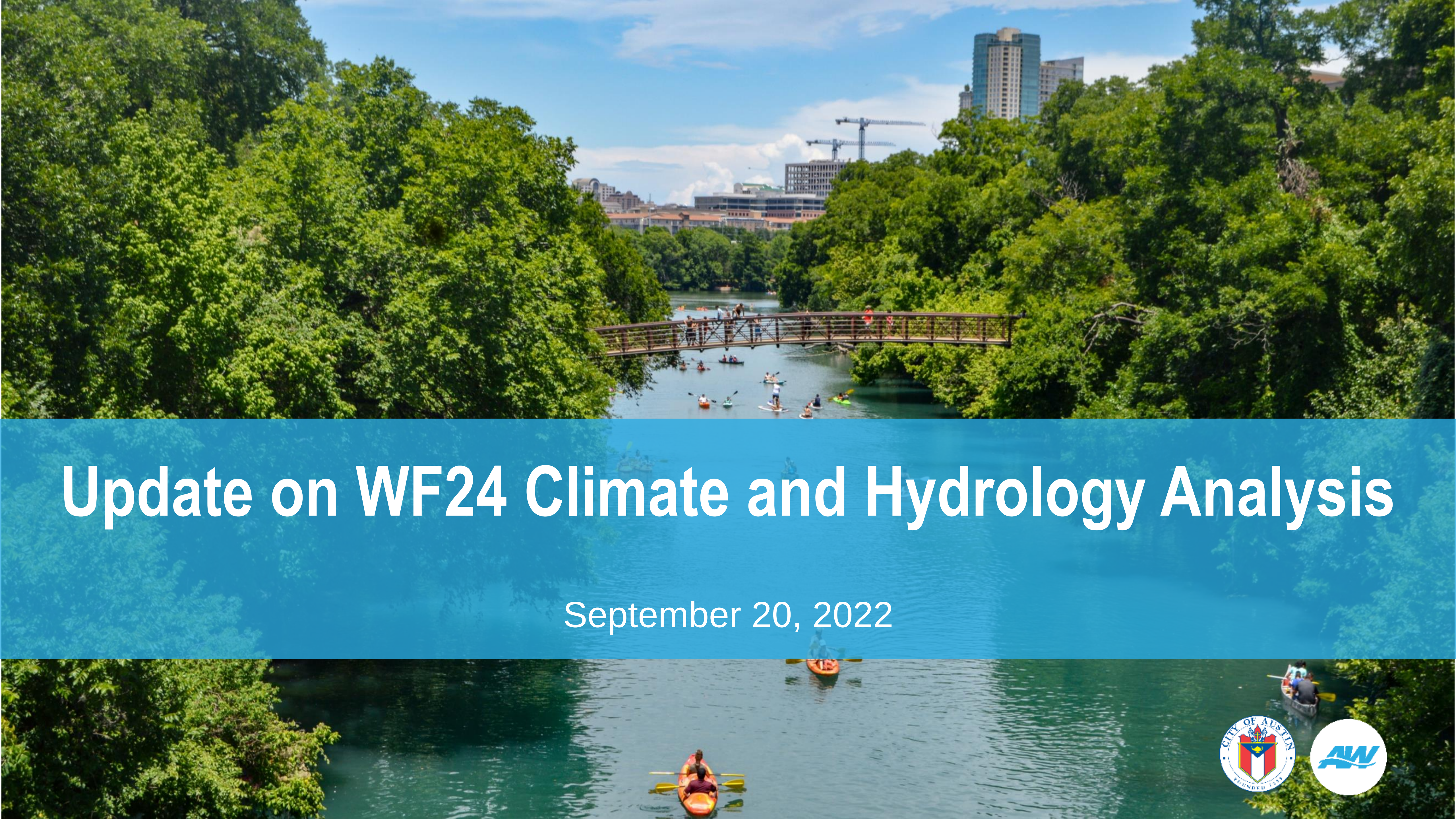
