# Revising soil water retention curve in CTSM via NCAR-NEON system

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# Contents

# Background

- Soil moisture significantly affects the land surface water cycling via ground evaporation and plant transpiration.
- It remains an open question as to how evapotranspiration (ET) responds to future soil moisture dynamics, especially under drought.
- The soil moisture dynamics in CTSM are calculated using the two equations of soil water retention curve, and unsaturated soil hydraulic conductivity.

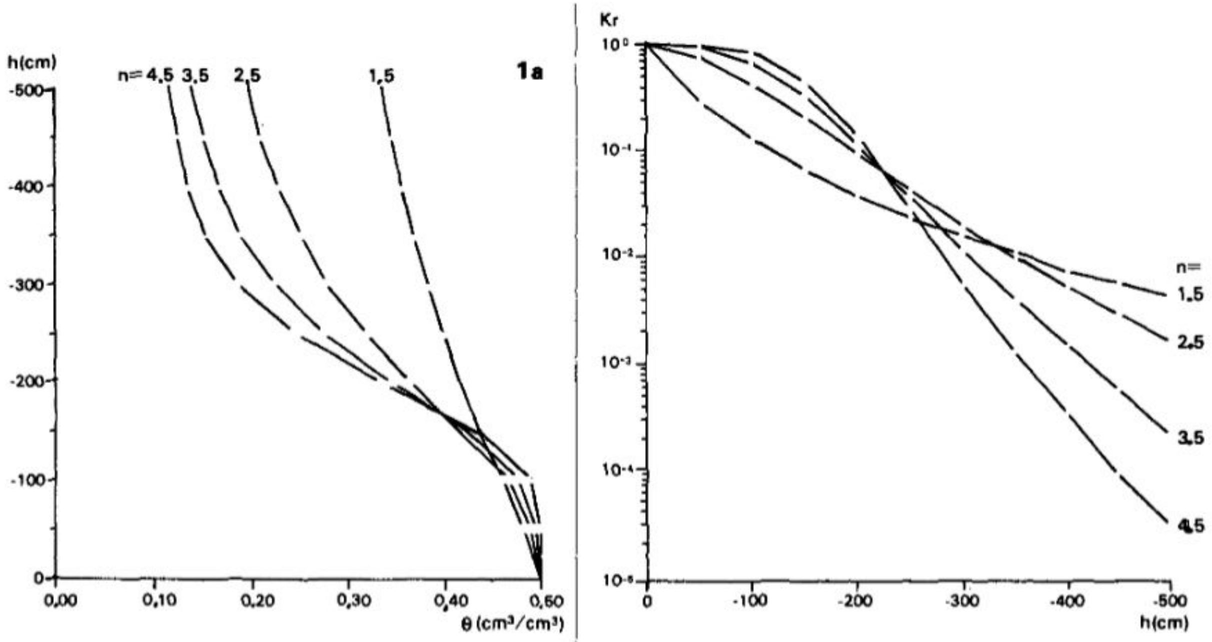
$$\psi = f(\theta) \qquad k = f(\theta)$$

# Background

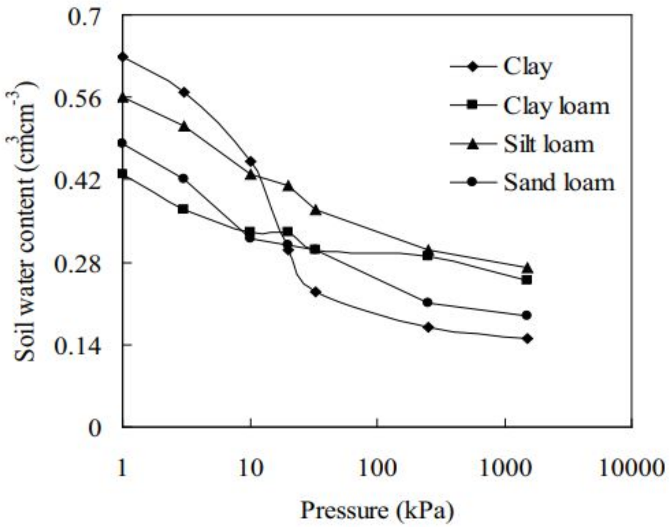
- van Genuchten-Mualem (VGM) (1980)

$$\psi(\omega) = -\frac{1}{\alpha}\left[\left(\frac{\omega}{\omega_{\text{sat}}}\right)^{-1/m} - 1\right]^{1/n}$$
with $m = 1 - \frac{1}{n}$

$$k(\psi) = k_{\text{sat}} \cdot S^{l}[1-(1-S^{1/m})^{m}]^{2}$$
with $S = \left[1 + |\alpha\psi|^{n}\right]^{-m}$




(Wösten & Van Genuchten 1988)




(Yang & You, 2013)

