VARIABLE INFILTRATION CAPACITY (VIC) MODEL

ERT 474/574

Open-Source Hydro Data Analytics

Oct 27nd 2025

University at Buffalo The State University of New York

Announcement

- Week 10: VIC Hydrologic Modeling & Modeling Practices
- Week 11: Routing Modeling & River Networks
- Week 12: Meteorological Forcings & Regridding
- Week 13: Parameter Sensitivity/Improving Model Performance
- Week 14 (Thanksgiving): Progress Update
- Week 15: FAIR & CARE Principals
- Week 16: Final Presentation!!

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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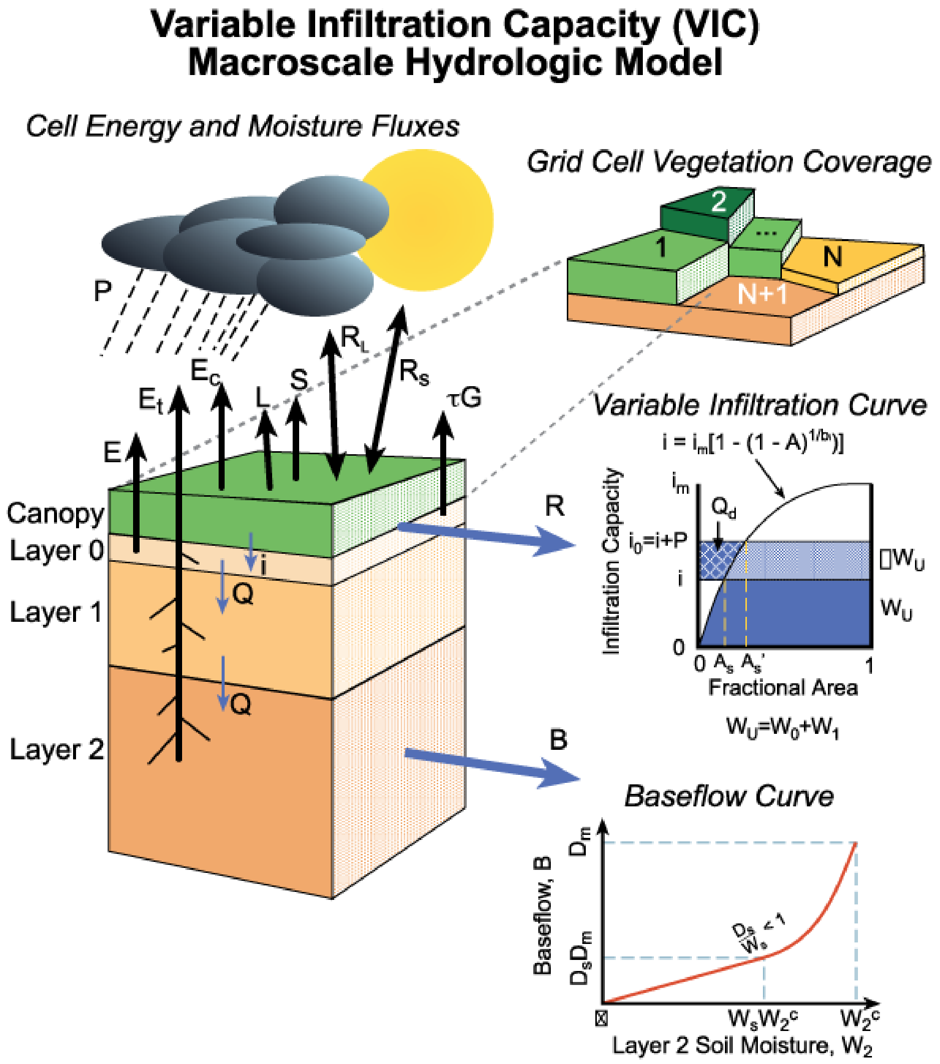
The VIC Model

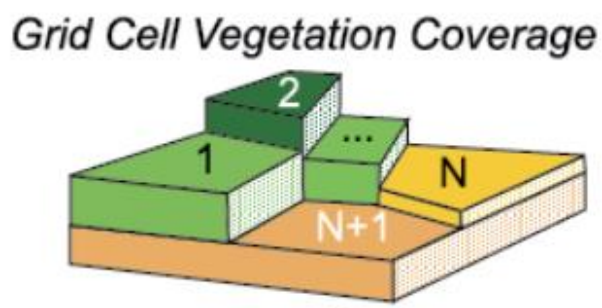
- The **Variable Infiltration Capacity (VIC)** Model
- **Grid-based** land surface representation
- Simulates land surface-atmosphere fluxes of **moisture** and **energy**
- Developed for coupled Land surface model (LSM) – Global Circulation Model (GCM) simulations
    - Considered **a research model**
- **Open-source** development



