Using CSDMS Modeling Tools in the Classroom

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Community Surface Dynamics Modeling System
University of Colorado at Boulder

CSDMS
COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

Objectives

- Learn about the Web Modeling Tool
- New options for access to Blanca/HPCC for instructors and for teaching classes.
- Stepping from GUI to command line: the Web Modeling Tool to Jupyter Notebooks.
- Contribute to the discussion of future development of the Web and Python Modeling Tools.

Outline of Webinar

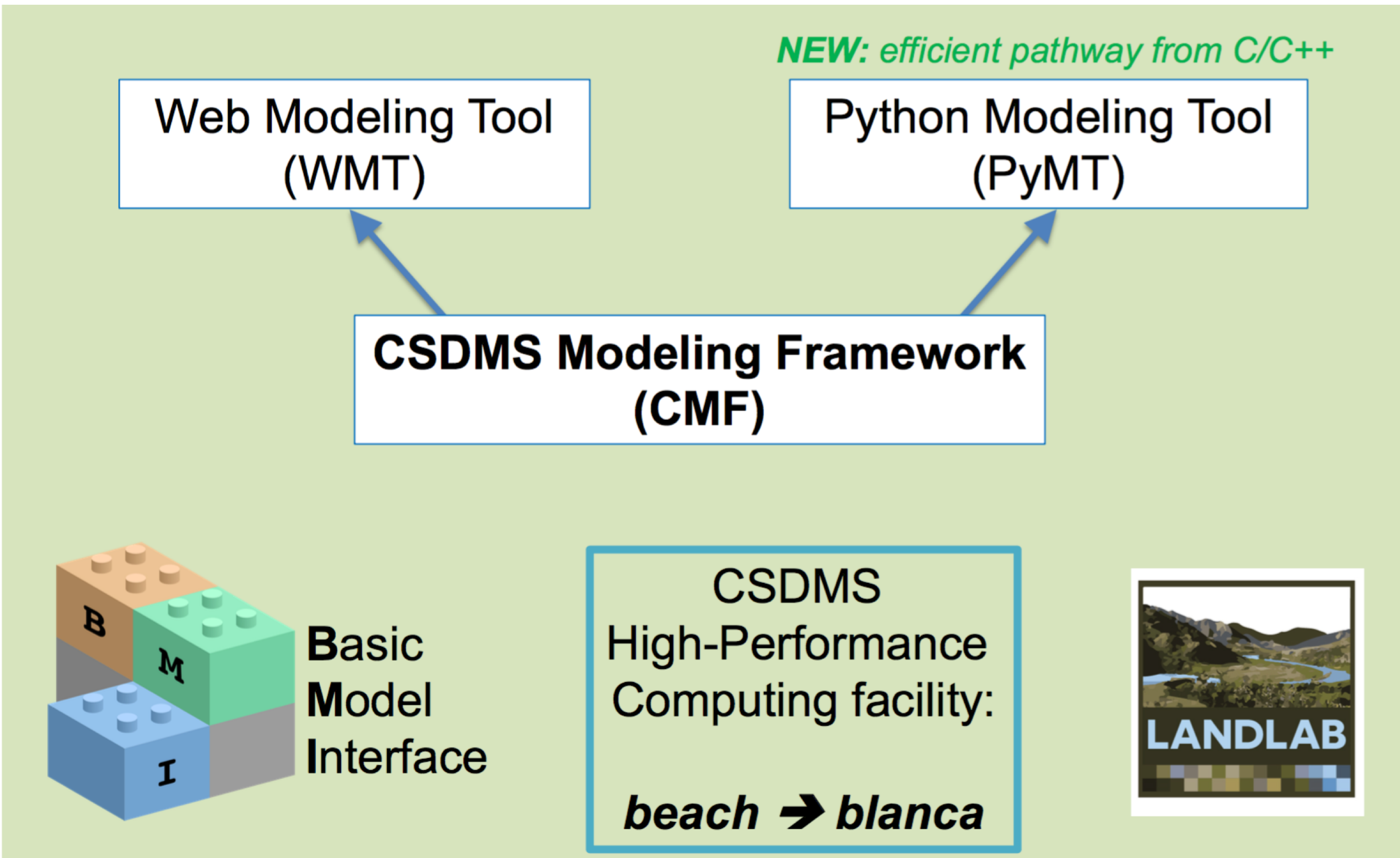
- Update on CSDMS tools for teaching (20 minutes)
- Demonstration of modeling in WMT (10 min)
- Sneak peak into Jupyter notebooks for educational labs (10 min)
- Discussion on what developments are useful, feasible, and planned, and how you want to be involved (10 minutes)

CSDMS Educational Mission

CSDMS Modeling Toolbox develops easy-to-access and comprehensive cyberinfrastructure to promote earth surface processes modeling

- EKT working group prioritized undergraduate students
- NCED and CSDMS collaboration focused more on graduate students
- Adopting faculty used tools with grad students

CSDMS cyberinfrastructure



Development and Support Team

Mark Piper
WMT developer

Eric Hutton
PyMT developer

Lynn McCready
Resources/Account Support

Albert Kettner
Web and Data Services

Greg Tucker
Director

Irina Overeem
Education Repo

Develop Models as ‘Components’

- Models receive a ‘Basic Model Interface’
- Specify with precision which parameters components do need, which parameters do they generate (Standard Names).
- BMI creates potential for coupling to other process components.
- Components generate netCDF output

Components in WMT

Components available in WMT

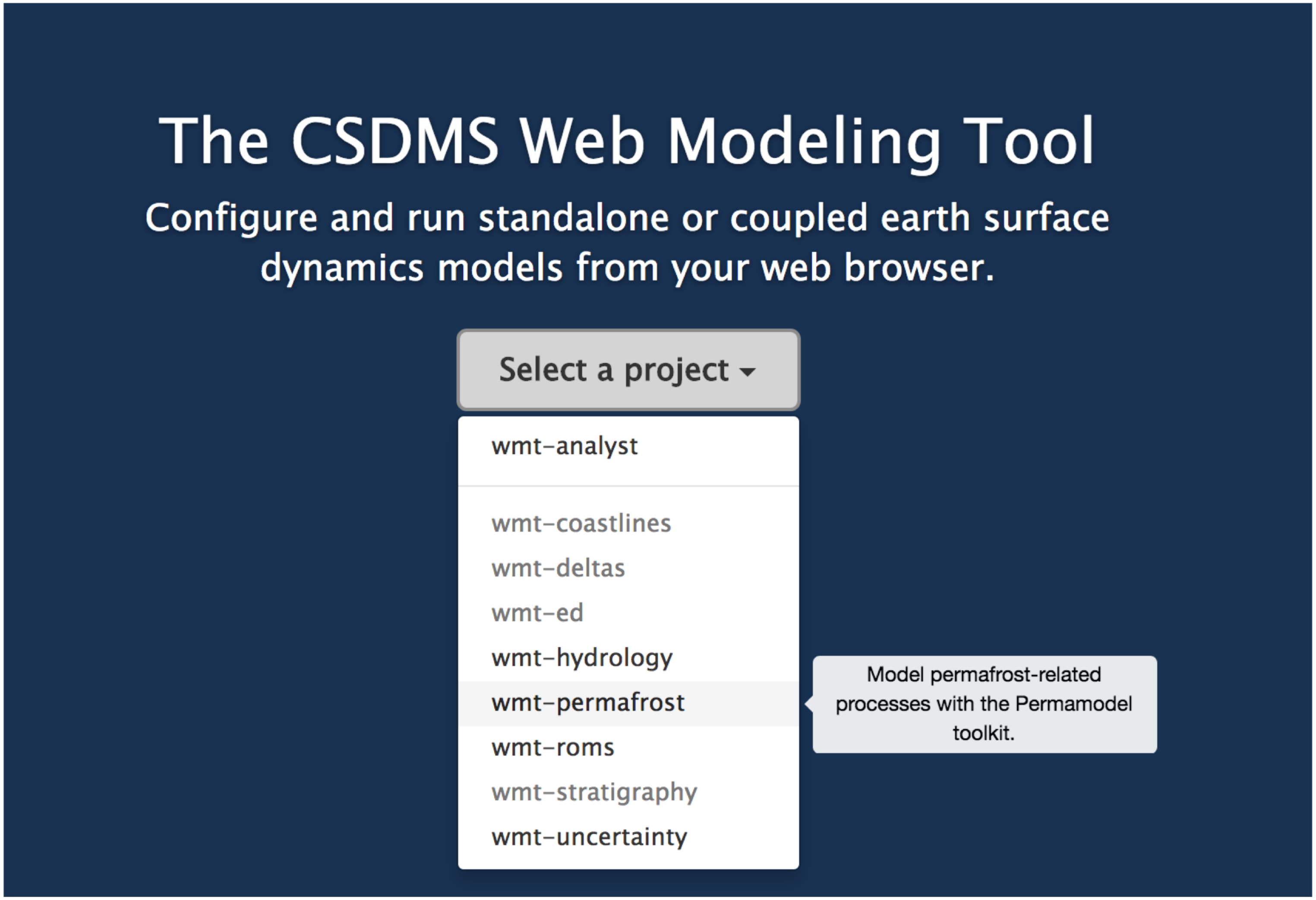
For using any of the models or tools listed below, go to: https://csdms.colorado.edu/wmt.

Model or tool	Description	Developer	Help pages
Avulsion	Stream avulsion model	**Hutton**, Eric	?
Bifurcation	Flow-partitioning and avulsion in a river delta bifurcation	**Salter**, Gerard	?
CEM	Coastline evolution model	**Murray**, A. Brad	?
CHILD	Landscape Evolution Model	**Tucker**, Greg	?
CMIP	Data component provides monthly mean temperature for Permafrost Region 1902-2100	**Overeem**, Irina	?
CruAKTemp	cruAKtemp is a data component to access a subsample of CRU NCEP data temperature for Alaska	**Stewart**, Scott	?
Dakotathon	A Python API for the Dakota iterative systems analysis toolkit.	**Piper**, Mark	?
DeltaRCM	River delta formation and evolution model with channel dynamics	**Liang**, Man	?
ErosionDeposition	Landlab component for fluvial erosion/deposition.	**Shobe**, Charles	?
Frost Model	Frost model predicts the likelihood of occurrence of permafrost in the land surface based on the monthly temperature distribution	**Overeem**, Irina	?
FwDET	Calculate floodwater depth based on an inundation polygon (e.g. from remote sensing) and a DEM	**Cohen**, Sagy	?
HydroTrend	Climate driven hydrological transport model	**Kettner**, Albert	?

