Lawrence Berkeley National Laboratory

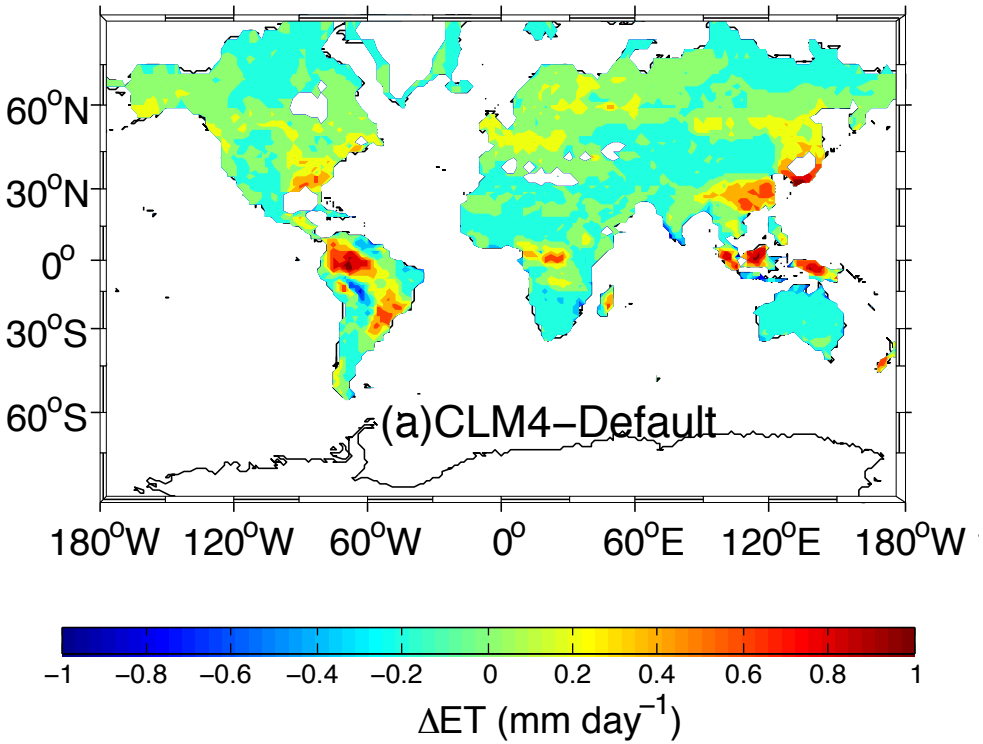
ESD
EARTH SCIENCES DIVISION

Modeling Root Hydraulic Redistribution in CLM4.5: Pitfalls and Gains

Jinyun Tang and Bill Riley

Earth Sciences Division
Lawrence Berkeley National Laboratory

One Motivation for this Work: the "Likely ET Bias" from Vegetation Removal



- Removing vegetation increased ET in some places

Tang and Riley, 2013

Suspected Causes for the Likely ET Bias

- Soil resistance
- Boundary layer turbulent transport parameterization
- Time stepping
- Pedotransfer function for hydraulic properties
- Btran or root water uptake function
- Numerical solver of the Richards' equation
- Rooting depth and profile
- Saturated and unsaturated zone coupling
- Driving data, e.g. precipitation, soil texture
- Surface albedo parameterization
- Missing processes, e.g. hydraulic redistribution

Investigated Two Possible Culprits (Tang and Riley 2013)

- Soil resistance
- Boundary layer turbulent transport parameterization
- Time stepping
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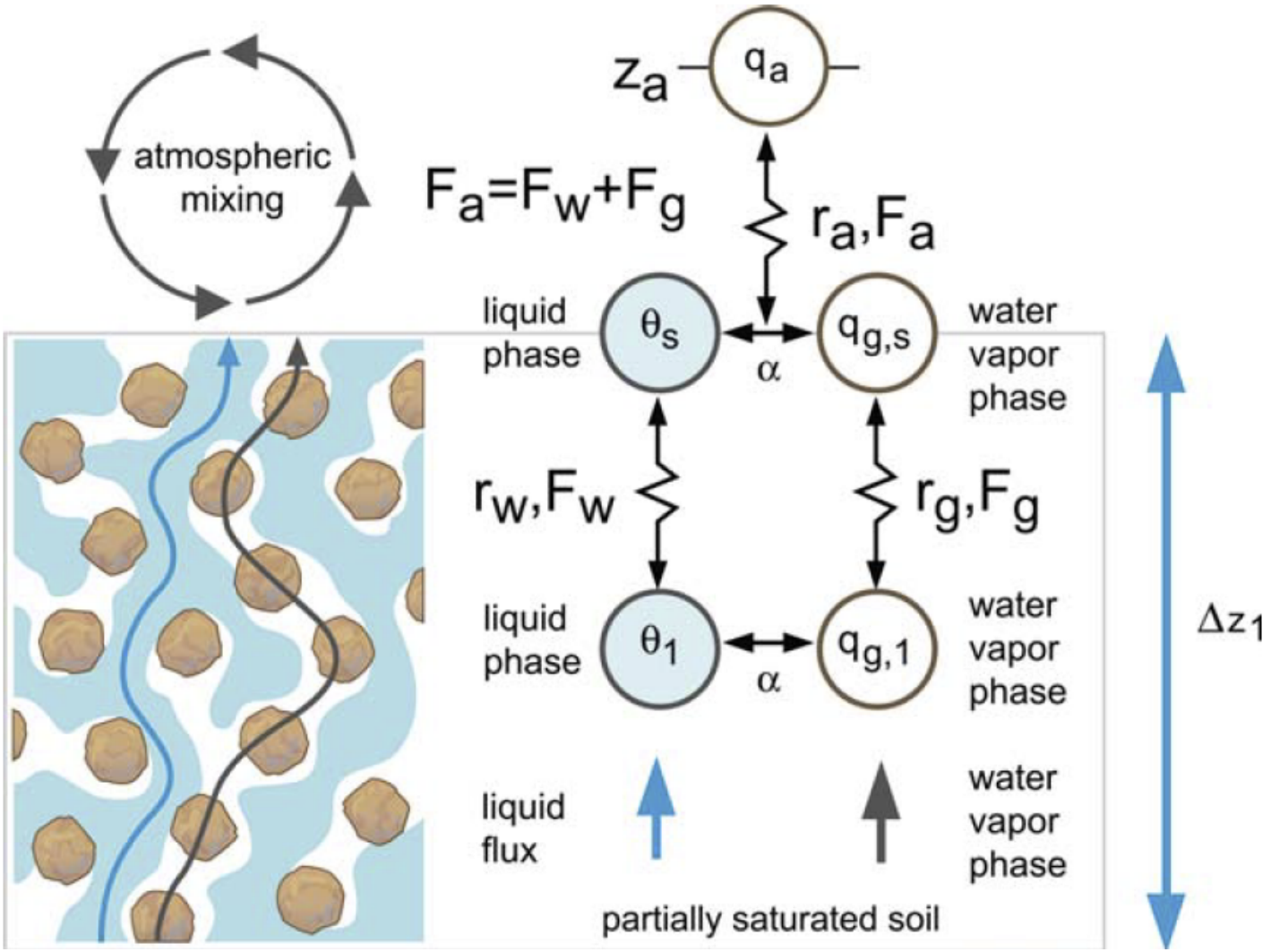
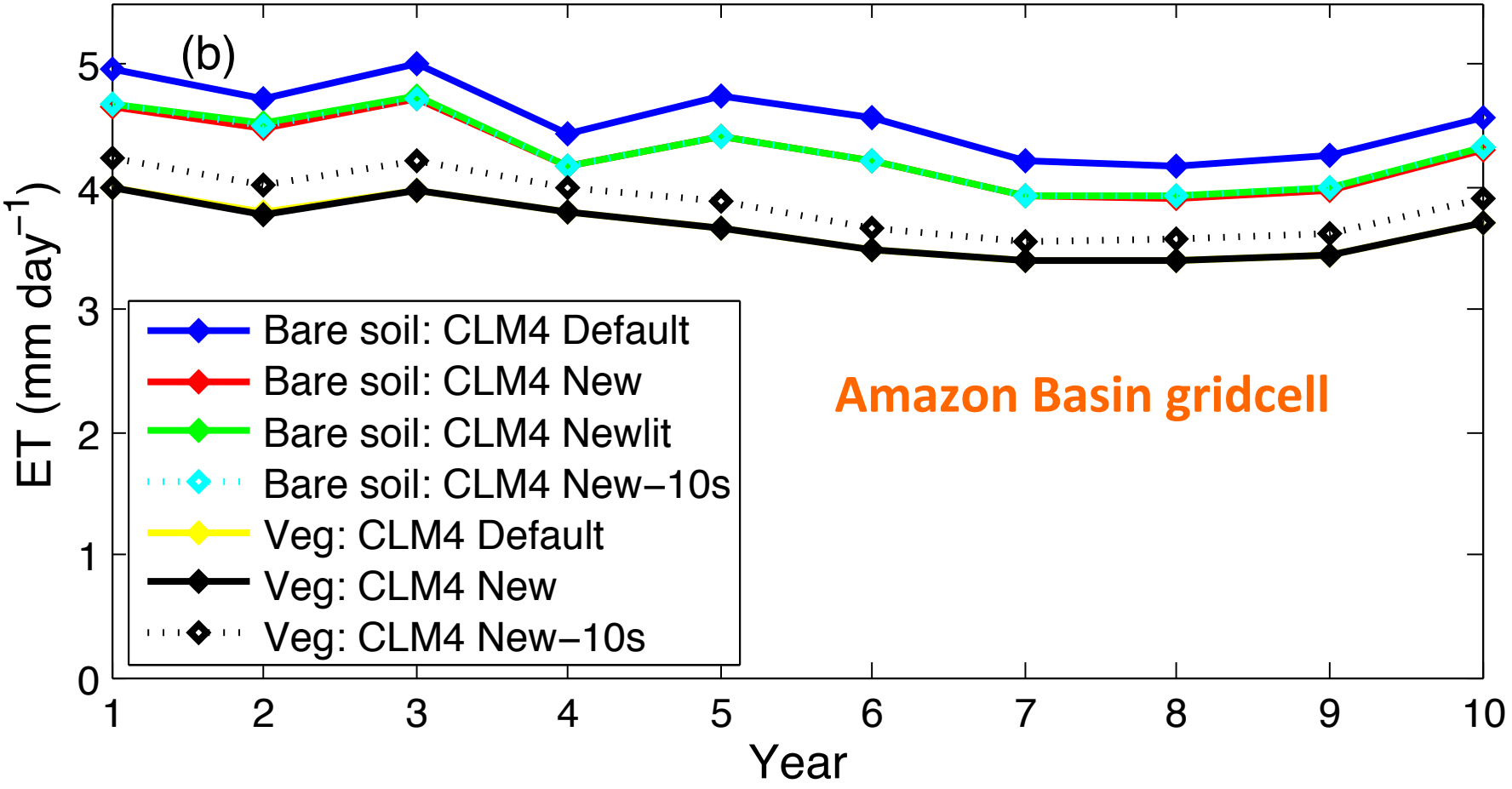


