemble median and 10th to 90th percentile range from 1950-2099 (**Figure 8**). The percentile range omits the highest and lowest models, but plots 80% of the ensemble (ie 16/20 models). Unlike the previous charts, the model selection in left control panel does not apply here, as the ensemble is displayed rather than an individual model. The map will still reflect the currently selected climate model. Like the Climograph chart, the timeseries can be viewed as either raw values or change (relative to the 1981-2010 base period) (**Figure 9**). The mouse can be used to hover over the timeseries to display detailed information for an individual year. The chart cannot be clicked on to update the map selection.

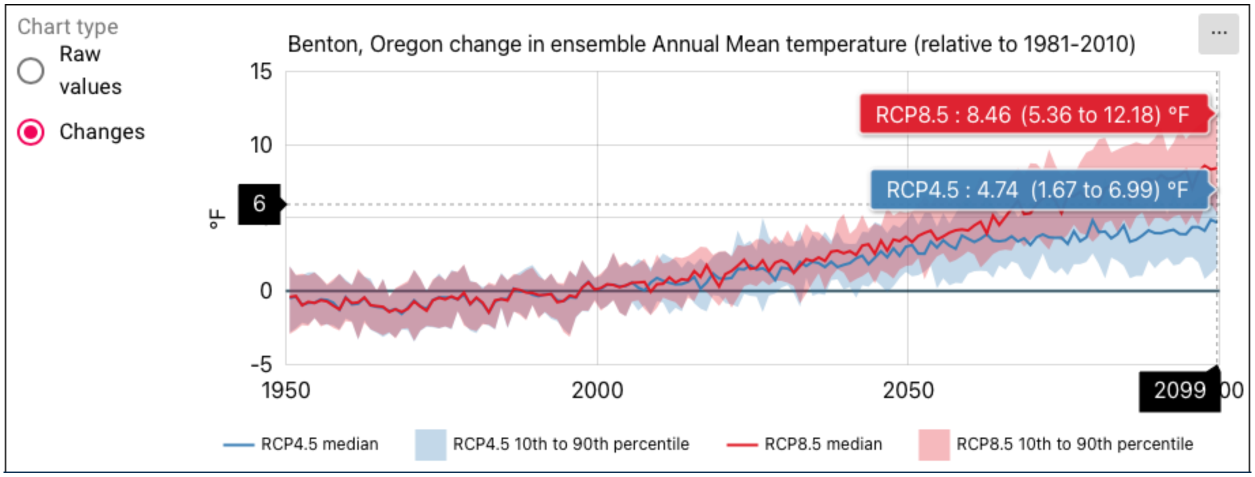
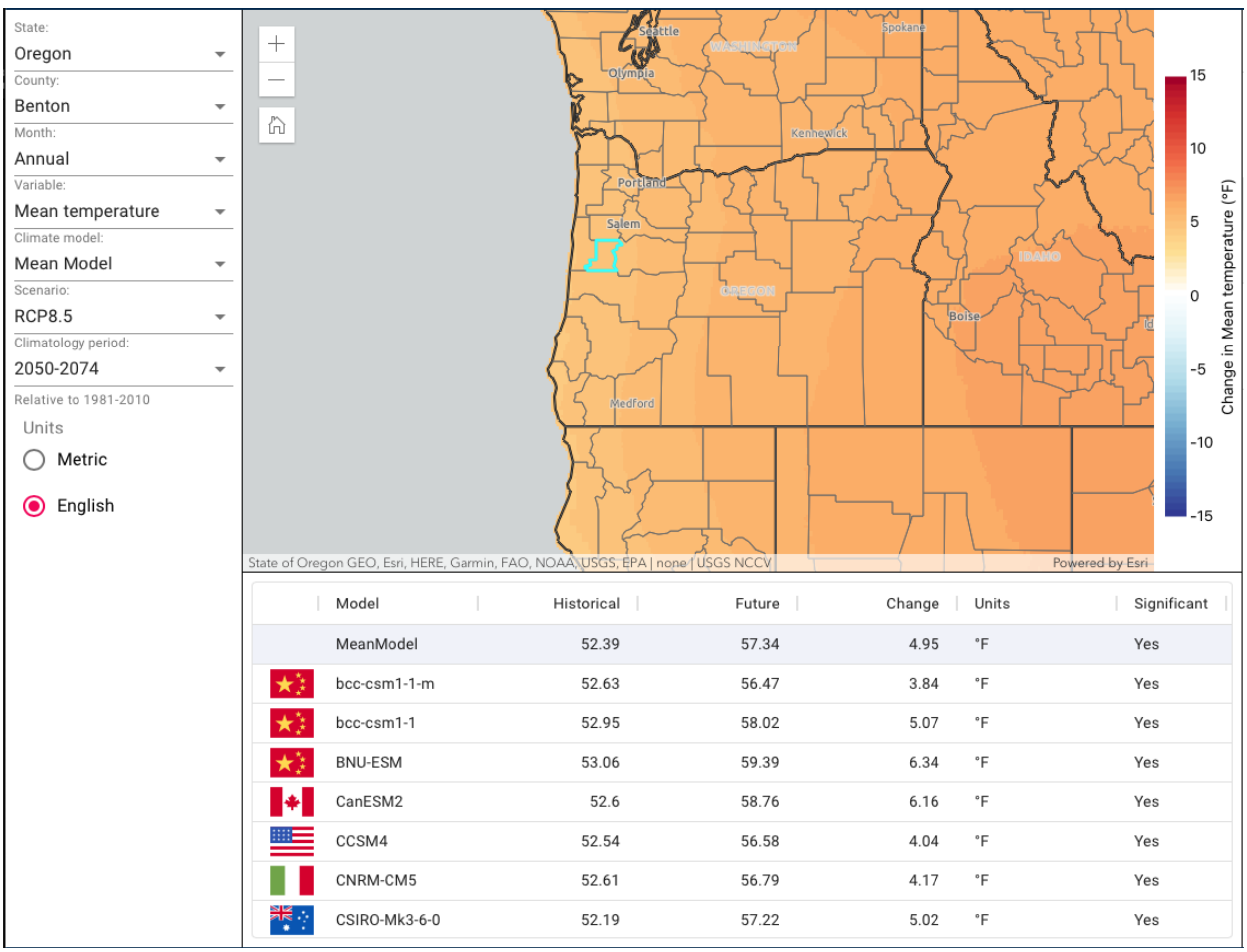


