CAUSES OF NUTRIENT HOTSPOT FORMATION IN THE MINERAL HORIZON OF SIERRA NEVADA FOREST SOILS: MODELING APPROACH AND IMPACT ON NITRATE LEACHING

Casandra Woodward: Graduate Research Assistant University on Nevada, Reno

Arnaud Legout: Unité Biogéochimie des Ecosystèmes Forestiers (UR 1138)Centre INRA de Nancy and Dale W. Johnson: Natural Resources and Environmental Science University of Nevada, Reno

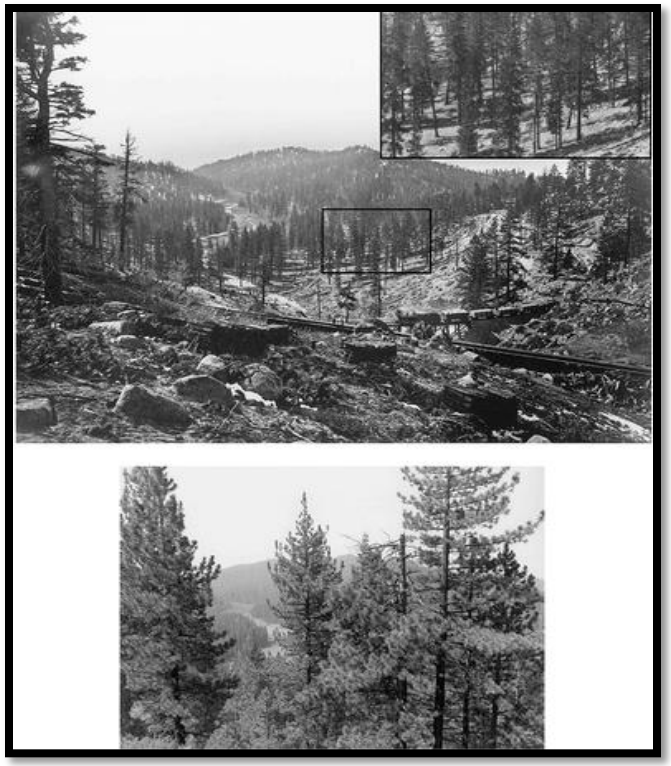
Outline

- Introduction
- Existence of Hot Spots
- Hydrus® 2-D modeling of nitrate
- Conclusions

Introduction

- Before Anglo-European settlement, Sierra Nevada forests were less dense, had thin organic horizons, and experienced a higher frequency of fire.
  - Mean pre-settlement fire return intervals: 10-25yrs
  - Larger trees
  - Less dense understory

Top photo taken in 1873, bottom in 1990



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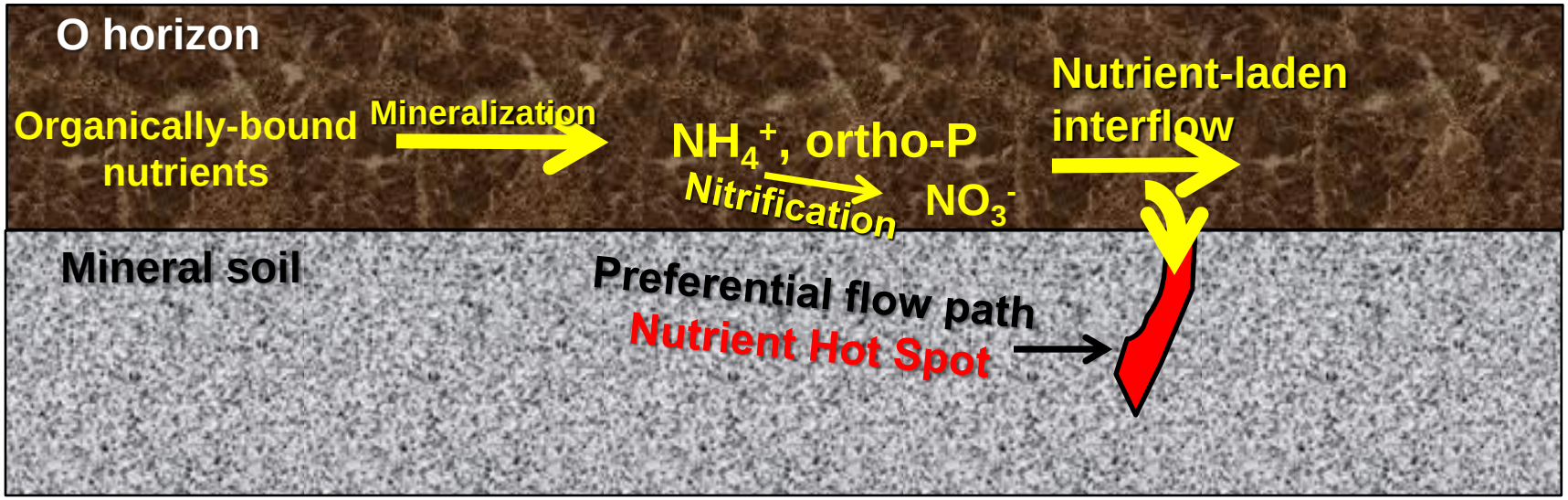
Introduction

- Current Conditions
  - High amount of organic matter build-up on the forest floor
  - Less heterogeneity in tree species
  - Increased amount of understory
  - Slower nutrient cycling

Introduction

- Nutrient concentrations in run-off from the O-horizon are 10 to 1000 times higher in inorganic nitrogen than in stream water or mineral soil solution.
- In the summer, soils in the Sierra tend to be *hydrophobic*
- Hydrophobic soils, high amounts of organic matter buildup, and lack of rooting in the O-horizon can lead to **hot spots** (zones of high nutrient concentration) within the mineral soil.



