

The Monthly Water Balance Model Futures Project and Portal

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SOUTH CENTRAL
CLIMATE SCIENCE CENTER

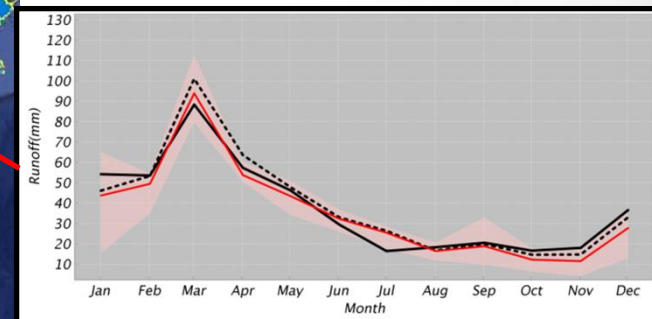
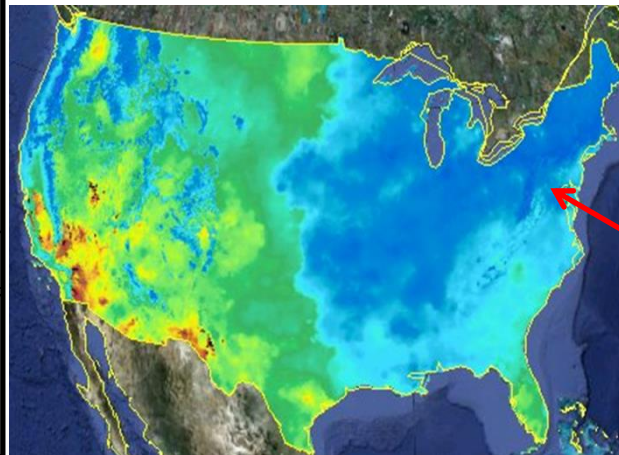
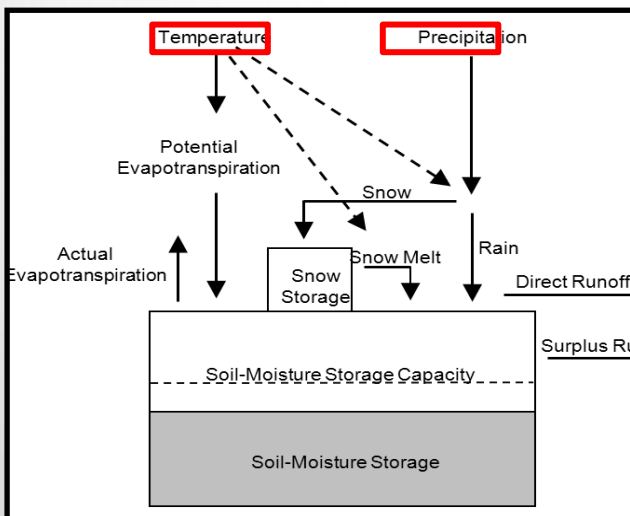
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National Hydrologic Model (cont.)

- Simulation of hydrologic processes across the country
 - Incorporates multiple models
 - Monthly time-step rainfall-runoff, daily time-step deterministic watershed hydrology, coupled groundwater-surface water, energy-flux based stream temperature
 - Assimilate best available national-extent data for model forcing and parameters
 - Tools to disseminate data and information to the public



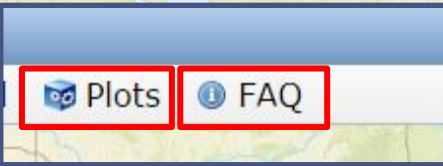
Monthly Water Balance Model Futures Portal

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend **Plots** **FAQ**



Switch Basemap



Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: *

Location from map: *

Variable of interest: *

Period of record (water years): *

Runs (select at least 1): *

Subset

Click to Plot **Click to Download** **Clear**

Measured and simulated historical streamflow at selected gage: mean monthly
Envelope of future conditions based on downscaled GCMs: annual moving average
Future conditions: mean monthly box plots
Future conditions: mean seasonal box plots

Plots To Screen

Download plot (.png) or data (.csv)

Frequently Asked Questions

- About
- Summary
- Disclaimers
- Portal Background
- Climate Inputs
- Spatial Data
- Monthly Water Balance Model
- Navigating in the Portal
- Generating Plots
- Examples of Plots
- Troubleshooting
- References
- Appendices
- Commonly-used Acronyms

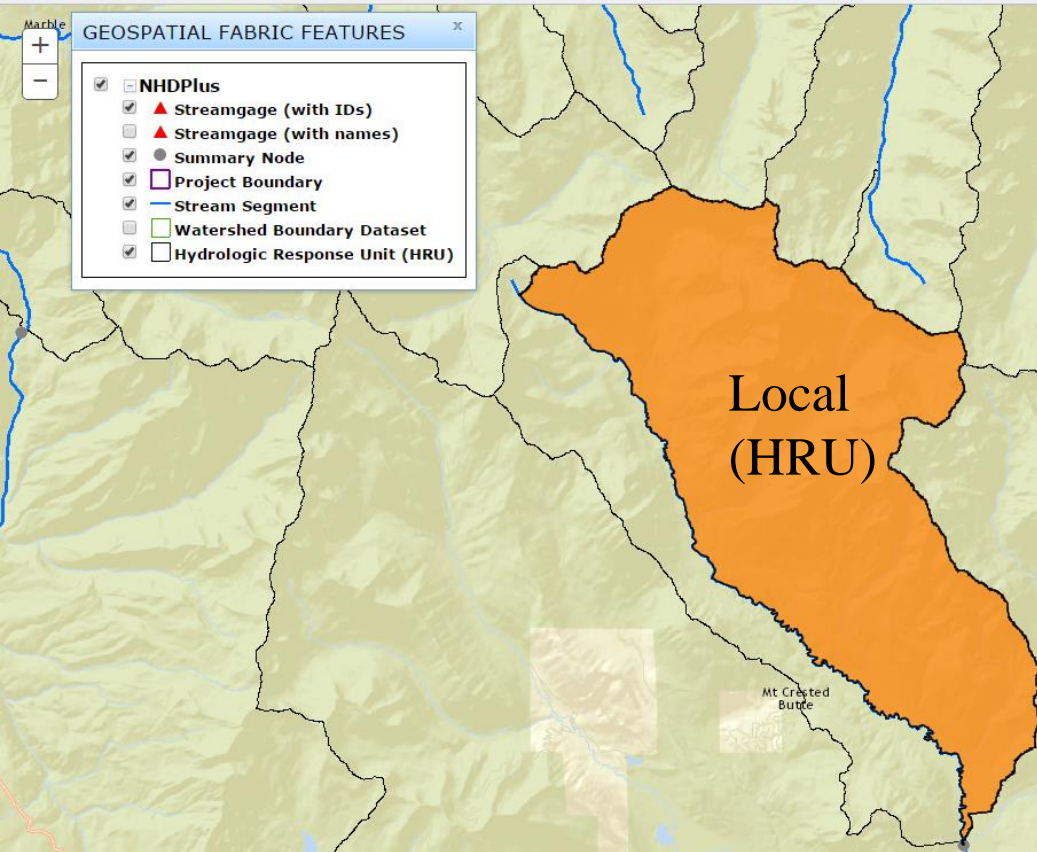
This frequently asked questions (FAQ) web page provides instruction on how to navigate and generate plots and summaries on the U.S. Geological Survey Monthly Water Balance Model Futures Portal, as well as background on a number of topics related to the portal and Monthly Water Balance Model Futures project.

<https://my.usgs.gov/mows/>

Spatial Summary Type

MoWS - Monthly Water Balance Model Portal

Full Extent Prev Extent Next Extent Measure Legend Plots Download FAQ



Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Local (HRU)

Location from map: * HRU: 2087

Variable of interest: *

Period of record (water years): *

Runs (select at least 1): *

Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

- Selection for hydrologic response units, summary nodes, and streamgages

Spatial Summary Type

MoWS - Monthly Water Balance Model Portal

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GEOSPATIAL FABRIC FEATURES

- NHDPlus
- Streamgage (with IDs)
- Streamgage (with names)
- Summary Node
- Project Boundary
- Stream Segment
- Watershed Boundary Dataset
- Hydrologic Response Unit (HRU)

Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Accumulated (summary node or streamgage) ▾

Location from map: * East River (244)

Variable of interest: * ▾

Period of record (water years): * ▾ to ▾

Runs (select at least 1): * 📁

Subset by KS test p-value: * No Subset ▾

[Click to Plot](#) [Click to Download](#) [Clear](#)

Spatial summary type: * Accumulated (summary node or streamgage) ▾

Location from map: * East River (244)

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

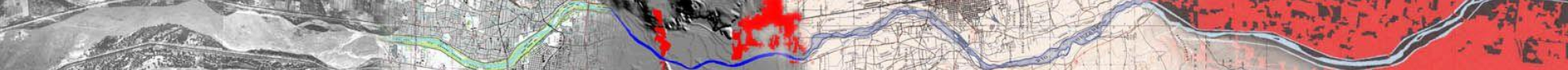
Local

Upstream Accumulated

Mt Crested Butte

Crested Butte

- Selection for hydrologic response units, summary nodes, and streamgages



Variable of Interest

- Temperature = degrees Celsius (°C)
- All other variables = millimeters (depth per unit area)

Variable of interest: *

by HRU →

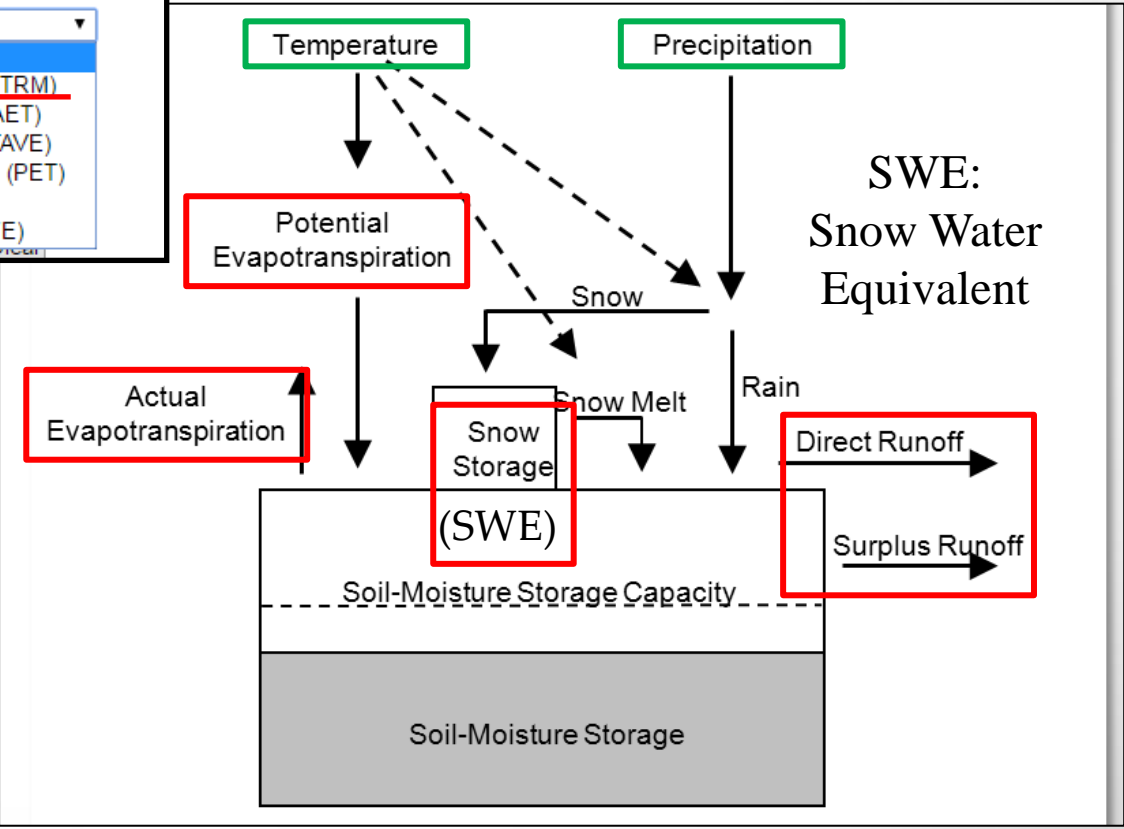
- Actual evapotranspiration (AET)
- Atmospheric temperature (TAVE)
- Potential evapotranspiration (PET)
- Precipitation (PPT)
- Runoff (RO)
- Snow water equivalent (SWE)

Variable of interest: *

by Summary node →

- Accumulated streamflow (STRM)
- Actual evapotranspiration (AET)
- Atmospheric temperature (TAVE)
- Potential evapotranspiration (PET)
- Precipitation (PPT)
- Snow water equivalent (SWE)


- Simulated runoff (RO) summarized locally for hydrologic response units; simulated streamflow (STRM) along the stream network at summary nodes



Runs (Climate Dataset Selection)

Full Extent Prev Extent Next Extent Measure Legend Plots Download FAQ

- GEOSPATIAL FABRIC FEATURES**
- NHDPlus
 - ▲ Streamgage (with IDs)
 - ▲ Streamgage (with names)
 - Summary Node
 - Project Boundary
 - Stream Segment
 - Watershed Boundary Dataset
 - Hydrologic Response Unit (HRU)

Runs (select at least 1): * 

Select runs (by clicking on the cells in the right 2 columns). Use Cl


Station Based (SB)	BCSD	CMIP3	GSD	
Statistically Downscaled GCMs (SDS)			BCCR_BCM2_0	
			CCCMA_CGCM3_1	
			CNRM_CM3	
			CSIRO_MK3_0	
			GFDL_CM2_1	
			GISS_MODEL_E_R	
			INMCM3_0	
			IPSL_CM4	
			MIROC3_2_MEDRES	
			MIUB_ECHO_G	
			MPI_ECHAM5	
			MRI_CGCM2_3_2A	
			NCAR_CCSM3_0	
			NCAR_PCM1	
			UKMO_HADCM3	
			CMIP5	BCC_CSM1_1_M
			BCC_CSM1_1	
BNU_ESM				

Plots

Simulated historic conditions: mean monthly plots


Choose:

Spatial summary type: * Accumulated (summary node or streamgage) ▾

Location from map: *  East River (244)

Variable of interest: *

Period of record (water years): * to

Runs (select at least 1): *  ←

Subset by KS test p-value: * No Subset ▾

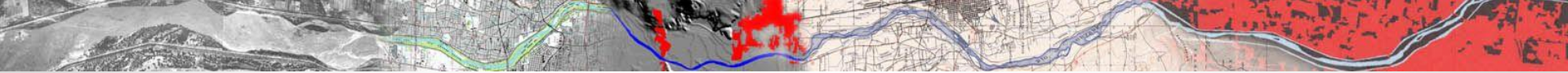
Climate dataset selection

Measured and simulated historical streamflow at selected gage: mean monthly

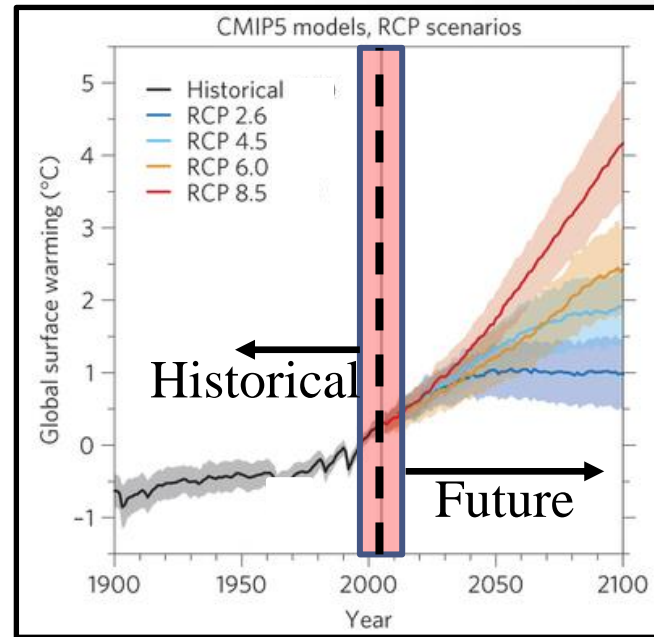
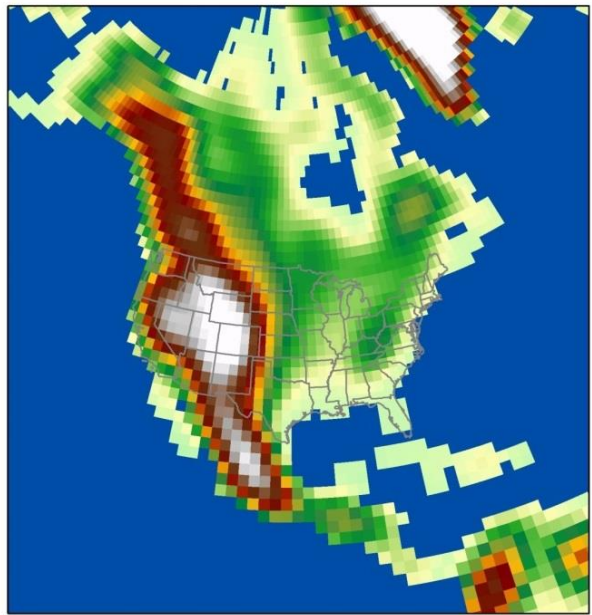
Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

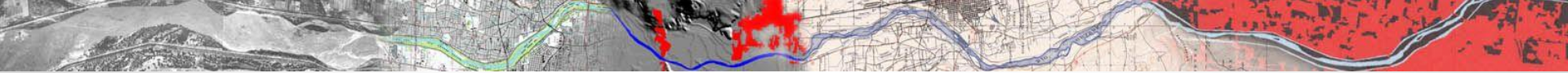
Future conditions: mean seasonal box plots



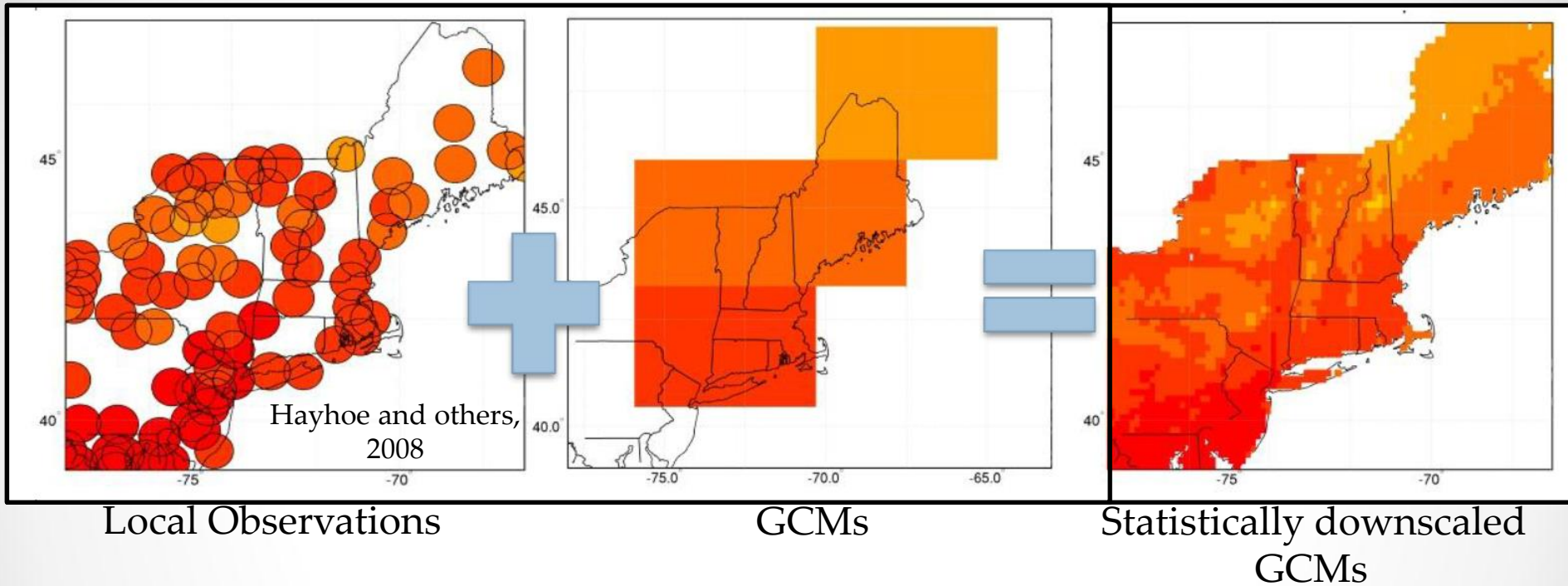
Downscaled General Circulation Models (GCMs)



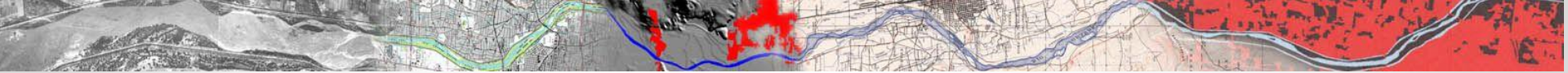
- One portion of GCM is historical conditions, and one portion is future conditions



Downscaled General Circulation Models (GCMs)



- One portion of GCM is historical conditions, and one portion is future conditions
- Statistical Downscaling: develop statistical relationships between observed climate variables and the coarse-scale GCM variables
- Can be used for finer-scale applications



