Assessment of Uncertainty in Doppler-Radar Estimated Precipitation

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The Data

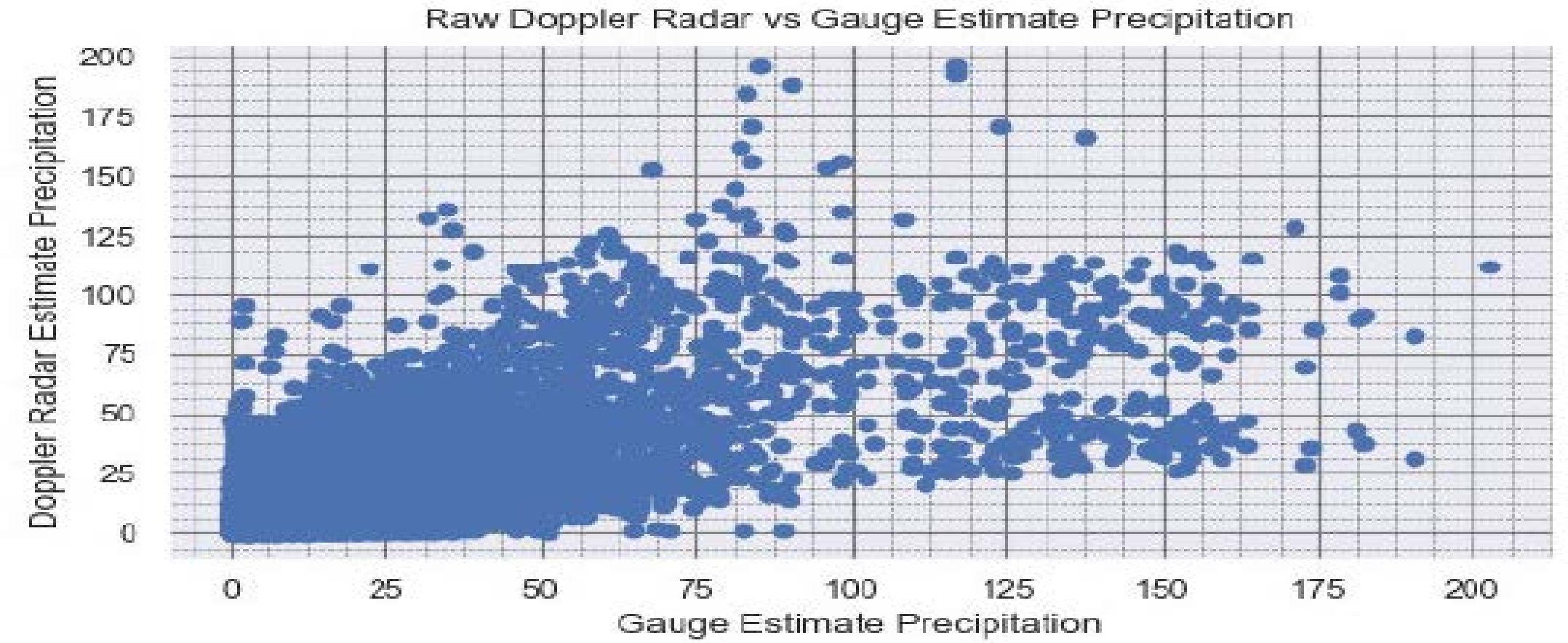
Taken from multiple sources. In this analysis, published literature in cited references 1-10 contain the data in the form of scatter plots and tables. The data compares the Doppler radar derived rainfall estimates with the observed local gauge values, spread across multiple storms and geographical domains with the overwhelming majority categorized via total storm accumulation. Pulling from each reference, digitizing software reads the graphs and tabulates the data for later concatenating.

