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Simulation of Infiltration at Yucca Mountain

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By Teklu Hadgu[a], Laura Price[a], Palmer Vaughn[a], Josh Stein[a] and Daniel Levitt[b]

[a]*Sandia National Laboratories, MS 1369, P.O. Box 5800, Albuquerque, NM 87185*

[b]*Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM, 87545*

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Introduction

- Near surface infiltration is an important component of hydrology of Yucca Mountain
- This presentation outlines development and results of the MASSIF net infiltration model
- MASSIF used field capacity approach to model net infiltration
- The MASSIF model was used to support the YMP License Application

MASSIF = Mass Accounting System for Soil Infiltration and Flow

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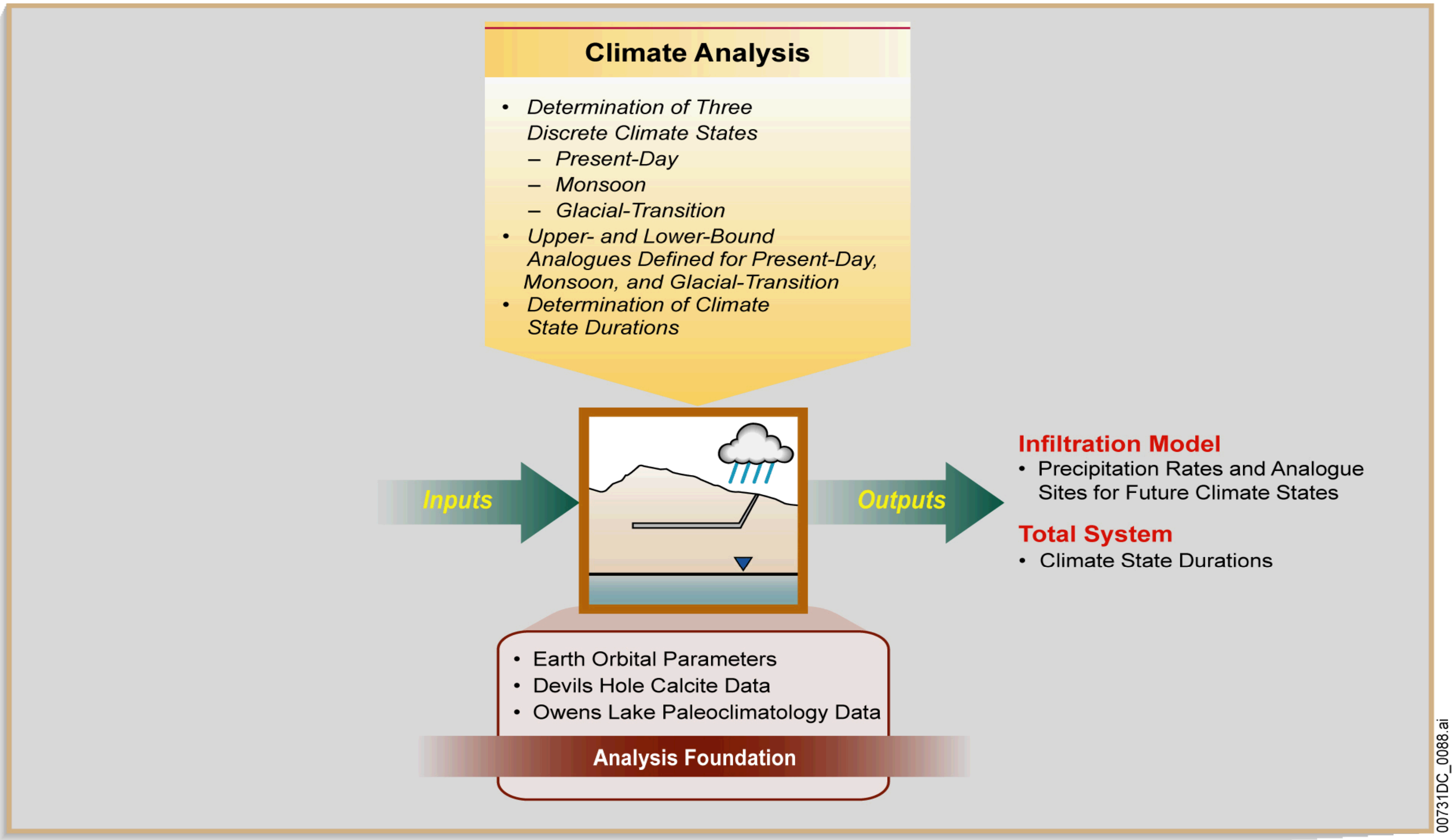
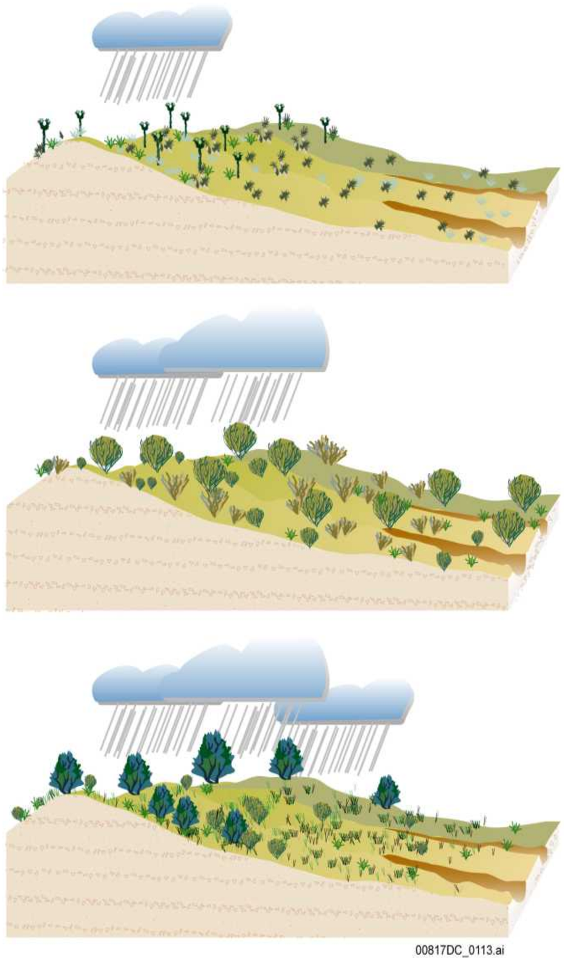
Climate Analysis



