Modelling the extent of the Greenland ice-sheet during past warm periods using an efficient ice sheet - climate coupling methodology

1st October 2013, Ice sheet climate workshop, University of Reading

Emma J Stone

Introducing the Last Interglacial

University of BRISTOL

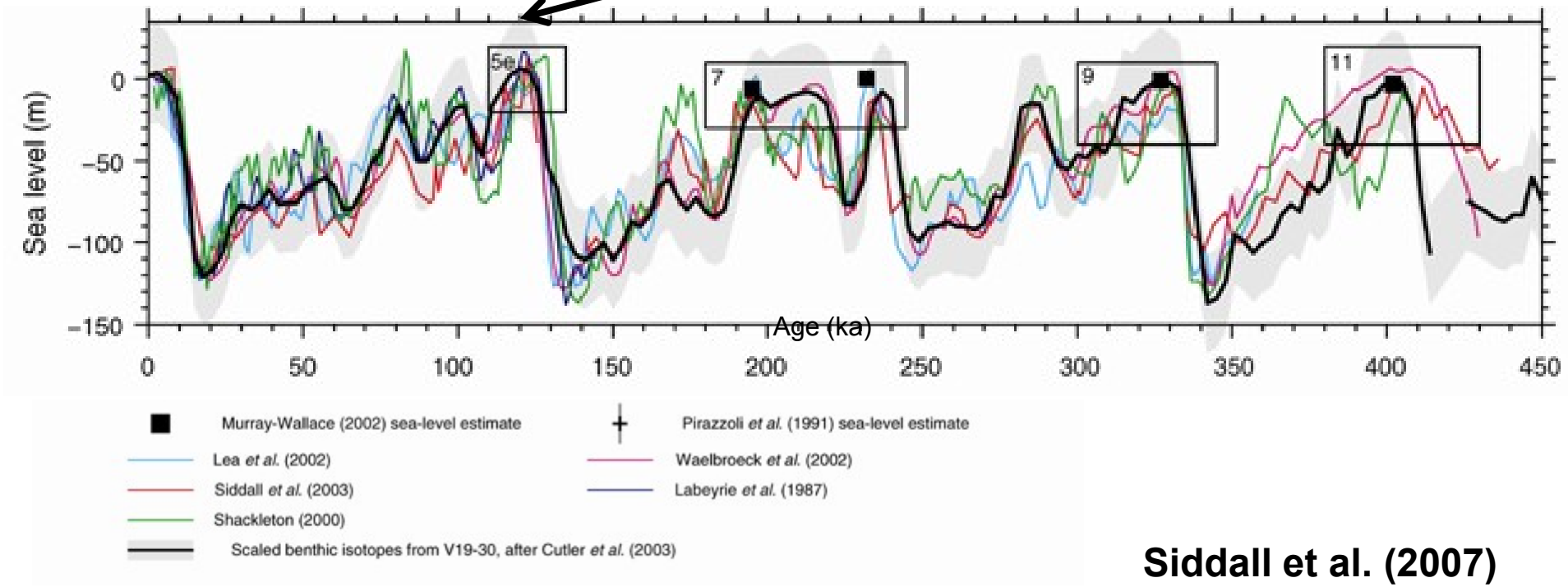
PAST.4.FUTURE

iGlass
Using interglacials to assess future sea-level scenarios

Sea-level over the last 400ka

MIS 5e

- CO_2 similar to today, orbital insolation very different



Siddall et al. (2007)

Q1: Why the Last Interglacial?

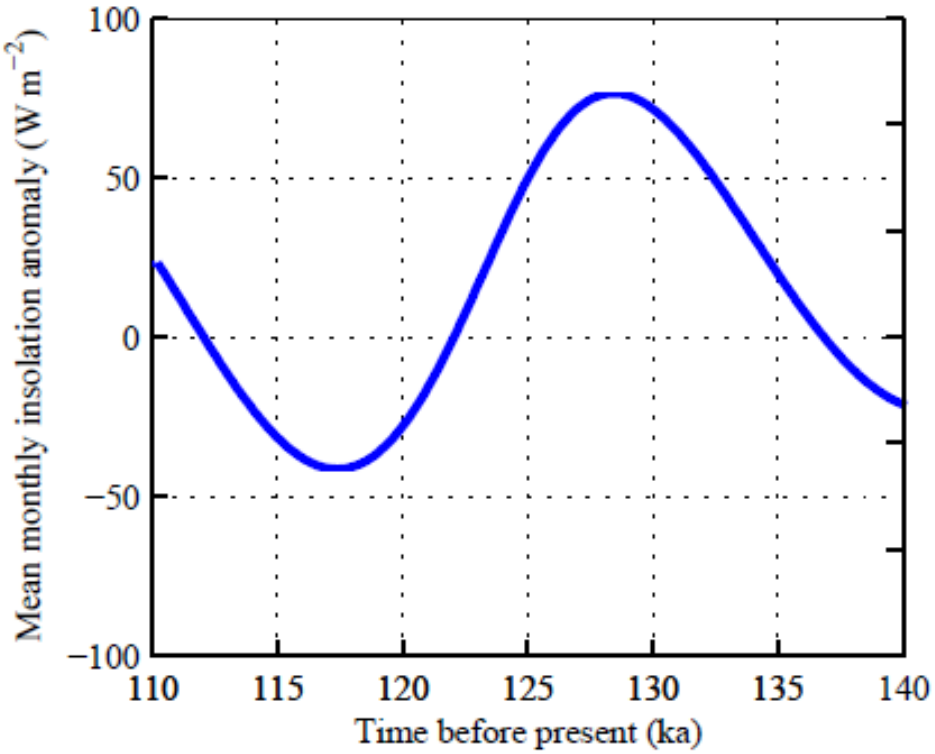
Q2: Why are we interested in the high latitudes?

Q3: Are patterns of temperature response coincident between the Northern and Southern Hemispheres in timing and magnitude?

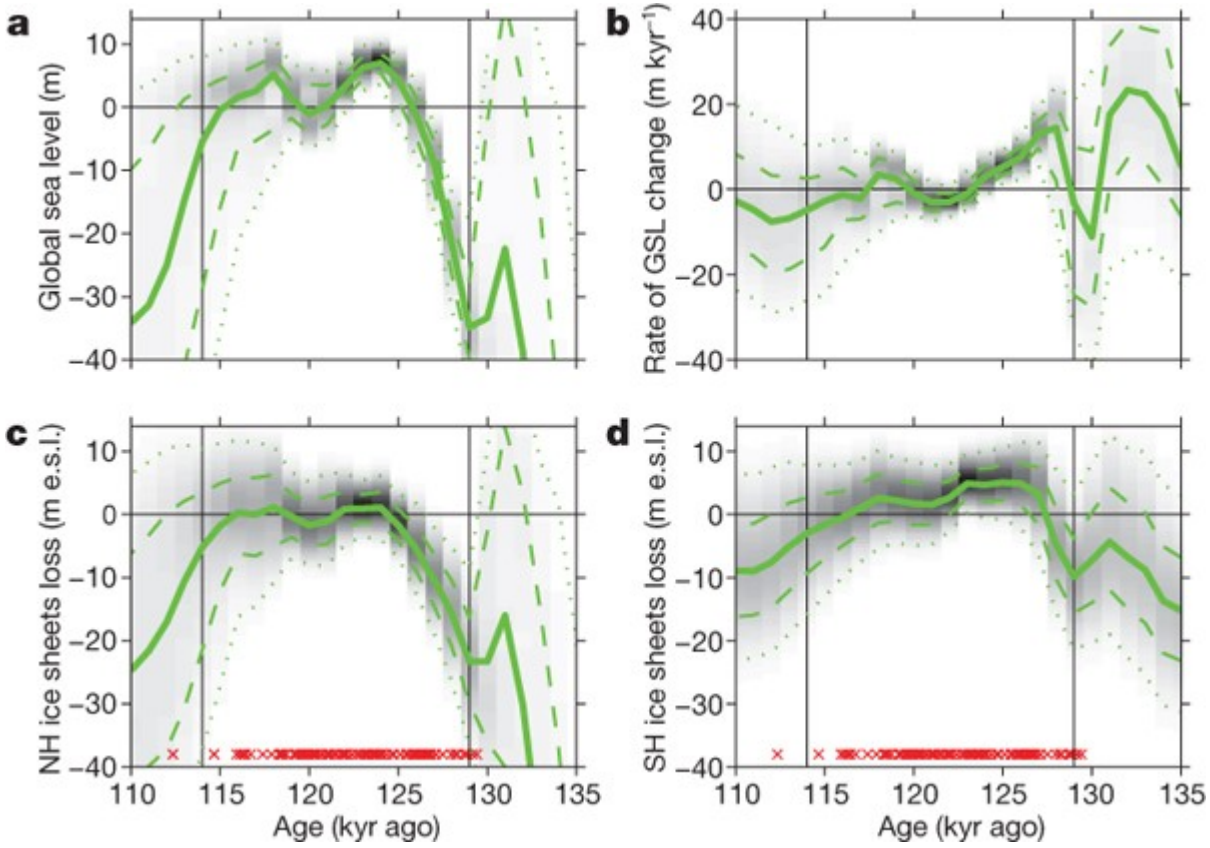
Q4: Can we replicate the patterns observed in the data record with a model?

