



Implementing a deep, dynamic root water uptake scheme in Noah-MP

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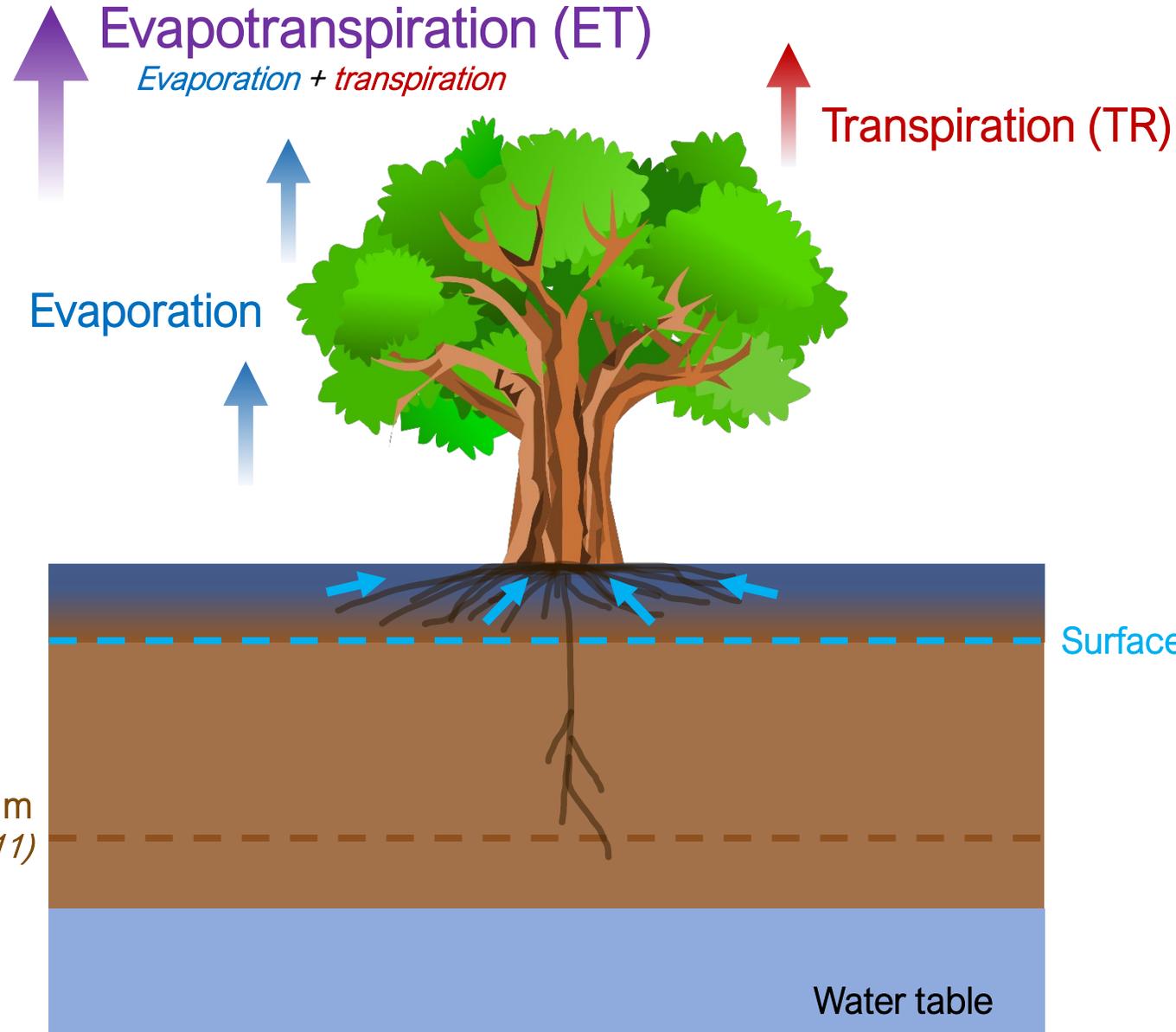
²Universidade de Santiago de Compostela, ³Rutgers University

2024 Noah-MP International Workshop

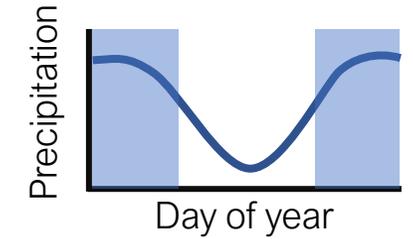
3-4 June 2024



Mature forests in the Amazon rely on deep roots to avoid water stress during the dry season.



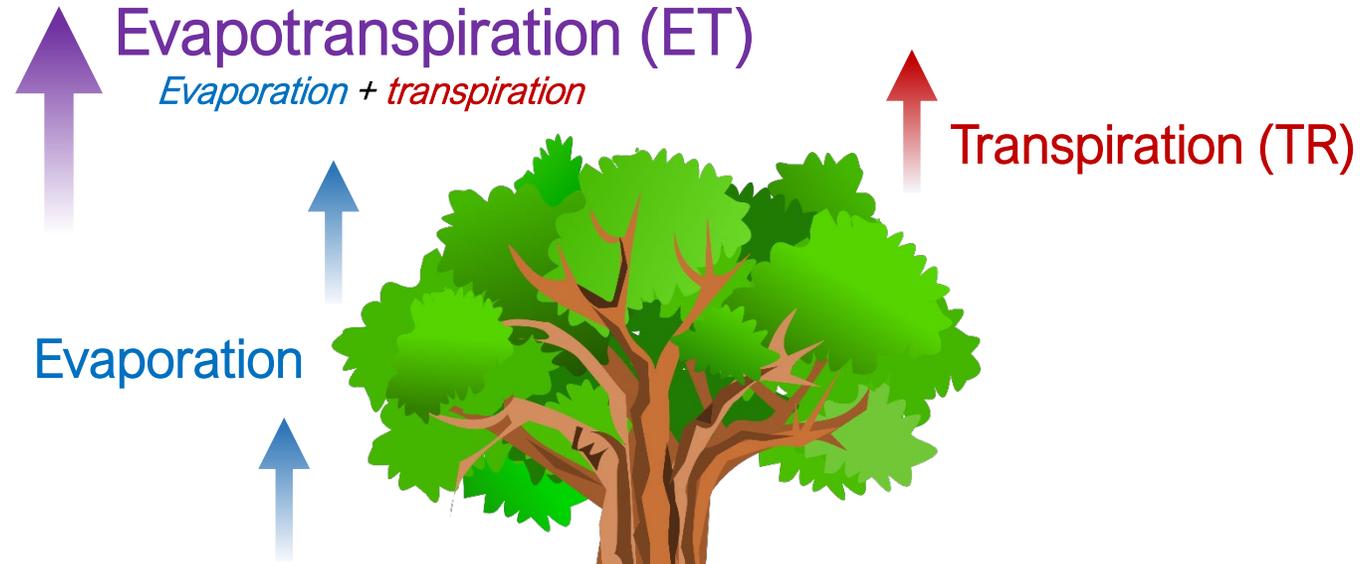
October - May



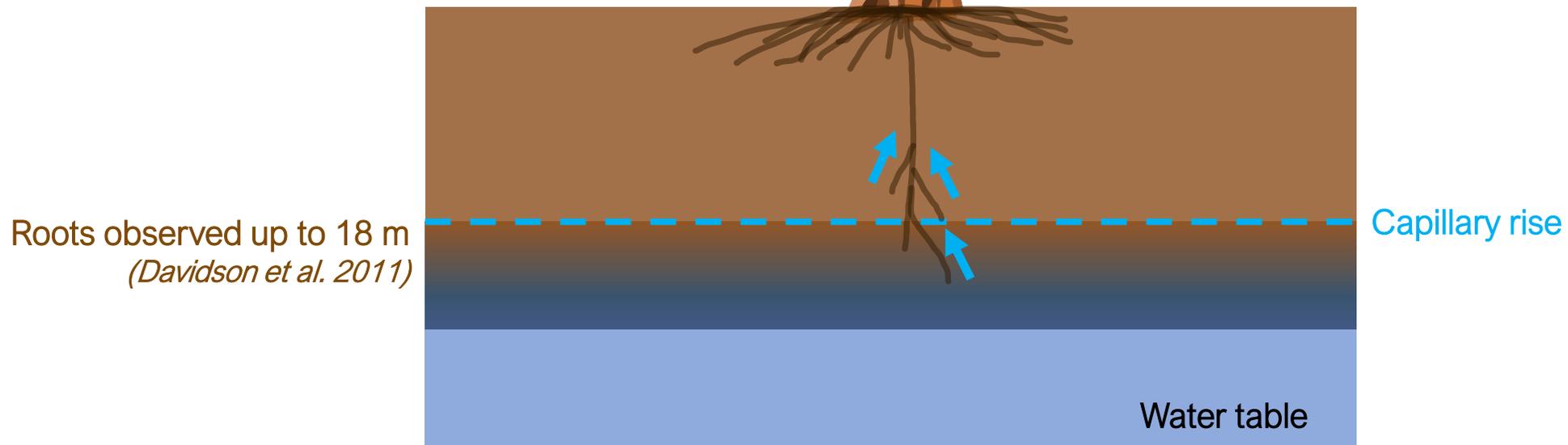
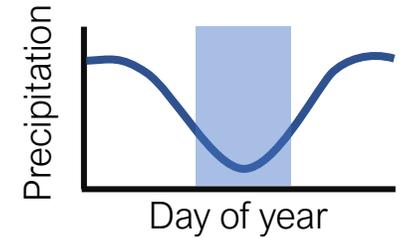
Roots observed up to 18 m
(Davidson et al. 2011)

Water table

Mature forests in the Amazon rely on deep roots to avoid water stress during the dry season.



June - September



Topographical variations are central to determining the location of the water table & root access to deep moisture.

