AnnAGNPS:

Accounting for Snowpack, Snowmelt, and Soil Freeze-Thaw

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AnnAGNPS:

a word of apology and agnopsian etymology

First, there was “AGNPS” (nops, nips)

AGricultural
Non
Point
Source
Pollution Model

what?

“AGNPSPM”?

AnnAGNPS:

continuing agnopsian etymology

AGNPS was a single-event watershed model that…

Evolved into a *continuous simulation* watershed model.

Input: years and years of daily data.

Output: among other things,"*annualized*" information.

AnnAGNPS:

A continuous simulation watershed model

used to analyze movement of

water,

sediment,

chemicals

in mixed-landuse primarily agricultural lands, so as to

determine source areas,

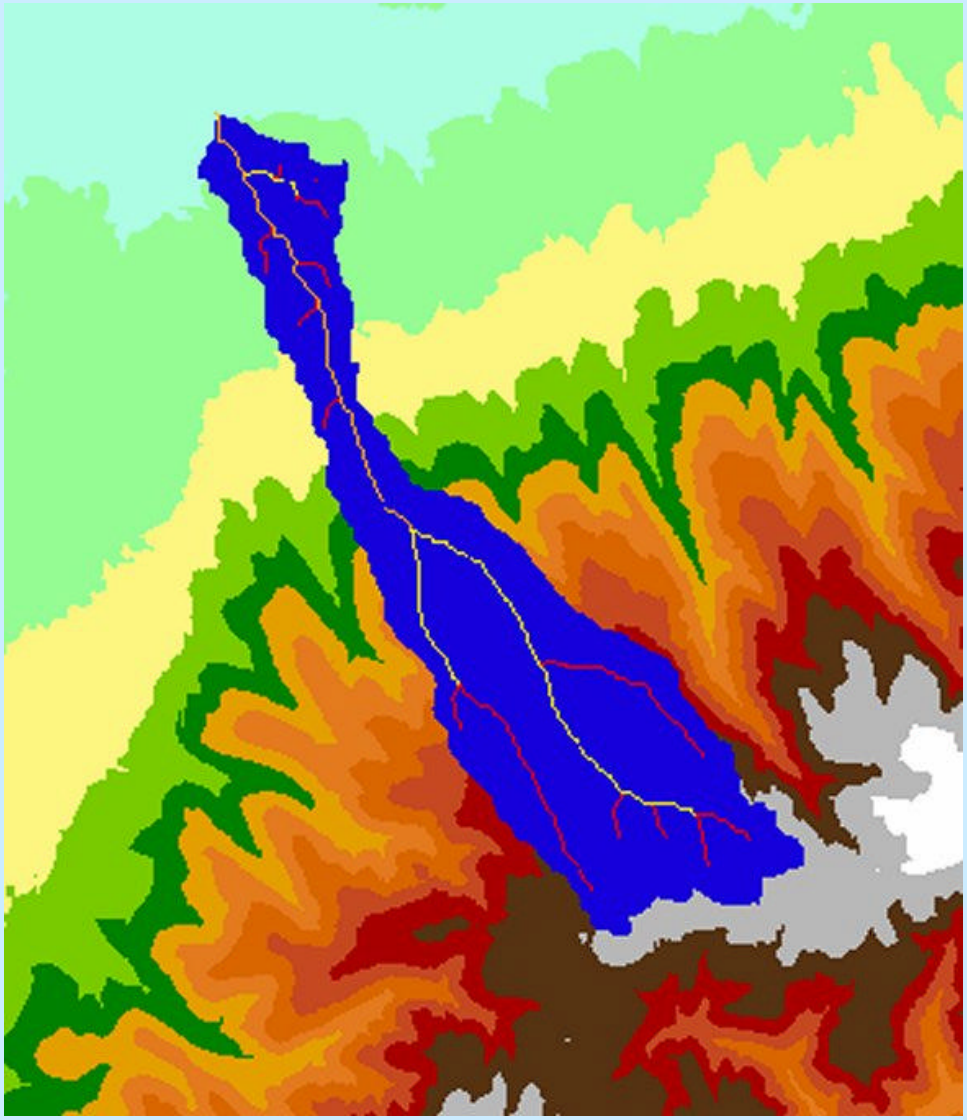
guide selection of BMPs and

setting of TMDLs, as well as provide

input to benefit/cost and risk analyses.

