Understanding Impacts of Subsurface and Surface Heterogeneity on Evapotranspiration in Mountain Pine Beetle Infested Watersheds

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GSA 2013 Annual Meeting
Session T40. Applications and Developments of Coupled Hydrologic Models

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COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

What we know: Subsurface heterogeneity influences land surface processes

Influences of subsurface heterogeneity and vegetation cover on soil moisture, surface temperature and evapotranspiration at hillslope scales

Adam L. Atchley · Reed M. Maxwell

Quantifying the effects of three-dimensional subsurface heterogeneity on Hortonian runoff processes using a coupled numerical, stochastic approach

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Available online 19 February 2008

… plus many more!

as well as,

- infiltration
- vegetation
- atmospheric conditions

Something else to consider: Scaling

Scaling, soil moisture and evapotranspiration in runoff models

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The role of scaling laws in upscaling

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029/2009WR008730, 2010

Proof of concept of regional scale hydrologic simulations at hydrologic resolution utilizing massively parallel computer resources

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… plus more!

in terms of,

- hydrologic processes
- application in models

The unknowns: Questions to ponder…

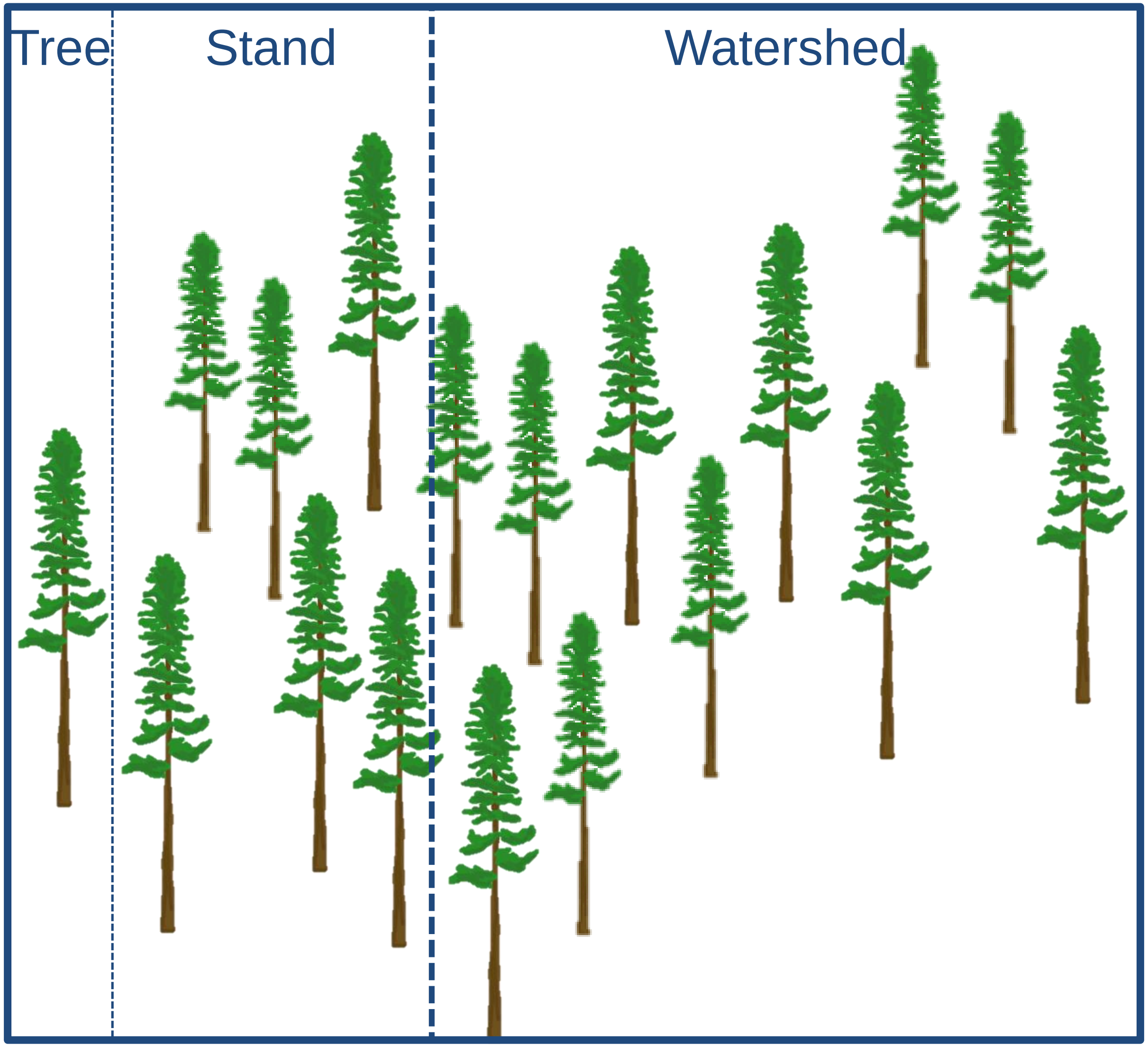
- How can we take small scale heterogeneities like that of soil moisture or evapotranspiration which may vary significantly over one watershed and apply them at a regional scale?

- Do vegetation and climate dynamics influence the degree that scale matters?

- Do subsurface characteristics combined with landscape changes compound or counteract the importance of scale?

