Evaluating the Roles of Orbital and Greenhouse Gas Forcing on Last Interglacial Climate using a General Circulation Model

Emma J. Stone[1] and Daniel J. Lunt[1]

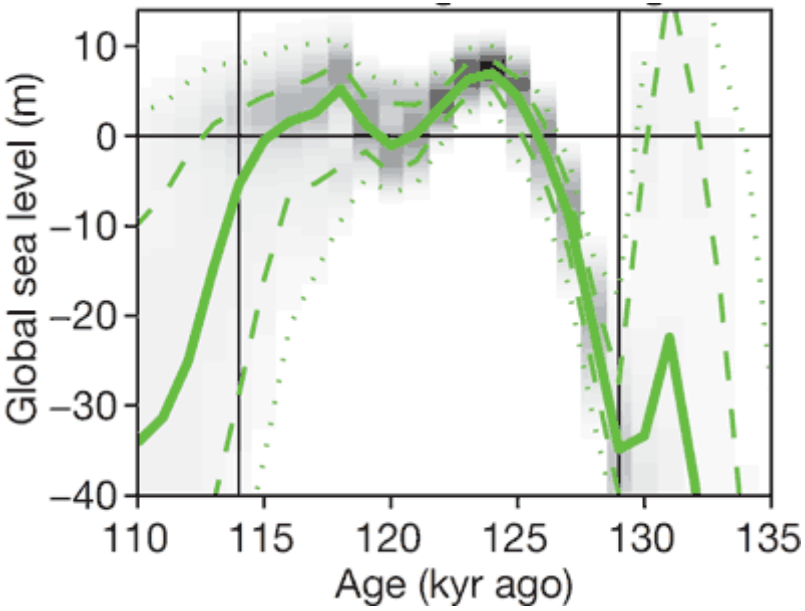
(With thanks to Pepjin Bakker, Stefan Ritz, Sylvie Charbit)

[1]BRIDGE, School of Geographical Sciences, University of Bristol, UK

emma.j.stone@bristol.ac.uk

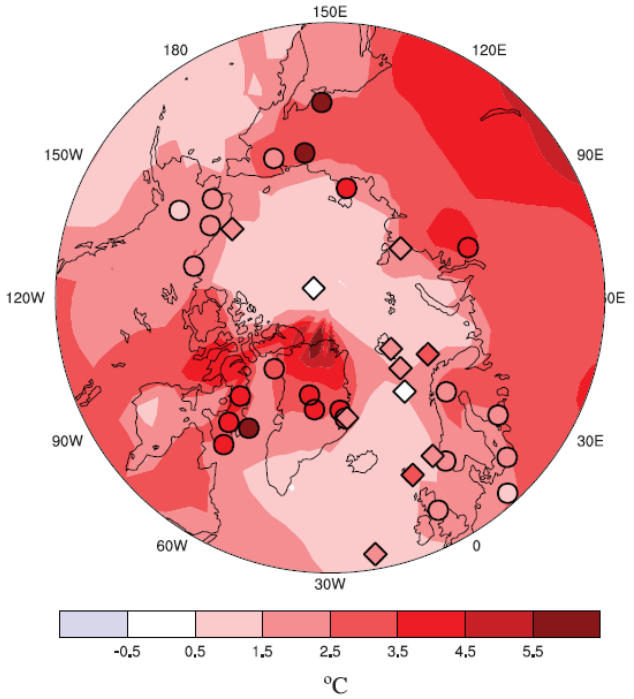
Background to the LIG

Sea-level



(*from* Kopp *et al.* 2009)

Climate

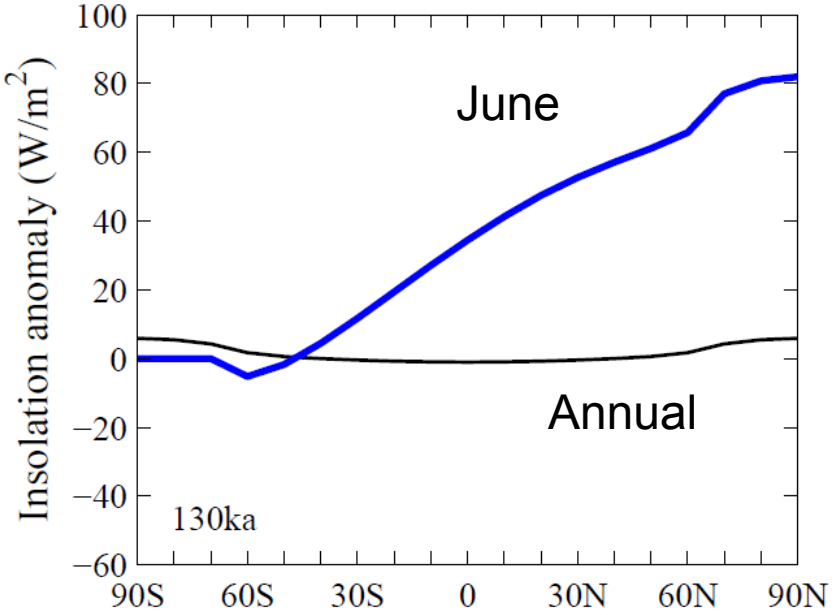


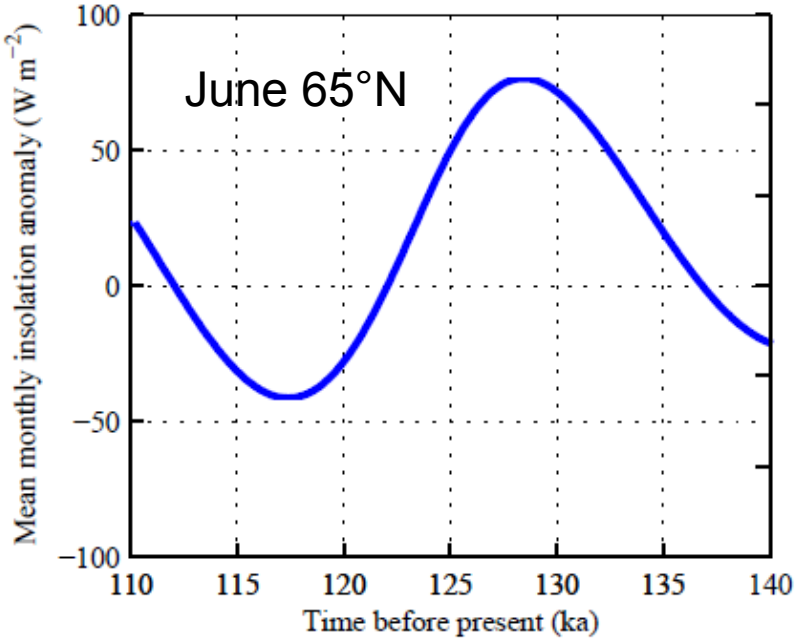
Palaeodata and AOGCM indicate summer warming of ~2 - 5 C (IPCC, 2007)

University of BRISTOL
emma.j.stone@bristol.ac.uk

What caused this warming?

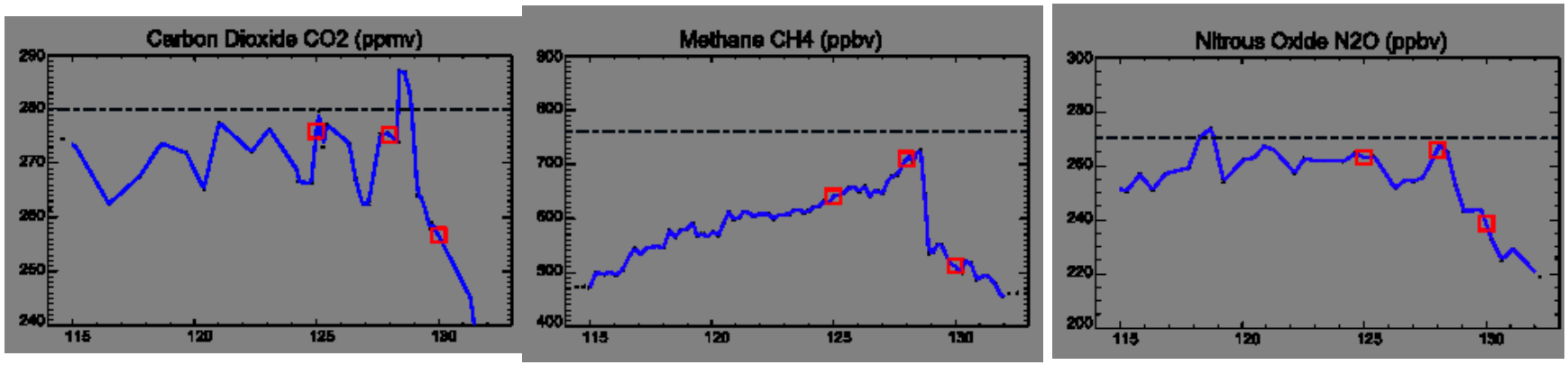
1. Insolation changes





What caused this warming?