Figure 9

Data table



	Model	Historical	Future	Change	Units	Significant
	MeanModel	52.39	57.34	4.95	°F	Yes
	bcc-csm1-1-m	52.63	56.47	3.84	°F	Yes
	bcc-csm1-1	52.95	58.02	5.07	°F	Yes
	BNU-ESM	53.06	59.39	6.34	°F	Yes
	CanESM2	52.6	58.76	6.16	°F	Yes
	CCSM4	52.54	56.58	4.04	°F	Yes
	CNRM-CM5	52.61	56.79	4.17	°F	Yes
	CSIRO-Mk3-6-0	52.19	57.22	5.02	°F	Yes

Figure 10

The Data table displays the full tabular information for the current selection of location, variable, scenario and climatology period for all 20 climate models. The columns can be sorted by value and the rows can be clicked on to select an individual climate model. Used in combination, these features can be useful to sort the climate models by the magnitude of the future change and click on individual rows to visualize how the spatial patterns of change vary among high or low sorted models.

Scatter plot

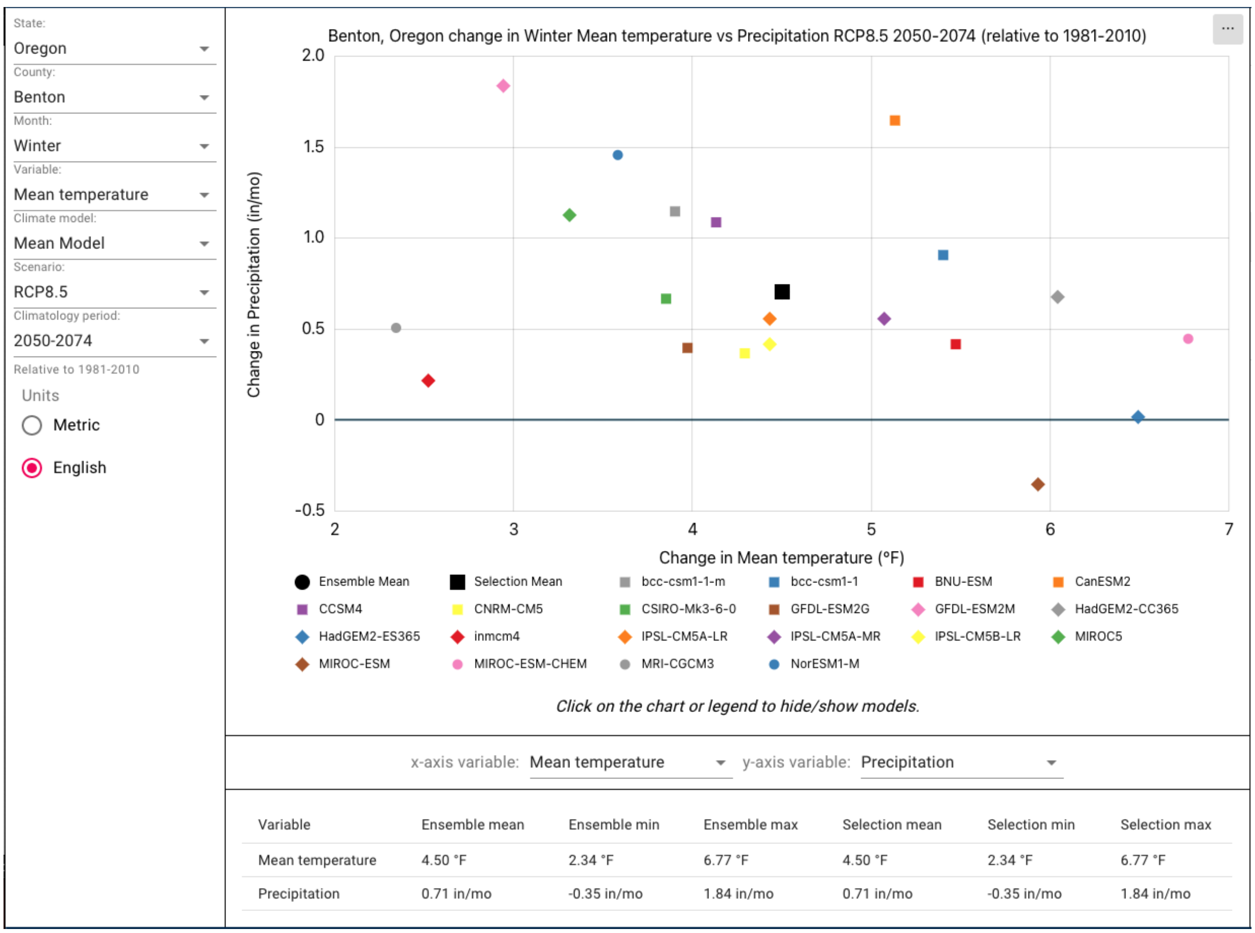


Figure 11

The Scatter plot graph allows users to explore multivariate response of climate change for a given location (**Figure 11**). The graph plots the future minus historical changes for two selected climate or water balance variables for a given month, scenario, and climatology period. This chart is useful to users interested in climate model selection for additional analysis, where it might be impractical to use the full model ensemble. Individual climate models can be turned on and off by clicking on the symbol in the chart or on the legend. Below the chart the table displays the full ensemble mean and range in addition to the current selection mean and range when a group of models have been excluded. In the example of **Figure 12**, 14 out of 20 models have been disabled. As indicated by the close agreement of the 6-model selection mean (black square) and the full 20-model ensemble mean (black circle) the change in temperature and precipitation means and ranges in the subset of 6 models is preserved, indicating that these models are representative of the full ensemble for this location and selected variables. The Scatter plot can also be useful to test the response of removing models that may be outliers relative to the larger ensemble.