And more..... 34 total

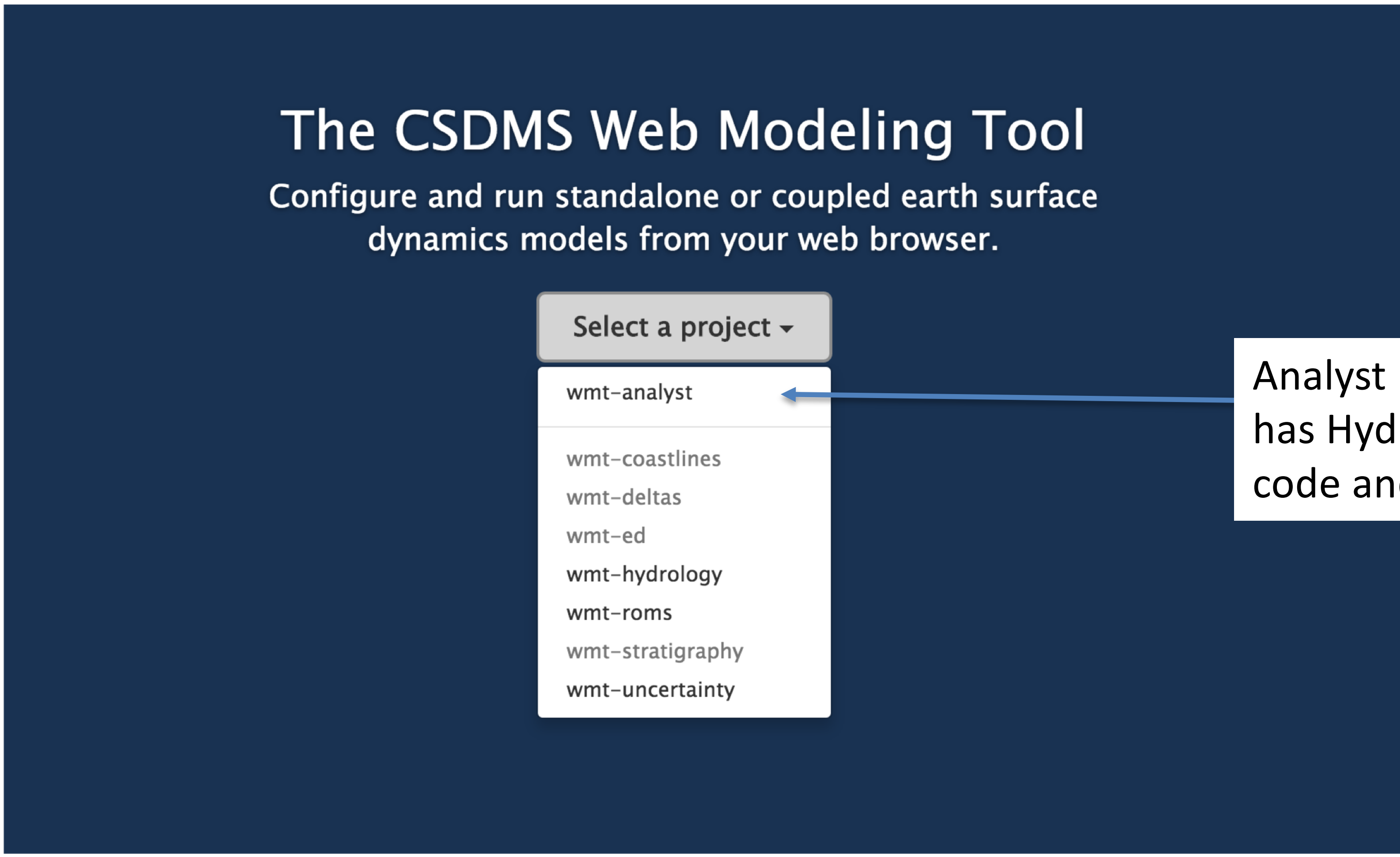
Find the complete list of components here:
https://csdms.colorado.edu/wiki/WMT_run_models

Web Modeling Tool



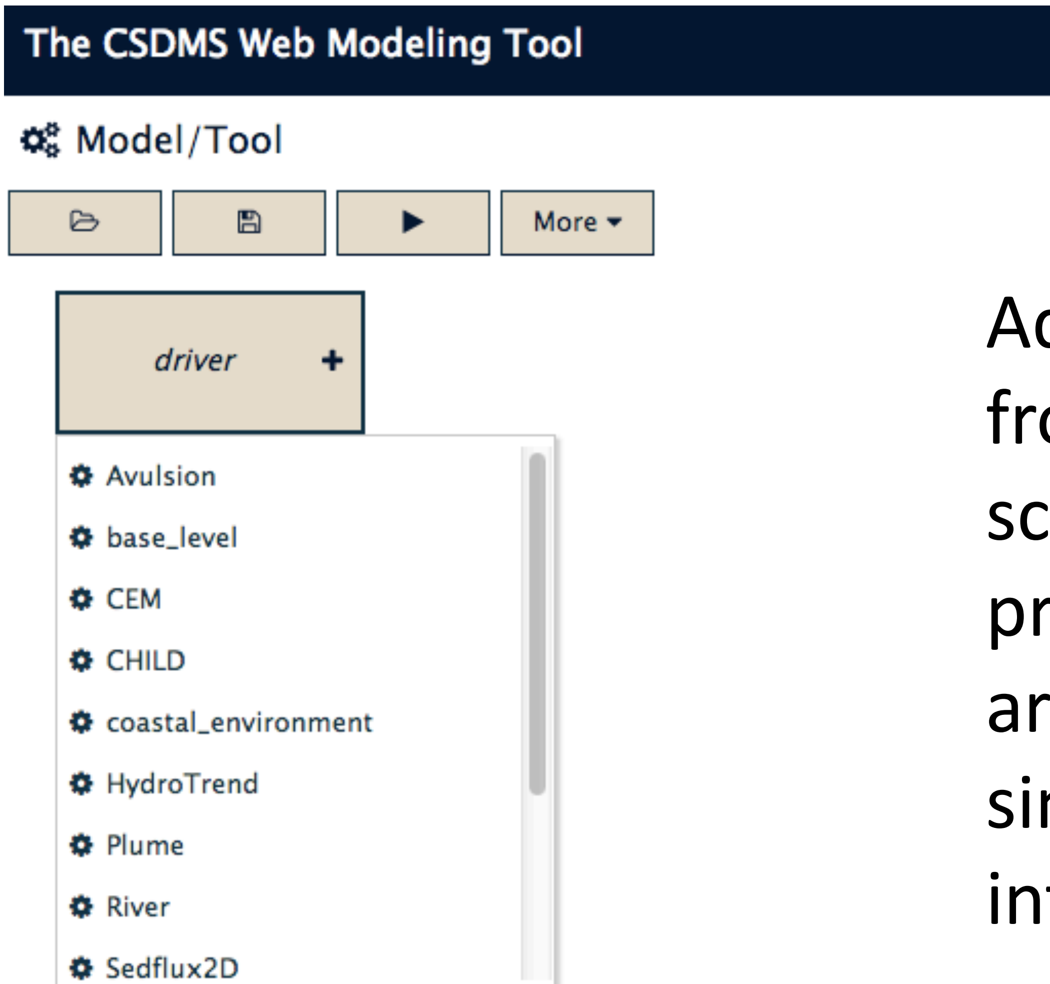
https://csdms.colorado.edu/wmt/

Projects with compatible models



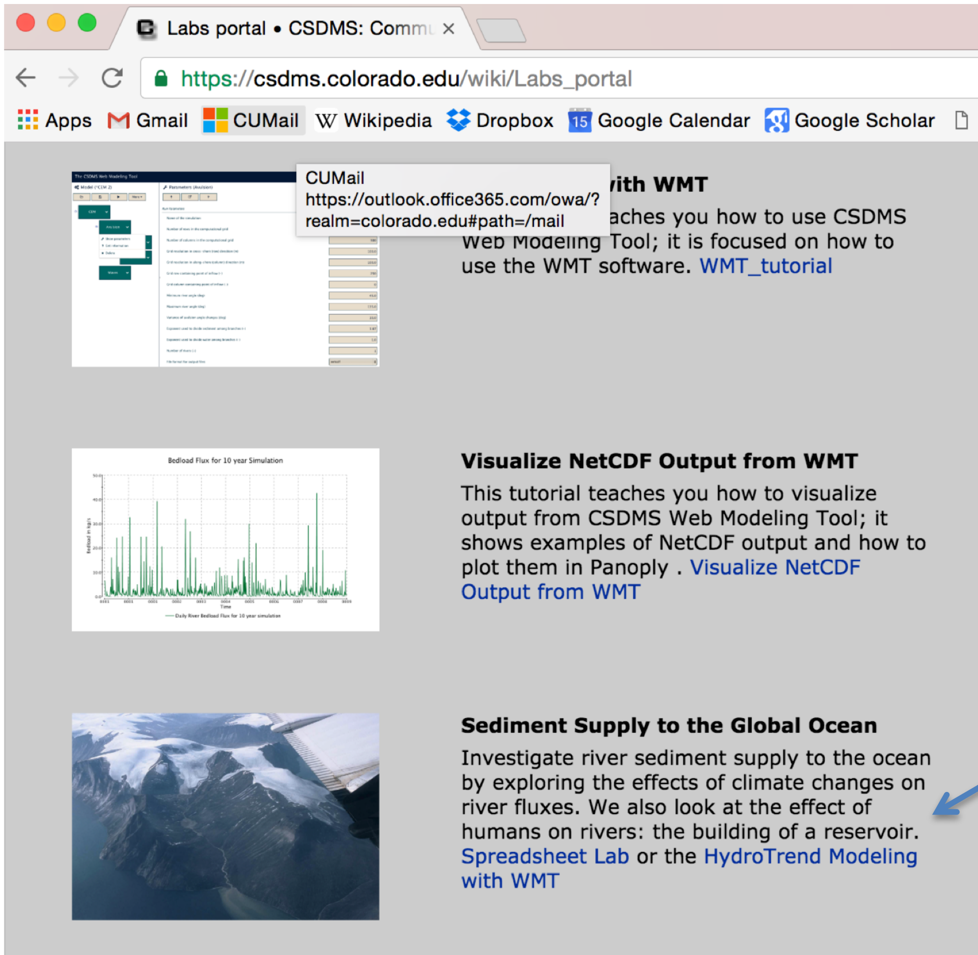
Analyst project
has Hydrotrend
code and most others

Models in WMT



Advantage for users: models from different contributing scientists, in different programming languages, all are ‘exposed’ through a similar graphical user interface.

