CE 374 K – Hydrology

Precipitation

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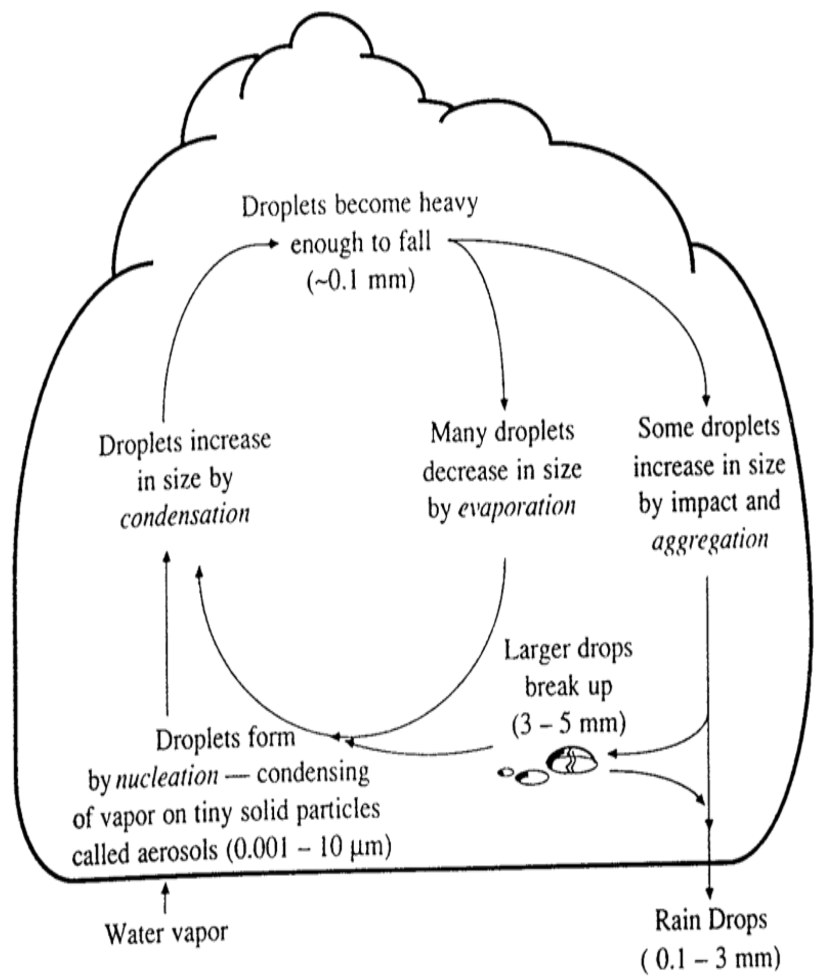
Precipitation

- Lifting cools air masses so moisture condenses
- Condensation nuclei
  - Aerosols (10^{-3} – 10 μm)
  - water molecules attach
- Rising & growing
  - Critical size (~0.1 mm)
  - Gravity overcomes and drop falls

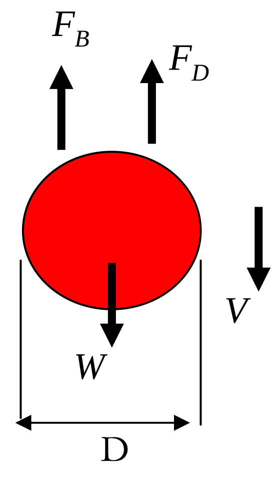


Terminal Velocity

- Three forces
  - Buoyancy, Friction, Gravity

$$\sum F_{vert} = 0 = F_B + F_D - W$$

$$= \rho_a g \frac{\pi}{6} D^3 + C_d \rho_a \frac{\pi}{4} D^2 \frac{V^2}{2} - \rho_w g \frac{\pi}{6} D^3$$



- Accelerate until terminal velocity, V_t
  - Where forces balance

$$F_D = F_B - W$$

$$C_d \rho_a \frac{\pi}{4} D^2 \frac{V_t^2}{2} = \rho_a g \frac{\pi}{6} D^3 - \rho_w g \frac{\pi}{6} D^3$$

