Weather Generator & Surface Water Modeling
Lower Santa Cruz River Basin Study

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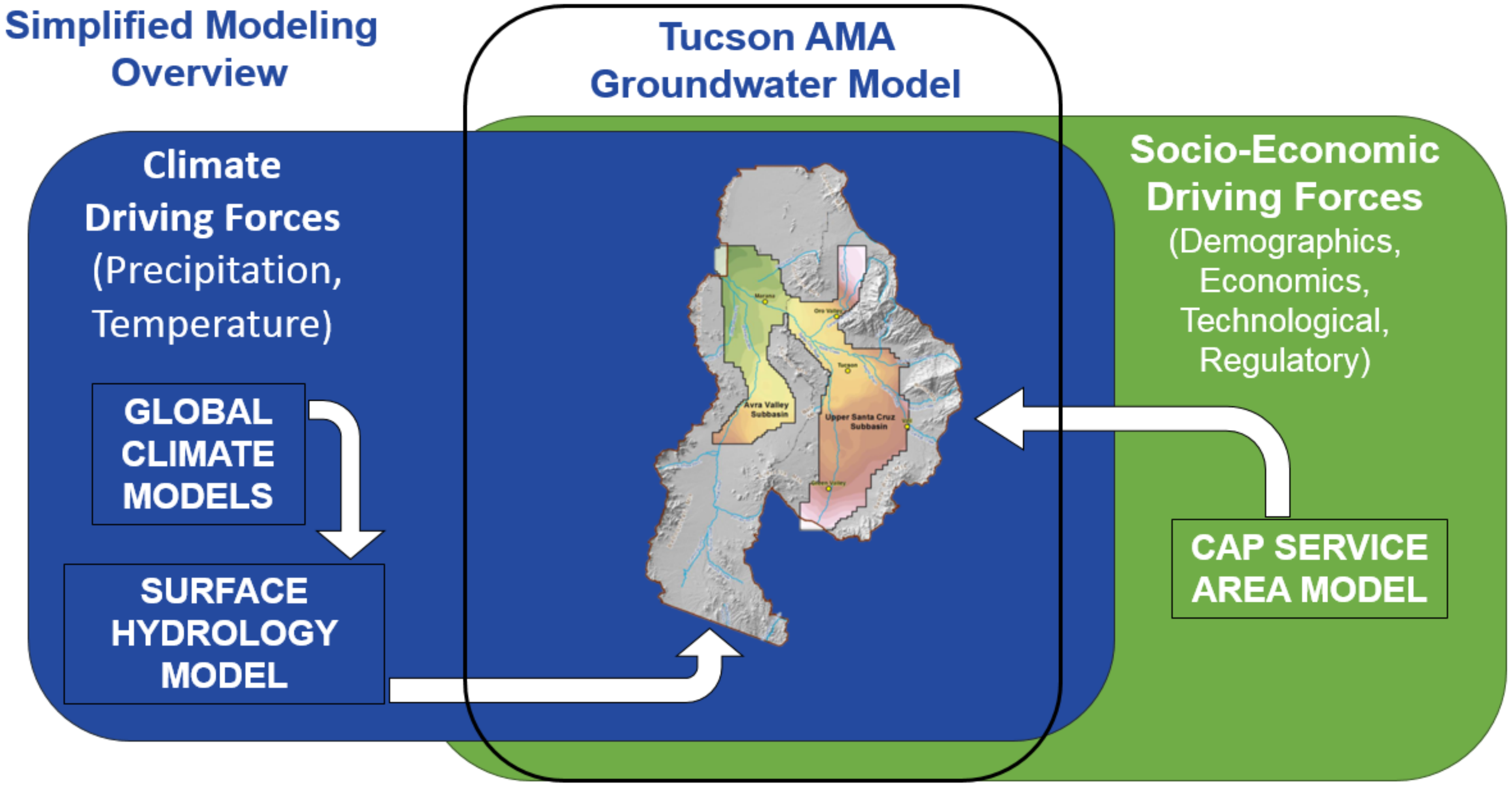
May 23, 2019 | Basin Study All Teams Meeting

RECLAMATION

OUTLINE

1. Introduction
2. Climate Scenarios
3. Weather Generator
4. Surface Water
5. Discussion



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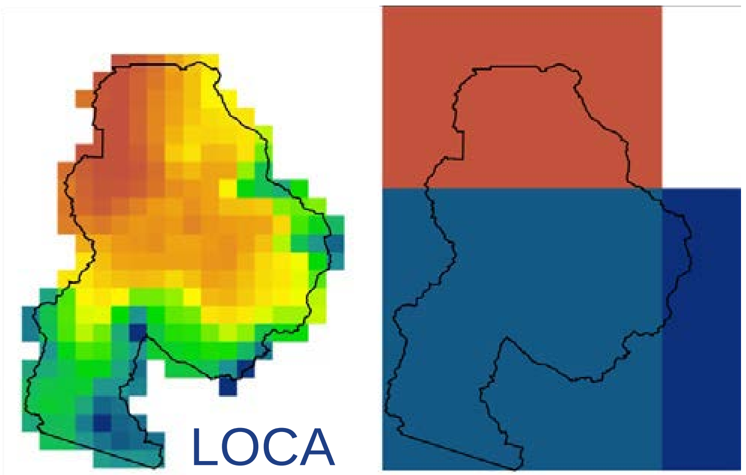
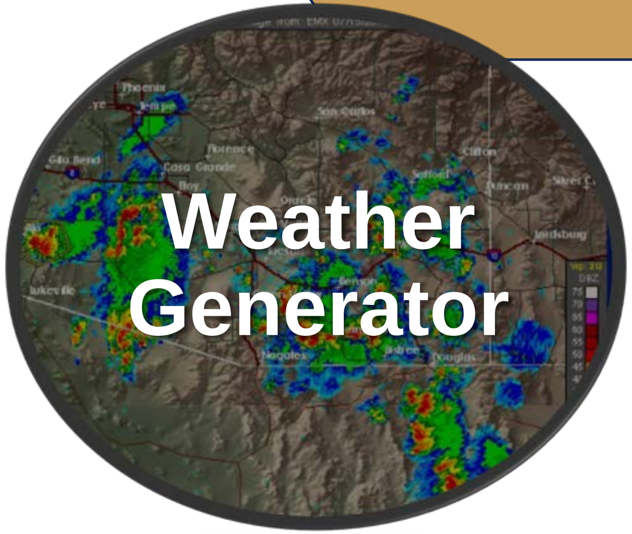
Process Overview

1. Downscaled Climate Projections

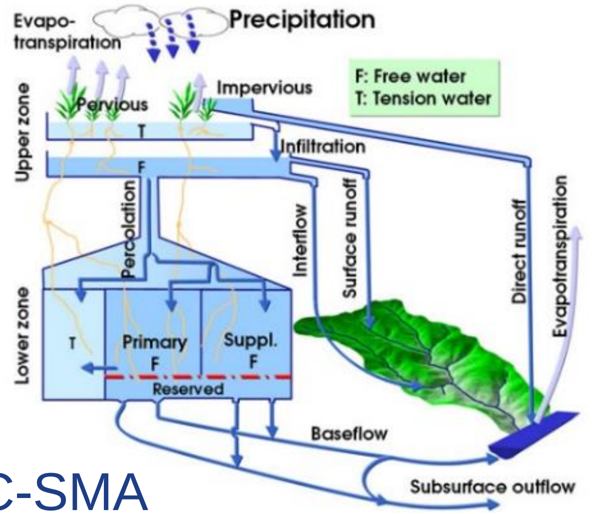


LOCA ~GCM

Precipitation & Temperature



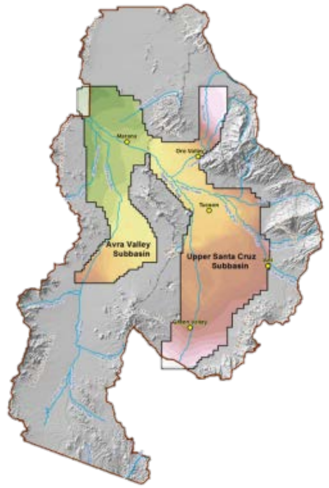
2. Surface Water Modeling



SAC-SMA

RECHARGE

3. Groundwater Modeling



TAMA

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Future Climate Scenarios

Worse: Based on **RCP 8.5** DD data

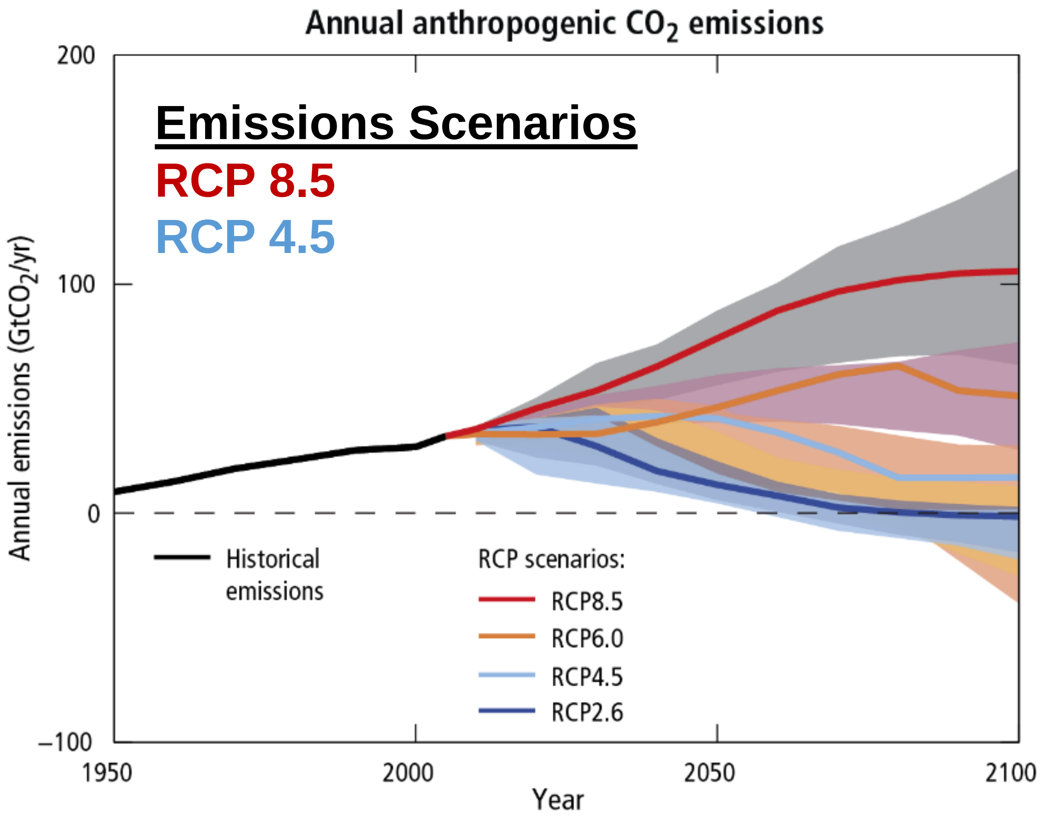
Dynamically Downscaled (DD): WRF

Weather Research and Forecasting Model (https://www.mmm.ucar.edu/weather-research-and-forecasting-model)

Best: Based on **RCP 4.5** SD data

Statistically Downscaled (SD): LOCA

Localized Constructed Analogs (http://loca.ucsd.edu/)
DD not available for RCP 4.5



RCP = Representative Concentration Pathways
From CMIP5 climate model intercomparison

LOCA Best Practices and Limitations

For more information on the ensemble of LOCA projections and analysis over the LSCR basin, see the draft report titled: *Lower Santa Cruz River Basin Study LOCA-derived Hydroclimate Assessment*.

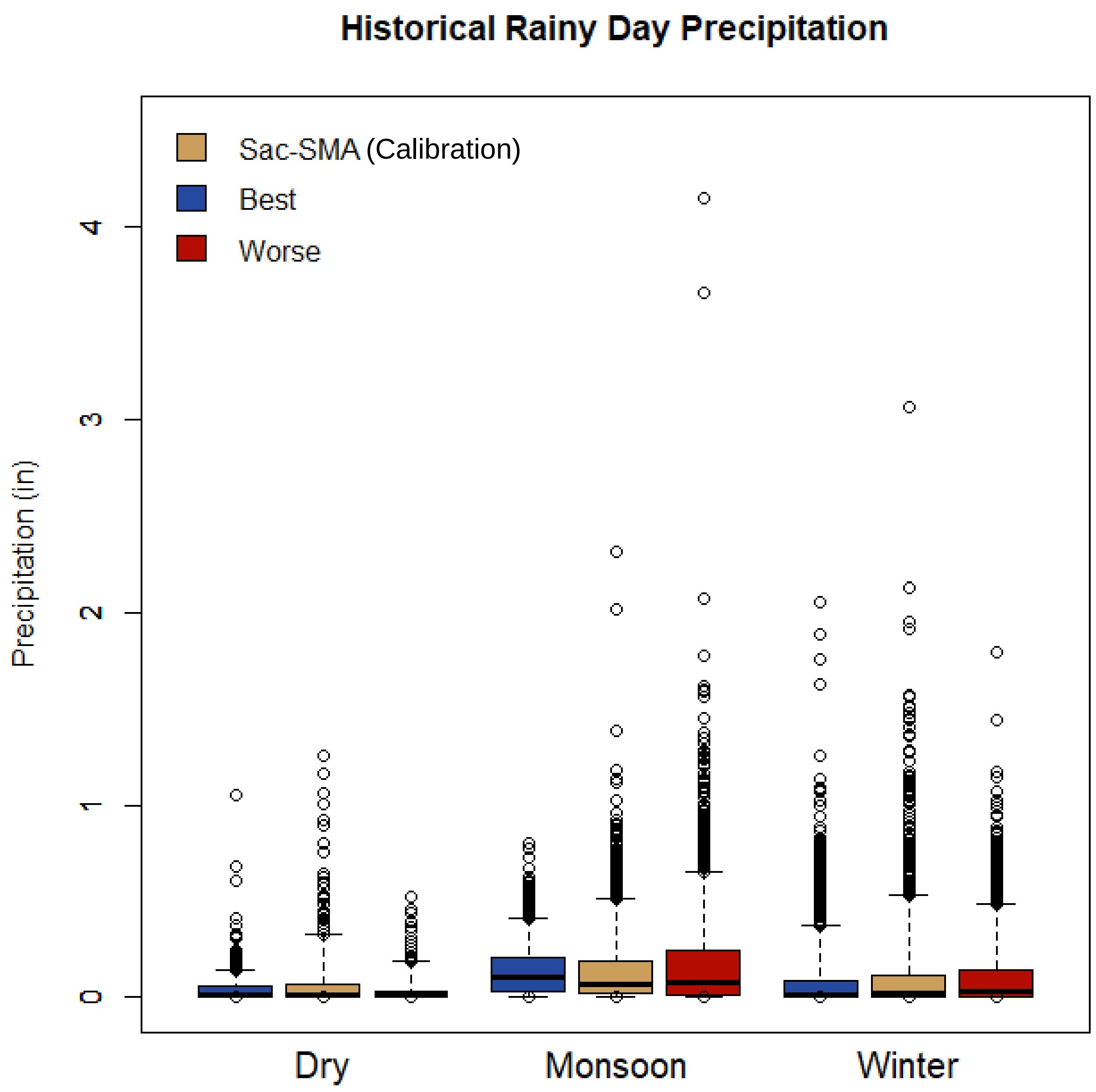
- LOCA developers and user-community do not recommend using single projections for analysis.
- LOCA does not reflect the physics of the atmospheric patterns in the same way that dynamical downscaling does. Selecting a GCM that is well performing for a region does not guarantee that the processes for which it was selected are retained.
- Here, larger monsoon season precipitation events are not well represented in the LOCA MPI projections, while other projections may better reflect the magnitude of monsoon precipitation.
- The weather generator was built around a models ability to capture these seasonal and synoptic events.

HISTORICAL
Daily Precipitation

Best: Based on RCP 4.5 SD data

Worse: Based on RCP 8.5 DD data

*Note the importance of comparing within the same dataset.



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Future Climate – Analysis Periods

Historical: 1970-1999

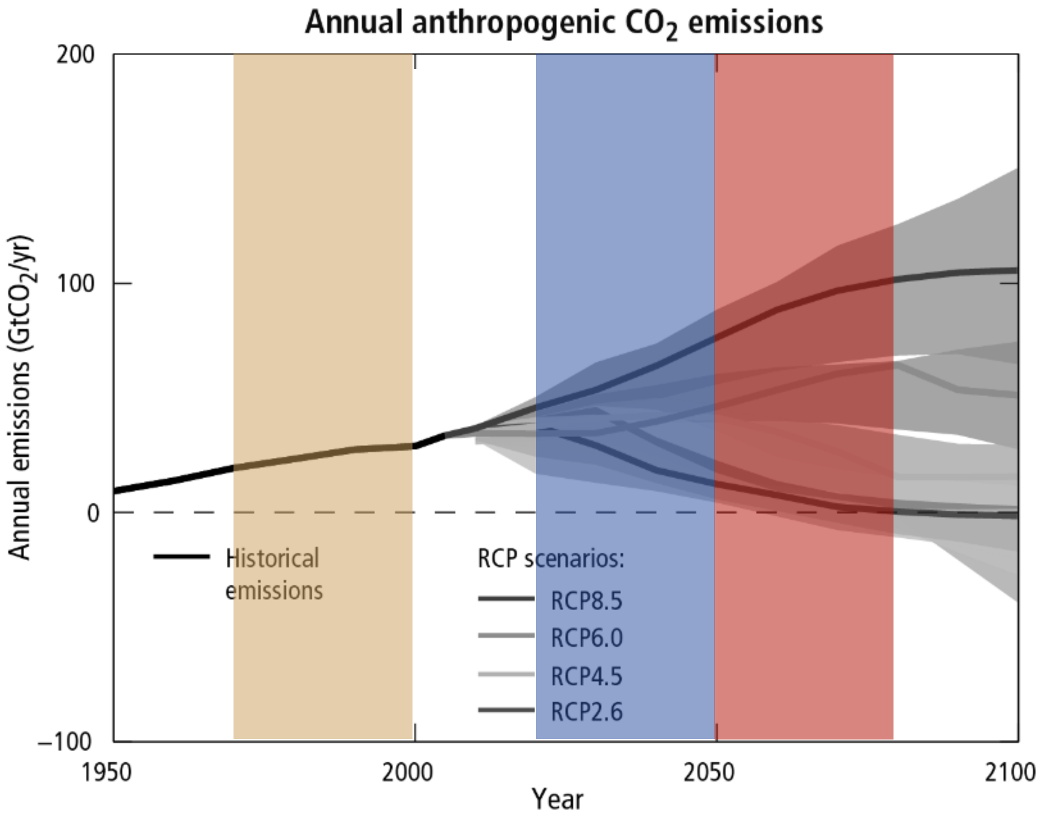
- SAC-SMA calibration period
- Prior to 2006 start of GCM "Futures"

"2030's" Future: 2020-2049

- Near future

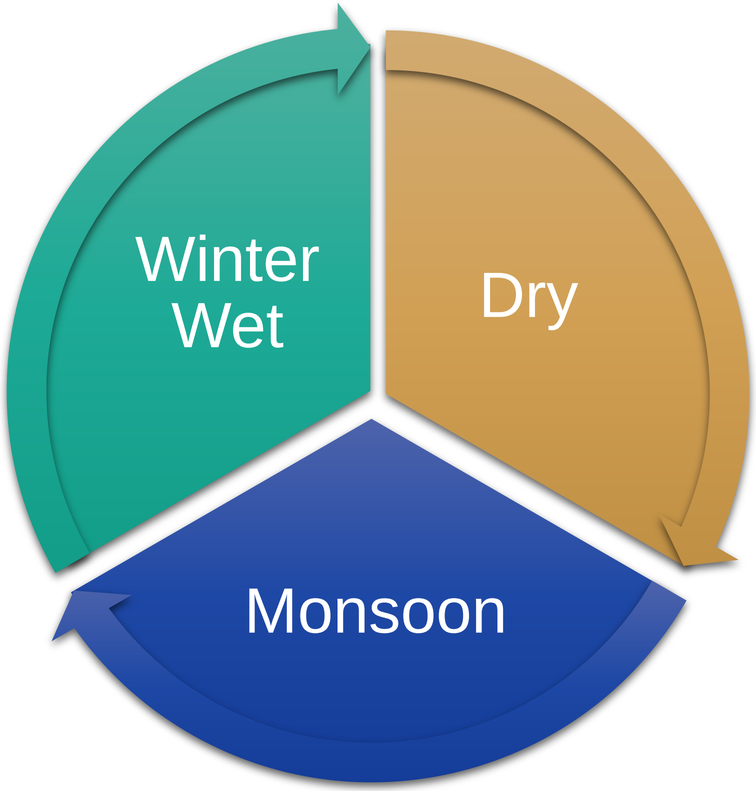
"2060's" Future: 2050-2079

- Far future
- Lower Santa Cruz study through 2060
- Aligns with Colorado River Basin Study analysis through 2060



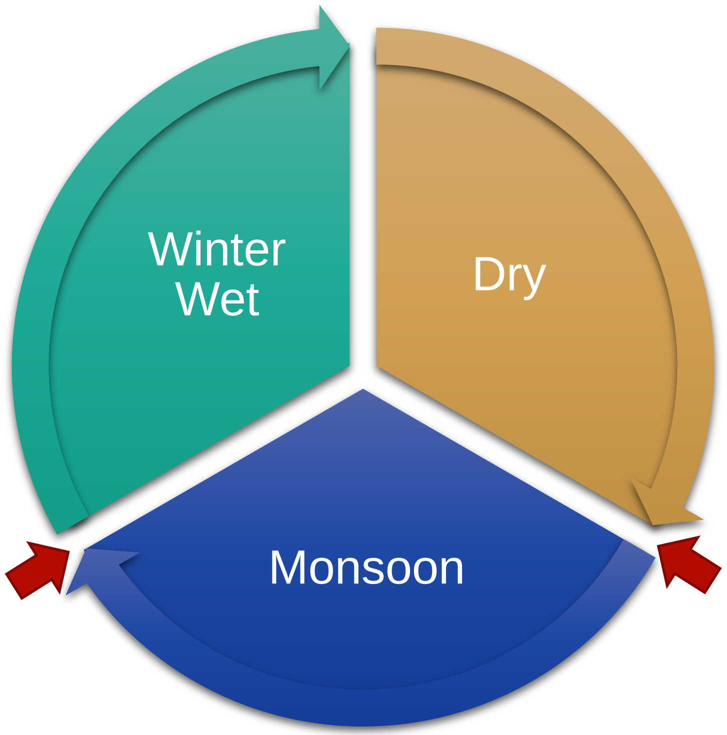
Review of Climate Metrics

1. Extreme events: intensity and frequency, temperature and precipitation
2. Monsoon onset
3. Dry period onset



Monsoon Season

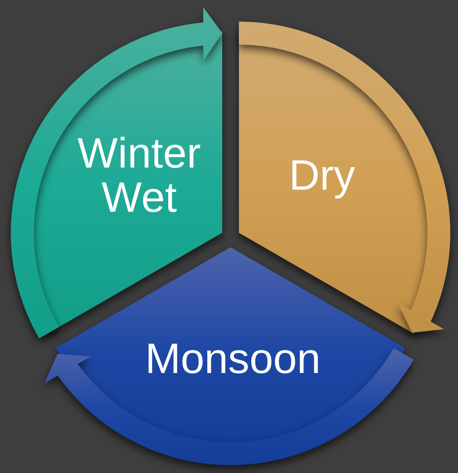
- Onset defined by the first of three days with a mean daily dewpoint temperature greater than a threshold.
- Demise is defined here as the day after the last three consecutive days above the dewpoint temperature threshold

