Acknowledgments:

Wisconsin Groundwater Research and Monitoring program [USGS 104(b)]

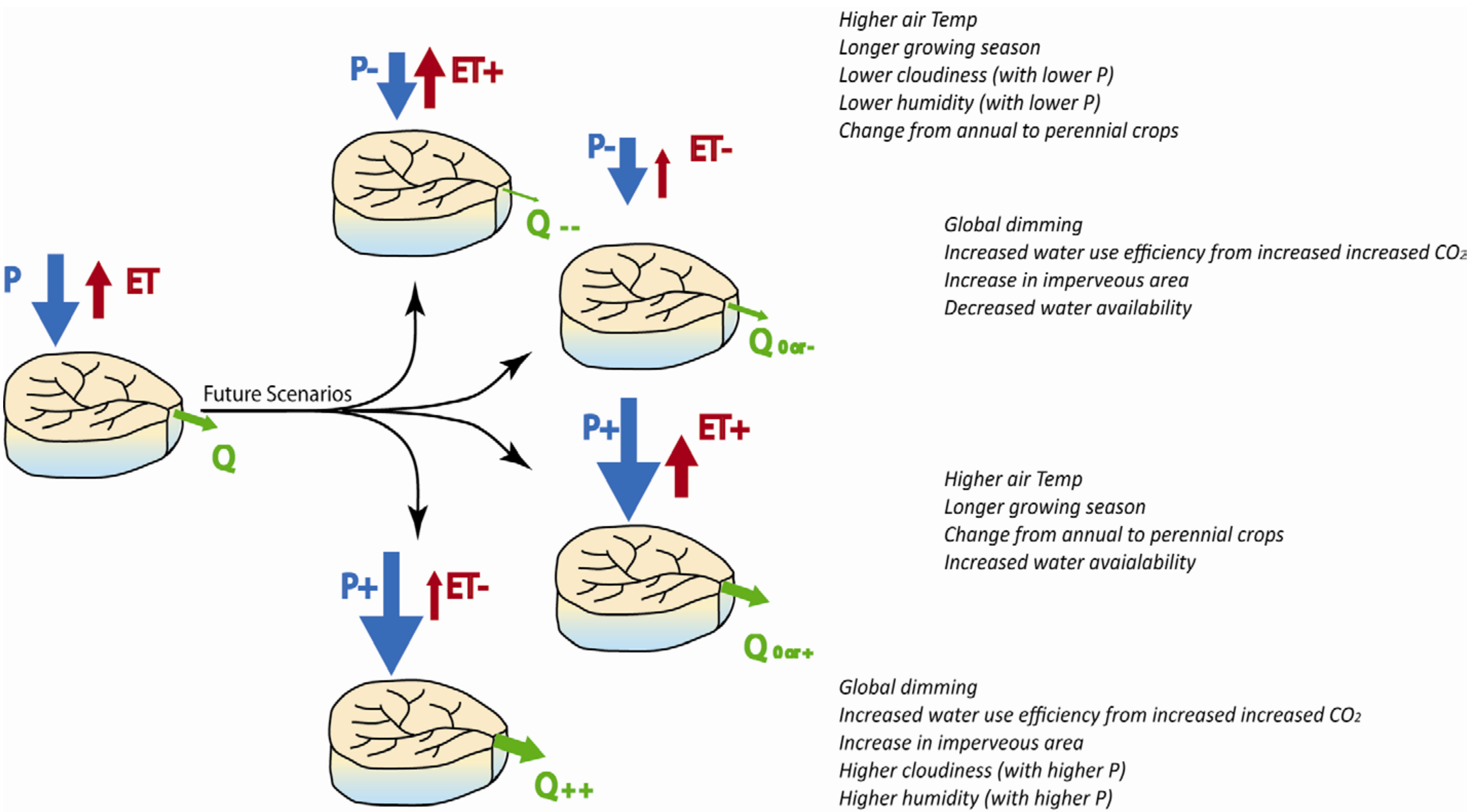
Development of a User-Friendly Interface for Predicting Climate Change Induced Changes in Evapotranspiration
(WRI Project Number WR10R001)

PREDICTING CLIMATE CHANGE INDUCED CHANGES IN EVAPOTRANSPIRATION (ET)

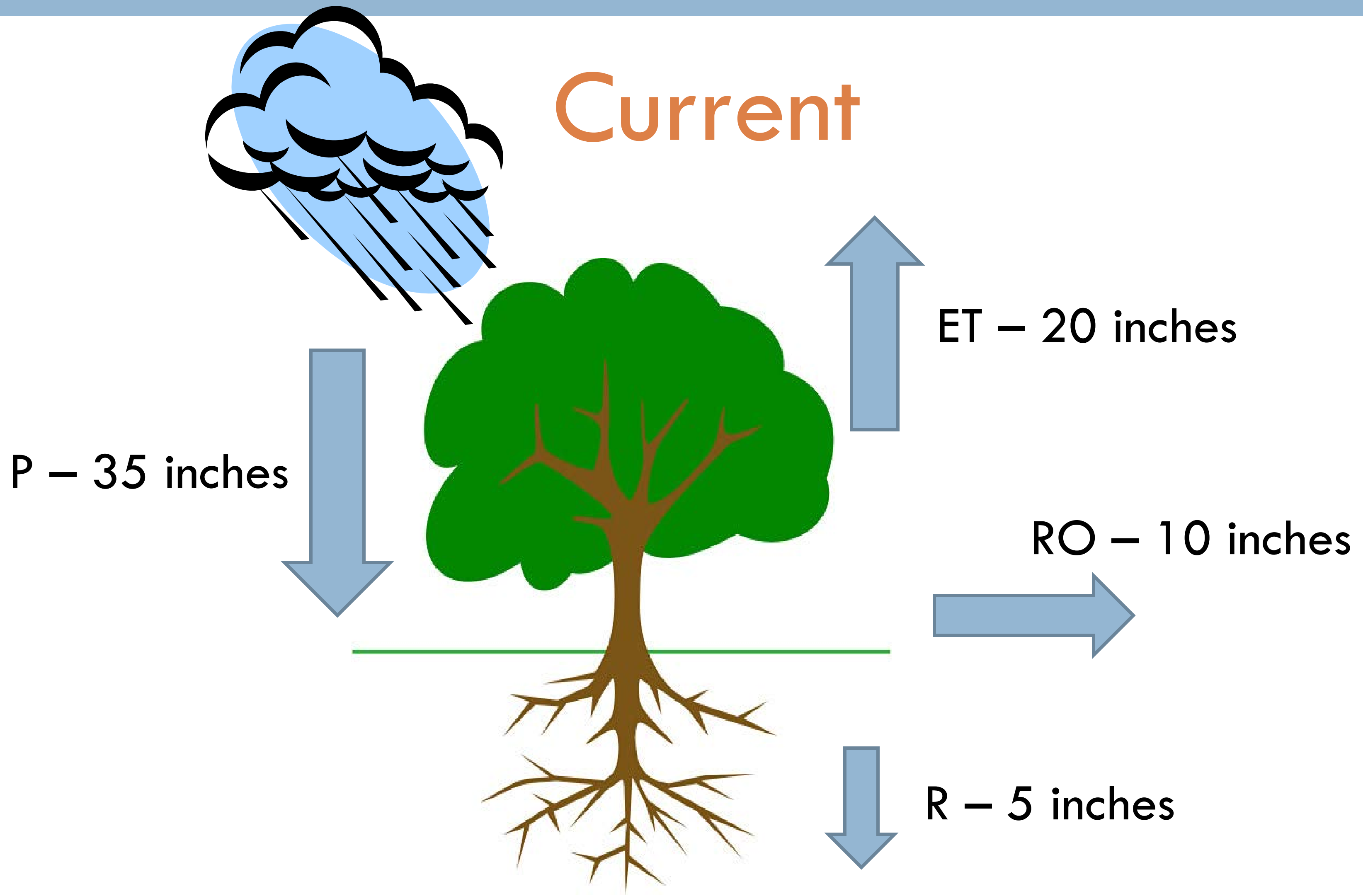
WRI
University of Wisconsin

Steven Loheide, Doug Joachim (Aug 2, 2013)

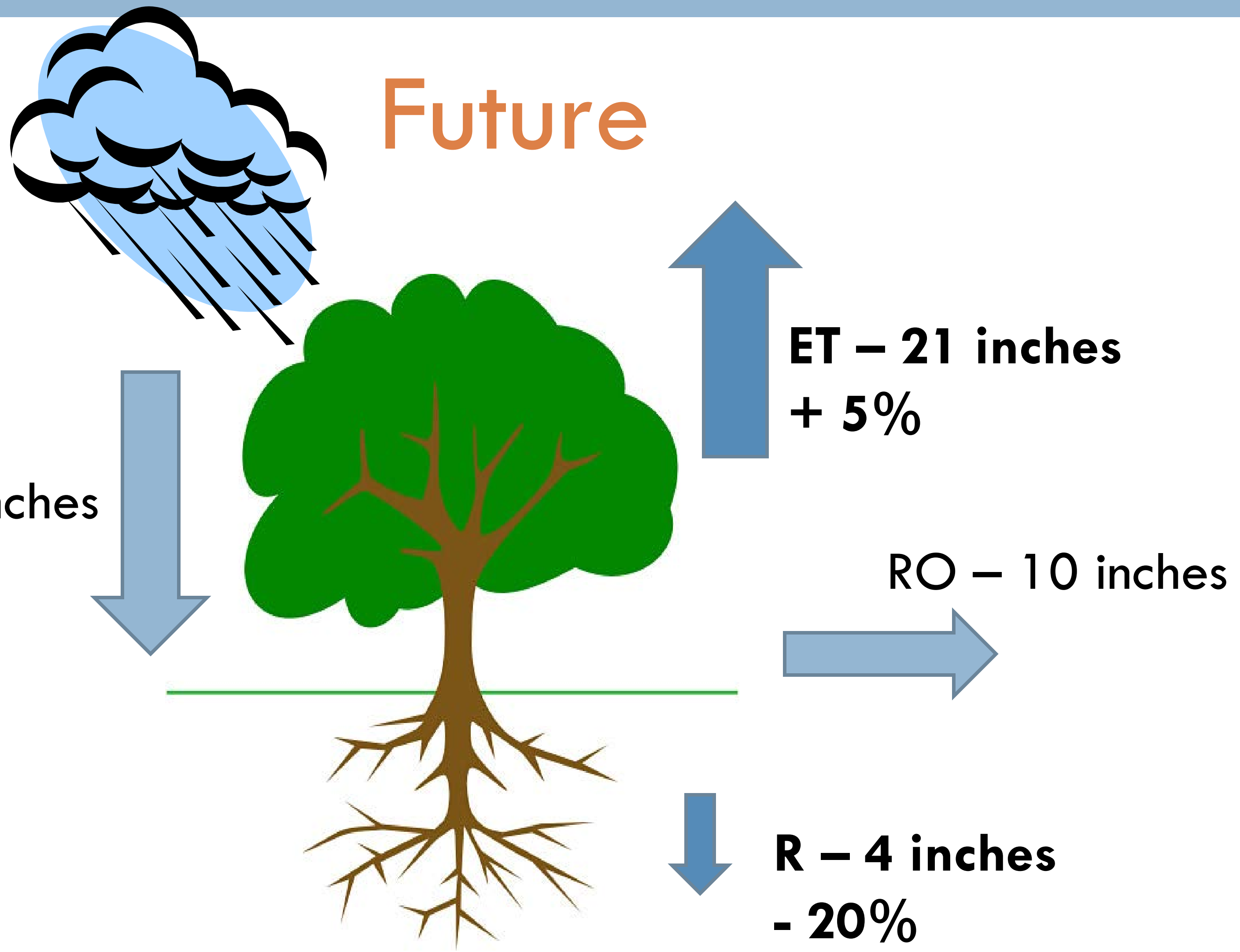
A *nonstationary* water budget? What is the role of ET?