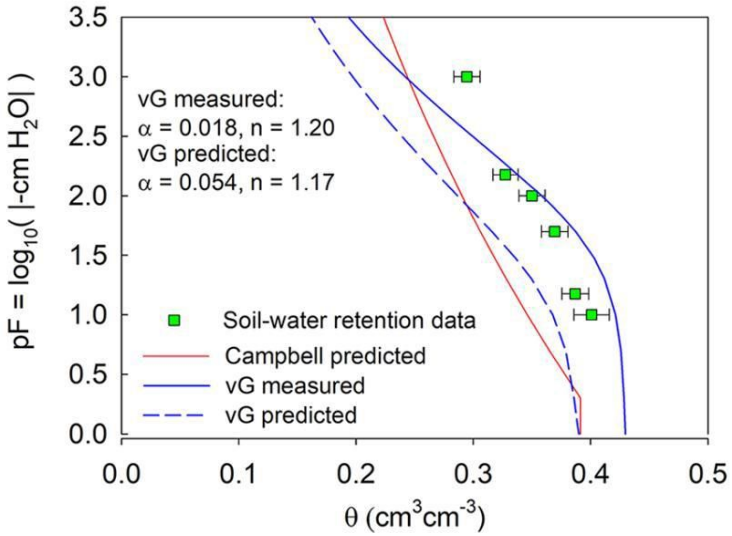
# Background

- Current ClappHornberger (1978) equations in CTSM oversimplified the soil water characteristics.

$$\psi_i = \psi_{sat,i}\left(\frac{\theta_i}{\theta_{sat,i}}\right)^{-B_i}$$

$$k\left[z_{h,i}\right] = \Theta_{ice} k_{sat}\left[z_{h,i}\right]\left(\frac{\theta_i}{\theta_{sat,i}}\right)^{2B_i+3}$$

(CLM technical note)




(Varvaris et al., 2019)

- Because soil water dynamics control the water supply for ET, inadequate soil hydraulics result in large uncertainties in the simulation and prediction of the ET components on land under anthropogenic climate change.

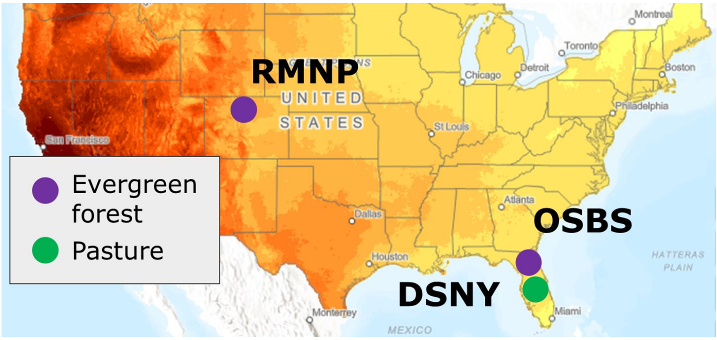
# Objective

- To improve the simulation of ET components by implementing VGM equations into the CLM5 model (NCAR) at NEON sites ranging across dry to wet soil conditions.

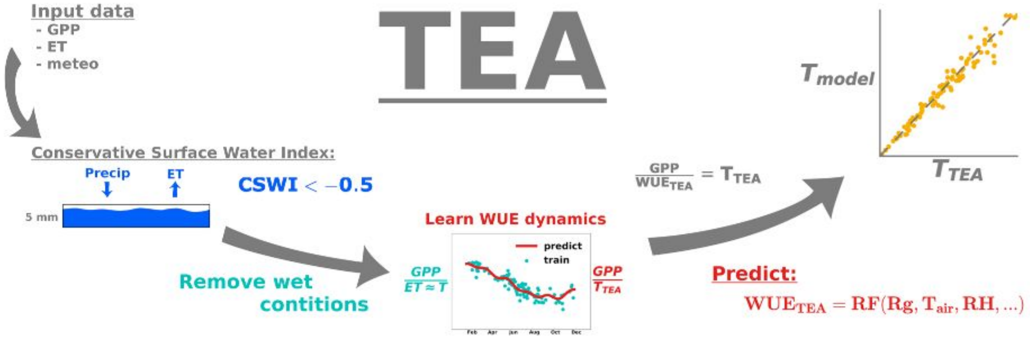
# Methods

- NCAR-NEON system

- Selected NEON sites:
  - OSBS, DSNY, RMNP




- Ground truth flux partition
  - Transpiration Estimation Algorithm – TEA (Nelson et al., 2018)
  - AmeriFlux OneFlux-pipeline input

