RECLAMATION
Managing Water in the West

Climate Time Series Projections for Input to the Weather Generator

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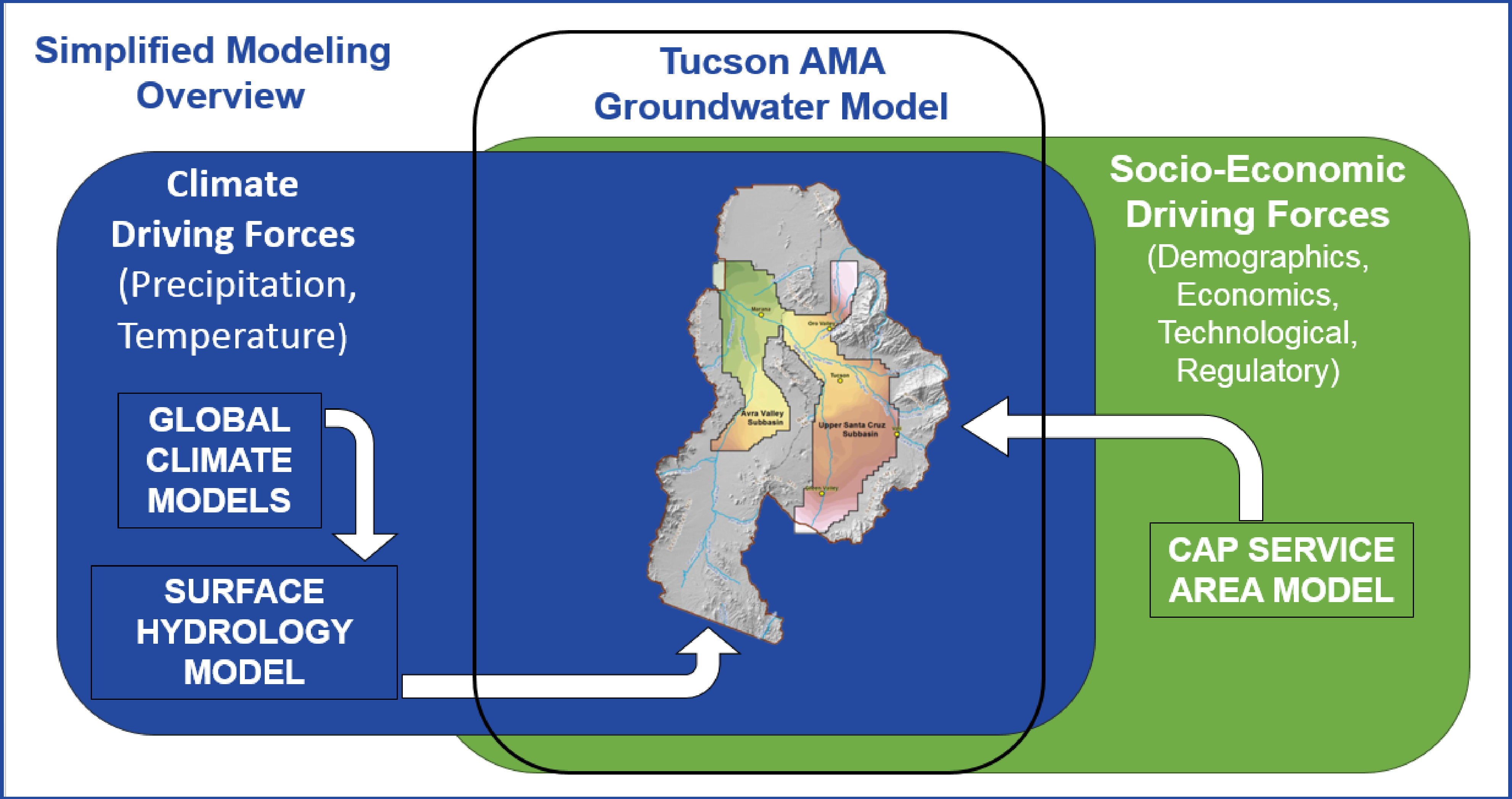
Bureau of Reclamation, TSC

December 4, 2018

Basin Study All Teams Meeting

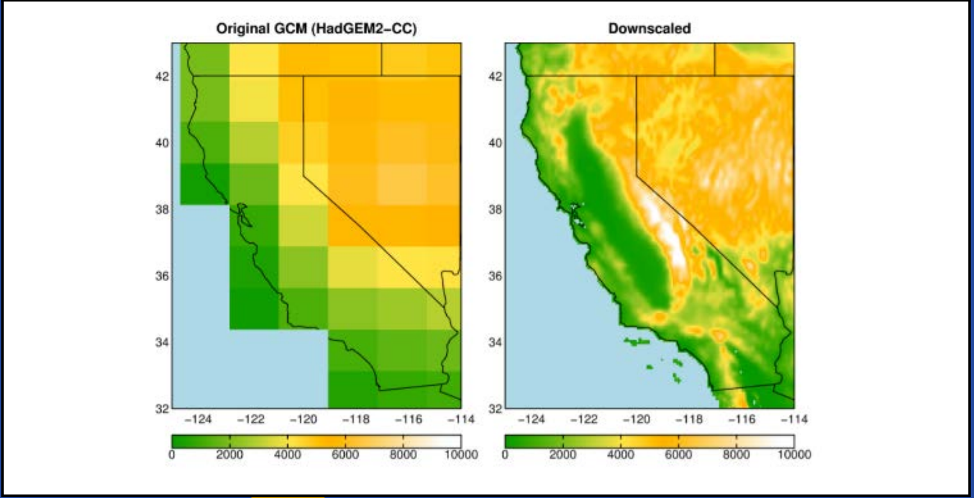


OUTLINE

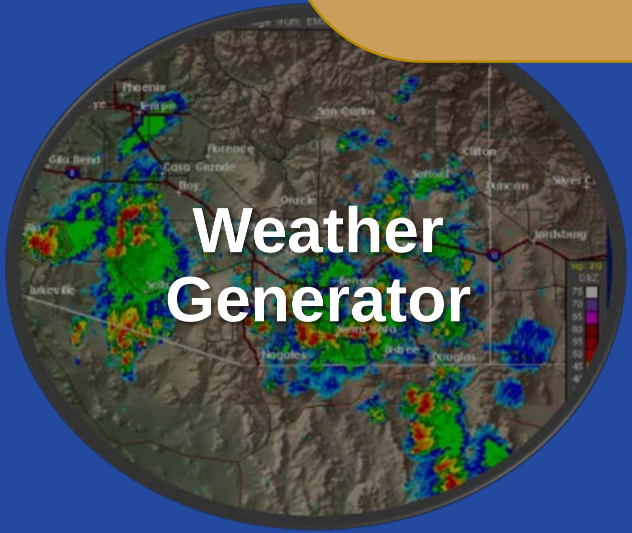
1. Introduction 2. Background 3. Future Climate Scenarios 4. Metrics 5. Discussion

Process Overview

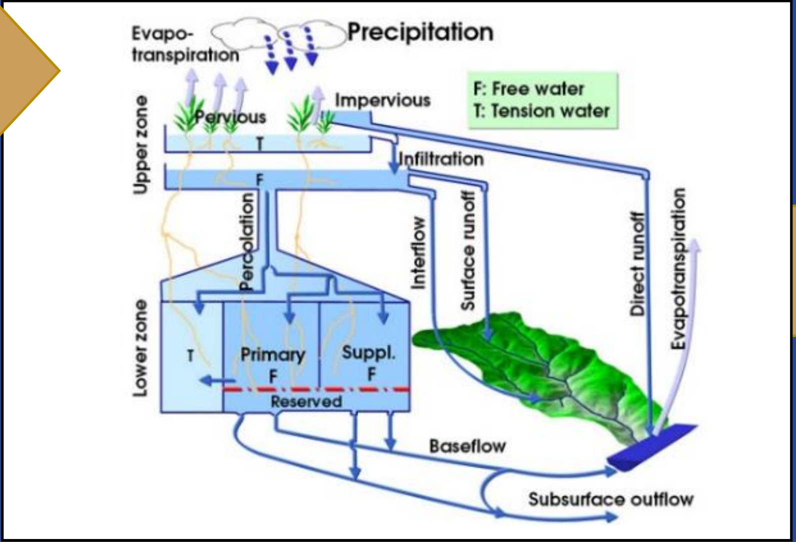
1. Downscaled Climate Projections



Precipitation
& Temperature



2. Surface Water Modeling



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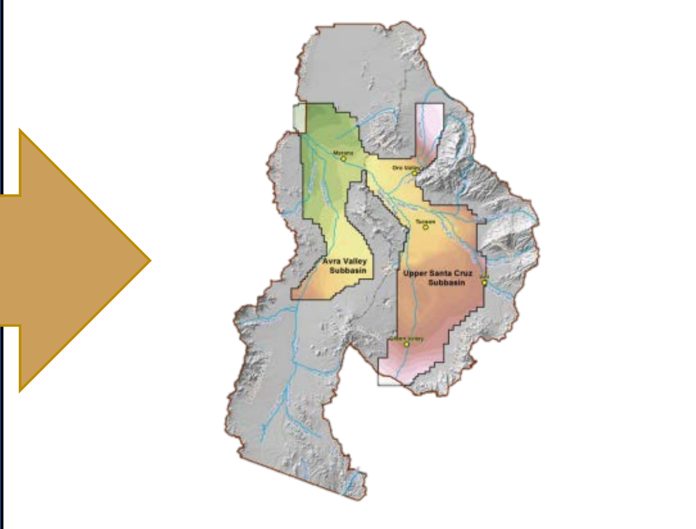
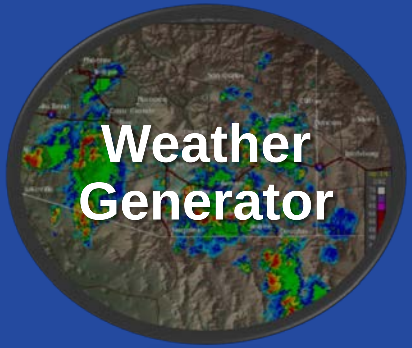


