

Ice Sheet System Model 2008

Code Validation Guide

Authors:

Hélène Seroussi^{2,3}
Mathieu Morlighem^{2,3}
Éric Larour¹

¹Division 35, Thermal and Cryogenics Section,
Mechanical Division, MS 157-316.
Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

²Division 33, Radar Science and Engineering Section,
Communications, Tracking and Radar Division, MS 157-316.
Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

³Laboratoire de Mécanique des sols, Structures et matériaux (MSSMat)
École Centrale Paris, CNRS UMR 8579
Grande Voie des Vignes, 92295 Châtenay-Malabry Cedex, FRANCE

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Chapter 1

EISMINT

The tests described in this chapters follow the work of Vincent Rommeleare [\[10\]](#).

1.1 Test 1: Mass concervation

1.1.1 Setup of the experiment

We use an idealized geometry of a square ice shelf of length 200km. The velocity is imposed everywhere as $u_0 = 400\text{m/yr}$ and the initial thickness is 500m.

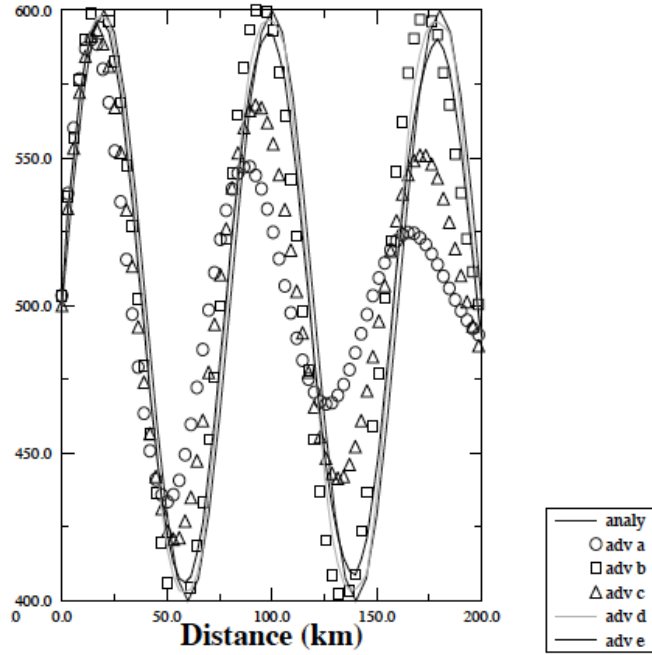
The boundary conditions are free radiation on all sides except on the left boundary where a thickness wave is imposed:

$$H(t) = H_0 + \frac{H_0}{5} \sin\left(\frac{2\pi t}{T}\right) \quad (1.1)$$

We want to check if the conservation scheme is able to propagate the signal along the shelf. The analytical solution is:

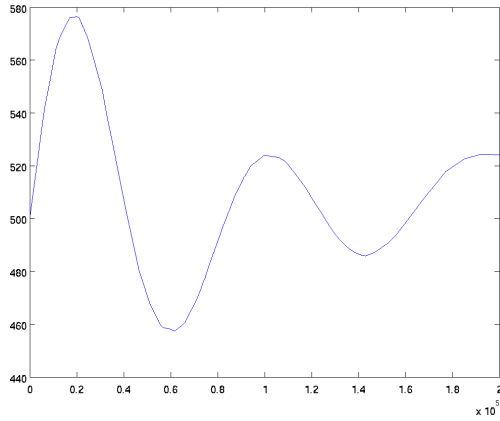
$$H(x, y, t) = H_0 + \frac{H_0}{5} \sin\left(\frac{2\pi}{T} \left(t - \frac{x}{u_0}\right)\right) \quad (1.2)$$

1.1.2 Results and comparisons

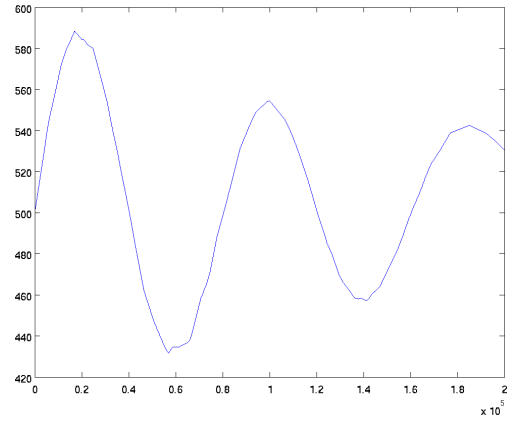


(a) Vincent Rommeleare's results

(b)



(c) Thickness with artificial diffusivity

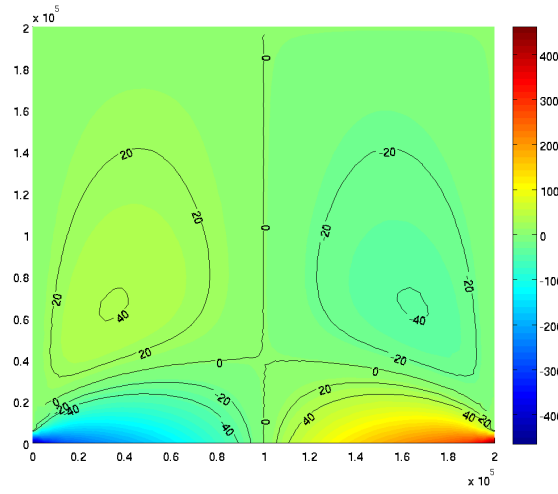


(d) Thickness without artificial diffusivity

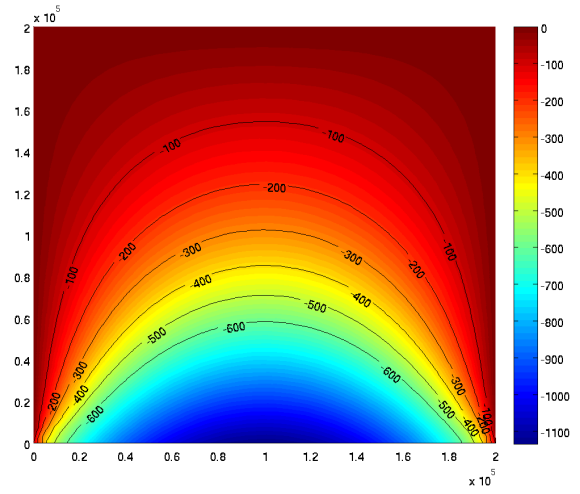
Figure 1.1: Comparison of the ISSM results with Vincent Rommeleare's

1.2 Test 2: Diagnostic 1

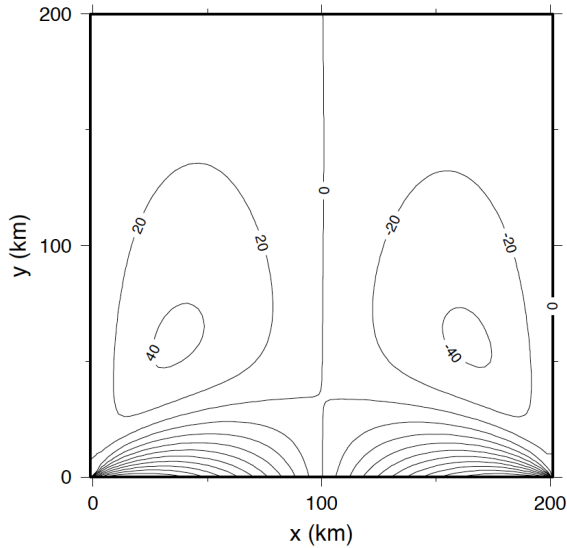
We use a square ice shelf with an imposed velocity everywhere except on the front where a dynamic boundary condition is imposed (water pressure). Here are the results:



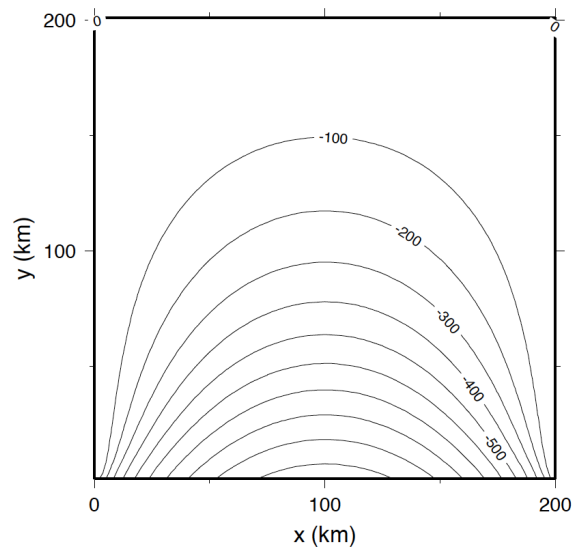
(a) V_x (m/yr) computed by ISSM



(b) V_y (m/yr) computed by ISSM



(c) V_x (m/yr) found by Romelaere



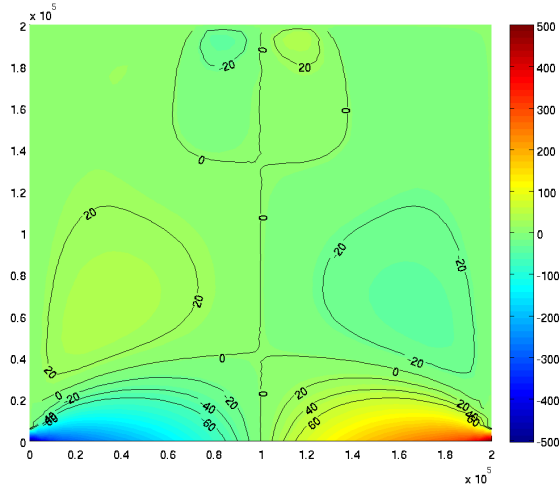
(d) V_y (m/yr) found by Romelaere

Figure 1.2: Comparison of the ISSM results with Vincent Rommeleare's

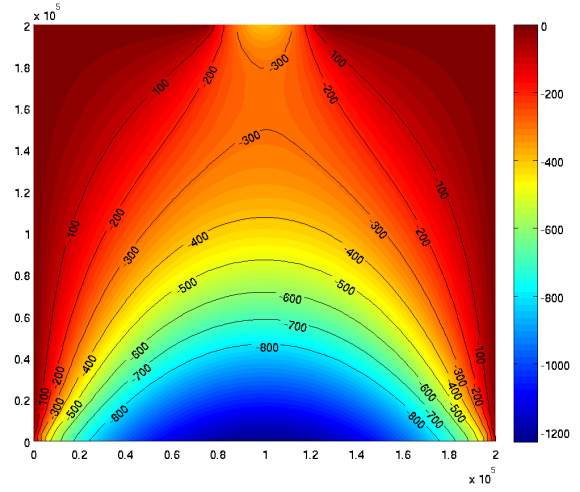
1.3 Test 3: Diagnostic 2

The geometry is exactly the same as the previous one except that the upper boundary condition is change to account for an ice stream entering the ice shelf. The y-velocity becomes:

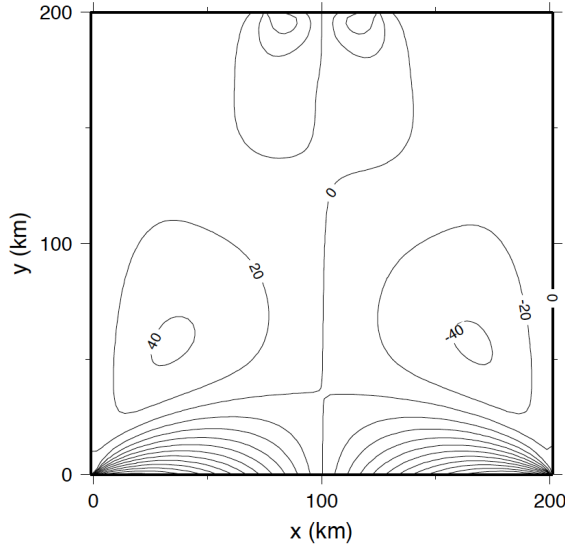
$$v(x, (y = L)) = 400 \left(\left[\frac{x - 100}{25} \right]^2 - 1 \right) \text{Heav} \left(1 - \left[\frac{x - 100}{25} \right]^2 \right) \quad (1.3)$$



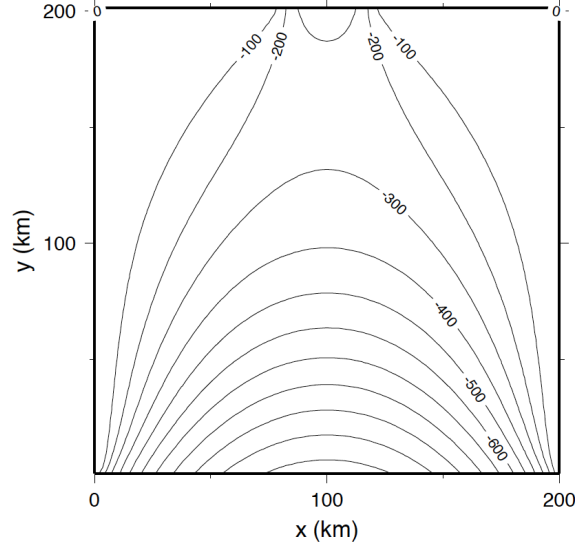
(a) V_x (m/yr) computed by ISSM



(b) V_y (m/yr) computed by ISSM



(c) V_x (m/yr) found by Romelaere



(d) V_y (m/yr) found by Romelaere

Figure 1.3: Comparision of the ISSM results with Vincent Rommeleare's

Chapter 2

ISMIP-HOM

The tests described in this chapters follow the works of Laura Perichon [9] and Frank Pattyn [4]. For a comprehensive description of the experiment, please see [6].

2.1 Test A

2.1.1 Geometry

This is a 3d ice-sheet flow over a bumpy bed experiment. Periodic boundary conditions are applied. The geometry follows:

- surface $s(x, y) = -x \tan(0.5^\circ)$
- bed $b(x, y) = s - 1000 + 500 \sin\left(\frac{2\pi}{L}x\right) \sin\left(\frac{2\pi}{L}y\right)$
- $5 \text{ km} \leq L \leq 160 \text{ km}$

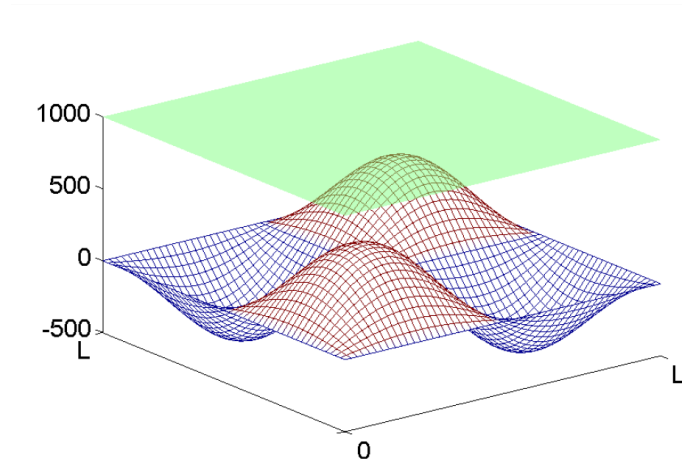
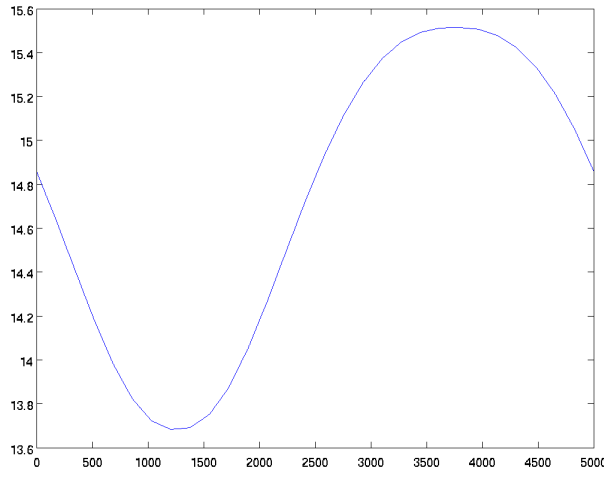


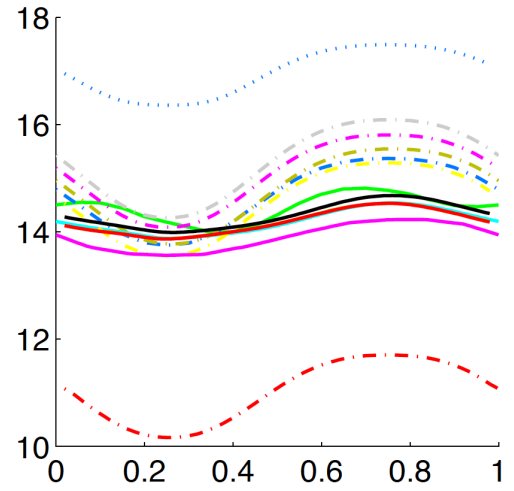
Figure 2.1: Test A geometry

2.1.2 Results

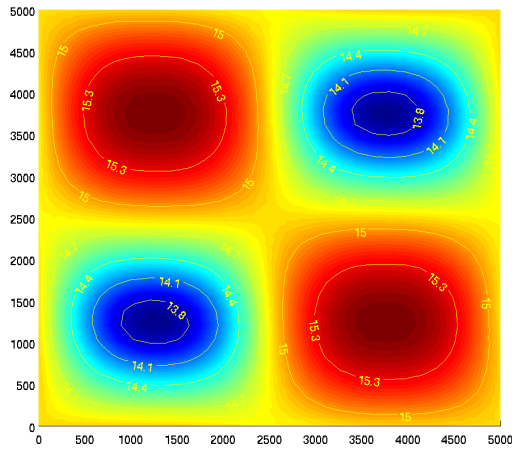
2.1.2.1 5km



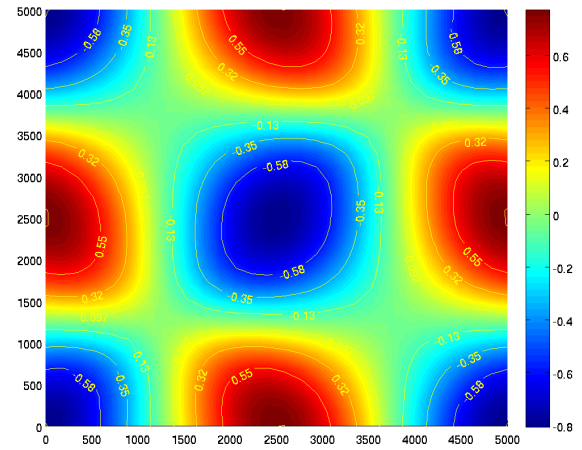
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line



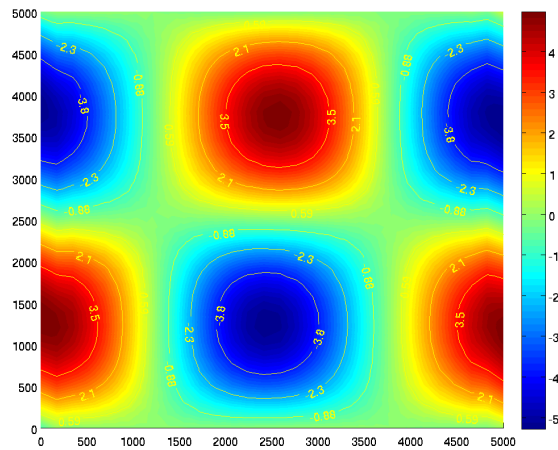
(b) V_x (m/yr) comparison



(c) V_x (m/yr) computed by ISSM (Pattyn)

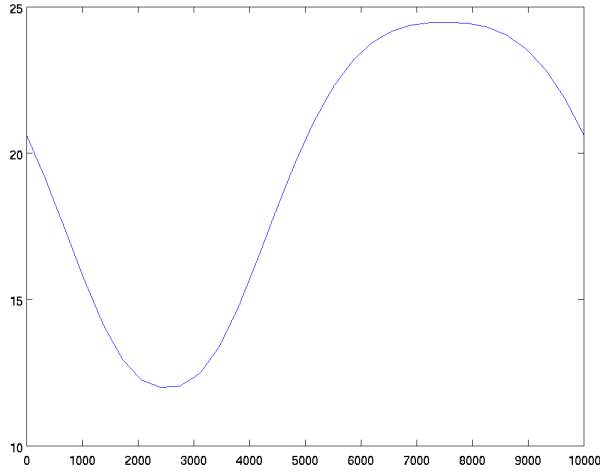
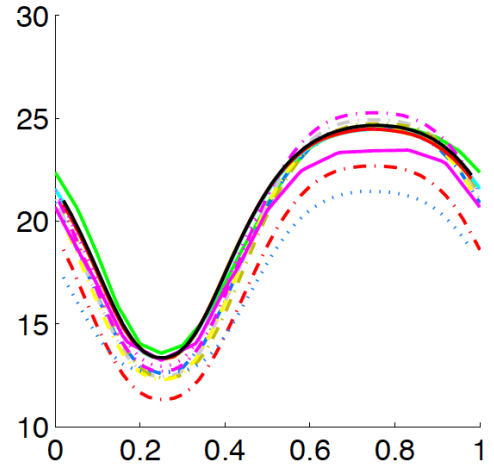
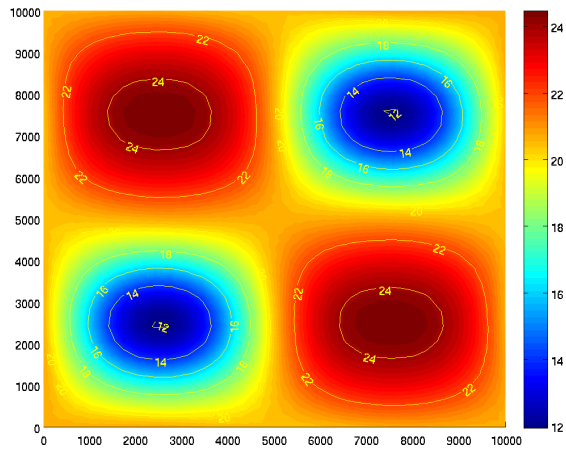
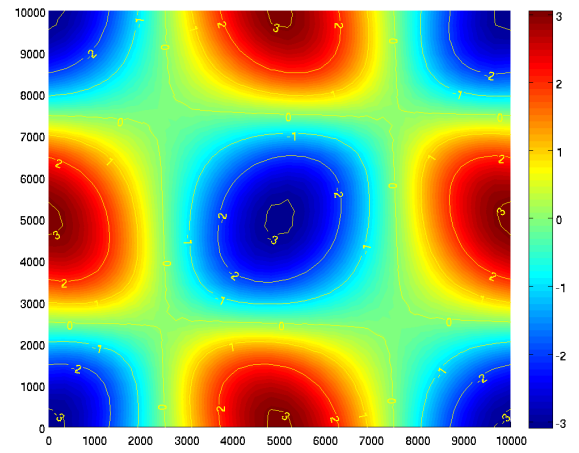
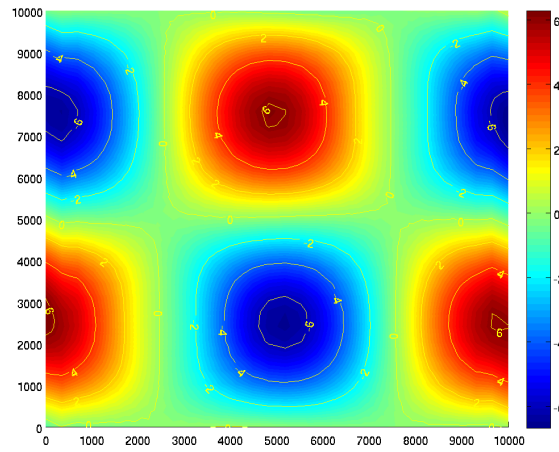