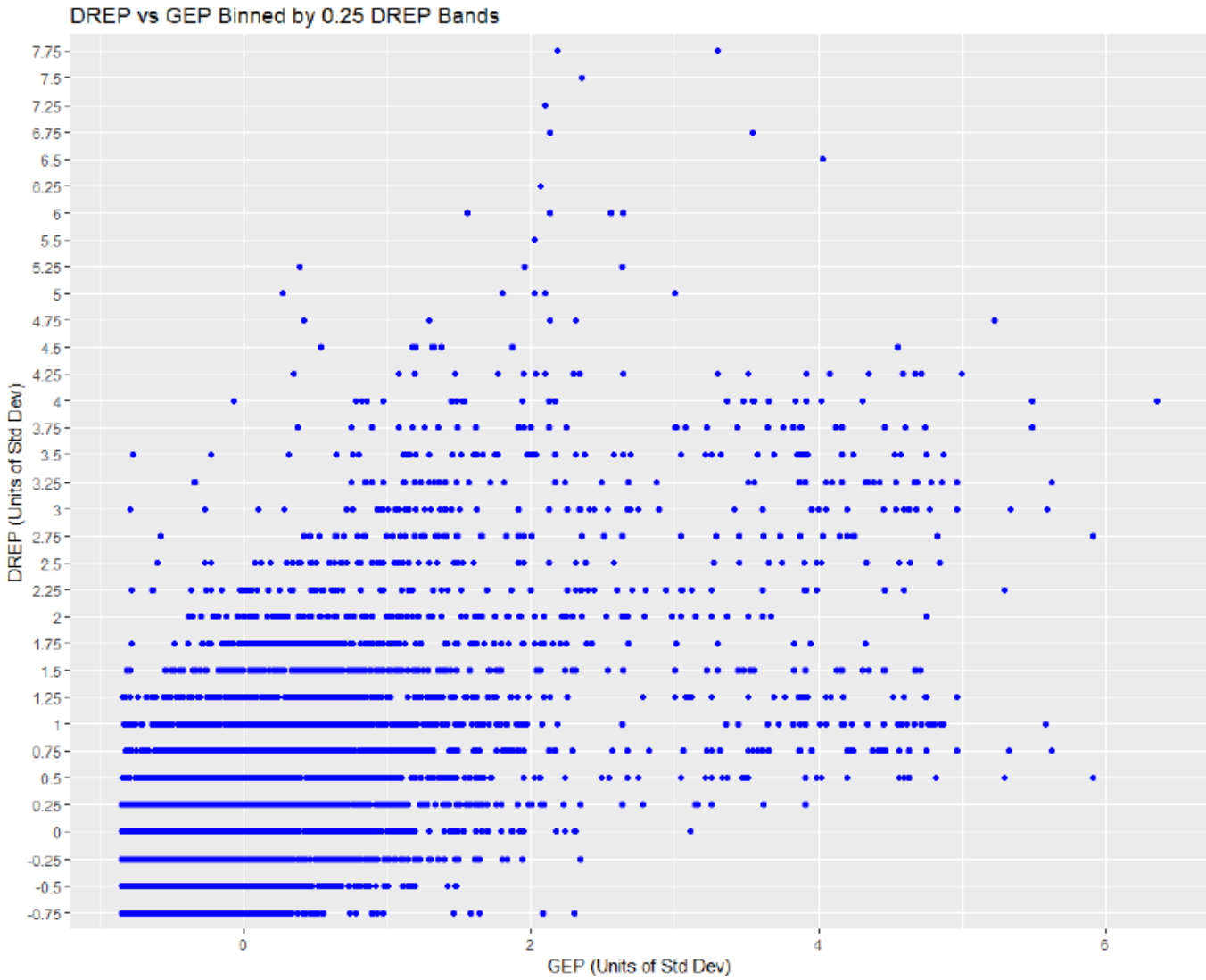
Radar Type	Paper ID	# of ordered pairs (N)	Radar Data		Gauge Data	
			Mean	SD	Mean	SD
Doppler (WSR-88D)	1-10	8846	20.9	22.8	23.8	28.1

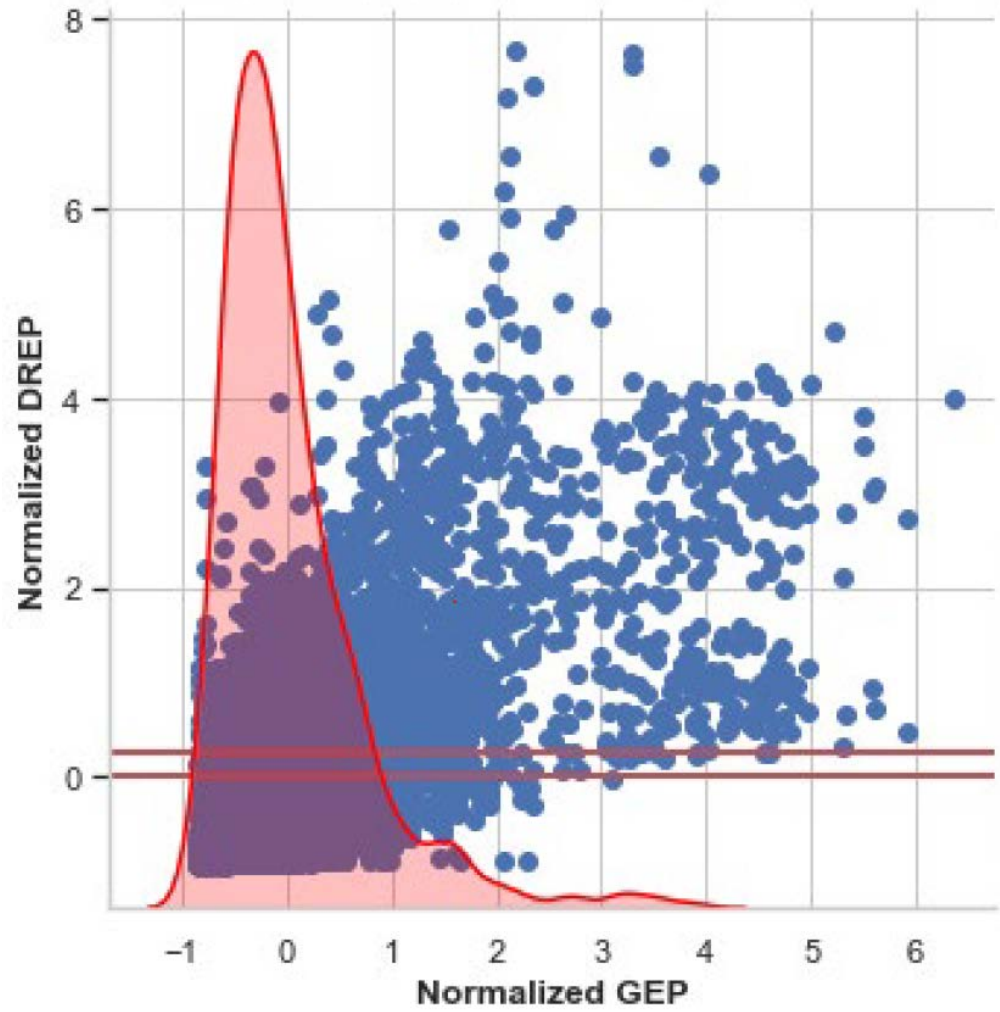
Table 1 - Summary of Doppler (WSR-88D) Data Characteristics