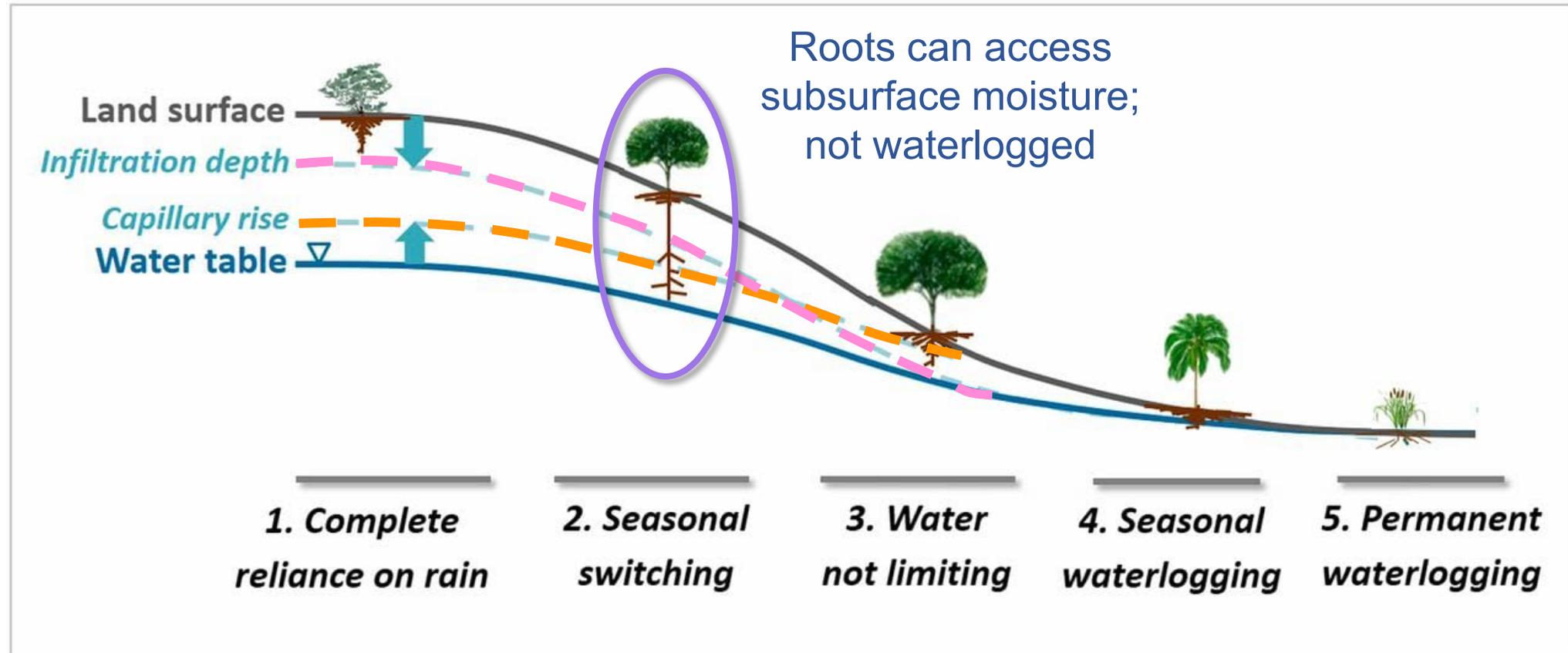
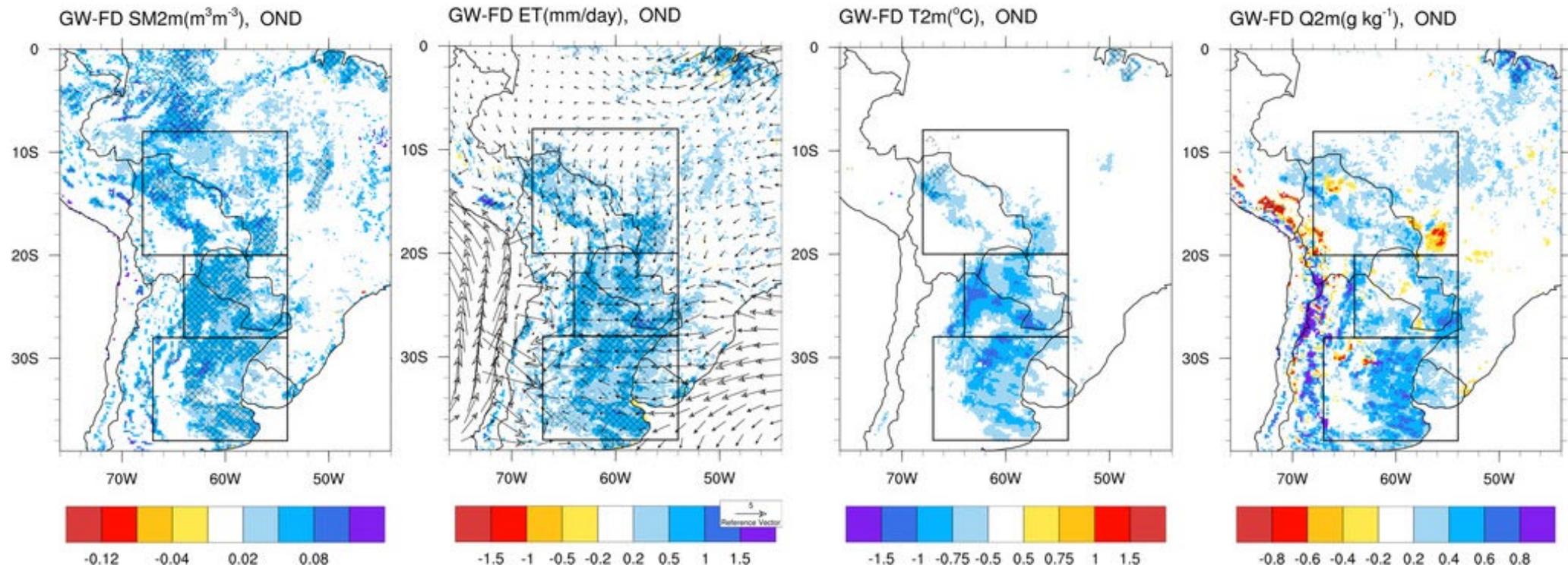


Figure: Fan et al. (2017)

Previous work studied the inclusion of a groundwater (GW) scheme in Noah-MP/WRF and simulated high-resolution water table depth variations in space.



Figures: Martinez et al. (2016)

We build on this work with addition of a deep, dynamic root water uptake (DRWU) scheme in Noah-MP.

We make several changes to Noah-MP, including implementation of a dynamic root water uptake (DRWU) scheme.

Original setup, Noah-MP Version 4.5 (Niu et al. 2011)

4 soil layers to 2 m

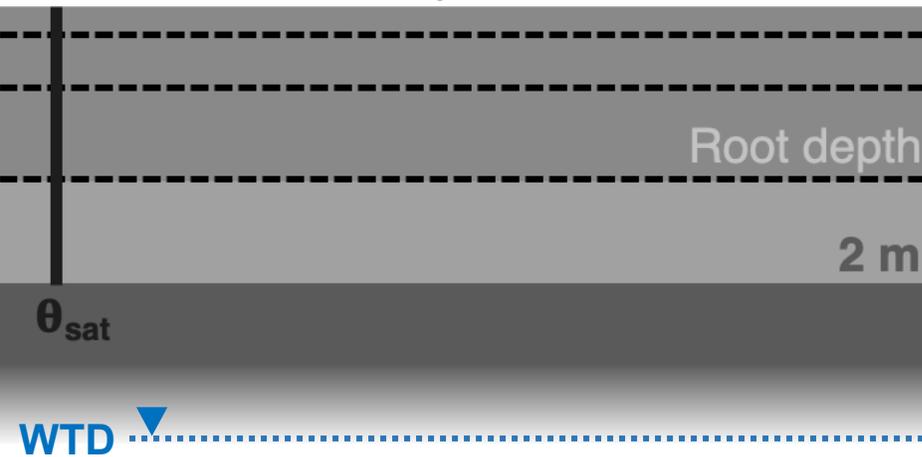


Rooting depth static in time
Soil props static w/ depth
 β used in root water uptake

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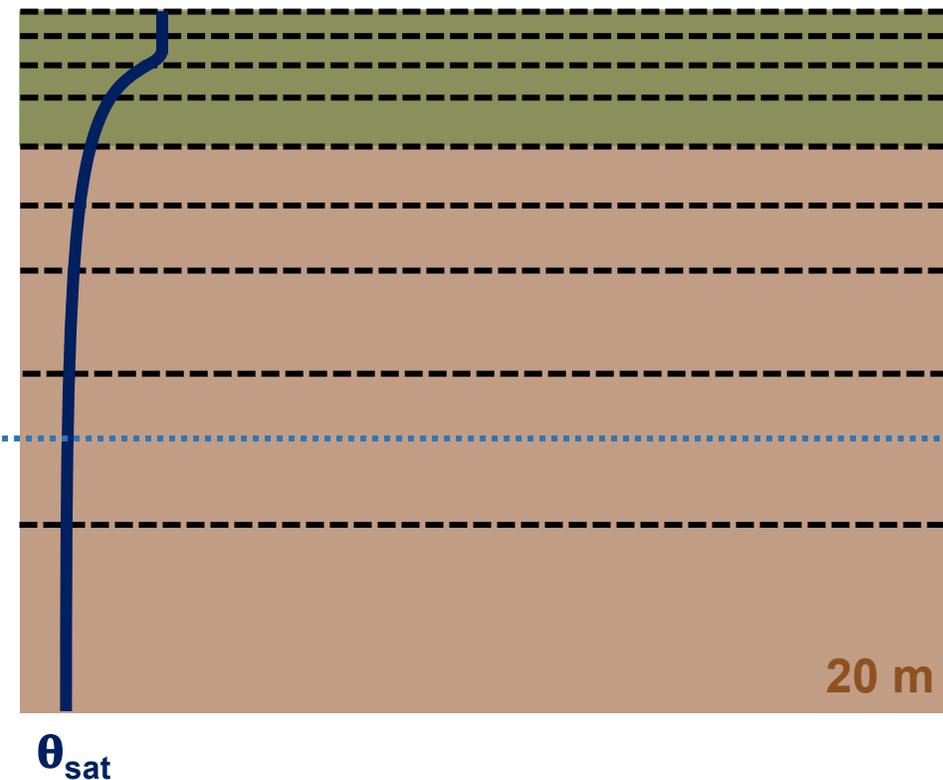


$$RWU_1 = \beta_1 TR$$

$$RWU_N = \beta_N TR$$

Modified setup

12 soil layers to 20 m



$$RWU_1 = r_1 TR$$

$$RWU_N = r_N TR$$

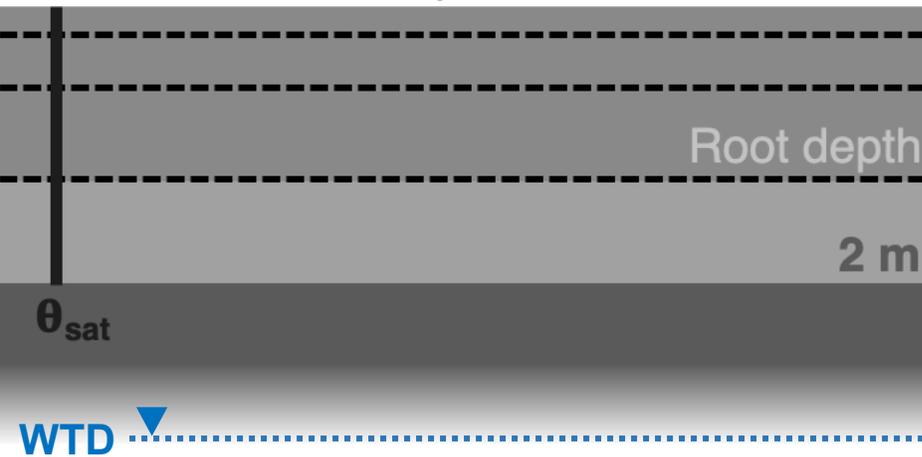
Rooting depth static in time
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 β used in root water uptake

Rooting depth varies in time
Use exponential function to vary soil props w/ depth
 r used in root water uptake