(d) V_y (m/yr) computed by ISSM (Pattyn)

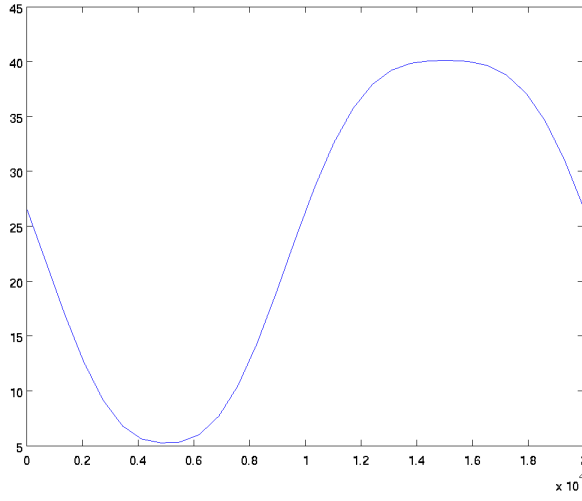
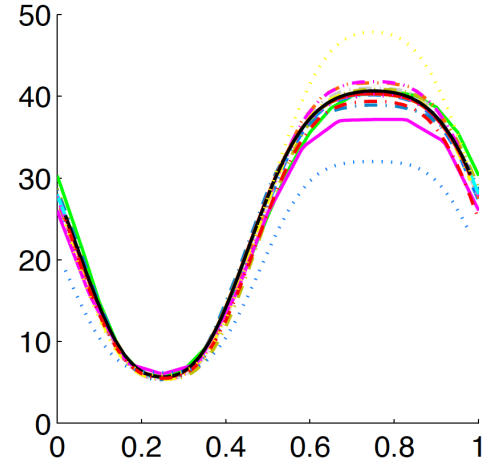
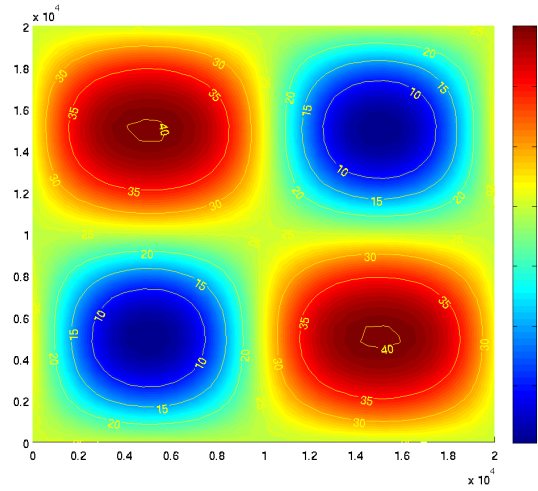
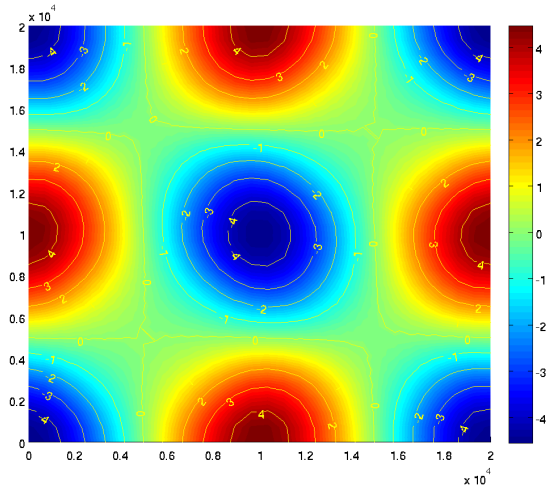
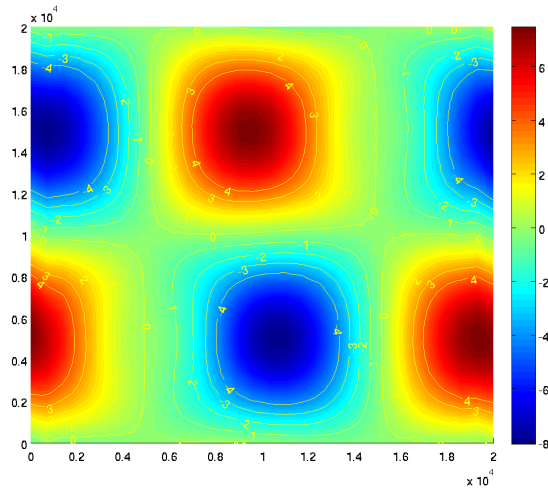


(e) V_z (m/yr) computed by ISSM (Pattyn)

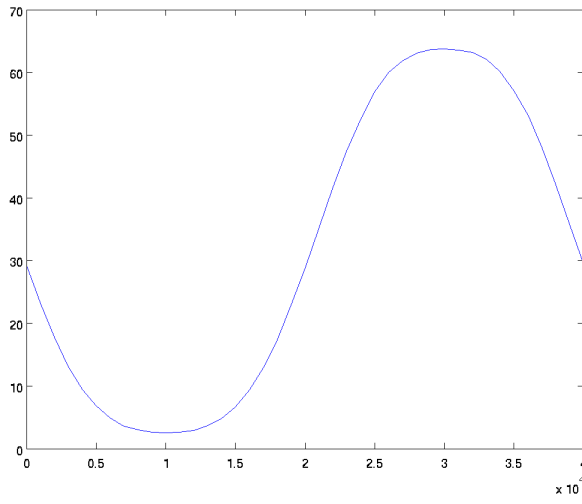
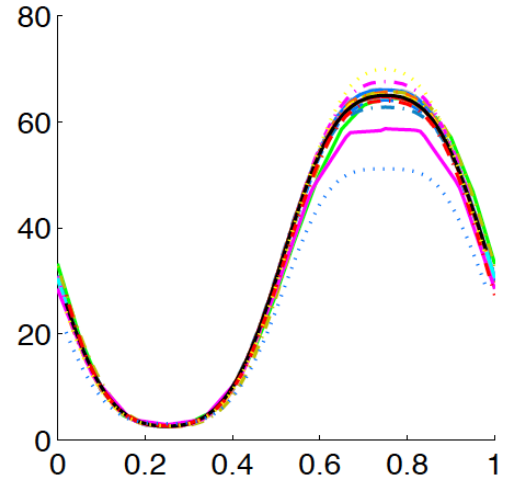
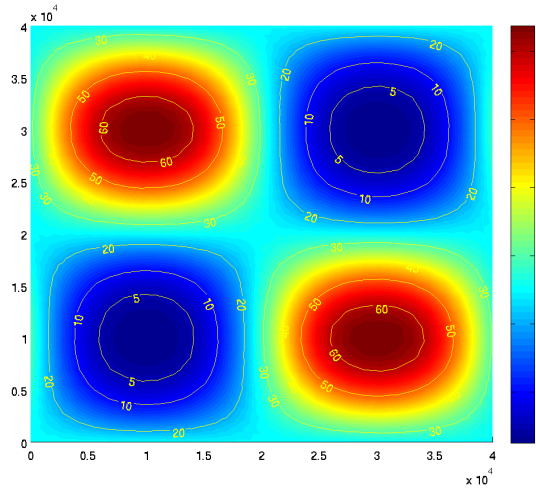
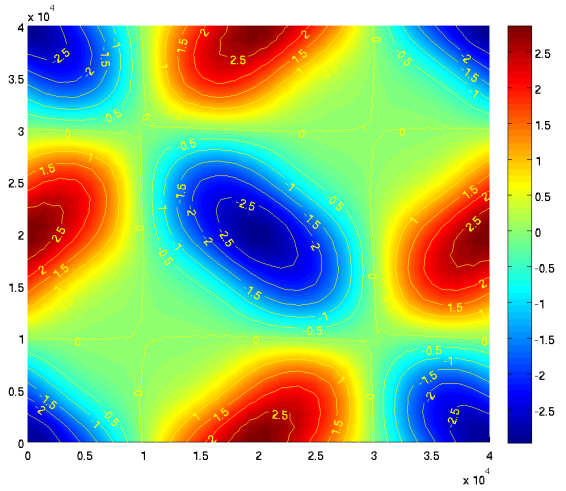
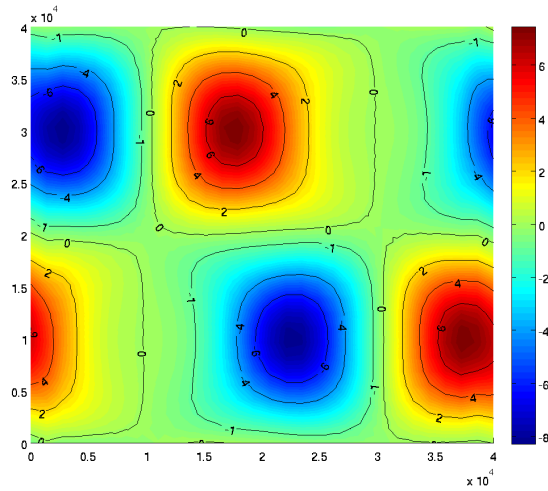
2.1.2.2 10km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_y (m/yr) computed by ISSM (Pattyn)(e) V_z (m/yr) computed by ISSM (Pattyn)

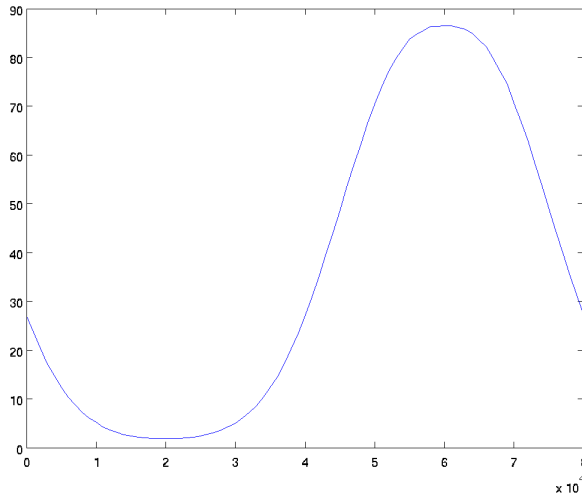
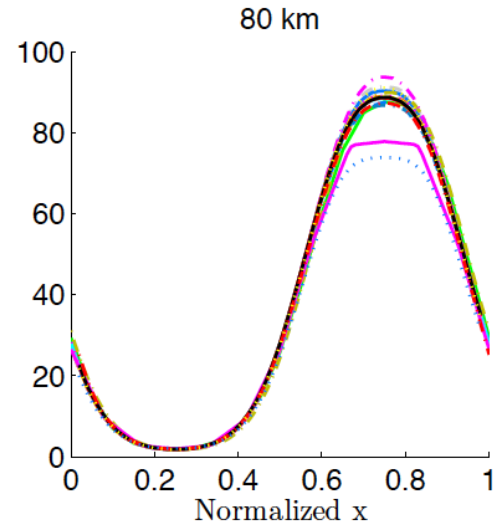
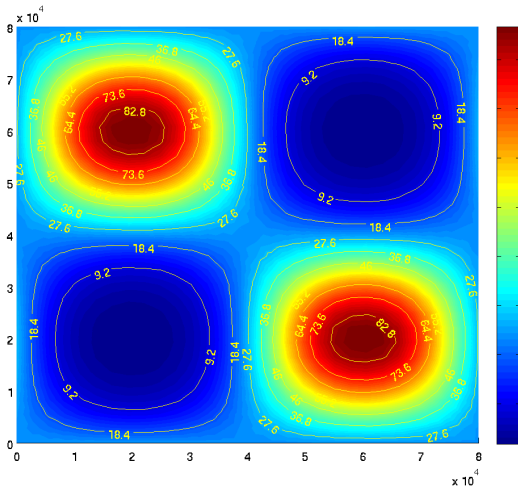
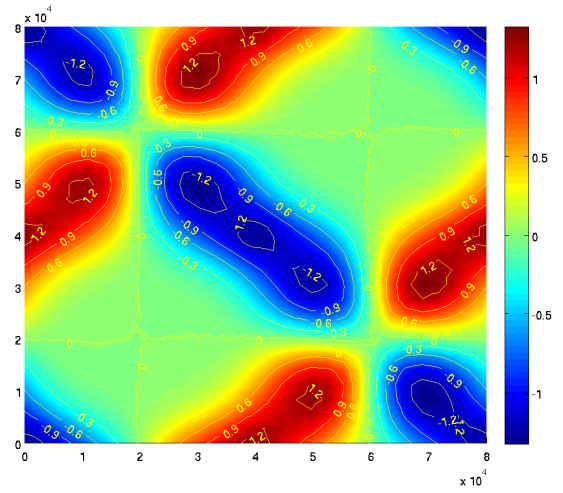
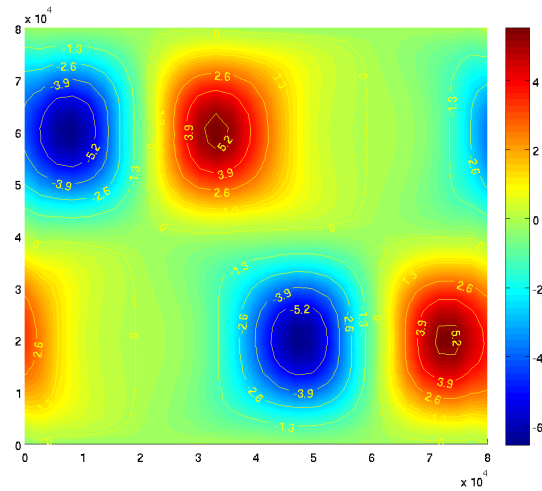
2.1.2.3 20km

(f) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(g) V_x (m/yr) comparison(h) V_x (m/yr) computed by ISSM (Pattyn)(i) V_y (m/yr) computed by ISSM (Pattyn)(j) V_z (m/yr) computed by ISSM (Pattyn)

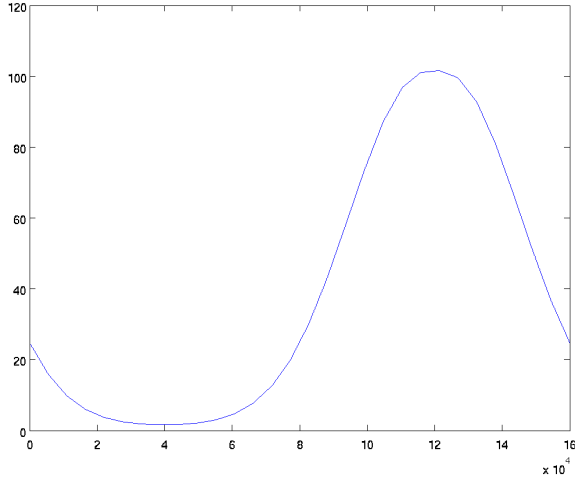
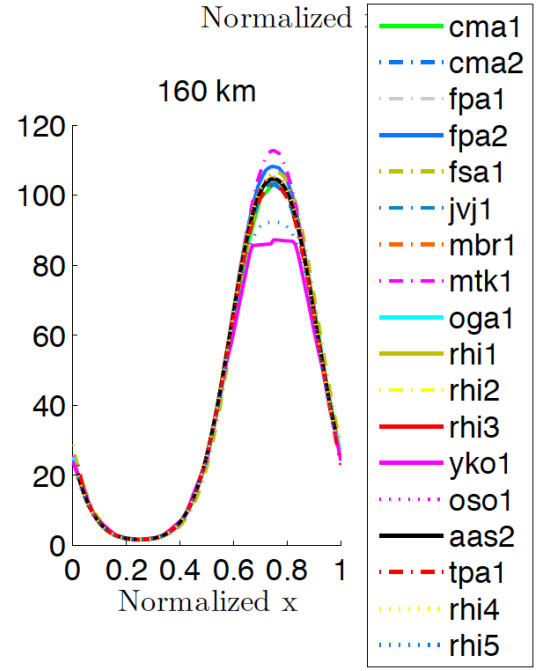
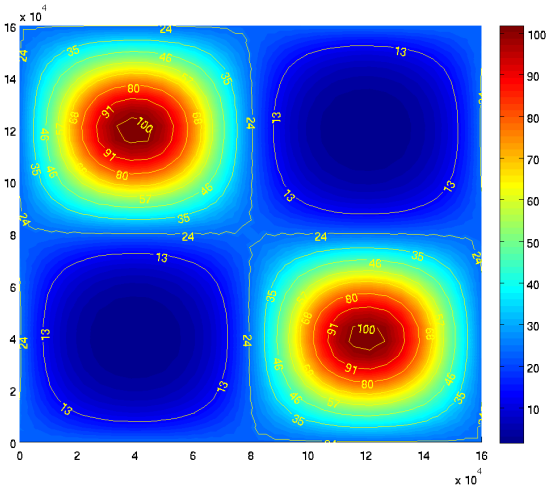
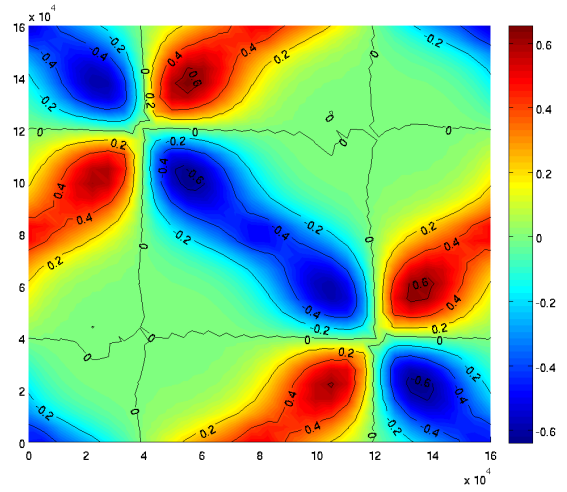
2.1.2.4 40km

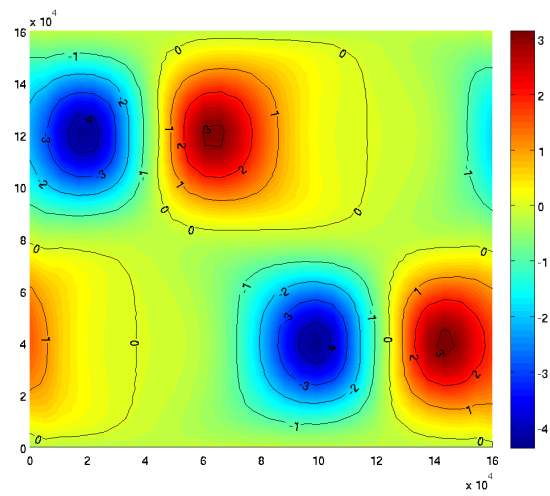
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_y (m/yr) computed by ISSM (Pattyn)(e) V_z (m/yr) computed by ISSM (Pattyn)

2.1.2.5 80km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_y (m/yr) computed by ISSM (Pattyn)(e) V_z (m/yr) computed by ISSM (Pattyn)

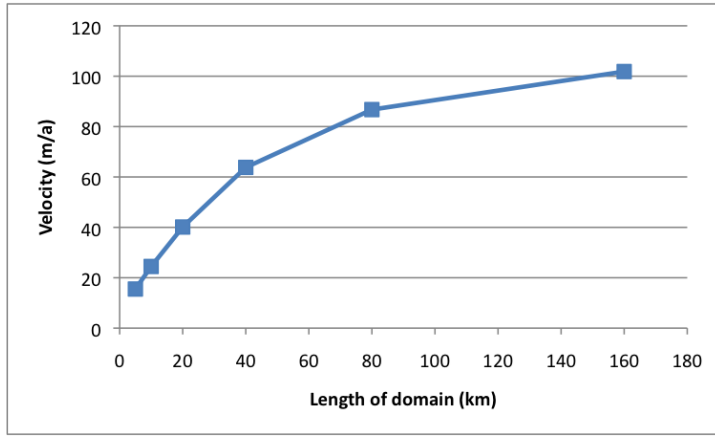
2.1.2.6 160km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_y (m/yr) computed by ISSM (Pattyn)

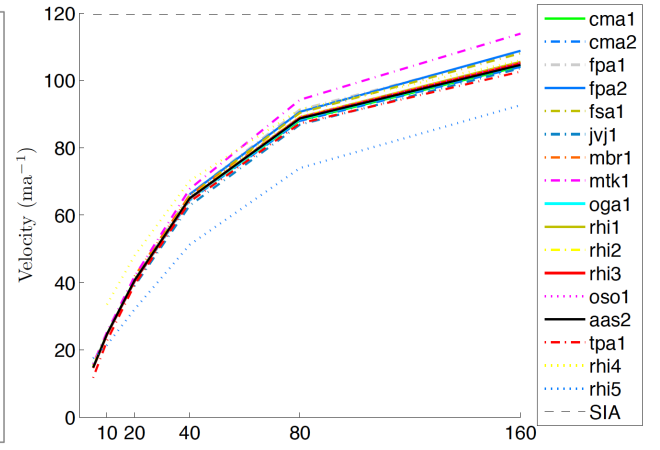


(e) V_z (m/yr) computed by ISSM (Pattyn)

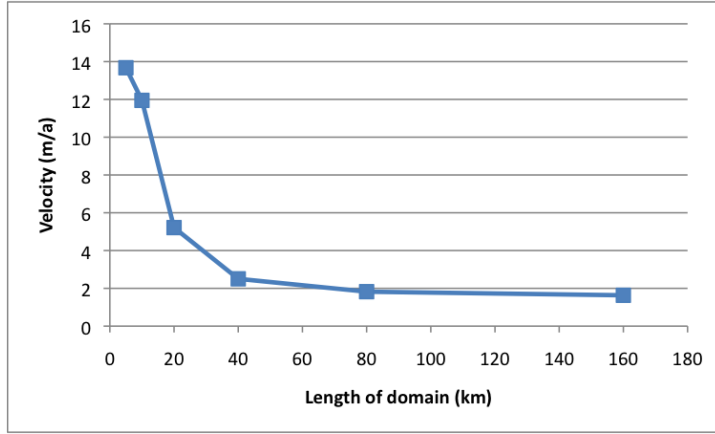
2.1.2.7 global (comparison)