Source: https://vic.readthedocs.io/en/master/Overview/ModelOverview/

Sub-Grid Representation: Vegetation

- Spatial distribution and parameters for vegetation classes are specified within input files
- Energy and water balance terms are **computed independently for each vegetation class**
- Each class has a **different parameterization**:
  - Leaf-Area Index
  - Rooting Depth
  - Surface Roughness
  - etc.



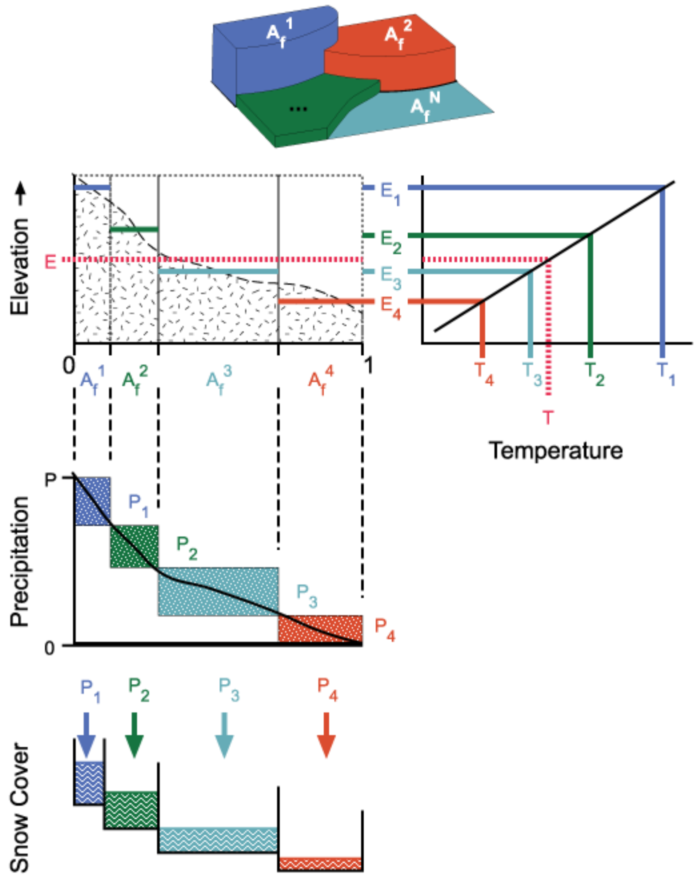
- Classes **must add up to 100% area** or VIC's **bare soil scheme is used for the remainder**
- Example: 33% Forest, 36% Grassland
  - What's the bare soil percentage?
  - **100 – 33 – 36 =31% bare soil**