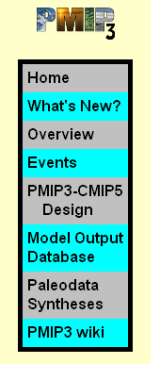
2. Greenhouse gas forcing



3. Other forcings?

Aim

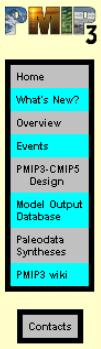
“To characterise the baseline trend and variability of climate during the last interglacial”



Transient 130ka-125ka (EXTRA)

	PMIP3	Alternative solution
Orbital parameters	varying, model interpolates values given on a 1k resolution. See values here: http://www.paleo.bris.ac.uk/~ggdjl/pmip/orbit_pmip.out Values are given for 132-115ka.	
Date of vernal equinox	March 21 at noon	
Trace gases	varying, model interpolates values given on a 0.1k resolution. See values here: http://www.paleo.bris.ac.uk/~ggdjl/pmip/pmip_hol_lig_gases.txt Values are given for 132-115ka.	
Aerosols	Same as PI	
Solar constant	1365 W/m^2	
Vegetation	Pre-industrial fixed	
Ice sheets	Same as PI	
Topography and coastlines	Same as PI	

Please use the discussion panel to **comment** this table!



Boundary conditions

130ka (CORE - TOP PRIORITY)

	PMIP3	Alternative solution
Orbital parameters	[ecc = 0.038209] - [obl = 24.242°] - [peri-180° = 228.32°]	
Date of vernal equinox	March 21 at noon	
Trace gases	[CO_2 = 257 ppm] - [CH_4 = 512 ppb] - [N_2O = 239 ppb] - [CFC = 0] - [O_3 = Same as PI]	
Aerosols	Same as PI	
Solar constant	1365 W/m^2	As in PI
Vegetation	Pre-industrial fixed	
Ice sheets	Same as PI	
Topography and coastlines	Same as PI	

Please use the discussion panel to comment this table!

128ka (EXTRA)

	PMIP3	Alternative solution
Orbital parameters	[ecc = 0.039017] - [obl = 24.131°] - [peri-180° = 259.65°]	
Date of vernal equinox	March 21 at noon	
Trace gases	[CO_2 = 275 ppm] - [CH_4 = 709 ppb] - [N_2O = 266 ppb] - [CFC = 0] - [O_3 = Same as PI]	
Aerosols	Same as PI	
Solar constant	1365 W/m^2	As in PI
Vegetation	Pre-industrial fixed	
Ice sheets	Same as PI	
Topography and coastlines	Same as PI	

Please use the discussion panel to comment this table!

125ka (CORE)

	PMIP3	Alternative solution
Orbital parameters	[ecc = 0.040013] - [obl = 23.798°] - [peri-180° = 307.14°]	
Date of vernal equinox	March 21 at noon	
Trace gases	[CO_2 = 276 ppm] - [CH_4 = 640 ppb] - [N_2O = 263 ppb] - [CFC = 0] - [O_3 = Same as PI]	
Aerosols	Same as PI	
Solar constant	1365 W/m^2	As in PI
Vegetation	Pre-industrial fixed	
Ice sheets	Same as PI	
Topography and coastlines	Same as PI	

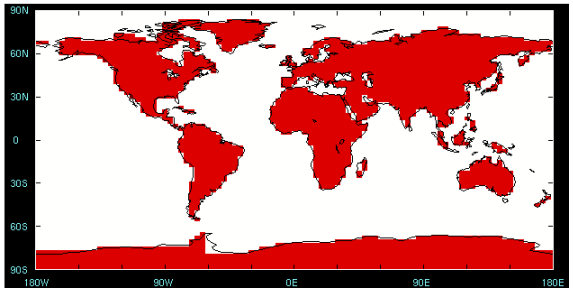
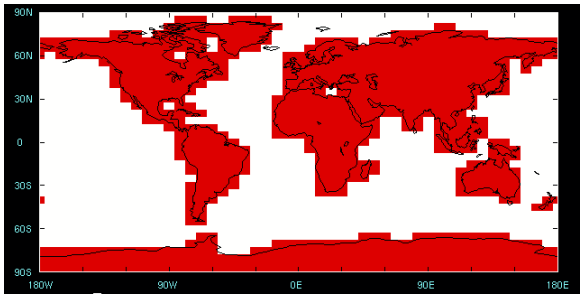
Following PMIP3 protocol...

University of BRISTOL

The Models

Snapshots

Transients

	HadCM3	FAMOUS
Ocean resolution	1.25° x 1.25°	2.5° x 3.75°
Atmosphere resolution	2.5° x 3.75°	5° x 7.5°
Vertical layers in the atmosphere	19	11
Atmospheric time step	30 min	1hour
Land-sea mask		

University of BRISTOL

emma.j.stone@bristol.ac.uk

PAST·4·FUTURE

Experimental Design

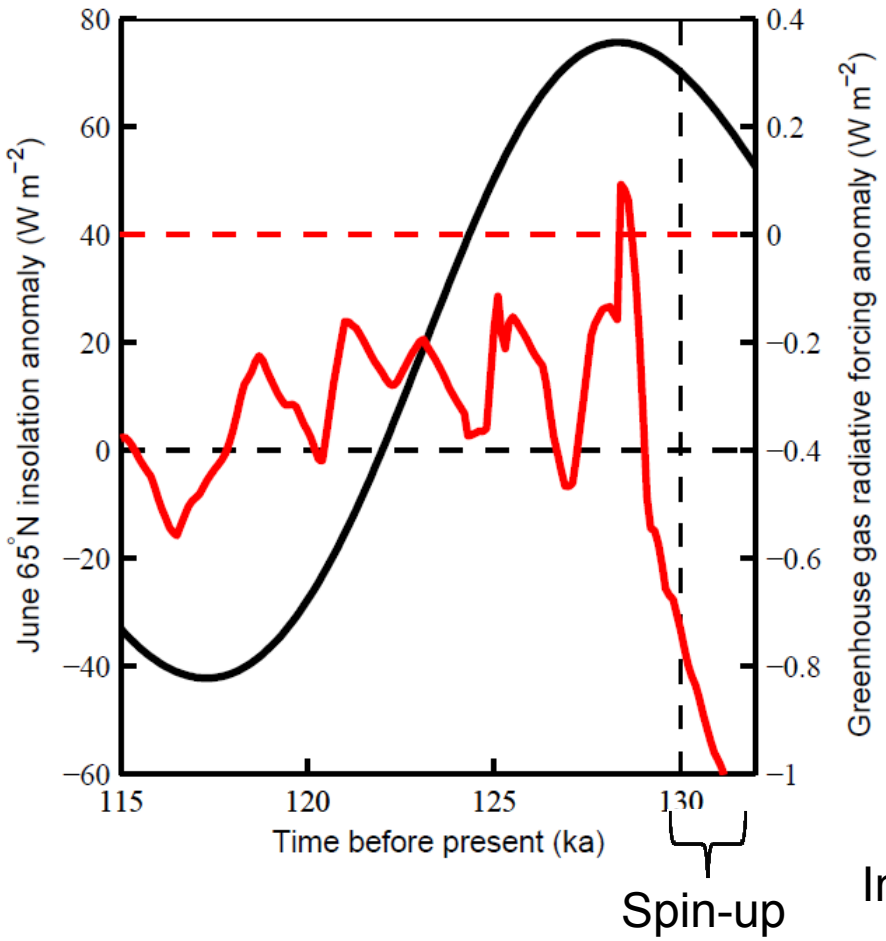
- **HadCM3 = SNAPSHOTS**
  - **4 simulations of 500 model years: 130, 128, 125 and 0 ka (BP)**

