

# Could vegetation feedbacks determine whether the Greenland ice sheet regrows after deglaciation?

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## Outline

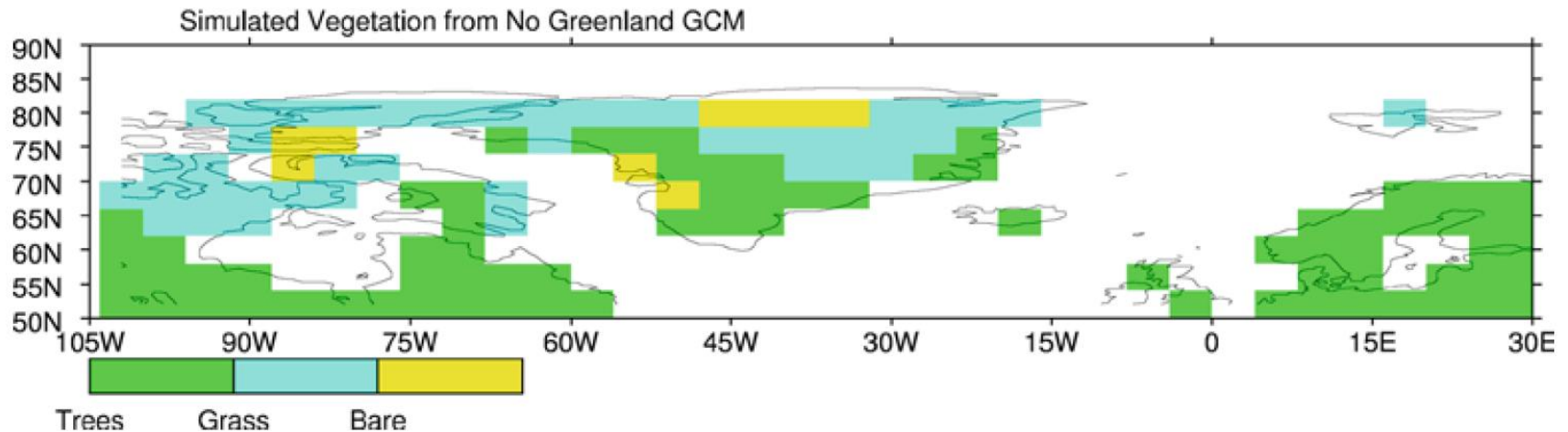
- Background and motivation
- Aims and experimental design
- Results
- Conclusions & Future work

# 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<sub>2</sub> levels stabilising at or near pre-industrial levels?
- Various studies have looked at reglaciation on Greenland e.g.

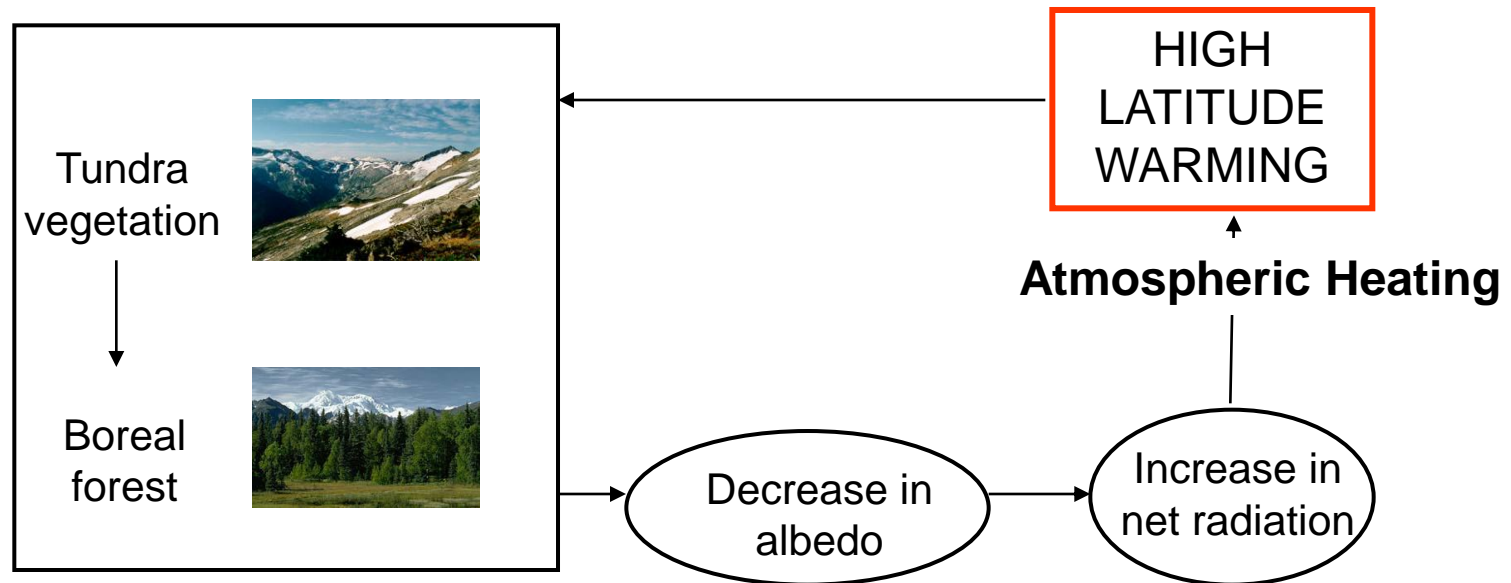
| Study                         | Atm            | Ocn            | Veg         | Ice         | Result       |
|-------------------------------|----------------|----------------|-------------|-------------|--------------|
| Crowley & Baum (1995)         | EMIC           | EMIC           | None        | None        | No inception |
| Toniazzo <i>et al.</i> (2004) | Full GCM       | Full GCM       | None        | None        | No inception |
| Vizcaíno <i>et al.</i> (2008) | Low Resol. GCM | Low Resol. GCM | Yes-coupled | Yes-coupled | No inception |
| Charbit <i>et al.</i> (2008)  | EMIC           | EMIC           | Yes-coupled | Yes-coupled | No inception |
| Lunt <i>et al.</i> (2004)     | Full GCM       | Full GCM       | Yes-offline | Yes-offline | Inception    |
| Mine                          | Full GCM       | Full GCM       | Yes-coupled | Yes-offline | ???          |

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



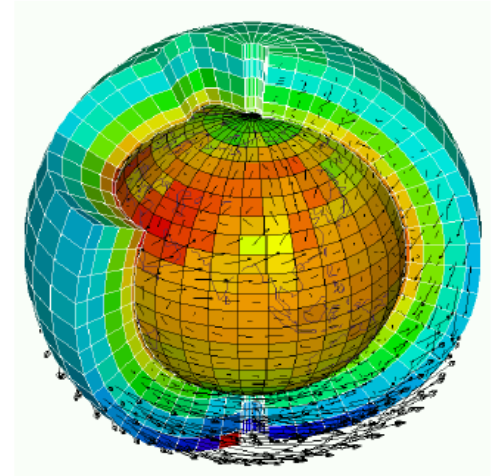
- Research into the evolution of the Greenland ice sheet will investigate the roles of and interactions between:
  - vegetation
  - ice sheet thermodynamics & dynamics
  - climate

