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The Role of Groundwater and River water Interactions in Modulating Land Surface and Subsurface States and Fluxes:

A Local-Scale Case Study along the Columbia River Shoreline

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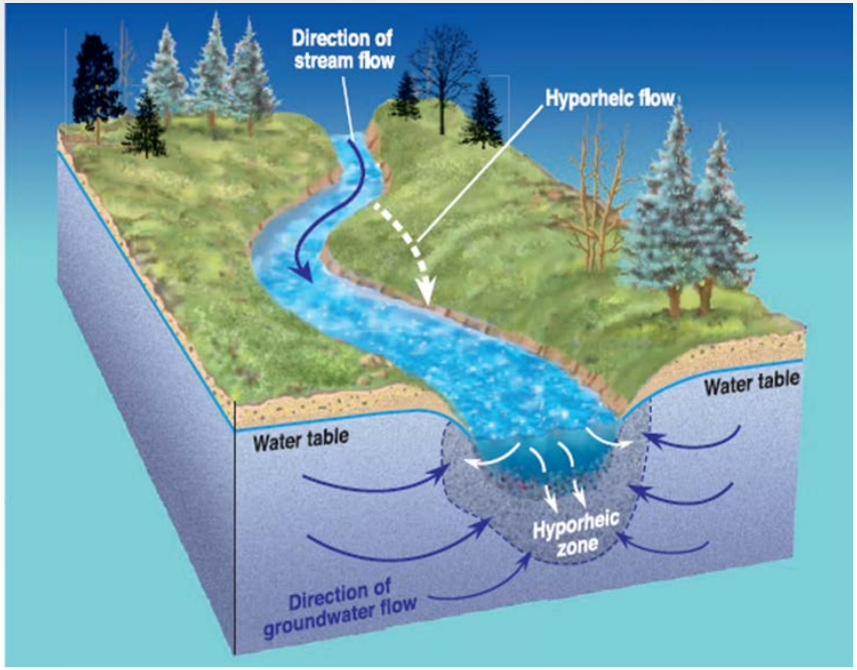
Objective

- Land-atmosphere exchanges and, in turn, regional and global climate can be influenced significantly by subsurface processes.
- Lateral flow and transport between groundwater and river water through the subsurface interaction zone (SIZ), in particular, is a major pathway for energy, water, solute, and gas transfer between terrestrial and aquatic systems.
- Groundwater – surface water exchange is significant at multiple scales, but is not adequately resolved in Earth System Models (ESMs).

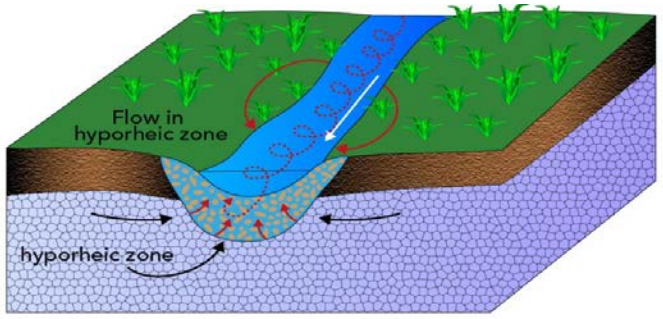


The Subsurface Interaction Zone (SIZ) is a Complex Hydrologic Domain

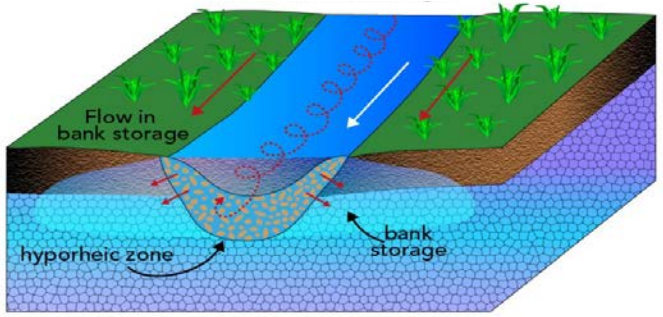
- The structure and extent of the SIZ depends on river stage/discharge and hydrogeologic properties
  - Hyporheic zone
  - Bank storage
  - River or hyporheic corridor flow
- Controlling factors
  - Geologic structures
  - Type/texture of geologic material
  - Hydraulic conductivity
  - Hydrologic cycle effects
  - Groundwater and surface water carbon and nitrogen
- Linkage to Earth System Modeling
  - SIZ processes have sufficient impact on land-atmosphere exchanges and riverine C/N transport and outgassing to be included in ESMs

