Precipitation, Infiltration, Evapotranspiration, and Wind

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IWR

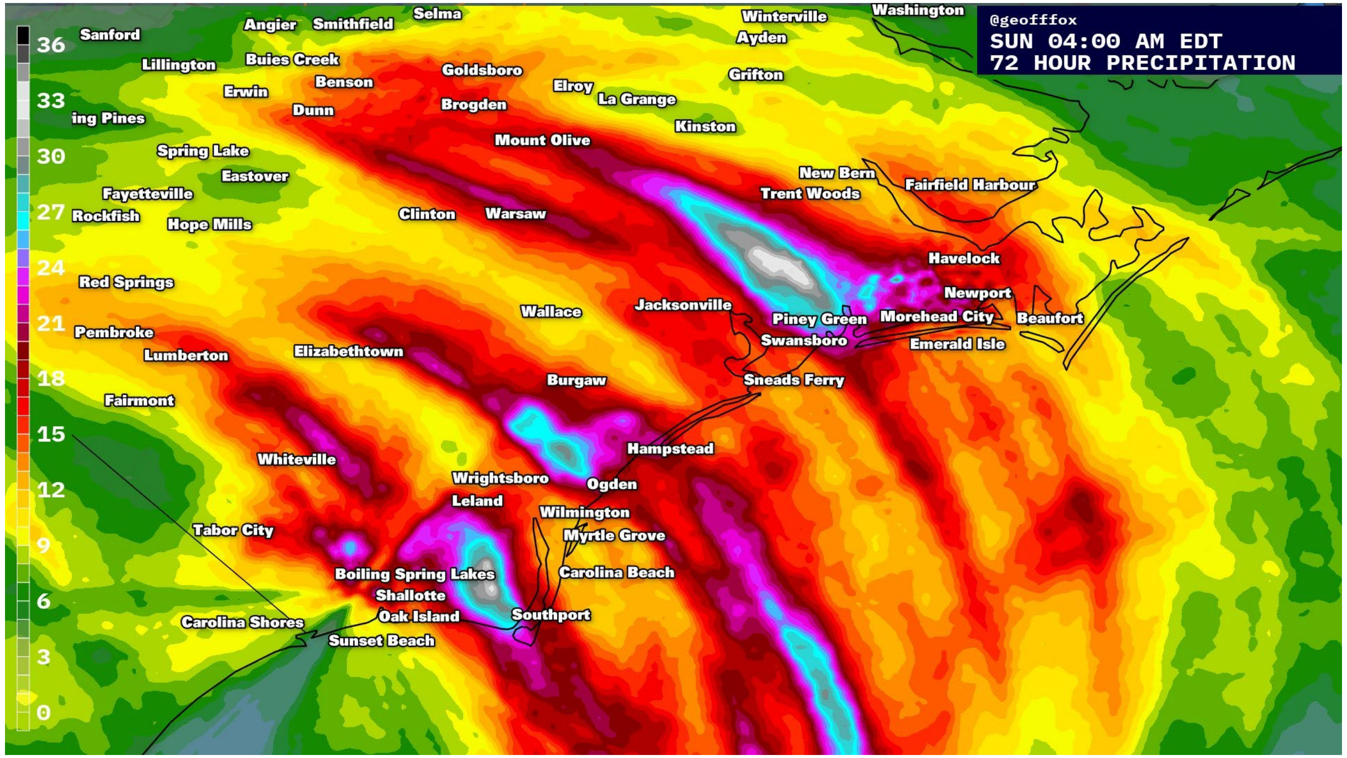
HEC

Overview

- Precipitation
  - Input Data Types
- Infiltration
  - Methods
  - Input Data
- Evapotranspiration
  - Methods
- Percent Impervious
- Wind
  - Formulation and Options
  - Input Data

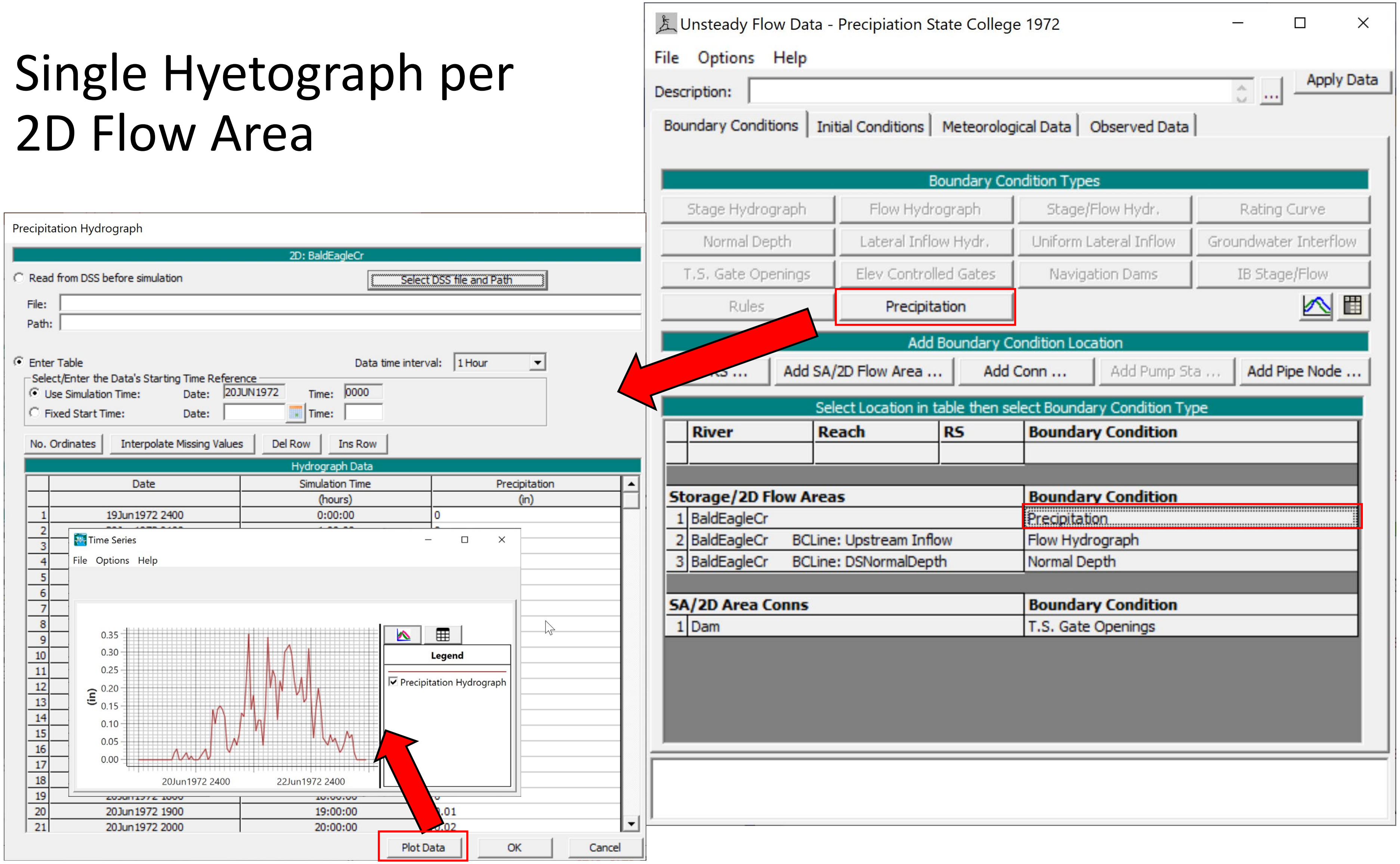
Precipitation

- Per 2D Flow Area
- Global
  - Constant Rate
  - Gridded Data
    - HEC-DSS file format (from HEC-MetView)
    - National Weather Service
      - GRIB
      - NetCDF
    - National Centers for Environmental Information
      - NetCDF
  - Point Gage Data
    - HEC-DSS time series
      - Regular Interval
      - Irregular Interval
    - User-specified time-series



