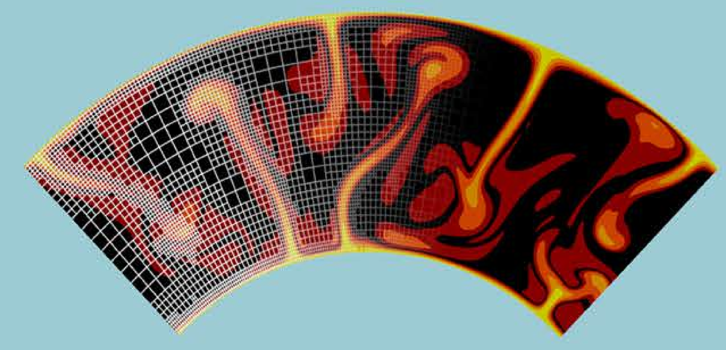
# Developing a 3D glacial isostatic adjustment modeling code using ASPECT

M.F.M. Weerdesteijn[1], C.P. Conrad[1], K. Selway[2], J. Naliboff[3], R. Gassmöller[4]
Contact: m.f.m.weerdesteijn@geo.uio.no
[1] Centre for Earth Evolution and Dynamics, University of Oslo, Oslo, Norway
[2] Department of Earth and Planetary Sciences, Macquarie University, Sydney, Australia
[3] New Mexico Institute of Mining and Technology, USA
[4] Department of Geological Sciences, University of Florida, USA

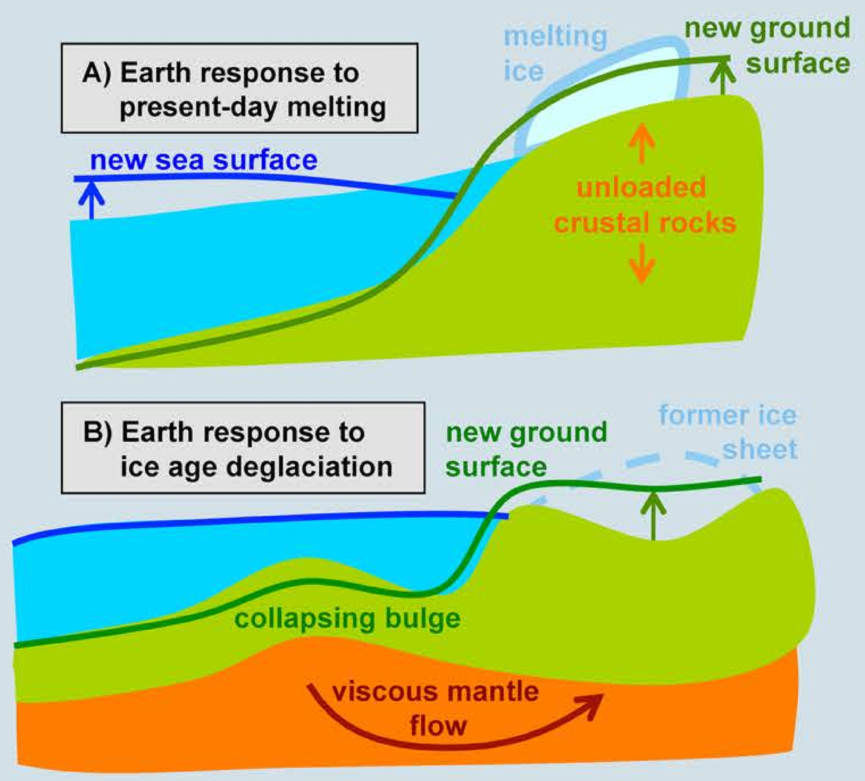
CIG COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

ASPECT



## 1. INTRODUCTION AND GOAL

Glacial isostatic adjustment (GIA)
=
solid Earth response to surface load changes by ice and ocean water
+
gravitationally consistent redistribution of seawater across the global ocean.



