PUB
Prediction of Ungauged Basins
Possible Unified Behavior ... Models/Hydrologists

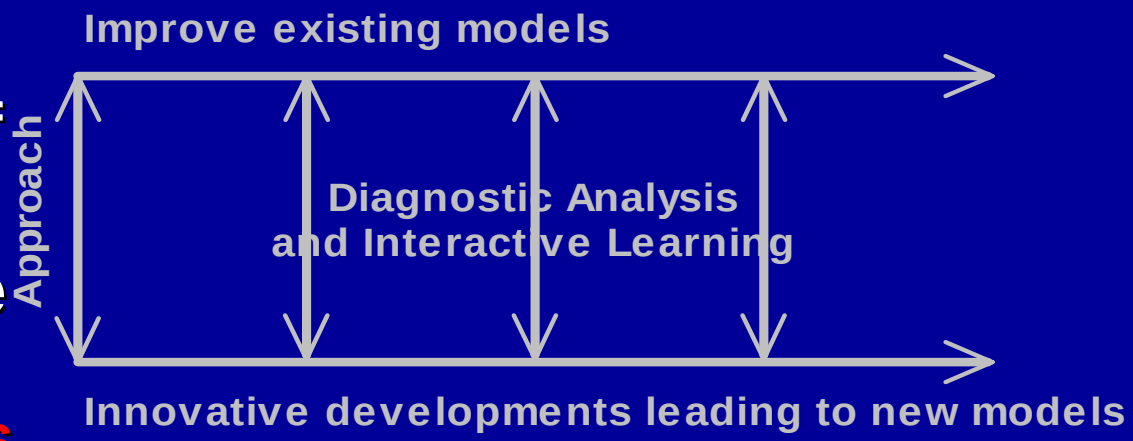
Erwin Zehe

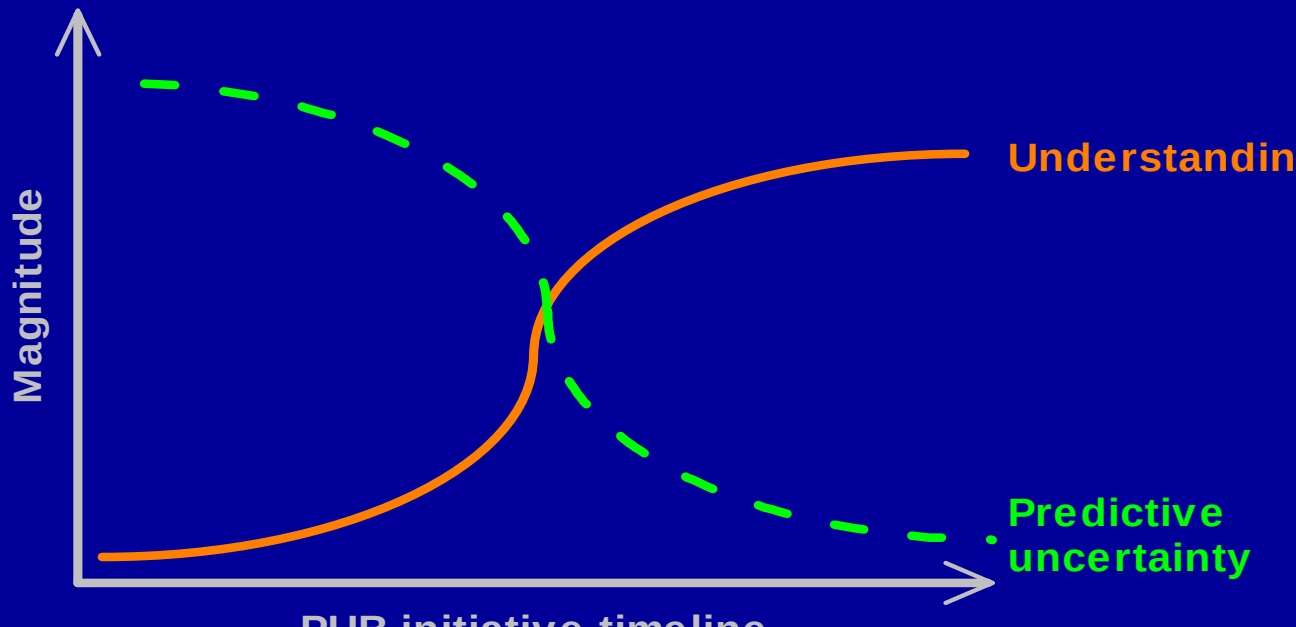
Outline

- How do we fit into PUB
- Short (biased) summary of promising things
- How can we benefit
  - Small scale process observations + process models
  - New data sources
  - Ecological concepts/models
- Key PUB science questions/Conclusions

