Modeling Permafrost – a CMT component

Elchin Jafarov
Vladimir Romanovsky
Sergei Marchenko

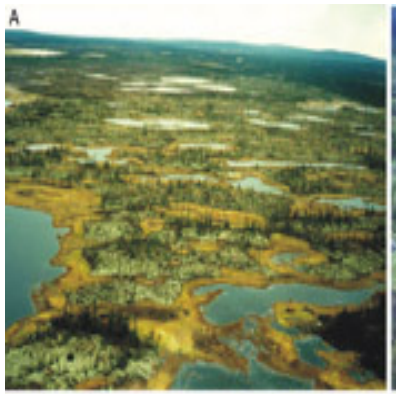
Geophysical Institute
University of Alaska Fairbanks

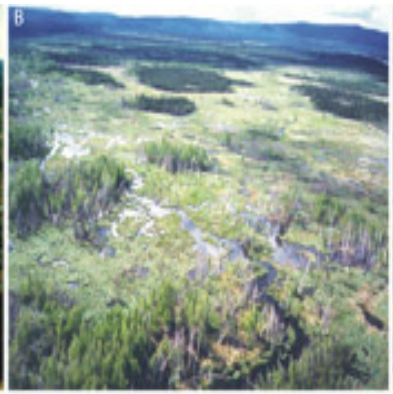
Boulder, October, 2011

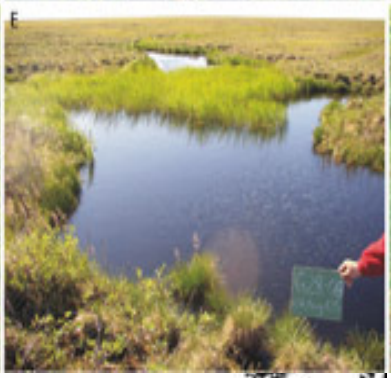
Frozen Soil (Permafrost)

Figure 1. Latitudinal zonation of permafrost. Source: Brown and colleagues (1998).

Thawing Permafrost

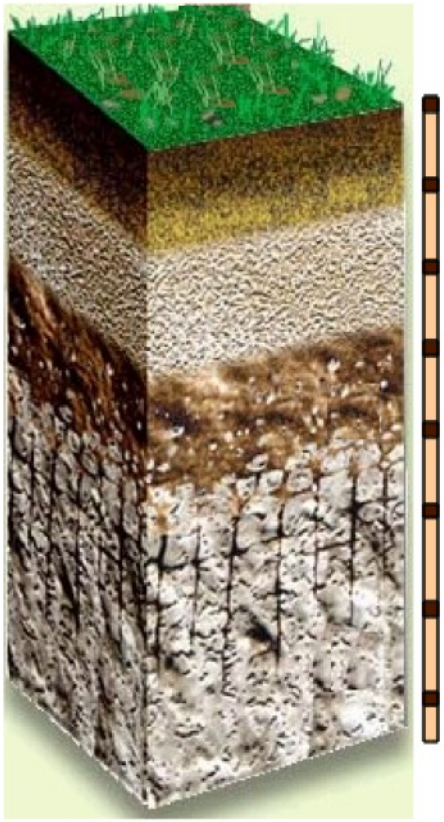




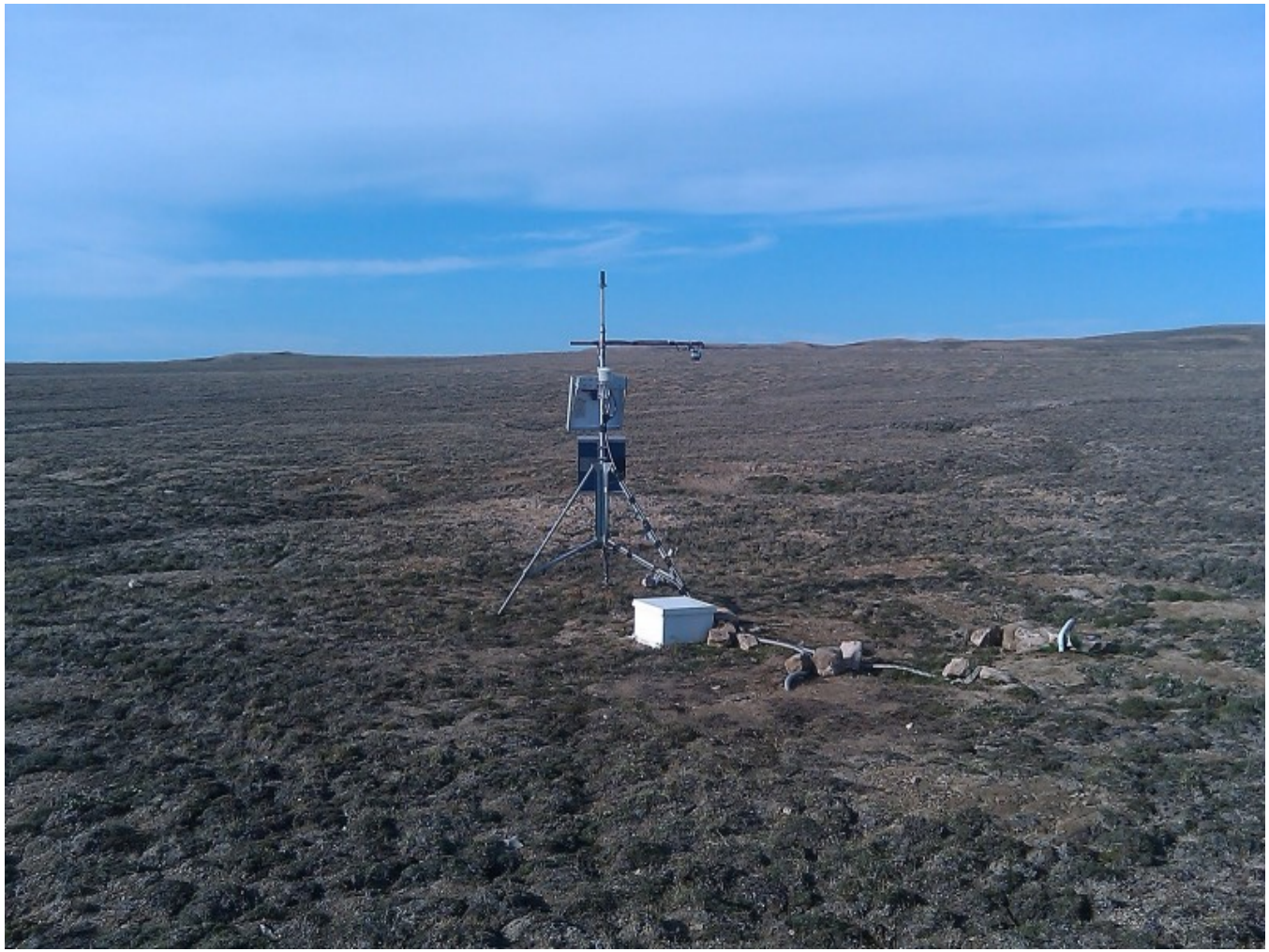


http://www.libraryindex.com/pages/3372/Permafrost.html
http://ipy.arcticportal.org/index.php?/ipy/detail/permafrost/
http://nasadaacs.eos.nasa.gov/articles/2005/2005_permafrost.html

