Stratigraphic Modeling

1 Set up the CSDMS Modeling Tool

These are three required steps:

Step 1 Activate your Secure Connection
You will need to have a VPN (Virtual Private Network) to have a secure encrypted tunnel from your computer to the University of Colorado's network when you are on the CU campus on the wireless or off campus. Please install VPN-Network Connect Software on your own system. Find this software at the University of Colorado site:
http://www.colorado.edu/cns/vpn/
To then log in to the CU network, you will need to know your CU user name, and your password. Connect to the University of Colorado.

Step 2 Download the latest CMT tool
Download the CMT tool from the CSDMS website.
http://csdms.colorado.edu/wiki/CMT_download

Step 3 Start CMT and Log In to Beach
Double-click on the CMT icon.
You will be requested to log in to the CSDMS High Performance Computing Cluster (the HPCC is called Beach). You requested an account for this and received login information from us. For this step you will need again your CU user name, and password. Note is sometimes takes 2 tries, especially when the supercomputer is busy.

Step 4 Go to the CMT Workspace and Open Relevant Project
Now you are in the CSDMS Modeling Tool. It will automatically start up in the CMT Help, for the exercises we will use the 'CMT Workspace'.

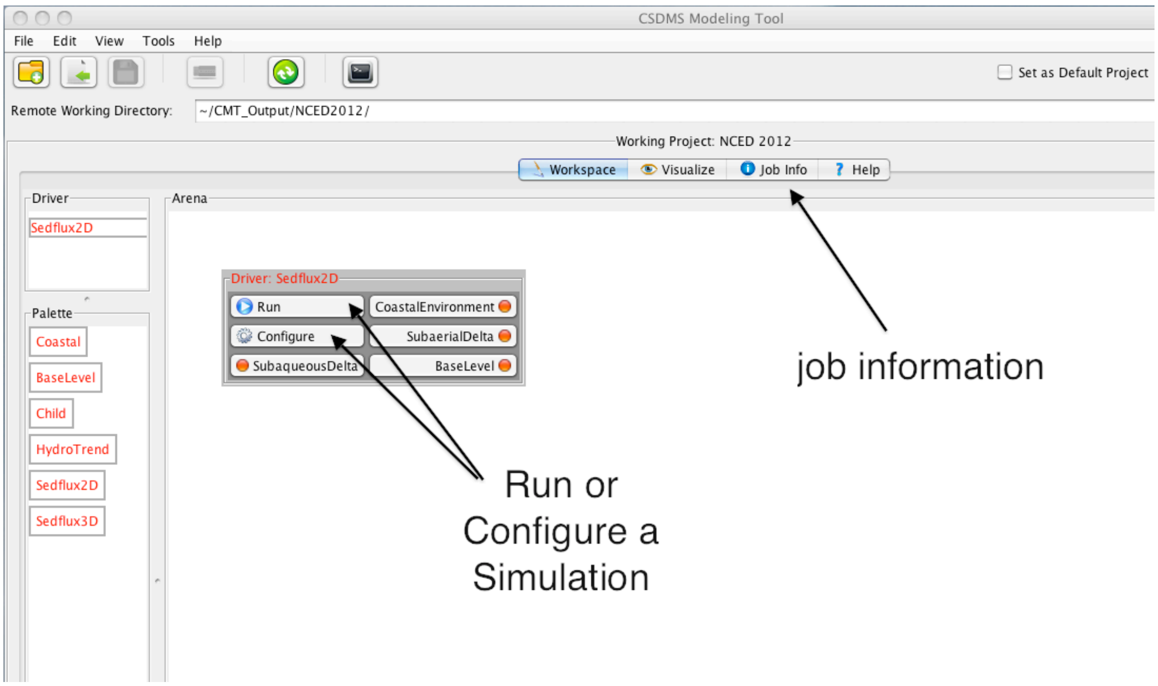
- Under the File Menu, choose 'Open project'.
- Go to the 'Courses' Group. Open Project: NCED2012
- Change your Remote Working Directory to: ~/CMT_Output/NCED2012 /
- Make sure you see that your working directory is indeed set to this path, CMT wil report this change in the 'Console' window.

Now you are ready to import examples, adapt and run simulations
We will use the stratigraphical model called 'Sedflux2D'.