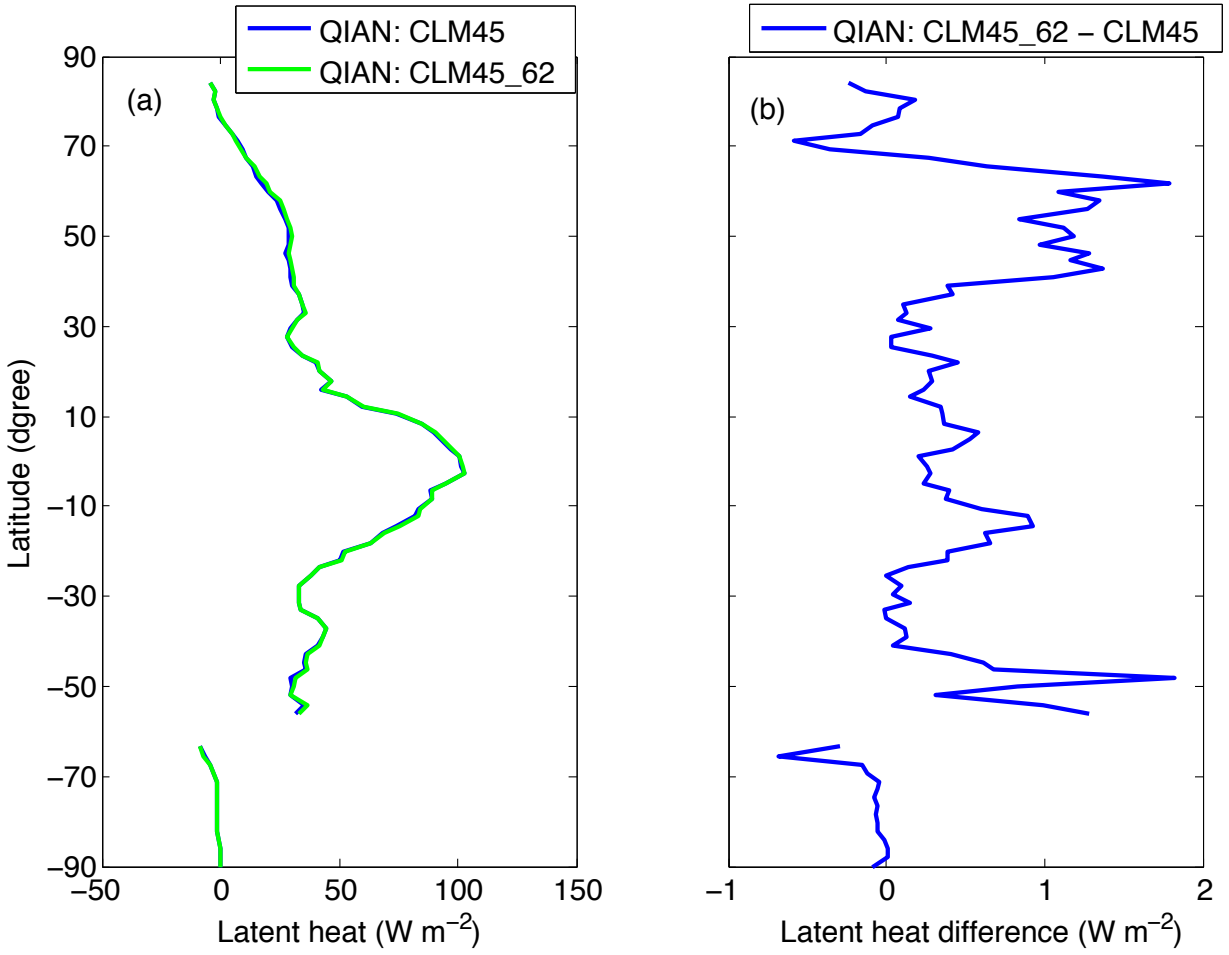
Tang and Riley, 2013

Recap: Explored potential causes



Tang and Riley, 2013

Effect of New Soil Resistance in CLM4.5 is Relatively Small



Next Set of Suspected Culprits

- Soil resistance
- Boundary layer turbulent transport parameterization
- Time stepping
- Pedotransfer function
- Btran or root water uptake function
- Numerical solver of the Richards' equation
- Rooting depth and profile
- Saturated and unsaturated zone coupling
- Driving data, e.g. precipitation
- Missing processes, e.g., hydraulic redistribution
- Others, e.g. surface albedo parameterization

Objectives

- Implement root hydraulic redistribution using the Amenu-Kumar model (HESS, 2008)
  - *Hypothesis: Root hydraulic redistribution will enhance ET over vegetated soil*