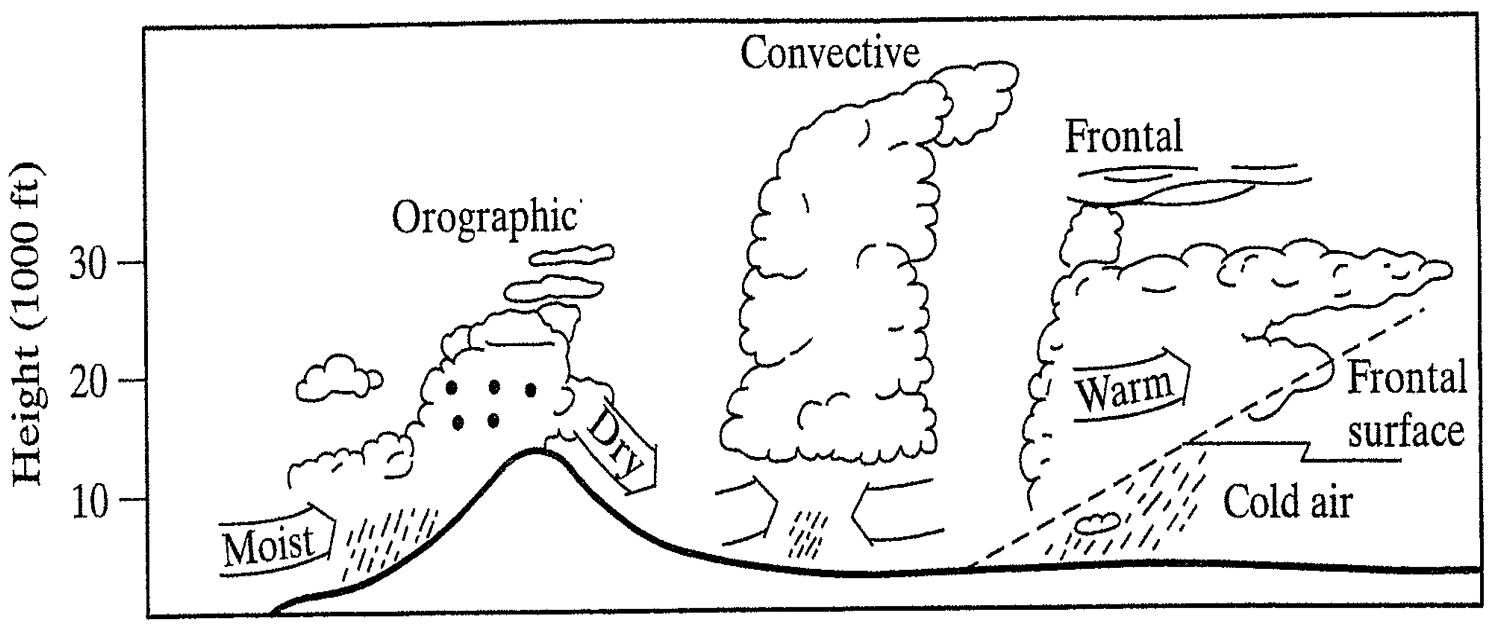
- Stokes Law

$$C_d = \frac{24}{\text{Re}} \qquad \text{Re} = \frac{\rho_a V D}{\mu_a}$$

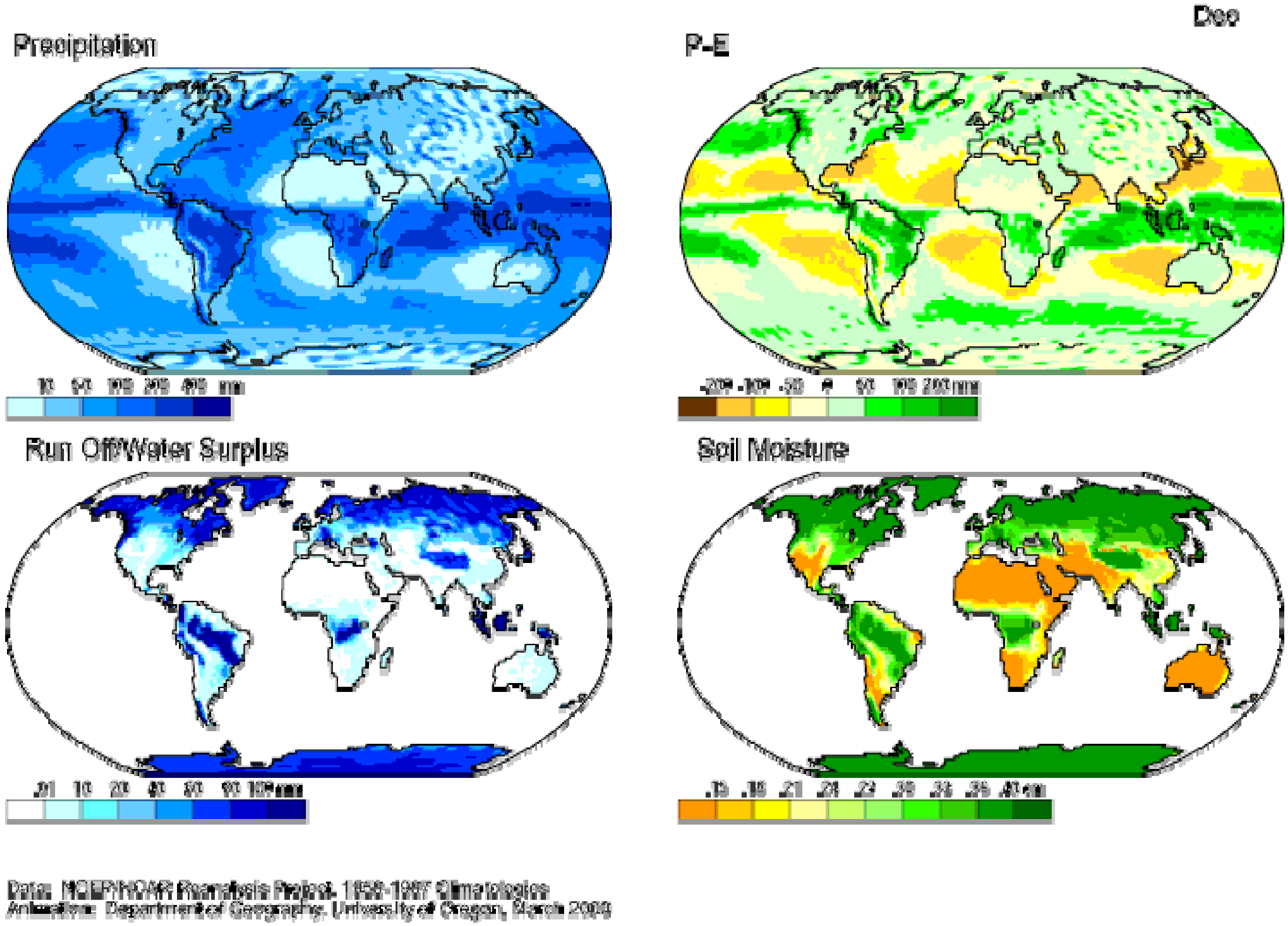
$$V_t = \sqrt{\frac{4gD}{3C_d}\left(\frac{\rho_w}{\rho_a} - 1\right)}$$

Precipitation Mechanisms

- **Convective**
  - Heating of air at ground level leads to expansion and rise of air
- **Frontal** (Cyclonic)
  - Movement of large air mass systems (warm & cold fronts)
- **Orographic**
  - Mechanical lifting of air masses over windward sides of mountain ranges