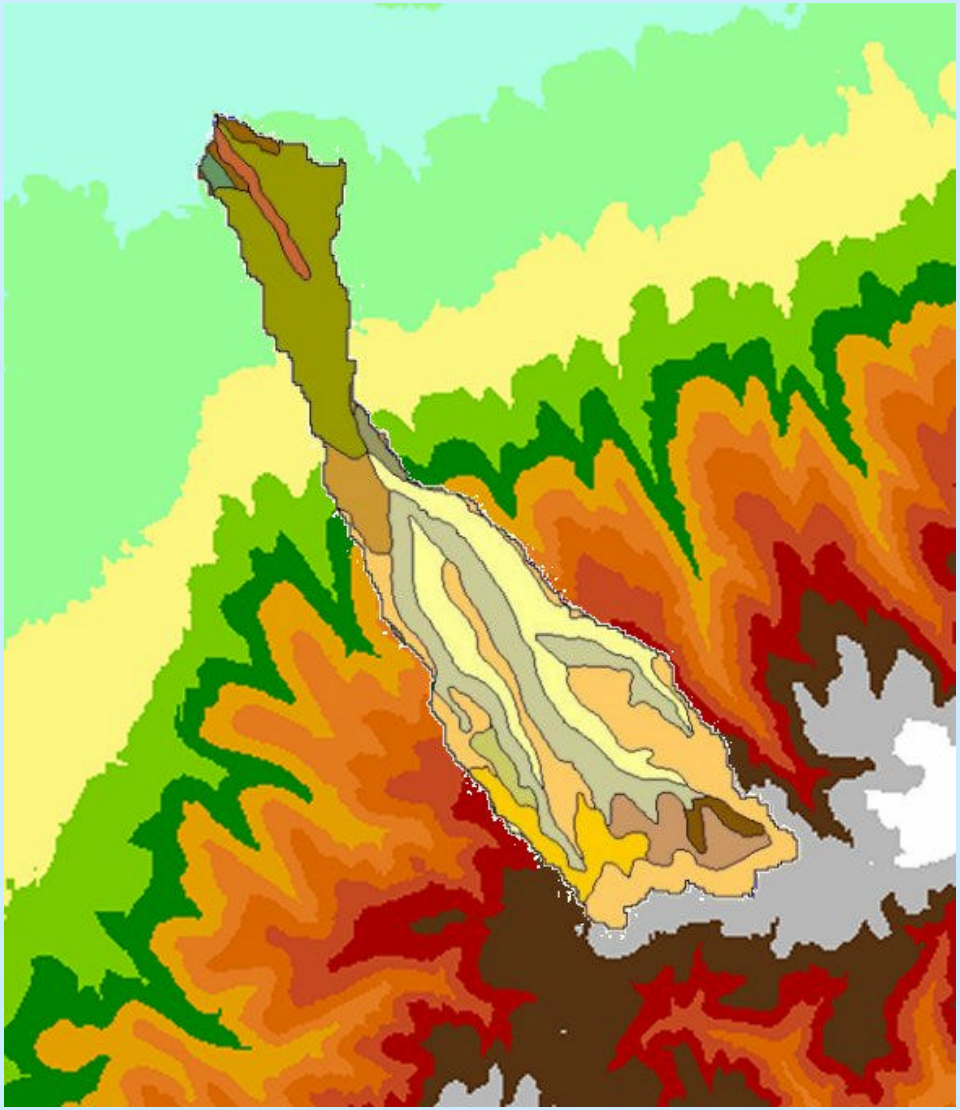
AnnAGNPS uses a lot of spatially distributed data…

DEMs



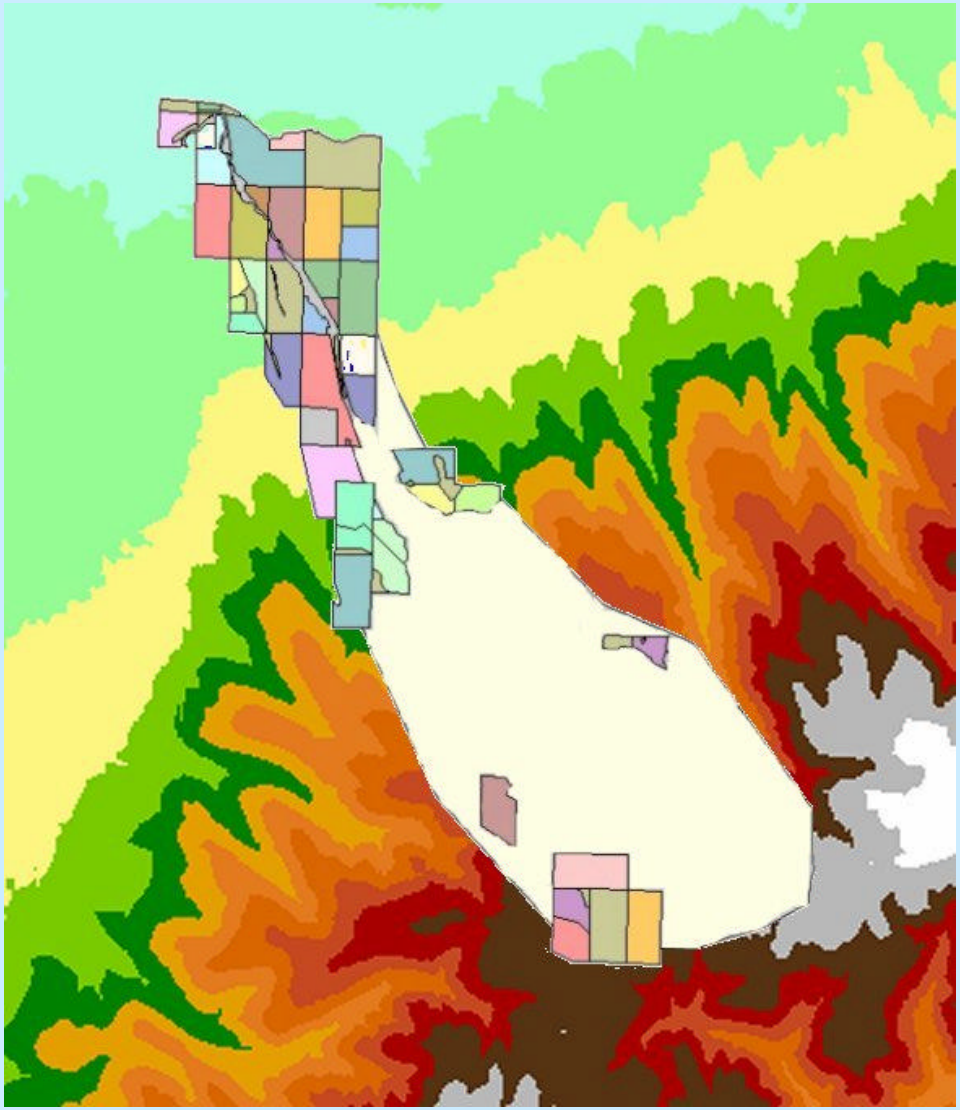
AnnAGNPS uses a lot of spatially distributed data…

