Irrigation and Plant Hydraulics Parameterizations in CLM5

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Outline

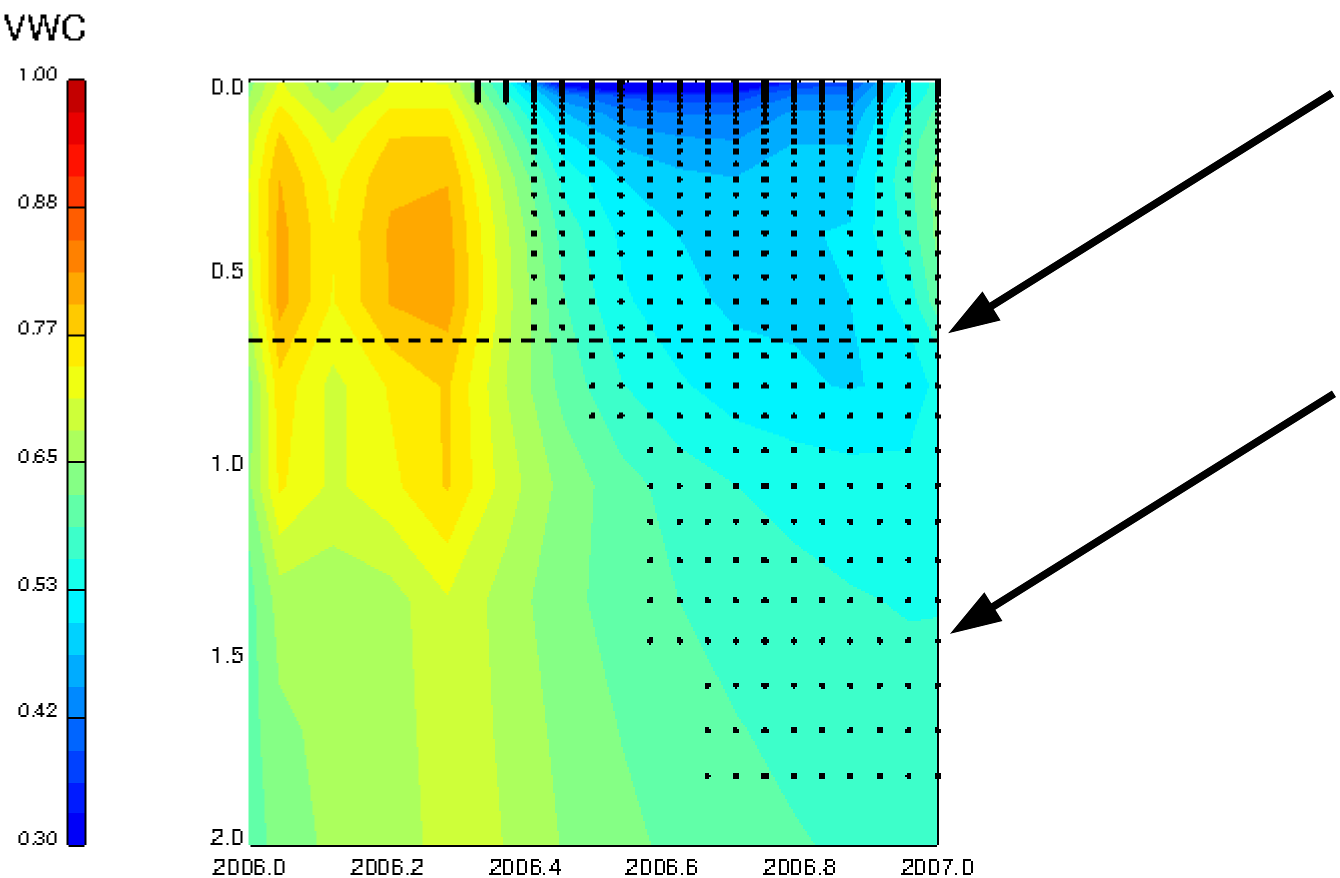
- Update to Irrigation
- Update to Plant Hydraulics
- Update to Irrigation Update

Motivation for Irrigation Modifications

- Based on *ad hoc* transpiration beta function
- Irrigation deficit considered entire soil column
- Indications that runoff ratio was too high

New Irrigation Triggering Parameterization

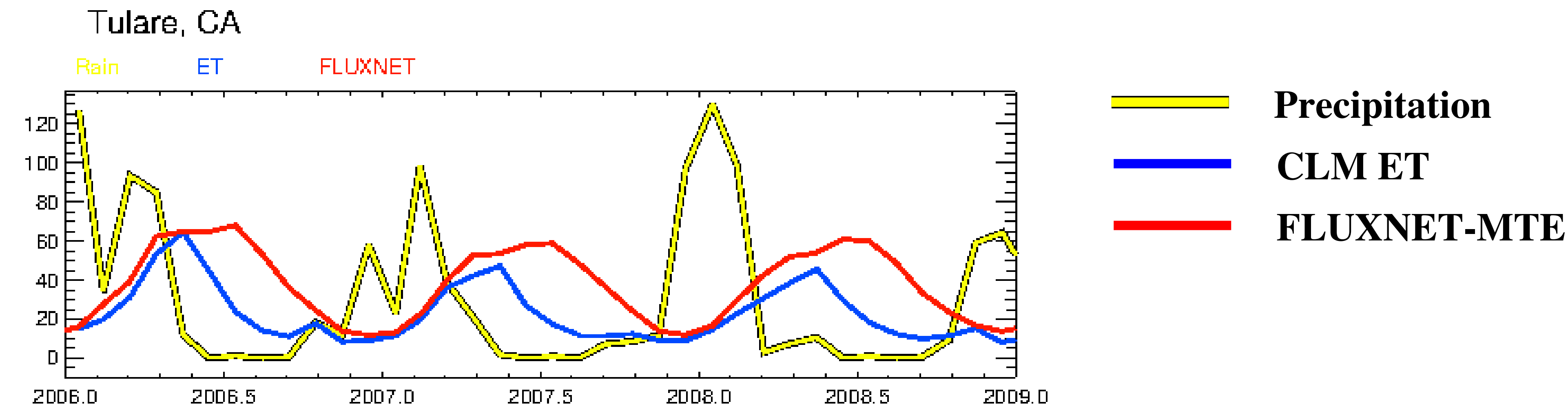
- Based on soil moisture state in root zone
- Three parameters: root zone depth, target soil moisture, and distance from target