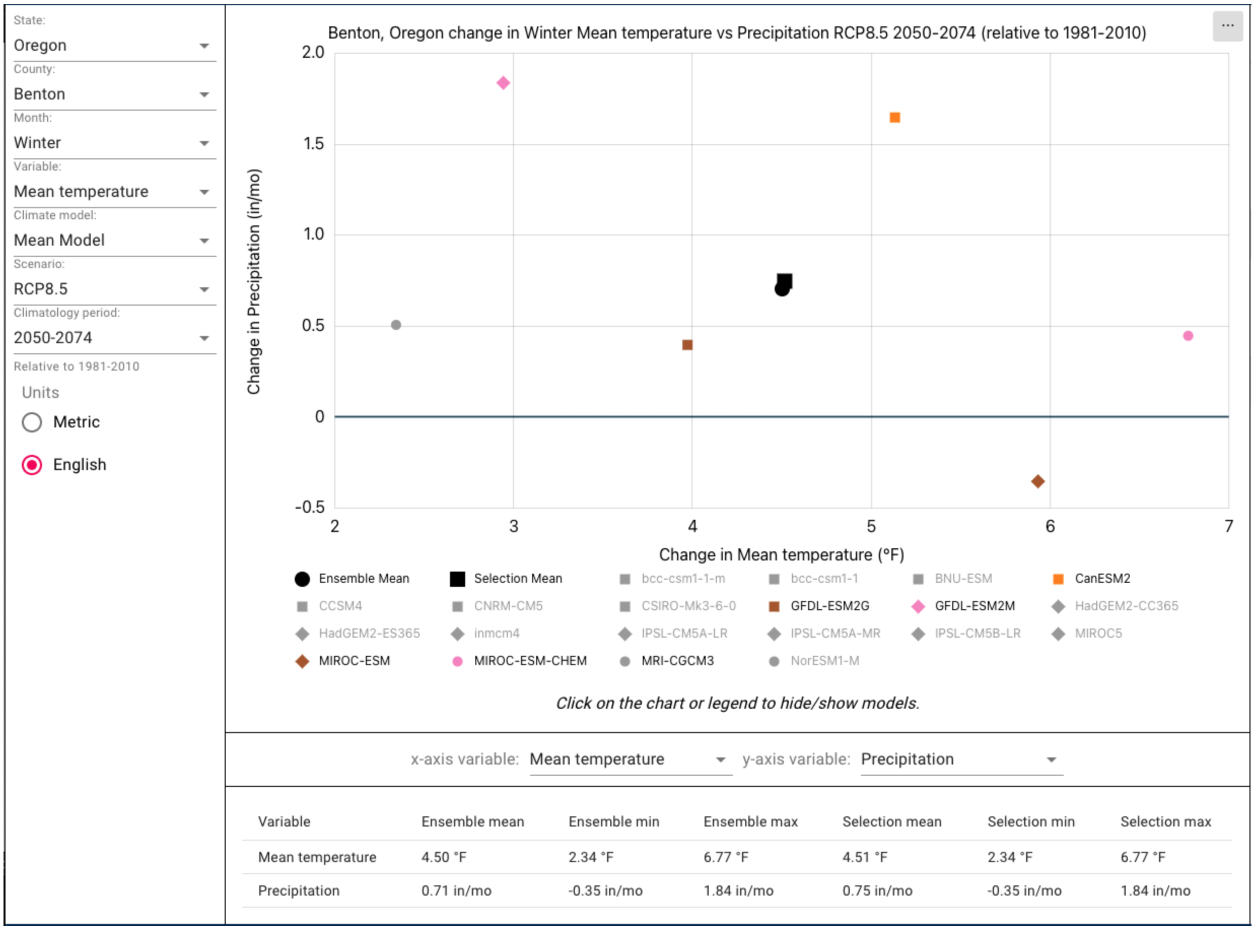


Figure 12

Download data

Chart data, monthly time series and summary PDF reports for each county, state, and watershed can be downloaded in either English or metric units (**Figure 13**). The PDF reports (**Figure 14**) provide a comprehensive summary of the climate projections for a given location through a suite of graphics similar to those found in the viewer. Graphics are provided for all the variables used in the application. The PDF reports summarize the model ensemble rather than an individual model.

The downloadable comma separated variable (CSV) files contain the 1950-2099 monthly timeseries of all variables for both RCP4.5 and RCP8.5 (**Figure 15**). Time series files for each model are available for additional analysis outside the application. Metadata is included to describe the file contents and the monthly values for the two scenarios are registered in time by the model year and month. Note that the data are the raw averages and not the differences between the scenarios and the historical period. The data files used to create the charts within the application can also be downloaded as compressed JSON files. While not in the Download data view, any chart displayed in the application can be downloaded by clicking the […] menu in the top right of each graphic (see **Figure 6**).

