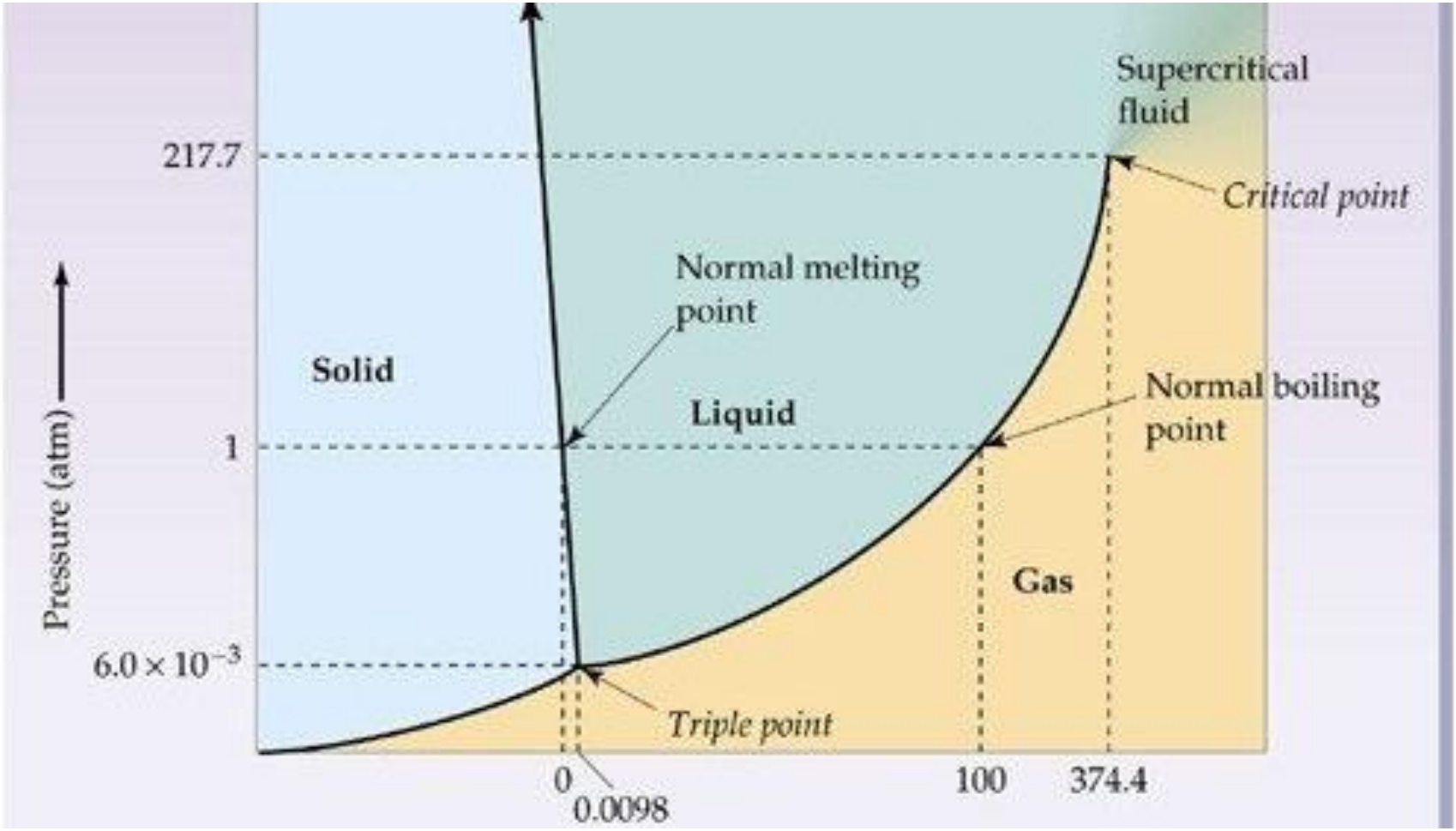
The Three Phases of Water



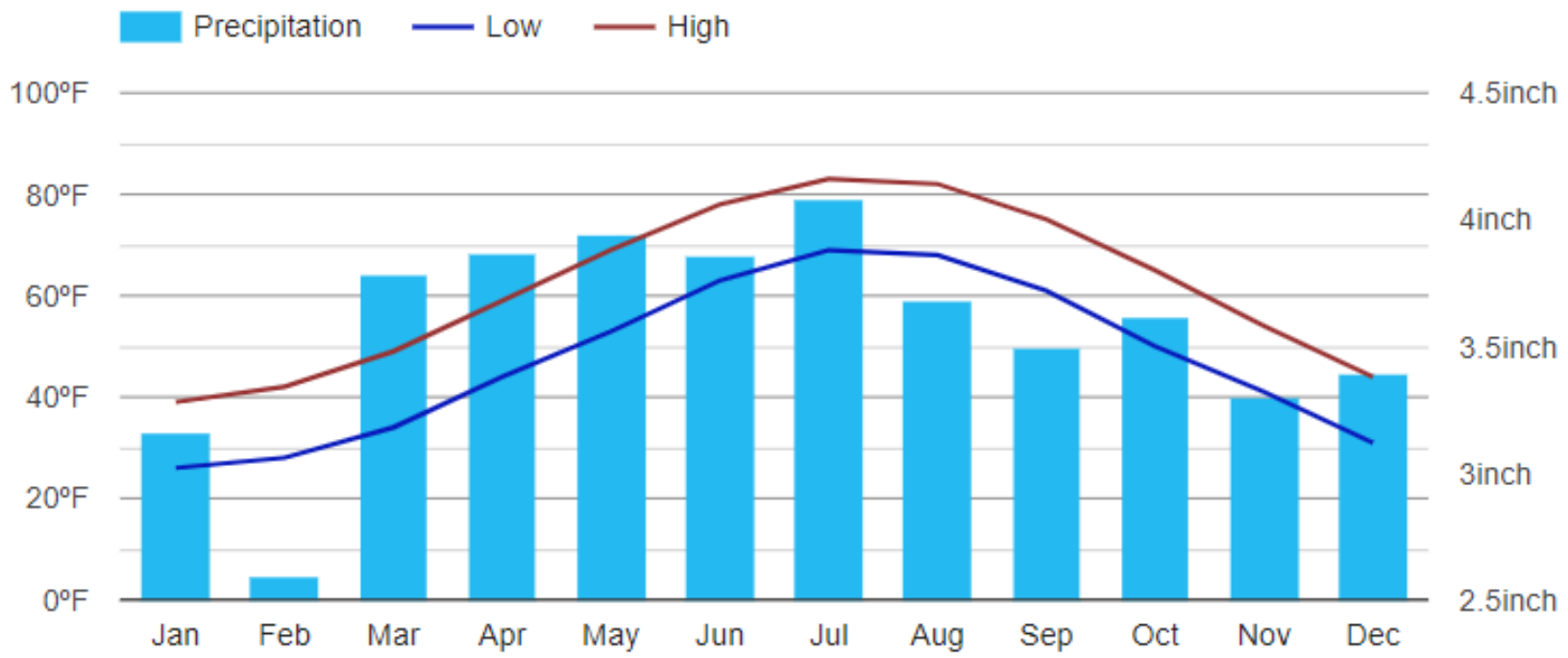
Precipitation

- Include: rain, snow, sleet, hail.
- How do raindrops form? (fall velocity > updraft speed)
- Precipitation vary greatly geographically and with time, even at small scale.
- World record (annual average): Hawaii - 450 inches per year !