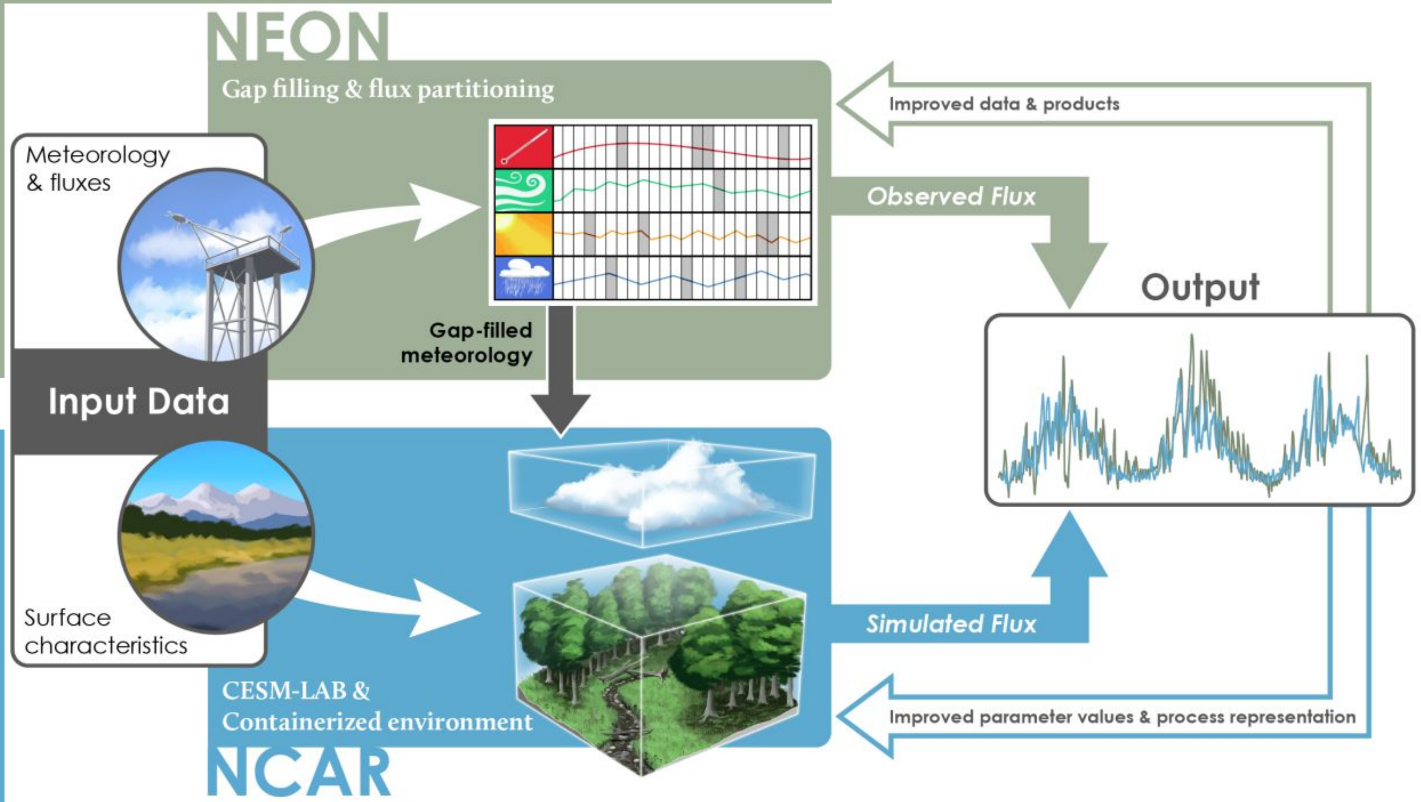


# Methods

- Why NCAR-NEON system?

- Environmental gradient
  - 47 terrestrial sites
- Rich data products
  - Ground observation
  - Flux towers
  - Airborne remote sensing

- Simple
  - containerized
  - single-point simulations
- Easy to use
  - all-in-one configuration
  - python tools & tutorials



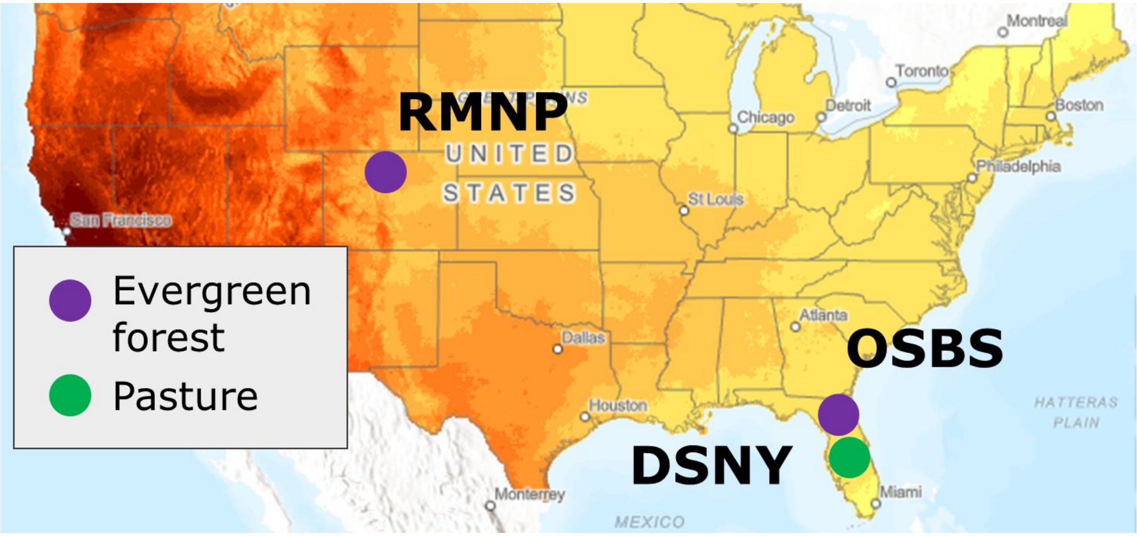

(Lombardozzi et al., 2023)

# Methods

- Why three NEON sites?