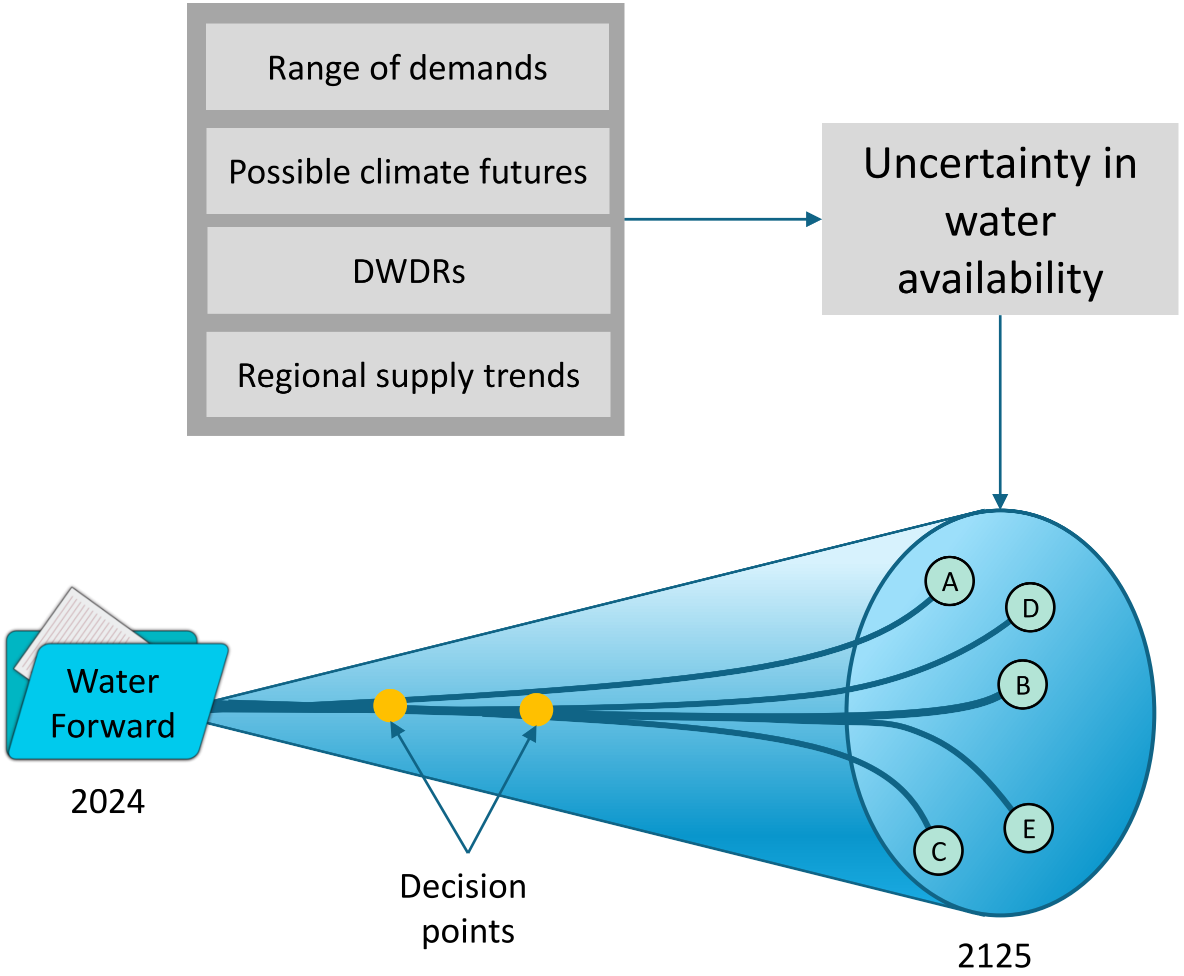


