16C.5 CHARACTERISTICS OF TROPICAL CYCLONE RAINFALL IN THE UNITED STATES

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1. INTRODUCTION

Tropical cyclone rainfall plays an important role within the overall climatology of the Southern, Southeastern, and Eastern United States. In these regions, the amount of tropical cyclone rainfall can range from light drizzle to an extreme deluge. The effect of this rainfall is broad in scope, as it can impact local hydrologic, agricultural, and societal concerns. These societal concerns can specifically include contamination of drinking water during extreme rainfall, displacing persons from their homes, and creating dangerous transportation conditions. This study seeks to further understand physical and statistical characteristics of tropical cyclone rainfall. More specifically, this study employs an exploratory data analysis (EDA) approach (Tukey, 1977) to gain further insight into the statistical properties of daily tropical cyclone rainfall over affected areas of the United States. The results are also stratified according to larger controlling modes of tropical cyclone activity the El Nino/Southern Oscillation (Landsea, 2000) and the Atlantic Multidecadal Oscillation (Goldenburg et al., 2001).

2. DATA

Data for this study were compiled primarily from two sources. The first source, in-situ rainfall data, were taken from the 1) Global Historical Climatology Network – Daily dataset (hereafter GHCND), and the 2) tropical cyclone tracks dataset (Neumann, 1999). Additional supplementary data included El Nino Southern Oscillation (hereafter, ENSO) indices, and Atlantic Multidecadal Oscillation (hereafter, AMO) (Goldenburg et al., 2001) annual indices. The GHCND rainfall data were quality controlled for values exceeding the known world daily extremes and excessive streaks of the same non-zero values.

3. METHODS

The analysis attempted to quantify spatial, temporal and distributional characteristics of tropical cyclone rainfall. In order to accomplish this, the rainfall stations were carefully screened to ensure that the record during the 1950 to 2004 analysis period contained no more than 10% missing data. There were 1751 stations that satisfied this criterion, spread out over 26 Southern, Southeastern, and Eastern States. In order to adequately separate the rainfall into tropical cyclone and non-tropical cyclone components, a partition methodology was created. Because no clear demarcation can truly be made between these two types of rainfall, the simplest method possible was chosen, due to the desire to simplify both the computations and the conceptual understanding. This partition method required calculating the distance between the tropical cyclone center coordinate and each station location. If this distance was found to be less than or equal to 600 km, then for that day, that particular station's rainfall was considered to be tropical cyclone rainfall. The 600 km distance is believed to satisfactorily account for the majority of all the rainfall associated with the tropical cyclone. These computations were carried out for the entire period of record for all stations within the analysis domain. The resultant rainfall, essentially a tropical cyclone rainfall dataset, was then further stratified by ENSO phase (e.g. cold, neutral, warm), and AMO phase (cold, warm). Each day for each station was therefore assigned to one of the sub-phases of each of the larger atmospheric-oceanic phases.

4. SPATIAL PATTERNS

The first component analyzed was the spatial variability over three time periods. In particular Figure 1 depicts the spatial variability of the mean ratio of tropical cyclone rainfall to total rainfall (expressed as a percent). The spatial relationships depicted are relative to the "hurricane season," June through November. The majority of the inland regions primarily experience tropical cyclone rainfall that contributes between 0% and 4% of the total rainfall during that time period, the near coastal regions experience between 4% to 12% tropical cyclone rainfall contribution, and the coastal regions are interspersed with stations that experience between 8% and 16%. From August through October, many stations increase in terms of their percentage contribution, with the most notable increases occurring along the coastal regions (including a few stations within North and South Carolina that reported over a 20% contribution of tropical cyclone rainfall to the total local climatological rainfall). During the peak month of tropical cyclone activity, September, the coastal and near coastal regions receive between 8% and 16% contribution of

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tropical cyclone rainfall, and parts of Southern Alabama, and the Eastern portion of North Carolina received contributions greater than 20%.

6. TEMPORAL VARIABILITY

Figure 2 displays the time series of daily tropical cyclone rainfall for the entire study period, 1950 to 2004, stratified by ENSO phase. The most dominant features for June through November are the late 1990's La Niña (ENSO cold event) and the early 2000's El Niño (ENSO warm event). In addition, ENSO neutral events are responsible for significant rain events during the mid 1960's, mid 1980's, and the mid 1990's. During August through October and September the cold phase of the late 1990's and the warm phase of the early 2000's still predominate, with some of the most intense rainfall (e.g. > 200mm) occurring during these events. These same time series are displayed in Figure 3, only the stratification is done by AMO phase. In particular, the warm rainfall events of the 1950's closely parallel the 1990's, with higher frequencies of amounts in the extreme range (>200mm) occurring in the 1990's. The mid 1980's observed a relative abundance of below 200mm amounts during the AMO cold phase.