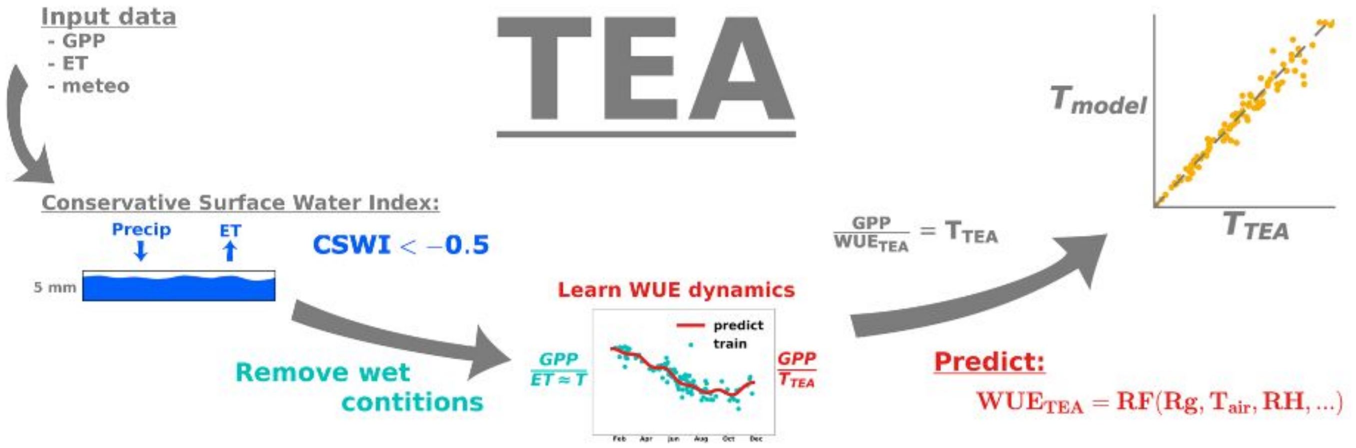
  - Moisture Regime
    Energy-limited (OSBS, DSNY) vs
    Moisture-limited (RMNP)

  - Vegetation
    Evergreen forest (OSBS RMNP) vs
    Pasture (DSNY)



# Methods

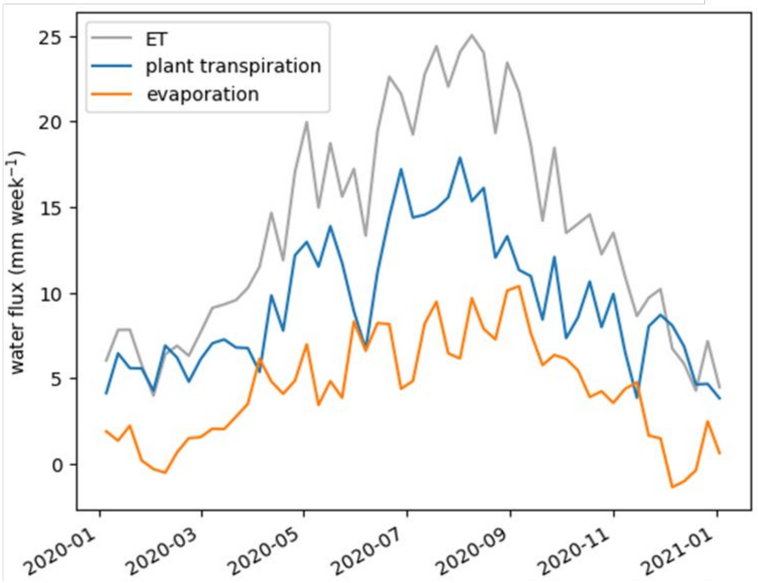
- Why TEA method?
  - Data-driven
  - Non-parametric
  - Validated against model output
  - Tested against independent sap flow-based estimates (Nelson et al., 2020)



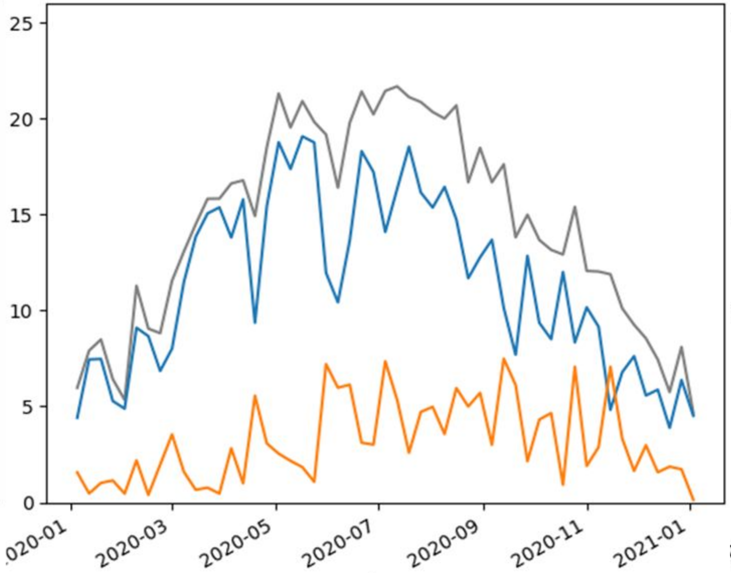

(Nelson et al., 2018)