What causes the LIG warming?

Insolation changes



MIS 5e – sea-level



Kopp et al. (2009)

Estimates from models for Greenland contribution to LIG sea-level:

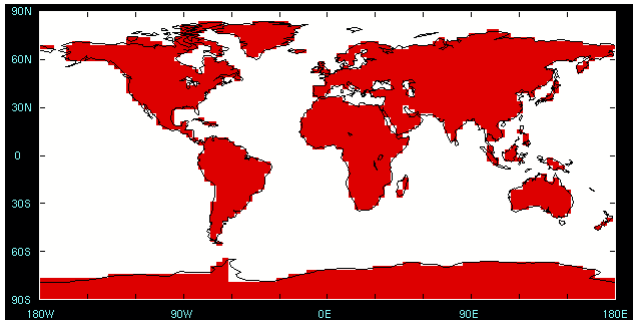
0.4 to 5.5 m

Methodology

Climate model setup

- **HadCM3, MOSES 2.1**

  - Coupled atmosphere-ocean sea-ice models
  - Ocean has a resolution of 1.25° x 1.25°
  - Horizontal resolution 2.5° x 3.75°
  - 19 levels in the vertical

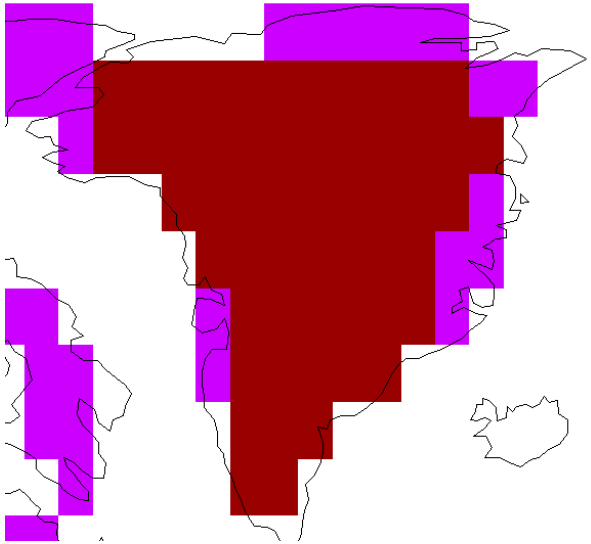


- **Simulations: 130, 125, 120 ka and 0 ka (BP)**

Changed orbital parameters (insolation)	✓
Changed GHGs	✘
Changed ice sheet	✘
Vegetation feedbacks	✘
Freshwater forcing	✘