Global Precipitation



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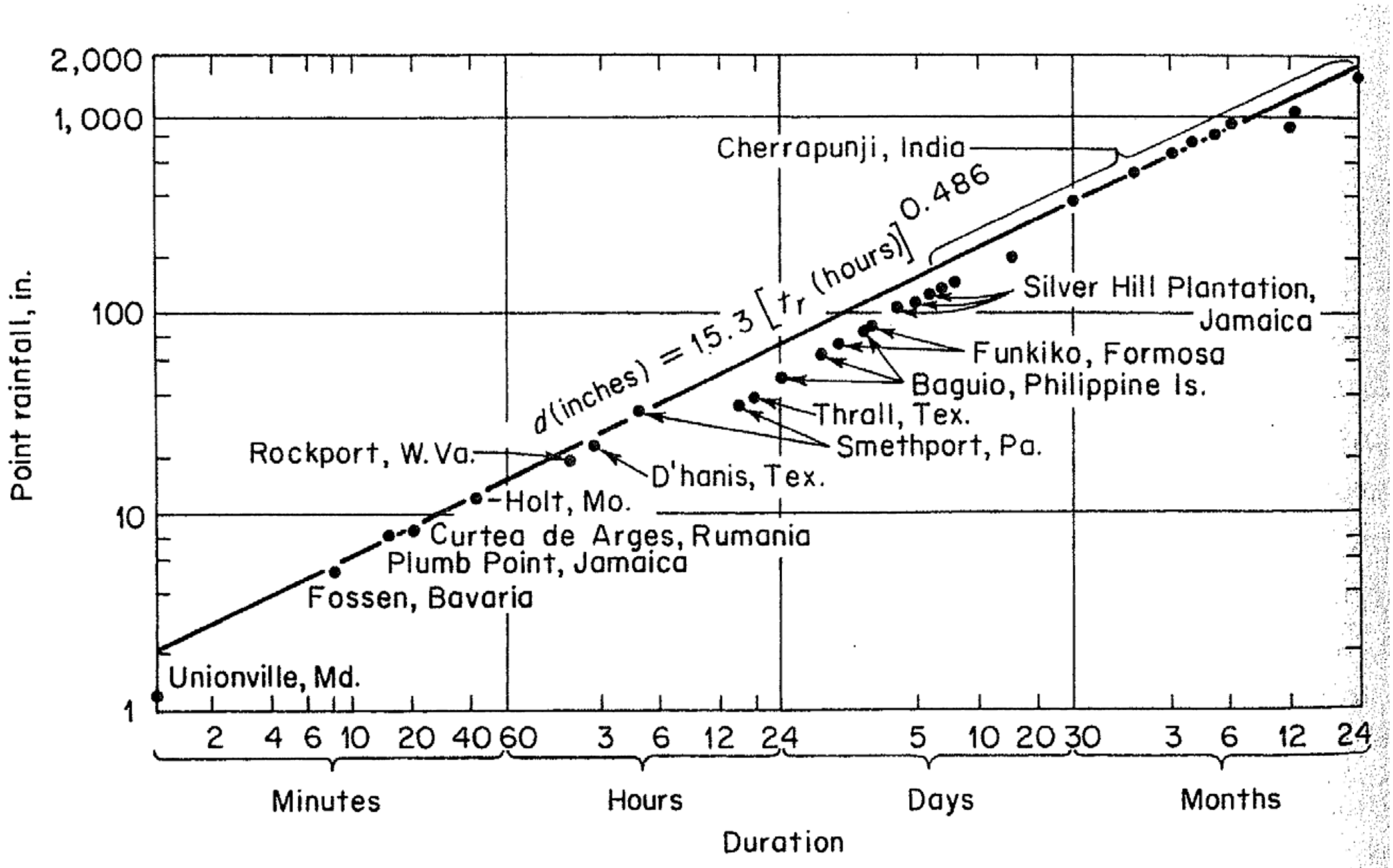
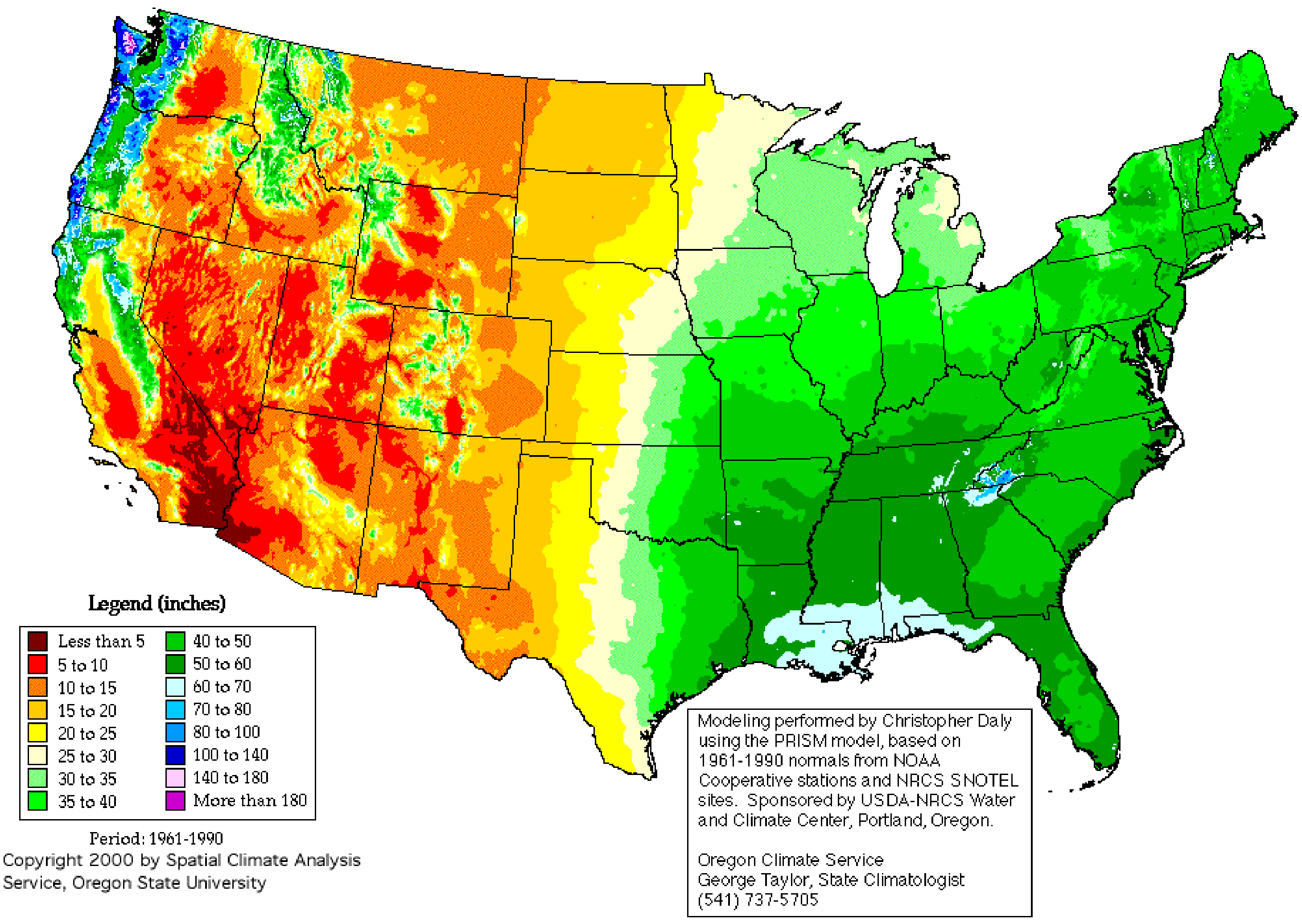
Greatest Rainfalls

