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California Drought Projections Based on Climate Change Models' Effects on Water Availability

Lauren Lynam
Chapman University, lynam@chapman.edu

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Introduction

- Southwestern United States drought
  - Decreased water availability
  - Increases competition among water secors
  - Affects economic security
- Local and state governments implementing conservation plans
  - Colorado River basin experiencing Tier 1 shortage in late 2021
- Previous studies
  - General climate models and their effects on climate change [7]
  - Precipitation and Streamflow Indexes to analyse droughts in other countries [5]
- Conduct drought analysis, based on general climate models
  - Enable California's water management to understand drought implications
  - Allow for water management planning and preparation

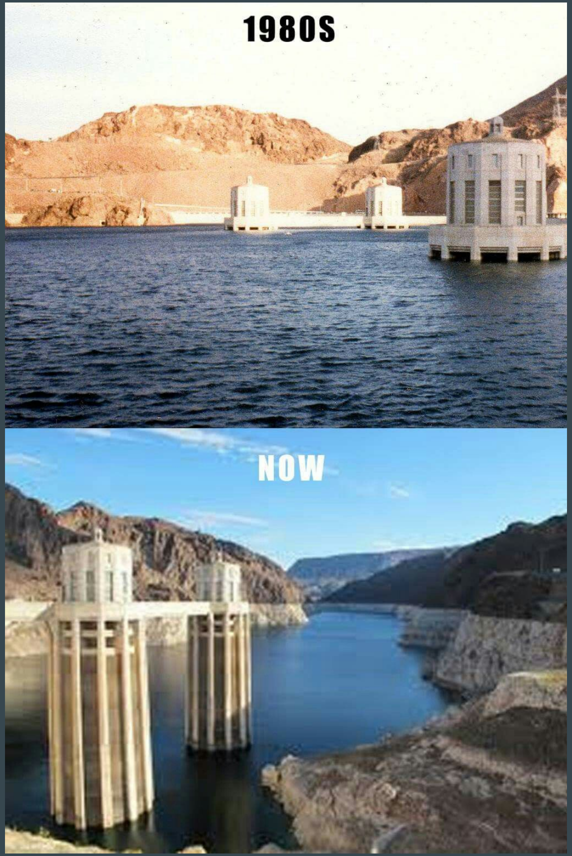

Figure 1: Colorado Basin from 1980s till now

Methods

- Collected yearly historical (1950-2015) streamflow data ft3/sec from eleven rivers [9]
- Collected yearly projected (2020-2099) streamflow data ft3/sec for each river [9]
- Two emission level possibilities as representative concentration pathways (RCP)
  - Warm Dry RCP 4.5
  - Average RCP 4.5
  - Cool Wet RCP 4.5
  - Other RCP 4.5
  - Warm Dry RCP 8.5
  - Average RCP 8.5
  - Cool Wet RCP 8.5
  - Other RCP 8.5

Figure 2: Map of station locations at each river [8, 10]

Methods

- Yearly streamflow data transformed from ft3/sec to million-acre feet of water per year (MAF)
- Identifying projected droughts
  - Drought defined as 2+ where streamflow is below the historical average streamflow
  - River drought year = Yearly projected streamflow (MAF) - Average historical (MAF)
- Three severity categories: drought quantity, duration, and intensity.
  - Drought quantity (MAF) = summation of streamflow deficit in each individual drought
  - Drought duration (years) = number of years in which consecutive streamflow deficits occurred
  - Drought intensity (MAF/years) = Drought quantity / Drought duration

Methods

- All resulting values standardized with Z - Score
- Two tailed difference in means t-tests were conducted on the standardized data
    - Significance level of 0.05
    - Comparing general climate model projected streamflow with historical streamflow
    - Did this for individual rivers and an aggregate of standardized values

Results - Rivers Aggregated by Climate Model

Drier Conditions

Wetter Conditions

	Deficit (MAF)	Intensity (MAF/Year)	Duration (Years)
Historical vs Warm Dry RCP 4.5			
Historical vs Average RCP 4.5			
Historical vs Cool Wet RCP 4.5			
Historical vs Other RCP 4.5			
Historical vs Warm Dry RCP 8.5			
Historical vs Average RCP 8.5			
Historical vs Cool Wet RCP 8.5			
Historical vs Other RCP 8.5			

Table 1: Aggregated river analysis using two tailed difference in means t-tests with a significant difference in drought category. Highlighted boxes indicate a significant difference between historical and model projected means. Red represents a higher projected mean than historical. Blue represents a lower projected mean than historical.

