Demo 2: Model Setup

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Model Conceptualization

"hypothesis-driven numerical experiments"

- Observations of A, B, and C at Study area X are well-represented by simulations of a 2D hillslope.
- Observation A is sensitive to the representation of process Z in areas like X under conditions Y.

Model Conceptualization

- domain
- process & parameters
- boundary & initial conditions
- model output & observations

Model Conceptualization

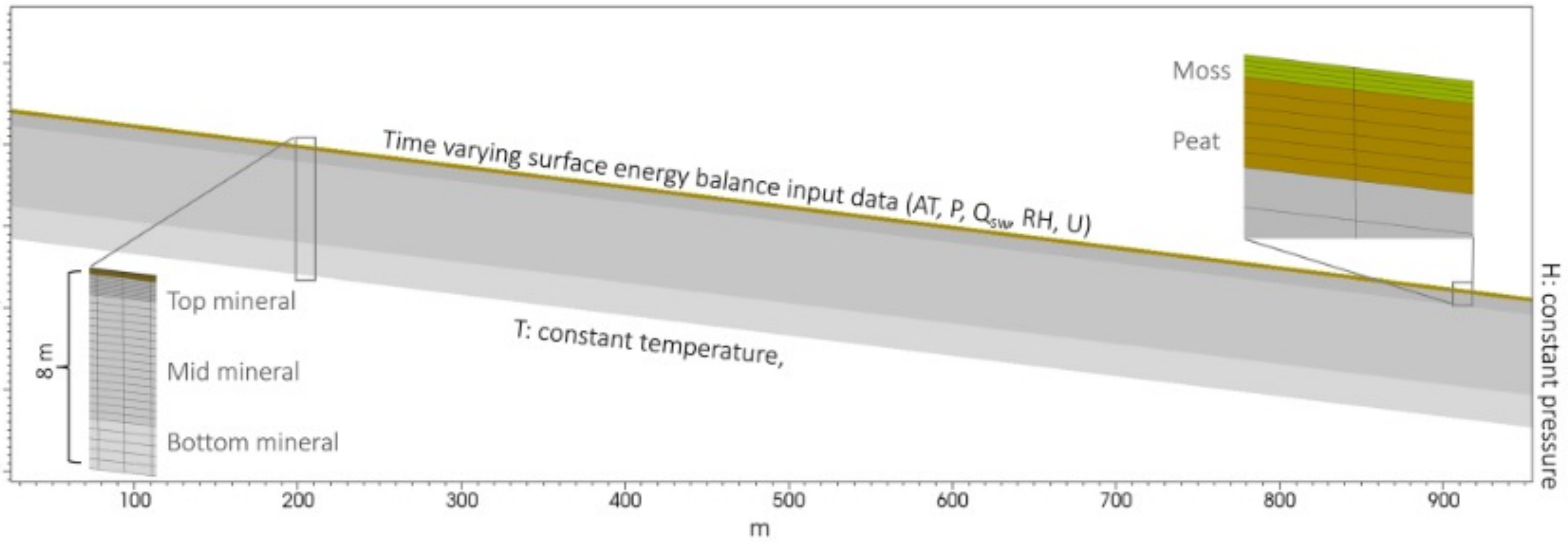
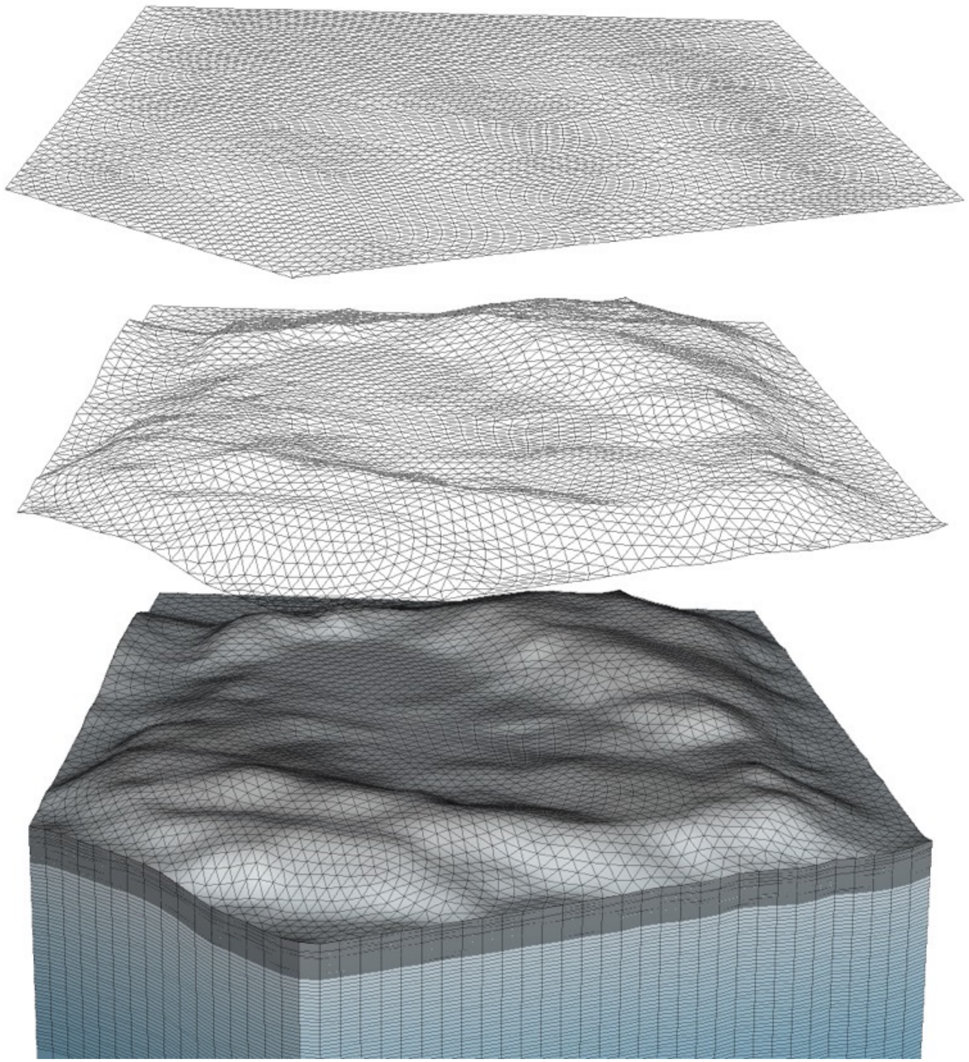