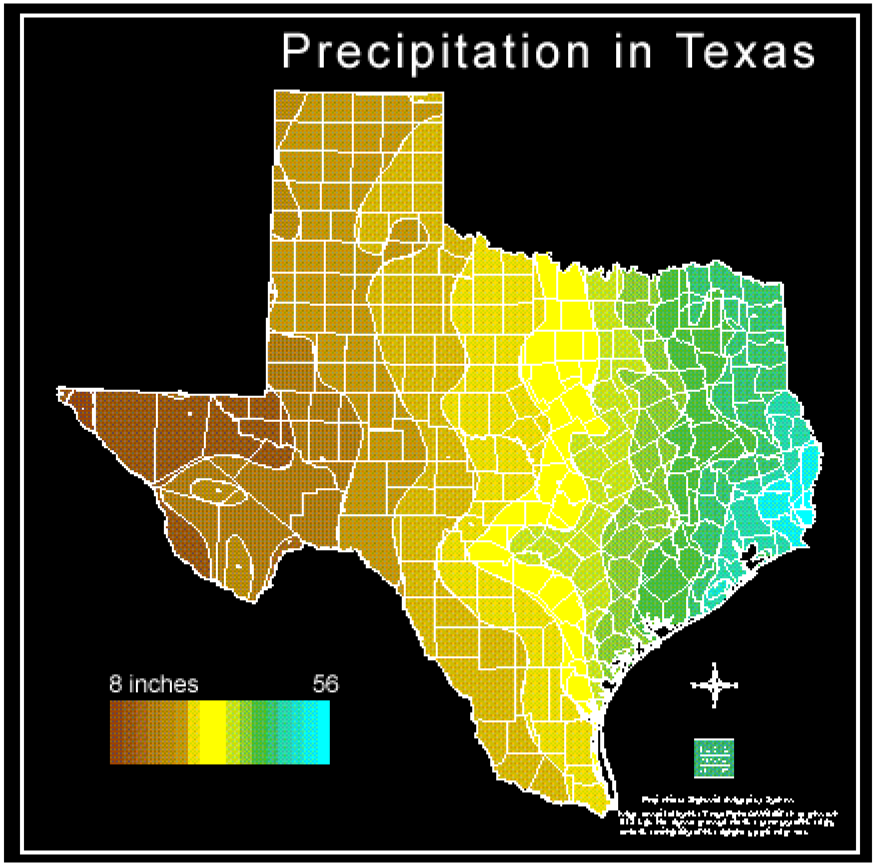


US Precipitation



Texas Precipitation

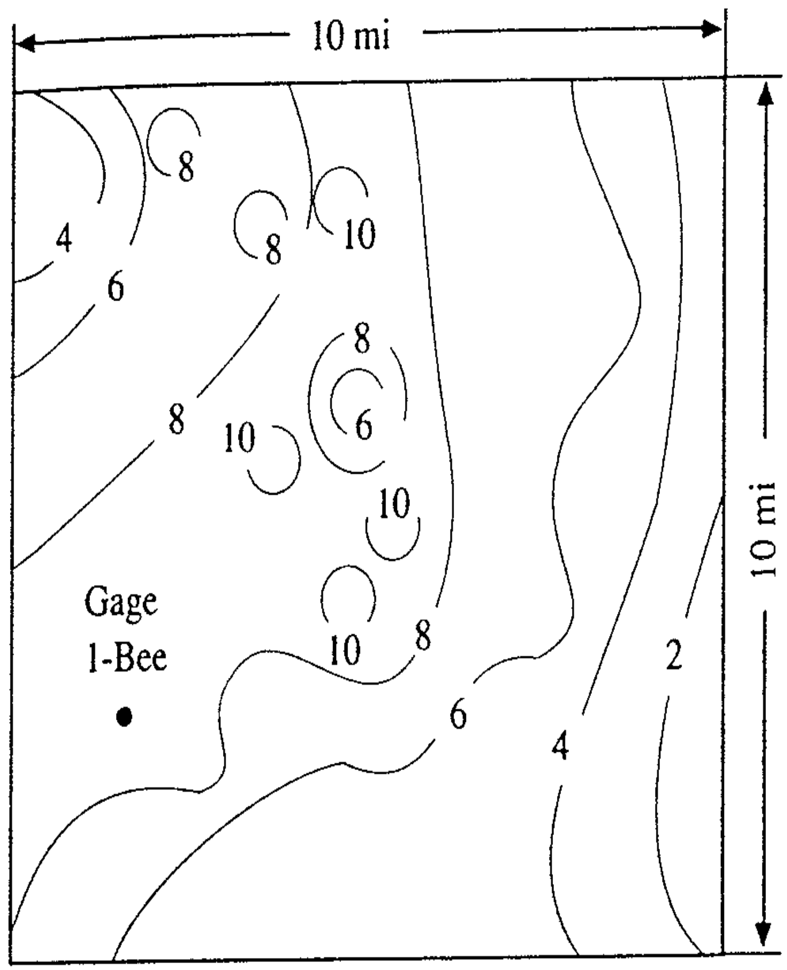
- Hyetograph – Graph of Precipitation
- Isohyet - Contour of equal precipitation



