Thoughts on Parameterization

(from a process person)

Sean K. Carey

Dept. Geography & Environmental Studies

Carleton University, Ottawa

The Context

- Massive amounts of observation data
- Difficult to synthesize

- At smaller scales, we have processes that are apparently common, yet at larger scales, we have "catchment functioning" which, certainly in the literature, presents every catchment as a unique situation.

The Context

- It is difficult to extrapolate what we observe at the plot/slope scale to larger scales – even the HRU scale – as most of our process knowledge is “control volume” based, and larger scale theories are often overtly complex and/or just theories.

- We have never “proven” HRUs exist – they just do for our convenience.

Perspectives on parameterization

- Don’t reinvent the wheel.

Perspectives on parameterization

- Be cognizant of the data. In most cases, there is little or no data (or reanalysis data)
- This should be considered when developing parameterization schemes – or at least testing them. Why would we make our parameterization schemes reliant on massive amounts of data?
- However….. We should base them on massive amounts of data and direct observation.

Parameterization in IP3

- Basin-scale controls on runoff:
  - Thaw
  - Infiltration/redistribution in organic soils
  - Runoff
- Don’t start parameterizing until we know that we know what we know…..

An example – ground thaw

- Objectives:
  - Evaluate the performance of commonly used simulation algorithms in permafrost regions
  - Evaluate commonly used soil parameterization schemes for both mineral and organic soil
  - Provide guidelines for the implementation of appropriate ground thermal models

Simulation Algorithms

Semi-empirical → **Accumulated Temperature Index Algorithm (ATIA)**

$$Z = \beta F^{0.5}$$

Analytical

- **Two Directional Stefan Algorithm (TDSA)**

$$Z = [2KF/(\rho L\theta)]^{0.5}$$

- **Hayashi's Modification to Stefan Algorithm (HMSA)**

$$Z = [2/(\rho L\theta)]^{0.5}[86400\sum(K_b T_s)]^{0.5}$$

Numerical

- **Finite Difference Thermal Conduction Method with DECP (FD_DECP)**
- **Finite Difference Thermal Conduction Method with AHCP (FD_AHCP)**
- **Finite Element Thermal Conduction Method with AHCP (FE_TONE)**

Latent Heat Parameterisation

DECP: Decoupled Energy Conservation Parameterisation

AHCP: Apparent Heat Capacity Parameterisation

Parameter tests

Tests of soil thermal conductivity parameterisation

- --Johansen'formulation
- --De Vries's formulation

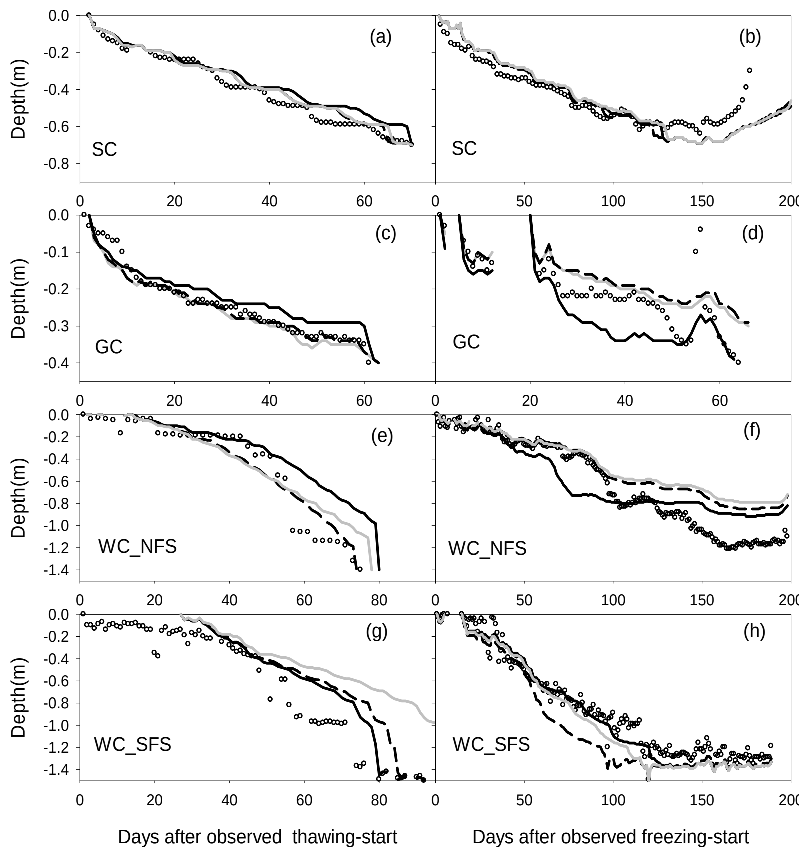
Test of unfrozen water parameterisation

- --Segmented linear functions
- --Power function
- --Water potential-freezing point depression formulation