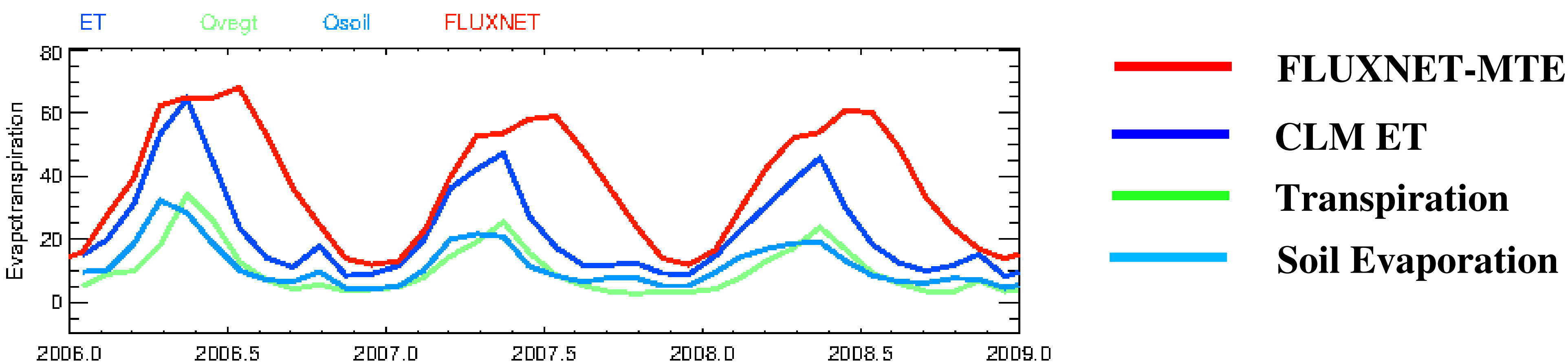


Root zone depth

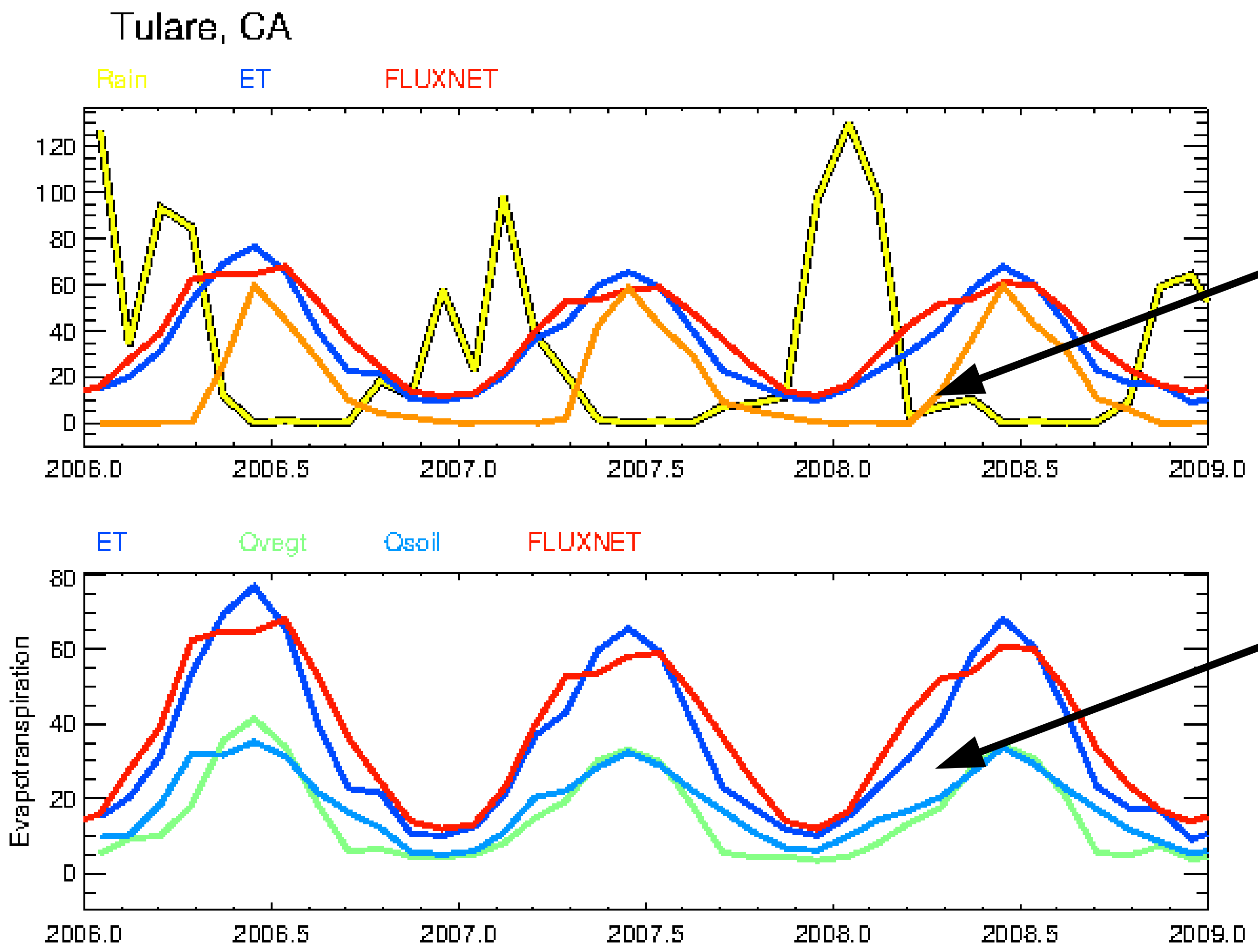
Stippling indicates soil moisture below threshold value

