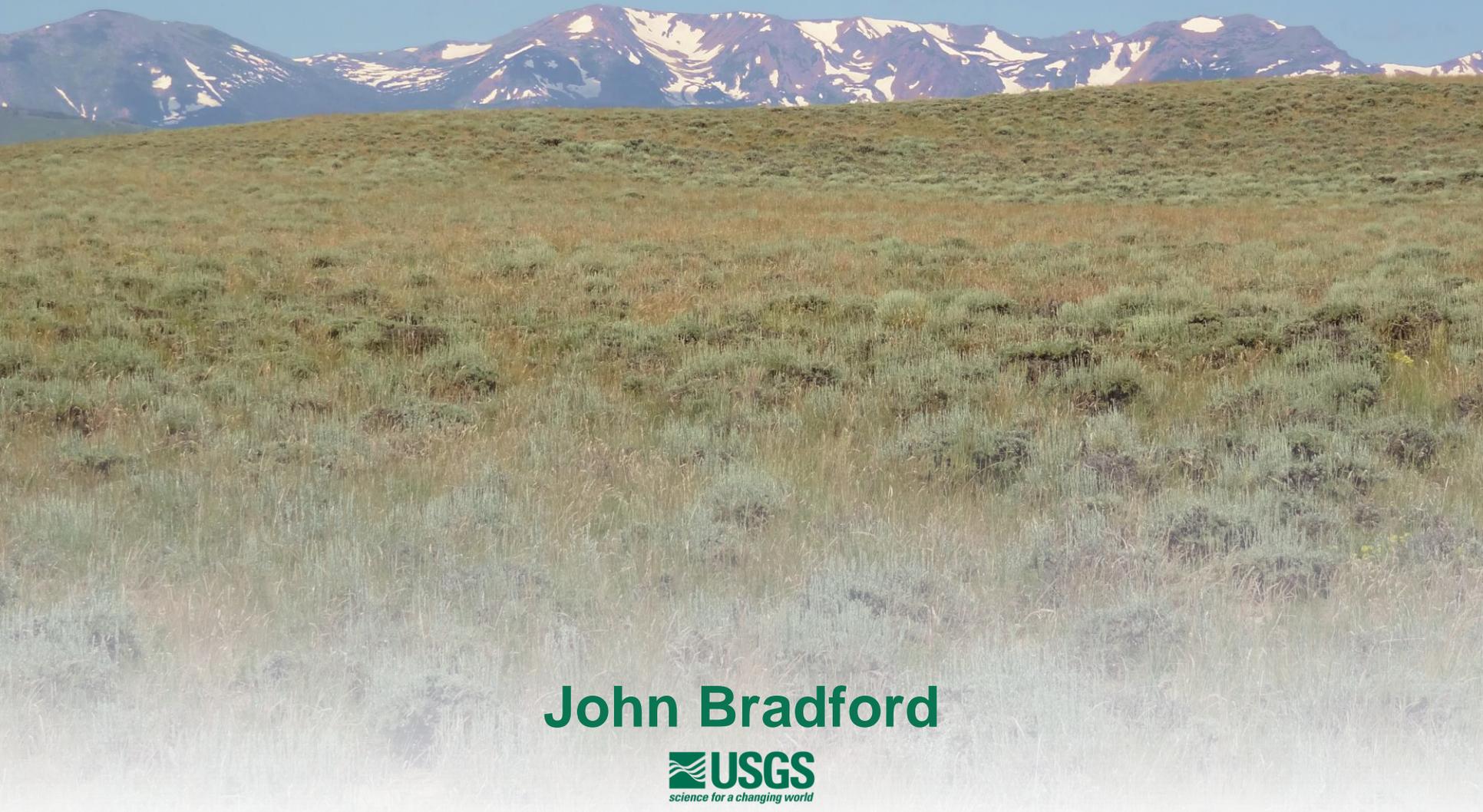


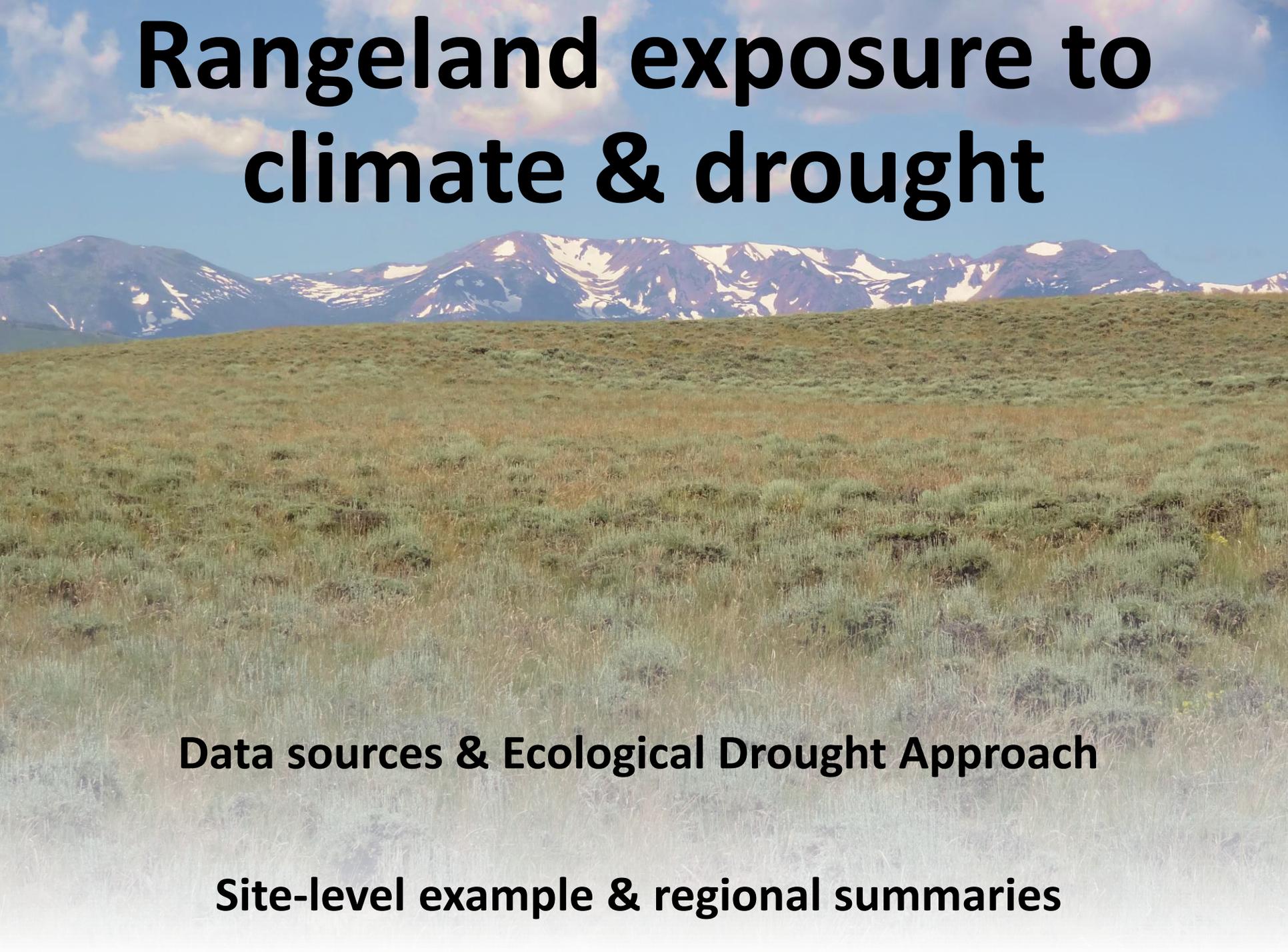
Rangeland exposure to climate & drought



John Bradford



Rangeland exposure to climate & drought



Data sources & Ecological Drought Approach

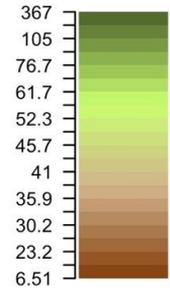
Site-level example & regional summaries

Exposure data

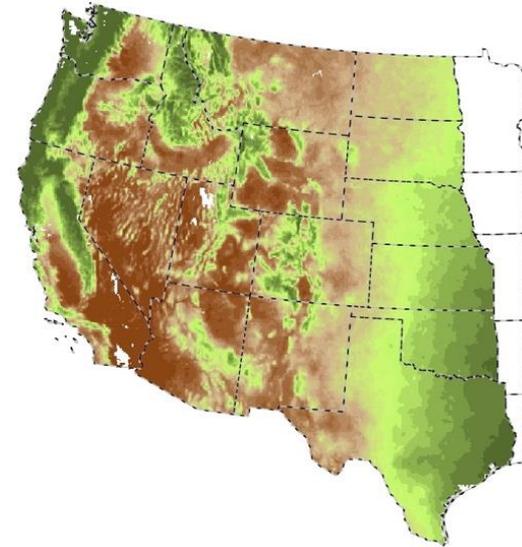
Historical

- Gridded daily data: Livneh et al. 2013
<https://www.esrl.noaa.gov/psd/data/gridded/data.livneh.html>
- 1/16 degree spatial resolution across the western U.S.
- 1916-2015

Annual Precipitation (cm)



1970 - 2010



Exposure data

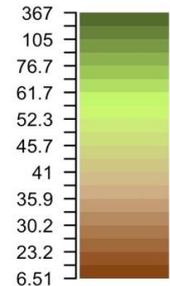
Historical

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- 1/16 degree spatial resolution across the western U.S.
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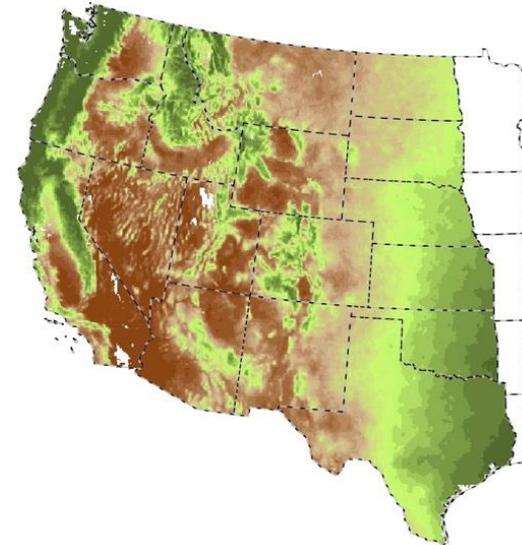
Future

- Data: "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" BCSD-monthly
(Maurer et al. 2007) http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/
- 2 Representative Concentration pathways: RCP4.5 & RCP8.5
- 11 climate models per RCP, selected to represent model diversity and for best performance in the western U.S.
- Near-term future: 2020-2059
- Long-term future: 2060-2099

