Fully coupled simulation of the Northern Hemisphere climate and ice sheets during the Last Glacial Maximum with CESM2.1-CISM2.1

Sarah L. Bradley & Michele Petrini

M. Vizcaino, E. Kluzek, B. Lecavalier, J. Ely, W. Lipscomb, B. Sacks, M. Lofverstrom and C. Clark
and support from **many colleagues at NCAR**

TU Delft

European Research Council
Established by the European Commission

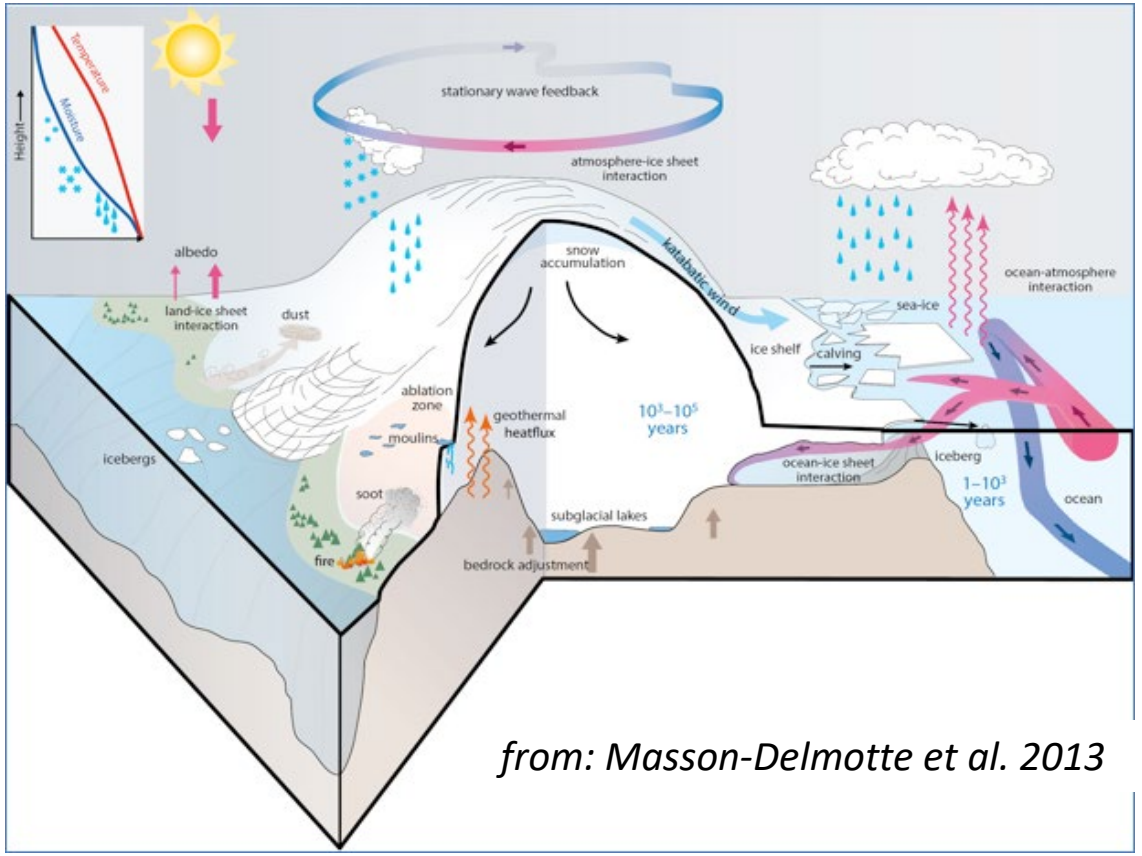
The University Of Sheffield.

PALGLAC
Paleoglaciological advances to understand Earth's ice sheets by landform analysis

Main Goal of Project

Produce first transient fully coupled climate/ice sheet simulation of the last deglaciation using the newly released Community Earth System Model 2.1 (CESM2.1)

investigate different feedbacks + dynamical processes controlling the deglaciation of the Northern Hemisphere ice sheets.



from: Masson-Delmotte et al. 2013

Main theme of this talk

Producing a Last Glacial Maximum (LGM) climatology using the newly released Community Earth System Model 2.1 (CESM2.1)

Outline of talk

Overview of CESM2.1 model setup

Stage 1: Introduction of LGM **paleo-vegetation** datasets

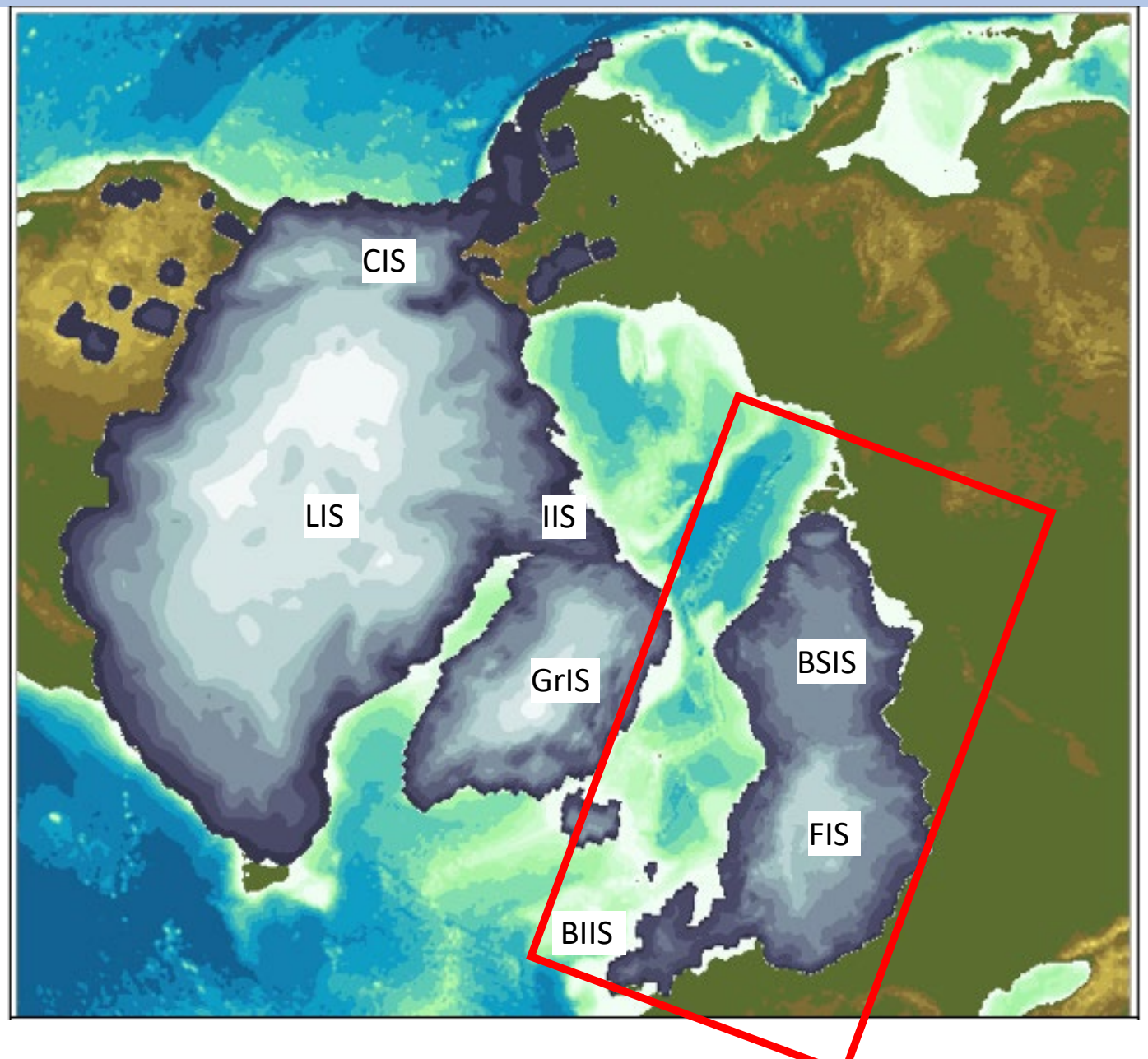
Generating a **spun-up snowpack** and revised SMB

