Problems in Estimating Evaporation in Prairie Environments

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Objectives

- Evaluate several common evaporation estimation routines in prairie environments
- Consider problems in calculating evaporation when environment becomes exceedingly dry
- Examine interaction of soil moisture mass balance component of hydrologic models with evaporation routines for prairie conditions

St. Denis Field Campaign (May – Sept 2006)

- Met data & Eddy Covariance

- Temp (air, surface)
- RH
- Wind
- Turbulent latent & sensible heat flux
- Available energy (all-wave, α), soil heat flux
- Soil moisture

Estimating Evaporation

- Met data drives ET models
  - Monteith (1965)

$$E = \frac{\Delta \frac{(Q_n - Q_g)}{l} + \left(r C_p \frac{\left(e_a^* - e_a\right)}{r_a} \right)}{\Delta + g\left(1 + \frac{r_c}{r_a}\right)}$$

  - Dalton type bulk transfer

$$E = \frac{l\, r\, (q_s - q)}{r_a + r_c}$$

Observed surface temp drives humidity gradient

Canopy Resistance (Verseghy et al, 1993)

$$r_c = r_{cmin} f_1 f_2 f_3 f_4$$

r_{cmin} represents unstressed canopy resistance

$f_1(K\downarrow) = \max(1.0, (500 / K\downarrow - 1.5))$

$f_2(\Delta e) = \max(1.0, (\Delta e / 5.0))$

$f_4(t) = 1.0$ if $t < 40\ °C$ and $> 0\ °C$

OR

if $t > 40\ ^oC$ or $< 0\ ^oC$ then

$f_4(t) = 5000 / r_{cmin}$

Canopy Resistance (Verseghy et al, 1993)

$f_3(\psi) = \max(1.0, \psi / 40.0)$

Ψ is the soil moisture tension determined from the power-law relationship of Campbell (1974):

$$y(q) = y_{ae}\left(\frac{f}{q}\right)^{b}$$

Representative values for y_{ae}, f, and *b* can be found for characteristic soil textures (Clapp and Hornberger, 1978)

Volumetric soil moisture, θ, in the upper soil profile obtained from measurements or can be modelled

Estimating Evaporation

– Granger/Gray (1989); G-D relationship

$$E = \frac{\Delta G \frac{(Q_n - Q_g)}{l} + gGE_A}{\Delta G + g}$$

Where:

relative evaporation (actual/potential)

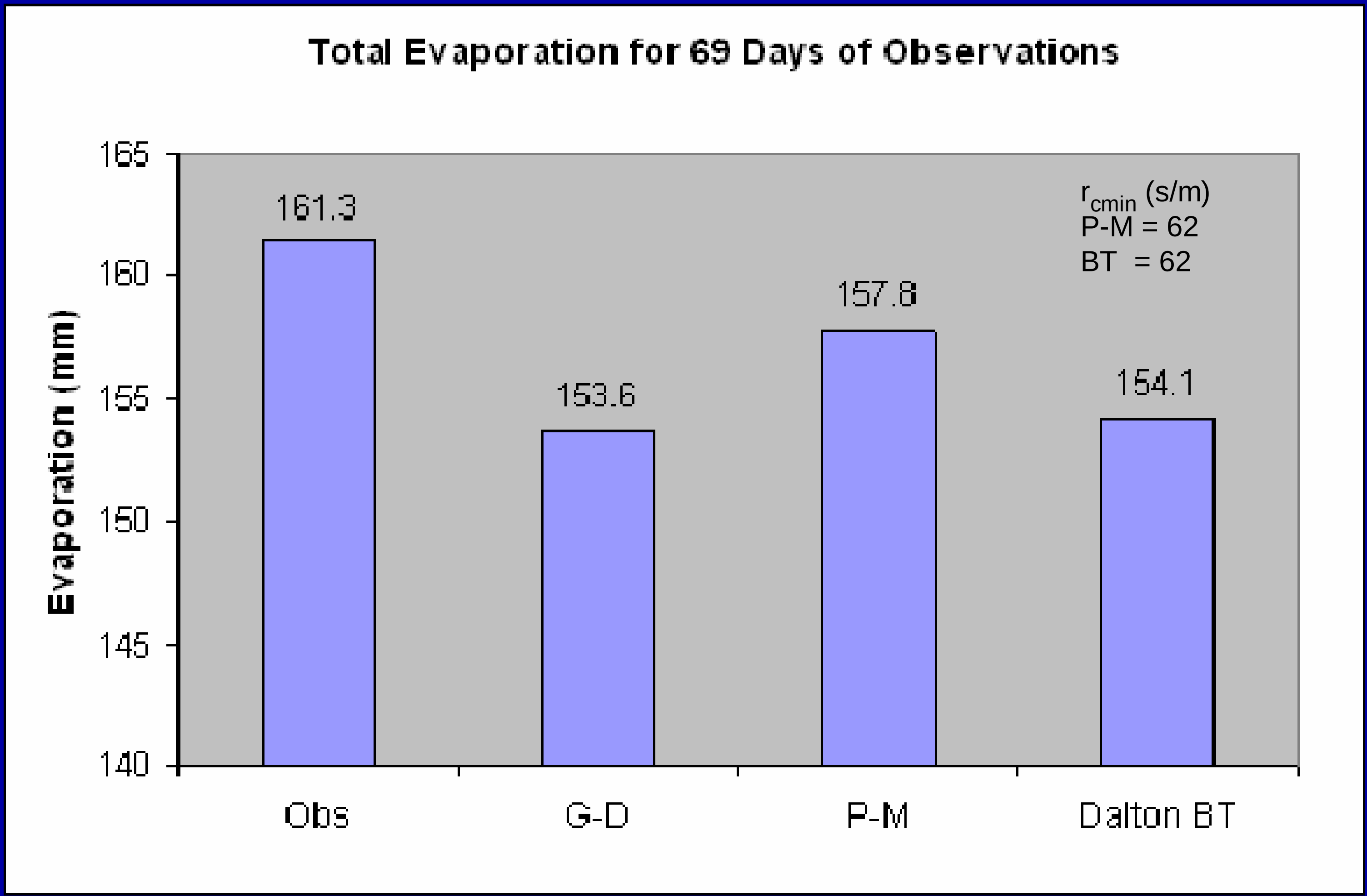
$$G = \frac{1}{0.793 + 0.2e^{4.902D}} + 0.006D$$

