

Ecosystem processes and landscape evolution modeling

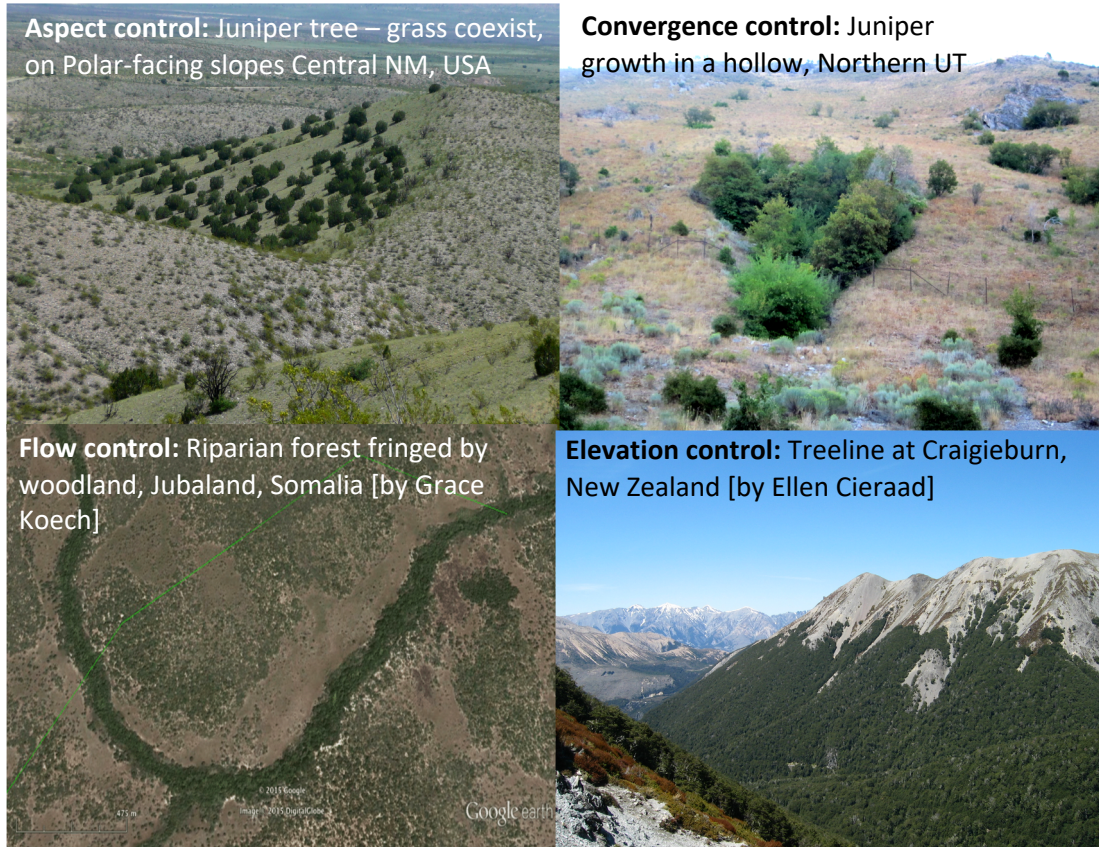
Erkan Istanbuluoglu



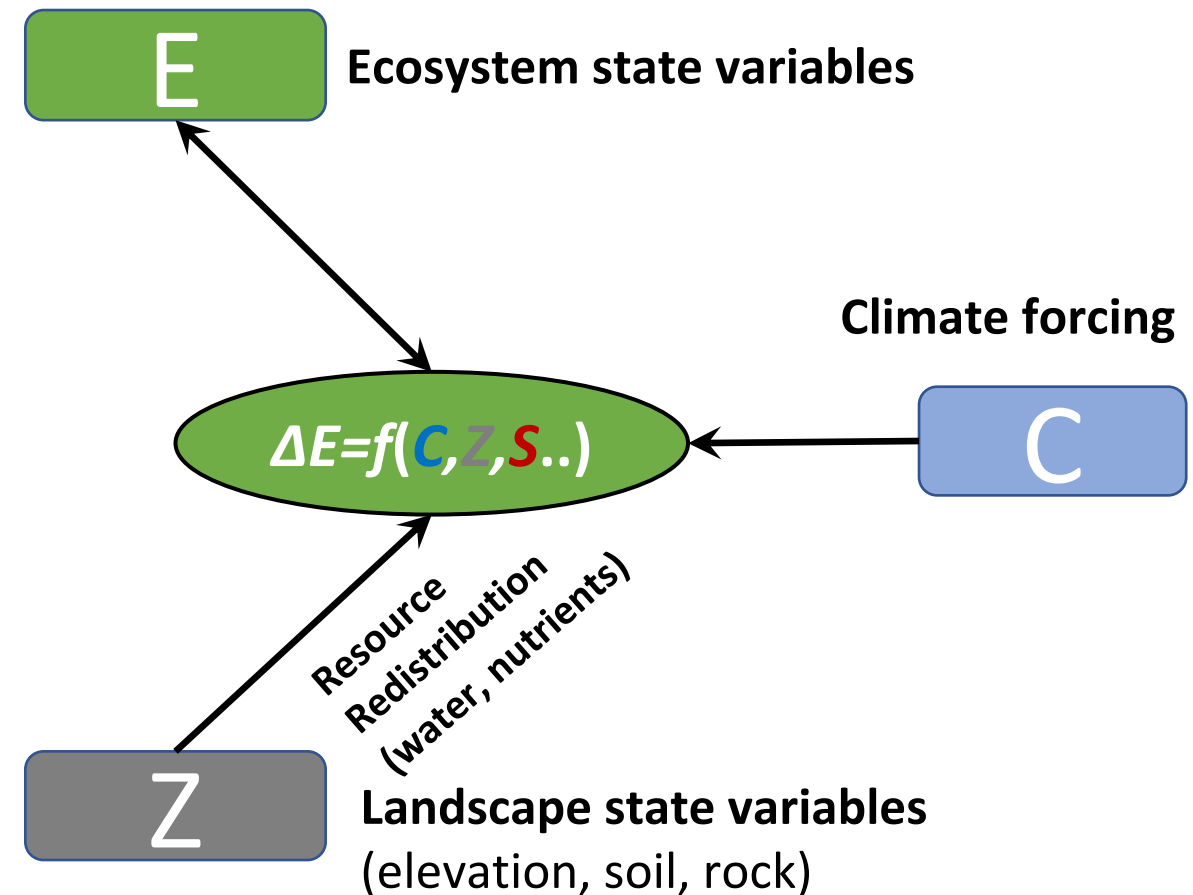
Civil and Environmental Engineering
University of Washington, Seattle

Linking Ecosystem and Earth Surface models: Three fundamental questions

1. How do climate and topography control ecosystems? [Ecosystem timescale]

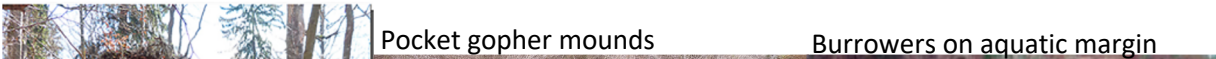


- **Distributed Ecohydrology models** predict these patterns [e.g., Fatichi et al. 2016].
- **Limitations:**
 1. Disturbance feedbacks (fires, insects)
 2. Competition, establishment, mortality
 3. Computational scalability

