A New Method for Representing Subgrid Heterogeneity in Land Models

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Soil Moisture Heterogeneity

Fang et al., 2013

(i) NLDAS $\theta^{av}$ from August 9, 2005

(ii) AMSR-E $\theta^{av}$ from August 9, 2005

(iii) 1 km $\theta^{av}$ from August 9, 2005

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Plant Response to Soil Moisture

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

canopy status as a function of soil moisture

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

\[ E = E_p f(W) \]

\[ < E > \neq E_p f(< W >) \]

\[ f(x) \neq f(\bar{x}) \]
A New Approach: Wetness Bins

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

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

\[
\langle E \rangle = E_p \int_A f(W)\,da
\]

\[
\int_A f(W)\,da \sim \sum_{j=1}^{n\text{bins}} f(W_j)a_j
\]
From the Toy to the Full Model

- Medina et al., JAMES, 2014

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

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From the Toy to the Full Model

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

Simple Biosphere Model, version 3.0

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

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

\[
\sum_{j=1}^{nbins} W_j a_j = \sum_{i=1}^{nsoil} W_i, z_i
\]
Results: A Site That Works (PEG)


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

3. BINS

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

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Results: A Site That Works (PEG)

Drying

Moistening

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Results: A Site That Works

2002

Evaporation control \( f(w) \)

Fraction of saturation/bin

Bin number

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Results: A Site That Doesn’t Work

Manaus, Brazil: K34
- control
- BINS
- control with realistic Soil Stress
- OBSERVATIONS

f(w) for the control run (red)

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

BR-K34
- Monthly Mean RADIATION
- Monthly Mean TEMPERATURE

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Results: A Site That Doesn’t Work

annual cycle

infiltration/runoff partition

evaporation control \( f(w) \)

fraction of saturation/bin

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Sunday, March 1, 15
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?