Development Efforts in Soil Hydrology and Instream Water Quality

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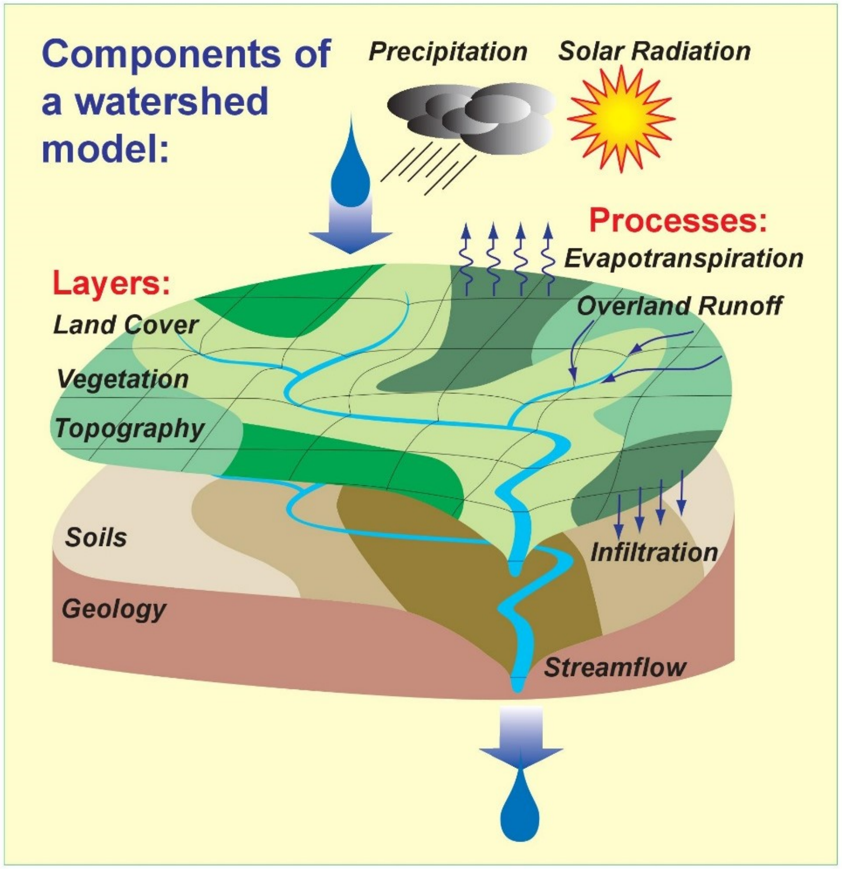
Introduction

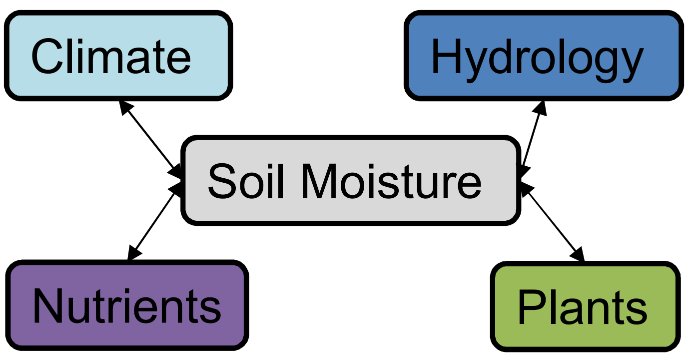
- Model developments are required to:
  - *improve confidence in the model*
  - *provide representative predictions*
- Potential for improving various landscape and channel processes



Objectives

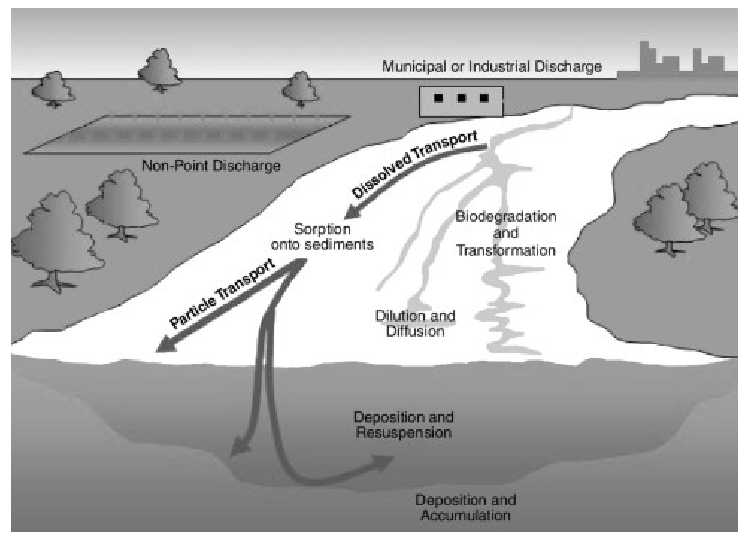
To improve two key processes in SWAT model:

1) Soil water hydrology



Critical linking process in water quality predictions, but dynamics have limited representation

2) Instream water quality



Need to refine water quality algorithms in SWAT (Migliaccio et al., 2006; Gassman et al., 2007)

1. Soil Water Hydrology

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Soil Water Modeling Approaches

