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Impacts of Root Hydraulic Redistribution on Site, Regional, and Global Evapotranspiration and Soil Moisture

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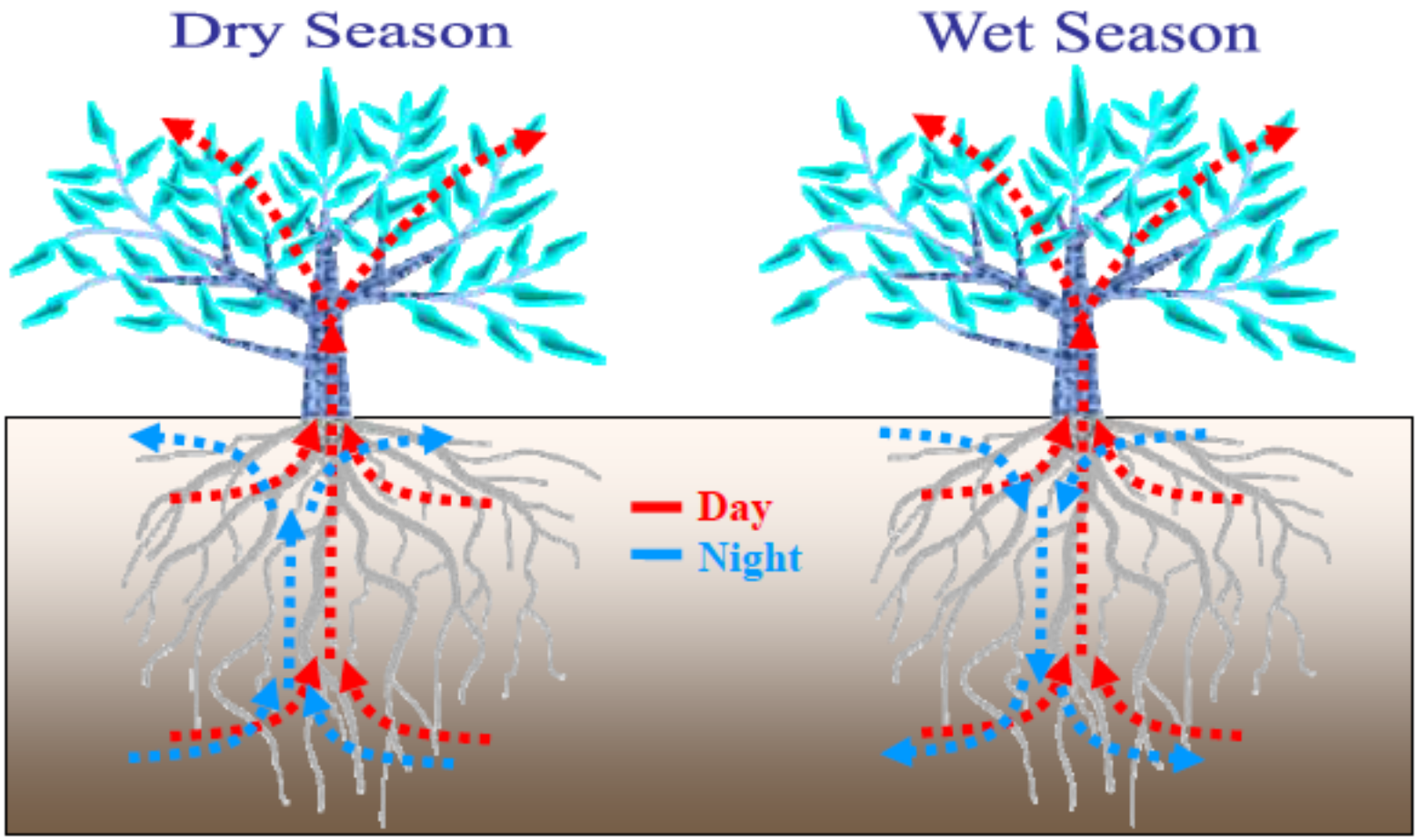
Root Hydraulic Redistribution



Amenu and Kumar (2008)

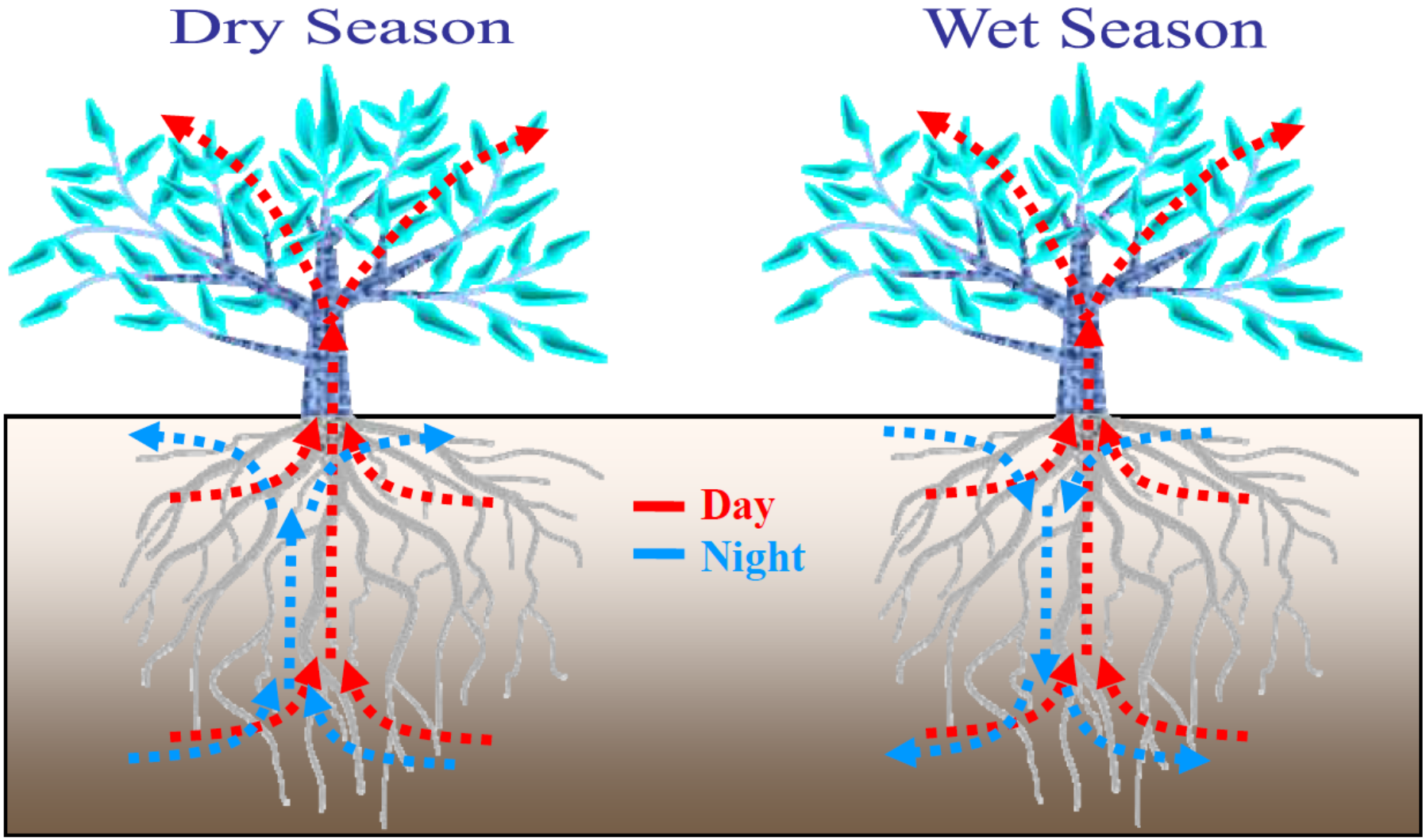
Background

- Lee et al. (2005), Wang (2011)
  - Root Hydraulic Redistribution (RHD) increases ET and photosynthesis during dry season
  - Enhances ground water depletion and recharge
  - Modifies regional climate
- Amenu and Kumar (2008)
  - Deep root hydraulic redistribution enhances the connection between surface and ground water

