CLIMATE CHANGE: NATURAL VARIABILITY IS A BIG DEAL TOO!

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Abstract: Climate changes. That's what climate does. It is a natural and dynamic process. The National Weather Service (NWS) recognizes on-going climate change by publishing new figures for average climate every ten years. Climate averages for precipitation, temperature, and other weather parameters are computed on a 30-year basis but only updated once per decade.
With all of the discussion about anthropogenic (i.e. man-made) climate change, it is easy to overlook just how variable our natural climate can be in the relatively short-term. Our climate can and does vary by significant amounts within one human lifetime and well within the design lifetime of our water infrastructure. Sometimes this fact gets lost in the noise of the climate change debate. Part of the reason is the relatively short records of our key meteorologic and hydrologic parameters.

Here's an example. Sacramento, CA, has one of the longest rainfall records in the western US. Annual rainfall totals are available from 1850 to present. Over the 164 year record from 1850-2014, the average annual rainfall was 18.34 inches. However, the 30-year moving average rainfall varies from 20.42 inches in 1896 down to 14.51 inches in 1937 and up again to 20.47 inches by 2007. That's 30-40% swing of 30-year average rainfall in a single lifetime. (Human lifetime, not geologic time!) Most of our short records completely miss that signal. Recent streamflow reconstructions of Sacramento River flows using tree ring data show this signal repeatedly over the past 1100 years. That such significant changes can occur relatively fast has major implications for water resources infrastructure design. That such significant changes can occur relatively fast has major implications for water resources infrastructure design.

This presents explores and presents findings regarding rapid variation of "climate averages" in northern California and Oregon using long-term rainfall records. It also emphasizes the importance selecting climate models that replicate this multi-decadal signal when analyzing impacts of climate change. These results suggest that not only is stationarity dead, it likely wasn't really alive in the first place. We simply assumed it was.

INTRODUCTION

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With all of the discussion about anthropogenic (i.e. man-made) climate change, it is easy to overlook just how variable our natural climate can be in the relatively short-term. Our climate can and does vary by significant amounts within one human lifetime and well within the design lifetime of our water infrastructure. Sometimes this fact gets lost in the noise of the climate change debate. Part of the reason is the relatively short records of our key meteorologic and hydrologic parameters.

This paper explores findings regarding rapid variation of "climate averages" in northern California using long-term rainfall records and insights from paleoclimatological proxies. It also emphasizes the importance selecting climate models that replicate this multi-decadal signal when analyzing impacts of climate change. These results suggest that not only is stationarity dead, it likely wasn't really alive in the first place. We simply assumed it was

RECENT OBSERVATIONS

In the western US, most precipitation and stream gages were installed in the latter half of the 20th Century. As such, 50-80 year records are considered long. Only a handful of gages date back to the 1800s. Sacramento, CA, has one of the longest rainfall records in the western US. Annual rainfall totals are available from 1850 to present. Figure 1 shows the highly variable annual Sacramento rainfall from 1850. The average annual rainfall for the past 164 years is a little more than 18 inches. The rainfall trend over the entire period of record, shown in Figure 2, indicates just a very slight downward trend.

The linear rainfall trend shown in Figure 2 suggests that, overall, rainfall amounts in Sacramento have been stable over the past century and a half. However, that is not the whole story.

The US National Weather Service reports climate averages on a 30-year basis. These averages are updated once per decade. In addition to being a standard reporting interval for climate averages, the 30-year time frame is similar to the time horizons used in common planning studies for civil infrastructure.

A much more dynamic picture emerges by shifting the trend analysis for the full Sacramento record to a shorter trend on the same scale as planning studies. As Figure 3 suggests, the 30-year moving average rainfall ranges from a peak of more than 20 inches annually in the 1890s to a minimum of less than 15 inches before recovering to more than 20 inches again by the 1990s. Overall, that's a 30-40% swing of 30-year average rainfall in a single lifetime. (Human lifetime, not geologic time!) Most rainfall records completely miss that signal. What these rainfall records do capture is a precipitation regime with a strong upward trend over the last 60-70 years of the 20th Century.