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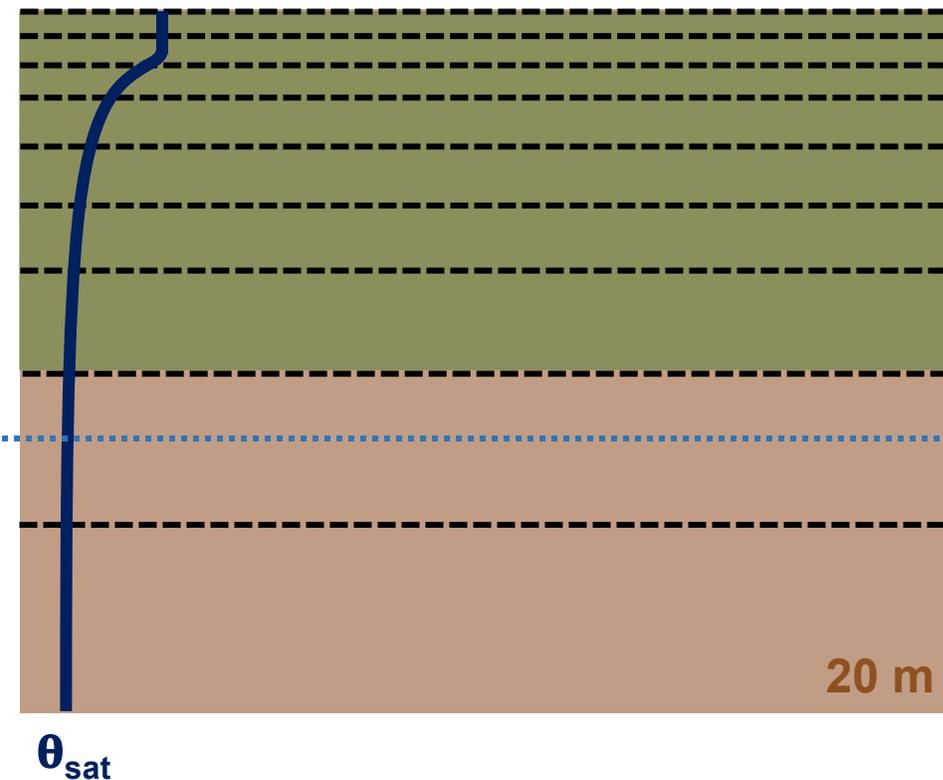


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The DRWU scheme is simple, scalable, and based on the soil water profile.

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 (-2 MPa)

h_{veg} canopy height

d_j layer depth

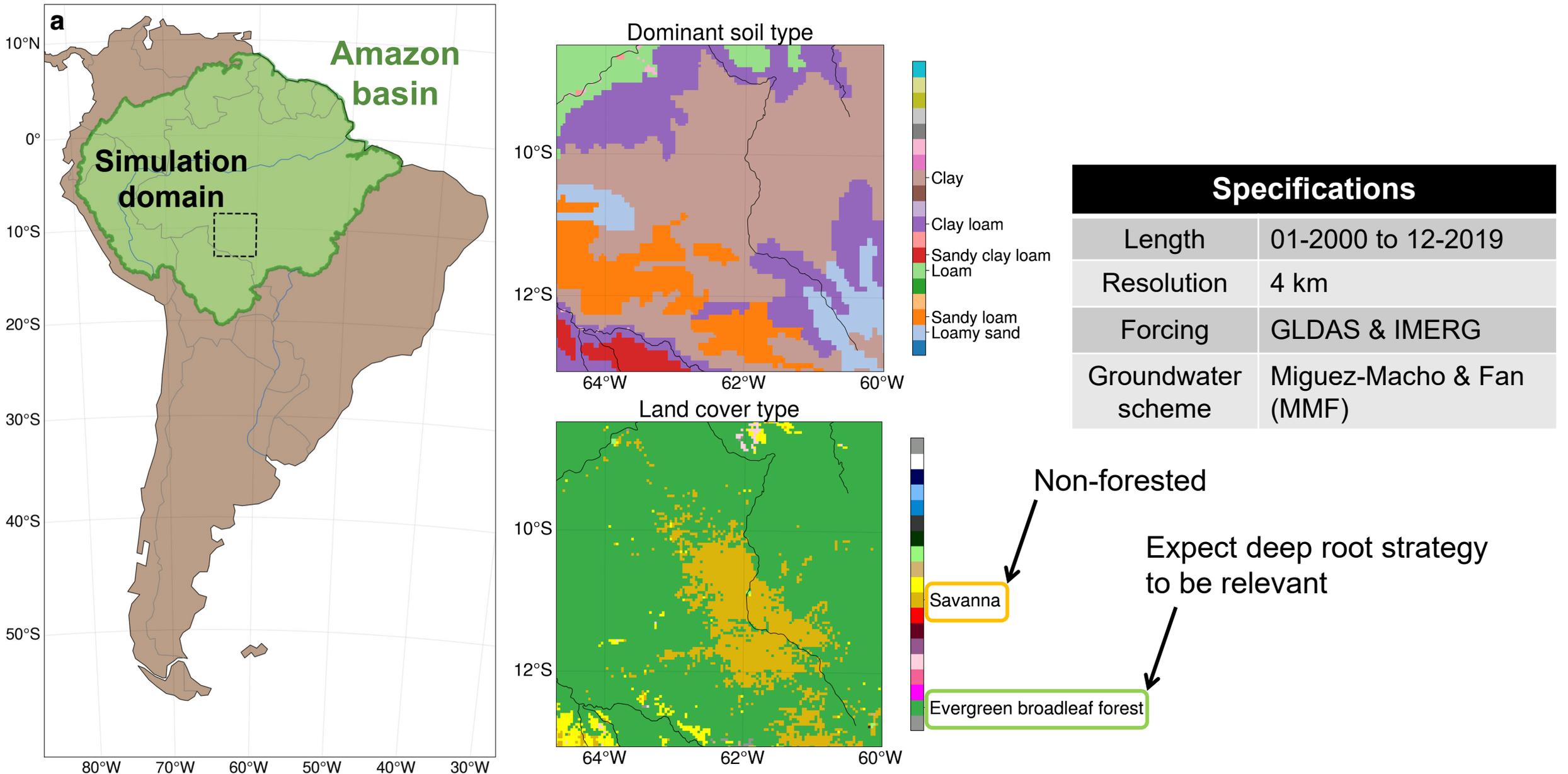
less effort for wetter and shallower layers

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.



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

Case 1
CONTROL

Default
Noah-MP

Case 2
GW

Default
Noah-MP
+
GW scheme

Case 3
SOIL

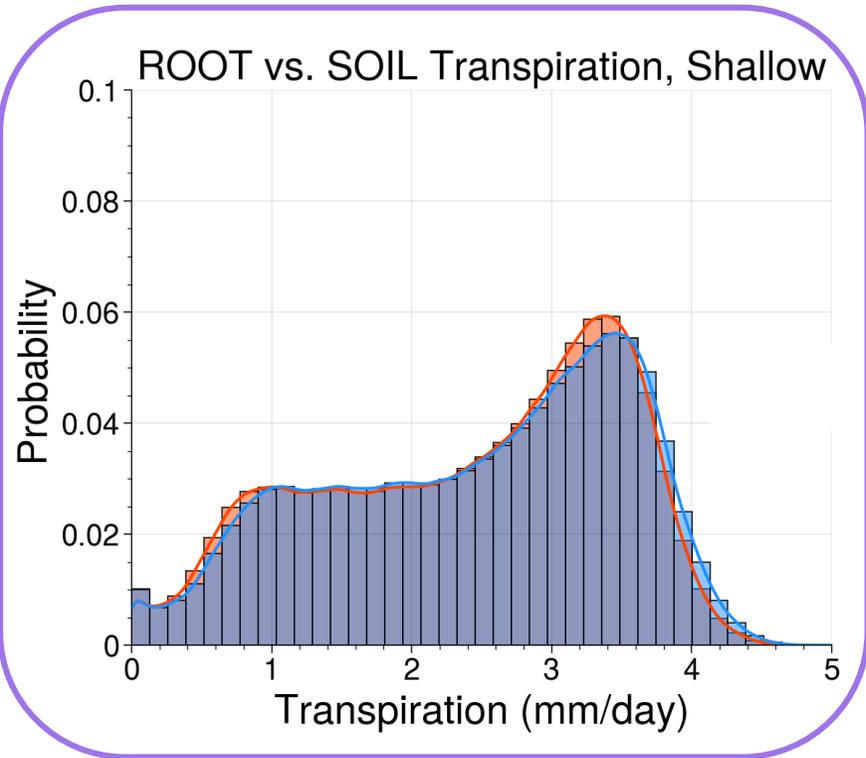
Default
Noah-MP
+
GW scheme
+
Added soil
layers

Case 4
ROOT

Default
Noah-MP
+
GW scheme
+
Added soil
layers
+
DRWU
scheme

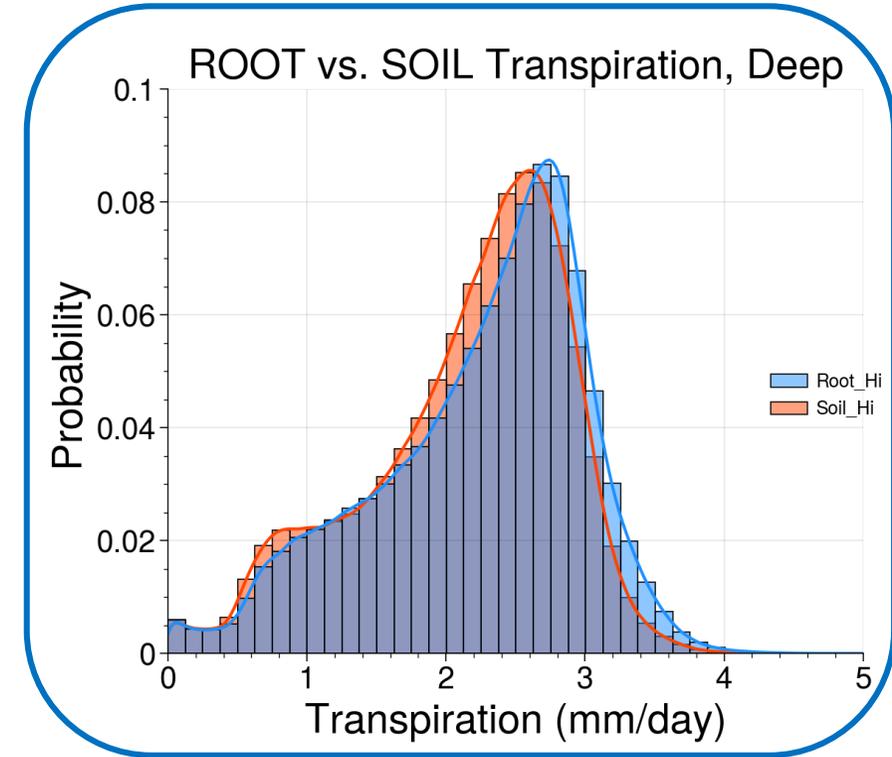
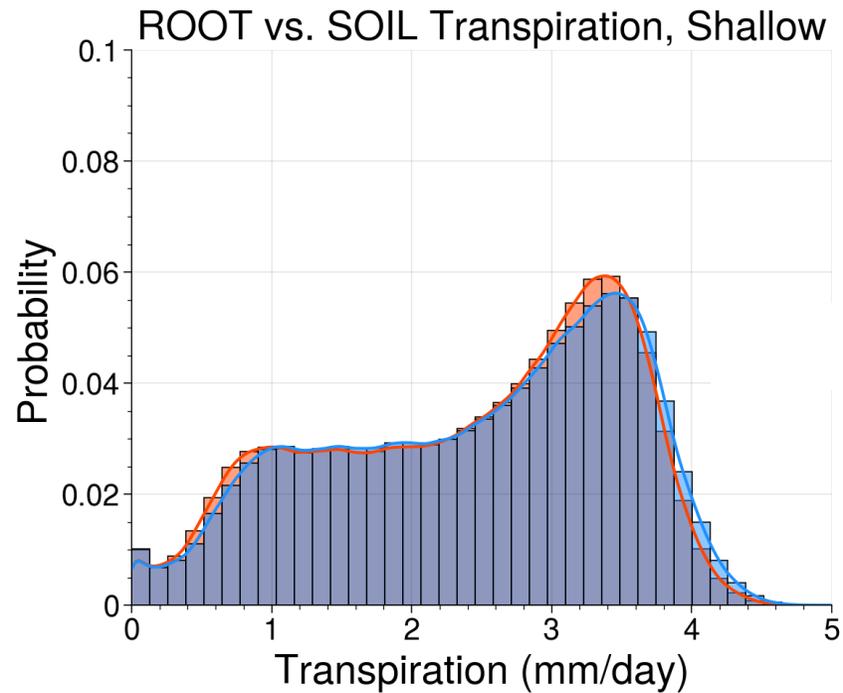
We see a clear shift in the distribution of mean dry season TR for grid points without waterlogging & with accessible deep moisture.

