VILLANOVA UNIVERSITY
COLLEGE OF ENGINEERING
CENTER FOR RESILIENT WATER SYSTEMS

Determining how Future Rainfall Years Could be Classified using Extensive Observations

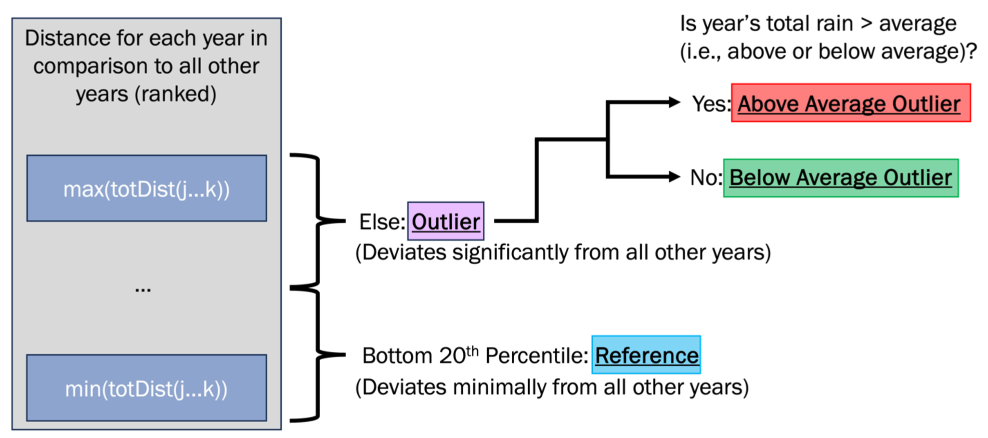
Matthew McGauley[1], Dr. Bridget Wadzuk[1]
[1]Villanova Center for Resilient Water Systems, Villanova University, Villanova, PA

VUSP Stormwater Symposium 2024
October 16 & 17

1 Introduction

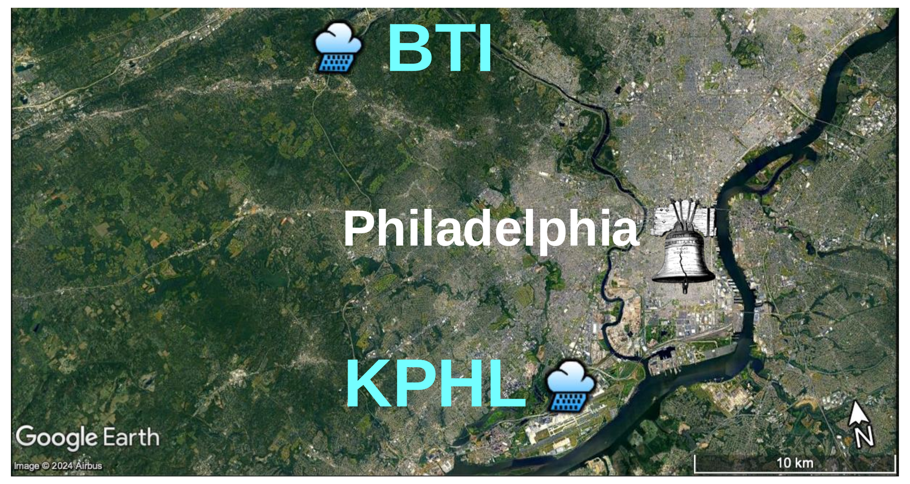
- Albright and Schramm (2018) introduced a novel methodology for the assessment of reference years of cumulative rainfall
- Represent the most typical rainfall patterns from a historical set of observations.
- Determines the cumulative square difference of a given year against all other years on record.

$$\text{Dist}(j, j+1\ldots k) = \text{totDist}(j) = \sum_{j+1}^{k} \sqrt{\sum_{i}^{n} \left(x_{i,j} - x_{i,j+1}\right)^2}$$



- Identifies the typical annual pattern, does not identify the driving force for those patterns, especially when considering what is atypical in extreme (dry or wet) years.
- It was hypothesized that behavior during the wettest portion of the year controlled classification.
- An unsupervised machine learning workflow was used to examine the weather patterns that result in a typical or atypical year of rainfall across 83 years of observations (1941-2023).
- Using climate change projections, this workflow could determine if atypical years on record are indicative of the norm of a future climate.

