How to improve process realism in physically-based predictive approaches?

Jeff McDonnell

Institute for Water and Watersheds

Oregon State University

Acknowledgements

How to improve process realism?

- Cody Hale, PhD student at OSU
- Kevin McGuire, now Virginia Tech University
- Taka Sayama, now International Center for Water Hazards
- Jan Seibert, now University of Zurich
- Kellie Vache, now Dept. Biological and Ecological Engineering, OSU
- Markus Weiler, now Freiburg University

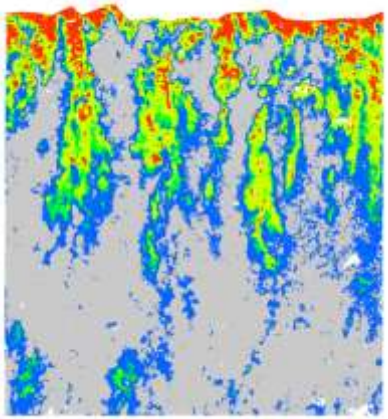
Process realism and my PUB mantra

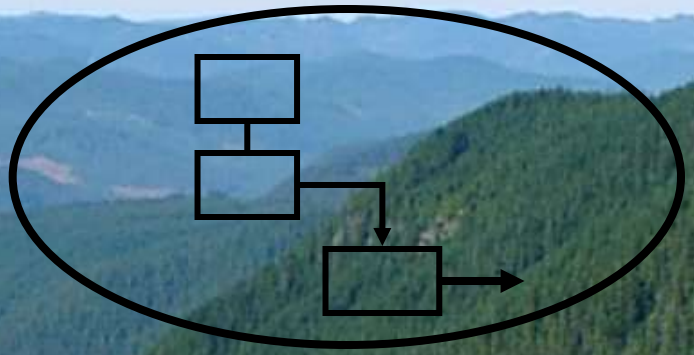
How to improve process realism?

"Accurate prediction of the headwater hydrograph implies adequate modeling of **sources, flowpaths and residence time** of water and solutes.

Hewlett and Troendle, 1975

How to improve process realism in physically-based predictive approaches?





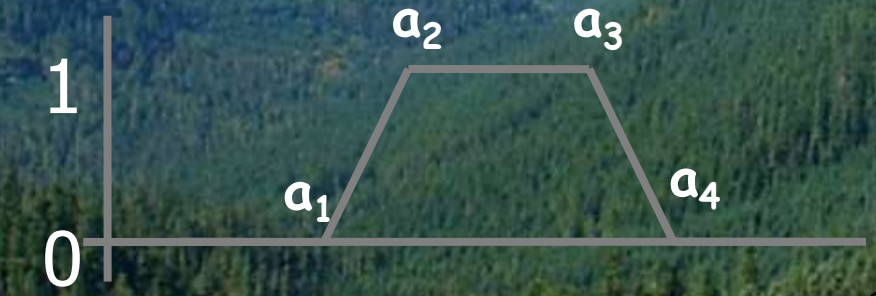
Experimentalist

Evaluation rules

Modeller

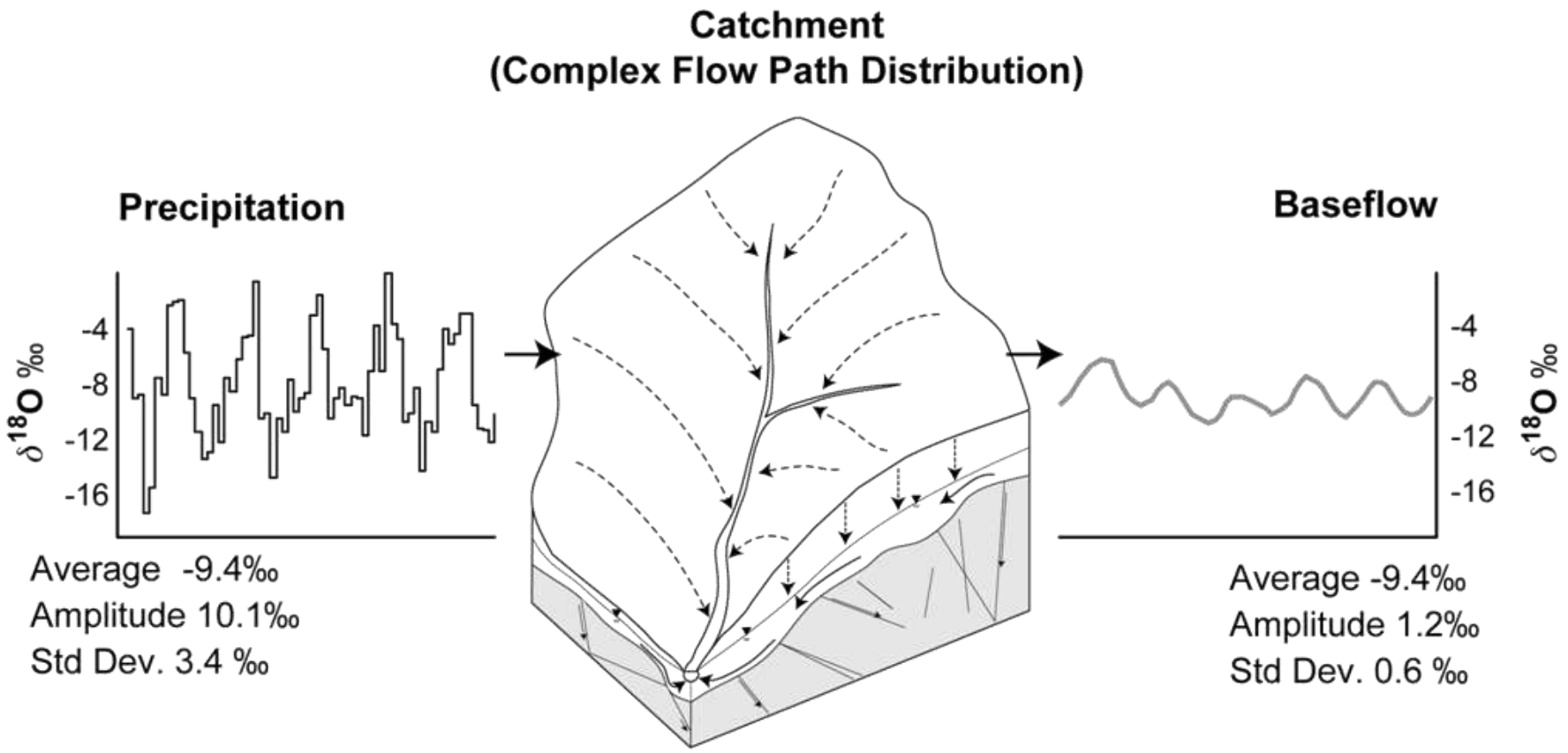
Values for evaluation rules (a_i)

"Degree of acceptability"



Another approach we're explored…

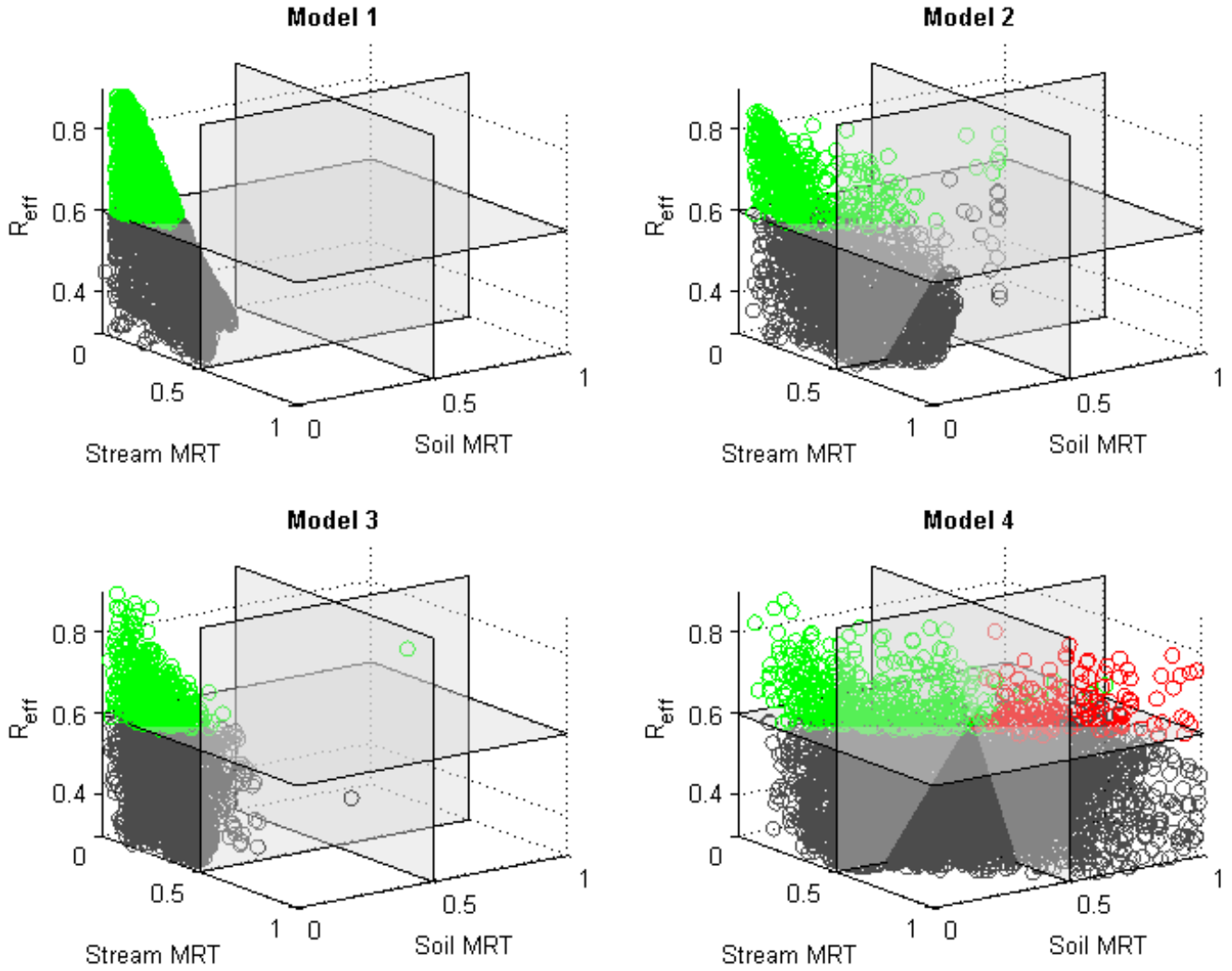
How to improve process realism?



