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Mount Whitney Sunrise, Alabama Hills © ElizabethCarmel.com

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How Large (in the scheme of things) are Precipitation Extremes in California's Mountains?

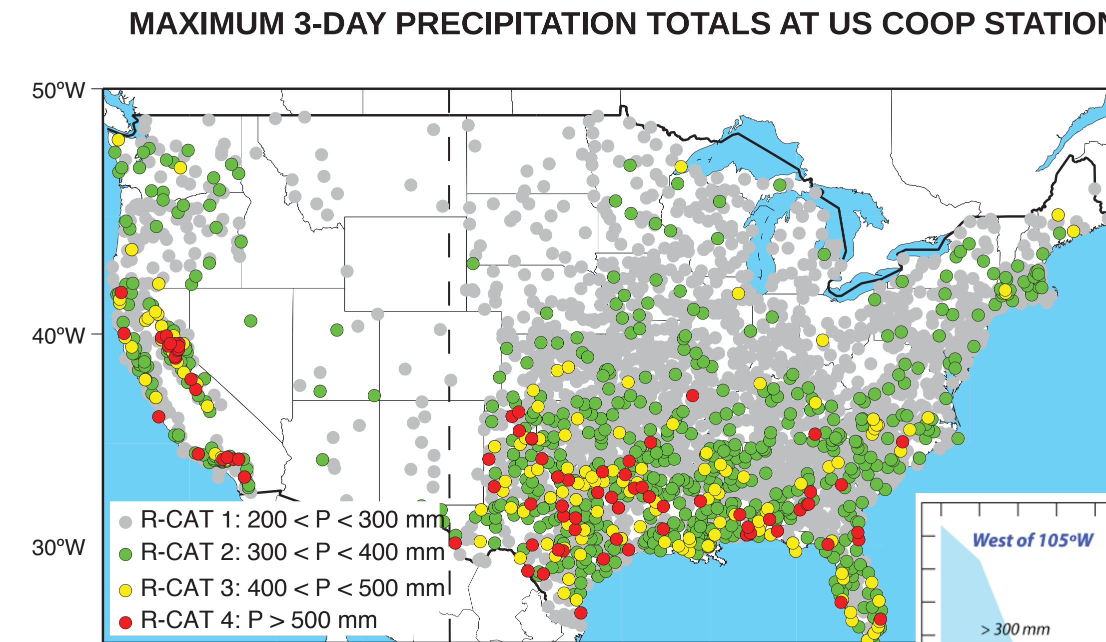
F. M. Ralph[1] and M. D. Dettinger[2]
[1]*NOAA/ESRL, Physical Sciences Division, Boulder, Colorado*
[2]*U.S. Geological Survey, Scripps Institution of Oceanography, La Jolla, California*

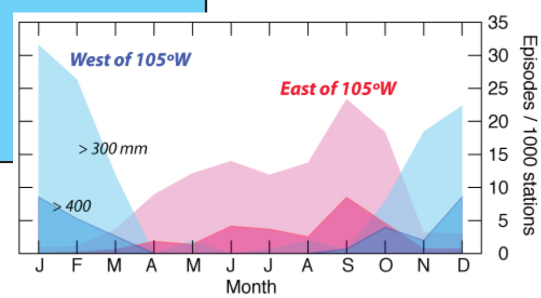
Extreme precipitation events frequently batter the mountains of the Western US, fueled by a variety of large-scale meteorological processes and enhanced (relative to surrounding lowlands) by the orographic uplift that occurs when storms blow up and over the mountainous terrains. The bigger storms can result in landslides and erosion, thick disabling snowpacks, and widespread flooding in both the mountain reaches and down below, and so such storms are high on our lists of dangerous extremes. In a recently accepted article for the Map Room section of the Bulletin of the American Meteorological Society (Ralph and Dettinger, in press), we used the major winter storm of mid December 2010 as a reason to explore the question: Are our biggest western storms really as big, or bigger, than storms elsewhere in the country?