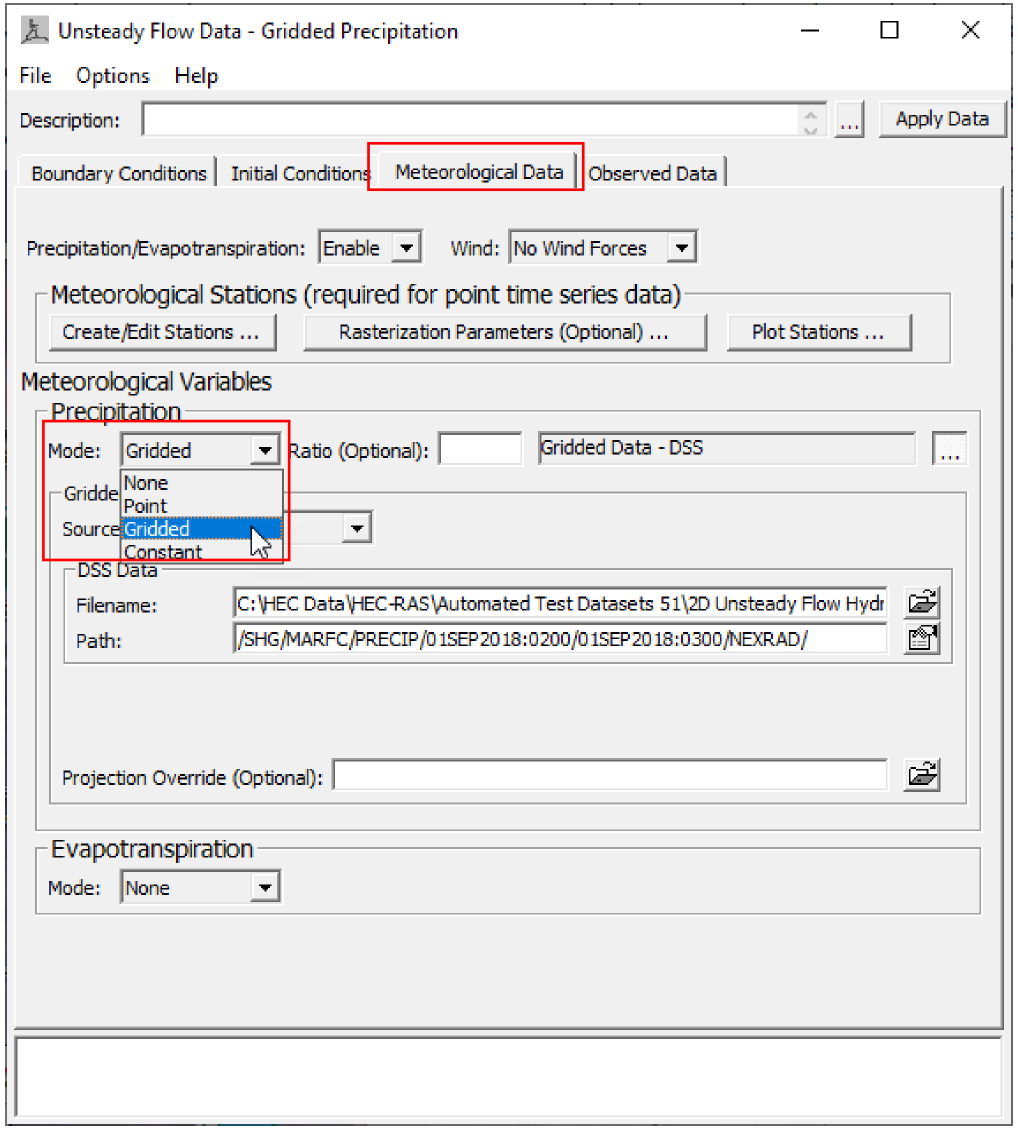
Boundary Conditions

- Single Hyetograph per 2D Flow Area



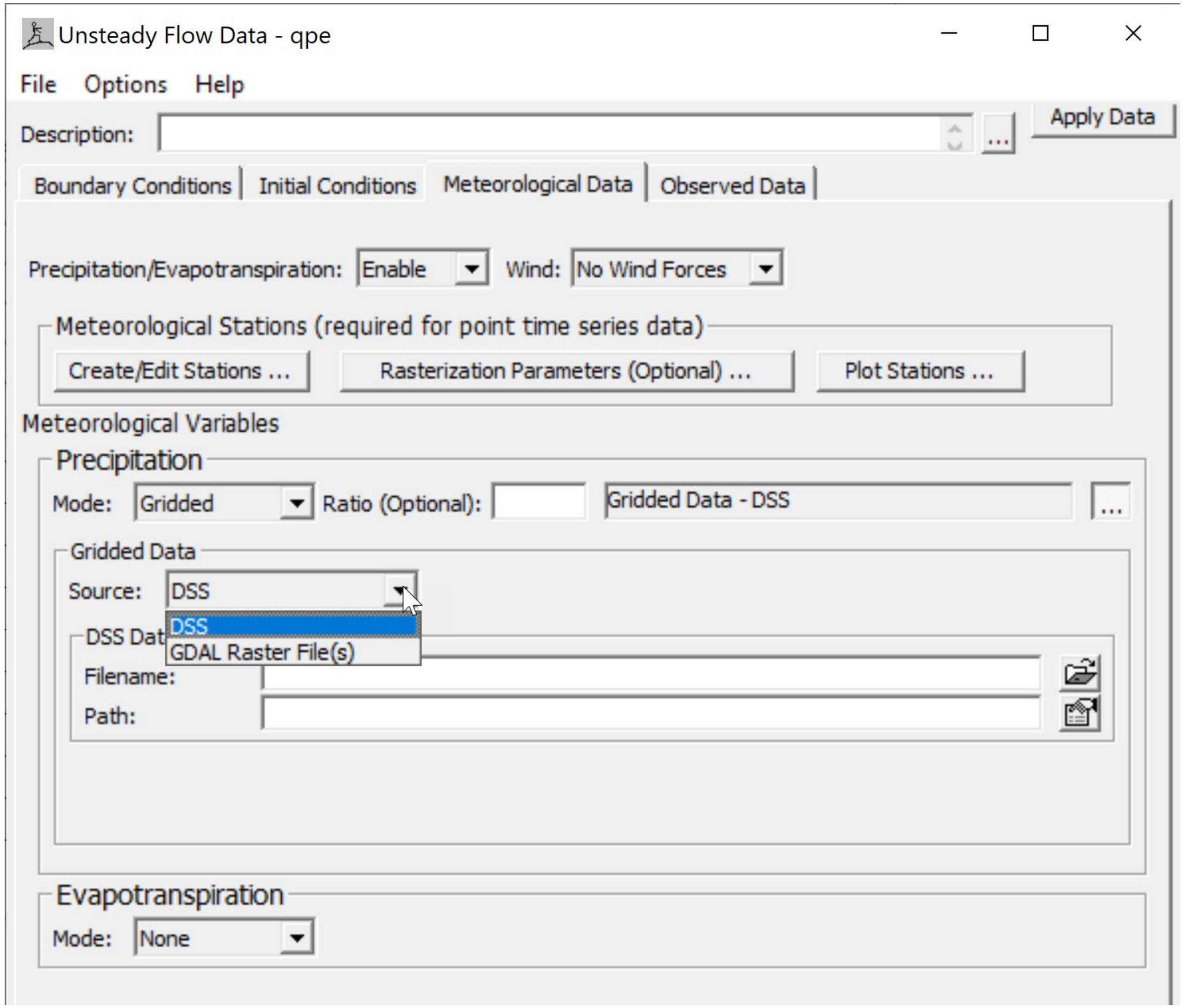
Meteorological Data - Precipitation

- Gridded Data
  - HEC-DSS file format (from HEC-MetView)
  - National Weather Service
    - GRIB
    - NetCDF
  - National Centers for Environmental Information
    - NetCDF
- Meteorological Station Data
  - HEC-DSS time series
    - Regular Interval
    - Irregular Interval
  - User Entered into a Table
- Constant Rate



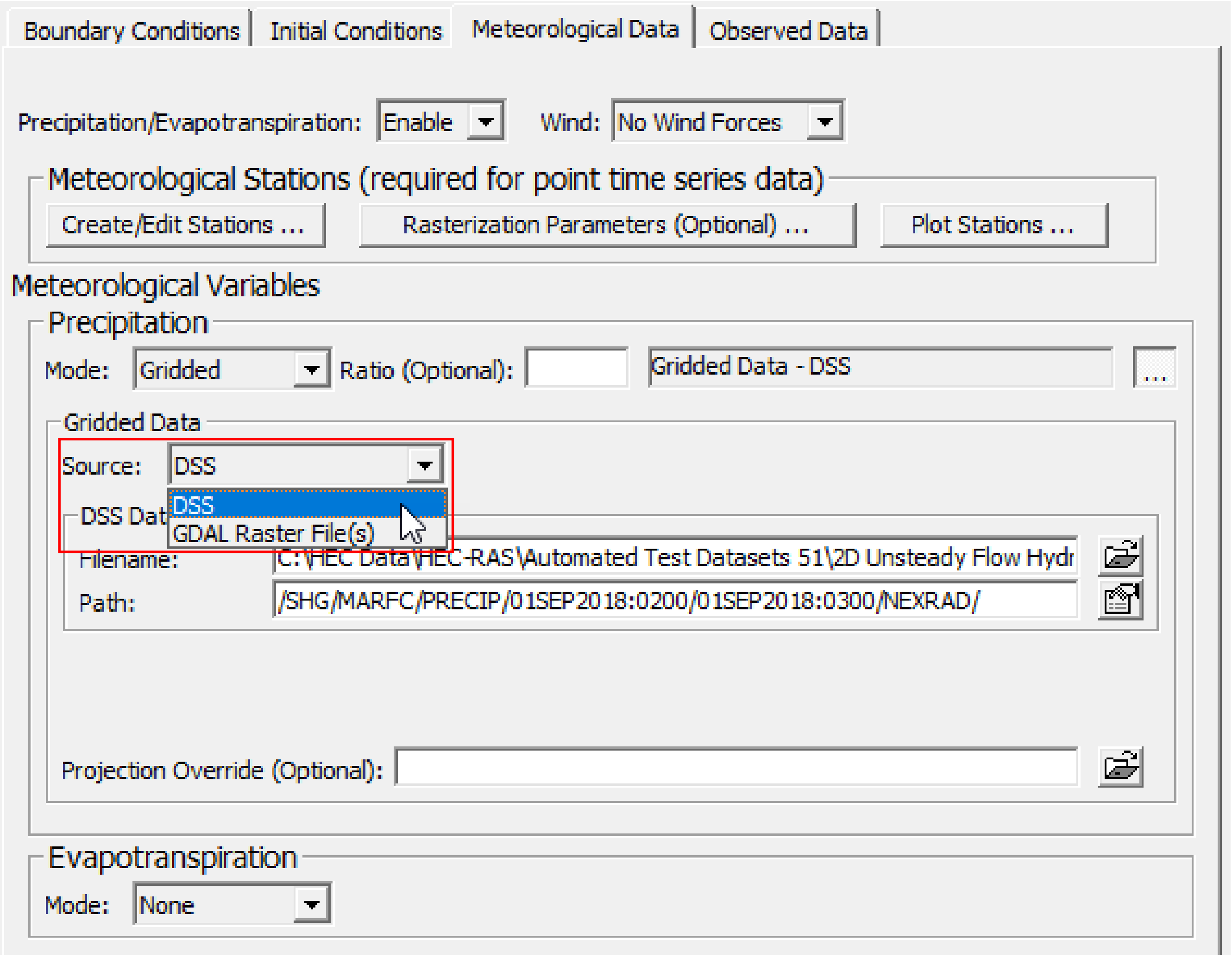
Gridded Precipitation

- Input Formats
  - DSS Grids
  - GDAL Raster File(s)
    - NetNCDF
    - GRIB
    - etc.
- Ratio (Optional)
  - Used to scale precipitation

