



Beginner's Course 2022

Introduction

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contributions from Peter RABACK⁽²⁾, Fabien GILLET-CHAULET⁽³⁾, Olivier GAGLIARDINI⁽³⁾

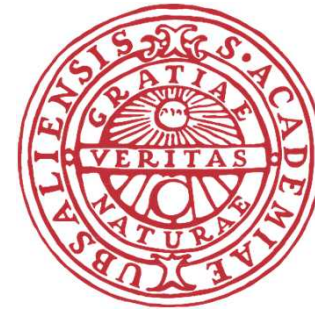
(1) University of Lausanne - Switzerland

(2) CSC - IT Center for Science Ltd. – Espoo – Finland

(3) University Grenoble – IGE -France

Thanks to ...

- **University of Uppsala**, Rickard Pettersson
- **Academy of Finland** (project COLD) and **CSC-IT Center for Science** supporting Thomas Zwinger's travel and stay
- **UNIL** for supporting Samuel Cook's travel and stay
- **You** for being here



UNIL | Université de Lausanne



**ACADEMY
OF FINLAND**

Program

Day 1, Oct. 24th - Introduction + Synthetic Glacier

- **09:00** – 10:30 Welcome and introduction to Elmer/Ice + SIF crash course
- 10:30 – 11:00 Break
- 11:00 – 12:30 Synth Glacier Step 1
- 12:30 – 13:30 Lunch
- 13:30 – 14:30 Synth Glacier Step 2
- 14:30 – 15:00 Break
- 15:00 – **16:00** Synth Glacier Step 3

Day 2, Oct. 25th – Case Midtre Lovénbreen (MLB)

- **09:00** – 10:30 Diagnostic runs
- 10:30 – 11:00 Break
- 11:00 – 12:00 Numerical optimization
- 12:00 – 13:00 Lunch
- 13:00 – 14:30 SMB and Relaxation
- 14:30 – 15:00 Break
- 15:00 – **16:00** Discussion and wrap-up

Elmer and Elmer/Ice



- **Elmer** (= multi-physics package) with additional routines for Glaciology
- Maintained and supported by **CSC**
- **Open Source** (GPL2 or later)
 - Transparency (you co-own the code)
 - Sustainability (no license fees)
 - Viral effect of GPL (new code also GPL)
 - Linking to library allowed under LGPL
- Large international user community
 - Knowhow of well-established institutions
- Good level of support/documentation
<http://elmerice.elmerfem.org>

- 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 their development is supported by various groups and funding...



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NordForsk



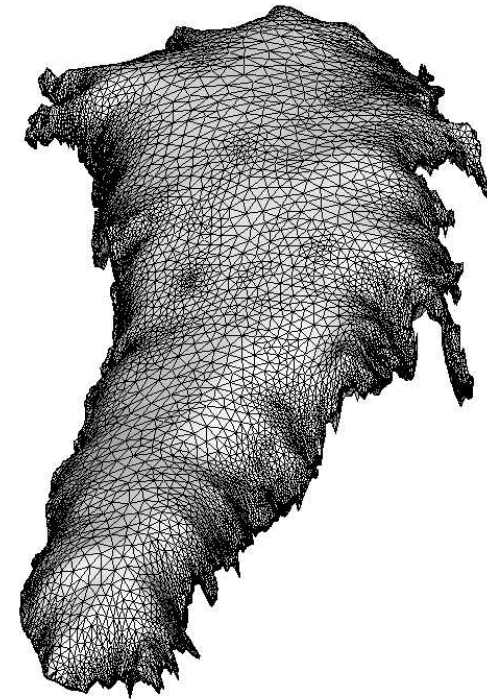
Tipping Points in Antarctic
Climate Components



Elmer/Ice



- **Full-Stokes** (also SIA and SSA) with post processing for stress/strain
- **Mesh:** Unstructured, vertically extruded, deforming and moving meshes
- **Temperature** solver accounting for pressure melting point or Enthalpy solver
- **Rheology:** Glen, anisotropy, firn densification, damage mechanics
- Special **sliding laws:** Weertman, Coulomb, Budd, Tsai
- Basal **hydrology** models (2): GlaDS and double continuum
- **NetCDF**-readers (for geometry as well as coupling to climate)
- Simple SMB (**PDD**)
- **Calving** models (3 approaches)
- **Inverse methods** for data assimilation
- Methods for **tracer transport/dating**



