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UNIVERSITY OF BRISTOL
Bristol Glaciology Centre

# The importance of vegetation feedbacks on the past and future reglaciation of Greenland

Emma J. Stone, Dan J. Lunt, Paul J. Valdes

## Outline

- Background and motivation
- Aims and experimental design
- Results
- Conclusions
- Future work

NATURAL ENVIRONMENT RESEARCH COUNCIL

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# Motivation & Background

- Investigation of long-term behaviour of ice sheets in the Earth system

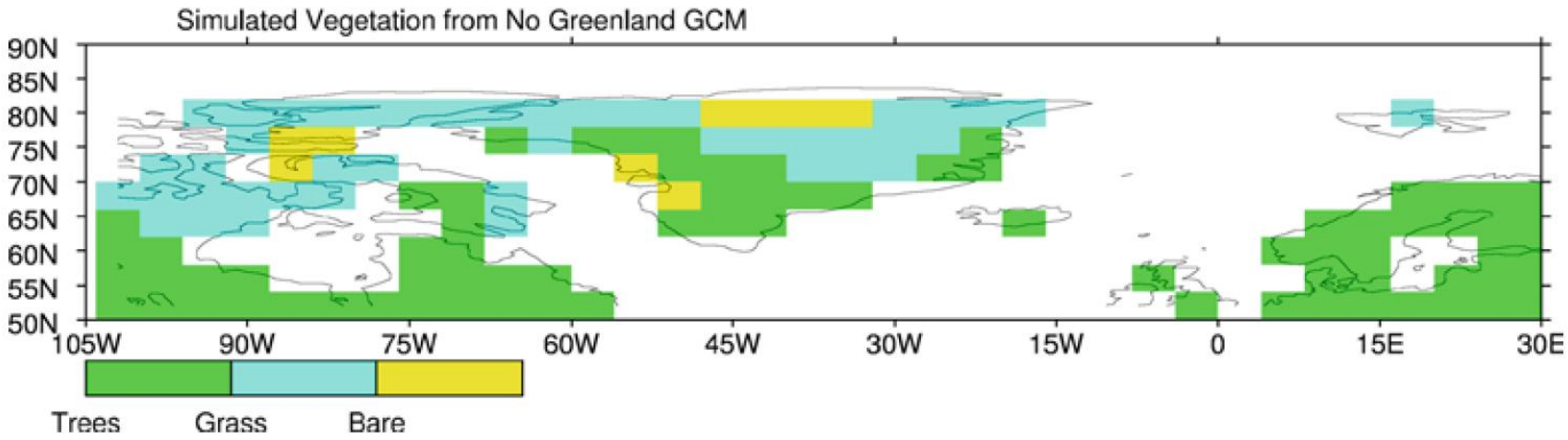
- If the Greenland ice sheet melts…
  - Will it regrow under $CO_2$ levels stabilising at or near pre-industrial levels?

- Various studies have looked at reglaciation on Greenland e.g.

  - Crowley & Baum (1995) →**no inception**
  - Toniazzo et al. (2004) →**no inception**
  - Lunt et al. (2004) →**inception**
  - Vizcaíno et al. (2008) →**no inception**

# Aims

- Previous work has neglected important feedbacks such as ***vegetation***




- Research into the evolution of the Greenland ice sheet will investigate the roles of and interactions between:
  - vegetation
  - ice sheet thermodynamics & dynamics
  - climate

