Modeling Plant-Scale Root Zone Water Dynamics in an Oak Savanna

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Abstract

Study of water exchange between soil, plants, and the atmosphere in response to seasonal or periodic droughts is critical to modeling the hydrologic cycle and biogeochemical processes in water-controlled ecosystems. The difficulties in such studies arise from insufficient understanding of the complex interactions between the various processes and their scale-dependence. The purpose of our study is to establish and calibrate a plant biophysical model that couples plant-soil and plant-atmospheric interactions to calculate the water exchange through the soil-plant-atmosphere continuum at a plant scale (a few m^2), with the regulation of root water uptake and evaporative fluxes by water deficits and climatic conditions explicitly considered.

The complexity required for modeling water dynamics at the plant scale will be investigated in future study. We started with coupling a big-leaf biophysical model with a bucket soil water balance model, with soil water loss regulated by soil water availability in a linear fashion. The alternative biophysical models with increasing complexities include the dual-source model that divide the canopy into shaded and sunlit parts and a multi-layer 1-D model with sophisticated radiation transfer and energy balance modules. The level of detail in subsurface water dynamics is adjusted by changing the dimensionality of the Richard's equation. The impact of soil water availability on water loss is modified to a nonlinear pattern as desired. The models are calibrated and compared using a cluster of measurements collected on single trees, which includes multiple soil moisture probes that monitor soil moisture profile vertically and laterally and sap flow sensors at different tree heights for measuring tree transpiration. This study forms the basis for scaling up the water dynamics to a stand scale (~100 to ~10000 m^2) or other larger scales.

1. Introduction

1.1 Objective

- Study water uptake pattern at plant scale in water-limited ecosystem
- Model water dynamics at plant scale under water stress

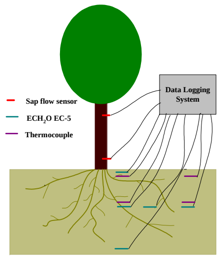
1.2 Site Information

- Located on the lower foothill of the Sierra Nevada
- Annual precipitation ~ 560mm
- Mean annual air temperature ~ 16.6^{o}C
- Hot and dry in summer, cold and wet in winter
- Soil: rocky silt loam

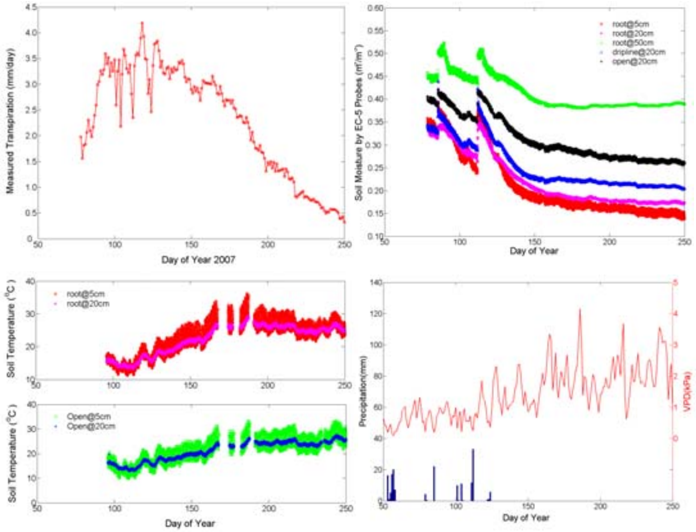
2. Plant-Scale Data Collection

2.1 Data collection system

- Sap flow sensors at two heights
- EC-5 soil moisture probes at multiple depths within and outside of tree canopy
- Soil temperature monitored at two depths Within and outside of tree canopy

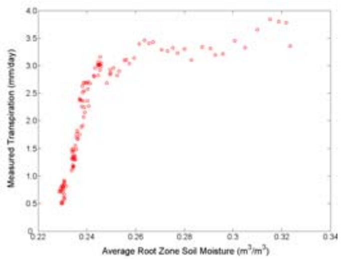


2.2 Data collected in 2007 growing season



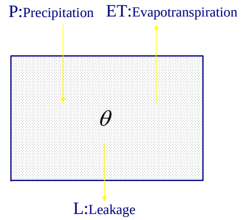
2.3 Impacts of soil moisture on plant-scale transpiration

- No impact when soil moisture is above a threshold value
- Transpiration decays approximately linearly below the threshold value
- This relation is important for water dynamics modeling at plant scale



3. Water Dynamics Modeling

3.1 Methodology



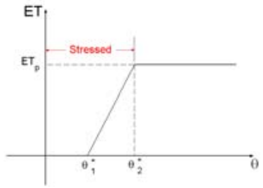
Water Balance: $\Delta\theta = P - ET - L$

Assuming:

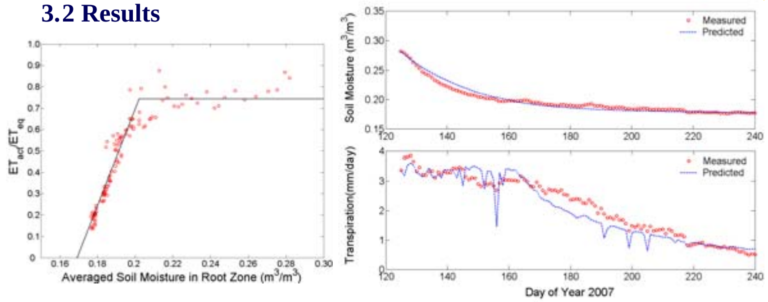
- No lateral flow
- Leakage negligible in dry season
- ET can be approximated by Priestley-Taylor equation modified by soil water availability

$$ET_{act} = \alpha(\theta)\cdot ET_p = \alpha\beta\cdot ET_{eq}$$

$$ET_{eq} = \frac{1}{\lambda}\frac{s}{s+\gamma}(R_n - G)$$



3.2 Results



4.Conclusions and Future Work

- The proposed model captures seasonal patterns of soil moisture in bucket and transpiration at plant scale fairly well
- Uncertainties in model and observed data need be addressed and incorporated into future modeling
- Effects of model complexities in soil water balance model and biophysical model will be investigated in future
- Data collection will continue in next growing season and water dynamics models will be validated

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