

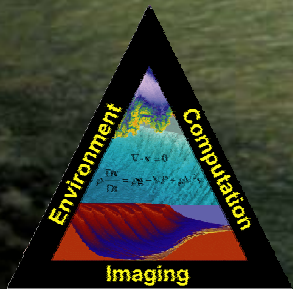
# *TopoFlow*

## A New Distributed Hydrologic Model Based on ARHYTHM and RiverTools

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*University of Colorado, Boulder*

*December 8, 2002*

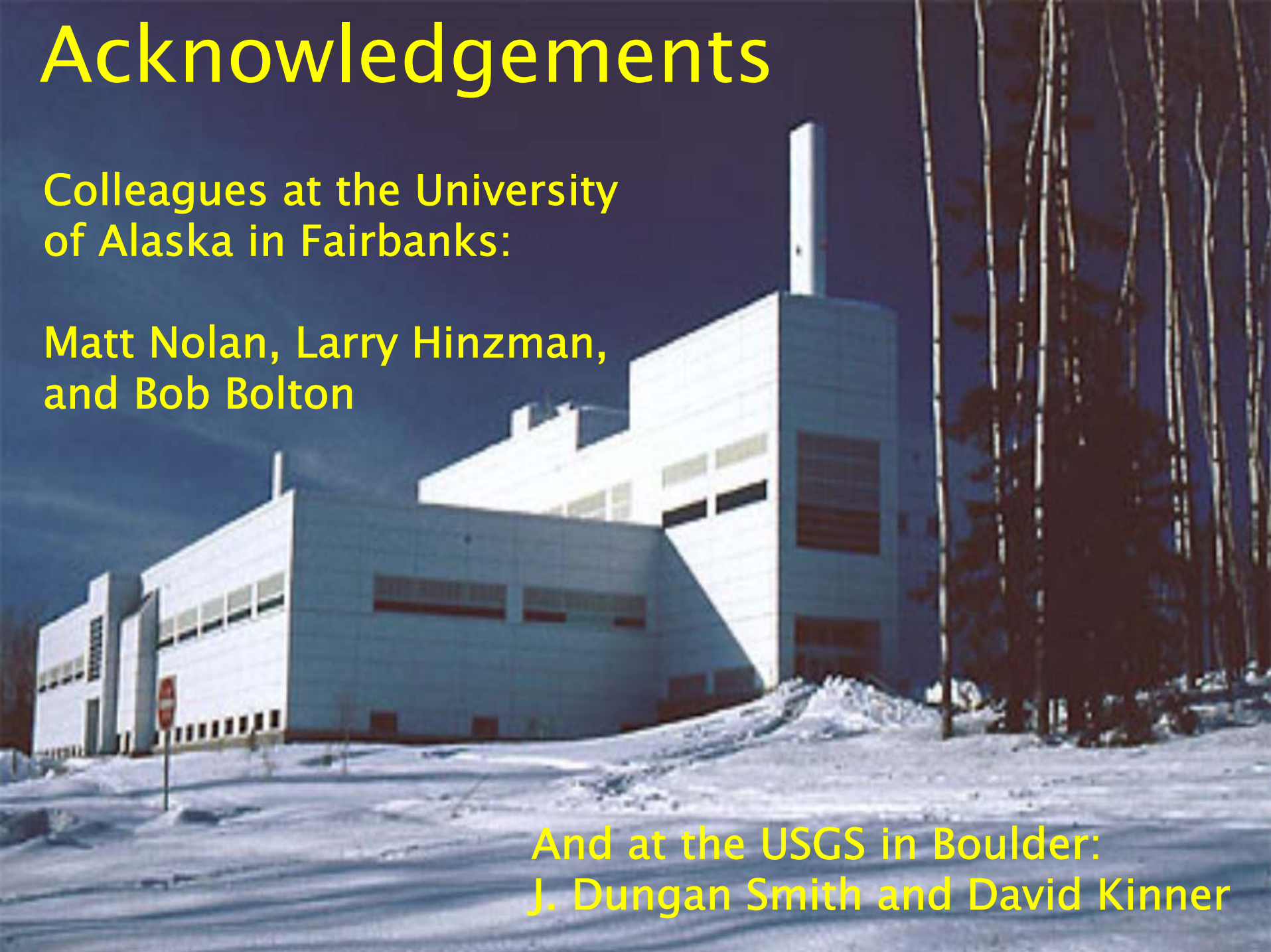


# Acknowledgements

Colleagues at the University  
of Alaska in Fairbanks:

Matt Nolan, Larry Hinzman,  
and Bob Bolton

And at the USGS in Boulder:  
J. Dungan Smith and David Kinner





# What is RiverTools?



RiverTools is a commercially-sold application for digital terrain and river network analysis. It is a full-featured Windows-style program with raster and vector GIS capabilities, ability to import many DEM formats, advanced visualization and analysis tools, and a wide variety of additional tools for working with DEMs and flow grids. ([www.researchsystems.com](http://www.researchsystems.com))

# What is ARHYTHM?

ARHYTHM is a spatially-distributed hydrological model that incorporates thermal processes for use in the Arctic. It is physically based and is written in Fortran.

See Zhang, Z., Kane, D.L., Hinzman, L.D. (2000) Development and application of a spatially-distributed Arctic hydrological model and thermal process model (ARHYTHM), *Hydrol. Proc.*, **14**, 1017-1044.

Atmosphere

Advected Water & Energy

Wind

Precipitation  
(Rain & Snow)