7. RAINFALL DISTRIBUTION

While the temporal examination can provide general clues into the overall amplitude of extremes within each season, it is difficult if not impossible from that analysis alone to ascertain the actual rainfall distributions for each phase. Thus inverse cumulative frequency diagrams (expressed in percent) were created for each of the three time periods and the respective phases. These diagrams represent the percentage of observations that are at or below a certain amount of rainfall. Figure 4 suggests that the ENSO cold events consistently, have higher amounts of rainfall than the relatively similar ENSO warm and ENSO neutral events. However, during the peak of the season, (September, Figure 4), there is a relatively small difference between each of the three phases. This is in contrast to the AMO, where the warm phase has the highest amounts in the central portion of the distribution for all three time periods.

7. CONCLUSIONS

In this study, exploratory data analysis techniques were used to investigate the spatial, temporal, and distributional aspects of United States tropical cyclone rainfall. Furthermore, the results were stratified by ENSO and AMO phases. With respect to spatial considerations, tropical cyclone rainfall contributes on average, depending upon the season, between 0% to as much as 20% or more rainfall to the total seasonal rainfall. In addition, as expected, percentages are higher toward the coastal areas, and peak mean contributions occurred in the Eastern Carolinas and the Panhandle of Florida. The interannual variability of ENSO phases along with the cold and warm phases of the AMO play a role in tropical cyclone rainfall, with the most notable aspect being the higher percentage occurrence of rainfall events during ENSO cold phases.

8. REFERENCES

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Tukey, J., Exploratory Data Analysis, Addison-Wesley, 1977.

a)
b)
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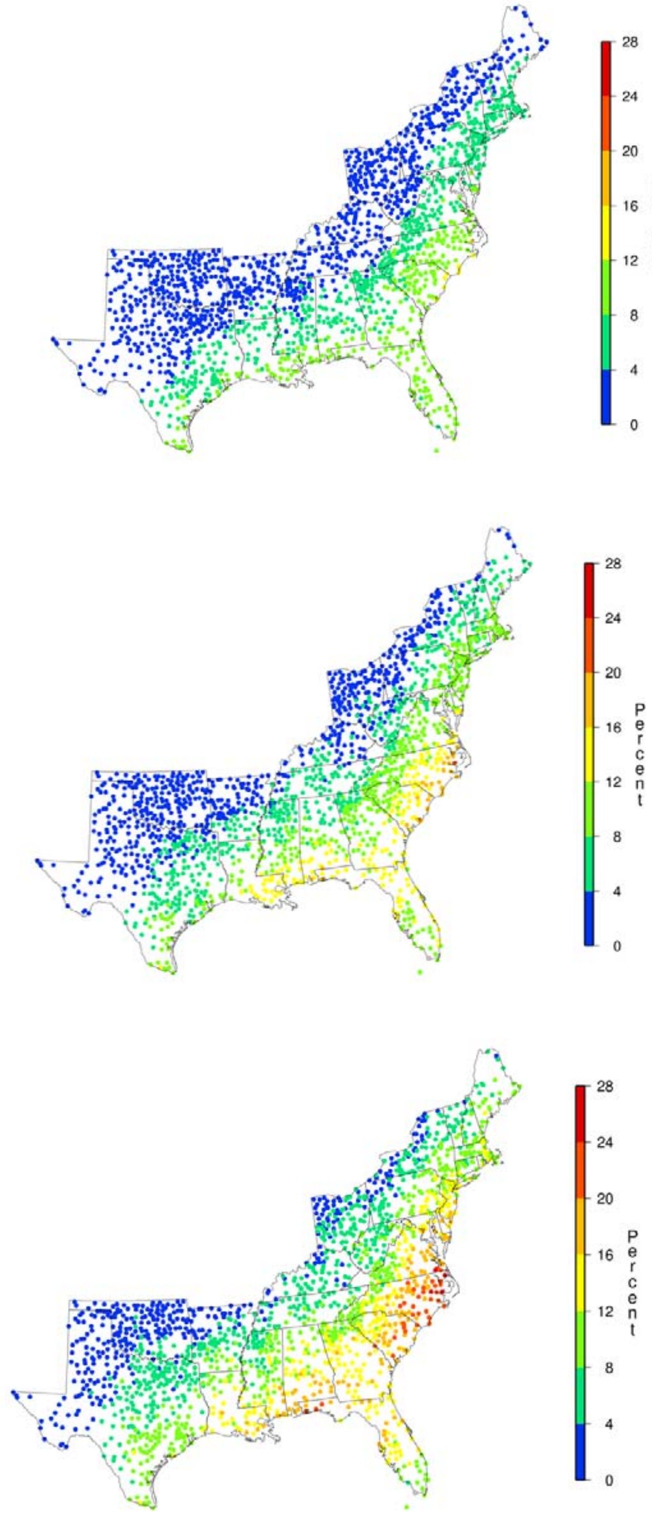
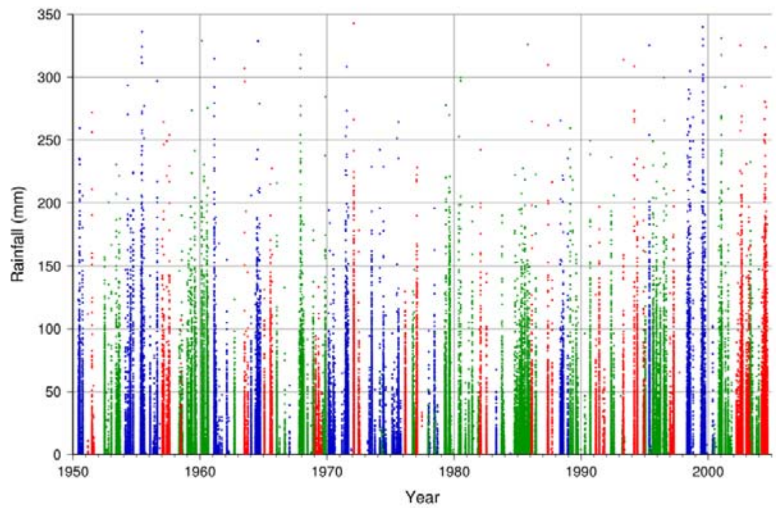