2 Run and visualize a model simulation

Under the File menu, choose 'Open Example Configuration'. Here examples of previously wired model simulations are stored. These files are called *.bld files.

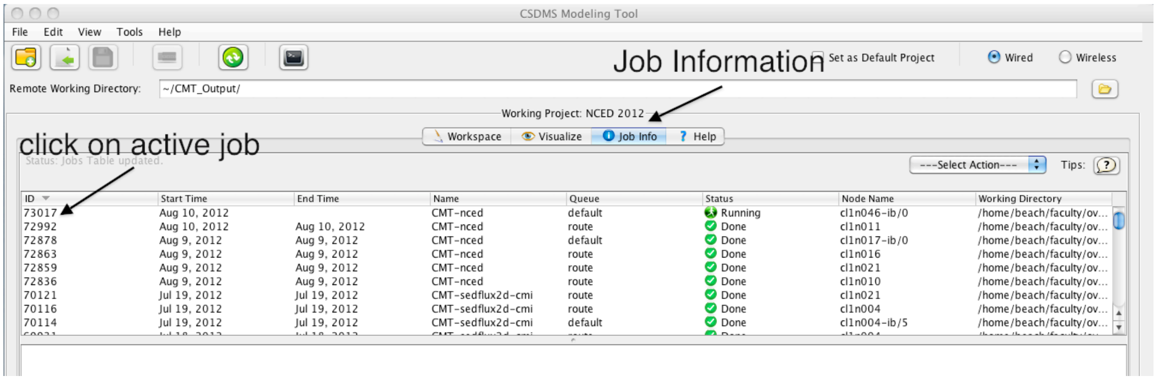
>> Open the directory for nced2012
>> Find the file 'sedflux2d_basecase10kv2.bld'
>> Click it and it will open the Sedflux Component with a set configuration



The Bld file brings up the pre-wired configuration as shown here. The SedFlux2D component is the sole driver of this simulation.

This pre-configured SedFlux2D simulation runs a simple 5000 year simulation. It simulates the evolution of a longitudinal profile of 100 km, starting 5 m above sealevel and sloping to -100m at 100 km offshore. The delta profile receives constant river water flux of almost 2000m3/s with 3 grainsizes traveling at capacity (bedload, and 2 classes of suspended load). For this example simulation the sea level is stable at 0m (this happens when sea level is switched 'OFF').

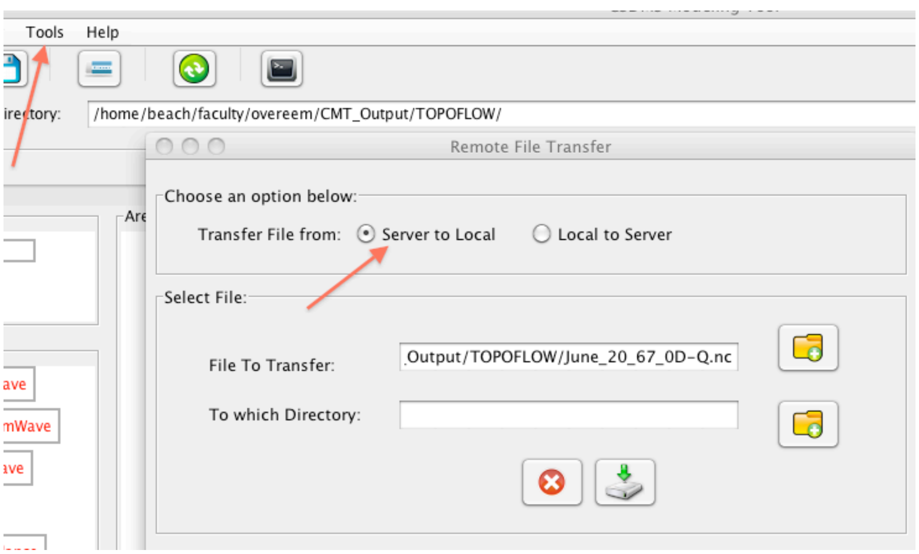
>> Browse through the configure tab to see the pre-wired parameters
>> Run this simulation.
>> To get information on your run, go from the workspace to the Job Info space. There your jobs on Beach are listed with their ID's and you can manage and query them.



