Effects of soil dryness, plant litter and under-canopy atmospheric stability on ground evaporation in NCAR CLM3.5

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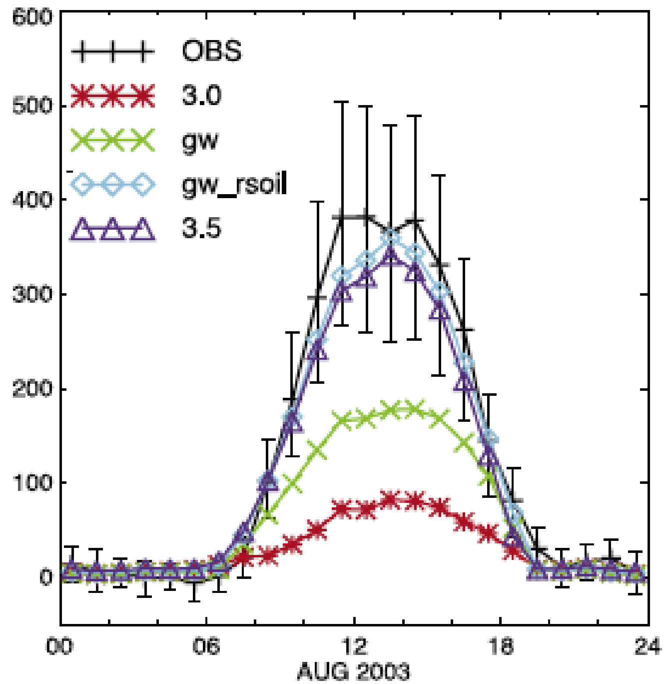
Improvement to ET components by soil resistance

$$E_g = -\rho_{atm}\frac{(q_s - q_g)}{r_{aw}' + r_{soil}} \qquad r_{soil} = (1 - f_{sno})\exp(8.206 - 4.255 s_1)$$ (Oleson et al., 2008)

LH flux (W/m^2)



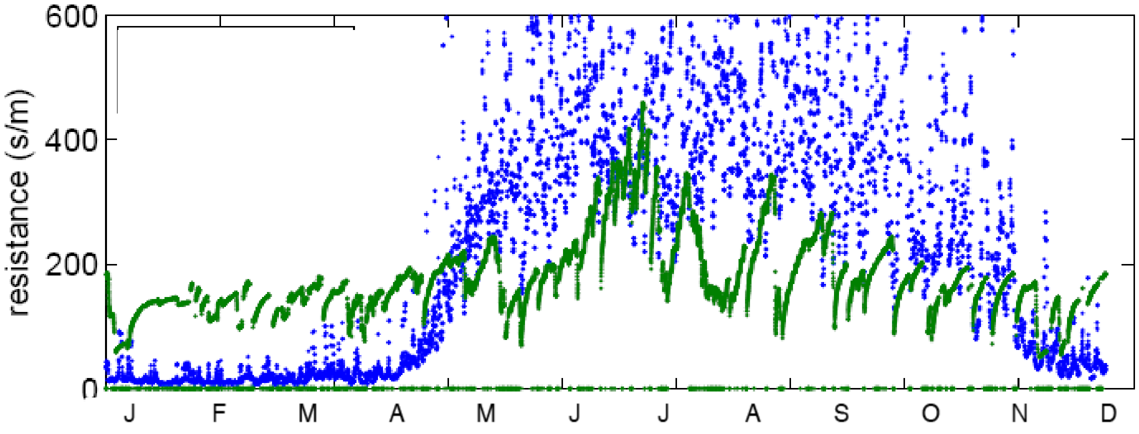
Monthly mean diurnal cycle
From Stöckli et al., 2008

- ET in other spatial & temporal scales were also improved

Issues with soil resistance

1. Physically inconsistent over wet soil (r_{soil}= 52 s/m at saturation)

Harvard forest, 2003 simulation



Blue: $r_{aw}' = \frac{1}{C_s u_*}$

Green: r_{soil}

2. Implicitly includes the effect of plant litter

Mesoscale model study by Song et al., 1997 :
high litter content reduced evaporation at FIFE site

