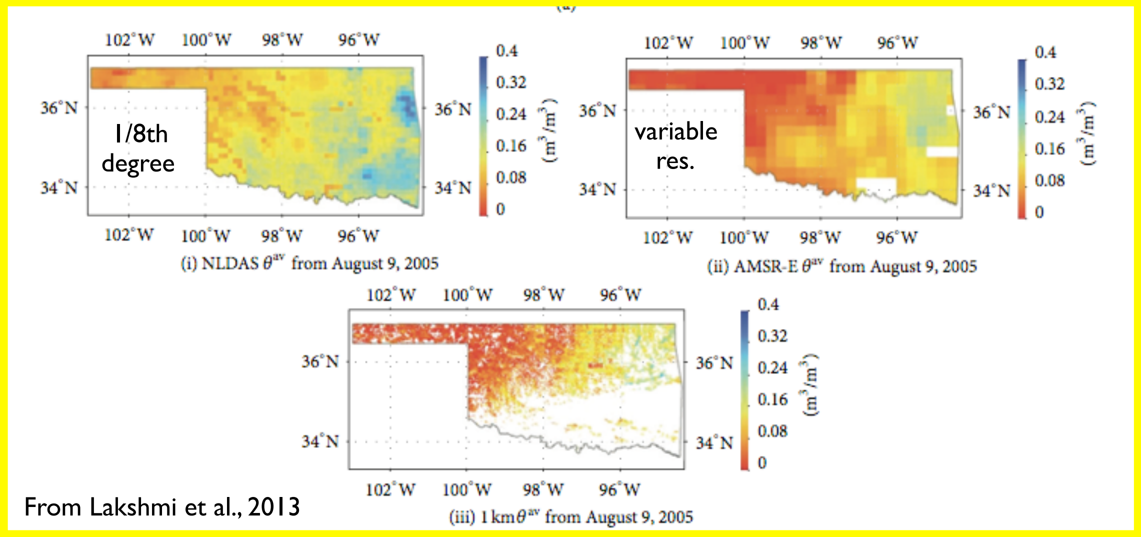
Modeling the Effects of Variable Soil Moisture

Piers Sellers[2], Ian Baker[1], Scott Denning[1], David Randall[1], Isaac Medina[1], Parker Kraus[1]

1: Atmospheric Science Department, Colorado State University, Fort Collins CO, USA
2: NASA GSFC, Greenbelt MD, USA

Surface Heterogeneity

- Surface varies on scales smaller than gridcell
- Slope/aspect
- Vegetation
- Soil Moisture



Soilwater Constraint on ET

$$E = E_p f(W)$$

- Roots and stomates link soil water to ET
- 1= no stress; 0 = no transpiration
- Nonlinear; position depends on sand/clay %
- Scale Gap
- Problems when this f(W) is applied on GCM gridcells (Amazon)

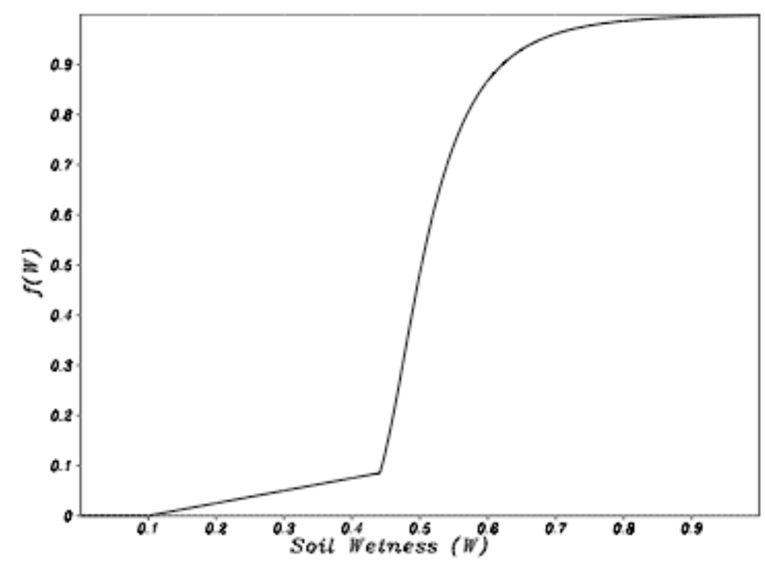
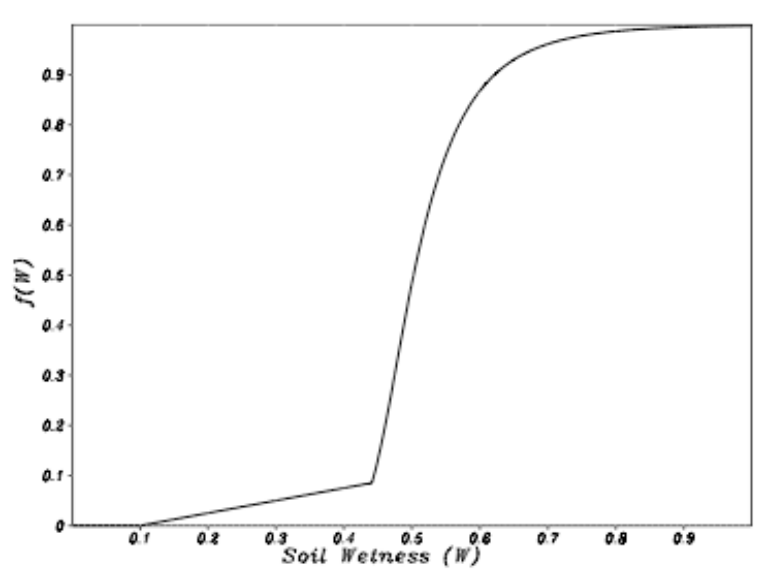


Figure 1. Relationship between the soil moisture stress function $f(W)$ and soil moisture W as used in this study (see equation (2)). This function is based on data presented by *Colello et al.* [1998] for the FIFE prairie grassland site in Kansas, USA.

