

# Modeling Glacier Growth and Melt Rate

*GC2D Lab description, November 18<sup>th</sup>, 2010*

*Note for Users. This lab relies on the CSDMS Tool. The use of the CSDMS Tool is free for members, but it requires an account on the CSDMS HPCC system. You can sign up here:*

*[http://csdms.colorado.edu/wiki/Help:HPCC\\_account\\_request](http://csdms.colorado.edu/wiki/Help:HPCC_account_request)*

*You will also need a secure way of accessing the system (f.e. VPN software) and to download the CMT tool as well as Visit. More information:*

*[http://csdms.colorado.edu/wiki/Help:Ccaffeine\\_GUI](http://csdms.colorado.edu/wiki/Help:Ccaffeine_GUI)*

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*Glacier tongues draining from local ice cap, West-Greenland*

## Introduction

In this lab we will be using a stripped-down version of the GC2D model - a two-dimensional finite difference numerical model that simulates the formation and evolution of temperate valley glaciers on a two-dimensional topographic surface with a specified meteorological setting. Driven by a time series of mass balance (snow precipitation - melt rate), the model calculates ice surface elevations above a

two-dimensional terrain by solving equations for ice flux and mass conservation using explicit methods.

In this lab we run the GC2D model on a DEM of the Colorado San Juan Mountains, the Animas River basin.

Useful references:

*MacGregor, K.R., Anderson, R.S., Anderson, S.P., Waddington, E.D., 2000. Numerical Simulations of Glacial-Valley Longitudinal Profile Evolution. Geology, 28, 11,1031-1034.*

*Kessler, M.A., R.S. Anderson, and G.S. Stock (2006), Modeling topographic and climatic control of east-west asymmetry in Sierra Nevada Glacier length during the Last Glacial Maximum, J. Geophys. Res., 111, F2, F02002, doi:10.1029/2005JF000365.*

*Mark A. Kessler, Robert S. Anderson, Jason P. Briner, 2008. Fjord insertion into continental margins driven by topographic steering of ice. Nature Geoscience 1, 365-369 (11 May 2008) doi:10.1038/ngeo201 Letter*

## **Exercise 1: Explore the base-case glacier growth time-stepping**

An example bld-file can be opened: Animas\_23May.bld This simulation needs an input grid, and rain rate, these are all to organized under this preset input directory.

- 1.1 GC2D applies dynamic time-stepping. This makes it more difficult to couple to other components. Let's explore this concept: Run a "base-case" simulation for 5000 time steps. Set the output time interval to 200.
- 1.2 Is the time step constant? To how many years of simulation do the 5000 time steps translate? You can see the runtime reported in the console.
- 1.3 Can give a reason why model algorithms would need to be run with a dynamic time-step?
- 1.4 Pull up the three output grid files (h=ice thickness, z=topography including ice, mr=melt rate). Open the 3 files in Visit. How many instances are there in the movie stack? Is this according expectation? Please explain.

## **Exercise 2: How does a glacier system respond to climate change; a few simple scenarios for the coming century.**

2.1) Please explain the main processes in the GC2D model . What is a mass balance in glaciological context? How does GC2D calculate the ice surface?

Useful references for this question:

*MacGregor, K.R., Anderson, R.S., Anderson, S.P., Waddington, E.D., 2000. Numerical Simulations of Glacial-Valley Longitudinal Profile Evolution. Geology, 28, 11,1031-1034.*

Kessler, M.A., R.S. Anderson, and G.S. Stock (2006), *Modeling topographic and climatic control of east-west asymmetry in Sierra Nevada Glacier length during the Last Glacial Maximum*, *J. Geophys. Res.*, 111, F2, F02002, doi:10.1029/2005JF000365.

Mark A. Kessler, Robert S. Anderson, Jason P. Briner, 2008. *Fjord insertion into continental margins driven by topographic steering of ice*. *Nature Geoscience* 1, 365-369 (11 May 2008) doi:10.1038/ngeo201 Letter

2.2) Explore the effect of a changing climate. What happens to ice thickness if the initial ELA would be 200m higher? How much thinner is the maximum ice thickness?

2.3) Systematically change the mass balance properties; do a set of 4 experiments, list your input changes in a small table and justify your choice for the change magnitude in the input parameters.

2.4) Visualize the final ice thickness and the melt rate grids for the two most extreme mass balance input parameter settings. Describe your findings.

