



January 19, 2024

Via email

State Water Resources Control Board
Sacramento, CA
Email: SacDeltaComments@waterboards.ca.gov

To whom it may concern:

The following technical memo is submitted as comments on the DRAFT STAFF REPORT IN SUPPORT OF POTENTIAL SACRAMENTO/DELTA UPDATES TO THE WATER QUALITY CONTROL PLAN FOR THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY.

Sincerely,

A handwritten signature in black ink, appearing to read "D. Des Jardins", is positioned above the typed name.

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Nonlinear trends in temperature and precipitation in California

Climate change impacts have been accelerating in the 21st Century. This report shows how the hydroclimate in California has fundamentally shifted.

The Water Board cannot rely on modeling which implicitly assumes the 20th Century hydrology to show that flow and temperatures thresholds needed for survival of species and achievement of Water Quality Control Plan objectives will be met.

Increases in temperature and frequency of extremes

The past decade has seen a huge increase in extreme weather events across the globe. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Working Group I IPCC Working Group I (IPCC AR6 WG1 2021) found:

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.
(p. 25.)

In western North America, the Southwest has seen a megadrought, the driest two decades for soil moisture in the last 1200 years (Williams et al. 2020; Williams et al. 2022). California saw the driest four year period in the observational record in 2012-2015 (CDWR 2016).

German climate scientist Stefan Rahmstorf published an analysis showing that Germany has warmed over 2°C (3.6 °F) since the 19th century (Figure 1) while the linear trends used by the German Weather Service show warming of only 1.6°C (Figure 2). Figure from (Rahmstorf 2020).

The warming of over 2 °C in Germany is consistent with global trends, which show that warming over land regions has been more rapid than warming of the ocean and warming in the Northern Hemisphere than warming in the Southern Hemisphere.

The state of California has similarly been using linear trends to characterize regional temperature increases. See, for example, the OEHHA report, "Indicators of Climate Change in California." (OEHHA 2022 Nov), which states that California has been warming at a rate of approximately 2 °F per century. However, just as in Germany, using linear trends significantly underestimates the magnitude of recent warming.

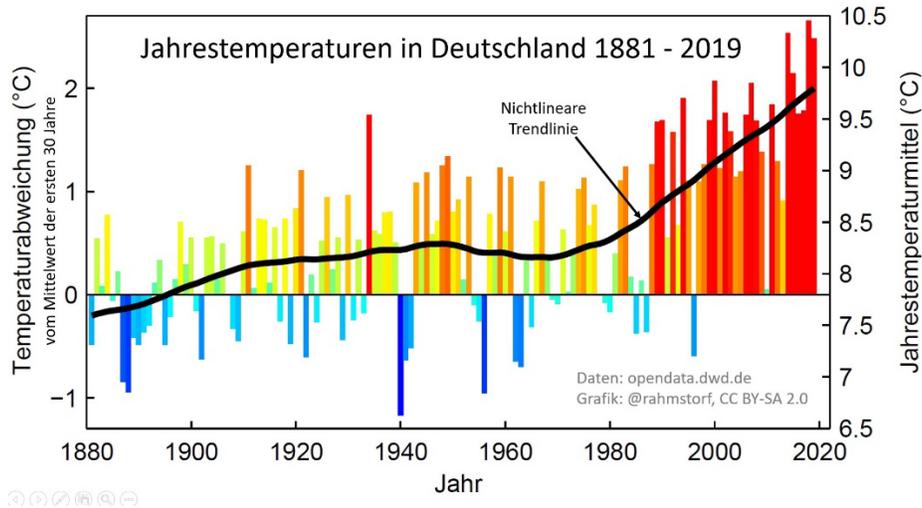


Figure 1 Nonlinear trends in temperature in Germany (Stefan Rahmstorf)

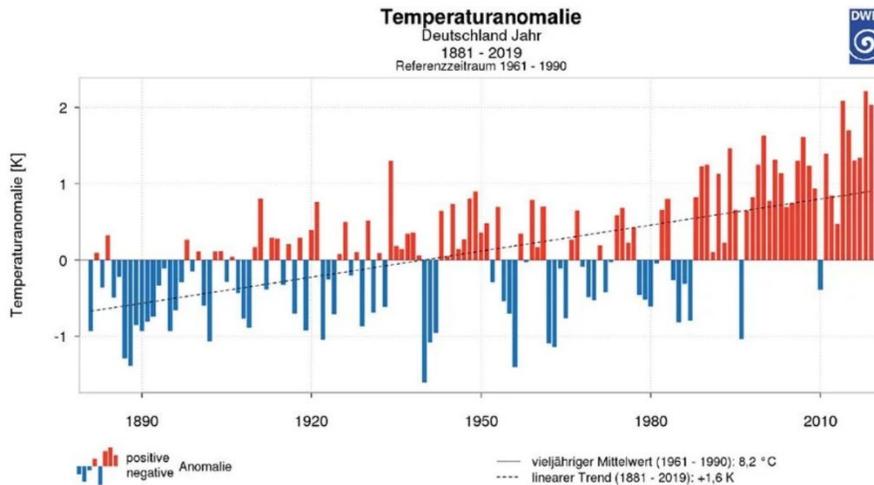


Figure 2 Linear trends used by the German Weather Service

NOAA National Centers for Environmental Information provides timeseries of climate data by US Climate Division from 1895 to the present (NOAA NCEI 2023 Dec). A map of the California Climate Divisions is shown in Figure 3. The Sacramento and San Joaquin Drainage divisions are the watersheds for the Sacramento and San Joaquin Rivers, respectively. The North Coast drainage includes the watershed for the Trinity River.

Figure 4 shows the increase in mean monthly 2 meter air temperatures for the past decade, compared to the period 1895-1925. Warming in 2013-2023 is as high as 3.6-4.3 °F (2-2.3 °C) in Northern California, and as high as 4.0-5.4 °F (2-3 °C) on the South Coast. Temperature increases in California in 2013-2023 have also been among the highest in the Western US in many months. (See Figure 16 in the Appendix.)