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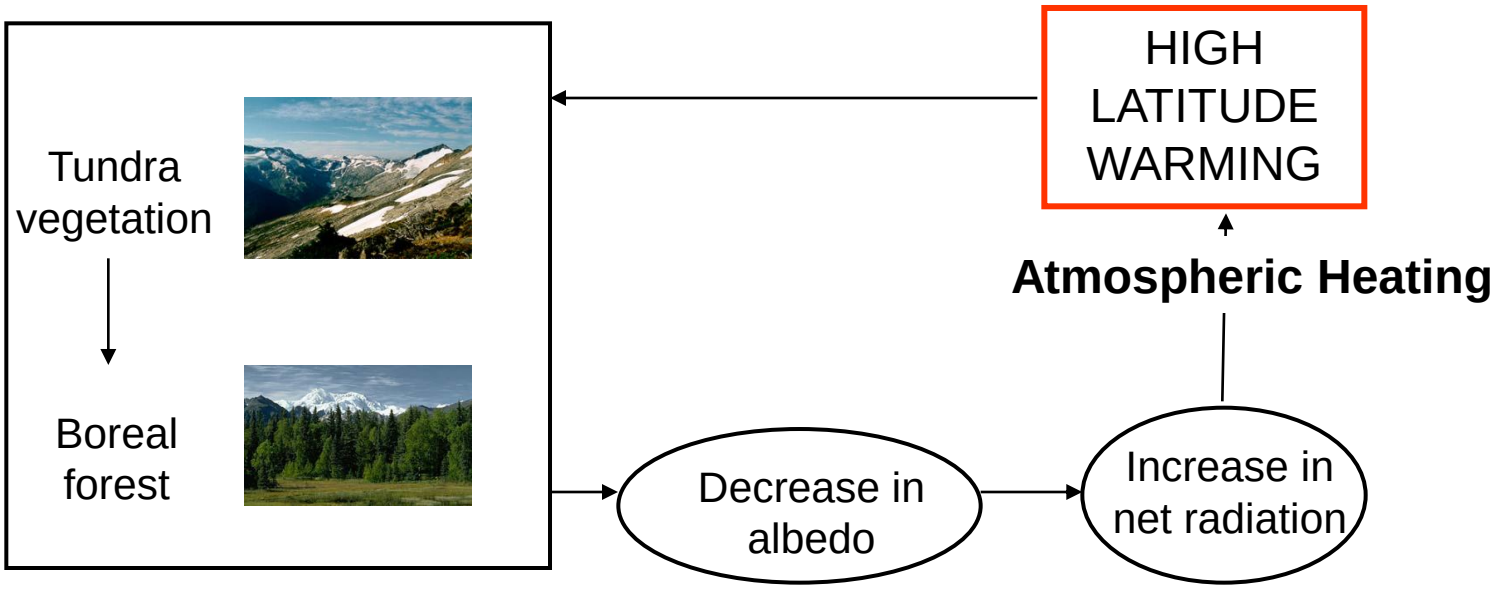
# Feedback processes

- Ice-albedo feedback
- Ice-elevation feedback
- Vegetation-snow-climate feedback

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# Experimental design -The Models

- **GENIE-2** (Grid-ENabled Integrated Earth system model)

**Atmosphere Module (IGCM3)**
- ➢surface fluxes & turbulence
- ➢Surface albedo
- ➢Soil moisture
- ➢Land surface temperature
- ➢Albedo and surface roughness length define vegetation type

**Sea Ice Module**
- ➢FIXED Sea Ice
- ➢Slab Sea Ice
- ➢3D Sea Ice

**Ocean Module**
- FIXED Ocean
- 3D Ocean Model
- Slab ocean

- **GLIMMER** (GENIE Land Ice Model with Multiply Enabled Regions)

**Ice Module**
- ➢PDD Surface mass balance model
- ➢Coupled ice flow
- ➢Thermodynamics & ice-thickness evolution
- ➢Isostatic readjustment

GENIE

(www.genie.ac.uk)

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# Experimental design

- **5 GENIE-2 experiments (100 yrs)**

1. ICE SHEET CONTROL

– Present day orography and ice sheet extent

1. Ice sheet with bare soil in exposed regions on Greenland

2 -5 NO GREENLAND ICESHEET

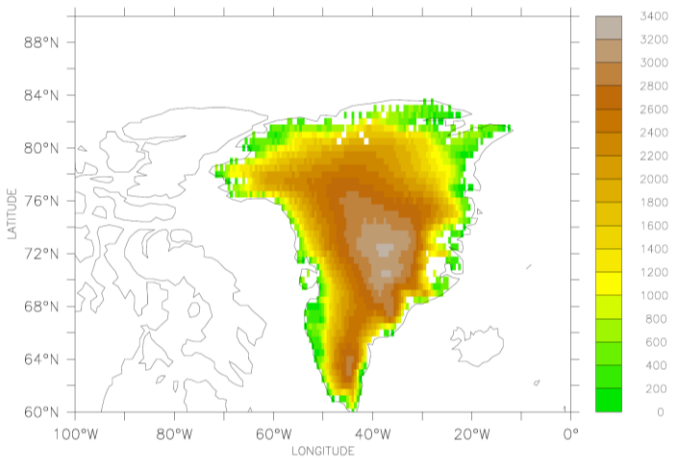
– Rebounded bedrock for orography
– Vegetation in place of ice sheet

