A New Method for Representing Subgrid Heterogeneity in Land Models

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1: Colorado State University, Atmospheric Science Department
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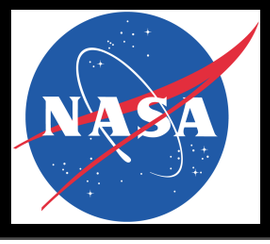

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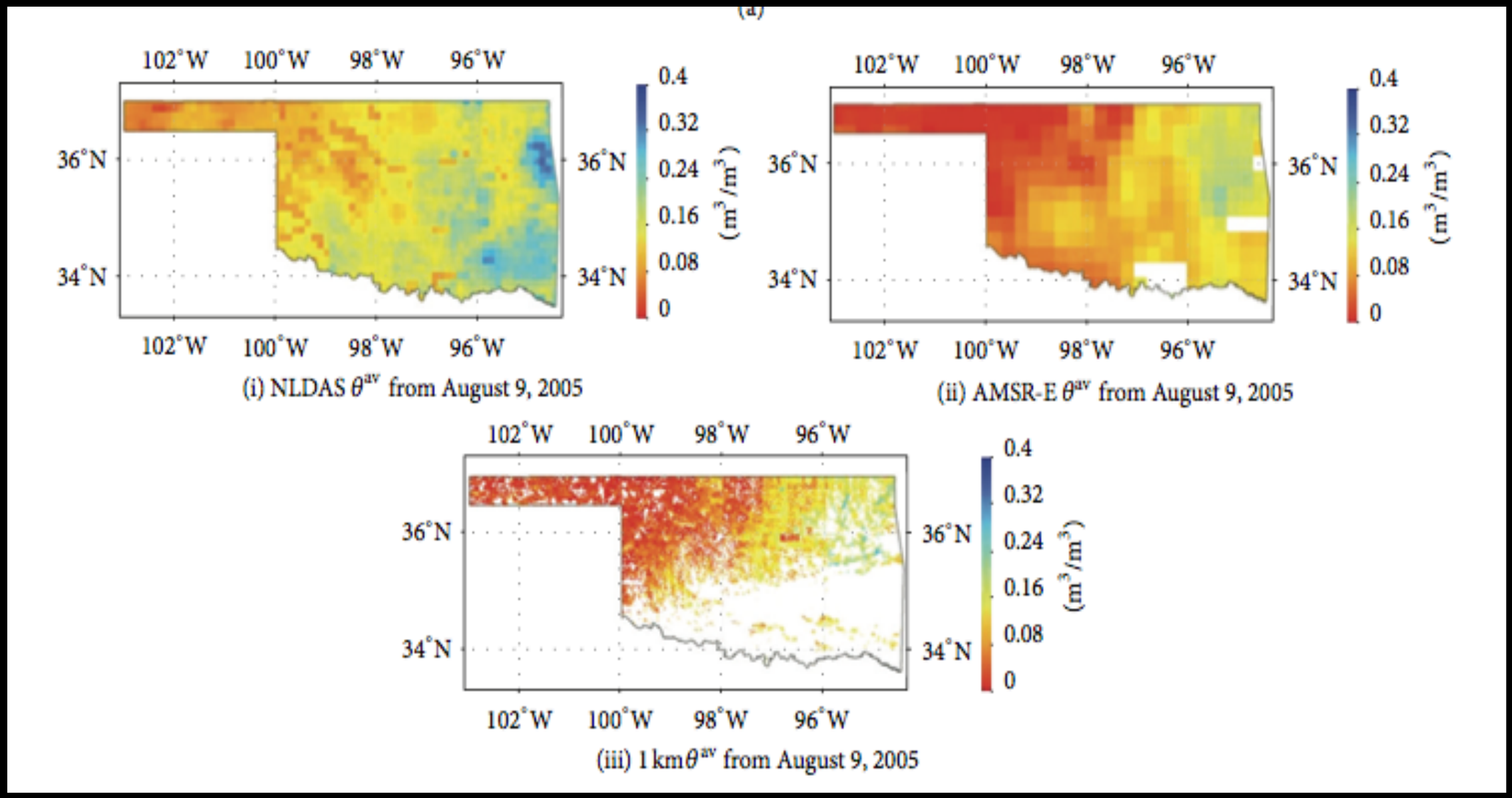
Soil Moisture Heterogeneity



Fang et al., 2013

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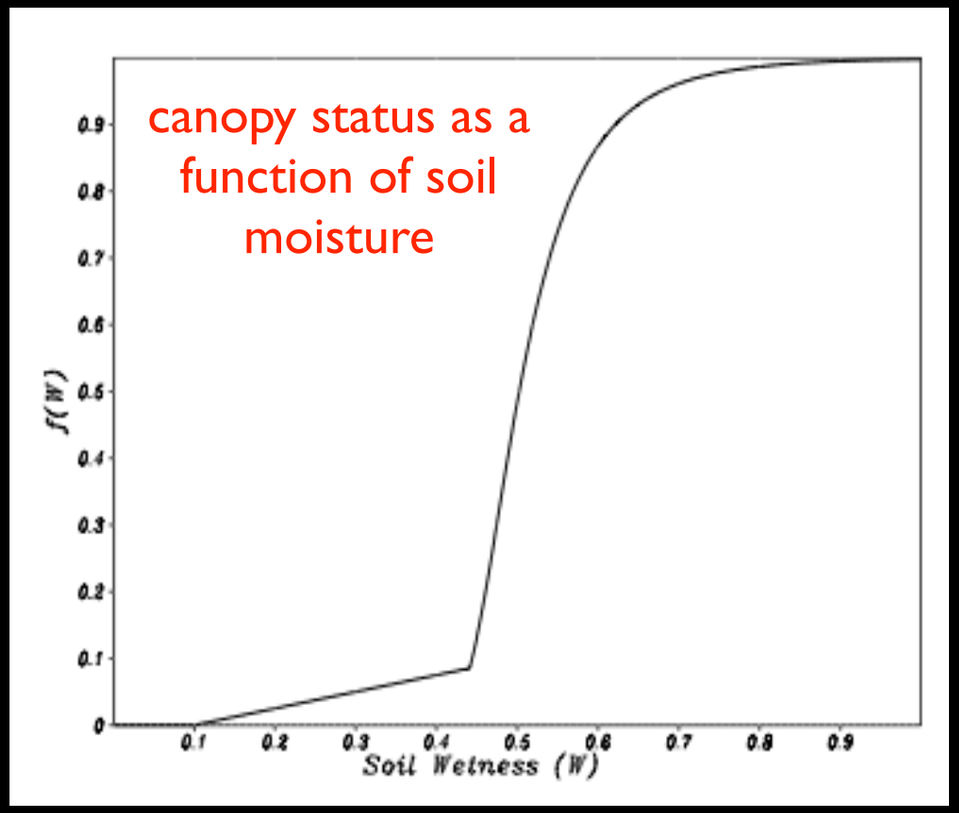
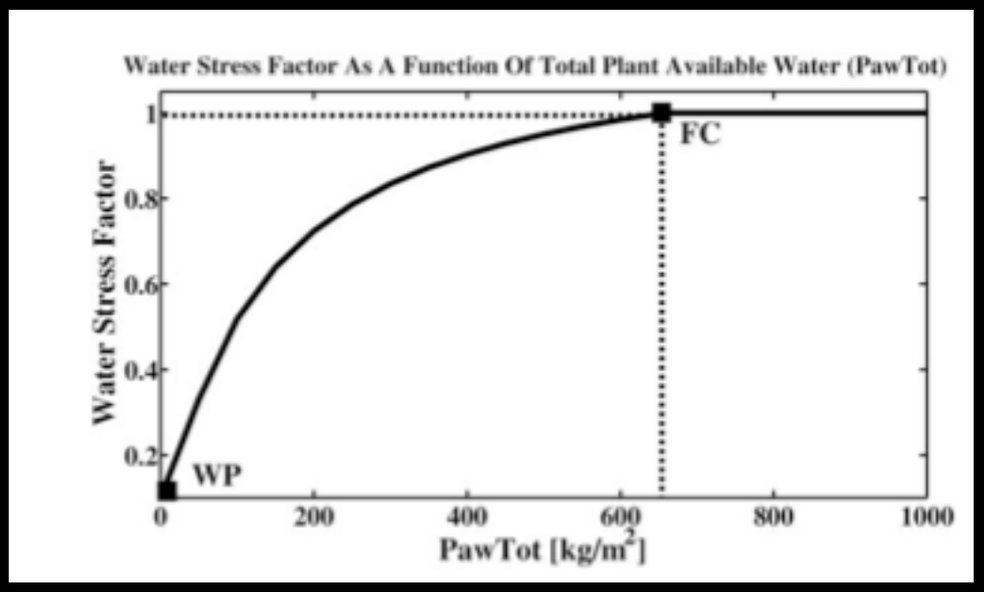
Plant Response to Soil Moisture