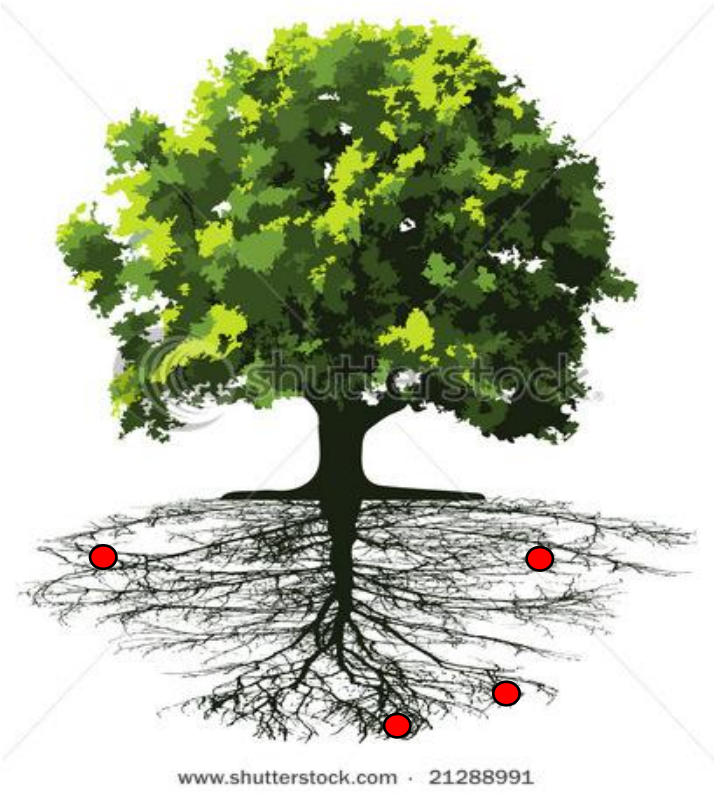
Introduction

- **Nutrient hot spots (described by McClain et. al.) are "patches [in the soil] that show disproportionately high reaction rates relative to the surrounding matrix."**
- Hot spots are a new field of research, and much is unknown as to their formation, period of existence in the soil, or how they affect the surrounding environment.
- Hot spots may:
  - play a large role in the biogeochemical cycling of nutrients
  - help plants outcompete microbes
  - contribute to nutrient stream loads

Introduction

Nutrient Hotspots:

- Their non-normal distributions were once seen a problematic
- Hotspots are exploited by plants, allowing them to outcompete microbes (similar to the fertilizer spike approach)



Existence of Hot Spots

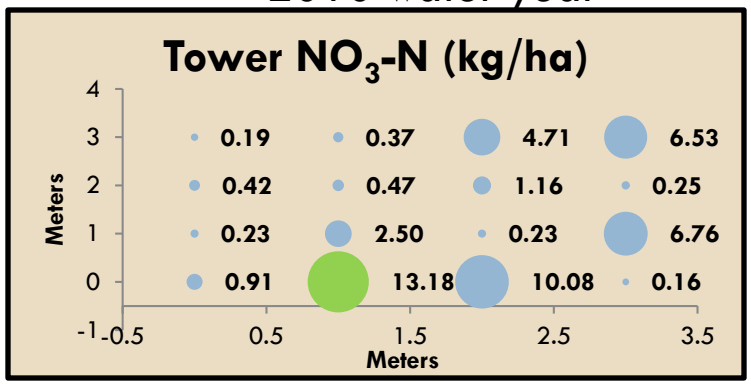
- Hot spots in the form of extreme and moderate outliers have be in the Sierra Nevada Mountains
- Kings River Experimental Watershed (KREW)
  - Nitrogen hot spots tend to be the most frequently found
    - Resin sampling methods
    - Water extractable soil nutrient concentrations
    - Location varies year to year

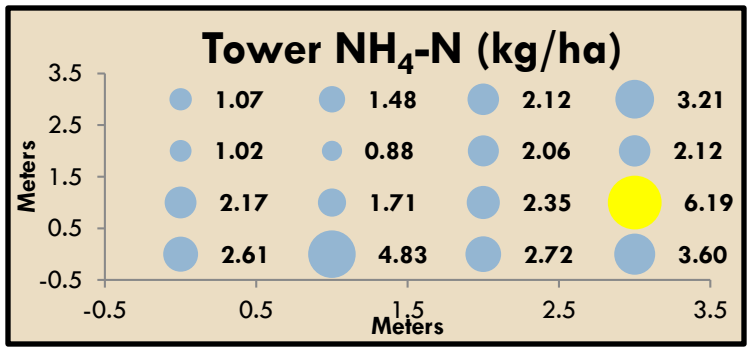
Extreme outliers:
$x > Q3 + 3IQR$
Moderate outliers
$x > Q3 + 1.5IQR$
x = the value
Q3 = the third quartile value (75^{th} percentile), and
IQR = interquartile range (range from 25th to 75^{th} percentile)