Soils



AnnAGNPS uses a lot of spatially distributed data…

landuse



GIS
comes in handy

The watershed is divided into “cells”.

Rainfall results in

runoff

and

erosion.

Water quality modeler task #1: “get the water right”

AnnAGNPS takes daily rainfall data,
(which can be distributed to sub-daily timesteps)
and determines runoff using the
SCS “curve number”method.

An infiltration index

Assumes an “initial abstraction” due to
interception,
storage in numerous small-scale sinks,
initial wetting

Internally adjusted CN
due to changing soil moisture conditions.

Water quality modeler task #1: “get the water right”

Issues about the curve number method:

Originally designed for single event, storm peak determination

Easy to implement -- widely used

Sometimes pushed beyond its range of applicability

What if it snows or the ground freezes?

To “get the water right” with winter conditions
greater analytical complexity is required.

Fortunately, AnnAGNPS already accomodates all the required data:

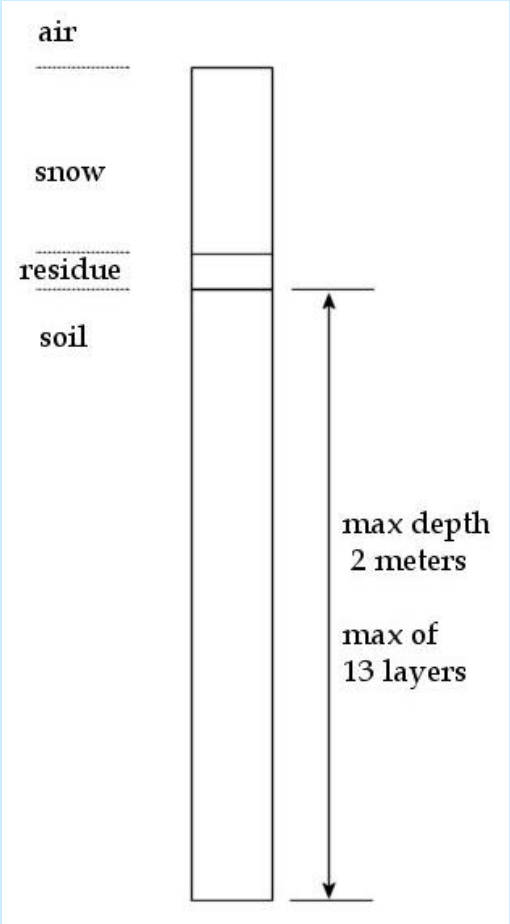
For snowpack accumulation and melt:

- air temperature
- precipitation
- dewpoint temperature
- humidity
- land slope & aspect
- solar radiation
- cloud cover
- wind speed

