Ice Sheet System model

Application to Jakobshavn Isbrae, West Greenland

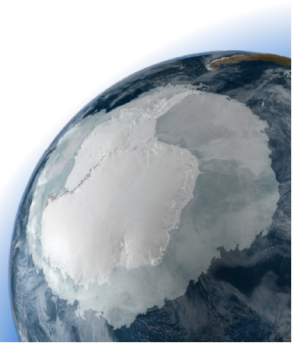
Eric LAROUR[1], Eric RIGNOT[1,3], Mathieu MORLIGHEM[1,2], Hélène SEROUSSI[1,2] **Chris BORSTAD**[1], Feras HABBAL[1,3], Daria HALKIDES[1,4], Behnaz KHAKBAZ[1], John SCHIERMEIER[1], Nicole SCHLEGEL[1]

[1]Jet Propulsion Laboratory - California Institute of Technology

[2]Laboratoire MSSMat, École Centrale Paris, France

[3]University of California, Irvine

[4]Joint Institute for Regional Earth System Science & Engineering, UCLA



©Copyright 2011. All rights reserved

Overview

1. Meshing
2. Paramaterization
3. Control Method Solution
4. Plotting

File runme.m

The runme.m file is a list of commands to be run in sequence at the MATLAB command prompt. Simply type "runme" at the command line to execute the commands.

- The variable *steps* defines which step(s) of the runme file to execute
- *printflag* can be switched to true for printing a plot to file
- *cluster* sets parameters for parallel computation
- *ncdata* defines the path to the SeaRISE netcdf file ("Greenland Developmental Data Set" at `http://websrv.cs.umt.edu/isis/index.php/Present_Day_Greenland`)

```
steps=[1 2 3 4];

%Hard coded parameters
cluster=generic('name',oshostname,'np',2);
ncdata='~/issmjpl/projects/ModelData/SeaRISE/Greenland5km_v1.2/Greenland_5km_dev1.2.nc';
```

Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

File runme.m

Here we use *if* statement blocks to delineate different run steps. If the variable *steps* contains the value 1, the commands of the following block will be executed.

```
%Run Steps
if any(steps==1)

   disp('   Step 1: Mesh creation');
```

Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

First Run Step: Meshing

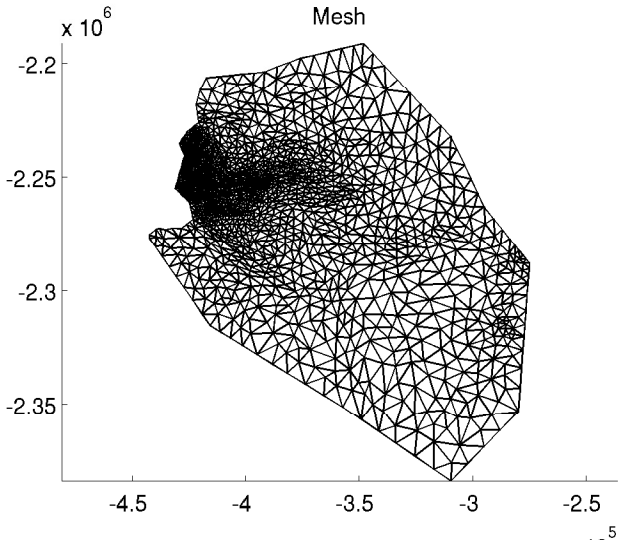
- **11** Create a triangle mesh with 2000 m resolution using the domain outline file "Jks3_trimmed.exp" and store it in the model named md.
- **14-20** Interpolated observed velocity data onto the newly-created mesh
- **23** Refine mesh in areas of higher observed velocity
- **26** Save model to file compatible with MATLAB v7.3 and later

```
8   if any(steps==1)
9
10      disp('   Step 1: Mesh creation');
11      md=triangle(model,'Jks3_trimmed.exp',2000);
12
13      %Get observed velocity field on mesh nodes
14      x1=double(ncread(ncdata,'x1'));
15      y1=double(ncread(ncdata,'y1'));
16      velx=double(ncread(ncdata,'surfvelx'));
17      vely=double(ncread(ncdata,'surfvely'));
18      vx=InterpFromGridToMesh(x1,y1,velx',md.mesh.x,md.mesh.y,0);
19      vy=InterpFromGridToMesh(x1,y1,vely',md.mesh.x,md.mesh.y,0);
20      vel=sqrt(vx.^2+vy.^2);
21
22      %refine mesh using surface velocities as metric
23      md=bamg(md,'hmin',1200,'hmax',15000,'field',vel,'err',5);
24
25      name='JKS.Mesh_generation';
26      save(name,'md','-v7.3')
27  end
```

Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

First Run Step: Meshing

Mesh plot



Second Run Step: Parameterization

33 All ice is considered grounded. The setmask function can be used to define the boundary between grounded and floating ice.