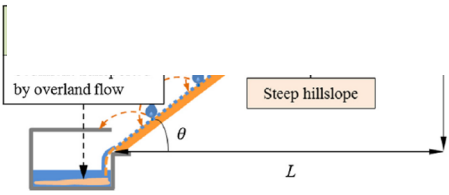
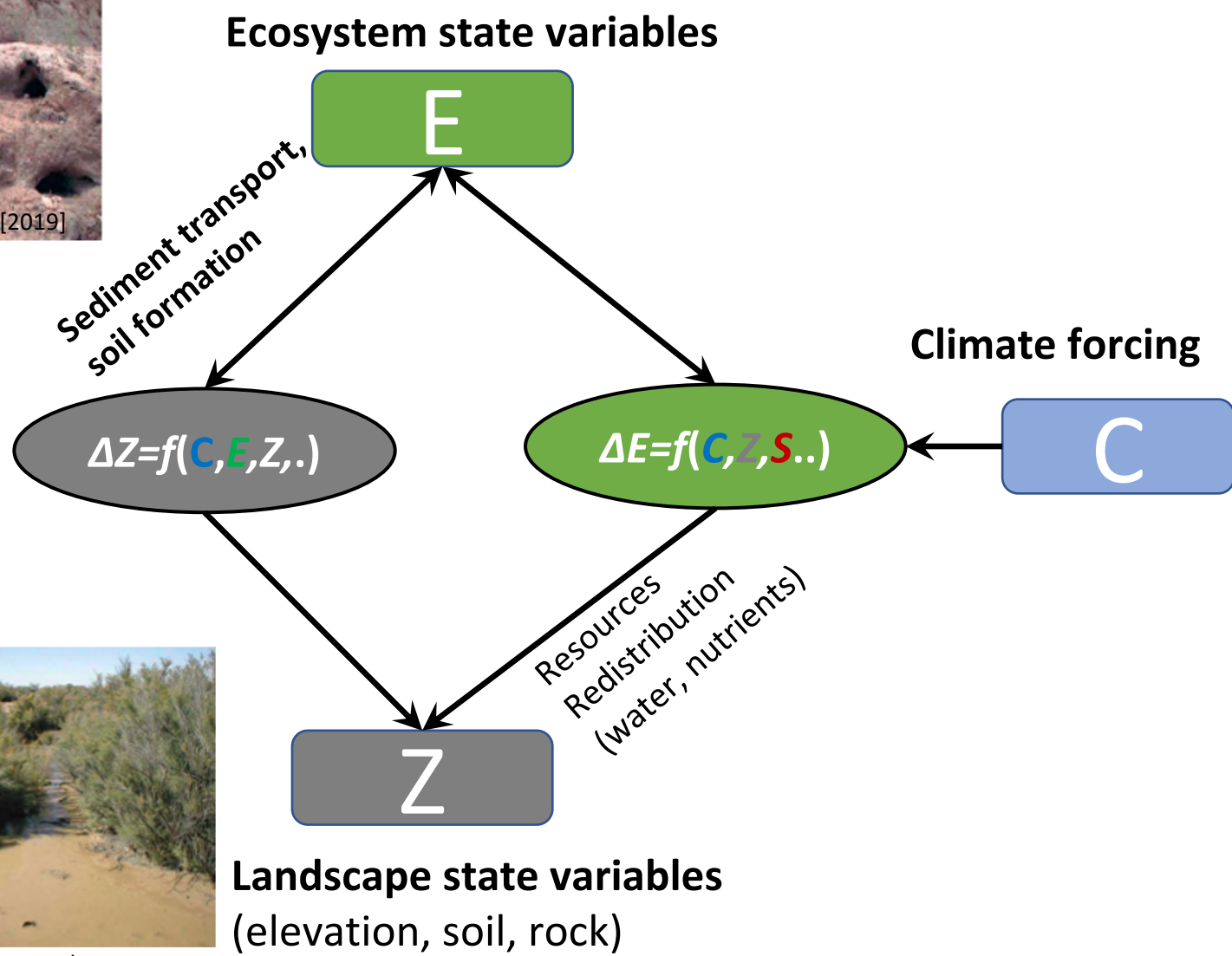
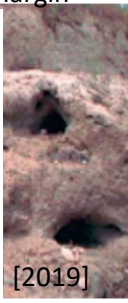


2. How do climate and ecosystems regulate geomorphic processes?

Bioturbation



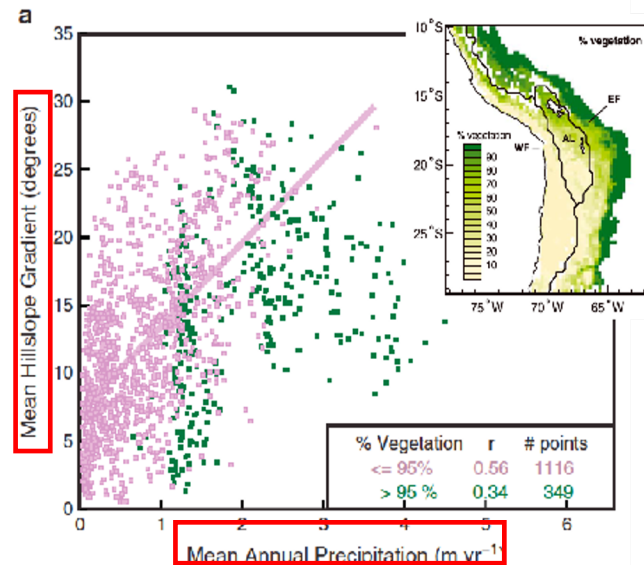
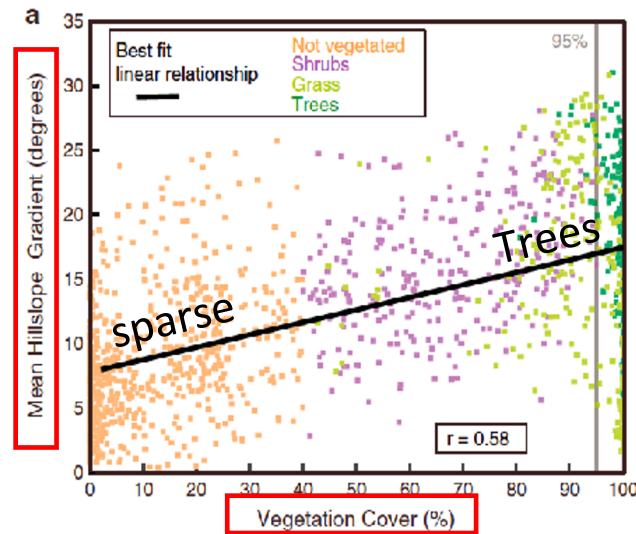
- **Implicit formulations** using long-term **Geomorphic Transport Laws** (Dietrich et al., 2003; Perron, 2017)
- **Mechanistic formulations** for range of “diffusive” processes (e.g. Gabet and Mudd, 2010; Yoo et al., 2005; Yoo and Mudd, 2008; Ben-Asher et al., 2017)
- **Fluid mechanics (Eco-hydraulics)** for vegetation-flow interactions (Le Bouteiller & Venditi, 2015; Beudin et al., 2017)
- **Mechanistic Landslide models** (Arnone et al. 2016; Bellugi et al., 2015; Strauch et al., 2018)



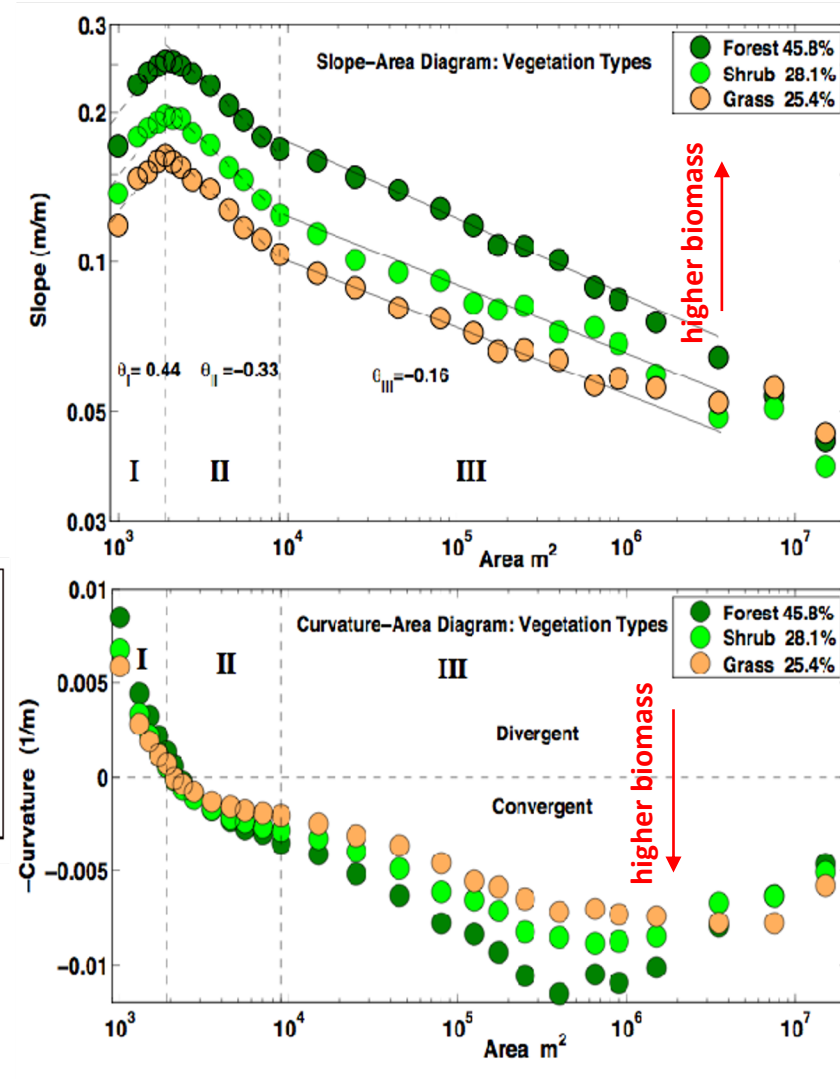
3. What are the emergent outcomes of a coupled eco-geomorphic system ?