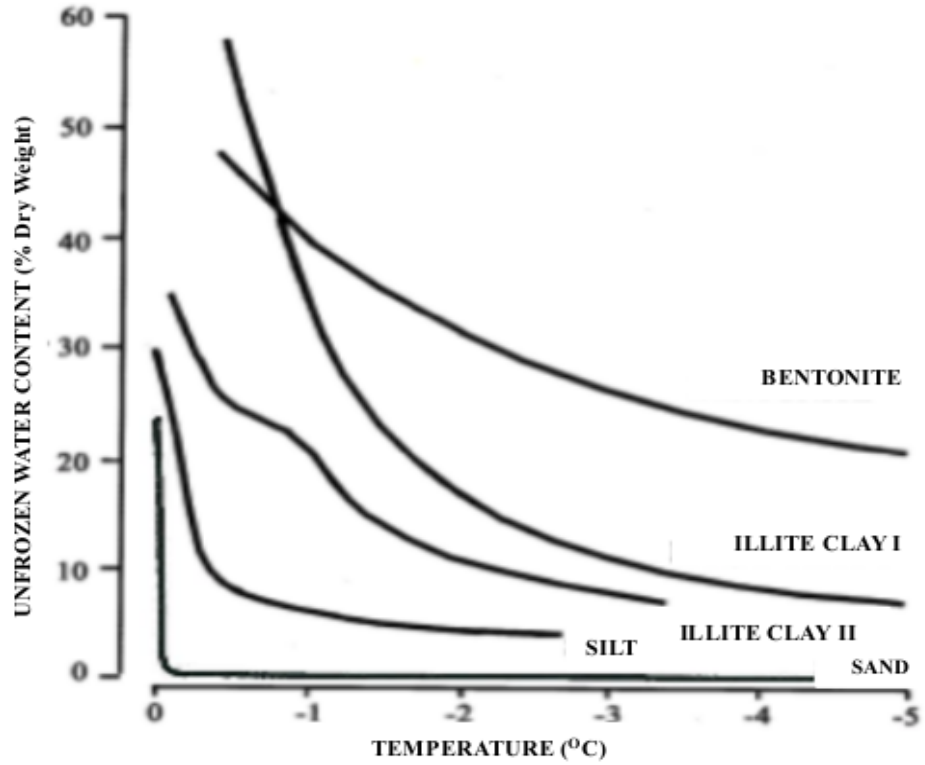
Measurements



- Temperature sensor



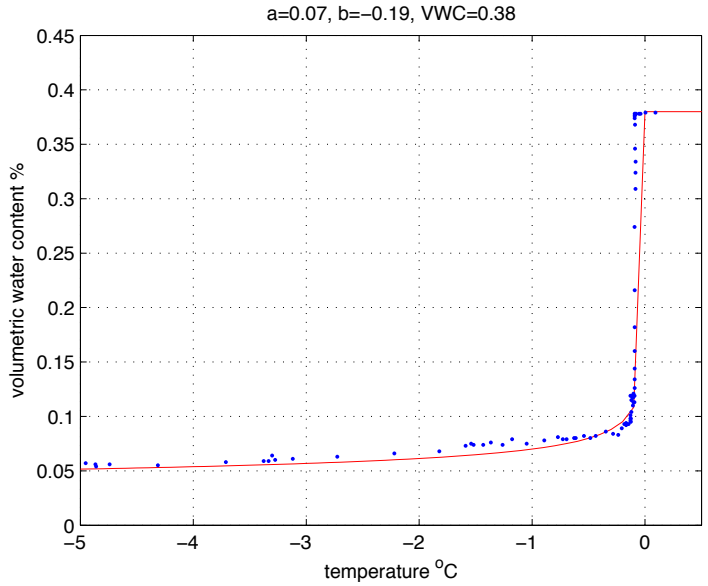
Soil Moisture



Neil Davis “Permafrost”

Soil texture by grain size table

Texture Name	Diameter Limits
Boulders>Cobbles>Pebbles	Larger than 2 cm
Gravel	2cm – 5 mm
Very Coarse Sand	1 mm – 2 mm
Sand	0.05 mm – 1 mm
Silt	0.002 mm – 0.05 mm
Clay	Less than 0.002 mm



Mathematical Model

$$\frac{\partial H(x,t)}{\partial \tau} = \frac{\partial}{\partial x}\left(k(x,t)\frac{\partial t(x,\tau)}{\partial x}\right)$$

$$H(x,t) = \int_0^t C(x,s)ds + L\Theta(x,t)$$

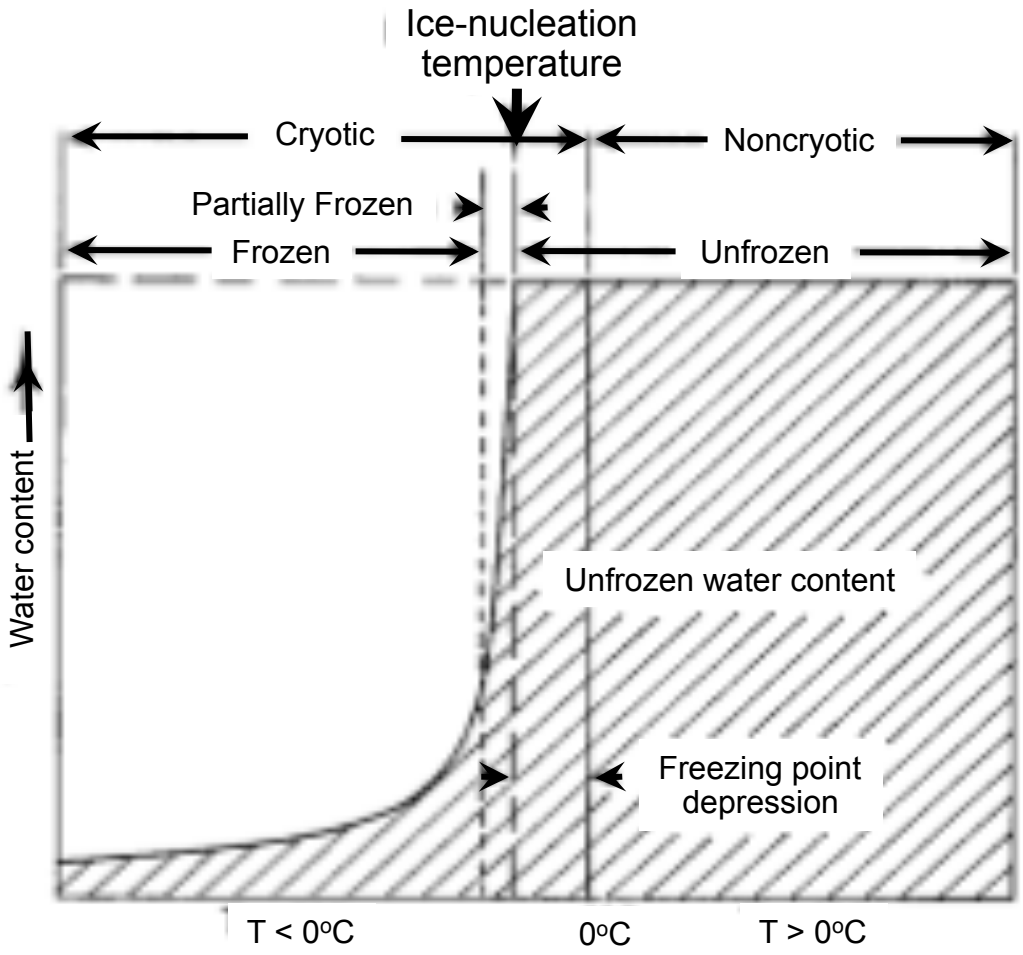
boundary and initial conditions

$$t(l_1,\tau) = t_{air}$$
$$\frac{\partial t(l_2,\tau)}{\partial x} = g$$
$$t(x,0) = t_0(x).$$