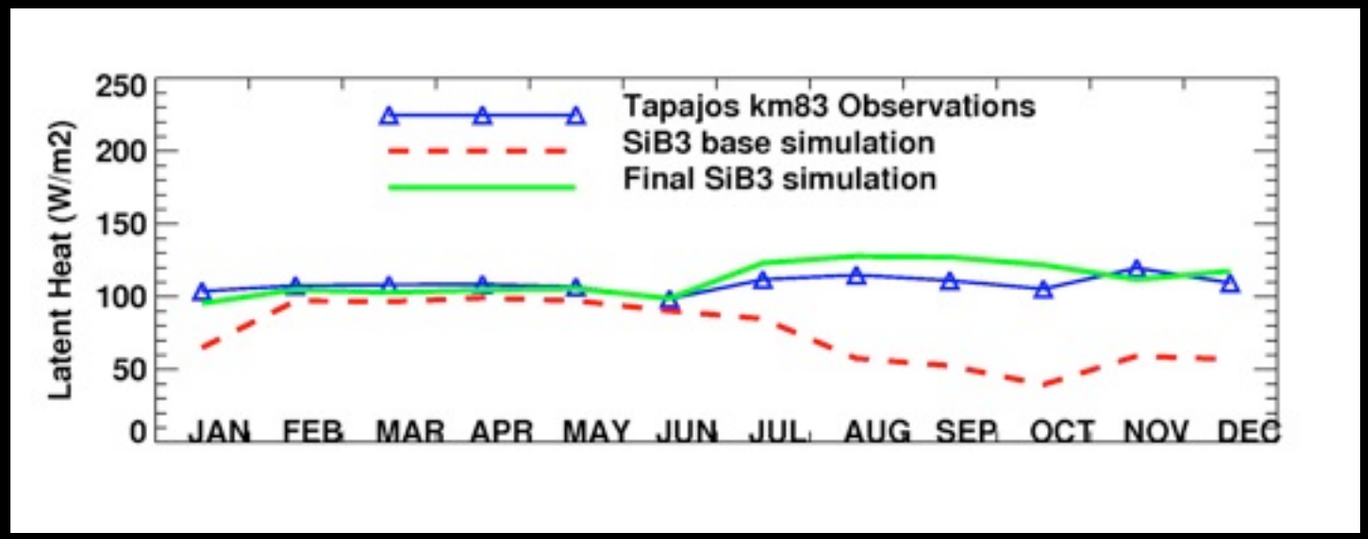


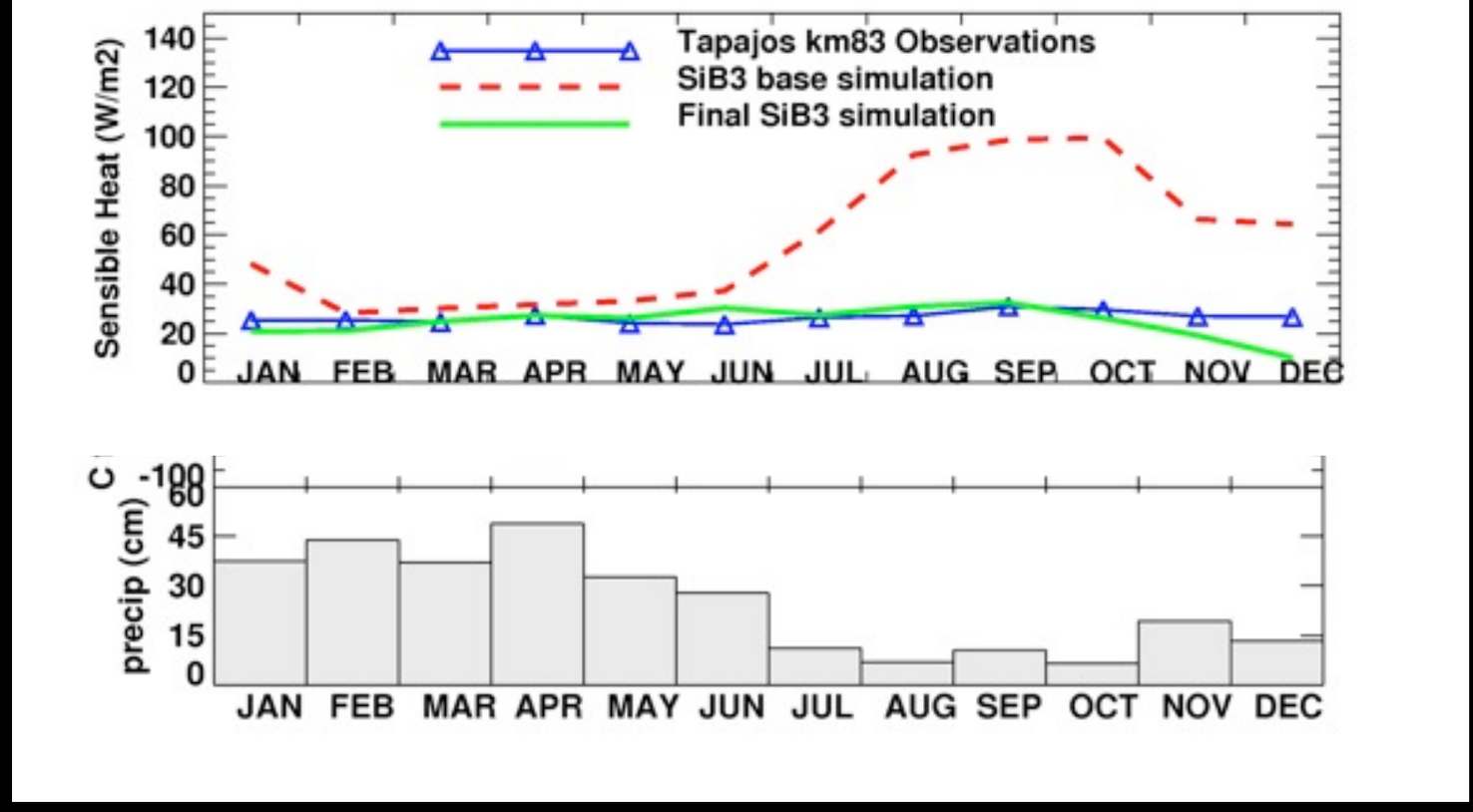
Data from FIFE (Colello et al., 1998; Sellers et al., 2007)



Parameterized evaporation control:
Baker et al. (2008), Medina et al. (2014)

Baker et al. (2008)





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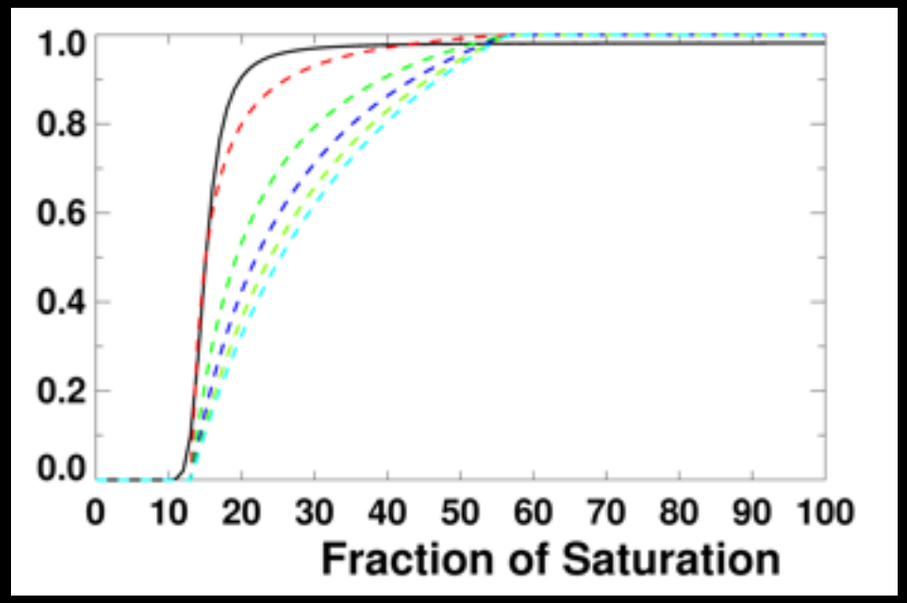
The problem with doing it this way

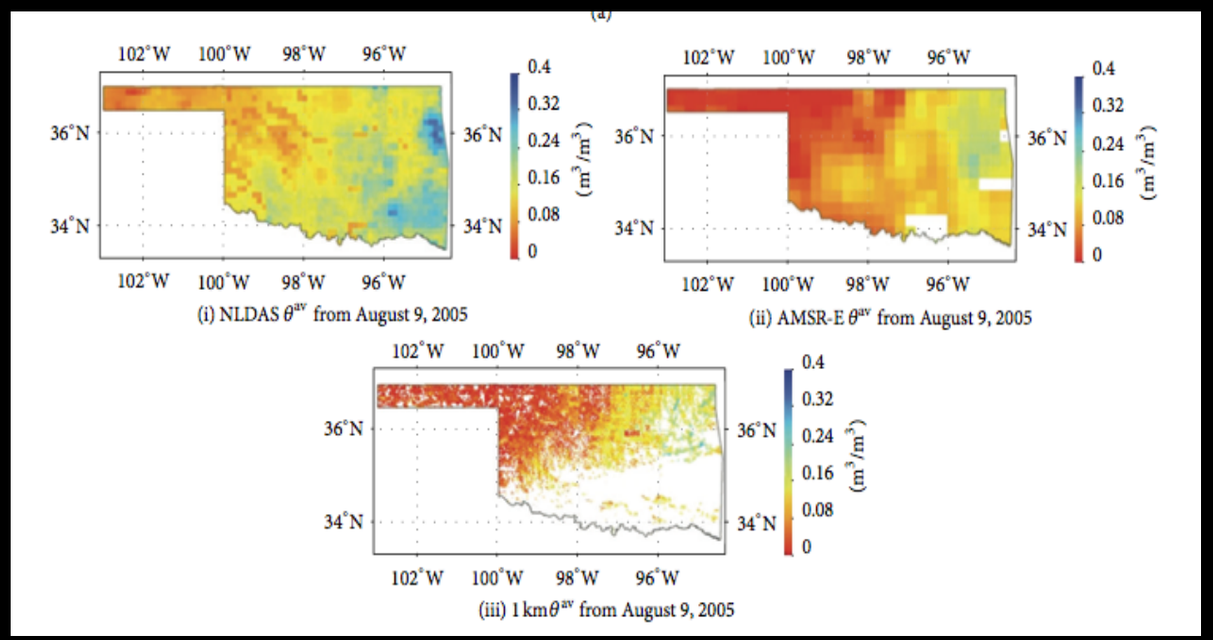
f(w)



$$E = E_p f(W)$$

$$< E > \neq E_p f(< W >)$$

$$\overline{f(x)} \neq f(\bar{x})$$



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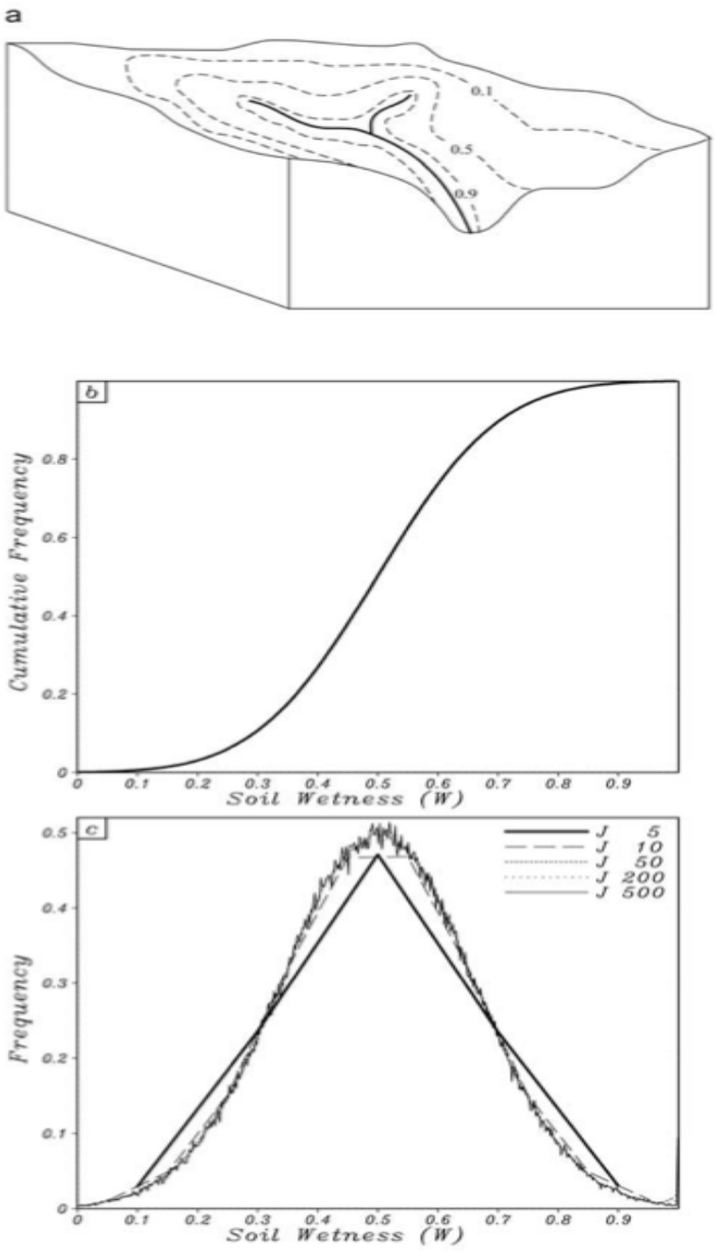
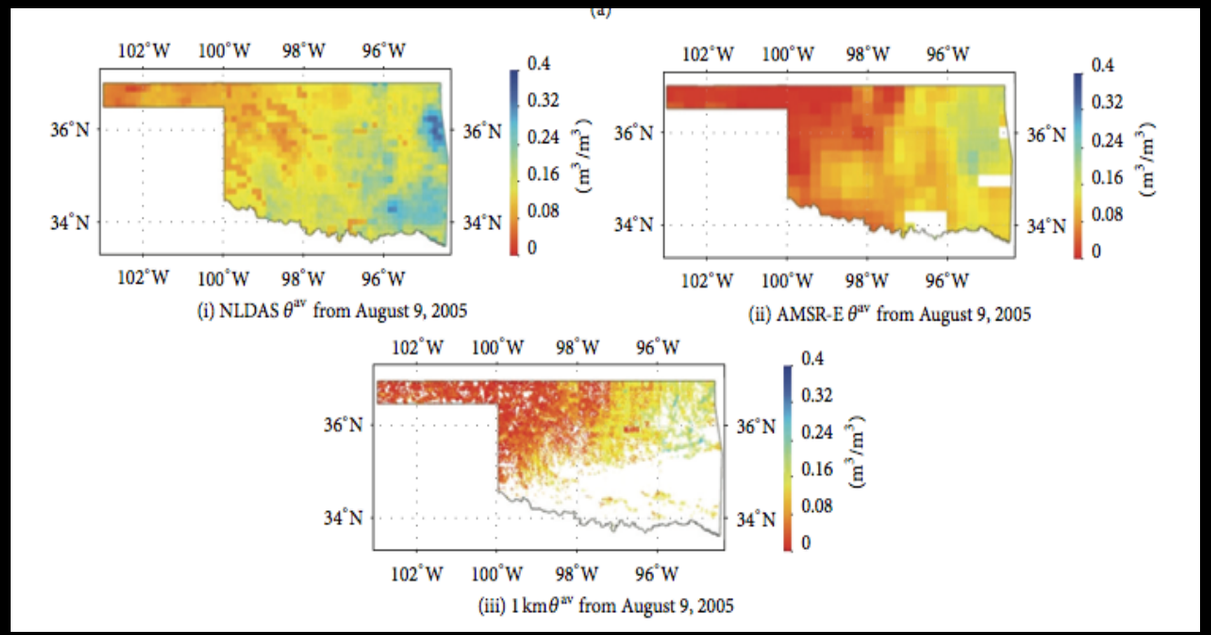
A New Approach: Wetness Bins