Precipitation Variation

- Influenced by
  - Atmospheric circulation and local factors
    - Higher near coastlines
    - Seasonal variation – annual oscillations in some places
    - Variables in mountainous areas
    - Increases in plains areas
    - More uniform in Eastern US than in West
    - Precipitation over the US:
      - http://weather.noaa.gov/radar/mosaic.loop/DS.p19r0/ar.us.conus.shtml

Isohyetal Map
Memorial Day Flood, Austin, 1981

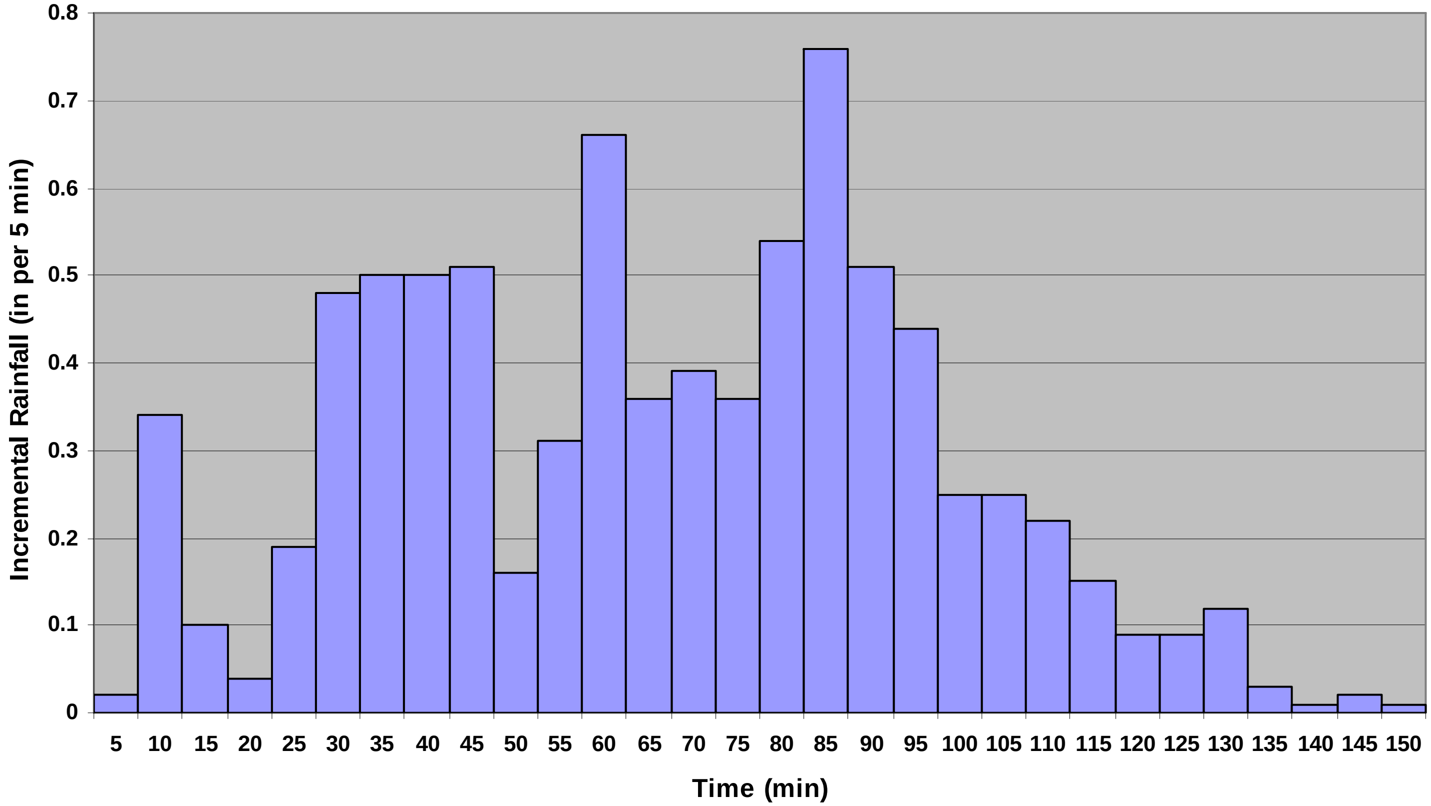


(*b*) Storm of May 24—25, 1981, in Austin, Texas. Maximum rainfall of 11 in. recorded over 3 hours. Isohyets are in inches depth of total rainfall in the storm. (*Source*: Massey, Reeves, and Lear, 1982.)

