natESM Land-ice component

Anlass / Besprechungsthema

KickOff natESM land-ice component

Tagungsort

Online
Zoom-Link

Moderation

Thomas Jung & Kira Rehfeld

Memo

The participants; basic key points were provided by project assistant Maria Rompe.

Beginn

25.10.23, 09:00 Uhr

Ende

25.10.23, 12:10 Uhr

	Last name	First name	Affiliation	Comments
1	Aizinger	Vadym	Uni Bayreuth	
2	Albrecht	Torsten	PIK	PISM presentation I
3	Ehlert	Iris	DKRZ	natESM process coordinator
4	Fürst	Johannes	FAU Erlangen	
5	Garbe	Julius	PIK	
6	Humbert	Angelika	AWI	ISSM presentation I
7	Jung	Thomas	AWI	natESM steering-group member
8	Kapsch	Marie	MPI-M	
9	Kleiner	Thomas	AWI	
10	Kreuzer	Moritz	PIK	
11	Marotzke	Jochem	MPI-M	natESM steering-group member
12	Marzeion	Ben	Uni Bremen	
13	Müller	Ralf	TU Darmstadt	
14	Rehfeld	Kira	Uni Tübingen	natESM steering-group member
15	Robinson	Alexander	AWI	
16	Rodehacke	Christian	AWI	
17	Rompe	Maria	DKRZ	natESM project assistant
18	Rückamp	Martin	BADW	ISSM presentation II
19	Schannwell	Clemens	MPI-M	PISM presentation II

PLEASE NOTE: This document is not a protocol and does not depict the specific sequence of discussions during our KickOff. Instead, its purpose is to capture the most significant outcomes for the implementation of a natESM land-ice component.

Agenda

9:00	Welcome	Thomas Jung & Kira Rehfeld
	Tour de table	
	Overview of natESM	Iris Ehlert
9:30	Presentations of possible natESM land-ice components	
	1. Ice sheet modeling using the Ice Sheet and Sea Level System Model ISSM	Angelika Humbert (AWI)
	2. Modeling of Alpine Glaciers in the Earth System with ISSM	Martin Rückamp (BADW)
	3. Ice sheet modeling with PISM	Torsten Albrecht (PIK)
	4. Using PISM to account for dynamic ice-sheet changes in long-term ESM simulations	Clemens Schannwell (MPI-M)
10:40	Open discussion	
	Next steps	Kira Rehfeld
12:10	End of workshop	

1 Introduction

As part of the natESM initiative, we invited the German land-ice community to a KickOff meeting to discuss the possibilities to implement a land-ice component into the natESM framework. Feedback indicated that **two ice-sheet models are currently in use and being further developed within the German community: ISSM and PISM**, both originating in the USA.

ISSM

- Used for large-scale polar ice sheets Greenland/ Antarctica; also for small-scale glaciers
- Data assimilation (“inversion”)
- Capability for sea-level fingerprints
- Works on unstructured grids
- Primarily use and development at AWI
- Further developers and users at TU Darmstadt (TUD), Bayerische Akademie der Wissenschaften (BAdW), DLR
- Code parts are developed, written and find submission in main branch
- Performance analysis existing

PISM

- Used for large-scale polar ice sheets and regional studies, tipping point analysis, ensembles and sea-level projections, easily coupled to other models, covered period in various studies: deep time (snowball earth) to long-term future
- Capability for sea-level fingerprints (VILMA coupling)
- Works on structured grids
- Primarily use and development at PIK (open repository at github)
- Broad developer and user base around Germany (user manual and code documentation)
- Performance analysis and scaling tests on various HPC systems exist

2 Discussion

- **Exascale-readiness**: At the moment, researchers are focusing on knowledge-based issues. GPU vs. CPU has often been discussed but then decided against. Instead, the decision was to proceed with parallelization on CPUs.
  - → would need some re-writing of some code (apply for support through natESM-Sprint?), fundamental is PETSc's GPU capability
  - → 2 options:
    1. rewriting code to optimize for GPUs;
    2. focus on parallelization on CPUs.
  - → mixed-architecture usage
    1. ISSM: decided against GPU development (at the moment)
    2. PISM: done some tests, decided to stay with CPU (parallelize more)
  - → GPU-development in future also concerns energy efficiency and costs
- **Usage in Germany**: PISM is integrated into several ESMs.
- **Complexity of the code**: ISSM provides a greater variety of dynamics formulations, including full Stokes solver
- Mountain glaciers have different requirements to the stress balance approximation than large ice sheets, due to the different aspect ratio
- High resolution of ice sheet models is very important for ice sheets (in particular at margins, grounding lines) and mountain regions. Currently a big problem/gap.
- natESM needs a sufficiently large impact on the model (core developer) to design and apply sustainably.
- Resolution requirements and bias in forcing data coming from ESM need to be addressed.
- To get ice sheets right on long time scales, ice-sheet spreading/retreating needs to be simulated correctly (weak point so far).
- Need more intense exchange between RSEs and modelers about technical aspects of the model code

Zoom-chat contributions

Angelika Humbert: What my group has developed for ISSM is available to all users. Greenland well resolved and in higher-order approximation 30 million DOF.

Christian Rodehacke: PISM uses PETSC library to solve the model equations. PetSC is currently adding GPU support for "NVIDIA using CUDA, and AMD and Intel using OpenCL/ViennaCL and HIP" So it might be easier in the future for PISM.

Angelika Humbert: ISSM is also using PETSc.

Iris Ehlert: Links to our latest newsletter, our sprint website, a list of the already accepted sprints, and the template to apply for a full sprint.