Landscape scale outcomes

Central Andes (Jeffery et al., 2014)

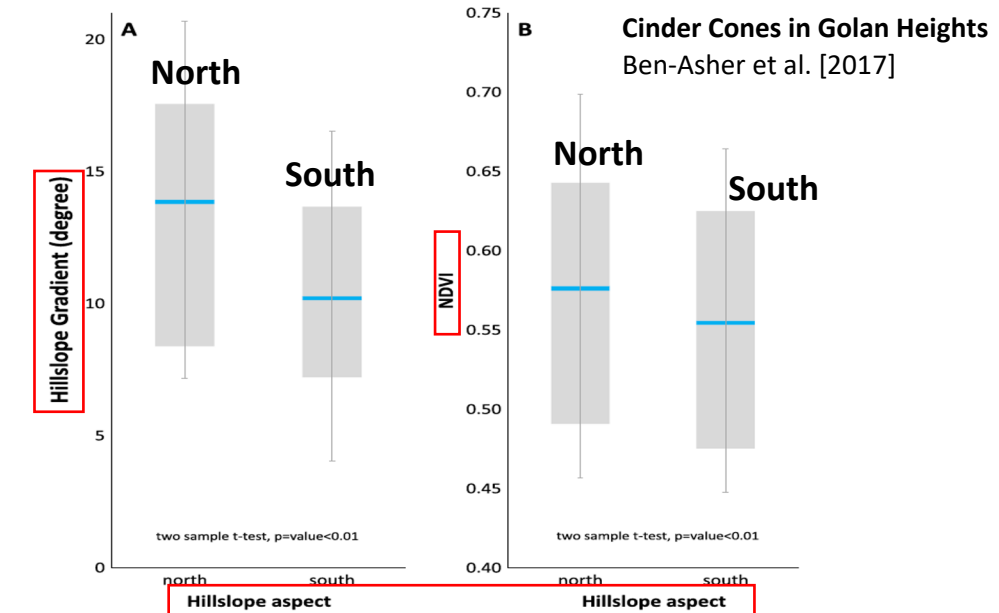
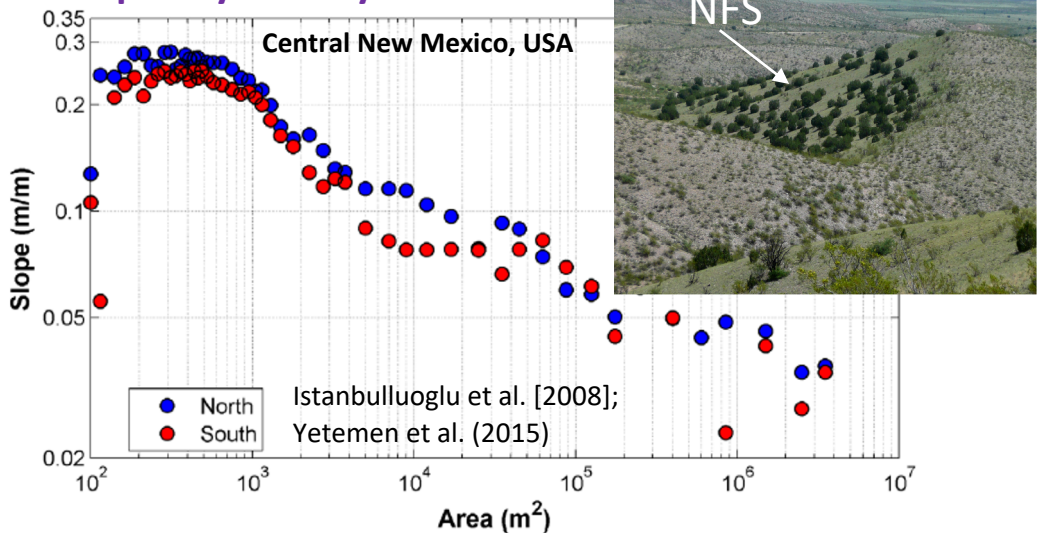


Central New Mexico (Yetemen et al., 2010)

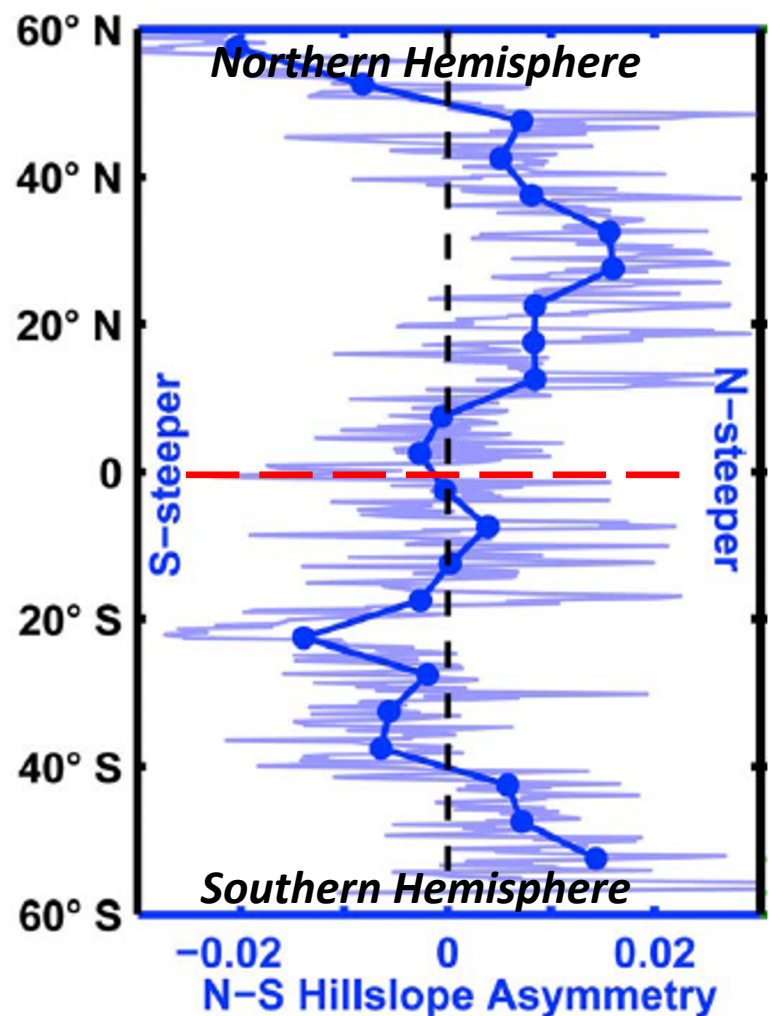


3. What are the emergent properties of a coupled eco-geomorphic system ?

Hillslope Asymmetry



Global Outcome: Steeper Polar Facing Slopes



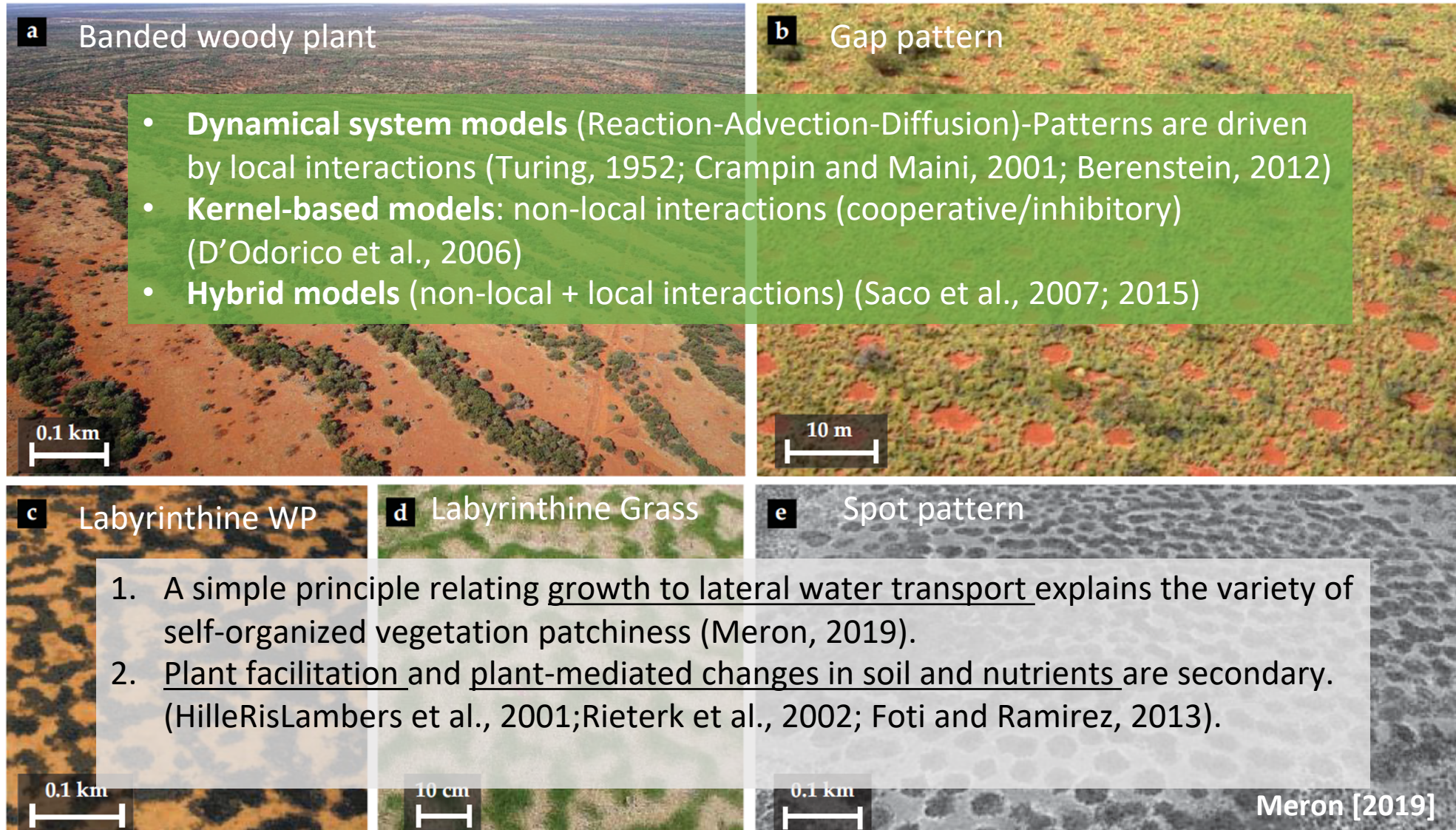
$$HAI_{N-S} = \log_{10} \frac{\text{median}(^{\circ}N)}{\text{median}(^{\circ}S)}$$

Poulos et al (2012): GRL Vol.39.