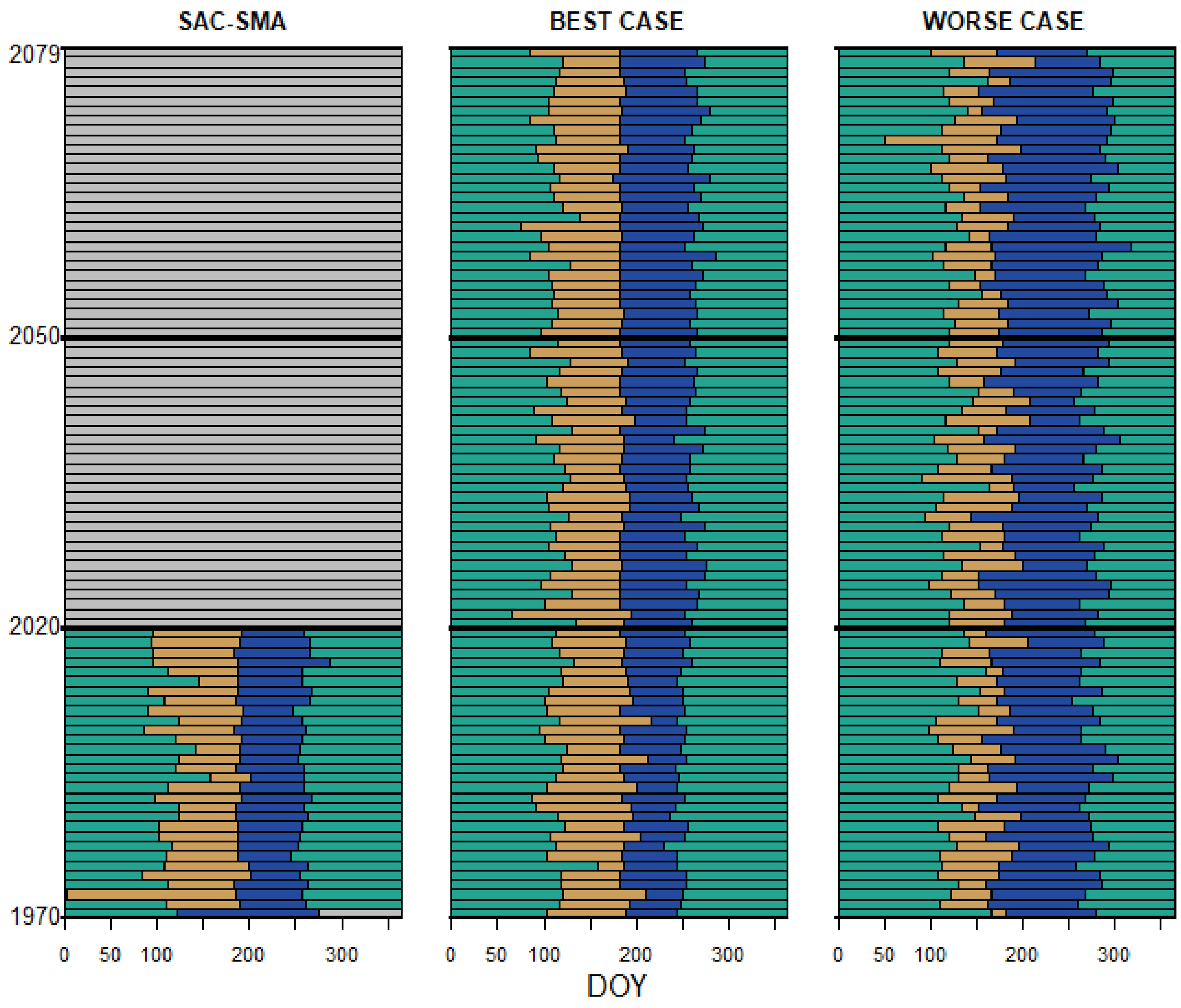


Dry Season

- The dry season in Tucson is characterized by prolonged periods with low to no rainfall. The transition to this season typically occurs by the start of May and dry conditions persist until the start of the monsoon season.
- Prolonged dry spells signified the transition out of the winter rains and into the dry season. Here, we used a two week dry spell, based on the historical SAC-SMA data and Tucson Airport weather station analysis.
- Dry spell is consistent with the guidance of Michael Crimmins and uses a daily precipitation threshold of 0.01” to define events.
- Additional constraints:
  - Dry periods ending before May 1 cannot be considered the "dry foresummer" trigger
  - Dry periods starting after June 15 cannot be considered the "dry foresummer" trigger
  - May 1 dry period start enforced if metric failed to identify onset.

Future Climate
New Timing





*Note the importance of comparing within the same dataset.

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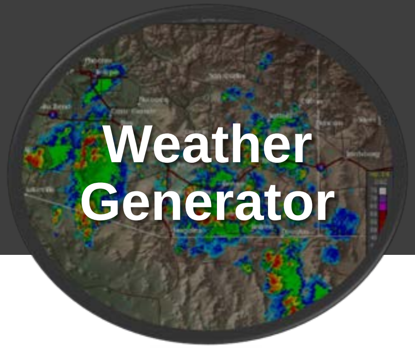
Weather Generator Motivation

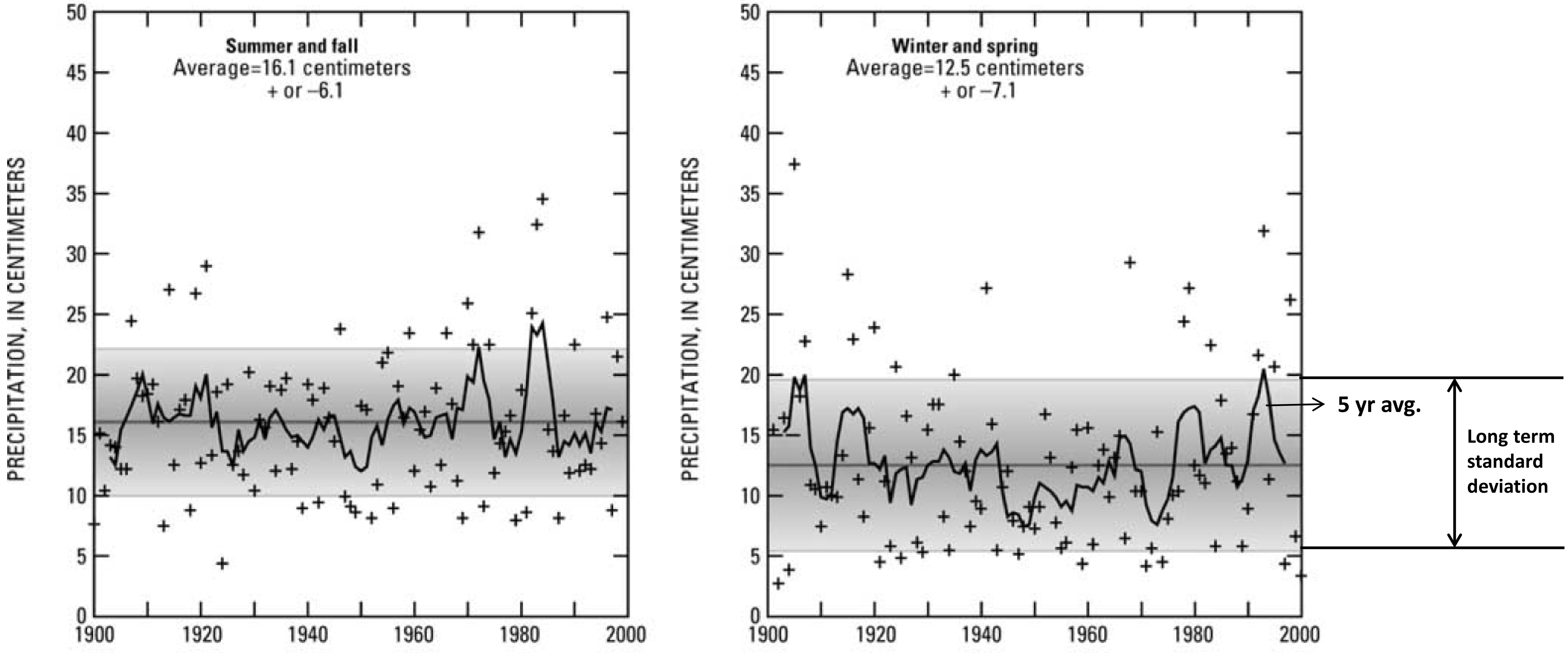


- Scale (spatial and temporal) that is relevant for local surface water modeling

- Natural precipitation variability is particularly important in this region. The weather generator is used to introduce variability around the broader climate projection trends.

- The resulting ensemble (large group) of likely rainfall timeseries represents a range of plausible amounts, daily patterns, and seasonality that will drive a resulting range of streamflows.

Precipitation Variability in the Tucson Area



Seasonal precipitation at the the University of Arizona Campbell Road Farms, 1900 - 2000

Source: Pool, D.R., Variations in climate and ephemeral channel recharge in southeastern Arizona, U.S. Water Resources Research, Volume 41, W11403, 2005.

Weather Generator

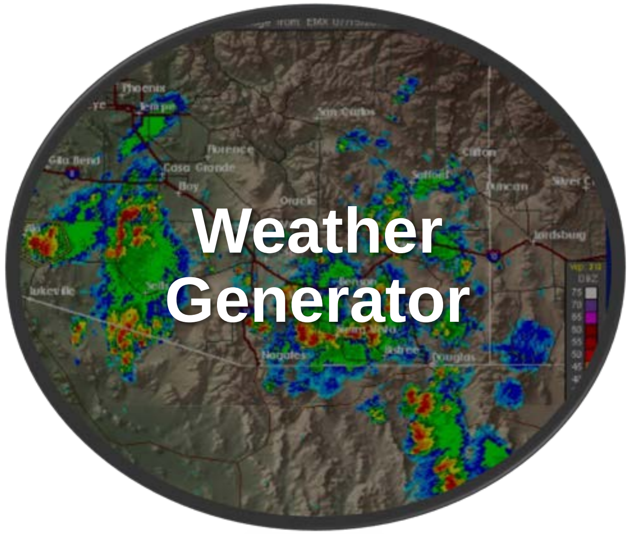
Purpose: simulate plausible future weather possibilities based on climate projections for the Lower Santa Cruz River Basin

Validation data

- CBRFC's SAC-SMA calibration dataset
- Categorized into *three states* (i.e. seasons)

Future climate scenarios

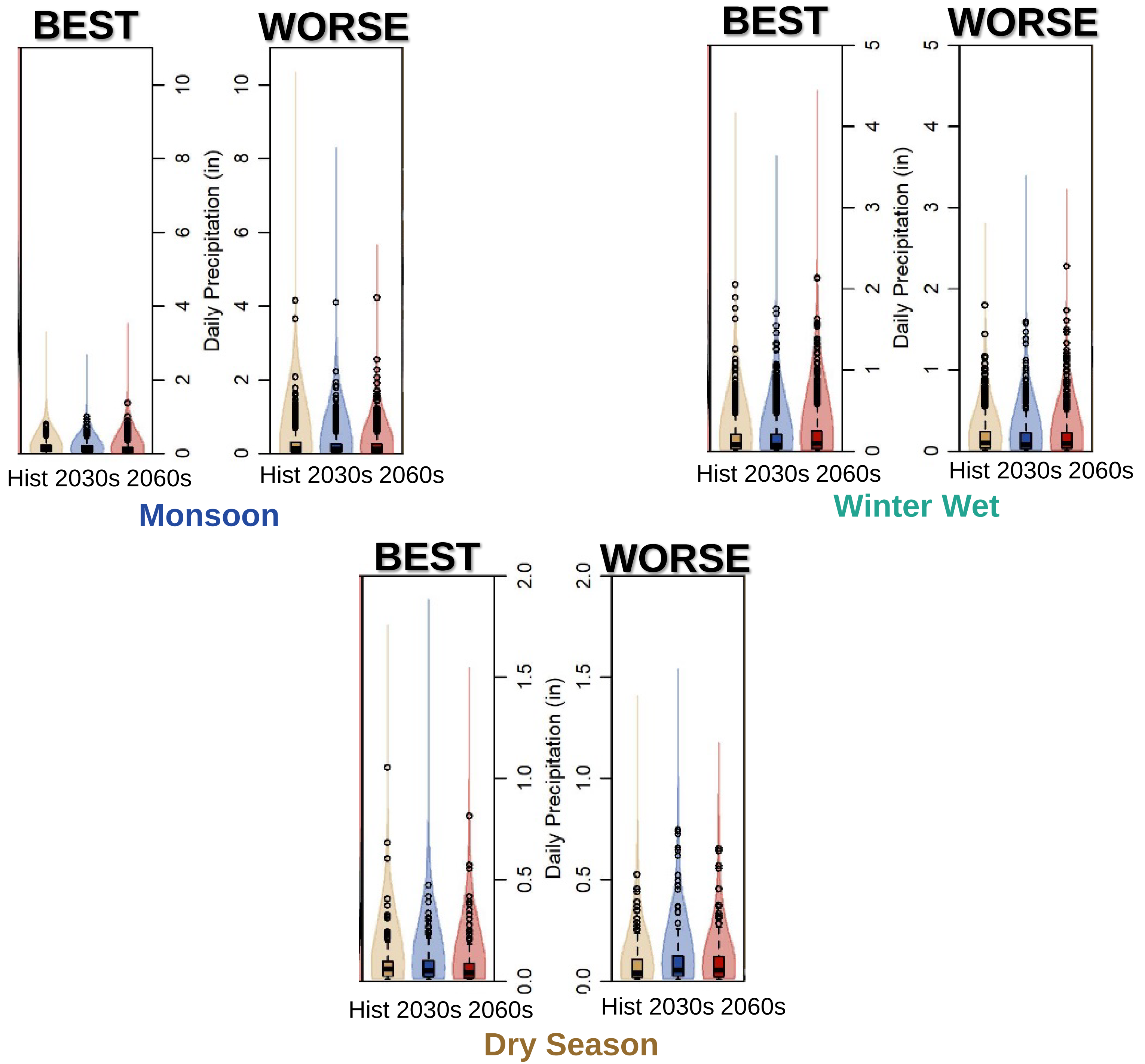
- **Best case**
  Near and Far Future
- **Worse case**
  Near and Far Future



Future time series of precipitation and temperature inputs to SAC-SMA surface water model.

Future Scenario 1: Daily Precipitation

Weather Generator Input Dataset



Best: Based on **RCP 4.5** SD data

Worse: Based on **RCP 8.5** DD data

*Note the variability of daily precipitation.

*Note the importance of comparing within the same dataset.

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Future Scenario 2:
Daily Precipitation

Weather Generator Input Dataset

Best: Based on **RCP 4.5** SD data

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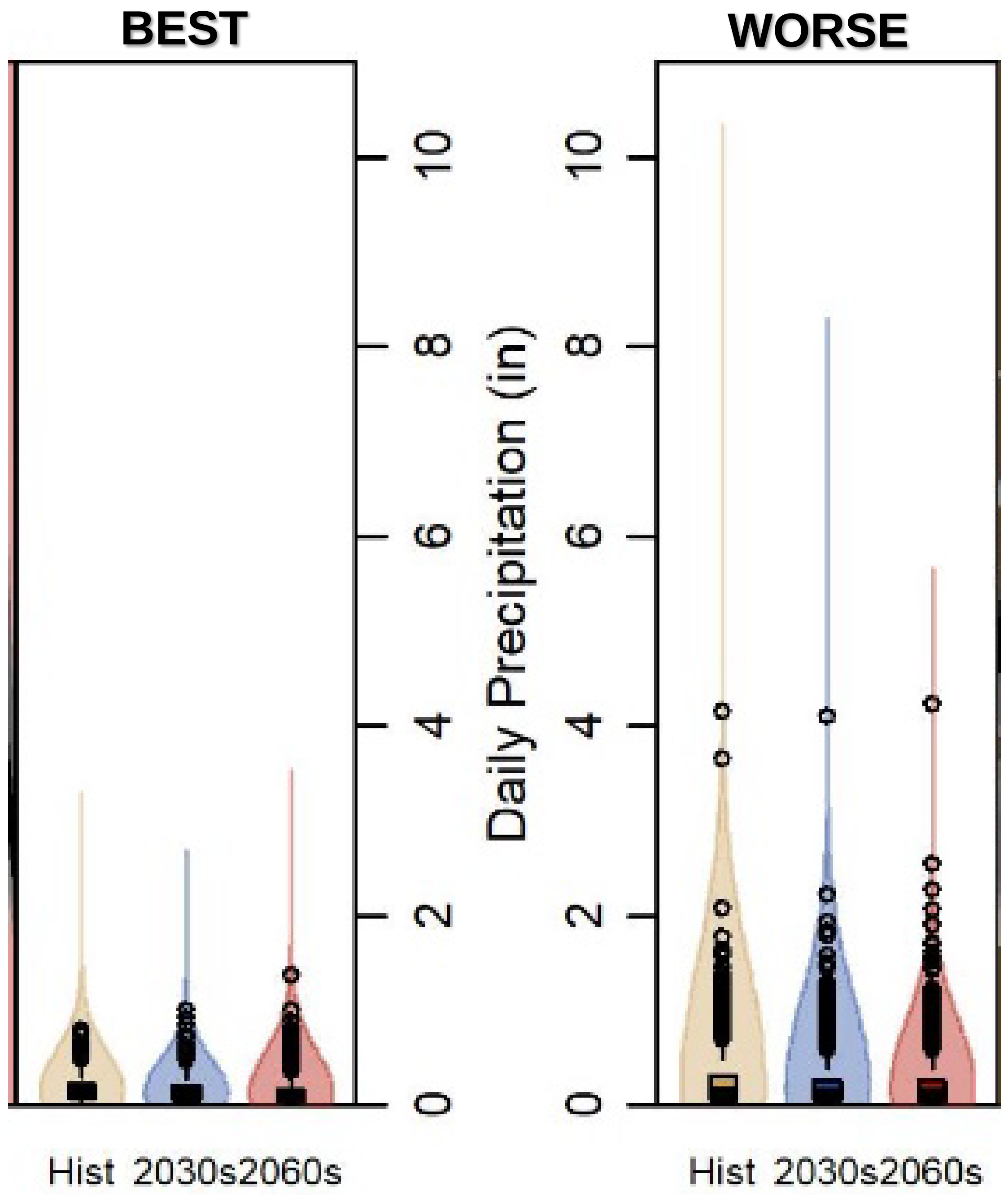
*Note the variability of daily precipitation.

*Note the importance of comparing within the same dataset.

Monsoon

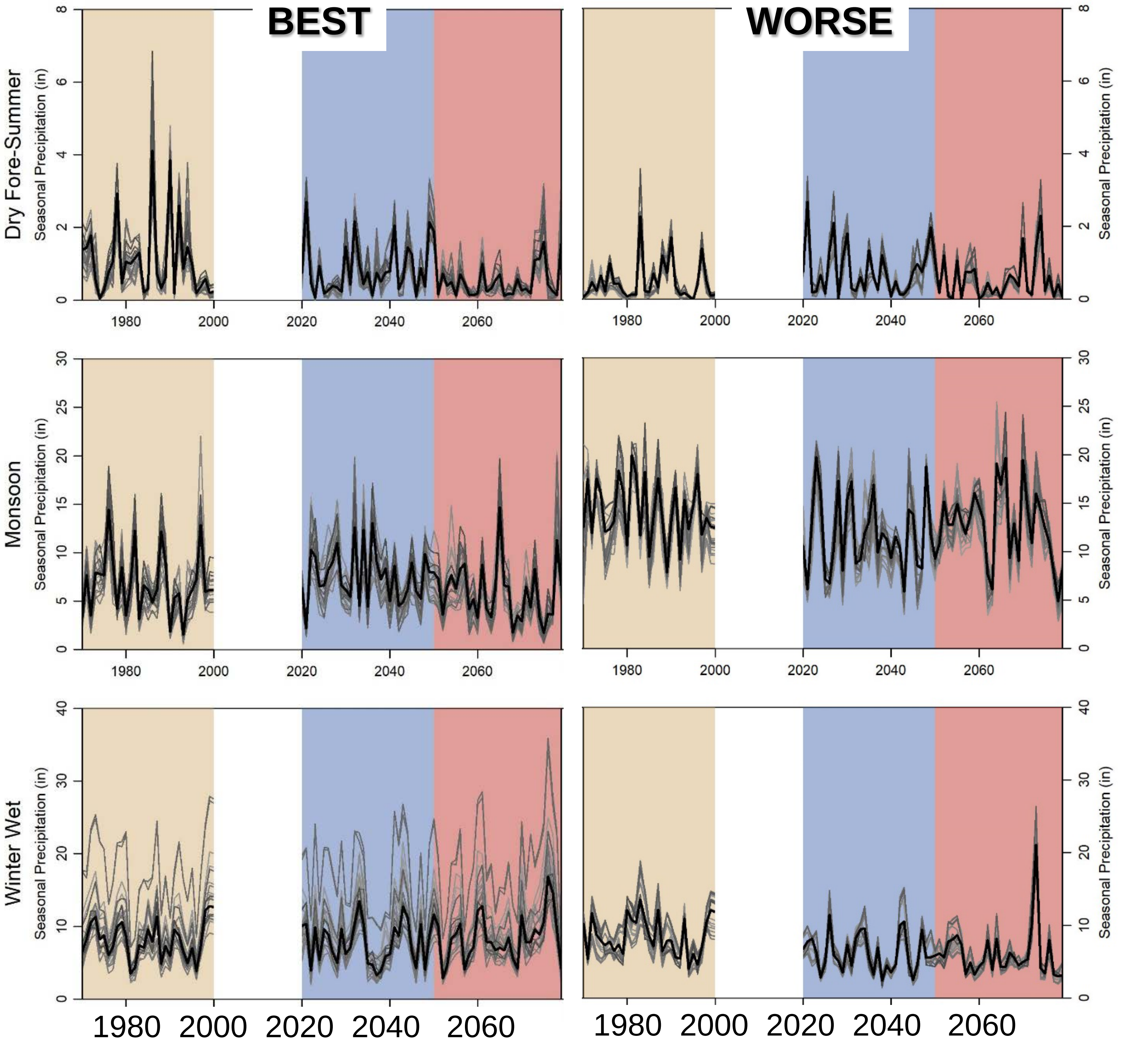


FUTURE
Seasonal Precipitation

Weather Generator Input Dataset

Best: Based on **RCP 4.5** SD data
Worse: Based on **RCP 8.5** DD data

*Note the variability of daily precipitation.