Quantifying streamwater mean residence time

Orthogonal measures for model evaluation

How to improve process realism?



Vache and McDonnell, 2006 WRR

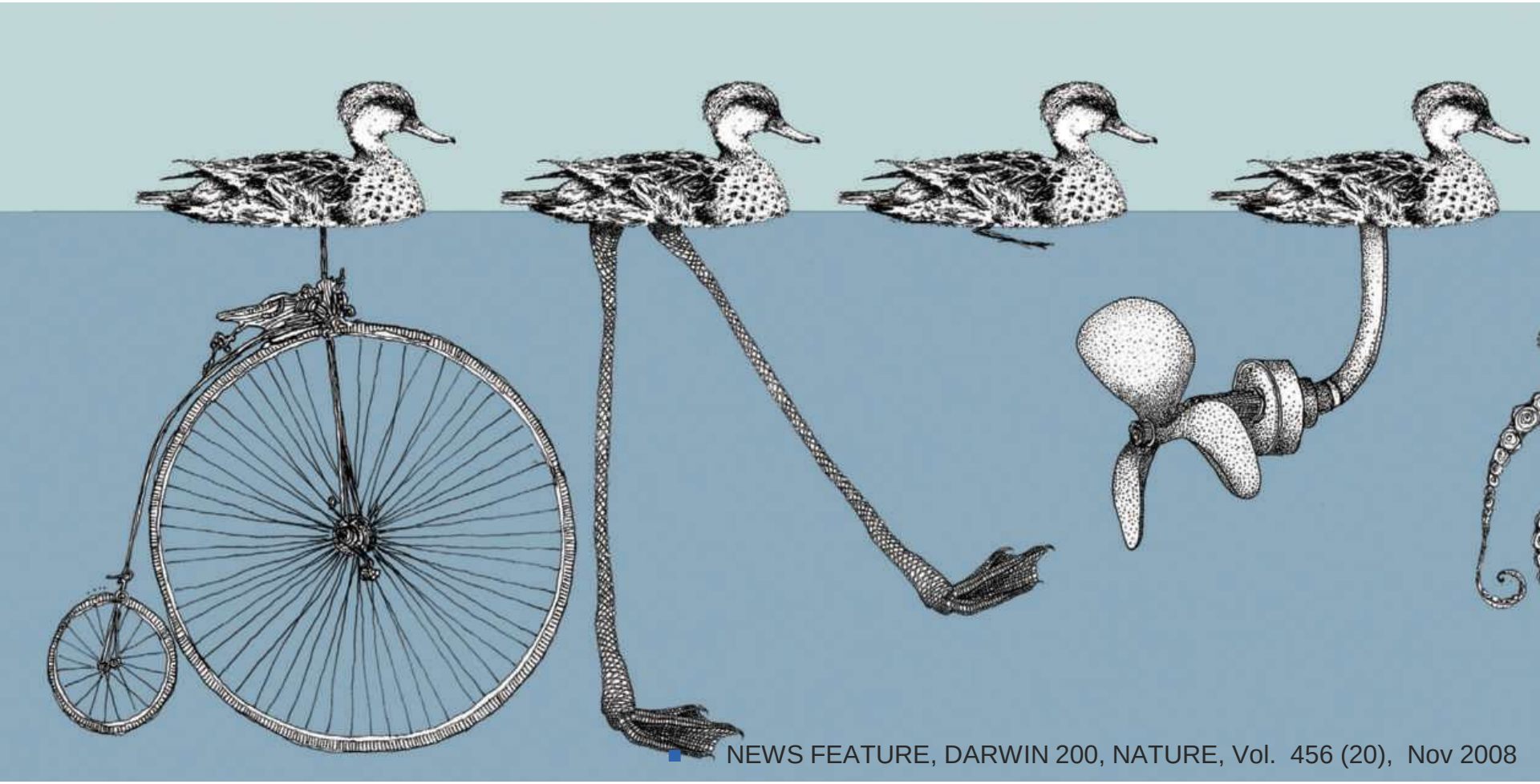
Outline for today

How to improve process realism?

- Scaling realism as process realism
  - The ultimate top-down approach
  - How scaling rules aggregate key process information
  - How such information might be used in physically-based predictive approaches
    - Model testing, catchment classification
    - 3 examples from Oregon and California

A PUB Process-Modeling Grand Challenge

How to improve process realism?



NEWS FEATURE, DARWIN 200, NATURE, Vol. 456 (20), Nov 2008

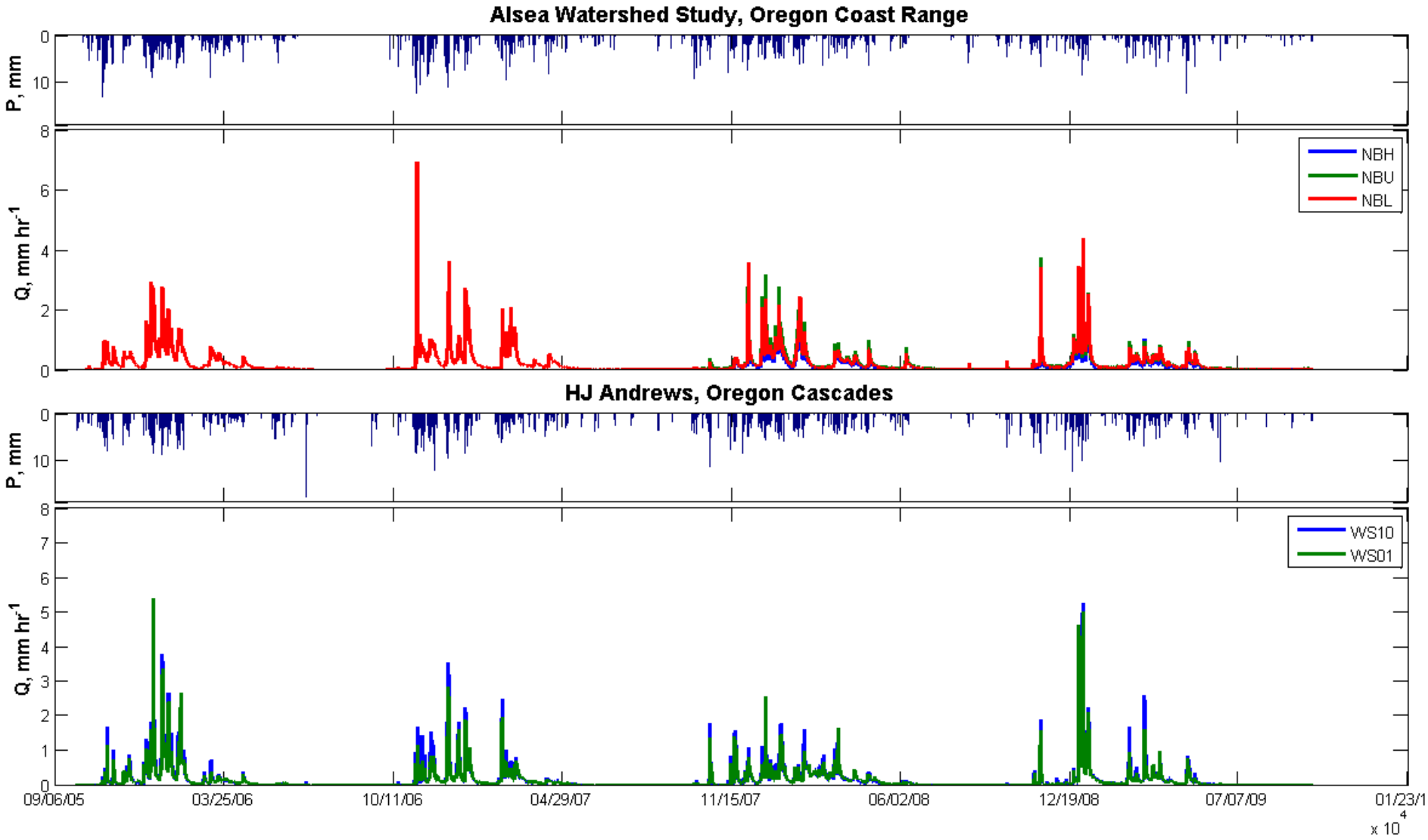
Similar forms can hide radically different wiring…

"Identical" rainfall-runoff relations…very different residence time scaling

How to improve process realism?