Evapotranspiration/Condensation

Radiation

Convection

Snowmelt

Overland Flow

Vegetation

Channel

Routing

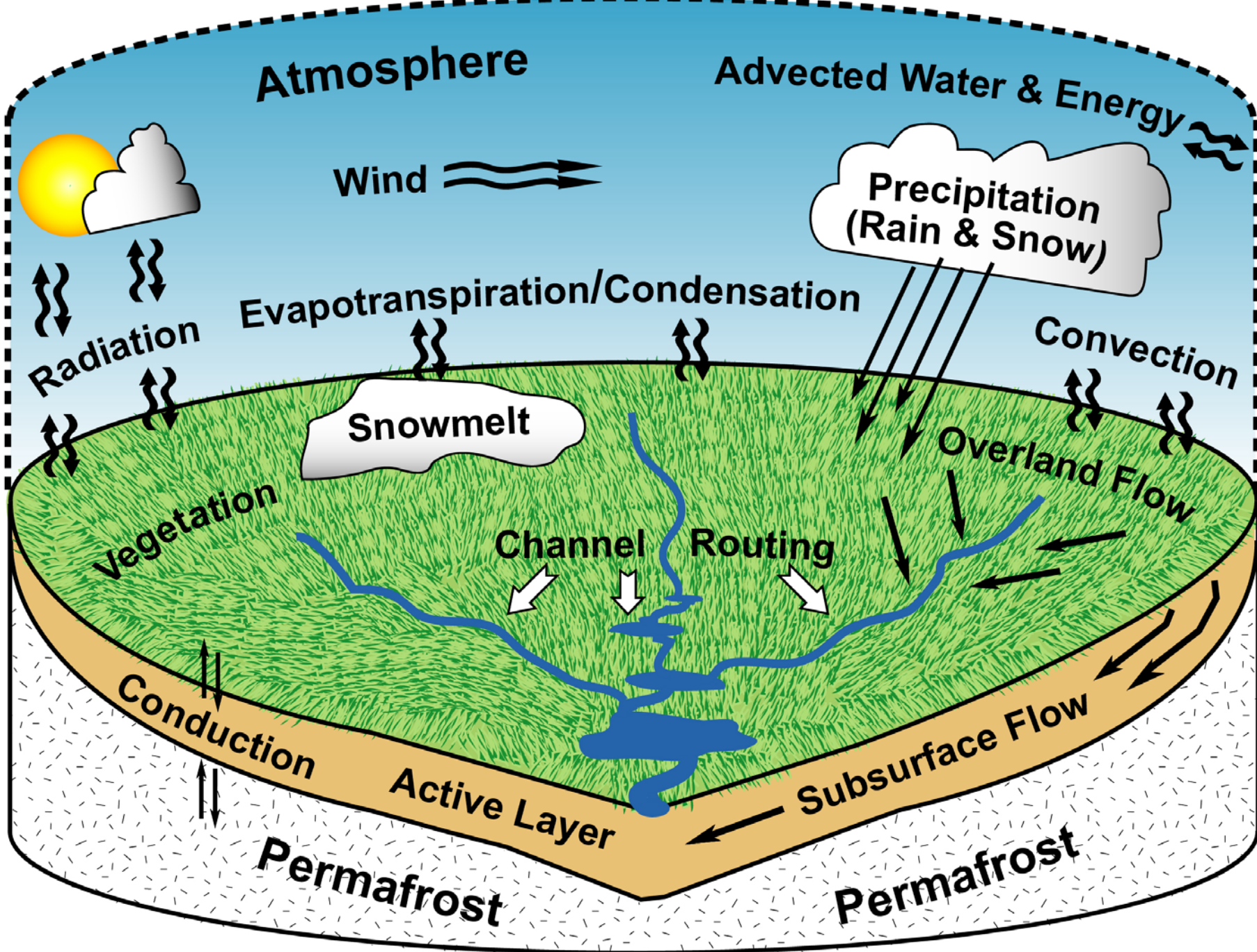
Conduction

Active Layer

Subsurface Flow

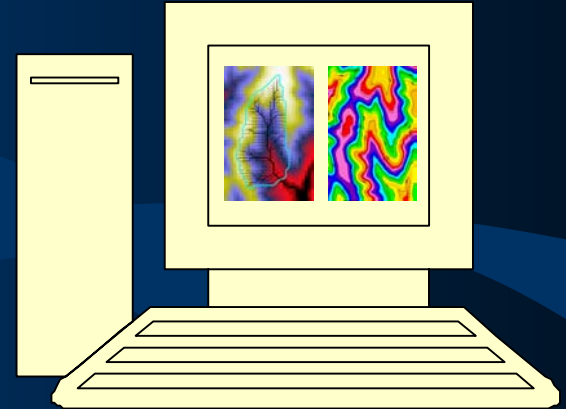
Permafrost

Permafrost



# Design Criteria for TopoFlow

- ✓ User-friendly interface
- ✓ User-extendible
- ✓ Open-source code
- ✓ Structured, consistent, clean
- ✓ Different timesteps for processes
- ✓ Multiple output options:
  - Grid sequences, hydrographs for multiple outlets, etc.
- ✓ Flexible input options:
  - Any input variable can be a scalar or grid.
  - Note: IDL's dynamic data typing is perfect for this.



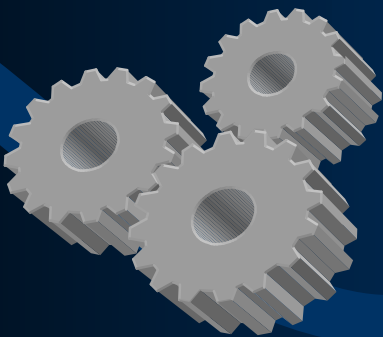
# Overall Design Paradigm

**Physical Process:** (e.g. Snowmelt, ET, Overland Flow, Channel Flow)

**Method:** (None/Simple/Complex, e.g. None, Degree-Day, Energy Balance)

**Formulas:** (These define the method. Need enough to solve for all the output variables. Implemented as functions.)

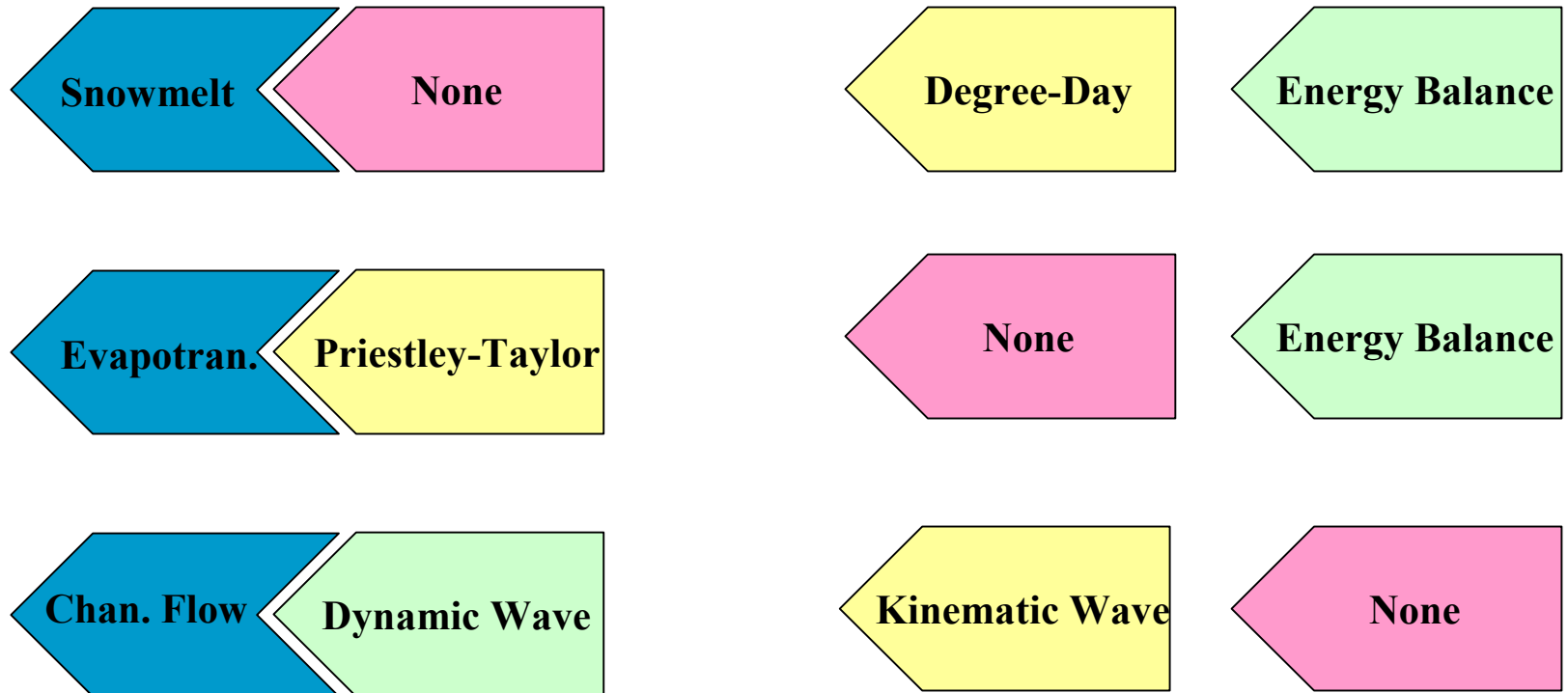
**Variables:** (Input/Output, Scalar/Grid, Deterministic/Random)



## Other Issues:

Timesteps  
Stopping Criteria  
Output Methods

# Multiple Methods per Process



Each method has a similar set of dialogs to specify or collect input and output variables. Any process can be turned off.



# TopoFlow Main Dialog

**TopoFlow 1.0 Dialog** [9/27/02]

Model run prefix:

Model run directory:

Model run comments:

Stopping criterion:

---

Physical process: Method to model process:

Snowmelt:	<input type="text" value="Energy Balance"/>	<input data-bbox="1033 662 1209 716" type="button" value="Formulas..."/>	<input data-bbox="1249 662 1424 716" type="button" value="Input Vars..."/>	<input data-bbox="1464 662 1639 716" type="button" value="Output Vars..."/>
Evapotranspiration:	<input type="text" value="None"/>	<input data-bbox="1033 739 1209 793" type="button" value="Formulas..."/>	<input data-bbox="1249 739 1424 793" type="button" value="Input Vars..."/>	<input data-bbox="1464 739 1639 793" type="button" value="Output Vars..."/>
Precipitation:	<input type="text" value="Uniform in space for intervals"/>	<input data-bbox="1033 816 1209 871" type="button" value="Formulas..."/>	<input data-bbox="1249 816 1424 871" type="button" value="Input Vars..."/>	
Infiltration:	<input type="text" value="None"/>	<input data-bbox="1033 893 1209 948" type="button" value="Formulas..."/>	<input data-bbox="1249 893 1424 948" type="button" value="Input Vars..."/>	<input data-bbox="1464 893 1639 948" type="button" value="Output Vars..."/>
Subsurface flow:	<input type="text" value="None"/>	<input data-bbox="1033 971 1209 1025" type="button" value="Formulas..."/>	<input data-bbox="1249 971 1424 1025" type="button" value="Input Vars..."/>	<input data-bbox="1464 971 1639 1025" type="button" value="Output Vars..."/>
Overland flow:	<input type="text" value="None"/>	<input data-bbox="1033 1048 1209 1102" type="button" value="Formulas..."/>	<input data-bbox="1249 1048 1424 1102" type="button" value="Input Vars..."/>	<input data-bbox="1464 1048 1639 1102" type="button" value="Output Vars..."/>
Channel flow:	<input type="text" value="Kinematic Wave, Manning (by order)"/>	<input data-bbox="1033 1125 1209 1179" type="button" value="Formulas..."/>	<input data-bbox="1249 1125 1424 1179" type="button" value="Input Vars..."/>	<input data-bbox="1464 1125 1639 1179" type="button" value="Output Vars..."/>
Sediment flux:	<input type="text" value="None"/>	<input data-bbox="1033 1202 1209 1256" type="button" value="Formulas..."/>	<input data-bbox="1249 1202 1424 1256" type="button" value="Input Vars..."/>	<input data-bbox="1464 1202 1639 1256" type="button" value="Output Vars..."/>





