# Lab Exercise 2: Extreme Event Analysis

## 1. Introduction

During the first two days of November 2000, a severe rainstorm struck the Island of Hawai`i. The storm was fueled by the remnants of Tropical Storm Paul and resulted in catastrophic flooding. A tropical depression developed off the west coast of Mexico on 22 October and was designated as a tropical storm on the 26th of October. Tropical Storm Paul largely dissipated by the 29th, having traveled about halfway to Hawai`i. However, deep tropical moisture associated with Paul continued westward, and as the enhanced plume of moisture approached the Big Island on November 1st, it encountered an upper-level trough approaching from the west. The timing of the interaction of the tropical moisture and the upper-level trough was such that it turned the moist air mass northward and lifted it directly across Hawai`i, setting the stage for torrential rains. The extensive flash floods that resulted are estimated to have caused $70 million in property damage and the impacts on roads and other infrastructure persisted for years afterwards.

The maximum rainfall was recorded by the rain gauge at Kapapala Ranch on the south slope of Mauna Loa. This gauge recorded 989 mm (>39 inches) of rain over 36 hours and very heavy rainfall was recorded over the southern and eastern portions of the Island. At the Hilo Airport, the amount of rainfall recorded during a 1-hour period was nearly 6 inches, the amount recorded during a 12-hr period was 22.55 inches, and the amount recorded during a 24-hr period was 26.89 inches. An investigation of the available data shows that the long duration of the heavy precipitation and the nearly stationary nature of the storm clouds can be attributed in part to lifting of the airflow by the slopes of Mauna Loa and Mauna Kea, which anchored the storm clouds to the mountainous terrain.

Insurance companies do not cover “acts of God,” which they define as events that occur only once in a century or more. Was this an act of God?
2. Extreme Value Theory

Extreme value theory is a branch of statistics dealing with the extreme deviations from the median of probability distributions, in other words extreme events in a data record. The general theory sets out to assess the type of probability distributions generated by processes. Extreme value theory is important for assessing risk for highly unusual events, such as 100-year storms. Extreme value distributions are the limiting distributions for the minimum or the maximum of a very large collection of random observations from the same arbitrary distribution. Emil Julius Gumbel (1958) showed that for any well-behaved initial distribution [i.e., $F(x)$ is continuous and has an inverse], only a few models are needed, depending on whether you are interested in the maximum or the minimum, and also if the observations are bounded above or below. The Gumbel distribution is a special case of the Fisher-Tippett distribution, named after Sir Ronald Aylmer Fisher (1890–1962) and Leonard Henry Caleb Tippett (1902–1985), and also known as the log-Weibull distribution. The cumulative distribution function of the Fisher-Tippett distribution is

$$F(x; \mu, \beta) = e^{-e^{(x-\mu)/\beta}},$$

which can also be written

$$F(x; \mu, \beta) = e^{-e^{(x-M)/\mu}},$$

where $M$ is the median and the shape parameter ($\varepsilon$) the scale parameter ($\beta$) and the location parameter ($\mu$) are returned.

To obtain recurrence intervals, first a series of extreme values must be obtained from the historical data set (e.g., series of yearly maxima of daily rainfall total). Then a generalized extreme-value cumulative-distribution function (eq. 2) is calculated from this series. This function contains shape, location, and scale parameters that are estimated based on the temporal length and distribution of values contained in the dataset. To fit values one can get the median straight away and then vary $\mu$ until it fits the list of values.
Objectives
To gain an understanding of extreme value statistics and their use in answering the question, “How unusual was this particular weather event?” In other words, what is the recurrence interval for such a storm?

Materials
Daily rainfall data from Hilo (in hundredths of an inch)
Matlab code used to create a recurrence interval plot for daily extreme rainfall data.

Part I
1. Download the daily rainfall data from NCDC (actually this step was done for you). Open data file for Hilo rainfall that is provided.
2. Use a Matlab script (or Excel) to create a data set of extreme daily values (hiloextremes.txt). Each value in this series is the largest measured daily rainfall total for an entire year. (i.e., the rainiest day of the year).
3. Create a histogram of the extreme daily rainfall values you got in step 2. An example histogram is provided at the end of this lab.

Part II
1. Use the Matlab code provided below to create a recurrence interval plot for daily rainfall data.
2. Use the basic fitting tool under the “tools” menu in the figure window to curve fit the data points using a cubic spline. An example graph is provided at the end of this lab.

Questions
1. What was the estimated recurrence interval for the 24-hr rains experienced in Hilo in early November 2000?
2. If this same rainfall amount had occurred in Lihue, what would the recurrence interval have been there? From your answer, which location, Hilo or Lihue has heavier extreme rainfall events?
3. Make a graph of the difference in rainfall between 5-yr, 10-year, 20-year, 50-yr, and 100-yr recurrence events. (e.g., \( R_{10} - R_0 \), \( R_{20} - R_{10} \), \( R_{50} - R_{20} \), … etc). What is happening in your graph?

4. Boulder, Colorado is planning for a 500-yr flood. Can you estimate a 500-yr flood from the graphs you created? How much rainfall is it?
Sample Code:

%%% This code uses extreme rainfall data to create return periods

clear all;

% Load the data

a=load('Hiloextremes.txt');
rain=a(1:43,2);
rain=sort(rain);

% Calculate parameters for return period

parmhat=gevfit(rain);
k=parmhat(1);
sigma=parmhat(2);
mu=parmhat(3);

% Calculate a probability a value will return

p=gevcdf(rain,k,sigma,mu);

% Calculate return period in years

ret=1./(1-p);

% Plot the data

figure(1)
plot(rain,ret,'or')
grid on
hold on
axis([0 20 0 250])
xlabel('Rainfall (inches)')
ylabel('Return Period (years)')
title('Return Period of Hilo Daily Rainfall (1949-2008)')
Sample Figures