2 Study Area



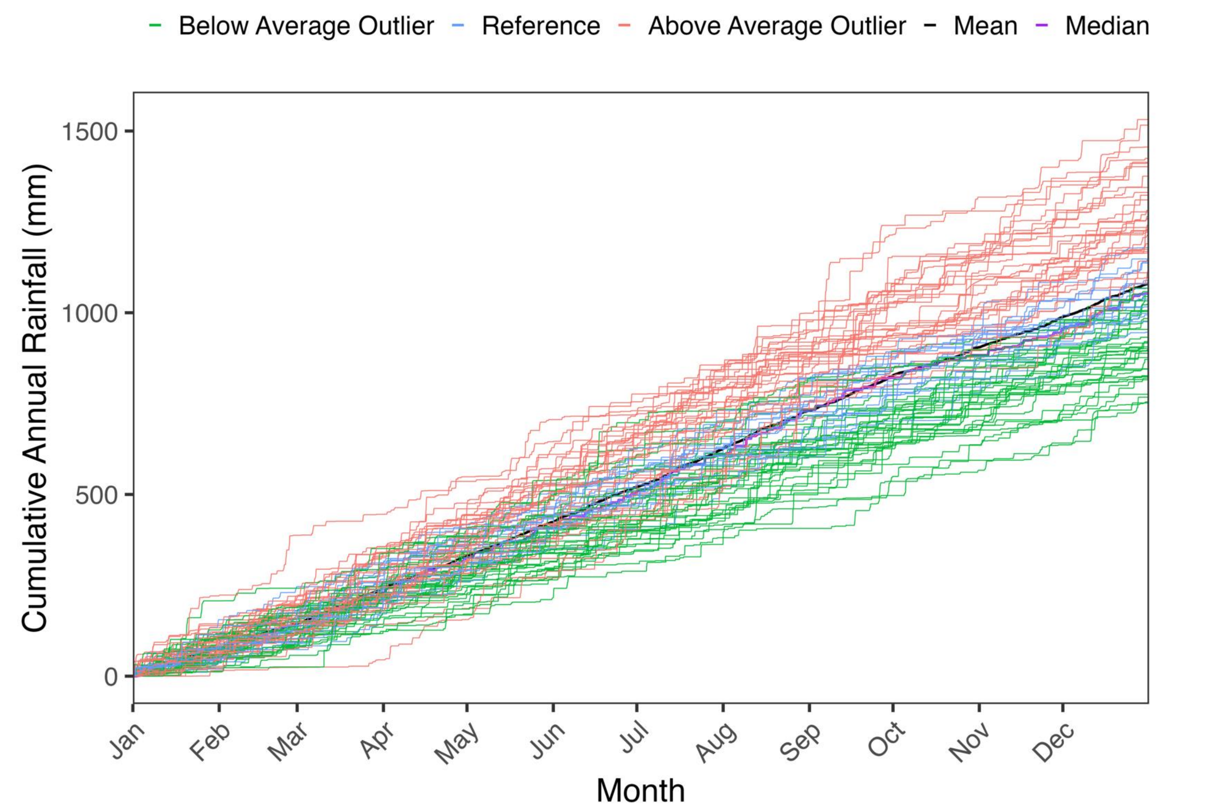
Hourly rainfall observations:
- Rain garden on the Villanova University Campus (BTI).
- Philadelphia Airport (KPHL) via the National Oceanic and Atmospheric Administration (NOAA).

Philadelphia is in the NOAA Type C Design Storm region and classified as a Köppen humid subtropical climate.