And

relative drying power

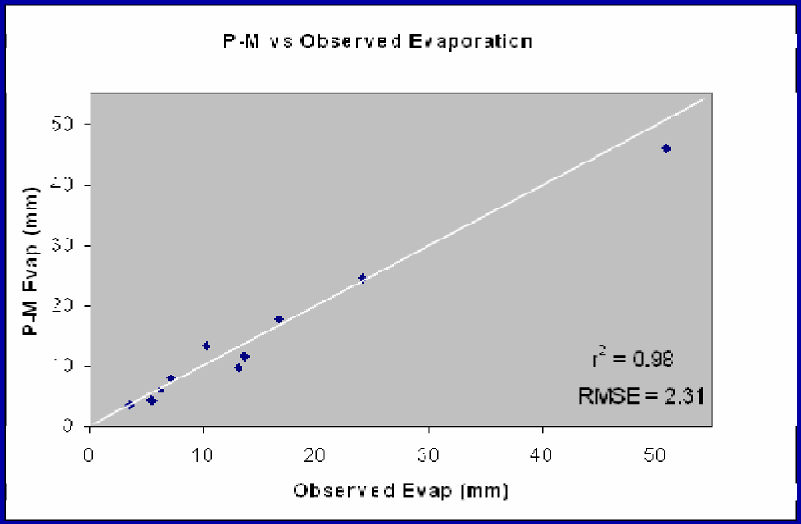
$$D = \frac{E_A}{E_A + \frac{(Q_n - Q_g)}{l}}$$

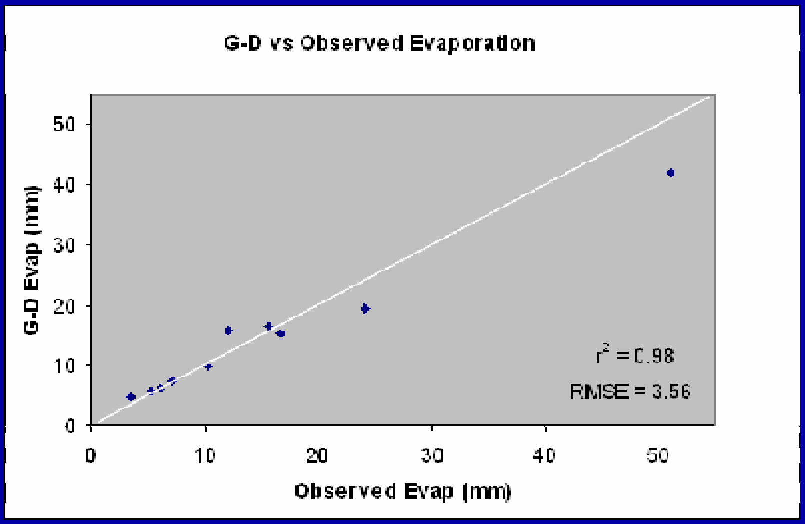
Models vs Measured
2006 - Good Moisture Availability