The Data

Plotted, the raw data file consists of two columns of rainfall data; namely, Doppler Radar Estimated Precipitation ("DREP") and Gauge Estimated Precipitation ("GEP"). The DREP column includes radar estimated values (mm) from the Doppler WSR-88D equipment whereas the GEP column includes precipitation values (mm) as measured by recording precipitation gauges. Combining the two columns creates a set of ordered pairs resulting in 8846 ordered pairs for the subject Doppler data file.




DREP vs GEP Binned by 0.25 DREP Bands
DREP (Units of Std Dev)
GEP (Units of Std Dev)
7.75
7.5
7.25
6.75
6.5
6.25
6
5.5
5.25
5
4.75
4.5
4.25
4
3.75
3.5
3.25
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
0
2
4
6


Normalized DREP
Normalized GEP
8
6
4
2
0
−1
0
1
2
3
4
5
6

Turning Data Into Realizations

$$DR = \{-0.3, 0.1, 0.4, 1, 3, 1.9, 1.4, 2.3, 2.8, 3.2, 3.5, 2.1, 0.9\}$$

For each day in the Doppler-Radar data daily string, a single day's Doppler-Radar reading is developed into a distribution of ***probable daily precipitation outcome readings*** via randomly sampling from each of the respective GEP marginal distributions.

Each of these outcome estimates are candidates to being an estimate of the actual precipitation measurement on the ground.

