The Monthly Water Balance Model Futures Project and Portal

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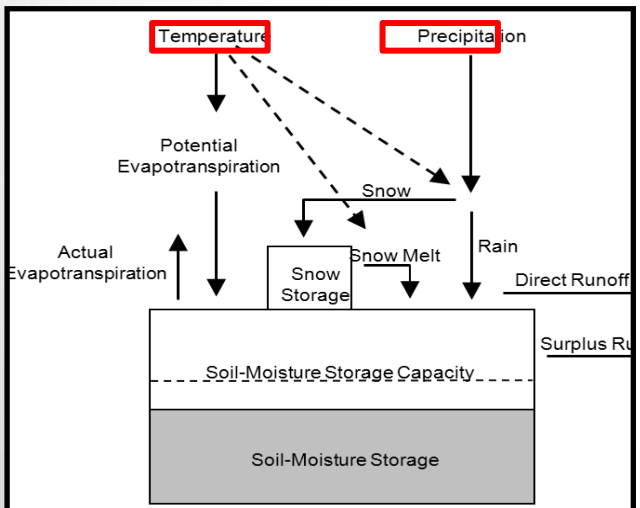
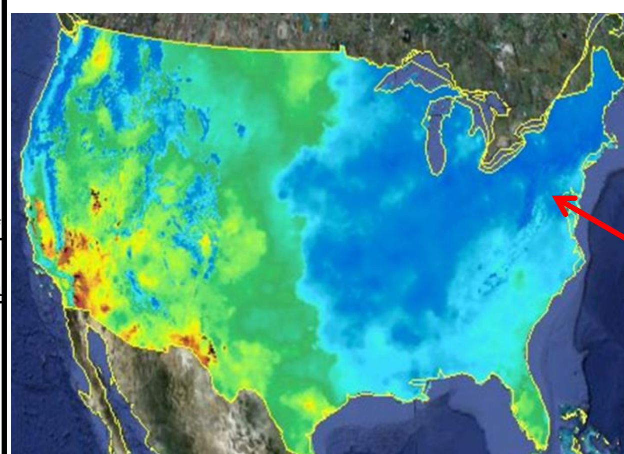
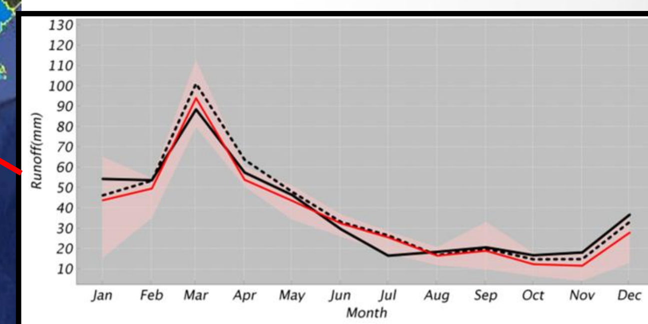
USGS science for a changing world
EPA
North Central Climate Science Center University Consortium
South Central Climate Science Center
Powell Center

National Hydrologic Model (cont.)

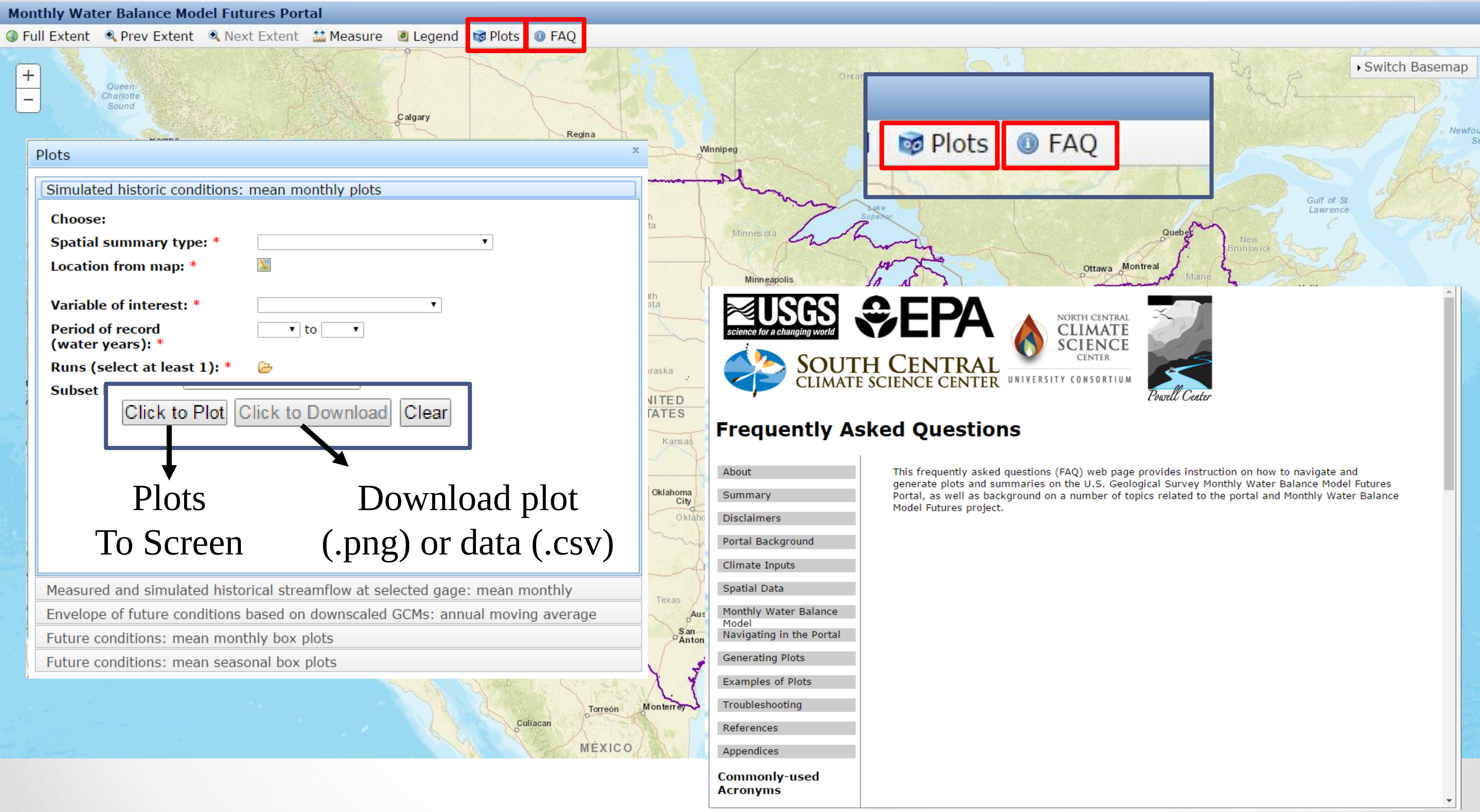
- Simulation of hydrologic processes across the country
  - Incorporates multiple models
    - Monthly time-step rainfall-runoff, daily time-step deterministic watershed hydrology, coupled groundwater-surface water, energy-flux based stream temperature
  - Assimilate best available national-extent data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





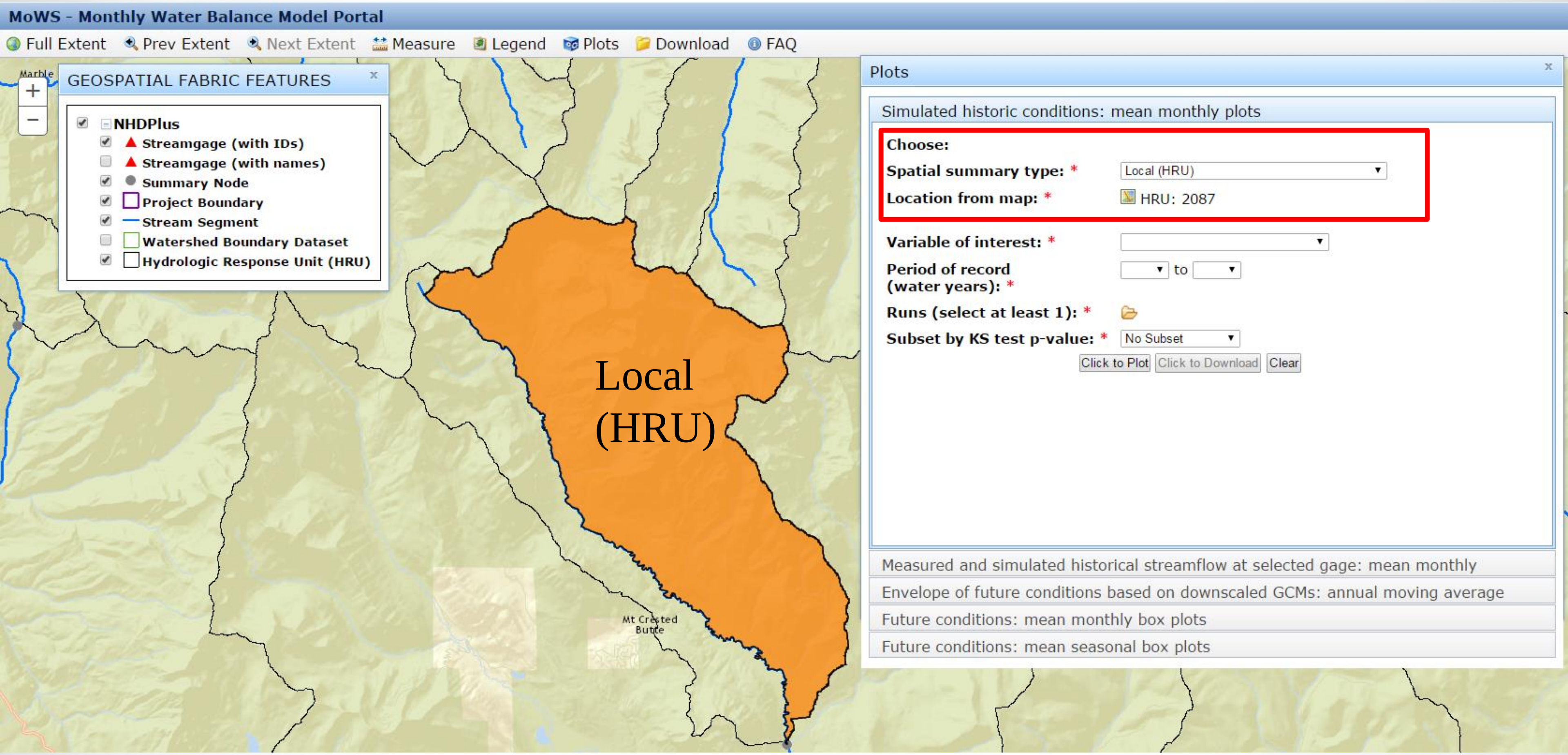


Monthly Water Balance Model Futures Portal



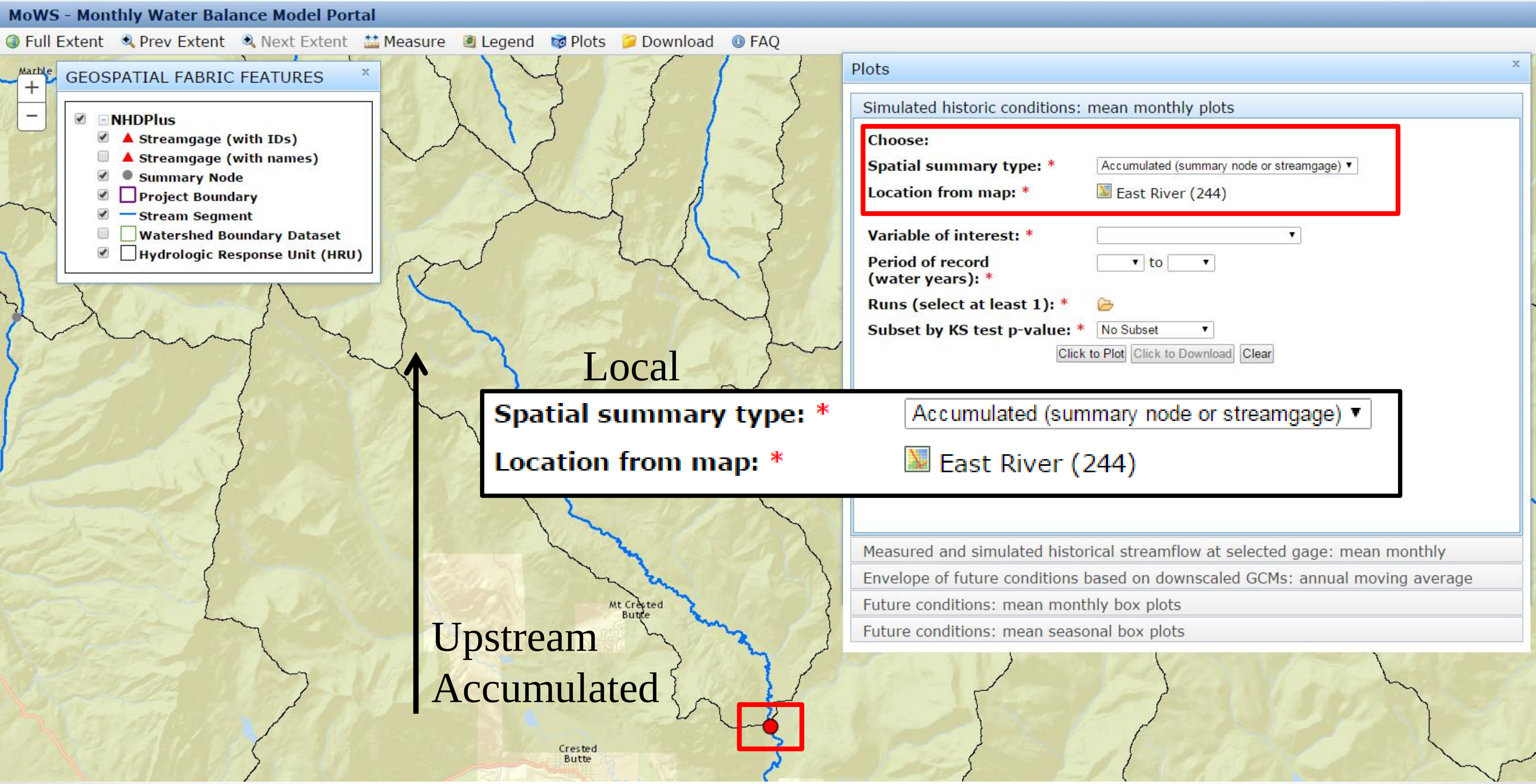
https://my.usgs.gov/mows/

Spatial Summary Type



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

Spatial Summary Type



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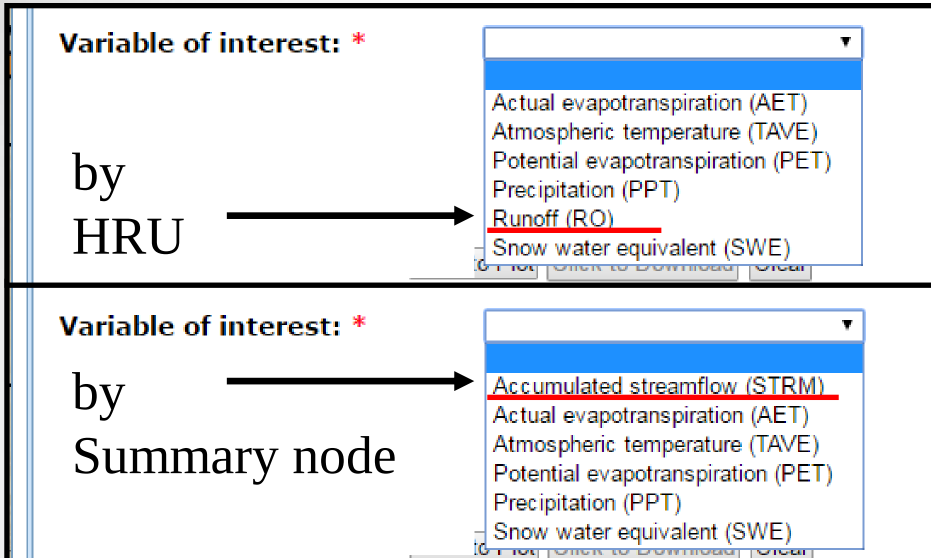
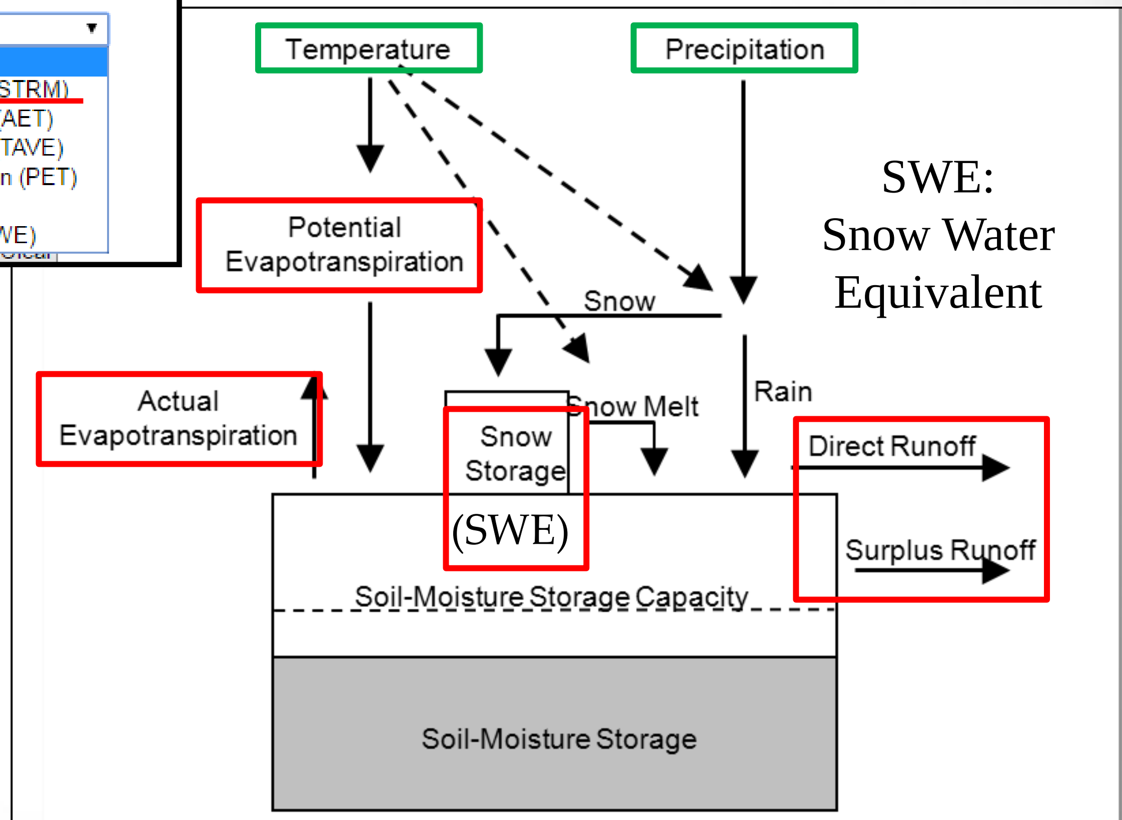
Variable of Interest

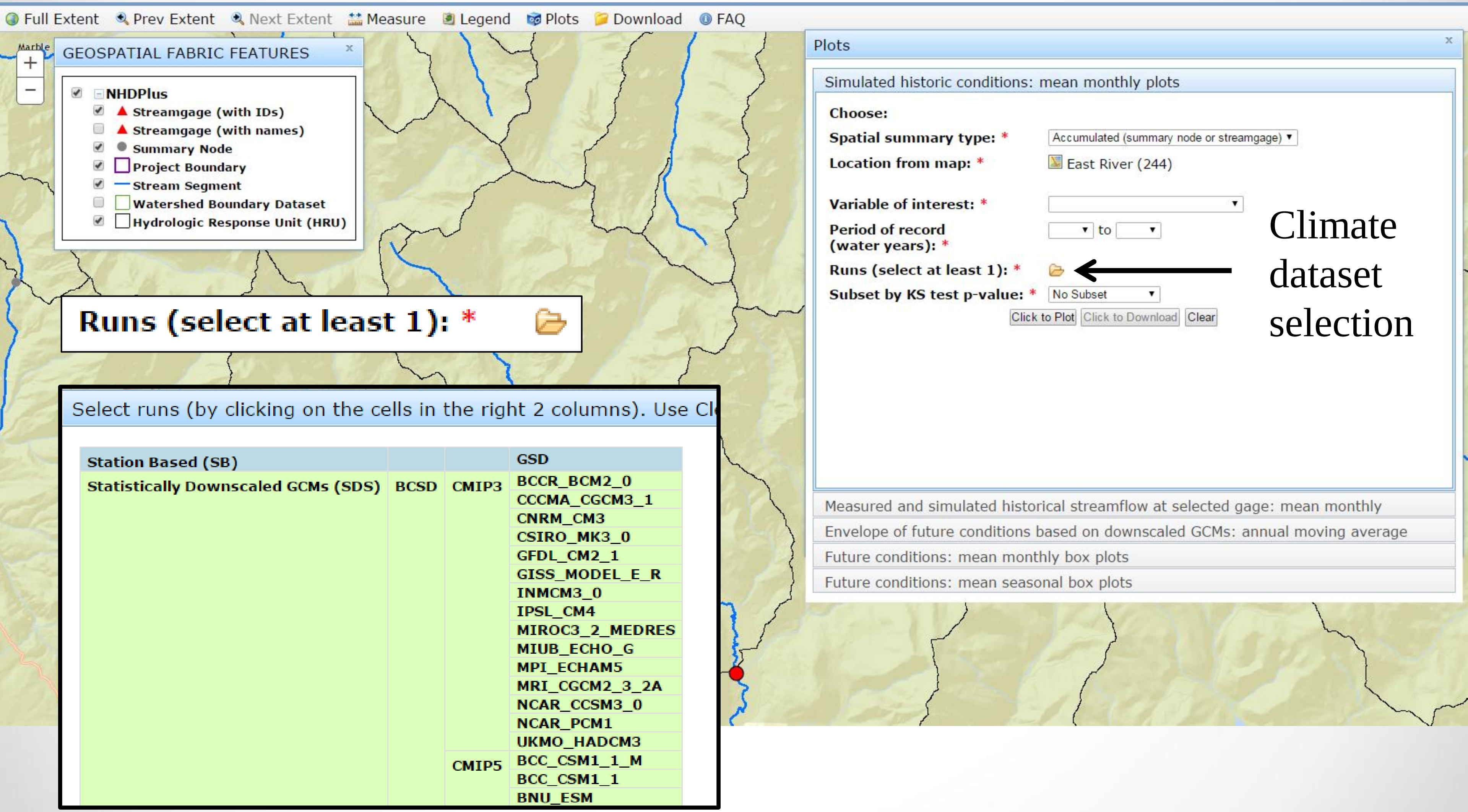


- Temperature = degrees Celsius (°C)
- All other variables = millimeters (depth per unit area)