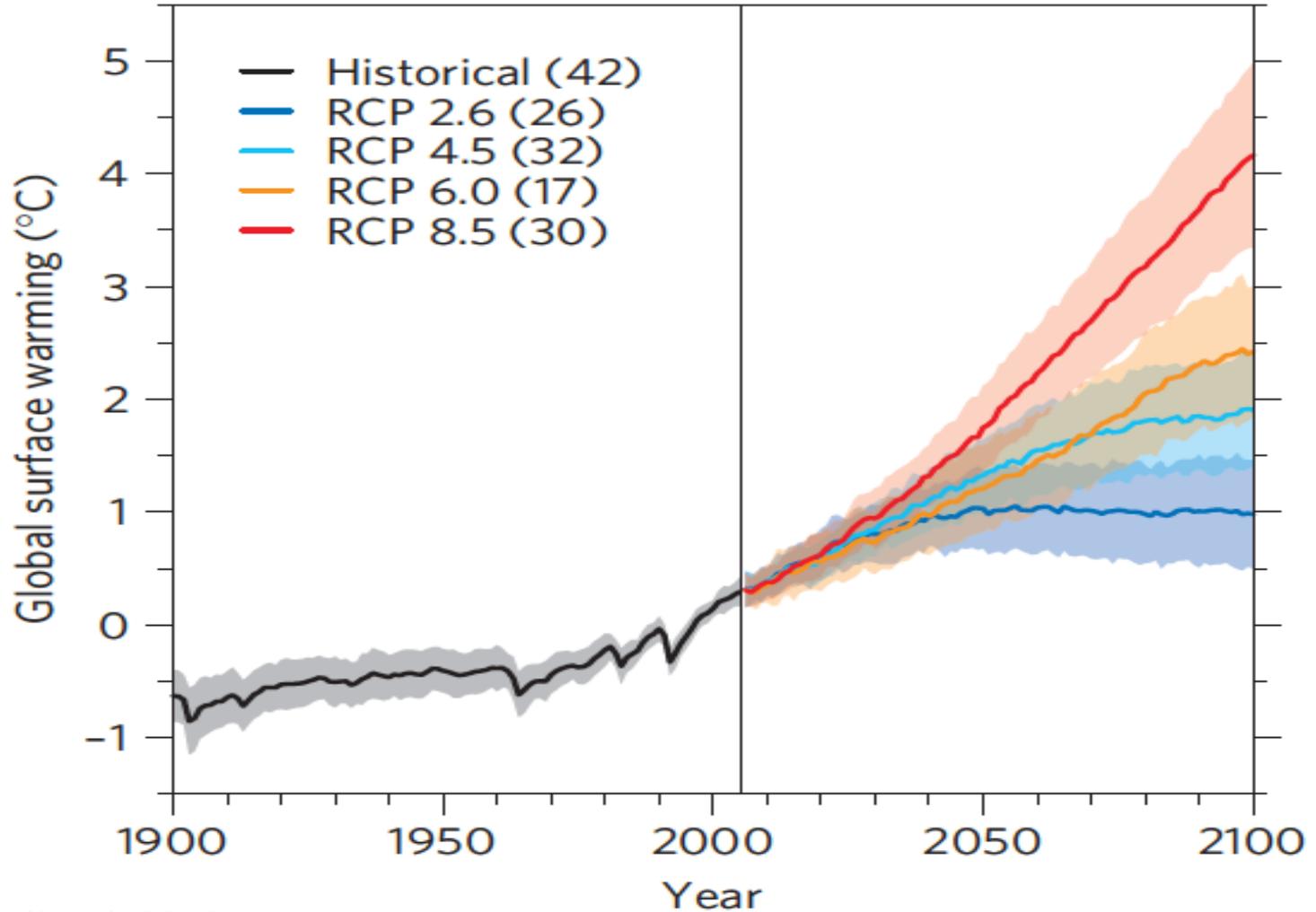
Annual Precipitation (cm)



