

# Elmer/Ice course

22<sup>nd</sup> and 23<sup>rd</sup> October 2018, Rovaniemi

## Introduction

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# Program

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## Monday 22<sup>nd</sup> October

9:00-9:30 Arrival of the participants

9:30-9:45 Welcome words by Rupert Gladstone, general announcements

9:45-10:30 Introduction Elmer/ice (OG)

10:30-11:00 Coffee break

11:00-12:00 Toy flow-line model: basic diagnostic (TZ)

12:00 Lunch

13:00-15:30 Toy flow-line model: thermo-mechanical coupling (TZ)

15:30-16:00 Coffee break

16h00-17h30 Toy flow-line model: sliding, prognostic runs (TZ)

19h Course dinner (place to be specified, on your own expense)

# Program

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## Tuesday 23<sup>rd</sup> October

9:00-10:00 Tête Rousse Context (OG)

10:00-10:30 Tête Rousse setup and diagnostic (OG)

10:30-11:00 Coffee break

11:00-12:00 Tête Rousse prognostic (OG)

12:00 Lunch

13:00-14:30 SSA prognostic (OG)

14:30-15:00 Coffee break

15:00-17:00 Questions on your own modeling

# Short history of Elmer/Ice (not anymore so short...) 1/3

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- ✓ EGU2002: OG was looking for a 3D FE code to model the flow of strain-induced anisotropic polar ice – meet TZ
- ✓ March 2003: OG visited CSC for few days: AIFlowSolver and FabricSolver partly implemented
- ✓ August 2005 – One year visit of OG at CSC (Anisotropy, cavity, glaciers, ISMIP tests, ...)
- ✓ February 2008 – First Elmer/Ice Course - Grenoble
- ✓ June 2011 – SVALI summer school – Finland
- ✓ 2012 – Elmer/Ice has now a website, a logo and a mailing list
- ✓ 2012 – Elmer/Ice comes as a Elmer Package – New wiki
- ✓ 2012 – Elmer/Ice course at UBC/SFU
- ✓ 2013 – Elmer/Ice courses at Univ. Washington and Univ. Alberta
- ✓ 9 April 2013 – First Elmer/Ice users meeting – EGU 2013



# Short history of Elmer/Ice (not anymore so short...) 2/3

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- ✓ May 2013 – Second SVALI summer school – Finland
- ✓ 2-day beginner Elmer/Ice course, 3-4 Oct. 2013, LGGE, Grenoble, France
- ✓ 3-day Elmer/Ice advanced workshop, 4-6 Nov. 2013, CSC, Espoo, Finland
- ✓ April 2014 – Second Elmer/Ice users meeting – EGU 2014
- ✓ 3-day beginner Elmer/Ice course, 27-29 Oct. 2014, IMO, Reykjavík, Iceland
- ✓ April 2015 – Third Elmer/Ice users meeting – EGU 2015
- ✓ 2-day beginner course, 1&2 Nov 2015, CIC, Copenhagen, Denmark
- ✓ 3-day Elmer/Ice advanced workshop, 30 Nov, 1&2 Dec 2015, LGGE, Grenoble, France
- ✓ 3-days beginner course, Oct 2016, Oslo
- ✓ April 2017 – Fourth Elmer/Ice users meeting – EGU 2017

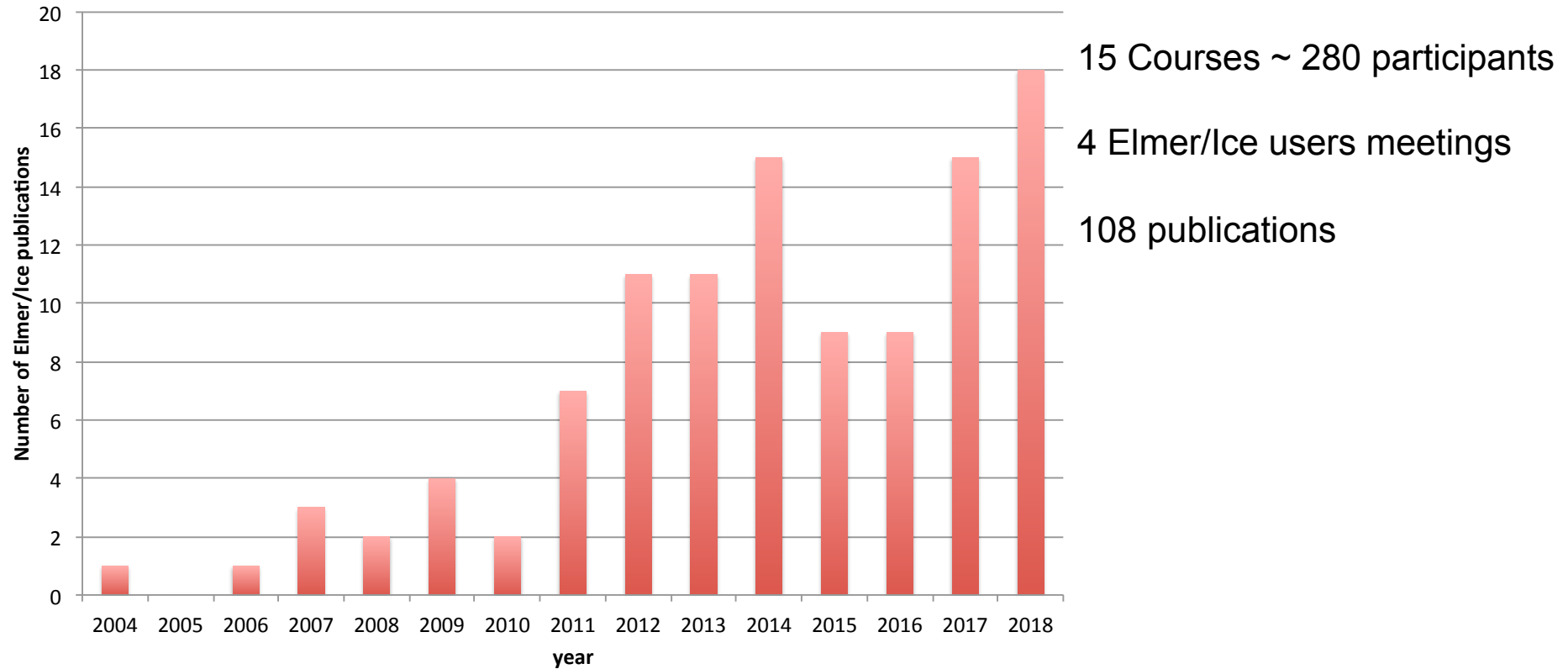
# Short history of Elmer/Ice (not anymore so short...) 3/3