Existing Model Labs with WMT



Example:
http://csdms.colorado.edu/wiki/
Labs_WMT_River_Sediment_Supply

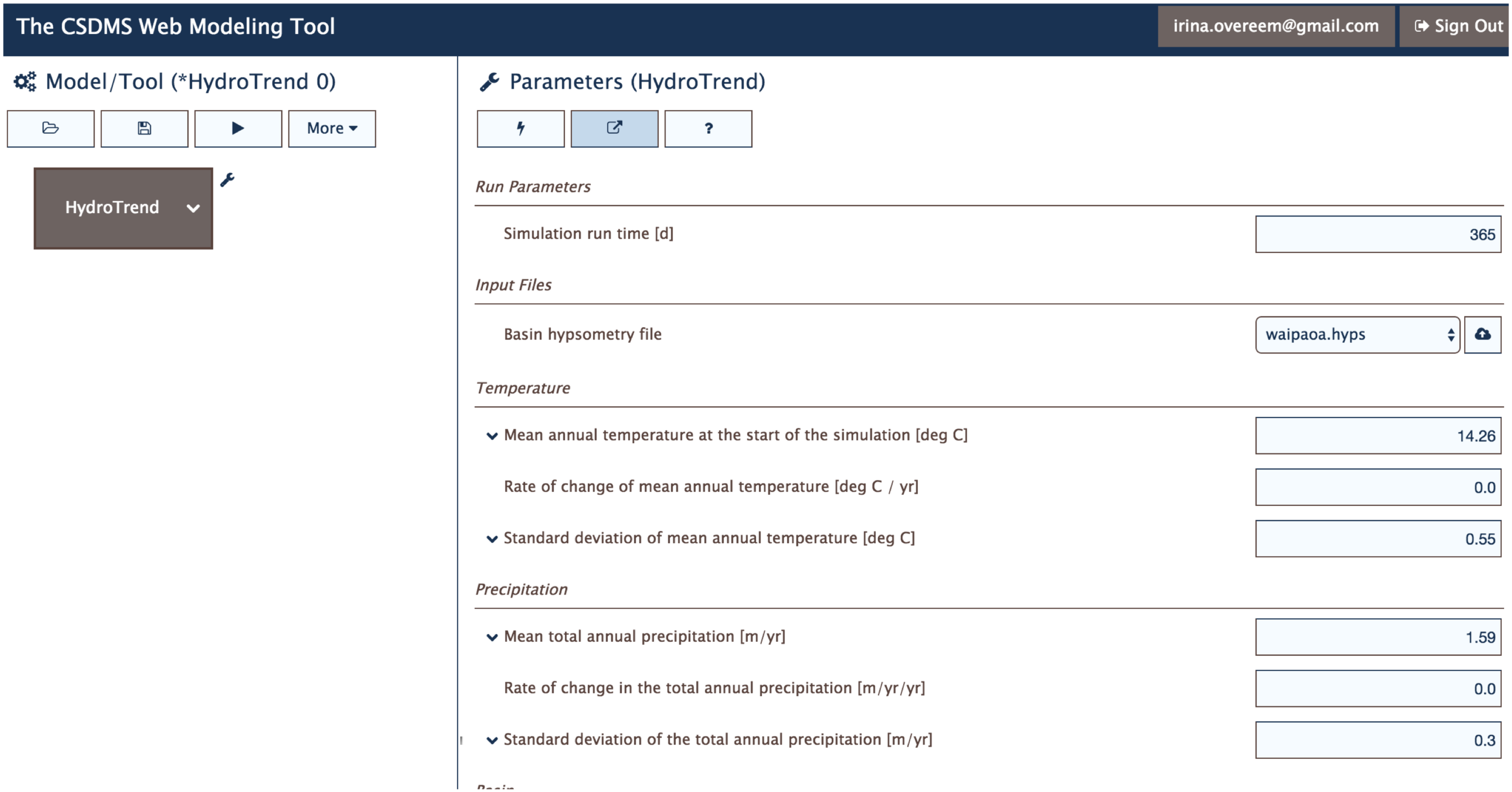
Overview of CSDMS EKT Labs:
http://csdms.colorado.edu/wiki/Labs_portal

Online Labs

- Topical learning objectives
- Practical instructions for simulations
- Guidance on useful/working experiments
- Questions to inquire the model output

https://csdms.colorado.edu/wiki/Labs_WMT_River_Sediment_Supply

Parameter SetUp



Guiding questions on model experiments/model output

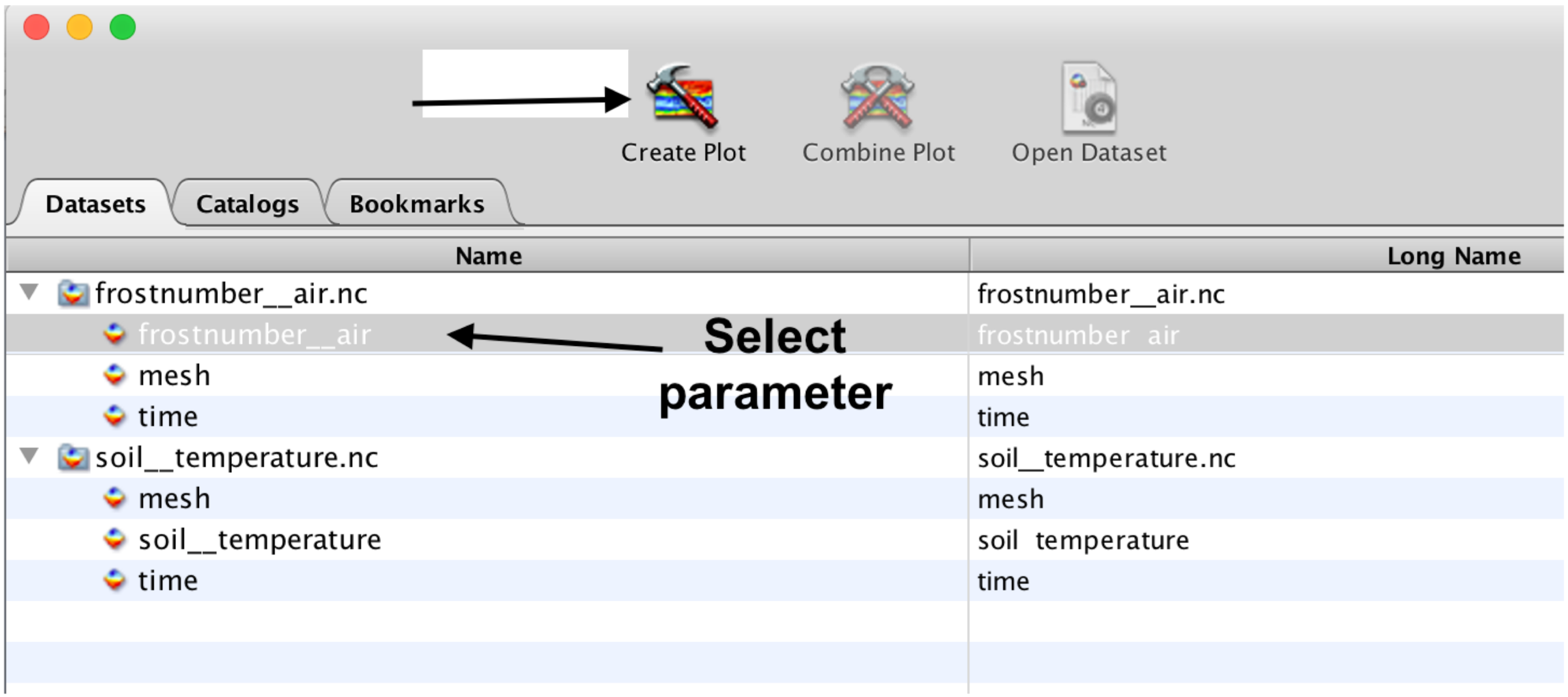
Question 1a
Calculate mean water discharge Q, mean suspended load Qs, mean sediment concentration Cs, and mean bedload Qb.
Note all values are reported as daily averages. Q= m3/s, Cs=kg/m3, Qs =Qb = kg/s.

Question 1b
Identify the highest flood event for this simulation. Is this the 50-year flood?
Plot the year of Q-data which includes the flood.

Question 1c
Calculate the mean annual sediment load for this river system.

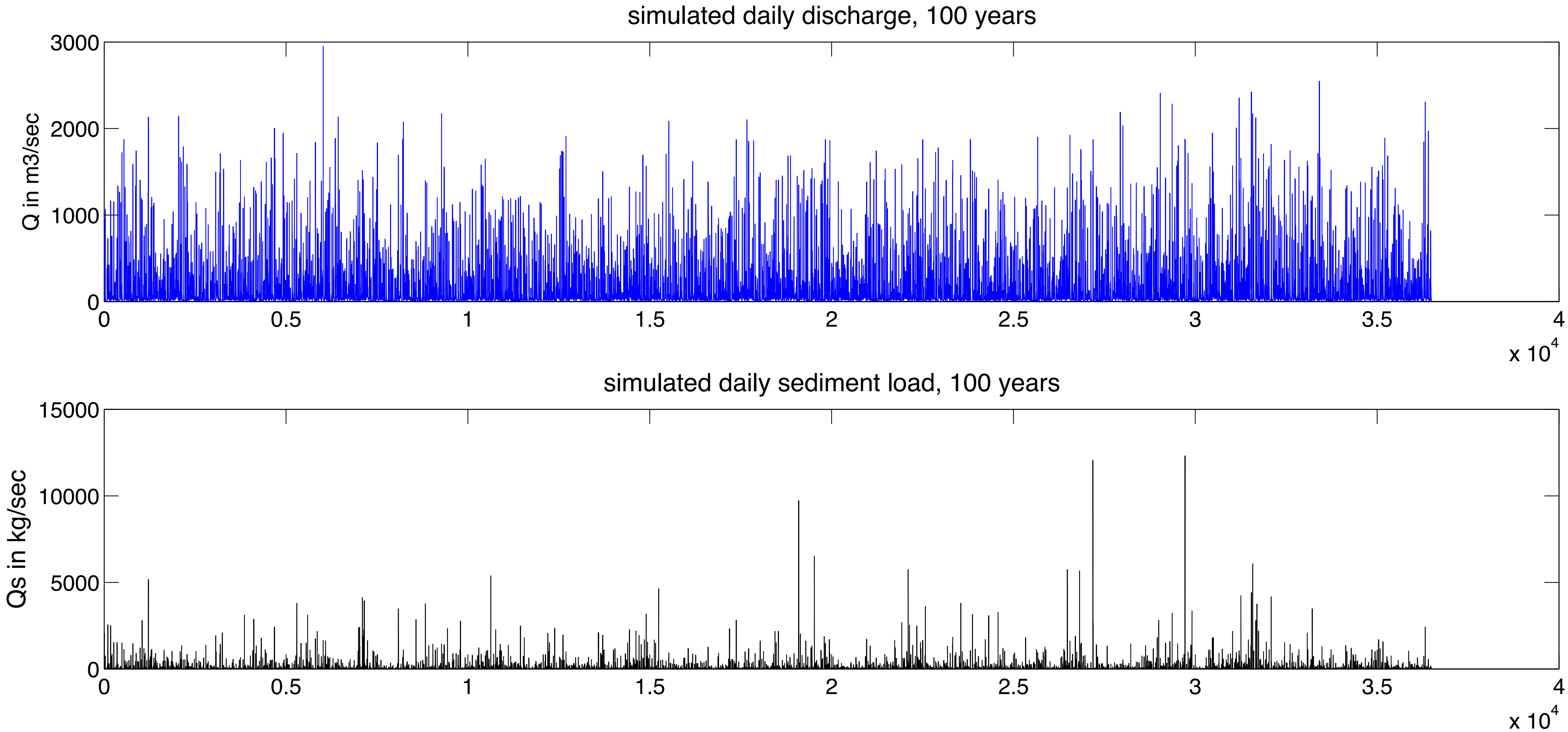
Question 1d
To compare the mean annual load to other river systems you will need to calculate its sediment yield.
Sediment Yield is defined as sediment load normalized for the river drainage area;
so it can be reported in $T/km^2/yr$. How does the sediment yield of this river system compare to the present-day Mississippi River?

