# VARIABLE INFILTRATION CAPACITY (VIC) MODEL (CONT.)

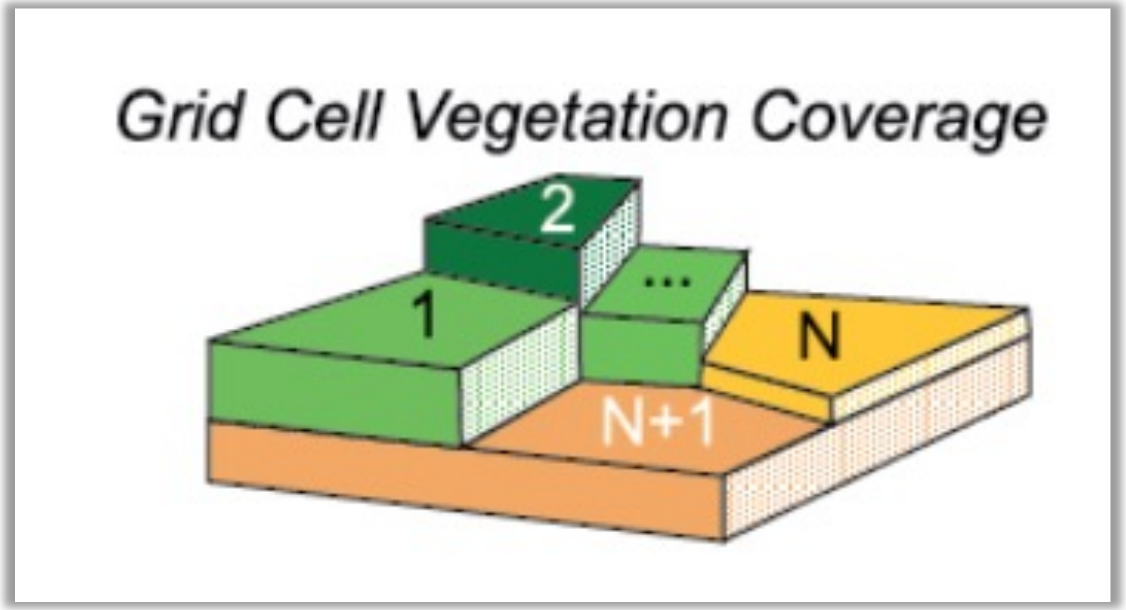
GLY606 Water Data Analysis & Modeling

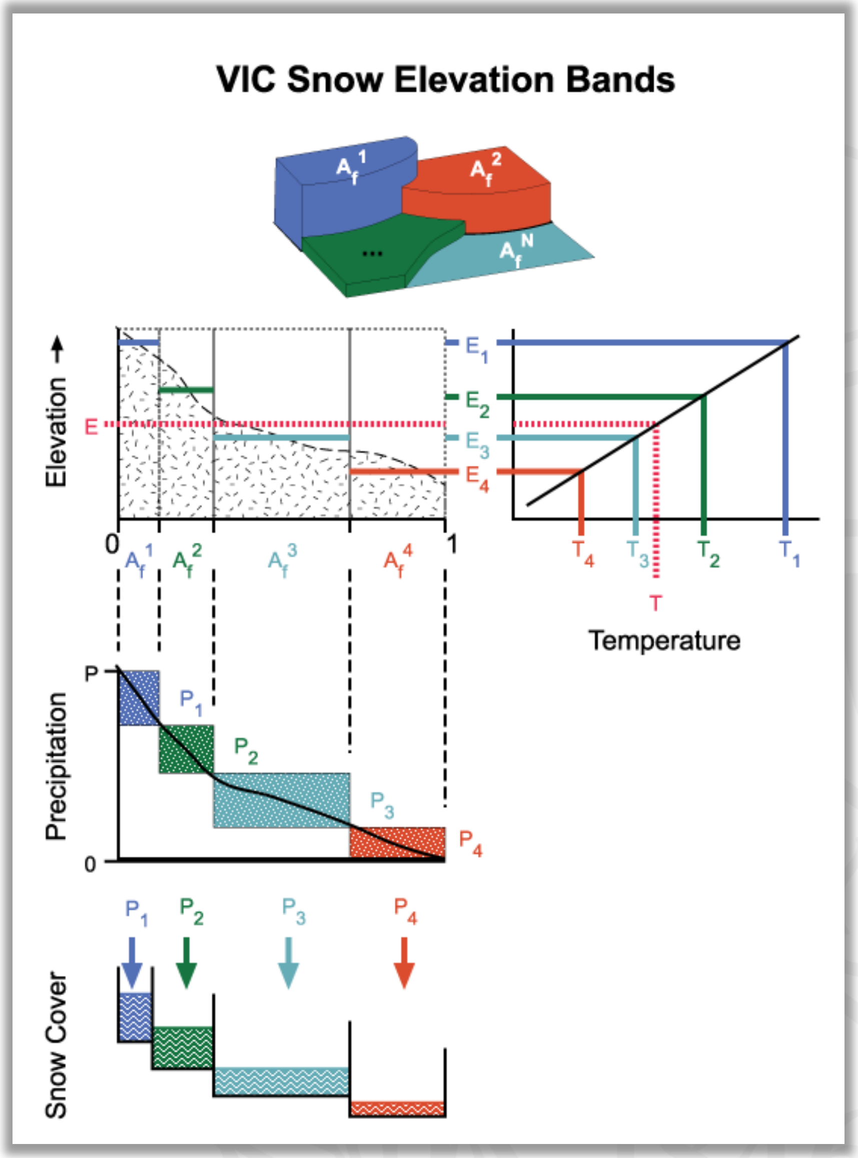
Oct 21st 2024

University at Buffalo The State University of New York

# Recap – VIC model

- **Sub-grid variability**
  - Elevation (Level 1)
  - Vegetation (Level 2)