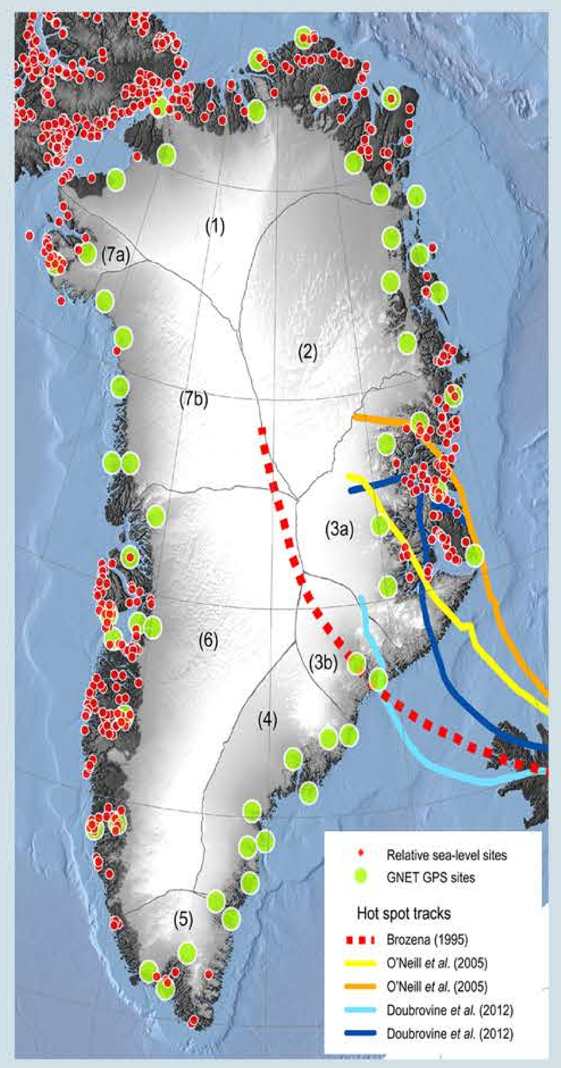



Figure: Locations of the GNET GPS stations (red dots) and relative sea level (RSL) observations (green dots). Black curves denote the major drainage basins numbered from 1 to 7. The colored curves show reconstructions of the Iceland hot sport track. Bathymetry is shown over the ocean and surface elevation over the land/ice. *Khan et al. (2016).*

For Greenland:

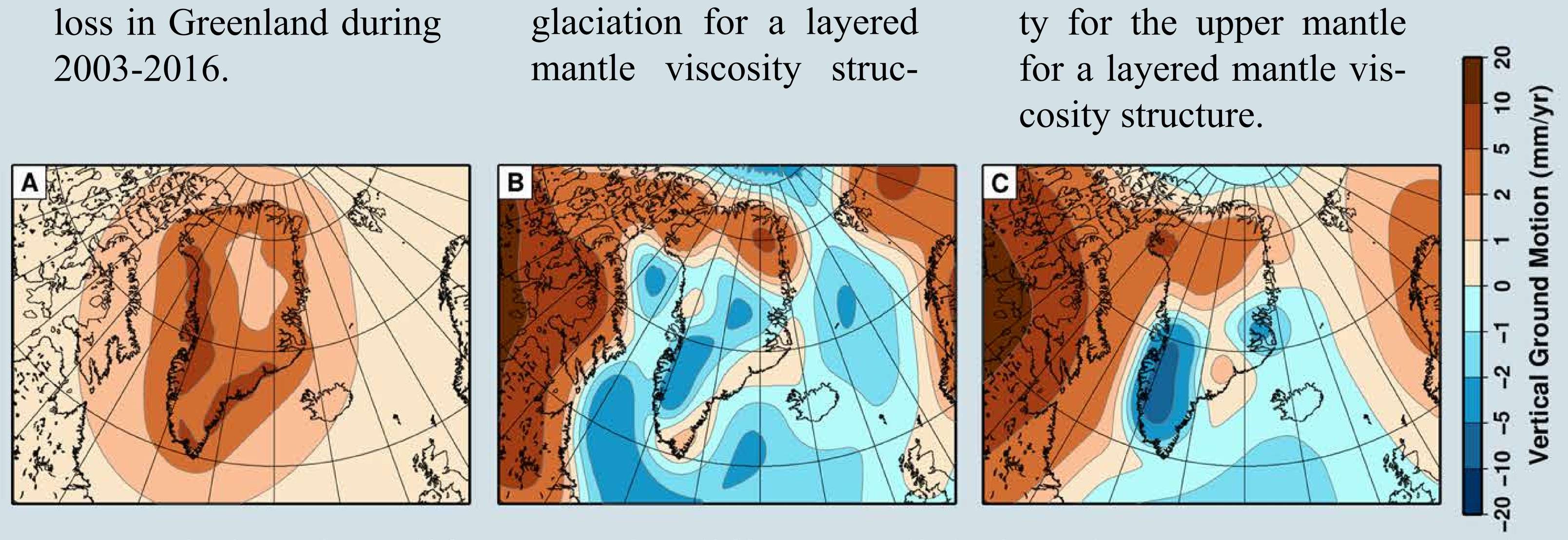
1. Mantle viscosity is largely unconstrained.
2. Low viscosity zone present due to Iceland plume.
3. Impact of these viscosity variations is untested.

