Implementing a dynamic rooting scheme in Noah-MP to capture deep root water uptake

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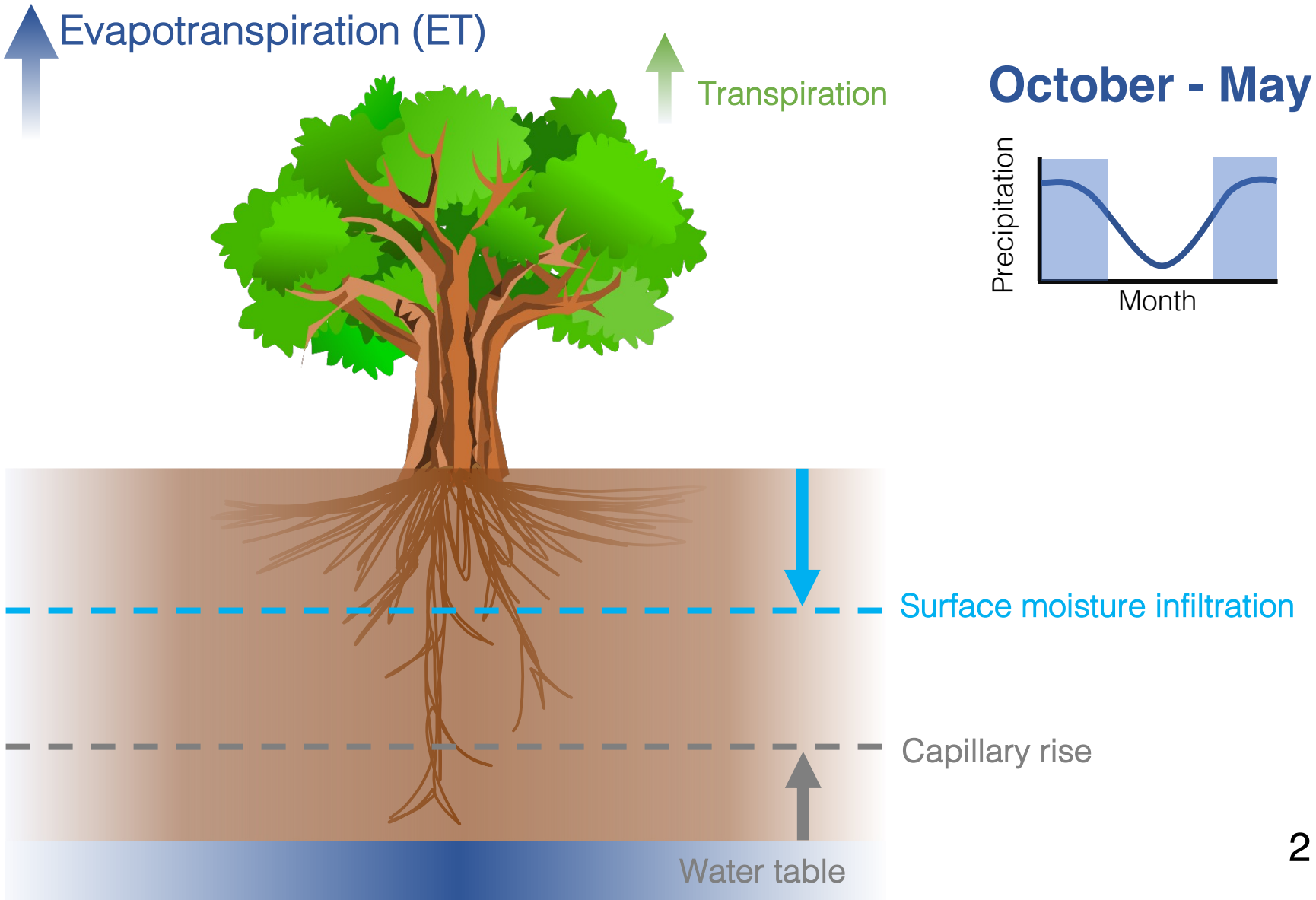
Mature forests in the Amazon rely on **deep roots** for water uptake during **seasonally dry** periods.