Several ways to consider wetness: from Sellers et al. (2007)



- We can define a finite number of 'bins' within the model to represent spatial variability in wetness

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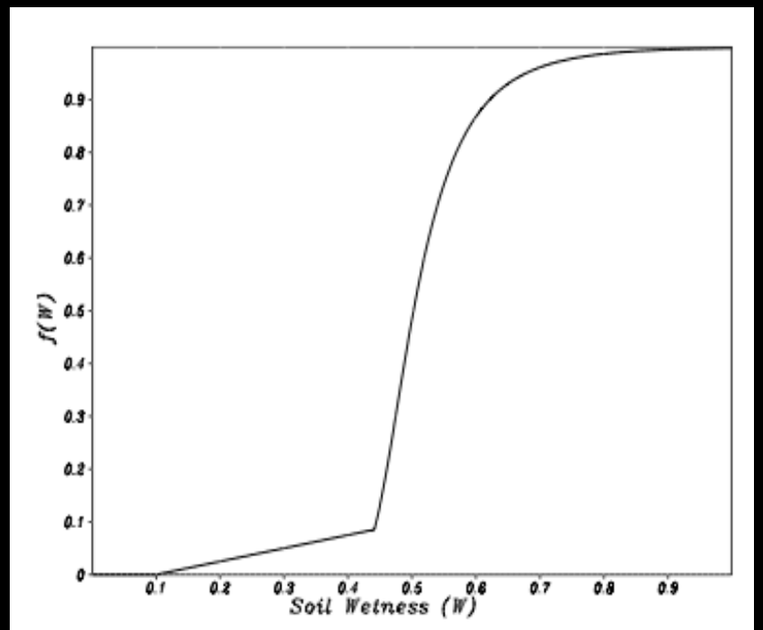
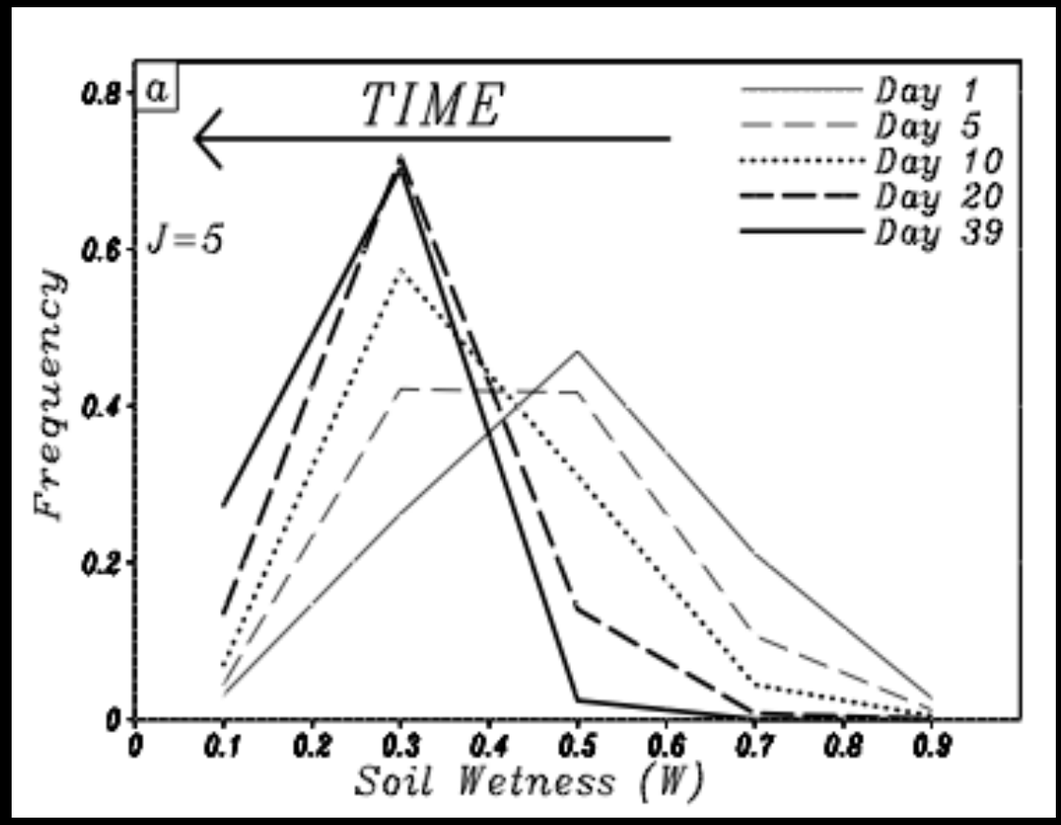
Toy Model

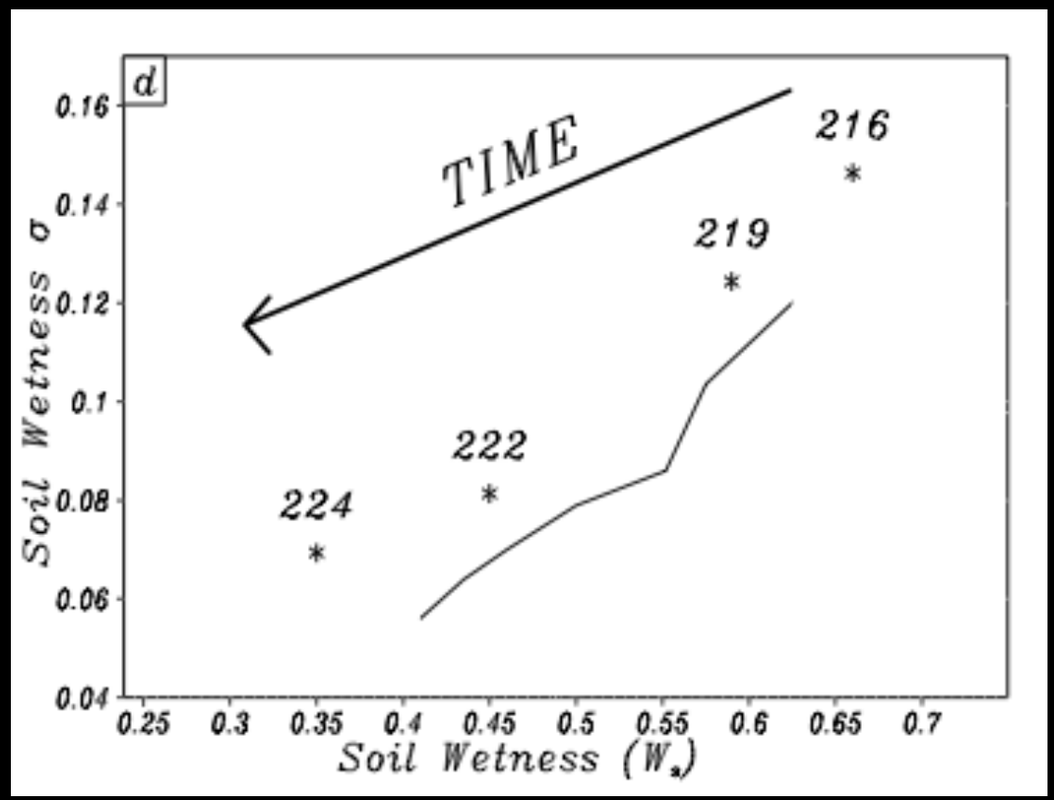
(Sellers et al., 2007)