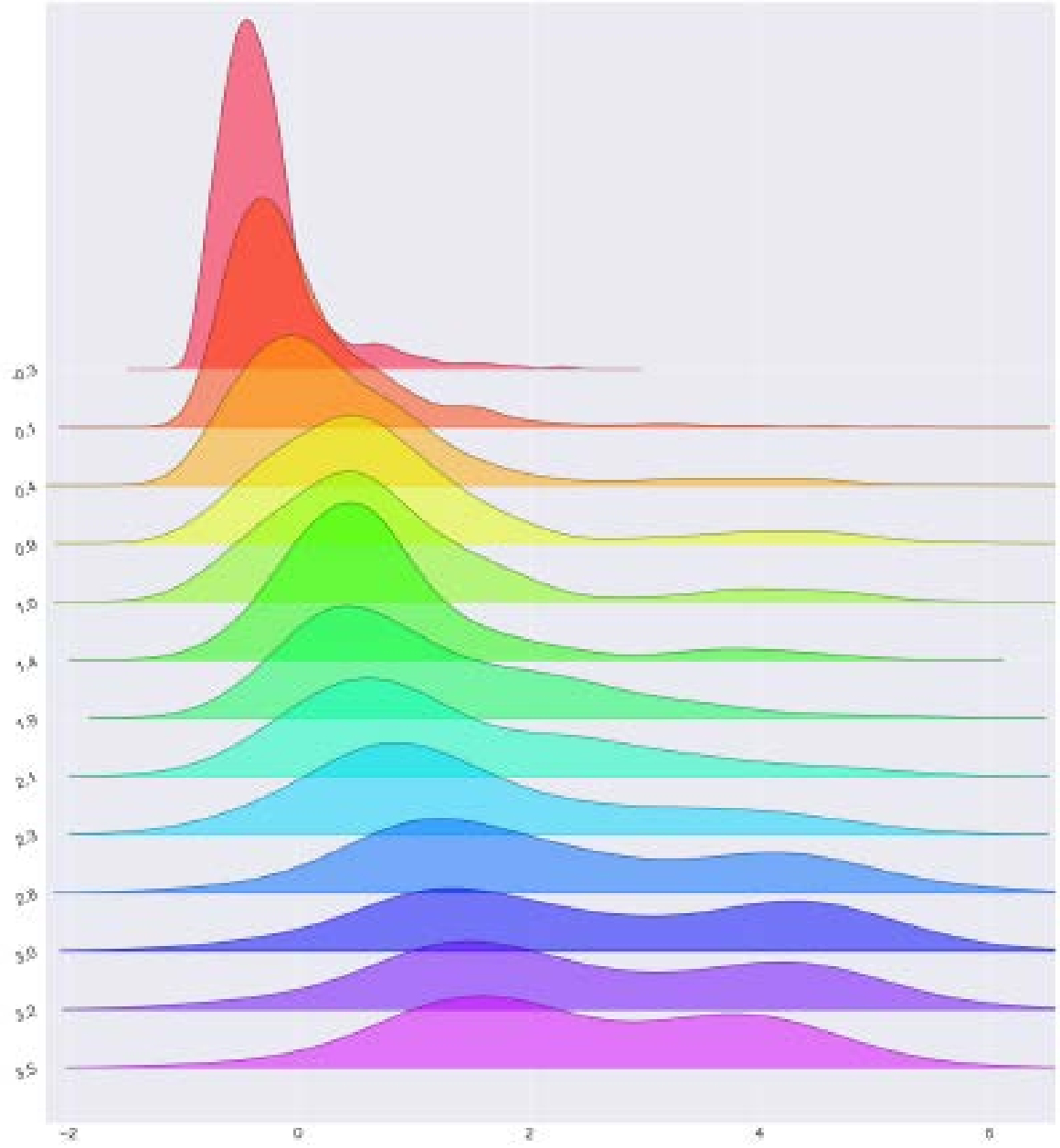
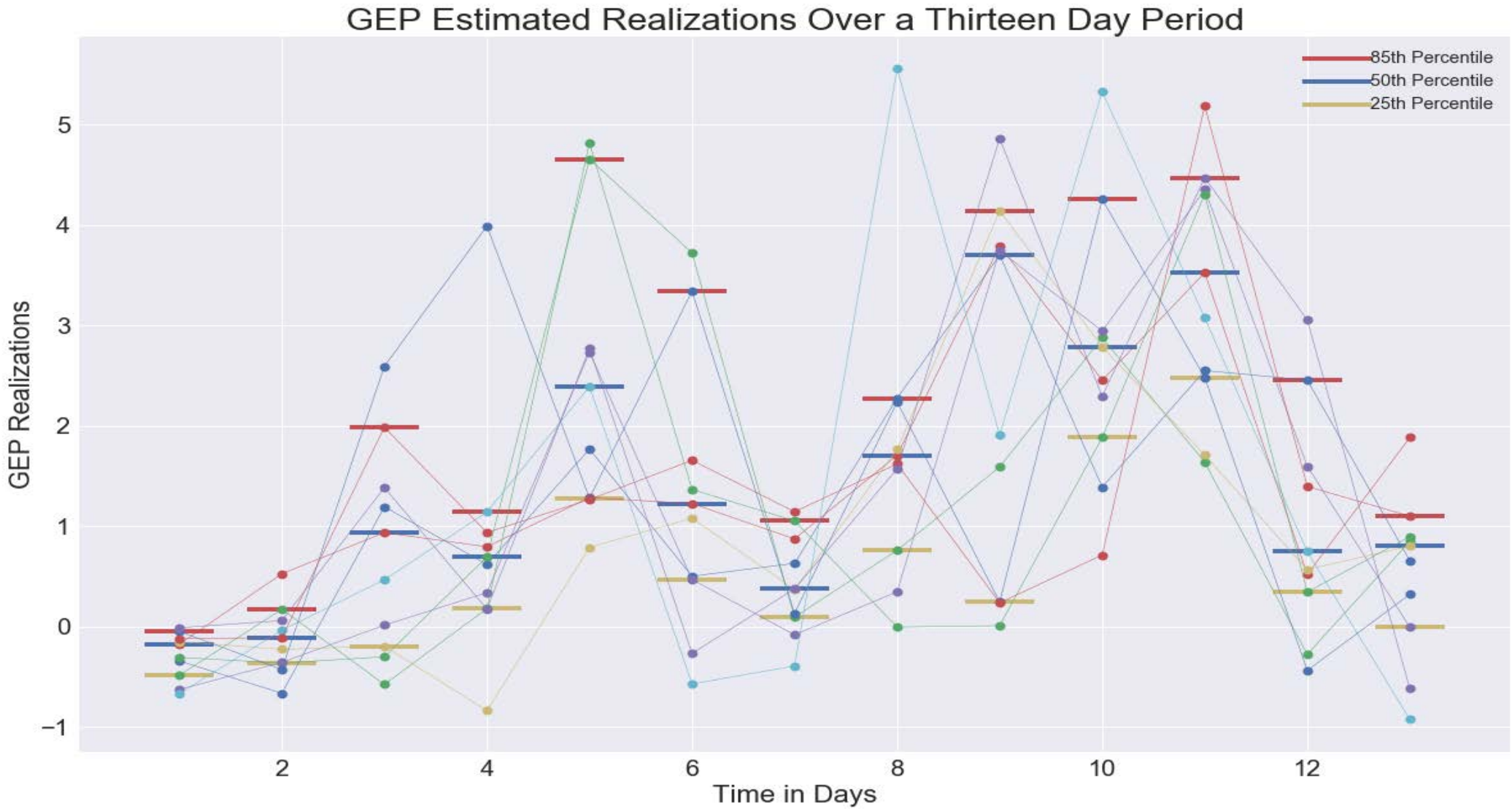