Figure 3. Geometry, specified thermal (T) and hydrological (H) boundary conditions, and soil layers represented in the modeling mesh. No specified thermal and hydrological conditions constitute no flow boundaries. The surface energy balance model is driven by daily data for air temperature (AT), snow and rain precipitation (P), shortwave radiation (Q_{sw}), relative humidity (RH), and wind speed (U). (Note that the geometry is modified to optimize visualization of soil layers, by exaggerating the thickness [8 m] while maintaining the slope [0.1] of the domain).

Meshes

- Generated vs *ExodusII file*
- Often include material types via "labeled sets" in the subsurface and/or on surface faces
- Keep in mind extracted meshes:
  - Surface meshes
  - Columnar assumptions
- No assumption of structure!



Mesh Generation

- `${ATS_SRC_DIR}/tools/ats_meshing` *(this demo)*
  - A python-based approach to writing extruded polyhedral meshes
  - Simple to use for columns, transects
- Watershed Workflow *(Coon & Shuai 2021 in review, this demo)*
  - https://github.com/ecoon/watershed-workflow
  - Automates downloading and creating meshes for watersheds
- TINerator & PyLaGrit *(Livingston Lightning Talk)*
  - Based on LaGrit https://lagrit.lanl.gov
  - Most powerful selection, allows for more complex meshes, non-extruded meshes, embedded structures/fractures, etc