2. Bare soil
3. Tundra vegetation
4. Boreal forest vegetation
5. Mixed vegetation (based on Lunt et al., 2004)

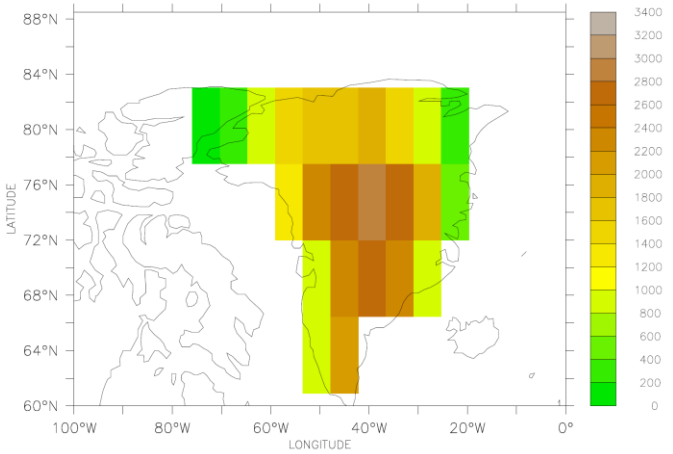
# Experimental design

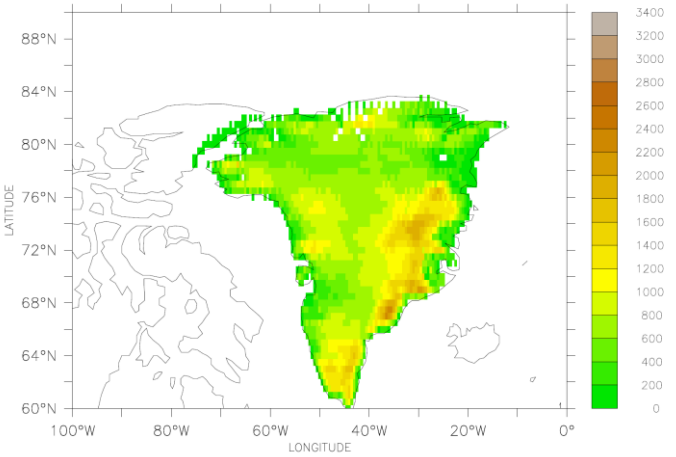
## High resolution orography

## Resolution of GENIE-2

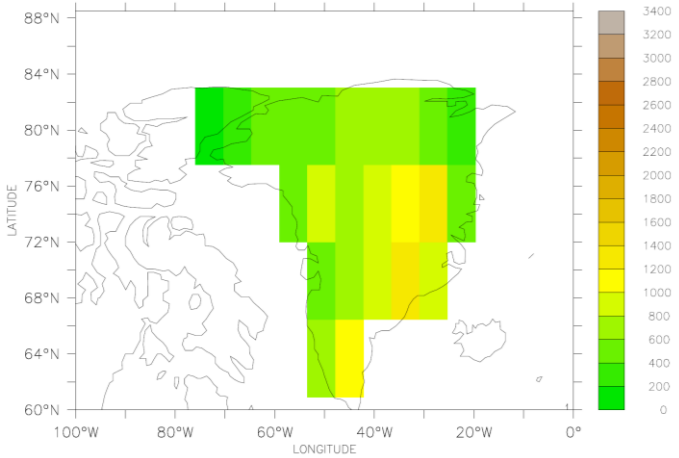



**Present day orography With ice sheet**




**Relaxed bedrock**

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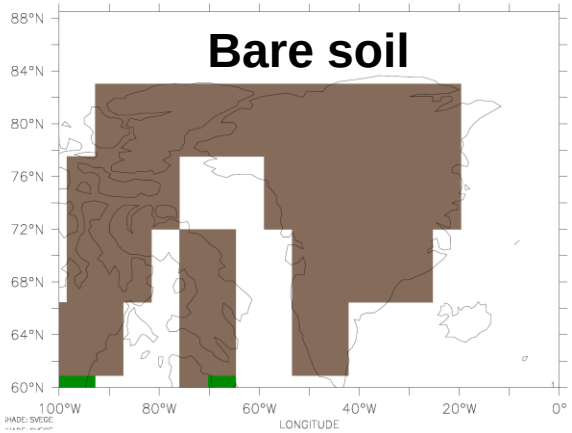
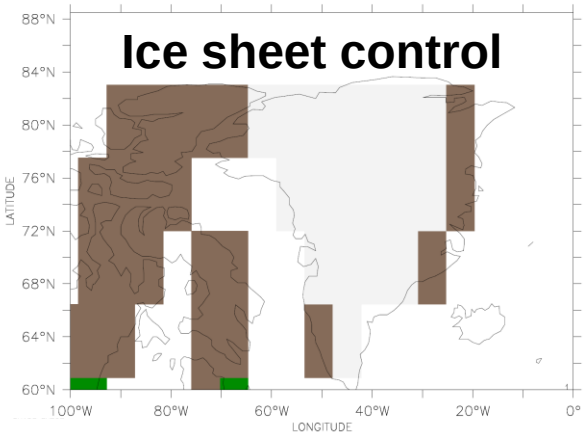
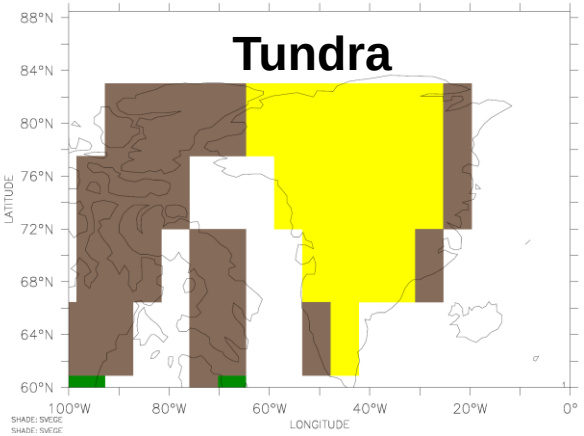
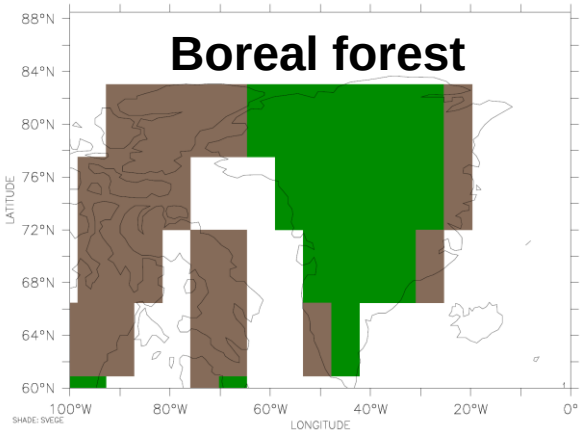
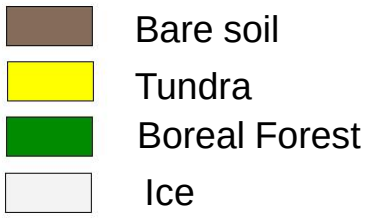
# Experimental design