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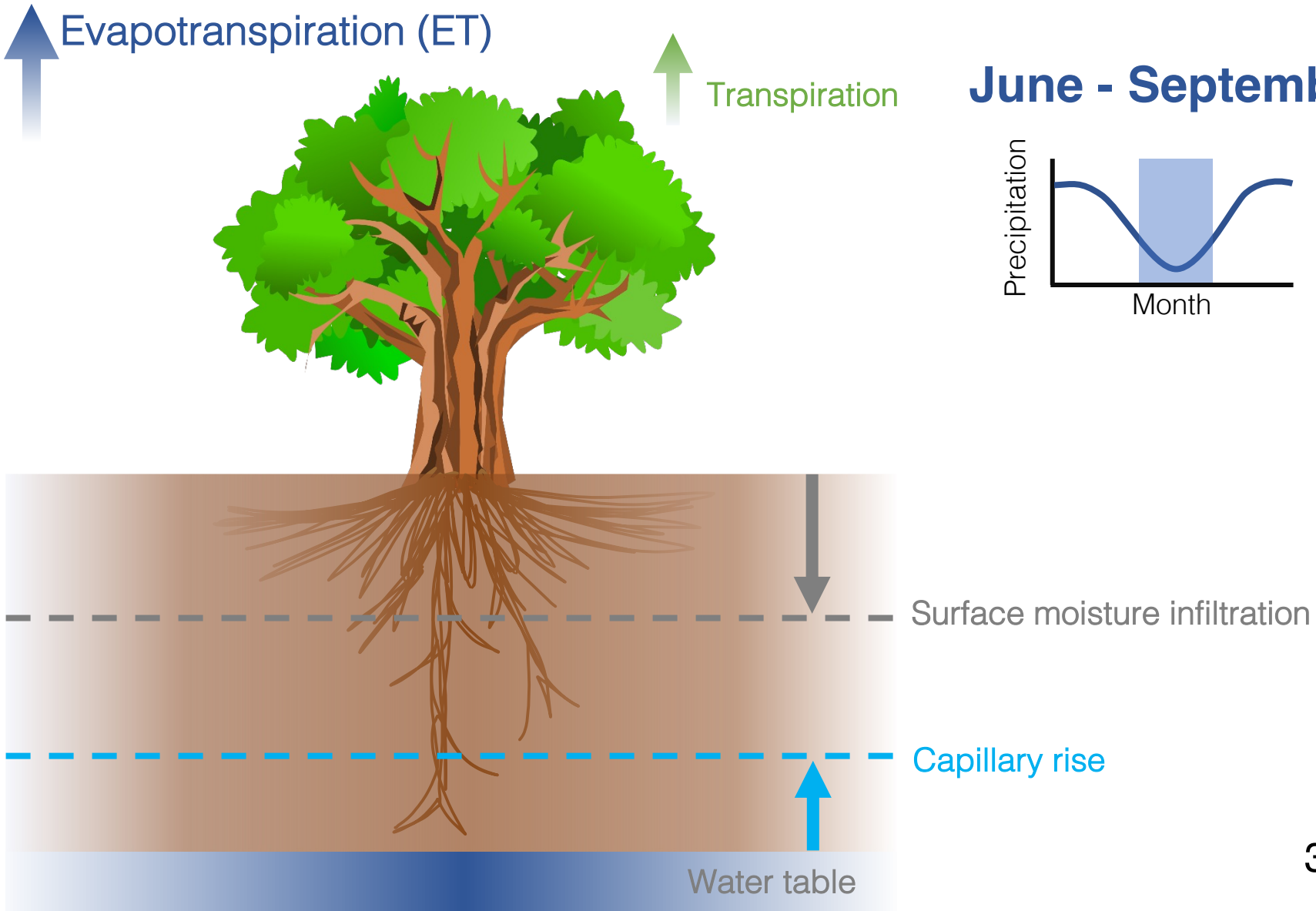
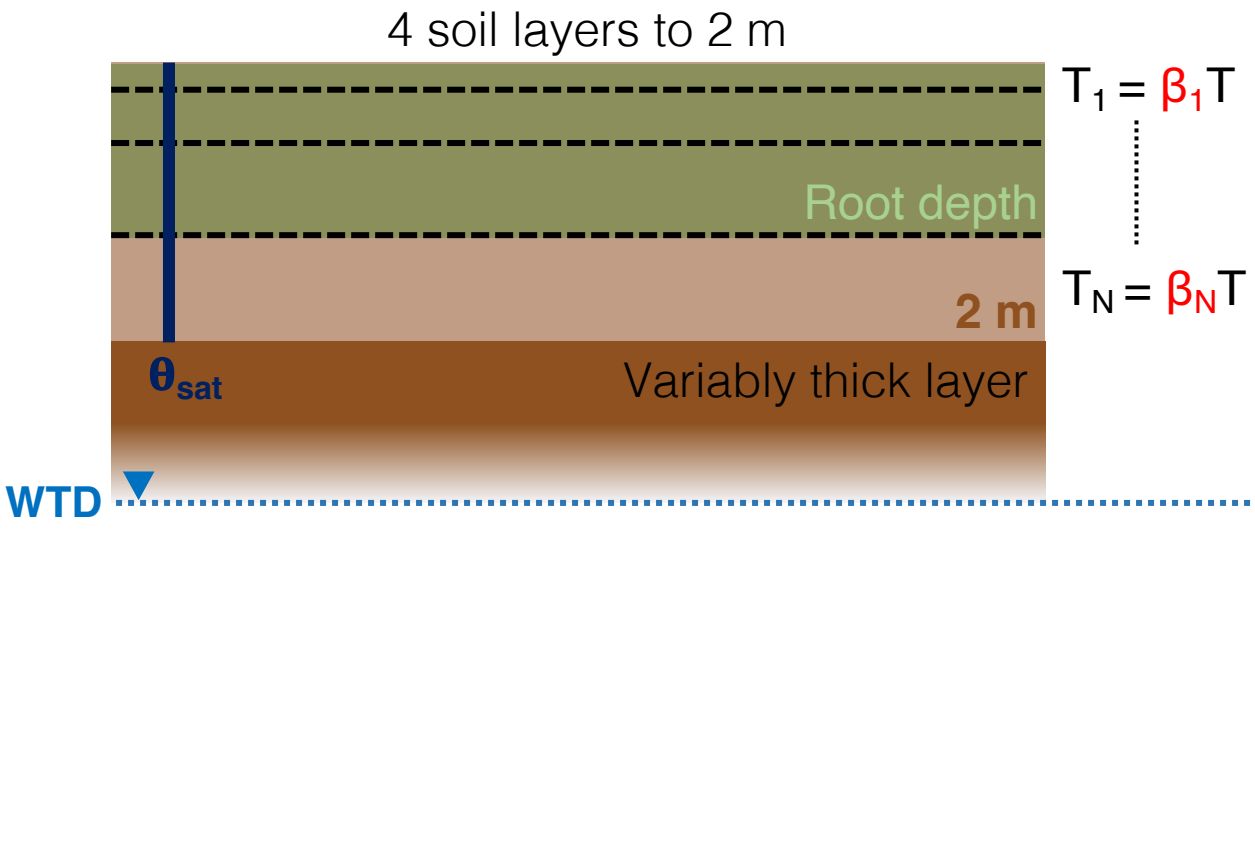


Science question

How does addition of a dynamic root scheme in Noah-MP affect transpiration in a southern Amazonian region?

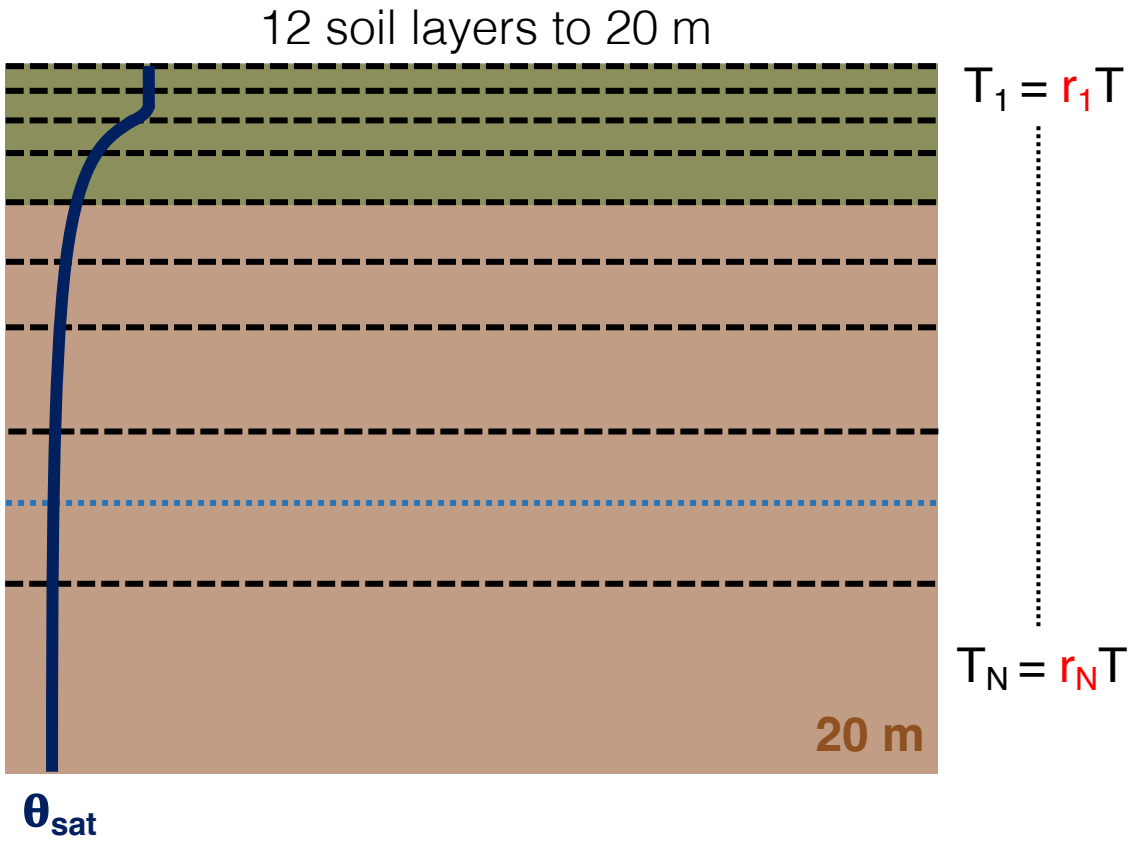
We make several **changes** to Noah-MP, including implementation of a **dynamic root scheme** that allows for **deep water uptake.**