Future Climate State Assumptions



__Precipitation Analog Sites__:

__Present Day__
Yucca Mountain region

__Monsoon__
Lower Bound—Present day
Upper Bound—Hobbs, NM and Nogales, AZ

__Glacial Transition__
Lower Bound—Beowawe, NV and Delta, UT
Upper Bound—Spokane, Rosalia, and St. John, WA

- **Present day conditions forecast for the next 600 years**
- **The subsequent 1,400 years, a warmer and much wetter monsoon climate is forecast**
- **The forecast for remainder of the 10,000 year period is wetter and cooler than the monsoon climate**

MASSIF Mass Balance Equations

$$NI = P + R_{on} - R_{off} - \Delta\theta - ET$$

$$P = P_{rain} + SM \qquad \Delta SP = SF - SM - SUB$$

NI = Net Infiltration

P = Precipitation

R_{on} = Runon

R_{off} = Runoff

$\Delta\theta$ = Change in storage

ET = Evapotranspiration

P_{rain} = Rainfall

SM = Snowmelt

ΔSP = snowpack change in water storage

SF = Snowfall

SUB = Sublimation

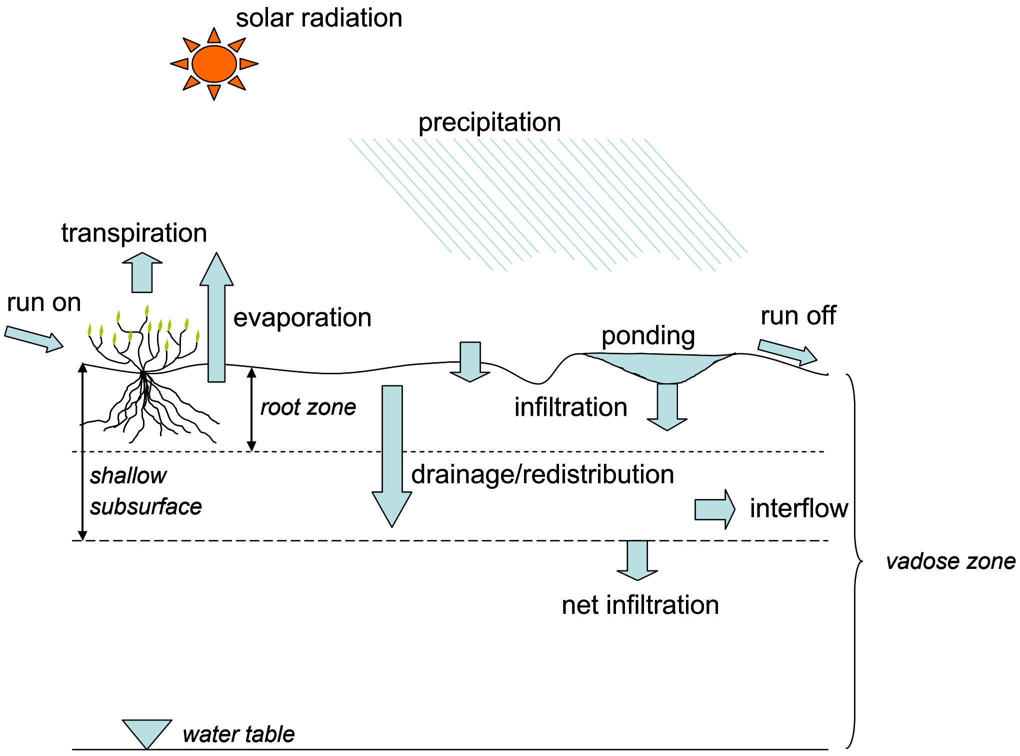


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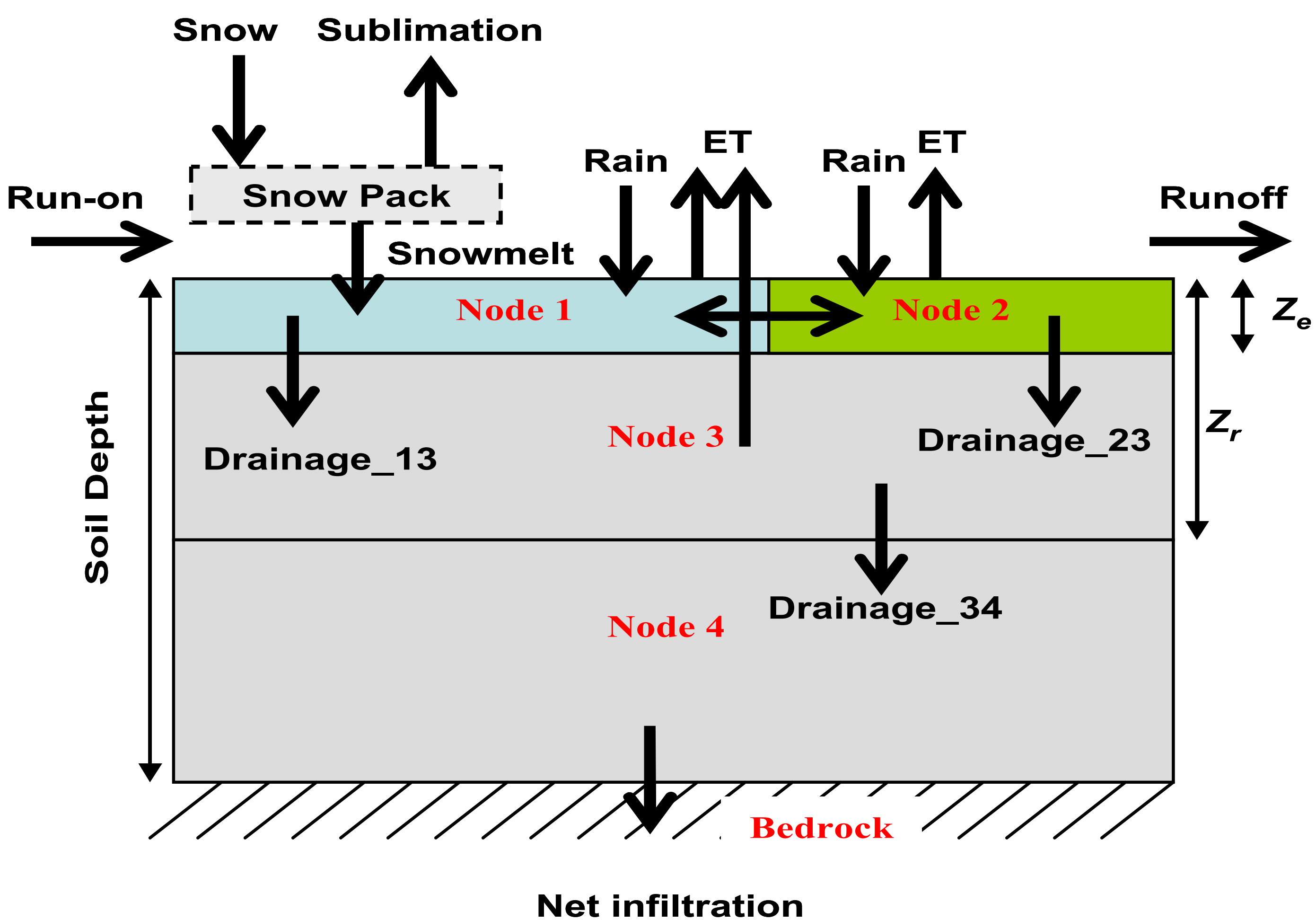
Illustration of the Water Reservoirs and Fluxes Used in the MASSIF Model