From Sellers et al., 2007

Non-Linear Relationship

$$E = E_p f(W)$$



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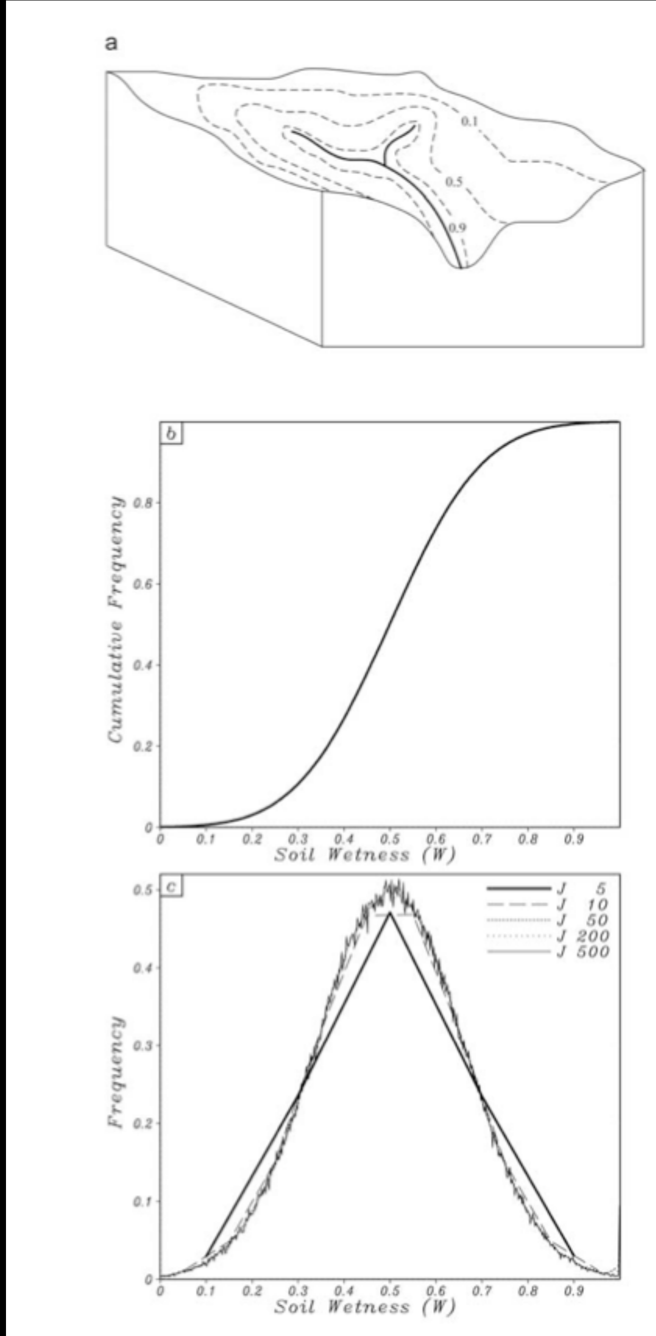
From Sellers et al., 2007

$$F(\overline{W}) \neq \overline{F(W)}$$

Soil Wetness ‘BINS’