ROOT SOIL



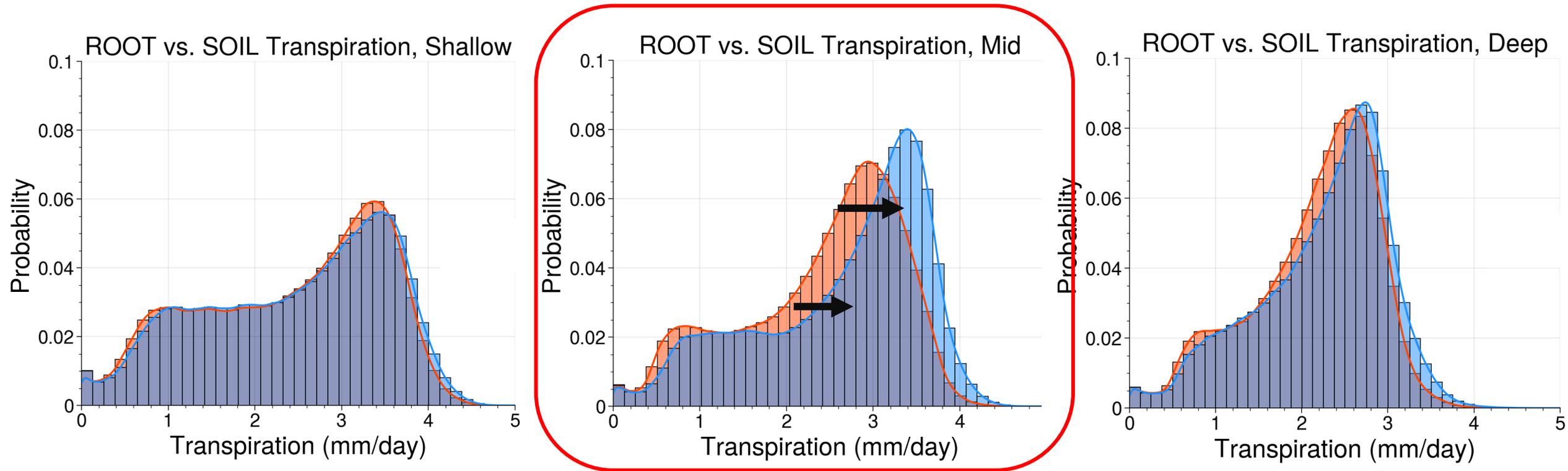
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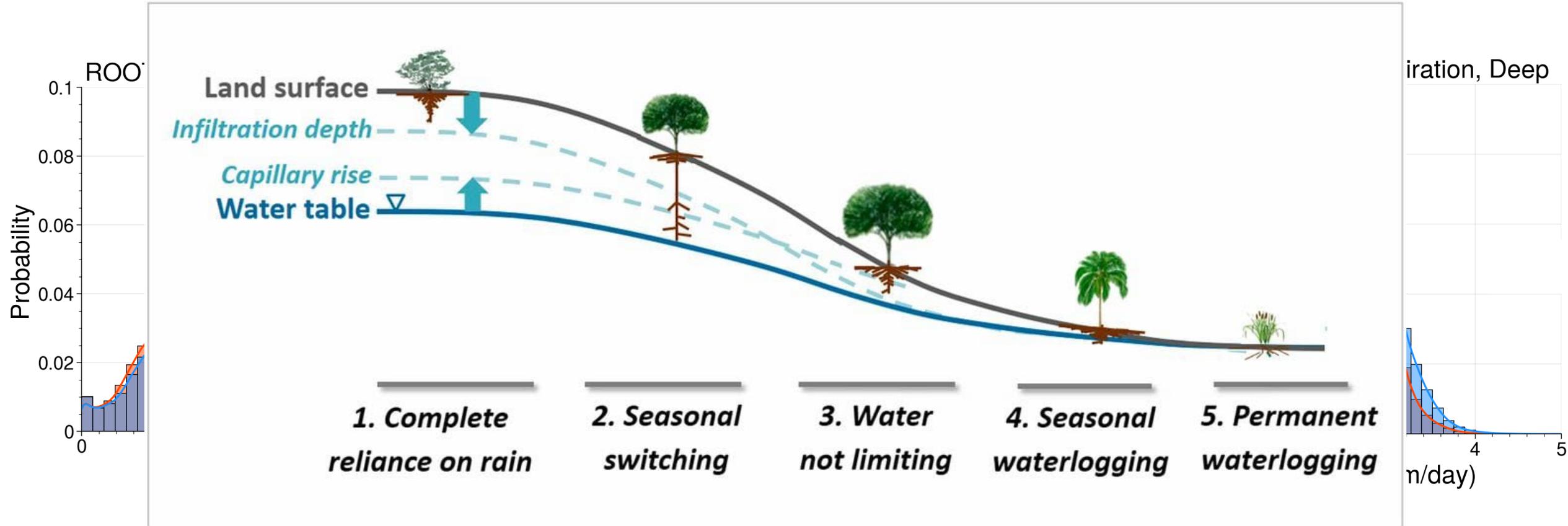
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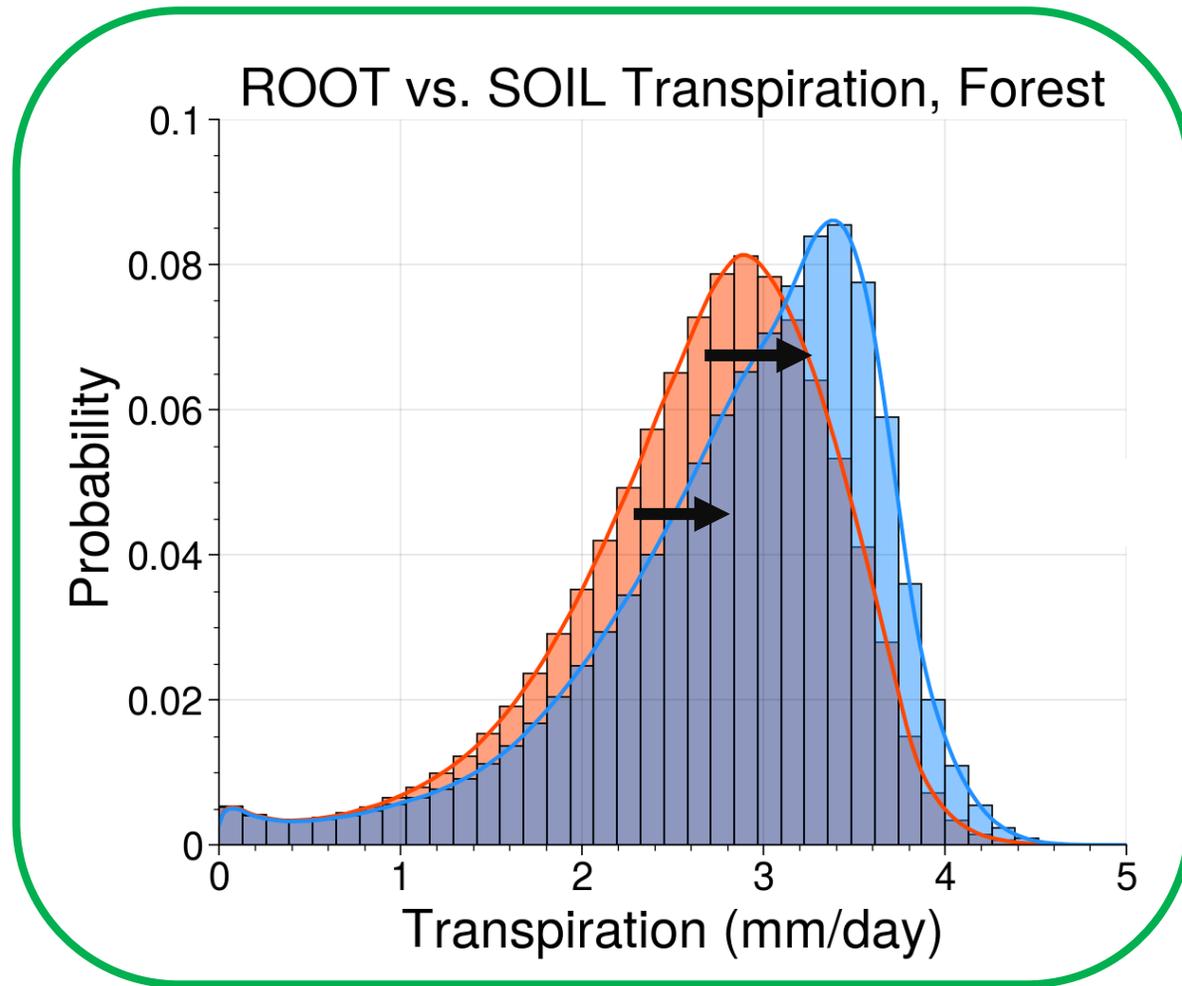
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ROOT
 SOIL