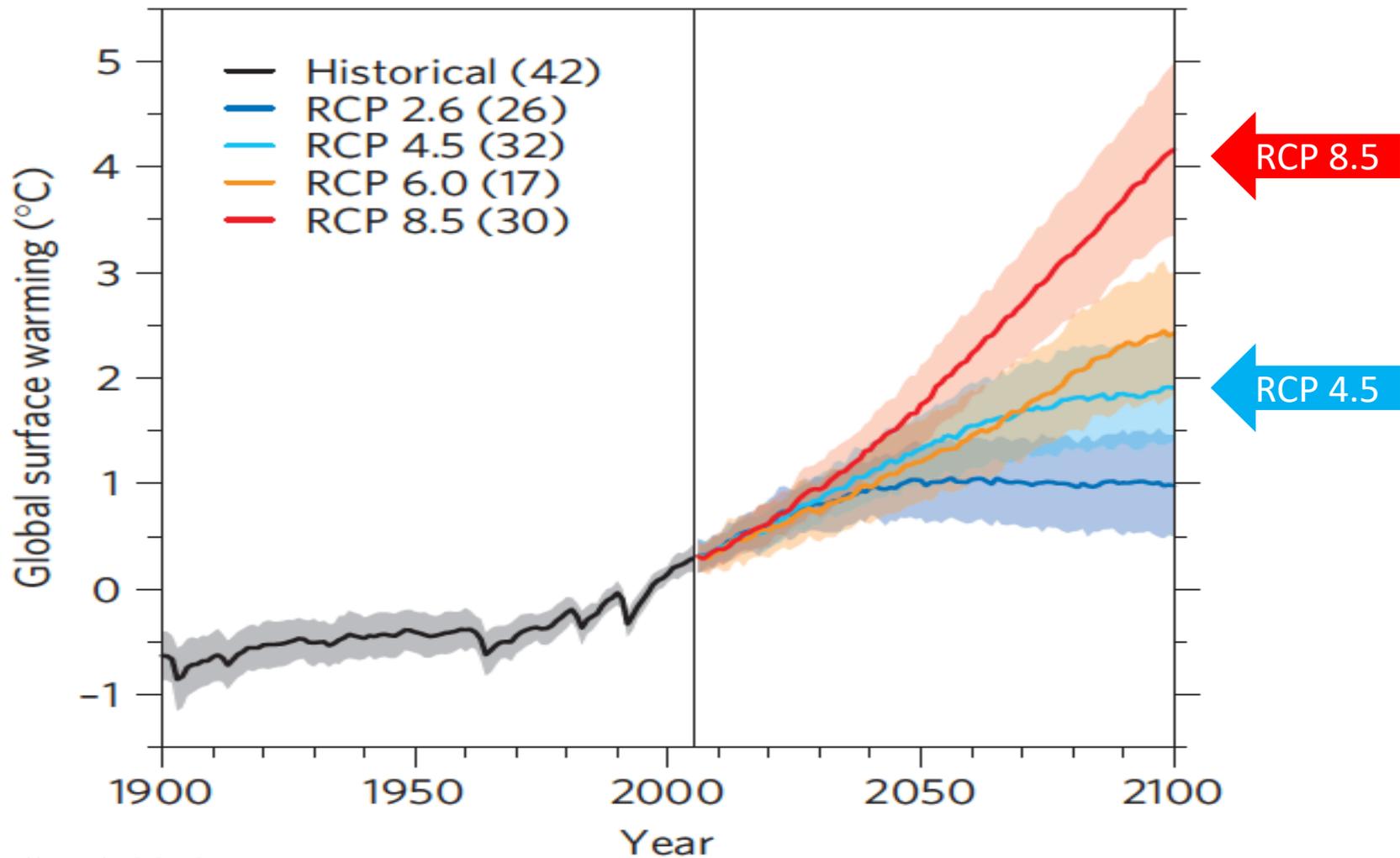
1970 - 2010



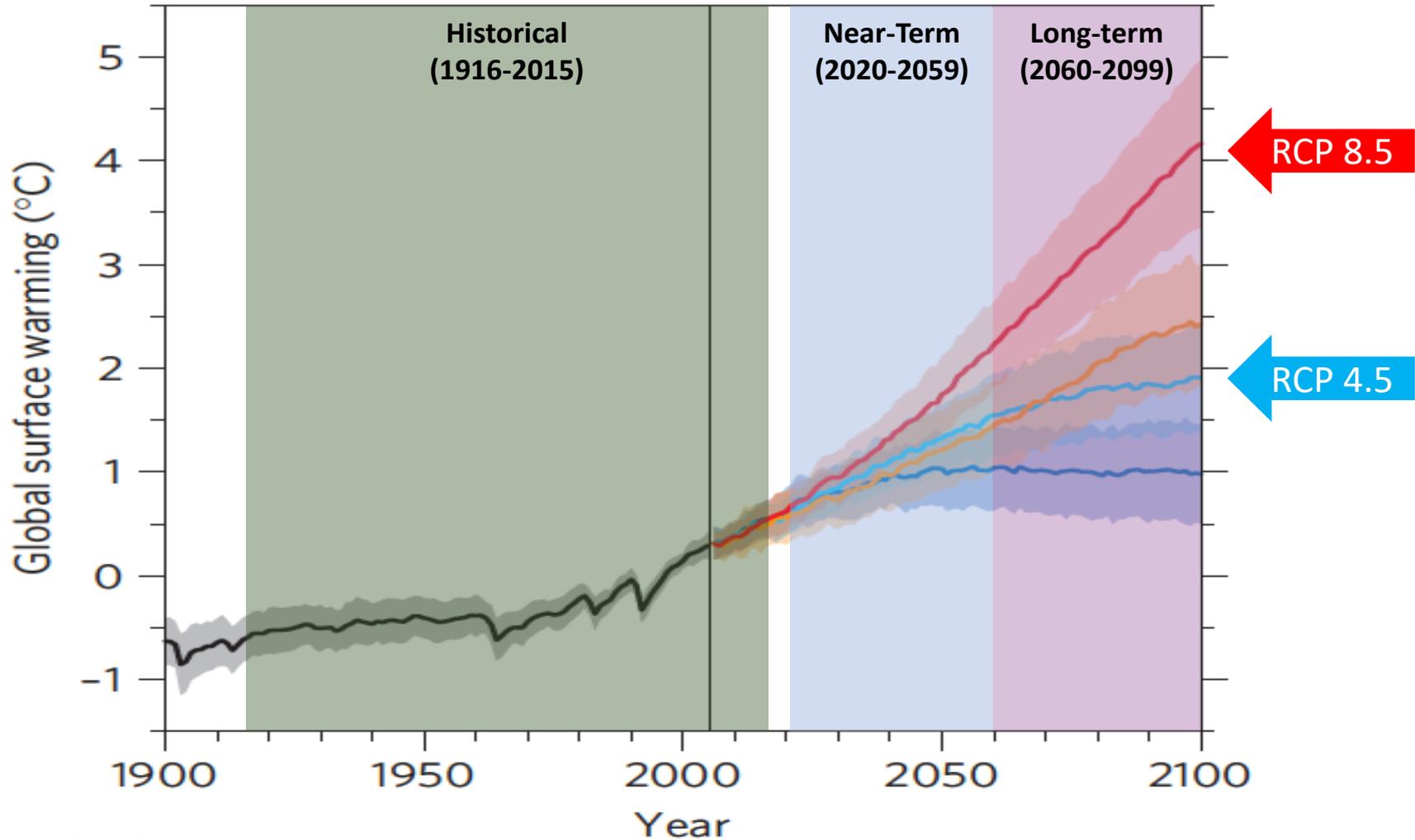
Exposure data



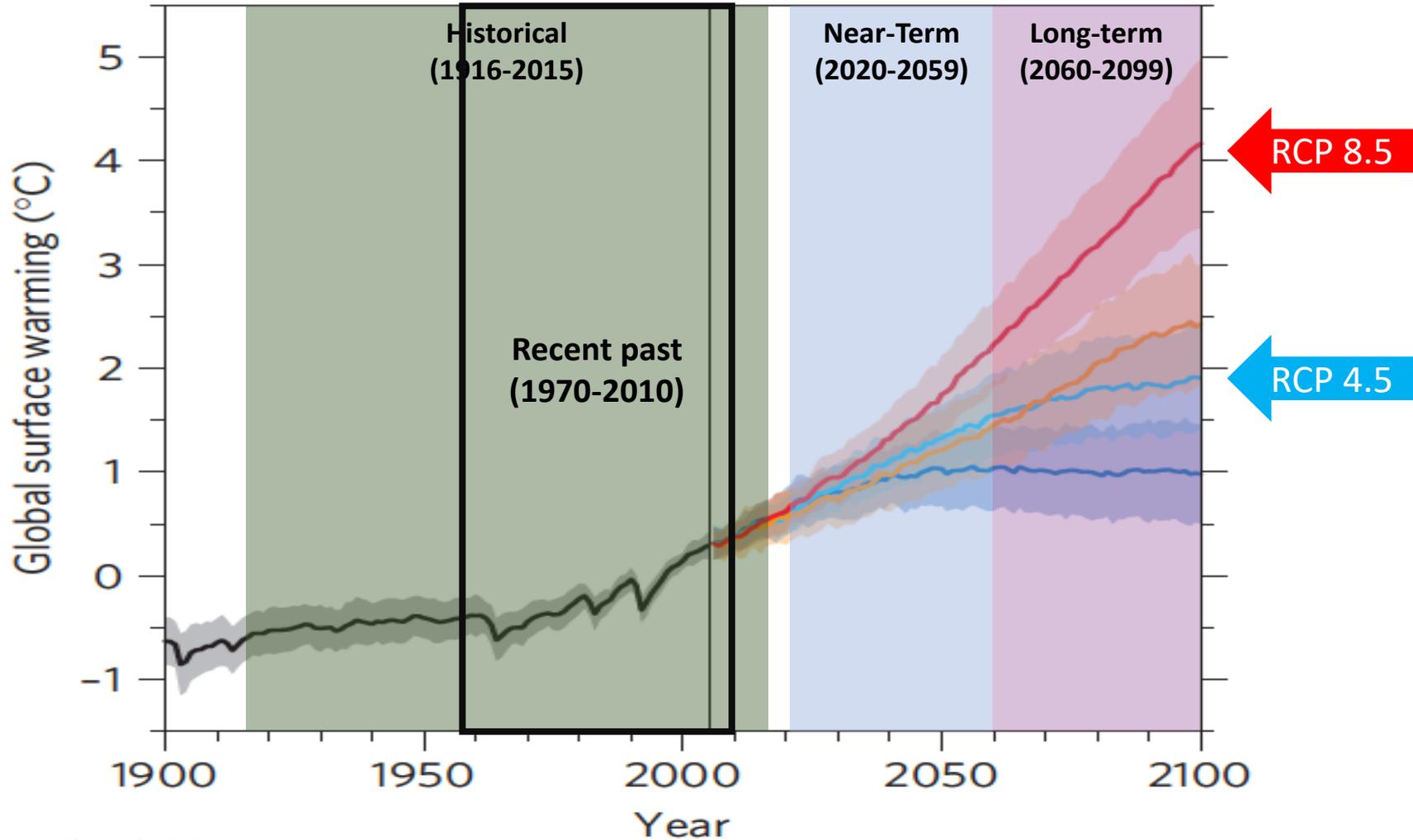
Exposure data



Exposure data



Exposure data



Quantifying ecological drought: SOILWAT2

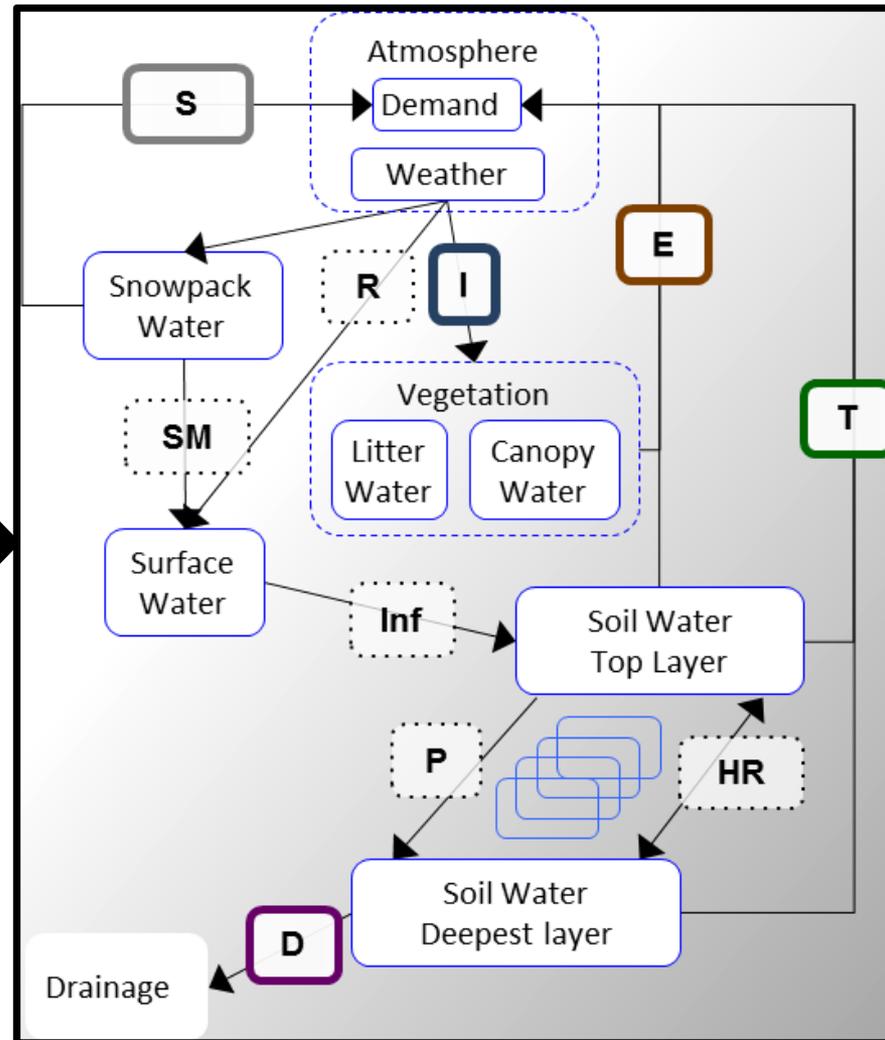
Weather

Soil Conditions

ISRIC Wise Global v1.2 dataset (Batjes 2012)

Vegetation Structure

Monthly biomass & phenology by plant functional type (Bradford et al 2014)



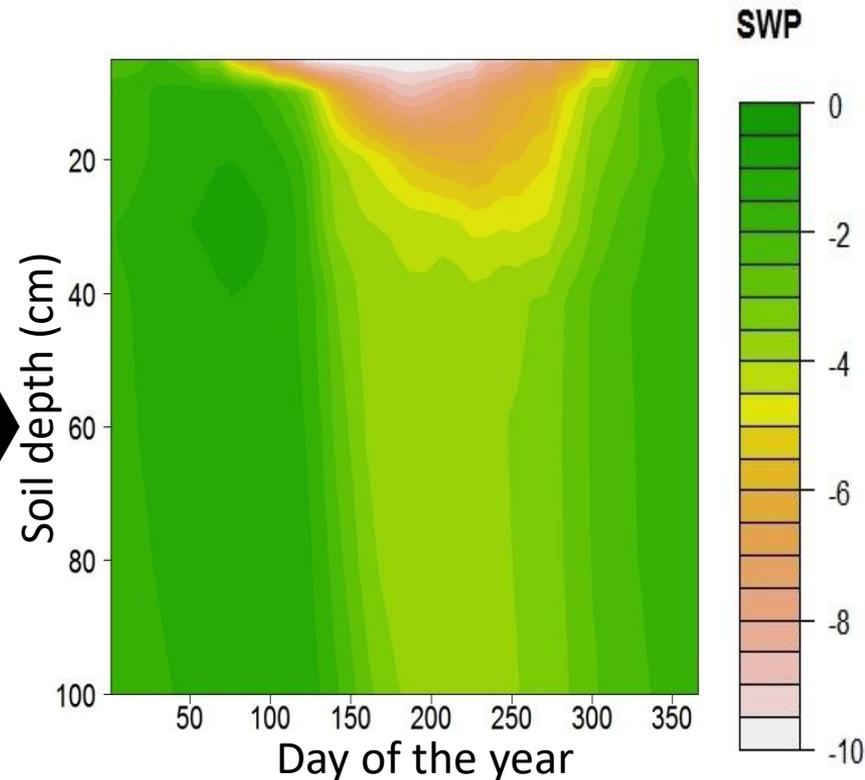
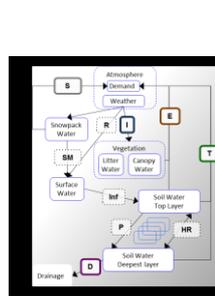
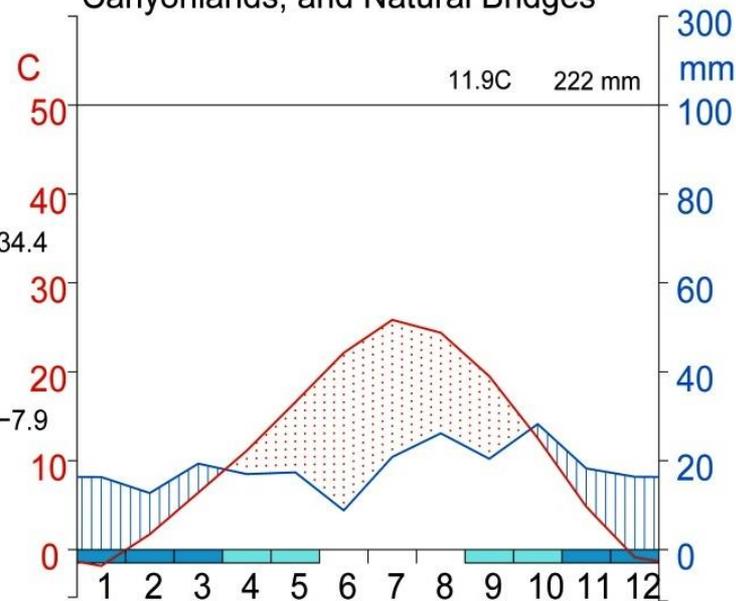
Water balance