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Precipitation Modeling

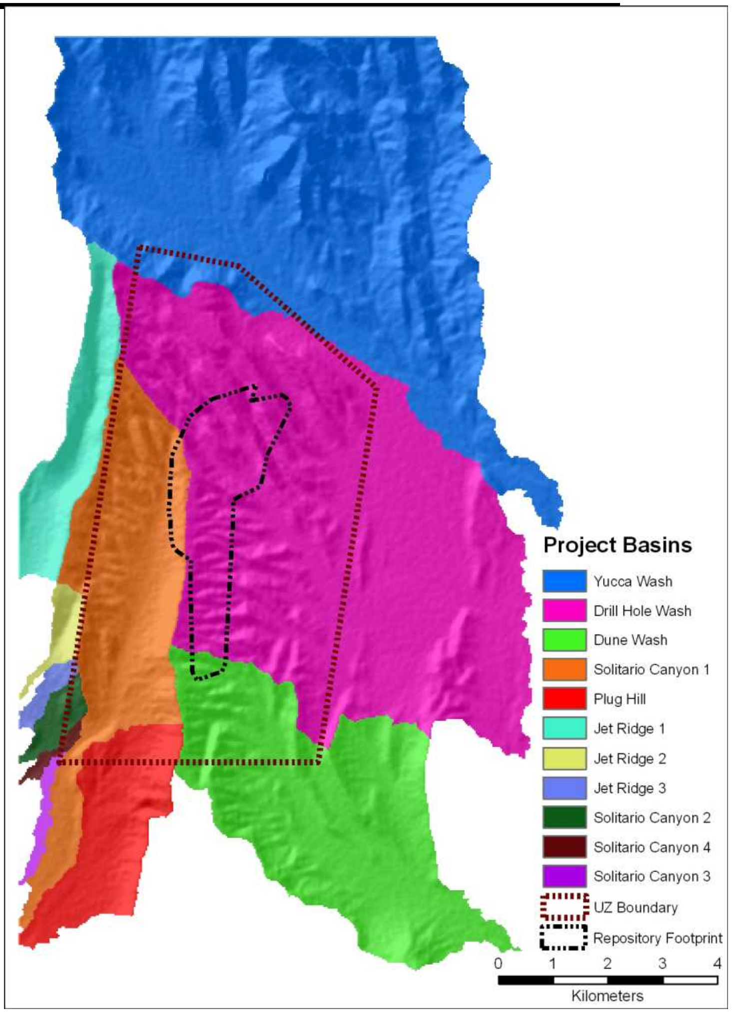
- Precipitation data obtained from analog stations
- Stochastic simulations of daily precipitation:
  - Markov chain model of precipitation frequency
  - Probability distribution for daily precipitation amount
- Distributions defined for stochastic parameters estimated from weather stations
- LHS used to sample stochastic parameters

Precipitation Modeling (Contd.)

- Precipitation corrected for elevation
- Precipitation duration estimated from weather station data
- Precipitation is assumed to be snowfall for average daily temperatures equal to or less than 0°C
- Snow reaches the soil as snowmelt when average daily temperature is above 0°C
- Part of the snow is lost as sublimation

Runoff and Run-on

- **Infiltration domain divided into 11 separate watersheds using ARC GIS**
- **Runoff estimated from water balance analysis**
- **Each cell drains to the neighboring cell with the lowest elevation**
  - **Runoff from one cell becomes run-on for another cell**
- **Each watershed drains to a single cell at the boundary of the infiltration model domain**
  - **cell with lowest elevation**



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Evapotranspiration (ET) Model

- FAO-56 method (Allen et al. 1998) used to calculate ET
  - Guidelines for calculating ET
- ET has components of evaporation and transpiration
- ET calculated using dual crop FAO-56 method, as a function of reference ET (ET_0):

$$ET = (K_e + K_s \cdot K_{cb})\, ET_0$$

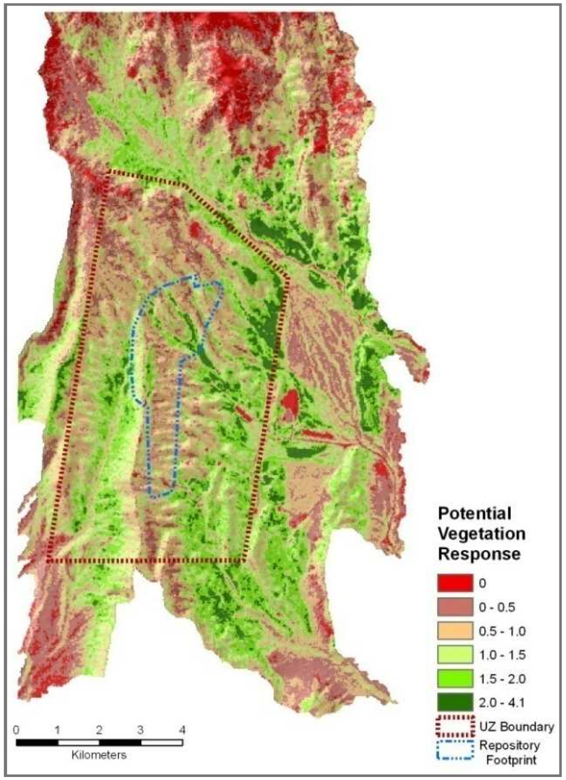
K_e = Soil evaporation coefficient [0 to 1] *f(soil props, vegetation)*