Elmer/Ice

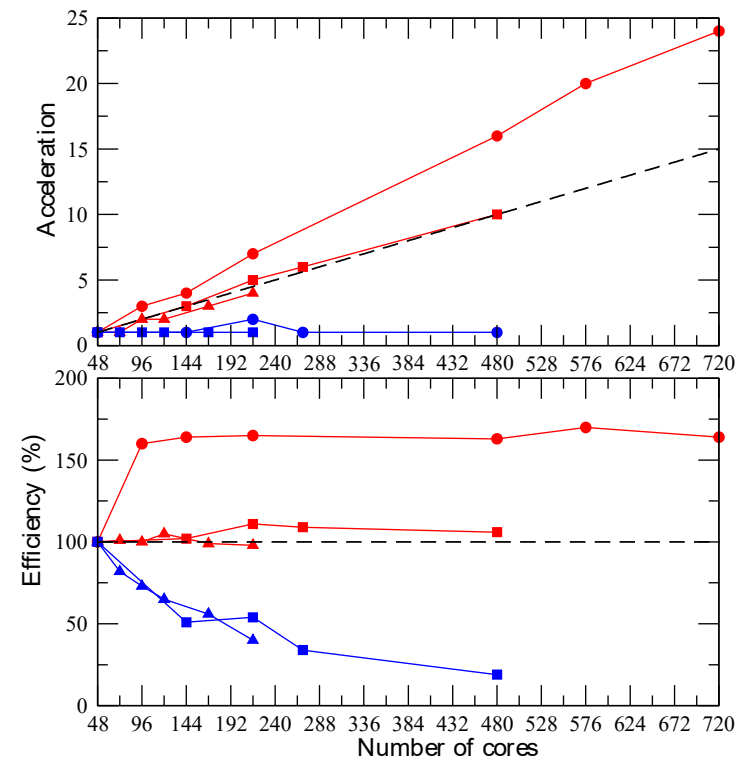


	Flow equations	Stokes	SSA	SSA*	SIA	ISCAL
Rheology	Glen	X, Inv Adj + Rob	X, Inv Adj	X	X	X
	GOLF	X				
	CAFFE	X				
	POROUS	X				
	Damage	X	X	X	X	X
Basal friction	Linear	X, Inv Adj + Rob	X, Inv Adj	X		
	Weertman	X	X	X		
	Coulomb	X	X	X		
	Budd	X	X	X		
	Tsai		X	X		
Free surface	dS/dt	X	X	X	X	X
	dH/dt	X, 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		

Elmer/Ice

- Finite element method (FEM)
 - Using linear elements and standard Galerkin with Stabilized Finite Elements or residual free bubbles
- Flow law → viscosity changes by order of magnitudes → bad conditioned system:
 - Direct parallel or tuned block-preconditioned iterative Solver
- (Large scale) parallel computing
 - MPI
 - OpenMP multi-threading and vectorization (SIMD)
 - Currently working towards GPUs (AMGX)

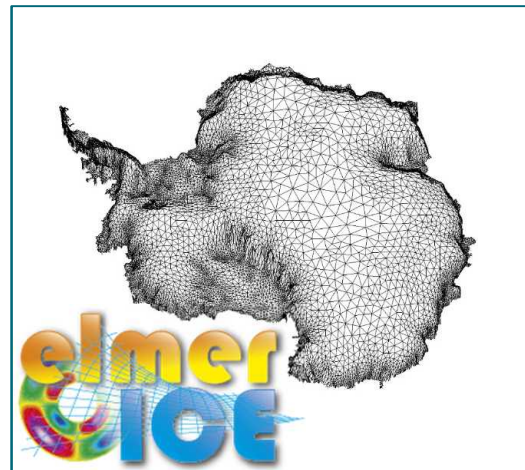
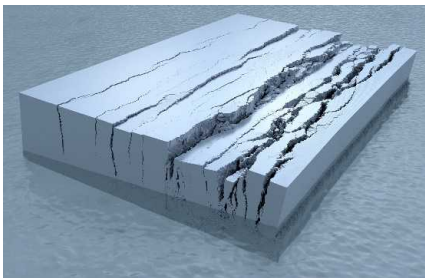
Elmer/Ice Beginner's Course, 2022, Uppsala



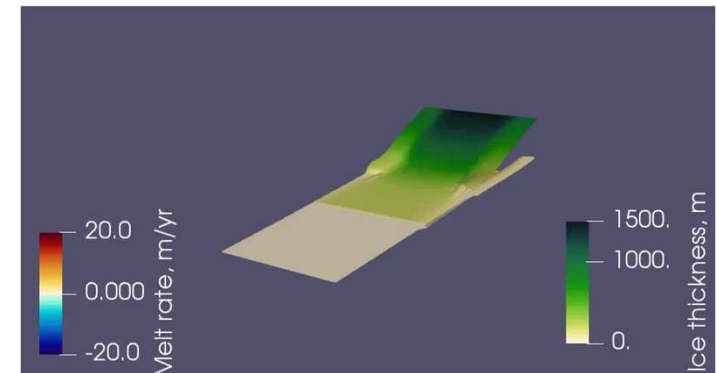
Gagliardini, O., T. Zwinger, F. Gillet-Chaulet, G. Durand, L. Favier, B. de Fleurian, R. Greve, M. Malinen, C. Martín, P. Råback, J. Ruokolainen, M. Sacchetti, M. Schäfer, H. Seddik, and J. Thies, 2013. *Capabilities and performance of Elmer/Ice, a new-generation ice sheet model*, Geosci. Model Dev., 6, 1299-1318, doi:[10.5194/gmd-6-1299-2013](https://doi.org/10.5194/gmd-6-1299-2013).