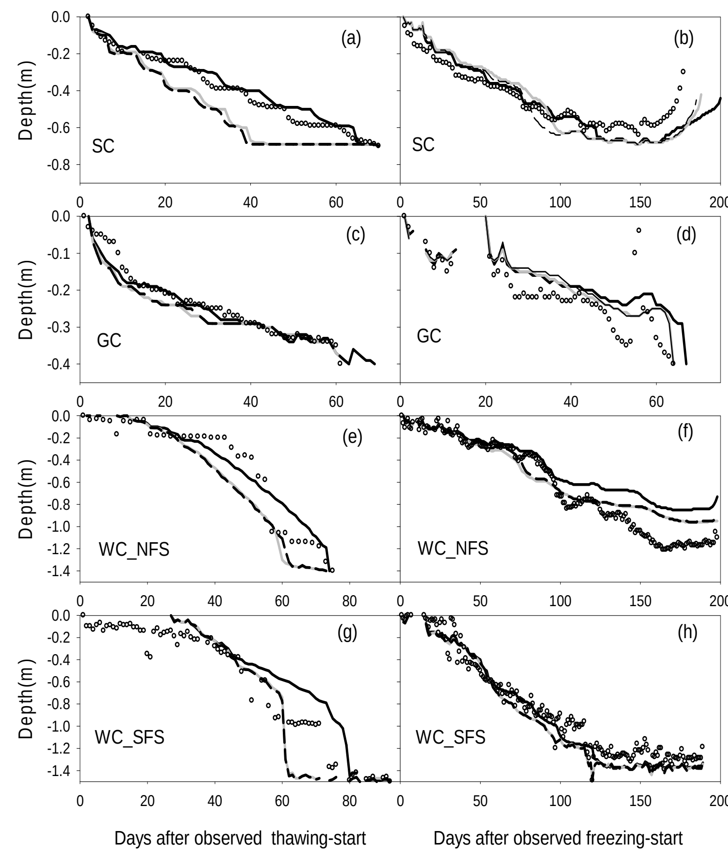
Tests of simulation algorithms (best parameterisation)

- --Run1: All the available inputs (T_{top}, T_{bot}, θ_w, θ_{ice},$T_{s,ini}$)
- --Run2: Without T_{bot}, lower boundary conditions and θ_w, θ_{ice},$T_{s,ini}$ have to be assumed.
- --Run3: Only T_{top} was supplied. Soil water assumed to be saturated at all times.

Model Results

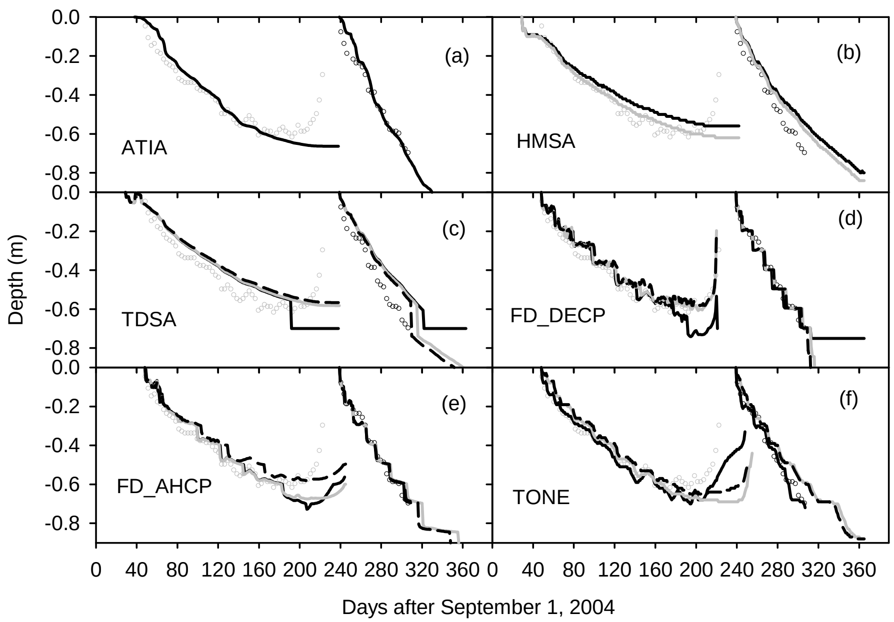


Tests of different soil thermal conductivity parameterisation methods, *i.e.* Complete Johansen's equations (dark solid lines), Commonly used Johansen's equations (grey solid lines), and a simplified de Vries's method (dashed lines). Open circles are observations.

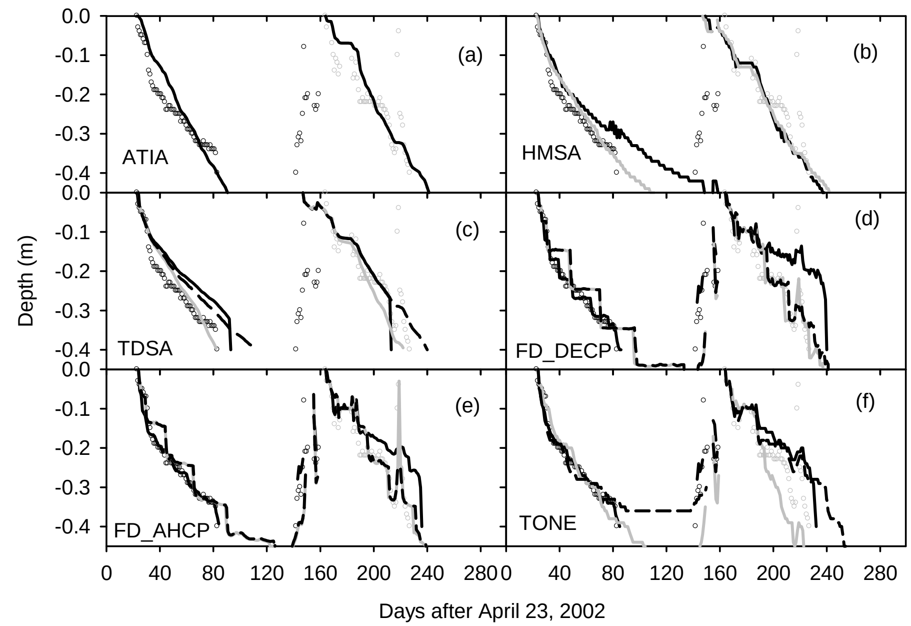


Test of unfrozen water parameterisation methods, *i.e.* segmented linear function (dark solid lines), power function (grey solid lines) and water potential-freezing point depression