Figure. 1. Mean, period of record contribution, of tropical cyclone rainfall to total rainfall for a) June through November, b) August through October, and c) September.

a)



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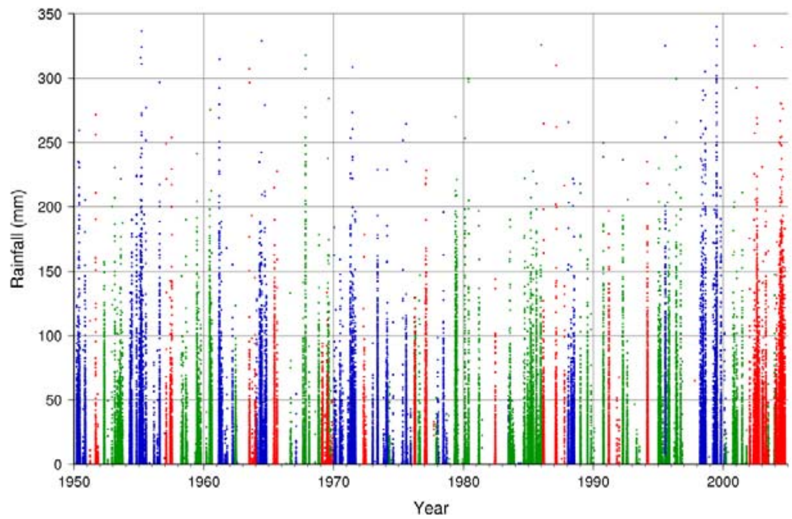

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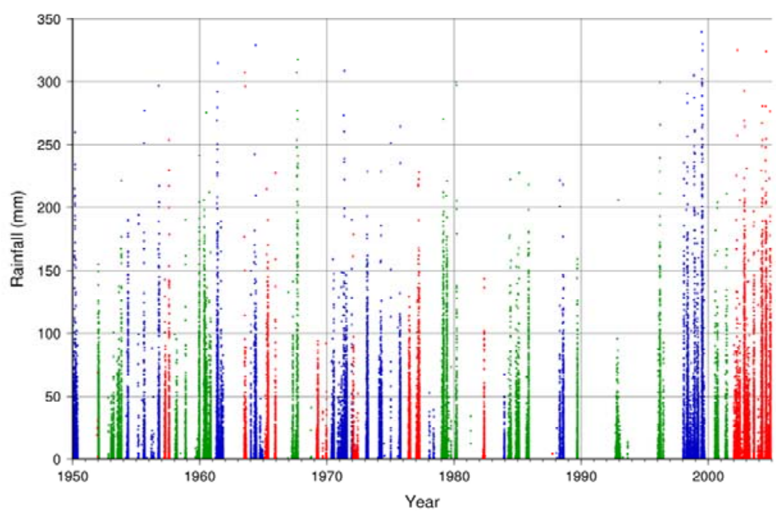