Effects of increasing ET on recharge



Effects of increasing ET on recharge



Combined Method
Penman-Montieth Equation

$$ET_o = \frac{1}{\rho_w \lambda}\left[\frac{\Delta(R_n - G) + \rho_a * c_p * \frac{(e_s - e_a)}{r_a}}{(\Delta + \gamma * (1 + \frac{r_s}{r_a}))}\right]$$

cloudiness

temperature

humidity

wind speed

stomatal response (standardized for *reference* ET)

where

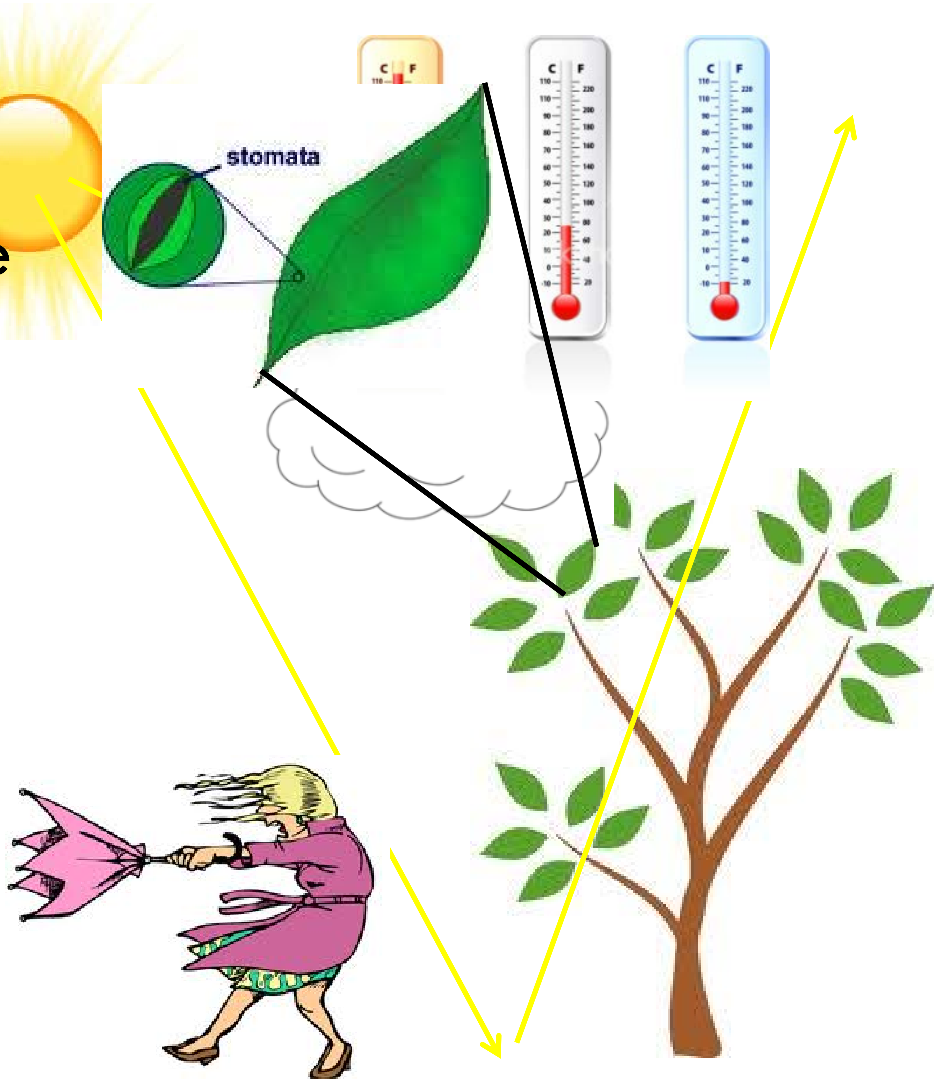
- $(R_n\text{-}G)$ =Available Energy= net radiation – soil heat flux (W/m2)
- ρ_w (ρ_a)= density of water (air)
- c_p = specific heat of air
- r_s = net resistance to diffusion through the surfaces of the leaves and soil (s/m)
- r_a = net resistance to diffusion through the air from surfaces to height of measuring instruments (s/m).
- λ = latent heat of vaporization
- γ = psychrometric constant
- Δ = de/dT (known)
- e_s (e_a) = saturated vapour pressure at air temperature (ambient vapor pressure)

Fully modeling ET requires knowledge about energy, weather, and vegetation

1. Net radiation is one of the most important drivers of ET

2. Wind speed, humidity, air temperature also important

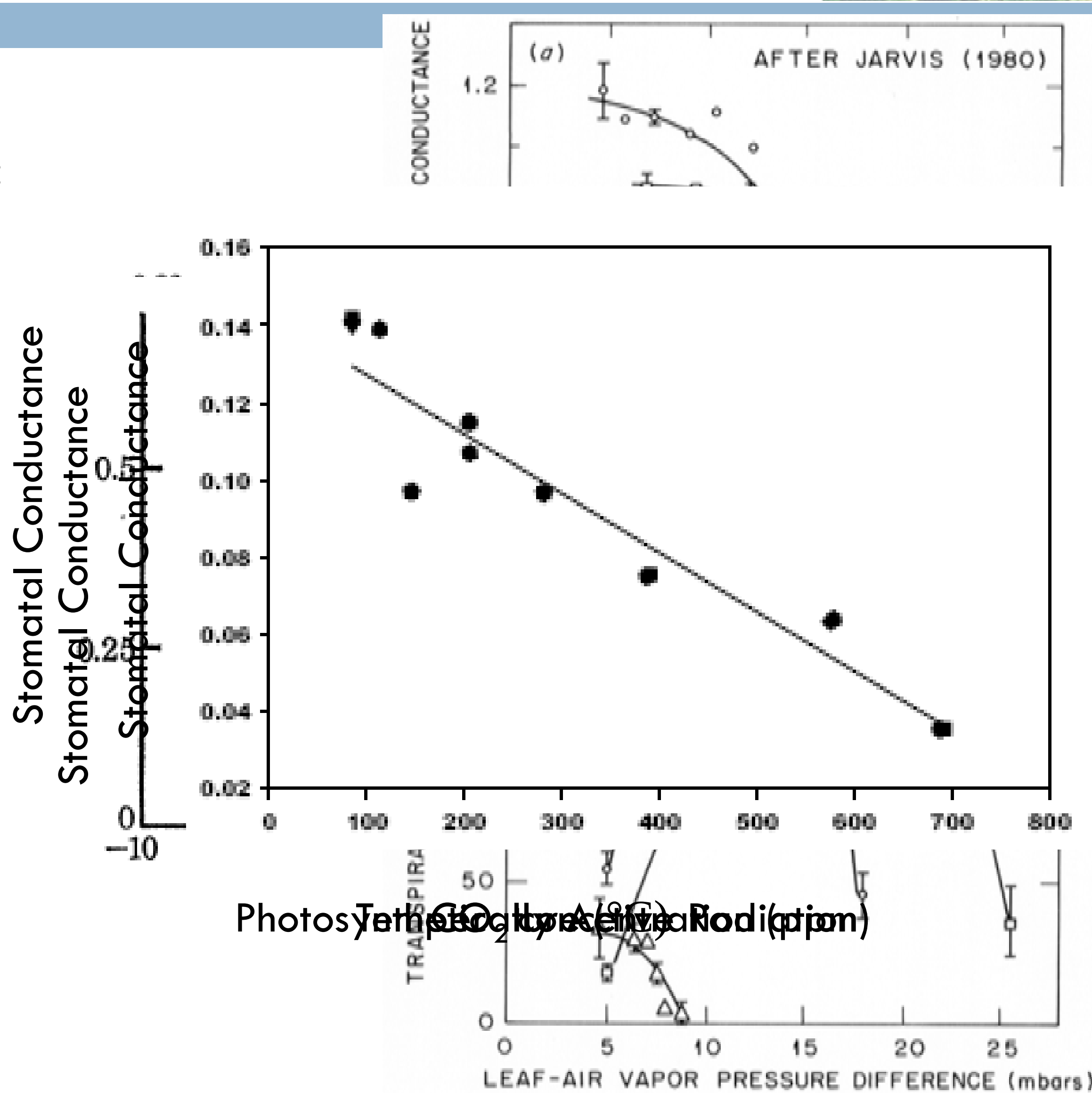
3. Stomatal conductance important for transpiration



Stomatal response to climate factors is important for ET calculations

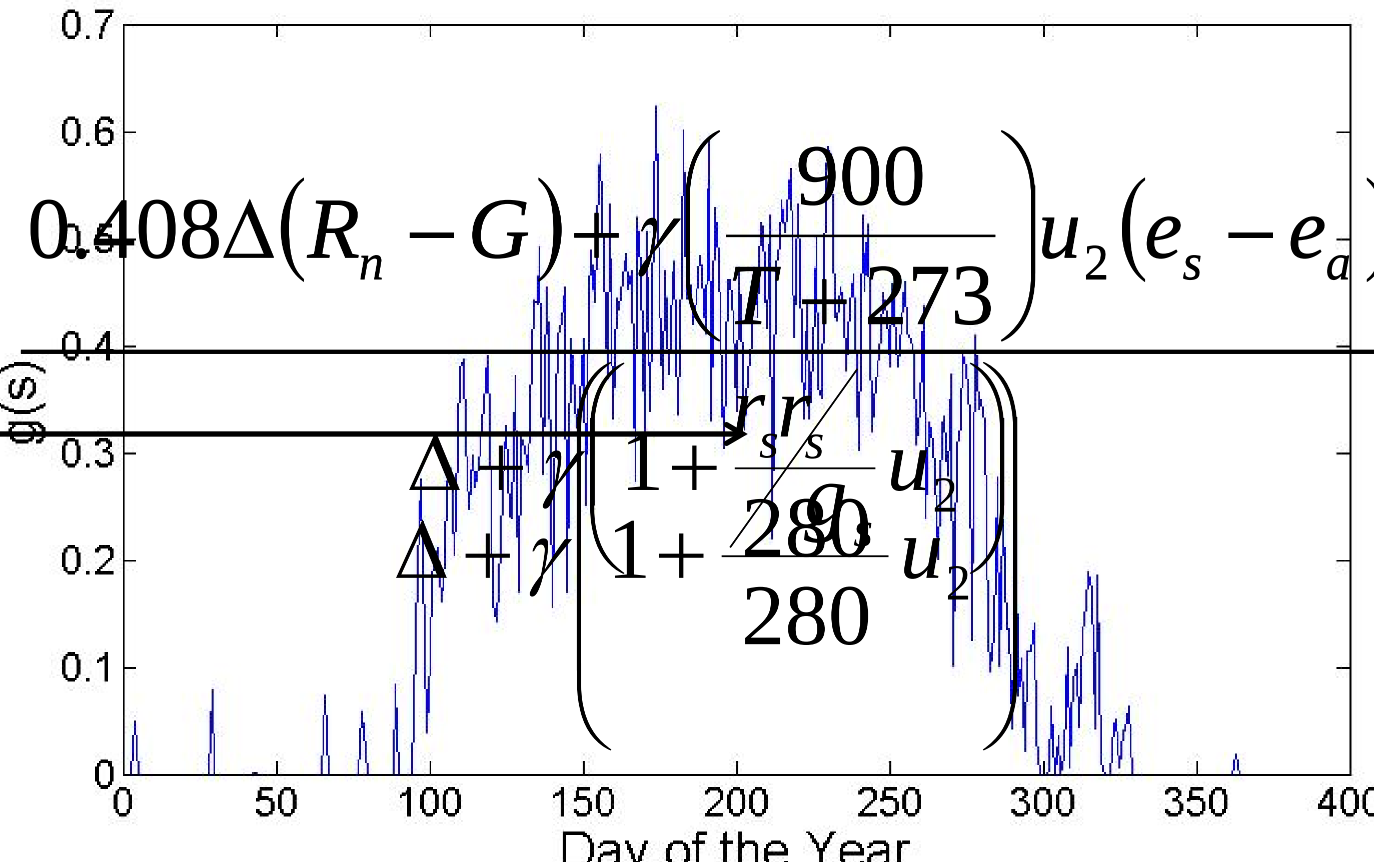
Stomata respond to:

1. Solar Radiation
2. Temperature
3. Vapor Pressure Deficit
4. Carbon-dioxide Concentration



Stomatal response to climate factors is vegetation-dependent

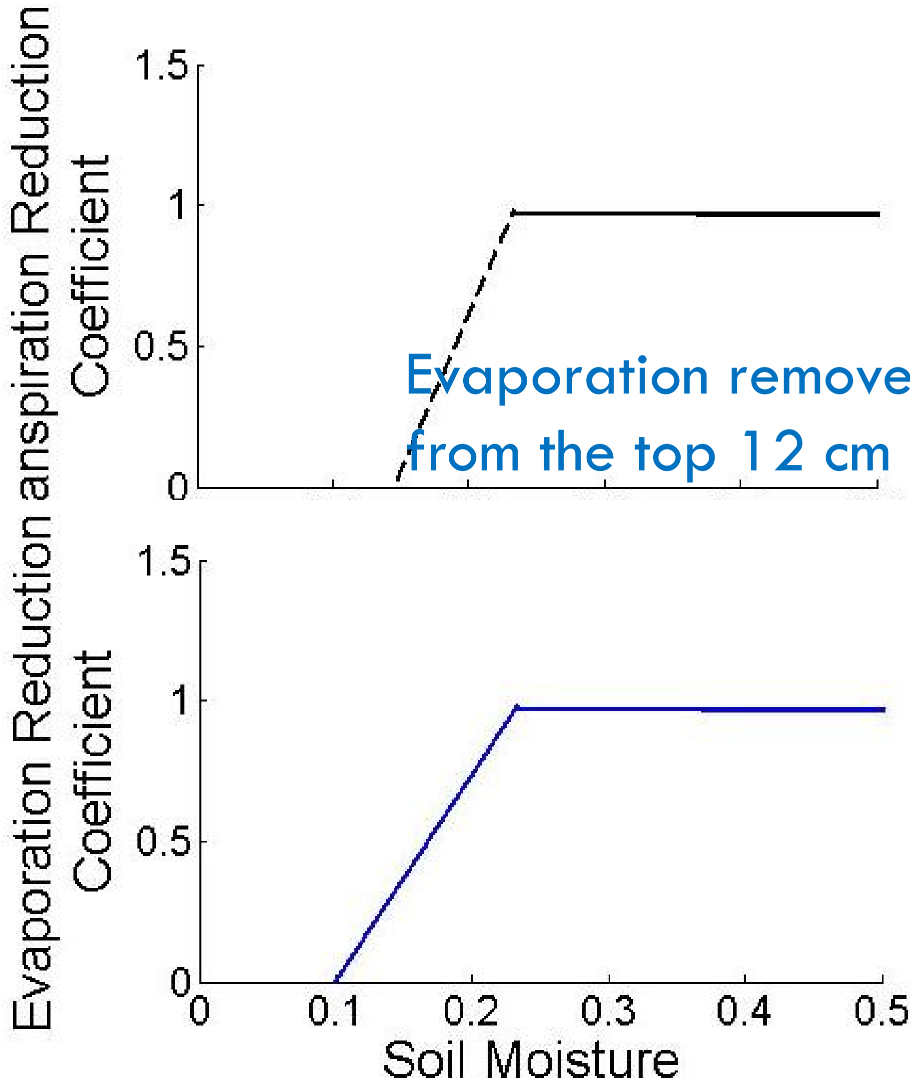
$$g_s = g(R_s)\,g(VPD)\,g(T_{air})\,g(CO_2)$$



$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma\left(1 + \frac{r_s}{280}u_2\right)}$$

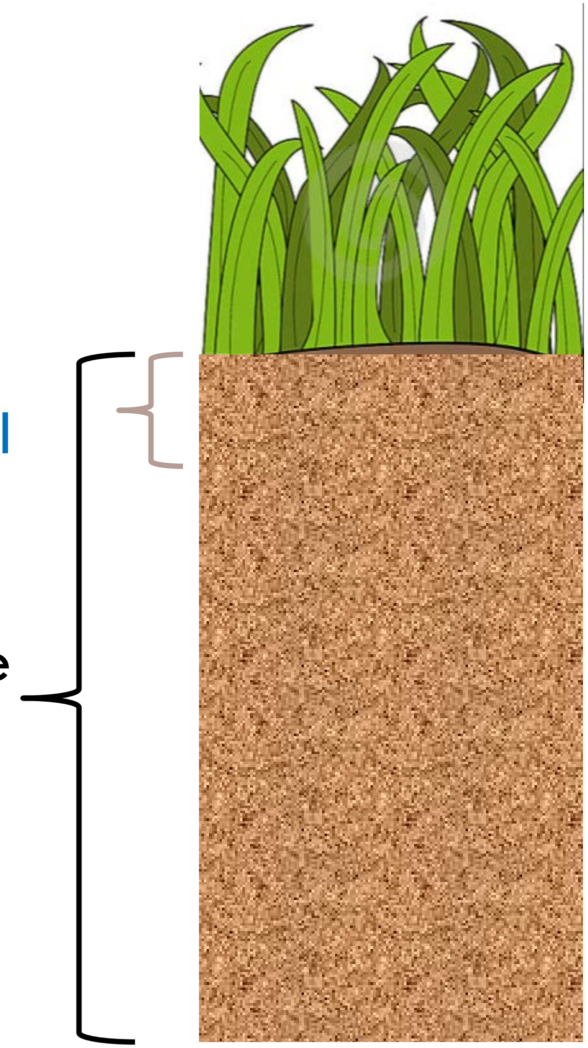
$$\Delta + \gamma\left(1 + \frac{1}{280}u_2\right)$$