unfrozed water content function

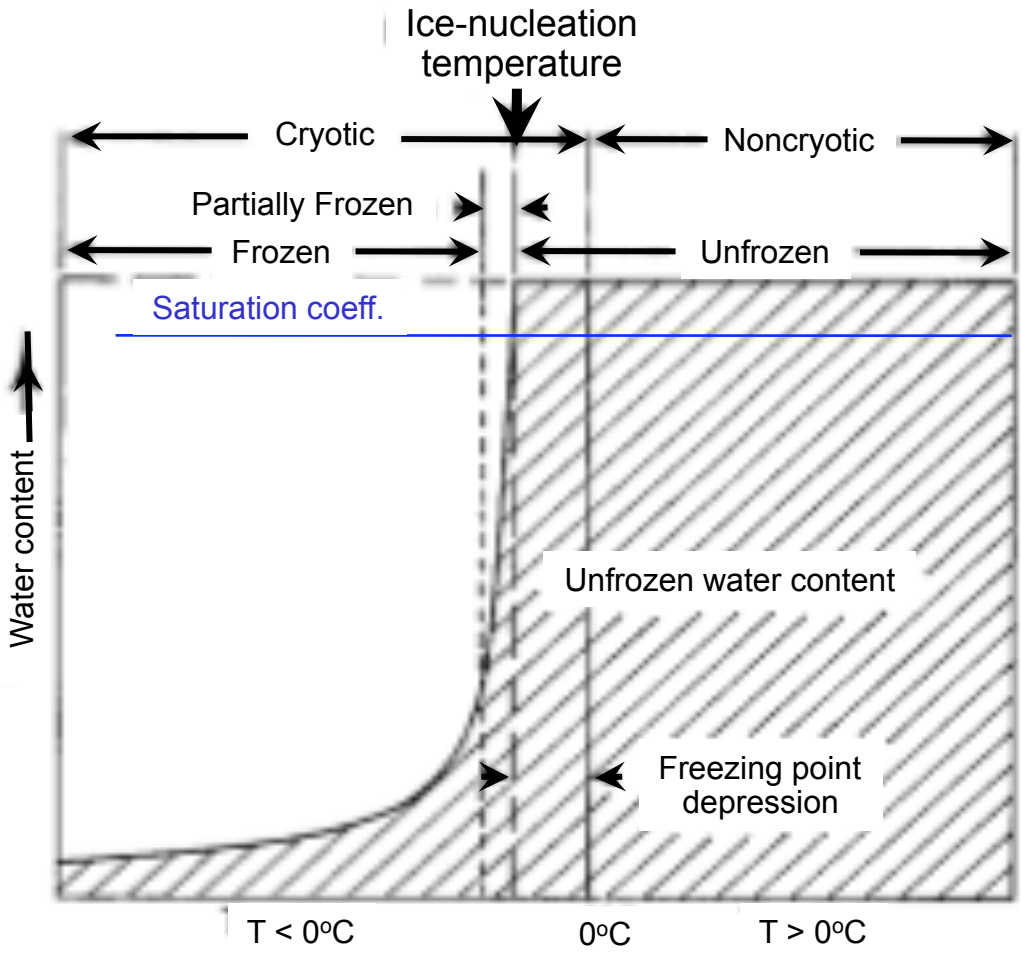
$$\Theta(x,t) = \eta(x) \cdot \begin{cases} 1, & t \geq t_* \\ a|t|^{-b}, & t < t_* \end{cases}.$$

Active Layer Thickness



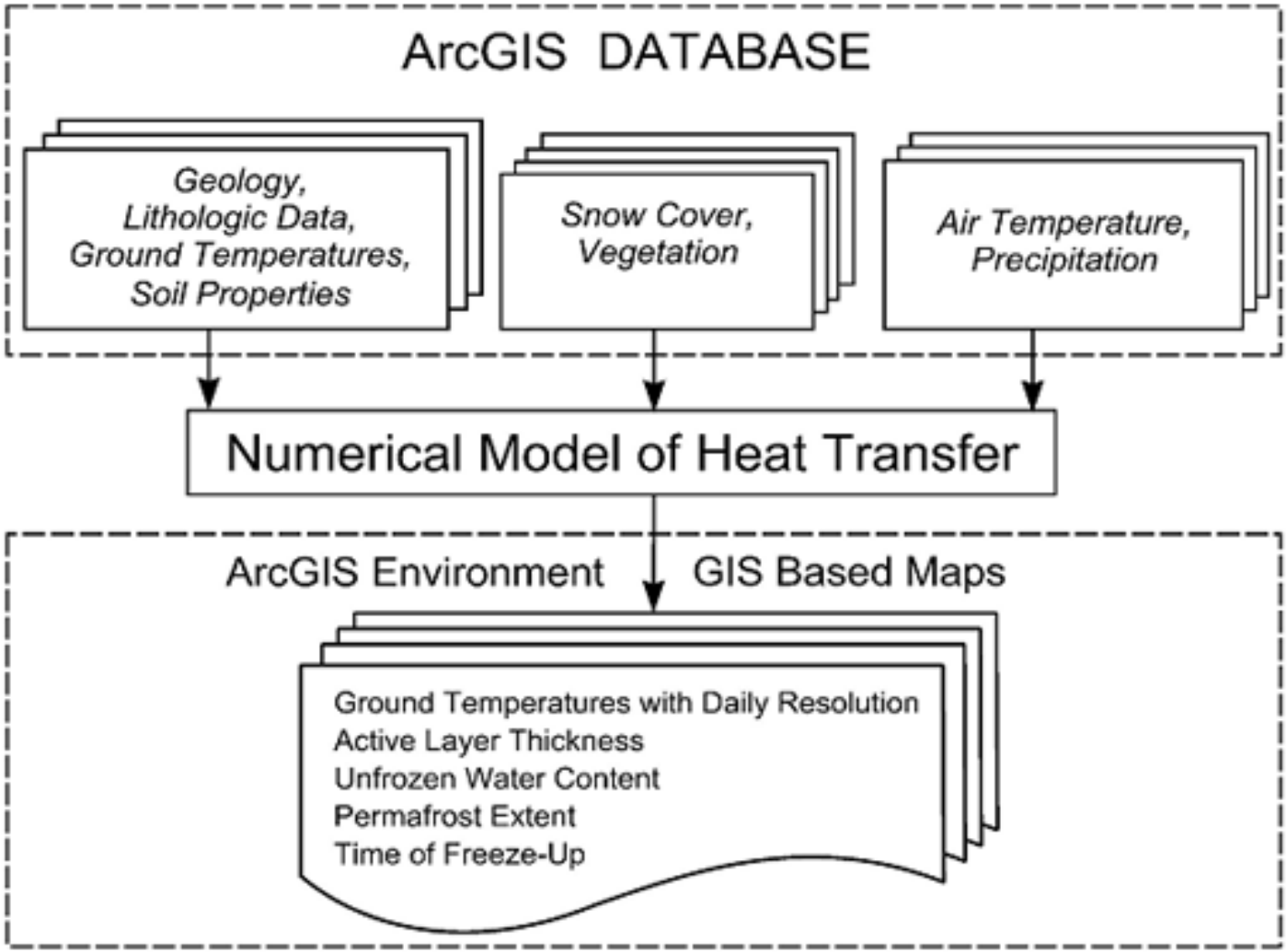
C.R. Burn. (1999). The Active Layer: Two Contrasting Definition.