Case Study: California's Central Valley





Initial Results with New Irrigation Trigger

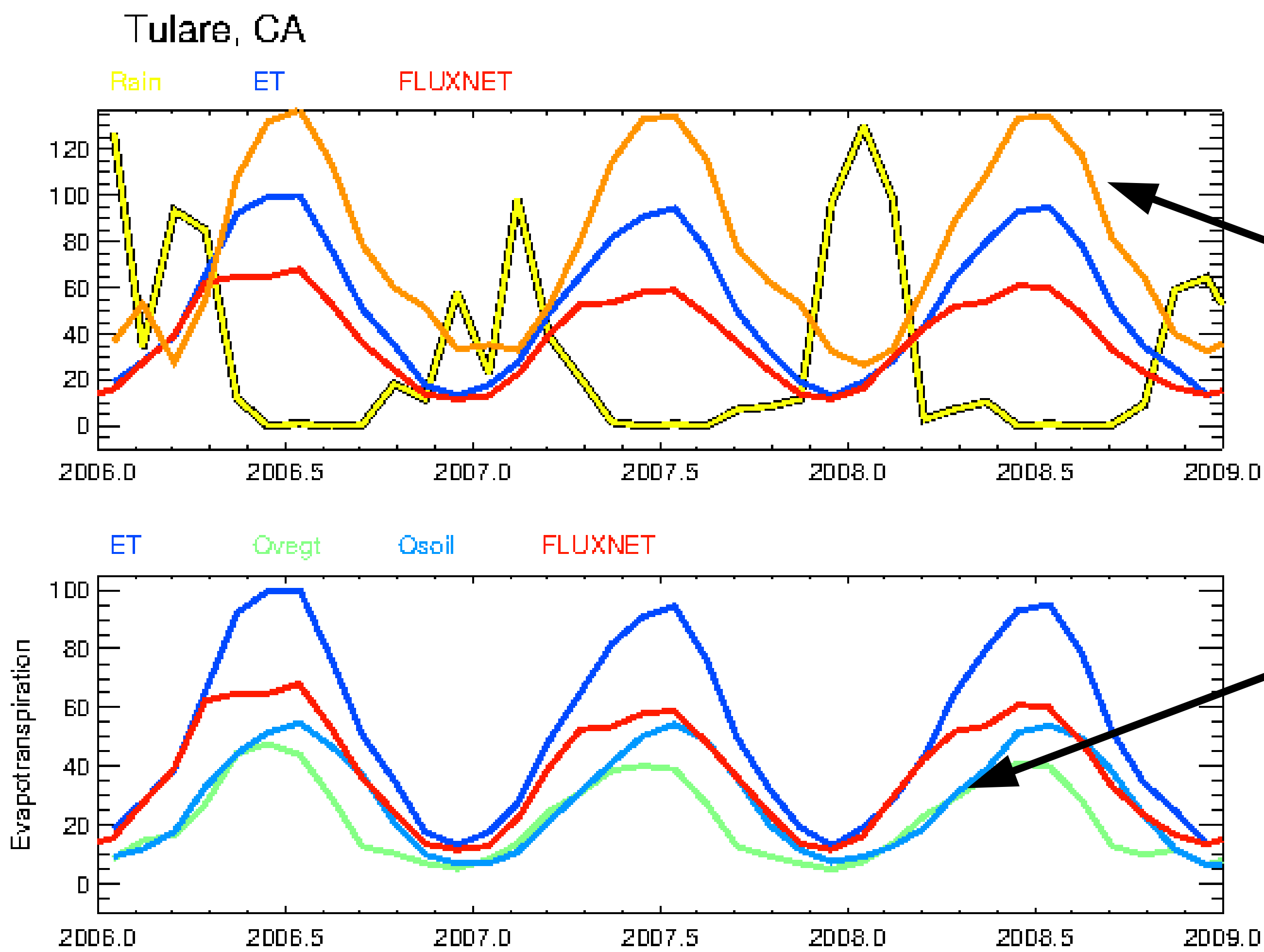


CLM Irrigation

Irrigation occurs during dry season

ET partitioning roughly equal

Sensitivity to Very Large Irrigation Flux



CLM Irrigation

Irrigation can be set to very high levels

Transpiration shows little increase

Summary of Irrigation Modifications

- Irrigation triggering parameterization works as expected
- The response of crops to irrigation did not conform to expectations
- Why do crops not respond to irrigation?

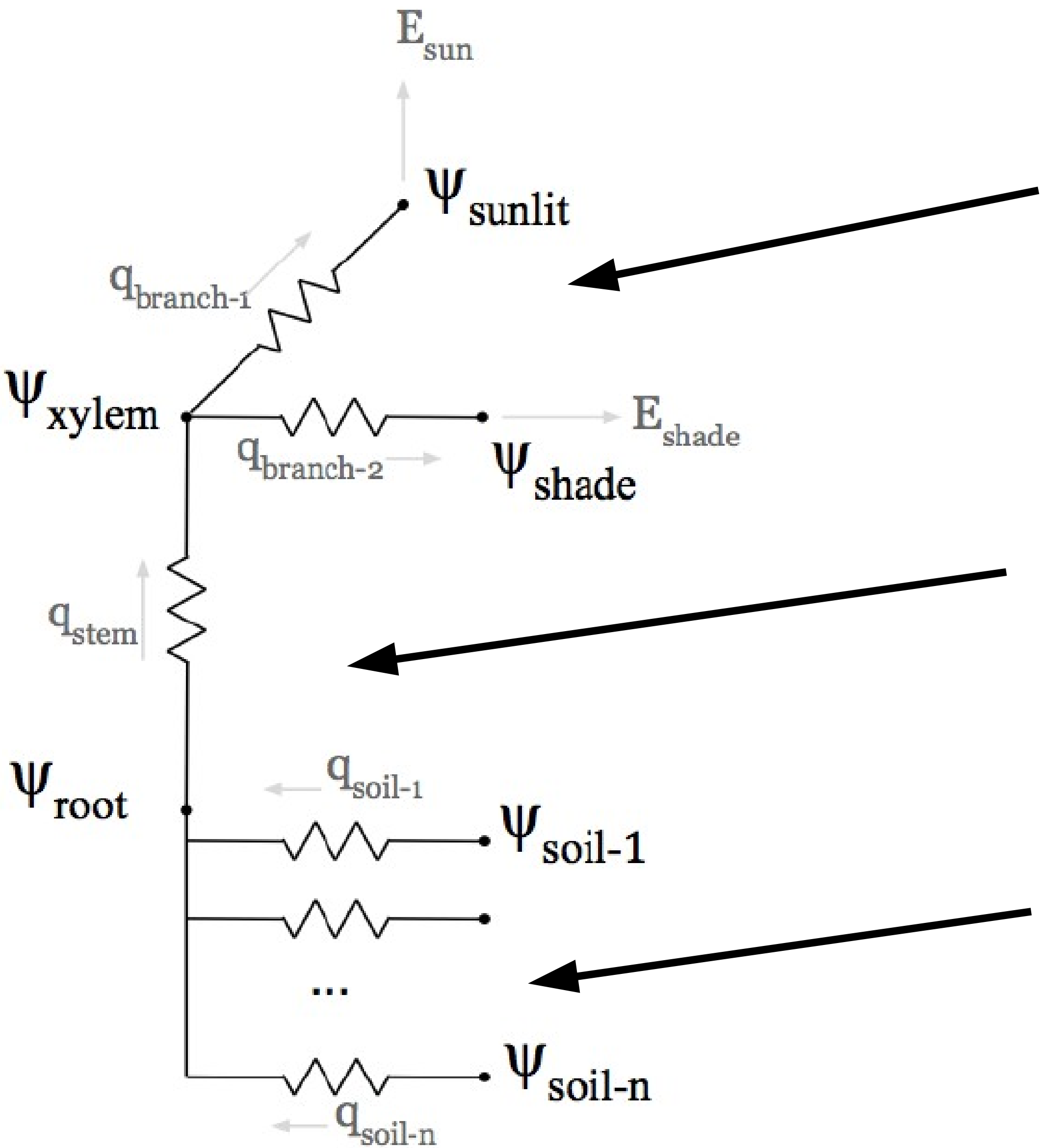
Plant Hydraulics

To mechanistically represent gradients in water potential through the soil-vegetation-atmosphere continuum, Kennedy and Gentine introduced a “Plant Hydraulic Stress” parameterization in CLM5.