Soil moisture is important for both evaporation and transpiration

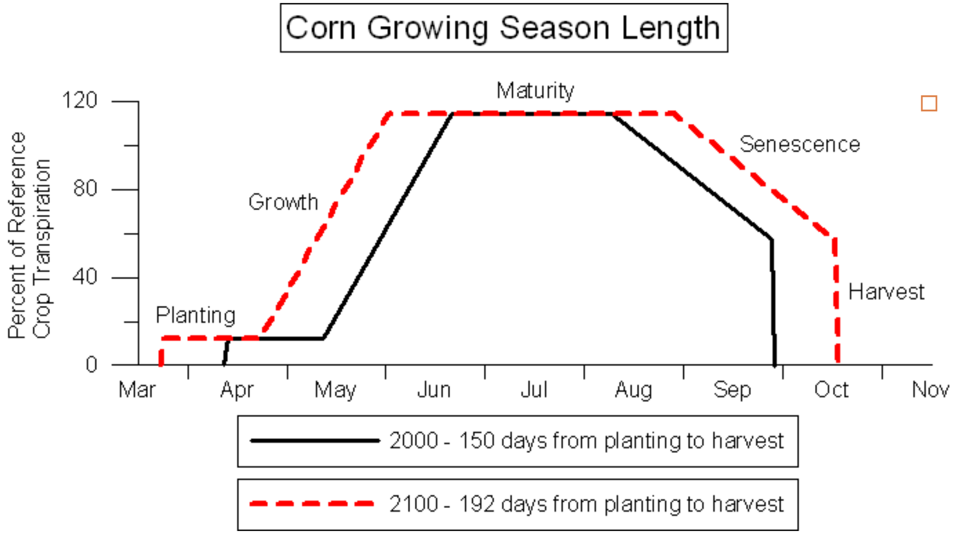


Evaporation removes water from the top 12 cm of the soil

from the

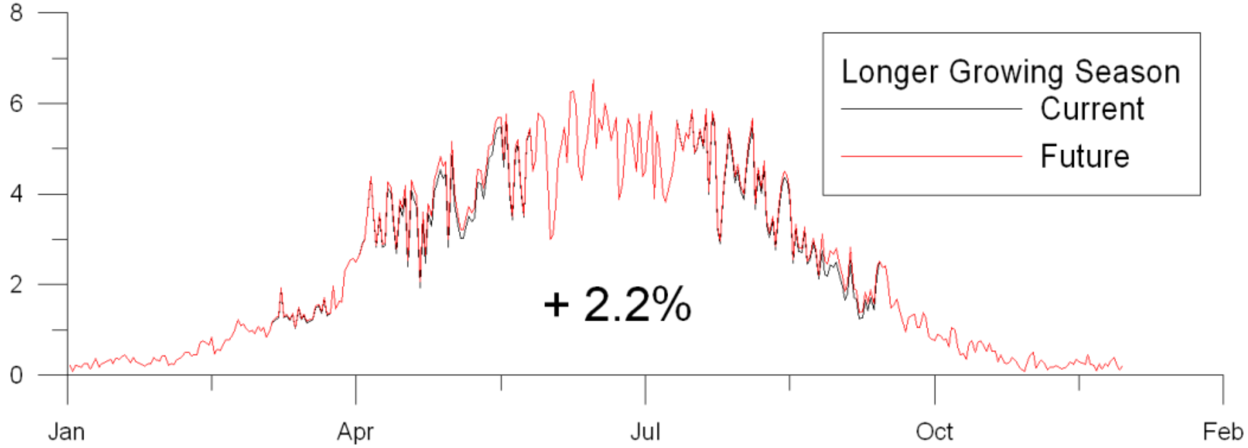


Effects of growing season length on *potential* ET

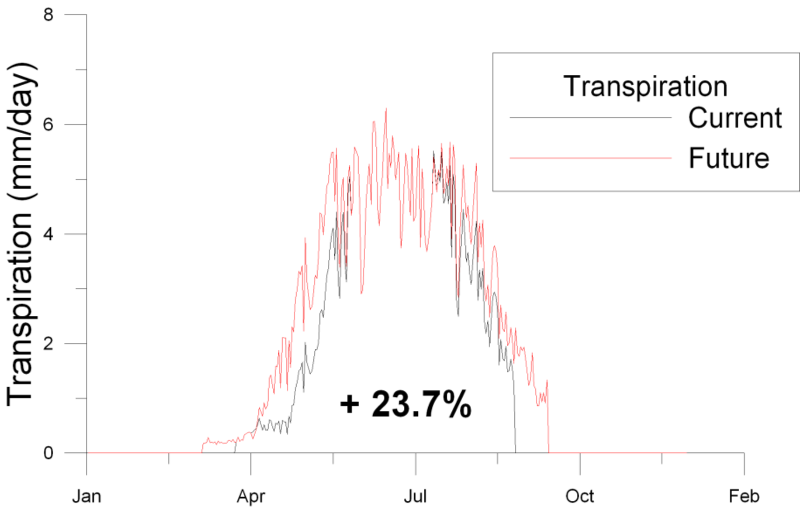


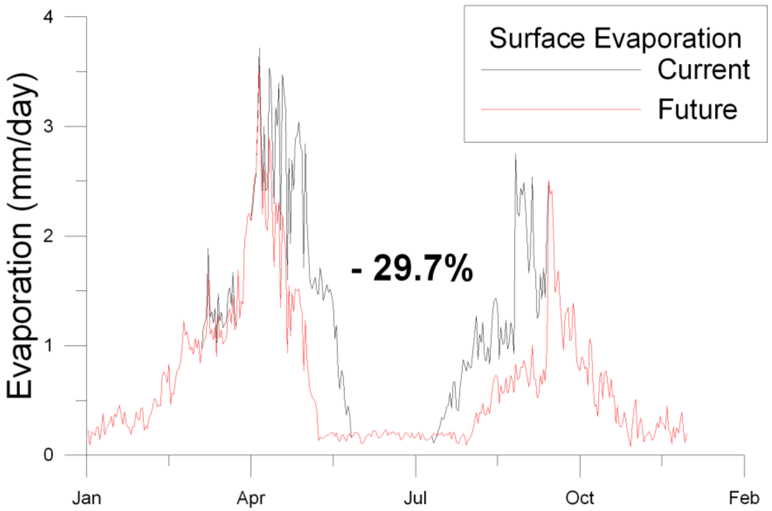
- 42 day increase in growing season length by 2100

ET (mm/day)

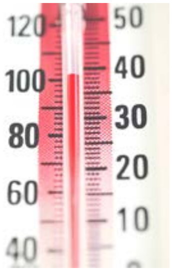


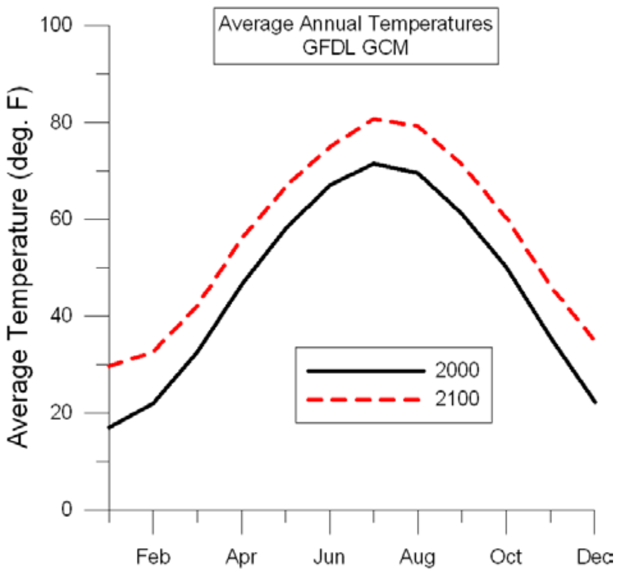
Effects of growing season length on *potential* evaporation vs. transpiration





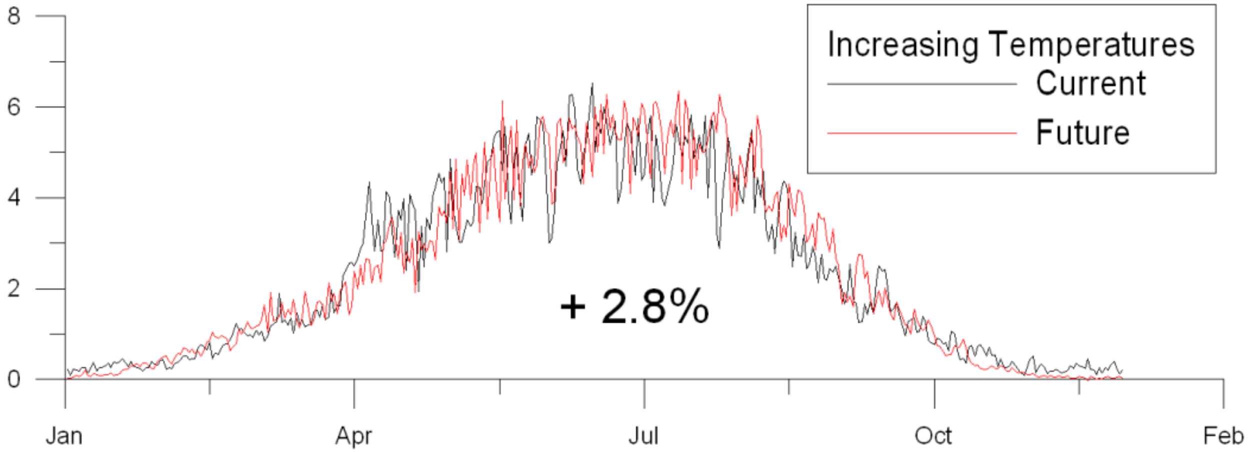
Effects temperature changes on *potential* ET



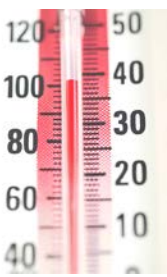


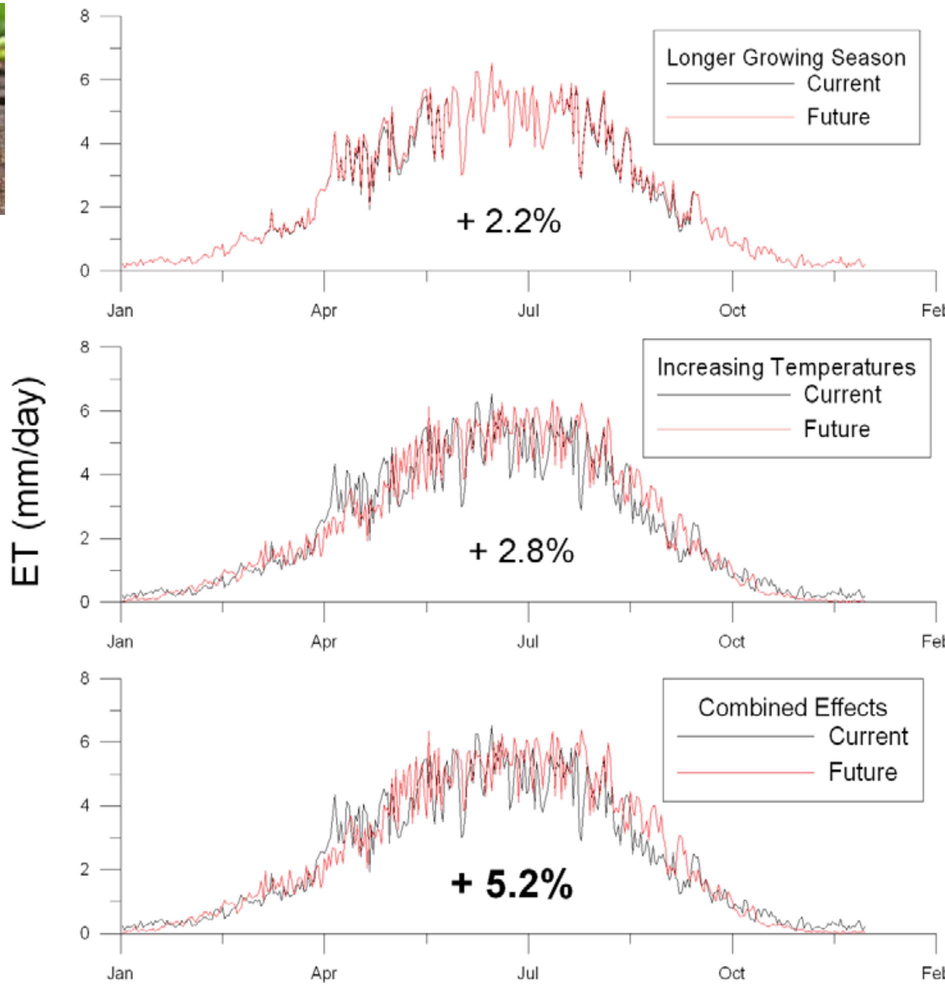
- Geophysical Fluid Dynamics Laboratory GCM
- “middle of the road” scenario (+9°F)
- 2100

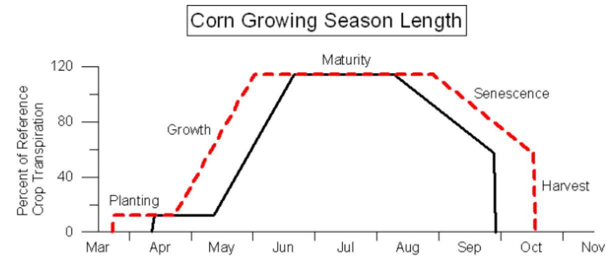
ET (mm/day)