# Snowmelt: Energy Balance Method

**Variables for Snowmelt: Energy Balance Method**

Variable:	Type:	Scalar or Grid Filename:	Units:
Qnet:	Scalar	1.0	[W/m <sup>2</sup> ]
T <sub>air</sub> :	Scalar	0.000000	[deg_C]
T <sub>surf</sub> :	Scalar	0.000000	[deg_C]
e <sub>air</sub> :	Scalar	0.000000	[mbar]
e <sub>surf</sub> :	Scalar	0.000000	[mbar]
p0:	Scalar	0.000000	[mbar]
uz:	Scalar	1.00000	[m/s]
z:	Scalar	1.00000	[m]
z0 <sub>air</sub> :	Scalar	0.0200000	[m]
h <sub>snow</sub> :	Scalar	1.00000	[m]
rho <sub>snow</sub> :	Scalar	300.00000	[kg/m <sup>3</sup> ]
Cp <sub>snow</sub> :	Scalar	9999	[J/kg/deg_C]
rho <sub>air</sub> :	Scalar	1.26140	[kg/m <sup>3</sup> ]
Cp <sub>air</sub> :	Scalar	1005.70	[J/kg/deg_C]
Timestep:		1.0000000	[hours / timestep]



OK Help Cancel

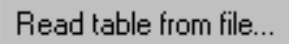
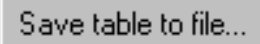
# Uniform Precipitation Dialog

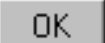

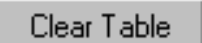

 **Variables for Uniform Precip Method** 

Precipitation Rates and Durations by Interval:

	Rate [ $10^{-5}$ m/s]:	Duration [min]:
1	0.1587500	8.0000000
2	2.1166666	3.0000000
3	1.0583333	6.0000000
4	1.7991668	4.0000000
5	2.3585715	7.0000000
6	4.6096296	9.0000000
7	2.9633334	11.0000000
8	2.7516668	4.0000000
9	0.8466667	4.0000000
10	2.9028571	7.0000000
11	2.6246667	5.0000000
12	2.0461111	6.0000000
13		

# Subsurface Flow Dialog

**Variables for Darcy's Law Method (GW)**

Variable:	Type:	Scalar or Grid Filename:	Units:
Elevation of bed:	Grid	Treynor_DEM.rtg	[m]
Elev. of water table:	Grid	Treynor_H2Otable.rtg	[m]
Depth to nonfrozen:	Scalar	0.0	[m]

Timestep: 1.0000000 [hours / timestep]

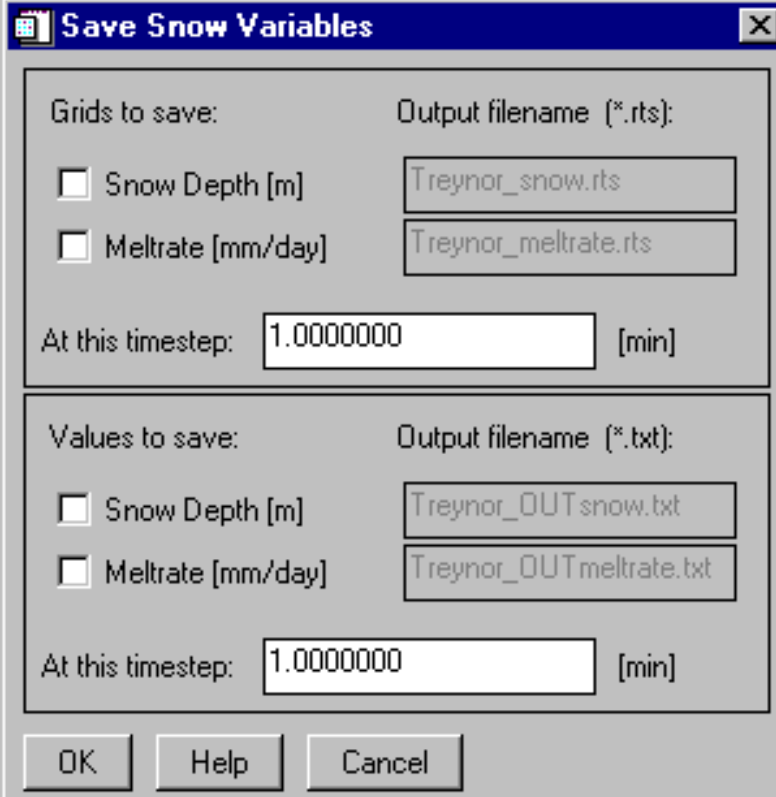
Soil Layer Properties: (top to bottom)

	Thickness [m]:	K [ $10^{-5}$ m/s]:	Porosity: [unitless]
Layer 1	0.100000	5.00000	0.500000
Layer 2	0.100000	5.00000	0.500000
Layer 3	0.100000	5.00000	0.500000
Layer 4	0.100000	5.00000	0.500000
Layer 5	0.100000	5.00000	0.500000

Read table from file... Save table to file...

OK Help Cancel

# Output Methods



The dialog box is titled "Save Snow Variables" and contains two sections for saving data. The top section, "Grids to save:", has two checkboxes: "Snow Depth [m]" and "Meltrate [mm/day]". To the right of these checkboxes are two text input fields for "Output filename (\*.rts)", containing "Treyndor\_snow.rts" and "Treyndor\_meltrate.rts" respectively. Below these is a label "At this timestep:" followed by a text input field containing "1.00000000" and a unit label "[min]". The bottom section, "Values to save:", also has two checkboxes: "Snow Depth [m]" and "Meltrate [mm/day]". To the right are two text input fields for "Output filename (\*.txt)", containing "Treyndor\_OUTsnow.txt" and "Treyndor\_OUTmeltrate.txt". Below these is another "At this timestep:" label with a text input field containing "1.00000000" and a unit label "[min]". At the bottom of the dialog are three buttons: "OK", "Help", and "Cancel".

**Save Snow Variables**

Grids to save:      Output filename (\*.rts):

☐ Snow Depth [m]      Treyndor\_snow.rts

☐ Meltrate [mm/day]      Treyndor\_meltrate.rts

At this timestep: 1.00000000 [min]

Values to save:      Output filename (\*.txt):