Elmer/Ice – coupling to other (Elmer) components

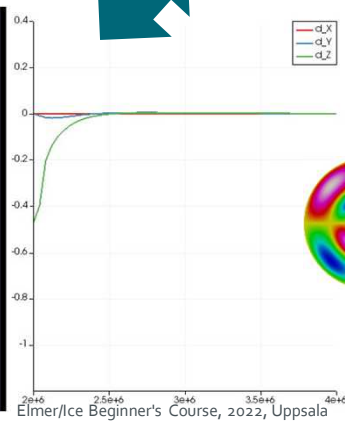
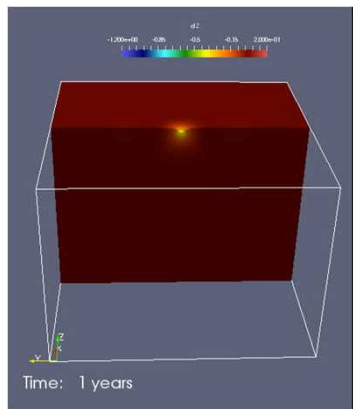
Calving - DEM (HiDEM)



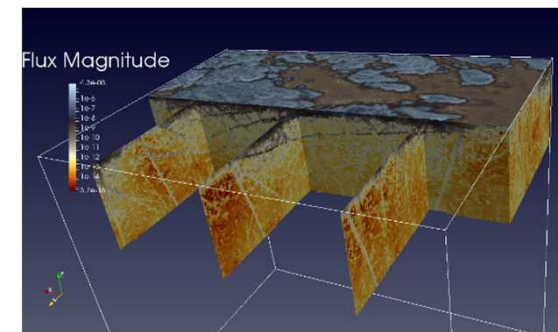
Ice-ocean coupler (FISOC)