- Tracks water potential through the canopy
- Uses a resistance network to model moisture flow
- Calculates a new transpiration beta function (“b-tran”)

PHS Resistance Diagram

Figure 1: Circuit Analog Schematic



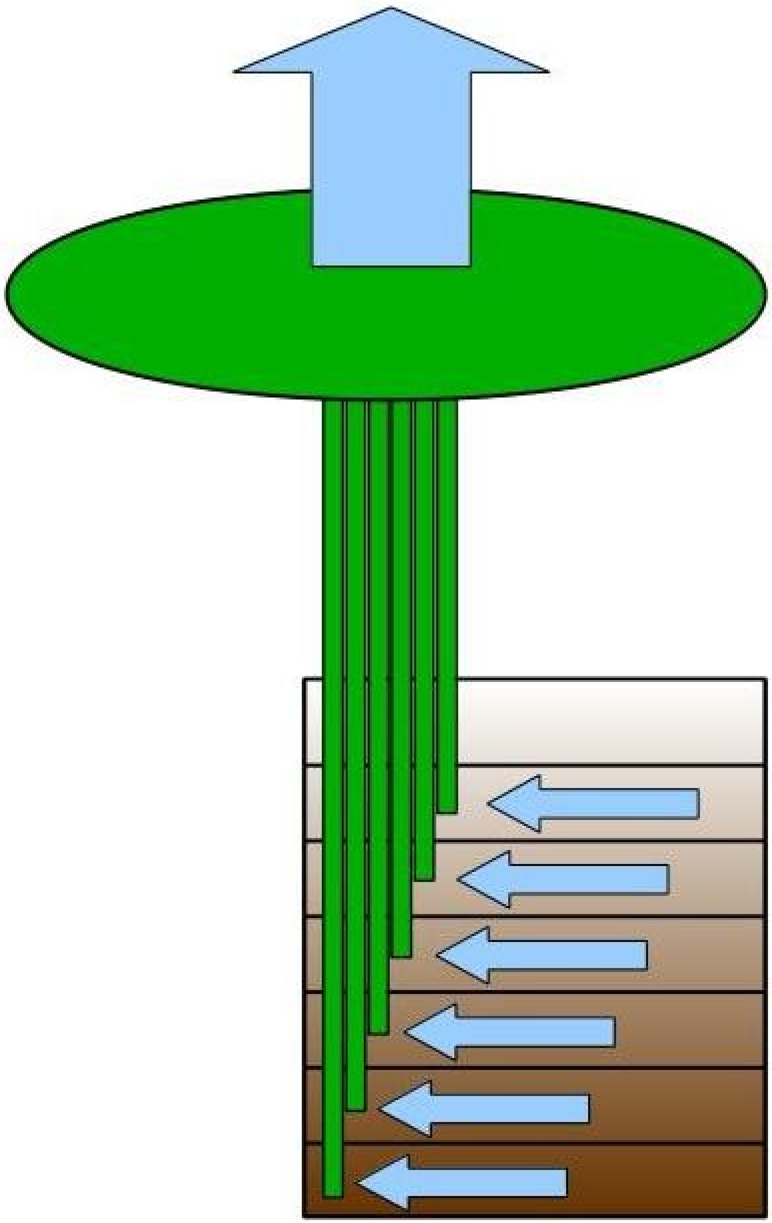
Separate terms for sunlit and shaded portions of canopy