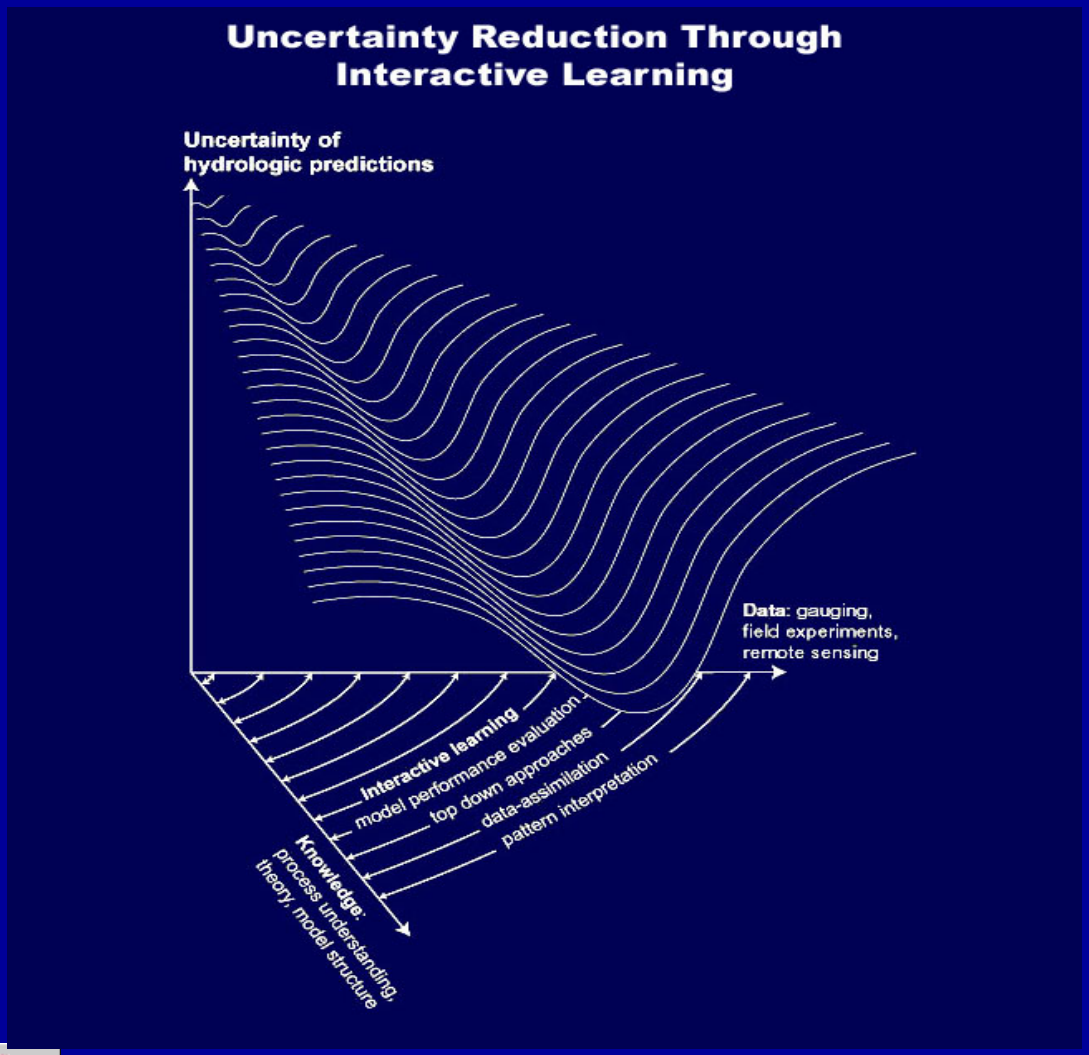
Overall Goal

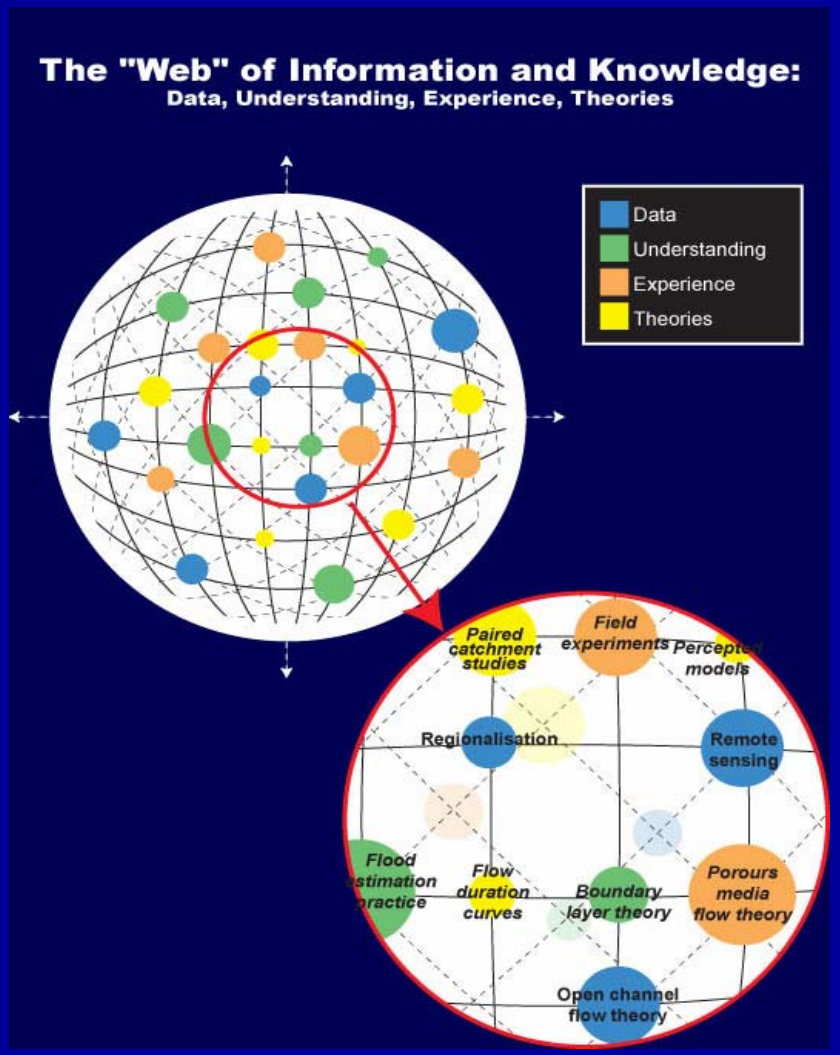
- Models to explain/ understand behavior of Hydrological Systems
- Reduction of Predictive uncertainty in different Biomes/Hydro-Climates
  - Streamflow
  - ET
  - Water Quality
  - Ecology (Niche)