- **FAMOUS = TRANSIENTS**
  - **132-115ka**

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

University of BRISTOL
emma.j.stone@bristol.ac.uk

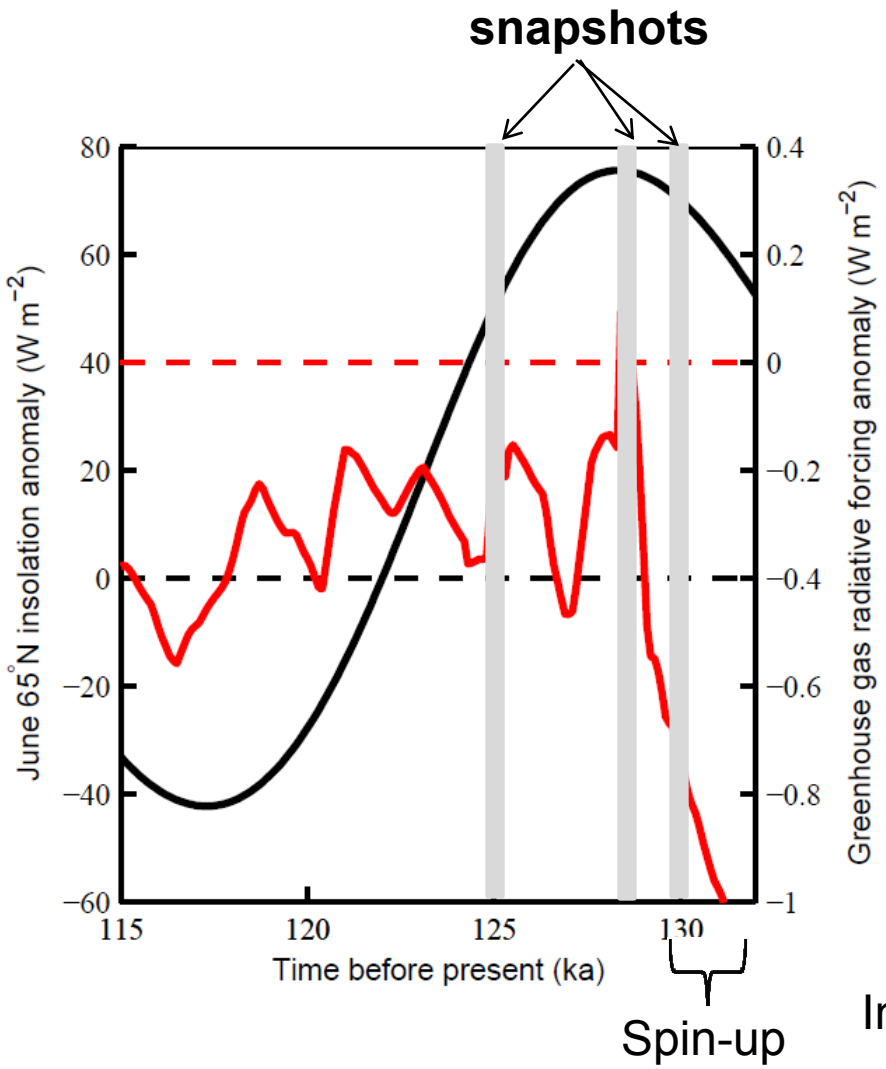
Forcings



- Greenhouse gases on 100 year resolution
- Orbital parameters updated on 1000 year resolution

University of BRISTOL
emma.j.stone@bristol.ac.uk

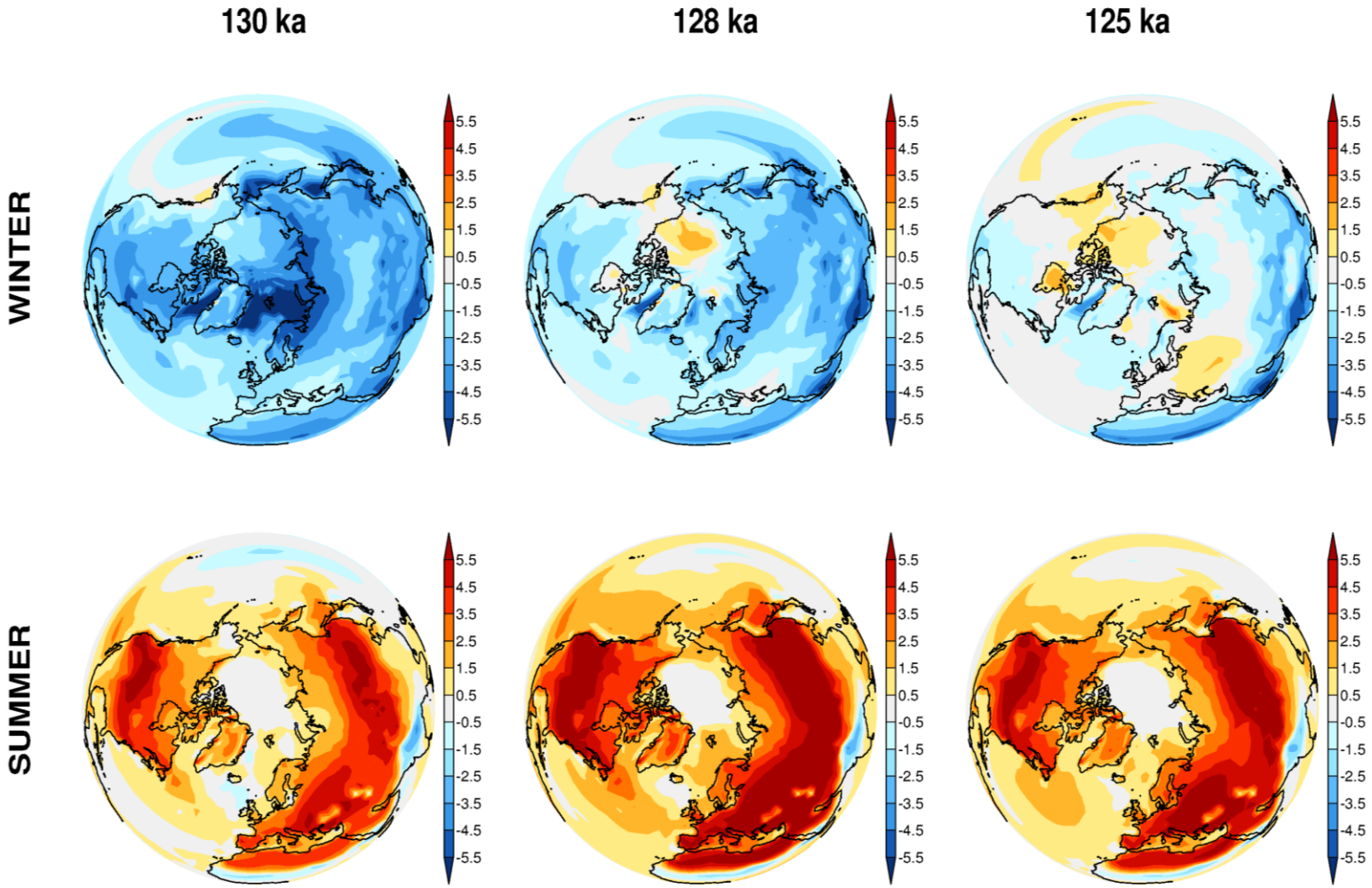
Forcings



- Greenhouse gases on 100 year resolution
- Orbital parameters updated on 1000 year resolution