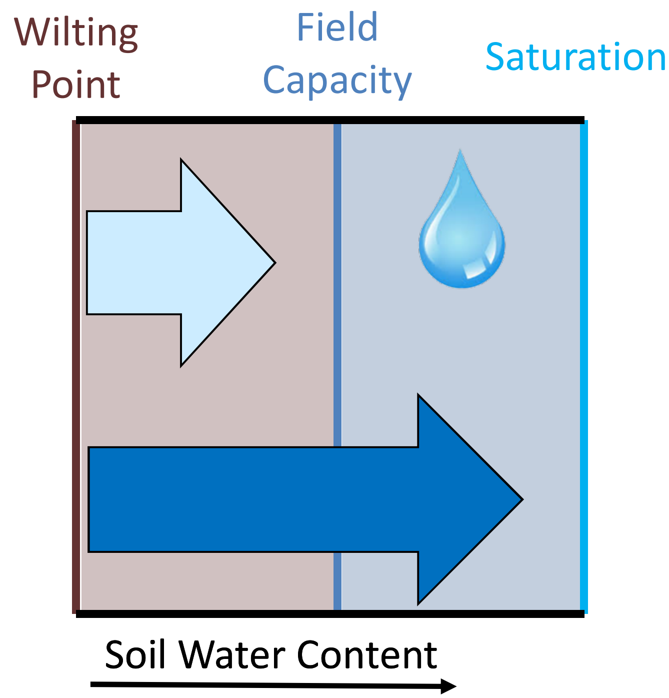
1) Bucket Approach

- Threshold function
- Simple, efficient
- Ignores some conditions
- Ex: WEPP, SWAT

2) Richard’s Equation

- Physically based
- Numerical solutions
- Captures all conditions
- Ex: HYDRUS, MIKE-SHE

SWAT Soil Water



Tends to completely drain layer when field capacity exceeded

Modified Soil Hydrology Approach

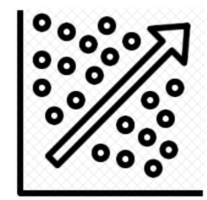
Darcy's Law

$$q = \frac{Q}{A} = K(h) * \frac{dh}{dl}$$ → Assume constant downward flow → $$q \cong K(\theta)$$

Hydraulic Conductivity

$$K(\theta) = f(\theta)^b$$ → Parameterize →

OR



Key = Equations based on Relative Saturation

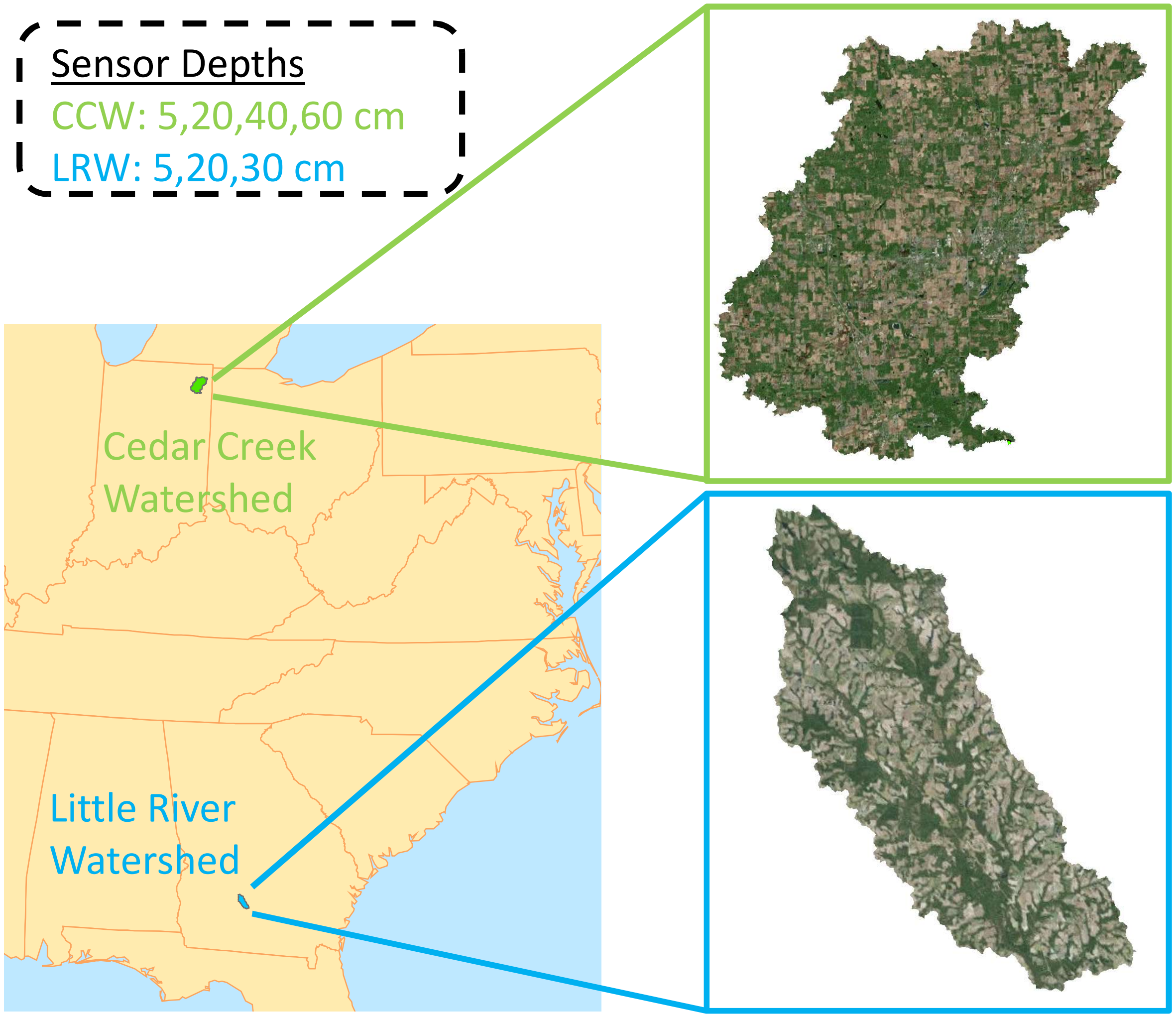
Campbell 1974 (CA)	van Genuchten 1980 (VG)
$K(\theta) = K_{sat} (\theta/\theta_{sat})^{3+2b}$	$K(\theta) = Ksat(\theta/\theta_{sat})1/2\{1-[1-(\theta/\theta_{sat})^{1/m}]^{m}\}^{2}$