Our approach

a) Revisited surface resistance / moisture limitation

Kondo et al., 1990; Mahfouf & Niolhanm, 1991; Lee & Pielke 1992

b) New formula for the explicit effect of plant litter: r_{litter}

Bristow et al.,1986; Bussiére & Cellier, 1994; Schaap and Bouten, 1997

+

c) Developed a formula for under-canopy atmospheric stability

Baldocchi et al., 2000; Niu and Yang, 2004; Miller et al., 2007;

a) Revisited surface resistance

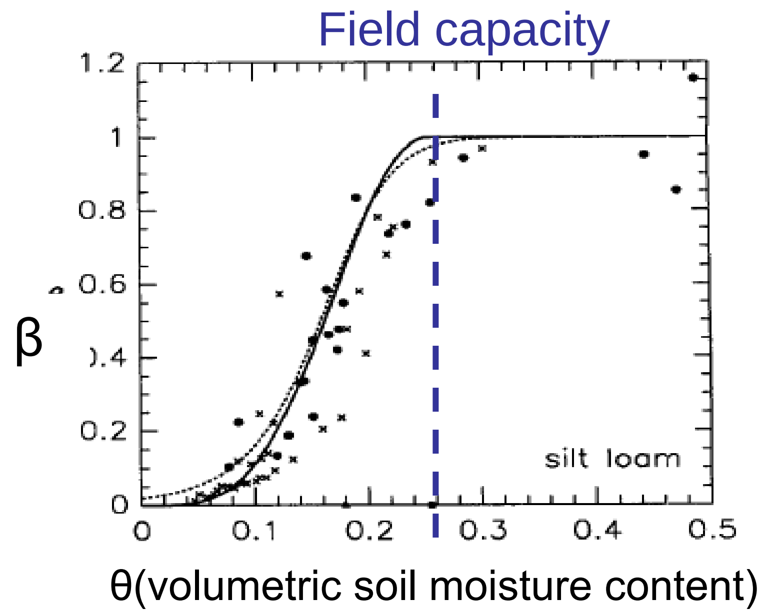
$$E_g = -\rho_{atm} \frac{\left(q_s - \alpha q_{sat}^{T_g}\right)}{r_{aw}' + r_{soil}}$$ CLM3.5

$R_{soil} \approx 300$ s/m

$$E_g = -\rho_{atm} \frac{\beta\left(q_s - \alpha q_{sat}^{T_g}\right)}{r_{aw}'}$$ New

$\beta = 1$ $\quad\theta_1 \geq \theta_{fc}$ or $q_s > q_g$

$$\beta = \frac{1}{4}\left[1 - \cos\left(\frac{\theta_1}{\theta_{fc}}\pi\right)\right]^2 \qquad \theta_1 < \theta_{fc}$$