Data

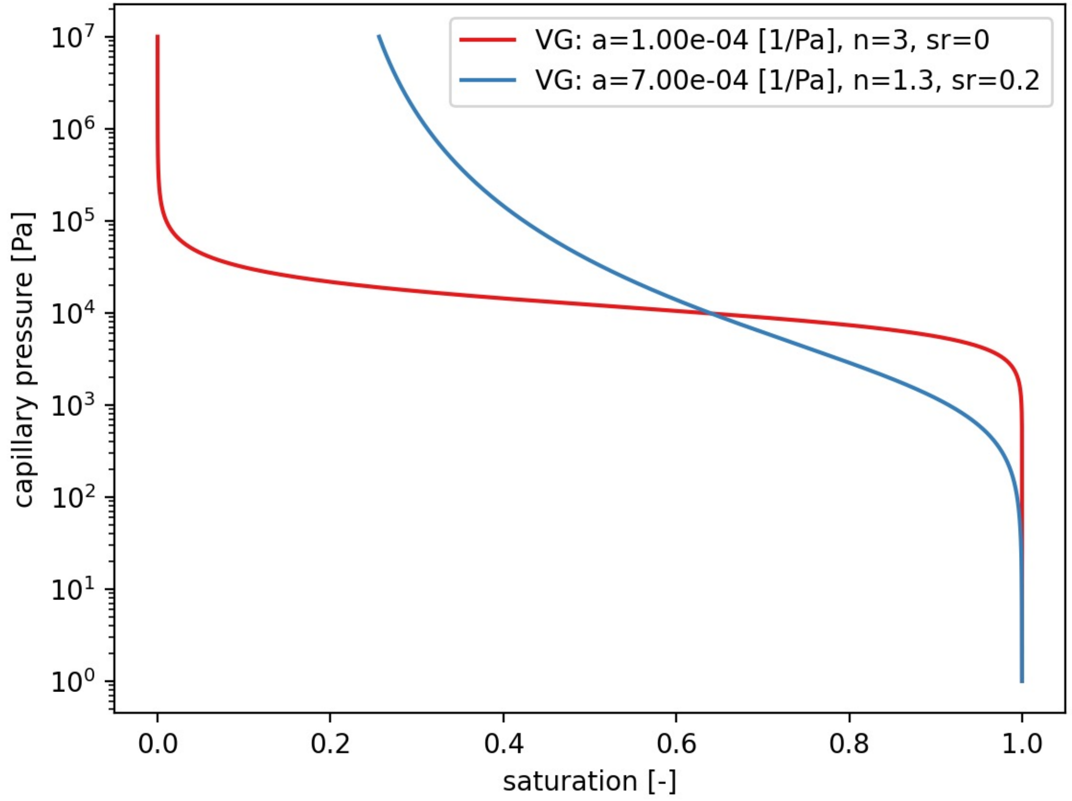
- Independent variables
  - Constant values
  - Functions (t,x,y,z)
  - Time series from HDF5 files *(e.g. point-mode met data)*
  - Interpolated from structured rasters (t,x,y) in HDF5 *(e.g. spatially variable met data)*
  - Scripts and workflows to support downloading datasets in the right format in `daymet_to_ats.py; daymet_to_ats_box.py; smooth_met.py; …`
- Model parameters typically appear in the input file, by region

Meteorological Forcing Datasets

- Most runs require: precipitation, air temperature, relative humidity, incoming shortwave radiation
- Data must be gap filled – ATS assumes linear interpolation in time, and will not gap fill for you.
- Time 0 of the simulation usually expressed relative to Met data
- Scripts to download DayMet for anywhere in North America:
  `$ATS_SRC_DIR/tools/utils/daymet_to_ats.py; daymet_to_ats_box.py`
- Scripts for smoothing and averaging
  `$ATS_SRC_DIR/tools/utils/smooth_met.py; smooth_met_box.py`
- Jupyter notebooks showing how to write HDF5 format from CSV or XLS in python via pandas

Soil Properties

- Soil structure – labels mapping soil type to mesh entities
- Porosity (saturated water content)
- Permeability (saturated hydraulic conductivity)
- van Genuchten parameters, α in units of [Pa^{-1}]! (water retention curve, could add Brooks-Corey, Clapp & Hornberger, etc if requested)