**Our goal is to constrain present-day ice mass change rates in Greenland by accurately correcting the observed uplift rates for GIA from the past deglaciation.**

A. Earth's elastic response to recent ice mass loss in Greenland during 2003-2016.

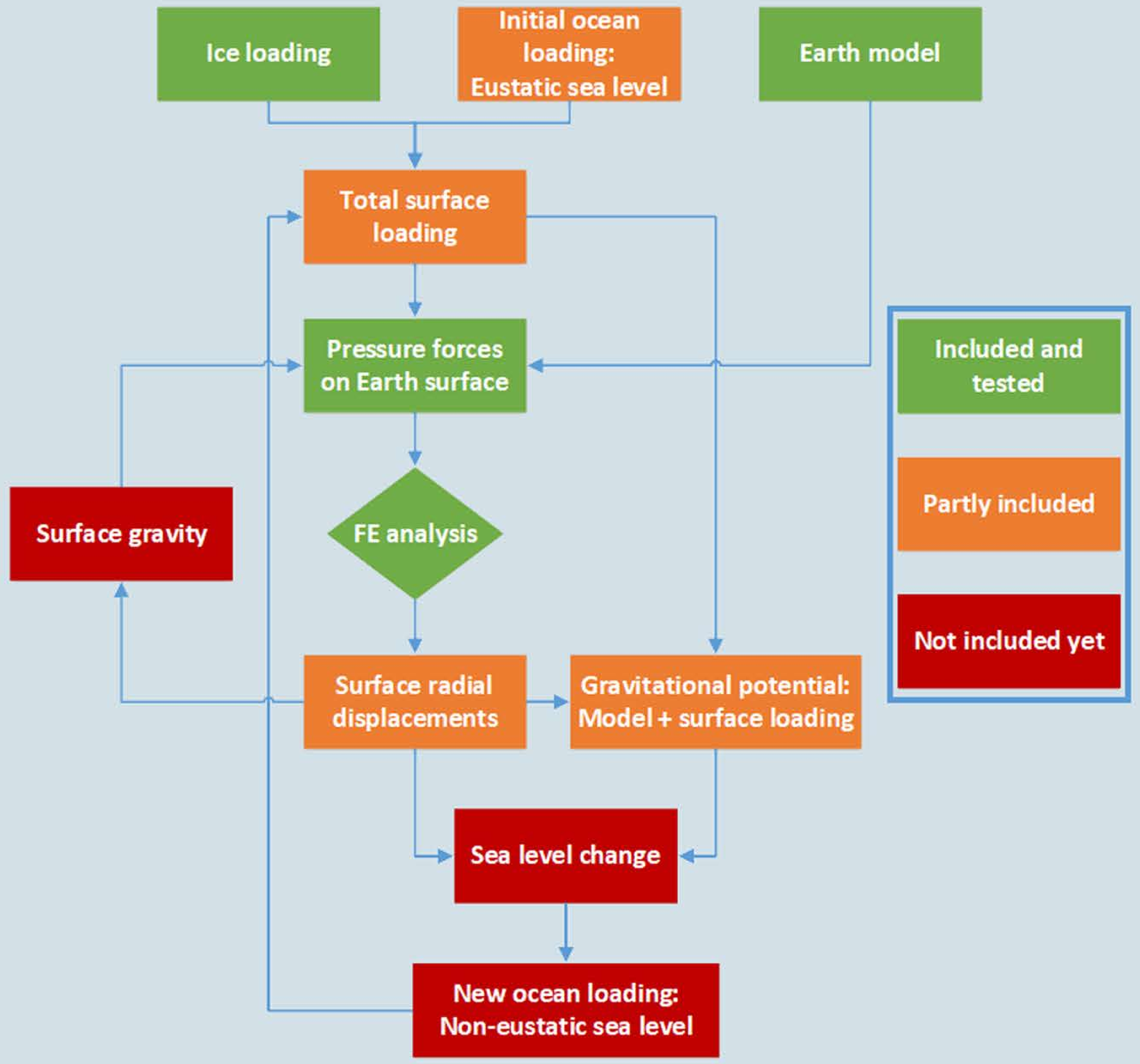
B. Earth's ongoing viscous response to past deglaciation for a layered mantle viscosity structure.