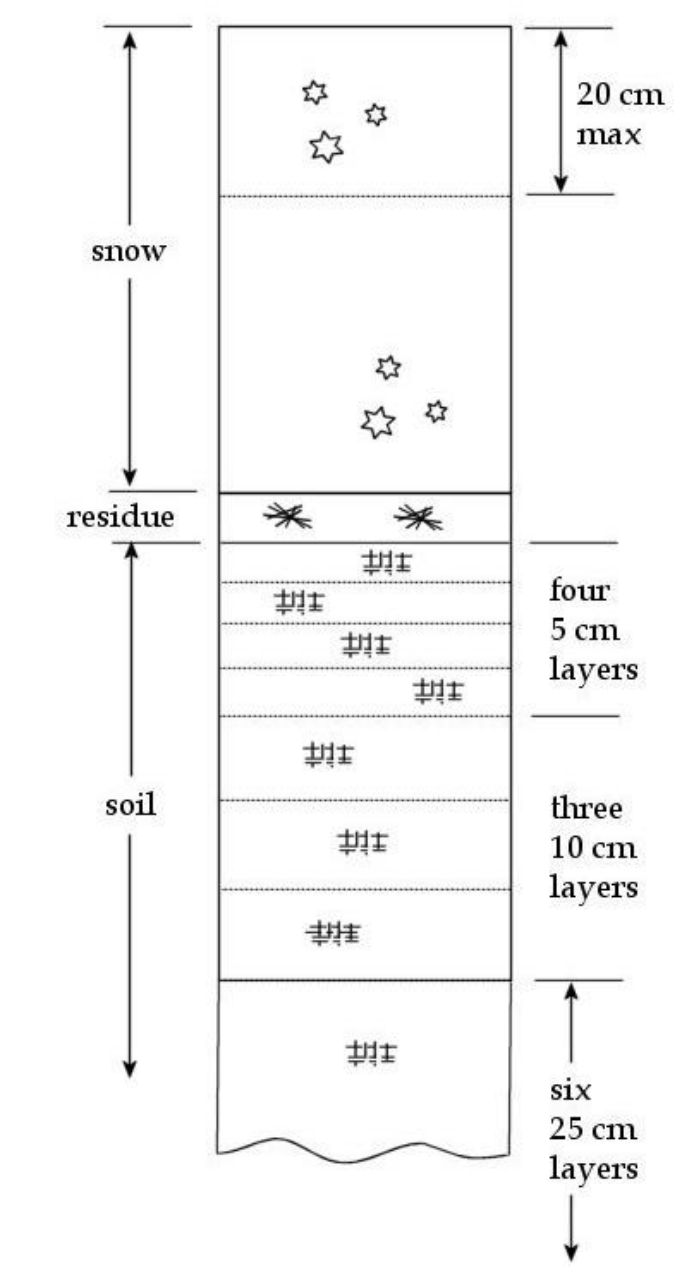
Additionally, for soil temperature:

- soil composition by depth
- soil moisture by depth

The winter algorithm divides the snow / soil column into thermal layers:

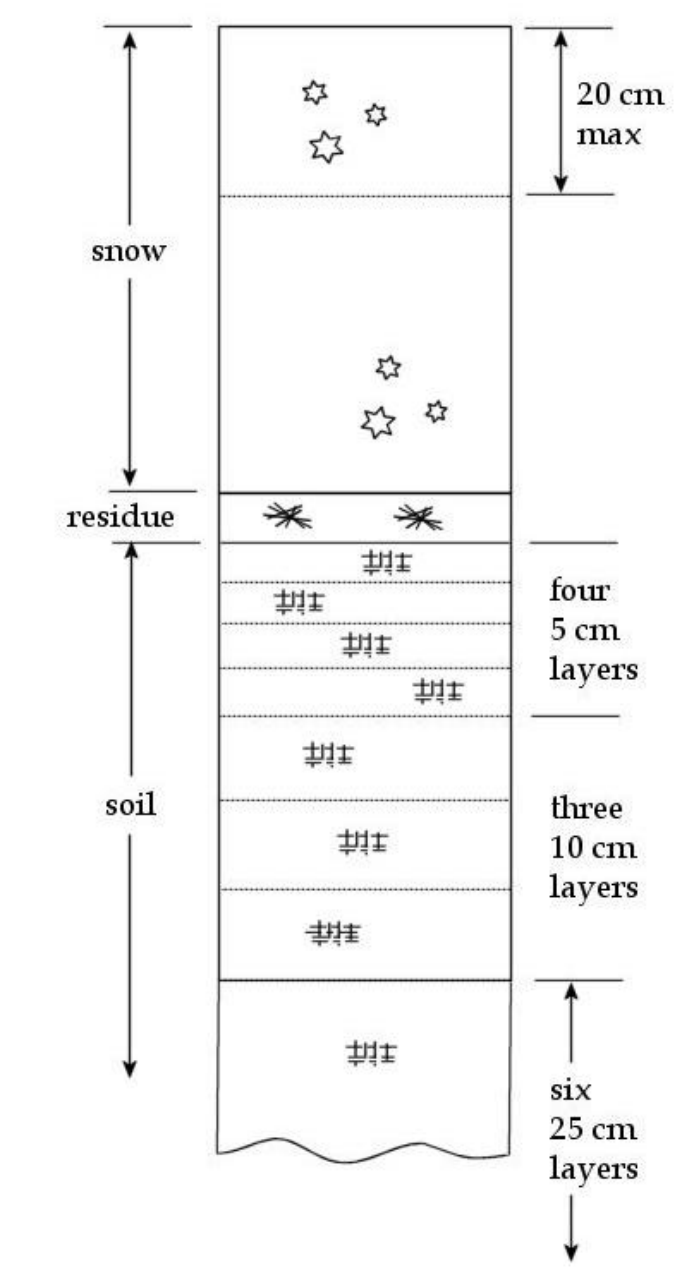


Or,
to take a closer look…



Up to 2 snow layers

up to 13 soil layers
of fixed thickness
varying with depth



Thermodynamics based on:

SHAW

Simultaneous
Heat
And
Water
model.

