Strength *in* Numbers

Daily Precipitation Extremes over CONUS

Adapted from “Who Received the Most Rain Today?: An Analysis of Daily Precipitation Extremes in the Contiguous United States using CoCoRaHS and COOP Reports,” by **P. E. Goble** (Colorado Climate Center), **N. J. Doesken**, **I. Durre**, **R. S. Schumacher**, **A. Stewart**, and **J. Turner**. Published online in *BAMS*, June 2020. For the full, citable article, see [DOI:10.1175/BAMS-D-18-0310](https://doi.org/10.1175/BAMS-D-18-0310).

Every day, thousands of volunteers across the United States report the amount of precipitation they have received in the past 24 h. The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) and the Cooperative Observer Program (COOP) form a basis for monitoring, mapping, and categorizing daily precipitation extremes (DPEs), and other aspects of extreme precipitation, with

* Of in situ DPEs, 76% have a magnitude of 50–175 mm, 18% are above this range, and 6% are below. This distribution shifts toward higher values in summer and lower values in winter. In situ DPEs ranged from 11 to 635 mm.

The seasonal cycle of maximum DPEs is ***▶** apparent in both in situ and PRISM data and is consistent with the Clausius–Clapeyron relation between temperature and available water vapor. Though the PRISM DPE spatial distributions may show effects of additional networks and interpolations that show extremes where CoCoRaHS and COOP are not located, on average this difference does not translate to higher winter extremes for PRISM.

considerable spatial detail. Using these two large networks, we assess how magnitude and location of contiguous United States (CONUS)-wide precipitation maxima, or daily precipitation extremes (DPEs), vary on a daily and seasonal basis.

We collected the highest 24-h precipitation totals observed between 0500 and 0900 LT across CONUS from the CoCoRaHS and COOP networks from 1 January 2010 to 31 December 2017 (CoCoRaHS has only been active in every state since December 2009). CoCoRaHS and COOP combined averaged more than 14,848

15-Day Moving Average Maximum Precipitation Report for Each Julian Day

a)

15-Day Moving Average Maximum Precipitation Report for Each Julian Day

b)

Location of CoCoRaHS Top Five Percentile Maximum Precipitation Reports

a)

Highest Five Percent of Daily Precipitation Extremes Sorted by Value

b)

daily precipitation reports at these observation times.

Both datasets were quality controlled. Errors corrected include multiday reports recorded as 24-h totals, date-shifted observations, snowfall reported as liquid precipitation, and observations that cover more than 24 h, and are identified and corrected daily.

Despite the large number of observations, the true nationwide rainfall maximum on any given day may be missed; heavy convective precipitation events in particular can occur on small spatial scales, in between CoCoRaHS

***▶** The largest daily extremes (i.e., ~95th-percentile in situ DPEs) ranged from 250 to 635 mm. Only 13% of reports fell in noncoastal states. (a) ~95th-percentile DPEs for 1 Jan 2010–31 Dec 2017. (b) Cumulative density function of ~95th-percentile DPEs. The highest DPEs were generally produced by tropical cyclones. For example, Hurricane Harvey in Dayton, Texas, on 27 Aug 2017 produced a DPE of 635 mm. The second- and eighth-highest reports were also from Harvey. On 5 Oct 2015, the seventh-highest DPE was recorded in South Carolina (481 mm), as it drew remnant moisture from Hurricane Joaquin. The ~95th-percentile DPE occurring farthest from all others is the 252-mm report in Boulder, Colorado, on 12 Sep 2013, enhanced by lifting over the eastern slopes of the Rockies.

a)

b)

c)

d)

and COOP reporting stations. By contrast, gridded datasets leverage satellite and radar retrieval algorithms to interpolate between gridded observations, creating full coverage maps of CONUS precipitation. The analysis presented here is therefore primarily based on point observations, but for comparison, we include a similar analysis with the 4-km grid dataset, Parameterized Regression on Independent Slopes Model (PRISM).

Results

The average Daily Precipitation Extreme (DPE) was 128 mm, with 63% between 75 and 175 mm. The magnitude of DPEs recorded from CoCoRaHS and COOP over CONUS varies day-by-day, sometimes by hundreds of millimeters. The highest daily rainfall extreme (635 mm) in this study was 58 times as large as the lowest (11 mm).

