VARIABLE INFILTRATION CAPACITY (VIC) MODEL

ERT 474/574

Open-Source Hydro Data Analytics

Oct 29nd 2025

University at Buffalo The State University of New York

Announcement

- Homework #7
  - Please form a group of 2-3 members
  - Pick one river basin (medium size, basin area ranges between 1000 and 2000 km^2)
  - Reading literature about the mizuRoute routing model

An Overview of the VIC Model

- Hydrology model comparison/selection
- VIC model features
  - Cell size
  - Sub-grid representations
- VIC model processes
  - Vegetation
  - Snow
  - Evapotranspiration
  - Runoff/Infiltration
  - Baseflow

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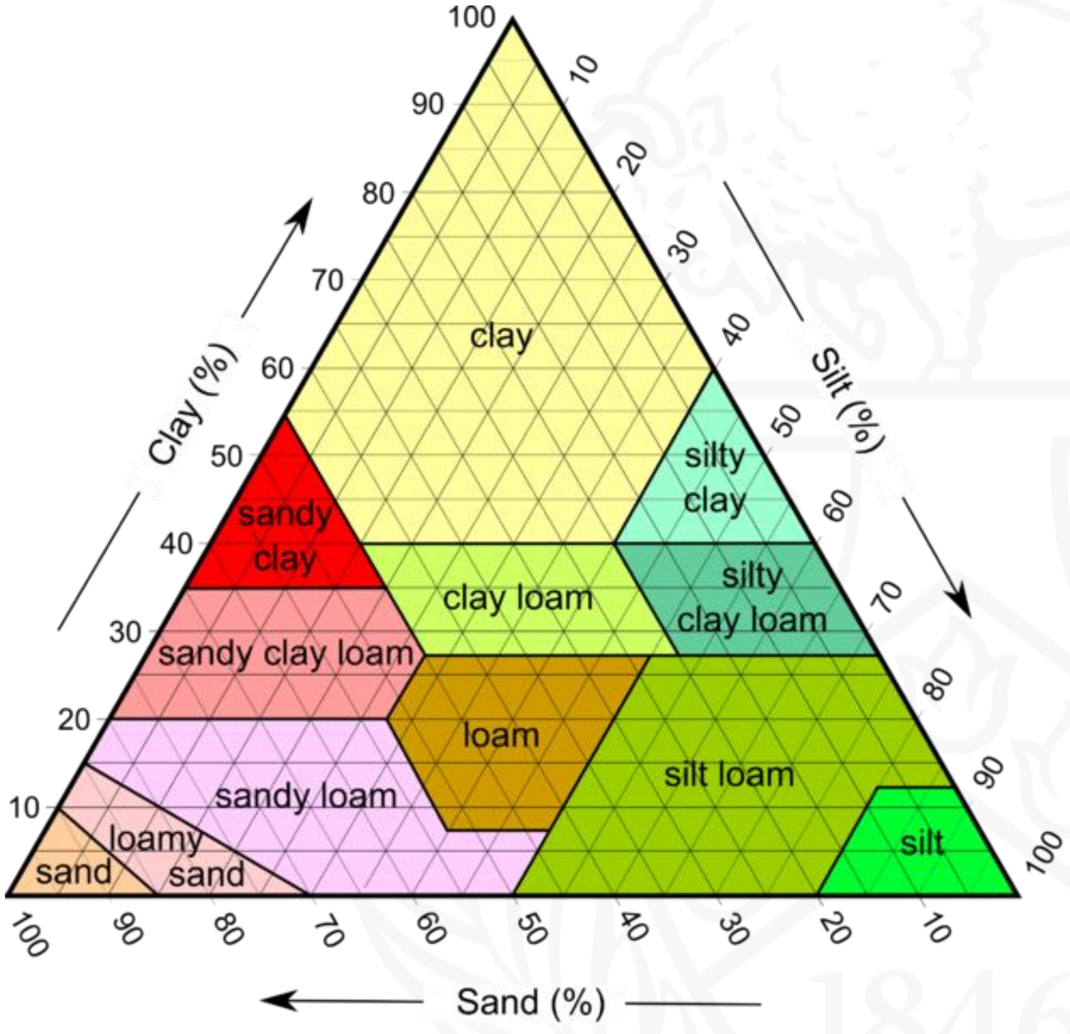
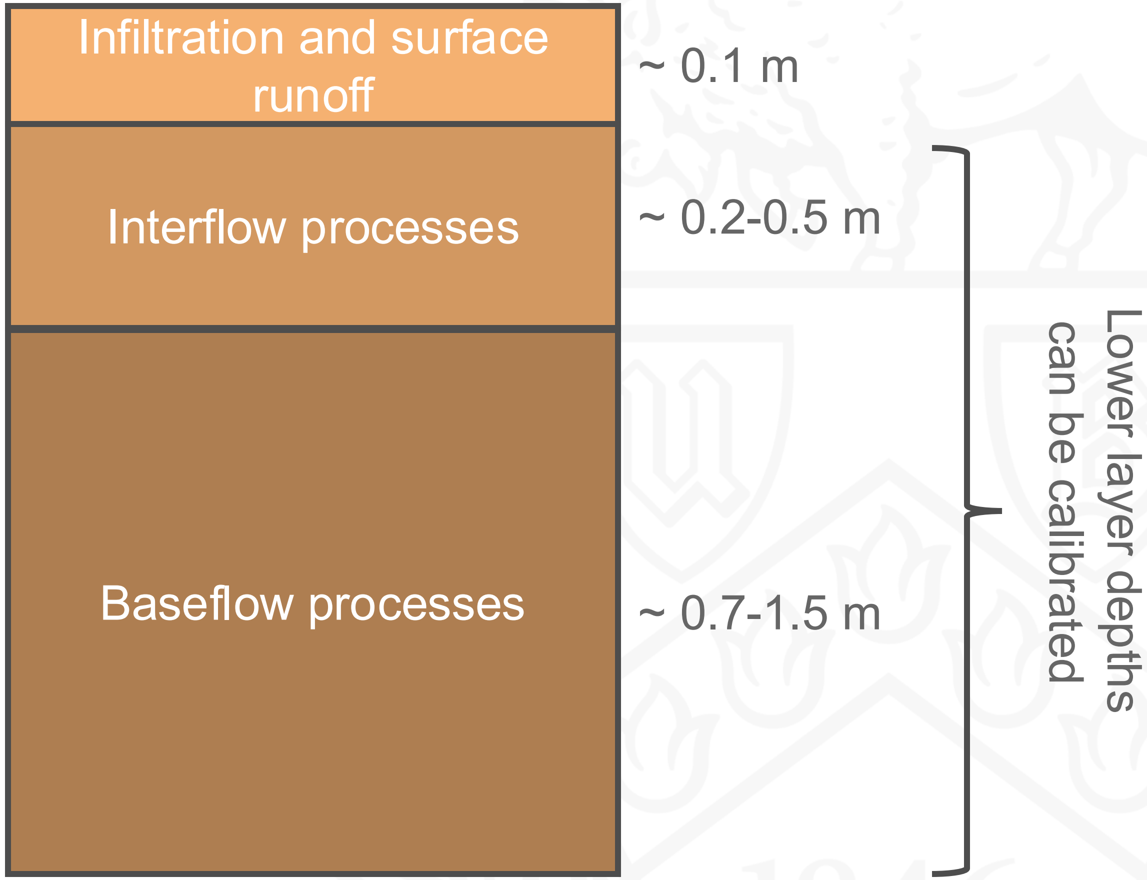
Parameterization of Soils