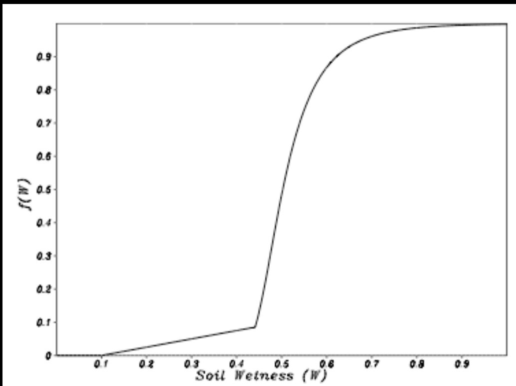
From Sellers et al., 2007



- Experiment: 3 methods to calculate ET in an idealized setting

1. Explicit, 10^6 gridcells
2. Single calculation of $f(\overline{W})$
3. BINS, J=5 to 500

$$E = E_p \sum_{i=1}^{n} a_i f(W_i)$$



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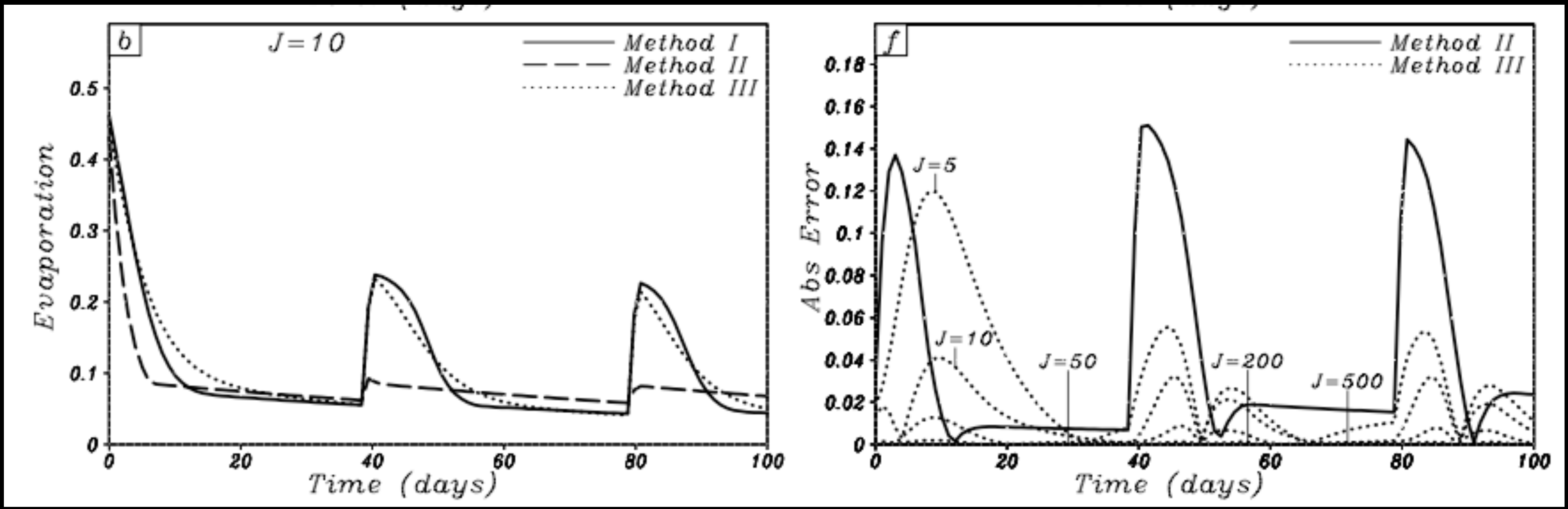
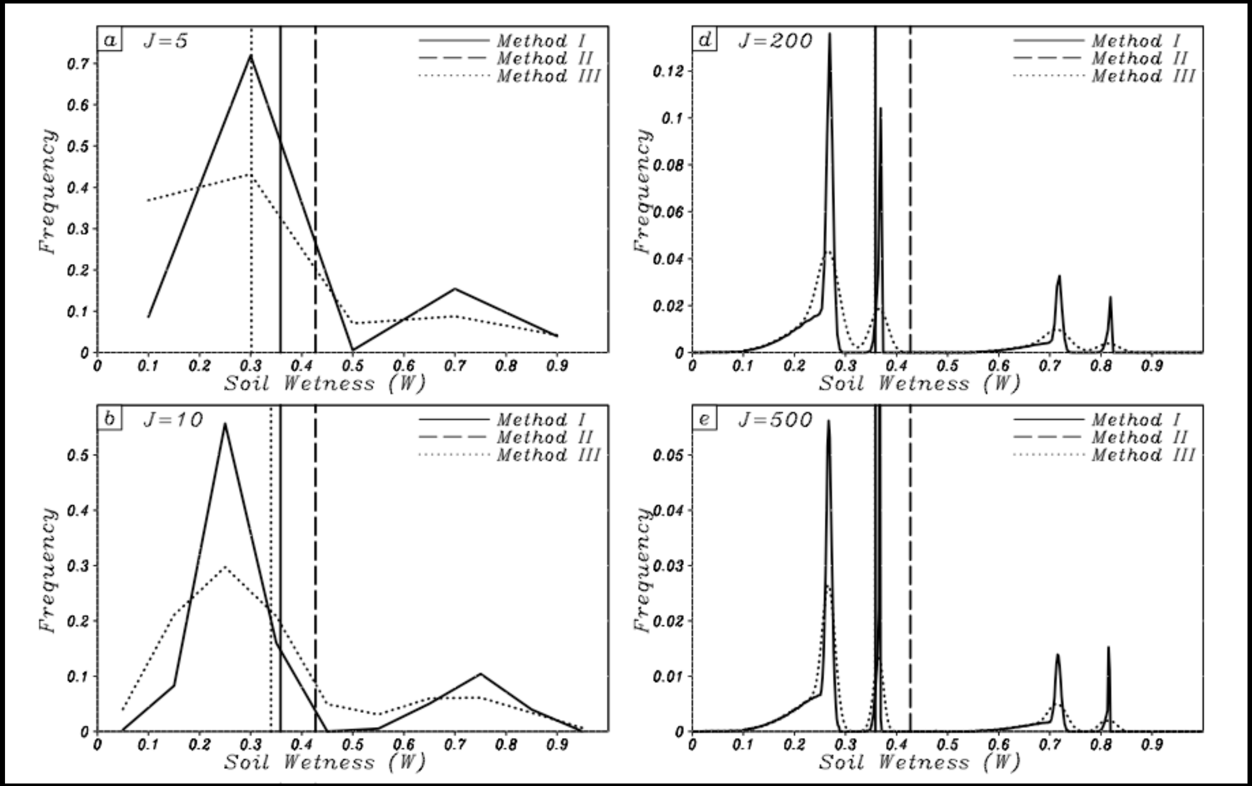
How Well Does the Conceptual Model Work?



From Sellers et al., 2007

- 500 bins is indistinguishable from explicit method
- 10 bins is a reasonable approximation
- Even 5 bins is better than single $\overline{W}$

BIN distribution over time



From Sellers et al., 2007

- Wetting events (precipitation) manifest as positive area on the right (wet) of the distribution
- Drying moves area to the left, decreases variability (narrower distribution)