Visualize Output with Panoply



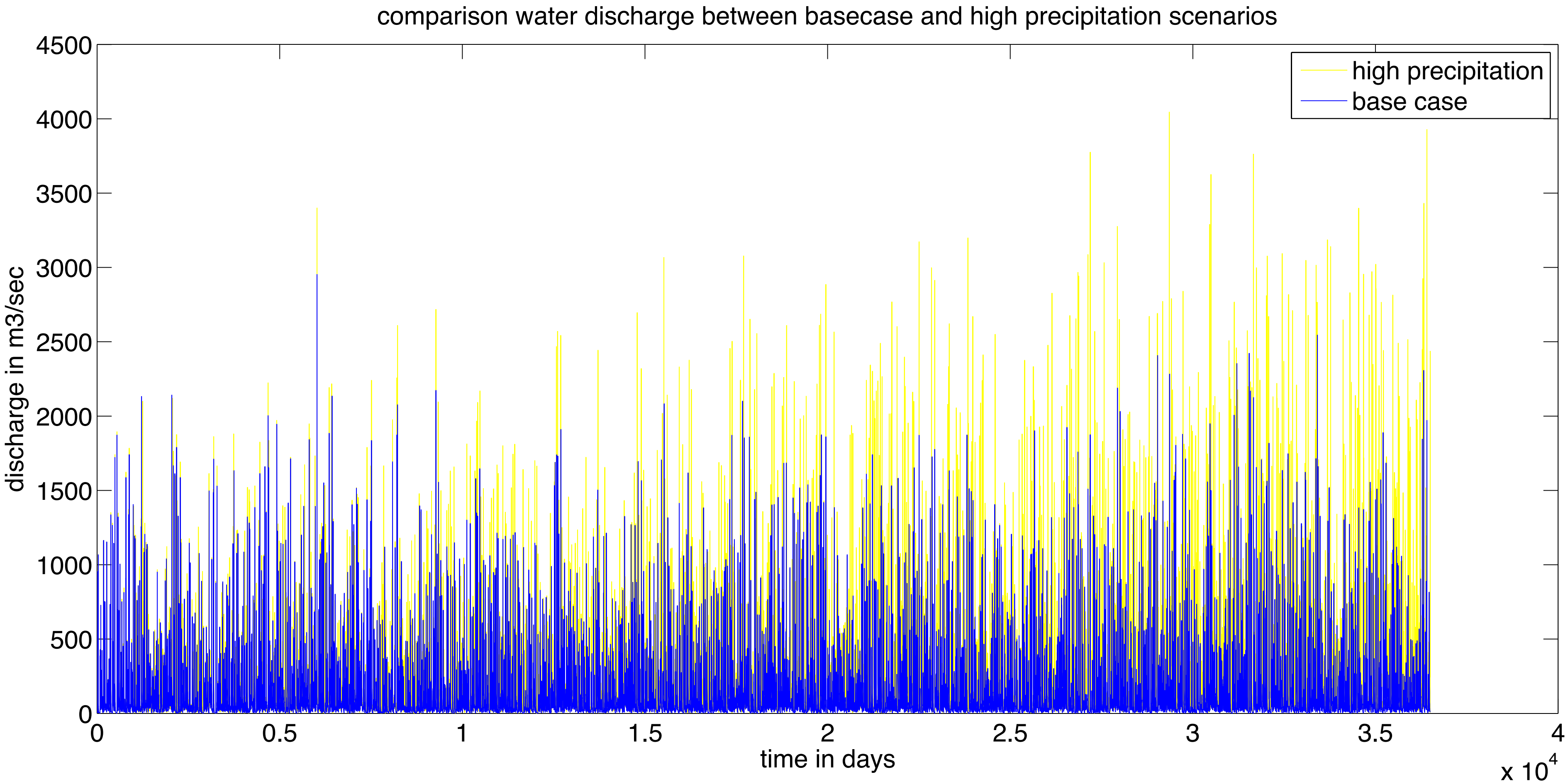
https://www.giss.nasa.gov/tools/panoply/

Example: visualize Basecase Simulation



-Great variation in water discharge events over 100 years
- Mean Peak flood = 2950 m3/sec, Peak Sed Load = 12321 kg/s
-Q = 78 m3/sec,

Wetter Climate Scenario



-Evident Trend in Discharge over 100 years.

-Can look whether it is directly proportional to the posed precipitation trend? If not, what could potentially be happening?

WMT runs on HPCC Blanca

- To run simulations with the WMT as an instructor, you will need an account with the CU/CSDMS Blanca supercomputing system.

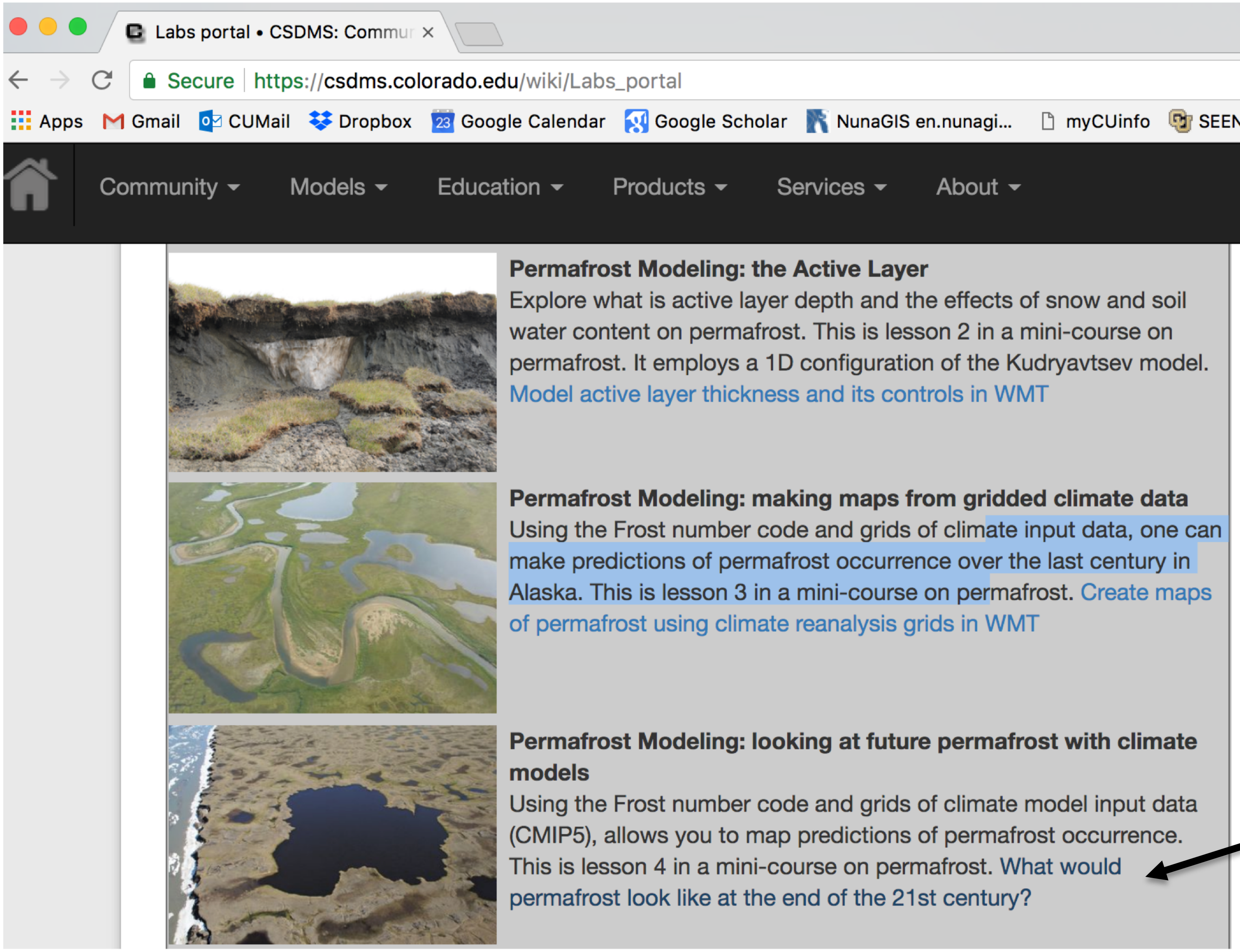
- Apply here:
- https://csdms.colorado.edu/wiki/HPCC_account_request
- Your account will be set within 5-7 working days.

- Main email contact: csdms@colorado.edu

New option for one-time use of WMT with students

- Faculty instructor still needs to be 1) CSDMS member and 2) have an active Blanca HPCC account.
- But once instructor credentials are established, you can request a list with anonymous teaching account logins and passwords for a given class time/class day.
- This can be set up beforehand by talking to us:
- csdms@colorado.edu
- Or directly to research computing: rc-help@colorado.edu