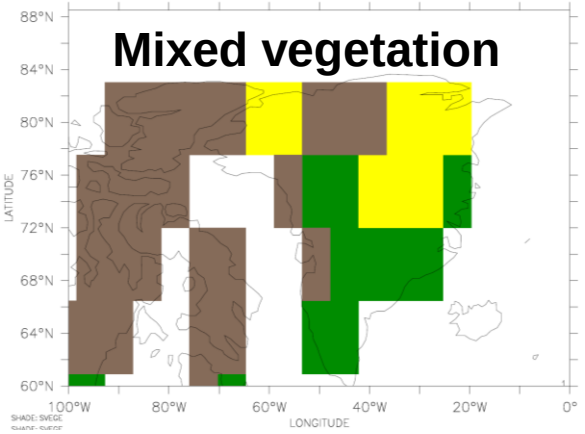
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# Experimental design

- **5 GENIE-2 experiments (100 yrs)**

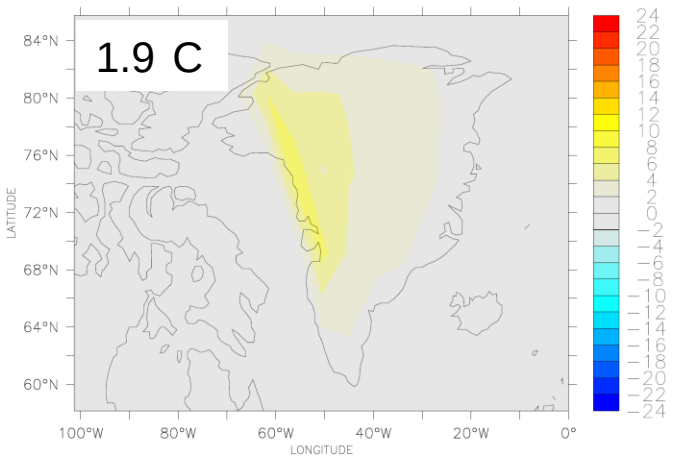
  1. ICE SHEET CONTROL
  - Present day orography and ice sheet extent
  - Ice sheet with bare soil in exposed regions on Greenland

  2 -4 NO GREENLAND ICESHEET
  - Rebounded bedrock for orography
  - Vegetation in place of ice sheet

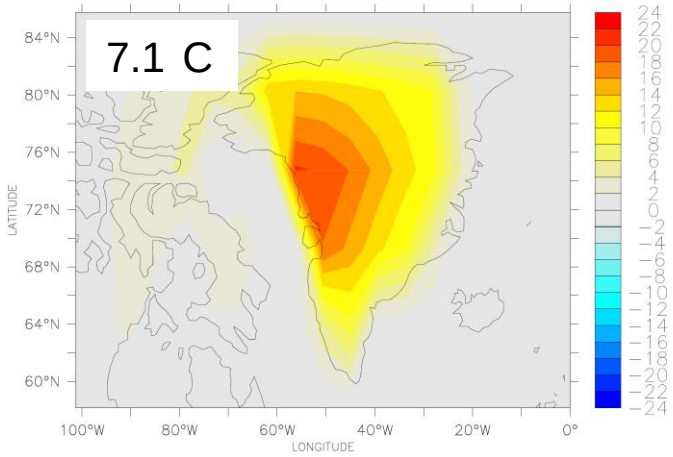
  2. Bare soil
  3. Tundra vegetation
  4. Boreal forest vegetation
  5. Mixed vegetation (based on Lunt et al., 2004)