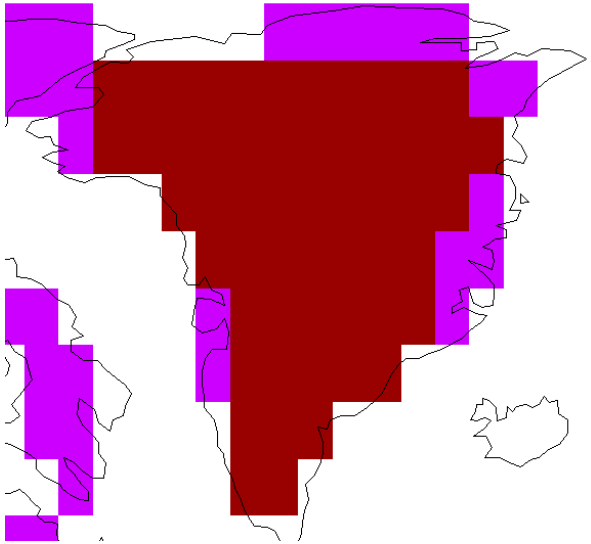
Climate model setup

Modern day ice

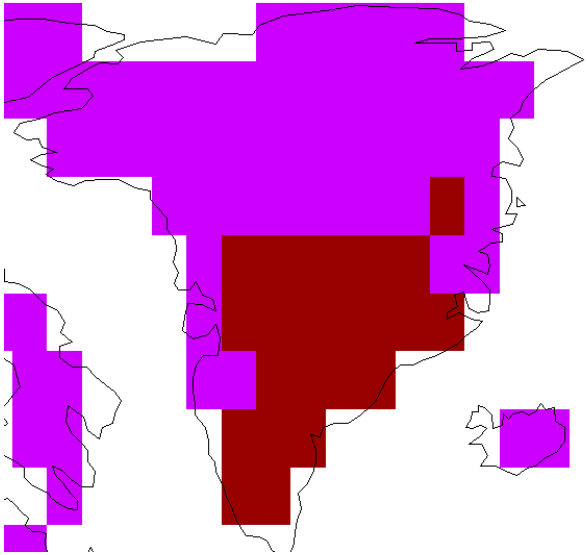


Climate model setup

Modern day ice

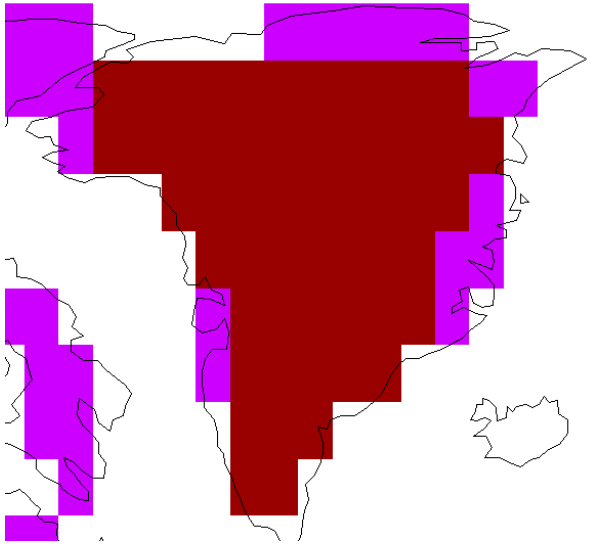


Partial ice sheet

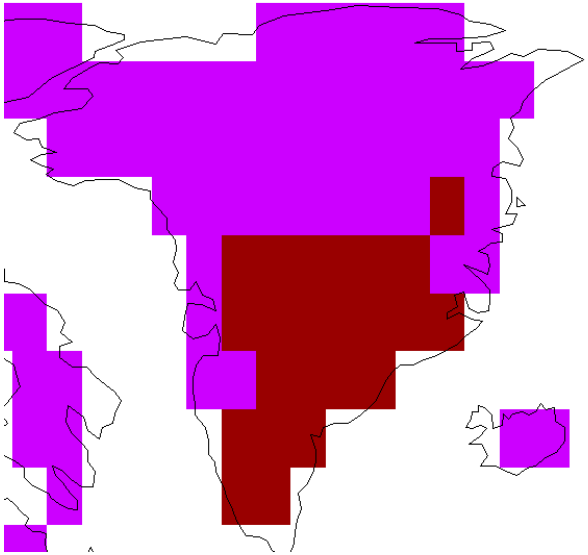


Climate model setup

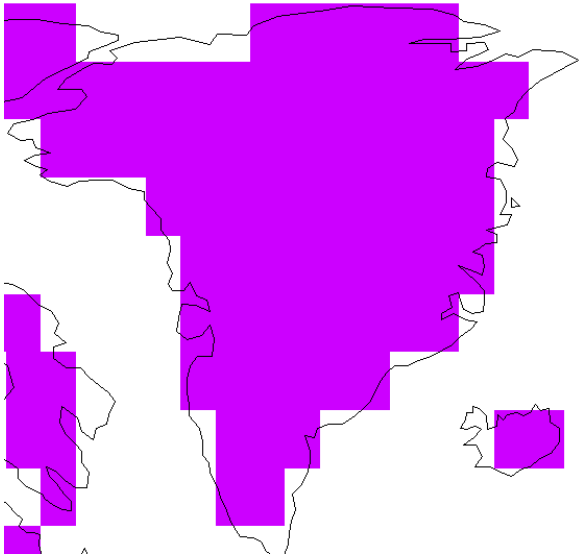
Modern day ice



Partial ice sheet



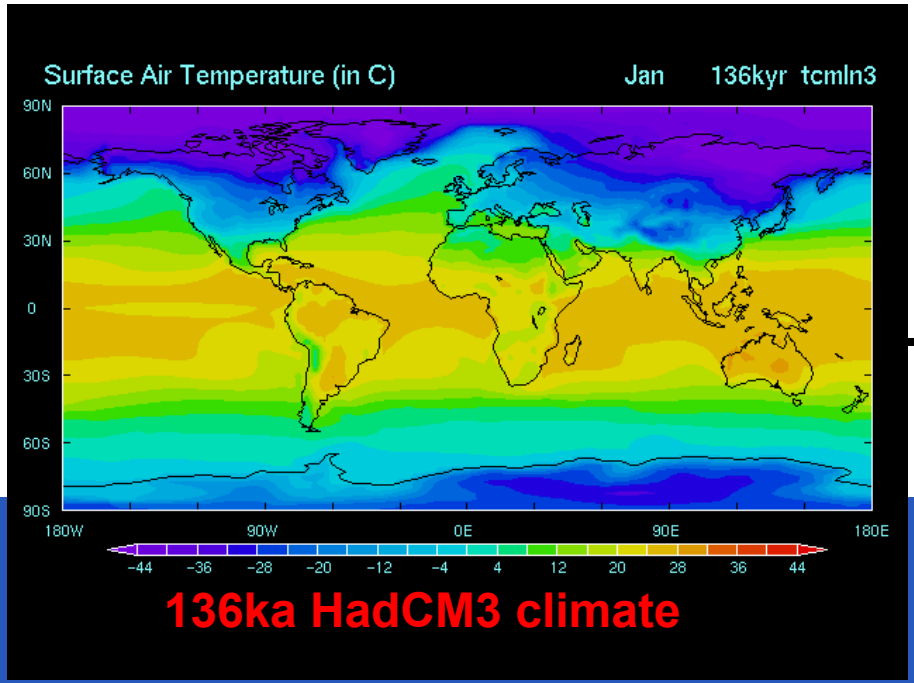
No ice sheet

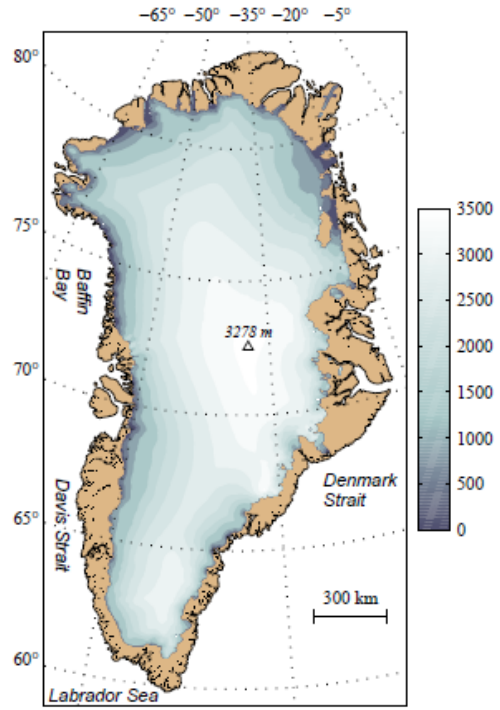


Ice sheet model set up

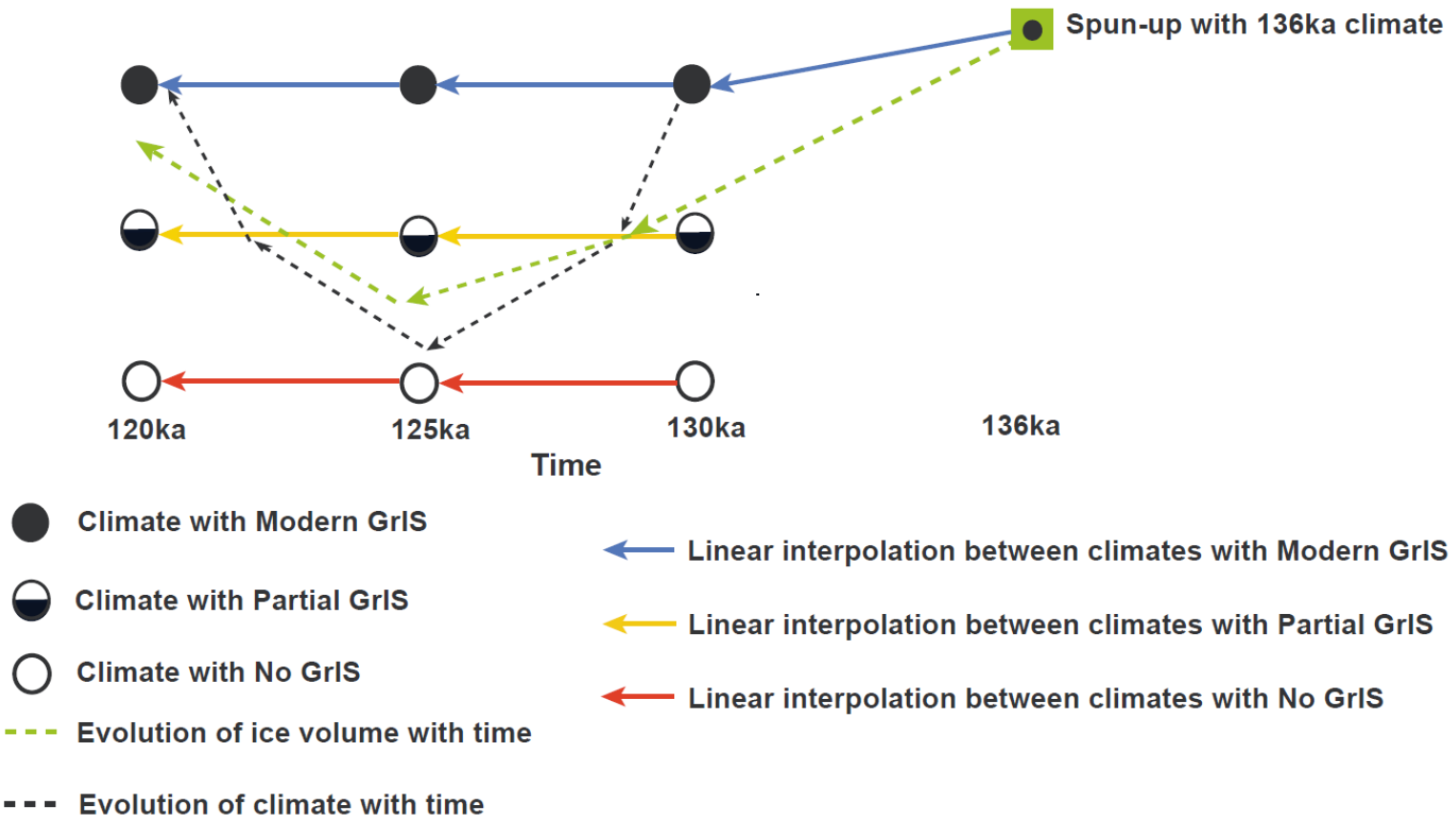
Glimmer (Payne, 1999; Rutt et al., 2009)