See Pelletier et al. [2018] for review on hillslope asymmetry

3. What are the emergent outcomes of a coupled eco-geomorphic system ?

Patterned Vegetation

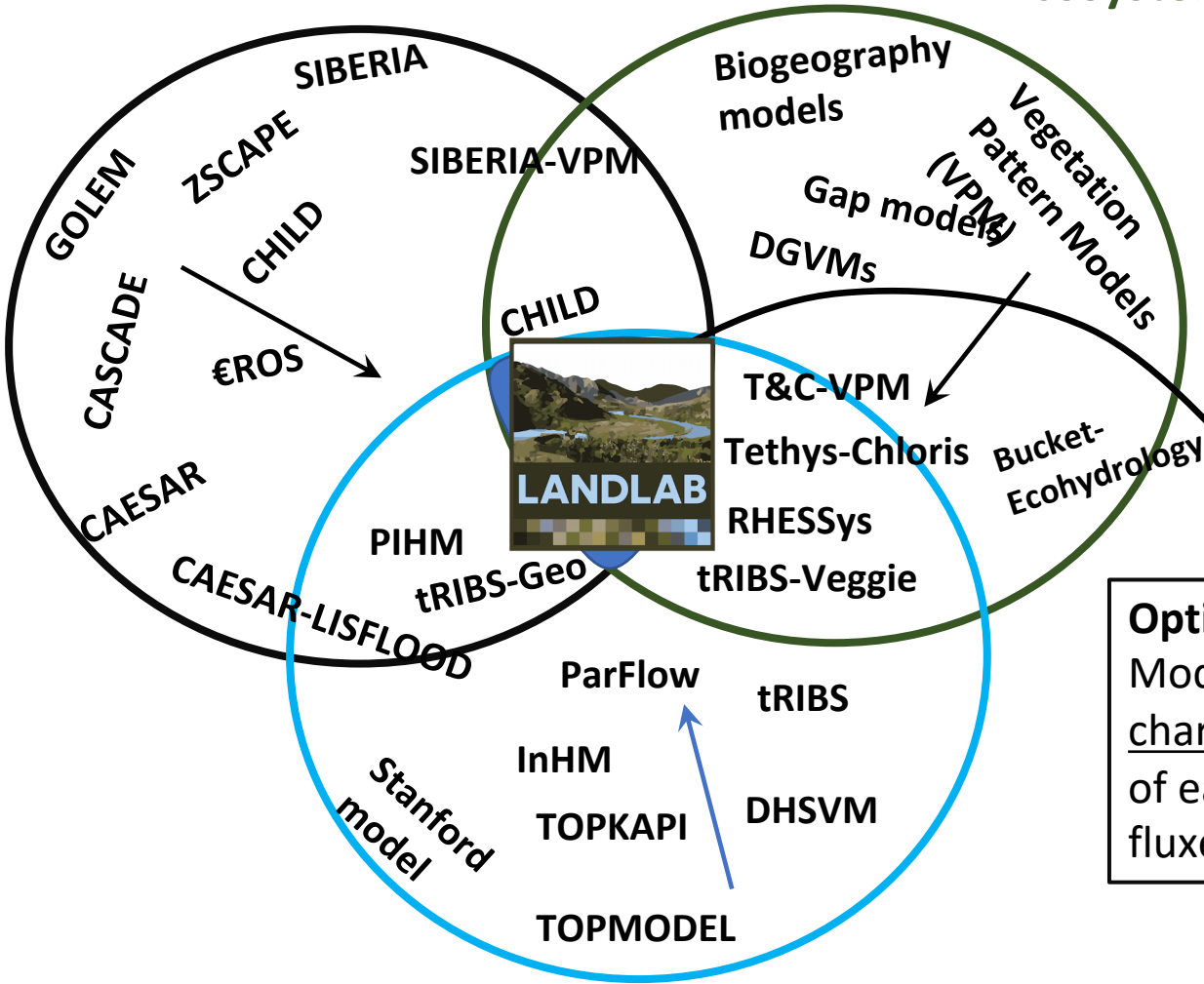


Linking Ecosystem and Earth Surface models: Three fundamental questions

Landscape Evolution Models

Ecosystem Models

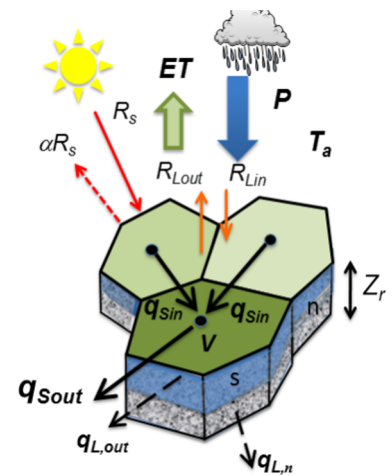
Growing
interdisciplinary
complexity
CPU time →



Optimal model complexity:
Model sufficiently captures
characteristic space-time dynamics
of each coupled state variable and
fluxes.