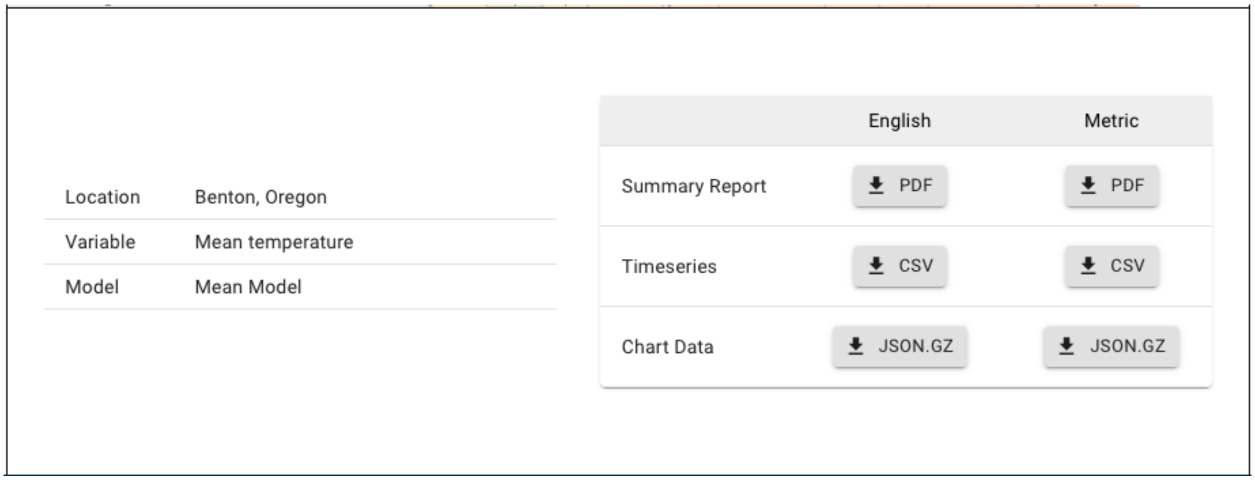


Figure 13

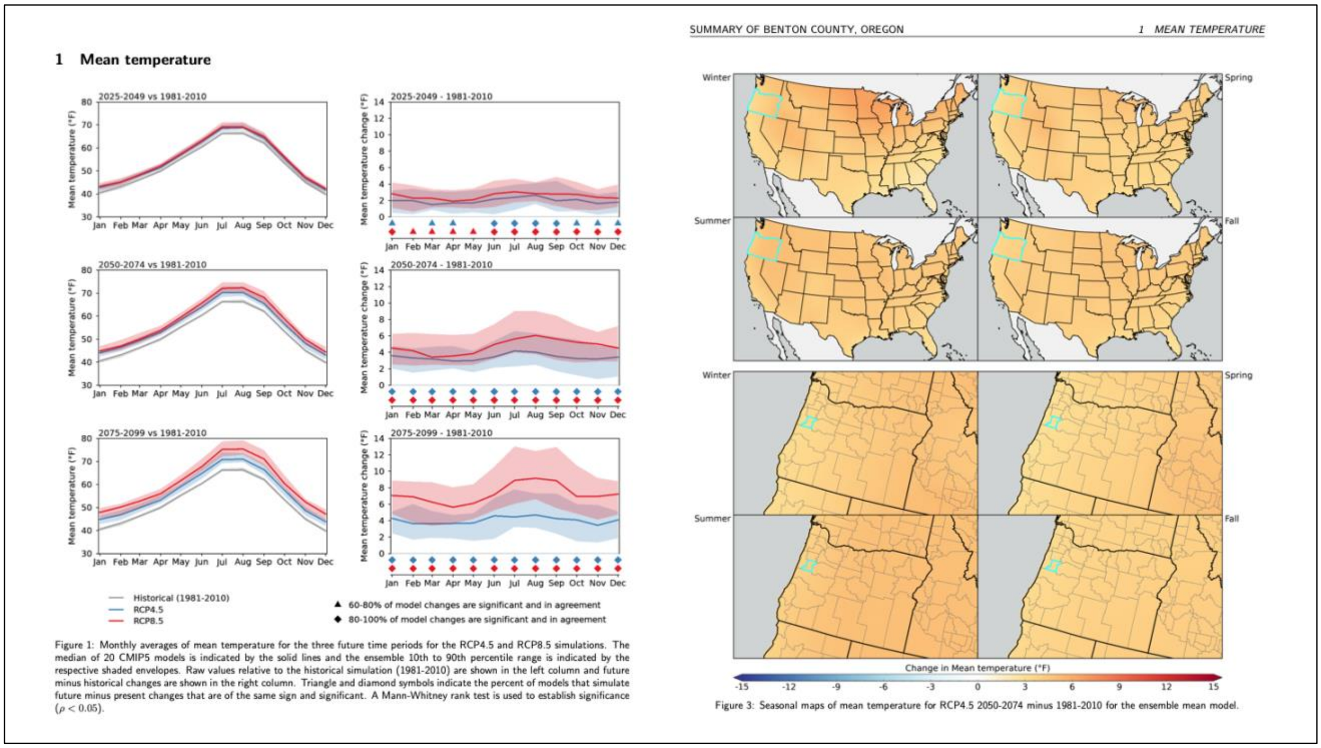


Figure 14

These freely available, derived data sets were produced by J. Alder and S. Hostetler,
US Geological Survey (Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer.
US Geological Survey https://doi.org/10.5066/F7W9575T). Climate forcings in the MACAv2-METDATA were
drawn from a statistical downscaling of global climate model (GCM) data from the Coupled Model
Intercomparison Project 5 (CMIP5, Taylor et al. 2010) utilizing a modification of the Multivariate
Adaptive Constructed Analogs (MACA, Abatzoglou and Brown, 2012) method with the METDATA(Abatzoglou, 2011)
observational dataset as training data. No warranty expressed or implied is made by the
USGS regarding the display or utility of the derived data on any other system, or for
general or scientific purposes, nor shall the act of distribution constitute any such
warranty. The USGS shall not be held liable for improper or incorrect use of the data
described and/or contained herein.

Data revised on : Wed Apr 28 10:25:03 2021

County : Benton, Oregon
Model : MeanModel (r1i1p1)

Years from 1950-2005 are from the Historical experiment and the years from 2006-2099 are from
either the RCP4.5 or RCP8.5 experiments

Date	RCP4.5 Mear	RCP4.5 Max	RCP4.5 Min t	RCP4.5 Preci	RCP4.5 Vapo	RCP4.5 Runo	RCP4.5 Snow	RCP4.5 Soil s	RCP4.5 Evap.	RCP8.5 Mear	RCP8.5 Max	RCP8.5 Min t	RCP8.5 Preci	RCP8.5 Vapo	RCP8.5 Runo	RCP8.5 Snow	RCP8.5 Soil s	RCP8.5 Evap.
1/15/1950	40.039	46.202	33.876	8.518	0.021	7.015	1.46	6.415	0	40.039	46.202	33.876	8.518	0.021	7.015	1.46	6.415	0
2/15/1950	42.547	50.116	34.979	8.169	0.032	7.346	1.283	6.415	0	42.547	50.116	34.979	8.169	0.032	7.346	1.283	6.415	0
3/15/1950	45.01	53.758	36.261	6.723	0.042	6.591	0.648	6.415	0	45.01	53.758	36.261	6.723	0.042	6.591	0.648	6.415	0
4/15/1950	49.801	60.166	39.437	4.498	0.062	4.616	0.264	6.159	0	49.801	60.166	39.437	4.498	0.062	4.616	0.264	6.159	0