Based on Lee & Pielke, 1992

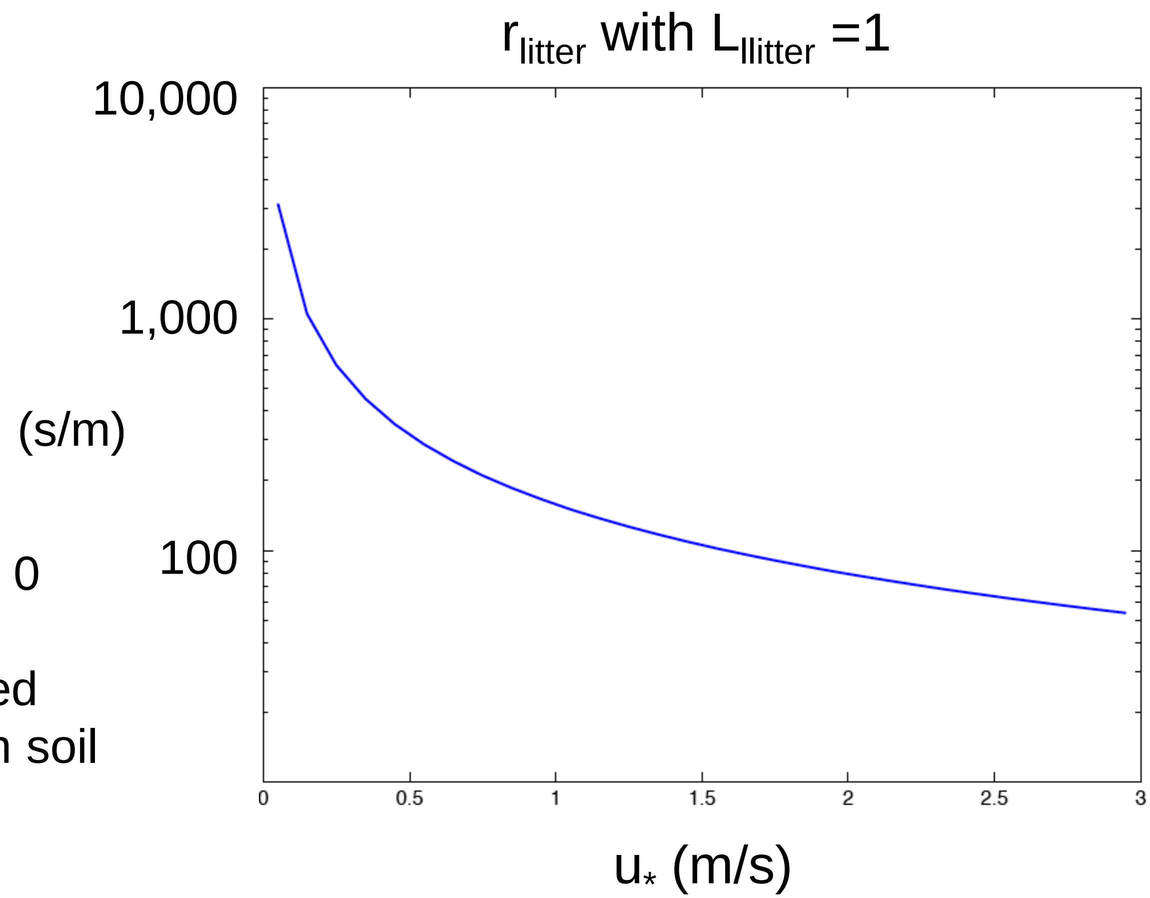
- Reduce evaporation only when the soil is dry

b) Plant litter resistance

$$E_g = -\rho_{atm} \frac{\beta\left(q_s - \alpha q_{sat}^{T_g}\right)}{r_{aw}' + r_{litter}}$$

$$r_{litter} = \frac{1}{0.004 \cdot u_*}\left(1 - \exp\left(-L_{litter}^{eff}\right)\right)$$

- Converge to zero when L_{litter} = 0
- Consider only dry plant litter
- Snow cover effect is considered
- Assumed to be isothermal with soil
- For this study, L_{litter} = 1.0



- Magnitude is comparable to soil resistance and observed litter resistance (Schaap and Bouten,1997)
- Applied only over vegetated surface

c) Stability effect of under-canopy air

$$r_{ah}' = r_{aw}' = \frac{1}{C_s u_*} \qquad C_s = C_{s,bare} W + C_{s,dense}(1 - W) \qquad C_{s,dense} = 0.004$$

CLM3.5

$$C_{s,dense} = \frac{0.004}{1 + 0.5 \cdot \min(S, 10)}$$ with $$S = \frac{gh(T_s - T_g)}{T_s u_*^2}$$

$T_s > T_g$ (stable)

$$C_{s,dense} = 0.004$$

$T_s < T_g$ (unstable)

- maximum reduction of $C_{s,dense}$ is 1/6 for stable condition, to be conservative
- The model was not sensitive to modification for unstable condition