- Measured with rain gauge, Radar data
- Can be data logged.

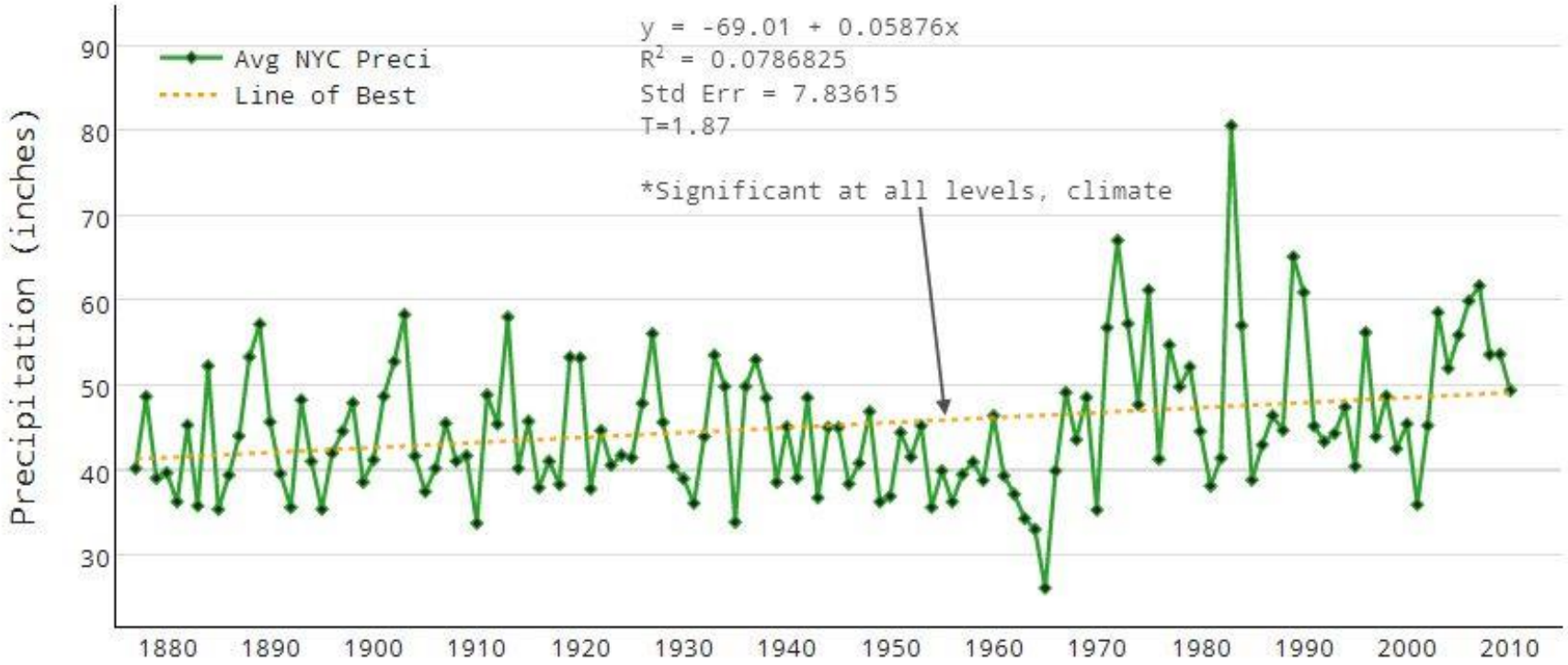
Tipping Bucket Rain Gauge

1. Can be data logged for remote access or later retrieval
2. Precipitation goes through a screen and funneled into a bucket
3. When bucket is full, it tips
4. Every tip is 0.01 cm
5. # of tips is recorded by sensors
6. Widely used.