Separate terms for xylem, stems, and roots

Soil pathways vertically resolved

From Daniel Kennedy, *personal communication*

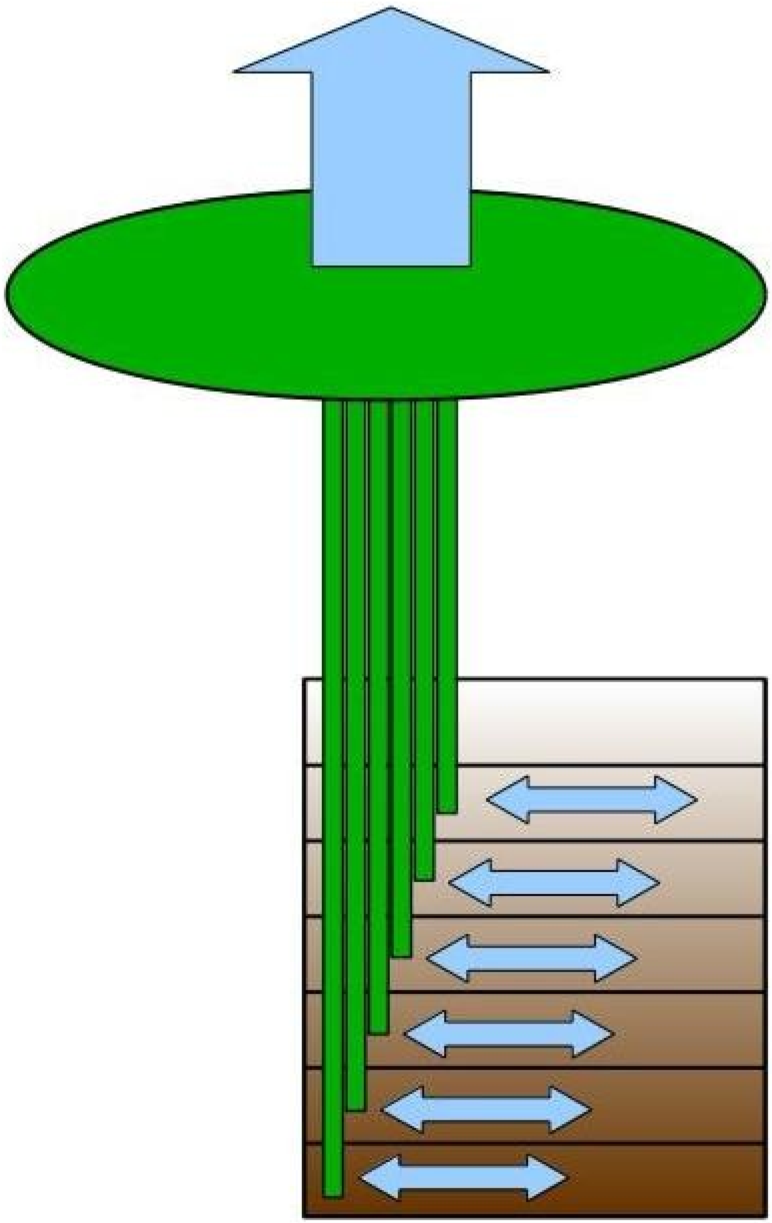
Transpiration in CLM ≤ 4.5



In CLM4.5, the total transpiration flux is partitioned across soil layers

By construction, all fluxes are positive out of the soil

Transpiration in CLM 5

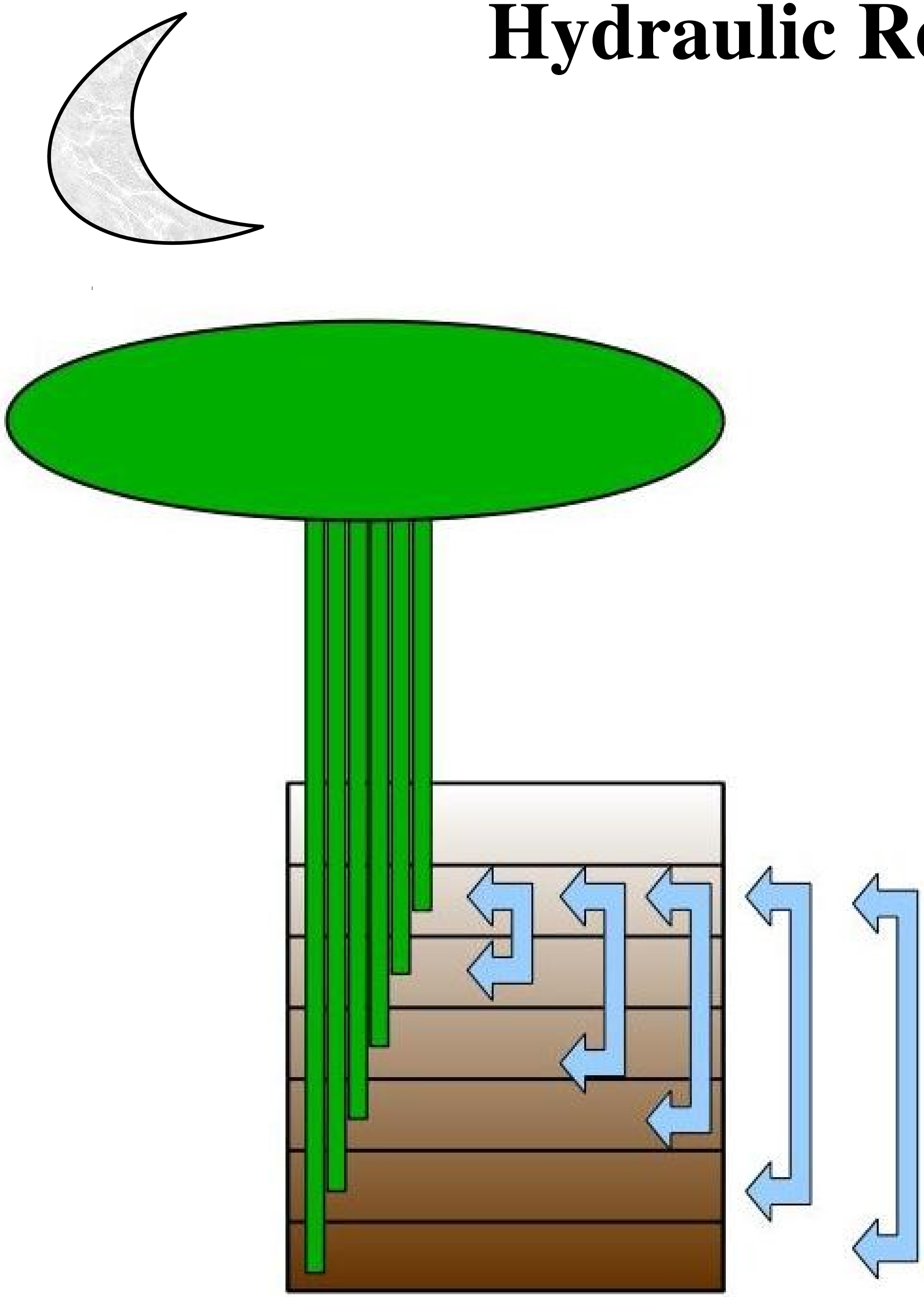


In CLM5, the transpiration fluxes are not constrained to be positive

Furthermore, because of the model structure, different soil layers may interact via the root system

This allows plant-mediated hydraulic redistribution

Hydraulic Redistribution



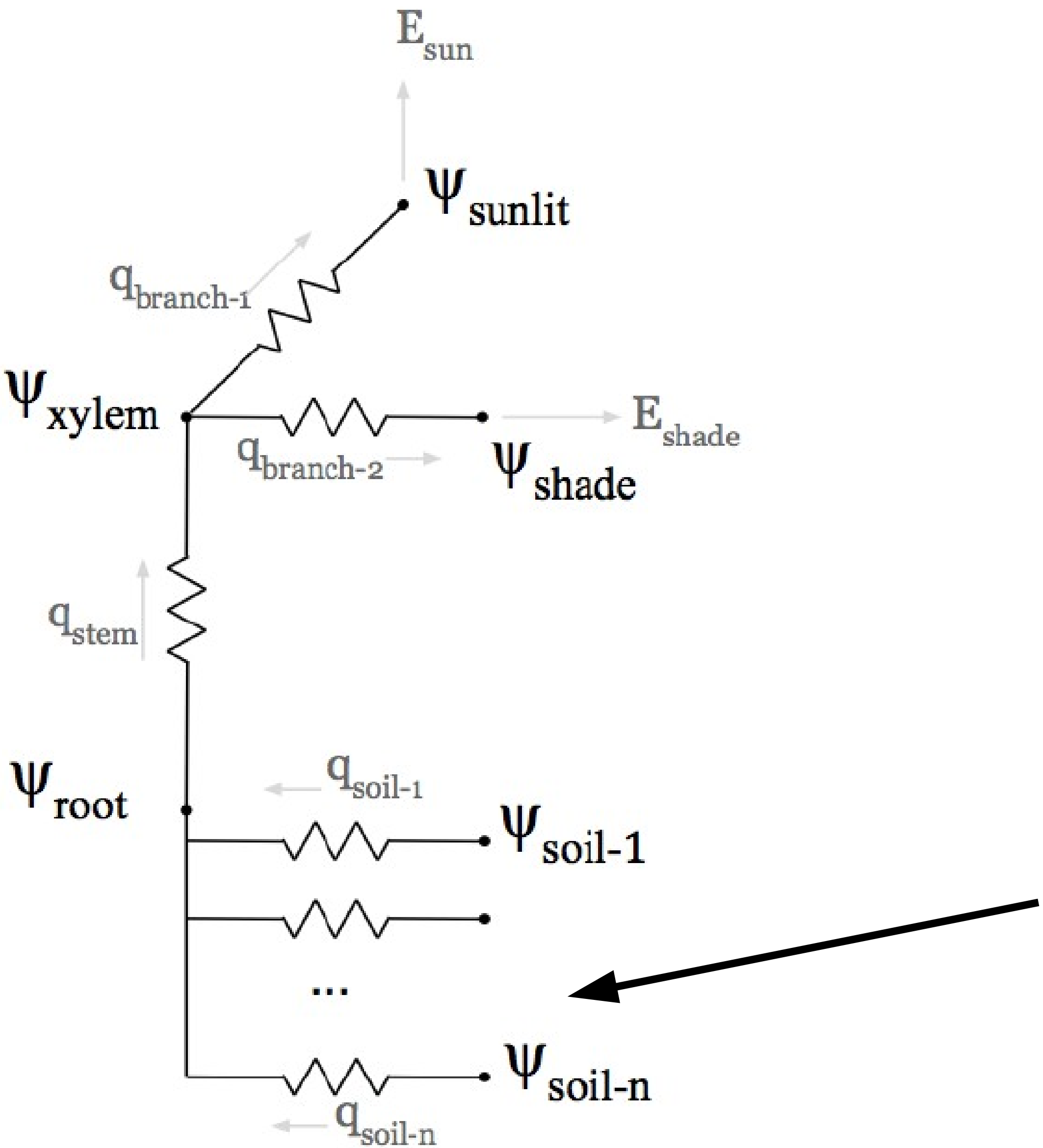
Particularly at night, when transpiration tends to zero, gradients in soil moisture are reduced by this process