Demo

- `02_model_setup/simple_meshes.ipynb`

Watershed Workflow Overview

- https://github.com/ecoon/watershed-workflow
- A python package and a collection of Jupyter notebooks to generate **unstructured meshes** and **meterological forcing** for ATS and others.
- Automates the acquisition and curation of open data products (including USGS, USDA, DOE, USFS) for watershed models in the US
  - Automatically pull DEM, NHD Plus, land cover, soil and geology maps, and depth-to-bedrock
  - Automatically generate soil and geologic properties from database
- Requires only a HUC code or shapefile as an input
- Fully reproducible workflow

Watershed Workflow: a toolset for parameterizing data-intensive, hyperresolution hydrologic models★

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ABSTRACT

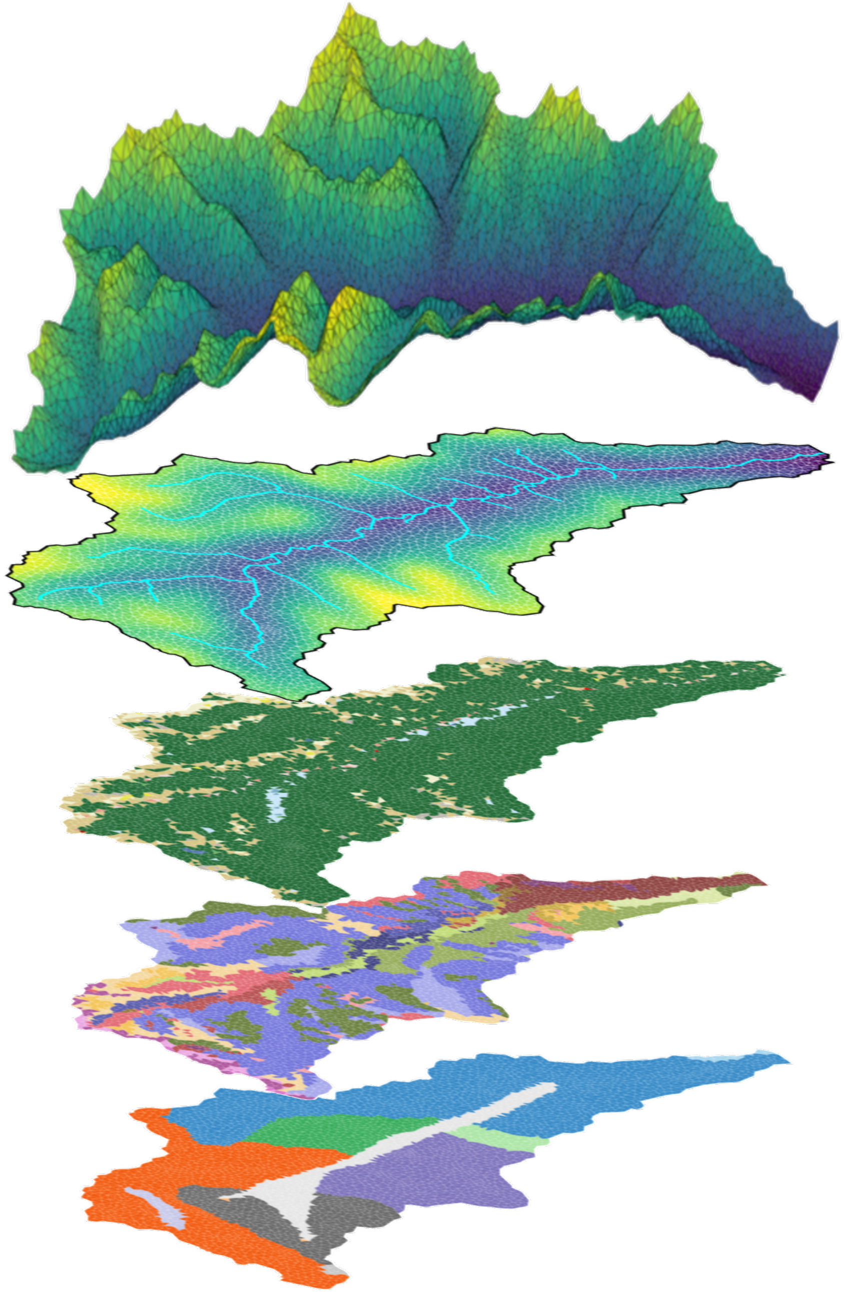
Hyperresolution hydrologic models leverage advances in computational power and data accessibility to improve predictive understanding of the water cycle. While improve predictive advances in this area of environmental modeling has been accomplished in the past few years, such models are still rarely used, partially because of the difficulty of integrating model and data. This research describes the release of Watershed Workflow version 1.0, a new library aiming to automate and enable complex workflows defining inputs to hyperresolution hydrologic models. Watershed Workflow provides tools enabling the discovery, acquisition, curation, and integration of watershed geometry, land cover, soil properties, and meteorological data. It enables the construction of unstructured meshes that incorporate this data, and provides tools for automating a "first" simulation on any watershed in the United States. We present the design of the workflow tool, and describe best practices for its usage, culminating in a final example from watershed specification to simulation at the Coweeta Hydrologic Laboratory.