☐ Snow Depth [m]      Treyndor\_OUTsnow.txt

☐ Meltrate [mm/day]      Treyndor\_OUTmeltrate.txt

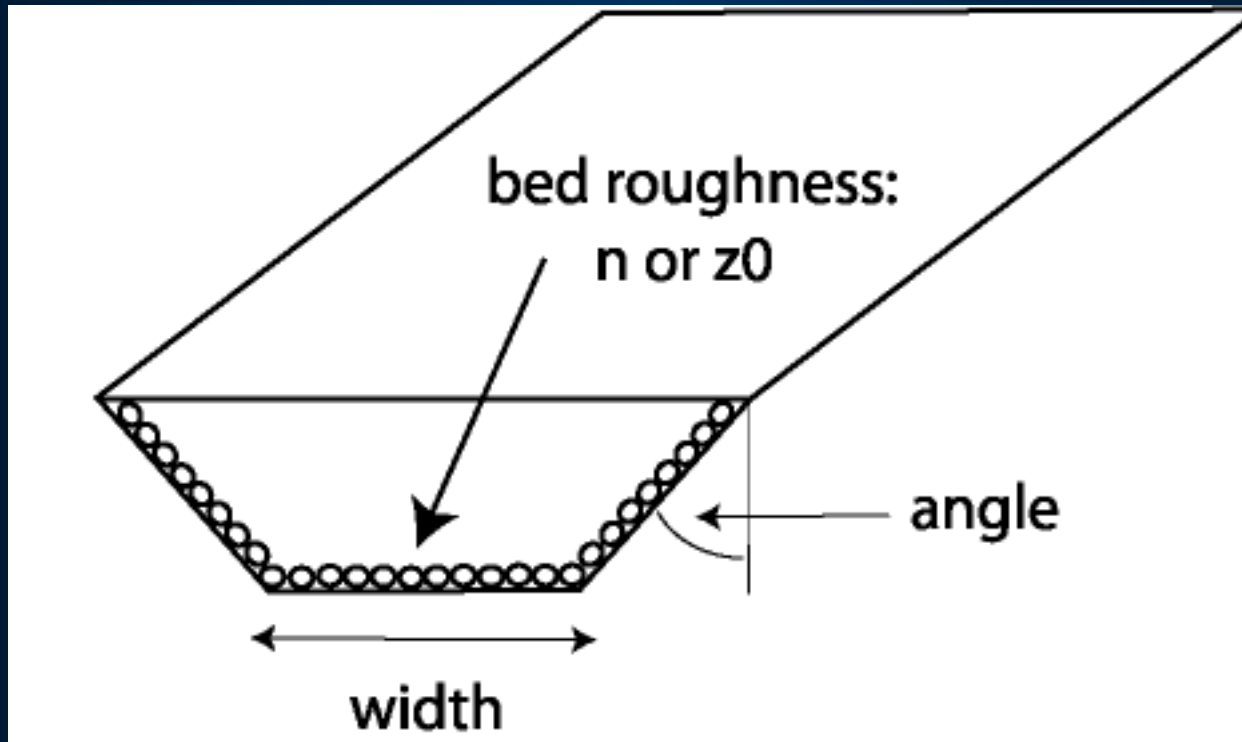
At this timestep: 1.00000000 [min]

OK    Help    Cancel



# Trapezoidal Channel Cross-Sections

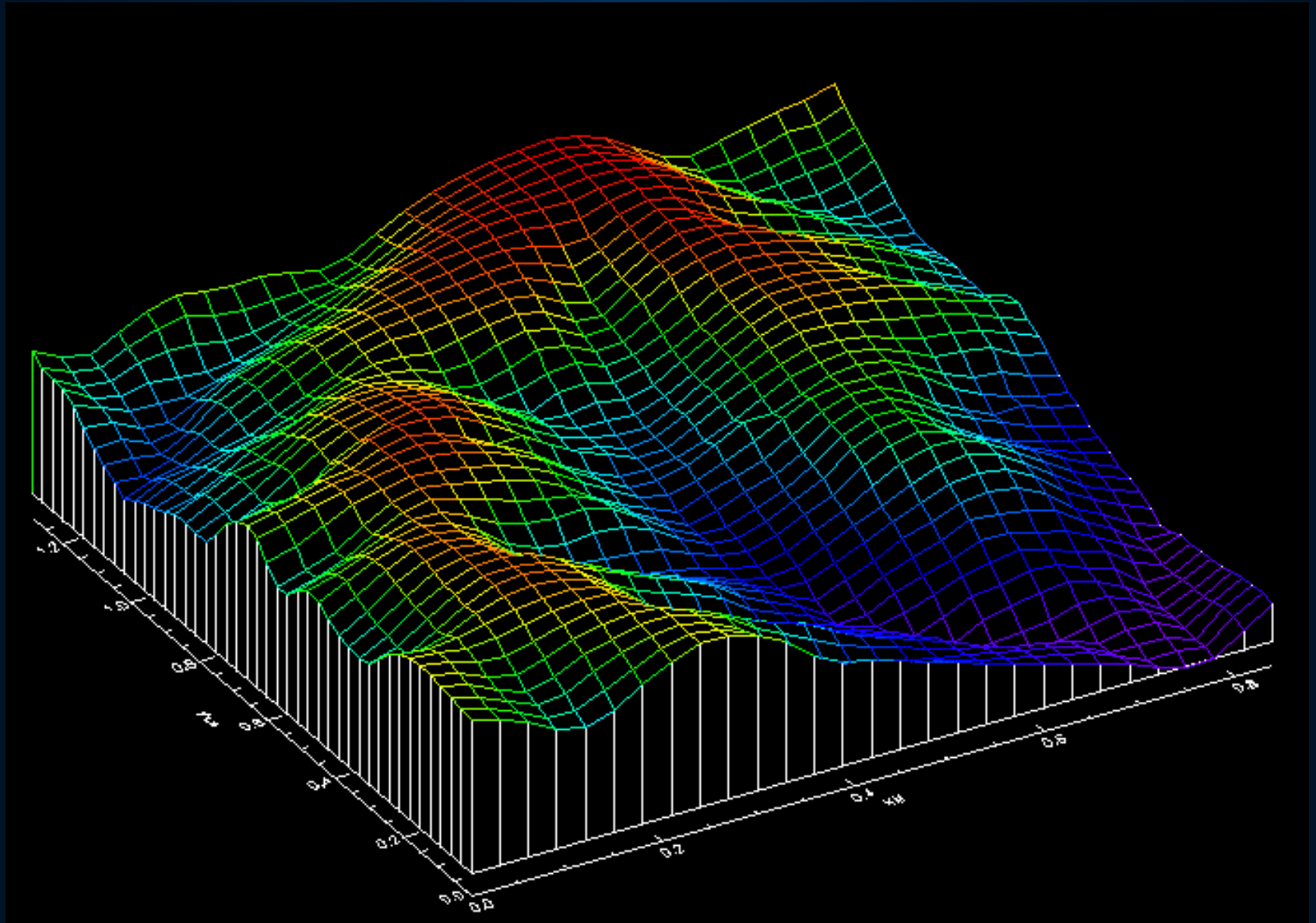
(attributes can depend on HS Order)



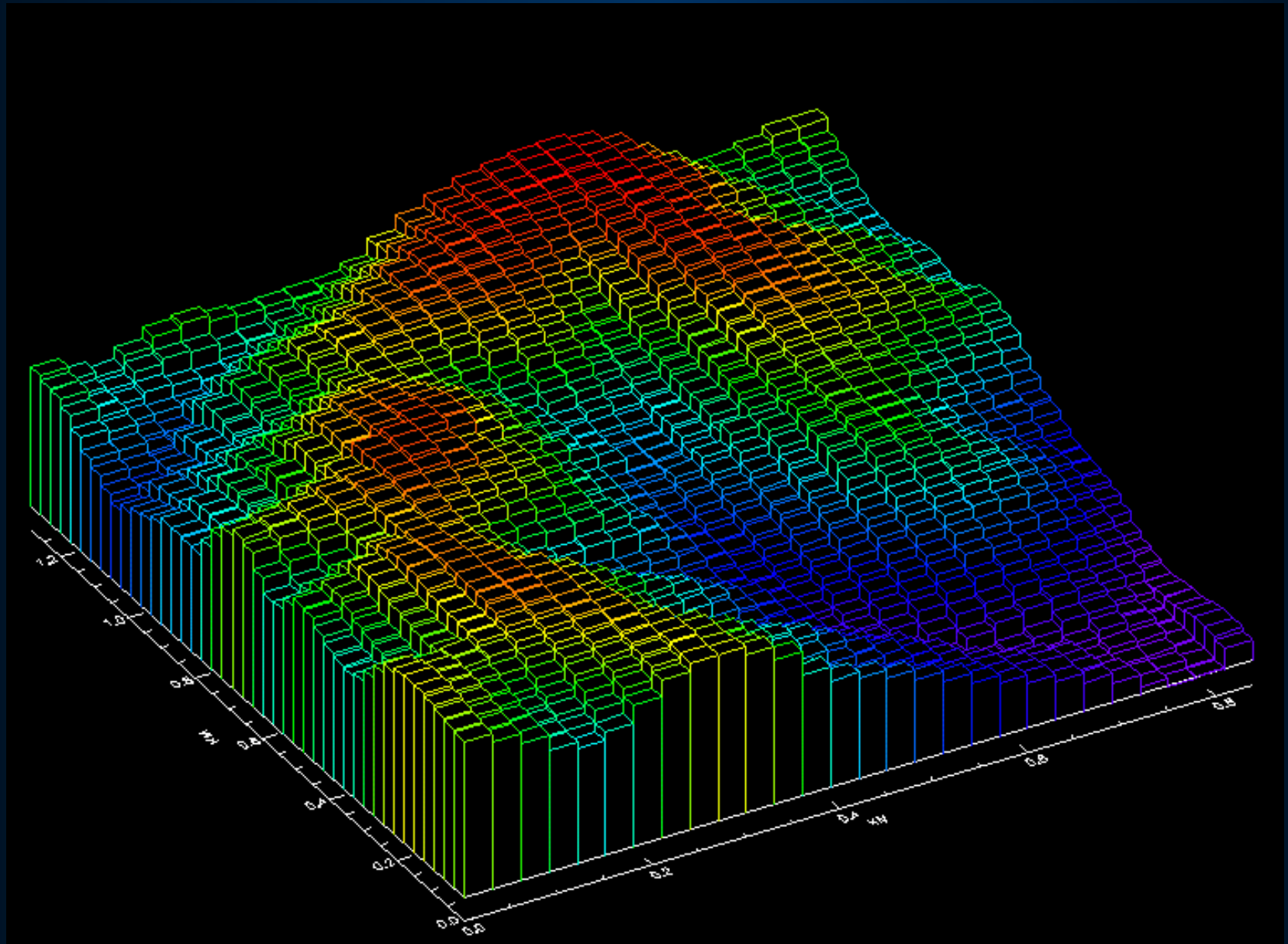
Flow Resistance Options:  
Manning's Formula ( $n$ )  
Law of the Wall ( $z_0$ )