>> Highlight your sedflux job and click on the 'Check Status' button.
>> Basic information on this job will be reported in the console.
>> Print statements are minimized to make the runs faster, but you wil see the simulation time running

Question 1
What was the duration of this model simulation?
Will all models have a fixed time step? If not, why not?
Can you think of a geological reason to run a stratigraphic model other than at a fixed time step? Motivate why.

>> To get output from your run, transfer files from Beach to your local machine.
>> Under the tools menu, choose remote file transfer, port files from your Beach account to your local machine.



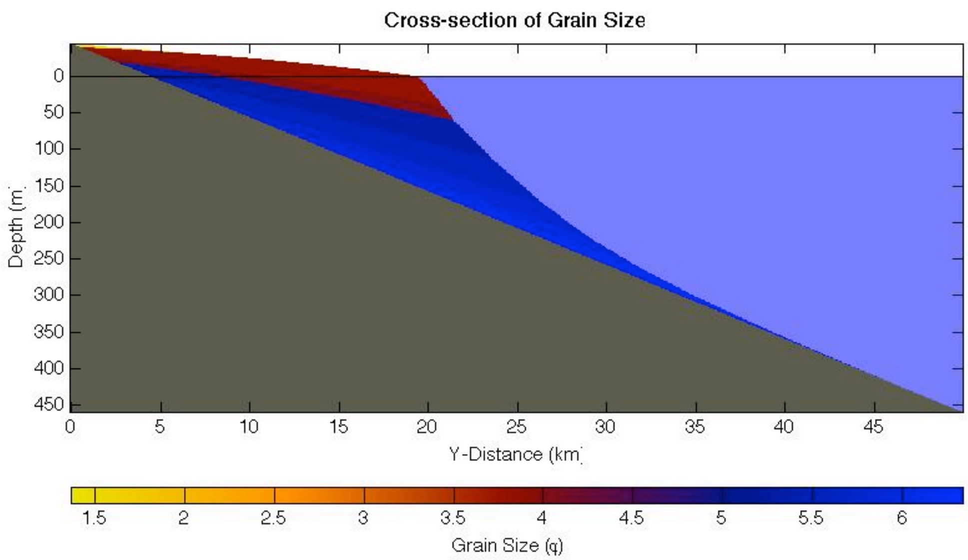
>> You now have the generated output files. The CMT tool generates the original output files as defined by the model developer. I switched on the grainsize profiles;

*these files have extension *.grain. One file is written every 1000 yrs of simulation time. We will use matlab to visualize these files.*

>> Open matlab
>> go to your directory where you downloaded the output files
>> make sure the directory with sedflux m-files are included in the path for matlab

To plot a longitudinal profile, showing the mean grain size:

>> plot_property('Sedflux2D0001.grain')



To plot a 'pseudo-core', showing the grainsize at a single location at 17km:

>> plot_property_core('Sedflux2D0004.grain', 17)

If you have all files for the run (a crossection every 1000 years):

>>film_property('Sedflux')*

Question 2
What do you see in this simple model experiment?
Does the pseudo-core show typical delta stratigraphy? What is this pattern called?

*In addition, CMT generates NetCDF files as default format as time-series or grid stacks. These files have an extension *.nc. You can visualize NetCDF files a.o. with VisIT.*

3 Learn about model theory and manipulation

Models should not function as a 'black box'. In the next section we look at your options to peak into the machinerie of Sedflux.

>> *Under the File menu, choose 'Open Example Configuration*
>> *Open the directory for Sedflux*
>> *load any *.bld file*
>> *Click on configure*

>> *Use the configure buttons to explore the settings of the different components.*
>> *Use the help button under the configuration menu to explore the background information of the different components*

Question 3
Can you figure out from the configuration tabbed dialogues which components are being used and which are not in this pre-wired simulation?

Question 4
How is bedload distributed in Sedflux 2D, please list the equation.
What parameters influence this process?
Is the value set for 'bedload dumping distance' in the configuration realistic?