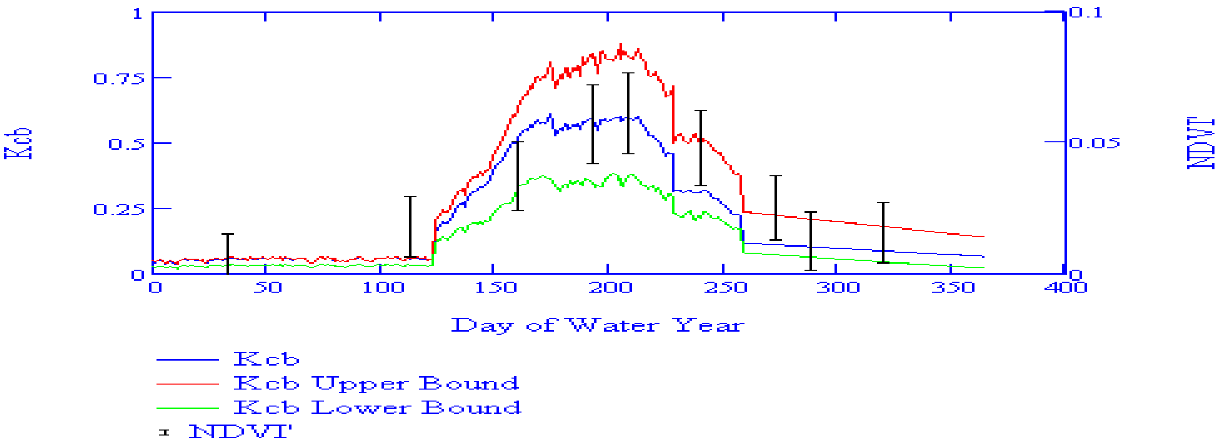
K_{cb} = Basal crop coefficient [0 to 1.35] *f(vegetation)*

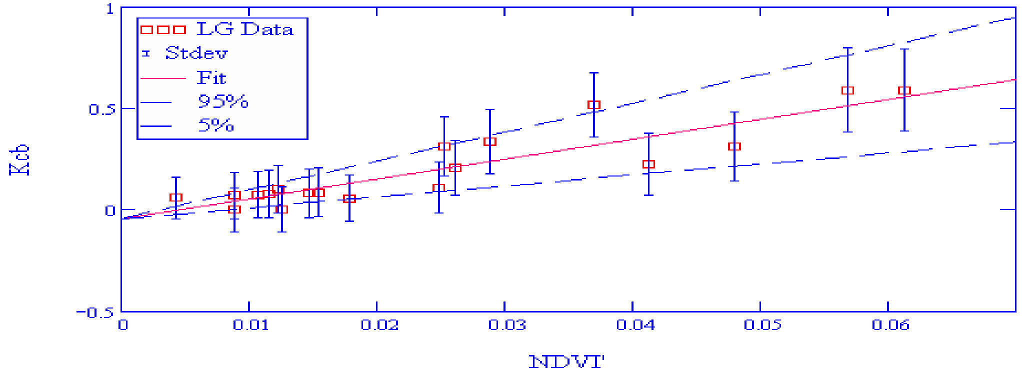
K_s = Water stress coefficient [0 to 1] *f(soil props, vegetation)*

Estimating K_{cb}