If large gradients exist, large inter-layer soil moisture fluxes occur that can cause numerical instabilities

This was constrained via parameter value selection

PHS Modifications

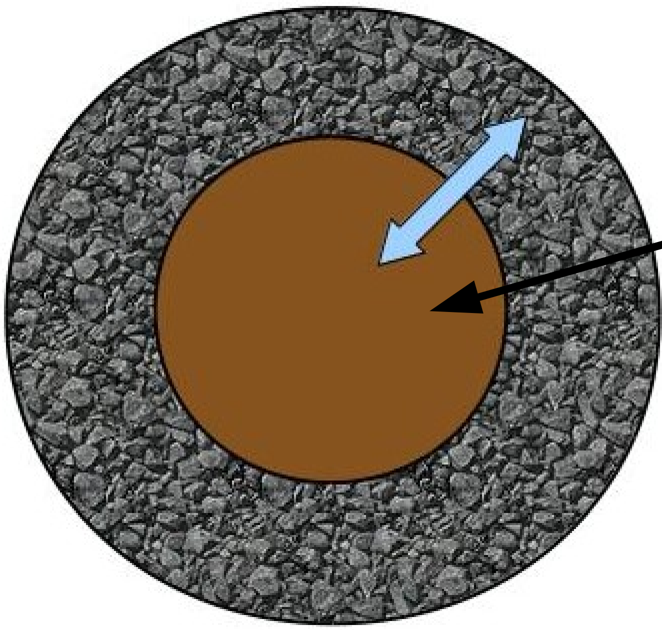
Figure 1: Circuit Analog Schematic



Resistances between soil and roots did not fully account for soil hydraulic properties

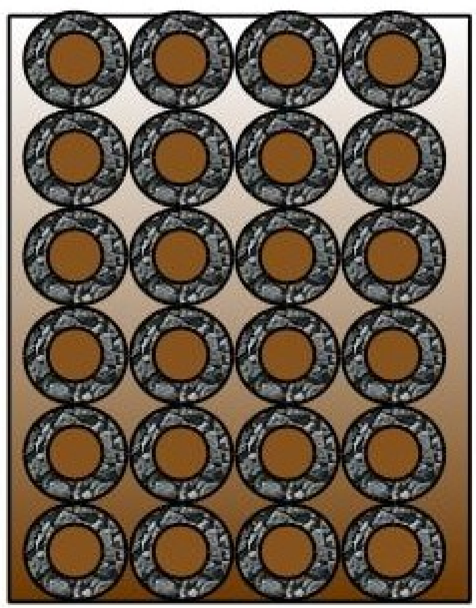
A separate resistance representing soil hydraulic conductivity was added to the original formulation