Source: https://vic.readthedocs.io/en/master/Overview/ModelOverview/

Sub-Grid Representation: Elevation

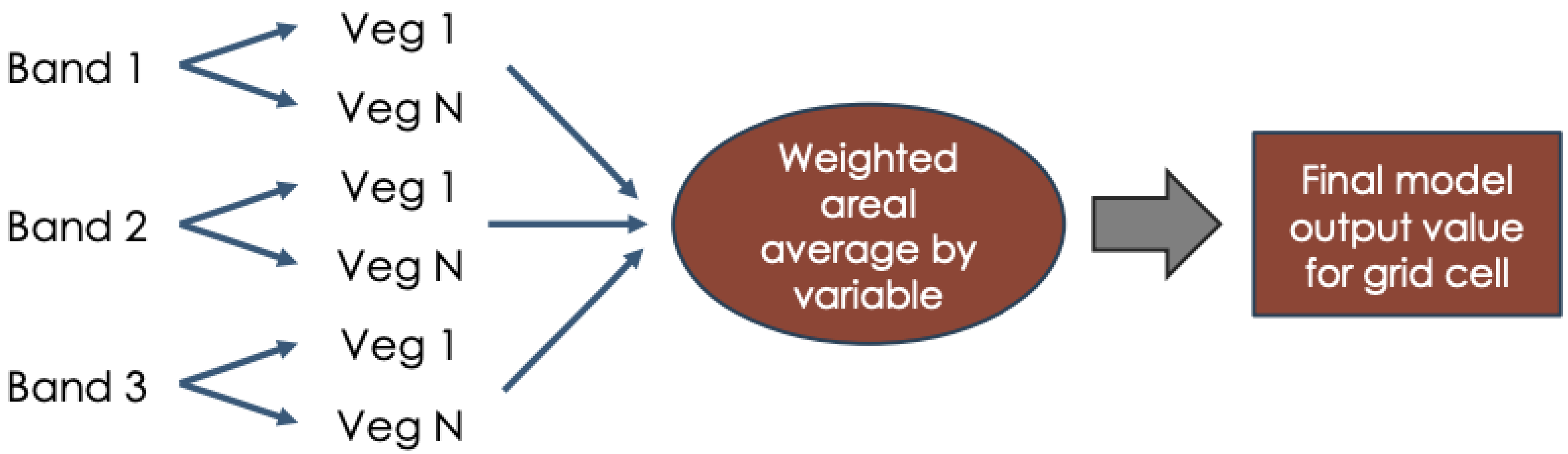
- Simulates **orographic effects** on precipitation/snowfall and snowpack processes
- Important for representing the differences in **snow accumulation and snow melt timing** between high and low elevations
- **User-specified** snow (elevation) bands
  - Fractional area and mean elevation for each band
- Mean pixel **temperature is lapsed to each elevation band**
  - Precipitation falls as either liquid or solid depending on the lapsed temperature

VIC Snow Elevation Bands



Sub-Grid Representation: Aggregation

- Sub-grid processes are combined through **weighted areal average**
- Computed by elevation bands and then vegetation cover
  - **Order of operations is important**



- More elevation bands and vegetation types significantly increase computation time!

Quiz Question

With the VIC model, what is the smallest grid cell size in which we can run the model and still have a representation of the physics, and why?

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With the VIC model, what is the smallest grid cell size in which we can run the model and still have a representation of the physics, and why?

1 km to 3 km. There is no strict rule concerning the smallest grid size. We would not recommend running VIC for grid cells smaller than 1 km.

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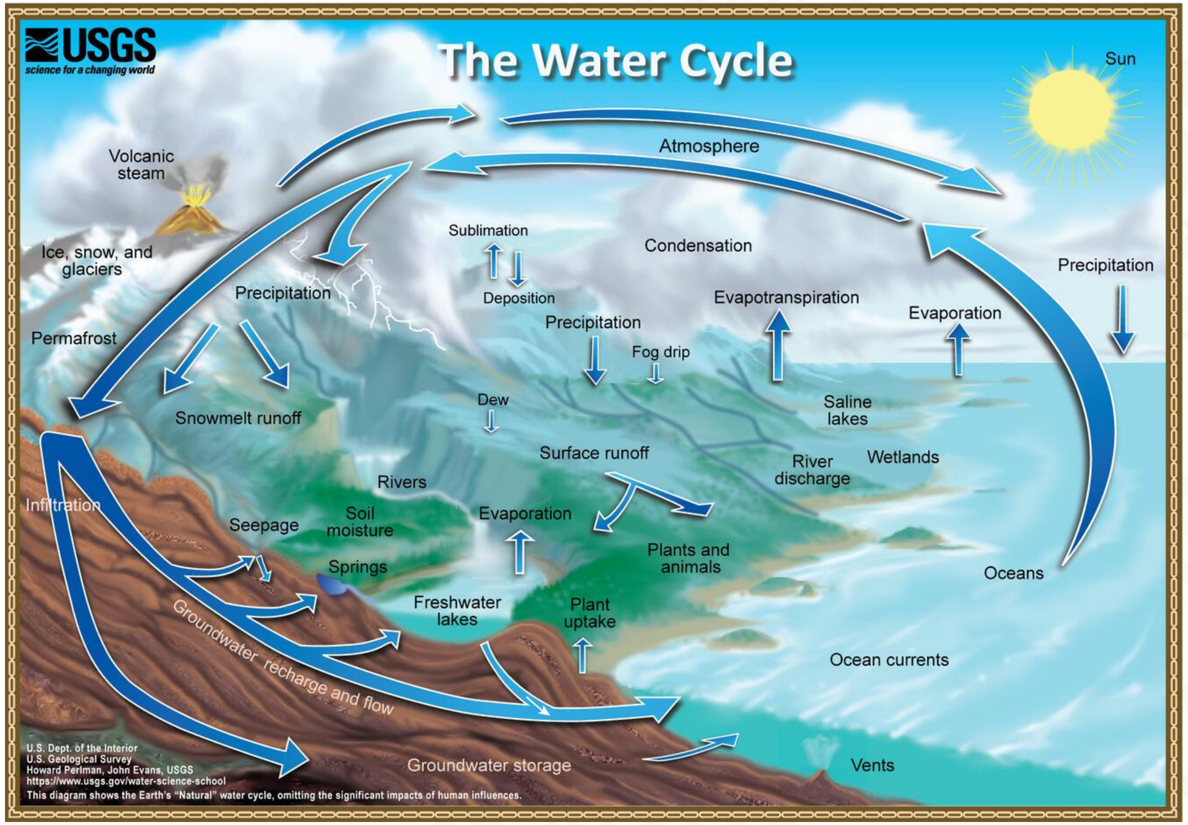
Hydrologic Process Representation