A Framework for Reduction of Predictive Uncertainty





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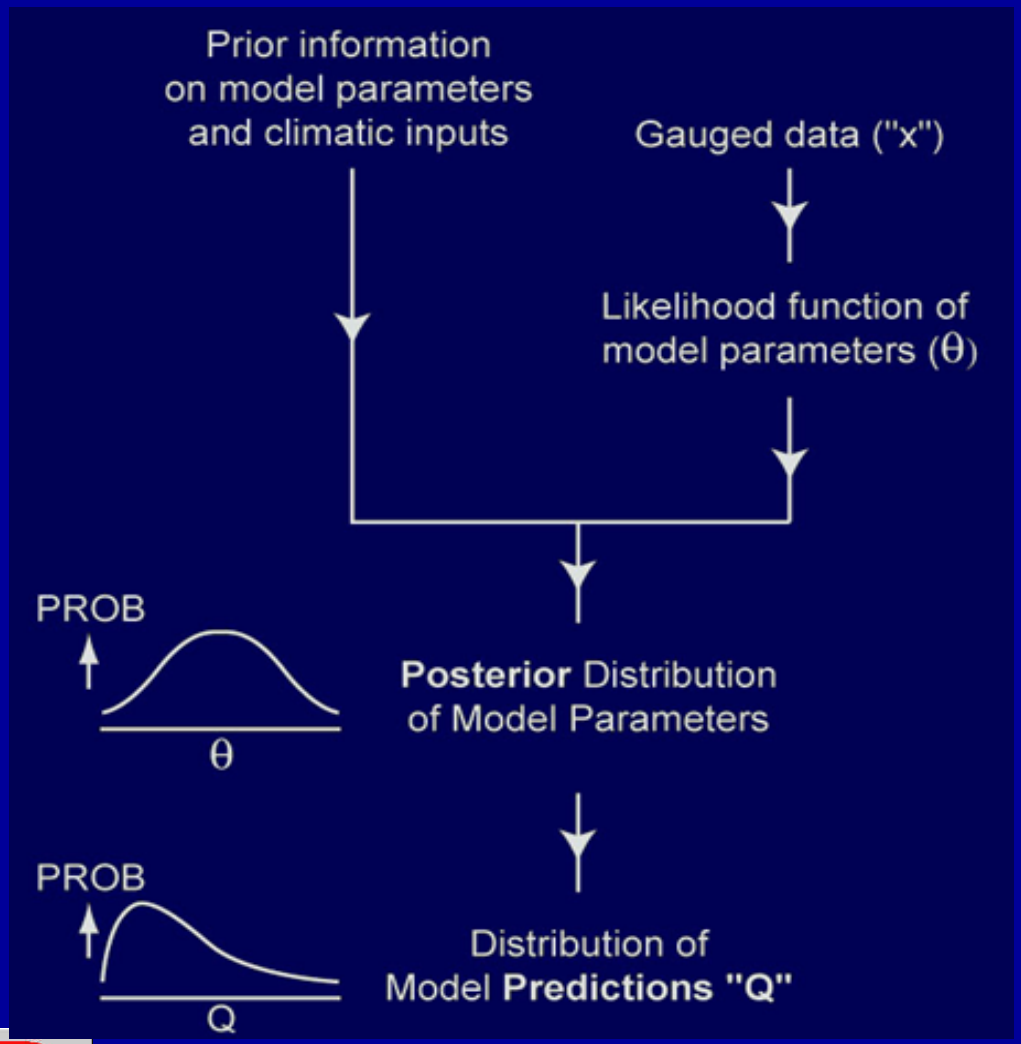
A Framework for Uncertainty Estimation



Variety of approaches for

- **Estimation predictive uncertainty**
- **Sampling response surface/parameter space**
  - **MCMC,**
  - **Bayesian approach**
  - **Fuzzy logic**
  - **Informational entropy, GLUE**
- **Know Status quo**
  - **Pro/ cons**

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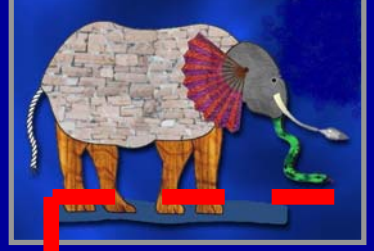

Theorie/ Model / Simulated Dynamics

Inductive updating

Process Concepts/ Equations

+

Parameter Set

+

Data on Input & States & Fluxes

Assumptions Uncertainty

Calibration Uncertainty

Observations Uncertainty

Nature of dominating processes

+

Real catchment

+

Forcing / States Reaction

Nature/ Landscape/ Real World Dynamics

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Data

Model structure

Shape of response surface

Prior

Performance measure

Process knowledge

Goal

Towards PUB

- A priory characterization of response surface possible
  - Ideally based on understanding/ landscapes
  - Different search algorithms for different shapes
- Consistency of models in space & time

Ideal:

L (Model equation, Parameters, Landscape, Period)

András' talk

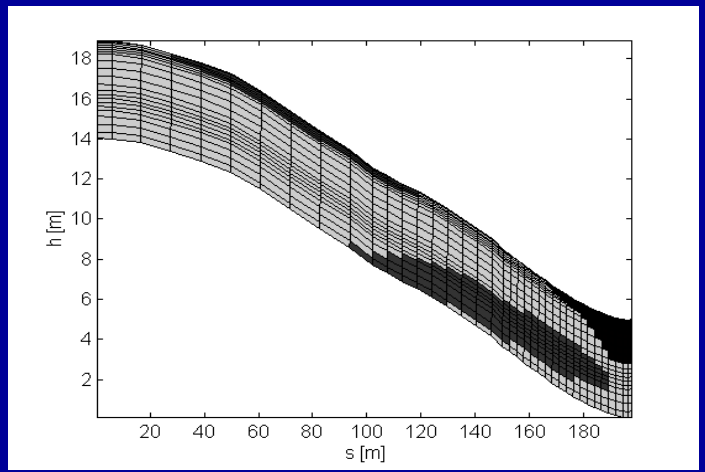
Wishes/Ideas

- Assessment of data/additional information to estimate/test model/process concepts (Hoshin)??
- Come up with synthetic experiments for better planning of field measurements/ observations (iterative) we need for more information??
- Anything ahead from??
  - Process community (Data & models)
  - Hydro-Geophysics
  - Ecology (next time)

Scale gap in understanding

If at all

- Understand/observe processes at the plot/hillslope scale
- Heterogeneity, Thresholds & Emerging of fast processes
- No simple upscaling due to non linear dynamics!



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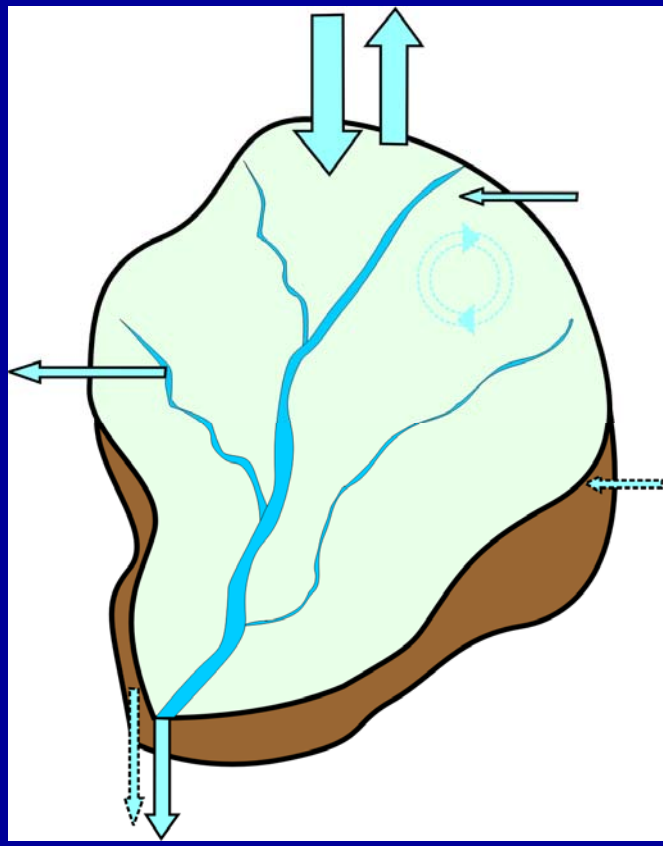
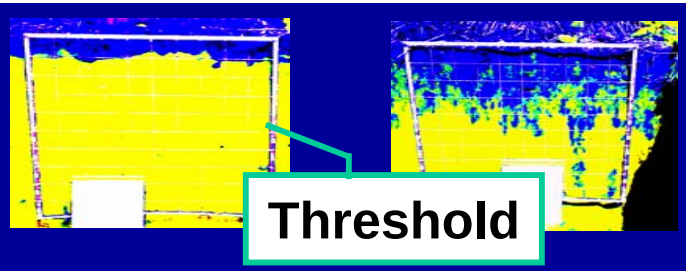