New York-JFK Intl Arpt Climate Graph - New York Climate Chart



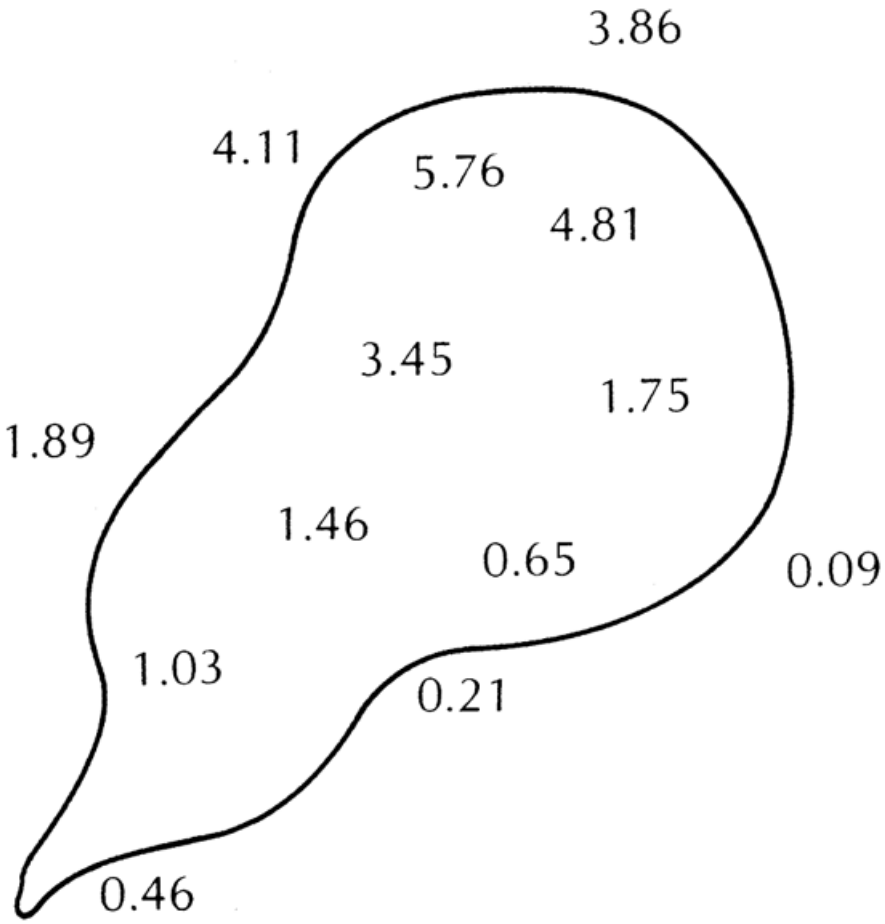
Average Annual Precipitation at New York City Since 1877



