From: Archie Paulson <archie.paulson@colorado.edu>
Subject: **glacier model**
Date: January 30, 2008 1:24:06 AM MST
To: Chris Malley <cmalley@pixelzoom.com>
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1 Attachment, 7.1 KB Save

Chris,

Here is a model for the variables you need now (on the basic panel). In the end, I had to give up on making the true model work, so instead this is a way to get decent results without a physically accurate glacial model behind the scenes. Hopefully your design will include the possibility to change some of the numerical values later (within reason), if need be.

In the development of the stuff below, I wrote some python code to make sure things work. I have attached it, just in case you care.

Please let me know when questions arise about this. I will continue to work on the climate change user interface and model. I'll try harder to get those done before you need them.

I'm terribly sorry for the long delay. My big bad.

-Archie

##
Note: x**y means 'x to the power of y'

1. temperature control:
   range from -15 to 10 (cold to warm)
   call this variable 'ref_temp' for reference temperature
   initial default ref_temp=0

2. snowfall control:
   range from 1e-3 to 1e-4 (little snowfall to lots)
   call this variable 'snowfall_lapse_rate'
   initial default snowfall_lapse_rate=5e-4

3. temperature gauge:
   given the ref_temp, the temperature as a function of
   elevation (z, in meters) is
      20.+ref_temp - 6.5*z/1e3

4. accumulation:
   given
      (a) the constant snowfall_max=2.0, and
      (b) the snowfall_lapse_rate,
   the accumulation as a function of elevation (z) is
      z*snowfall_lapse_rate,
      clipped to a minimum of 0 and a max of snowfall_max

5. ablation:
   given
      (a) the constant melt_v_elev=-0.011,

(b) the constant melt_v_temp=1.3,
(c) the constant melt_temp0=45.0,
(d) the ref_temp,
the ablation as a function of elevation (z) is
melt_v_elev*z + melt_temp0 + melt_v_temp*ref_temp,
clipped to a minimum of 0

6. mass_balance:
given
(a) accumulation as a function of z,
(b) ablation as a function of z,
the mass_balance as a function of elevation (z) is
accumulation - ablation
note this is also called the 'glacial budget';
note the mass_balance as a function of x can be found as follows:
given
(a) the unchanging valley floor elevation, F:
F= 4e3 - x/30. + exp(-(x-5e3)/1e3)
(b) mass_balance as a function of z
the mass_balance as a function of x is
mass_balance(F(x))

7. ELA:
given the mass_balance as a function of z,
ELA = elevation at which mass_balance=0
note: ELA stands for equilibrium line altitude; it is
the elevation of the equilibrium line

8. ice volume flux (Q):
given
(a) the unchanging valley width, W:
W= 1e3 + 5e3*exp(-((x-5e3)/2e3)**2)
(b) the mass_balance as a function of x
the ice volume flux as a function of X is
integral (from 0 to X) of W * mass_balance,
clipped to a minimum of 0
call this variable 'Q'

9. the length of the glacier (x_terminus):
given the ice volume flux, Q
the length of the glacier is the x-coordinate at which Q becomes 0
call this variable 'x_terminus'

10. ice thickness at steady state (H):
given
(a) the constant max_thickness=500.0,
(b) the ice volume flux, Q
(c) the maximum value of Q, max_Q
(d) the length of the glacier, x_terminus
(e) the constant length of valley, x_max=80e3
the steady state (or equilibrium) glacier thickness as a function of x is
Q * (max_thickness/max_Q) * (x_terminus/x_max)
call this variable 'H'

11. vertically-averaged deformation ice velocity (u_deform_ave):
given
(a) the variable u0ave which is the average of H**2,
where the average is over the nonzero of H,
the vertically-averaged deformation ice velocity as a function of x is

```
H**2 * 20/u0ave
```

call this variable 'u_deform_ave'

12. vertically-averaged total ice velocity (u_ave):
given
(a) the constant u_slide=20
(b) the variable u_deform_ave as a function of x
the vertically-averaged total ice velocity as a function of x is

```
u_deform_ave + u_slide
```

call this variable 'u_ave'

13. vertical velocity profile
given
(a) the variable zz which varies from 0 at the base of the glacier (rock-ice interface) to 1 at the top of the glacier (air-ice interface)
(b) the vertically-averaged ice deformation velocity, u_deform_ave
(c) the point X (within the domain of x) at which to measure the vertical velocity profile
(d) the constant u_slide=20
the vertical velocity profile (as a function of zz) is

```
u_slide + u_deform_ave[X]*5.*( zz - 1.5*zz**2 +
                               zz**3 - 0.25*zz**4 )
```

note that u_deform_ave[X] means u_deform_ave evaluated at the postition x=X

14. climate change timescale
given an ELA, the climate change timescale is

```
-35.7/300. * ELA + 484.6,
```

clipped to a minimum of 20 and a max of 50
call this variable 'timescale'

15. model for simple time-dependence
In the basic panel, when a control is changed, the time-dependence between the original climate (call it climate_0) and the new climate (call it climate_1) can be computed as follows
(a) calculate the ELA for climate_0
(b) calculate the ELA for climate_1
(c) calculate the climate change timescale for climate_0
(d) calculate the climate change timescale for climate_1
(e) calculate the average of these two timescales, call it T
(f) calculate a new glacier thickness, H, for climate_1
(g) evolve each point in the glacier from the original thickness to the new thickness with an exponentially decaying time-dependence of characteristic time T;

for example, going from H0 (for climate_0) to H1
(for climate_1) looks like
    H(t) = H0 + (H1-H0)*(1 - exp(-t/T))

##

model.py (7.1 KB)