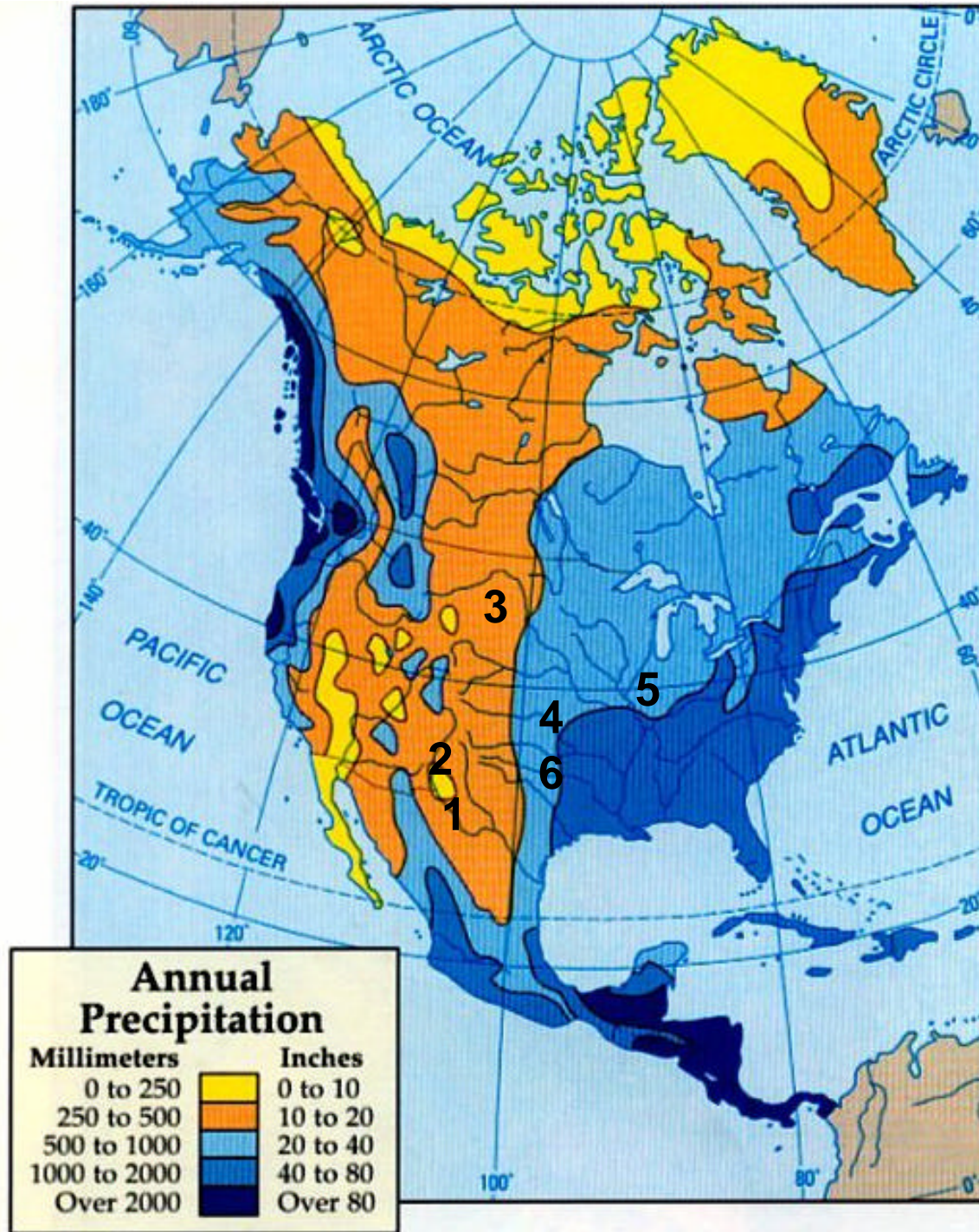


# **Quantifying the Exchange of Water and Energy between Land and Atmosphere in Semi-arid Area**

Jie Song  
Department of Geography  
Northern Illinois University  
USA



**1. Audubon Research Ranch, Arizona**

**2. Santa Rita Mesquite, Arizona**

**3. Fort Peck, Montana**

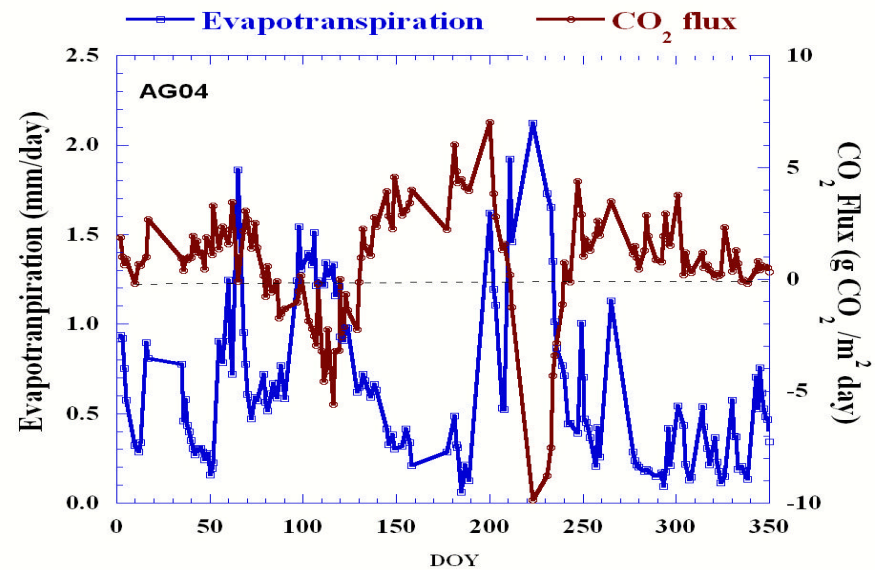
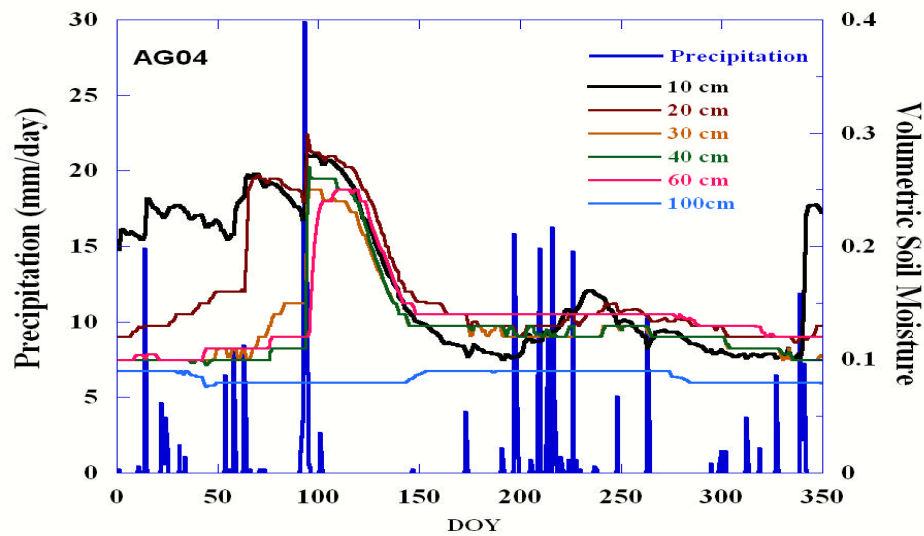
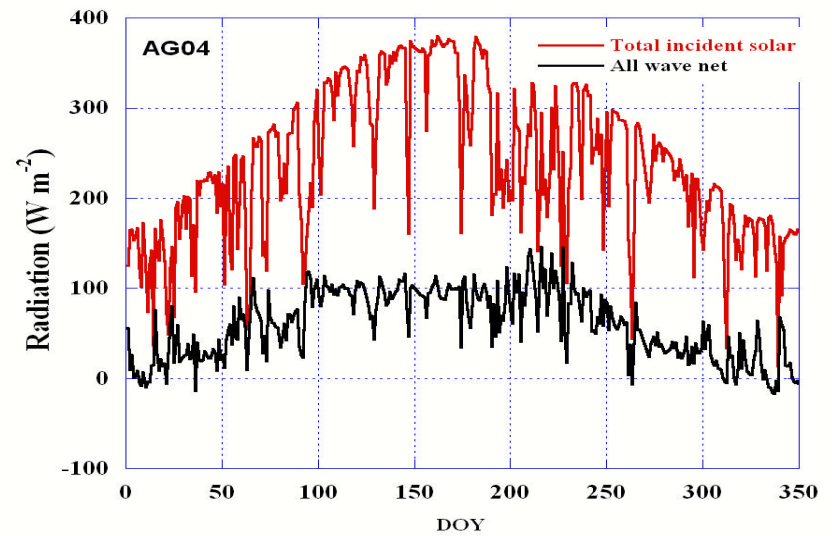
**4. Walnut River Watershed, Kansas**

**5. Bondville, Illinois**

**6. Southern Great Plains, Oklahoma**

# Audubon Research Ranch, Arizona

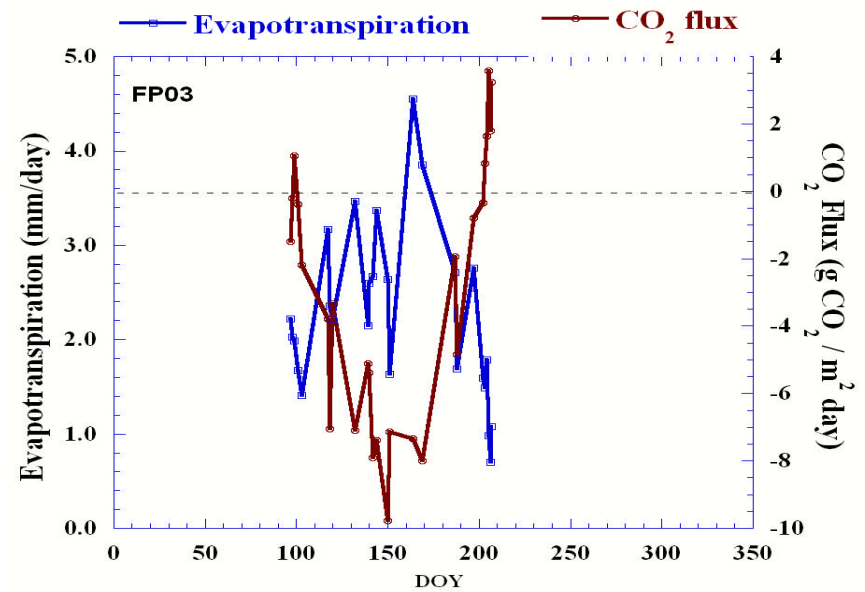
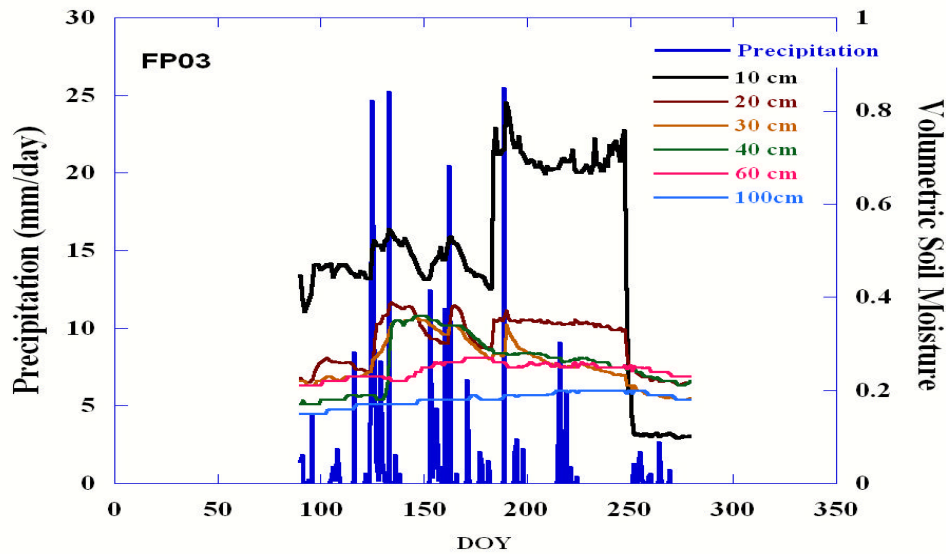
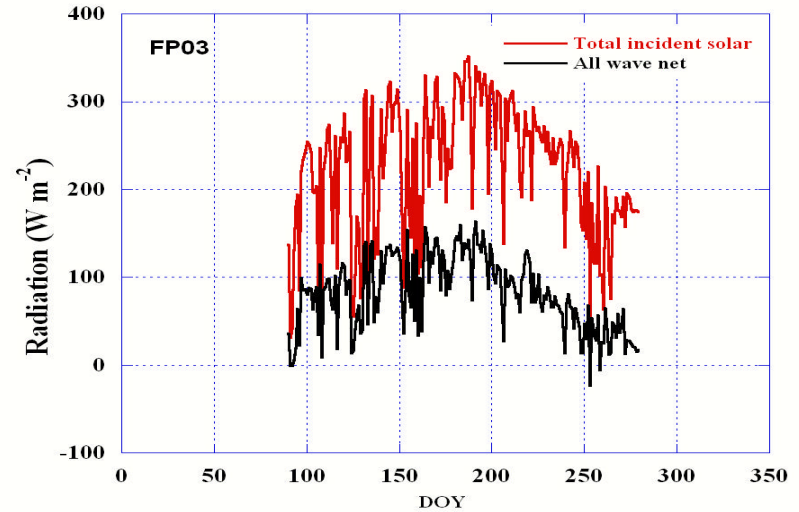
**Climate:** Temperate arid, **Precipitation:** ~ 200mm  
**Vegetation:** Desert grassland