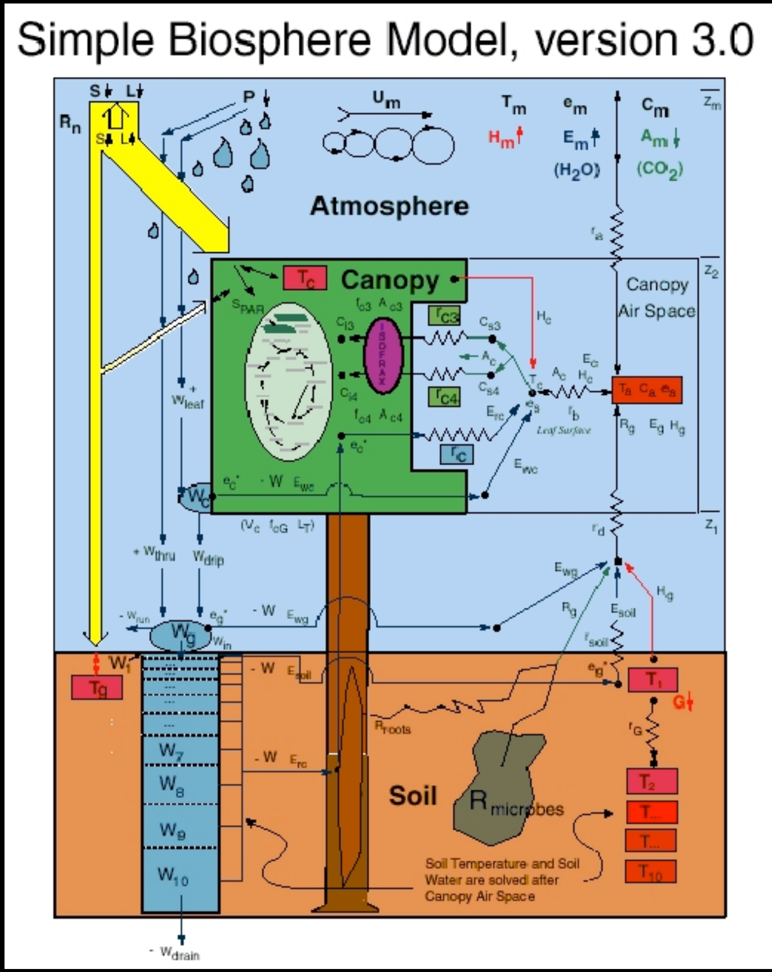
Can We Implement BINS in a 'Real' Model?