Model Results



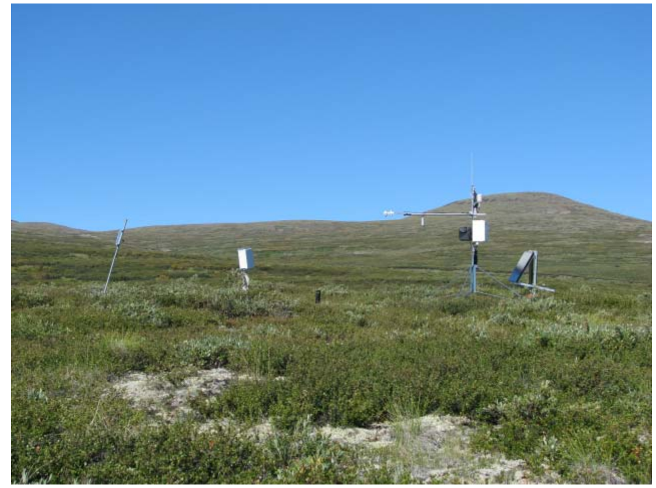
Comparisons of observed (symbols) and simulated (lines) thawing (dark circles for observation) and freezing (grey circles for observation) depths at Scotty Greek with six algorithms and three sets of model runs, *i.e.*, Run1 (dark solid lines), Run2 (dark dashed lines) and Run3 (grey solid lines).

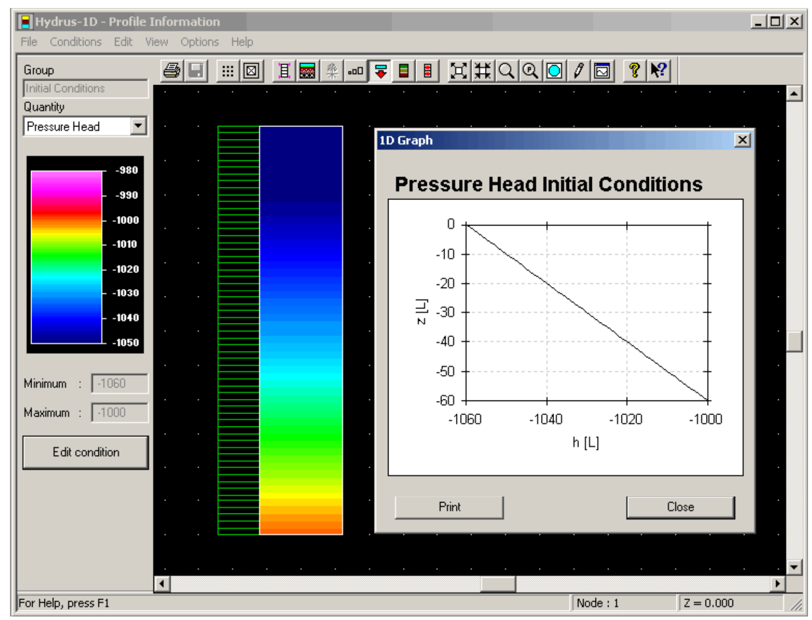


Comparisons of observed (symbols) and simulated (lines) thawing (dark circles for observation) and freezing (grey circles for observation) depths at Granger Greek with six algorithms and three sets of model runs, *i.e.*, Run1 (dark solid lines), Run2 (dark dashed lines) and Run3 (grey solid lines).