# Fort Peck, Montana



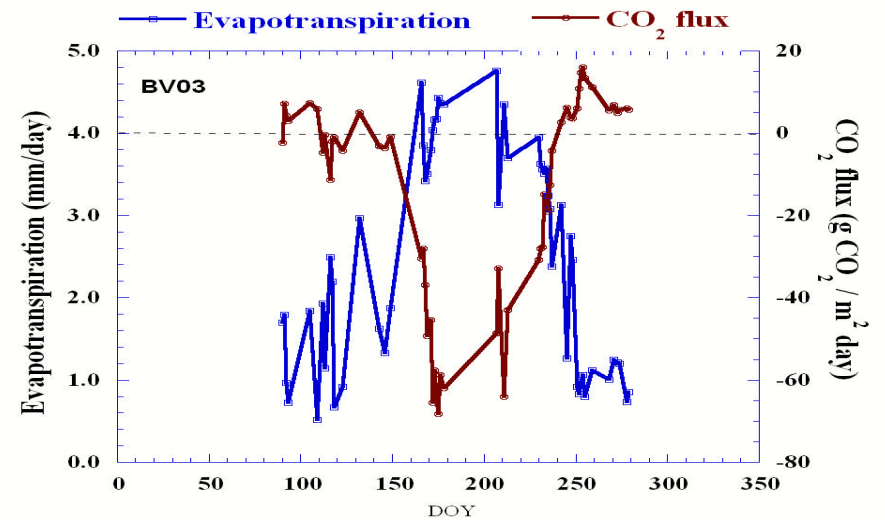
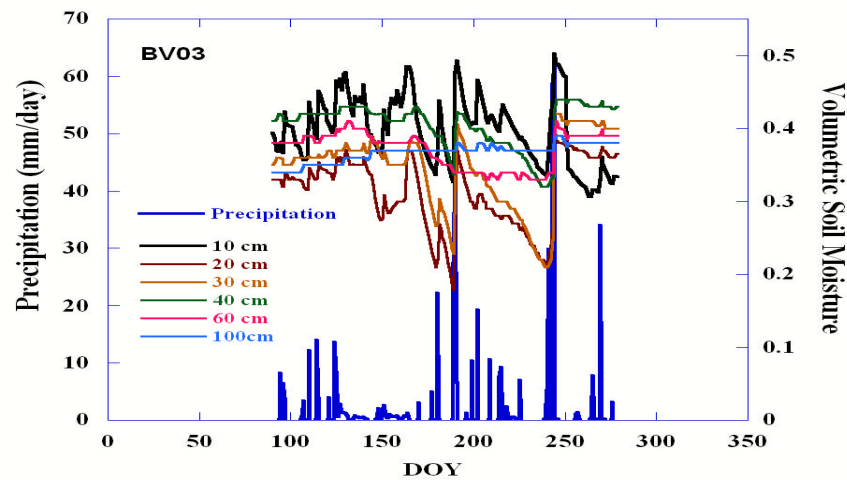
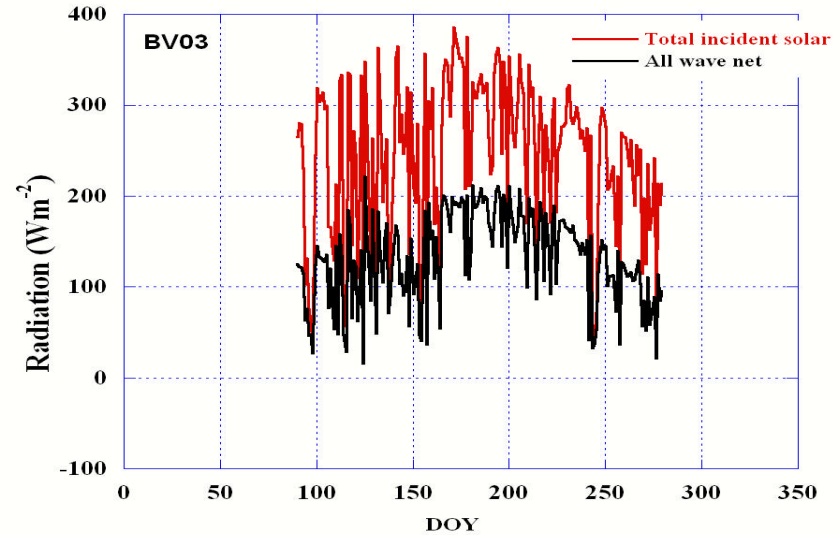
Precipitation: ~ 400 mm  
Vegetation: temperate grassland,  
LAI~2, canopy height 20~40 cm



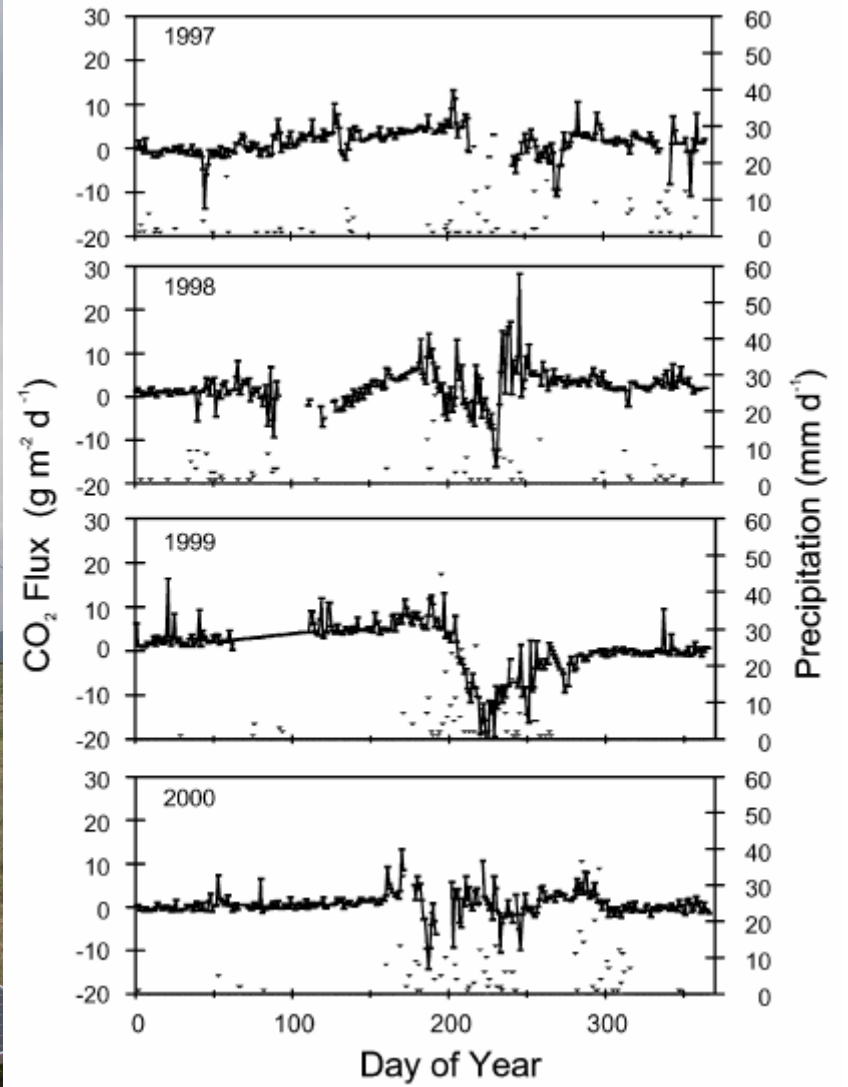
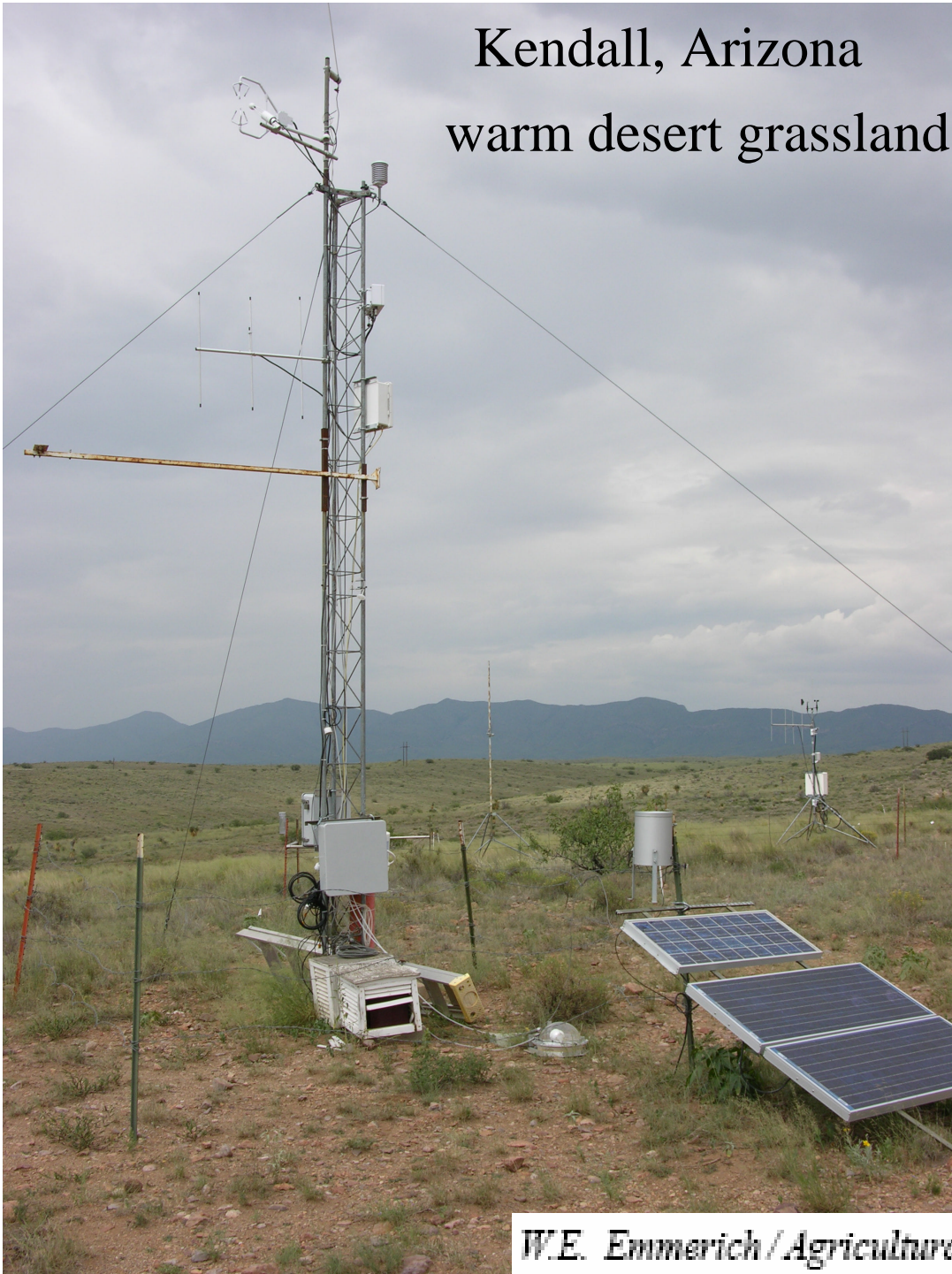