Toy Model

- Single Soil layer
- Single control - f(W) - on ET
- no diurnal cycle

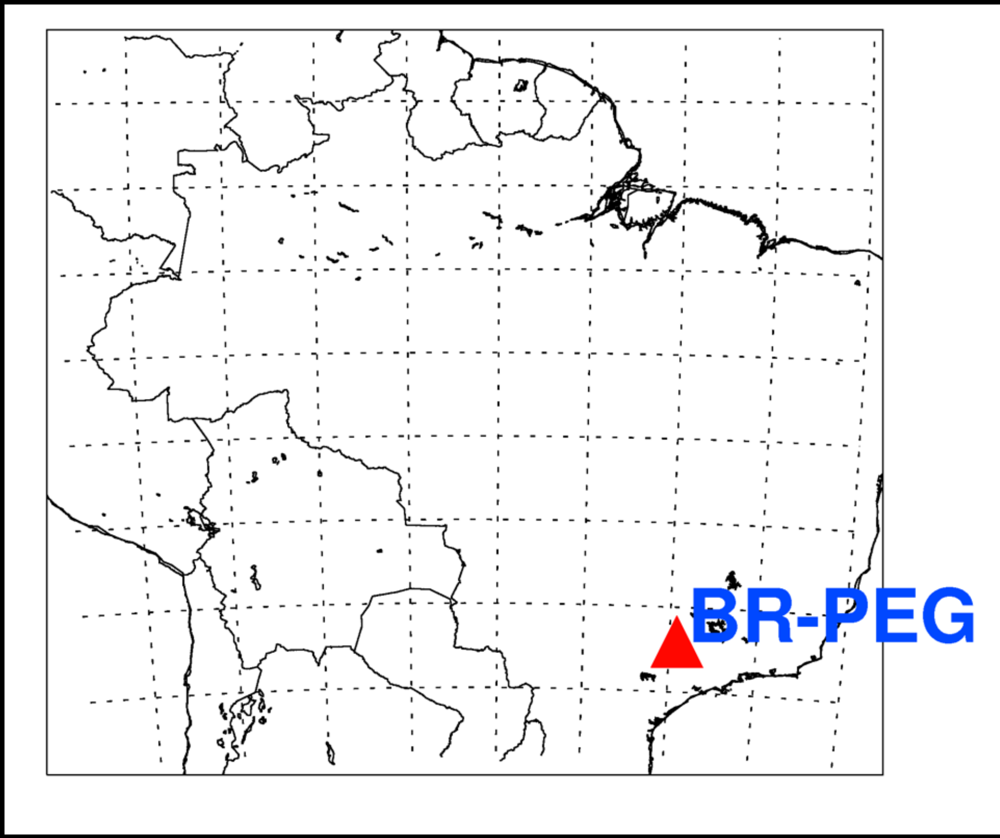
Real Model

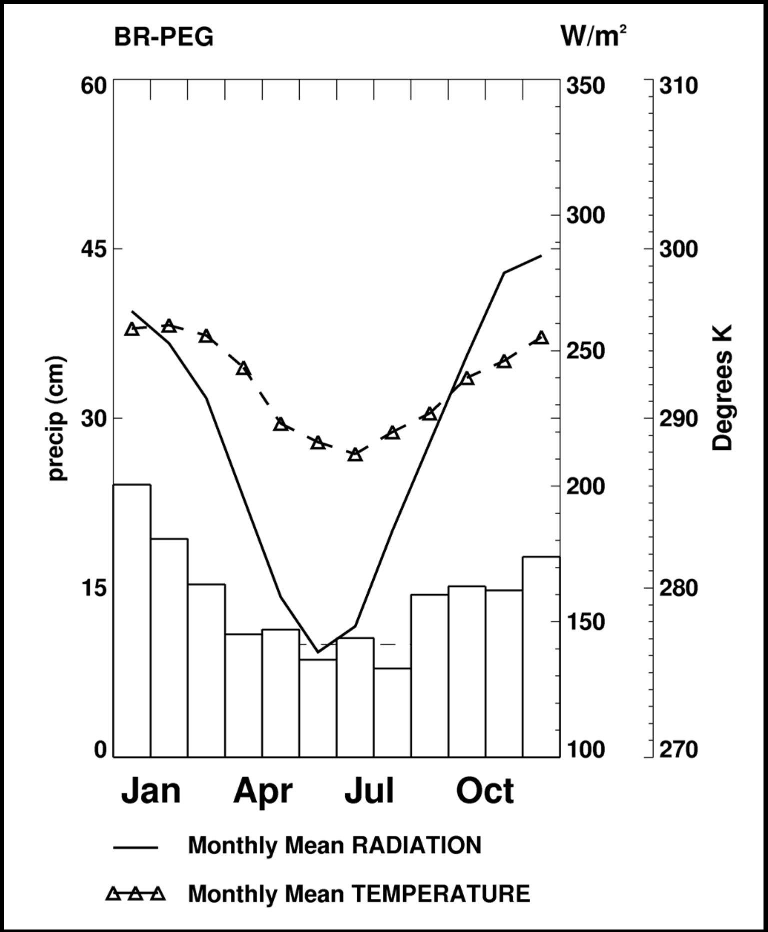
- Multiple Soil layers - with roots
- ET responds to W, temp., RH, Rnet, phenology
- diurnal, synoptic, seasonal cycles, IAV (10-minute timestep)
- tested using 10 BINS

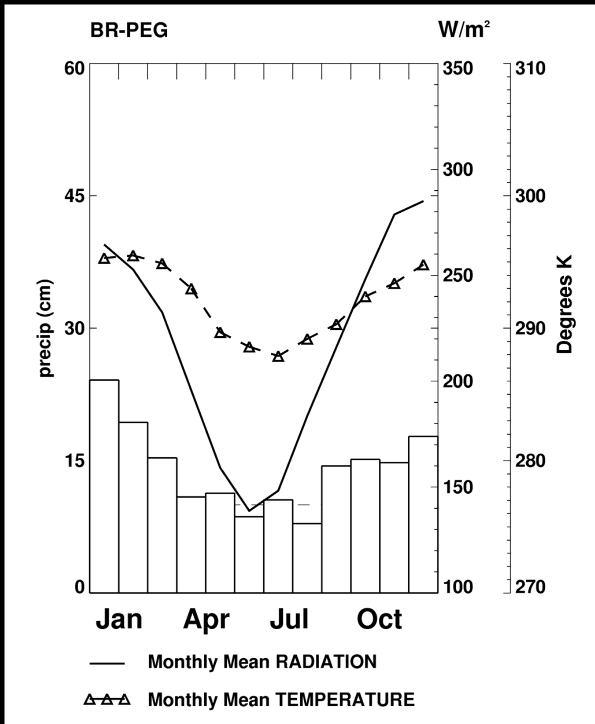


SiB3; Baker et al., 2003, 2008, many previous back to Sellers et al., 1986

Does It Work?