Weather Generator Motivation



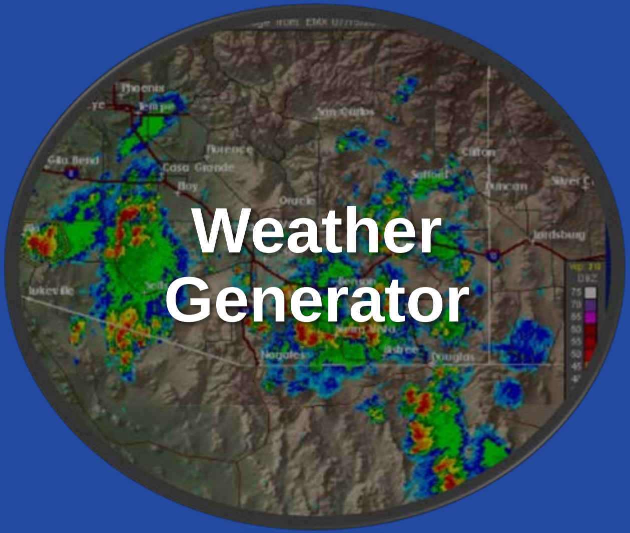
- Scale (spatial and temporal) that is relevant for local surface water modeling
- Natural precipitation variability is particularly important in this region. The weather generator is used to introduce variability around the broader climate projection trends.
- The resulting ensemble (large group) of likely rainfall timeseries represents a range of possible amounts, daily patterns, and seasonality that will drive a resulting range of streamflows.

Weather Generator Introduction - 1

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

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

Future climate scenarios
- Best case
- Worse case



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

Weather Generator Introduction - 2

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

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- Best case
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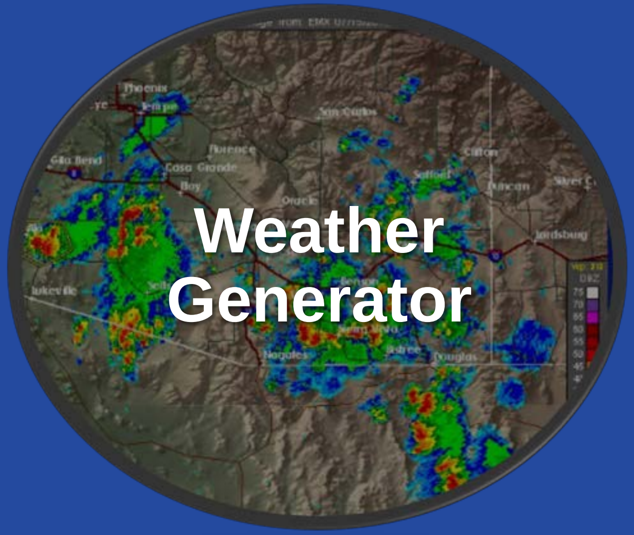


Future time series of precipitation and temperature inputs to SAC-SMA surface water model

Future Climate Scenarios

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

Dynamically Downscaled (DD): WRF

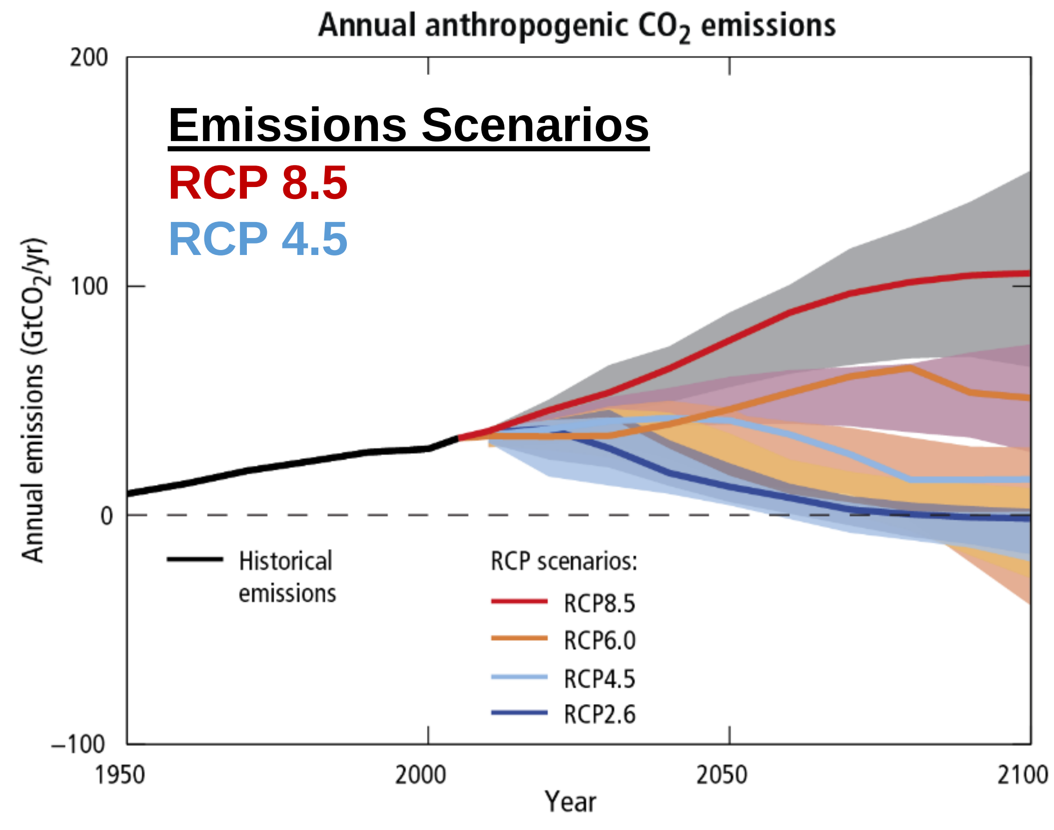
Weather Research and Forecasting Model (https://www.mmm.ucar.edu/weather-research-and-forecasting-model)

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

Worse Case: WRF-MPI RCP 8.5

- WRF-MPI preferred model from University of Arizona analysis
  - Simulated monsoon timing in the area
- Other DD models evaluated were determined to:
  - Provide inconsistent future changes, or
  - Require additional data screening.

Best Case: LOCA-MPI RCP 4.5

- Same physics and underlying Global Climate Model as worse case
- Using model that was determined to do well for the DD scenarios with statistical downscaling because DD was not available.

Future Climate – Analysis Periods

Historical: 1970-1999

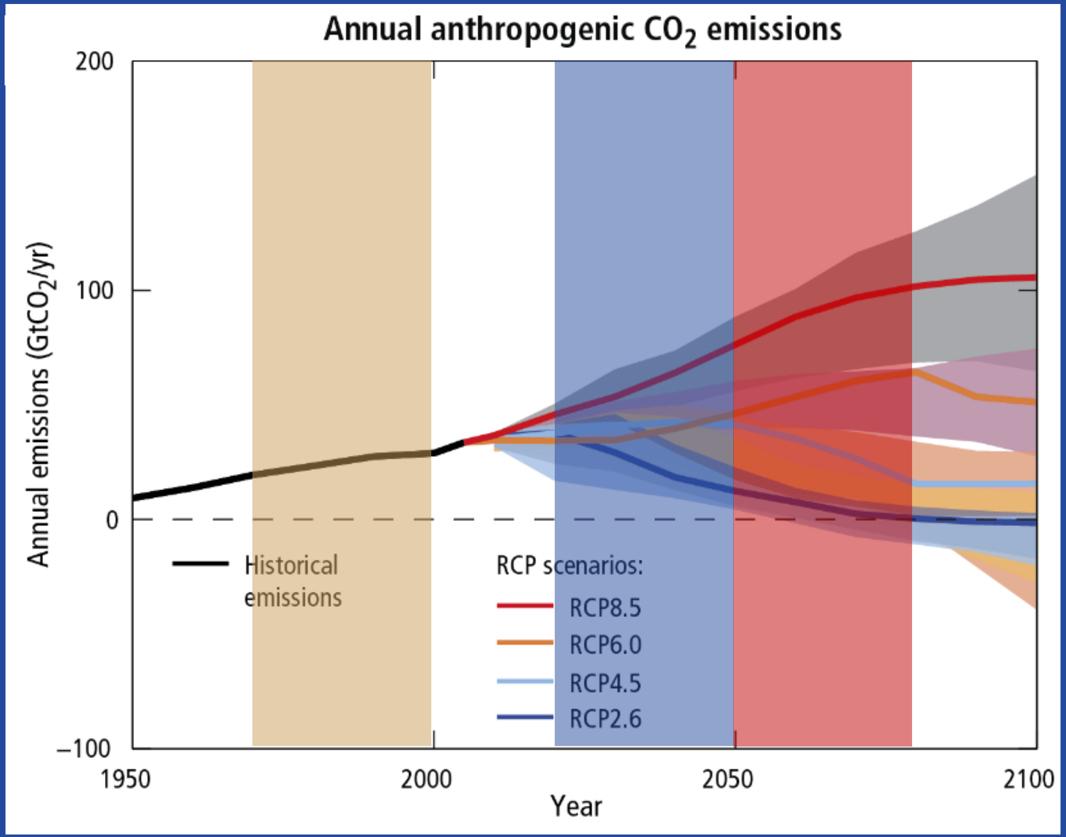
- SAC-SMA calibration period
- Prior to 2006 start of GCM "Futures"