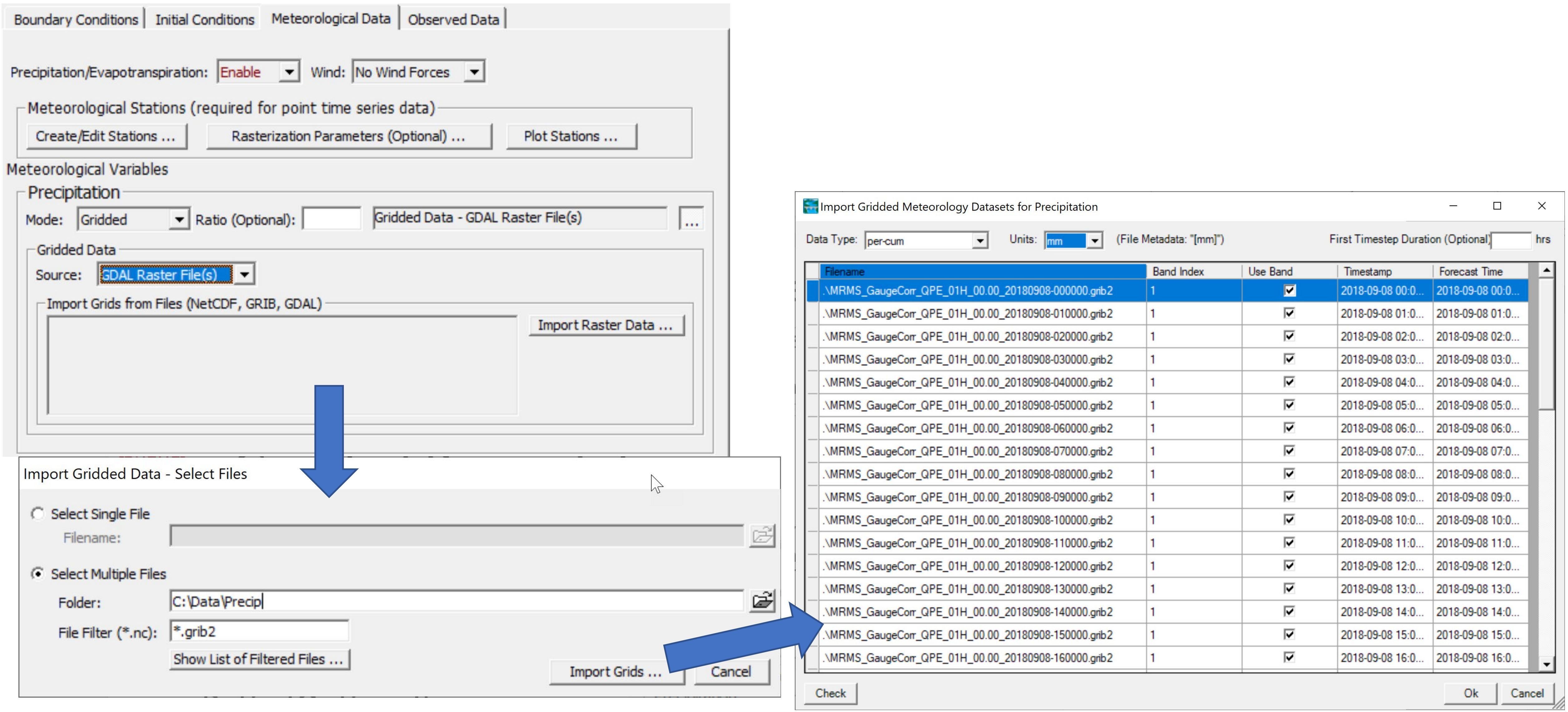


Gridded Precipitation

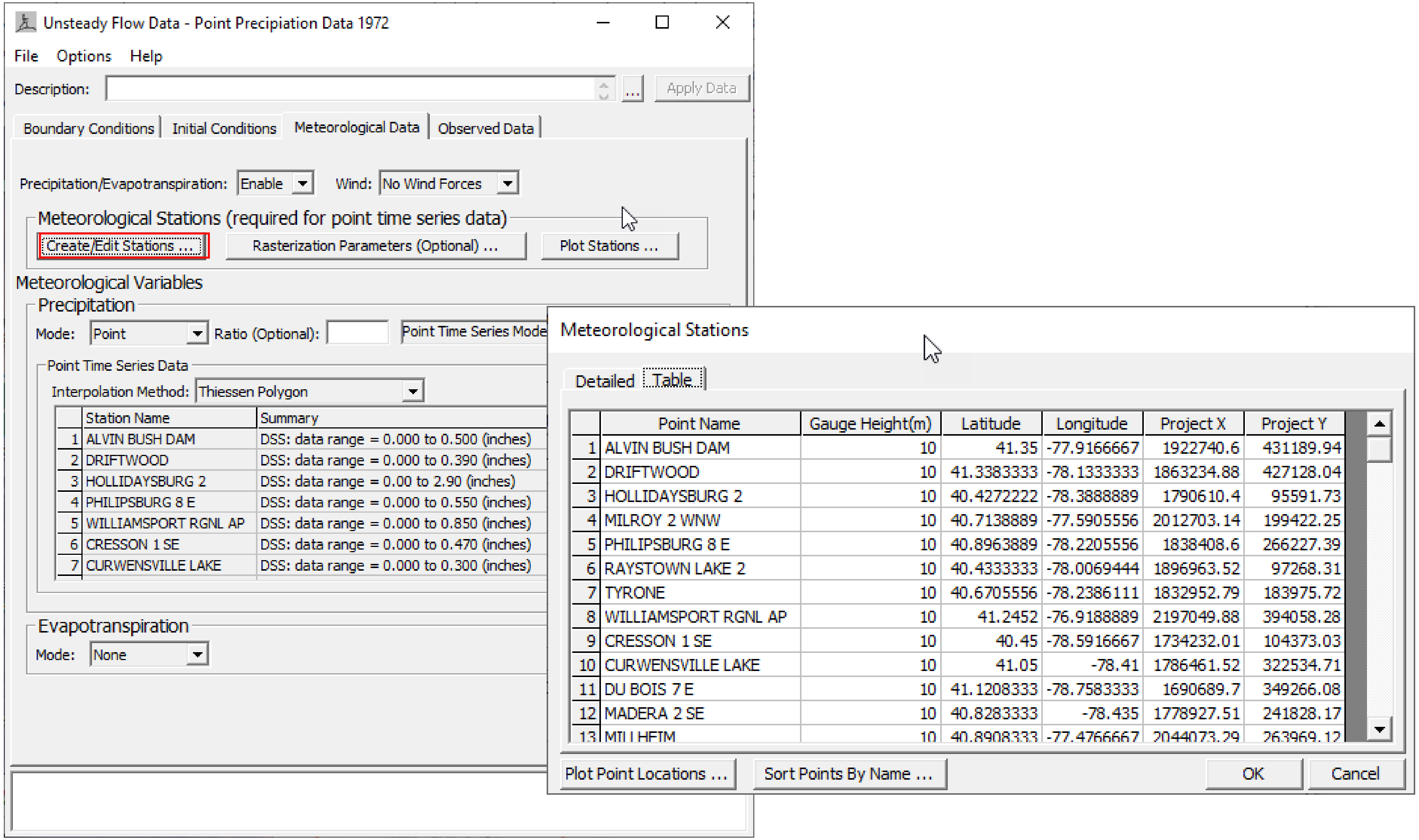
- Projection Override
  - If data has a different projection from RAS project