# Bondville, Illinois

Temperate continental climate  
Vegetation: corn/soybean



Kendall, Arizona  
warm desert grassland

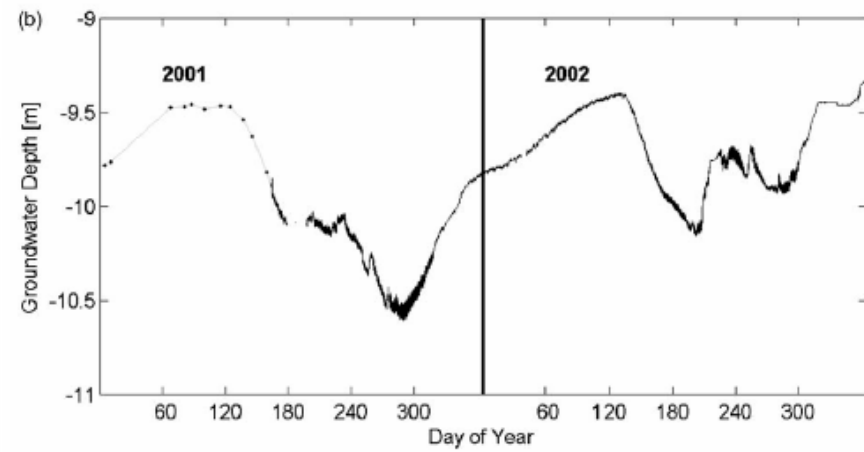
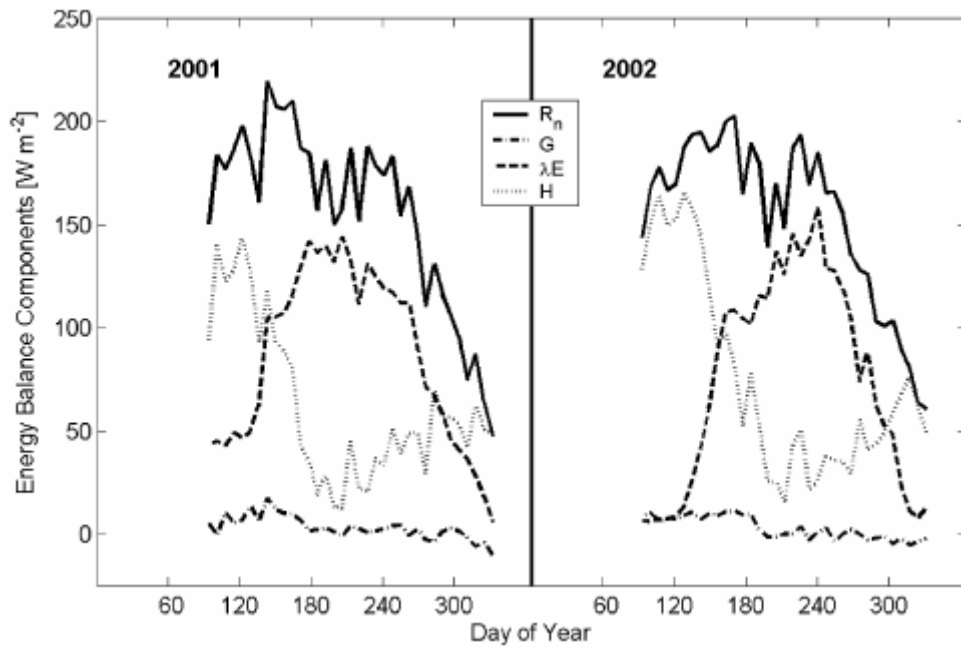
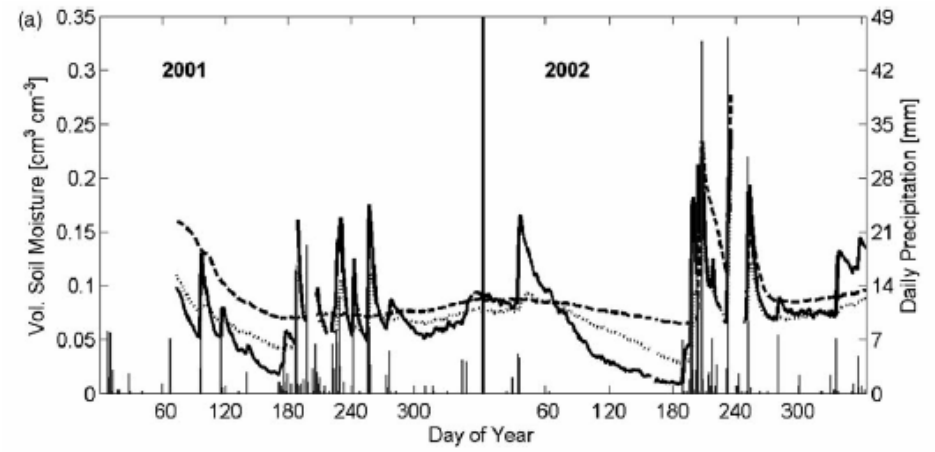
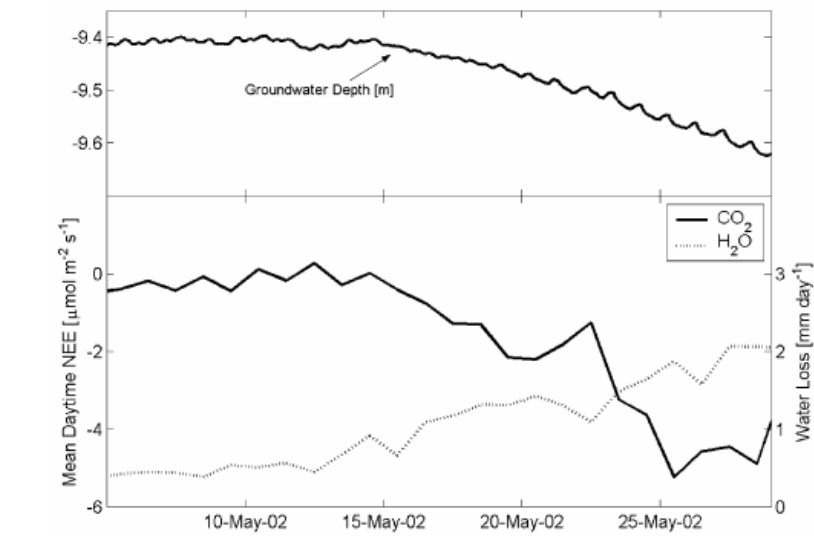




## **Santa Rita Mesquite, Arizona**

**Precipitation:** ~ 330mm  
Subtropical arid climate  
experimental research  
rangeland

**Stand age:** 100 years ago  
nearly all native C4 grassland,  
now mesquite dominated  
savanna with introduced C3  
grass