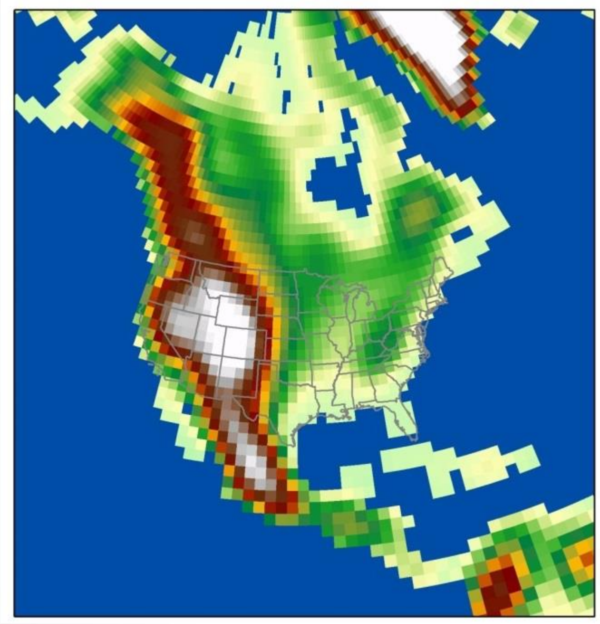


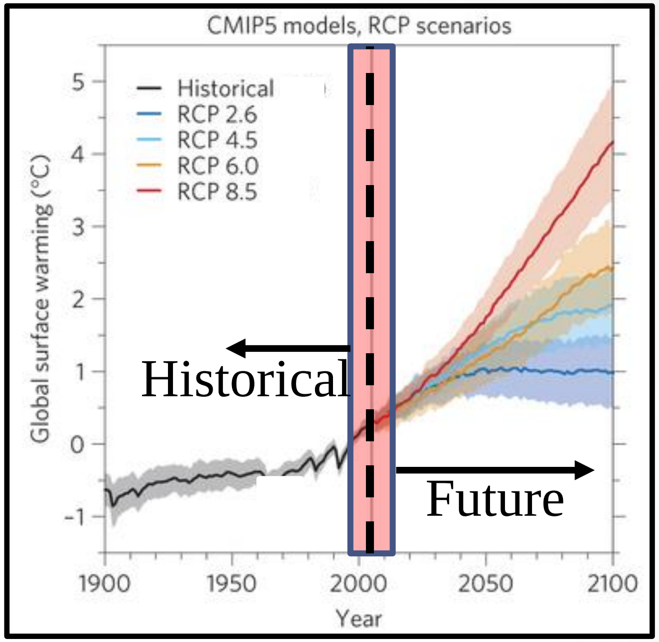
- Simulated runoff (RO) summarized locally for hydrologic response units; simulated streamflow (STRM) along the stream network at summary nodes

Runs (Climate Dataset Selection)



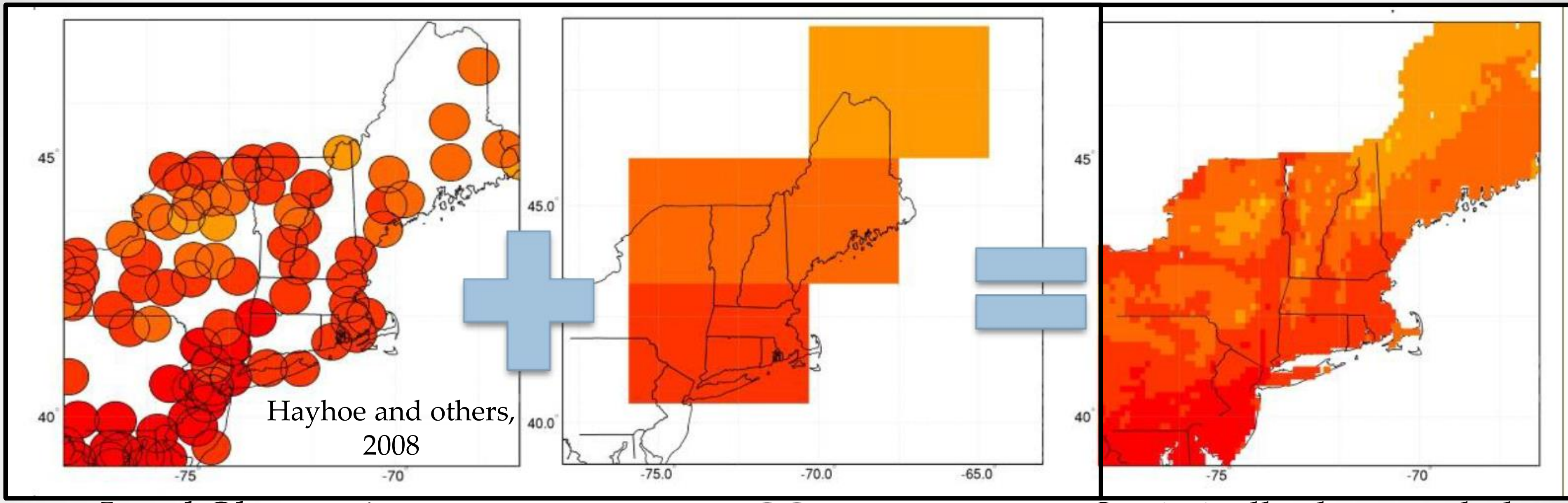
Downscaled General Circulation Models (GCMs)





- 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	

[1]Maurer and others, 2002,
[2]Bureau of Reclamation, 2011, [3]Bureau of Reclamation, 2013

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

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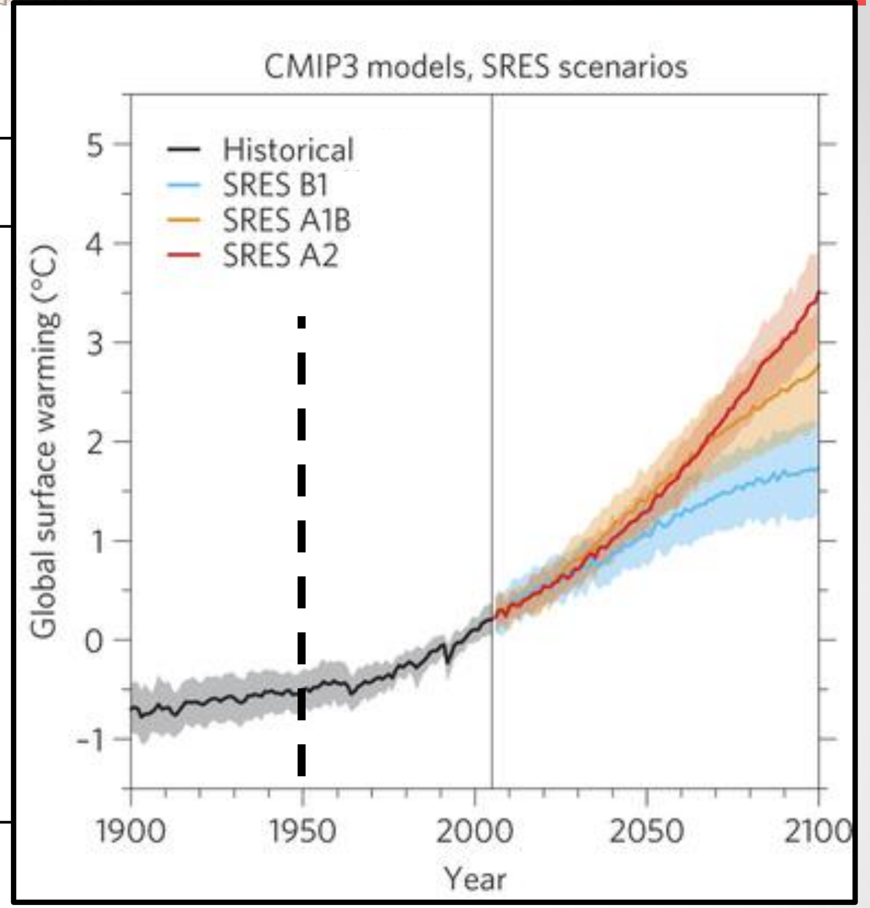

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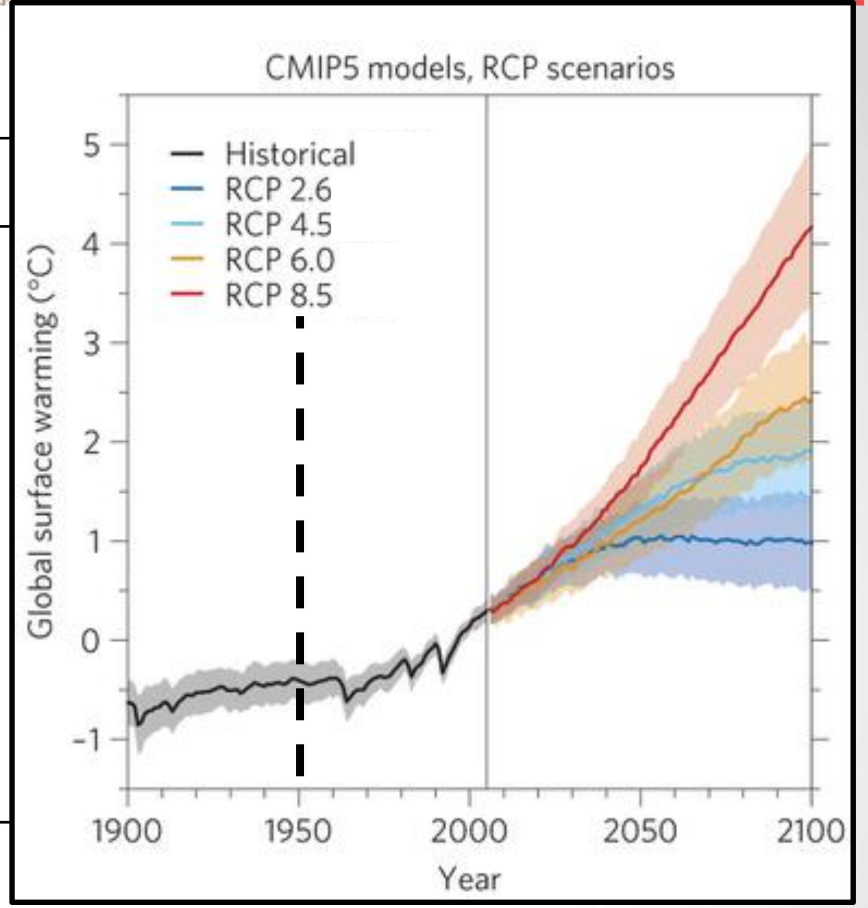

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- Bias-corrected spatially disaggregated (BCSD) general circulation models (GCM)
- Includes ancillary data and other model components

Runs (Climate Dataset Selection) (cont.)

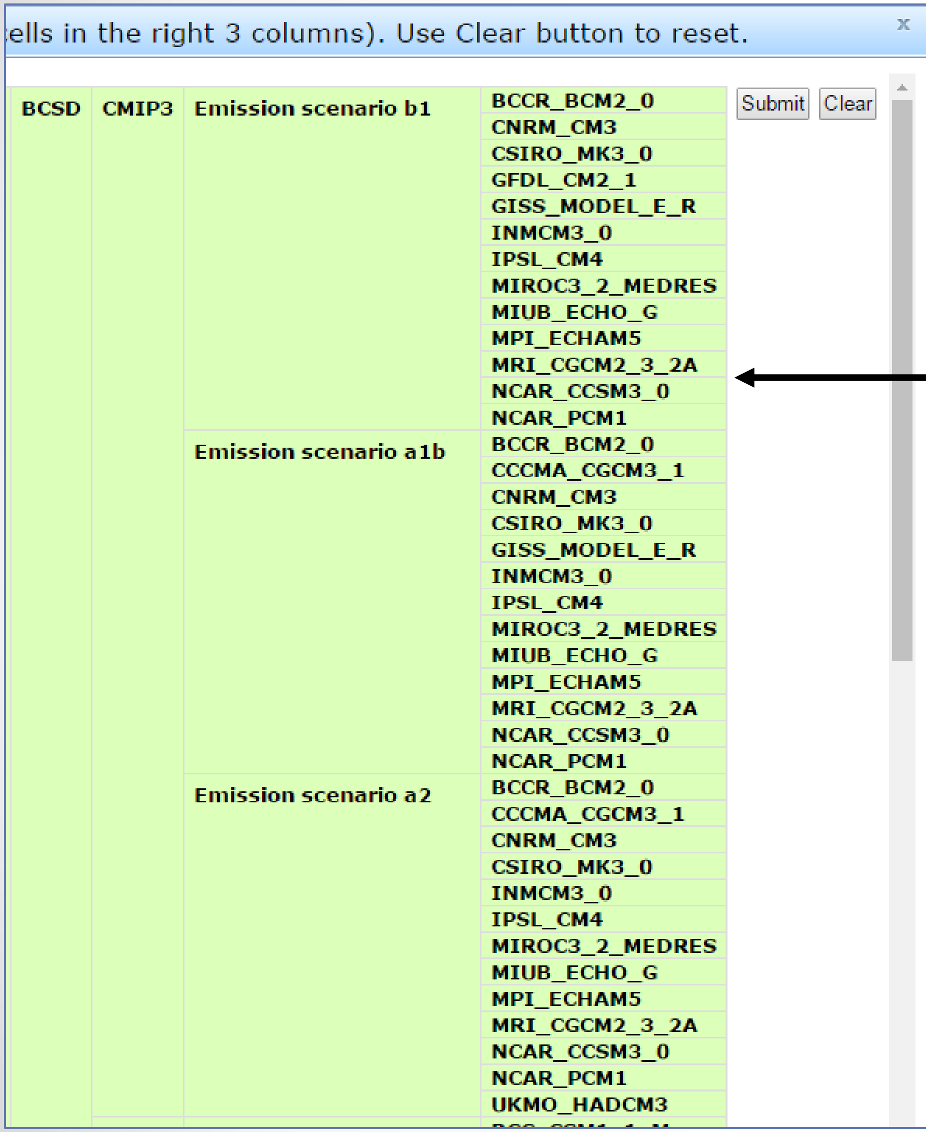
Select runs (by clicking on the cells in the right 2 columns). Use Cl

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)

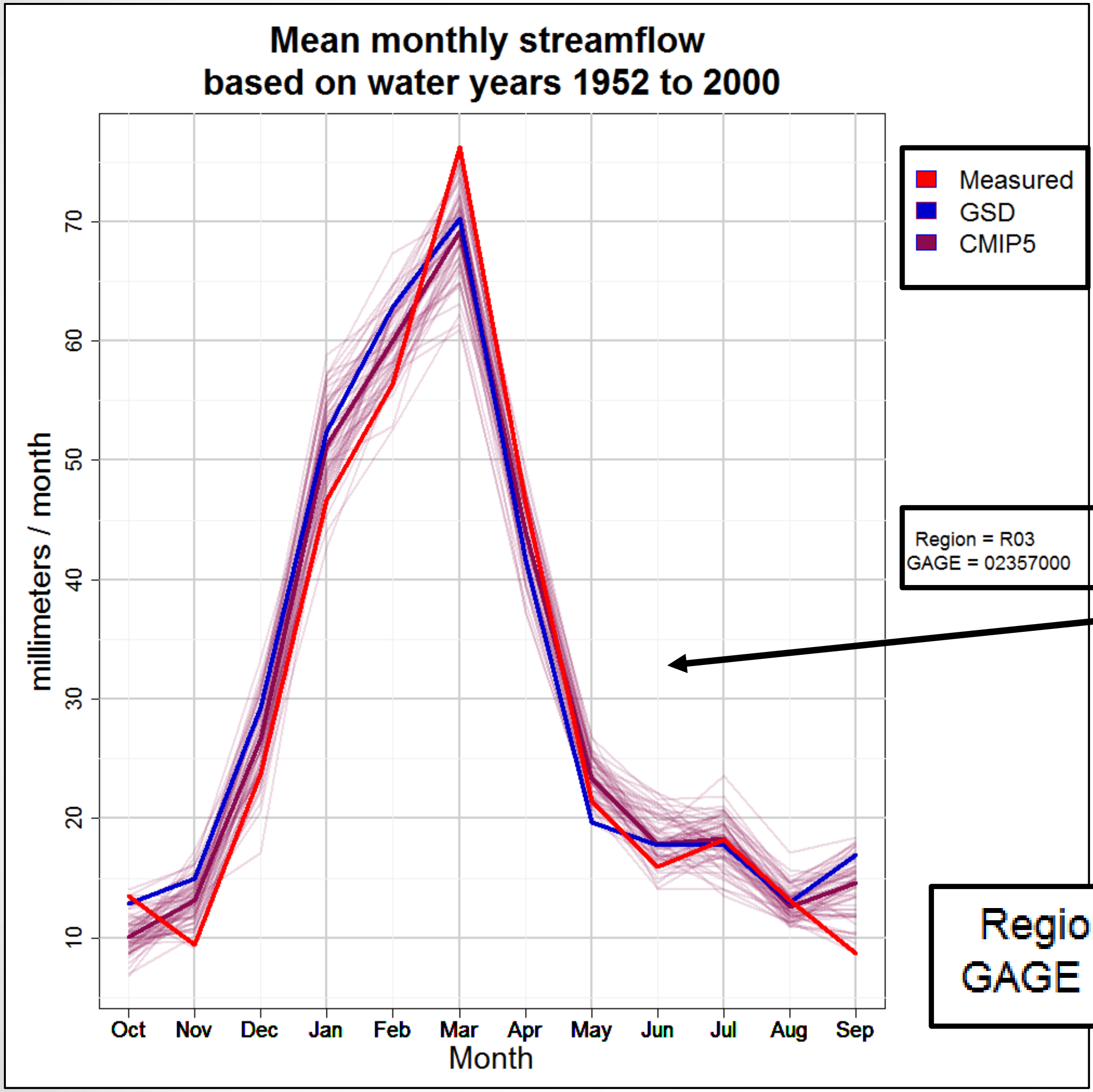
Runs (Climate Dataset Selection) (cont.)



by GCM
Emission Scenario
Model Group

Selection interface for plots based on future conditions

Historical Conditions: Mean Monthly Plots

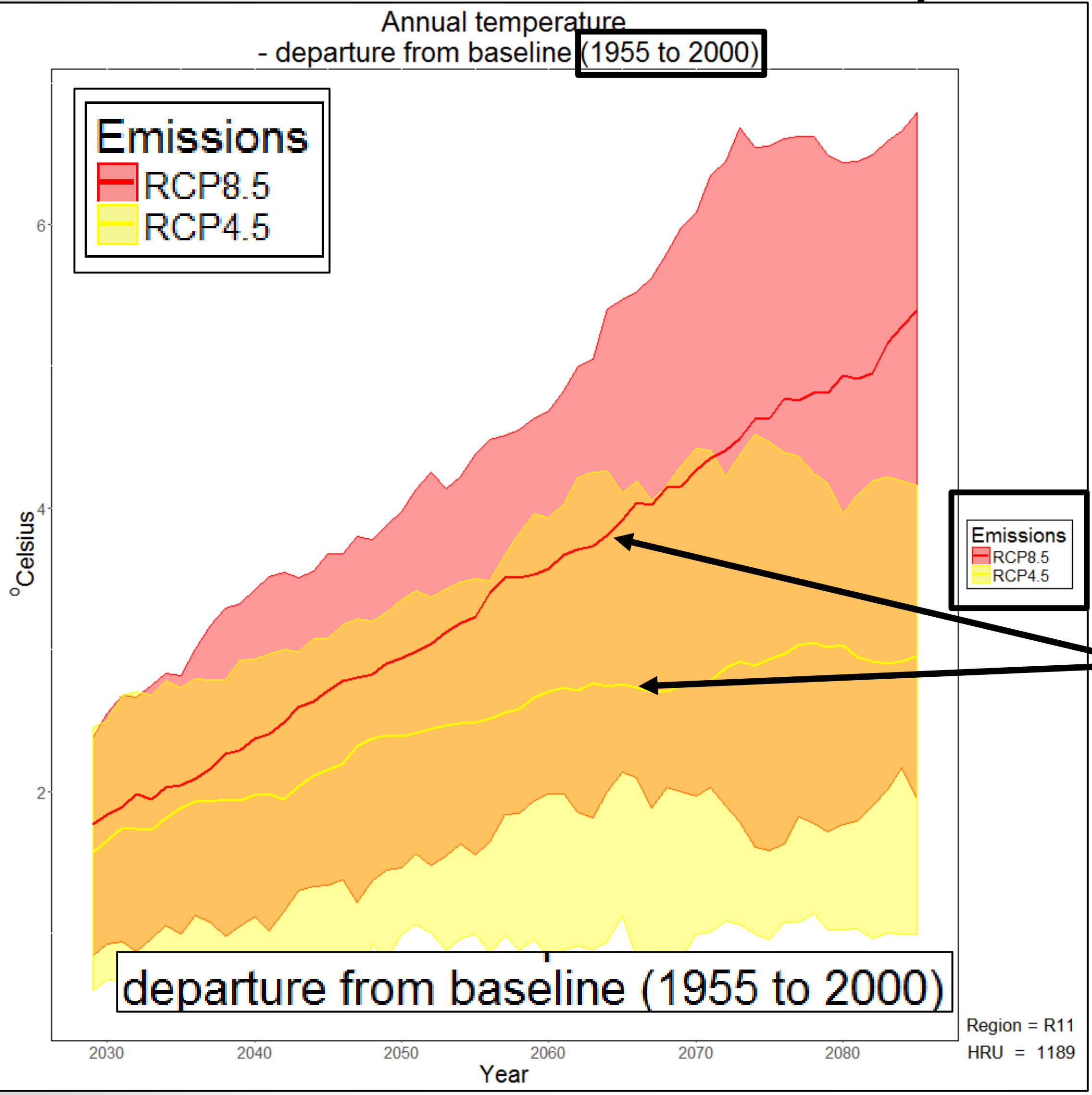


- Plotting MWBM variables during historical conditions (1952 through 2005)
- Line for each GCM simulation, with thick line denoting the median of the historical conditions