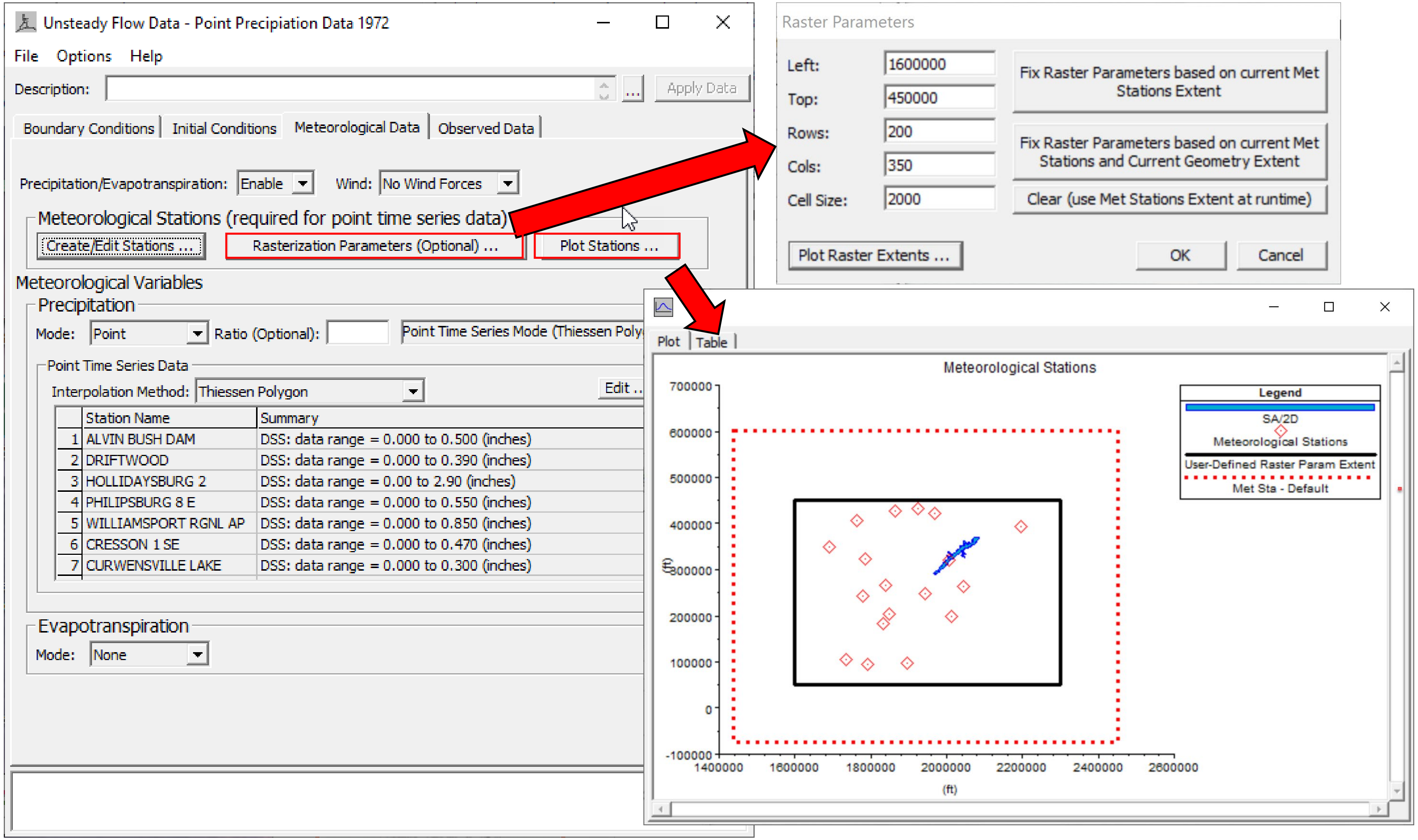
Gridded Precipitation - GRIB



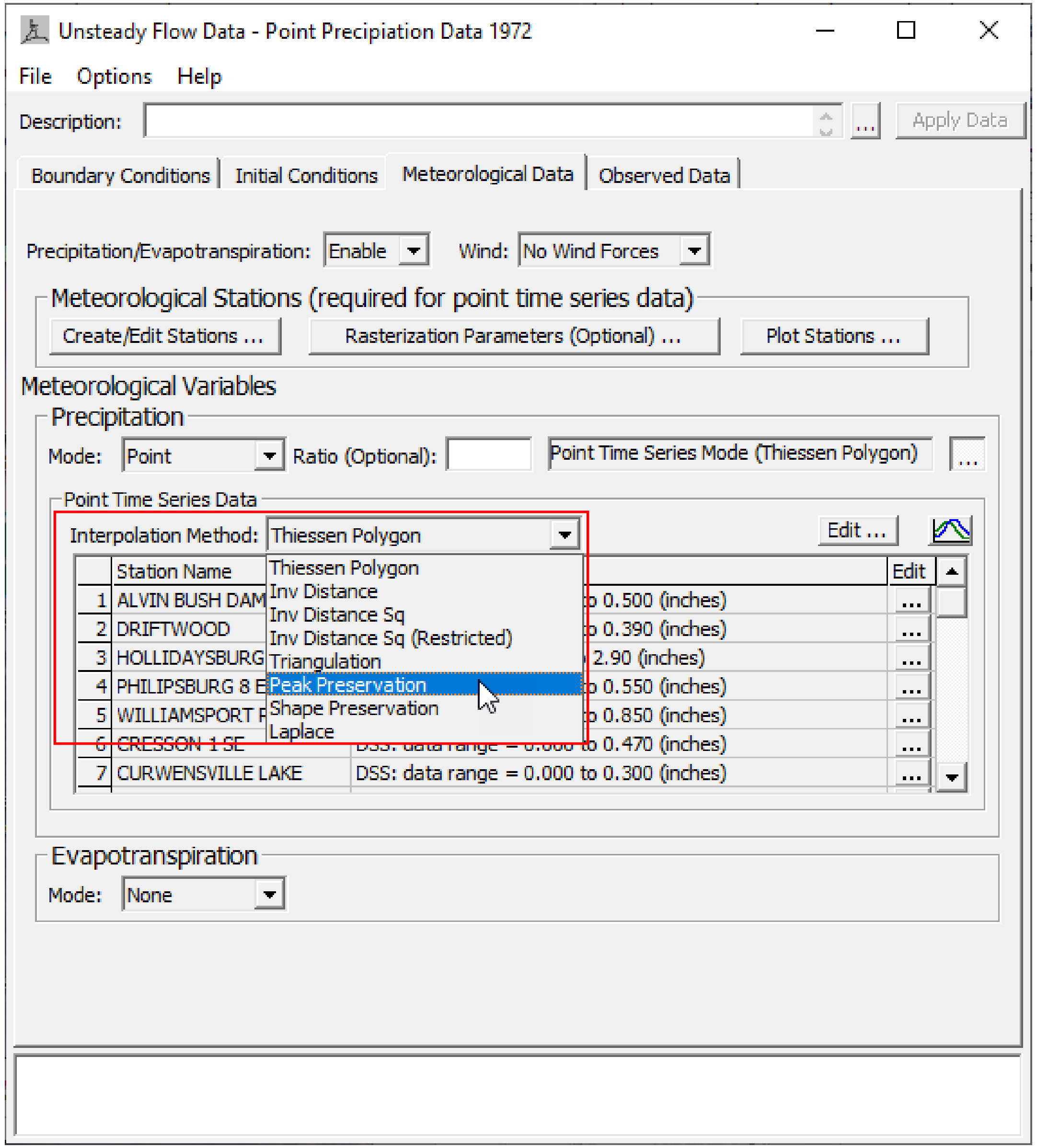
Point Gage Precipitation



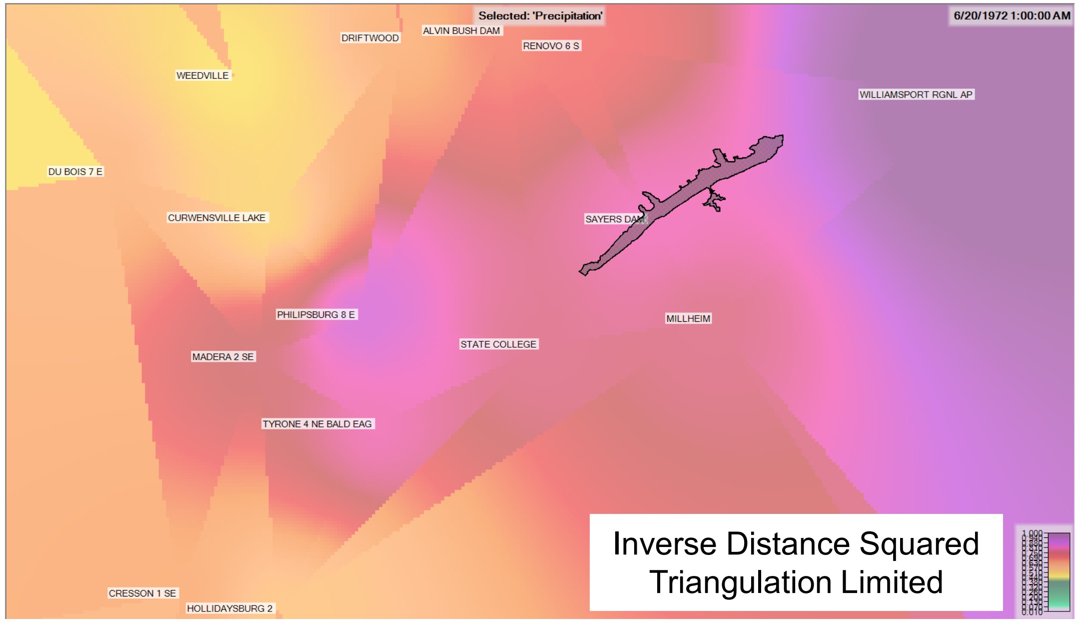
Point Gage Precipitation

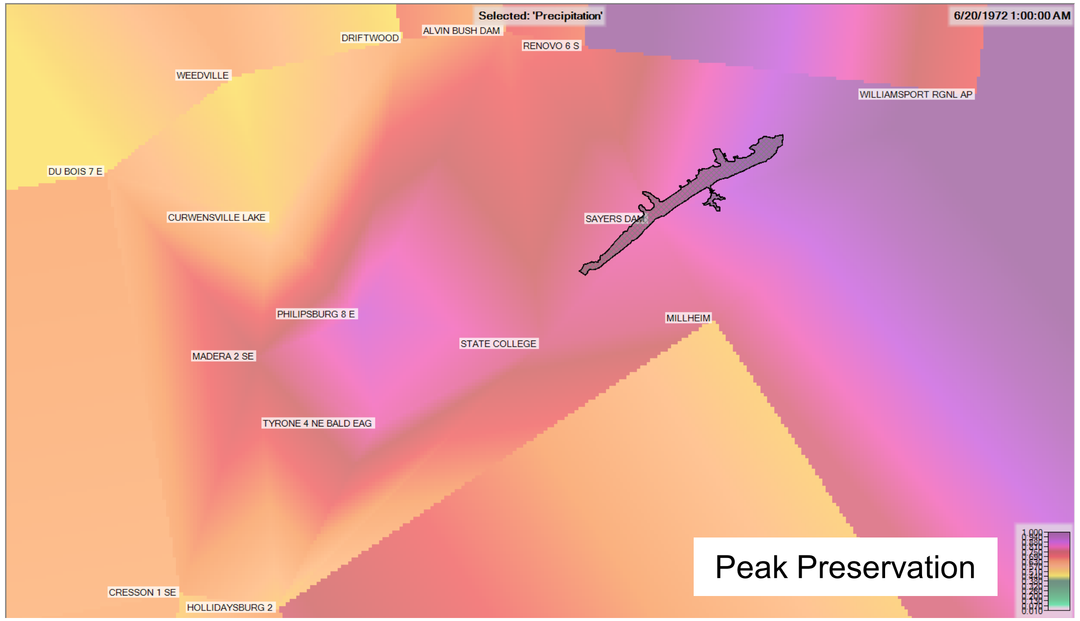


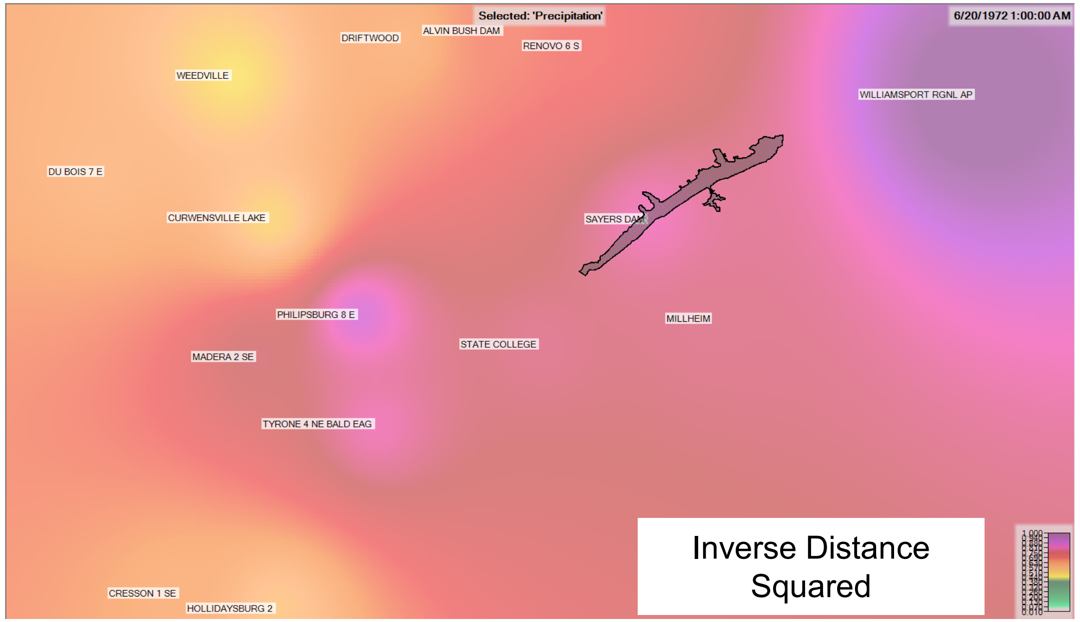
Point Gage Interpolation Methods

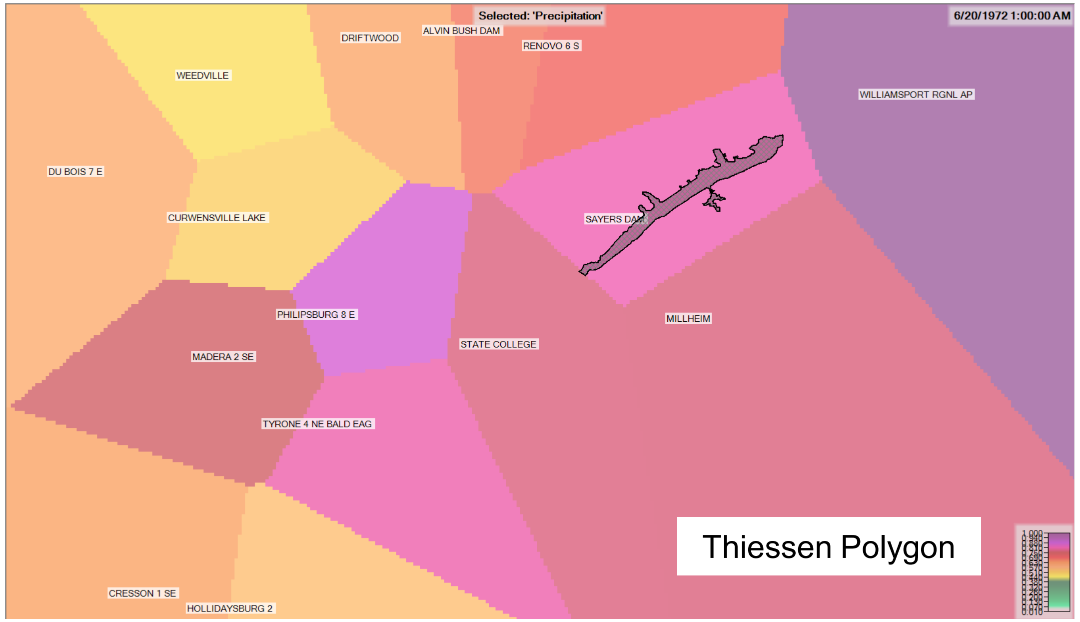


Cumulative Rainfall

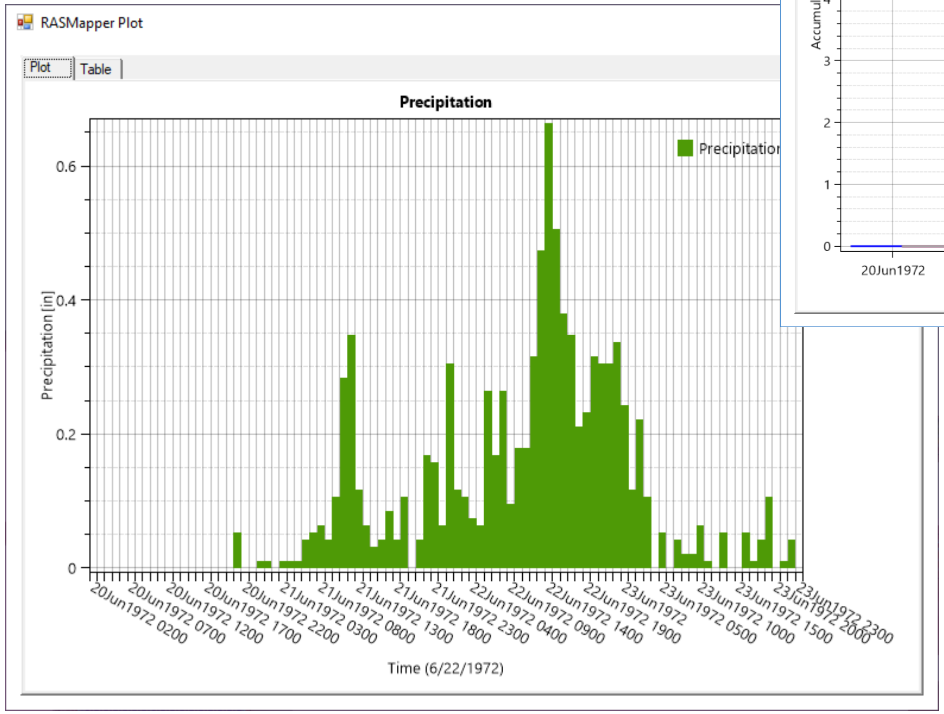


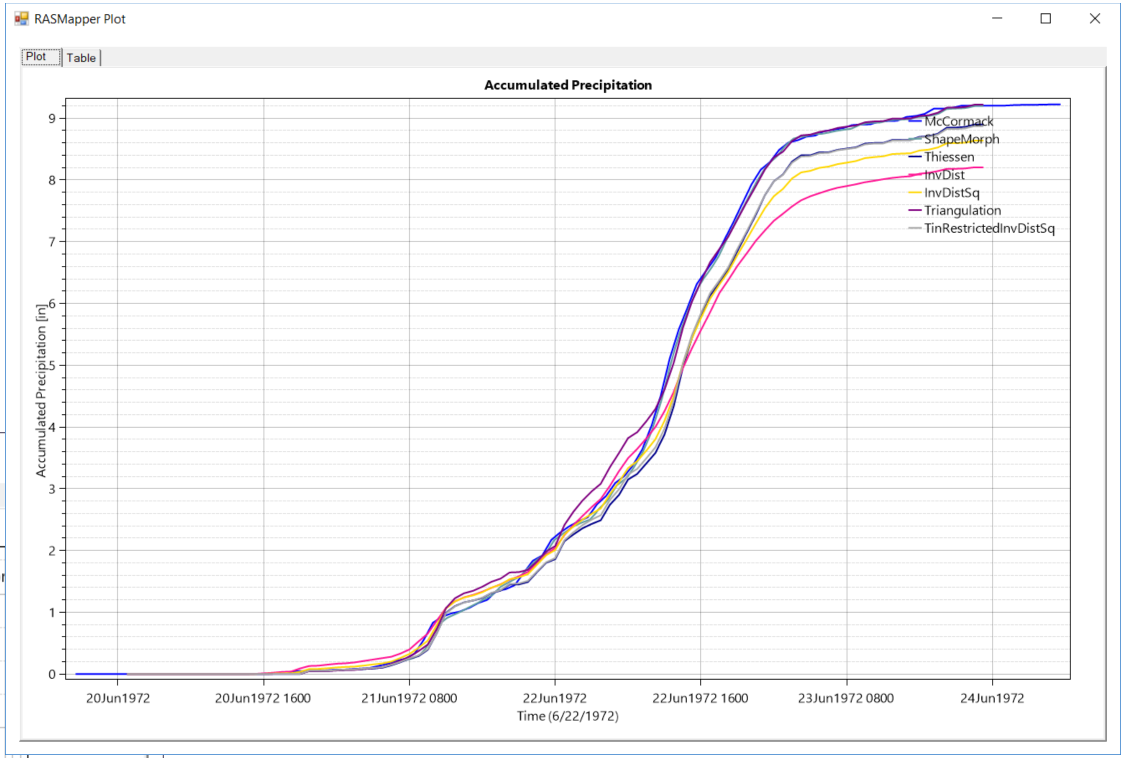




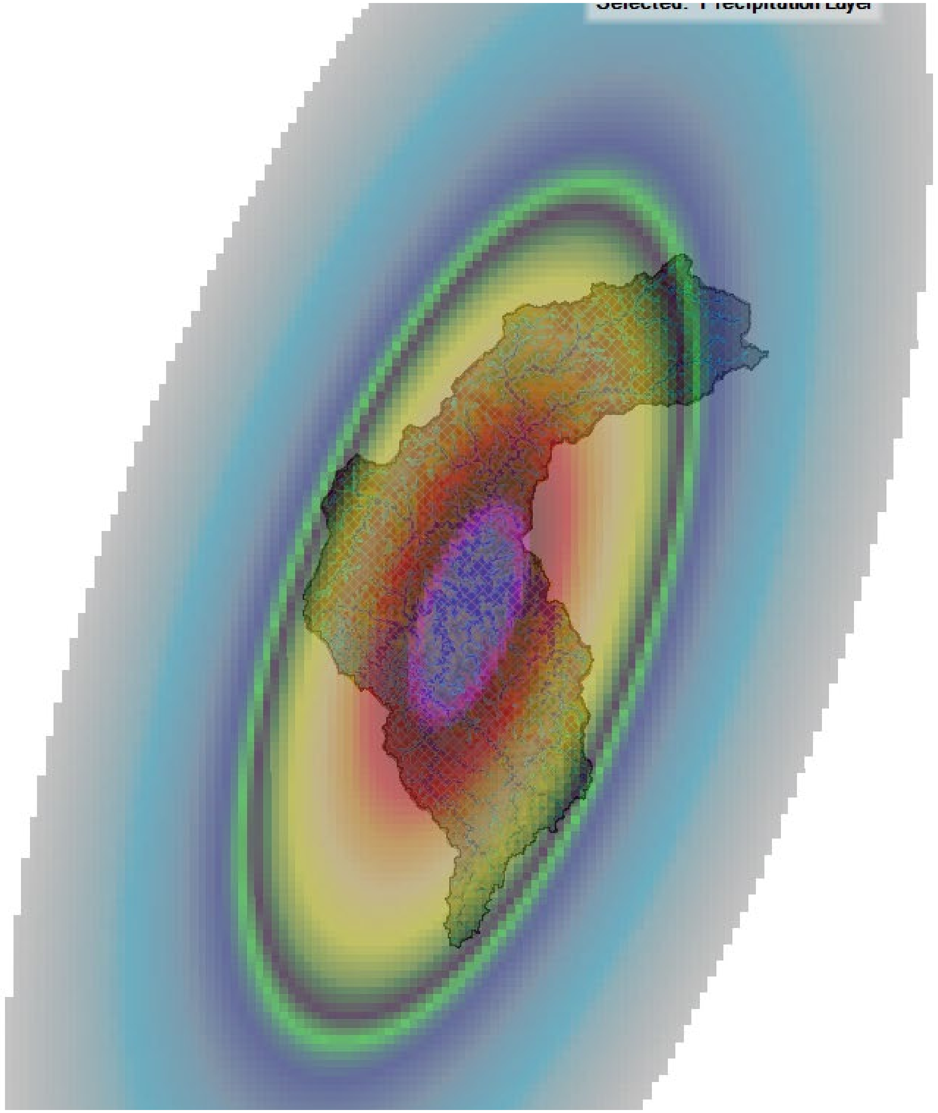


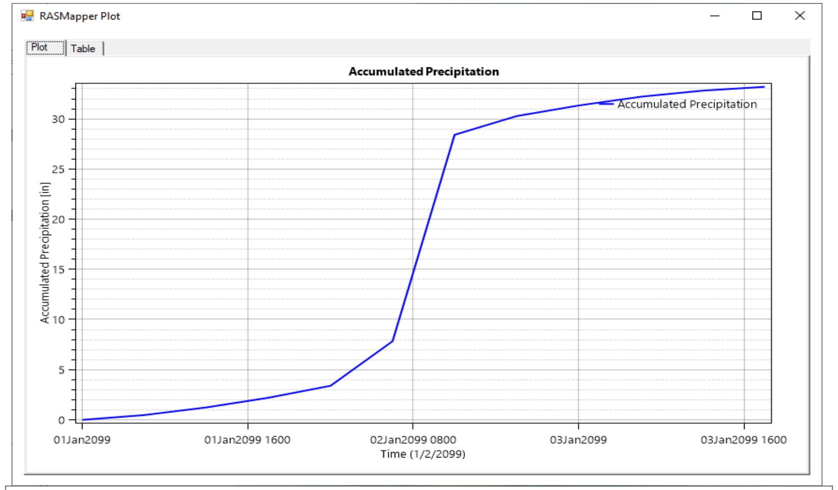
Rainfall Time Series Plots

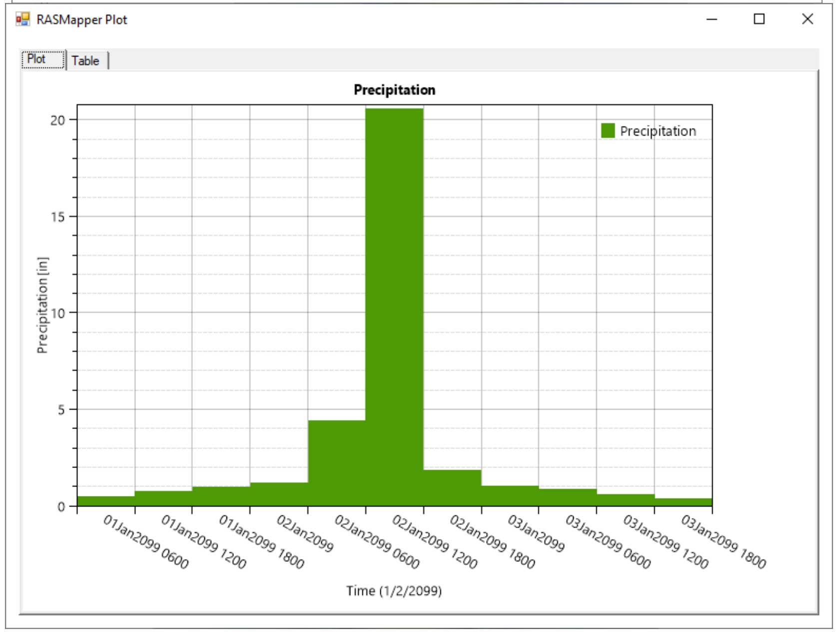




Probable Max Precipitation Example







Infiltration

- Computed at 1D XS's, Storage Areas, and 2D Cells
- Supported in all Equation Sets
- Methods
  - Deficit-Constant (DC)
  - SCS Curve Number (CN)
  - Green and Ampt without (GA) and with Redistribution (GAR)
- Parameterization based on
  - Soils
  - Land cover
- Other Optional Data
  - Percent Impervious

Deficit-Constant Method

- Governing Equation

$$\frac{dD}{dt} = E_v - f + p$$

where

D: Soil moisture deficit [L]

E_v: Soil evaporatranspiration [L/T]

f: Infiltration [L/T]