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- ✓ - 2-day beginner Elmer/Ice course, 23rd and 24th Oct. 2017, University of Stockholm, Sweden
- ✓ 3-day advanced Elmer/Ice workshop, 22nd, 23rd and 24th Nov. 2017, IGE, Grenoble, France

and now Rovaniemi and Helsinki next week

# A growing community



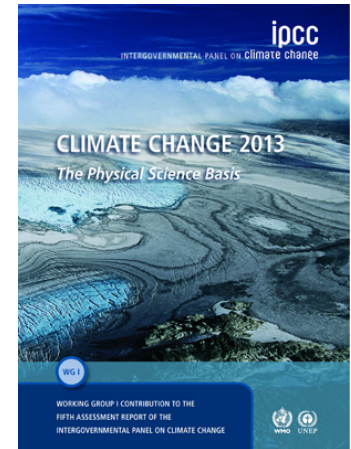
Since few years, first authors are not only anymore only from CSC or IGE (ex LGGE)...

# Elmer/Ice applications

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108 (known) publications using Elmer/Ice since 2004

- ISMIP, MISMIP, MISMIP-3d
- 2D and 3D Grounding line dynamics
- Ice2sea and SeaRISE contributions (Greenland)
- Inverse methods (Variegated, Vestfonna ice-cap, GIS)
- Flow of anisotropic ice
- Glaciers
- 9 cited references including results from Elmer/Ice in the 5th IPCC report



see <http://elmerice.elmerfem.org/publications>



News

Publications

Capabilities

Elmer Ice-Sheet

Users Community

FORUM

Courses Tutorials

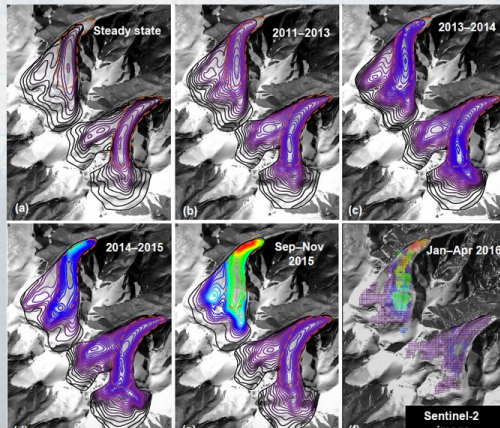
Materials Documentations

search...