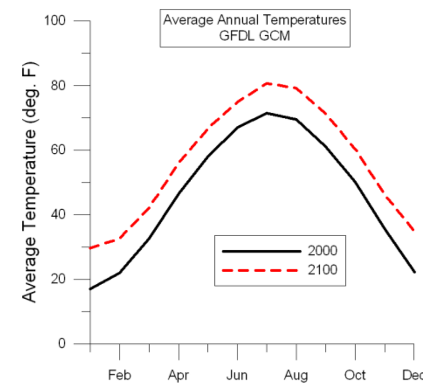


Effects of growing season length and temperature changes on *potential* ET

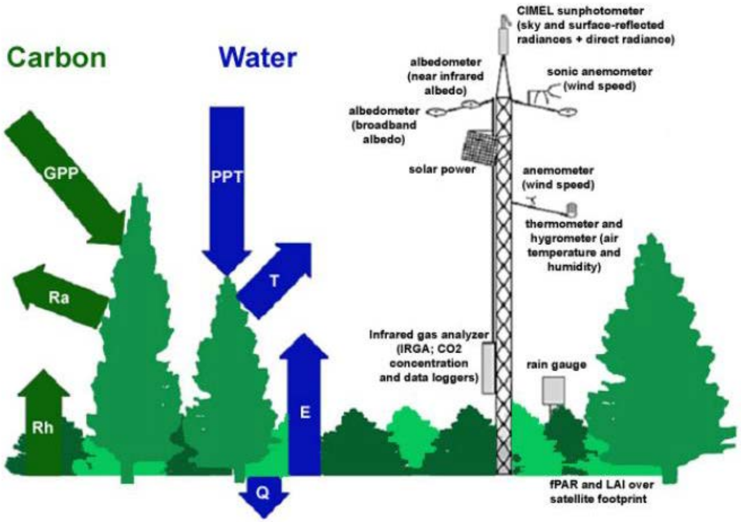


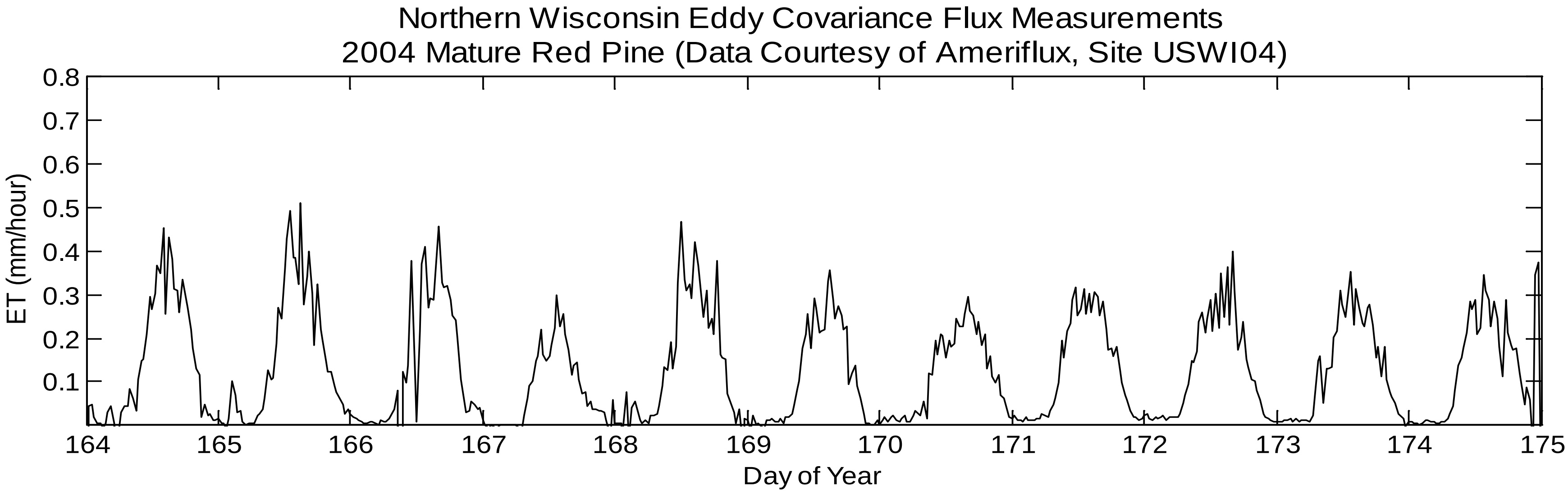




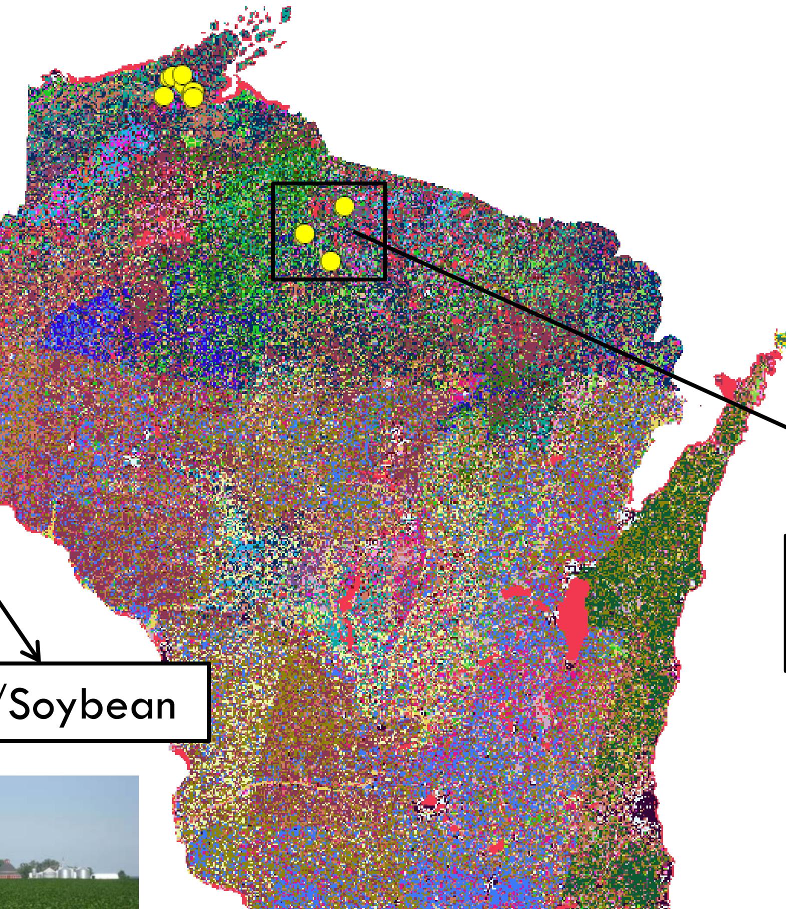


Eddy Covariance





Eddy Covariance



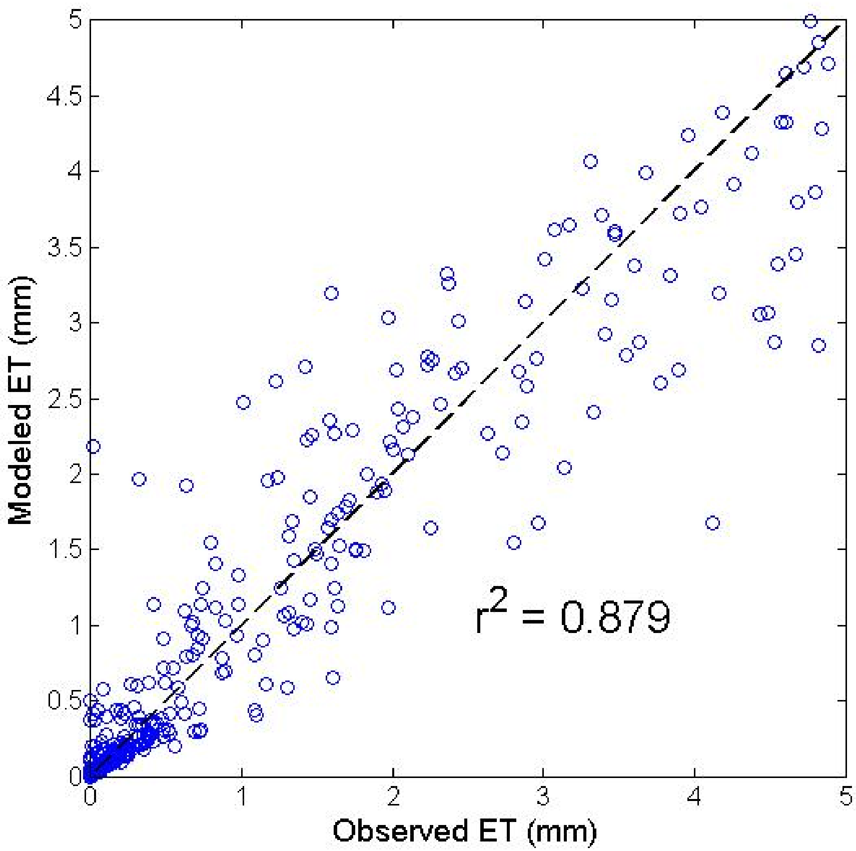
Deciduous Broadleaf/ Shrub

Corn/Soybean

Restored Prairie

ET model was calibrated to match actual ET record

Adjust parameters affecting stomatal conductance and growth onset and rates to get the best fit (Markov Chain Monte Carlo approach)