**Mesquite site, Arizona**

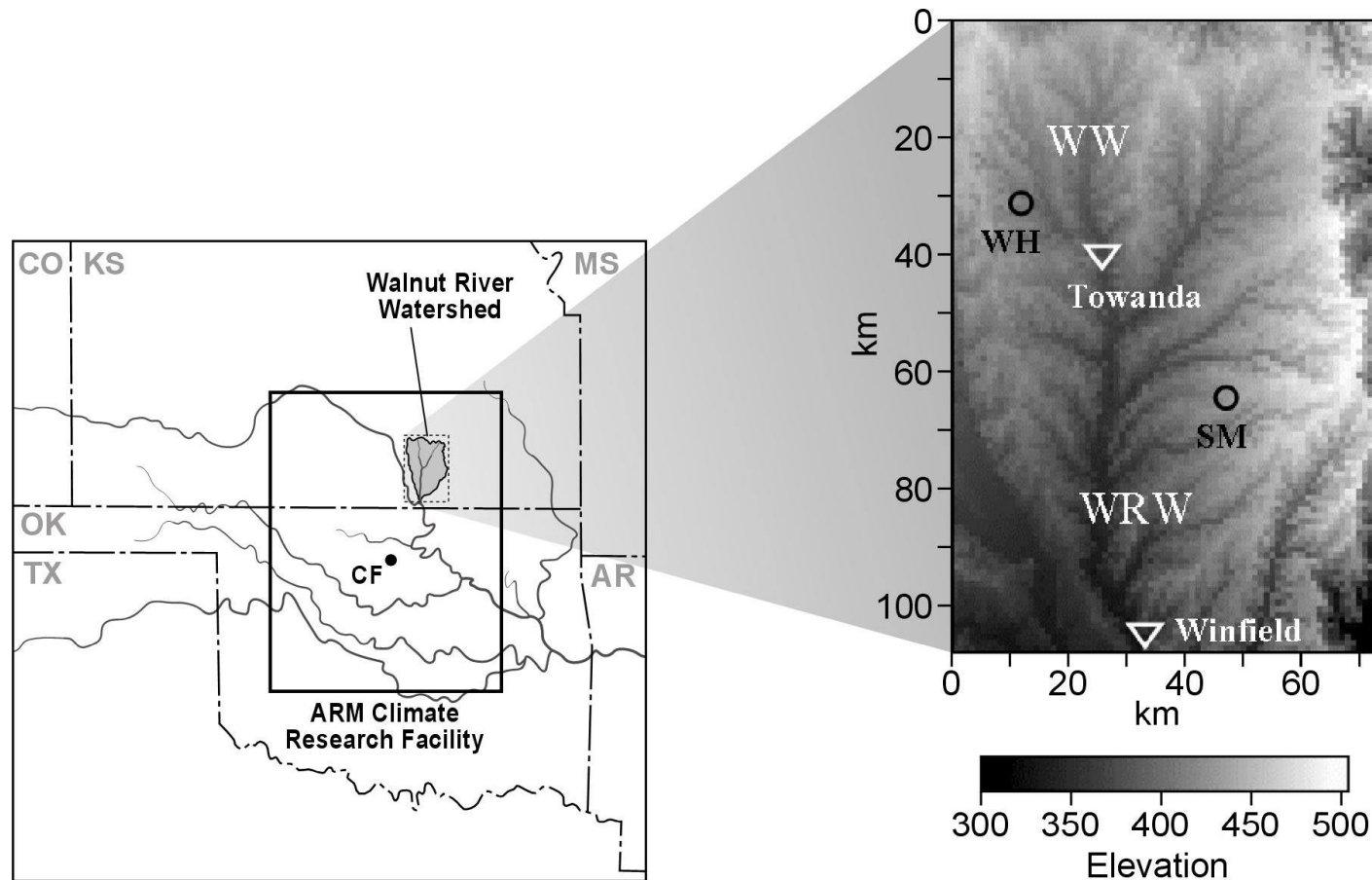


# Southern Great Plains ARM site, Lamont, Oklahoma

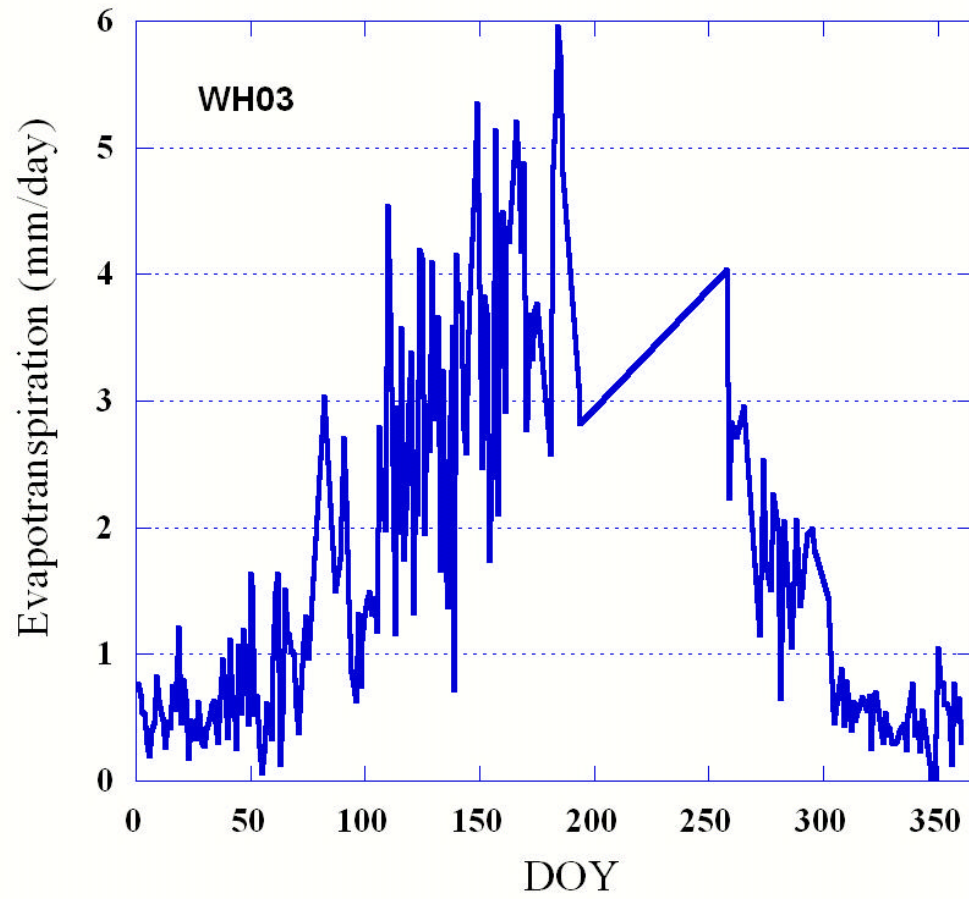


# Estimating the Long-Term Hydrological Budget over Heterogeneous Surfaces

Song et al. *JHM*, 2006 Vol. 7, No. 1, 203–214.

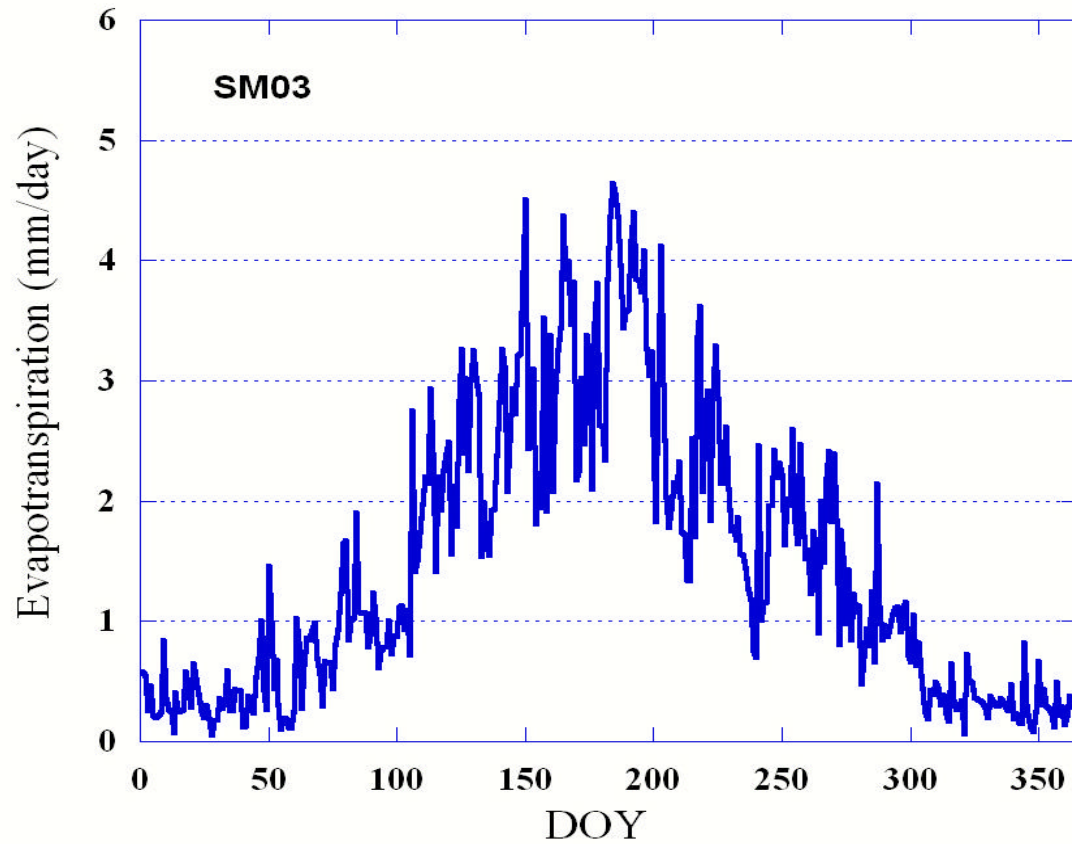


Walnut River Watershed (WRW with outlet at Winfield) and Whitewater Watershed (WW with outlet at Towanda): geographic locations, topography



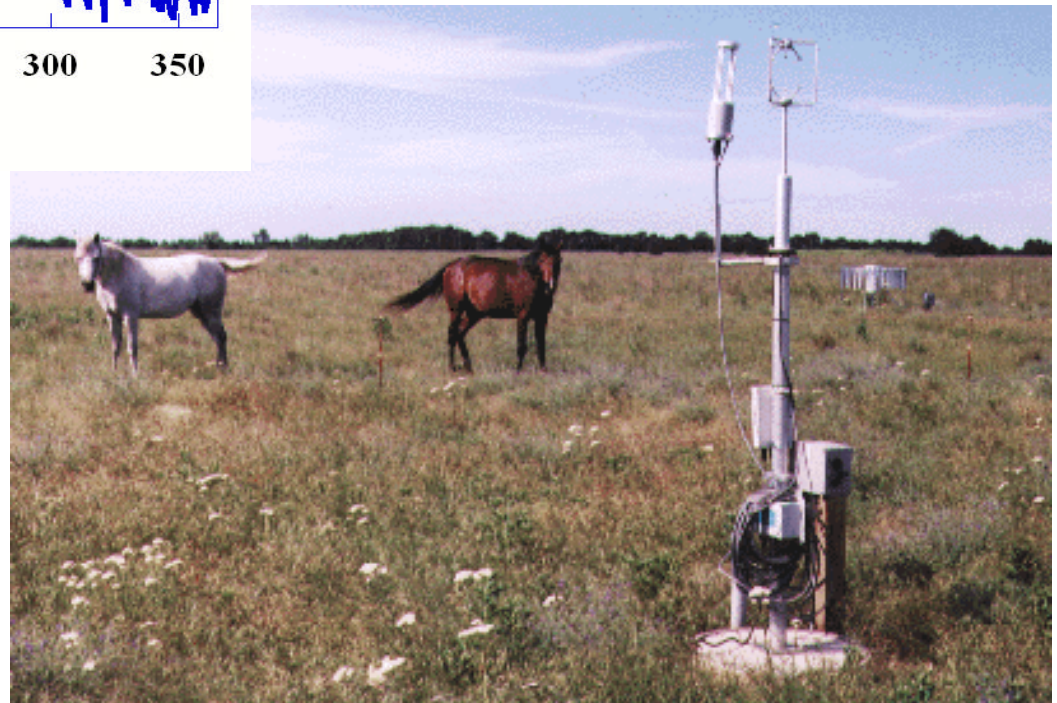
Whitewater, Kansas





## Smileyberg, Kansas

**Climate:** Temperate continental  
C3/C4 mixed grassland,  
tallgrass prairie



# Coupling Satellite Observation with Surface Measurements

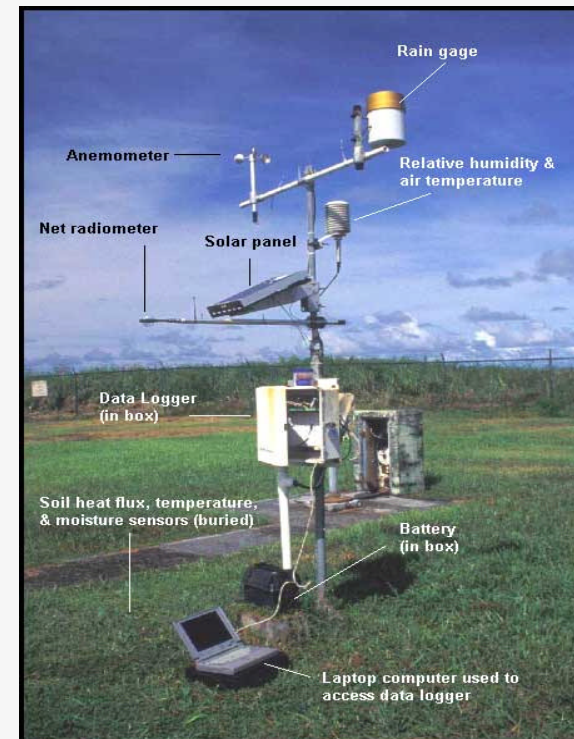
## Satellite Observation

Spatially covered  
Temporally intermittent



## Surface Station

Spatially localized  
Temporally continuous



# Procedure to Estimate Root-Zone Soil Moisture

## Model Inputs

Satellite data:

$$\text{NDVI}^i \text{ or } \text{SR}^i, T_s^i$$

Meteorological observations:

$$\bar{K} \downarrow, \bar{T}_a, \overline{\text{RH}}, \bar{u}$$

Land use data and  $q_A$

## Precalculation

pixel   means

$$\mathbf{a}^i \quad \bar{z}_o$$

$$\Gamma^i \quad \bar{G}_c$$

$$z_o^i \quad \overline{\text{SR}}$$

$$G_c^i \quad \bar{T}_s$$

## Subgrid -Scale Distribution

$$u^i = \bar{u} \left[ \frac{\ln(z/z_o^i)}{\ln(z/\bar{z}_o)} \right]^{1/2}$$

$$T_a^i = \bar{T}_a + \mathbf{a}_T (T_s^i - \bar{T}_s)$$

$$e_a^i = \bar{e}_a + \mathbf{a}_e (e_{sf}^i - \bar{e}_{sf})$$

## Postcalculation

$$u_*^i$$

$$R_a^i$$

$$G_c^i$$

## Energy Balance

$$R_n^i = (1 - \mathbf{a}^i) \bar{K} \downarrow + L^i \downarrow - L^i \uparrow$$