Data: NCDC

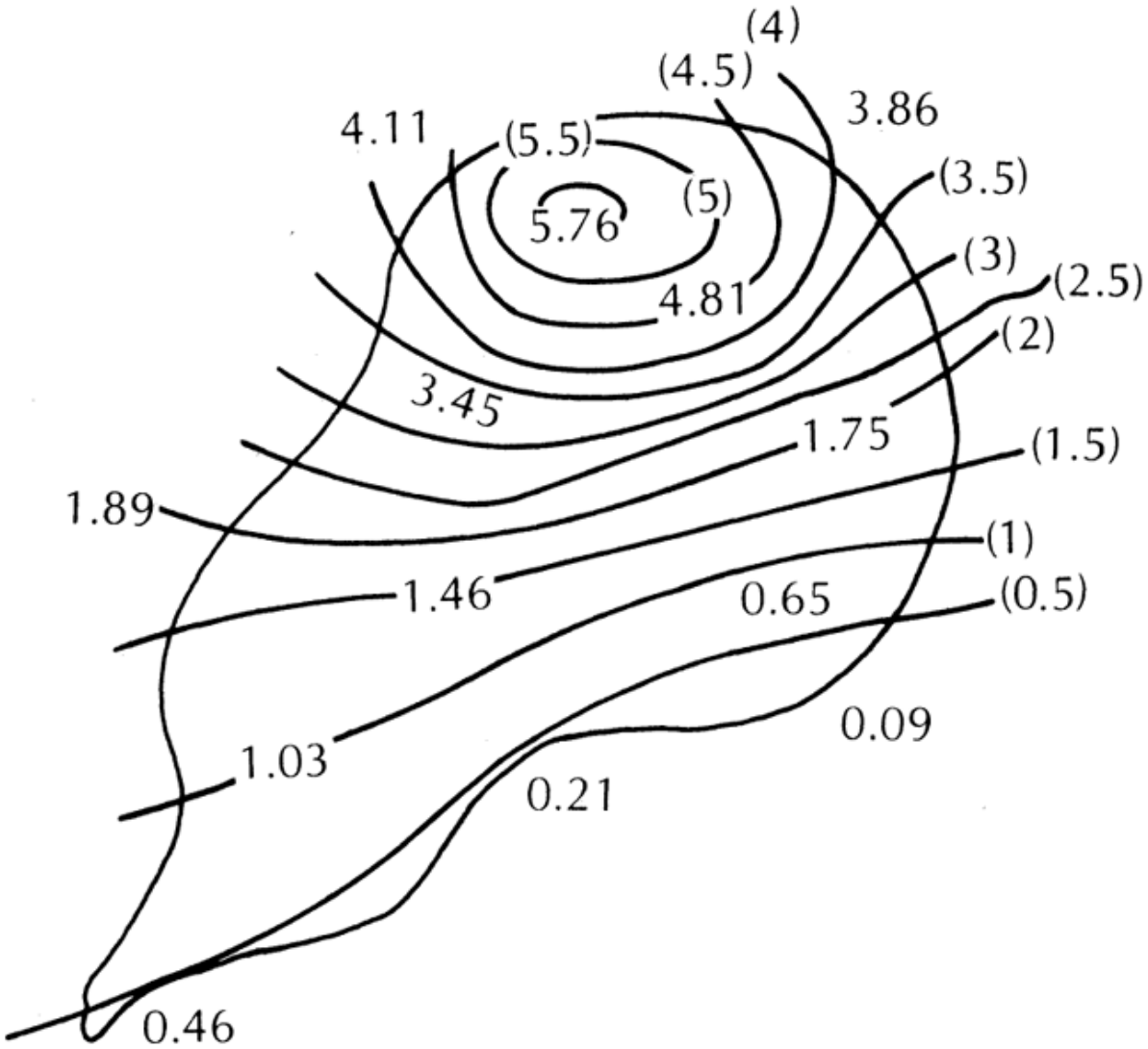
Precipitation

- Average depth of precipitation over a drainage basin.
- Arithmetic mean
- Isohyetal lines (Fig. 2.5 on P35)
- Thiessen Method (Fig. 2.6 on P35)