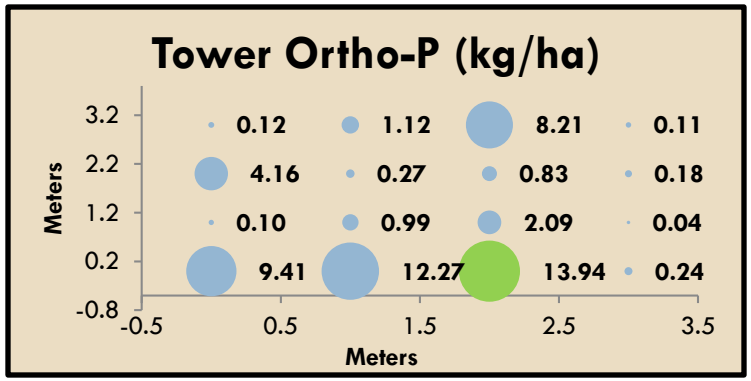
Existence of Hot Spots

Tower Site

2010 water year





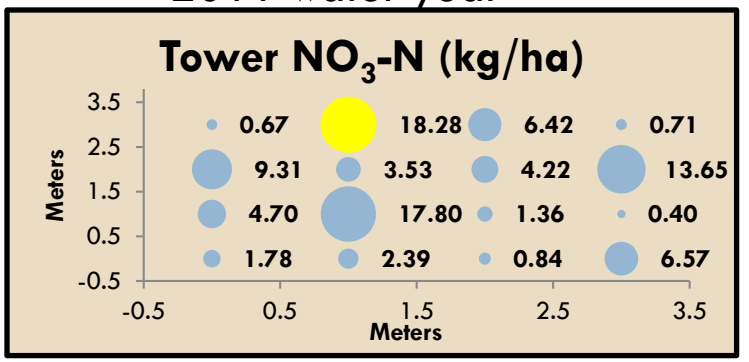


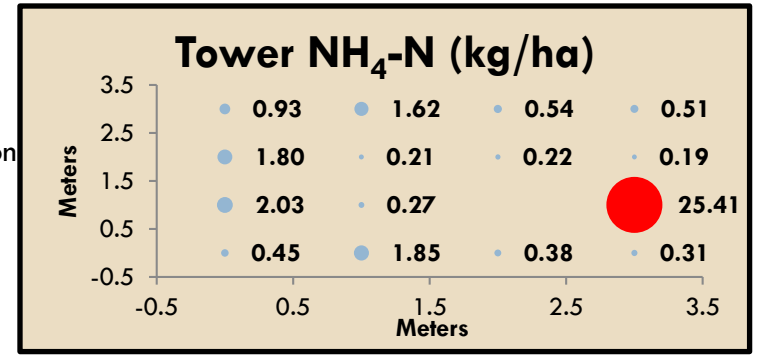
= Extreme outlier

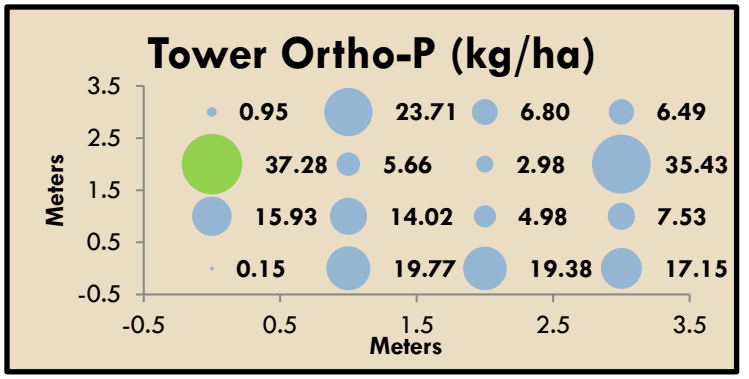
=Moderate outlier

=Highest Concentration

2011 water year



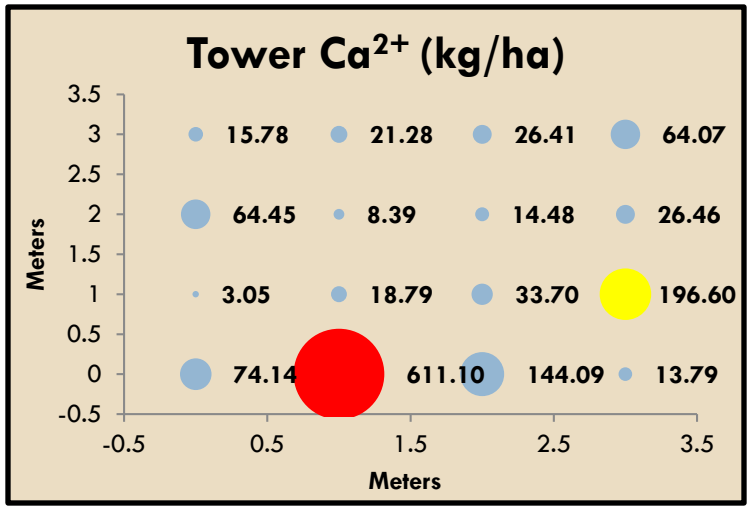




Existence of Hot Spots

Tower Site

2010 water year



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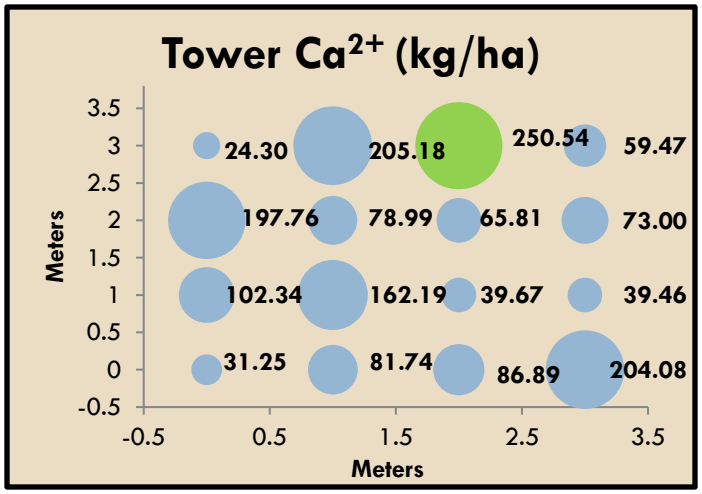
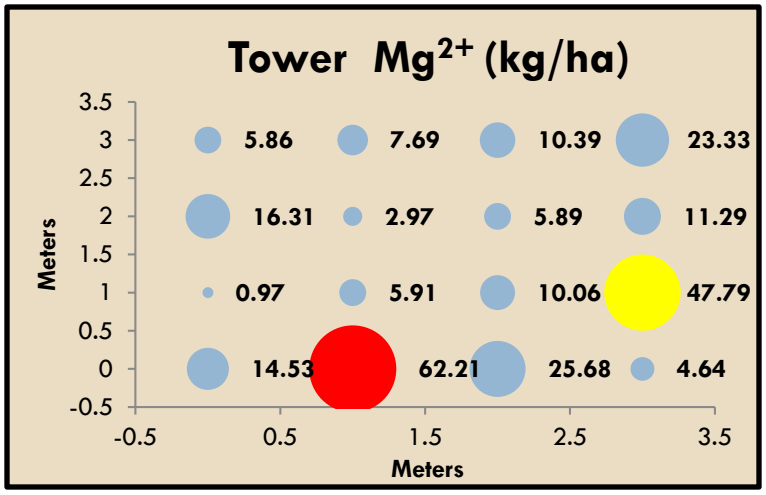
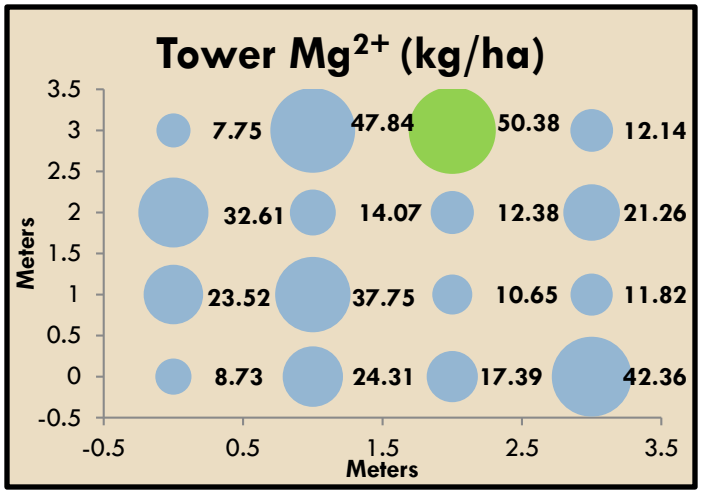
2011 water year