- 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



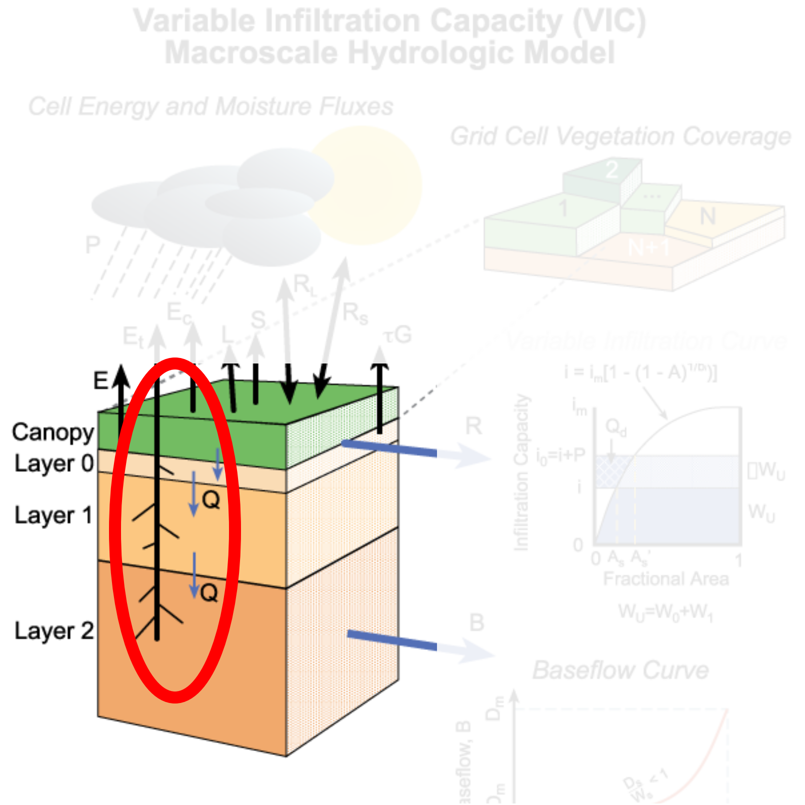
Soil Column

- 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

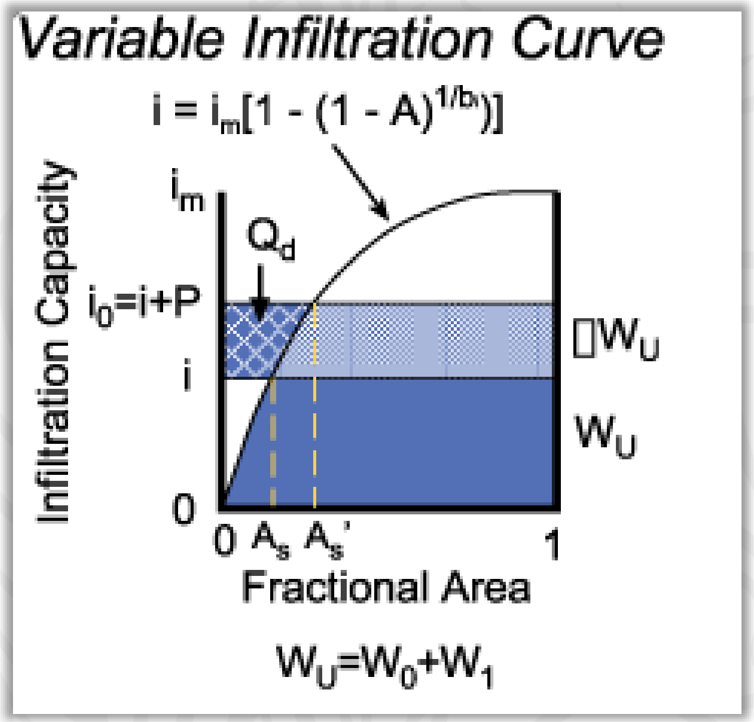
Global estimation of effective plant rooting depth: Implications for hydrological modeling