"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



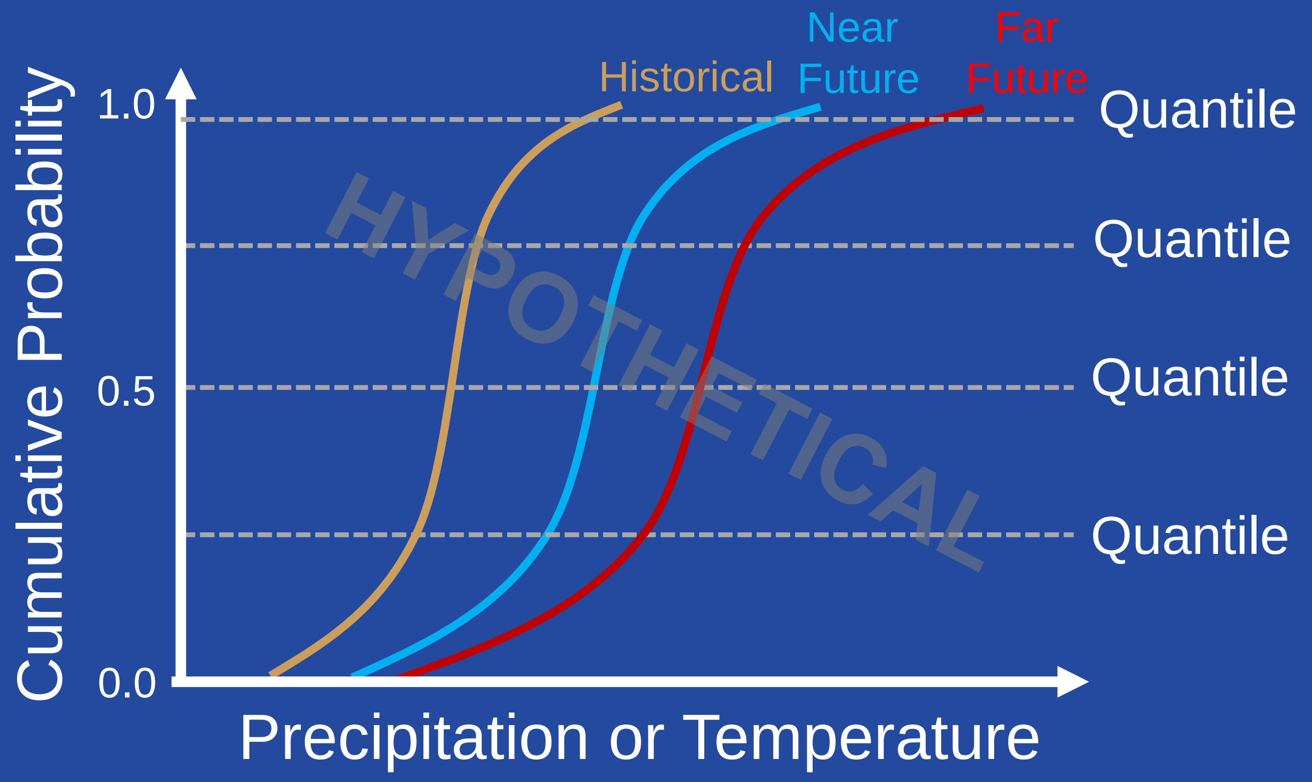
Future Climate – Changes in Magnitude - 1

Hybrid Delta Ensemble (HDE) approach based on monthly changes of precipitation and temperature from climate models

- Adjust quantiles separately
- Historical: ***modeled***
- Change: reduces effect from model biases

Bias = systematic error in model results

Too hot? Too cold? Too wet? Too dry?

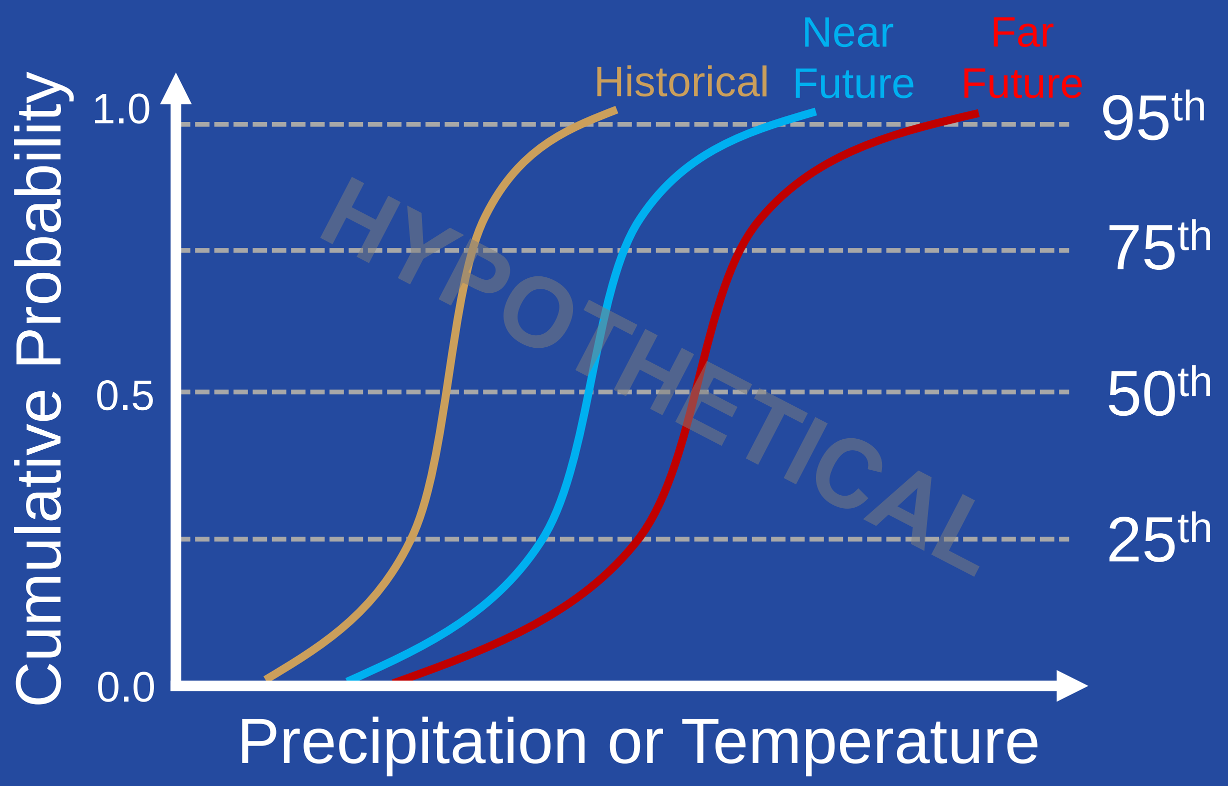


Future Climate – Changes in Magnitude - 2

Use the probability perspective to look at changes in precipitation and temperature for three states (seasons):

1. Dry Month (May)
2. Wet Winter Month (December)
3. Monsoon Month (August)

- Values are basin-averaged
- Precipitation on rainy days (P≥0.01”) M. Crimmins, personal communication