Figure 3 Map of California Climate Divisions

Figure 5 shows the increase in mean monthly 2 meter air temperatures for the period 1998-2013. 2013-2023 saw a significant increase from 1998-2013, particularly in Northern California and the San Joaquin Valley, where the change from 1895-1925 increased by 100% or more in some months.

Figure 6 shows the nonlinear trend in mean monthly temperatures, compared with the linear trend. The nonlinear trend for the 2013-2023 period is much larger than the linear trend and has been associated with significant drying in California watersheds. Figure 5 shows the nonlinear trend in anomalies of the Palmer Drought Severity Index, or PDSI. However, there has also been a significant decrease in precipitation in California in the period 2013-2023 and 1998-2023. Figure 7 shows the nonlinear and linear trends in precipitation.

Methods

The nonlinear trend was calculated using locally weighted scatterplot smoothing (Lowess) with a 30 year window (Cleveland 1979). (Clarke and Richardson 2021) proposed using the Lowess trend with a 40 year window for IPCC estimates of global temperature.

The linear trend was calculated using Sen's slope and pyMannKendall. (Hussain and Mahmud 2019). Sen's slope was chosen over least squares regression because least squares assumes that data is independent and identically distributed, and also that the variance is not changing. California climate data is not identically distributed, and the variance is increasing. Sen's slope is more robust.