Region = R03
GAGE = 02357000

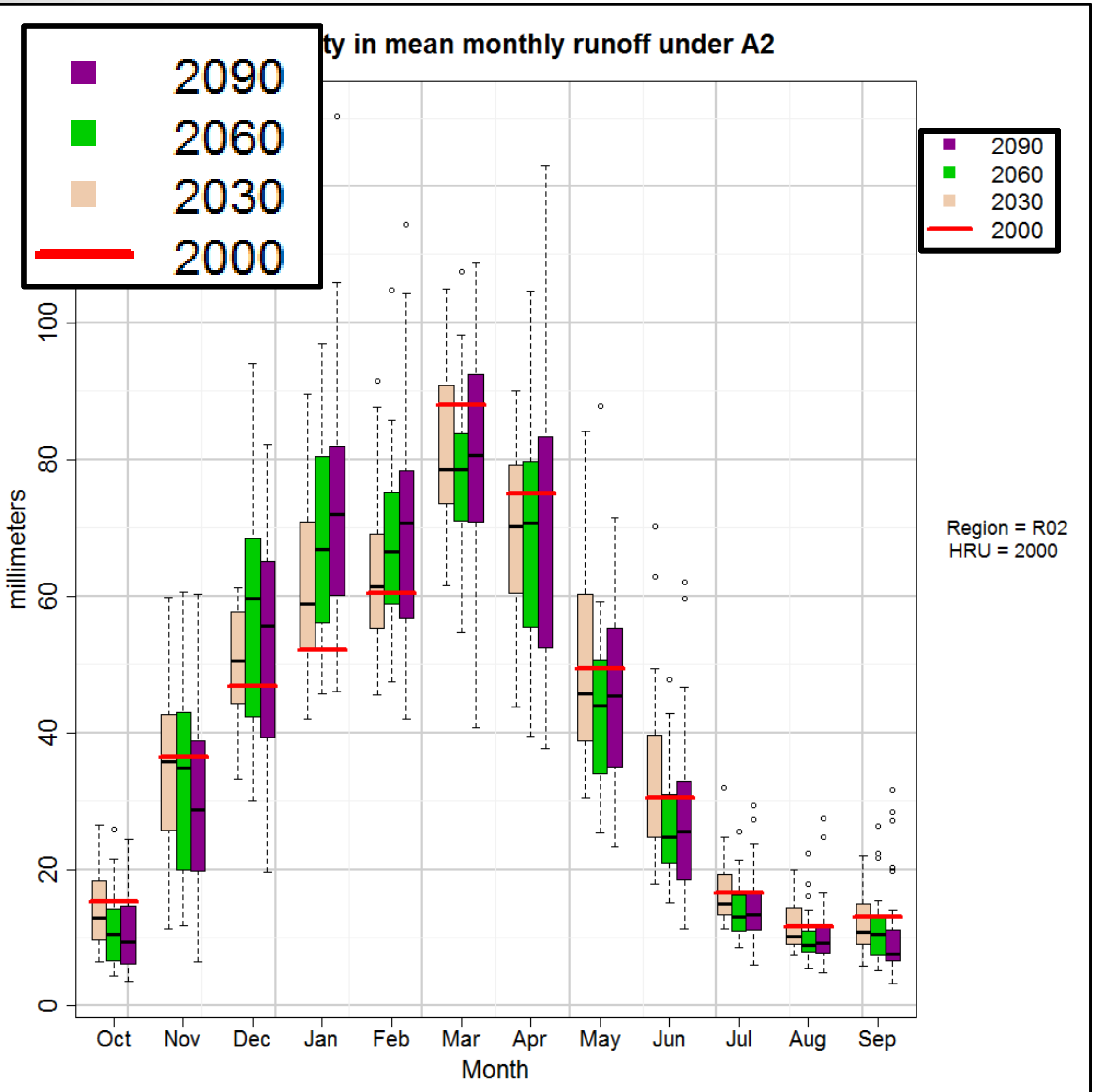
Measured
GSD
CMIP5

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

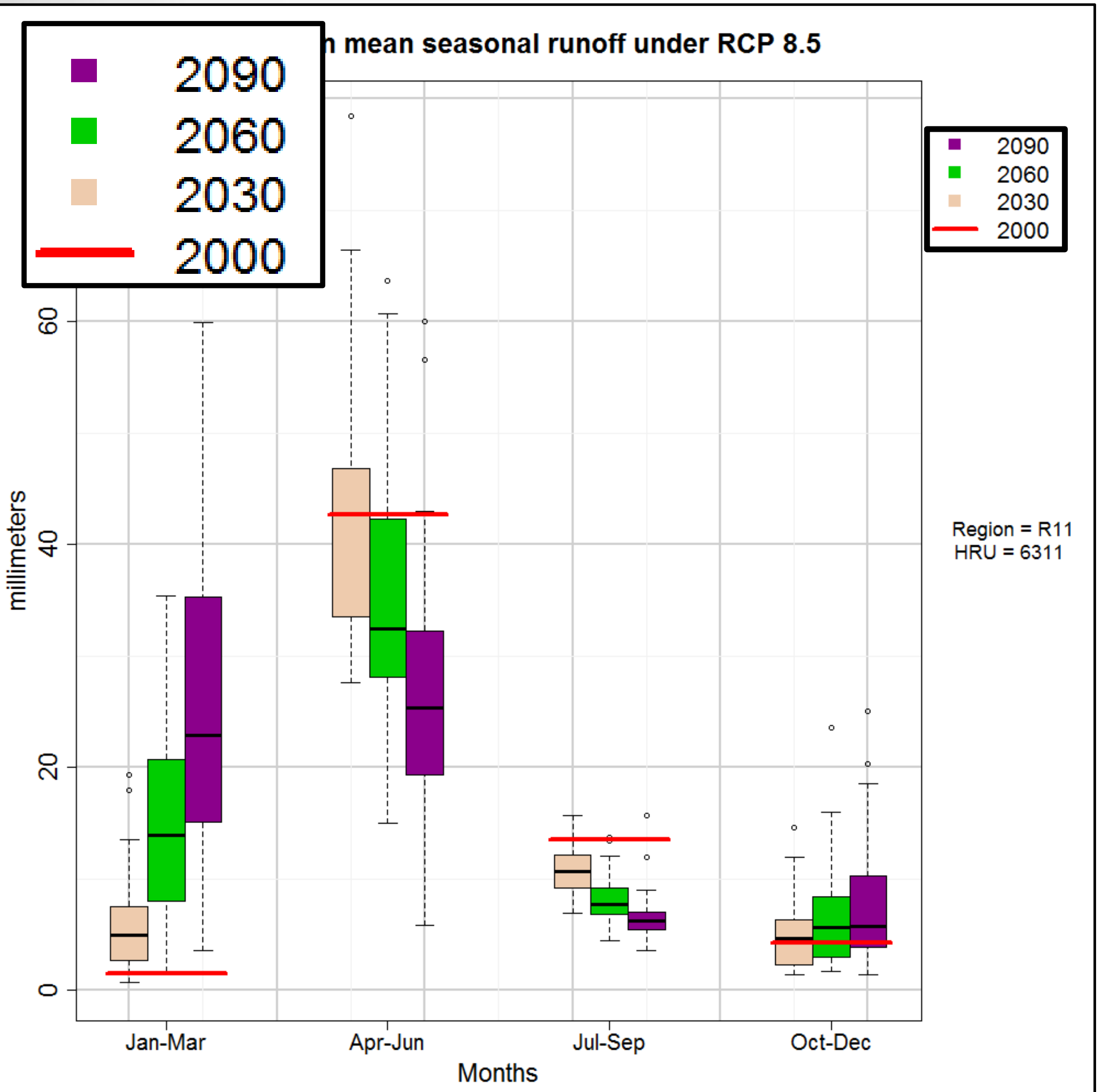
Future Conditions: Box Plots



- 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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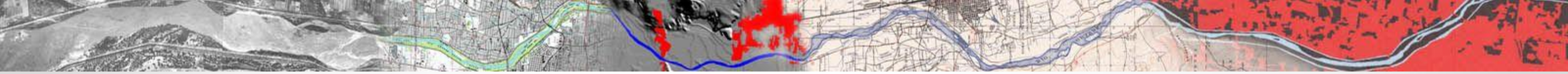
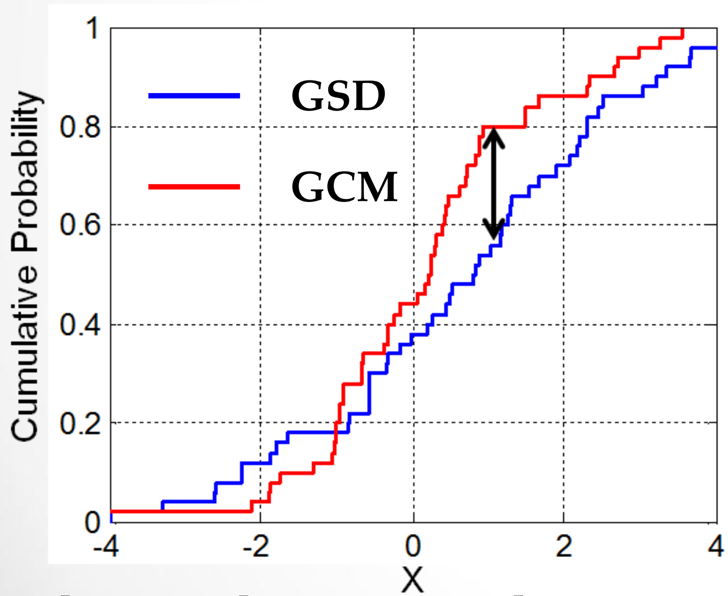
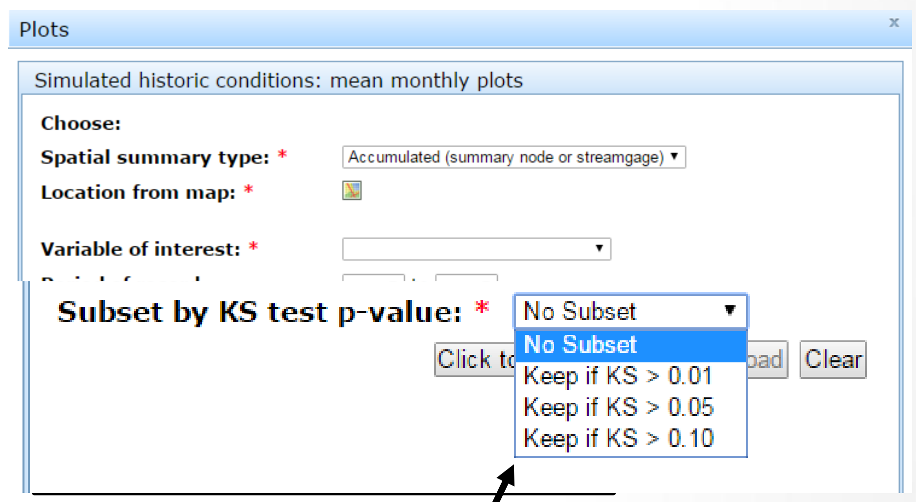


Sub-setting Climate Dataset Selections

- Portal uses the Kolmogorov-Smirnov (KS) test (Conover, 1971) to subset GCM selection to those that best reproduce past conditions (Hay and others, 2014)

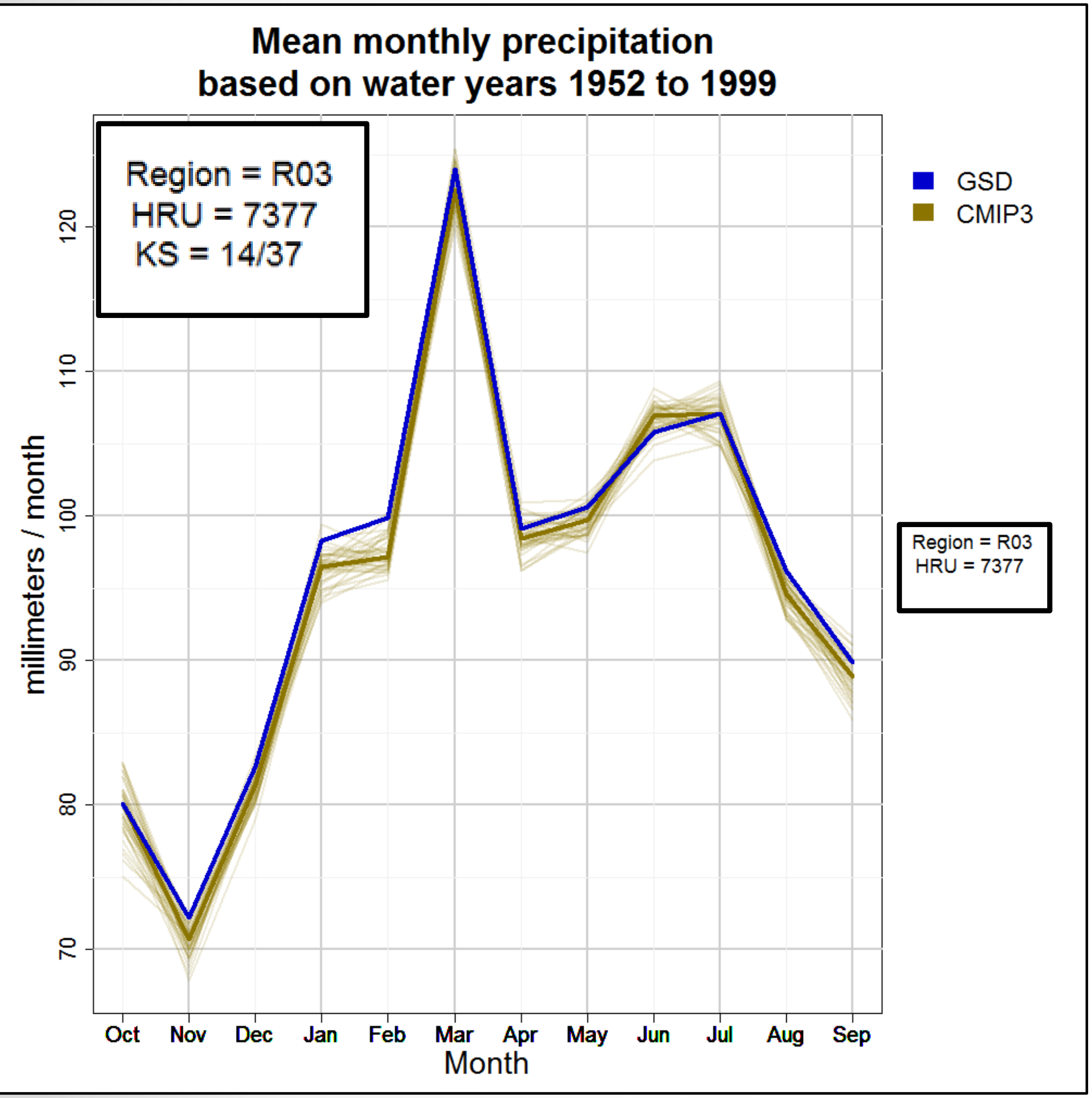
- Compares empirical cumulative distribution of downscaled GCM simulation data and that of the station-based dataset (GSD) used for the downscaling procedure



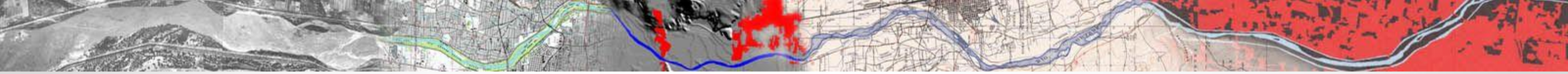


- Chosen climate simulations not meeting KS test p-value thresholds are withheld from plotting data and attributed in the time series csv

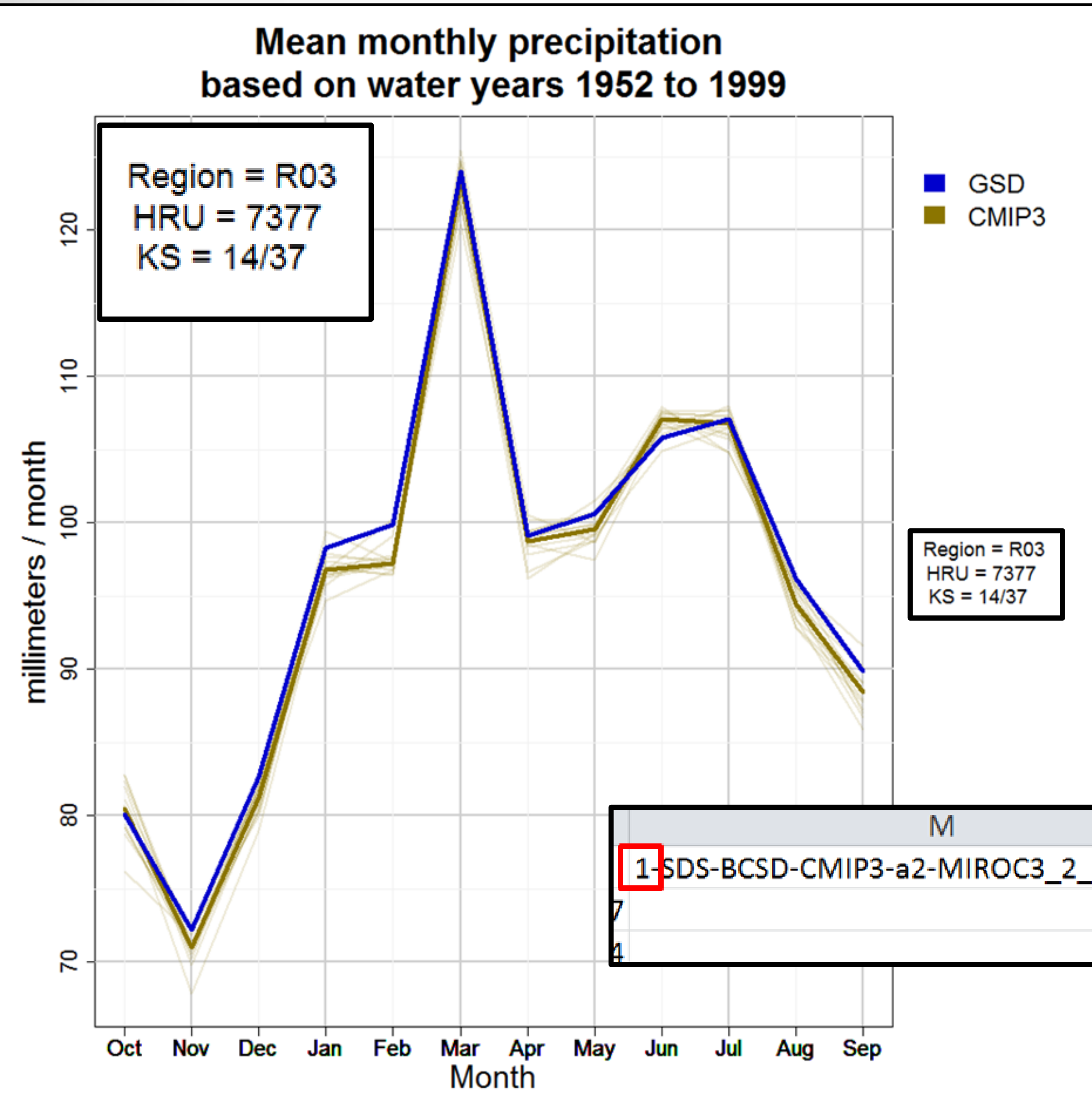
Sub-setting Climate Dataset Selections (cont.)



- 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.)