- K_{cb} calculated from NDVI (Normalized Difference Vegetation Index)







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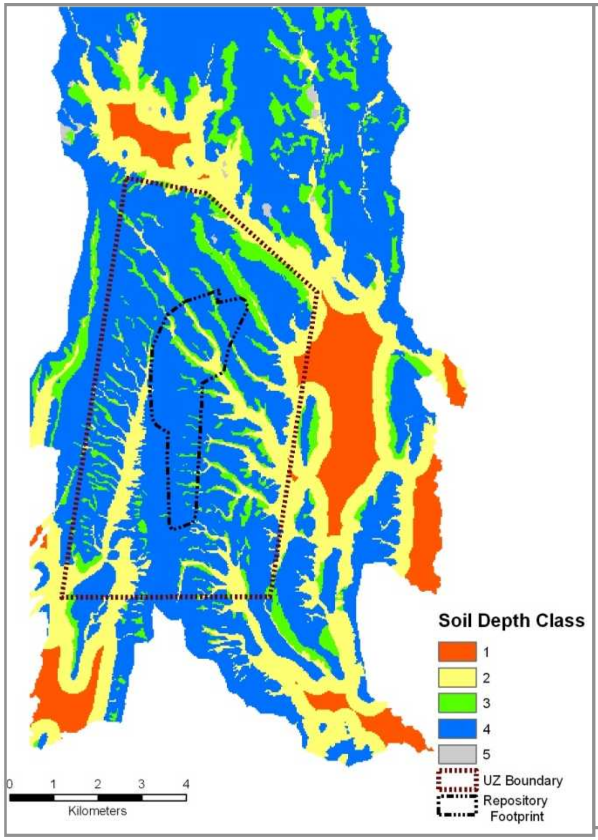
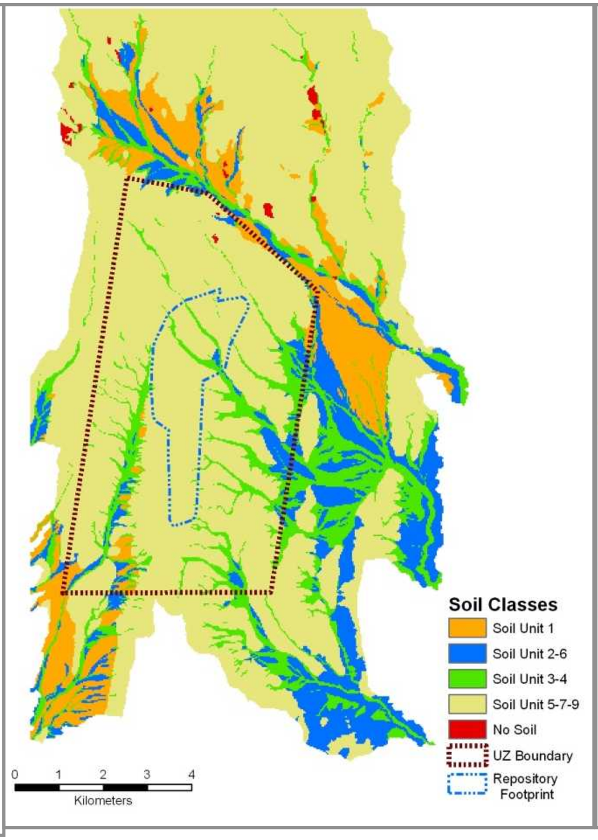
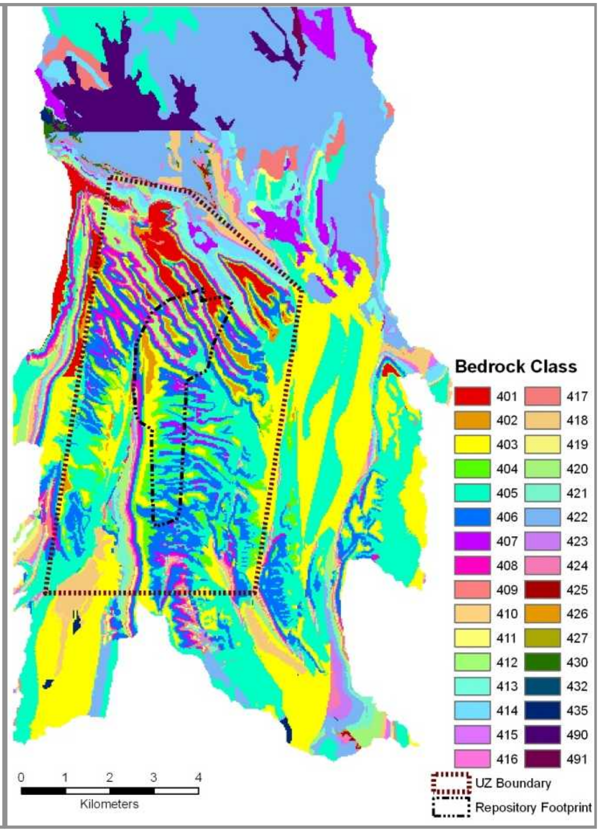
Soil and Bedrock Maps