Gerald Flerchinger
ARS Research Hydraulic Engineer
Northwest Watershed Research Center,
Boise Idaho

Water quality modeler task #1: “get the water right”

Issues about SHAW:

A research-level “point model”.

Performs iterative balance of temperature & moisture profiles.

The methodology be “cpu intensive” with long computer runtimes.

Water quality modeler task #1: “get the water right”

Adapting SHAW for AnnAGNPS:

Run the “point model” for each cell to represent the entire cell.

Relax iterative balance tolerances (±0.0001 to ±0.1 ºC)

Increase timesteps (default hourly to default 3-hour)

Ignore freezing-point depression, heat flux due to vapor transfer, etc.

Why try to model freezing soil?

The freeze-thaw process weakens soil layers, increases erodibility.

A thawed layer over a deeper frozen layer
greatly increases erodibility.

A thawed layer over a deeper frozen layer
increases surface saturation and runoff.

Why try to model snowpack accumulation and melt?

The runoff lag of water stored in snow is highly significant.

Snowpack insulates the ground (frozen or not).

Rain on snow can be the most erodible weather events.

Water quality modeler task #1: "get the water right"

A bonus that comes with this methodology:

Curve number runoff is superceded by a more closely physically-based, non-index approach.

On a timestep to timestep basis
infiltration is calculated by considering

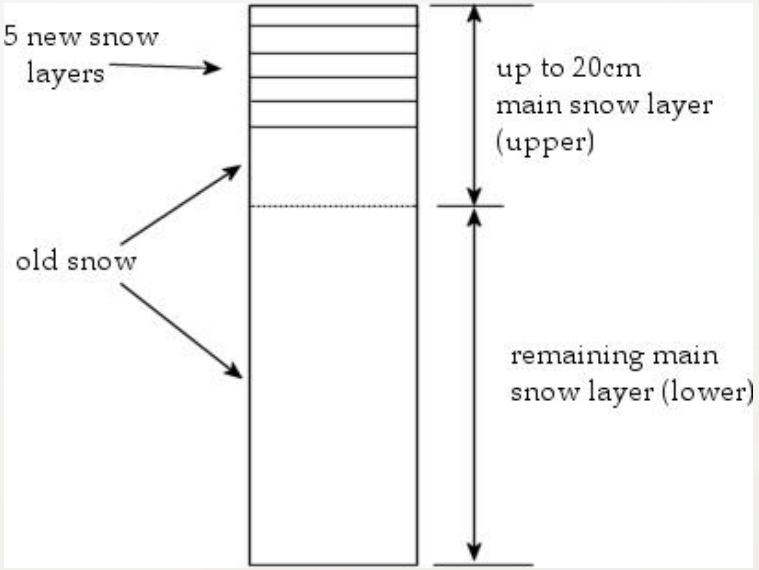
surface saturation due to high intensity
rainfall via Green-Ampt equation

percolation via hydraulic conductivity

snowpack details

photo credit: Brett Hampton, U. of Nebraska Institute of Agricultural and Natural Resources