Update on WF24 Climate and Hydrology Analysis

September 20, 2022

Planning for Uncertainty

- Develop range of futures
- Find common near-term strategies that work for a broad range of futures
- Develop adaptive plan with key decision points
- Re-evaluate at key decision points



Goals of Climate & Hydrology Analysis Update

- Look at a range of possible future climate scenarios
- Identify high-level climate trends in the basin
- Generate climate change-adjusted streamflow data to test in the Water Forward Water Availability Model (WF WAM)

Differences from 2018 WF Plan

- Partnership with UT Austin
- Climate technical advisory group
- Looking at multiple climate scenarios
- New hydrologic models

Climate and Hydrology Analysis Update – Tasks

2022

2023

Task 1: Project management and external communication (WFTF, climate TAG, etc.)

Task 2: Select GCMs representative of the region to use for update

Task 3: Perform GCM downscaling and trend analysis

Task 4A/B: Develop hydrologic models to predict streamflow from downscaled GCM outputs

Task 4C: Generate time series of naturalized flows

Task 5: Package flow data for use in the WF Water Availability Model

Task 6: Develop stochastic drought sequences using historical and climate-adjusted hydrology

Task 7: Continue coordination with WF update process (communication, presentations, reports, etc.)

Through 2024

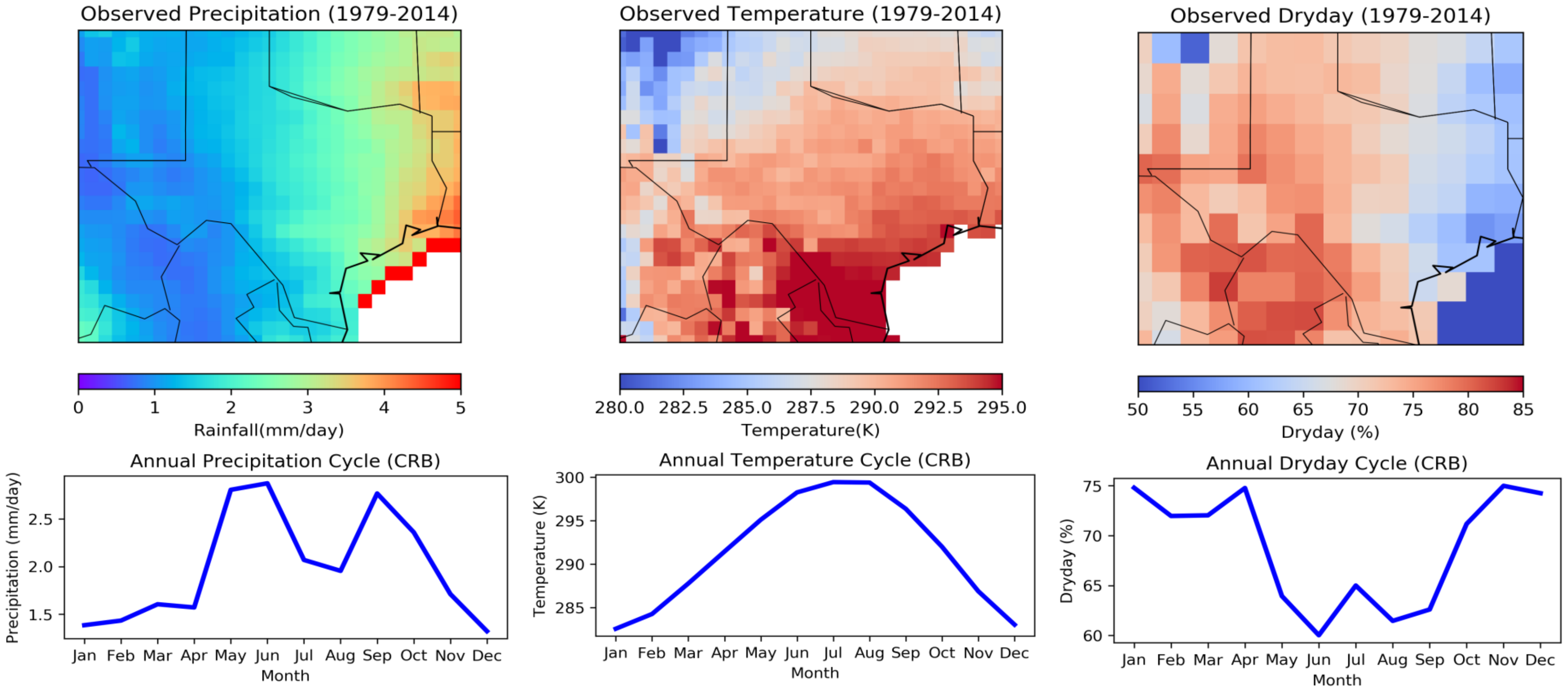
We are here

Selection of GCMs

- **What**: choose global climate models (GCMs) that best represent climate over the Colorado River Basin
- **Why**: want to use GCMs that can best project possible climate futures for the Colorado River Basin
- **How**: evaluate how well GCMs simulate historical climate over the Colorado River Basin and select the best performing set of models

Evaluation of GCMs

- Historical simulations of 35 global climate models (GCMs) from the Coupled Model Intercomparison Project Phase 6 (CMIP6) are evaluated on their ability to represent the following observed characteristics:



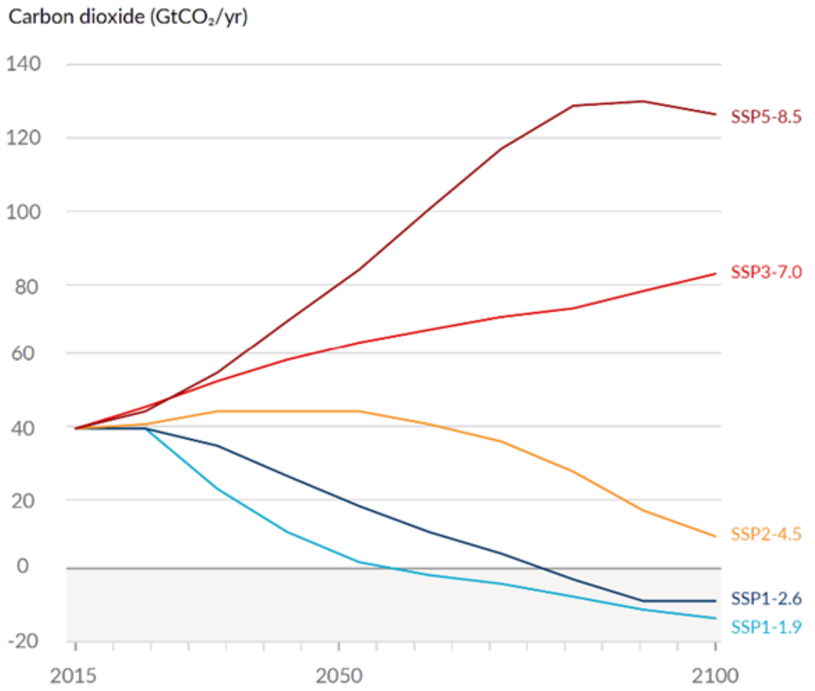
Top-scoring GCMs

Top 10 best-scoring GCMs based on model performance over the Colorado River Basin (CRB), as measured by skills scores (S)