MWBM Futures Database

Dataset	# of Datasets	Period of record on Portal
Gridded station data ¹	1	1952-2005 (historical)
BCSD CMIP3 ²		1952-2005 (historical)
SRES b1	32	2020-2099 (future)
SRES a1b	33	
SRES a2	29	
BCSD CMIP5 ³		1952-2005 (historical)
RCP 4.5	52	2020-2099 (future)
RCP 6.0	25	
RCP 8.5	50	

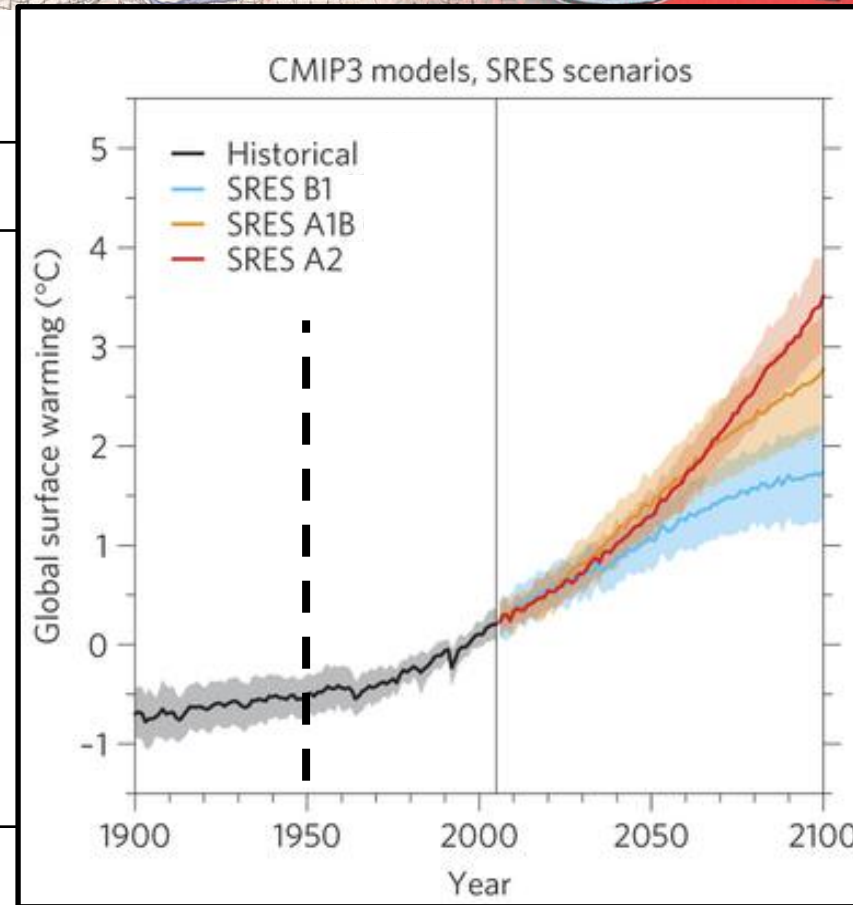
¹Maurer and others, 2002,

²Bureau of Reclamation, 2011, ³Bureau of Reclamation, 2013

- Bias-corrected spatially disaggregated (BCSD) general circulation models (GCM)
- Includes ancillary data and other model components

MWBM Futures Database

Dataset	# of Datasets
Gridded station data ¹	1
BCSD CMIP3 ²	
SRES b1	32
SRES a1b	33
SRES a2	29
BCSD CMIP5 ³	
RCP 4.5	52
RCP 6.0	25
RCP 8.5	50



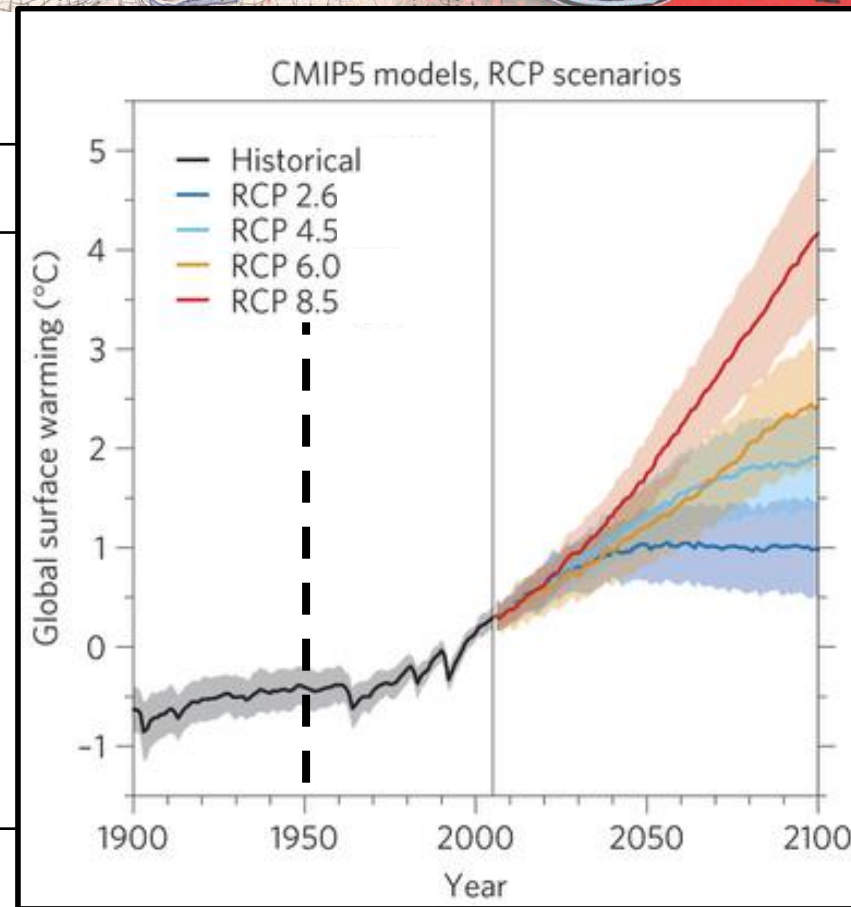
¹Maurer and others, 2002,

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MWBM Futures Database

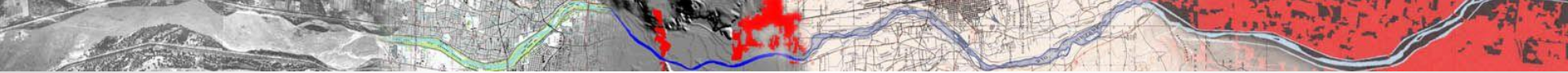
Dataset	# of Datasets
Gridded station data ¹	1
BCSD CMIP3 ²	
SRES b1	32
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- Includes ancillary data and other model components

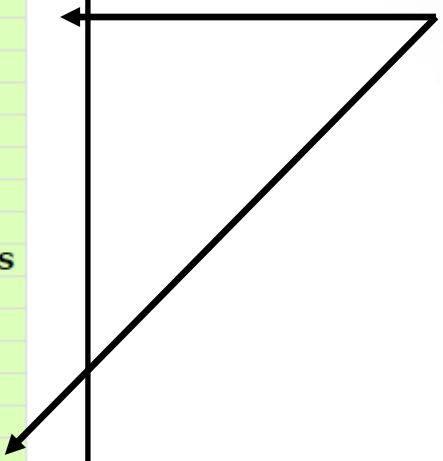


Runs (Climate Dataset Selection) (cont.)

Select runs (by clicking on the cells in the right 2 columns). Use Cl

Station Based (SB)			GSD	
Statistically Downscaled GCMs (SDS)	BCSD	CMIP3	BCCR_BCM2_0	
			CCCMA_CGCM3_1	
			CNRM_CM3	
			CSIRO_MK3_0	
			GFDL_CM2_1	
			GISS_MODEL_E_R	
			INMCM3_0	
			IPSL_CM4	
			MIROC3_2_MEDRES	
			MIUB_ECHO_G	
			MPI_ECHAM5	
			MRI_CGCM2_3_2A	
			NCAR_CCSM3_0	
			NCAR_PCM1	
			UKMO_HADCM3	
			CMIP5	BCC_CSM1_1_M
			BCC_CSM1_1	
			BNU_ESM	

by GCM/Model Group



Selection interface for plots based on historical conditions members)

Runs (Climate Dataset Selection) (cont.)

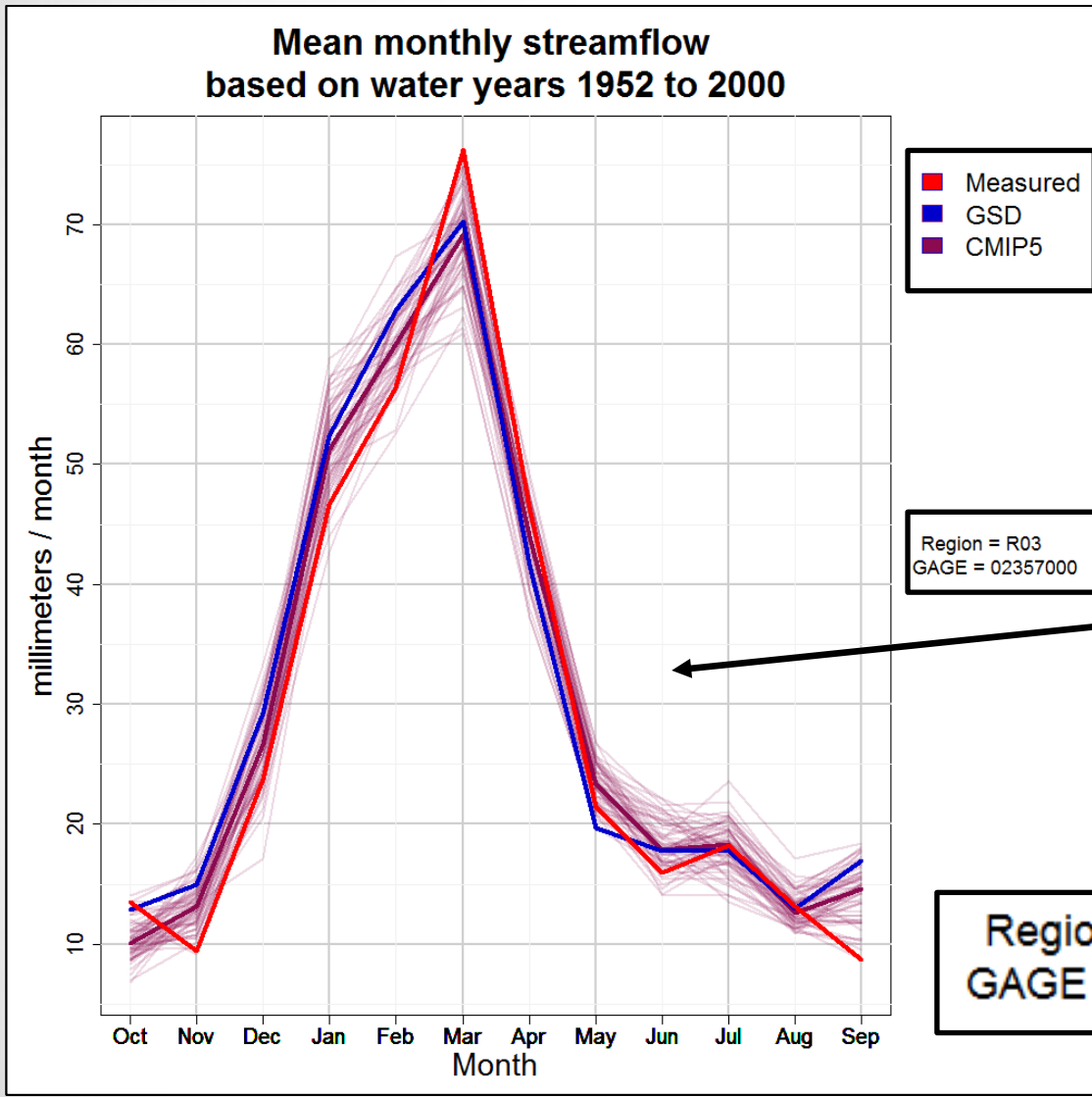
ells in the right 3 columns). Use Clear button to reset.

BCSD	CMIP3	Emission scenario b1		Submit	Clear
			BCCR_BCM2_0		
			CNRM_CM3		
			CSIRO_MK3_0		
			GFDL_CM2_1		
			GISS_MODEL_E_R		
			INMCM3_0		
			IPSL_CM4		
			MIROC3_2_MEDRES		
			MIUB_ECHO_G		
			MPI_ECHAM5		
			MRI_CGCM2_3_2A		
			NCAR_CCSM3_0		
			NCAR_PCM1		
		Emission scenario a1b	BCCR_BCM2_0		
			CCCMA_CGCM3_1		
			CNRM_CM3		
			CSIRO_MK3_0		
			GISS_MODEL_E_R		
			INMCM3_0		
			IPSL_CM4		
			MIROC3_2_MEDRES		
			MIUB_ECHO_G		
			MPI_ECHAM5		
			MRI_CGCM2_3_2A		
			NCAR_CCSM3_0		
			NCAR_PCM1		
		Emission scenario a2	BCCR_BCM2_0		
			CCCMA_CGCM3_1		
			CNRM_CM3		
			CSIRO_MK3_0		
			INMCM3_0		
			IPSL_CM4		
			MIROC3_2_MEDRES		
			MIUB_ECHO_G		
			MPI_ECHAM5		
			MRI_CGCM2_3_2A		
			NCAR_CCSM3_0		
			NCAR_PCM1		
			UKMO_HADCM3		

← by GCM
Emission Scenario
Model Group

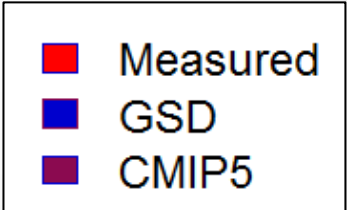
Selection interface for plots
based on future conditions

Historical Conditions: Mean Monthly Plots

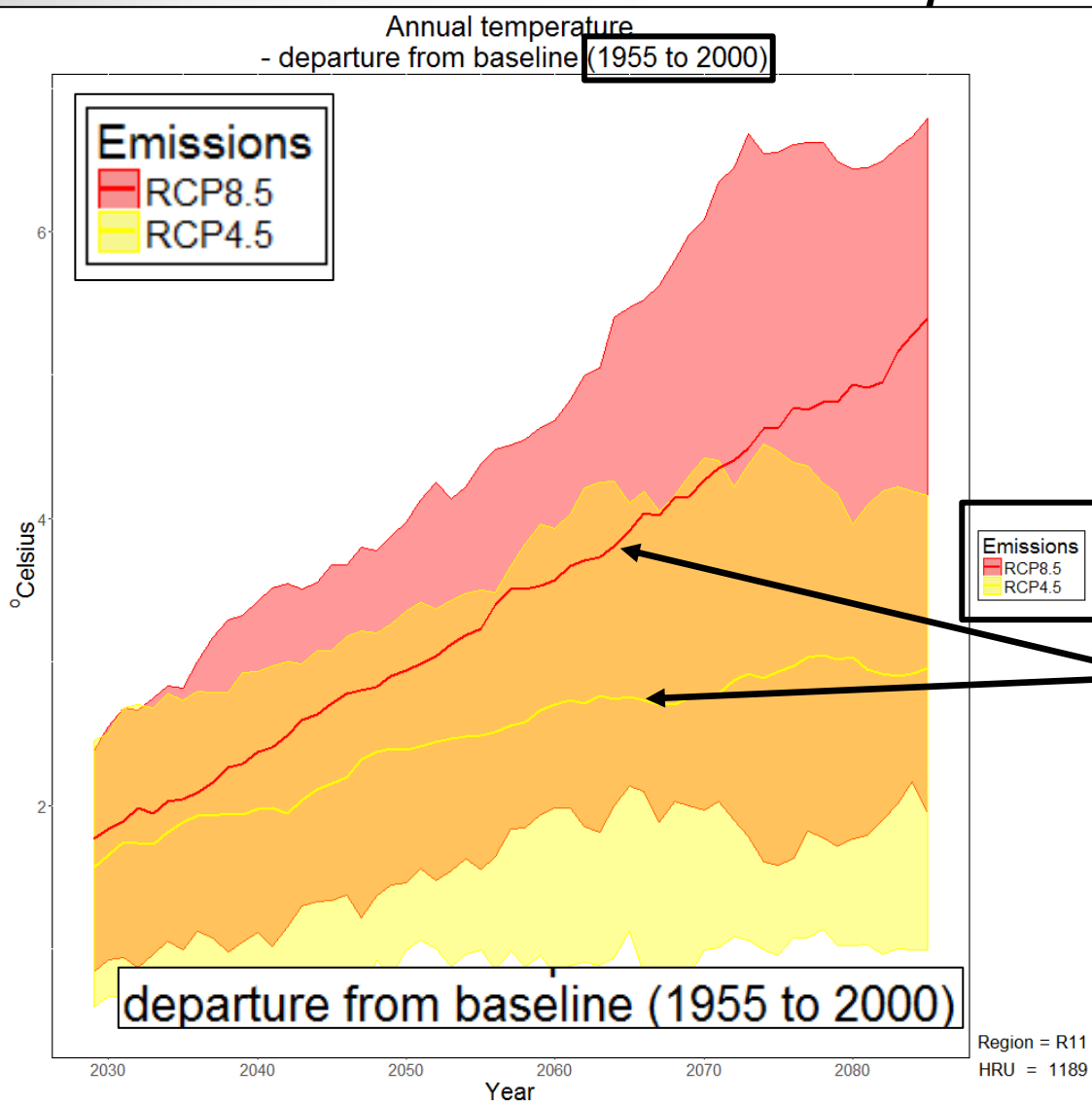


- Plotting MWBM variables during historical conditions (1952 through 2005)
- Line for each GCM simulation, with thick line denoting the median of the historical conditions

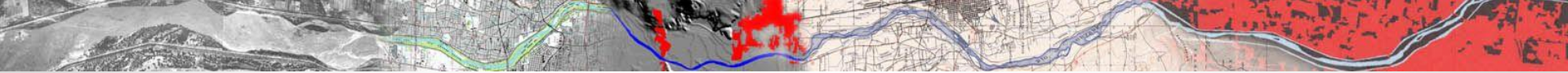
Region = R03
GAGE = 02357000



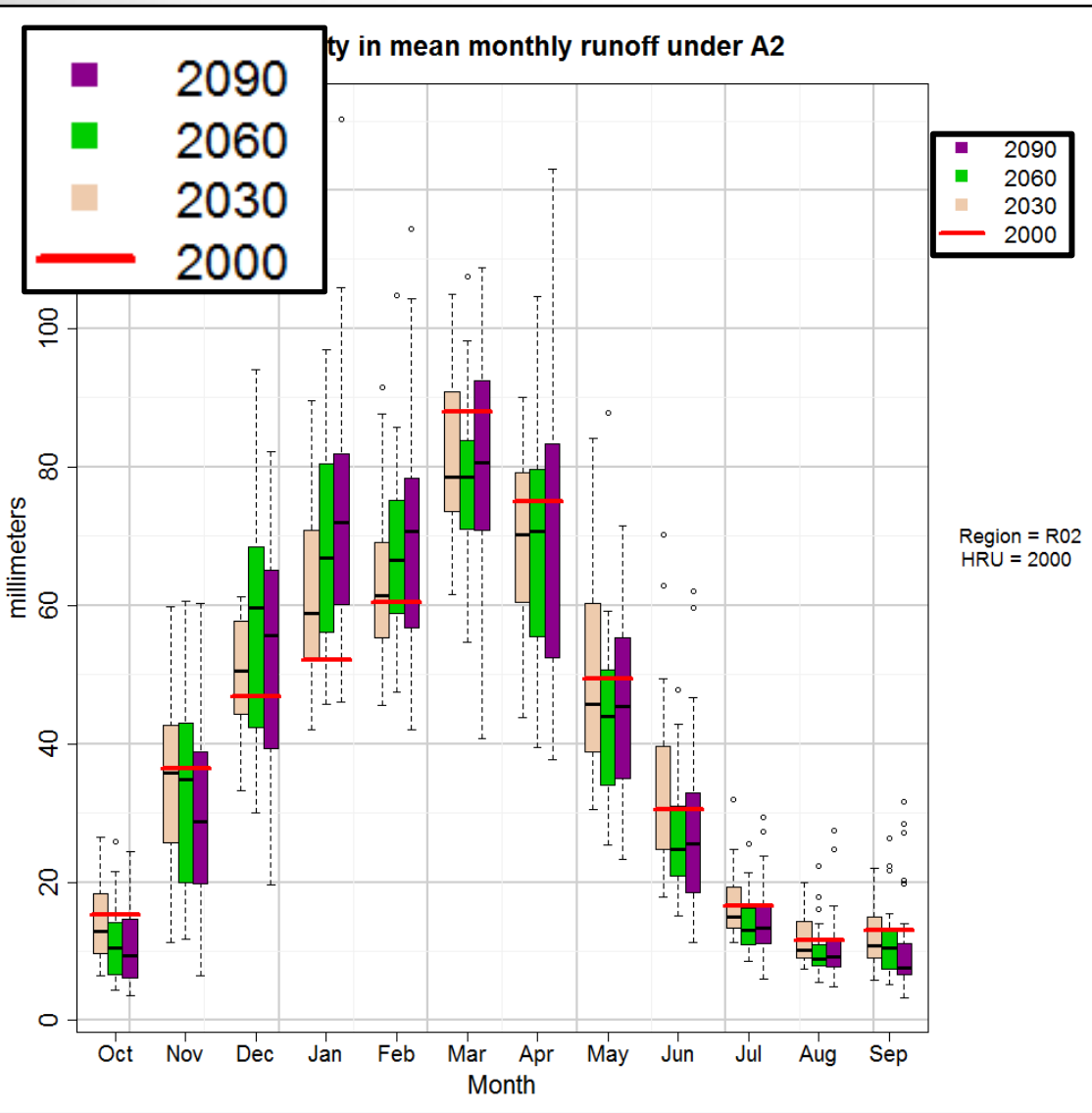
Future Conditions: Envelope Plots



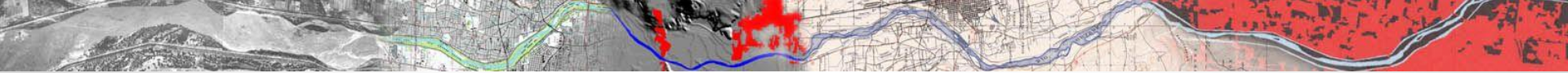
- Plotting MWBM variables for future conditions (2020 through 2099)
- Change from historical conditions into the future
- Envelope bracketing min/max of each emission scenario ensemble, with single line denoting the median of each ensemble
- Each emission scenario given its own color
- Several unique arguments