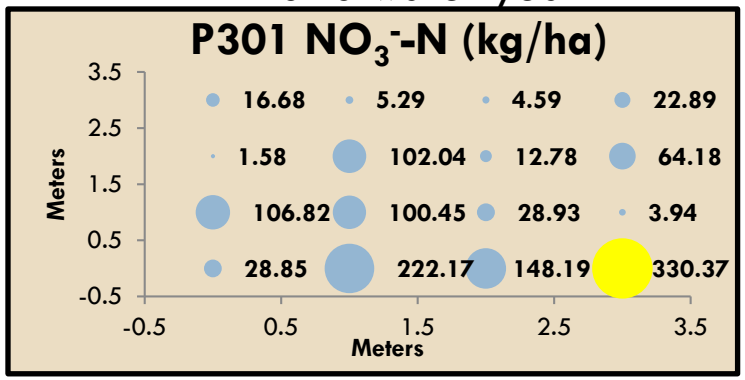


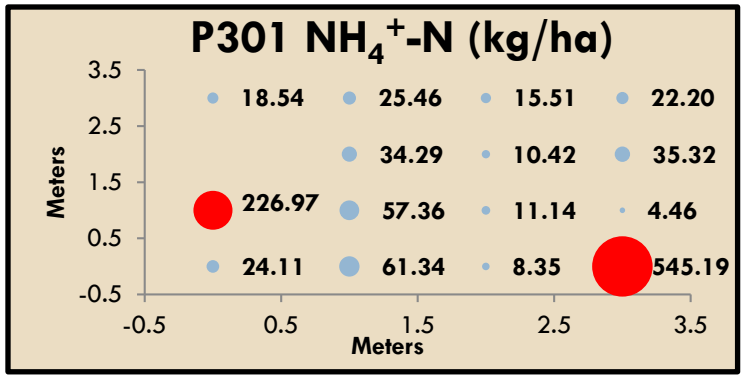


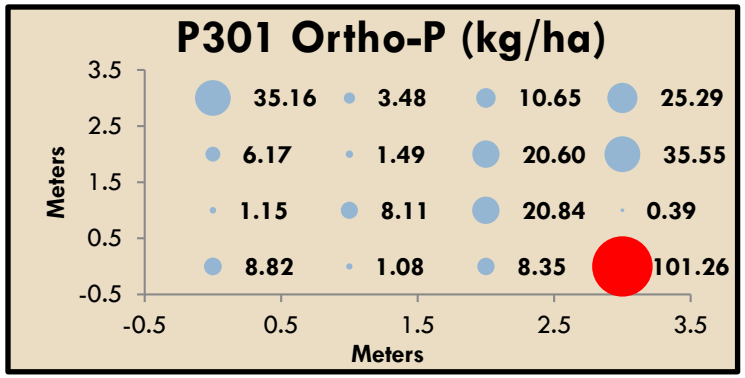
Existence of Hot Spots

P301 Site

2010 water year







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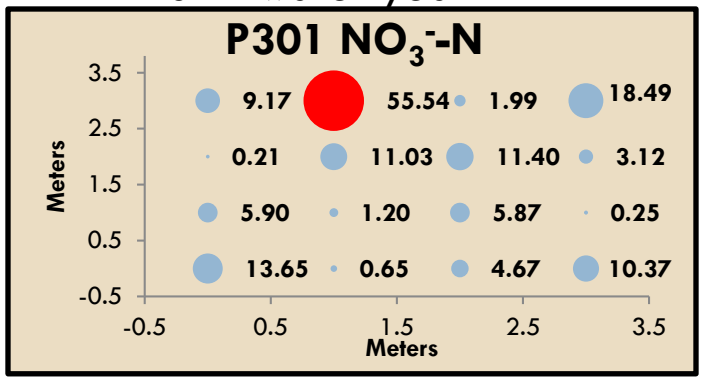
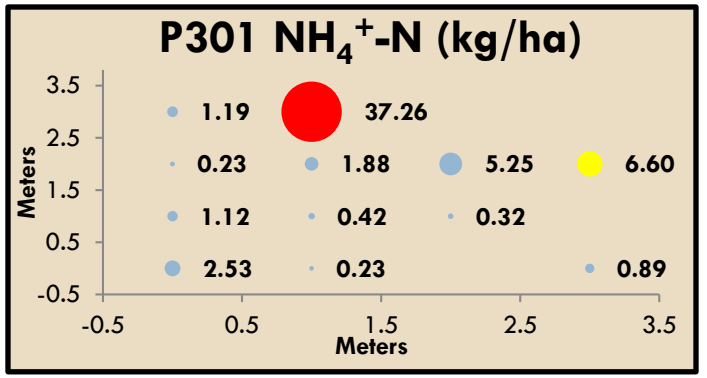
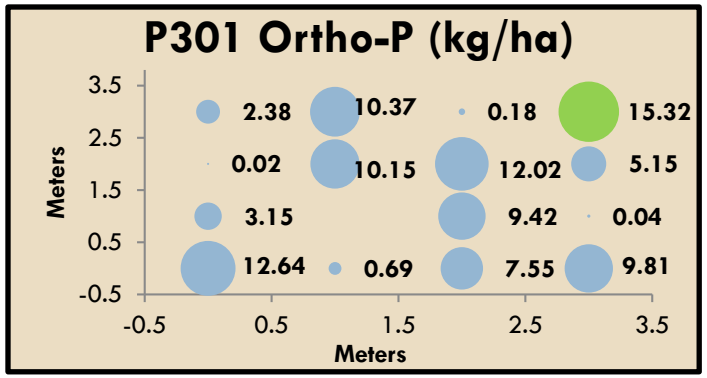
2011 water year