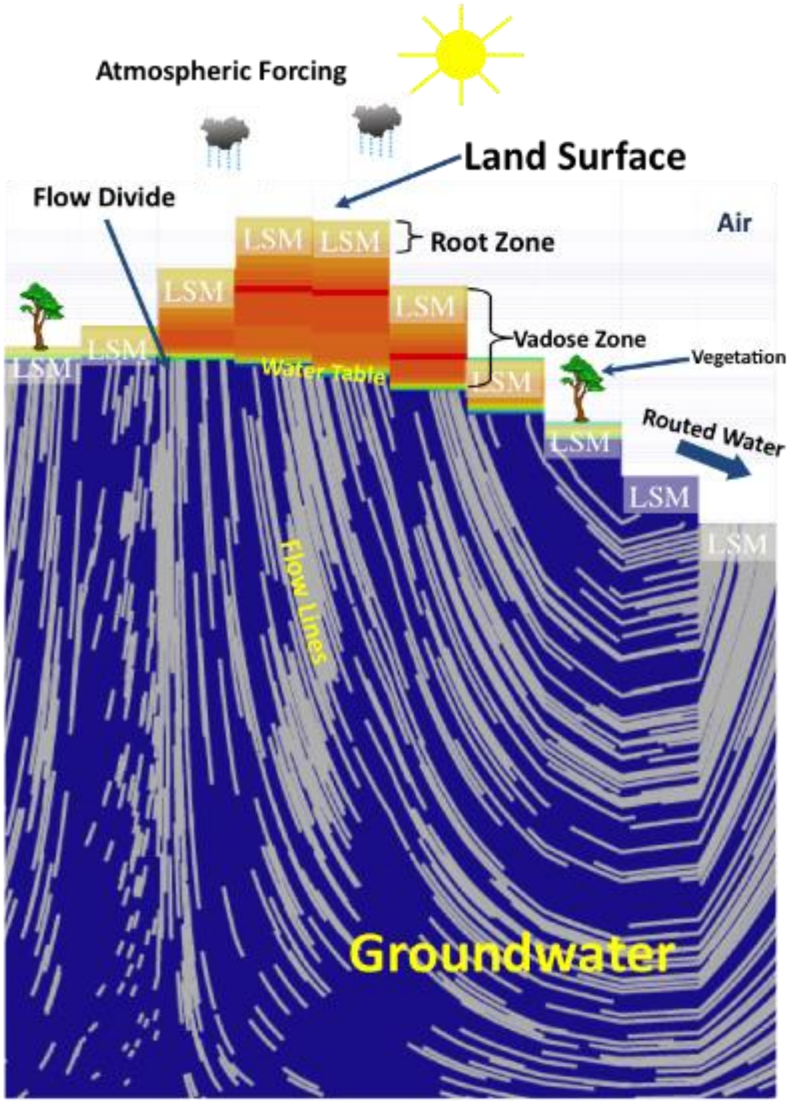
- What changes do we see in evapotranspiration as we move from the small to large scale with a heterogeneous subsurface?

Evapotranspiration and scale



Does ET from a tree or stand really represent the watershed?

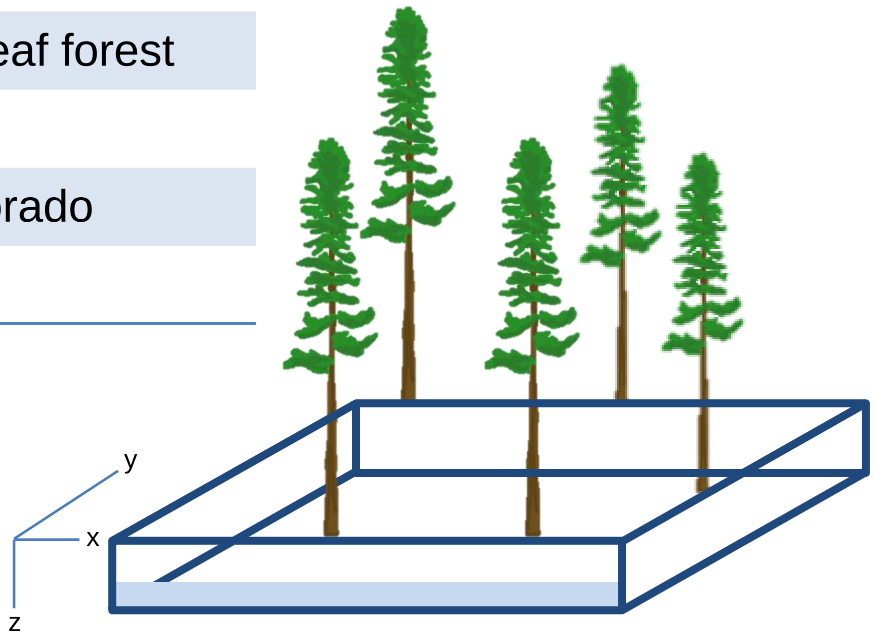
ParFlow: A tool for hydrologic modeling



- Integrated surface water-groundwater model
- Land surface: Vegetation processes through Common Land Model (CLM), coupled water-energy balance
- Overland flow/surface runoff: Diffusive/kinematic wave and Manning's equation
- Groundwater flow: variably-saturated, three-dimensional Richards equation
- Fully coupled, mass conservative, parallel implementation