p: Percolation [L/T]

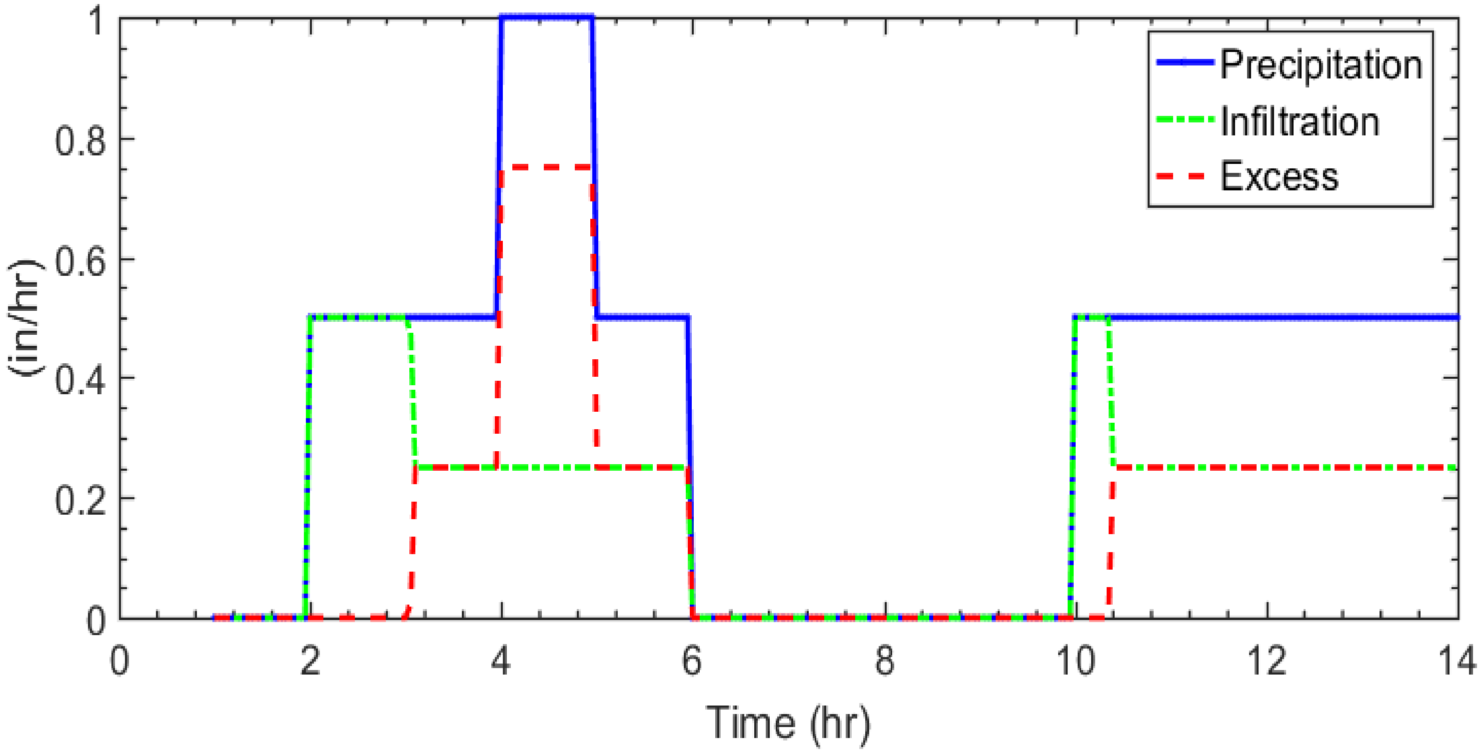
- Input
  - ▶ Initial deficit [L]
  - ▶ Maximum deficit [L]
  - ▶ Potential percolation rate (loss rate) [L/T]

SCS Soil Group	Description	Loss Rates (in/hr)
A	Deep sand, deep loess, aggregated silts	0.3 - 0.45
B	Shallow loess, sandy lam	0.15 - 0.30
C	Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay	0.05 - 0.15
D	Soils that swell significantly when wet, heavy plastic clays, and certain saline soils	0.00 – 0.05

Deficit-Constant Verification

- Comparison with HEC-HMS dataset from PROSPECT Class

Time (hrs)	Precipitation (in)	Deficit (in)	Loss (in)	Excess (in)
1	0.0	0.5	0.0	0.0
2	0.5	0.0	0.5	0.0
3	0.5	0.0	0.25	0.25
4	1.0	0.0	0.25	0.75
5	0.5	0.0	0.25	025
6	0.0	0.05	0.0	0.0
7	0.0	0.1	0.0	0.0
8	0.0	0.15	0.0	0.0
9	0.0	0.2	0.0	0.0
10	0.5	0	0.35	0.15
11	0.5	0	0.25	0.25
12	0.5	0	0.25	0.25
13	0.5	0	0.25	0.25
14	0.5	0	0.25	0.25



SCS Curve Number Method

- Equations

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \qquad S = \frac{1000}{CN} - 10 \qquad I_a = r_a S$$

where

P_e : Accumulated excess depth [L]

P : Accumulated rainfall depth [L]

CN: Curve number [-]

I_a: Initial abstraction [L]