- **Forcing of GLIMMER offline for 50kyrs**

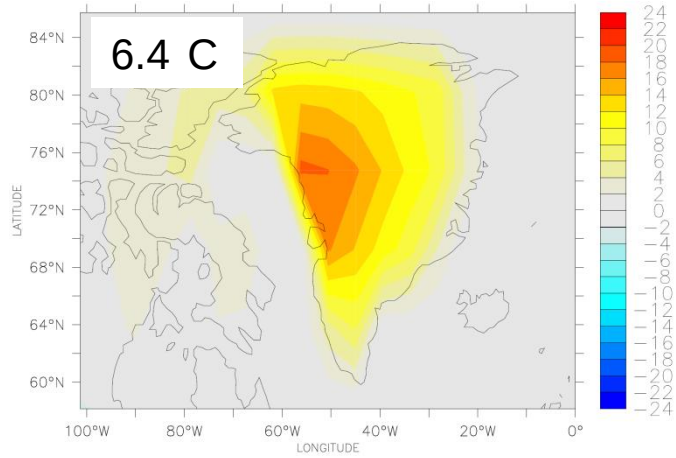
# GENIE-2 Results



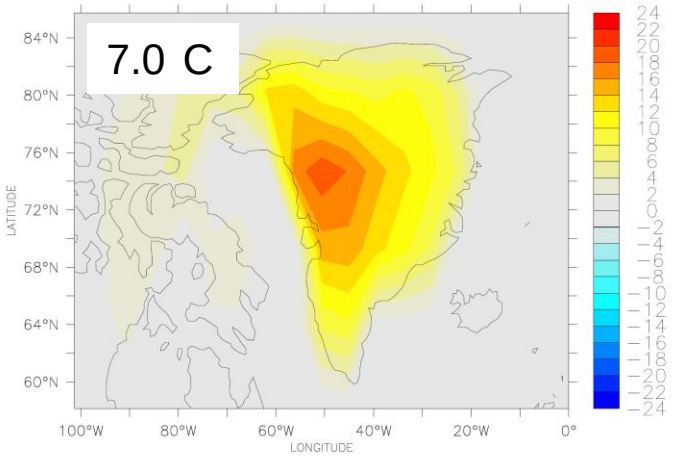

BARE SOIL – ICESHEET CONTROL




BOREAL FOREST – ICESHEET CONTROL




TUNDRA - ICESHEET CONTROL




MIXED VEGETATION – ICESHEET CONTROL

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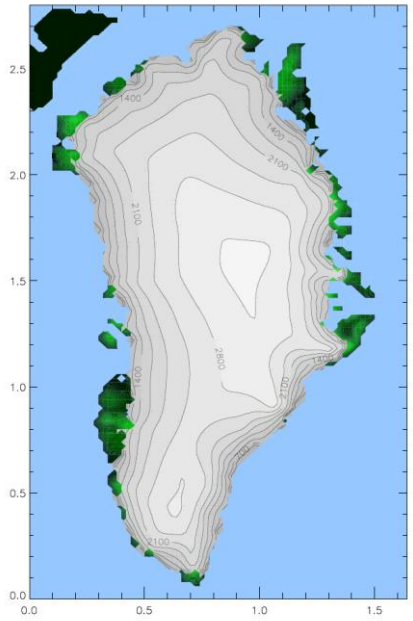
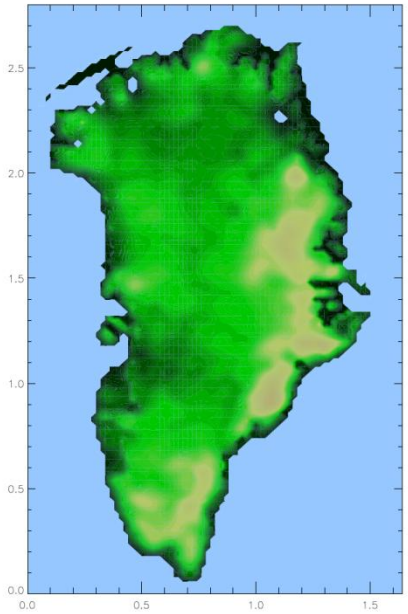
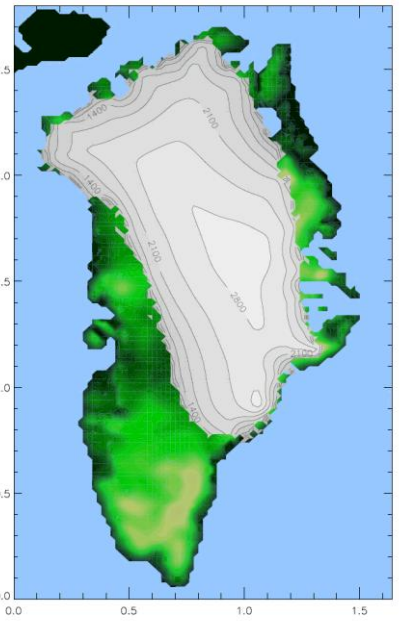
# GLIMMER results