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



- **HadCM3 (UK Met Office Model)**

- Coupled atmosphere-ocean sea-ice models
- Ocean has a resolution of  $1.25^\circ \times 1.25^\circ$
- Horizontal resolution  $2.5^\circ \times 3.75^\circ$
- 19 levels in the vertical



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

- PDD Surface mass balance model
- Coupled ice flow
- Thermodynamics & ice-thickness evolution
- Isostatic readjustment

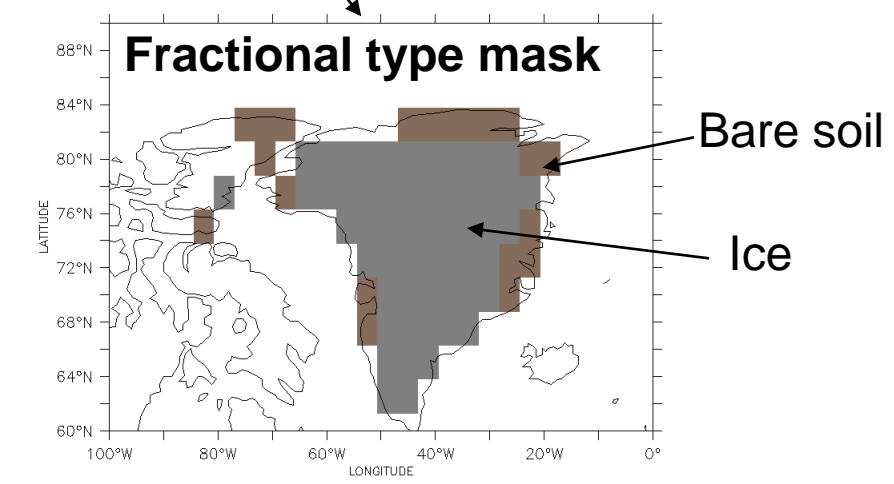
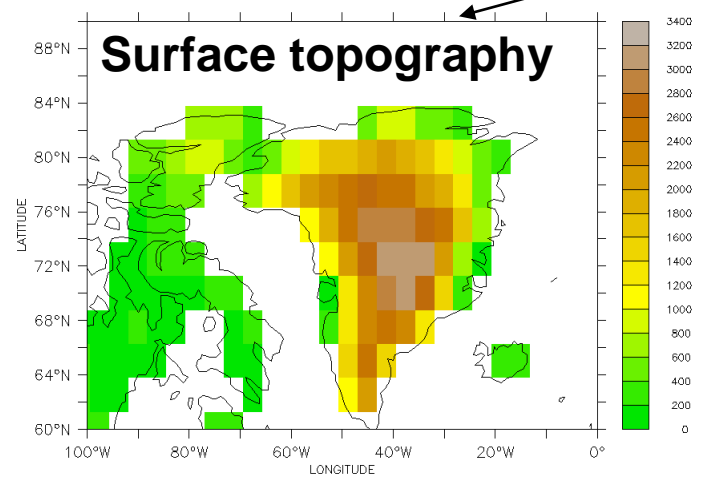
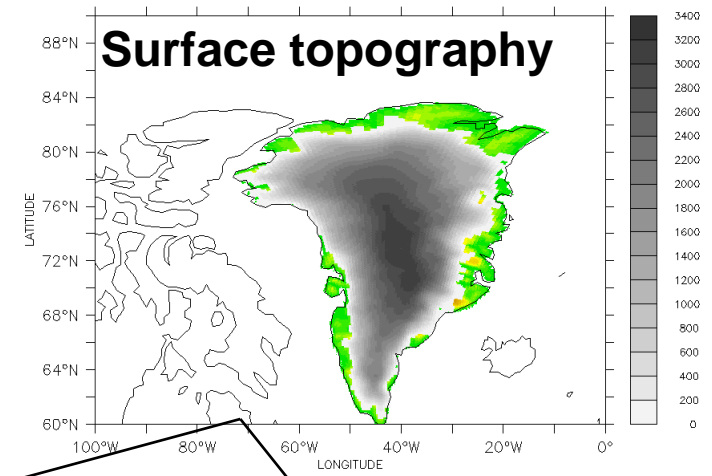
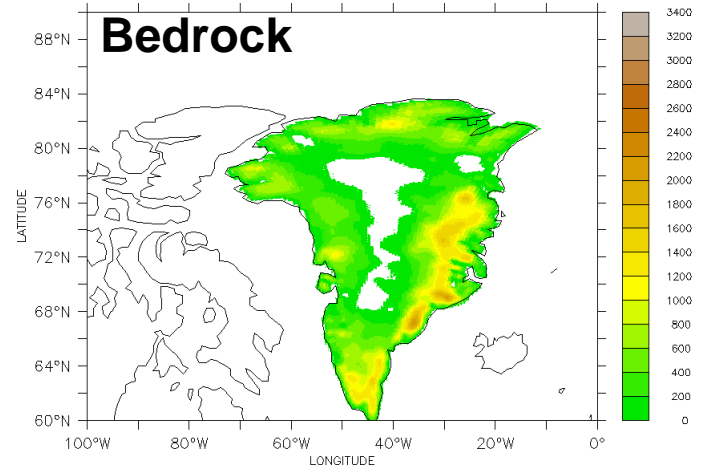
- **7 HadCM3 experiments (100 yrs)**

- 1. ICE SHEET CONTROL**

- Present day orography and ice sheet extent
    - Ice sheet with bare soil in exposed regions on Greenland

# Experimental design-Fixed Vegetation

## High resolution orography



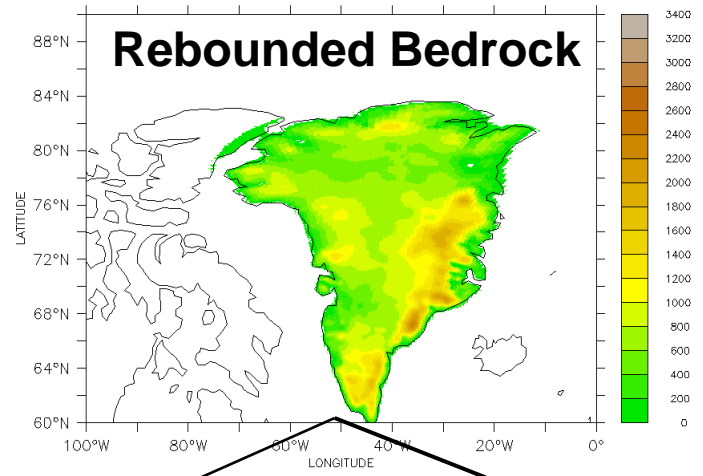
## Resolution of HadCM3

- 7 HadCM3 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 -7 **NO GREENLAND ICESHEET**
    - **Rebounded bedrock for orography**
    - **Vegetation in place of ice sheet**
      2. Bare soil
      3. Broadleaf
      4. Needle leaf
      5. C3 grass
      6. C4 grass
      7. Shrubs
- **Forcing of GLIMMER offline for 50kyrs using an anomaly method**