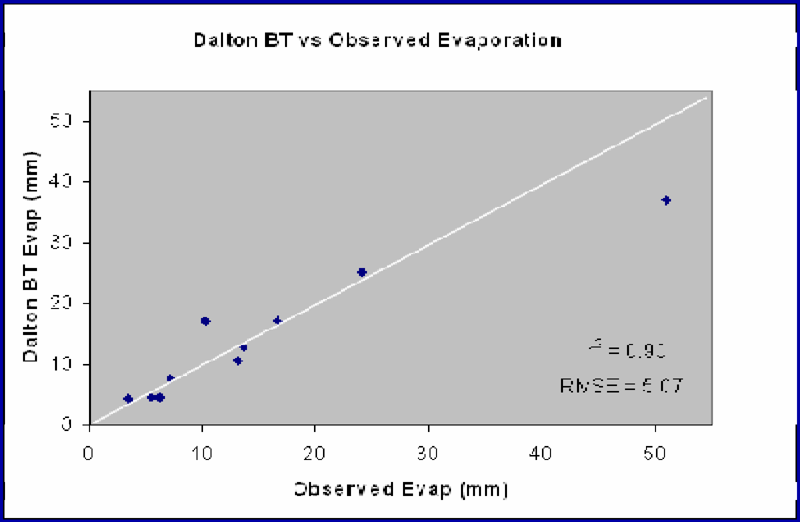
2006 St. Denis

Models vs Measured – Golden Periods 2006



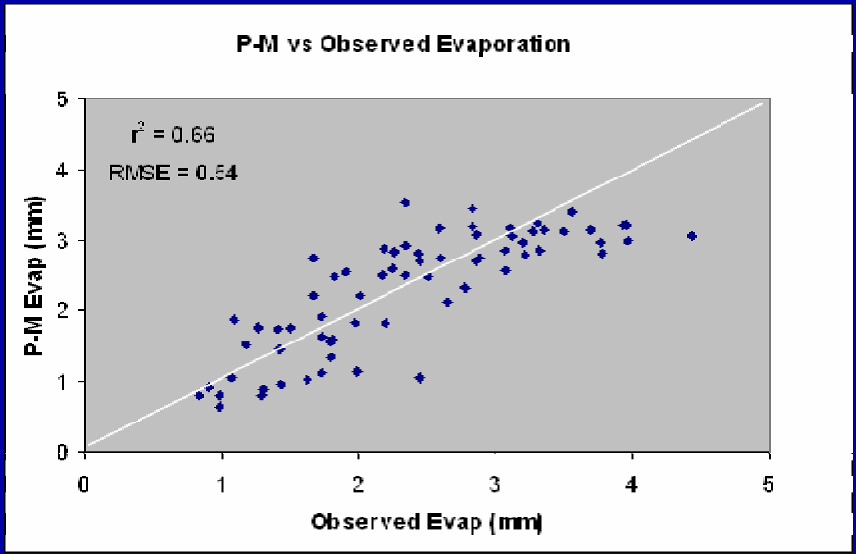


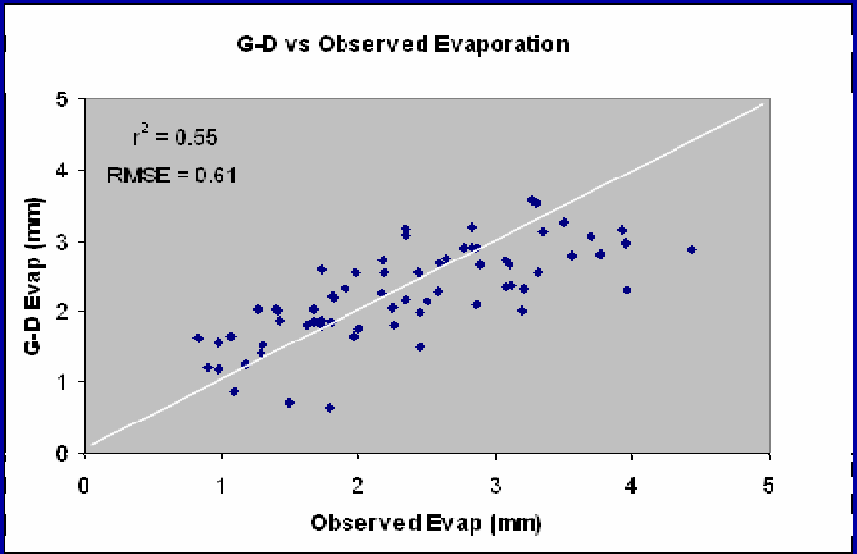
Golden Periods from 2 days to 2 weeks with instruments working well and full field measurements