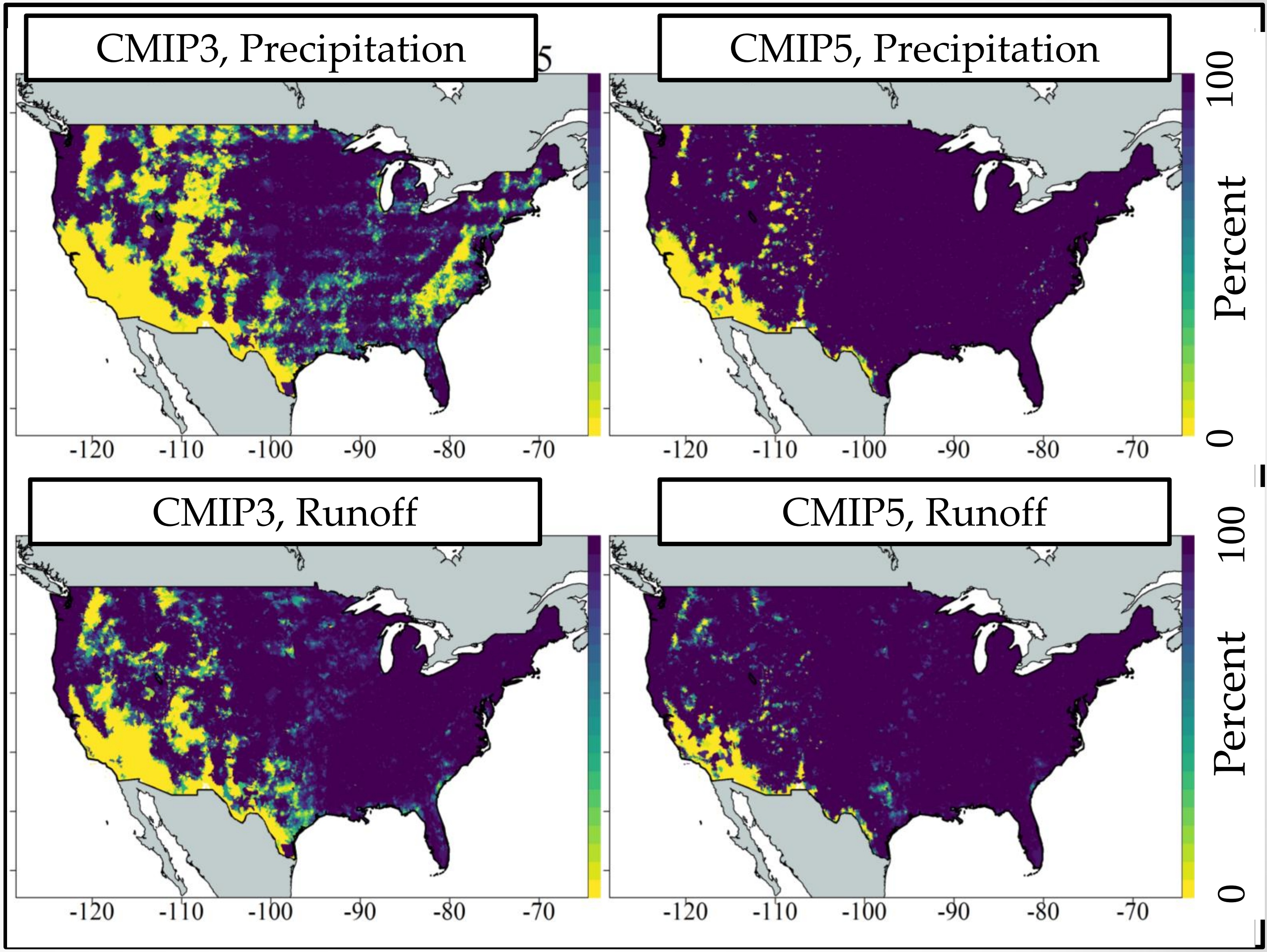


	M	N
	1-SDS-BCSD-CMIP3-a2-MIROC3_2_MEDRES_3	0-SDS-BCSD-CMIP3-a2-MIUB_ECHO_G_1
7	162.27077	102.9931
4	215.4929	109.87238

- 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

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\

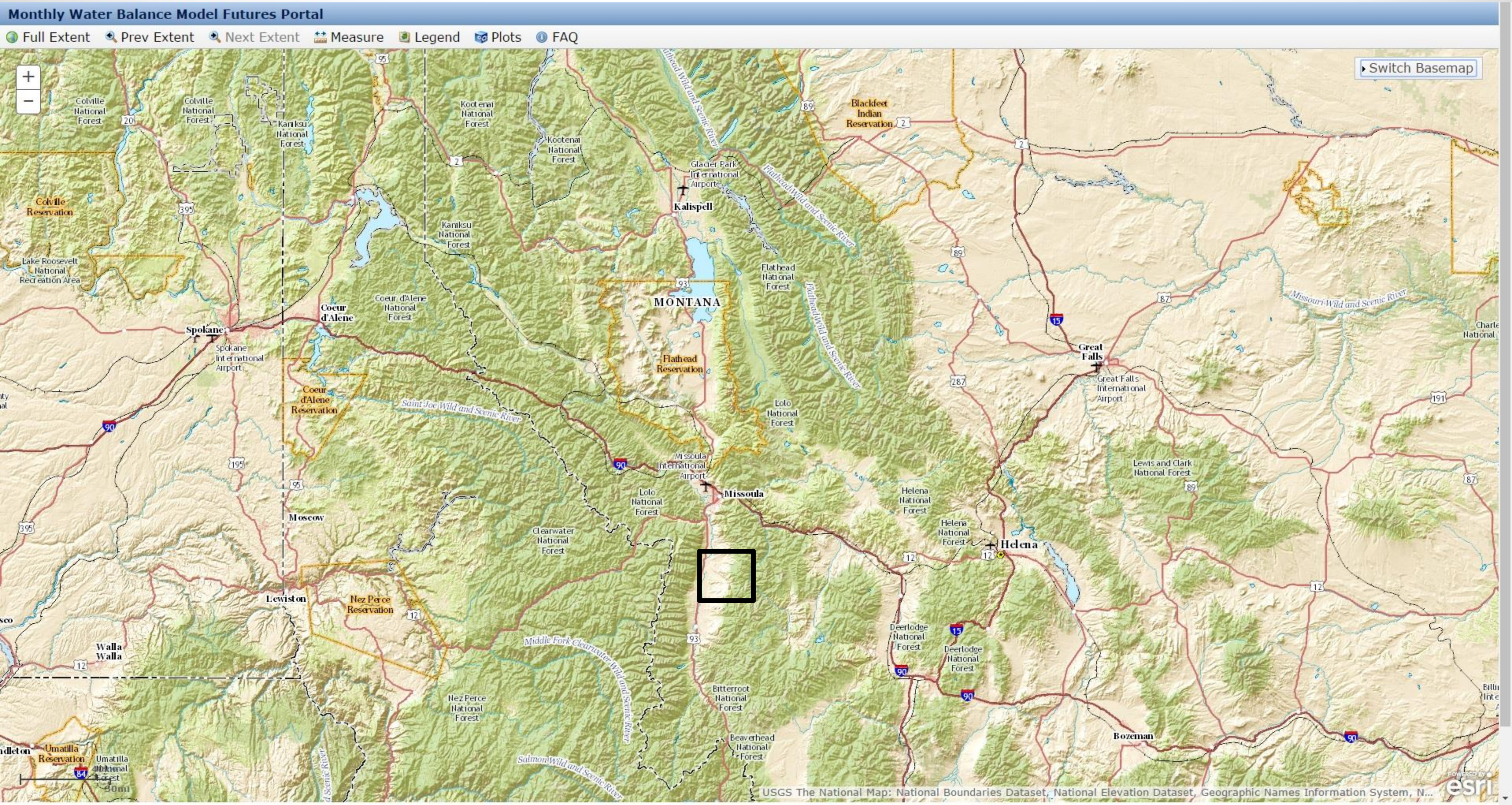
- USGS Information Products

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



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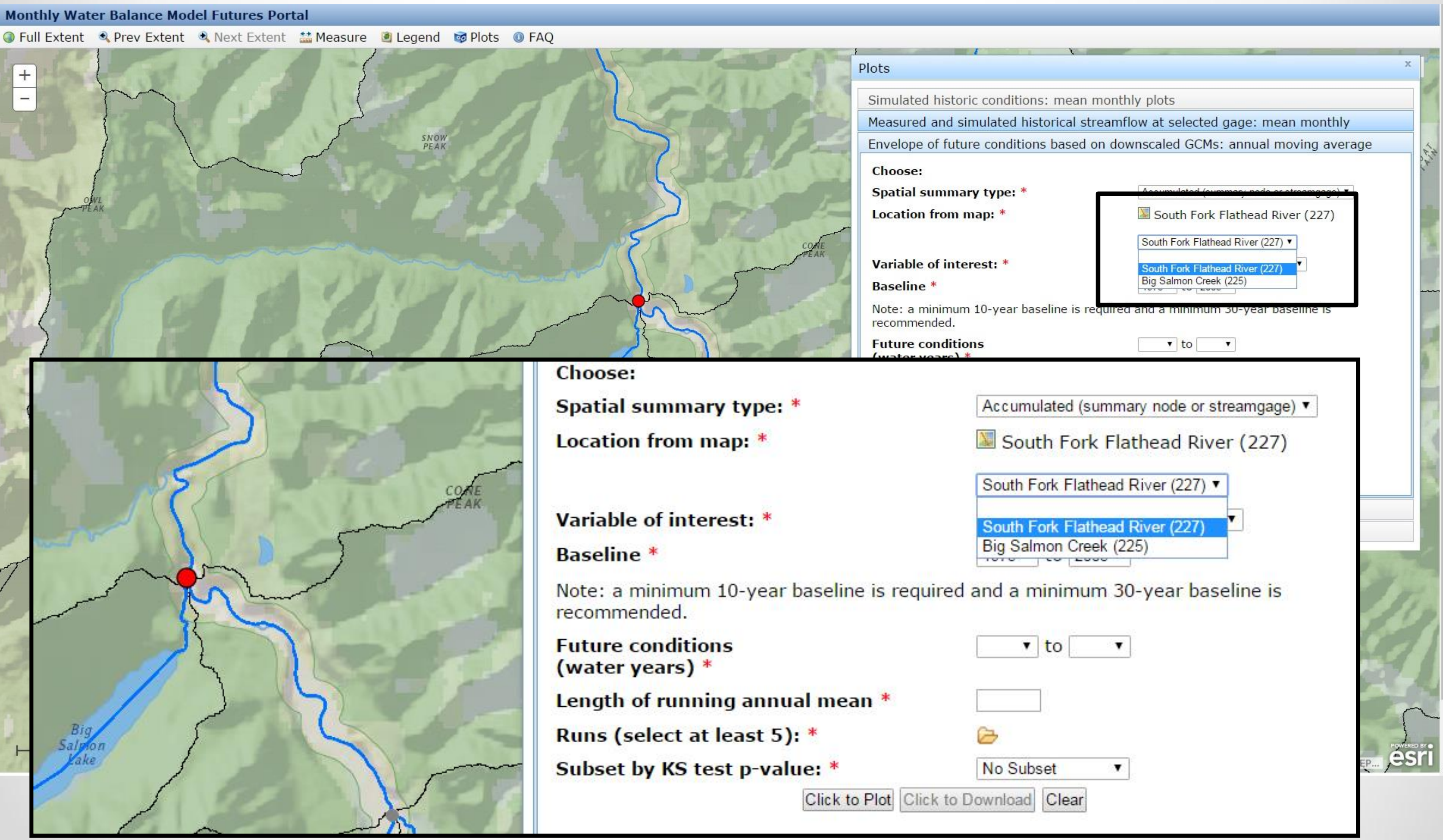

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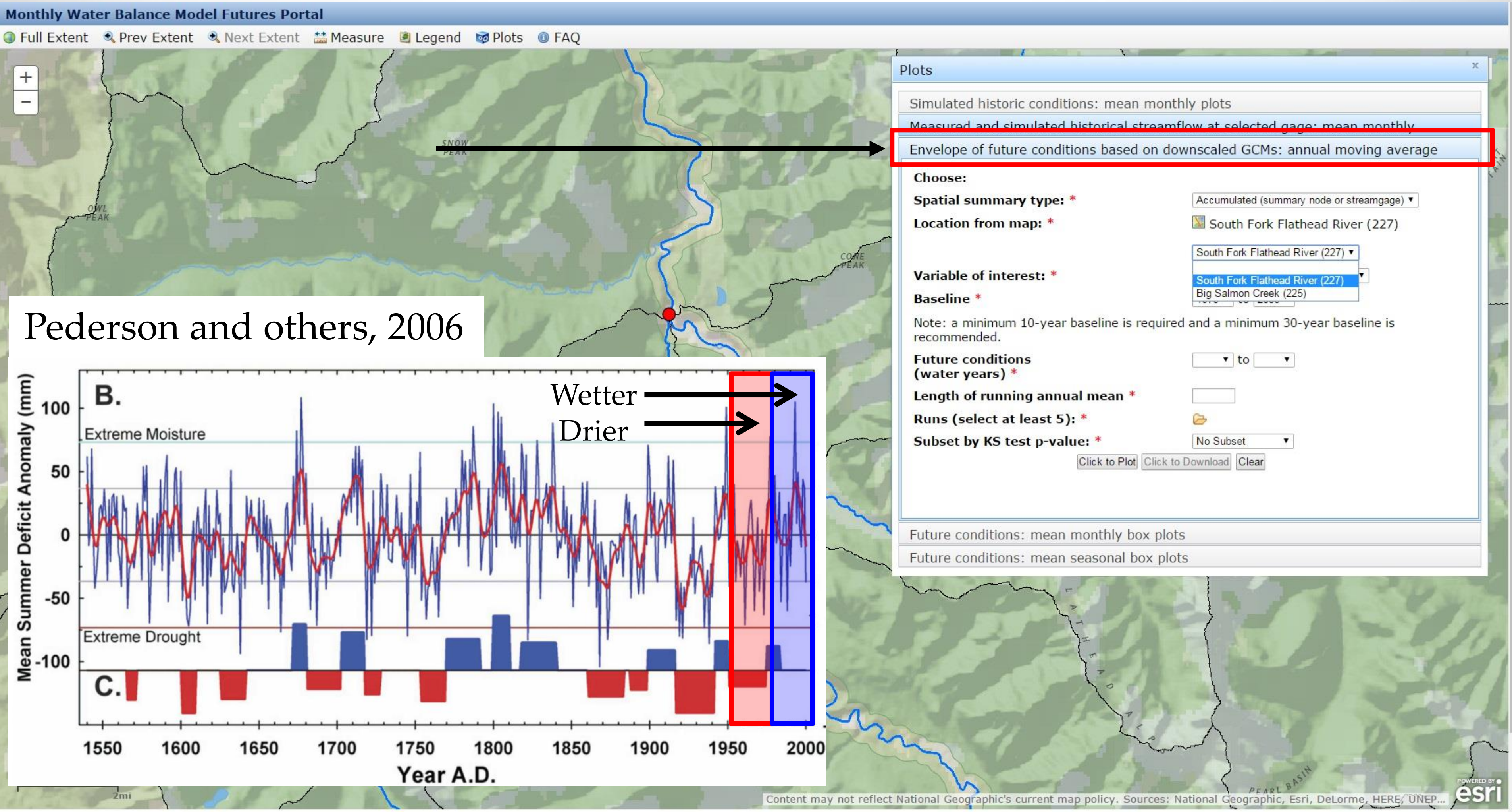
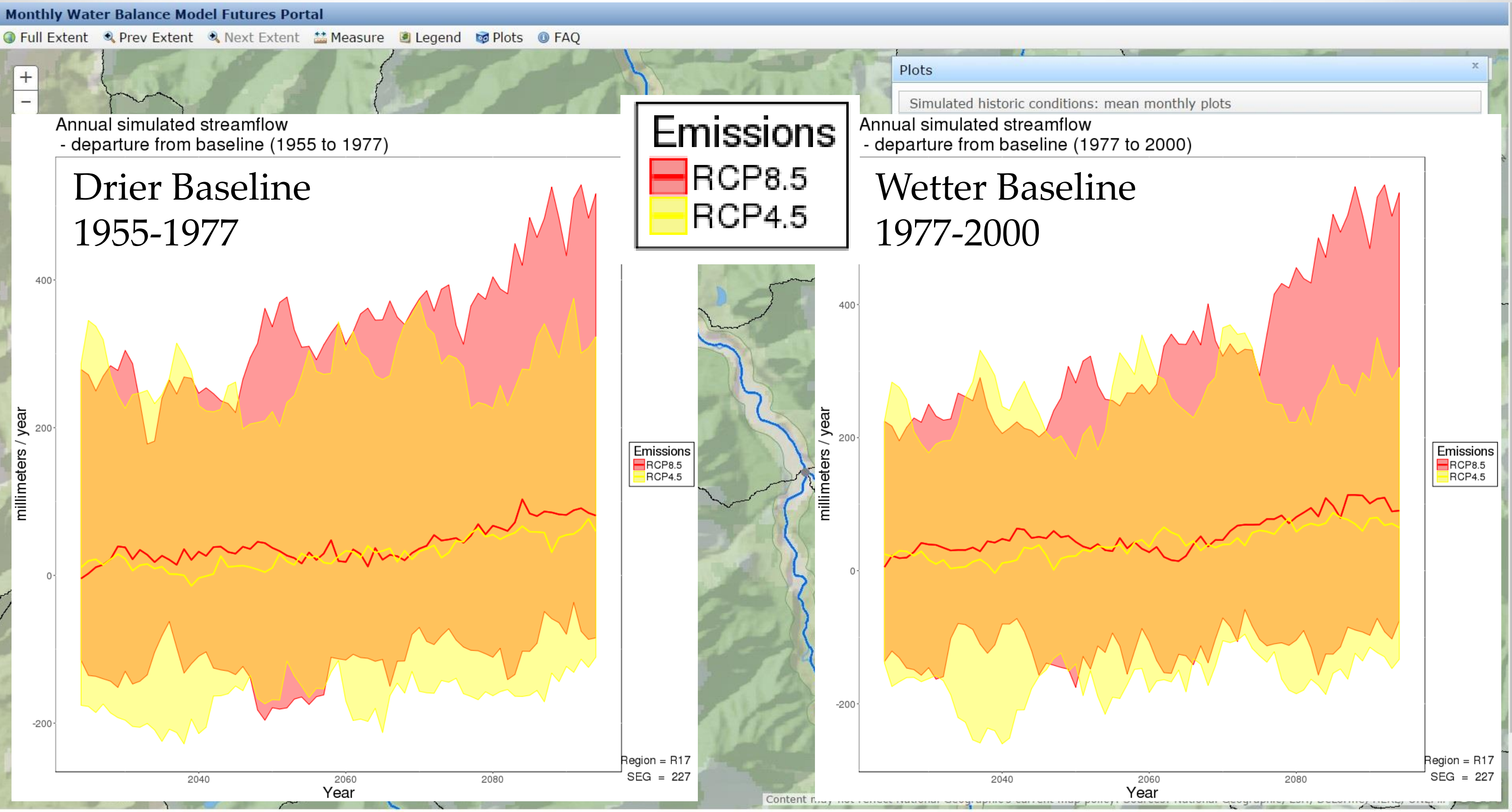


Examine potential future streamflow using two different baselines for comparison

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



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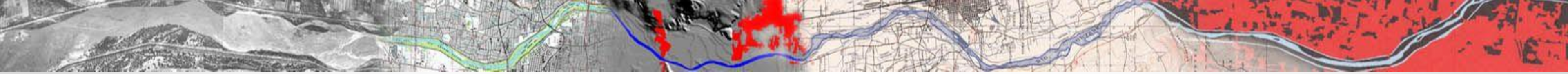
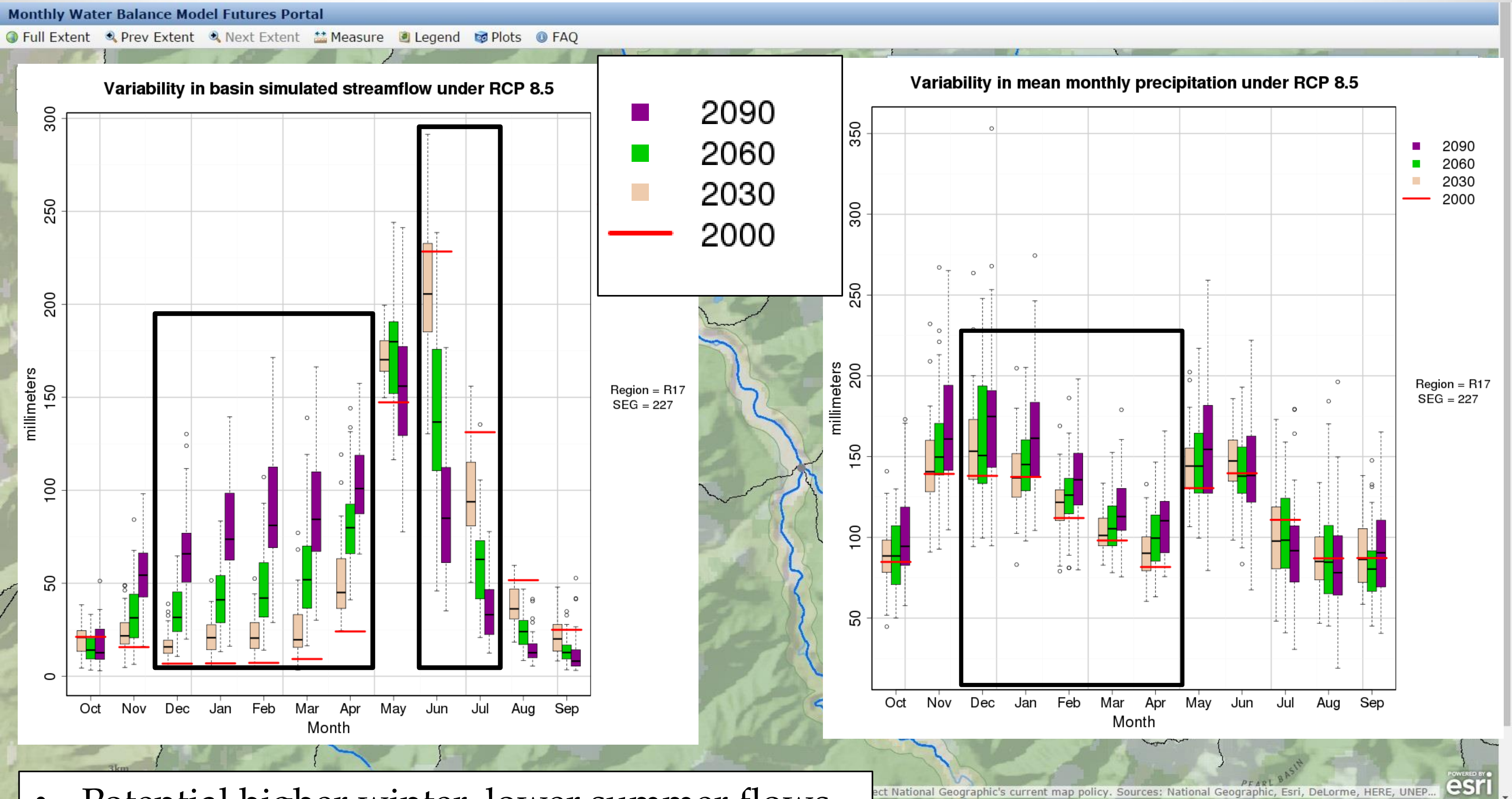
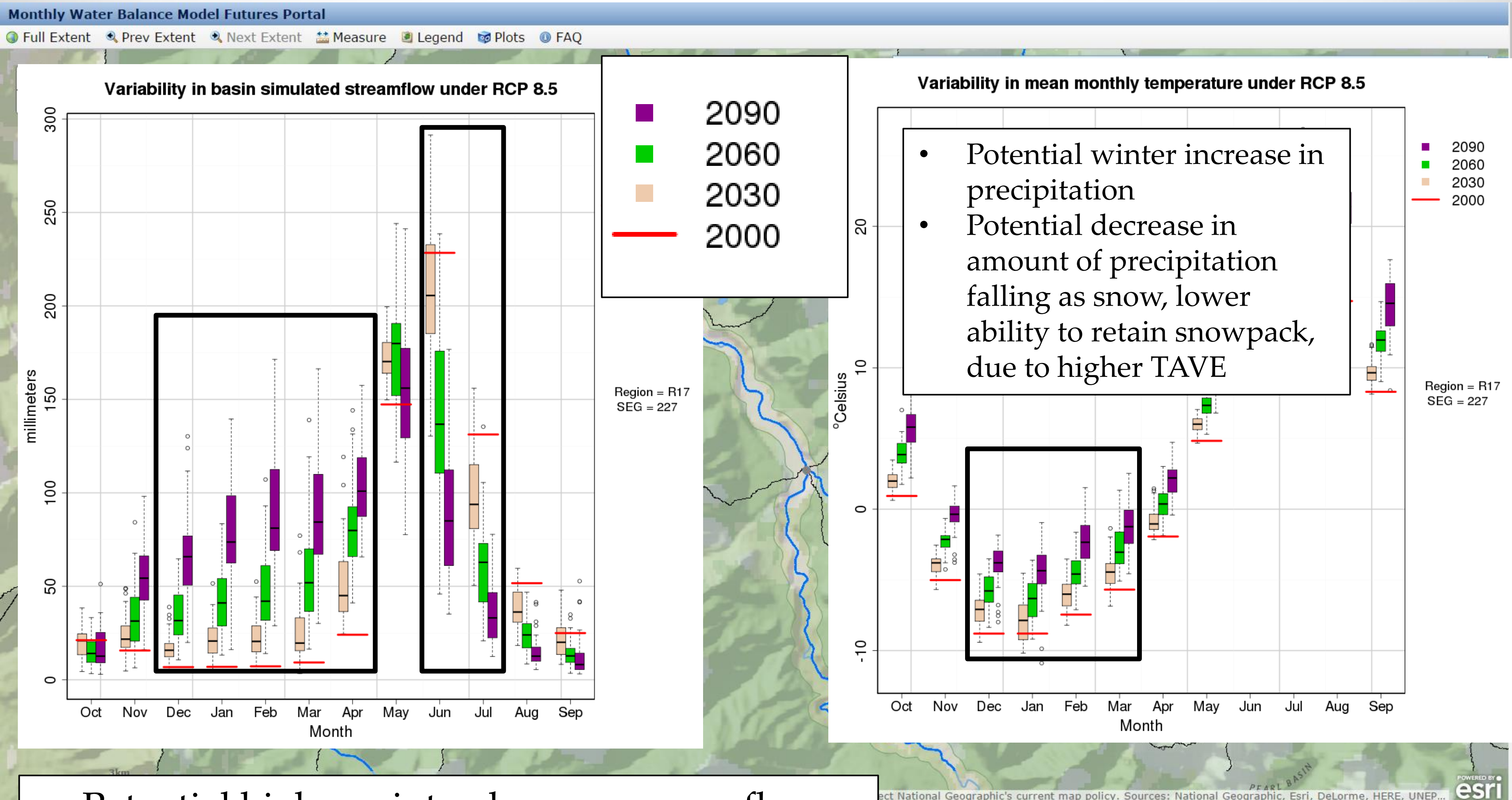