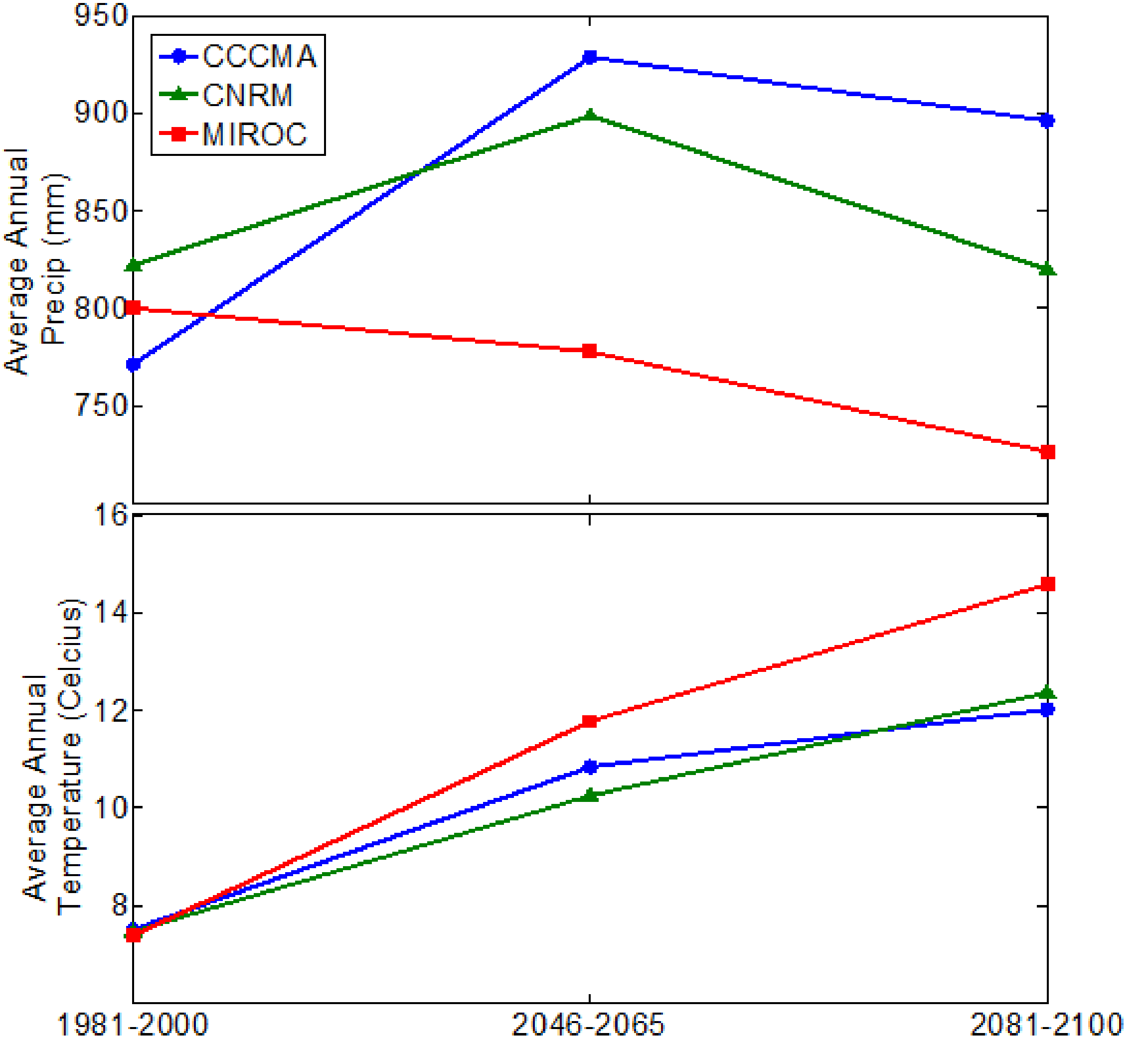


Three separate climate models provide a range of possible changes

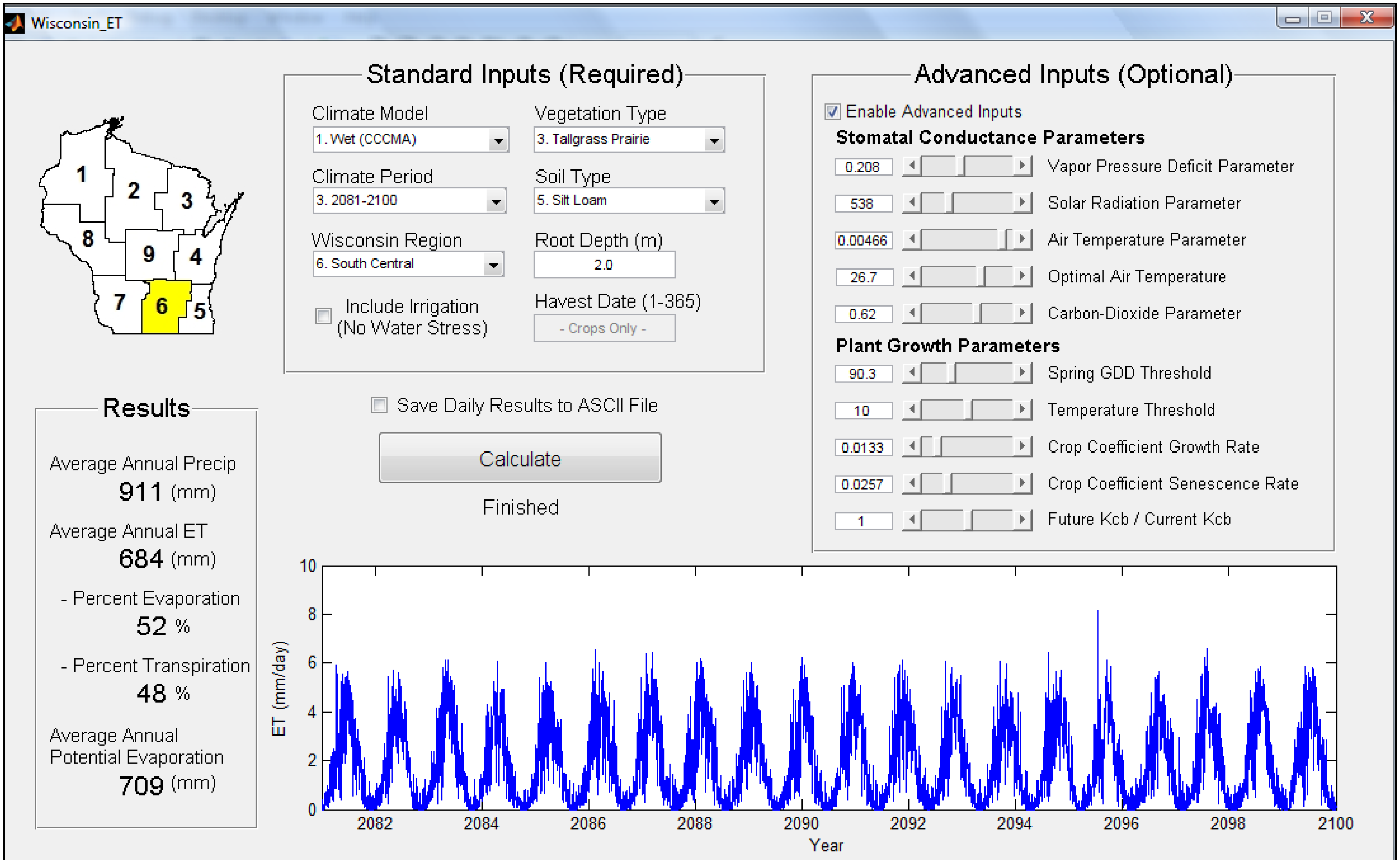
CCCMA (wet)

CNRM (intermediate)

MIROC (dry, hot)

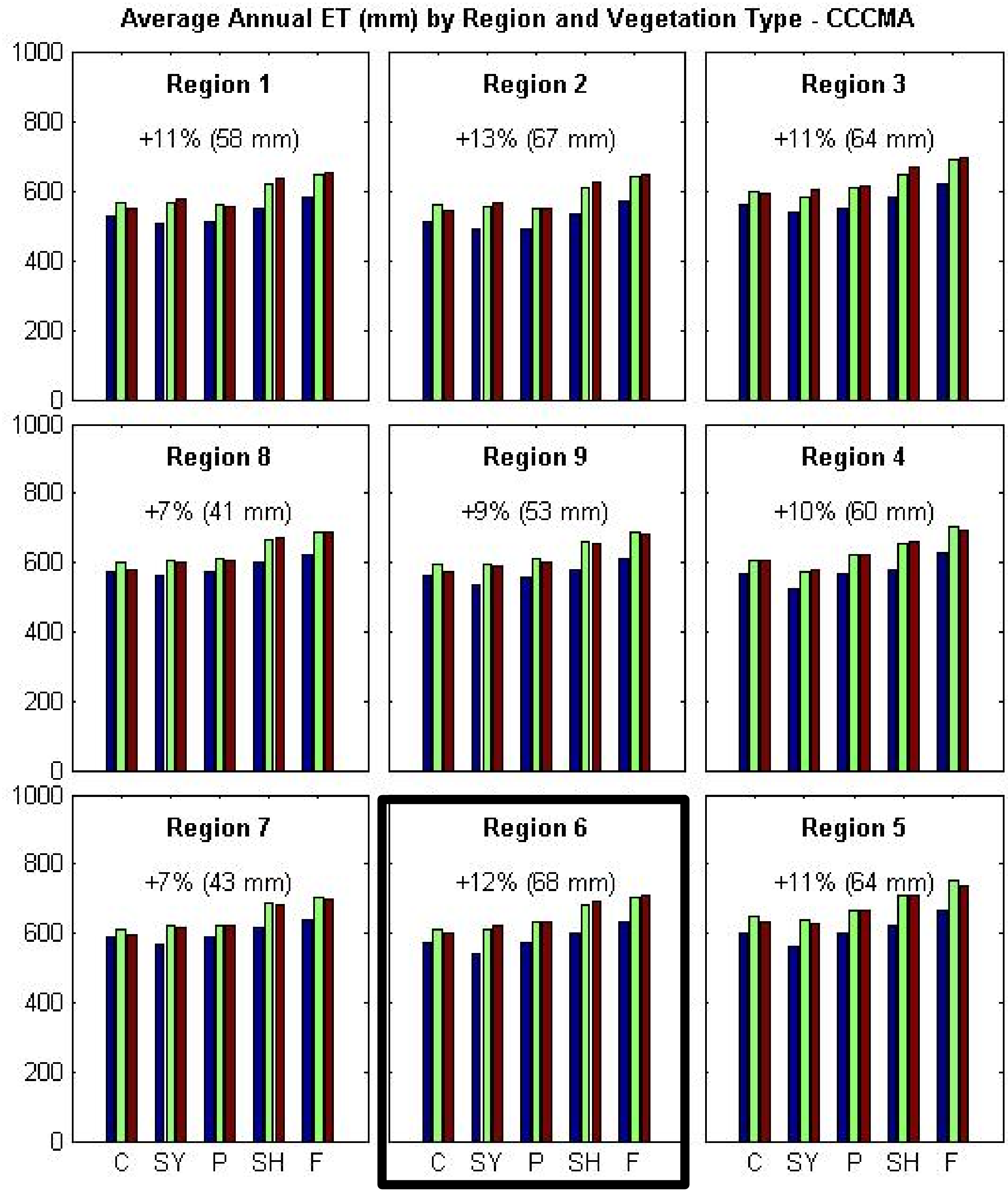


With future climate data and our calibrated model….



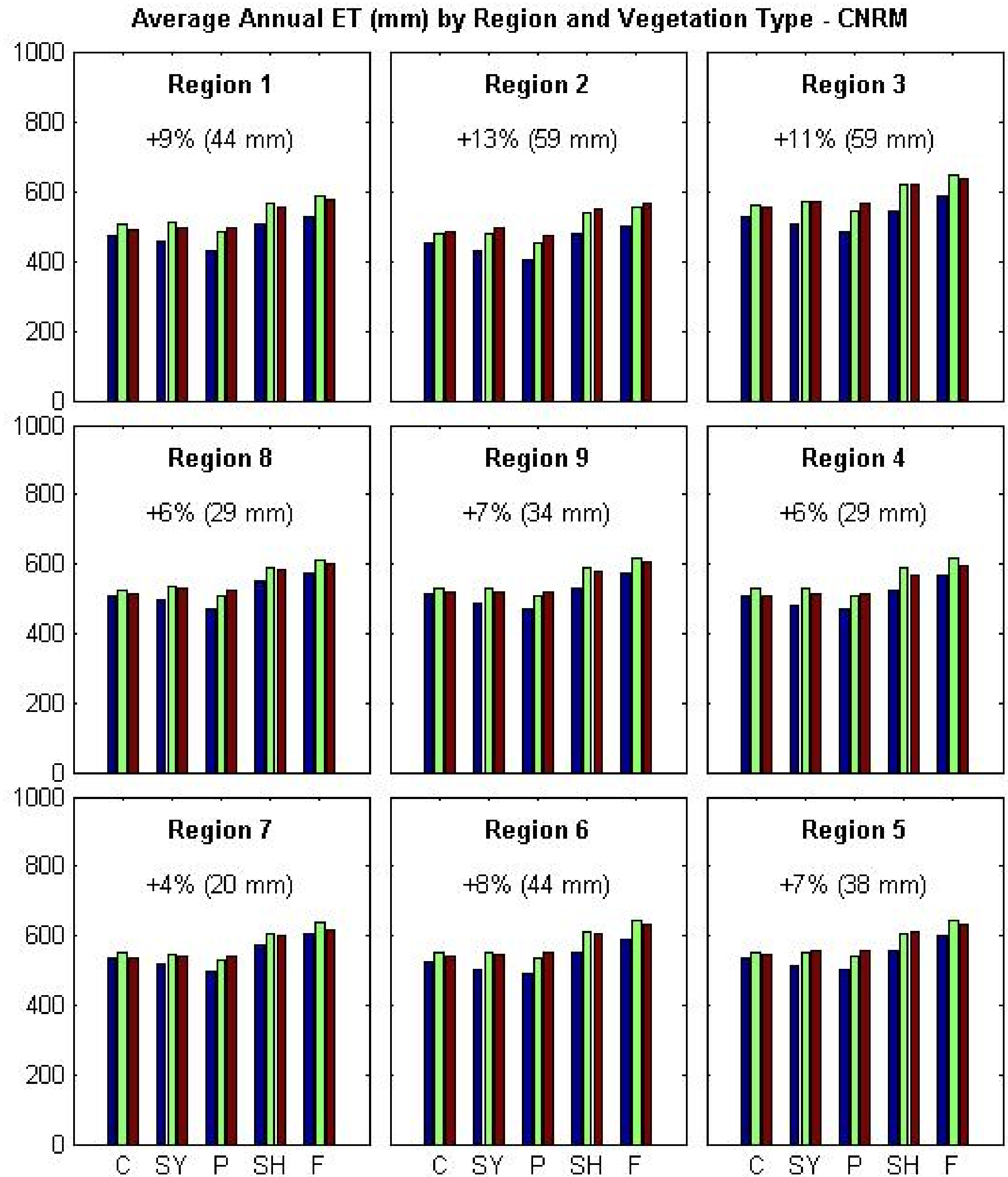
Average Annual ET from CCCMA GCM (wet)