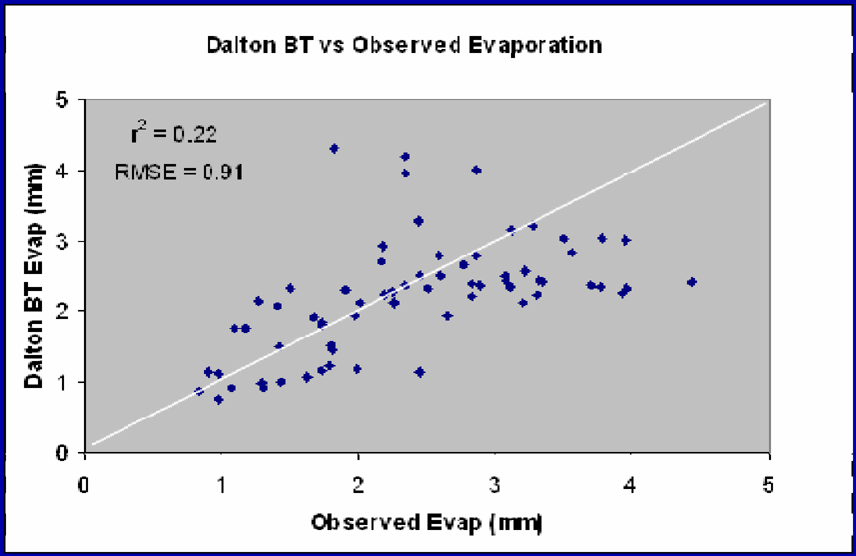


2006 St. Denis

Models vs Measured – Golden Period Daily

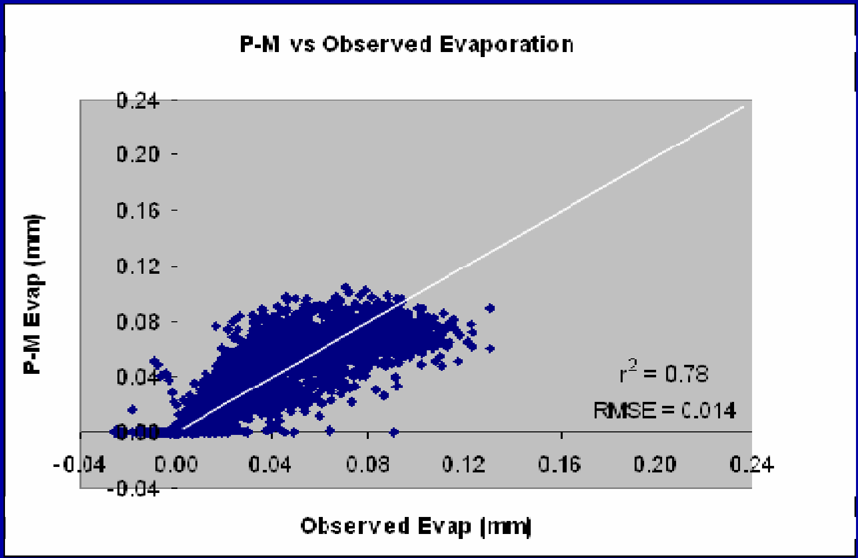


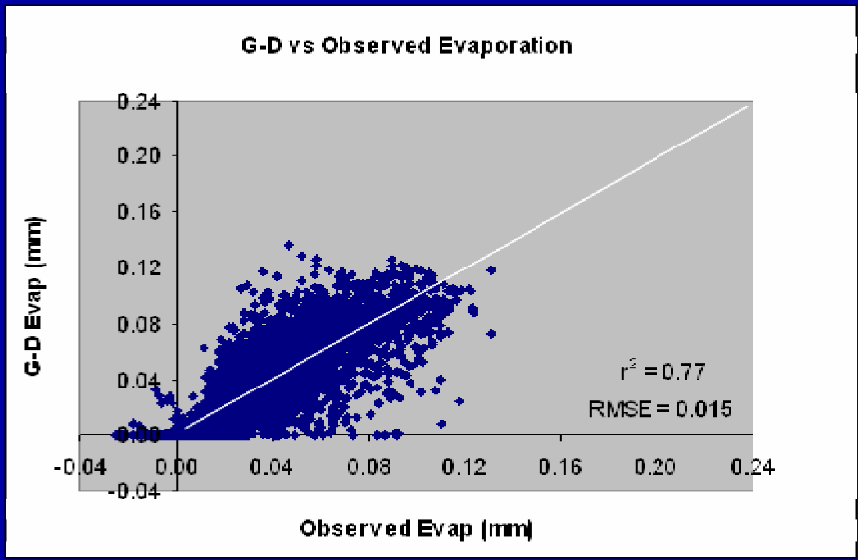


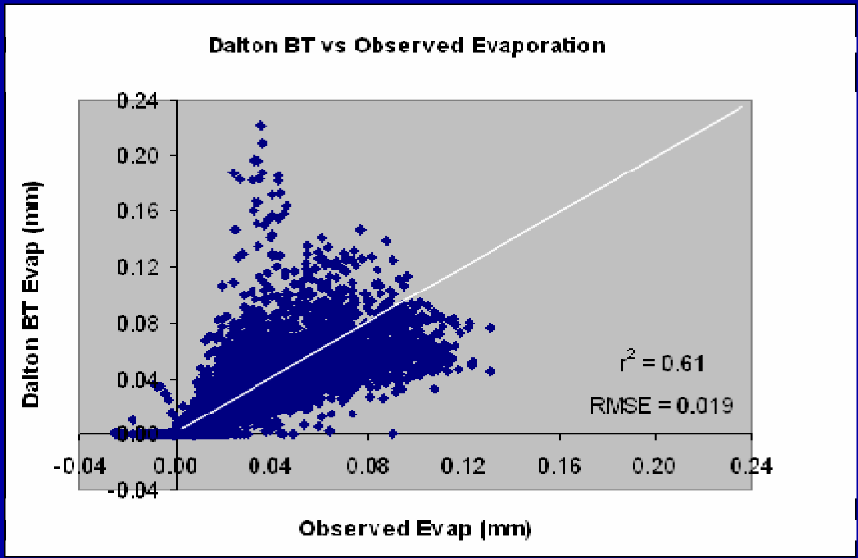


2006 St. Denis