Increase in water volume, contact time, and transport distance

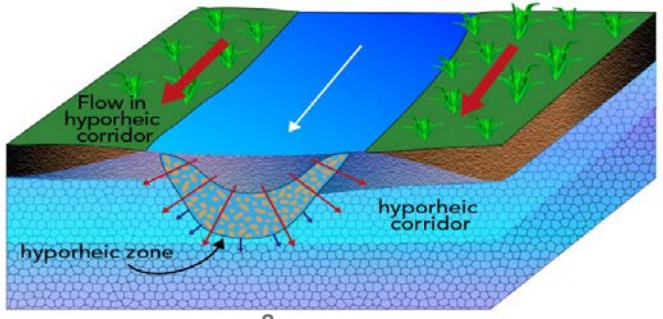
Hyporheic Zone



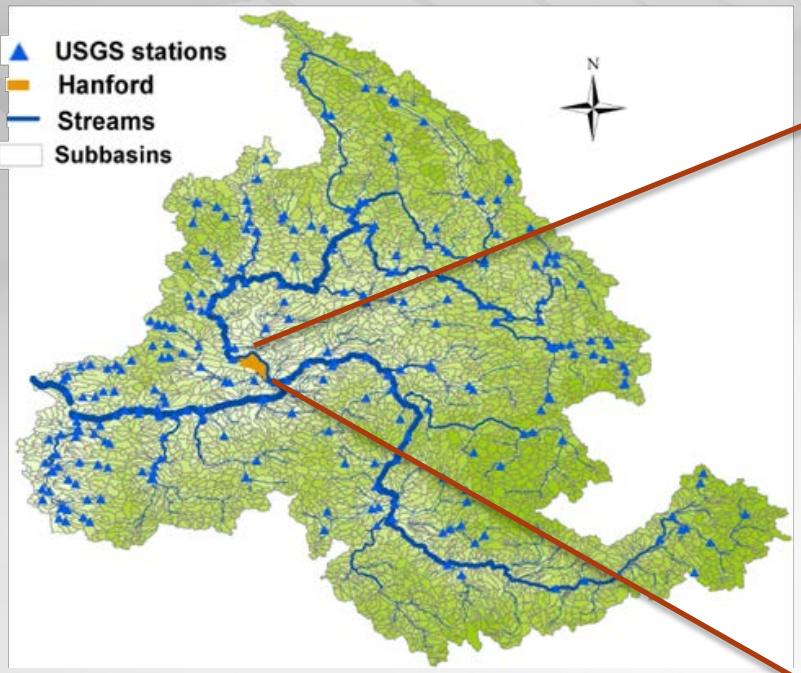
Bank Storage

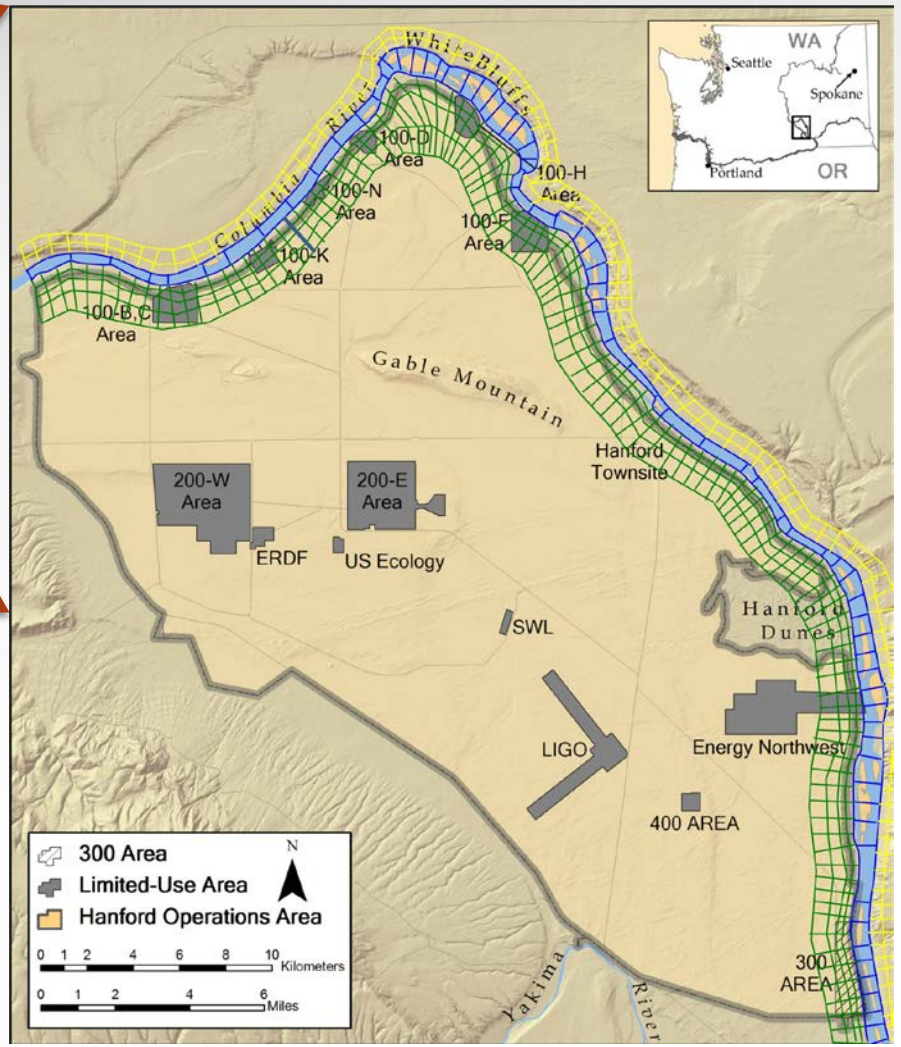


Hyporheic Corridor

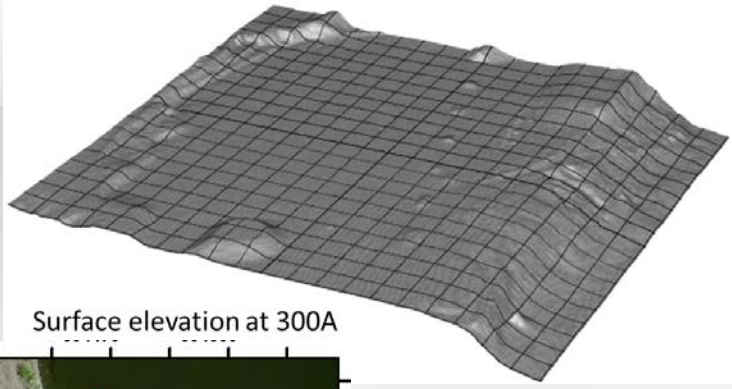


Site description





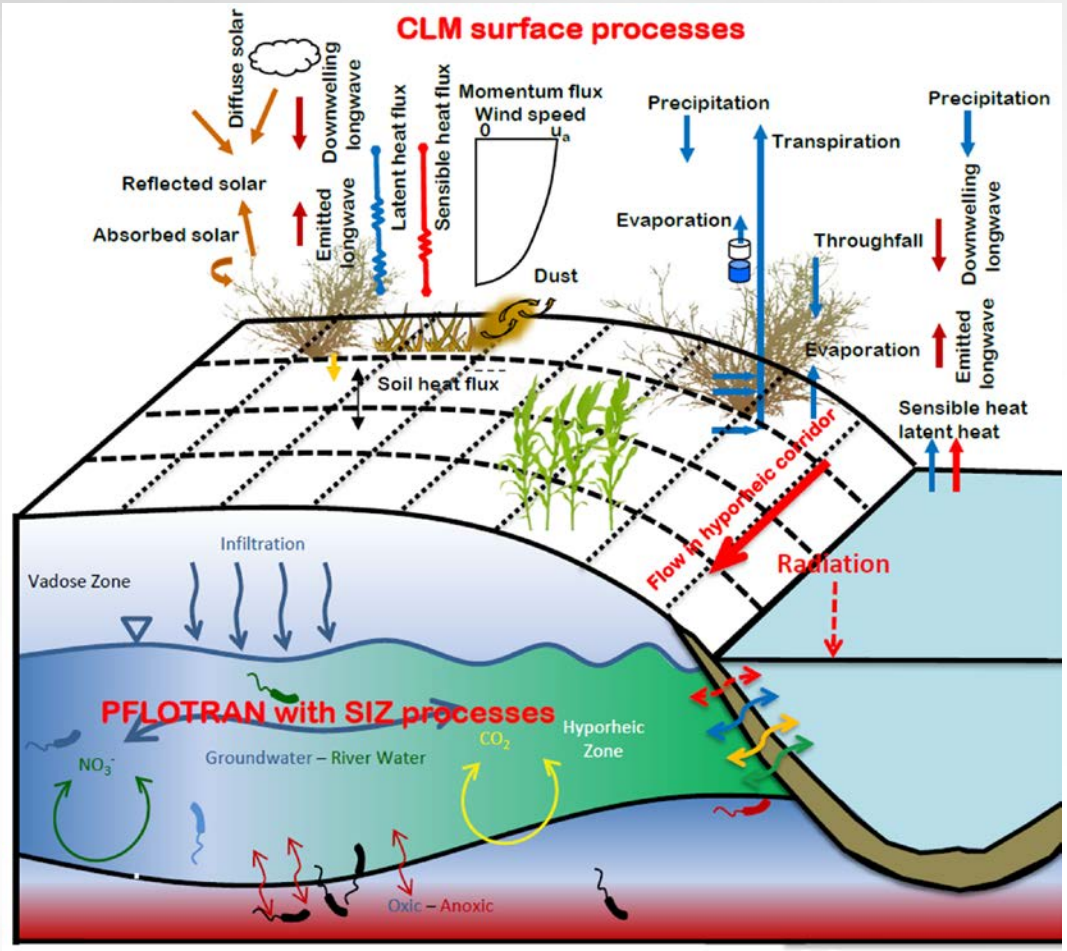
Modeling domain



Objectives & Approach