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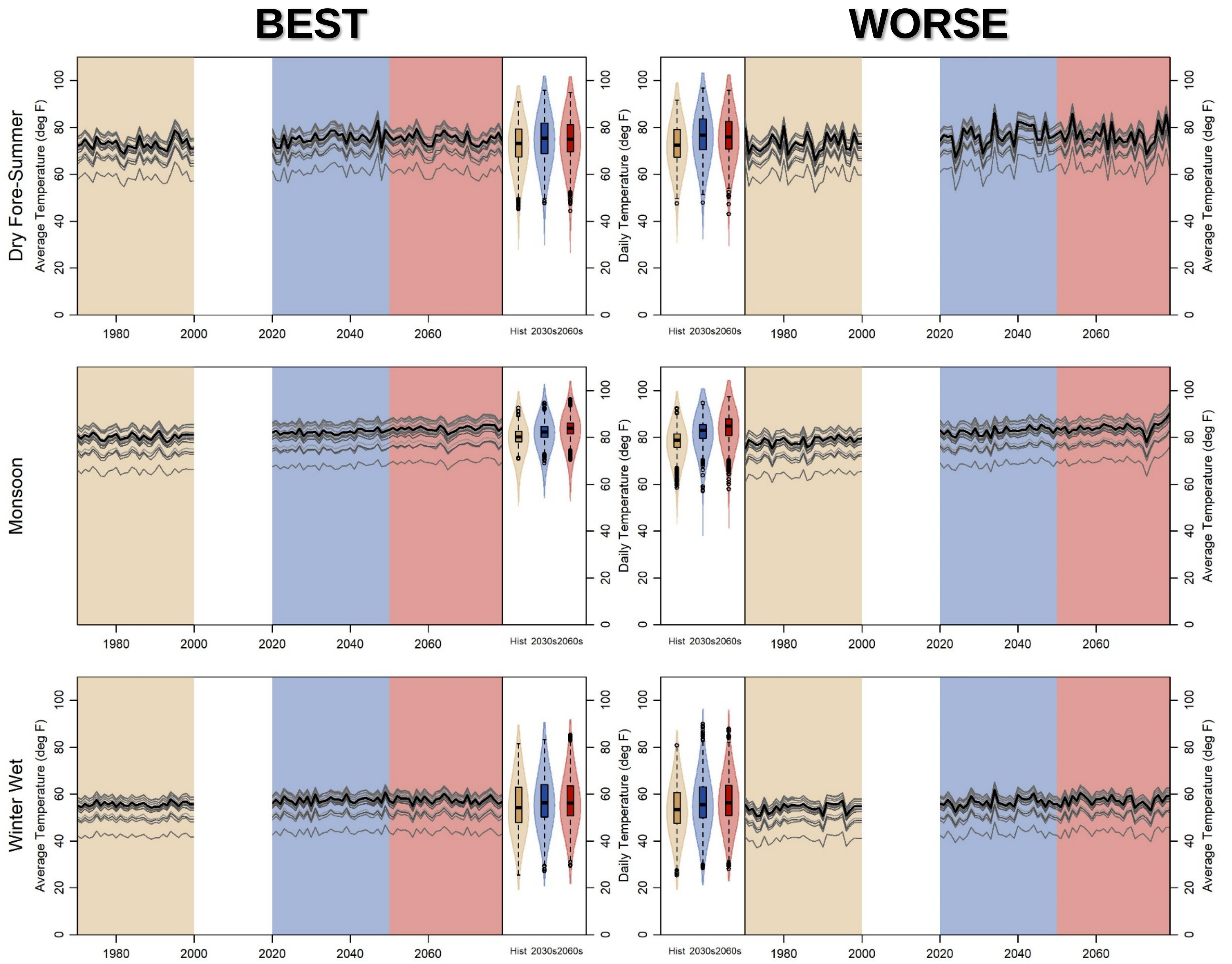
FUTURE
Temperature

Weather Generator Input Dataset

(Bias corrected)

Best: Based on **RCP 4.5** SD data

Worse: Based on **RCP 8.5** DD data



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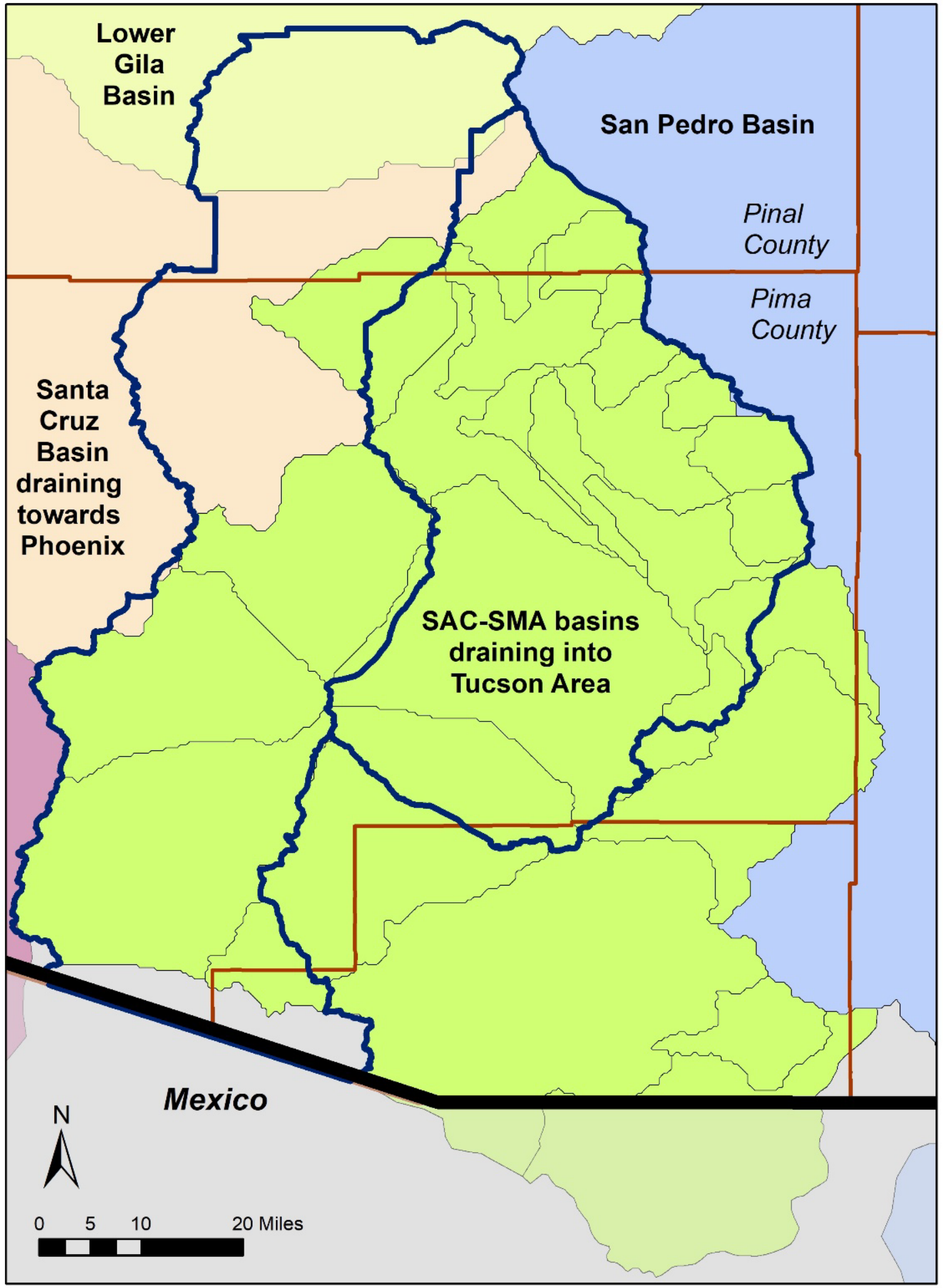
Surface Water Basin Configuration



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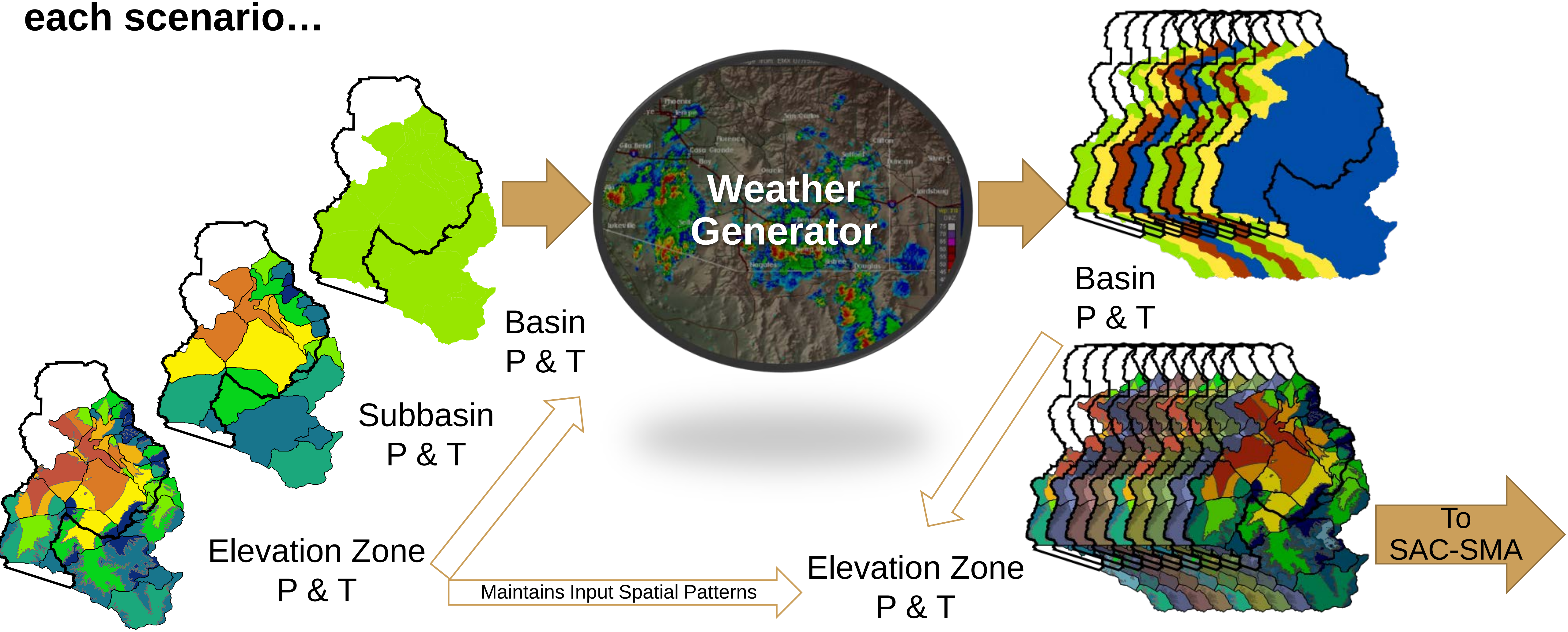
Daily Weather Generator

For each day of each scenario…

100 daily realizations



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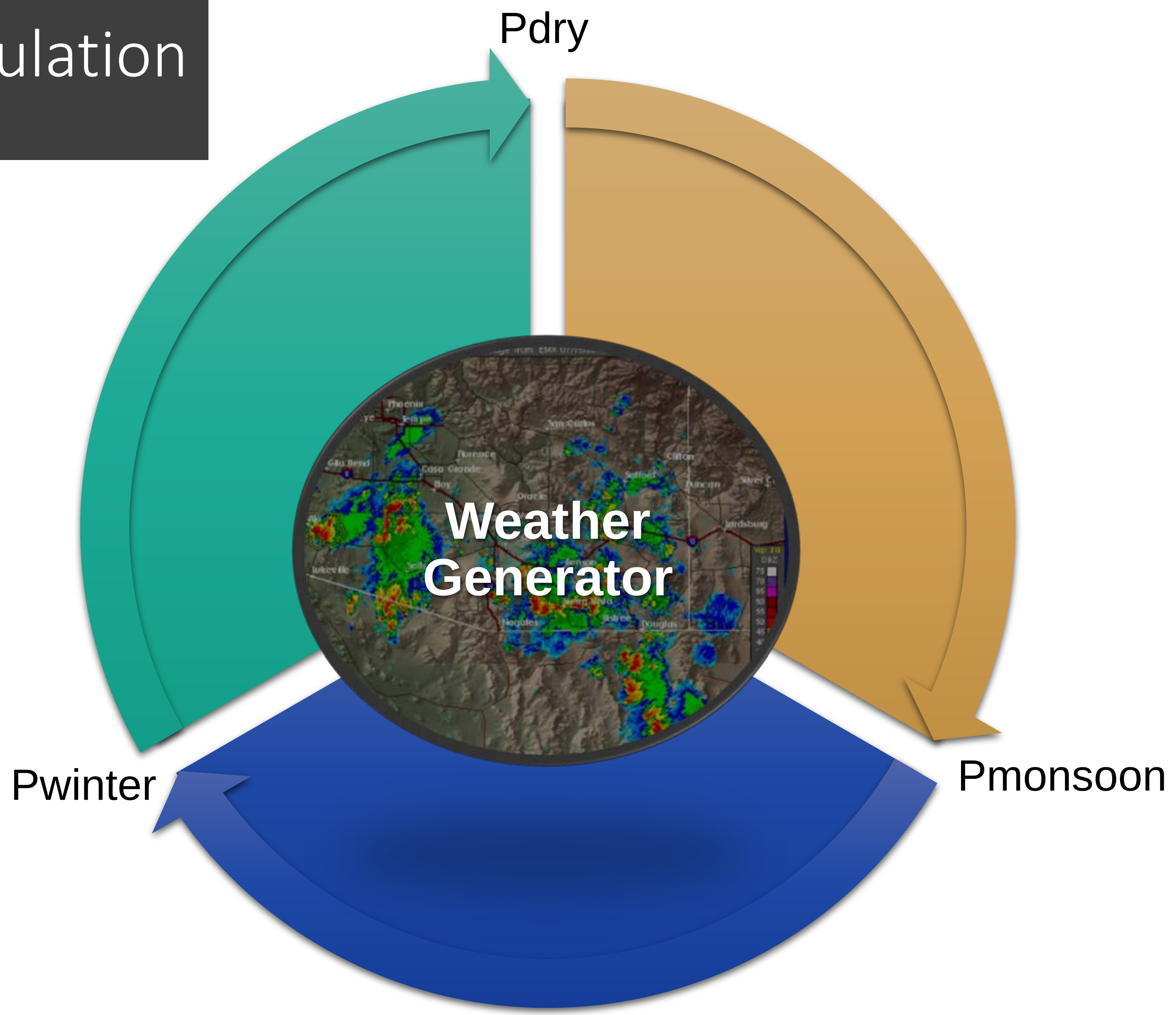
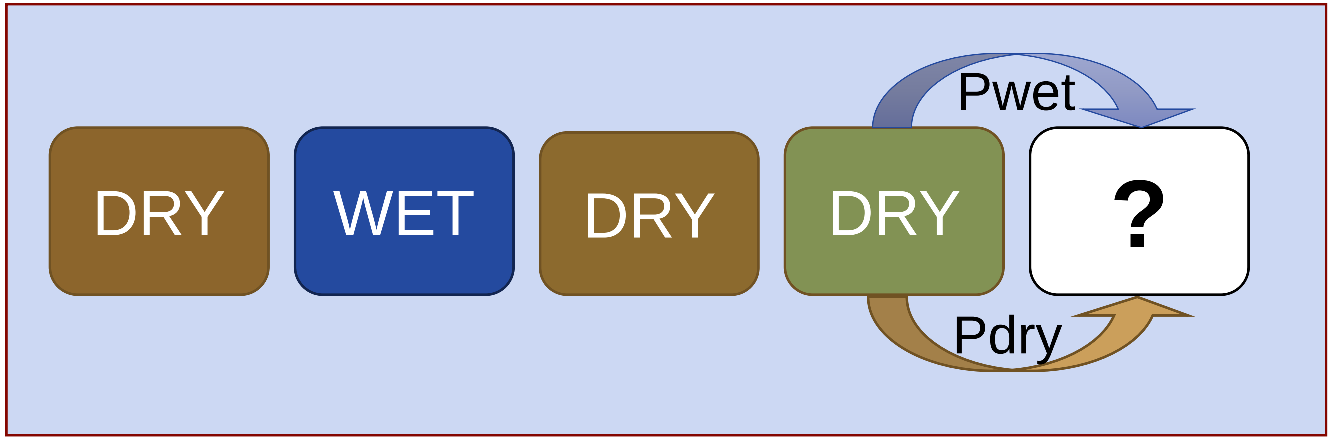
Precipitation Simulation



Wet/Dry day analysis



- A two-state Markov Model is defined to address wet and dry spells.
- Precipitation occurrence is defined as any daily precipitation greater than 0.01”.
- Transition probabilities are computed for each season (dry, monsoon, winter).
- This analysis is how the weather generator accounts for storm *frequency* by including *the length of time between storm events*.

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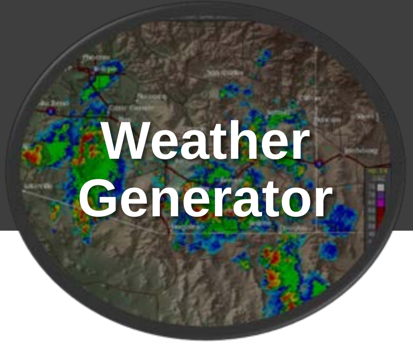
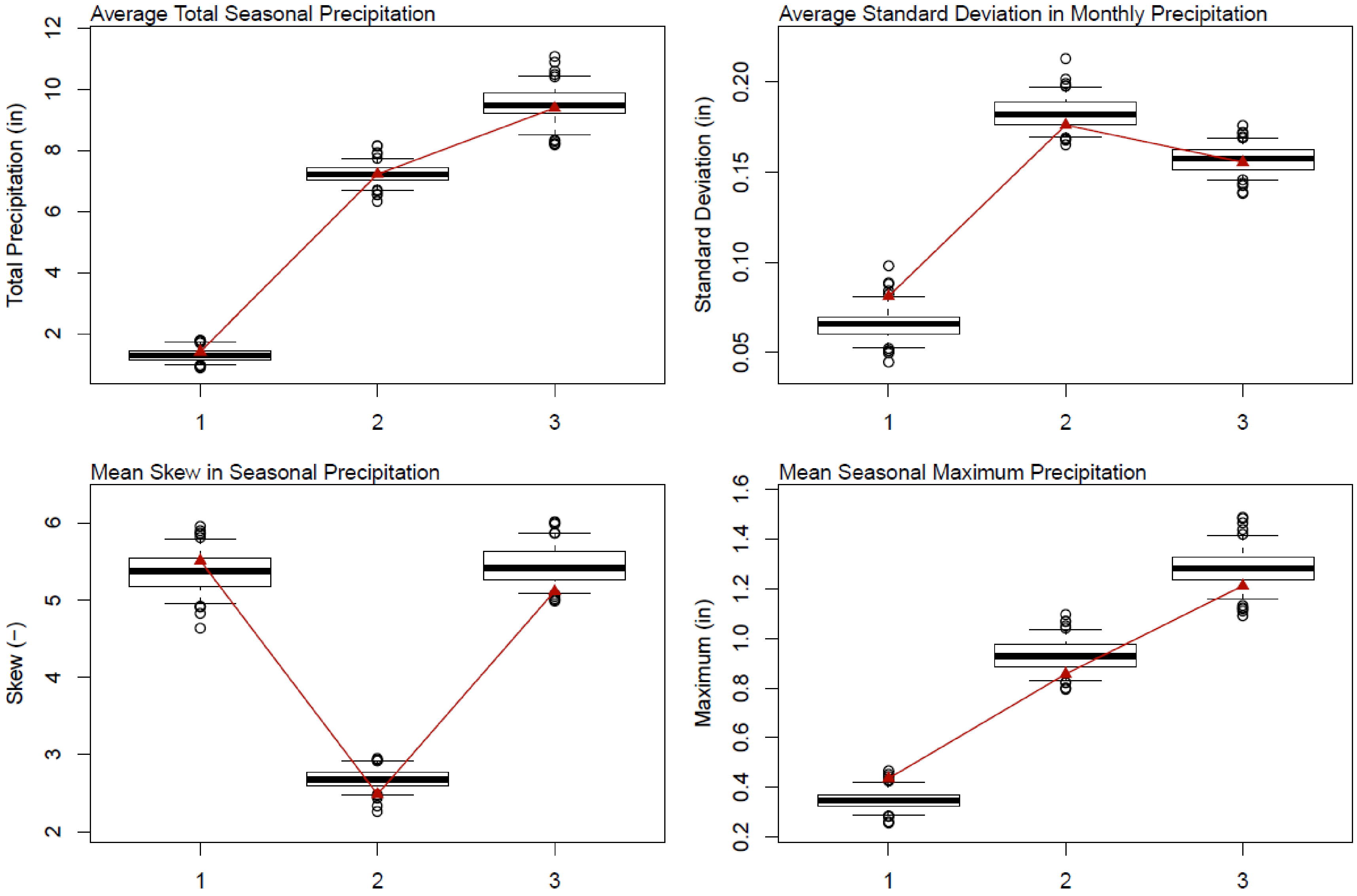
Weather Generator Validation





SAC-SMA calibration dataset
Statistics presented by season.

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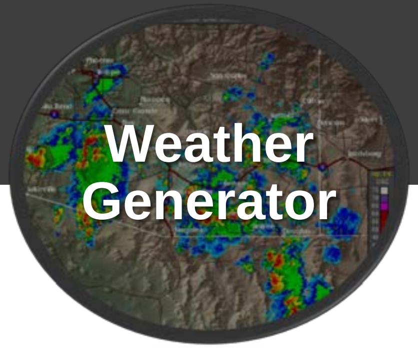
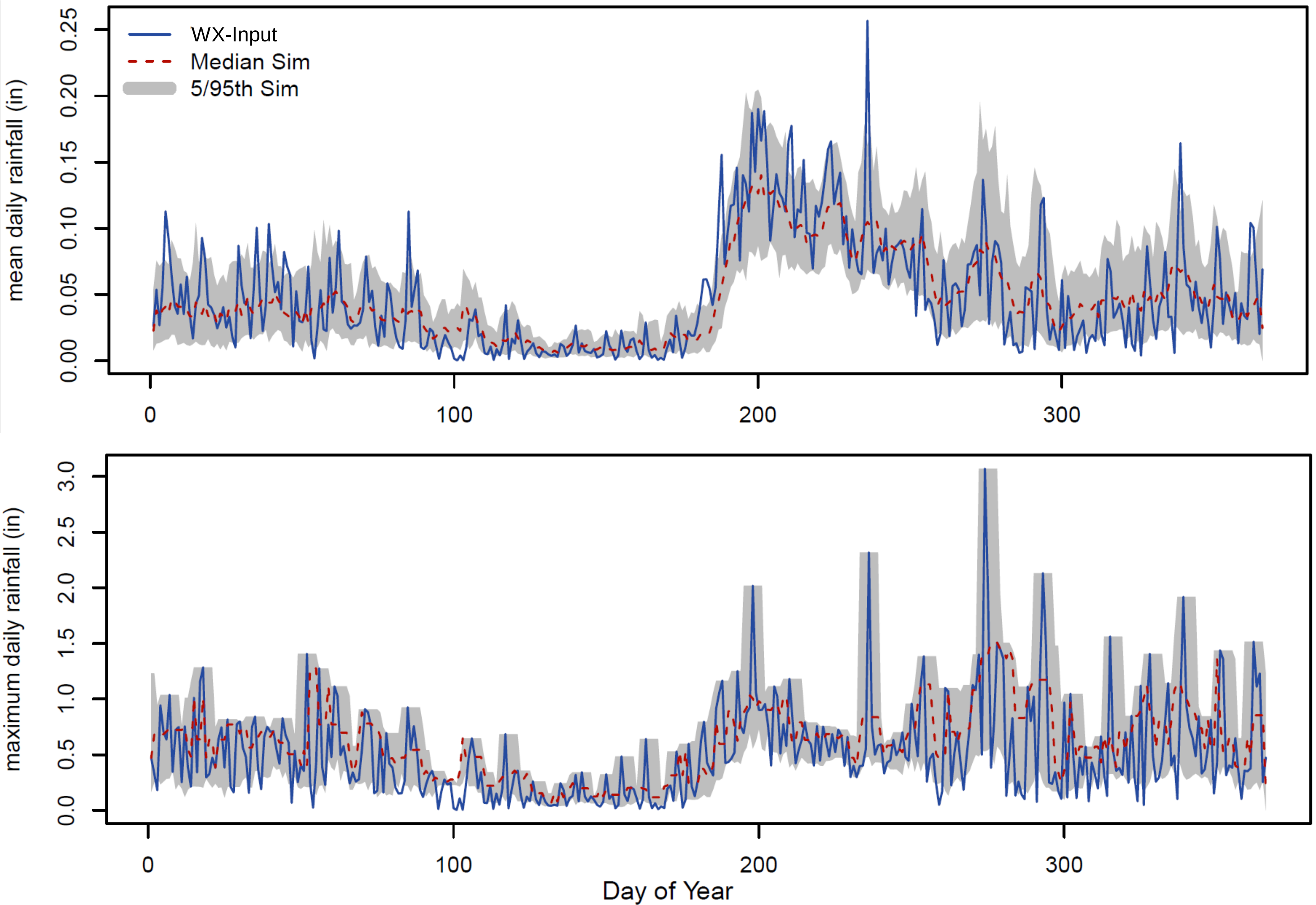
Weather Generator Validation





SAC-SMA calibration dataset
Statistics presented by Julian day.