Models vs Measured – 15 min interval

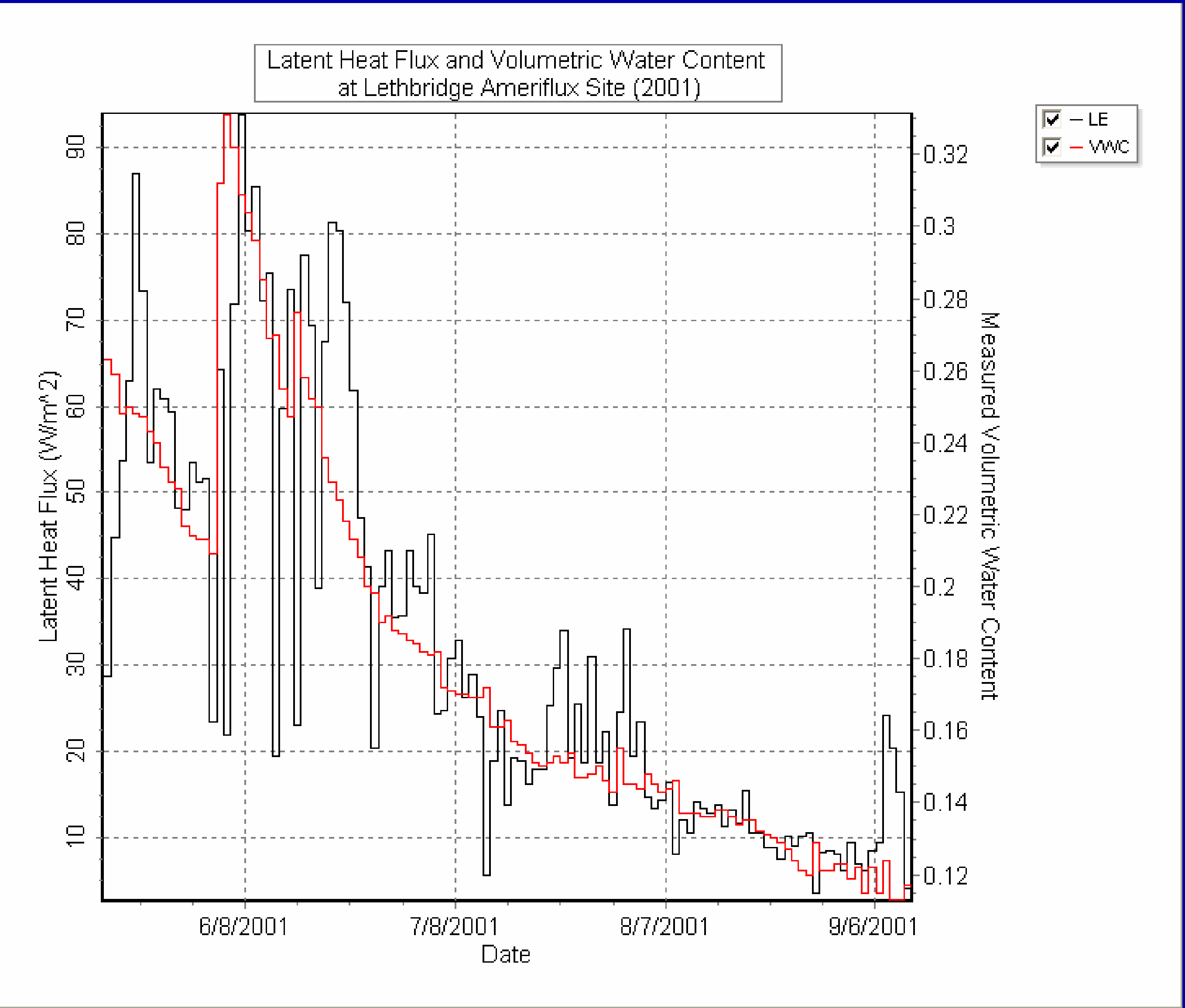






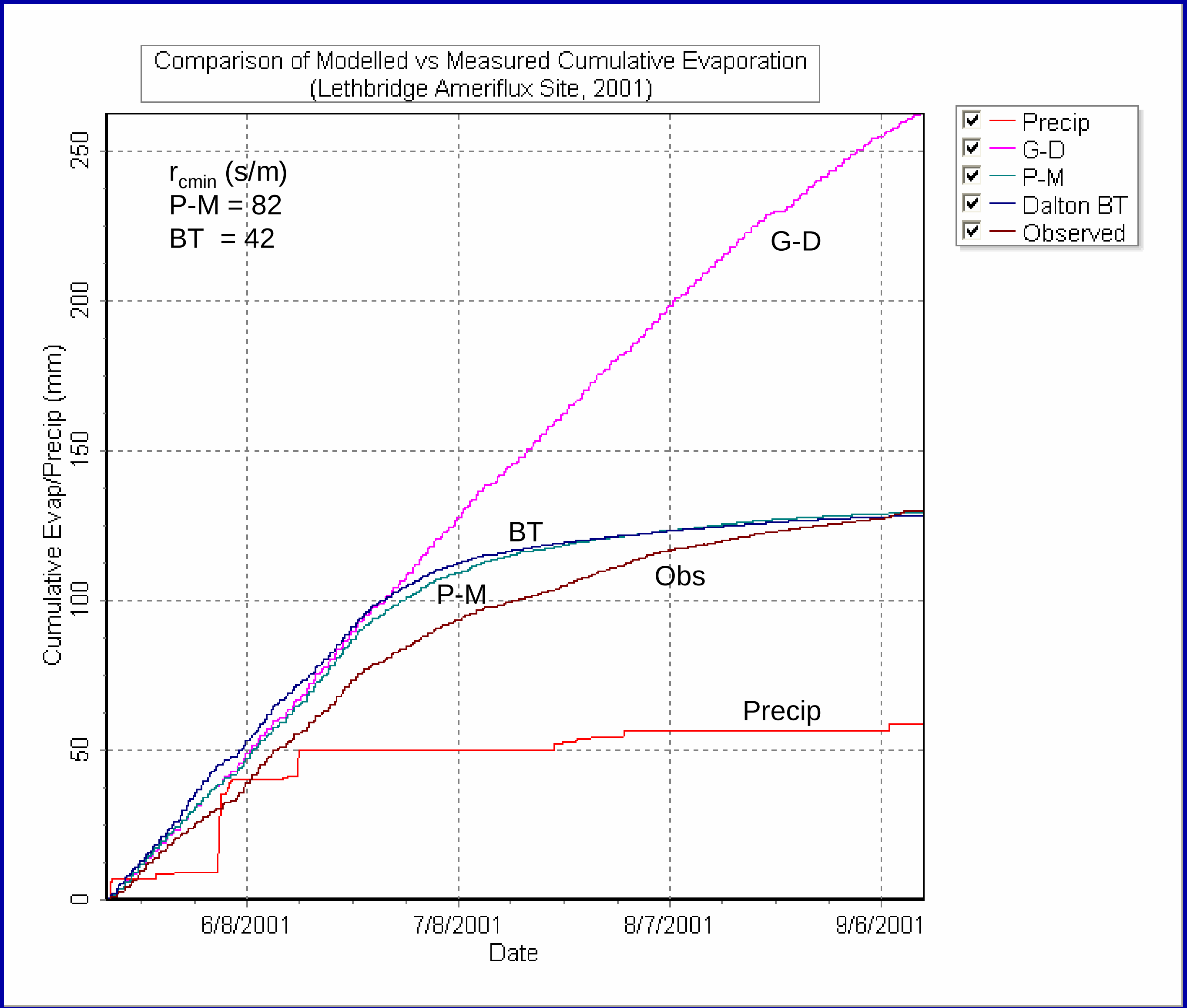
2006 St. Denis

Lethbridge Ameriflux Site (2001)



Drought conditions

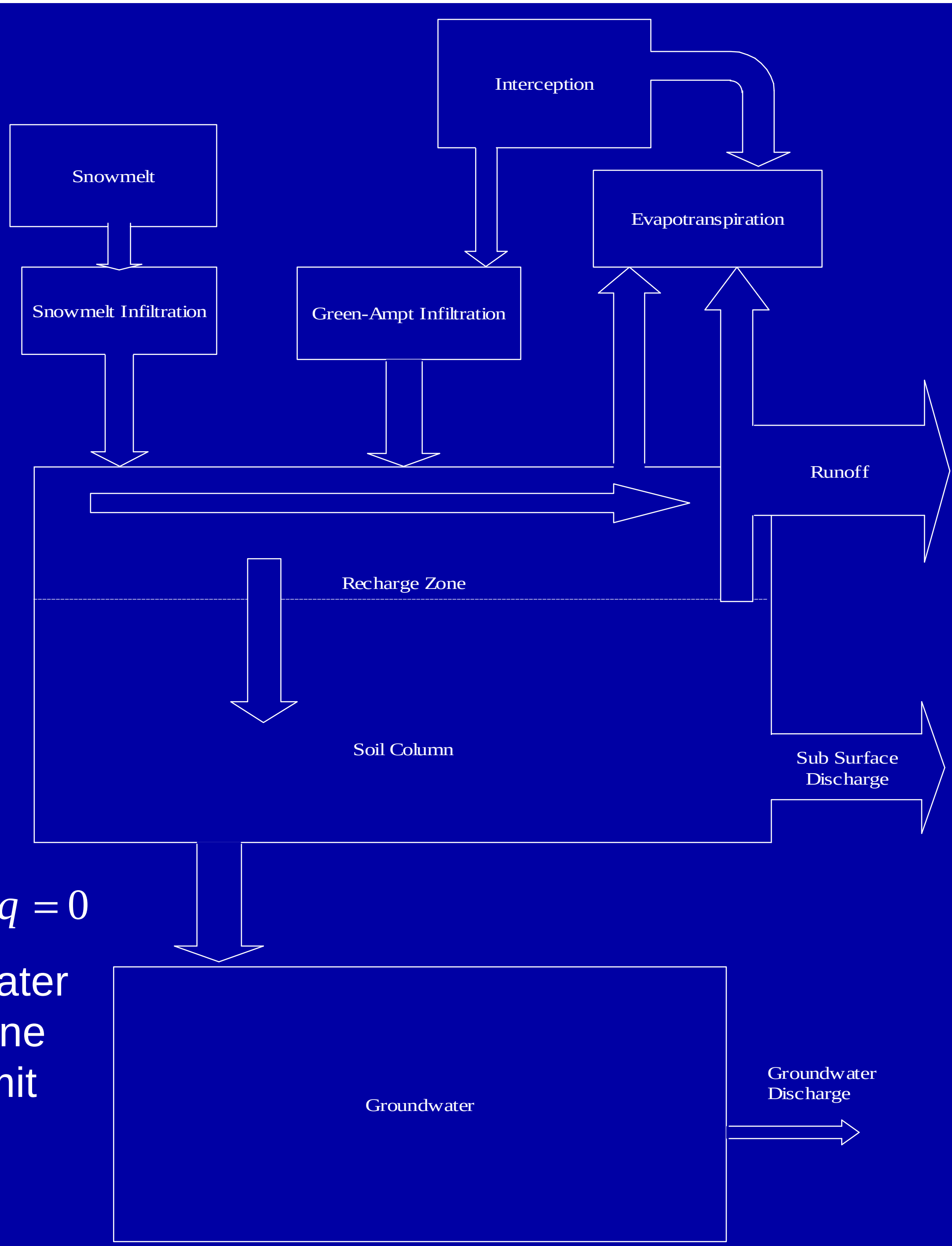
Lethbridge Ameriflux Site (2001)