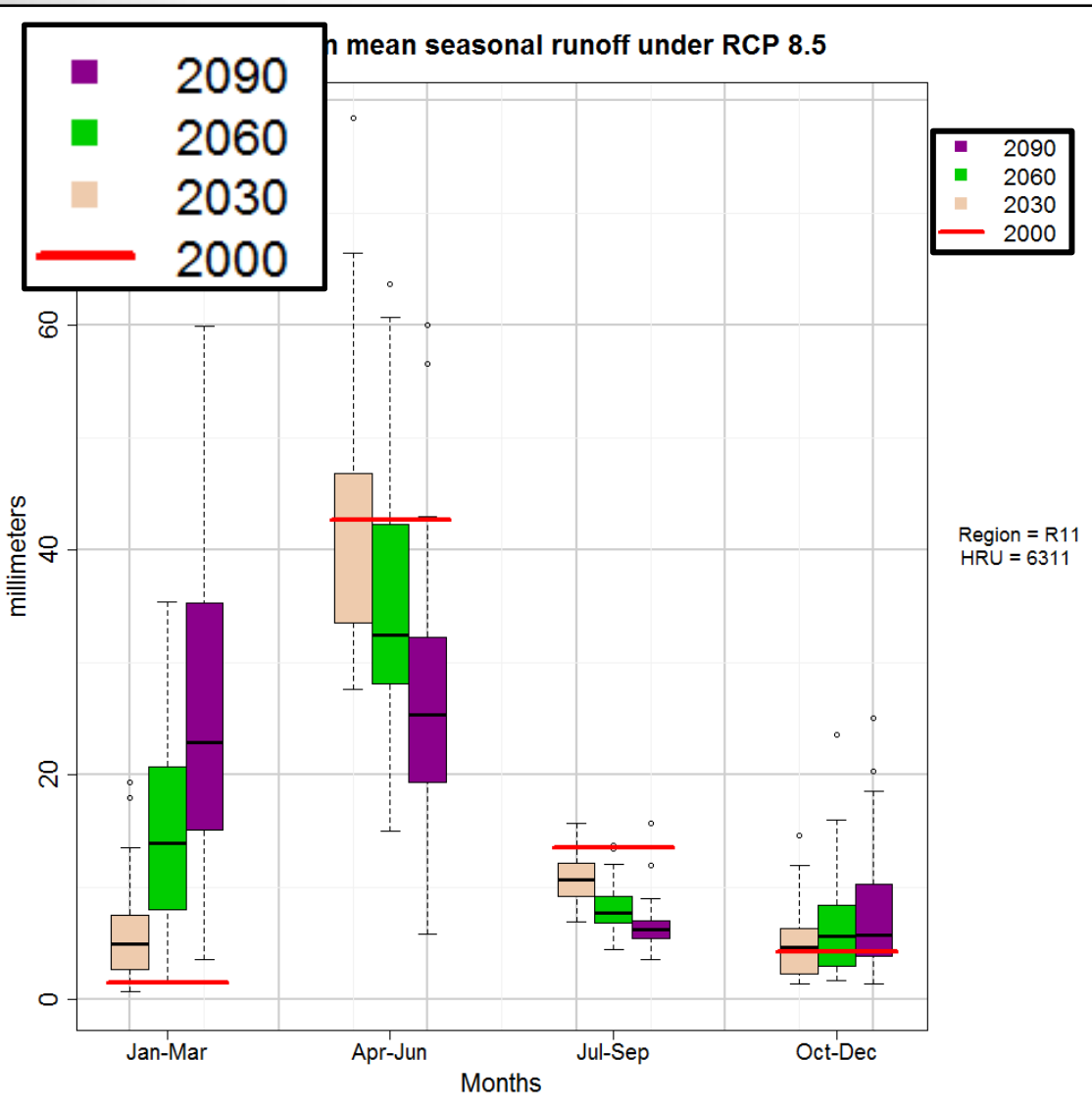
Future Conditions: Box Plots



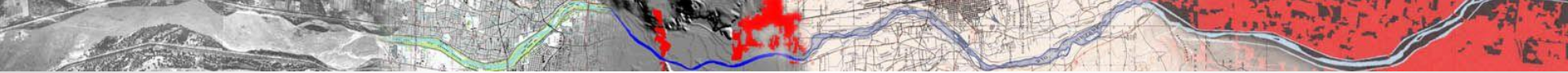
- Monthly or seasonal variability for GCMs of a single emission scenario around three future time periods (2030, 2060, and 2090) compared to a baseline (red line, the median of the climate simulations in the chosen emission scenario [SRES] or representative concentration pathways [RCP])
- 2000: 1995 through 2005
2030: 2025 through 2035
2060: 2045 through 2055
2090: 2085 through 2095



Future Conditions: Box Plots

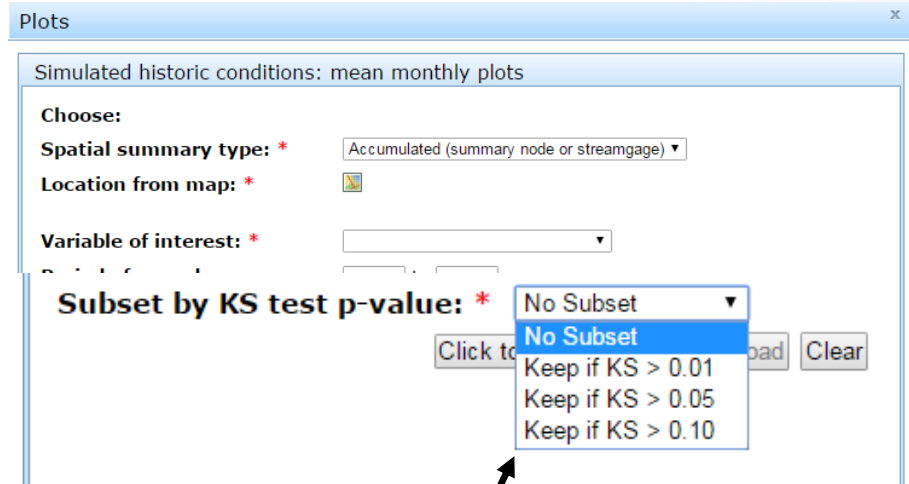
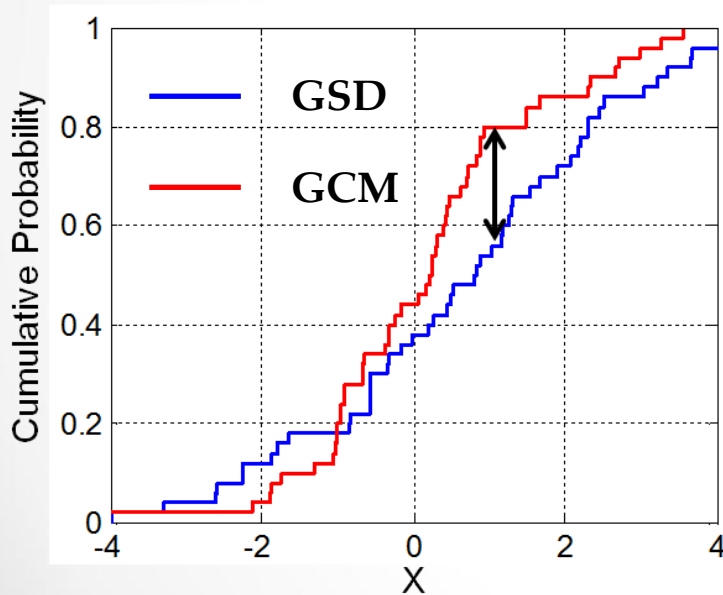


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- 2000: 1995 through 2005
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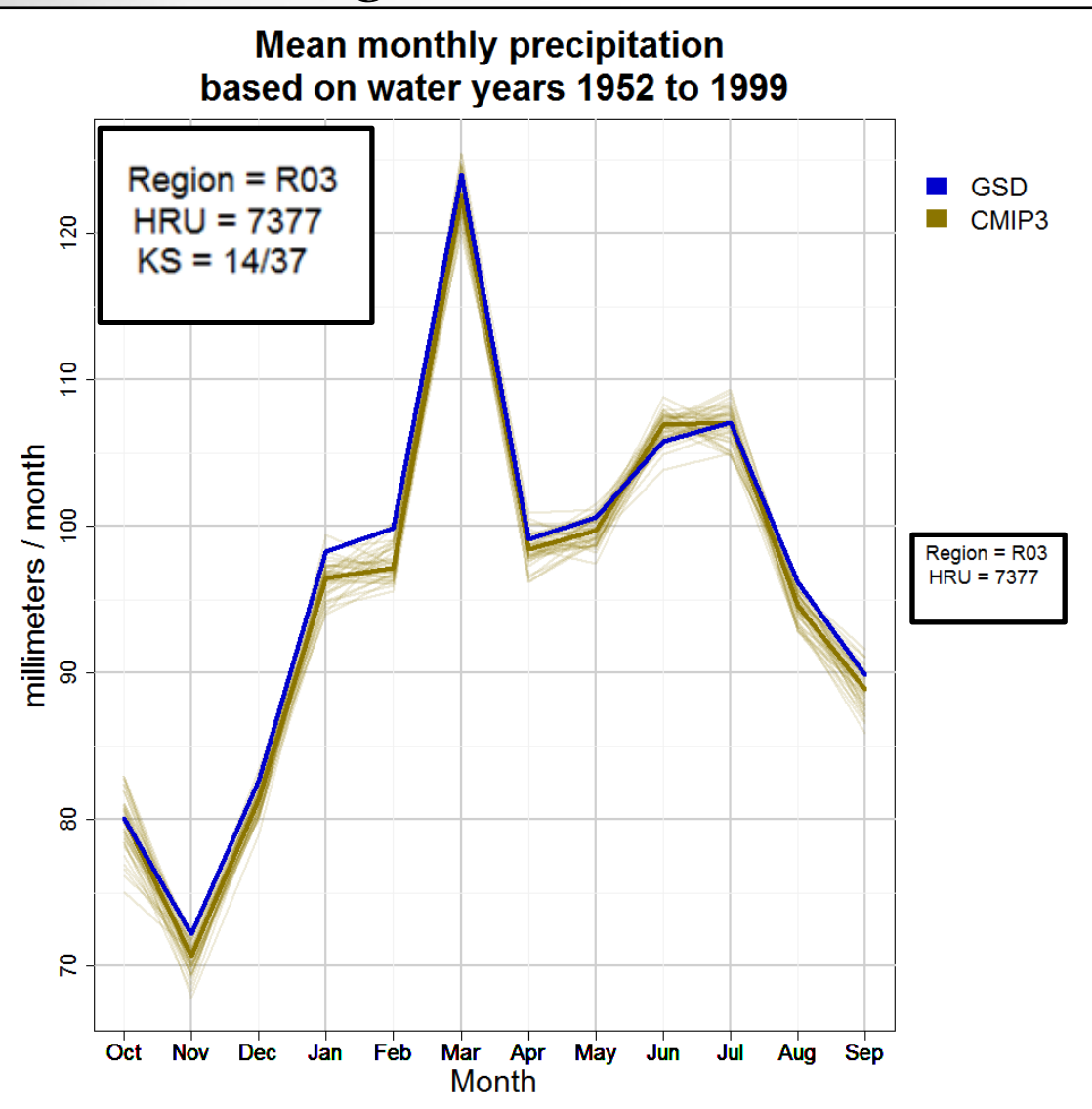
Sub-setting Climate Dataset Selections

- Portal uses the Kolmogorov-Smirnov (KS) test (Conover, 1971) to subset GCM selection to those that best reproduce past conditions (Hay and others, 2014)
- Compares empirical cumulative distribution of downscaled GCM simulation data and that of the station-based dataset (GSD) used for the downscaling procedure



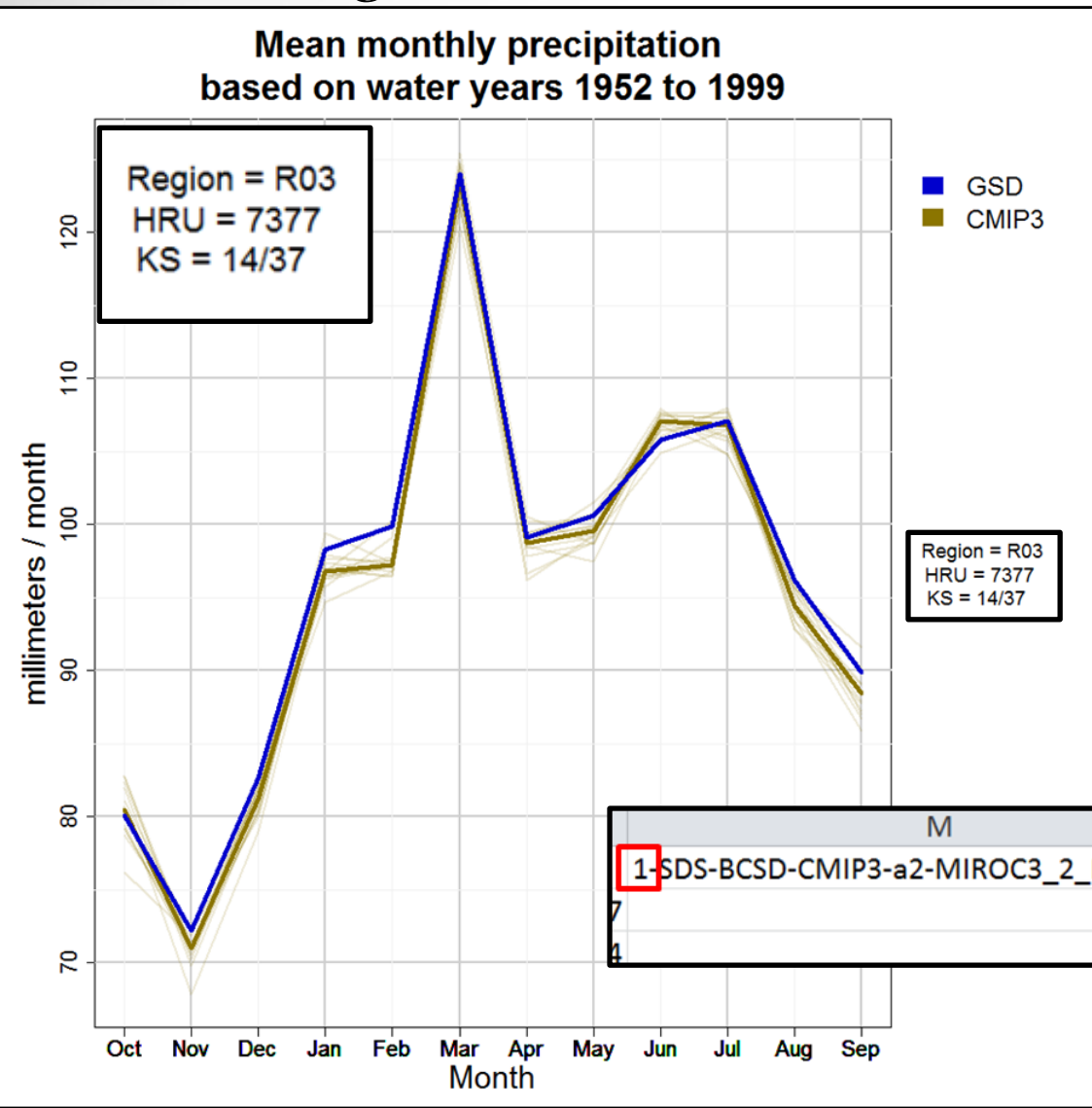
- Chosen climate simulations not meeting KS test p-value thresholds are withheld from plotting data and attributed in the time series csv

Sub-setting Climate Dataset Selections (cont.)



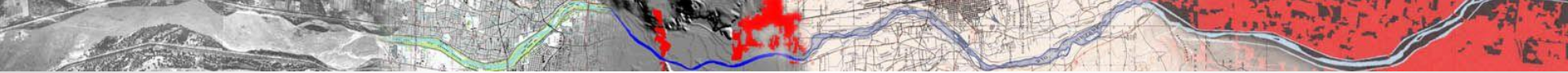
- Number of downscaled GCM simulations that meet the KS test threshold are noted in the plot annotation and csv header (plots based on KS test p-value of 0.01)

Sub-setting Climate Dataset Selections (cont.)



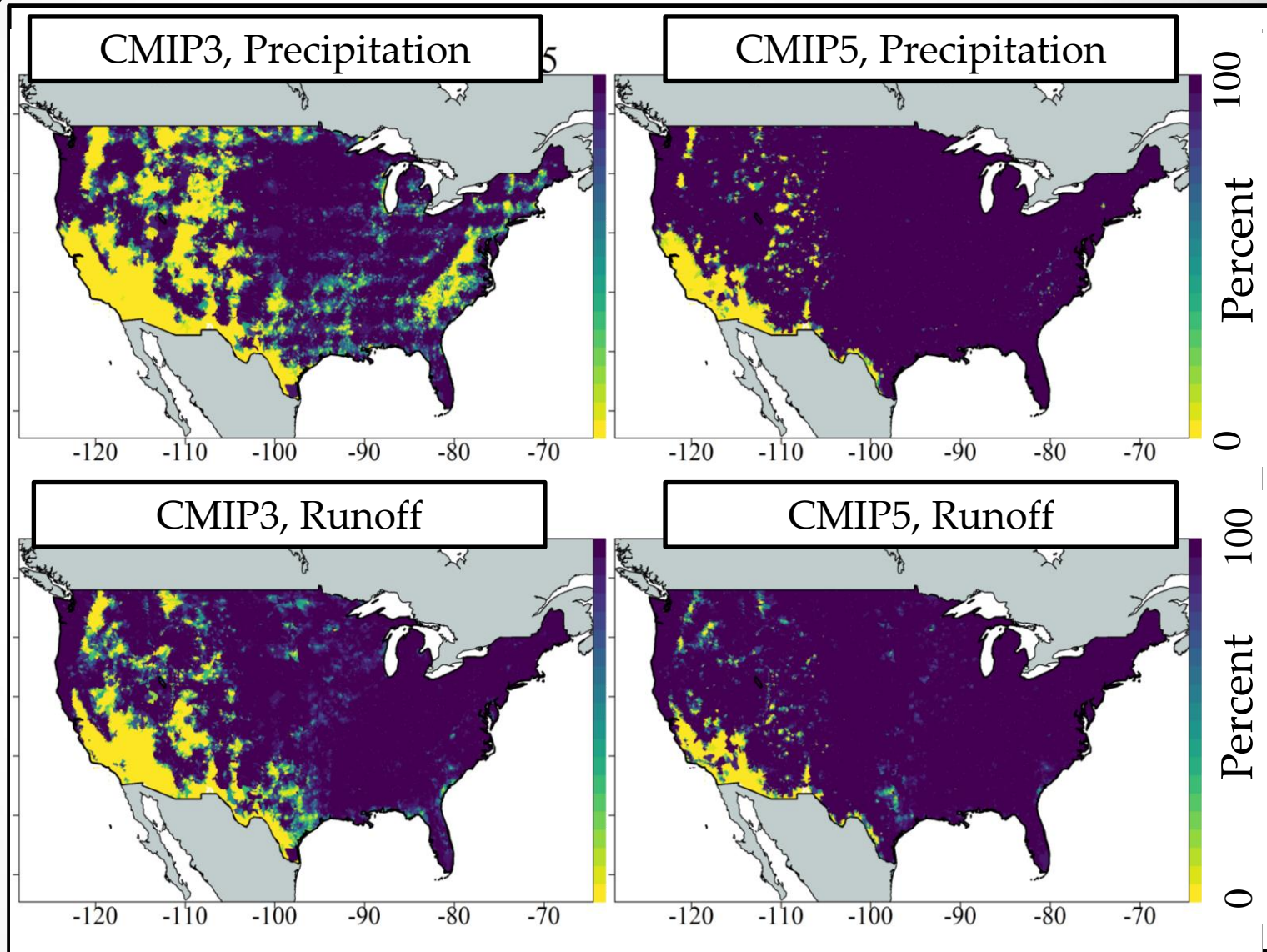
- Number of downscaled GCM simulations that meet the KS test threshold are noted in the plot annotation and csv header (plots based on KS test p-value of 0.01)

	M	N
1-SDS-BCSD-CMIP3-a2-MIROC3_2-MEDRES_3	162.27077	102.9931
0-SDS-BCSD-CMIP3-a2-MIUB_ECHO_G_1	215.4929	109.87238



Sub-setting Climate Dataset Selections

Percent of downscaled general circulation models (GCMs) that replicate historic conditions across MWBM variables (using a KS test p-value threshold of 0.05).