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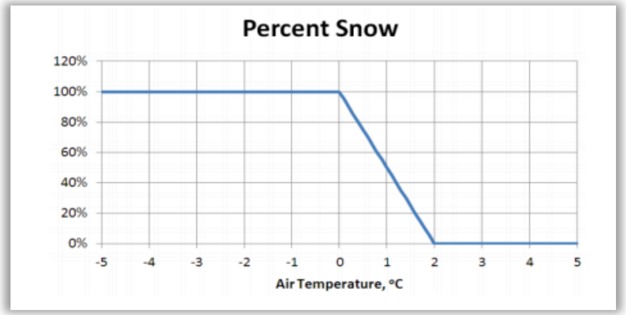
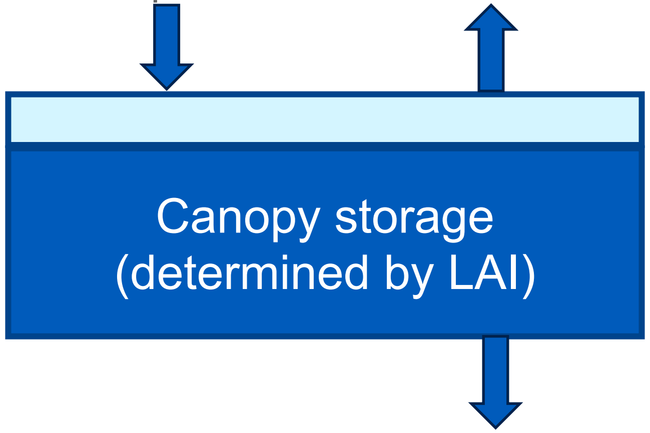
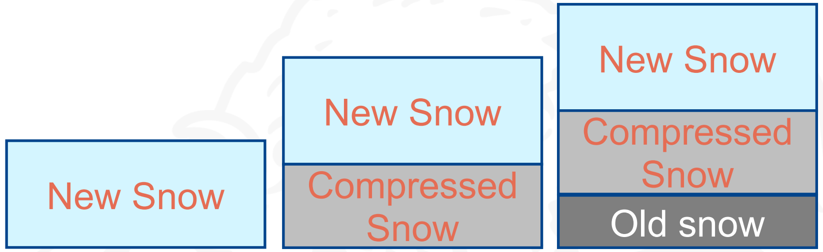


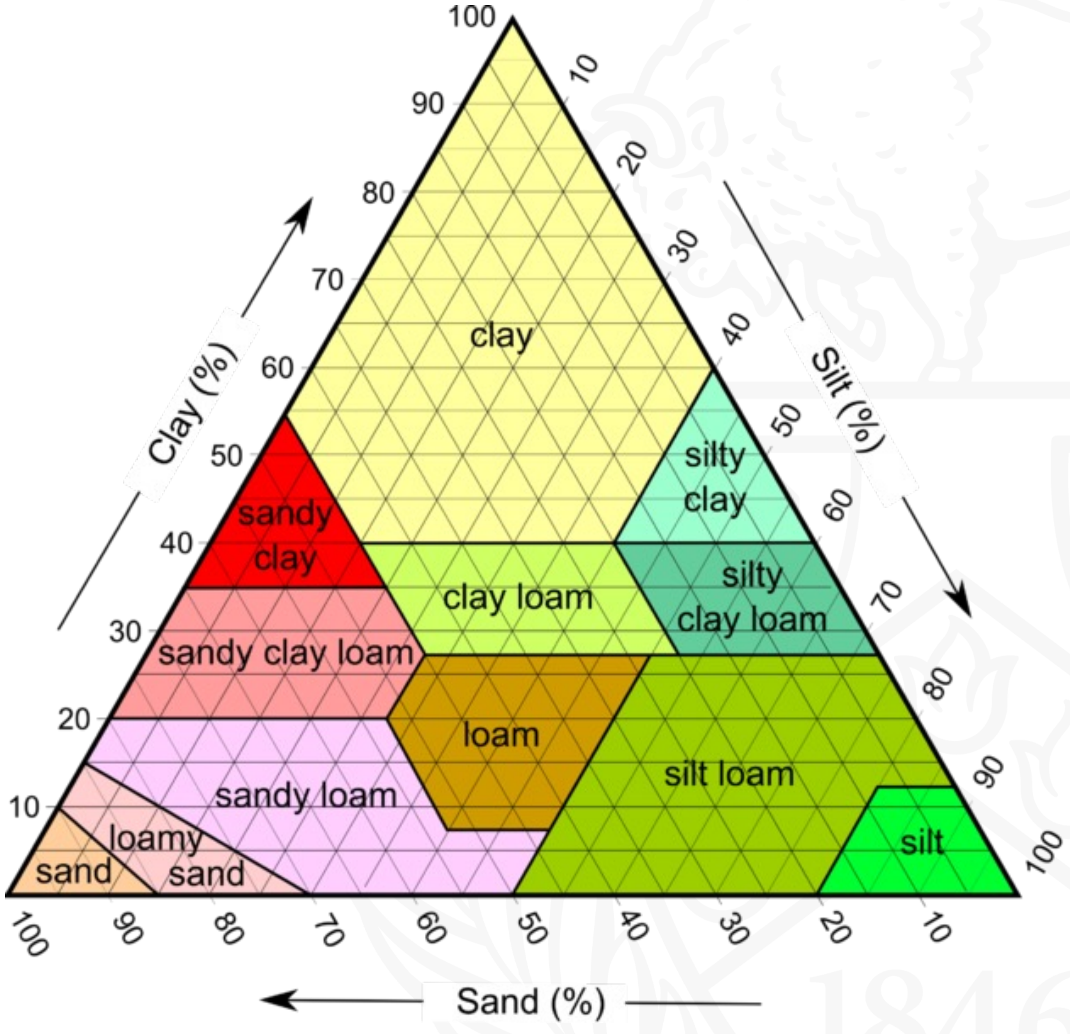

Multi-layer snow

Physically-based Penman Monteith approach [Monteith, 1965]