Special Cases:  
Rectangular: width = 0  
Triangular: angle = 0

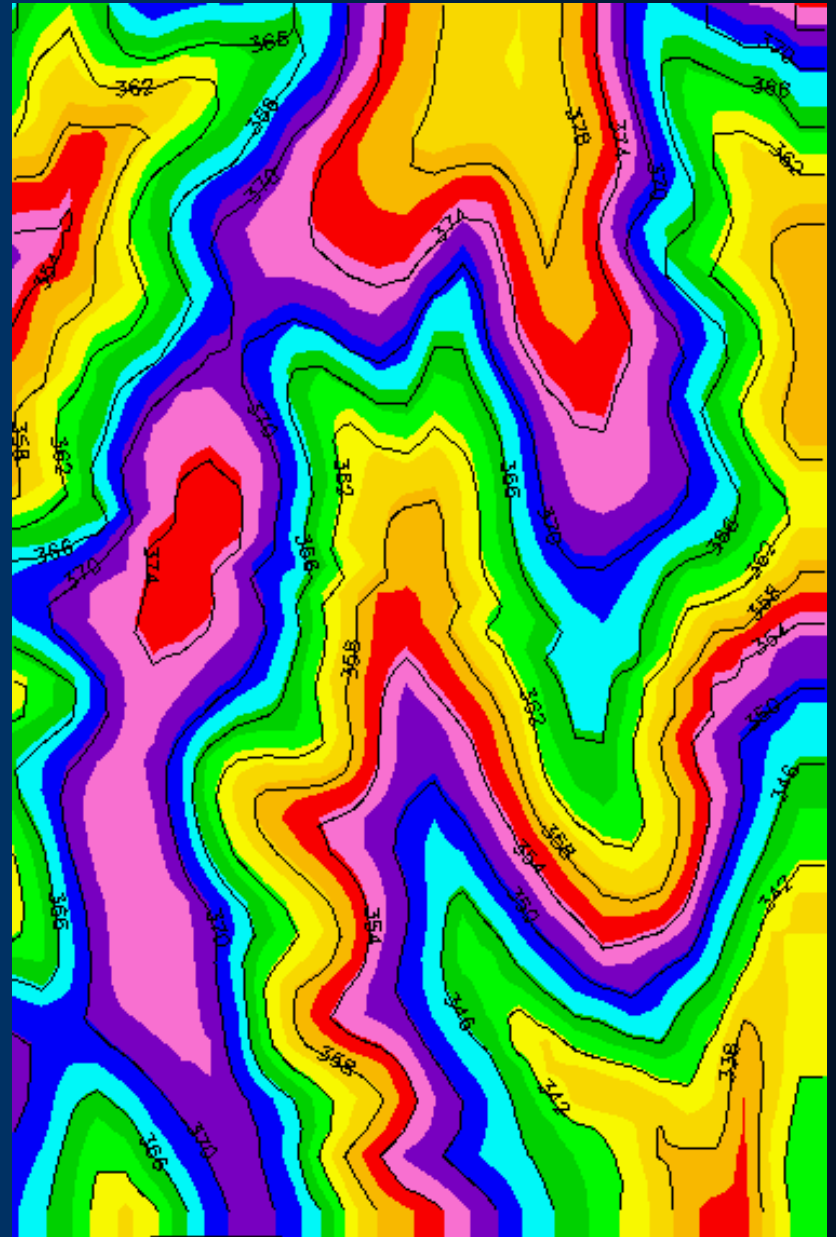
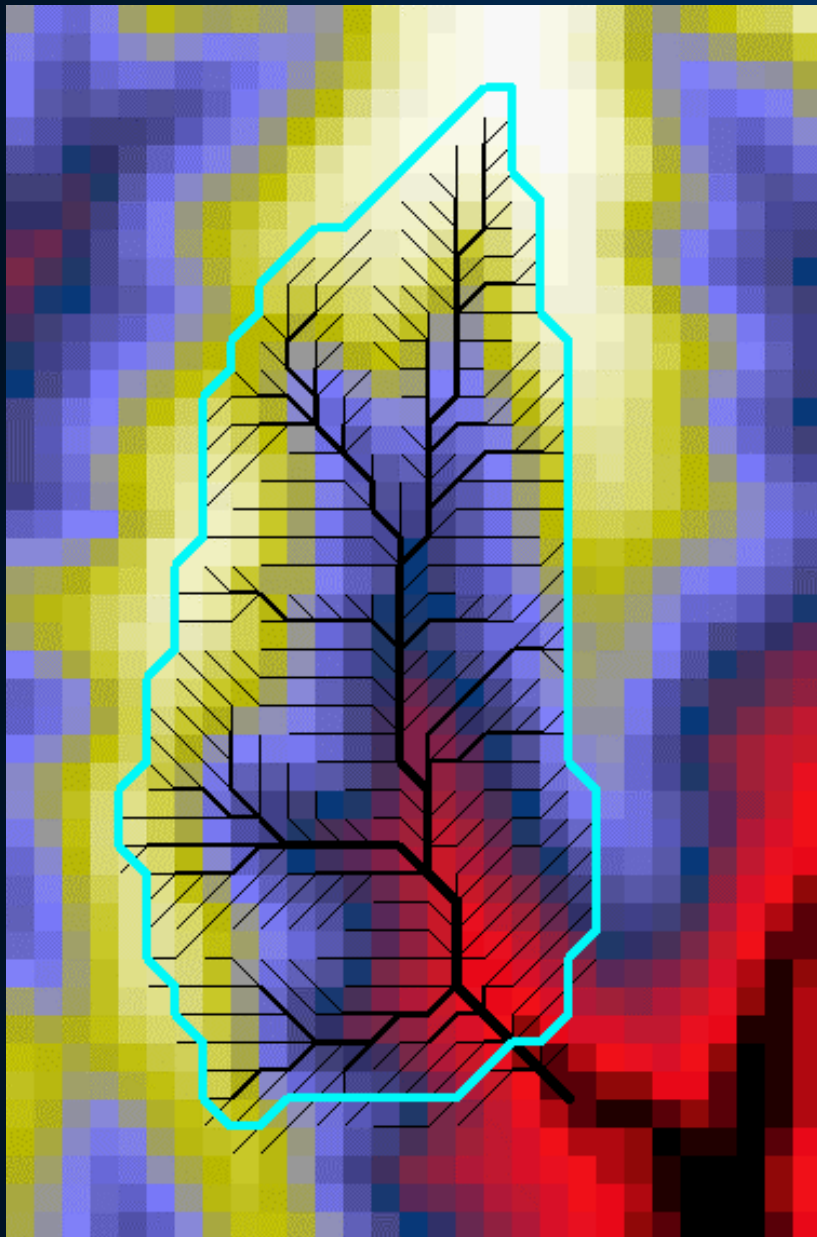
# Treynor Watershed Surface Plot