If you are an experienced modeler, you may prefer to download the original source code for Sedflux. All source code of available models is shared through the CSDMS model repository:

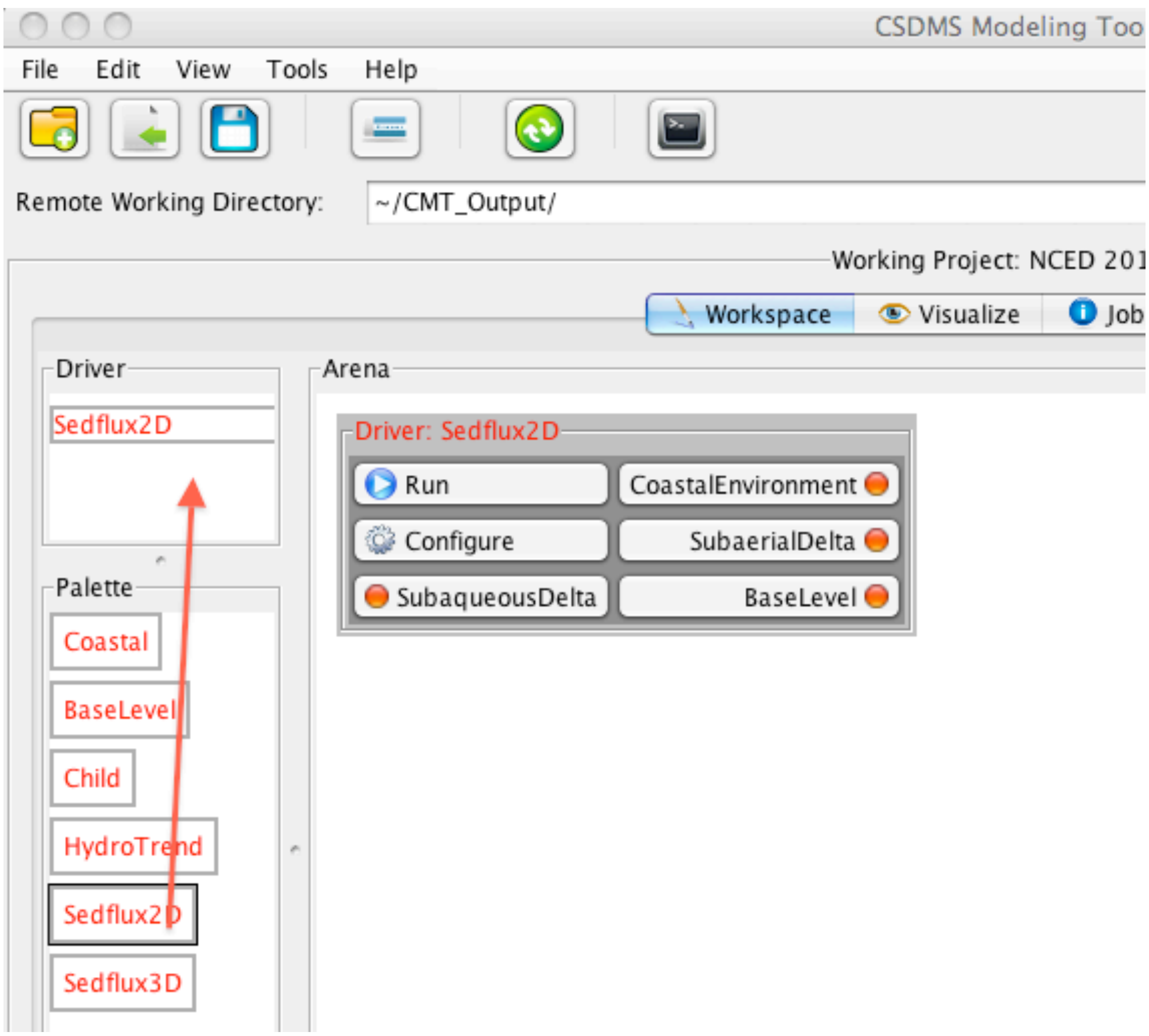
Downloads of all models in the CSDMS repository:
http://csdms.colorado.edu/wiki/Download_models

4 Sea Level Change Experiments

The key parameter that was historically called upon to explain stratigraphic patterns was sea level. Sea level explains a lot of longterm coastline shifting and specific patterns of progradation and retrogradation can be attributed to sea level change. In these exercises we will run a series of sea level scenarios: a rising sea level, a falling sea level and a full sea-level cycle.

>> PLEASE MAKE SURE YOU RESET YOUR WORKING DIRECTORY FOR DIFFERENT EXPERIMENTS!!! AND NOTE YOU WILL NEED TO NAME THE OUTPUT DIRECTORY IN CMT ACCORDINGLY.