3 Identifying the Driving Force of Rainfall Year Categories

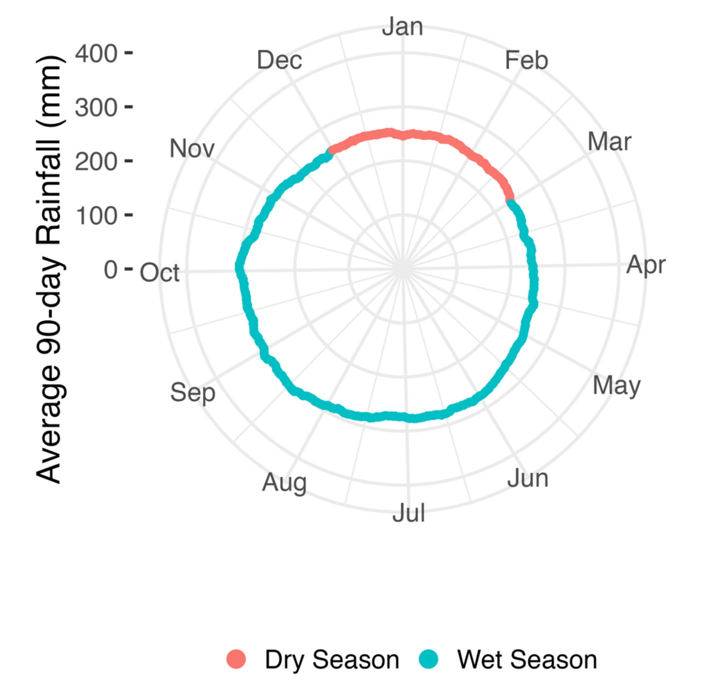
A Classify with Distance Metric

Albright and Schramm's (2018) distance metric was applied to all years on record to identify three categories of rainfall year: below average and above average outliers, and reference rainfall years.



B Define Focal Time Period

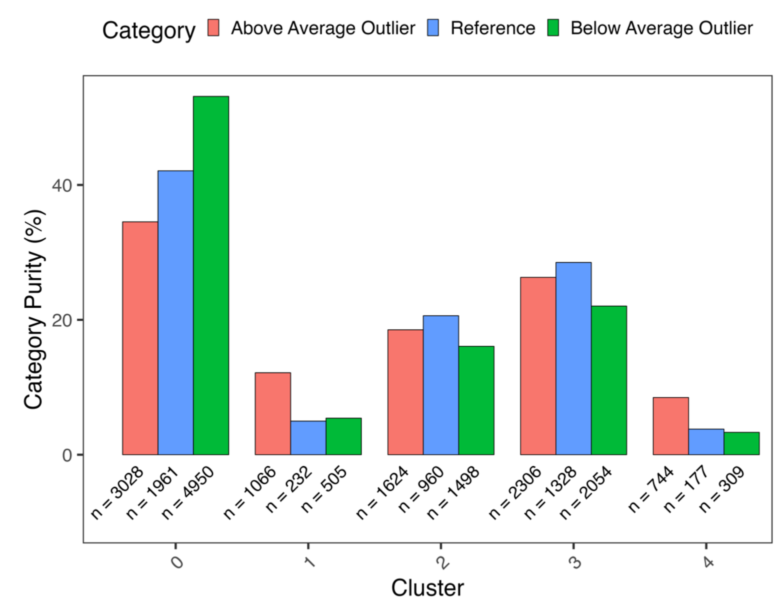
A focal time period, the wettest portion of the year, was determined. Because Philadelphia is a humid subtropical climate, most of the annual rainfall occurs during the warmer months. The exact time period this occurs during was determined using a 90-day moving rainfall sum across all years.



Based on this assessment, the focal time period spanned from early-March to mid-August, when the average 90-day moving rainfall sum was increasing. The wet period of the year was extended to November 30, when the Atlantic hurricane season ends.