Active Layer Thickness



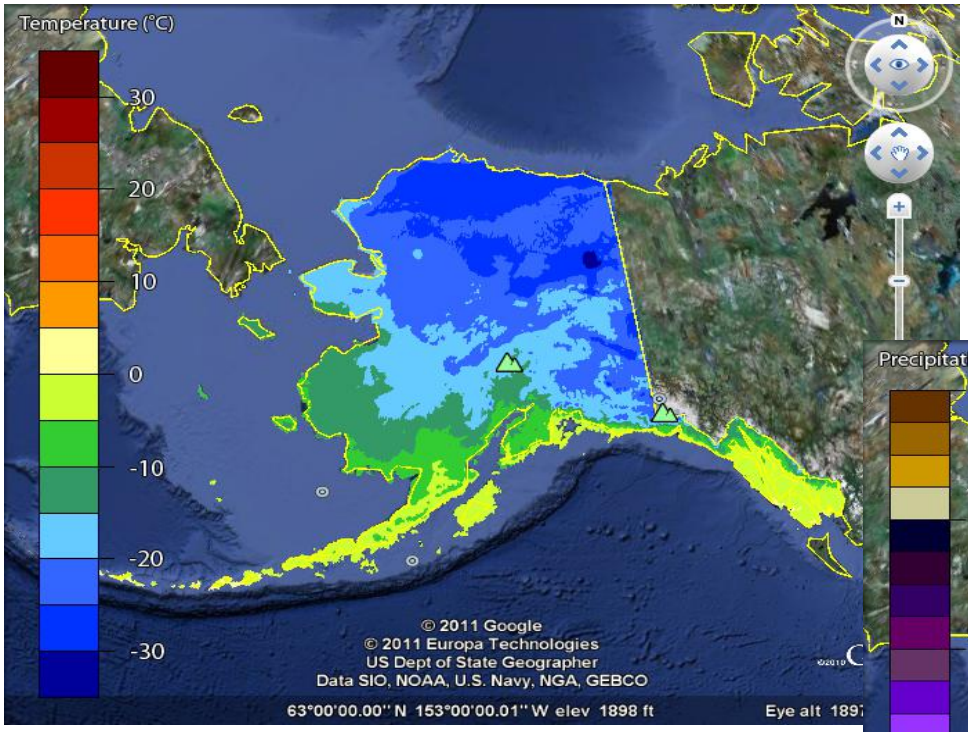
C.R. Burn. (1999). The Active Layer: Two Contrasting Definition.

GIPL2-MPI



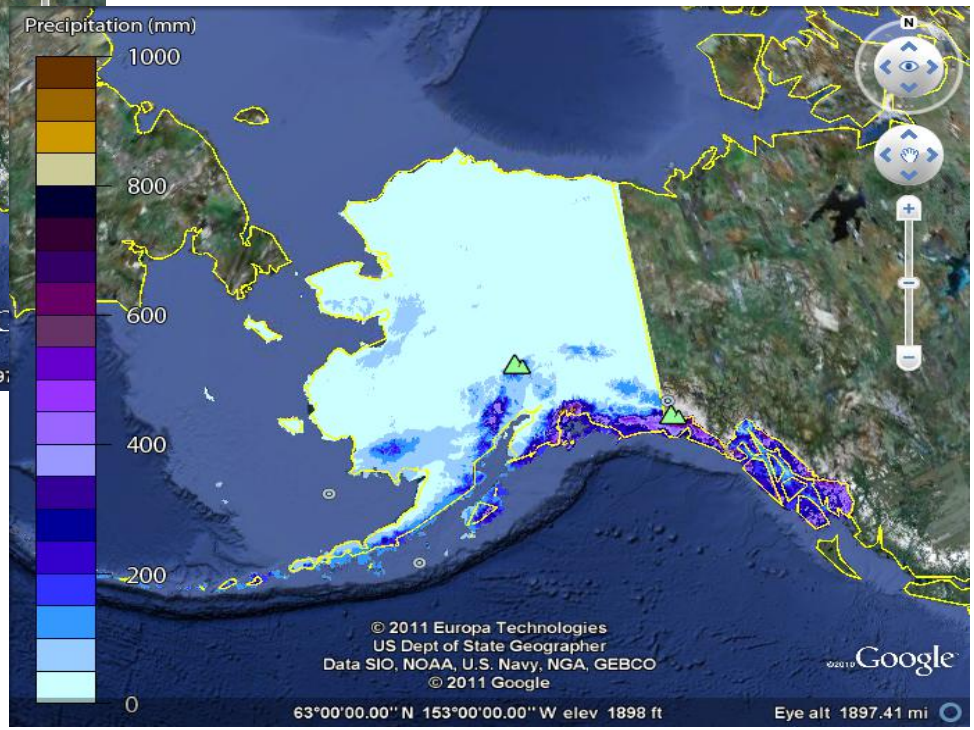
The GIPL-MPI model schematic diagram. S. Marchenko (2008)

Input Datasets



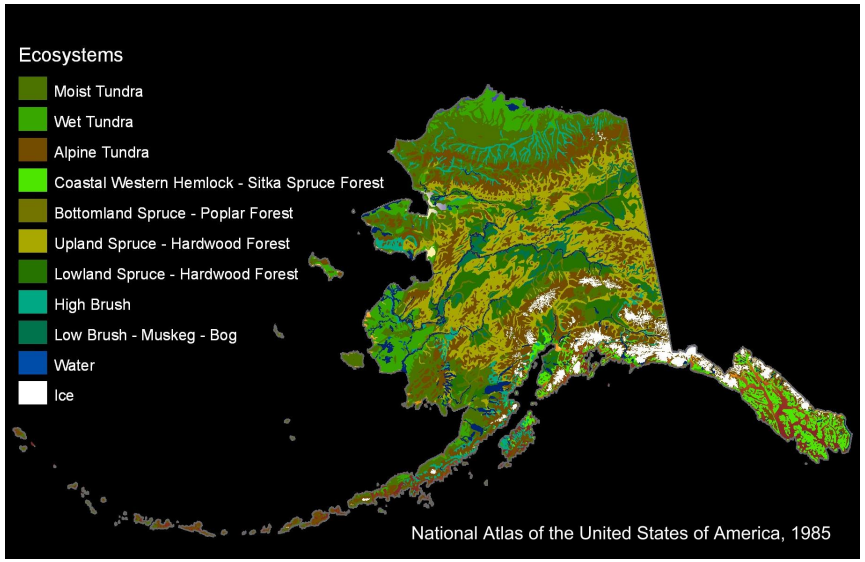
Monthly averaged air temperature (°C) during January 1980 (SNAP).