Results - Rivers Separated

	Sacramento River	Feather River	Yuba River	Tuolumne River	Stanislaus River	Mokelumne River	Calaveras River	American River	Bear River	Merced River	San Joaquin River
Historical vs Warm Dry RCP 4.5											
Historical vs Average RCP 4.5											
Historical vs Cool Wet RCP 4.5											
Historical vs Other RCP 4.5											
Historical vs Warm Dry RCP 8.5											
Historical vs Average RCP 8.5											
Historical vs Cool Wet RCP 8.5											
Historical vs Other RCP 8.5											

Table 2: River specific two tailed difference in means t-tests on drought deficit quantity. Highlighted boxes indicate a significant difference between historical and model projected means. Red represents a higher projected mean than historical. Blue represents a lower projected mean than historical.

Drier Conditions

Wetter Conditions

Results - Yuba River

- Becoming more frequent
- Drought 2060 - 2070 particularly large
- Historical worst: 4 years, 24 MAF
- Projected worst: 11 years, 73 MAF

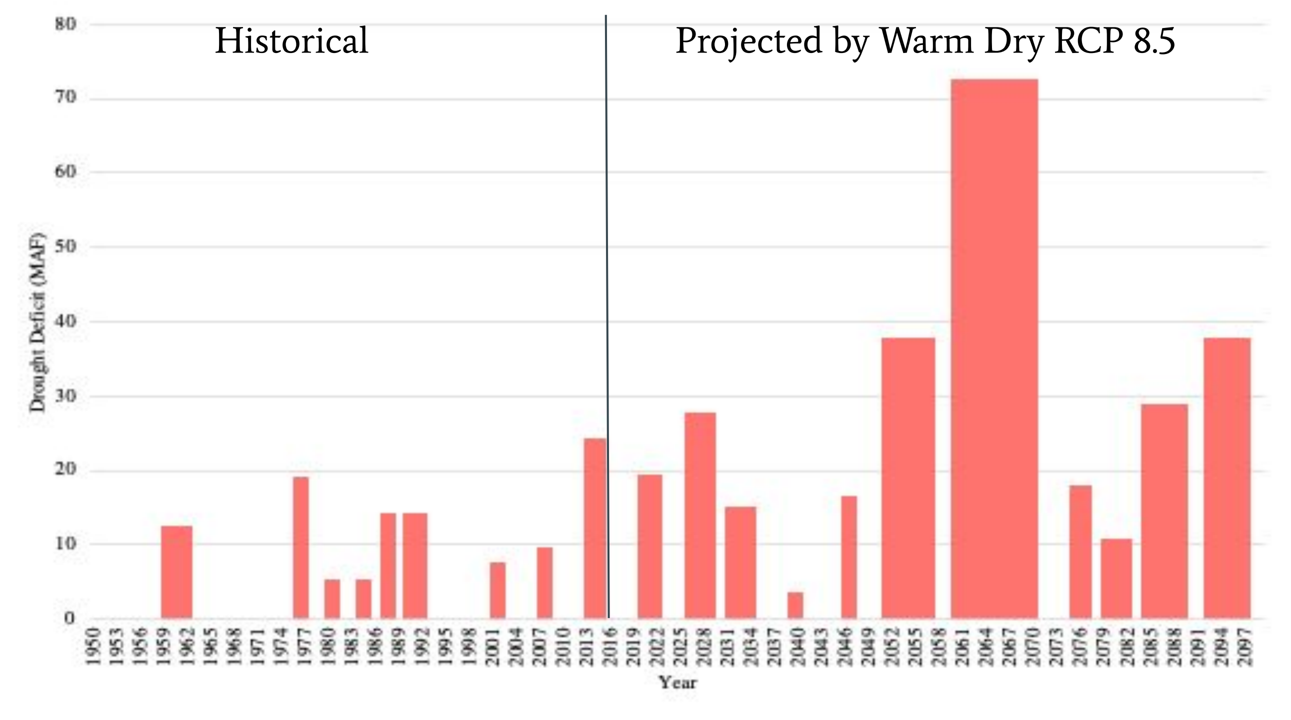

Figure 3: Yuba drought deficit quantities historical (1950-2015) and Warm Dry RCP 8.5 (2020-2099)