Original setup, Noah-MP Version 4.4 (Niu et al. 2011)



Rooting depth static in time
Inputs needed to vary soil props w/ depth
β used in root water uptake

Our setup



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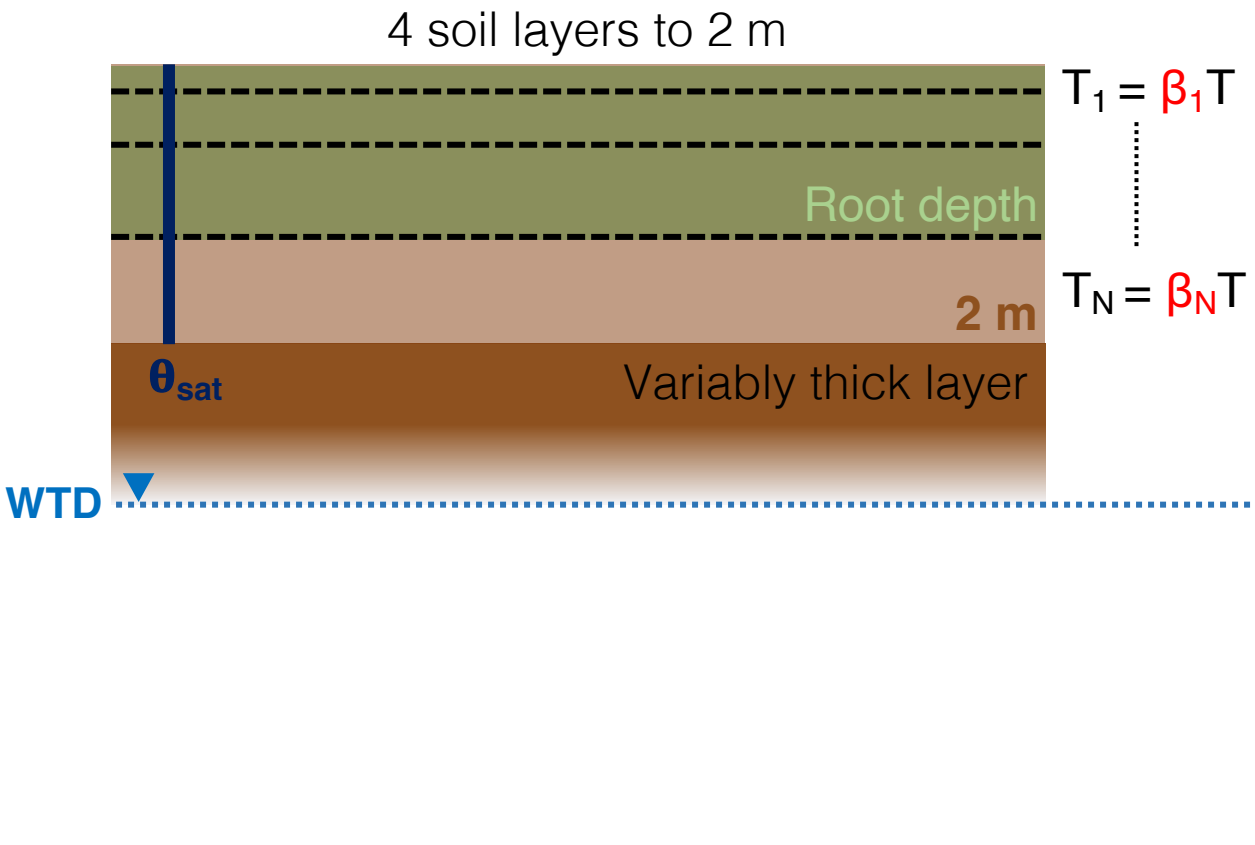

