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Hydrolink

STURM UND DRANG – CALIFORNIA'S REMARKABLE STORM-DROUGHT CONNECTION

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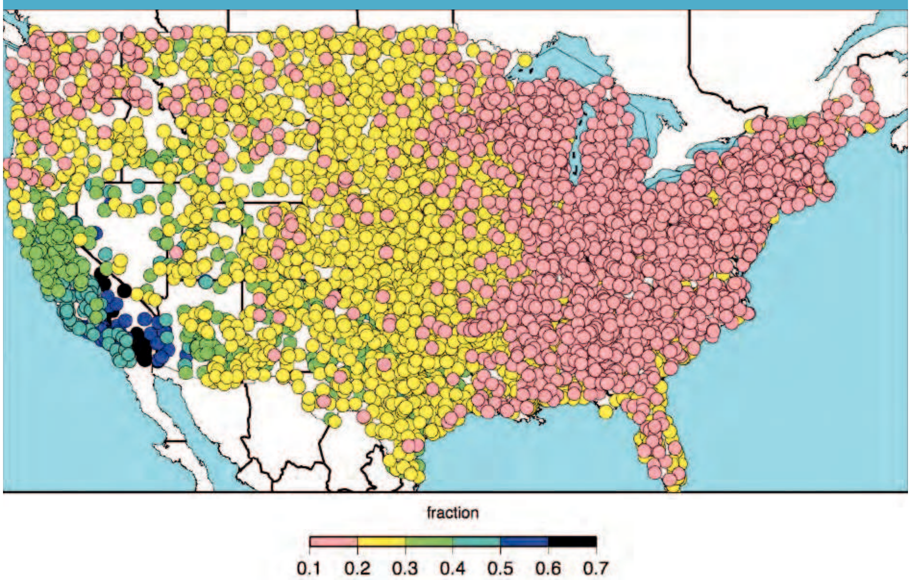
Storm and drought are essentially the whole story of water and life in California in ways that have always made hydro-environmental engineering a unique proposition there. To begin with, California experiences larger year-to-year variations in precipitation than elsewhere in the US, with standard deviations of annual precipitation between 30-50% of long-term averages, compared to 10-30% nearly everywhere else (Fig. 1). California's annual precipitation totals routinely vary from as little as 50% to more than 200% of long-term averages, with those dry excursions forming our droughts. This extreme variability arises because California's Mediterranean climate only provides a limited seasonal window of precipitation events, and within that period a small number of storms deliver most of the State's precipitation each year. If a few extra large storms reach California in a given winter, we can have a very wet year

Figure 1 - Coefficients of variation of water-year precipitation totals at long-term US National Weather Service COOP weather-monitoring stations, from water year 1951–2008 (from Dettinger et al. 2011)



indeed; if some are lacking, we face drought. But the storm-drought connection is deeper and more pervasive in California than anywhere else in the US.

For example, droughts in California, and nationwide, almost always begin gradually - as month-by-month precipitation deficits build up - but tend to end abruptly in a single very wet month (about 70-80% of the time in California; Dettinger 2013). In California (and northward along the West Coast), the wet, drought-busting months are typically reflections of one or two extremely large storms, with almost half of the large drought-busting storms resulting from landfalling atmospheric rivers (ARs) or "pineapple express" storms. More generally, these AR storms (Ralph and Dettinger 2011) contribute a substantial majority of the largest historical daily storm totals in California and, in turn, result in more that 80% of large floods in California and the Pacific Northwest (Dettinger and Ingram 2013; Neiman et al. 2012).

In addition to drought busting, year-to-year differences in large storms actually define California's multi-year droughts. Analyses of long-term historical records of precipitation, streamflow and lake levels reveal that past multi-year drought interludes have been due almost entirely to the absence of large storms (as opposed to normal-to-light storms). Specifically, water-year total precipitation contributions from storms that yield >95th-percentile daily-precipitation totals amount to about one-third of all California precipitation, but explain 92% of overall precipitation variability on 5-yr moving-average time scales (heavy curves, Fig. 2) and 85% of the variance of unfiltered water-year totals. In contrast, normal-to-light storms (<95th-percentile days) contribute the other two thirds of precipitation but capture a much smaller fraction (24%) of multi-year precipitation variability in California. Such a dominant role for California's largest storms may seem surprising, until you realize that a historical canvas of the very heaviest precipitation amounts across the US found that the largest storm totals along California's windward slopes have exceeded those anywhere else in the US except along the hurricane-dominated southeastern states, and California's largest storms are just as large as the largest storm totals there (Ralph and Dettinger, 2012).