Details: snowpack accumulation



Details: snowpack temperature

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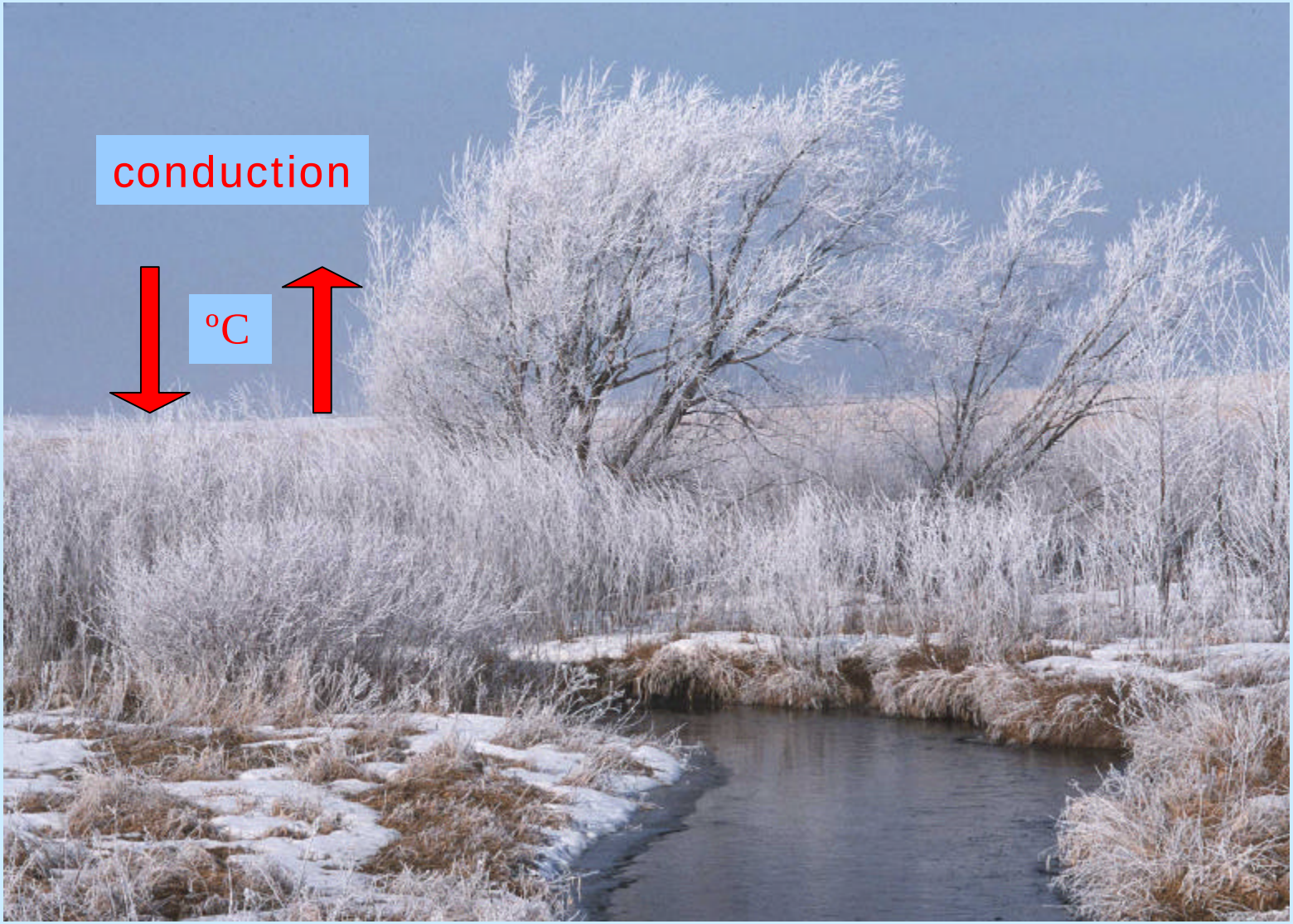

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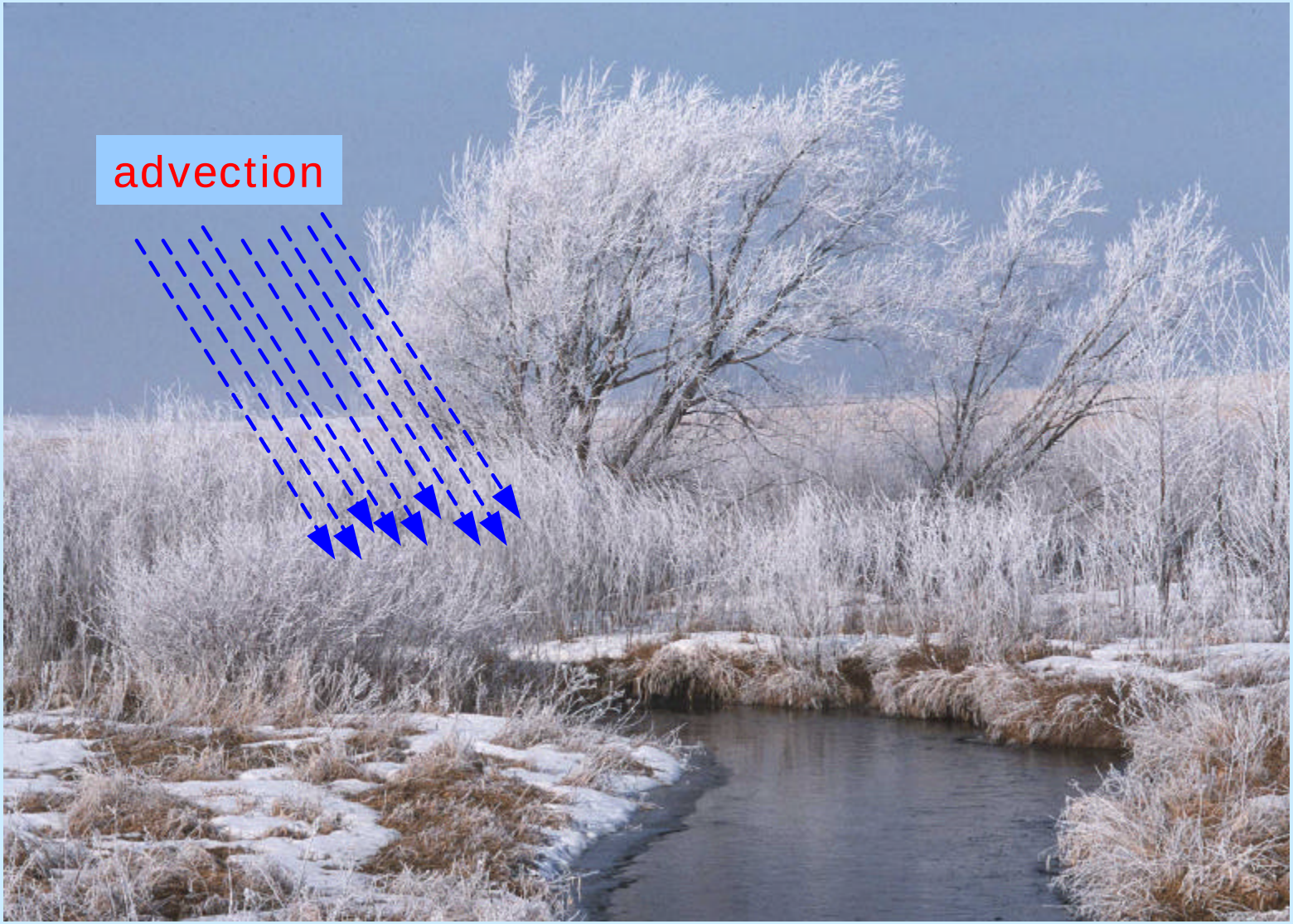