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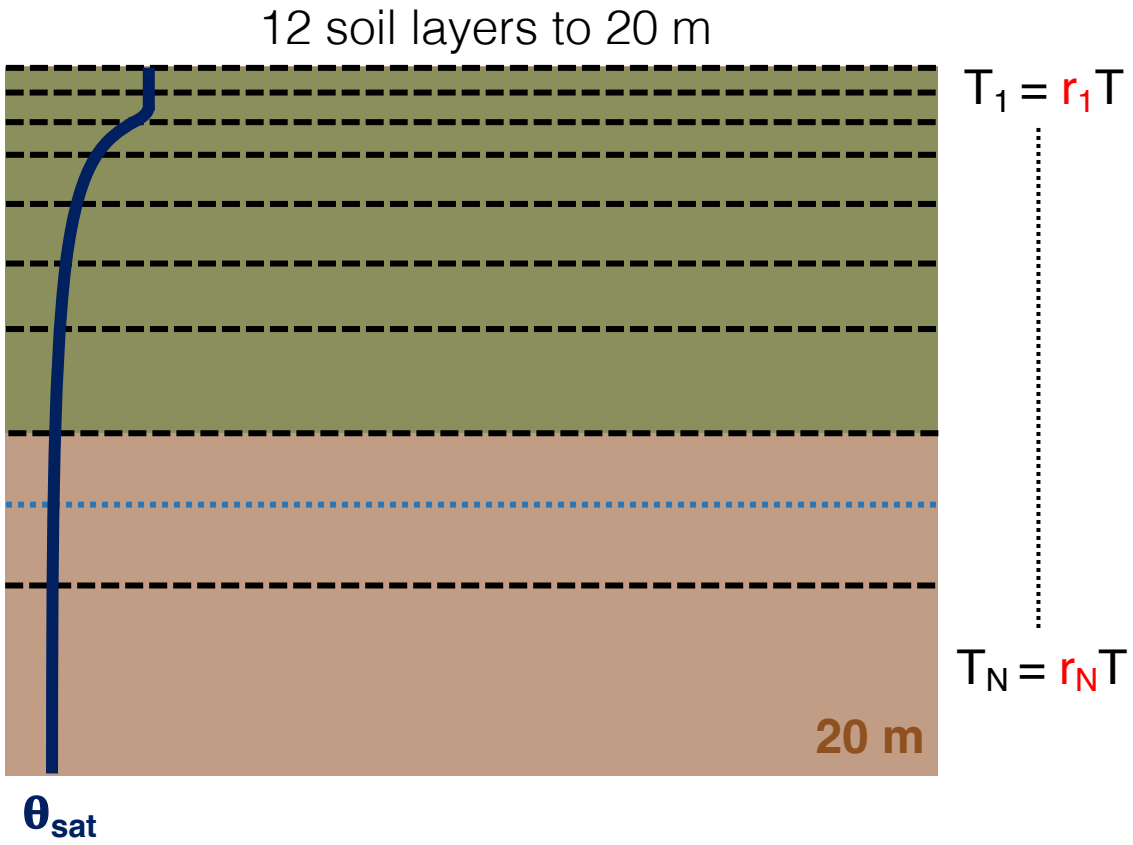

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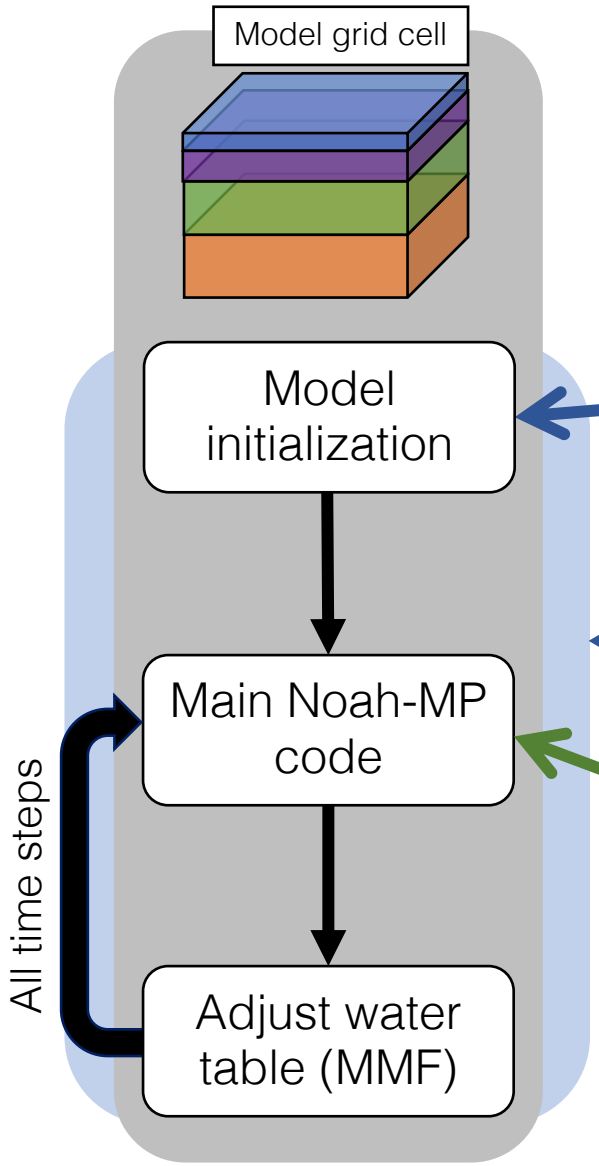
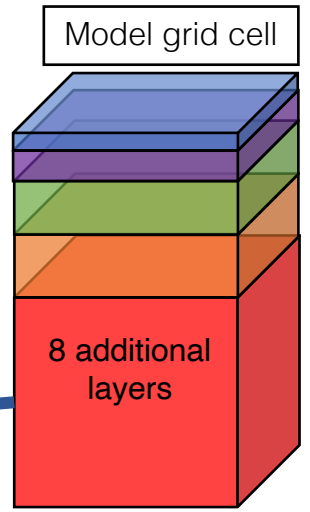
Original code (HRLDAS Noah-MP Version 4.4)



Our modifications



12-layer soil column
Infer deep initial values from input SM, T, and ZWT

Soil properties vary with depth

Root scheme

We calculate varying soil properties with depth based on an **exponential decay** function.

$\kappa_{sat}, \theta_{sat}, \theta_{wilt}, \psi_{sat}, D_{sat}$
vary exponentially with depth
on kilometer scales

$$K_{sat_i} = K_{o_{sat}} exp(\frac{-z}{f})$$

$$\psi_{sat_i} = -\psi_{o_{sat}} exp(\frac{z}{f})$$

$$\theta_{sat_i} = \theta_{o_{sat}} exp(\frac{-z}{f})$$

$$\theta_{wilt_i} = \theta_{o_{wilt}} exp(\frac{-z}{f})$$

$$D_{sat_i} = \frac{-K_{sat_i} \psi_{sat_i} B_i}{\theta_{sat_i}}$$

z → layer depth from surface
f → controls how fast permeability decreases with depth (input data for MMF)
$K_o, \psi_o, \theta_o, etc.$ → known value at top of column (table parameter; dependent on soil type)

Sources: Miguez-Macho & Fan (2012), Beven & Kirkby (1979)

The root scheme is **simple, scalable**, and based on the **soil water profile**.