Model	$S_{spatial,T}$	$S_{spatial,P}$	$S_{spatial,NDD}$	$S_{temporal,T}$	$S_{temporal,P}$	$S_{temporal,NDD}$	$S_{overall}$	Ranking
CNRM-CM6-1-HR	0.90	0.94	0.97	0.98	0.63	0.55	0.864	1
HadGEM3-GC31-MM	0.93	1.00	0.96	0.94	0.21	0.68	0.845	2
UKESM1-0-LL	0.92	0.88	0.70	0.94	0.75	0.68	0.818	3
HadGEM3-GC31-LL	0.91	0.91	0.70	0.95	0.54	0.75	0.809	4
CNRM-CM6-1	0.90	0.79	0.72	0.96	0.72	0.70	0.801	5
CNRM-ESM2-1	0.91	0.82	0.75	0.95	0.65	0.63	0.798	6
KACE-1-0-G	0.91	0.94	0.79	0.94	0.08	0.72	0.779	7
GFDL-ESM4	0.91	0.78	0.81	0.94	0.54	0.49	0.775	8
ACCESS-CM2	0.89	0.95	0.77	0.95	0.31	0.33	0.758	9
EC-Earth3	0.91	0.95	0.95	0.92	0.13	0.04	0.747	10

Selected GCMs

Climate Scenario #	CMIP6 SSP emission scenarios	Average End-of-Century Warming for CRB (°F)	Selected GCMs
1	1-2.6	4.4	ACCESS-CM2 CNRM-CM6-1 EC-Earth3 KACE-1-0-G UKESM1-0-LL
2	2-4.5	6.6	
3	5-8.5	11.6	



(image source: IPCC, 2021)

- Different Shared Socioeconomic Pathways (SSPs) for different greenhouse gas emission scenarios according to different climate policies
- Number of GCMs and emission scenarios selected covers a wide range of possible futures
- Wide range of possibilities will support robust decision-making approach

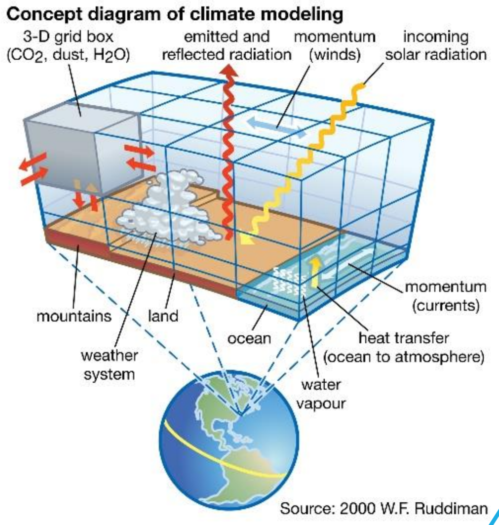
Downscaling and bias correction of GCM data

- **What**: downscale and bias correct data outputs from the global climate models into data that can be used over the Colorado River Basin
- **Why**: improves data resolution in the area of interest and removes biases in GCM data to allow for more in-depth analysis
- **How**: use statistical downscaling over the Colorado River Basin and bias correct downscaled GCM data based on statistical relationship with observed data

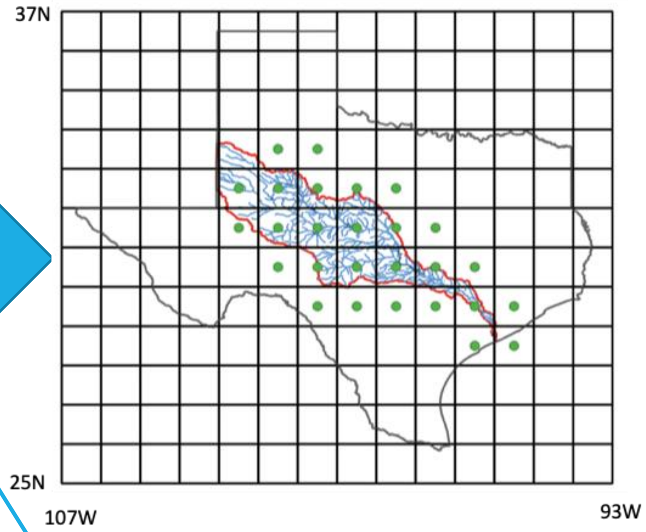
Downscaling process

Effectively bias-corrects modelled evaporation to match observation (TWDB monthly total lake evaporation)

Outputs of Global Climate Model (GCM)