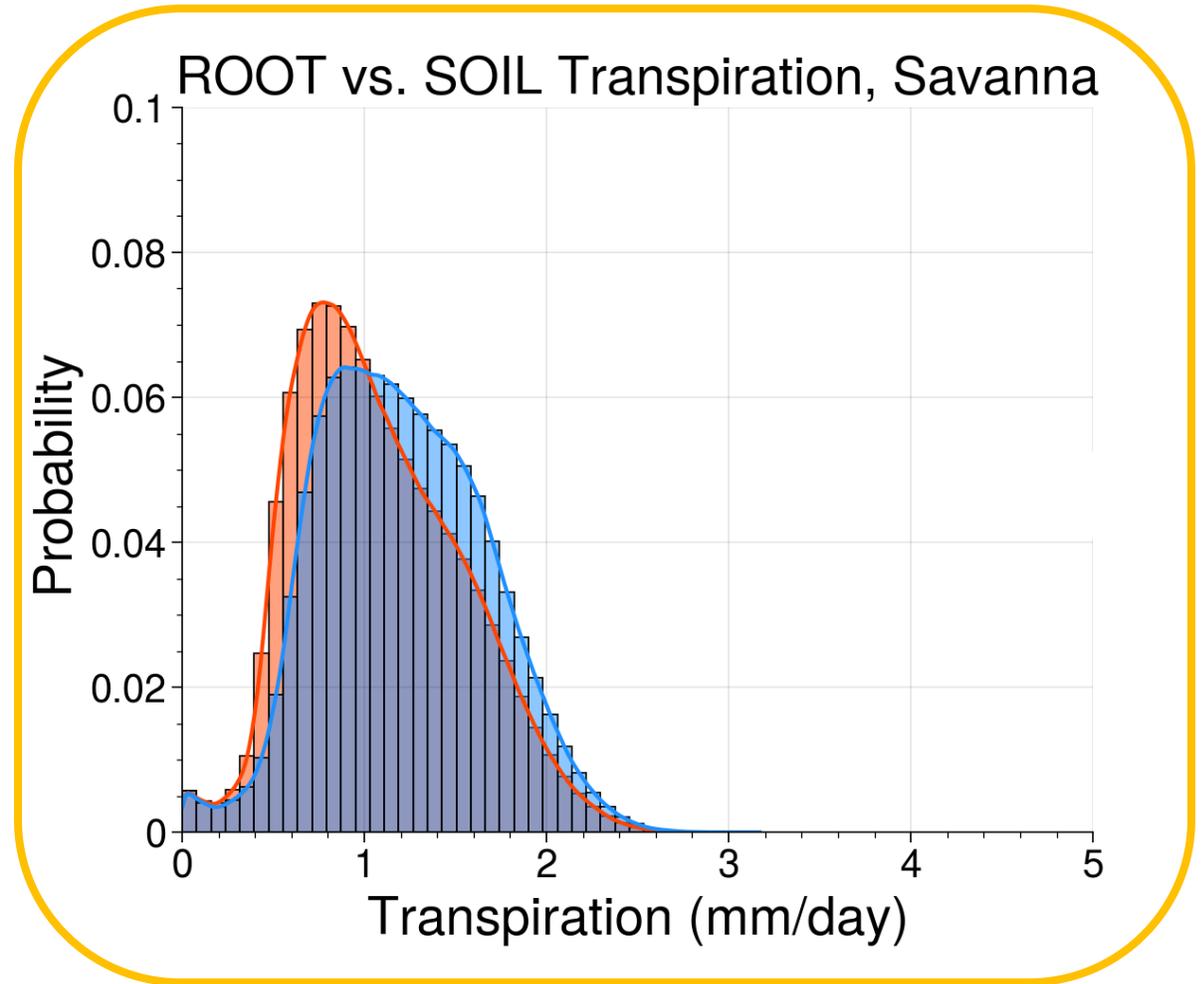
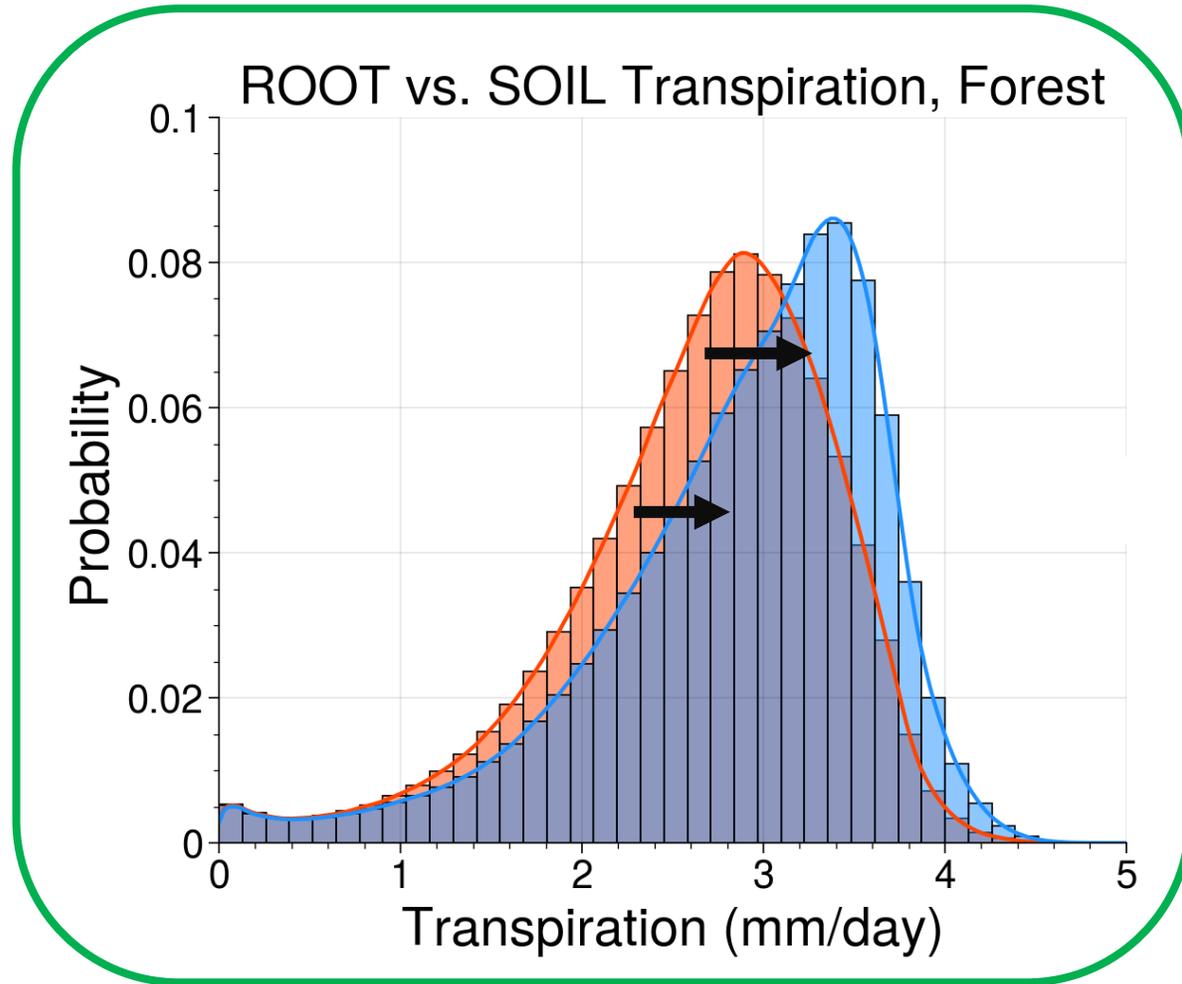
We see a clearer shift in the distribution towards higher values of dry season TR at forested grid points.

ROOT SOIL



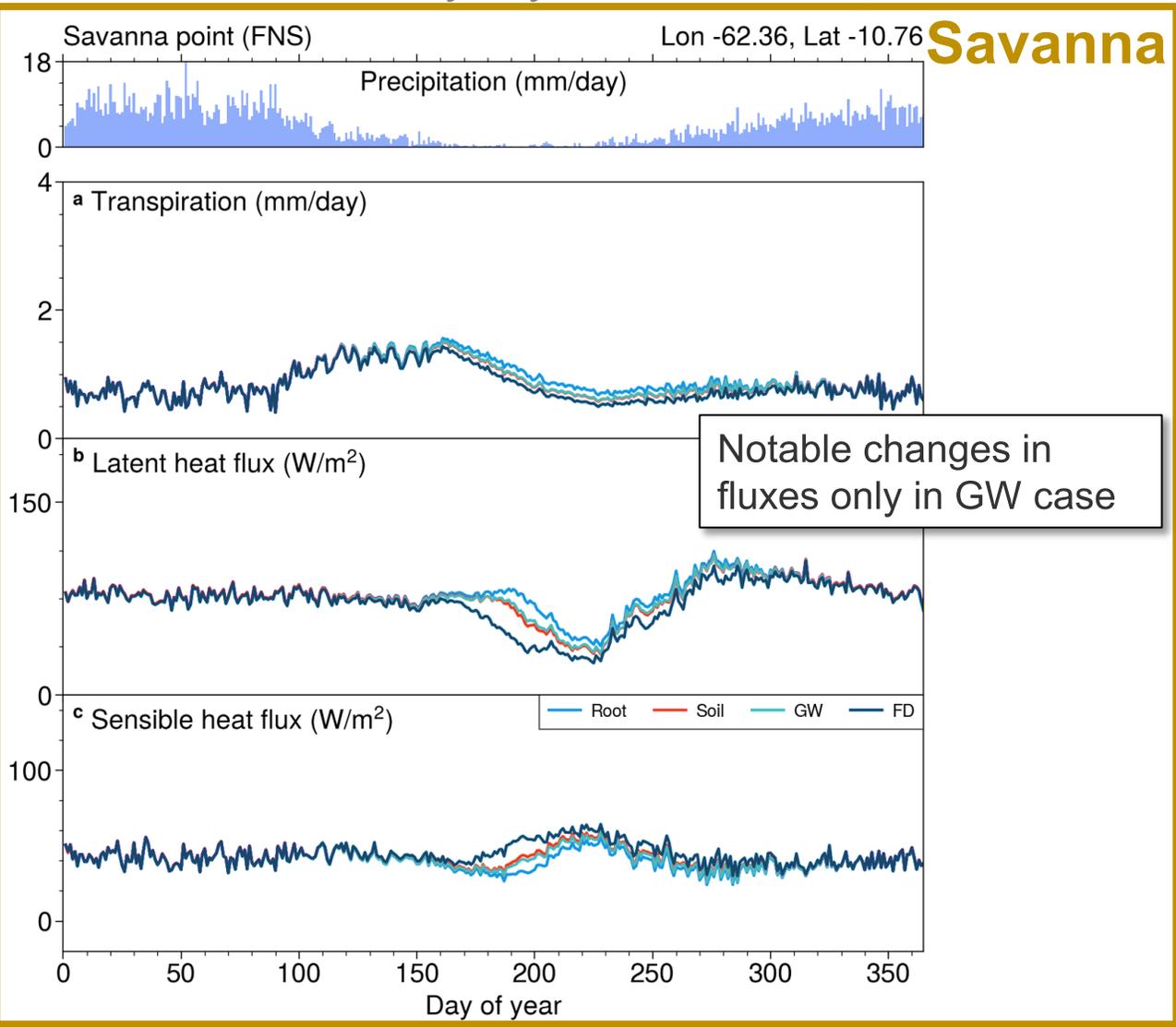
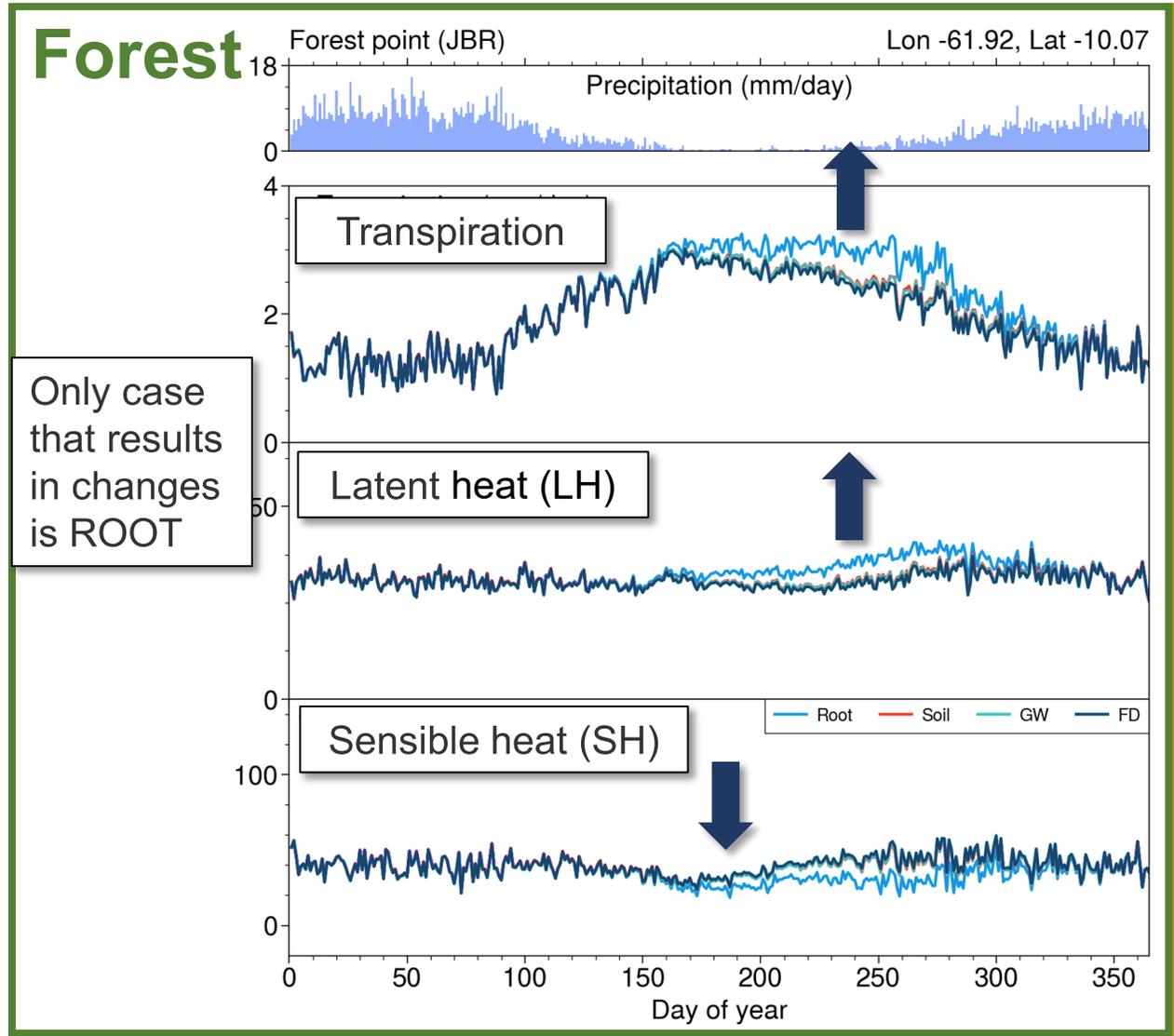
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ROOT SOIL