$$< E >= E_p \int_A f(W) da$$

$$\int_A f(W) da \sim \sum_{j=1}^{nbins} f(W_j) a_j$$

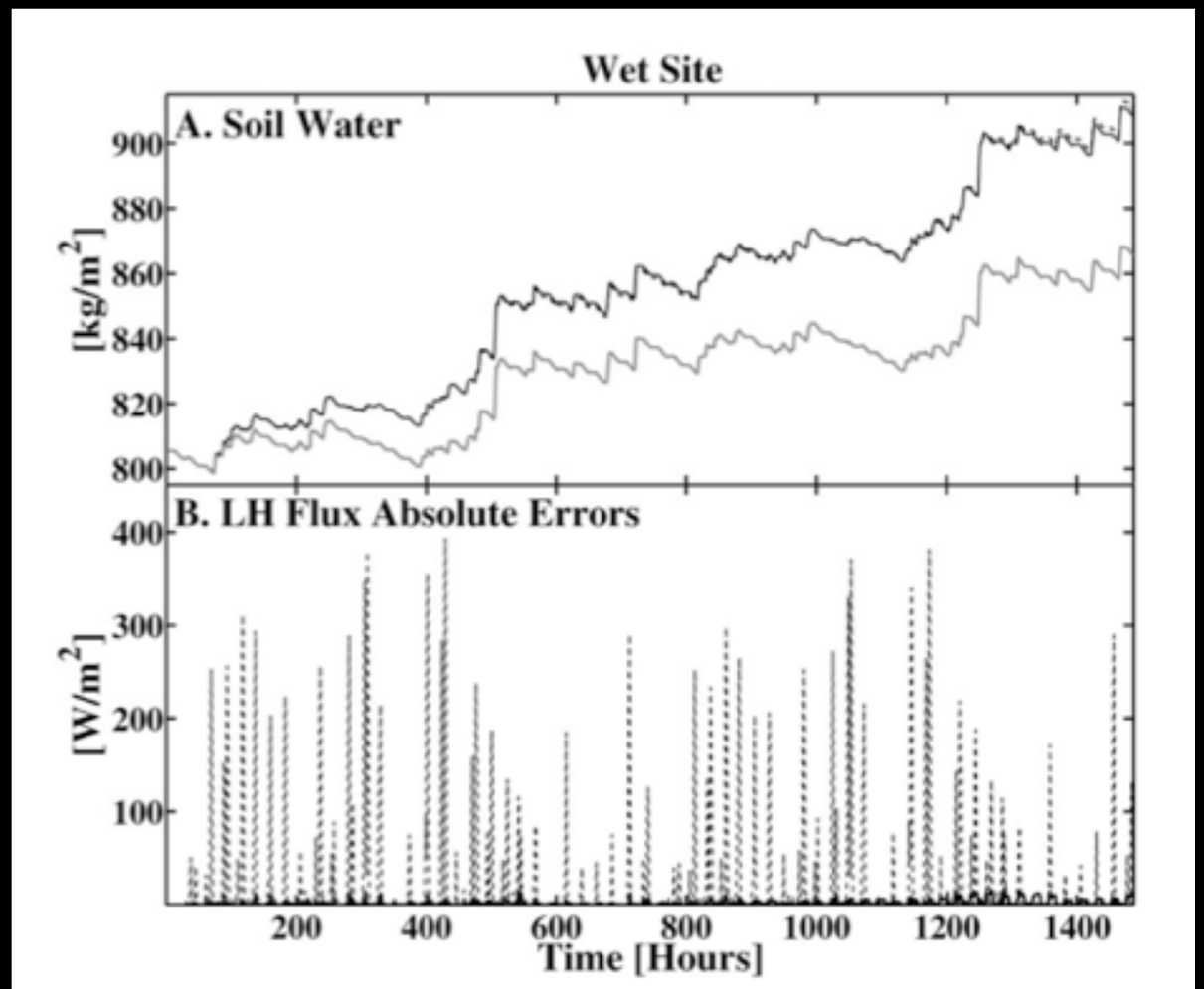


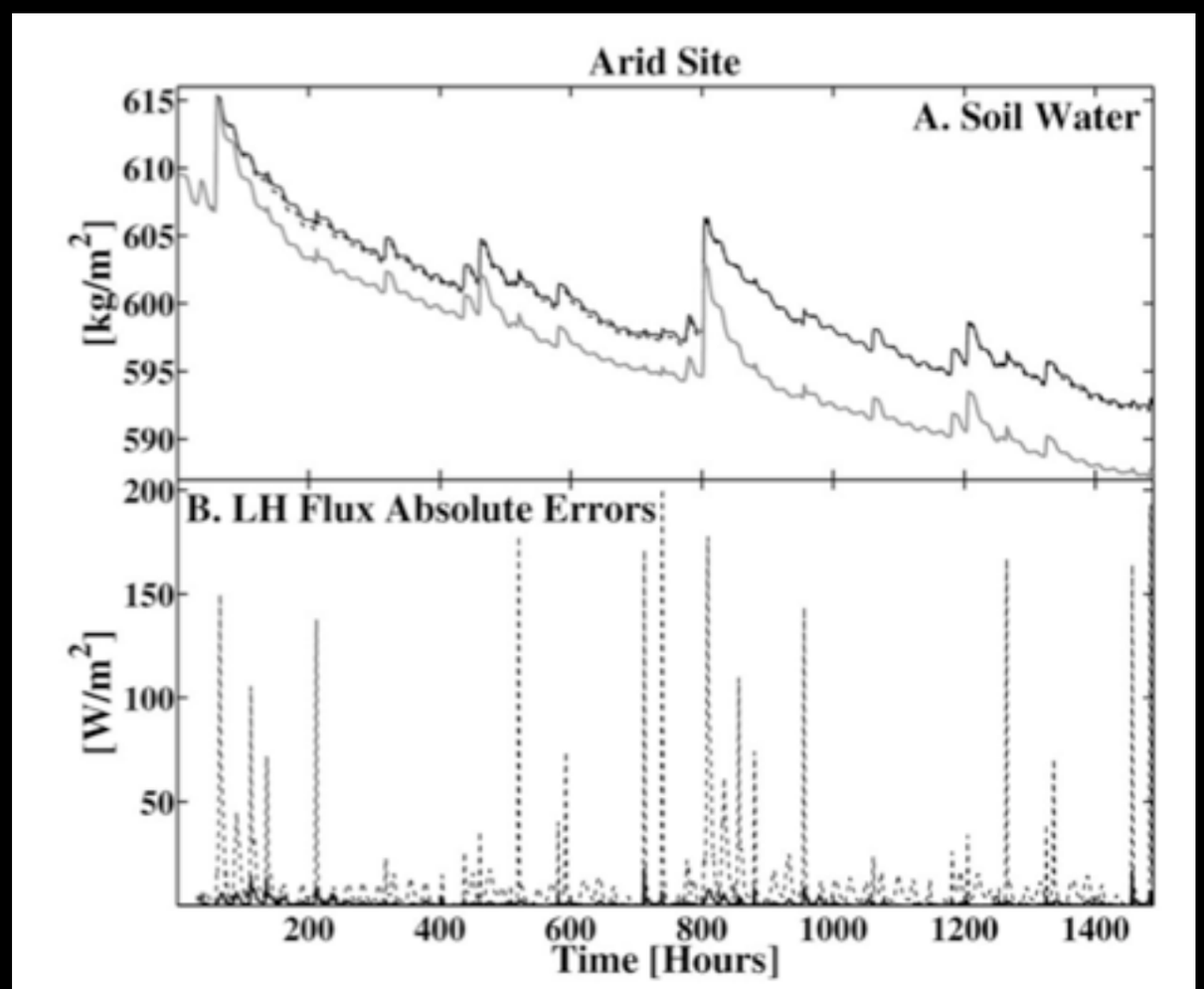


From the Toy to the Full Model

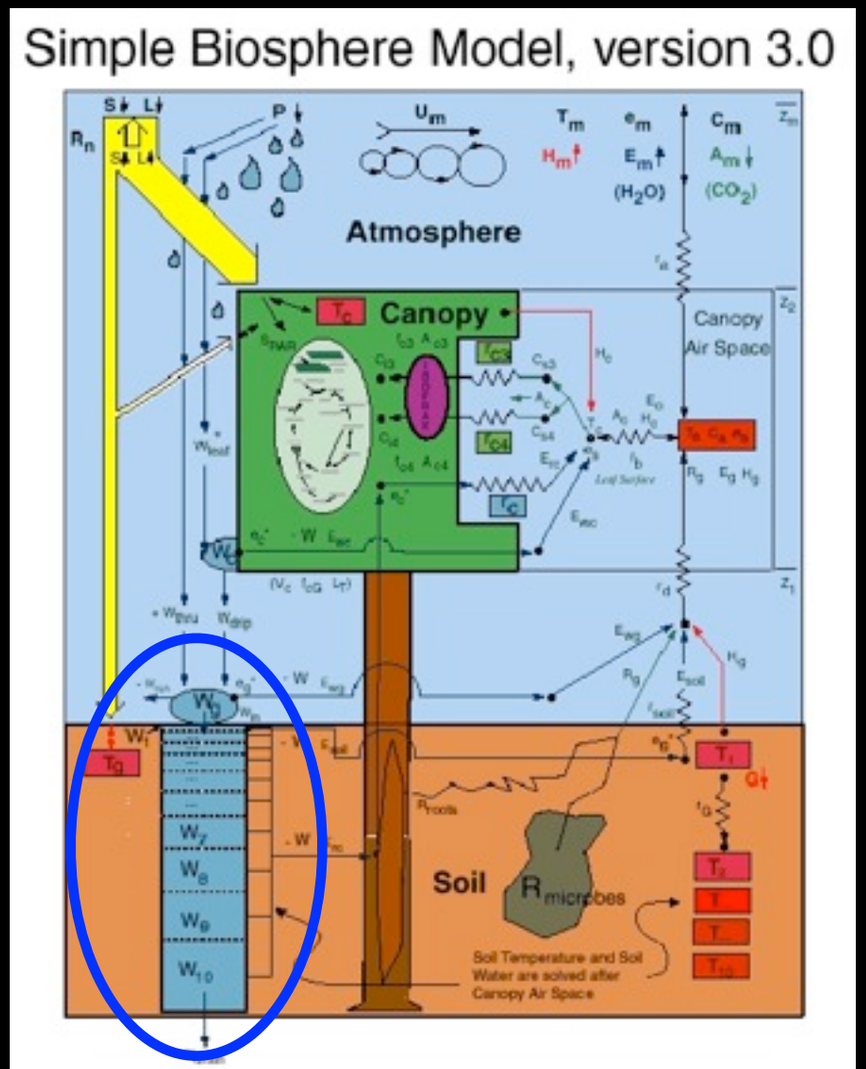
- Medina et al., JAMES, 2014

black = $\overline{f(x)}$ gray = $f(\bar{x})$ dashed = bins

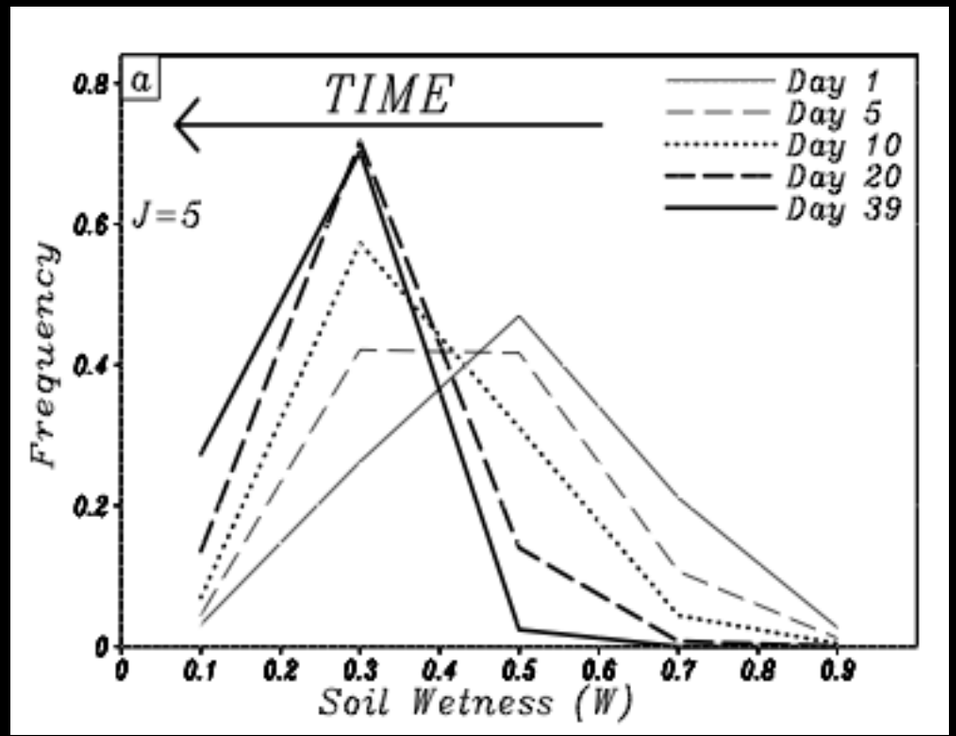




From the Toy to the Full Model



- PROBLEM: How can we reconcile a single'wetness' bin with a vertically-variable soil column?



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Solution: Modify Model Sequence

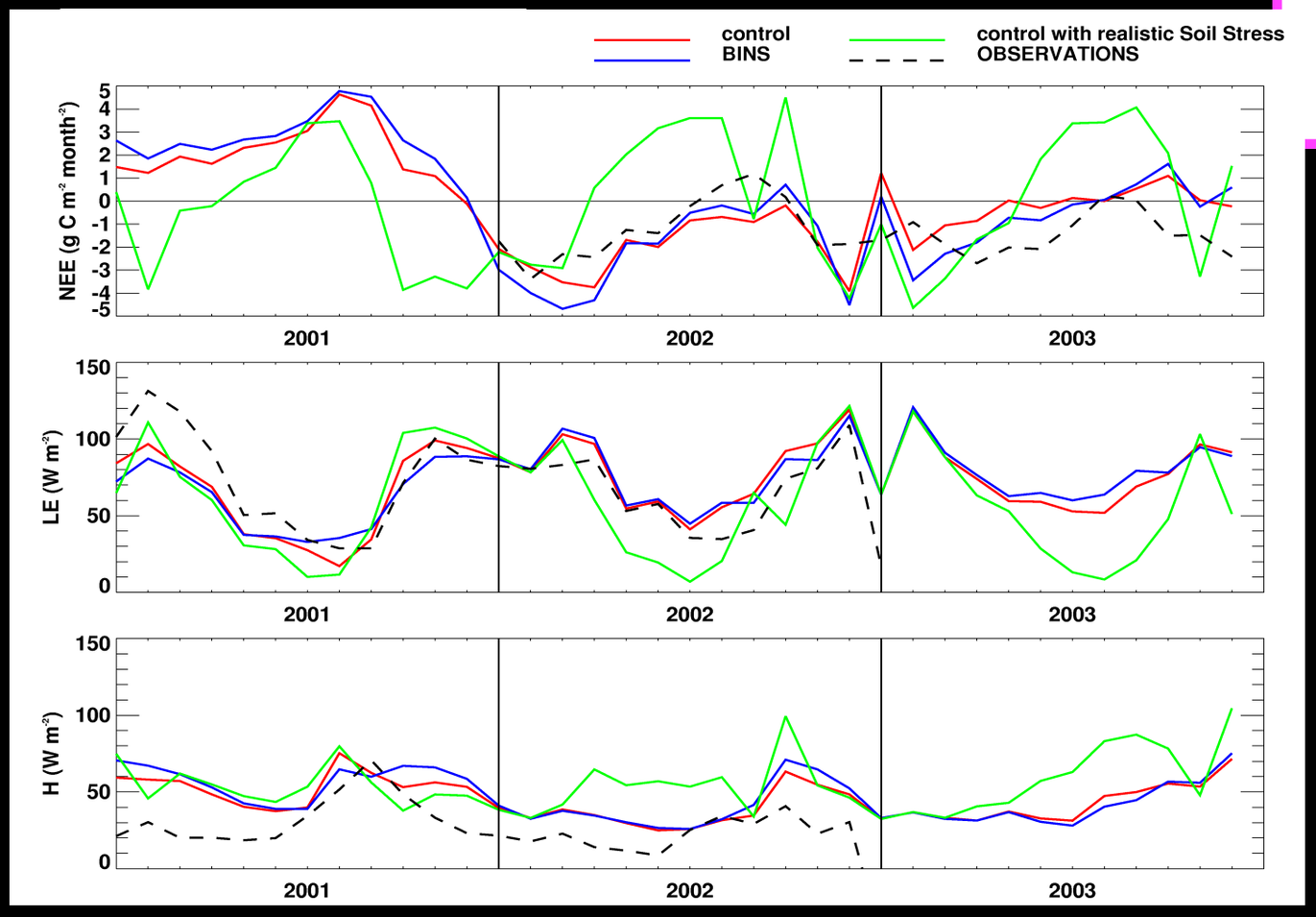
1. Precipitation onto canopy (throughfall, drainage)
2. Surface interception/runoff/infiltration
3. Update bins/z-column
4. Determine stress f(W)