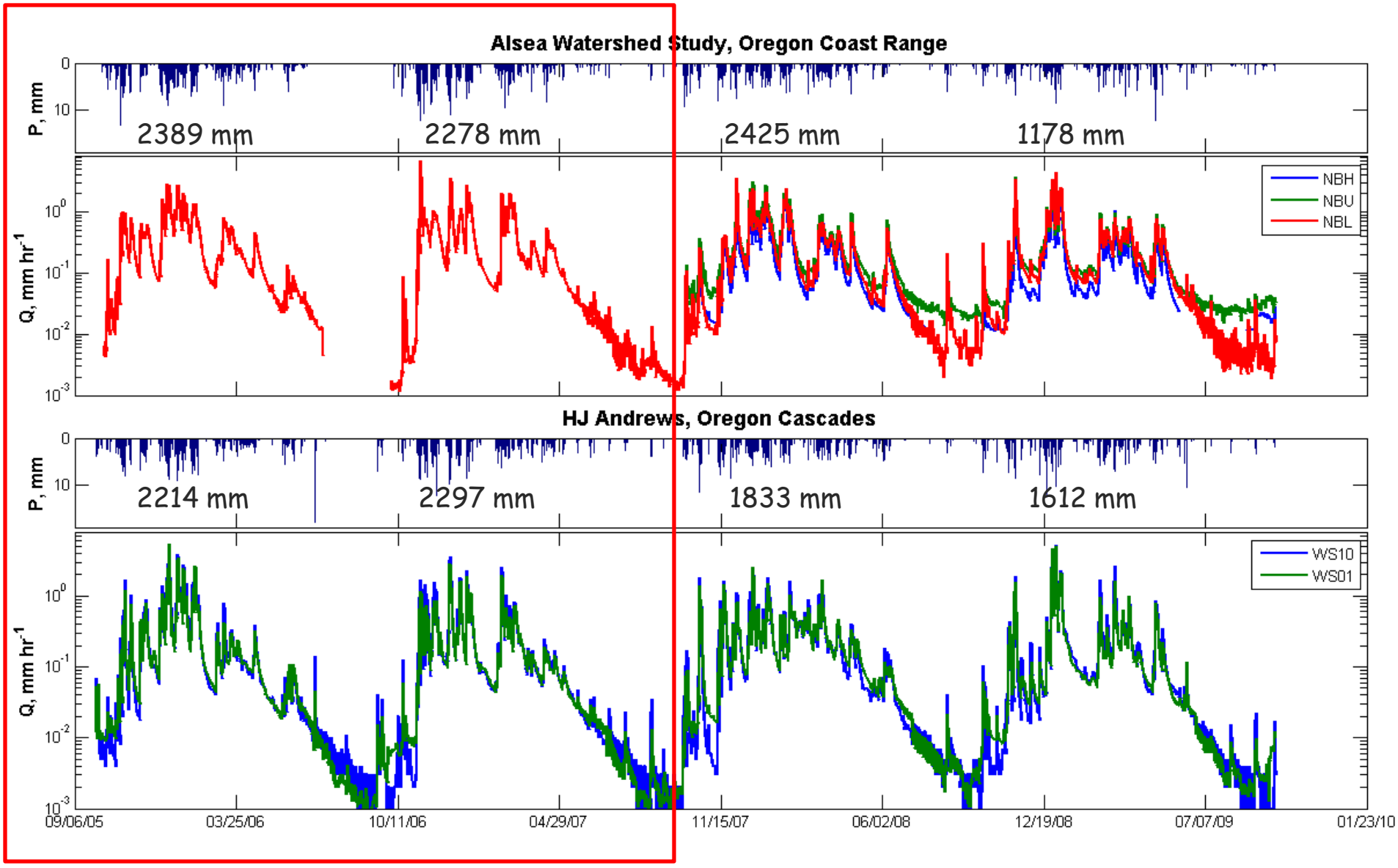
Rainfall-runoff for the two sites

How to improve process realism?



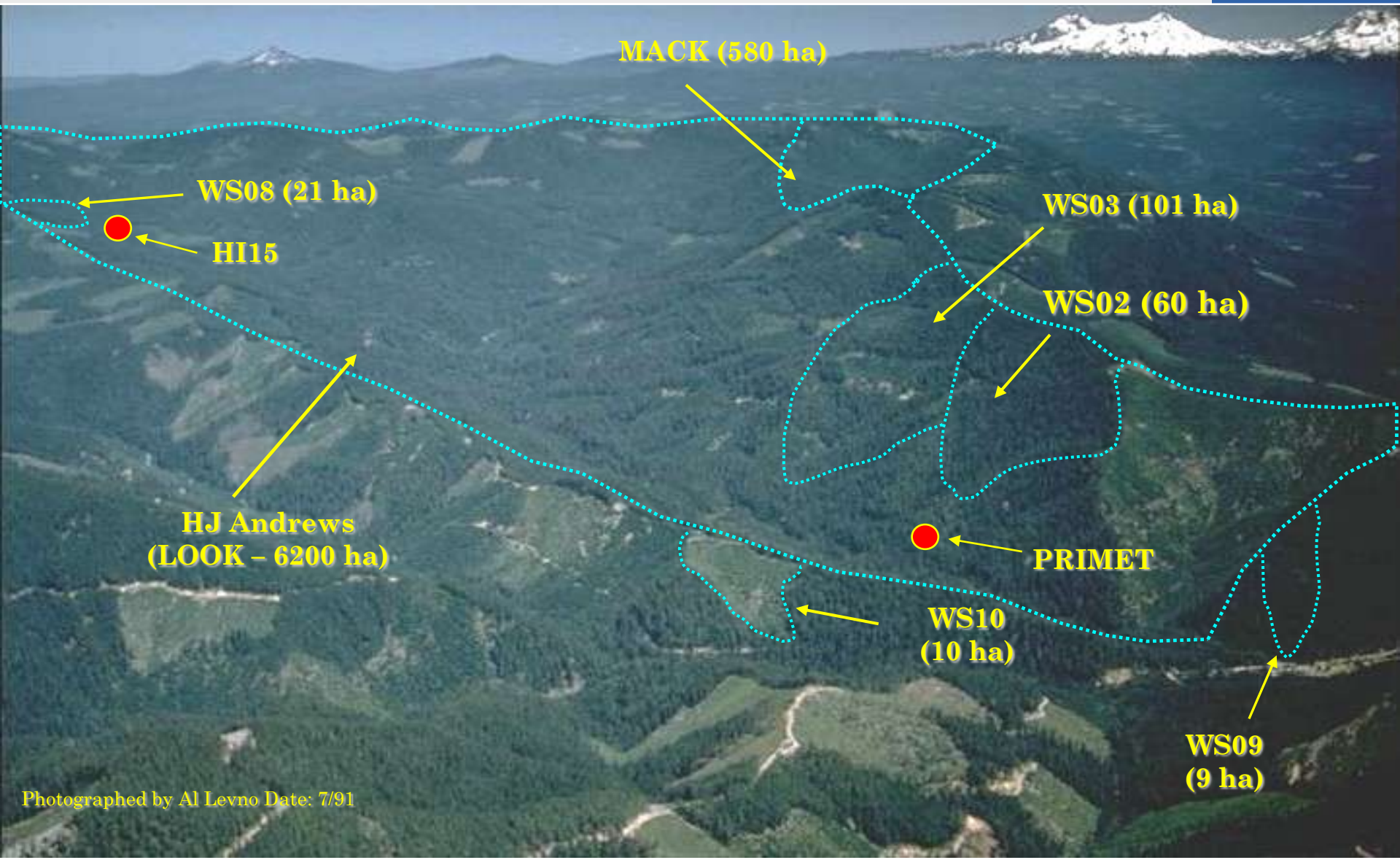
On a log scale

How to improve process



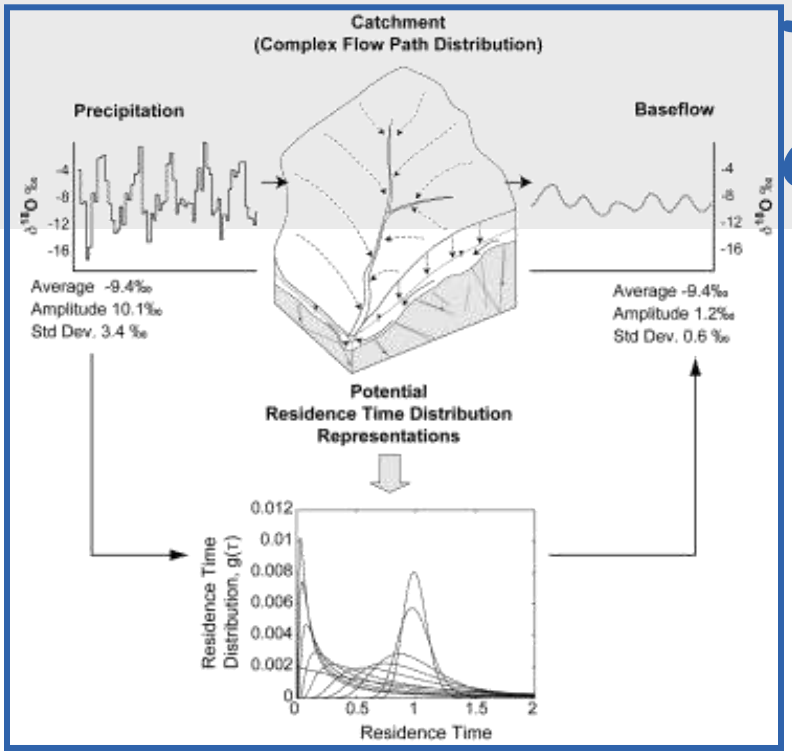
Exploring the scaling relations in low permeability rock

How to improve process realism?