Soil Depth Class **Soil Class** **Bedrock Class**

Soil and Bedrock Properties

- Pedotransfer approach used to estimate soil hydraulic properties
  - Soil texture samples from YM compared to samples from an analogous site (Hanford, WA)
  - Estimated parameters for each soil class: Saturated hydraulic conductivity, field capacity, etc.
- Soil depths evaluated using data from boreholes, surface deposits and geologic framework model.
- Bedrock classification mainly based on saturated hydraulic conductivity data

MASSIF Net Infiltration Simulation Setup

- Simulations conducted for each climate state
  - Parameter uncertainty distributions defined
  - Sampled input parameters
    - Two LHS replicates (20 realizations each)
  - Precipitation simulated outside of MASSIF
  - Weather input
    - Precipitation
    - Temperature
    - Wind speed
  - MASSIF run for each of the 11 watersheds separately

Summary of MASSIF Results for the Three Climate States

Present-Day	Mean (mm/yr)	SD (mm/yr)
Precipitation	173.6	25.1
Net Infiltration	14.3	8.7
ET	151.6	20.1
Runoff	3.7	2.8
Storage	3.3	3.3
Monsoon	**Mean (mm/yr)**	**SD (mm/yr)**
Precipitation	275.2	77.0
Net Infiltration	25.5	17.9
ET	230.4	57.8
Runoff	15.6	12.1
Storage	3.6	8.6
Glacial Tran.	**Mean (mm/yr)**	**SD (mm/yr)**
Precipitation	283.4	50.0
Net Infiltration	30.0	12.9
ET	243.7	41.7
Runoff	1.1	1.2
Storage	5.1	3.9