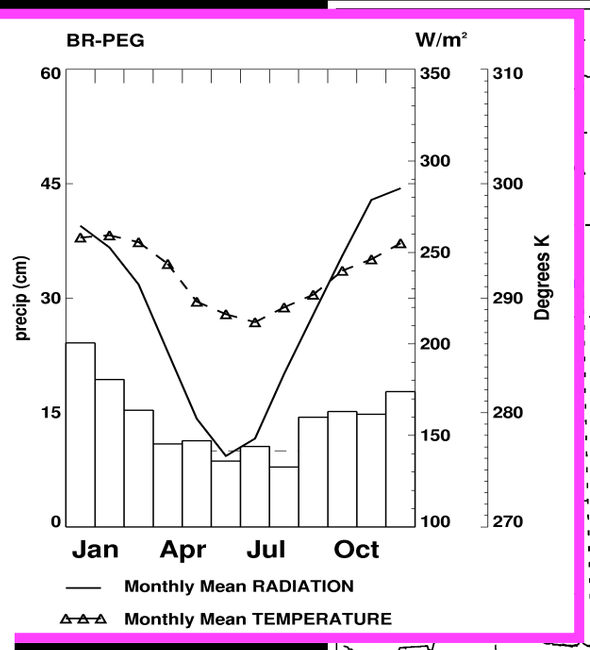
$$\int_A f(W)da \sim \sum_{j=1}^{nbins} f(W_j)a_j$$

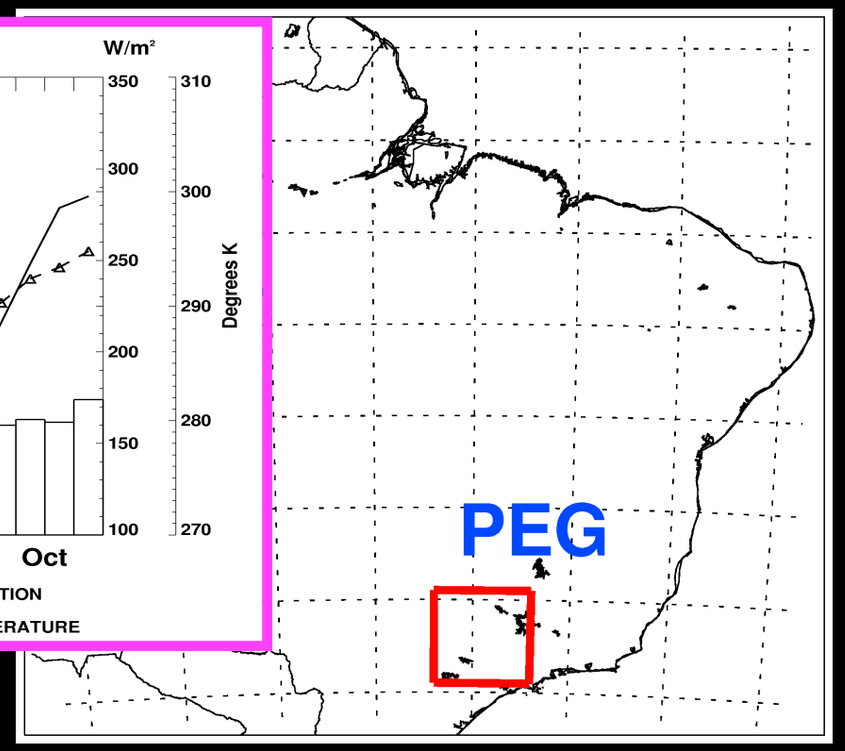
5. Calculate Energy/Moisture exchange
6. Remove water from soil (transpiration)
7. Update bins/z-column

$$\sum_{j=1}^{nbins} W_j a_j = \sum_{i=1}^{nsoil} W_i, z_i$$

Results: A Site That Works (PEG)



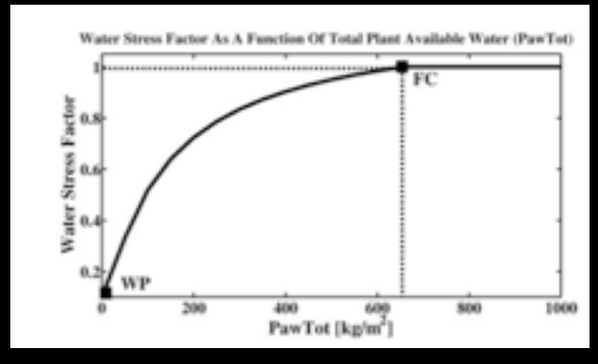




1. Control: Baker et al. (2013), 'adjusted' SW stress

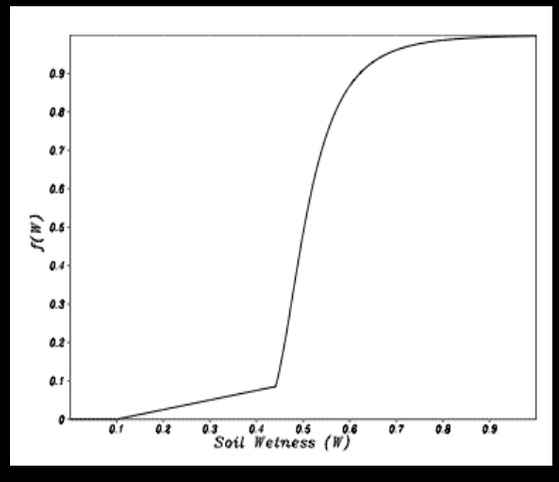
2. Control w/ realistic stress: 'Wrong answer, right reason'

3. BINS



f(w) for the control run (red)

f(w) for 'control w/ realistic' (green) and bin (blue) runs



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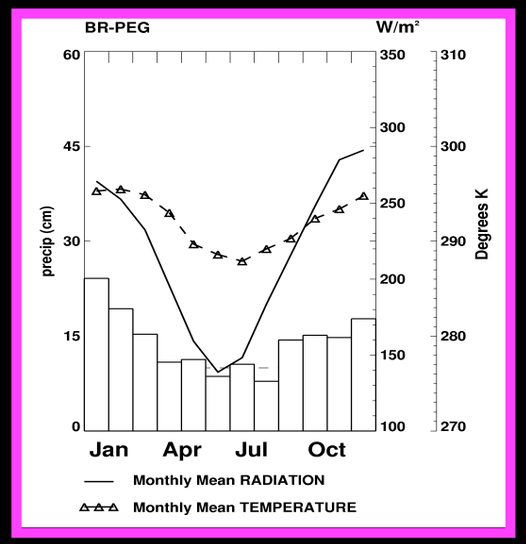
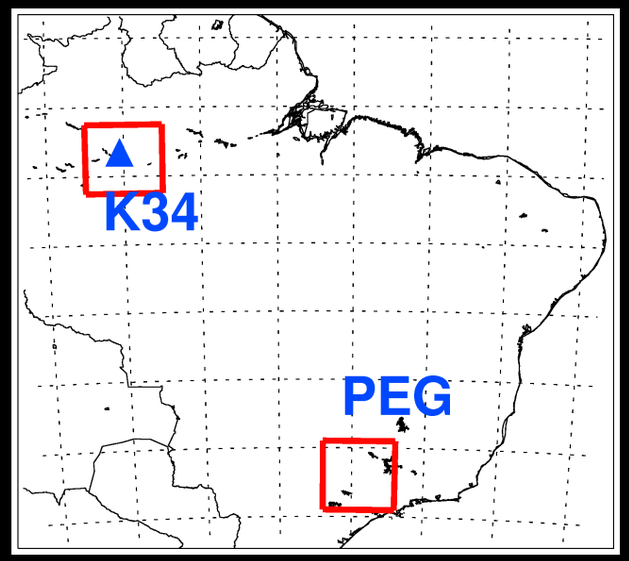
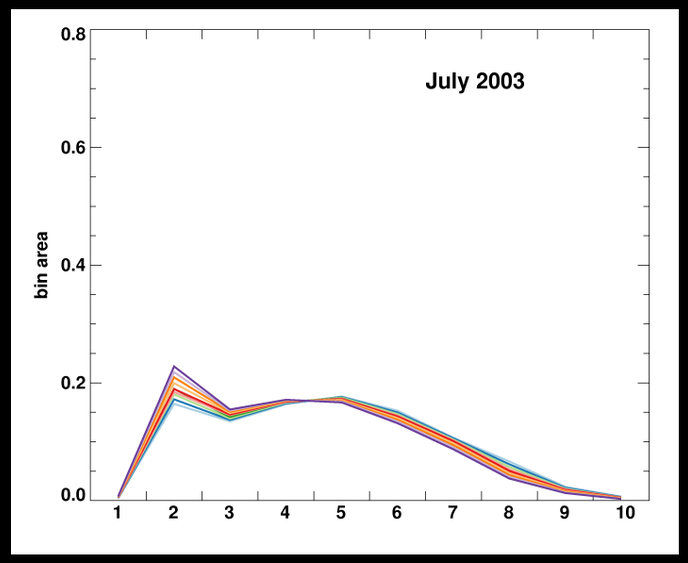
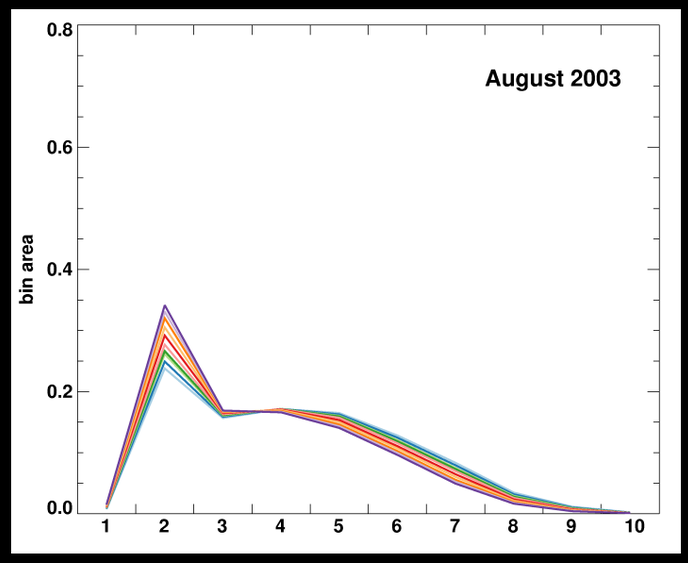
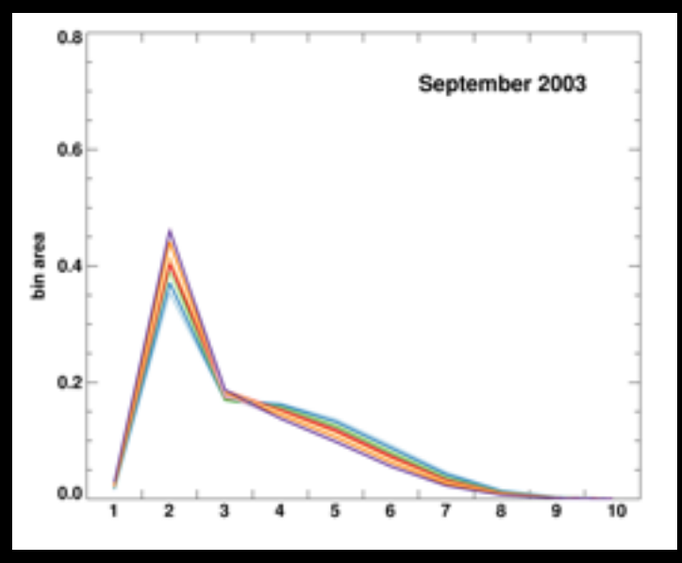