Mean annual cycles of fluxes indicate + LH and - SH at both points, but for different reasons.

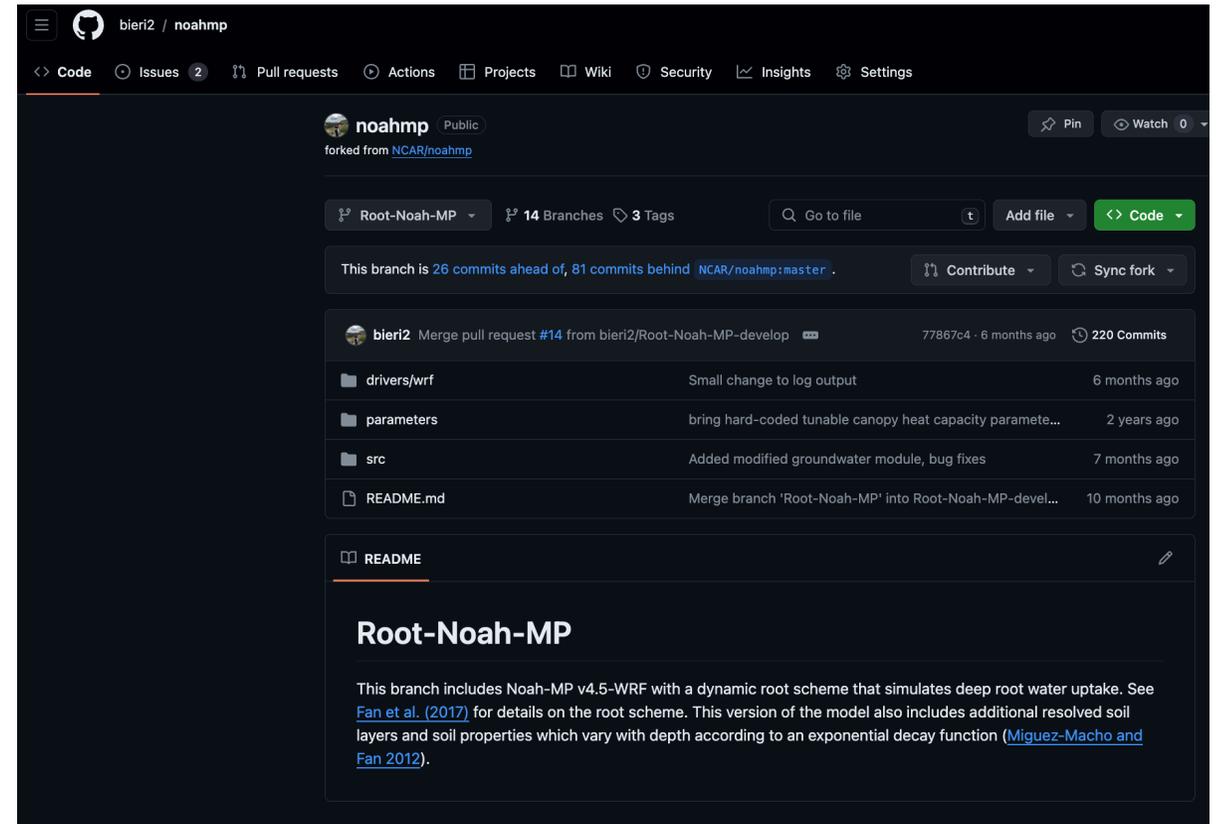
— Root — Soil — GW — CTRL *Day of year mean fluxes, 2001-2019*



Paper soon to be submitted to AMS
Journal of Hydrometeorology

Working with Tim Lahmers @ NASA
Goddard to implement root scheme in
LIS Noah-MP

Code will be available for others to view
on GitHub



The screenshot shows a GitHub repository page for 'noahmp' (Public) forked from 'NCAR/noahmp'. The repository is currently on the 'Root-Noah-MP' branch, which is 26 commits ahead of and 81 commits behind the 'NCAR/noahmp:master' branch. The page displays a list of recent commits:

Commit	Description	Time
bieri2 Merge pull request #14 from bieri2/Root-Noah-MP-develop		77867c4 · 6 months ago · 220 Commits
drivers/wrf	Small change to log output	6 months ago
parameters	bring hard-coded tunable canopy heat capacity paramete...	2 years ago
src	Added modified groundwater module, bug fixes	7 months ago
README.md	Merge branch 'Root-Noah-MP' into Root-Noah-MP-devel...	10 months ago

Below the commit list is a 'README' section with the following text:

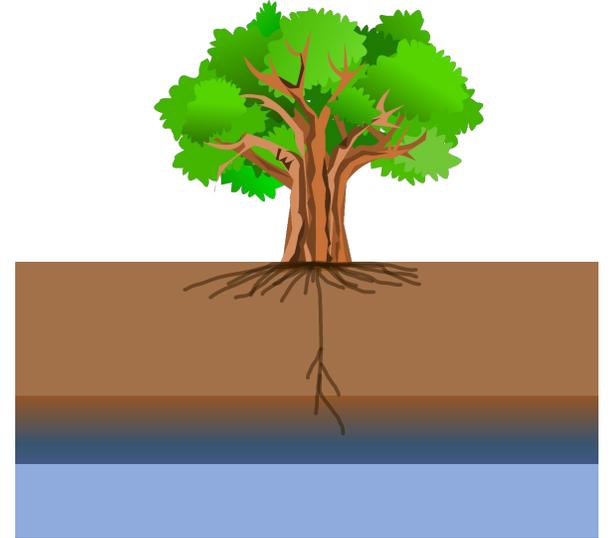
Root-Noah-MP

This branch includes Noah-MP v4.5-WRF with a dynamic root scheme that simulates deep root water uptake. See [Fan et al. \(2017\)](#) for details on the root scheme. This version of the model also includes additional resolved soil layers and soil properties which vary with depth according to an exponential decay function ([Miguez-Macho and Fan 2012](#)).

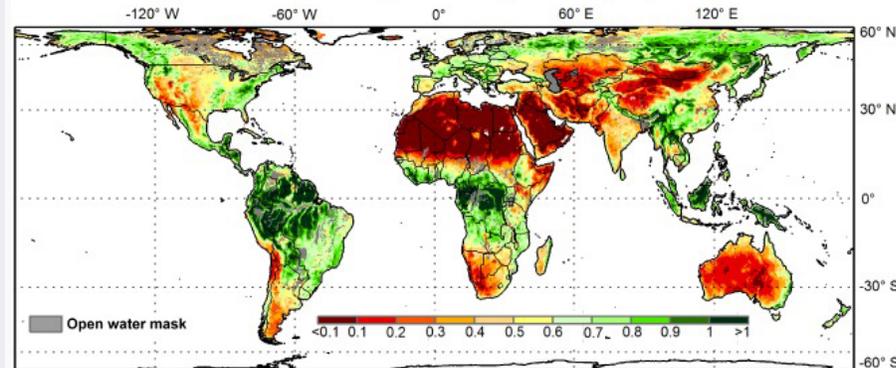
Conclusions

We implemented a deep, dynamic root water uptake scheme in Noah-MP and enhanced representation of the deep soil column.

A step forward for representation of soil moisture, RWU, and land surface fluxes in Noah-MP



(a) Annual mean vegetation optical depth (VOD)



Future work will focus on validation of results using vegetation optical depth data. We also hope to study the effects of the scheme in a coupled framework.



Thank you!

Mature forests in the Amazon rely on deep roots to avoid water stress during the dry season.