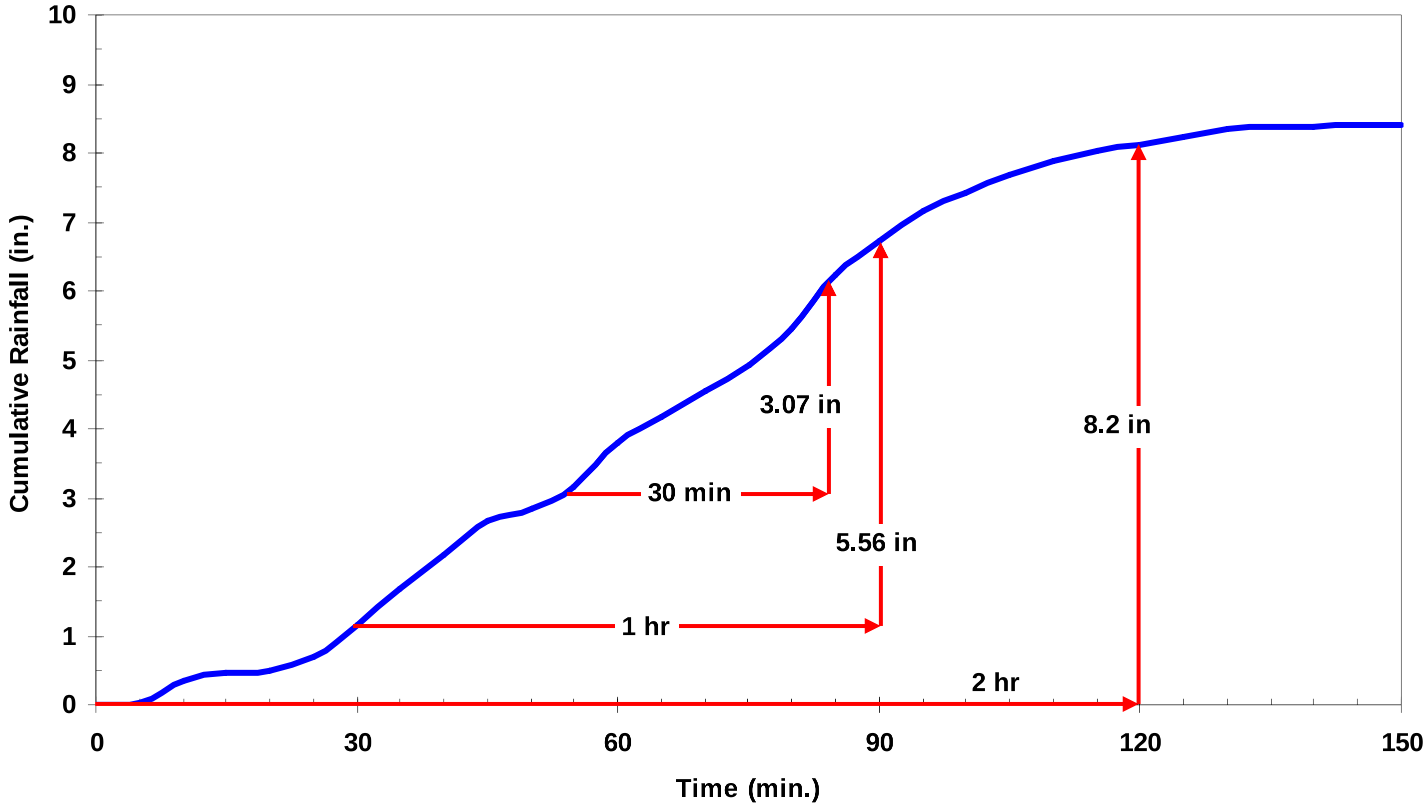
Rainfall Depth and Intensity

			Running Totals		
Time (min)	**Incremental Rainfall (in)**	**Cumulative Rainfall (in)**	**30 min**	**1 h**	**2 h**
0		0			
5	0.02	0.02			
10	0.34	0.36			
15	0.1	0.46			
20	0.04	0.5			
25	0.19	0.69			
30	0.48	1.17	1.17		
35	0.5	1.67	1.65		
55	0.31	3.15	2.46		
60	0.66	3.81	2.64	3.81	
115	0.15	8.04	1.82	4.89	
120	0.09	8.13	1.4	4.32	8.13
150	0.01	8.41	0.28	1.68	7.24
Depth	0.76		3.07	5.56	8.2
Intensity	9.12364946		6.14	5.56	4.1

Incremental Rainfall



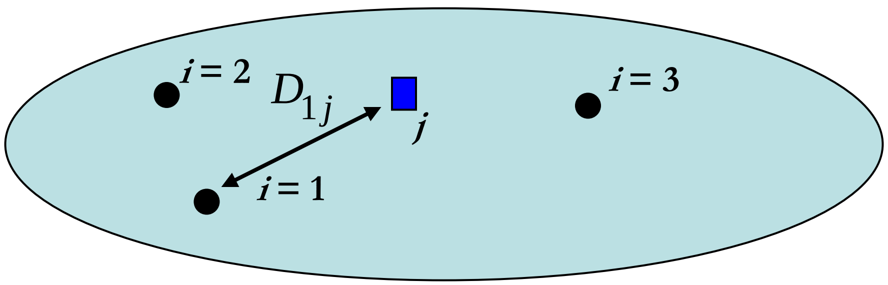
Cumulative Rainfall



Point Precipitation Estimates

- Estimate point rainfall at a given location from recorded values at surrounding sites

$$D_{ij}^2 = \left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2$$ **Distance from ungaged Point *j* to gage *i***



$$W_{ij} = \frac{1}{D_{ij}}$$ **Weight**

$$\hat{P}_j = \frac{1}{\sum_{i=1}^{I} W_{ij}} \sum_{i=1}^{I} W_{ij} P_i$$ **Precipitation Estimate at ungaged Point *j***