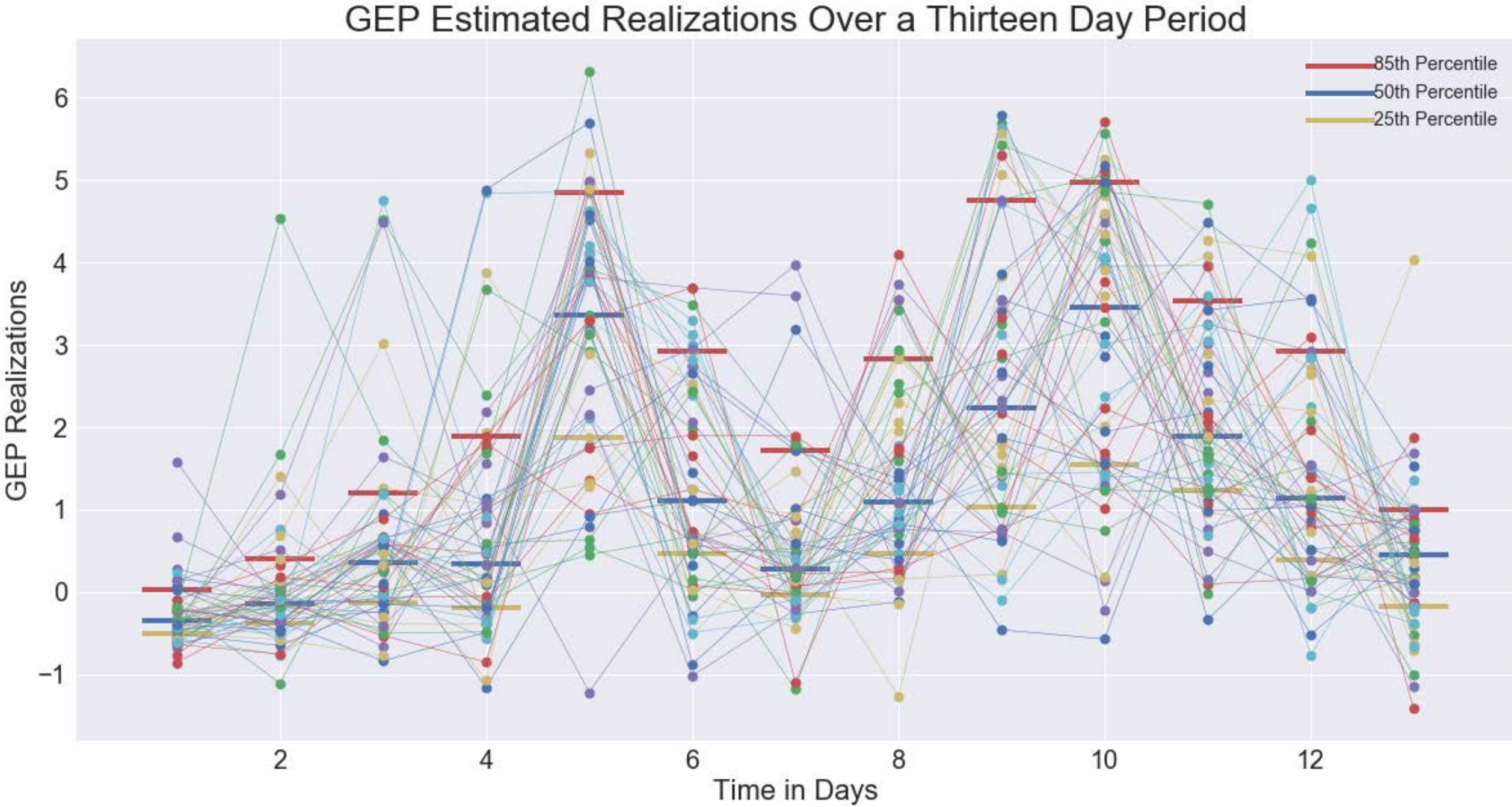