Towards process upscaling

Top Down: Based on understanding the Landscape

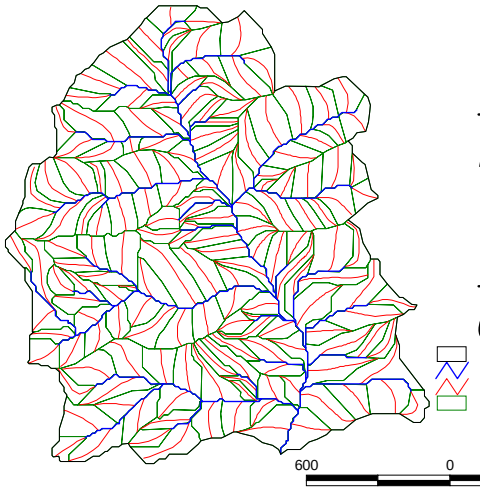
- Gain insight in typical process & process patterns & data structures
- Identify typical variability & structures in a catchment

Bottom up: Use this insight

- Set up physically based, fine scale catchment models
- Test model against observations of state variables & fluxes at local/small scales

Towards process upscaling

- Model output: Process consistent, distributed state variables & parameter fields
- Reflect typical influence of typical subscale process & parameter patterns at next larger scale
- Derive time series for updating state/ additional info

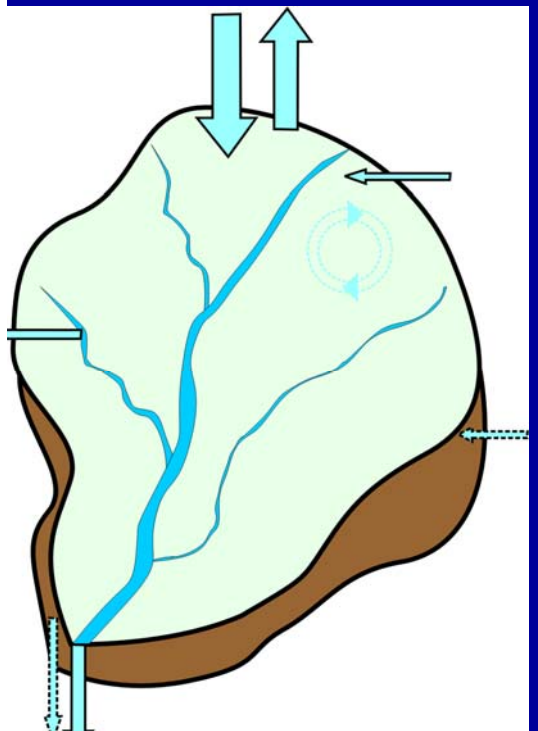


$$\overline{ET}(t) = \frac{1}{A_{Catchment}} \int_{EG} ET(x,y,t)\,dxdy$$

$$\overline{k(\theta)} \frac{1}{V_{Catchment}} \int_{Catchment} k(\theta(x,y,z,t))\,dxdydz$$

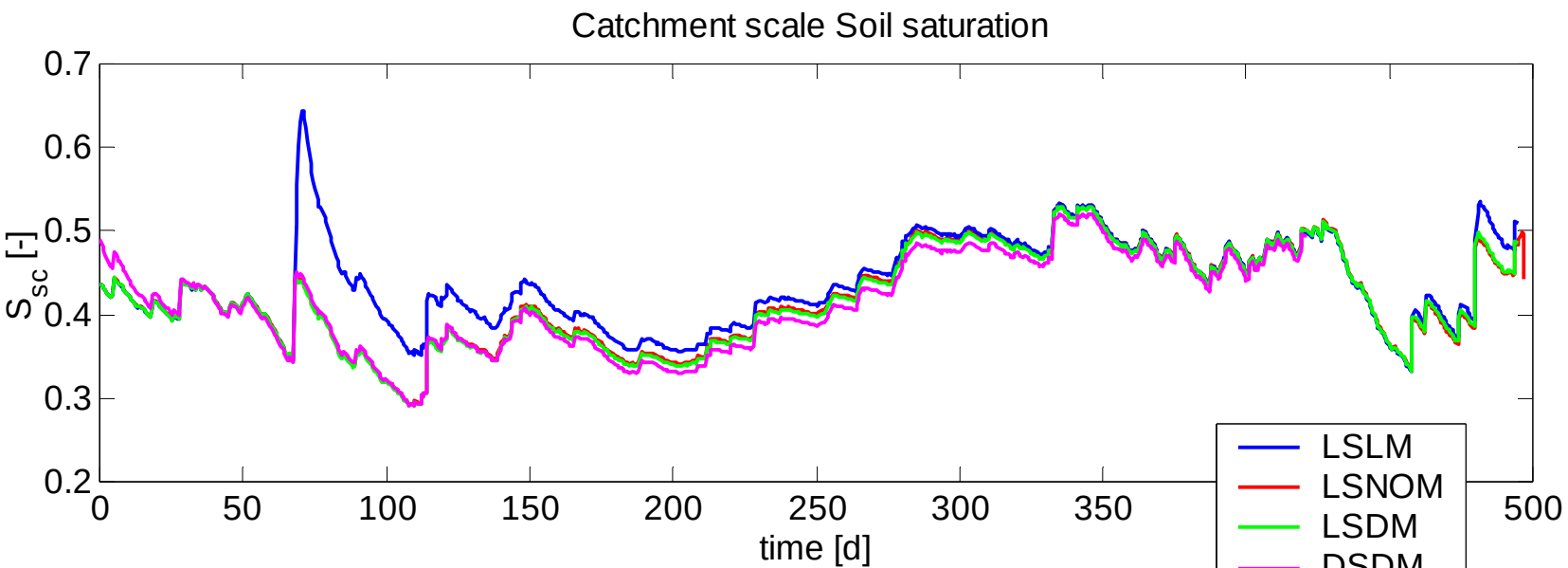
$$\overline{\theta}(t) \frac{1}{V_{Catchment}} \int_{EG} \theta(x,y,z,t)\,dxdydz$$