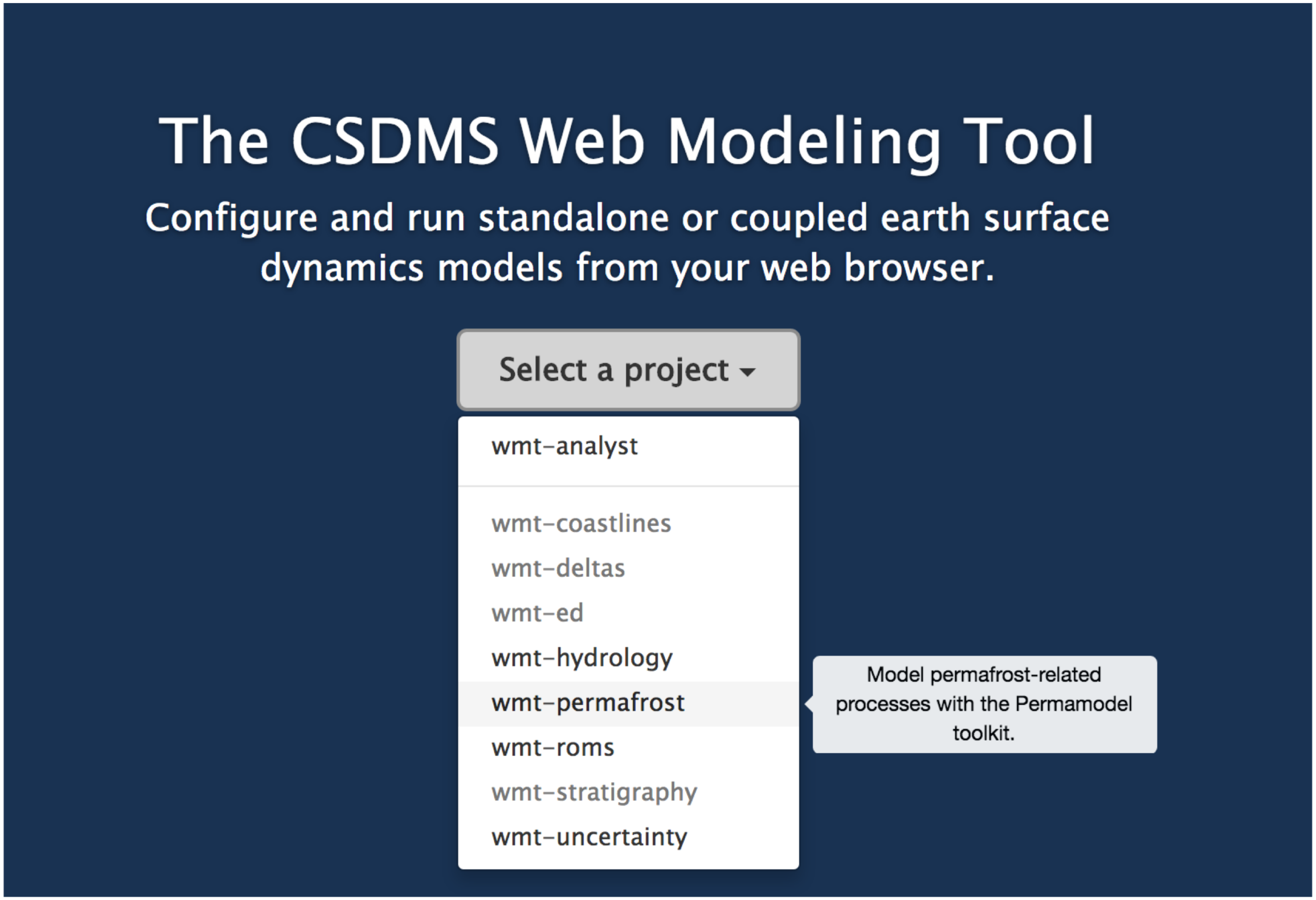
Educational Repository



PERMAFROST EXAMPLES FOR DEMO

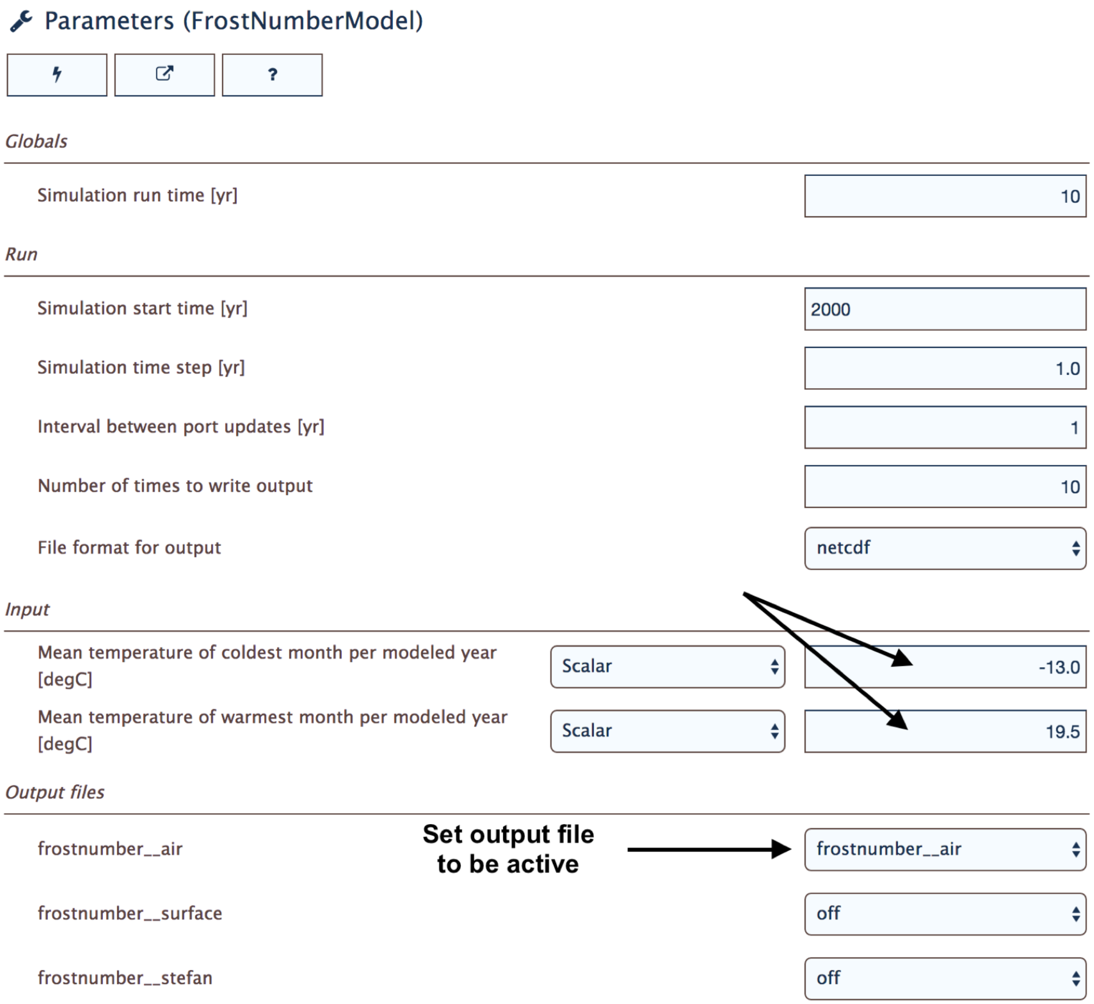
http://csdms.colorado.edu/wiki/Labs_portal

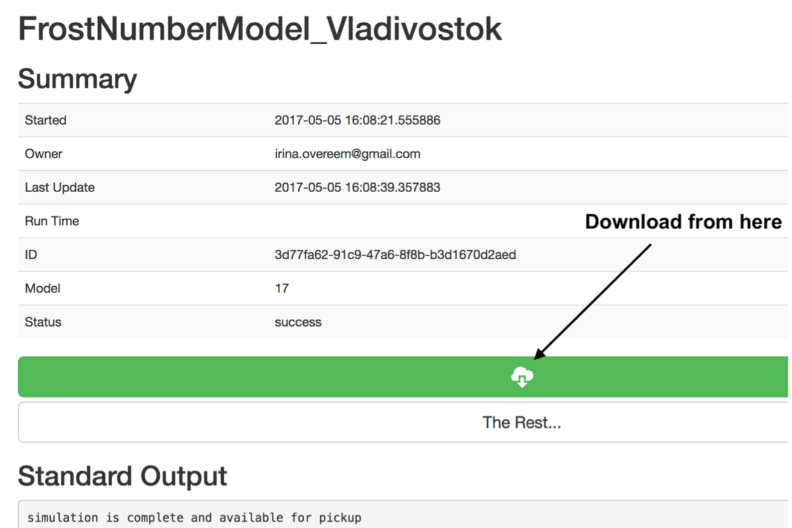
Demonstration



https://csdms.colorado.edu/wmt/

Web Modeling Tool

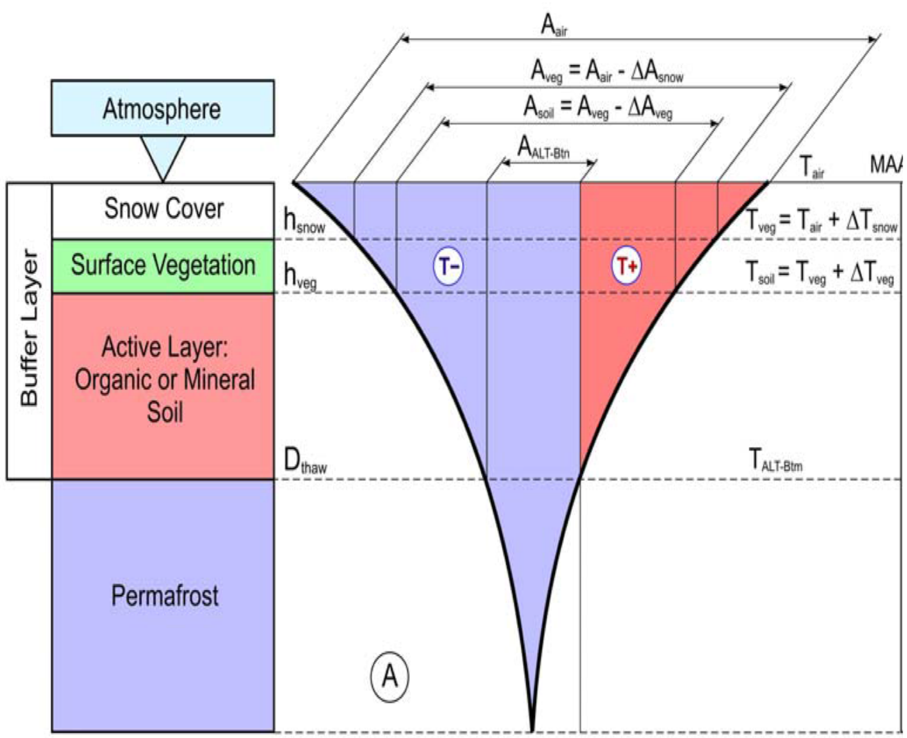




Web Modeling Tool allows new users to get familiar with main parameters of components. Example of the permafrost modeling toolbox, run simple simulations, download output.

Permafrost Example: Kudryavstev Model

- The Ku model is an semi-empirical model developed in 1970s.
- It essentially is an thermal equilibrium model.
- Calculates annual soil temperature, active layer thickness
- Includes layers of snow and vegetation.



(Anisimov et al., 1997)

Depth to freezing or thawing (Z)

$$Z = \frac{2\left(A_s - \bar{T}_z\right) \cdot \left(\frac{\lambda \cdot P \cdot C}{\pi}\right)^{1/2} + \dfrac{\left(2A_z \cdot C \cdot Z_c + Q_L \cdot Z\right) \cdot Q_L \left(\frac{\lambda \cdot P}{\pi \cdot C}\right)^{1/2}}{2A_z \cdot C \cdot Z_c + Q_L \cdot Z + \left(2A_z \cdot C + Q_L\right) \cdot \left(\frac{\lambda \cdot P}{\pi \cdot C}\right)^{1/2}}}{2A_z C + Q_L}$$

$$A_z = \frac{A_s - \bar{T}_z}{\ln\left(\dfrac{A_s + Q_L/2C}{\bar{T}_z + Q_L/2C}\right)} - \frac{Q_L}{2C}$$

$$Z_c = \frac{2\left(A_s - \bar{T}_z\right) \cdot \left(\frac{\lambda \cdot P \cdot C}{\pi}\right)^{1/2}}{2A_z \cdot C + Q_L}$$