Figure 1: Marginal distributions for GEP realizations

Example: Given 13 DREP measurements {-0.3, 0.1, 0.4, 1, 3, 1.9, 1.4, 2.3, 2.8, 3.2, 3.5, 2.1, 0.9}, then each of the strings below represents a candidate to being an estimate of the actual precipitation measurement on the ground




GEP Estimated Realizations Over a Thirteen Day Period
85th Percentile
50th Percentile
25th Percentile
GEP Realizations
6
5
4
3
2
1
0
−1
2
4
6
8
10
12
Time in Days

Rare Events

Of particular interest are "rare weather events." Hence, it is necessary to understand the distribution of the probable maximal outcomes of precipitation estimates.

In practice, one first generates the “N strings of probable outcomes of precipitation estimates” on the ground and from each collect the maximal value and build an estimated distribution for the entire collection of these maximal value.

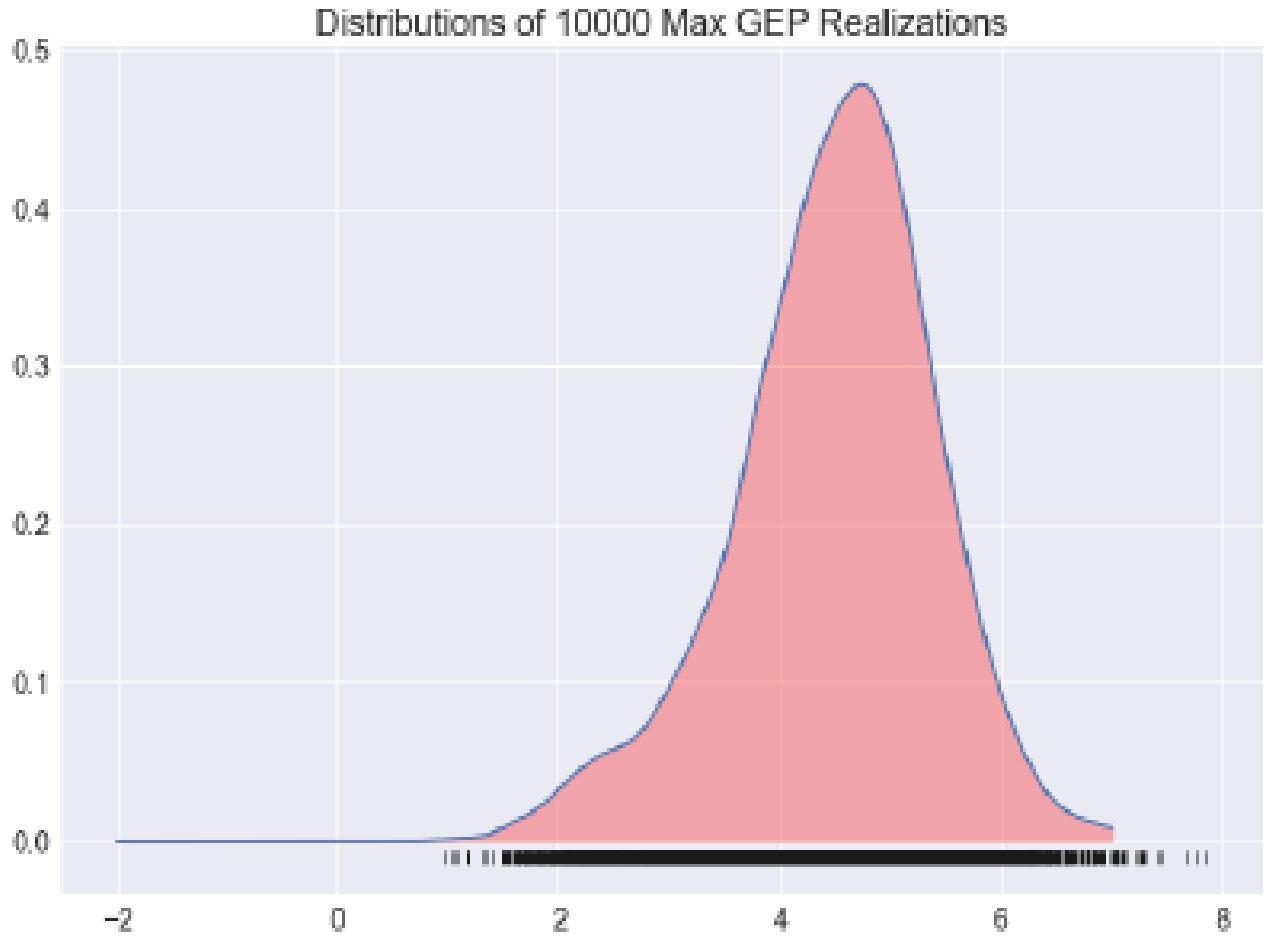


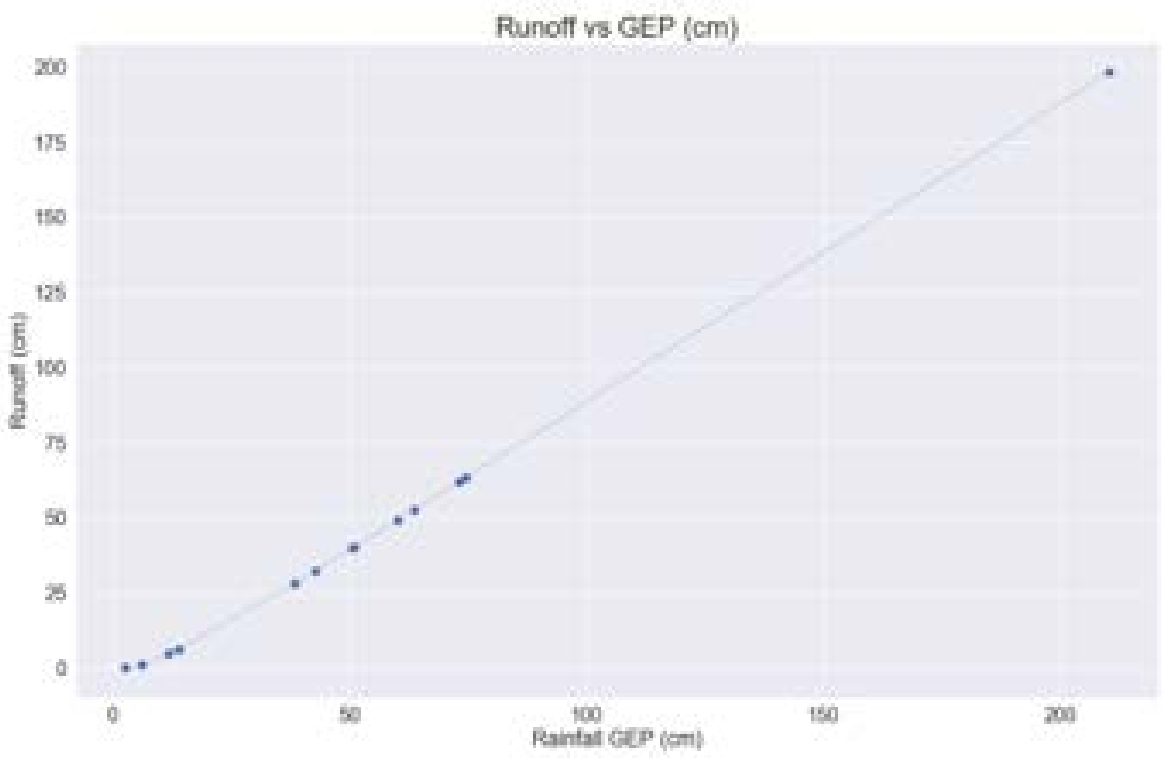
Figure 7: Distribution of GEP Max Readings for 10000 Samples