- To assess the importance of the SIZ in the context of climate change, an integrated land surface and subsurface model enhanced with SIZ processes within the land component of an ESM [i.e., CLM-PFLOTRAN] was built;

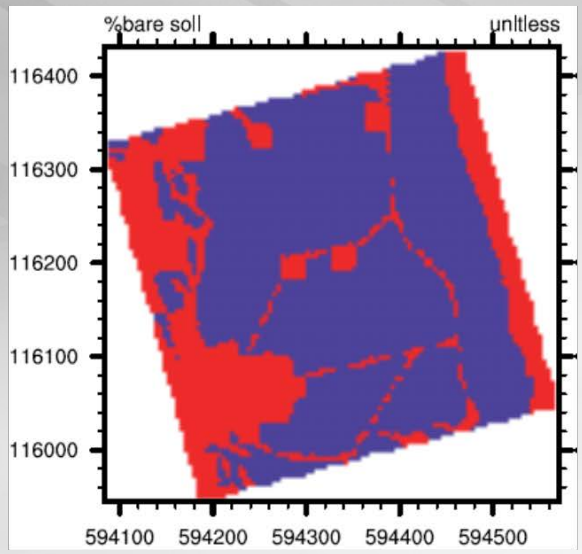
- The initial modeling objective is to investigate the impact of spatial scale in representing land surface and subsurface heterogeneity on regulating land surface and subsurface fluxes and state variables.