$$ET = \frac{\overbrace{\Delta(R_n - G) + \rho_a c_p\,(\delta e)\,g_a}^{\text{Volume flux rate}}}{(\Delta + \gamma\,(1 + g_a/g_s))\,L_v}$$

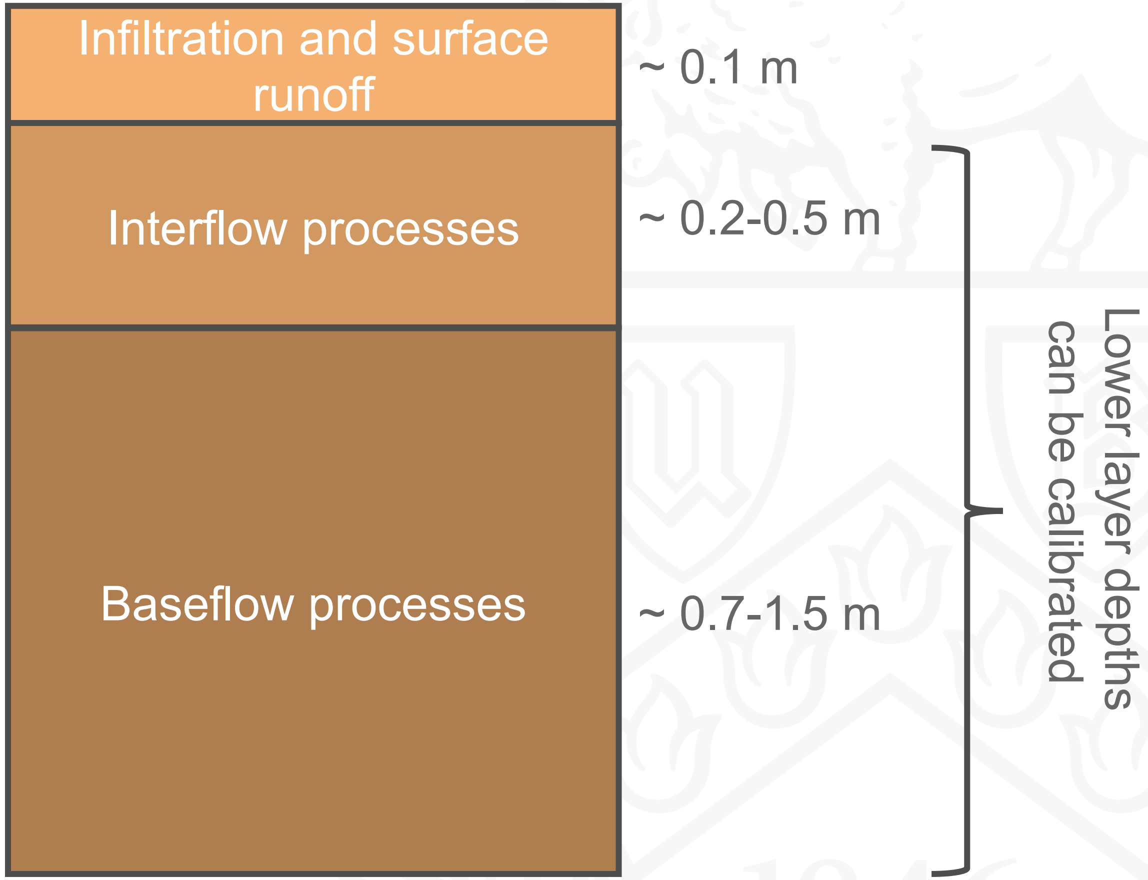
# Parameterization of Soils

- Soil information is poorly known
- **Pedotransfer functions**
  - Changing what we have into what we need
  - Soil texture info to physical units
  - Soil pedotransfer table
- Soil texture information is used to estimate:
  - Porosity
  - Ksat
  - Field capacity
  - Wilting point
  - Residual capacity
  - And other soil characteristics