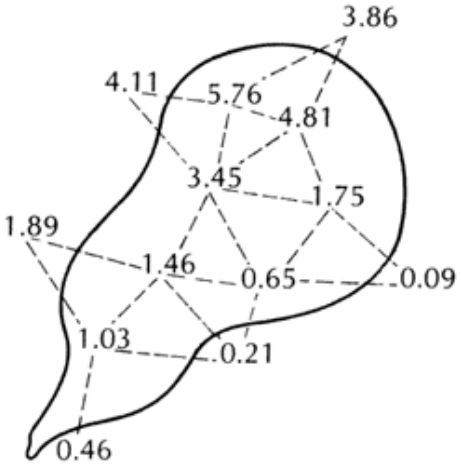
Precipitation

- Isohyetal lines

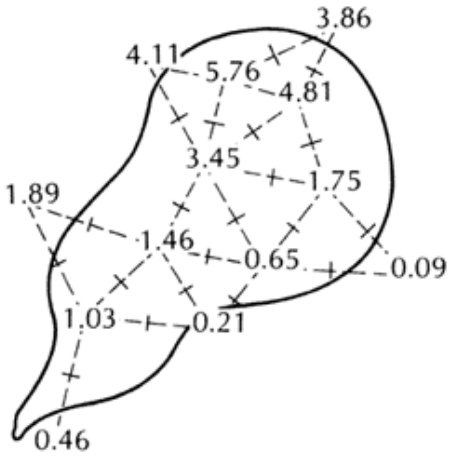


Precipitation

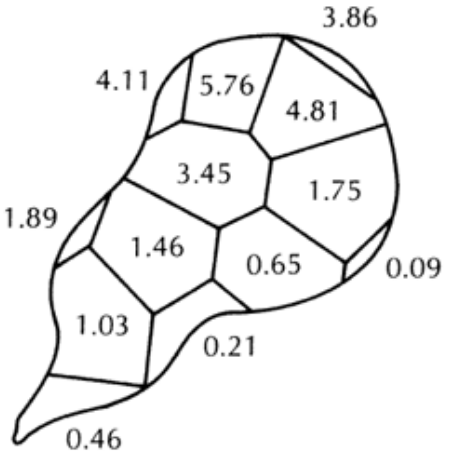
- Thiessen Method



A



B



C

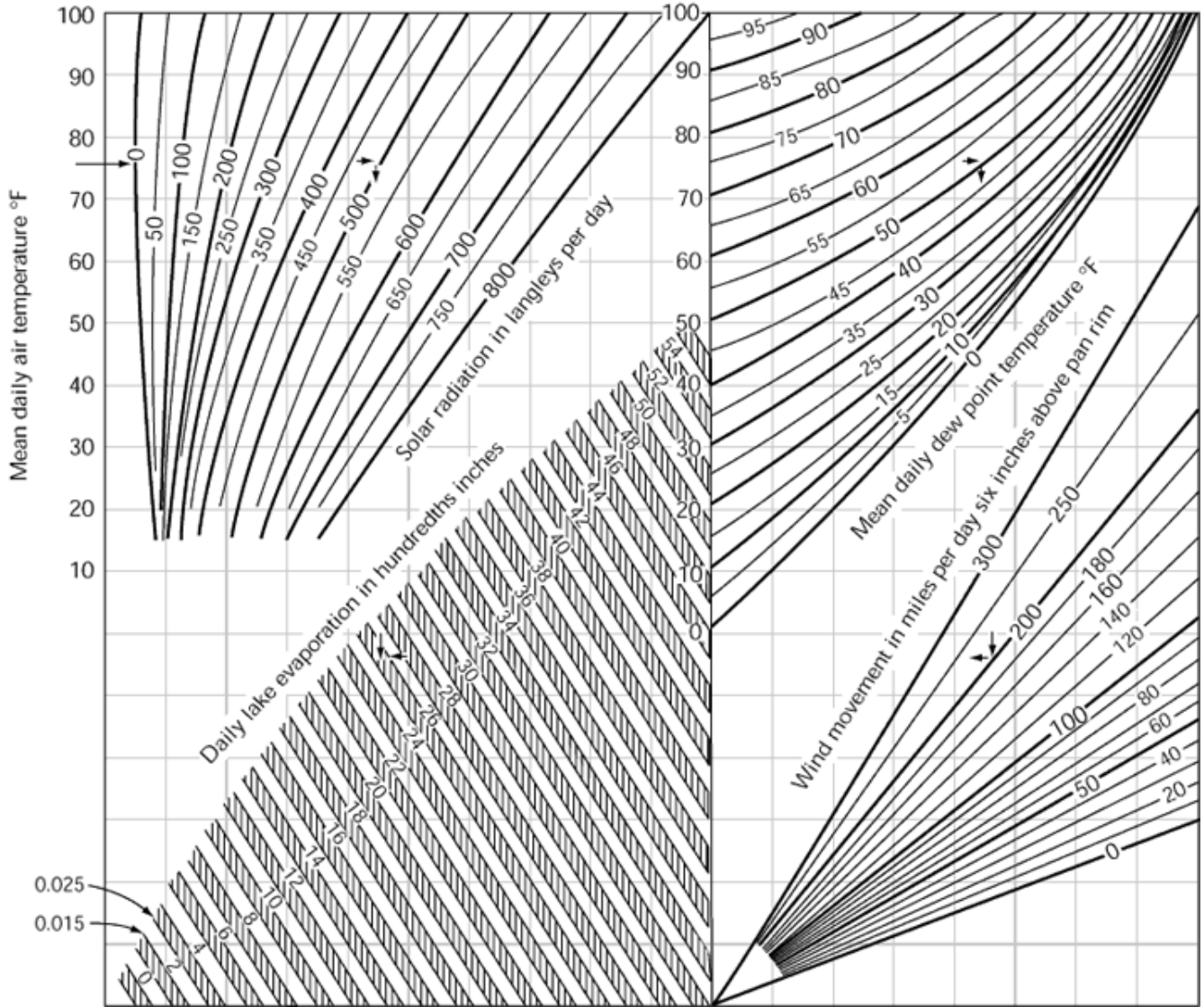
Evaporation

- Contributes to 90% of water vapor in atmosphere.
- Why does evaporation occur? (Hint: energy)
- When does evaporation occur?
- Are rates the same at different temperatures? At different humidity?
- Controlled by air temperature, solar radiation, dew point temperature, wind speed.
- At ocean, evaporation > precipitation; at land?

Evaporation

- Measured with Land pan
- Land pan coefficient (Table 2.2)
- Method to determine daily evaporation without a land pan (Fig. 2.1)

Evaporation



1. Begin reading the graph from the left side at the mean daily air temperature (F);
2. Draw horizontal line across the chart;
3. Perpendicular lines drawn at the intersections with the known values of solar radiation (langleys per day) and mean daily dew-point temperature (F);
4. The right perpendicular line extends from the dew-point temperature to the total daily wind movement (miles per day);
5. From the intersection in step 4 (perpendicular line and the known value of wind movement), draw a horizontal line to the left;
6. The horizontal line in step 5 and the left perpendicular line in step 3 crosses at an intersection.
7. From this intersection in step 6, the daily lake evaporation (in hundredths inches) can be read.

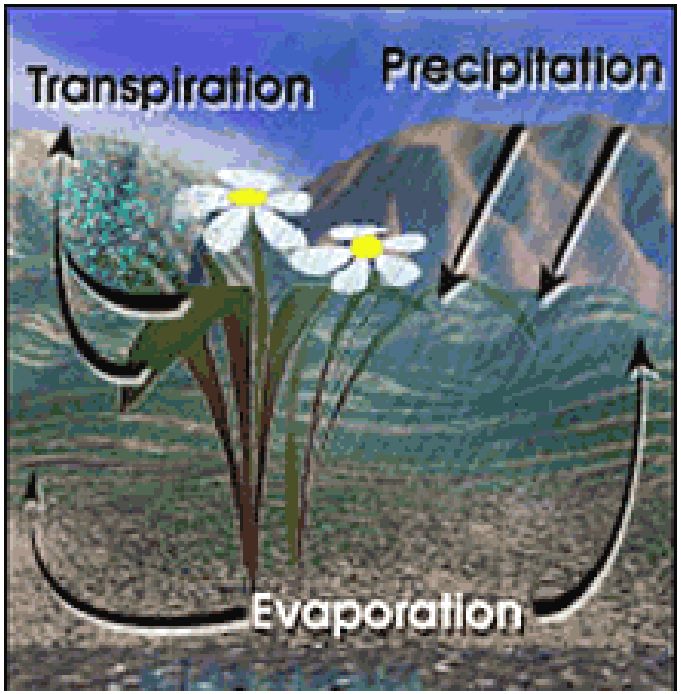
Evaporation

Table 2.2 Class A land pan coefficients for midwestern United States

January	0.62	August	0.75
February	0.72	September	0.73
March	0.77	October	0.69
April	0.77	November	0.63
May	0.78	December	0.58
June	0.77		
July	0.76		
	Annual 0.75		

Source: W. J. Roberts & J. B. Stall, Illinois State Water Survey Report of Investigation *(1967): 57.*