# Preliminary Results

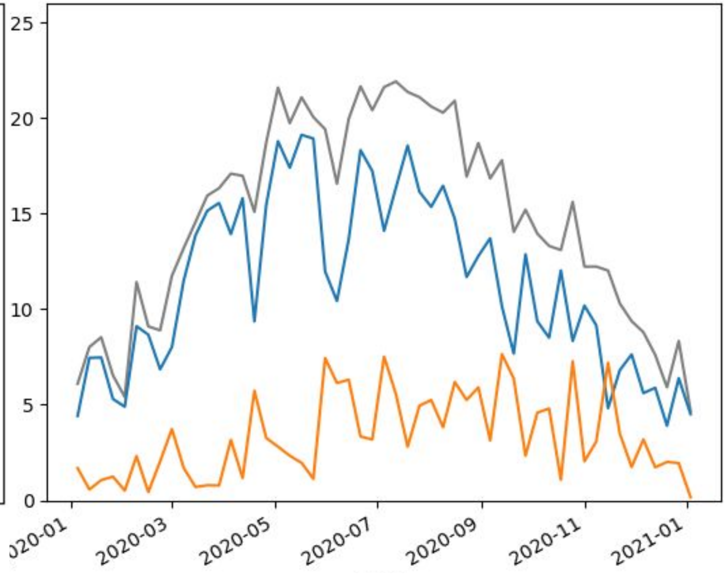
- Tower-derived and CLM5 simulated ET components at OSBS.




Tower-derived



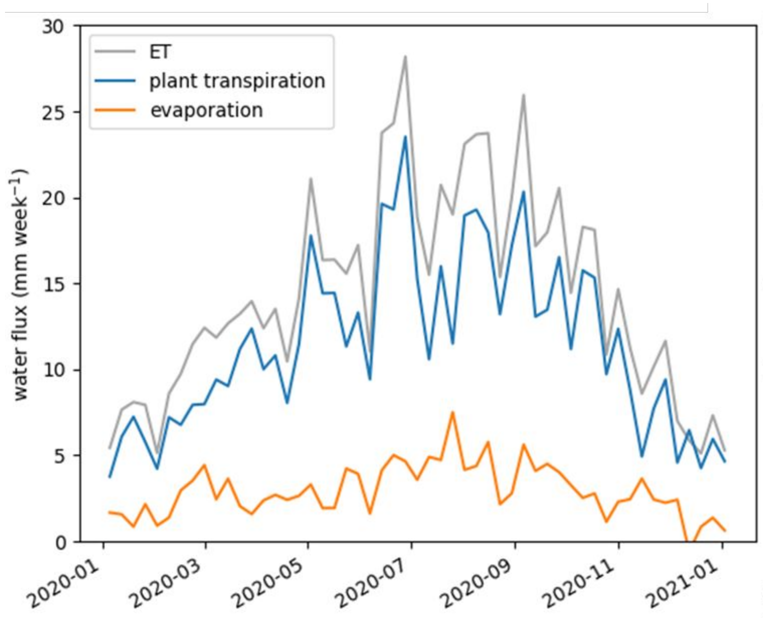

Model simulation (CH)



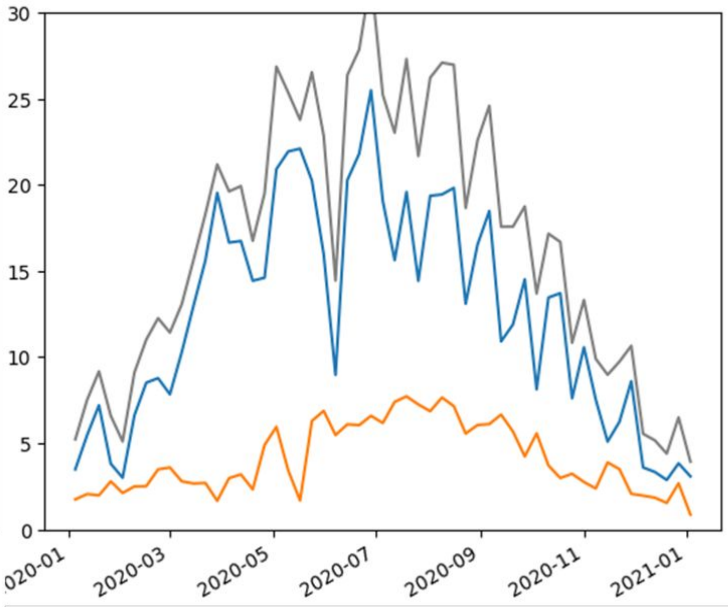

Model simulation (VGM)