## Elmer/Ice News

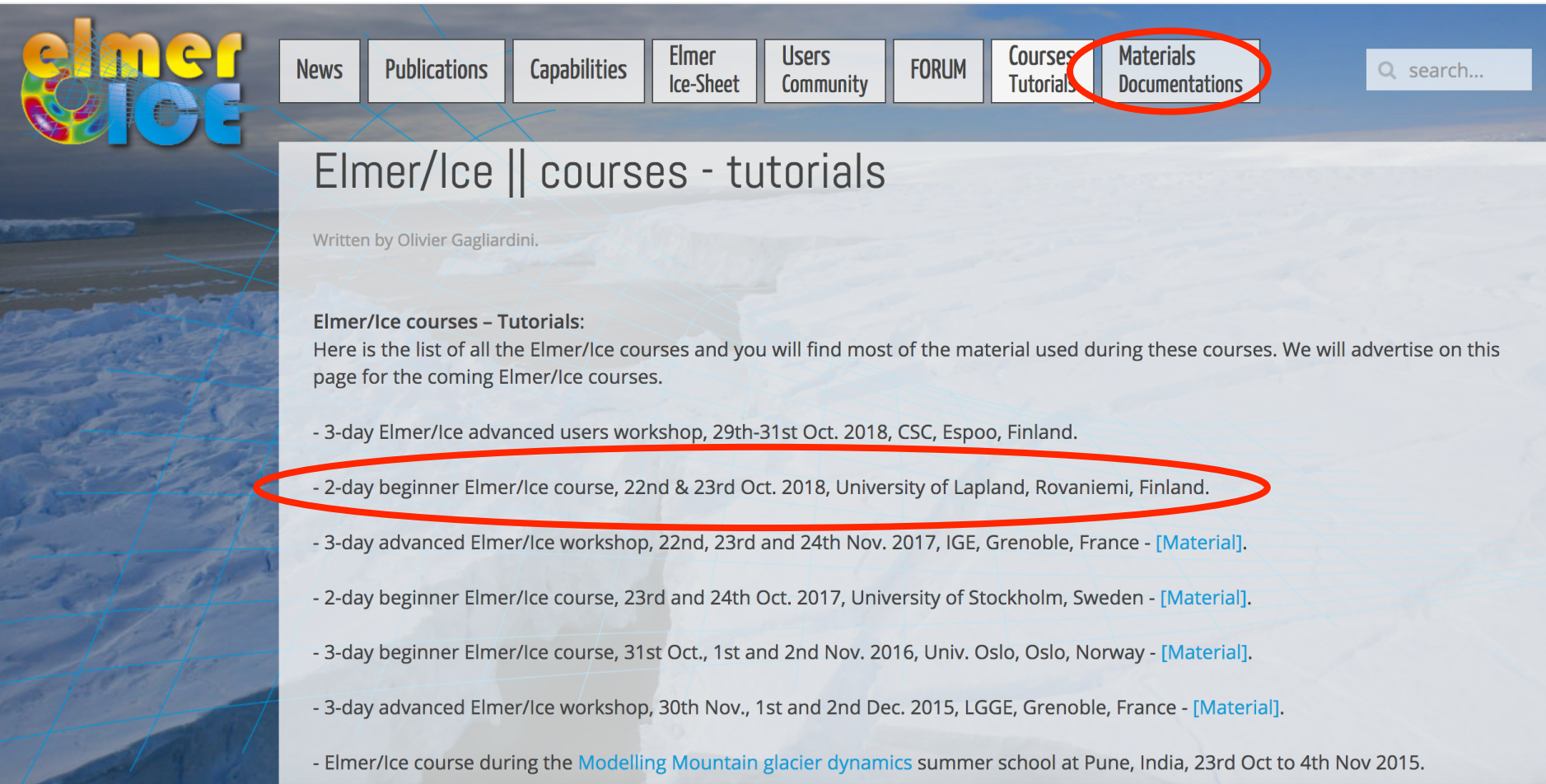
### Mechanisms leading to the 2016 giant twin glacier collapses, Aru Range, Tibet

Written by Olivier Gagliardini on 10 September 2018.



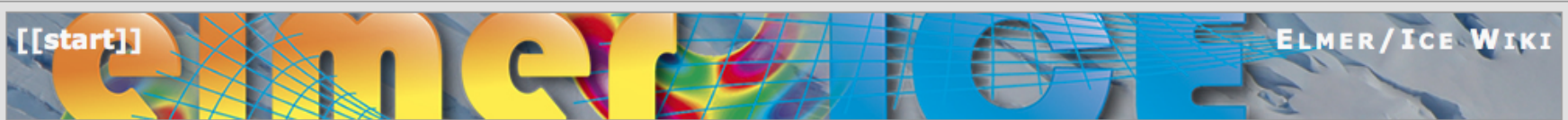
In north-western Tibet near lake Aru Co, the entire ablation areas of two glaciers (Aru-1 and Aru-2) suddenly collapsed on 17 July and 21 September 2016. The masses transformed into ice avalanches with volumes of  $68$  and  $83 \times 10^6 \text{m}^3$  and ran out up to  $7 \text{km}$  in horizontal distance, killing nine people. The only similar event currently documented is the  $130 \times 10^6 \text{m}^3$  Kolka Glacier rock and ice avalanche of 2002 (Caucasus Mountains). Using climatic reanalysis, remote sensing, and three-dimensional thermo-mechanical modelling, we reconstructed the Aru glaciers' thermal regimes, thicknesses, velocities, basal shear stresses, and ice damage prior to the collapse in detail. Thereby, we highlight the potential of using emergence velocities to constrain basal friction in mountain glacier models. We show that the frictional change leading to the Aru collapses occurred in the temperate areas of the polythermal glaciers and is not related to a rapid thawing of cold-based ice. The two glaciers experienced a similar stress transfer from predominant basal





The screenshot shows the Elmer/Ice website interface. At the top left is the Elmer/Ice logo. A navigation menu contains the following items: News, Publications, Capabilities, Elmer Ice-Sheet, Users Community, FORUM, Courses Tutorials, and Materials Documentations. The 'Materials Documentations' item is circled in red. To the right of the menu is a search bar with the text 'search...'. Below the menu is a page titled 'Elmer/Ice || courses - tutorials'. The page content includes the text 'Written by Olivier Gagliardini.' followed by a section header 'Elmer/Ice courses - Tutorials:'. Below this is a paragraph: 'Here is the list of all the Elmer/Ice courses and you will find most of the material used during these courses. We will advertise on this page for the coming Elmer/Ice courses.' A list of courses follows, with the second item circled in red: '- 2-day beginner Elmer/Ice course, 22nd & 23rd Oct. 2018, University of Lapland, Rovaniemi, Finland.'