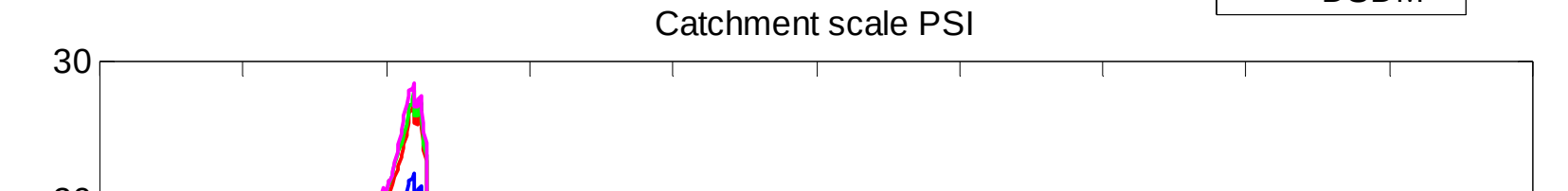
average



Example: Soil moisture

- Blue consistent with Subscale Data & Structures
- Disturbed/ inconsistent with Subscale Data & Structures
- Transfer of information is possible/ come up with framework for process upscaling

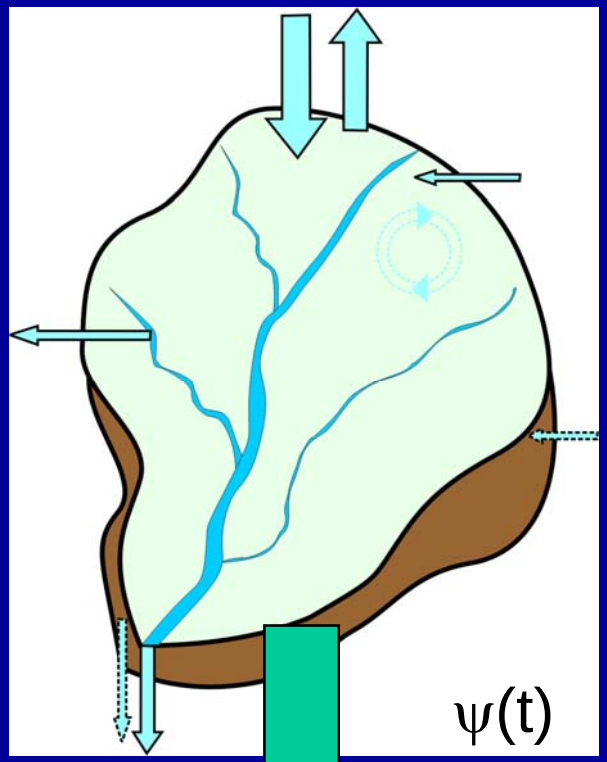


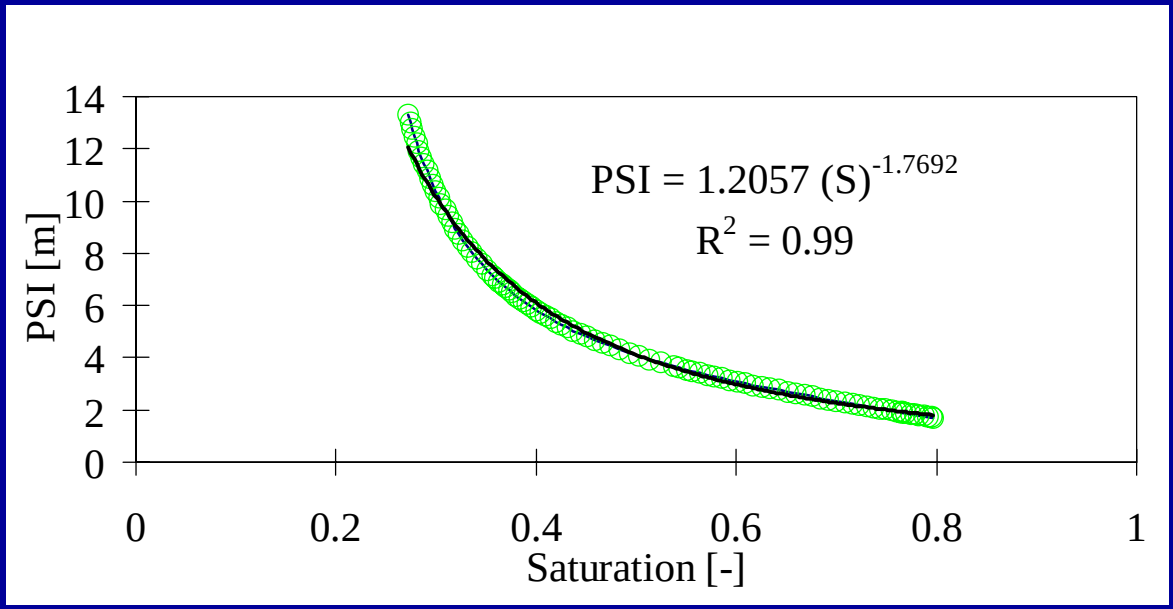


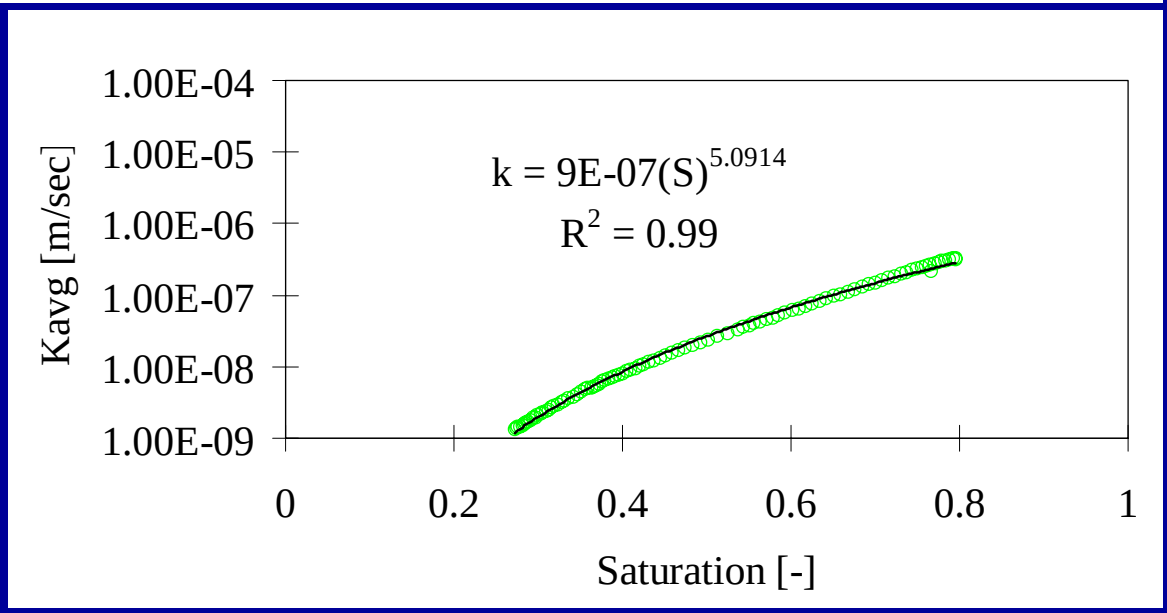
Simulate Catchment Multi step Outflow