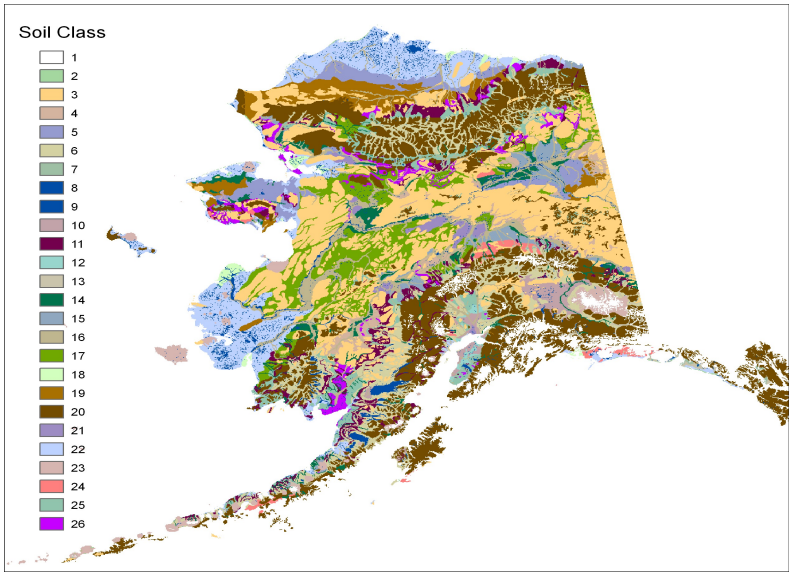
- The GCMs composite was downscaled to 2 by 2 km resolution using knowledge-based system PRISM.

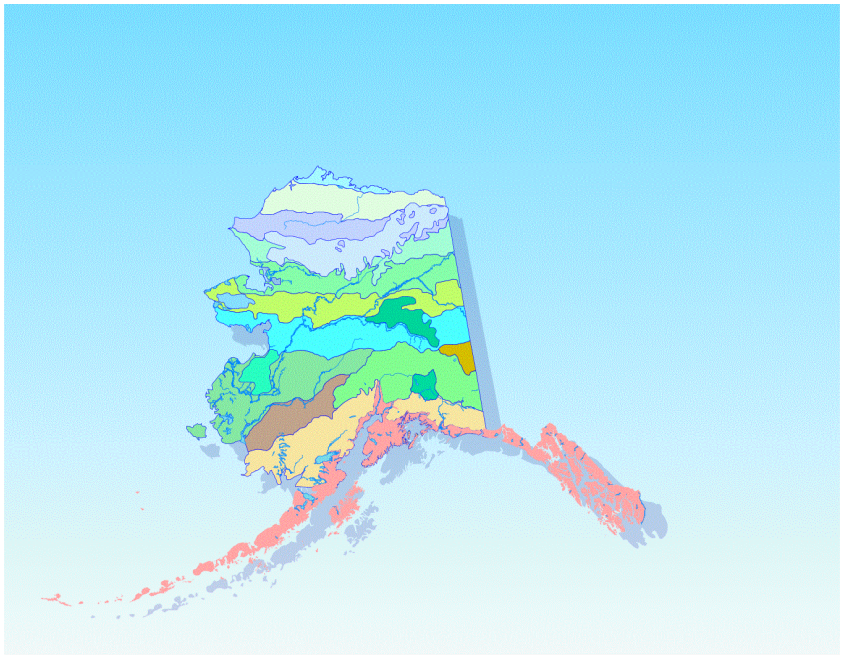


Monthly averaged precipitation (mm) during January 1980 (SNAP).