Average increases of about 60 mm statewide by 2100 (+10%)



Average Annual ET from CNRM GCM (intermediate)

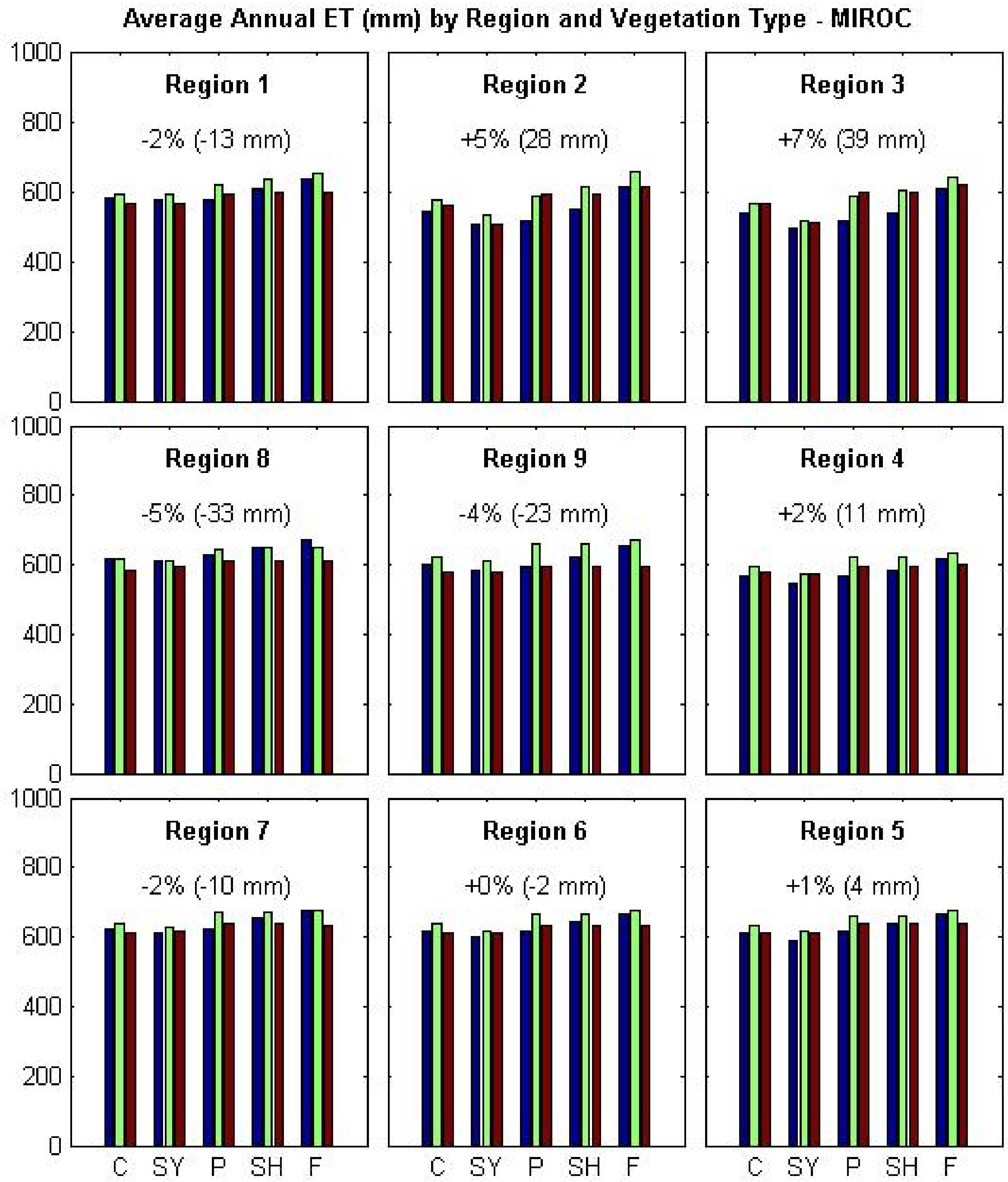
Average increases of about 40 mm statewide by 2100 (+8%)



Average Annual ET from MIROC GCM (dry)

Moderate declines in much of the state

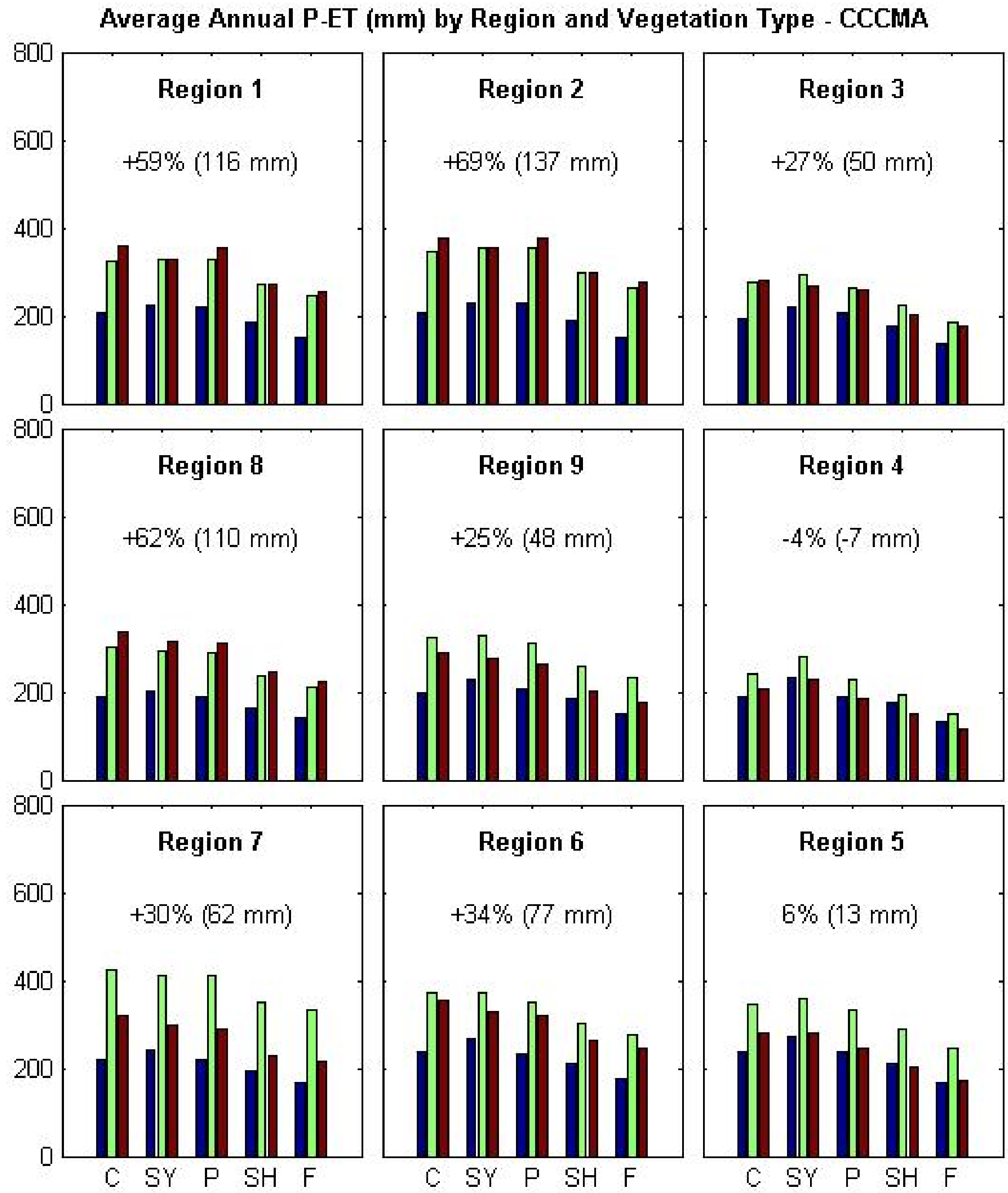
Increasing ET in northeast WI



Average Annual P – ET from CCCMA GCM (wet)

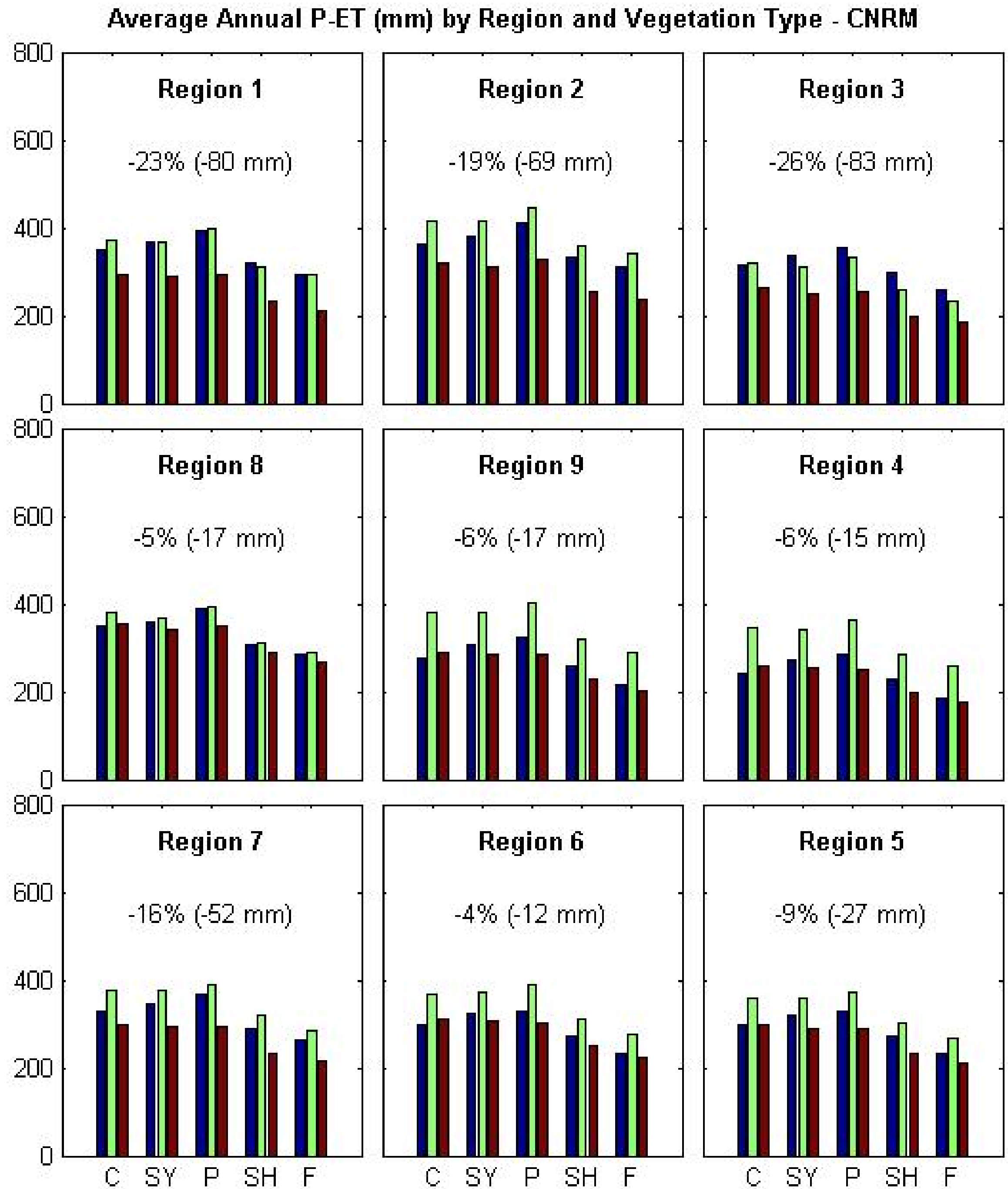
Substantial increase in P – ET across the state