Figure 2. 1950 to 2004 daily tropical cyclone rainfall measurements for a) June through November, b) August through October, and c) September. ENSO-cold=blue, ENSO-neutral=green, ENSO-warm=red. Note: Values greater than 350 mm (y-axis) are not displayed due to their low frequency of occurrence.

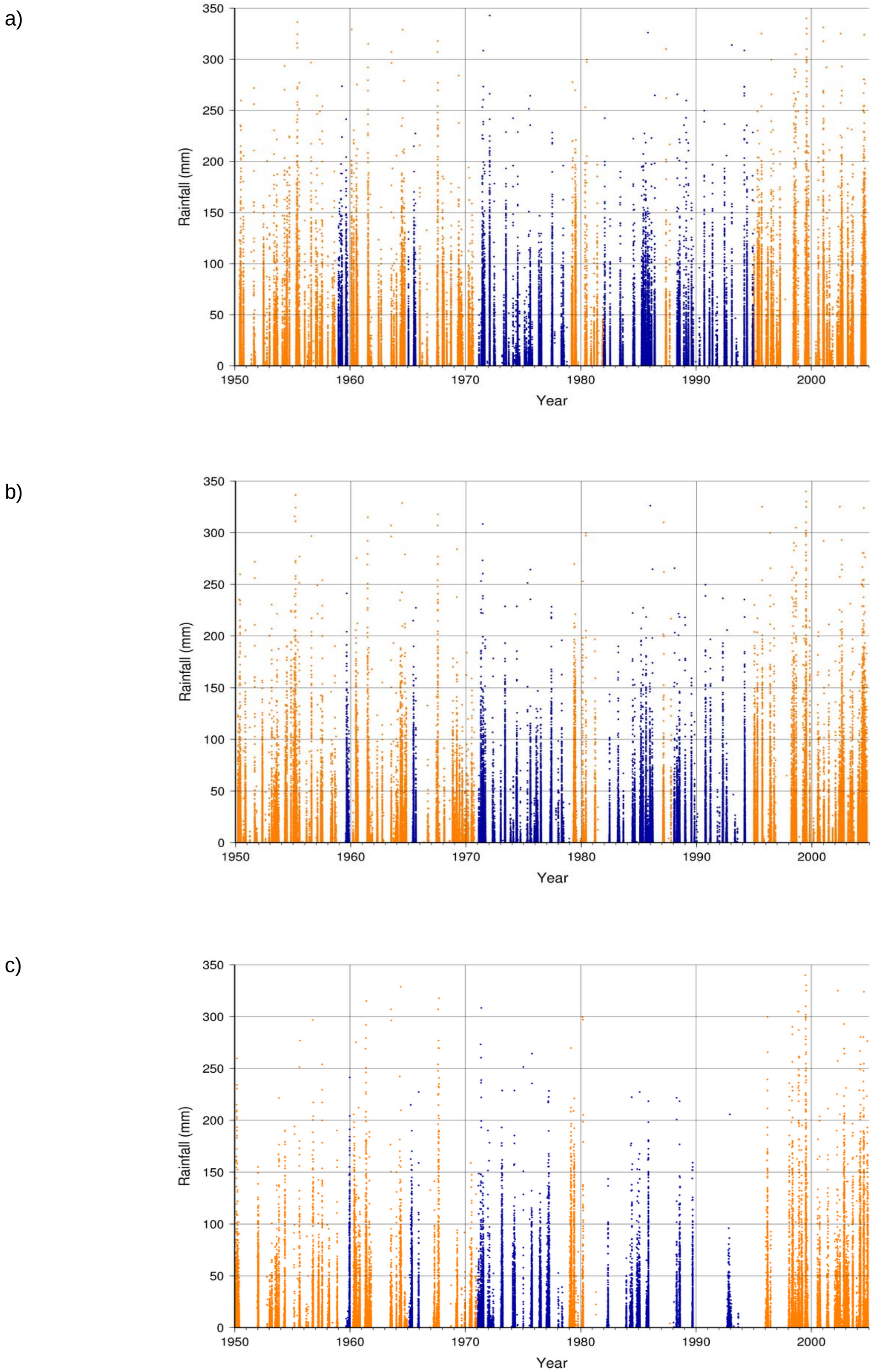

Figure 3. 1950 to 2004 daily tropical cyclone rainfall measurements for a) June through November, b) August through October, and c) September. AMO-cold=blue, AMO-warm=orange. Note: Values greater than 350 mm (y-axis) are not displayed due to their low frequency of occurrence.