S.Fork Flathead River (potential future scenarios, 2030/60/90)



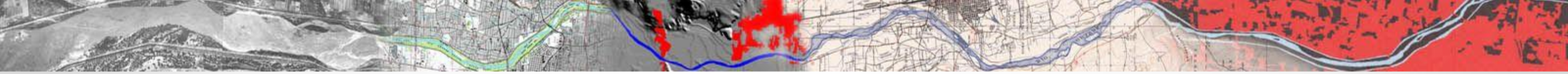
- Potential higher winter, lower summer flows, and lower SWE throughout the year

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

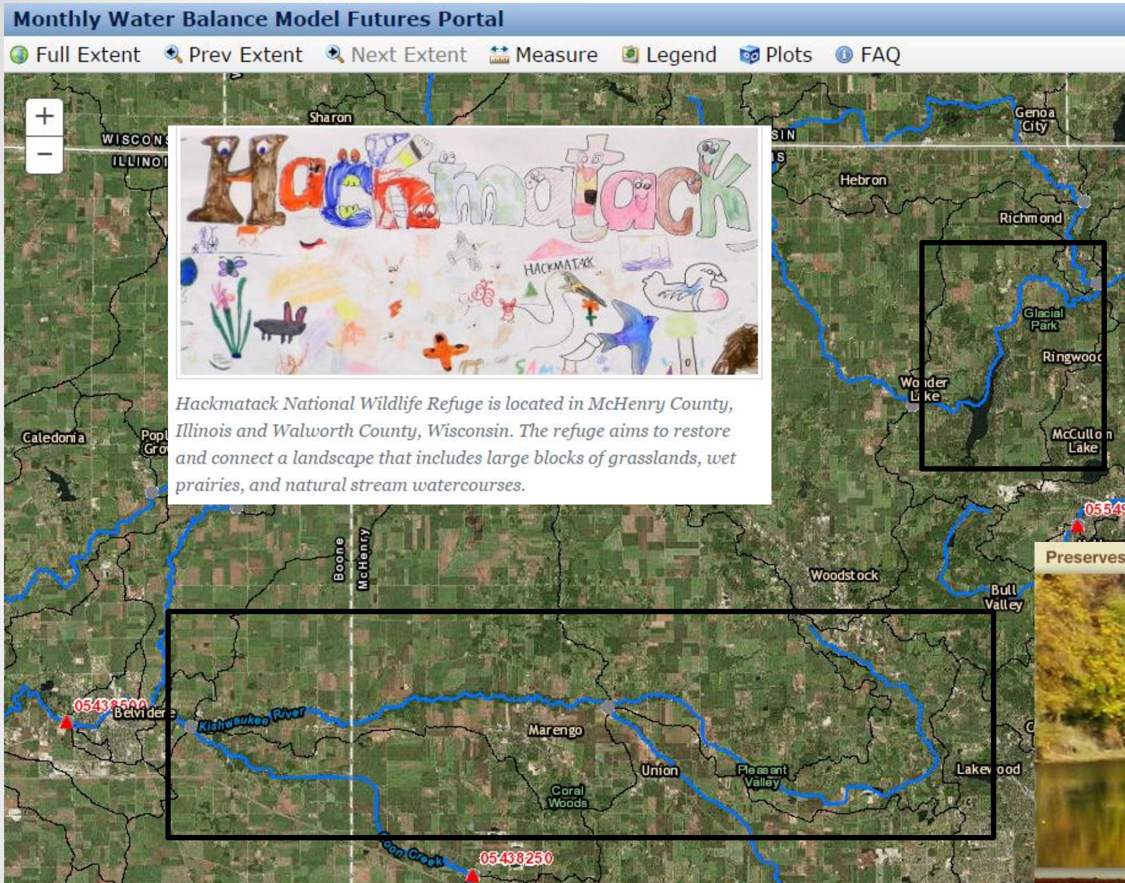


- Potential winter increase in precipitation
- Potential decrease in amount of precipitation falling as snow, lower ability to retain snowpack, due to higher TAVE

- 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.

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RIVERS

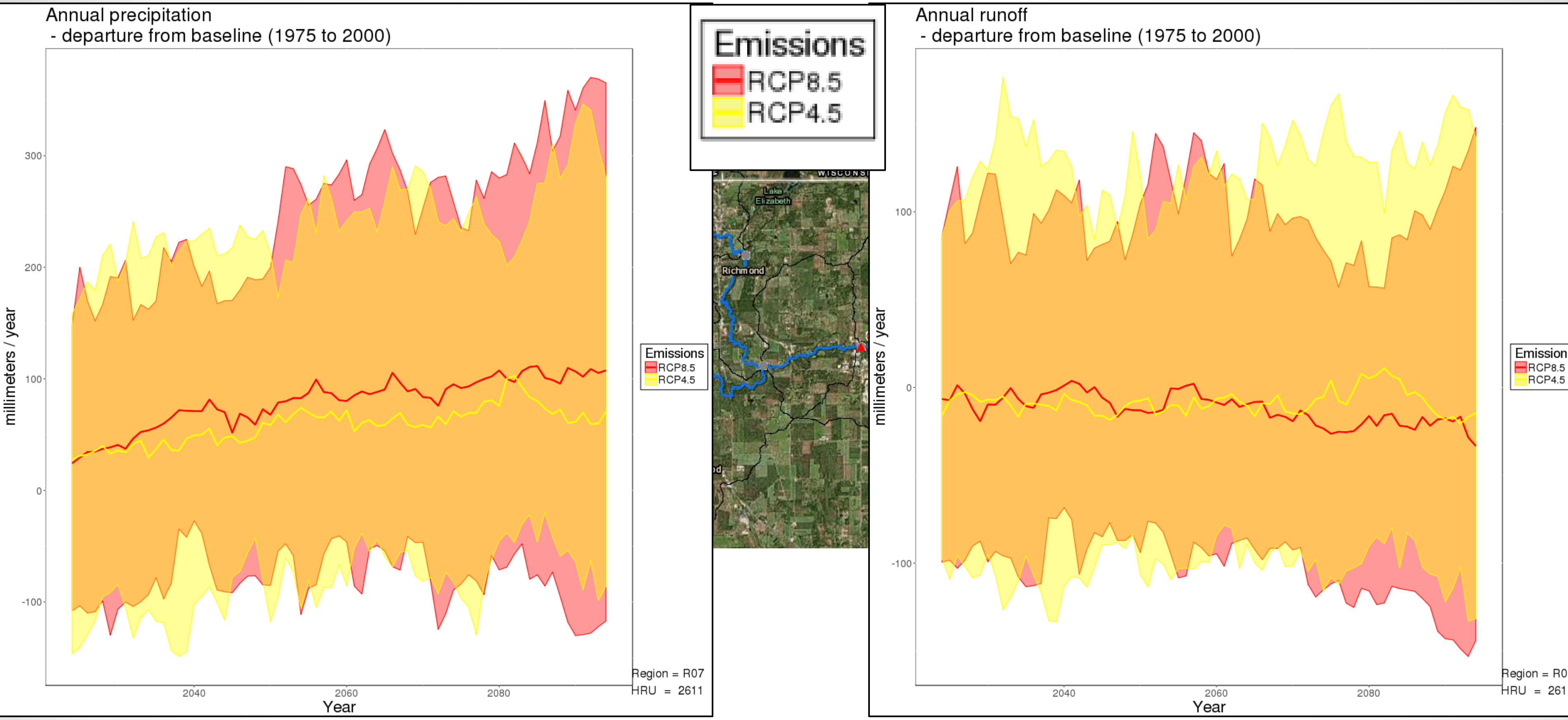
The Kishwaukee River

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*

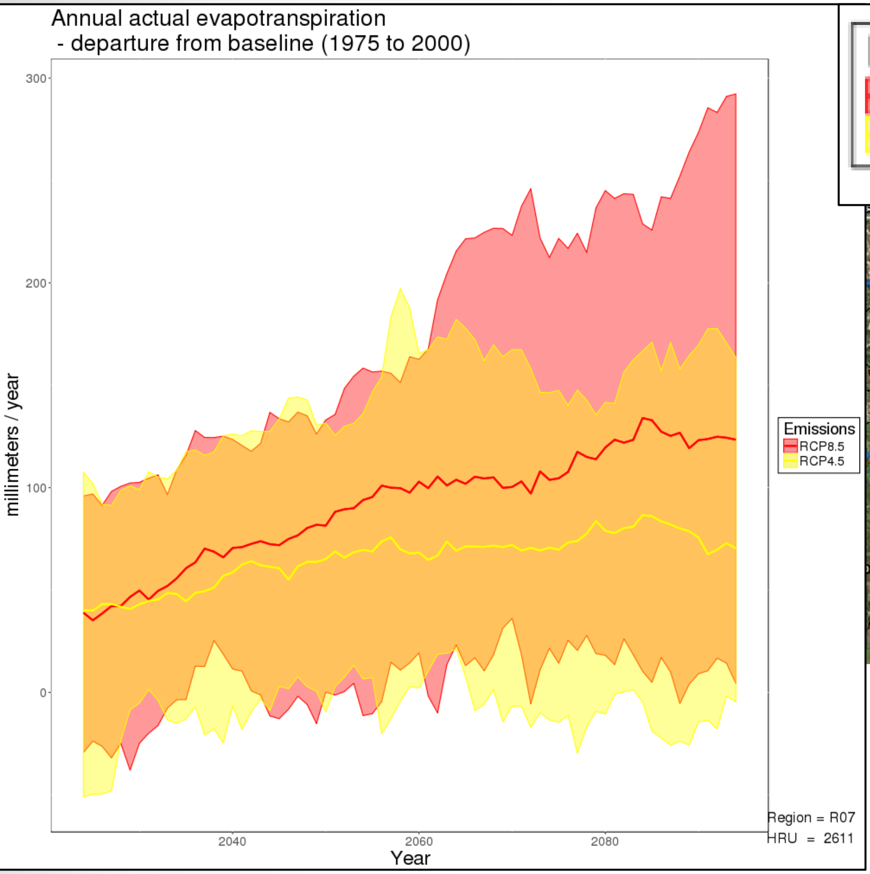
USGS science for a changing world

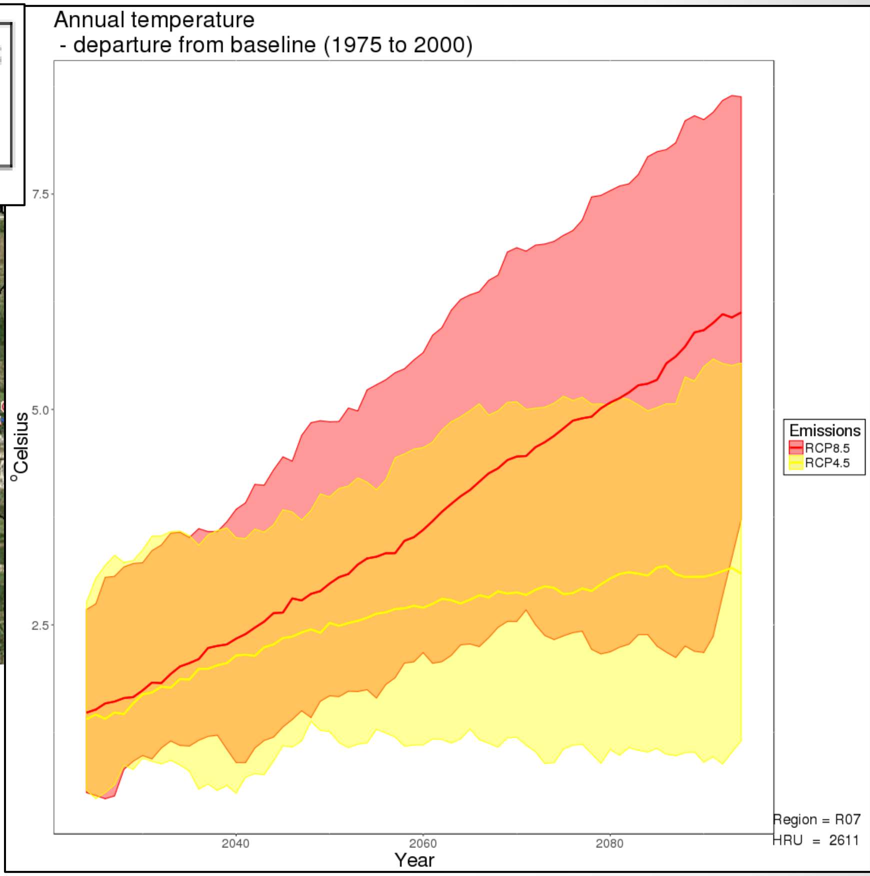
Ecological Impacts- Nippersink Creek



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





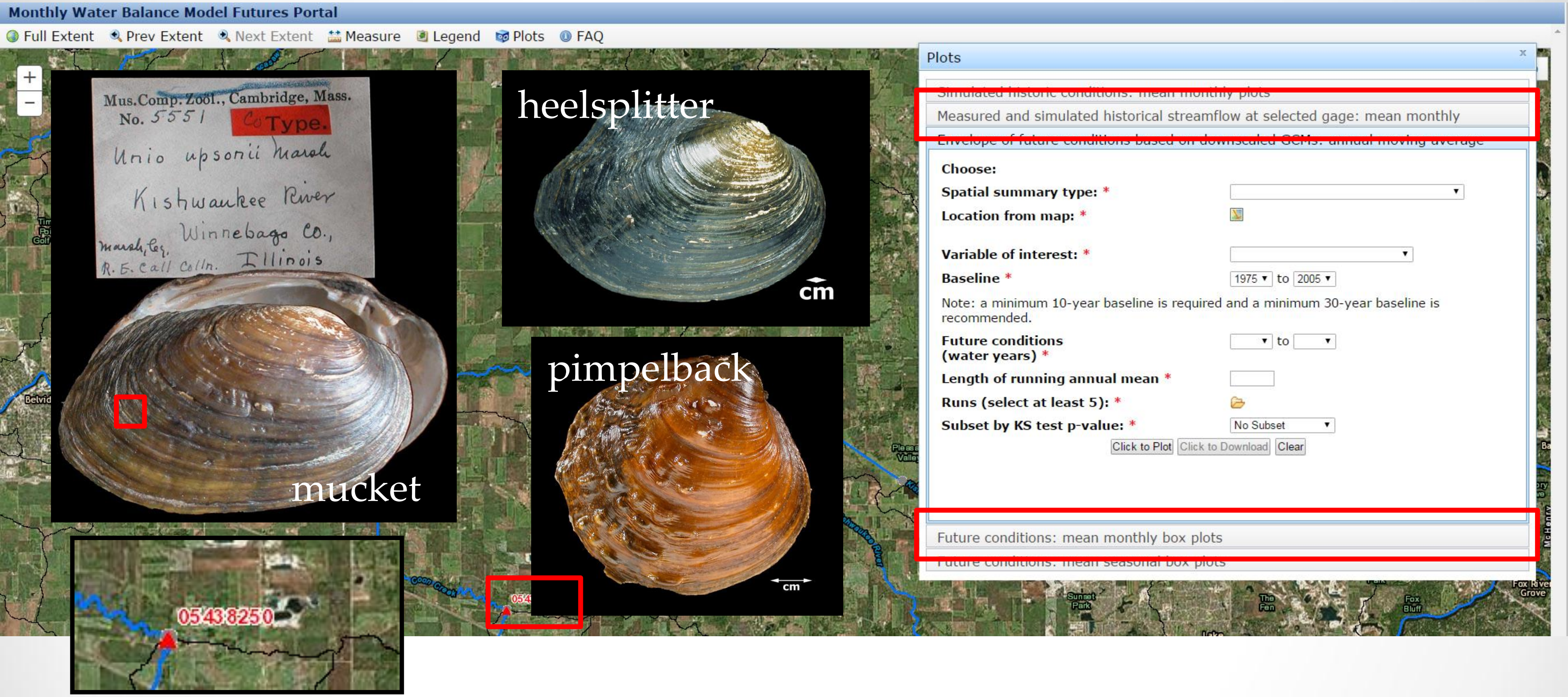
Evaluate Changes in Future runoff from contributing HRUS

-Increase in median precipitation for RCP 4.5 and 8.5

-Mixed trends for runoff

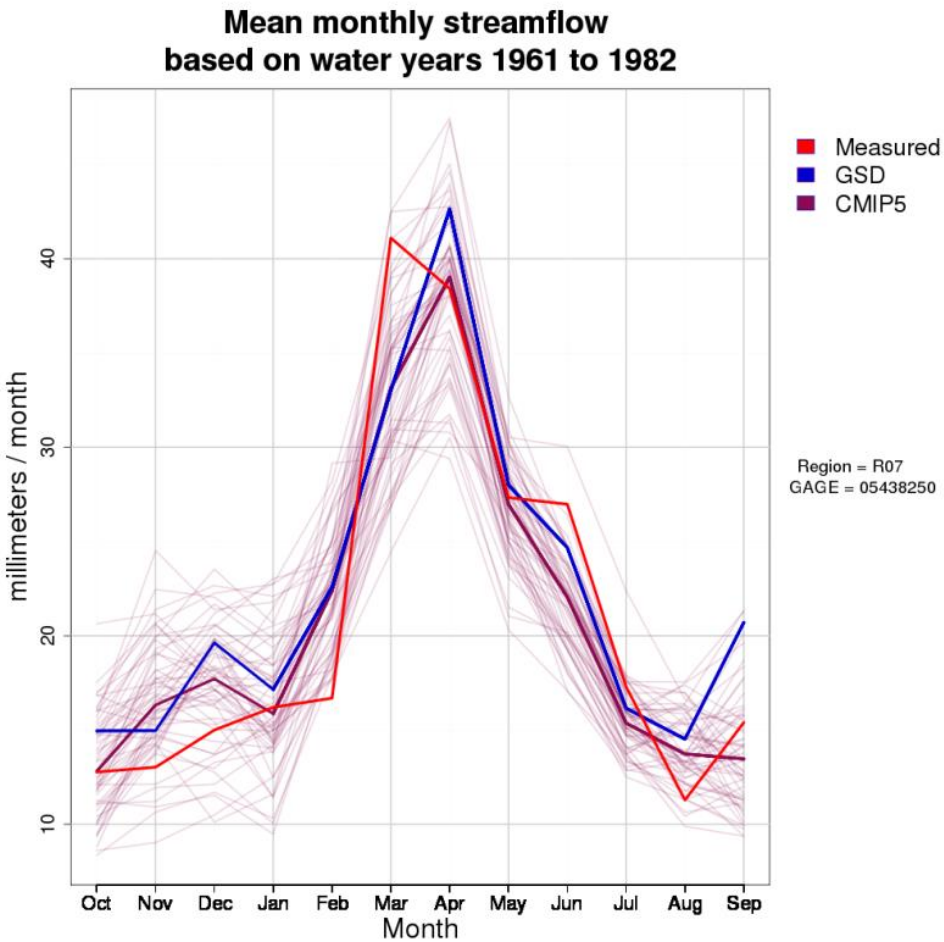
-Increase in median actual evapotranspiration (driven by increasing temperature)