Stage 2: First results from LGM CESM2.1 simulation –climatology

Stage 3: Response of **North Hemisphere ice sheets** to new SMB

Overview of CESM2.1 model setup

Model setup: Northern Hemisphere ice sheets



BSIS+FIS

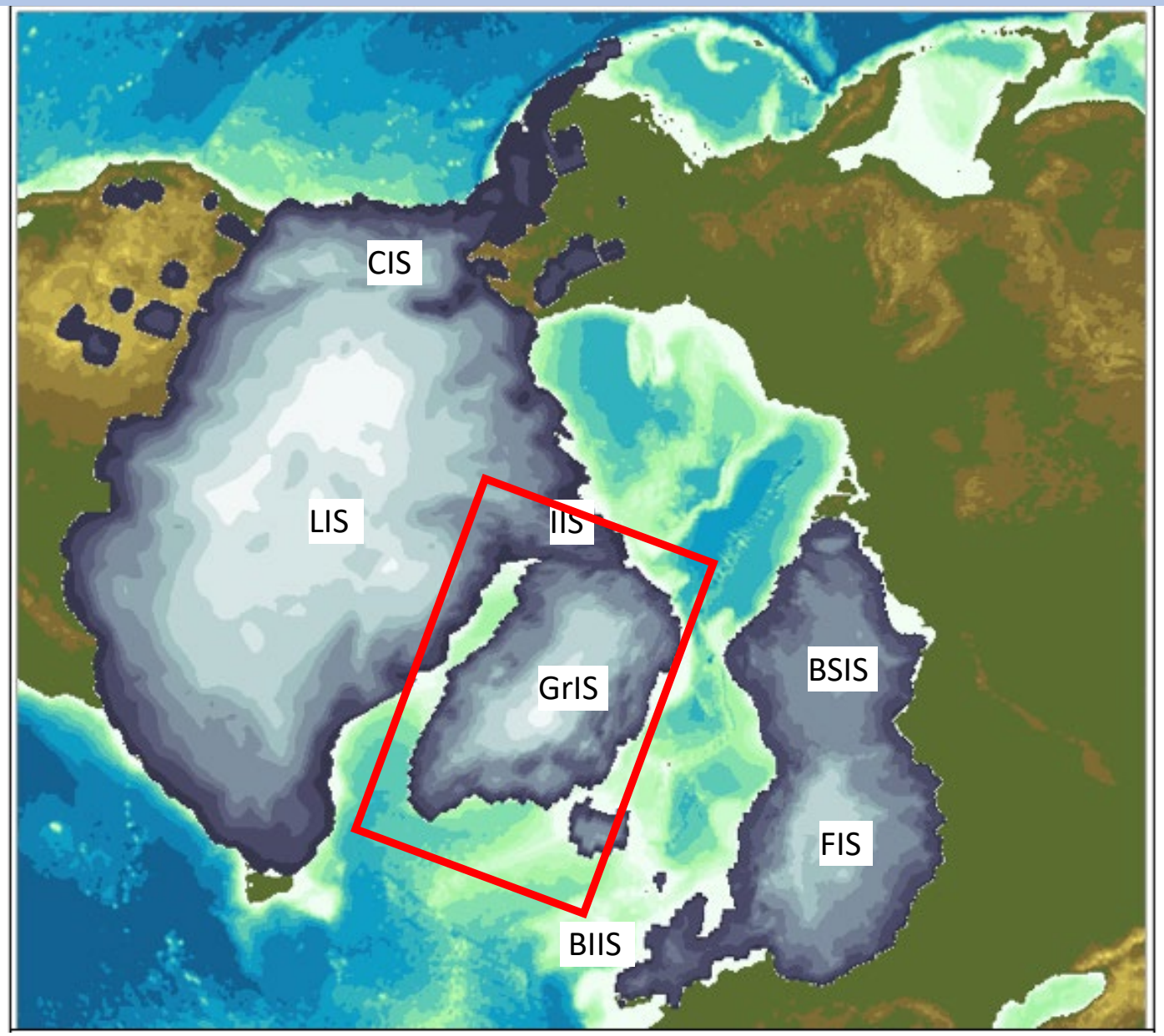
‘DATED-1’ *Hughes et al., 2016*

BIIS

BRITICE-CHRONO

BRITICE CHRONO

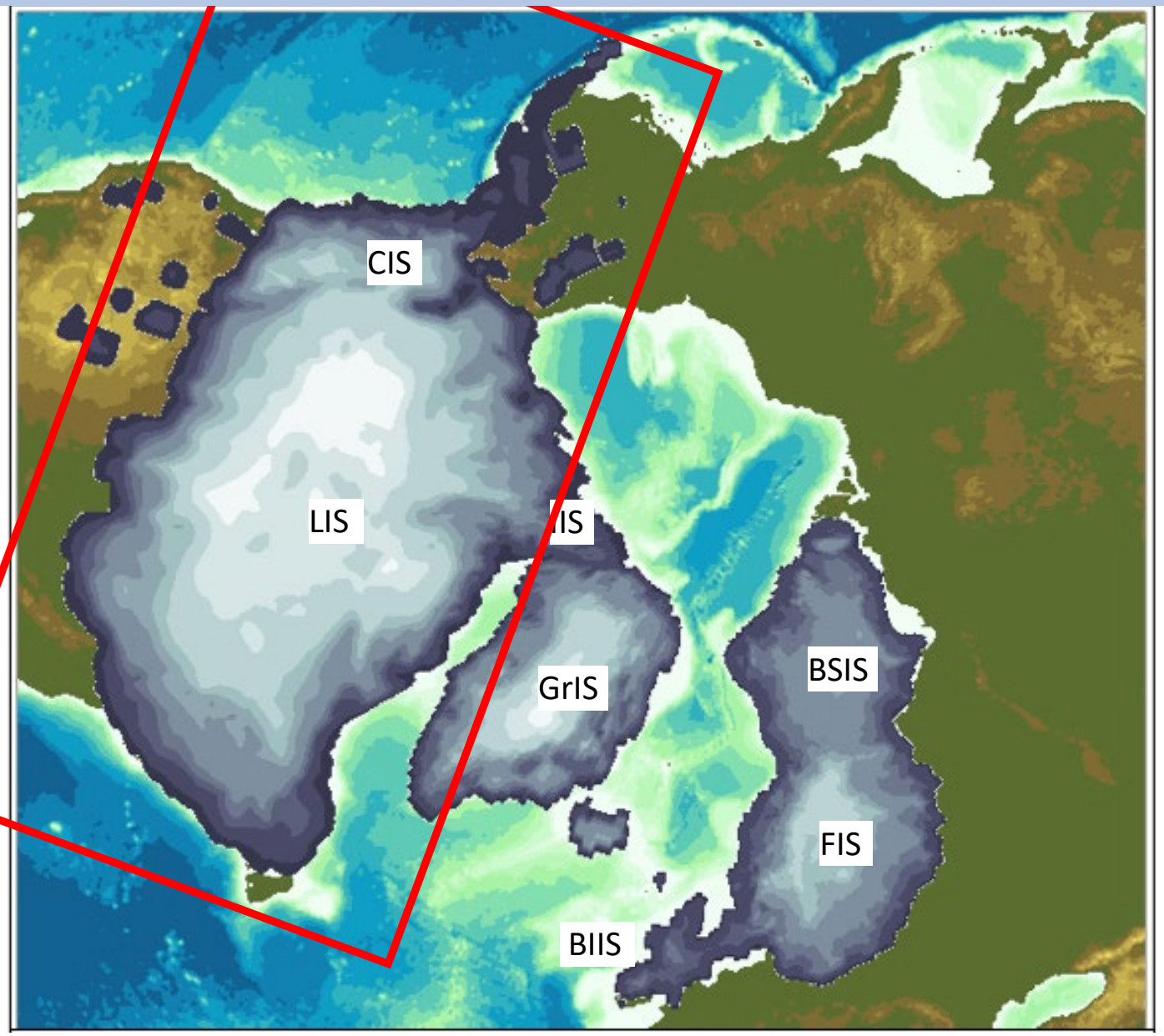
Model setup: Northern Hemisphere ice sheets



GrIS

Lecavalier et al., 2014

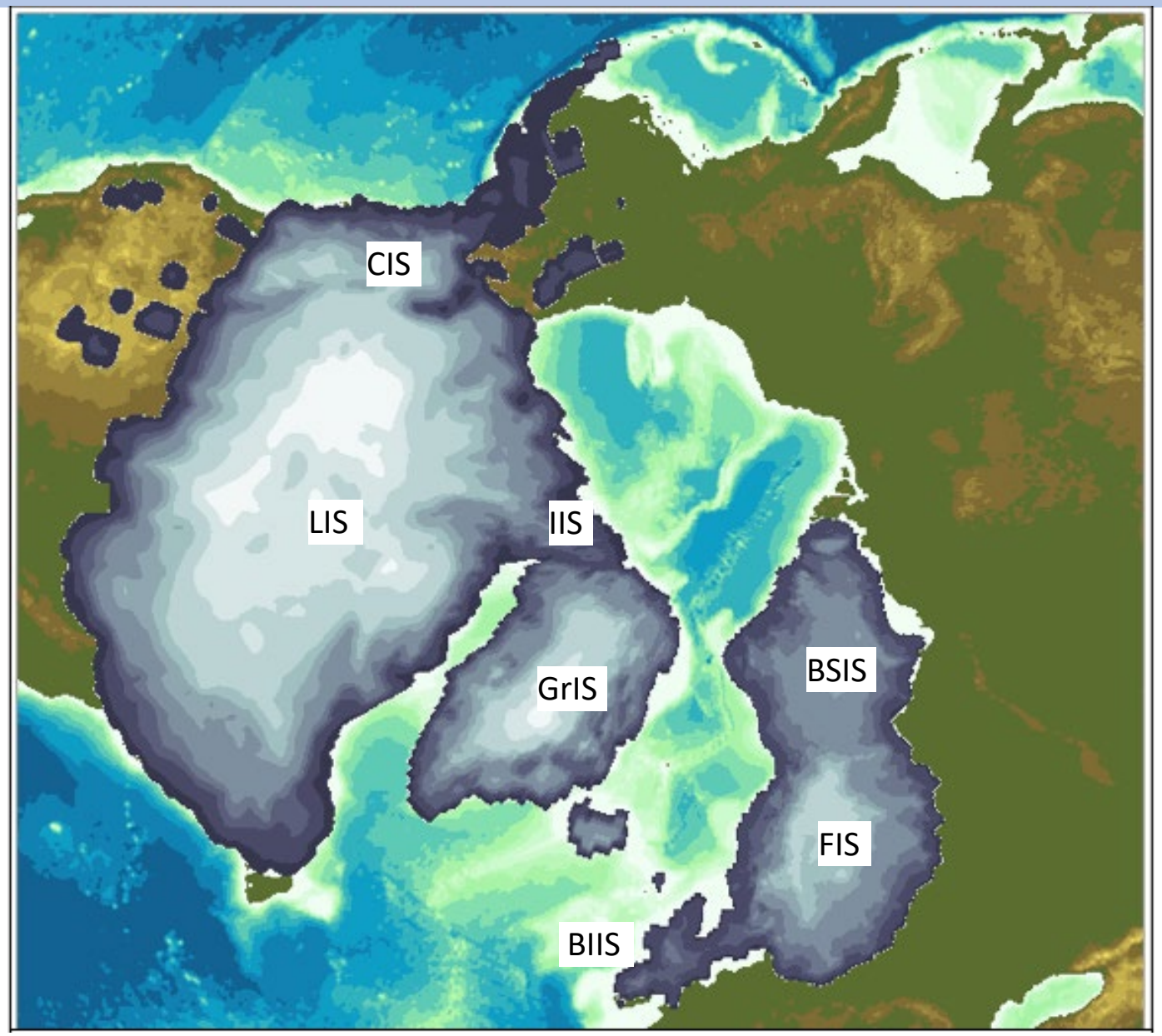
Model setup: Northern Hemisphere ice sheets



North American ice sheet complex

Tarasov et al., 2012

Model setup: Other parameters



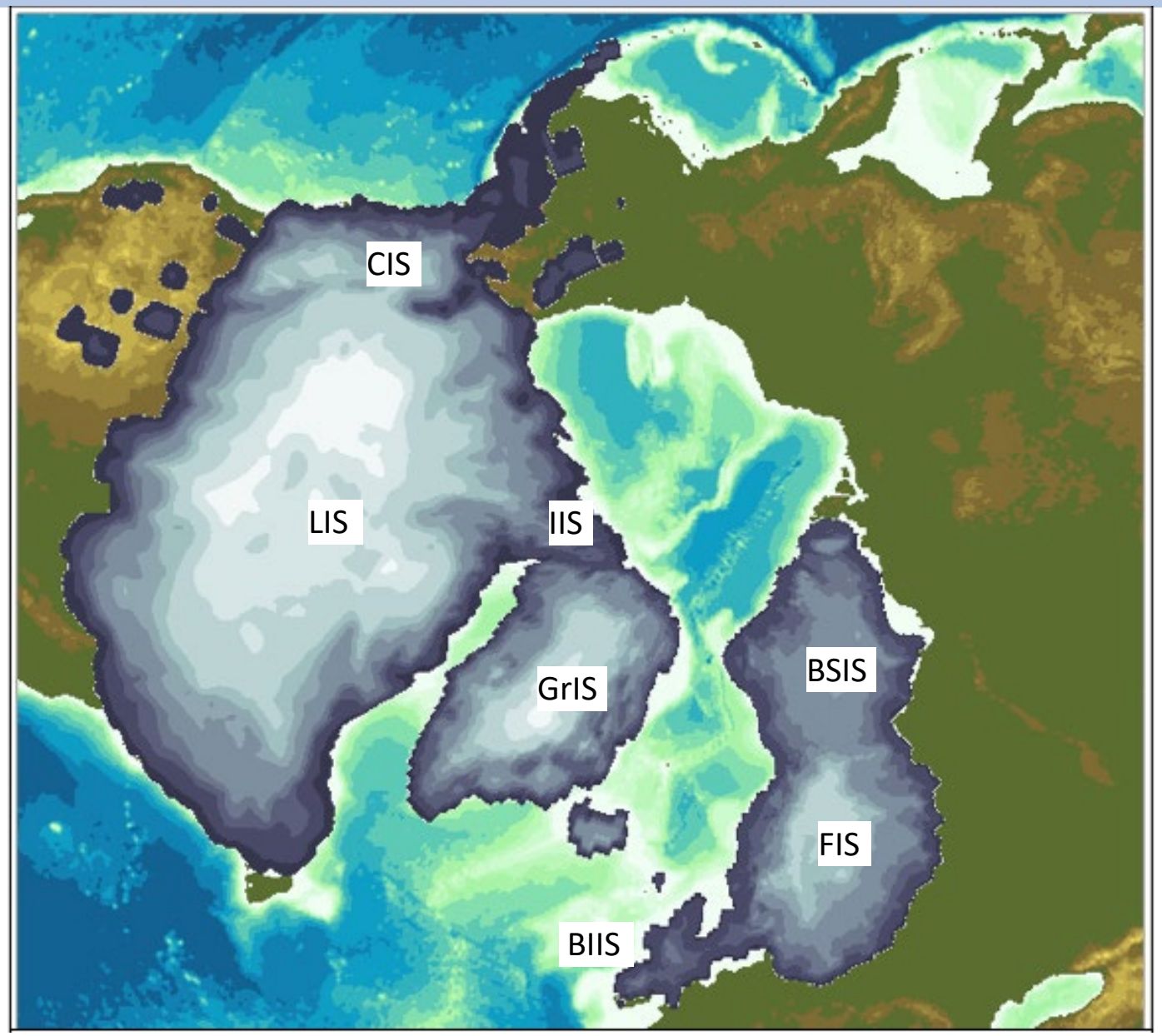
Orbital parameters, GHGS, solar constant

taken from PMIP4
Ivanovic et al., 2016

Model resolution

CESM2.1: 1°
CISM2.1: 4km

Model setup: Other parameters



Initial conditions

CAM/CICE/CLM

1850 CESM control

b.e20.B1850.f09_g17.pi_control.all.299

POP

LGM CESM1

b.e12.B1850C5.f19_g16.21ka.010

provided by Pedro Di Nezio

DiNezio et al.,2018

Stage 1:

Introduction of LGM **paleo-vegetation** datasets

Generating a **spun-up snowpack** and revised SMB

Stage 1: LGM vegetation reconstructions

Stage 1: LGM vegetation reconstructions

Under the PMIP4 guidelines: *Ivanovic et al., 2016*

1. **dynamic vegetation model**

not currently active in CESM2.1

Stage 1: LGM vegetation reconstructions

Under the PMIP4 guidelines: *Ivanovic et al., 2016*

1. **dynamic vegetation model**

   not currently active in CESM2.1

2. **prescribed PI/1850 vegetation**

   incorrect veg. close to ice sheet → impact albedo

   climate too cold → veg. will die

Stage 1: LGM vegetation reconstructions

Under the PMIP4 guidelines: *Ivanovic et al., 2016*

1. **dynamic vegetation model**

   not currently active in CESM2.1

2. **prescribed PI/1850 vegetation**

   incorrect veg. close to ice sheet → impact albedo

   climate too cold → veg. will die

How do we address this in our simulations?

Stage 1: LGM vegetation reconstructions

Ran an offline vegetation model: **BIOME4** *Kaplan et al., 2003 JGR*

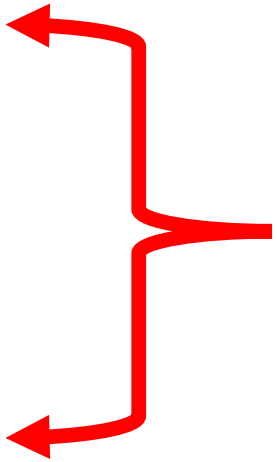
'coupled carbon and water flux model – predicts global steady state veg. distribution, structure + biogeochemistry'.