- Discuss uncertainties on simulated global ET resulting from using three different pedotransfer functions (Cosby eq. 4, Cosby eq. 5, and Noilhan-Planton) and numerical implementations
  - *Hypothesis: interpreting ET is clouded by many uncertainties*

The Amenu-Kumar model

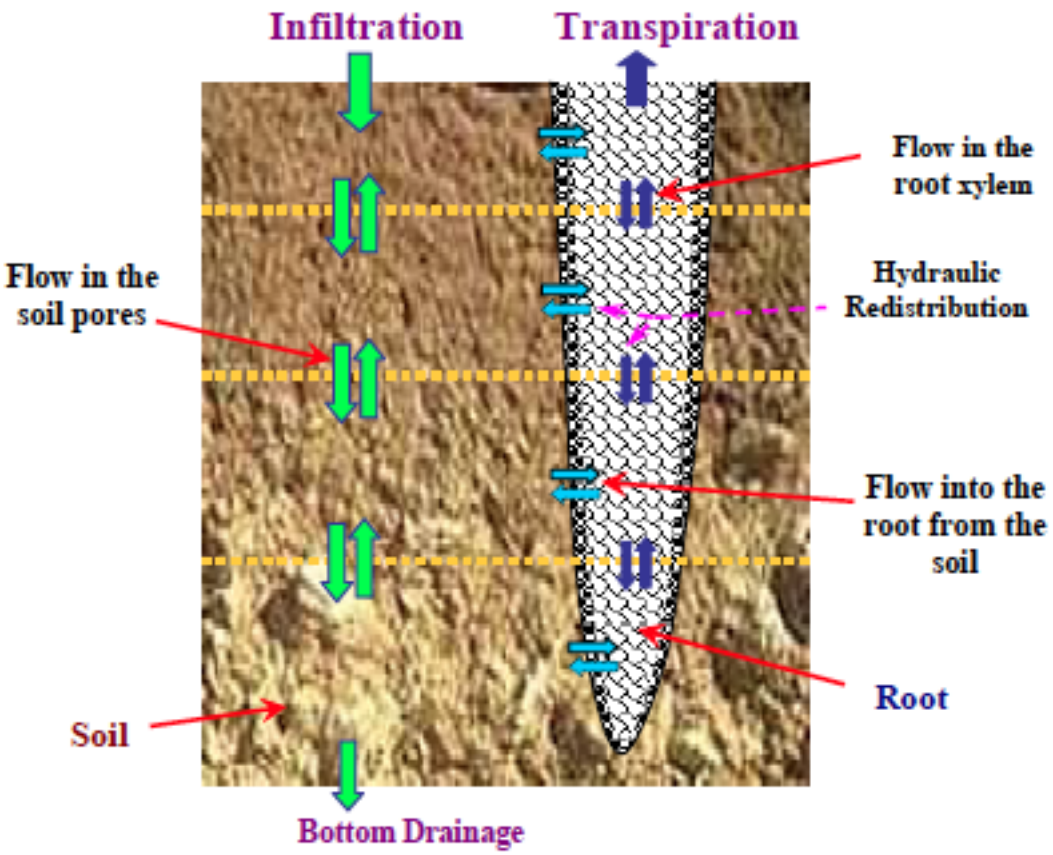


Fig. 2. Conceptual view of the hydraulic redistribution model as used in this study.