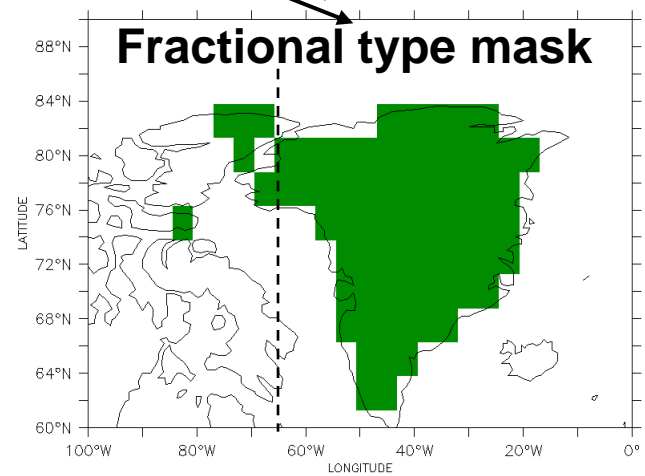
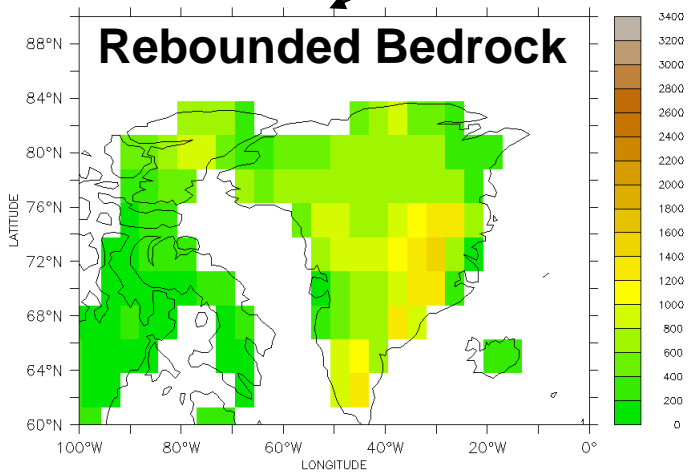
# Experimental design-Fixed Vegetation

## High resolution orography



Region to right of dashed line replaced with:

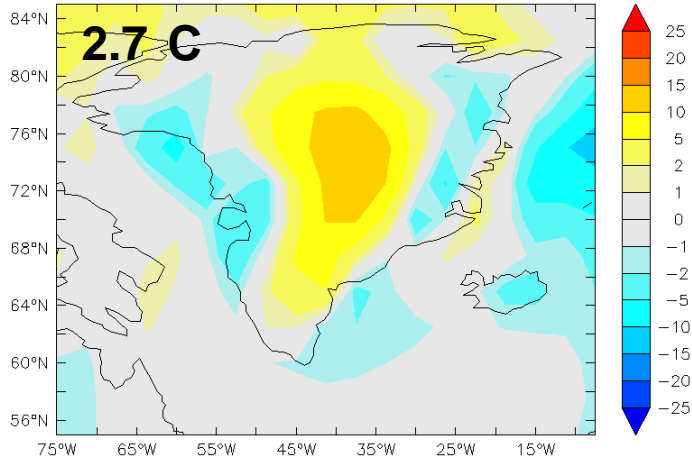
- Bare soil
- Broadleaf trees
- Need leaf trees
- C3 grasses
- C4 grasses
- Shrubs



## Resolution of HadCM3

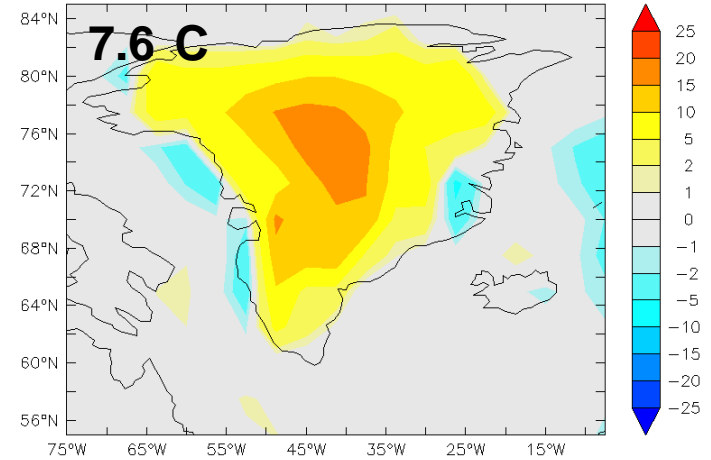
# Fixed Vegetation Results -Temperature

## DJF anomaly

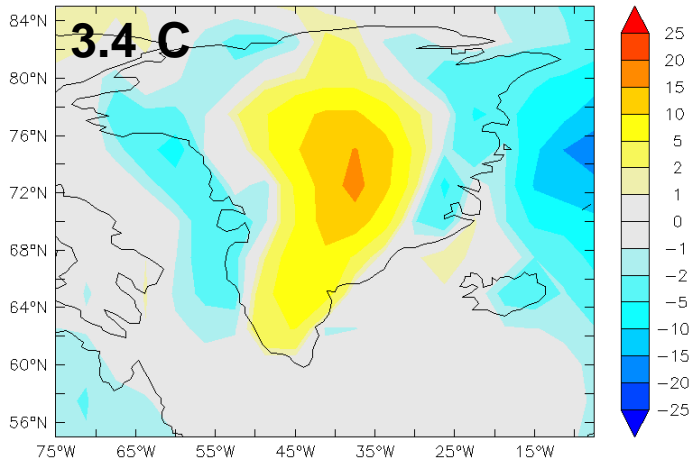


Bare soil - control

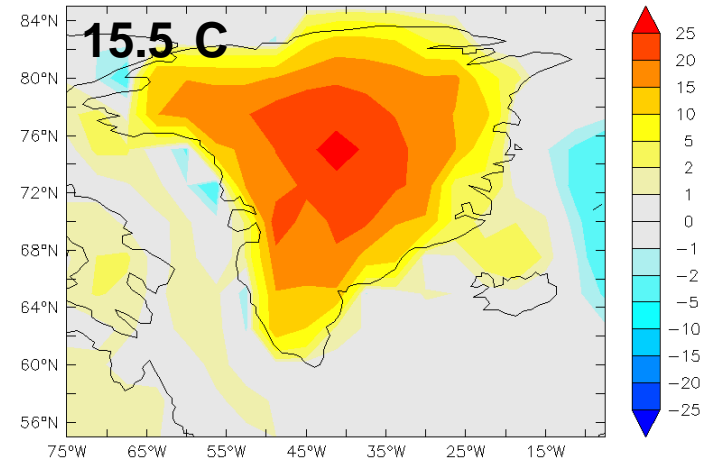
## JJA anomaly



Bare soil - control

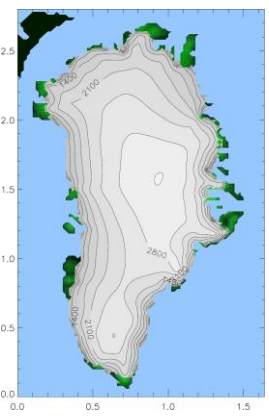


Needle Leaf - control

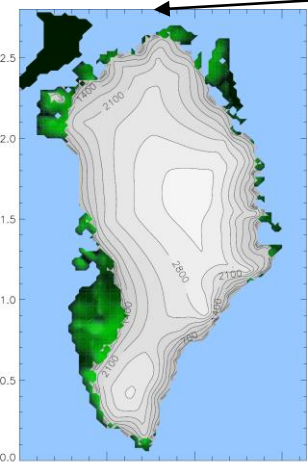
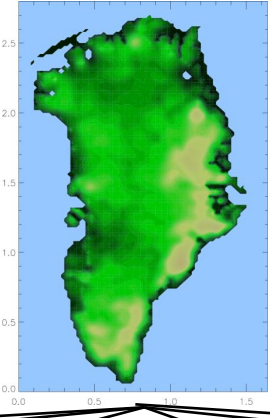