# Treynor Watershed Surface Plot

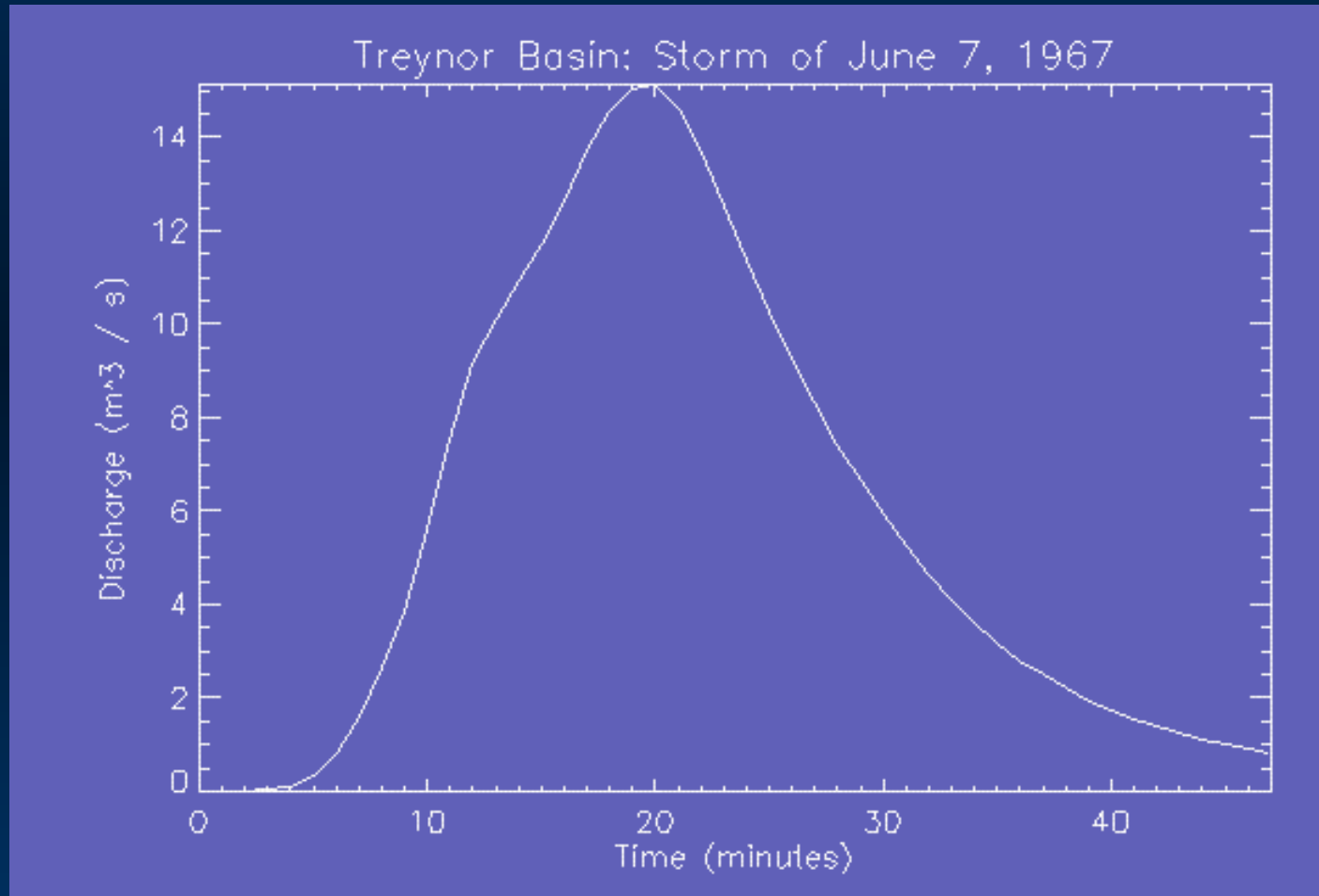


# Treynor Watershed, Iowa (0.43 sq km)

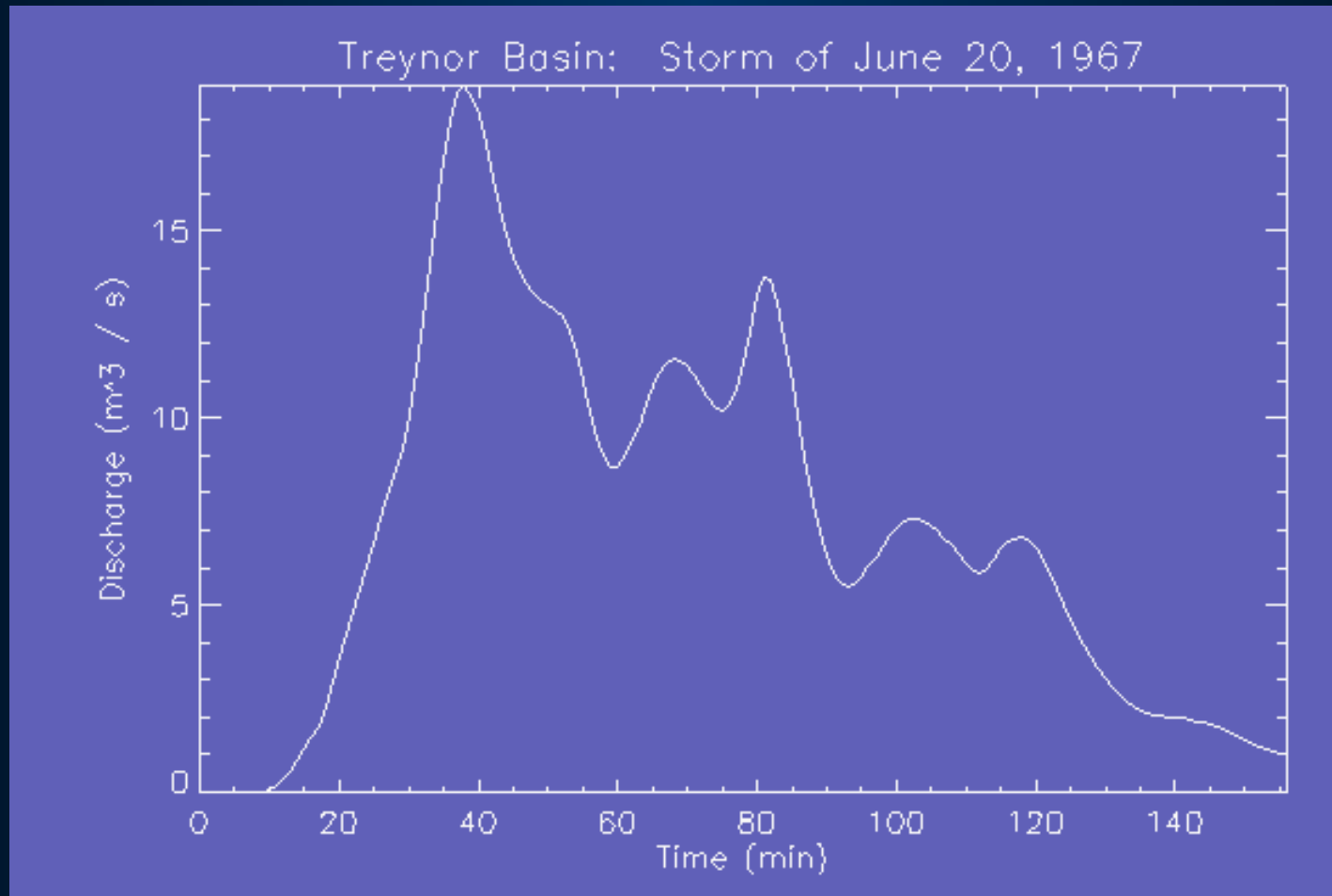




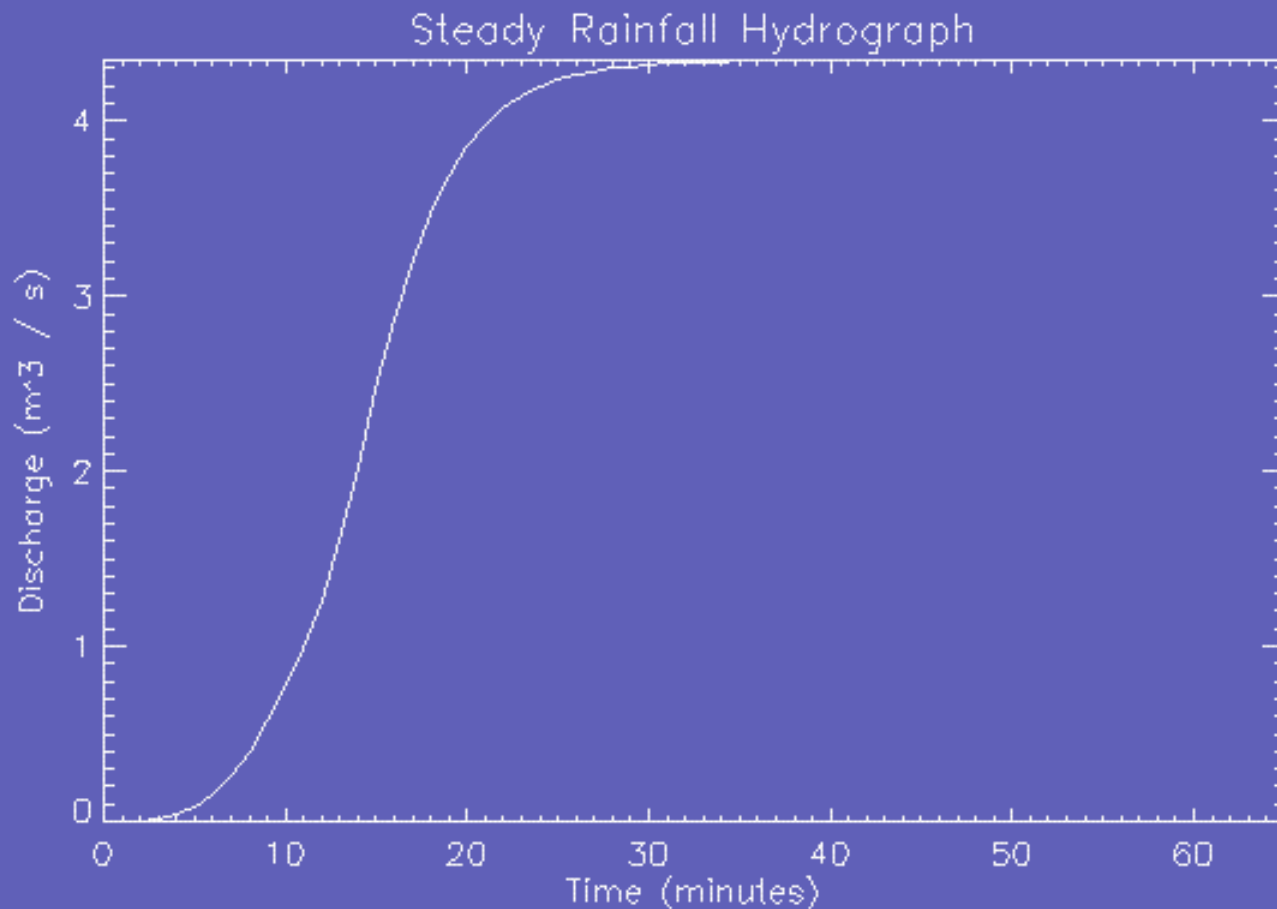