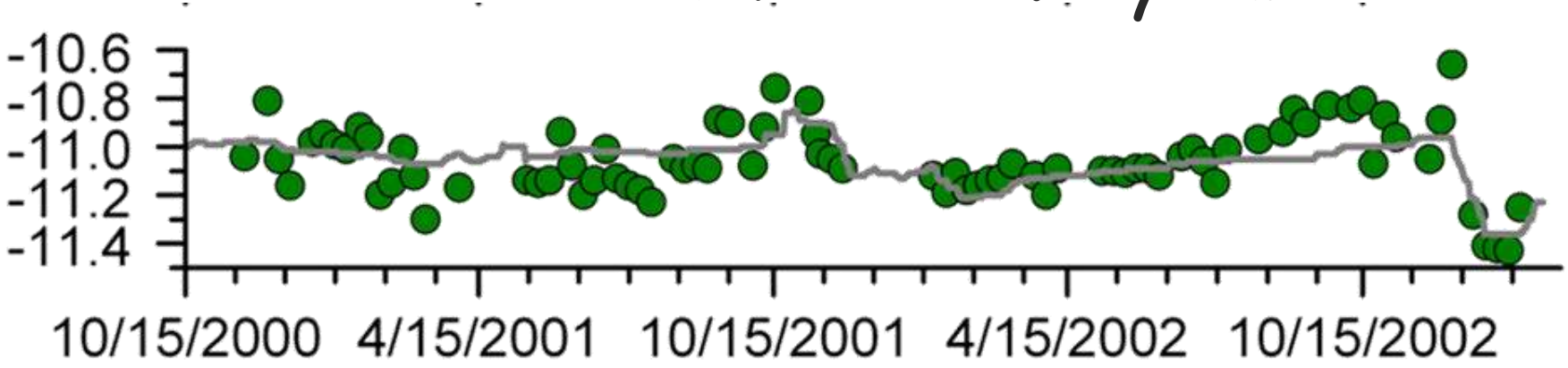


The standard convolution approach

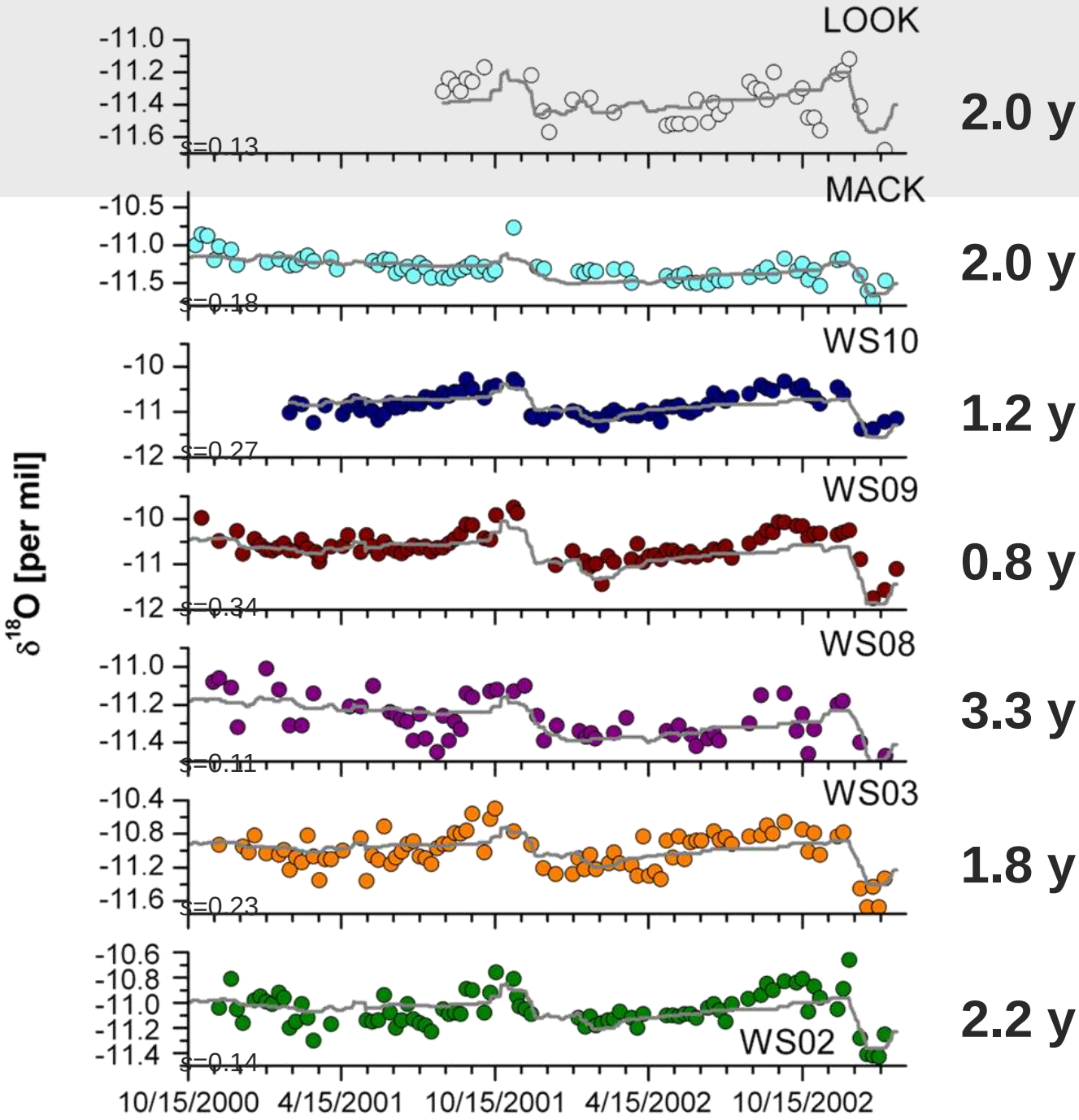
How to improve process realism?



MRT = 2.2 years

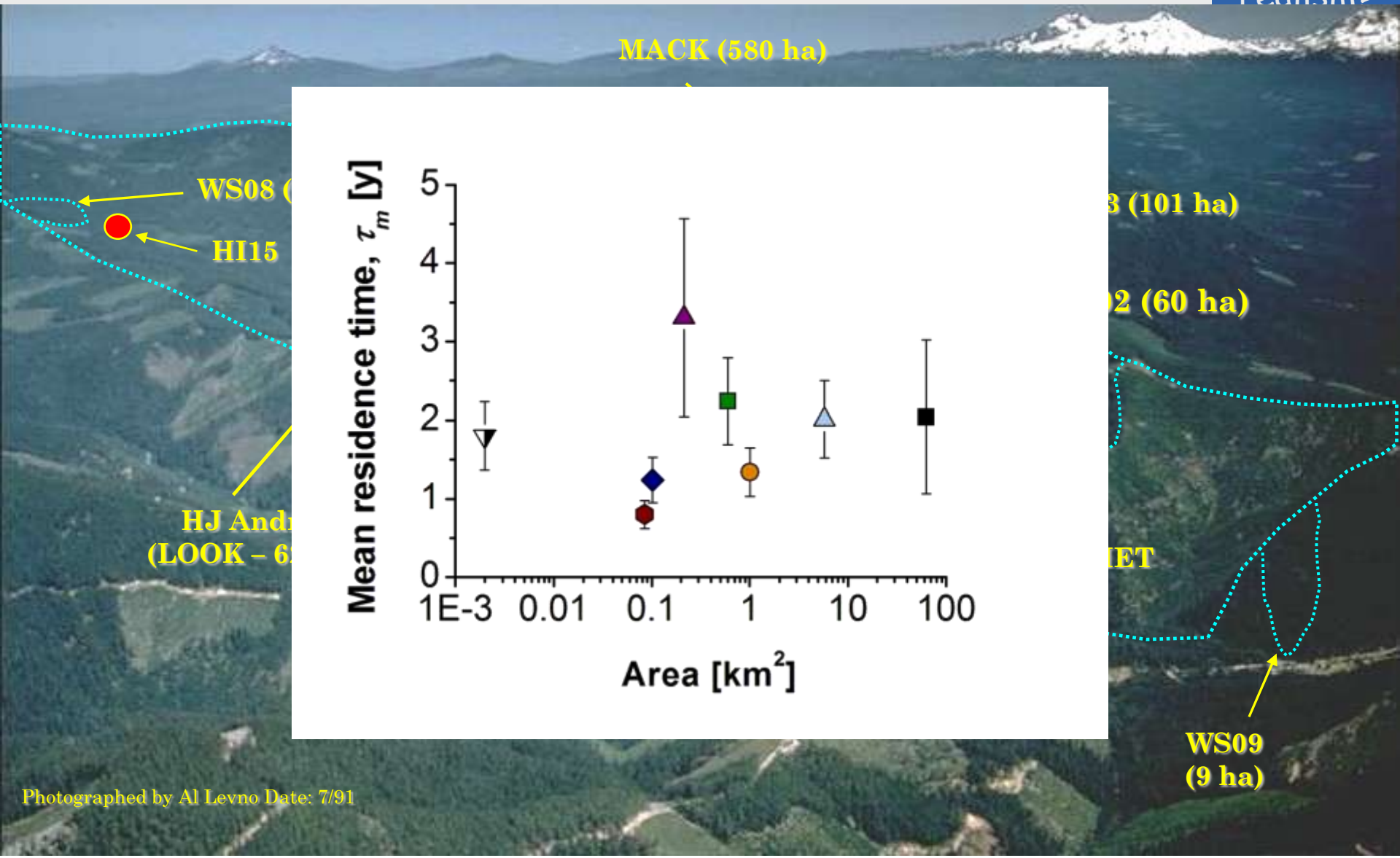


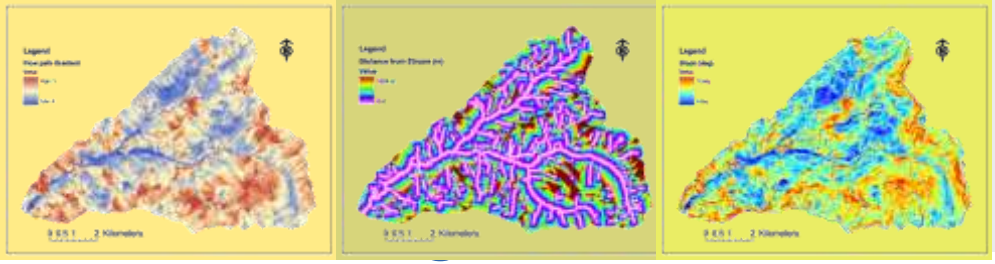
How to improve process realism?