$$H^i = r c_p (T_s^i - T_a^i) / R_a^i$$

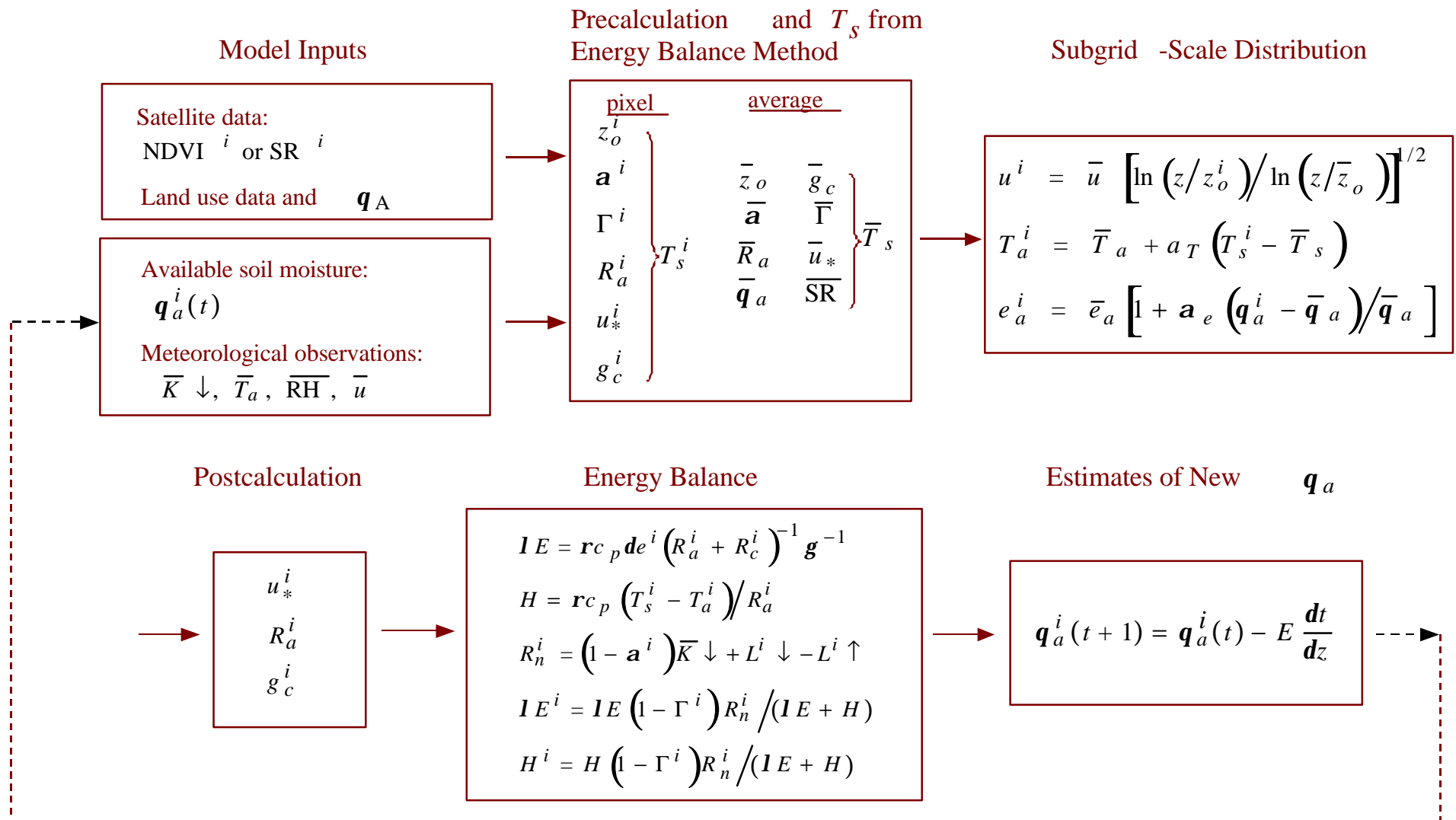
$$1E^i = R_n^i (1 - \Gamma^i) - H^i$$

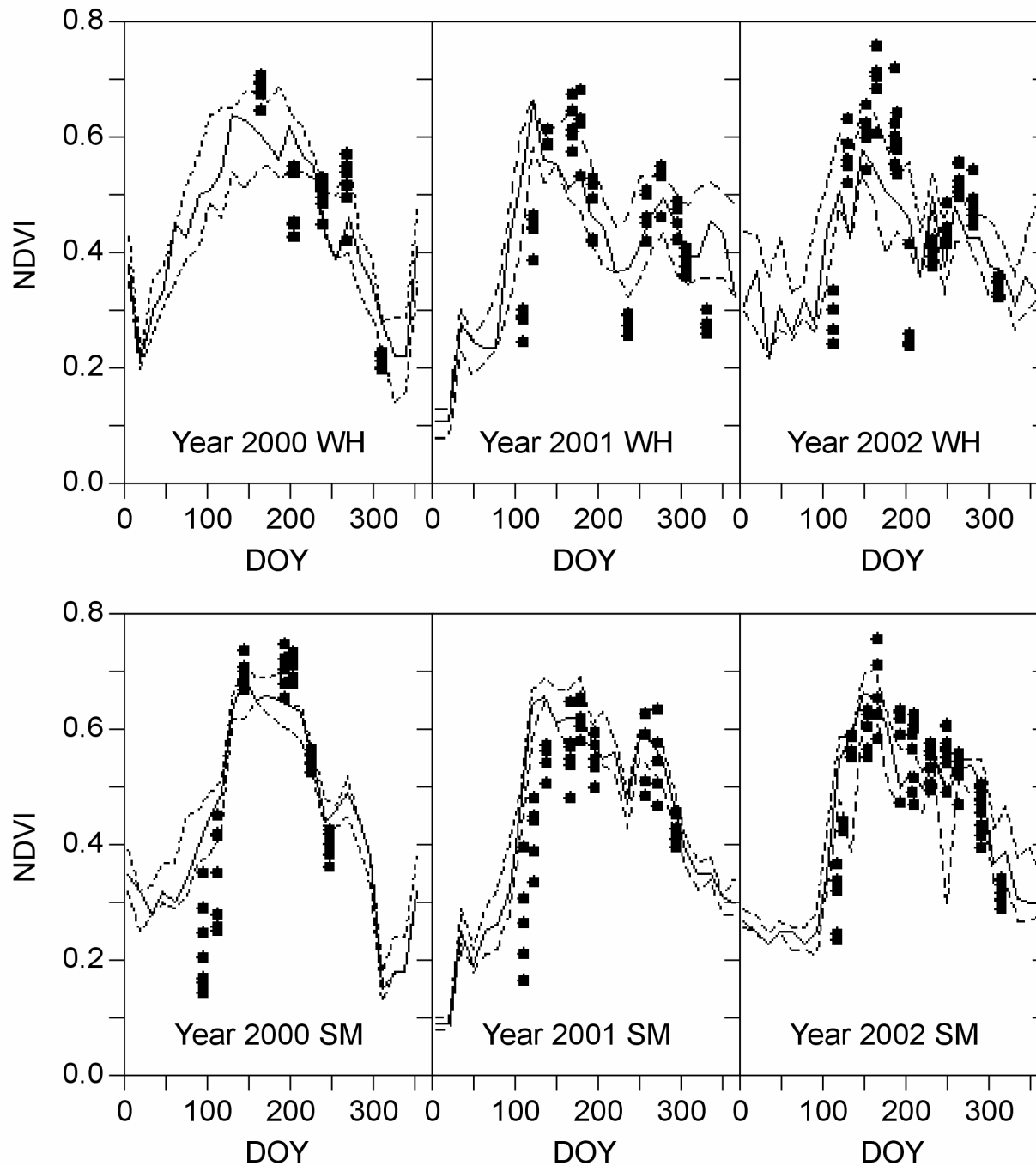
## Aerodynamic Method and Soil Moisture Estimate

$$g_c^i = \left[ r c_p \Delta e^i / (g l E^i) - R_a^i \right]^{-1}$$

$$q_a^i = q_A g_c^i / G_c^i$$

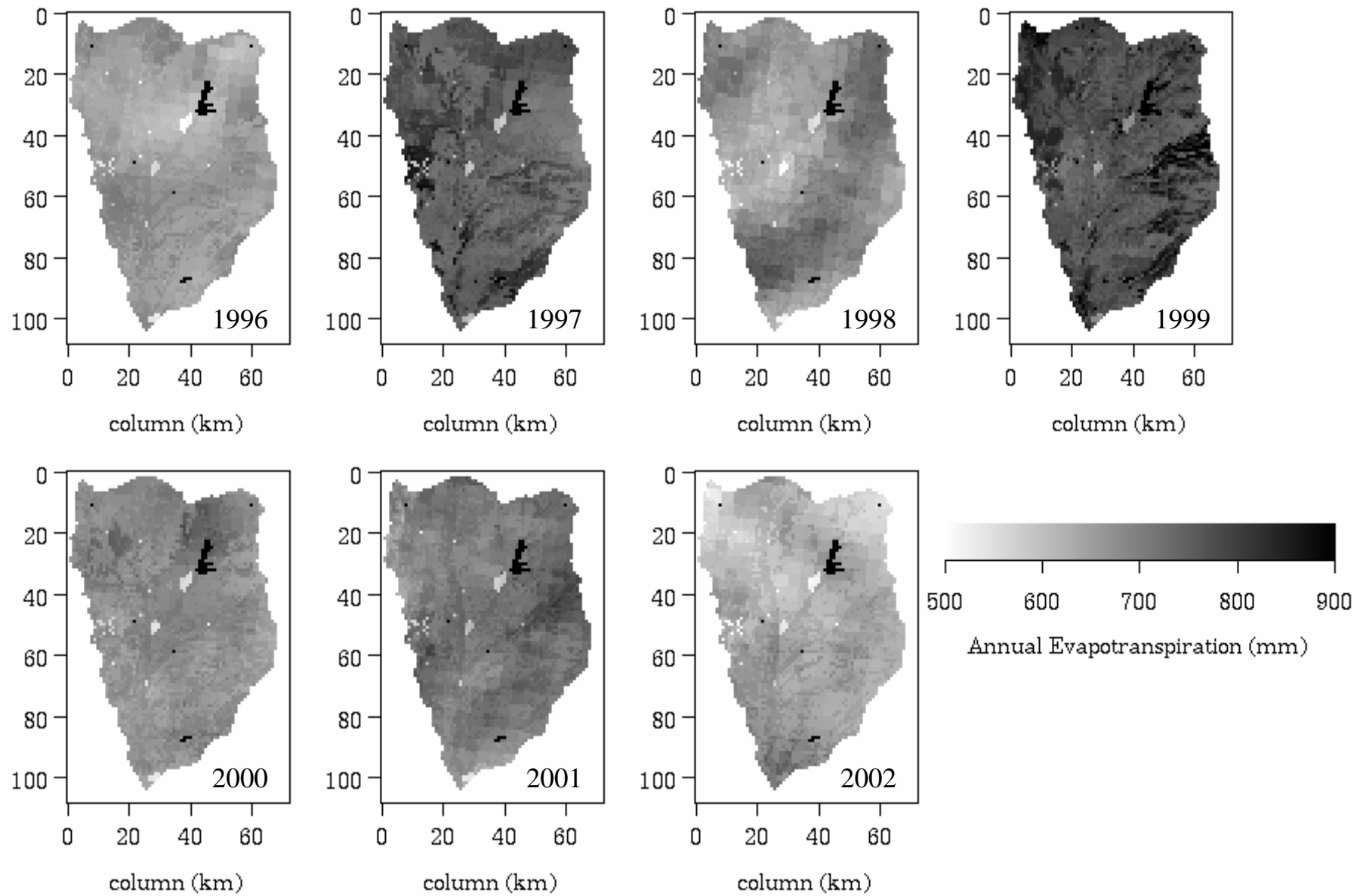
# Procedure to Estimate Daily Energy and Water Vapor Fluxes