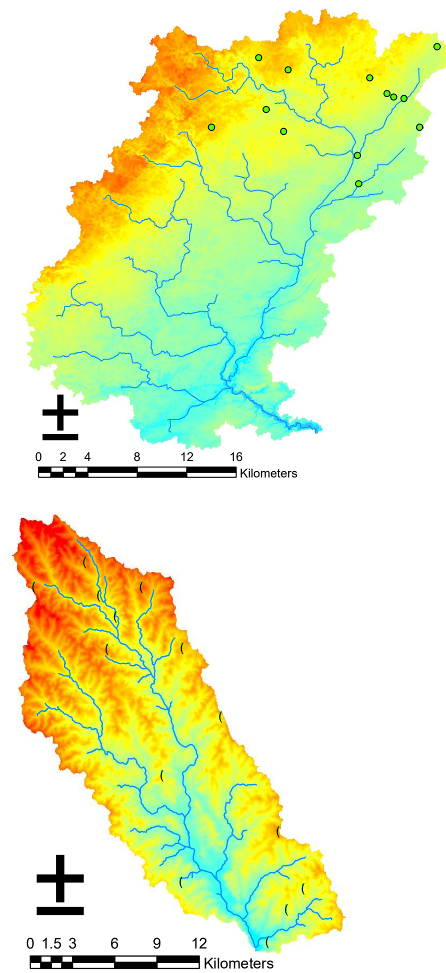
<u>Compare to default</u>

- Uncalibrated
- 8 years ('07-14)

Experimental Watersheds

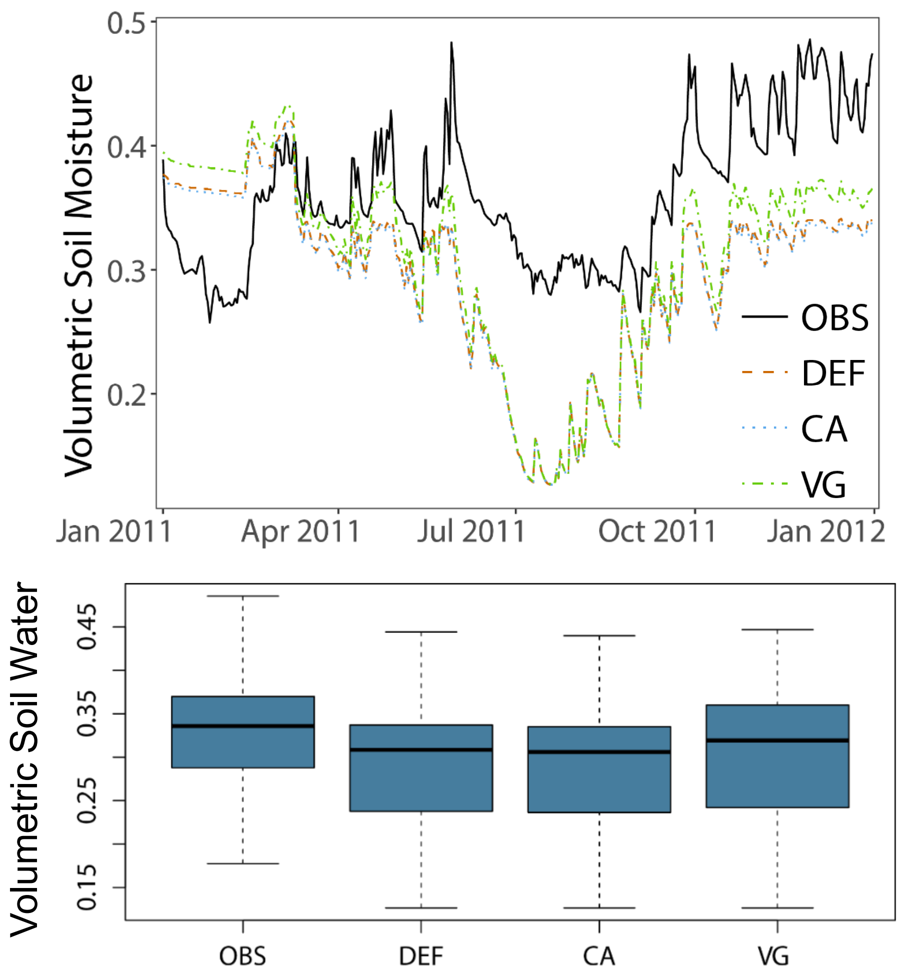
Sensor Depths
CCW: 5,20,40,60 cm
LRW: 5,20,30 cm