Objectives

- Evaluate impacts of RHD on hydrological states and fluxes
  - Implement RHD in CLM4.5 using the Amenu-Kumar model
  - Test impacts of numerical implementation
  - Test impacts of rooting distribution, depth, and properties
  - Test impacts of pedotransfer function, including for oxisols

The Amenu-Kumar (2008) Model of RHD



Sequential Coupling vs. Tight Coupling

Sequential model

- Process-splitting method

Step 1: solve Richards' equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K_{sh}\left(\frac{\partial \psi_{sm}}{\partial z} - 1\right)\right] - K_{rh,rad}\left(\psi_{sm} - \psi_{rp}\right)$$

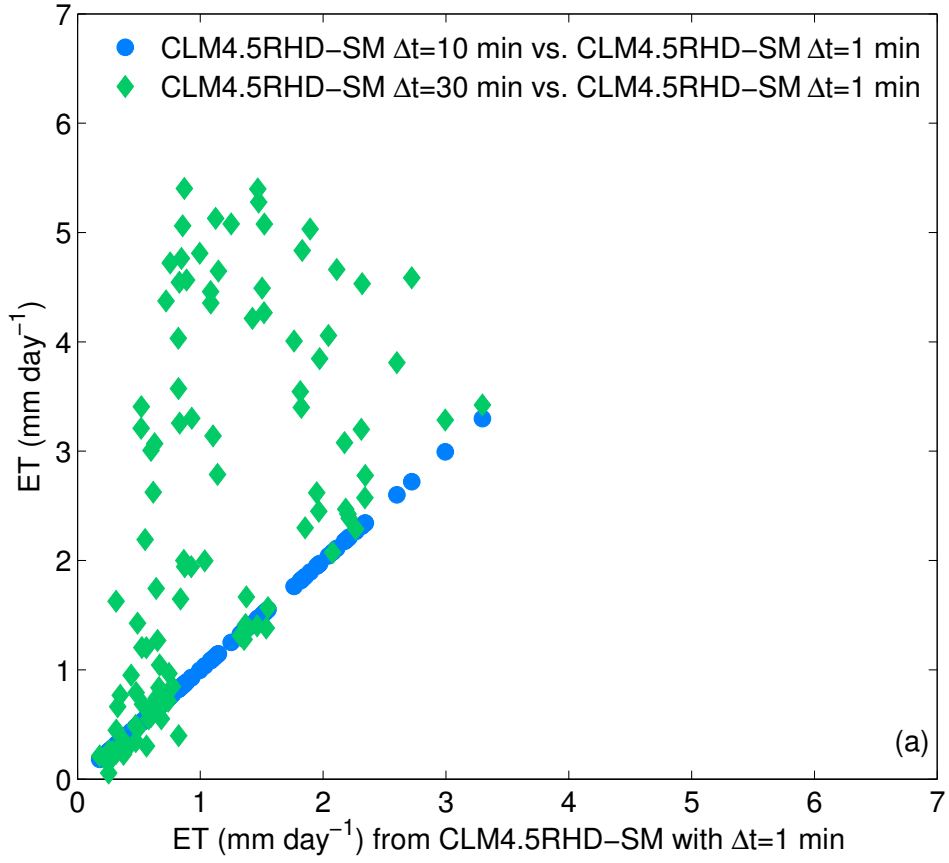
Step 2: solve root model

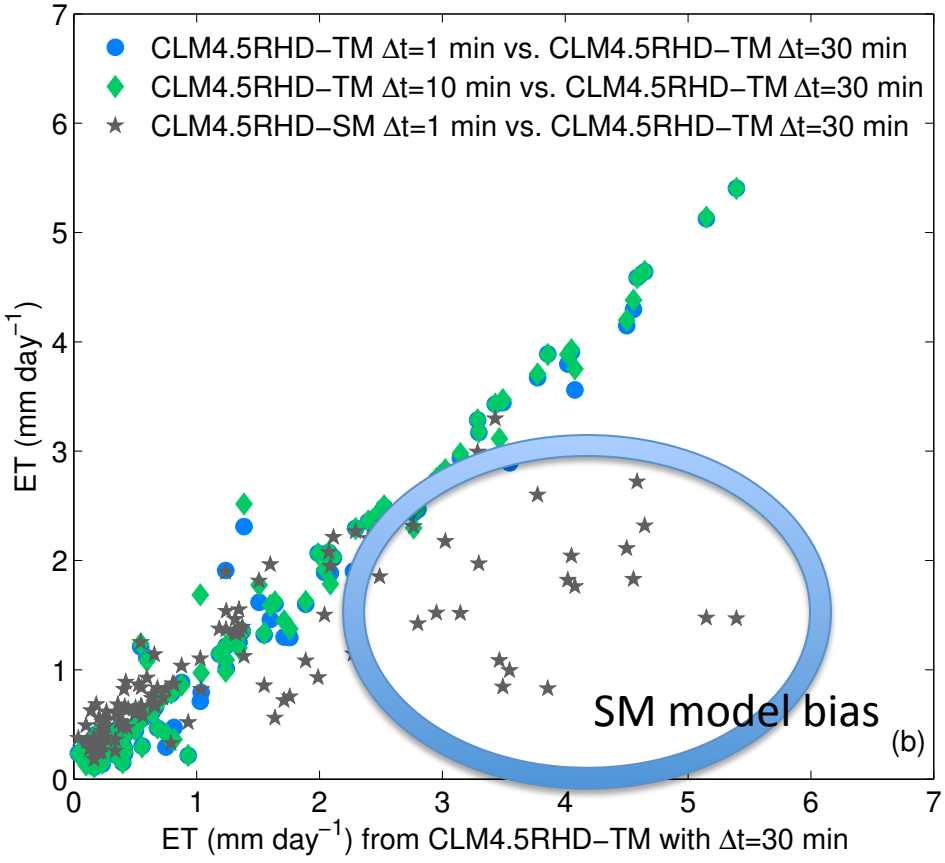
$$0 = \frac{\partial}{\partial z}\left[K_{rh,ax}\left(\frac{\partial \psi_{rp}}{\partial z} - 1\right)\right] + K_{rh,rad}\left(\psi_{sm} - \psi_{rp}\right)$$