# Simulated Hydrograph for Treynor Basin and 6/7/67 Storm



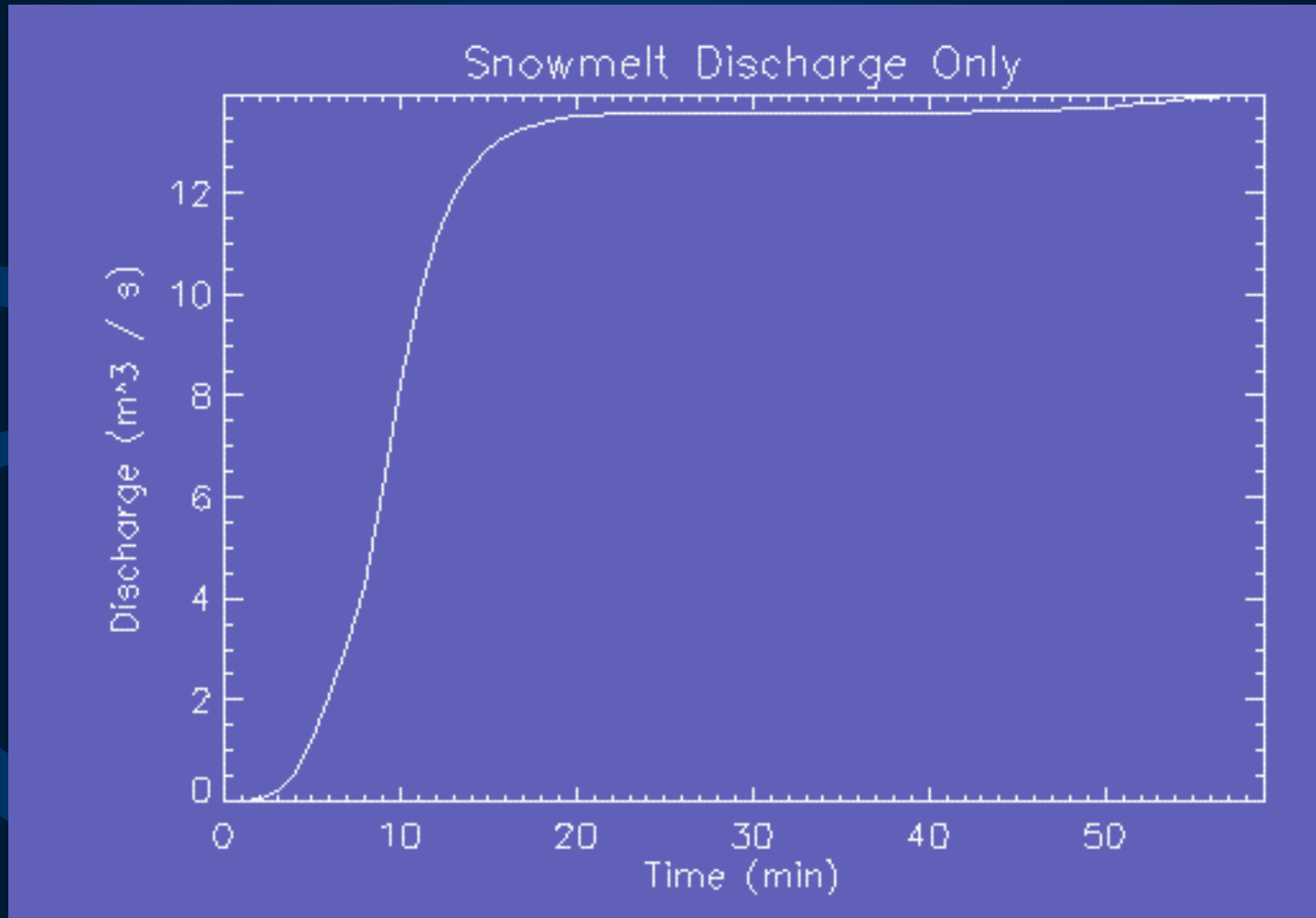
# Simulated Hydrograph for Treynor Basin and 6/20/67 Storm