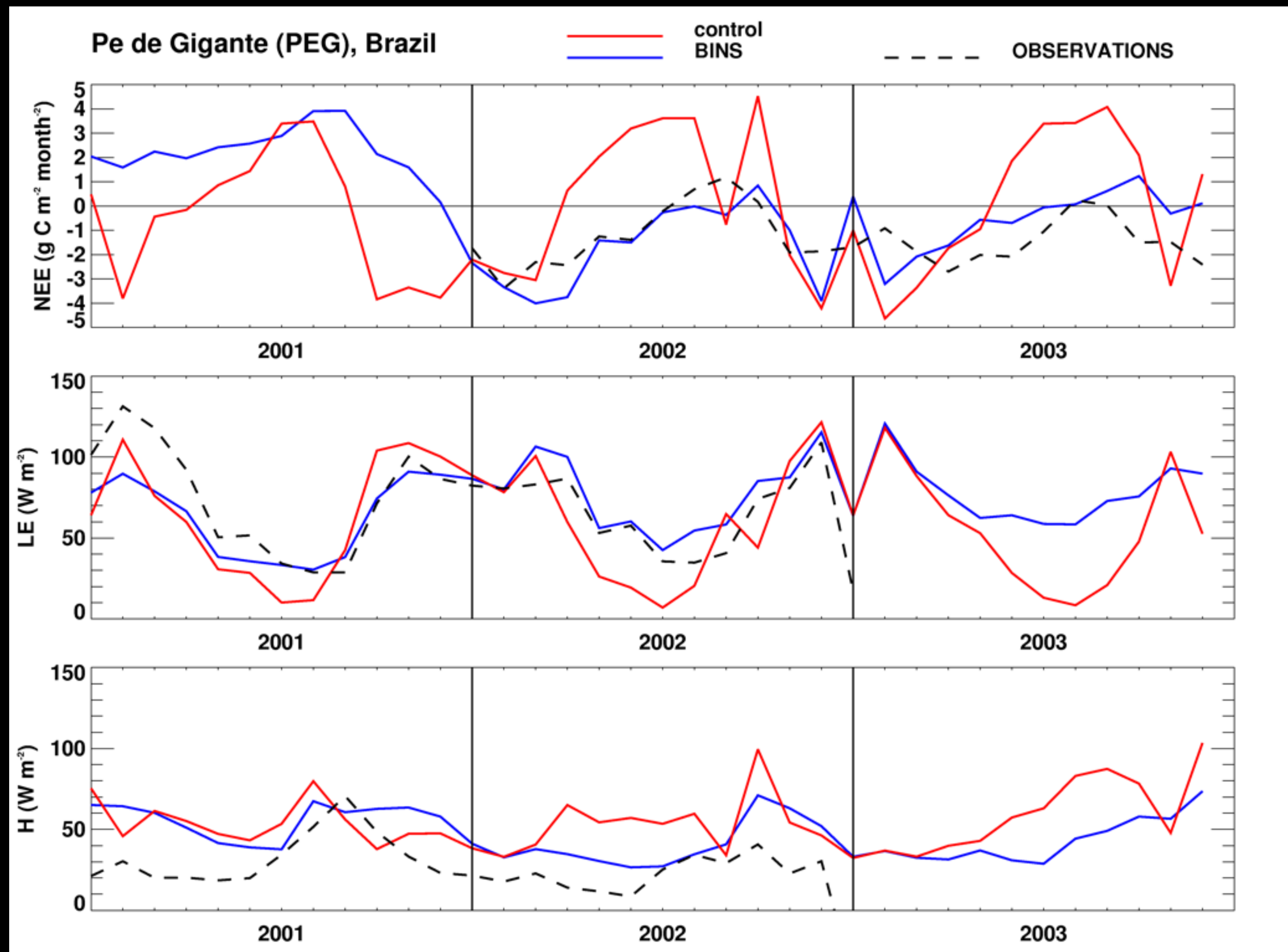

BR-PEG


BR-PEG
W/m²
60
45
30
15
0
precip (cm)
350
300
250
200
150
100
310
300
290
280
270
Degrees K
Jan
Apr
Jul
Oct
Monthly Mean RADIATION
Monthly Mean TEMPERATURE

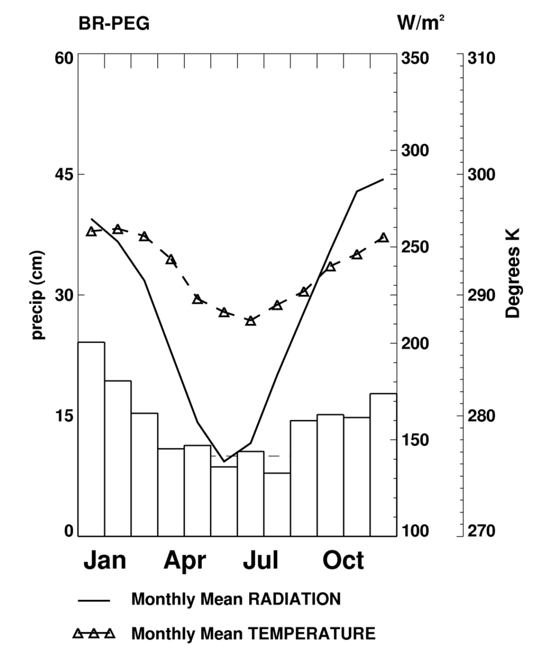