Water availability for plants

Quantifying ecological drought: SOILWAT2

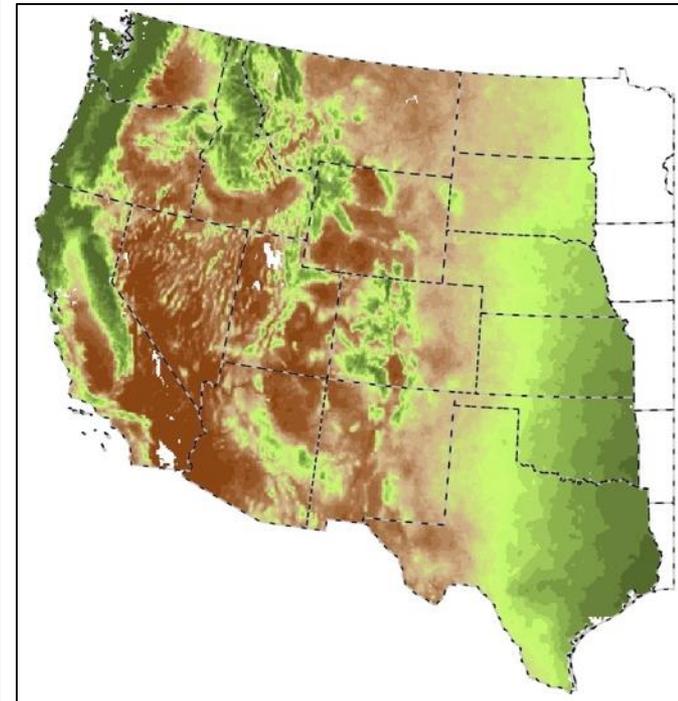
Climate & Soil -> Water availability

Colorado Plateau: Arches, Canyonlands, and Natural Bridges



Climate & drought exposure data

Temporal resolution	Daily
Spatial resolution	1/16 degree
Time periods	Past: 1916-2015 Future: 2020-2059 2060-2099 (Two RCPs & 11 climate models)
Variables	Temperature, precipitation, soil moisture....and others related to water balance and availability