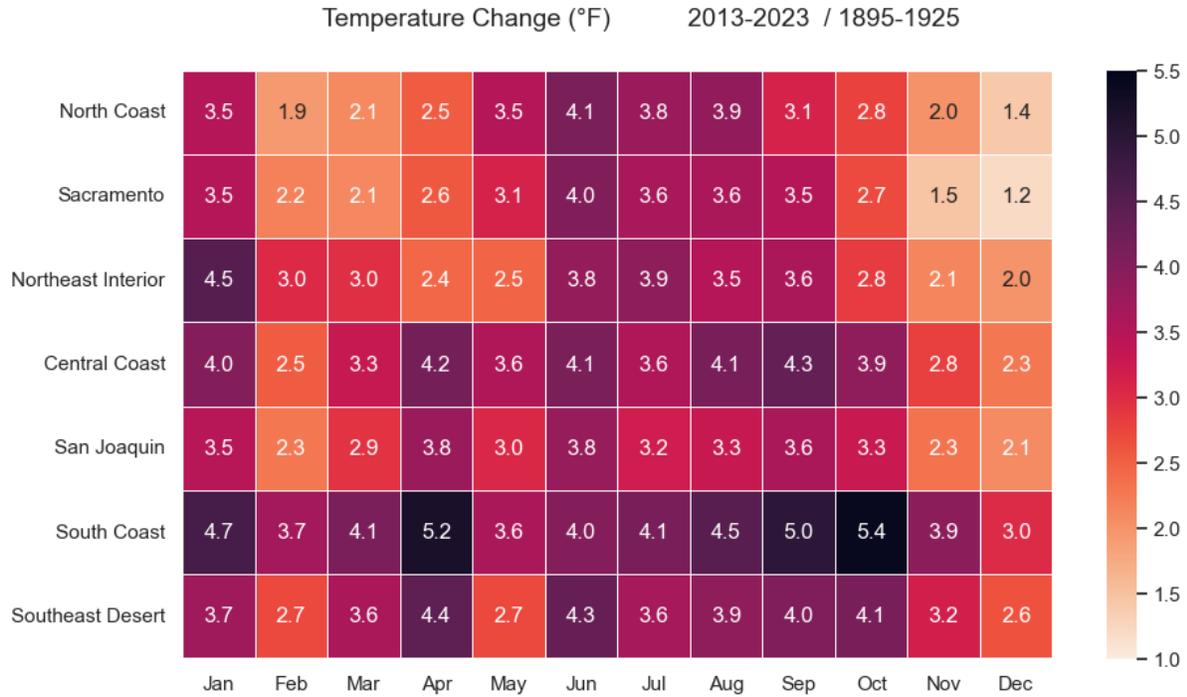


Figure 4 2m Temperature increase from 2013-2023, compared to 1895-1925

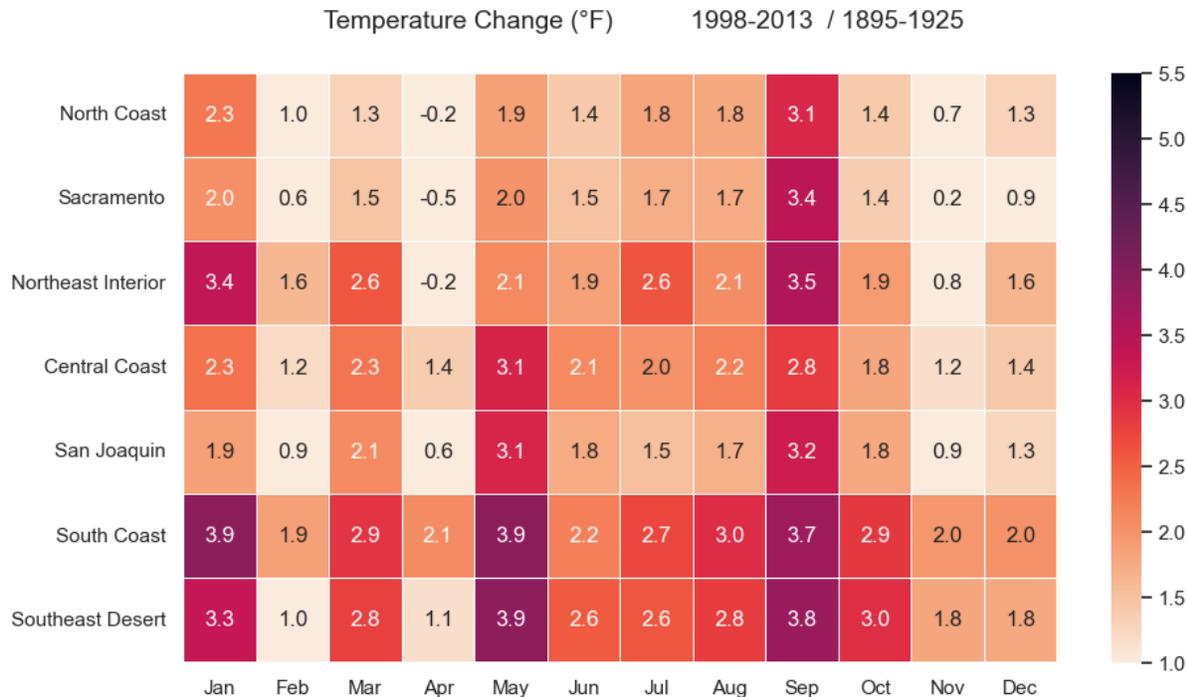


Figure 5 2m Temperature increase from 1998-2013, compared to 1895-1925

California WY Temperature Anomalies with Trends

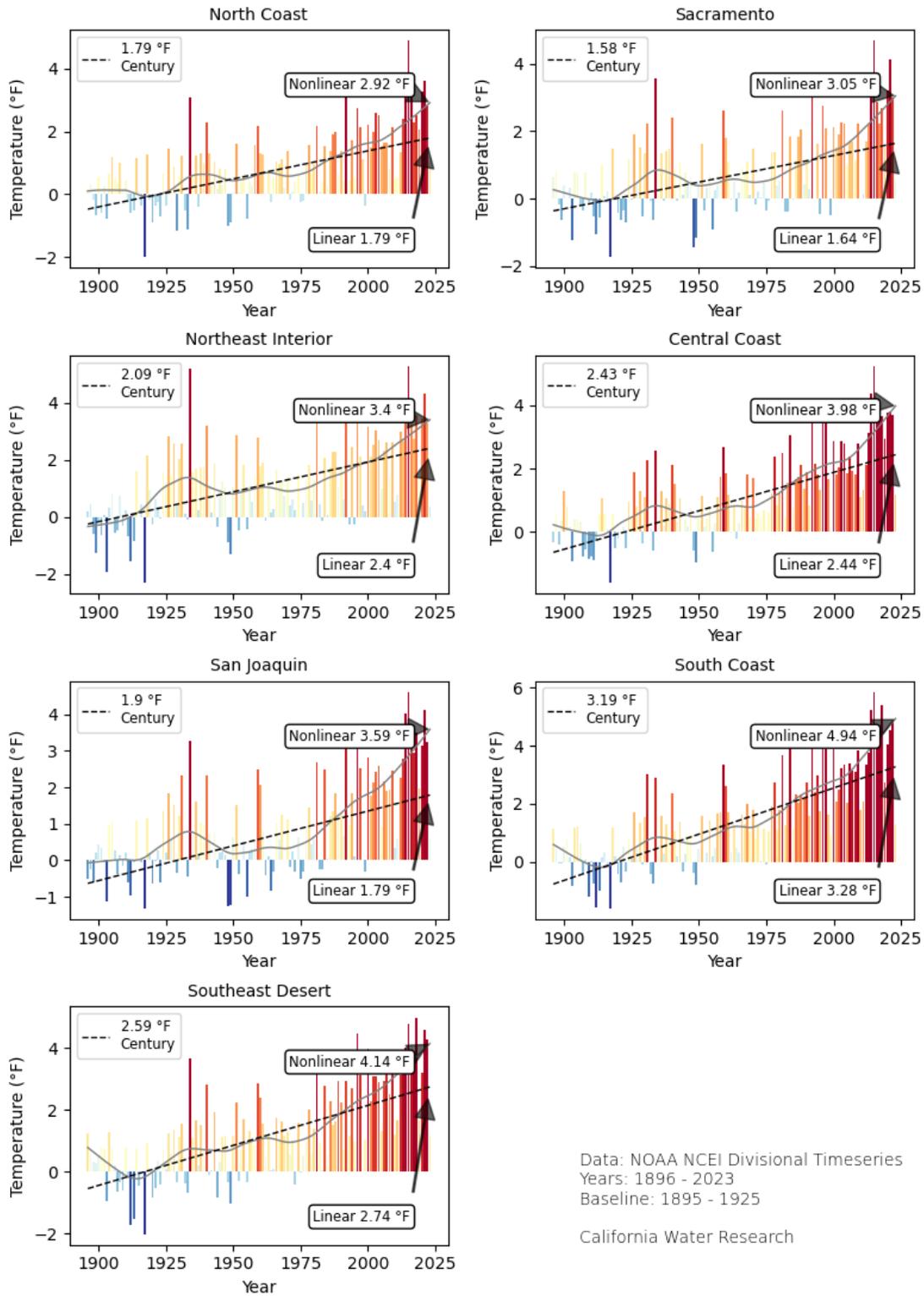


Figure 6 Nonlinear vs. linear trends in temperature in California Climate Divisions.