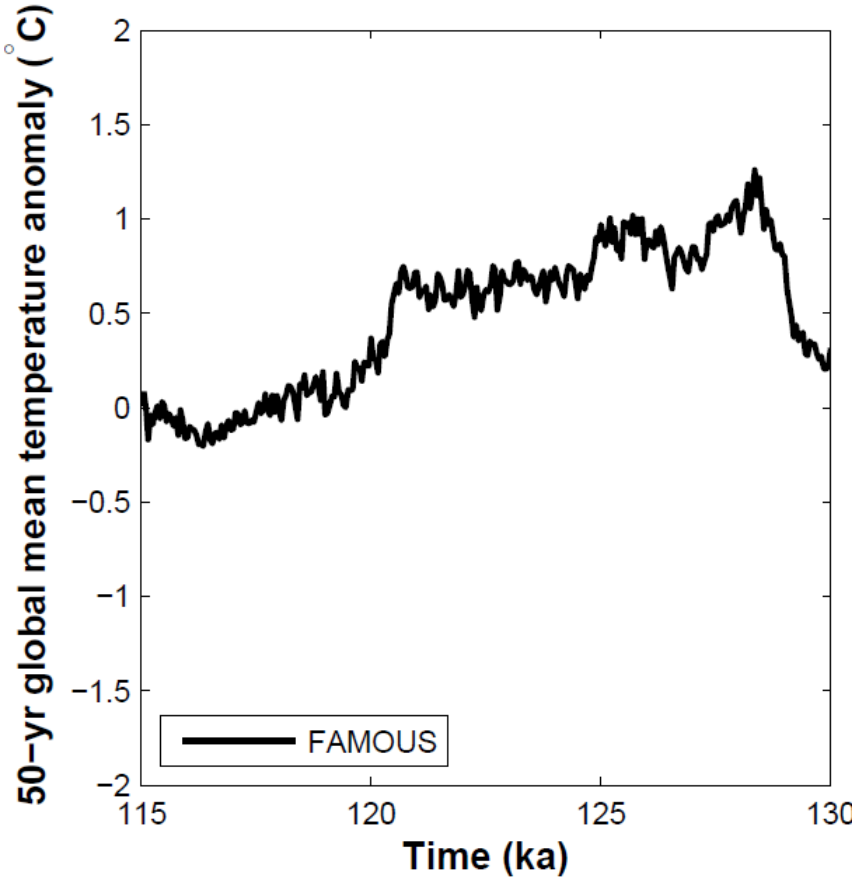
University of BRISTOL
emma.j.stone@bristol.ac.uk

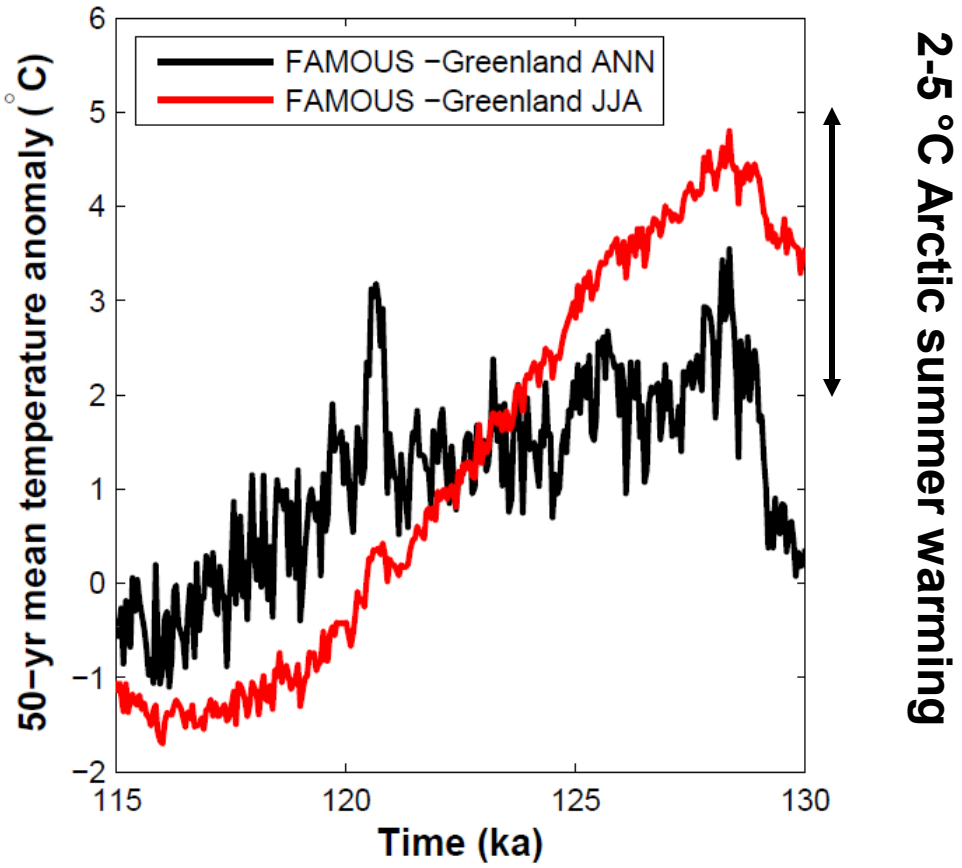
LIG temperature: snapshots



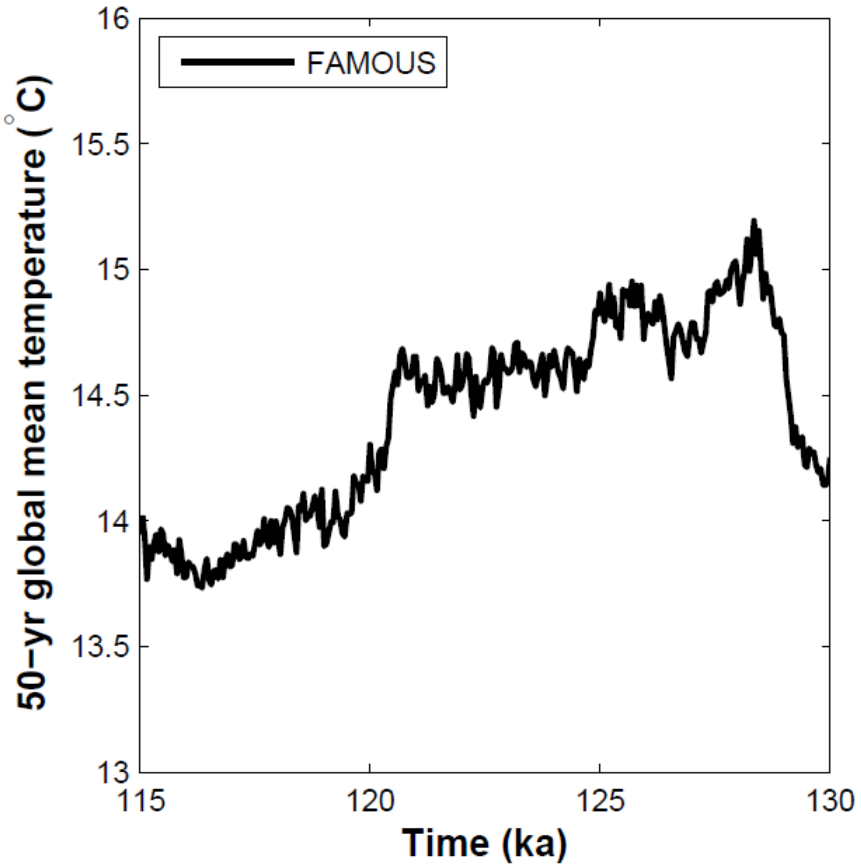
University of BRISTOL
emma.j.stone@bristol.ac.uk
PAST·4·FUTURE