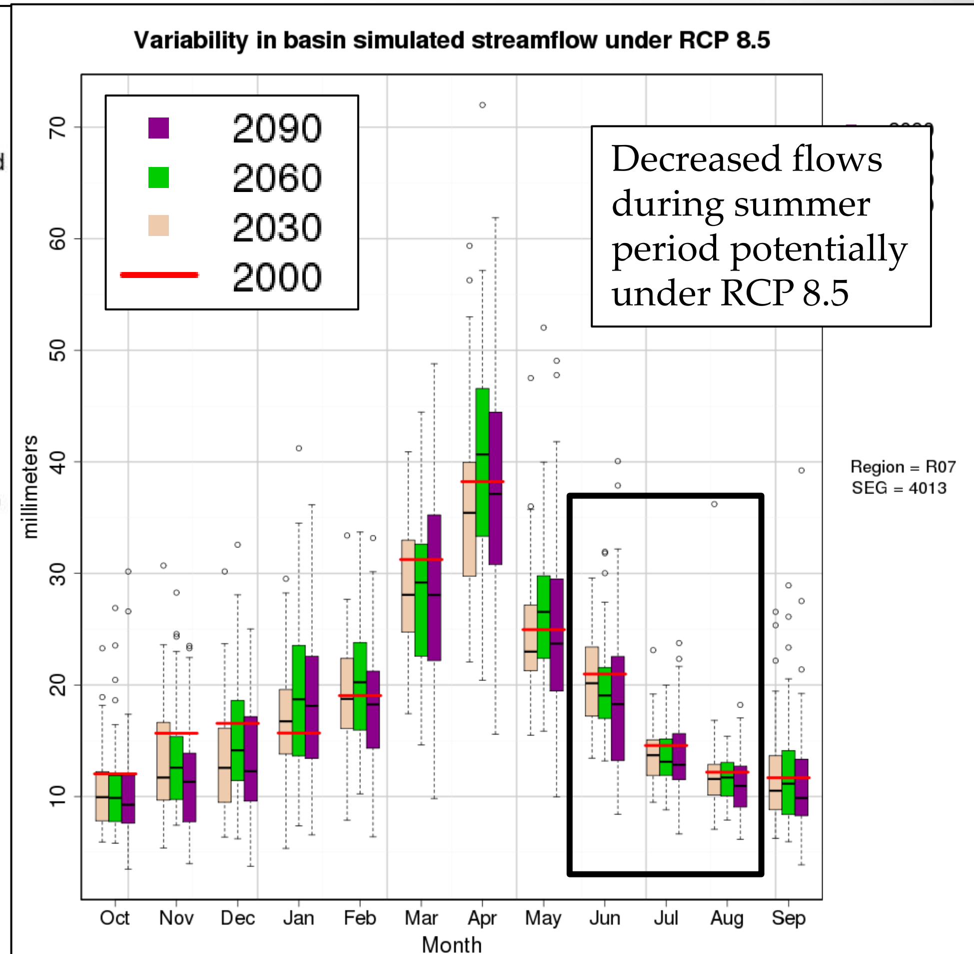
Kishwaukee River



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

Kishwaukee River

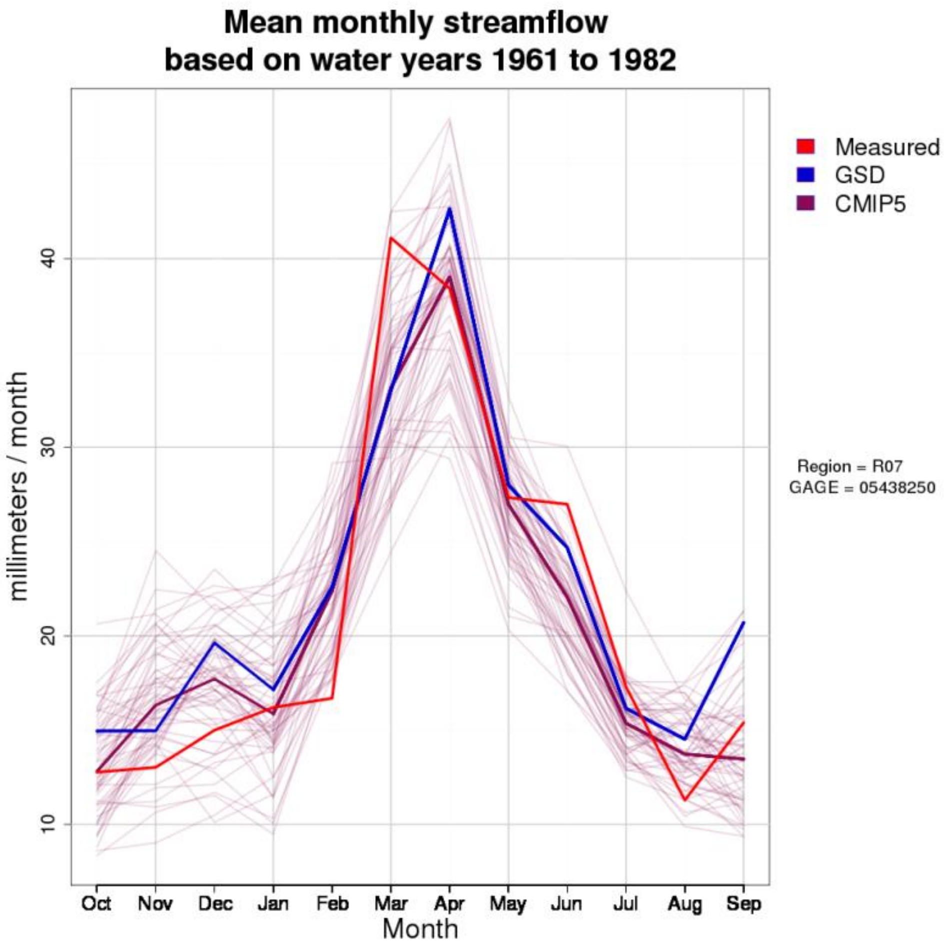


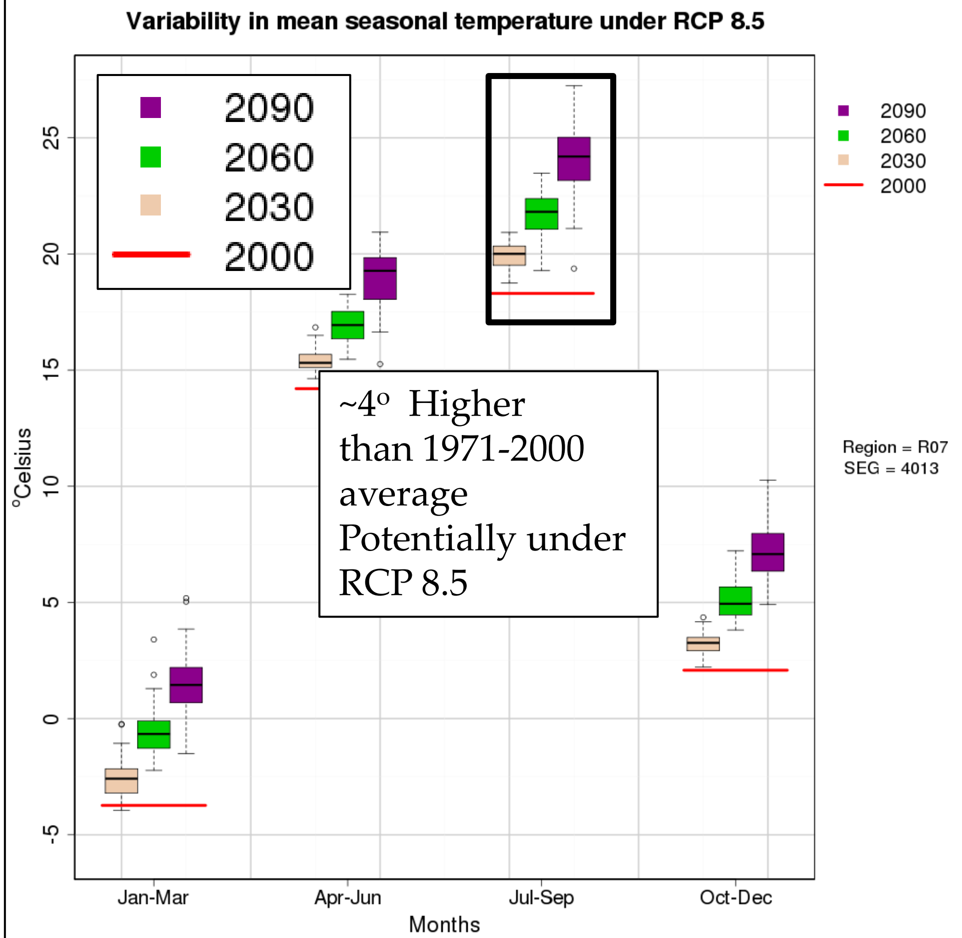


-What is the range of projected summer air temperature for potential future conditions under RCP 8.5?

-What is the range of projected streamflows under RCP 8.5?

Kishwaukee River





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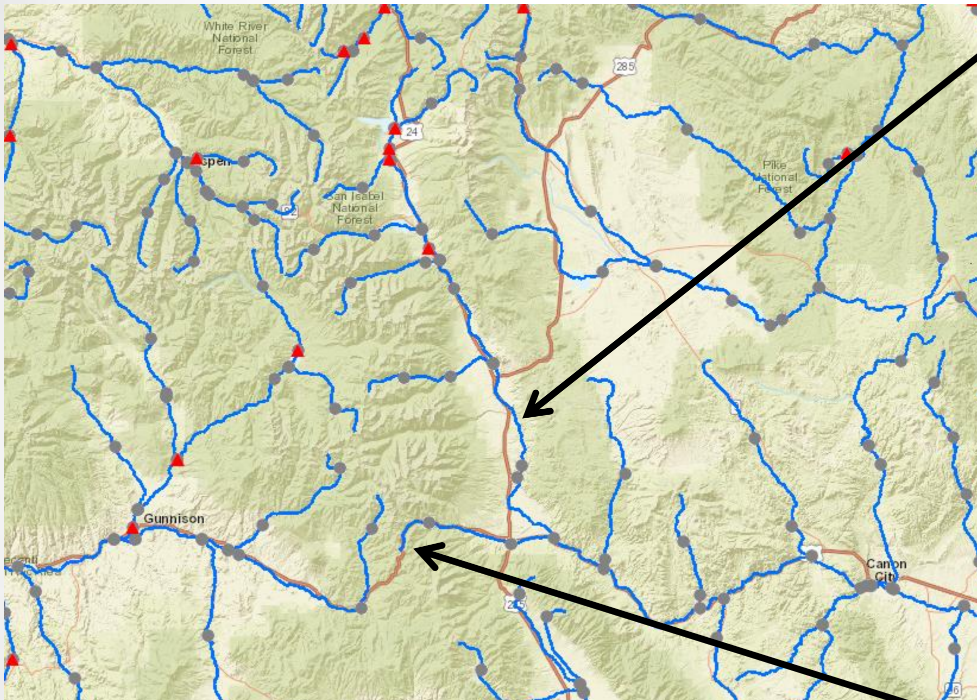
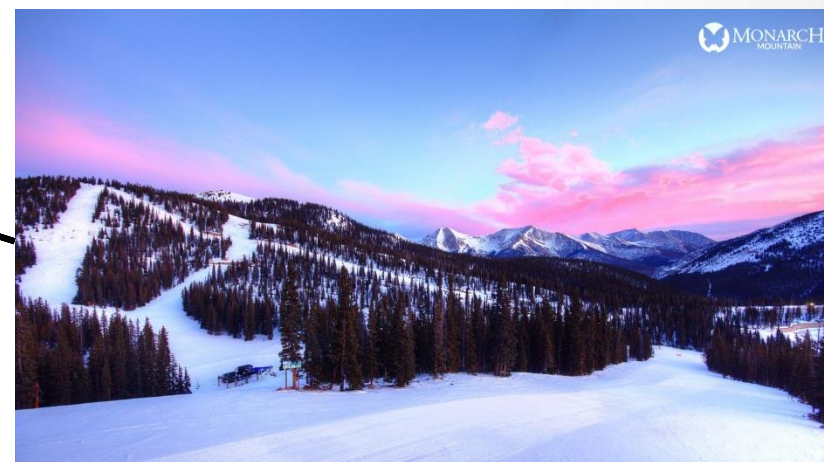
-What is the range of projected streamflows under RCP 8.5?

Potential Effects on Recreational Resources

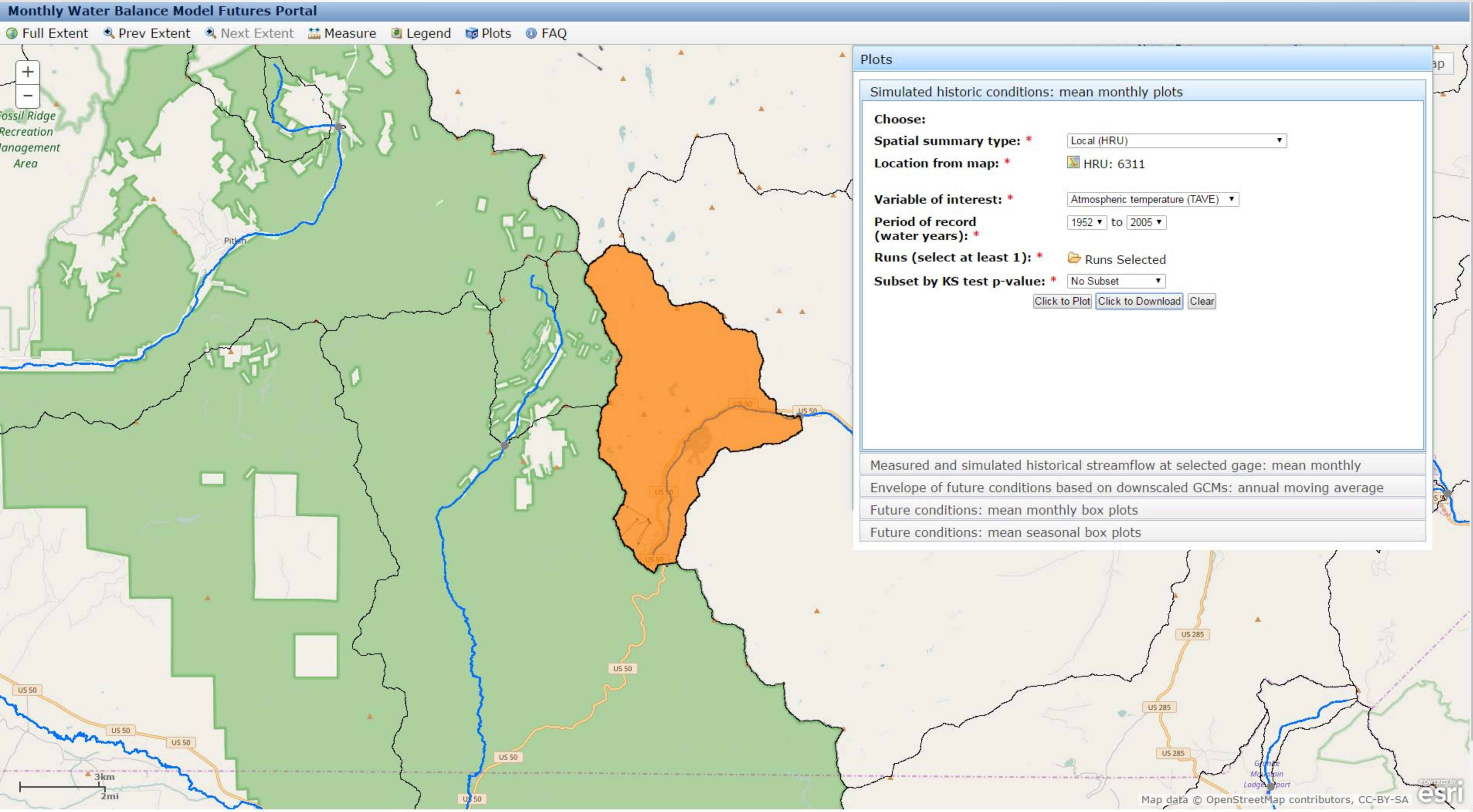


Brown's Canyon
Co. rafting industry
550,861 users in 2016



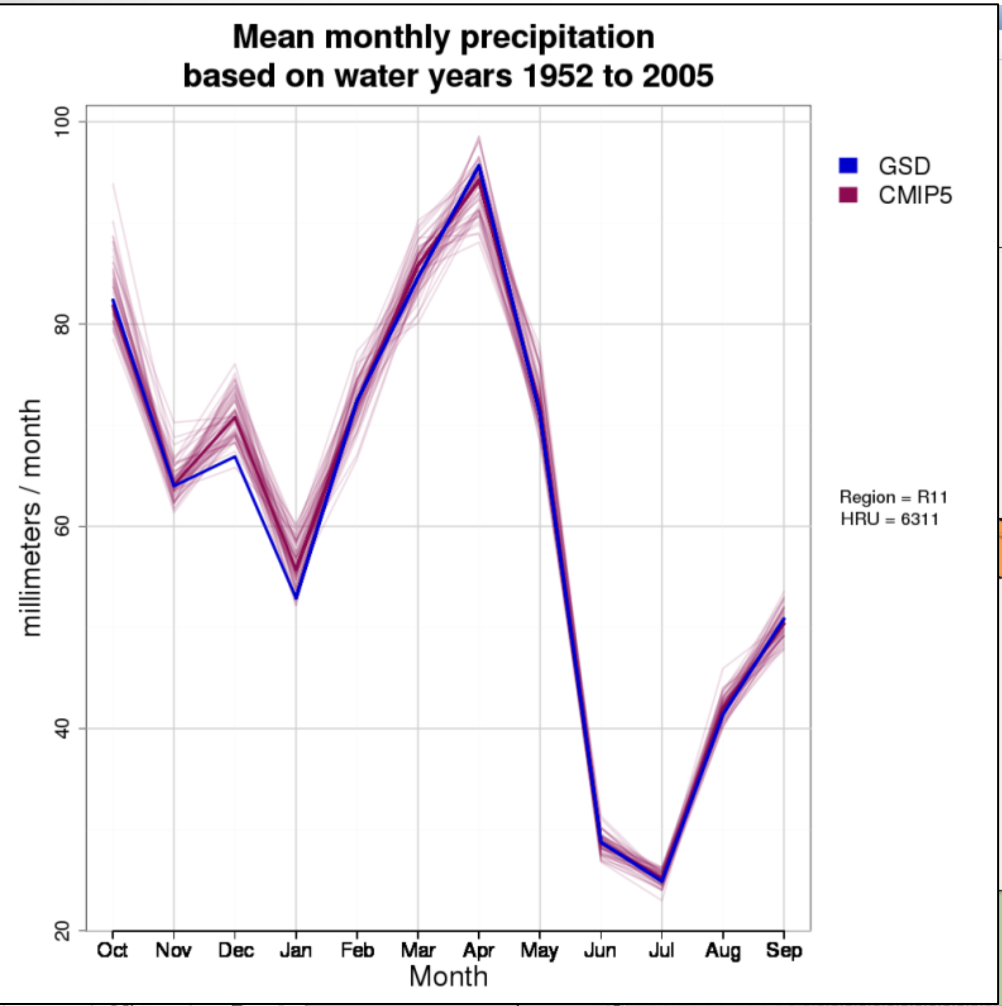
Monarch Ski Area
Elev. – 10,790 to 11,960 feet
Average Snowfall = 400 in./year (1971-2000)

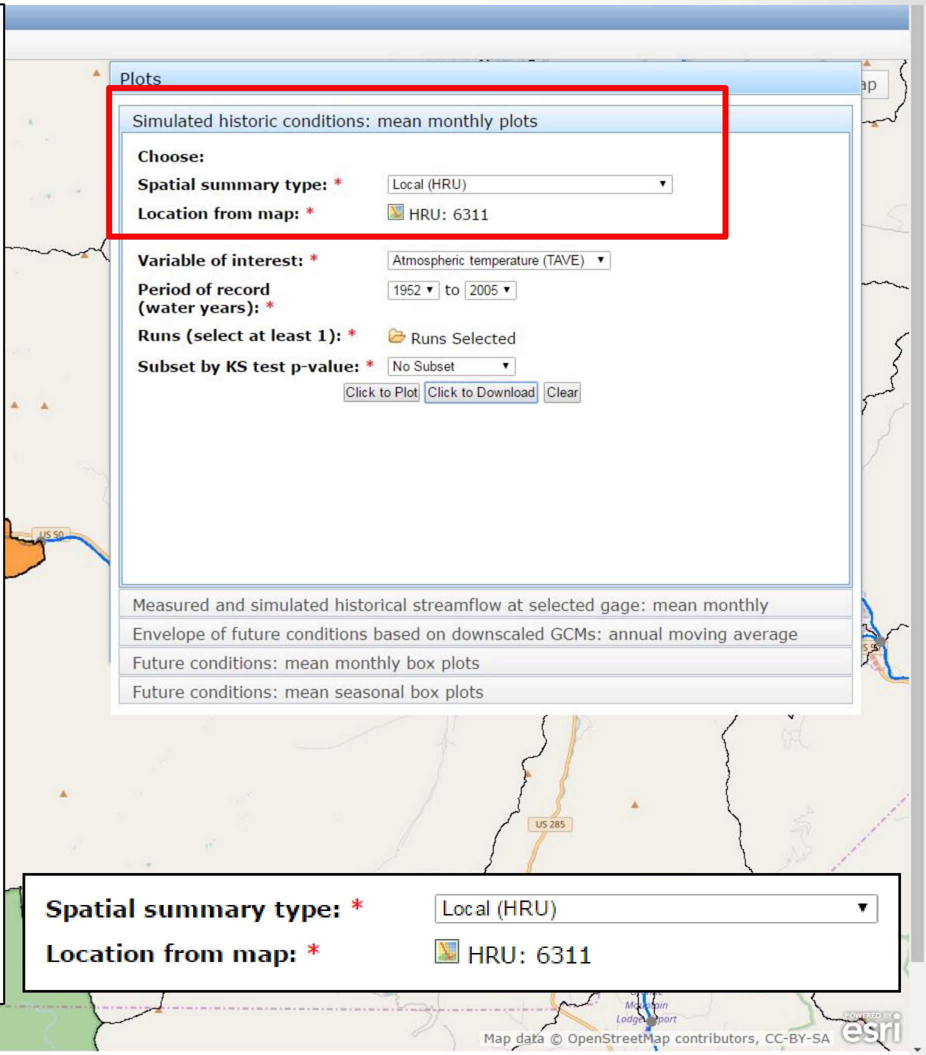
Monarch Ski Area (historical conditions, 1952 - 2005)



What's going on for historical conditions?