Tightly coupled model

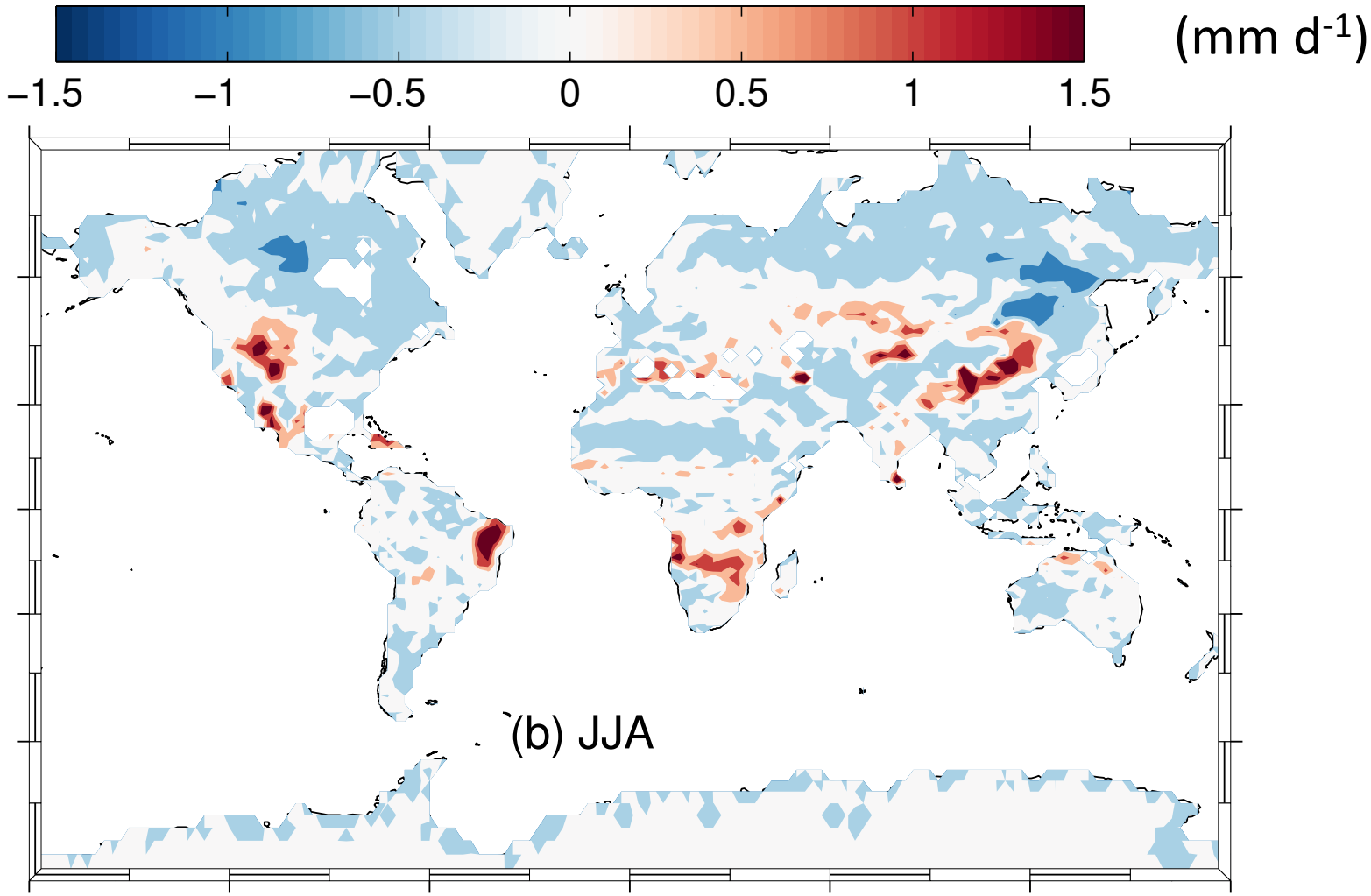
- Form and solve coupled system

Sequential Model (SM) Has Large Sensitivity to Time Step





Sequential Coupling vs. Tight Coupling: Non-Physical Changes in Global ET



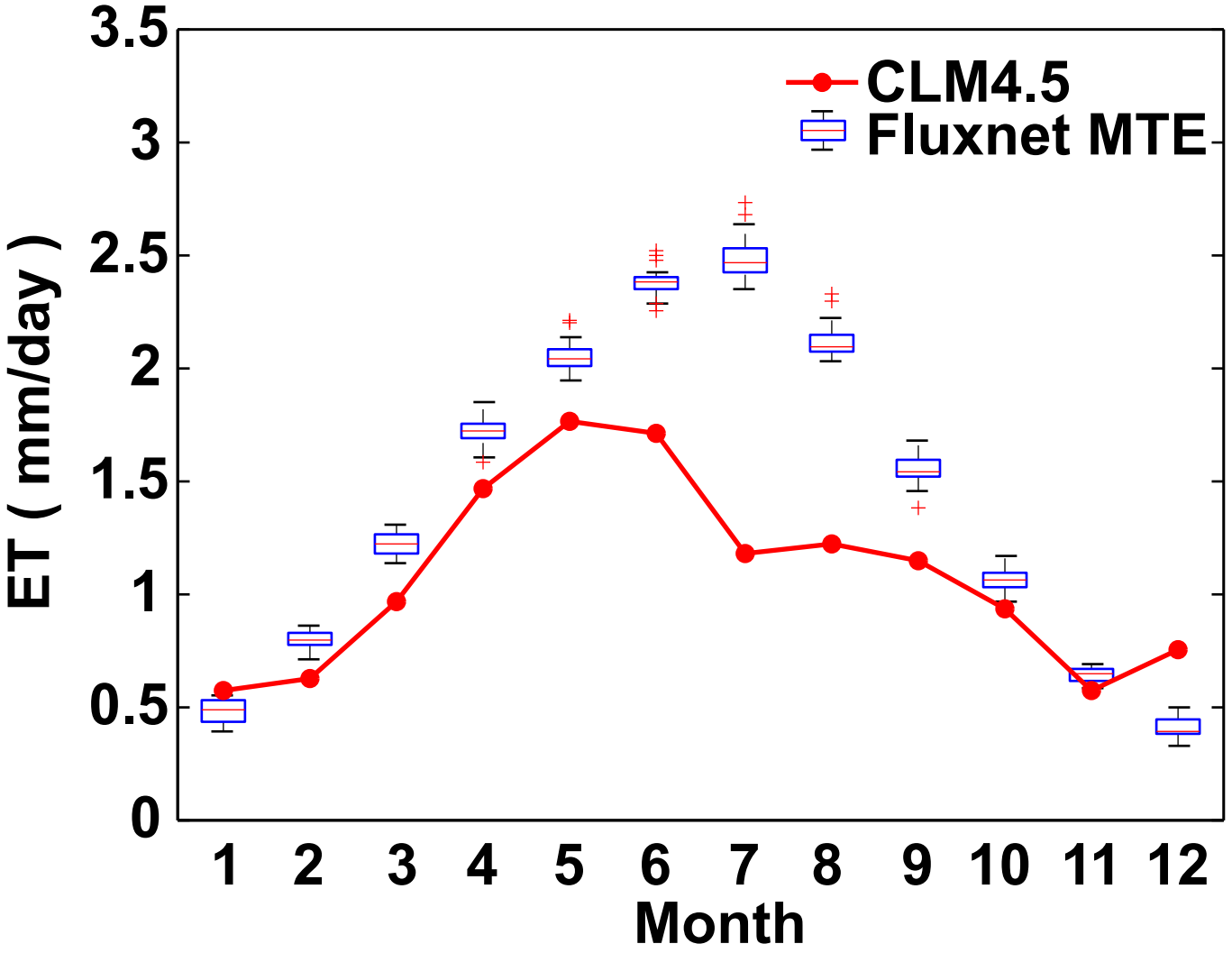
Coupling biases are as high as 3.5 mm day^{-1}