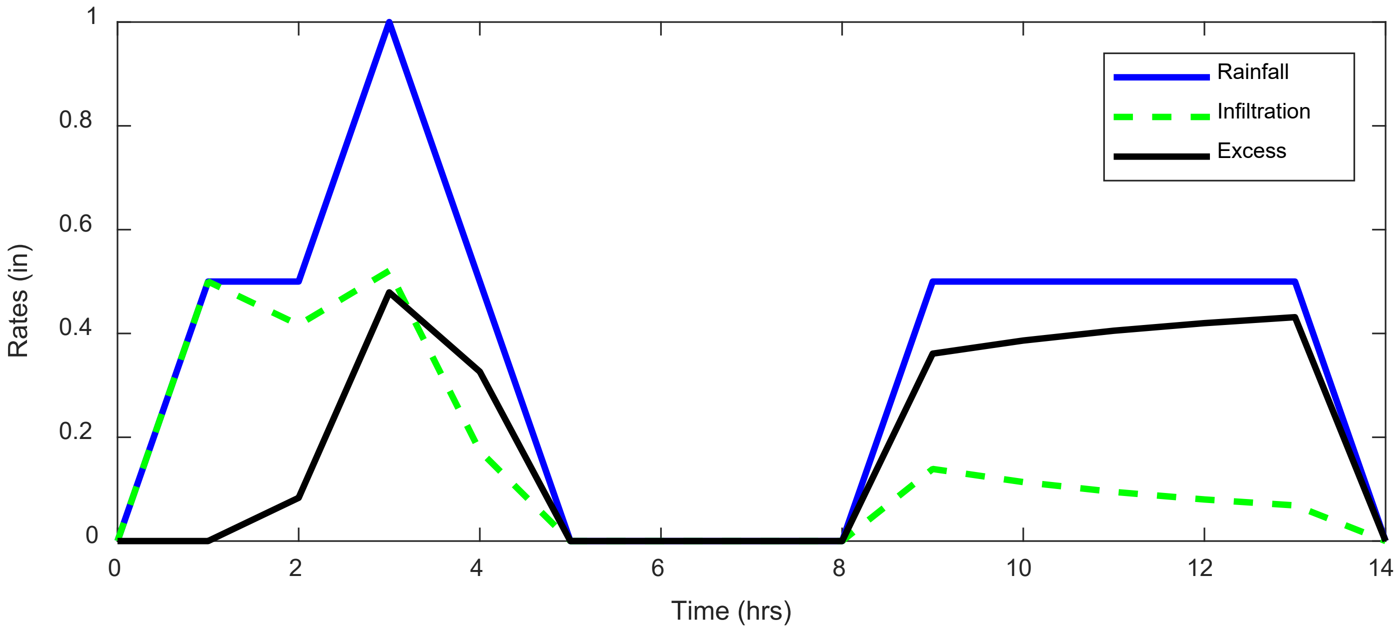
r_a : Abstraction ratio [-]

S : Potential maximum retention [L]

- Input
  - Curve Number
  - Abstraction ratio
  - Minimum infiltration rate (optional)
  - Dry period used to reset method (optional)

Cover			Hydrologic Soil Group			
Land Use	Treatment or Practice	Hydrologic Condition	A	B	C	D
Fallows	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
	Contoured	Good	39	61	74	80
		Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads (dirt)			72	82	87	89
(hard surface)			74	84	90	92

SCS CN Verification



Time	Precip (in)	HEC-HMS Loss (in)	Computed Loss (in)	HEC-HMS Excess (in)	Computed Excess (in)
1:00	0	0	0	0	0
2:00	0.5	0.5	0.5	0	0
3:00	0.5	0.417	0.4167	0.083	0.0833
4:00	1	0.521	0.5208	0.479	0.4792
5:00	0.5	0.174	0.1736	0.326	0.3264
6:00	0	0	0	0	0
7:00	0	0	0	0	0
8:00	0	0	0	0	0
9:00	0	0	0	0	0
10:00	0.5	0.139	0.1389	0.361	0.3611
11:00	0.5	0.114	0.1136	0.386	0.3864
12:00	0.5	0.095	0.0947	0.405	0.4053
13:00	0.5	0.08	0.0801	0.42	0.4199
14:00	0.5	0.069	0.0687	0.431	0.4313

Green-Ampt Method

- Equations

$$\frac{dF}{dt} = f \qquad f = \min(f_*, R) \qquad f_* = K_s\left(1 + \frac{\psi\theta_d}{F}\right)$$

where

f : Infiltration potential [L/T]

f_* : Infiltation potential (infiltration rate given unlimited [L/T]

R : Rainfall [L/T]

ψ : Wetting front suction [L]

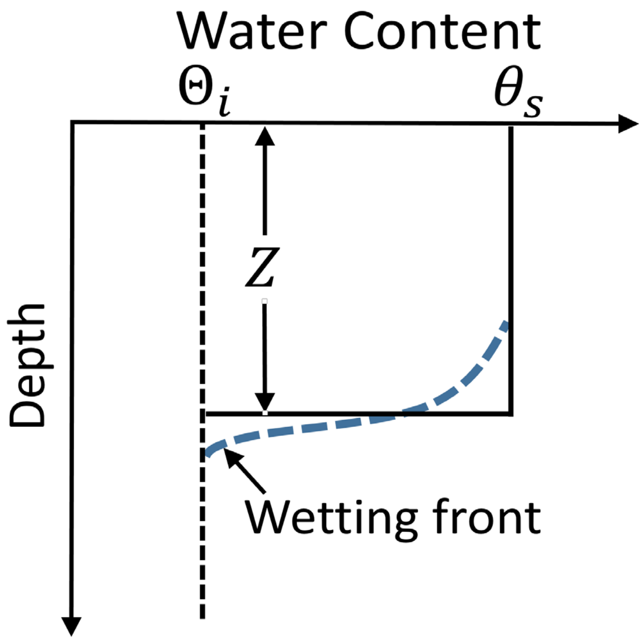
K_s : Saturated hydraulic conductivity [L/T]

F : Cumulative infiltration depth [L]

$\theta_d = \theta_s - \theta_i$: Moisture deficit [-]

θ_s : Saturated moisture content [-]

θ_i : Initialmoisture content [-]



Green-Ampt Input Parameters

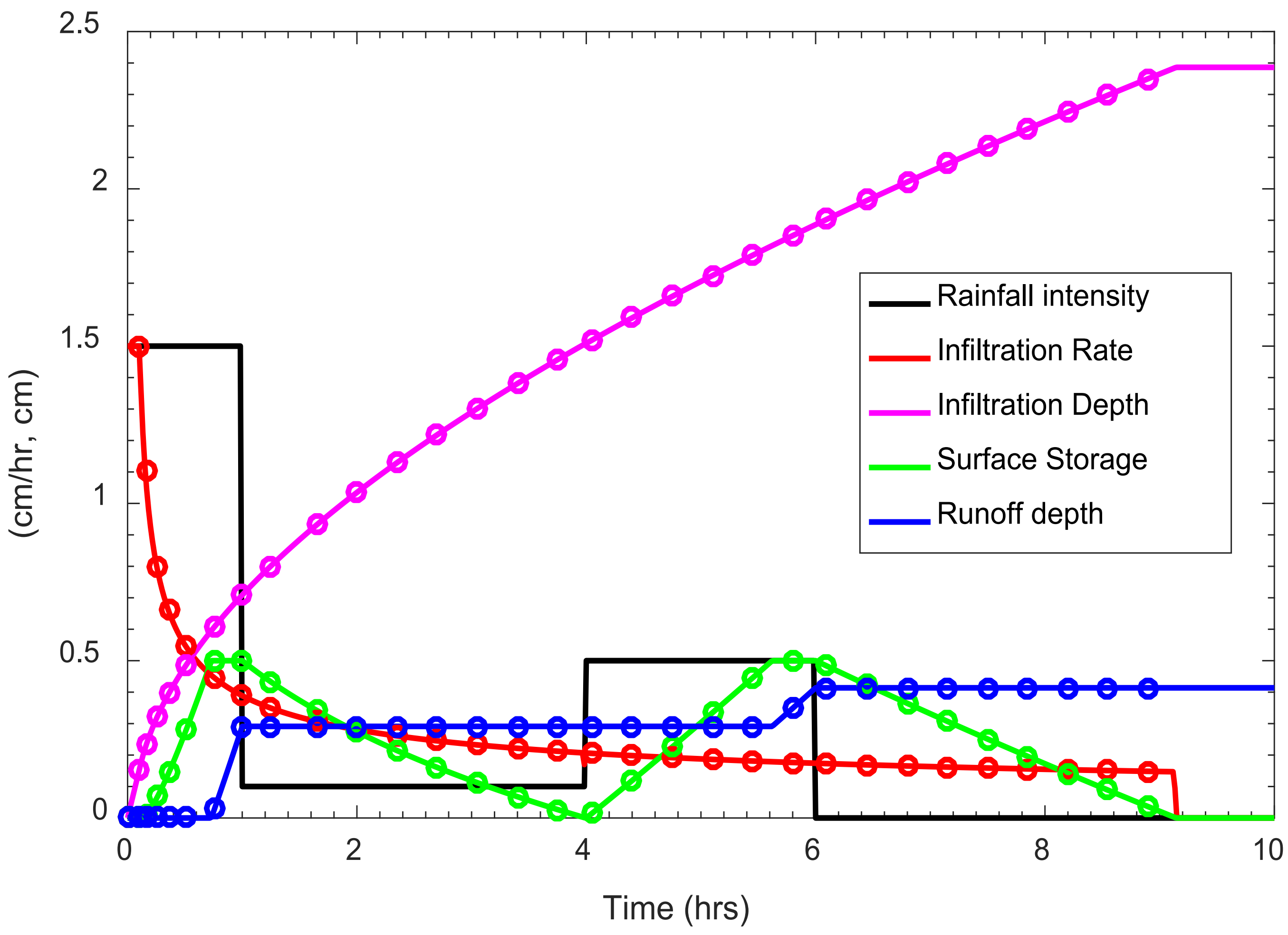
- GA
  - Initial soil water content [-]
  - Saturated hydraulic conductivity []
  - Wetting Front Suction [L]
- GAR (optional)
  - Same GA plus
  - Residual Water Content [-]
  - Pore-size distribution index
  - If either parameter is missing GA is used

Soil Texture	Residual Water Content (-)	Total Porosity (-)	Pore-size Distribution Index (-)	Saturated Hydraulic Conductivity (cm/hr)	Wetting Front Suction (cm)
Sand	0.02	0.437	0.694	21.0	10.6
Loamy sand	0.035	0.437	0.553	6.11	14.2
Sandy loam	0.041	0.453	0.378	2.59	22.2
Loam	0.027	0.463	0.252	1.32	31.5
Silt loam	0.015	0.501	0.234	0.68	40.4
Sandy clay loam	0.068	0.398	0.319	0.43	44.9
Clay loam	0.075	0.464	0.242	0.23	44.6
Silty clay loam	0.040	0.471	0.177	0.15	58.1
Sandy clay	0.109	0.430	0.223	0.12	63.6
Silty clay	0.056	0.479	0.150	0.09	64.7
Clay	0.09.	0.475	0.165	0.06	71.4

Green-Ampt Verification

- Comparison with code by Daliakopoulos (2015)
  - Computed – solid lines
  - Daliakopoulos (2015) - Circles

Parameter	Value
Saturated hydraulic conductivity (cm/hr)	0.044
Wetting front suction (cm)	22.4
Saturated water content (-)	0.499
Residual water content (-)	0.03
Initial water content (-)	0.25



Redistribution Method (GAR)

- Governing Equation (Ogden and Saghafian 1997)

$$\frac{d\theta_0}{dt} = \frac{1}{Z_0}\left\{ f - E_v - K_i - \left[K_0 + \frac{K_s G(\theta_i, \theta_o)}{Z_0} \right] \right\}$$

where

$G(\theta_i, \theta_o)$: Integral of the capillary drive through the saturated front [L]

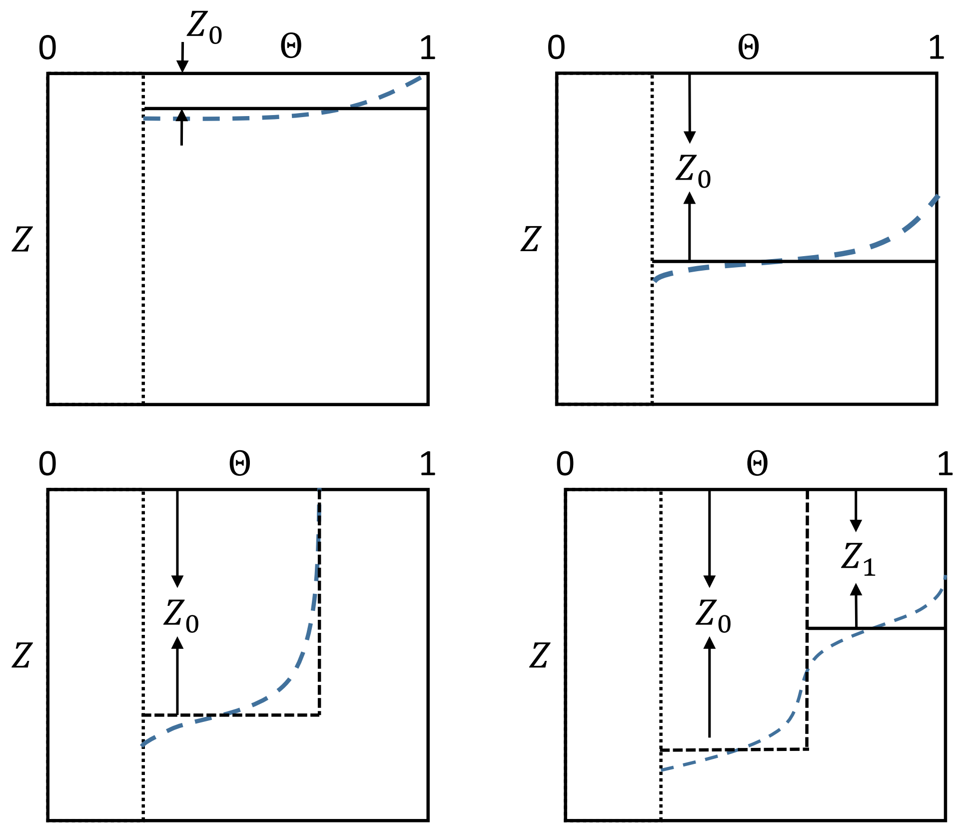
$Z_0 = F_0 / (\theta_0 - \theta_i)$: Depth of wetting front [L]

