SUTRA-ice

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1. Overall Aims

Modify the USGS Saturated-Unsaturated Transport Code (SUTRA) to include freeze-thaw functionality for saturated and unsaturated groundwater conditions in one, two and three dimensions.

Use code to address broad range of questions related to the interplay of groundwater and the cryosphere.

Provide a tool that other researchers can use.

2. Simulation Code
McKenzie, Voss, and Siegel (2007)

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

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www.elsevier.com/locate/advwatres

Groundwater flow with energy transport and water–ice phase change: Numerical simulations, benchmarks, and application to freezing in peat bogs

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Original SUTRA Code

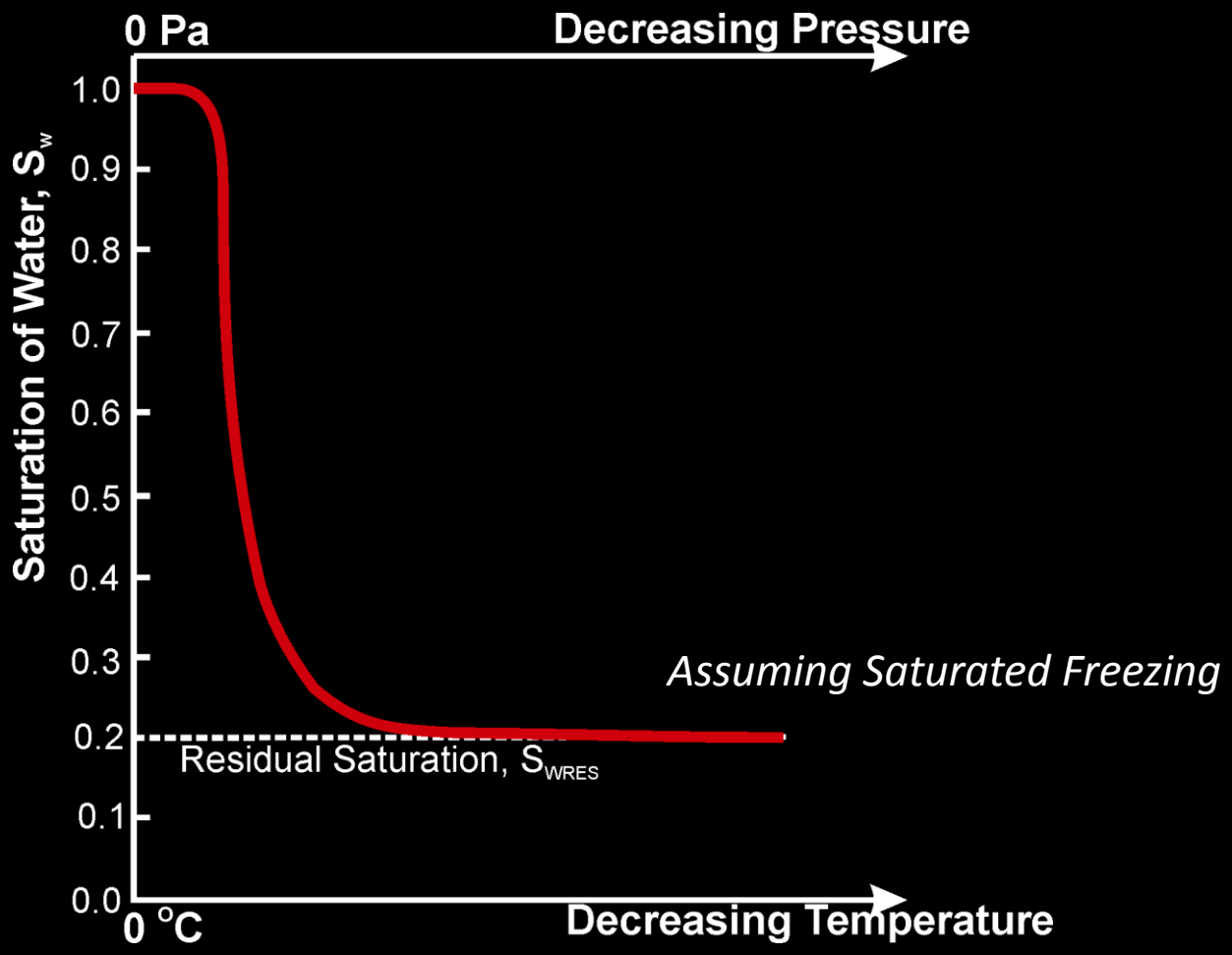
- Written initially by Cliff Voss (1984)
- Now also with Alden Provost
- Official USGS supported groundwater model
- Couples either energy or solute transport with groundwater flow
- Includes flow due to density differences
- Code is in FORTRAN