Blodgett Forest Site

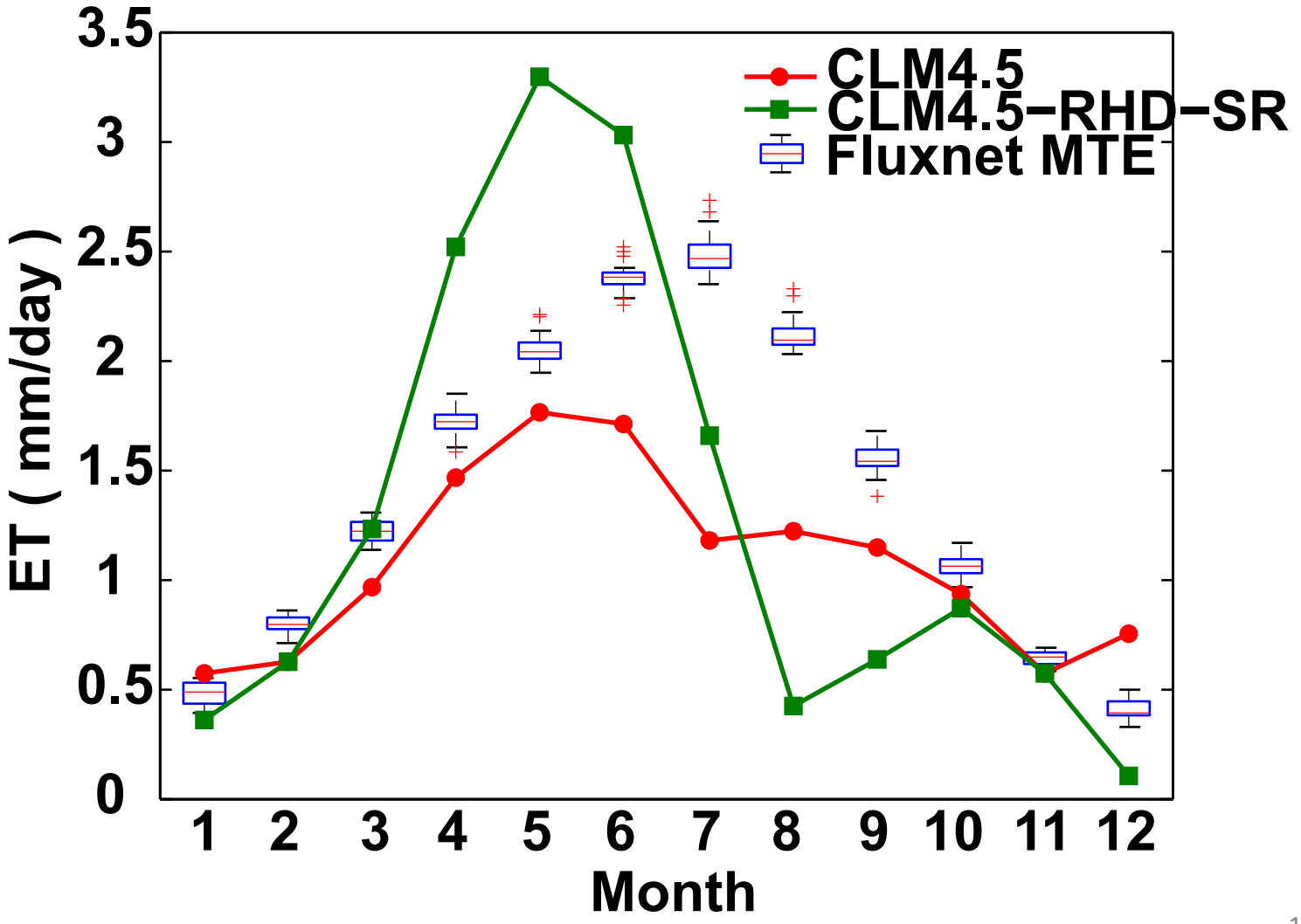
http://journalism.berkeley.edu/

http://fluxnet.ornl.gov/

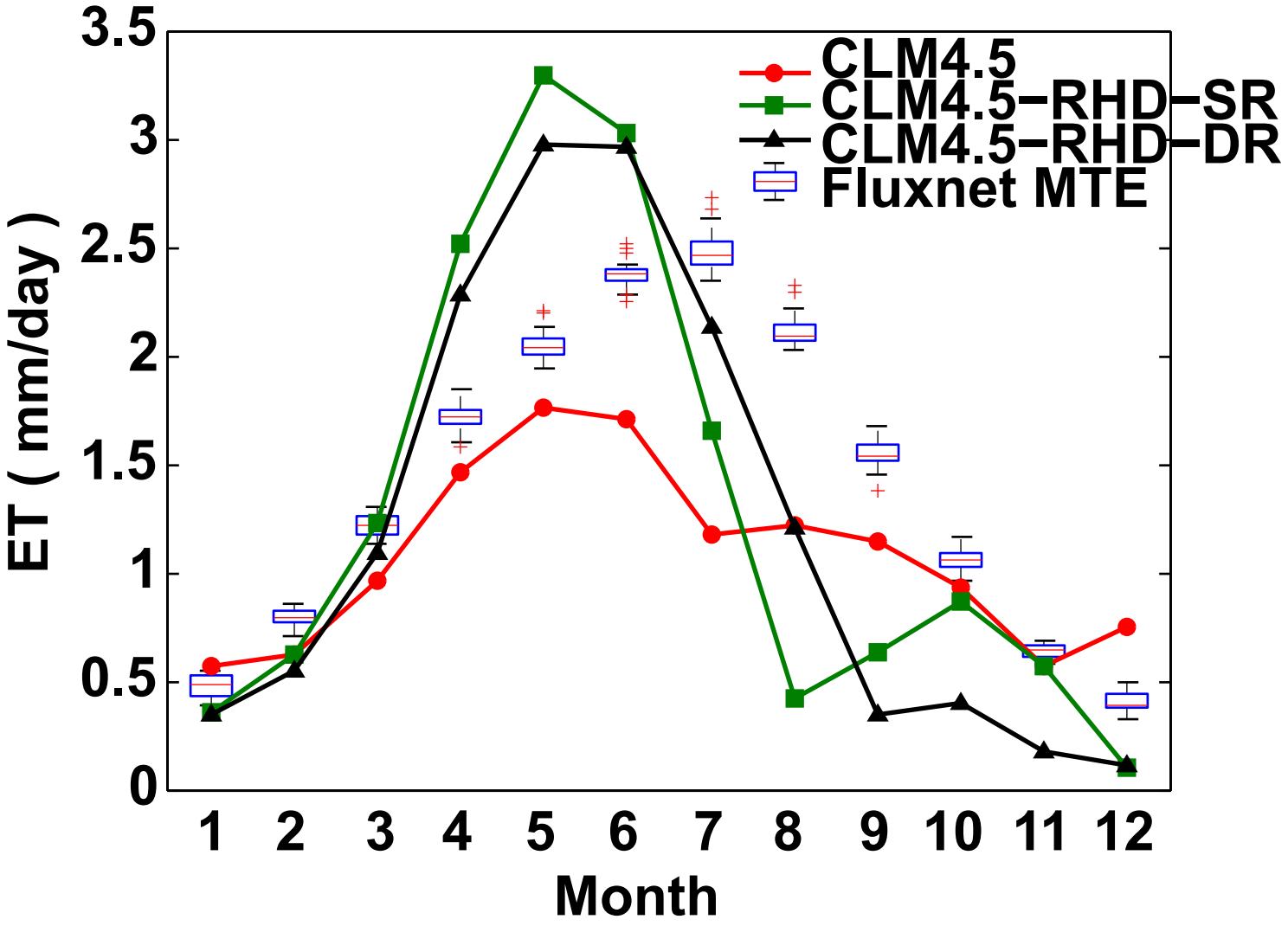
Sierra (Blodgett) LH Evaluation



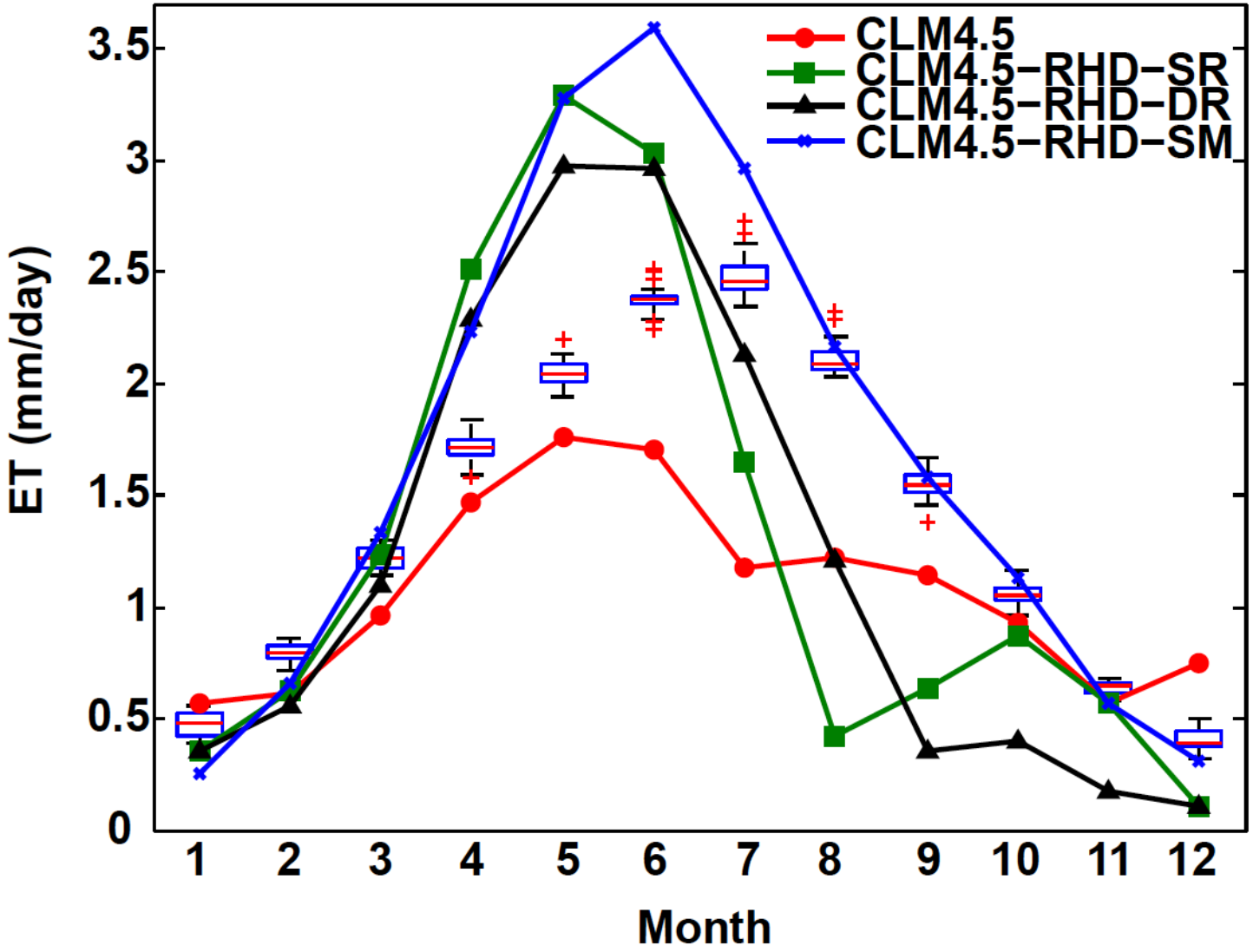
Sierra (Blodgett) LH Evaluation