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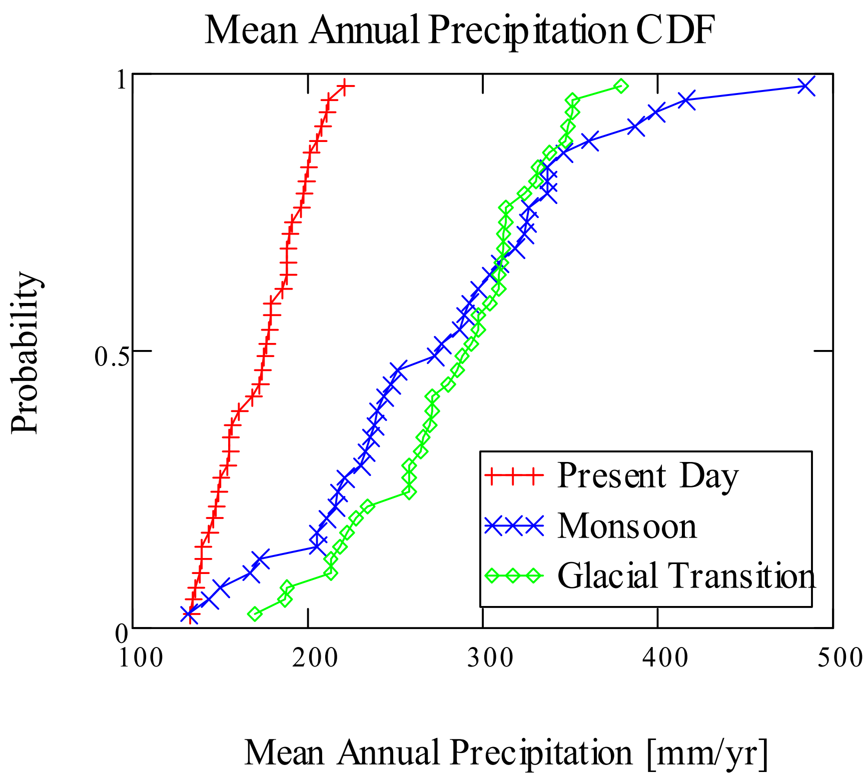
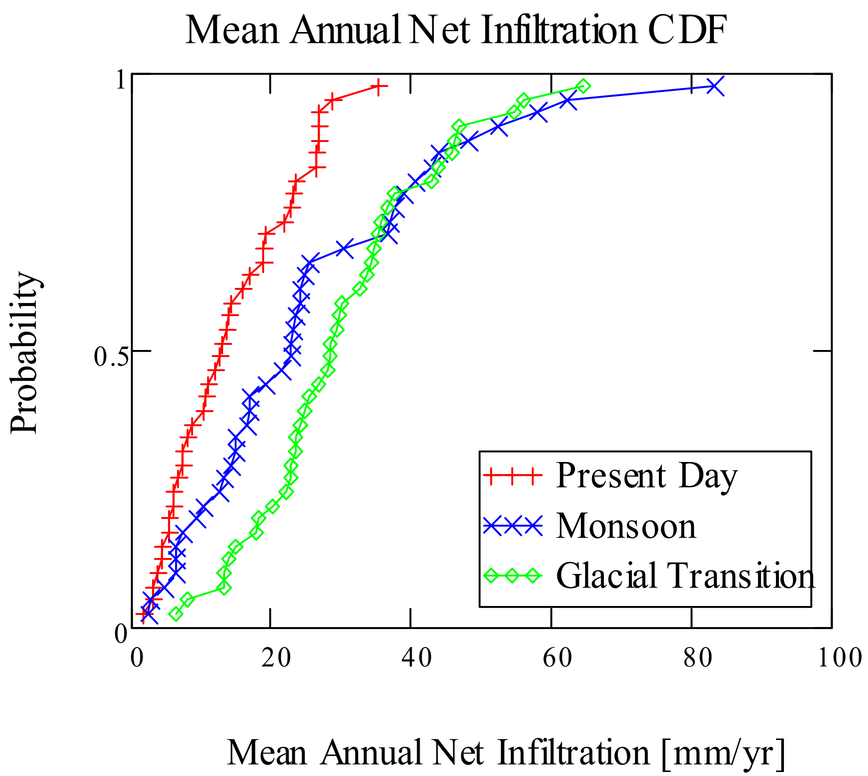
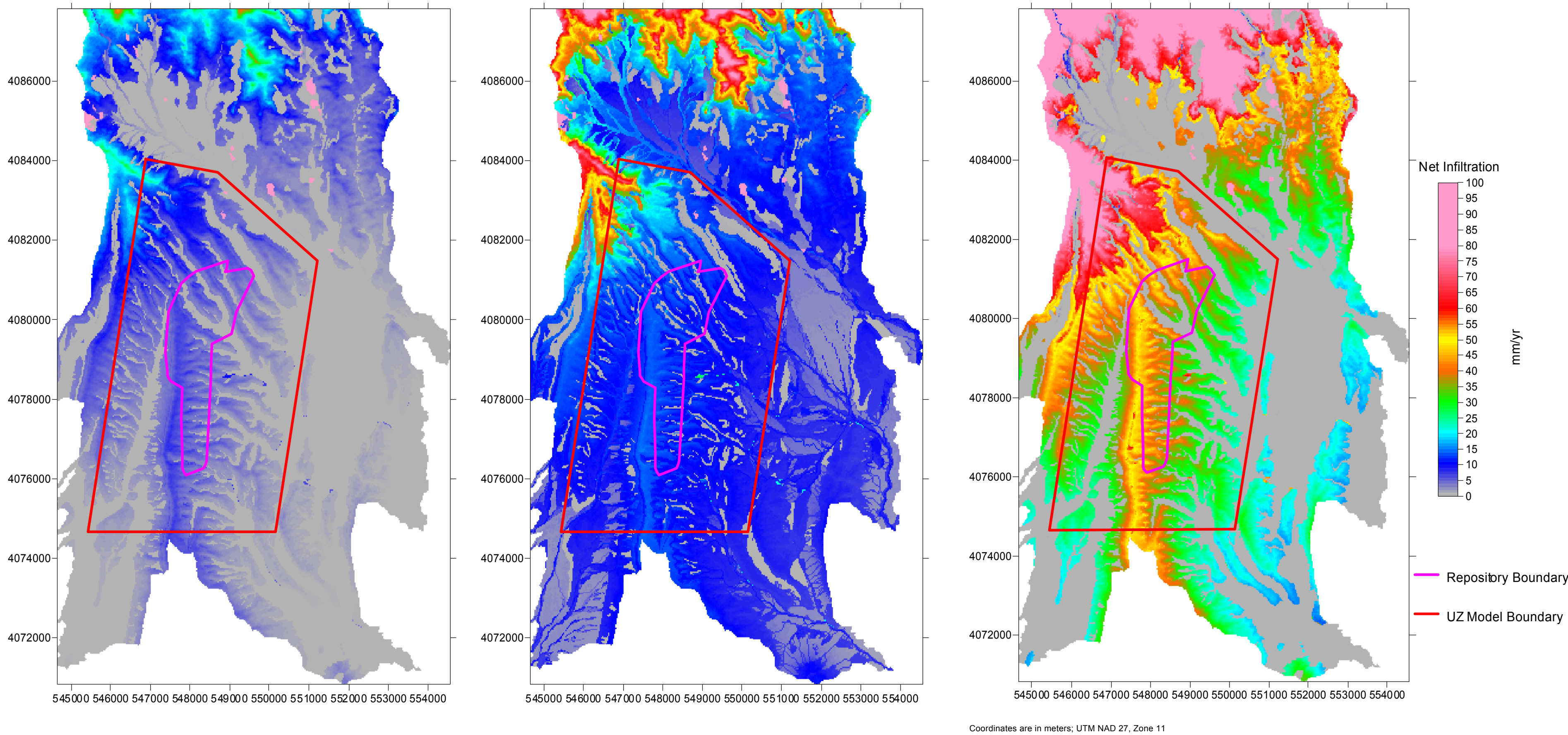
Uncertainty distributions of mean annual precipitation (left) and net infiltration (right)