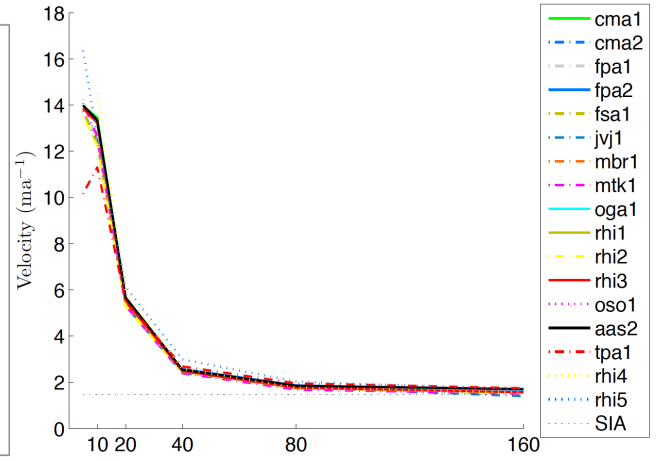
(f) Maximum Vx (m/yr) computed by ISSM (Pattyn)



(g) Maximum Vx (m/yr) comparison



(h) Minimum Vx (m/yr) computed by ISSM (Pattyn)



(i) Minimum Vx (m/yr) comparison

2.2 Test B

2.2.1 Geometry

This is a 2d ice-sheet flow over a rippled bed (flowline). Periodic boundary conditions are applied. The geometry follows:

- surface $s(x, y) = -x \tan(0.5^\circ)$
- bed $b(x, y) = s - 1000 + 500 \sin\left(\frac{2\pi}{L}x\right)$
- $5 \text{ km} \leq L \leq 160 \text{ km}$

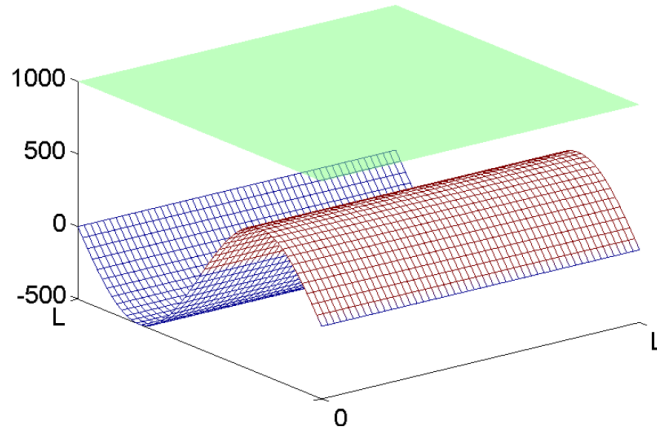
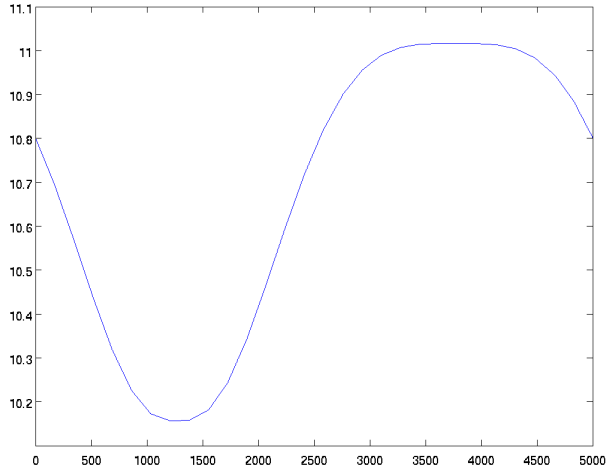


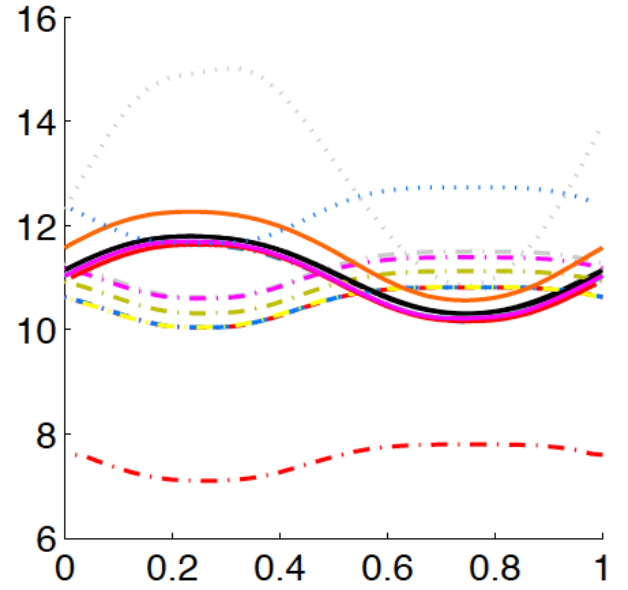
Figure 2.2: Test B geometry

2.2.2 Results

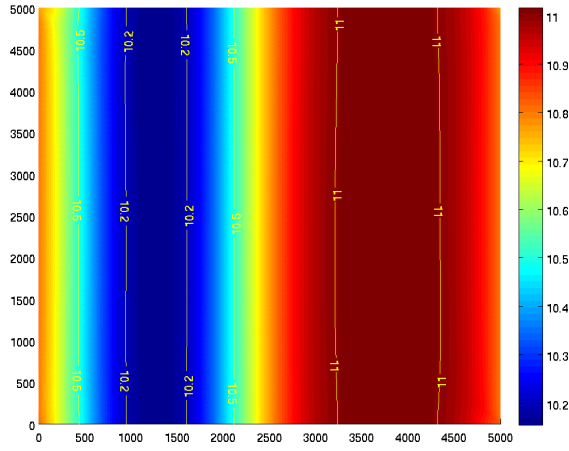
2.2.2.1 5km



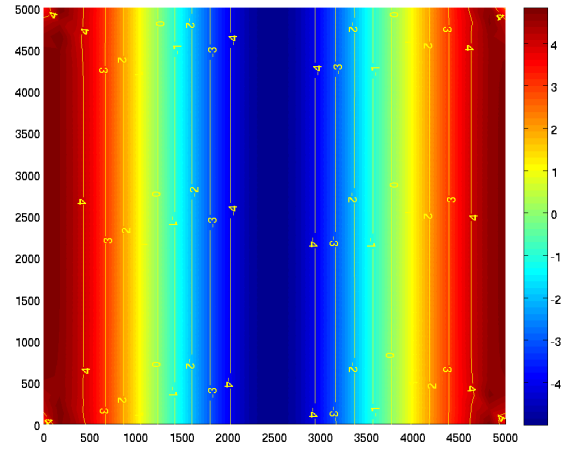
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line



(b) V_x (m/yr) comparison

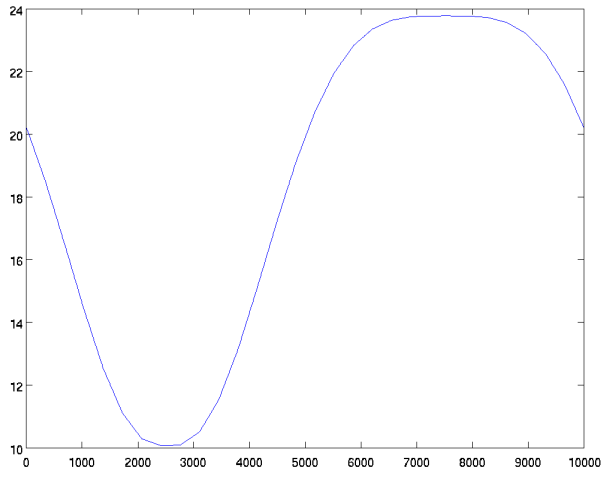
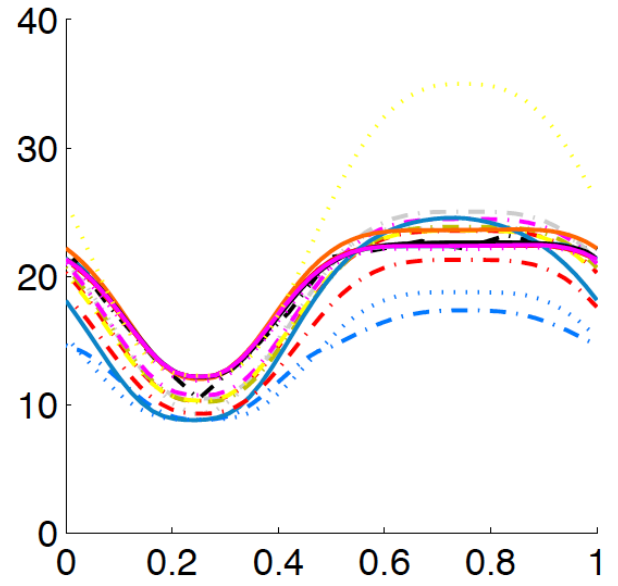
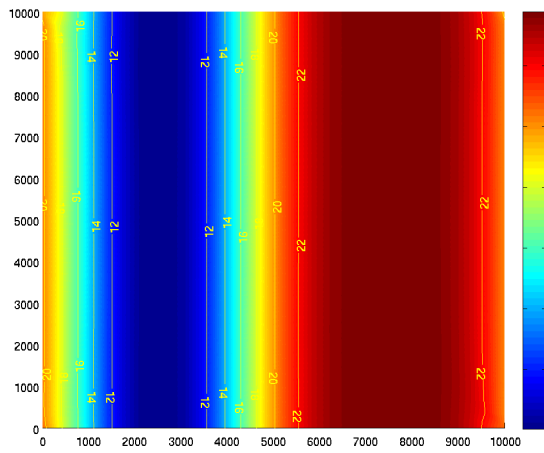
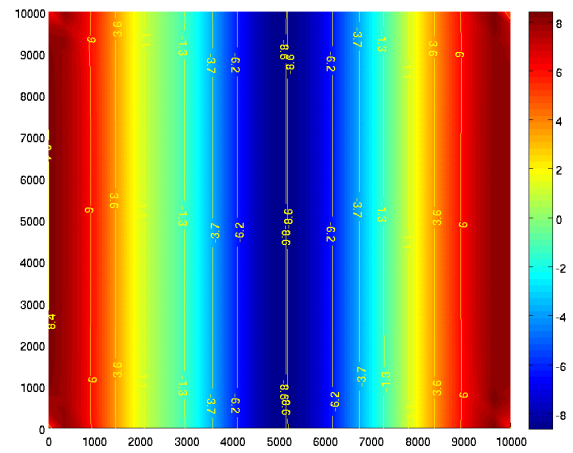


(c) V_x (m/yr) computed by ISSM (Pattyn)

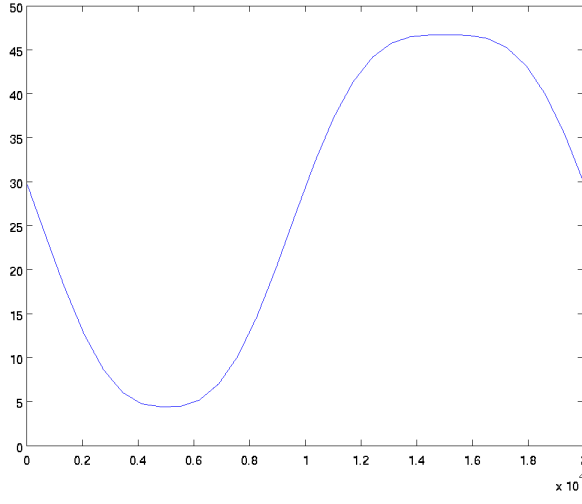
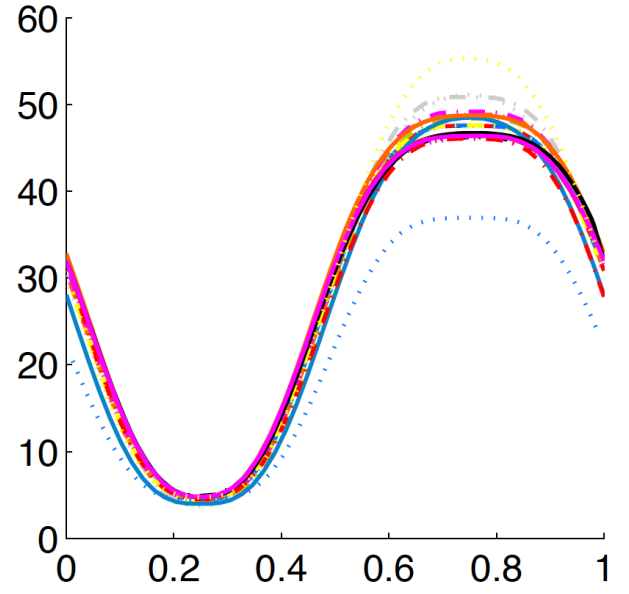
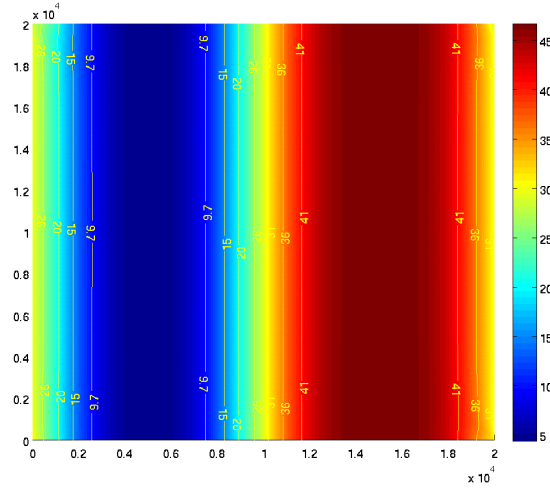
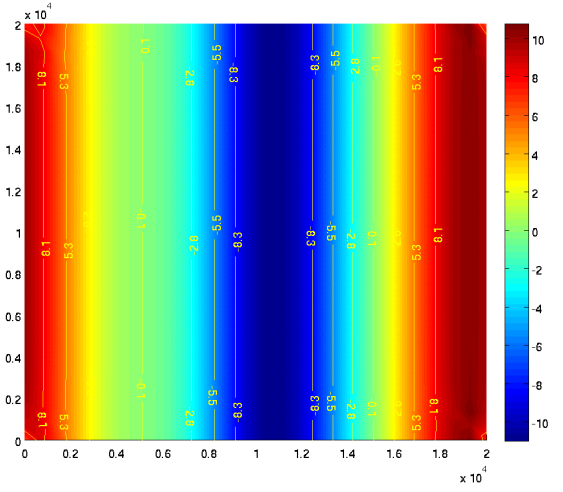


(d) V_z (m/yr) computed by ISSM (Pattyn)

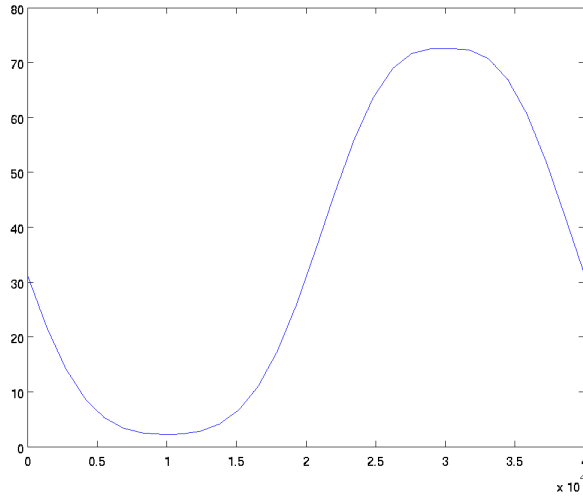
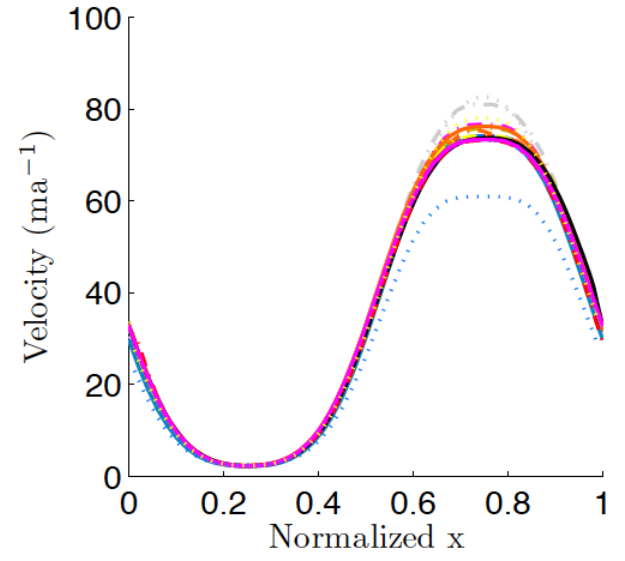
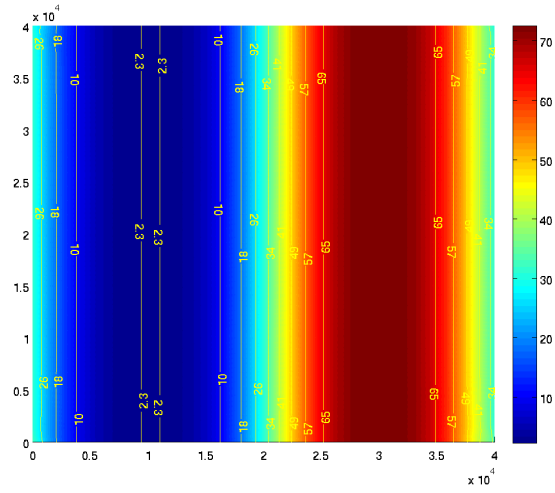
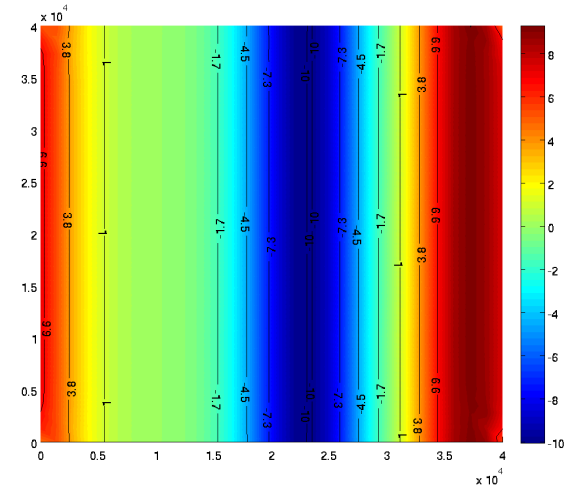
2.2.2.2 10km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_z (m/yr) computed by ISSM (Pattyn)

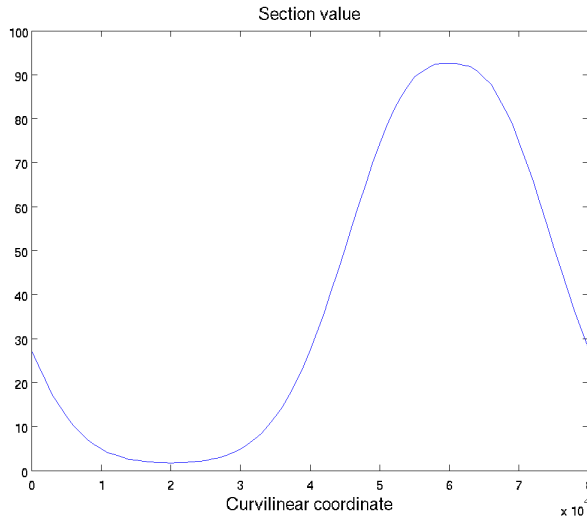
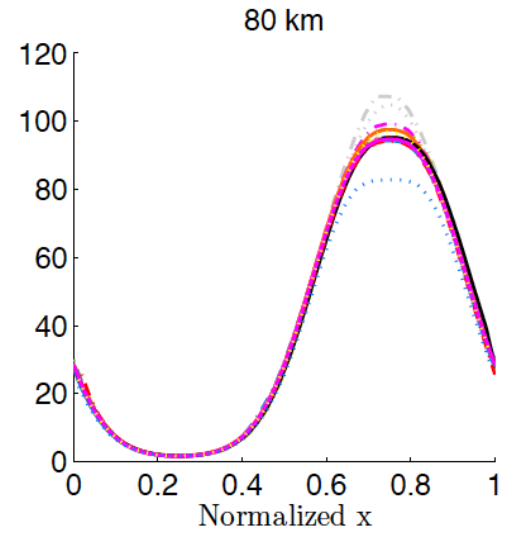
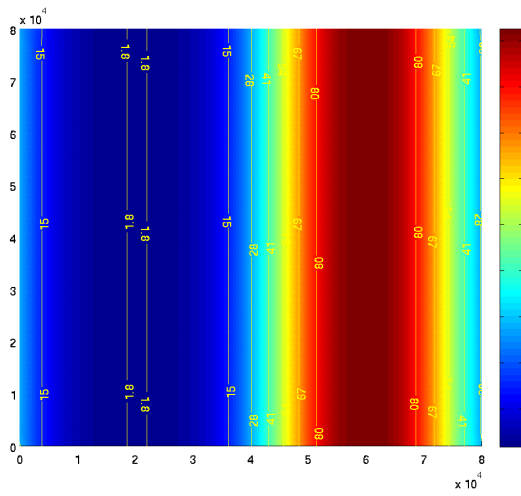
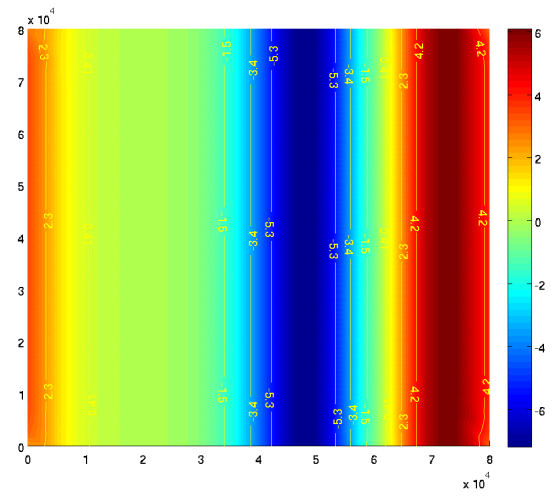
2.2.2.3 20km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_z (m/yr) computed by ISSM (Pattyn)