C Characterize Similarities

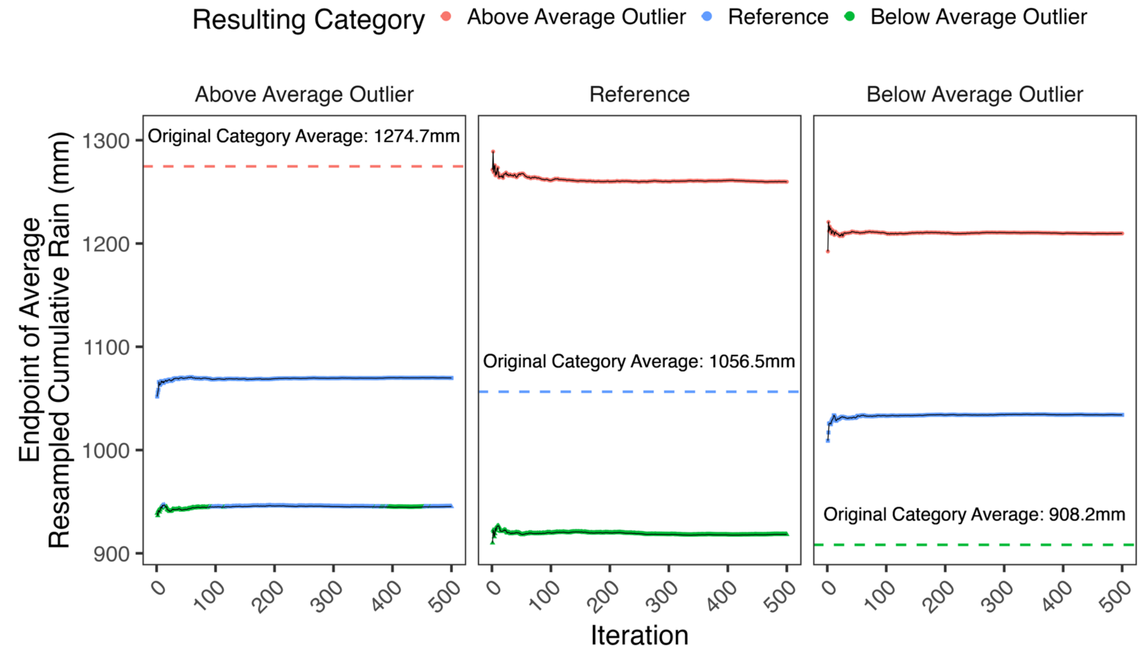
Daily rainfall statistics were aggregated for all days on record. Principle Component Analysis and a Gaussian Mixture model, unsupervised machine learning techniques, were applied to moving windows of daily observations to identify characteristically similar days across the three categories of rainfall year within the focal period. Exploratory analysis was performed to determine if there are clusters of days within each category of rainfall year that are more-common to each type of year.



- Six clusters were identified.
- The percentage of each rainfall year category represented by a cluster (purity) was measured.
- Some clusters are more-specific to certain categories.
- Extreme precipitation was an important predictor.