5/15/1950	54.511	65.59	43.432	3.038	0.083	2.638	0.061	5.303	0.059	54.511	65.59	43.432	3.038	0.083	2.638	0.061	5.303	0.059
6/15/1950	60.099	72.082	48.116	1.722	0.11	1.361	0.001	3.203	0.426	60.099	72.082	48.116	1.722	0.11	1.361	0.001	3.203	0.426
7/15/1950	66.167	80.38	51.955	0.469	0.163	0.661	0	1.038	2.241	66.167	80.38	51.955	0.469	0.163	0.661	0	1.038	2.241
8/15/1950	65.692	80.075	51.309	0.751	0.155	0.356	0	0.482	2.949	65.692	80.075	51.309	0.751	0.155	0.356	0	0.482	2.949
9/15/1950	61.766	75.253	48.278	1.206	0.136	0.221	0	0.518	1.809	61.766	75.253	48.278	1.206	0.136	0.221	0	0.518	1.809
10/15/50	52.81	62.882	42.739	4.317	0.063	0.455	0	2.886	0.234	52.81	62.882	42.739	4.317	0.063	0.455	0	2.886	0.234
11/15/50	44.468	51.256	37.681	9.269	0.026	3.152	0.014	5.823	0.007	44.468	51.256	37.681	9.269	0.026	3.152	0.014	5.823	0.007
12/15/50	39.921	45.638	34.204	11.373	0.019	6.369	1.002	6.411	0	39.921	45.638	34.204	11.373	0.019	6.369	1.002	6.411	0
1/15/1951	40.47	46.8	34.14	9.588	0.022	7.682	1.254	6.414	0	40.47	46.8	34.14	9.588	0.022	7.682	1.254	6.414	0
2/15/1951	42.97	50.235	35.704	7.915	0.031	7.571	0.95	6.415	0	42.97	50.235	35.704	7.915	0.031	7.571	0.95	6.415	0
3/15/1951	45.996	55.043	36.949	6.524	0.044	6.542	0.418	6.388	0	45.996	55.043	36.949	6.524	0.044	6.542	0.418	6.388	0
4/15/1951	48.833	58.807	38.859	4.79	0.058	4.722	0.183	6.127	0.001	48.833	58.807	38.859	4.79	0.058	4.722	0.183	6.127	0.001
5/15/1951	55.097	66.487	43.708	2.772	0.089	2.609	0.044	5.052	0.097	55.097	66.487	43.708	2.772	0.089	2.609	0.044	5.052	0.097
6/15/1951	59.848	71.646	48.049	1.641	0.108	1.345	0	3.072	0.602	59.848	71.646	48.049	1.641	0.108	1.345	0	3.072	0.602
7/15/1951	65.786	80.097	51.475	0.46	0.165	0.654	0	1.019	2.319	65.786	80.097	51.475	0.46	0.165	0.654	0	1.019	2.319
8/15/1951	66.169	80.579	51.758	0.453	0.161	0.338	0	0.423	3.241	66.169	80.579	51.758	0.453	0.161	0.338	0	0.423	3.241
9/15/1951	61.065	74.441	47.691	1.724	0.128	0.246	0	0.564	1.369	61.065	74.441	47.691	1.724	0.128	0.246	0	0.564	1.369