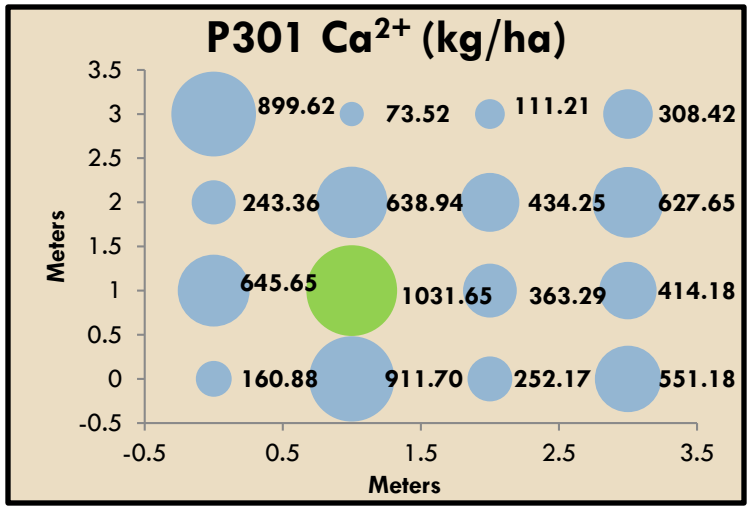




Existence of Hot Spots

P301 Site

2010 water year



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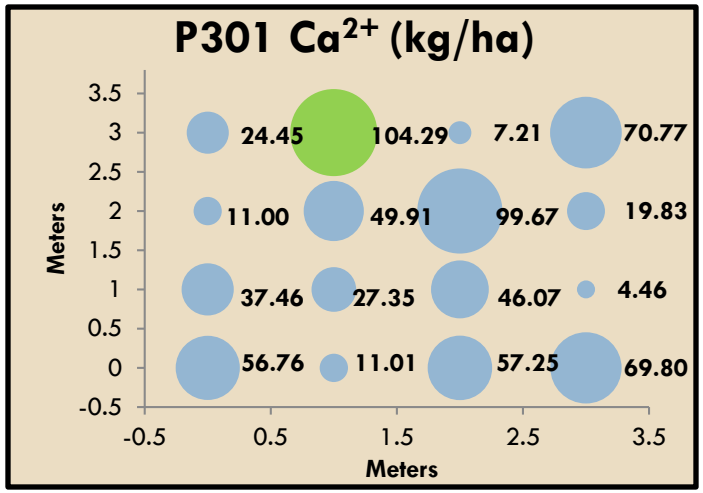
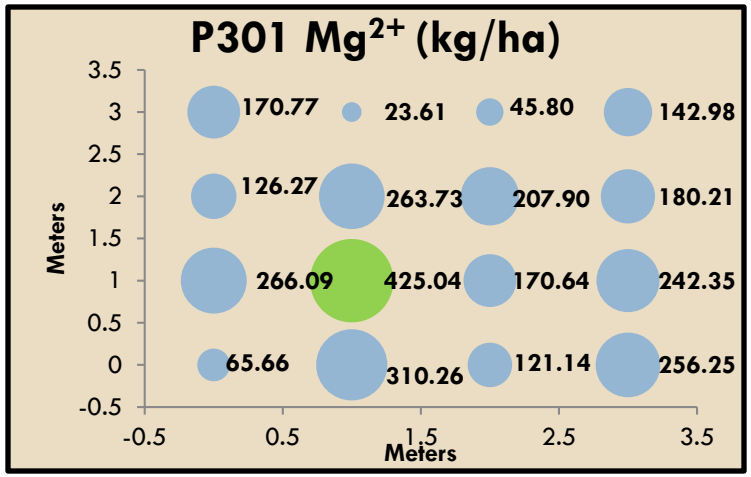
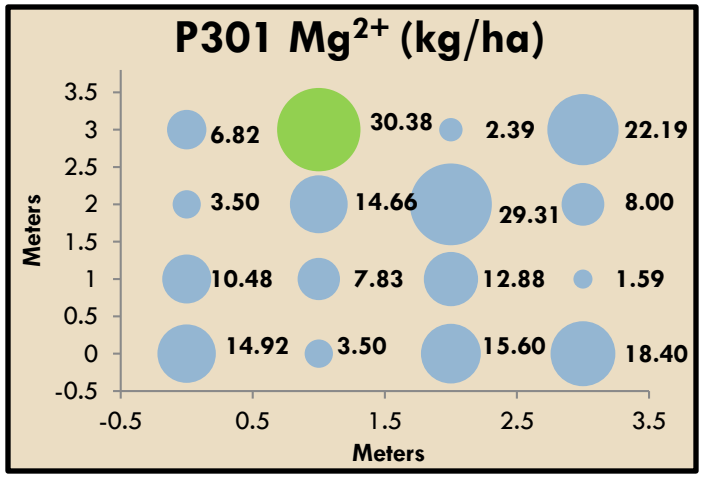






Modeling

- Hydrus® 2D is being used to look at how solute moves through a soil with patches of hydrophobic layers
- The modified Van Genuchten model is being used with no hysteresis (Vogel and Cislerova, 1988)
- Crank-Nicholson implicit scheme and Galerkin formulation for solute transport

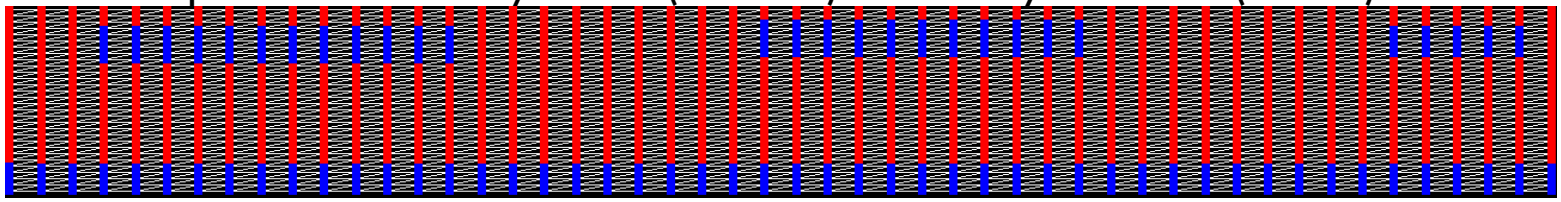
Modeling

- Hydrus® 2D
- The model was run for 90 days
  - 14 days there was only ET at 0.1 cm/day.
  - Precipitation event of 0.8cm for five days and 0.4 cm for ten days
  - The solute was entered in to the model at the beginning of the rain event
  - Transpiration of 0.4cm/day 40 days after precipitation
- Two soil types
  - Layer one Ks 14.4
  - Layer two Ks .144

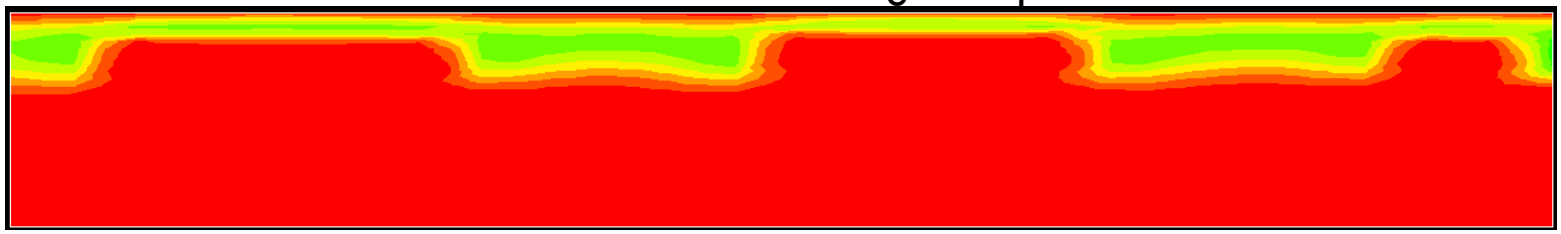
Modeling

- Uniform solute concentration along a heterogeneous surface
  - Soil was saturated at time of infiltration

Soil profile: Red is Layer one (Ks 14.4) Blue is layer two Ks (0.144)