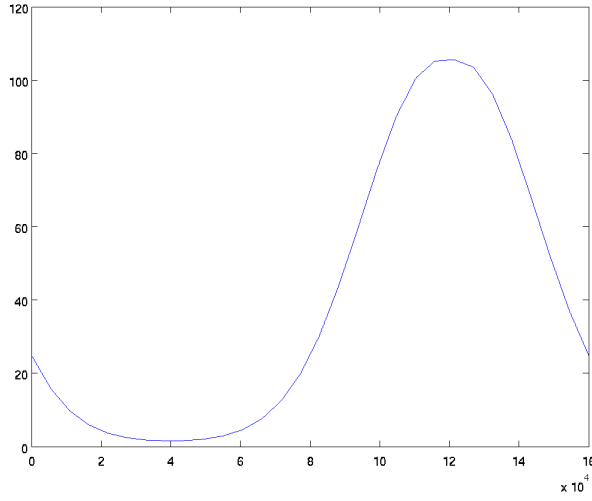
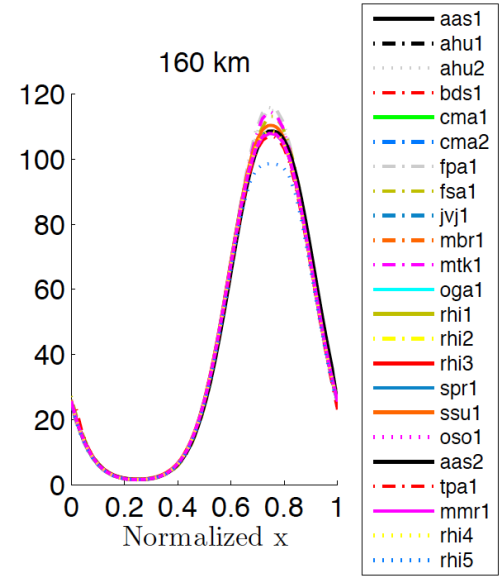
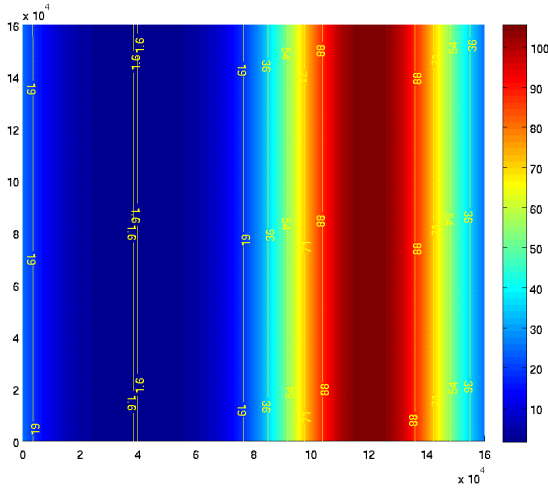
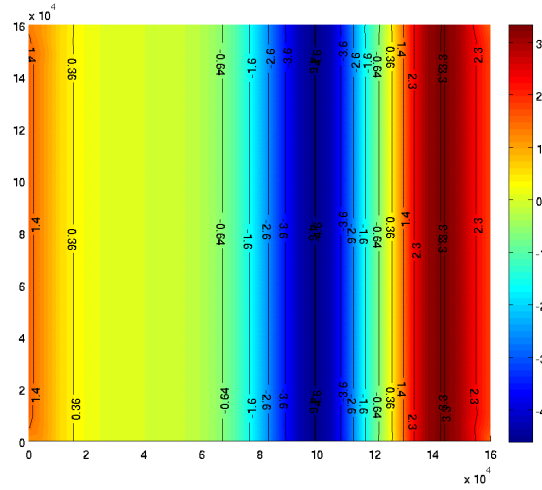
2.2.2.4 40km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_z (m/yr) computed by ISSM (Pattyn)

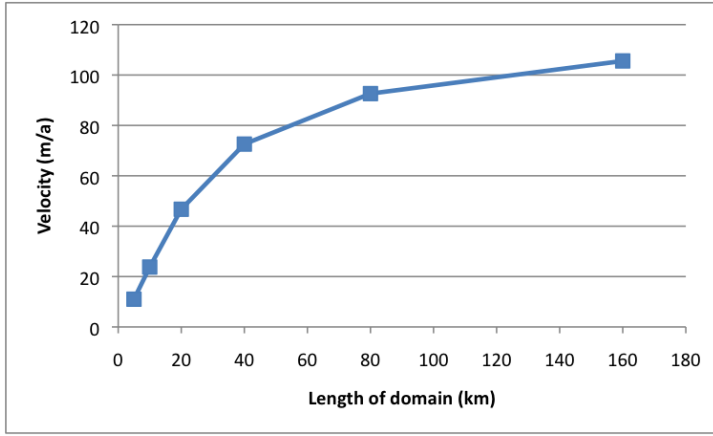
2.2.2.5 80km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_z (m/yr) computed by ISSM (Pattyn)

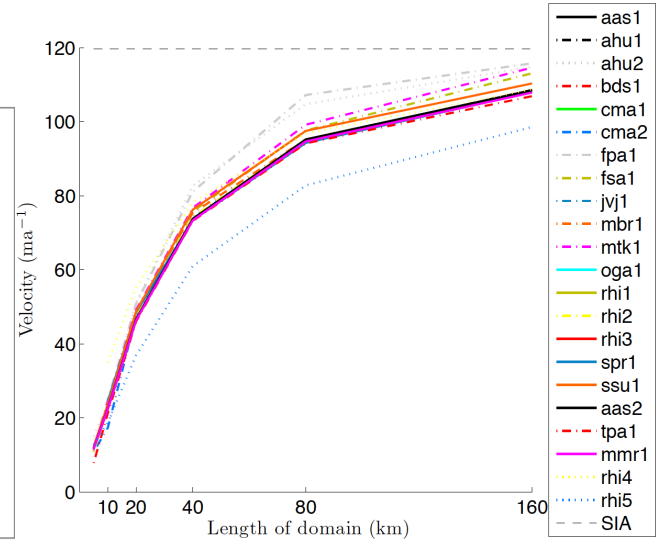
2.2.2.6 160km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) V_x (m/yr) computed by ISSM (Pattyn)(d) V_z (m/yr) computed by ISSM (Pattyn)

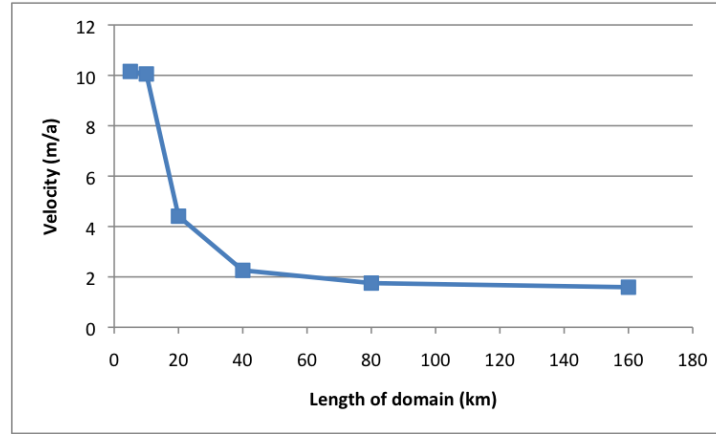
2.2.2.7 global (comparison)



(e) Maximum Vx (m/yr) computed by ISSM (Pattyn)



(f) Maximum Vx (m/yr) comparison



(g) Minimum Vx (m/yr) computed by ISSM (Pattyn)

2.3 Test C (detailed)

2.3.1 Geometry

This is a 3d ice-stream flow over a slippery bed. Periodic boundary conditions are applied. The geometry follows:

- surface $s(x, y) = -x \tan(0.1^\circ)$
- bed $b(x, y) = s - 1000$
- sliding $\alpha^2(x, y) = 1000 + 1000 \sin\left(\frac{2\pi}{L}x\right) \sin\left(\frac{2\pi}{L}y\right)$
- $5 \text{ km} \leq L \leq 160 \text{ km}$

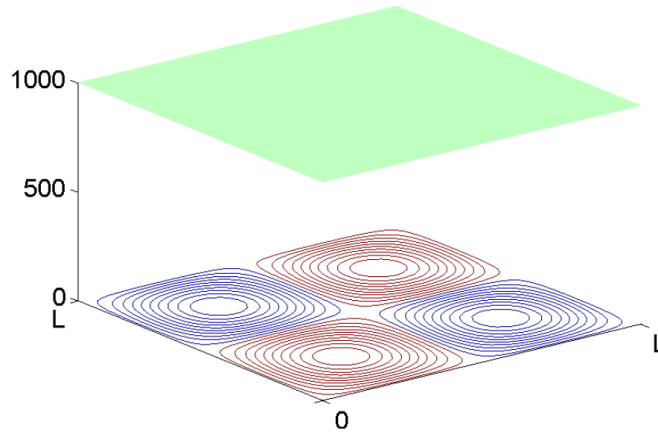
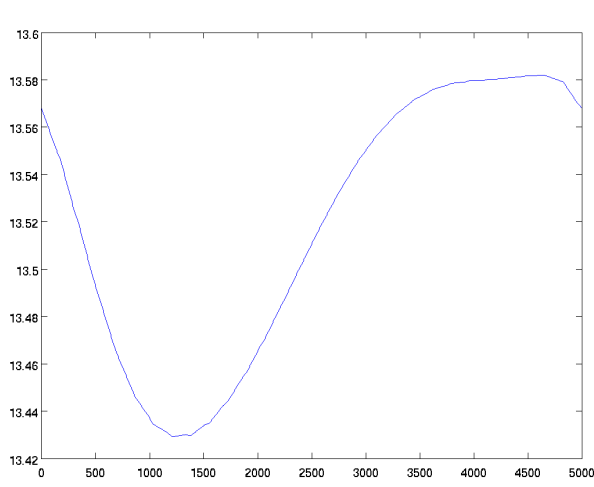


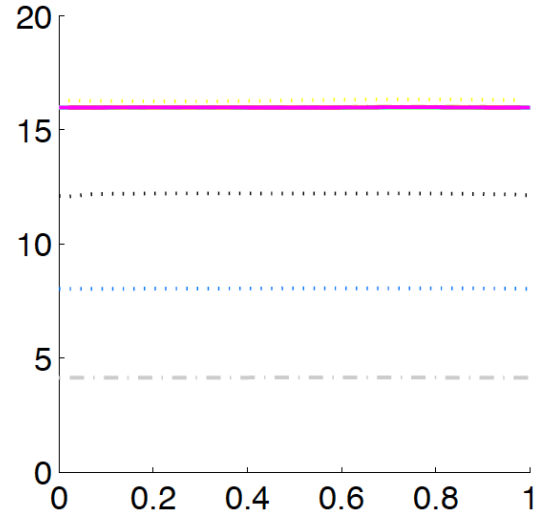
Figure 2.3: Test C geometry

2.3.2 Results

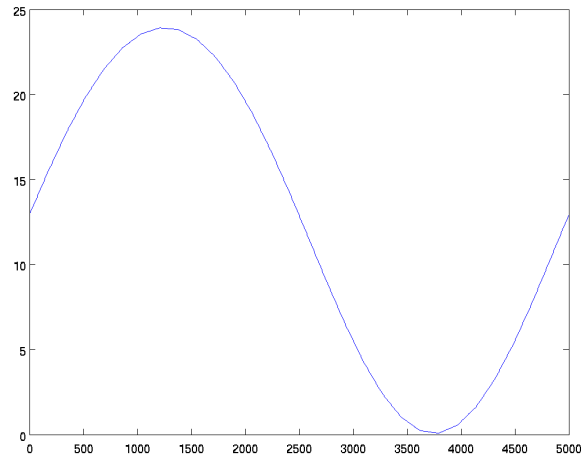
2.3.2.1 5km



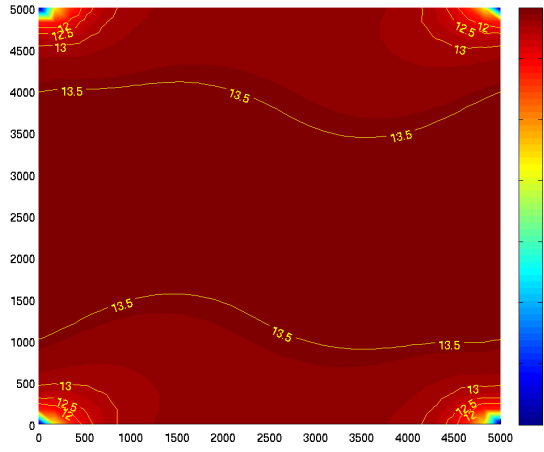
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line



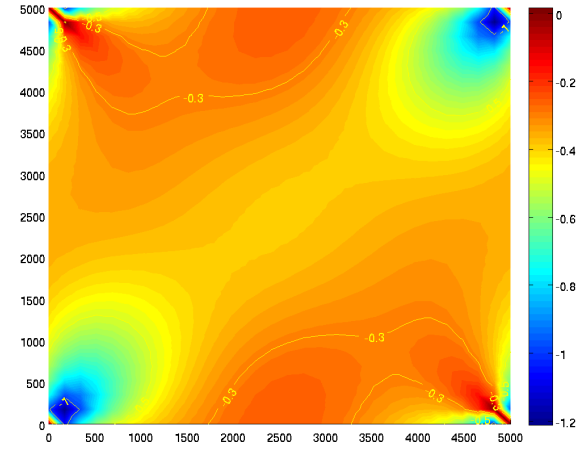
(b) V_x (m/yr) comparison



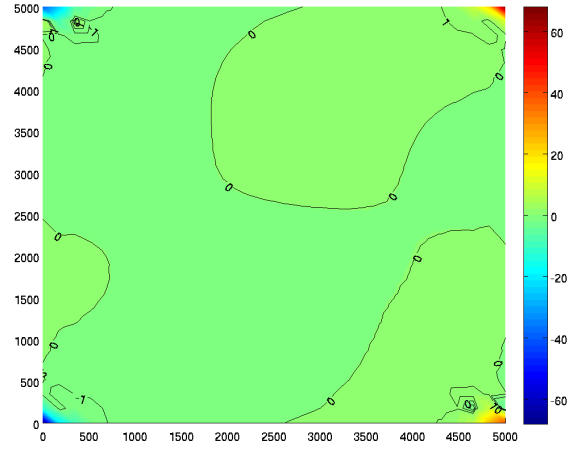
(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line



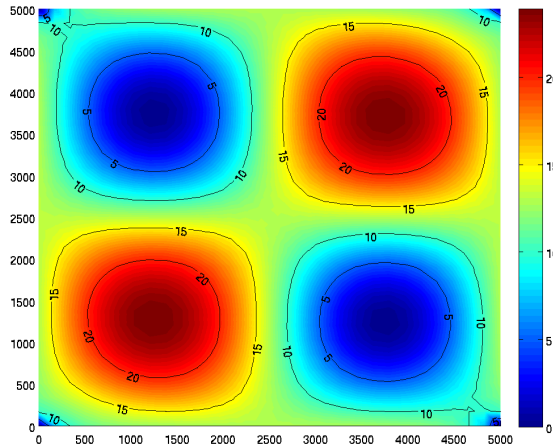
(d) V_x (m/yr) computed by ISSM (Pattyn)



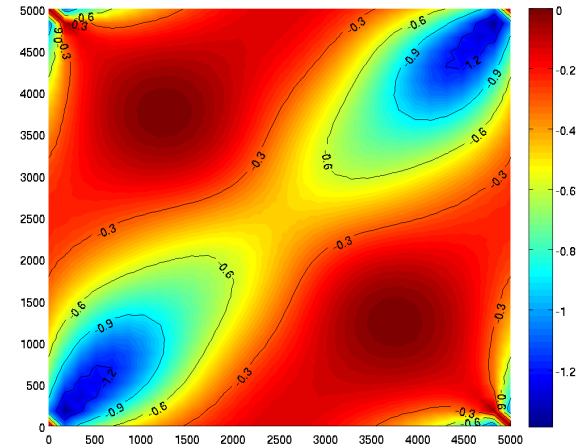
(e) V_y (m/yr) computed by ISSM (Pattyn)



(f) V_z (m/yr) computed by ISSM (Pattyn)

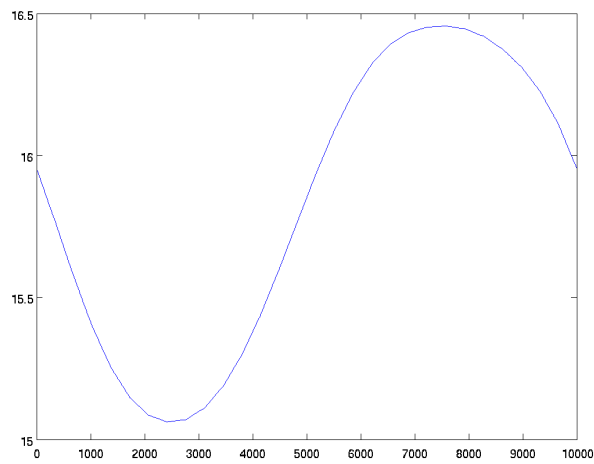
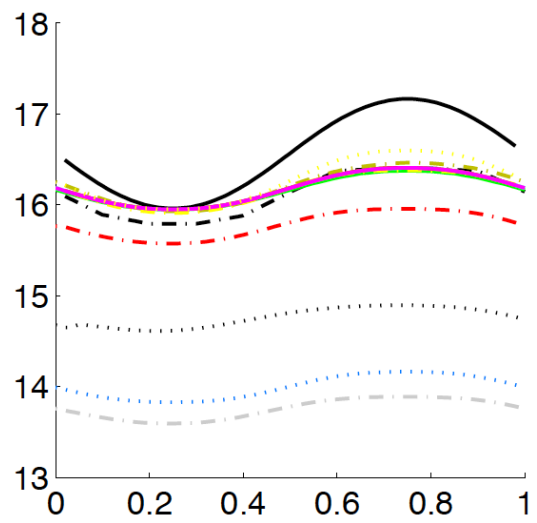
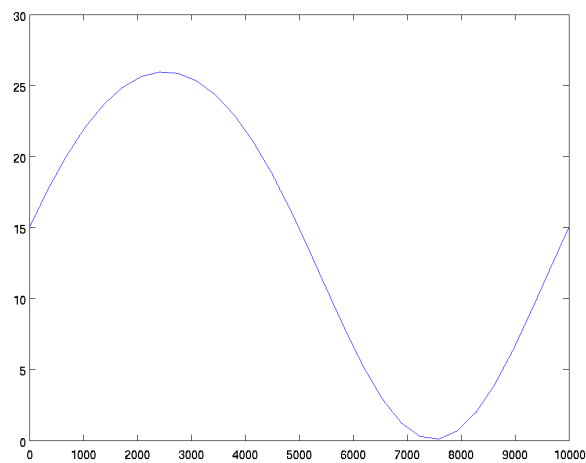


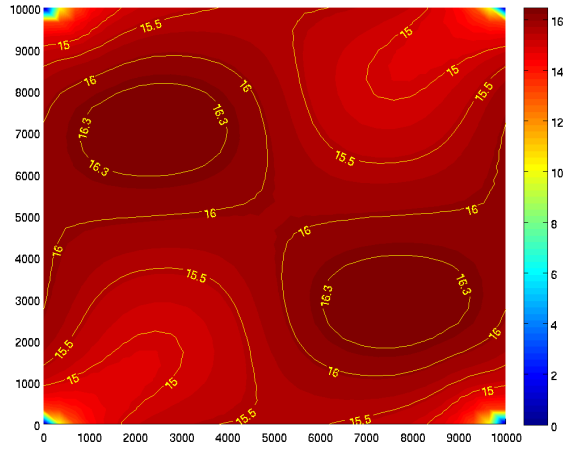
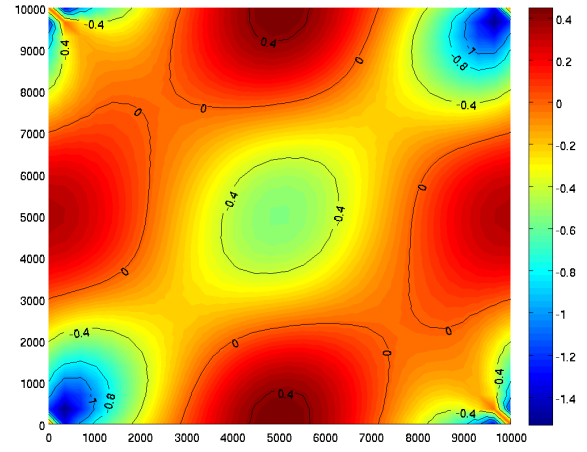
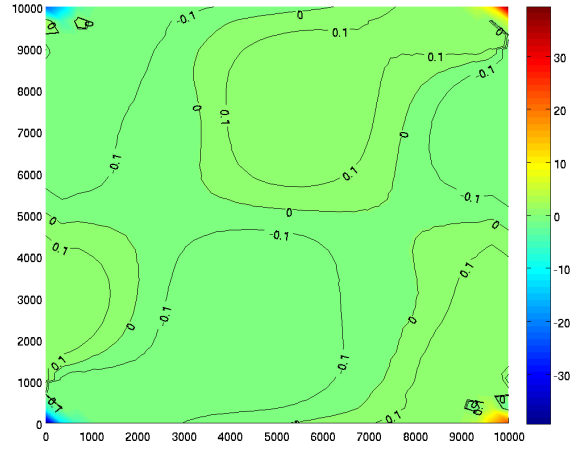
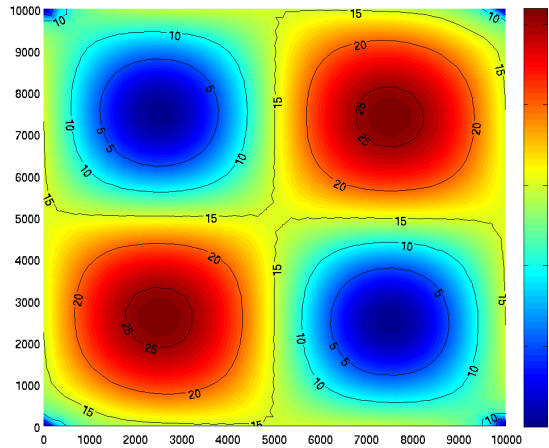
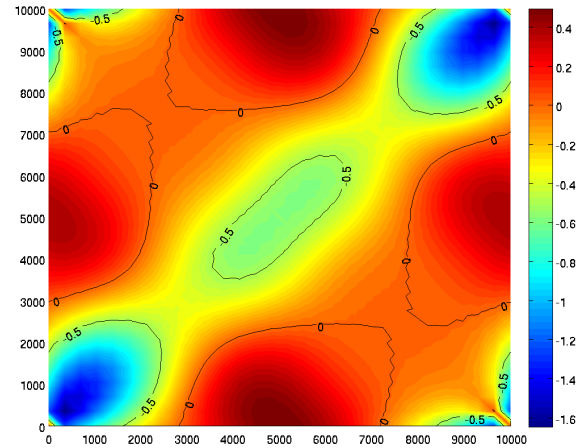
(g) T_{xz} (kPa) computed by ISSM (Pattyn)