Much more material available than what we will present today



Trace: • start

Show pagesource

Recent changes Sitemap Login

Search

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- [Problems](#)
- [Solvers](#)
- [User Functions](#)
- [Meshing Tools](#)
- [Tips and Tricks](#)
- [Meetings and Courses](#)
- [Compilation of Elmer/Ice](#)
- [Links](#)

## Welcome to the Elmer/Ice wiki

Elmer is an open-source, parallel, Finite Element code, mainly developed by the CSC-IT Center for Science Ltd. in Finland. Elmer/Ice builds on Elmer and includes developments related to glaciological problems. On this page you will find documentation and examples of the various solvers and user functions developed for **glaciological** applications using Elmer/Ice. Building Elmer/Ice on top of an existing Elmer installation is explained in the [Compilation Section](#).

The [Problems Section](#) presents the various categories of glaciological problems that can be solved using Elmer/Ice.

The [Solvers Section](#) and the [User Functions Section](#) describe the glaciology related solvers and user functions, respectively, that can be used to solve these problems.

Tools that can be used to mesh glacier and ice-sheet geometry are presented in the [Meshing Section](#).

The [Tips and Tricks Section](#) gives some useful demo of MATC, Post-treatments of results and more.

The [Courses Material Section](#) contains presentation as well as material proposed in the framework of the Elmer/Ice courses dispensed since 2008.

Some useful links are given in the [Links Section](#).

Scientific publications presenting glaciological applications with Elmer/Ice are listed in the [Elmer/Ice website](#).

start.txt · Last modified: 2012/12/03 17:45 by tzwinger

# Elmer/Ice mailing list

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To subscribe to the Elmer/Ice list [elmerice@elmerfem.org](mailto:elmerice@elmerfem.org), just sent an email to [majordomo@elmerfem.org](mailto:majordomo@elmerfem.org), with in the body the text:

subscribe elmerice

If you do not know how to use mailing lists run by majordomo you may sent a mail with "help" in the message body.



# Elmer/Ice Forum

Under

<http://www.elmerfem.org> :

- Go to **Elmer Forum**: find answers on all aspects of Elmer
- Click on **Elmer/Ice** link: find answers specific to Elmer/Ice
- To get access: **Register** in upper right corner

Elmer Discussion Forum • Index page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Elmer Discussion Forum • Inde...

www.elmerfem.org/forum/index.php

Most Visited Linux Mint Elmer/Ice elmerfem.org

phpBB Elmer Discussion Forum Bulletin Board for Elmer FEM Users

Search... Search Advanced search

Board index

FAQ Register Login

It's currently 02 Sep 2013, 10:54

View unanswered posts • View active topics

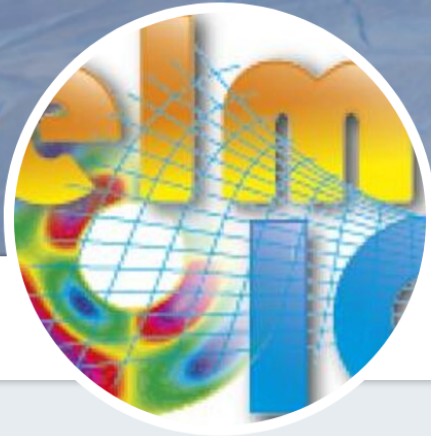
FORUMS	TOPICS	POSTS	LAST POST
<b>General</b> General discussion about Elmer	345	1289	by GastónGarcía 29 Aug 2013, 22:01
<b>Installation &amp; compilation</b> Discussion about building and installing Elmer	166	680	by Jyh-Shyong 30 Aug 2013, 18:02
<b>ElmerSolver</b> Numerical methods and mathematical models of Elmer	944	4108	by drueffer 30 Aug 2013, 16:54
<b>ElmerGUI</b> The graphical user interface of Elmer	228	908	by raback 26 Aug 2013, 00:05
<b>ElmerPost</b> Post processing utility for Elmer	90	346	by Edmund 30 Jul 2013, 11:01
<b>Elmer/Ice</b> Extension of Elmer in computational glaciology	8	27	by tzwinger 22 Aug 2013, 13:56
<b>External tools</b> Mesh generators, CAD programs, and other tools	113	558	by NickR7 30 Aug 2013, 18:04
<b>Software development</b> Discussion about coding and new developments	37	120	by Takala 22 Aug 2013, 09:02
<b>Bug reports</b> Clearly defined bug reports and their fixes	80	230	by millm 29 Aug 2013, 12:55
<b>Contributed Cases</b> Elmer cases by the users for the users	15	33	by sebastien ROUQUETTE 29 Apr 2013, 14:49
<b>HPC</b> High Performance Computing with Elmer	3	5	by madtom1999 21 Oct 2012, 15:34
<b>Commerical services</b> A forum for commercial service requests and offerings	3	3	by aether 12 Dec 2012, 11:33