Acknowledgments

This research was initiated with and is supported by the U.S. Environmental Protection Agency Office of Wetlands, Oceans, and Watersheds, and the U.S. Department of the Interior (DOI) South Central Climate Science Center.

Other funding and support was provided by the U.S. Geological Survey (USGS) WaterSMART initiative and John Wesley Powell Center for Analysis and Synthesis. The database and portal were developed in cooperation with the DOI North Central Climate Science Center, the USGS Center for Integrated Data Analytics, the USGS Community for Data Integration, and the USGS Fort Collins Science Center Web Applications Team. Further project support was provided by the USGS Core Science Systems Mission Area.



Associated Products

- Journal Articles

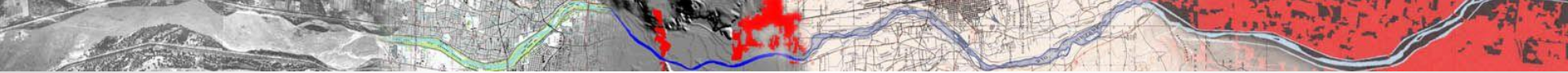
Bock, A.R., Hay, L.E., McCabe, G.J., Markstrom, S.L., and Atkinson, R.D., 2016a, Parameter regionalization of a monthly water balance model for the conterminous United States: *Hydrology and Earth System Sciences*, v. 20, p. 2861–2876.

McCabe, G.J., Hay, L.E., Bock, A.R., Markstrom, S.L., and Atkinson, R.D., 2015, Inter-annual and spatial variability of Hamon potential evapotranspiration model coefficients: *Journal of Hydrology*, v. 521, p. 389–394.

Hay, L.E., Bock, A.R., McCabe, G.J., and Markstrom, S.L., Do Downscaled General Circulation Models Reliably Simulated Current Climatic Conditions? (In Prep.)

- USGS Data Products

Monthly Water Balance Model Futures Portal: <https://my.usgs.gov/mows/>



Associated Products

- USGS Data Products (continued)

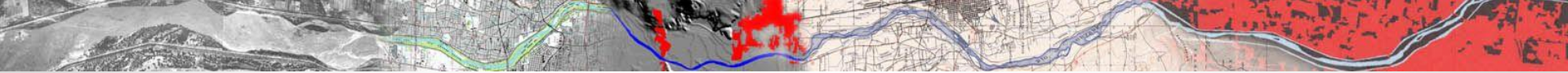
Bock, A.R., Hay, L.E., Markstrom, S.L., and Atkinson, R.D., 2016b, Monthly Water Balance Model Monthly Water Balance Model Futures: U.S. Geological Survey data release, accessed June 15, 2016, at <http://dx.doi.org/10.5066/F7VD6WJQ>.

Viger, R.J., and Bock, A.R., 2014, GIS features of the Geospatial Fabric for National Hydrologic Modeling: U.S. Geological Survey, doi: <http://dx.doi.org/10.5066/F7542KMD>

- USGS Information Products

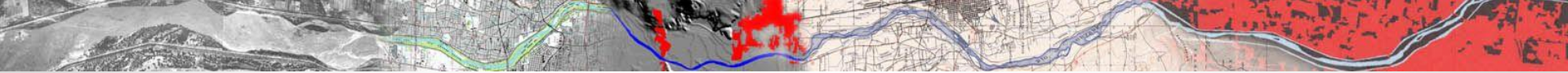
Bock, A.R., 2017, The U.S. Geological Survey Monthly Water Balance Model Futures Portal: U.S. Geological Survey Fact Sheet 2017-3002, 6 p., <https://doi.org/10.3133/fs20173002>.

Bock, A.R., Hay, L.E., Markstrom, S.L., Emmerich, Chris, and Talbert, Marian, 2016c, The U.S. Geological Survey Monthly Water Balance Model Futures Portal: U.S. Geological Survey Open-File Report 2016-1212, 21 p., <https://doi.org/10.3133/ofr20161212>



Potential Impacts on Ecological Resources

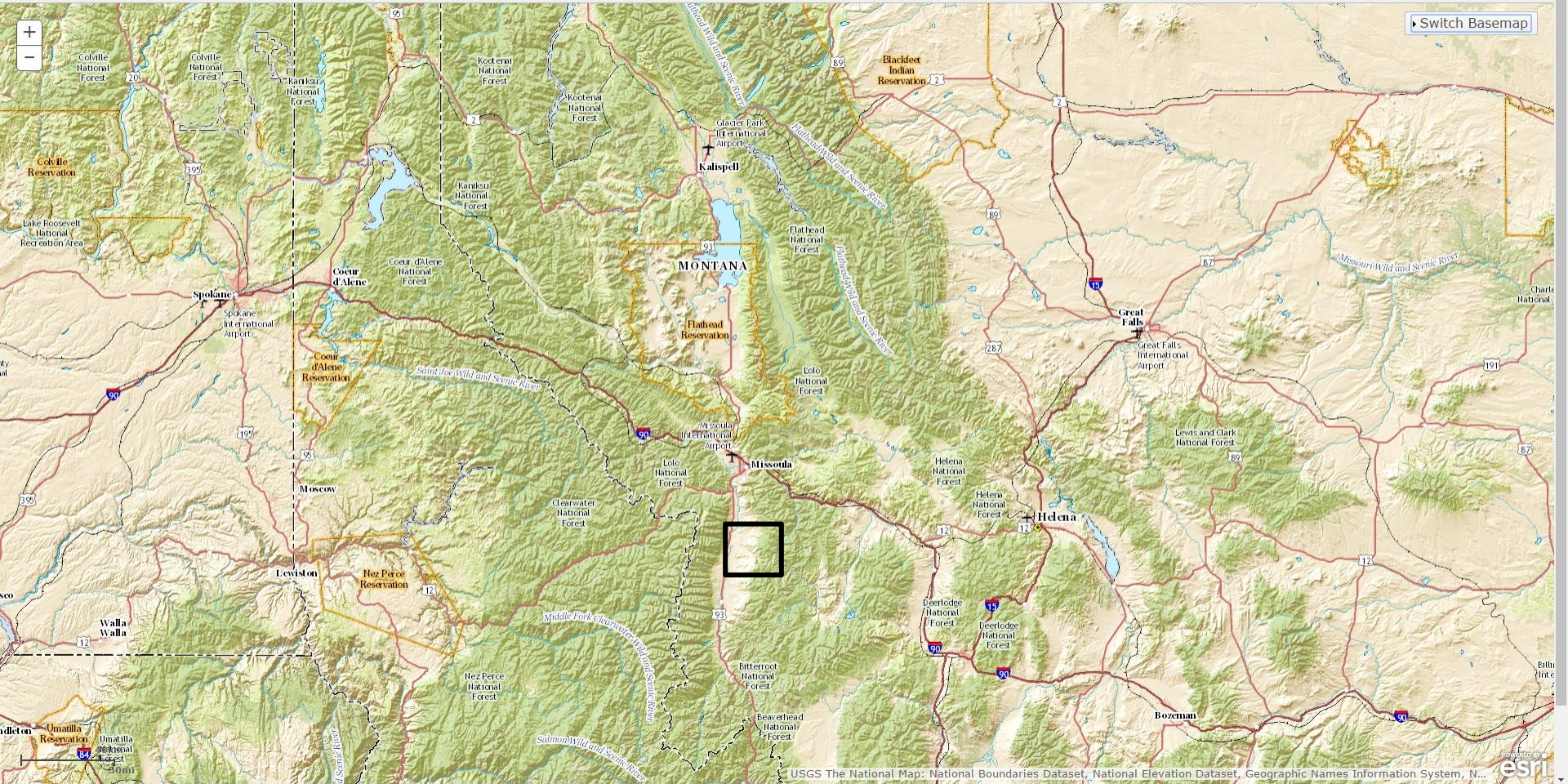


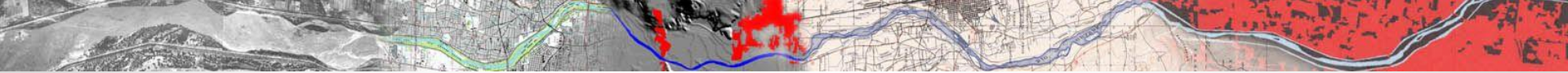


South Fork of the Flathead River, MT

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend Plots FAQ

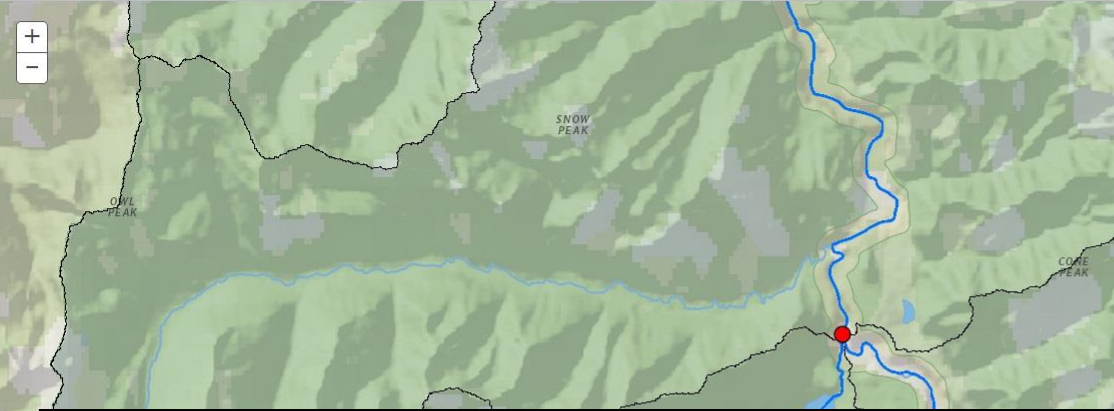




South Fork of the Flathead River, MT

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend Plots FAQ



Plots

Simulated historic conditions: mean monthly plots
Measured and simulated historical streamflow at selected gage: mean monthly
Envelope of future conditions based on downscaled GCMs: annual moving average

Choose:

Spatial summary type: *
Location from map: *
Variable of interest: *
Baseline *

Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.

Future conditions (water years) *
to

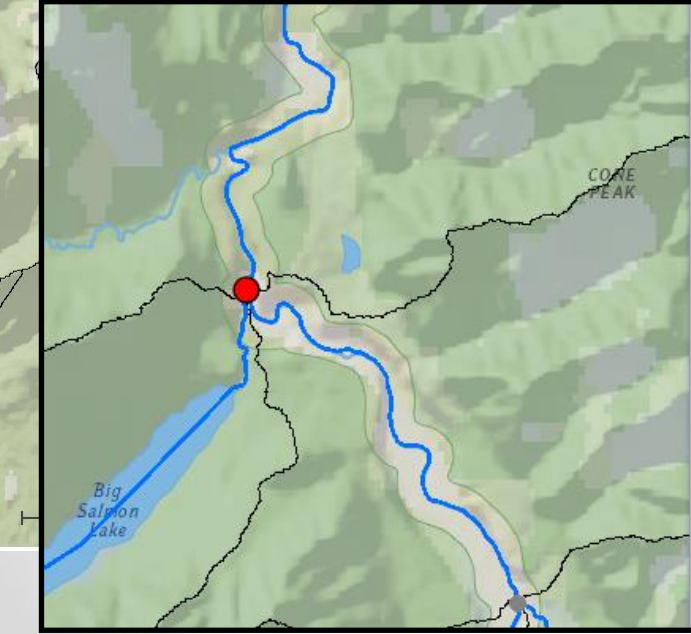
Accumulated (summary node or streamgage) *

South Fork Flathead River (227)

South Fork Flathead River (227) *

South Fork Flathead River (227)

Big Salmon Creek (225)



Choose:

Spatial summary type: *
Location from map: *
Variable of interest: *
Baseline *

Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.

Future conditions (water years) *
to

Length of running annual mean *
to

Runs (select at least 5): *
to

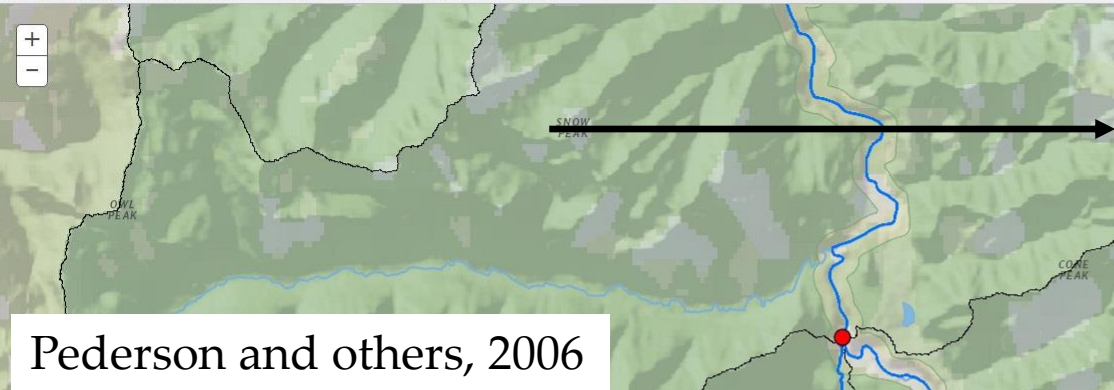
Subset by KS test p-value: *
No Subset

Click to Plot Click to Download Clear

South Fork of the Flathead River, MT

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend Plots FAQ



Plots

Simulated historic conditions: mean monthly plots
Measured and simulated historical streamflow at selected gage: mean monthly
Envelope of future conditions based on downscaled GCMs: annual moving average

Choose:
Spatial summary type: * Accumulated (summary node or streamgage) ▾
Location from map: * South Fork Flathead River (227) [Map Icon]
South Fork Flathead River (227) ▾
Variable of interest: * South Fork Flathead River (227) ▾
Big Salmon Creek (225) ▾

Baseline *
Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.

Future conditions (water years) * ▾ to ▾

Length of running annual mean * []

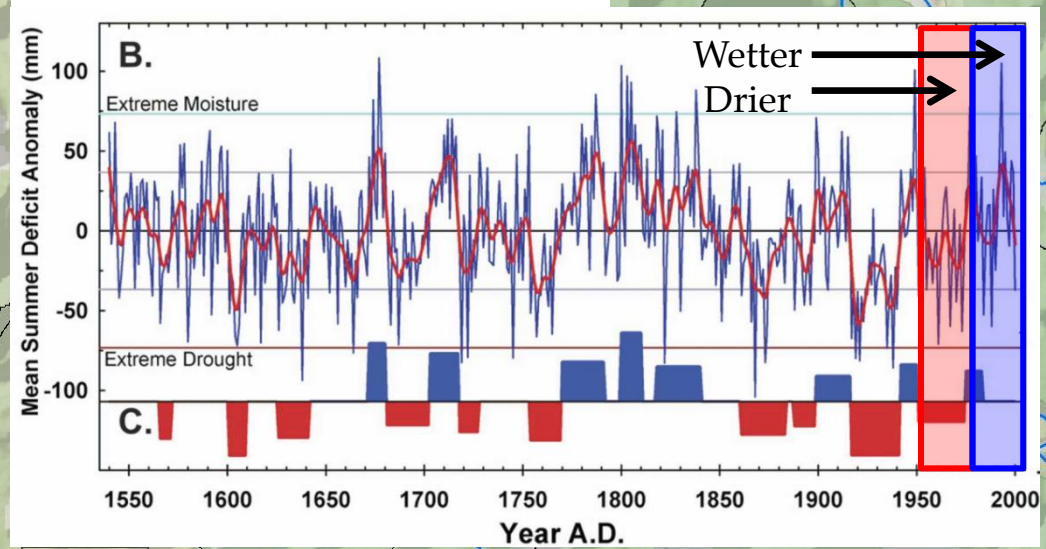
Runs (select at least 5): * [Folder Icon] No Subset ▾

Subset by KS test p-value: * []

Click to Plot Click to Download Clear

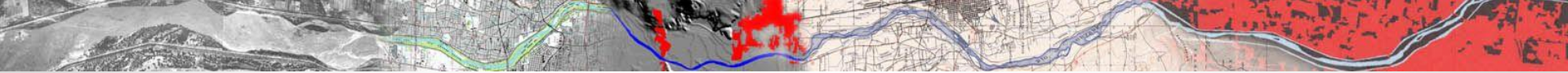
Future conditions: mean monthly box plots
Future conditions: mean seasonal box plots

Pederson and others, 2006

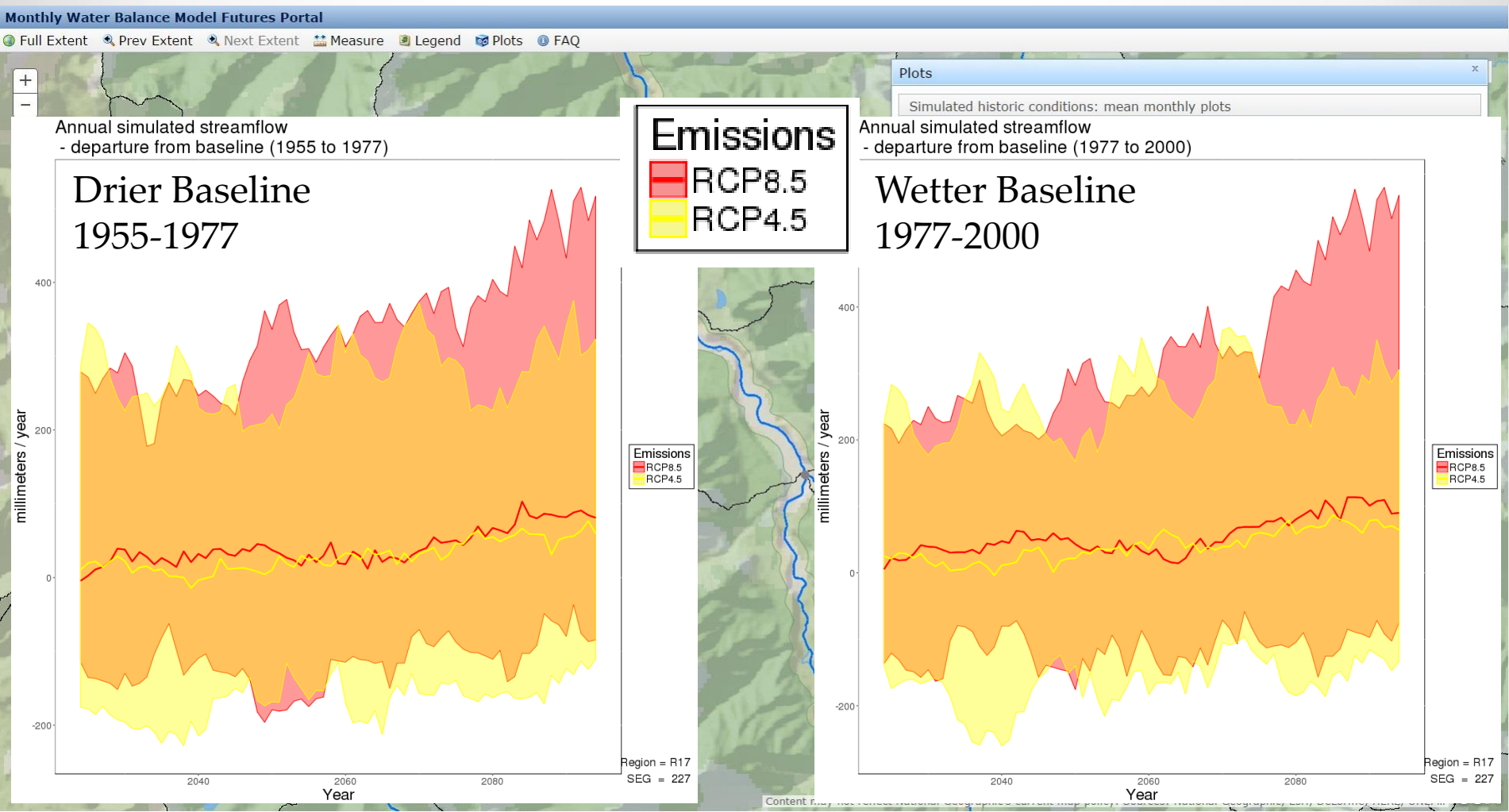


Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP...