Ease function

$$e_j = \left(\frac{\psi_{lmin} - \psi_j}{\frac{2}{3} h_{veg} + d_j} \right)$$

Ψ_j matric potential at soil layer j
Ψ_{lmin} minimum leaf water potential (usually -2 MPa)
h_{veg} canopy height
d_j layer depth

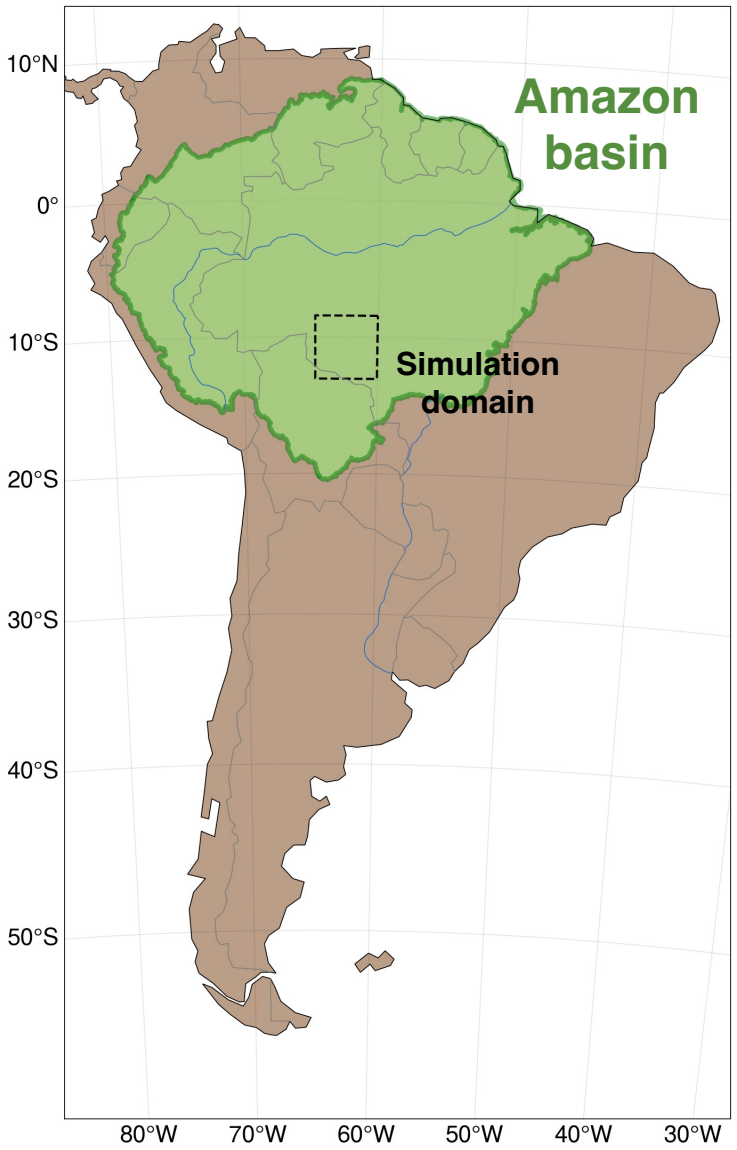
less effort for wetter and shallower layers

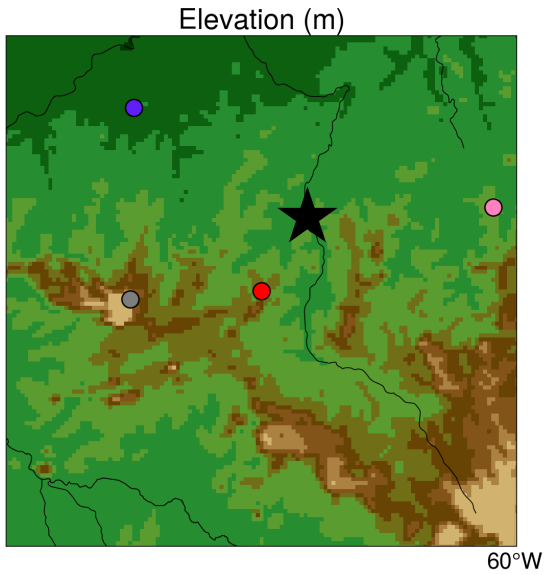
more effort for drier, deeper layers and taller vegetation

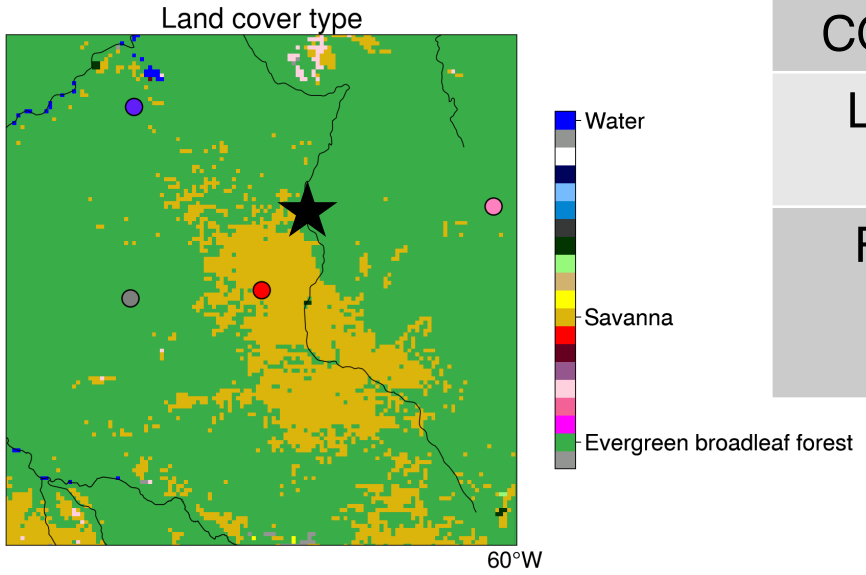
quantifies where & when it is advantageous for vegetation to take up deep moisture

For more details, see Fan et al. (2017), PNAS: *Hydrologic regulation of plant rooting depth*

We carry out **uncoupled** Noah-MP simulations for a domain in the **southern Amazon**.