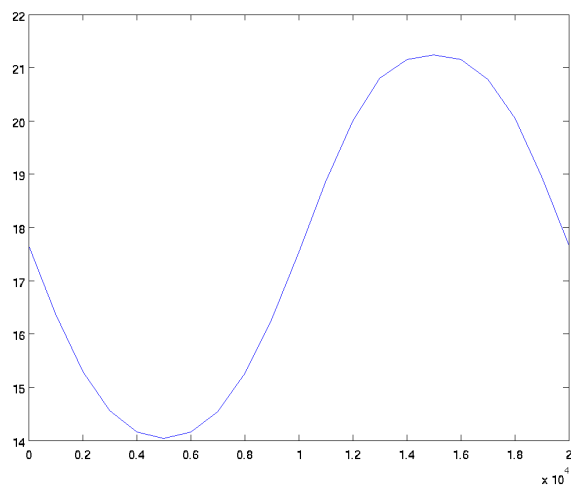
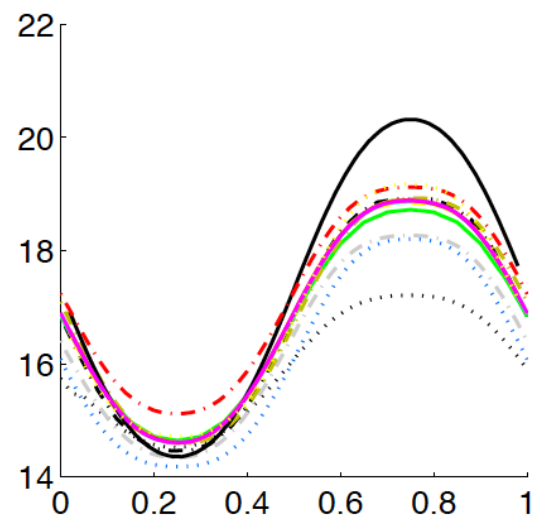
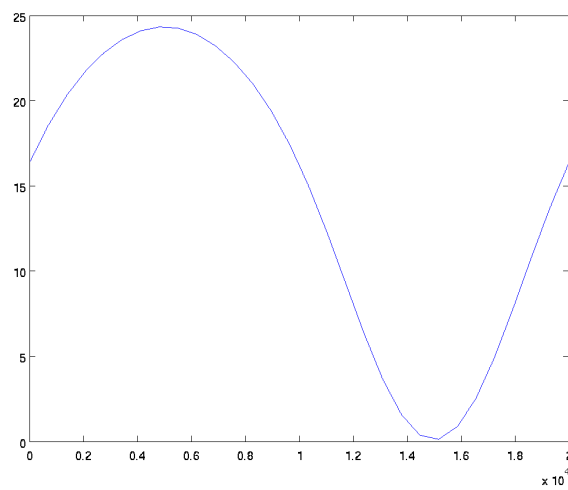
(h) T_{yz} (kPa) computed by ISSM (Pattyn)

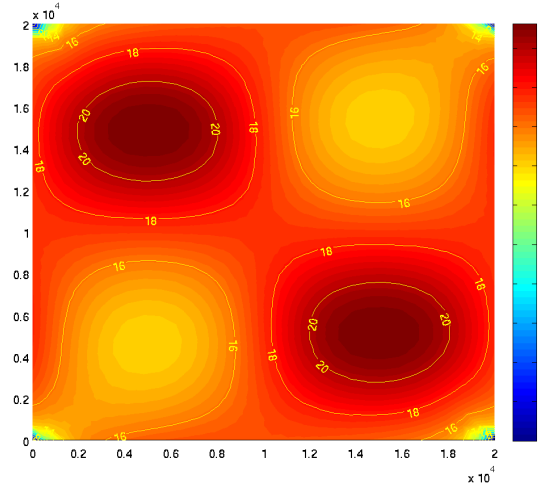
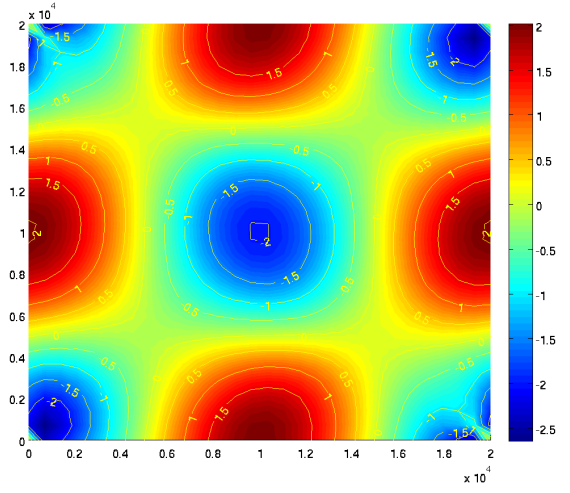
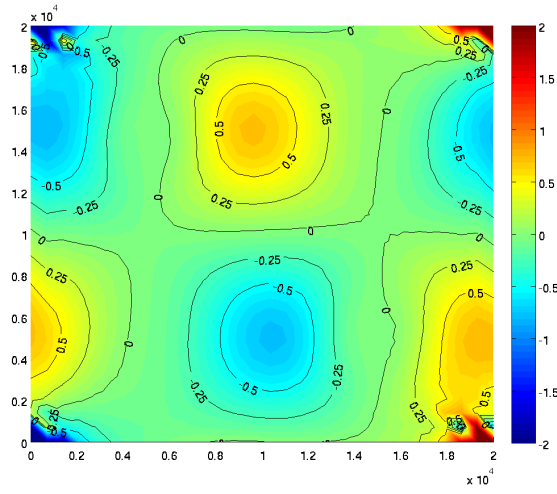
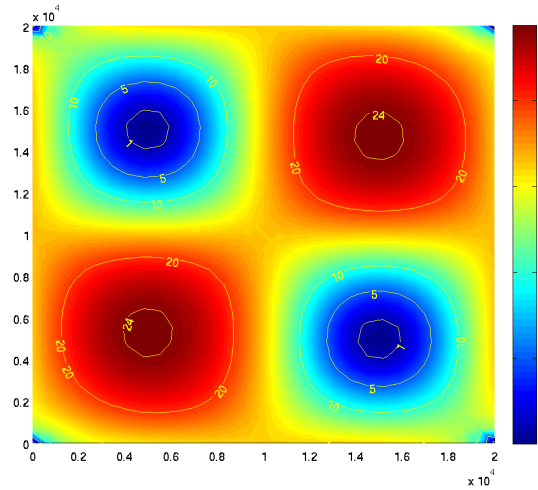
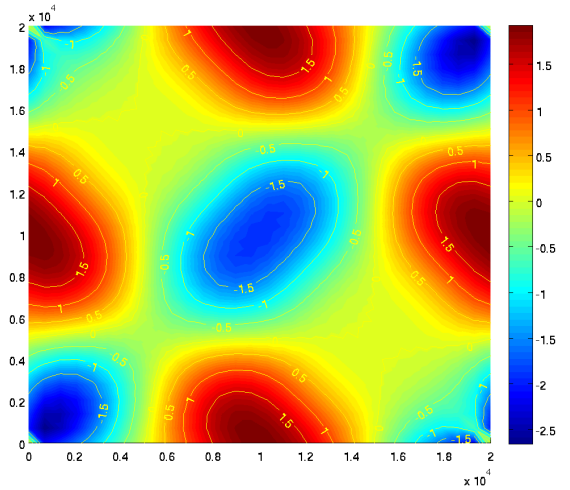
2.3.2.2 10km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line

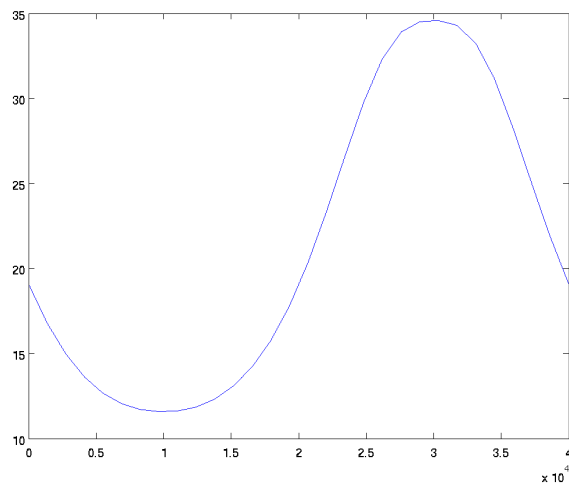
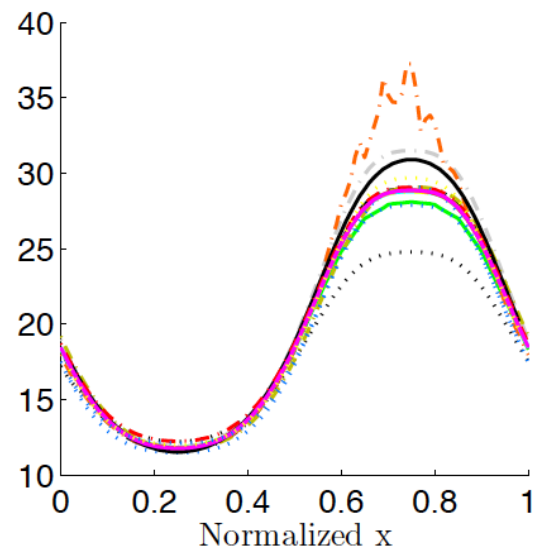
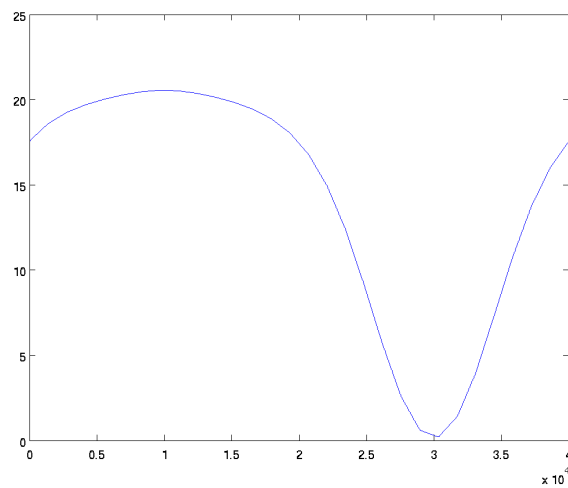
(d) V_x (m/yr) computed by ISSM (Pattyn)(e) V_y (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)(h) T_{yz} (kPa) computed by ISSM (Pattyn)

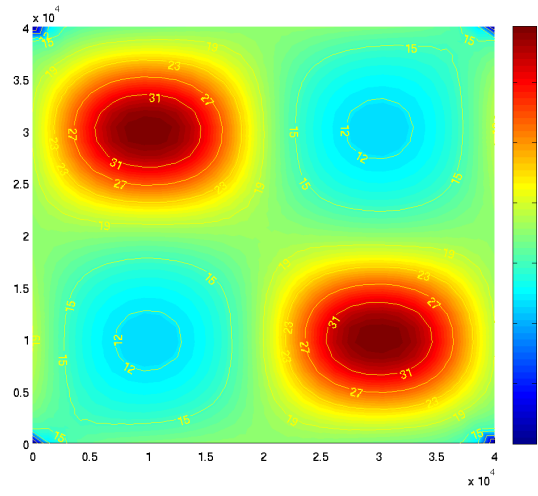
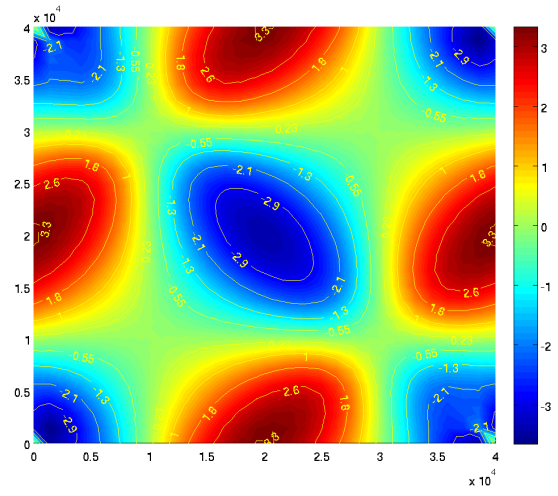
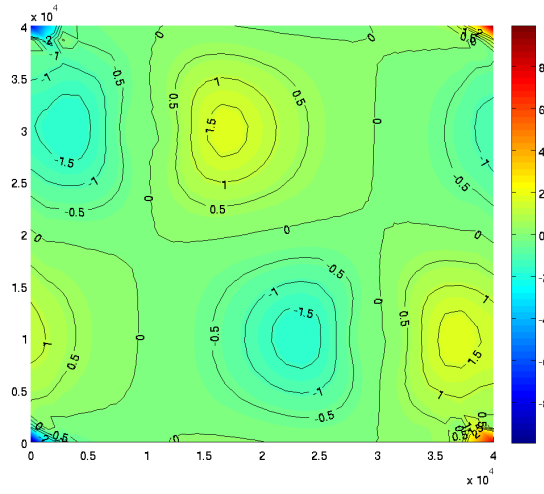
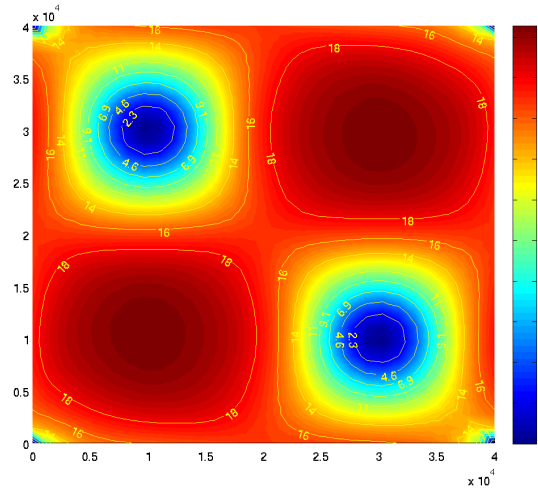
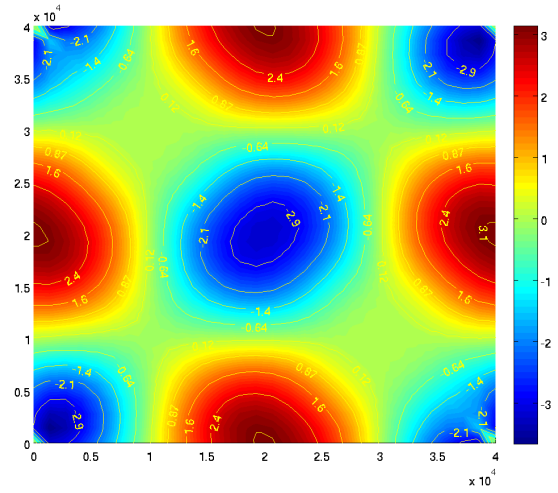
2.3.2.3 20km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line

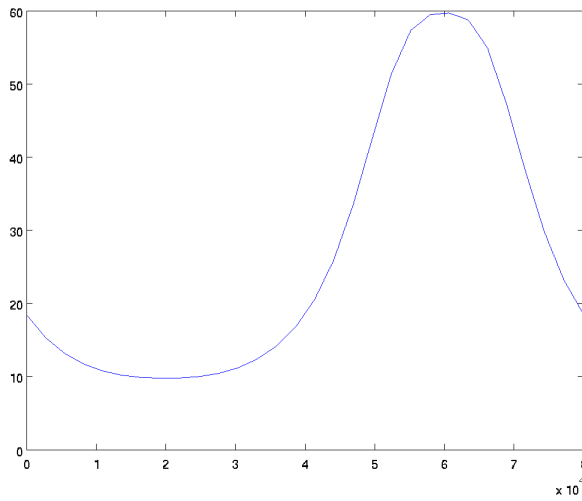
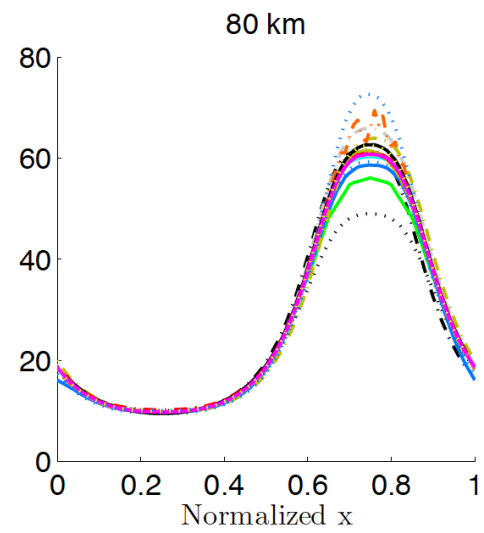
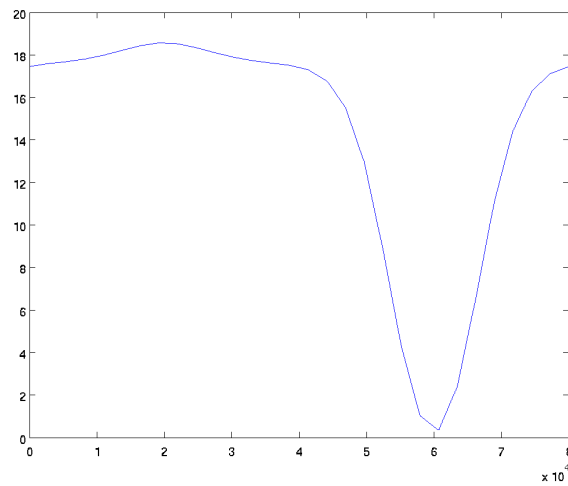
(d) V_x (m/yr) computed by ISSM (Pattyn)(e) V_y (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)(h) T_{yz} (kPa) computed by ISSM (Pattyn)

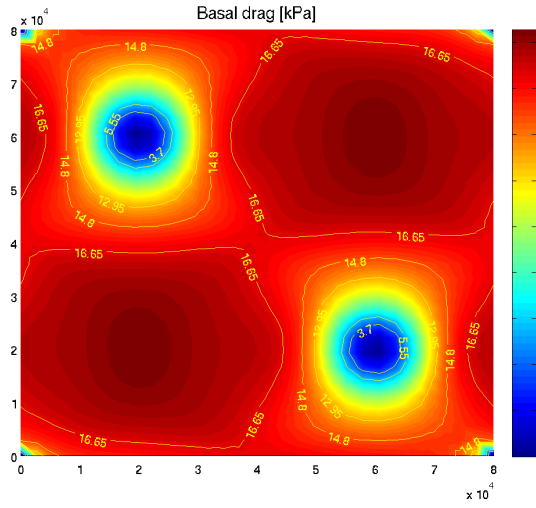
2.3.2.4 40km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line

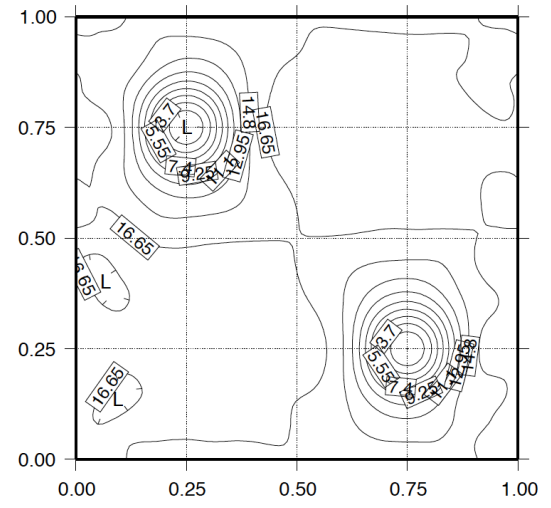
(d) V_x (m/yr) computed by ISSM (Pattyn)(e) V_y (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)(h) T_{yz} (kPa) computed by ISSM (Pattyn)

2.3.2.5 80km

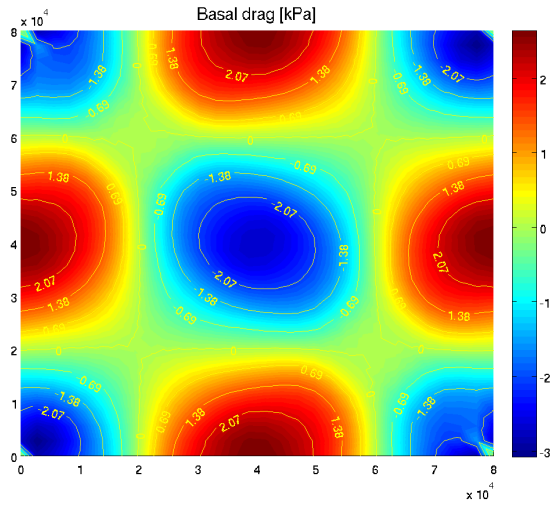
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line



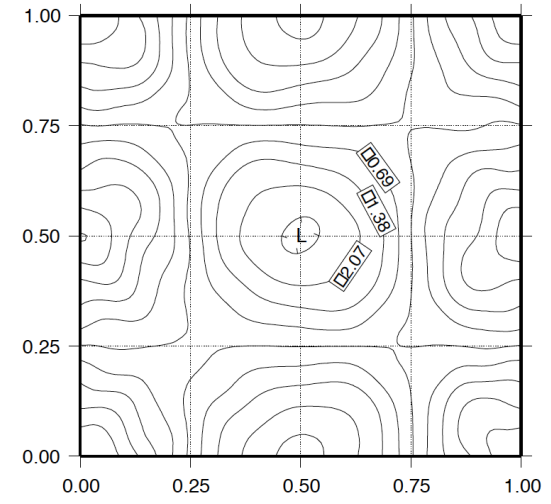
(j) Txz (kPa) computed by ISSM (Pattyn)



(k) Txz (kPa) comparison

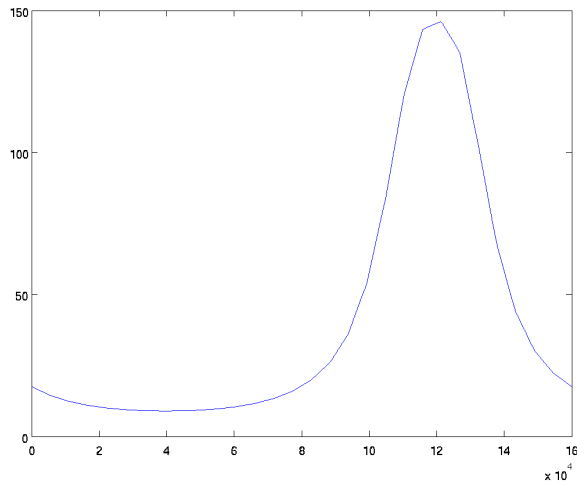
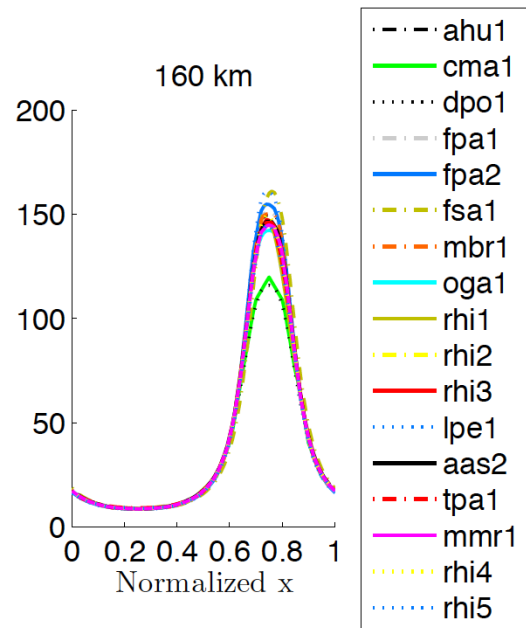
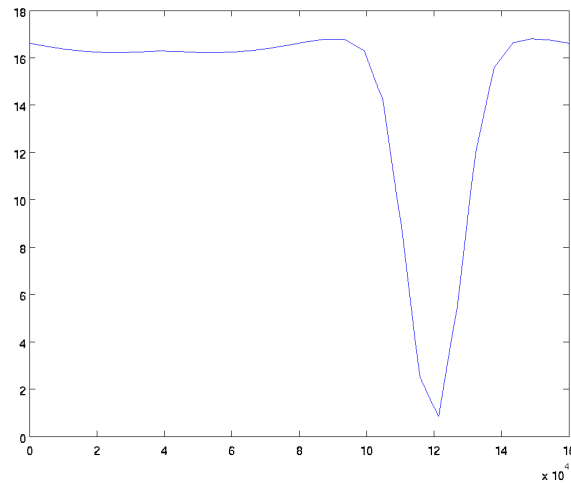