SUTRA-ice (Started ~2004)

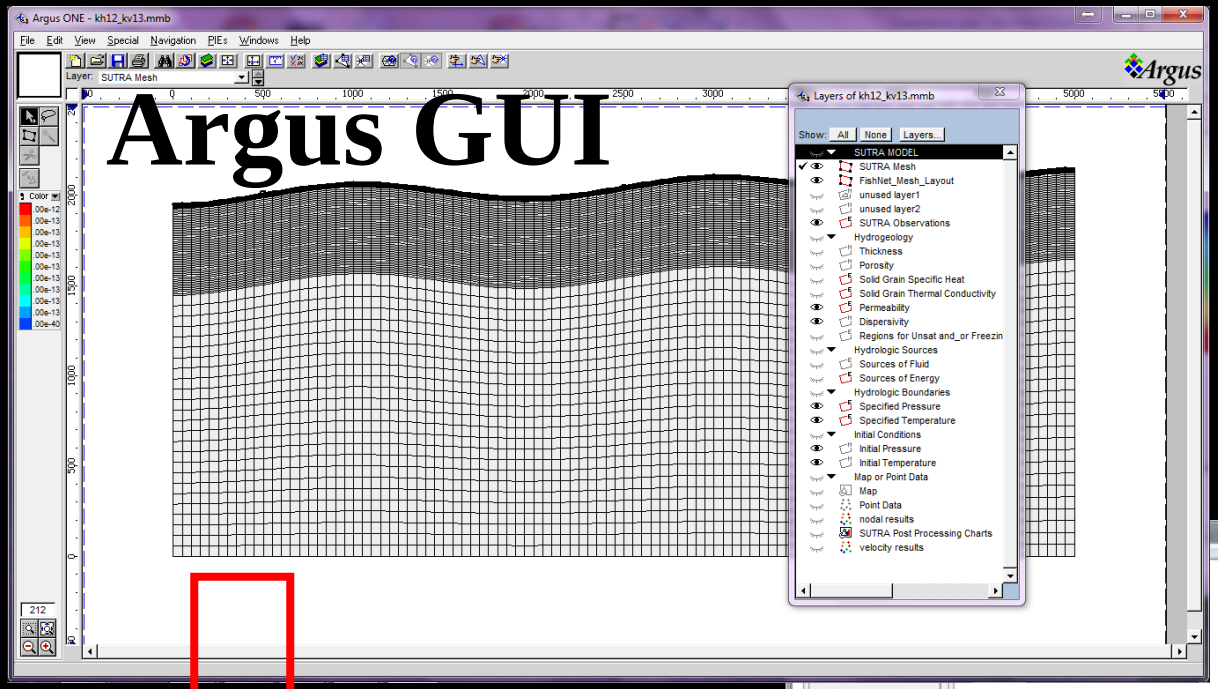
With freezing, the code accounts for changes to :

- Variable volumetric heat capacity
- Variable bulk thermal conductivity
- Liquid porosity and effective porosity (of liquid water)
- Permeability
- Latent heat