## **Exercise 4: Glacier Model Couplings**

4.1 What process models can be coupled to a glacial model like GC2D? Think of an example of climatic processes, or drainage basin processes as well as downstream processes.

4.2 Can you describe a model or process that *could potentially* be two-way coupled. Describe why this coupling would be scientifically interesting. Can you also think of an applied problem that would need a glacial model component to be coupled to another process model? Please describe.

Even better; find an appropriate model in the CSDMS model repository....

## Appendix 1: Notes on running GC2D simulations with the CMT Tool

>> Download the CMT Tool

>> Open Project: go to Group Terrestrial, Select TOPOFLOW + GC2D project.

>> We will be running GC2D in stand-alone mode. There is an example configuration already built:

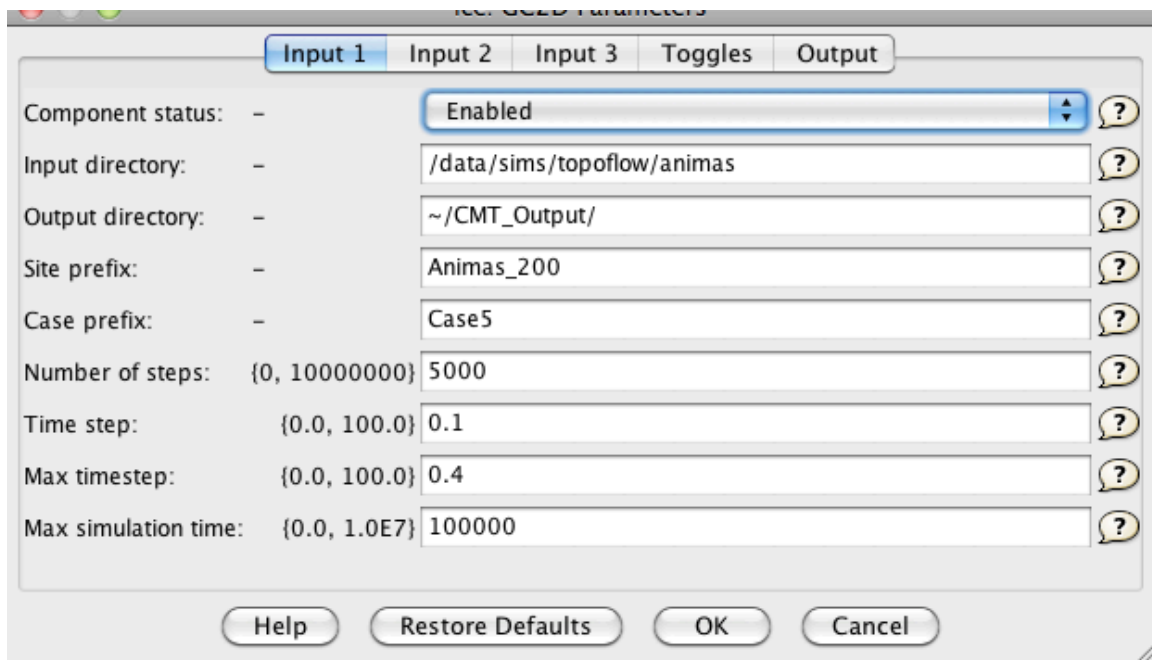
>> GC2D will now be active in the CMT Arena. The GC2D Configure Menu is used to set the parameters for the simulations. You can set the parameters by going through the different tabs under the configure menu and subsequently run it by hitting the green run button.

The two components that GC2D appears to be coupled with are inactive at this point.

You can find the fixed input files at the listed input directory on beach.

### >> To run the base case scenario

>> Make sure you have the first tab of the 'Configure Menu'. Keep all settings to the default except the number of steps. This can be adapted to 5000.



The screenshot shows the 'GC2D Parameters' dialog box with the 'Input 1' tab selected. The dialog has five tabs: 'Input 1', 'Input 2', 'Input 3', 'Toggles', and 'Output'. The 'Input 1' tab contains the following settings:

Parameter	Value	Help
Component status:	Enabled	?
Input directory:	/data/sims/topoflow/animas	?
Output directory:	~/CMT_Output/	?
Site prefix:	Animas_200	?
Case prefix:	Case5	?
Number of steps:	5000	?
Time step:	0.1	?
Max timestep:	0.4	?
Max simulation time:	100000	?

At the bottom of the dialog are four buttons: 'Help', 'Restore Defaults', 'OK', and 'Cancel'.