Areal Precipitation Estimates

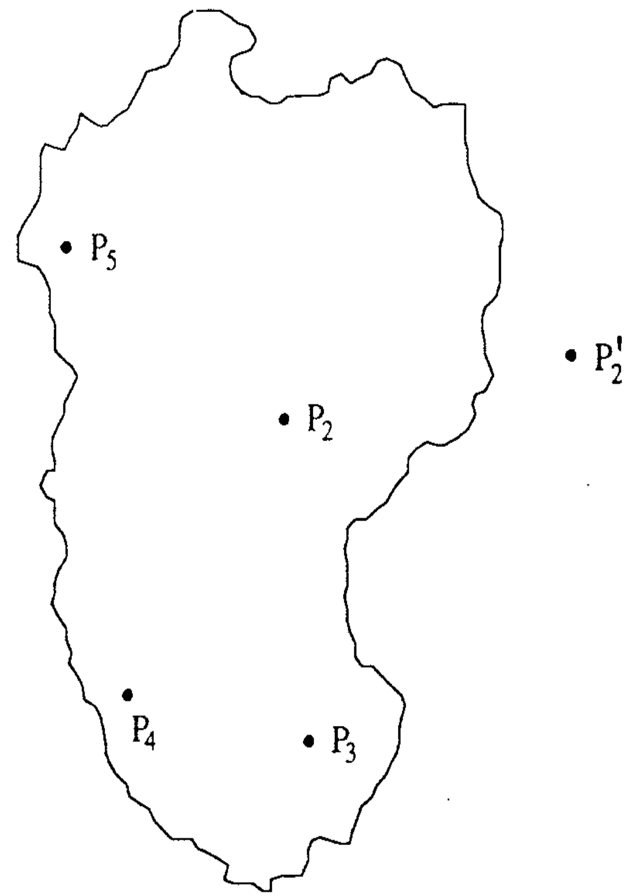
- Precipitation is highly variable in time and space
- Mean areal precipitation
  - Areal mean $$P_1 = \frac{1}{A}\int_A f(x)dx$$
  - Precipitation at point *x* $f(x)$
  - Long-term areal average $$P_2 = \frac{1}{T}\frac{1}{A}\sum_{t=1}^{T}\int_A f(x,t_i)dx$$
  - Precipitation at point *x* and time t_i $f(x,t_i)$
  - Unfortunately, we don't know the precipitation value at all points *x*, so we have to use an approximation

Areal Precipitation Estimates: Arithmetic Mean

$$\overline{P} = \frac{1}{J} \sum_{j=1}^{J} P_j$$

Station, *j*	**Observed Rainfall Mm, P_j**
P2	20
P3	30
P4	40
P5	50
	140

Ave. Rainfall = 140/4 = 35 mm

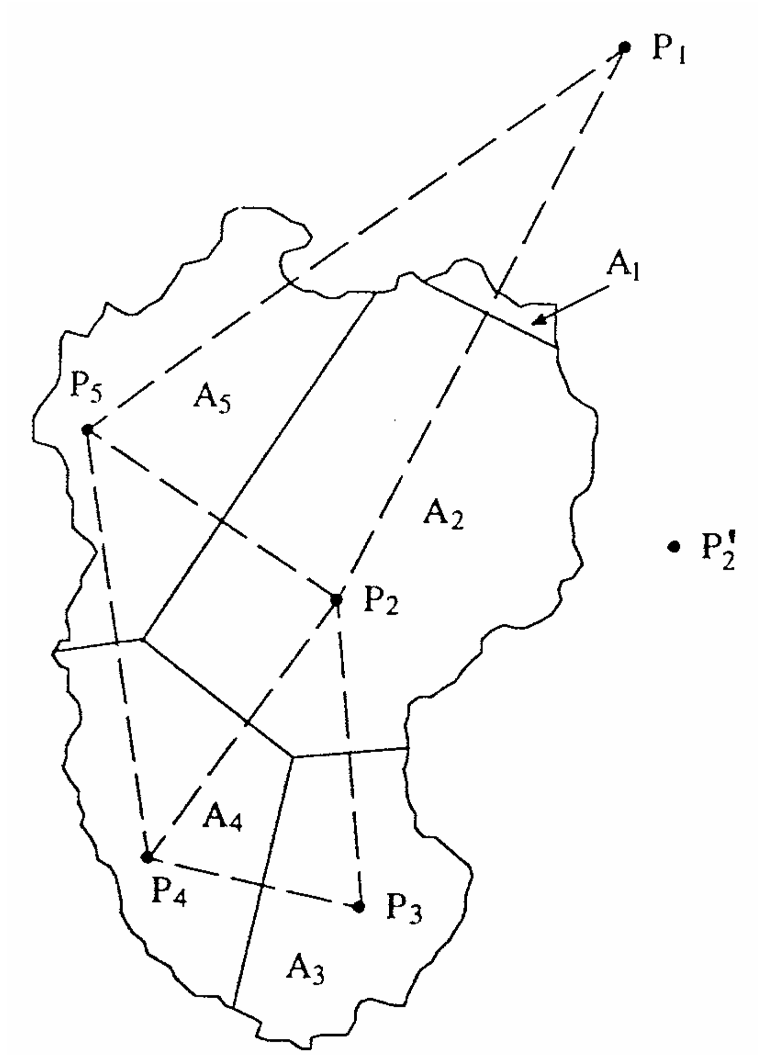


Areal Precipitation Estimates: Thiessen Polygon Method

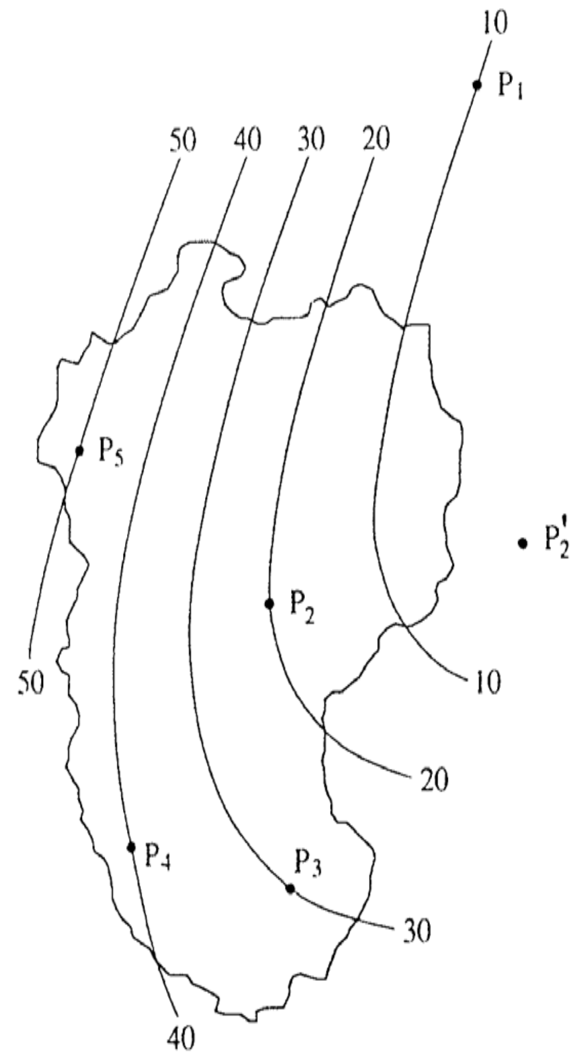
$$\overline{P} = \frac{1}{A}\sum_{j=1}^{J} A_j P_j$$