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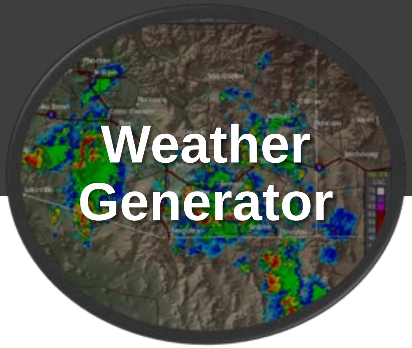
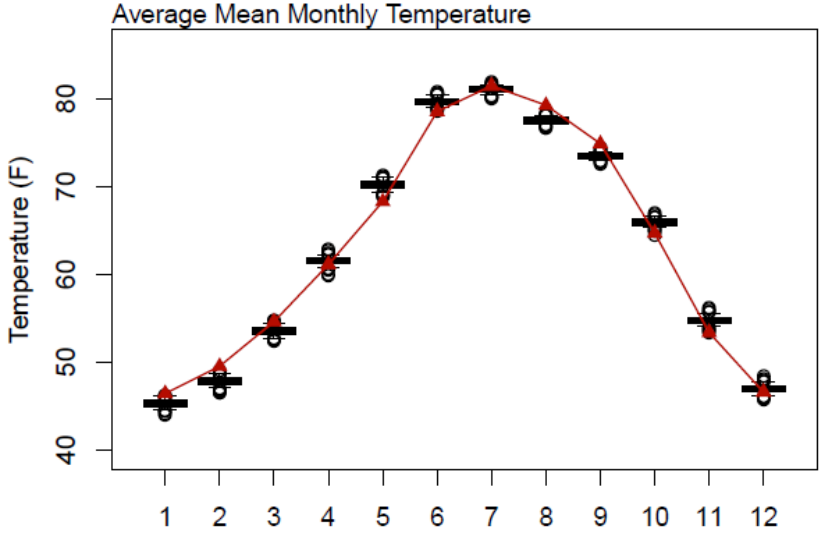
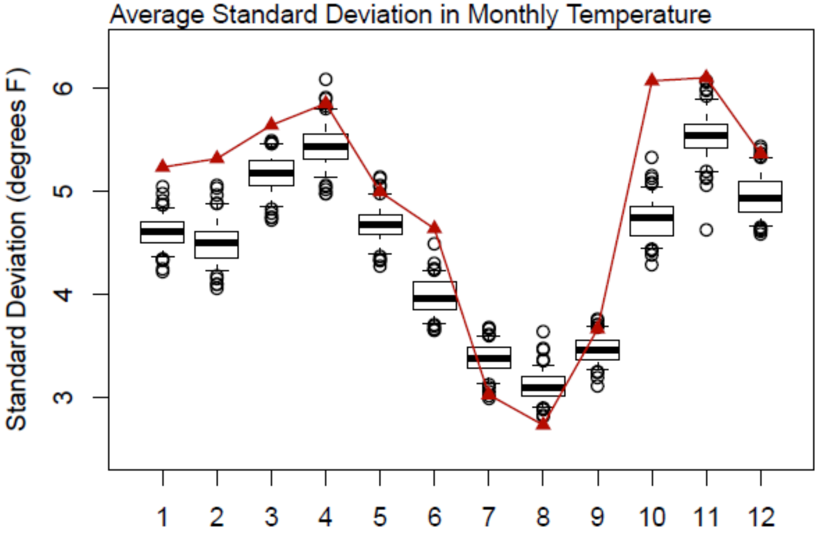
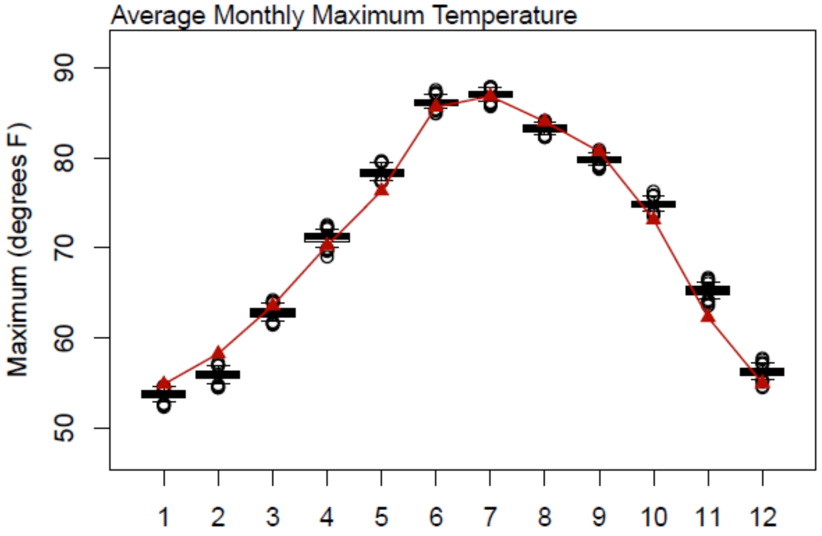
Validation Averages





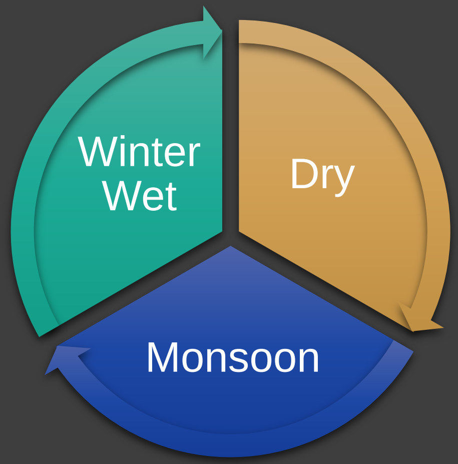


SAC-SMA calibration dataset
Statistics presented by month.



Precipitation Seasonal Change – Basin Average

Weather Generator Output



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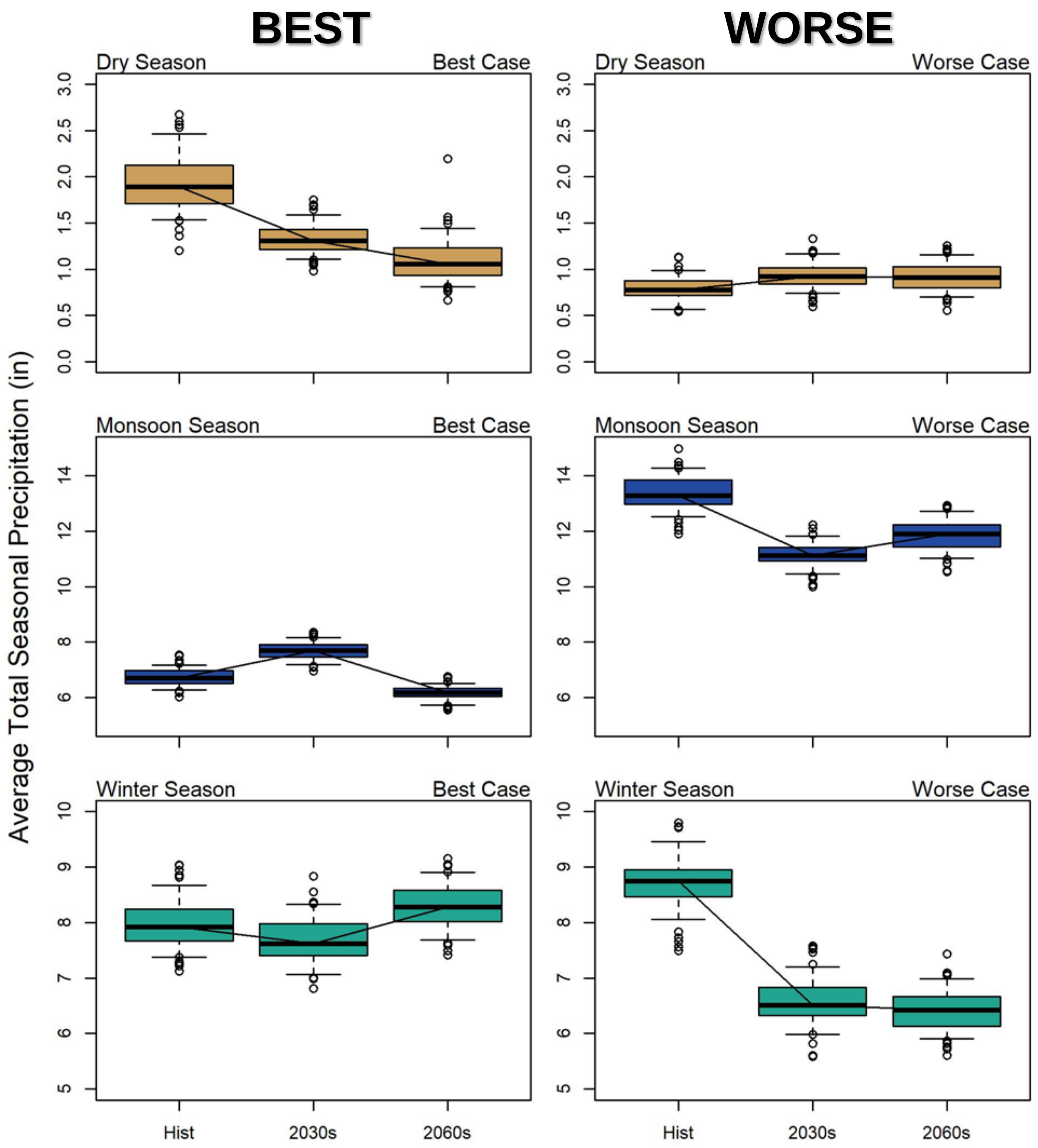

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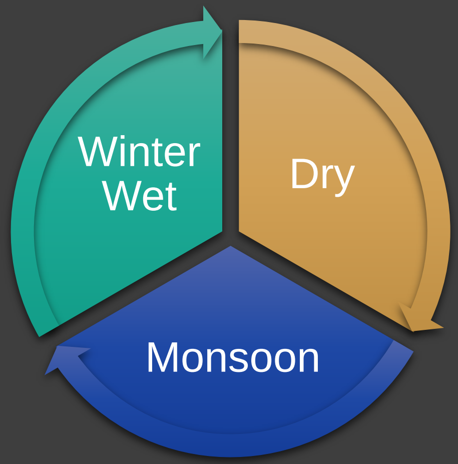
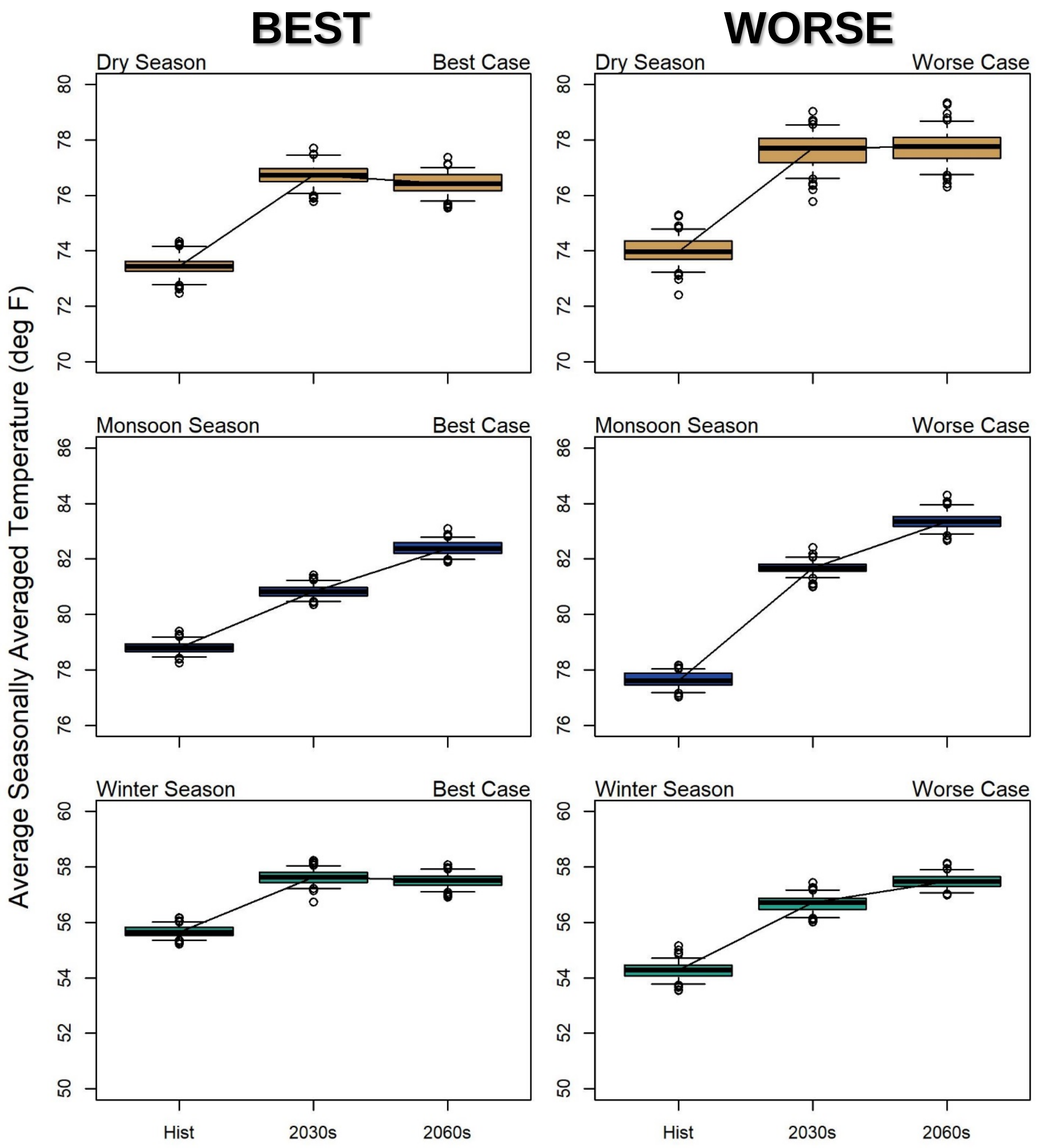
Temperature Seasonal Change – Basin Average

Weather Generator Output





Best: Based on **RCP 4.5** SD data

Worse: Based on **RCP 8.5** DD data

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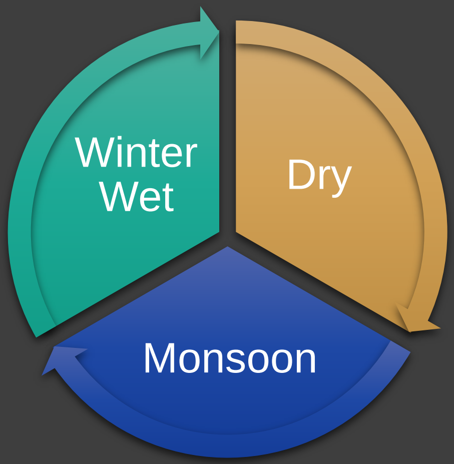
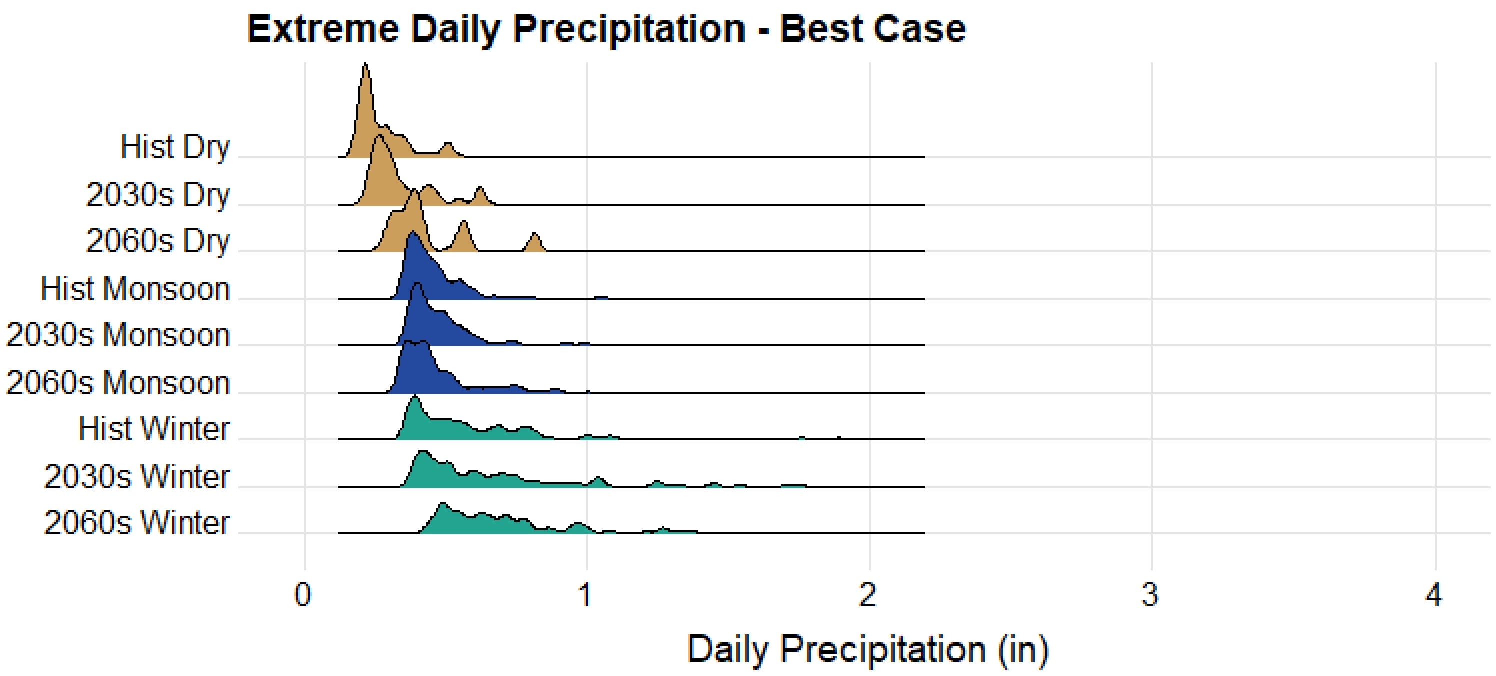
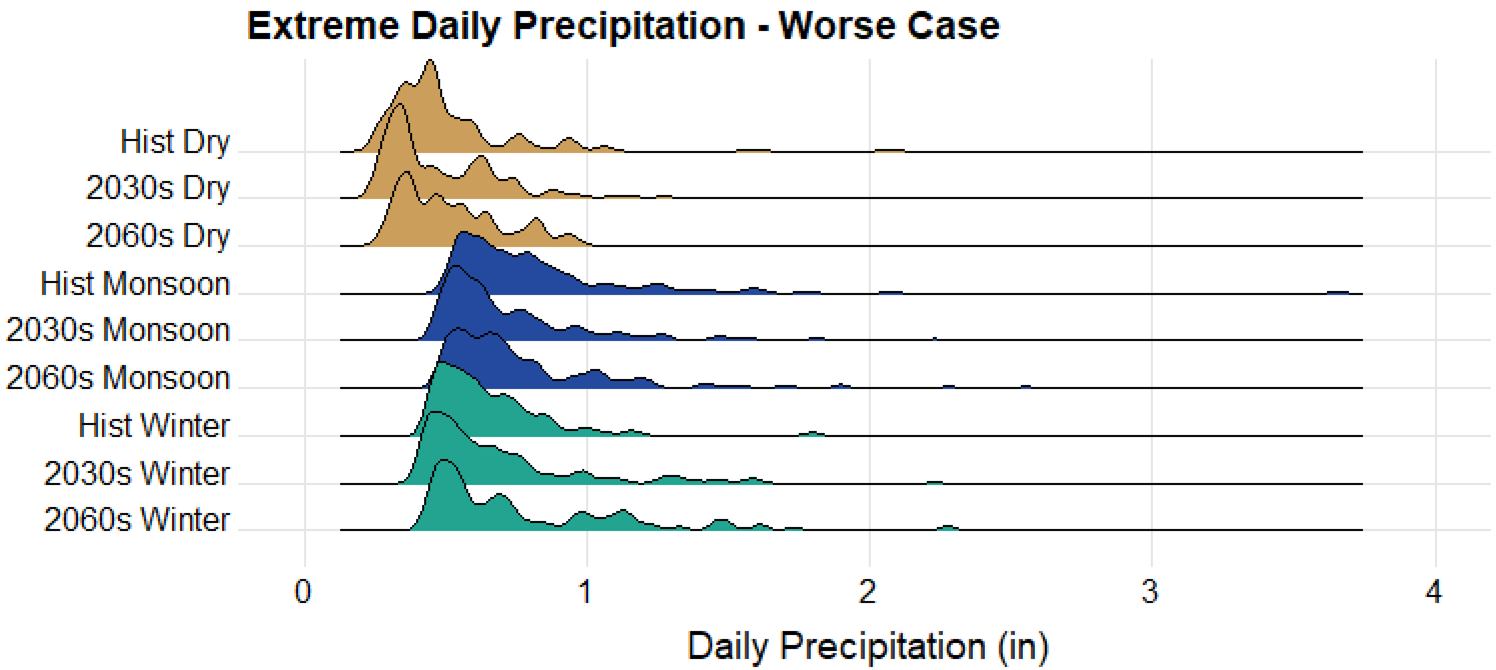
Extreme Events
Top 10% of Daily Precipitation