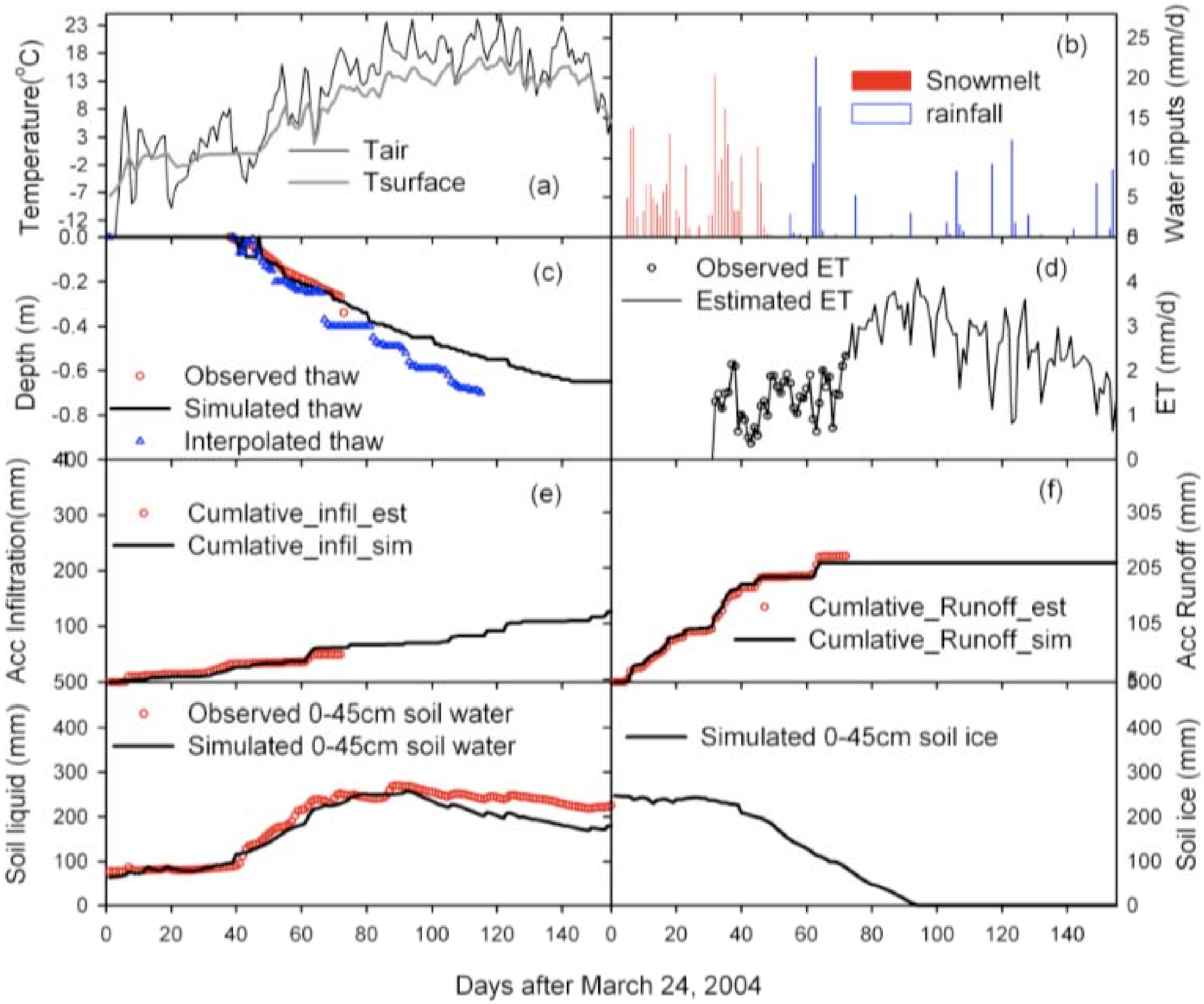
Infiltration into frozen soils

- New Field Experiments
- New Instrumentation (MFHPP)
- New Modelling
  - Modify Hydrus 1-D
  - SHAW
  - HAWTS