Needle Leaf - control

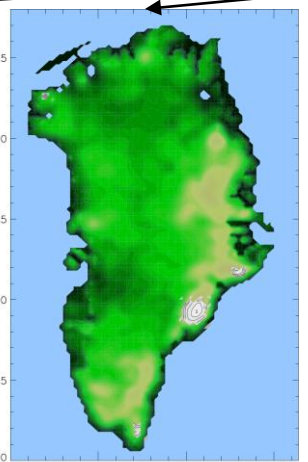
# Fixed Vegetation -GLIMMER Results



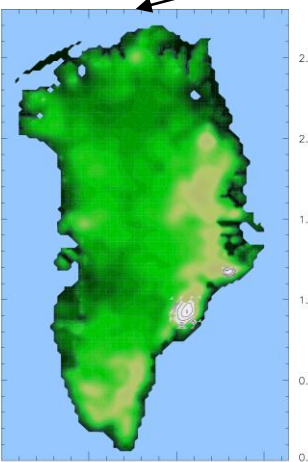
**Control**



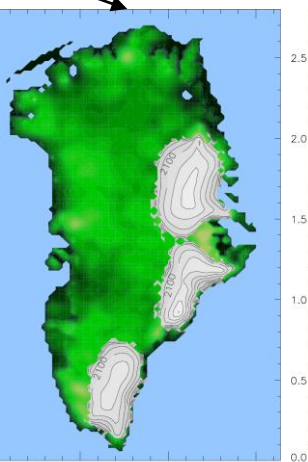
**Bare soil**



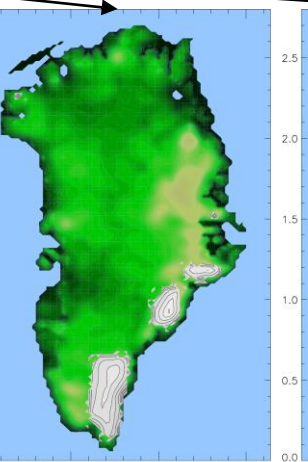
**Broadleaf**



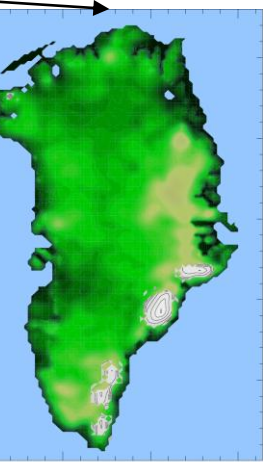
**Needle Leaf**



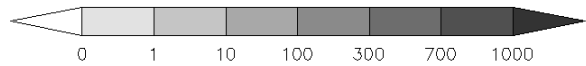
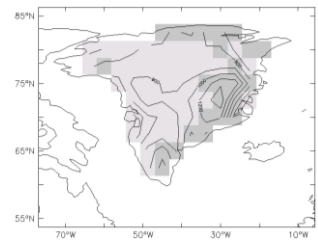
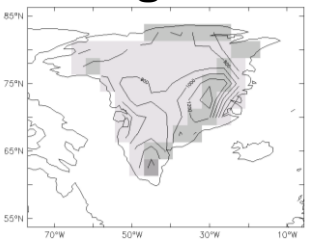
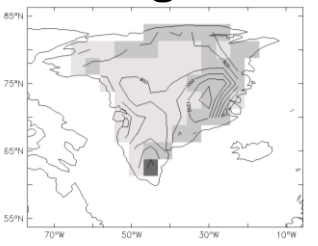
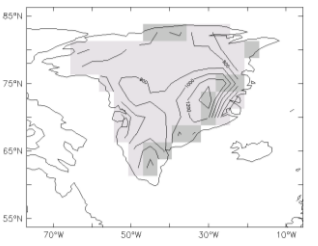
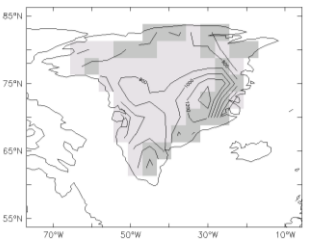
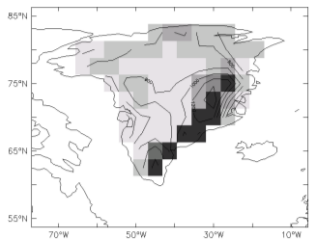
**C3 grass**