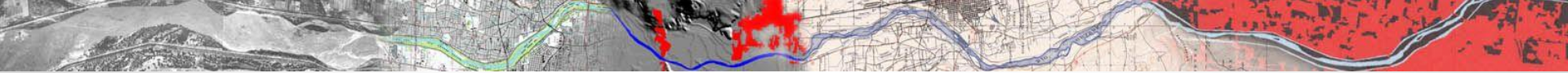
Examine potential future streamflow using two different baselines for comparison



S. Fork Flathead River (potential future scenarios, 2020-2090)



Examine potential future streamflow using two different baselines for comparison

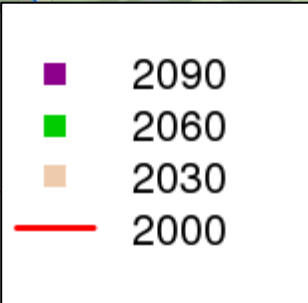
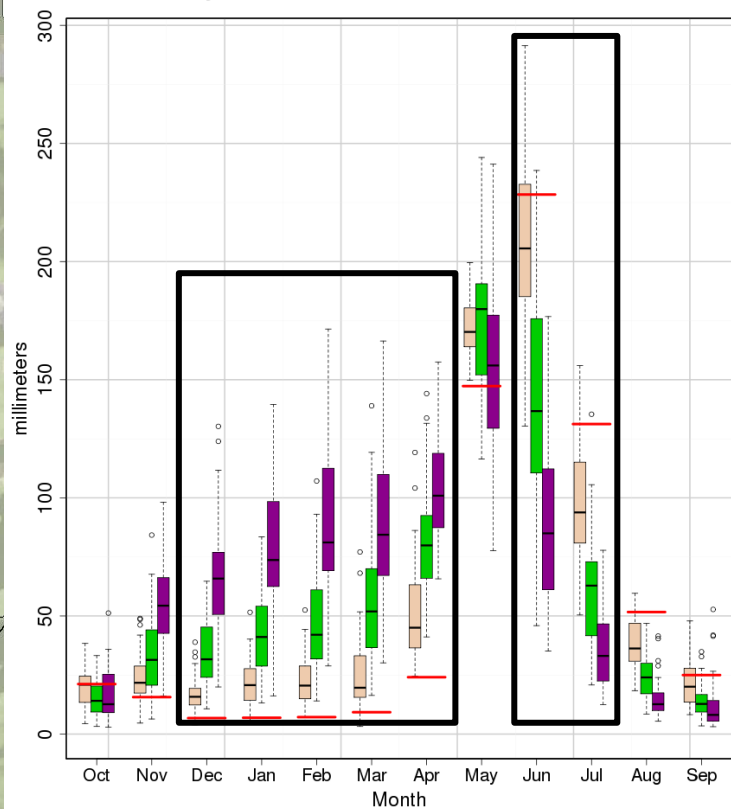


S. Fork Flathead River (potential future scenarios, 2030/60/90)

Monthly Water Balance Model Futures Portal

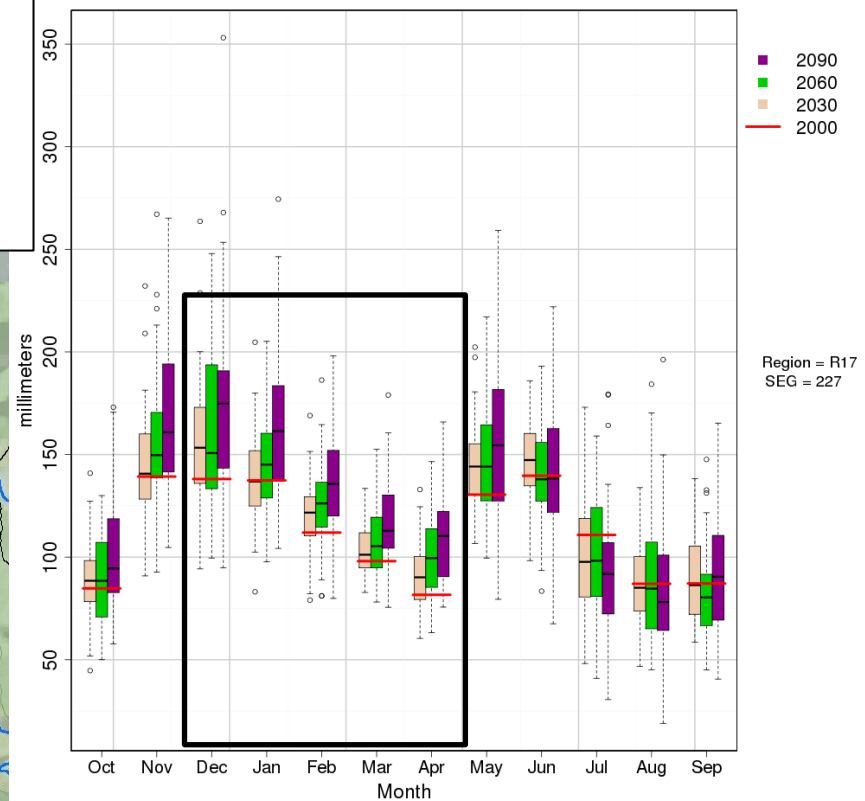
Full Extent Prev Extent Next Extent Measure Legend Plots FAQ

Variability in basin simulated streamflow under RCP 8.5



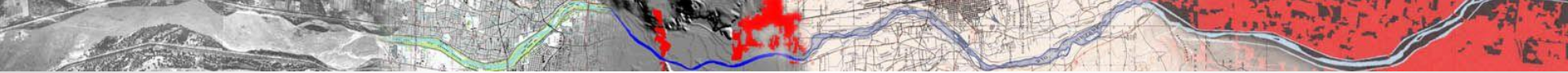
Region = R17
SEG = 227

Variability in mean monthly precipitation under RCP 8.5



Region = R17
SEG = 227

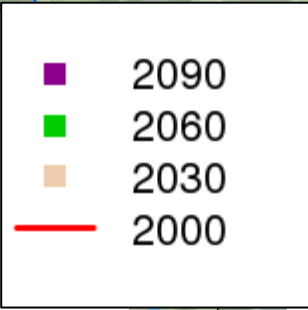
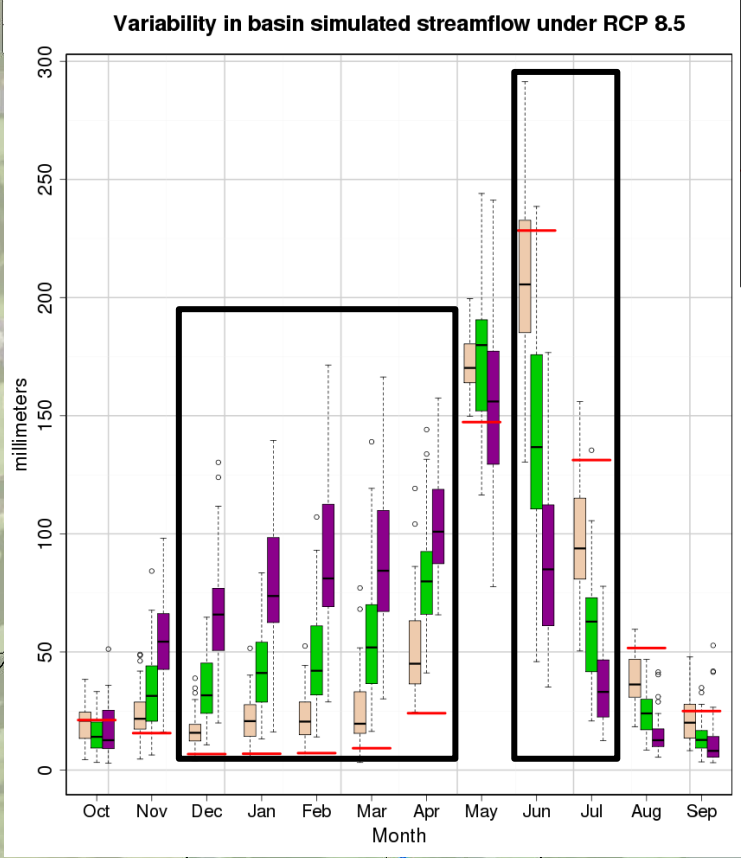
- Potential higher winter, lower summer flows, and lower SWE throughout the year



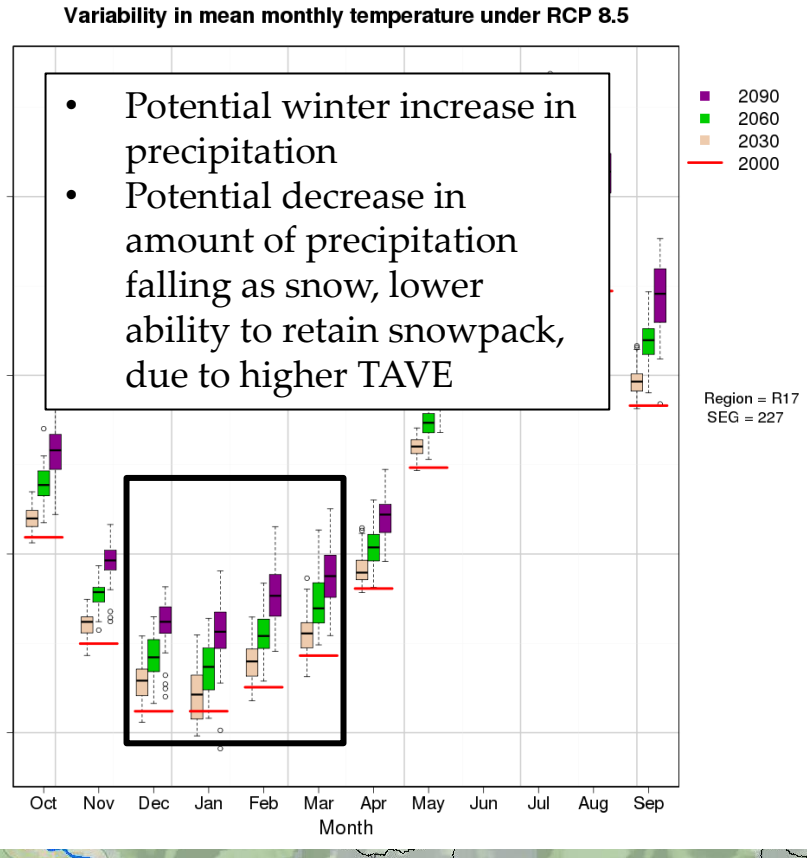
S. Fork Flathead River (potential future scenarios, 2030/60/90)

Monthly Water Balance Model Futures Portal

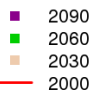
Full Extent Prev Extent Next Extent Measure Legend Plots FAQ



Region = R17
SEG = 227



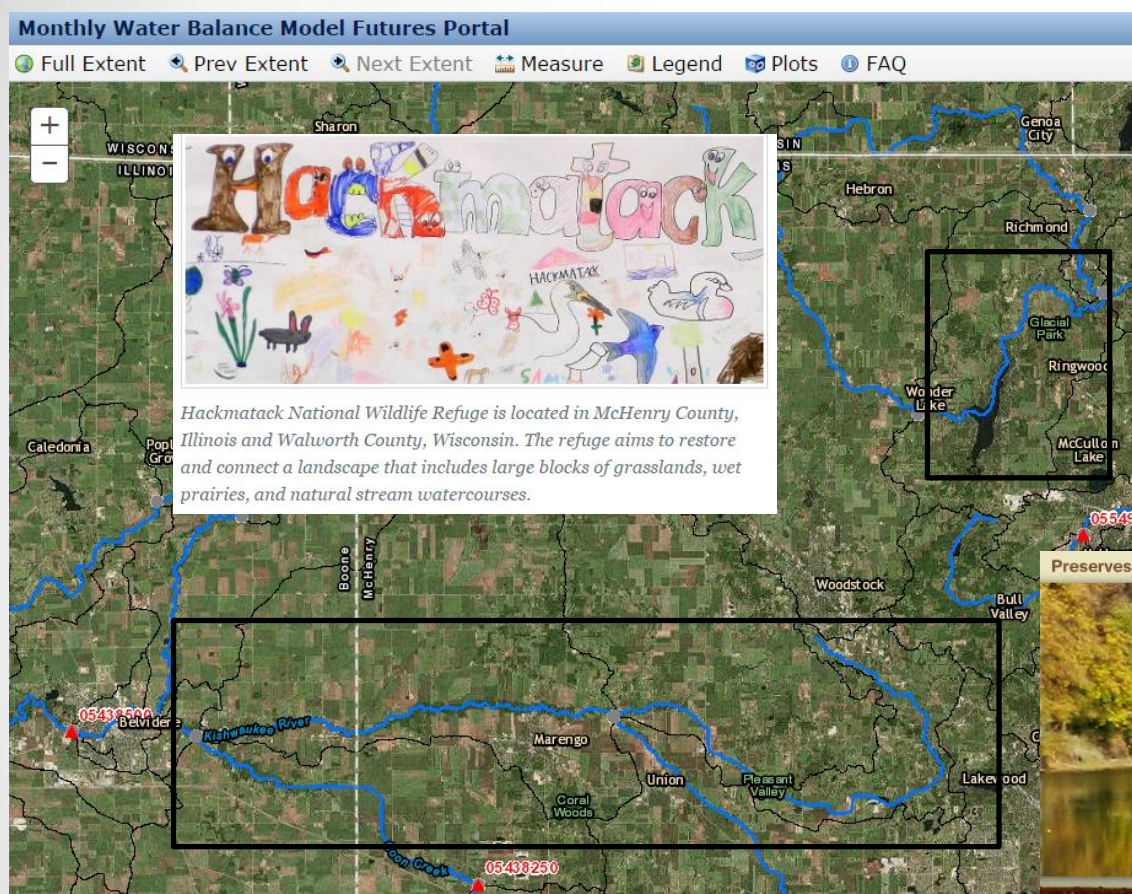
- Potential winter increase in precipitation
- Potential decrease in amount of precipitation falling as snow, lower ability to retain snowpack, due to higher TAVE



Region = R17
SEG = 227

- Potential higher winter, lower summer flows, and lower SWE throughout the year

Northern Illinois



Hackmatack National Wildlife Refuge is located in McHenry County, Illinois and Walworth County, Wisconsin. The refuge aims to restore and connect a landscape that includes large blocks of grasslands, wet prairies, and natural stream watercourses.

Banking on Nature – The Nippersink 206 Project

Once completed, 25% of this 27 mile long creek will have undergone restoration, from Keystone Landing to just beyond Pioneer Landing, thereby improving the ecological integrity of the entire watershed.

The project is being funded by a \$4.9 million US Army Corps of Engineers Section 206 grant, with the match, required from the District, being covered by the value of past land purchases acquired within Glacial Park that lie within the project area. The footprint of the project area covers 507 acres.

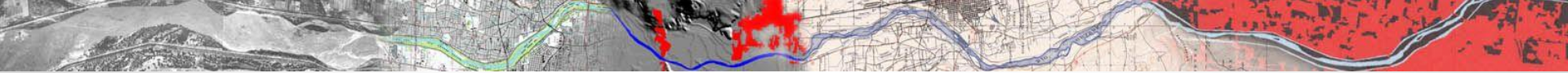
Preserves Activities Conservation Education Golf Governance About Us Contact Us

RIVERS

The Kishwaukee River

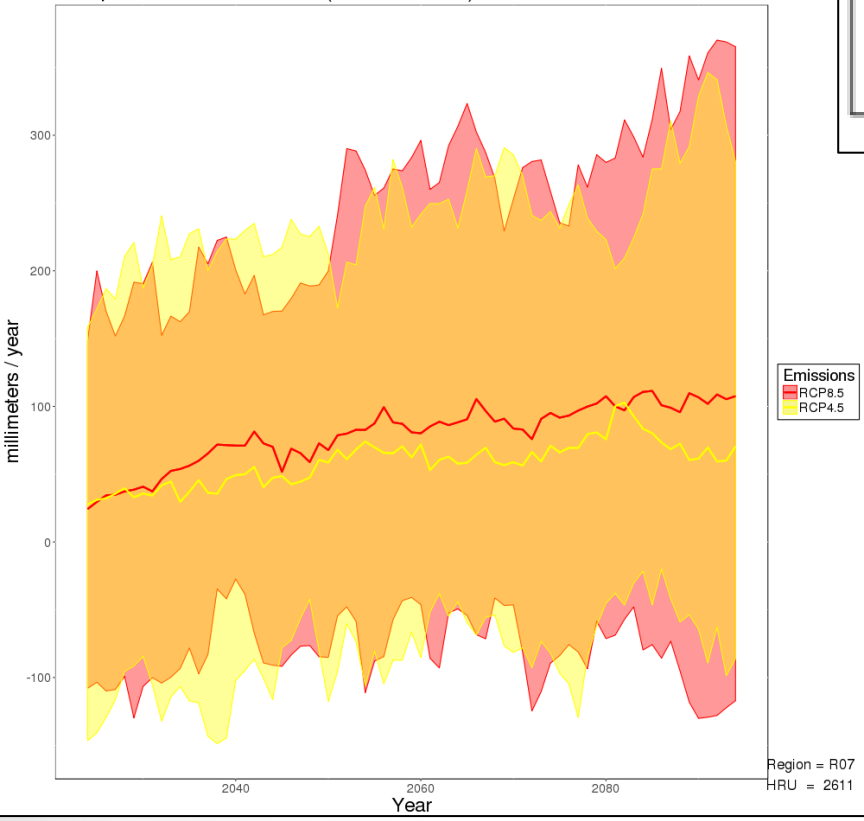
The Kishwaukee River is considered to be one of the highest quality streams in Illinois due to its relatively clean water and the diversity of life it supports. Designated an **Illinois Resource Rich Area** and a **Biologically Significant Stream**, the "Kish" watershed supports numerous threatened and endangered plant and animal species. Yet, its location, sandwiched between the spreading metropolitan regions of Rockford, IL and Chicago, make it increasingly vulnerable to numerous threats.

- *Regional, bond-funded programs that emphasize aquatic restoration and biodiversity*
- *Heavy corn and soybean agriculture*

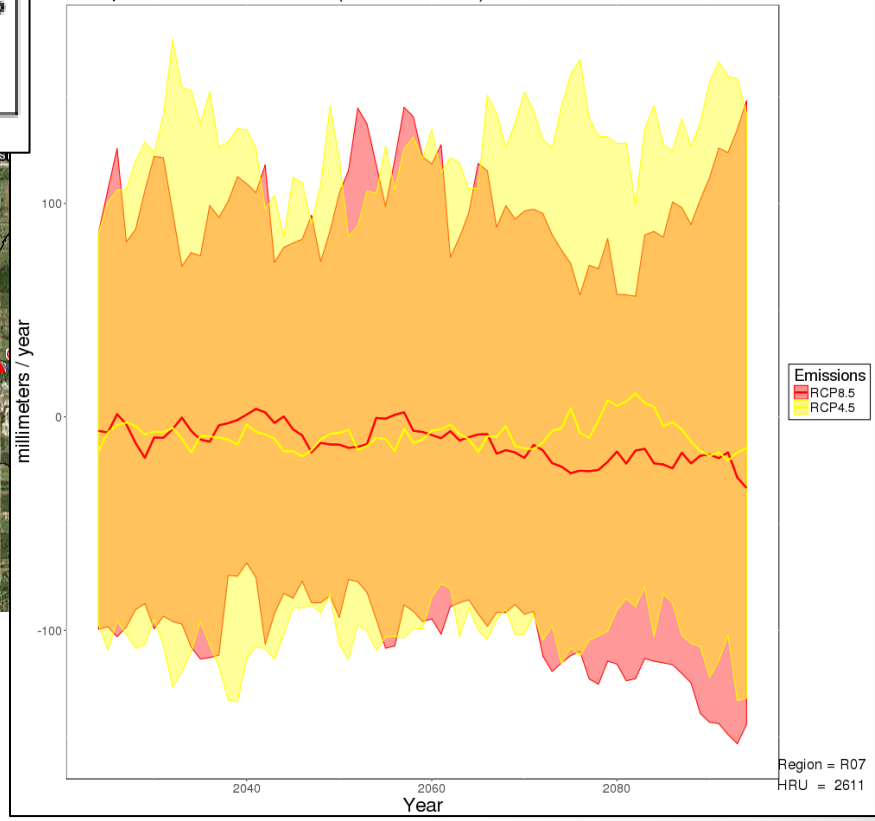


Ecological Impacts- Nippersink Creek

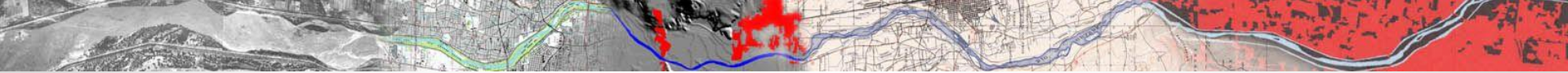
Annual precipitation
- departure from baseline (1975 to 2000)



Annual runoff
- departure from baseline (1975 to 2000)

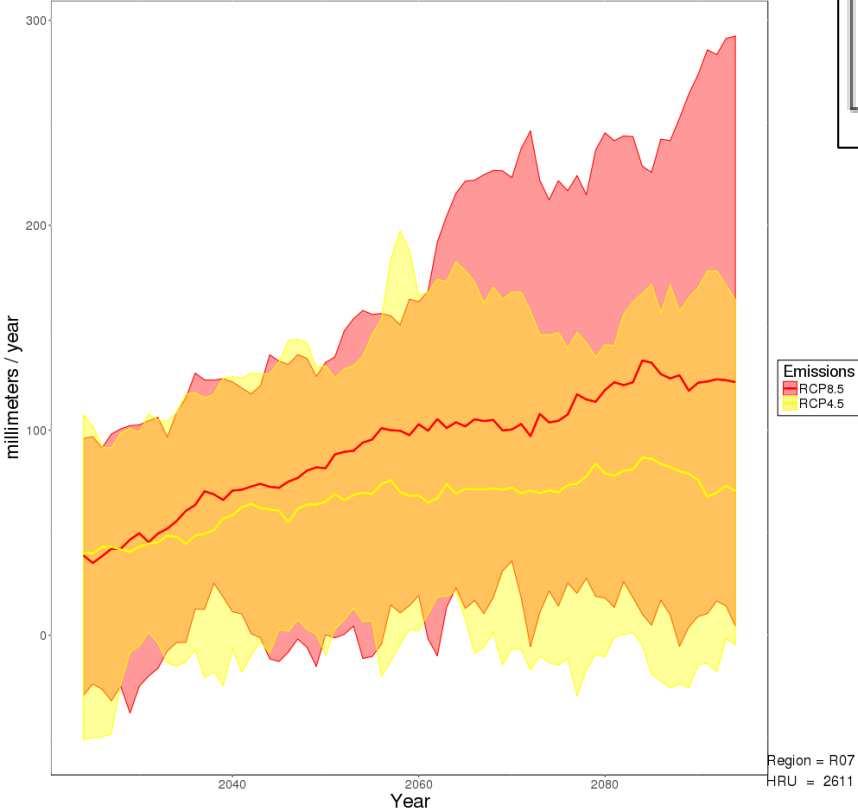


Evaluate Changes in Future runoff from contributing HRUS
-Increase in median precipitation for RCP 4.5 and 8.5
-Mixed trends for runoff