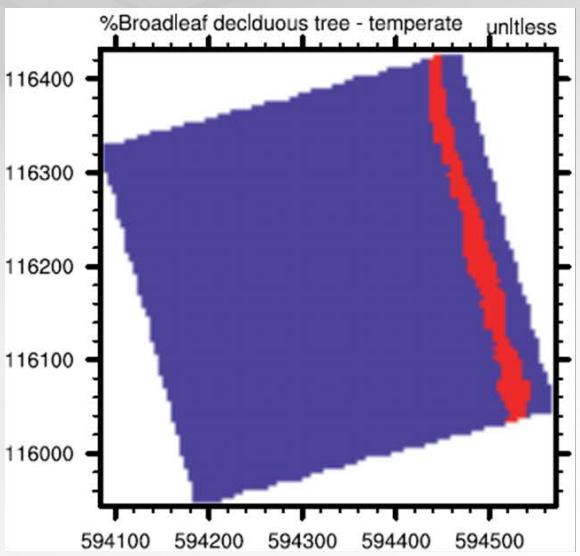


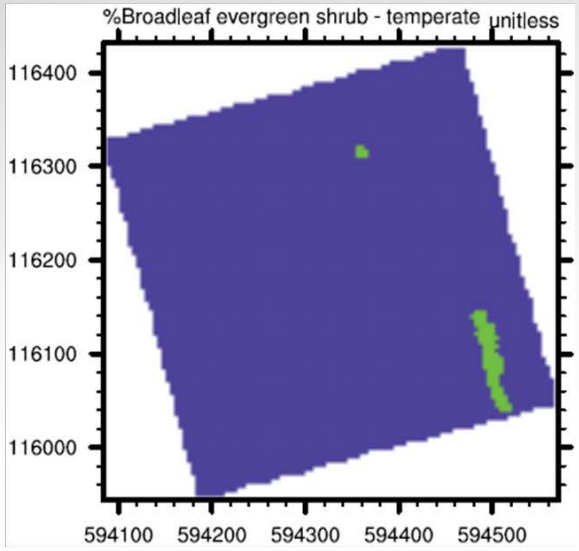
Numerical Experiments

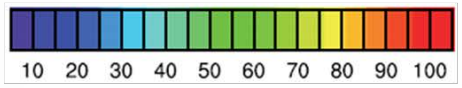
- CLM and CLM-PFLOTRAN are configured and run at 2m, 10m, 20m resolutions in a 400mx400m domain over the 300 Area, where subsurface properties and processes have been well-documented through sediment characterization, pump tests, tracer experiments, and field monitoring of river water intrusion events driven by river stage changes:
  - Site specific land cover and soil parameters for CLM;
  - Meteorological forcing from a local meteorological station;
  - PFLOTRAN vertical domain extends from soil surface to the Ringold formation with low permeability;
  - PFLOTRAN lateral boundary condition provided by groundwater monitoring wells and observed river stage.
- Simulation period: 04/2012 – 07/2012;