**C4 grass**

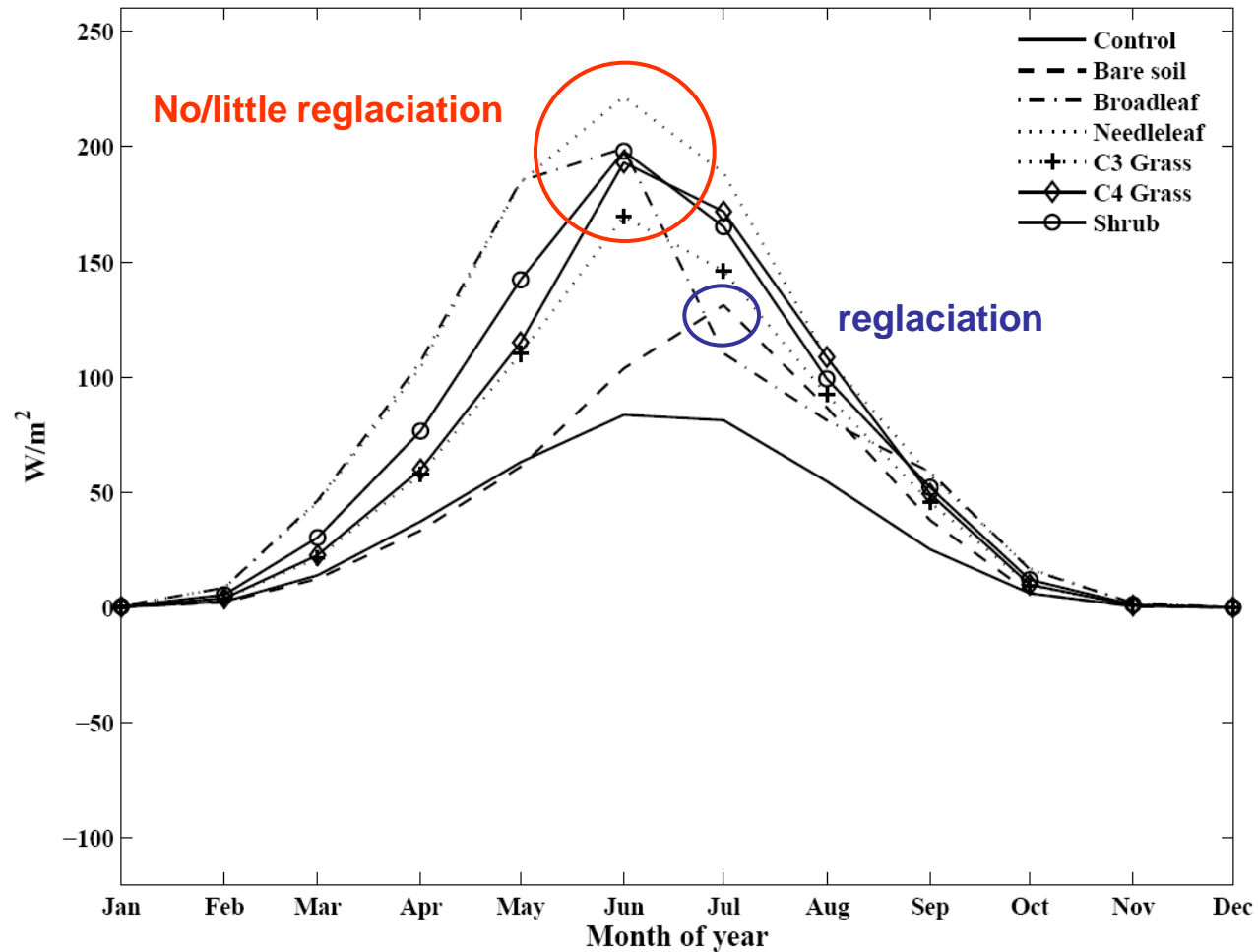


**Shrub**



**Snow depth (mm water equivalent)**

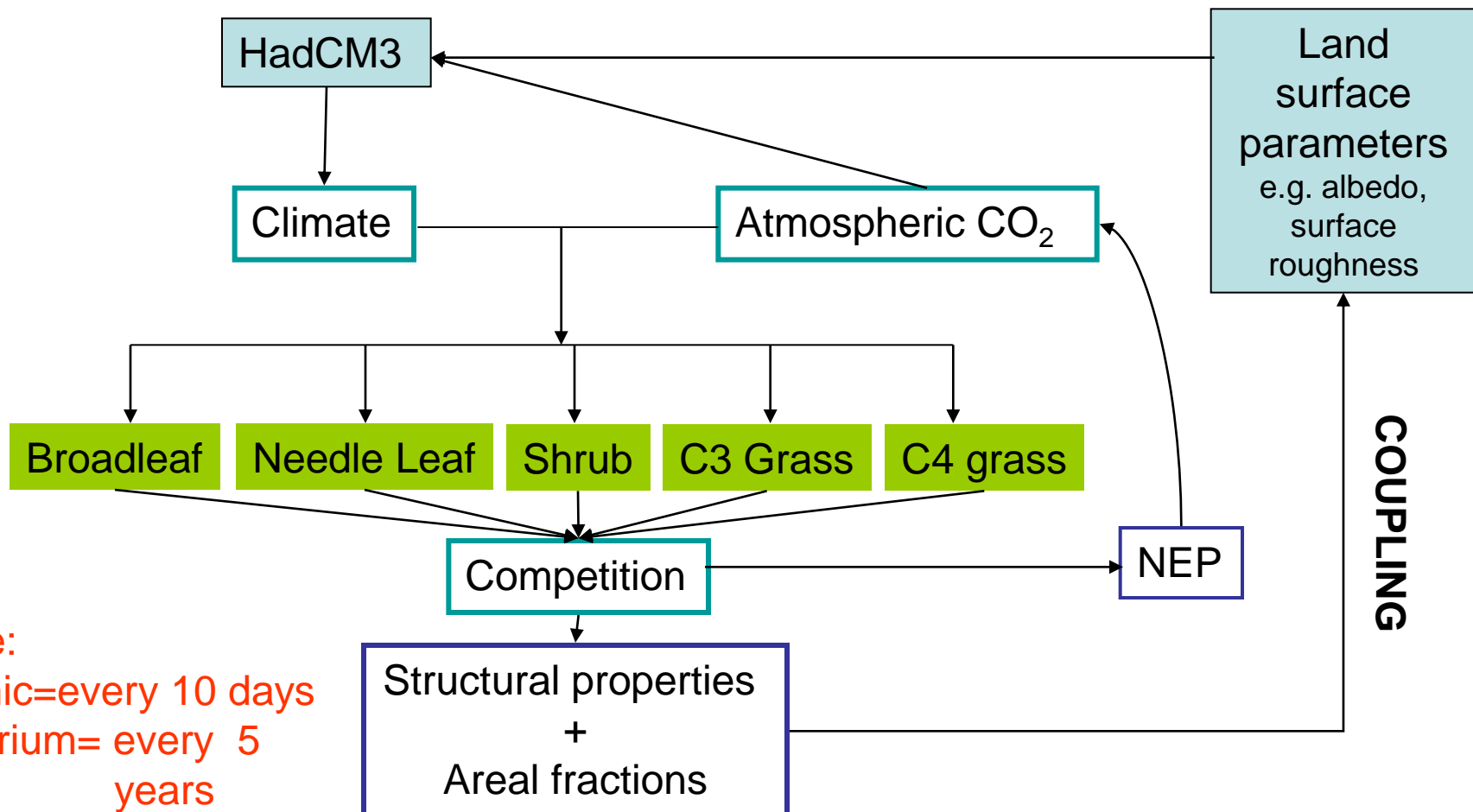
# Albedo Sensitivity



Net Short-wave radiation over Greenland

HadCM3 with:

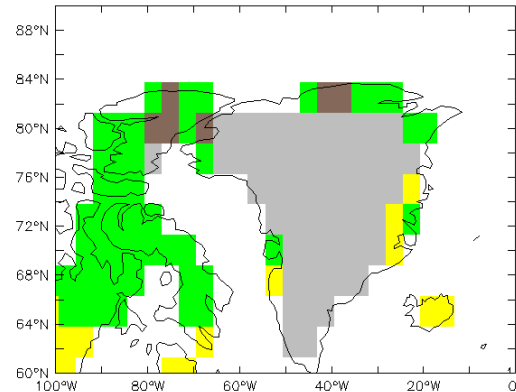
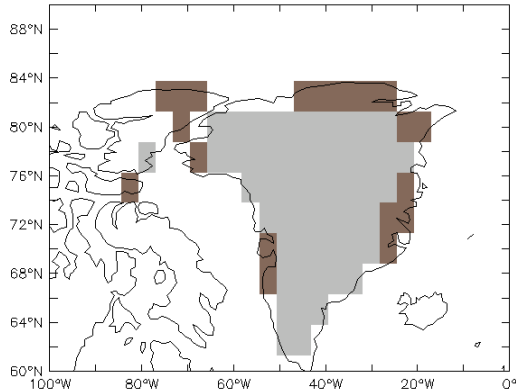
- Moses 2.1 land Surface Scheme
- Interactive Vegetation Model: TRIFFID (Cox, 2001)