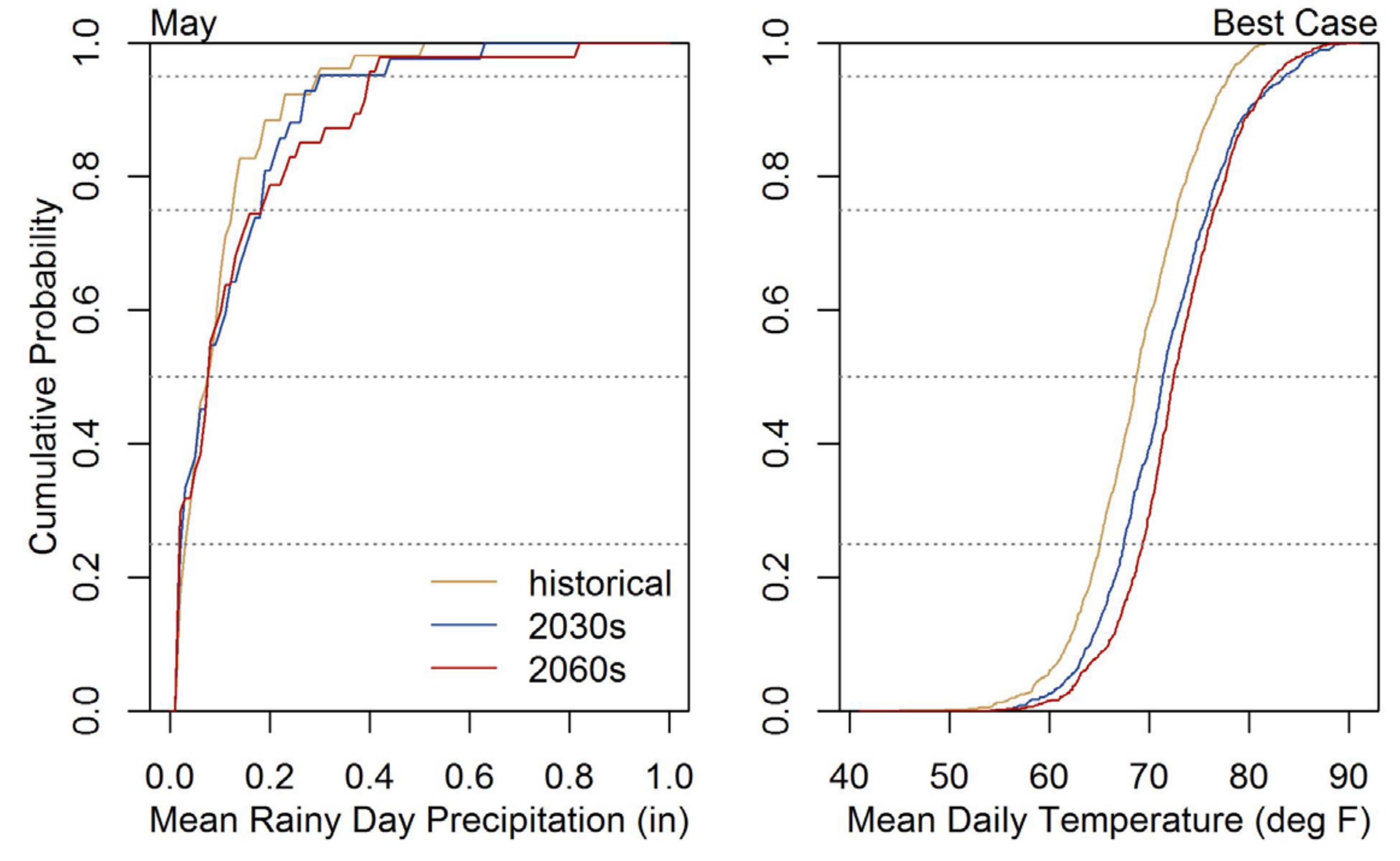


Best Case: LOCA-MPI RCP 4.5 (May)

Dry Month (May)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	-0.01 | -0.02	2.4 | 4.3
Median (50th)	0.00 | 0.00	2.7 | 3.7
High (75th)	0.06 | 0.04	3.1 | 3.7
Extreme (95th)	0.01 | 0.10	5.7 | 4.9

*For days with greater than 0.01 inches of rain

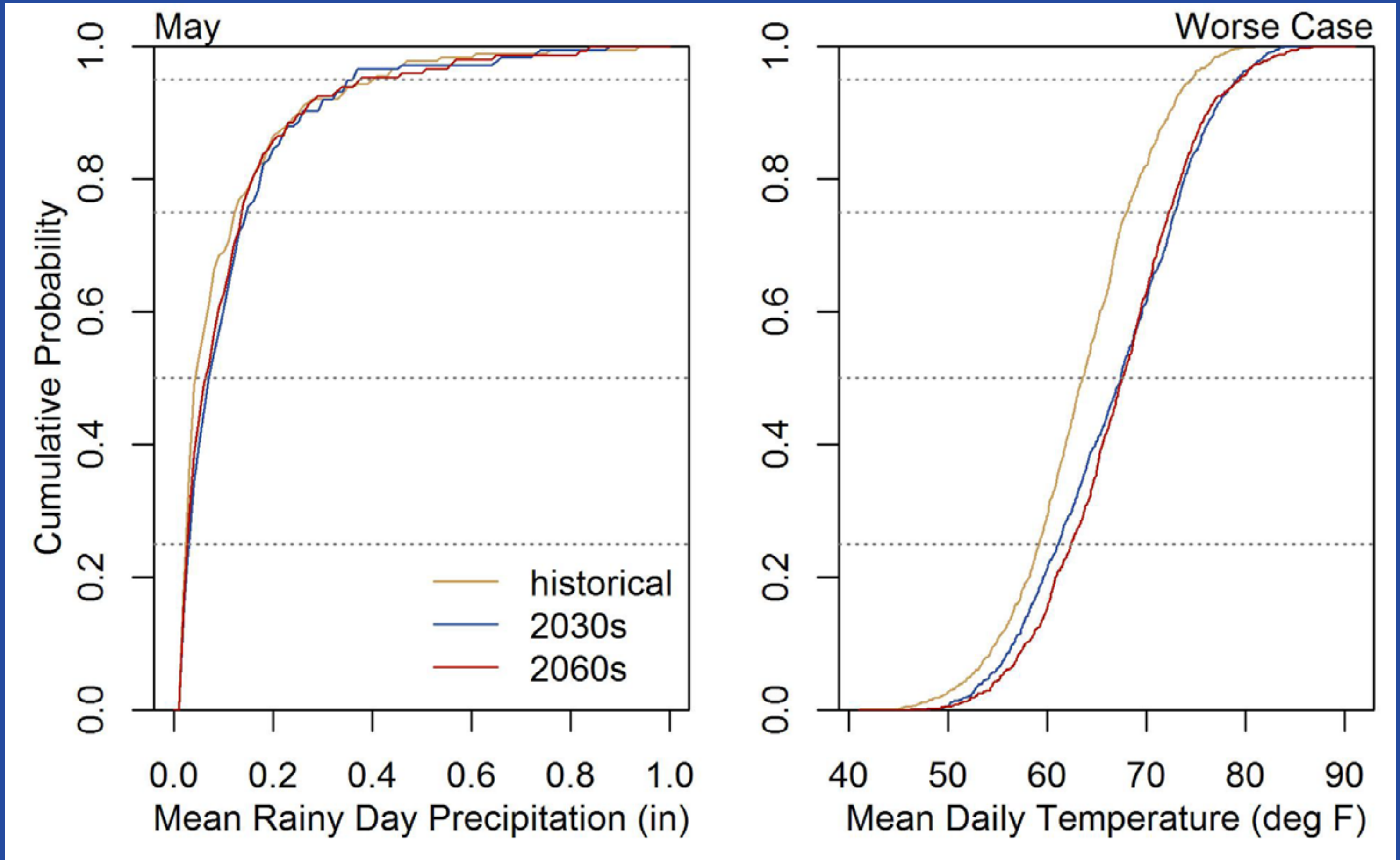


Worse Case: WRF-MPI RCP 8.5 (May)

Dry Month (May)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	0.01 | 0.00	2.0 | 3.3
Median (50th)	0.03 | 0.02	3.9 | 4.1
High (75th)	0.03 | 0.02	4.9 | 4.2
Extreme (95th)	-0.04 | -0.02	4.6 | 4.8

Dry Season precipitation events are few and small so changes are also small but can have more relative influence.

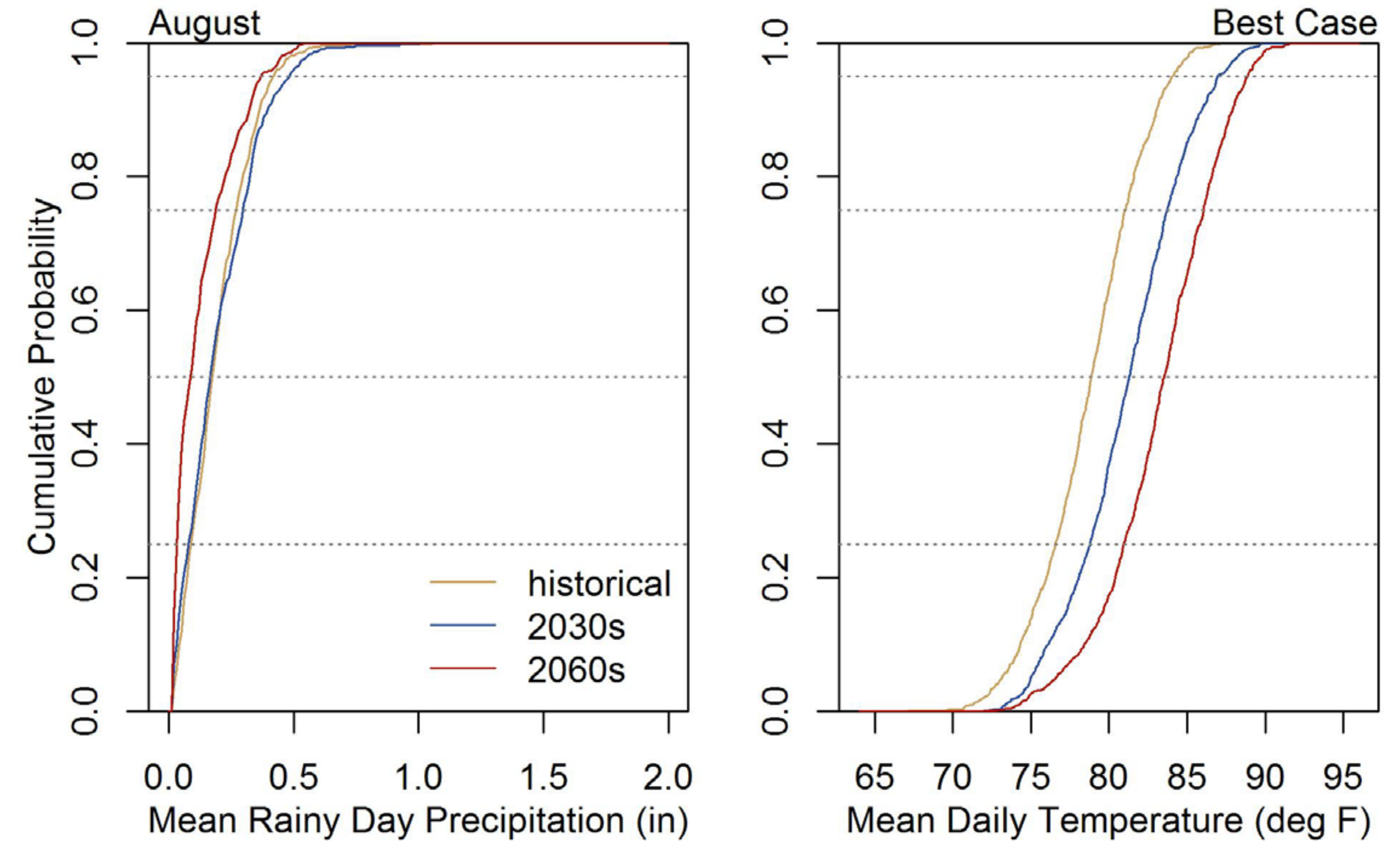


Best Case: LOCA-MPI RCP 4.5 (August)

Monsoon Month (August)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	-0.01 | -0.06	2.2 | 4.4
Median (50th)	-0.01 | -0.09	2.5 | 4.7
High (75th)	0.03 | -0.08	2.7 | 5.1
Extreme (95th)	0.07 | -0.04	2.9 | 4.8

Decreases in precipitation are more pronounced for mid-sized storms in the far future.