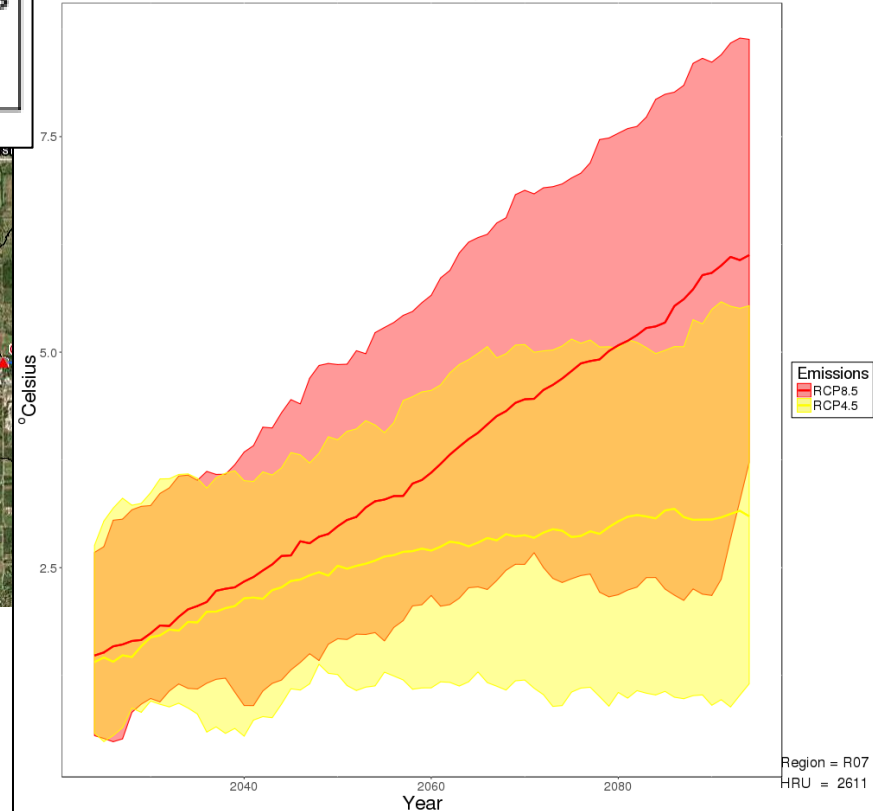


Ecological Impacts- Nippersink Creek

Annual actual evapotranspiration
- departure from baseline (1975 to 2000)



Annual temperature
- departure from baseline (1975 to 2000)

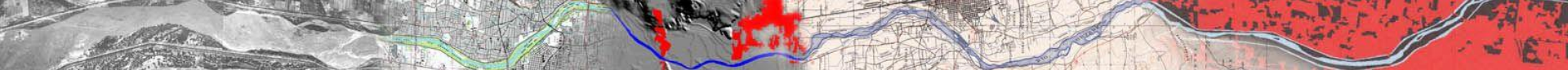


Evaluate Changes in Future runoff from contributing HRUS

- Increase in median precipitation for RCP 4.5 and 8.5

- Mixed trends for runoff

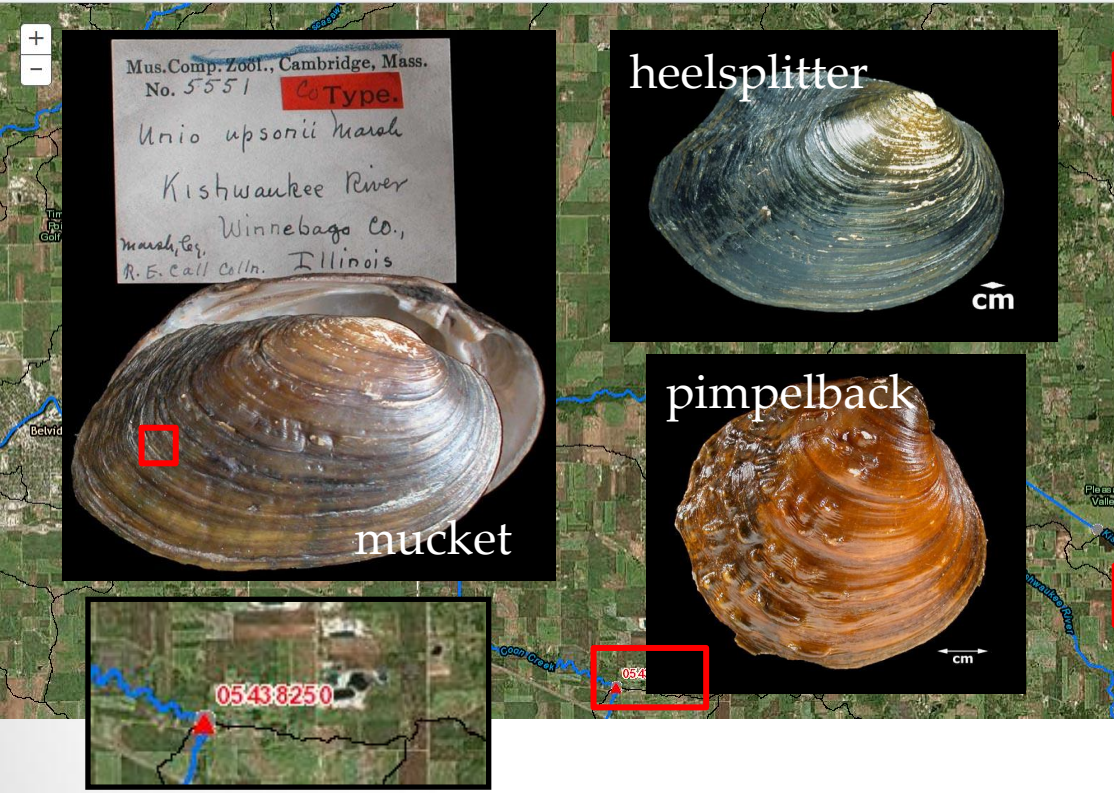
- Increase in median actual evapotranspiration (driven by increasing temperature)



Kishwaukee River

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend Plots FAQ



Plots

Simulated historic conditions: mean monthly plots

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Choose:

Spatial summary type: *

Location from map: *

Variable of interest: *

Baseline * 1975 to 2005

Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.

Future conditions (water years) *

Length of running annual mean *

Runs (select at least 5): *

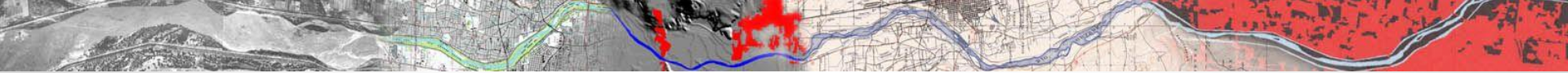
Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Future conditions: mean monthly box plots

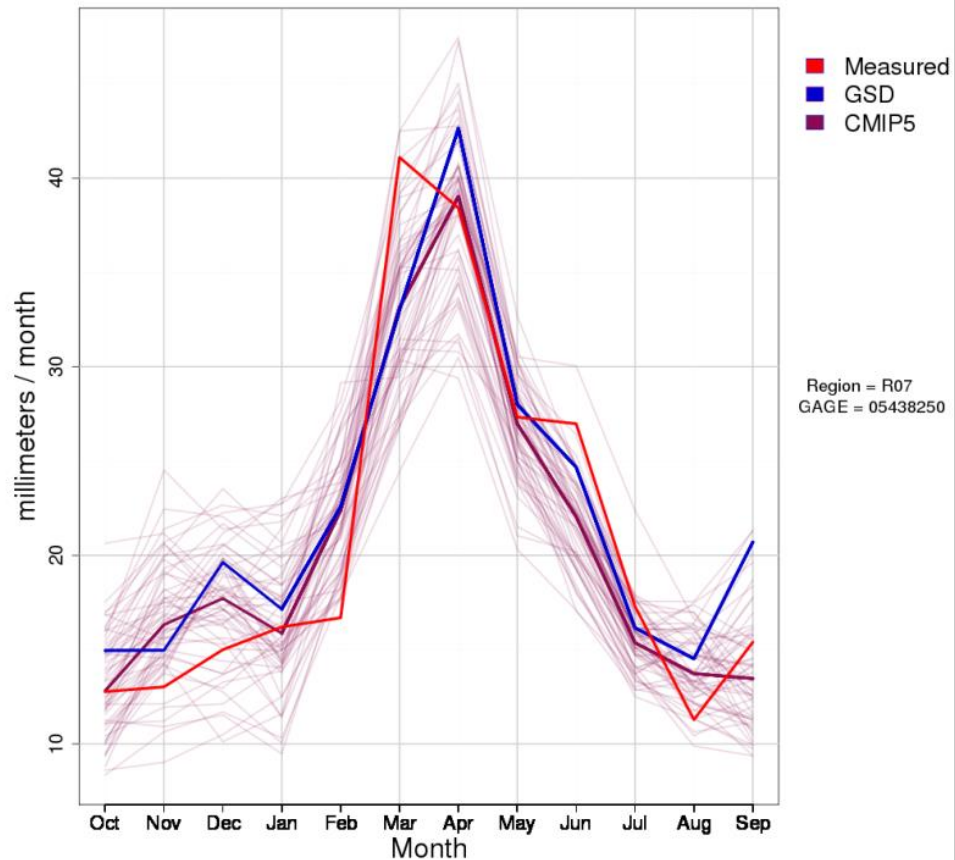
Future conditions: mean seasonal box plots

Evaluate potential changes in summer streamflow and air temperature for RCP8.5

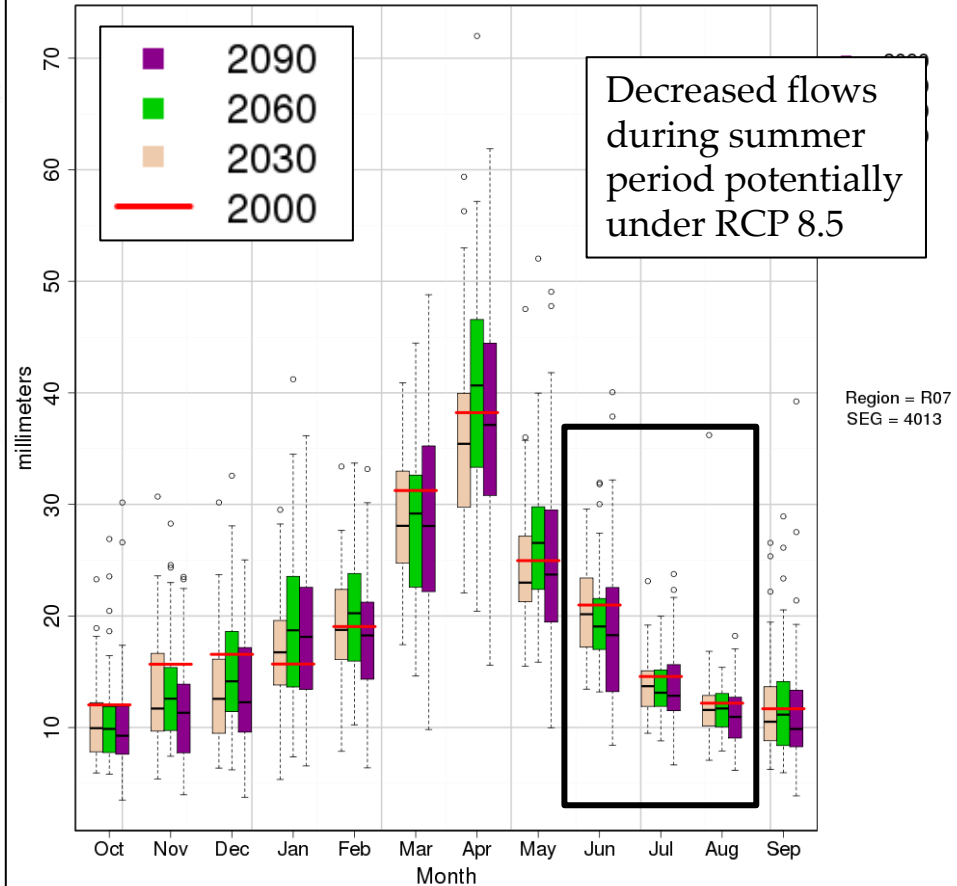


Kishwaukee River

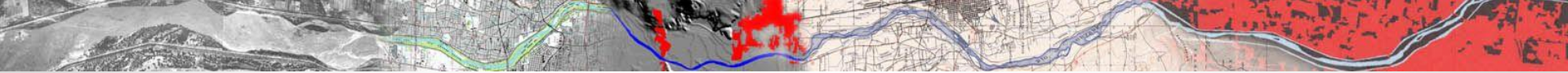
Mean monthly streamflow
based on water years 1961 to 1982



Variability in basin simulated streamflow under RCP 8.5

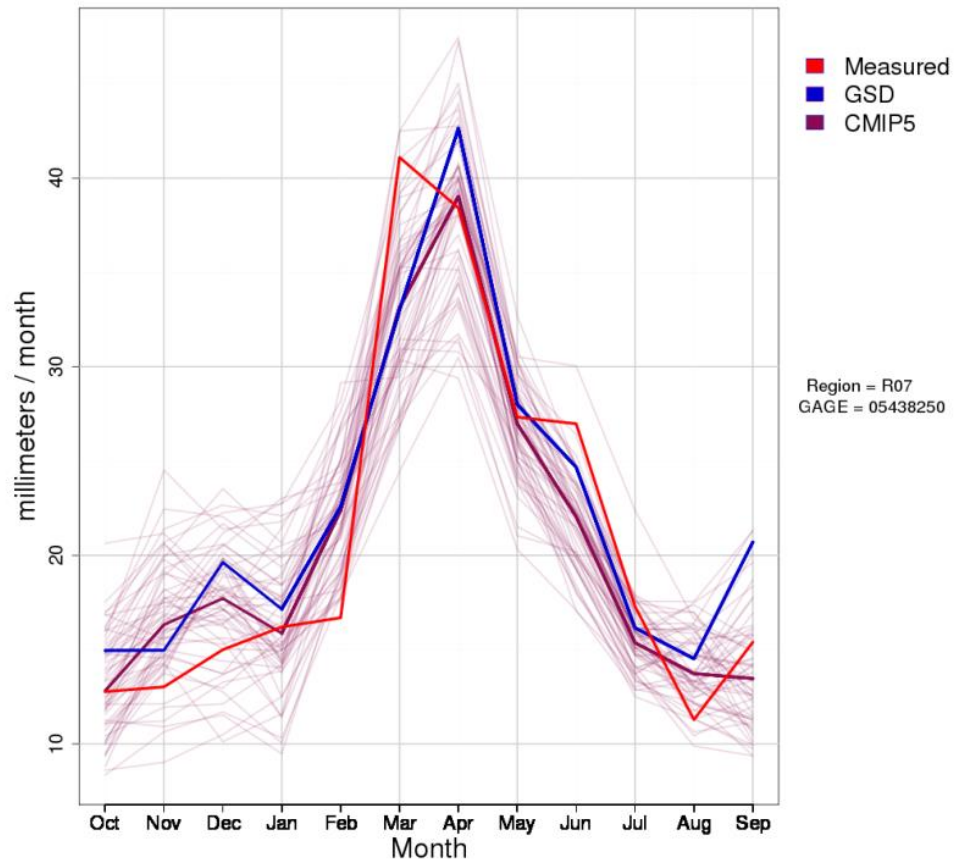


- What is the range of projected summer air temperature for potential future conditions under RCP 8.5?
- What is the range of projected streamflows under RCP 8.5?

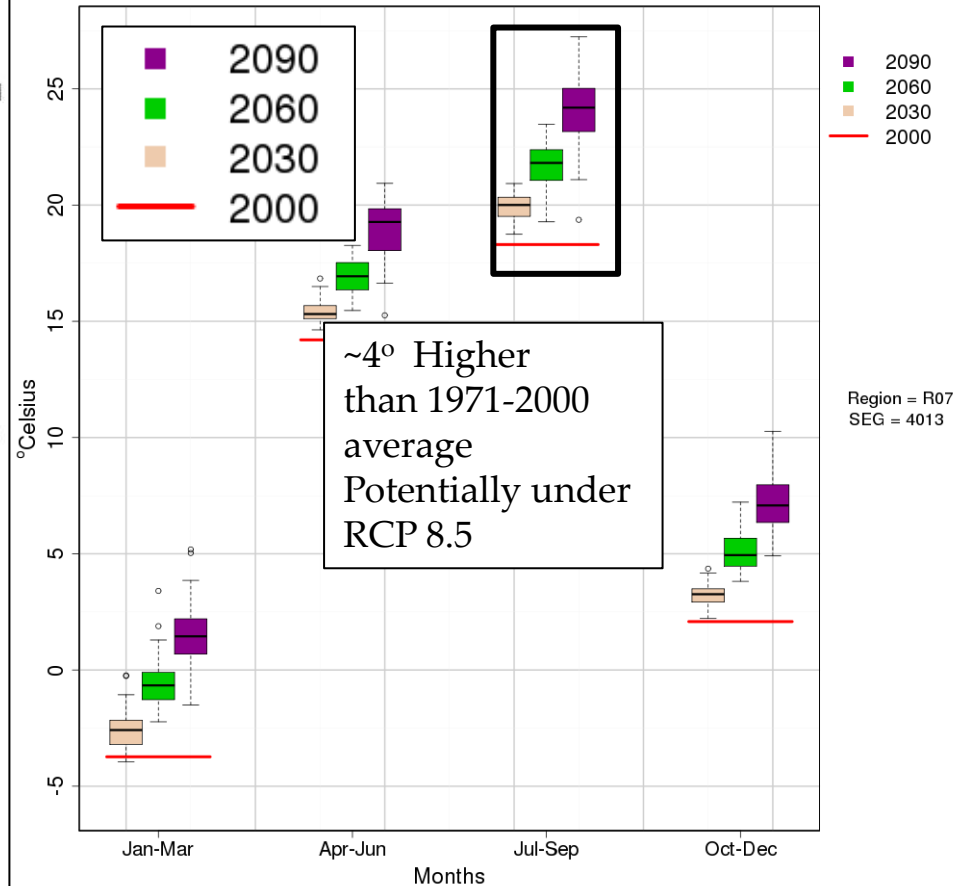


Kishwaukee River

Mean monthly streamflow based on water years 1961 to 1982

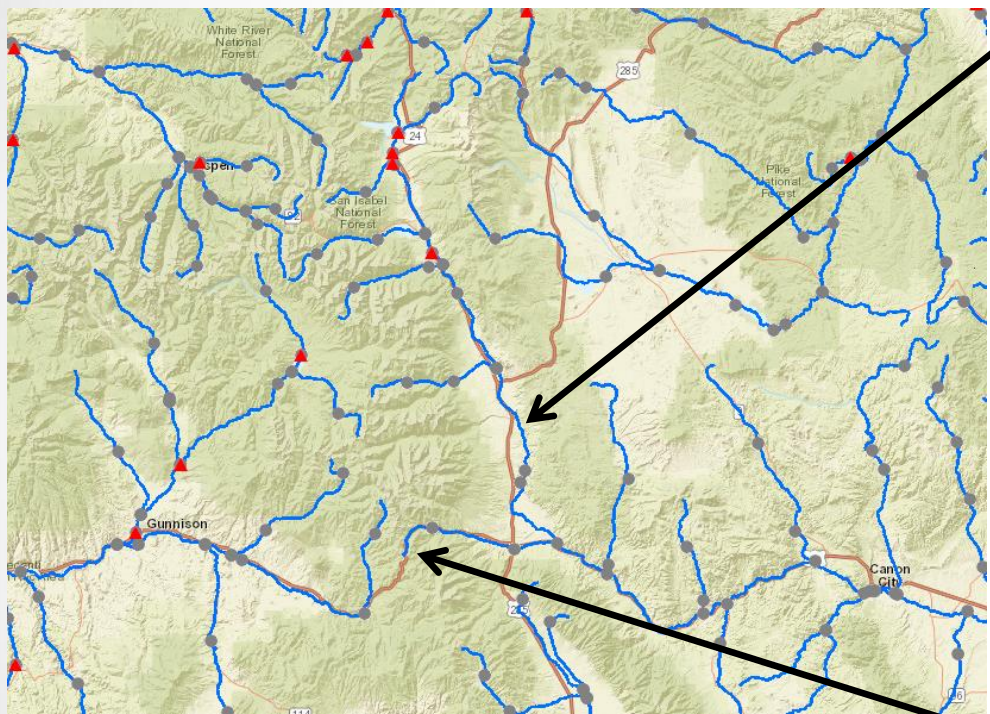


Variability in mean seasonal temperature under RCP 8.5

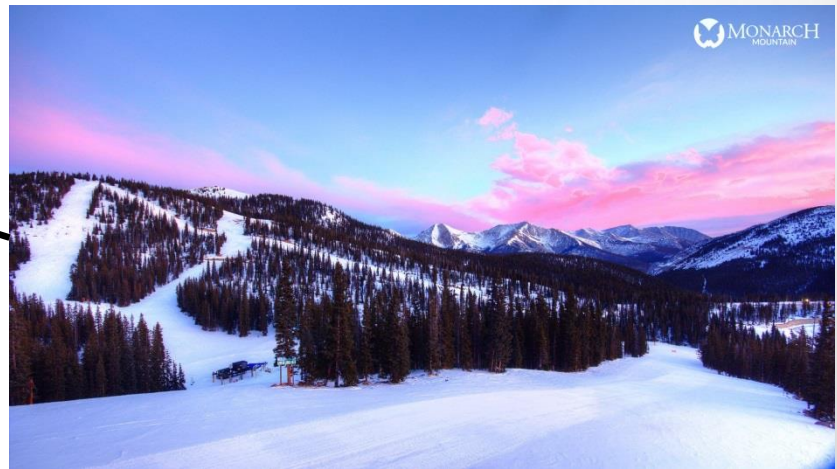


- What is the range of projected summer air temperature for potential future conditions under RCP 8.5?
- What is the range of projected streamflows under RCP 8.5?