Not surprisingly, ARs are at the heart of this storm-drought connection too. Historical multi-year droughts in California reflect a close relation (75% of variance) between precipitation totals and annual counts of landfalling atmospheric rivers in the State (Fig. 2b). Thus, among the year-to-year variations of AR arrivals, periods with fewer AR storms are droughts in California result in droughts; periods with more are wet. This close connection between California's largest storms and its droughts is actually quite unusual within the US. Precipitation contributions from 95th-percentile storms are important elsewhere, but contribute only 40-70% of multi-year precipitation variations (compared to 92% in California). Because the connections between California's storms and droughts are so uniquely strong, solutions to the State's hydro-environmental problems necessarily have their own peculiar flavors. In particular, design and planning for "normal" conditions in California can seem all but irrelevant sometimes, and planning for floods and droughts can never quite be completely disentangled.

> **"planning for floods and droughts can never quite be completely disentangled"**

References

Dettinger MD. 2013. Atmospheric rivers as drought busters on the US west coast. J Hydromet 14:1721-1732.
Dettinger M, Ingram, L. 2013. The coming megafloods. Scientific American 308:64-71.
Dettinger MD, Ralph FM, Das T, Neiman PJ, Cayan D. 2011. Atmospheric rivers, floods, and the water resources of California. Water 3:455-478.
Neiman PJ, Schick LJ, Ralph FM, Hughes M, Wick GA. 2011. Flooding in western Washington--The connection to atmospheric rivers. J Hydromet 12:1337–1358.
Ralph FM, Dettinger MD. 2011. Storms, floods and the science of atmospheric rivers. Eos 92:265-266.
Ralph FM, Dettinger MD. 2012. Historical and national perspectives on extreme west-coast precipitation associated with atmospheric rivers during December 2010. Bull. Amer. Meteorol. Soc. 93:783-790.

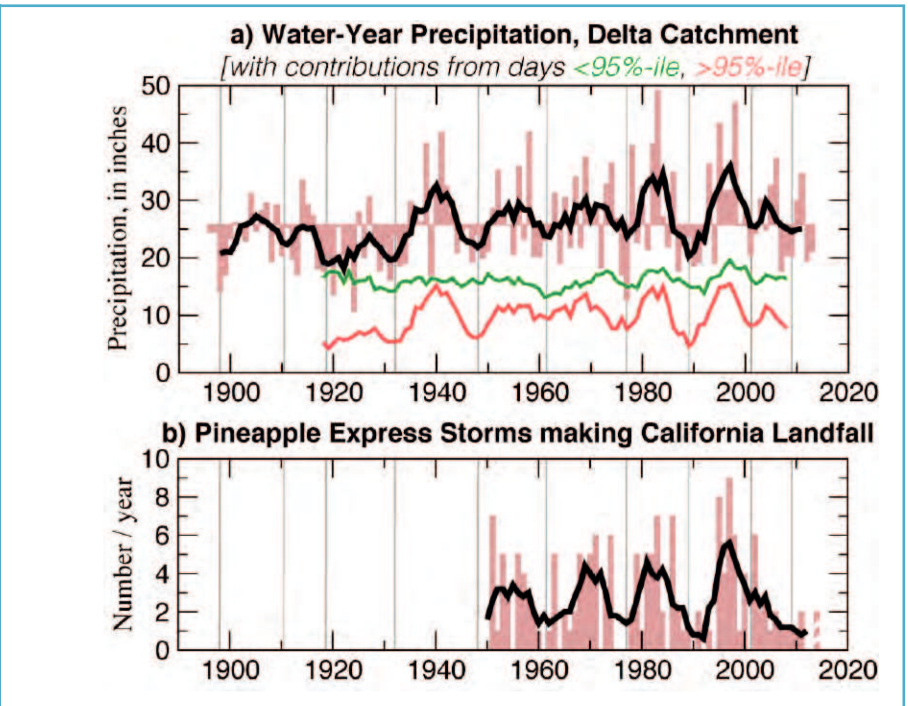


Figure 2 - (a) Water-year precipitation totals (brown bars and black curve) in Delta's catchment (Central Valley and surrounding mountain ranges, 1895-present, and 5-yr moving averages of contributions to totals from the wettest 5% of wet days (days with precipitation > 95th percentile; darker, red curve) and all other wet days (< 95th percentile; lighter, green curve), 1916-2010, and (b) numbers of pineapple-express (AR) storms making landfall between 35°N and 42.5°N per water year (using counts from Dettinger et al. 2011, updated through March 2014). Heavy curves are 5-yr moving averages in both frames; vertical grey lines are approximate centers of persistent droughts in upper panel (from Dettinger and Cayan, 2014)