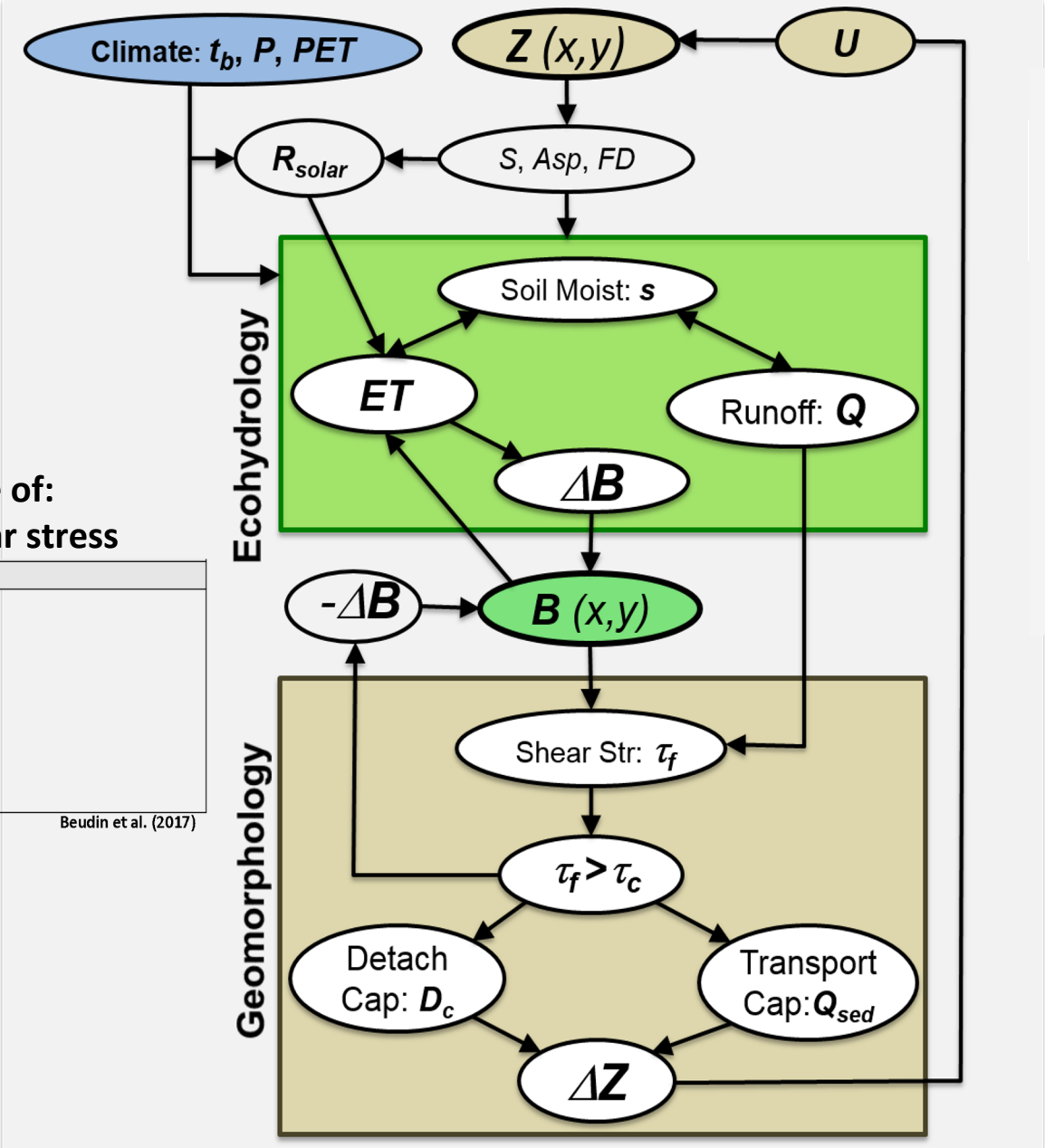
Hydrology Models

Linking Ecosystem and Earth Surface models: CHILD LEM study

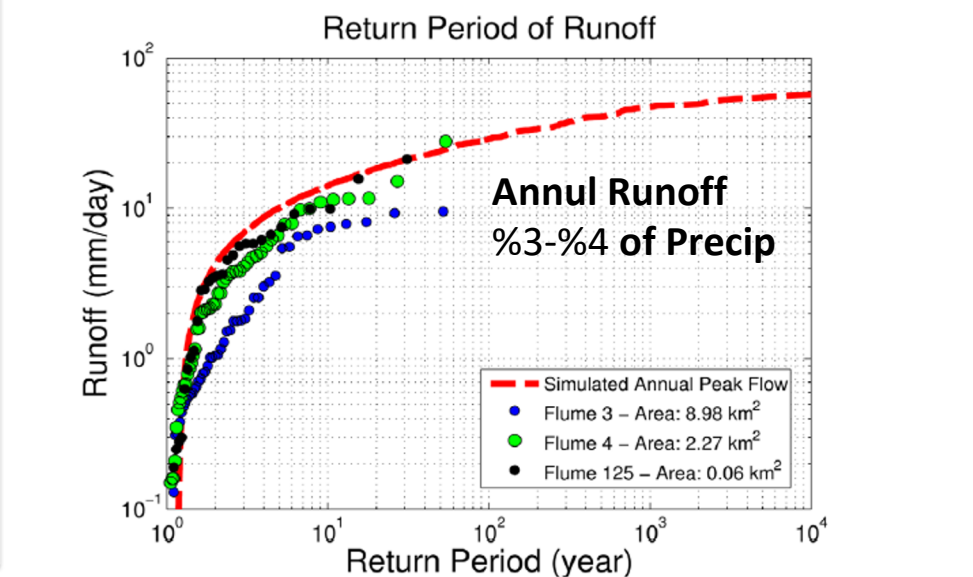
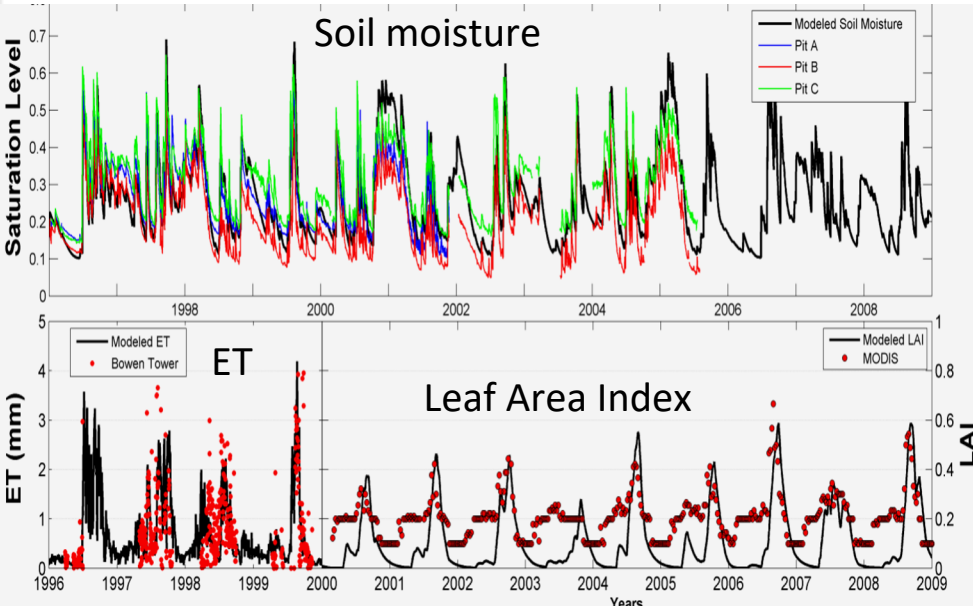


Geomorphic outcome of:
Biomass reduces shear stress

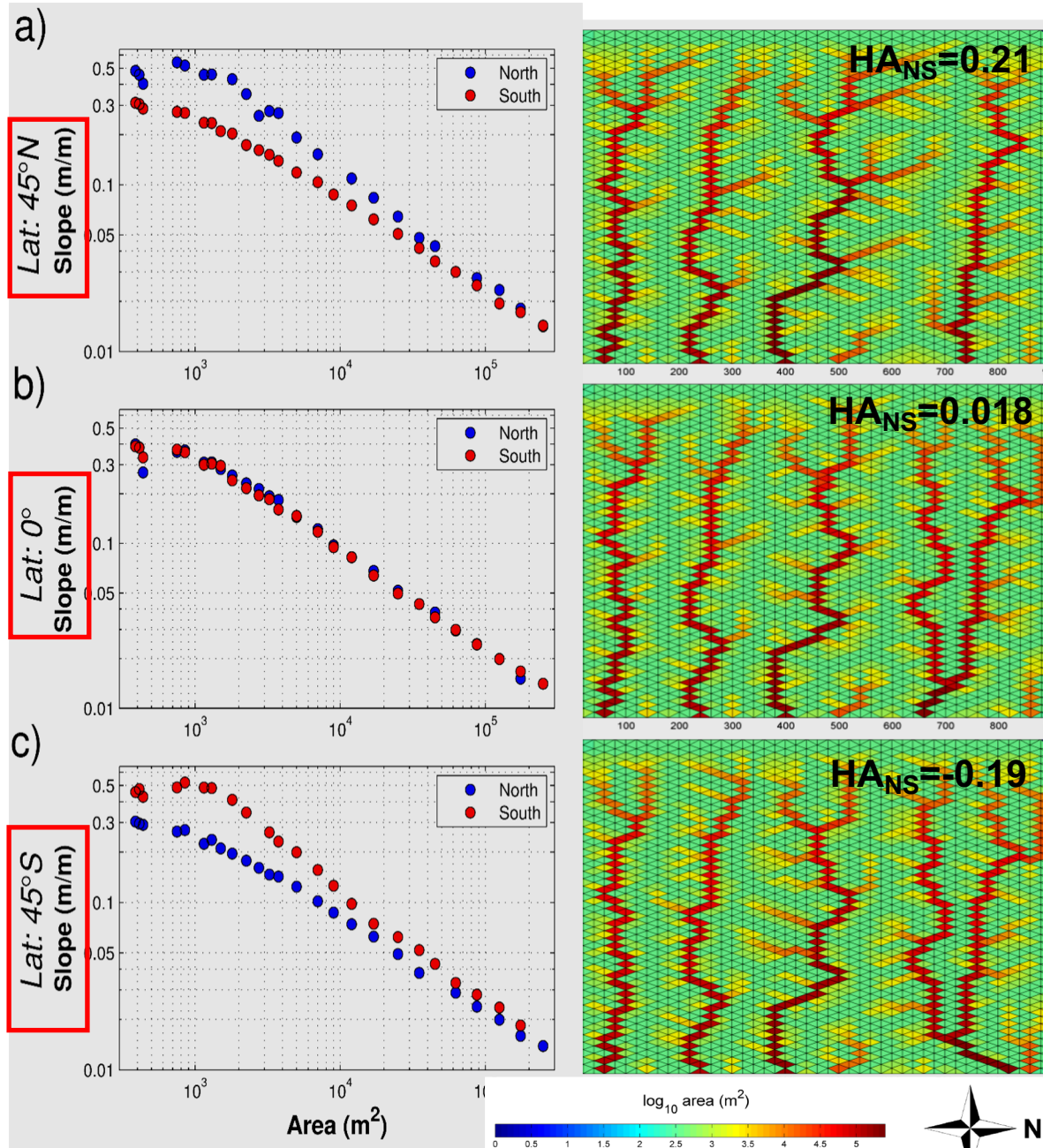
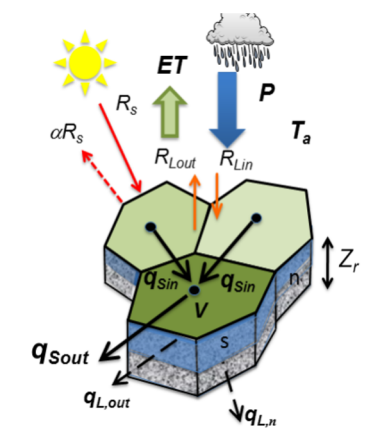
Beudin et al. (2017)