Weather Generator Output



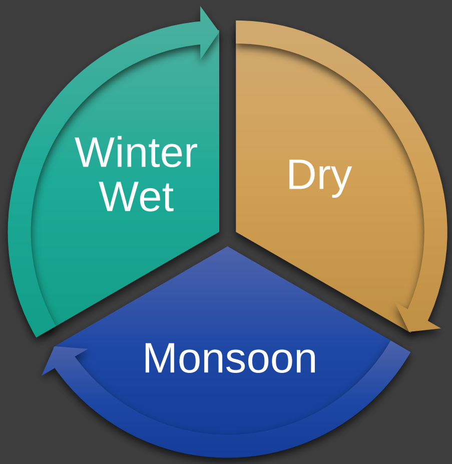


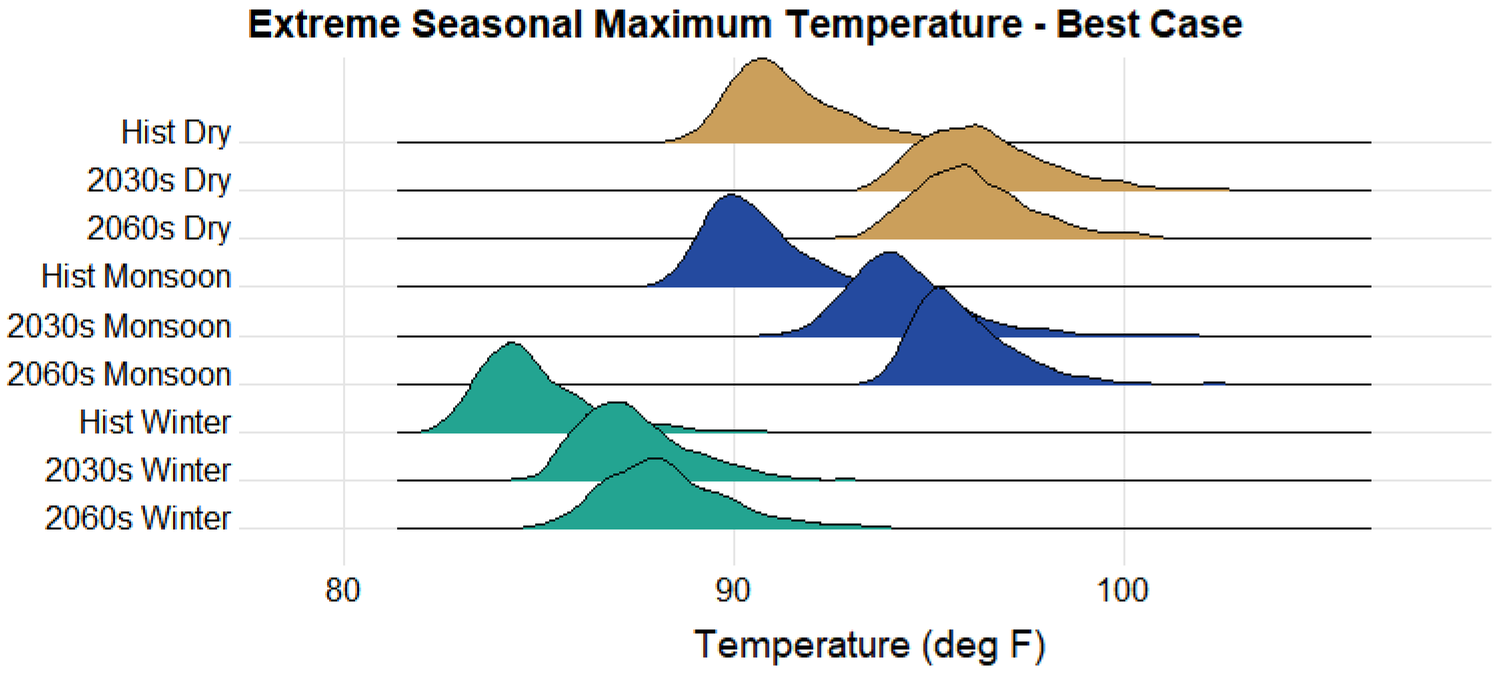


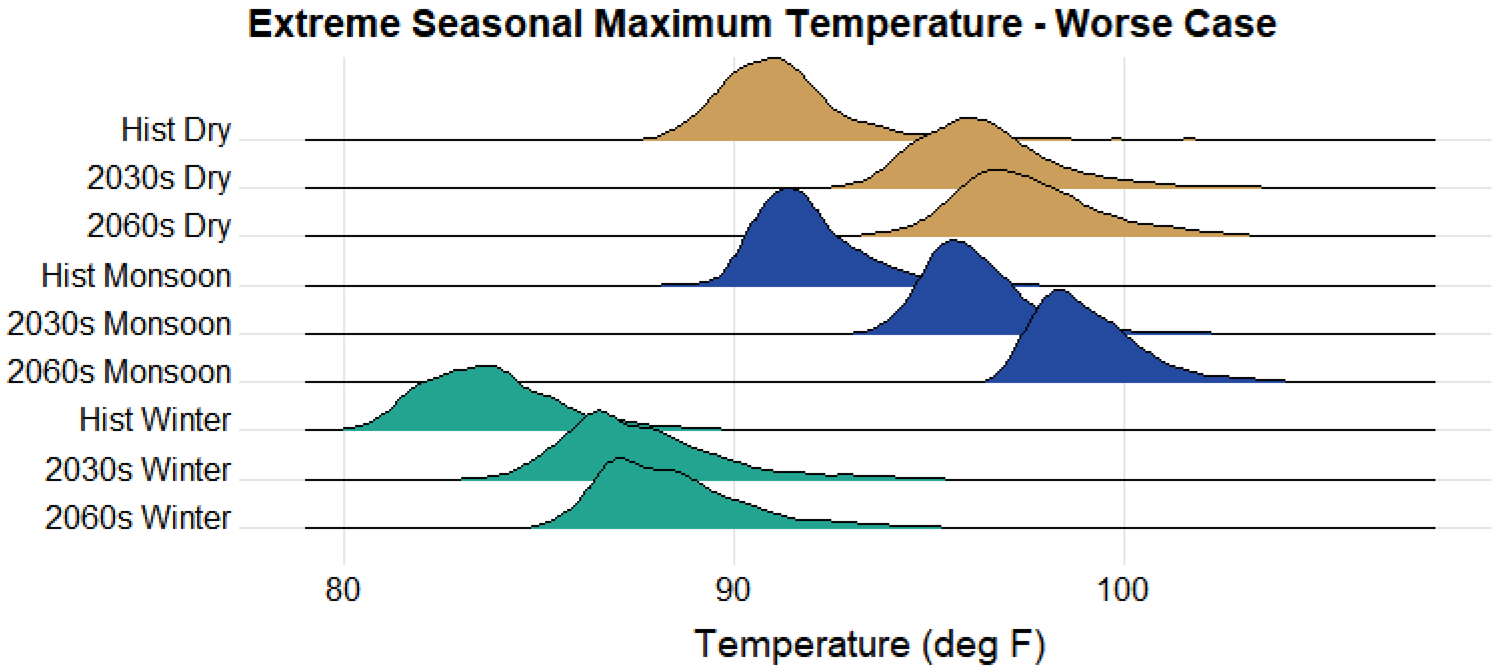
RECLAMATION

Extreme Events
Top 10% of Seasonal Max Temperature

Weather Generator Output







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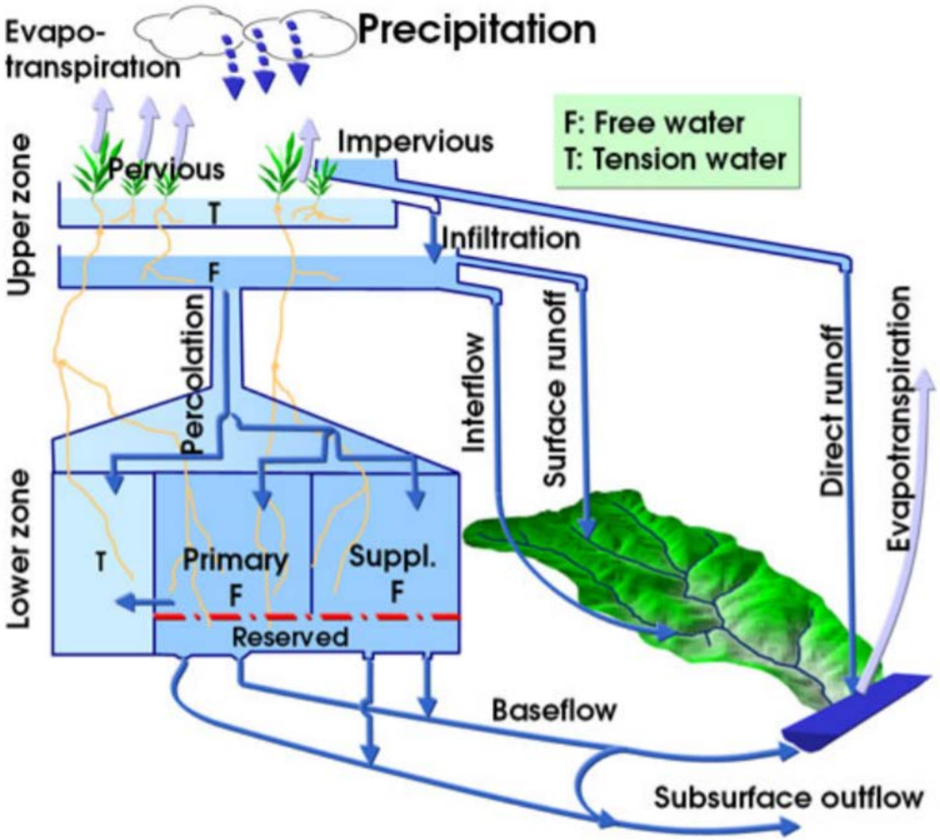
Surface Water Model Refresher

- From: CBRFC's SAC-SMA[1] model
- Simulates basin runoff and soil moisture
- Spatially Lumped: based on mean basin inputs :
  - Precipitation,
  - Temperature,
  - Potential evapotranspiration (ET)

  and outputs:
  - runoff,
  - baseflow,
  - actual ET.
- Daily & Continuous: has memory of previous soil moisture in system.



1. Colorado Basin River Forecast Center – SACramento Soil Moisture Accounting

PET adjustment

- Sac-SMA requires monthly estimates of Potential Evapotranspiration (PET) for each elevation zone.
- PET was adjusted for each scenario by scaling the Sac-SMA calibration dataset values by the change in temperature between the historical and future periods.

Water Resources Research

Research Article | Free Access |

The twenty-first century Colorado River hot drought and implications for the future

Bradley Udall, Jonathan Overpeck

First published: 17 February 2017 | https://doi.org/10.1002/2016WR019638 | Cited by: 33

azcentral.

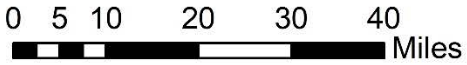
PART OF THE USA TODAY NETWORK

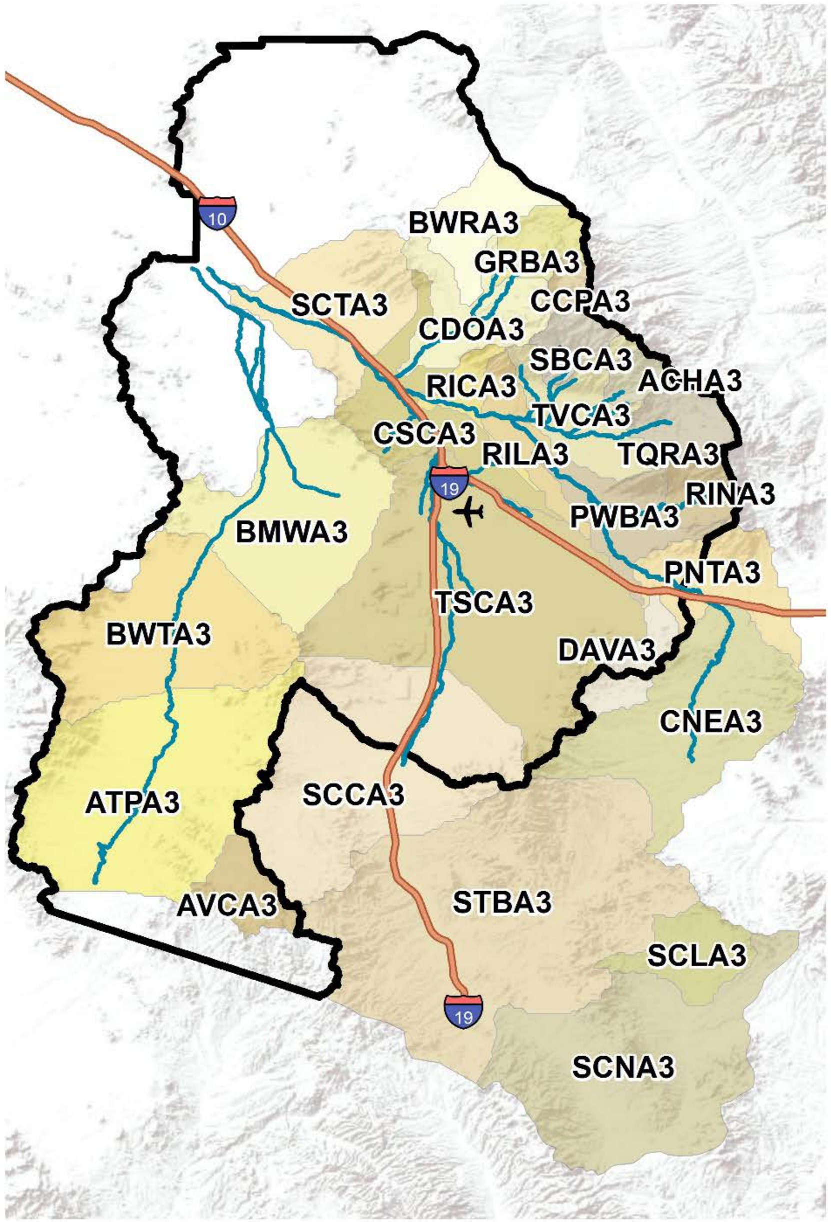
'A hot drought': Warming is driving much of the Colorado River's decline, scientists say

Ian James, Arizona Republic Published 10:54 a.m. MT Sept. 7, 2018 | **Updated 1:48 p.m. MT Sept. 7, 2018**

Surface Water Modeling Domain

Basin ID	Description
ACHA3	AGUA CALIENTE WASH - HOUGHTON RD
ATPA3	ALTAR WASH - NR THREE POINTS AZ
AVCA3	ARIVACA CK AT ARIVACA AZ
BMWA3	BRAWLEY WASH - AT MILEWIDE RD
BWRA3	BIG WASH - CANADA DEL ORO
BWTA3	BRAWLEY WASH - THREE POINTS
CCPA3	CANADA DEL ORO - CORONADO CAMP
CDOA3	CANADA DEL ORO - BLO INA RD NR TUCSON
CNEA3	CIENEGA CK - NR SONOITA
CSCA3	SANTA CRUZ - AT CORTARO
DAVA3	DAVIDSON CANYON
GRBA3	CANADA DEL ORO - GOLDER ROAD BRIDGE
PNTA3	PANTANO WASH - NR VAIL
PWBA3	PANTANO WASH - BROADWAY BLVD.
RICA3	RILLITO CREEK - LA CHOLLA BLVD AT
RILA3	RILLITO CREEK - TUCSON AT DODGE BLVD.
RINA3	RINCON CREEK - NR TUCSON
SBCA3	SABINO CREEK - NR TUCSON
SCCA3	SANTA CRUZ - CONTINENTAL
SCLA3	SANTA CRUZ - NR LOCHIEL
SCNA3	SANTA CRUZ - NR NOGALES
SCTA3	SANTA CRUZ - TRICO RD AT MARANA NR





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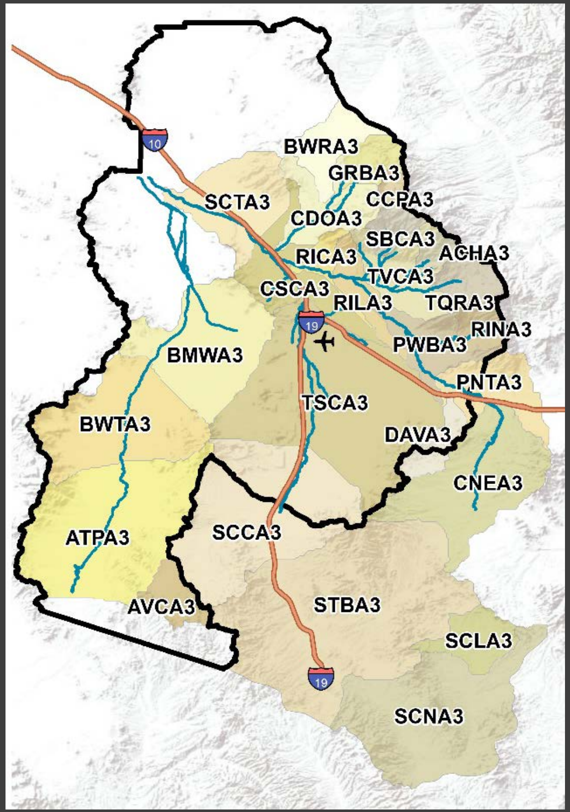
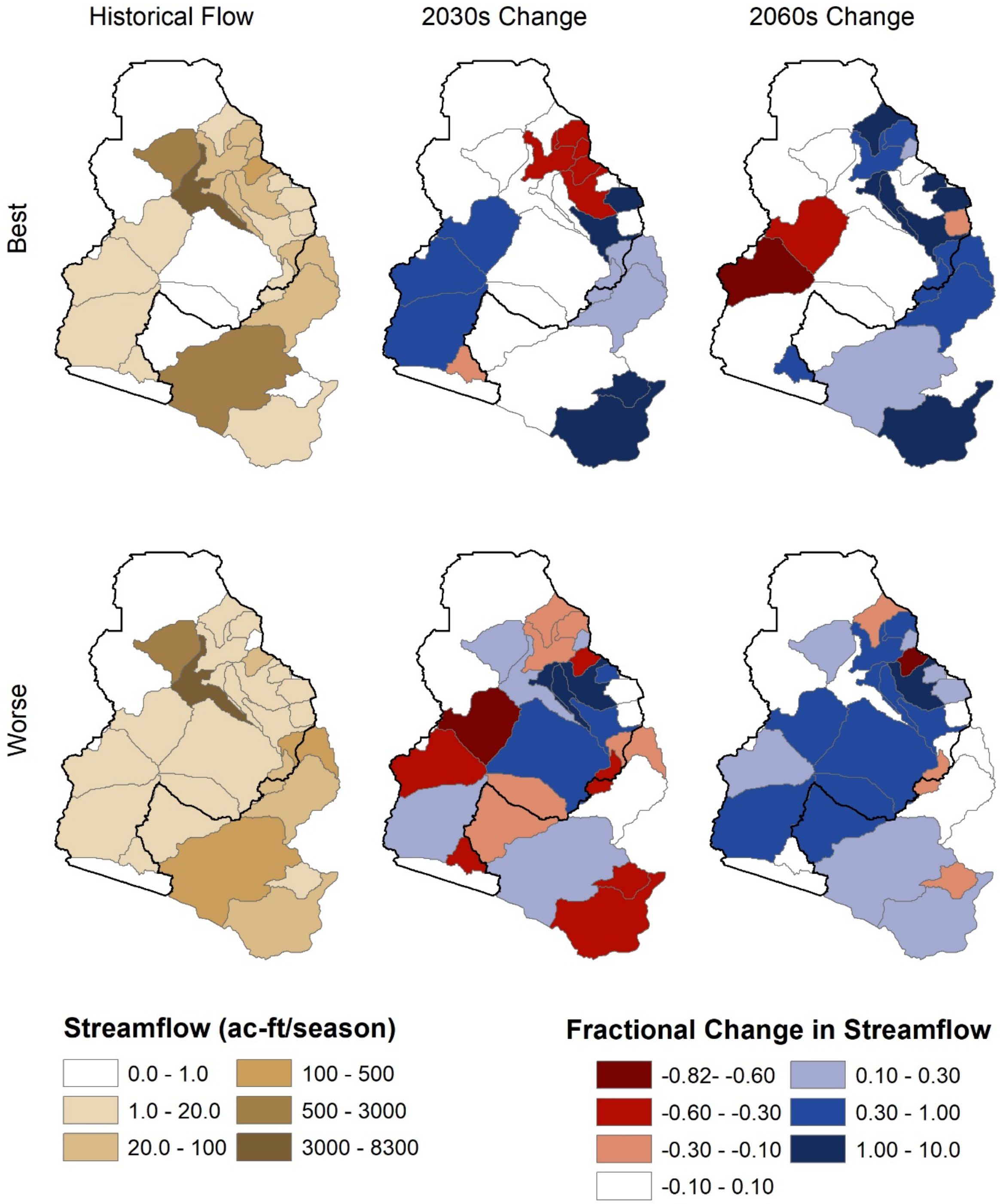
Dry Season
Spatial Streamflow





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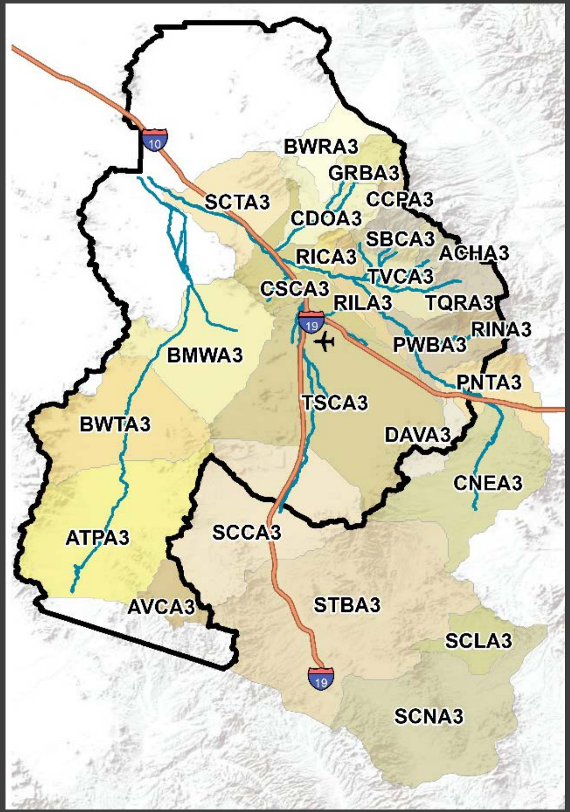
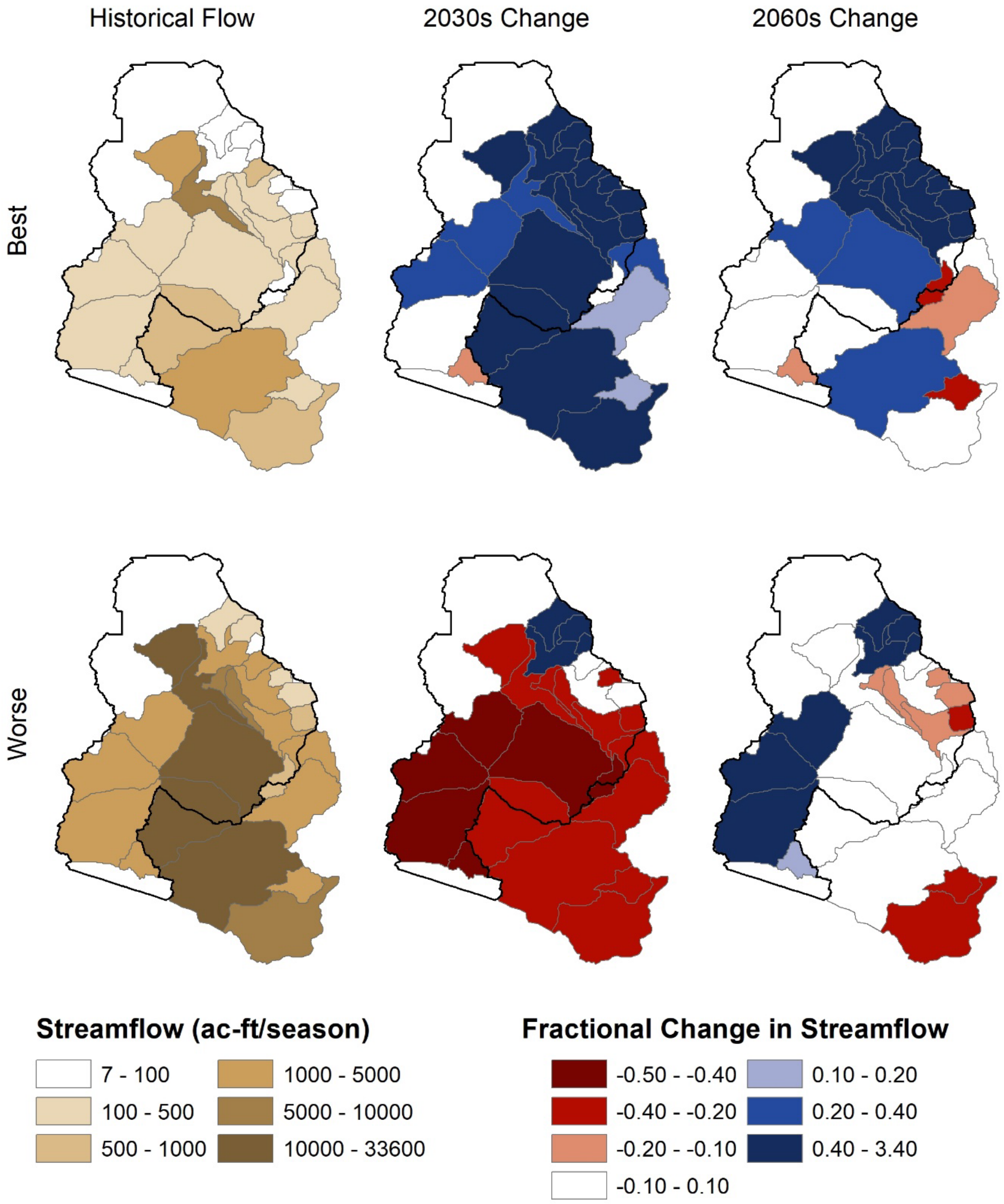
Monsoon Season
Spatial Streamflow