California WY PDSI Anomalies with Trends

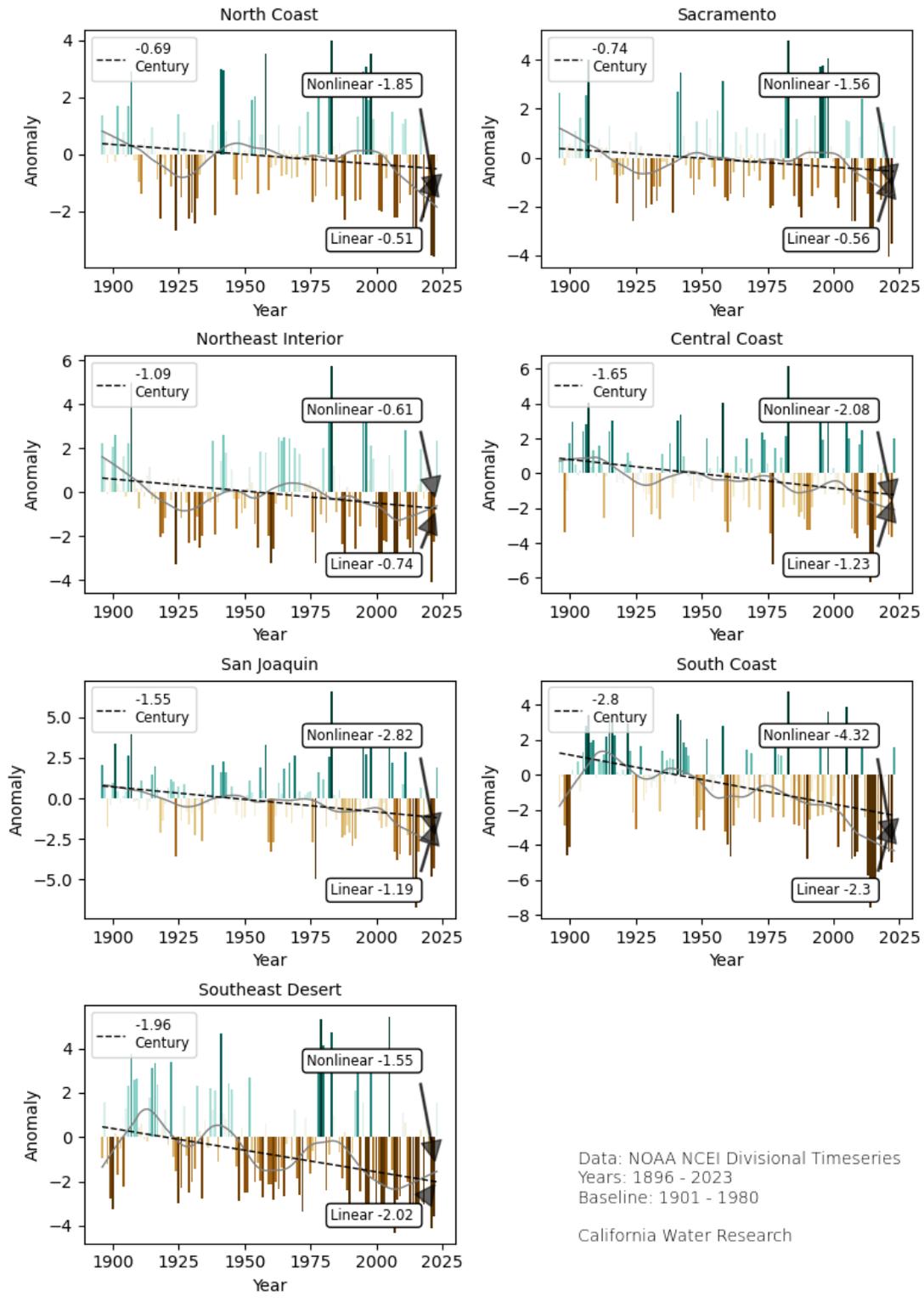


Figure 7 Nonlinear vs. linear trends in PDSI in California Climate Divisions.

California WY Precipitation Anomalies with Trends

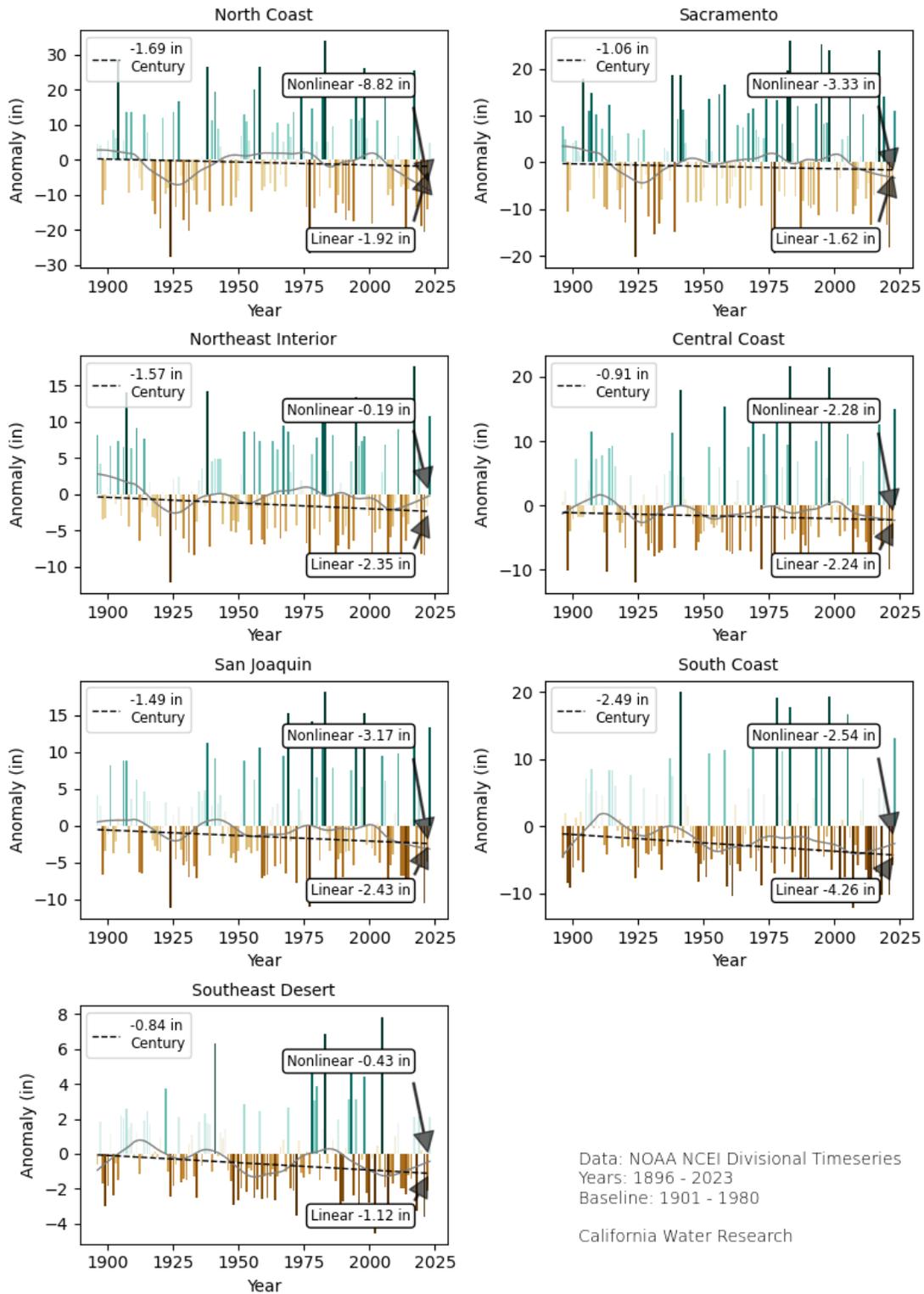


Figure 8 Nonlinear vs. linear trends in precipitation in California Climate Divisions.