Evapotranspiration



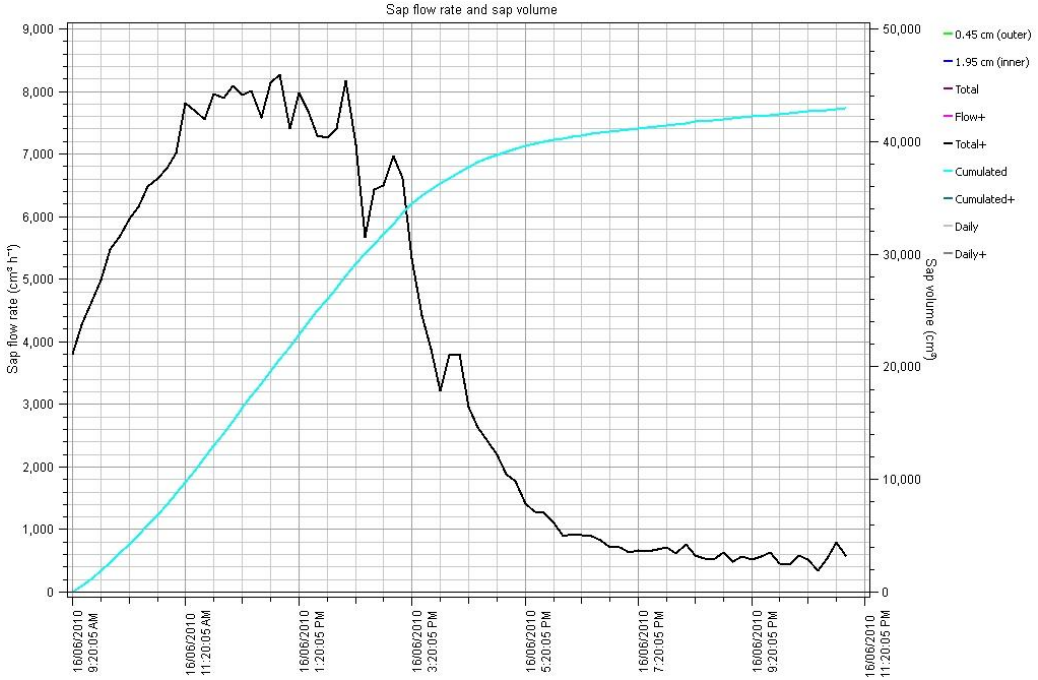
Hailey King, NASA, GFSC

Evaporation + Transpiration

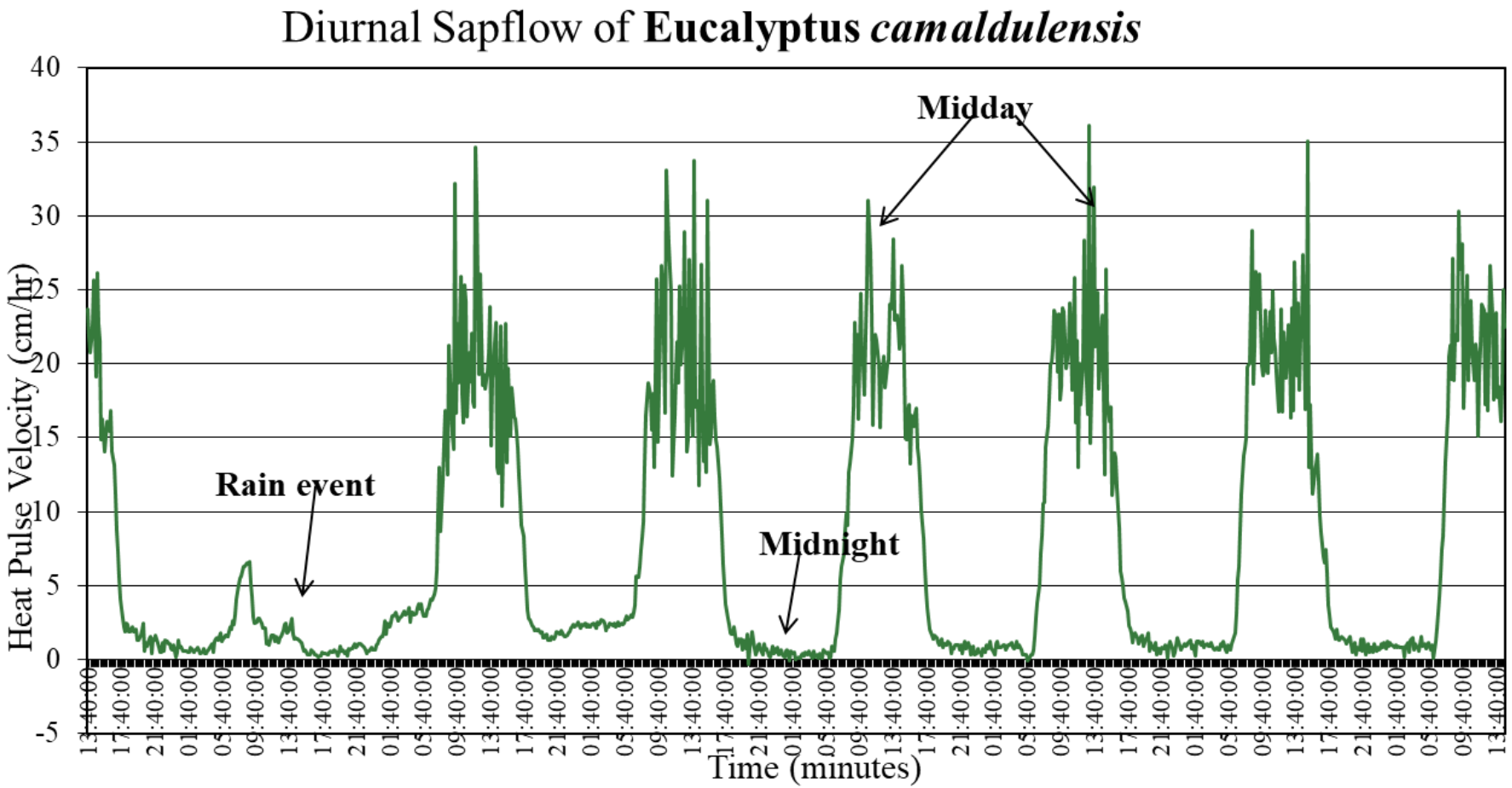
Factors affecting rates: Temperature, humidity, wind-air movement, soil moisture, type of plant