Model setup for forest domain in Colorado

Property	Description
Domain Size	1000m x 1000m x 3m
Resolution	2m (surface), 0.1 (subsurface)
Surface Cover	Evergreen needleleaf forest
Subsurface Soil	Sandy, clay loam
Atmospheric Forcing	Breckenridge, Colorado
Simulation Duration	1 year

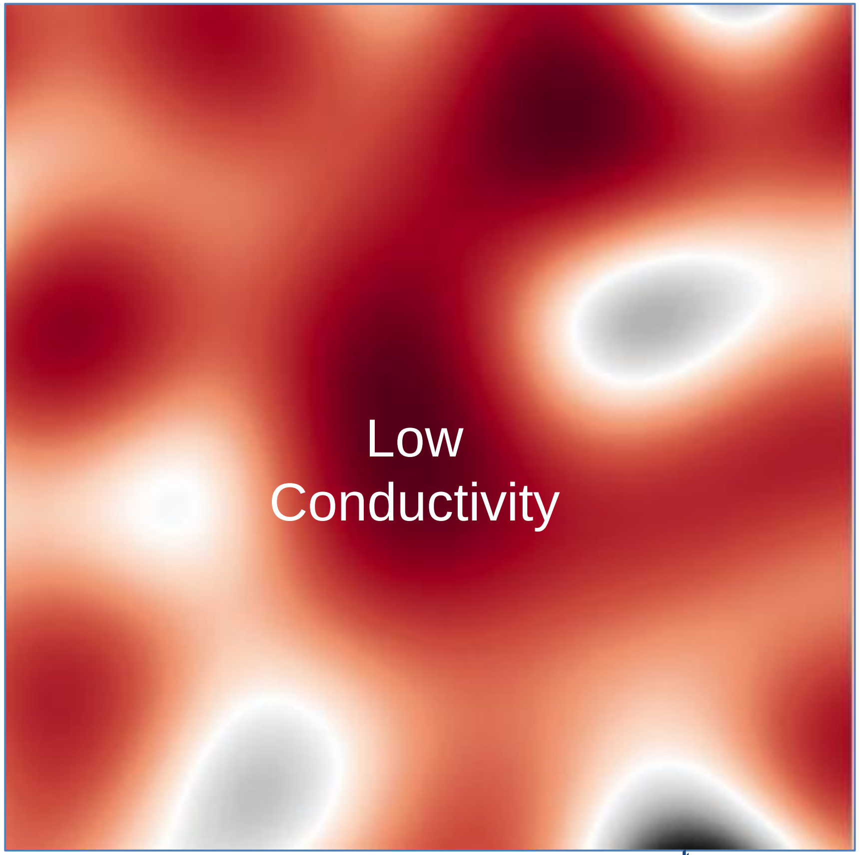


Varied parameters:

- Subsurface anisotropy:
  $\lambda_x = \lambda_y = 10\text{m}$ and $\lambda_x = \lambda_y = 50\text{m}$ ($\lambda_z = 1\text{m}$)
- Subsurface heterogeneity:
  $\sigma^2 = 0.1$ (~homogenous) and $\sigma^2 = 1$ (heterogenous)

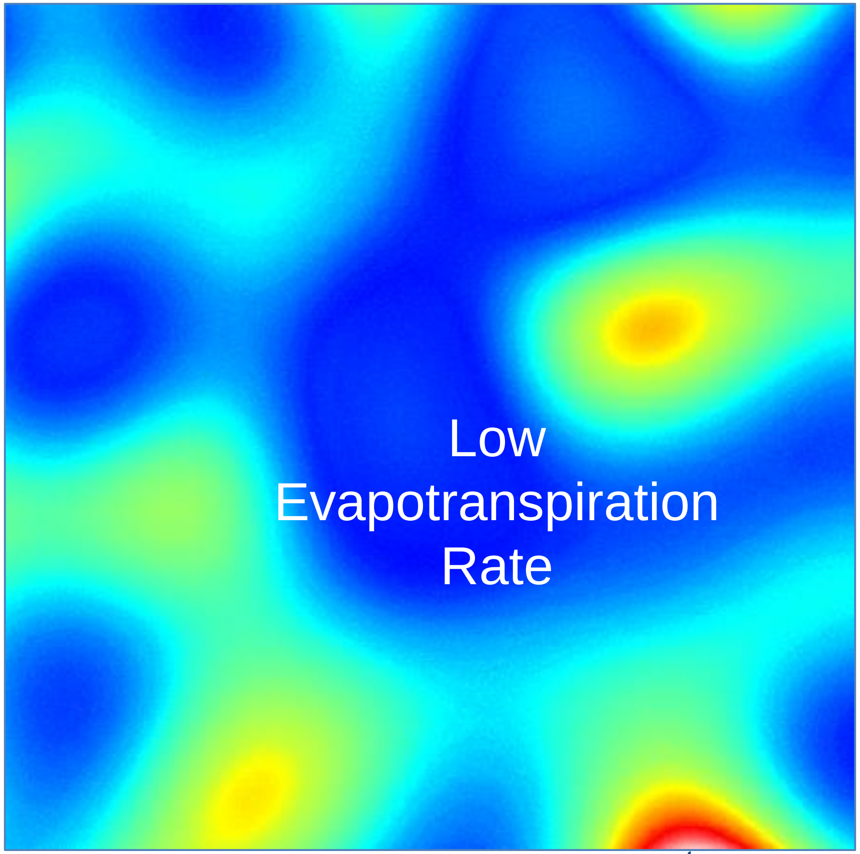
Subsurface heterogeneity reflects spatial ET distribution