Discussion

Decadal-scale variability in California temperature and precipitation has been associated with sea surface temperatures in the North Pacific. From 1998-2013, there was a pattern of cool sea surface temperatures in the Northeastern Pacific, associated with a predominantly cool phase of the Pacific Decadal Oscillation (PDO).

The PDO was first defined by (Mantua et al. 1997), as the dominant pattern in decadal scale variations in monthly sea surface temperatures in the North Pacific. (Power et al. 1999) defined an Interdecadal Pacific Oscillation, which encompasses the entire Pacific. There are a number of other indices which collectively represent Pacific Decadal Variability, but are not independent (IPCC AR6 WG1 2021).

Other predominantly cool PDO periods include 1905-1925 and 1947-1976, with predominantly warm periods in between. (Deser, Clara et al. 2022). The warm PDO period of 1977-98 was a wetter period. The period since 2013 has been mixed.

Figures 8 and 9 show changes in the distribution of precipitation and temperature in California, by Pacific Decadal Oscillation period. While there has been an increase in wet extremes during 1977-98 and also from 2013-2023, there was a significant increase in dry extremes from 2013-2023, and the median of the distribution has shifted. Figures 11 and 12, in the appendix, show similar distributions and shifts in distributions for the North Coast, Sacramento, and San Joaquin Climate Divisions.

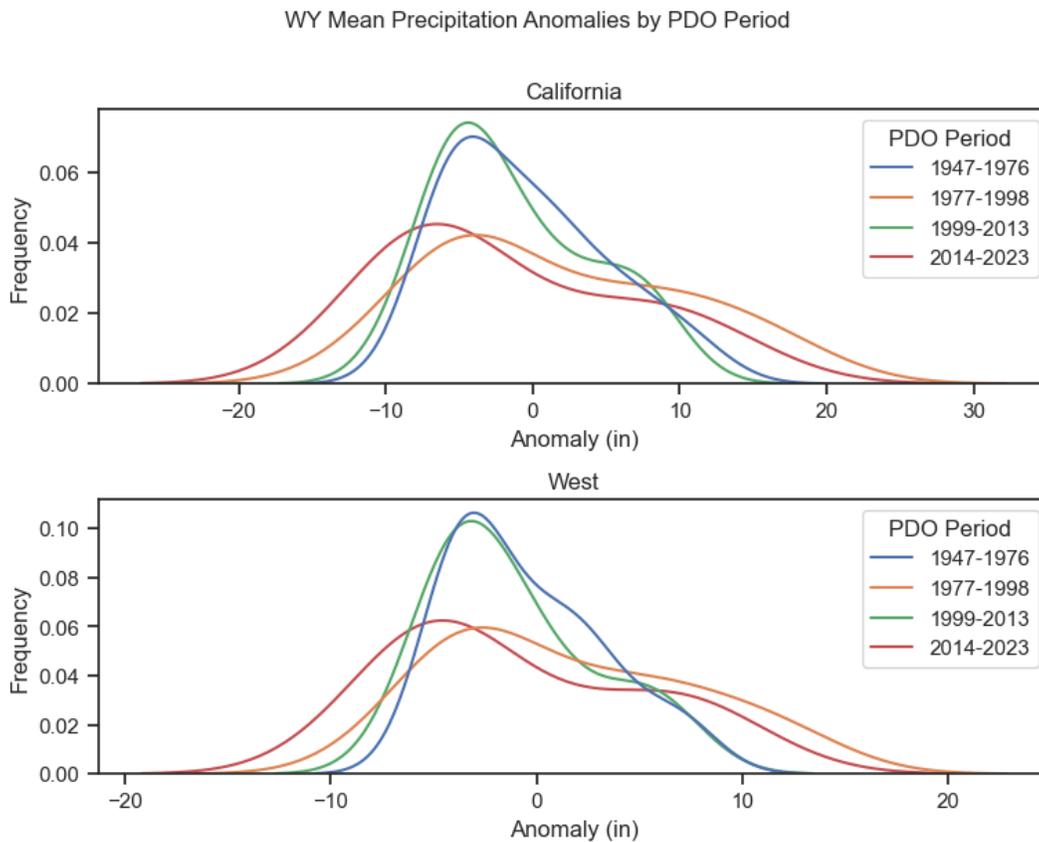


Figure 9 Changing distributions of precipitation in California and the Western US