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

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

Sequential Coupling vs. Tight Coupling

Sequential model

- Process-splitting method

Step 1: solve Richards' equation

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

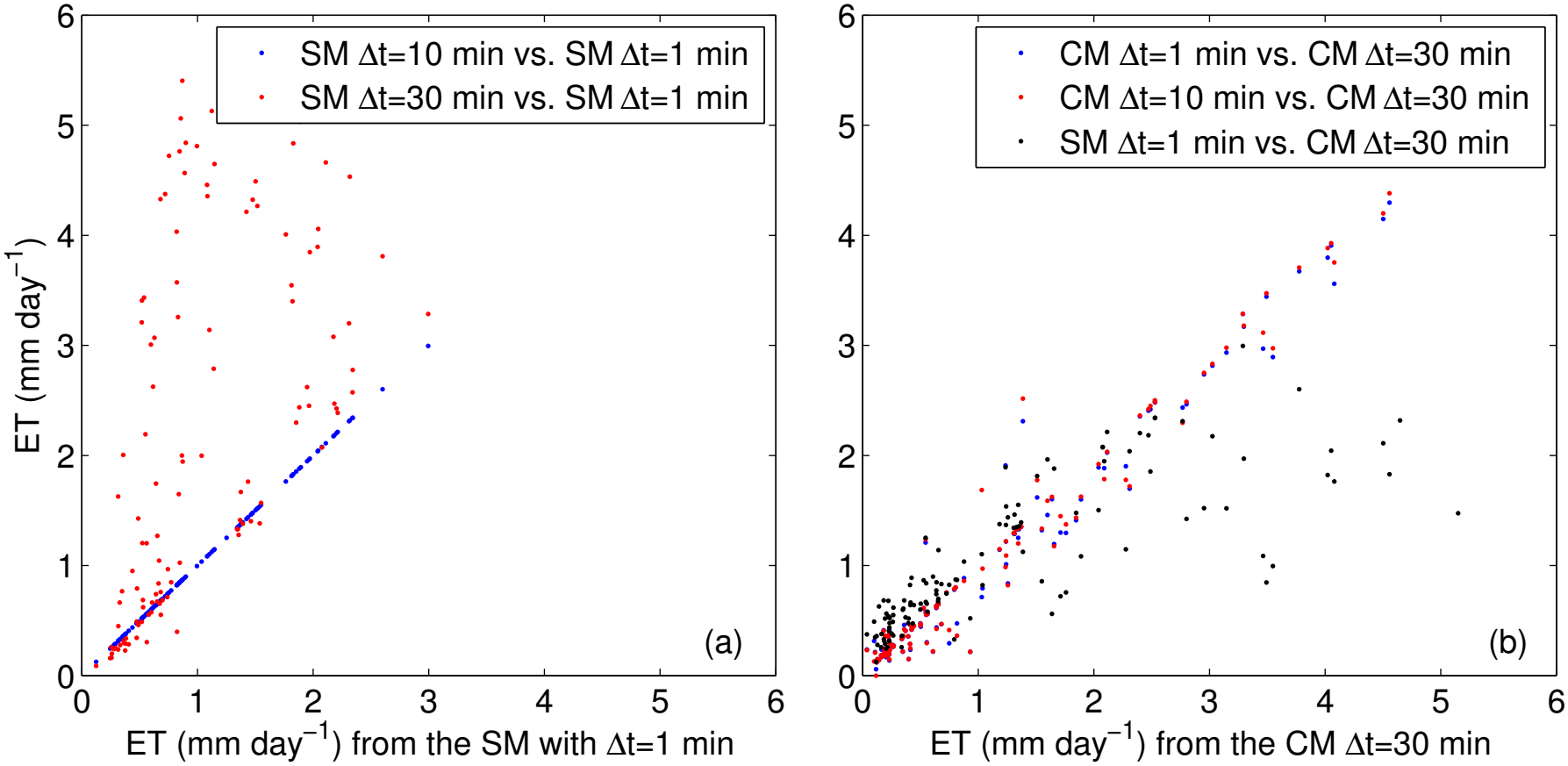
Step 2: solve root model

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

Coupled model

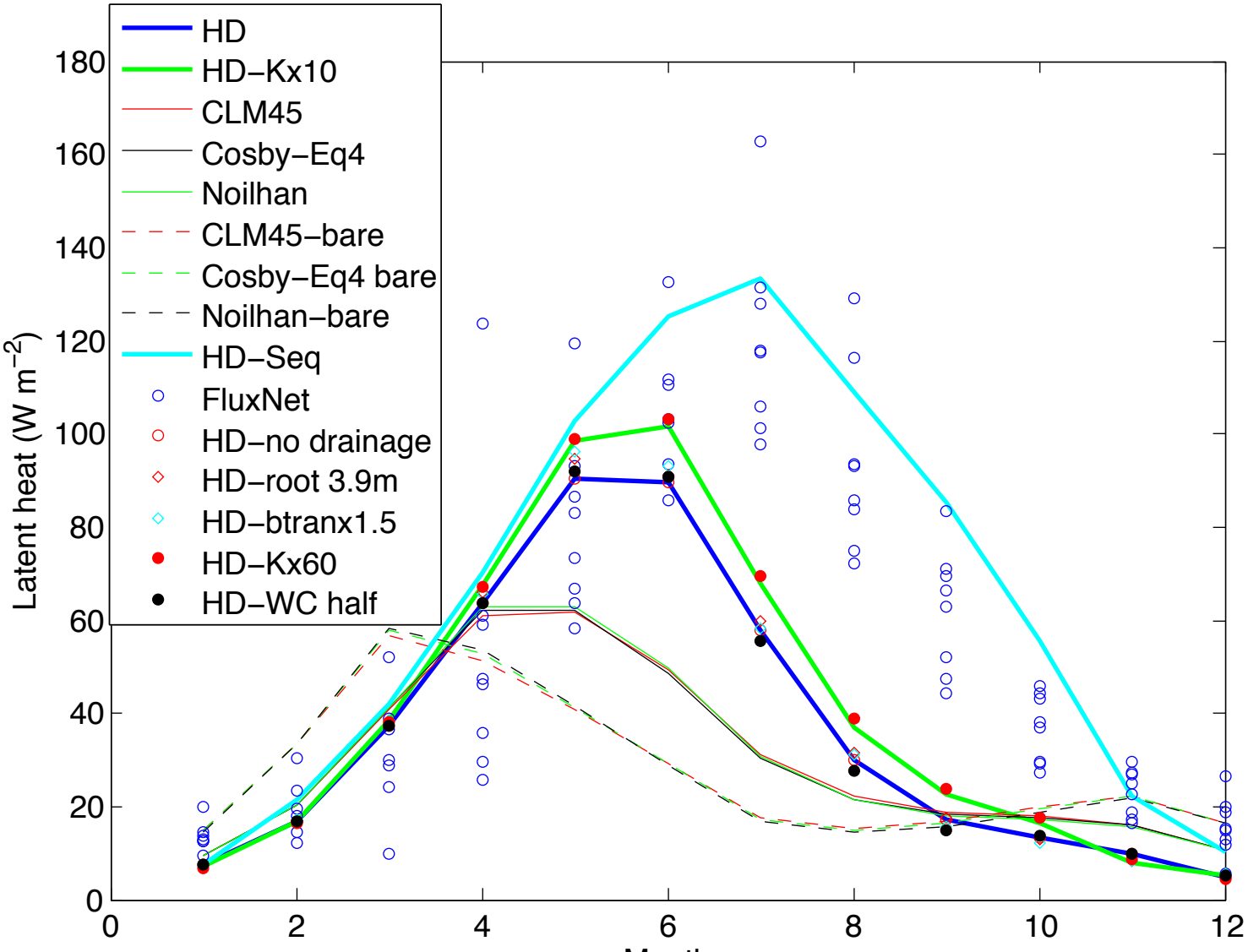
- Form and solve coupled system

Sequential model (SM) showed a large sensitivity to time stepping while the coupled model (CM) did not

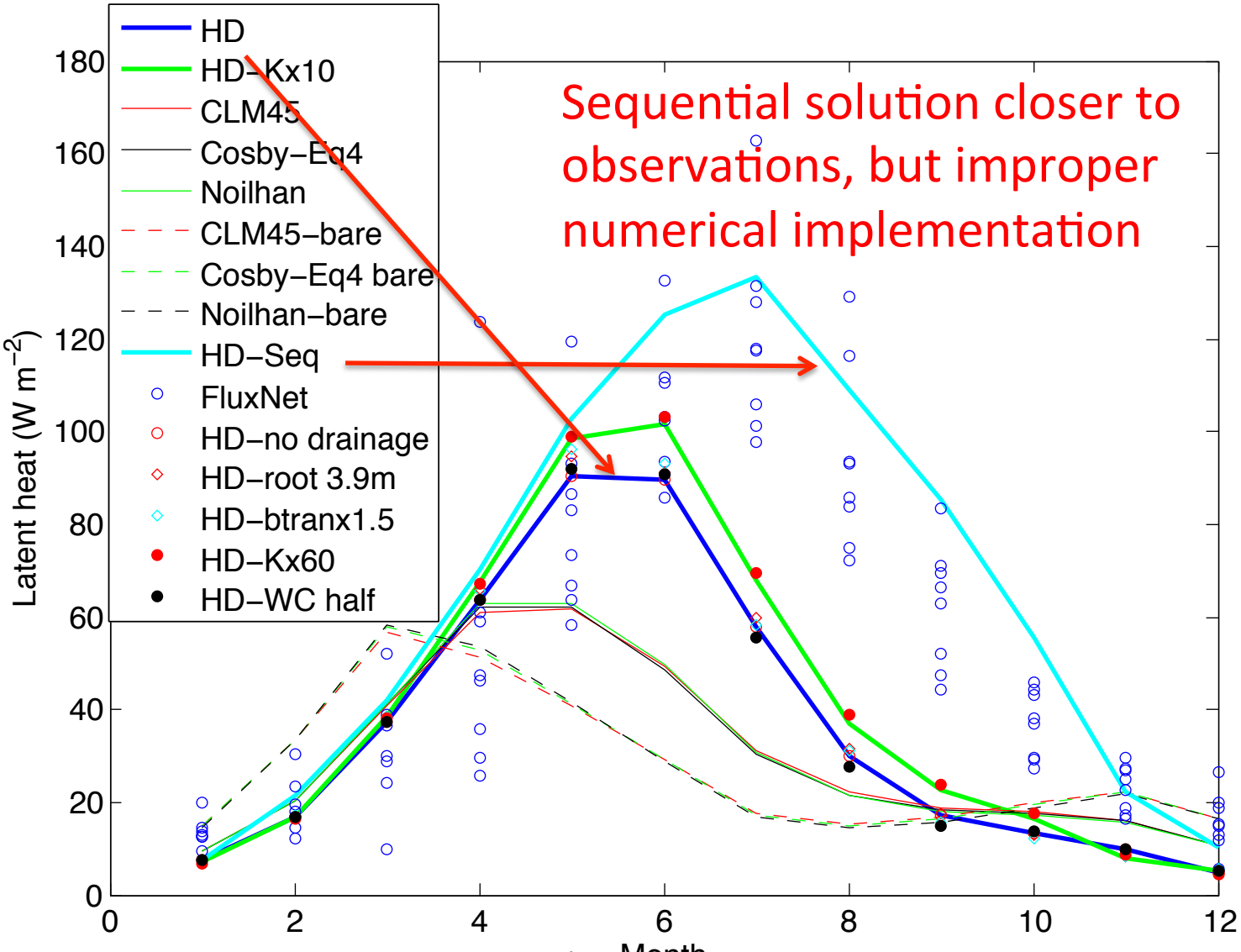


- We explored several uncertainty sources using the coupled model:
  - Root conductivity
  - Pedotransfer function
  - Drainage parameterization
  - Root depth
  - Btran
  - Convection velocity in Monin-Obukhov parameterization