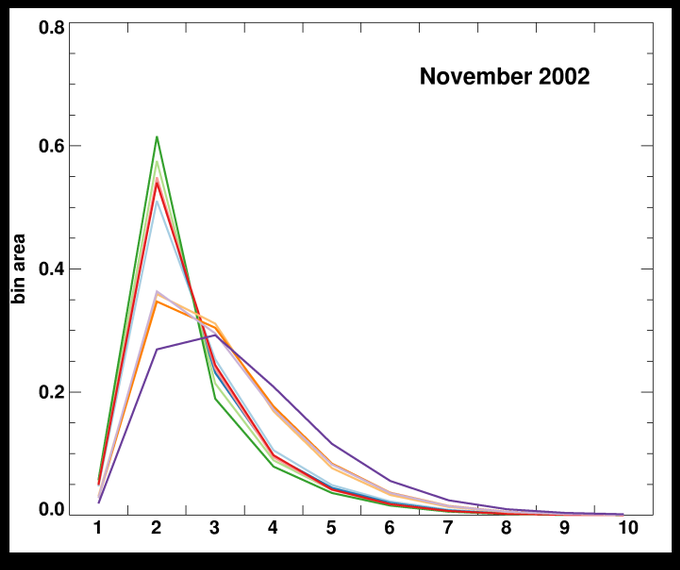
Drying

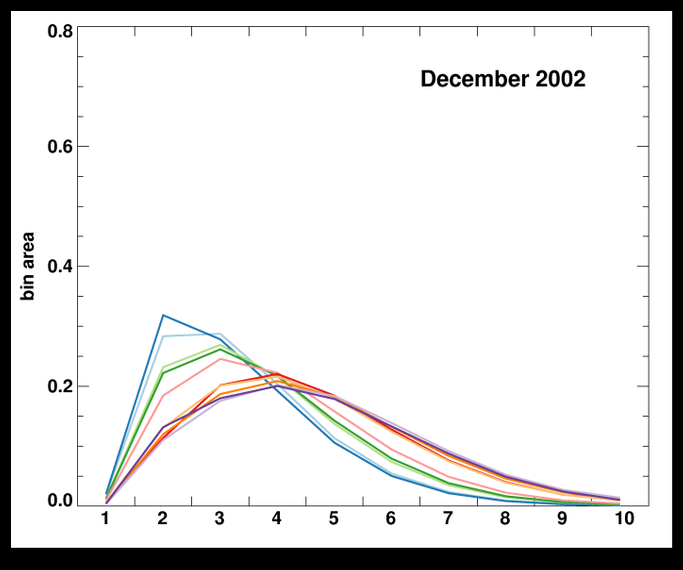


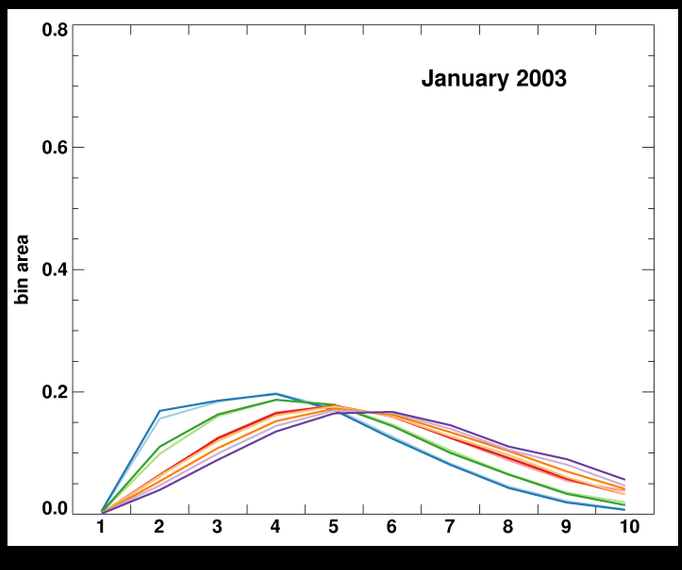




Moistening







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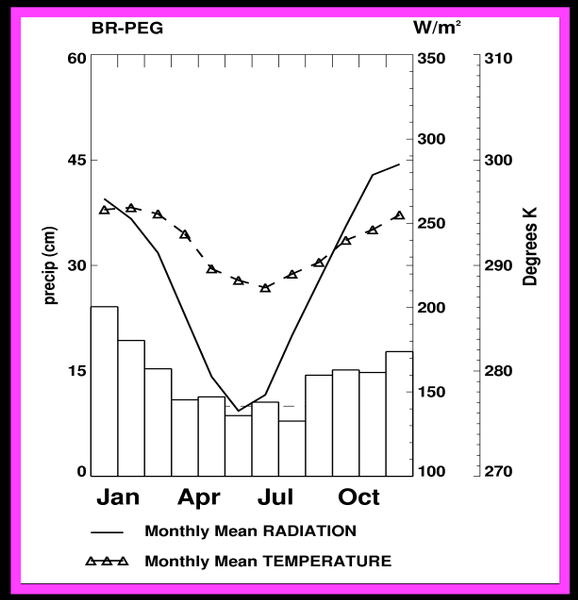
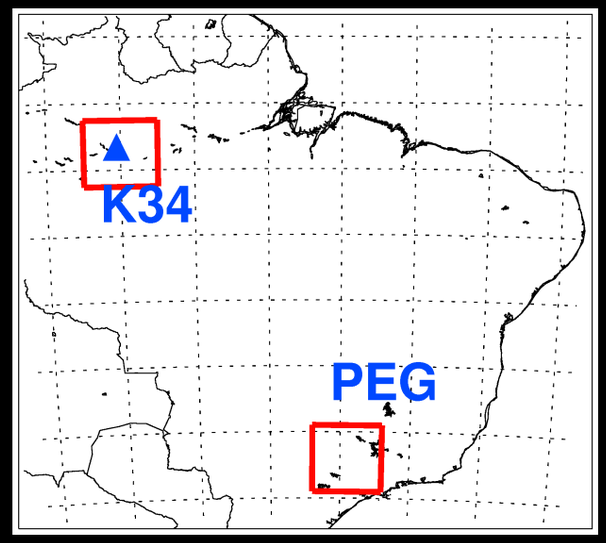
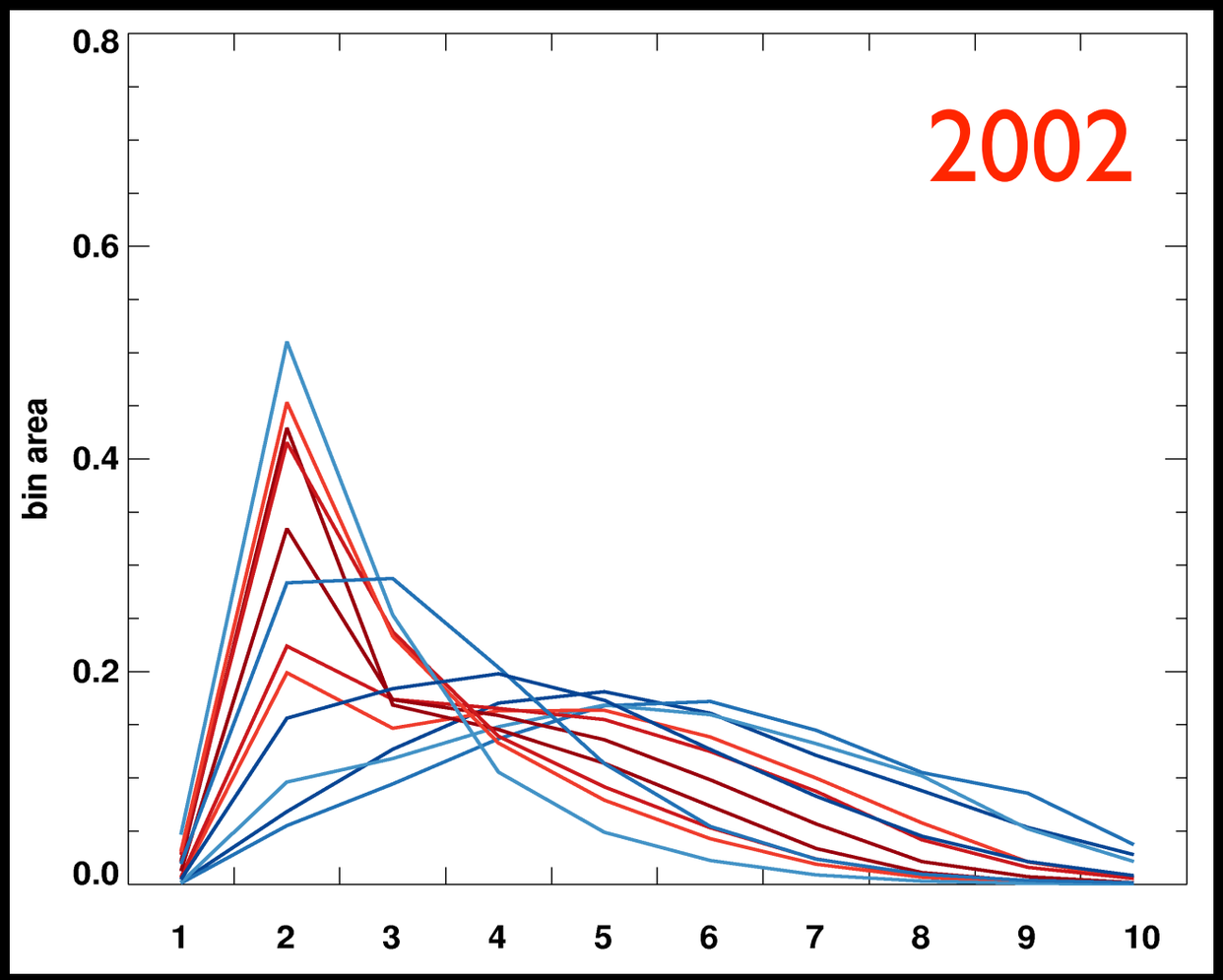
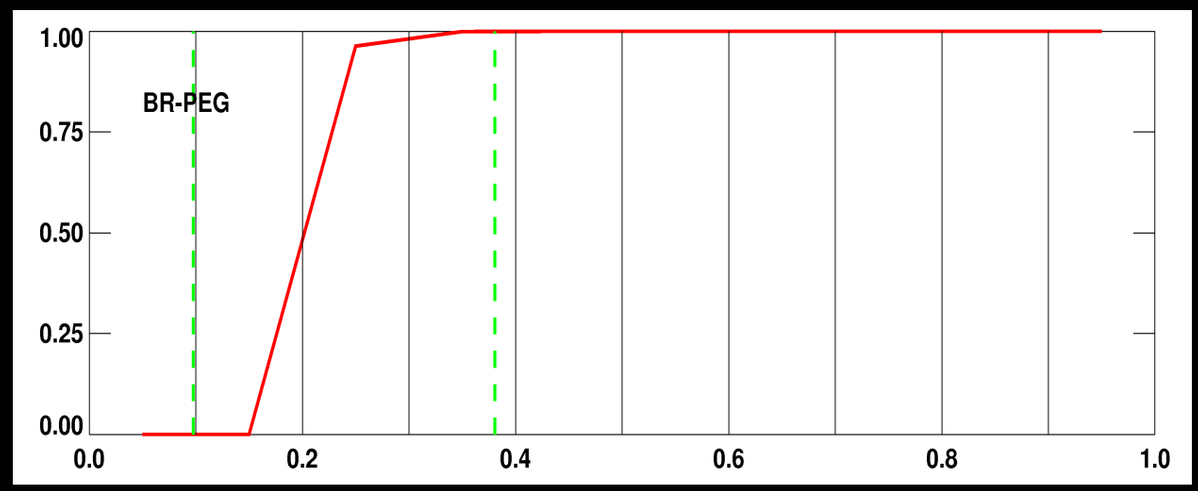
Results: A Site That Works