Hydraulic Conductivity



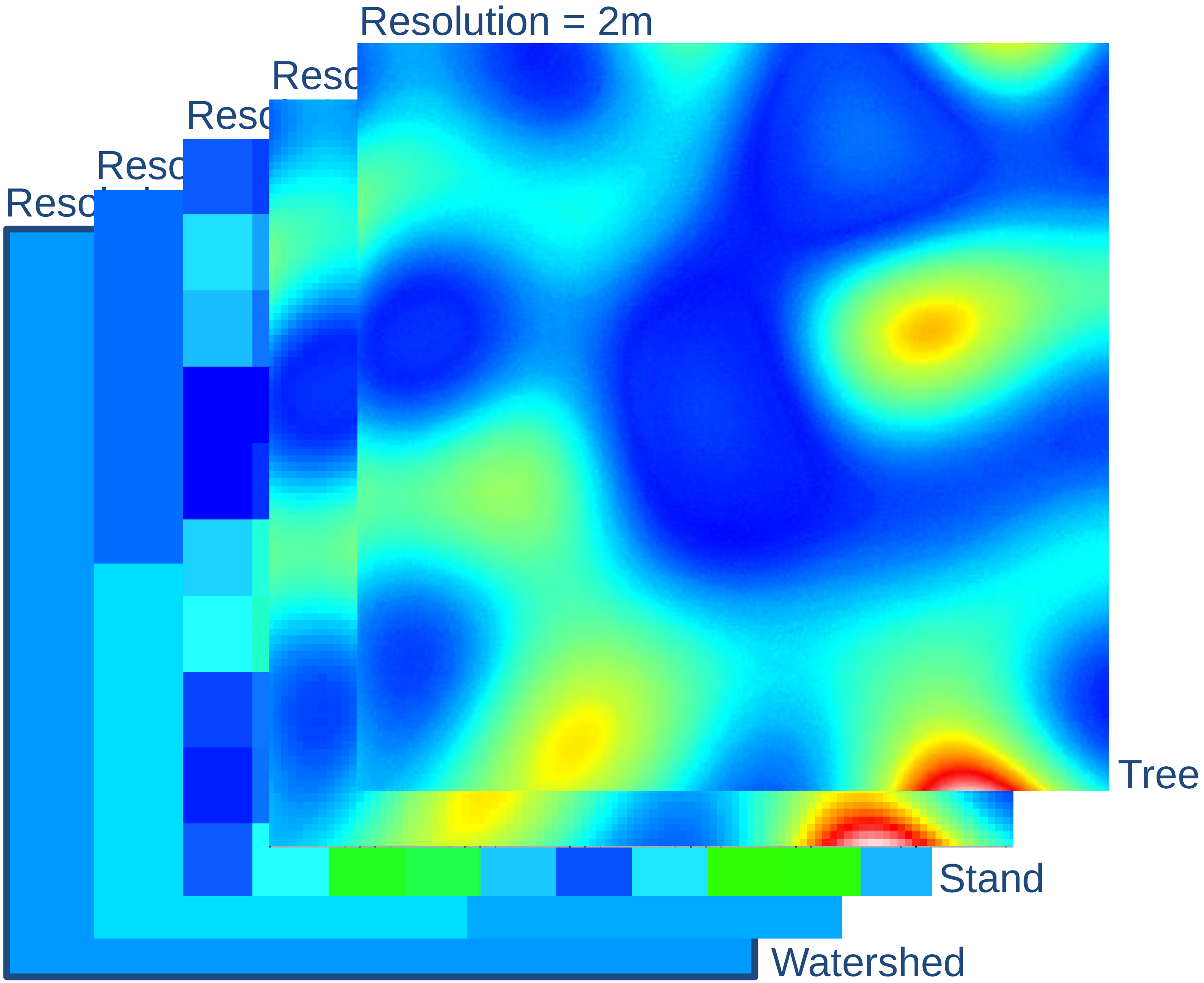
High Conductivity

Evapotranspiration

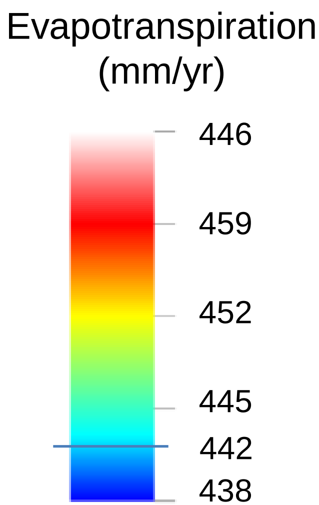