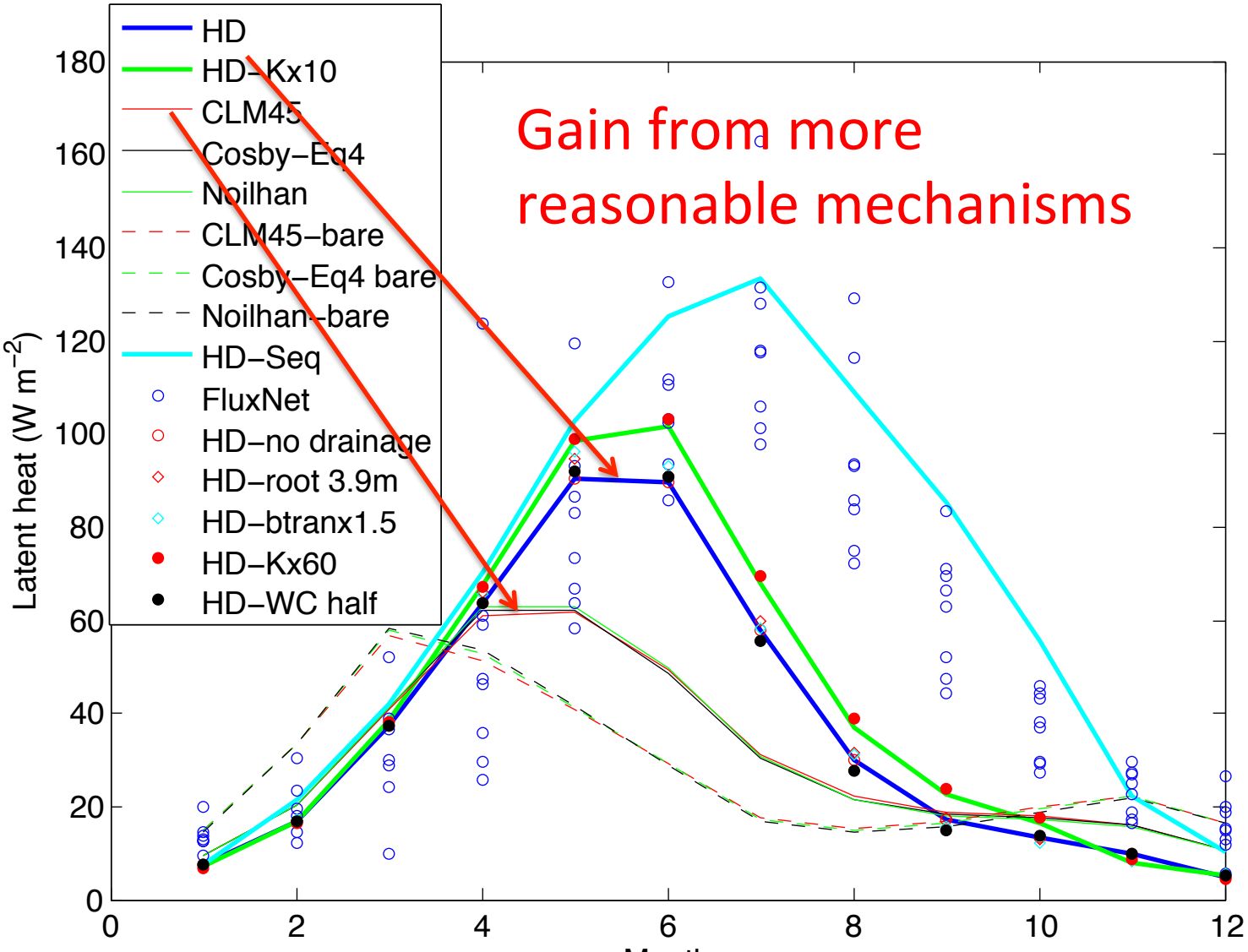
Sierra site latent heat evaluation



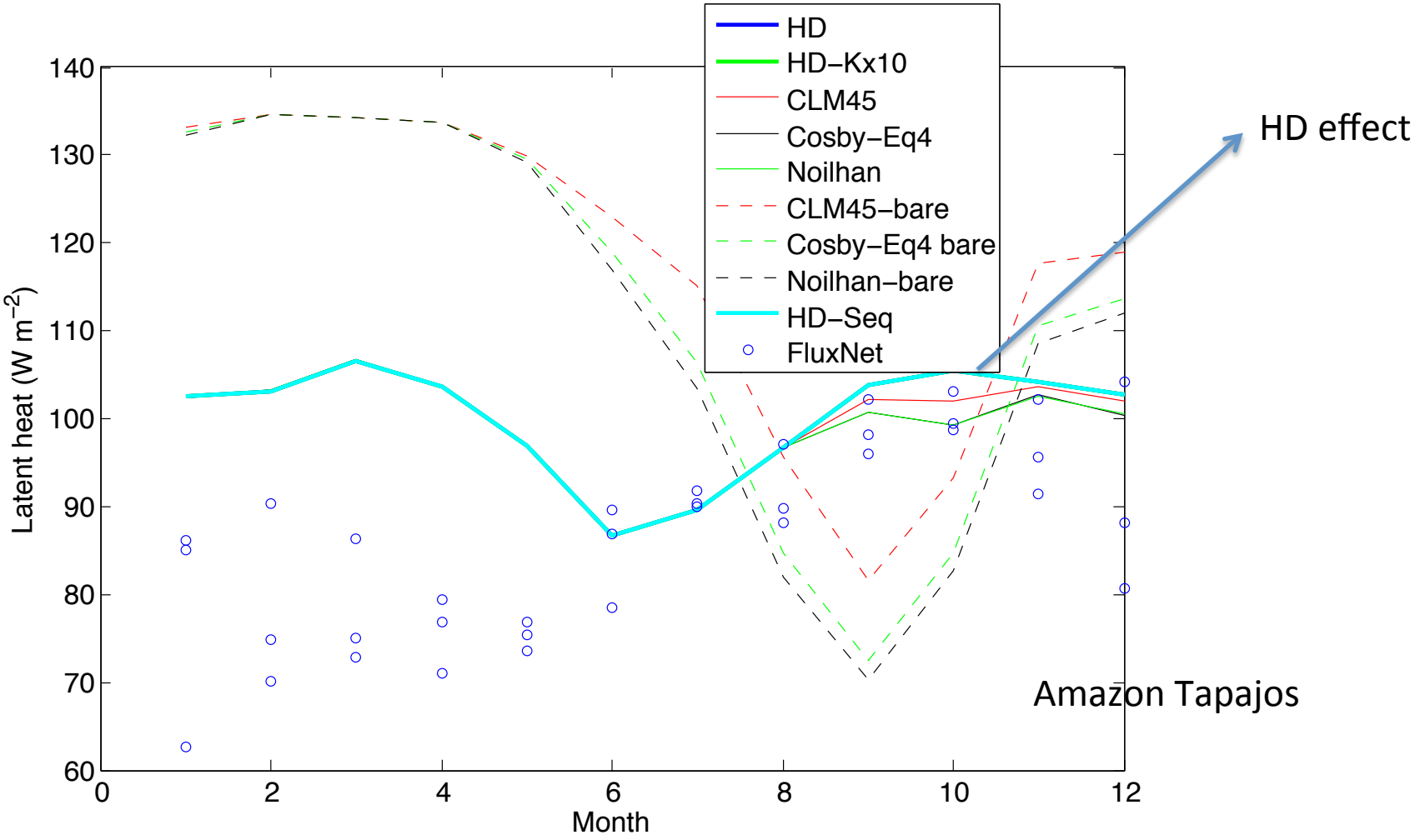
Sierra site latent heat evaluation



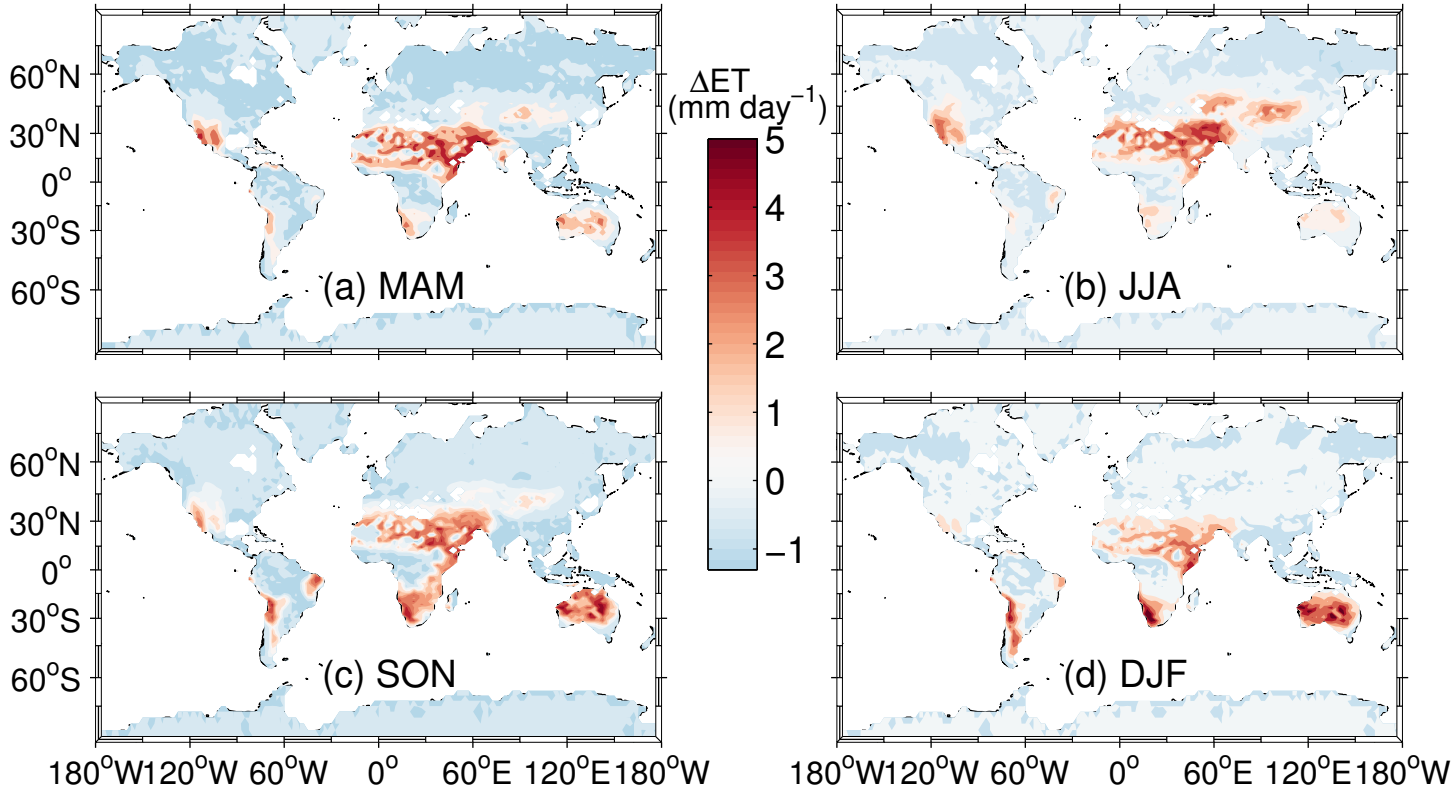
Sierra site latent heat evaluation



Small hydraulic redistribution at high precipitation sites