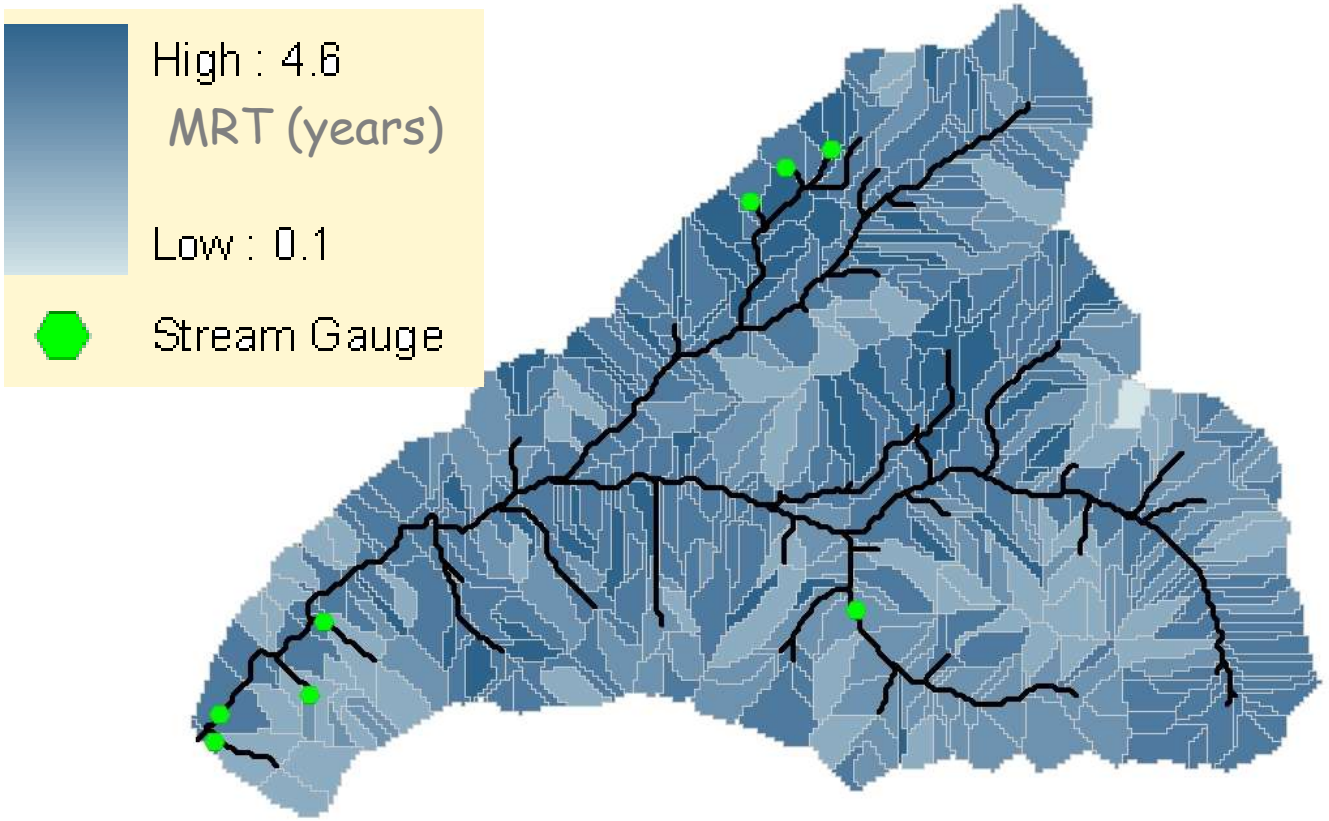
…no relation to basin area, but…

How to improve process realism?





- We can regionalize these values for model testing and development

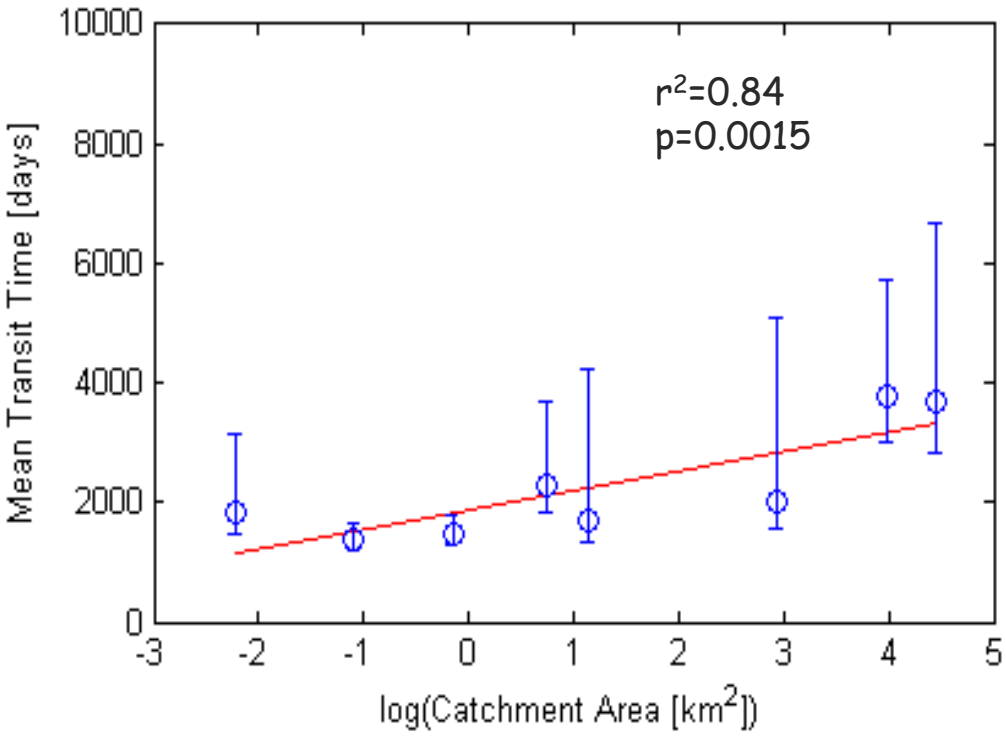


Scaling relations in permeable rock

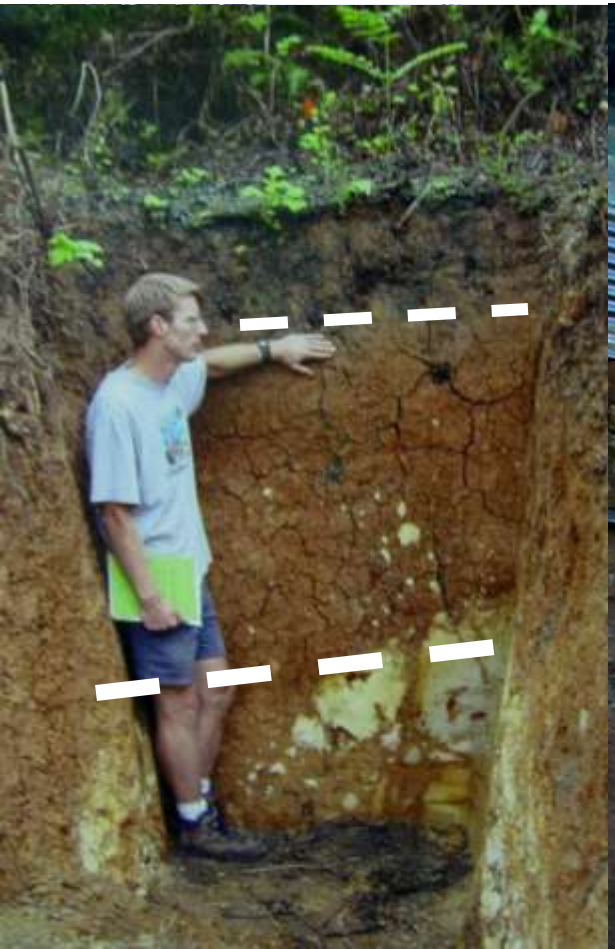
How to improve process realism?

The opposite finding!

How to improve process realism?



Why? The subsurface flow processes are very different

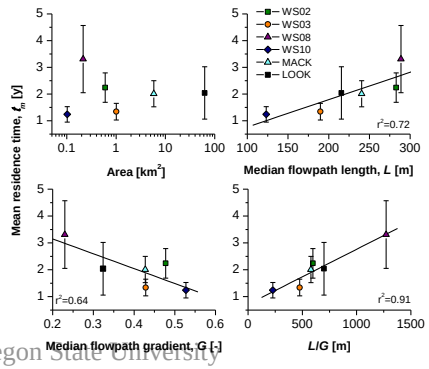


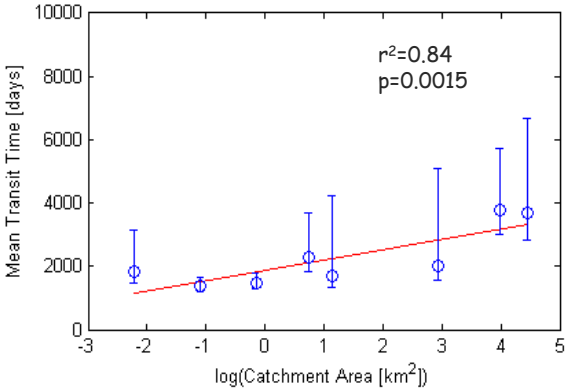
Bedrock groundwater

"Getting the right answers for the right reasons" Kirchner (2006 WRR)

How to improve process realism?