Software availability

Software name: Watershed Workflow
Developers: Ethan Coon, Pin Shuai
Year first official release: 2021
Hardware requirements: PC
System requirements: Windows, Linux, Mac
Program language: Python3
Program size: 2 MB
Availability: `https://github.com/ecoon/watershed-workflow`
License: BSD 3-clause
Documentation: User guide, API documentation, and examples hosted at `https://ecoon.github.io/watershed-workflow`

(Coon and Shuai, 2021 Under review)

An example with American River Watershed, WA



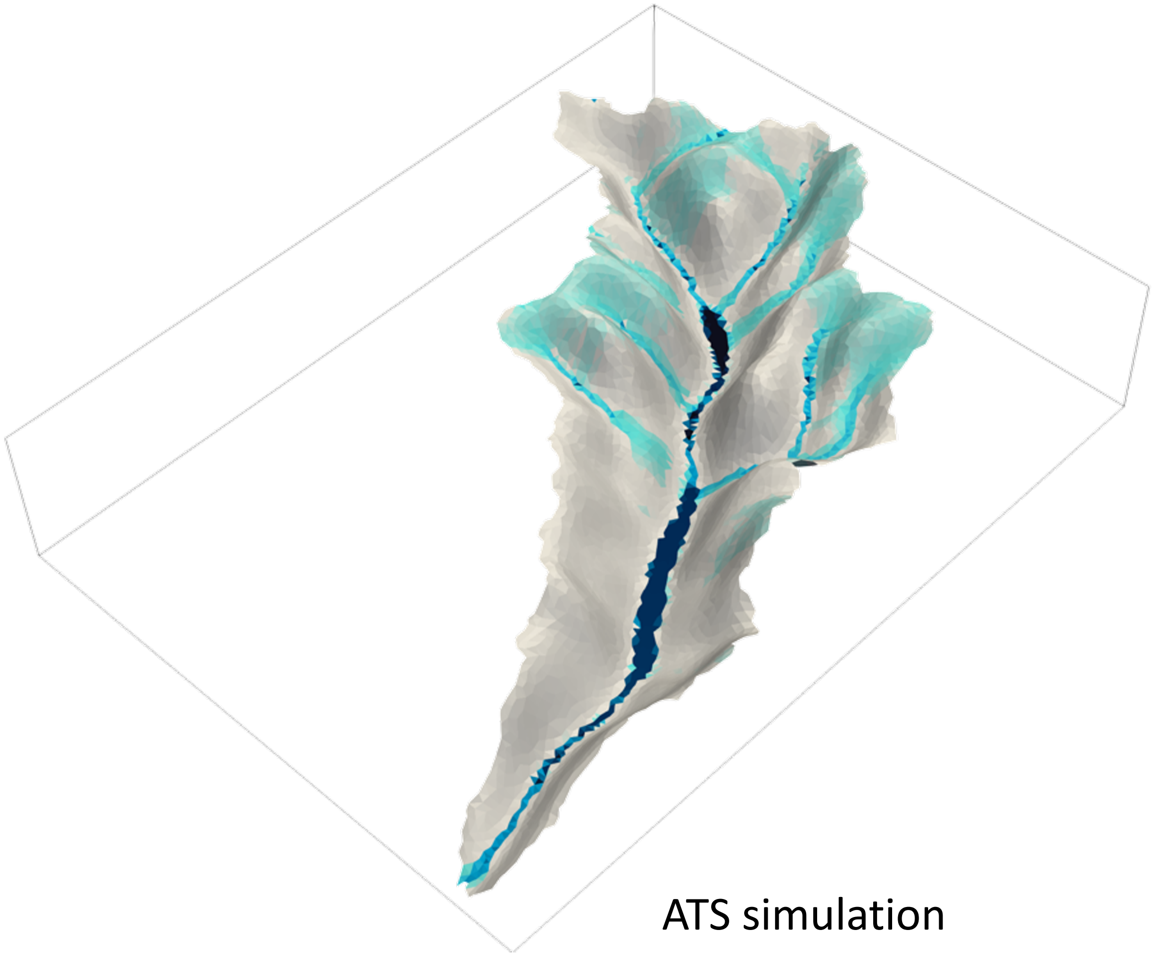
Mesh

DEM + NHD Plus

Land cover