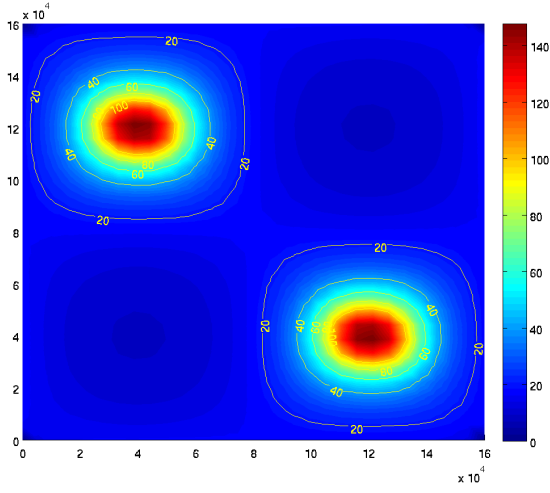
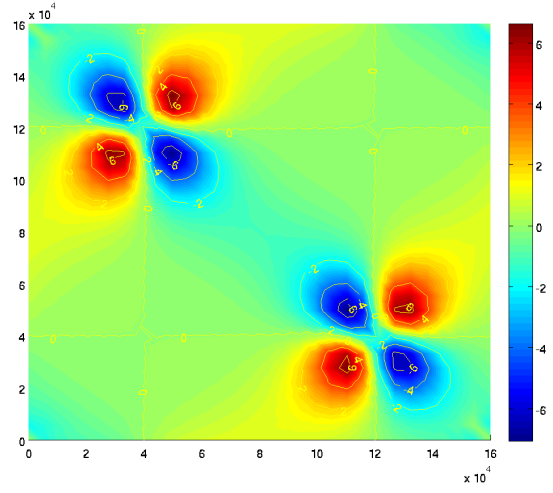
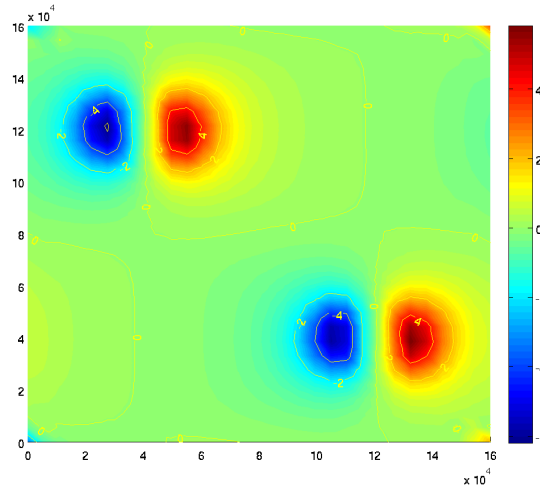
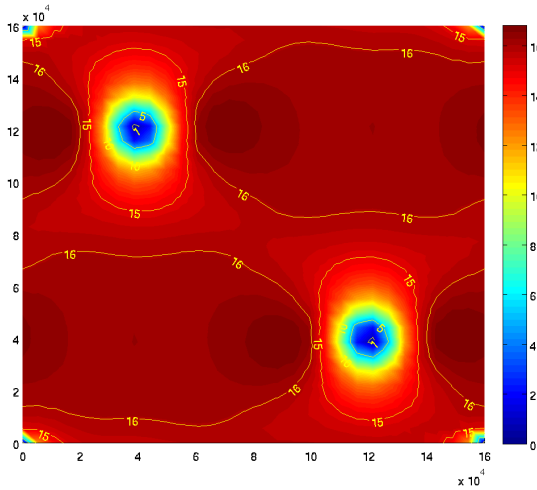
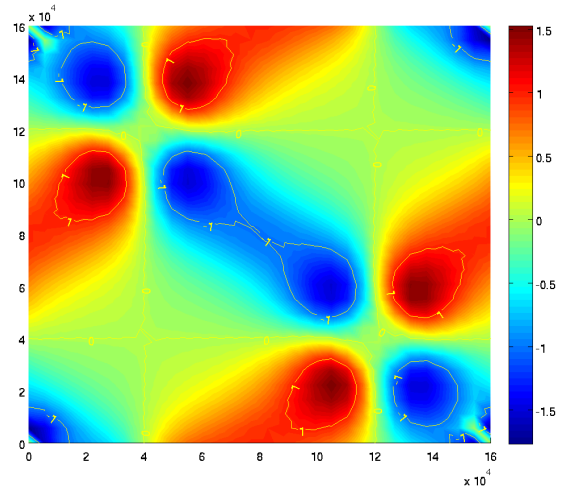
(l) Tyz (kPa) computed by ISSM (Pattyn)



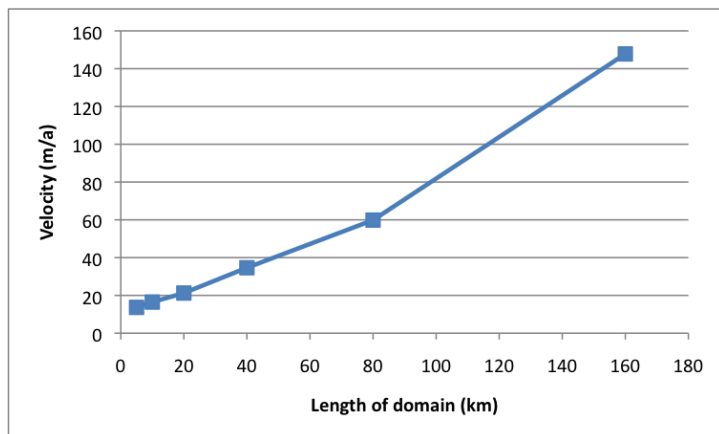
(m) Tyz (kPa) comparison

2.3.2.6 160km

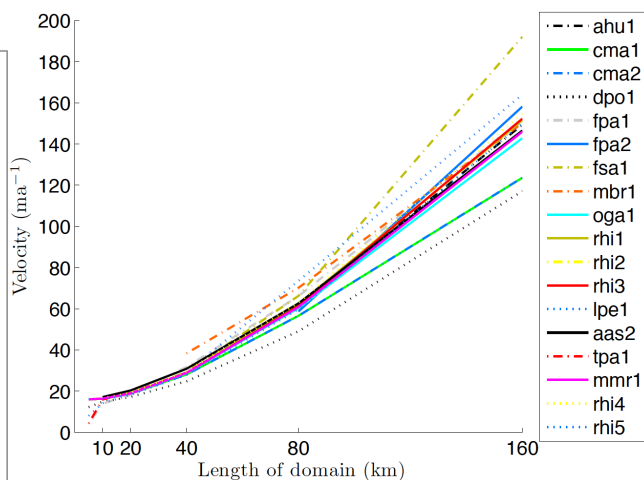
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line

(d) V_x (m/yr) computed by ISSM (Pattyn)(e) V_y (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)(h) T_{yz} (kPa) computed by ISSM (Pattyn)

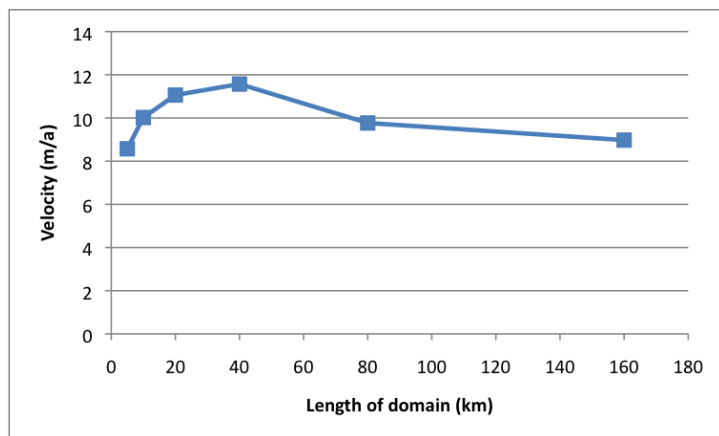
2.3.2.7 global (comparison)



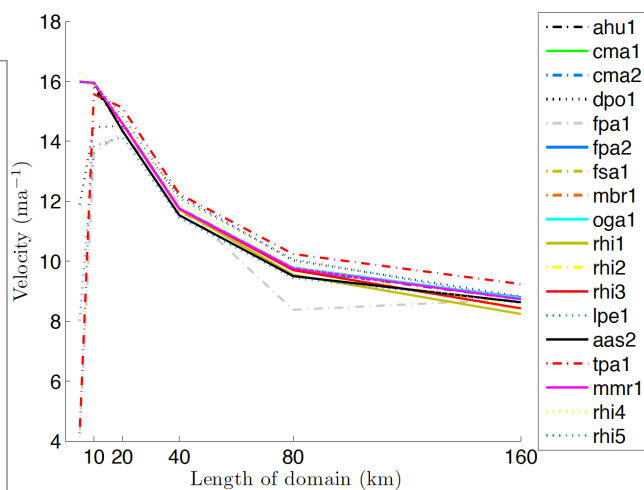
(i) Maximum V_x (m/yr) computed by ISSM (Pattyn)



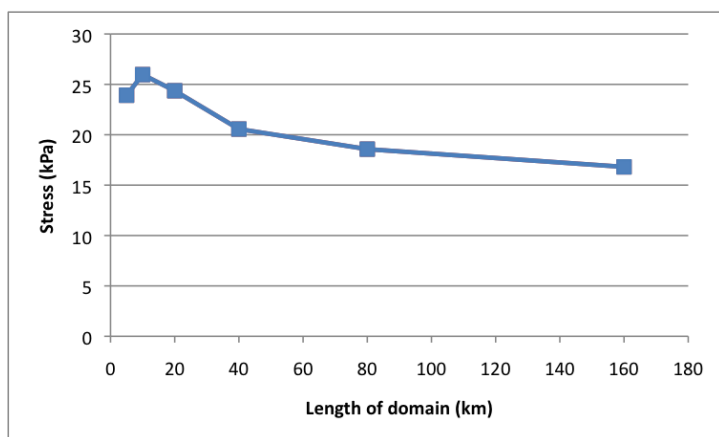
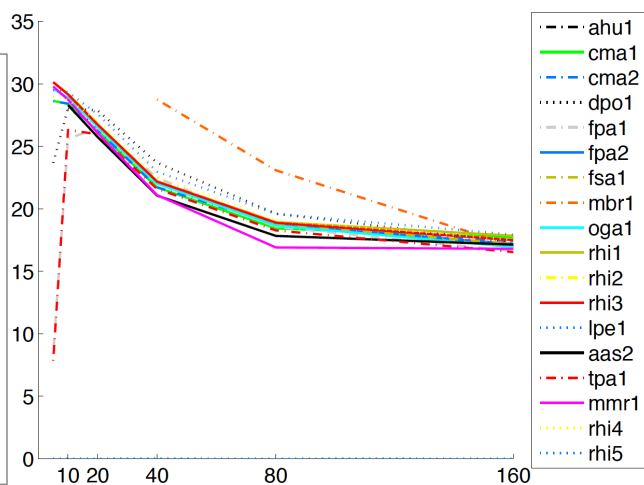
(j) Maximum V_x (m/yr) comparison



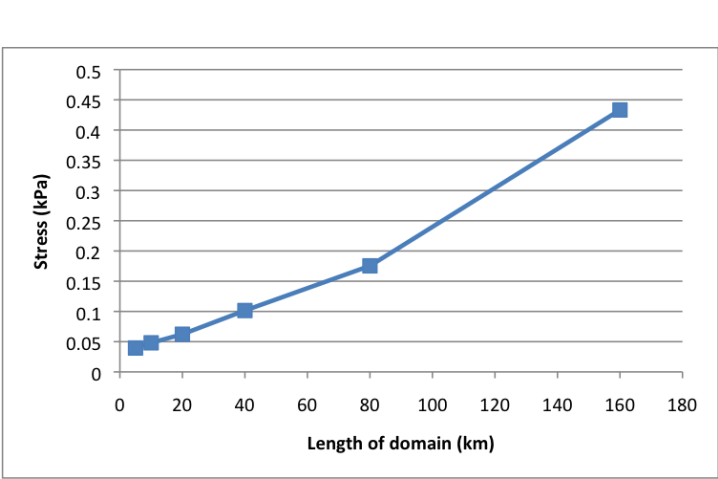
(k) Minimum V_x (m/yr) computed by ISSM (Pattyn)



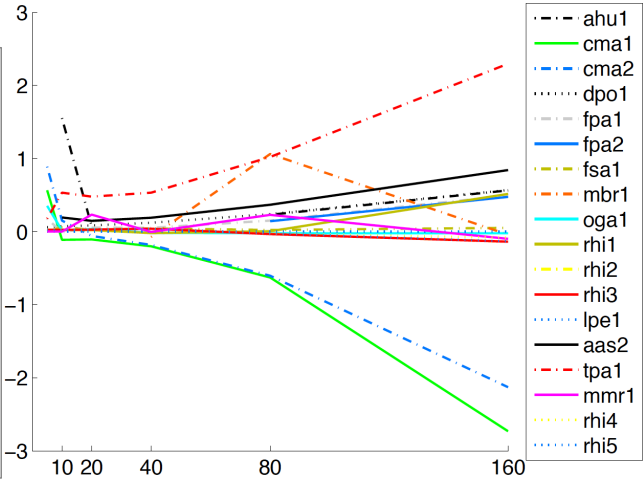
(1) Minimum V_x (m/yr) comparison

(m) Maximum T_{xz} (kPa) computed by ISSM (Pattyn)

(n) Maximum T_{xz} (kPa) comparison



(o) Minimum Txz (kPa) computed by ISSM (Pattyn)



(p) Minimum Txz (kPa) comparison

2.4 Test D

2.4.1 Geometry

This is a 2d ice-stream flow over a slippery bed (flowline). Periodic boundary conditions are applied. The geometry follows:

- surface $s(x, y) = -x \tan(0.1^\circ)$
- bed $b(x, y) = s - 1000$
- sliding $\alpha^2(x, y) = 1000 + 1000 \sin\left(\frac{2\pi}{L}x\right)$
- $5 \text{ km} \leq L \leq 160 \text{ km}$

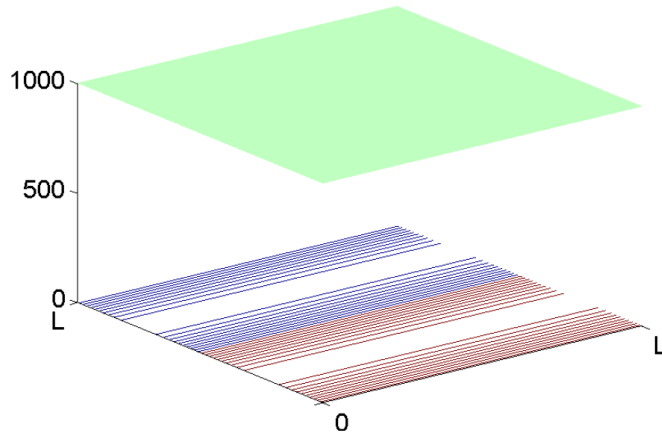
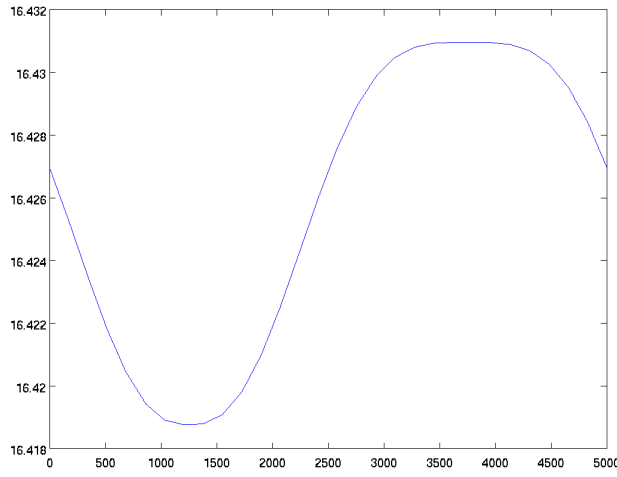


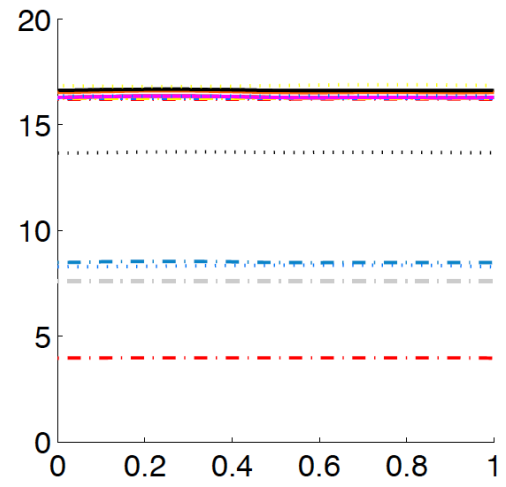
Figure 2.4: Test D geometry

2.4.2 Results

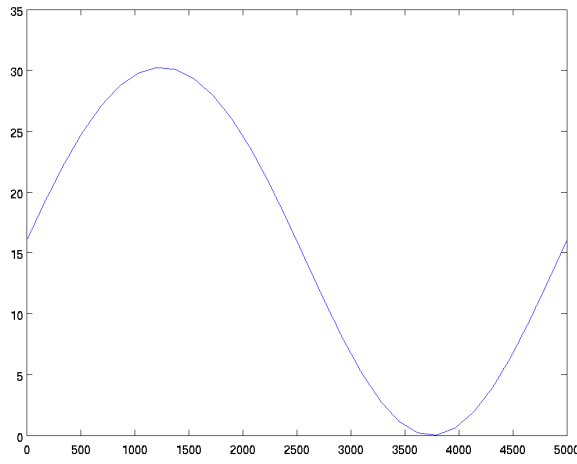
2.4.2.1 5km



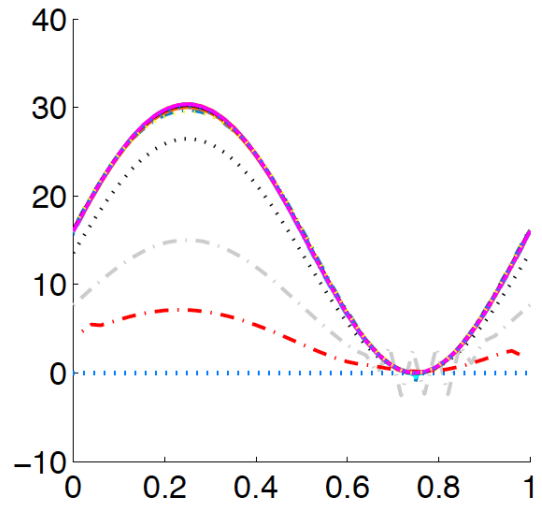
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line



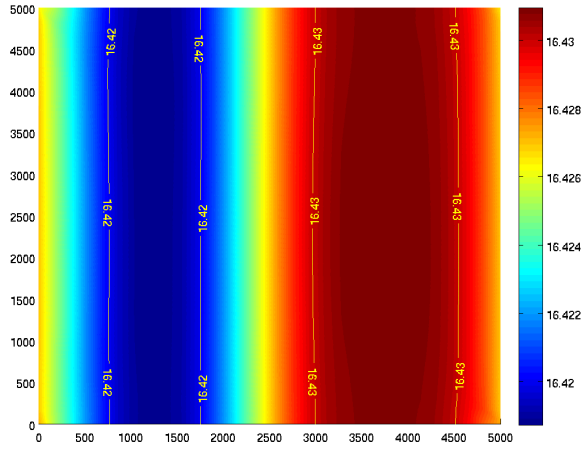
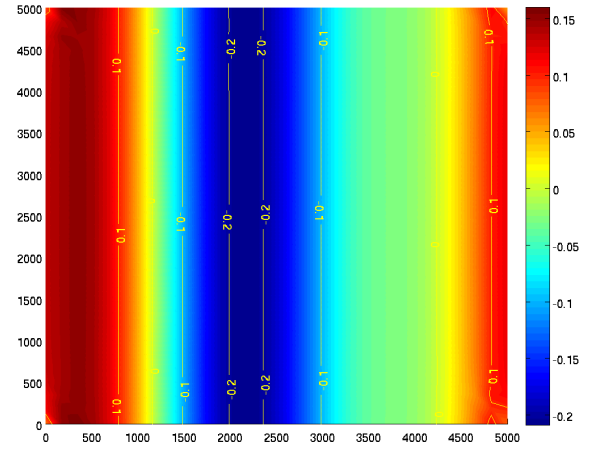
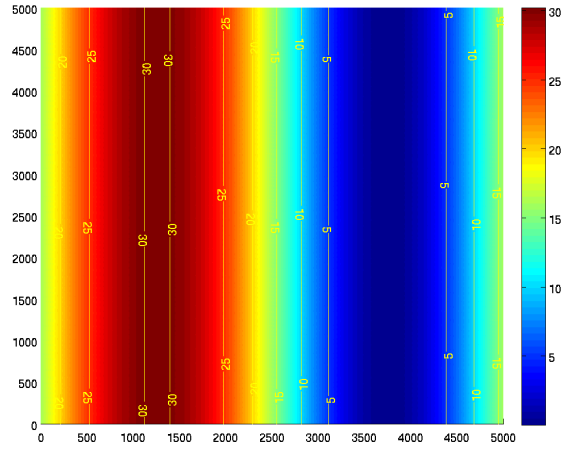
(b) V_x (m/yr) comparison