- Requires detailed parameterization
  - Important for climate-sensitive regions
  - Parameterization versus Parameters
- Contains modules and options to capture specific processes



Parameters ≠ Parameterization

- For example, to evaluate the evapotranspiration, we can use multiple parameterization methods!

Penman-Monteith Equation

$$\lambda_v E = \frac{\overbrace{\Delta(R_n - G) + \rho_a c_p (\delta e) g_a}^{\text{Energy flux rate}}}{\Delta + \gamma(1 + g_a/g_s)}$$

g_a = Conductivity of air, atmospheric conductance (m s^{-1})
g_s = Conductivity of stoma, surface or stomatal conductance (m s^{-1})

Pristley-Taylor Equation

$$ET_o = \alpha(R - G)\frac{\Delta}{\Delta + \gamma}$$

Parameterization

α = an empirical constant accounting for the vapor pressure deficit and resistance values [-]

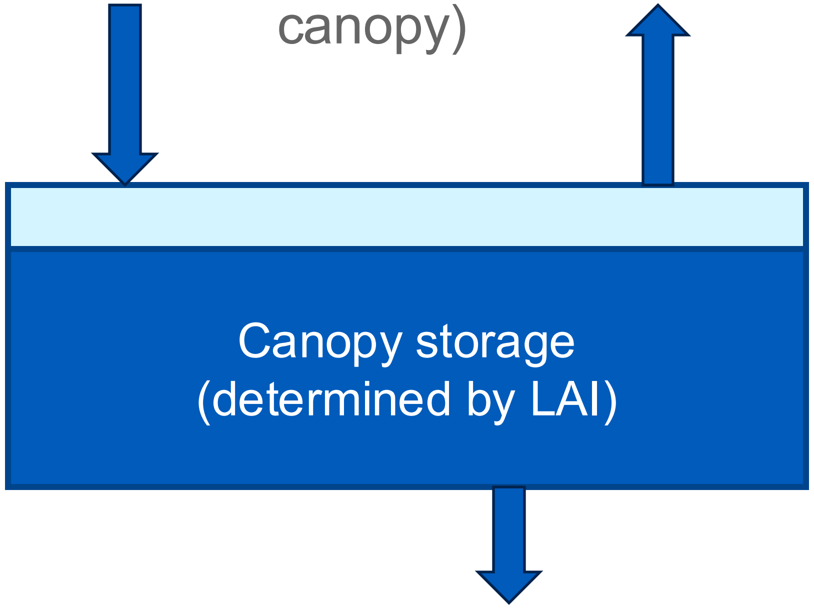
Parameters

Source:
Penman-Monteith Equation: https://en.wikipedia.org/wiki/Penman%E2%80%93Monteith_equation
Pristley-Taylor Equation: https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/evaporation-and-transpiration/priestley-taylor-method