Stage 1: LGM vegetation reconstructions

Ran an offline vegetation model: **BIOME4** *Kaplan et al., 2003 JGR*

Inputs

Monthly air temperature
Monthly precipitation
Minimum air temperature



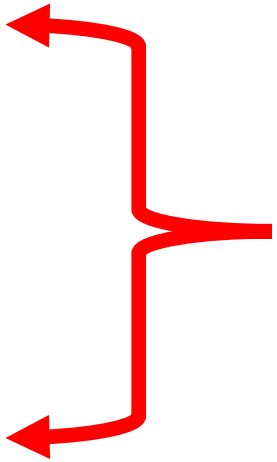
20 year data atmosphere (CAM)

Stage 1: LGM vegetation reconstructions

Ran an offline vegetation model: **BIOME4** *Kaplan et al., 2003 JGR*

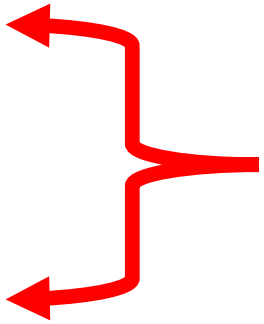
Inputs

Monthly air temperature
Monthly precipitation
Minimum air temperature



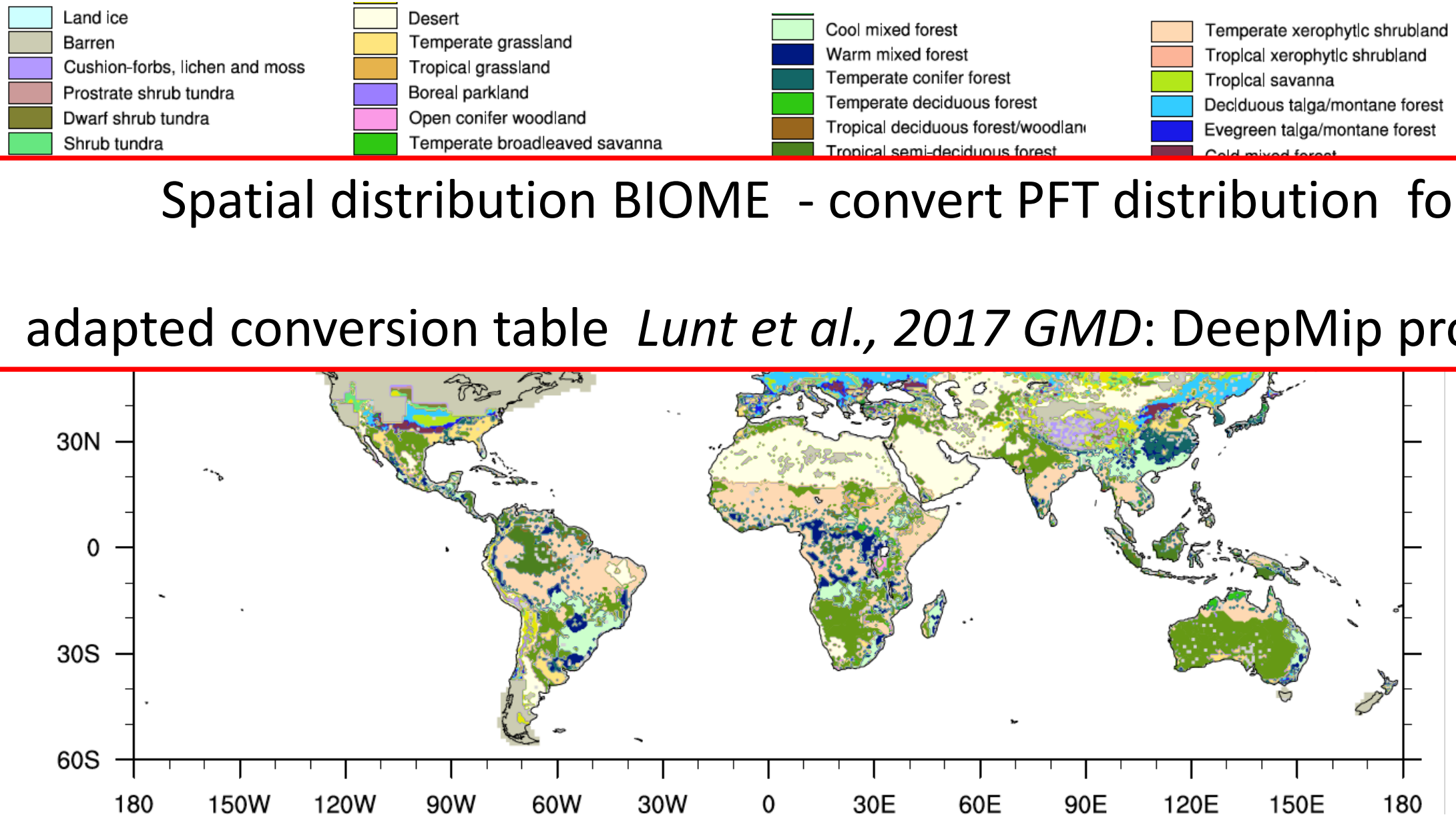
20 year data atmosphere (CAM)

Soil percolation index
Soil water holding capacity



provided by Jed Kaplan

Stage 1: LGM vegetation reconstructions



Spatial distribution BIOME - convert PFT distribution for CLM5

adapted conversion table *Lunt et al., 2017 GMD*: DeepMip project

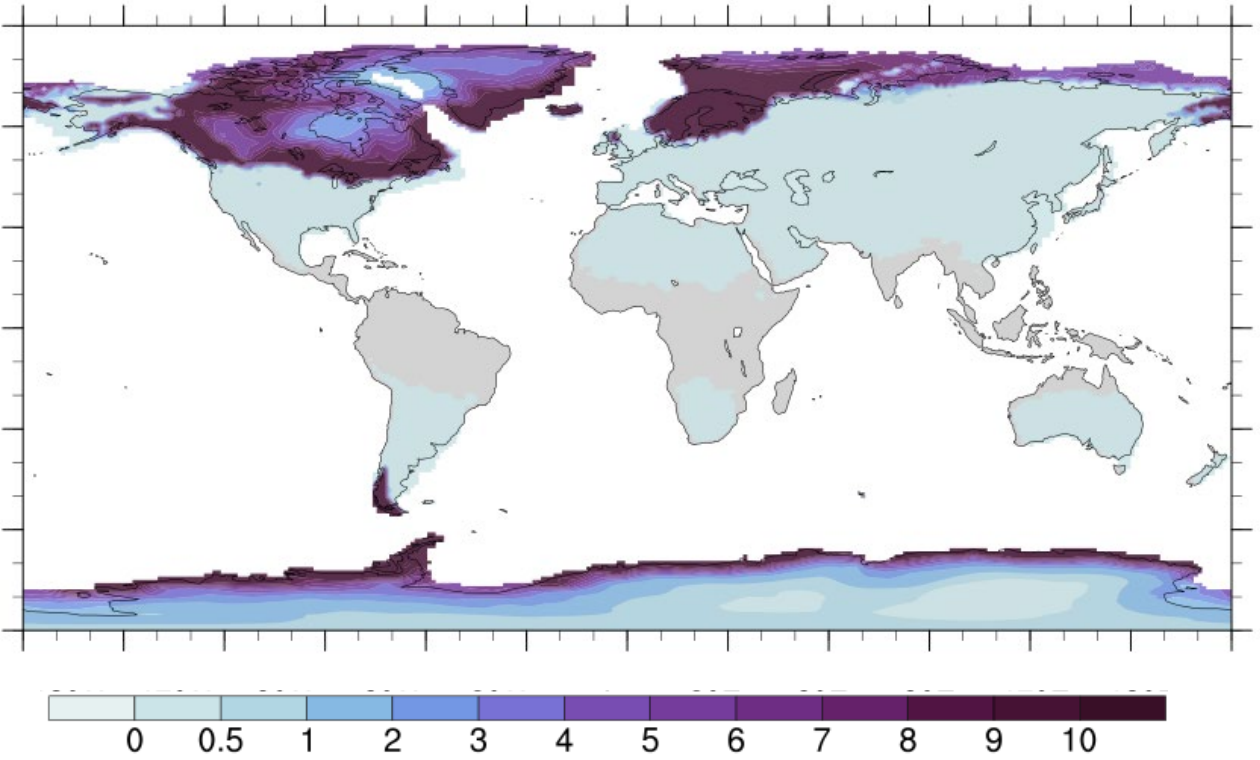
Results of Land-model simulation

Ran a 500 year land-only simulation

Input of new LGM PFT distribution

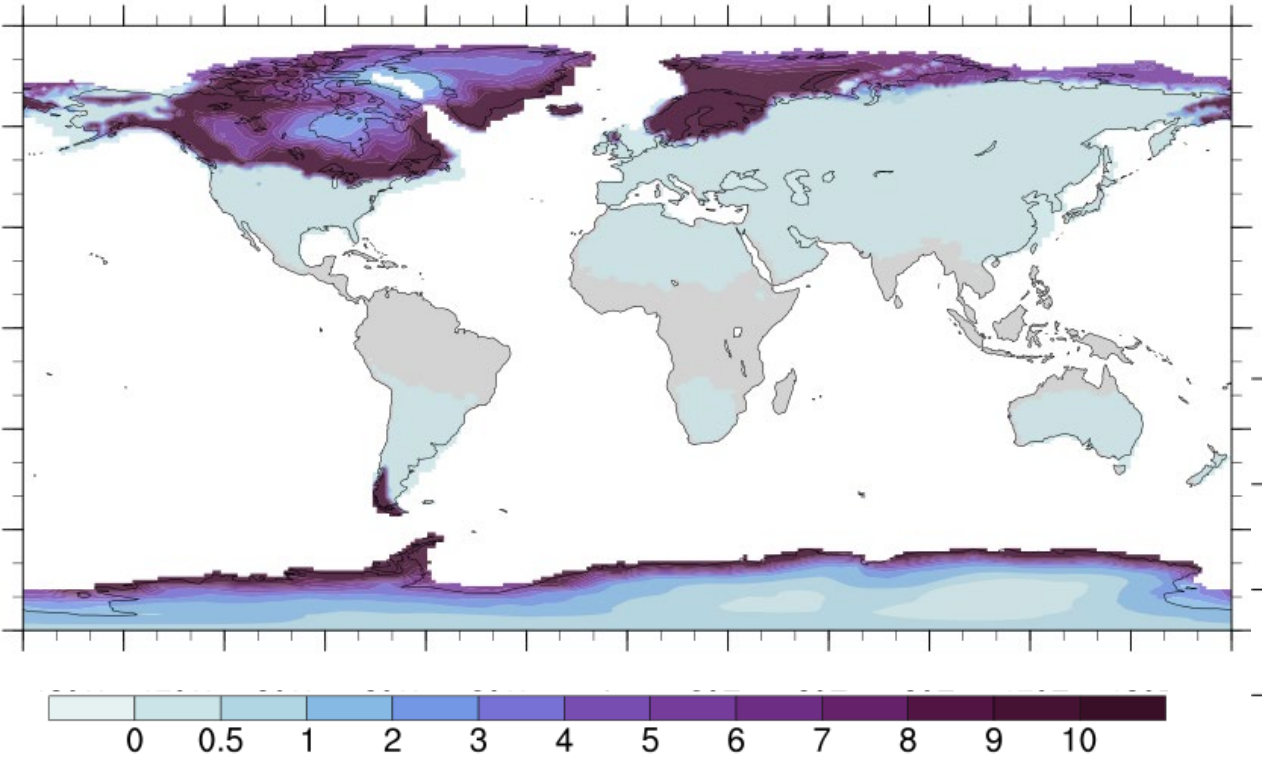
20 year DATM forcing from 90 yr LGM CESM2.1

Annual snow depth (m/w.e)



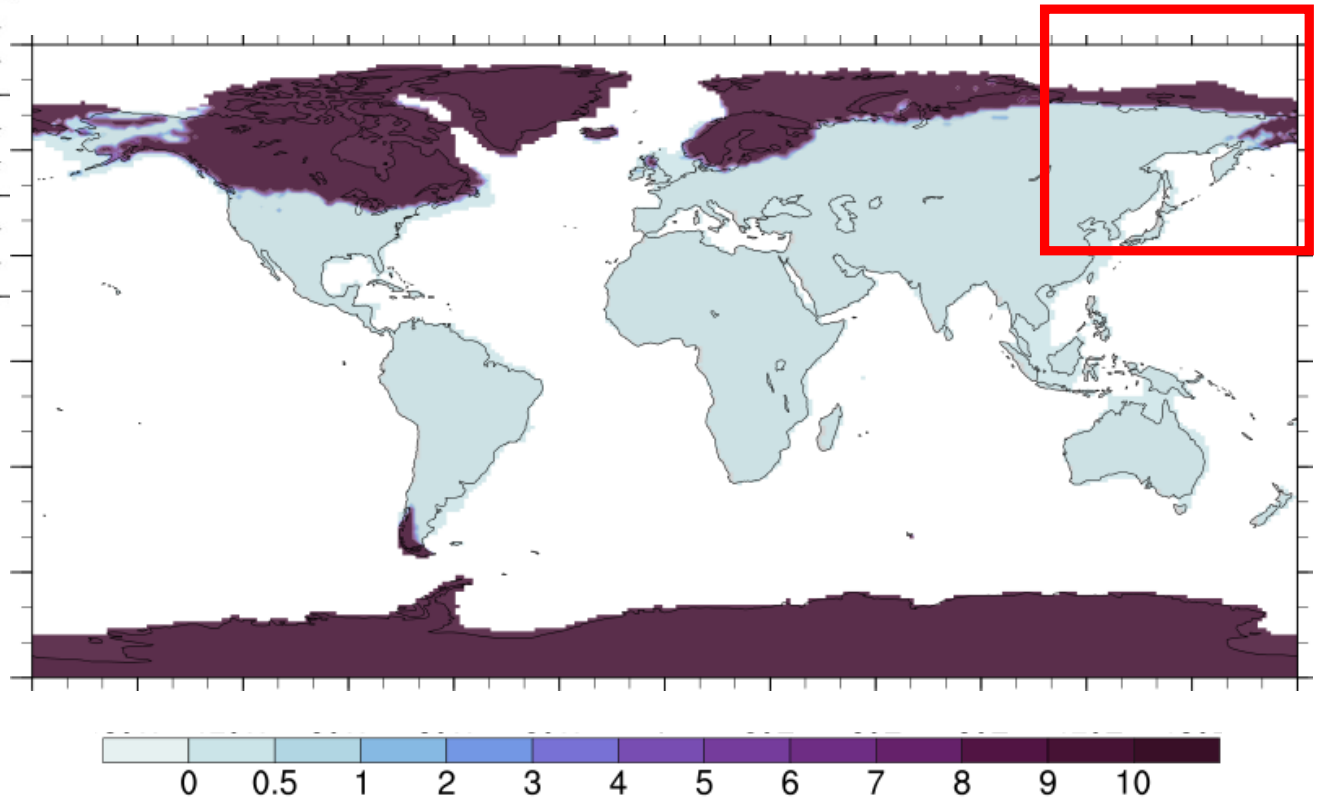
CESM2.1 90 yr simulation

Annual snow depth (m/w.e)