A_s = annual amplitude of surface temperature

T_z = mean annual temperature at depth of seasonal thawing

λ = thermal conductivity $W\ m^{-1}\ C^{-1}$

C = volumetric heat capacity $J\ m^{-3}\ C^{-1}$

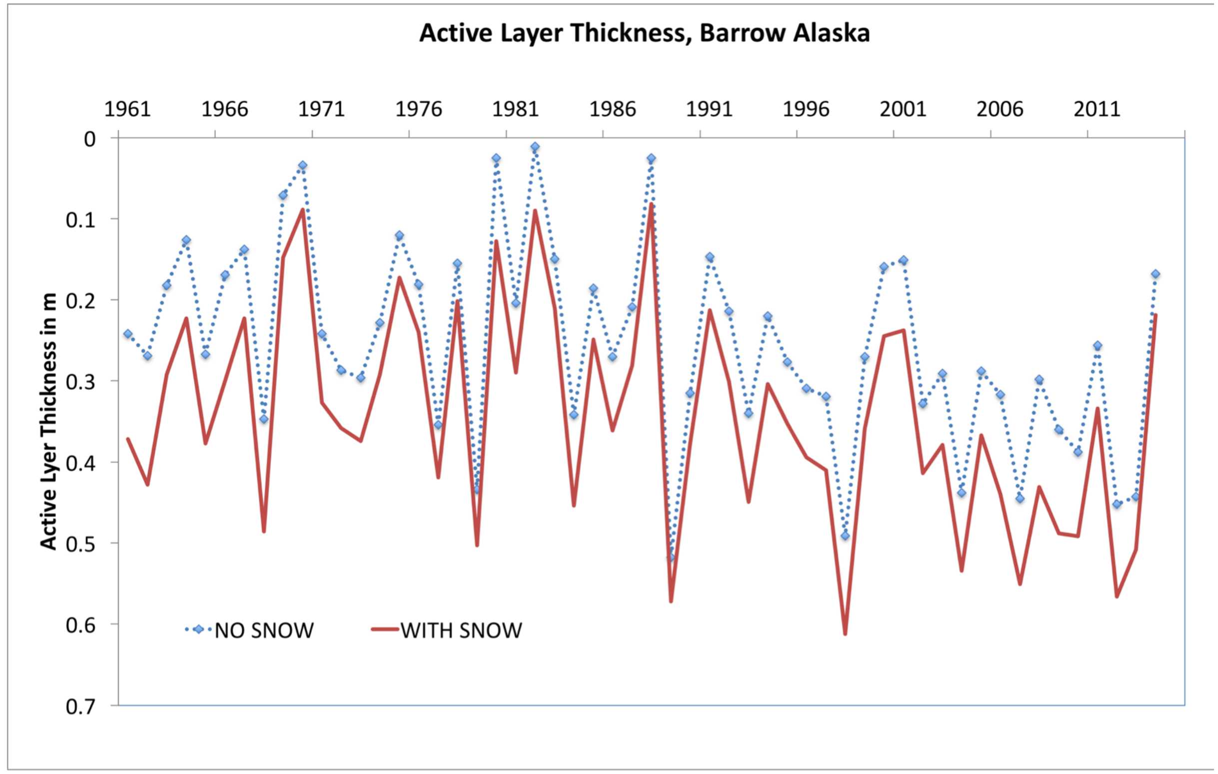
Ql = volumetric latent heat of fusion $J\ m^{-3}$

Snow thermal effect

$$\Delta T_{sn} = A_a \left\{ 1 - \exp\left[-Z_{sn} \left(\frac{\pi \cdot C_{sn}\, \rho_{sn}}{P \cdot \lambda_{sn}} \right)^{1/2} \right] \right\}$$

Z_{sn}	= snow cover thickness in m
λ_{sn}	= snow thermal conductivity W m^{-1} C^{-1}
C_{sn}	= snow volumetric heat capacity J m^{-3} C^{-1}
ρ_{sn}	= density of snow in kg m^{-3}

What is the use of such a medium complexity model?



Discussion within federal agency with request to support in-situ snow monitoring on the Alaskan North Slope?
If we'd would not have data on seasonal snow thickness, our predictions of permafrost active layer thickness would be impacted. Ku model can quickly demonstrate this bias for a given location.

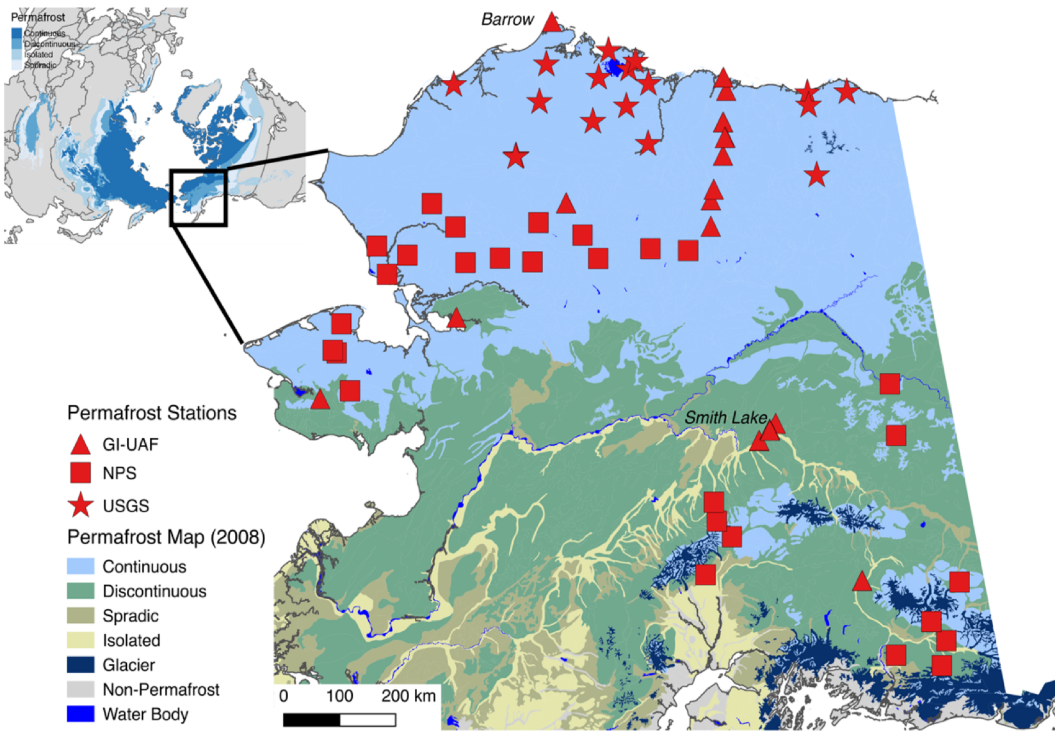
New Direction – Bring in Data Components

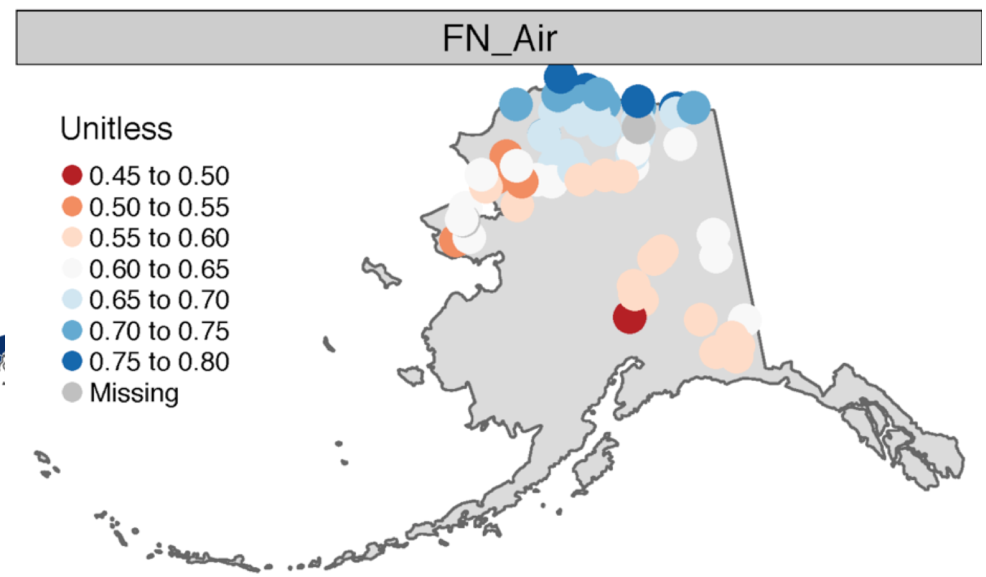
- User-specified at single location
- Time-series (Barrow and Fairbanks)

- Reanalysis grids (CRU-AKtemp)
- Climate model output for future (CMIP5)

Increasing complexity

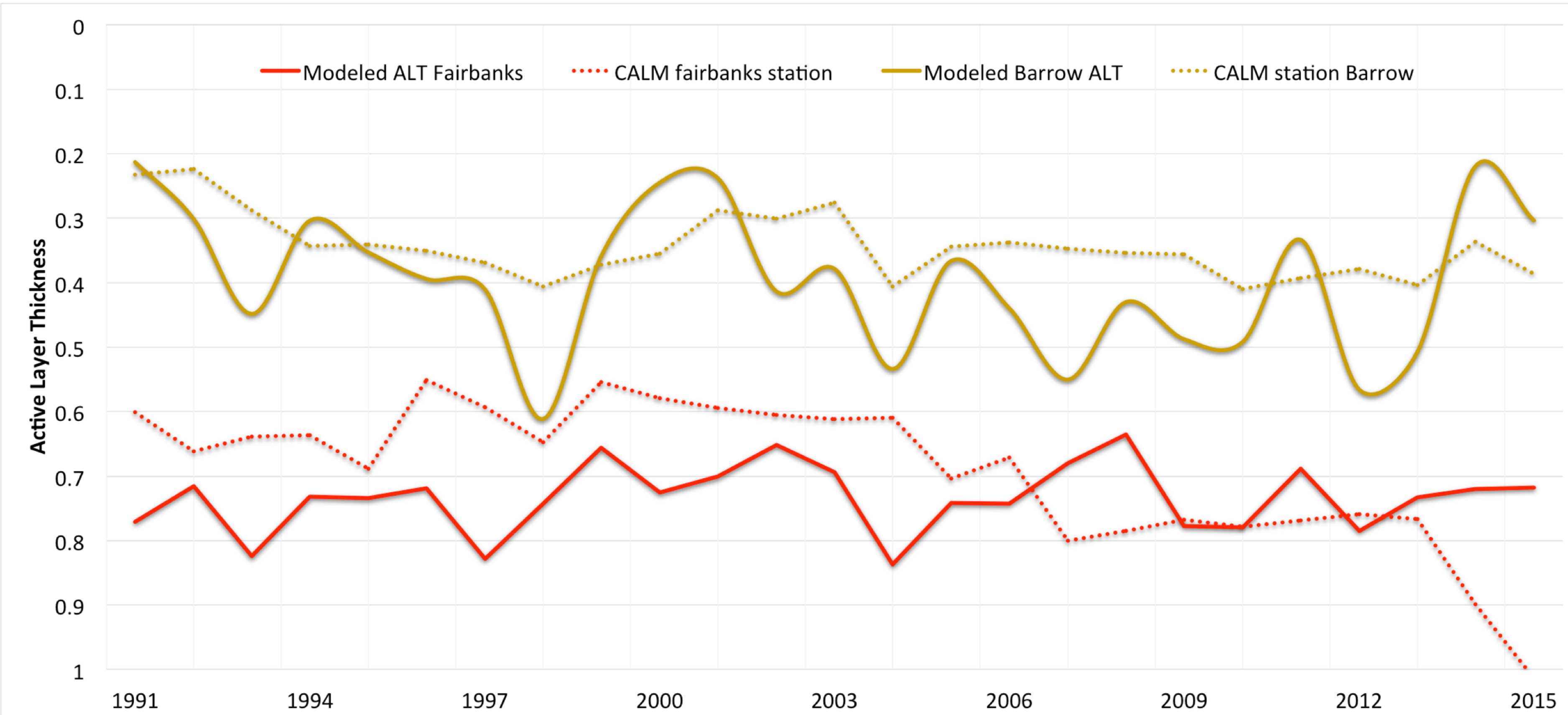
Example of benchmark against in-situ data