Last interglacial temperature: transient



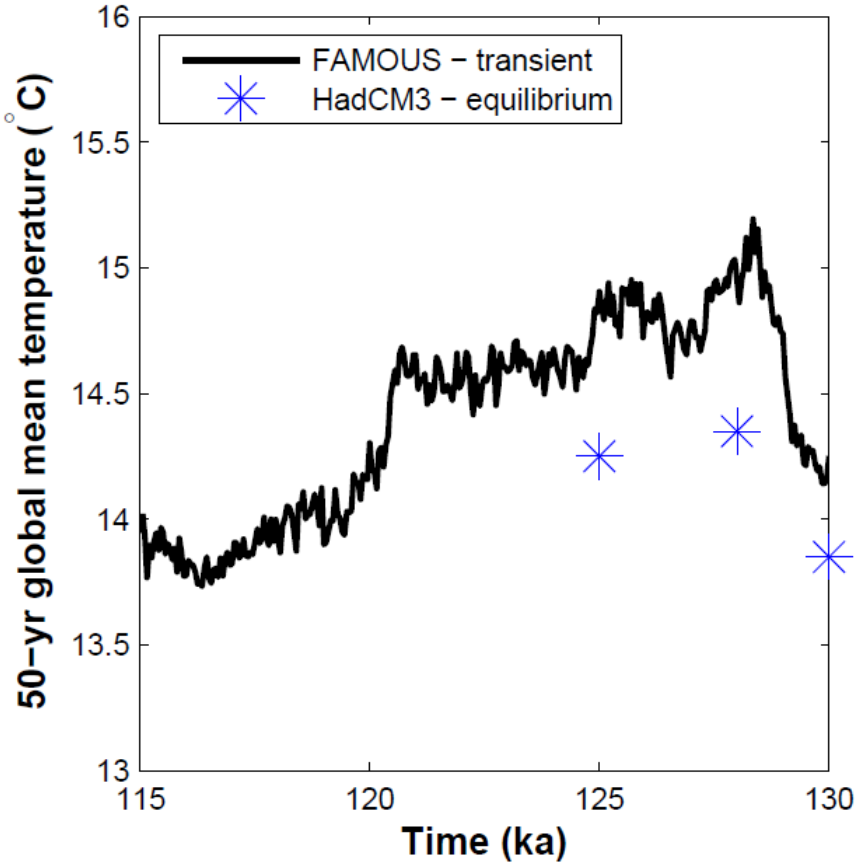


Last interglacial temperature: evaluation



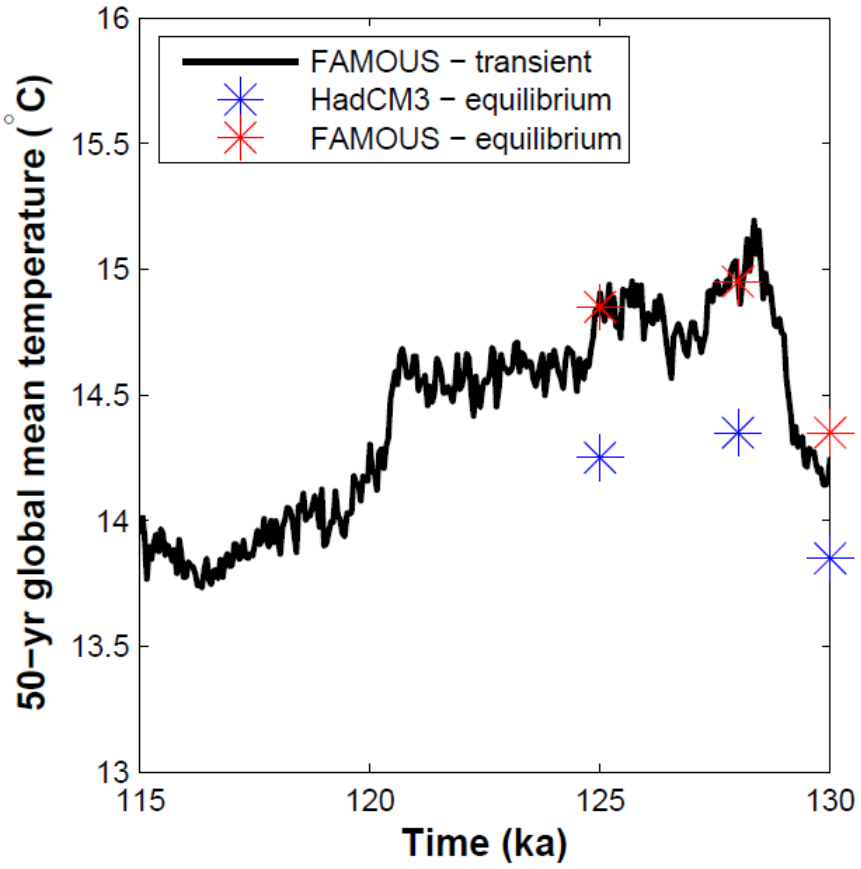
University of BRISTOL
emma.j.stone@bristol.ac.uk

Last interglacial temperature: evaluation



University of BRISTOL
emma.j.stone@bristol.ac.uk

Last interglacial temperature: evaluation

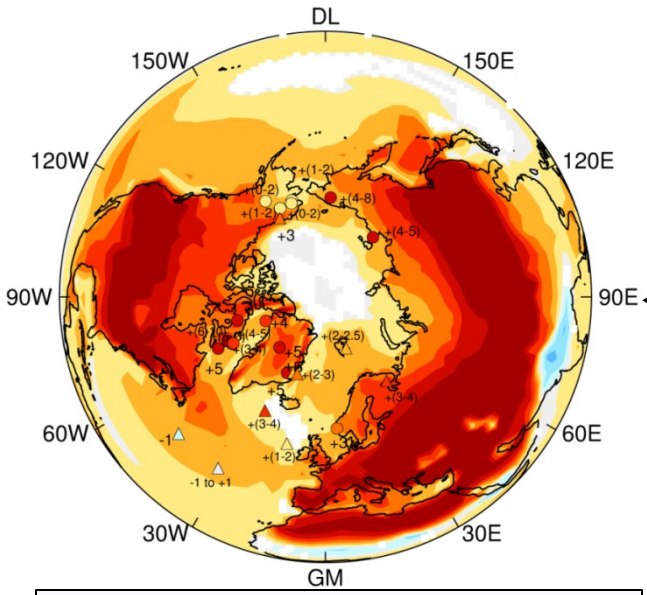


University of BRISTOL
emma.j.stone@bristol.ac.uk

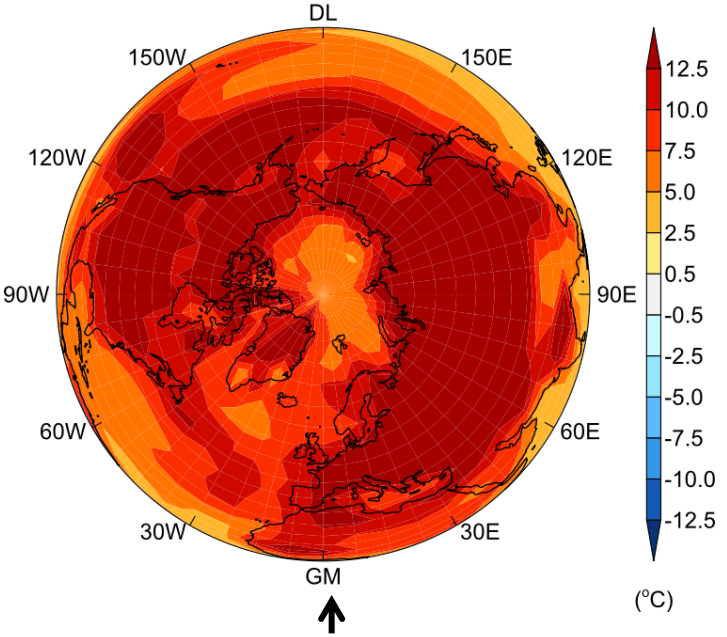
Last interglacial: how do we compare with data?

- **Time-series data?**
- **Time-averaged data?**
  - Summer peak temperature?
  - Summer average temperature?
  - Warmest annual temperature?
  - Annual precipitation-weighted temperature?

emma.j.stone@bristol.ac.uk

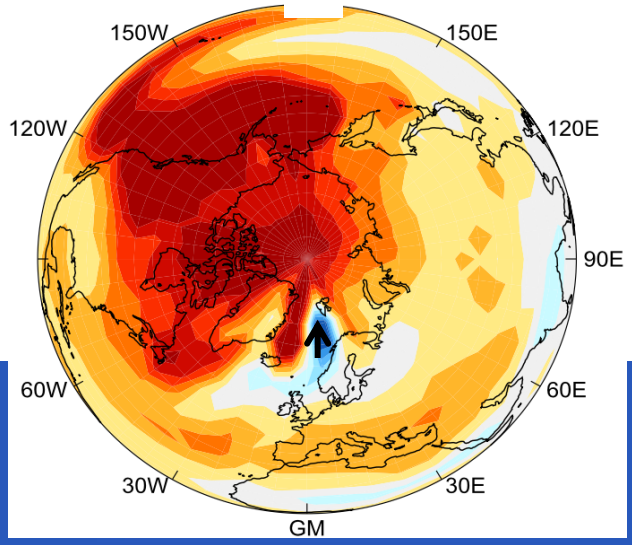


HadCM3 equilibrium simulation: Max JJA temperature anomaly derived from 130,128 and 125ka