Potential Effects on Recreational Resources



*Brown's Canyon
Co. rafting industry
550,861 users in 2016*

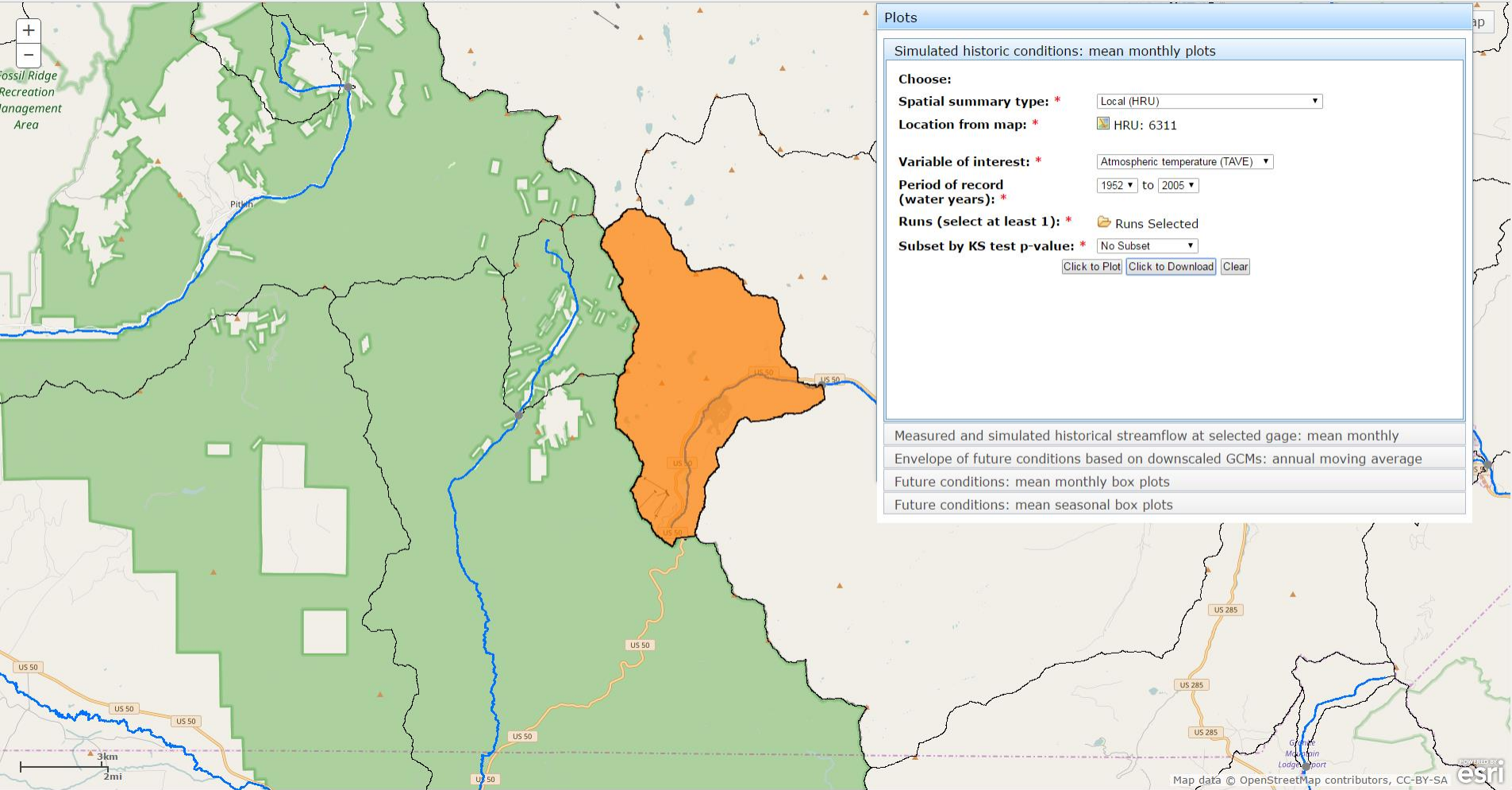


*Monarch Ski Area
Elev. – 10,790 to 11,960 feet
Average Snowfall = 400 in./year (1971-2000)*

Monarch Ski Area (historical conditions, 1952 - 2005)

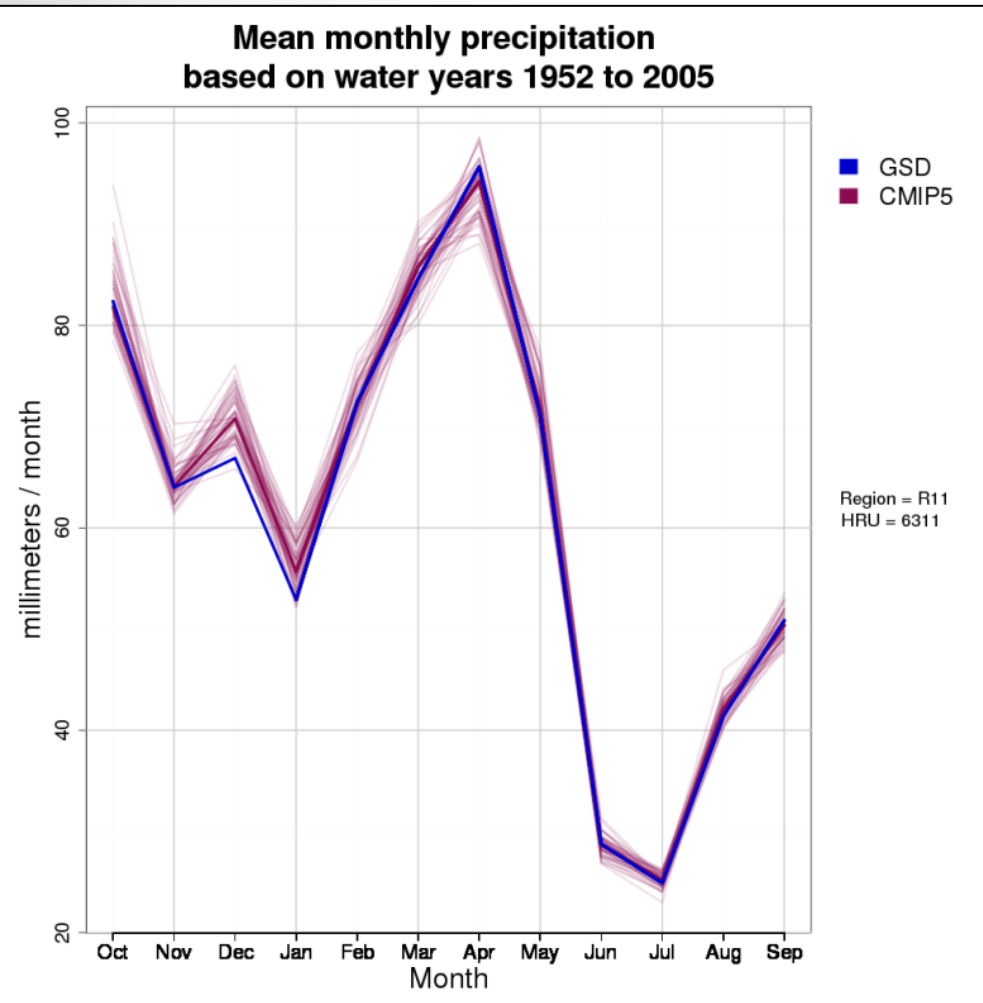
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What's going on for historical conditions?

Monarch Ski Area (historical conditions, 1952 - 2005)



Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Variable of interest: * Atmospheric temperature (TAVE)

Period of record (water years): * 1952 to 2005

Runs (select at least 1): * Runs Selected

Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

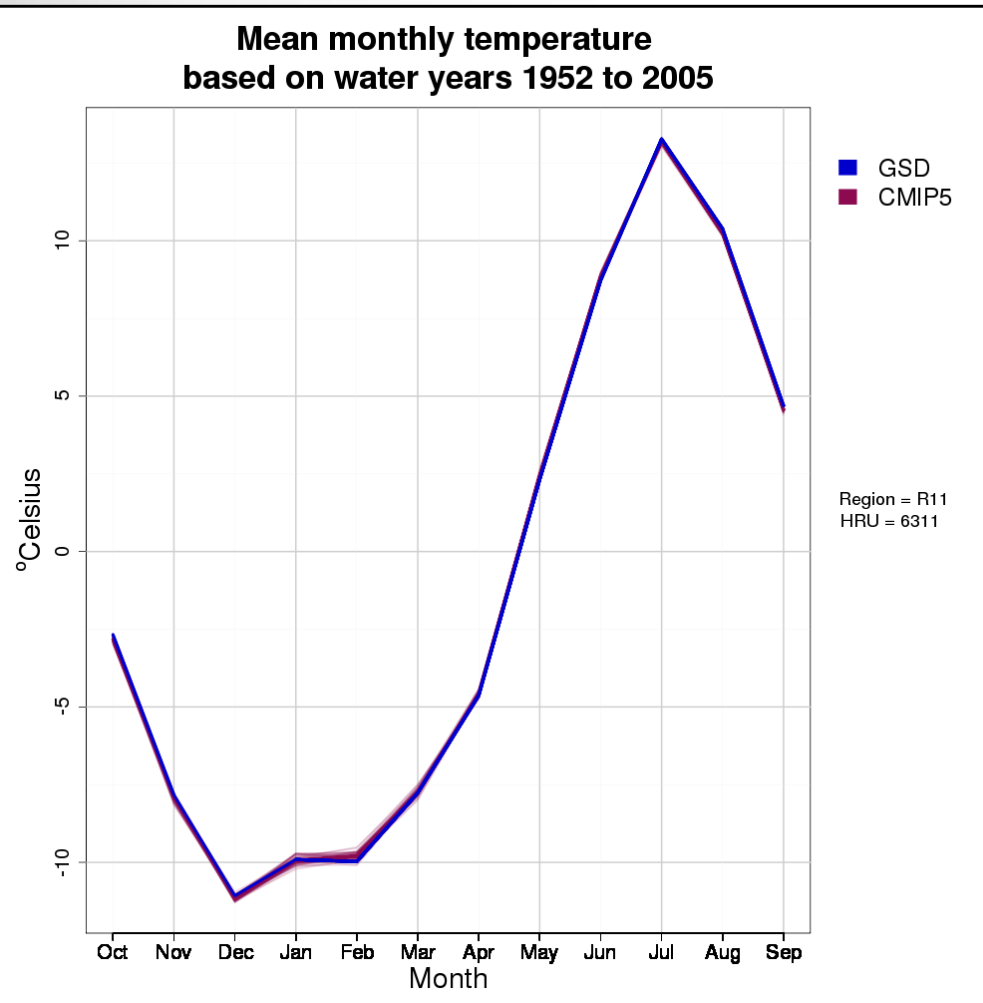
Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Map data © OpenStreetMap contributors, CC-BY-SA esri

What's going on for historical conditions?

Monarch Ski Area (historical conditions, 1952 - 2005)



Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Variable of interest: * Atmospheric temperature (TAVE)

Period of record (water years): * 1952 to 2005

Runs (select at least 1): * Runs Selected

Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

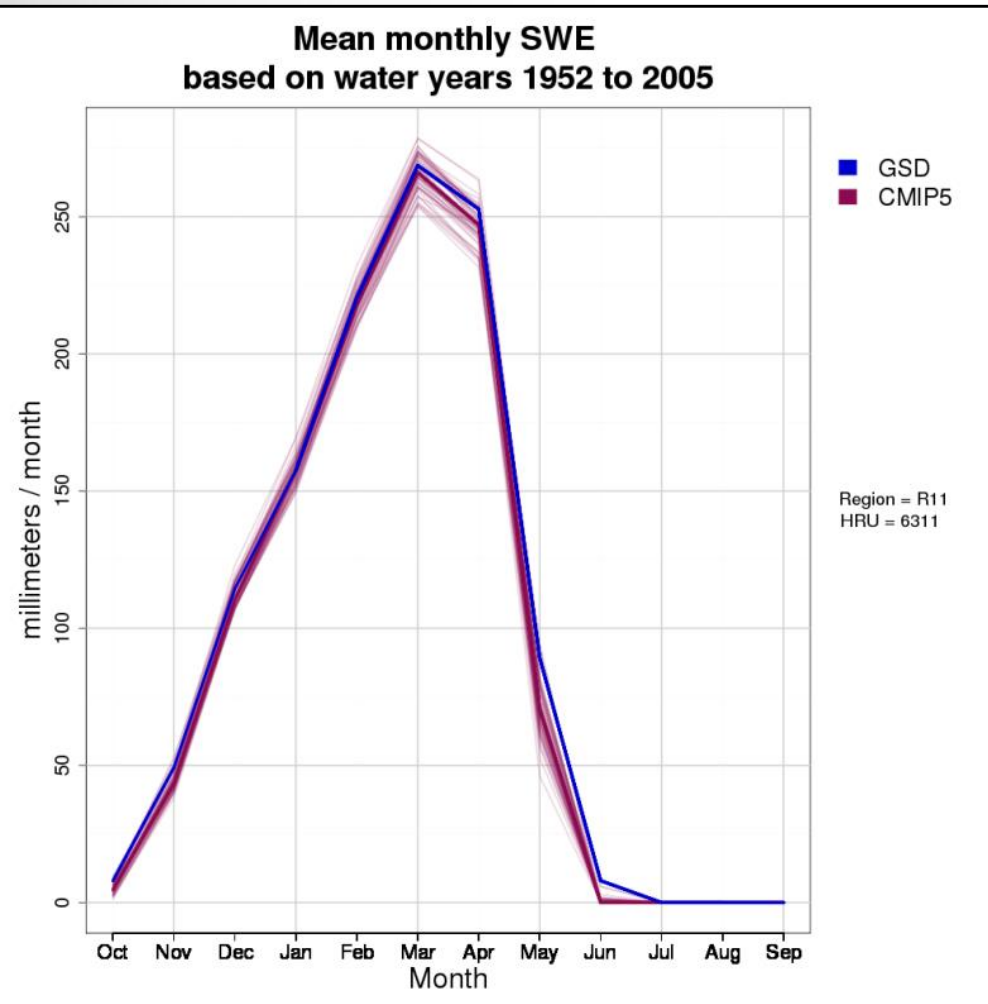
Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Map data © OpenStreetMap contributors, CC-BY-SA esri

What's going on for historical conditions?

Monarch Ski Area (historical conditions, 1952 - 2005)



Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Variable of interest: * Atmospheric temperature (TAVE)

Period of record (water years): * 1952 to 2005

Runs (select at least 1): * Runs Selected

Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

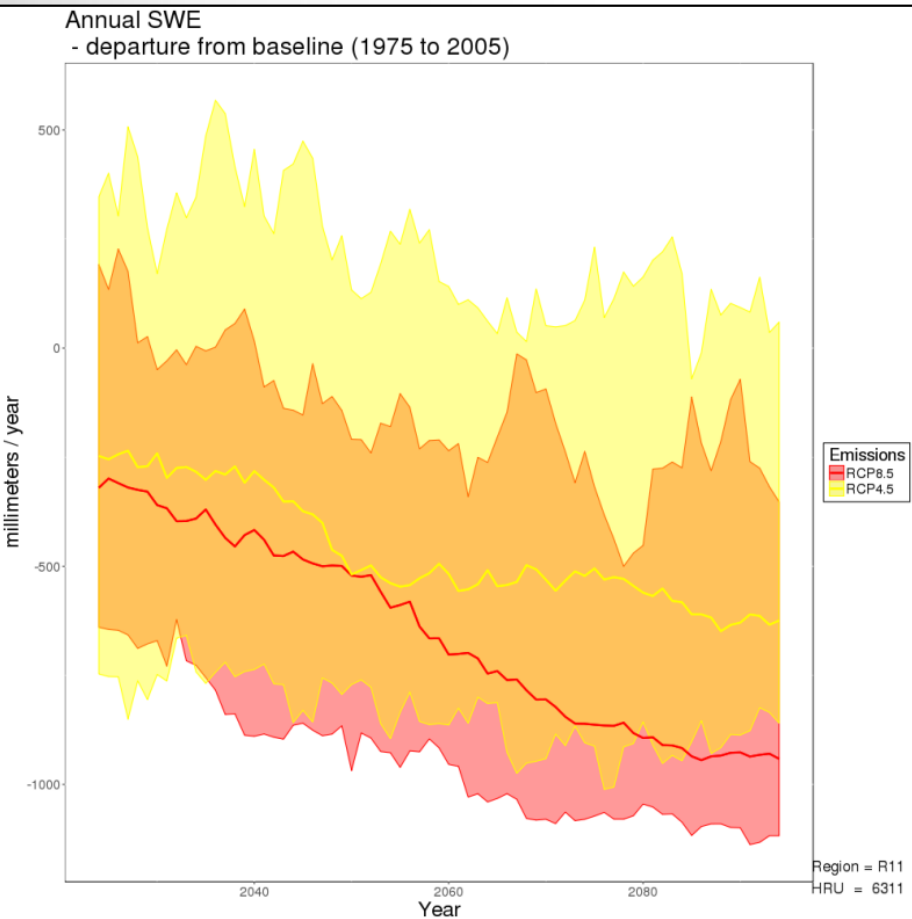
Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Map data © OpenStreetMap contributors, CC-BY-SA esri

What's going on for historical conditions?

Monarch Ski Area (potential future scenarios, 2020 - 2099)



Plots

Simulated historic conditions: mean monthly plots
 Measured and simulated historical streamflow at selected gage: mean monthly
Envelope of future conditions based on downscaled GCMs: annual moving average

Choose:
 Spatial summary type: * Local (HRU)
 Location from map: * HRU: 6311
 Variable of interest: * Precipitation (PPT)
 Baseline * 1975 to 2005
 Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.
 Future conditions (water years) * 2020 to 2099
 Length of running annual mean * 10
 Runs (select at least 5): * Runs Selected
 Subset by KS test p-value: * No Subset

Click to Plot Click to Download Clear

Emissions
 RCP8.5
 RCP4.5

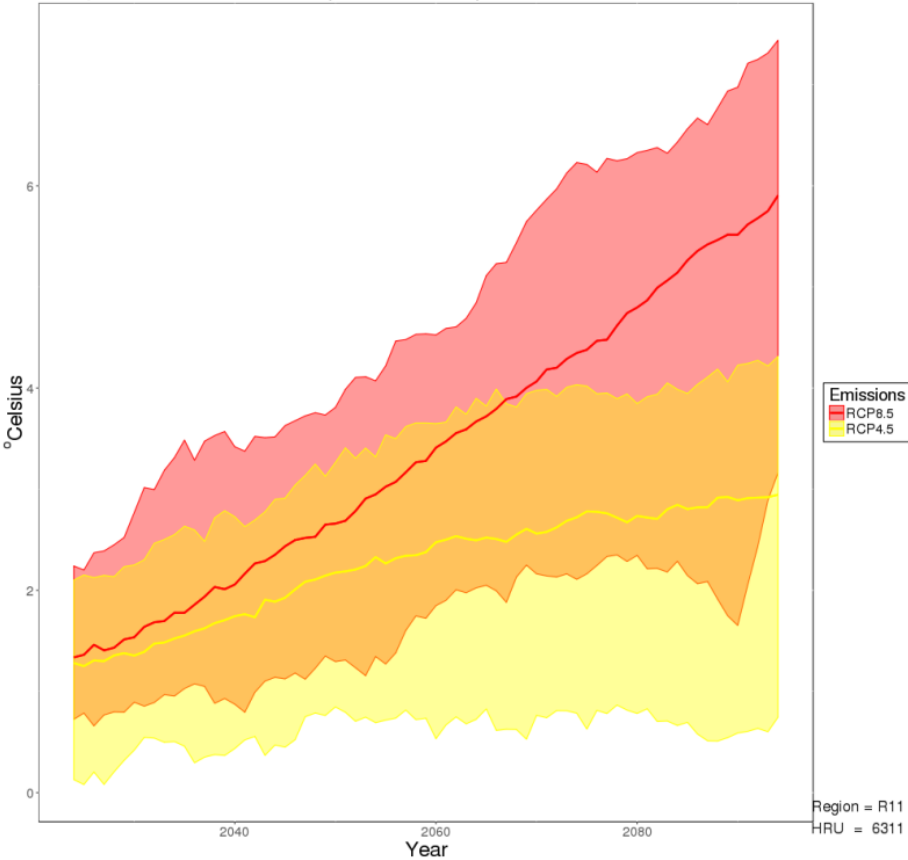
- Variability in PPT
- Increase in TAVE
- Decrease in SWE

Map data © OpenStreetMap contributors, CC-BY-SA esri

What does the data tell us about SWE under modeled potential future climate projections?