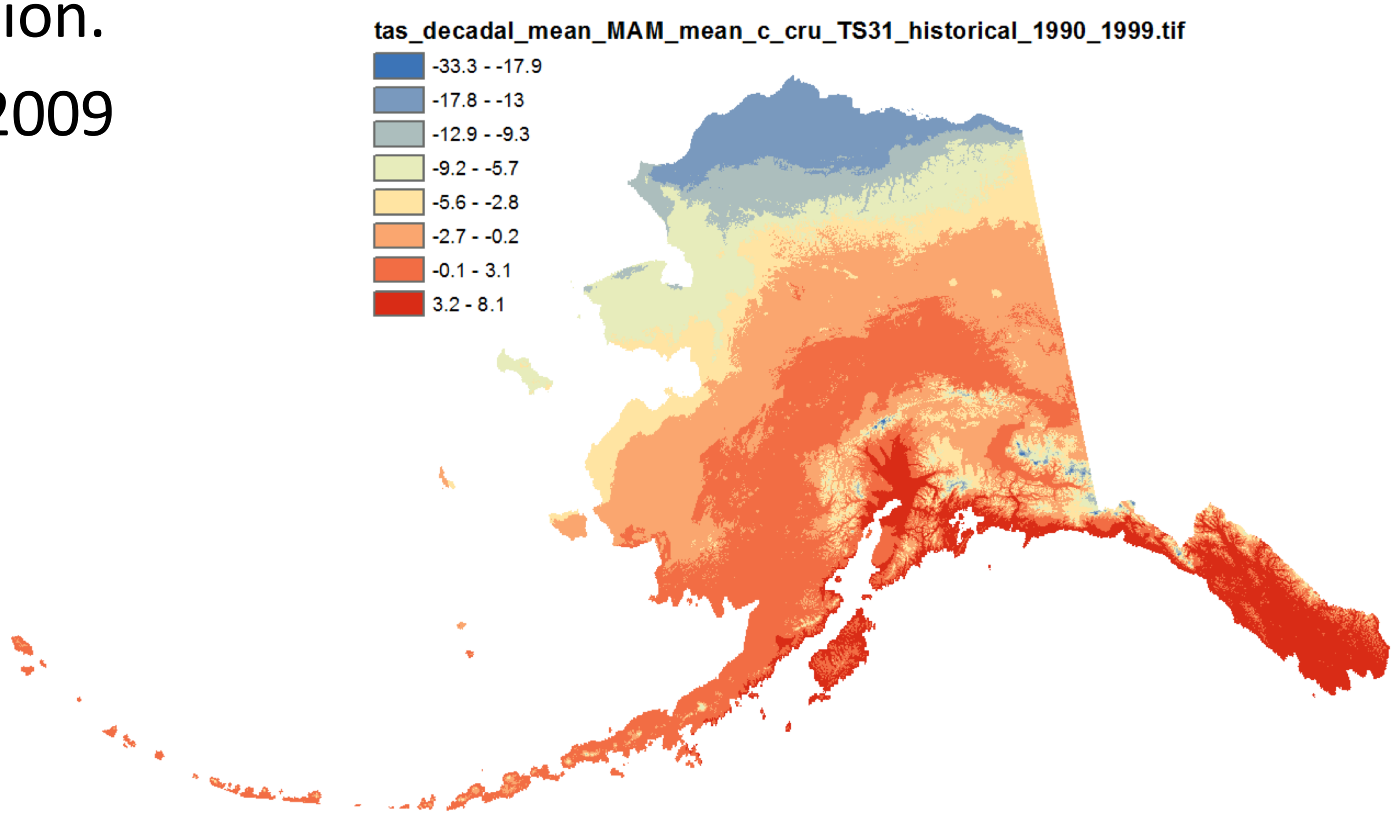
Wang et al., in review,
Earth System Science Data

Data-Model Comparison



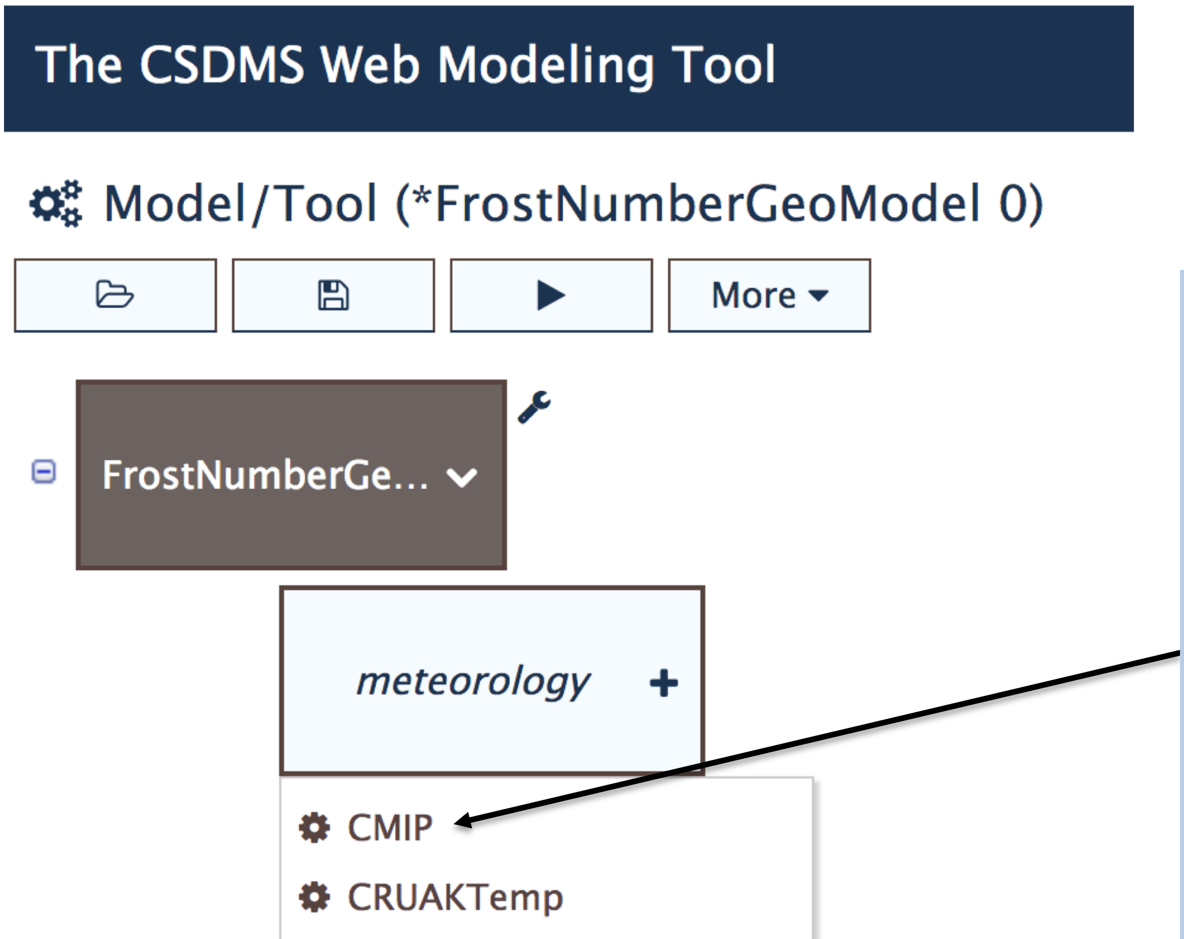
Climate Reanalysis Data Component

- Original data source was CRU-TS3 monthly climate data at 771 * 771 m resolution.
- It covers 1900-2009



http://ckan.snap.uaf.edu/dataset/historical-monthly-and-derived-temperature-products-771m-cru-ts

Predicting Permafrost?

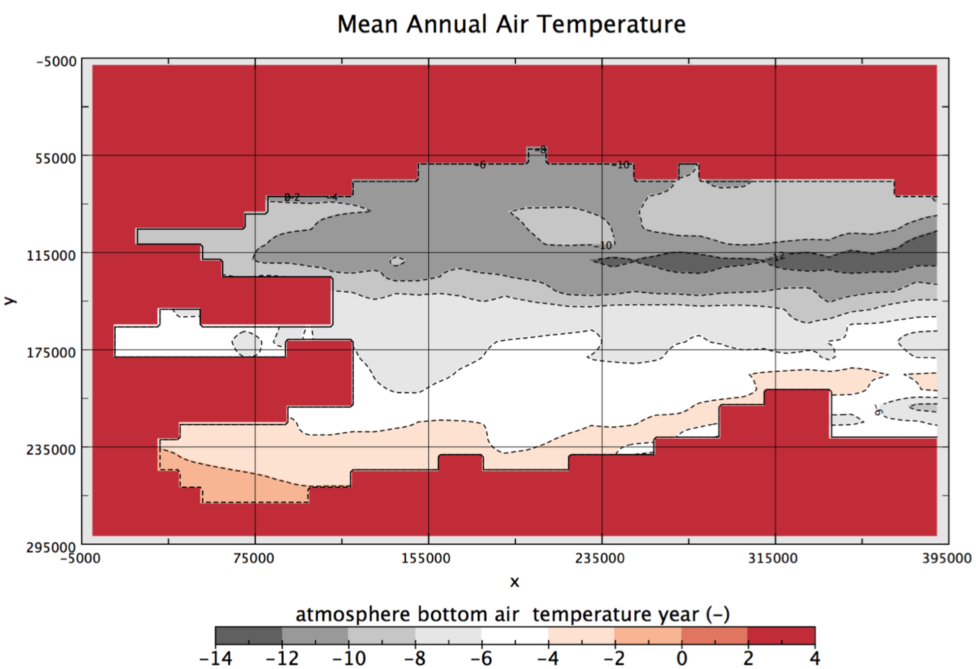


Climate Model Intercomparison Project (CMIP) data set: output of the atmosphere ocean global climate models