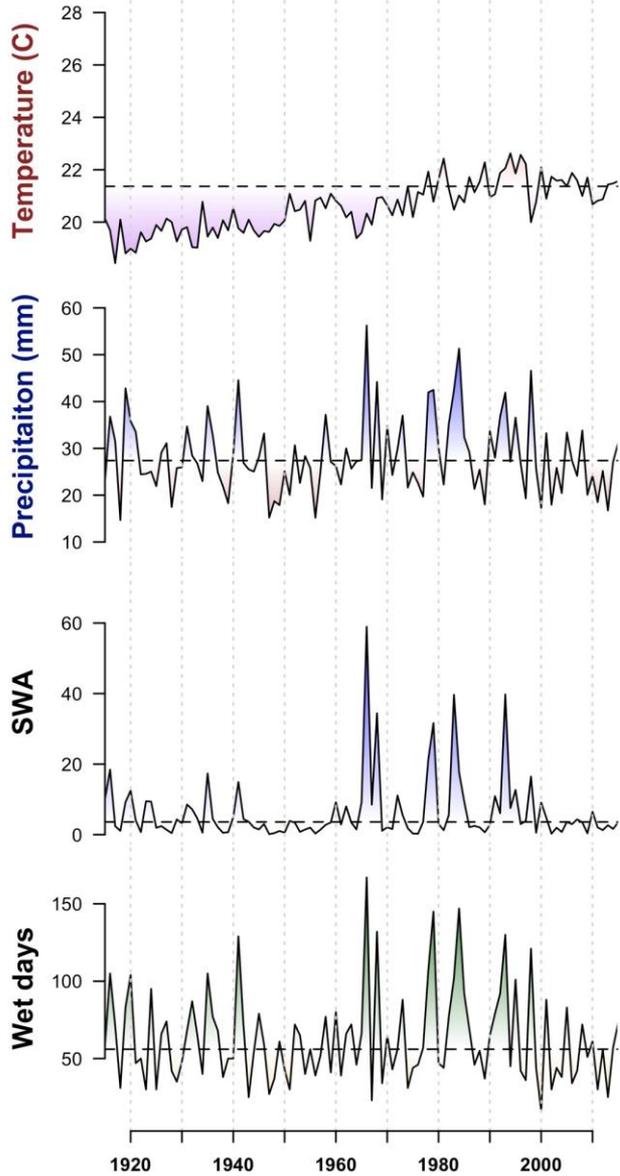
Rangeland exposure to climate & drought

Data sources & Ecological Drought Approach

Site-level example & regional summaries

Tucson

Historical Time Series



Annual temperature

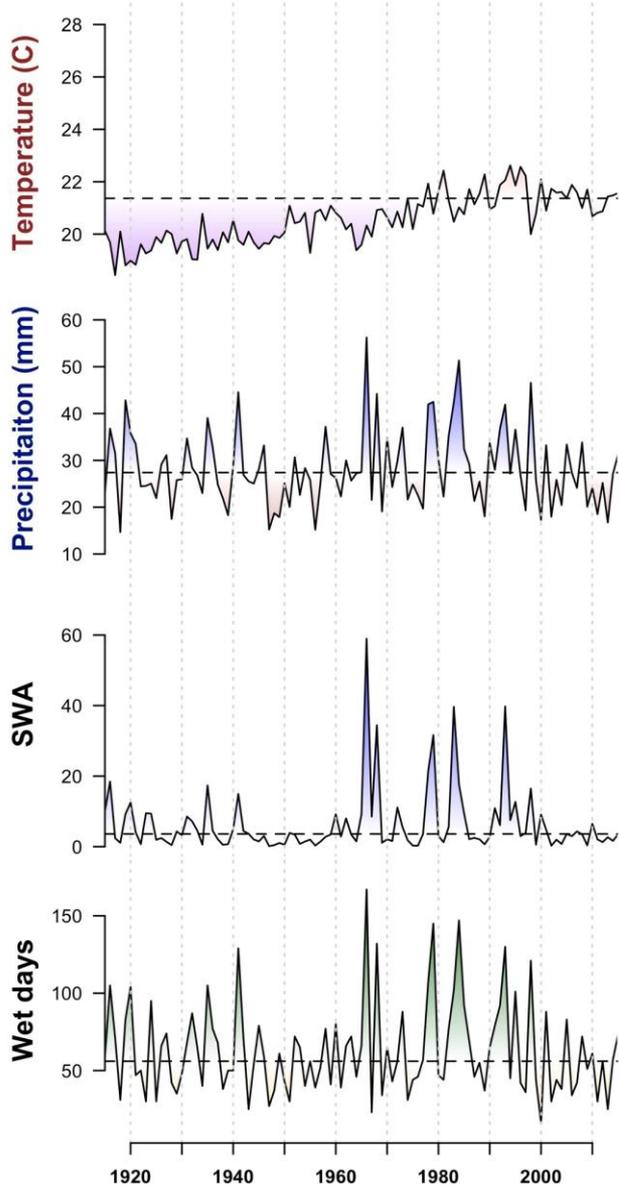
Annual Precipitation

Annual soil water available for plants

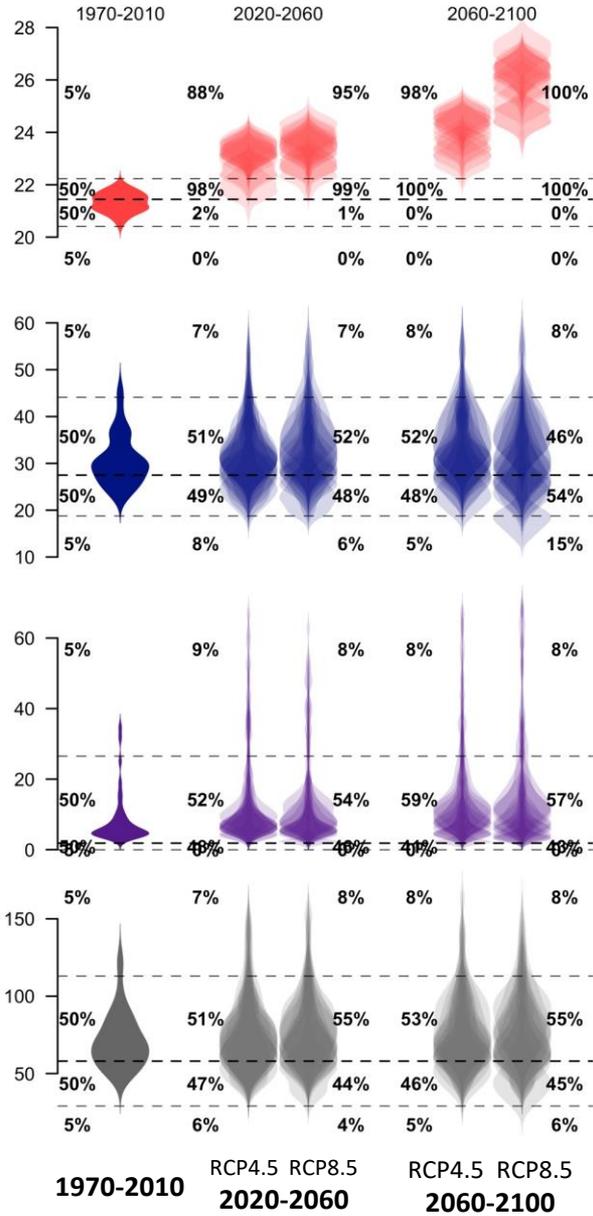
Annual number of days with wet soil

Tucson

Historical Time Series

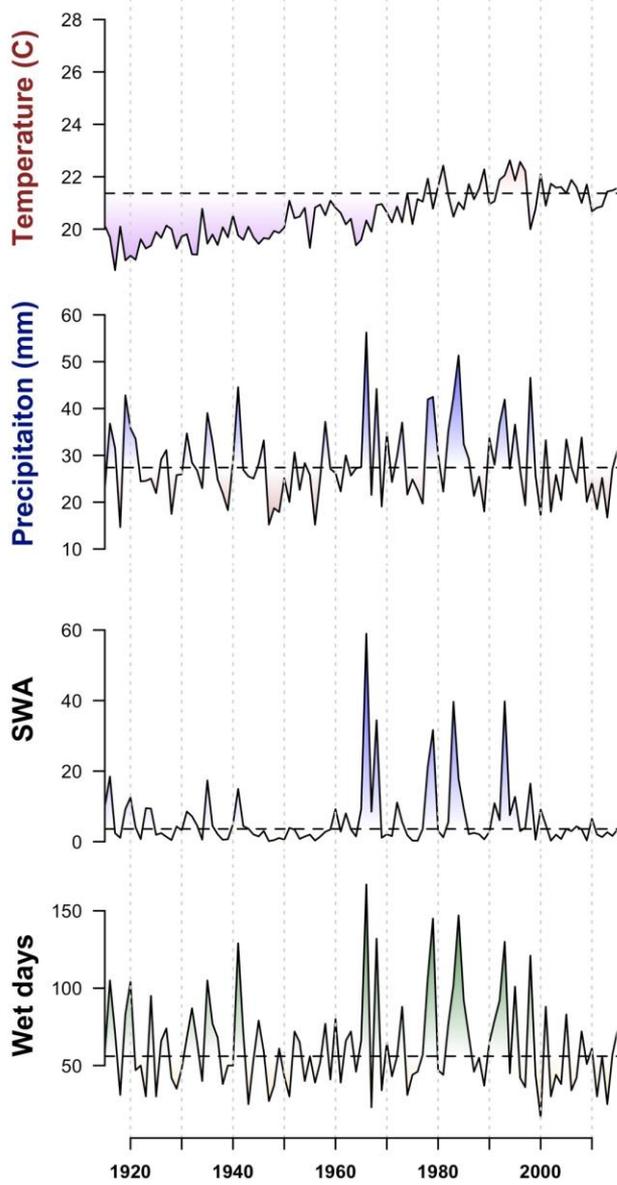


Future Trajectories

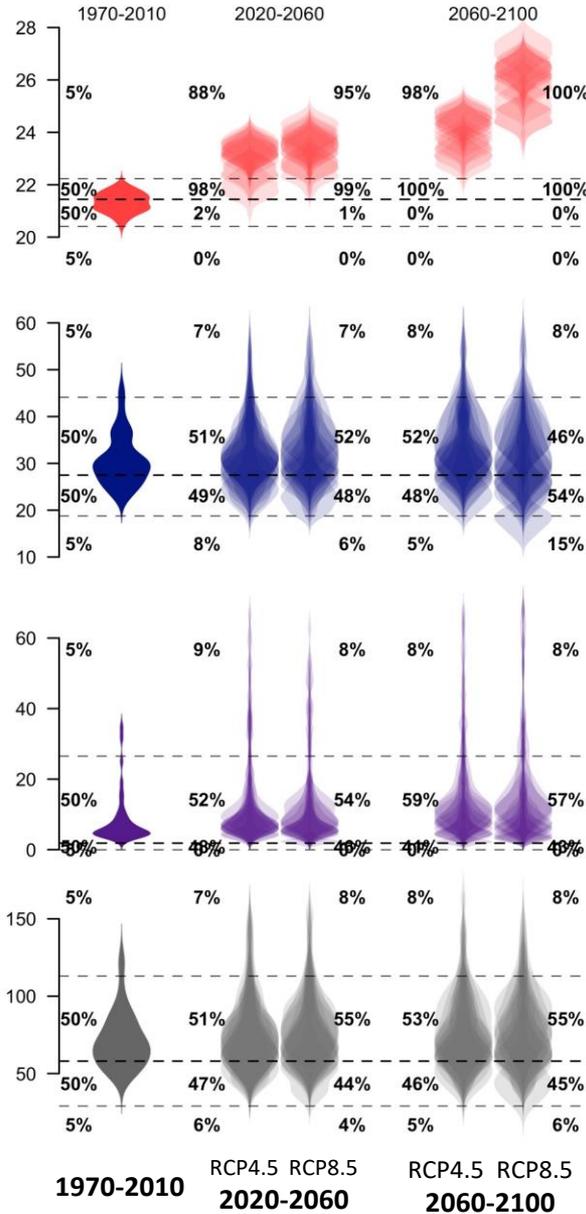


Tucson

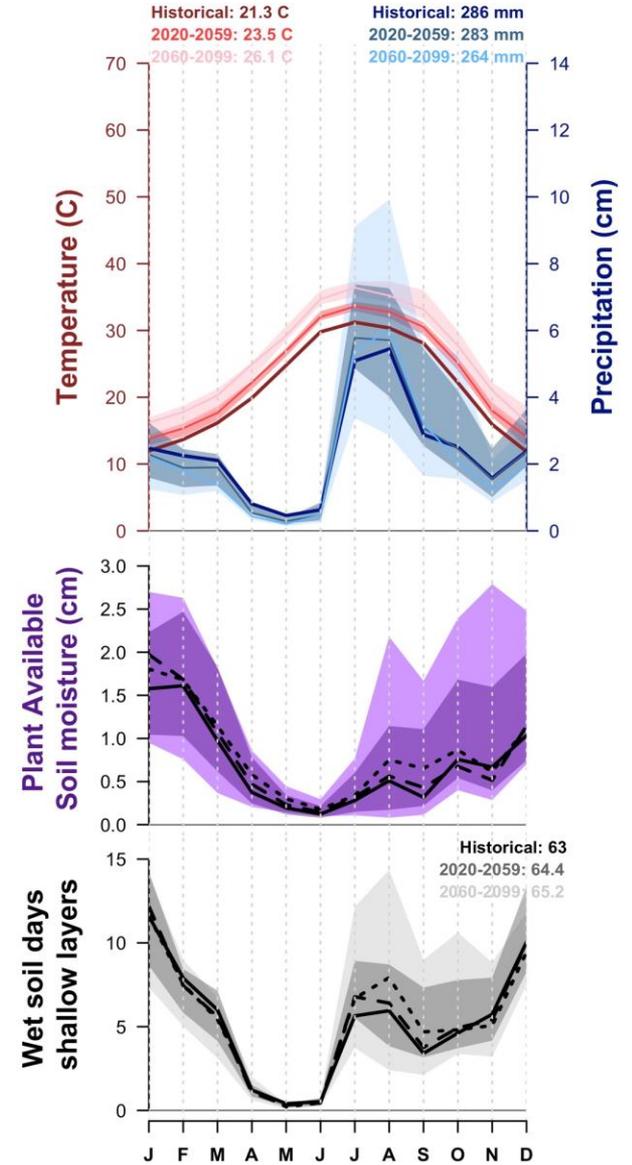
Historical Time Series



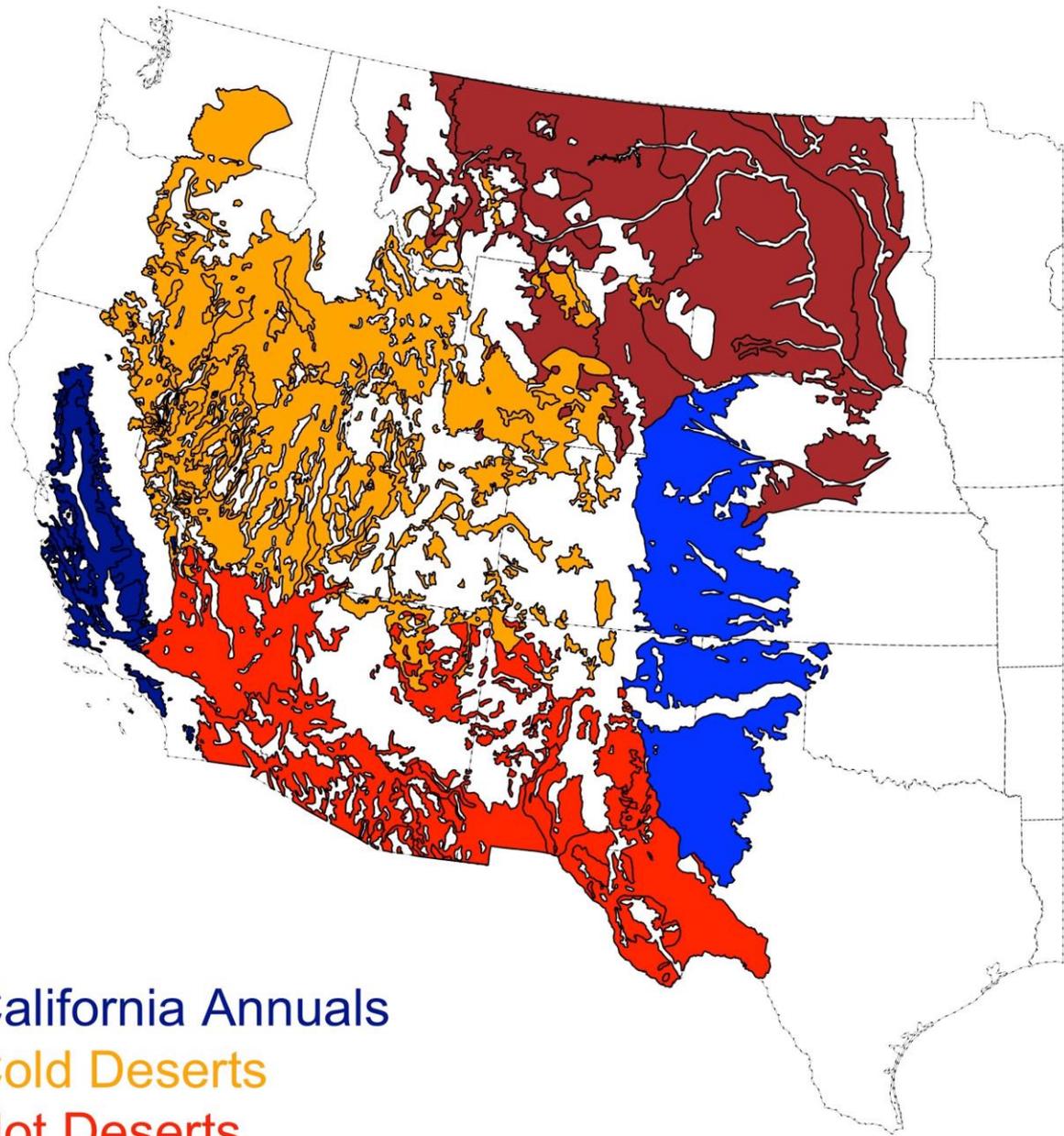
Future Trajectories



Seasonal Patterns



Regional Summaries



California Annuals

Cold Deserts

Hot Deserts

Shortgrass Steppe

Northern Mixed Prairies

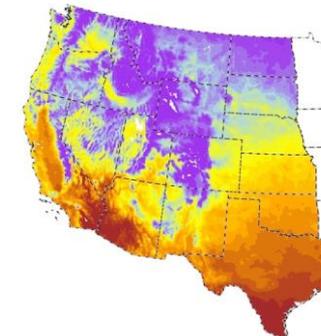
Annual Temperature



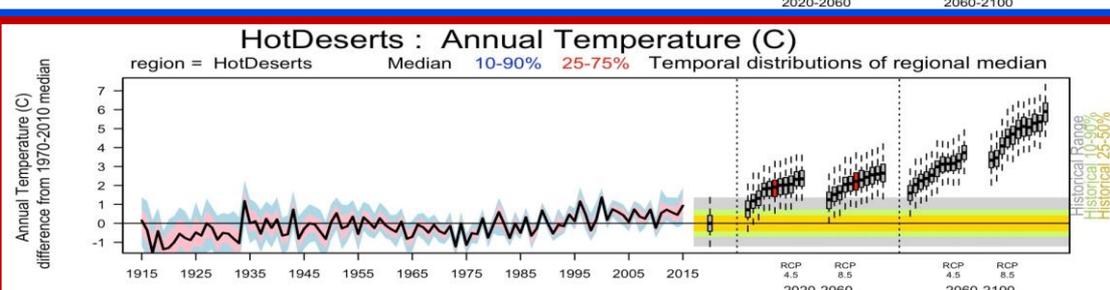
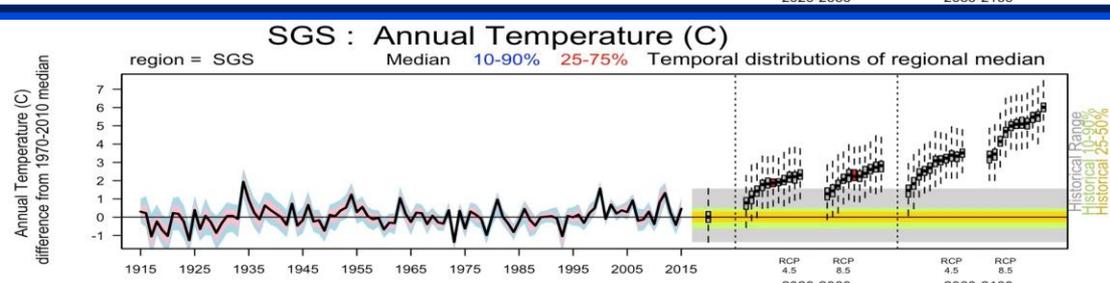
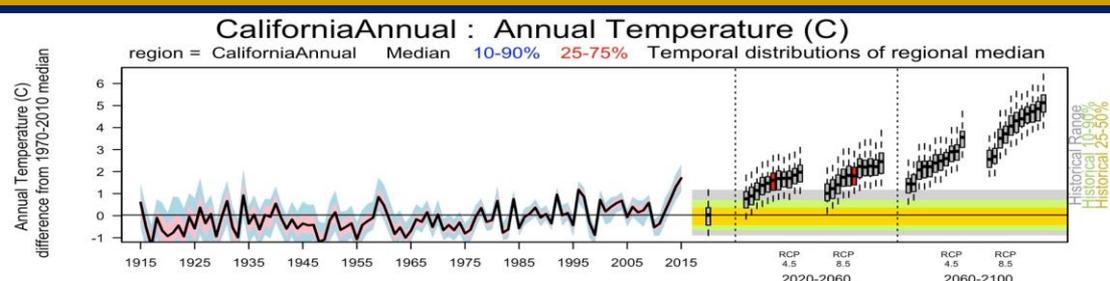
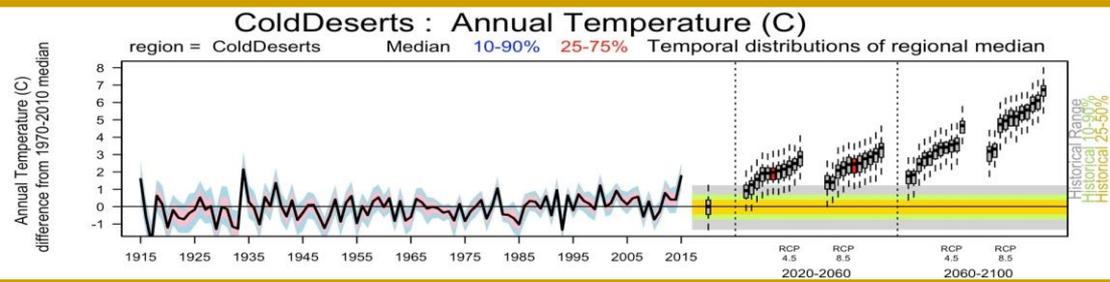
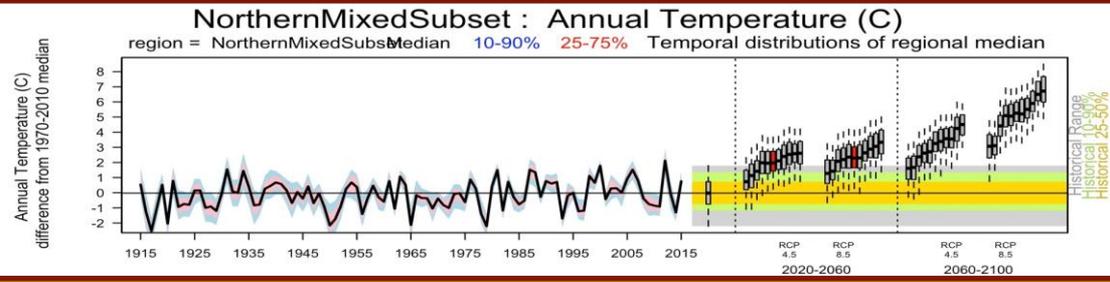
California Annuals
Gold Deserts
Hot Deserts
Shortgrass Steppe
Northern Mixed Prairies

- Increasing in all regions
- Slightly greater increases in the north
- Mean 2020-2060 temperatures are projected to be higher than the hottest year between 1970-2010

1970 - 2010

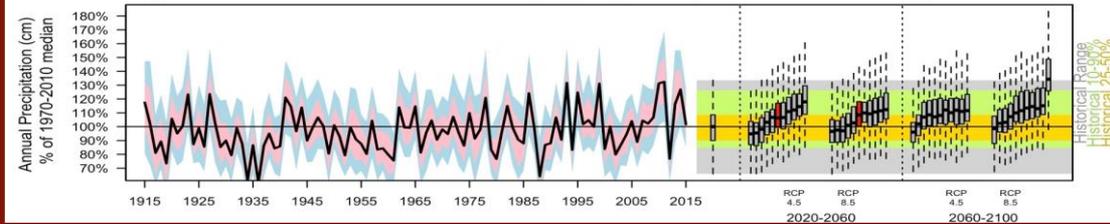