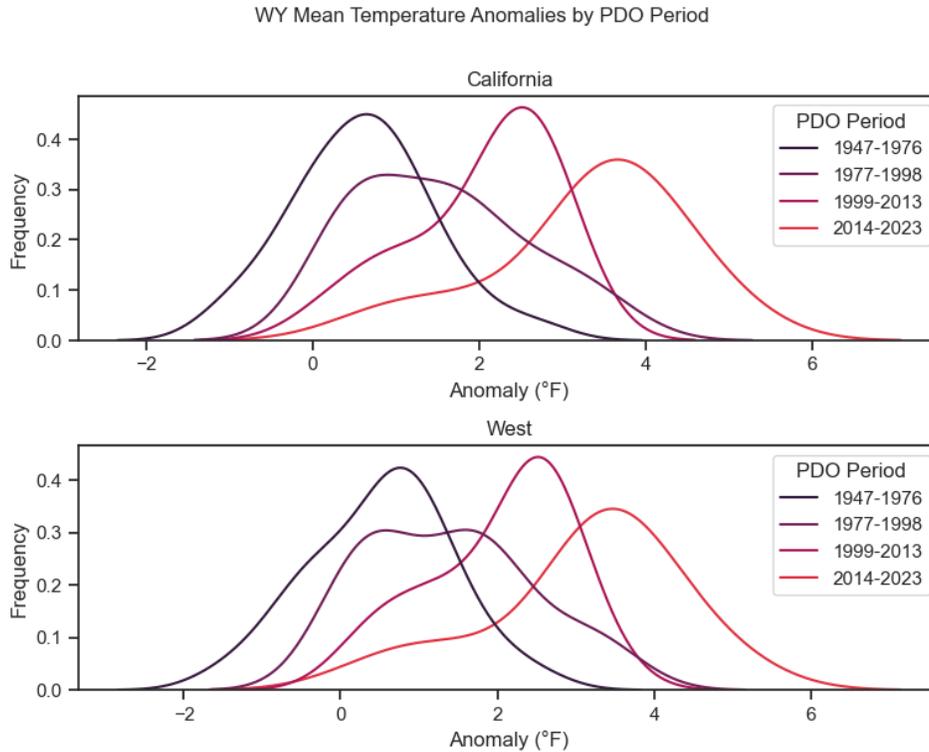


Figure 10 Changing distributions of temperature in California and the Western US

The shifts in distribution in precipitation in California are also associated with a decline in landfalling atmospheric rivers. (Gershunov et al. 2019) used automated detection methods on reanalysis data from 1951-2000 to find landfalling ARs from January to March. Surprisingly, the supplemental information shows a reduction in the number of landfalling ARs on the west coast, and an even larger reduction in California, as well as a reduction in duration of ARs. The authors found:

a change in the average number of landfalling ARs on the west coast of -1 (1%), and a reduction in duration of 0.27 days (14%) (Table S3)

a change in the average number of landfalling ARs in California of -2(15%) and a reduction in duration of 0.21 days (9%) (Table S4)

(Gershunov et al. 2019) also found an overall decrease in AR-related precipitation on the west coast of North America, and more in California.

a reduction in annual AR precipitation on the west coast of -16 mm (14%), compensated for by an increase in non-AR precipitation of +47 mm (9 %) (Table S6)

a reduction in annual AR precipitation in California of -70 mm (32%), compensated for by an increase in non-AR precipitation of +112 mm (28%). (Table S5)

Figure 11 shows the marked decrease in the Standardized Precipitation Index (1 month) in January and February from 2013 to 2023 over the base period of 1901-1980. In contrast, the period from 1977-98 was wetter in most months. There are similar reductions in precipitation in January and February across the Western US (Appendix, Figure 15.)