Solute distribution as it moves through the profile

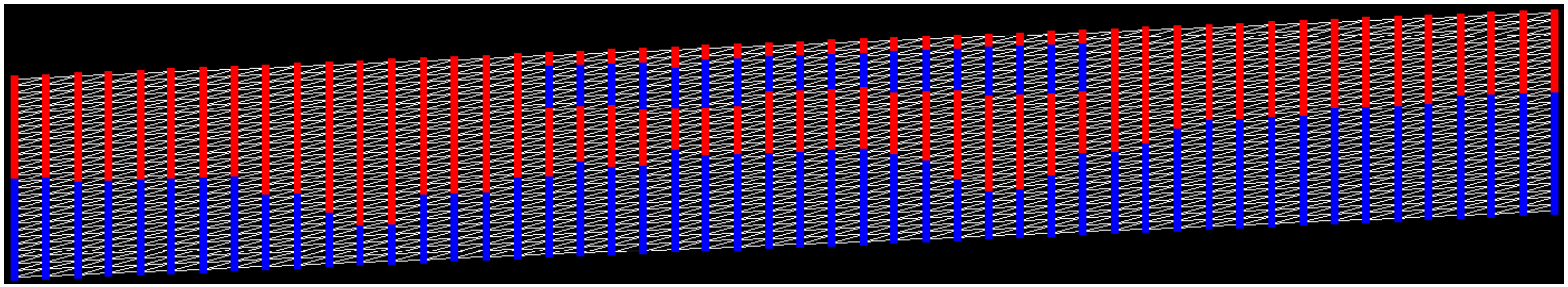


Solute distribution at the end of the simulation

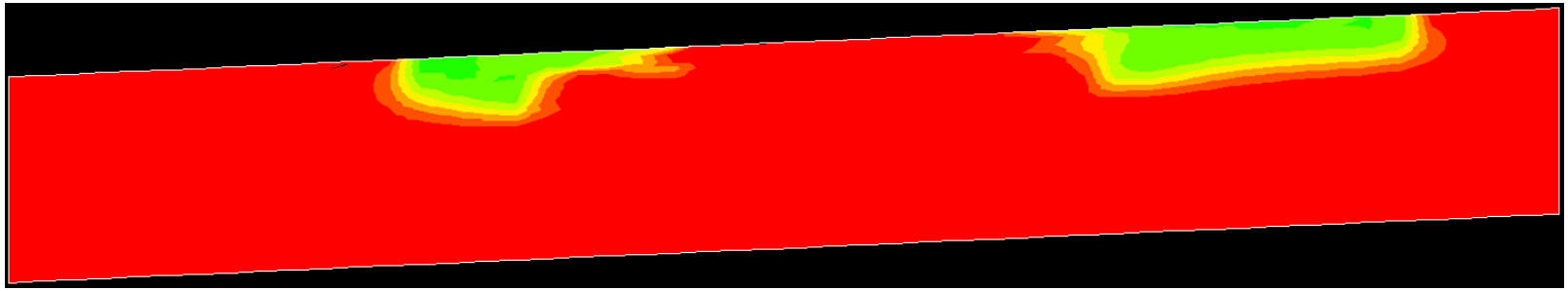
Modeling

- Slope, non-uniform solute concentration
  - 0.1 slope
  - Two locations of solute infiltration

Soil profile: Red is Layer one (Ks 14.4) Blue is layer two Ks (0.144)

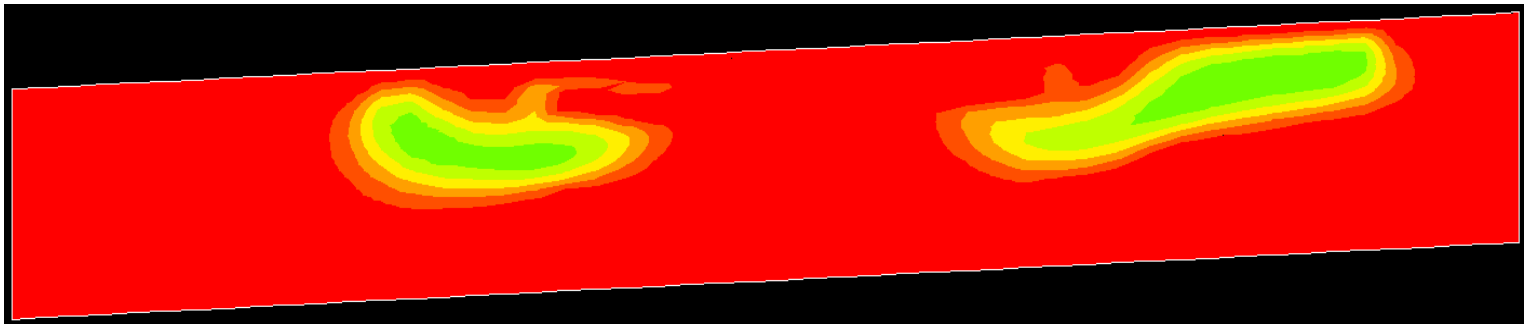


Solute infiltration locations

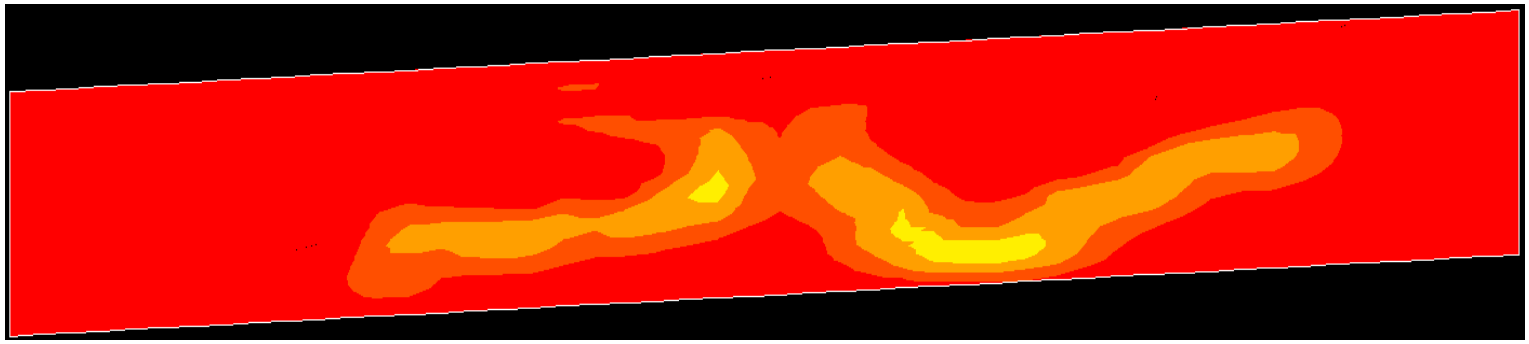


Modeling

Solute migration



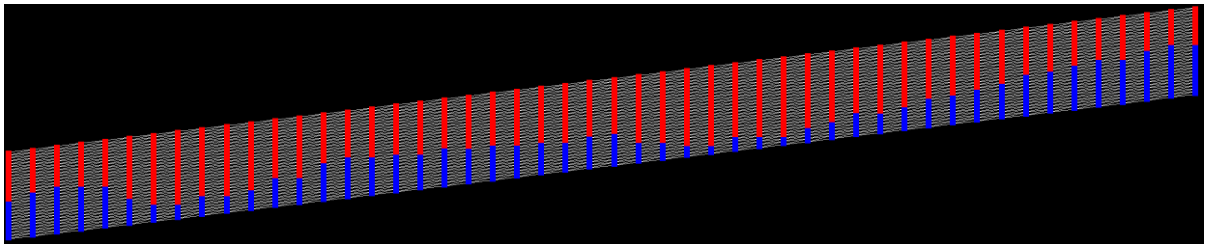
Solute distribution at the end of the simulation