Annual Temperature (C)
25.2
19.5
17
14.4
12.3
10.8
9.47
8.36
7.03
5.13
-2.65



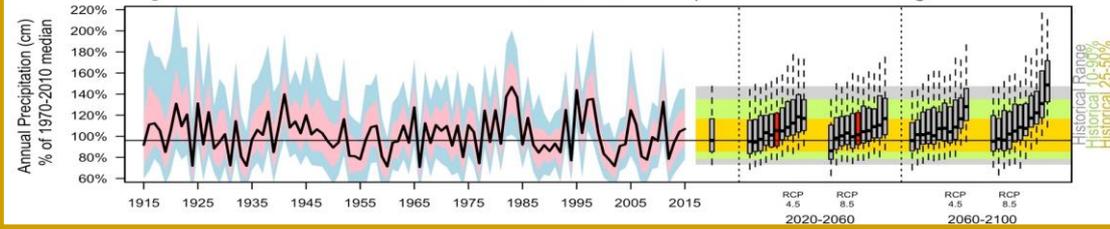
NorthernMixedSubset : Annual Precipitation (cm)

region = NorthernMixedSubset Median 10-90% 25-75% Temporal distributions of regional median



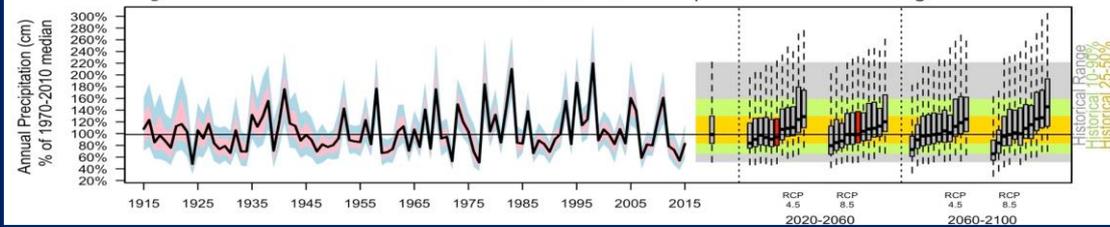
ColdDeserts : Annual Precipitation (cm)

region = ColdDeserts Median 10-90% 25-75% Temporal distributions of regional median



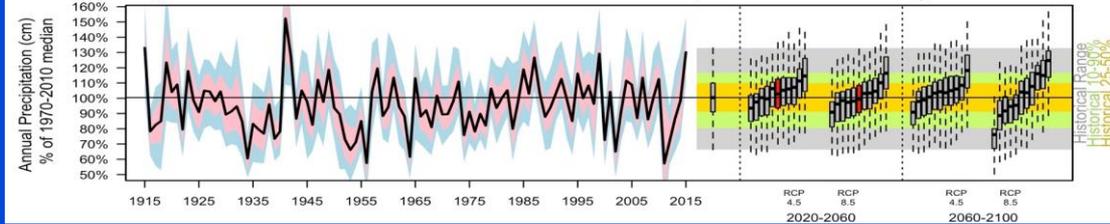
CaliforniaAnnual : Annual Precipitation (cm)

region = CaliforniaAnnual Median 10-90% 25-75% Temporal distributions of regional median



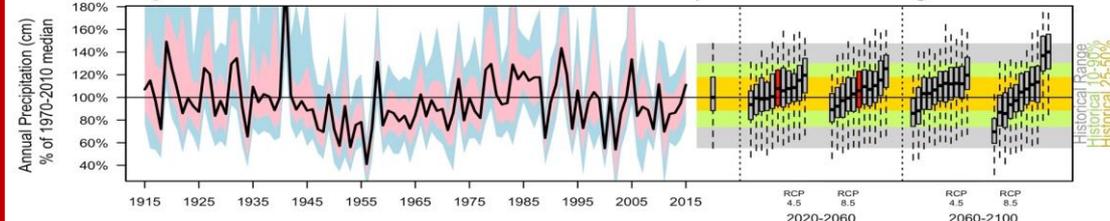
SGS : Annual Precipitation (cm)

region = SGS Median 10-90% 25-75% Temporal distributions of regional median



HotDeserts : Annual Precipitation (cm)

region = HotDeserts Median 10-90% 25-75% Temporal distributions of regional median

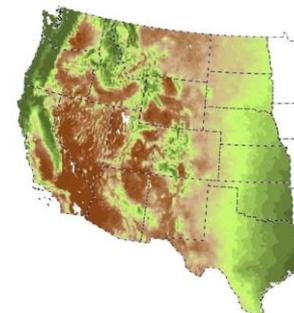


California Annuals
Cold Deserts
Hot Deserts
Shortgrass Steppe
Northern Mixed Prairies

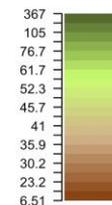
Annual Precipitation

- Modest increases overall
- Divergent projections among climate models
- More consistent projected increases in the northern regions
- Year-to-year fluctuations:
 - Uniform in California annuals
 - Variable in hot deserts

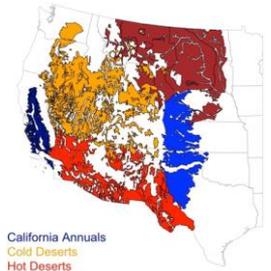
1970 - 2010



Annual Precipitation (cm)