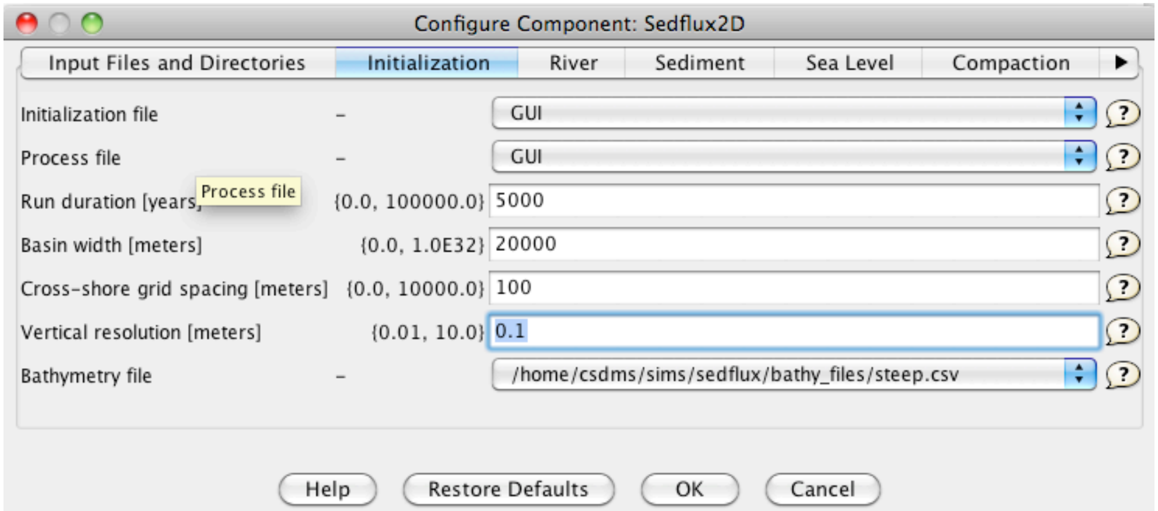
>> drag in the Sedflux2D component as a driver. This means it drives the model simulation, in our case we are running it as stand-alone.