Drought conditions

Soil Moisture Balance Control of Evaporation

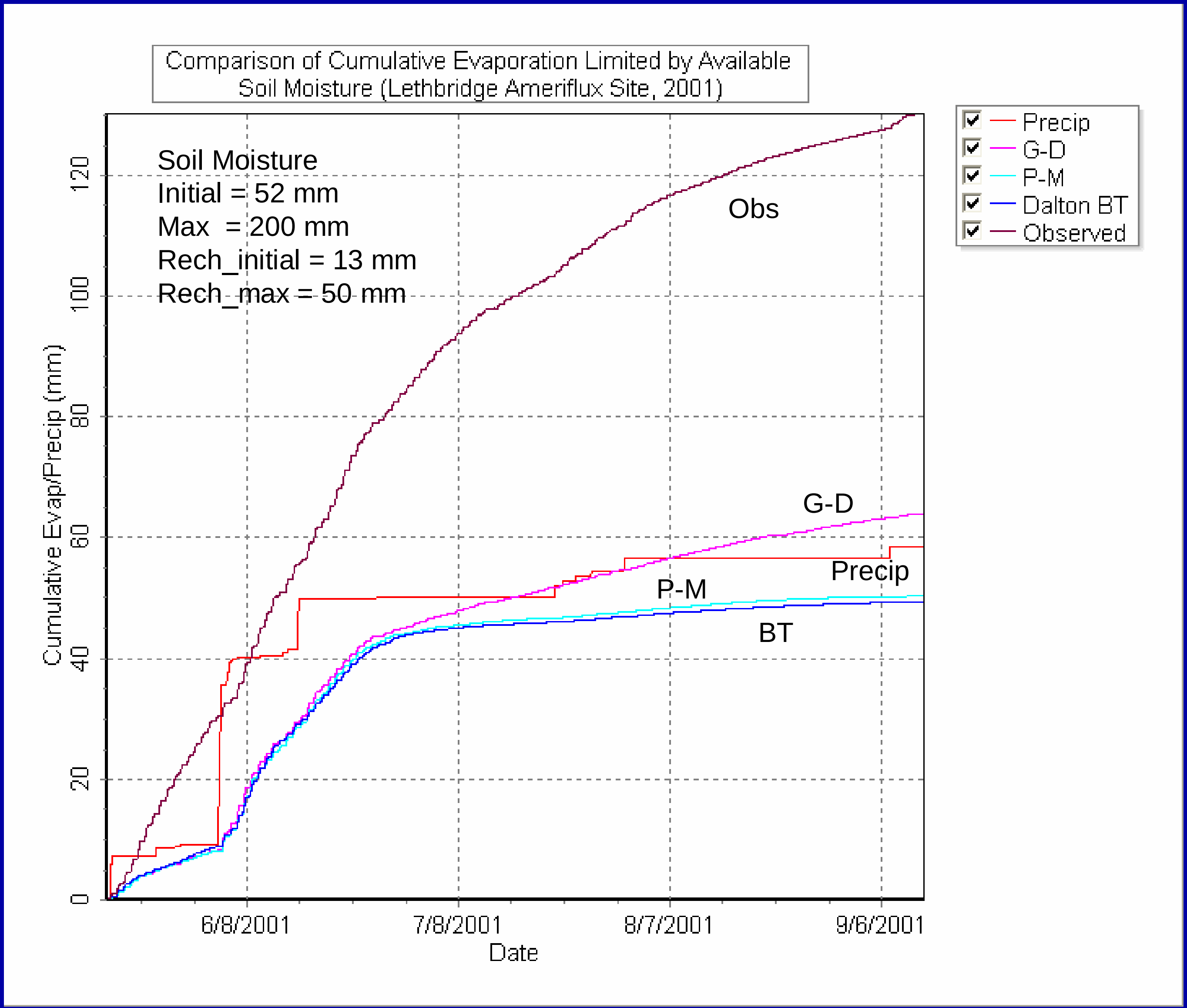
Mass balance and flow from
2 soil layers & groundwater



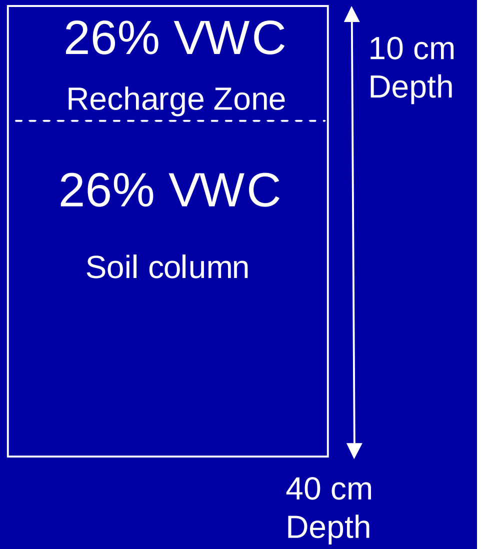
$$INF - GW - SSR - E_{SURFACE} - Trans - \Delta q = 0$$

Model evaporation controlled by water supply in interception, recharge zone soils and deep soils, possible to limit evaporation to recharge zone and interception

Lethbridge Ameriflux Site (2001)