# Preliminary Results

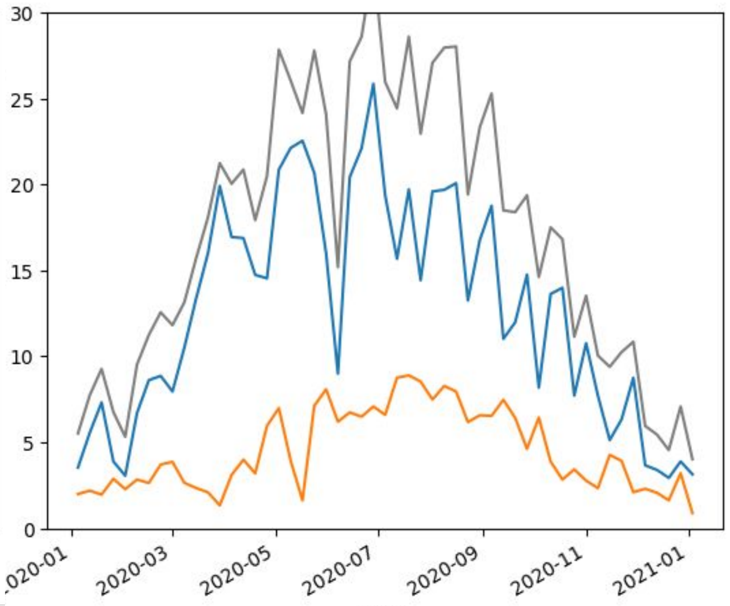
- Tower-derived and CLM5 simulated ET components at DSNY.




Tower-derived



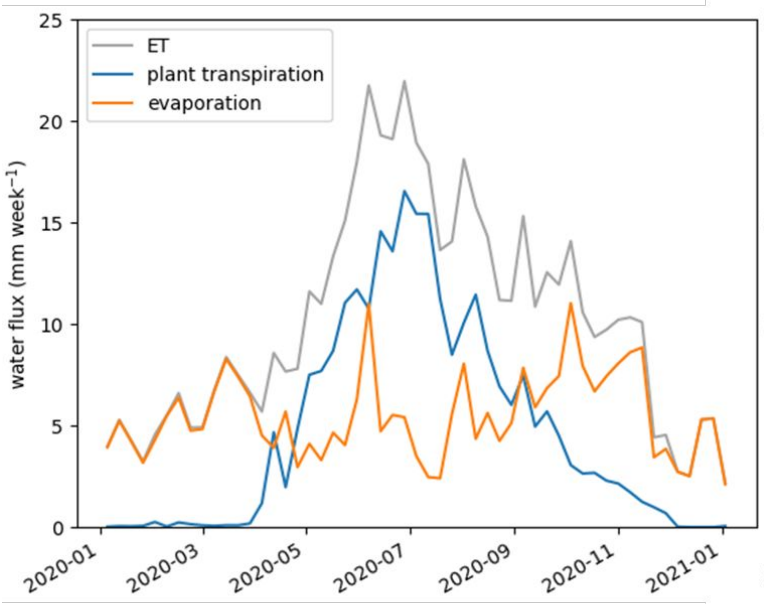

Model simulation (CH)



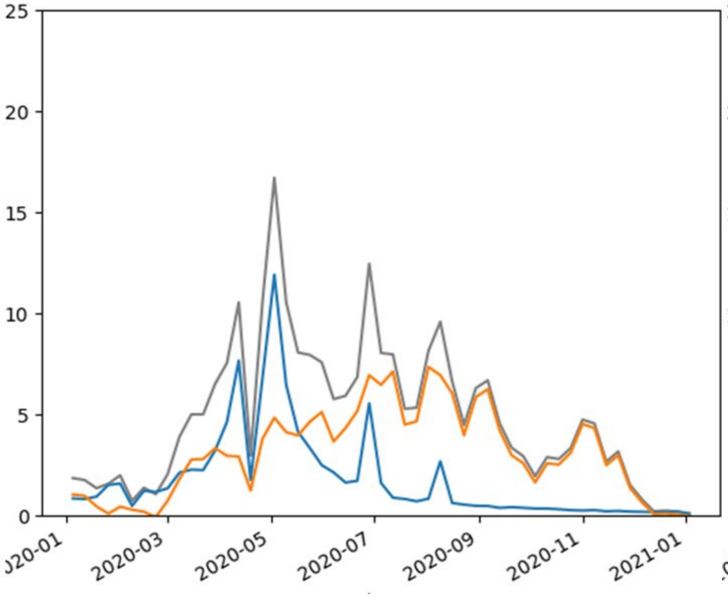

Model simulation (VGM)