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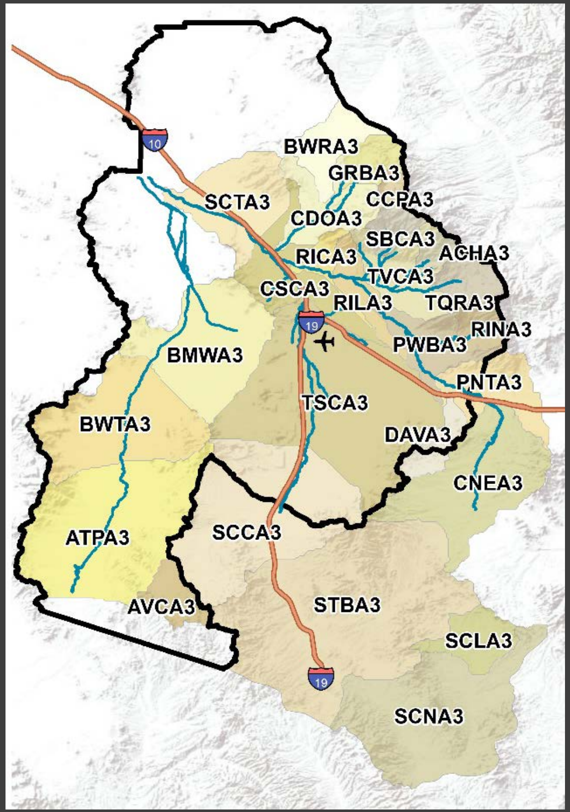
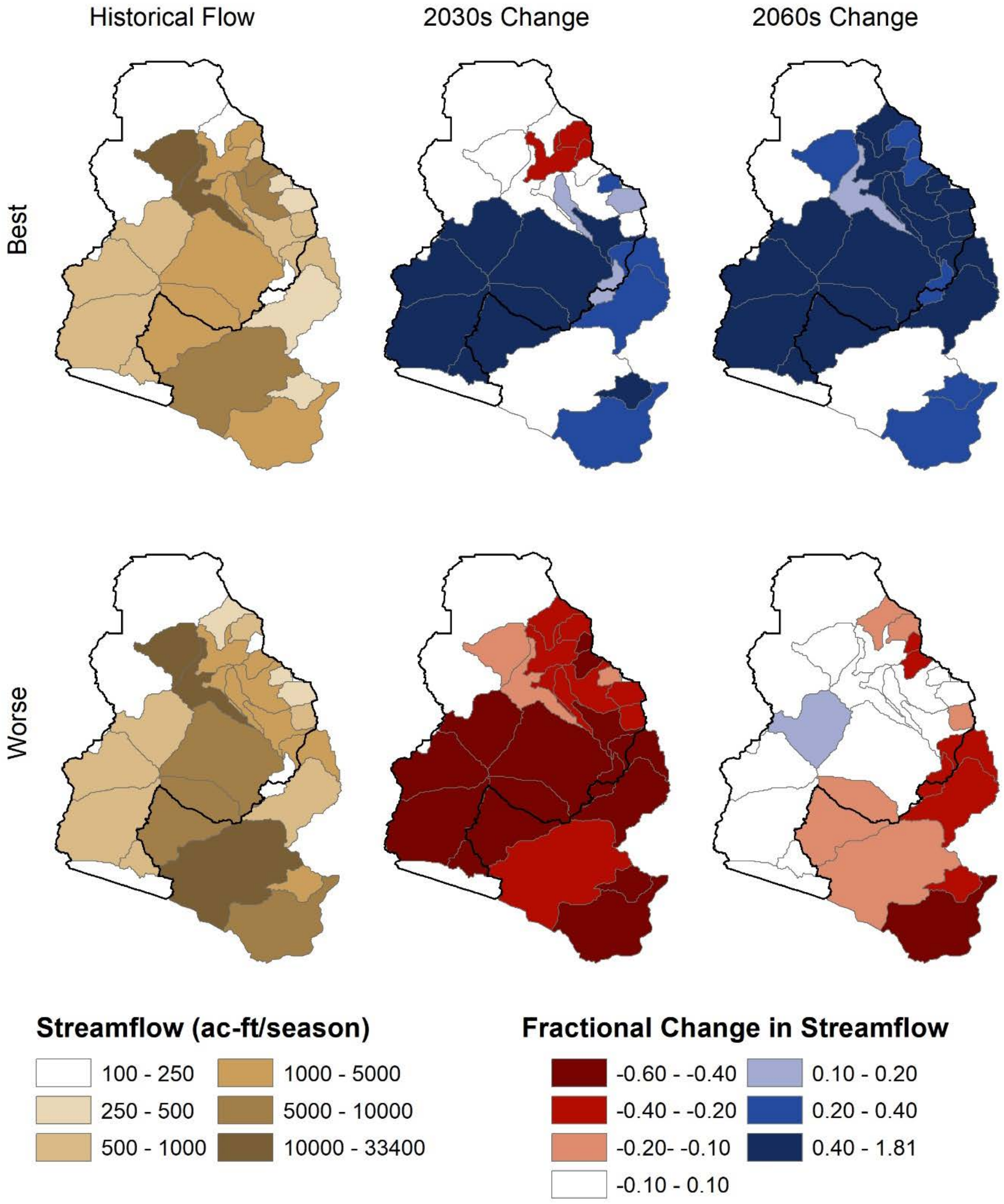
Winter Season
Spatial Streamflow





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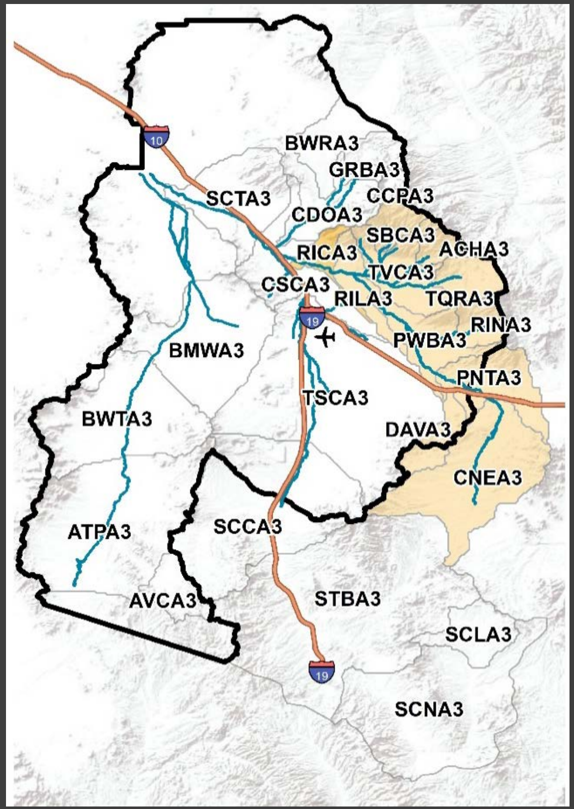
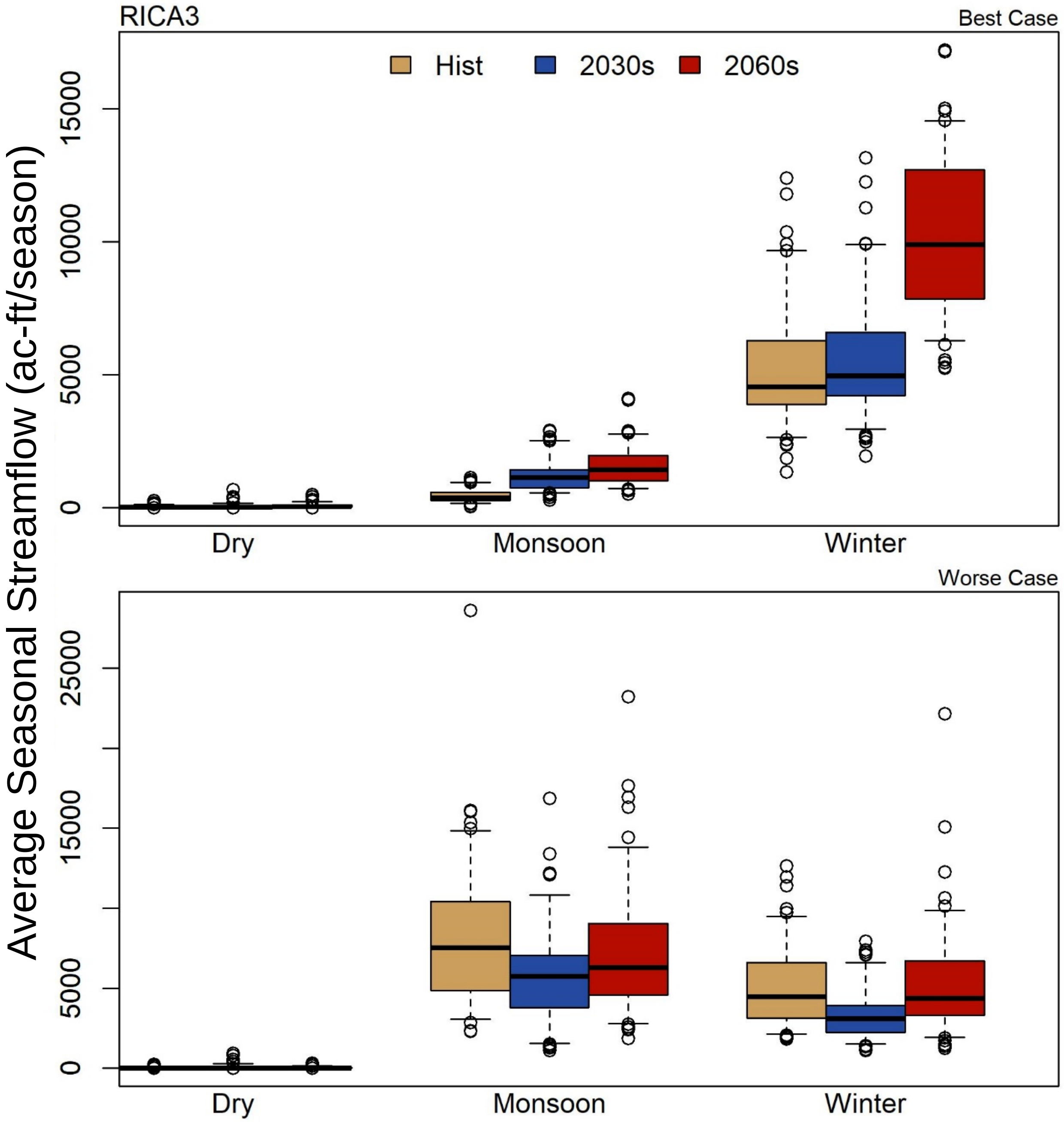
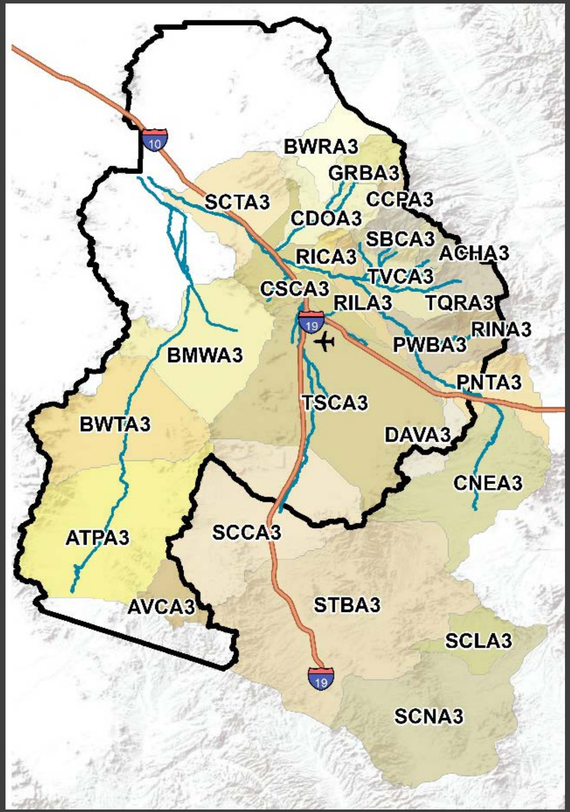
Streamflow Example

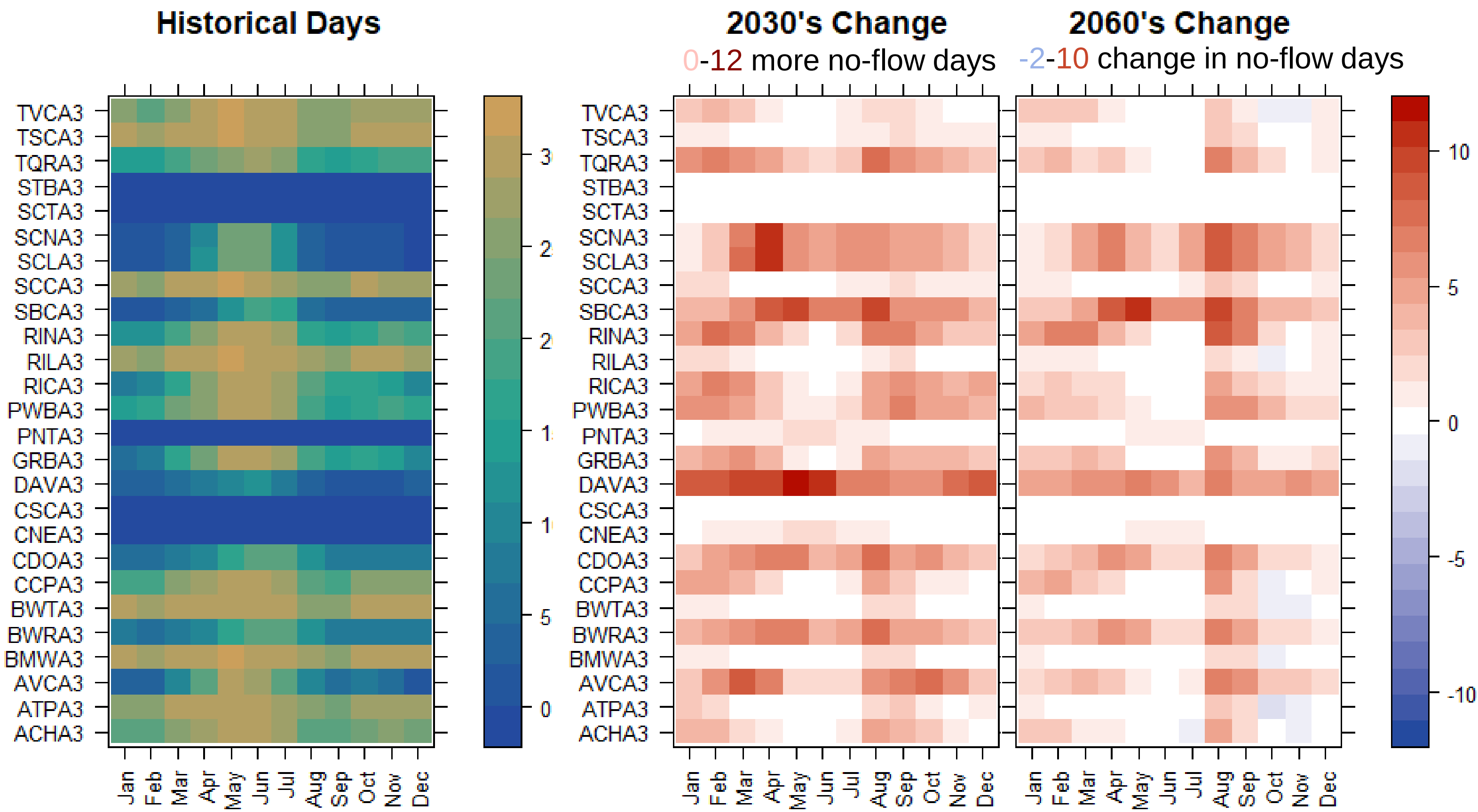
RILLITO CREEK AT LA CHOLLA BLVD





Streamflow No-Flow Days Worse Case

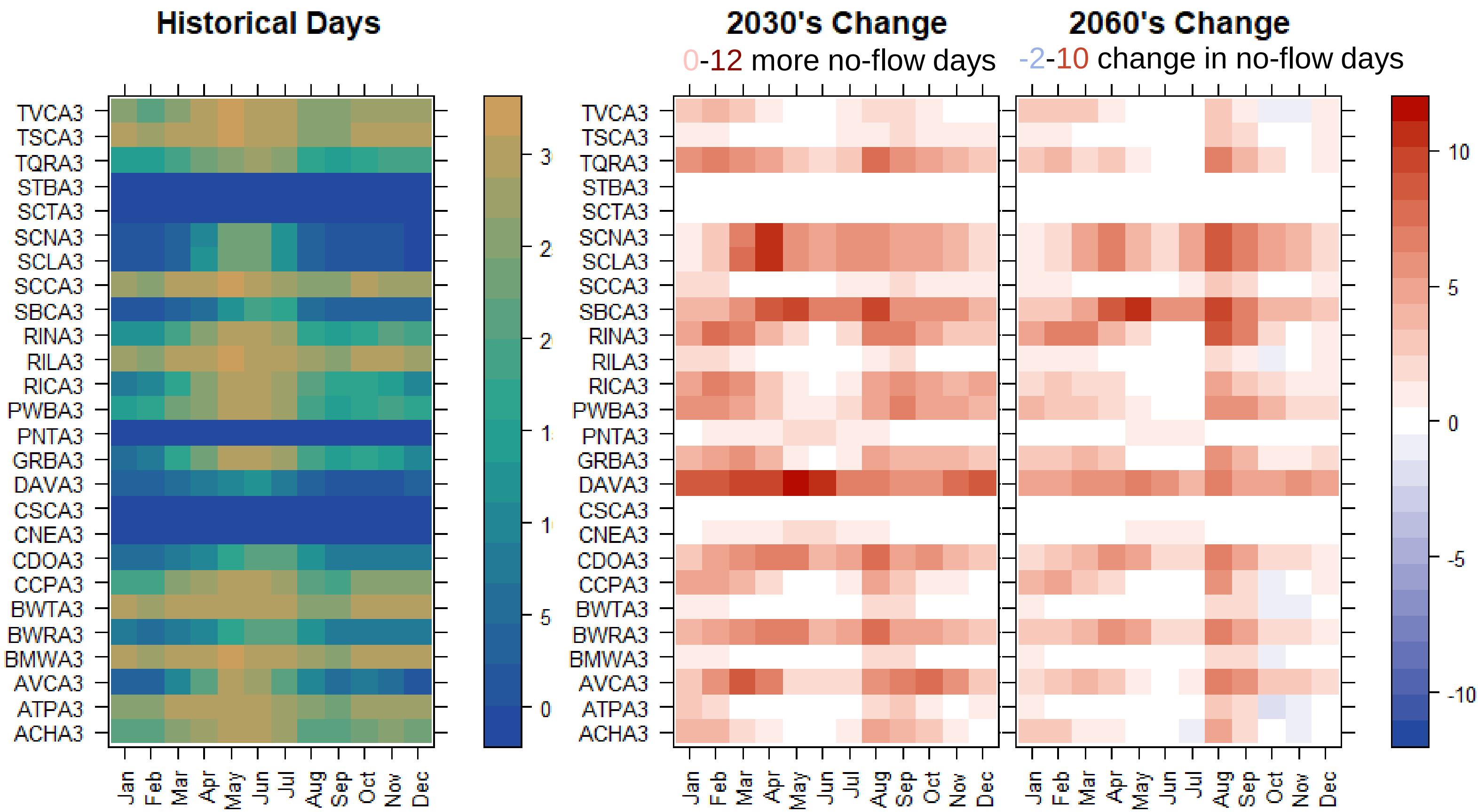




RECLAMATION

Streamflow No-Flow Days Worse Case for 2030s

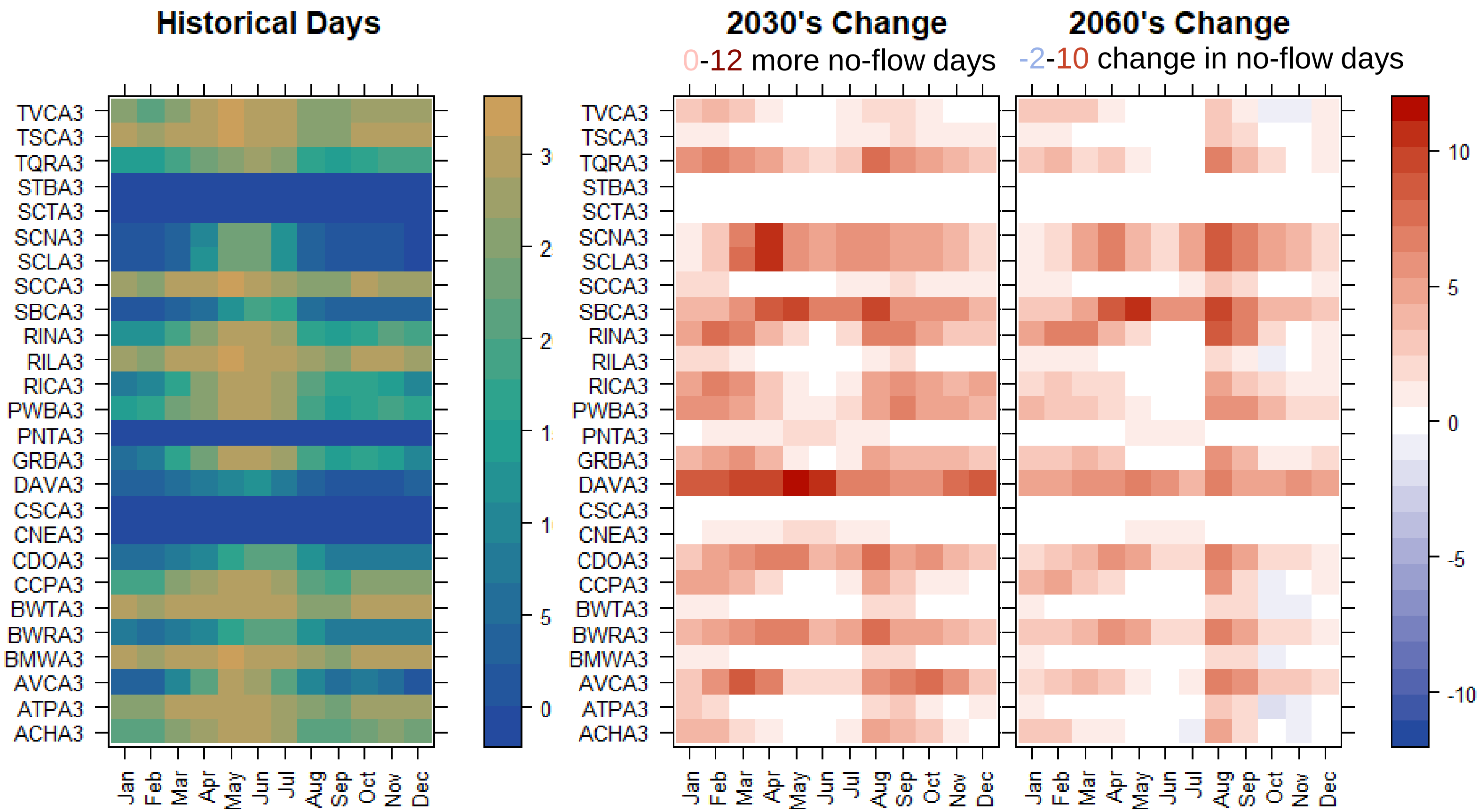
2030's - Top 5 increase in dry days (#)		
Davidson Canyon (DAVA3)	May	12
Davidson Canyon (DAVA3)	June	11
Santa Cruz nr Nogales (SCNA3)	April	10
Santa Cruz nr Lochiel (SCLA3)	April	10
Sabino Creek (SBCA3)	May	10



