

# Interannual-scale to Century-scale Climate Variability in Western North America<sup>1</sup>

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## **“All our direct observations are from a ‘treatment’ of the system.”**

Nobel prizewinner Paul Crutzen argues that the Holocene period of Earth history has ended, within the past century or so, and that we are now at the beginning of the “Anthropocene,” the period in which the face of the Earth and the composition of its atmosphere has been altered by our species. One indicator of this is the concentration of carbon dioxide in the Earth’s atmosphere, which started to climb in the 19th century and has now reached higher levels than for millions of years. This has implications for global climate and also for the functioning of both terrestrial and aquatic ecosystems in all regions. These implications may be serious for mountainous regions, which may be particularly vulnerable to climatic and other atmospheric change. These global changes have important implications for our understanding of how the Sierra Nevada systems work, because all our scientific observations, including those made by John Muir, were made on an altered system. If we are to have a “control” for this global unplanned experiment, we must look back to the centuries and millennia immediately before the Industrial Revolution.

## **The Climatic Theater and the Ecological Play**

*(with apologies to G. Evelyn Hutchinson)*

It is not unusual to think anecdotally of the consequences of extremes of weather or climate. So, for example, it may not seem too provocative to link the death of many sugar pine trees to the 1988 drought in the Sierra Nevada although a forest entomologist or pathologist might well feel that the anecdote needs elaboration. There are many good reasons for adopting a more systematic approach to the analysis of the effects of climate variability on ecosystems and resource systems. The one I emphasize here is that it is a mistake to think of climate variability as random. There is temporal structure in climate variability: there have been periods of several decades when events like the 1988 drought have been consistently either more or less frequent.

The species composition and age structure of many forests in the western United States have been strongly influenced by two episodes, a severe drought in the late 16th century and two decades or more of remarkably wet conditions in the early 17th century. Those episodes were apparently caused by shifting climatic “regimes” over the whole Pacific Basin in both hemispheres and represent patterns which may well recur naturally. Thus, it is not valid to assume that climate variability is random and may be ignored in models (whether conceptual or numerical) of ecological processes. In order to understand the dynamics of ecosystems, we must know their climate history.

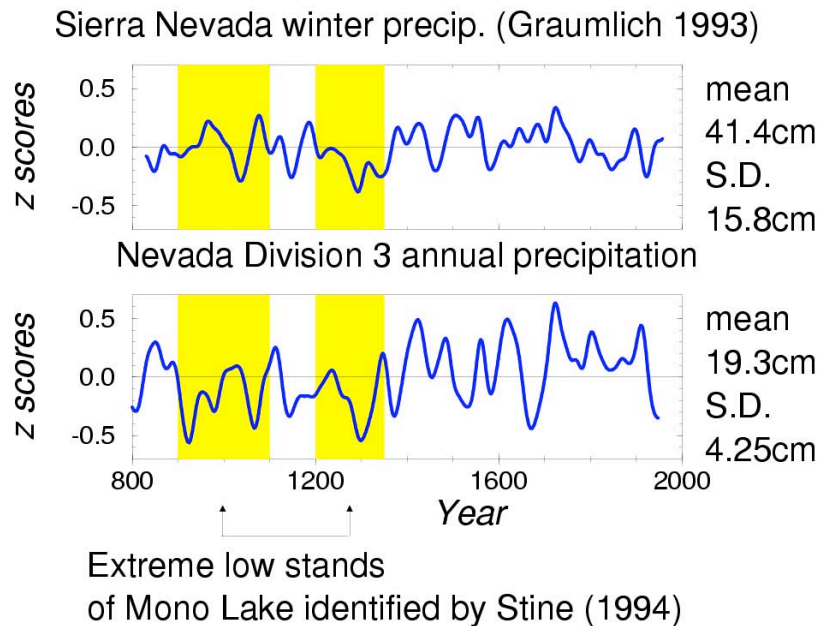
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<sup>1</sup> This paper was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## The Texture of Climate Variability in the Sierra Nevada

Natural archives of climate variability, such as tree rings and geomorphic features, show that the 20th century was not a representative sample of climate variability in the Sierra Nevada in recent millennia. Climate has varied on interannual to century timescales long before the addition of excess greenhouse gases to the atmosphere, and it will continue to vary although probably in modified forms. Certain general conclusions may be drawn on the basis of current information. First, in several respects, the Sierra Nevada region’s 20th-century climate was unusually benign. Droughts were less severe and less persistent than in earlier times, for example, in the period before A.D. 1500 (*fig. 1*). Several sources indicate that multidecadal extreme droughts, unlike any in the past few centuries, occurred between A.D. 400 and 1500 in the central and southern Sierra Nevada. Single-year droughts like that of 1977 occurred four times as frequently in some centuries than in the 20th century. Some of these, for example, the drought in 1580, were markedly more severe than the 1977 drought. There is evidence that the sustained but less extreme drought of the late 1980s and early 1990s was weaker than hundreds of other droughts in the past 8,000 years. Secondly, this variability is neither completely random in time nor strongly cyclical, but it does have considerable temporal structure. Some of the most severe multidecadal droughts in the central Sierra Nevada (for example, in the 10th–14th centuries) probably coincided with wetter-than-average periods in Oregon and northern California.



**Figure 1**— Two smoothed records of past precipitation derived from tree rings. The upper panel shows a record for the central Sierra Nevada published by Graumlich (1993) and the lower a record from the White Mountains (Hughes and Funkhouser 1998), just to the east of the central Sierra. Note that both records show greater wetness in the past 500 years than before and that severe multidecadal droughts coincide with the sustained extreme low stands of Mono Lake described by Stine (1994) for the period between A.D. 900 and 1350.

## Conclusions and a Caution

All our direct observations were made on a changed planet.

Even apart from this, the 20th century is an inadequate example of climatic variations—much more extreme fluctuations have occurred in recent millennia. For example, the 20th century was relatively drought free.

The climate record relevant to the Sierra Nevada is textured on several time scales, so it should not be thought of as varying randomly. Basing future expectations on a recent 30-year mean or standard deviation could be misleading and perhaps even wrong in the absence of consideration of global warming.

## References

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