Modified SUTRA Code for Water Freezing and Melting



SUTRA Workflow

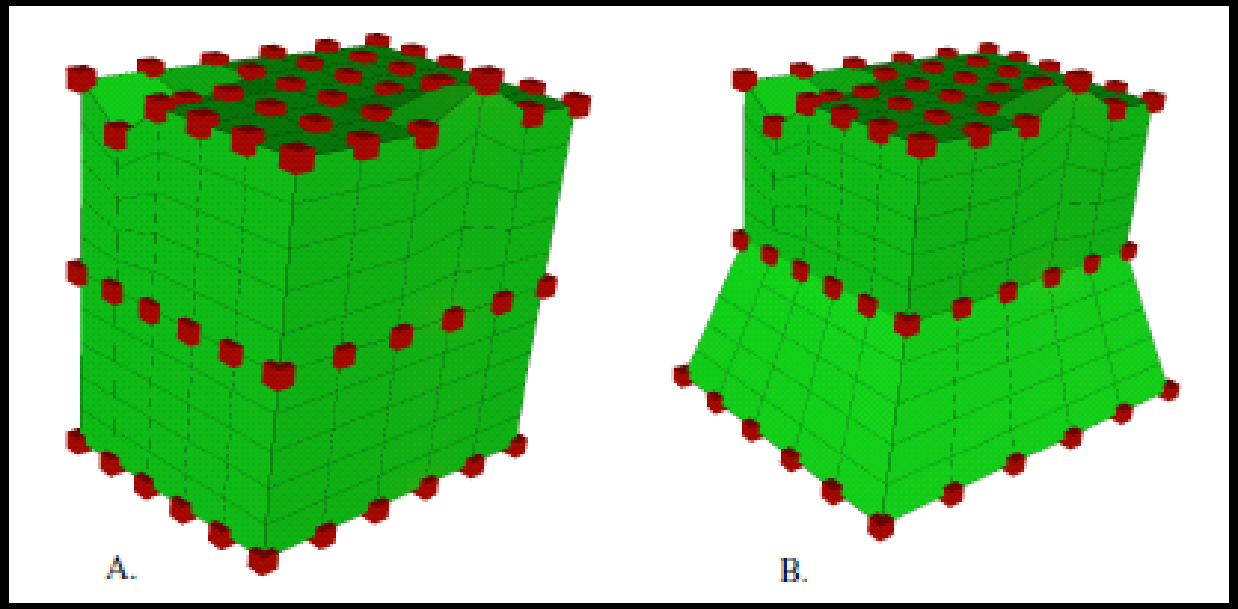


SUTRA Executable

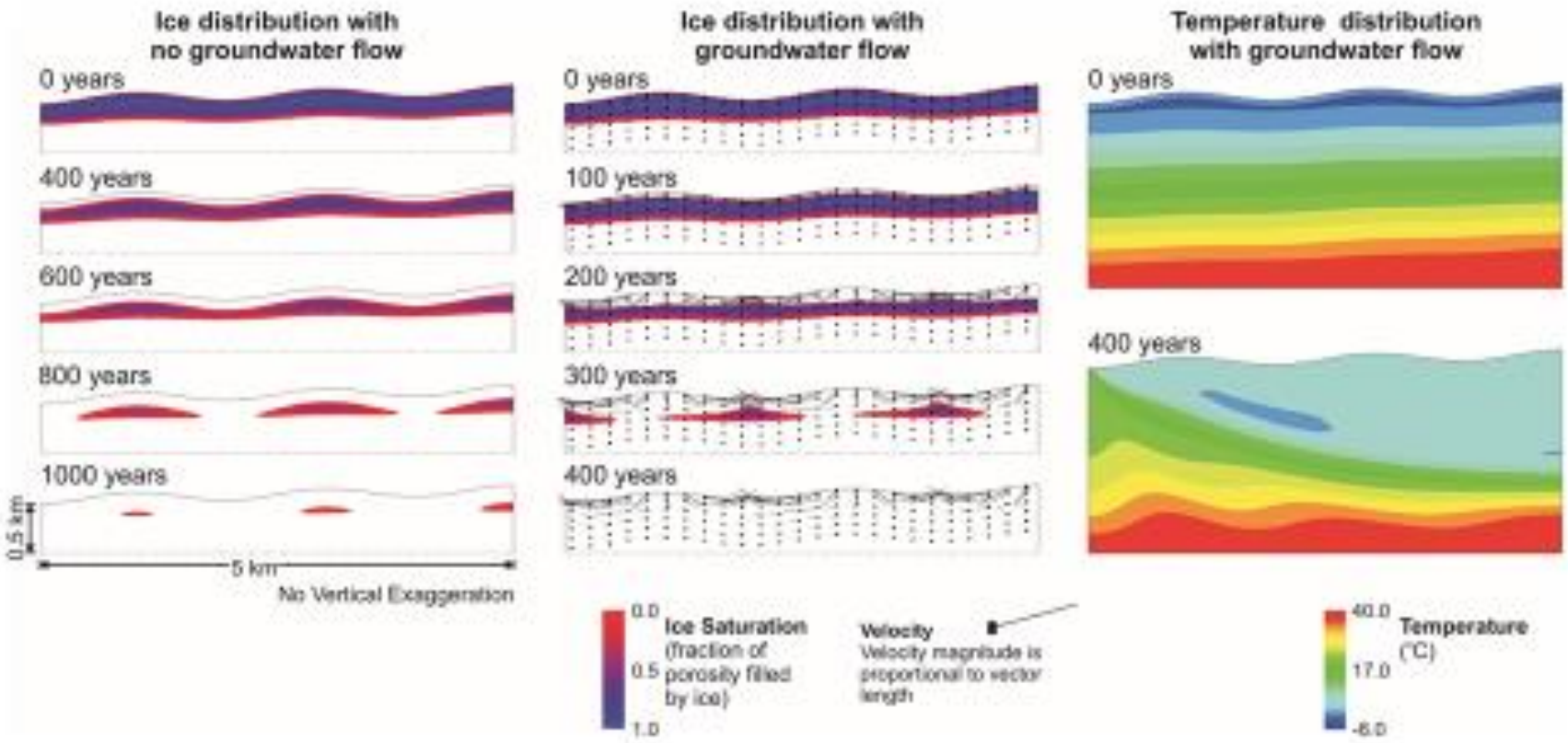
ModelViewer *et al.*

Other SUTRA-ice capabilities:

- Saturated **and** Unsaturated Freezing
- 1-, 2-, and 3- Dimensional



Tothian Hills



Applications

Twelvemile Lake Study Site

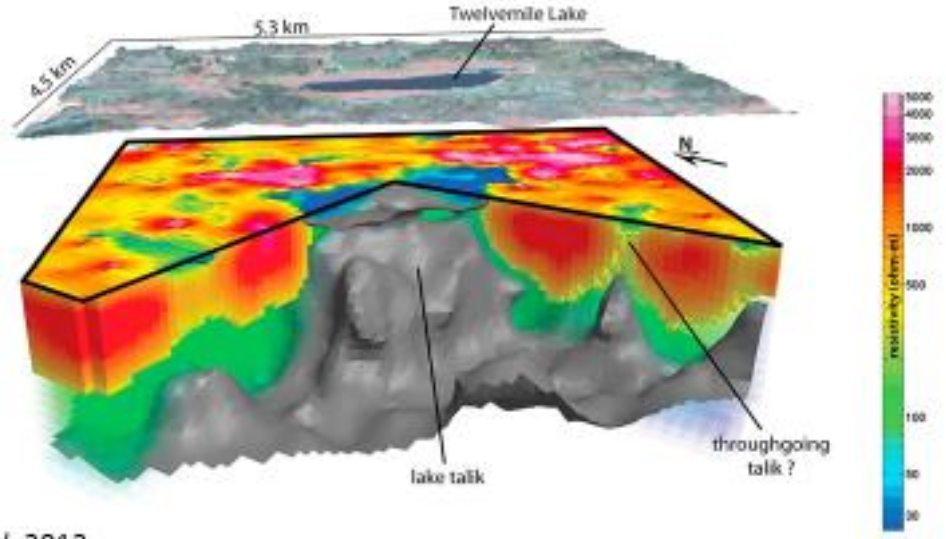
Annual Mean T = -6 C

Annual Precip. = 0.17 m

Watershed Area = 9.8 km^2

Permafrost ~100m thick

Soil – 50 m of Sand/Gravel



Minsley *et al*. 2012

Open Meadow

Moderate Shrub Effect

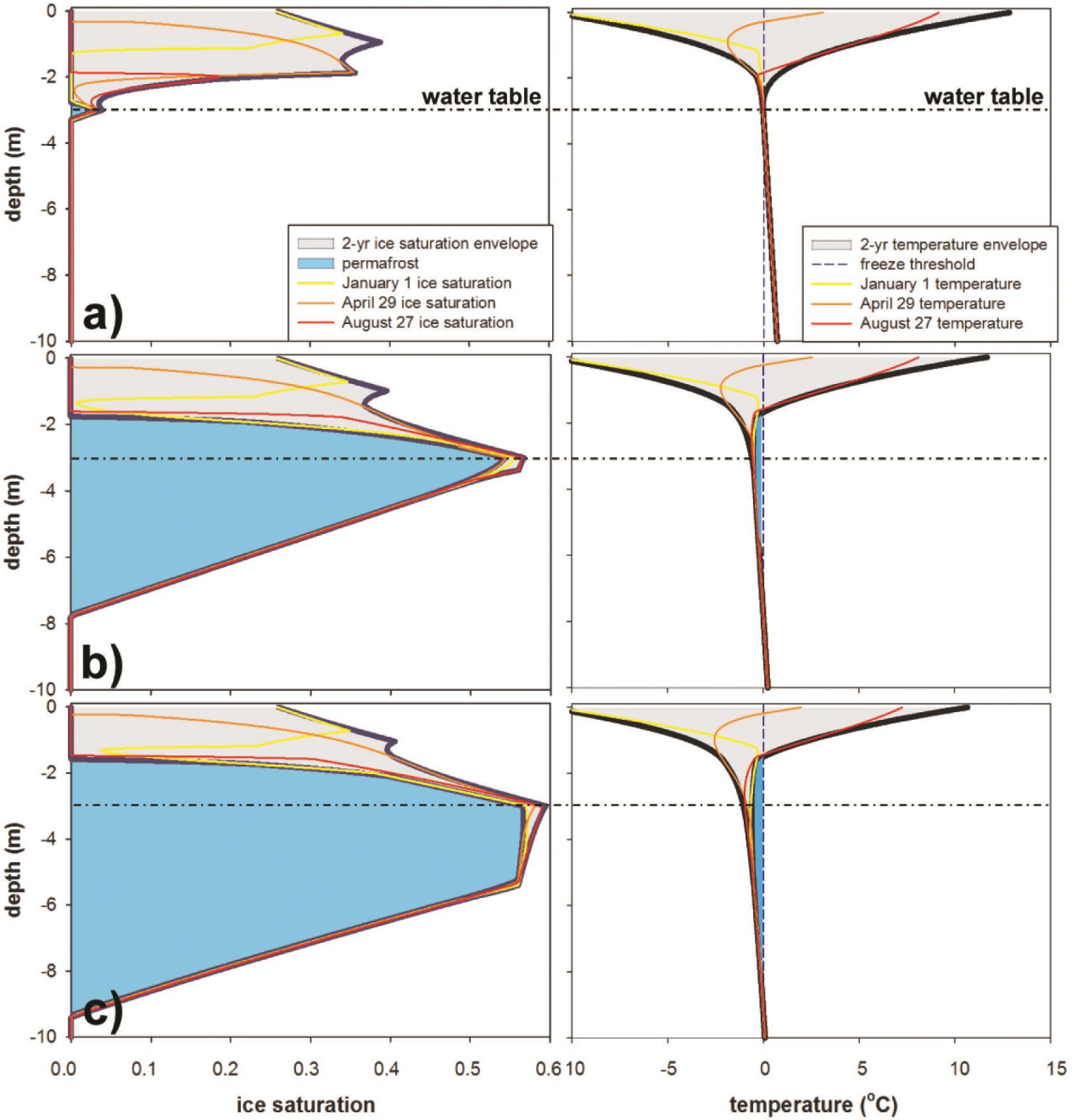
R_{sumer} =0