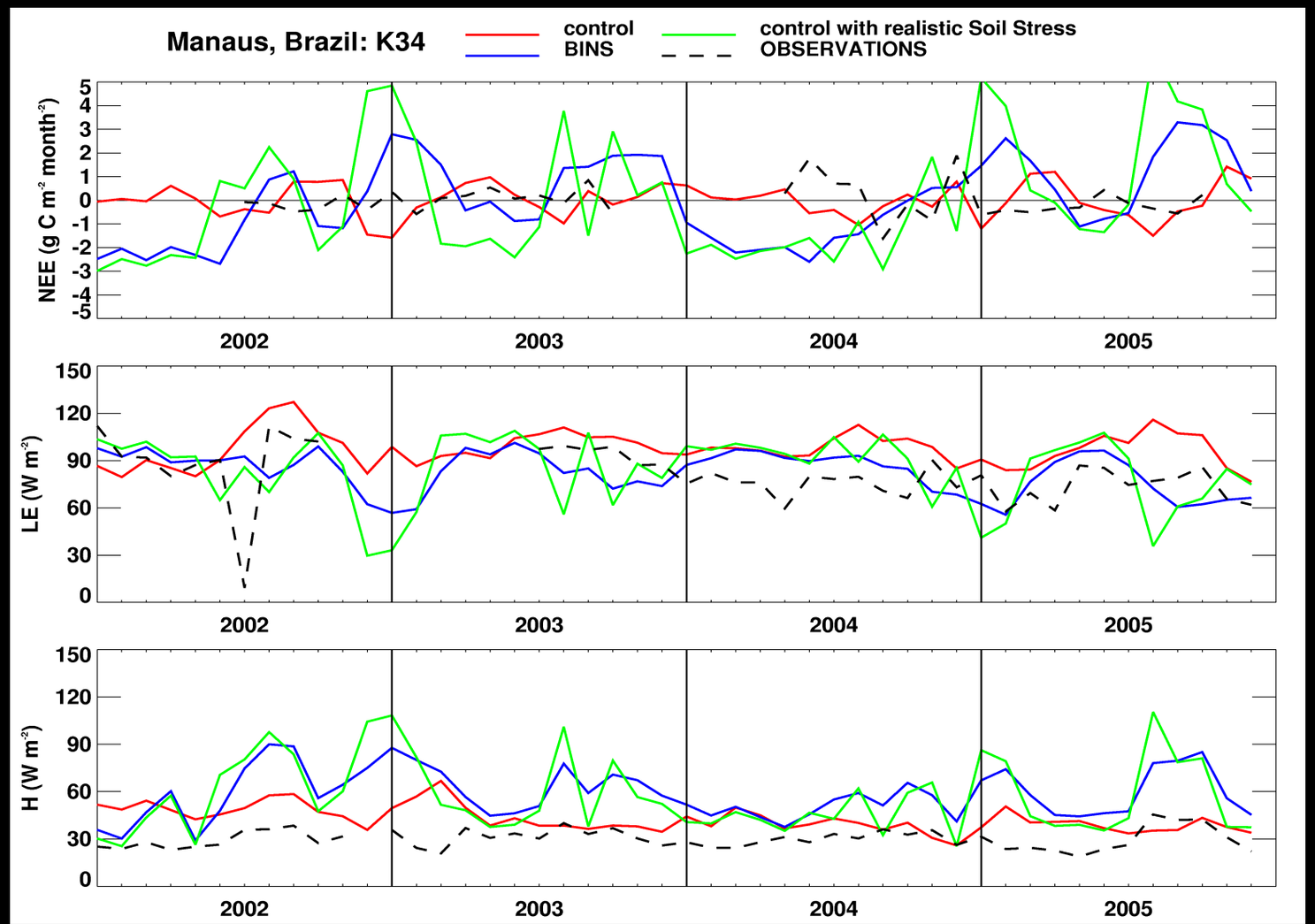


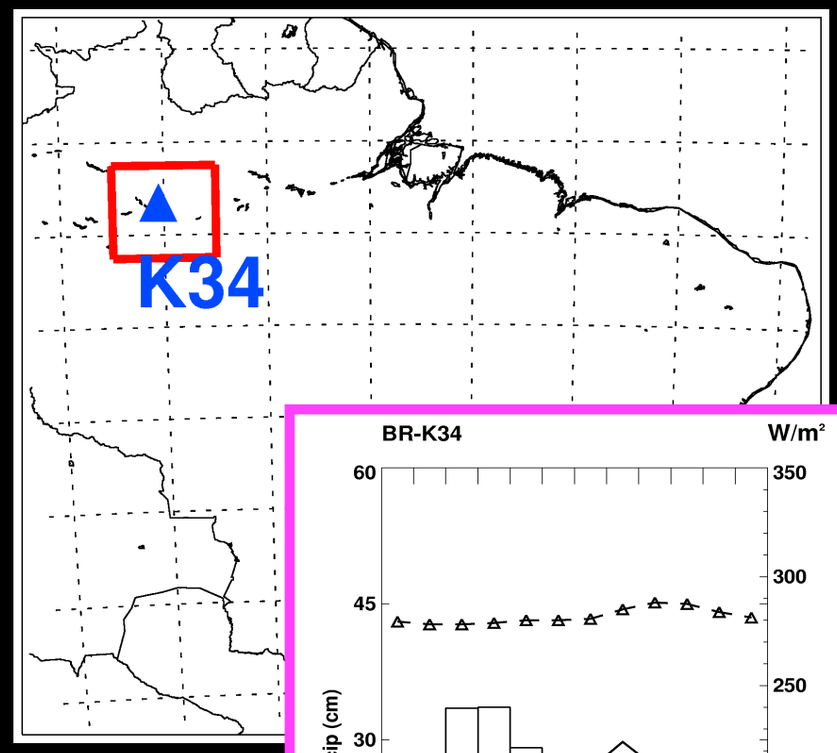
evaporation control f(w)

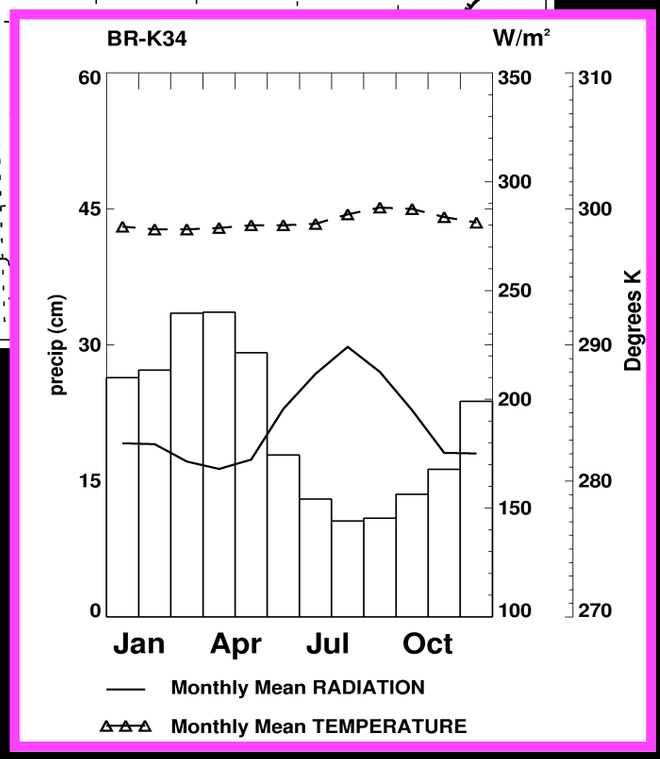


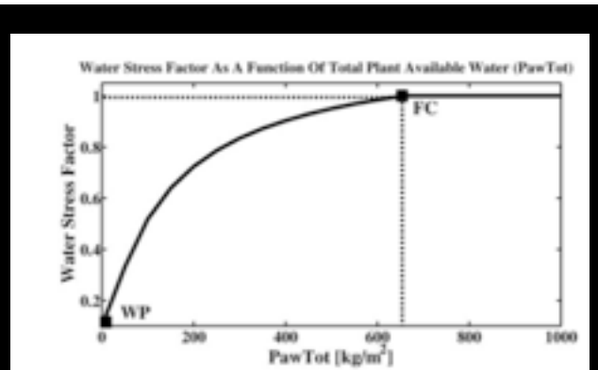
fraction of saturation/bin

Results: A Site That Doesn't Work









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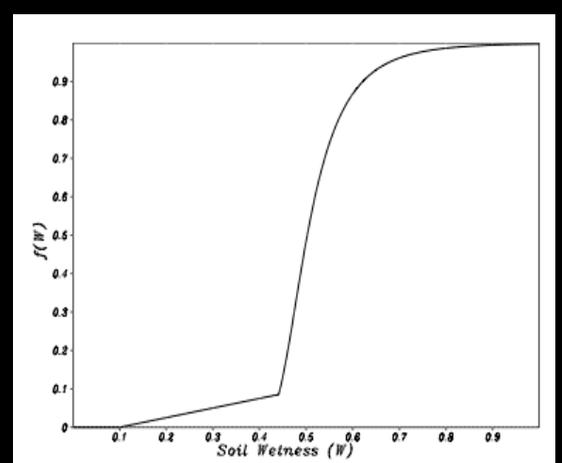