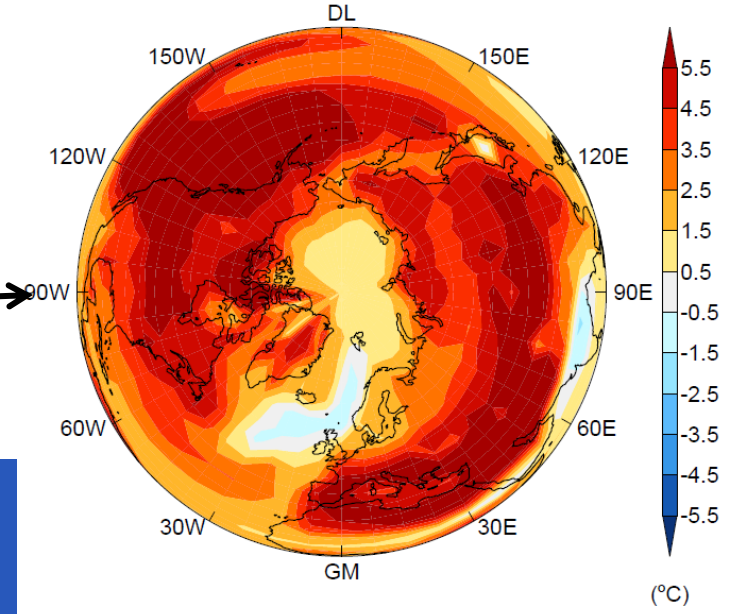


FAMOUS transient simulation: Max. annual temperature anomaly

FAMOUS transient simulation: Max temperature anomaly



FAMOUS transient simulation: Max JJA average temperature anomaly



Understanding the role of GHGs and orbital forcing

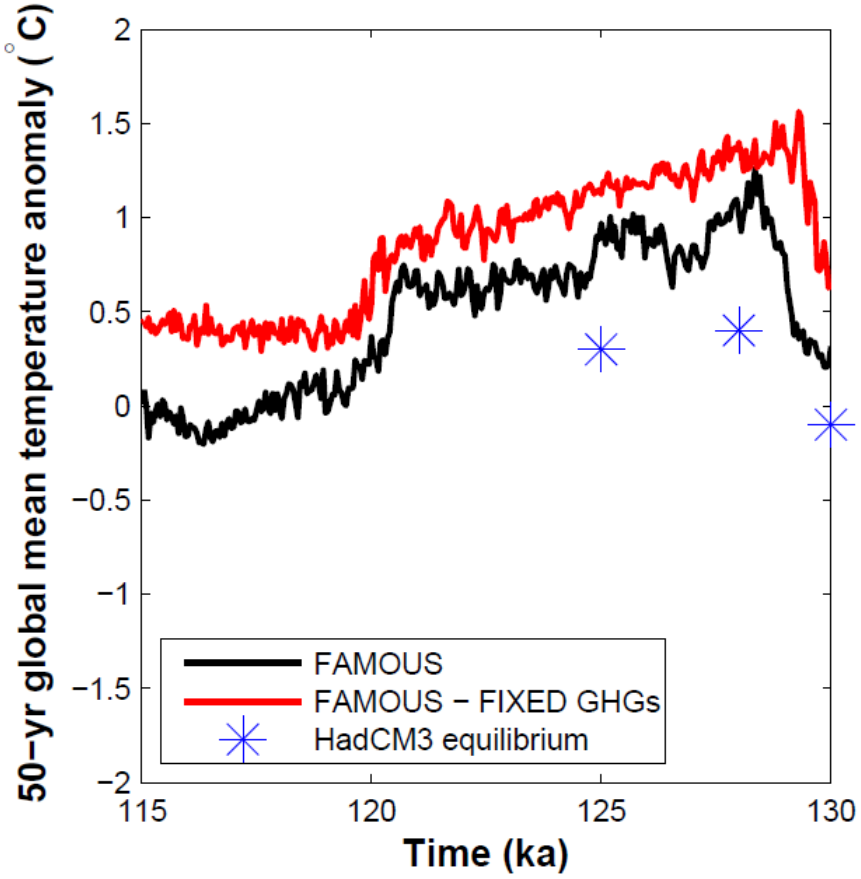
- Sensitivity to major applied forcings and feedbacks in the transient simulations
- In order to ascertain their relative importance in determining the varying mean state and variability during the interglacials
- **GHGs FIXED at Preindustrial values**

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

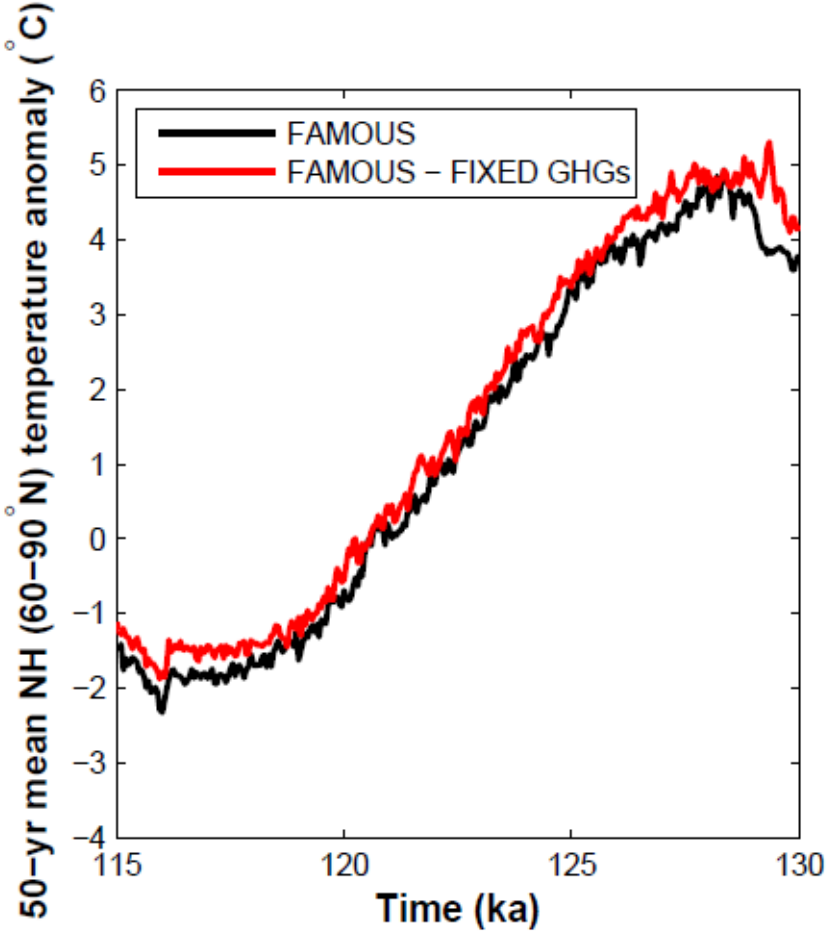
University of BRISTOL
emma.j.stone@bristol.ac.uk

Temperature sensitivity

Global



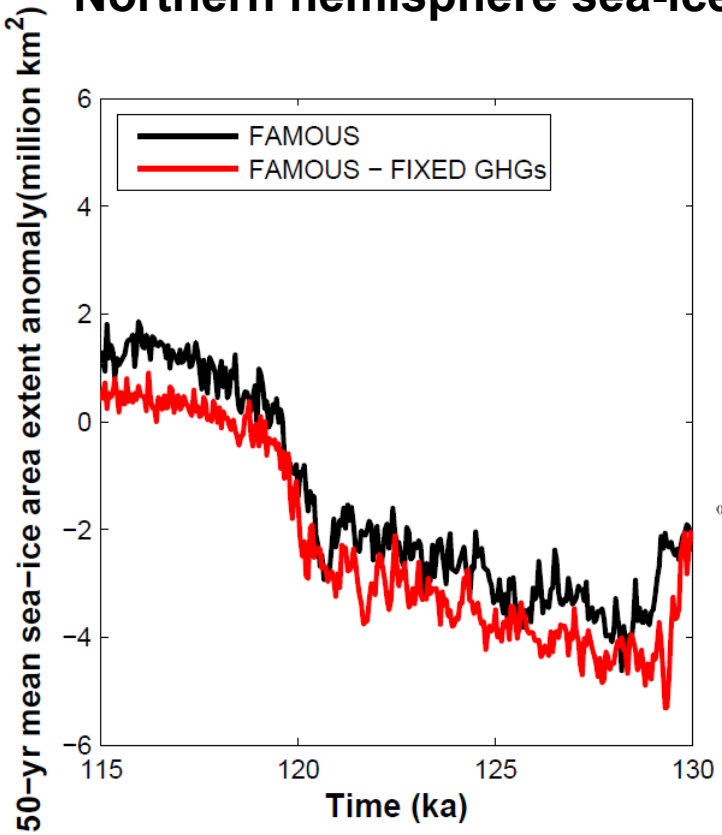
Northern hemisphere (high latitudes)