Soil

Geology



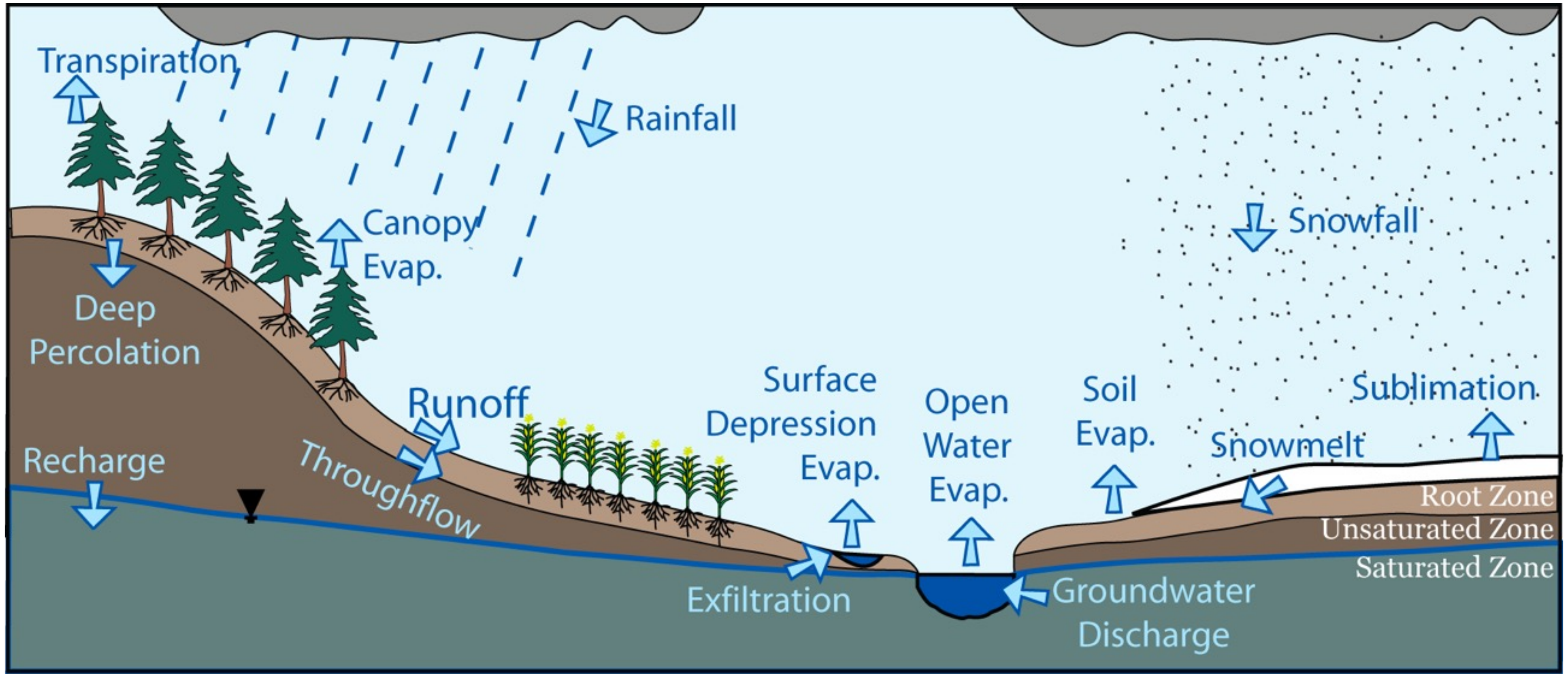
ATS simulation

Demos

- `02_model_setup/mesh_Coweeta_demo.ipynb`
- `02_model_setup/get_Daymet.ipynb`

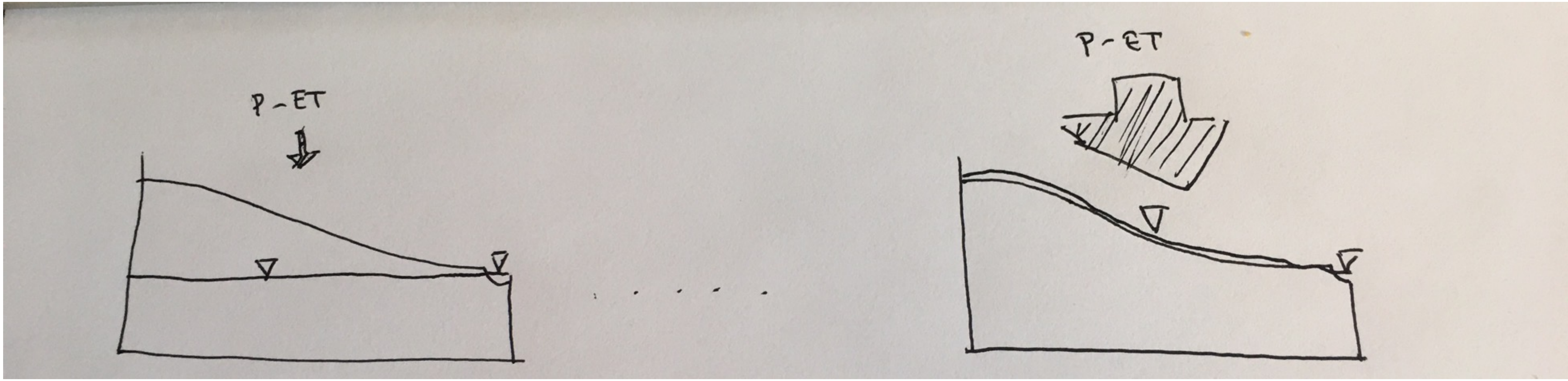
Integrated, distributed hydrologic models

Integrated: includes both surface water and subsurface water



Distributed: spatially explicit parameters (e.g. soil properties) with a given x,y coordinate.

Model Spinup



The true answer is somewhere in between…

Goal: pick an initial condition that is consistent with antecedent soil water content.

Extremely important for accurate predictions!