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

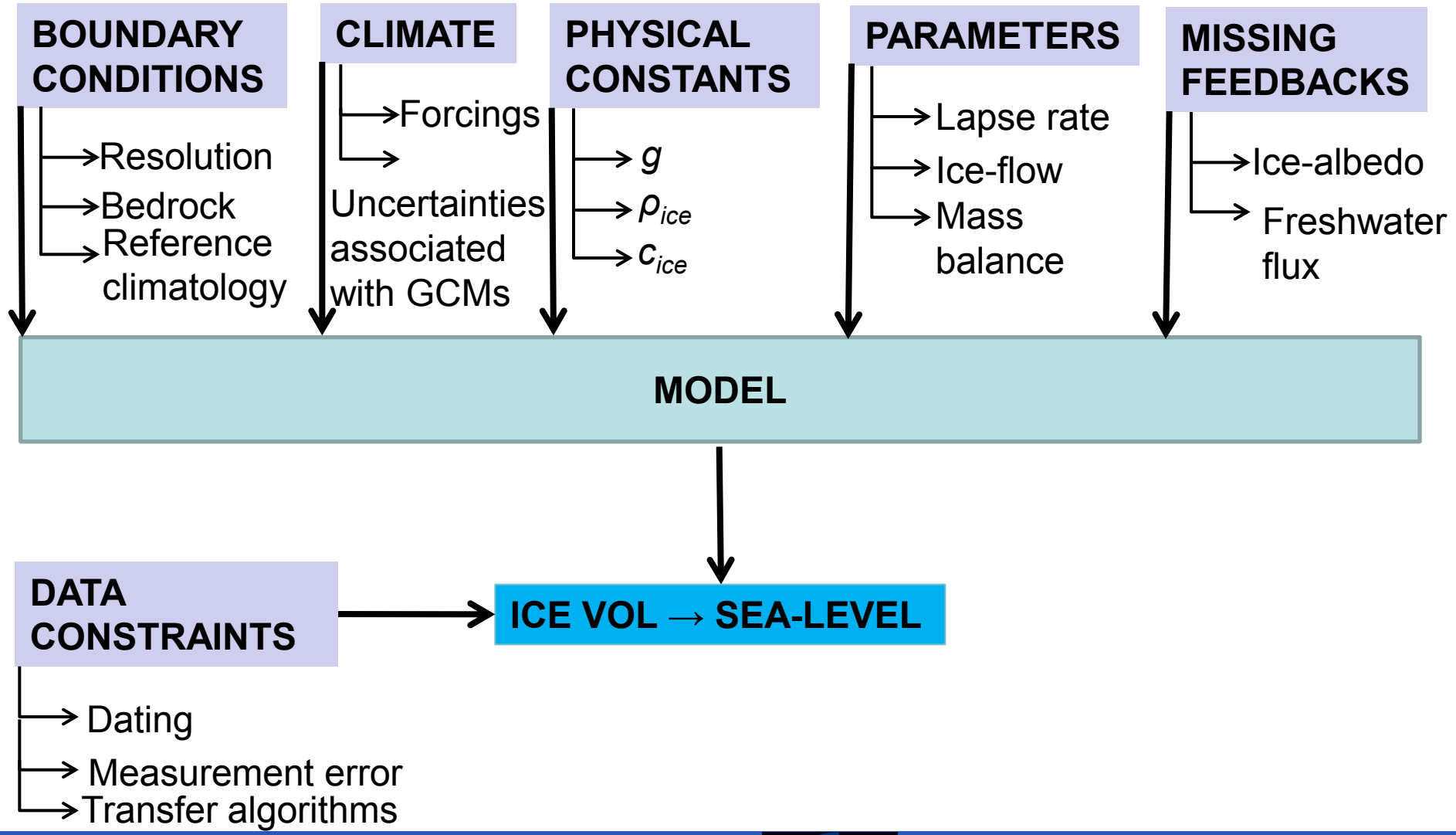




Experimental design using HadCM3 and Glimmer



Uncertainty taxonomy



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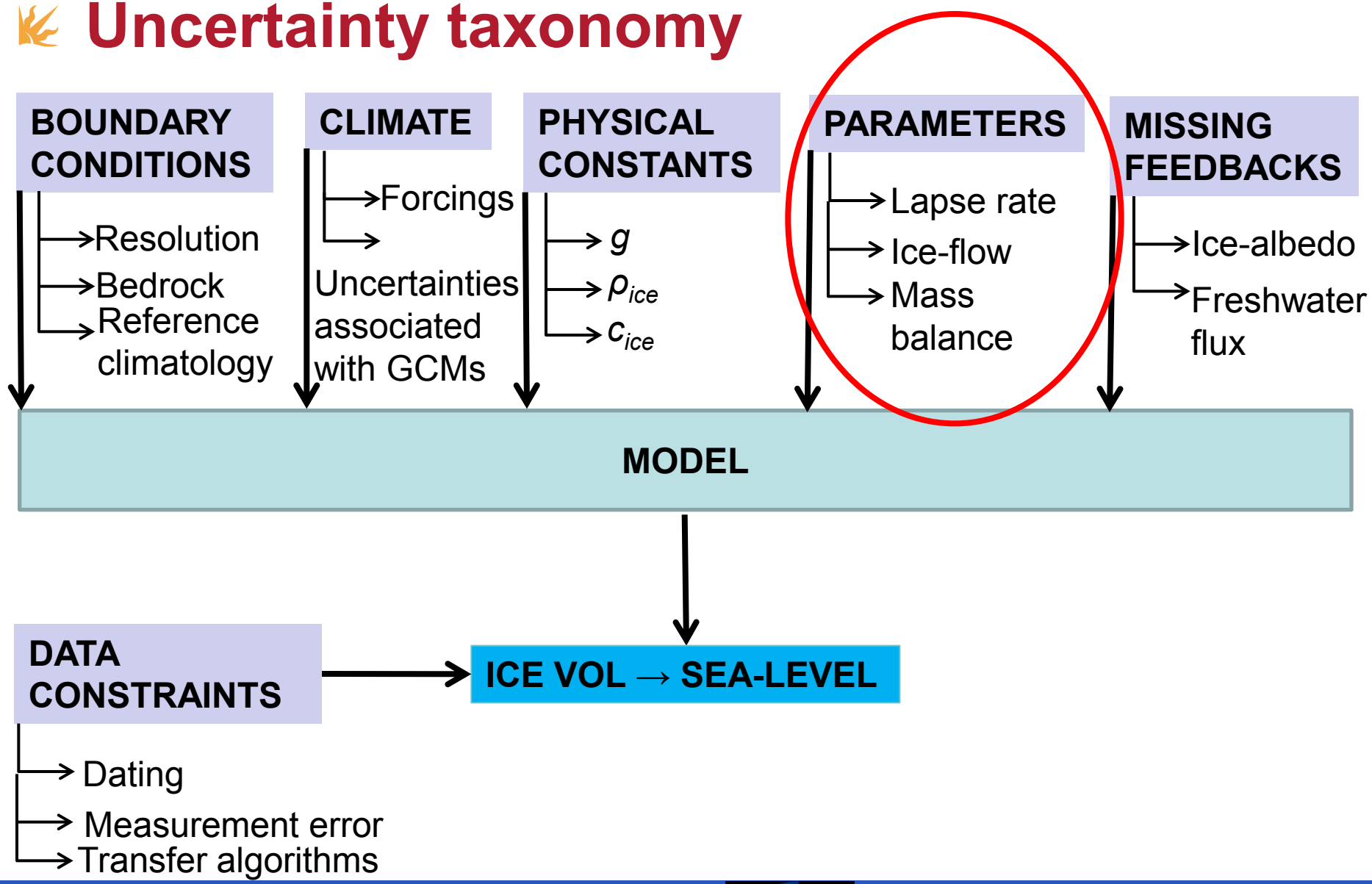