C. Same as B, but with a factor 5 reduced viscosity for the upper mantle for a layered mantle viscosity structure.




Large variations in uplift pattern for different radial viscosity structures. To test the impact of lateral viscosity variations we need a **numerical model**.

## 2. CODE SCHEMATIC OVERVIEW




### Scheme summary

**Simulation input**

**Geometry**: 3D spherical shell model
**Simulated time**: the last glacial cycle ~100 ka
**Boundary conditions**: top free surface, fixed CMB: no mesh deformation, only tangential flow
**Boundary traction**: known ice loading history. For first iteration, ocean loading is based on eustatic sea level from known ice loading change.
**Earth model properties**: laterally heterogeneous viscosity structure

**Highlights**

**New boundary traction plugin**: ocean loading based on eustatic sea level from known ice loading change

**Improved `geoid` postprocessor**: geoid perturbation from a fixed surface using the `dynamic topography` postprocessor, or from a free surface independently of any postprocessor

**New `sealevel` postprocessor**: relative sea level based on the solid Earth deformation and the perturbed gravitational potential of the complete system (model and surface loading)

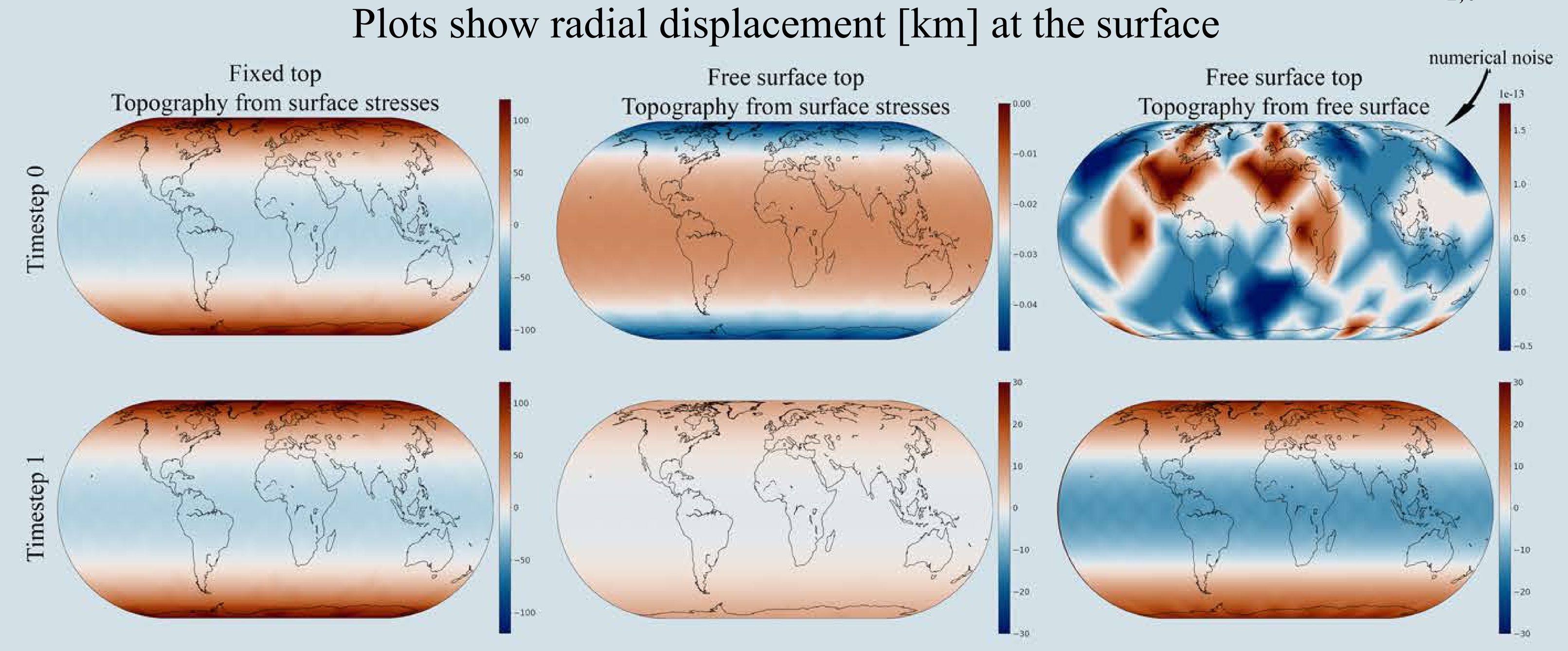
**New `oceanbasin` plugin**: used in the `sealevel` postprocessor, and the ocean basin is updated through time based on new ocean loading