Model Spinup

Stage 1: steady-state simulation

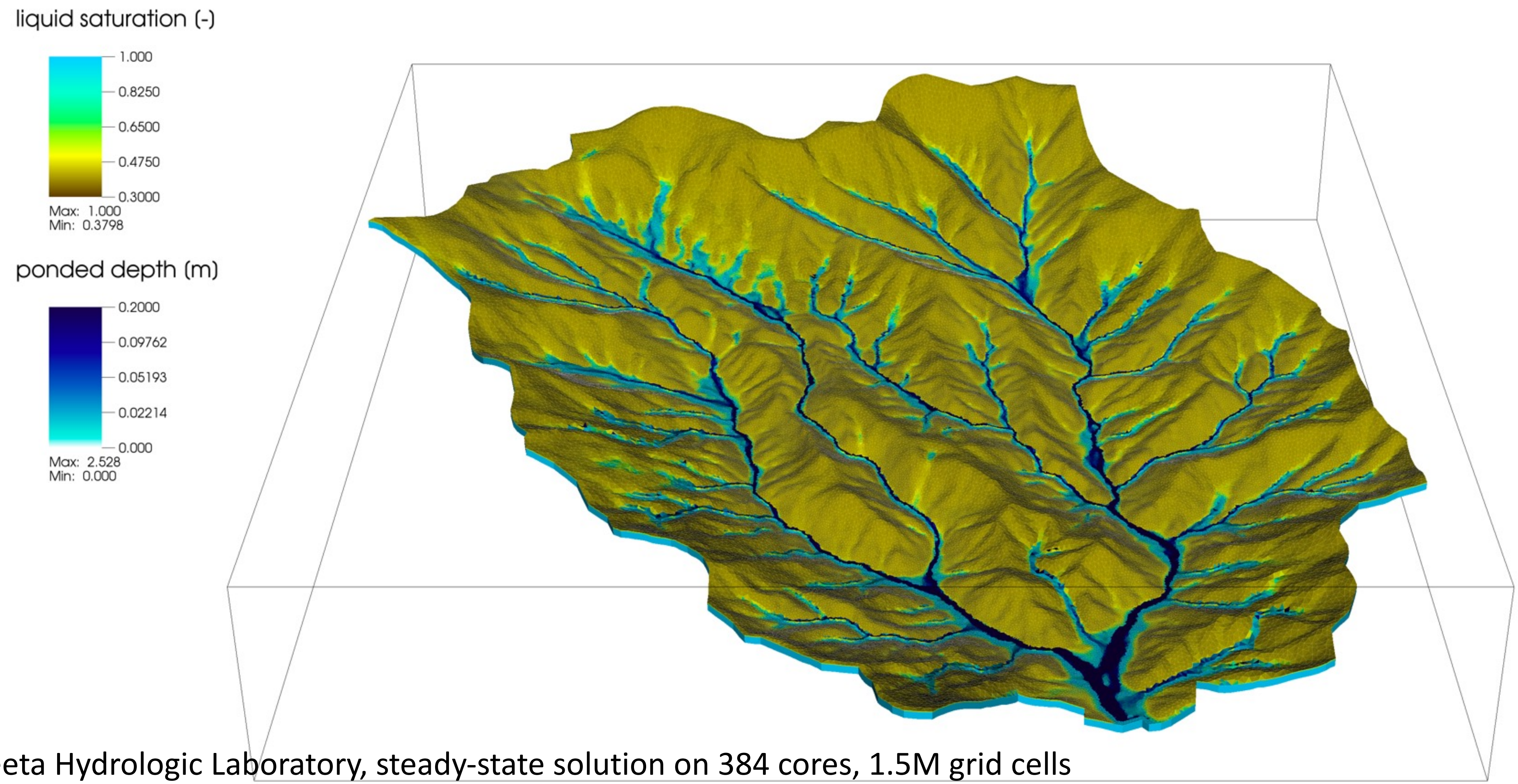
- Start from some level of hydrostatic balance (constant head)
- Run transient solution with uniform P-ET for a *very* long time (~10-1000 years) Note, ATS's timestep will start small but grow – by the end of the simulation should be taking year-long timesteps!
- Monitor discharge and total water content and watch them relax to steady-state.

Model Spinup

Stage 2: pseudo-steadystate

- Run a transient "cyclic steady state" run, repeating your forcing data for a few years
- Alternatively, run transient but ignore your first few years of data.

Integrated, distributed hydrologic models



Coweeta Hydrologic Laboratory, steady-state solution on 384 cores, 1.5M grid cells