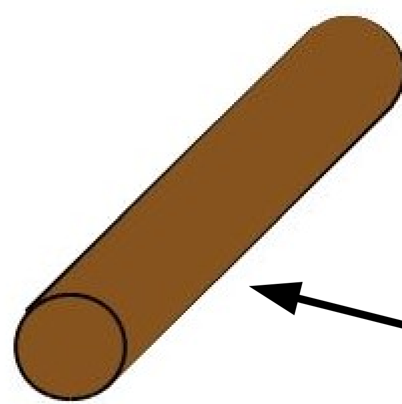
Soil – Root Resistances



Soil-to-root resistance is modelled as a coaxial cable

Roots are assumed to uniformly fill a soil layer

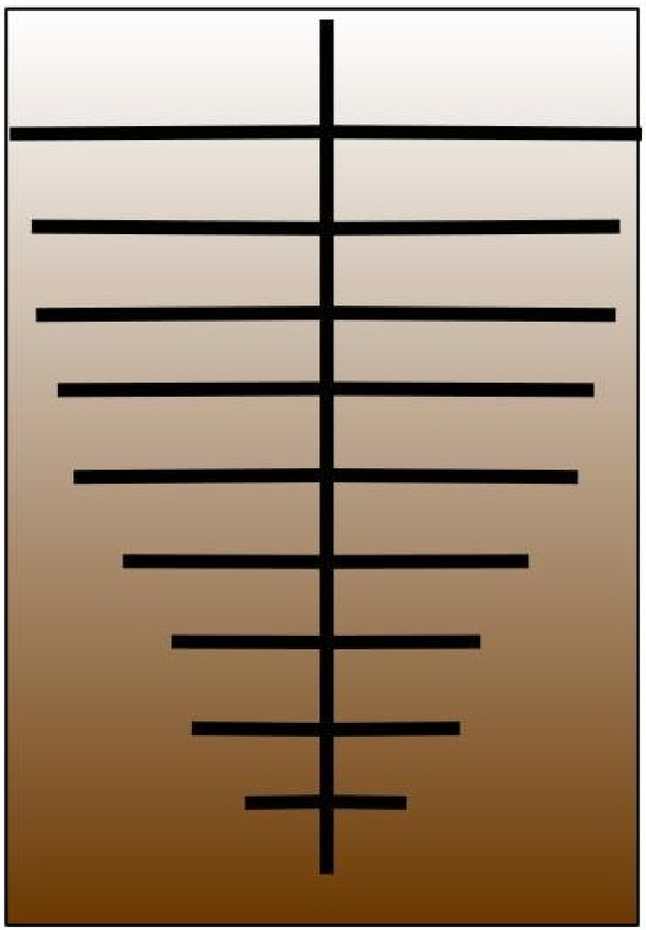




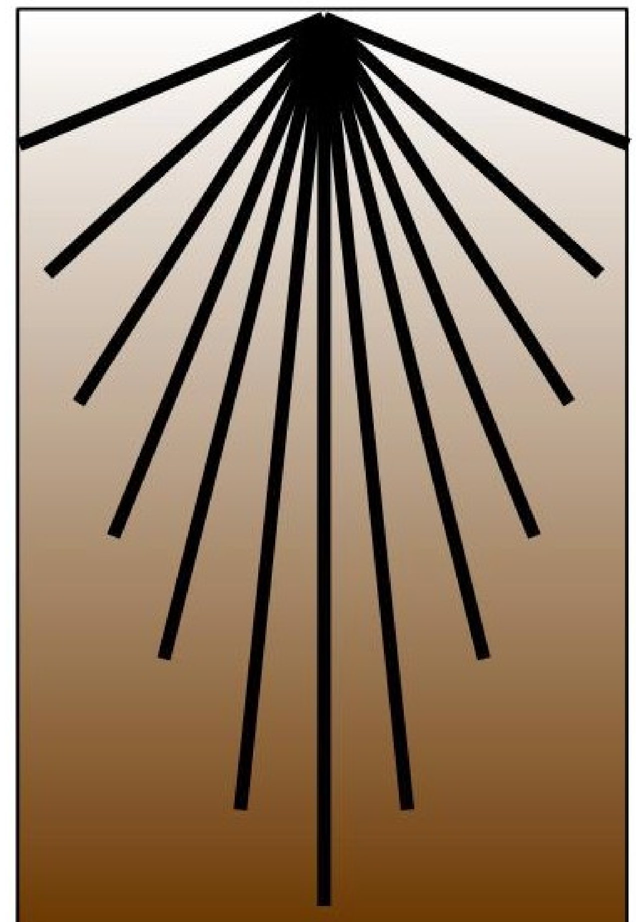
Root length is derived from root biomass and assumptions of root geometry and size

Root Connectivity

Roots can be modeled as an array of roots communicating with a central “tap” root



Roots can be modeled as extending radially from a single root “ball”



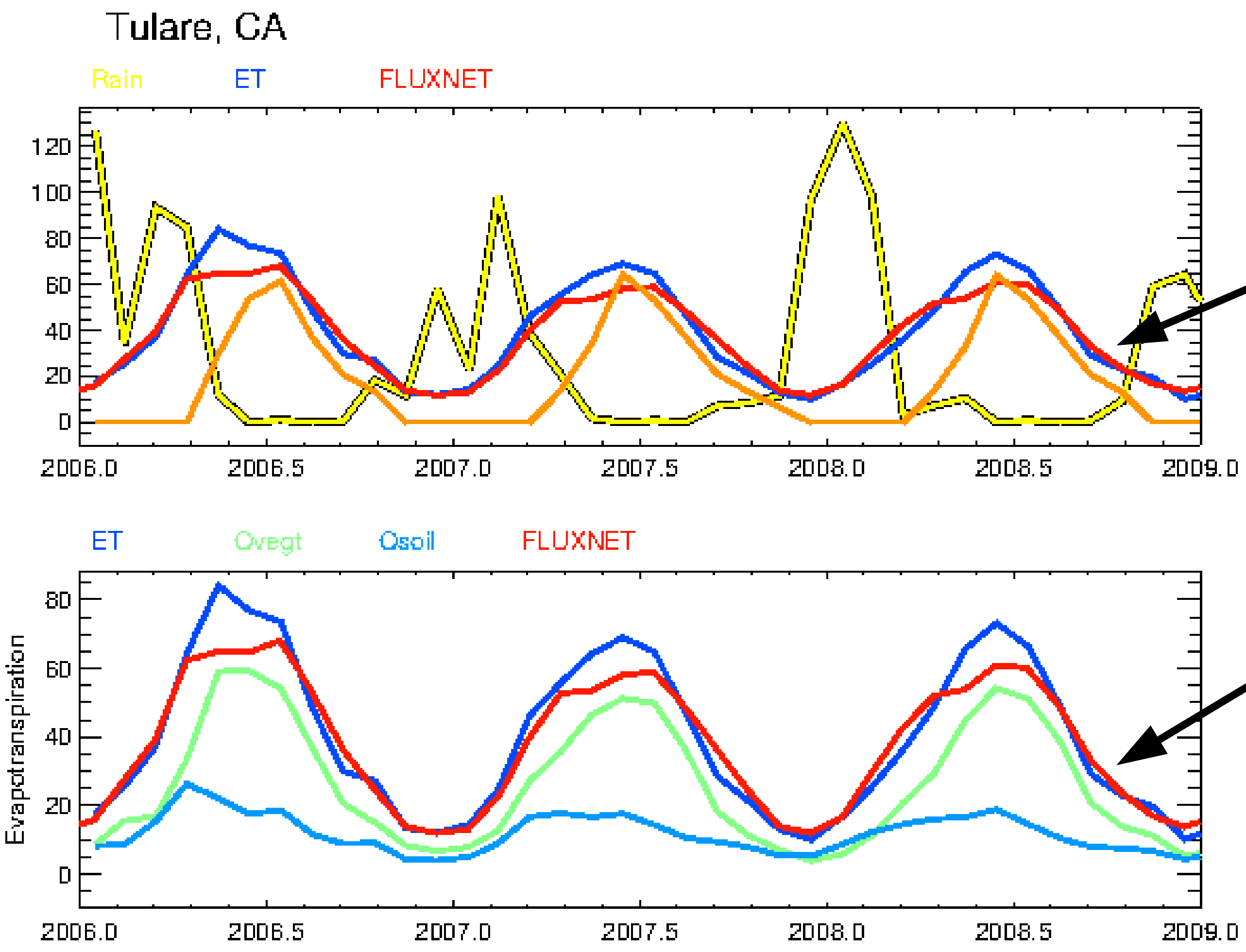
Summary of Plant Hydraulics

- The effect of soil moisture state on vegetation water potential is explicitly modeled
- This also allows root-mediated soil moisture redistribution
- The original implementation required modifications to reduce numerical instabilities related to overly large hydraulic redistribution

Update to Crop Response to Irrigation

- Why do crops not respond to irrigation?
- Crops could not respond to irrigation because of PHS constraints
- With larger plant hydraulic conductivities, crop response is greater