Duration: 1902-2100

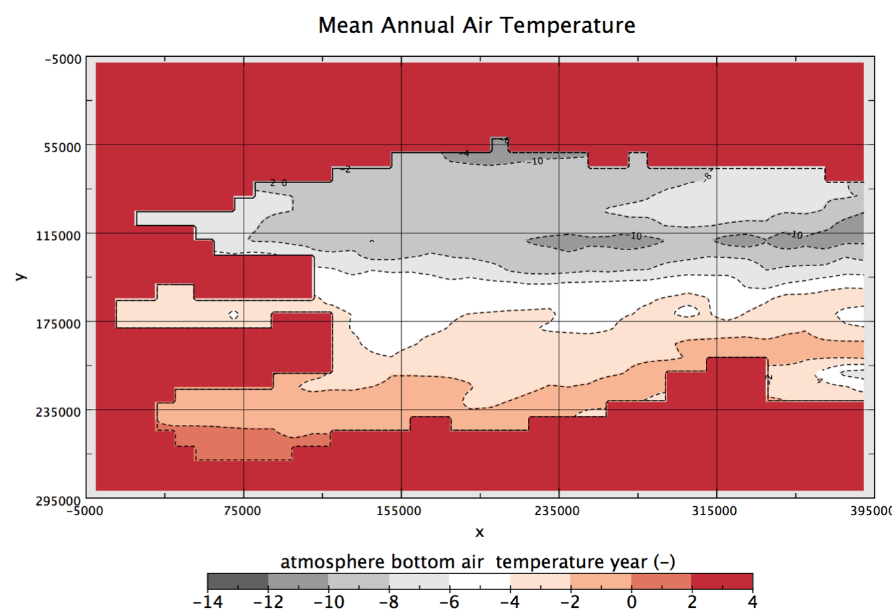
https://github.com/permamodel/cmip

CMIP5 provides mean annual air temperature to Frost and Ku models

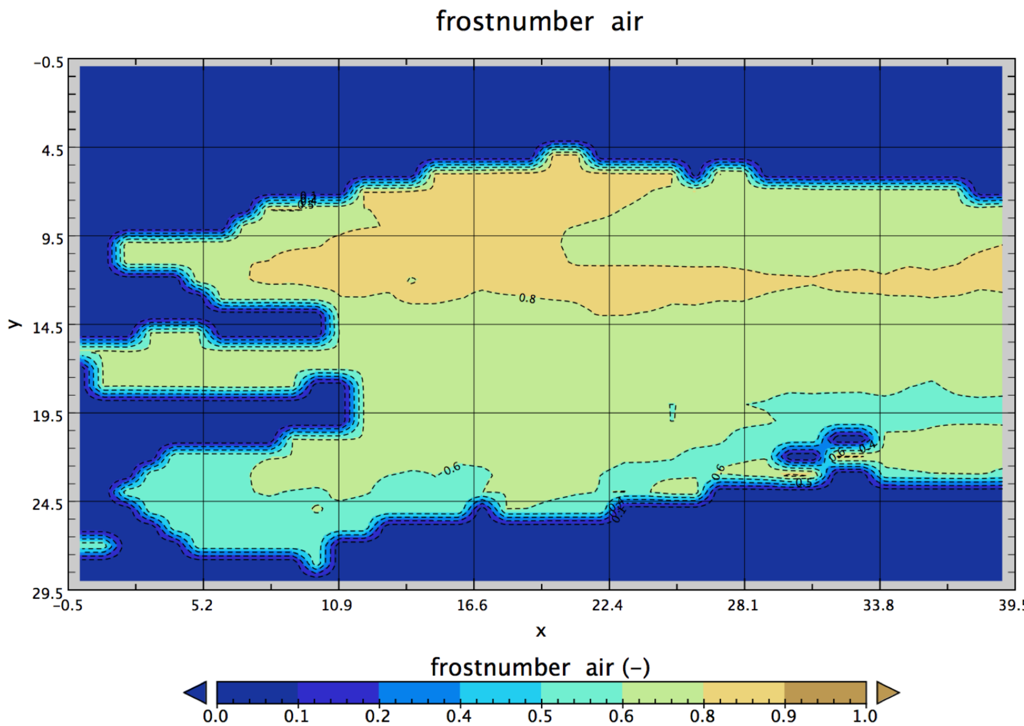


1955

2095



Predictions of Permafrost



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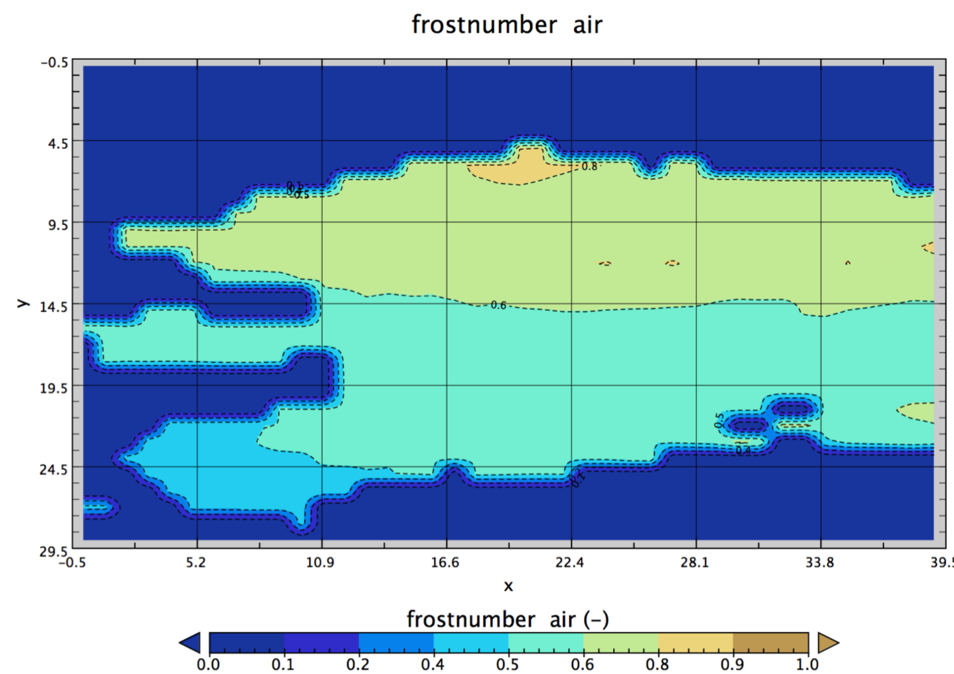


Strengths & Weaknesses of WMT?

- Easy to use through GUI, no coding required
- Clear and similar interface for large variety of very different codes
- Teaches students to set up numerical experiments and test hypothesis with models
- Way to familiarize new users with complicated models

- Limited flexibility to do experiments of own design
- Does not teach students to code
- Cannot do quantitative analysis without additional software

New alternative: Jupyter Notebooks?

jupyter Lesson_2_Kudryavtsev_modelv2 Last Checkpoint: 6 hours ago (autosaved) Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Python [conda env:anaconda]

Markdown

Introduction to Permafrost Processes - Lesson 2 Kudryavtsev Model

This lab has been designed and developed by Irina Overeem and Mark Piper, CSDMS, University of Colorado, CO with assistance of Kang Wang, Scott Stewart at CSDMS, University of Colorado, CO, and Elchin Jafarov, at Los Alamos National Labs, NM. These labs are developed with support from NSF Grant 1503559, 'Towards a Tiered Permafrost Modeling Cyberinfrastructure'

Part 1

We will run the Kudryatsev model for conditions in Barrow, Alaska in a very cold year, 1964. The mean annaul temperature for 1964 was -15.21C, the amplitude over that year was 18.51C. It was close to normal snow year, meaning the average snow thickness over this winter was 0.22m.

Adapt the settings in the Ku model for Barrow 1964. Make sure you request an output file. Save the simulation settings and submit your simulation. Download the model results and open them in Panoply.

```
In [20]: config_file, run_folder = ku.setup(T_air=-15.21, A_air=18.51)

In [21]: ku.initialize(config_file, run_folder)

         Ku model component: Initializing...

In [22]: ku.update()

In [23]: ku.output_var_names
Out[23]: ('soil__temperature', 'soil__active_layer_thickness')

In [24]: ku.get_value('soil__active_layer_thickness')
Out[24]: array([ 0.25622575])
```

EXAMPLE OF A LAB PRESENTED AS A NOTEBOOK

Notebooks can run through Anaconda

- Currently in first design phase….release in Feb 2019
- Notebooks would be archived on csdms github repository
- Links and documentation to notebooks to be provided through CSDMS wiki via the EKT repository

- Install on local machine with conda install
- Run as jupyter notebooks

Strengths & Weaknesses of Notebooks?

- More flexibility to do experiments of own design
- Does give more insight in programming and thus teaches students first steps towards coding
- Teaches students to set up numerical experiments and test hypothesis with models
- Can do quantitative analysis without additional software

- Command-line, requires some familiarity with Python
- Every student needs to set up a anaconda environment
- Not very suitable for bigger complicated models

Discussion on WMT Development Targets (1)

- Who would want to use WMT?
- Design of documentation: for teaching rather topical entry points, versus model entry points?
- What are strengths and weaknesses?

Your involvement?

- Can you use WMT with undergraduates?
- Who would like to contribute labs?

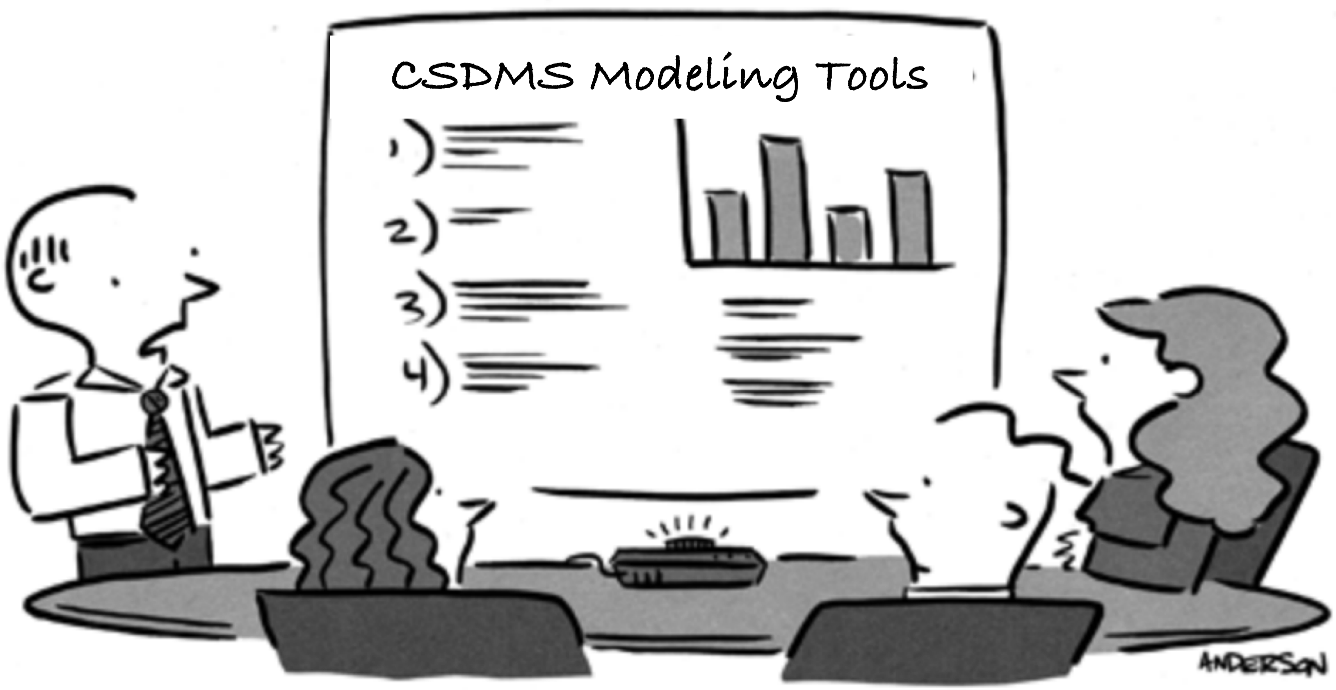
Discussion on Python notebooks Development Targets (2)

- Is it feasible to first learn with WMT, and then step to notebooks as a pathway to learning to code?
- Design of documentation: for teaching rather topical entry points, versus model entry points?

Your involvement:

- Who would want to use Jupyter notebooks?
- Can you use Jupyter notebooks with undergraduates?
- Who would like to contribute notebooks and labs?

Other ideas?



"The good news is we're getting a lot of feedback.
The bad news is we're getting a lot of feedback."

For more information
EMAIL: CSDMS@Colorado.edu