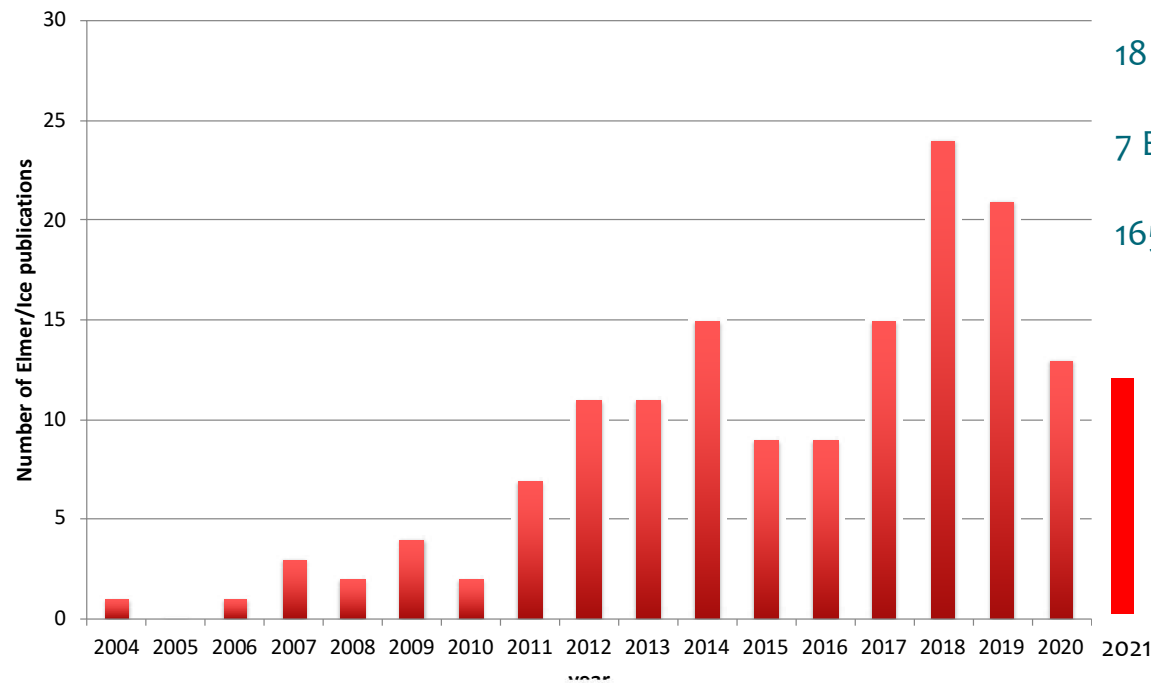
Glacial isostasy – VE model



Groundwater and Permafrost model



Elmer/Ice -Community



18 Courses ~ 380 participants

7 Elmer/Ice users meetings

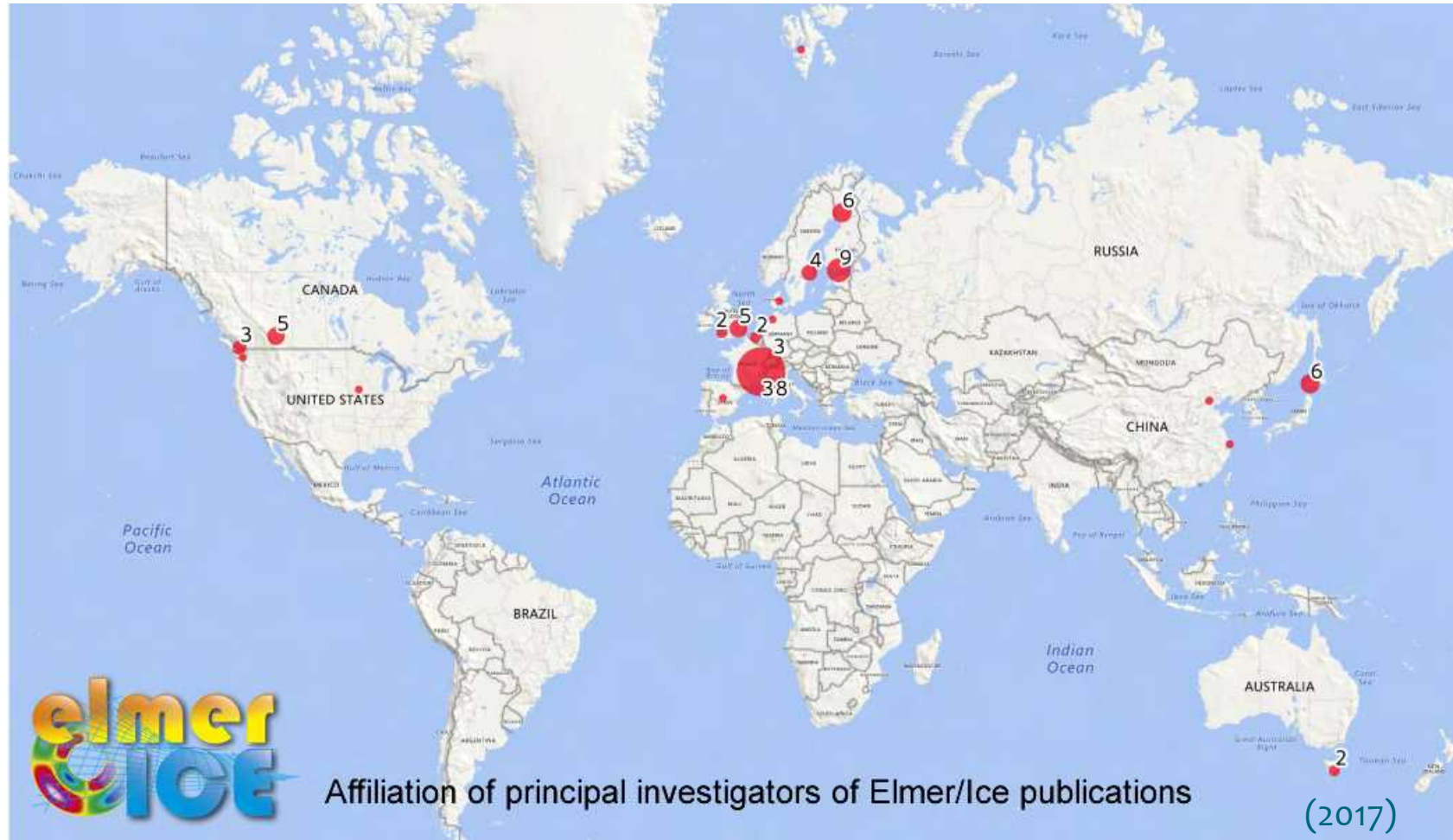
165 publications

Publication count 23.10.2022: **193**

Elmer/Ice Peer Reviewed Publications

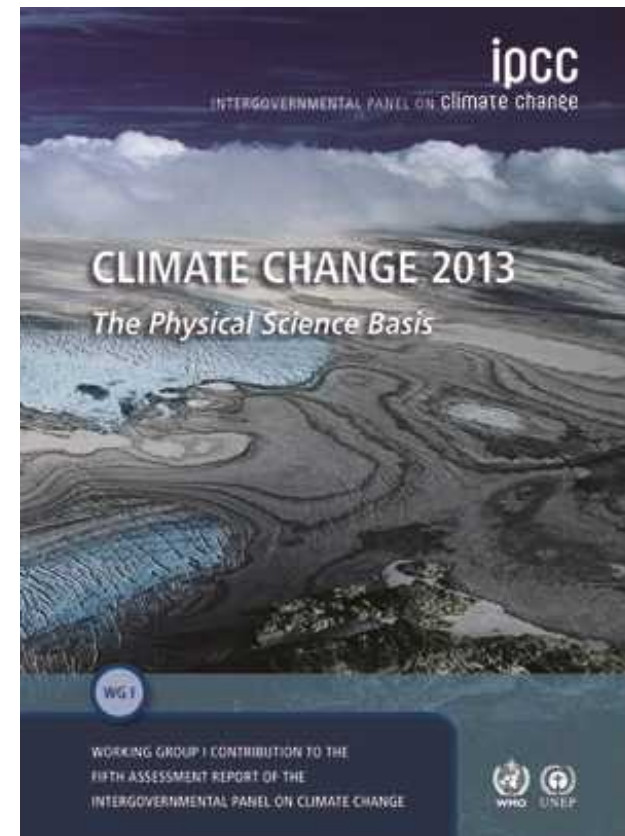
Here is the list of peer-reviewed papers presenting developments or applications using Elmer/Ice. A list for the other publications (mainly Phd thesis) can be found on the Elmer/Ice wiki. Currently we are counting **193 articles** since 2004.