- During a growing season, a leaf will transpire many times more water than its own weight.
- An acre of corn gives off about 3,000-4,000 gallons (11,400-15,100 liters) of water each day,
- A large oak tree can transpire 40,000 gallons (151,000 liters) per year.

Sapflow Meter



Plant Response to Changes in Soil Water Content



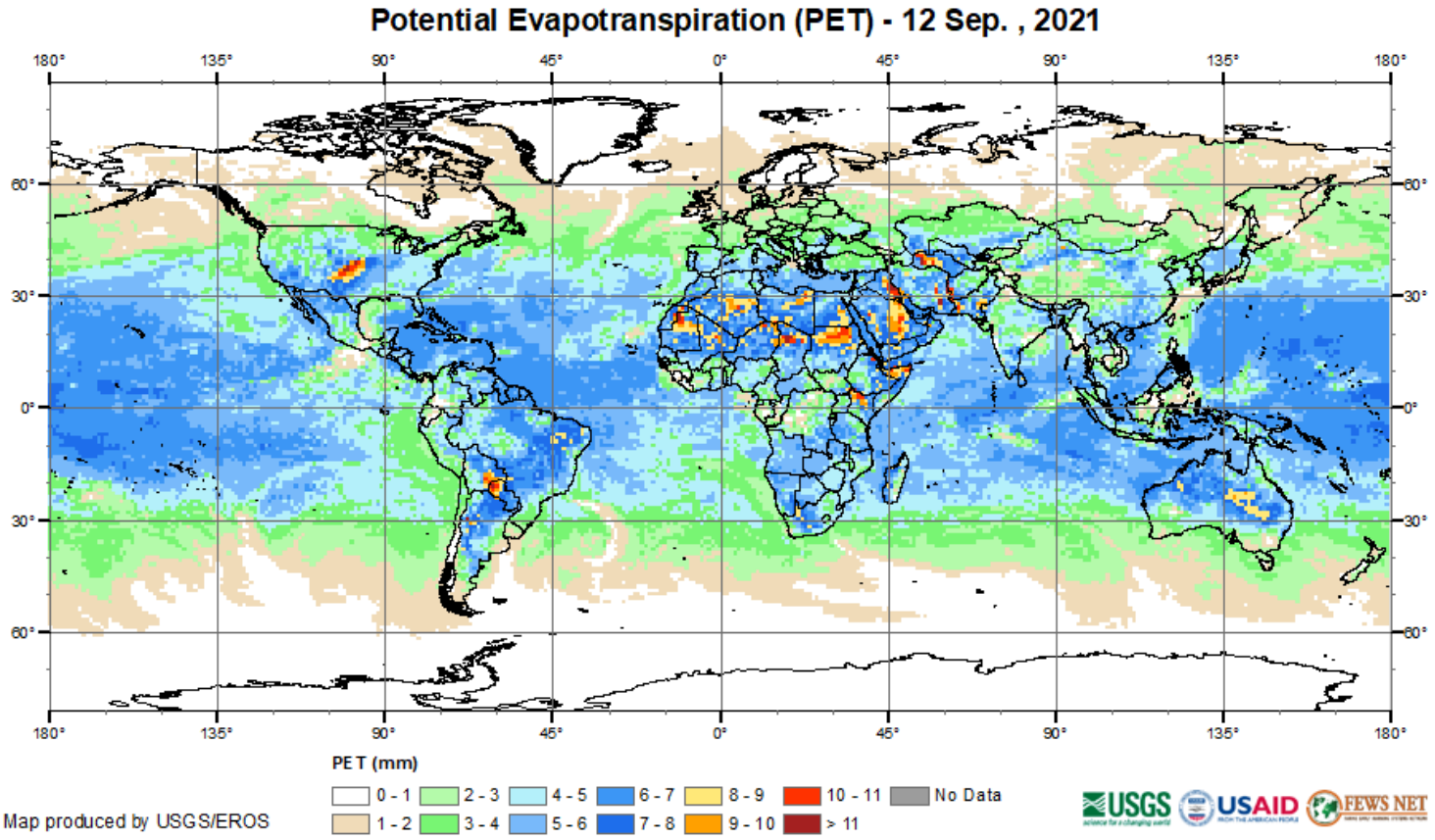
Evapotranspiration

Lysimeter

https://www.sciencedirect.com/topics/earth-and-planetary-sciences/lysimeters

Potential Evaporation & Evapotranspiration

- The amount of evaporation that would occur if a sufficient water source were available.
- If the actual evapotranspiration is considered the net result of atmospheric demand for moisture from a surface and the ability of the surface to supply moisture, then PET is a measure of the demand side.
- Surface and air temperatures, insolation, and wind all affect this.