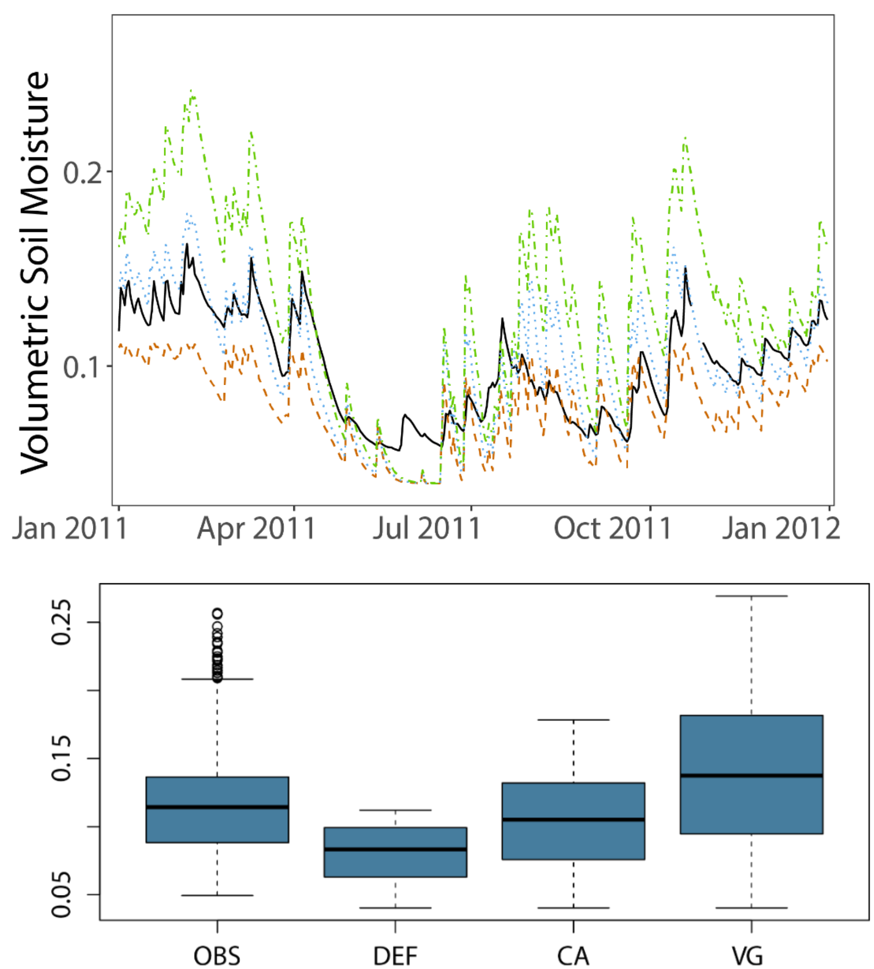


New approaches tend to retain more water in soil

CCW

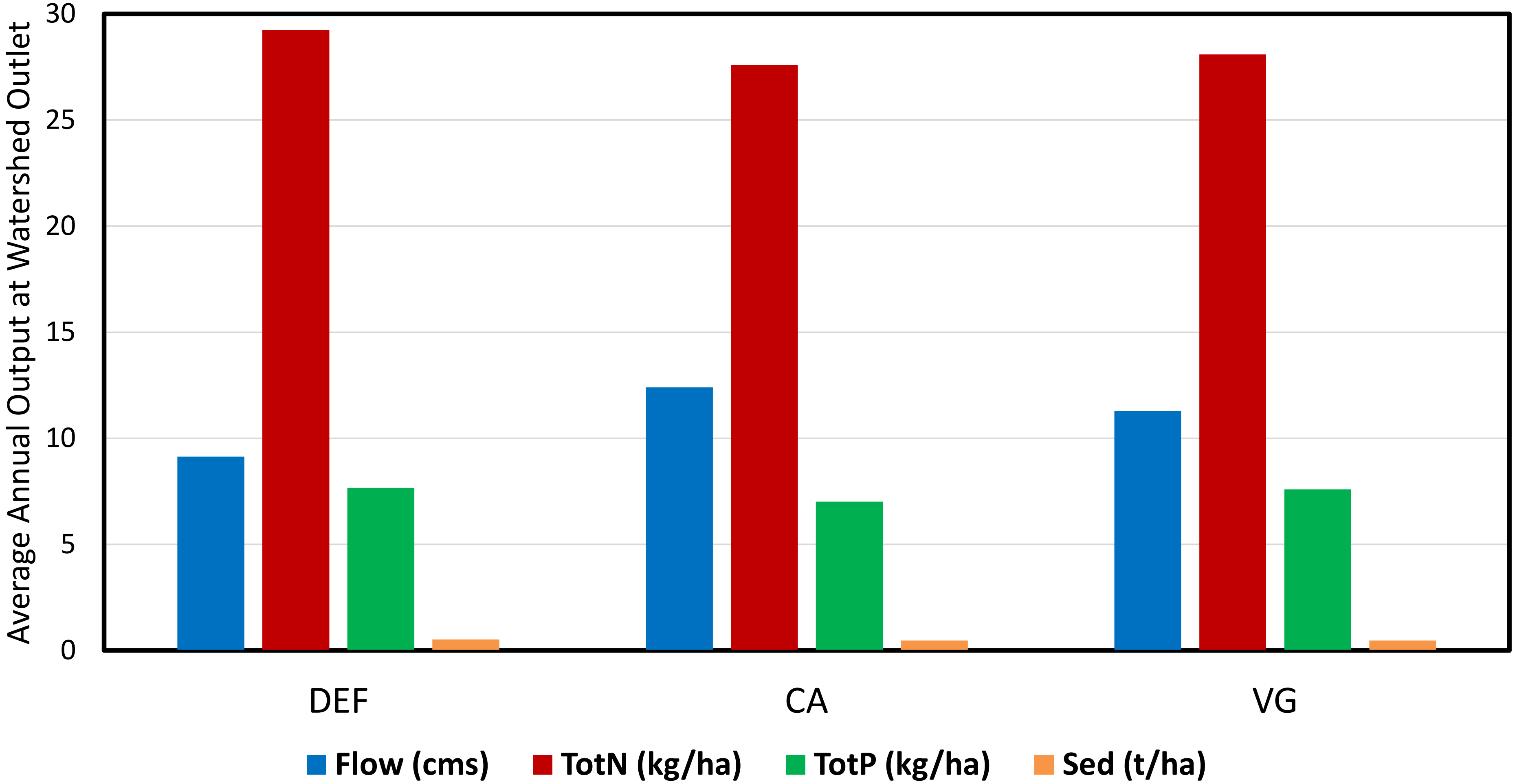


LRW



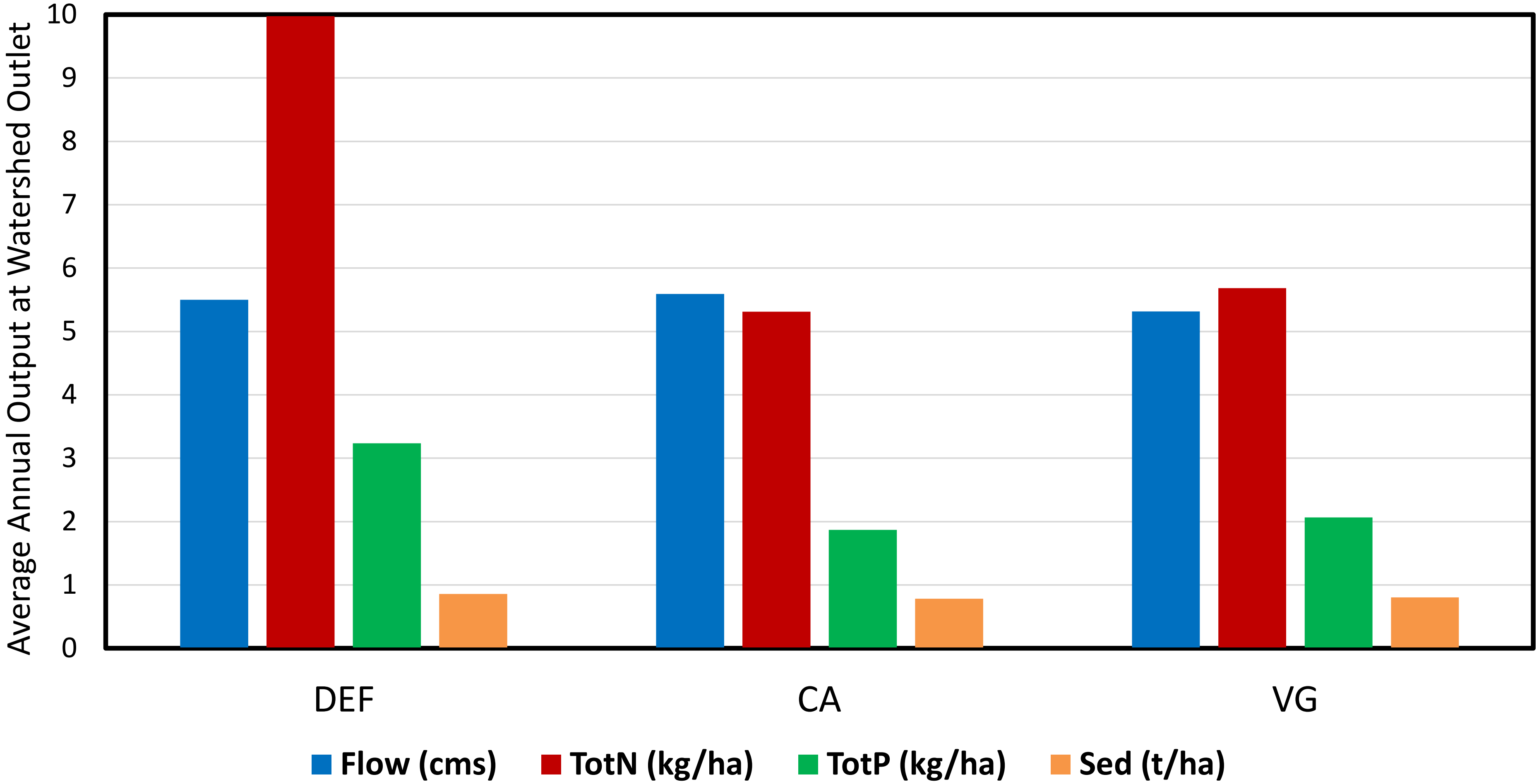
More retention of soil water decreases subsurface transport of nutrients

CCW



More retention of soil water decreases subsurface transport of nutrients

LRW



Summary & Future Efforts

Model Development

- New soil water equations implemented

Key Findings

- More water retention with new approaches, potentially less flushing
- Water balance reflects relative rate of vertical conductivity
- Changes in water quality dependent upon subsurface soil transport