Figure 15

Water Balance Variables

In addition to information about temperature and precipitation, related projections of future change in the terrestrial hydrological cycle are of interest. We applied a simple water-balance model driven by the 4-km MACAv2-METDATA temperature and precipitation from all the included CMIP5 models to simulate changes in the monthly water balance through the 21st century.

Overview and limitations of the Water-Balance model

The water-balance model (WBM) was developed by USGS scientists G. McCabe and D. Wolock (*J. Am. Water Resour. Assoc.*, 35, 1999, doi:10.1111/j.1752-1688.1999.tb04231.x). It has been applied to investigate the surface water-balance under climate change over the US and globally (McCabe and Wolock, *Climatic. Change*, 2010, doi:10.1007/s10584-009-9675-2; Pederson et al., *Geophysical Research Letters*, 2013, doi:10.1002/grl.50424, 2013). A detailed evaluation of the water-balance model using our specific configuration is also available (Hostetler, S.W. and Alder, J.R., Water Resources Research, 52, 2016, doi:10.1002/2016WR018665).

From inputs of temperature, precipitation, and potential solar radiation, the WBM accounts for the partitioning of water through the various components of the hydrological system (**Figure 16**). Air temperature determines the portion of precipitation that falls as rain and snow, the accumulation and melting of the snowpack, and evapotranspiration (PET and AET). Rain and melting snow are partitioned into direct surface runoff (DRO), soil moisture (ST), and surplus runoff that occurs when soil moisture capacity is at 100% (RO). Potential evapotranspiration is determined from temperature and potential solar radiation by the Oudin method (Oudin et al. 2005).

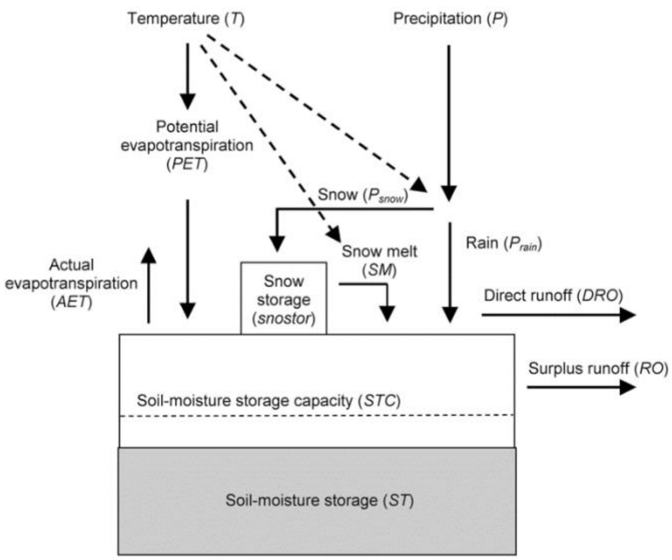


Figure 16 From McCabe and Markstrom, 2007, US Geological Survey Open-File Report 2007-1088.