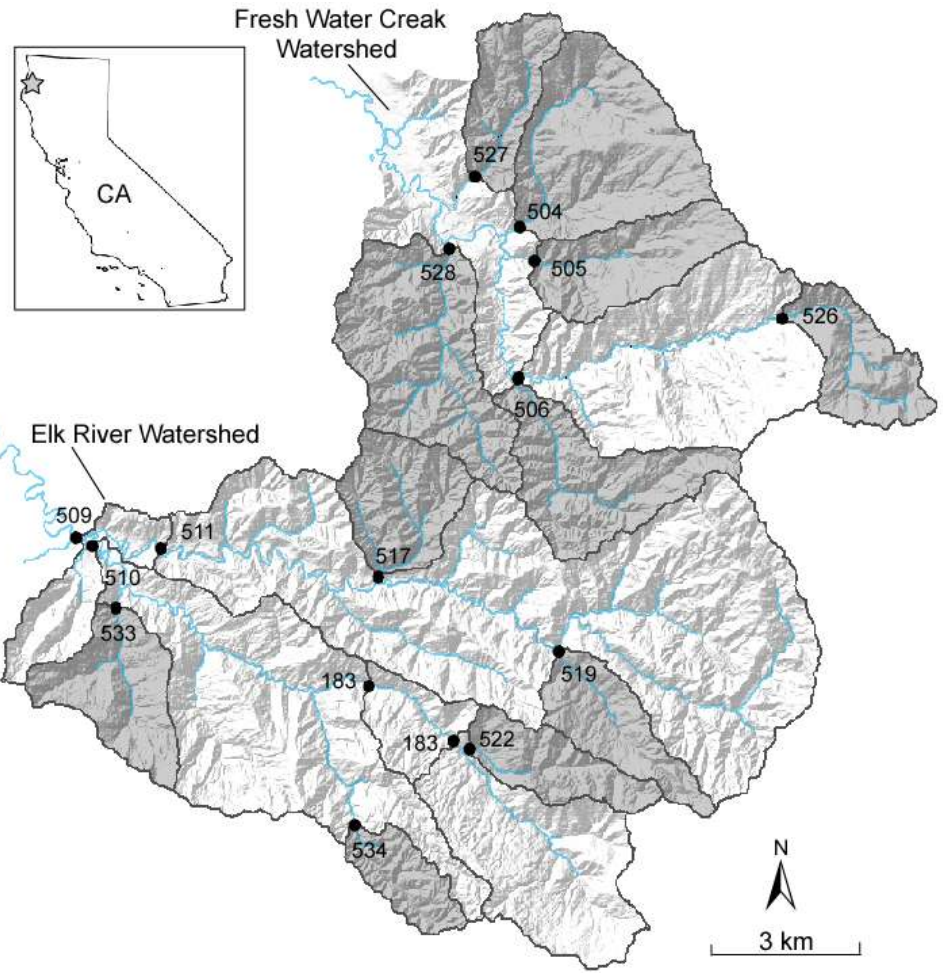
- Developing models that are minimally parameterized and therefore stand some chance of failing the tests that they are subjected to
- Experimentalists delivering orthogonal measures (but not all the gory details) that can be used for model testing

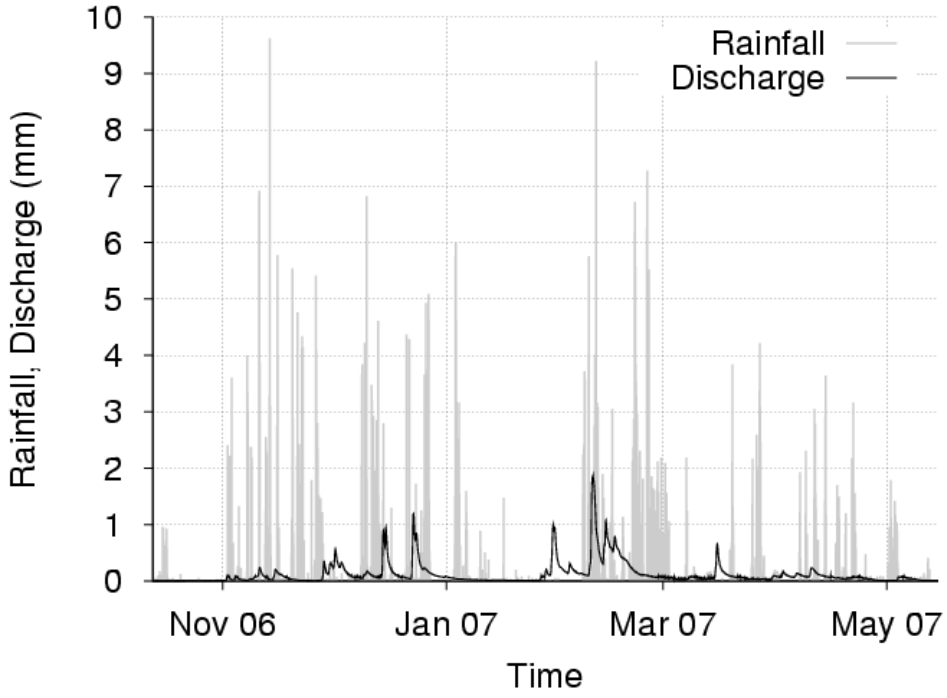




Another Coast Range catchment with permeable bedrock

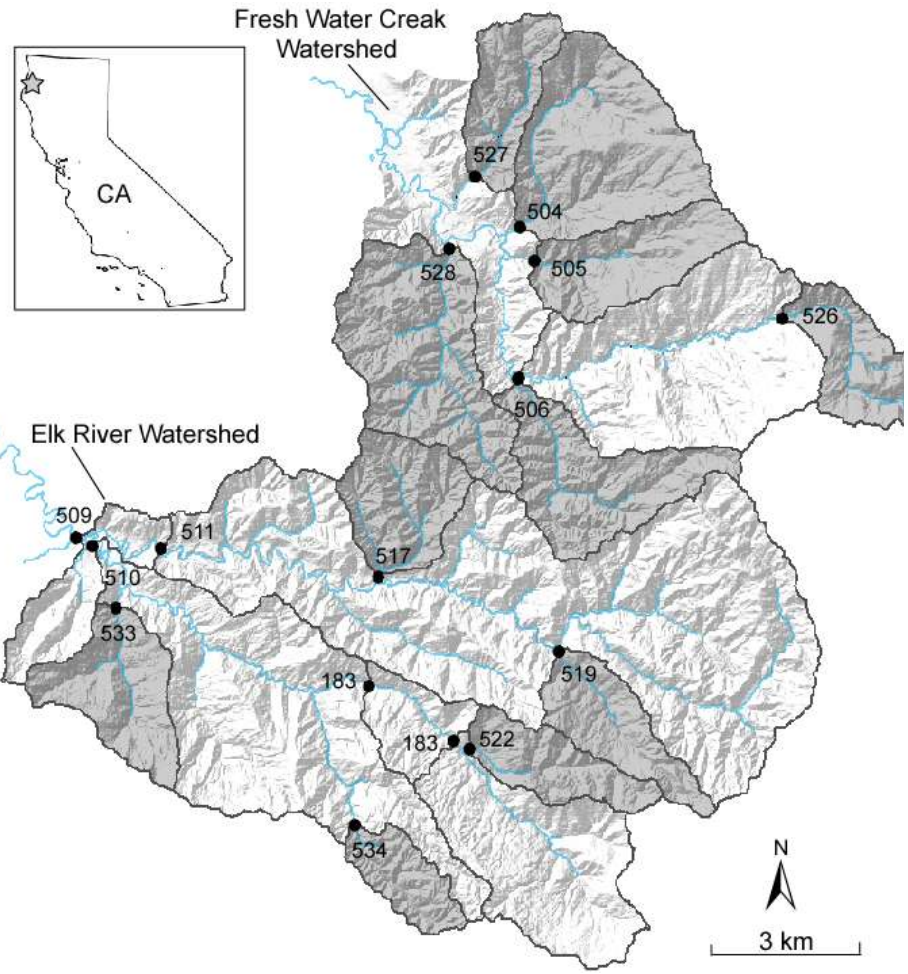
How to improve process realism?



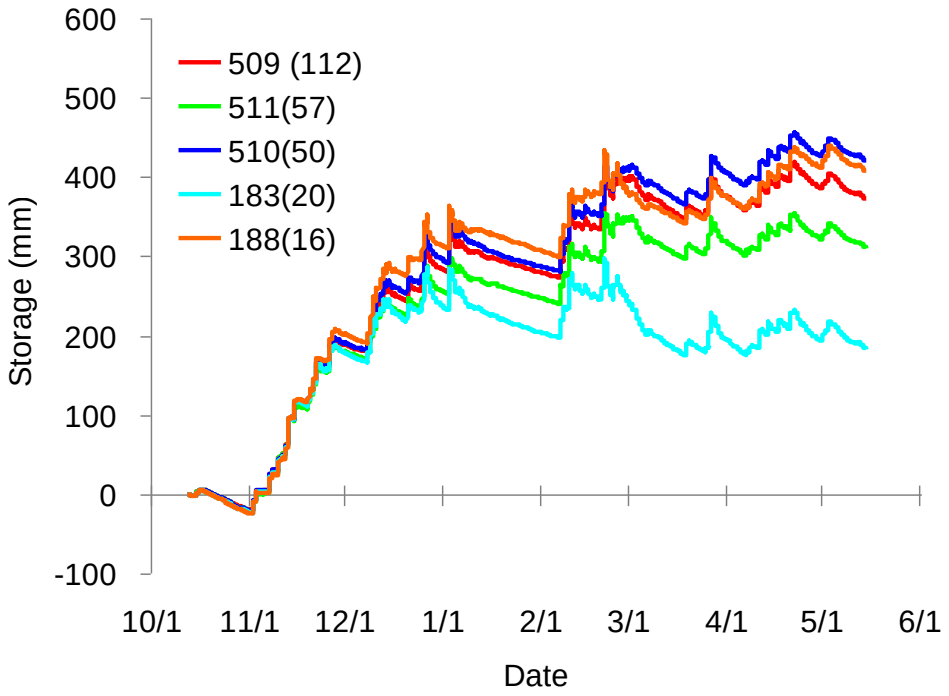


"The secret to 'doing better hydrological science': change the question!" Sivapalan, (2009, HP)

How to improve process realism?