Soil Hydraulic Func-tions

- No parameter averaging
- Average dynamics (Zehe& Lee, 2004)







Useful Measurements

- Tracer/Residence Times
- Remote sensing
- Hydro-Geophysics
  - STDR
  - Geolelectrics/GPR/Seismic

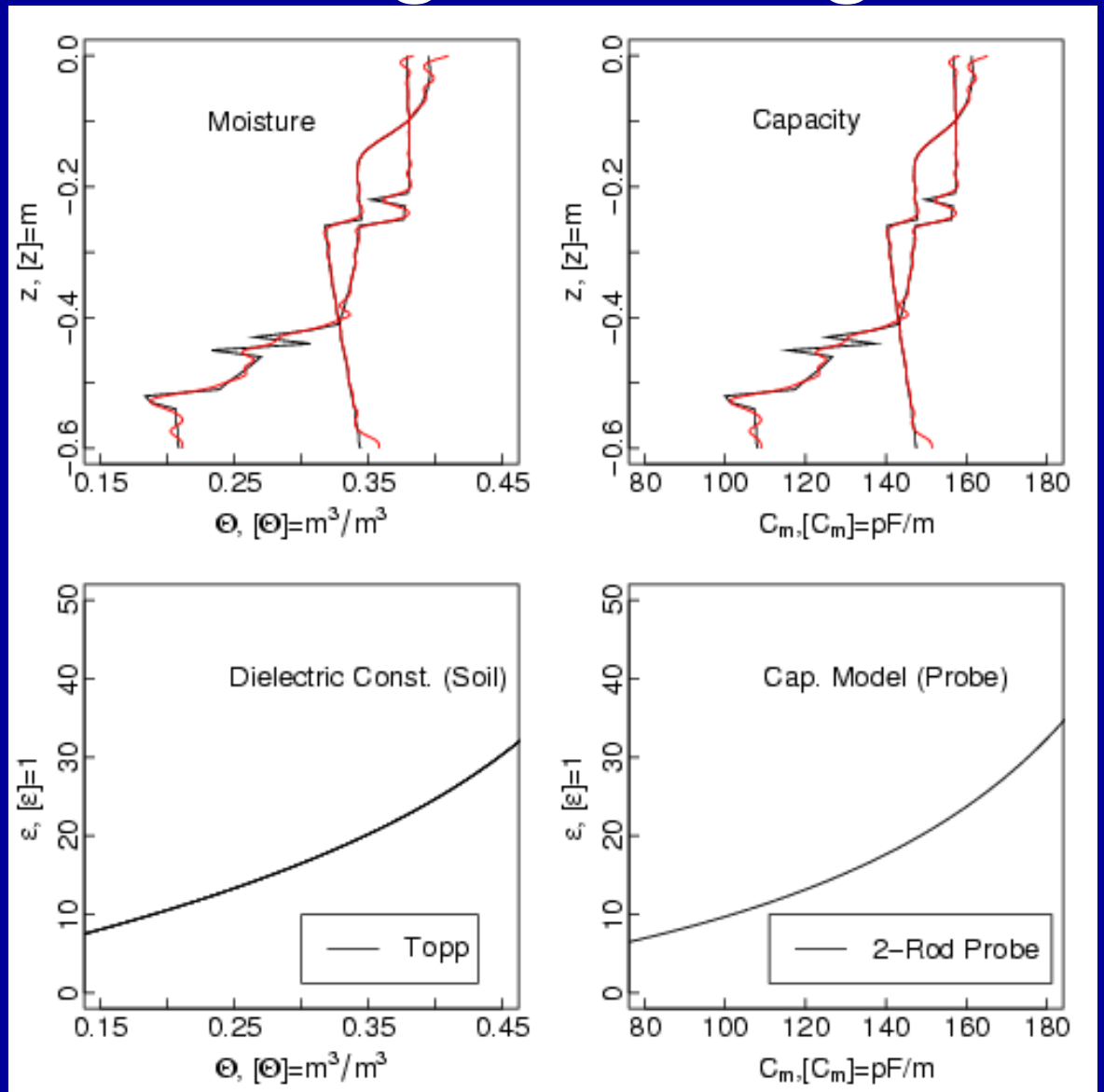
Assess moisture profiles along single wave guids

Inverse Estimation

- Estimate the capacity profile C*
- Simulate the TDR-signal compare to observed C_{obs}

