HYDRAULIC REDISTRIBUTION BY PLANT ROOTS:
A Mechanism of Interaction between the Biosphere Moisture Reservoirs of the Deep Soil, the Near-Surface Soil, and the Lower Atmosphere

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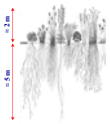
1. INTRODUCTION

Objective:

To model hydraulic redistribution and investigate its effect on (a) soil moisture profile and (b) fluxes at land-atmosphere interface in water-limited ecosystems.

Motivation:

- The long-memory nature of deep soil layer
- The availability of plant roots at deeper soil layers



Hypothesis:

"The hydrologically active depth of rooting zone in current climate models is underestimated and that the long-memory deep soil-layer may have significant impact on land-atmosphere interaction in vegetated environments."

3. MODEL

INPUT DATA	SOURCE
Atmos. Forcing	NARR
Soil Properties	Global Soil Data Task
Land Cover	IGBP-DIS
Vegetation Properties	AVHRR

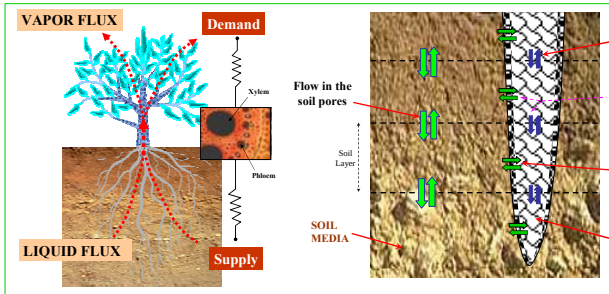


Fig.2: Conceptual representation of the soil-plant-atmosphere continuum (left) and the hydraulic redistribution model (right) as used in this study.

MODULE	PRINCIPAL ALGORITHM
Soil Model	Based on Darcy's Law $\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial z}\left[K_{soil}\left(\frac{\partial\psi_{soil}}{\partial z}+1\right)\right]=-\rho_{root}K_{r,mg}(\psi_{soil}-\psi_{xylem})$
Root Model	Based on Hagen-Poiseuille's Law $-\frac{\partial}{\partial z}\left[\rho_{root}K_{root}\left(\frac{\partial\psi_{xylem}}{\partial z}+1\right)\right]=\rho_{root}K_{r,mg}(\psi_{soil}-\psi_{xylem})$
Stomatal Conductance	Jarvis Algorithm $g_s=g_{s,max}f(Rad)f(T)f(\psi_{leaf})f(D)f(C)$
Canopy Transpiration	Penman-Monteith Algorithm $E=\frac{[\Delta Q_n+\rho_a c_p(e_s-e_a)g_a]g_c}{\lambda[\Delta g_c+\gamma(g_c+g_a)]}$
Carbon Assimilation	Farquhar-Collatz Algorithm $A=\min(A_c,A_q,A_s)$

2. STUDY SITE

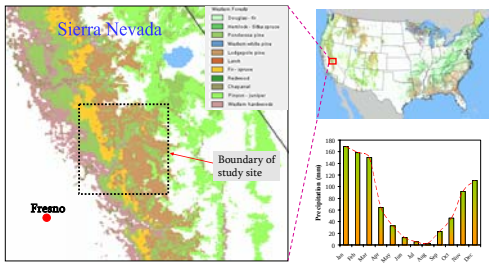


Fig.1: Location of case study site – Sierra Nevada ecosystem

Soil Depth & Root Distribution

- The depth to center of i^{th} soil layer:

$$z_i = 0.025\left(e^{0.5(i-0.5)}-1\right)$$

- The root fraction in the i^{th} soil layer:

$$F_{root}(z_i)=-\Delta z\frac{c}{z_{50}}\left(\frac{z_i}{z_{50}}\right)^{c-1}\left[1+\left(\frac{z_i}{z_{50}}\right)^{c}\right]^{-2},\quad c=\frac{1.27875}{\log\left(\frac{z_{50}}{z_{95}}\right)}$$

Where z_{50} and z_{95} are vegetation-dependent constants.