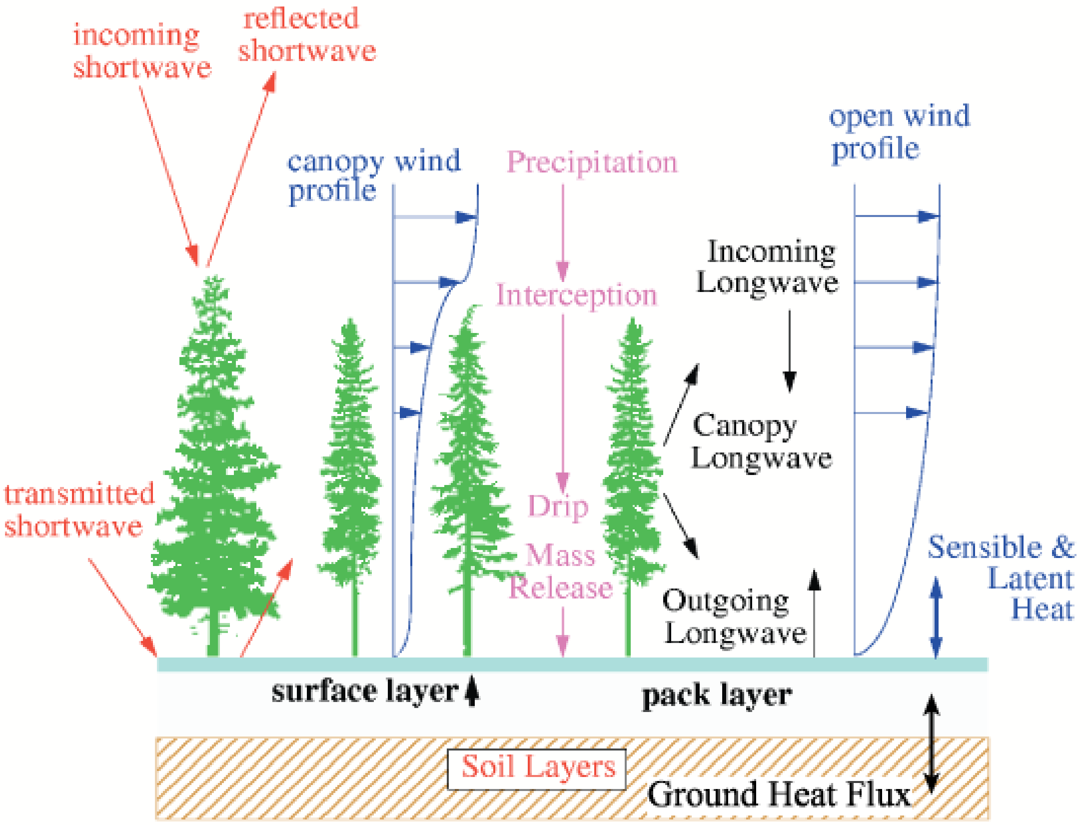
Vegetation Canopy

Precipitation

Canopy evaporation (wet canopy or snow) or Transpiration (dry canopy)



Canopy “throughfall” occurs when additional precipitation exceeds the canopy storage capacity in the current time step