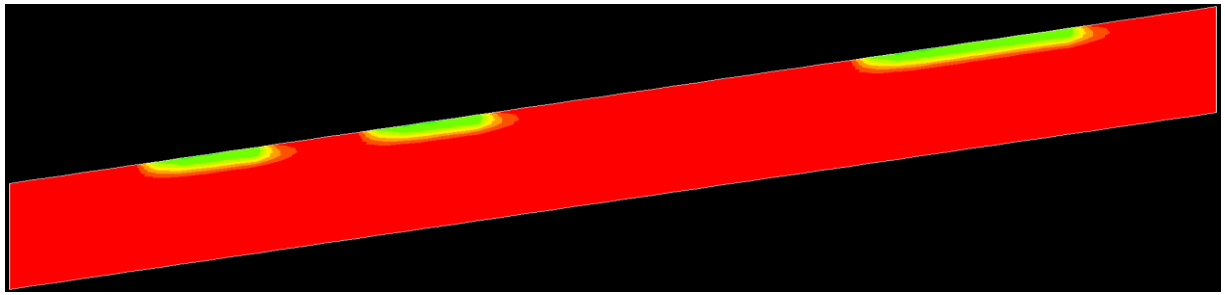
Modeling

- Slope, non-uniform solute concentration, no hydrophobic layer on top
  - 0.5 slope
  - Three locations of solute infiltration

Soil profile: Red is Layer one (Ks 14.4) Blue is layer two Ks (0.144)

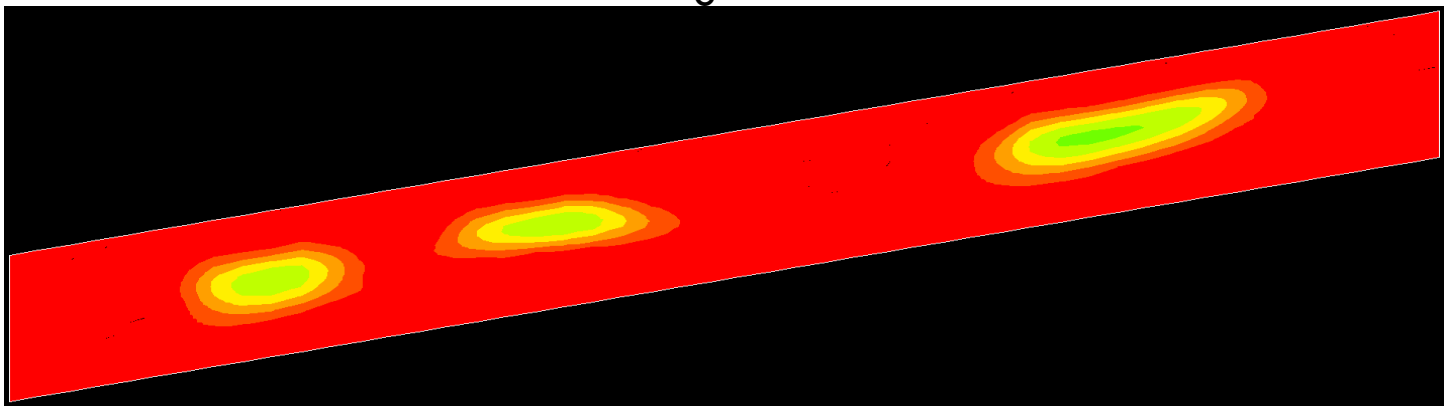


Solute infiltration locations

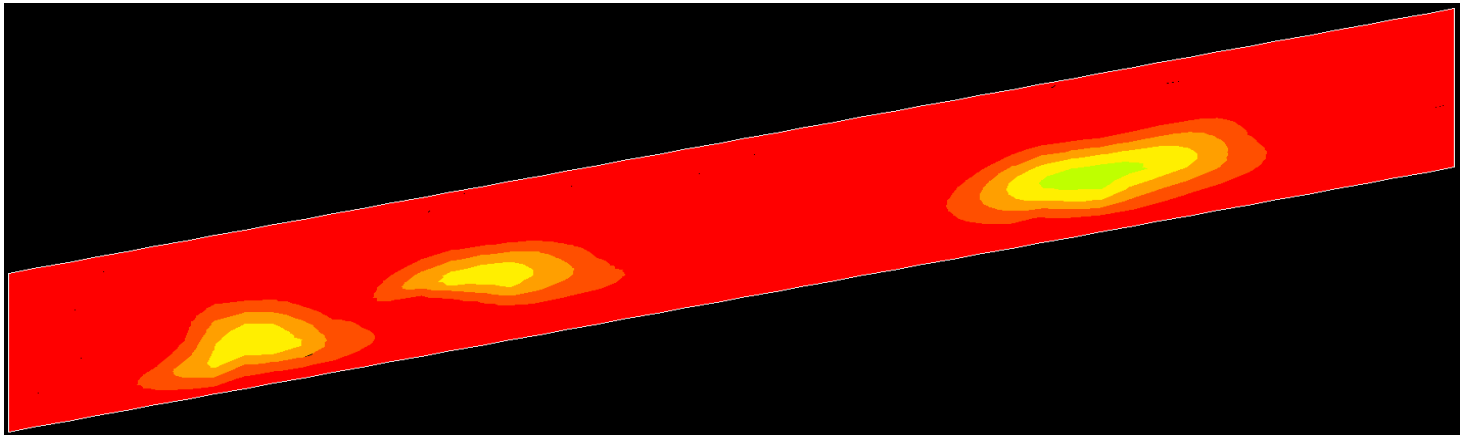


Modeling

Solute migration



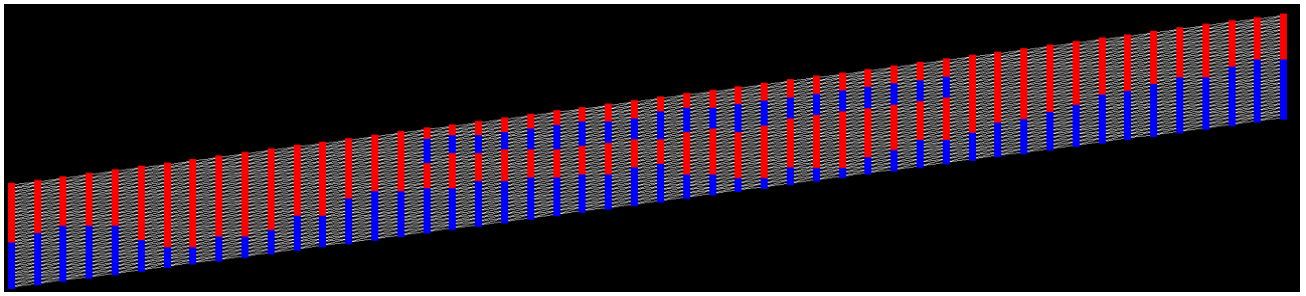
Solute distribution at the end of the simulation