Drought conditions



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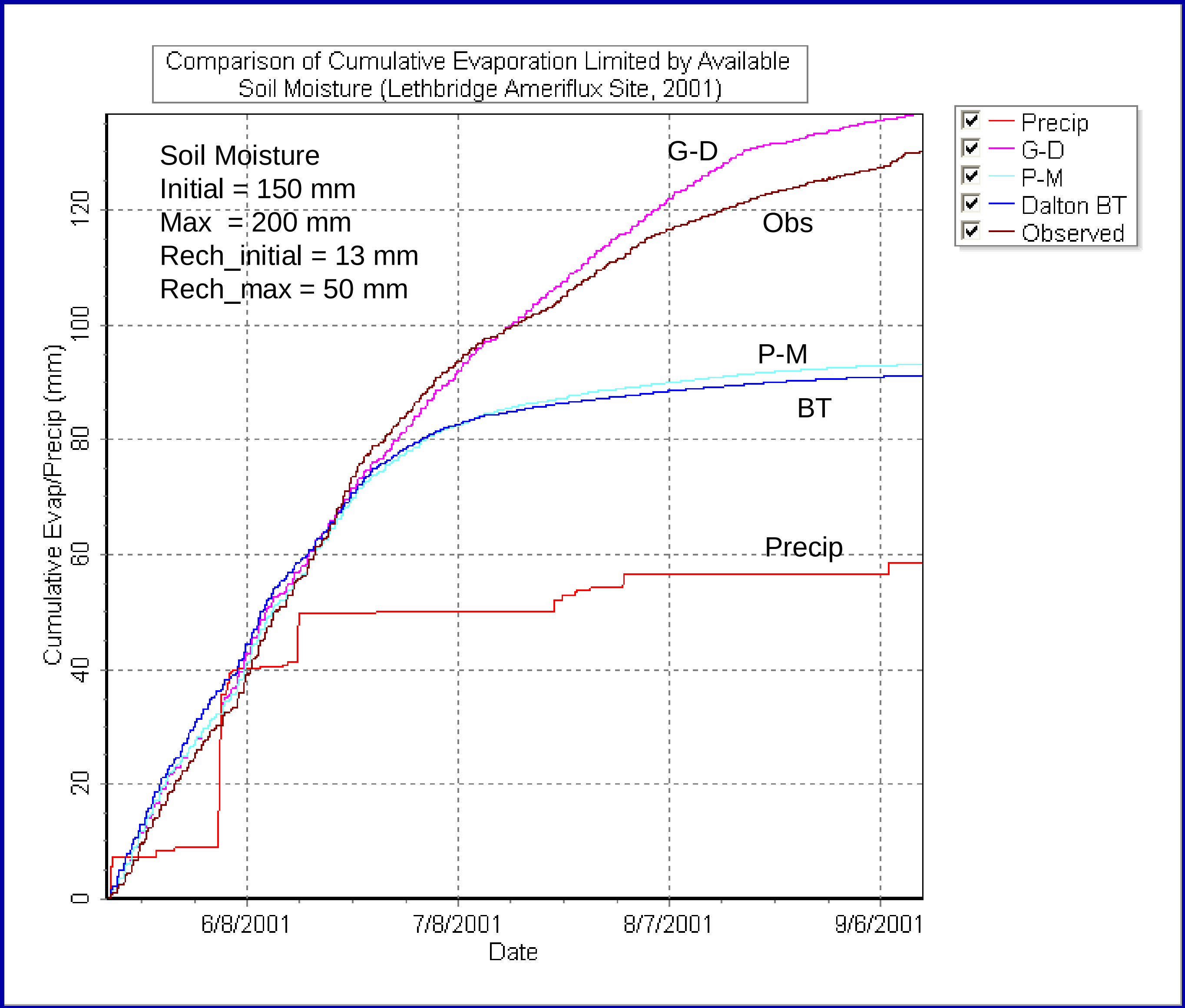


