Drought impacts on plant water stress in a mountain headwaters system using an integrated hydrologic model

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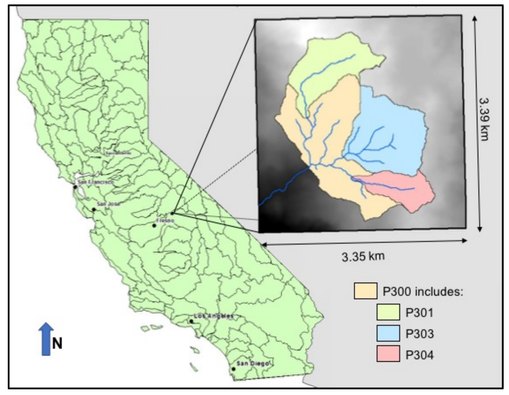
Background and Motivation



Mountain headwaters are particularly vulnerable to climate change. The ecohydrologic relationships between subsurface water storage and plant water stress with changing climate regimes in these systems are especially important.

Providence Creek (P300) watershed is an alpine headwaters catchment located at the NSF-funded Southern Sierra Critical Zone Observatory (SSCZO). Evidence of **groundwater-dependent vegetation** and **drought-induced tree mortalit**y at P300 with uncertainties surrounding regolith water storage and **the impact of regolith on mountain ecohydrology** motivates this study.[1,2]

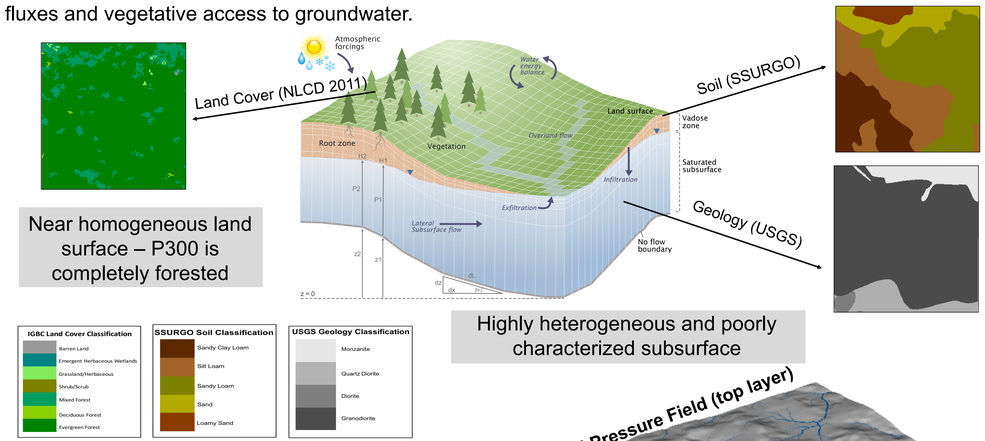
Using **ParFlow-CLM**, this study will assess the importance of subsurface water storage and lateral groundwater flow on plant water use and plant stress during drought conditions.

Integrated Modeling Approach

ParFlow is a parallel simulation code that can simulate surface and subsurface flow in both steady-state and variably saturated conditions by using the three-dimensional Richard's equation with an overland flow boundary condition.[3,4] When coupled with the **Common Land Model** (CLM)**, ParFlow-CLM** can simulate land-surface processes, such as energy balance and dynamic snow processes while accounting for vegetative and soil-related fluxes.[5-10]

The coupled physically-based model, ParFlow-CLM, provides an opportunity to evaluate the groundwater-dependency of P300 vegetation and assess the tolerance of that vegetation to drought conditions at the small watershed scale.

Model inputs include topography, land surface, soil, and geology. The model domain consists of 335 columns (NX), 339 rows (NY), and 11 vertical layers (NZ) ranging from 10.0 m to 0.05 m within a terrain-following grid framework for a total of **1,249,215 cells** over 11.4 km^2. An extensive vertical discretization resolves near-surface fluxes and vegetative access to groundwater.