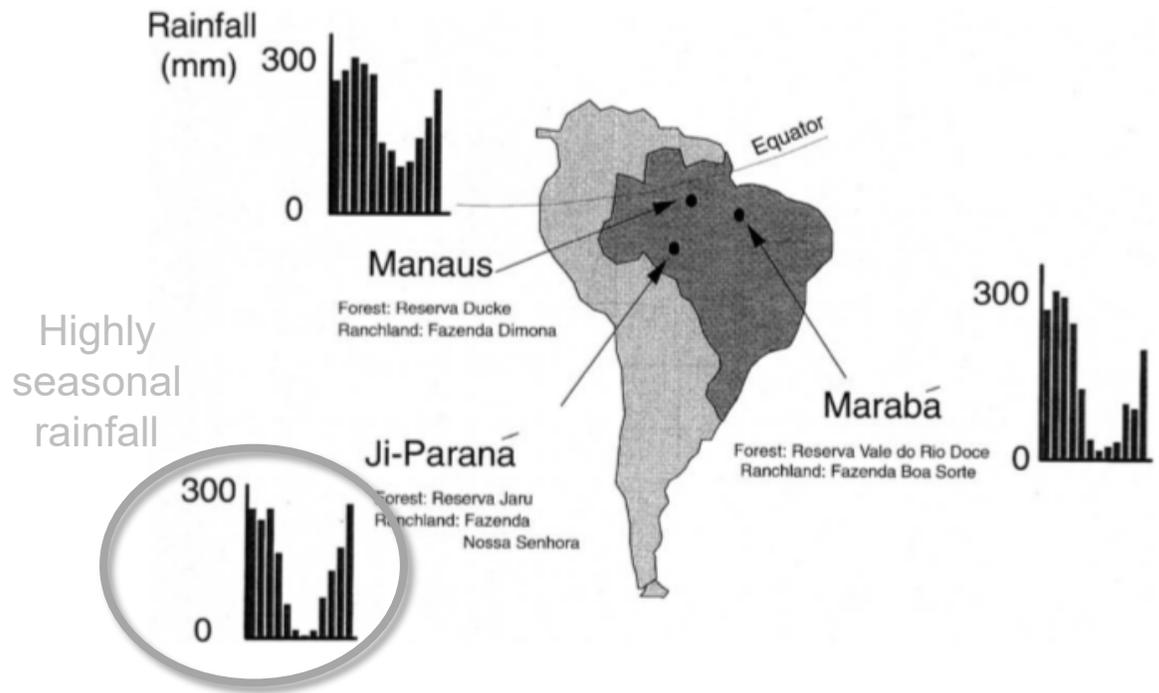


Figure: Gash and Nobre (1997)

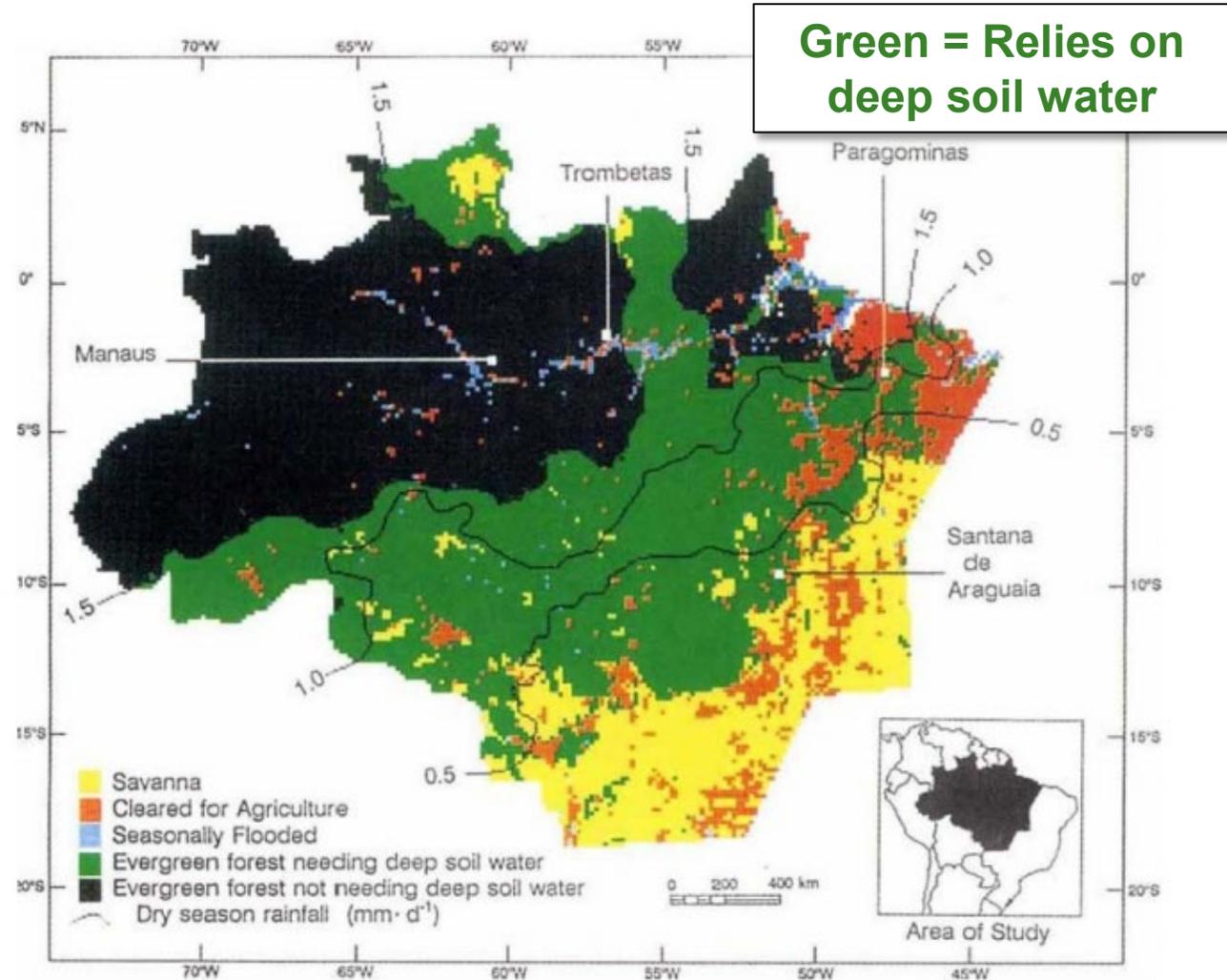


Figure: Nepstad et al. (1994)

The DRWU 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 (-2 MPa)

h_{veg} canopy height

d_j layer depth

Root activity

$$r_j = \frac{e_j \Delta z_j}{\sum e_j \Delta z_j}$$

Contribution from
each soil layer

**Ease function weighed by layer
thickness (soil water store)**

Δz_j thickness of soil layer j

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

We calculate varying soil properties with depth based on exponential decay functions.

κ_{sat} , θ_{sat} , θ_{wilt} , ψ_{sat} , D_{sat}
vary exponentially with depth
on kilometer scales

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

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

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

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

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

z → layer depth from surface

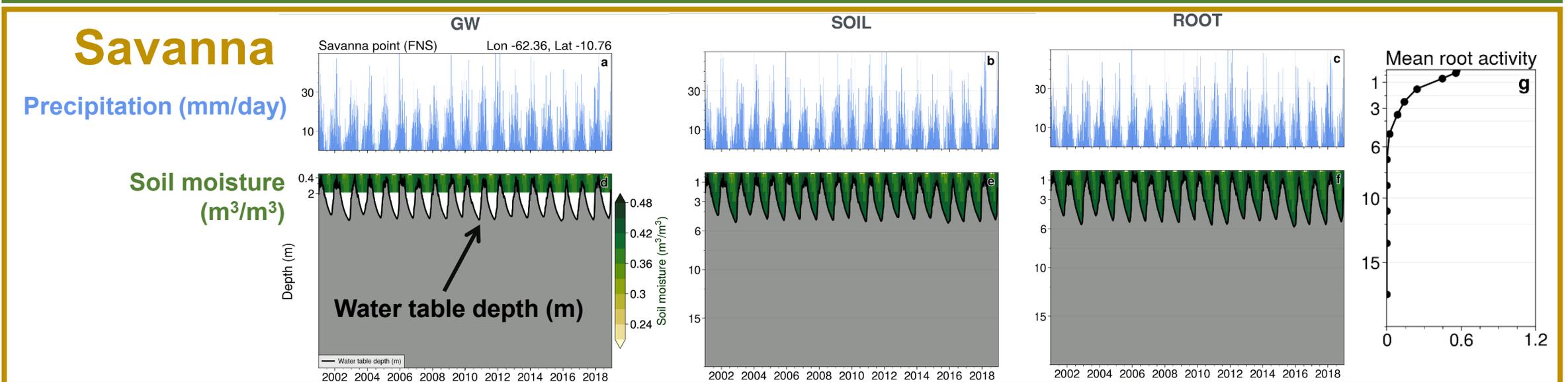
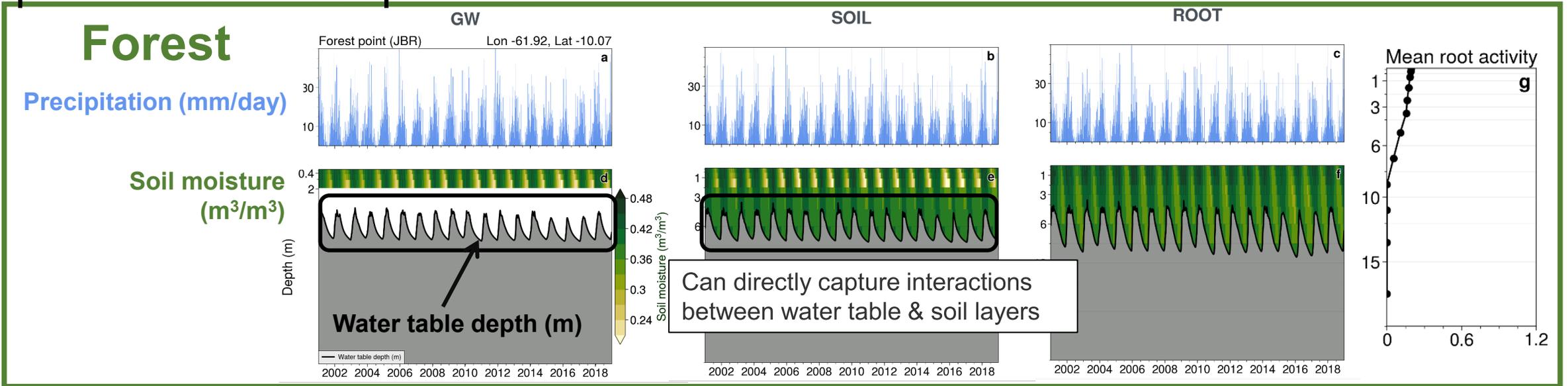
f → controls how fast permeability decreases with depth (input data for MMF)

K_o , ψ_o , θ_o , etc. → known value at top of column (table parameter; dependent on soil type)