>> Set the output interval to 200 duration in the output tab.

>> For the base case scenario we will leave all process parameters as default values.

>> But we do need to specify what output files will be generated, and at what time interval ( $dt_{output} = 200$  (timesteps?). You will want to save the H,Z and MR netCDF files.

The screenshot shows the 'ICE: GRID Parameters' dialog box with the 'Output' tab selected. The dialog has four tabs: 'Input 1', 'Input 2', 'Input 3', and 'Output'. The 'Output' tab contains the following settings:

Parameter	Value	Help
Save grid dt:	{1.0, 100000.0} 200	?
Save Hi grids toggle:	Yes	?
Save Hi grids file:	<case_prefix>_2D_iceH.nc	?
Save Zi grids toggle:	Yes	?
Save Zi grids file:	<case_prefix>_2D_iceZ.nc	?
Save MR grids toggle:	Yes	?
Save MR grids file:	<case_prefix>_2D_iceMR.nc	?
Save time series dt:	{1.0, 1000.0} 10	?
Save Hi time series toggle:	No	?
Save Hi time series file:	<case_prefix>_0D_iceH.txt	?
Save Zi pixels toggle:	No	?
Save Zi time series file:	<case_prefix>_0D_iceZ.txt	?
Save MR time series toggle:	No	?
Save MR time series file:	<case_prefix>_0D_iceMR.txt	?

At the bottom of the dialog are four buttons: 'Help', 'Restore Defaults', 'OK', and 'Cancel'.

>> **To run the climate change scenarios**

>> Use the input 3 tab to modify ELA setting, and the mass balance setting.

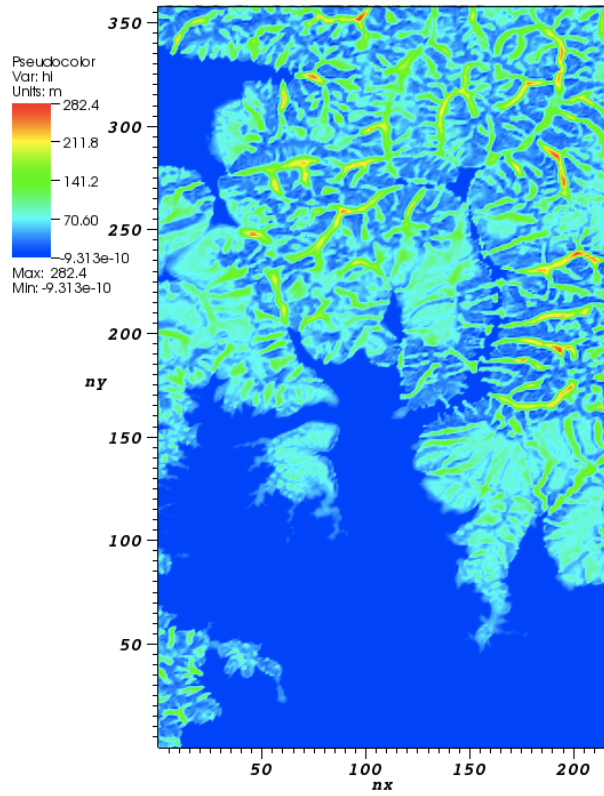
	Input 1	Input 2	Input 3	Toggles	Output
Initial ELA value:	{2500.0, 4500.0}		3350		?
ELA step size:	{-100.0, 100.0}		-10		?
ELA step interval:	{50.0, 1000.0}		500		?
Mass balance gradient:	{0.0010, 0.1}		0.05		?
Max mass balance:	{1.0, 10.0}		2		?
Spinup time:	{0.0, 1000.0}		200		?
Sea level:	{-200.0, 200.0}		-100		?
Heat capacity (ice):	{2000.0, 2100.0}		2060		?
Geothermal heat flux:	{100000.0, 1.0E7}		1.575e+06		?
Geothermal gradient:	{-0.1, 0.0}		-0.0255		?

Help   Restore Defaults   OK   Cancel

>> Output files are generated in your specified output directory on beach. You can grab the files and use your own favorite data analysis software. An easy way of doing this is to go to Tools→Remote File Transfer. This opens a menu to bring files from the remote server beach to your local machine.

>> For visualization with VisIt it will be easiest to use the NetCDF files. These have extension\*.nc.

>> Output files with extension h = ice thicknes, z = topography + ice, MR = melt rate.



*Example of Ice Thickness Grid of Animas Basin-GC2D simulation*