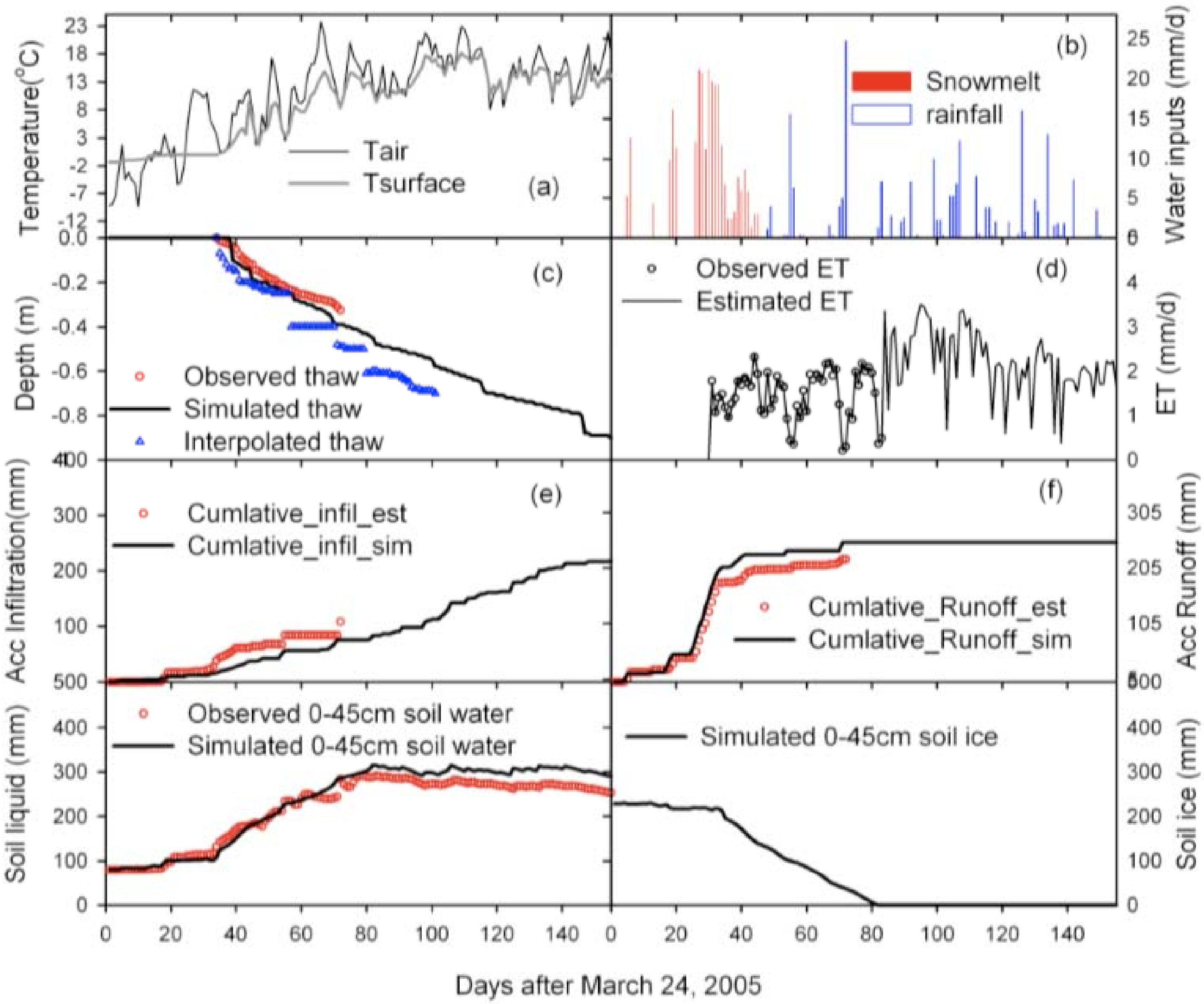




SHAW – 2004 Scotty Creek



SHAW – 2005 Scott Creek



Detailed heat/water simulations

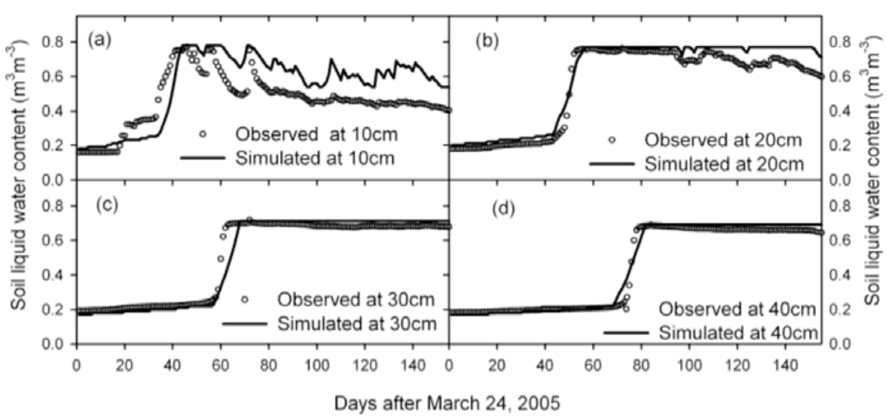
$$C_s \frac{\partial T}{\partial t} - \rho_i L_f \frac{\partial \theta_i}{\partial t} = \frac{\partial}{\partial z}\left[k_s \frac{\partial T}{\partial z}\right] - \rho_l c_l \frac{\partial q_l T}{\partial z} - L_v\left(\frac{\partial q_v}{\partial z} + \frac{\partial \rho_v}{\partial t}\right)$$ Heat

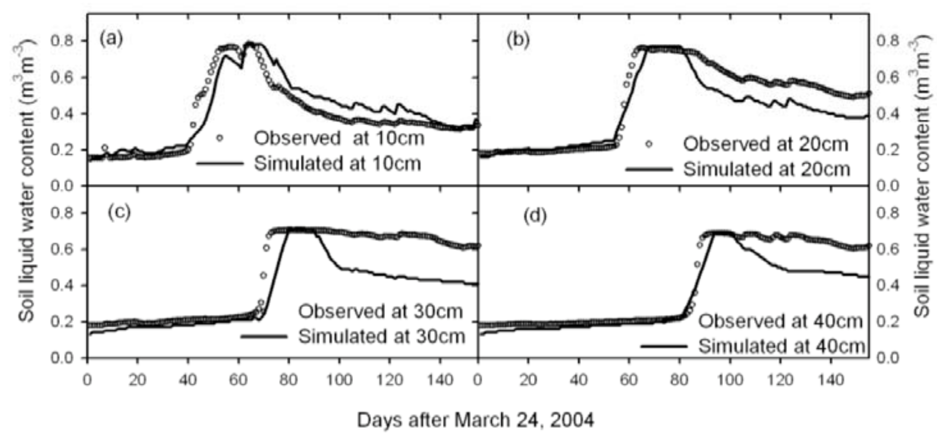
$$\frac{\partial \theta_l}{\partial t} + \frac{\rho_i}{\rho_l}\frac{\partial \theta_i}{\partial t} = \frac{\partial}{\partial z}\left[K\left(\frac{\partial \psi}{\partial z} + 1\right)\right] + \frac{1}{\rho_l}\frac{\partial q_v}{\partial z} + U$$ Water

Devries

$$\psi = \frac{L_f}{g}\left(\frac{T}{T_k}\right) + \frac{cRT_k}{g} = \psi_e\left(\frac{\theta_l}{\theta_0}\right)^{-b}$$

Clapp-Hornberger





Infiltration

- Paramterization…….? Not yet…..

Runoff

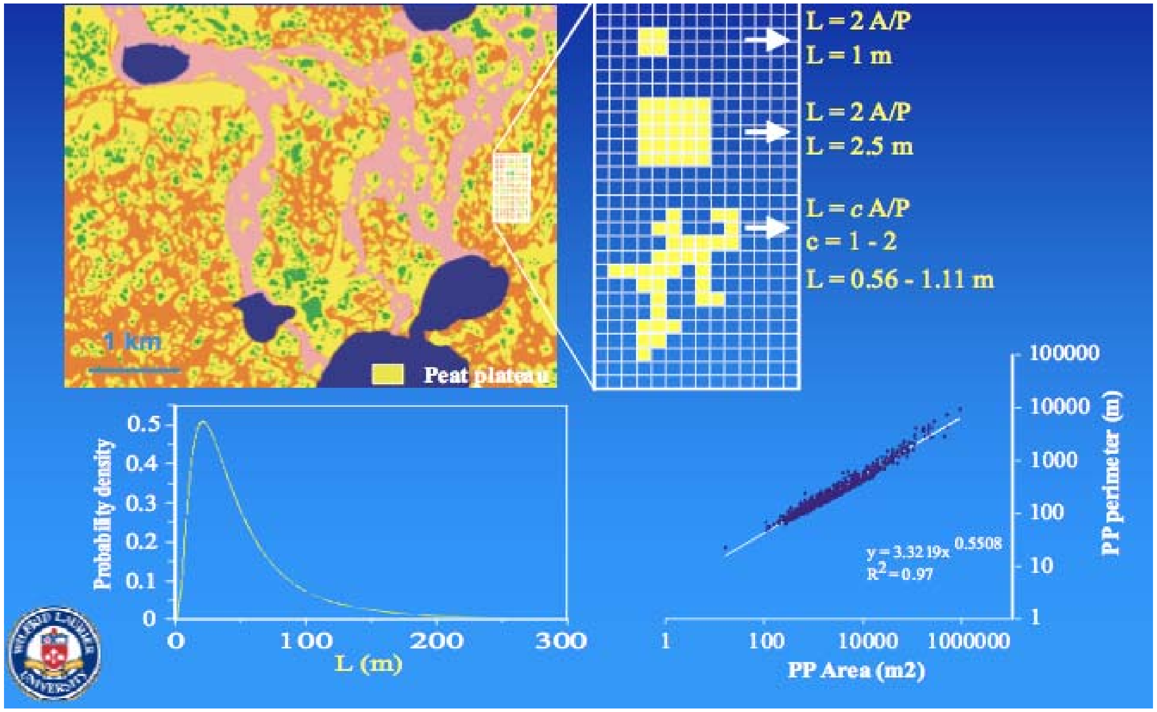
- While it may seems straight-forward, modelling runoff (we've been doing it for decades), at the HRU scale it is challenging.
- "Emergence" is a term rapidly polluting itself in the runoff community.
- Do our plot/field scale results have any relevance at the HRU or larger scale?