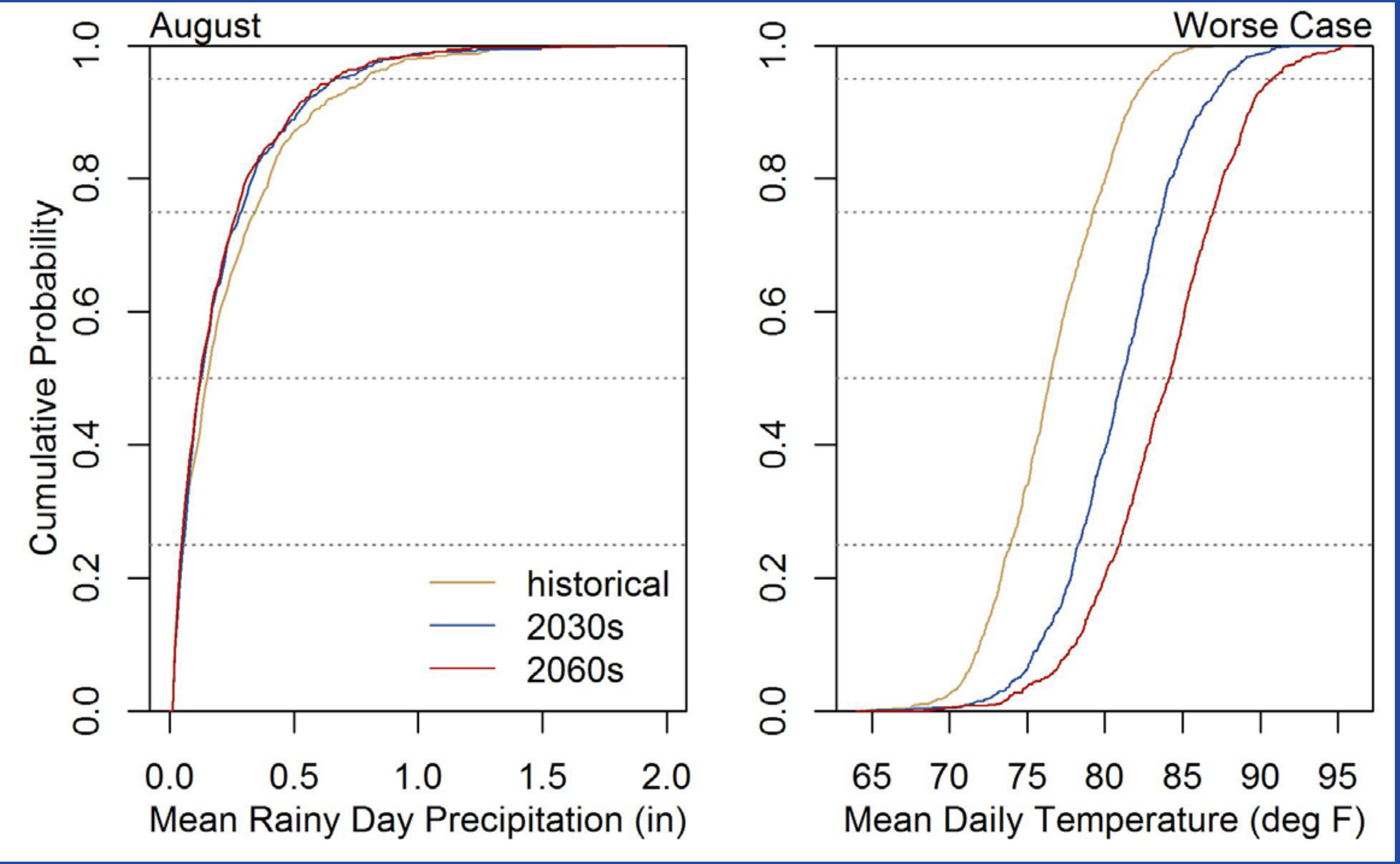


Worse Case: WRF-MPI RCP 8.5 (August)

Monsoon Month (August)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	0.01 | 0.00	4.3 | 7.0
Median (50th)	-0.03 | -0.03	4.6 | 7.7
High (75th)	-0.06 | -0.07	4.4 | 7.7
Extreme (95th)	-0.12 | -0.13	5.0 | 8.1

Greater decreases in large precipitation events during the monsoon season are consistent between futures.

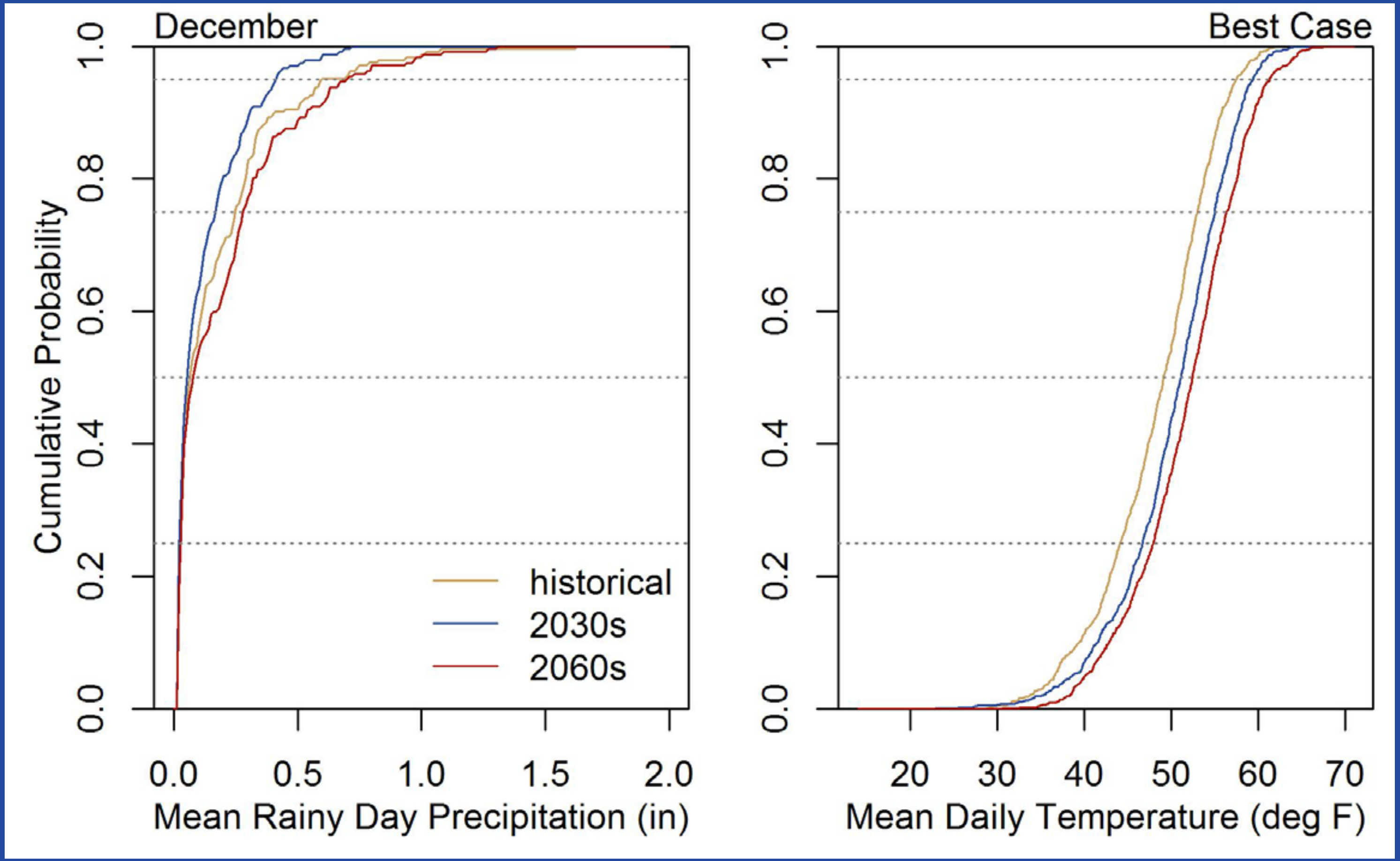


Best Case: LOCA-MPI RCP 4.5 (December)

Winter Month (December)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	0.00 | 0.00	2.6 | 3.8
Median (50th)	-0.01 | 0.01	2.0 | 3.4
High (75th)	-0.08 | 0.03	2.0 | 3.3
Extreme (95th)	-0.19 | 0.10	1.9 | 3.8

- Precipitation changes are inconsistent & only for larger events
- Temperature changes are smaller but could alter snowpack.