To answer this question in the most straightforward possible way, we analyzed historical precipitation records from thousands of long-term weather stations across the US, and defined a very simple categorization of 3-day precipitation totals that allows direct comparison and characterization of the largest recorded events at each station, in absolute terms. The categorization of any given precipitation event at any given station is simply based on whether the 3-day precipitation total was greater than 200 mm of (rainfall category, R-Cat, 1), greater than 300 mm (R-Cat 2), greater than 400 mm (R-Cat 3), and so on. Three-day totals were used because many of the most damaging storm impacts require sustained rains to really get rolling. Also, when we did the analyses with 2-day totals the numbers of extremes being categorized fell by about half and when we did them with 4-day totals, we found that the fourth day contributed, on average, less than 5% of the storm totals anyway.

Historical patterns of extreme-precipitation reports as labeled by these R-Cats showed, first, that the most extreme precipitation events historically have been concentrated in near-coastal states (Fig. 1). While R-Cat 1 and 2 site events have occurred in most states, the clear majority of R-Cat 3 and 4 site events have been in California, Texas, and in the southeastern states. In the West, those R-Cat 3 and R-Cat 4 events are also clearly restricted to the Coastal Ranges and western Sierra Nevada of California. Not surprisingly, those extreme events were from winter storms (inset to Fig. 1), and usually they are orographically enhanced storms. In order to understand the storm mechanisms more broadly, we identified storm "episodes" categorized by the largest R-Cat value achieved anywhere west, or east, of 105ºW in each 3-day period. Evaluation of meteorological conditions during R-Cat episodes showed that, during all 17 episodes that met or exceeded the R-Cat 2 threshold from 1997-2005 and during 44 of 48 R-Cat 3 and 4 episodes from 1950-2008, an atmospheric river (Ralph and Dettinger, 2011) was making landfall on the west coast. Atmospheric rivers (ARs) are long, narrow zones within extratropical cyclones that contain large quantities of water vapor and strong winds, and are responsible for > 90% of all atmospheric water vapor transport in midlatitudes (Zhu and Newell, 1998). They are 1000s of km long and, on average, only 400 km wide (Ralph et al. 2004), with 75% of the water vapor transport occurring below 2.25 km altitude (Ralph et al. 2005a). ARs produce extreme precipitation because they transport such large and sustained quantities of water vapor (typically about 10 Mississippi River's worth, lasting from hours to a few days) and because they set up almost ideal conditions for producing heavy orographic rains and flooding when they encounter mountains (Ralph and Dettinger 2011, Neiman et al. 2011, and references therein). In contrast, the only other comparable historical precipitation maxima above R-Cat 3 thresholds in the US—those in Texas and the southeast—were summertime events, arising from tropical storms and hurricanes (roughly half of the events) and other mechanisms like Mesoscale Convective Systems.

Thus, 3-day precipitation extremes associated with landfalling ARs in the Coastal Ranges and Sierra Nevada of California have historically been heavier than extreme storms anywhere else in the country outside the southeast US, and they are comparable with even those often-hurricane-fueled storms. And, yes, the big storm of 17-22 December 2010 was in this league, producing more than 670 mm (26 inches) of precipitation in the San Bernadino Mountains of southern California and 3-5 m (10-15 ft) of snowpack in the southern Sierra Nevada. The storm also penetrated far into the intermontane west, dumping 432 mm (17.0 inches), causing serious flooding, in the mountains of southern Utah over 5 days between 18-23 December. In terms of 3-day precipitation totals, it reached R-Cat 3 levels in southern California and R-Cat 2 levels in Utah!





	CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4
DEFINING 3-DAY PRECIPITATION THRESHOLDS (mm)	200 < P < 300	300 < P < 400	400 < P < 500	P > 500
NUMBER OF STATIONS REACHING THESE 3-DAY TOTALS PER YEAR	173	23	4	2
NUMBER OF 3-DAY PERIODS WITH STATION(S) REACHING THIS LEVEL/YR	48	9	2	1
AVERAGE SITES > 200 mm / EPISODE	2	7	13	15

Figure 1. Historical maximum 3-day precipitation totals from 5877 long-term NWS cooperative weather observer stations across the conterminous US, with (inset) the numbers of 3-day episodes achieving the highest precipitation totals, east and west of 105ºW, by month of year, and (table) frequency of occurrence nationally. 105ºW was used based on the natural break between the two distributions at R-Cat 3 and 4 (figure).

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