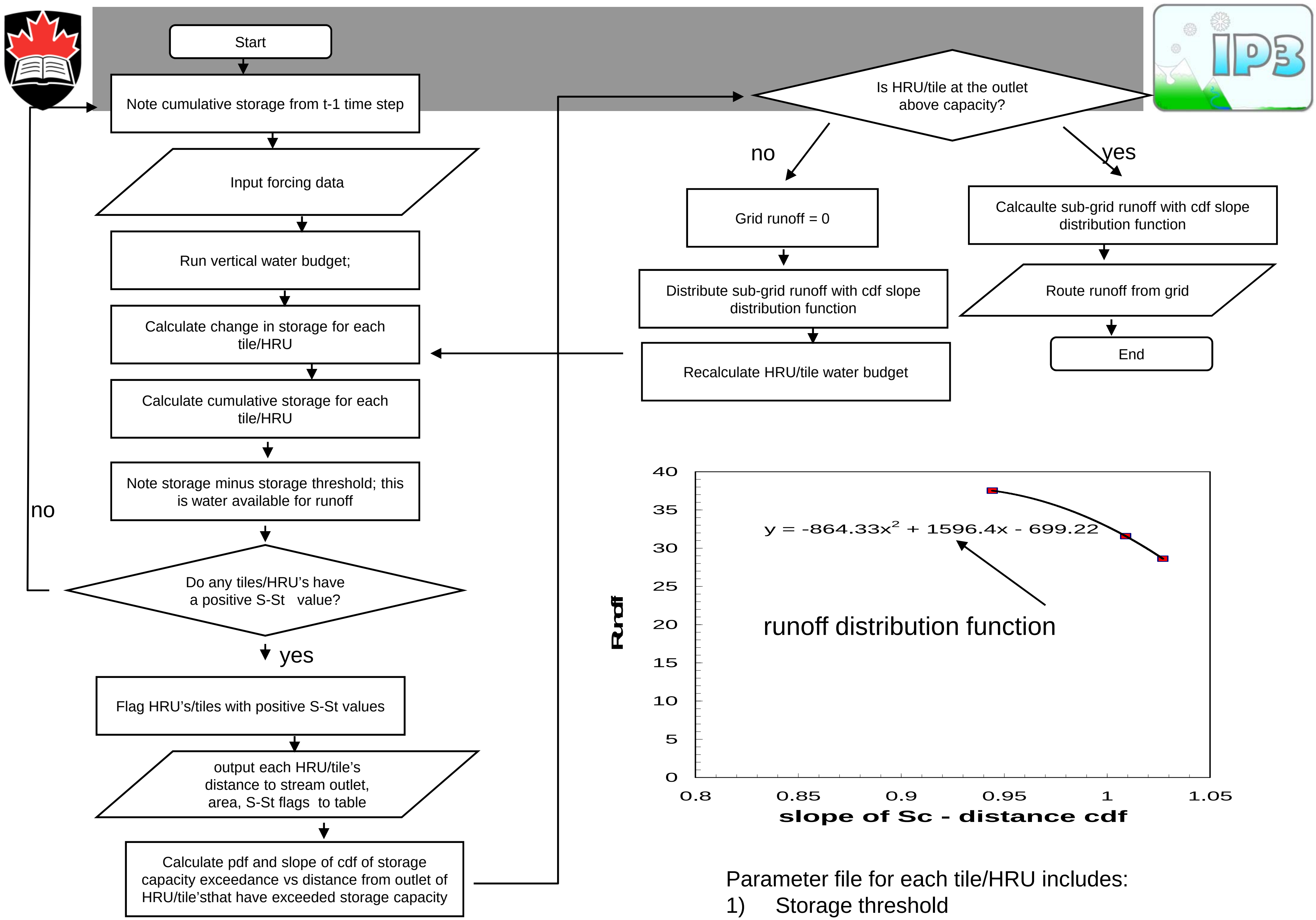
Runoff

- Some debating points:
  - Should we base parameterization on conservation equations at the point scale?
  - How do we scale other linked properties like momentum? Or do we even need to?
  - Environmental mechanics typically use some sort of gradient/potential approach – is this appropriate at larger scales? Field-scale Ksat increases an order of magnitude for every magnitude of scale increase.

Runoff

- Landscape Geometry
  - Travel/Residence time based on terrain geometry and soil attributes.
  - Advantages: relatively easy extraction from DEM/Satellites
  - Drawbacks: Do we really know that each HRU is an HRU? What field evidence do we even have that HRUs exist?