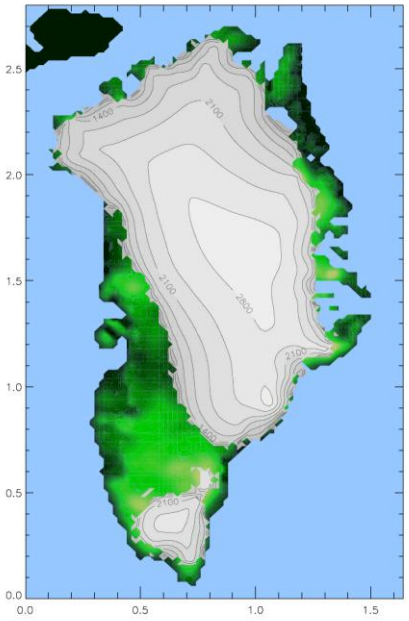


Bare soil vegetation



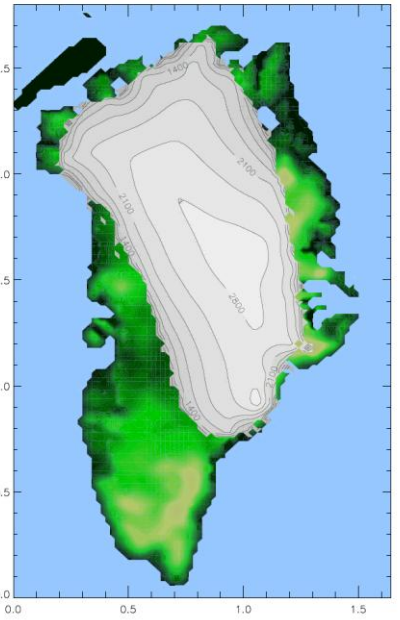
Boreal forest vegetation





Tundra vegetation

Mixed vegetation



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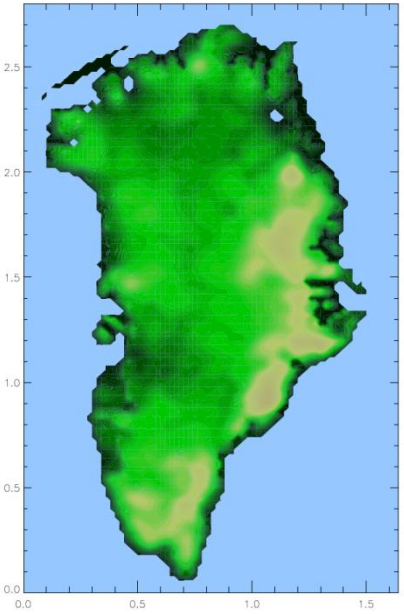
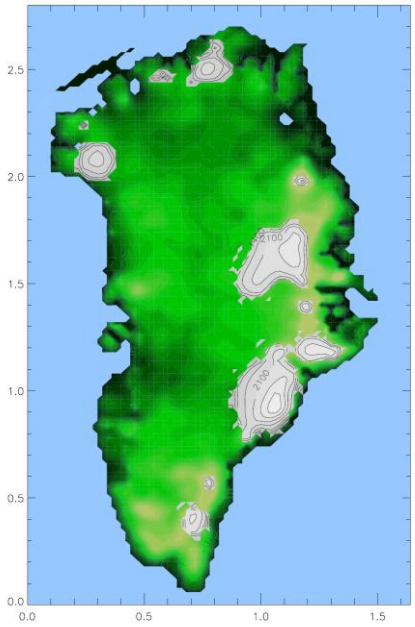
# GLIMMER results