ANNOUNCEMENTS	TOPICS	POSTS	LAST POST
<b>Updates</b> Updates in software, documentation, sites etc.	20	83	by mzenker 08 Jul 2013, 16:20
<b>Events</b> Courses, user meetings, seminars etc.	14	17	by raback 12 Apr 2013, 13:54

MISCELLANEOUS	TOPICS	POSTS	LAST POST
<b>Testing</b> Here you can test posting, attachments, ...	4	6	by Takala 03 Apr 2013, 10:16

# Elmer/Ice on Twitter

# @ElmerIce1



**Elmer/Ice**

@ElmerIce1

[elmerice.elmerfem.org](http://elmerice.elmerfem.org)

Inscrit en janvier 2014

Tweets **51** Abonnements **43** Abonnés **152** J'aime **1** Listes **0** Moments **0**

Tweets **Tweets & réponses**



**Elmer/Ice** @ElmerIce1 · 10 sept.

The giant twin glacier collapses in Tibet explained using #ElmerIce1 [elmerice.elmerfem.org/news/108-mecha...](http://elmerice.elmerfem.org/news/108-mecha...)

Traduire le Tweet



↻ 2

♥ 6



**Elmer/Ice** @ElmerIce1 · 26 août

An application showing the coupling between hydrology (GlaDS) and #ElmerIce1 [elmerice.elmerfem.org/news/107-coupl...](http://elmerice.elmerfem.org/news/107-coupl...)

Traduire le Tweet



↻ 3

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# Important links (summary)

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Elmer at CSC (documentation, how to install, ...)

<http://www.elmerfem.org/>

<http://www.csc.fi/english/pages/elmer>

Elmer Forum

<http://elmerfem.org/forum/>

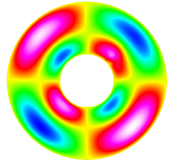
Elmer/Ice webpage

<http://elmerice.elmerfem.org/>

Elmer/Ice wiki

<http://elmerice.elmerfem.org/wiki/doku.php?id=start>

# Elmer/Ice in relation to Elmer



Elmer is an open-source, parallel, Finite Element code, mainly developed by the CSC-IT Center for Science Ltd. in Finland.

Elmer is constantly developed towards improved performance, utilizing international projects such as FP7 PRACE and HPC Europa2.



Elmer/Ice builds on Elmer and includes developments related to glaciological problems. Elmer/Ice includes a variety of dedicated solvers and user functions for glaciological applications and its development is supported by various groups and funding...



norden

Top-level Research Initiative



# Elmer/Ice Package

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All the Solvers, User Functions and Meshers presented on the Elmer/Ice wiki comes as an Elmer/Ice package on the Elmer distribution (in `elmerice/`)

To get Elmer/Ice installed, add the following option to the cmake build command:

```
-DWITH_ElmerIce:BOOL=TRUE
```

To use it (in the SIF file):

```
Procedure = File "ElmerIceSolvers" "NameSolver"
```

or

```
Procedure = File "ElmerIceUSF" "NameUSF"
```

# Important notices

---

## In this course

- We will not teach finite element method (can give references)
- We will focus on some technical aspects of using Elmer for glaciological applications

## What we expect from this course ?

- giving you a kick-start in Elmer/Ice
- some fruitful collaborations to begin

# Elmer/Ice capabilities

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- **Full-Stokes** equations but also SIA, SSA, diagnostic or transient
- Various **rheologies** (Glen's law, firn/snow and anisotropic flow laws)
- **Temperature** solver accounting for the upper limit at melting point (+ enthalpy solver)
- **Transport equations** for density, fabric, age ...
- **Post-processing solver** for strain-rate and stress fields
- Various **friction laws** (Weertman, effective-pressure dependent friction law)
- **Free surface evolution** as a contact problem (Grounding line dynamics)
- **Inverse methods** (linear adjoint and Arthern and Gudmundsson 2010 methods)
- Tools or plug-ins for **meshing** (YAMS, external and internal extrusion of footprint)
- **Highly parallel** Stokes solver
- **Basal hydrology** (2 approaches on the distribution)
- **Calving** (3 approaches, one in the distribution)
- **Damage mechanics**