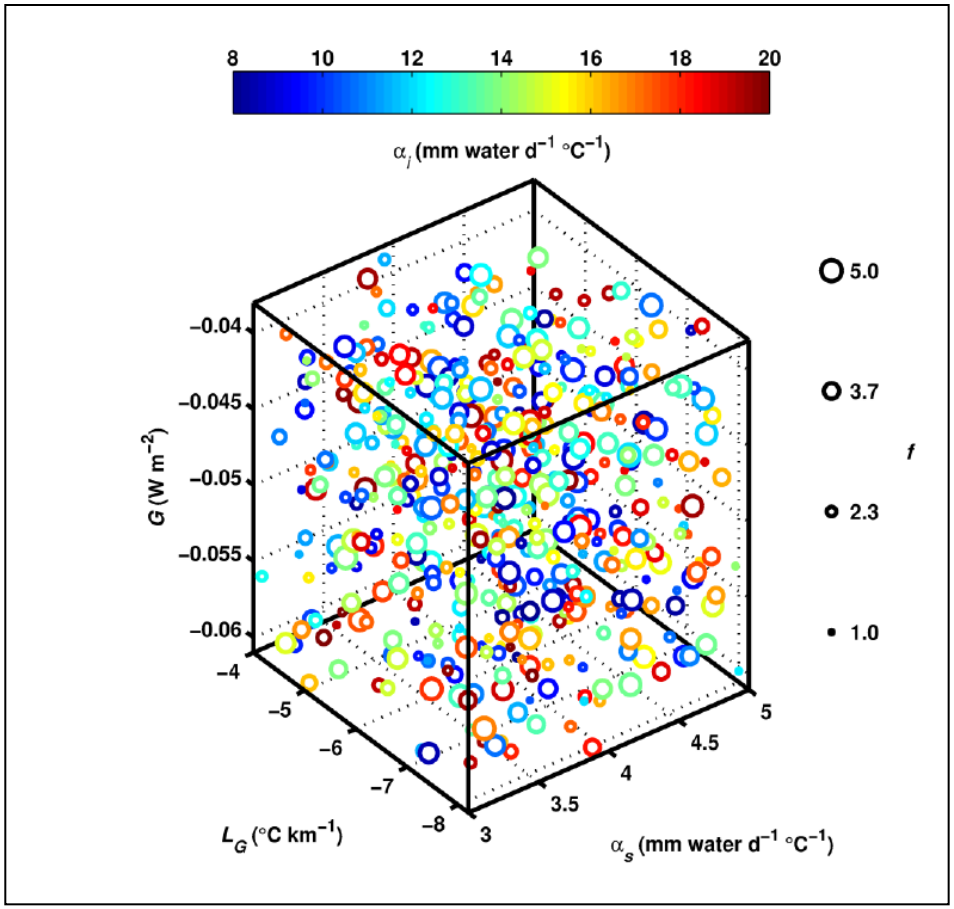


Probabilistic Modelling

Ice-sheet model parameter uncertainty

500 ice sheet model experiments



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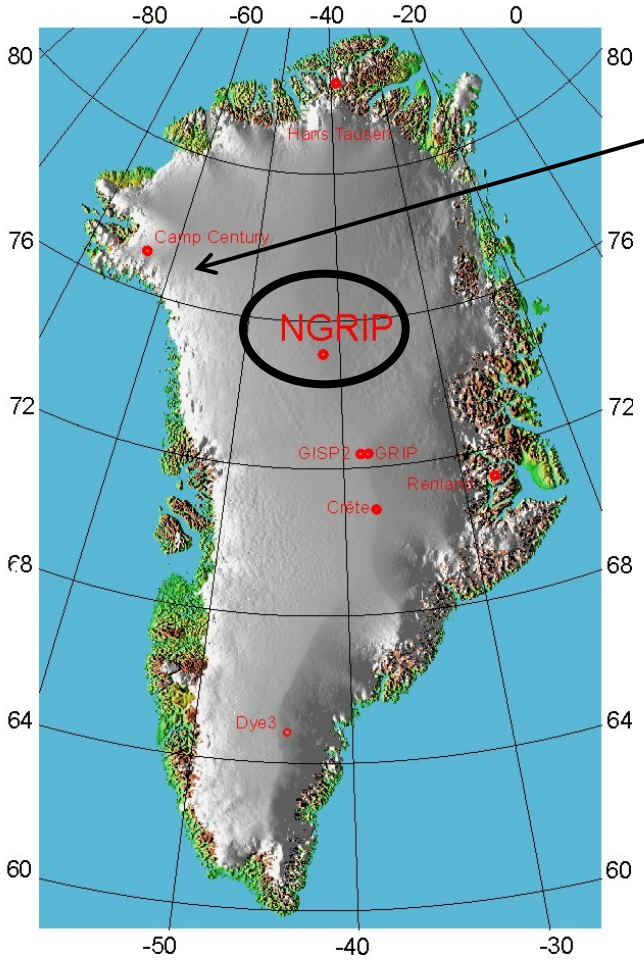
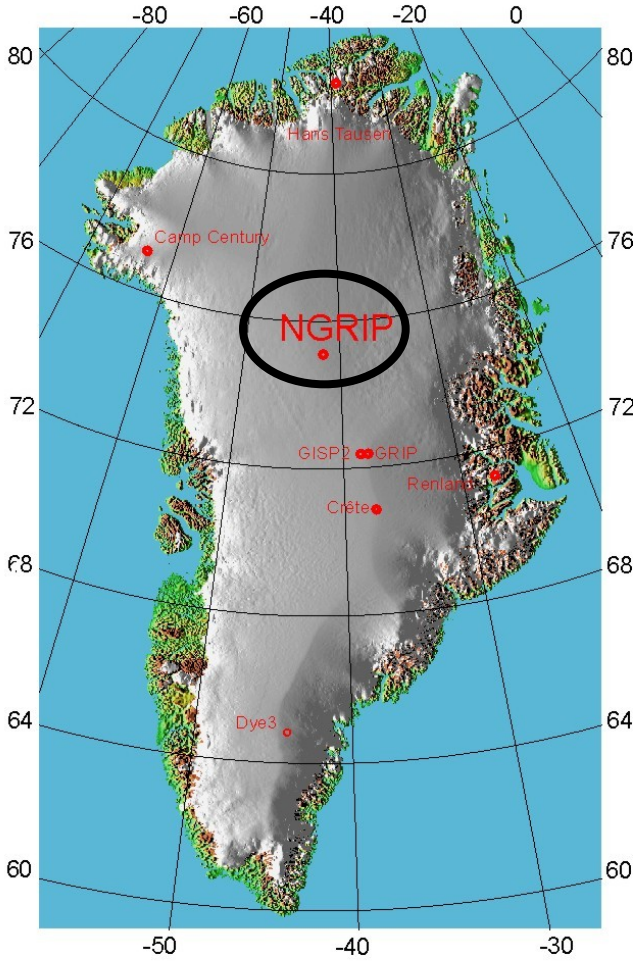
Results