RECLAMATION

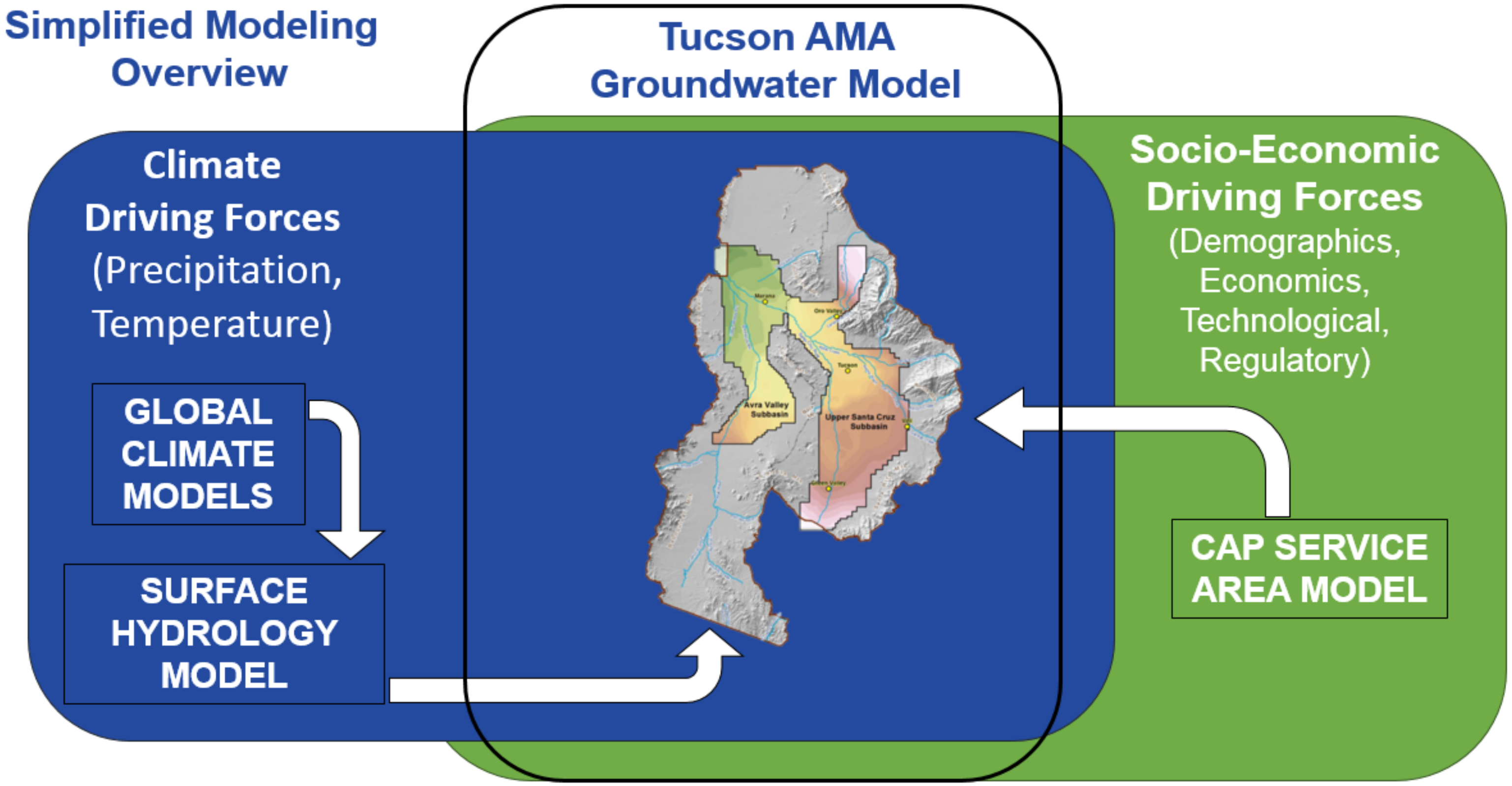
Streamflow No-Flow Days Worse Case for 2060s

2060's - Top 5 increase in dry days (#)		
Sabino Creek (SBCA3)	May	10
Sabino Creek (SBCA3)	August	10
Sabino Creek (SBCA3)	April	9
Santa Cruz nr Lochiel (SCLA3)	August	9
Santa Cruz nr Nogales (SCNA3)	August	9



Next Steps

1. Develop recharge scenarios for groundwater modeling
2. Prepare input for Environmental Subteam’s riparian vegetation assessment



Summary

- Models and scenarios consistently identify increases in temperature, with larger increases in the worse scenario.

- The best case provides a scenario with relatively minimal change in seasonal precipitation; in the worse case scenario, total precipitation decreases in the monsoon and winter wet seasons.

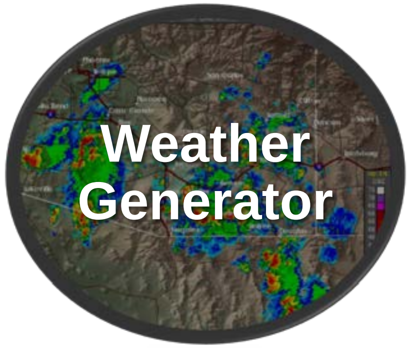
- The number of no-flow days per month consistently increases in the worse case.

RECLAMATION

Managing Water in the West

Lindsay Beaurp
lbearup@usbr.gov

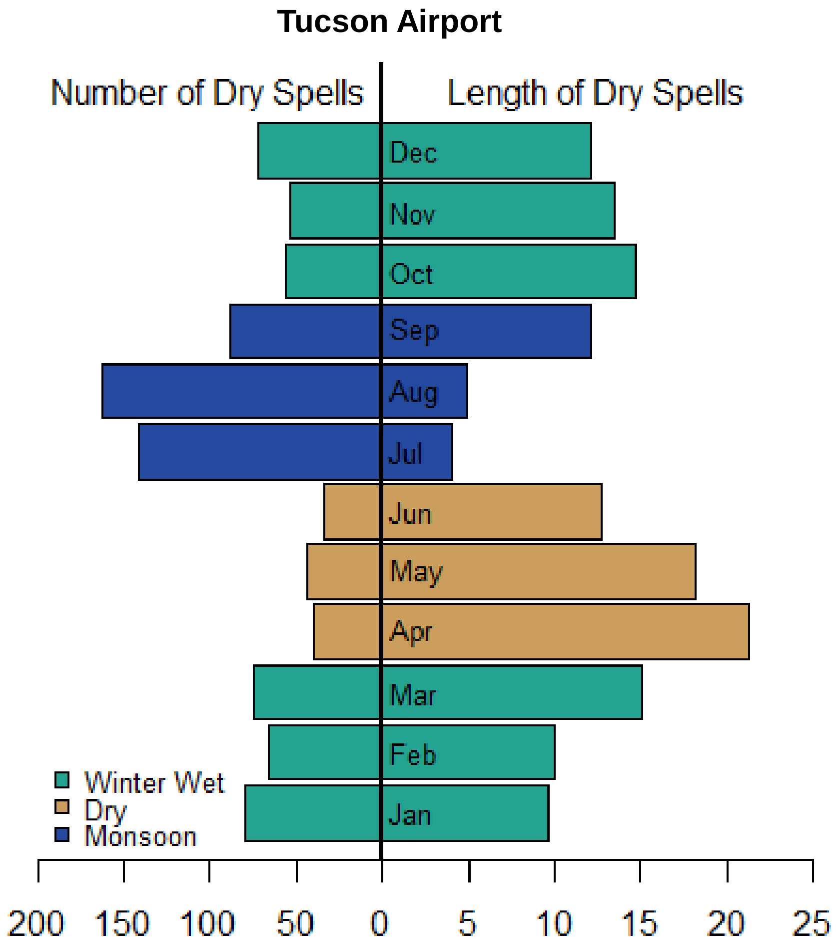
Weather Generator - Noteworthy

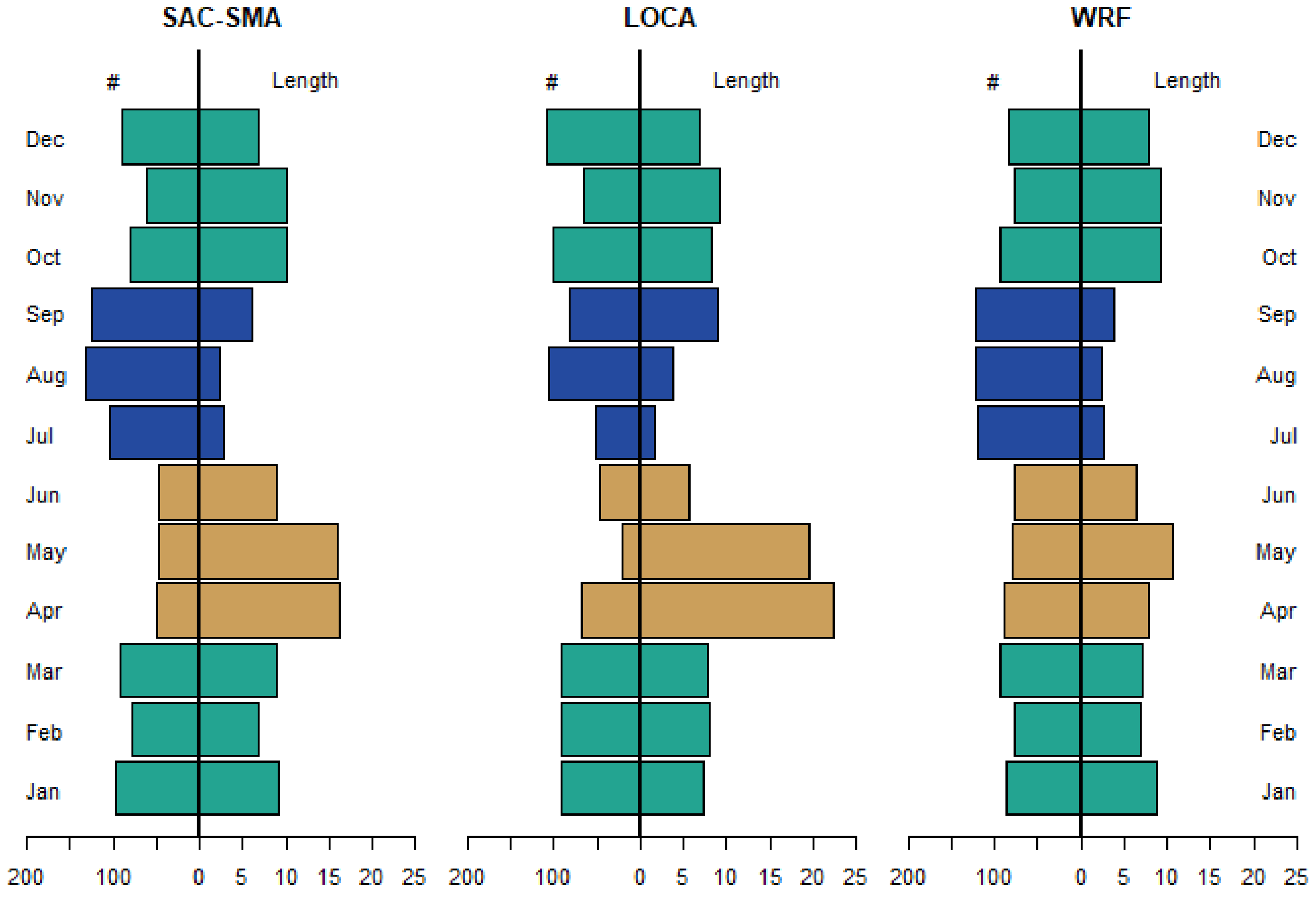


Didn't use HD approach as previously discussed because of the character of extremes in the LSCR basin. The "tails" of the distribution were such that we felt it altered the signals from the DD models inappropriately.

