# Contents



# 1. Precipitation Estimation

We need to estimate areal precipitation from point measurements.

Figure 1: Figure 4.22

The average precipitation over a region is represented as:

$$P = \frac{1}{A} \int \int_A p(x, y) dx dy \tag{1}$$

We can either directly use the gauge measurements or use a surface-fitting method and then calculate the integral.

**1a.** *Direct Weighted Average*

$$\hat{P} = \sum_{g=1}^{G} w_g p_g \tag{2}$$

where G is the number of gages and $w_g$ are weights where $\sum_{g=1}^{G} w_g = 1$, and $p_g$ is the precipitation measured at each gage.

**Arithmetic Average** $w_g = 1/G$ for all gages, so we just use the arithmetic mean. $\hat{P} = \frac{1}{G}\sum_{g=1}^{G} p_g$

**Thiessen Polygons** We divide into subregions and calculate the areas $a_g$, so $w_g = a_g/A$. Then $\hat{P} = \frac{1}{A}\sum_{g=1}^{G} a_g p_g$. The areas are calculated by drawing straight lines between gages, then perpendicular bisectors of each line are constructed and extended until they intersect to form irregular polygons.

**Two-Axis Method** Based on the nearness of each gage to the center. You draw the longest straight line that can be drawn on a map of the region, then draw a perpendicular bisector (minor axis). One draws two lines from each of the gages, one line to farther end of the major axis, the other to the farther end of the minor axis. The angle between these two lines $\alpha_g$ is measured and the sum of all the angles is computed $\dot{A} = \sum_{g=1}^{G} \alpha_g$. Then $\hat{P} = \frac{1}{\dot{A}}\sum_{g=1}^{G} \alpha_g p_g$

**1b.** *Surface Fitting Methods*

Measure the precipitation values at all points in the surface, modeling the spatial variability of precipitation. Surface fitting methods can be based on smoothing (the values at the gages will not be retained exactly) or interpolation (the values at gages are retained exactly). Our goal is to construct surfaces of equal precipitation (isohyets) where the precipitation in the are within two isohyets is $\hat{p}_i = 0.5(p_{i-} + p_{i+)}$. The regional average is then calculated as:

$$\hat{P} = \frac{1}{A}\sum_{i=1}^{I} a_i \hat{p}_i \tag{3}$$

**Note: One shouldn't use a method that is more elaborate than is warranted by the quality of the data. Keep in mind the actual spatial variability of precipitation in a given ares (as with topography).

**Conventional Hypsometric Method** is a deterministic, smoothing, surface-fitting method. Appropriate for regions where orographic effects are important and precipitation is a strong function of elevation. We need a DEM.

1. Plot the measured $p_g$ values against station elevation $z_g$ and establish a relationship called the "orographic equation" (usually a linear regression).

2. Construct a graph relating elevation $z$ to area above a given elevation $A(z)$ called a hypsometric curve. (use DEMs if possible).

3. Select an elevational interval $\Delta z$, divide total elevation into increments of $\Delta z$ and from the hypsometric curve determine the fraction of total area within each increment.

4. Estimate the precipitation at each elevation $z_h$ where $z_h$ is the central elevation in each increment.

5. Compute the estimated areal average precipitation as $\hat{P} = \sum_{h=1}^{H} \hat{p}(z_h)a_h$

Computer algorithms have been developed that use DEM to estimate precipitation in mountainous regions. One of the most famous ones is PRISM (Precipitation-elevation REgrestion on Independent Slopes Model). PRISM also evaluates uncertainty.

# 2. Precipitation and Rainfall Climatology

Depending on the application, we might need information about precipitation in terms of:

- Long term average - 30-year normal precipitation is the norm. (NCDC)
- Seasonal Variabiity - determines the seasonality of streamflow and groundwater recharge. Particularly important in Monsoonal regimes
- Inter-annual variability - standard deviation of the annual values.
- Extreme Values - used to estimate design floods, for drainage systems, culverts and flood-control structures, floodplain management.

**2a.** *Depth-Duration-Frequency Analysis*

Designs are based on the flood that is estimated to have a specified **exceedence probability** the inverse of which is the **return period**. Estimation of the rainfall depths with a given return period for various storm durations at a given rain-gage station is called **depth-duration-frequency DDF analysis**, if using intensities **intensity-duration-frequency IDF analysis**.

- Flood with a return period of 25yr (exceedence probability of .04) is used for culverts.

- 100-year flood (.01 exceedence probability) is used to delineate floodplains for land-use planning.

Duration increases with drainage area. As in Figure 4-48. To perform IDF of DDF analysis:

1. Develop a time series of annual maximum values of rainfall for selected durations at selected gages.

2. Determine the quantiles for the timeseries.