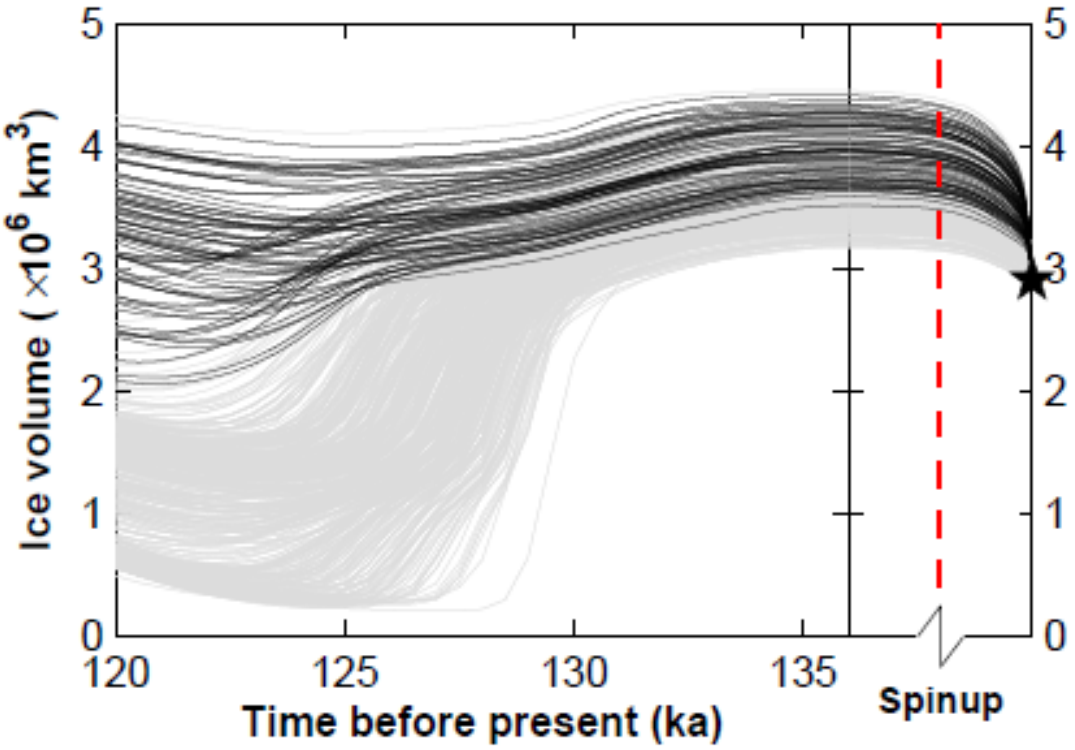
What is the contribution to LIG sea-level rise from Greenland?



NEEM

What is the contribution to LIG sea-level rise from Greenland?





Stone et al. (2013) –Clim. Past.

What is the contribution to LIG sea-level rise from Greenland?

OBSERVATIONS

Skill-score

Observation

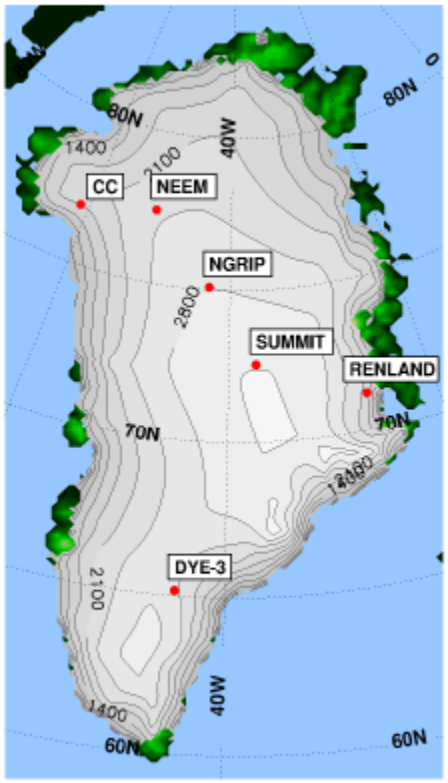
Ensemble member

$$s(\theta) = -\frac{1}{2n}\sum_{i=1}^{n}\frac{(x_i - f_i(\theta))^2}{\sigma^2+\tau^2},$$