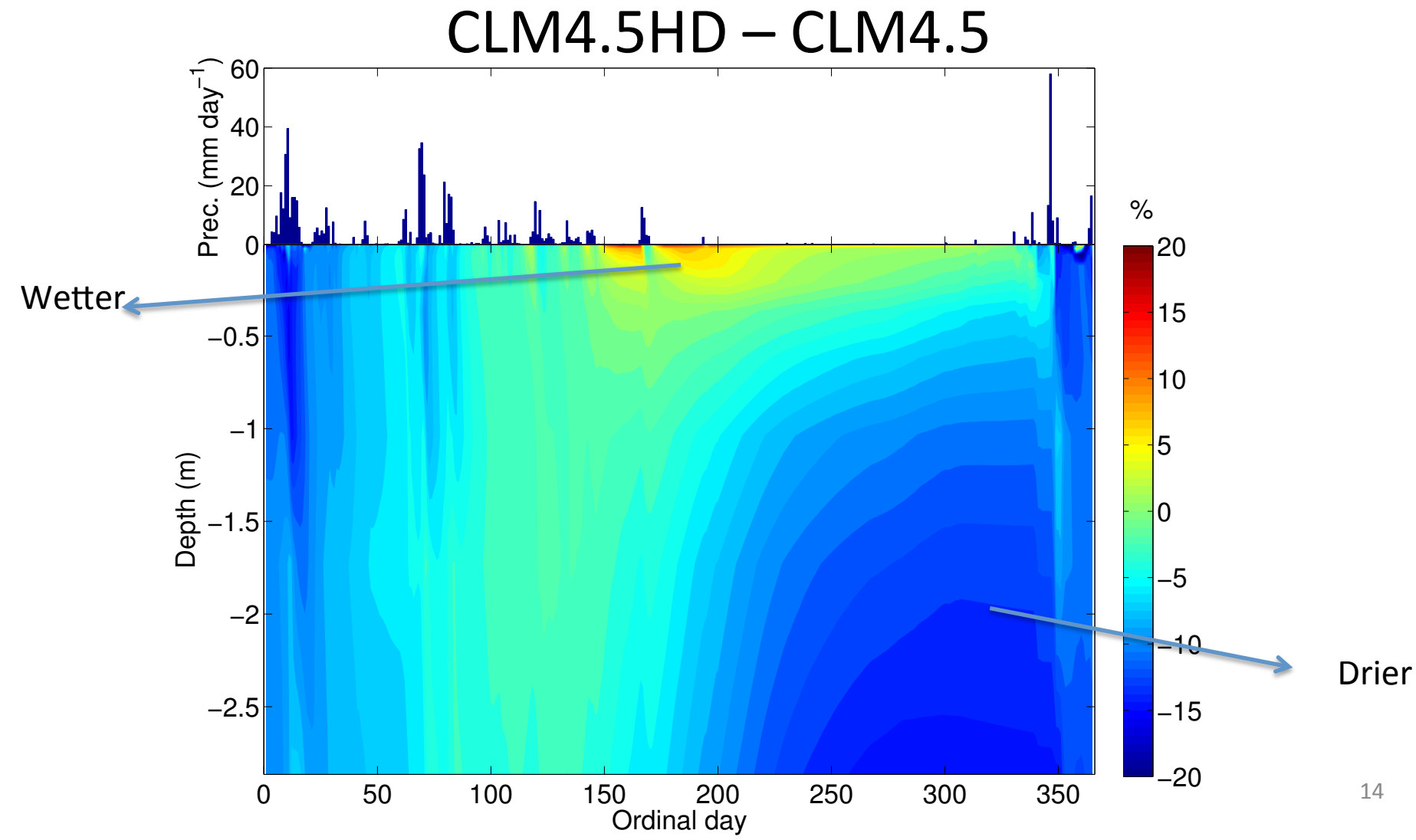
Sierra (Blodgett) LH Evaluation

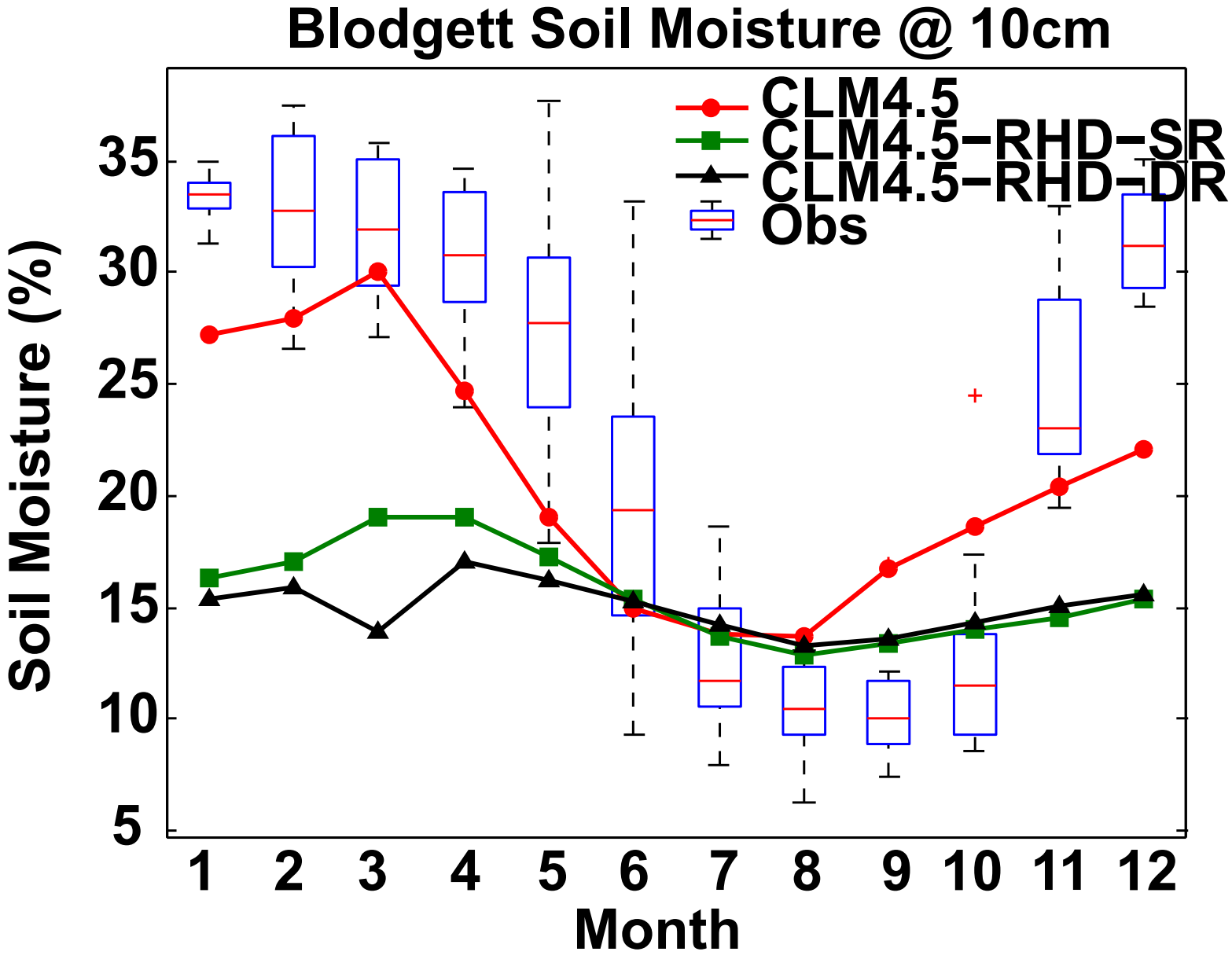


Sierra (Blodgett) LH Evaluation



Hydraulic redistribution affects seasonal soil moisture (Blodgett)



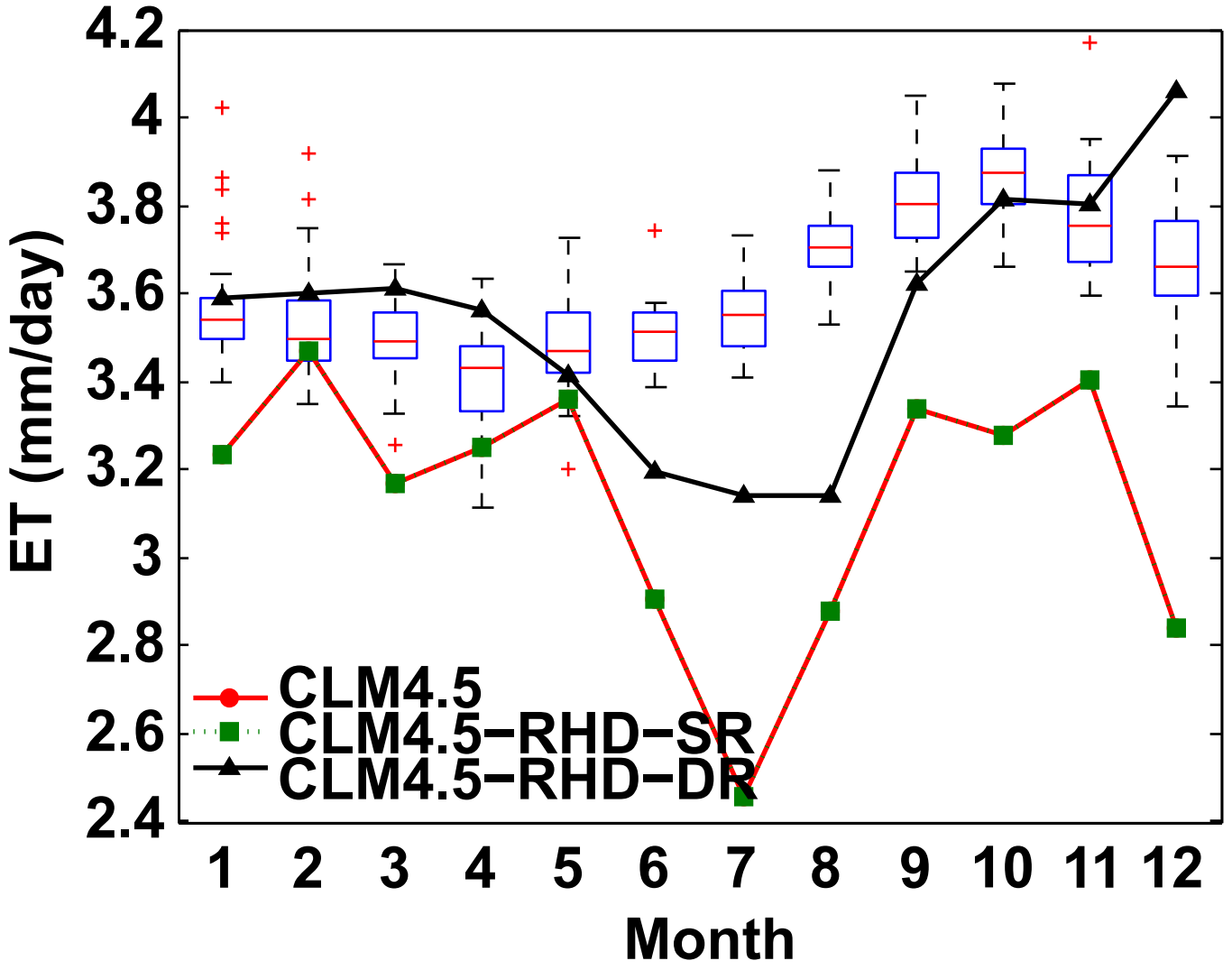