We include four water balance variables in the viewer (**Figure 16**):

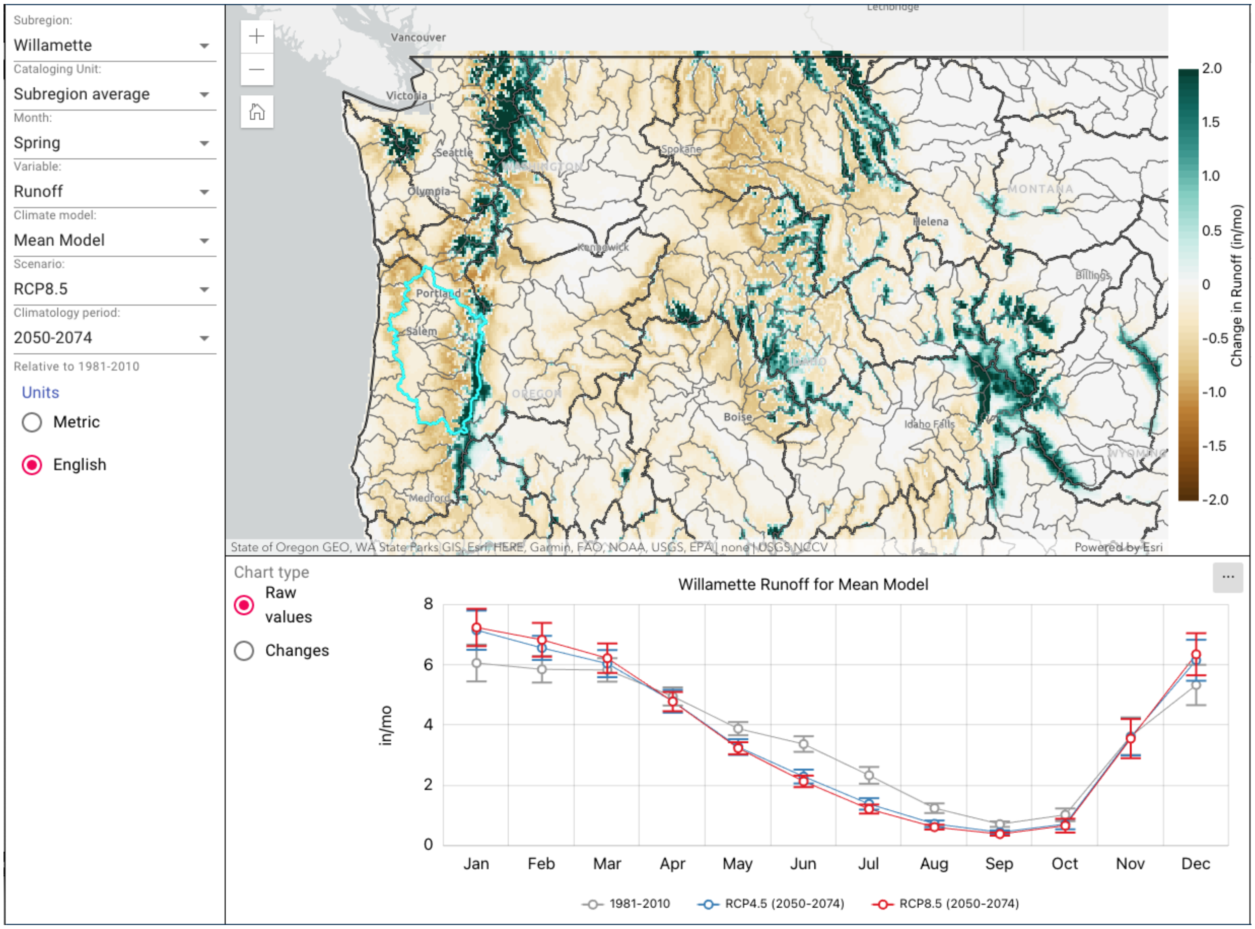
- Snow water equivalent (SWE), the liquid water stored in the snowpack,
- Soil water storage, the water stored in soil column,
- Evaporative deficit, the difference between potential evapotranspiration (PET), which is the amount of evapotranspiration that would occur if unlimited water were available, and actual evapotranspiration (AET) which is what occurs but can be water limited, and
- Runoff, the sum of direct runoff (DRO) that occurs from precipitation and snow melt and surplus runoff (RO) which occurs when soil moisture is at 100% capacity

The values for all variables are given in units of average depth (e.g., inches or millimeters) over the area of the selected state, county or HUC.

The simplicity of the WBM facilitates the computational performance needed to run 40 implementations of the model for 150 years over the 4 km MACAv2-METDATA grid cells. An additional strength of the WBM is that it provides a common method for simulating change in the water balance, as driven by temperature and precipitation from the CMIP5 models, thereby producing outputs that are directly comparable across all models (**Figure 17**).