# Preliminary Results

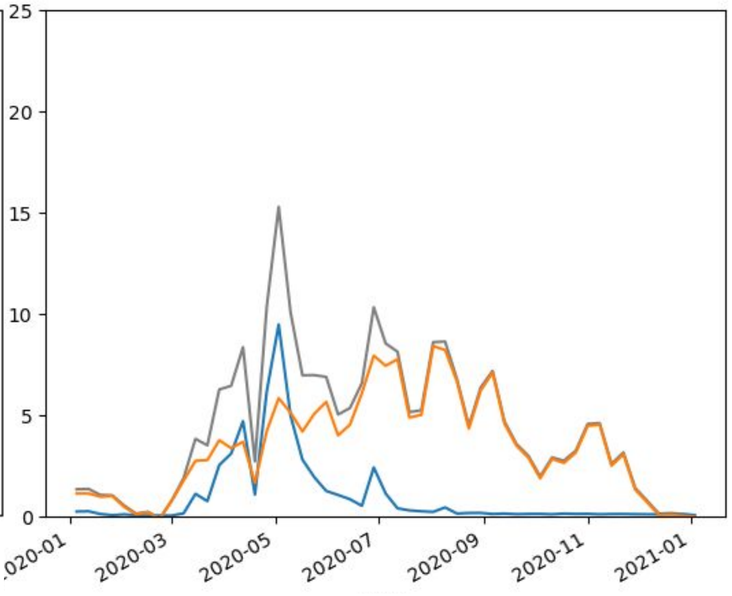
- Tower-derived and CLM5 simulated ET components at RMNP.




Tower-derived




Model simulation (CH)




Model simulation (VGM)

# Discussions: within-site comparison

- Why there's little difference between CH and VGM results?

  - Parameters

$$\begin{cases} n \approx 1 + b^{-1} & \text{for Mualem theory} \\ \alpha \approx |\psi_{sat}|^{-1} & \end{cases}$$

b comes from CH!

  - Derivatives

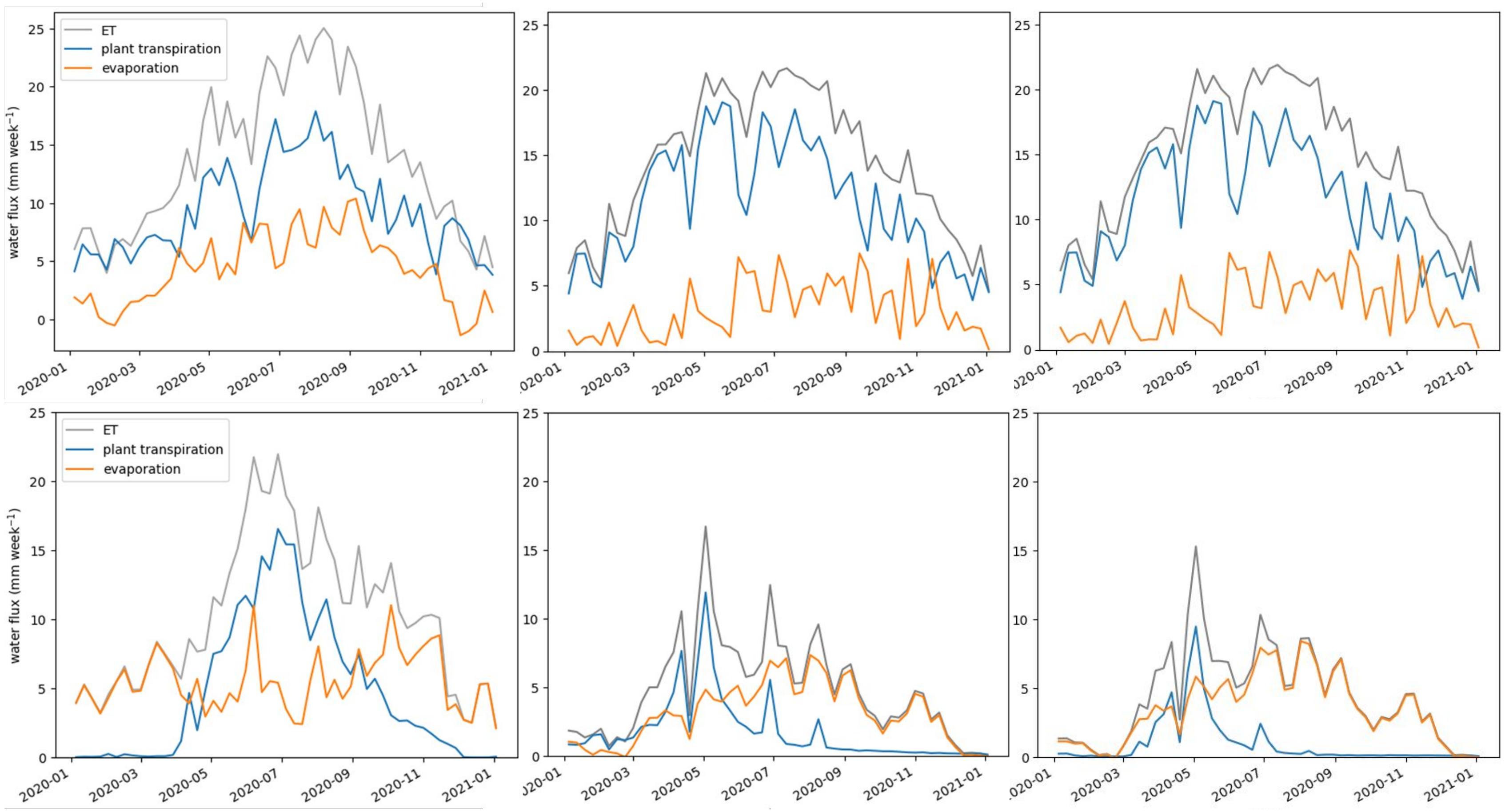
```
dhkds=(2._r8*bsw+3._r8)*hk/s
dsmpds=-bsw*smp/s
```