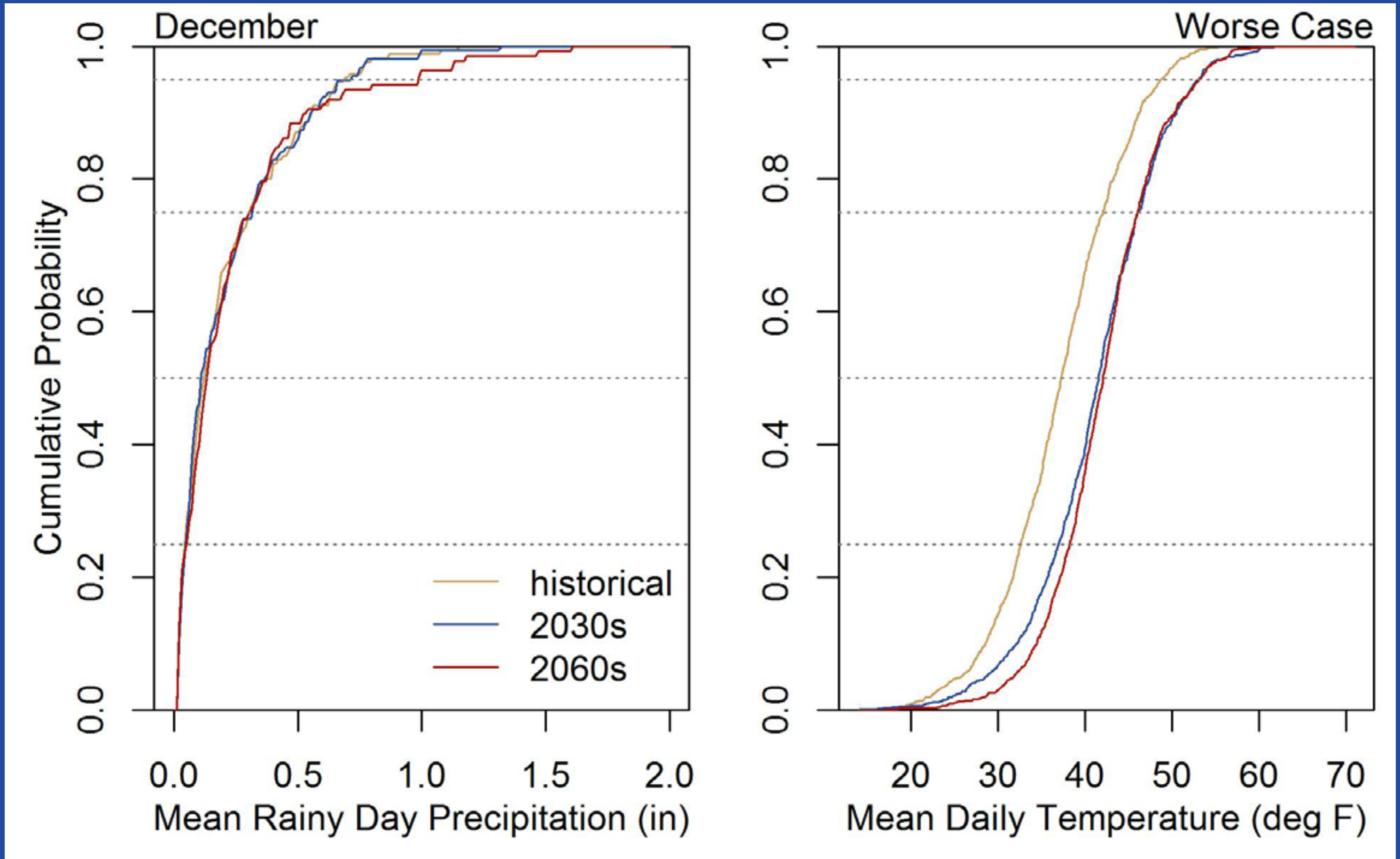


Worse Case: WRF-MPI RCP 8.5 (December)

Winter Month (December)

	Precip.* (in/day) 2030s | 2060s	Temp. (deg F) 2030s | 2060s
Low (25th)	0.00 | 0.01	4.3 | 5.6
Median (50th)	-0.02 | 0.01	4.3 | 4.8
High (75th)	0.02 | 0.00	4.1 | 4.0
Extreme (95th)	0.00 | 0.31	4.3 | 4.4

- Increase in extreme precipitation
- Temperature change limited after near future period

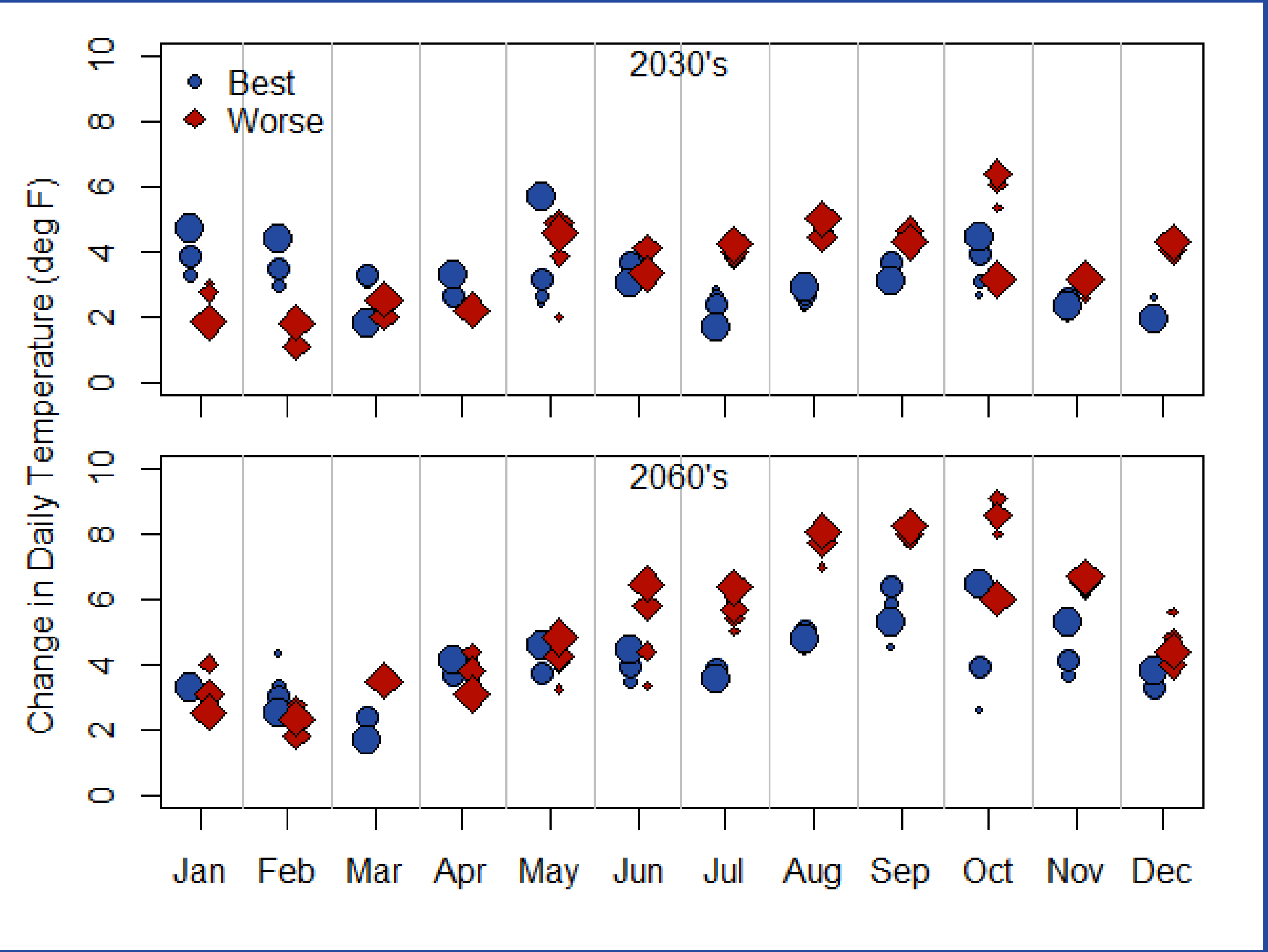


Monthly Temperature Change - Summary

Temperatures are consistently warmer than historical for the near and far future, with change increasing in time.

Greatest increases are projected for the late summer months in the worse case scenario.

** Values subject to change slightly with Reclamation technical check.



Monthly Precipitation Change - Summary

Precipitation changes are small and often limited to the larger storm events (largest shapes).

Greatest increase occurred for extreme events in the fall.

Decrease occurred during monsoon season and end of winter wet season.