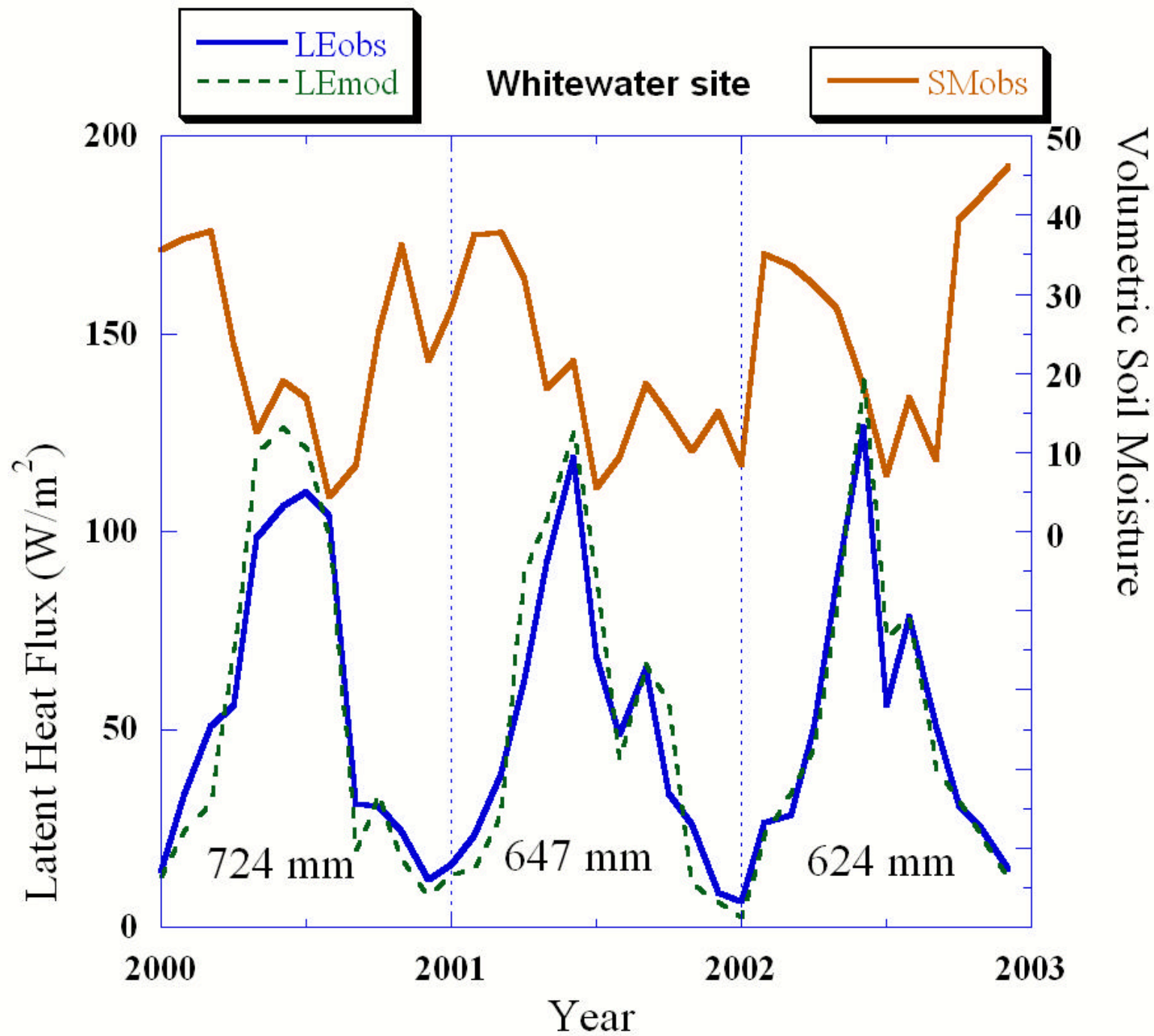


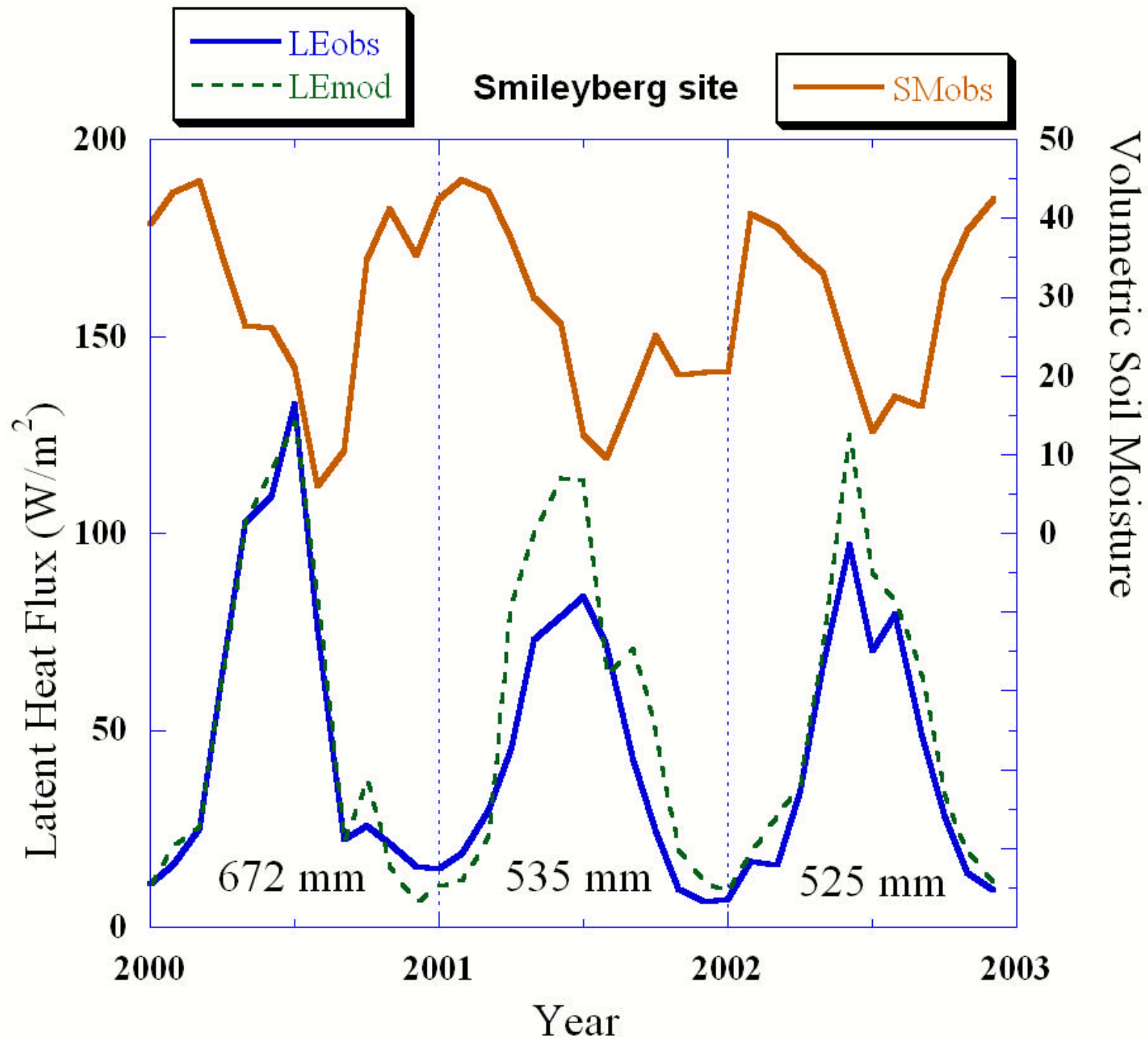
Comparison of NDVI derived from satellite (solid lines) with in situ measurements (filled circles) at Whitewater (WH) and Smileyberg (SM). Upper and lower dashed lines around each solid line represent maximum and minimum NDVI, respectively, within a 3 km by 3 km area centered at each site.



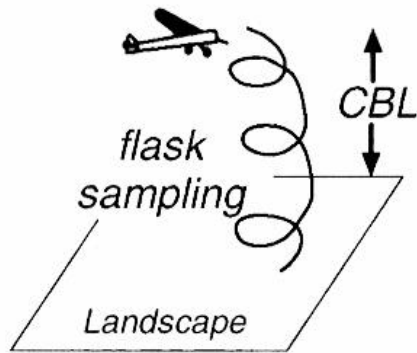


Spatial patterns of modeled evapotranspiration accumulated in 1996–2002.

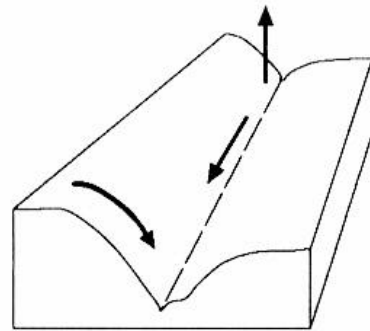




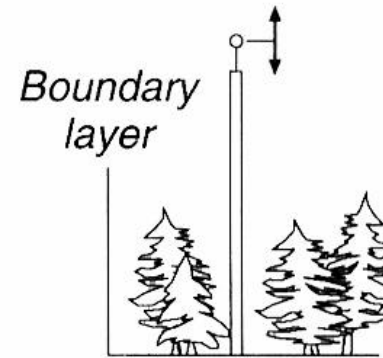
## FLUX MEASUREMENTS



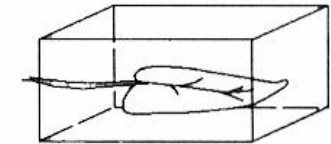
*Convective  
boundary layer  
integration*



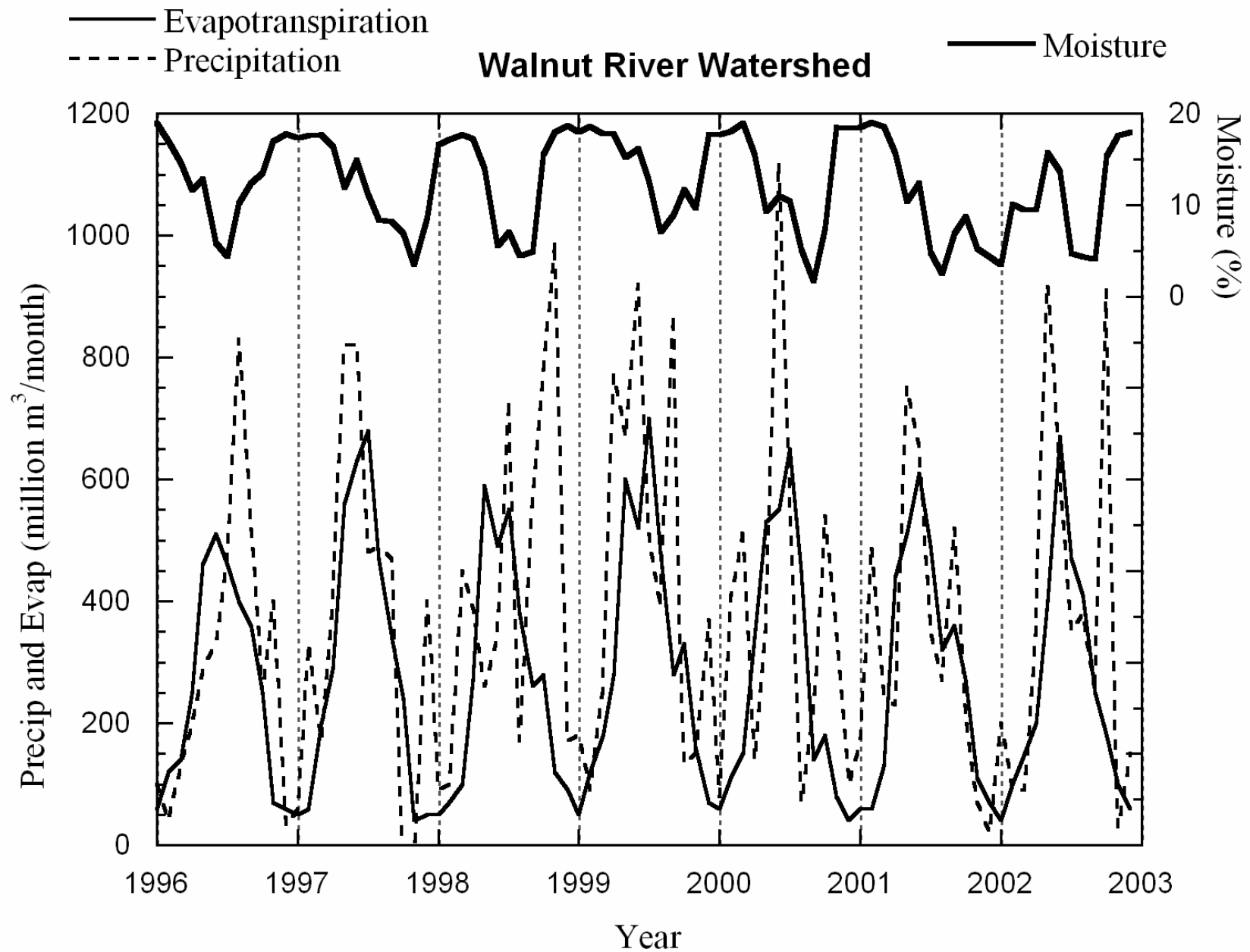
*Watershed  
(horizontal &  
vertical fluxes)*