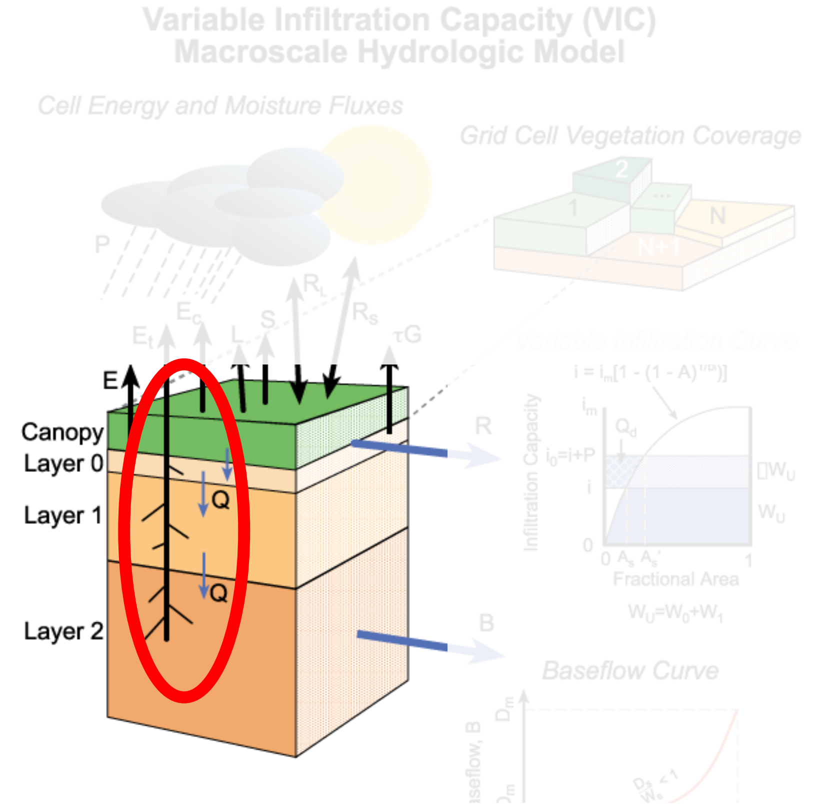
# Soil Column

- Parameterize arbitrary number of soil layers at different depths
  - Model requires at least two soil layers for water balance calculations and three soil layers for energy balance calculations
  - No theoretical limit to the number of layers
- **Typically, three layers** are defined for simulations
  - NLDAS VIC 3 layers (approx. 0-0.15, 0.15-0.55, and 0.55-1.35 m)
  - GLDAS VIC 3 layers (0-0.1, 0.1-1.6, and 1.6-1.9 m)



# Rooting Depths

- Rooting depths are independent of soil layer depths
- Rooting depths and distributions are user-defined
    - Defined for each vegetation type in each grid cell
- Important parameterization for vegetation transpiration calculations
    - Determines available water at soil depths for uptake by vegetation
- Rooting parameterization taken from literature or estimated




Water Resources Research

Research Article | Free Access

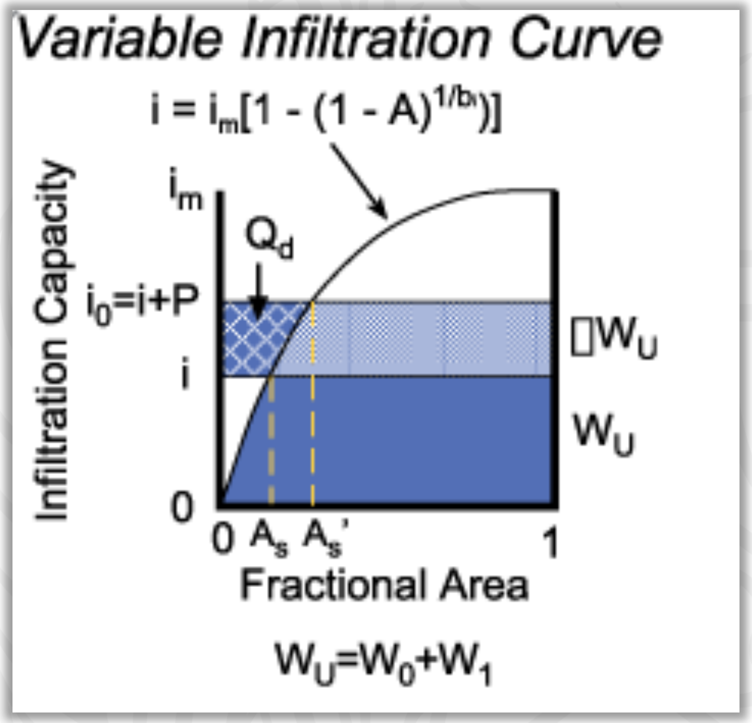
**Global estimation of effective plant rooting depth: Implications for hydrological modeling**

Yuting Yang, Randall J. Donohue, Tim R. McVicar

First published: 11 October 2016 | https://doi.org/10.1002/2016WR019392 | Citations: 168

# Runoff-Soil Infiltration

- Surface runoff/soil infiltration defined by the **variable infiltration curve** [Wood et al., 1992]
- Scales maximum infiltration with **a non-linear function** of fractional saturated area
  - Enables runoff calculations **for subgrid-scale areas**
- Curve shape defined by $b_{inf}$ parameter (typically between $10^{-5}$ and 0.4)
  - Amount of infiltration capacity relative to the saturated gridcell area
- Greater value of $b_{inf}$ yields lower infiltration and more runoff ($Q_d$)