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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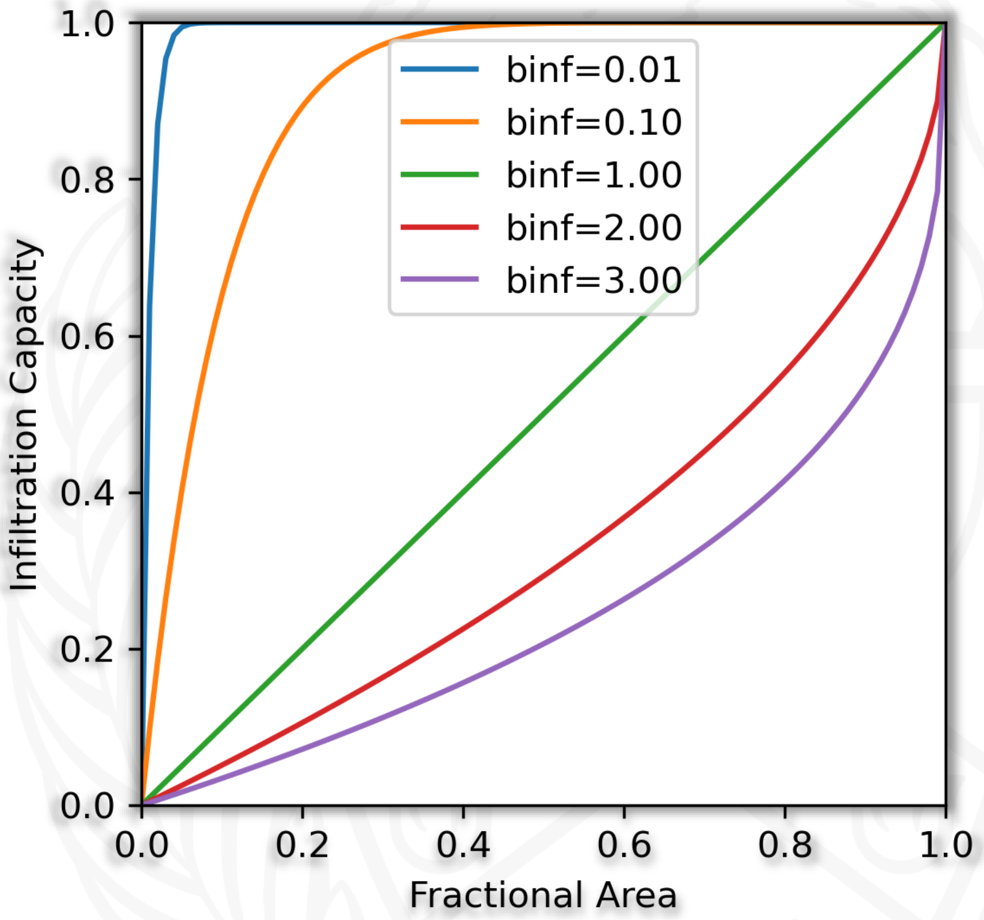
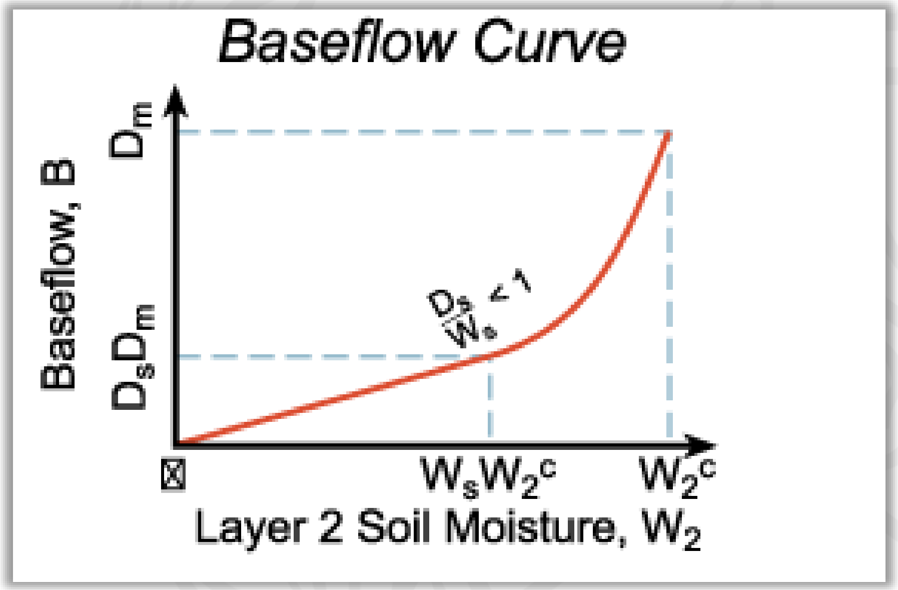


Sub-surface Flow

- 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 RASM
  - 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

CONCEPT

Important concept about hydrologic modeling

Important concept

- Overall workflow
- Configuration file
- Initial conditions / State files
- Model Spin-up

Overall workflow

Download the source code	Compile the source code	Prepare all model input data	Prepare Configuration file	Run the model

`git clone`	`make`
	
	`vic.exe`
		• Domain file
		• Parameter file
		• Meteorological forcing
		• Initial condition file*
			Example config file:
			
			global_param.Stehekin.L2015.txt
				`vic.exe -g [config file]`

Configuration files

- The configuration file is the backbone of any hydrologic model setup. It defines how the model runs, including:
- **Model parameters**: Time step, simulation period, solver settings.
- **Input/output paths**: Locations of input data (e.g., precipitation, temperature) and where outputs are saved.
- **Modules and processes**: Which hydrologic processes are activated (e.g., infiltration, evapotranspiration, routing).
- **Spatial and temporal resolution**: Grid size, time step intervals.