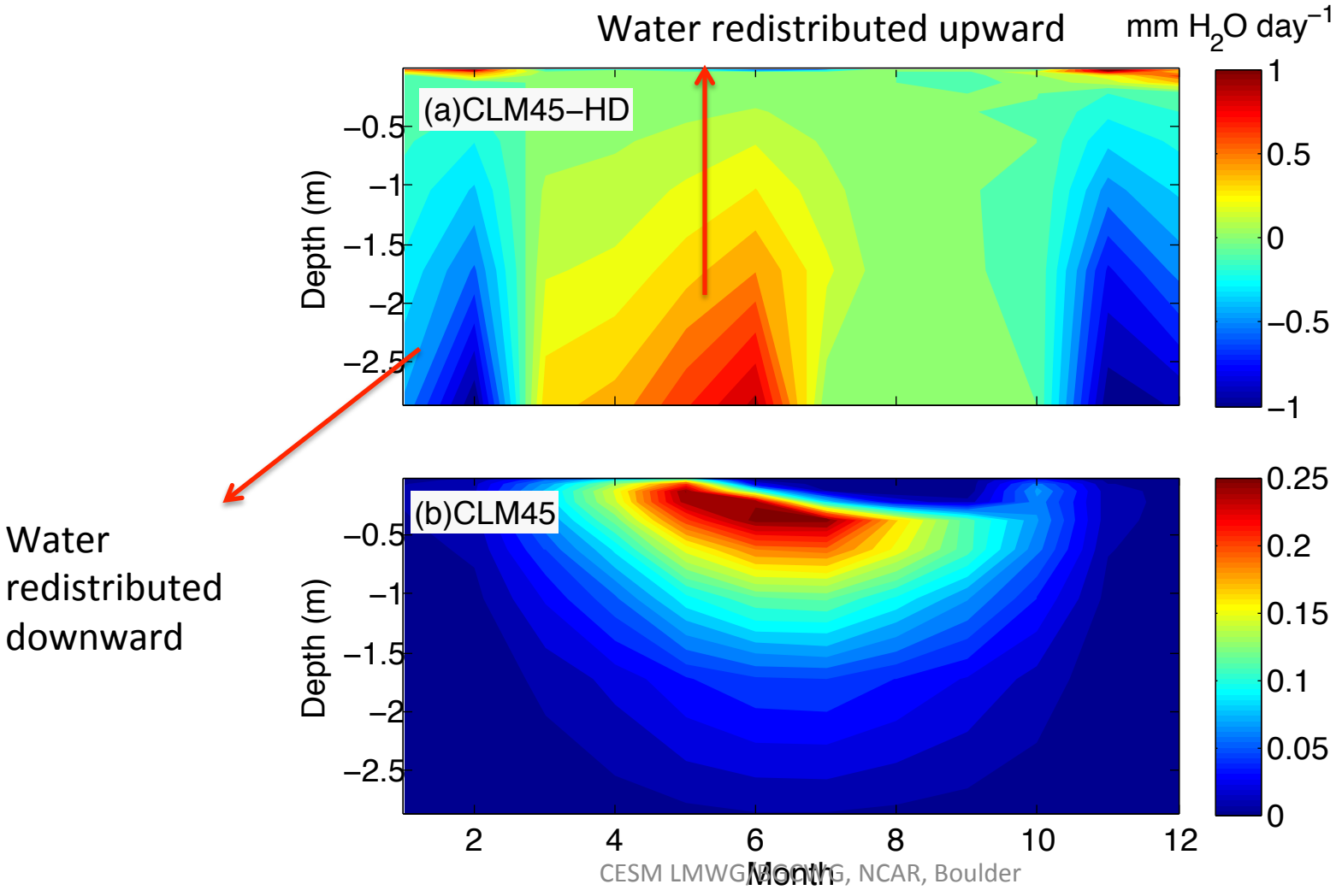


Sequential coupling vs. tight coupling: Nonphysical change in global ET

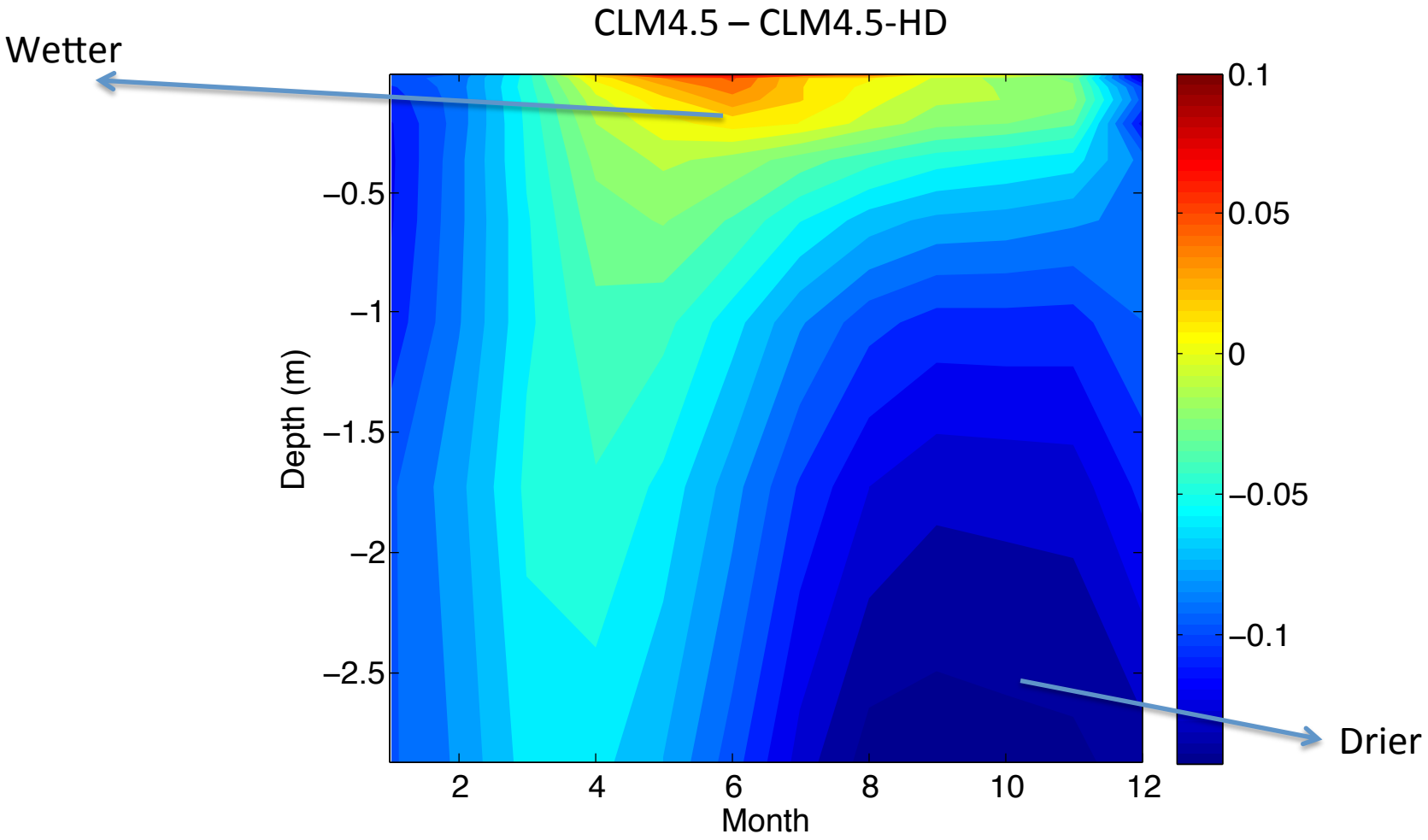


Sequential coupling minus tight coupling

Example: hydraulic redistribution affects seasonal root water uptake