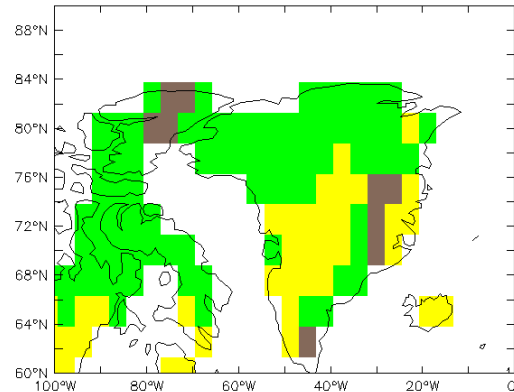
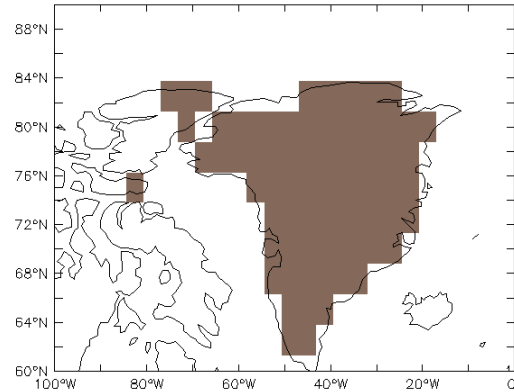
Update:  
Dynamic=every 10 days  
Equilibrium= every 5  
years

# Predicted Vegetation from TRIFFID

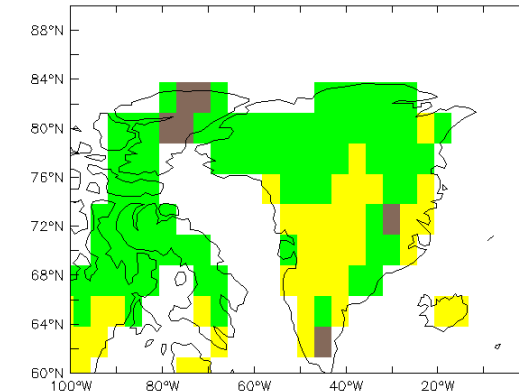
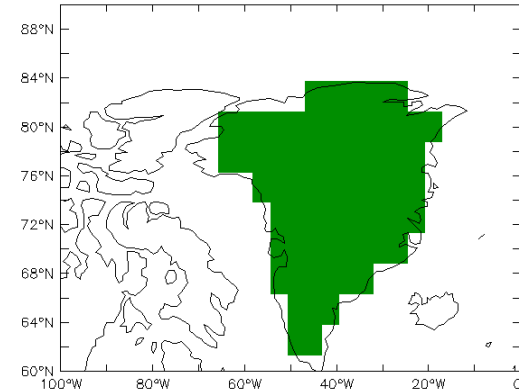
## Initial control



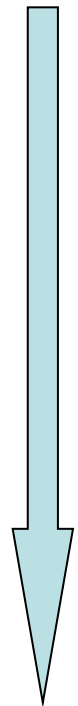
## Initial bare soil



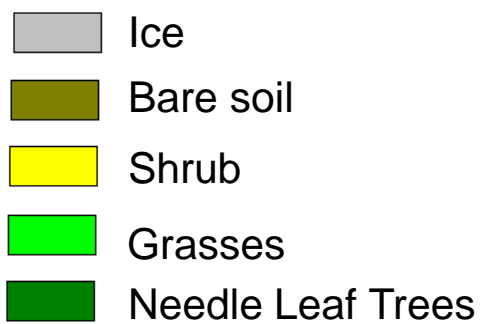
## Initial needle leaf



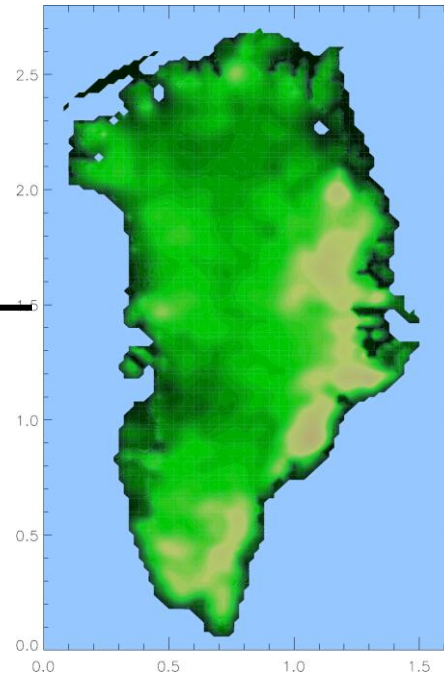
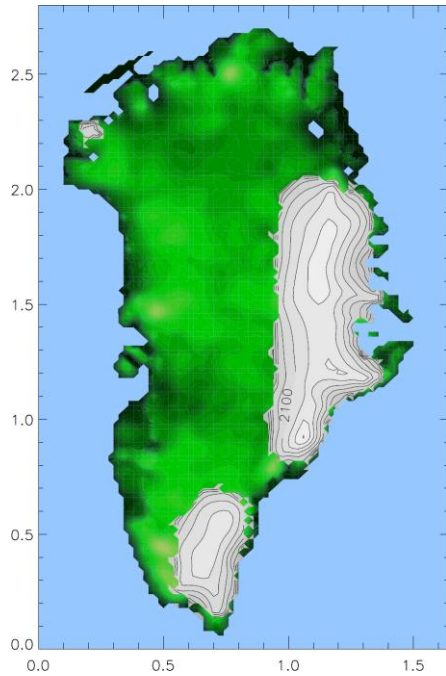
0