Irrigation Response after PHS Changes



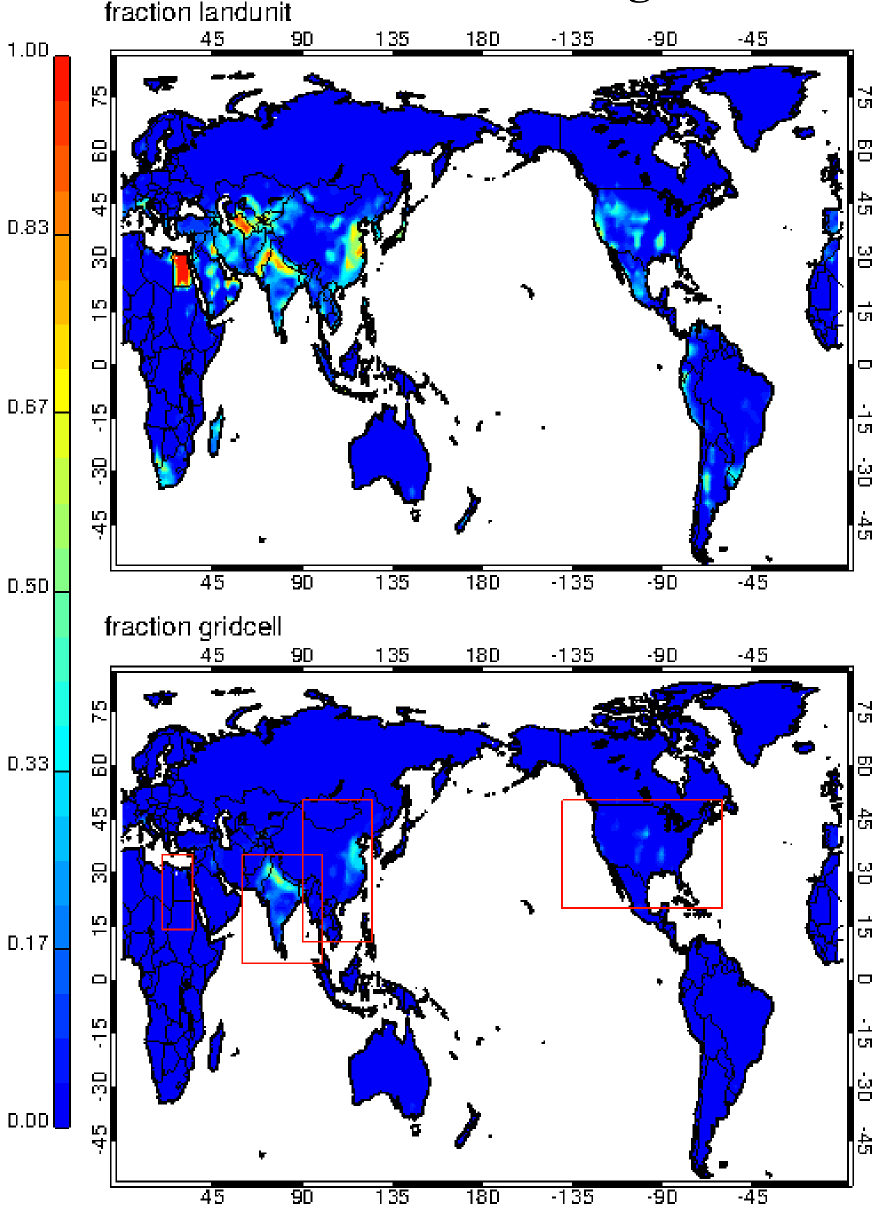
CLM Irrigation

Irrigation fulfills ET demand

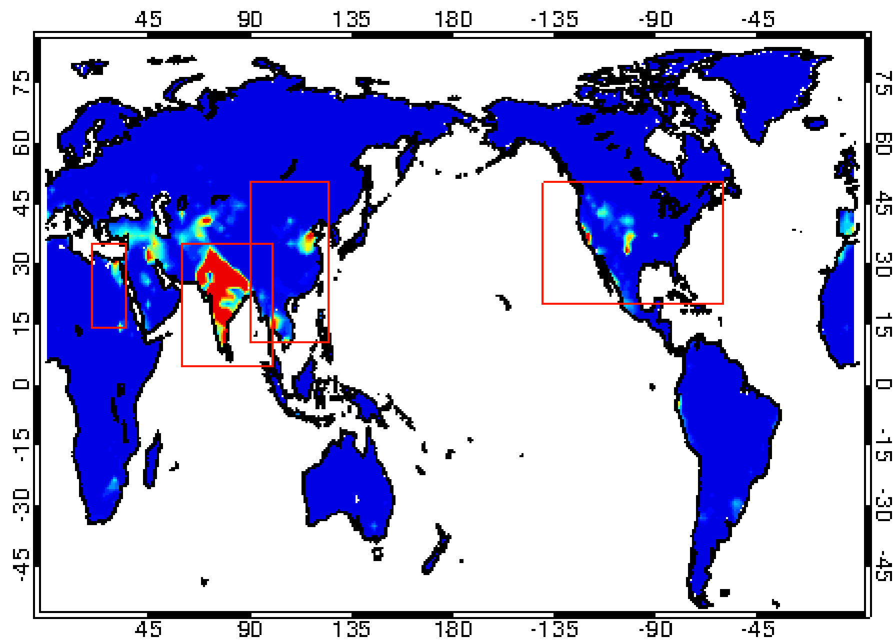
Transpiration is the dominant component of the ET budget

Global Irrigation Status

Irrigated Area



CLM Irrigation Amount

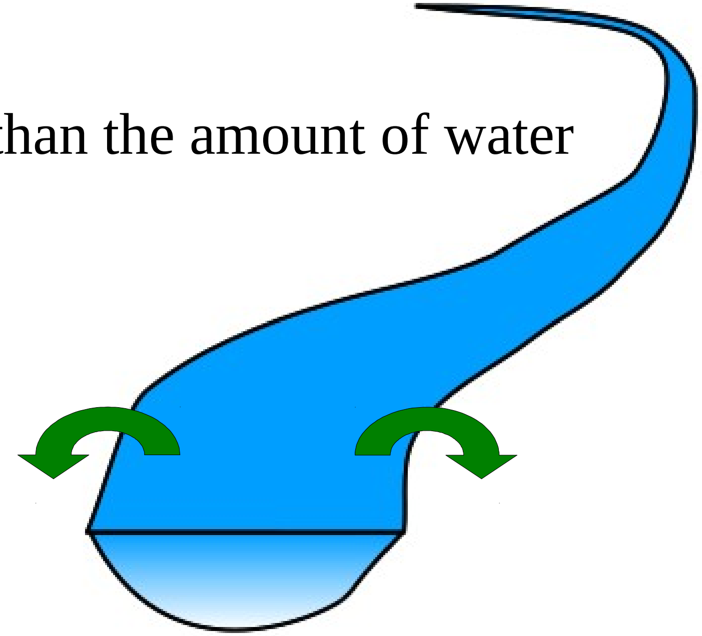


Regional Irrigation Amounts (Target)

Global:	650 km3/yr	(1000 - 2400)
US:	55 km3/yr	(110 - 180)
China:	60 km3/yr	(120 - 350)
India:	365 km3/yr	(220 - 650)

Irrigation Limitation

- Irrigation demand is calculated independently of knowledge of water availability
- In areas where irrigation is supplied by surface water, irrigation is limited by amount of waters in rivers and streams
- In CLM5, irrigation can be constrained to be less than the amount of water in the river routing model



Summary

- Irrigation demand is based directly on soil moisture state

- Irrigation demand can be limited to water available in river network

- Crop response to irrigation is coupled to plant hydraulic state

- Plant hydraulic stress parameterization updated to account more explicitly for soil moisture limitation