Much wetter conditions overall

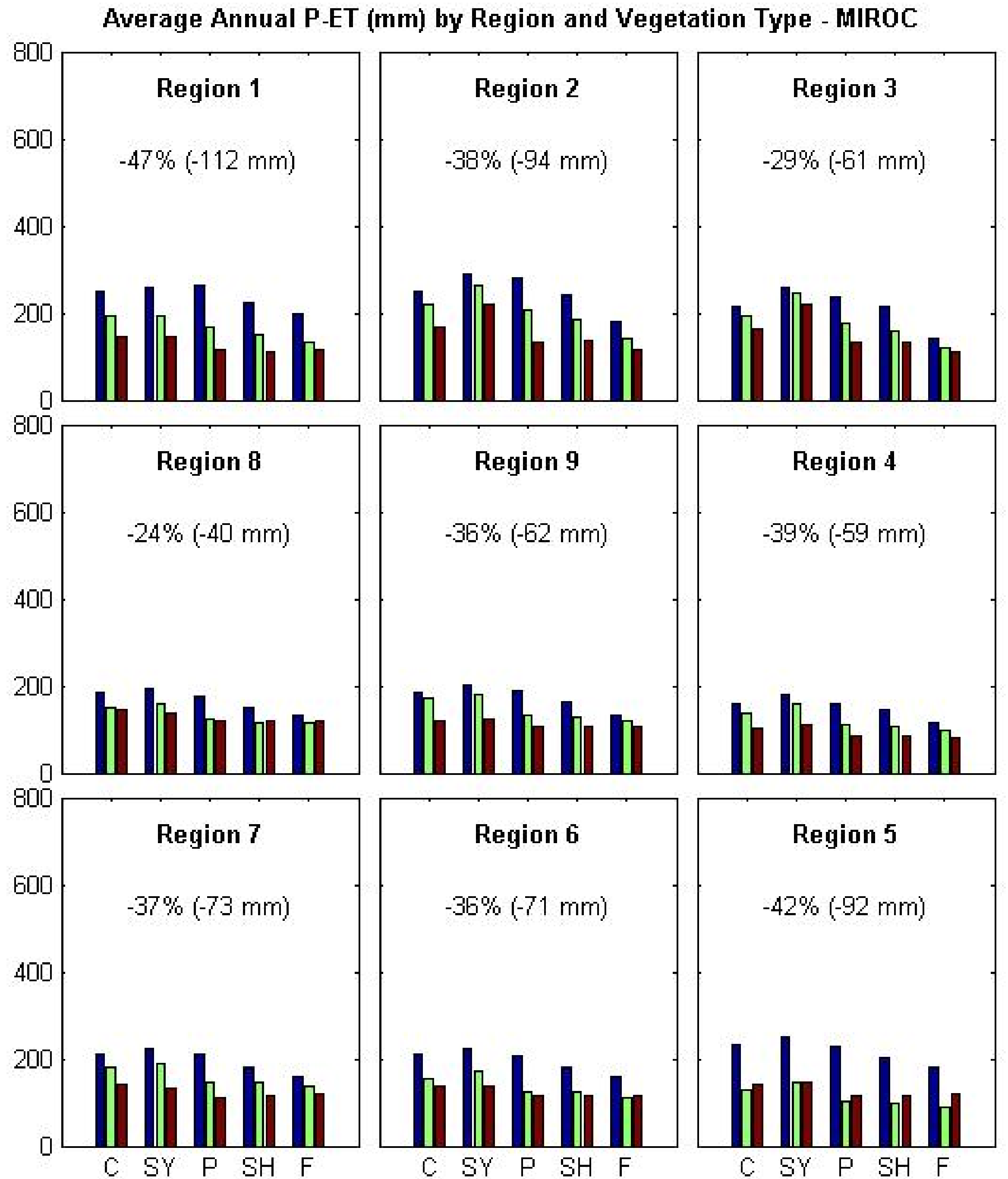


Average Annual P – ET from CNRM GCM (intermediate)

Increase in P – ET through 2065, but decreases by 2100



Average Annual P – ET from MIROC GCM (dry)

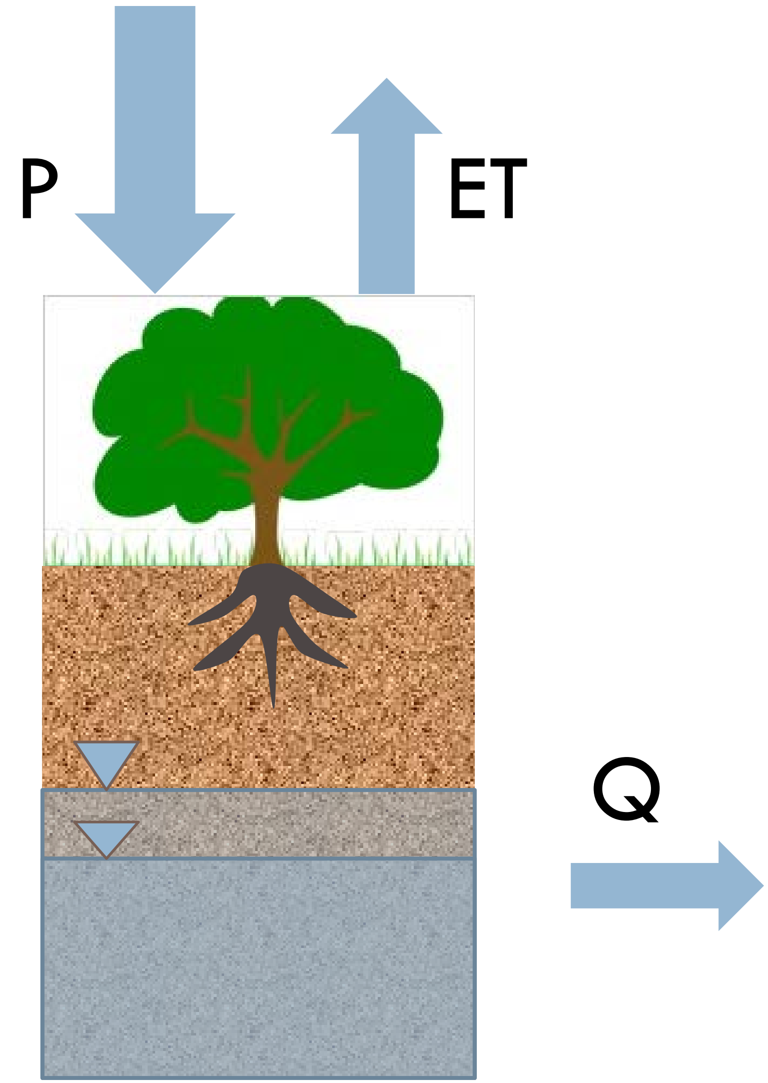


Large decrease in P – ET across the state

Much drier conditions overall by 2100

Conclusions

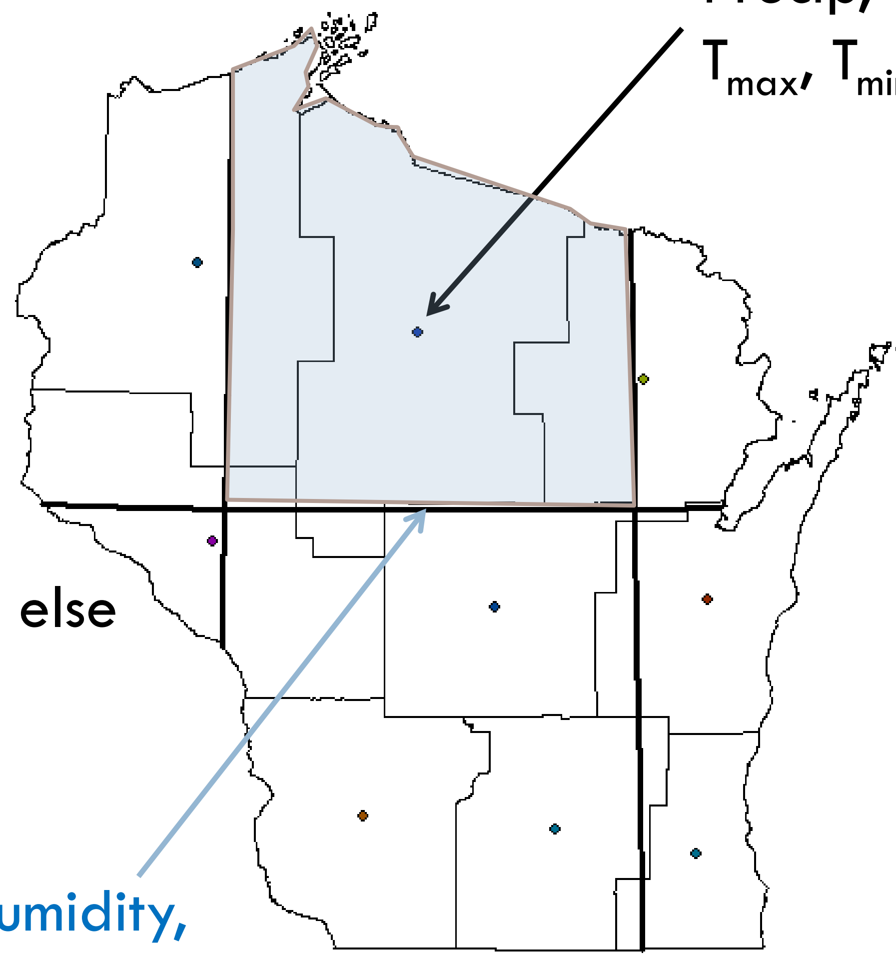
- ET is expected to increase across the state, particularly by 2046-2065. [*The only exception occurs if P decreases substantially*]
- However, the changes to P – ET are most important and depend on precipitation.
- Unless P increases more than ET, water availability will decrease.



Future climate predictions can then be used to estimate how ET will change

Downscaled data for daily Tmax, Tmin, and Precip

Precip, T_{max}, T_{min}



Wisconsin Climate Divisions – State Climatology Office

Coarser resolution for everything else

Radiation, humidity, wind speed