Elmer/Ice -Community



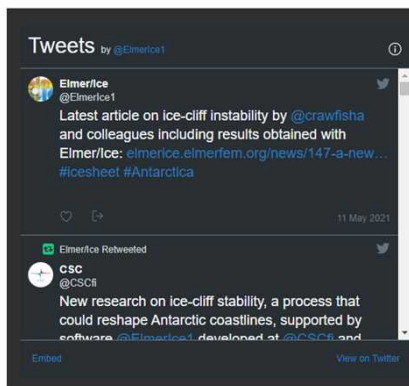
Elmer/Ice -Community

- Used in many applications
 - Antarctica, Greenland, ice-caps and glaciers
 - Used by institutions all over the planet
- 164 peer reviewed articles:
<https://elmerice.elmerfem.org/publications>
- Elmer/Ice contributed with cited articles in the IPCC AR5 (2013) and IPCC AR6 /WG1 (2021)



Elmer/Ice - Community

- Community web-portal: <http://elmerice.elmerfem.org>
 - Latest news
 - List of publications
 - Forum (see later)
 - Courses (indirect link to Wiki)
 - Direct link to Wiki
- Some integration with social media (Twitter)



Elmer/Ice

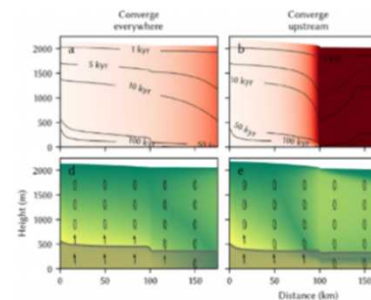
Open Source Finite Element Software for Ice Sheet, Glaciers and Ice Flow Modelling

Elmer/Ice is a full-Stokes, finite element, ice sheet / ice flow model. The aim of this website is to present the capabilities of Elmer/Ice and to distribute course materials and tutorials.

Elmer/Ice is an add-on package to **Elmer**, which is a multi-physics FEM suite mainly developed by CSC-IT Center for Science Ltd., Espoo, Finland. Initially started by CSC, IGE and ILTS, currently multiple institutions and individuals contribute to the development of Elmer/Ice.

WRITTEN BY OLIVIER GAGLIARDINI.

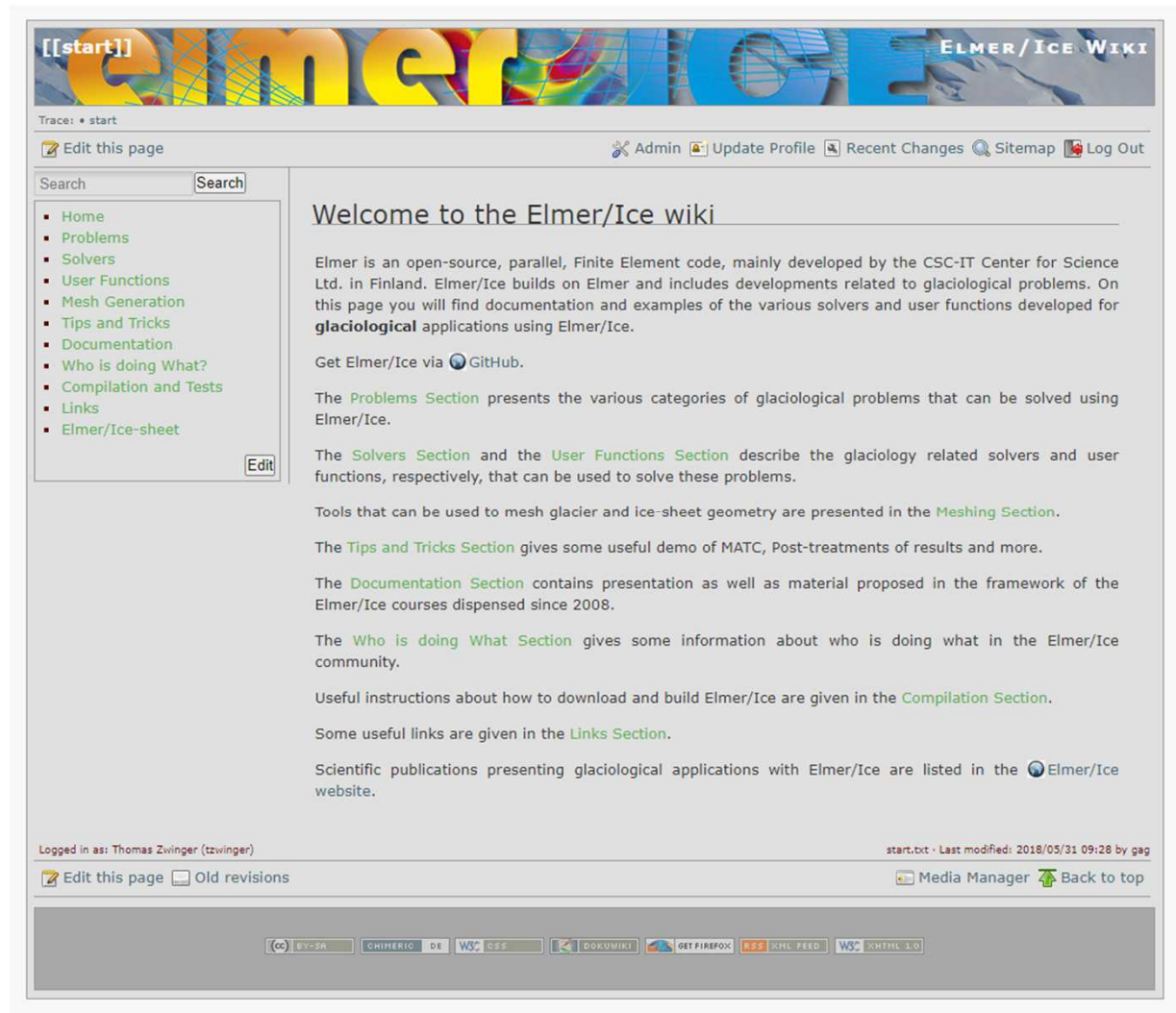
Modeling Ice-Crystal Fabric as a Proxy for Ice-Stream Stability