# Elmer/Ice capabilities

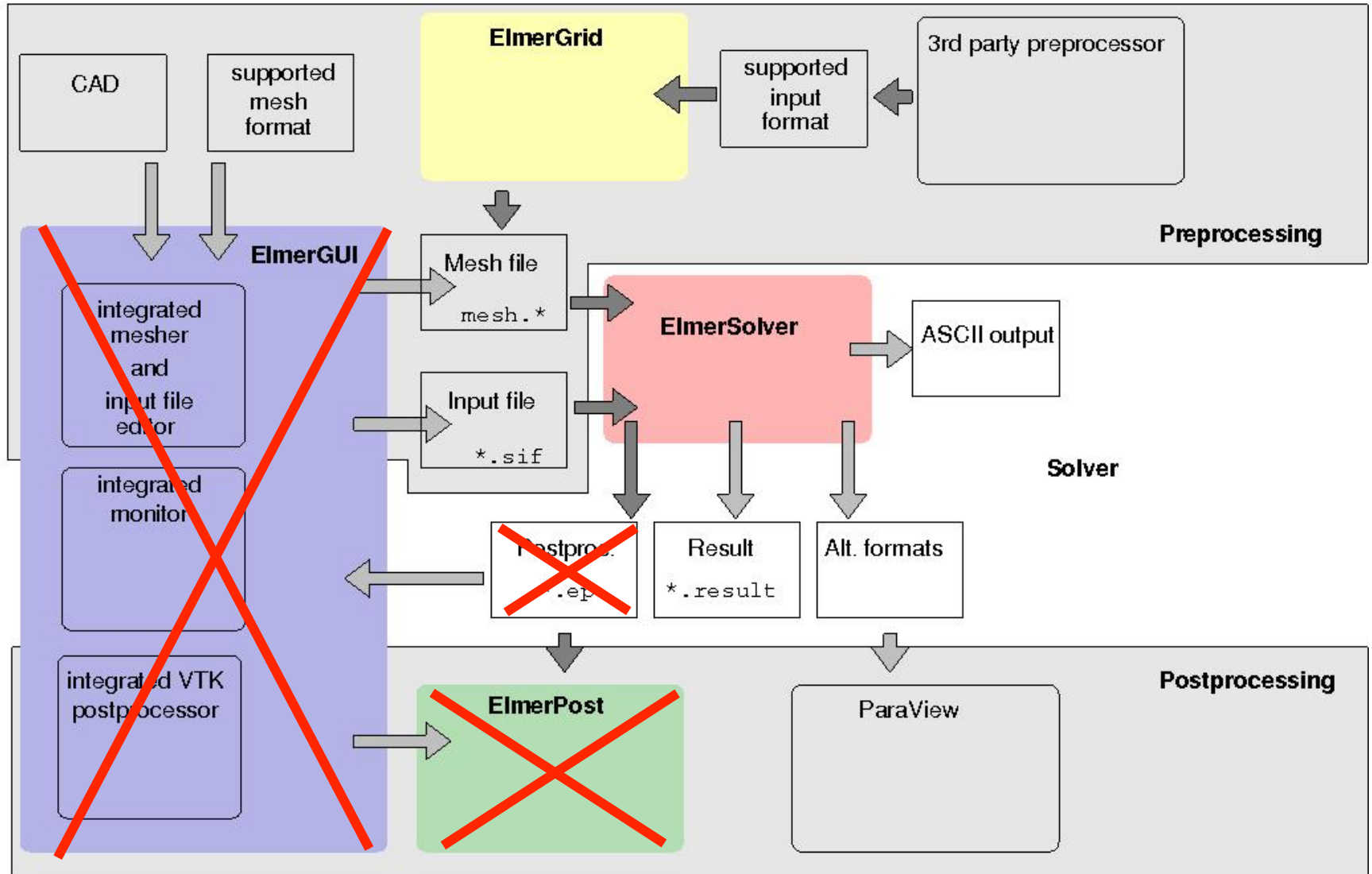
	Flow equations	Stokes	SSA	SSA*	SIA	ISCAL
Rheology	Glen	X, Inv Adj + Rob	X, Inv Adj	X	X	X
	GOLF	X				
	CAFFE	X				
	POROUS	X				
	Damage	X	X	X	X	X
Basal friction	Linear	X, Inv Adj + Rob	X, Inv Adj	X		
	Weertman	X	X	X		
	Coulomb	X	X	X		
	Budd	X	X	X		
	Tsai		X	X		
Free surface	dS/dt	X	X	X	X	X
	dH/dt	X, Inv	X, Inv	X, Inv	X, Inv	X, Inv
Grounding line	Contact	X				
	Hydrostatic	X	X	X	X	
Calving	Fracture+Damage	2D				
	crevasse depth	X				
Temperature	Temperate	X	X	X	X	X
	Enthalpy	X	X	X	X	X
Hydrology	Two layers	X	X	X		
	<i>GlaDS</i>	X	X	X		



---

# How does it work ?

# Elmer structure



# Sequence of a serial simulation

---

- build a mesh in Elmer format, i.e. a directory containing `mesh.header`, `mesh.nodes`, `mesh.element`, `mesh.boundary`
- fill in a solver input file (`mysif.sif`)
- compile object files linked with Elmer of your user functions and solvers (if needed)
- Execute :  
\$ **ElmerSolver mysif.sif**
- Should create a \*.vtu files (output files in vtu format)
- Visualise :  
\$ **paraview**

# We will see

---

- how to construct a simple mesh
- what is the content of a sif file
- how to execute
- how to visualise the results

---

# How to get a mesh ?

# Different possibilities to get a mesh

---

- use **ElmerGrid** alone
- use **another mesher** (gmsch, gambit) and then transform it in Elmer format - ElmerGrid can do this for many other mesh formats (just launch ElmerGrid without any argument to get list)
- Glacier particularities :
  - Small aspect ratio (horizontally elongated elements)
  - In 3D, mesh a footprint with an unstructured mesh, and then vertically extrude it (externally or internally)

will see this later during the course...