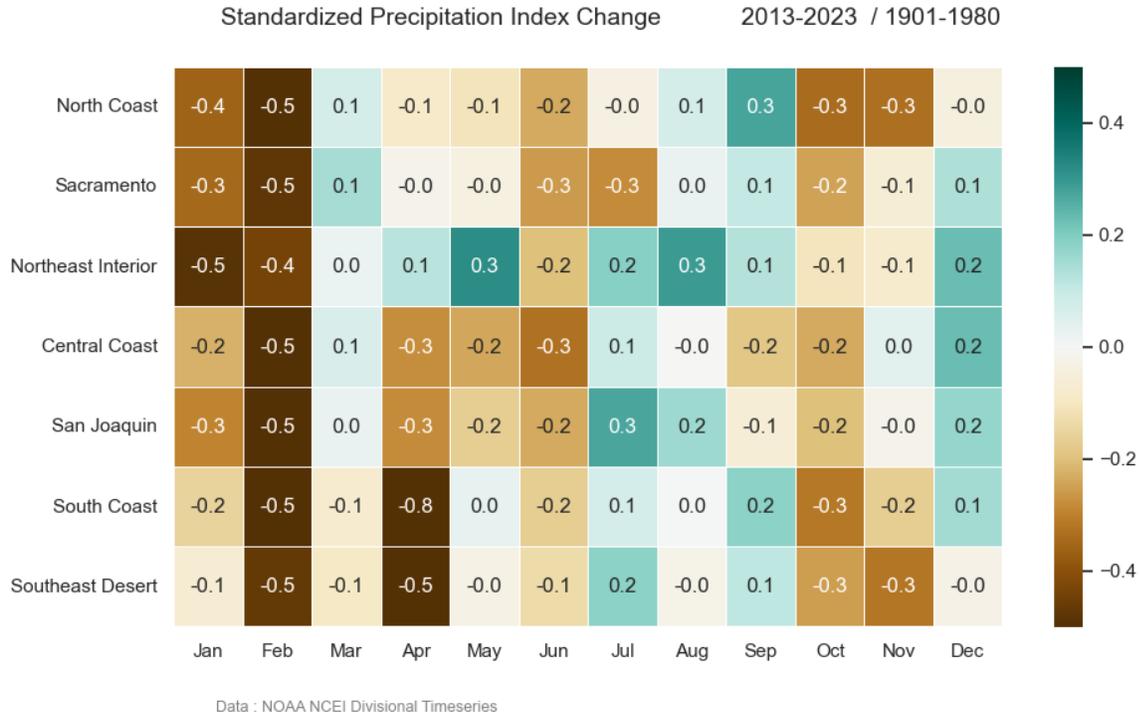


Figure 11 Standardized Precipitation Index change, 2013-2023

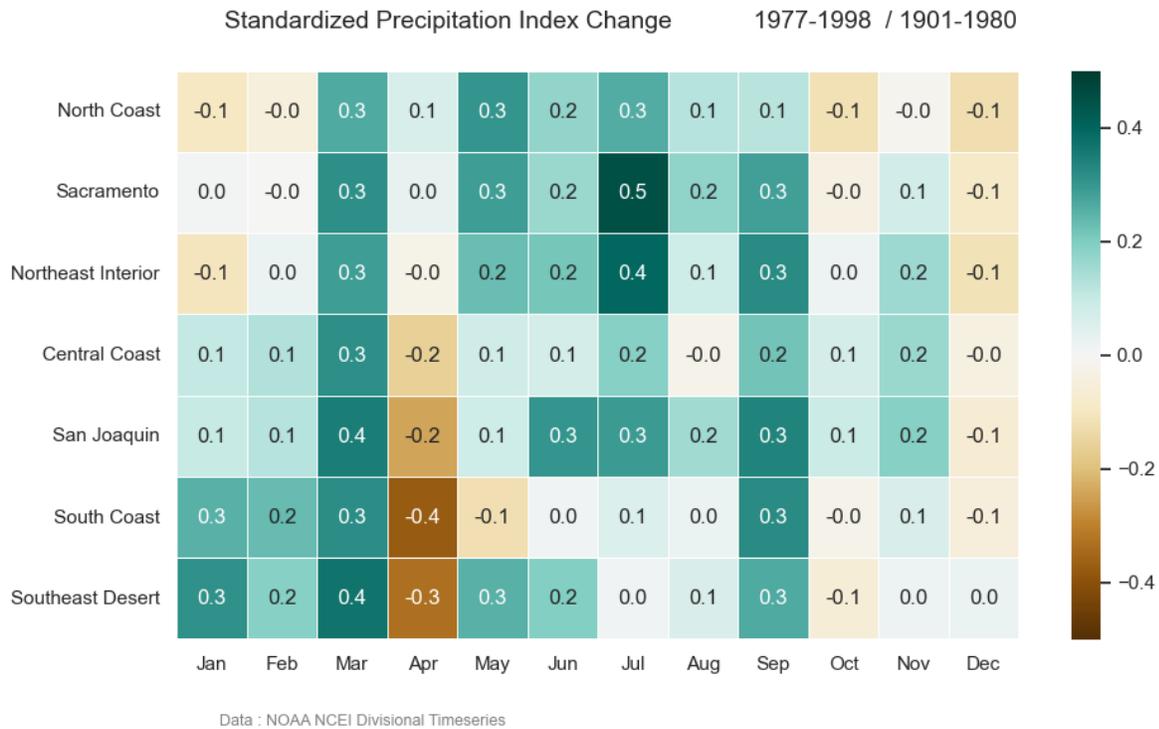


Figure 12 Standardized Precipitation Index change 1977-98

Climate adaptation under increasing uncertainty

(Dettinger and Culberson 2008) observed rather presciently that “human-induced climate changes, mostly in the form of long-term trends, are projected to be larger and more sustained than those long-term fluctuations in the historical period, and comparable to—or larger than—natural climate excursions in the past several millennia.”

Recent years have seen increasing uncertainty about the causes of reduced precipitation in western North America. A recent study by Seager et al. (2022) significantly undermines the conclusion that the precipitation deficit in recent western droughts was caused by internal variability. The authors used large ensembles to evaluate the ability of climate models to reproduce observation-based trends in Pacific sea surface temperature. The study found that the latest climate models fail to reproduce these trends, leading the authors to conclude that observed trends are “extremely unlikely” to be consistent with model internal variability.

(Fasullo et al 2020) also used large ensembles to evaluate the representation of Pacific Decadal Variability (PDV) in the current generation of climate models from the Fifth and Sixth Coupled Model Intercomparison Project (CMIP5 and CMIP6). (IPCC AR6 WG1 2021) found that the observed PDV is “in the tails of the model distributions,” and that

even if one cannot rule out that the observed PDV over the instrumental era represents an exceptional period of variability, it is plausible that the tendency of the CMIP5 models to systematically underestimate the low frequency variance is due to an incomplete representation of decadal-scale mechanisms in these models. This situation is slightly improved in CMIP6 historical simulations but remains a concern...

In the face of such uncertainty, the public trust demands that the Water Board assume that the current climate trends may continue.