Glacier ice is composed of individual grains, or crystals. These grains can have different orientations, similar to how a pile of snow has many flakes all pointing in different directions. When ice accumulates as snowfall, the grains point in approximately random directions. However, as glaciers move, the orientation of the grains is changed, leading to characteristic "fabrics," where the grains tend to point in distinctive directions. Here, we try to understand how one could work backwards, from the orientation of the grains, to determine how the ice flowed in the past. We use an ice-flow model to understand whether instabilities in ice streams, "rivers" of fast flowing ice in Greenland and Antarctica, would be recorded in the fabric. We find that changes in ice-stream flow could indeed be seen in the fabric for thousands or tens of thousands of years, depending on the exact type of change. We then show that these changes to fabric are large enough that they could be measured in ice cores or with specialized ice-penetrating radars. This helps lay the groundwork for better understanding of long-term

Elmer/Ice -Community

- Elmer/Ice wiki:
 - <http://elmerfem.org/elmerice/wiki>
 - Or use link indicated at previous slide
- Contains documentation on Solvers, Userfunctions and also methods
 - We are porting documentation of software to GitHub (see following slides)
- Contains also material of courses



The screenshot shows the Elmer/Ice Wiki homepage. At the top, there is a banner with the text "[[start]]" and "ELMER/ICE WIKI". Below the banner, there is a navigation bar with links for "Admin", "Update Profile", "Recent Changes", "Sitemap", and "Log Out". A search box is located on the left side of the page. The main content area is titled "Welcome to the Elmer/Ice wiki" and contains several paragraphs of text. The text describes Elmer/Ice as an open-source, parallel, Finite Element code, mainly developed by the CSC-IT Center for Science Ltd. in Finland. It also mentions that Elmer/Ice builds on Elmer and includes developments related to glaciological problems. The text further explains that the page will find documentation and examples of the various solvers and user functions developed for glaciological applications using Elmer/Ice. There are several sections mentioned, such as "Problems Section", "Solvers Section", "User Functions Section", "Meshing Section", "Tips and Tricks Section", "Documentation Section", "Who is doing What Section", and "Compilation Section". The text also mentions that useful instructions about how to download and build Elmer/Ice are given in the "Compilation Section". Some useful links are given in the "Links Section". Scientific publications presenting glaciological applications with Elmer/Ice are listed in the "Elmer/Ice website". At the bottom of the page, there is a footer with the text "Logged in as: Thomas Zwinger (tzwinger)" and "start.txt · Last modified: 2018/05/31 09:28 by gag". There are also links for "Edit this page", "Old revisions", "Media Manager", and "Back to top". At the very bottom, there are several logos for various services, including CC BY-SA, CHIMERIC, DE, WY, CSC, DOKUWIKI, GET FIREFOX, RSS, XML FEED, and W3C XHTML 1.0.