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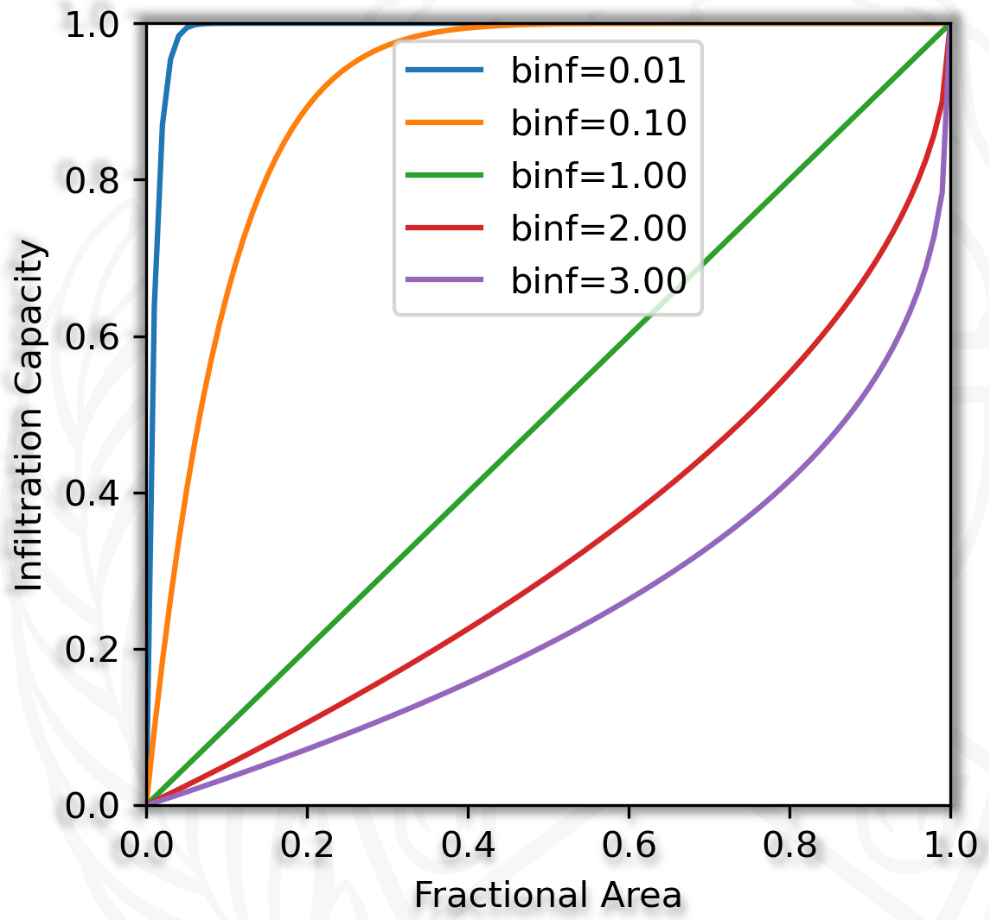
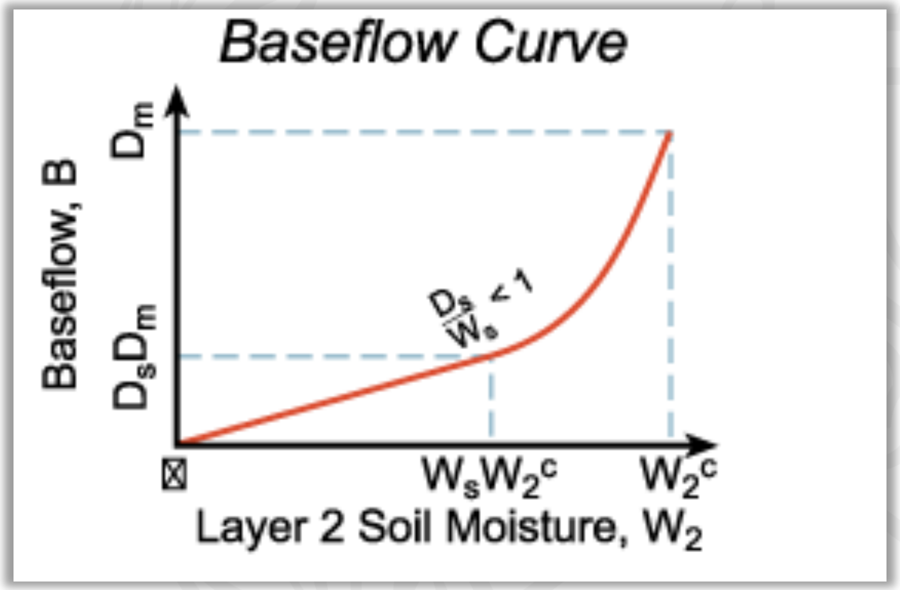


# Sub-surface Flow

- Subsurface flow (baseflow) is estimated using the Arno baseflow model [Francini and Pacciani, 1991]
- Function of soil moisture in the lowest layer
- Linear at low soil moisture content
  - Reduces responsiveness of baseflow during dry conditions
- Non-linear at high soil moisture content
  - Rapid baseflow response during wet conditions

Linear baseflow: $B = \frac{D_S \cdot D_{Smax}}{W_S W_n^c} \cdot W_n$



# Baseflow Formulation

- Important to **understand baseflow dynamics and parameterization for calibration**
- Baseflow calculation example: **https://goo.gl/5qFCKM**
- Assume one time step (t1 to t2) and the lowest layer's soil moisture increases from 300 to 310 mm. Find the change in baseflow for the time step using different parameterization
  - Change model parameters for different results

| Dsmax [mm] | Ds [-] | Ws [-] | Wnc [mm] | Qbase(t1) [mm day-1 | Qbase(t2) [mm day-1 | *ΔQbase [mm day-1]* |
|---|---|---|---|---|---|---|
| 50 | 0.2 | 0.9 | 50 | 66.66666667 | 68.88888889 | *2.222222222* |
| 30 | 0.2 | 0.6 | 50 | 60 | 62 | *2* |
| 30 | 0.05 | 0.8 | 50 | 11.25 | 11.625 | *0.375* |
| 5 | 0.05 | 0.6 | 50 | 2.5 | 2.583333333 | *0.08333333333* |
| 5 | 0.4 | 0.8 | 50 | 15 | 15.5 | *0.5* |
| 5 | 0.3 | 0.4 | 50 | 22.5 | 23.25 | *0.75* |

| Soil moisture(t1) [mm] | Soil moisture(t2) [mm] |
|---|---|
| 300 | 310 |

- $W_n^c$ (or $W_s$, $D_{smax}$) parameters defined by soil parameters
  - $W_n^c$ = porosity * soil depth

# Computational Considerations

- Compiled using free GNU C compilers
  - Can use other compilers but needs to be tested
- Simulation runs cell by cell, can be very **efficiently parallelized by dividing the domain into separate runs**
- VIC is typically run using **LINUX operating systems**
  - Possible to run using Windows OS but not supported
- Simulations usually use about 5 MB of RAM
  - Memory usage does not increase with basin size but simulation time does!
  - Parallelization would require more memory as well.
- **Need a considerable amount of storage** for I/O data
  - Dependent on basin size, time step, etc.