a)

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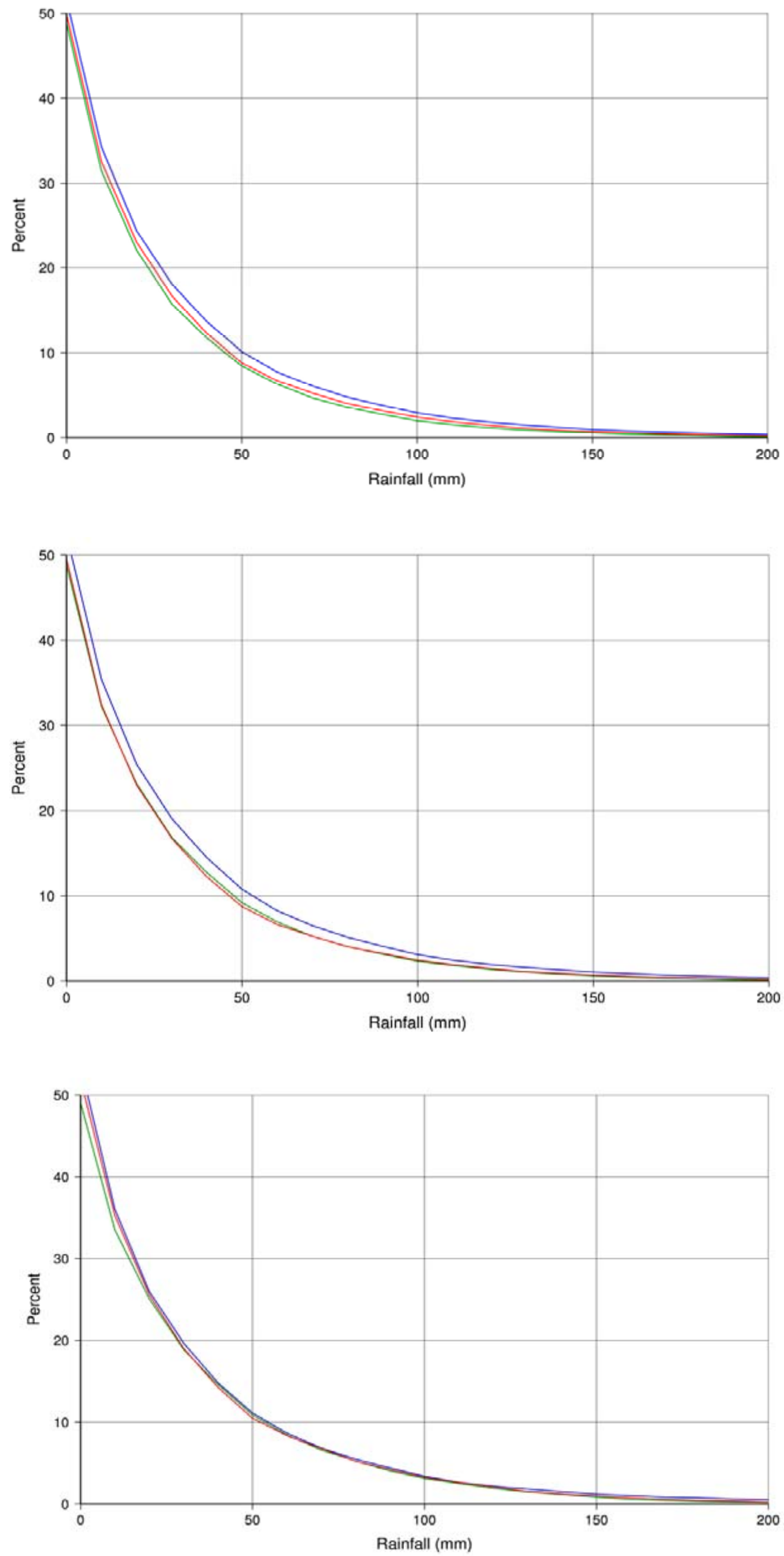
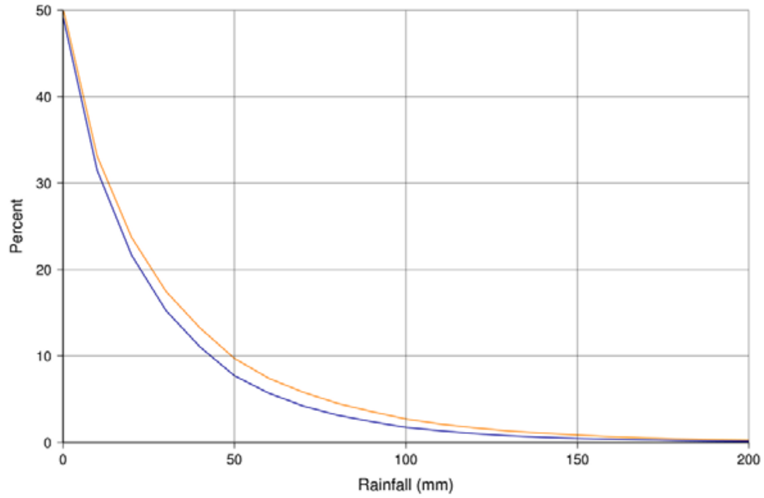