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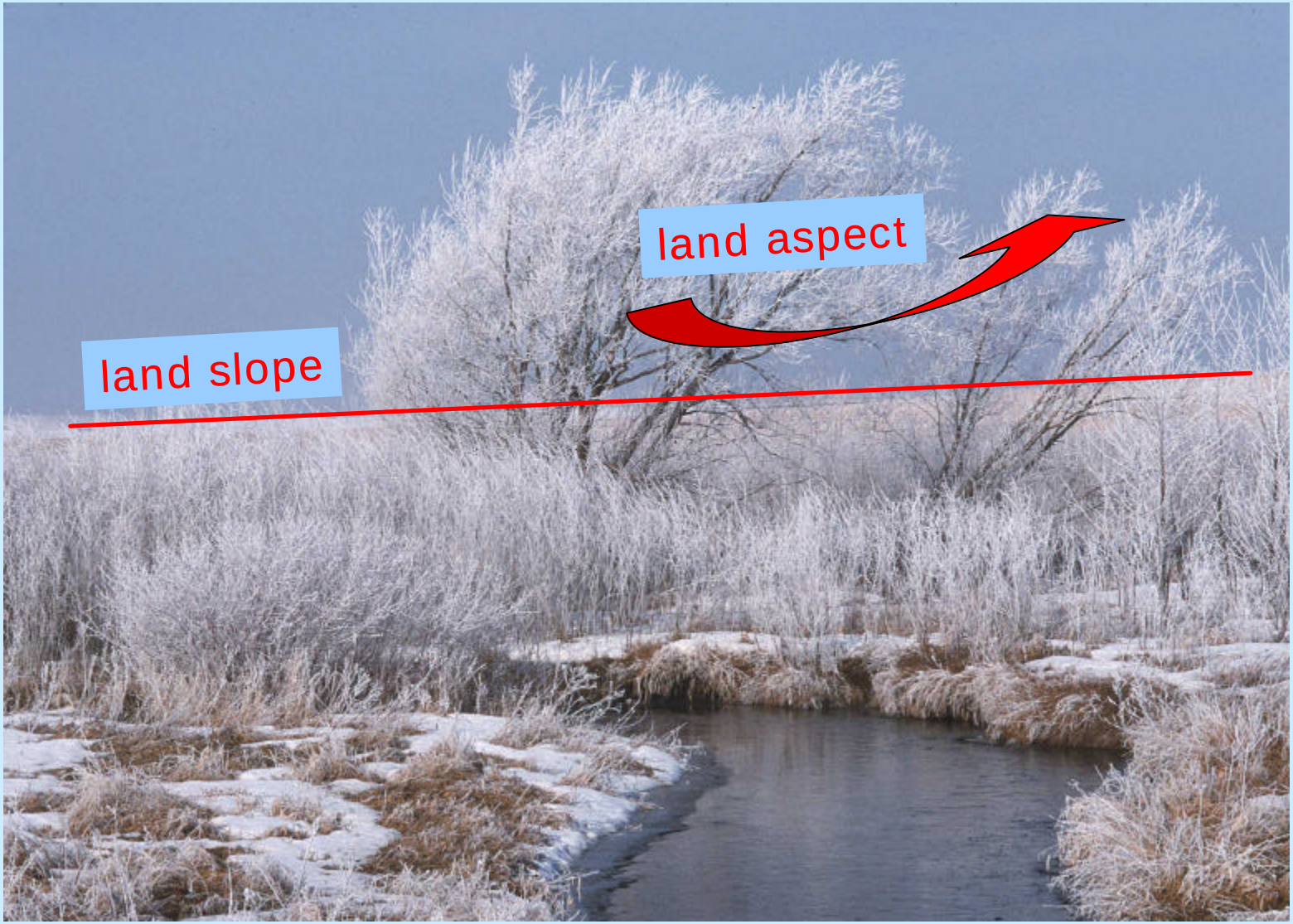
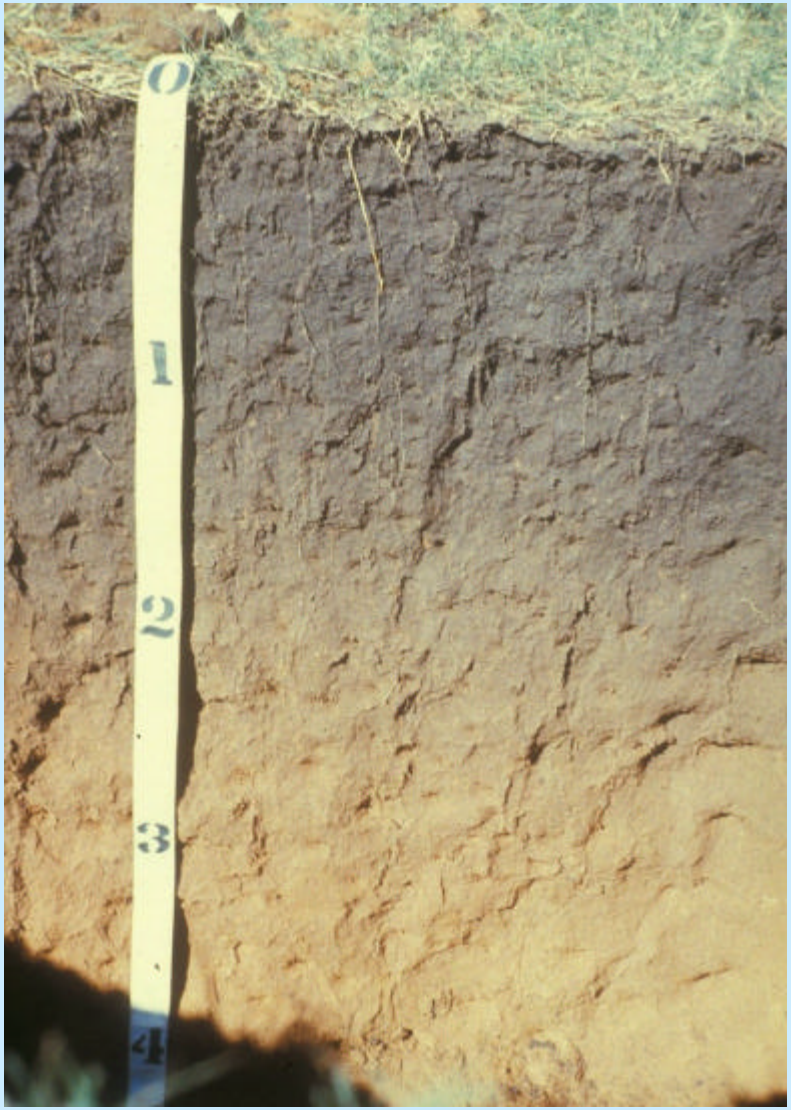
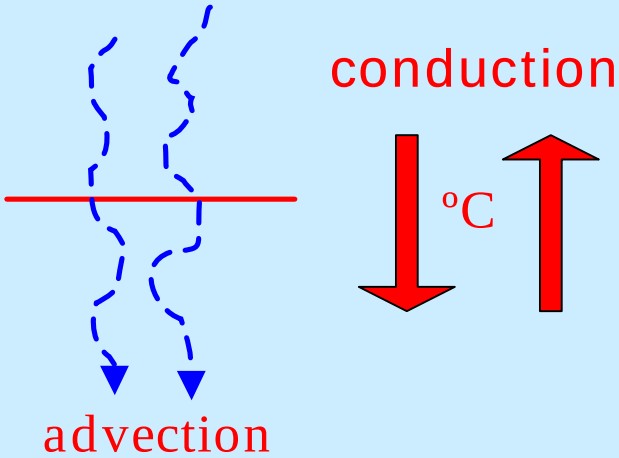


Details: soil temperature





Details: temperature balance, all layers

Matrix of thermal flux equations for
up to 2 snow layers
up to 13 soil layers
solved simultaneously in
8 timesteps per day

How long might a model run take?

Test dataset: International Falls MN (avg ann. T = 37º F)
run time: 0.45 seconds / year / cell

run of 100 years, 500 cells → 6.25 hours

What about calibration?

What about it?

Questions?