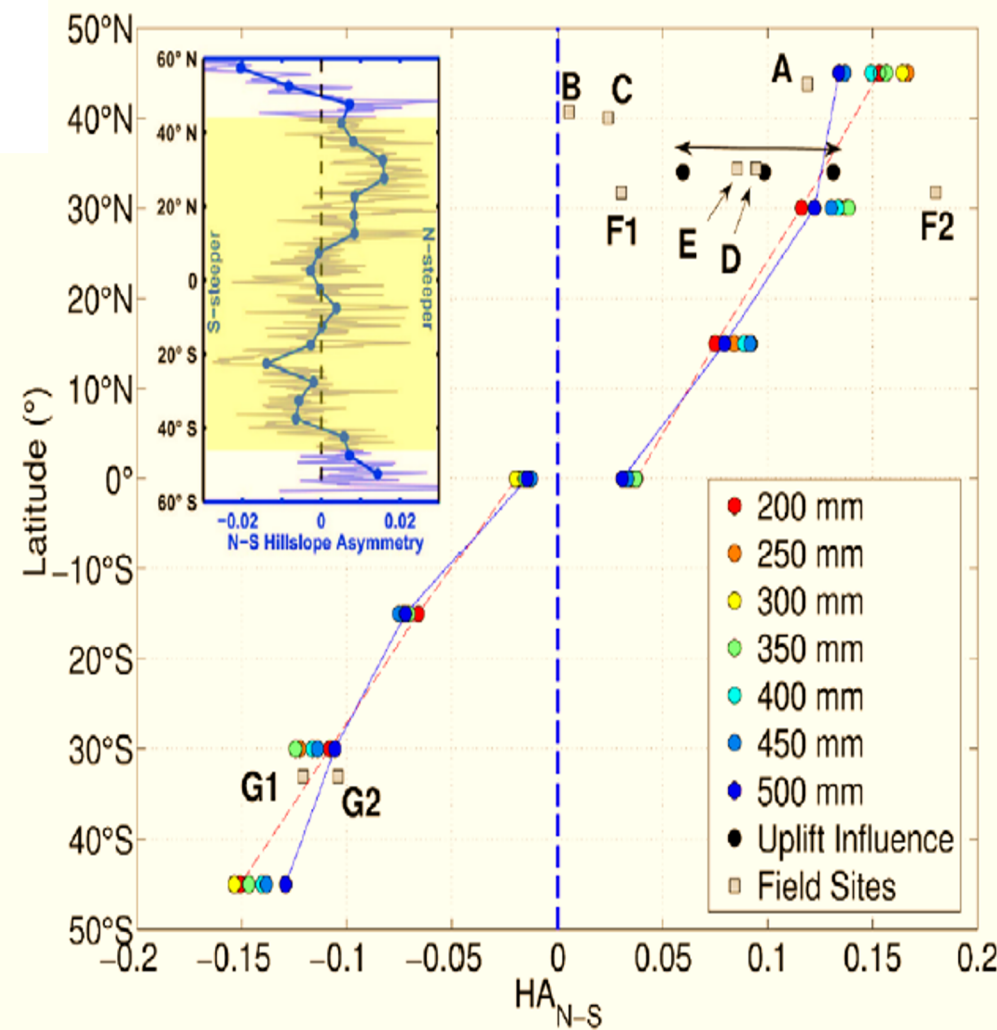
Ecohydrologic Validation



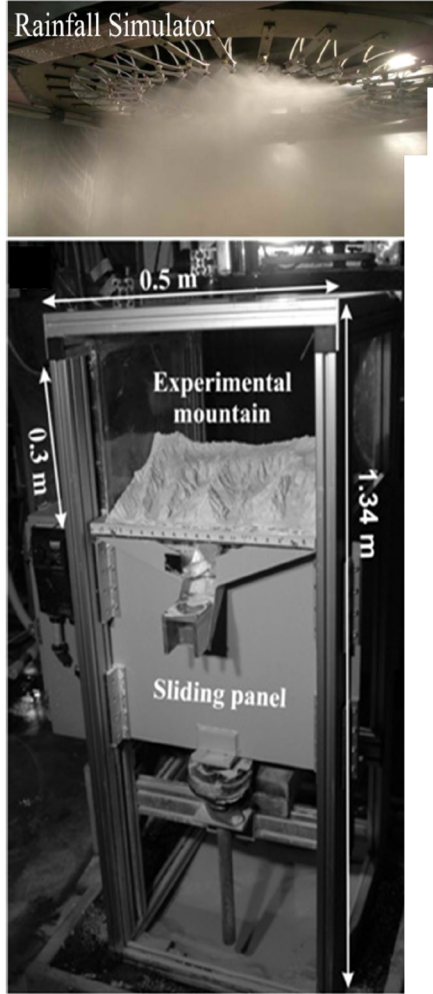
Linking Ecosystem and Earth Surface models: CHILD LEM study



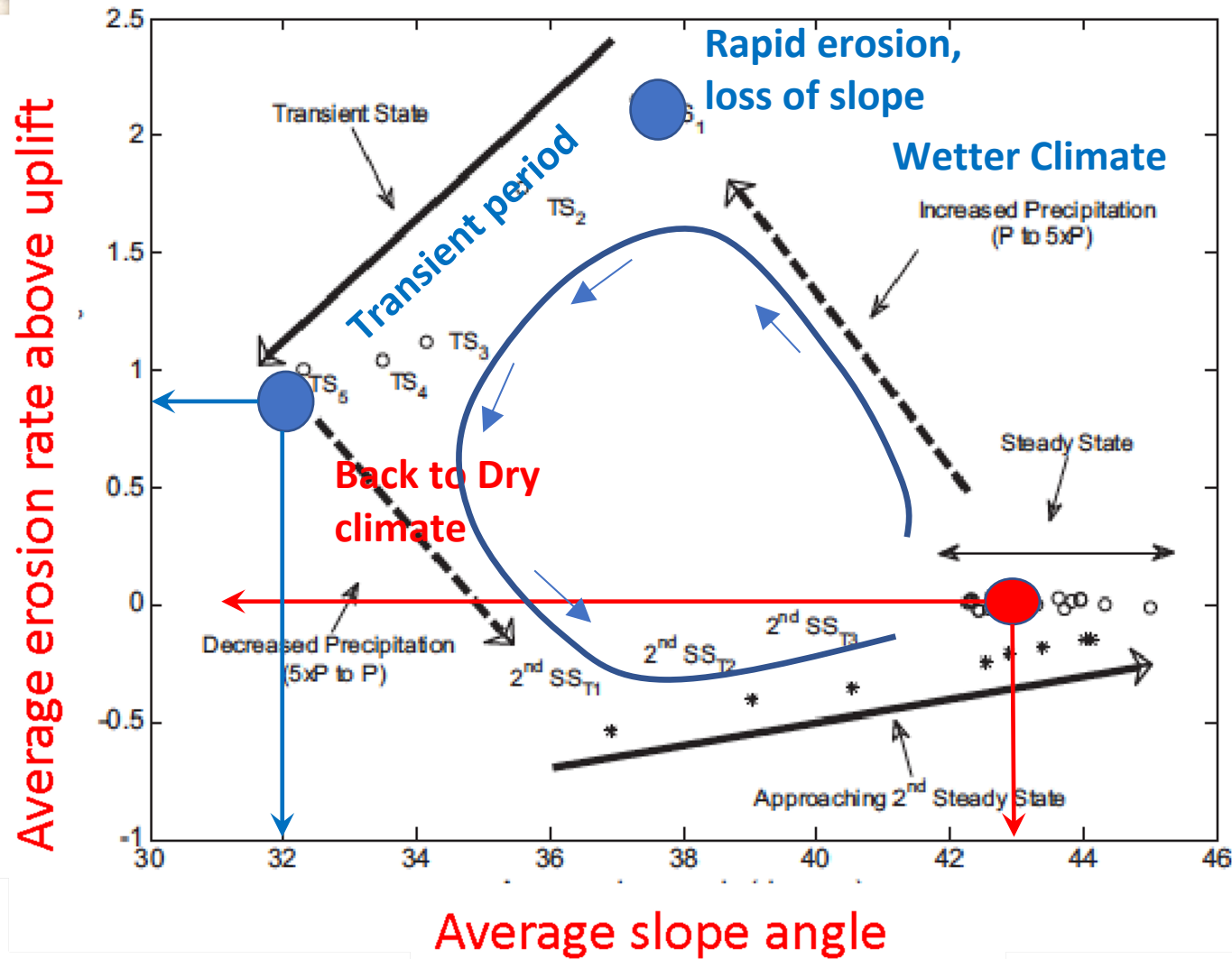
Model predicts Latitudinal variation of HA