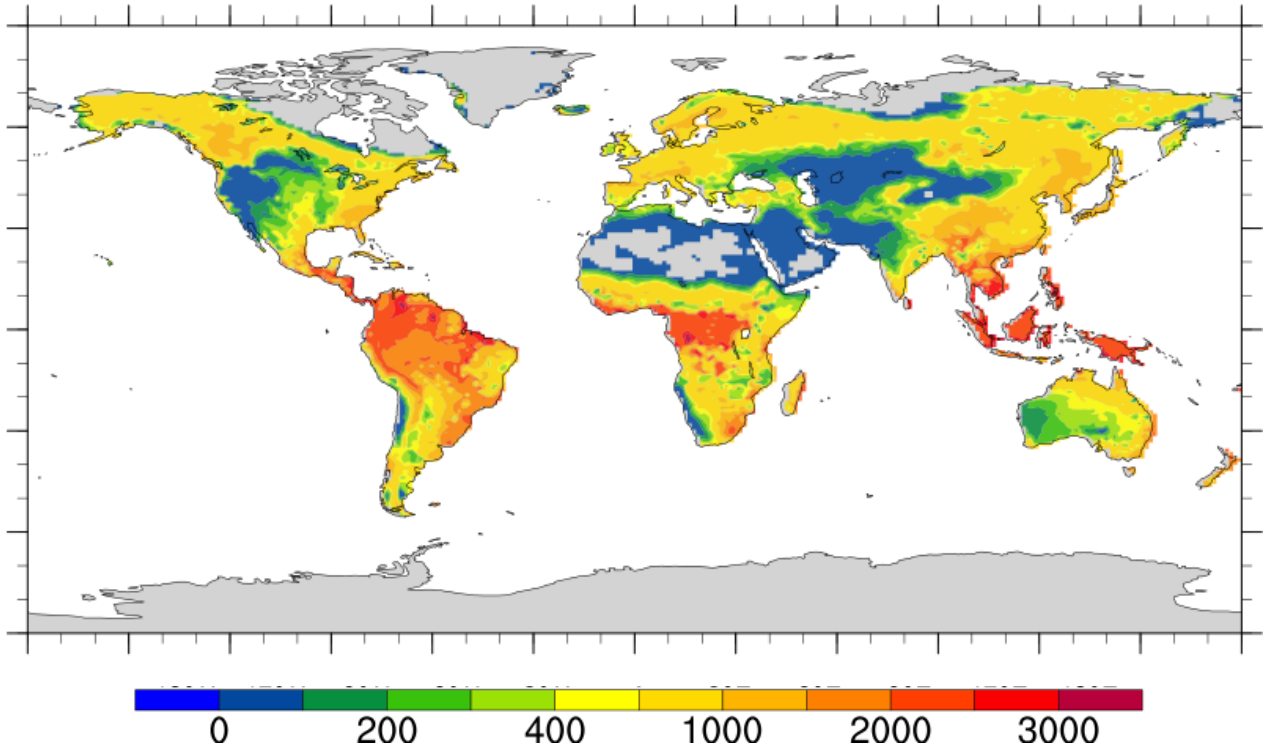


CESM2.1 90 yr simulation

Land-only simulation



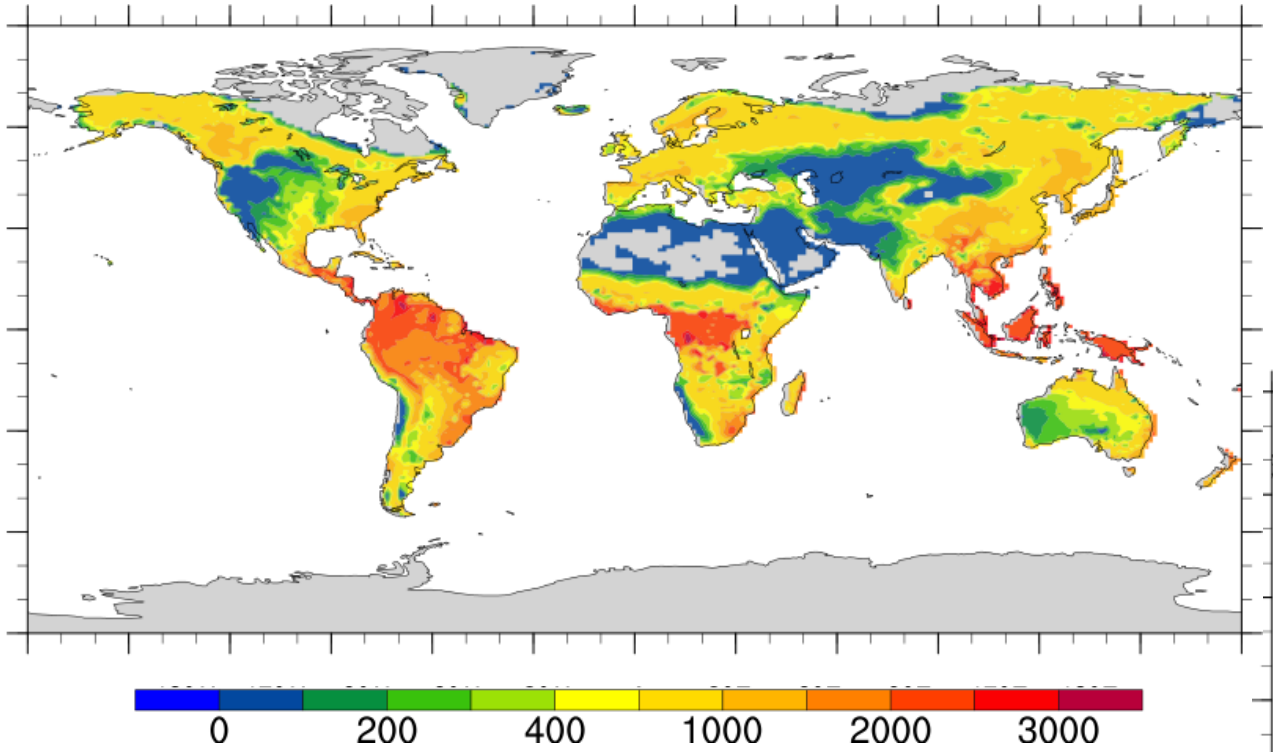
Impact of revised PFT distribution



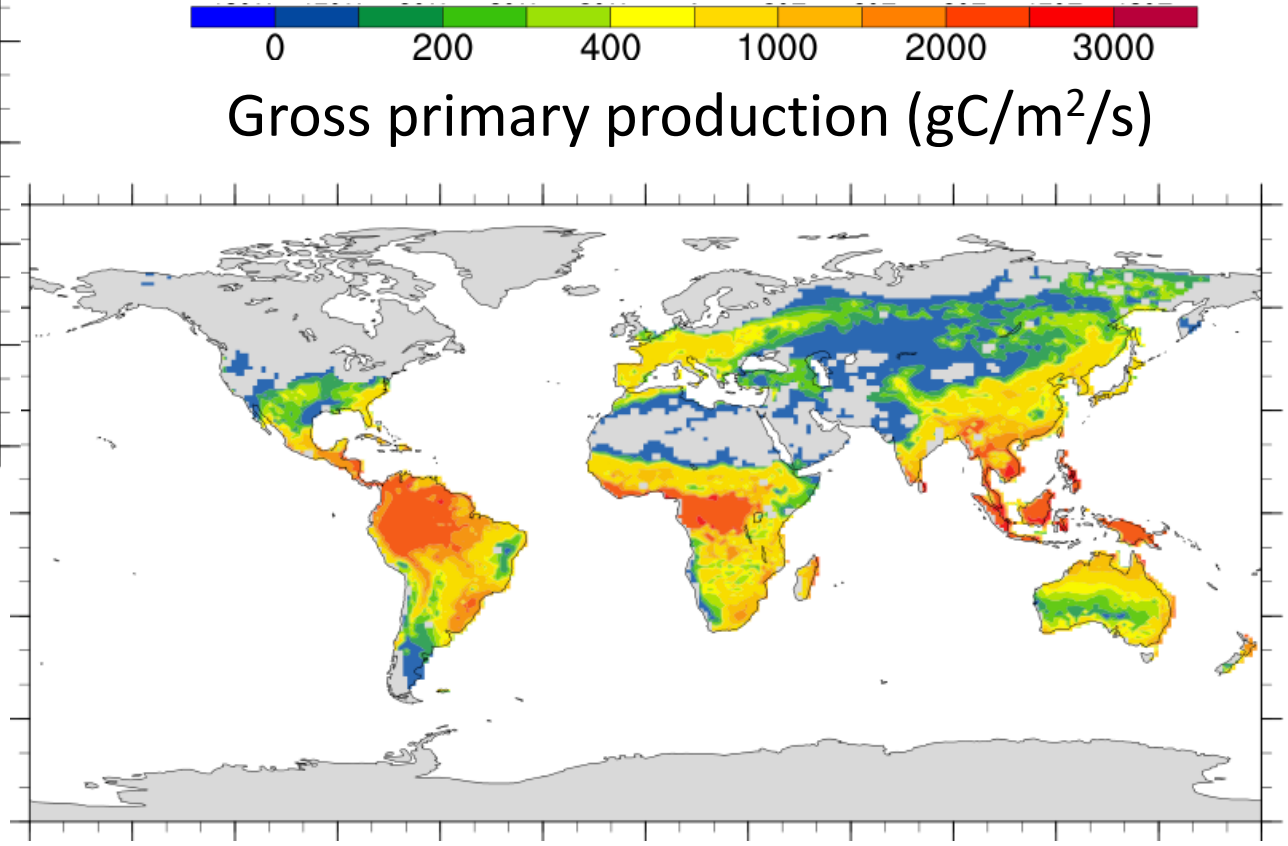
Gross primary production (gC/m^2/s)

1850 CESM control simulation

Impact of revised PFT distribution

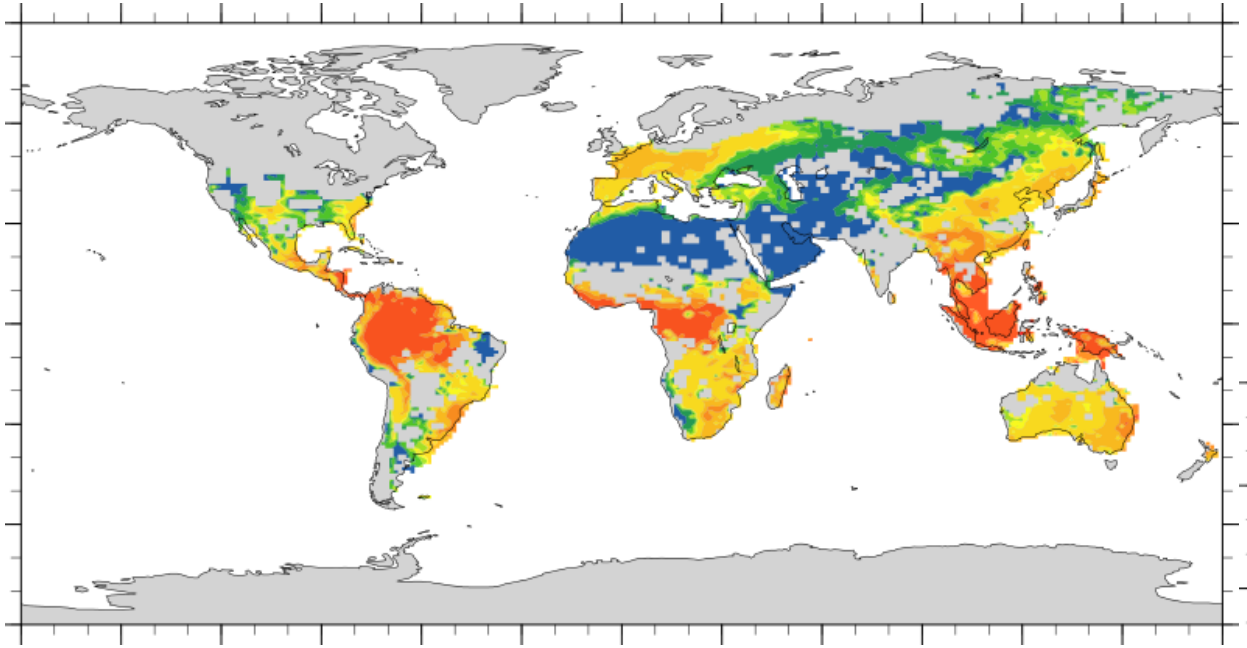


1850 CESM2.1 control simulation



LGM simulation: **1850 veg**. dataset

Impact of revised PFT distribution



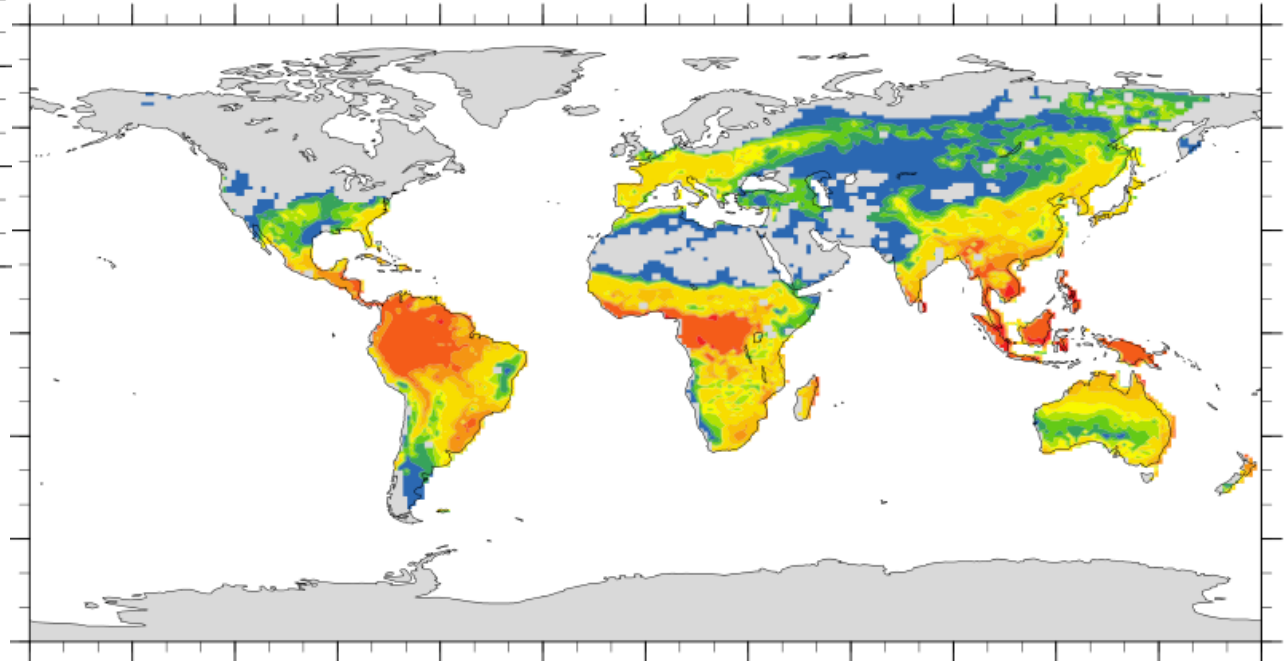
0 200 400 1000 2000 3000

Gross primary production (gC/m^2/s)