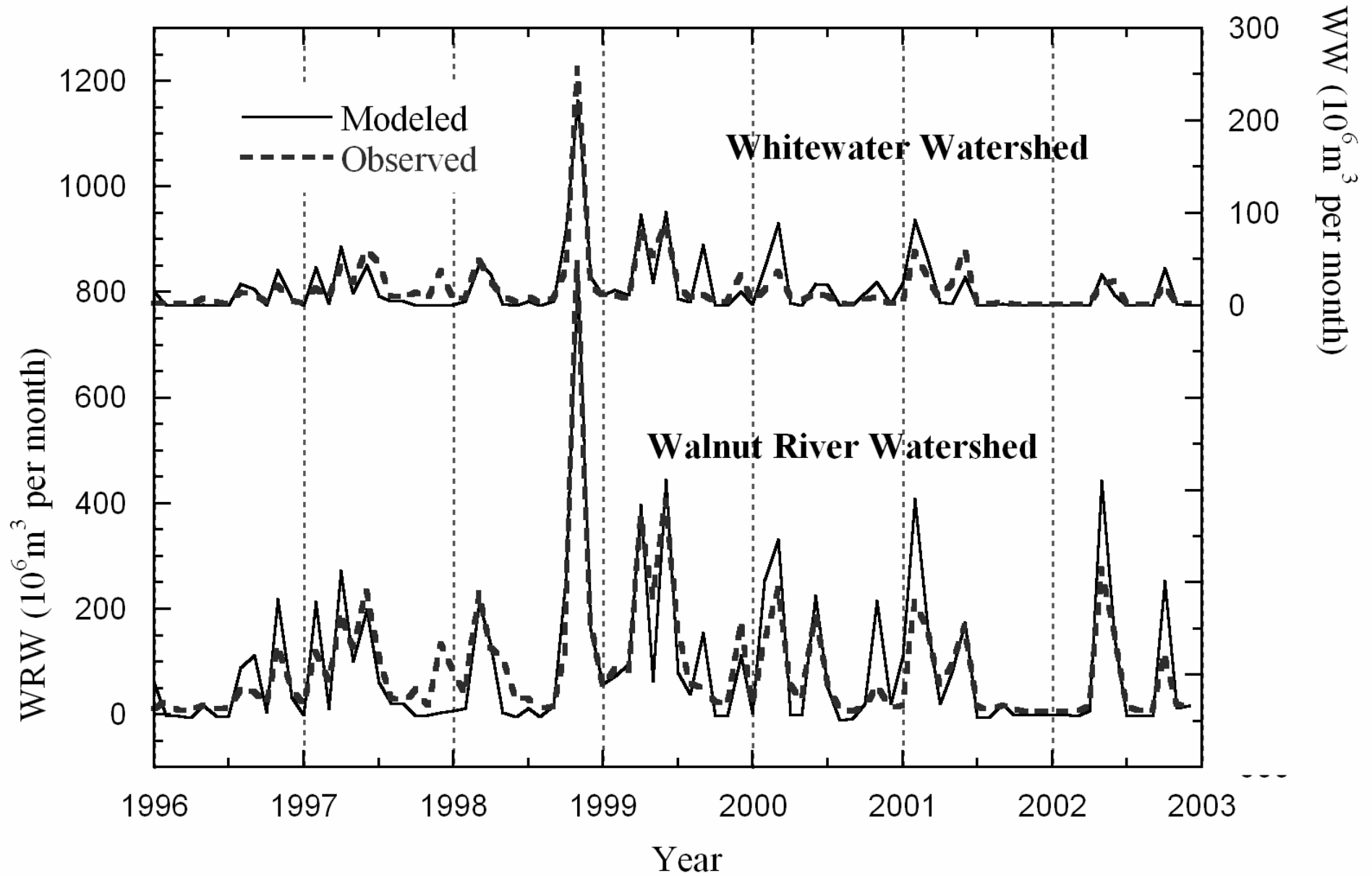
*Eddy  
covariance  
flux tower*



*Leaf level  
chamber  
experiments*



Basin-scale observed precipitation and modeled evapotranspiration, with modeled mean root-zone available moisture.



Comparison of modeled runoff and stream gauge observations.

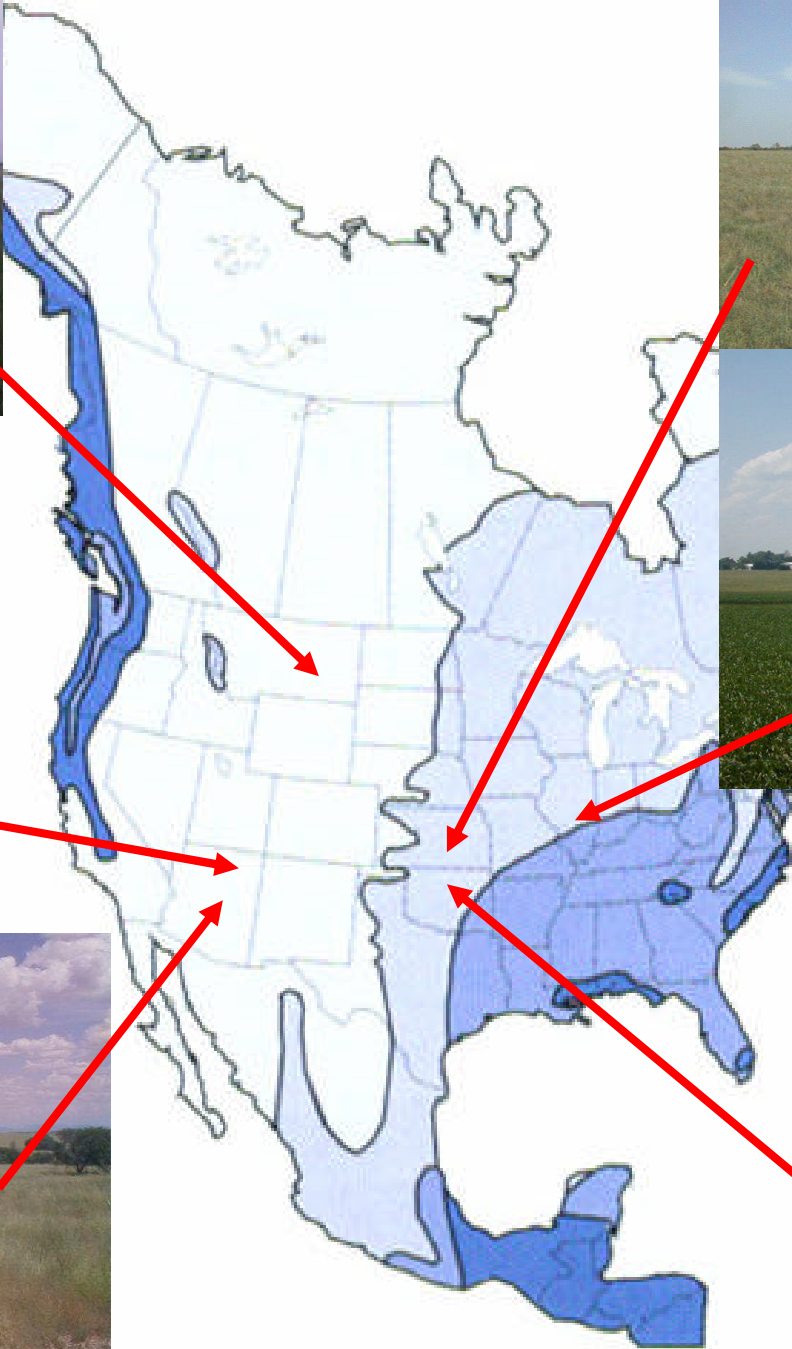
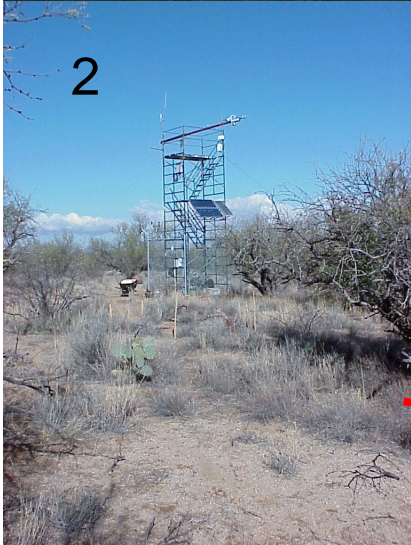
# Annual water budget in the Walnut River Watershed

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## Water Budget ( $\times 10^9 \text{ m}^3$ )

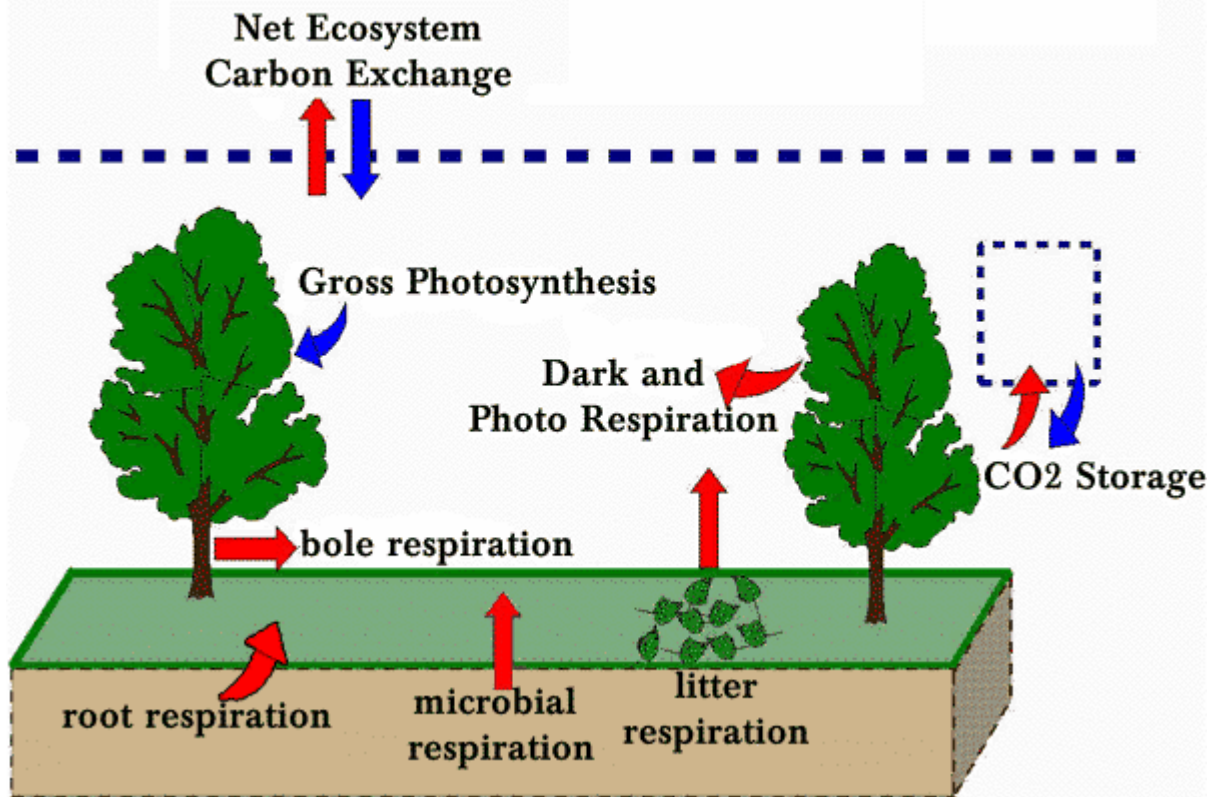
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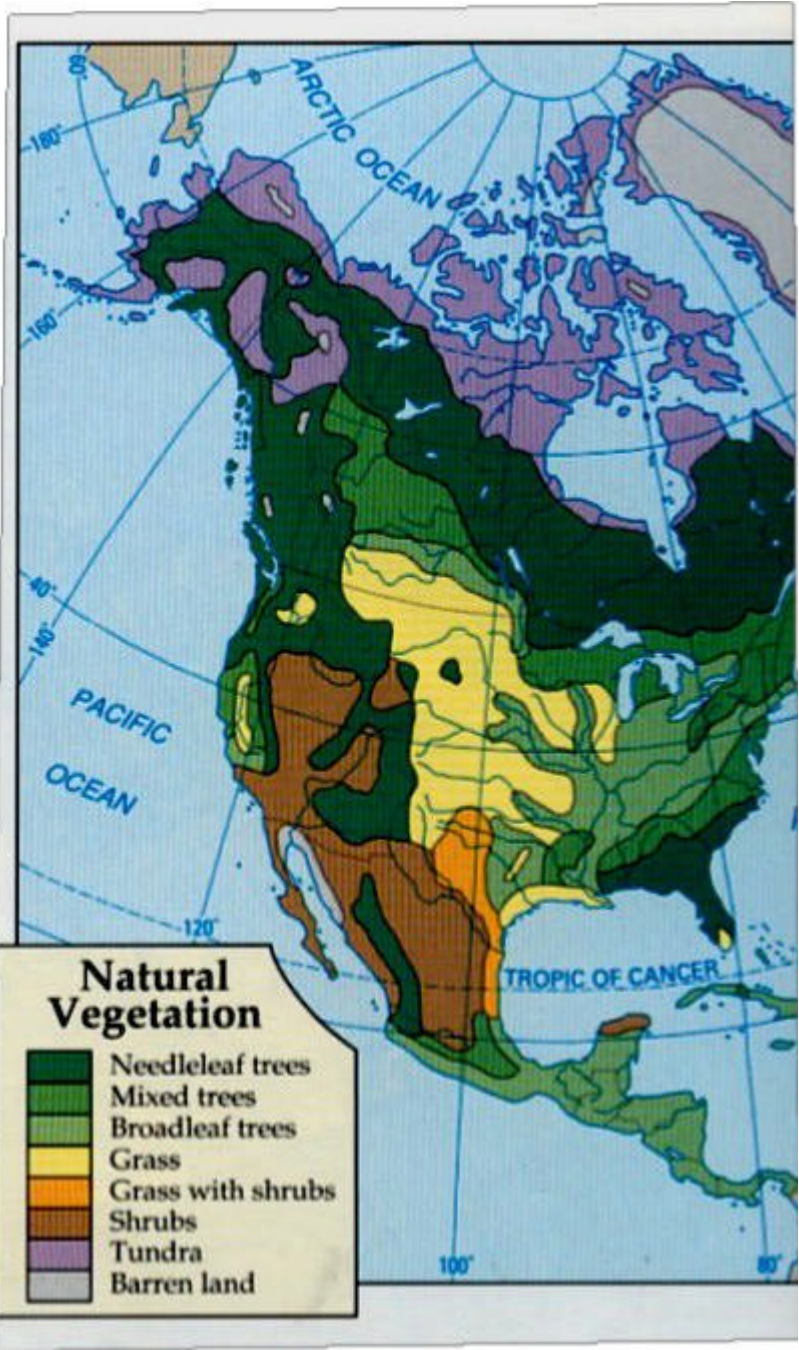
Year	Precipitation Observed	Evaporation Modeled	Runoff Modeled	Stream Flow Observed
1996	3.60	3.16	0.51	0.37
1997	4.45	3.64	0.89	1.12
1998	5.05	3.31	1.63	1.81
1999	5.31	3.82	1.50	1.70
2000	4.49	3.37	1.09	0.82
2001	3.97	3.46	0.96	0.76
2002	4.34	3.07	0.86	0.63
<b>Total</b>	<b>31.22</b>	<b>23.83</b>	<b>7.45</b>	<b>7.21</b>