## 3. `GEOID` POSTPROCESSOR

Geoid surface: the equipotential surface of the Earth's gravity field which best fits the global mean sea level. We need to find the perturbed gravitational potential to solve for the relative sea level in the `sealevel` postprocessor.

Testing the `geoid` postprocessor for a fixed top and free surface top

**Fixed**: no mesh deformation, only tangential flow
**Dynamic topography**: instant deformation based on stress at the surface.
**Free surface**: the model deforms such that there is zero stress at the surface.
3D spherical shell with temperature perturbation of spherical harmonic degree 2 ($C_{2,0}$)
Plots show radial displacement [km] at the surface




**Order of processes**: 1. Mesh advection 2. Solver 3. Postprocessors
Large topography signal due to imposed internal densities from temperature perturbation
**Question**: Why are the upper left and middle left topographies not equal?

## 4. OUTLOOK

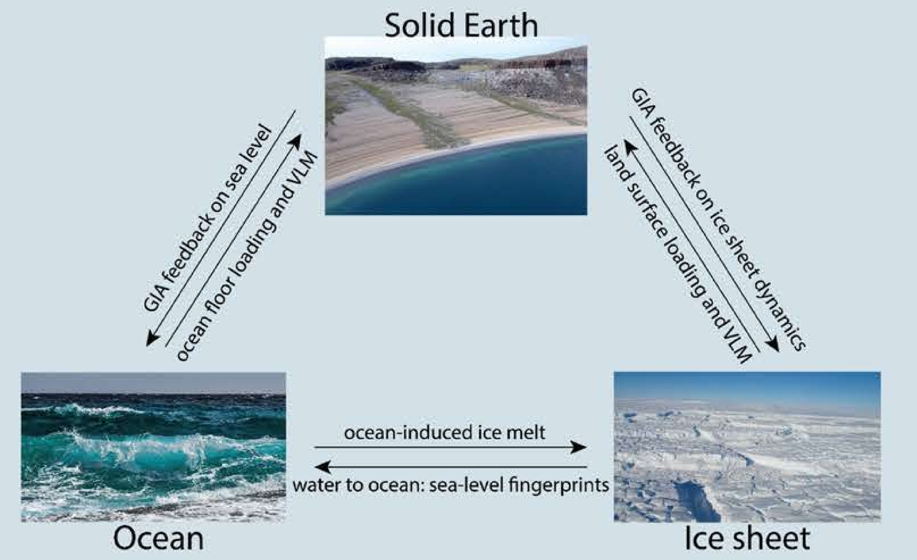



Figure: Interactions between Solid Earth, Ice Sheet and Ocean in the GIA process. *After presentation by Whitehouse (2019)*

**Coupling GIA to ice sheet dynamics**

**Interested in how we constrain the viscosity structure underneath Greenland? Visit magpiegreenland.wordpress.com for more information, stories, and photos of the overarching MAGPIE project and Greenland fieldwork 2019.**

The Research Council of Norway
UiO : University of Oslo
CEED The Centre for Earth Evolution and Dynamics
MACQUARIE University SYDNEY · AUSTRALIA
EASTGRIP ice core THE EAST GREENLAND ICE-CORE PROJECT
UNIVERSITY OF BERGEN