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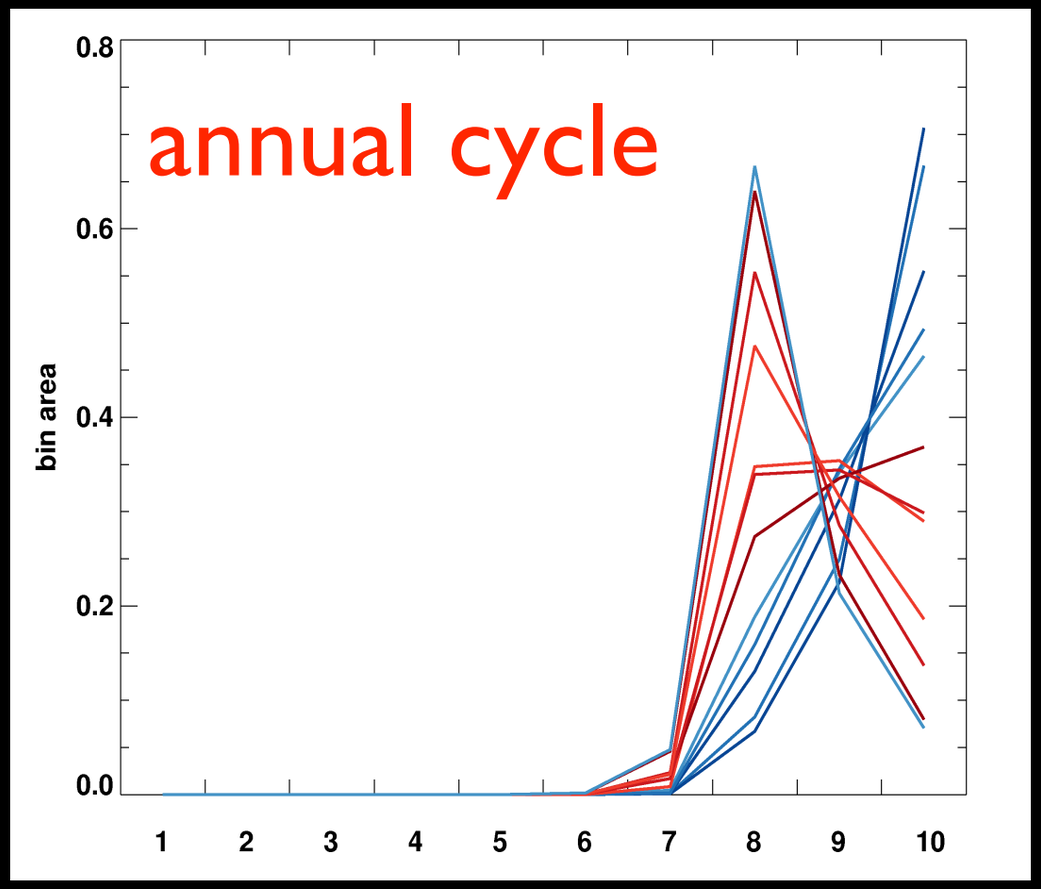
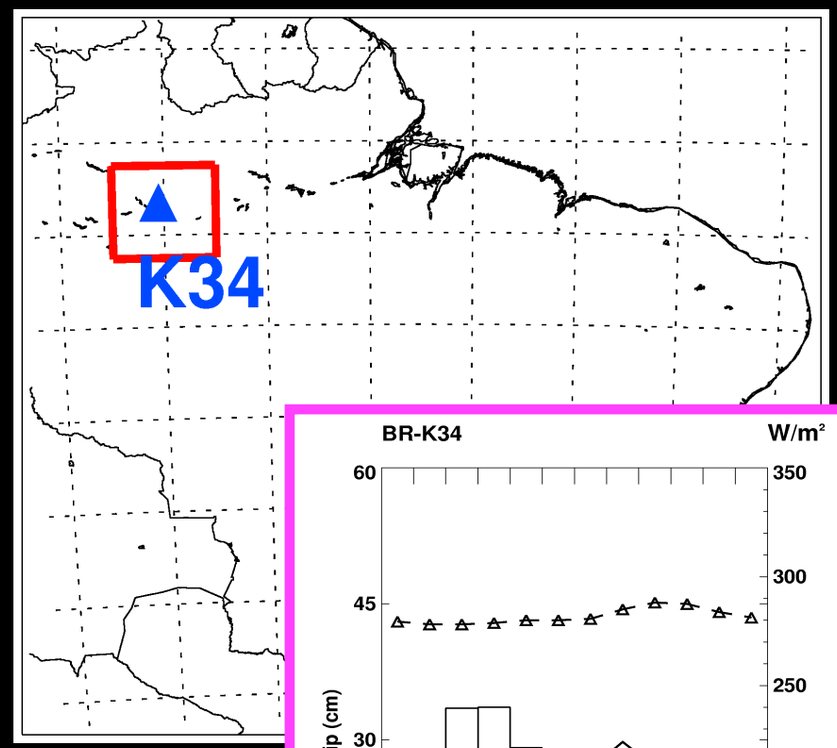
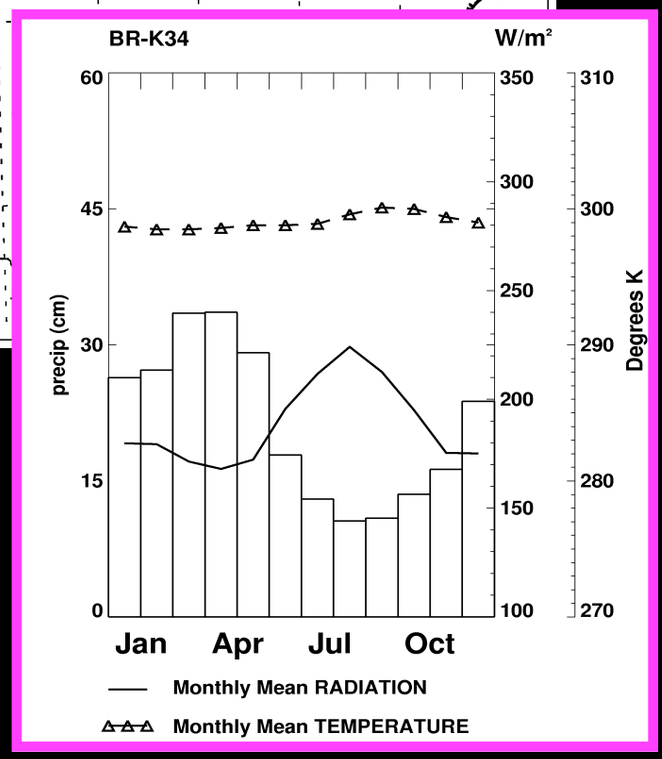
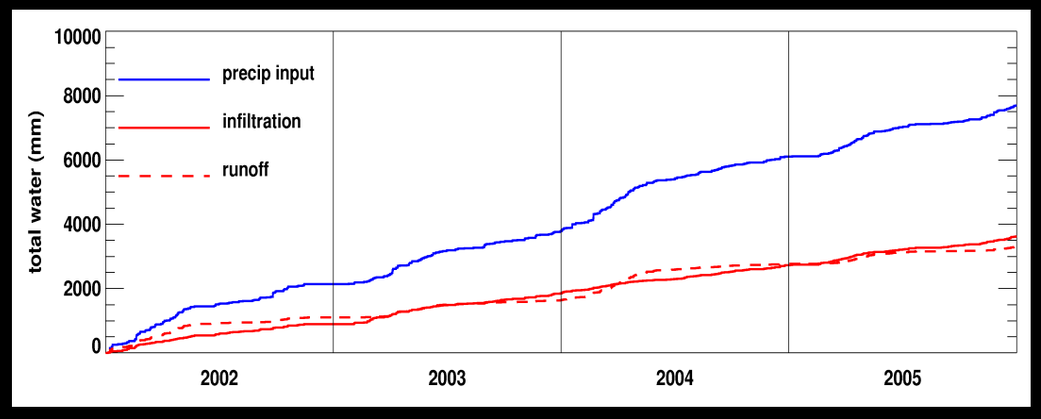
Results: A Site That Doesn't Work



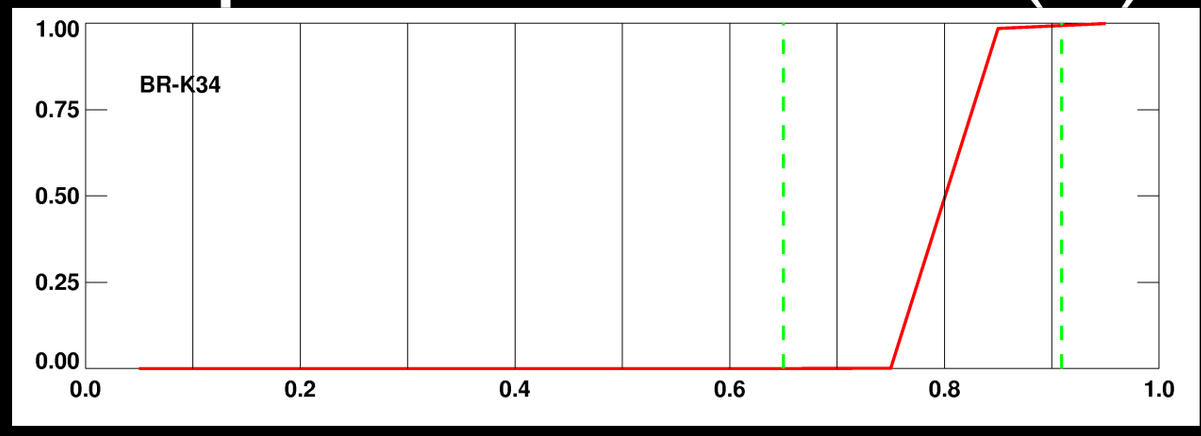




infiltration/runoff partition



evaporation control f(w)



fraction of saturation/bin

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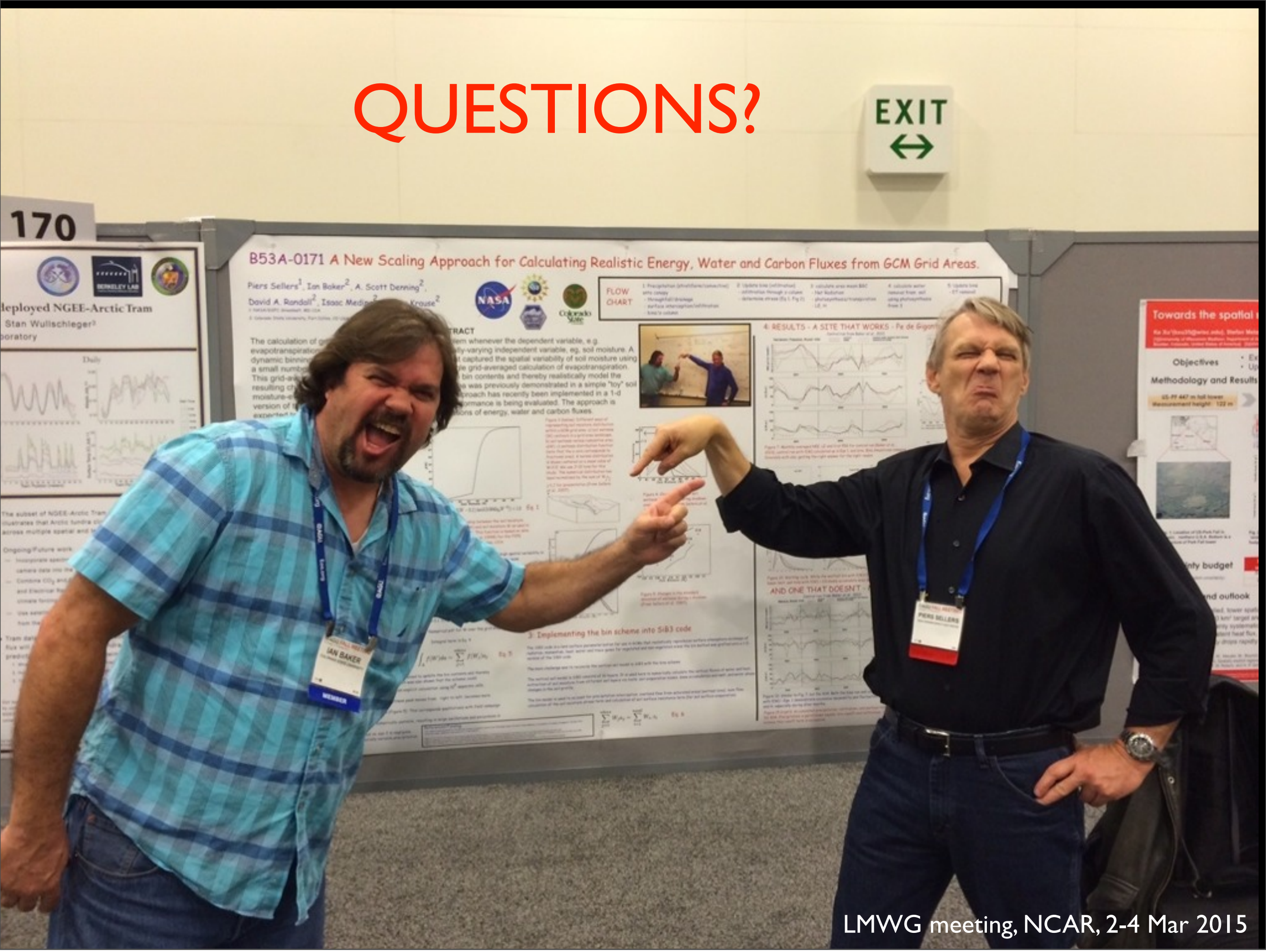
Conclusions

- The bins work quite well in semi-arid to arid regions
- Some problems in wet tropical forests
- Code is robust to bin number, bin spacing
- Energy and water balance to machine precision (bin- and z-columns)

Implementation

- Should we see bins as an alternative to CRMs?
- Are bins a complement to MASL?
- Or would bins coupled to MAML provide a link to hydrology?
- How would bins interact with subgrid tiling of PFTs?

QUESTIONS?



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