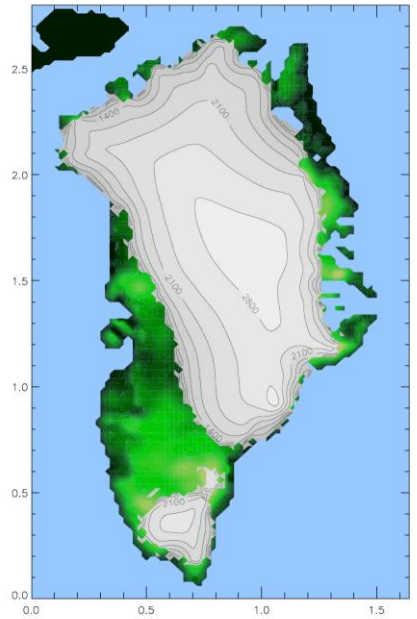



**Time: 0 yrs**




**Time: 4kyrs**

**TUNDRA VEGETATION**




**Time: 50kyrs**

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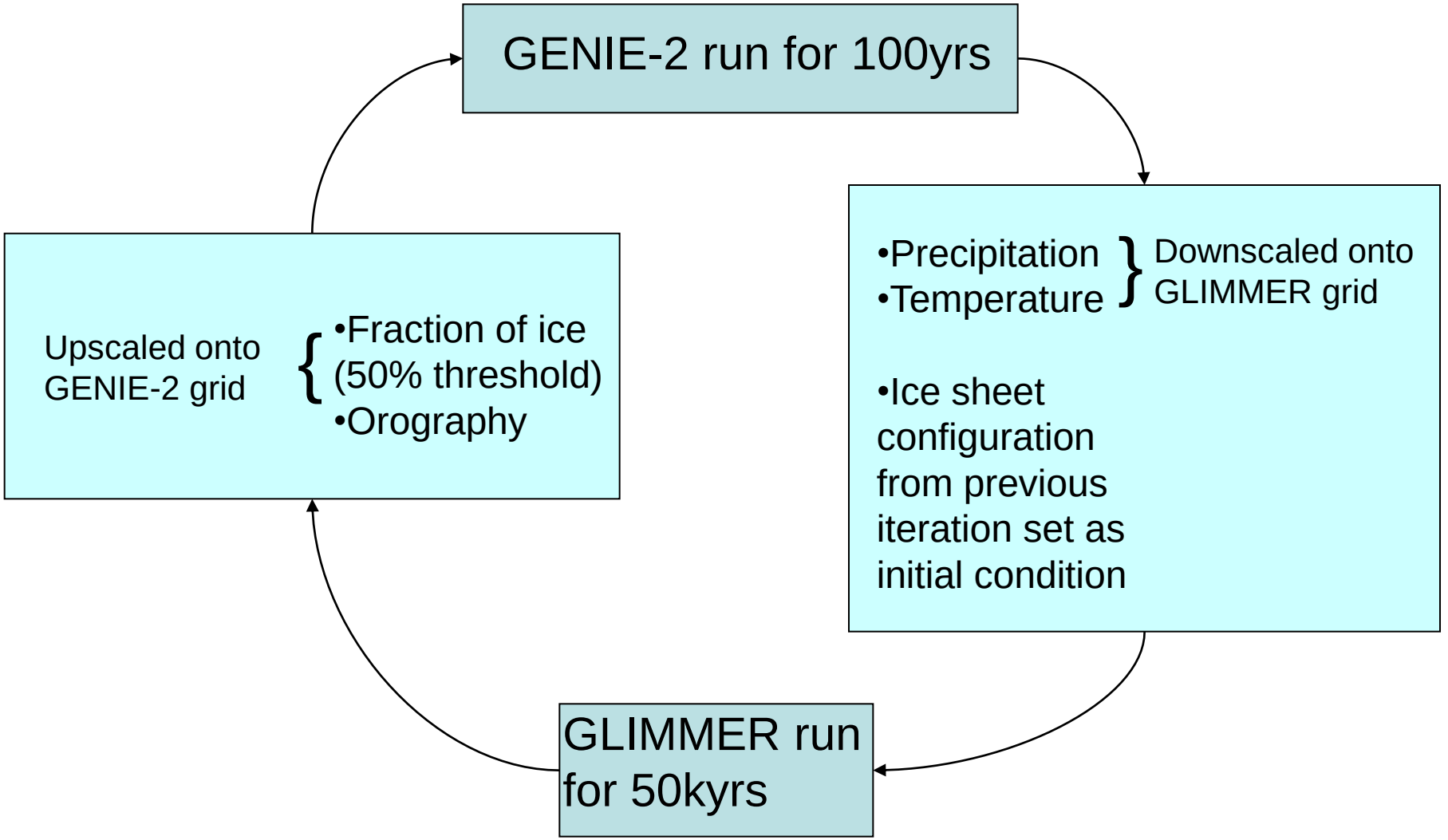
# Asynchronous Coupling