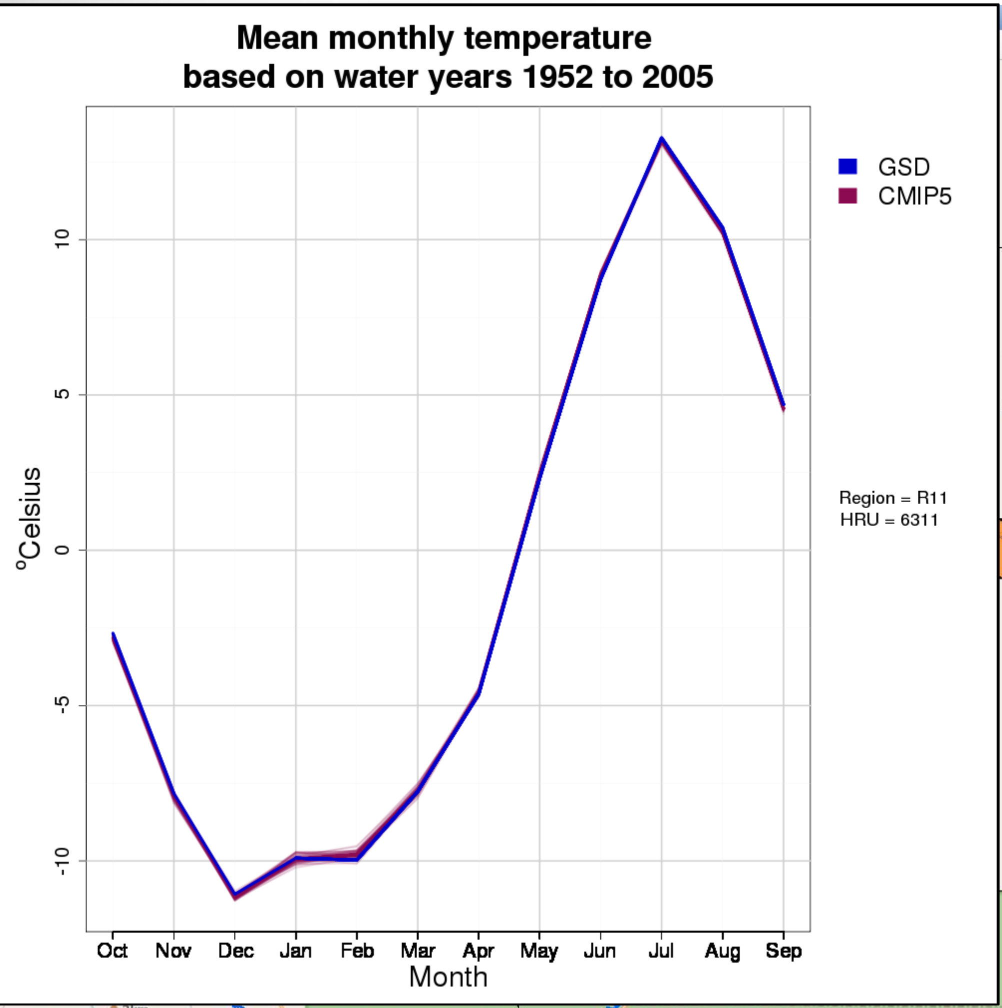
Monarch Ski Area (historical conditions, 1952 - 2005)

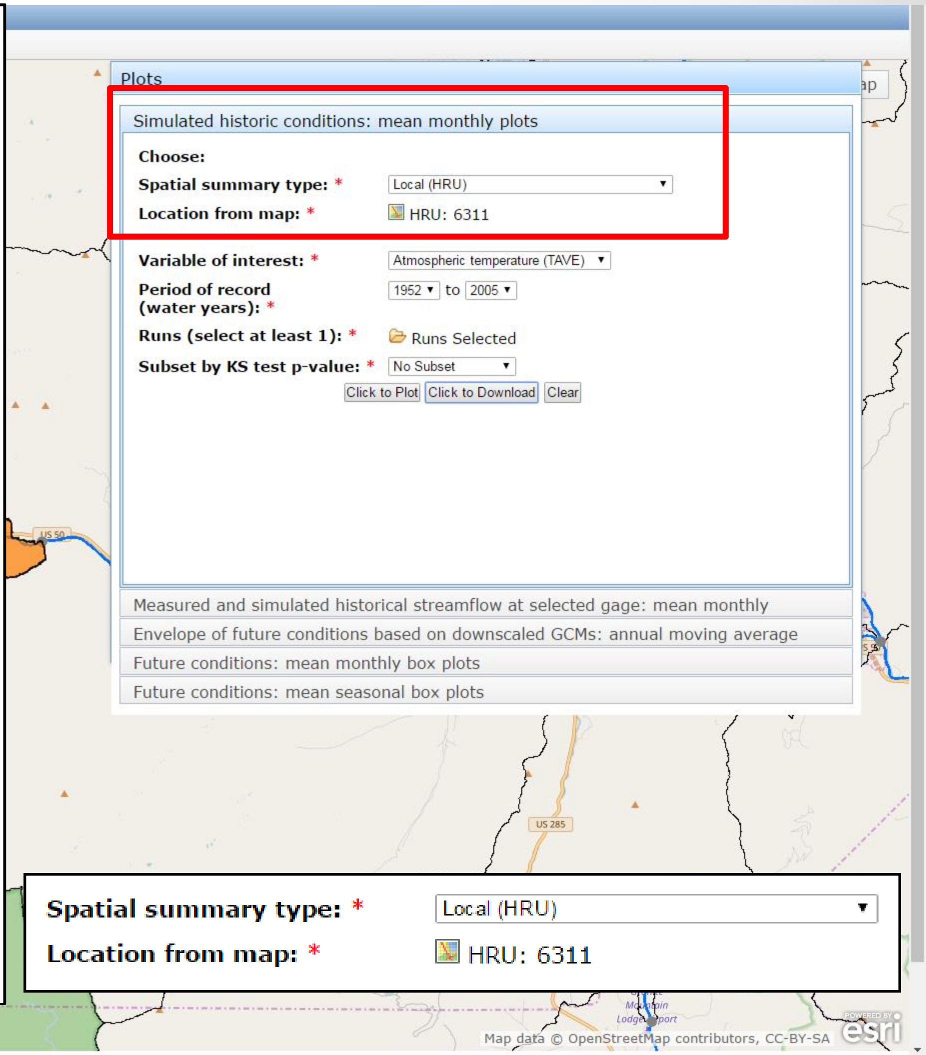




What's going on for historical conditions?

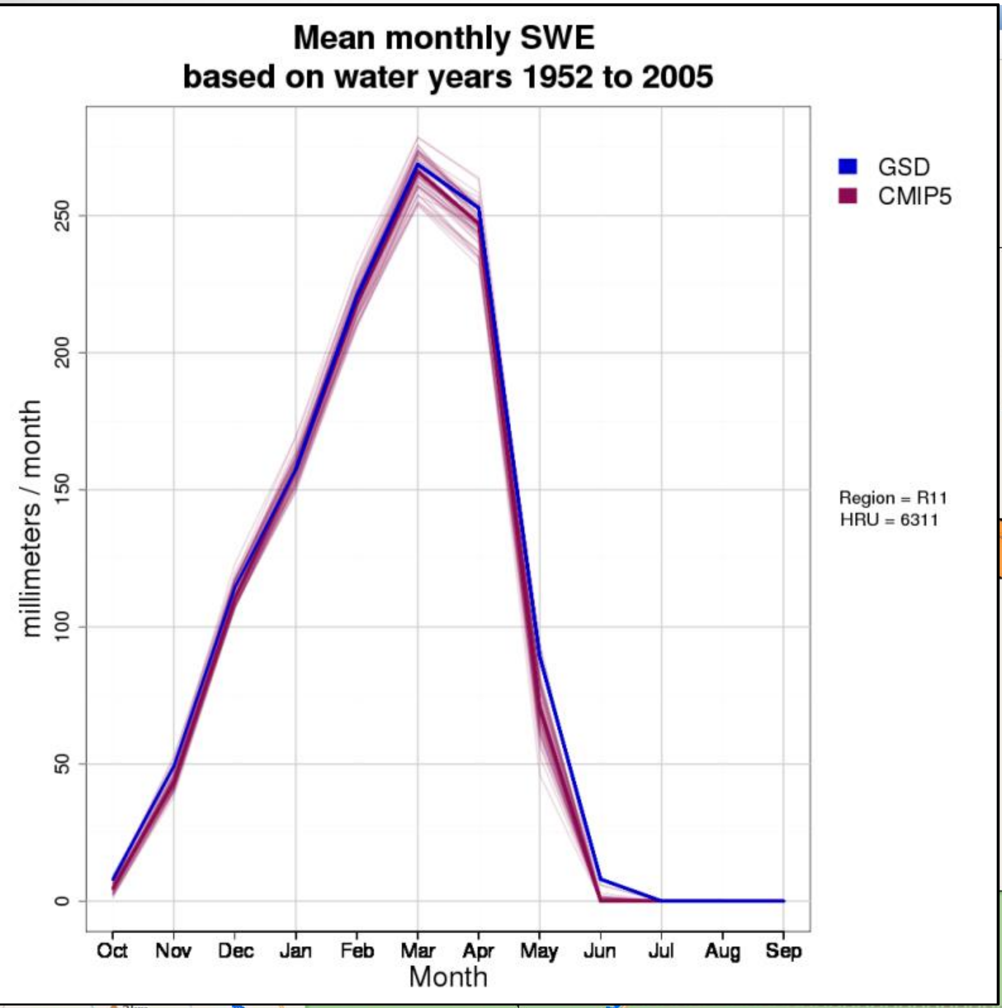
Monarch Ski Area (historical conditions, 1952 - 2005)

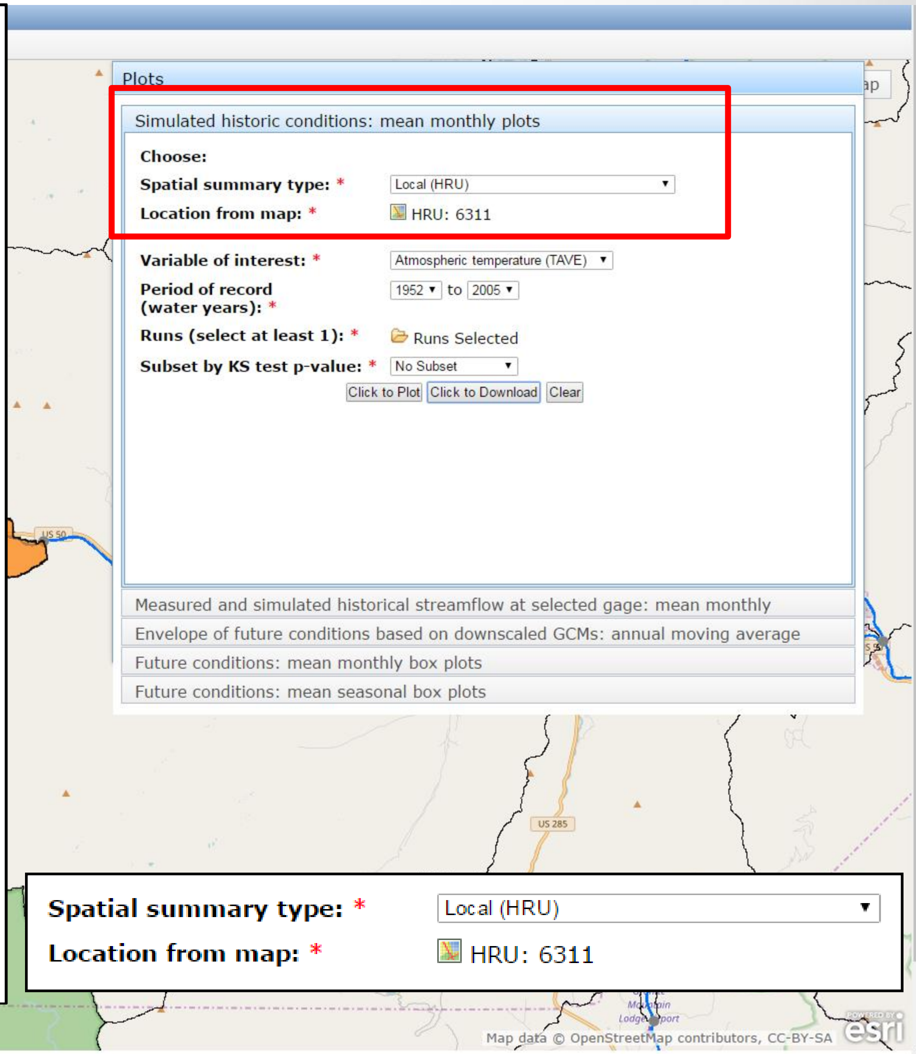




What’s going on for historical conditions?

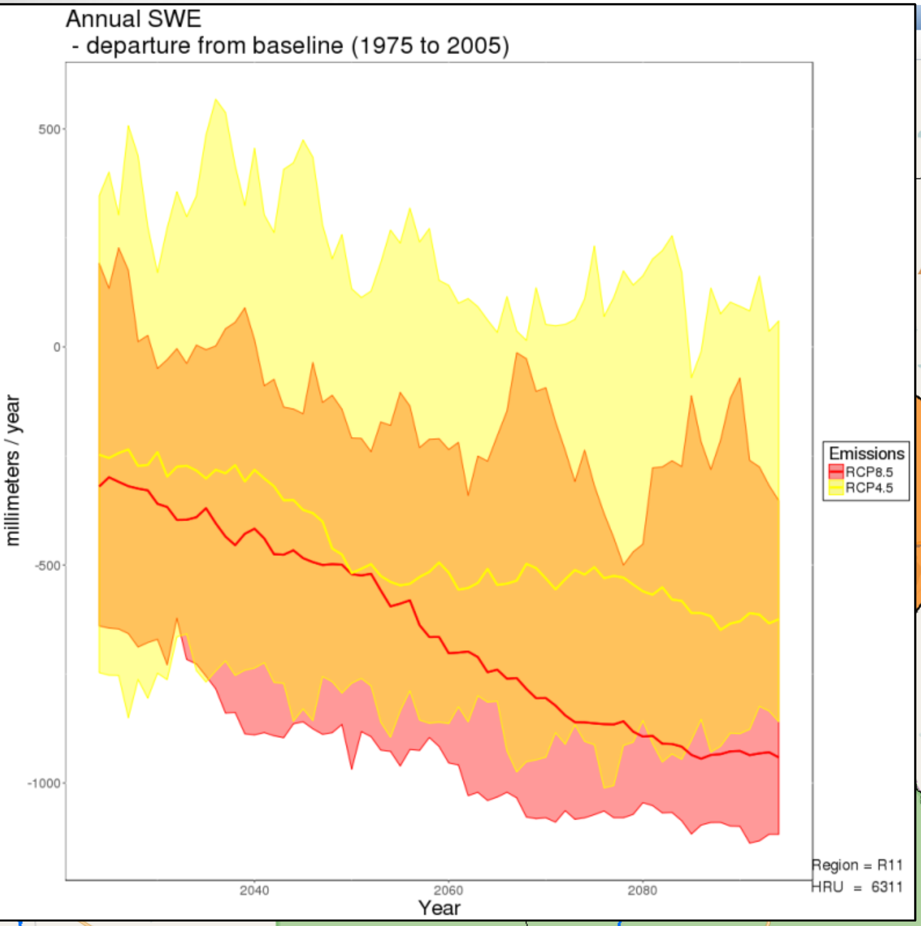
Monarch Ski Area (historical conditions, 1952 - 2005)

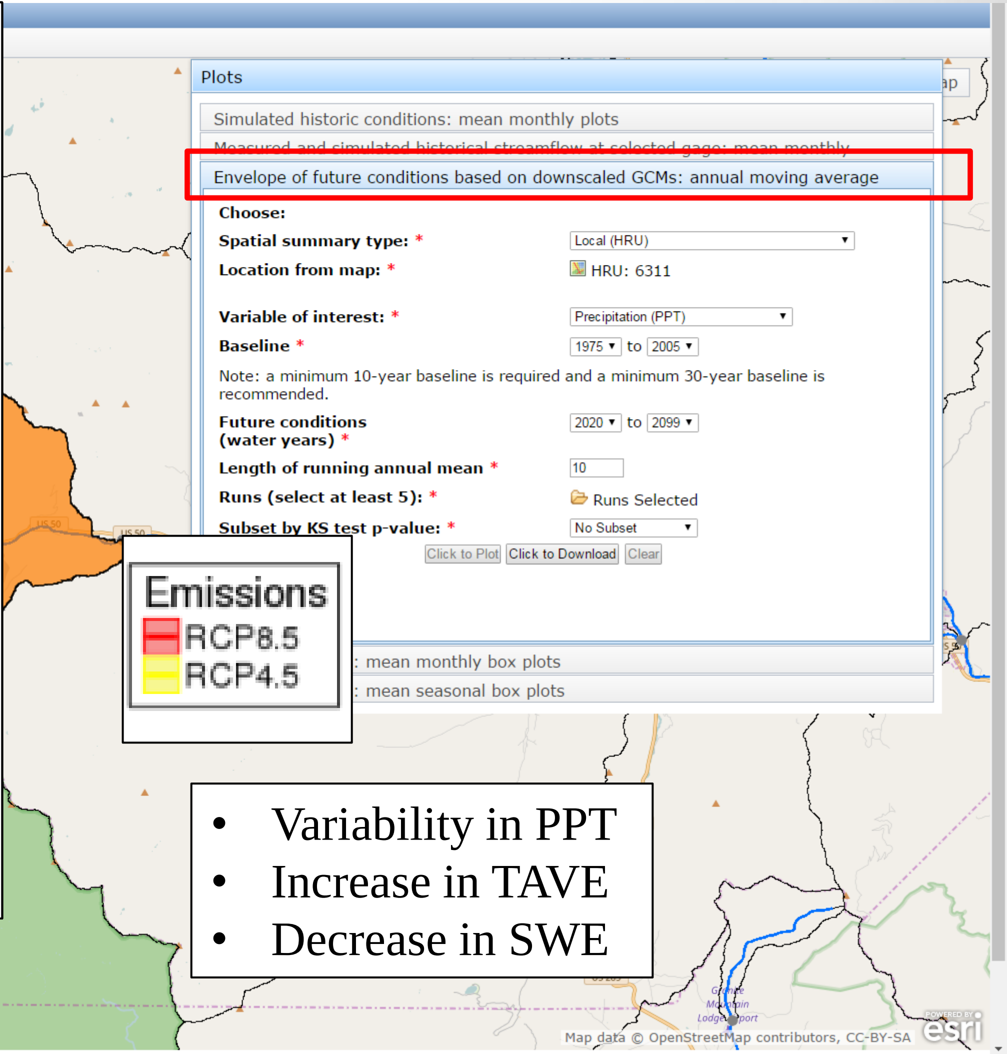




What's going on for historical conditions?