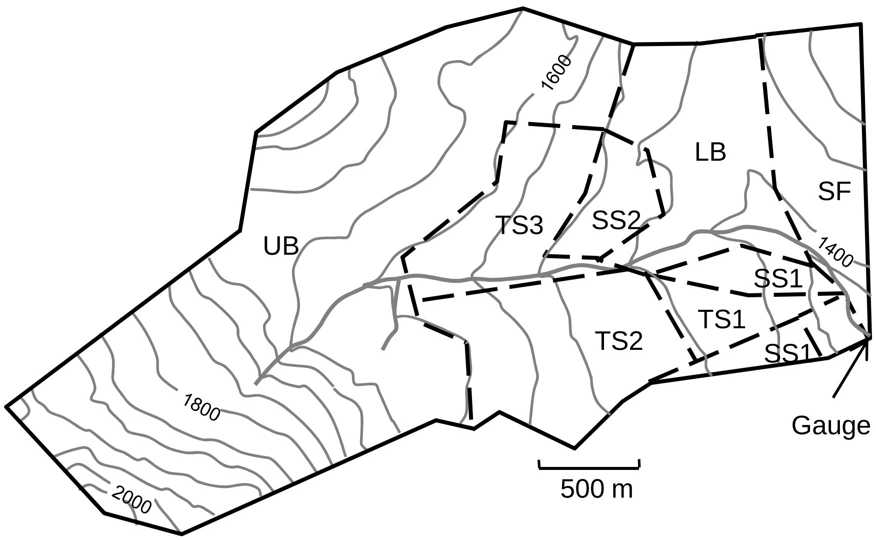


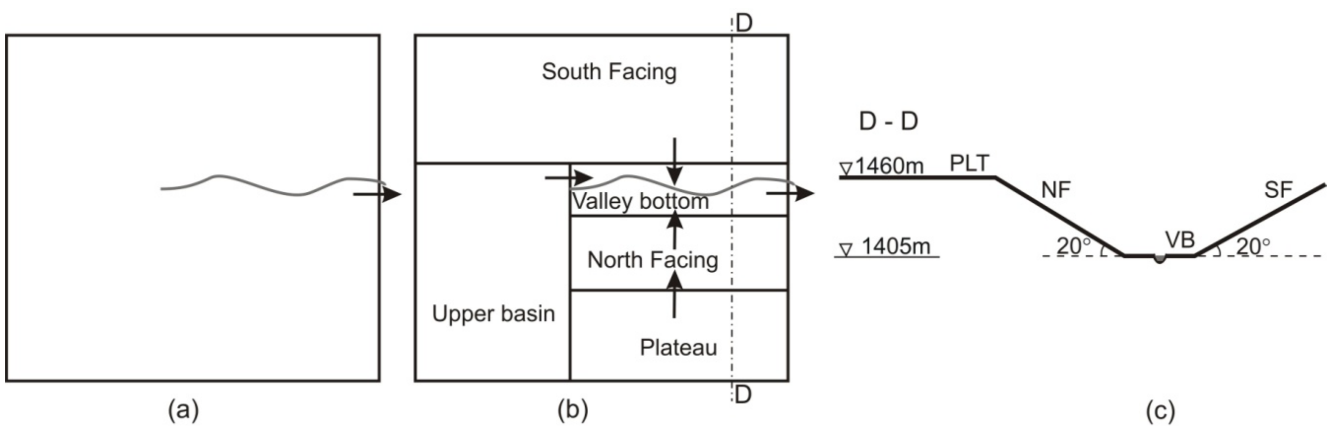


Parameter file for each tile/HRU includes:

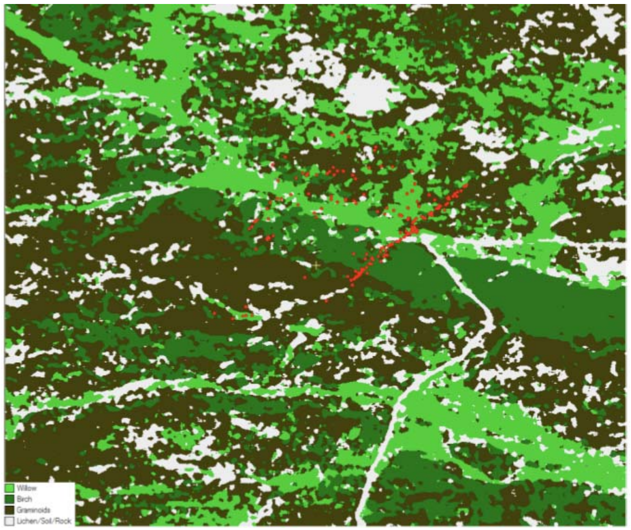
1) Storage threshold
2) Distance from outlet
3) Area
4) Runoff distribution function