Statio, *j*	Observed Rainfall Mm, P_j	Area, *A* km²	Weighted Rainfall, $A_j P_j$ mm
P1	**10**	**0.22**	**2.2**
P2	**20**	**4.02**	**80.4**
P3	**30**	**1.35**	**40.5**
P4	**40**	**1.60**	**64.0**
P5	**50**	**1.95**	**97.5**
		9.14	**284.6**

Ave. Rainfall = 284.6/9.14 = 31.1 mm



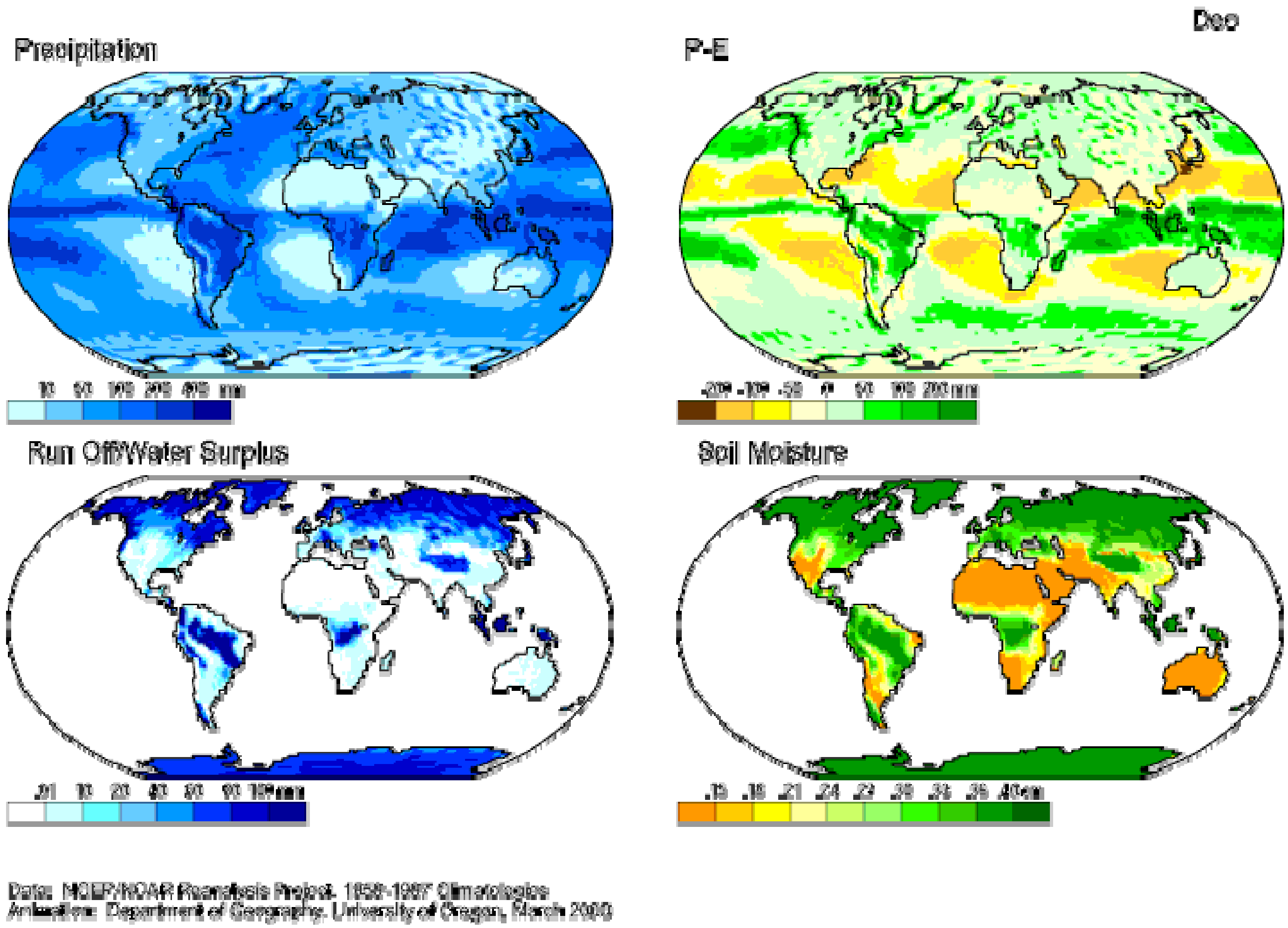
Areal Precipitation Estimates: Isohyetal Method



Ave. Rainfall = 255.2/9.14 = 27.9 mm

Areal Precipitation Estimates
Three Methods

- **Arithmetic Average**
  - Gages must be uniformly distributed
  - Individual variations must not be far from mean rainfall
  - Not accurate for large area where rainfall distribution is variable
- **Thiessen Polygon**
  - Areal weighting of rainfall from each gage
  - Does not capture orographic effects
  - Most widely used method
- **Isoheytal**
  - Most accurate method
  - Extensive gage network required
  - Can include orographic effects and storm morphology



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