# Canopy Carbon Balance

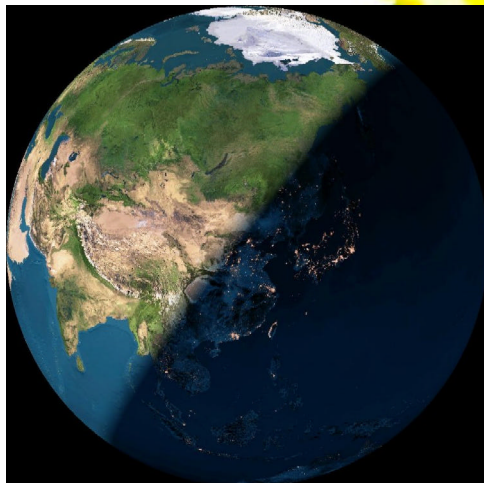
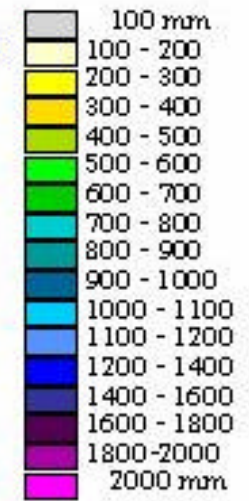
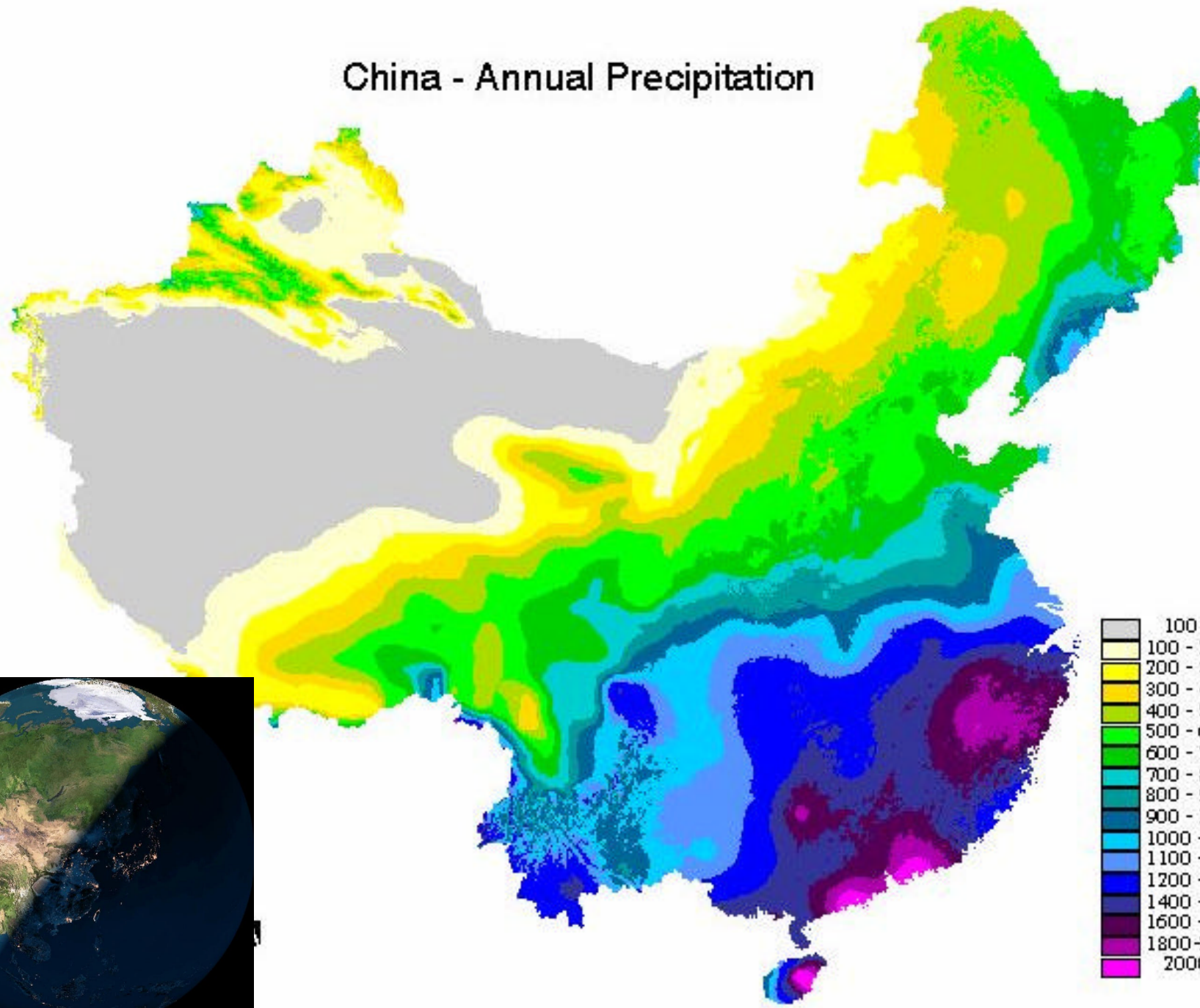




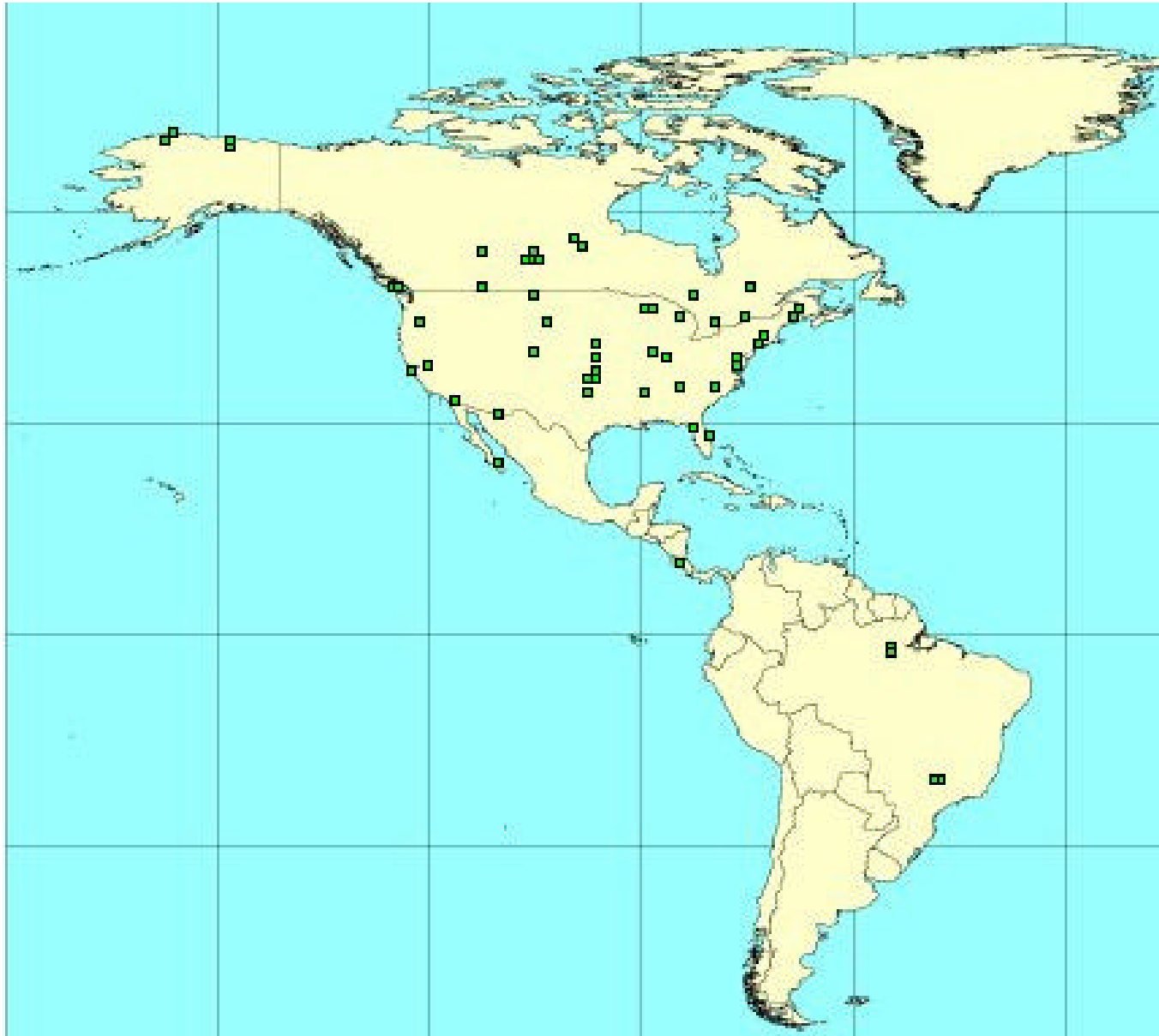
### Natural Vegetation

- Needleleaf trees
- Mixed trees
- Broadleaf trees
- Grass
- Grass with shrubs
- Shrubs
- Tundra
- Barren land

# China - Annual Precipitation



# Ameriflux site map



# Chestnut Ridge, Oak Ridge, Tennessee

**Location:** Chestnut Ridge, Oak Ridge, Tennessee (TN,USA)

**Latitude:** 35° 55' 51.9348" N

**Longitude:** 84° 19' 56.7264" W

**Climate:** Temperate

**Principal Investigator:** Tilden Meyers