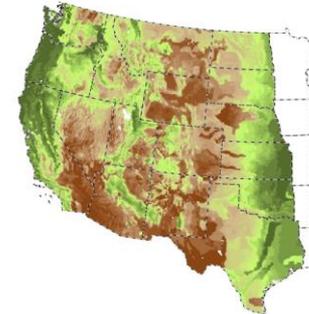


Winter soil moisture

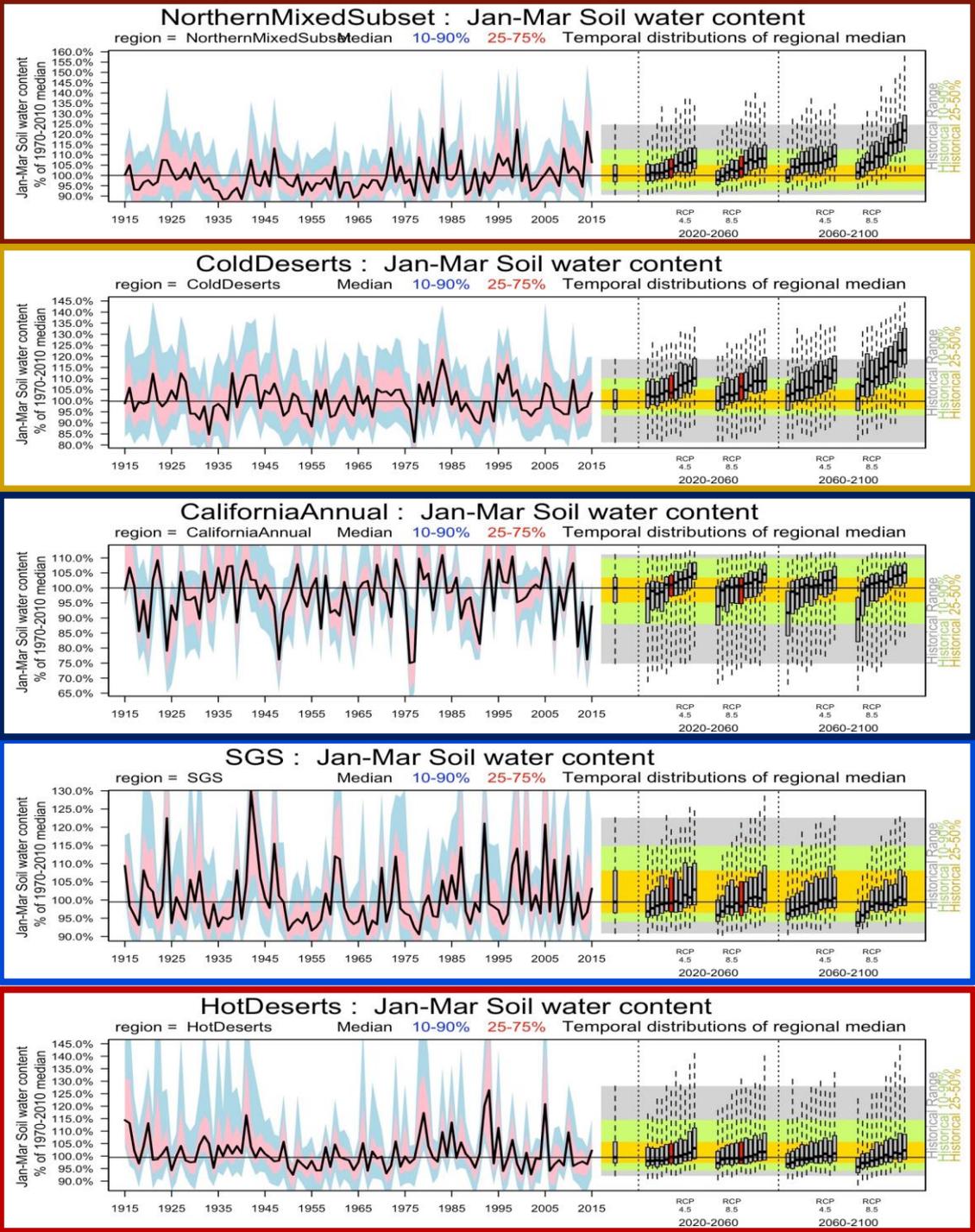
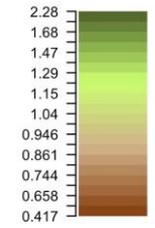


- Modest projected increases
- In northern regions, increases are relatively consistent among climate models
- Divergent projections among climate models for other regions
- Potential for more frequent drought years in California

1970 - 2010

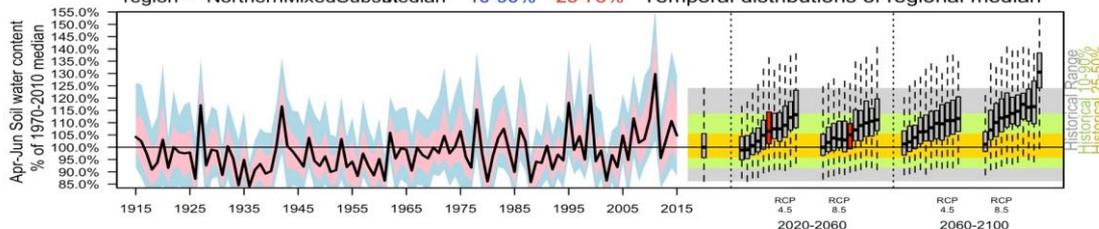


Jan-Mar Soil water content



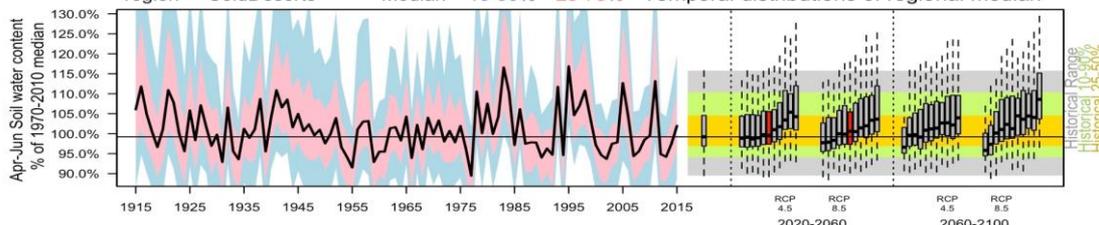
NorthernMixedSubset : Apr-Jun Soil water content

region = NorthernMixedSubs Median 10-90% 25-75% Temporal distributions of regional median



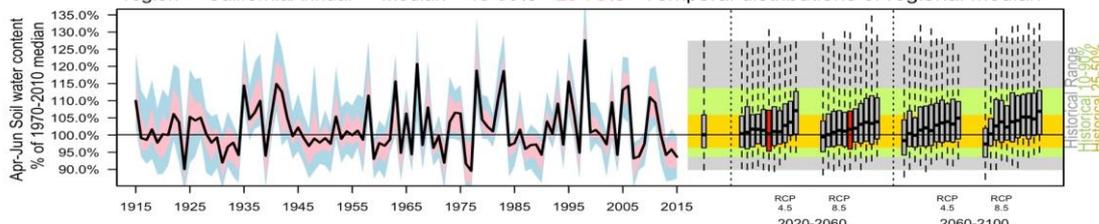
ColdDeserts : Apr-Jun Soil water content

region = ColdDeserts Median 10-90% 25-75% Temporal distributions of regional median



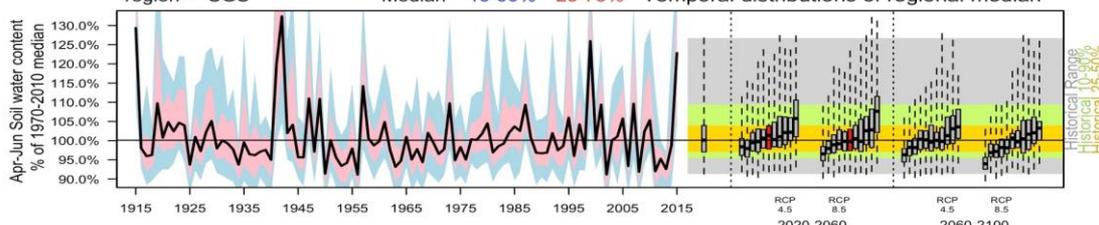
CaliforniaAnnual : Apr-Jun Soil water content

region = CaliforniaAnnual Median 10-90% 25-75% Temporal distributions of regional median



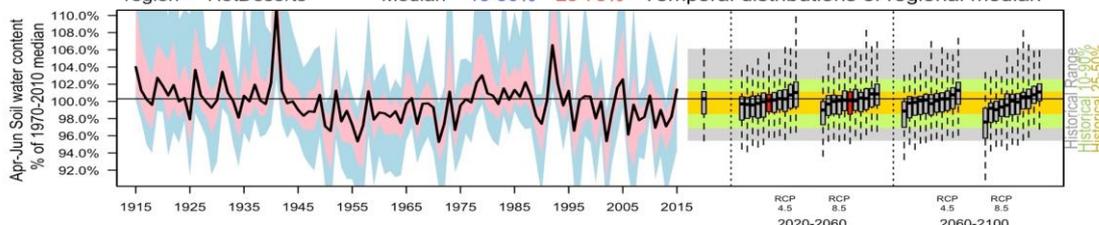
SGS : Apr-Jun Soil water content

region = SGS Median 10-90% 25-75% Temporal distributions of regional median



HotDeserts : Apr-Jun Soil water content

region = HotDeserts Median 10-90% 25-75% Temporal distributions of regional median



California Annuals
Cold Deserts
Hot Deserts
Shortgrass Steppe
Northern Mixed Prairies

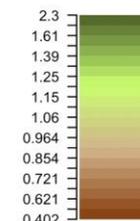
Spring soil moisture (April-June)

- Increasing in northern mixed prairies
- Modest increases in cold deserts and California annuals
- Relatively unchanged in the shortgrass steppe
- Potential declines in hot deserts

1970 - 2010

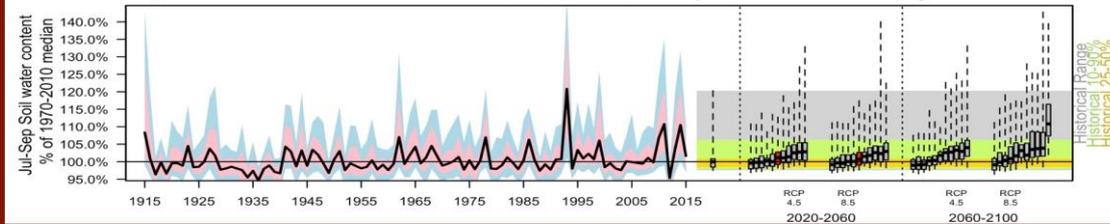


Apr-Jun Soil water content



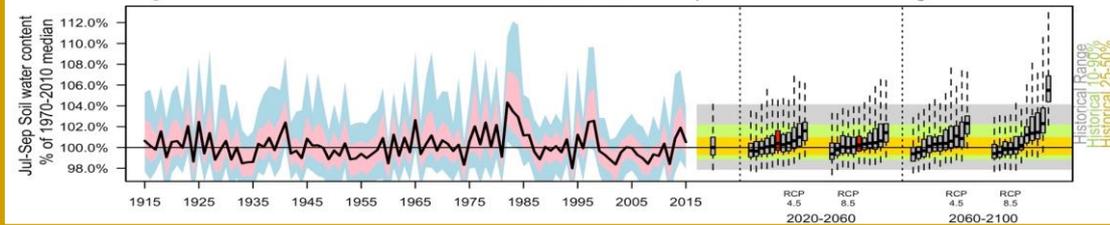
NorthernMixedSubset : Jul-Sep Soil water content

region = NorthernMixedSubset Median 10-90% 25-75% Temporal distributions of regional median