High Evapotranspiration
Rate

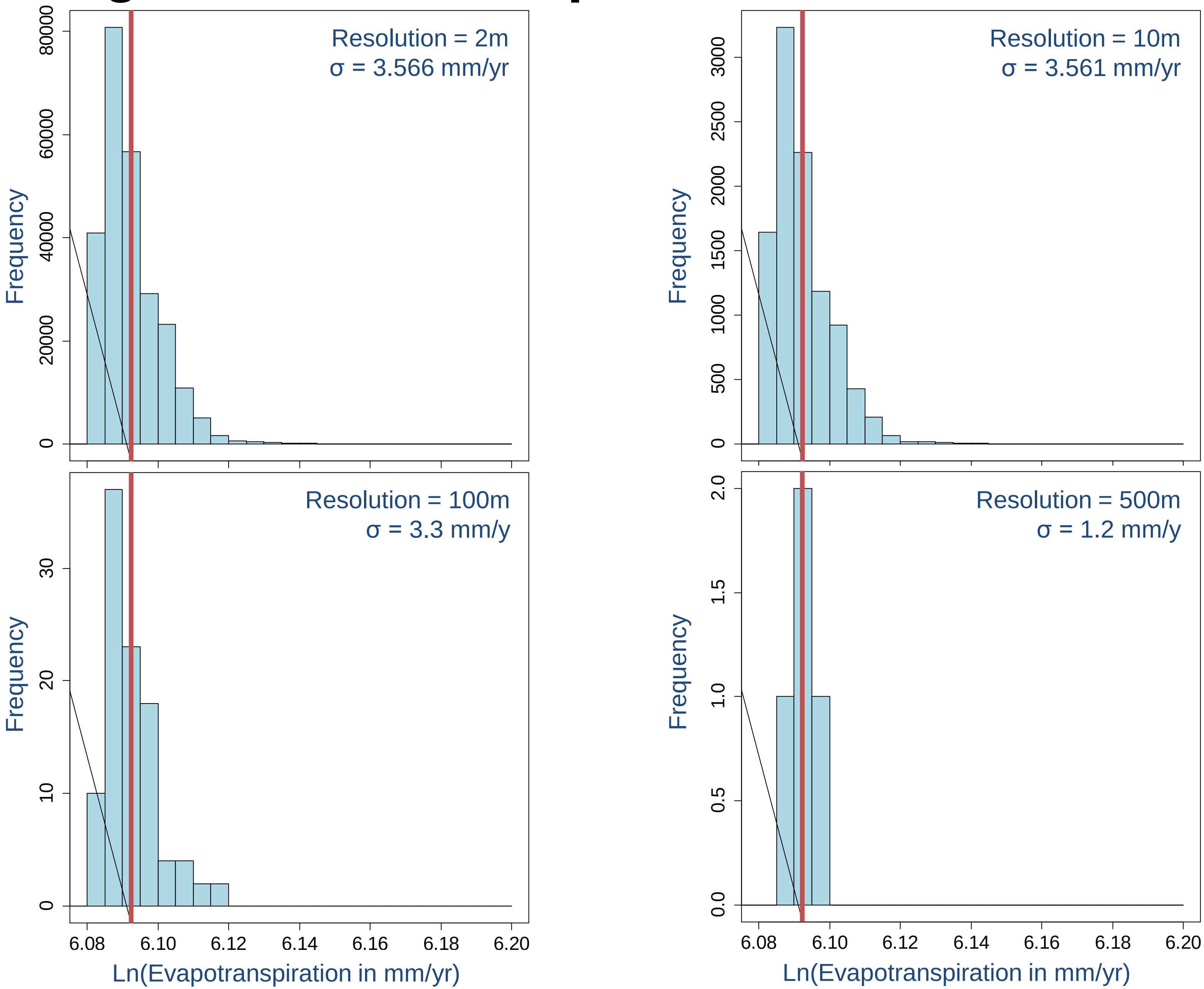
ET at different resolutions shows highly variable spatial patterns