Blodgett Soil Moisture @ 10cm
CLM4.5
CLM4.5−RHD−SR
CLM4.5−RHD−DR
Obs
Soil Moisture (%)
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
Month

Tapajos site

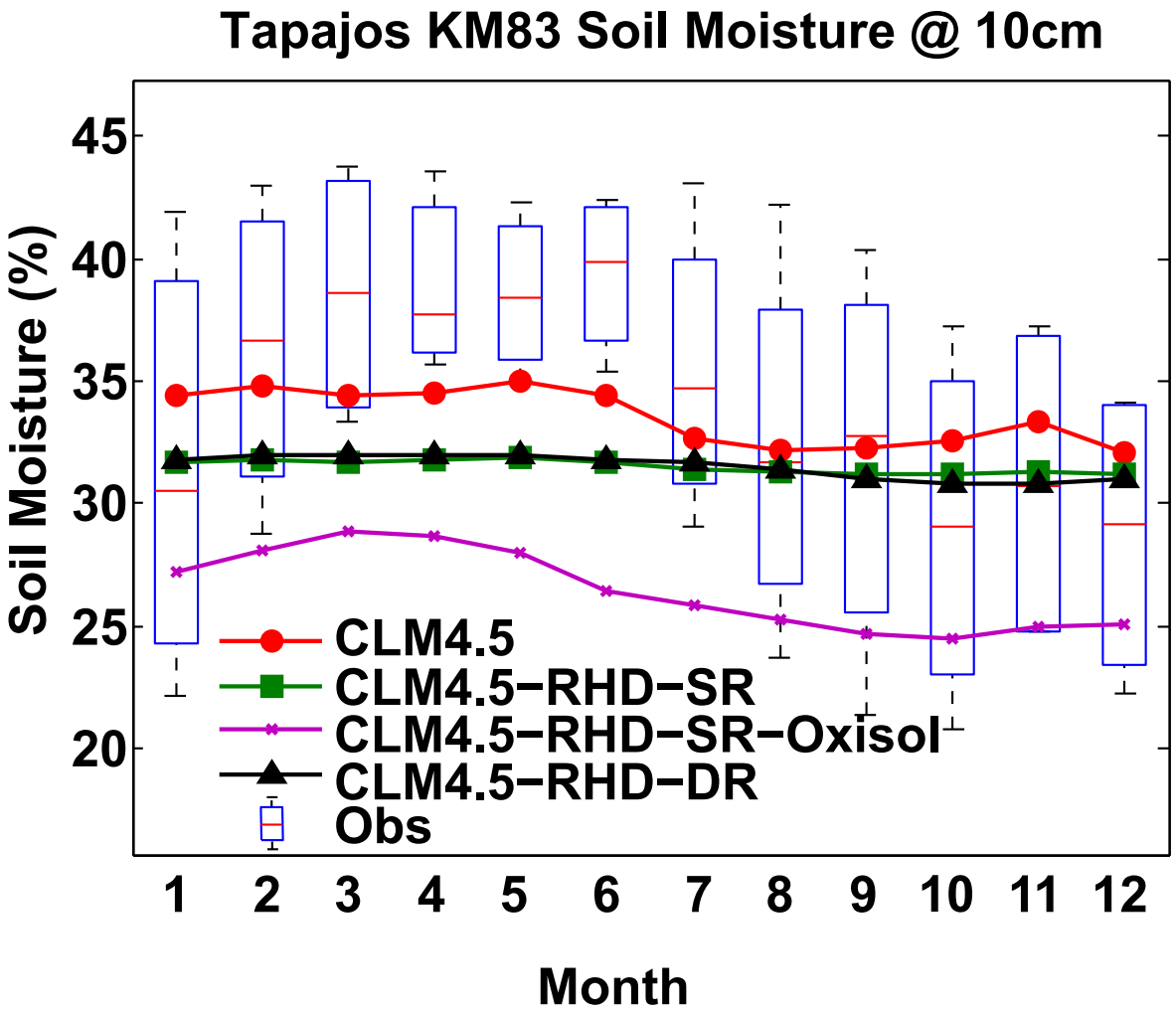
From: http://hydrodictyon.eeb.uconn.edu/