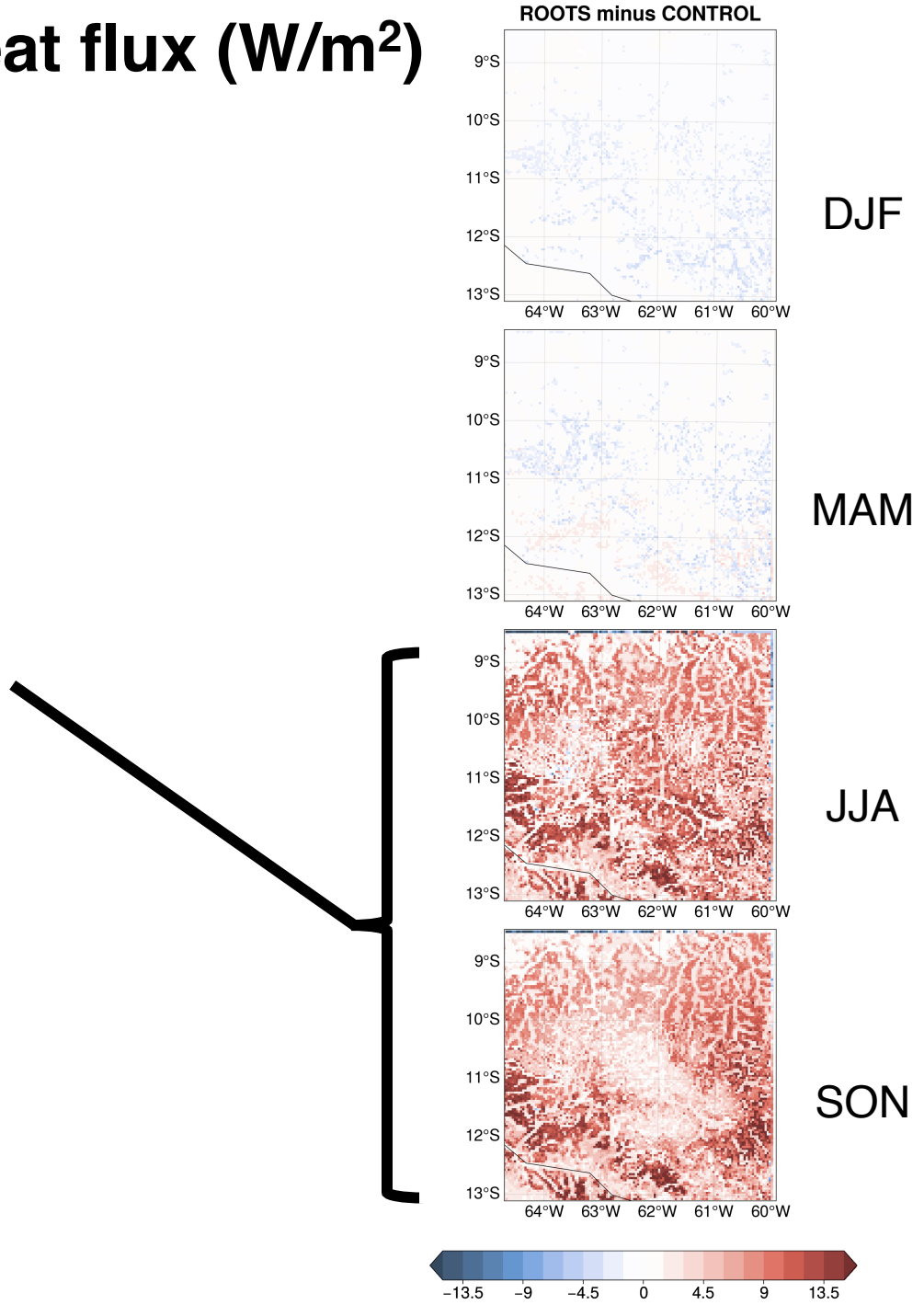


Specifications	
Length	01-2000 to 12-2009
Resolution	4 km
Forcing	GLDAS
Groundwater scheme	Miguez-Macho & Fan (MMF); RUN_OPT = 5

Configurations	
CONTROL	Noah-MP default
LAYERS	12 soil layers; soil parameters vary
ROOTS	12 soil layers; soil parameters vary; root scheme active

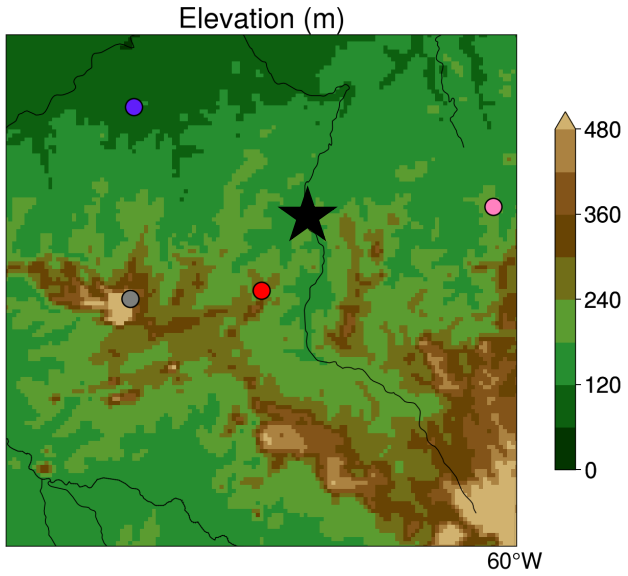
Latent heat flux (W/m^2)

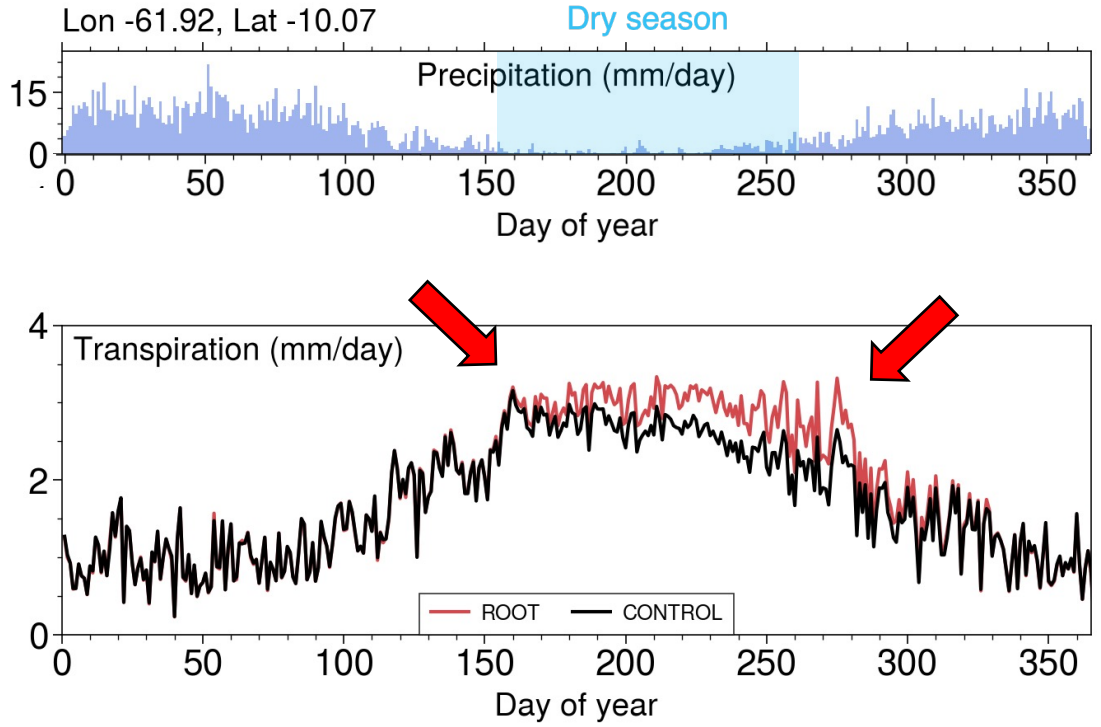
Mean differences between simulations are largest in **dry** months and longer-lasting in areas with **forest**.