Average DPE magnitude and location varies as a function of season. On average, precipitation extremes are greater during the warm season. The average magnitude of DPEs peaks in late August at a value of 237 mm.

▲ *** Many DPEs fall in the Southeast in every season. Among seasonal variations: DPEs are highest in the Midwest in summer when convection dominates and in November–March on the Pacific Coast. Only one DPE was recorded along the Pacific Coast in summer. In August and October, the interior states are cool and dry and the Atlantic Gulf Stream stays warm and moistens air as both tropical and extratropical systems may produce DPEs in the East. Dot size is scaled by precipitation amount (circles = CoCoRaHS, squares = COOP).**

Spatial distribution of DPEs is also a function of season. Seasonal variation was strongest in the West. Nearly one-quarter of DPEs in meteorological winter (DJF) occur in coastal Pacific states, compared to less than 1% in meteorological summer. Conversely, the north-central portion of the country is far more likely to record the DPE in summer than winter. Generally, coastal states are much more likely to capture the day's highest rainfall total.

The largest DPE measurements were typically located near a warm body of water, such

Overall, DPEs were most frequent in coastal states, * particularly Florida, Louisiana, and Mississippi. The three Pacific states were all top-10 ranking states for number of DPEs per observation as well (and the PRISM data showed more DPEs in Pacific states). Few DPEs occur in the Intermountain West states.

as the Gulf of Mexico or Atlantic Gulf Stream. Exceptions were DPEs occurring over the central United States, mainly in summertime. A number of the highest 5% of all DPEs were traceable to tropical cyclones, including notorious storms like Hurricane Katrina and Hurricane Harvey. Others could be linked to tropical moisture interaction with extratropical systems.

Despite gaps in CoCoRaHS and COOP observing networks, DPEs were similar between ground truth (CoCoRaHS + COOP) and gridded (PRISM) data sources. Differences in seasonal cycles between observed and gridded datasets were not statistically significant. Differences between ground truth and gridded data were more obvious spatially. More DPEs were recorded in Pacific states in the gridded dataset. More DPEs were recorded in the southeastern United States in the observational dataset.

Future research

Even with so many measurements in these two in situ networks, additional observations in time and space would improve our understanding of DPEs. For instance, CoCoRaHS and COOP likely undersample high-elevation West Coast DPEs. The Snowpack Telemetry network would therefore be an appropriate addition to future studies, as would high-quality state mesonet data. Establishment of an operational database could facilitate tracking patterns of DPEs over time.

One possible future investigation would be to relate CONUS DPEs to additional weather and climate phenomena, such as global teleconnections like the El Niño–Southern Oscillation (ENSO). Furthermore, one could relate DPEs more closely to weather systems. For example, even though the highest DPEs are often recorded over the southeastern or central CONUS, days with low DPEs often fit the following profile: a November–March day with light to moderate rainfall recorded in the northwestern and/or northeastern CONUS, and dry conditions across the southern and central CONUS. Finally, future studies should seek to identify DPE trends and how they relate to a warming climate. ••

States Ranked by Number of Daily Extremes Captured per Number of Observations (2010–2017)

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BAMS: What would you like readers to learn from this article?

Peter Goble (Colorado Climate Center): *I hope this adds to readers' understanding of when/where heavy precipitation is most likely to occur in the contiguous United States. I also hope readers come away with an enhanced, or renewed, appreciation for the value of plentiful and consistent ground truth observations.*

BAMS: How did you become interested in daily extremes?

PG: *The CoCoRaHS team, as well as many others, watch and discuss our maps daily. We like to talk about where the highest daily totals were, how extreme they were, and what meteorological ingredients led to them. It was easy to become curious about what we would find if we did a thorough investigation of these daily extremes.*

BAMS: What surprised you the most about the results?

PG: *It surprised me that the modeled and observational daily precipitation extreme datasets were so similar in both magnitude and seasonality, but were not nearly as similar when we analyzed the locations of daily precipitation extremes. The two datasets arrived at similar answers, but in different ways.*

BAMS: What was the biggest challenge in working with these data?

PG: *Data quality control is an ongoing issue. While error rates are low in both CoCoRaHS and COOP programs (we calculate less than 1% overall), the errors disproportionately impact the analysis of daily extremes.*