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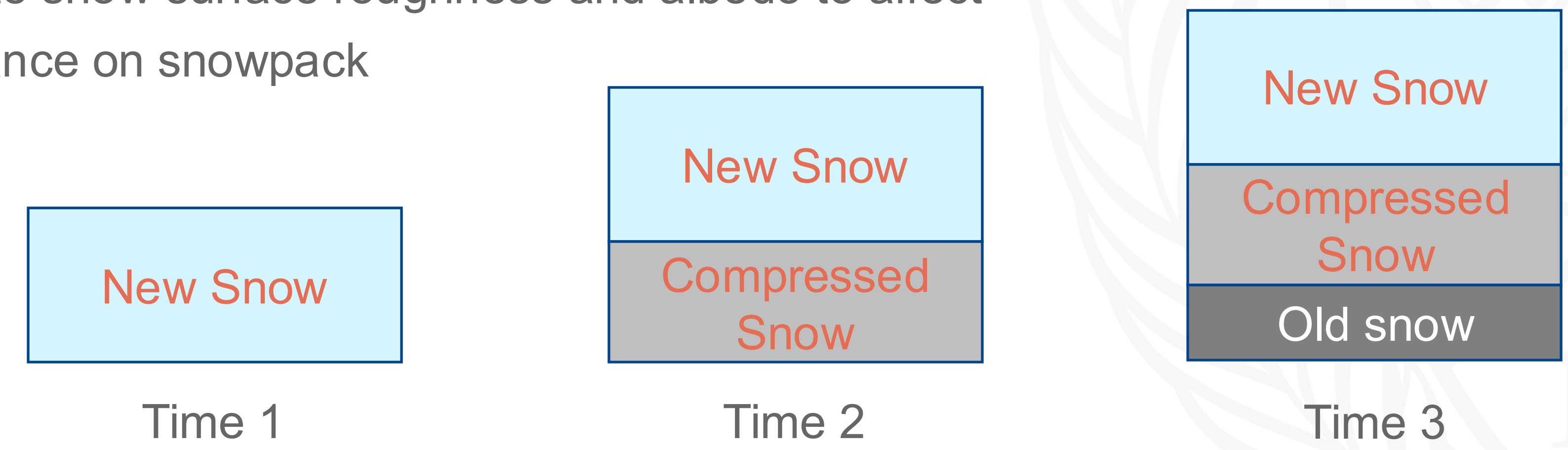
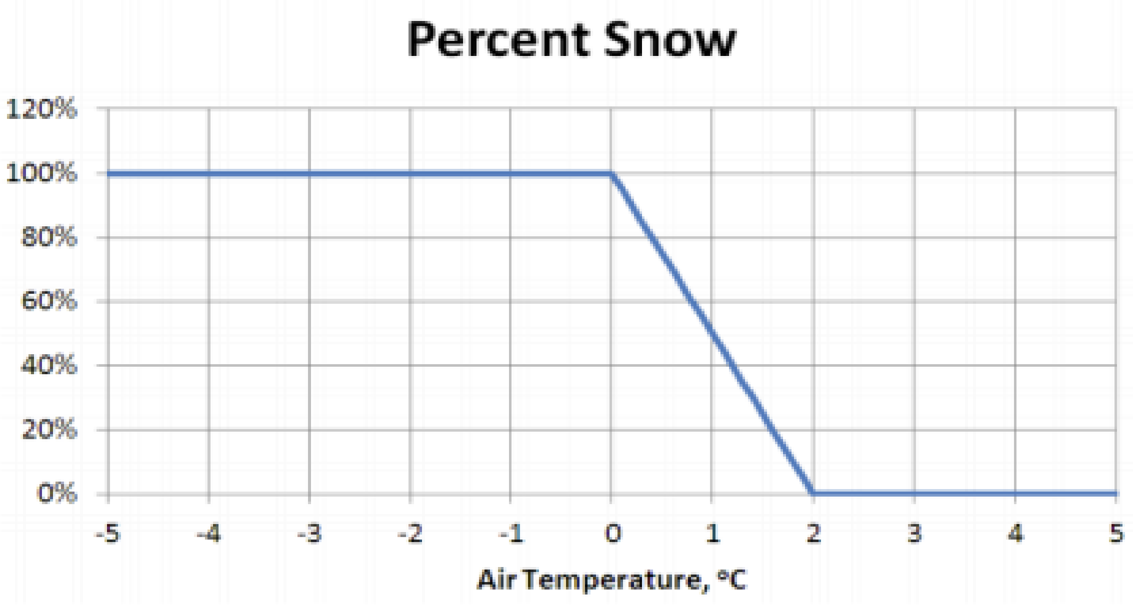
Snow Simulations

- Snow within the vegetation canopy is directly related to LAI
- Uses quasi two-layer energy balance model at the snow surface
  - Thin surface layer (solving the energy balance at the pack surface)
  - Pack layer
- Albedo and snowpack size evolve with snow ages
- We can calibrate snow surface roughness and albedo to affect the energy balance on snowpack



Rain-Snow Partitioning

- VIC used a **simple (linear) method** to determine the **percentage of liquid (rain) or solid (snow) precipitation**
- Example: Rain Minimum = 0.0 °C
- Snow Maximum = 2.0 °C
- The **rain minimum and snow maximum parameters are calibratable**
- For this example, 0.5°C would produce 75% snow and 25% rain



Evapotranspiration Simulation

- Physically-based Penman Monteith approach [Monteith, 1965]

Volume flux rate

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

Δ = Rate of change of saturation specific humidity with air temperature. (Pa K^{-1})
R_n = Net irradiance (W m^{-2}), the external source of energy flux
G = Ground heat flux (W m^{-2}), usually difficult to measure
c_p = Specific heat capacity of air (J kg^{-1} K^{-1})
ρ_a = dry air density (kg m^{-3})
δe = vapor pressure deficit (Pa)
g_a = Conductivity of air, atmospheric conductance (m s^{-1})
g_s = Conductivity of stoma, surface or stomatal conductance (m s^{-1})
γ = Psychrometric constant ($\gamma \approx 66$ Pa K^{-1})