Results - San Joaquin River

- Becoming less frequent
- Historical: 8 droughts total
- Projected: 6 droughts total

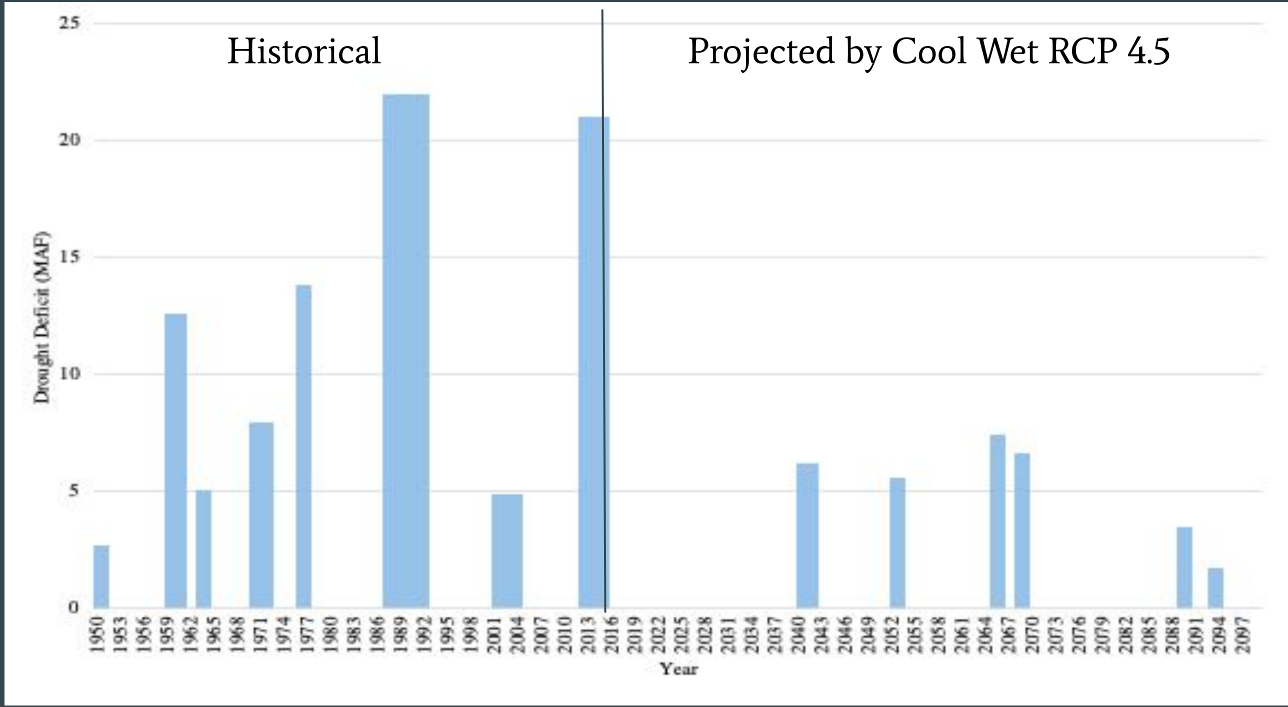

Figure 4: San Joaquin drought deficit quantities historical (1950-2015) and Cool Wet RCP 4.5 (2020-2099)

Discussion and Conclusions

- Drought may become more prevalent in future years [1]
  - Only likely to occur if real world event follow Warm Dry or Other RCP 4.5 or 8.5 climate models.
  - Drought may occur less if world event follow Cool Wet or Average RCP 4.5 or 8.5 climate models.
- More frequent droughts as projected by Warm Dry and Other climate models.
  - Need to utilize other water sources
  - Groundwater may be used to fulfill water needs [3]
  - Socio-economic issues may arise
  - Other environmental concerns: seawater intrusion, wetland devastation [4], climate feedback-loops [3]
- Less frequent droughts as projected by Cool Wet and Average climate models.
  - Means a larger than historical streamflow
  - Could lead to flooding: human losses, flood damage, welfare reduction [2]

Discussion and Conclusions

- Streamflow analysis done in this project
  - Anticipate droughts dependent on climate model
  - Enables better water management and planning
  - Understand implications of each potential climate model
- Further Research
  - Further repercussions of overdrawing groundwater
  - Areas in California that are susceptible to river flooding
  - Communities can best mitigate the effects of drought

Figure 5: California River

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Thank you