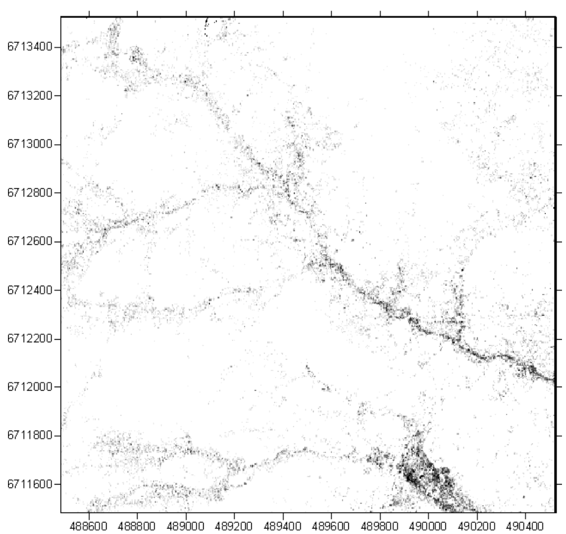
Landscape Classification

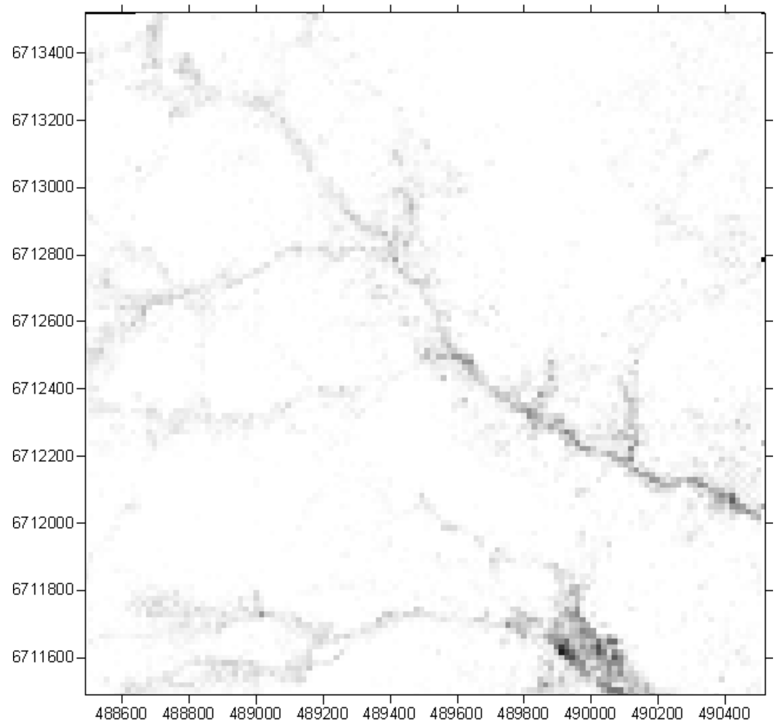




More classification

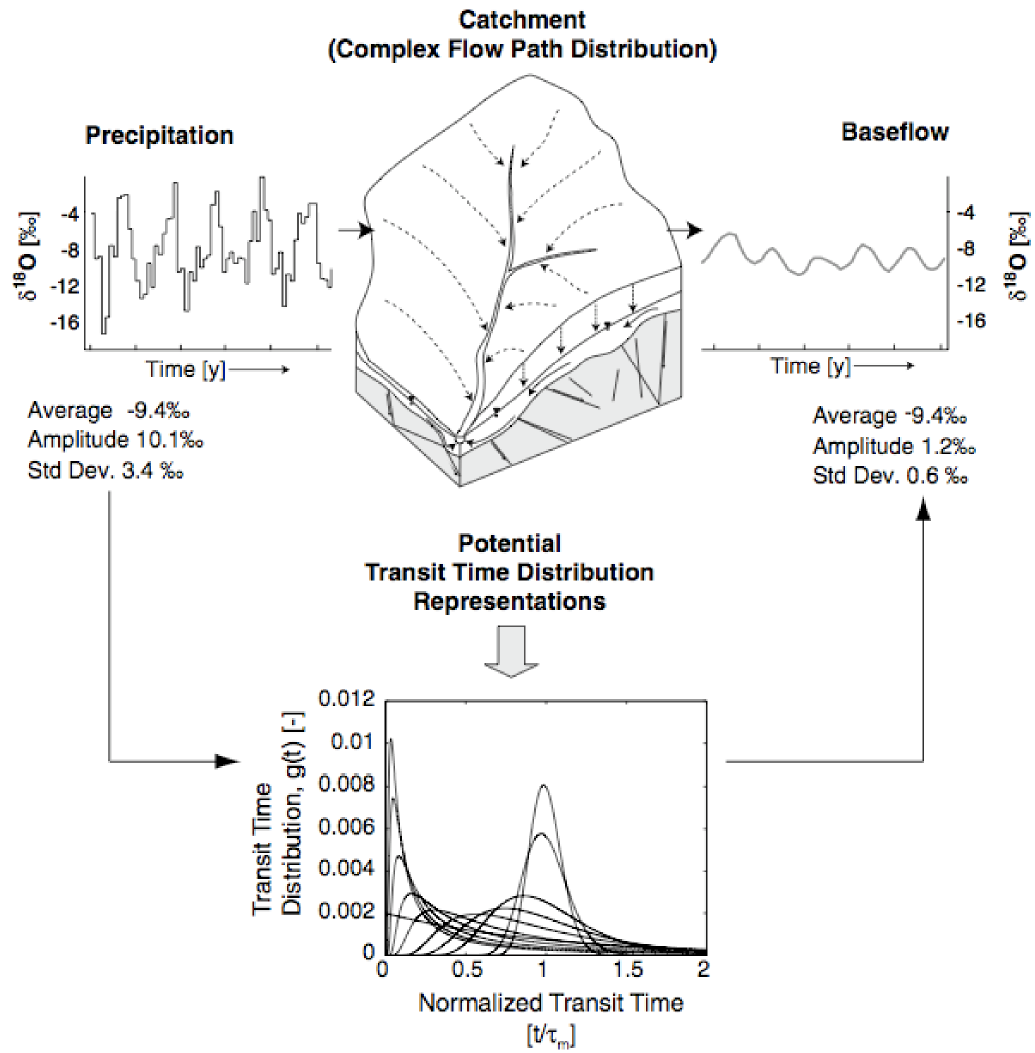






Runoff

- Tracers
  - We still have not fully utilized tracers in our work. Residence Time Distribution determinations are becoming increasingly common in the literature, yet not used here. This may be the best way to physically-stochastically parameterize runoff at larger scales.
  - Can tracer-based RTD be linked to basin-scale attributes? It can in other environments, but in IP3 basins, we have a unique set of problems.



Runoff

- The key to parameterization (I think) is capturing these emergent properties at the HRU scale not observed at the slope/plot scale. While we often model HRU scale variables (like mean thaw depth with the appropriate moments) – how do these moments act to affect infiltration/runoff, etc?