Input Datasets

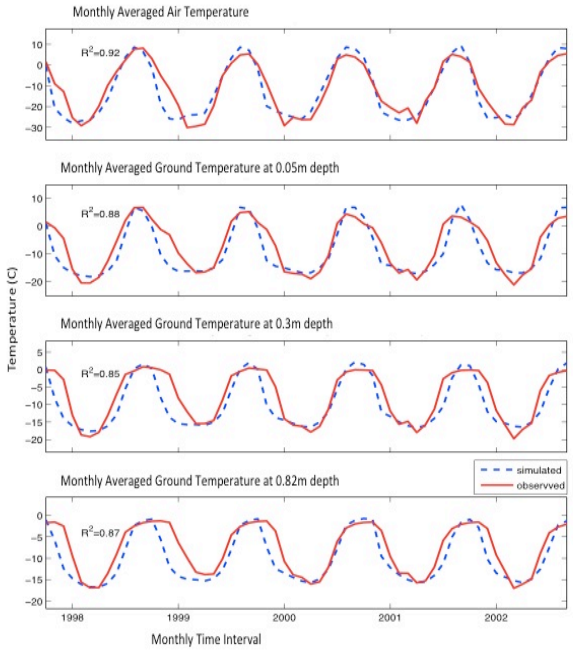


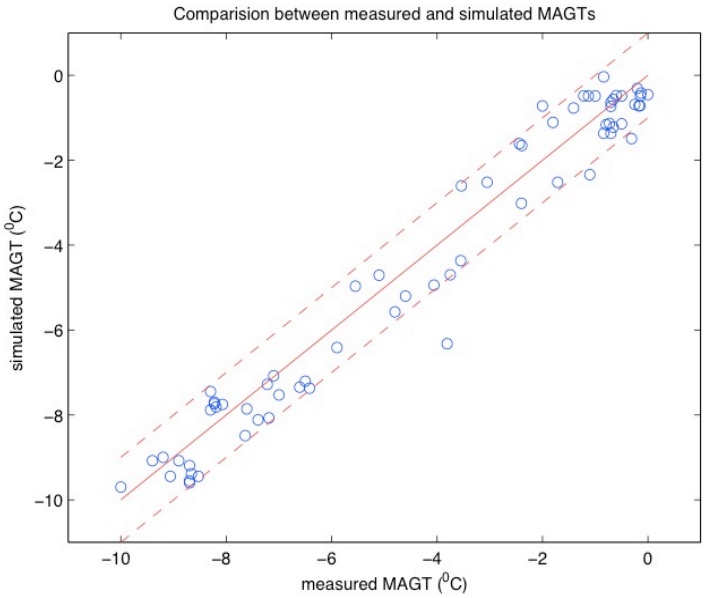


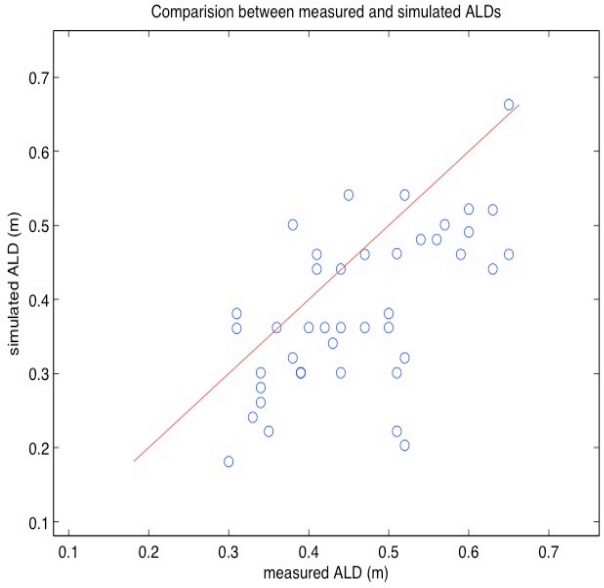


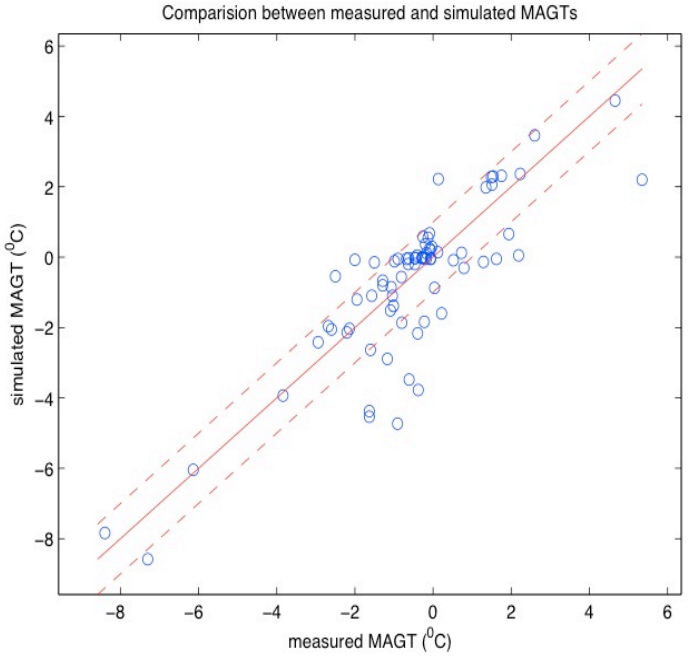
Karlstrom, T.N.V., et al., 1964. Surficial geology of Alaska. U.S. Geol.Surv., Misc. Geol. Inv. Map I-357, scale 1:1,584,000