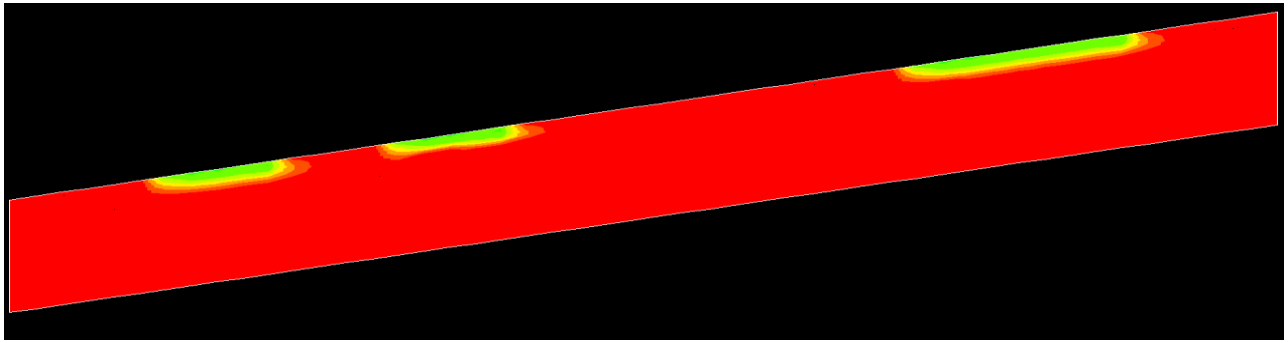
Modeling

- Slope, non-uniform solute concentration, hydrophobic layer near surface
  - 0.5 slope
  - Three locations of solute infiltration

Soil profile: Red is Layer one (Ks 14.4) Blue is layer two Ks (0.144)

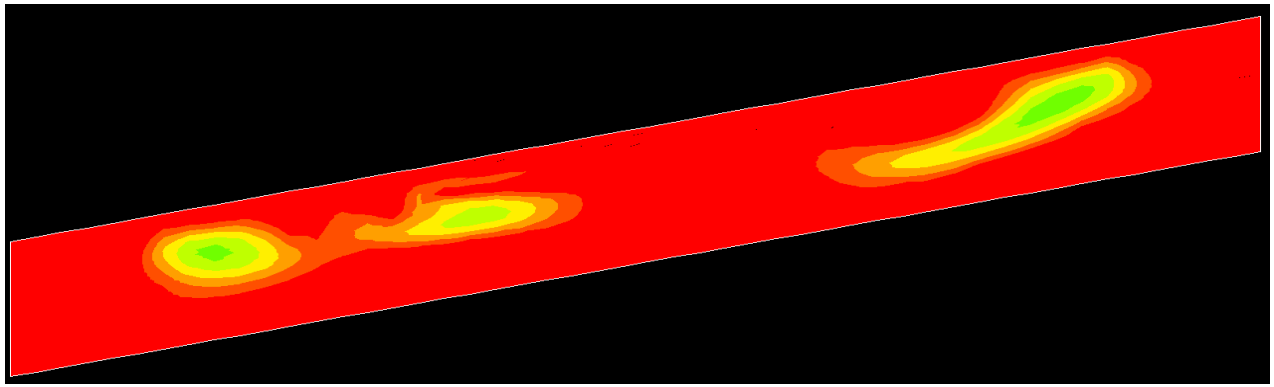


Solute infiltration locations

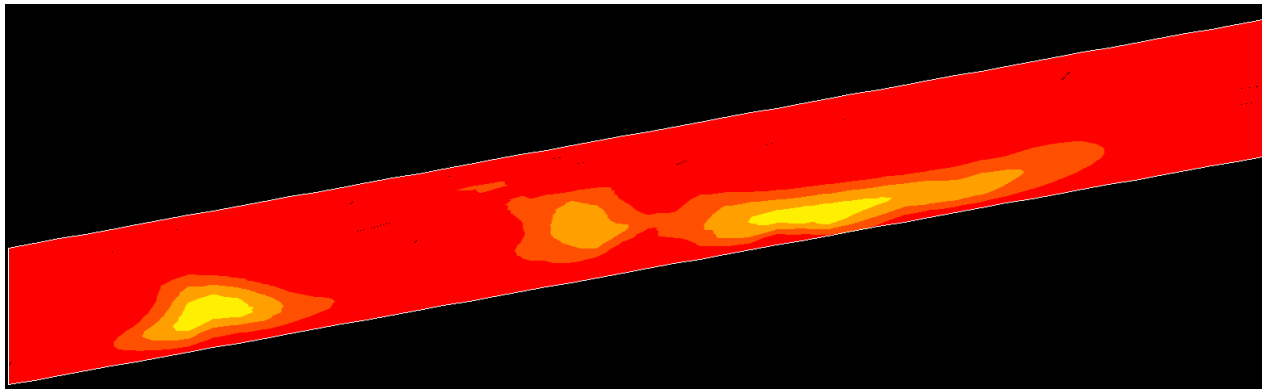


Modeling

Solute migration



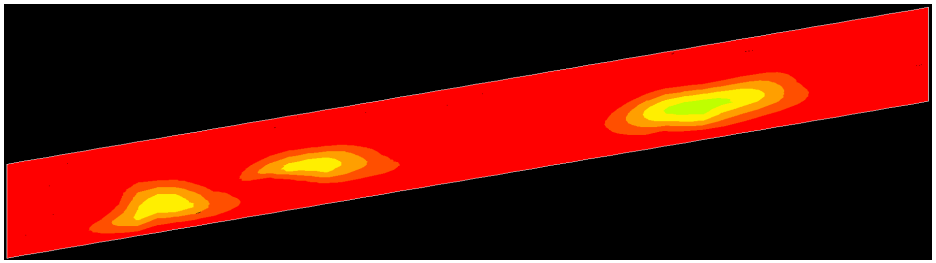
Solute distribution at the end of the simulation



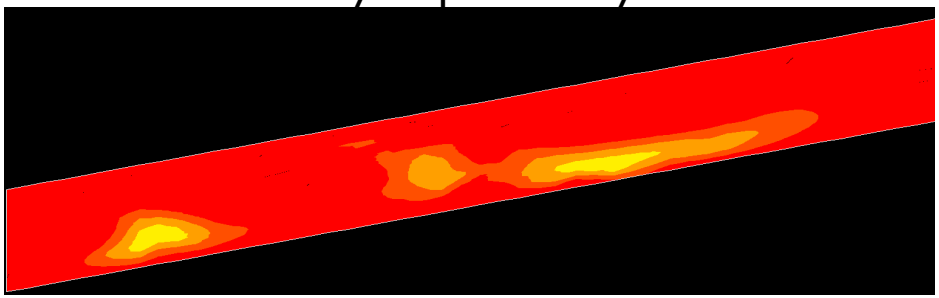
Conclusions

- Nutrient hot spots exist in the soil matrix
- Hot spots can vary in location from year to year
- Hydrophobic layers are more important in the migration of solutes than slope

Without hydrophobic layer



With Hydrophobic layer



Questions