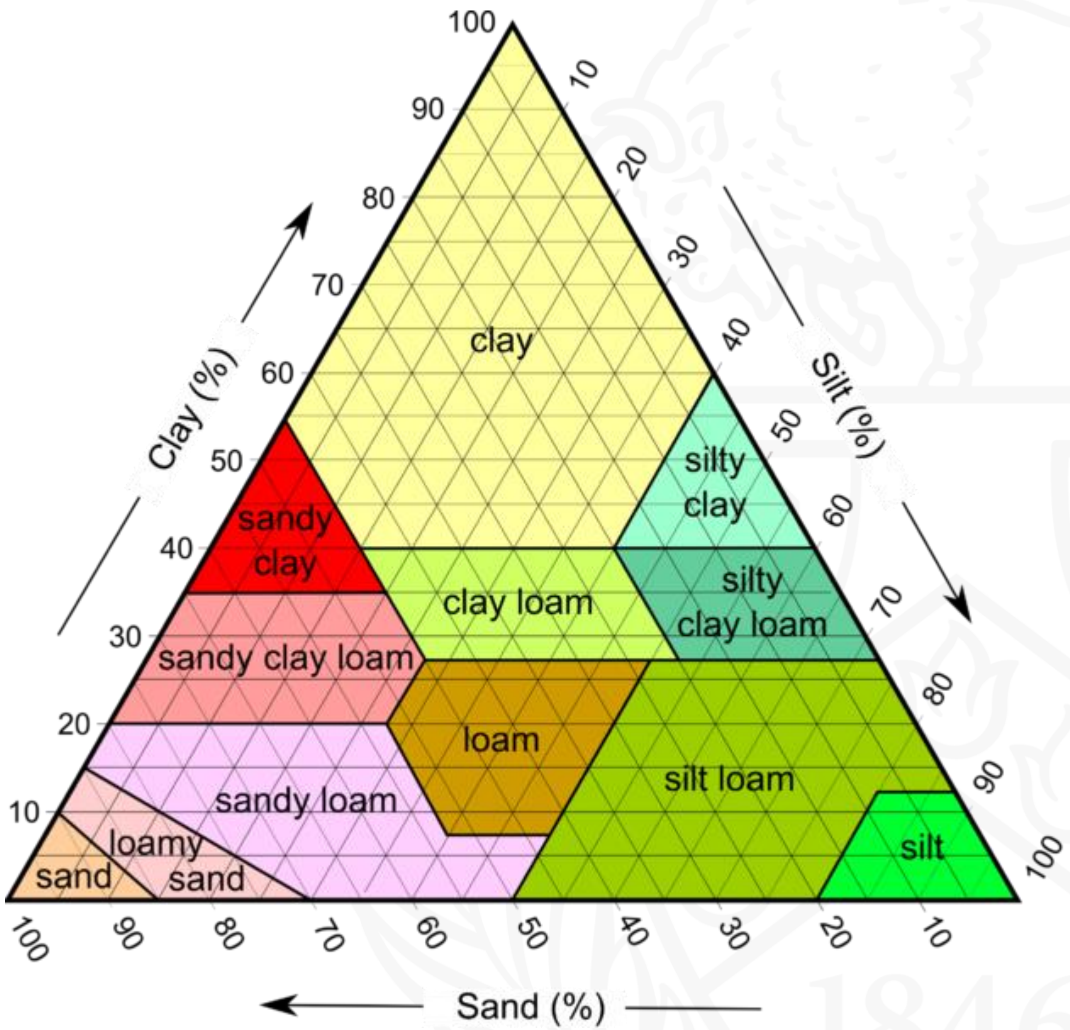
- Made up of three components for each elevation band and vegetation type

- ET
  - Canopy evaporation
  - Canopy transpiration
  - Bare soil surface evaporation

- Bare soil calculations are similar but include resistance terms for soil-atmosphere moisture transfer

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



VIC resources

- Current VIC website:
  - https://vic.readthedocs.io/en/master/

- Source Code Availability
  - https://github.com/UW-Hydro/VIC

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