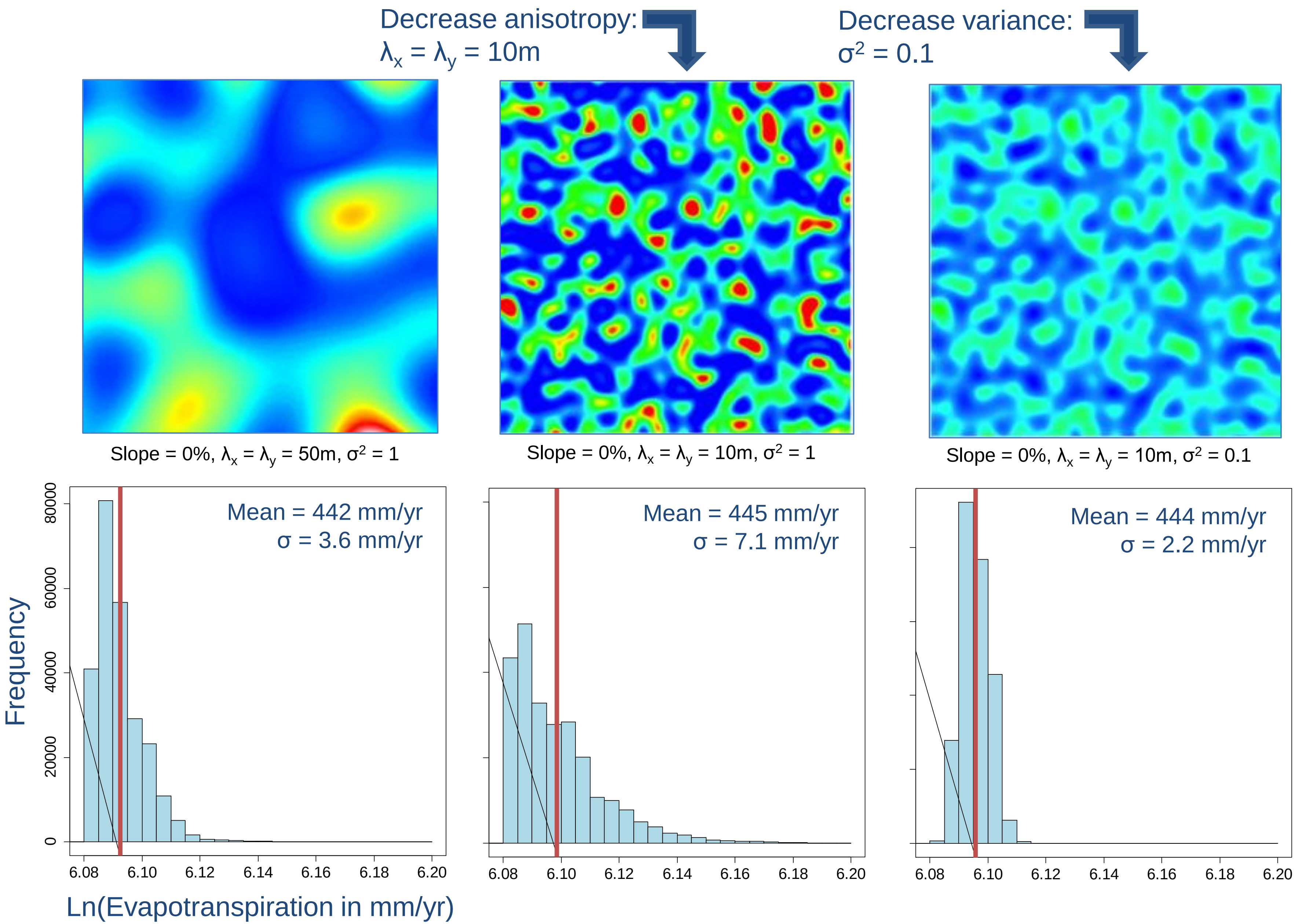
Parameters:
Slope = 0%
$\lambda_x = \lambda_y = 50m$
$\sigma^2 = 1$



Histograms reinforce spatial variations



Subsurface characteristics further influence ET



Conclusions from modeling

- Modeling **scale** does change the **range of ET** values observed
  - Increase in variability at smaller scales
  - Average values remains the same

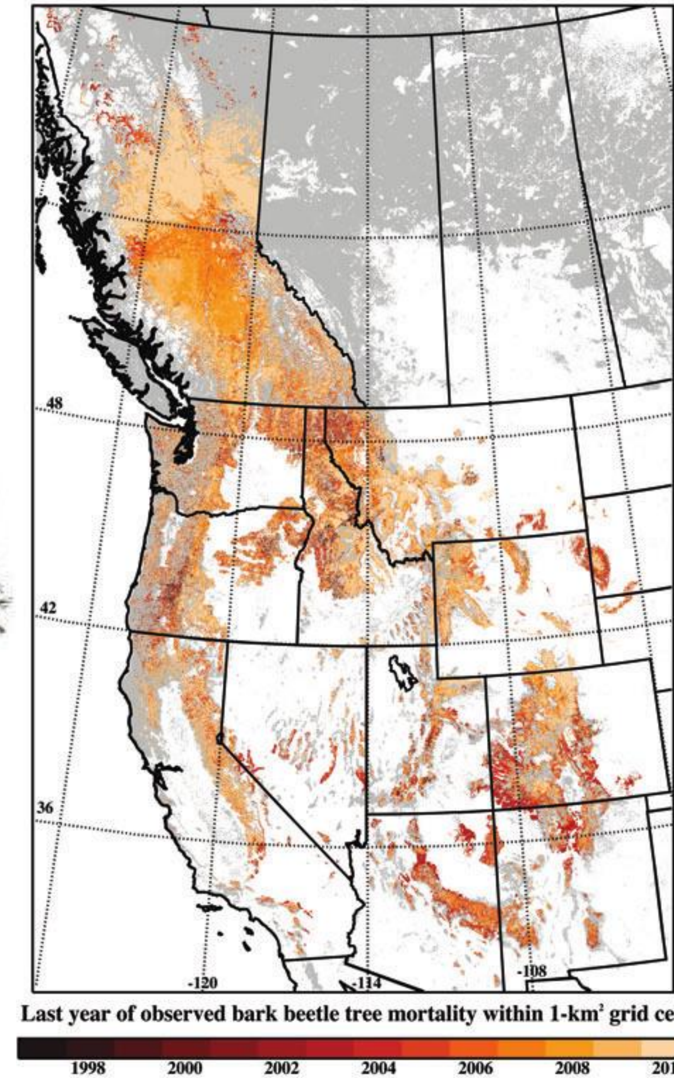
- The distribution of ET values is **influenced by subsurface** properties.

- So, what is next?!

Application to landscape changes from Mountain Pine Beetle

Pitch tubes.

Mountain pine beetle (*dendroctonus ponderosae*).