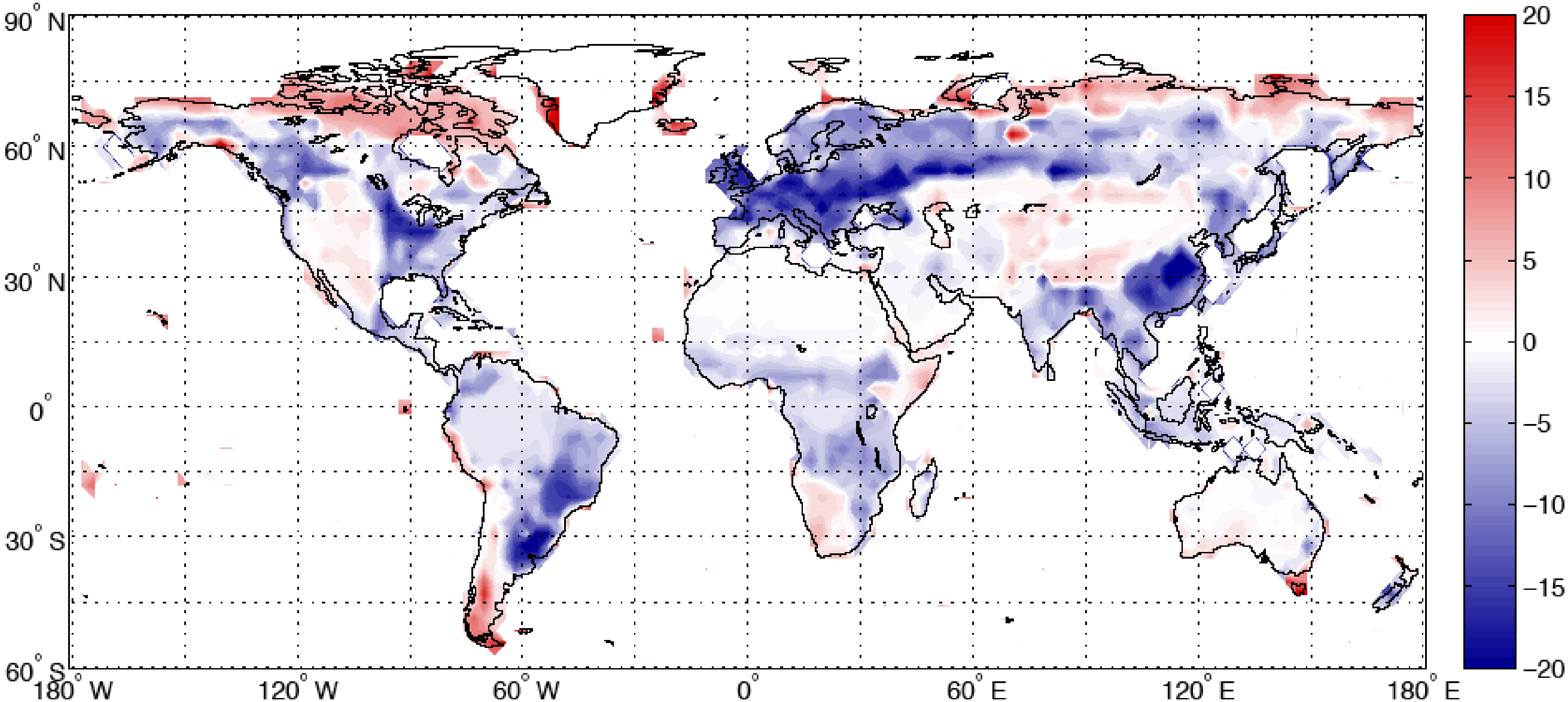
S8

Average over global land from 2000 - 2004

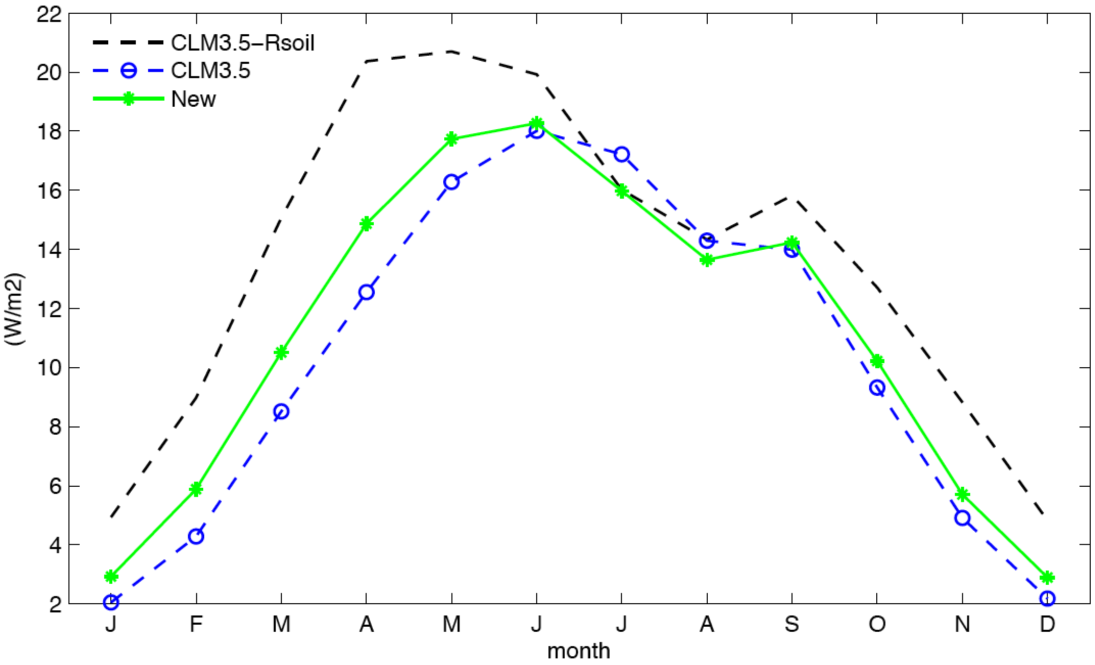
Ground evaporation	CLM3.5 w/o Rsoi	CLM3.5	Beta	Stability	Rlitter	All New
mm / day	0.67	0.47	0.66	0.66	0.48	0.48
% of total ET	52.00	41.00	51.00	52.00	41.00	41.00