Drought conditions

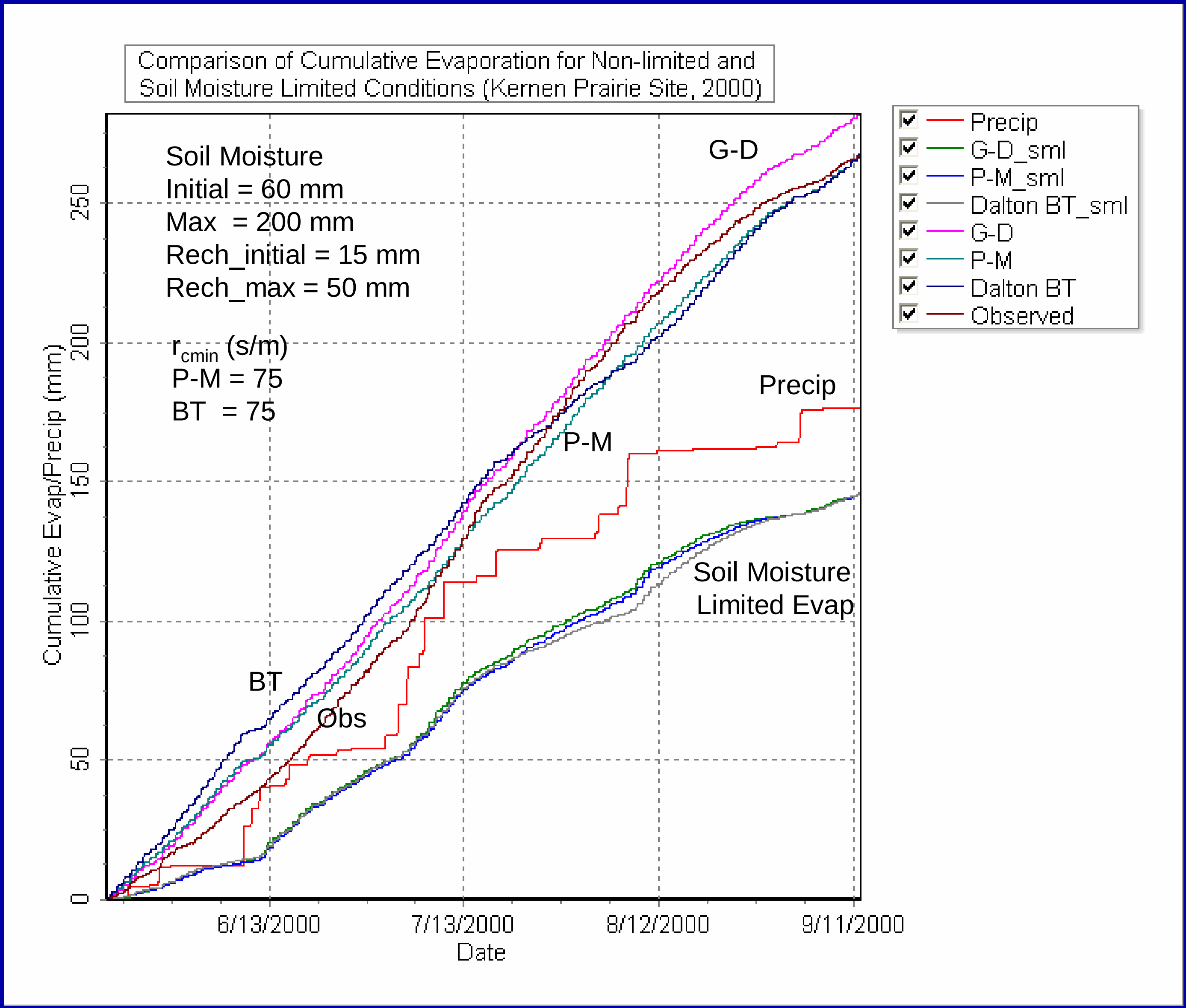
26% VWC

Recharge Zone

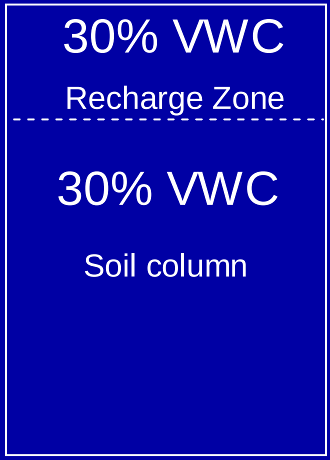
75% VWC

Soil column

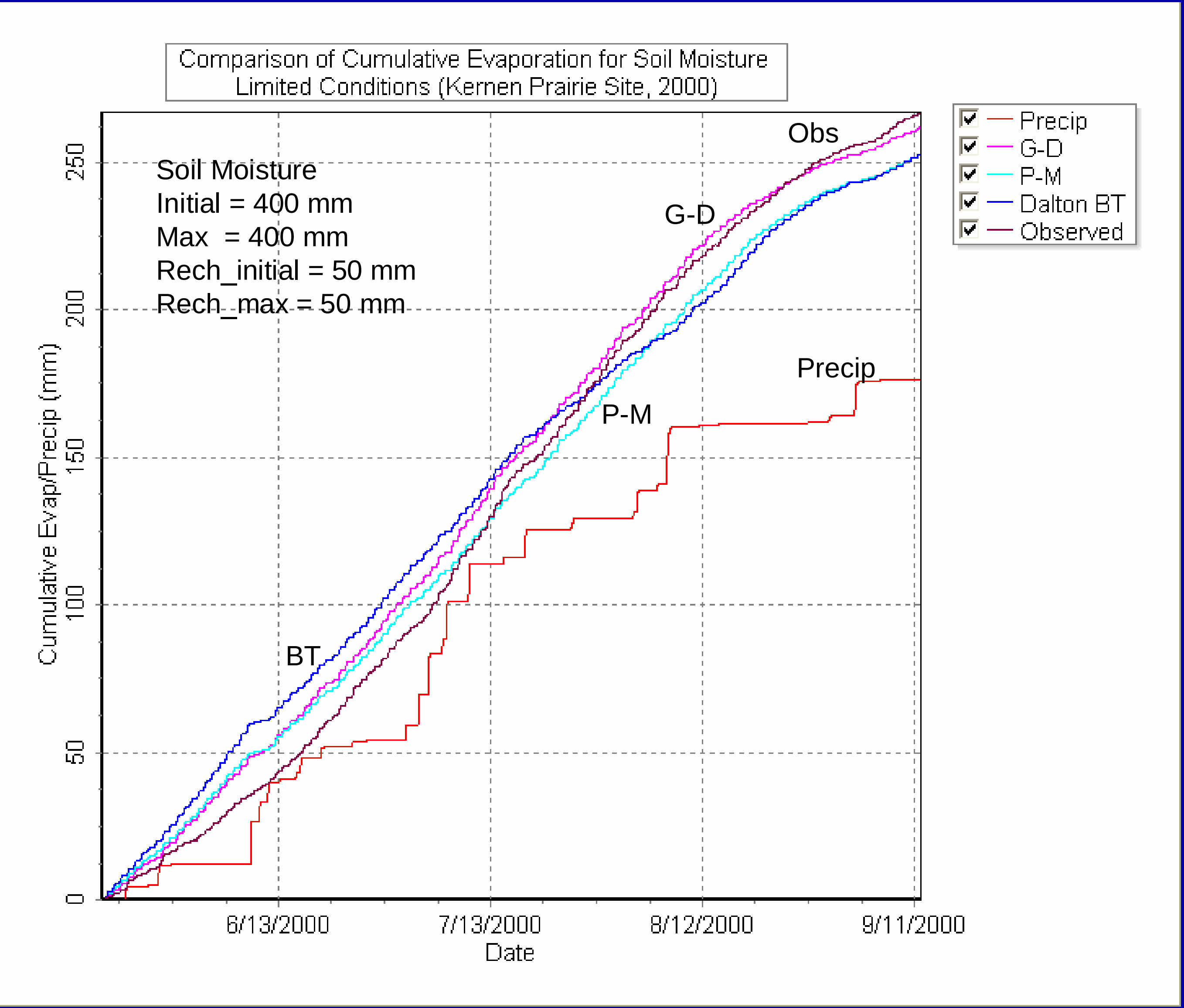
Kernen Prairie Site (2000)



Drought conditions



Kernen Prairie Site (2000)



Drought conditions

Full

Recharge Zone

Full

Soil column

Problems To Consider

- Difficult to parameterize canopy resistance with common meaning for P-M and Dalton BT methods
- “Representative” values used as equation parameters for specific soil types may not always result in “well behaved” models (e.g. soil moisture tension and Green-Ampt)
- Overestimating evaporation during dry conditions and underestimating evaporation during wet conditions are common problems
- Limiting evaporation using typical hydrological model continuity approaches (ratio of water content to maximum content) may be too limiting for natural grasses that can access deeper sub-surface moisture than is generally considered part of the ‘soil profile’

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