# VIC resources

- Current VIC website:
  - https://vic.readthedocs.io/en/master/
- Source Code Availability
  - https://github.com/UW-Hydro/VIC

# VIC EXAMPLE TUTORIAL

Let’s compile the code and run VIC on CUASHI JupyterHub!

# Let's use "**SUMMA Modeling**" environment

## Server Options

### Python v3.9.7 - JupyterLab Interface

This is a general-purpose scientific computing environment built on Python version 3.9.7. When using this server, you will be working through the JupyterLab interface. It comes with pre-configured, widely used scientific libraries including scipy, pandas, geopandas, sympy, scikit-learn, matplotlib, ulmo, landlab, gdal, xarray, TauDEM, hsclient, dataretrieval, rasterio, pyproj, fiona, geemap, fsspec, and others.

### R v4.2.3 - JupyterLab Interface

This serves as a general-purpose scientific computing environment built on the R programming language. When using this server, you will have access to both the JupyterLab and RStudio interfaces. The environment is pre-configured with commonly used tools and libraries, including randomForest, forecast, sf, rjsonio, ncdf4, ggmap, dataRetrieval, and WaterML.

### SUMMA Modeling

This is a computing environment built on Python version 3.9 and pre-installed tools to support using the Structure for Unifying Multiple Modeling Alternative (SUMMA). SUMMA is a hydrologic modeling framework that can be used to configure a wide range of hydrological model analysis. When using this server, you will be working through the JupyterLab interface. The environment comes with limited pre-installed scientific Python packages. For more information on the SUMMA model, visit the project webpage.

### WRF-Hydro v5.1 - NWM v2.0

This computing environment is structured around Python version 3.9 and is tailored for seamless operation with the WRF-Hydro model because it has the source code pre-compiled. WRF-Hydro is a community hydrological model suitable for a range of projects, including real-time flash flood prediction, long-term water supply projections, and evaluations of regional hydroclimate impacts. Notably, WRF-Hydro has been used as the core hydrological module within the National Water Model (NWM) versions 2.0 and 2.1. When using this server, you will be working through the JupyterLab interface. While the environment features a curated selection of pre-installed scientific Python packages, users can follow CUAHSI's guideline to create a customized conda environment, and then install specific Python packages that cater to their unique project requirements. For more information on the WRF-Hydro model, visit the project website.

# How do we run VIC?

1

Download source code

- A taste of GitHub

2

Compile source code

- Correct path to the NetCDF library

3

Download example dataset

- We can use GitHub to download it as well

4

Prepare configuration file

- Relative path or absolute path?

5

Run the model!

# Step 1: Download the source code – set up git in CUASHI

1.1. Open a terminal in the CUASHI JupyterHub, and type the following two commands to set your user name and email address

### Your Identity

The first thing you should do when you install Git is to set your user name and email address. This is important because every Git commit uses this information, and it's immutably baked into the commits you start creating:

```
$ git config --global user.name "John Doe"
$ git config --global user.email johndoe@example.com
```

```
$ git config --global user.name “Yifan Cheng”
$ git config --global user.email “ycheng46@buffalo.edu”
```