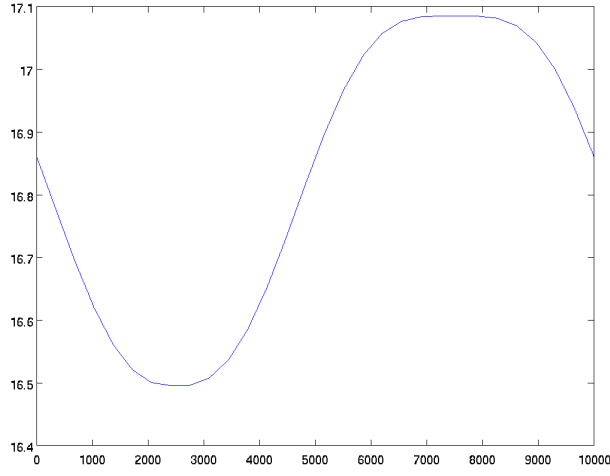
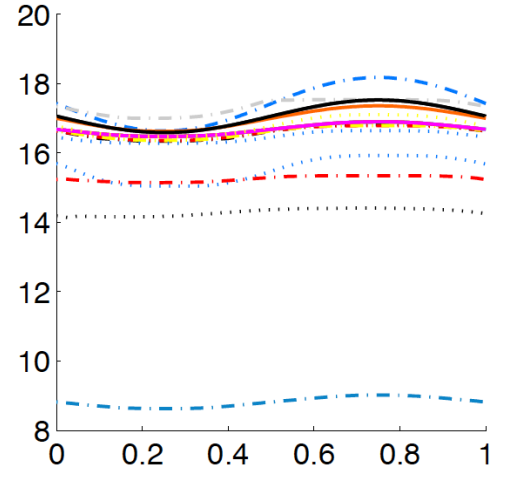
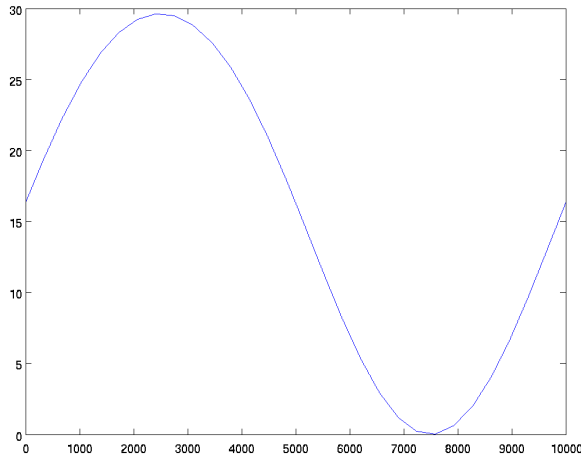
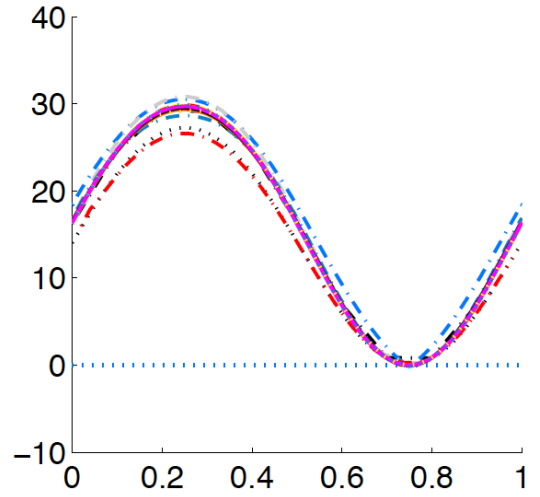
(c) T_{xx} (kPa) computed by ISSM (Pattyn) on a cross line

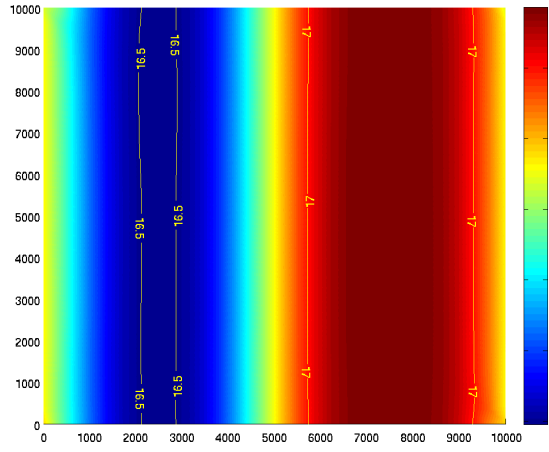
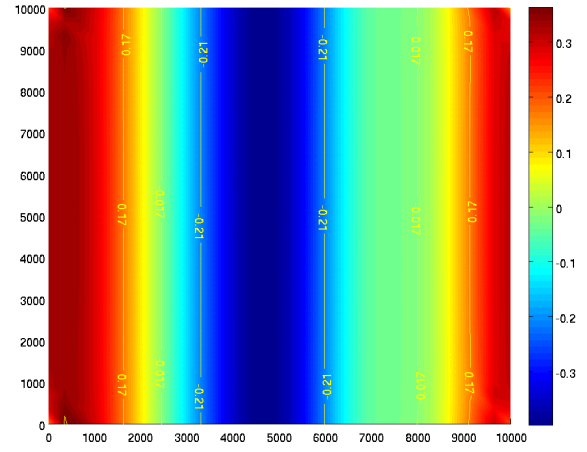
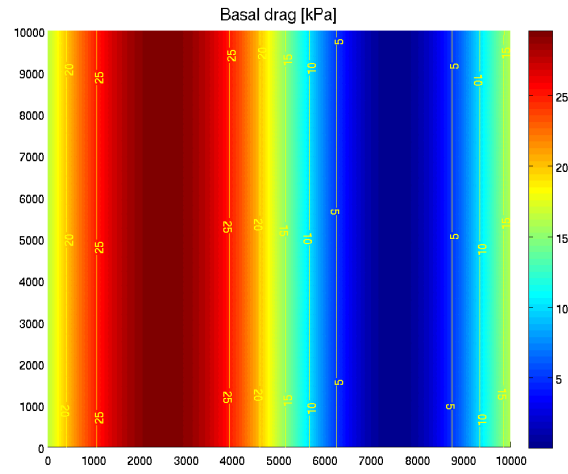


(d) T_{xx} (kPa) comparison

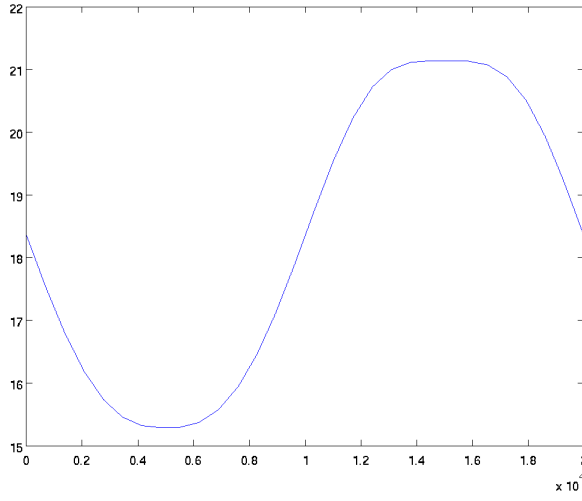
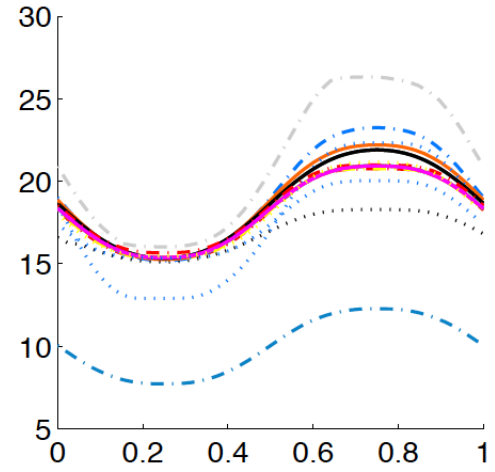
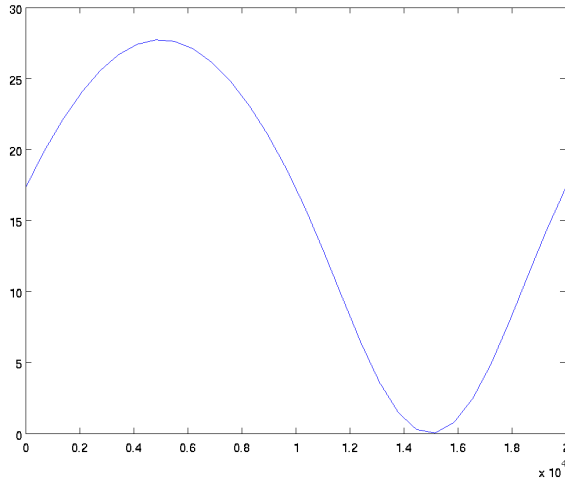
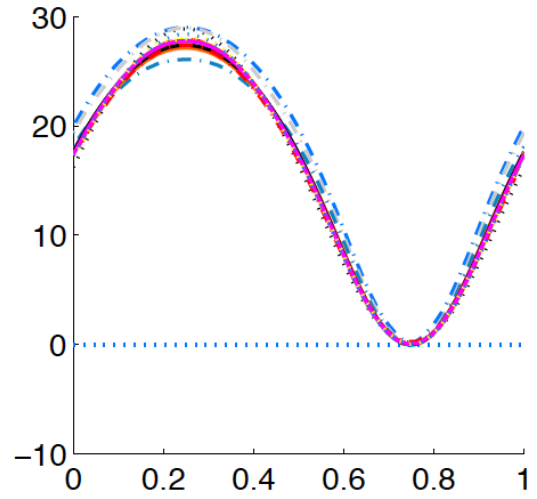
(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

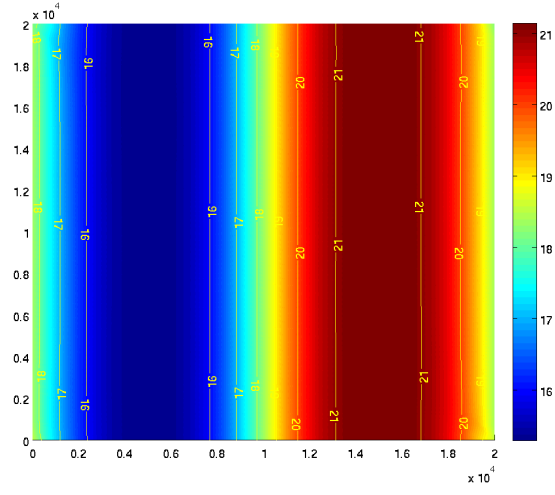
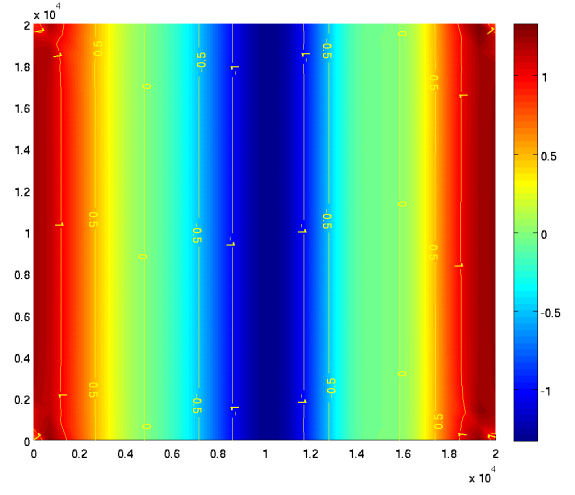
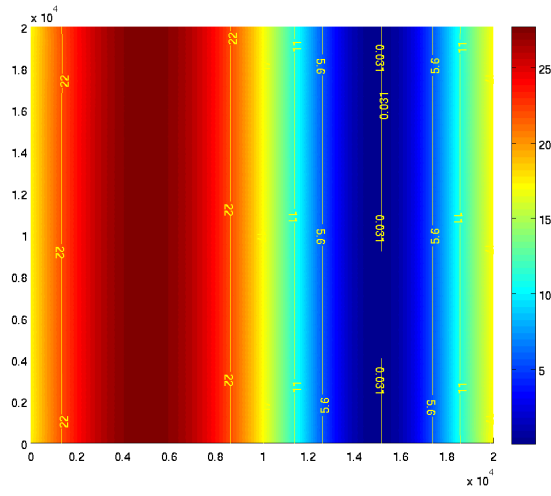
2.4.2.2 10km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line(d) T_{xz} (kPa) comparison

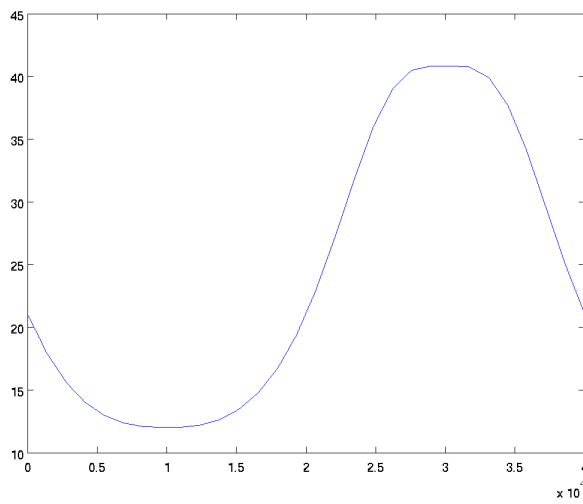
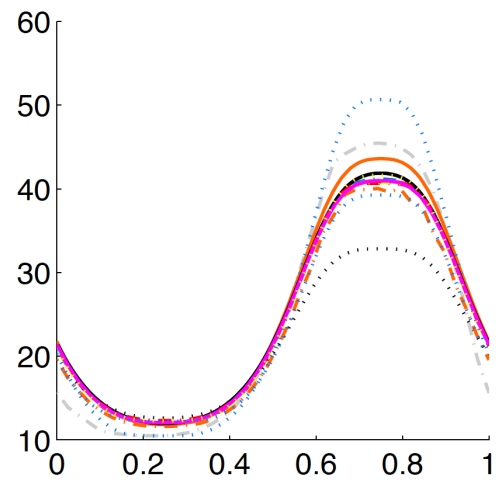
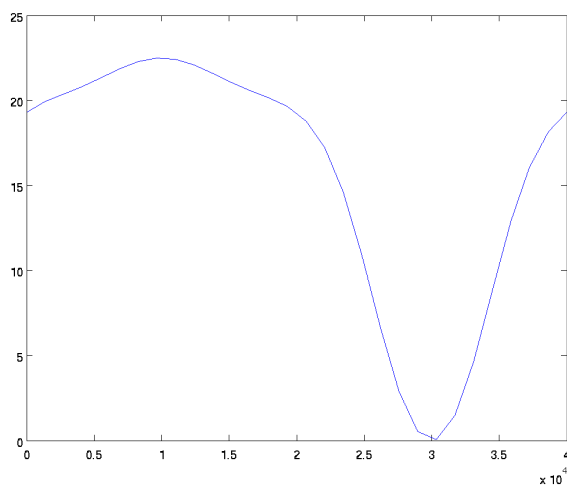
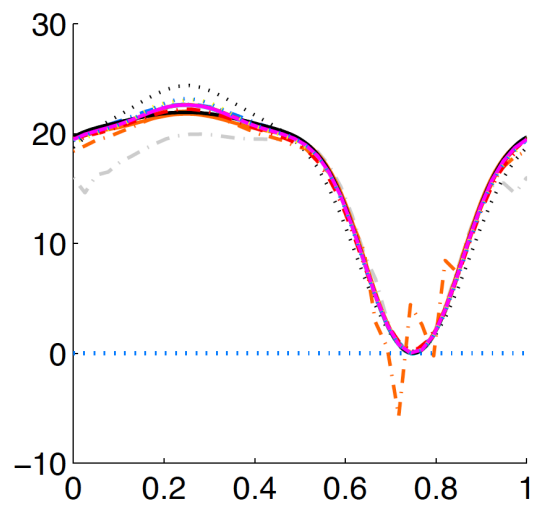
(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

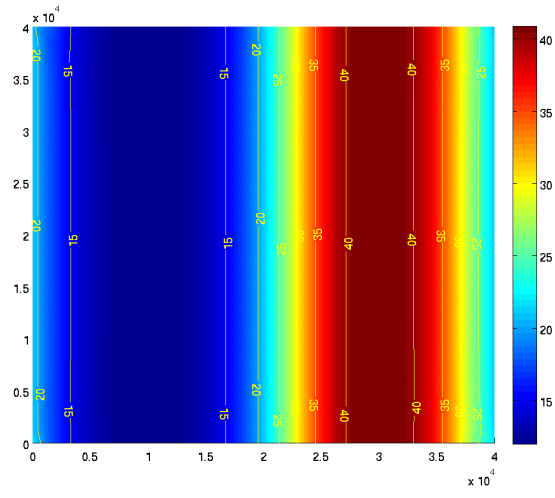
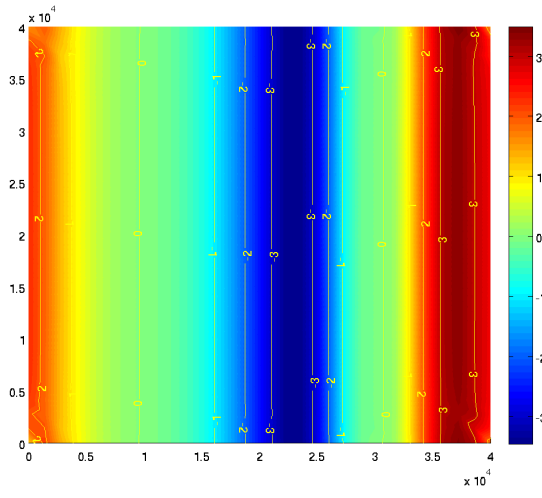
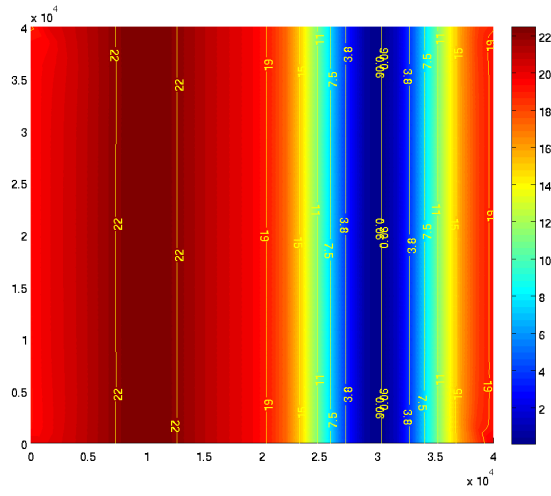
2.4.2.3 20km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xx} (kPa) computed by ISSM (Pattyn) on a cross line(d) T_{xx} (kPa) comparison

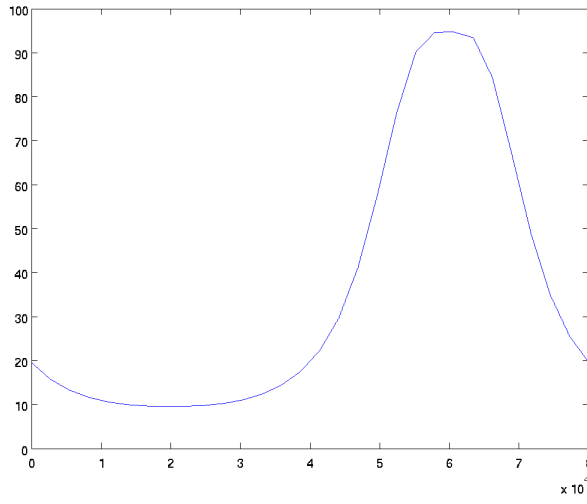
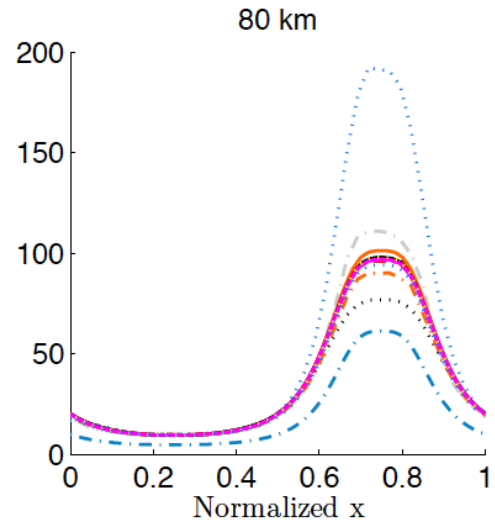
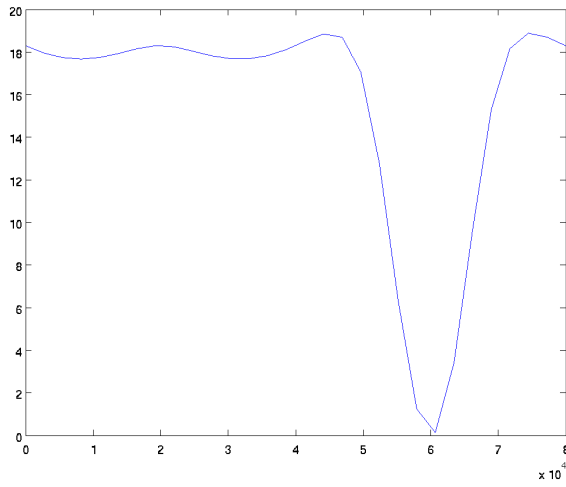
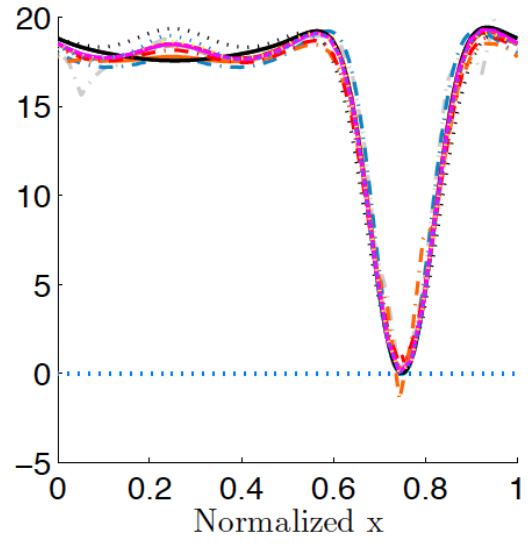
(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

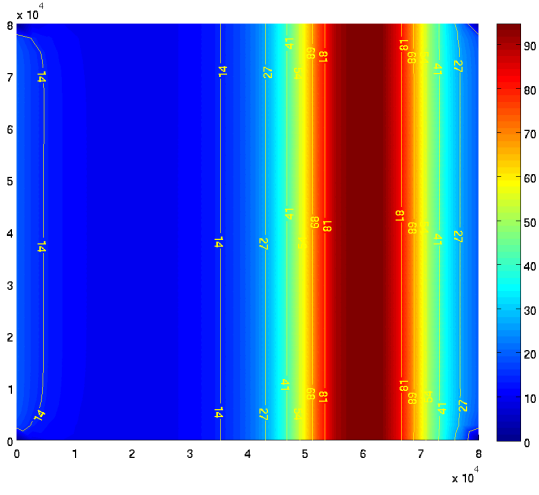
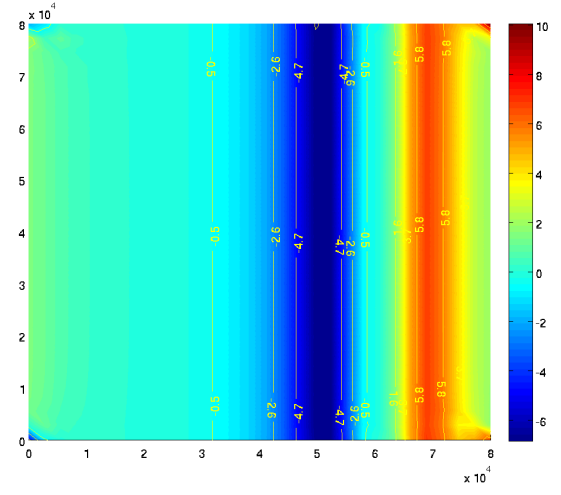
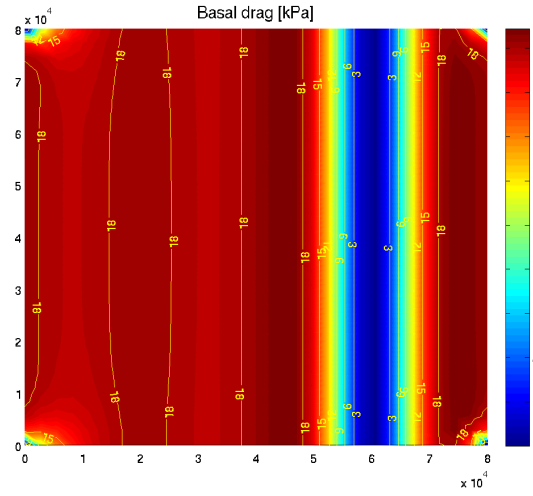
2.4.2.4 40km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xz} (kPa) computed by ISSM (Pattyn) on a cross line(d) T_{xz} (kPa) comparison