Model error

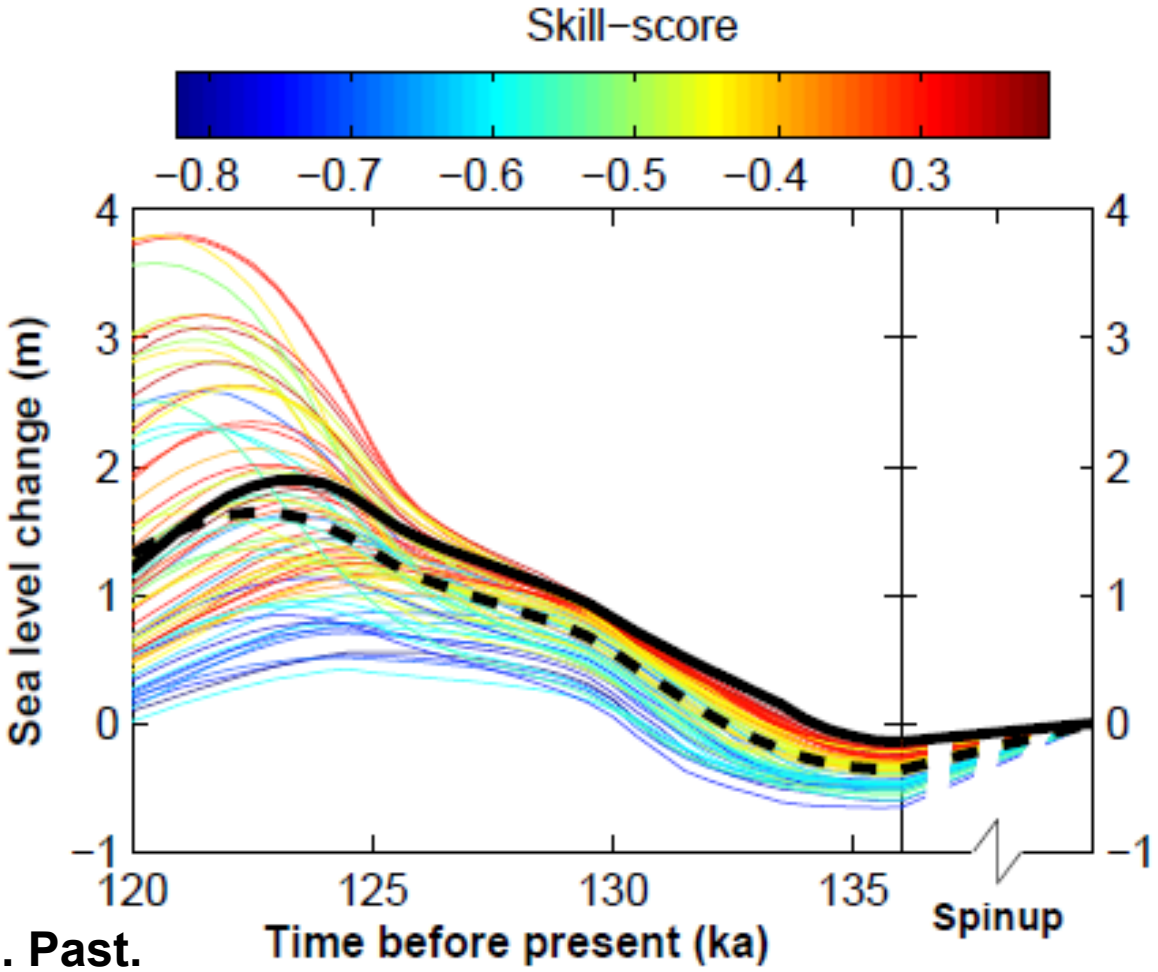
Measurement error

SIMULATED MODERN ICE SHEET



What is the contribution to LIG sea-level rise from Greenland?

0.4 to 3.8 m



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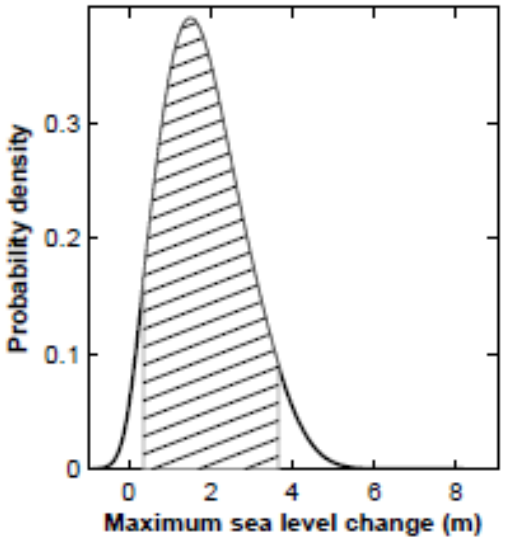
What is the contribution to LIG sea-level rise from Greenland?

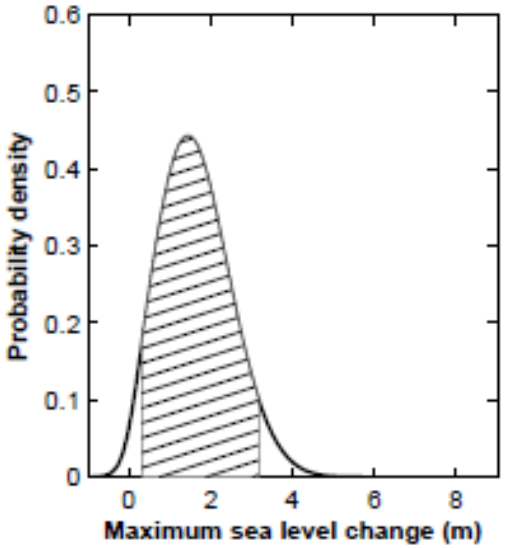
Stone et al. (2013) –Clim. Past.

NOT INCLUDING NEEM CONSTRAINT



0.3 to 3.6 m (90% probability)

INCLUDING NEEM CONSTRAINT



0.3 to 3.0 m (90% probability)

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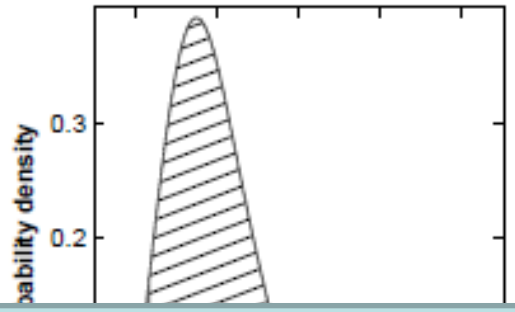
What is the contribution to LIG sea-level rise from Greenland?

Stone et al. (2013) –Clim. Past.

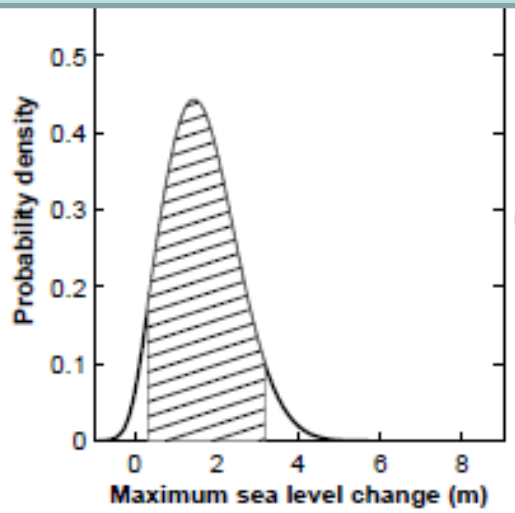
NOT INCLUDING NEEM CONSTRAINT



0.3 to 3.6 m (90% probability)

Implicates Antarctic Melt

INCLUDING NEEM CONSTRAINT



0.3 to 3.0 m (90% probability)

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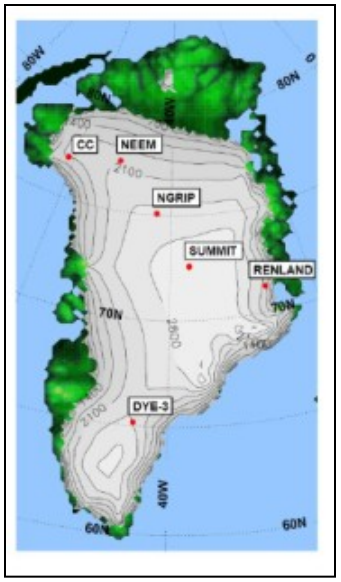
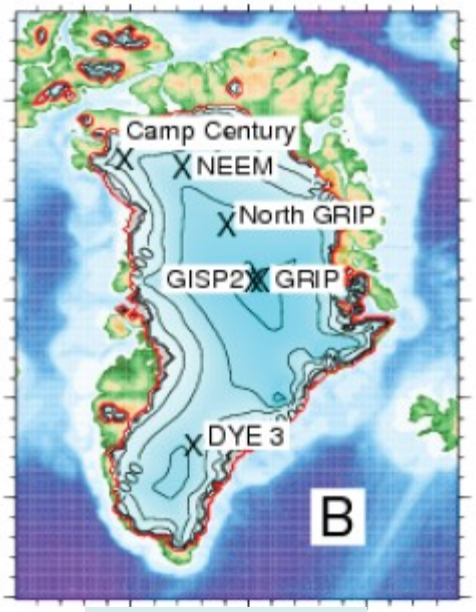
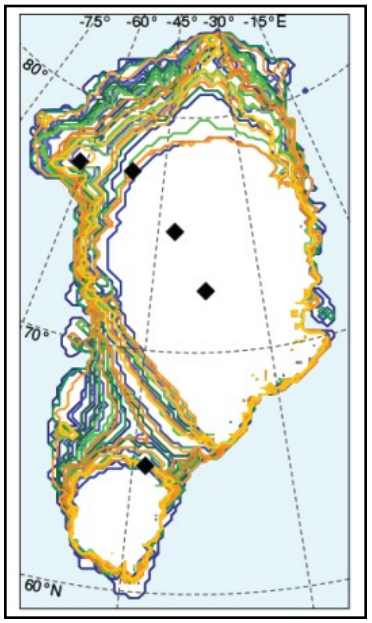
Retreat in the SOUTH