Eg % of total ET: [New formulation] - [CLM3.5]

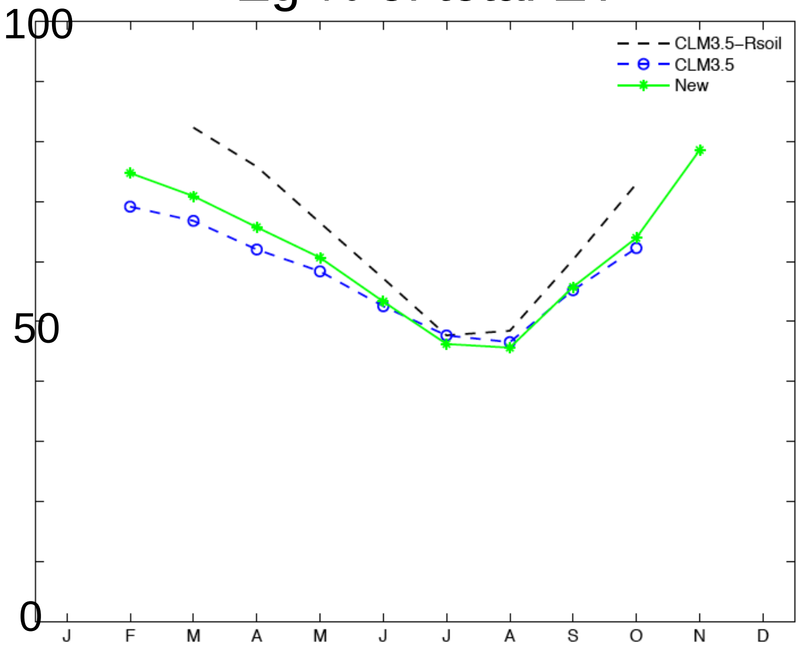
global mean difference = -0.4%



Monthly Eg in Western U.S.