Reference Evapotranspiration (ET_0)

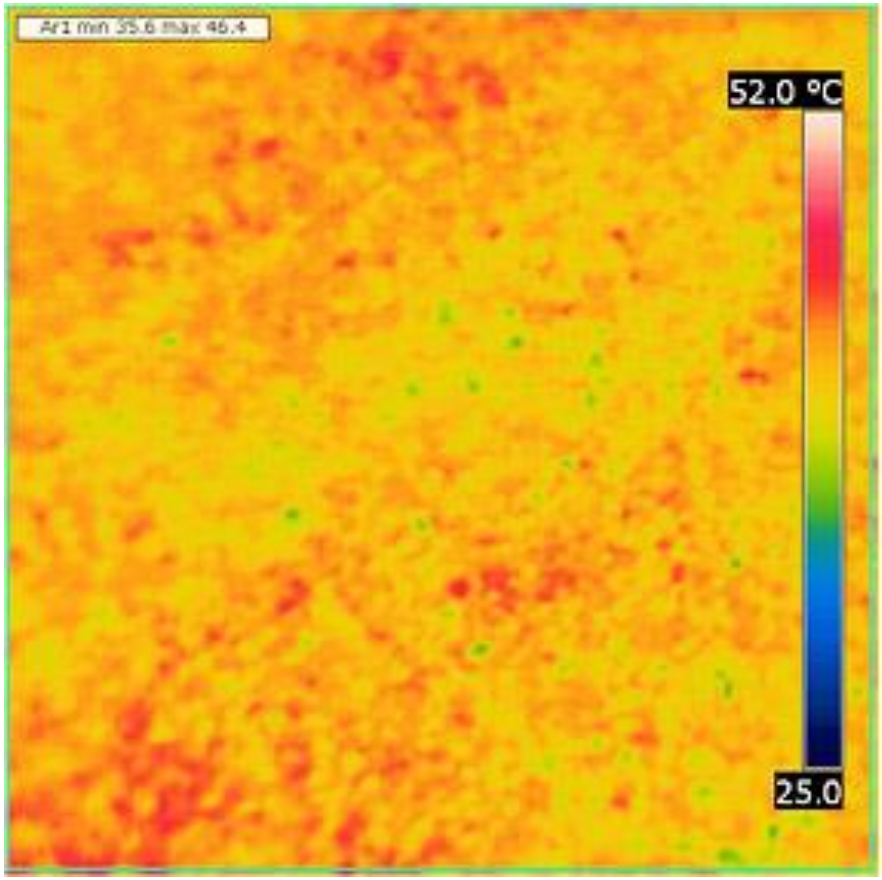
1. A hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23.
2. FAO Penman-Monteith Equation
3. Calibrated for ten day or monthly calculation, not for daily

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \dfrac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \dfrac{r_s}{r_a}\right)}$$

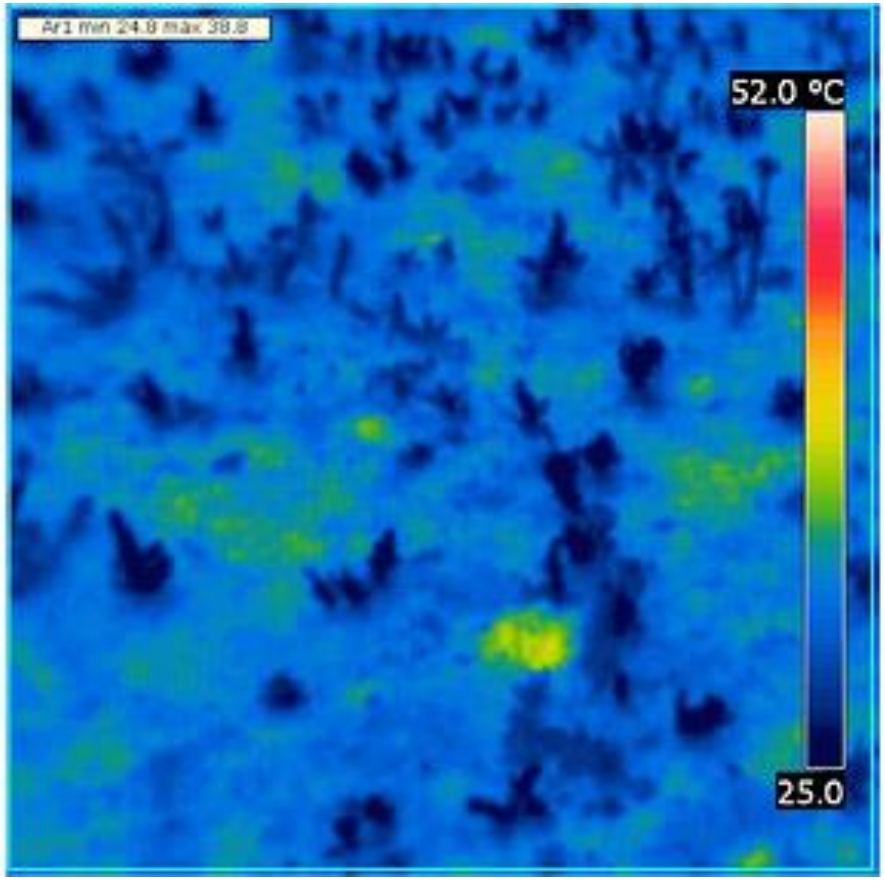
http://www.fao.org/3/X0490E/x0490e06.htm#reference%20surface

Evapotranspiration Cools Surrounding Area

Infra-red Images Comparing Roof Surface Temperature



Conventional Roof



Green Roof