# Step 1: Download the source code

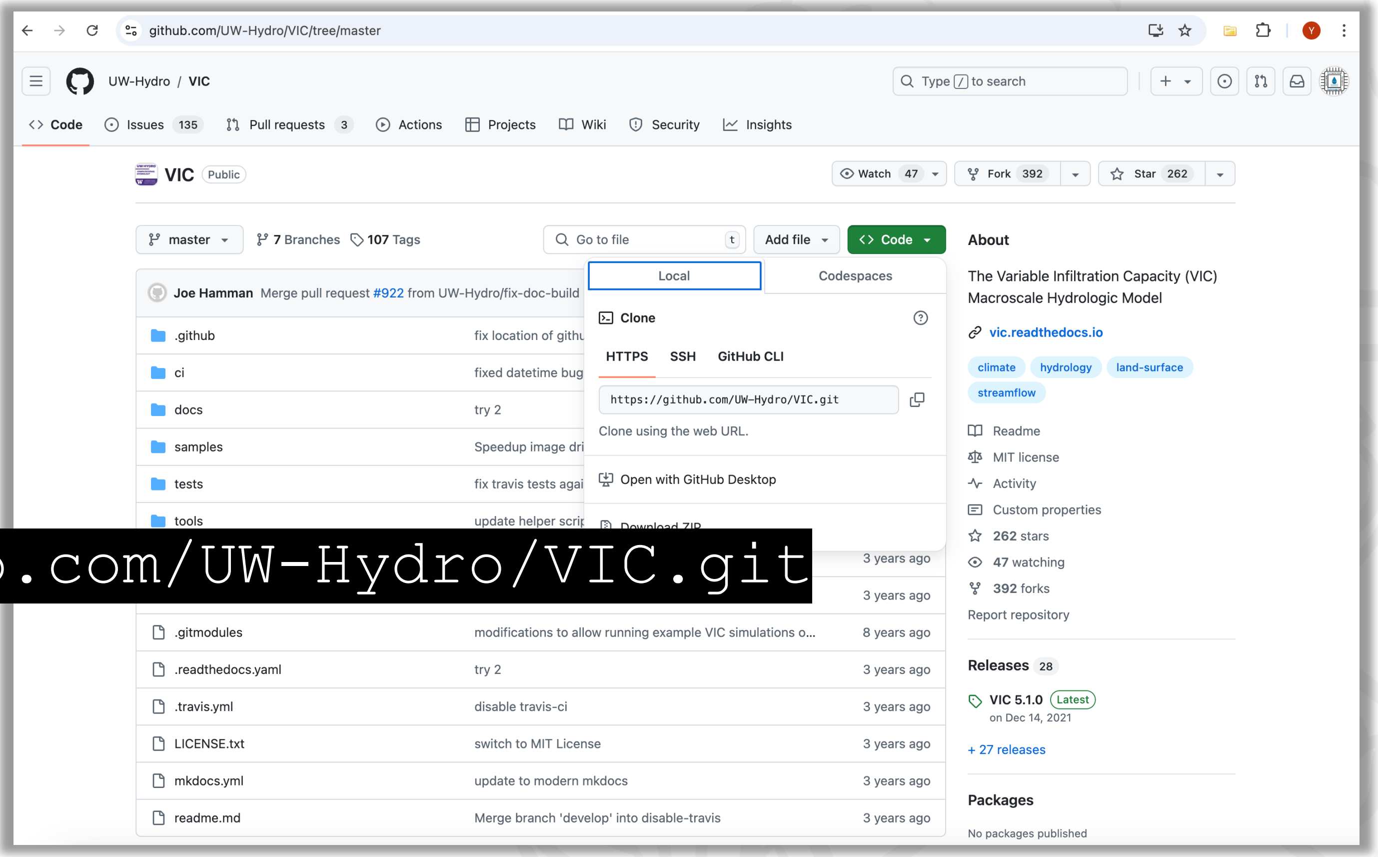
1.2. Go to your home directory, create a folder name “model”

```
$ cd ~
$ pwd
$ mkdir model
$ cd model
```

```
jovyan@jupyter-yifancheng
(base) jovyan@jupyter-yifancheng-5fub:~$ pwd
/home/jovyan/data
(base) jovyan@jupyter-yifancheng-5fub:~$ mkdir model
(base) jovyan@jupyter-yifancheng-5fub:~$ cd model/
(base) jovyan@jupyter-yifancheng-5fub:~/model$
```

# Step 1: Download the source code

1.3. Type following command to download the VIC model source code in "model" folder




```
$ git clone https://github.com/UW-Hydro/VIC.git
```

2

## Compile source code

- Correct path to the NetCDF library

# Step 2: Compile source code

- 2.1. Access the “**.bashrc**” file

```
$ cd ~
$ vim .bashrc
```

Files and folders starting with “.” are hidden. It will not be displayed if you only type “ls”.

```
jovyan@jupyter-yifancheng

(base) jovyan@jupyter-yifancheng-5fub:~/model$ cd ~
(base) jovyan@jupyter-yifancheng-5fub:~$ ls -a
.               .condarc     .hs_auth              .jupyter      .viminfo
..              .config      .hs_pass              .local        website
assignment      downloads    .hs_user              lost+found
.bash_history   .git         in_class_practice     model
.bashrc         .gitconfig   .ipynb_checkpoints    .profile
.cache          GLY606       .ipython              test
(base) jovyan@jupyter-yifancheng-5fub:~$ vim .bashrc
```

# Step 2: Compile source code

- 2.2. Add the highlighted code in the **.bashrc** file

```
# Set Netcdf path
```

```
export LD_LIBRARY_PATH="/opt/conda/lib:${LD_LIBRARY_PATH}"
```

jovyan@jupyter-yifancheng

```
# ~/.bashrc: executed by bash(1) for non-login shells.
# see /usr/share/doc/bash/examples/startup-files (in the package bash-doc)
# for examples

# Set Netcdf path
export LD_LIBRARY_PATH="/opt/conda/lib:${LD_LIBRARY_PATH}"

# If not running interactively, don't do anything
case $- in
    *i*) ;;
      *) return;;
esac

# don't put duplicate lines or lines starting with space in the history.
# See bash(1) for more options
HISTCONTROL=ignoreboth
```

```
$ source .bashrc  #(after you save the changes in the .bashrc file)
```

# Step 2: Compile source code

- 2.3. Add the highlighted code in the **.bashrc** file

```
cd model/VIC/vic/drivers/image
make > compile.log
```

```
(base) jovyan@jupyter-yifancheng-5fub:~$ cd model/VIC/vic/drivers/image
(base) jovyan@jupyter-yifancheng-5fub:~/model/VIC/vic/drivers/image$ ls
include  Makefile  readme.md  src
(base) jovyan@jupyter-yifancheng-5fub:~/model/VIC/vic/drivers/image$ make > compile.log
```