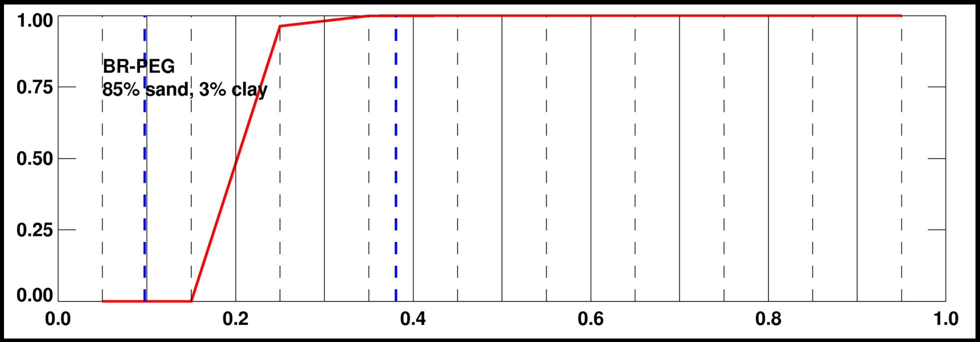
Does It Work?

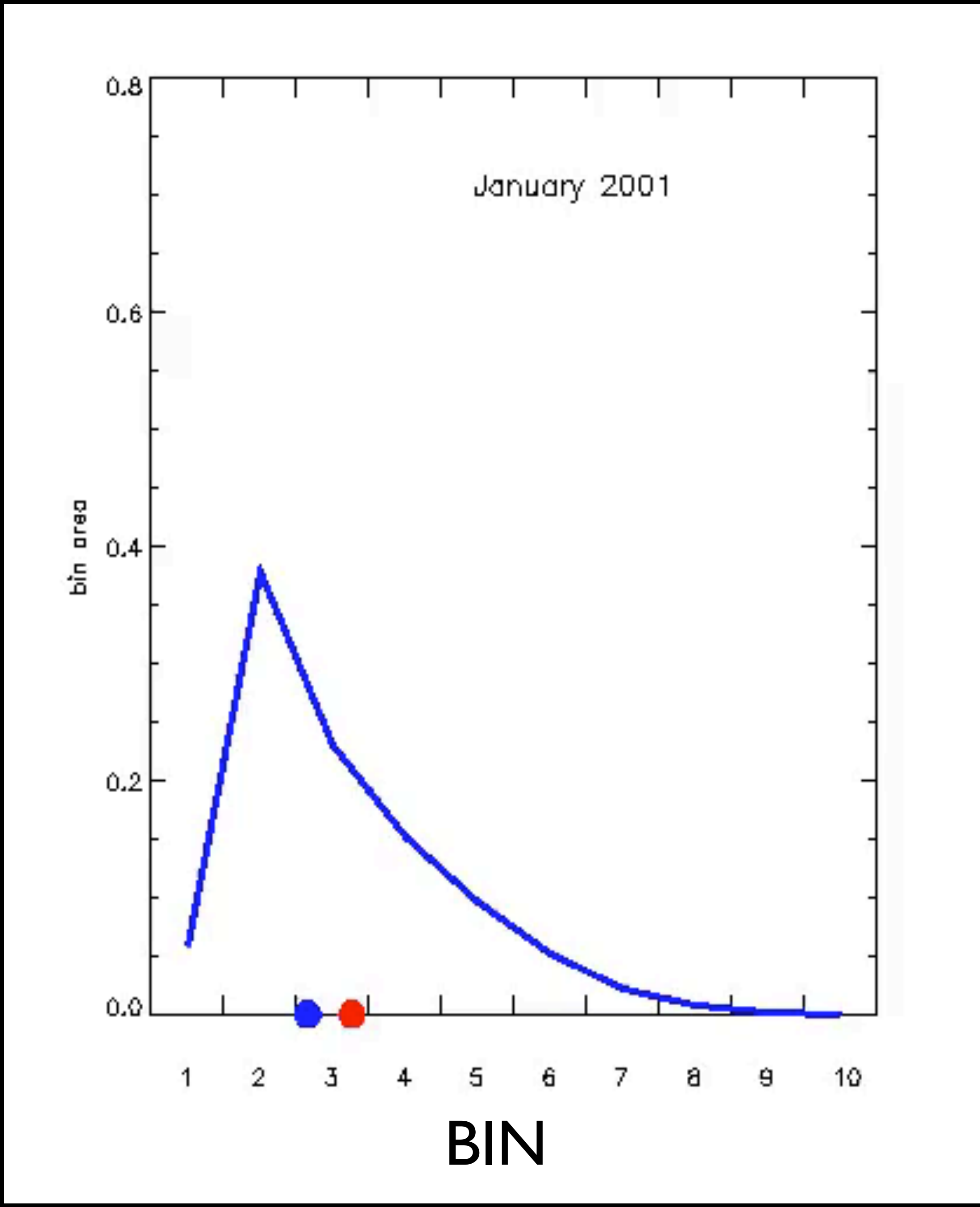
- Comparison to observations improves with BINS
- Control run (Method II) has large excursions when W is on the steep segment of f(W) curve