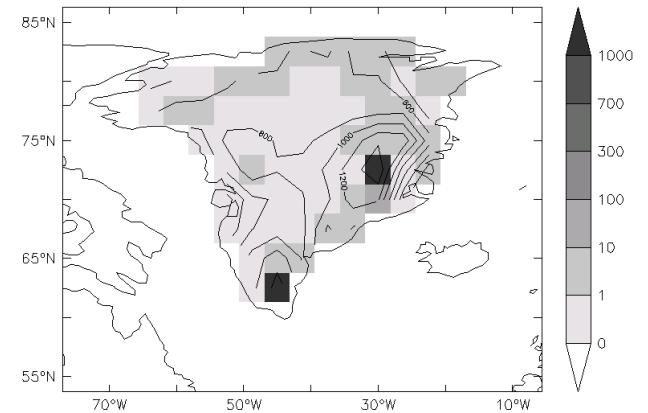
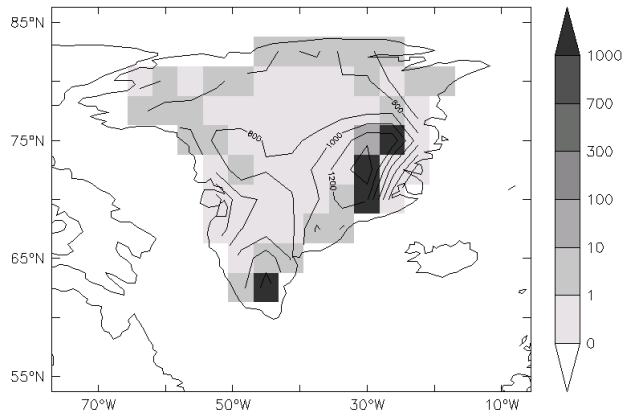
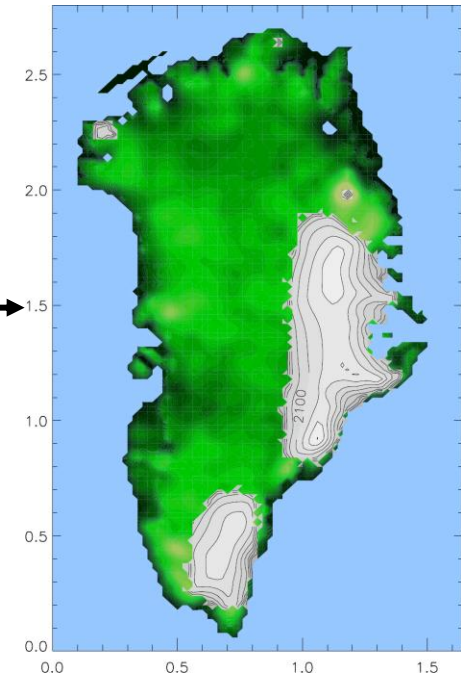
2200yrs



## Initiated with Bare Soil

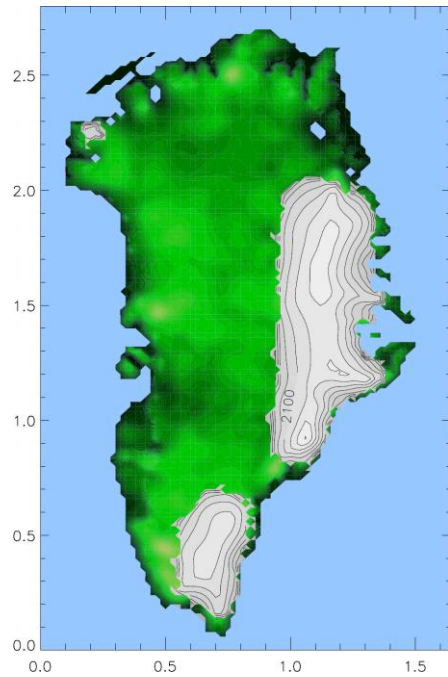


## Initiated with Needle Leaf

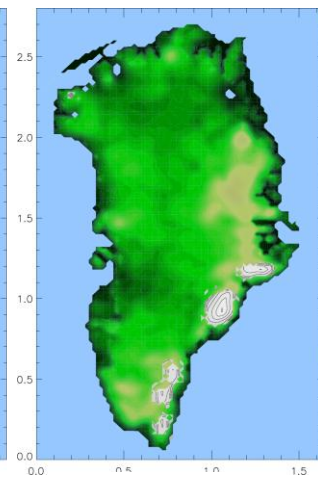
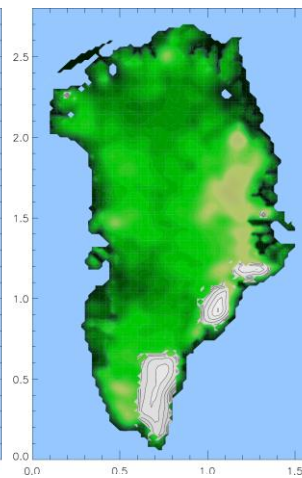
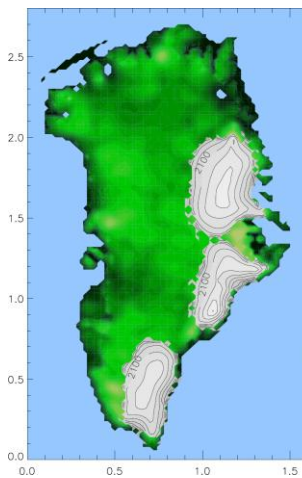
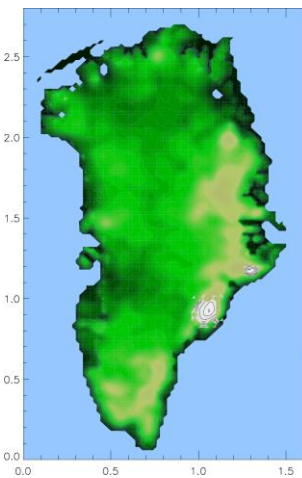
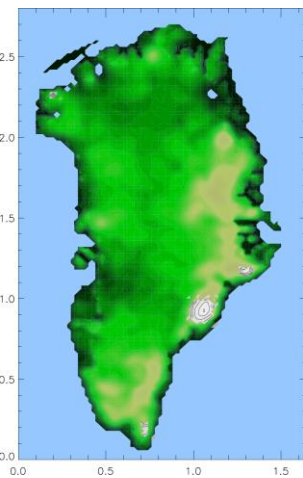
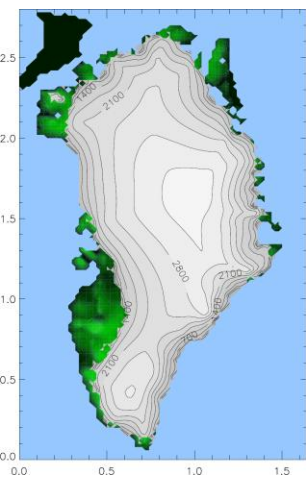
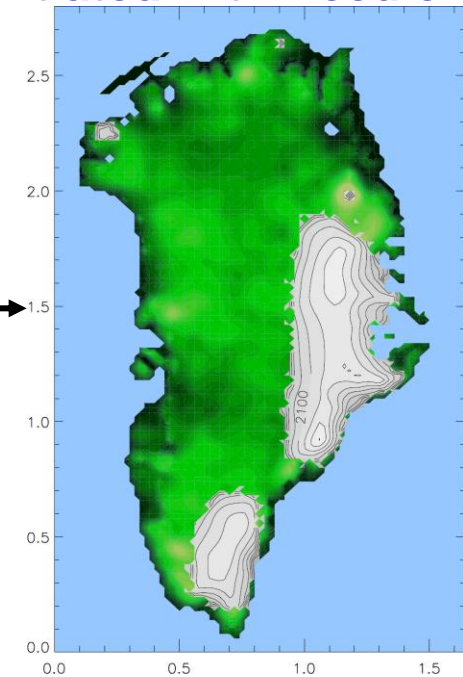
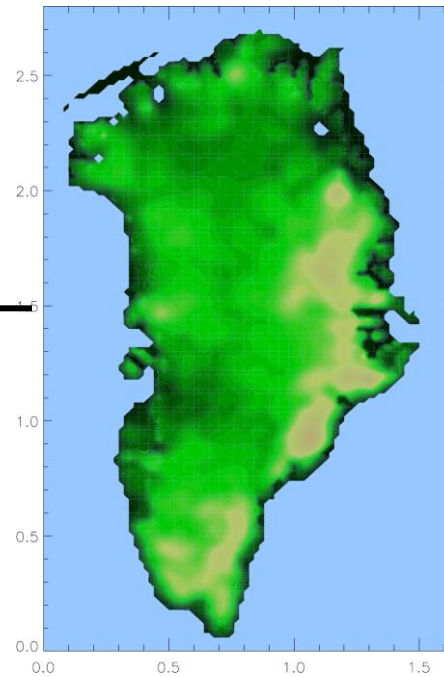