From: http://daac.ornl.gov/LBA

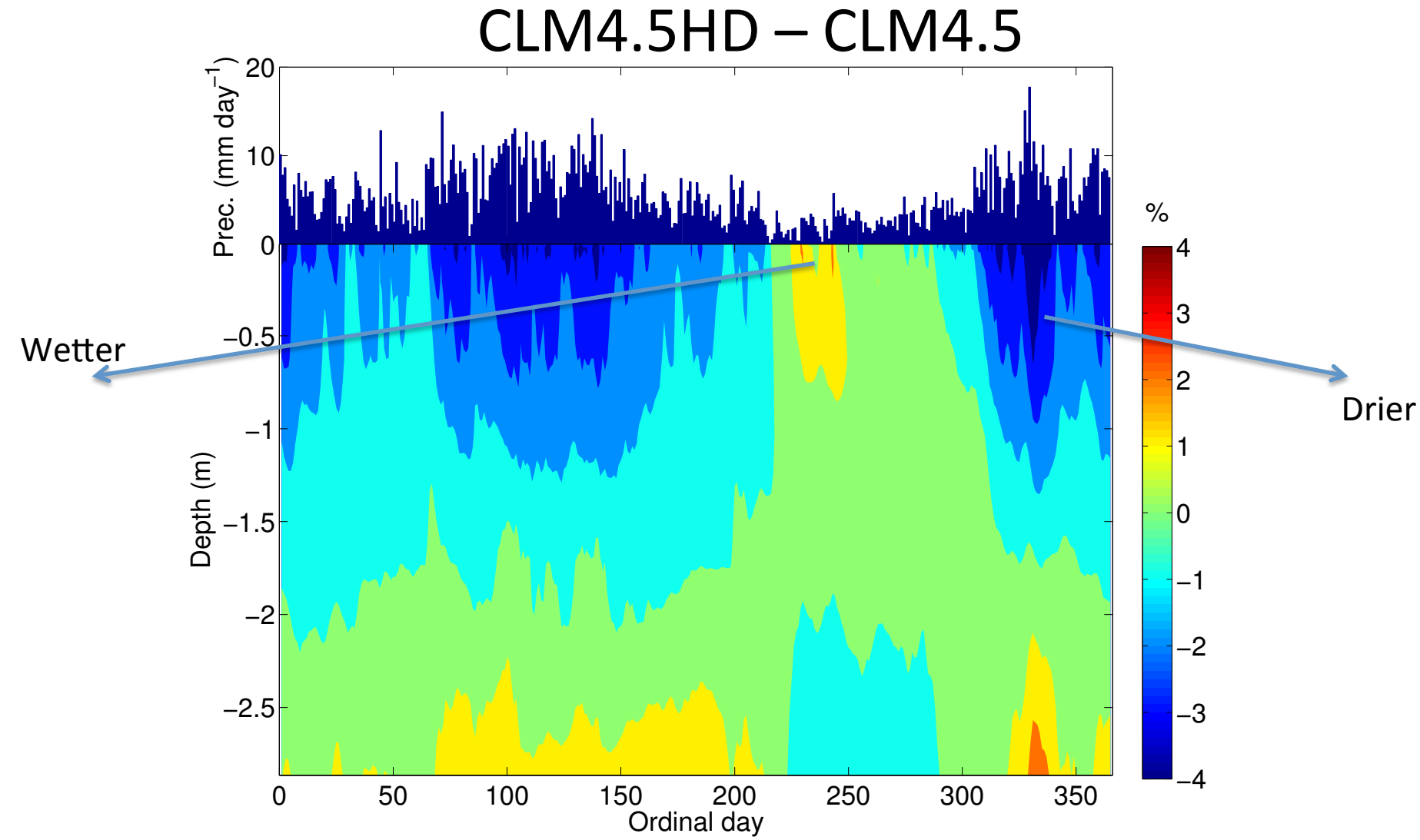
Tapajos Site LH Evaluation



Impacts on Soil Moisture



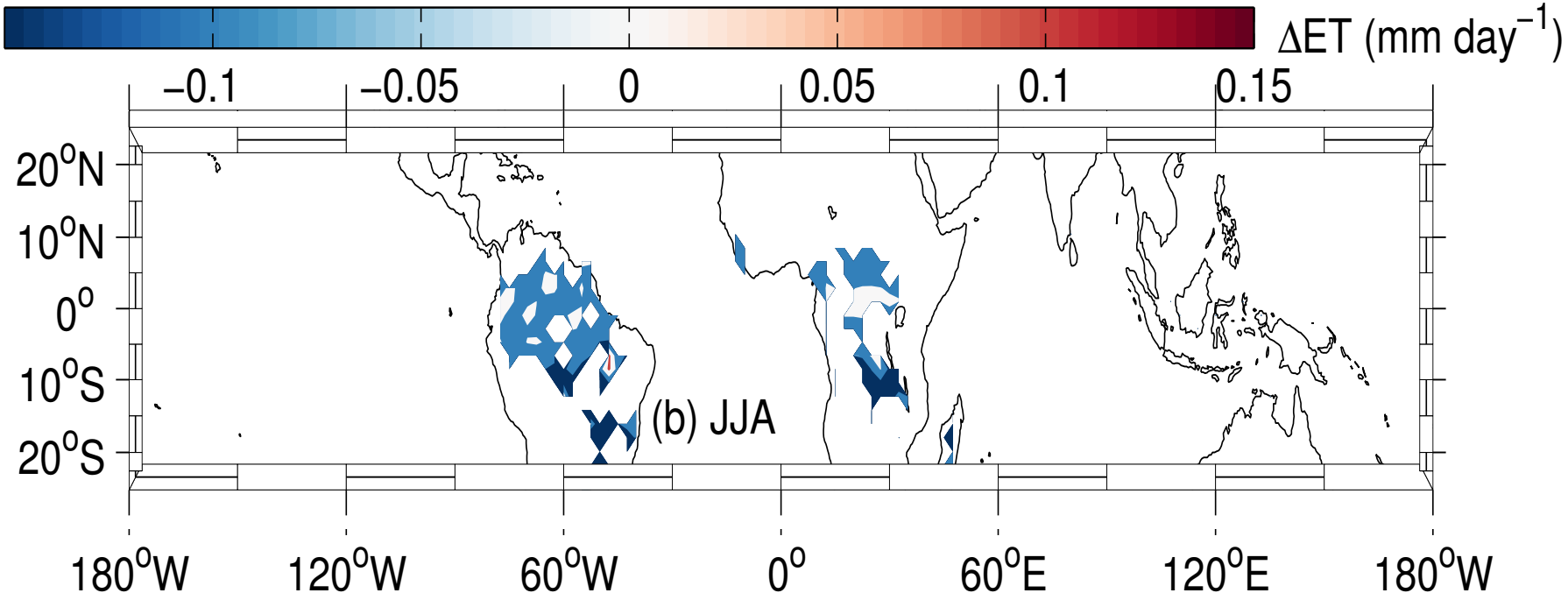
Hydraulic Redistribution Affects Seasonal Soil Moisture (Tapajos)