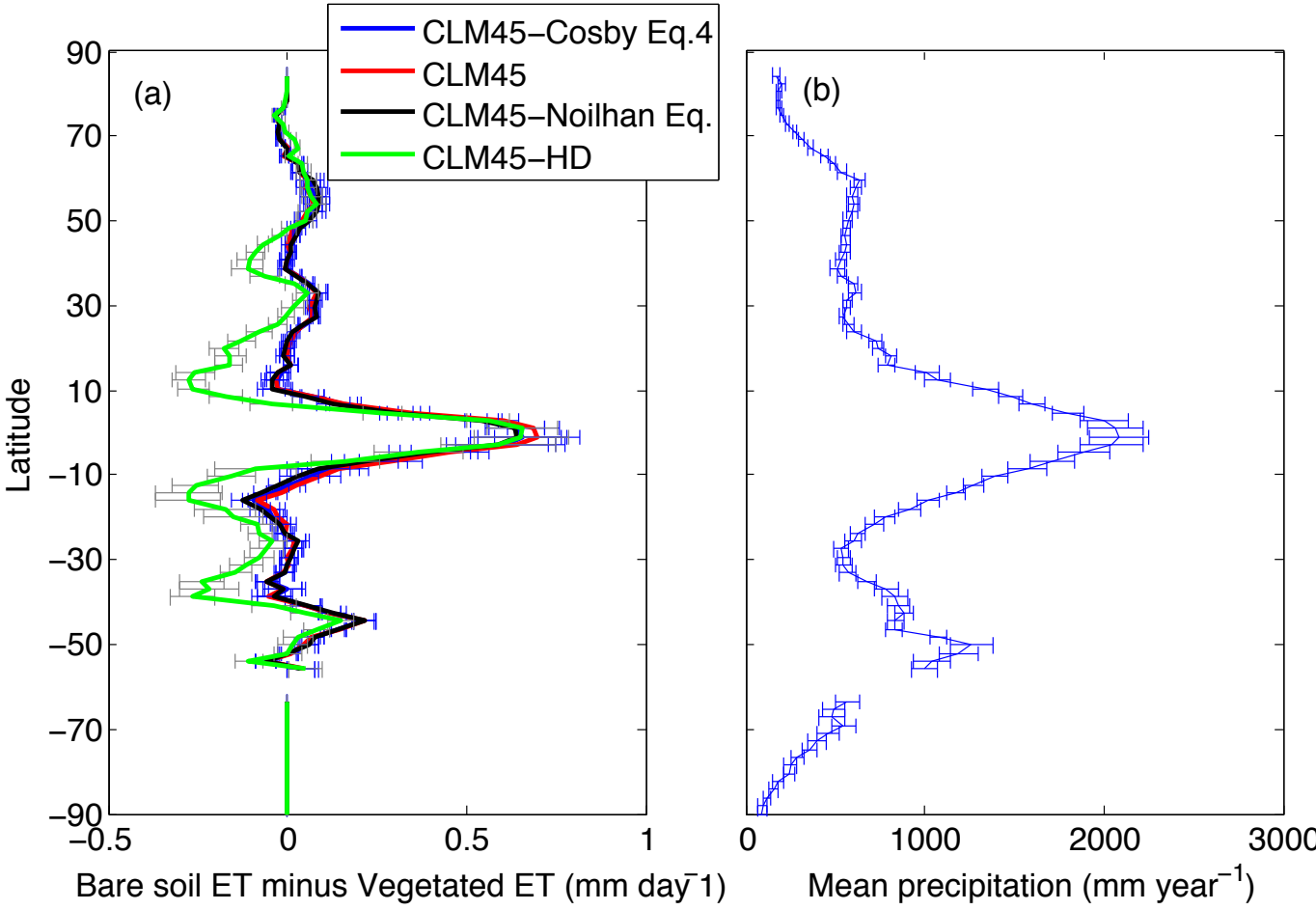


Example: hydraulic redistribution affects seasonal soil moisture



Change in latitudinal ET for vegetation removal experiments

Hydraulic redistribution impacts vegetation removal effect outside of high-precipitation regions