# Step 2: Compile source code

- 2.4. Add the highlighted code in the **.bashrc** file

```
cd model/VIC/vic/drivers/image
make > compile.log
ls
```

```
../../extensions/rout_stub/src/vic_store_extension.c:40:54: warning: unused parameter 'nc_state_fil
e' [-Wunused-parameter]
   40 |                                          nc_file_struct *nc_state_file)
      |                                          ~~~~~~~~~~~~~~~^~~~~~~~~~~~~
In file included from /usr/include/x86_64-linux-gnu/bits/libc-header-start.h:33,
                 from /usr/include/math.h:27,
                 from ../../vic_run/include/vic_def.h:15,
                 from ../../extensions/rout_stub/include/rout.h:12,
                 from ../../extensions/rout_stub/src/rout.c:7:
/usr/include/features.h:187:3: warning: #warning "_BSD_SOURCE and _SVID_SOURCE are deprecated, use
_DEFAULT_SOURCE" [-Wcpp]
  187 | # warning "_BSD_SOURCE and _SVID_SOURCE are deprecated, use _DEFAULT_SOURCE"
      |   ^~~~~~~
(base) jovyan@jupyter-yifancheng-5fub:~/model/VIC/vic/drivers/image$ ls
compile.log  include  Makefile  readme.md  src  vic_image.exe
(base) jovyan@jupyter-yifancheng-5fub:~/model/VIC/vic/drivers/image$
```

3

## Download example dataset

- We can use GitHub to download it as well

# Step 3: Download example data

- 3.1. Prepare the folder for the data

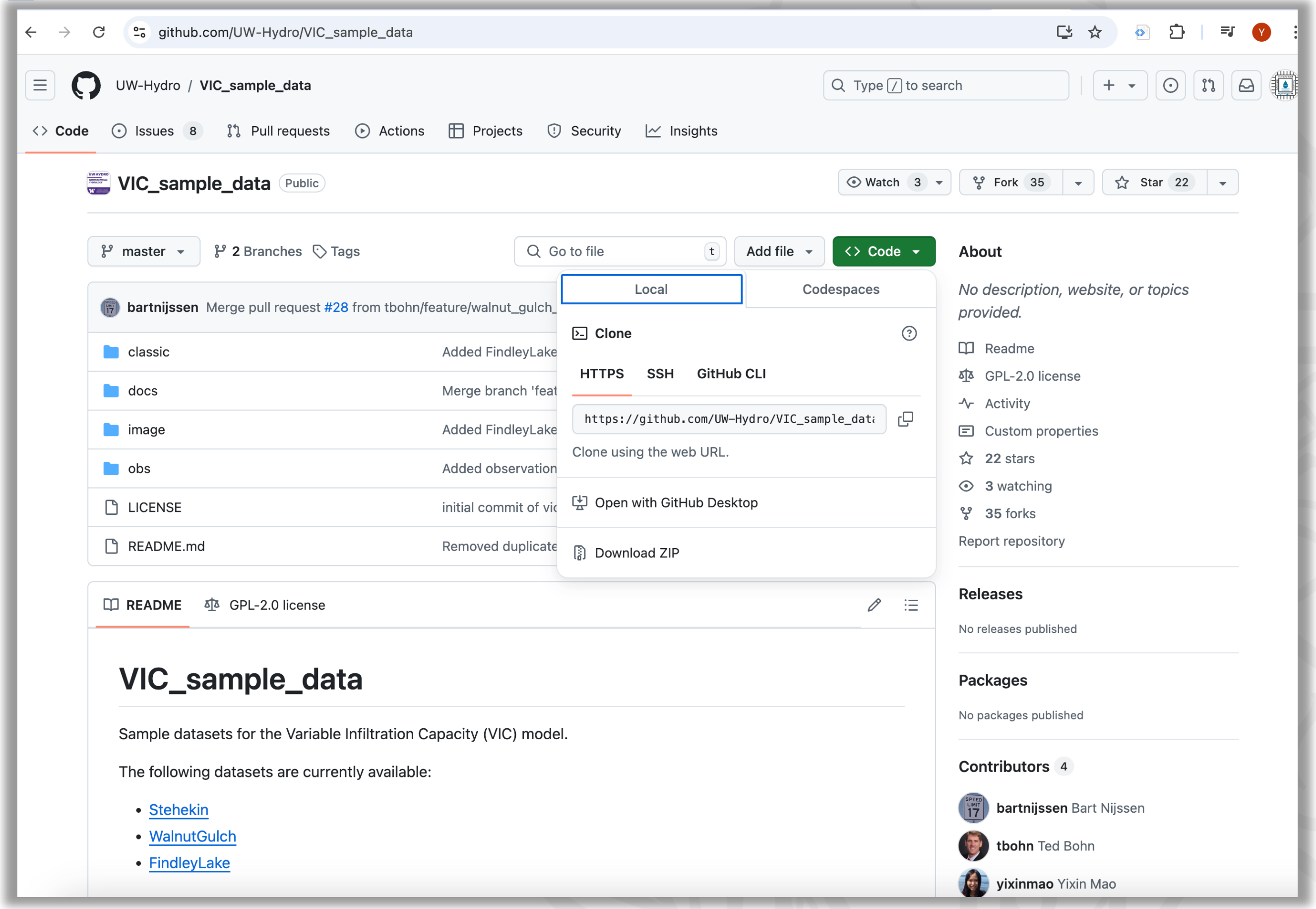
```
cd ~/model
mkdir example
cd example/
mkdir data
cd data
```

```
jovyan@jupyter-yifancheng
(base) jovyan@jupyter-yifancheng-5fub:~$ cd ~/model
(base) jovyan@jupyter-yifancheng-5fub:~/model$ mkdir example
(base) jovyan@jupyter-yifancheng-5fub:~/model$ cd example/
(base) jovyan@jupyter-yifancheng-5fub:~/model/example$ mkdir data
(base) jovyan@jupyter-yifancheng-5fub:~/model/example$ cd data/
(base) jovyan@jupyter-yifancheng-5fub:~/model/example/data$ ls
(base) jovyan@jupyter-yifancheng-5fub:~/model/example/data$
```

# Step 3: Download example data

- 3.2. Download the example dataset using git clone

```
git clone https://github.com/UW-Hydro/VIC_sample_data.git
```



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