$$\left\| C_{obs}(z) - C^*(z) \right\| < \varepsilon$$

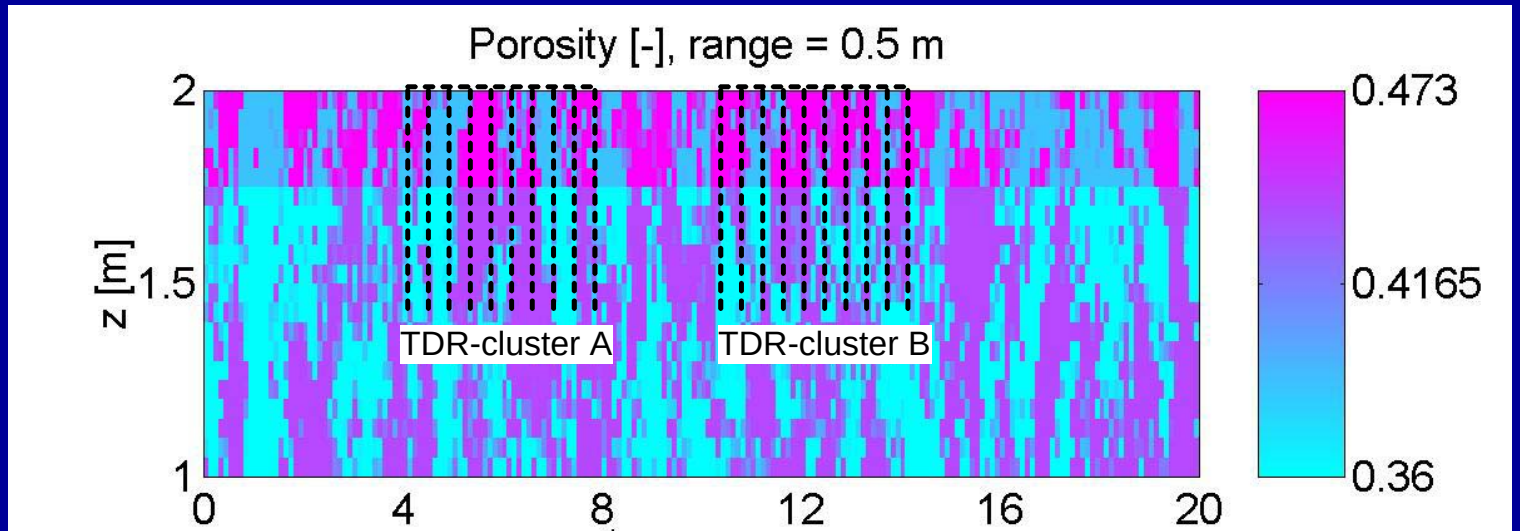
- Compute soil moisture profile
- Nice but point measurement



Towards higher scales

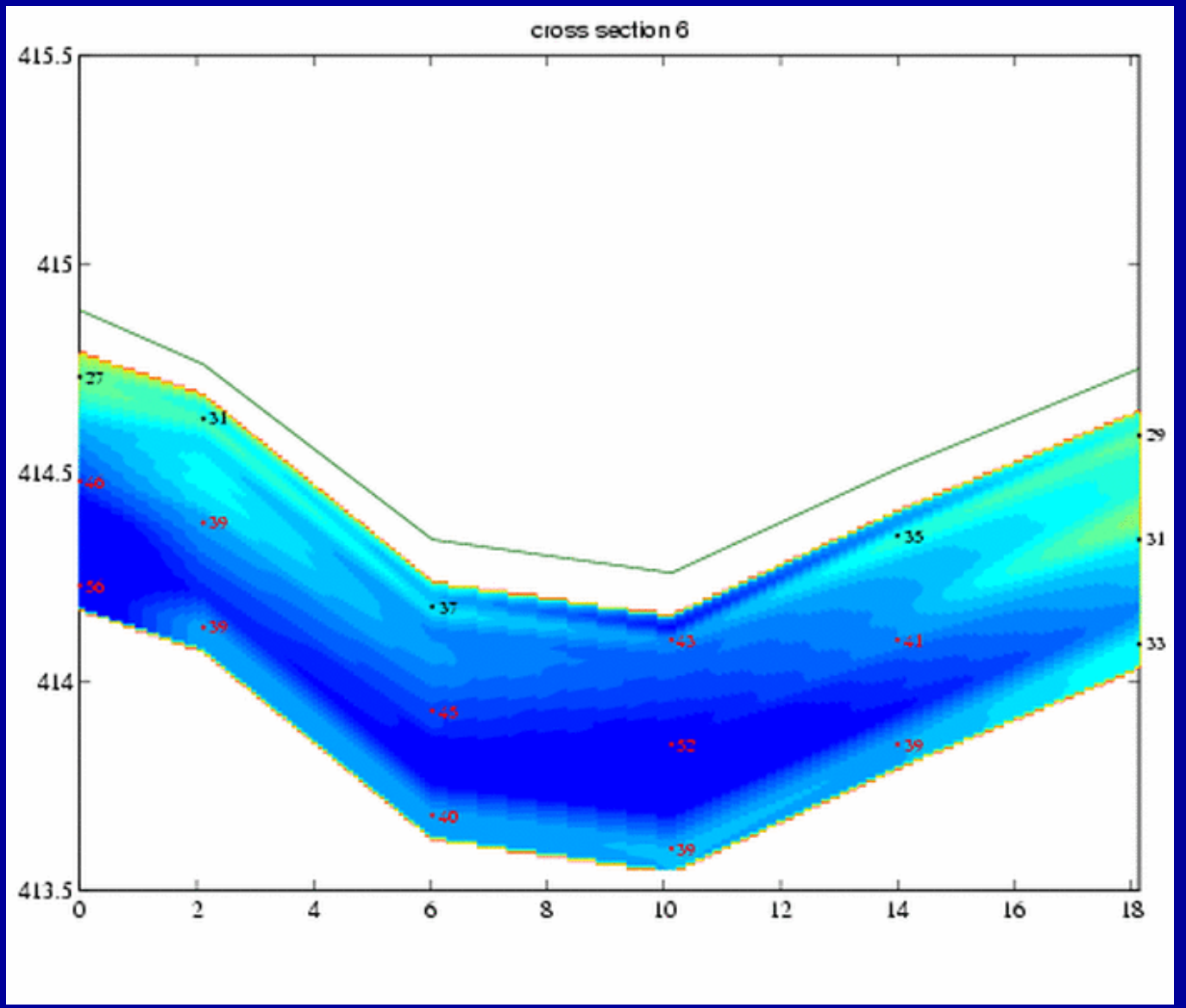
Set up clusters (40 Sensors + Multiplexers + Linux Logger, Cheap)

- Assess Soil moisture dynamics above the REV (4d)
- Assess characteristics of the pores space (nugget, range, sill of porosity, ks (Zehe & Becker, 2005)



Explore system bevahior

- Observe dynamics saturated area
- Check common grounds on runoff production



Towards higher scales

Set up clusters many clusters in a catchment

- For different Hydrotops (Vegetation, Soils, Topography)
  - 2 per Hydrotop
  - Understanding

$$f(\theta | Vege, Soil, Topo, Rain)$$

- Combine with GPR/Geoelectrics

Useful state measure for large scale models

It is more than just Physics

- Use vegetation societies as indicator
  - Plan/ uspcale measurements of soil moisture /ET (Lindenmaier et al, 2004 HP)
- Couple Hydrological Models & Population models (Ecology)??
  - Stationary Climate
  - Do we produce the right water balance to generate PN Vegetation /States?
- Ecology as generic test for models
- PUB Catchments are ungaged & undisturbed???