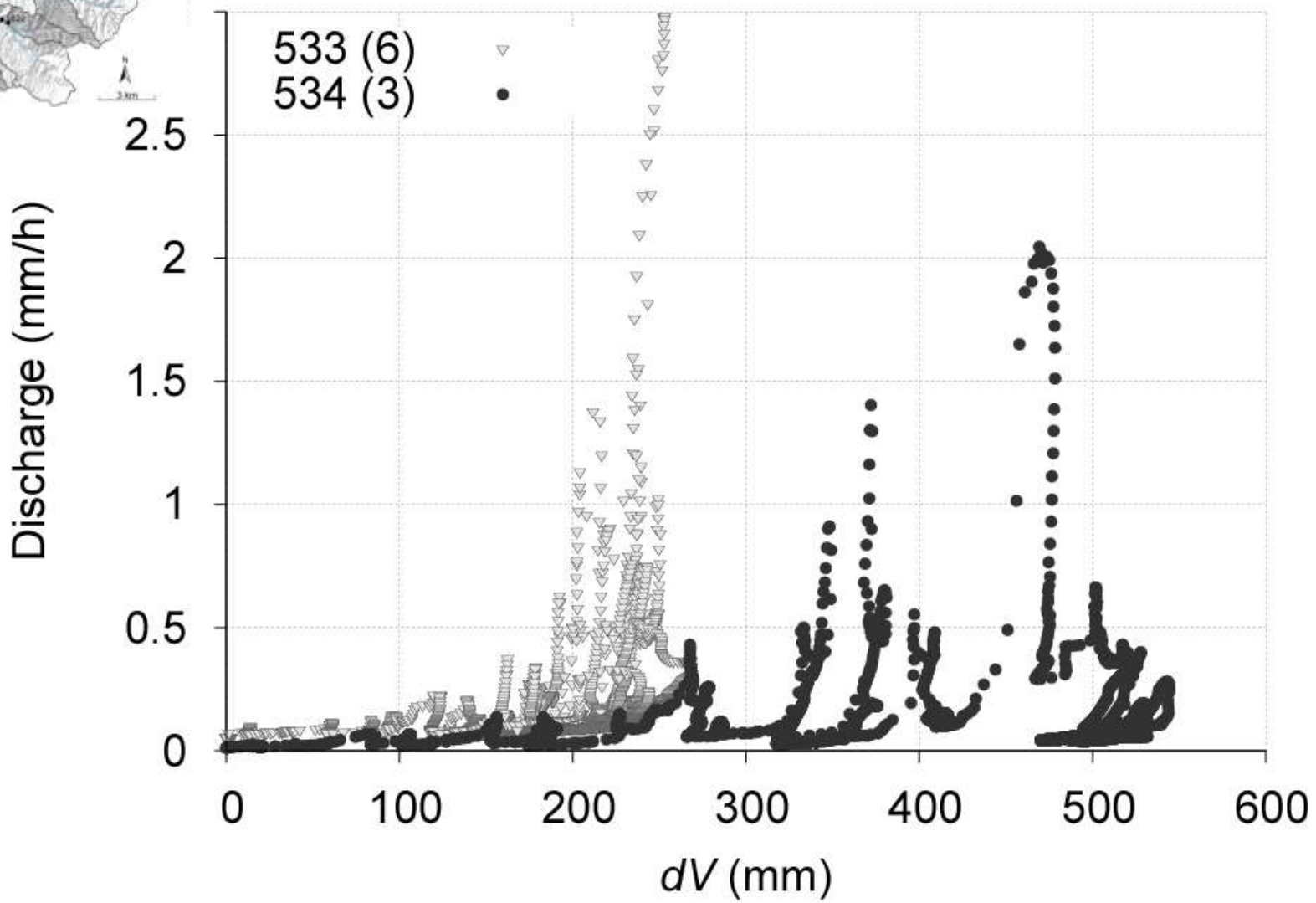


$$dV(t) = \sum_{t=1}^{t} \left(R(t) - Q(t) - E(t) \right)$$



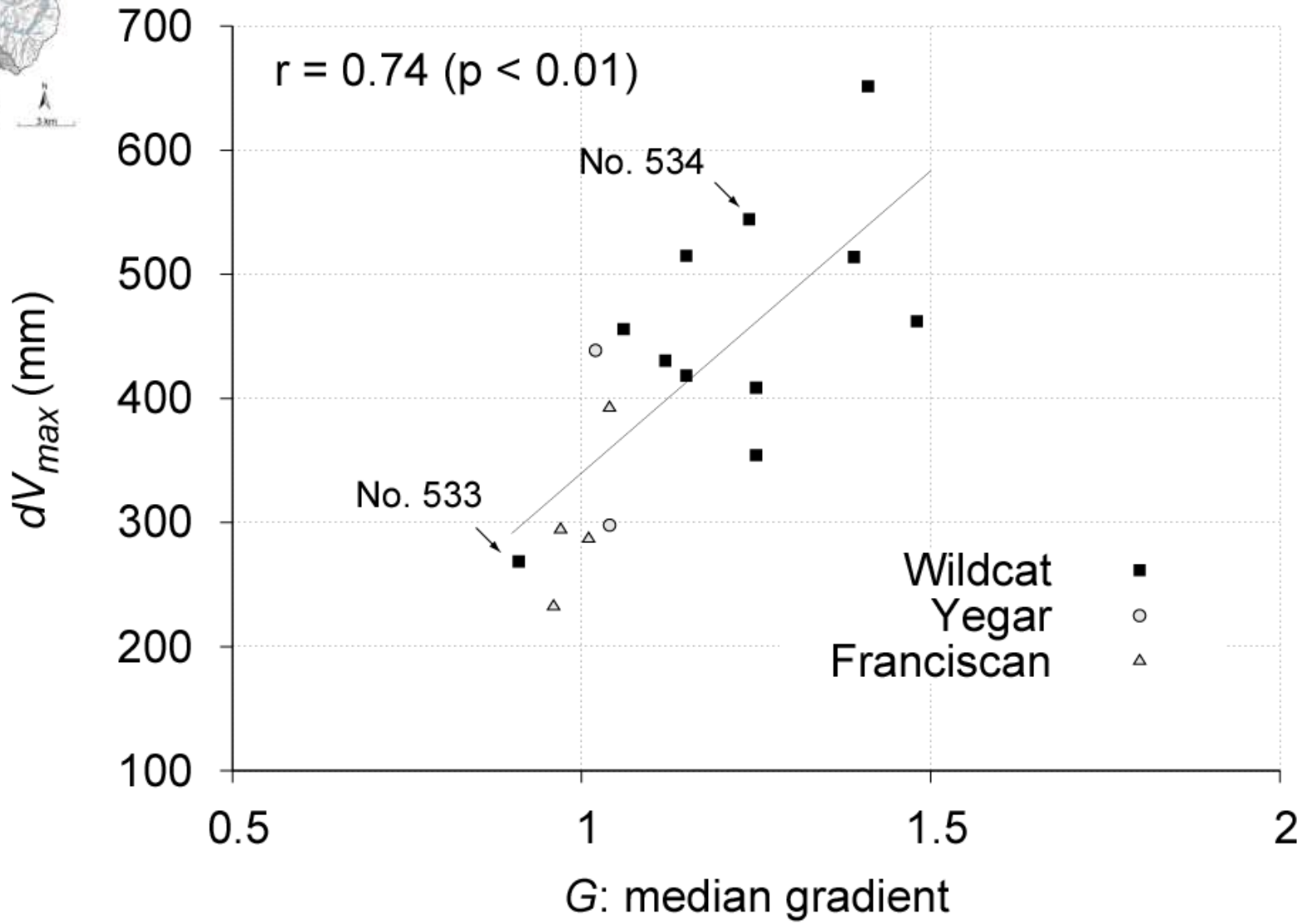
Storage filling before spilling

How to improve process realism?



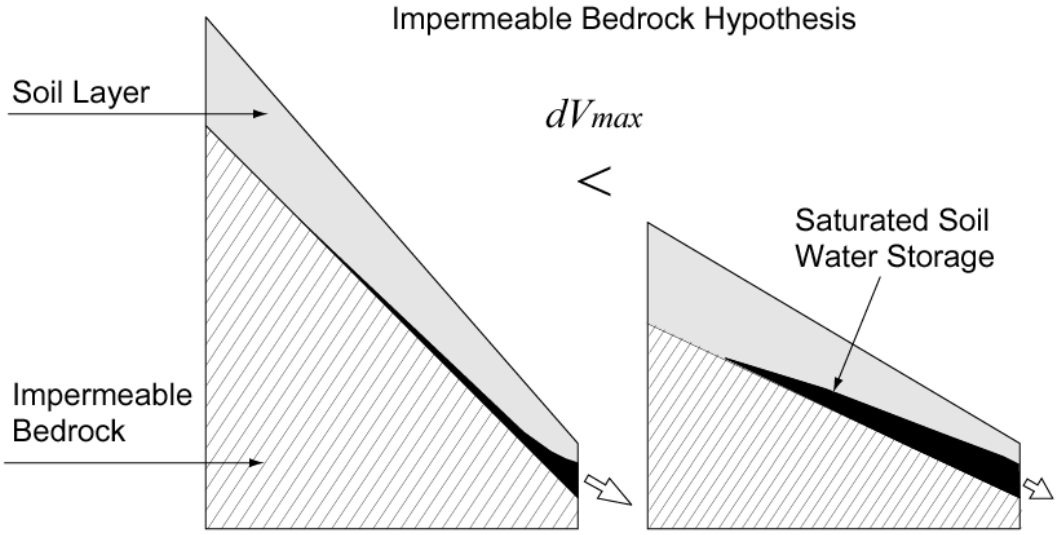
Topography positively related to storage?!