The California Department of Water Resources (DWR) monitors precipitation at 8 locations in a 15,700 square mile area in the northern Sierra Nevada Mountains (Roos, 2009). DWR has maintained the Northern Sierra 8 Station Index since 1921. Figure 4 presents a scatterplot of Sacramento's annual precipitation versus the Northern Sierra 8 Station Index during the overlapping period of record, 1921-2013. Sacramento's annual rainfall and the Northern Sierra 8 Station Index are highly correlated. Using the linear trend line shown on Figure 4, Sacramento's annual precipitation explains about 77% of the variance in the 92 year record on 8 Station Index values.

Such strong correspondence between the annual rainfall in Sacramento and conditions in the Northern Sierra since 1921 suggests that the Sacramento annual rainfall is a reasonable indicator of conditions throughout the Northern Sierra. Given this strong correspondence, it is likely that the Northern Sierra was relatively wet during the last half of the 19th century and became increasingly dry during the first half of the 20th century before rebounding to a relatively wet condition over the last 70 years.

LOOKING FURTHER BACK

Tree ring data are also useful indicators of past climate, when direct observations of rainfall or streamflow are unavailable. The California Department of Water Resources (DWR) recently commissioned a research project to reconstruct hydroclimates for the Klamath, San Joaquin, and Sacramento River basins from tree ring data. (Meko et al, 2014) The project reconstructed unimpaired streamflows in the Sacramento River basin for 1100 years, 900-2010 A.D. (See Figure 5)

The 30-year trailing average annual streamflow volume is plotted on Figure 5 as the heavy black line. Throughout the 1100 year record, Sacramento streamflow drifted back and forth from wet regimes to dry and back to wet again. The 30-year trailing average of reconstructed Sacramento River annual volumes over the last half of the 19th Century and through the 20th Century follows a pattern that is very similar to the 30-year trailing average of Sacramento's annual precipitation. This result is not unexpected as one would expect streamflow volumes to follow persistent precipitation patterns.

Looking again at the long-term trends in streamflow volumes (30-year trailing averages in Figure 5), repeated wet/dry cycles appear throughout 1100 year reconstructed record. The 30-year trailing average annual streamflow volume maxima is often 25-50% greater than preceding minima. Repeatedly the transition from a hydroclimate maximum to a hydroclimate minimum occurs relatively quickly; on the order of 3-4 decades.

Evidence that a warming atmosphere is already impacting the region comes from Salzar et al. (2009). Salzar examined tree ring widths from three locations in western North America near the tree line. Growth behavior at the tree line may be a sensitive indicator of a changing atmosphere. More hospitable conditions (i.e. warmer) may promote growth. Less hospitable or colder conditions may inhibit growth. Figure 6, using data from Salzar, shows recent growth rates unseen for more than 3,500 years. The authors suggest that dramatic environmental changes, most likely linked to increased temperature, promoted accelerated tree ring growth.