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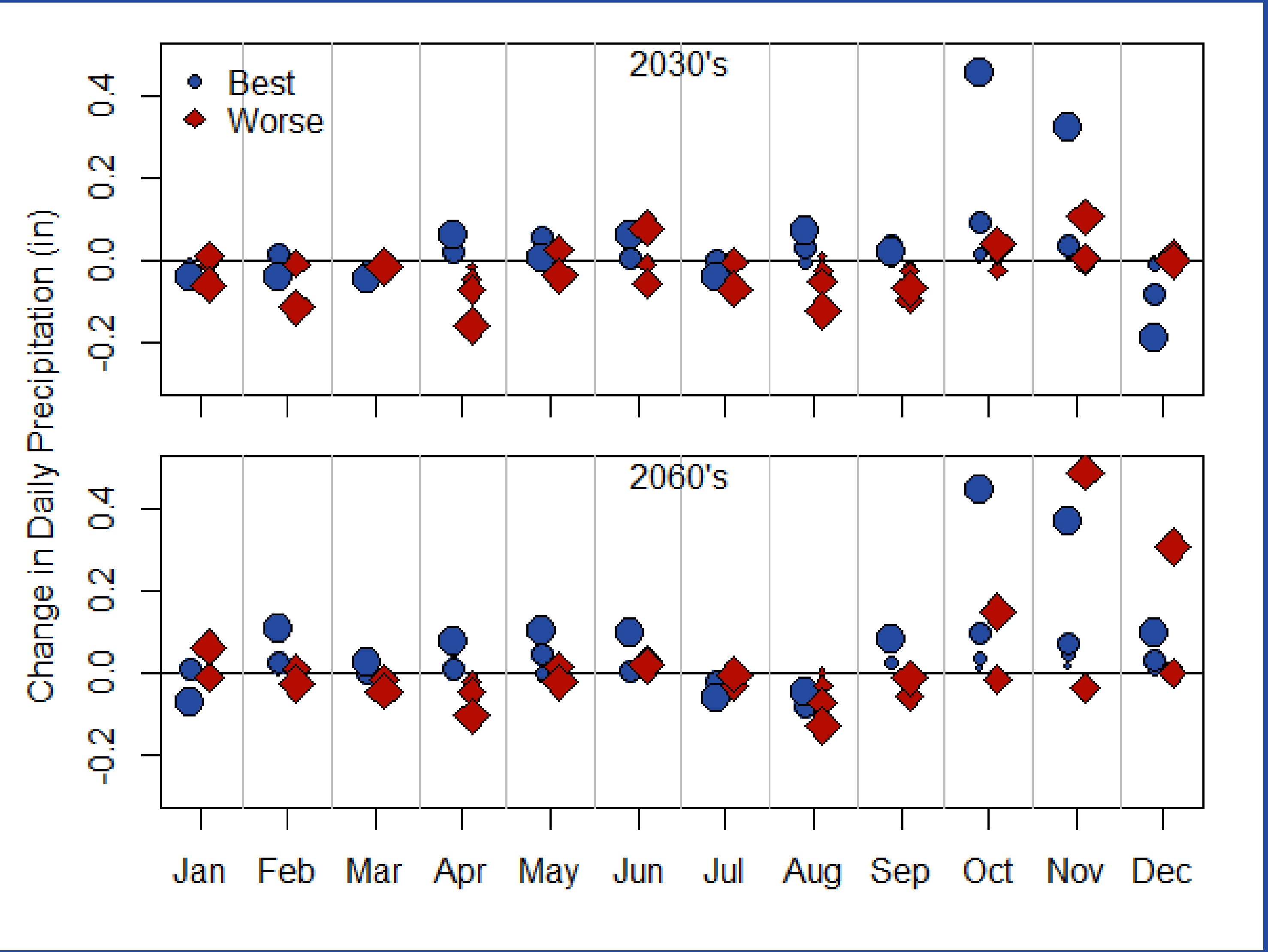
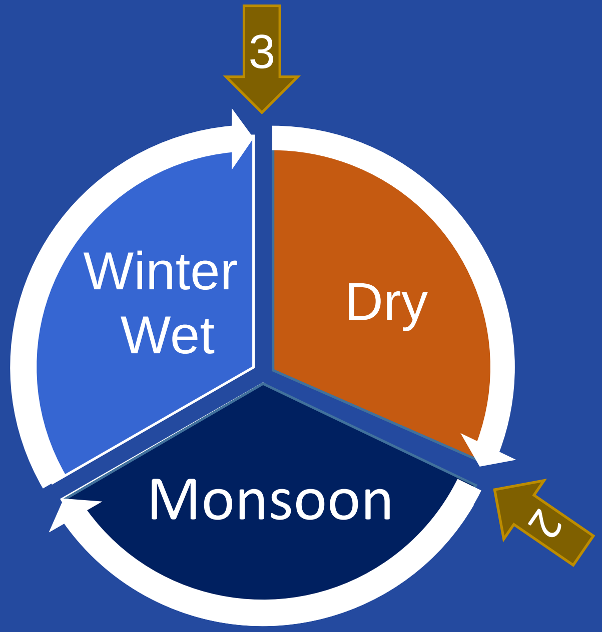
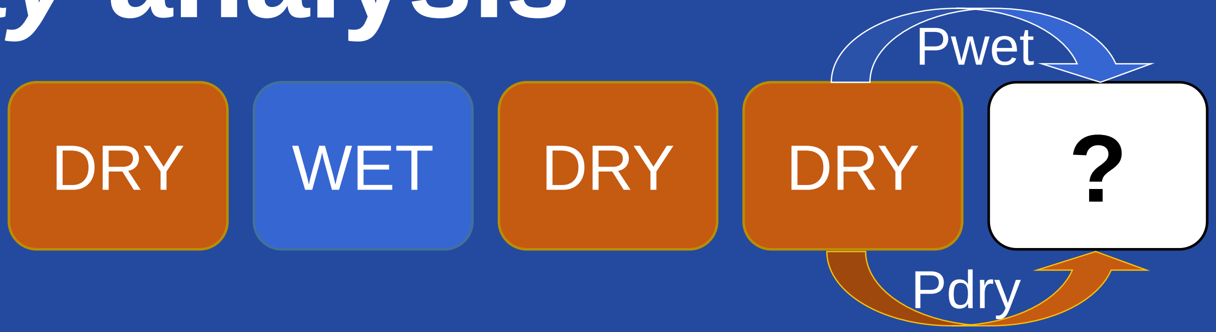


Review of Climate Metrics - 1

1. **Extreme events: intensity and frequency, temperature and precipitation**
   - ✓ Intensity
   - o Frequency explicitly accounted for through wet/dry day sampling for Weather Generator
2. **Monsoon onset: timing**
   - o First of 3 consecutive days with dewpoint temperature greater than threshold
3. **Dry period: timing of onset**
   - o Last day of winter storm to first day of spring
   - o Basin averaged rainfall less than 0.1 inches over 2 weeks



Wet/Dry *day* analysis

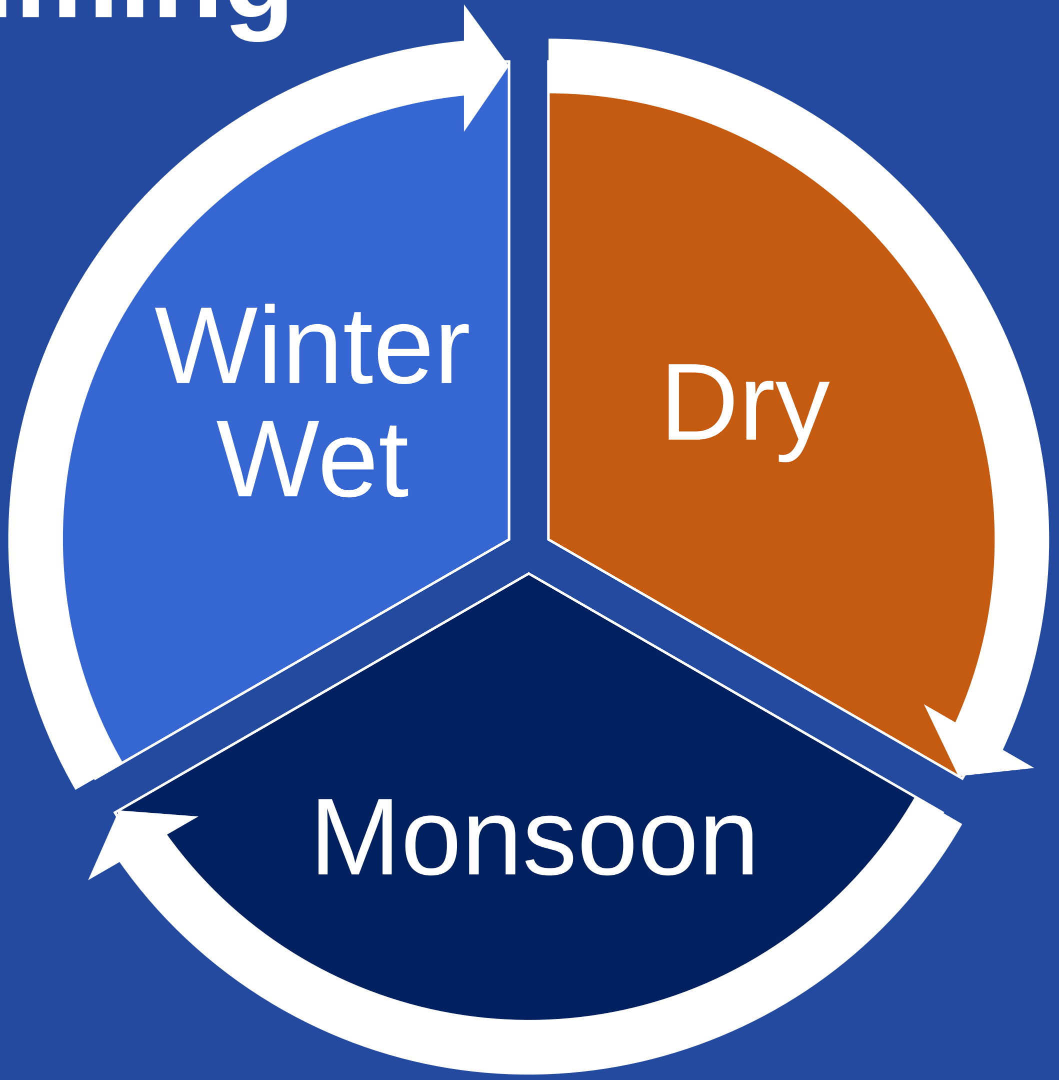


- **A nested two-state Hidden Markov Model is defined to address wet- and dry-spells.**
- **Precipitation occurrence is defined as any daily precipitation greater than 0.01”.**
- **Transition probabilities are computed for each season (dry, monsoon, winter).**
- **This analysis is how the weather generator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

Future Climate – New Timing

The weather generator breaks the year into three seasons (referred to as ‘states’) from which to sample weather.