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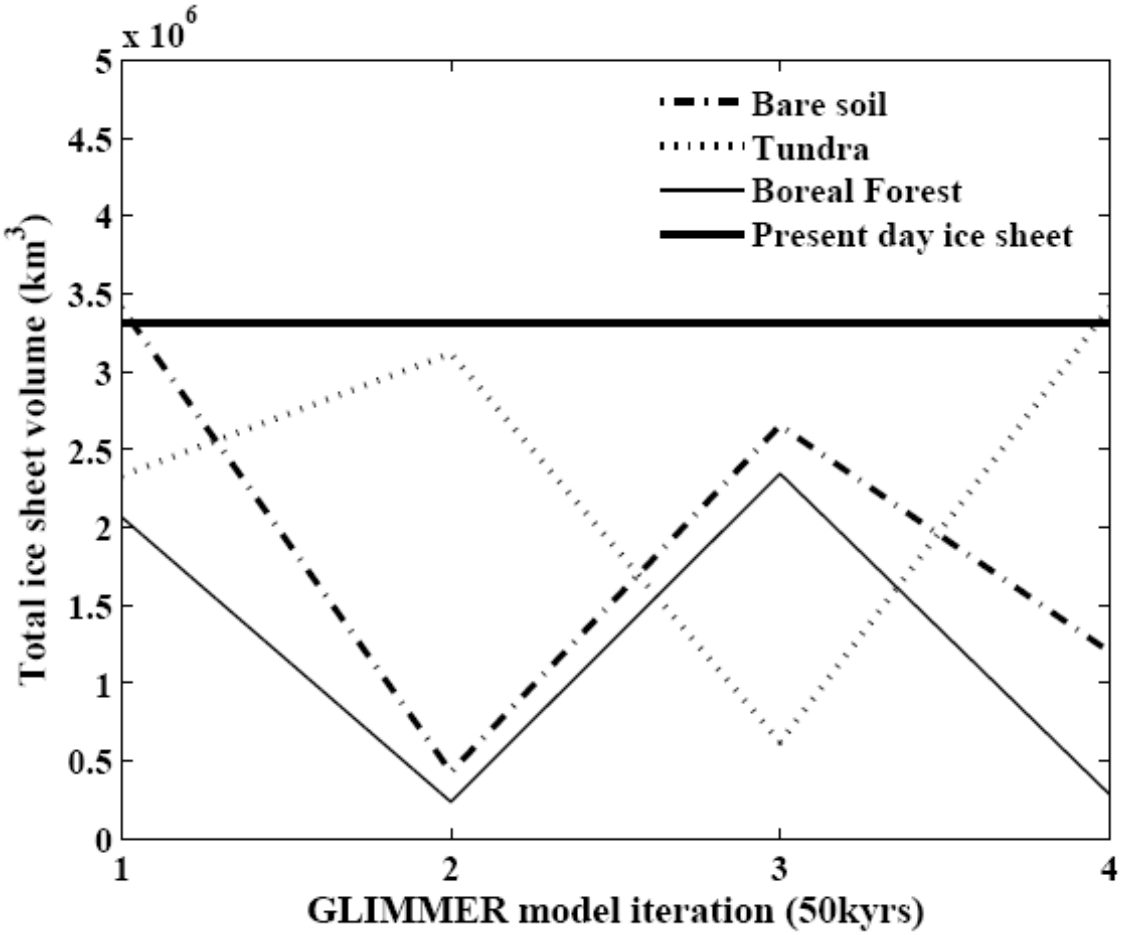
# Asynchronous coupling –initial results

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# Conclusions

- If the Greenland ice sheet melts there will be a local increase in surface temperatures with the largest change observed for boreal forest vegetation compared with tundra and bare soil

- The Greenland ice sheet regrows for all vegetation types for a GLIMMER model run of 50kyrs although the volume and extent of the ice sheet is vegetation type dependent with growth triggered in the high altitude eastern mountains

- Initial experiment with asynchronous coupling results in an oscillating ice sheet volume for boreal forest, tundra and bare soil due to a too long coupling timestep

# Future work

- Experimentation with asynchronous coupling times and lapse rates more consistent with those from GENIE-2
- Repetition of GENIE-2 experiments with HadCM3 (higher resolution and more physics included) looking at the effects of change in topographic height, albedo and surface roughness length on local surface temperature
- Use of a dynamic vegetation model, TRIFFID, to predict vegetation rather than prescribe when the Greenland ice sheet is removed
- Asynchronous coupling of vegetation, climate and ice sheet models
- Longer term the group at Bristol will apply the methodology to past and future changes in climate e.g.
  - Late Pliocene glacial inception using Pliocene $CO_2$, vegetation distribution and surface elevation

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