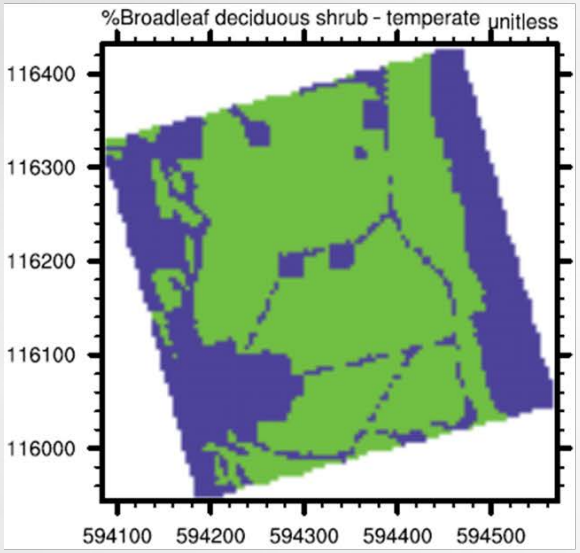
Percentage of plant functional types

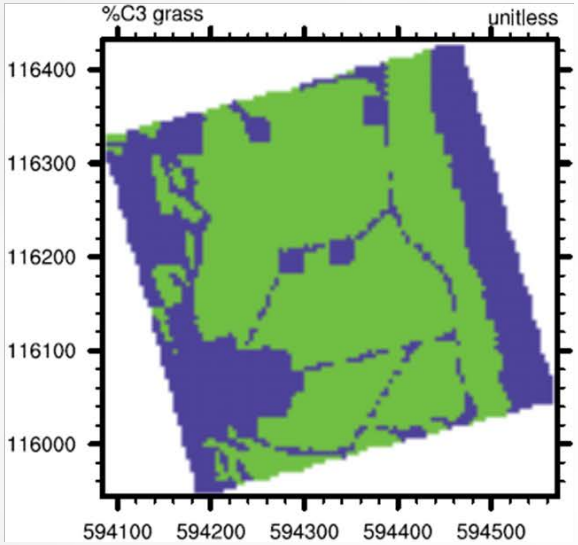












Topography and forcing

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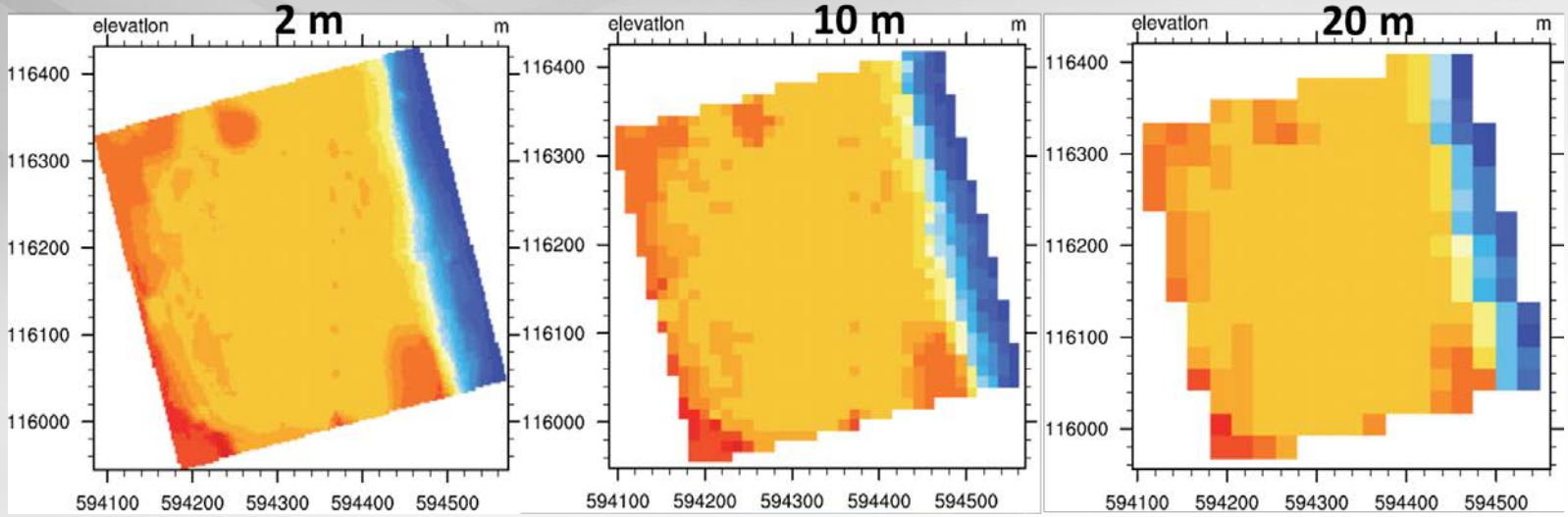

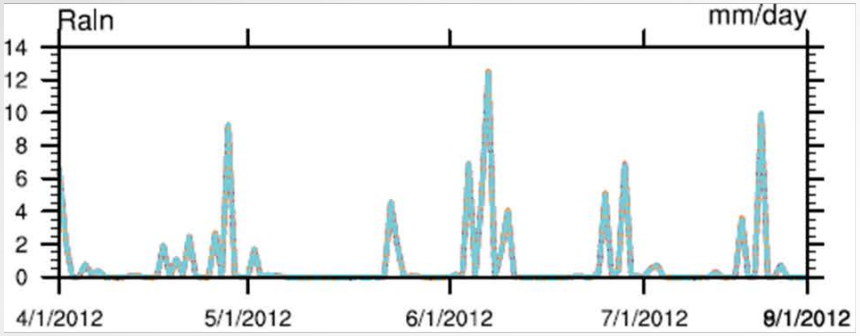

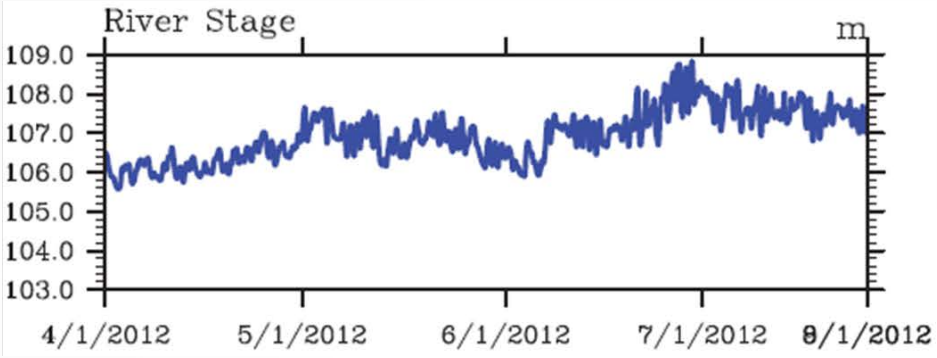

Latent heat flux in June (spatial variability)