34 Parameterize the model using the .par file

37-39 The domain outline file "WeakB.exp" defines a shear margin with softer ice. In this region, reduce B by a factor of 0.3

```
28  if any(steps==2)
29
30   disp(' Step 2: Parameterization');
31   md=loadmodel('JKS.Mesh_generation');
32
33   md=setmask(md,'','');
34   md=parameterize(md,'Jak.par');
35
36   %zones of shear margin softening
37   weakb=ContourToMesh(md.mesh.elements,md.mesh.x,md.mesh.y,'WeakB.exp','node',2);
38   pos=find(weakb);
39   md.materials.rheology_B(pos)=.3*md.materials.rheology_B(pos);
40
41   name='JKS.Parameterization';
42   save(name,'md','-v7.3')
43  end
```

Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

Contents of Jak.par File

Miscellaneous general parameters at head of file:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%Greenland parameters%%%%%%%%%%

    %Parameters for Jakobshavn tutorial

    modeldatapath = ...
         ['¬/issmjpl/projects/ModelData/SeaRISE/Greenland5km_v1.2'];

    %Name and hemisphere
    md.mesh.hemisphere='n';
    md.miscellaneous.name='SeaRISEgreenland';

    %some temporary parameters
    di=md.materials.rho_ice/md.materials.rho_water;
```

Contents of Jak.par File

Topography

16-18 Read and store x and y coordinates of SeaRISE data grid.

20-21 Read upper ice surface topography, interpolate from SeaRISE grid to mesh nodes, store in md.geometry.

23-25 Do same for bed topography, then calculate ice thickness from surface and bed.

27-30 Find any places with negative thickness and set thickness to 1. Re-calculate surface data.

```
16    ncdata=[modeldatapath '/Greenland_5km_dev1.2.nc'];
17  x1=double(ncread(ncdata,'x1'));
18  y1=double(ncread(ncdata,'y1'));
19
20  surface=double(ncread(ncdata,'usrf'));
21  md.geometry.surface=InterpFromGridToMesh(x1,y1,surface',md.mesh.x,md.mesh.y,0);
22
23  bed=double(ncread(ncdata,'topg'));
24  md.geometry.bed=InterpFromGridToMesh(x1,y1,bed',md.mesh.x,md.mesh.y,0);
25  md.geometry.thickness=md.geometry.surface-md.geometry.bed;
26
27  pos0=find(md.geometry.thickness<=0);
28  md.geometry.thickness(pos0)=1;
29
30  md.geometry.surface=md.geometry.thickness+md.geometry.bed;
```

Contents of Jak.par File

Observed velocity

33-34 Read SeaRISE surface velocity components.

36-38 Interpolate observed velocity onto mesh nodes, calculate velocity magnitude, store in md.inversion.

40-43 Also store observed velocities in md.initialization.

```
32  disp('      reading velocities ');
33  velx=double(ncread(ncdata,'surfvelx'));
34  vely=double(ncread(ncdata,'surfvely'));
35
36  md.inversion.vx_obs=InterpFromGridToMesh(x1,y1,velx',md.mesh.x,md.mesh.y,0);
37  md.inversion.vy_obs=InterpFromGridToMesh(x1,y1,vely',md.mesh.x,md.mesh.y,0);
38  md.inversion.vel_obs=sqrt(md.inversion.vx_obs.^2+md.inversion.vy_obs.^2);
39
40  md.initialization.vx=md.inversion.vx_obs;
41  md.initialization.vy=md.inversion.vy_obs;
42  md.initialization.vz=zeros(md.mesh.numberofvertices,1);
43  md.initialization.vel=md.inversion.vel_obs;
```

Contents of Jak.par File

Friction and Temperature

46-48 Set initial friction coefficients

51-52 Read and interpolate SeaRISE temperature data to mesh nodes

```
45  disp('      friction coefficient');
46  md.friction.coefficient=50*ones(md.mesh.numberofvertices,1);
47  md.friction.q=ones(md.mesh.numberofelements,1);
48  md.friction.p=ones(md.mesh.numberofelements,1);
49
50  disp('      loading temperature ');
51  temp=double(ncread(ncdata,'surftemp'));
52  md.initialization.temperature=InterpFromGridToMesh(x1,y1,temp',md.mesh.x,md.mesh.y,0)+273.15;
```

Contents of Jak.par File

Flow law and surface mass balance

55-58 Set B as a function of temperature and n as a constant

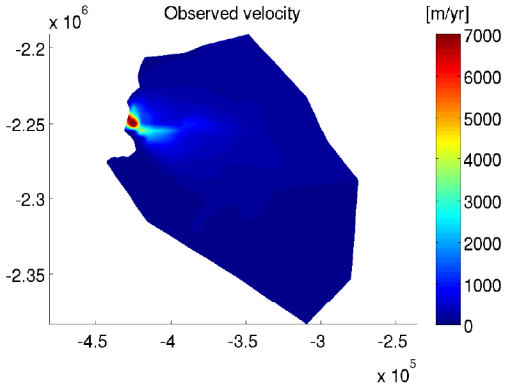
49-50 Read and interpolate SeaRISE surface mass balance data to mesh nodes