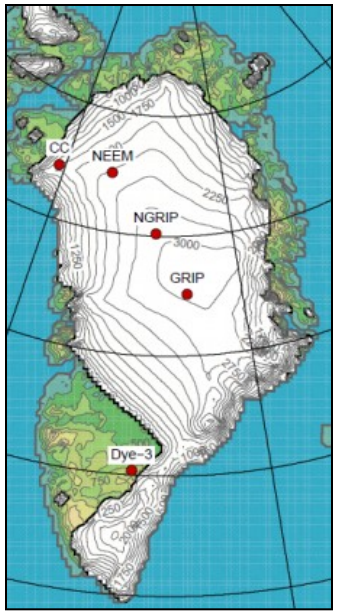
Stone et al. (2013)



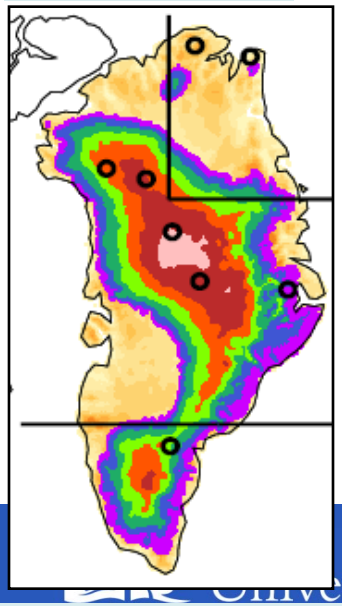
Quiquet et al. (2013)



Robinson et al.(2011)

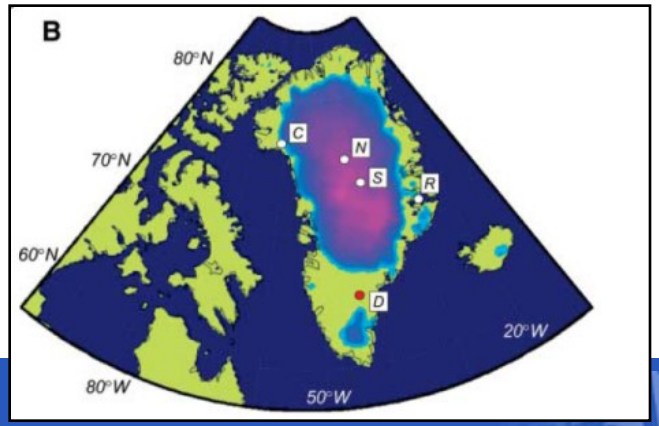


Helsen et al. (2013)



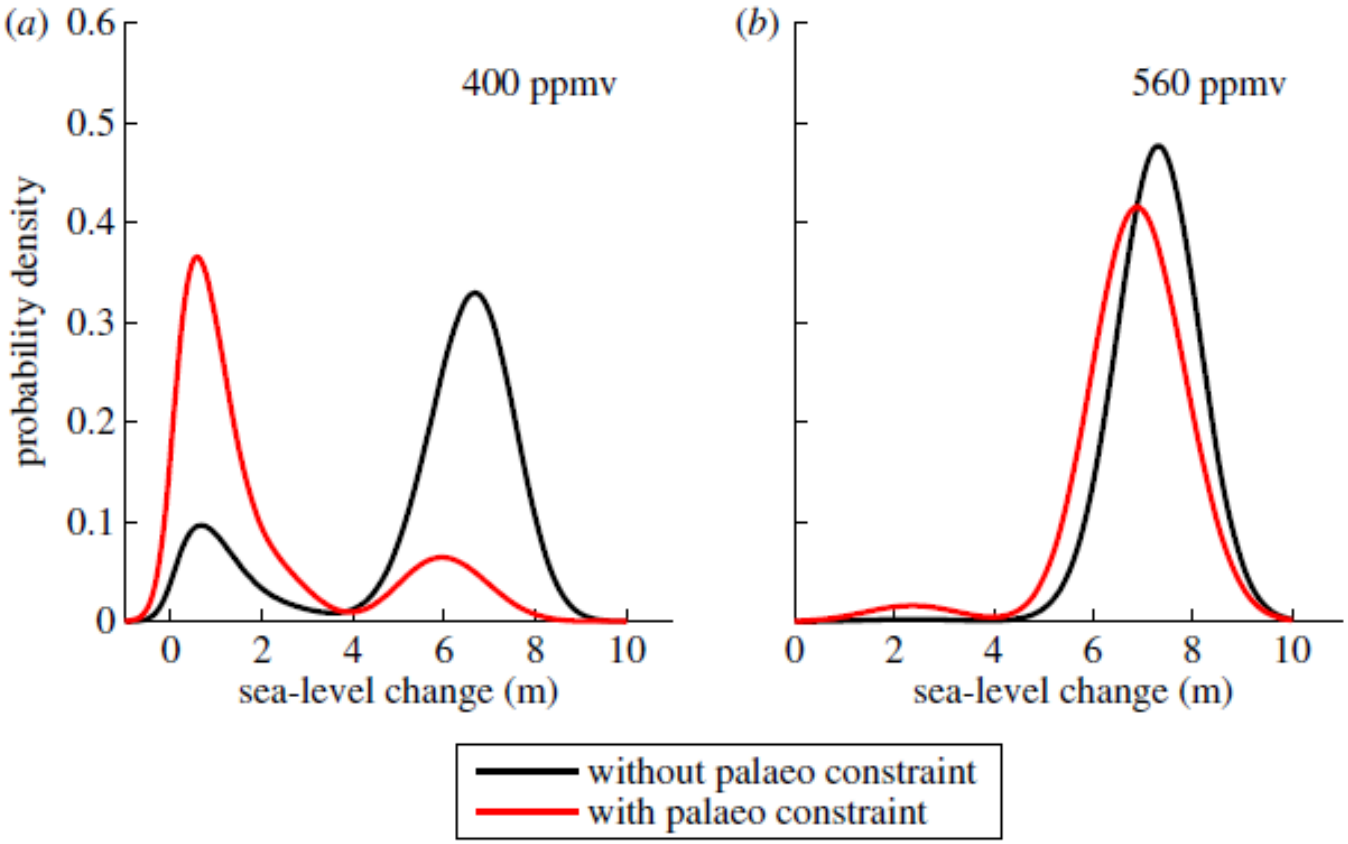
Born et al. (2012)

Retreat from the NORTH



Otto-Bliesner et al. (2006)

Using the past to constrain the future



Lunt et al. (2013) –Roy. Soc. Trans. A.

Conclusions and things to think about

- We show an efficient coupling methodology which allows parameter space to be explored.
- Our study suggests a 90% probability that Greenland ice melt contributed at least 0.6 m to LIG sea-level rise, but less than 10% probability that it exceeded 3.5 m - lower than several recent estimates.
- Our modelling & palaeo-data approach suggests that the Greenland ice sheet is less sensitive to orbital forcing than previously thought, and it implicates Antarctic melt as providing a substantial contribution to Last Interglacial sea-level rise.
- **Caveats**: PDD scheme, climate model uncertainty, missing processes, initial conditions, skill score etc

Thank you!

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