Next Steps

- Test with calibrated models
- More detailed analyses of results across layers

2. In-stream water quality

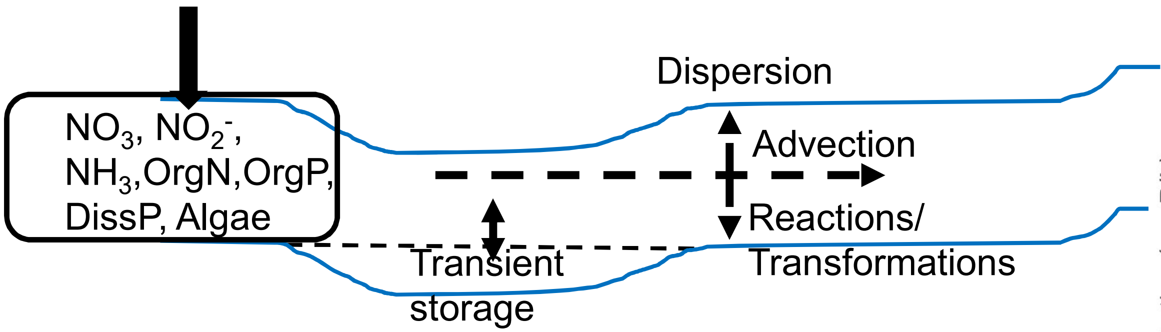
In-stream water quality modeling

- Water quality models are crucial for predicting water quality status in streams
  - QUAL2E/K, WASP (reach models)
  - SWAT, HSPF (watershed models)
  - OTIS (solute transport model)

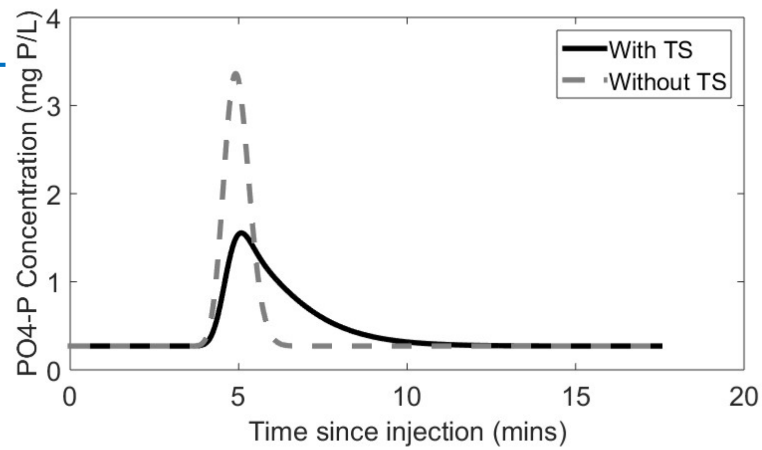
Existing Models

Transient storage (O'Connor et al., 2010)

In-stream processes

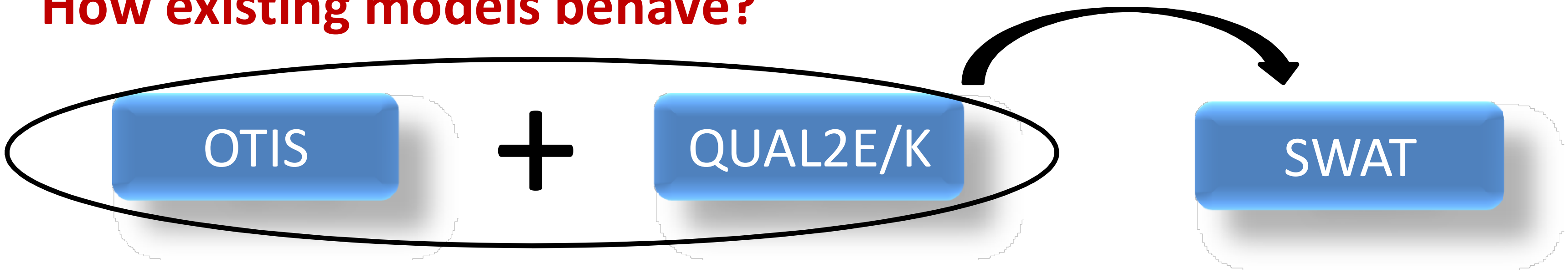


- Advection
- Dispersion
- Transformations/reactions
- Transient Storage exchange



Why do we need another model?

How existing models behave?



OTIS
- Processes: Advection, Dispersion, **Transient Storage**
- Sub-daily scale
- One value of decay rate

QUAL2E/K
- Processes: Advection, Dispersion, **Reactions**
- Sub-daily scale
- Steady state analysis

SWAT
- Processes: Reactions
- Daily scale

New Model: Advection, Dispersion, Reactions, Transient storage, Sub-daily scale

Model Development

Advection-dispersion-reaction model was developed based on finite difference approach using knowledge from existing water quality models

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - U\frac{\partial C}{\partial x} - kC\ (sources/sinks) + \alpha(C_s - C)$$