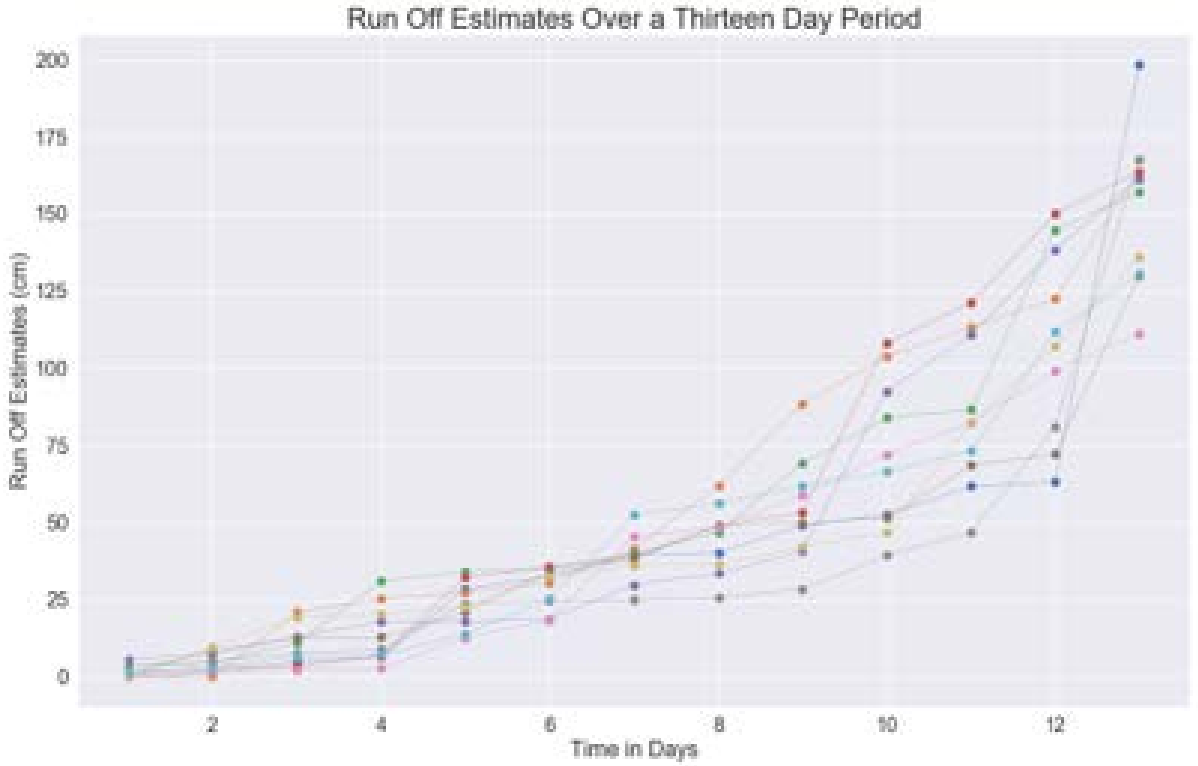
Runoff Estimates

Utilizing the realizations from the above method, an effective example application is in determining the approximate amount of direct runoff from a rainfall event in a particular area.

For this, we use the TR-55 method: (https://www.lmnoeng.com/Hydrology/hydrology.php)

Using arbitrary inputs, the visualization here depict runoff estimates over 13 days of measurement with the realizations calculated using the process in this manuscript.





References

1. Baeck, M. L., & Smith, J. A. (1998). Rainfall Estimation by the WSR-88D for Heavy Rainfall Events. Weather and Forecasting, 13(2), 416-436.
2. Gourley, J. J., Maddox, R. A., Howard, K. W., & Burgess, D. W. (2002). An Exploratory Multisensor Technique for Quantitative Estimation of Stratiform Rainfall. Journal of Hydrometeorology, 3(2), 166-180.
3. Fulton, R. (2000). Hydrometeorology Group's Projects and Plans for Improving WSR-88D Rainfall Algorithms and Products, Retrieved from http://www.nws.noaa.gov/oh/hrl/ papers/2000mou_pdf/chapter1.pdf.
4. Jayakrishnan, R., Srinivasan, R., & Arnold, J. (2004). Comparison of raingage and WSR-88D Stage III precipitation data over the Texas-Gulf basin. Journal of Hydrology, 292(1-4), 135-152.
5. Klazura, G. E., Thomale, J. M., Kelly, D. S., & Jendrowski, P. (1999). A Comparison of NEXRAD WSR-88D Radar Estimates of Rain Accumulation with Gauge Measurements for High- and Low-Reflectivity Horizontal Gradient Precipitation Events. Journal of Atmospheric and Oceanic Technology, 16(11), 1842-1850.
6. Morin, E., Maddox, R. A., Goodrich, D. C., & Sorooshian, S. (2005). Radar Z–R Relationship for Summer Monsoon Storms in Arizona. Weather and Forecasting, 20(4), 672-679.
7. Seo, D., & Breidenbach, J. P. (2002). Real-Time Correction of Spatially Nonuniform Bias in Radar Rainfall Data Using Rain Gauge Measurements. Journal of Hydrometeorology, 3(2), 93-111.
8. Seo, B., Dolan, B., Krajewski, W. F., Rutledge, S. A., & Petersen, W. (2015). Comparison of Single- and Dual-Polarization–Based Rainfall Estimates Using NEXRAD Data for the NASA Iowa Flood Studies Project. *Journal of Hydrometeorology,16*(4), 1658-1675.
9. Cunha, L. K., Smith, J. A., Baeck, M. L., & Krajewski, W. F. (2013). An Early Performance Evaluation of the NEXRAD Dual-Polarization Radar Rainfall Estimates for Urban Flood Applications. Weather and Forecasting, 28(6), 1478-1497.
10. Seo, B., & Krajewski, W. F. (2010). Scale Dependence of Radar Rainfall Uncertainty: Initial Evaluation of NEXRAD's New Super-Resolution Data for Hydrologic Applications. Journal of Hydrometeorology, 11(5), 1191-1198.