Example: VIC configuration file

```
DOMAIN          /workspaces/VIC_sample_data/image/Stehekin/parameters/domain.Stehekin.0.0625_deg.nc
```

```
FORCING1      /workspaces/VIC_sample_data/image/Stehekin/forcings/Stehekin_image_test.forcings_10days.0.0625_deg.
FORCE_TYPE    AIR_TEMP     tas
FORCE_TYPE    PREC         prcp
FORCE_TYPE    PRESSURE     pres
FORCE_TYPE    SWDOWN       dswrf
FORCE_TYPE    LWDOWN       dlwrf
FORCE_TYPE    VP           vp
FORCE_TYPE    WIND         wind
WIND_H        10.0
```

```
PARAMETERS       /workspaces/VIC_sample_data/image/Stehekin/parameters/params.Stehekin.L2015.nc
LAI_SRC          FROM_VEGPARAM
FCAN_SRC         FROM_DEFAULT
ALB_SRC          FROM_VEGPARAM
NODES            3
SNOW_BAND        TRUE
```

```
RESULT_DIR  /workspaces/VIC_sample_data/sample_image
```

The first thing we need to check is

1) Whether the input file exists
2) Whether the output directory exists

Input file

Output directory

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```
RESULT_DIR  /workspaces/VIC_sample_data/sample_image
```

How can we check whether a file exists?

We can use `ls`

See example in next slides

How to check?

This red error indicates that this file does not exist!

```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL    PORTS    JUPYTER                bash
⊗ @YifanCheng → /workspaces $ ls /workspaces/VIC_sample_data/image/Stehekin/parameters/parameters.Stehekin.L2015.nc
ls: cannot access '/workspaces/VIC_sample_data/image/Stehekin/parameters/parameters.Stehekin.L2015.nc': No such file or directory
● @YifanCheng → /workspaces $ ls /workspaces/VIC_sample_data/image/Stehekin/parameters/params.Stehekin.L2015.nc
/workspaces/VIC_sample_data/image/Stehekin/parameters/params.Stehekin.L2015.nc
○ @YifanCheng → /workspaces $ 
```

If we find out that this file does not exist, it is important to check whether there is a **typo** in the file names or file paths.

Initial Conditions / State Files

- Initial conditions define the starting point of the simulation, including:
    - **Soil moisture/temperature**
    - **Snowpack**
    - **Groundwater levels**
    - **Streamflow**
    - **…**
- Initial conditions are crucial for ensuring the model starts from a realistic state, especially for short-term simulations or forecasting.

Initial Conditions / State Files

- VIC model output State Files that can be later used as an Initial Conditions file.

INIT_STATE: defines which initial condition file to use

```
#INIT_STATE  ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake.19740101_00000.nc
STATENAME   ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake
STATEYEAR   1980
STATEMONTH  1
STATEDAY    1
```

STATExxxx: defines the outputting of the date/time of the state as well as the state file name.

Cold Start and Spin-Up

- Most hydrologic models begin with a **cold start**, meaning they initialize with default or zeroed values for key state variables such as:
  - Soil moisture
  - Groundwater storage
  - Snowpack
  - Streamflow
- These initial values are often far from realistic, especially for long-term simulations or regions with complex hydrologic dynamics. As a result, the model needs a **spin-up period** to allow these variables to evolve and stabilize toward a more realistic equilibrium.

```
STARTYEAR    1970
STARTMONTH   1
STARTDAY     1
ENDYEAR      1973
ENDMONTH     12
ENDDAY       31
CALENDAR     PROLEPTIC_GREGORIAN
```

What does the configuration file look like for **spin-up runs**?

```
#INIT_STATE  ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake.19740101_00000.nc
STATENAME   ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake
STATEYEAR   1974
STATEMONTH  1
STATEDAY    1
```

1. We commented out the INIT_STATE, meaning that 1) we do not have an initial condition file, and 2) we start from cold start
2. We defined the STATENAME, STATEYEAR, STATEMONTH, and STATEDAY to output the state file, which will be used as an initial condition in the **production run**.

```
STARTYEAR    1974
STARTMONTH   1
STARTDAY     1
ENDYEAR      1979
ENDMONTH     12
ENDDAY       31
CALENDAR     PROLEPTIC_GREGORIAN
```

What does the configuration file look like for **production runs**?

```
INIT_STATE   ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake.19740101_00000.nc
STATENAME    ${VIC_SAMPLE_DATA}/image/FindleyLake/state/state.FindleyLake
STATEYEAR    1980
STATEMONTH   1
STATEDAY     1
```

1. We used the state file that was generated in the previous run as an initial condition file.
2. We usually save the state file for the last timestep in a model production run.

References

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