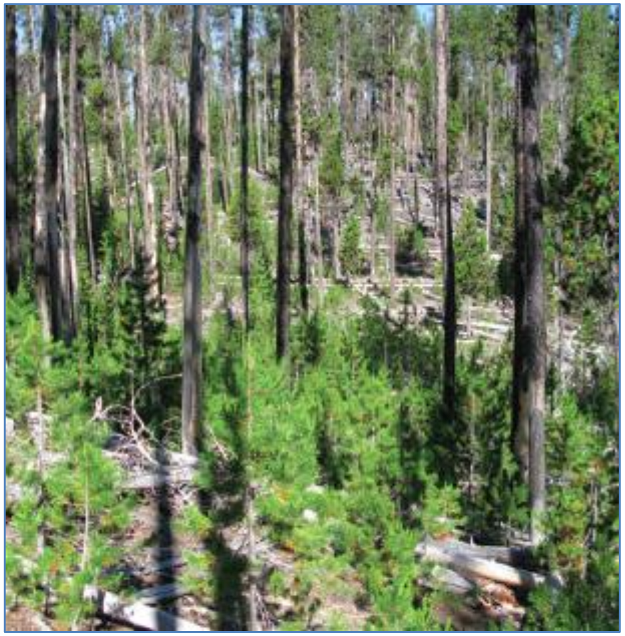


Edburg et al. (2012)

Future ET scaling work

Topography

Heterogeneity



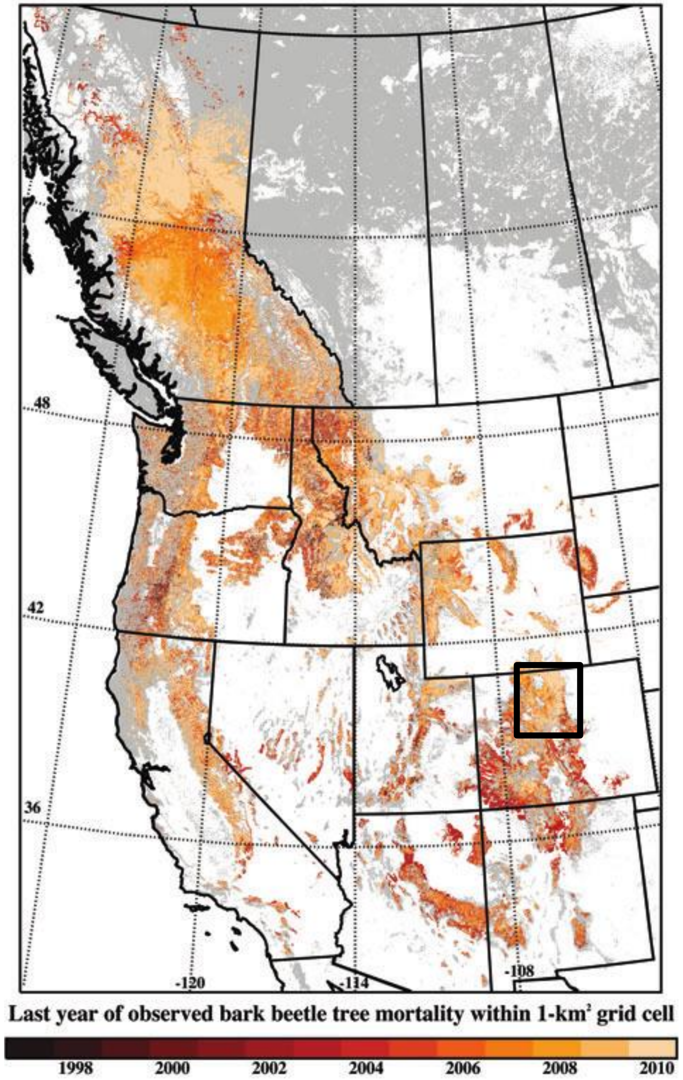
Regrowth

Thank you!