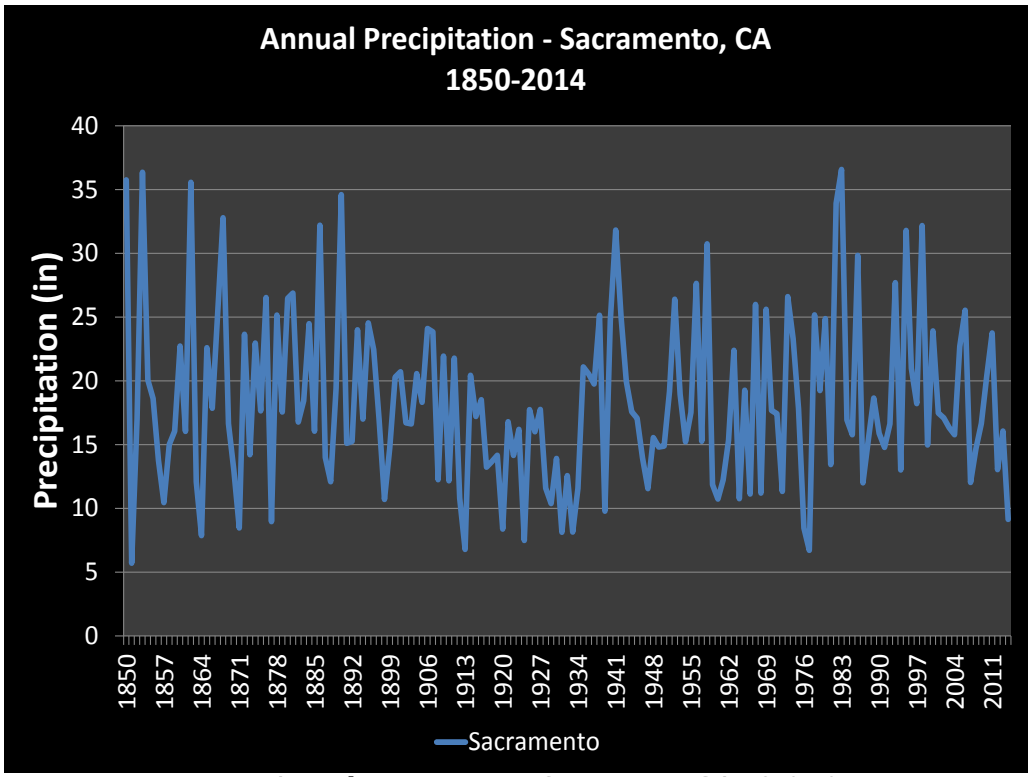

Figure 1 Annual Precipitation - Sacramento, CA 1850-2014

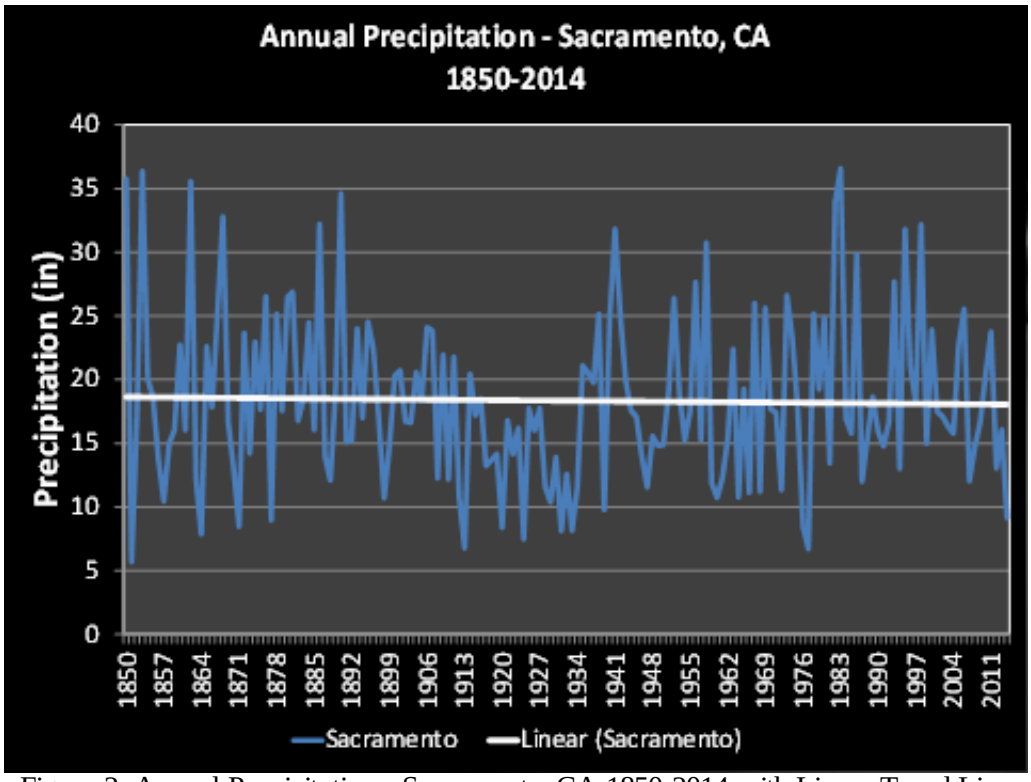

Figure 2 Annual Precipitation - Sacramento, CA 1850-2014 with Linear Trend Line

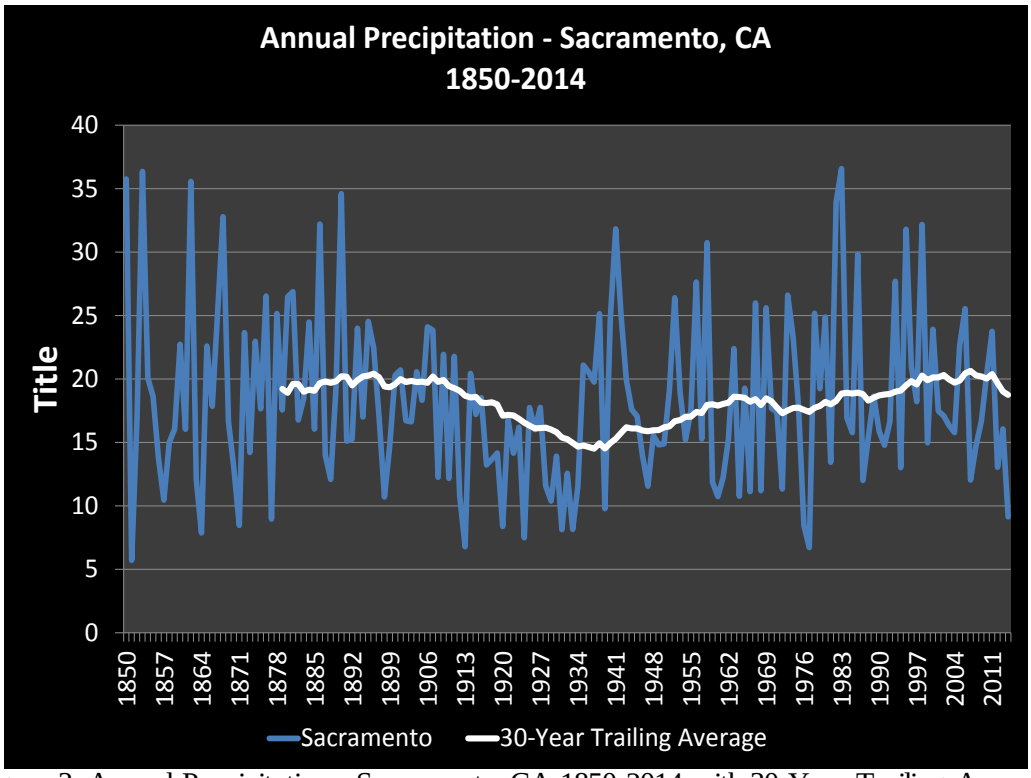

Figure 3 Annual Precipitation - Sacramento, CA 1850-2014 with 30-Year Trailing Average