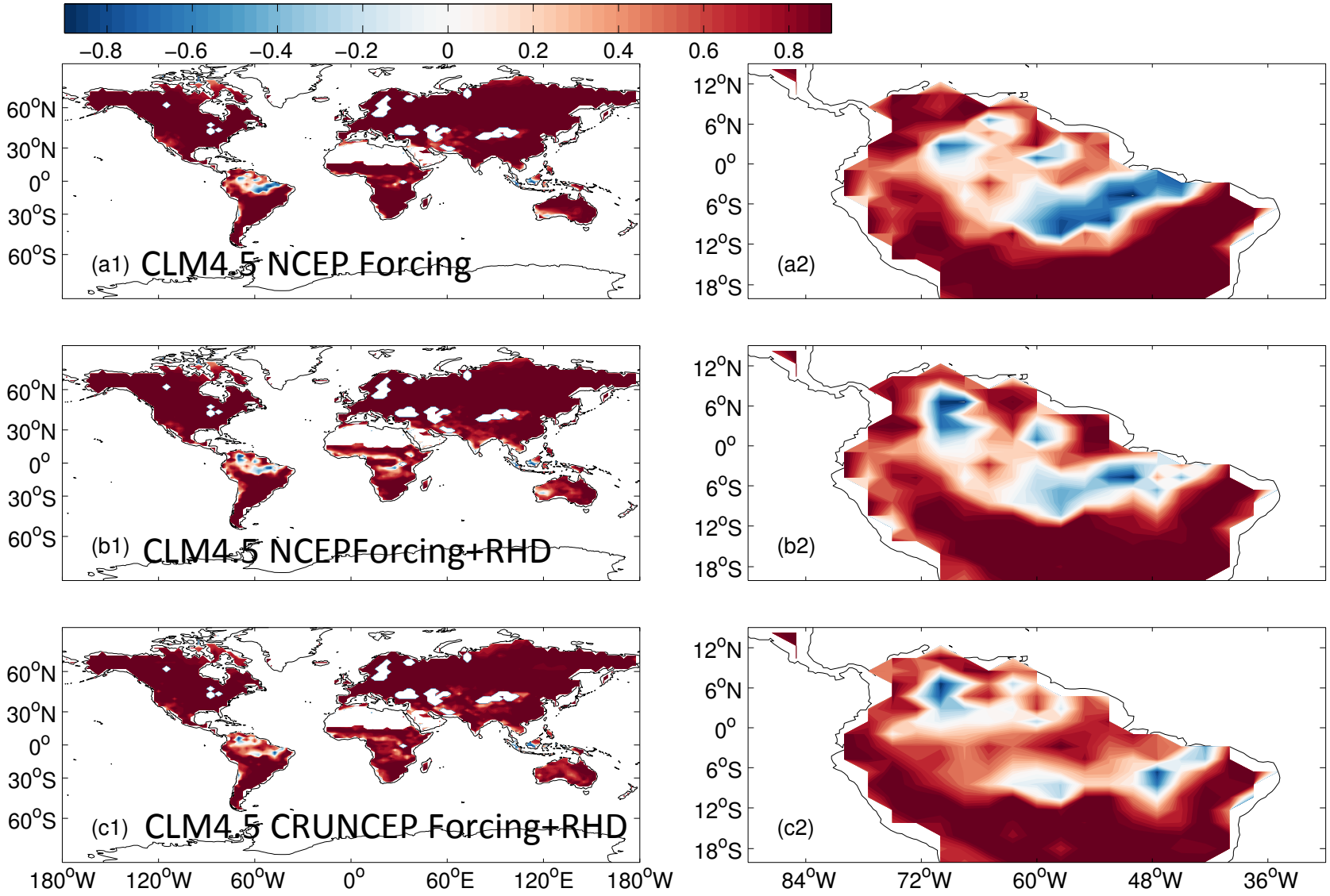
CLM Amazon Hydrology

- Pedotransfer function based on Cosby et al. or Noihan and Lacarrere (1995) do poorly for Amazon soils (Delire et al. 1997)
- CLM underestimates clay fraction in Amazon
- No account in CLM for preferential flow, which can be important
- Differences in climate forcing

Impacts of Oxisols in the Tropics



Impacts of RHD in CLM4.5 Compared to FLUXNET-MTE LH Flux



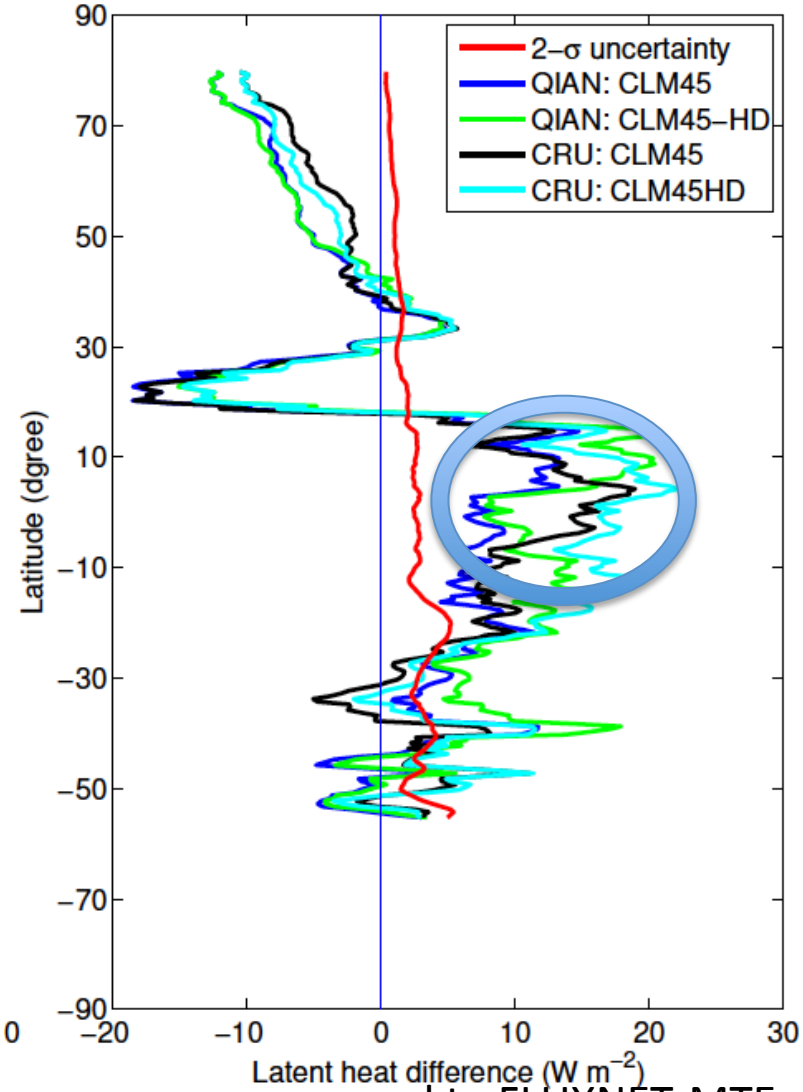
Summary

- Blodgett Forest
  - Correct numerical solution gave poorer fit to LH observations
  - RHD improved fit to LH but gave poorer soil moisture prediction
    - Comparable to Amenu and Kumar (2008) results
- Tapajos and Tropics
  - Deep roots improved ET seasonal cycle
  - Oxisol pedotransfer function resulted in ~small ET change
- Climate forcing has large impact on interpretation of mechanisms
- For a full hydrological evaluation, CLM needs restructuring to account for flexible formulations of pedotransfer function, root depth profile, soil resistance, root water uptake, etc.

Acknowledgements

- This work was supported by the U.S. DOE

LH Evaluation Against FLUXNET-MTE



compared to FLUXNET-MTE

Jinyun:

1. what component of the forcing creates the ~10 W/m2 difference in LH between Qian and CRU forcing around 0 degrees?
2. HD has higher bias than default. Why? How do we argue about the benefits of including HD if it makes the simulation worse?
3. Lee et al get ~40% increase in dry season LH. Is that about the same here?
4. Lee et al also argue that greater storage