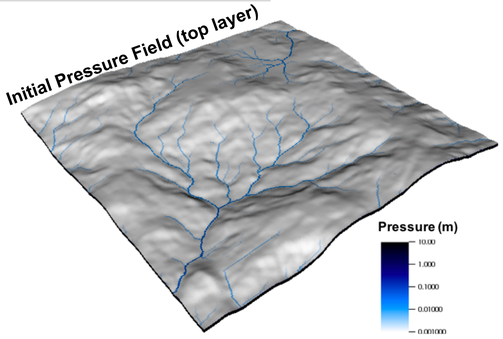


Near homogeneous land surface – P300 is completely forested

Highly heterogeneous and poorly characterized subsurface

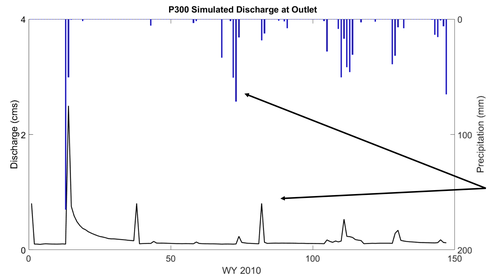
What is "spin up?"

Spin up is the process of achieving dynamic equilibrium in the model. Above ground processes stabilize quicker than groundwater; therefore, an initial pressure field is used in the PF-CLM model. This pressure field is obtained by running ParFlow decoupled from CLM with a general P-E forcing until a stable water table forms.



Preliminary Results

The PF-CLM model is currently 60% through the spin up phase.

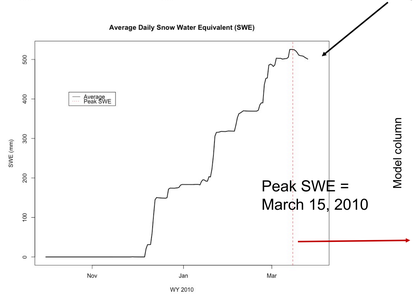


Preliminary results show that the Providence Creek (P300) PF-CLM model has functionality.

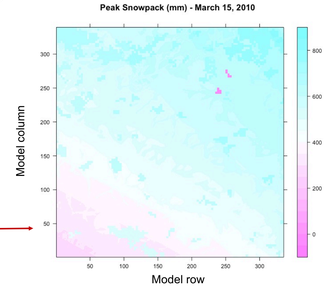
Appropriate catchment response to precipitation events

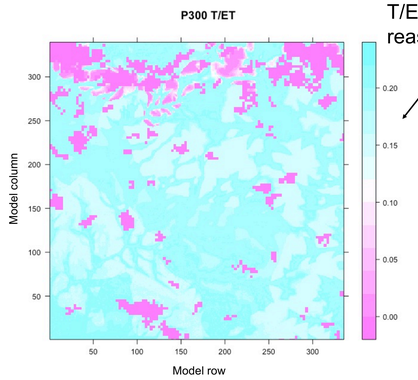
Peak SWE timing and volume as expected

Previous studies[11] demonstrate that PF-CLM is a plausible tool for studying groundwater-vegetation interactions.

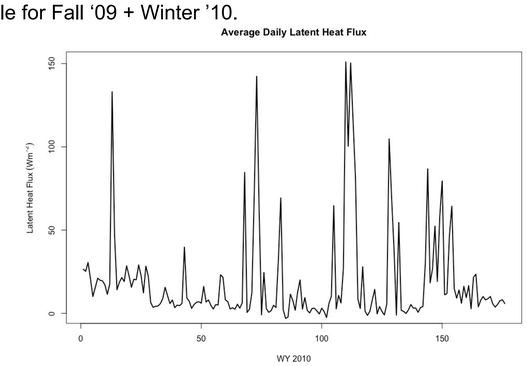


Peak SWE = March 15, 2010





T/ET for first 147 WY days is reasonable for Fall '09 + Winter '10.



Research Goals and Next Steps

- **Does groundwater-dependent vegetation dominate at Providence Creek (P300)?**
- **Can the model predict where vegetation is most susceptible to water-stress during drought conditions?**
- **Do our predictions match field observations?**

Evapotranspiration (ET) partitioning and analysis with water table depth (WTD) will assess groundwater (GW) dependence. Strong T/ET vs WTD correlation indicates vegetative GW-dependence. Spatial analysis with isotope field data collected across P300 will determine model functionality for this type of analysis.

References and Acknowledgements

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This research is supported by the Laboratory Direction Research & Development (LDRD).
Special thanks to the Maxwell Research Group at CSM and Ate Visser, Jessica Osuna, Andy Thompson, and Steve Smith at LLNL.