```
54  disp('      creating flow law paramters');
55  md.materials.rheology_B=paterson(md.initialization.temperature);
56  pos=find(md.materials.rheology_B≤0);
57  md.materials.rheology_B(pos)=-md.materials.rheology_B(pos);
58  md.materials.rheology_n=3*ones(md.mesh.numberofelements,1);
59
60  disp('      creating smb');
61  smb=double(ncread(ncdata,'smb'));
62  smb=InterpFromGridToMesh(x1,y1,smb',md.mesh.x,md.mesh.y,0);
63  md.surfaceforcings.mass_balance=[smb*1000/md.materials.rho_ice;1];
```

Third Run Step: Control Method for Basal Drag

Plot of observed velocity

This is a plot of the SeaRISE surface velocity data interpolated onto the mesh. This observed data is used in the control method.



Third Run Step: Control Method for Basal Drag

48 The setflowequation defines the material law for each element. In this case, use MacAyeal elements throughout.

51-55 Set general control method parameters.

58-60 Set cost functions

```
44  if any(steps==3)
45
46   disp(' Step 3: Control method friction');
47   md=loadmodel('JKS.Parameterization');
48   md=setflowequation(md,'macayeal','all');
49
50   %Control general
51   md.inversion.iscontrol=1;
52   md.inversion.nsteps=20;
53   md.inversion.step_threshold=0.999*ones(md.inversion.nsteps,1);
54   md.inversion.maxiter_per_step=15*ones(md.inversion.nsteps,1);
55   md.verbose=verbose('solution',true,'control',true);
56
57   %Cost functions
58   md.inversion.cost_functions_coefficients=ones(md.mesh.numberofvertices,1);
59   md.inversion.cost_functions(1:md.inversion.nsteps,1)=103;
60   md.inversion.cost_functions(floor(md.inversion.nsteps/2):md.inversion.nsteps,1)
```

Third Run Step: Control Method for Basal Drag

63-73 Additional control parameters

76 Set cluster parameters for parallel solution

77-78 Solver parameters

79 Call solution sequence

```
62   %Controls
63   md.inversion.control_parameters={'FrictionCoefficient'};
64   md.inversion.gradient_scaling(1:md.inversion.nsteps)=50;
65   md.inversion.gradient_scaling(5:end)=10;
66   md.inversion.min_parameters=1*ones(md.mesh.numberofvertices,1);
67   md.inversion.max_parameters=200*ones(md.mesh.numberofvertices,1);
68
69   %Additional parameters
70   md.diagnostic.restol=0.01;
71   md.diagnostic.reltol=0.1;
72   md.diagnostic.abstol=NaN;
73   md.inversion.cost_function_threshold=NaN;
74
75   %Go solve
76   md=setcluster(md,cluster);
77   md.solver=addoptions(md.solver,NoneAnalysisEnum,asmoptions);
78   md.solver=addoptions(md.solver,DiagnosticVertAnalysisEnum,jacobiasmoptions);
79   md=solve(md,DiagnosticSolutionEnum);
80
81   name='JKS.Control_friction_macayeal';
82   save(name,'md','-v7.3')
83 end
```

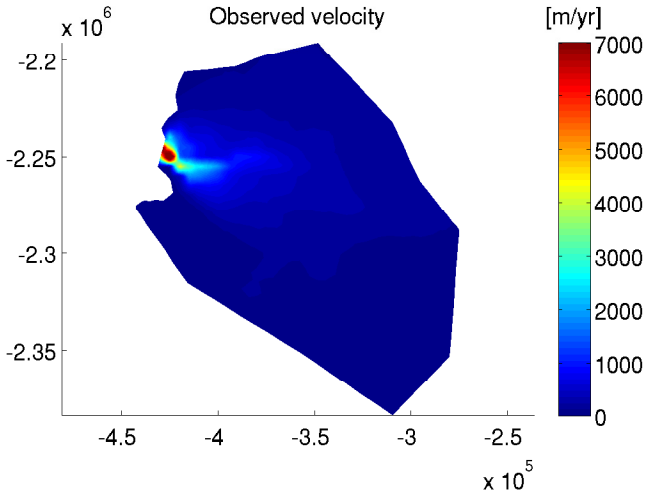
Fourth Run Step: Plotting Results