Mean Annual Net Infiltration for the 10th, 50th, and 90th percentile realizations of Present-day



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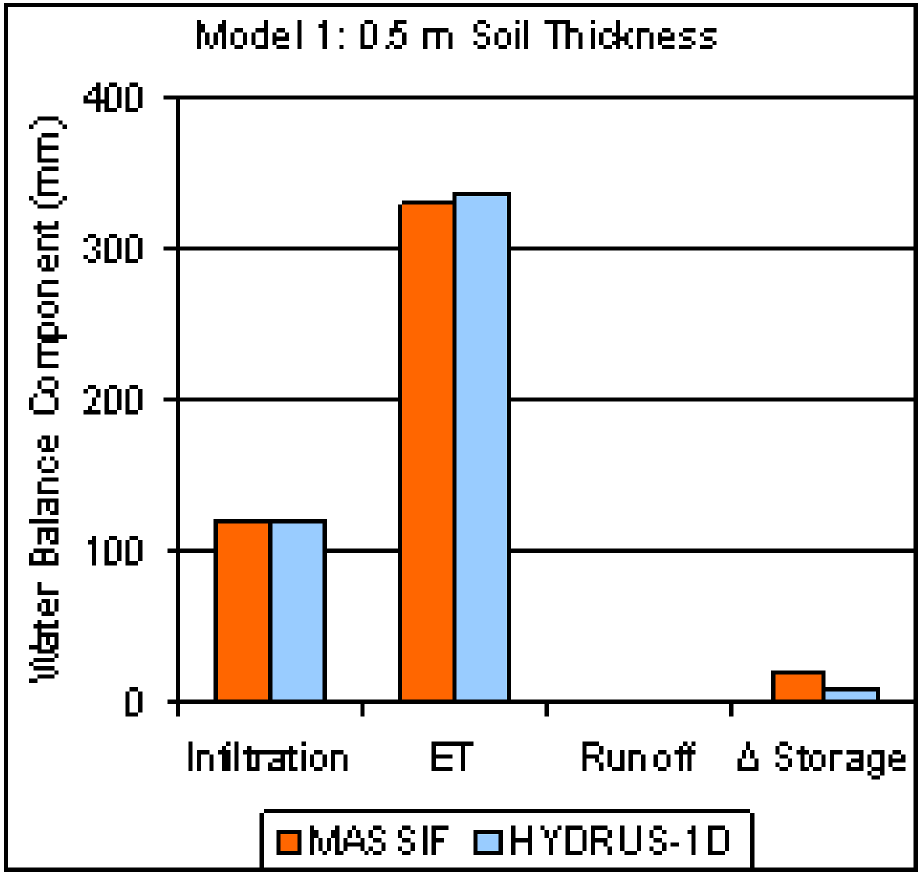
Model Validation: MASSIF vs. HYDRUS-1D

- MASSIF simulations were compared to HYDRUS-1D (Richards equation model)

- Cumulative responses were very close



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MASSIF Net Infiltration Estimates Compared with Estimates for Nevada Hydrographic Areas