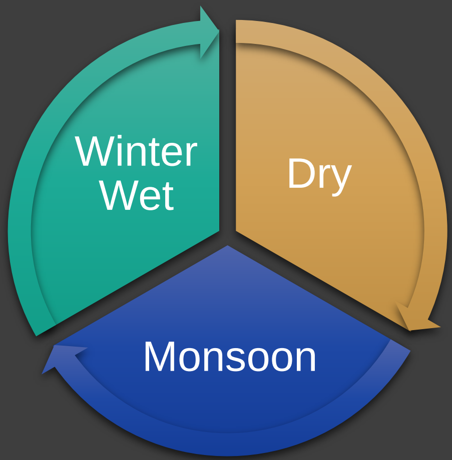
RECLAMATION

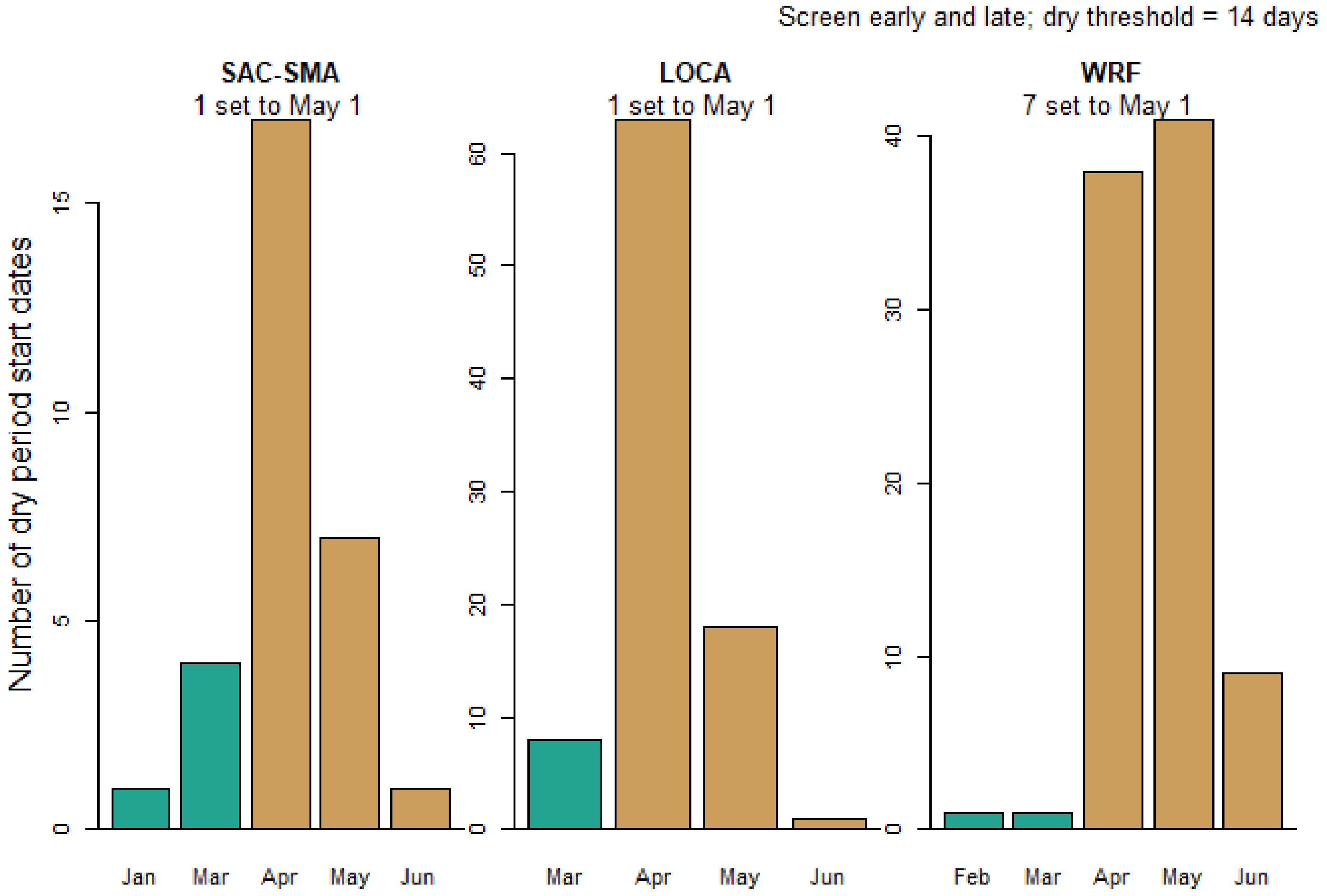
Dry Spells





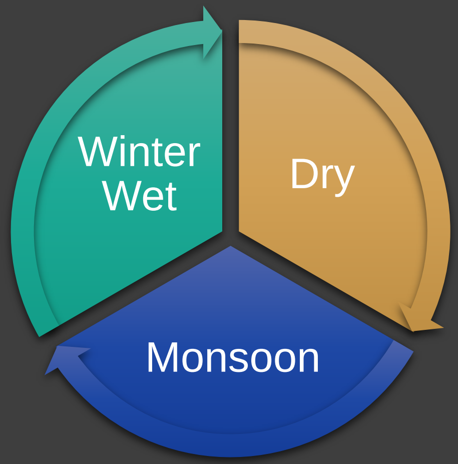
Dry Season Onset

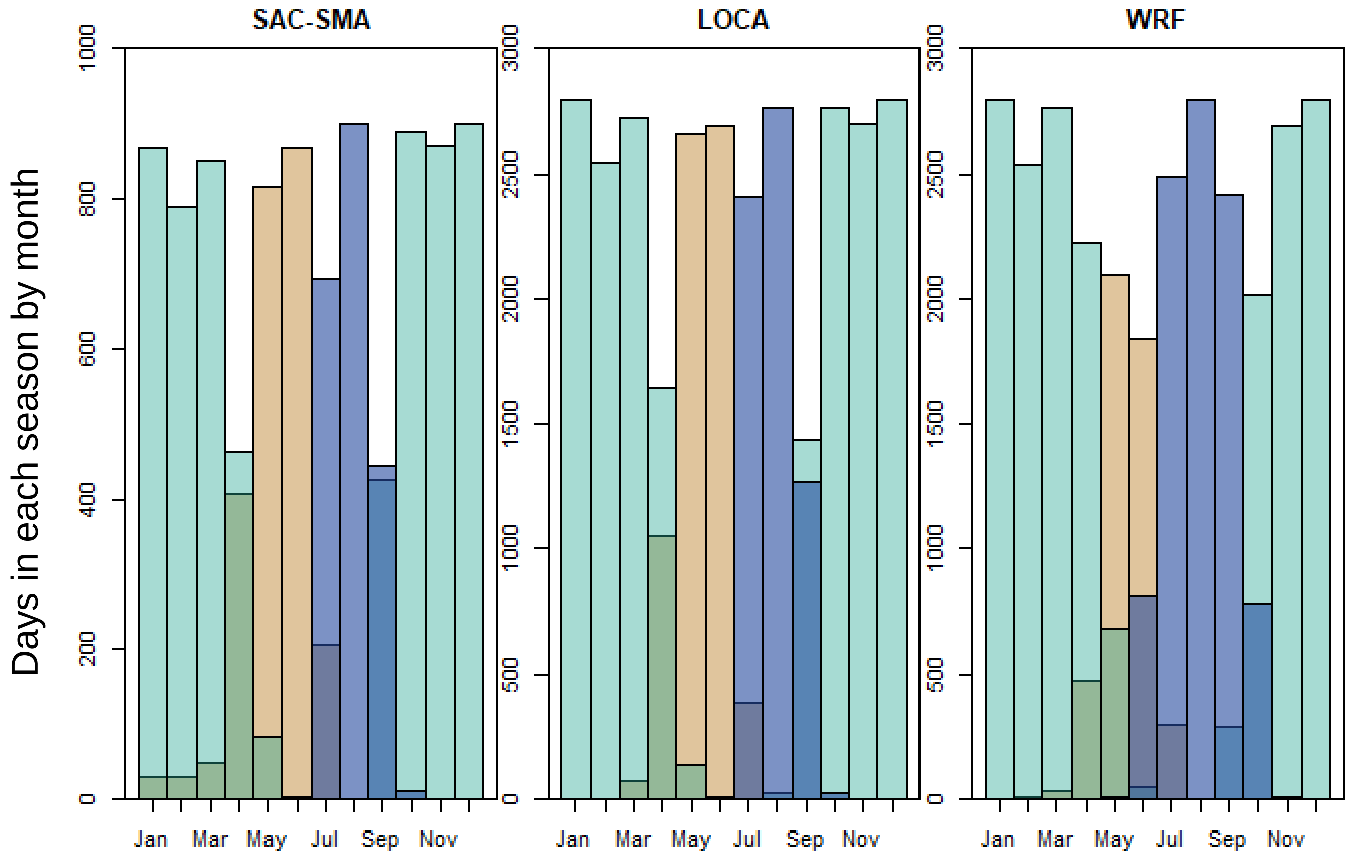




RECLAMATION

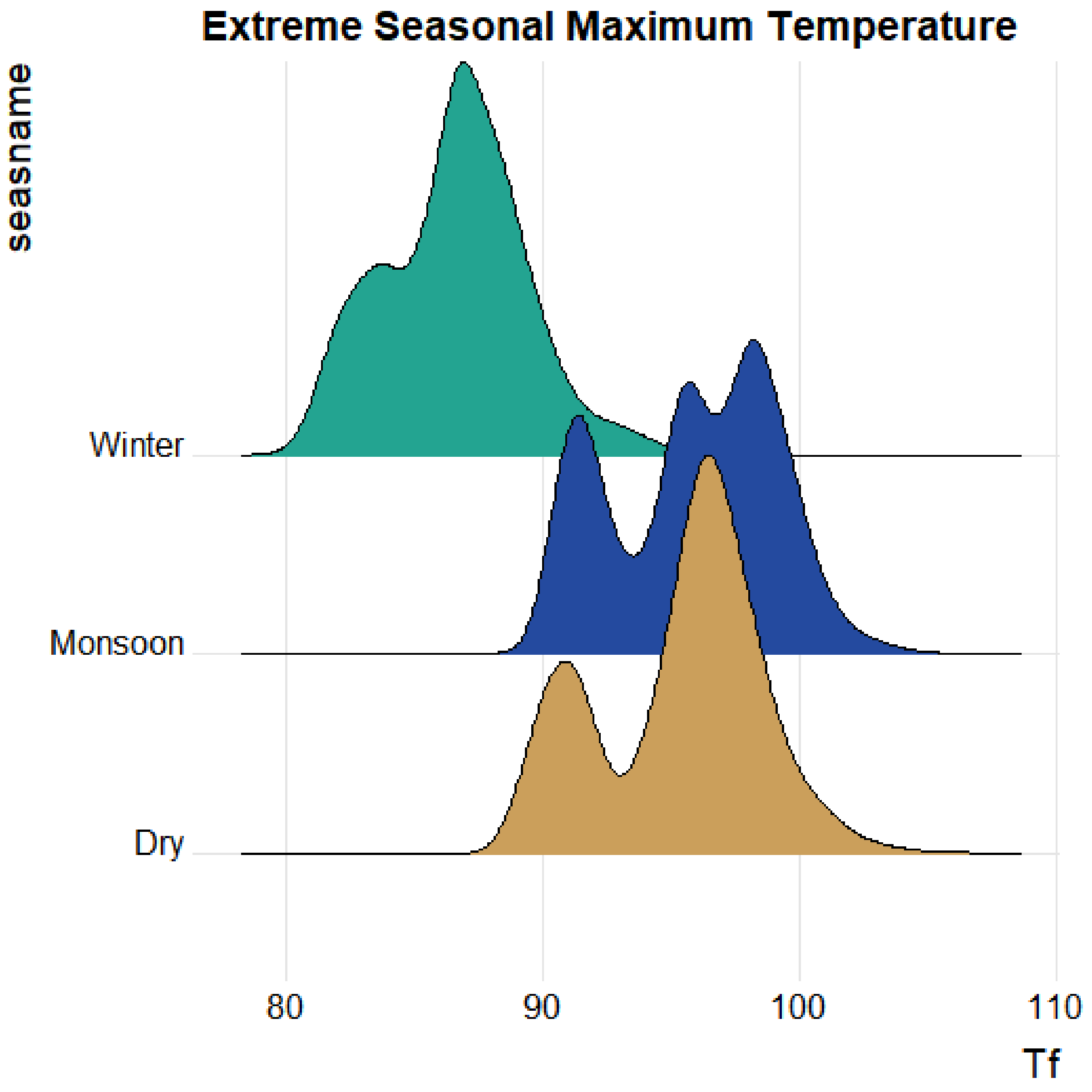
New Timing for Future Climate





RECLAMATION

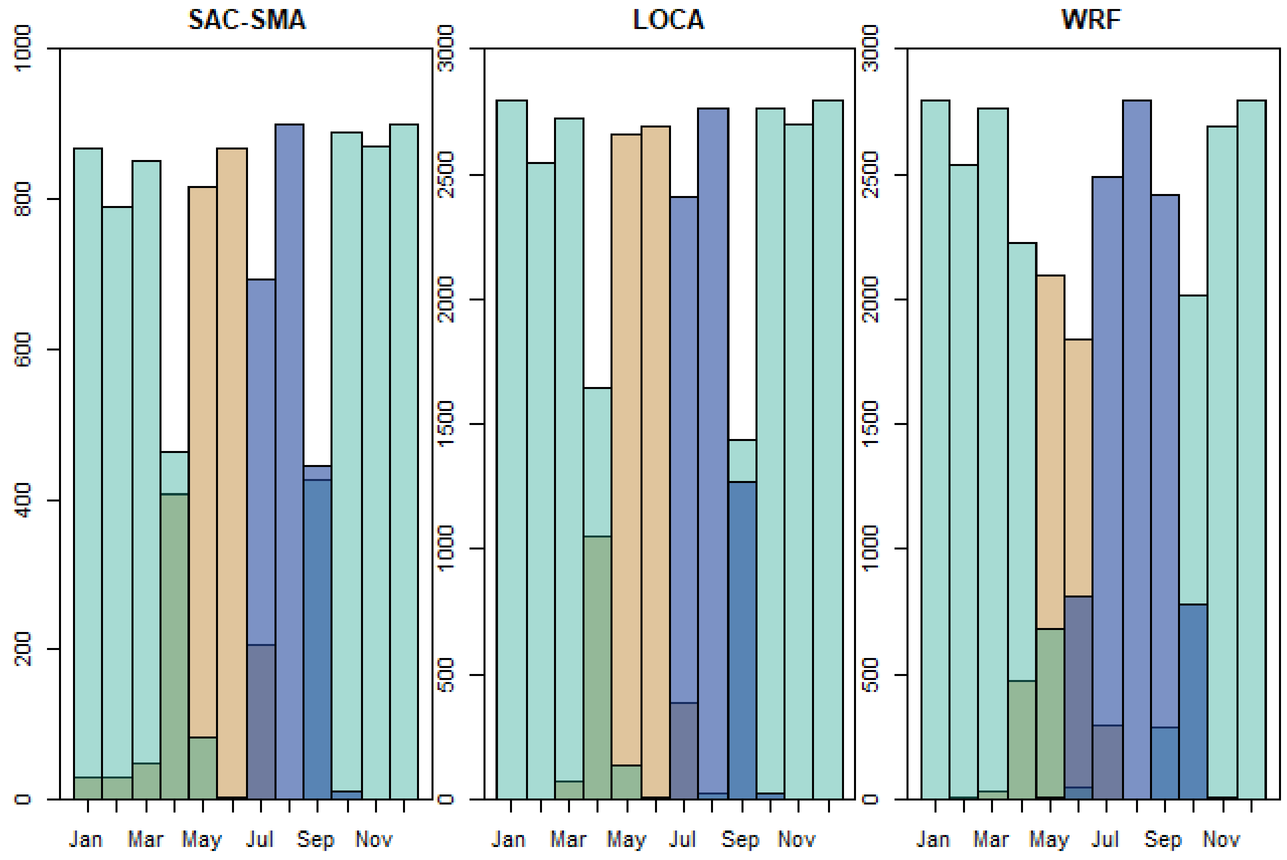
Extreme temperature changes most unique in monsoon



What's going on with LOCA mpi 4.5?

Seasonality based on incomplete information (Dewpoint not available for this projection)

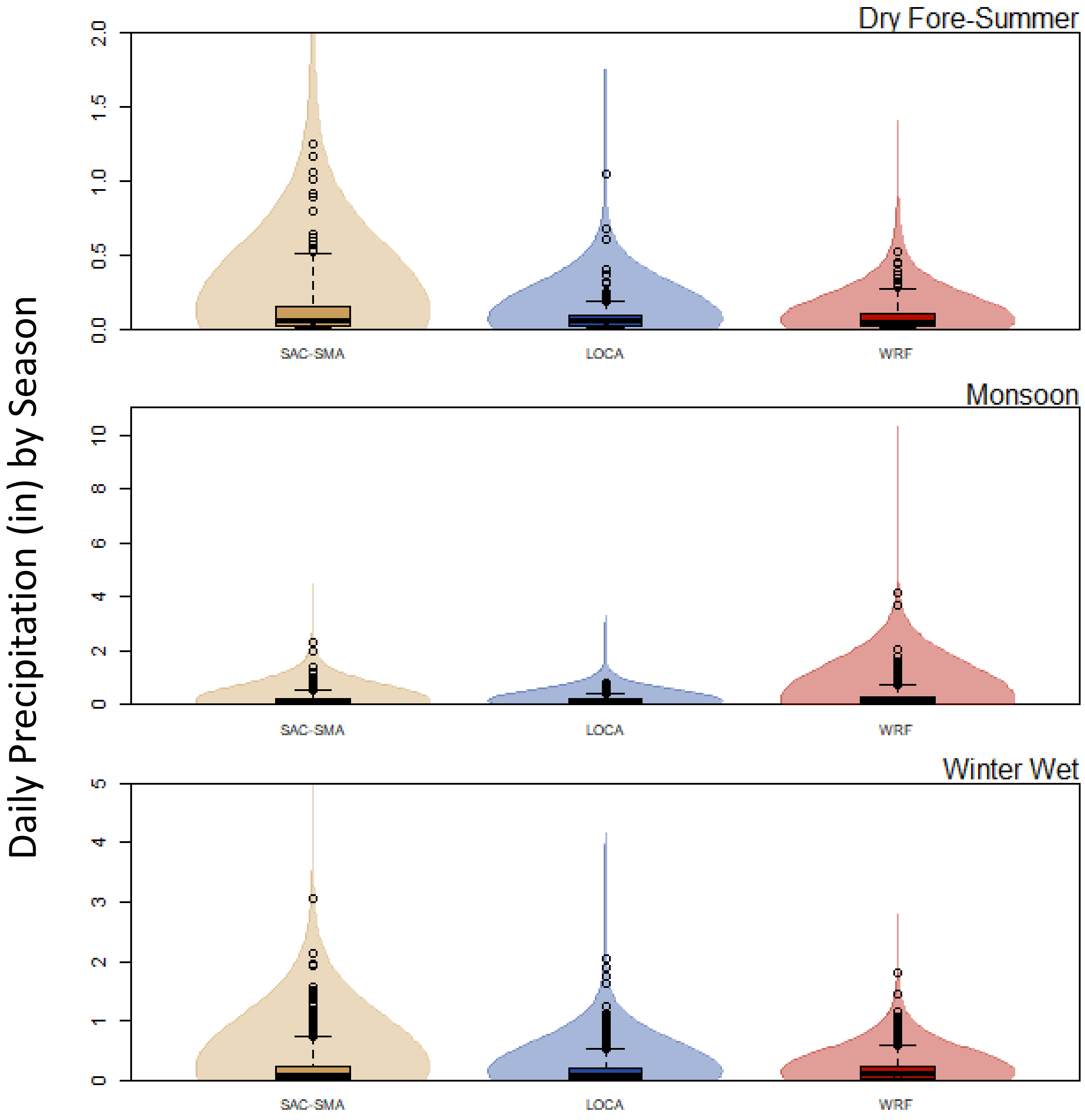
While the resulting seasonality looks consistent with expectations, the July precipitation from the LOCA downscaled MPI 4.5 data is consistently low…



First: What's going on with LOCA mpi 4.5?

July precipitation has a large number of small events and is missing larger events;

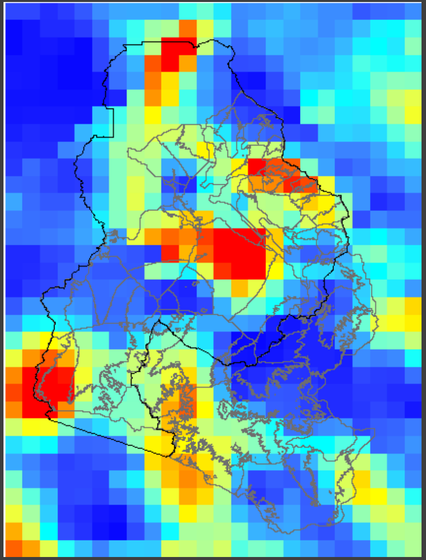
NO precip events in the monsoon season exceeds 0.8inches! (sac-SMA is 2.3")



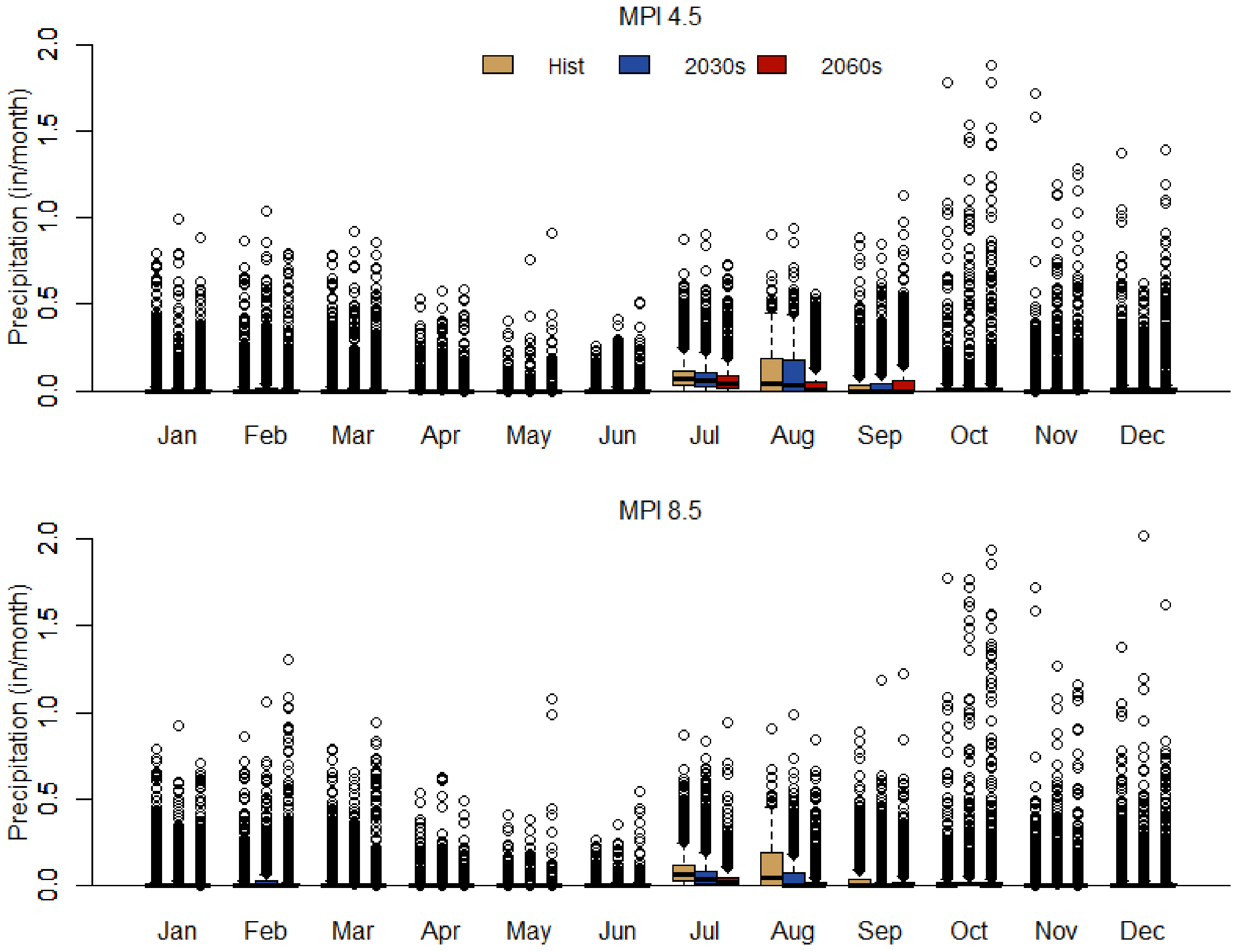
Second: What's going on with LOCA mpi 4.5?

Consistent with data averaged from LOCA grid directly. Highest July value is 0.9" on 7/23/1976 and goes down from there.

Random historical LOCA day of full grid shown here for reference

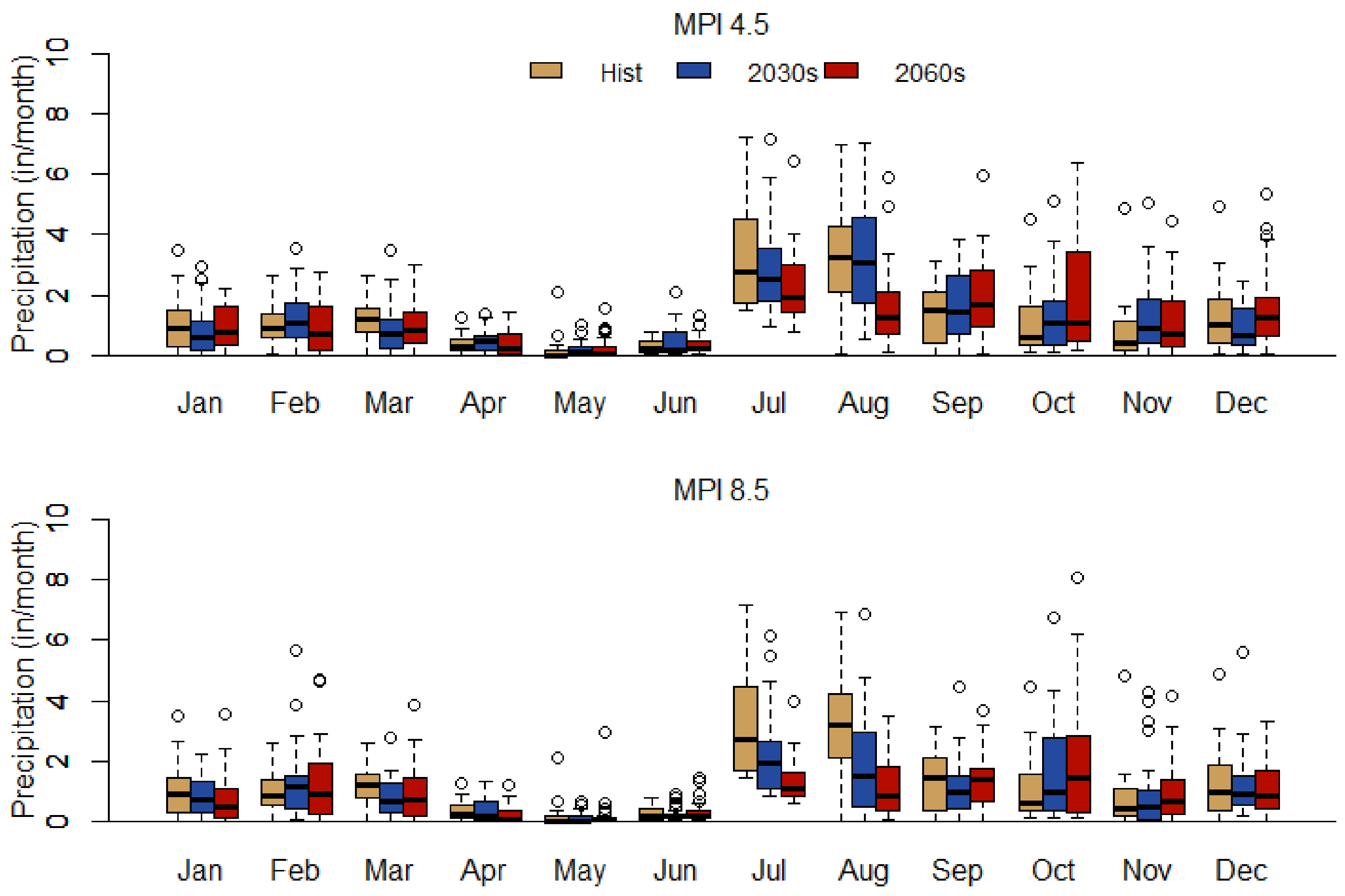


Precipitation (in/day) for all days in the period



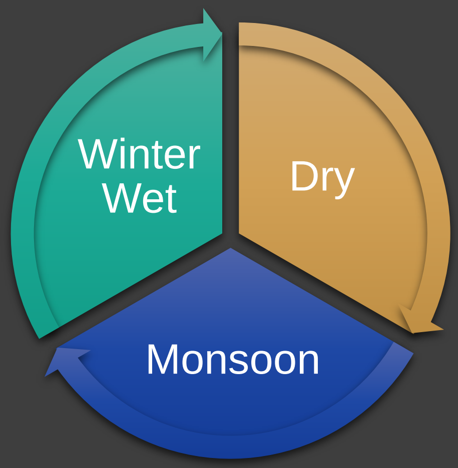
Thirdly: What's going on with LOCA mpi 4.5?

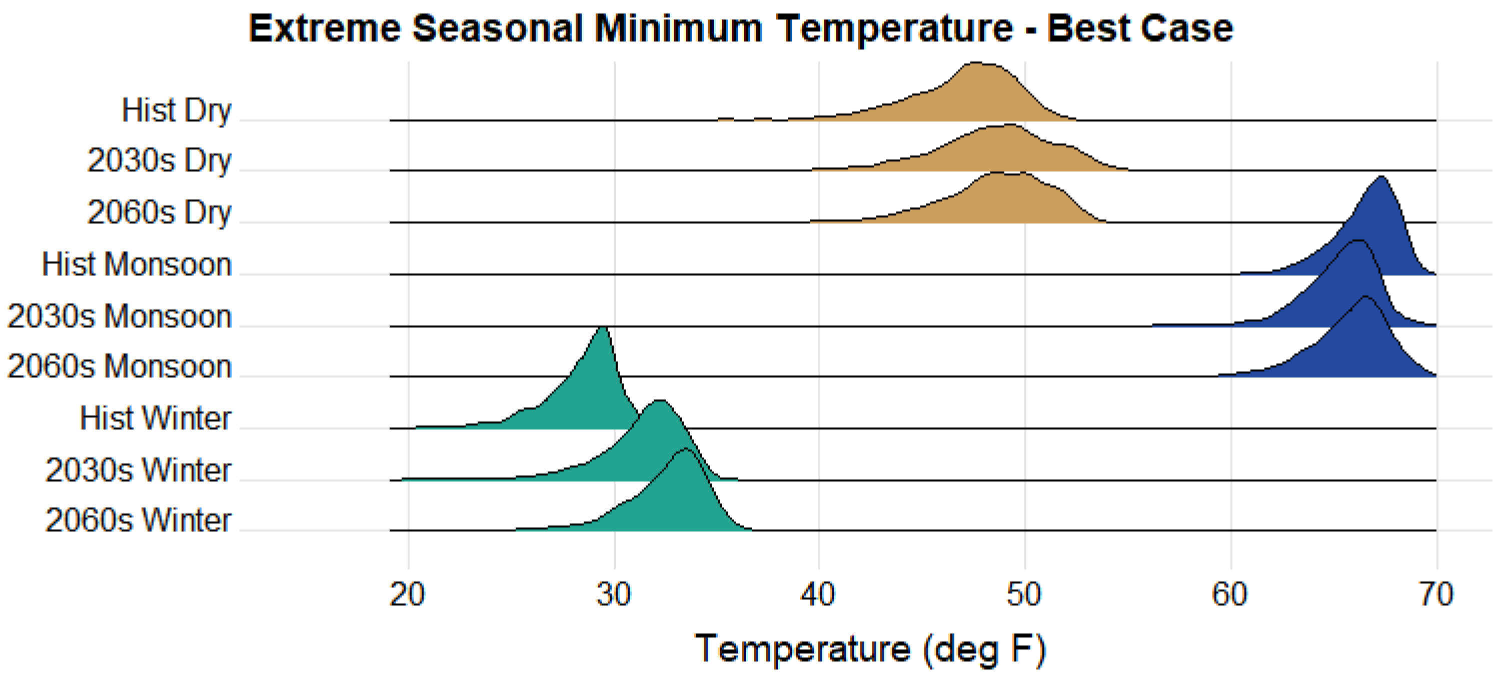
Although when summed to a monthly timescale the large number of small events adds up to reasonable precip…

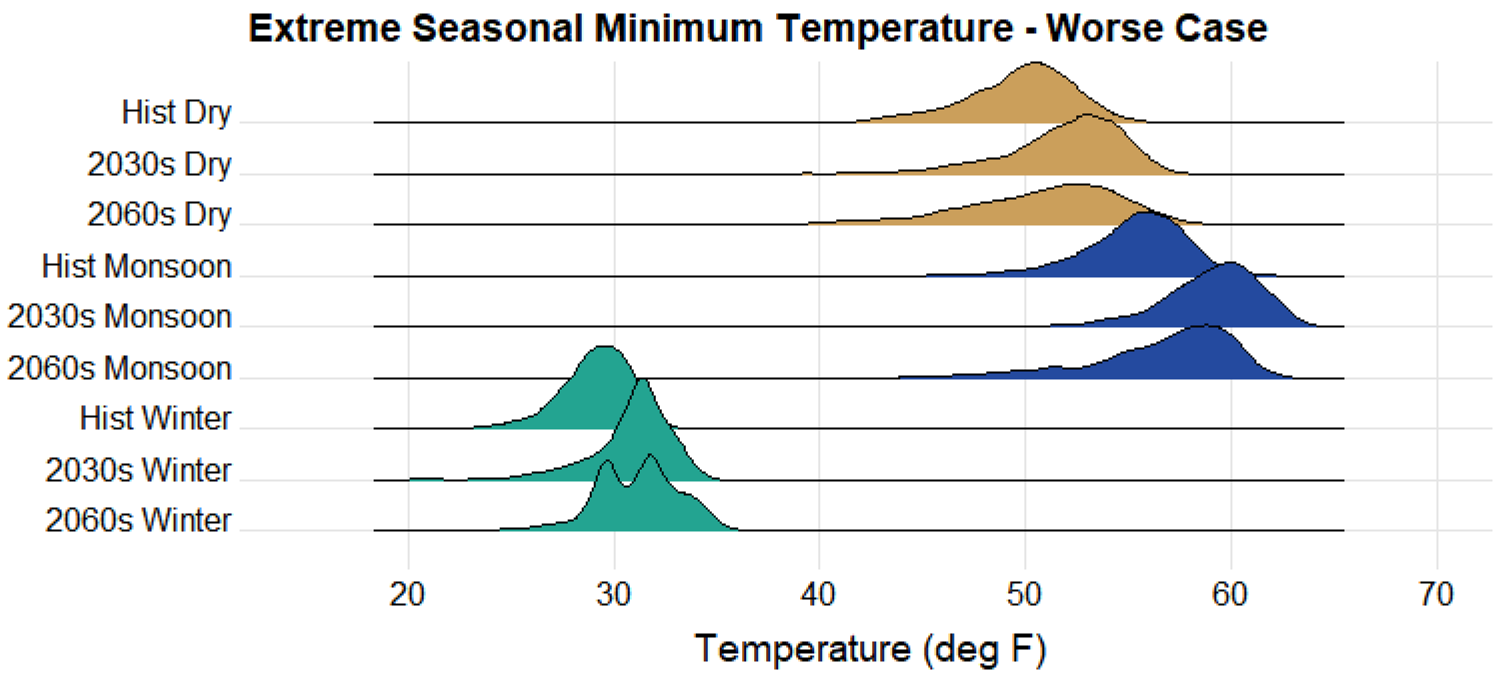


Extreme Events Bottom 10% of Seasonal Min Temperature

Weather Generator Output







RECLAMATION