Dispersion | Advection | Transformations | Transient storage exchange

Replaced with QUAL2E reactions

$$\frac{\partial C_s}{\partial t} = -\alpha\frac{A}{A_s}(C_s - C)$$

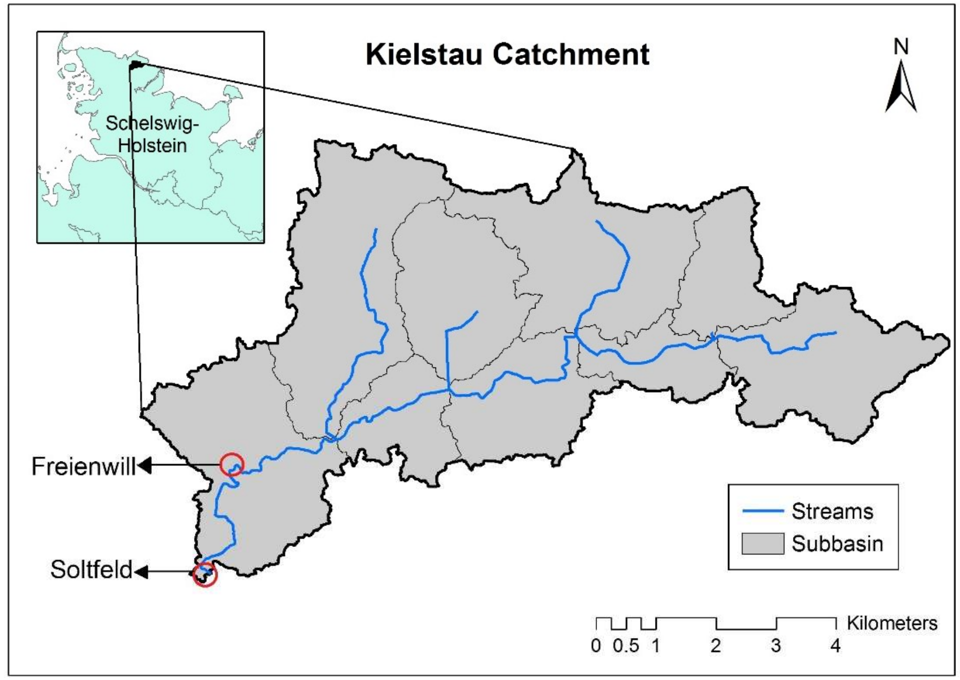
Breakthrough curve is fitted to calibrate the transient storage parameters

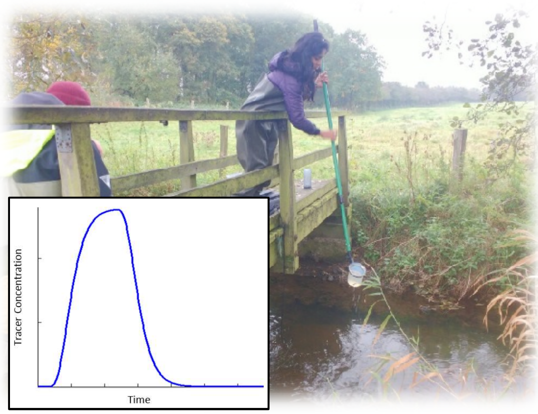
- A (cross-sectional area, m^2)
- A_s (transient storage area, m^2)
- D (dispersion coefficient, m^2/s)
- α (storage exchange coefficient, s^{-1})

Data Collection

Tracer tests were conducted in two separate stream reaches in Germany

- 30L salt solution mix (Chloride + Phosphate) injected instantaneously at an upstream location
- Downstream, conductivity was monitored and grab samples were taken to analyze nutrient concentrations over time