F_0: Cumulative infiltration [L]

θ_0: Soil moisture content corresponding to unsaturated front [L]

$K_0 = K(\theta_0)$: Unsaturated hydraulic conductivity corresponding to θ_0 [L/T]

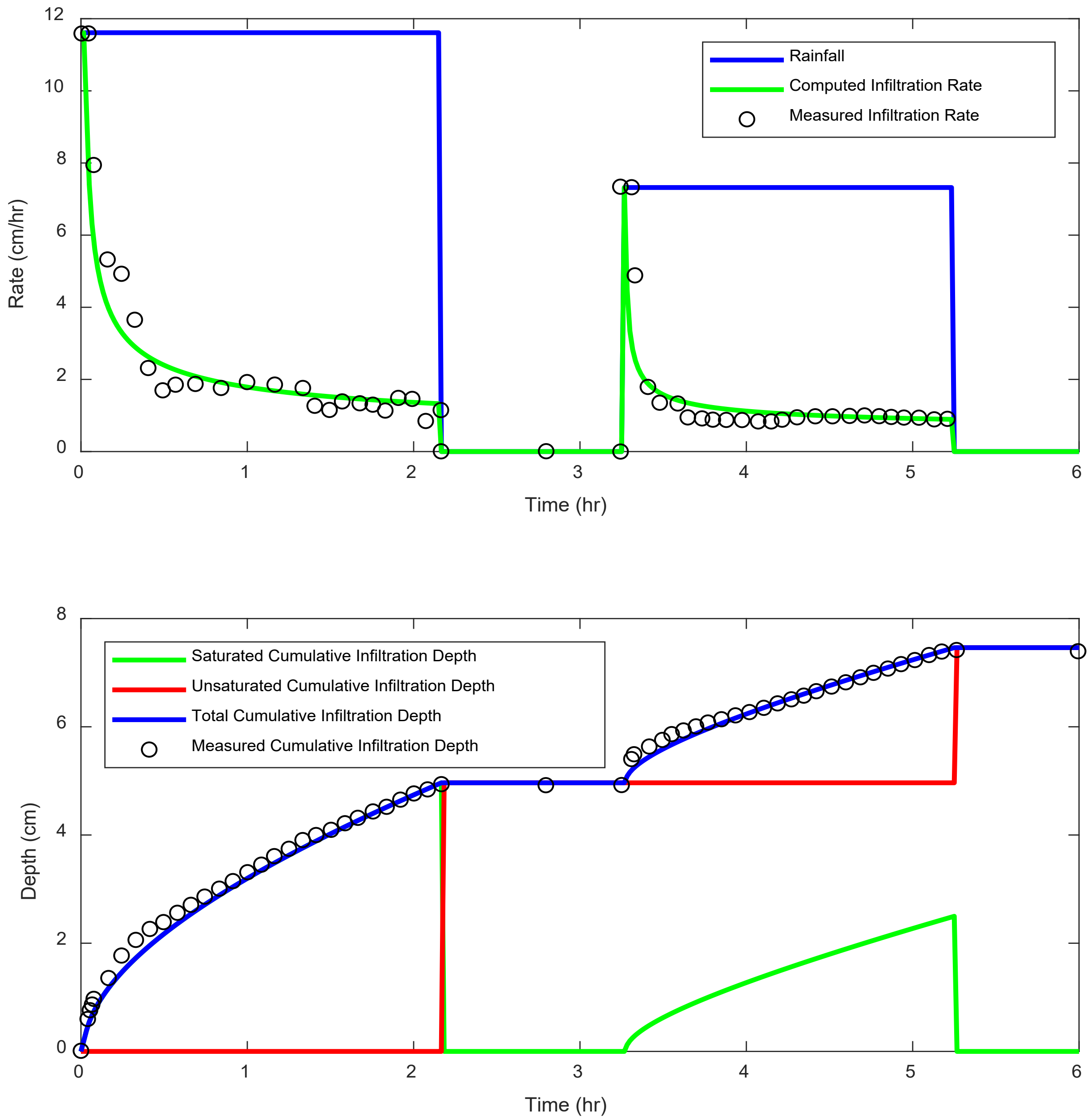
$K_i = K(\theta_i)$: Unsaturated hydraulic conductivity corresponding to θ_i [L/T]



GAR Validation

- Comparison with Alapaha Sand Tests (Rawls et al. 1976)

Parameter	Value
Saturated hydraulic conductivity (cm/hr)	0.47
Suction at the wetting front (cm)	45
Saturated water content (-)	0.38
Residual water content (-)	0.06
Initial water content (-)	0.19
Pore distribution index	0.45



Percent Impervious and Surface Excess

- Percent Impervious
  - Associated with **Land Cover** classification layer
  - Between 0 and 100
  - Usually set to 100 for open water
- Surface Excess Rate

$$v = R - \left(1 - \frac{P_{imp}}{100}\right) f$$

v : Excess [L/T]

R : Rainfall [L/T]

f : Infiltration [L/T]

P_{imp} : Percent impervious [%]

Evapotranspiration

- Evapotranspiration Potential ET_0
- Actual Evapotranspiration

$$ET = E_h + E_v$$

where

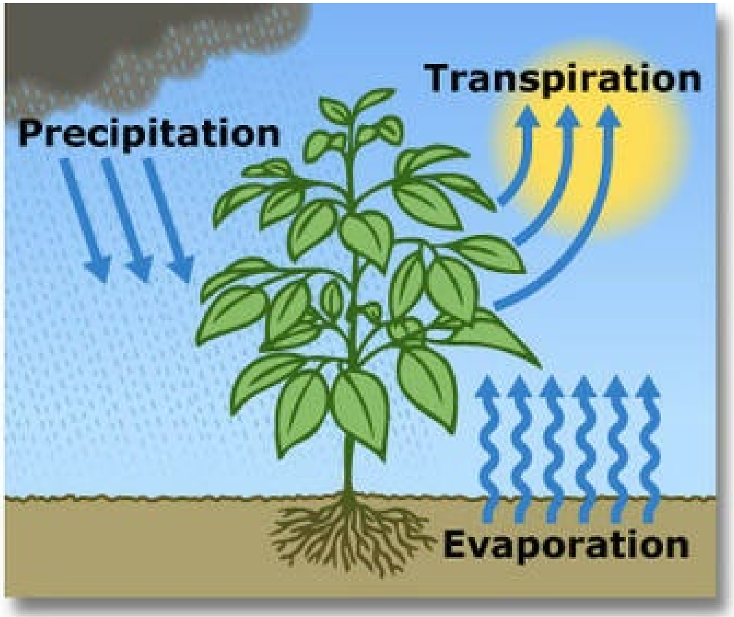
$E_h = \min\left(ET_0, h/\Delta t\right)$: Surface water evaporation [L/T]

$E_v = \min\left(ET_0 - E_h, S_w/\Delta t\right)$: Evapotranspiration [L/T]

h : Water depth [L]

S_w: Soil water [L]

Δt : Time step [T]



- Input Data Modes
  - Constant, Point Gage, or Gridded

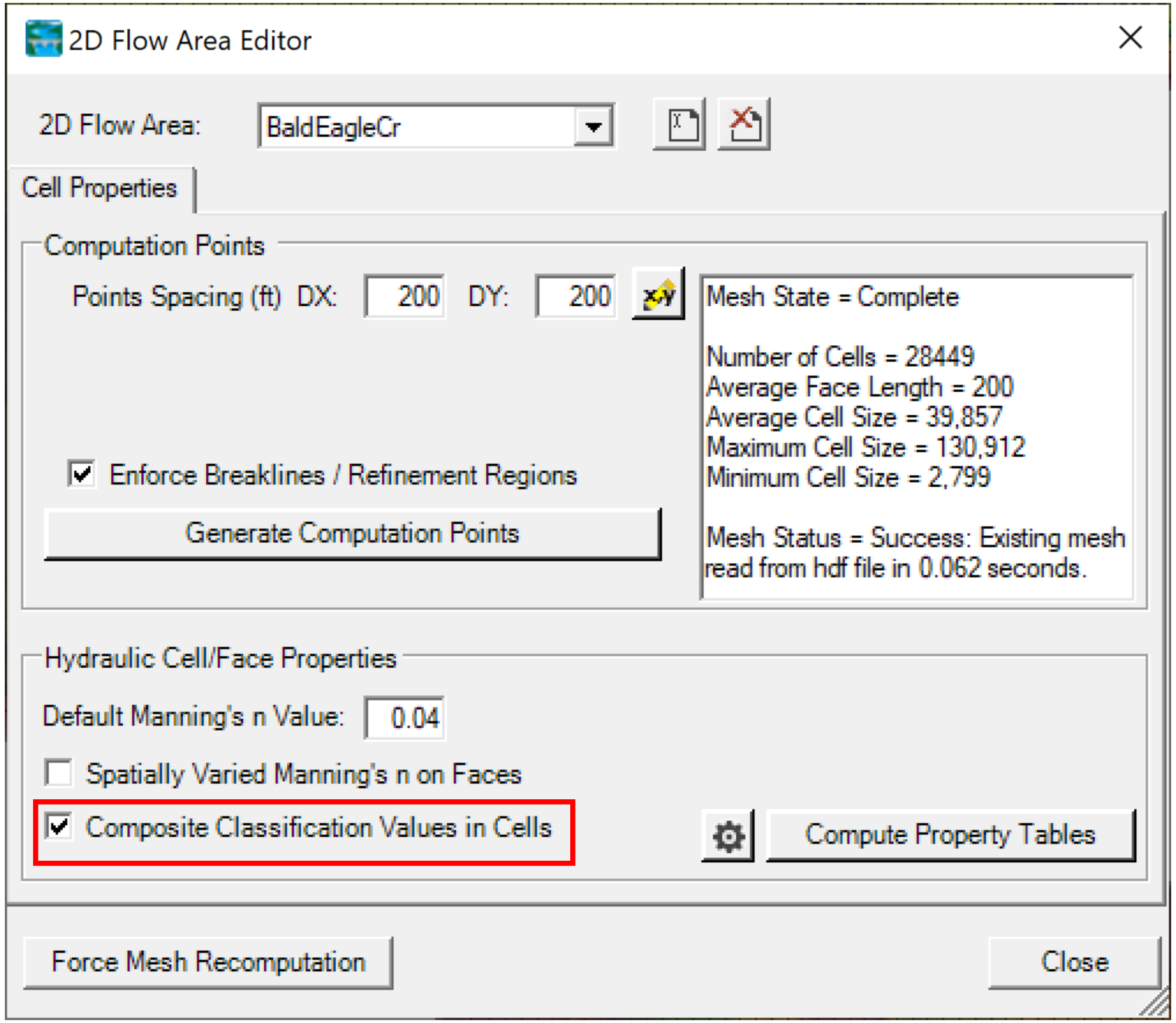
Spatial Compositing of Classification Values in Cells