Elmer/Ice Forum



Either via previous link or

<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

FORUMS	TOPICS	POSTS	LAST POST
General General discussion about Elmer	682	2967	Derivation magnetic co-energy by Itnschlgr Yesterday, 23:51
Installation & compilation Discussion about building and installing Elmer	359	1909	Re: ubuntu packages on lounch... by raback 30 Oct 2020, 16:51
ElmerSolver Numerical methods and mathematical models of Elmer	1943	9714	Re: Anisotropic electric cond... by raback Yesterday, 12:54
ElmerGUI The graphical user interface of Elmer	399	1970	Re: FreeCAD .step file doesn'... by Gary R 31 Oct 2020, 02:35
ElmerPost Post processing utility for Elmer	125	528	Re: Some artefacts (nodal for... by mabor 08 Jul 2020, 00:33
Elmer/Ice Extension of Elmer in computational glaciology	96	426	Re: Adding a Thermally Active... by alden Yesterday, 01:12
External tools Mesh generators, CAD programs, and other tools	190	926	Re: Meshing the flow but not ... by Gary R 31 Oct 2020, 20:33
Software development Discussion about coding and new developments	72	309	Re: Setting values to specifi... by hisham.noaman 19 Oct 2020, 17:42
Bug reports Clearly defined bug reports and their fixes	164	519	Re: Simple Hexahedral Mesh No... by gschrank Yesterday, 06:02
Contributed Cases Elmer cases by the users for the users	37	128	Re: Modelling Acoustics with ... by CrocoDuck 19 Jun 2020, 21:40
HPC High Performance Computing with Elmer	11	32	Pointer to -> HPC Europa3 cal... by raback 30 Jan 2020, 21:47
Commerical services A forum for commercial service requests and offerings	9	11	rdw.fi - when ever you are re... by joni 12 Feb 2019, 11:08

Elmer/Ice -Community

- Elmer source code:
- Elmer/Ice specific files in subdirectory `elmerice`
- Elmer/Ice specific developments in branch `elmerice`
 - We merge frequently between the main branch (`devel`) and `elmerice`-branch
- Porting documentation to GitHub
 - `elmerice/Solvers/Documentation`
 - `elmerice/UserFunctions/Documentation`

<https://github.com/ElmerCSC/elmerfem>



The screenshot shows the GitHub repository page for `ElmerCSC/elmerfem`. The repository is public and has 96 watchers, 607 stars, and 204 forks. The `elmerice` branch is selected, which is 12 commits ahead and 44 commits behind the `devel` branch. A recent commit by `fgillet` is highlighted, titled "Update Optimize_m1qn3Parallel.F90". Below the commit, a list of files and folders is shown with their respective update dates:

File/Folder	Description	Last Update
IceSheet	Elmerice inverse methods	12 months ago
Meshers	Update MeshToShp.py	3 months ago
ReleaseNotes	Update release_elmerice_9.0.md	12 months ago
Solvers	Update Optimize_m1qn3Parallel.F90	16 hours ago
Tests	Update Thickness solver documentation	6 days ago
UserFunctions	Added routine for interpretation of lin. Weertman in terms of regular...	5 months ago
cmake	Fix misc. typos in ./elmerice, ./utils, and ./cmake	2 years ago
examples	Move SaveGridDataNetCDF test case to examples for now	4 months ago
CMakeLists.txt	added permafrost functionality from permafrost-merge branch	2 years ago

Elmer/Ice -Community

- Subscribe to the **Elmer/Ice mailing list**:
- Low activity list, but important information
 - Bug reports
 - version updates
 - new publications
- Currently 71 members

http://mail.elmerfem.org/mailman/listinfo/elmerice_elmerfem.org

Elmerice -- Elmer/Ice mailing list

About Elmerice English (USA)

Official mailing list for news on Elmer/Ice

To see the collection of prior postings to the list, visit the [Elmerice Archives](#). *(The current archive is only available to the list members.)*

Using Elmerice

To post a message to all the list members, send email to elmerice@elmerfem.org.

You can subscribe to the list, or change your existing subscription, in the sections below.

Subscribing to Elmerice

Subscribe to Elmerice by filling out the following form. You will be sent email requesting confirmation, to prevent others from gratuitously subscribing you. Once confirmation is received, your request will be held for approval by the list moderator. You will be notified of the moderator's decision by email. This is also a hidden list, which means that the list of members is available only to the list administrator.

Your email address:

Your name (optional):

You may enter a privacy password below. This provides only mild security, but should prevent others from messing with your subscription. **Do not use a valuable password** as it will occasionally be emailed back to you in cleartext.

If you choose not to enter a password, one will be automatically generated for you, and it will be sent to you once you've confirmed your subscription. You can always request a mail-back of your password when you edit your personal options.

Pick a password:

Reenter password to confirm:

Which language do you prefer to display your messages? English (USA)

Would you like to receive list mail batched in a daily digest? No Yes

Elmerice Subscribers

(The subscribers list is only available to the list administrator.)

Enter your admin address and password to visit the subscribers list:

Admin address: Password:

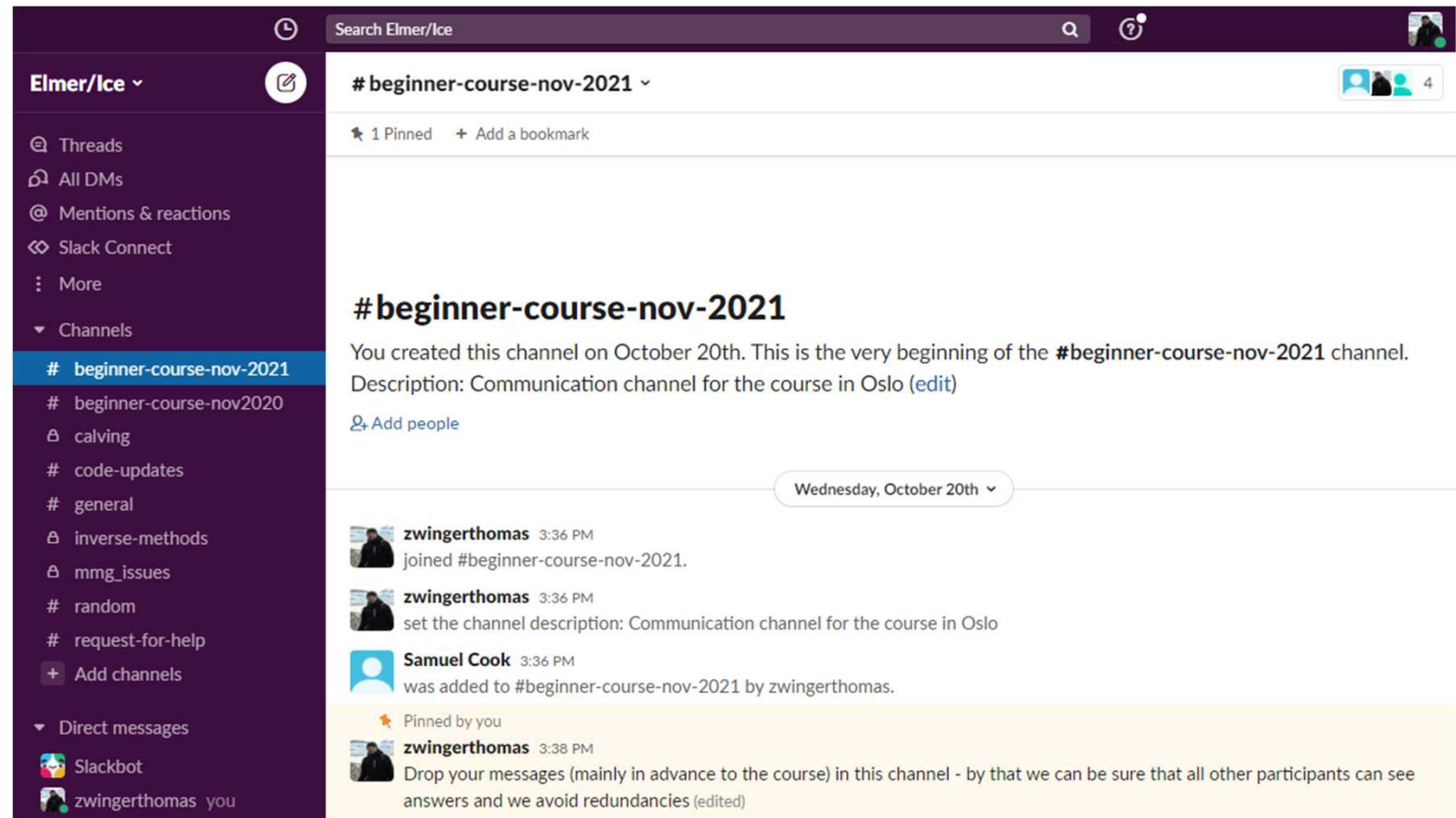
To unsubscribe from Elmerice, get a password reminder, or change your subscription options enter your subscription email address:

If you leave the field blank, you will be prompted for your email address

Elmer/Ice -Community

- **Elmer/Ice slack space**

- You should have received an invitation to join
- Can be used to ad-hoc communicate, particularly, in advance and during courses
- Is used by some members afterwards
- Main technical questions: please put them to the Forum, rather than in Slack! Thereby they can be looked up by a wider range of users.



The screenshot shows a Slack interface for the channel '# beginner-course-nov-2021'. The left sidebar lists various channels and direct messages. The main content area shows the channel description: 'You created this channel on October 20th. This is the very beginning of the #beginner-course-nov-2021 channel. Description: Communication channel for the course in Oslo (edit)'. Below the description, a date separator indicates 'Wednesday, October 20th'. The message history includes:

- zwingerthomas (3:36 PM) joined #beginner-course-nov-2021.
- zwingerthomas (3:36 PM) set the channel description: Communication channel for the course in Oslo
- Samuel Cook (3:36 PM) was added to #beginner-course-nov-2021 by zwingerthomas.
- A pinned message by zwingerthomas (3:38 PM) reads: 'Drop your messages (mainly in advance to the course) in this channel - by that we can be sure that all other participants can see answers and we avoid redundancies (edited)'.

Useful Links

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

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

<https://www.csc.fi/web/elmer>

- Elmer (and thereby Elmer/Ice) source code

<https://github.com/ElmerCSC/elmerfem>

- Elmer Forum

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

- Elmer/Ice webpage

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

- Elmer/Ice wiki

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

About 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
- **Expected outcome of this course :**
 - giving you a kick-start with Elmer/Ice
 - some possible fruitful collaborations to begin
- **Conduct:**
 - No CoVID19 restrictions are at place – just do not come to the course if you are feeling sick (common sense)