LGM simulation: **BIOME4 veg.** dataset

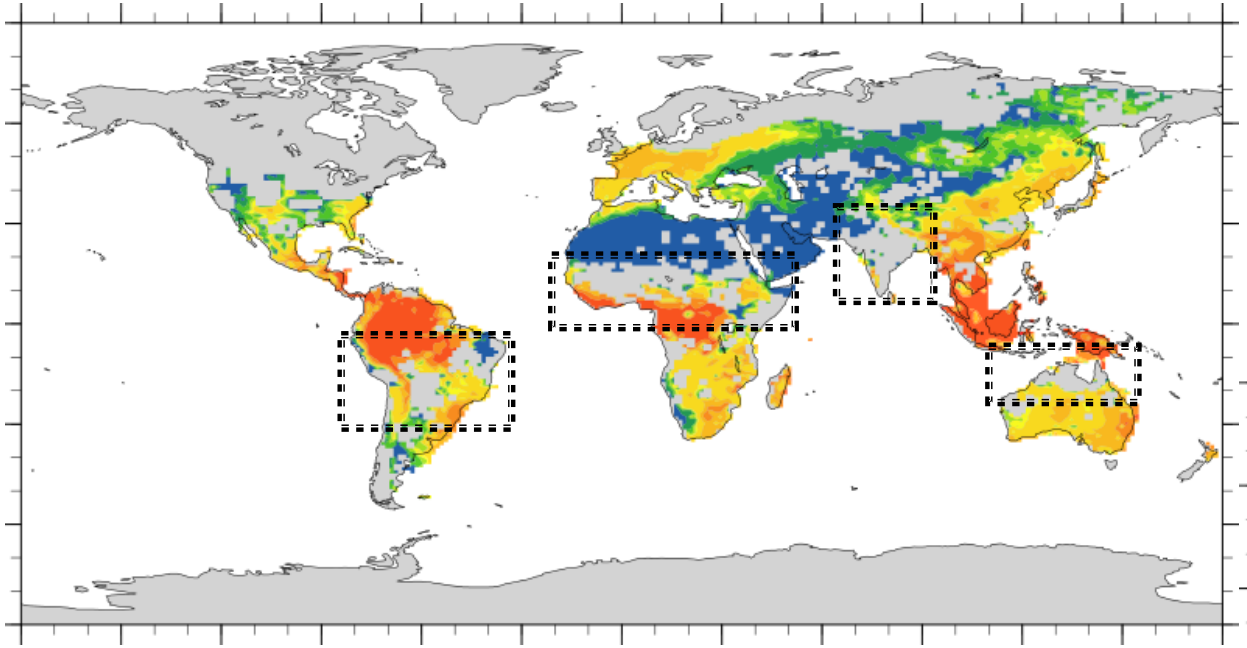
0 200 400 1000 2000 3000

Gross primary production (gC/m^2/s)



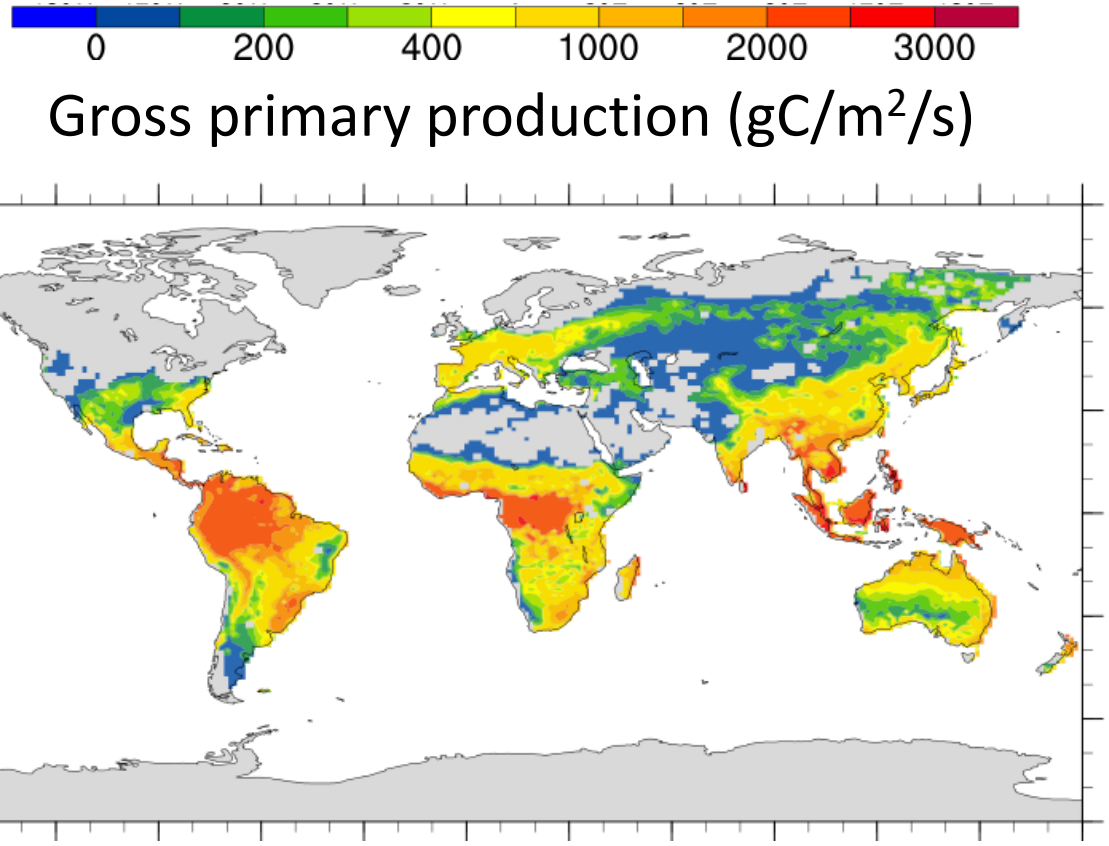
LGM simulation: 1850 veg. dataset

Impact of revised PFT distribution



Gross primary production (gC/m^2/s)

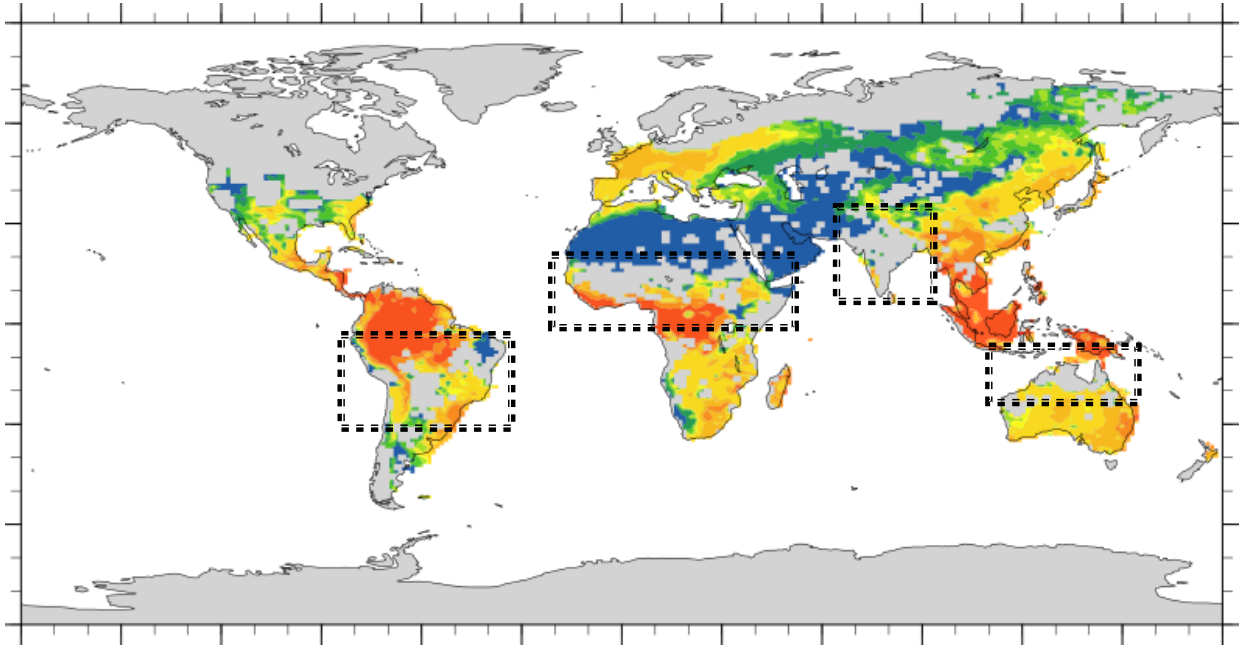
LGM simulation: **BIOME4 veg.** dataset



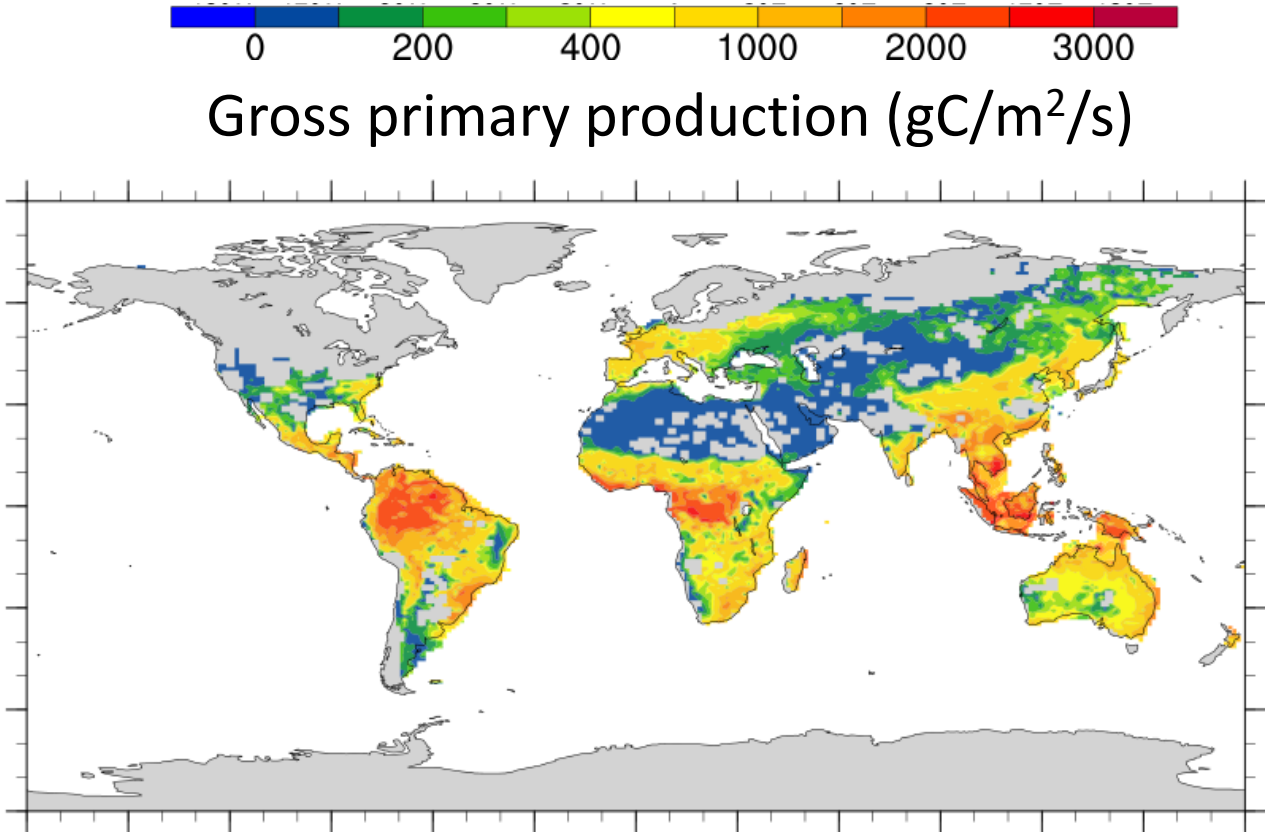
Gross primary production (gC/m^2/s)