Figure 4. Inverse cumulative frequency diagrams (expressed as percent), for all 1950 to 2004 tropical cyclone rainfall values for a) June through November, b) August to October, and c) September. ENSO-cold=blue, ENSO-neutral=green, and ENSO-warm=red.

a)



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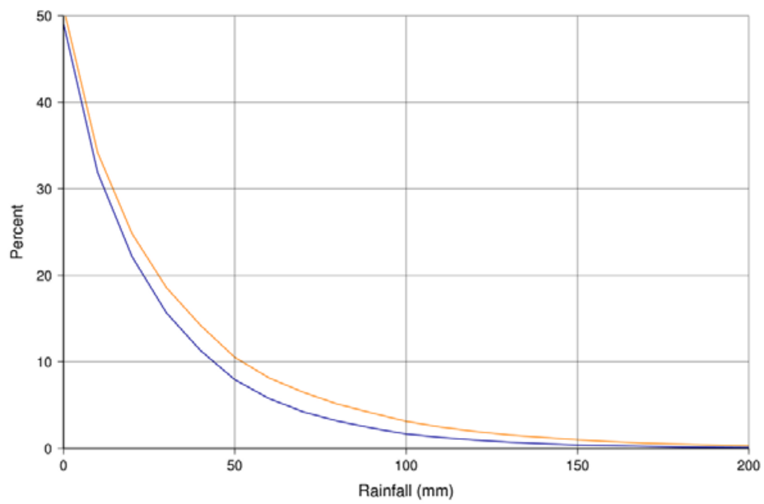

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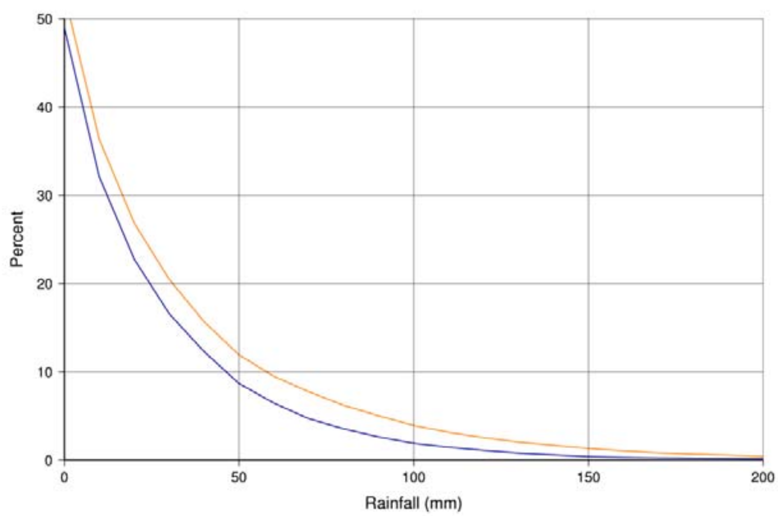

Figure 5. Inverse cumulative frequency diagrams (expressed as percent), for all 1950 to 2004 tropical cyclone rainfall Values for a) June through November, b) August to October, and c) September. AMO-cold=blue, AMO-warm=orange.