What surprises do we get from a coupled model: Sensitivity to abrupt climate change

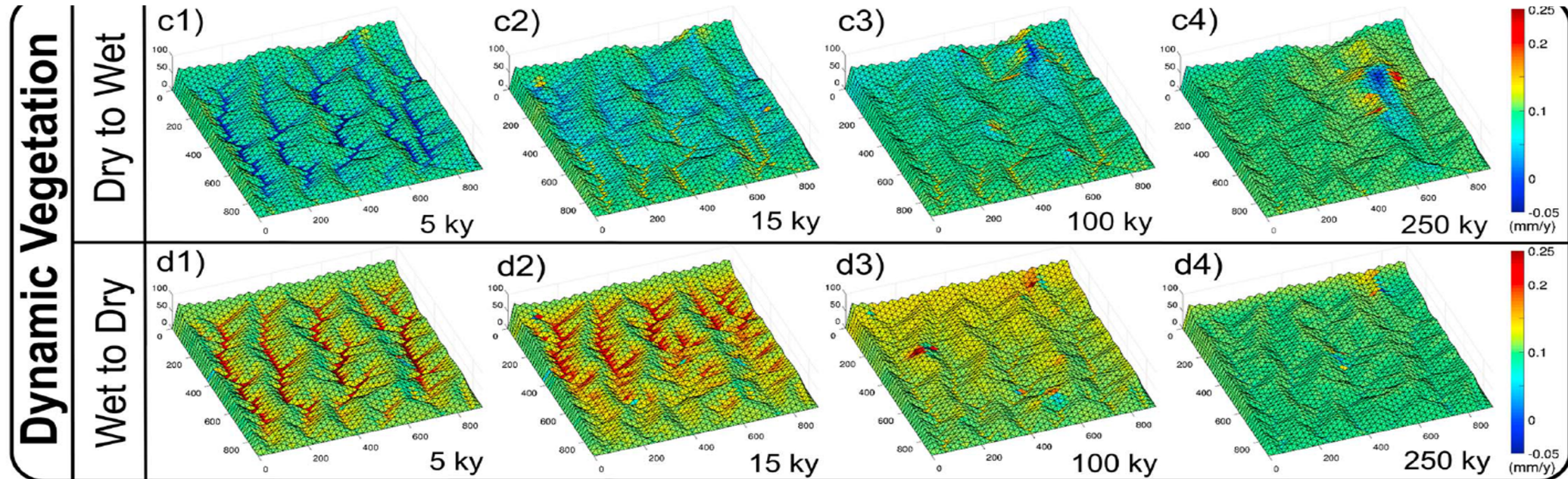
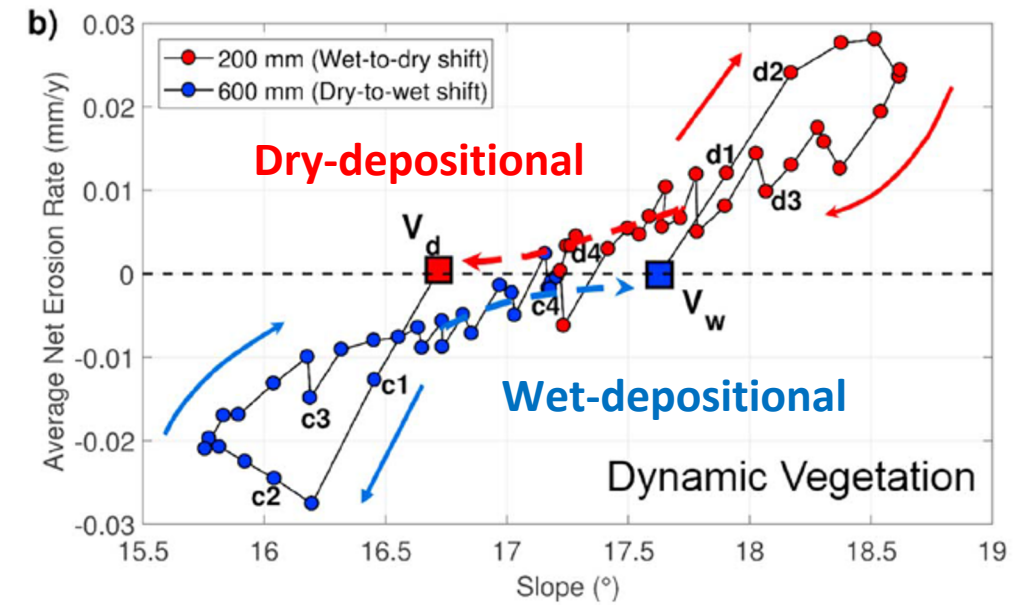
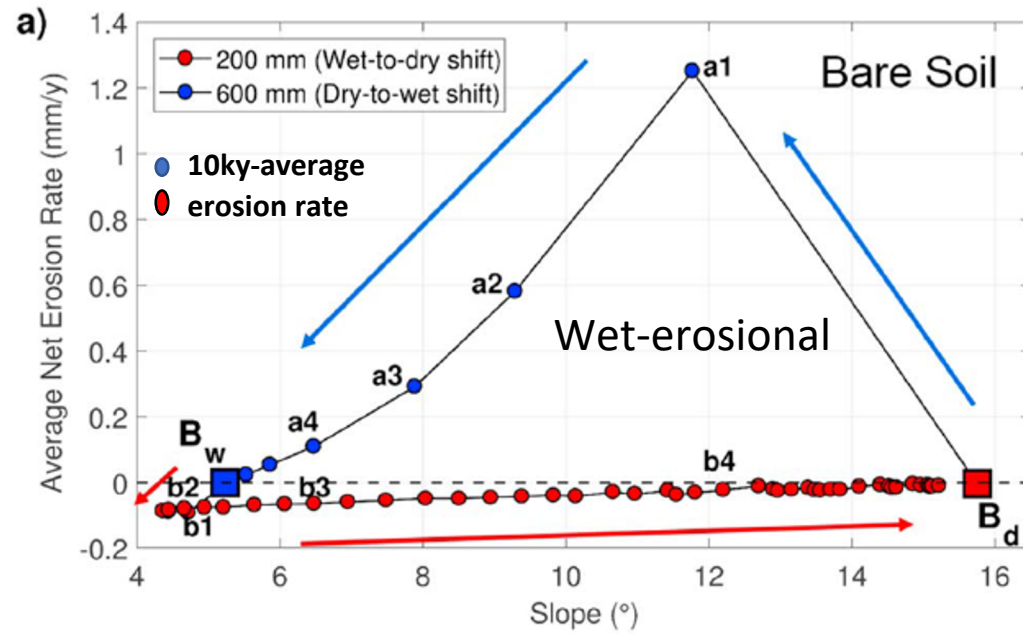


Experimental results of Singh et al. (2015)