- Applies to
  - Infiltration parameters (e.g. max deficit, CN, etc.)
  - % impervious
  - Manning's n
- Cell composite values computed as

$$X_c = \frac{\sum_i A_i X_i}{\sum_i A_i}$$

A_i : Area

X_i : Classification

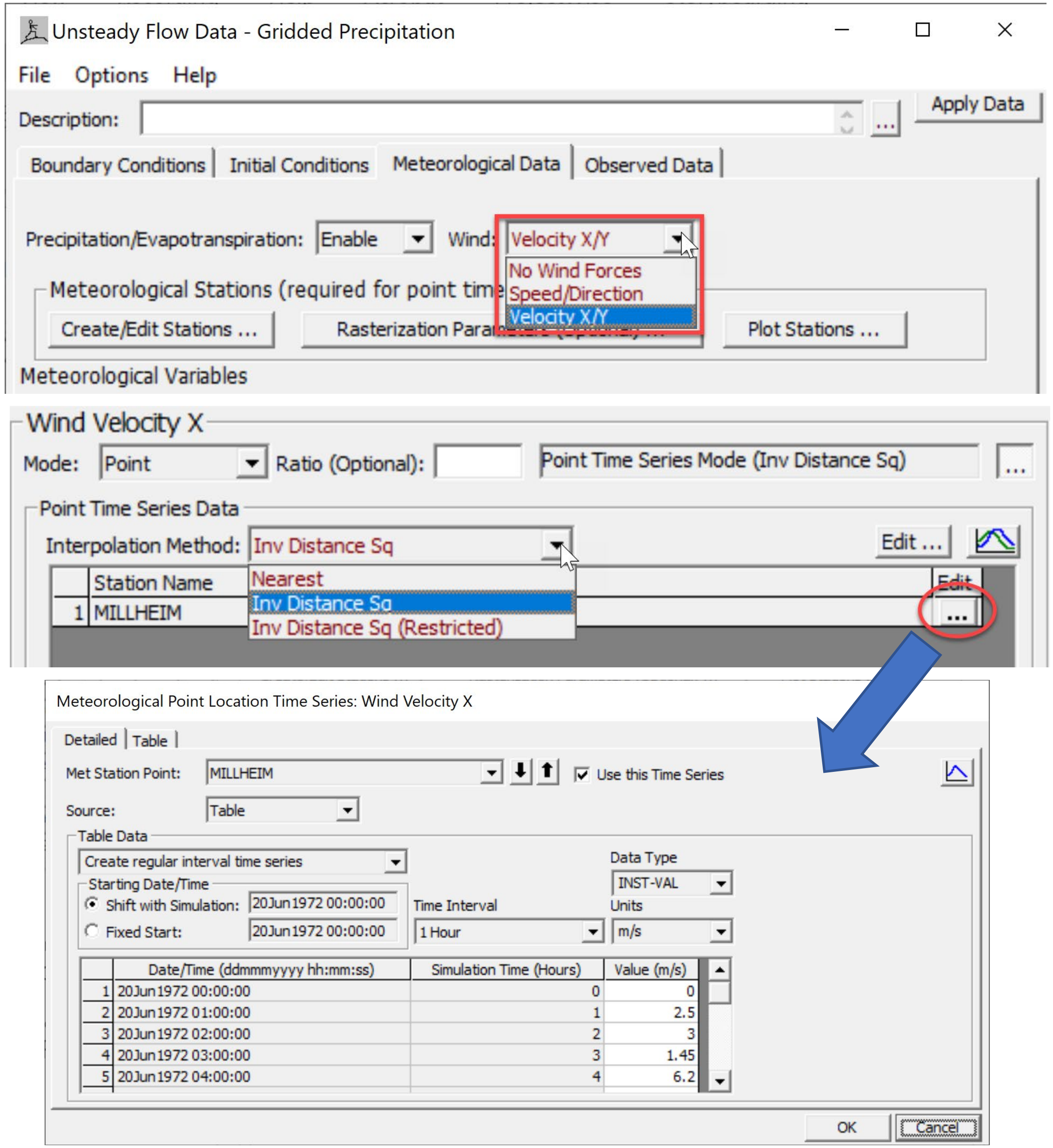


Limitations

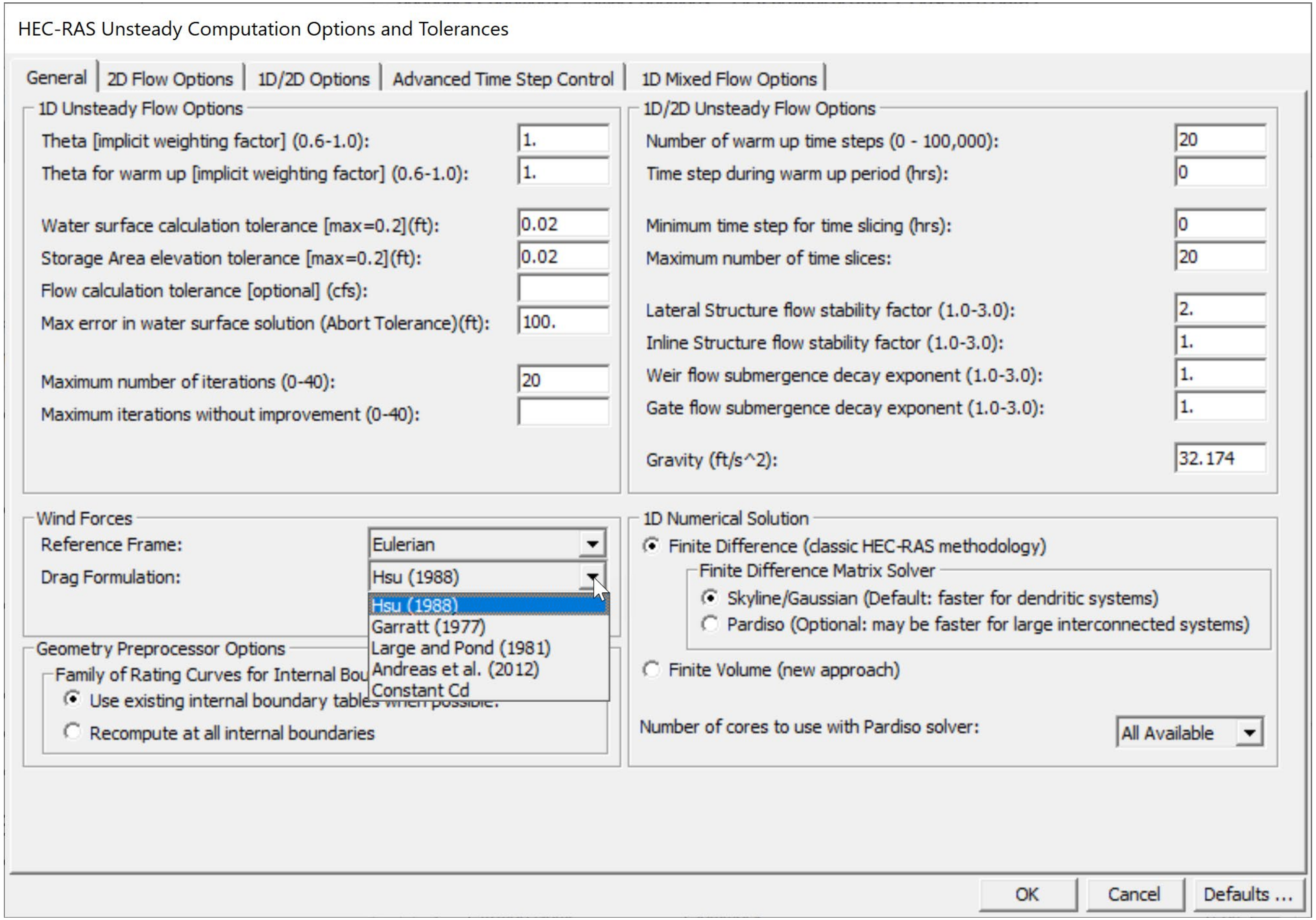
- Surface water cannot infiltrate
- Does not include
  - Inter-flow
  - Base-flow
  - Ground water flow
  - Canopy storage and dynamics
  - Depression storage

Meteorological Data - Wind

- Enabled in **Meteorological Data** tab of **Unsteady Flow Data** editor
- Velocities defined at 10-m height
- Input Data Modes
  - Gridded
    - HEC-DSS file format (from HEC-MetView)
    - GDAL Formats
  - Meteorological Station Data
    - HEC-DSS time series
    - User Entered into a Table
  - Constant Rate
- Interpolation Methods
  - Nearest
  - Inverse Distance
  - Inverse Distance Squared
- Ratio (optional)
  - Used to scale the wind velocities or convert height to 10-m



Wind Options



Wind Surface Stress

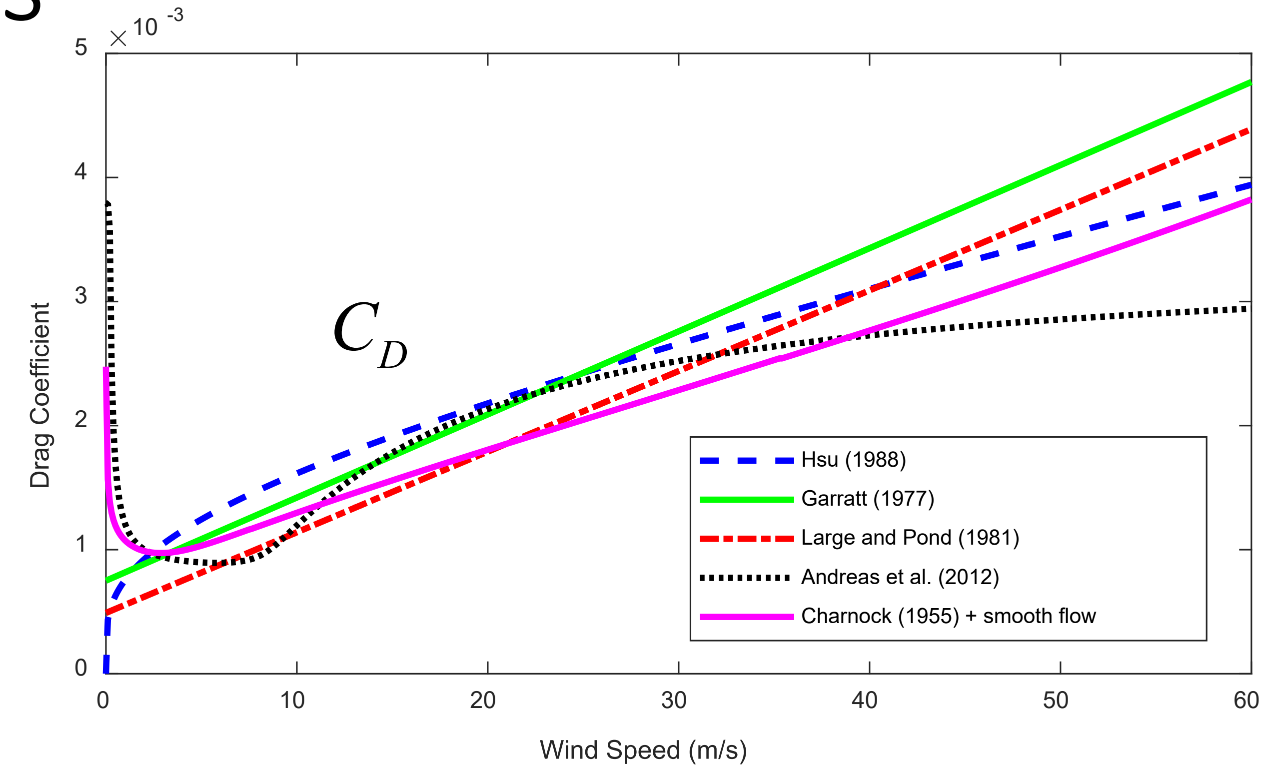
- Only for Shallow Water Equations
- Surface Stress is given by

$$\boldsymbol{\tau}_s = \rho_a C_D |\boldsymbol{W}_{10}| \boldsymbol{W}_{10}$$

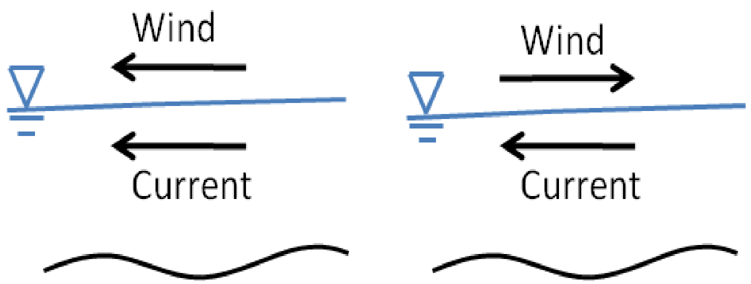
- Wind Reference Frame

$$\boldsymbol{W}_{10} = \begin{cases} \boldsymbol{W}_{10}^E - \boldsymbol{V} & \text{for Lagrangian} \\ \boldsymbol{W}_{10}^E & \text{for Eulerian} \end{cases}$$

- Input Data Modes
    - Constant
    - Point Gages
    - Gridded



Lagrangian Reference Frame



Thank You!

HEC-RAS Website:
https://www.hec.usace.army.mil/software/hec-ras/

Online Documentation:
https://www.hec.usace.army.mil/confluence/rasdocs

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