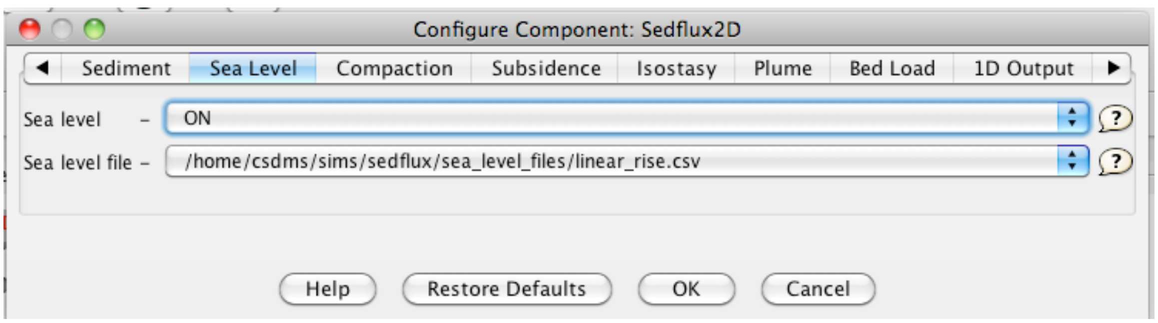


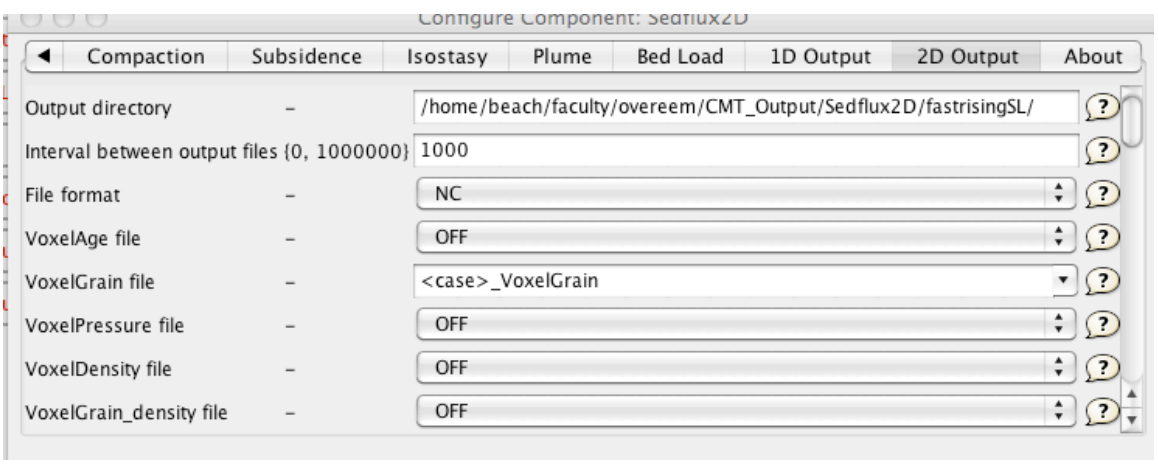
Then set up your initialization, these are the master parameters of the simulation. We'll keep the duration short (5001 years) to keep the run-time maneageable.

Similarly the basin width is set to be 20km, and grid spacing 100m long by 0.1m thick. Choose the 'steep.csv' bathymetric slope.

>> Set the following input parameters







>> Click on Run after you configured your simulation to submit your simulation. Check in the job info tab whether your job is running.

>> Configure and submit an additional job with a falling sea level file

>> Configure and submit an additional job with a full-cycle sea level file

These runs will take at least 20 minutes. In the meantime we will plot up the controlling input files to see what the pre-set sea level scenarios are.
Sedflux input files we use are posted on the CSDMS wiki page:

>> Import the sea level csv-files to your local machine from the wiki, and plot the 3 different sea-level records in Matlab.
>> Plot the bathymetry file (all simulations use the 'steep.csv' file).

Question 5
Formulate a 'model' for each of the scenarios. Draw out what you expect to happen to the stratigraphy. You can try to do this for the shape of the depositional wedge as well as the grain-size trend. Take into account the Sedflux is only running with 3 grain size classes for these experiments, which limits the complexity of your depositional package.

>> Now find the output files on beach and plot the profile for the different timeslices. You can grab the final output X-section by only selecting Sedflux2D0005.grain

>> film_property('Sedflux2D.grain')*

Question 5
What is the effect of a rapidly falling sea level on the stratigraphy? What is the effect of a rising sea level? What is the effect of a cosine-shaped sea level cycle?
Do the pseudo-well have different trends?

5 Slope Experiments in Sedflux

Another major control on stratigraphy is 'accommodation'. The space available for deposition, this is controlled by tectonics in the long-term. We will look at the control of accommodation on a much shorter time-scale, by looking at the effect of the initial bathymetric slope on the depositional package.

Use the stable sea level scenario, this helps you explore the effect of the different initial profile conditions independent of the sea level fluctuation. Or use the falling sea level scenario, since you know that will cause fast shifting of the depocenter.

>> Configure and submit an additional job with 'longramp.csv' for bathymetry
>> Configure and submit an additional job with 'shortramp.csv' for bathymetry
>> Configure and submit an additional job with 'gradualramp.csv' for bathymetry

These runs will take ~20 minutes. In the meantime we will plot up the controlling bathymetric files to see the initial profiles.

>> Import the bathymetry csv-files, plot the 4 different bathymetric files in Matlab

Question 6
You are now armed with more experience with simple Sedflux runs, formulate a 'model' for each of the bathymetry scenarios. Draw out what you expect to happen to the stratigraphy. You can try to do this for the shape of the depositional wedge as well as the grain-size trend.

Question 7
Once you have the output; what is the effect of slope on the stratigraphy? How fast does the coastline shift? Plot a pseudo-well on the shallow part of the profile and one in deeper water.