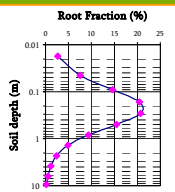


Fig.3: Root Profile

4. RESULTS

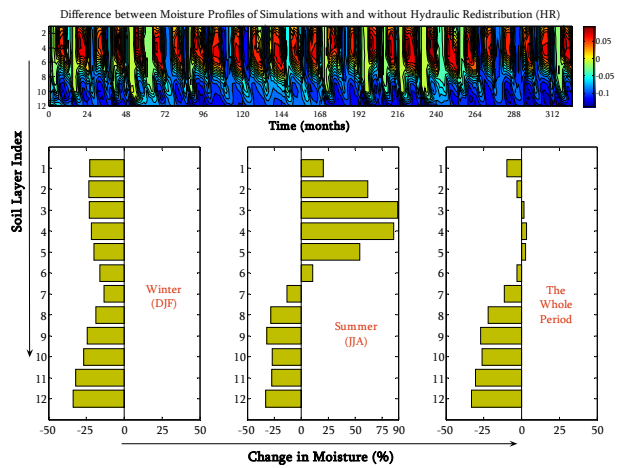


Fig.4: The effect of Hydraulic Redistribution (HR) on soil moisture profile. Positive (negative) values indicate an increase (decrease) in soil moisture due to HR.

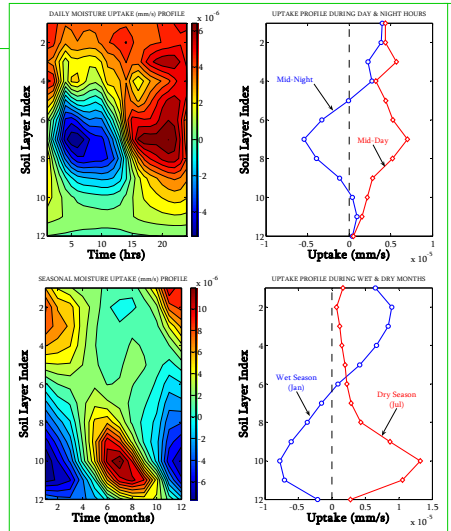


Fig.5: Daily (top) and Seasonal (bottom) profiles of water uptake by vegetation root system.

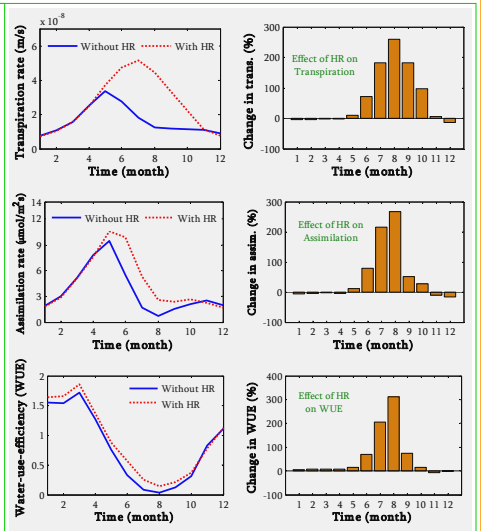


Fig.6: The effect of HR on Transpiration (top), Photosynthesis (middle) , & Water-Use-Efficiency (bottom).

5. CONCLUSIONS

- Hydraulic redistribution (HR) – a passive transport of soil water across soil layers via plant roots – could be modeled by assuming the plant root system as a conduit for moisture transport along a pressure gradient, analogous to pipe flow.
- HR coupled with rooting depth could be a main mechanism for facilitating the dynamic interactions between moisture reservoirs of the long-memory deep soil, the medium-memory near-surface soil, and the short-memory atmosphere.
- The incorporation of HR results in a significant (i) alteration in the profiles of soil moisture and moisture uptake, and (ii) increase in dry-season transpiration, carbon assimilation, and water-use-efficiency.
- By enhancing the effectiveness of water uptake by plant roots from long-memory deep soil moisture reservoirs (and hence, controlling the water, energy, and carbon cycles), the dynamic mechanism of HR may have an important implication for understanding processes that govern long-term climate and ecological predictions.

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7. REFERENCES

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