```
if any(steps==4)

 disp(' Plotting')
 md=loadmodel('JKS.Control_friction_macayeal');

 plotmodel(md,'nlines',2,'ncols',2,'unit#all','km','axis#all','equal',...
  'xlim#all',[min(md.mesh.x) max(md.mesh.x)]/10^3,...
  'ylim#all',[min(md.mesh.y) max(md.mesh.y)]/10^3,...
  'FontSize#all',12,...
  'data',md.initialization.vel,'title','Observed velocity',...
  'data',md.results.DiagnosticSolution.Vel,'title','Modeled Velocity',...
  'colorbar#1','off','colorbar#2','on','colorbartitle#2','[m/yr]',...
  'caxis#1-2',[0,7000],...
  'data',md.geometry.bed,'title','Bed elevation',...
  'data',md.results.DiagnosticSolution.FrictionCoefficient,...
  'title','Friction Coefficient',...
  'colorbar#3','on','colorbartitle#3','[m]','colorbar#4','on');

end
```

Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

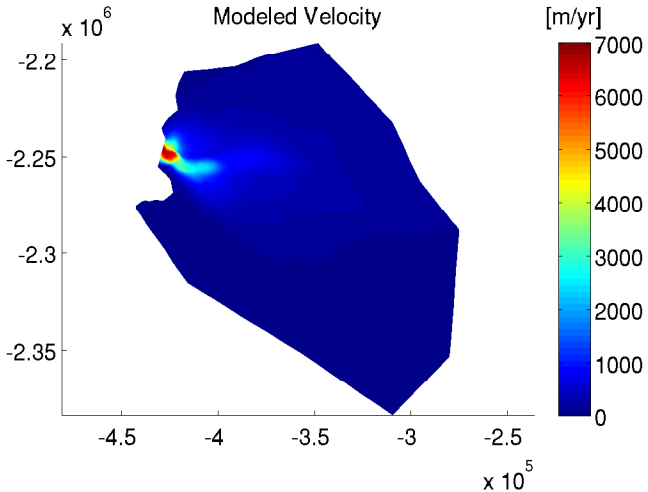
Fourth Run Step: Plotting Results

Observed velocity



Fourth Run Step: Plotting Results

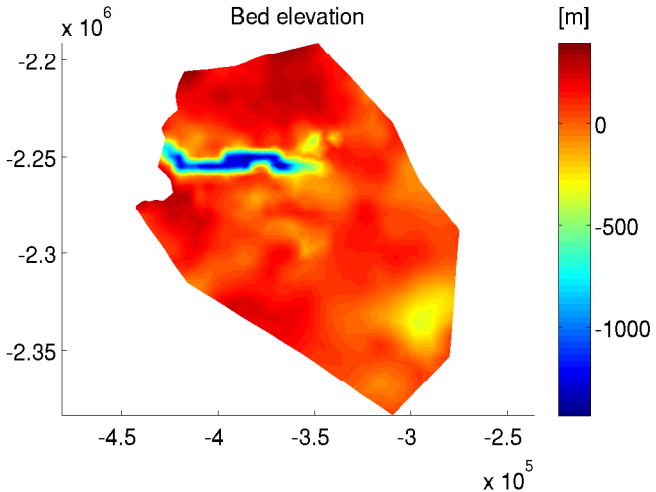
Modeled velocity



Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

Fourth Run Step: Plotting Results

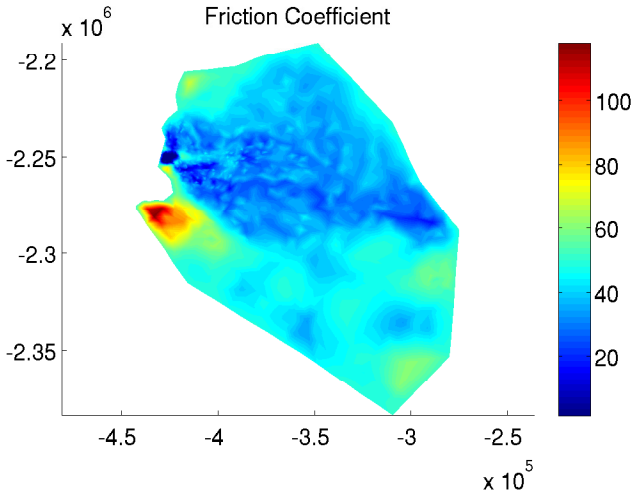
Bed elevation



Application Jakobshavn
Larour et al.
Meshing
Parameterization
Control Method Solution
Plotting

Fourth Run Step: Plotting Results

Modeled friction coefficient



Thanks!