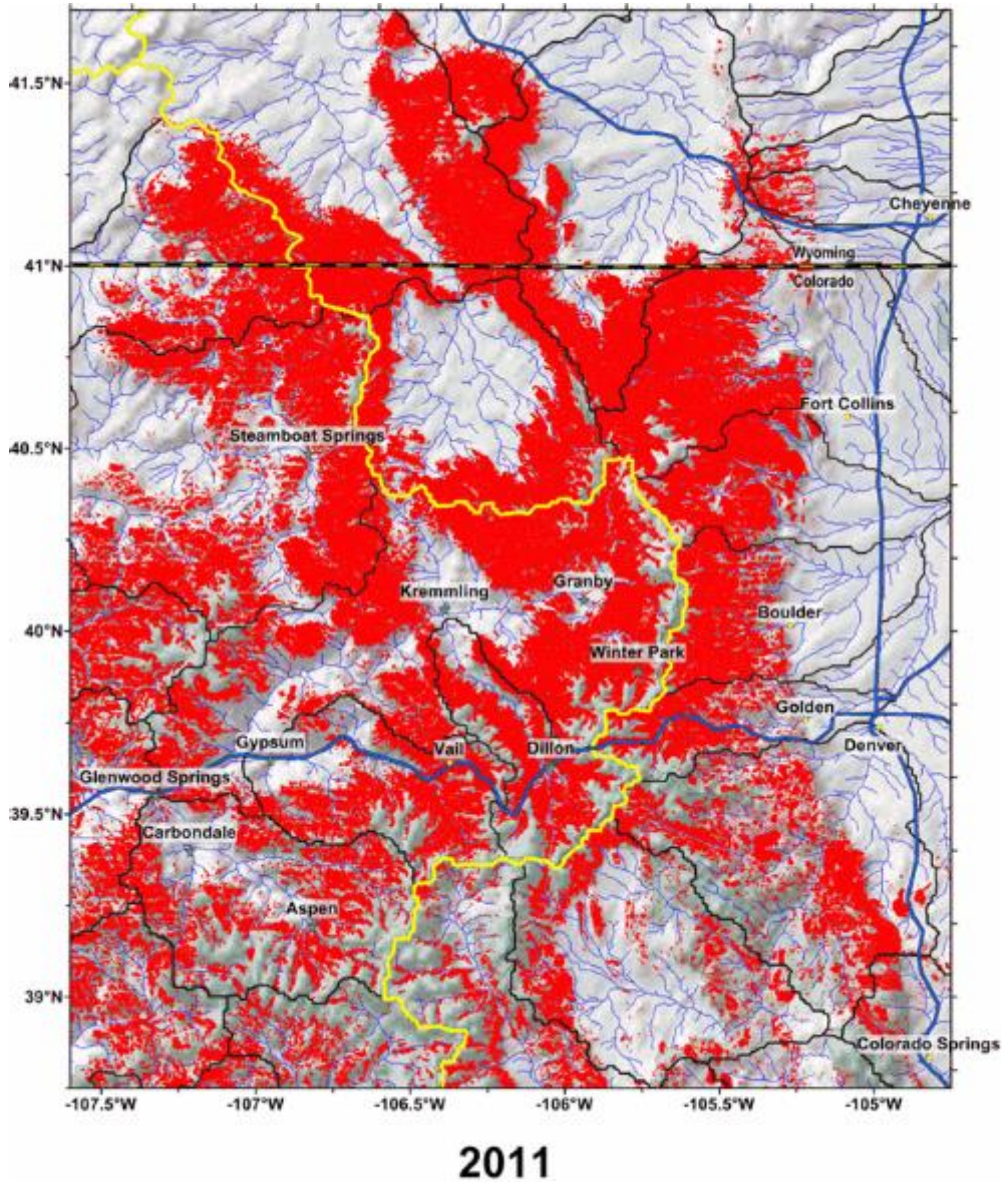
For more on mountain pine beetles:
Session T43. Ecohydrological Impacts from Climate-Induced Changes in Land Cover and Vegetation in Mountain Environments

Wednesday, October 30, 2013 from 8:00am-12:00pm, Room 302

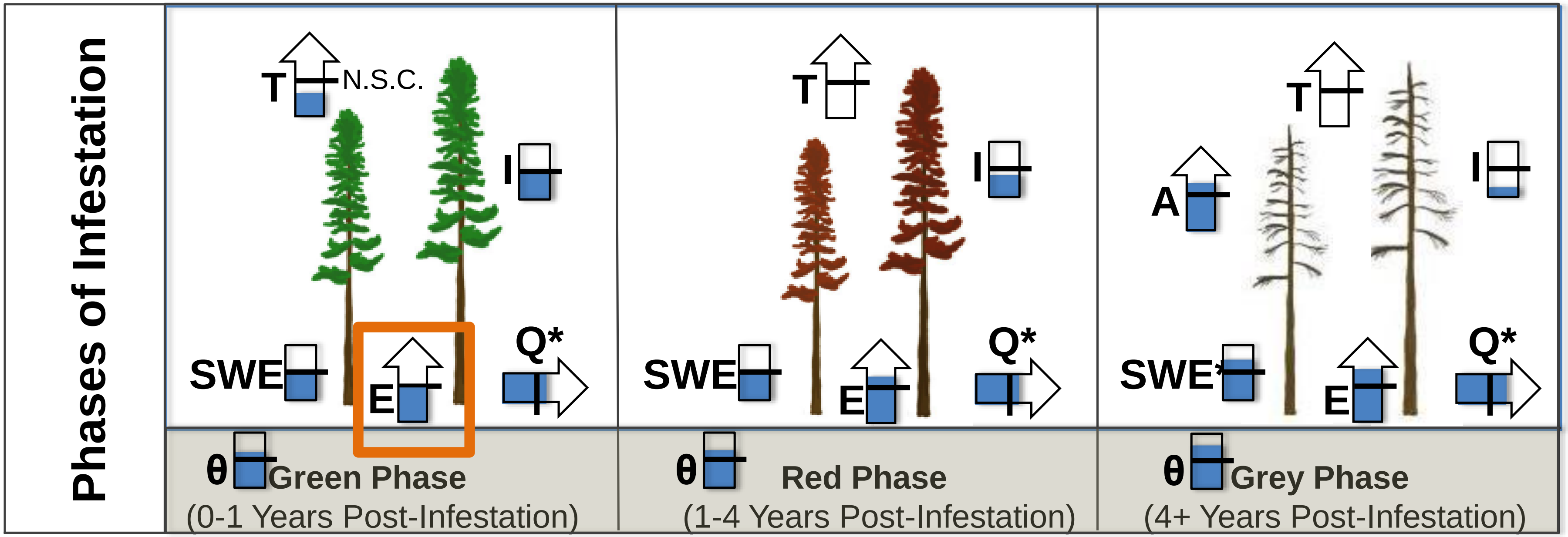
Mountain Pine Beetle in North America



Edburg et al. (2012)



Hydrologic Impacts



Modified from Mikkelson et al. (2013)

Why Now?

- Large uniform stands of mature lodgepole pine trees
- Stressed trees due to drought conditions
- Increased winter temperatures