LGM simulation: 1850 veg. dataset

Impact of revised PFT distribution



LGM simulation: BIOME4 veg. dataset



LGM simulation: Revised conversion

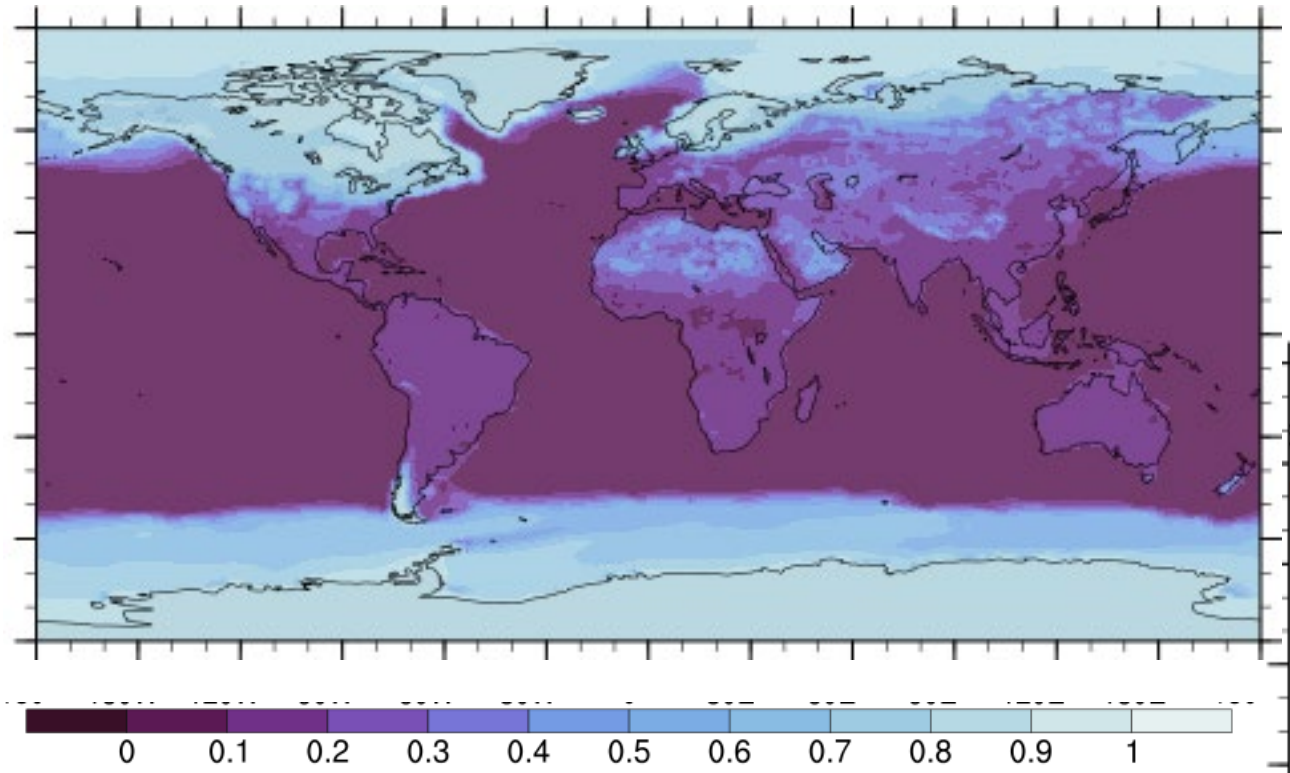
Stage 2: LGM climatology

Combined the output from land-only model +

Previous 90 year LGM CESM2.1

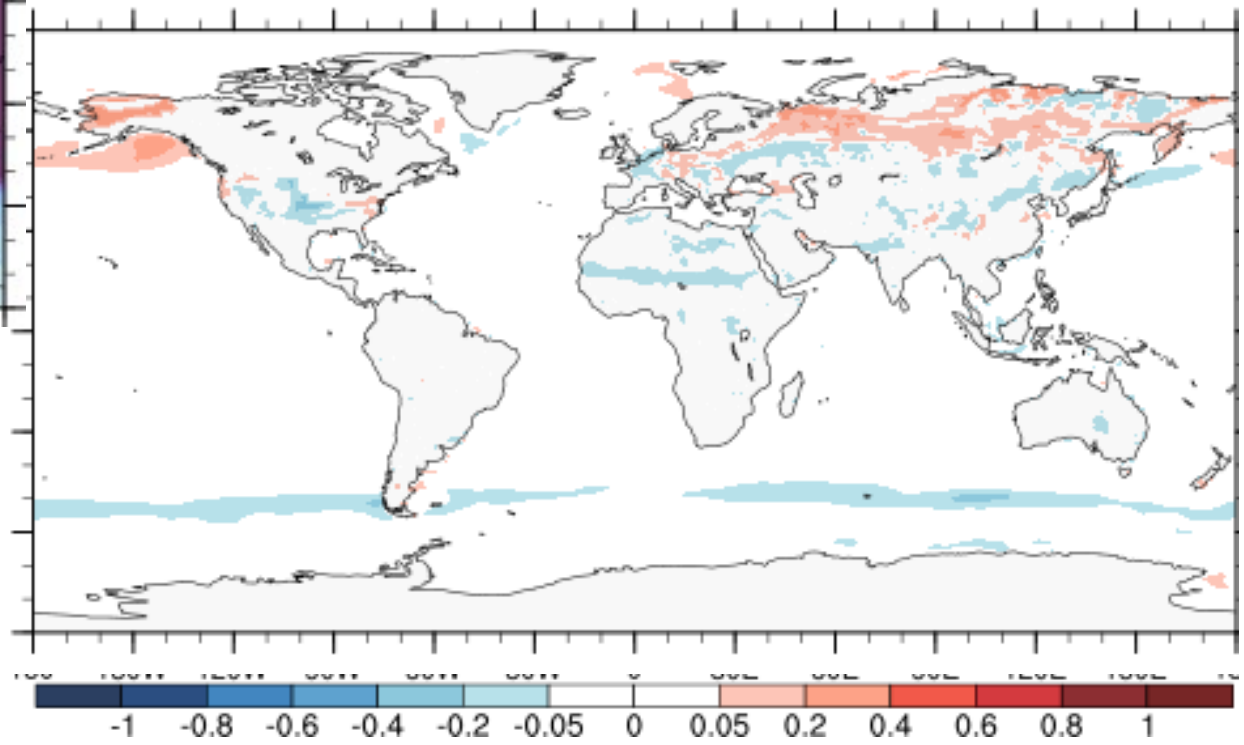
First results from updated LGM CESM2.1 simulation climatology

Albedo (W/m^2)



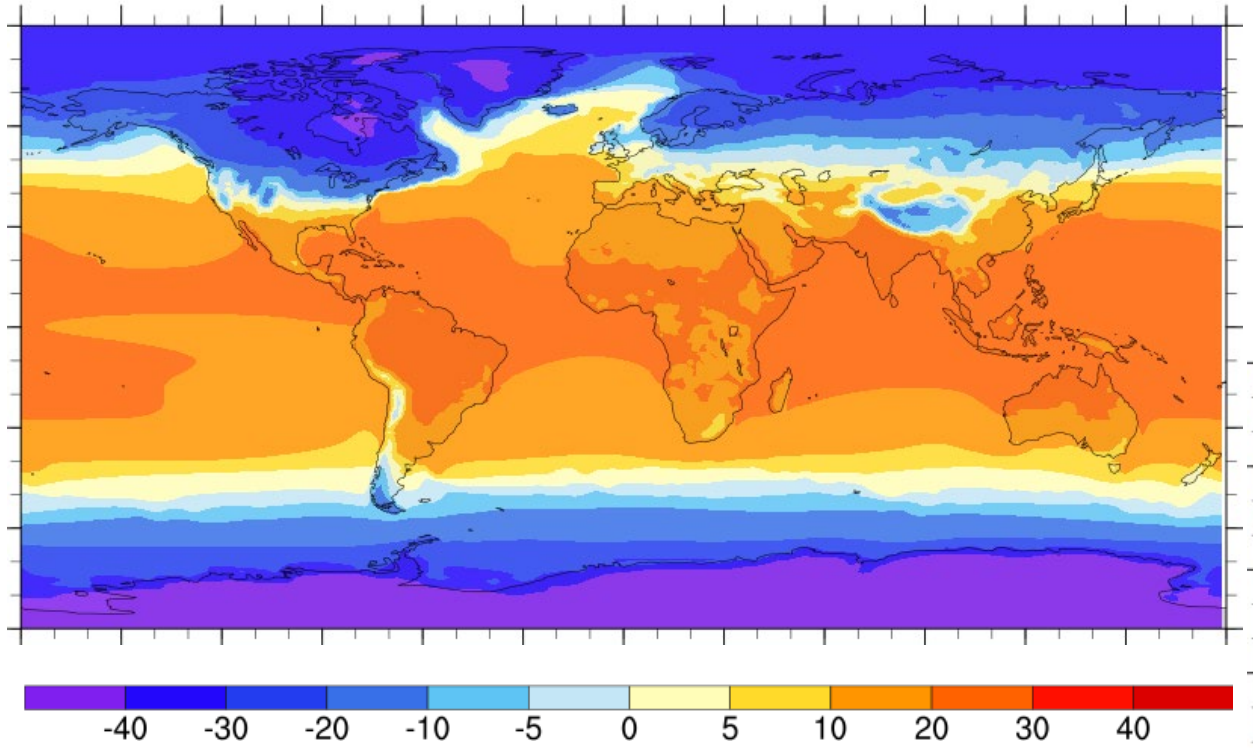
LGM CESM2.1

Including LGM veg. distribution



Difference relative to PI veg. distribution

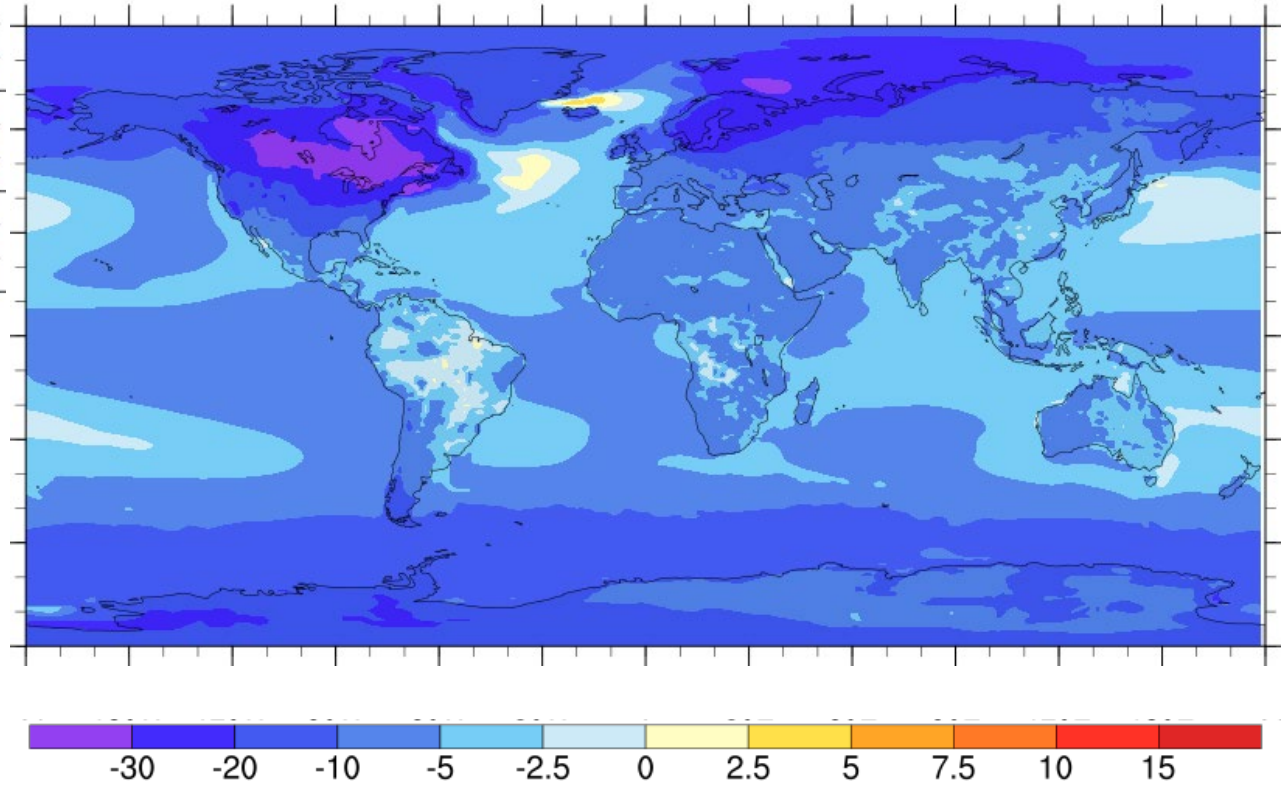
Annual Surface Temperature (°C)