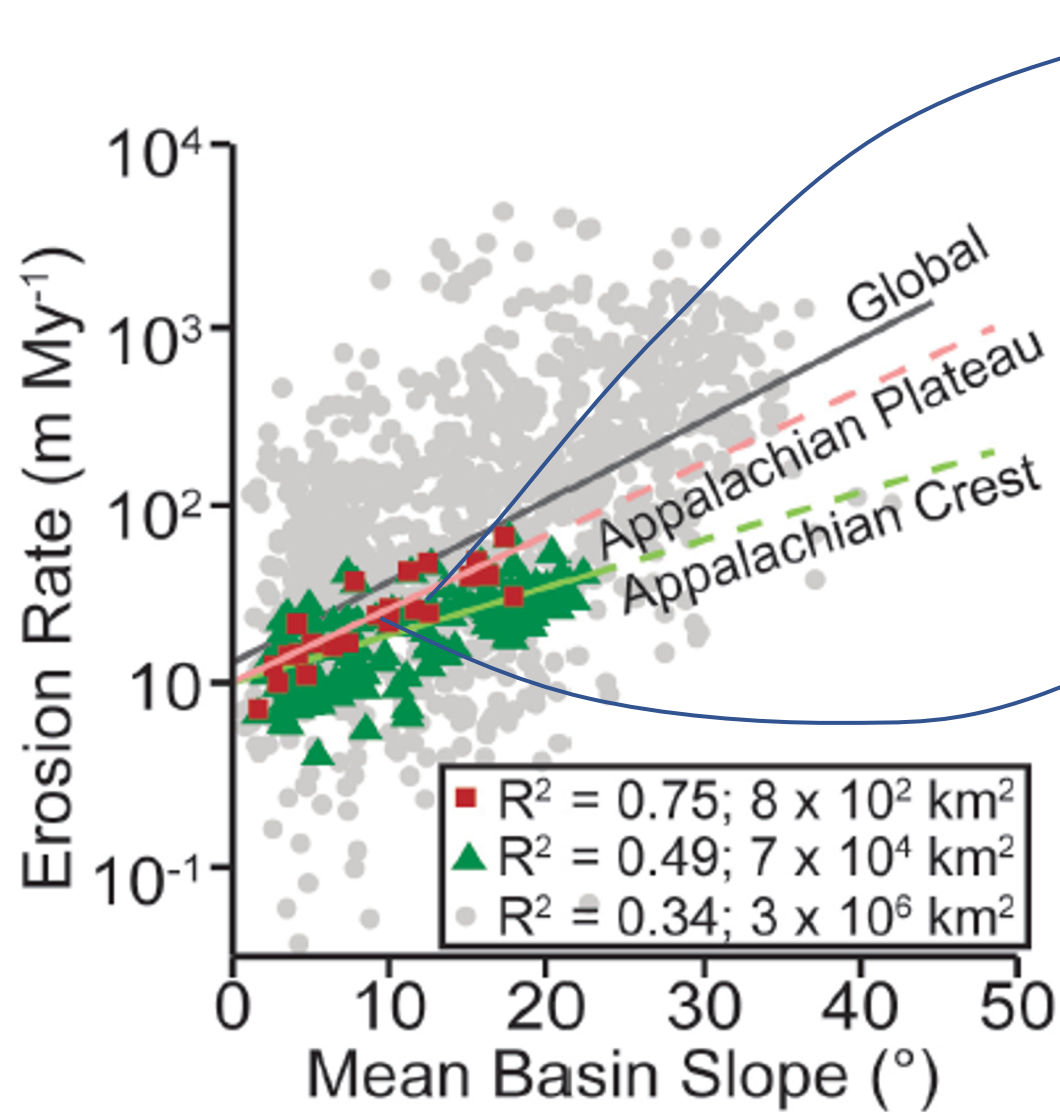


Counter clockwise response in the slope-erosion domain to wet-dry climate shift

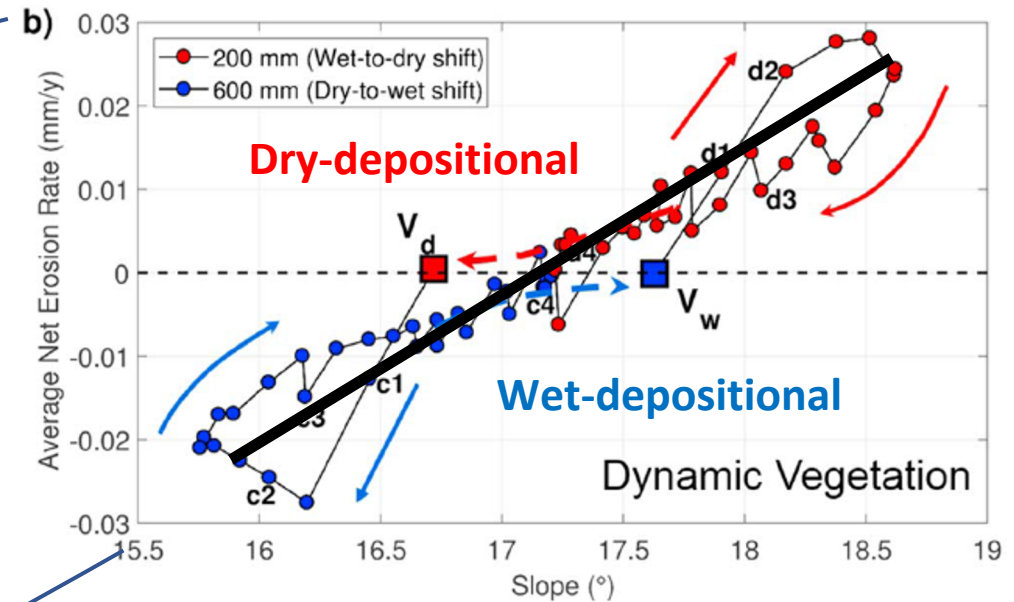
What surprises do we get from a coupled model: Sensitivity to abrupt climate change



What surprises do we get from a coupled model: Sensitivity to abrupt climate change



Portenga and Bierman (2011)

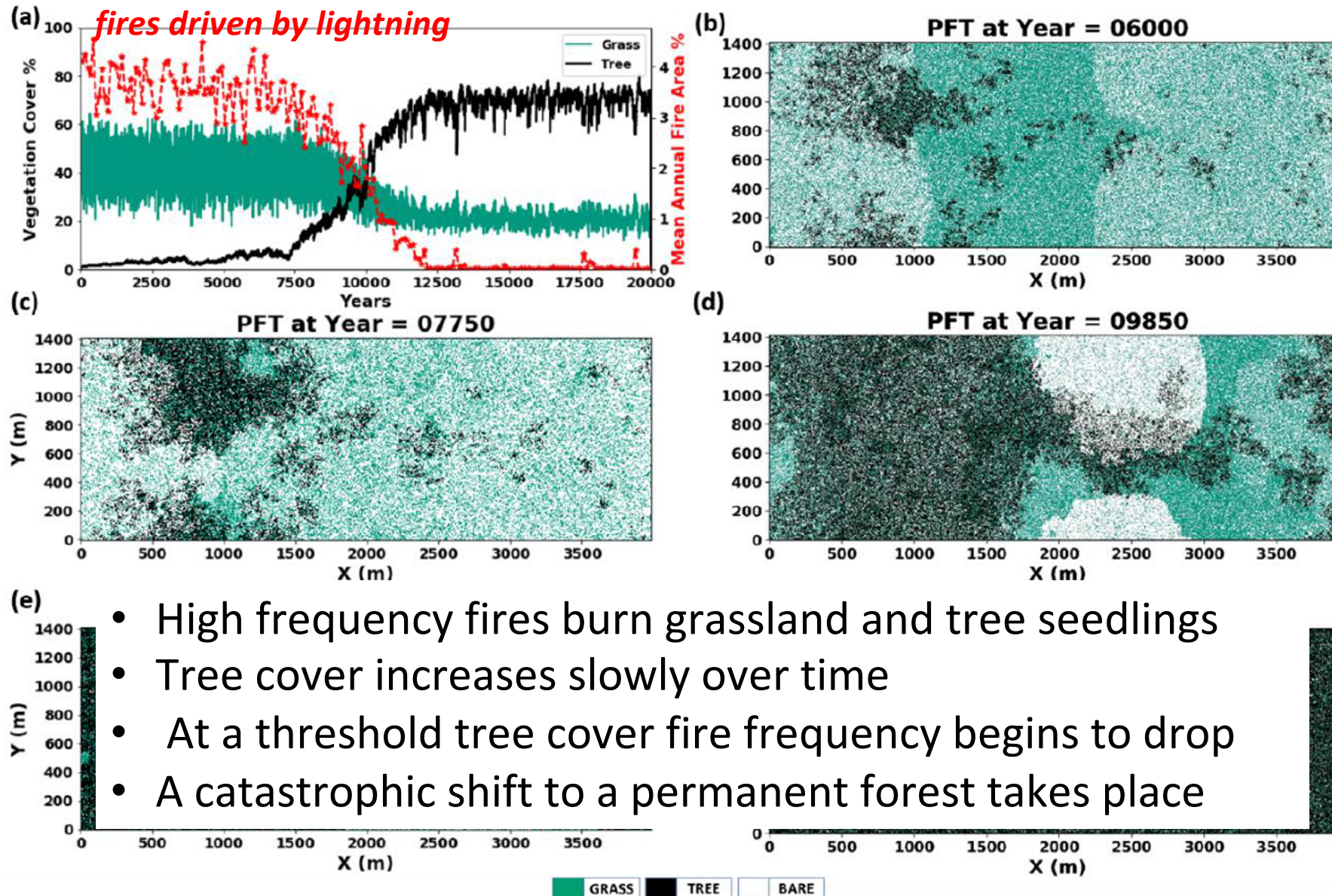


Dynamic vegetation:

- Governs transient landscape response
- Reverses the geomorphic response to climate change compared to bare soil.
- Lowers the variability of spatial-mean erosion and slope over time.

What surprises do we get from a coupled model: Savanna stability

Are savannas stable over the long-term maintained by disturbances?



Landlab Ecohydrology Models:

- Storm generator
- Solar Radiation
- Soil moisture
- Vegetation Dynamics
- Cellular Automaton spatial competition

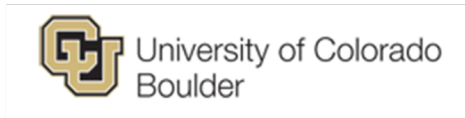
Many Thanks to..

UW Watershed dynamics group (former and current members) studying landscapes:

Sai Nudurupati, Omer Yetemen, Amanda Manaster, Xiaochi Zhou, Domenicco Carocciolo, Ronda Strauch, Christina Bandaragoda, Allison Pfeiffer, Zach Johnson, Jeff Keck, Zhuoran Duan, Jim Phuong.

Landlab Team:

Dan Hopley, Jordan Adams, Sai Nudurupati, Eric Hutton, Nicole Gasparini, Greg Tucker, Katy Barnhart, Nathon Lyons, Christina Bandaragoda, Amanda Manaster.



ICER 1663859
ACI-1148305
OAC-1450412