BIN Area Evolution

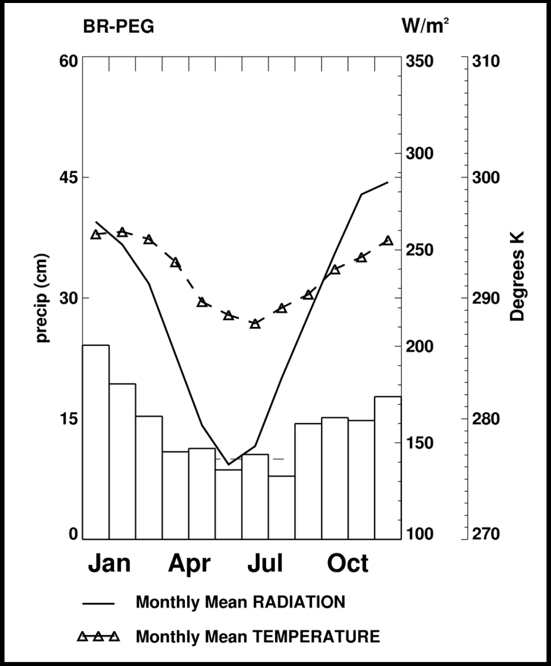


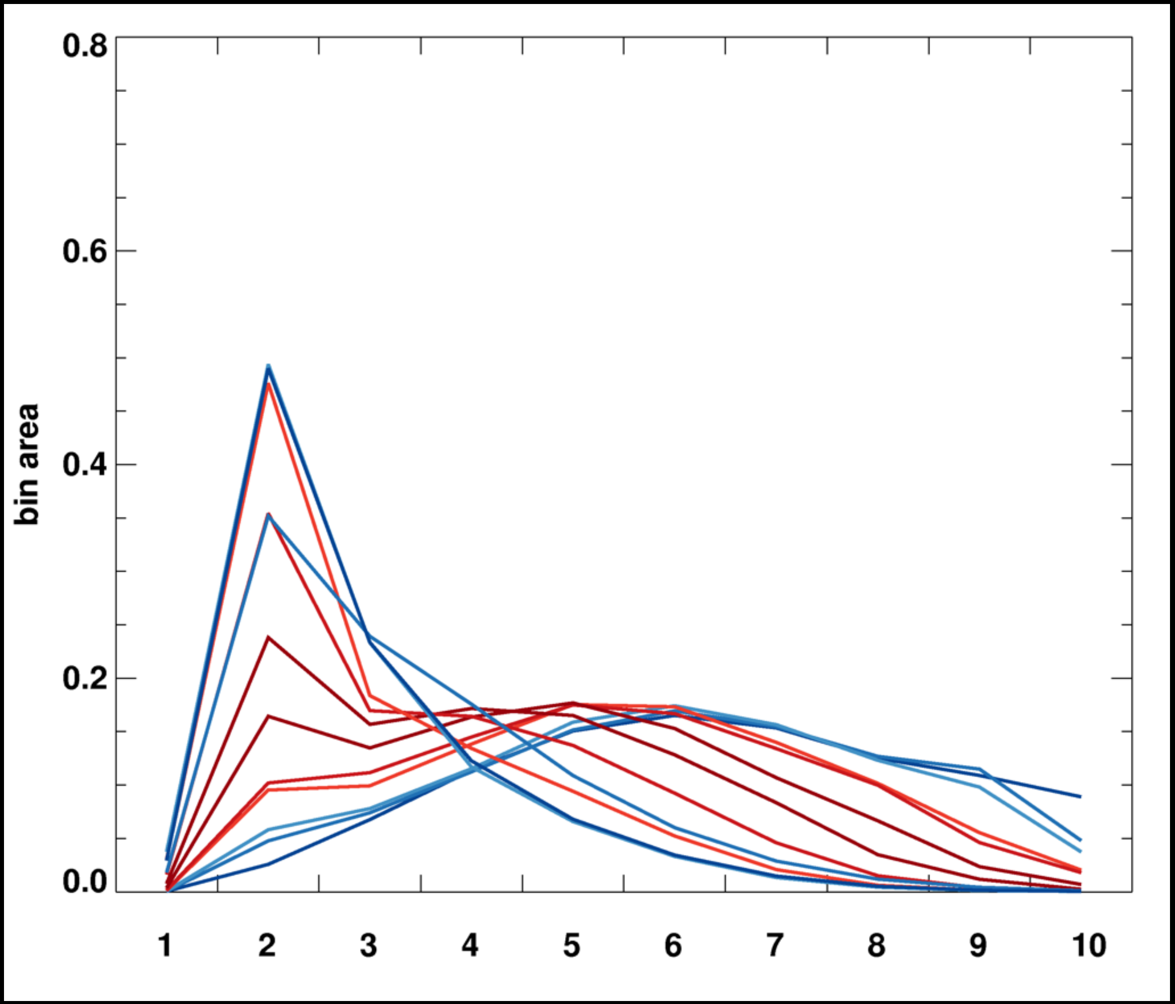




Bin Area for One Year

(in case the animation didn't work)



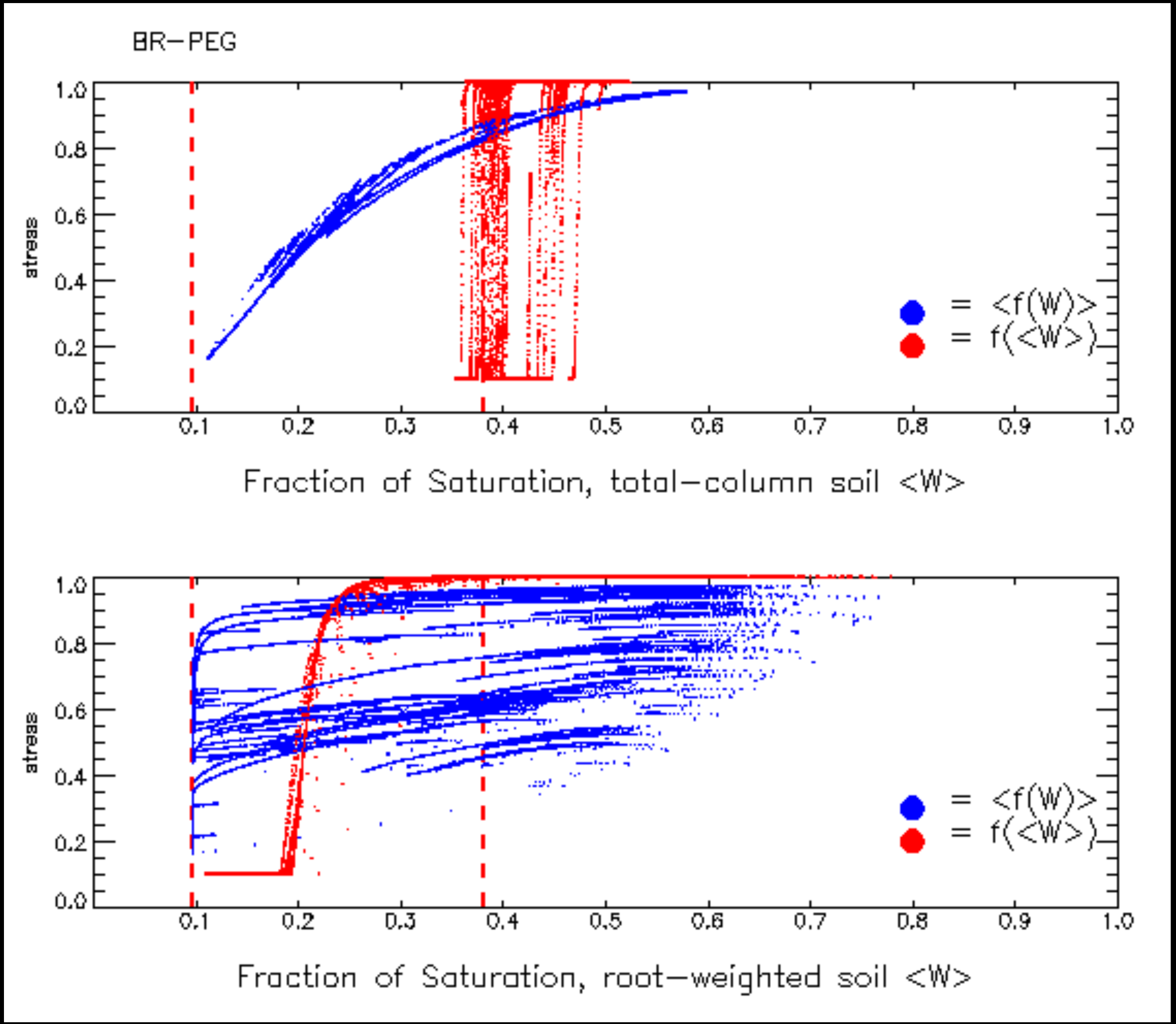


Summary

- The BINS scheme improves simulated surface fluxes when compared to control runs using a single soil wetness value to predict stress
- Numerical scheme is stable: BINS balances energy/water to machine precision
- BINS: convective precipitation
- High potential for grassland (semi-arid to arid)

Total Soil vs. Root-Weighted Column

- Dots represent column-mean wetness for control (method II-RED) and BINS (BLUE)
- Each dot corresponds to a single hour during a 3-year simulation
- BINS behaves smoothly when the whole column is considered
- Method II follows the f(W) curve in the root-weighted soil



Soilmoisture Stress Calculation