Eg % of total ET

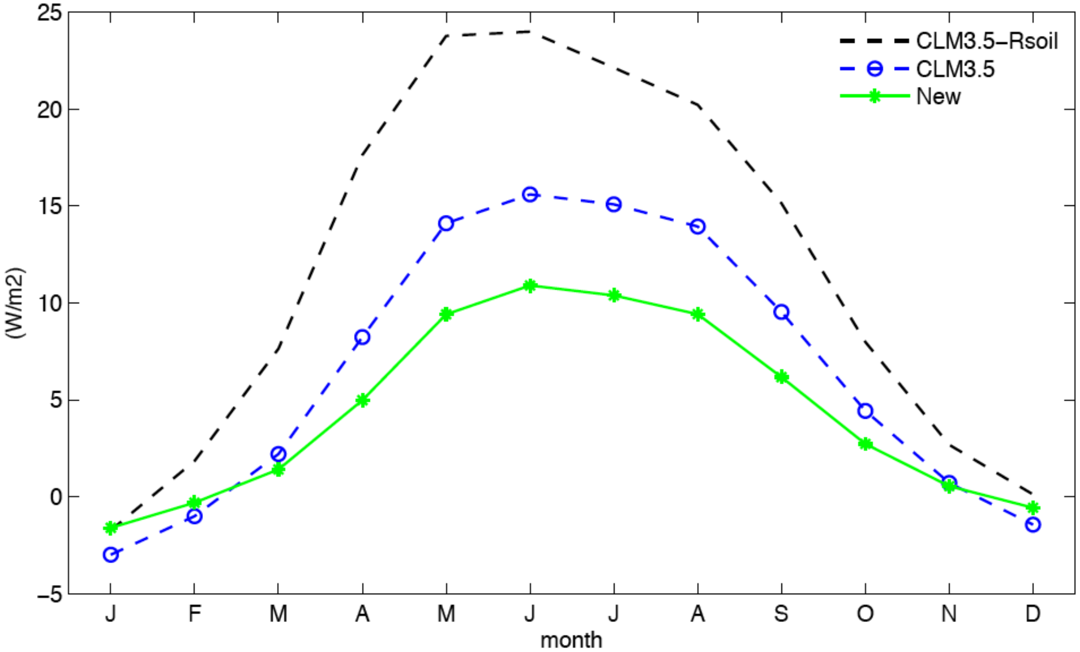


Lat: 30 ~ 50°N
Lon: 105 ~ 125°W
LAI+SAI = 1 ~ 1.7

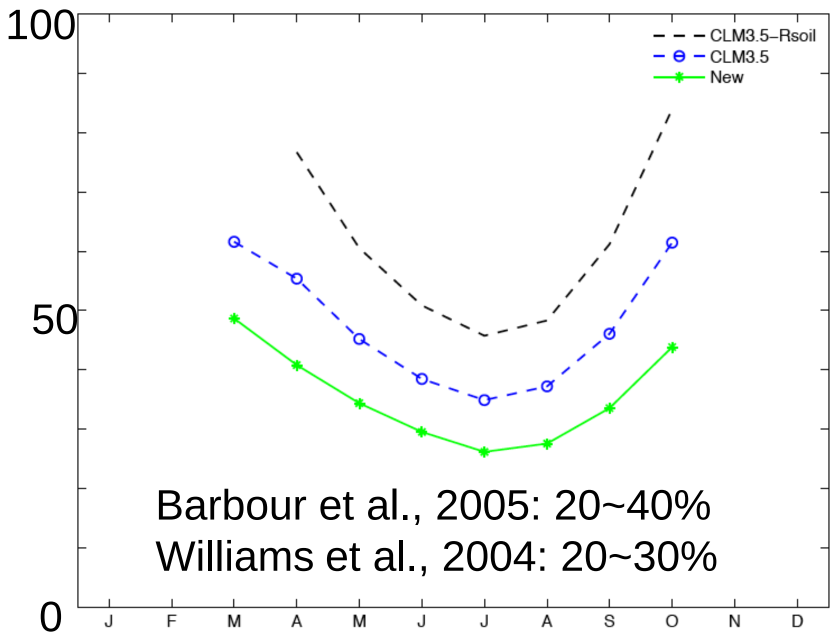
(Months with negative or very small E are excluded)