# ElmerGrid

---

- command line tool for mesh generation
- native mesh format: `.grd`
- help : just execute : `$ ElmerGrid`
- possible to import meshes produced by other free or commercial mesh generators (Ansys, Abaqus, Fluent/Neutral, Comsol, **gms**`h`, ...)
- Examples :

```
$ ElmerGrid 1 2 my_mesh.grd
```

```
$ ElmerGrid 14 2 my_gmsh_mesh.msh -autoclean
```

```
$ ElmerGrid 14 5 my_gmsh_mesh.msh -autoclean
```

---

# Solver Input File (sif)



# Example of sif file

---

- Comments start with !
- Not case sensitive
- Avoid non-printable characters (e.g., tabulators for indents)
- A section always ends with the keyword `End` or use `::`
- Parameters not in the Keyword DB need to be casted by types:  
Integer, Real, Logical, String and File
- `Parametername (n,m)` indicates a  $n \times m$  array

- Sections are

- Header
- Constants
- Simulation
- Solver *i*
- Body *i*
- Equation *i*
- Body Force *i*
- Material *i*
- Initial Condition *i*
- Boundary Condition *i*

```
Body Force 1
Heat Source = 1.0
End
```

**OR**

```
Body Force 1 :: Heat Source = 1.0
```

# Example of sif file

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!
!! Elmer/Ice Course - Application Step0 !!
!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Updated May 2011

check keywords warn
echo on

Header
  Mesh DB "." "square"
End

Constants
! No constant needed
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Simulation
  Coordinate System = Cartesian 2D
  Simulation Type = Steady State

  Steady State Min Iterations = 1
  Steady State Max Iterations = 1

  Output File = "ismip_step0.result"
  Post File = "ismip_step0.vtu"
  max output level = 100
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Body 1
  Equation = 1
  Body Force = 1
  Material = 1
  Initial Condition = 1
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Initial Condition 1
  Pressure = Real 0.0
  Velocity 1 = Real 0.0
  Velocity 2 = Real 0.0
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Body Force 1
  Flow BodyForce 1 = Real 0.0
  Flow BodyForce 2 = Real -1.0
End
```

- **Header** declares where to search for the mesh
- If any **constants** needed (i.e. Gas constant)
- **Simulation**
  - Type of coordinate system
  - Steady or Transient
    - If transient: time stepping parameters
  - Output files (to restart a run) and VTU file
  - Output level : how verbose is the code?
  - Restart information (optional)
- In **Body** are assigned the Equation, Body Force, Material and Initial Condition
- In **Initial Condition** sets initial variable values
- In **Body Force** specify the body force entering the right side of the solved equations

# Example of sif file

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Material 1
Density = Real 1.0

Viscosity Model = String "power law"
Viscosity = Real 1.0
Viscosity Exponent = Real 0.33333333333333333333
Critical Shear Rate = Real 1.0e-10
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Solver 1
Equation = "Navier-Stokes"

Stabilization Method = String Bubbles
Flow Model = String Stokes

Linear System Solver = Direct
Linear System Direct Method = umfpack

Nonlinear System Max Iterations = 100
Nonlinear System Convergence Tolerance = 1.0e-5
Nonlinear System Newton After Iterations = 5
Nonlinear System Newton After Tolerance = 1.0e-02
Nonlinear System Relaxation Factor = 1.00

Steady State Convergence Tolerance = Real 1.0e-3
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Equation 1
Active Solvers(1)= 1
End

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Boundary Condition 1
Target Boundaries = 1
Velocity 2 = Real 0.0e0
End

Boundary Condition 2
Target Boundaries = 4
Velocity 1 = Real 0.0e0
End

Boundary Condition 3
Target Coordinates(1,2) = Real 0.0 1.0
Target Coordinates Eps = Real 1.0e-3
Pressure = Real 0.0e0
End
```

- In **Material** sets material properties for the body (can be scalars or tensors, and can be given as dependent functions)
- In **Solver** specifies the numerical treatment for these equations (methods, criteria of convergence,...)
- In **Equation** sets the active solvers
- **Boundary Condition**
  - Dirichlet: Variablename = Value
  - Neumann: special keyword depending on the solver
  - Values can be given as function

# Variable defined as a function

---

1) Tables can be use to define a piecewise linear (cubic) dependency of a variable

```
Density = Variable Temperature
```

```
Real cubic
```

```
0 900
```

```
273 1000
```

```
300 1020
```

```
400 1000
```

```
End
```

Outside range: Extrapolation!

2) MATC: a library for online (in SIF file) numerical evaluation of mathematical functions

```
Density = Variable Temperature
```

```
MATC "1000*(1 - 1.0e-4*(tx-273.0))"
```

or as constant expressions

```
Viscosity Exponent = Real $1.0/3.0
```

Evaluated every time

Evaluated once

3) Build your own user function

```
Density = Variable Temperature
```

```
Procedure "filename" "proc"
```

*filename* should contain a shareable (.so on Unix) code for the user function

whose name is *proc*

# Example of User Function

---

in the filename.F90 file :

```
FUNCTION proc( Model, n, T ) RESULT(dens)
USE DefUtils
IMPLICIT None
TYPE(Model_t) :: Model
INTEGER :: n
REAL(KIND=dp) :: T, dens

    dens = 1000*(1-1.0d-4 *(T-273.0_dp))

END FUNCTION proc
```