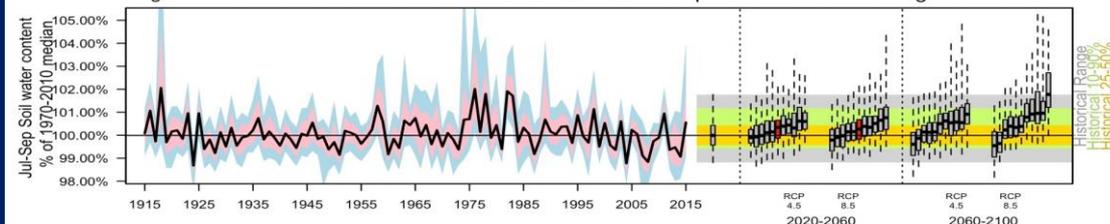
ColdDeserts : Jul-Sep Soil water content

region = ColdDeserts Median 10-90% 25-75% Temporal distributions of regional median



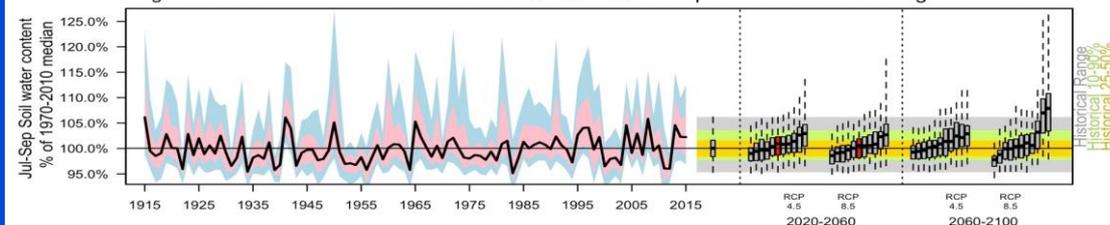
CaliforniaAnnual : Jul-Sep Soil water content

region = CaliforniaAnnual Median 10-90% 25-75% Temporal distributions of regional median



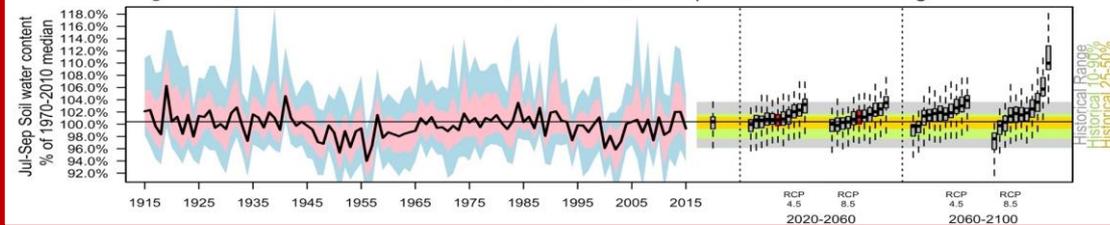
SGS : Jul-Sep Soil water content

region = SGS Median 10-90% 25-75% Temporal distributions of regional median



HotDeserts : Jul-Sep Soil water content

region = HotDeserts Median 10-90% 25-75% Temporal distributions of regional median

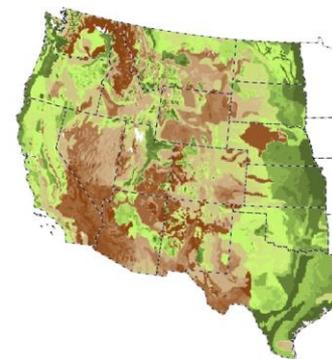


California Annuals
Cold Deserts
Hot Deserts
Shortgrass Steppe
Northern Mixed Prairies

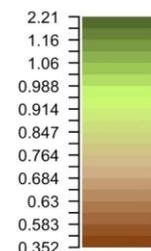
Summer soil moisture (Jul-Sep)

- Relatively unchanged in the most regions
- Projections diverge among climate models
- Especially in the hot deserts

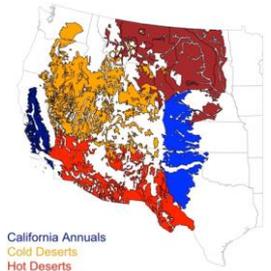
1970 - 2010



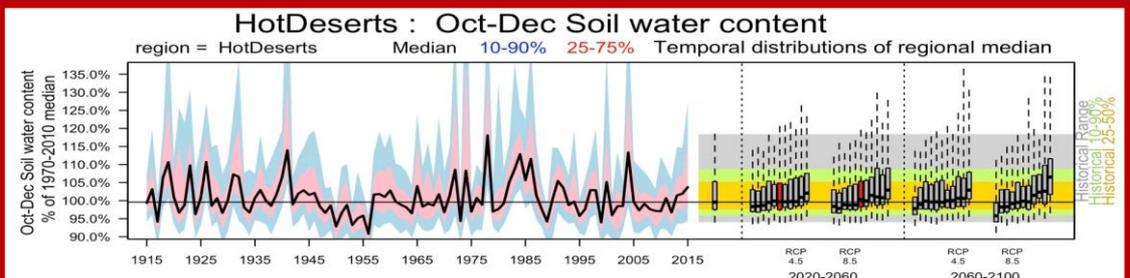
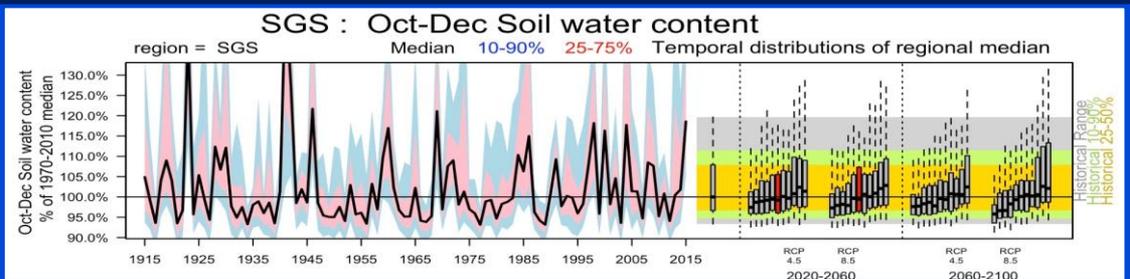
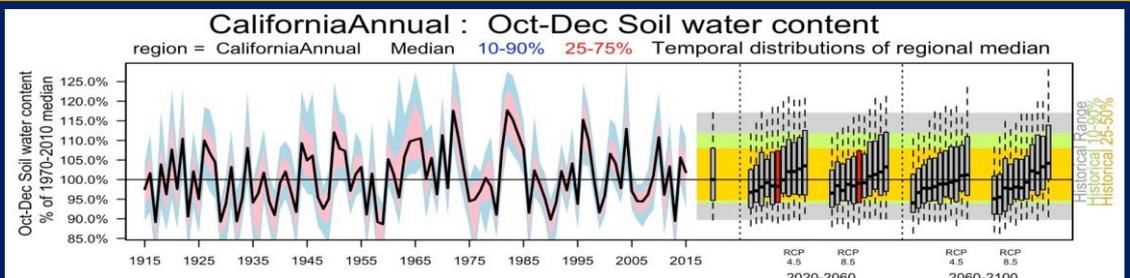
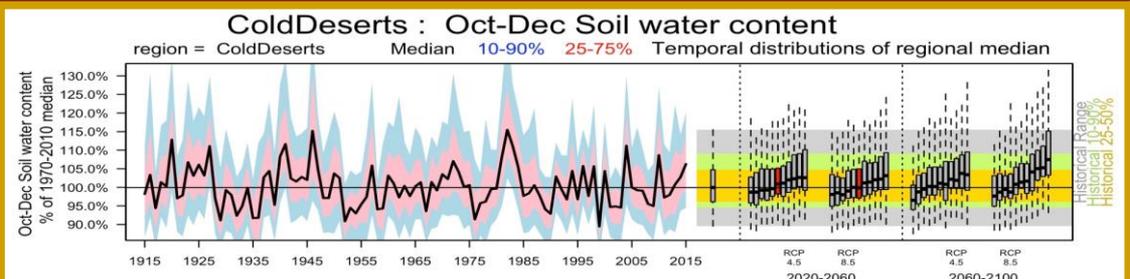
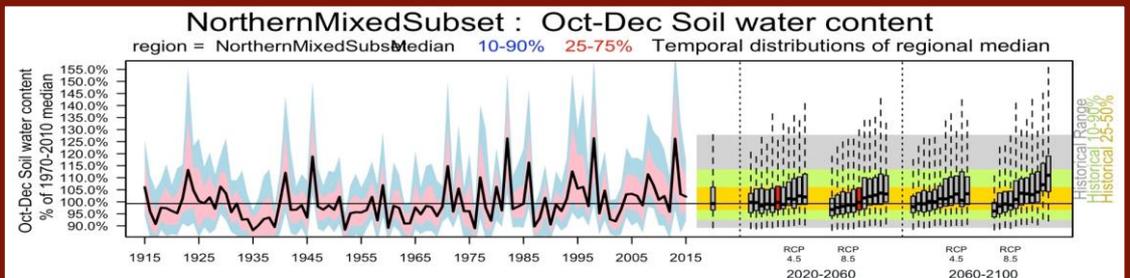
Jul-Sep Soil water content



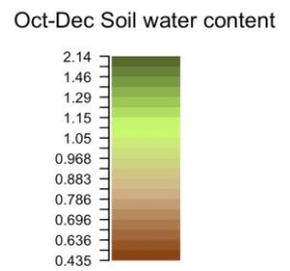
Fall soil moisture (Oct-Dec)



- Relatively unchanged
- Potentially drier in shortgrass steppe and CA annuals
- Approximately equal number of climate models indicating increases and decreases



1970 - 2010



Climate & drought exposure summary

Temperature

- Increases projected in all regions...slightly higher in northern areas
- Consistent among climate models (less under RCP4.5 than RCP 8.5)

Precipitation

- Much less consistent among models
- Potentially modest increases, especially in northern areas

Soil moisture is HIGHLY variable among climate models

- Some evidence for more winter & early spring moisture in northern mixed prairies, cold deserts and CA annuals
- Potentially drier spring soils in the hot deserts
- Potentially drier fall soils in shortgrass steppe & CA



Questions?

jbradford@usgs.gov