Sparse canopy → **β** Litter Stability — Small difference

Monthly Eg in Europe



Eg % of total ET



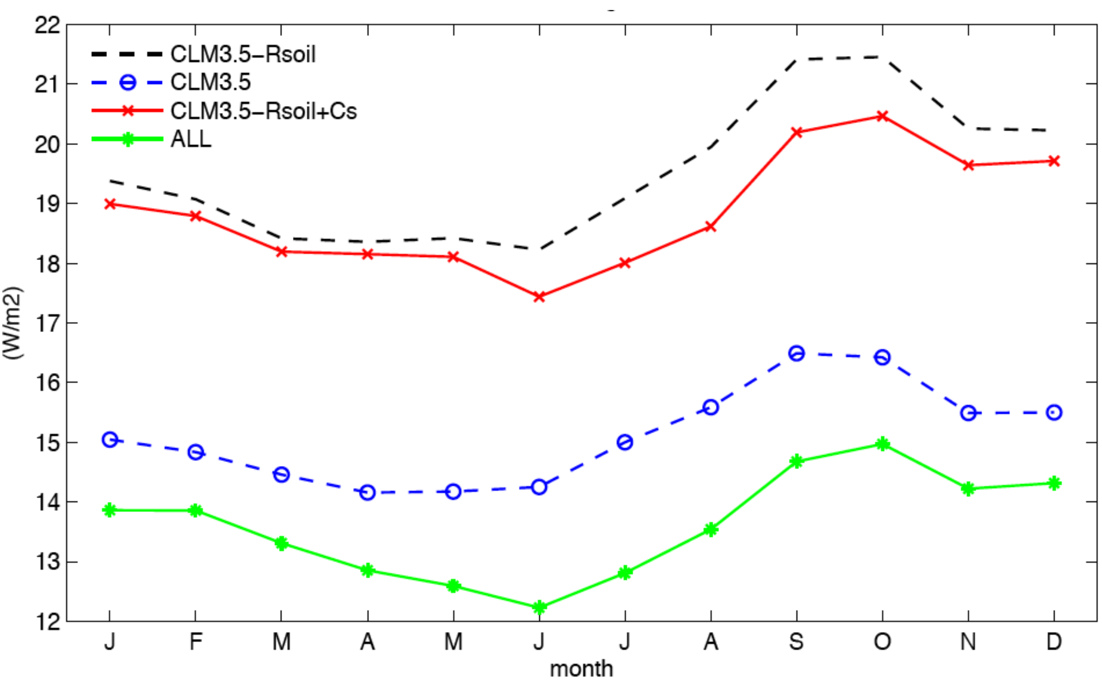
Lat: 45 ~ 60°N
Lon: 0 ~ 32°E
LAI+SAI = 1.2 ~ 2.8

Eg is a large component of total ET.

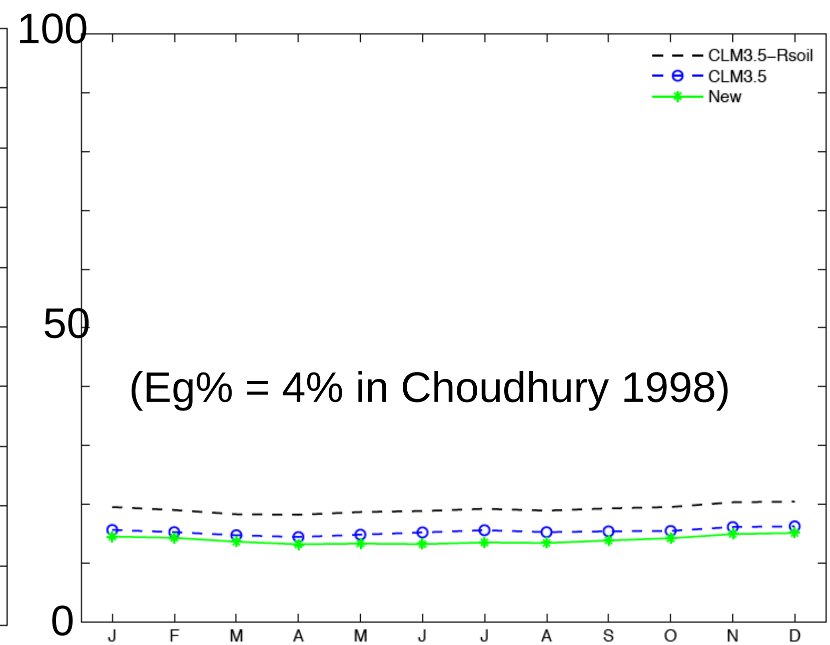
Intermediate canopy Thickness → β **Litter** Stability

Larger improvement on ET partitioning

Monthly Eg in Amazon forest



Eg % of total ET



Lat: 11°S ~ 11°N
Lon: 50 ~ 72°W
LAI+SAI = 4.5~5

Thick canopy → β **Litter** **Stability**

New formulation reduced Eg more.

Summary

1. Soil resistance in CLM3.5 significantly improved Eg compared to CLM3.0., but has two issues:
   a) Physically inconsistent in wet soil condition
   b) Implicitly includes litter effect
2. Developed more physically-based formulations for both wet and dry soil, plant litter resistance, and also under-canopy atmospheric stability.
3. These revisions did not change global average compared to CLM3.5, but improved ET partitioning over certain regions.
4. They are simple to implement. Litter resistance will also facilitate the direct use of CN-DGVM litter output in CLM Eg computation in the future.

Thank you!