27 1-degree grids bordering the Colorado River Basin



Regrid

Bilinear Interpolation

Daily Maximum and Minimum Temperature

Hargreaves Evapotranspiration equation

Nearest Neighbor Interpolation

Daily Precipitation

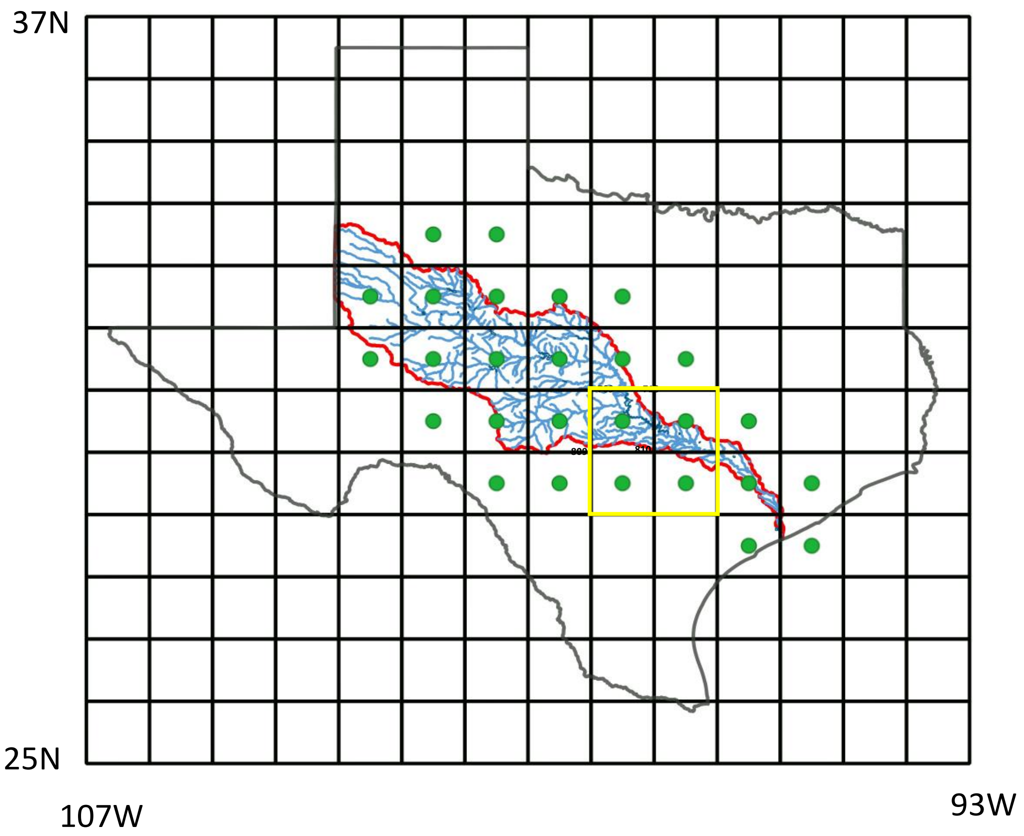
Monthly Total Lake Evaporation (Inch/Month)

Trend analysis of downscaled GCM data

- **What**: examine GCM projections of future climate and identify relevant trends in the data
- **Why**: trends in the data help us determine if temperature is generally increasing across all scenarios, if rainfall is generally decreasing, etc.
- **How**: Compare GCM future projections to historical data and identify differences

Trend analysis process

- Trend analysis performed on the variables below calculated using bias-corrected daily temperature and precipitation :
  - Annual average precipitation and temperature
  - Number of days in a year with precipitation below 0.01 inch (dry days)
  - Number of days in a year with precipitation above 2 inches (wet days)
  - Number of days in a year with maximum temperature above 90°F (hot days)
  - Number of days in a year with maximum temperature above 100°F (hot days)
  - Number of days in a year with minimum temperature below 32°F (cold days/nights)
  - Annual maximum 5-day total precipitation
- Trend analysis over Austin and CRB



Projected high-level climate trends in the basin

Based on initial results

Temperature

- Annual mean temperature is projected to increase
- Number of hot days with temperatures above 100°F are projected to increase