# Dynamic Vegetation-Glimmer Results

Initiated with Bare Soil



Initiated with Needle Leaf



Bare soil

Broadleaf

Needle Leaf

C3 grass

C4 grass

Shrub



- Fixed vegetation- indicate ice sheet may not regrow even under pre-industrial conditions
- Dynamic vegetation → distribution of grasses, shrubs and bare soil
- Partial regrowth of ice sheet when dynamic vegetation included
- **Vegetation feedbacks are important and must be included in simulations of long-term future and past climate**

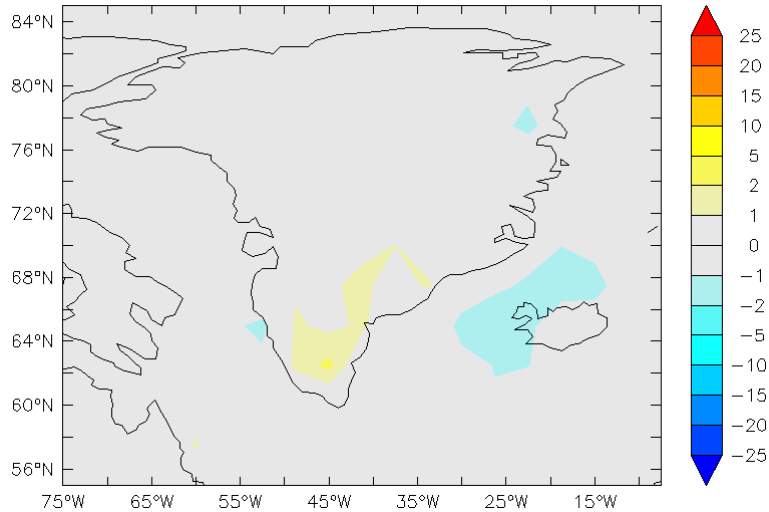
## Future work

- **Asynchronously couple HadCM3 with GLIMMER**
- 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<sub>2</sub>, vegetation distribution and surface elevation
  - the last Interglacial

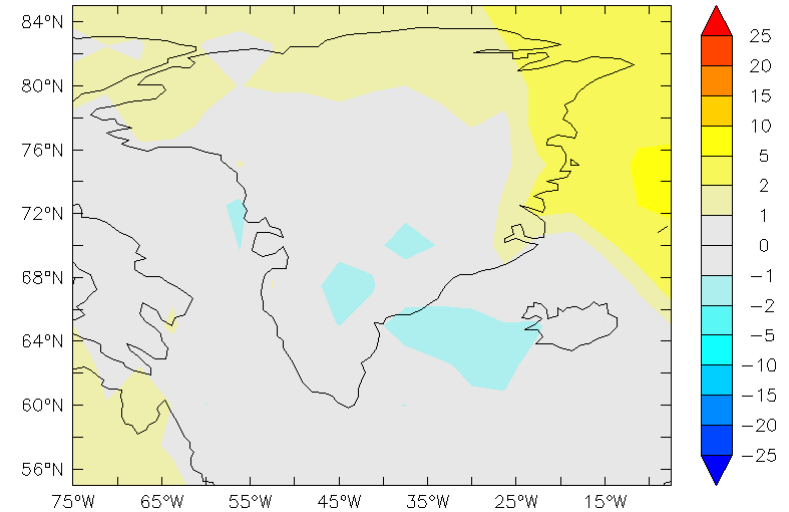
**[emma.j.stone@bristol.ac.uk](mailto:emma.j.stone@bristol.ac.uk)**

# Sensitivity to Roughness Length

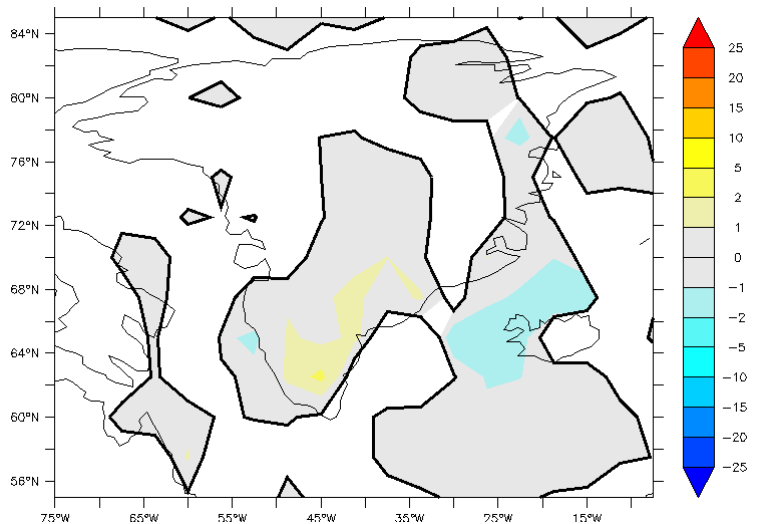
## JJA anomaly



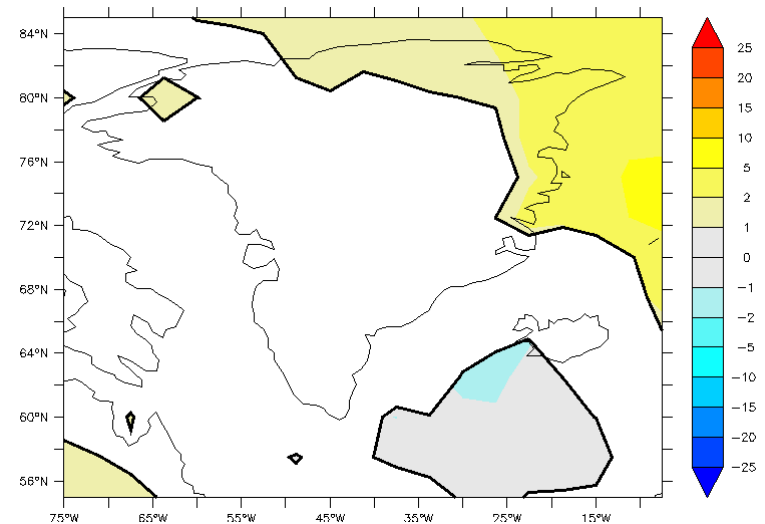
## DJF anomaly



## Needle Leaf<sub>z0=ice</sub> – Needle Leaf



## Needle Leaf<sub>z0=ice</sub> – Needle Leaf



Student T test white region:  $\text{mean}_{\text{NL}} = \text{mean}_{\text{NL}:z0=\text{ice}}$  at 5% sig. level