Monarch Ski Area (potential future scenarios, 2020 - 2099)

Annual temperature
- departure from baseline (1975 to 2005)



Plots

- Simulated historic conditions: mean monthly plots
- Measured and simulated historical streamflow at selected gage: mean monthly
- Envelope of future conditions based on downscaled GCMs: annual moving average**

Choose:

Spatial summary type: * Local (HRU)

Location from map: * HRU: 6311

Variable of interest: * Precipitation (PPT)

Baseline * 1975 to 2005

Note: a minimum 10-year baseline is required and a minimum 30-year baseline is recommended.

Future conditions (water years) * 2020 to 2099

Length of running annual mean * 10

Runs (select at least 5): * Runs Selected

Subset by KS test p-value: * No Subset

Emissions

- RCP8.5
- RCP4.5

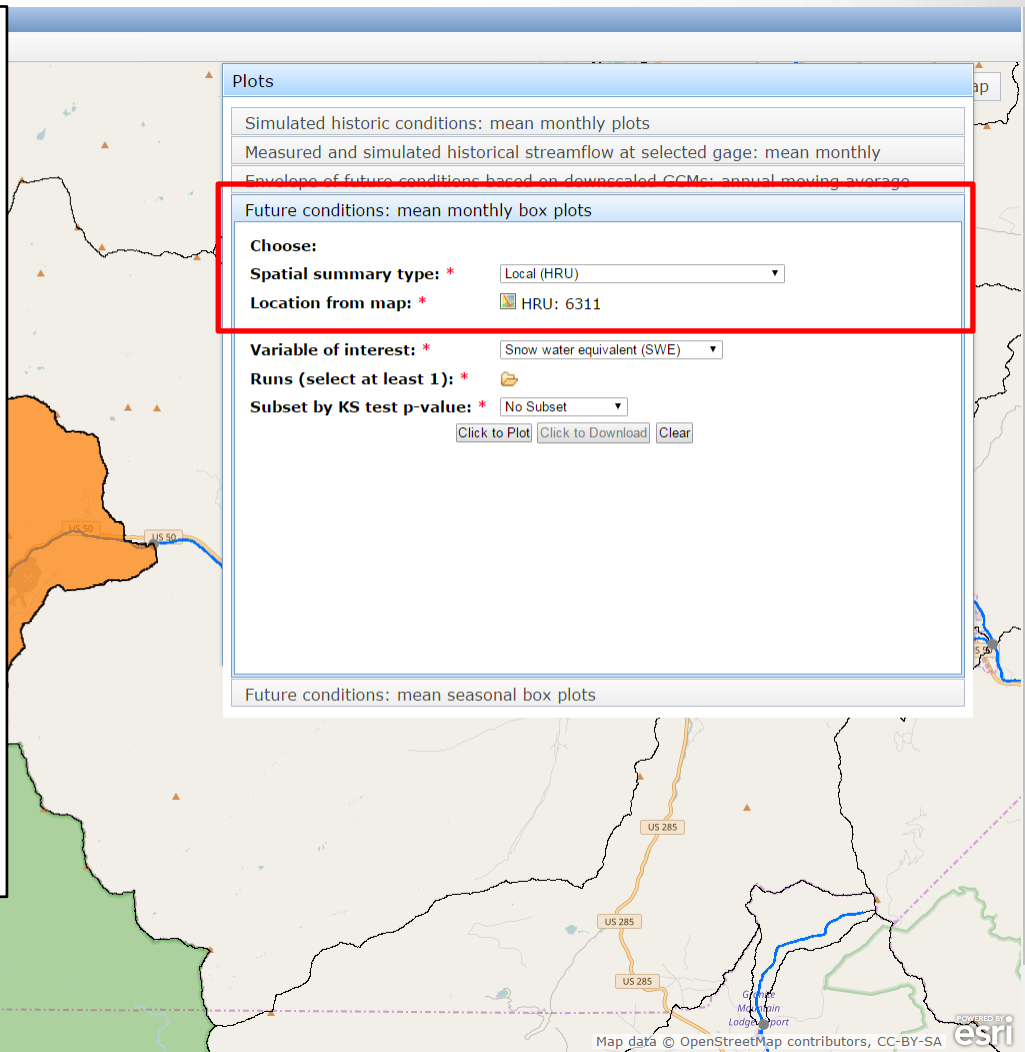
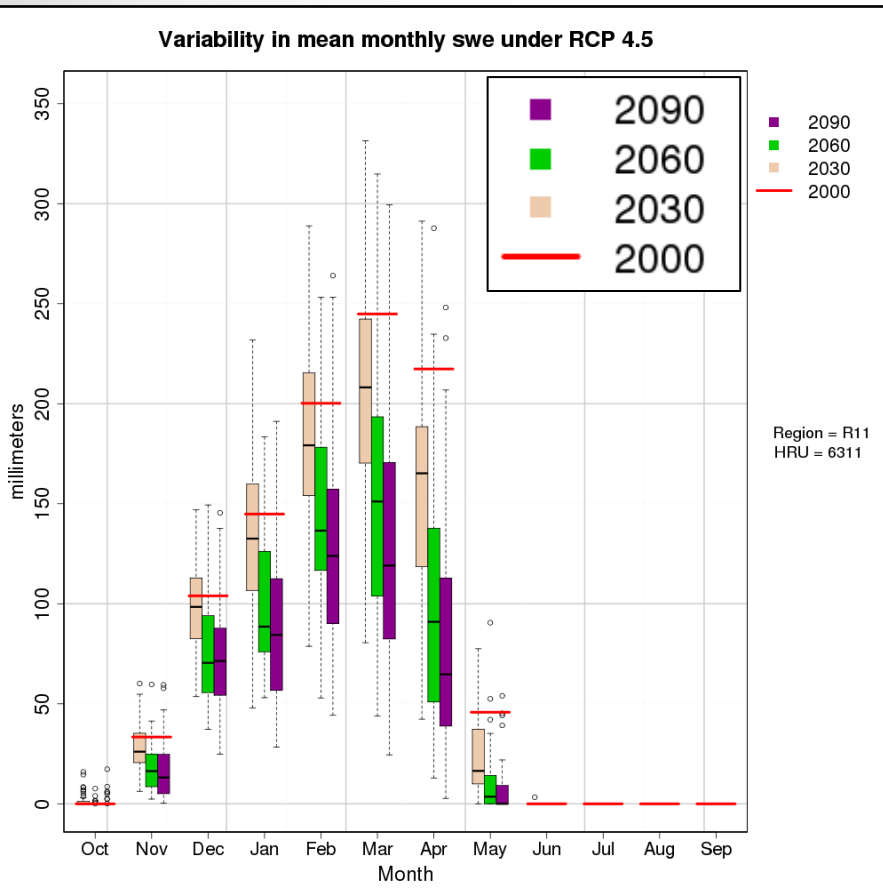
- mean monthly box plots
- mean seasonal box plots

- Variability in PPT
- Increase in TAVE
- Decrease in SWE

Map data © OpenStreetMap contributors, CC-BY-SA esri

What does the data tell us about SWE under modeled potential future climate projections?

Monarch Ski Area (potential future scenarios, 2030/60/90)



What does potential SWE look like for ski season?

Brown's Canyon (historical conditions, 1952 - 2005)

Monthly Water Balance Model Futures Portal

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Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Accumulated (summary node or streamgage) ▾

Location from map: * Arkansas River (698)

Variable of interest: * Accumulated streamflow (STRM) ▾

Period of record (water years): * 1952 ▾ to 2005 ▾

Runs (select at least 1): * Runs Selected

Subset by KS test p-value: * No Subset ▾

Measured and simulated historical streamflow at selected gage: mean monthly

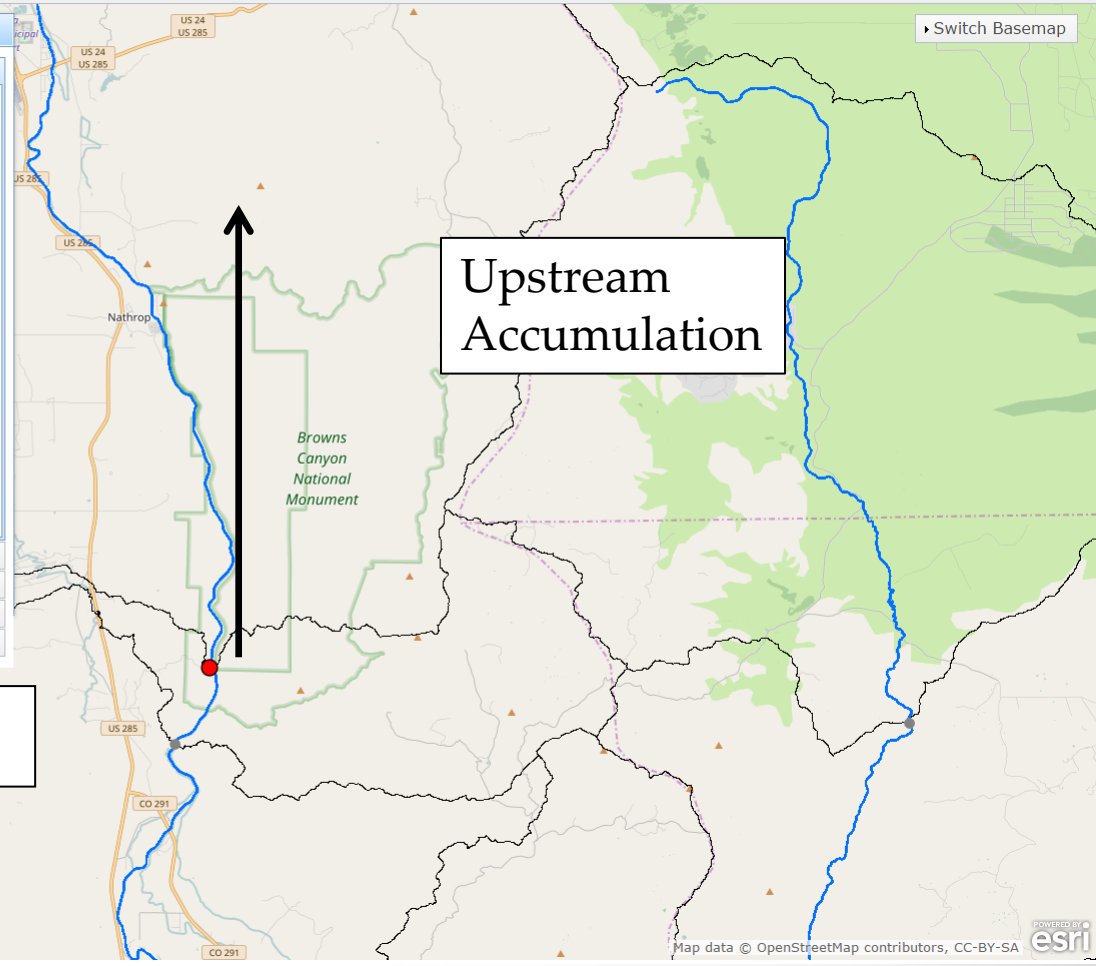
Envelope of future conditions based on downscaled GCMs: annual moving average

Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

Spatial summary type: * Accumulated (summary node or streamgage) ▾

Location from map: * Arkansas River (698)



Brown's Canyon (historical conditions, 1952 - 2005)

Monthly Water Balance Model Futures Portal

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Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: *

Location from map: *

Variable of interest: *

Period of record (water years): * to

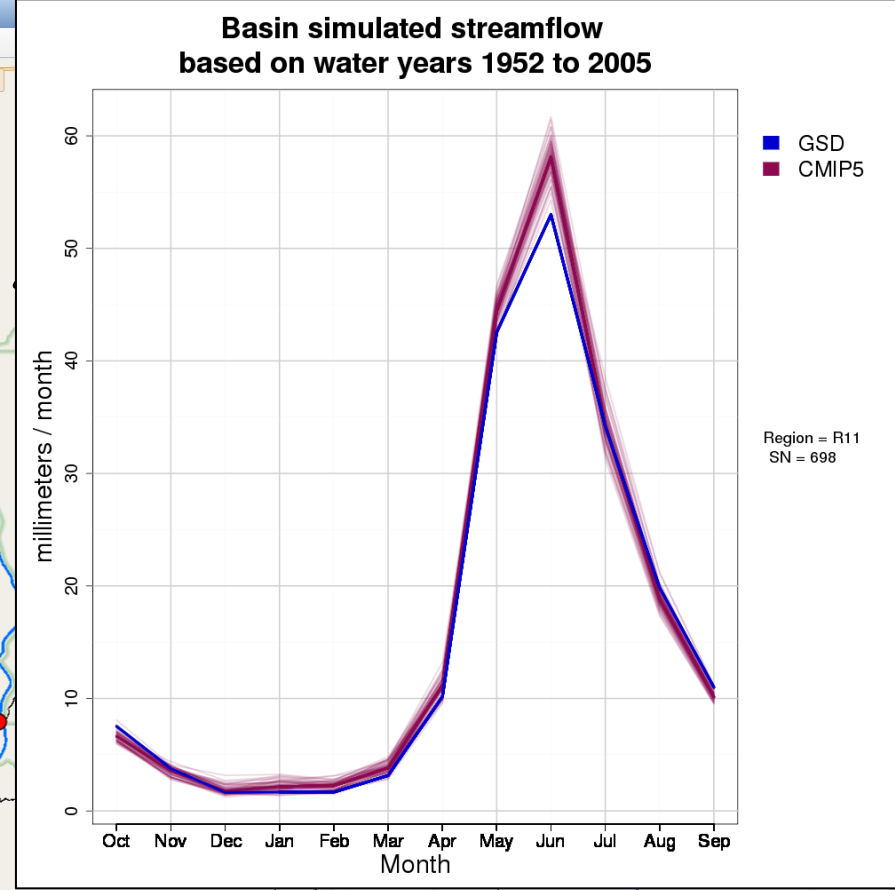
Runs (select at least 1): *

Subset by KS test p-value: *

- Measured and simulated historical streamflow at selected gage: mean monthly
- Envelope of future conditions based on downscaled GCMs: annual moving average
- Future conditions: mean monthly box plots
- Future conditions: mean seasonal box plots

Spatial summary type: *

Location from map: *



Brown's Canyon (potential future scenarios, 2030/60/90)

Monthly Water Balance Model Futures Portal

Full Extent Prev Extent Next Extent Measure Legend Plots FAQ

Plots

Simulated historic conditions: mean monthly plots

Choose:

Spatial summary type: * Accumulated (summary node or streamgage) ▼

Location from map: * Arkansas River (698)

Variable of interest: * Accumulated streamflow (STRM) ▼

Period of record (water years): * 1952 ▼ to 2005 ▼

Runs (select at least 1): * Runs Selected

Subset by KS test p-value: * No Subset ▼

Click to Plot Click to Download Clear

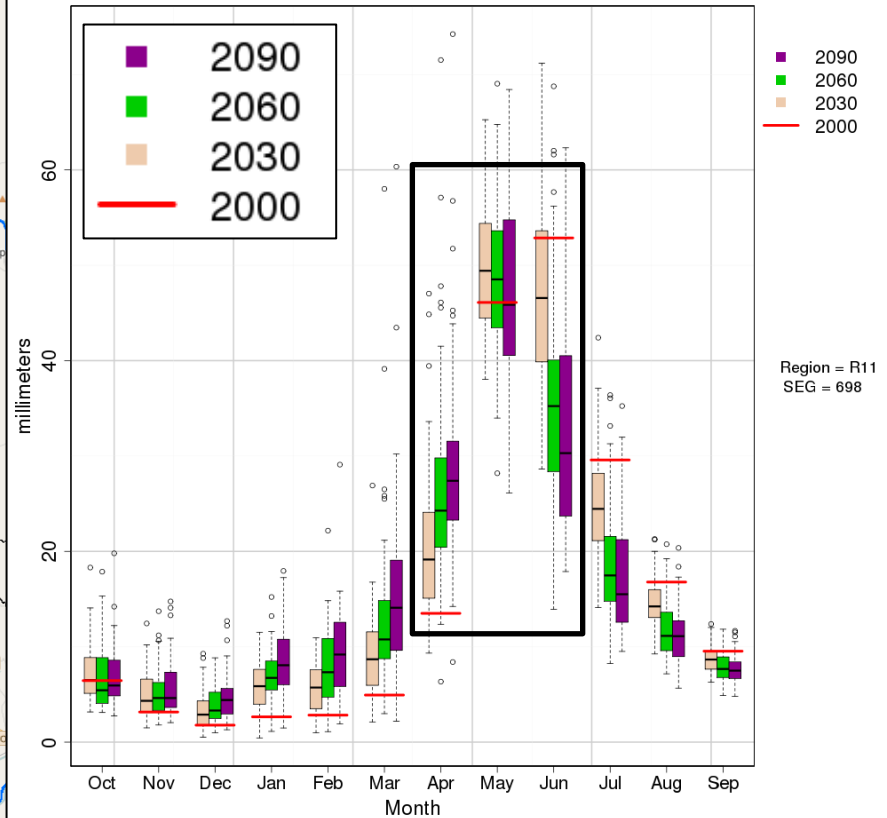
Measured and simulated historical streamflow at selected gage: mean monthly

Envelope of future conditions based on downscaled GCMs: annual moving average

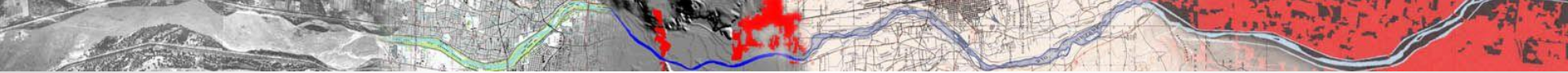
Future conditions: mean monthly box plots

Future conditions: mean seasonal box plots

Variability in basin simulated streamflow under RCP 4.5



Under the most mild CMIP5 scenario (RCP 4.5), potential period of peak flows is earlier in the season



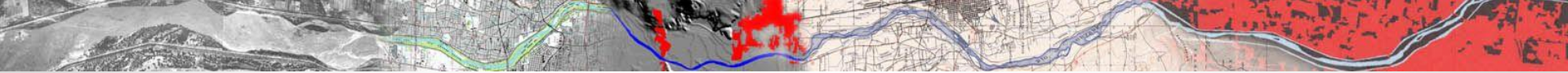
References

Bureau of Reclamation, 2011, West-wide climate risk assessments—Bias-corrected and spatially downscaled surface water projections: Technical Memorandum No. 86-68210-2011-01, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colo., 138 p.

Bureau of Reclamation, 2013, Downscaled CMIP3 and CMIP5 climate and hydrology projections—Release of hydrology projections—Release of downscaled CMIP5 climate projects, comparison with preceding information, and summary of user needs: prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colo., 110 p.

Conover, W.J., 1971, Practical nonparametric statistics: New York, John Wiley and Sons, 462 p.

Hay, L.E., LaFontaine, Jacob, and Markstrom, S.L., 2014, Evaluation of statistically downscaled GCM output as input for hydrological and stream temperature simulation in the Apalachicola–Chattahoochee–Flint River Basin (1961–99): *Earth Interactions*, v. 18, p. 1–32.



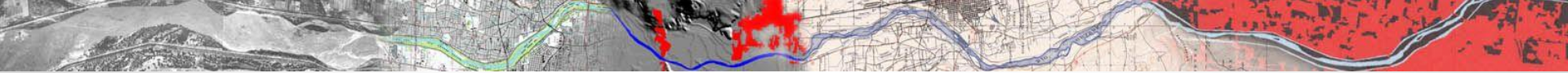
References (cont.)

Hayhoe, K., Wake, C.P., Anderson, B., Liang, X-Z, Maurer, E., Zhu, J., Bradbury, J., DeGaetano, A., Stoner, A.M., Wuebbels, D., 2008, Regional climate change projections for the Northeast USA. *Mitigation and Adaption Strategies for Global Change* 13: 425–436.

Markstrom, S.L., Regan, R.S., Hay, L.E., Viger, R.J., Webb, R.M.T., Payn, R.A., and LaFontaine, J.H., 2015, PRMS-IV the precipitation-runoff modeling system, version 4: U.S. Geological Survey Techniques and Methods, book 6, chap. B7, 158 p., <http://dx.doi.org/10.3133/tm6B7>.

Maurer, E.P., and others , 2002, A Long-Term Hydrologically-Based Data Set of Land Surface Fluxes and States for the Conterminous United States, *Journal of Climatology* 15.

McCabe, G.J., and S.L. Markstrom, 2007, A monthly water-balance model driven by a graphical user interface: U.S. Geological Survey Open File Report 2007-1088, 6 p.



References (cont.)

National Operational Hydrologic and Remote Sensing Center, 2004, Snow Data Assimilation System (SNODAS) data products at NSIDC, version 1: Boulder, Colo., National Snow and Ice Data Center, accessed October 23, 2014 at <https://doi.org/10.7265/N5TB14TC>

Pederson, G.T., Gray, S.T., Fagre, D.B., and Graumlich, L.J., 2006, Long-Duration Drought Variability and Impacts on Ecosystem Services: A Case Study from Glacier National Park, Montana, *Earth Interactions*, Vol. 10, <http://dx.doi.org/10.1175/EI153.1>.