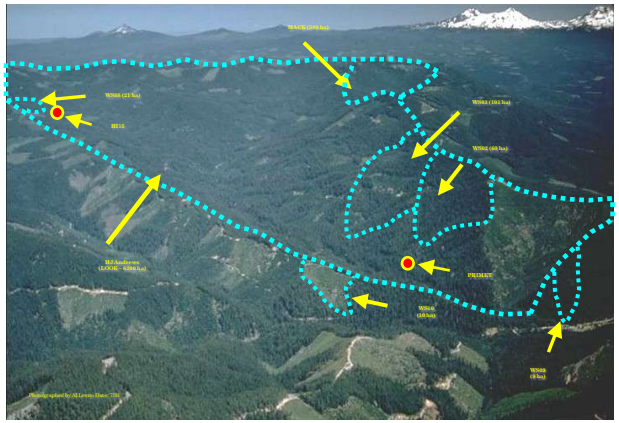
How to improve process realism?



"The boundary conditions are the science" Beven (2006 HESS)

How to improve process realism?





Wrap-up

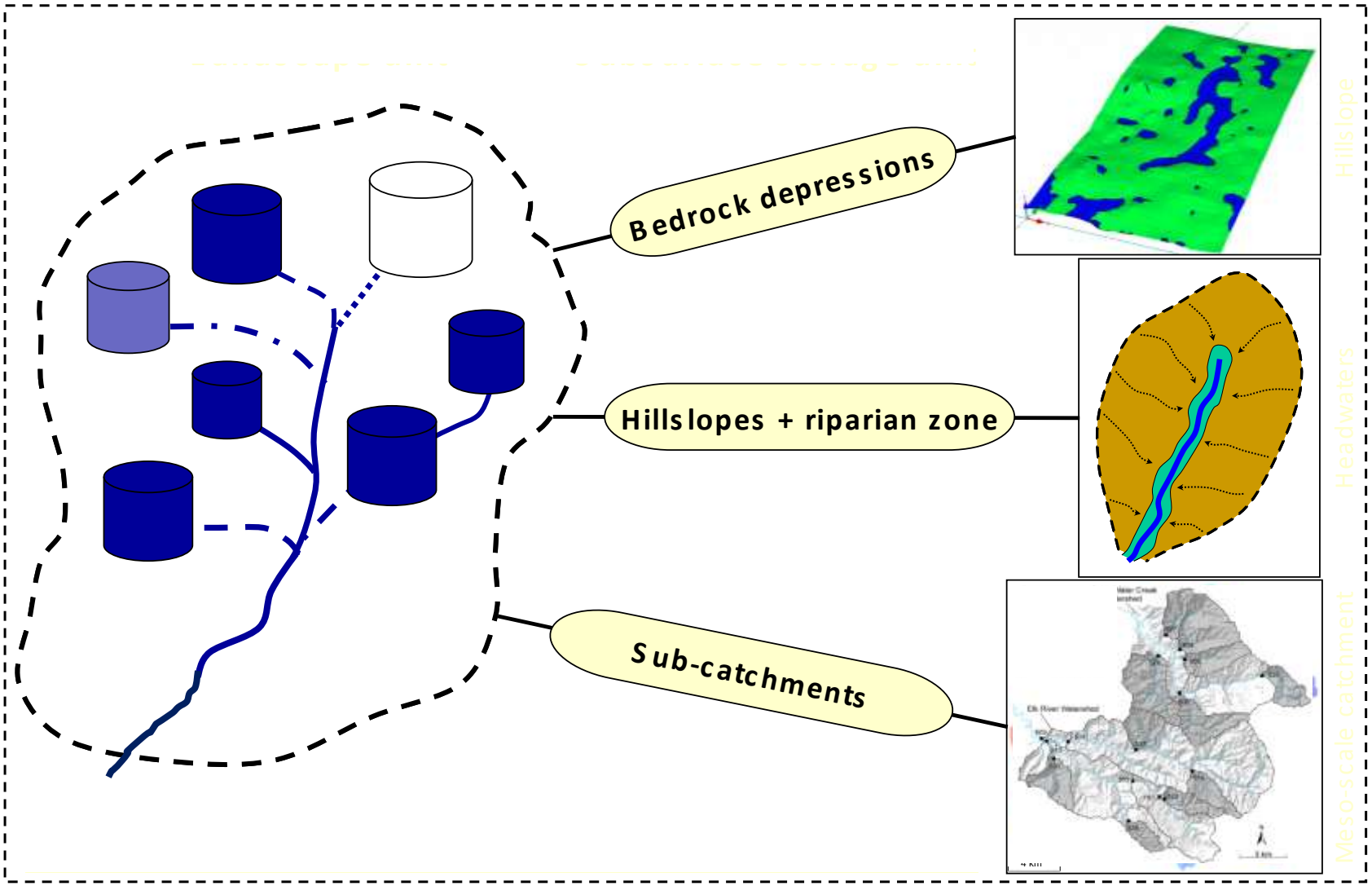
Summary I

How to improve process realism?

- Process realism as scaling realism
  - Scaling rules aggregate key process information
  - Residence time and storage make sense across all scales
  - Both are quantifiable
  - Such approaches may lead to classification metrics that go beyond rainfall-runoff

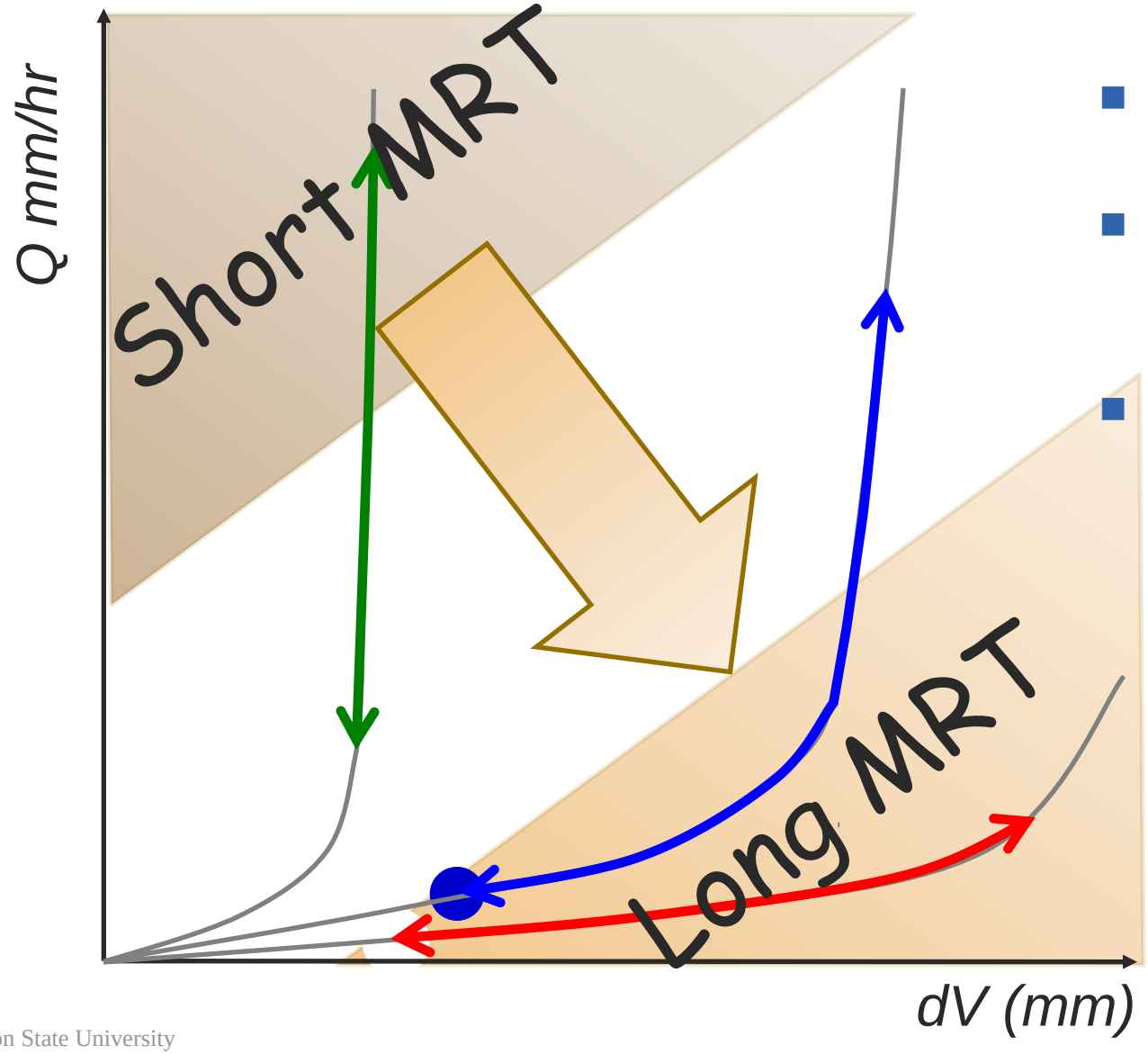
A storage-based view of runoff generation

How to improve process realism?



…the storage-residence time relation

How to improve process realism?



- Geology controls the shape of the curve
- Climate controls the amount of the curve traversed
- MRT = storage / discharge

Summary II

How to improve process realism?

- Defining residence time scaling can lead to significant improvements in process realism
- Data availability is on the cusp of radical change
  - laser spectrometers!
- A binary classification of permeable vs poorly permeable could be a good start
  - a landscape scale anisotropy metric
  - a way to reduce model structural uncertainty
- Basin parameter transfer could be addressed within broad geological units