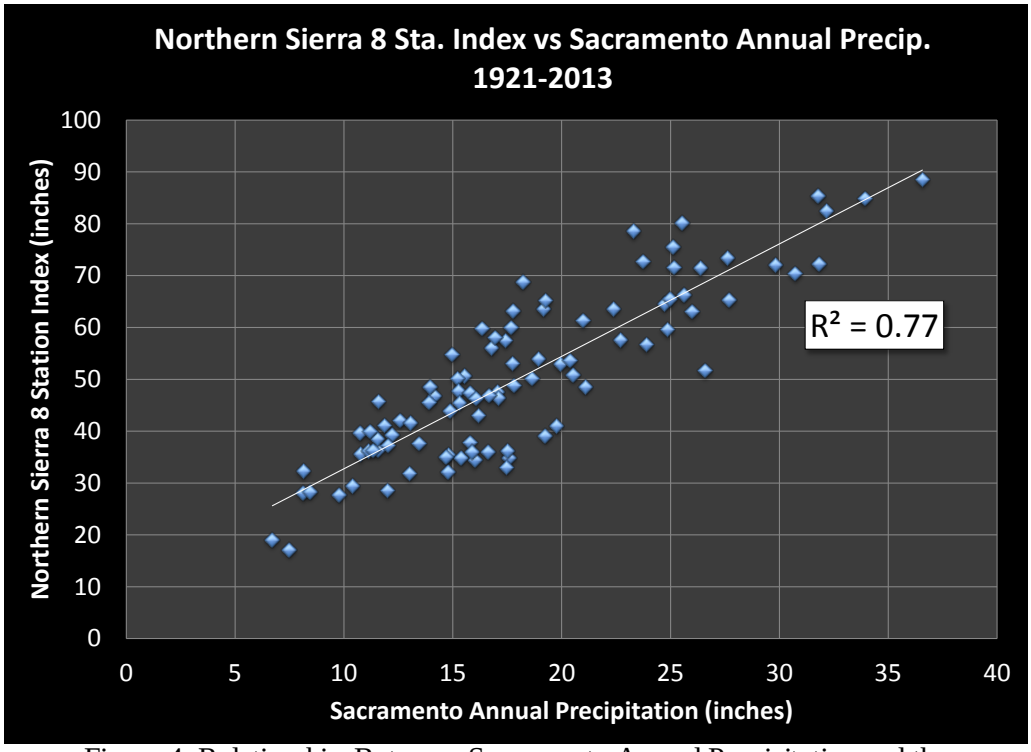

Figure 4 Relationship Between Sacramento Annual Precipitation and the Northern Sierra 8 Station Index.