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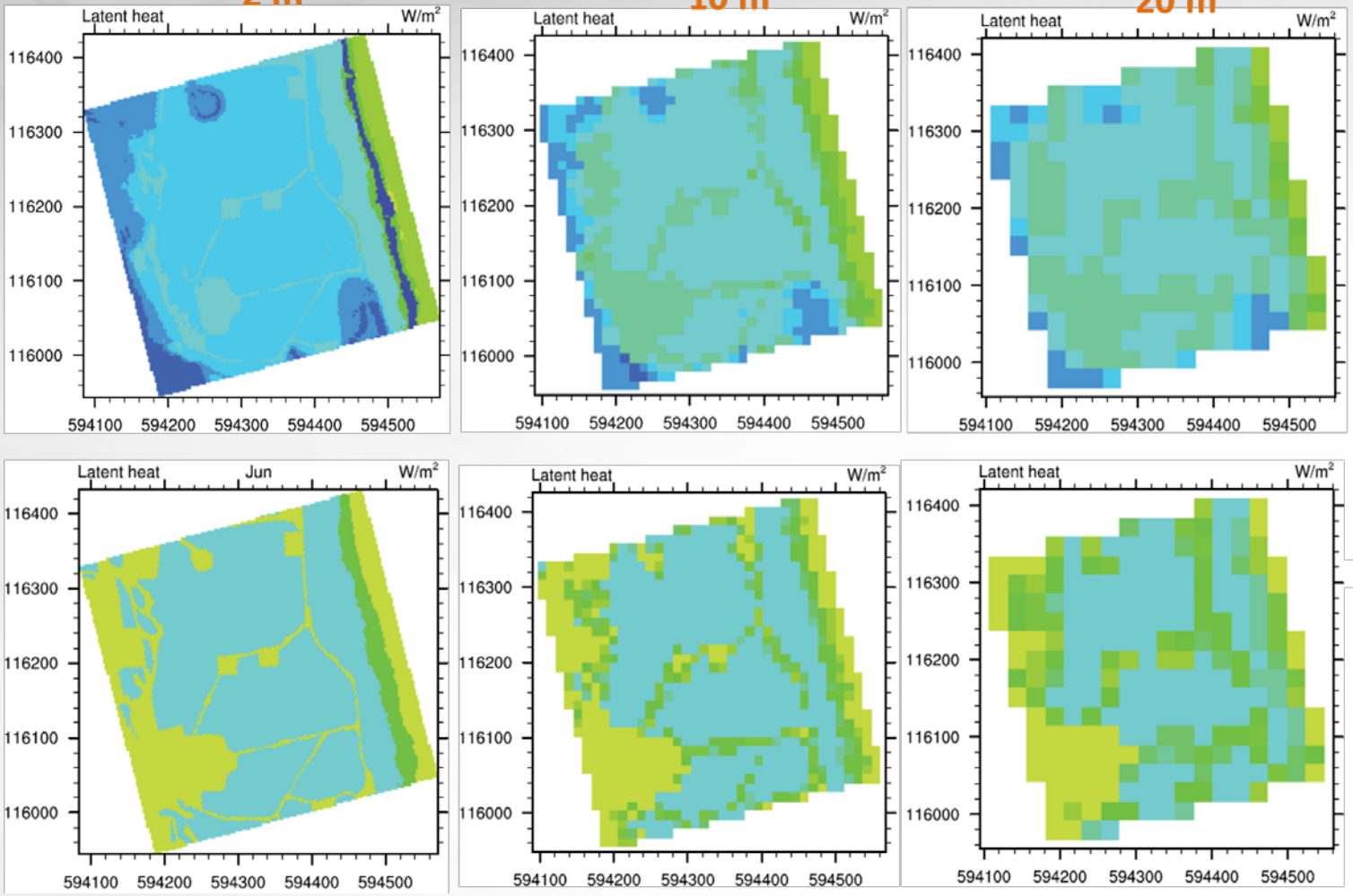
2 m 10 m 20 m

CLM4.5

CLM-PFLOTRAN



Surface and Subsurface States and Fluxes

(Summary Statistics)

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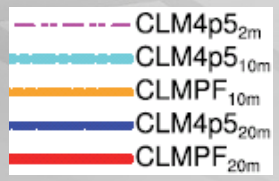
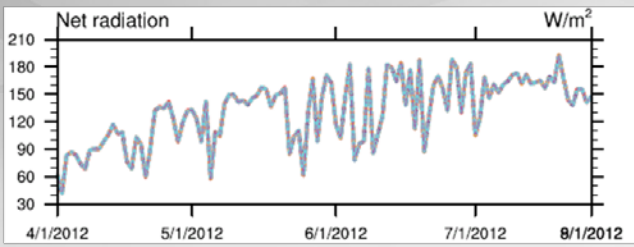
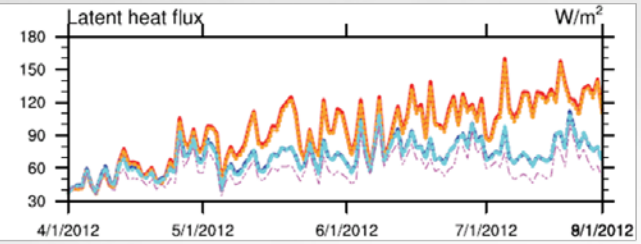
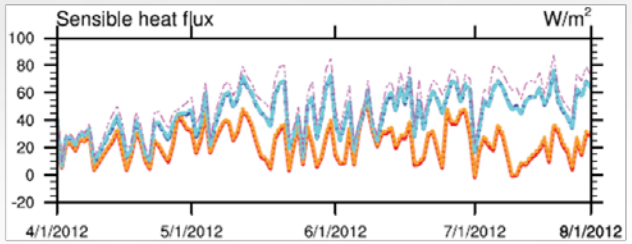


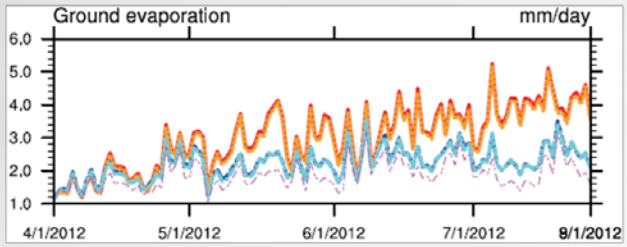
Energy budget (Domain average)