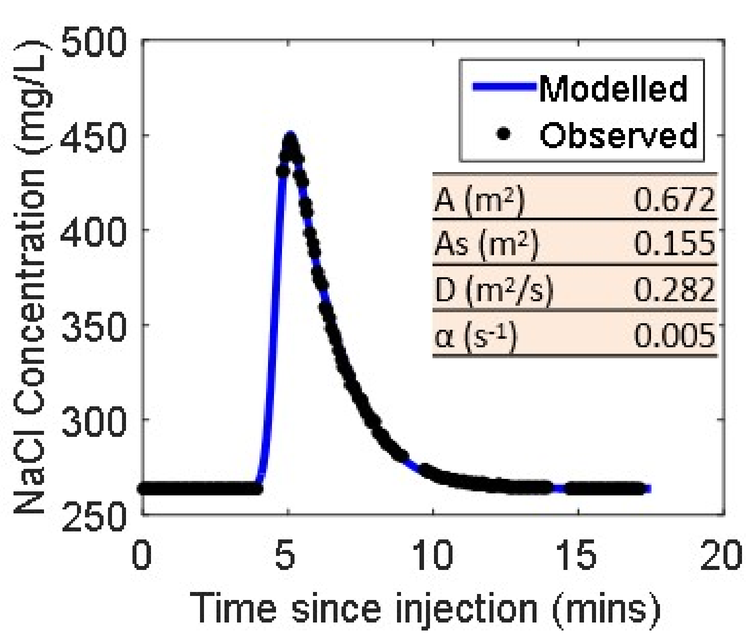


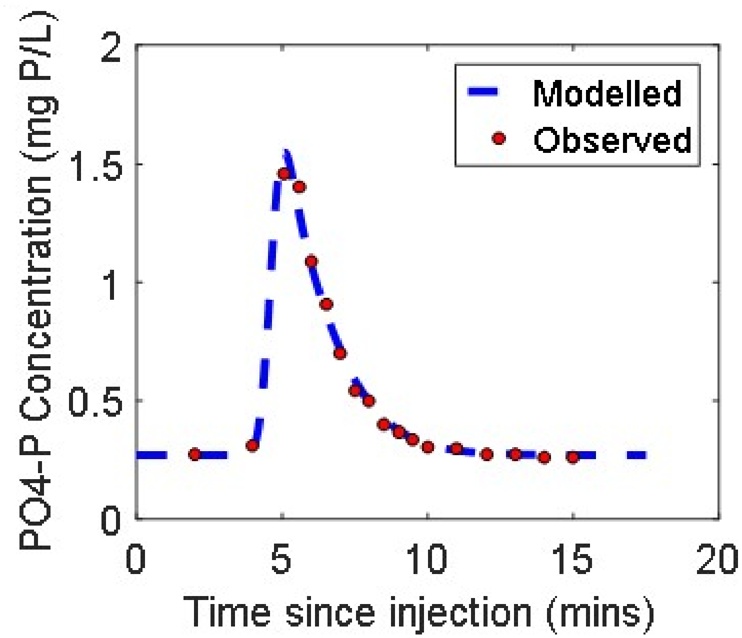
Location	Discharge (L/s)	Reach length (m)	Amount of NaCl (g)	Amount of KH_2PO_4 (g)
Soltfeld	124	120	8000	250
Freienwill	306	135	8000	250

Modelled breakthrough curves

Fitted transient storage parameters with NaCl curve → Tested phosphate curve with fitted parameters

Freienwill





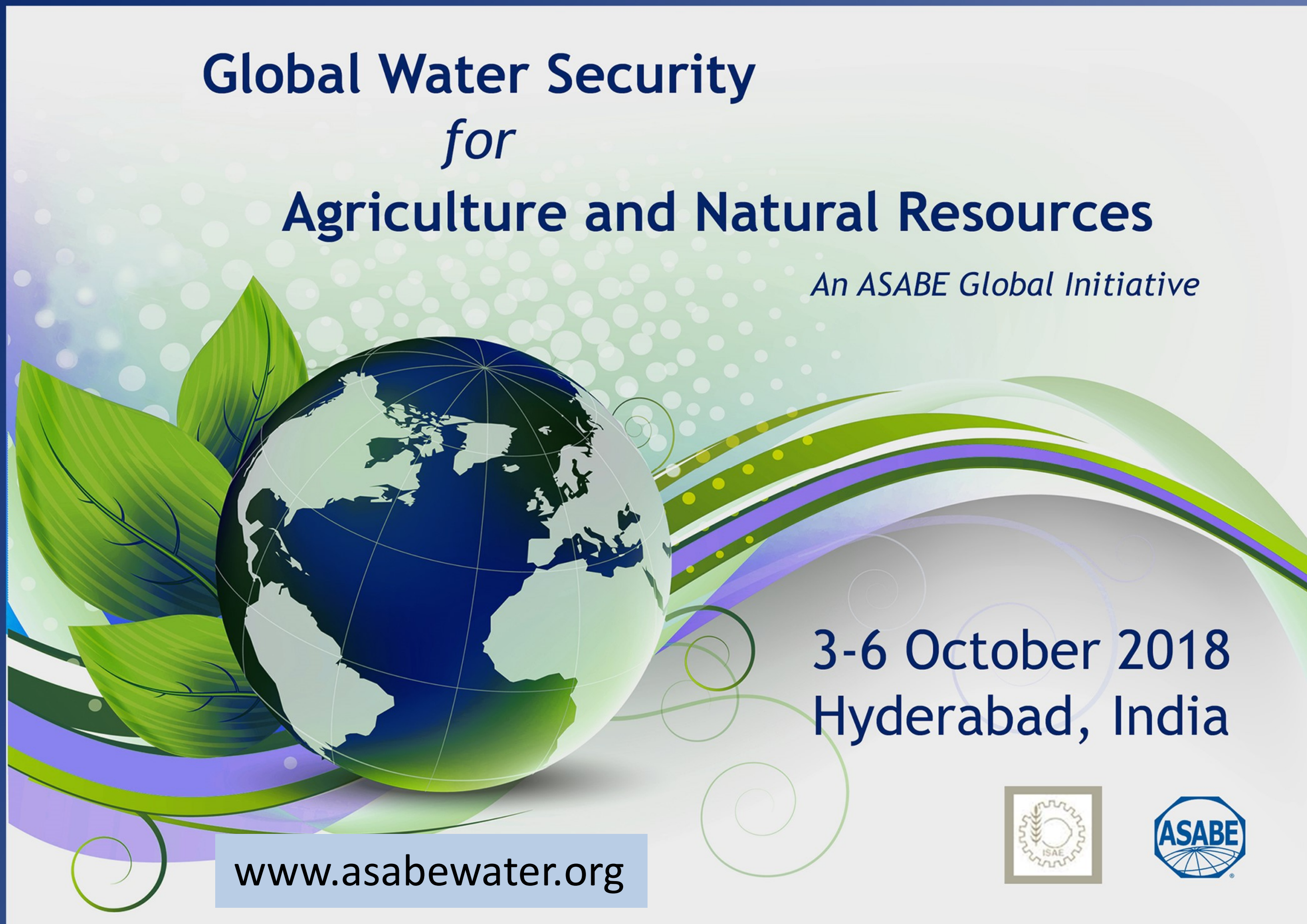
Summary & Future Efforts

Recent model development

Regression models were developed to estimate storage parameters from other easily available stream parameters (avoids extensive reach-specific calibration)

Key Takeaways

- ***Reasonable simulation of conservative and reactive solutes***
- Inclusion of reactions, transient storage, finite difference approach and sub-daily scale simulation gives the model ***better confidence compared to the existing models***
- Model ***will be validated with other test data*** showing significant N and P uptake
- The developed model along with regression estimates of storage parameters ***will be coupled with SWAT*** to improve nutrient predictions at sub-daily scale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