6 Grainsize Experiments in Sedflux

Plume dynamics are governed by the following modified steady 2D advection-diffusion equation:

$$\frac{\partial uI}{\partial x} + \frac{\partial vI}{\partial y} + \lambda I = \frac{\partial}{\partial y}\left(K\frac{\partial I}{\partial y}\right) + \frac{\partial}{\partial x}\left(K\frac{\partial I}{\partial x}\right)$$

where x, y are coordinate directions, u, v are velocities, K is turbulent sediment diffusivity, I is sediment inventory, λ is the first-order removal rate constant. The constant, lambda, has units of inverse time and is called the removal rate constant. It is essentially the inverse of the amount of time, on average, that a particle spends within the plume before crossing the lower boundary. It depends on the size, composition, settling velocity and tendency to flocculate of the suspended material. Due to turbulence, however, particle paths are not straight down and it cannot be computed as the quotient of the Stokes settling velocity and plume depth. A first-order approximation based on field observations is:

$$\lambda(D) = 0.222D + 1.57$$

wherein D is grainsize in microns.

Whereas the 2D advection-diffusion equation is further simplified in Sedflux, the removal rate is one of the key grain size parameters that influences depositional patterns. Please use one of your previous experiments (the base-case is easy) and now manipulate the grain size and settle rate.

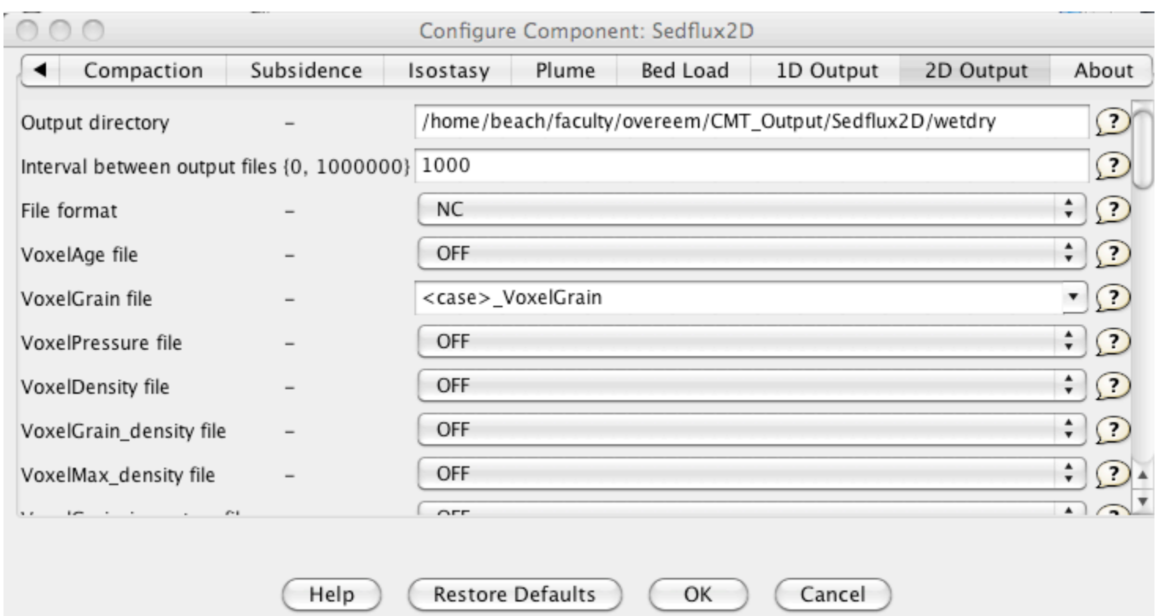
>> Reset your simulation to basic conditions; use the 'steep.csv' bathymetry and 'stable.csv' sea level curve.

>> Set up a simulation with much coarser sediment. Manipulate the grainsize and in conjunction the settle rate.

Question 8
One would expect the profile to be steeper and shorter with higher settle rates (why?). Is this the case for your simulation?

7 Climate Variability Experiments in Sedflux

Climate most directly influences stratigraphy through the river sediment flux. Sofar, we have run the simulations with uniform water and sediment input. There are two input files prepared to vary water and sediment flux over time: one with random variability and one with 10 year wet-dry cycles.



>> Reset your simulation to basic conditions; use the 'steep.csv' bathymetry and 'stable.csv' sea level curve.

>> Set up a simulation with wet-dry input file
>>Set up a simulation with random climate

Question 9
Do you see an effect of this variation in the respective pseudo-wells?
Zoom in……..what is the limiting factor in preserving flood layers within the model?

8 Coupling CHILD and Sedflux

Question 10
Think of a scenario in which you would have CHILD and Sedflux coupled together. We'll make an inventory all scenarios and discuss linkage and potential feedbacks between the two models.