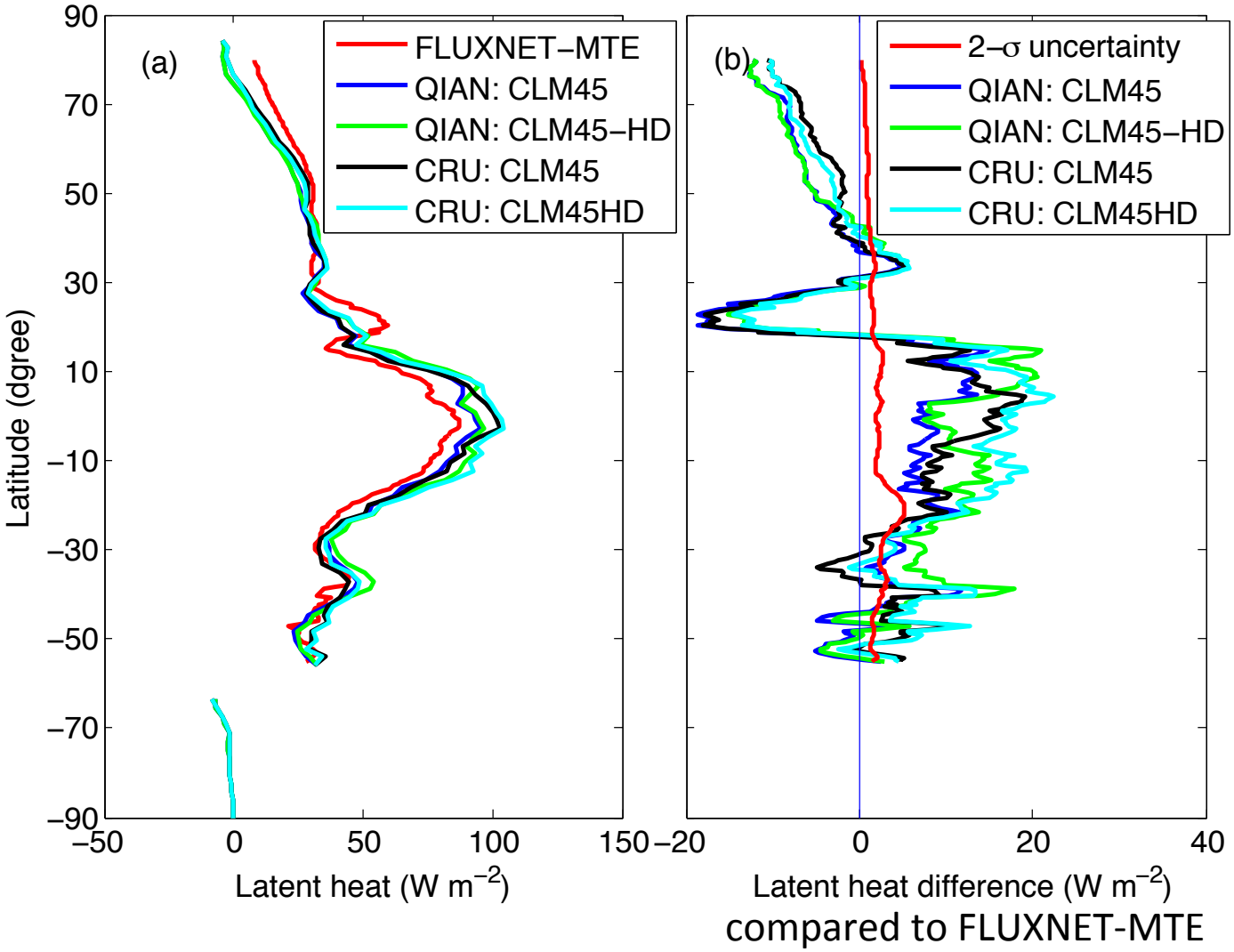
Summary and further work

- Robust numerical solution fit observation at Blodgett Forest worse than sequential solution
  - CLM is rife with these types of numerical solution problems
- Hydraulic redistribution reduces the possible ET bias in vegetation removal experiments by enhancing dry period ET
- The three pedotransfer functions did not result in very large differences in the ET anomaly from vegetation removal, but they likely underestimated the impacts (e.g. LBA experiment indicates very different soil texture compared to what CLM45 uses)
- For a full evaluation of the ET problem, CLM needs restructuring to account for flexible formulations of many processes, e.g., pedotransfer function, root depth profile, soil resistance, root water uptake, etc.

Acknowledgements

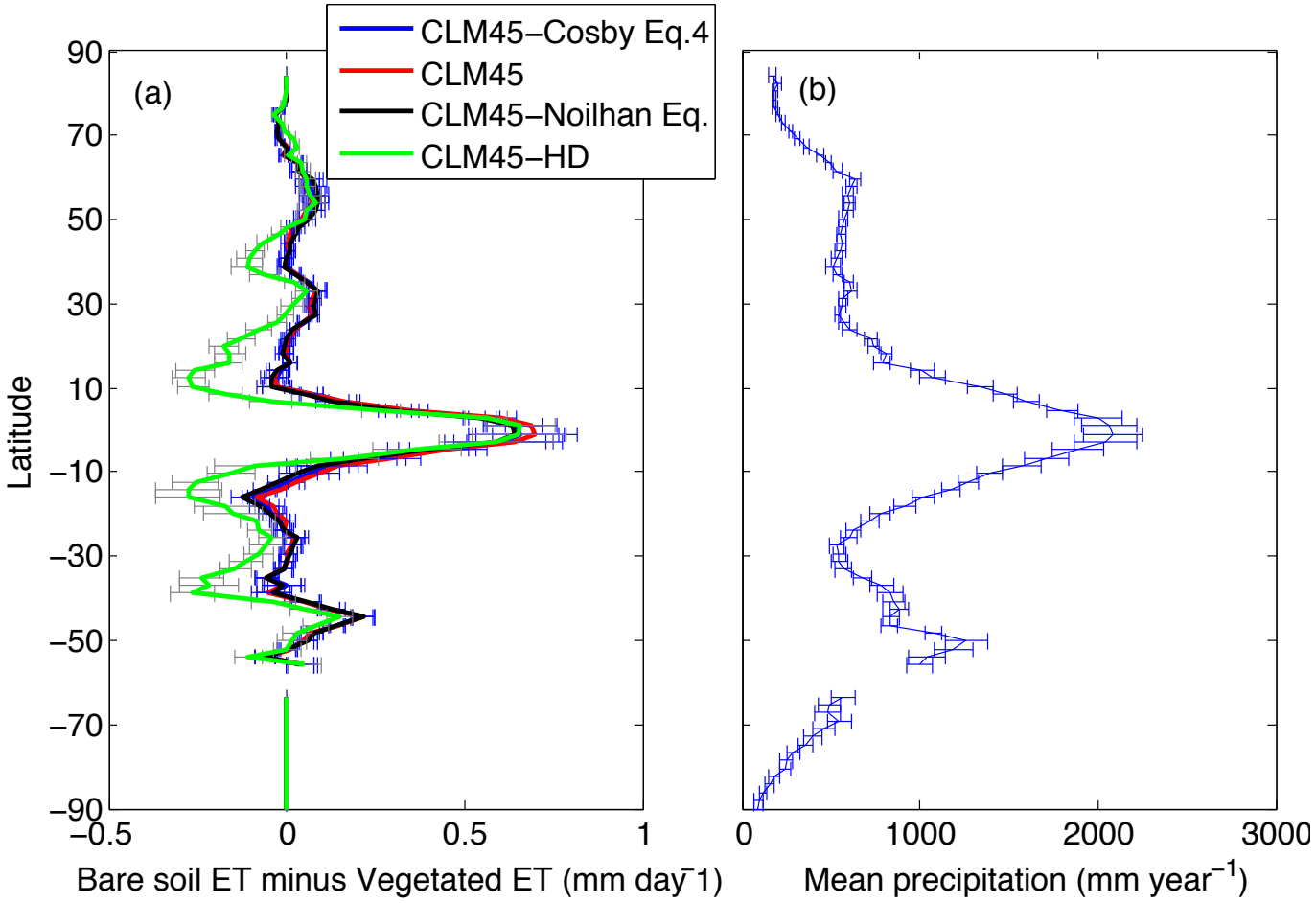
- This work was supported by DOE

LH evaluation against FLUXNET-MTE



Extra slides

Change in latitudinal ET for vegetation removal experiments



Uncertain hydraulic parameter estimation by pedotransfer function for soils in Iran