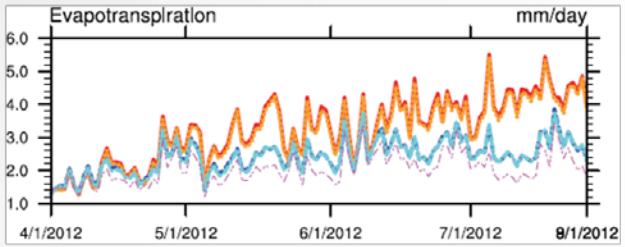


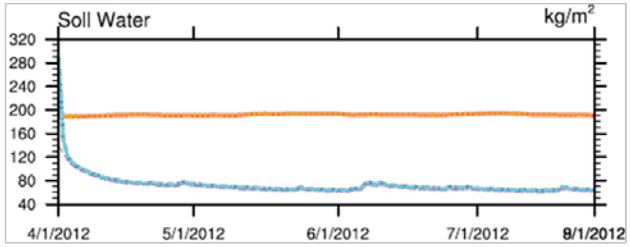




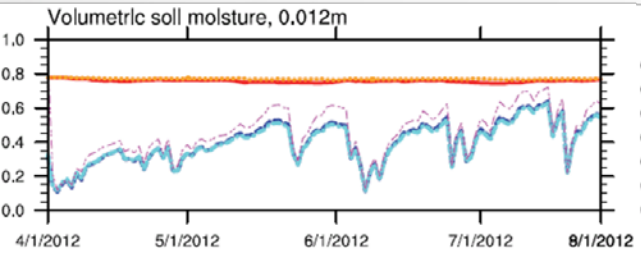
Water budget (Domain average)

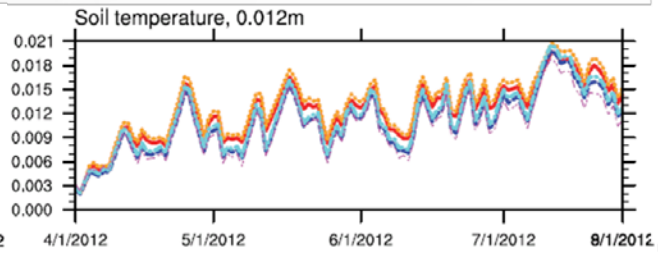


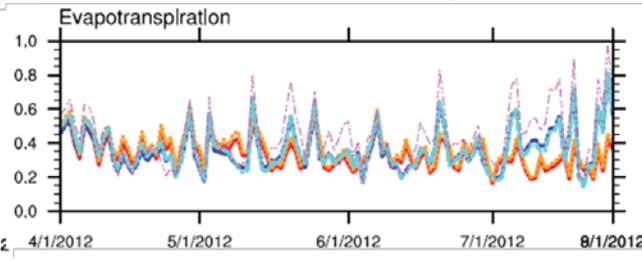




Spatial variability (coefficient of variance over the domain)







Conclusions and next steps

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- An integrated land surface - subsurface model enhanced with SIZ processes that couples the Community Land Model (CLM) and PFLOTRAN was developed for the Columbia River shoreline.
- The coupled model reveals the importance of interaction zone processes in regulating temporal and spatial variability in land surface and subsurface fluxes and state variables.
- The coupled model establishes a solid foundation for better understanding the spatial and temporal dynamics of biogeochemical cycling and biogenic gas generation in the SIZ, and their regulation by the changing water cycle and climate.
- Subsequent research will extend this modeling approach to the 75 km Hanford Reach, a scale relevant to Earth system modeling and analysis

Acknowledgement

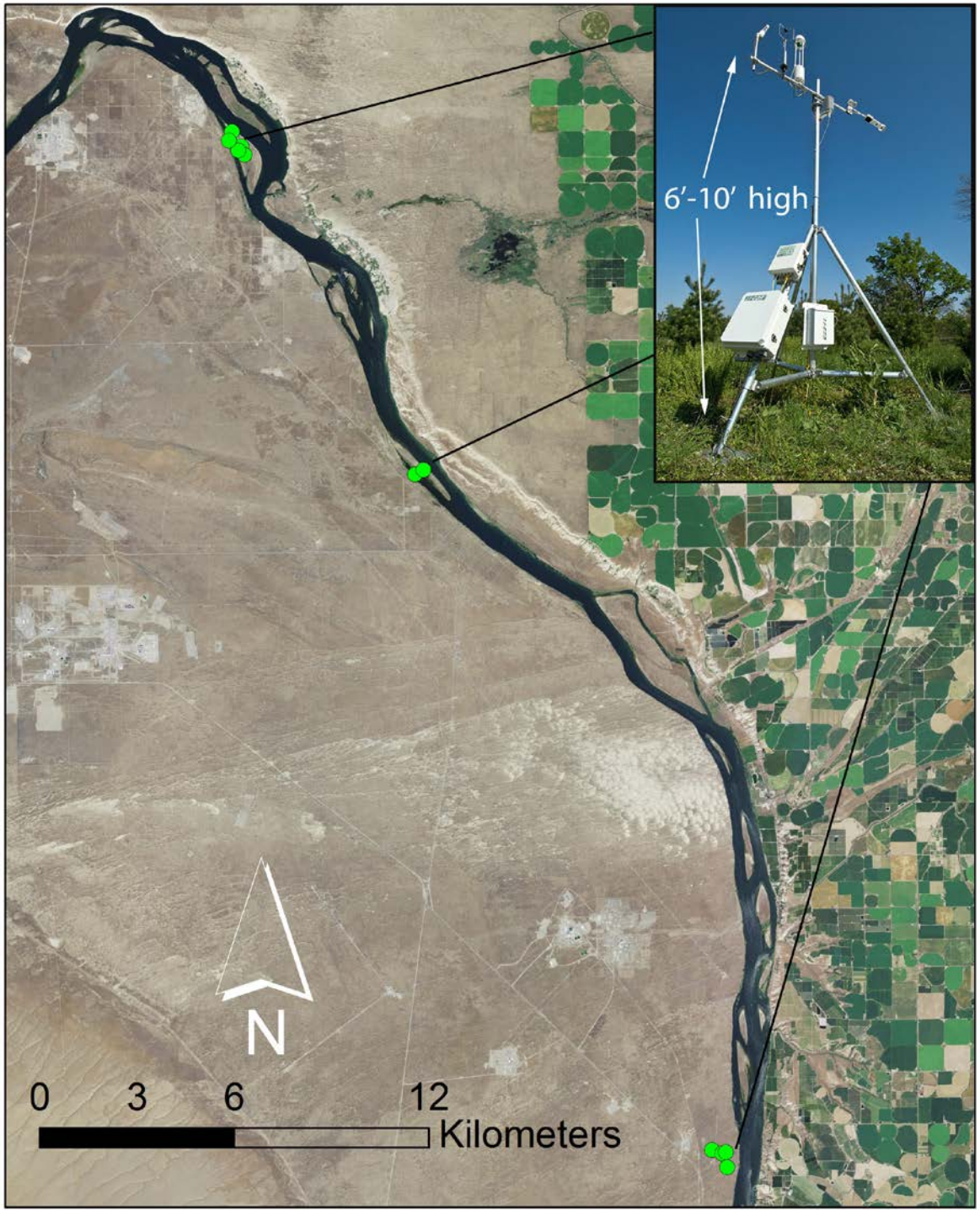
- DOE-BER:

  Subsurface Biogeochemical Research (SBR) Program

- PNNL SBR Science Focus Area project team

  http://sbrsfa.pnnl.gov

Backup: flux towers



Vegetation

Monitoring groundwater/surface water exchange

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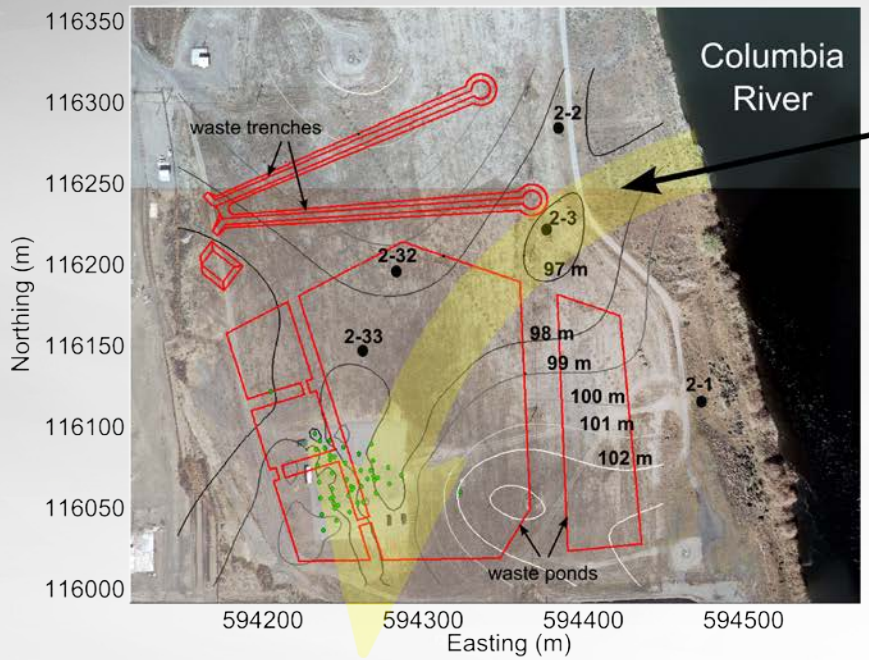
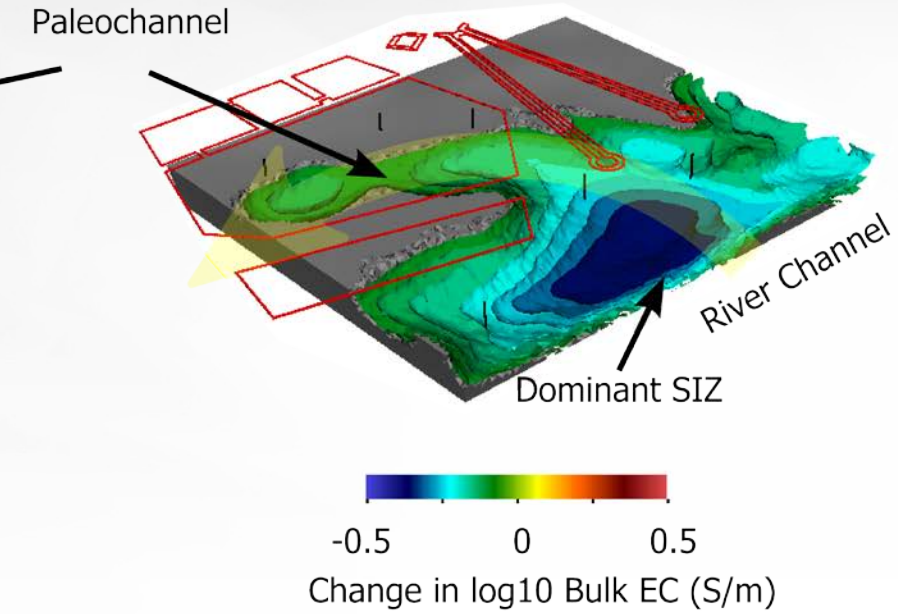
Courtesy: Dr. Tim Johnson

Wellbore-based lower confining unit elevation



High stage change in bulk EC (saturated zone)



- existence and dominating influence of high K paleochannel confirmed
- Hanford/Ringold contact illuminated
- Inland flow inhibited to north and south of channel