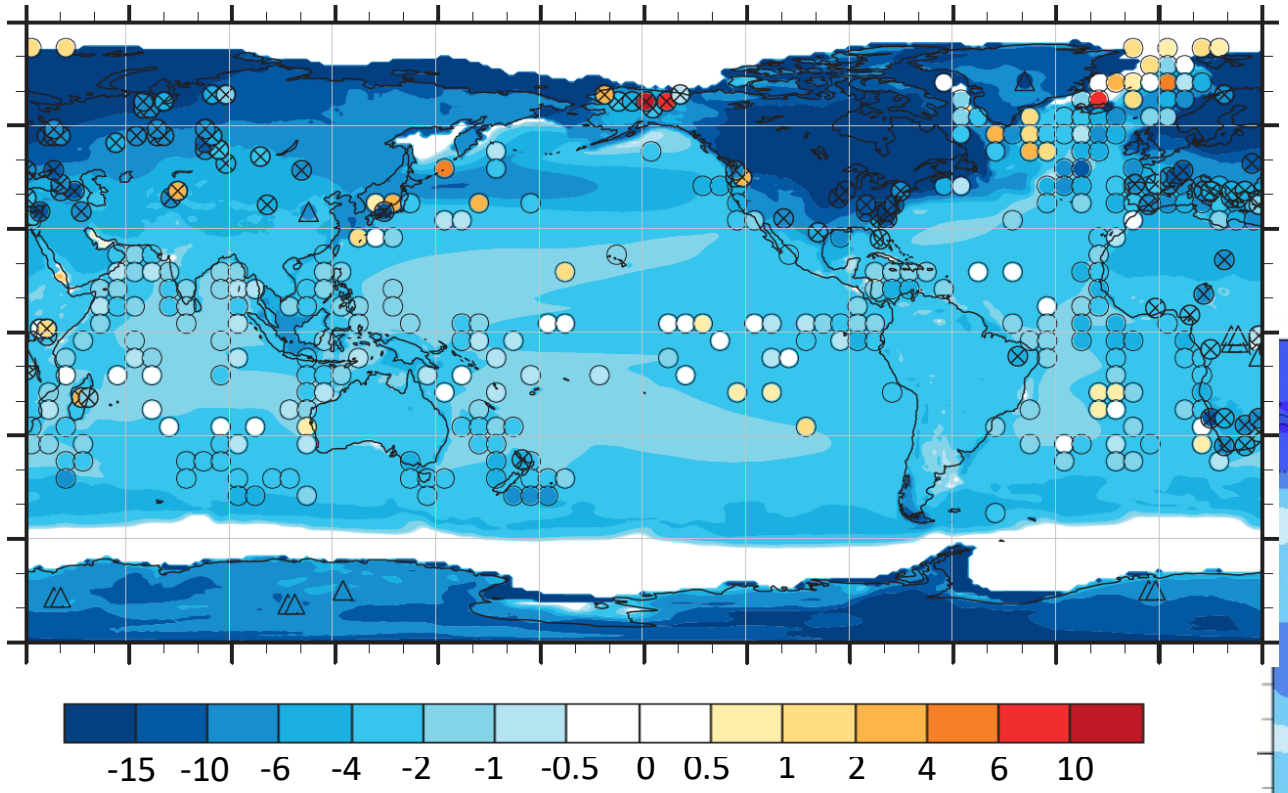
LGM CESM2.1

LGM CESM2.1

Difference relative to 1850 Control



Annual Surface Temperature (°C)