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

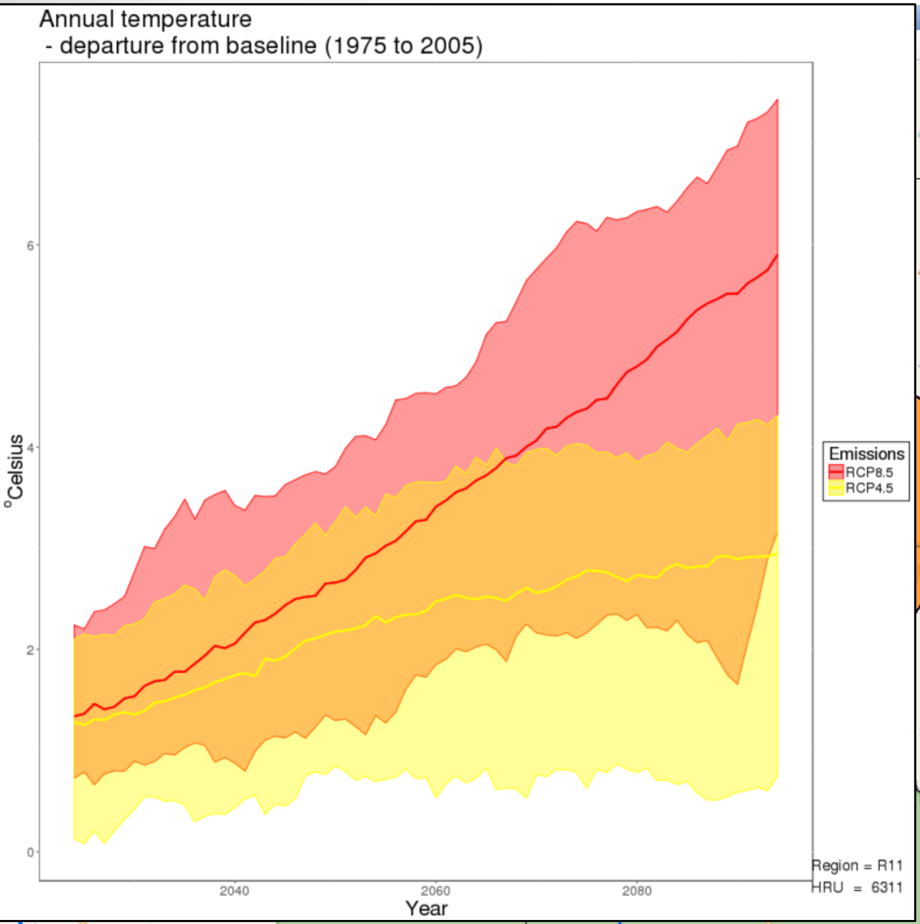


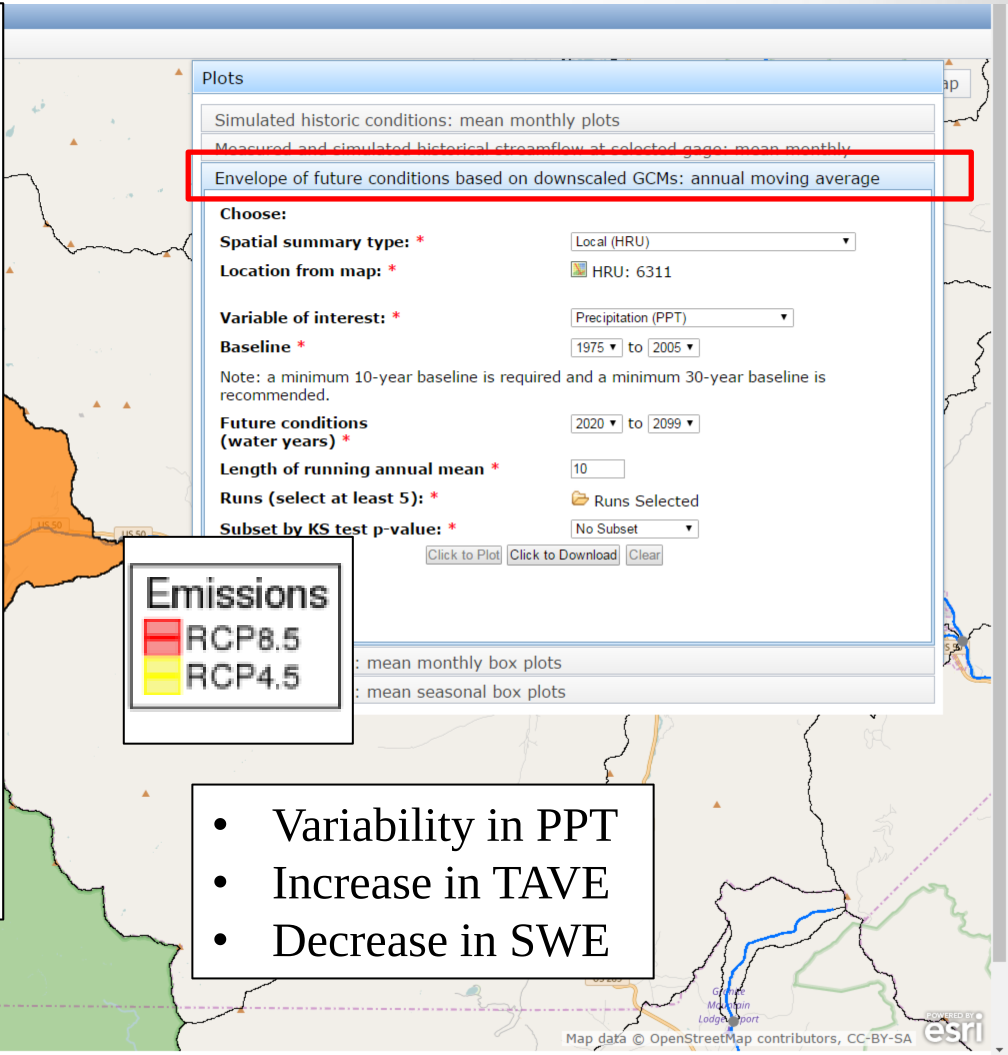


- Variability in PPT
- Increase in TAVE
- Decrease in SWE

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

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





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

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

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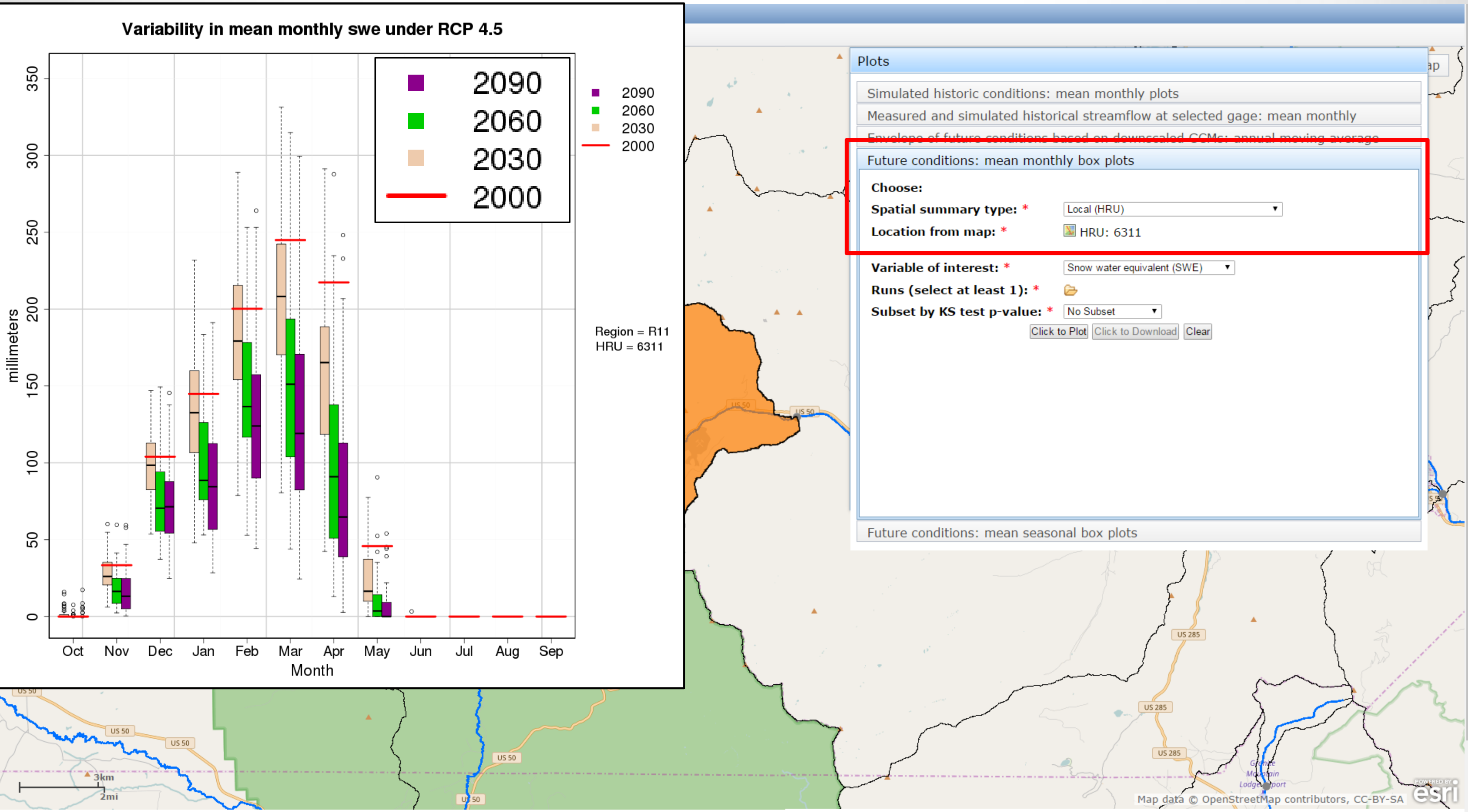
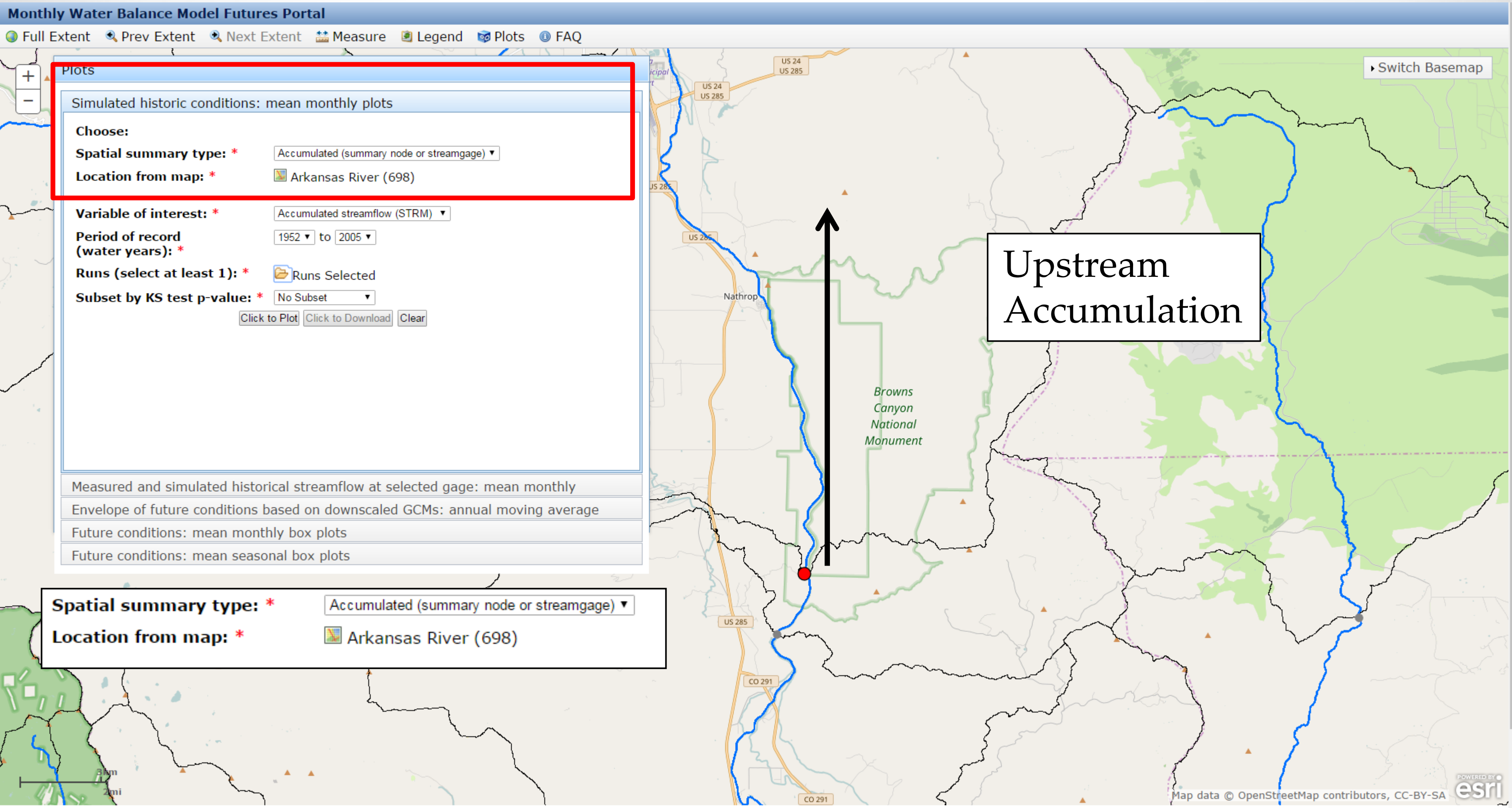
Monarch Ski Area (potential future scenarios, 2030/60/90)

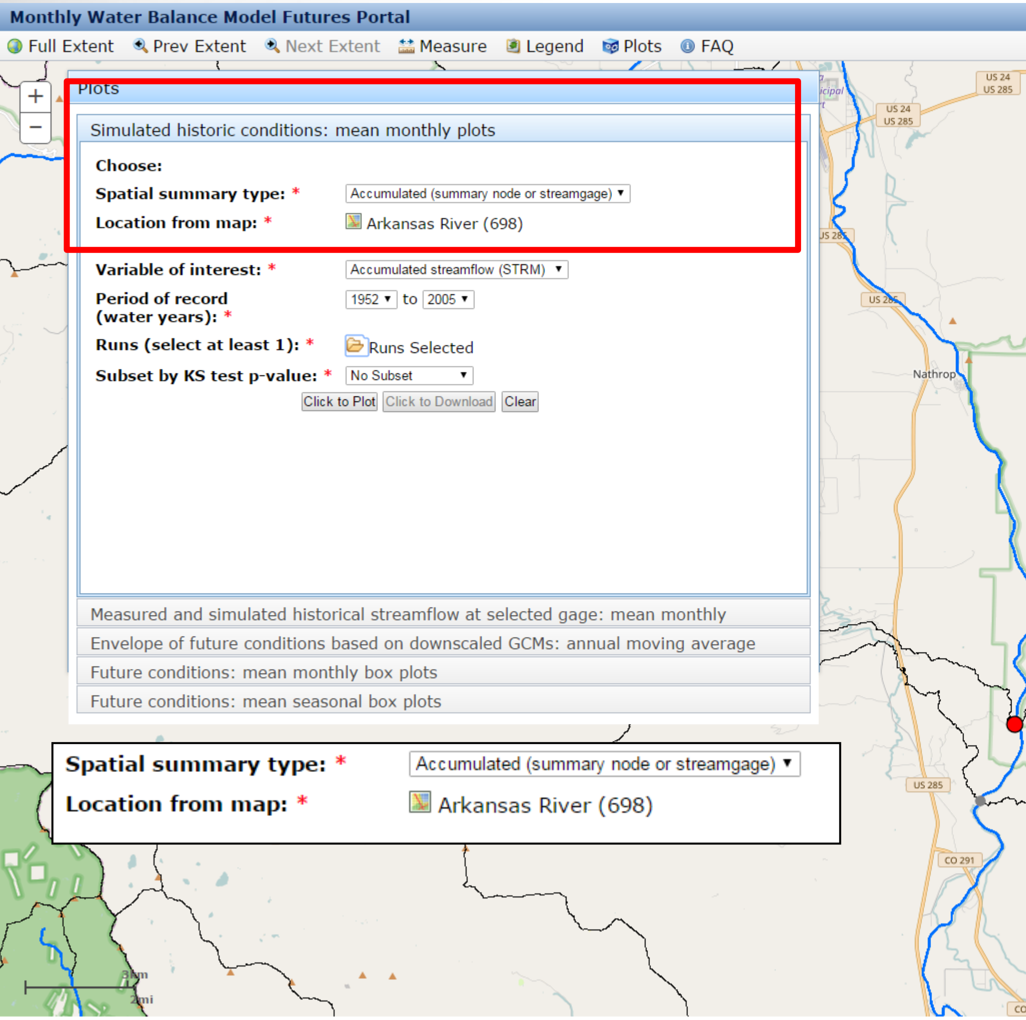


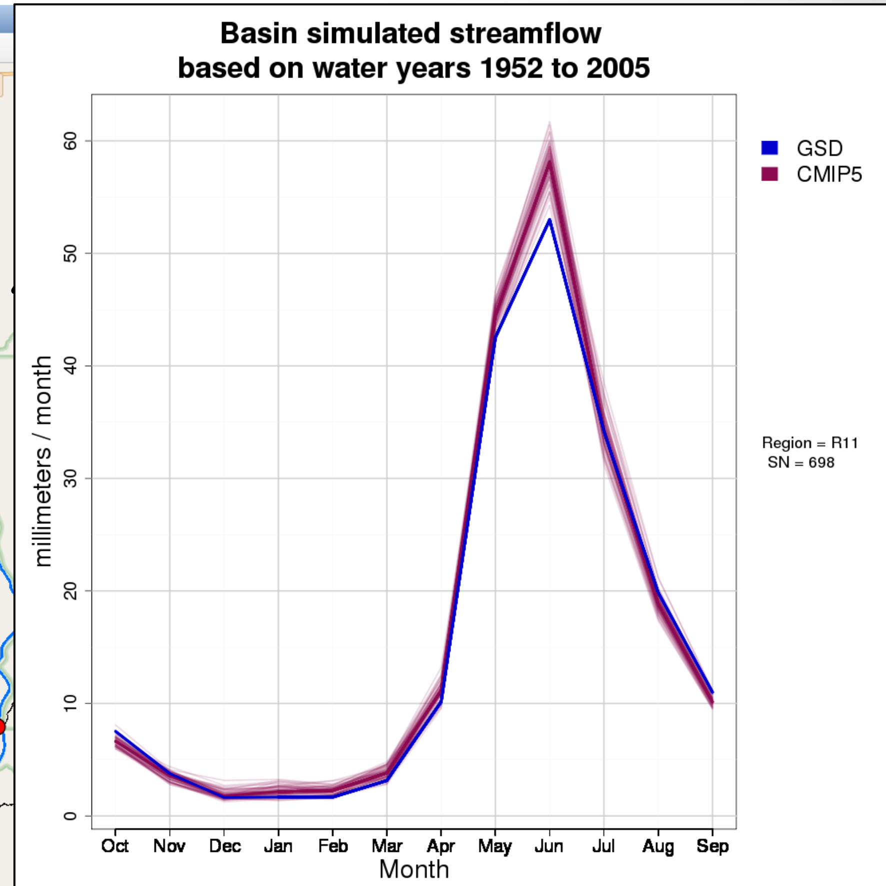
What does potential SWE look like for ski season?

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

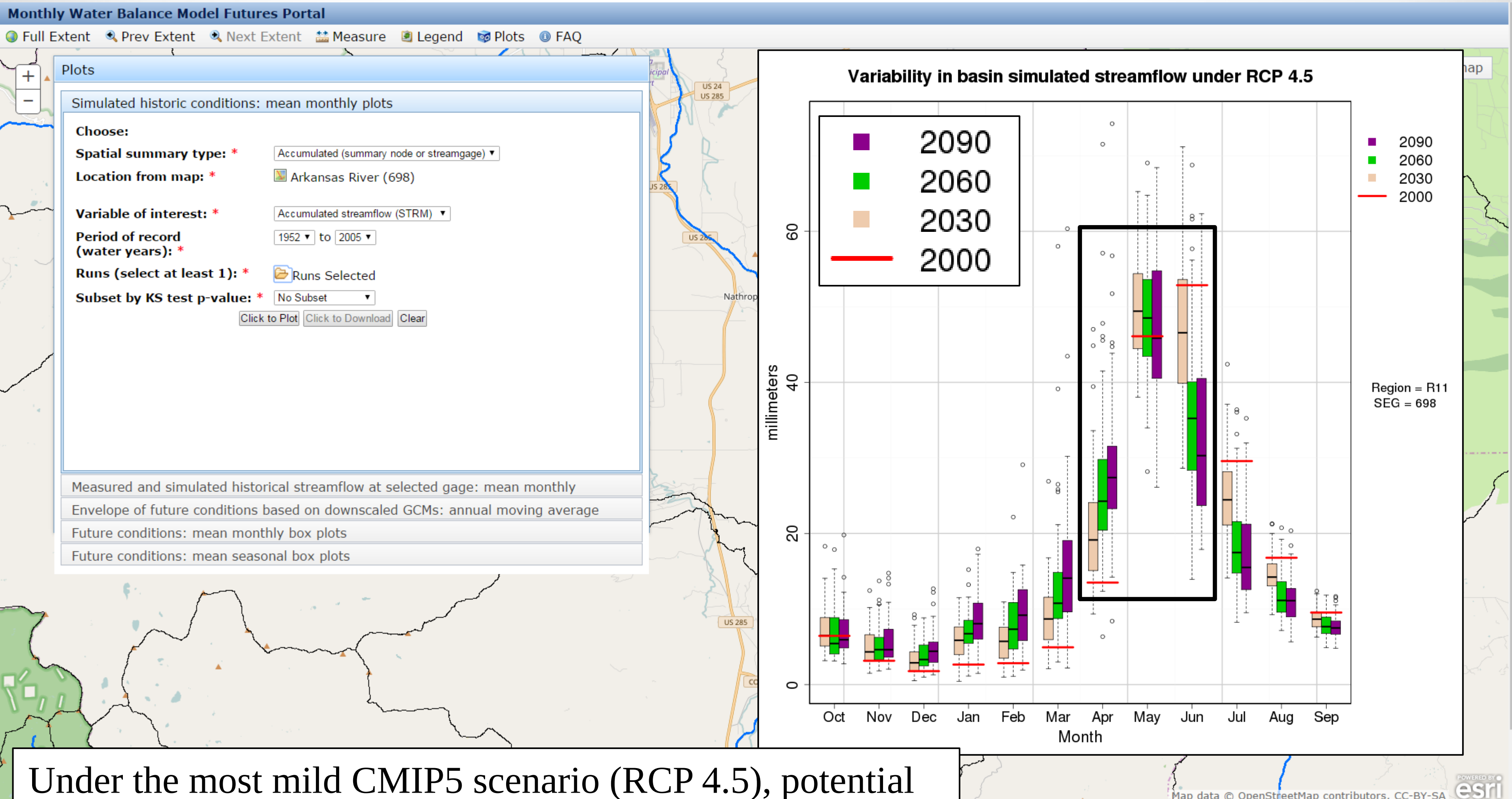


Brown's Canyon (historical conditions, 1952 - 2005)





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



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

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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., andGraumlich, 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.