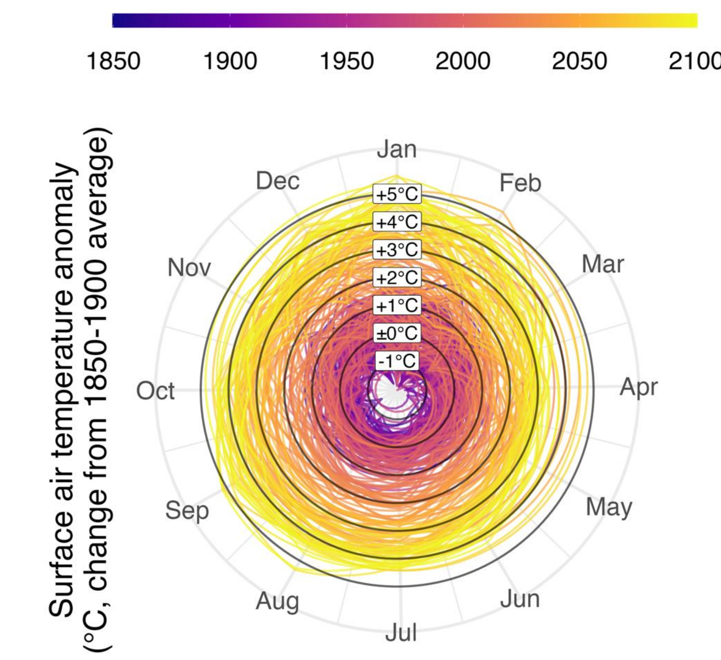
D "Knock Out" Similarities

Stratified random sampling was performed to "mutate" the rainfall years into an opposing category by matching the purity of the cluster for that category. Unique days of rainfall specific to a category were removed and replaced with days that are more unique to an opposing category. Finally, the "mutated" year was re-classified with the distance metric to assess if removing the unique qualities and replacing it with another can change the classification.

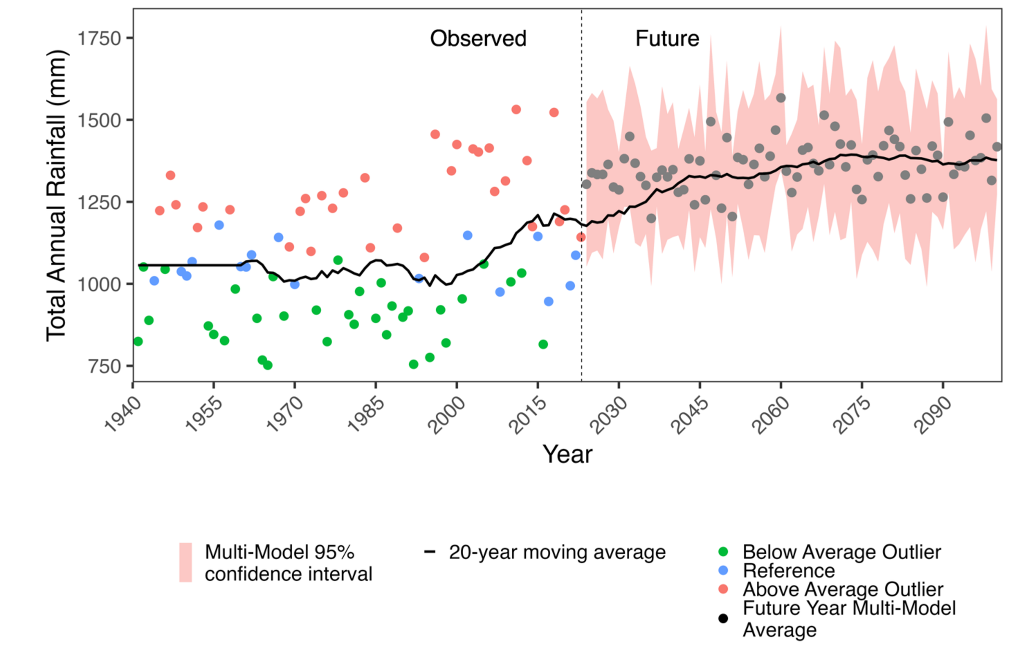


4 A Future Climate

Under the Shared Socioeconomic Pathway 2 with a radiative forcing of 4.5 W/m² (considered a "business as usual" scenario), surface air temperatures are expected to increase by as much as 4-5°C by 2100, when averaged across multiple climate models.



As a result in this change to the Earth's thermodynamic balance, precipitation patterns are expected to change. Present above average outlier years may become a norm of the future. Total rainfall in a year is projected to increase.



The current investigation seeks to use the framework defined herein to determine if extreme years on record are indicative of rainfall patterns of the future. This will aid in ground-truthing hydrologic simulations of the future.

5 References

Albright, C. M., and H. Schramm. 2018. "Improvements and Applications in Climate Data Analysis for Determining Reference Rainfall Years." Journal of Applied Meteorology and Climatology, 57 (2): 413–420. American Meteorological Society.

This work was supported by the Villanova Center for Resilient Water Systems (VCRWS), the EPA 319 Non-Point Source Program, and the Villanova University Civil and Environmental Engineering Department.