T_{summer} -1

Strong Shrub Effect

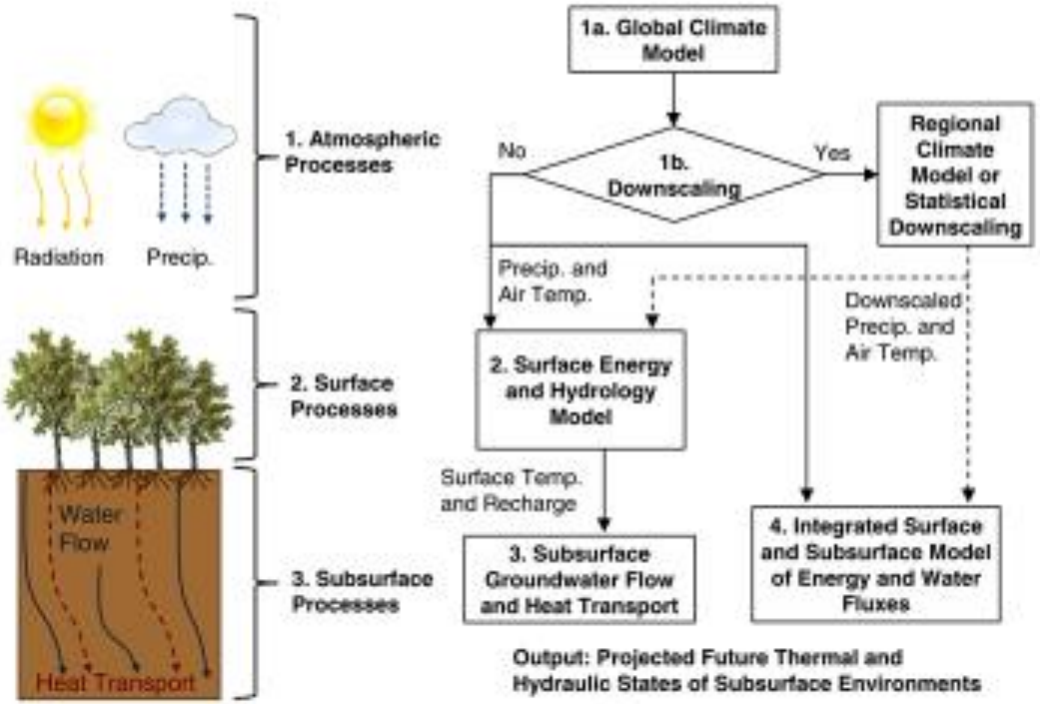
R_{summer} = 0

T_{summer} - 2



Surface Conditions

How to couple land surface and subsurface



Kurylyk *et al*, 2014

Status of SUTRA-ice

Current in *beta-testing* phase

Hopefully released next year as an official USGS code.

3. Interests in Benchmarking

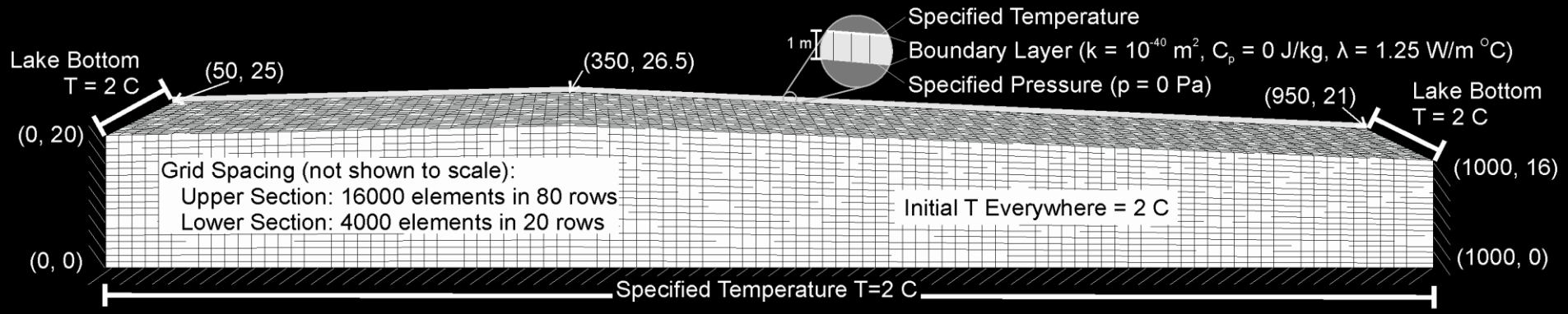
"Models that incorporate both mass and energy transport with ice formation are difficult to verify against analytical solutions because there are few solutions that solve this problem."

- SUTRA-ice Publication, 2007

Developing methods and best practices

- How do we use cold regions models?
- Particular problems:
  - Boundary conditions
  - Parameterization
  - Initial Conditions
  - Lack of Field Data

Hill Slope Benchmark



Units in meters