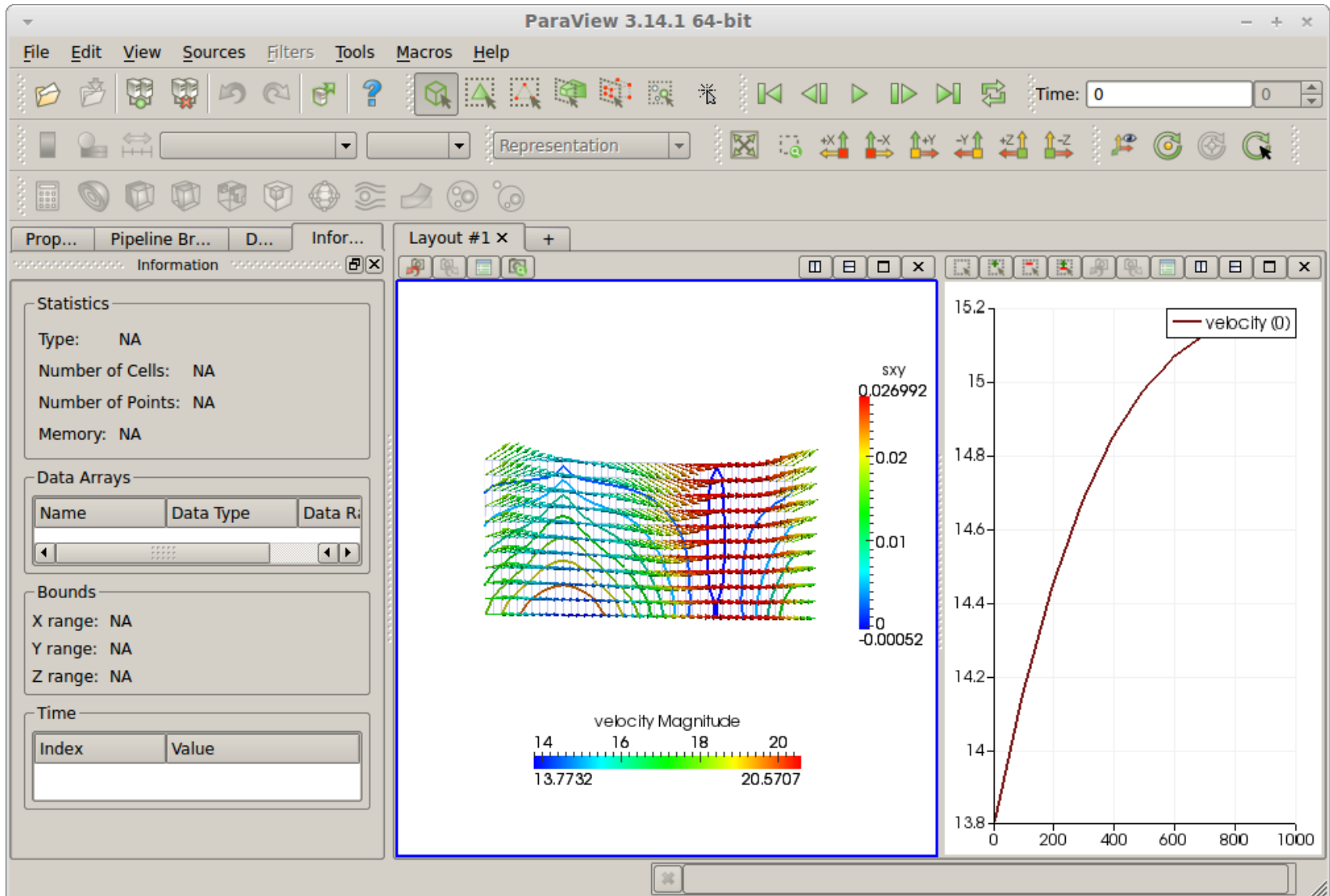
Compilation tools: `elmerf90`

```
$ elmerf90 filename.F90 -o filename.so
```

---

# How to visualise results

# Paraview



# ASCII Based Output

- SaveScalars e.g. CPU time, mean, max, min of a variable, Flux
- SaveLine save a variable along a line (boundary or a given line)
- SaveMaterials save a material parameter like a variable

Example:

```
solver 3
  Exec Solver = After All
  Procedure = File "SaveData" "SaveLine"
  Filename = "ismip_surface.dat"
  File Append = Logical False
End

solver 4
  Exec Solver = After TimeStep ! For transient simualtion
  Procedure = File "./MySaveData" "SaveScalars"
  Filename = "ismip_scalars.dat"
  File Append = Logical True ! For transient simualtion

  Variable 1 = String "Flow Solution"
  Operator 1 = String "Volume"

  Variable 2 = String "Velocity 1"
  Operator 2 = String "Max Abs"

  Variable 3 = String "Flow Solution"
  Operator 3 = String "Convective flux"

  Variable 4 = String "cpu time"

  Variable 5 = String "cpu memory"
End
```

```
! Upper Surface
Boundary Condition 3
  Target Boundaries = 3
  Save Line = Logical True
  Flux integrate = Logical True
End
```