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Resume

- *There is always hope*
- *I'm optimistic, so hopefully still young (Beven, 2004; modified)*

Key Science Questions, and Enabling Research

- **Question 2: What are the information requirements to reduce predictive uncertainty in the future?**

  ***Enabling Research**: Advance theories, data and models relating to the heterogeneity of climatic inputs, landscape properties and hydrological processes.*

- **Question 5: How can we improve the hydrological process descriptions that address key knowledge elements to reduce uncertainty**

  ***Enabling Research**: Advance process descriptions through field experiments and comparative evaluation of models in selected basins in a variety of environments*

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Key Science Questions, and Enabling Research

- **Question 6: How can we maximise the scientific value of available hard and soft data in generating improved predictions?**

  Enabling Research: Interpret existing hard and soft data, and patterns in such data, through assimilation with dynamic models

Key Science Questions, and Enabling Research

Conclusion:

"The steps outlined above will undoubtedly lead to new predictive approaches based on existing and potentially new data sets that are as yet unimaginable at the present time."

Predictable states in ecosystems

Geoelements
- Climate,
- Geology
- Hydrological Processes
(Process similarity)

Long term

Coevolution Similarity

PNS is equilibrium
- internal & external forces are balanced

Potential natural state of a Landscape typical patterns of
- soil
- vegetation
- geology

Organization

Human scale

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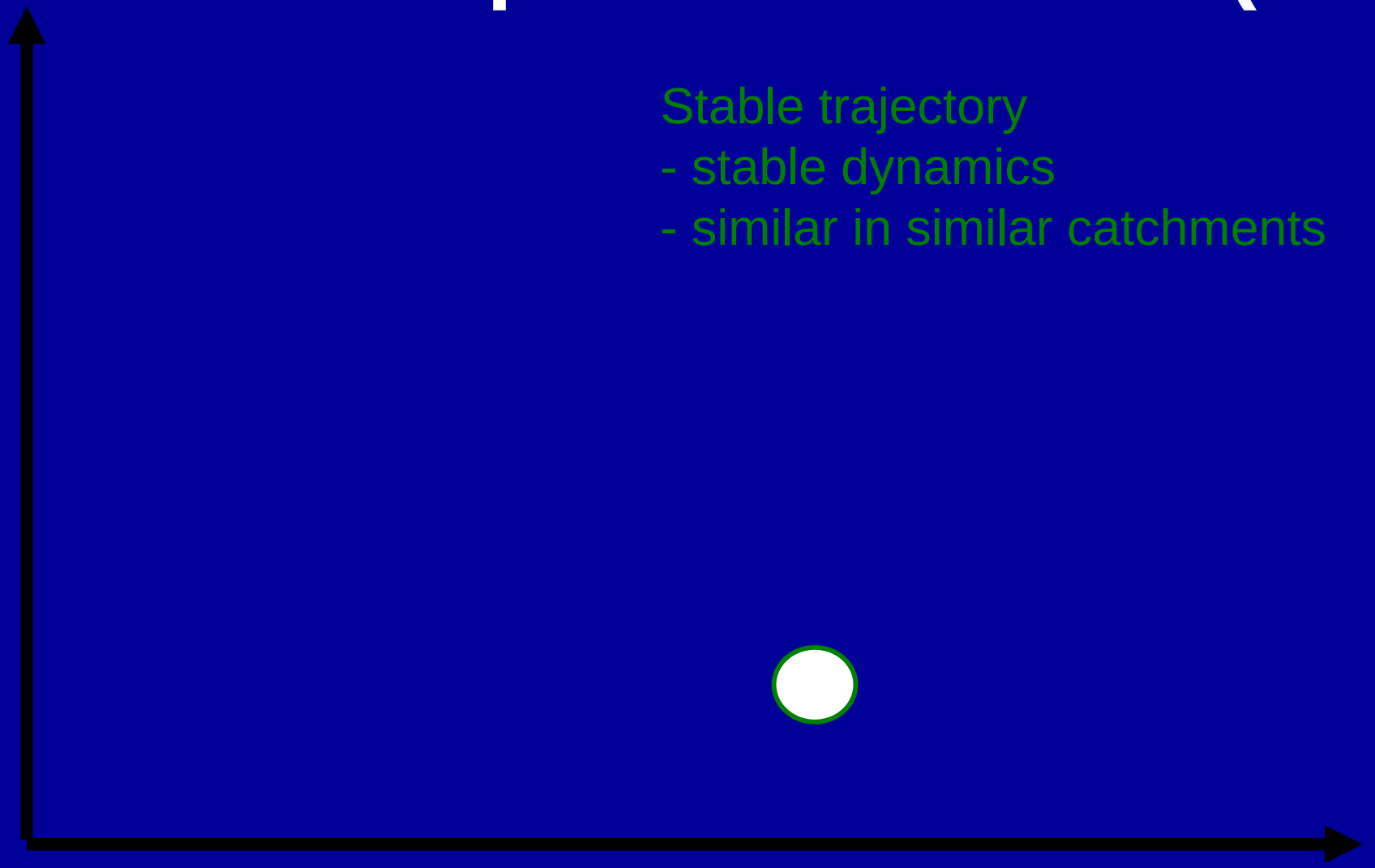
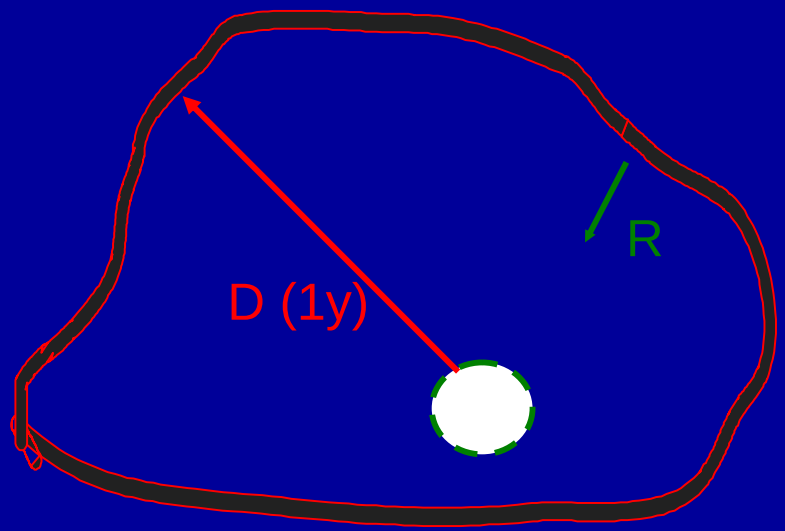
Predictable states are equilibrium states (PNS)

Stable trajectory
- stable dynamics
- similar in similar catchments



Predictable states are equilibrium states (PNS)

Disturbance
- energy input
- disturbed dynamics (non stationary)



Reduced Predictability

Relaxation time ??
(10 -100 y)