Rainfall

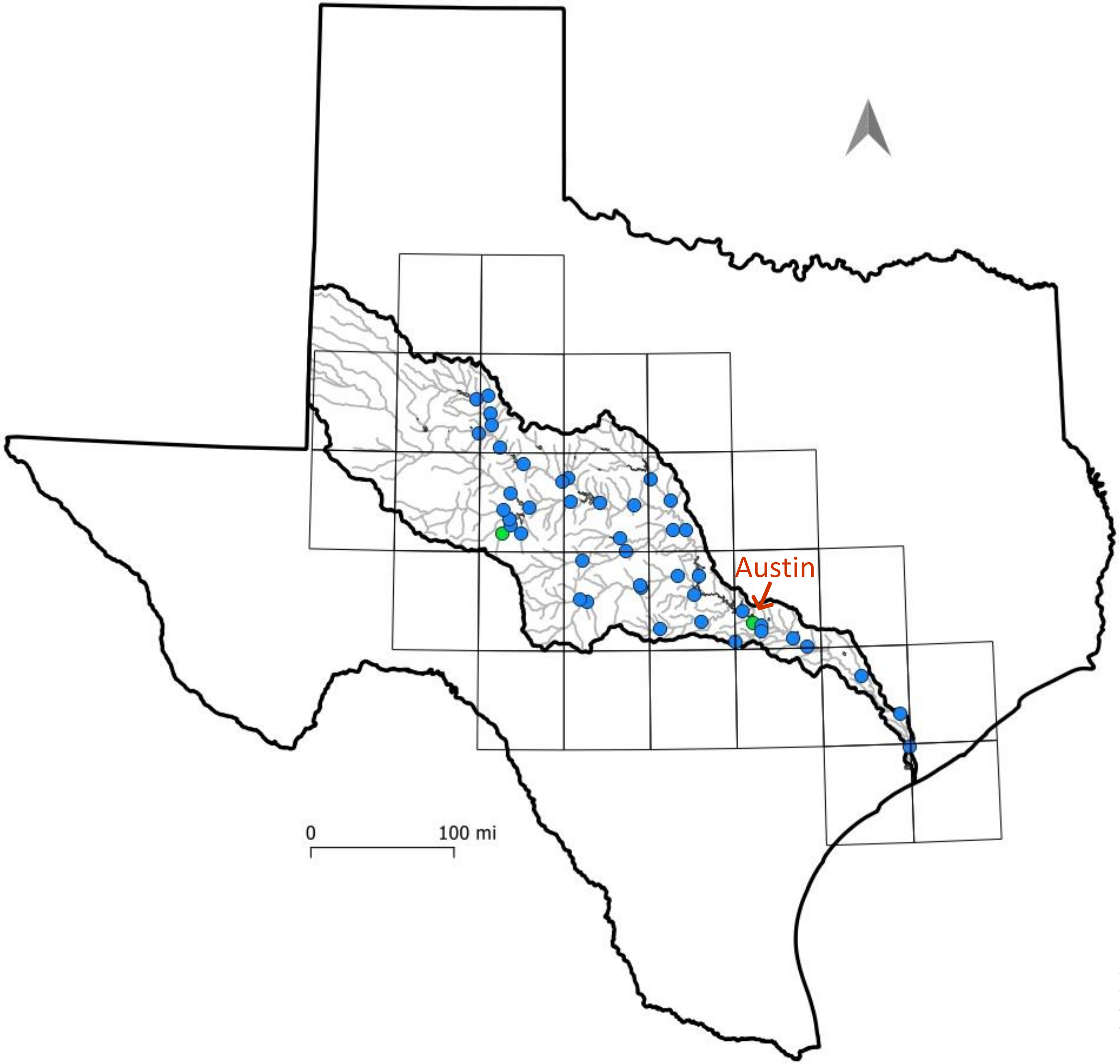
- Rainfall distribution is projected to change
- Less frequent and more intense rainfall events are projected

Dry Days

- Number of dry days with precipitation below 0.01” are projected to increase

Projection of streamflows using GCM data

- **What**: use precipitation and temperature data across the Colorado River Basin to develop streamflow projections
- **Why**: streamflow projections will be used in the water availability model to evaluate portfolios of strategies across future time horizons
- **How**: considered 2 modeling methods: runoff projections from GCM datasets and multivariate model similar to the method used in WF18



Colorado River Basin

- 31,000 square miles of drainage area
- 45 control points for flow inputs to the WAM
- 27 weather locations (quadrangles)