3 Questions that arose during the discussion

1. What are the conditions for the various approximations to hold? What do you need for what?
2. How good can the models be if we put some work in it (GPU optimization)?

3. Which critical resolutions do we need to be able to represent processes well?
4. How big is the problem (from the technical side)?
5. What are the critical physical properties that models have/need? Could we cover all issues with "just" 2 models –or are there more?
6. What are the different "philosophies" behind ISSM and PISM? What is best for what?
7. Does an ice-sheet model need to run on this unlimited number of cores (tens of thousands)?
8. Has anyone ever done a performance study to see if a bottleneck exists?
9. **Coupling to other components**: If models (atmosphere/ocean) run on GPU, is it then a problem if Ice sheet runs on CPU? Could ice-sheet models be a bottleneck?
10. Technical open issue: How will it look in the future with computers running on CPU?
11. **General: Do we want a model (from the US) and develop it further OR do we want expertise and develop an own model ?**

4 What are the strategic development priorities for ISSM and PISM?

- ISSM: priority in scientific questions: subglacial hydrology, calving laws, data assimilation
- PISM: high(er) resolution, ENSEMBLE predictions, efficiency gain via edge conditions
- General boundary conditions, regional patterns and differences for ice sheets

5 Open question: What is the most urgent problem/issue that should be solved concerning ice-sheet modeling / ESM?

→ HELP for code adaptation/ further developments on technical level: natESM Sprints or Sprint checks: https://www.nat-esm.de/services/support-through-sprints
Possible sprints:
  - PISM-FESOM coupling: make more efficient
  - Parallel I/O
  - ISSM/PISM: adapting to GPUs
  - Using YAC for coupling

→ Out-of-the-box-solutions ARE existing for different issues at Universities, but the link/ collaboration is still missing (and also the knowledge gap of what is existing) [Vadym Aizinger]

6 Conclusion / Next steps

- Outcome of the KickOff: suggestion of a NEW natESM working group focusing on land-ice component → Kira and Thomas as initial working-group leaders need to formulate a working-group proposal together with interested participants.
- Find answers to the open questions wrt the presented (and more?) models (Comparison-Matrix)
  → For PISM/ISSM
  → Also for CISM/ COSIPY?

→ Next meeting of the group during the natESM Community WS on 27/28.2.2024: https://www.nat-esm.de/services/trainings/events/ws_february2024 [Registration is now possible]

- New natESM Mattermost-Channel for the land-ice-component working group established (to join us on Mattermost klick here (or read our latest newsletter))

Feel free to invite individuals from your institution or universities if you believe they might be interested in joining the working group. Please inform the working-group leaders Thomas Jung and Kira Rehfeld (cc info@nat-esm.de).

7 Comparison Matrix

	ISSM	PISM
Development country	USA, Germany (AWI, BAdW, 12)	USA; Germany (PIK)
Users/Community in Germany	AWI, BAdW, DLR, TUD	PIK, MPI-M, AWI, MARUM, Uni Munich
Mesh	Unstructured grid (prism elements, triangular in horizontal direction), adaptive mesh capabilities available, in vertical direction higher order (P3) elements available	Structured Cartesian grid, quadratically varying resolution in the vertical
Resolution	variable, highest resolution for Greenland 250 m	up to 1 km for Antarctica, up to 0.45 km for whole Greenland
Stress balance model	Full Stokes (3D), Blatter-Pattyn, SSA, SIA	SIA-SSA hybrid (2D), Blatter-Pattyn (3D)
Code language	C++	C++
Thermal module	Aschwanden et al 2012	enthalpy based: Aschwanden et al. (2012)
SMB module	diverse, e.g. PDD, SEMIC, Evatt et al. 2017	dEBM-simple (Zeitz et al, 2021; Garbe et al, 2023), PDD
Moving front module	level set method, various calving laws, including von Mises, eigencalving, crevasse depth data assimilation of calving front	subgrid scale front motion: Albrecht et al. (2011), eigencalving for ice shelves: Levermann et al. (2012) and other calving methods (e.g. von Mises for outlet glaciers)

Mass transport module	ice thickness evolution equation, evolution of surface and base by kinematic boundary conditions (for full Stokes) data assimilation (inverse modeling) of surface elevation change	mass conserving upwind transport: Winkelmann et al. (2011), Eq. 18
Grounding line module	sub-grid schemes for basal friction and ice shelf basal melt, contact scheme for full Stokes	sub-grid interpolation for basal friction, two-sided driving stress scheme: Feldmann et al. (2014)
Used/ planned couplers	ISSM-MITgcm code intrinsic coupling, ESMF, preCICE (online coupling) / YAC, RANGO	used in MPI-ESM, AWI-ESM , EC-Earth , NASA/GISS ModelE, POEM, MAR offline coupling realized via python coupler, YAC coupling intended
Complies techn. Criteria of natESM?	detailed overview given on slides	all, as demonstrated on slides
Exascale-ready?	Not yet exascale-ready.	Good scaling for high resolution applications up to several 1000 CPU cores, further optimization with regard to domain composition, GPU possible, or implicit time stepping: Bueler & Farrell, (preprint)? Not yet exascale-ready.
Performance analysis	available, Fischler et al., 2022 GMD	e.g., Bueler et al., 2022
GIA (domain-wide)	point-wise, Lingle-Clark (E. Bueler, C. S. Lingle, and J. A. Kallen-Brown, 2007)…	point-wise isostatic, Lingle-Clark (Bueler et al., 2007), given (e.g., coming from VILMA), or offline coupled to global VILMA