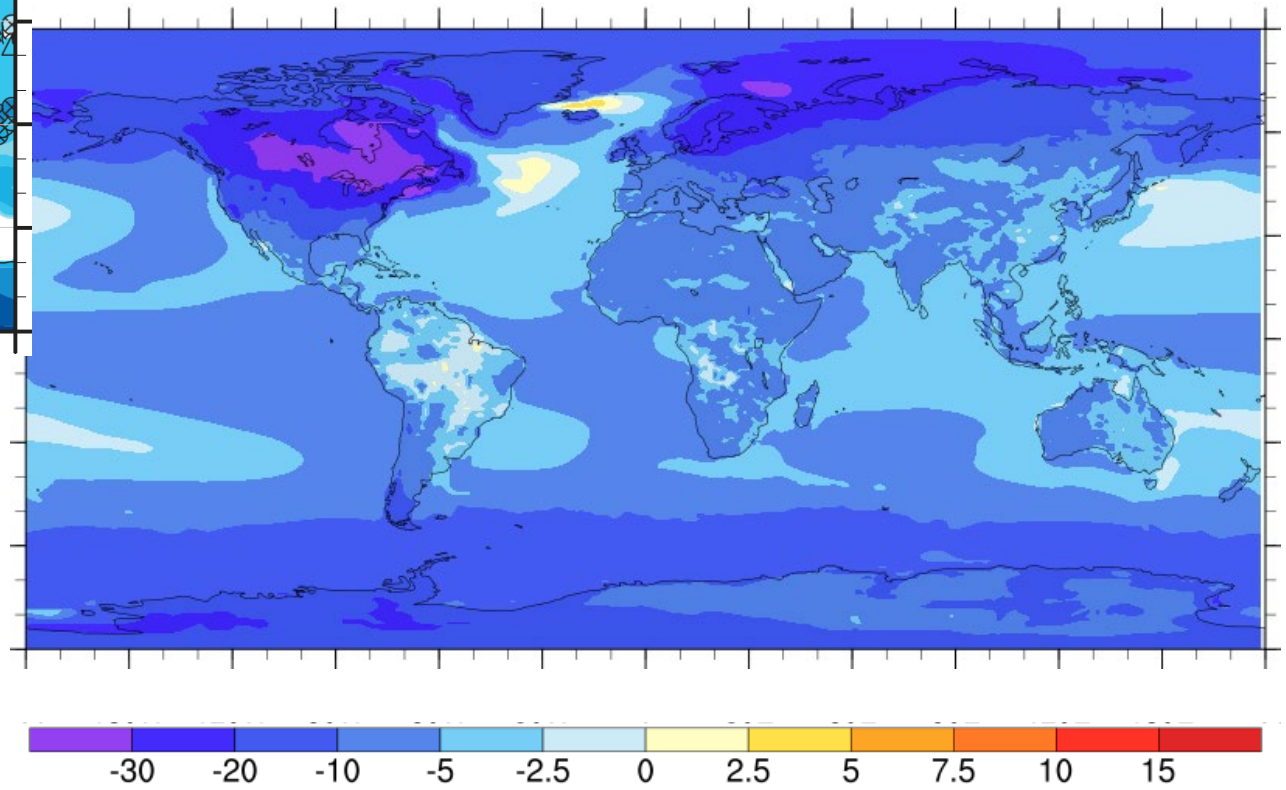


Difference relative to 1850 Control

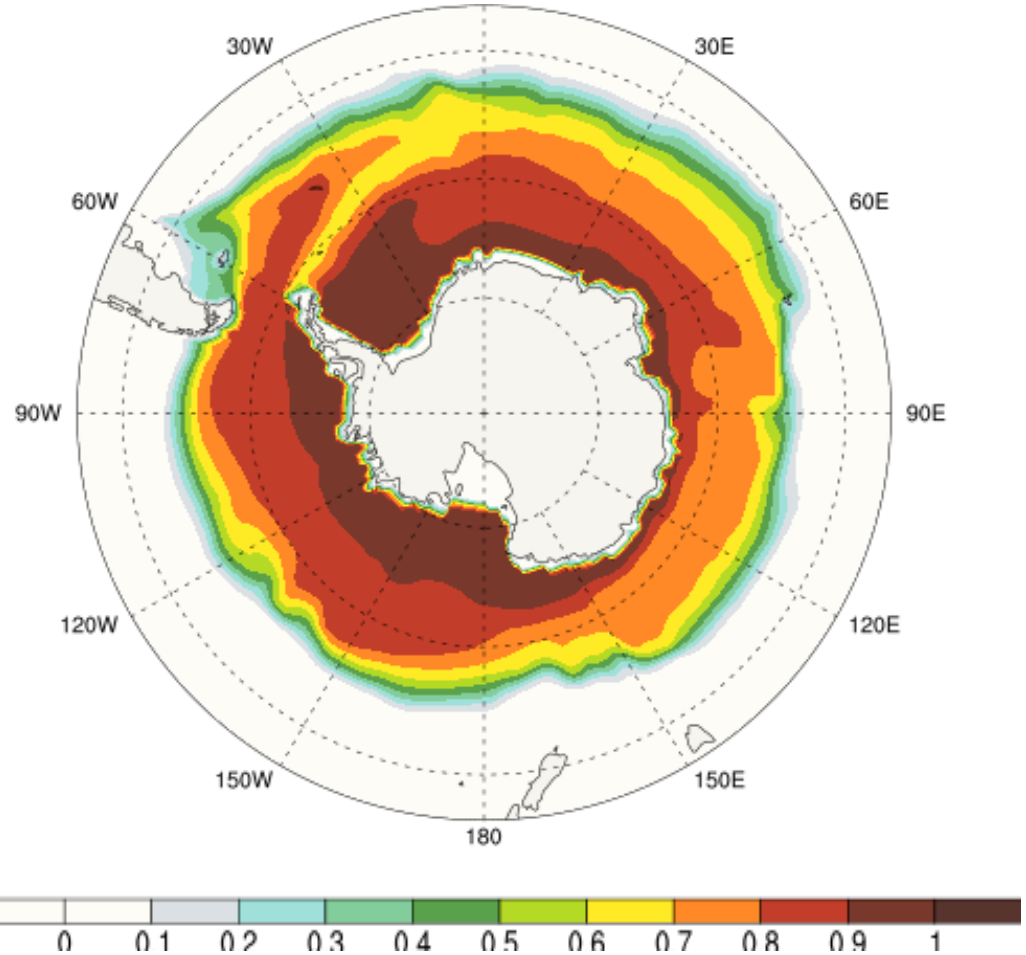
LGM CCSM4: Brady et al., 2013

LGM CESM2.1

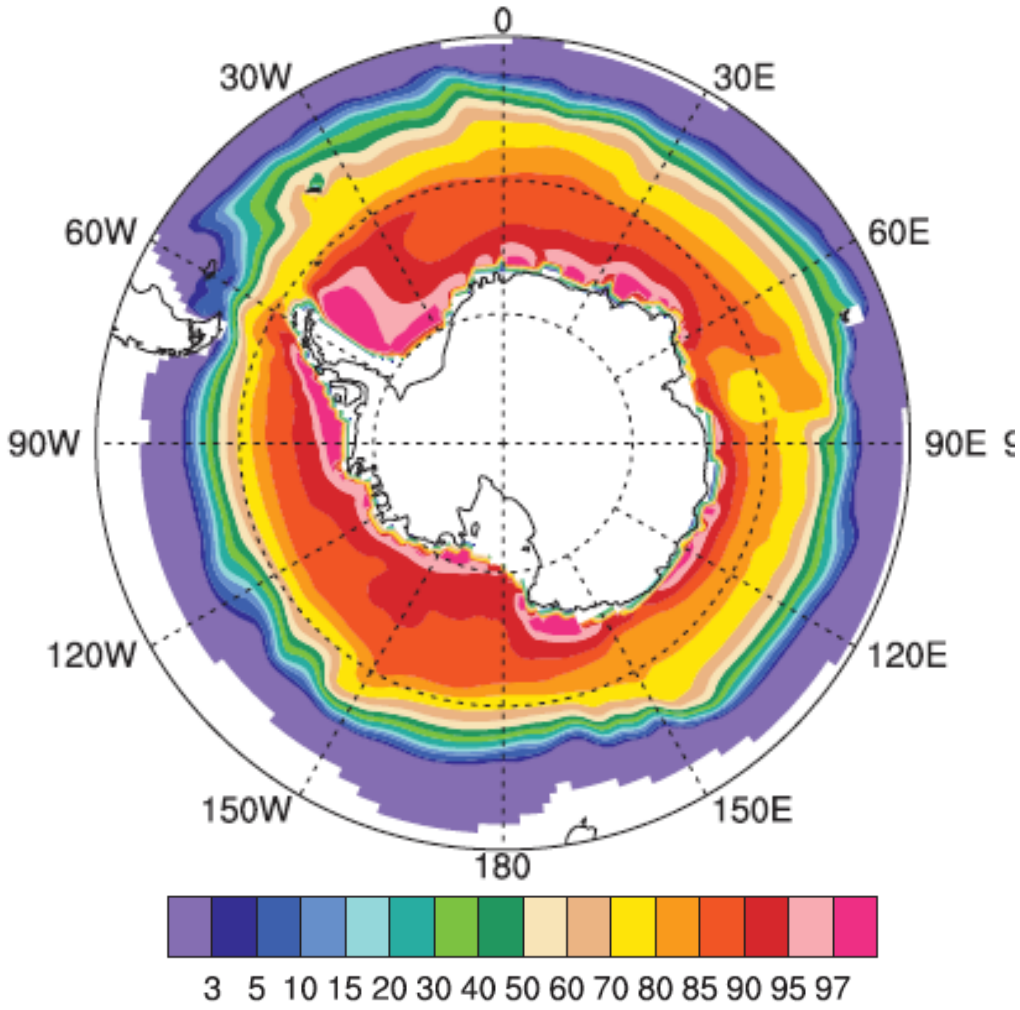
Difference relative to 1850 Control



Southern Hemisphere sea ice fraction

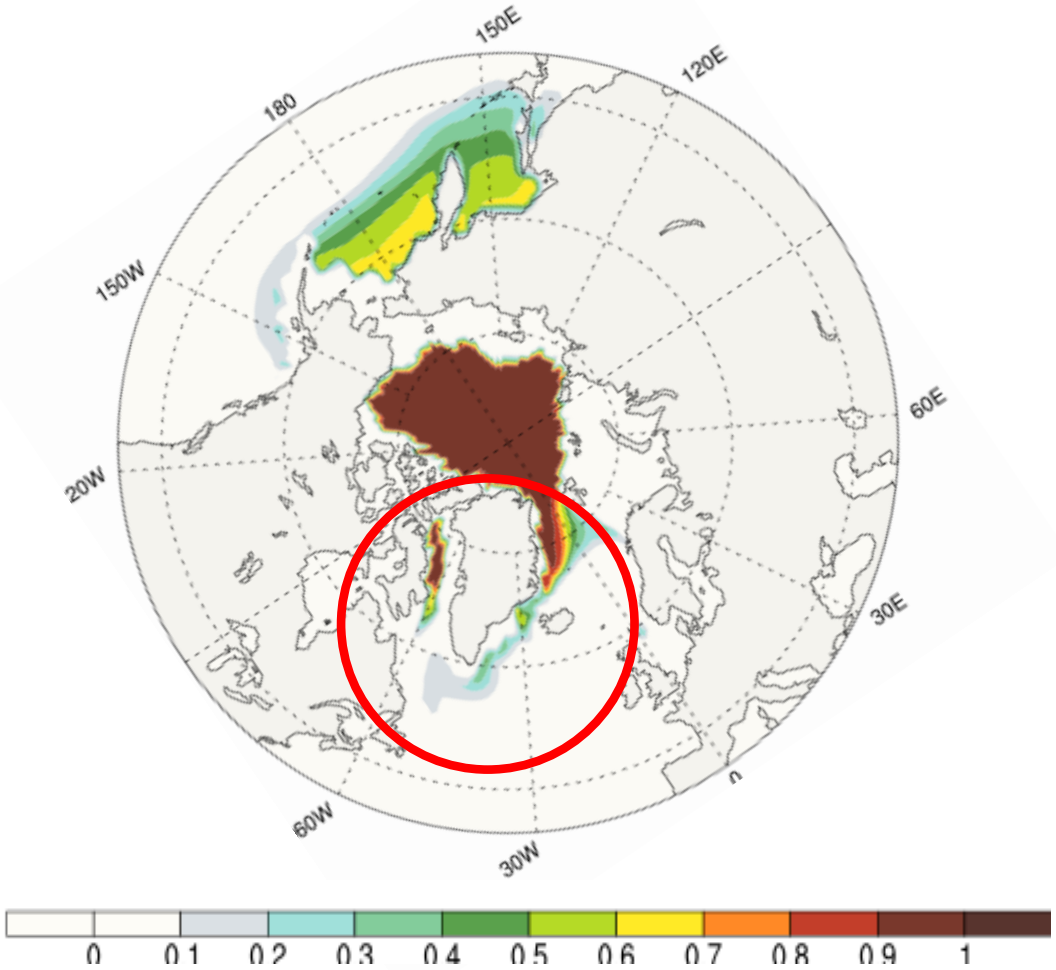


LGM CESM2.1

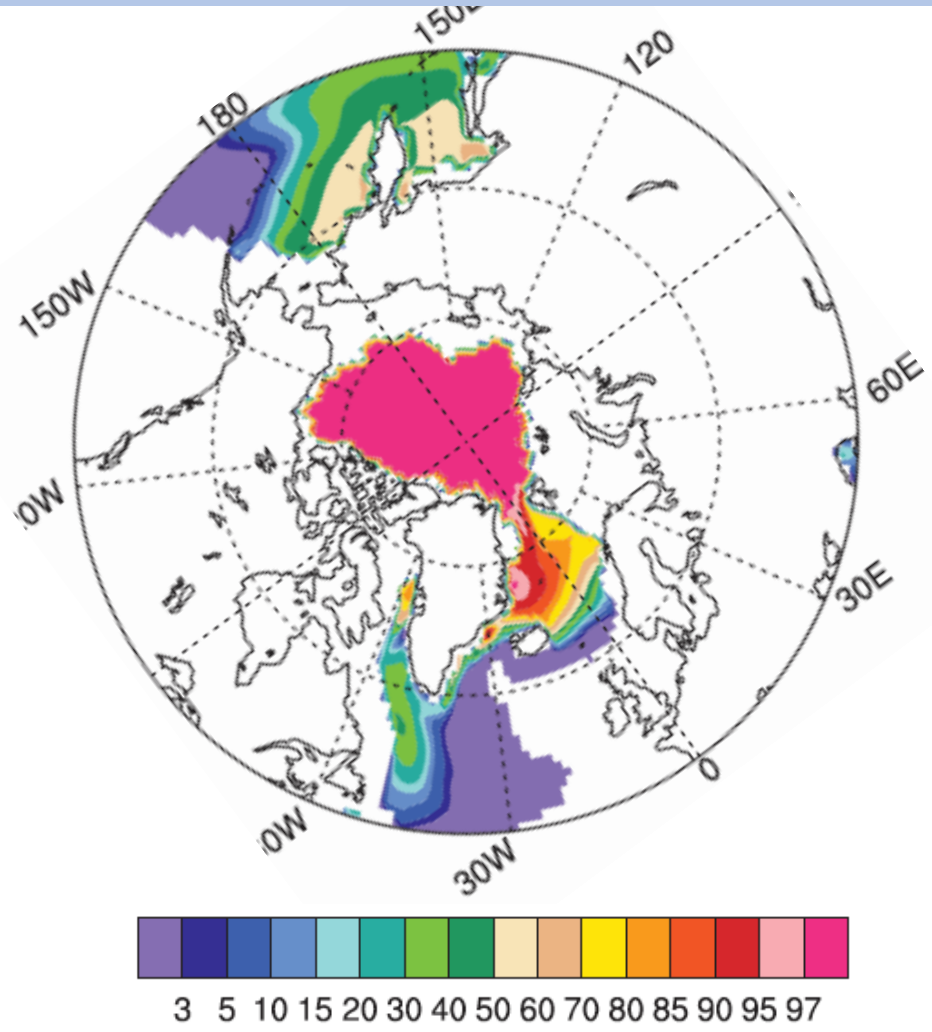


LGM CCSM4: *Brady et al, 2013*

Northern Hemisphere sea ice fraction



LGM CESM2.1



LGM CCSM4: *Brady et al, 2013*

LGM NHIS ice sheet simulation

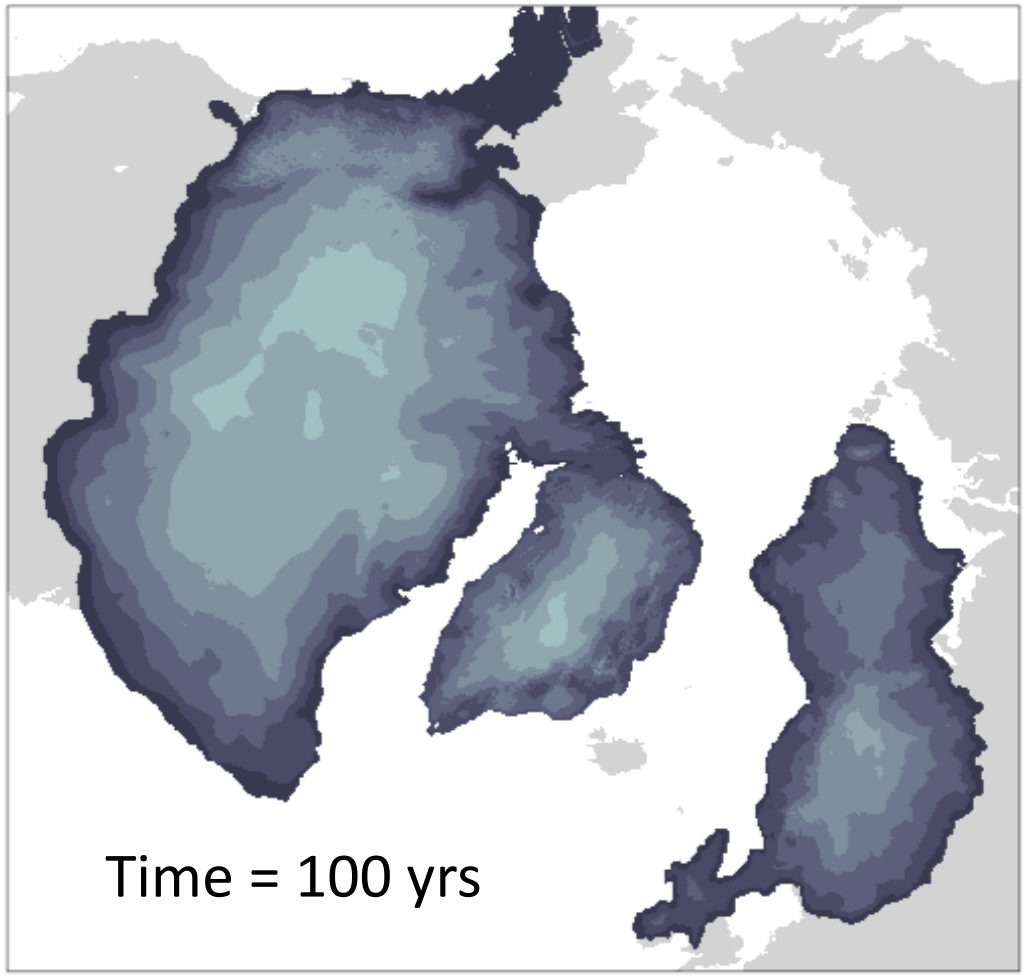
Stage 3: Response of **North Hemisphere ice sheets** to new SMB

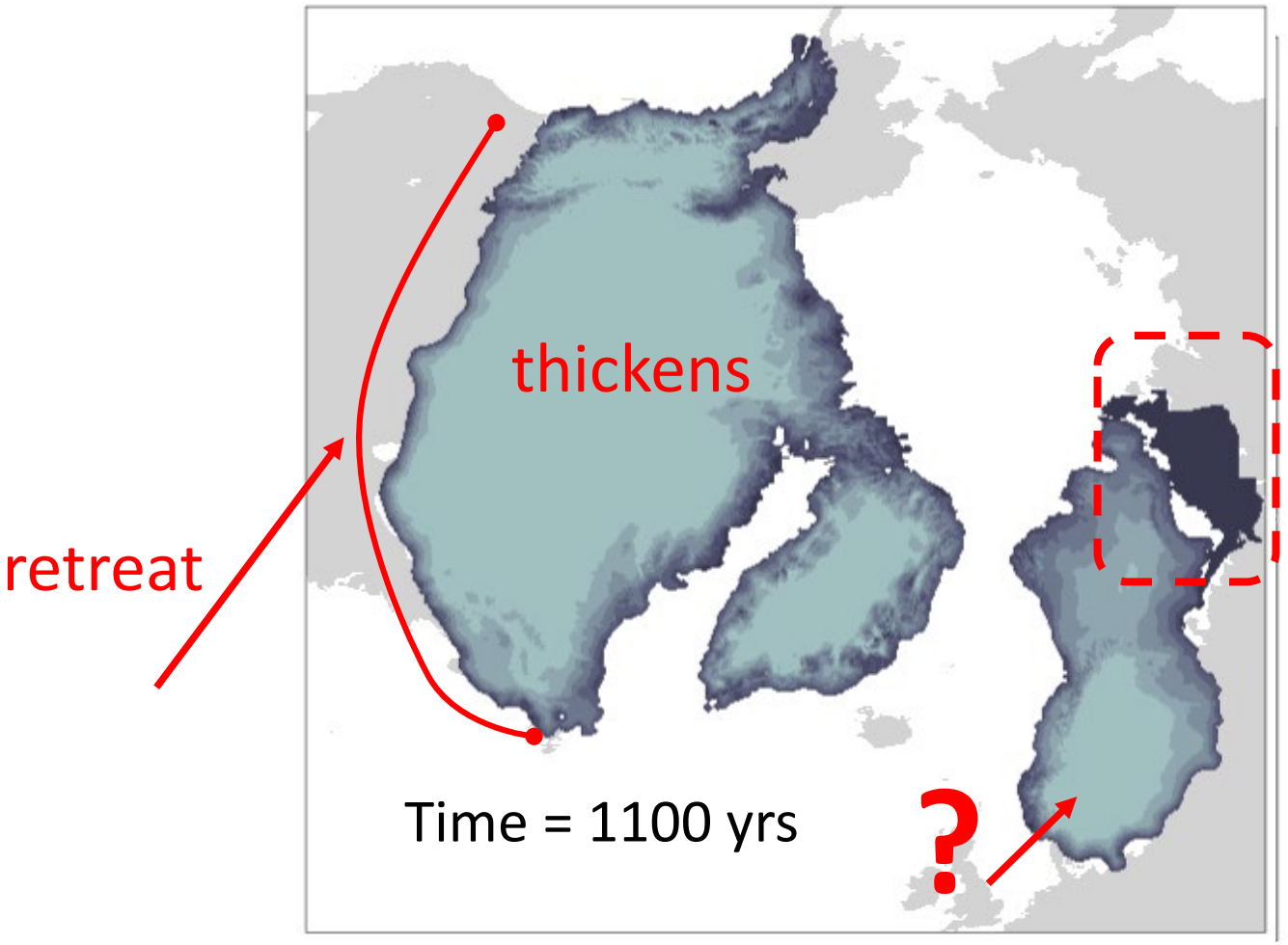
Performed a 1100 year CISM simulations of the North Hemisphere

20 years of surface mass balance and surface temperature fields – produced from CESM2.1

LGM NHIS ice sheet simulation

LGM NHIS ice sheet simulation





Summary

Ran an offline vegetation model: **BIOME4**
produced a new **LGM paleo-vegetation** dataset

Generated a **'spun-up' snowpack** and improved SMB

First **100 years** of LGM CESM2.1 climatology.

First results of **CISM2.1** using LGM climatology

any questions: s.l.bradley@sheffield.ac.uk
m.petrini@tudelft.nl