Calibration and Validation

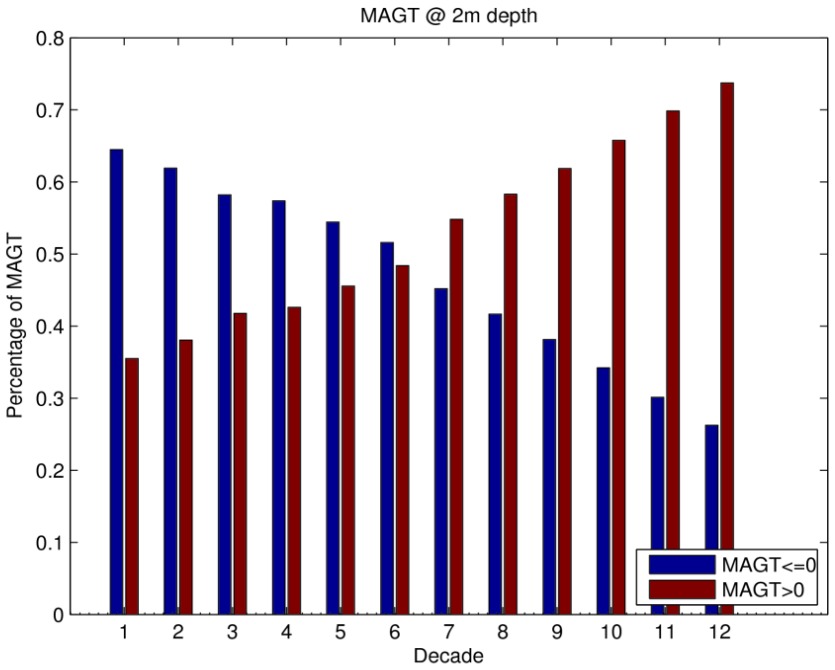


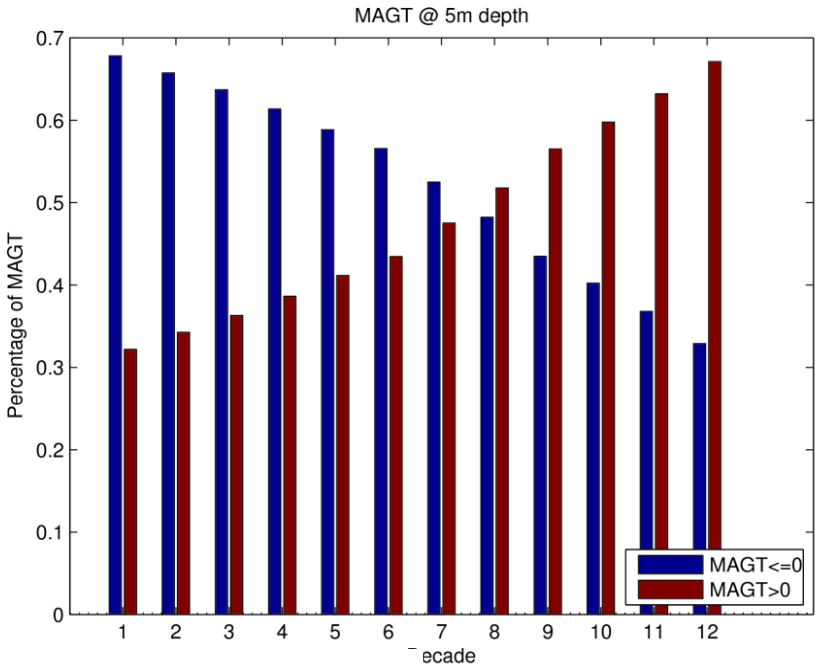


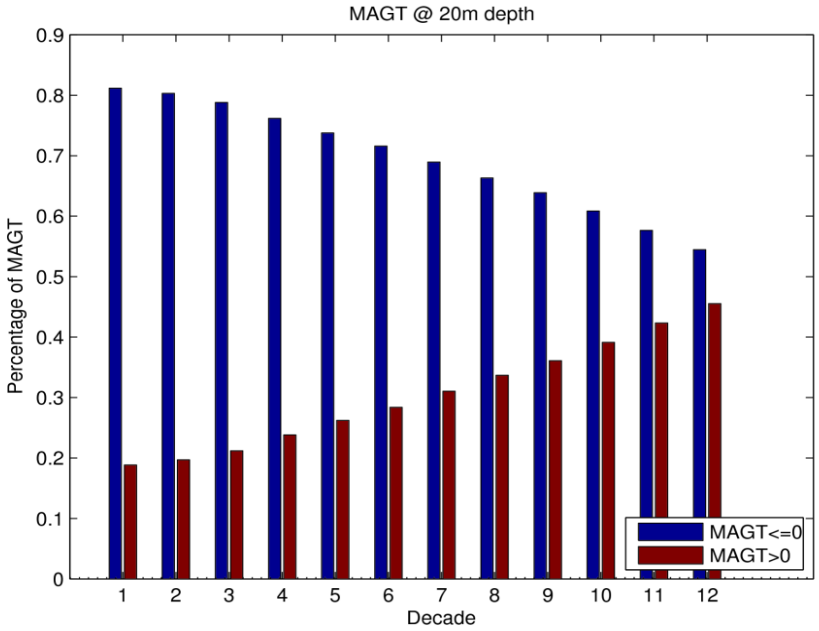




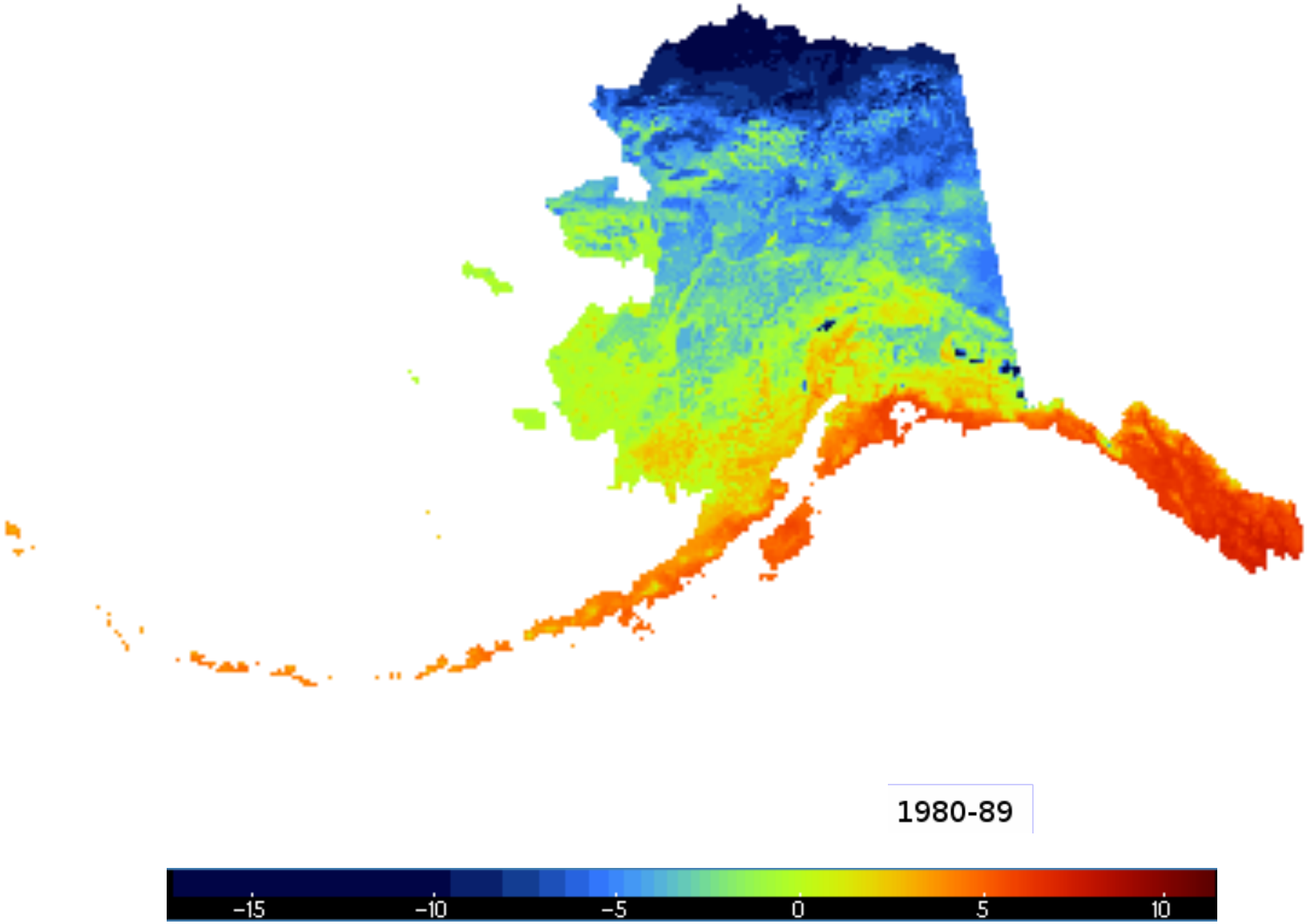
Results


MAGT @ 2m depth
Percentage of MAGT
Decade
MAGT<=0
MAGT>0

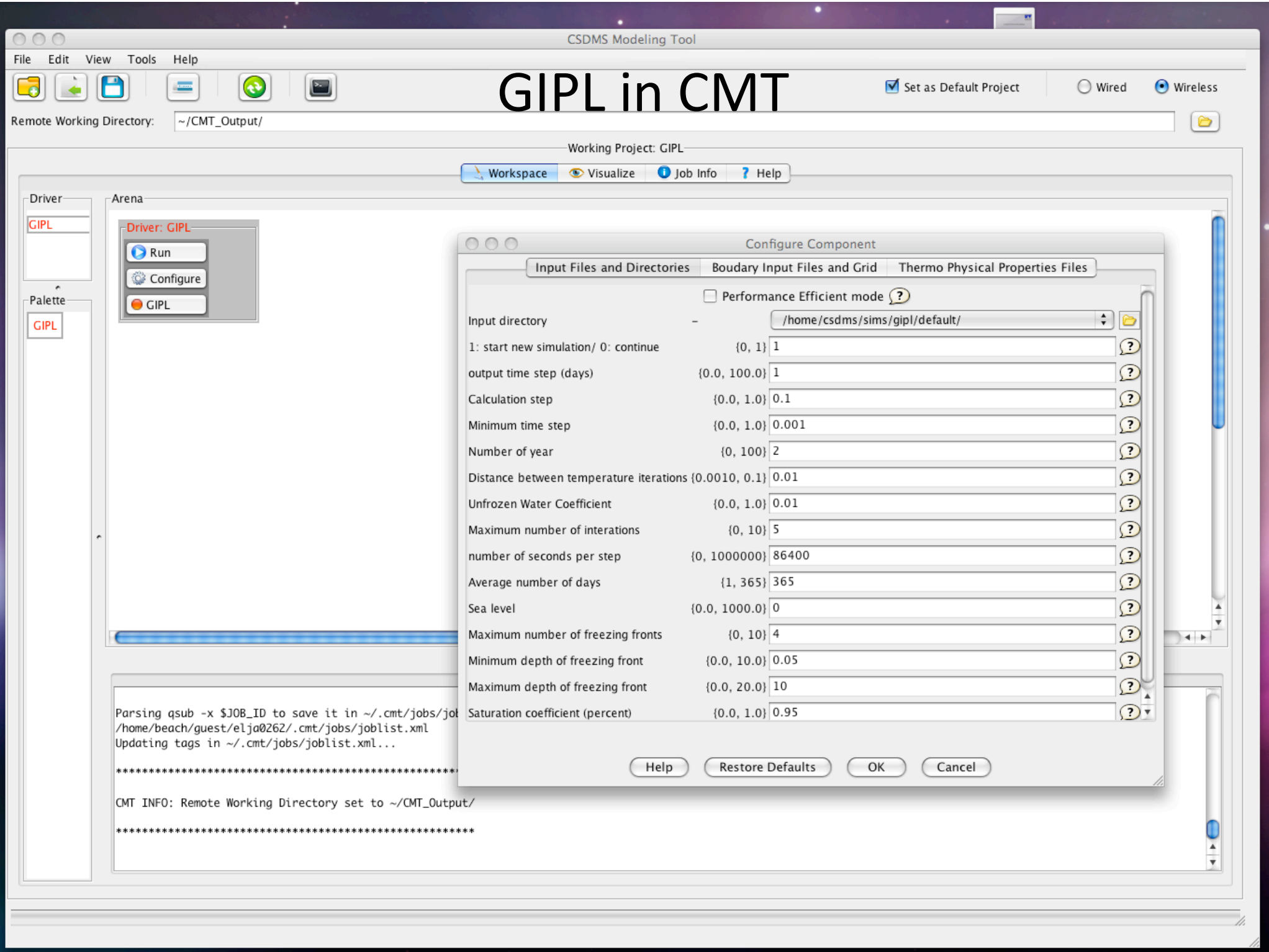

MAGT @ 5m depth
Percentage of MAGT
ecade
MAGT<=0
MAGT>0


MAGT @ 20m depth
Percentage of MAGT
Decade
MAGT<=0
MAGT>0

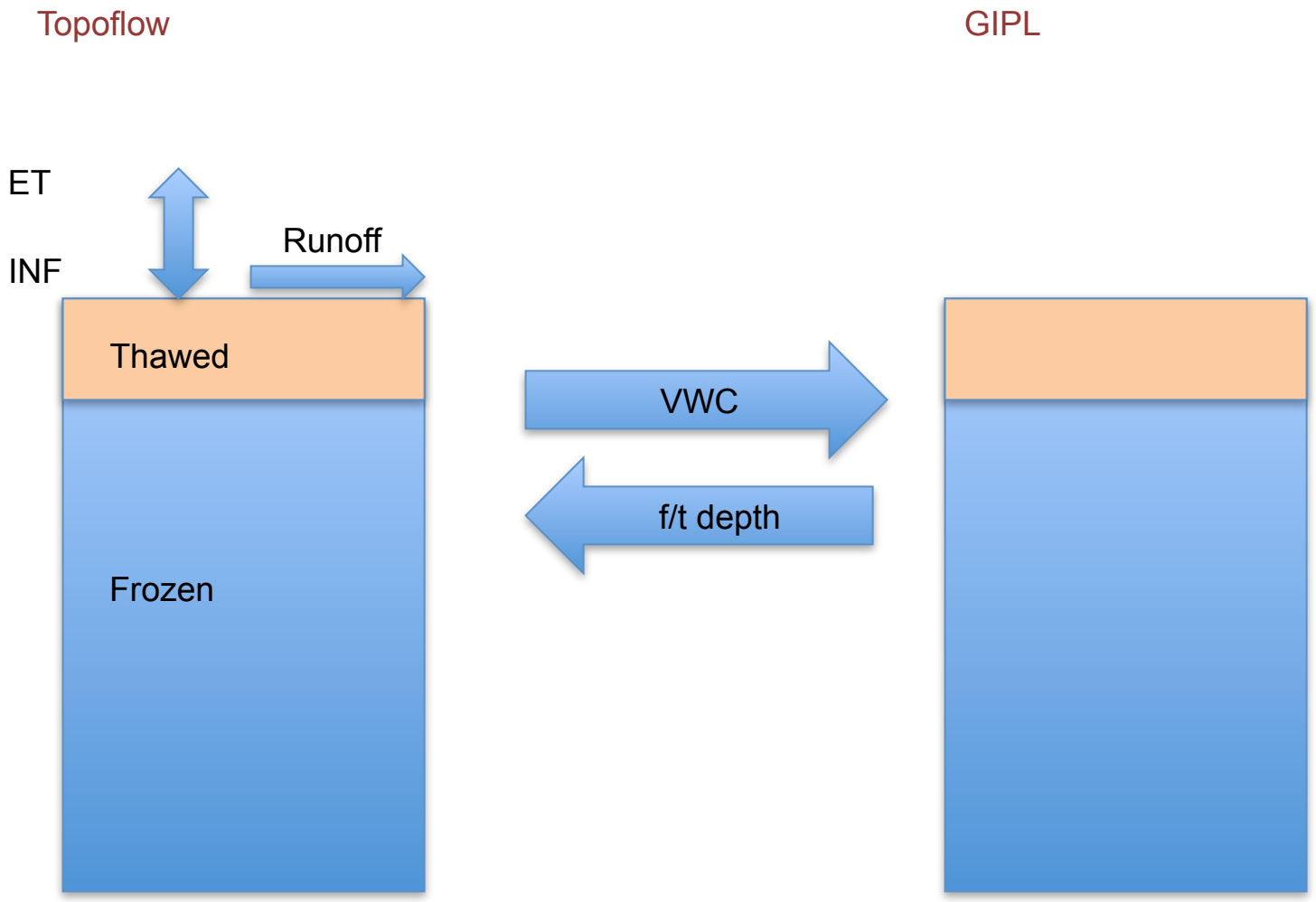
Results



Projections of the decadal average MAGT at 2 m depth


CSDMS Modeling Tool
File Edit View Tools Help
GIPL in CMT
Set as Default Project
Wired
Wireless
Remote Working Directory: ~/CMT_Output/
Working Project: GIPL
Workspace
Visualize
Job Info
Help
Driver
GIPL
Palette
GIPL
Arena
Driver: GIPL
Run
Configure
GIPL
Configure Component
Input Files and Directories
Boudary Input Files and Grid
Thermo Physical Properties Files
Performance Efficient mode
Input directory – /home/csdms/sims/gipl/default/
1: start new simulation/ 0: continue {0, 1} 1
output time step (days) {0.0, 100.0} 1
Calculation step {0.0, 1.0} 0.1
Minimum time step {0.0, 1.0} 0.001
Number of year {0, 100} 2
Distance between temperature iterations {0.0010, 0.1} 0.01
Unfrozen Water Coefficient {0.0, 1.0} 0.01
Maximum number of interations {0, 10} 5
number of seconds per step {0, 1000000} 86400
Average number of days {1, 365} 365
Sea level {0.0, 1000.0} 0
Maximum number of freezing fronts {0, 10} 4
Minimum depth of freezing front {0.0, 10.0} 0.05
Maximum depth of freezing front {0.0, 20.0} 10
Saturation coefficient (percent) {0.0, 1.0} 0.95
Help
Restore Defaults
OK
Cancel
Parsing qsub -x $JOB_ID to save it in ~/.cmt/jobs/jo
/home/beach/guest/elja0262/.cmt/jobs/joblist.xml
Updating tags in ~/.cmt/jobs/joblist.xml...
CMT INFO: Remote Working Directory set to ~/CMT_Output/

Coupling TopoFlow with GIPL2



Acknowledgments

Funding 

& State of Alaska