# Simulated Hydrograph for Treynor Basin from Steady Rain



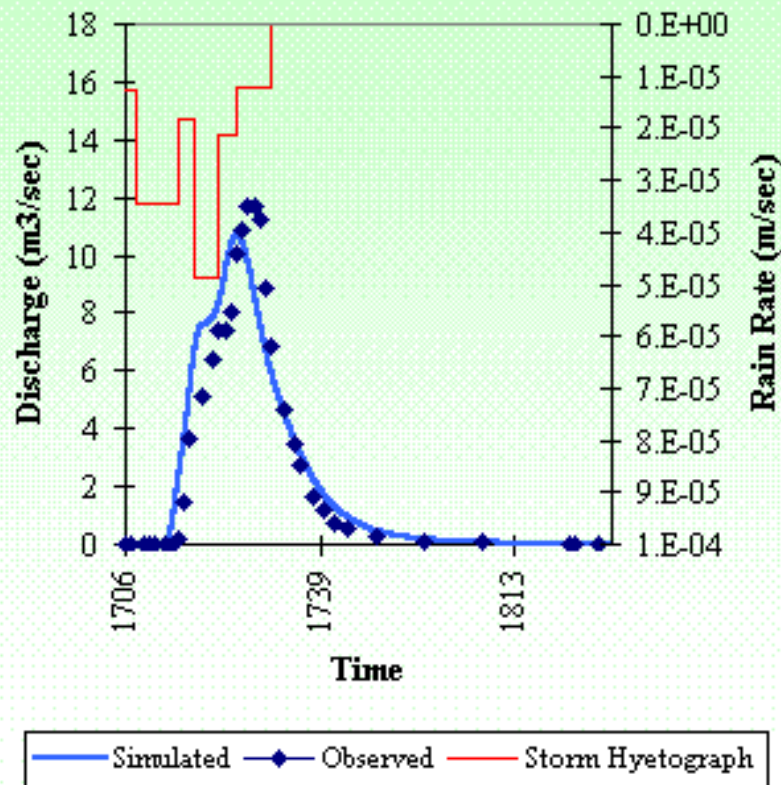
# Simulated Hydrograph for Treynor Basin from Snowmelt



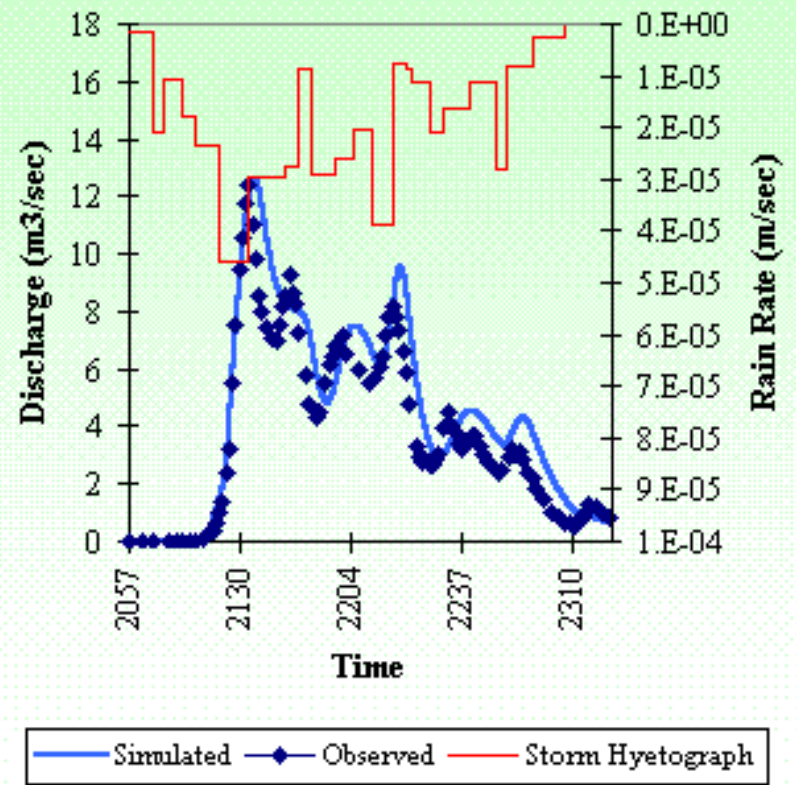


# Treynor Hydrographs vs. Data

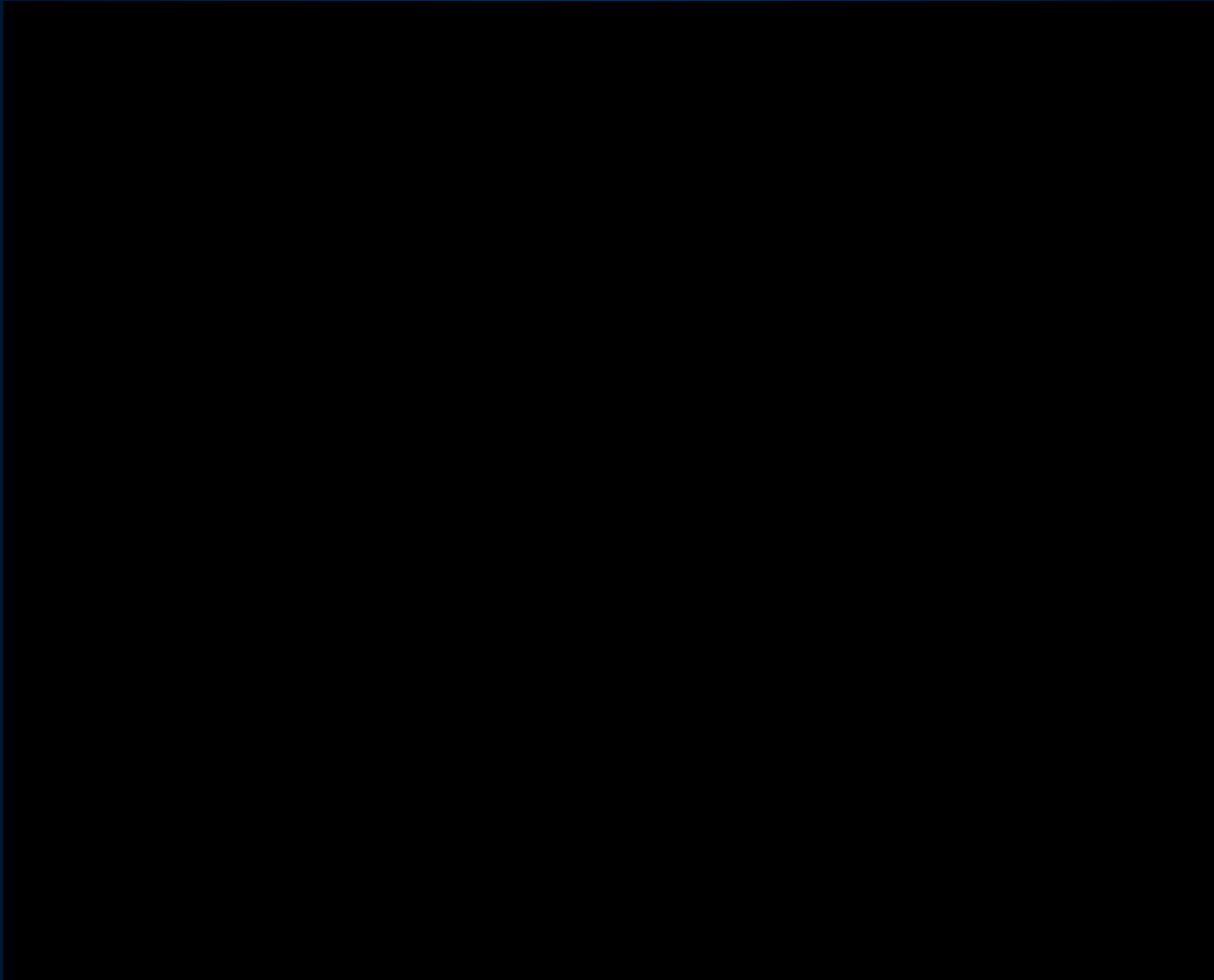
Comparison of Observed and Simulated Hydrographs: Treynor Watershed 1, 6/7/67



Comparison of Observed and Simulated Hydrographs: Treynor Watershed 1, 6/20/67



# Distributed Discharge Animations



# Extending TopoFlow:

## Steps for Adding a New Method

Suppose a user with basic programming skills wants to add a new method for modeling a given physical process.

1. Add string to the droplist of methods in code for main dialog.
2. Add name of routine to call when that method is selected.
3. Add any new input variables the method needs to the structure which contains all the input variables for given method.
4. Edit the “method caller” routine to add the new method.
5. Starting with code for an existing method’s GUI (viewed as a template), edit it to collect input variables that are needed by the new method.
6. Write a set of functions corresponding to the formulas that define the new method. Model these after examples.

# Summary

- *TopoFlow* is a new, user-friendly and user-extendible toolkit for spatially distributed hydrologic modeling.
- Although similar in spirit to models like CASC2D and MMS, it offers several advantages, such as the ability for any input variable to be provided as a scalar to be distributed uniformly or as a spatial grid. Similar support for grid sequences is planned.
- It's intuitive, open-source, structured design provides an environment for both research and education.





# UAF Campus