Model output at a **forest** point shows the largest changes in the **dry** season, **consistent** with expected behavior.

Forest





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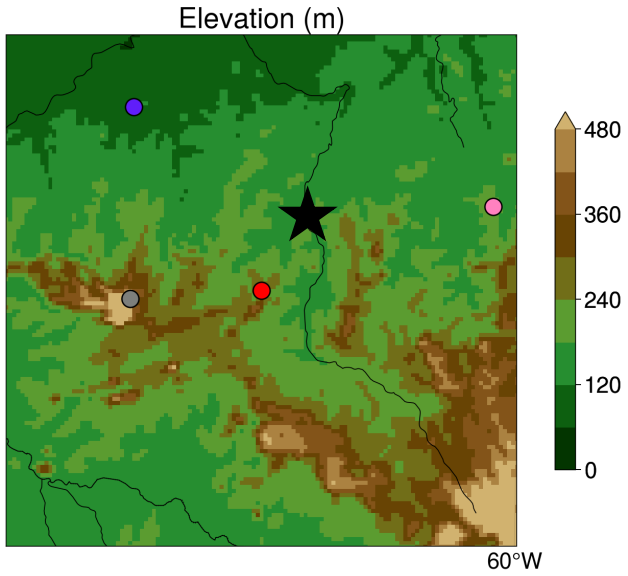
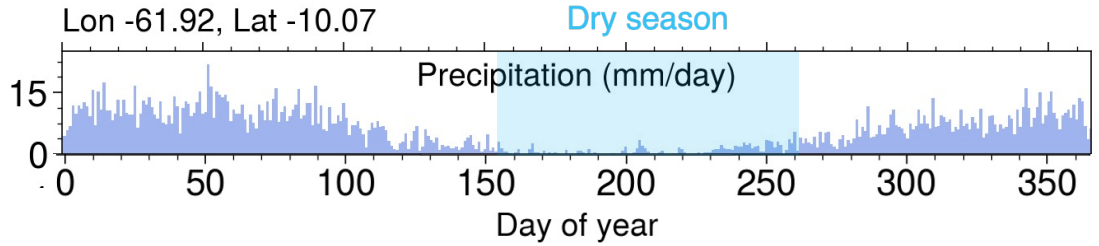
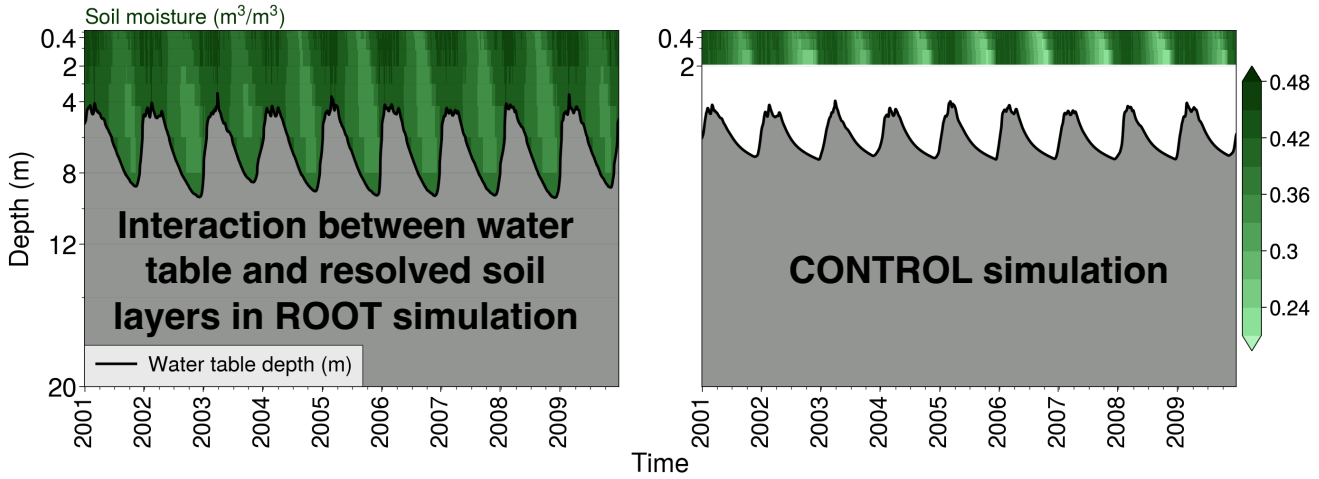
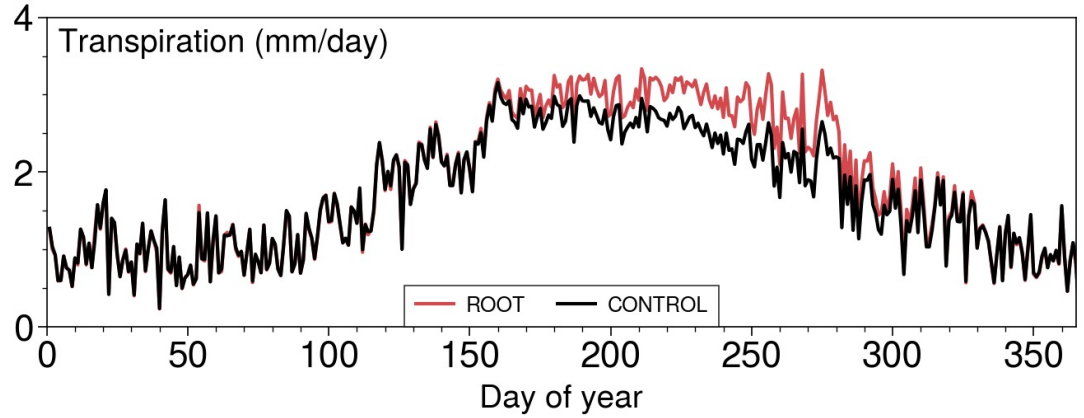
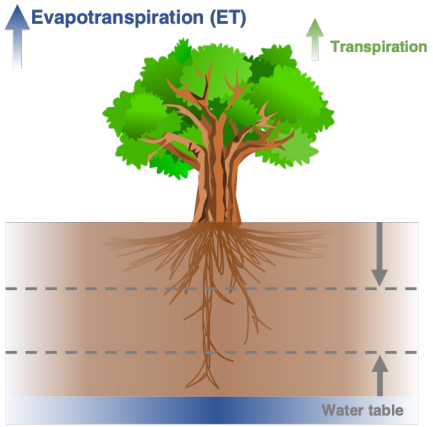