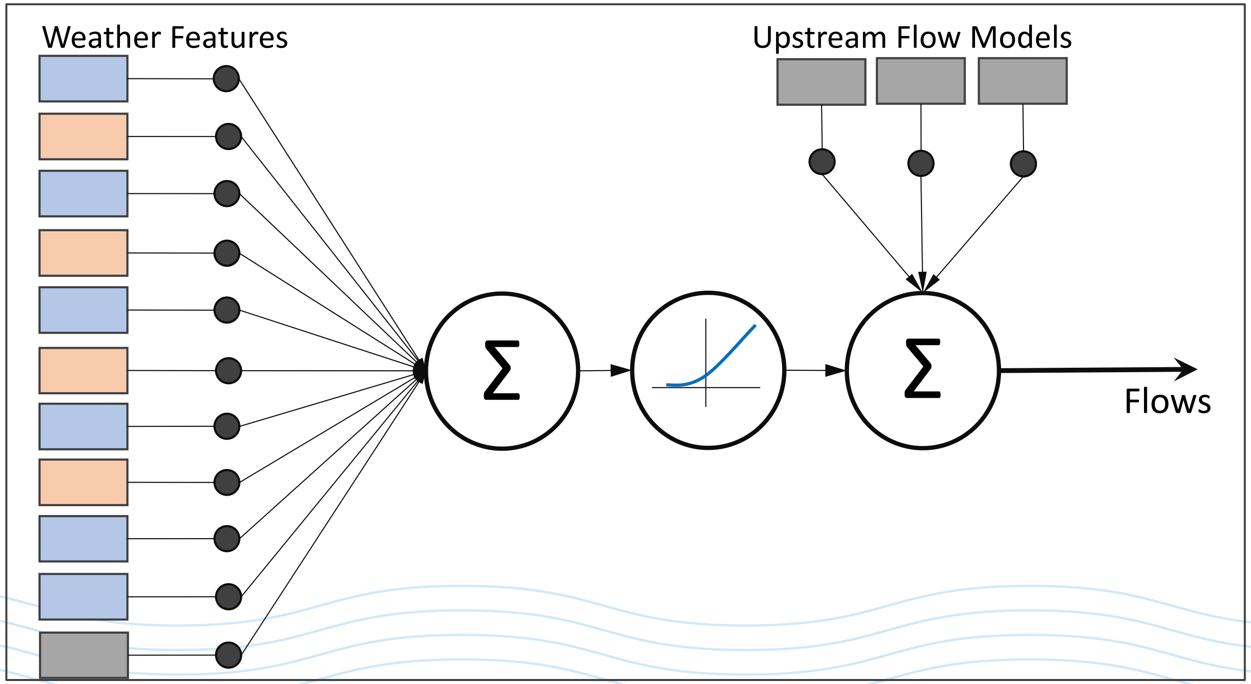
Precipitation and Temperature Features

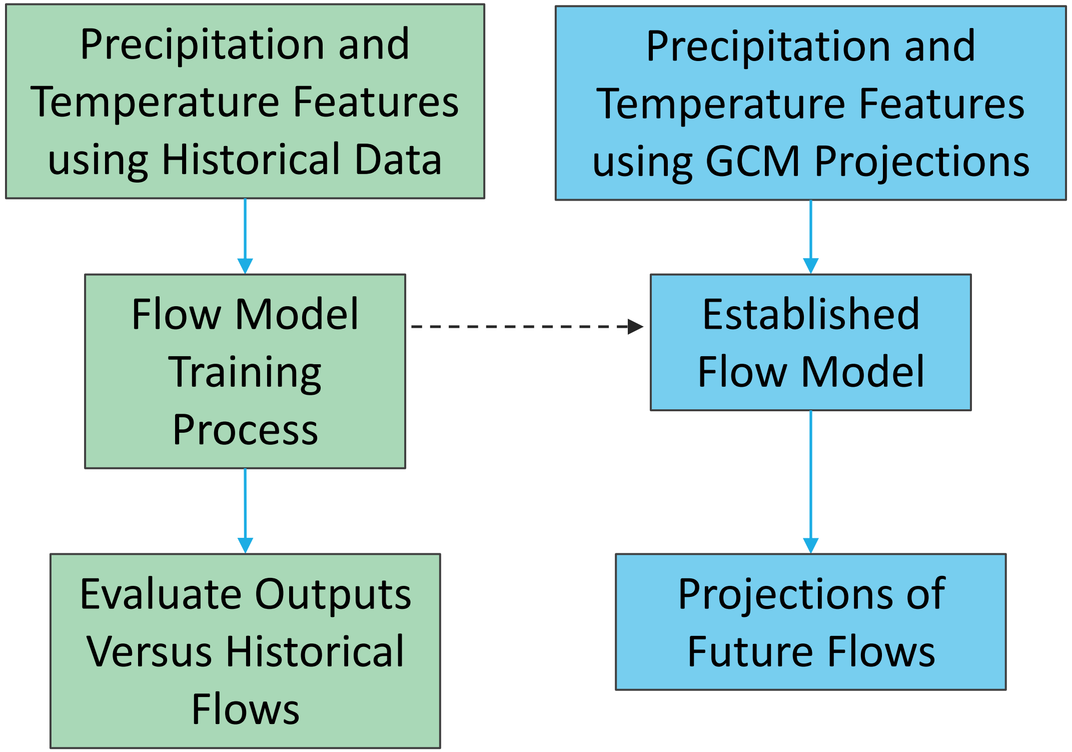
- Features created using measures of precipitation and temperature time series from nearby quadrangles
- 10 unique features selected for each flow control point
- Features selected for relevancy to flow at each location, and minimum redundancy between features

Pedernales River near Johnson City	Colorado River at Austin
Precipitation Exp. Avg., n = 6	Precipitation Exp. Avg., n = 4
Maximum Temperature Arith. Avg., 17 months	Minimum Temperature Arith. Avg., 11 months
Dry Days Exp. Avg., n = 11	Dry Days Exp. Avg., n = 24
Precipitation > 0.25” per day Arith. Avg., 13 months	Dry Days Current month only
Dry Days Exp. Avg., n = 2	Dry Days Arith. Avg., 4 months
Precipitation-Evaporation Arith. Avg., 8 months	Precipitation > 2” per day Current month only
Hottest 7 days per month Arith. Avg., 13 months	Precipitation-Evaporation Arith. Avg., 12 months
Max of daily Precip.-Evap. Exp. Avg., n = 8	Precipitation > 1” per day Current month only
Precip.-Evap. > 2” per day Exp. Avg., n = 2	Precip.-Evap. > 2” per day Arith. Avg., 3 months
Precip.-Evap. > 1” per day Arith. Avg., 2 months	Precipitation Arith. Avg., 7 months