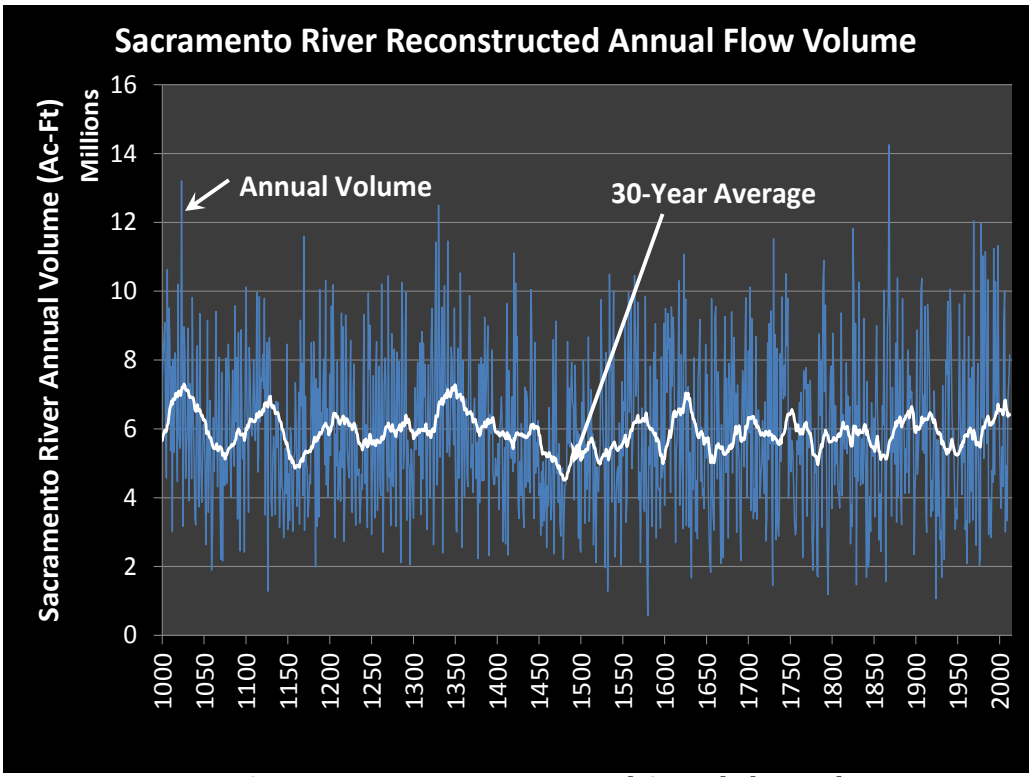

Figure 5 Sacramento River Reconstructed Annual Flow Volume

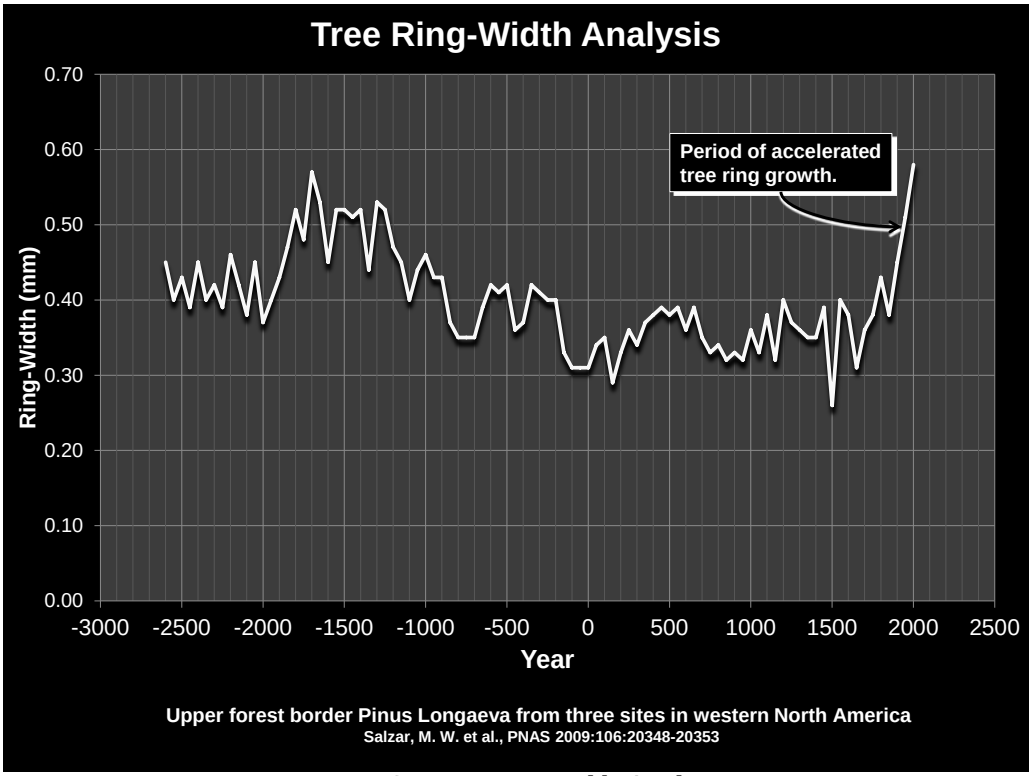

Figure 6 Tree Ring-Width Analysis

LOOKING AHEAD

Recent observations of precipitation in California and examination of paleo proxies for precipitation show that natural variability is an important feature of California's climate; a feature present long before the industrial age. Furthermore, Hawkins and Sutton (2011) suggest that natural variability will be the dominant source of total precipitation uncertainty over the next 10-30 years. Since this time frame is in line with time horizons of many water resources planning efforts, understanding and accounting for natural variability is imperative.

Changes in temperature and precipitation patterns have interrelated impacts on water resources. While natural variability will likely dominate California's precipitation uncertainty for the next several decades, it's clear that anthropogenicly driven temperature impacts such changing the rain/snow mix during winter months and earlier snowmelt may already be strongly present and can't be ignored.

Recognizing that there is a strong signal of natural variability emphasizes the importance selecting climate models that replicate this multi-decadal feature when analyzing impacts of future climate change. California's natural climate variability can either amplify or mitigate decadal scale anthropogenic climate change impacts.

Looking ahead, California water managers face a two-fold challenge. First, natural variability is a critical component to understand. Secondly, anthropogenic changes add an additional layer to California's climate complexity. Planning for California's water future must recognize and address a robustly dynamic climate now impacted by human activities of the post industrial age; impacts that we are just beginning to understand.

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