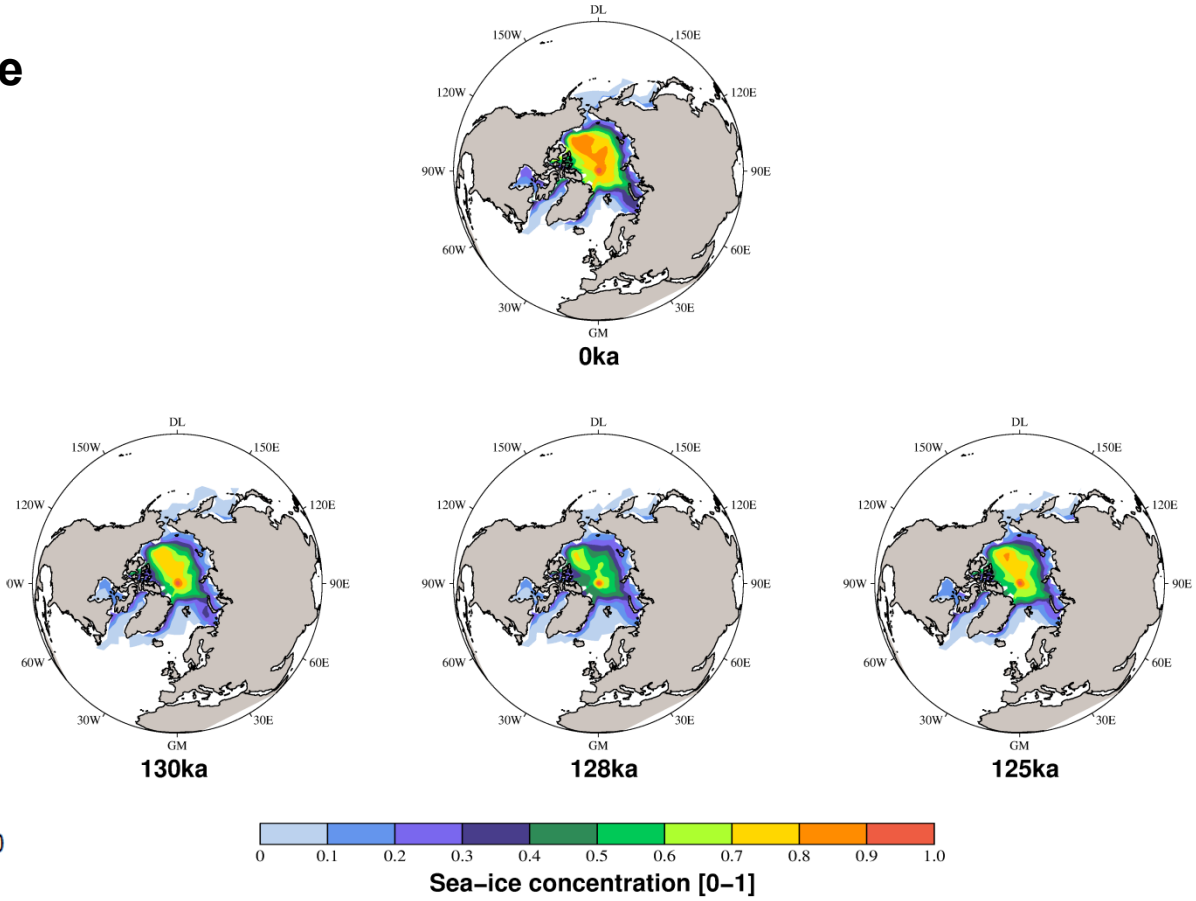


University of BRISTOL
emma.j.stone@bristol.ac.uk

Sea-ice changes

Northern hemisphere sea-ice

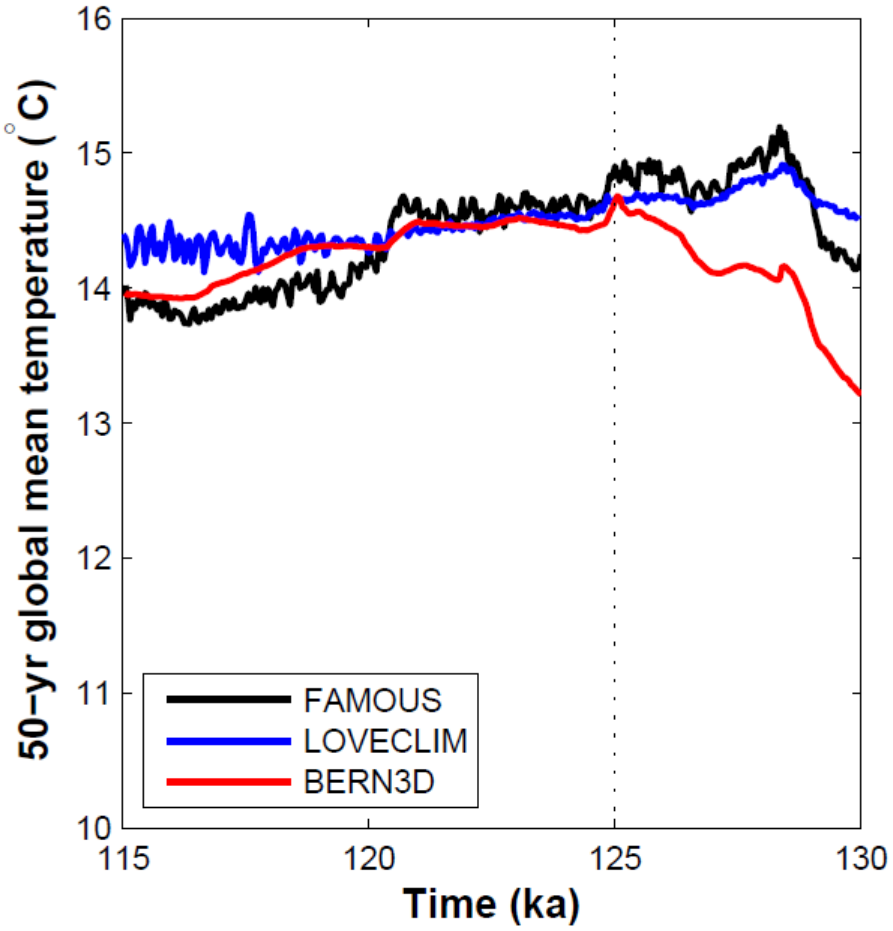




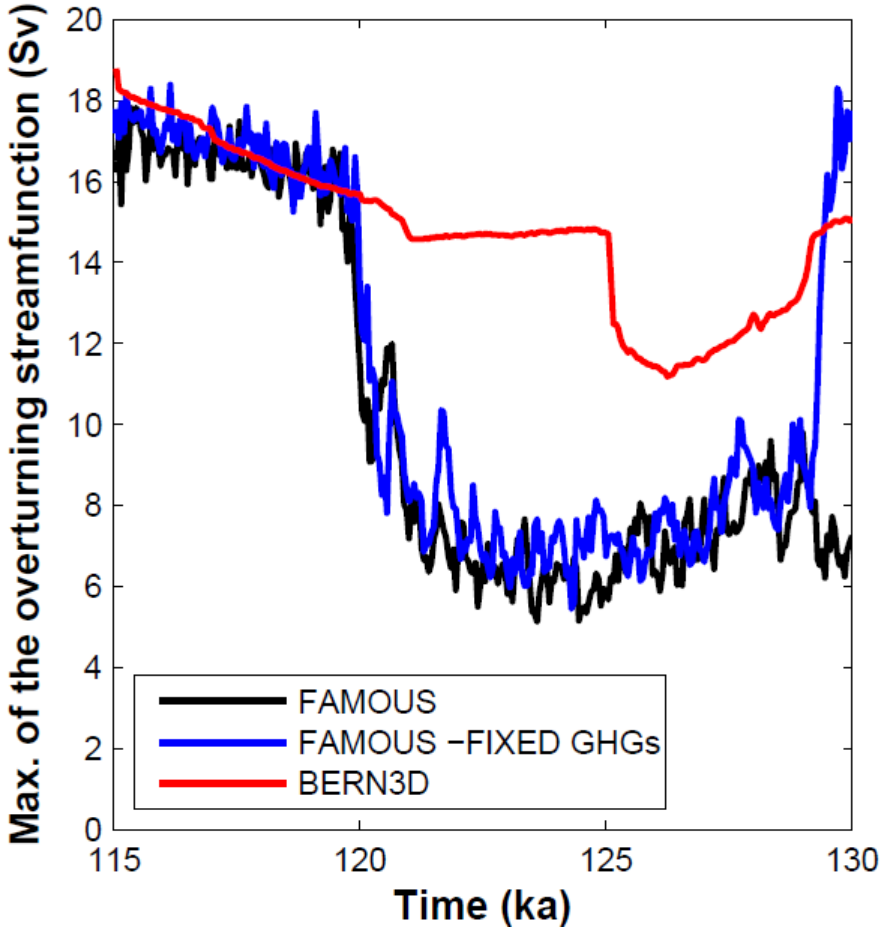
HadCM3 snapshots

University of BRISTOL
emma.j.stone@bristol.ac.uk

Inter-model comparison



Temperature



Maximum AMOC

University of BRISTOL
emma.j.stone@bristol.ac.uk

Conclusions and outlook

- Climate snapshot simulations show ~5ºC summer warming in Arctic region with peak warmth at ~128ka
- FAMOUS transient simulation shows global average peak warmth at 128ka
- Snapshot-transient comparison at 130, 128 and 125ka shows consistently lower global average temperature for the HadCM3 snapshots but… FAMOUS equilibrium simulations similar to the transient simulation
- Comparing transient simulations with time-averaged data: large discrepancy depending on how you average you transient simulation data for example
- Fixing GHGs at preindustrial values results in consistently higher globally averaged temperature anomaly throughout the LIG transient simulation