# Discussions: across-site comparison

- Underestimated T & ET at RMNP (moisture-limited)

OSBS

DSNY




Tower-derived | Model simulation (CH) | Model simulation (VGM)

# Next Steps

- To use the pedotransfer functions developed for calculating VGM parameters

ELSEVIER
Journal of Hydrology
Volume 251, Issues 3–4, 1 October 2001, Pages 163-176

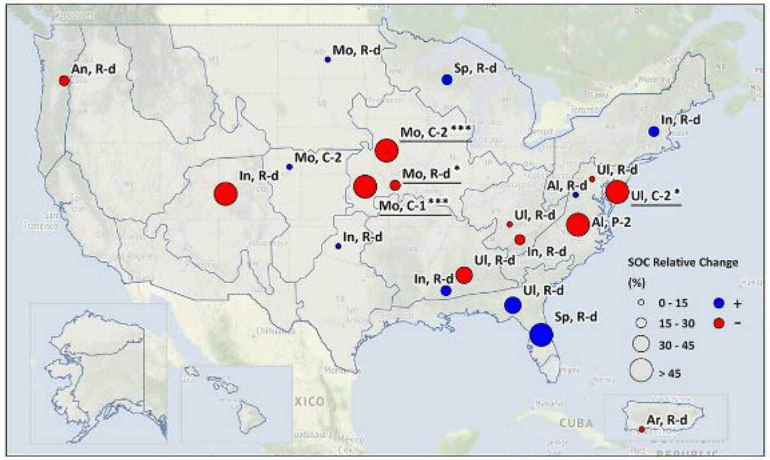
ROSETTA: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions

Marcel G. Schaap, Feike J. Leij, Martinus Th. van Genuchten

- To try other soil water retention curves (Fredlund-Xing-Wang, 2018) for soil hydraulics into CTSM

Soil water dynamics well represented at large suction (e.g. when soil is dry)

- To run on more NEON sites with different soil types (texture, SOC change, etc.)




(Hu et al., 2023)

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  https://neoncollab.ucar.edu/

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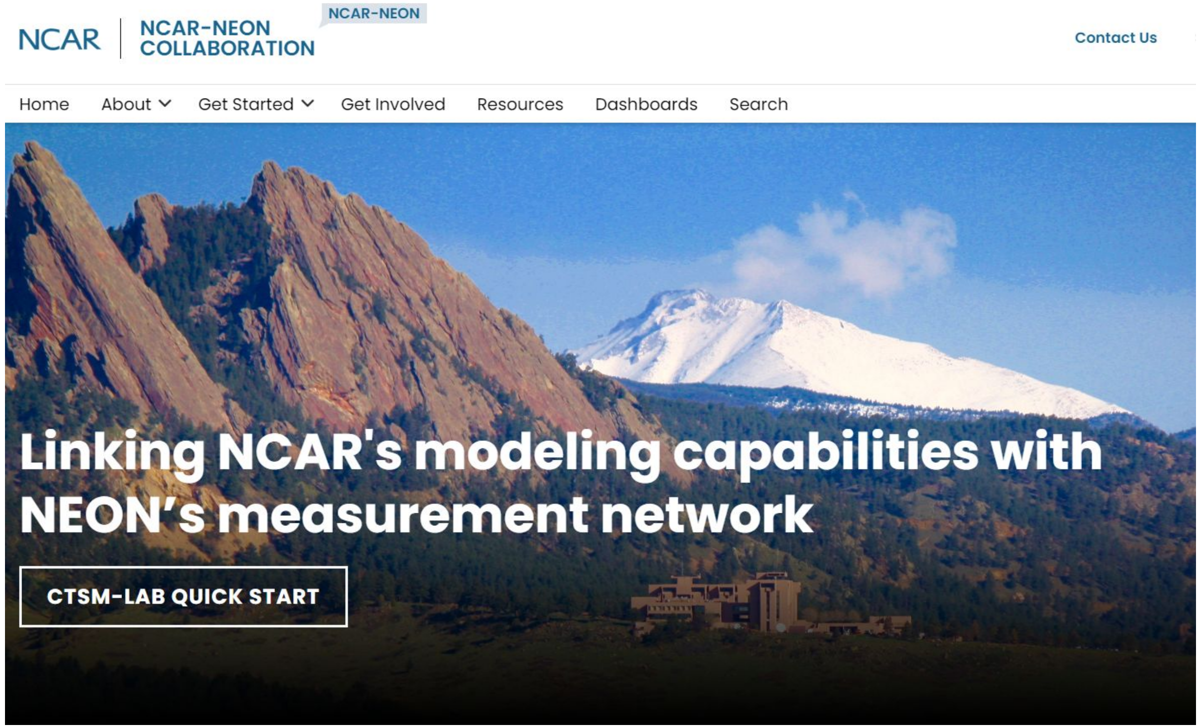

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