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

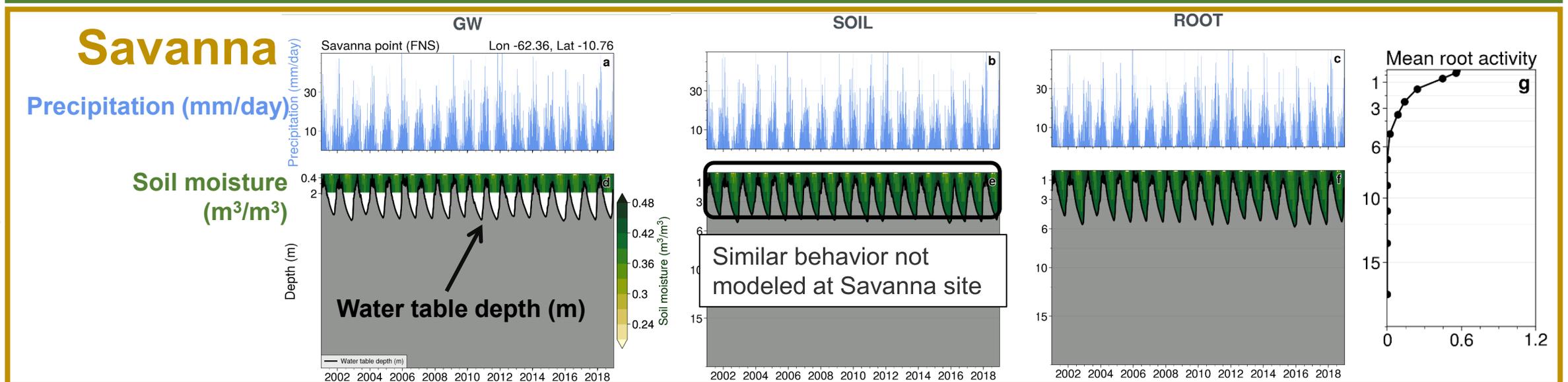
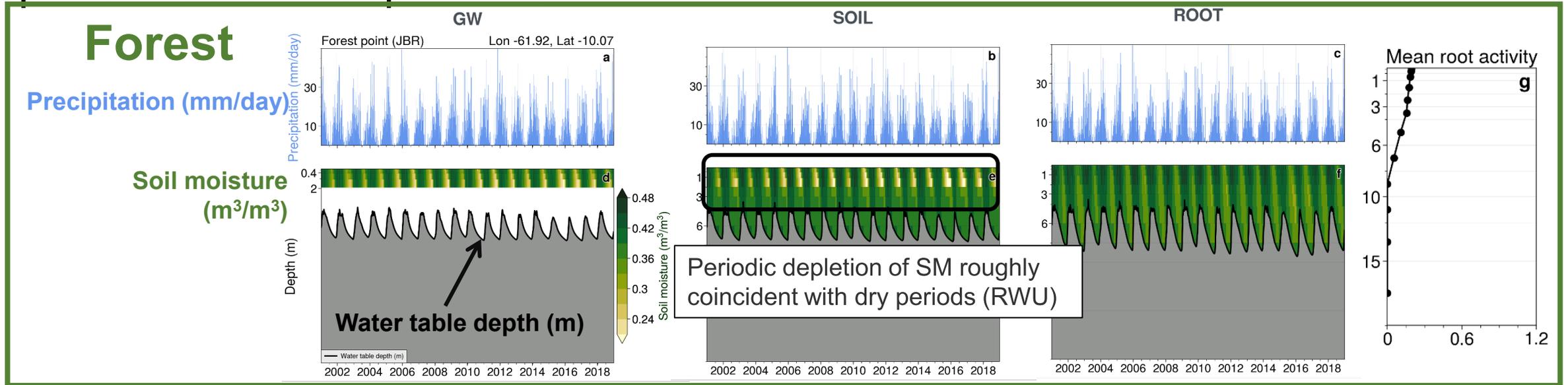
Time series at forest & savanna points reflect additional layers and seasonal dependence on deep RWU.

Daily mean time series, 2001-2019



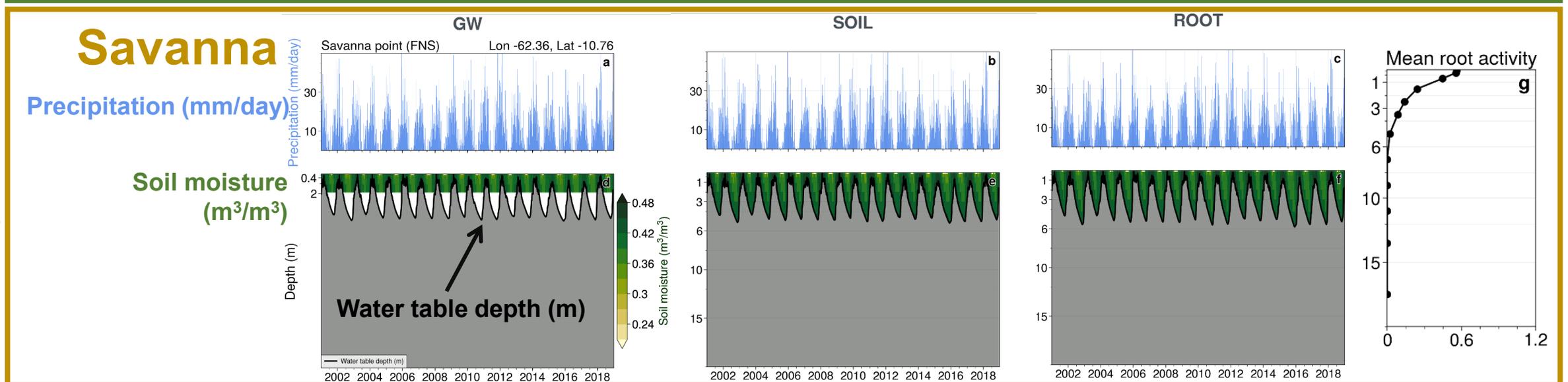
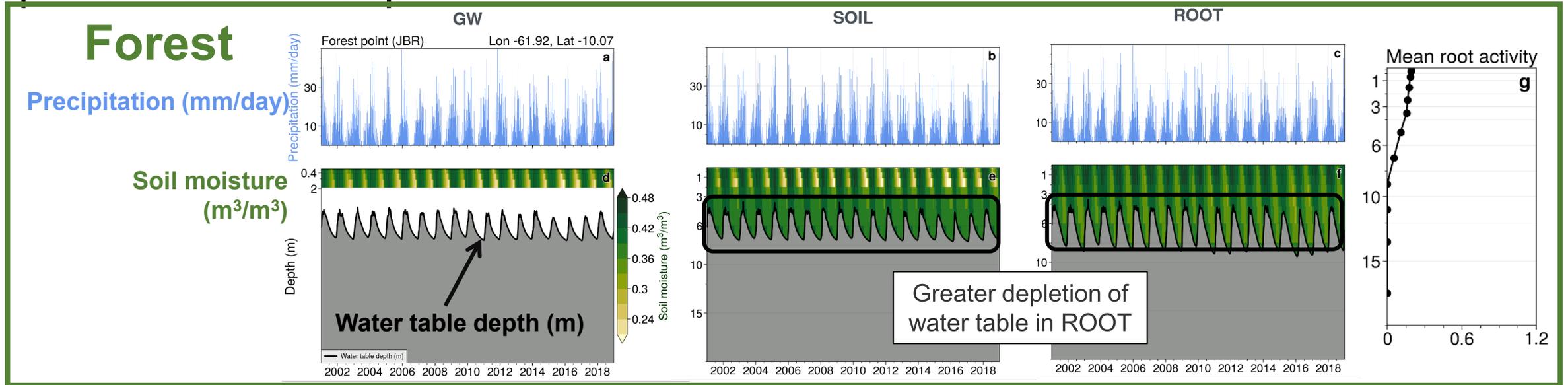
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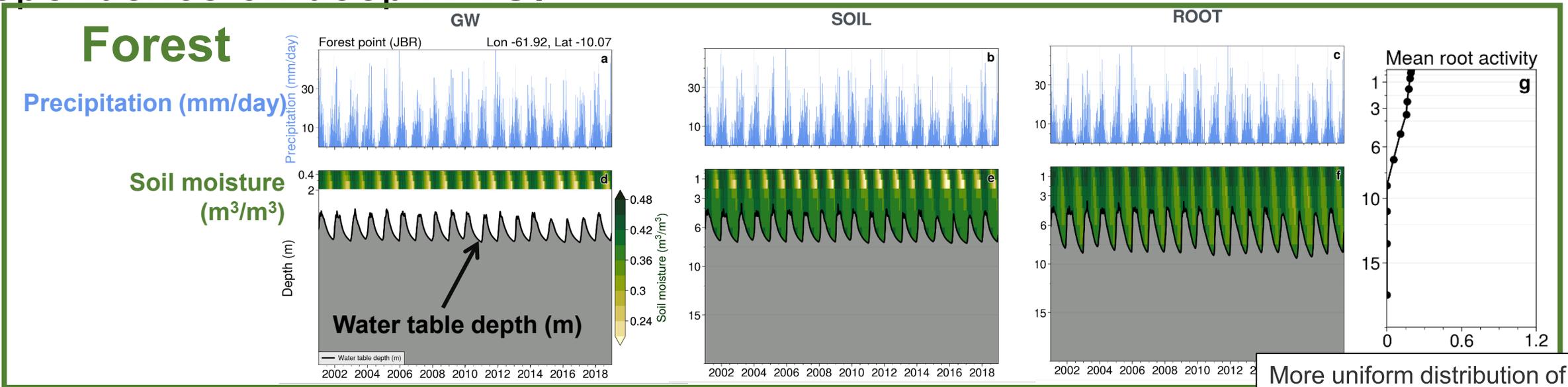
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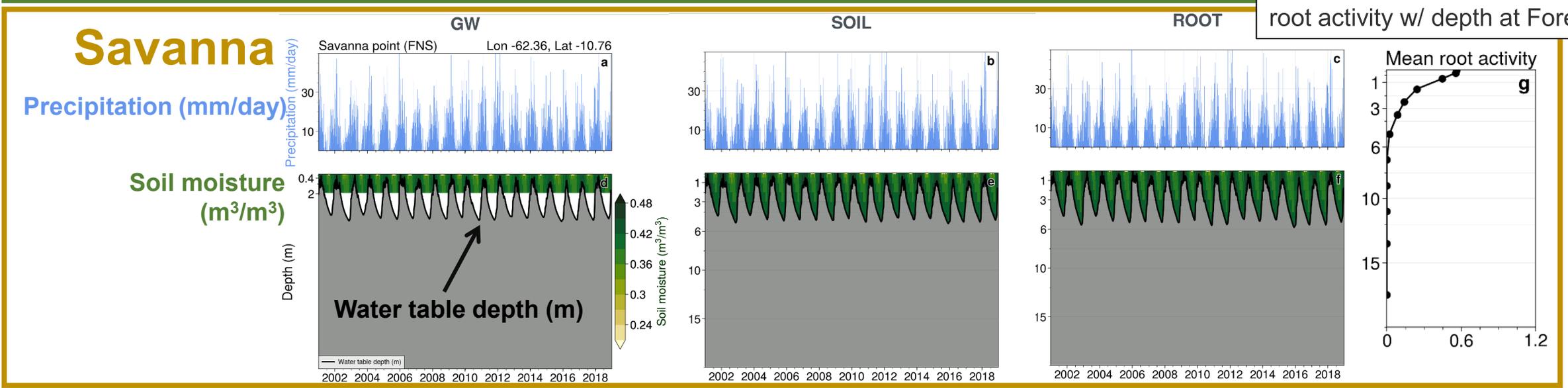


Time series at forest & savanna points reflect additional layers and seasonal dependence on deep RWU.

Daily mean time series, 2001-2019



More uniform distribution of root activity w/ depth at Forest



Mean annual cycles of fluxes indicate + LH and - SH at both points, but for different reasons.