There are tradeoffs, however, in using the simple WBM instead of more complex, calibrated watershed models that use more meteorological inputs (e.g., solar radiation, wind speed) and are adjusted to account for groundwater and water management. These limitations should be kept in mind when viewing the water balance components:

- the model is run on a monthly time step, so it does not capture day-to-day variability nor extreme events such as intense precipitation and floods;
- while physically based, the model simplifies more complex energy balance detail that determines evapotranspiration and snow dynamics;
- the model simulates the runoff of a grid cell but does not route runoff among grid cells or into stream networks or groundwater;
- the parameters used in the model are independent of land use and vegetation;
- surface elevation is implicit through the MACAv2-METDATA temperature and precipitation data, but the model does not account for detail of slope or aspect below the resolution of the 4-km by 4-km (2.5-mile by 2.5-mile) grid cells; and
- there are no man-made diversions or reservoirs.



Subregion:
Willamette
Cataloging Unit:
Subregion average
Month:
Spring
Variable:
Runoff
Climate model:
Mean Model
Scenario:
RCP8.5
Climatology period:
2050-2074
Relative to 1981-2010
Units
Metric
English
Vancouver
Victoria
Seattle
Olympia
Spokane
Kennewick
Portland
Salem
Medford
Boise
Idaho Falls
Helena
Billings
Change in Runoff (in/mo)
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
State of Oregon GEO, WA State Parks GIS, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA | none | USGS NCCV
Powered by Esri
Chart type
Raw values
Changes
Willamette Runoff for Mean Model
in/mo
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1981-2010
RCP4.5 (2050-2074)
RCP8.5 (2050-2074)

Figure 17

Appendix

Methods

The MACAv2-METDATA data set statistically downscales general circulation models with varying grid resolutions to 1/24-degree (~4 km). The 4 km gridded temperature and precipitation data facilitated water-balance modeling over the US, and the consistent grid spacing and fine resolution of the data sets simplified averaging the data over states, counties and watersheds. Here is an example for creating county averages. Application to the watersheds is identical.

Step 1 A GIS shapefile for all the counties in the United States is used to assign each 4 km grid cell a county ID for all the cells falling within the county's boundary. The example below shows counties within Oregon. Grid cells on the boundaries are spatially weighted by the fraction of the grid cell area within the county boundary (not shown).

Step 2 Changes or anomalies in temperature, precipitation and the components of the water-balance are calculated for the three 25-year averaging periods 2025–2049, 2050–2074 and 2075–2099 relative to the base period of 1981-2010. The 4 km anomalies are displayed as map in the application.

Step 3 The county ID mask created in Step 1 is used to calculate area weighted spatial averages of the anomalies for every county for each month between 1950–2099. The county averages are used in the application climographs, histograms, timeseries and data tables.

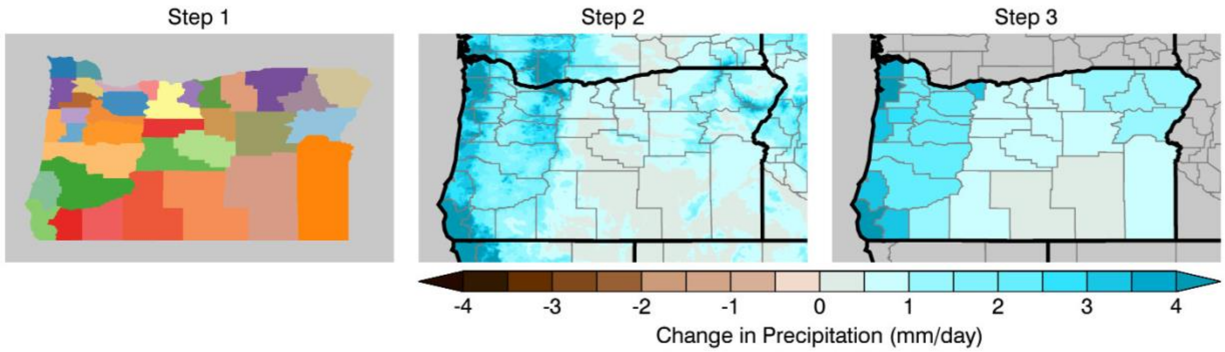


Figure 18

Models

bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4
CNRM-CM5	CSIRO-Mk3-6-0	GFDL-ESM2G	GFDL-ESM2M	HadGEM2-CC365
HadGEM2-ES365	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR
MIROC5	MIROC-ESM	MIROC-ESM-CHEM	MRI-CGCM3	NorESM1-M

Citation Information

Abatzoglou, J.T., 2011. Development of gridded surface meteorological data for ecological applications and modelling. International Journal of Climatology, doi: 10.1002/joc.3413.

Abatzoglou, J.T., and Brown T.J., 2012. A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology, doi: 10.1002/joc.2312.

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey https://doi.org/10.5066/F7W9575T.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

Disclaimer

These freely available, derived data sets were produced by J. Alder and S. Hostetler, US Geological Survey (Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey https://doi.org/10.5066/F7W9575T). Climate forcings in the MACAv2-METDATA were drawn from a statistical downscaling of global climate model

(GCM) data from the Coupled Model Intercomparison Project 5 (CMIP5, Taylor et al. 2010) utilizing a modification of the Multivariate Adaptive Constructed Analogs (MACA, Abatzoglou and Brown, 2012) method with the METDATA (Abatzoglou, 2011) observational dataset as training data. No warranty expressed or implied is made by the USGS regarding the display or utility of the derived data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The USGS shall not be held liable for improper or incorrect use of the data described and/or contained herein.