  - GHGs do not change the mean trend in global temperature (insolation controlled) rather they result in higher variability on shorter timescales

University of BRISTOL

emma.j.stone@bristol.ac.uk

Conclusions and outlook

- Decrease in Arctic sea-ice extent with minimum around 128ka consistent with HadCM3
- Initial inter-model comparison shows similarity between all models in terms of global temperature for the period 125 to 120ka. Large discrepancy at 130ka –model spin-up issue?
- Large reduction in AMOC in FAMOUS compared with Bern 3D during LIG
- Analysis required to show trends in temperature/precipitation/sea-ice throughout the LIG
- Further transient simulations :
  - Inclusion of vegetation feedbacks
  - Freshwater forcing
  - Ice-sheets

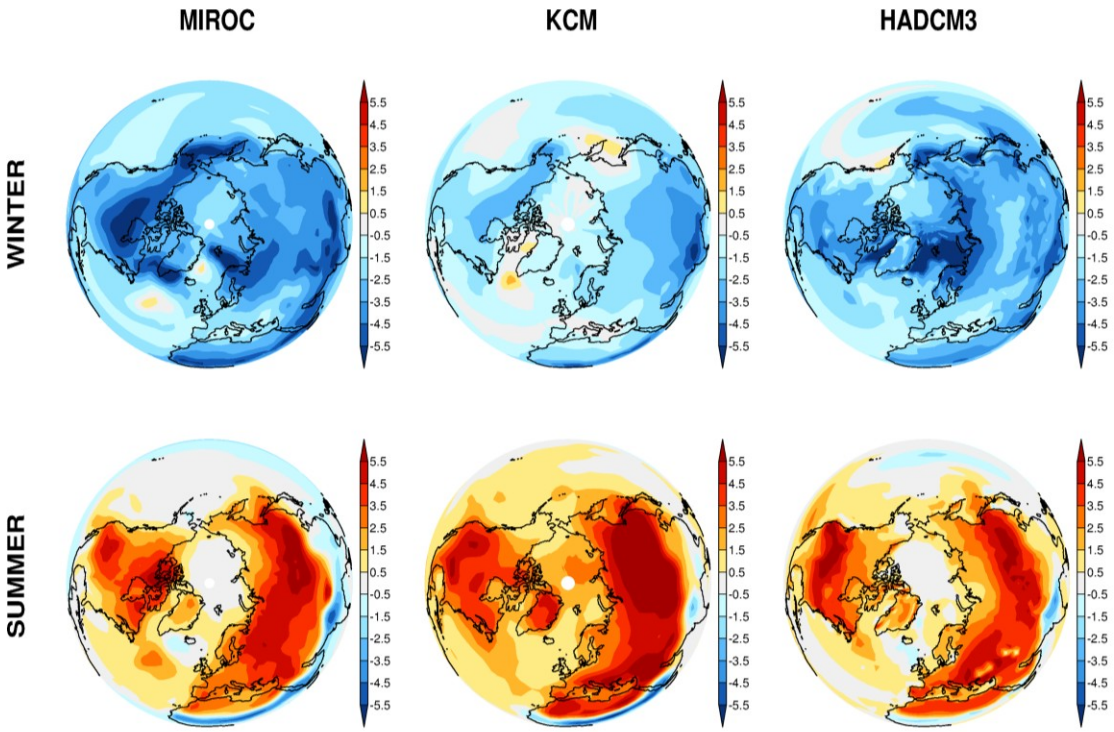
University of BRISTOL

emma.j.stone@bristol.ac.uk

Thank you

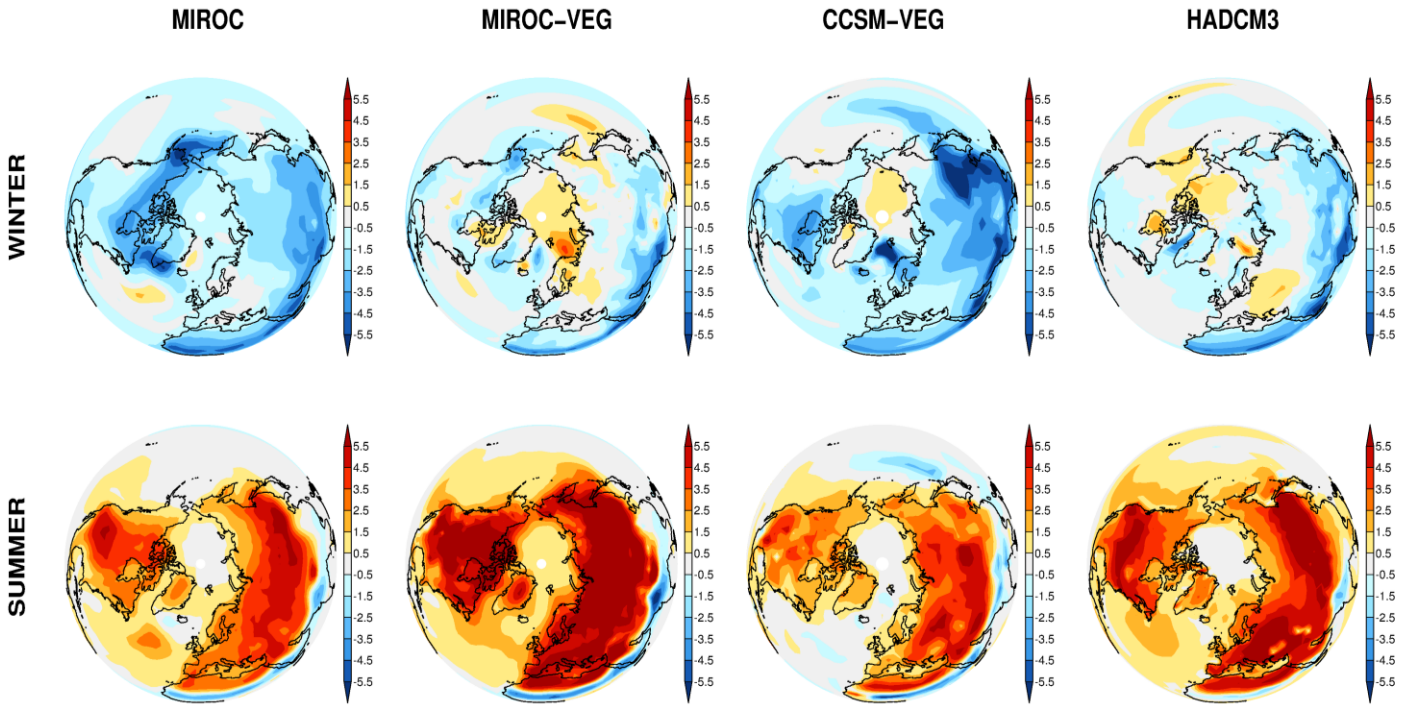
emma.j.stone@bristol.ac.uk

130 ka model comparison



University of BRISTOL
emma.j.stone@bristol.ac.uk
PAST·4·FUTURE

125 ka model comparison



University of BRISTOL

emma.j.stone@bristol.ac.uk