This allows us to incorporate metrics quantifying shifts in seasonality into the realizations of future weather.



Review of Climate Metrics - 2

1. **Extreme events: intensity and frequency, temperature and precipitation**
   - ✓Intensity: HDE analysis
   - o Frequency explicitly accounted for through wet/dry day sampling for Weather Generator
2. **Monsoon onset: timing**
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   - o last day of winter storm to first day of spring
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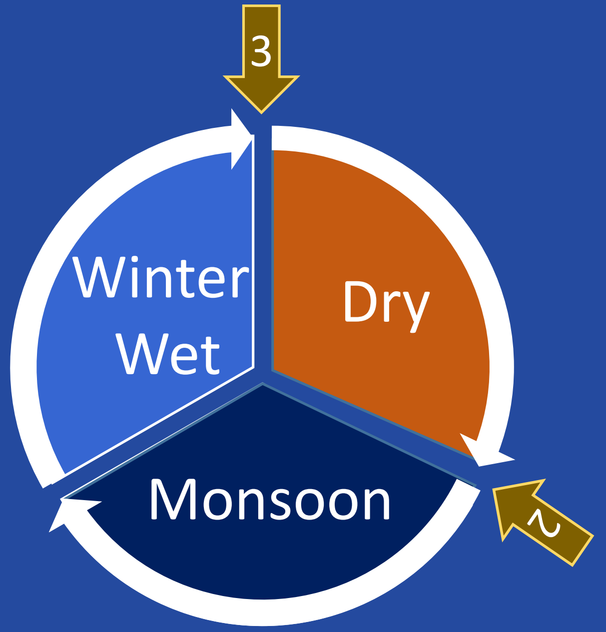
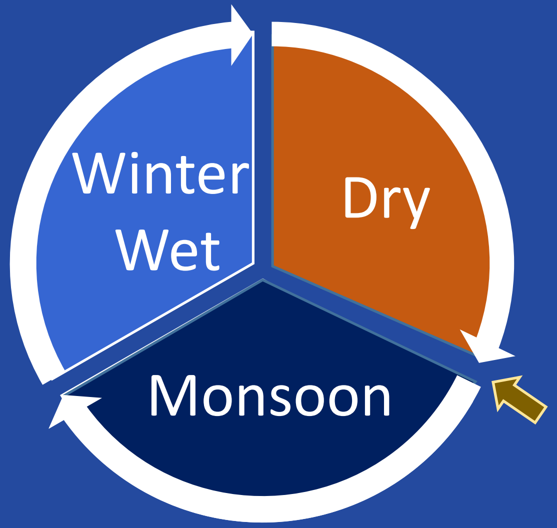


Monsoon Onset – Worse Case



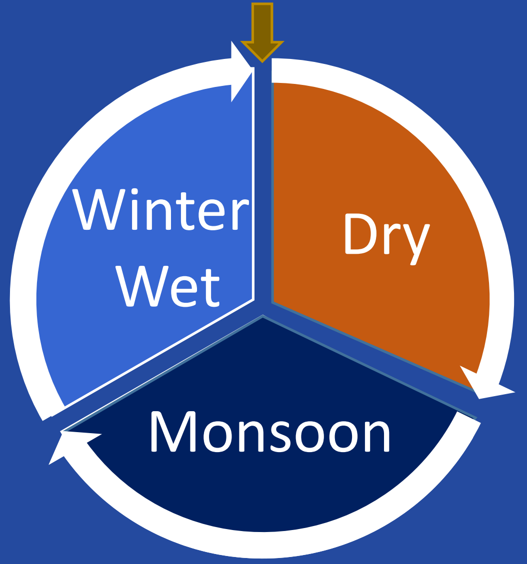
	Monsoon Onset Date
Observation (and Ellis et al 2004)	July 3
SAC-SMA historical mean/median	July 4 / July 3
WRF-MPI historical (worse case)*	July 2
WRF-MPI 2030's (worse case)**	2 days earlier
WRF-MPI 2060's (worse case)**	8 days earlier

Seasonal exceedance of bias-corrected dewpoint temperature thresholds is used to define the onset of monsoon season and *changes for worse case (DD) scenario only*.

*WRF-MPI historical from University of Arizona's May 7, 2018 presentation

** Values subject to change slightly with Reclamation technical check.

Dry Season Onset



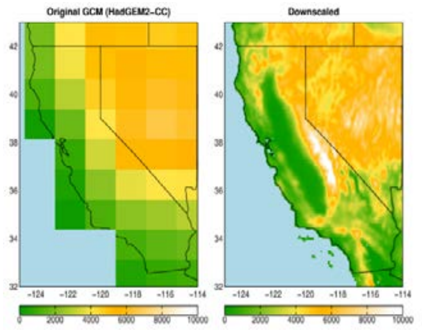
Basin averaged rainfall less than 0.1 inches over 2 weeks* defines the end of the winter rains and onset of dry season.

Median SAC-SMA and WRF (all periods) dry period onsets were in January. Metric is being refined with weather generator development.

* per May 8, 2018 meeting and following discussion with M. Crimmins

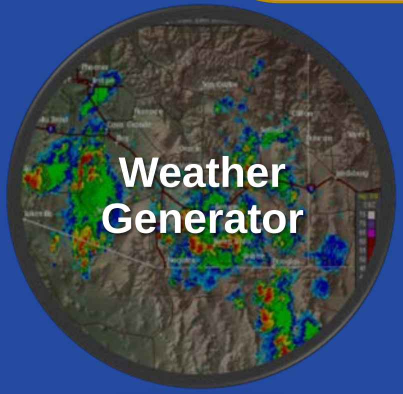
Next Steps - 1

1. Downscaled Climate Projections ✓



1. Climate scenarios described here are being prepared as weather generator inputs
2. Run weather generator and generate precipitation and temperature files
3. Run SAC-SMA rainfall-runoff modeling; present results
4. Prepare and run groundwater model; present results

Precipitation & Temperature



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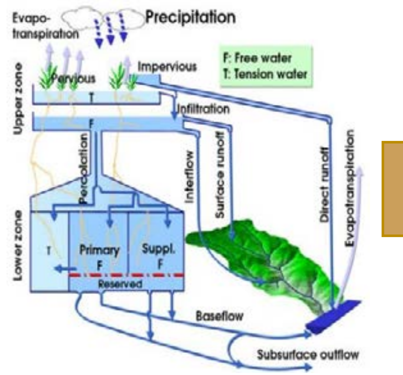

Streamflow, Recharge, ET

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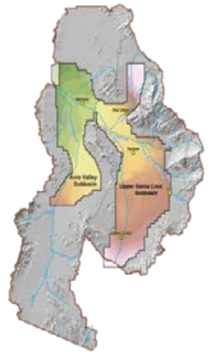

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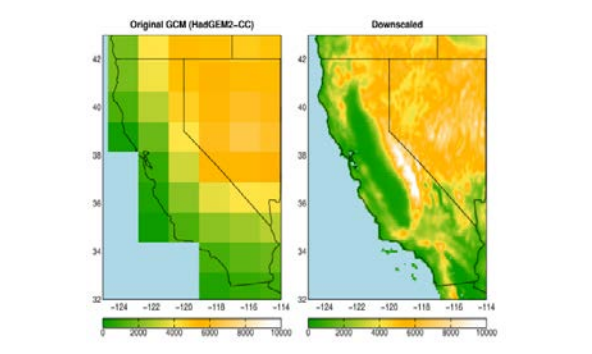
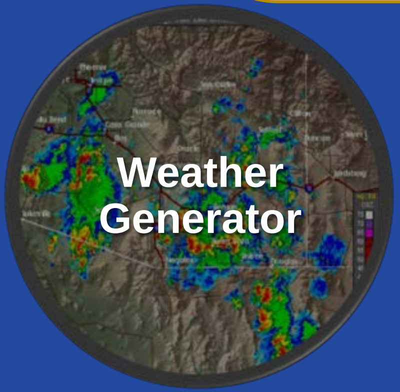


Precipitation & Temperature



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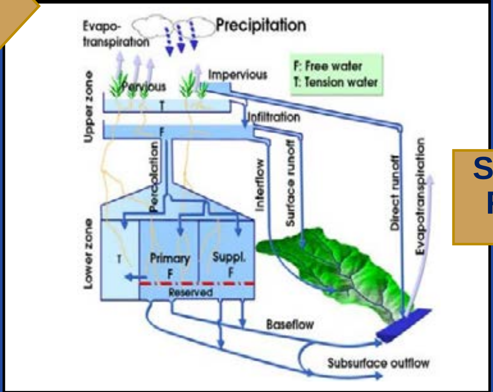

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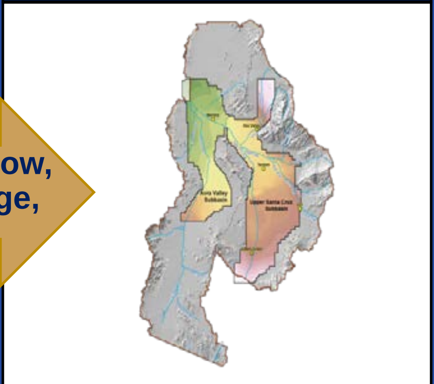

Questions?

RECLAMATION

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Contact Information

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