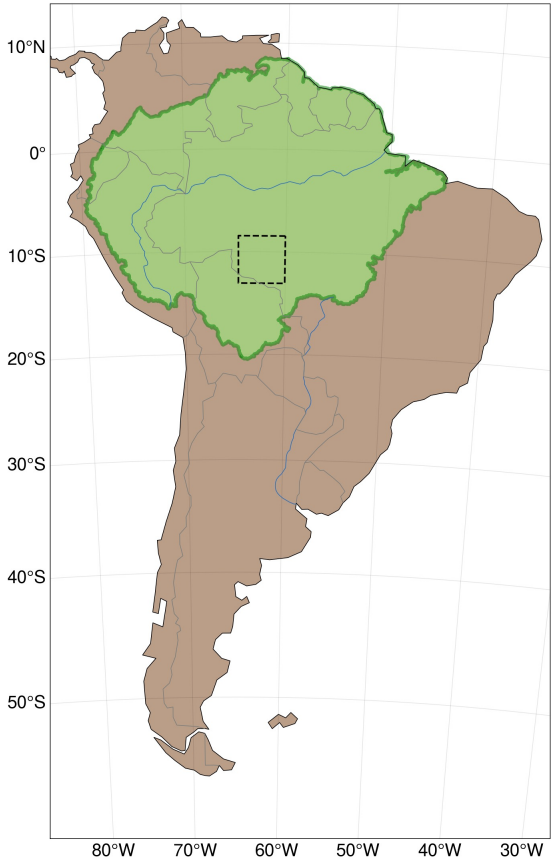


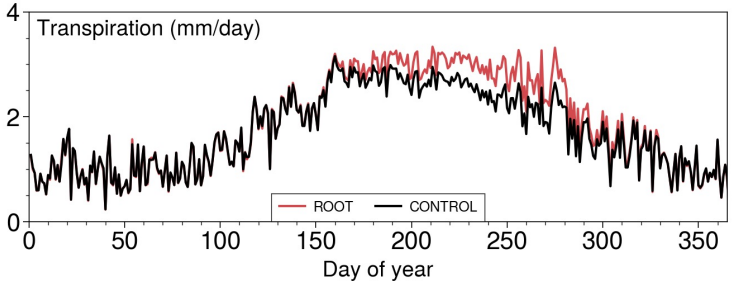




Addition of the root scheme in Noah-MP provides a critical link between deep subsurface moisture sources and the atmosphere, particularly in mature Amazon forests.

Future work will include coupled simulations using the Weather Research and Forecasting (WRF) model to elucidate effects on the atmosphere.





Mitigate temperature/moisture biases?

Our code changes have been implemented in Noah-MP Version 4.4 and will be shared on GitHub to facilitate inclusion in future versions of Noah-MP.

Thank you!

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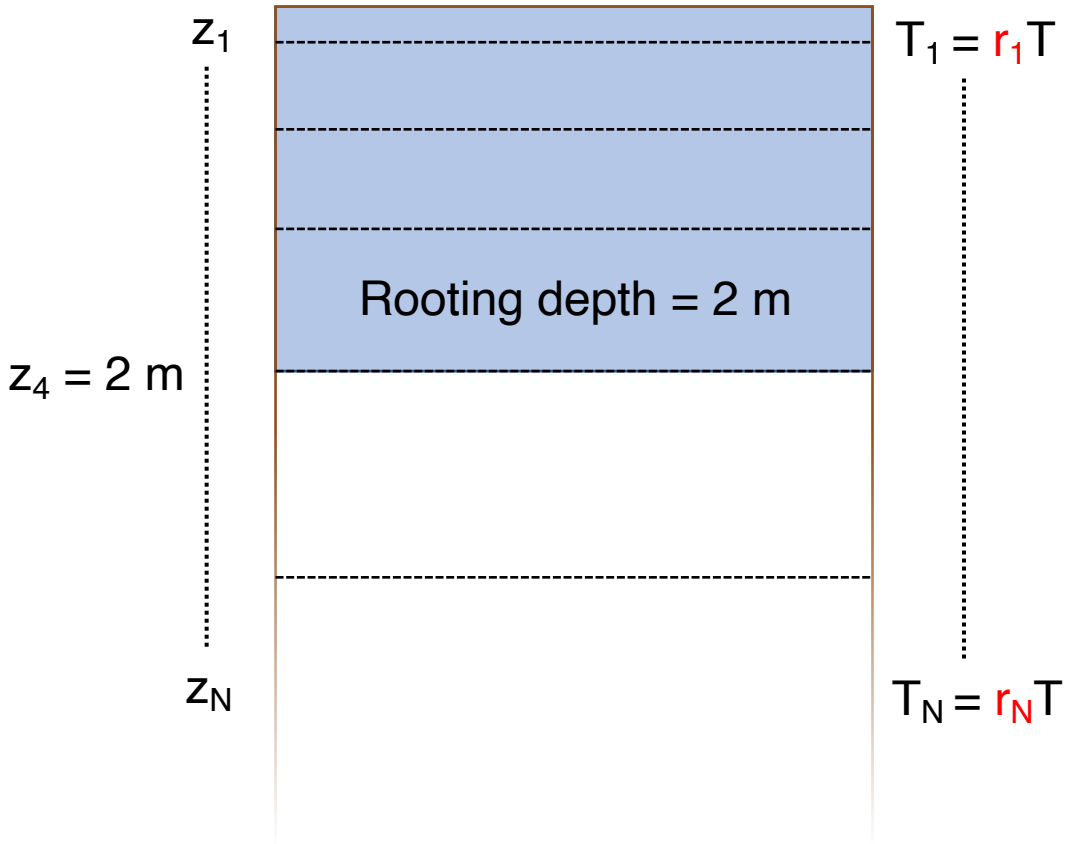
The rooting depth scheme is **simple, scalable**, and based on the **soil water profile**.

Other important parts of the root scheme:

- Designate layers as **inactive** if roots have not existed in that layer for at least one year
- "Rooting depth" defined as **layer depth at which sum of uptake >= 0.95 x T**



$$\frac{\sum_{N=1}^{4} T_N}{T} \geq 0.95$$