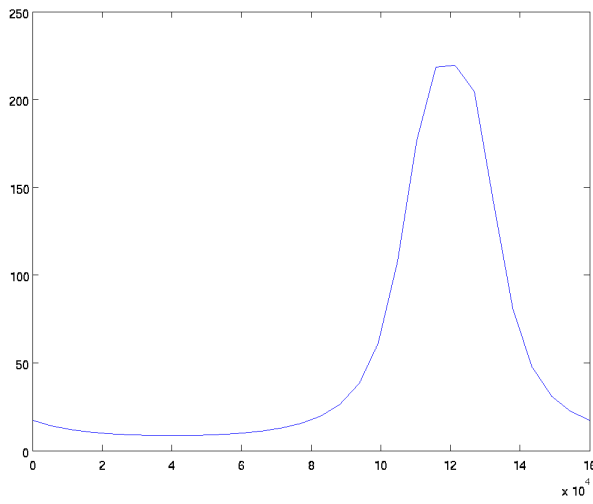
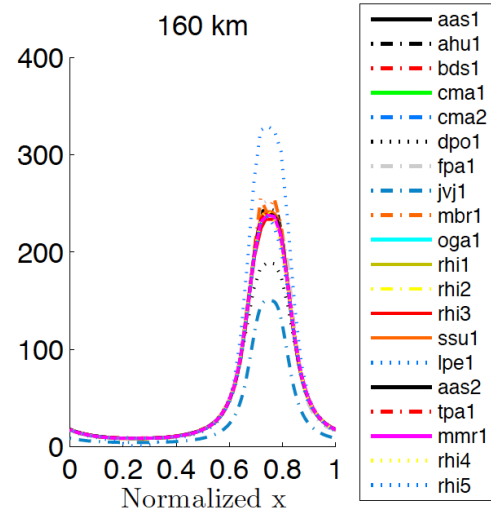
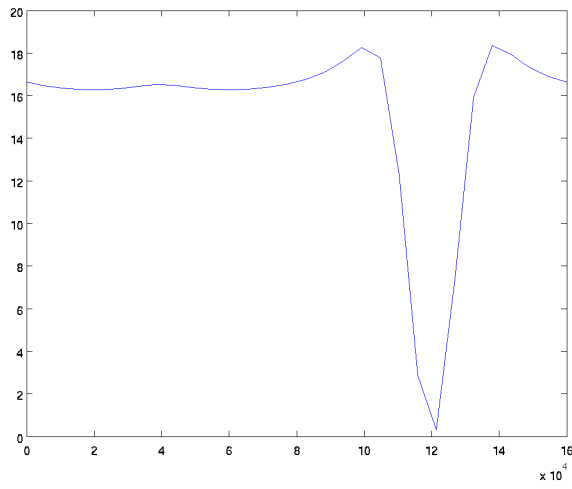
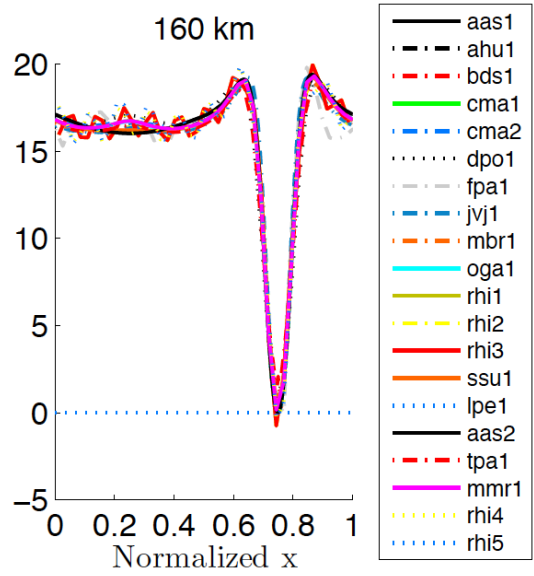
(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

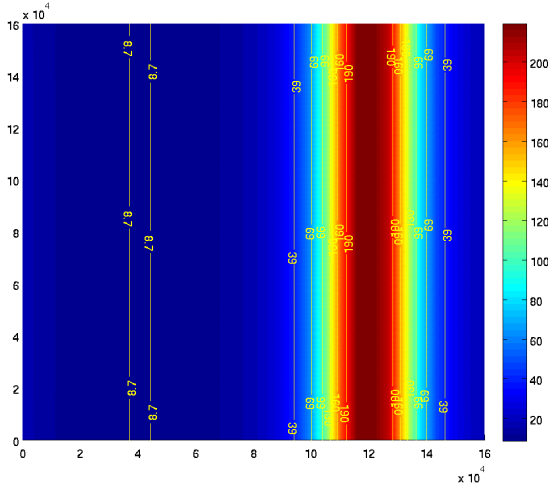
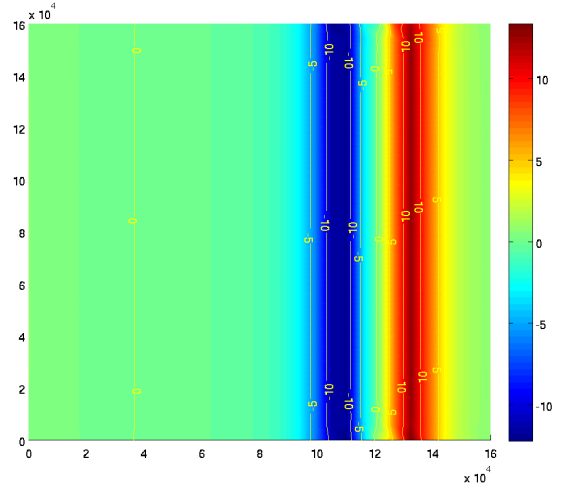
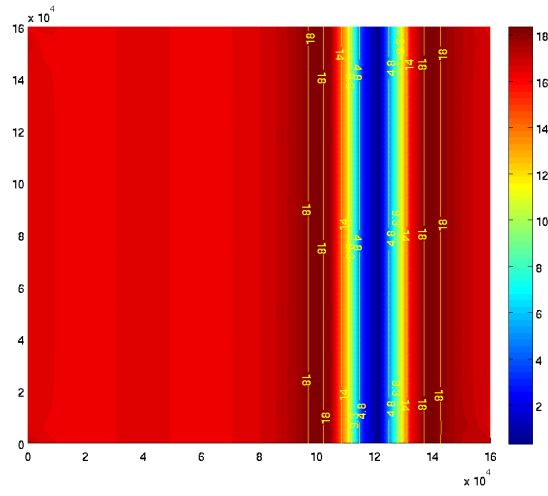
2.4.2.5 80km

(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xx} (kPa) computed by ISSM (Pattyn) on a cross line(d) T_{xx} (kPa) comparison

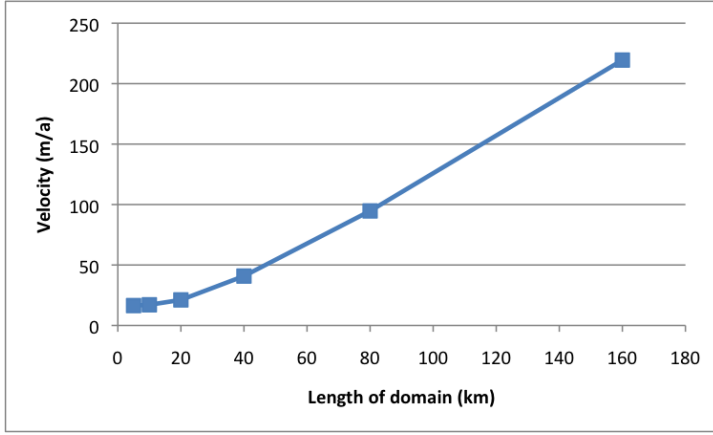
(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

2.4.2.6 160km

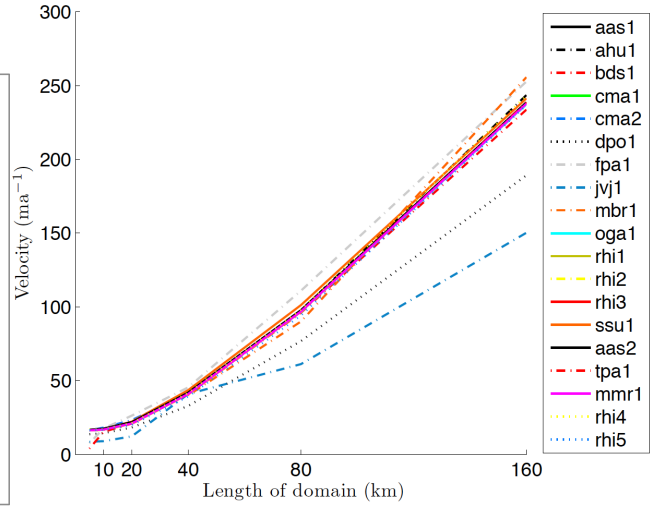
(a) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(b) V_x (m/yr) comparison(c) T_{xx} (kPa) computed by ISSM (Pattyn) on a cross line(d) T_{xx} (kPa) comparison

(e) V_x (m/yr) computed by ISSM (Pattyn)(f) V_z (m/yr) computed by ISSM (Pattyn)(g) T_{xz} (kPa) computed by ISSM (Pattyn)

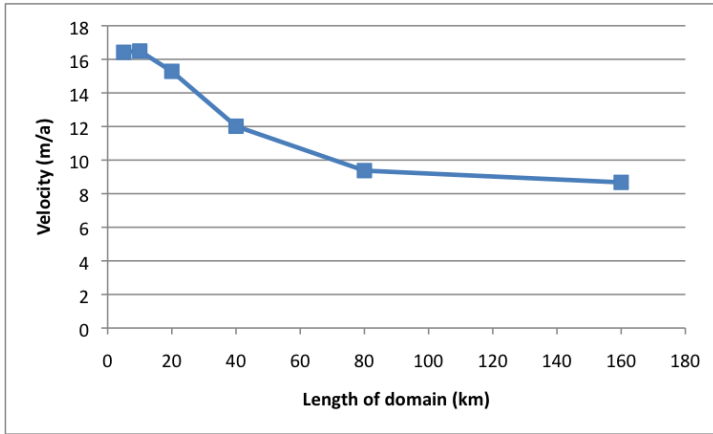
2.4.2.7 global (comparison)



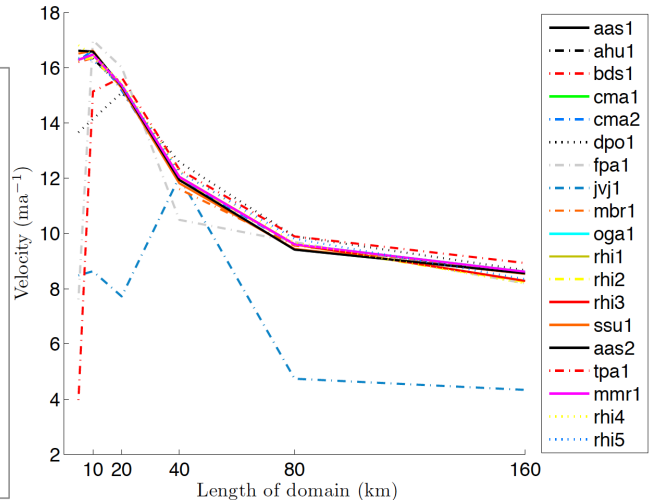
(h) Maximum Vx (m/yr) computed by ISSM (Pattyn)



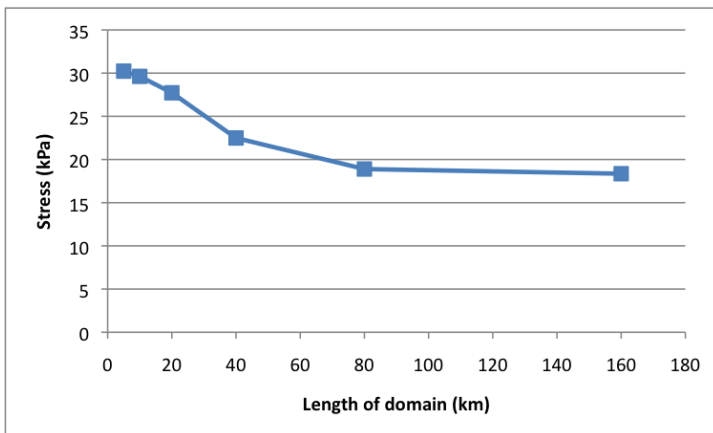
(i) Maximum Vx (m/yr) comparison



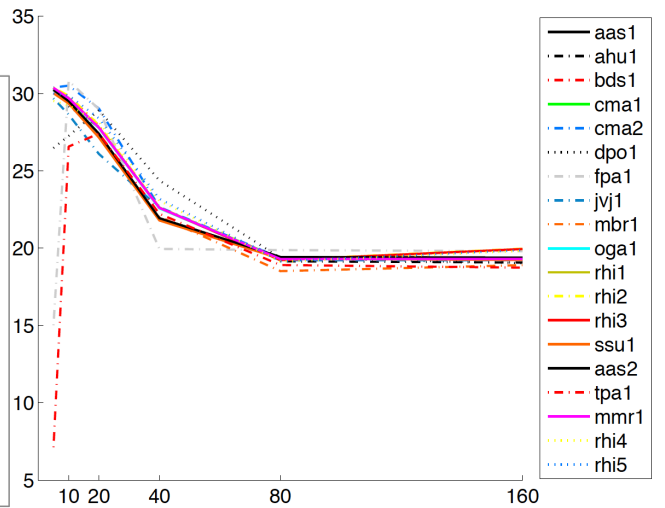
(j) Minimum Vx (m/yr) computed by ISSM (Pattyn)



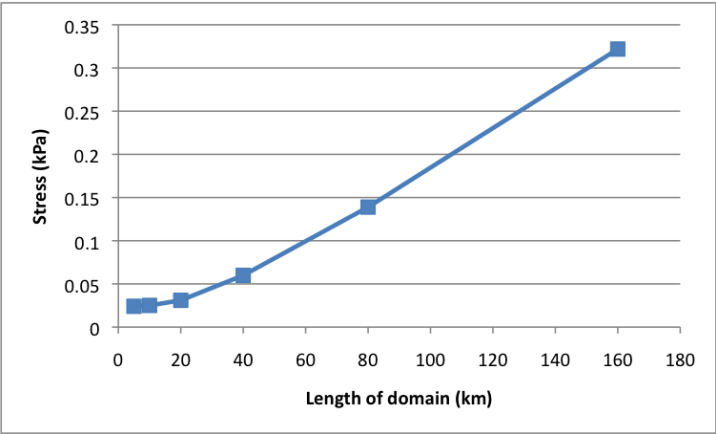
(k) Minimum Vx (m/yr) comparison



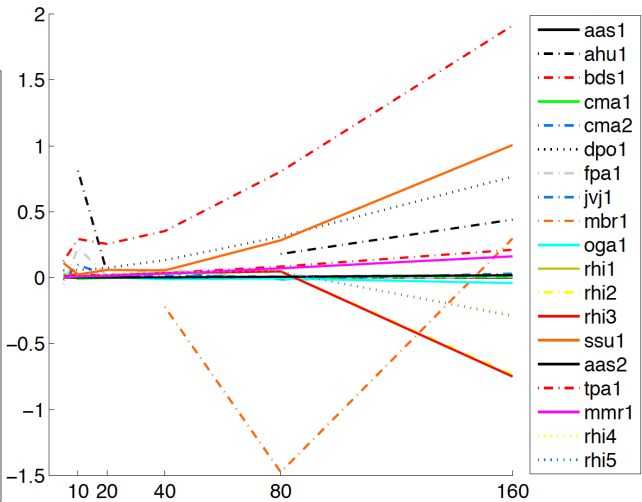
(l) Maximum Txz (kPa) computed by ISSM (Pattyn)



(m) Maximum Txz (kPa) comparison



(n) Minimum Txz (kPa) computed by ISSM (Pattyn)



(o) Minimum Txz (kPa) comparison

2.5 Test E

2.5.1 Geometry

This experiment deals with the cross section of a real glacier: *Haut Glacier d'Arolla*. Two cases are studied:

- basal velocity = 0 on the bed
- sliding $\alpha^2(x, y) = 0$ for $0.44 \leq x \leq 0.5$

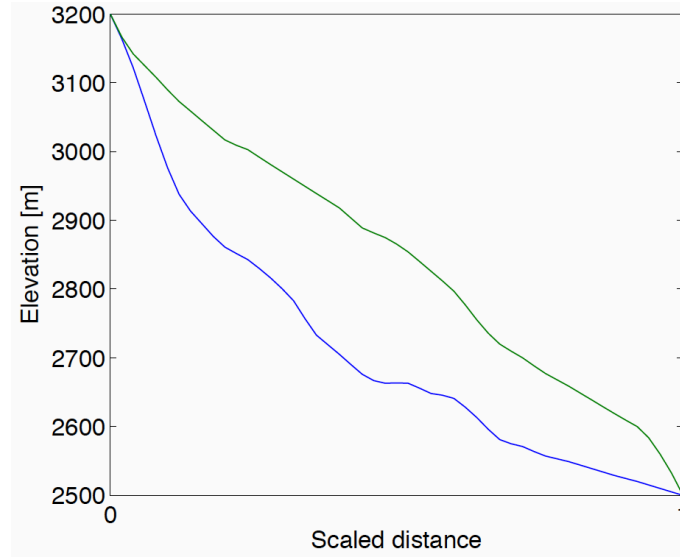
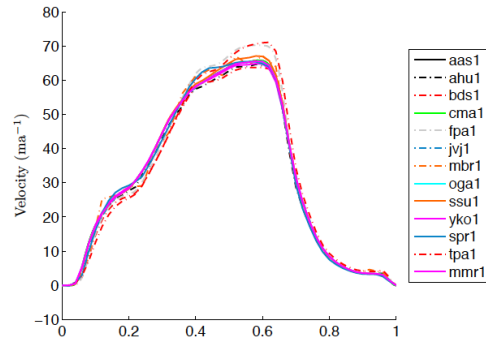


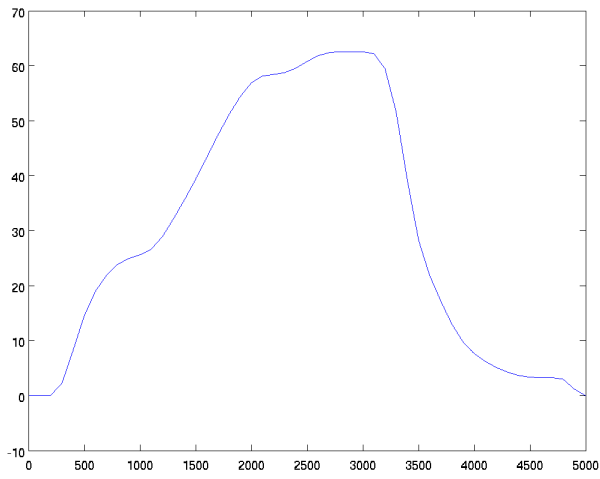
Figure 2.5: Test E geometry

2.5.2 Results

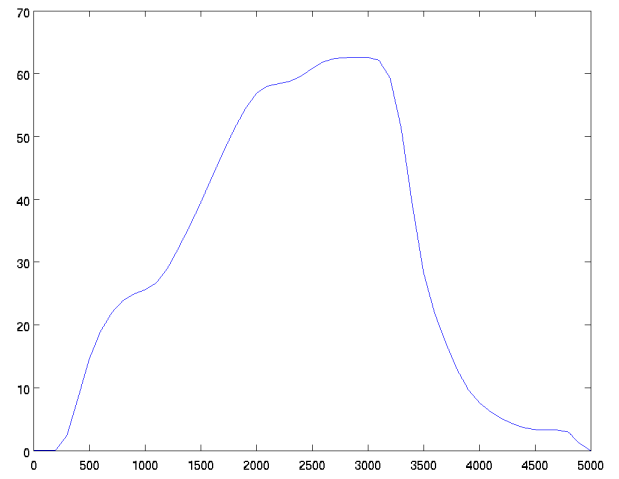
2.5.2.1 Frozen Bed



(a) V_x (m/yr) comparison

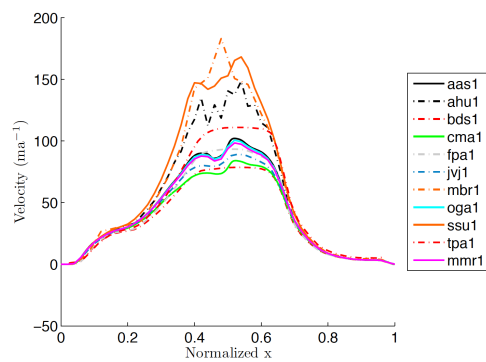
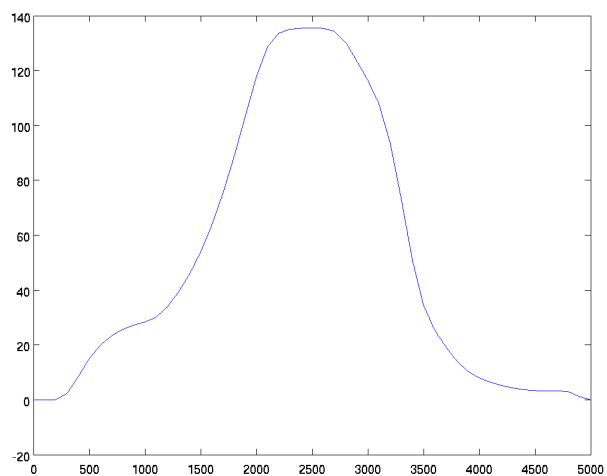
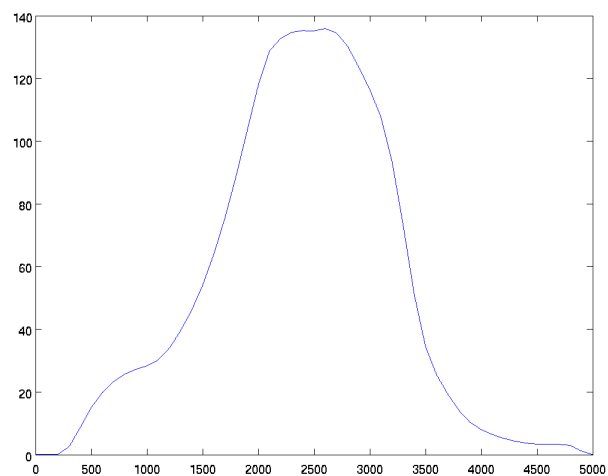


(b) V_x (m/yr) computed by ISSM (Pattyn) on a cross line



(c) V_x (m/yr) computed by ISSM (Stokes) on a cross line

2.5.2.2 Sliding

(a) V_x (m/yr) comparison(b) V_x (m/yr) computed by ISSM (Pattyn) on a cross line(c) V_x (m/yr) computed by ISSM (Stokes) on a cross line

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