Appendix

WY Mean Precipitation Anomalies by PDO Period

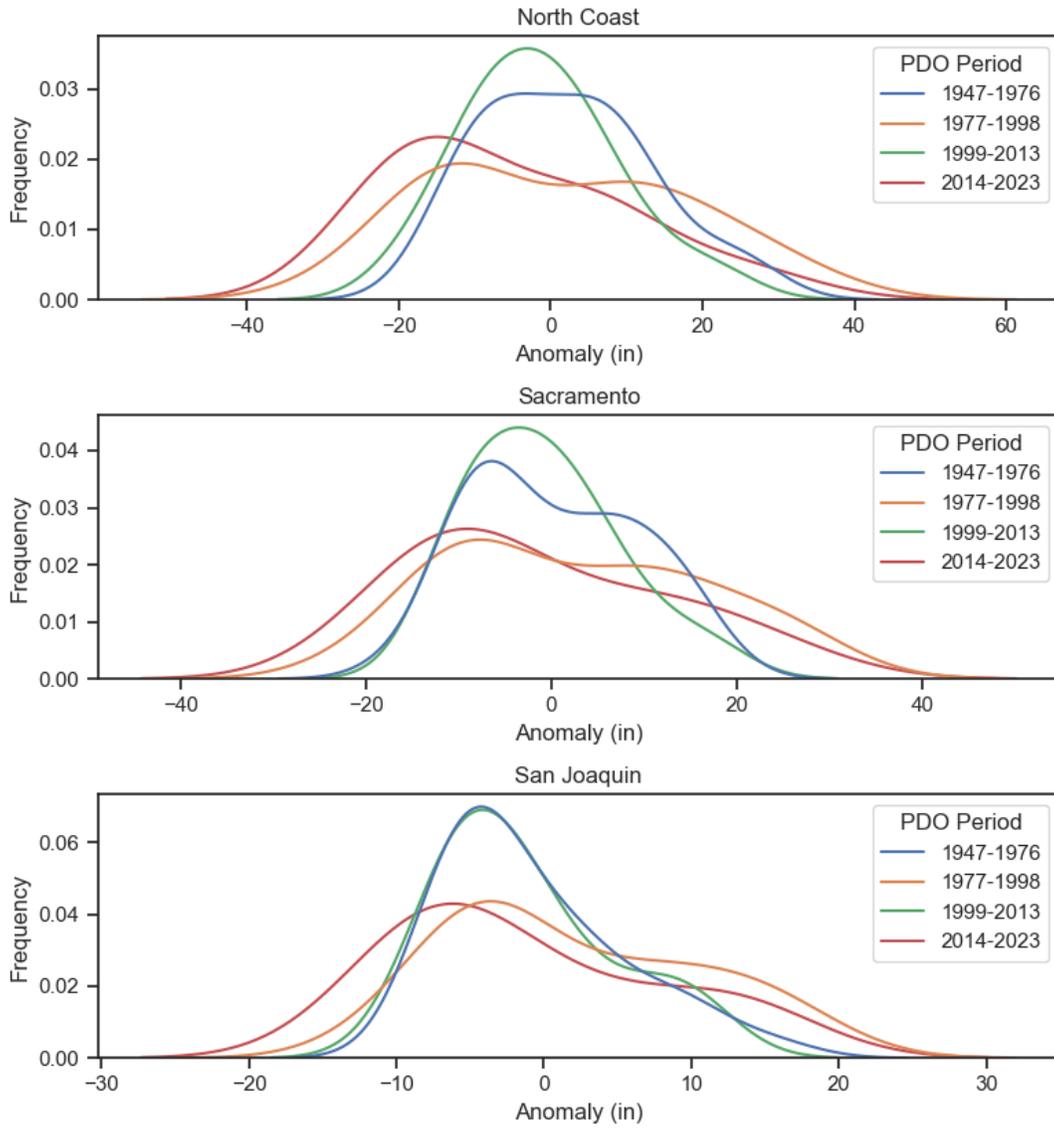


Figure 13 Changing distributions of precipitation in the North Coast, Sacramento, and San Joaquin Climate Divisions

WY Mean Temperature Anomalies by PDO Period

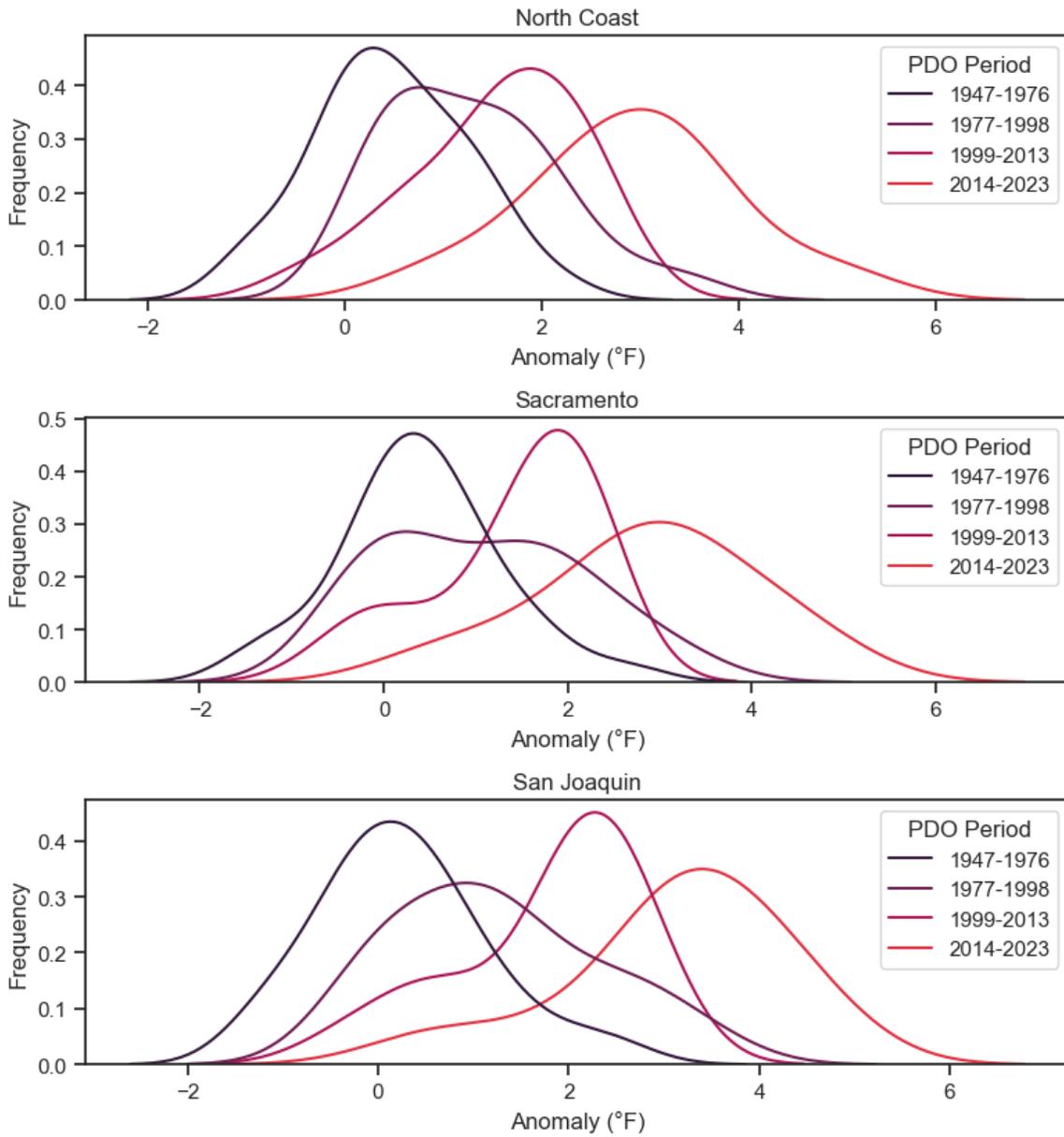


Figure 14 Changing distributions of Temperature in North Coast, Sacramento, and San Joaquin Climate Divisions

Standardized Precipitation Index Change 2013-2023 / 1901-1980



Data : NOAA NCEI Regional Timeseries

Figure 15 Changes in Standardized Precipitation Index in Western US Climate Regions

Temperature Change (°F) 2013-2023 / 1895-1925



Data : NOAA NCEI Regional Timeseries

Figure 16 Changes in Temperature in Western US Climate Regions

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