Flow Model Framework, Training, and Projections

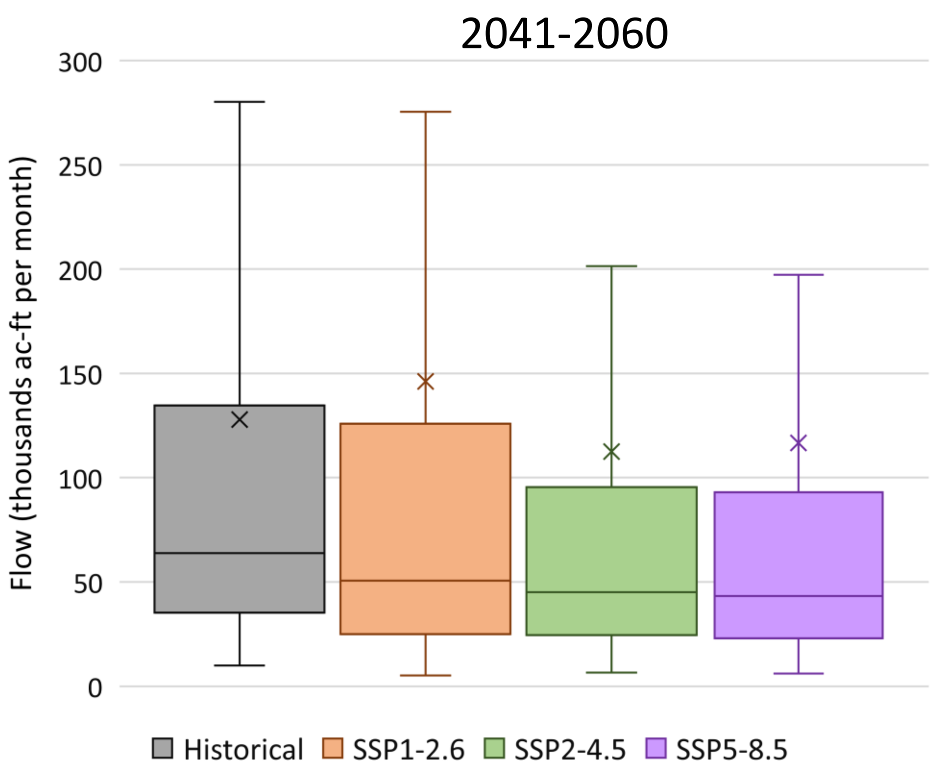
- Neural network flow models
- Flow models connect to downstream control point models

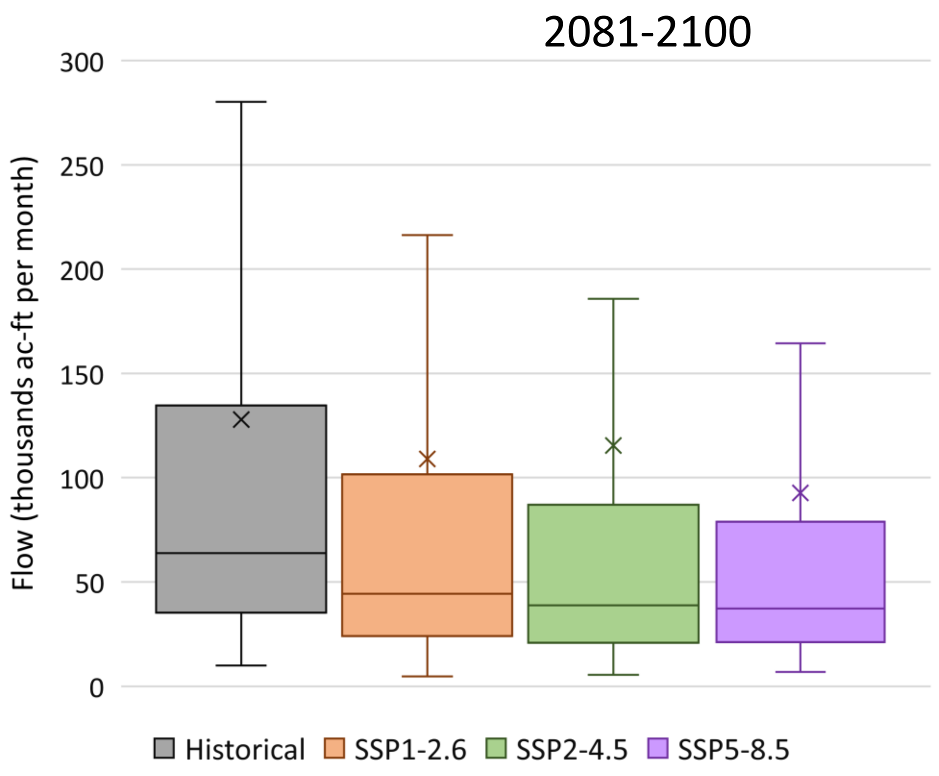




Flow Projection Overview

- Projections show greater frequency of lower flows as the climate warms over time.
- Extreme high flow events can increase in magnitude.





Climate & Hydrology Analysis Next Steps

- Create ensembles of streamflow data for testing in the WF WAM
- Develop stochastic streamflow series for both historical and climate-adjusted data
- Test water management strategies against all possible streamflow series developed
  - Determine which strategies perform best over the most scenarios

Questions?

Austin WATER