The Pliocene and IPCC -
How does the Pliocene inform the future?

Dan Lunt

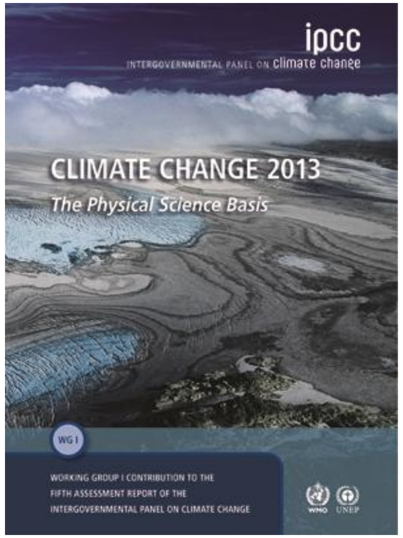
(1) The IPCC (Intergovernmental Panel on Climate Change)

(2) How can the past (Pliocene) inform the future?

(3) Climate sensitivity in the Pliocene
- (a) Direct estimates of climate sensitivity
- (b) Emergent constraints
- (c) Earth system sensitivity

(4) Ways forward

IPCC (Intergovernmental Panel on Climate Change)



- Created in 1988, the objective of the IPCC is to **provide governments at all levels with scientific information that they can use to develop climate policies.**

- Its role is to **assess the scientific, technical and socio-economic literature relevant to understanding climate change**, its impacts and future risks, and options for adaptation and mitigation.

- **Working Group I deals with The Physical Science Basis of Climate Change**, Working Group II with Climate Change Impacts, Adaptation and Vulnerability and Working Group III with Mitigation of Climate Change.

- 6th Assessment report (AR6) due 2021 (WG1). First Order Draft due 7th April!

IPCC (Intergovernmental Panel on Climate Change)

Chapters:

Box 1: Outline of the WGI AR6

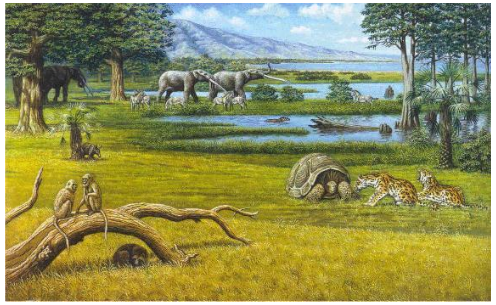
Summary for Policy Makers
Technical Summary

Chapter 1:	Framing, context, methods
Chapter 2:	Changing state of the climate system
Chapter 3:	Human influence on the climate system
Chapter 4:	Future global climate: scenario-based projections and near-term information
Chapter 5:	Carbon budgets, biogeochemical cycles and feedbacks
Chapter 6:	Short-lived climate forcers and air quality
Chapter 7:	The Earth's energy budget, climate feedbacks, and climate sensitivity
Chapter 8:	Water cycle changes
Chapter 9:	Ocean, cryosphere, and sea level change
Chapter 10:	Linking global to regional climate change
Chapter 11:	Weather and climate extreme events in a changing climate
Chapter 12:	Climate change information for regional impact and risk assessment

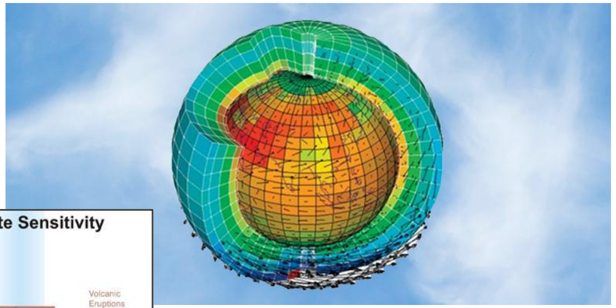
Each chapter is expected to build on all available lines of evidence, including:

- paleoclimatic evidence;

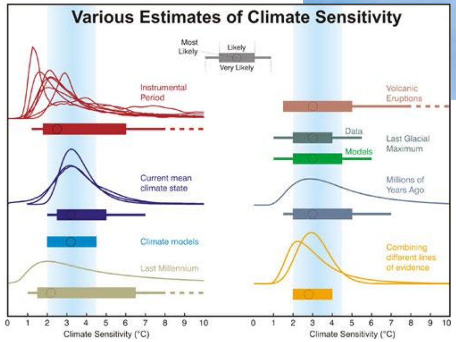
How can the past inform the future?



- Past climates provide a window on a world very different to our own. If the drivers of past change are similar to those in the future, the past time period may be an **analogue** for future change…



- Past climates provide geological data that we can use to **test** our climate models that are used for future projection.



- Past climates allow us to **quantify** key metrics such as climate sensitivity.

- Past climates allow us to estimate **long-term changes** that cannot be simulated with models.

How can the Pliocene inform the future?

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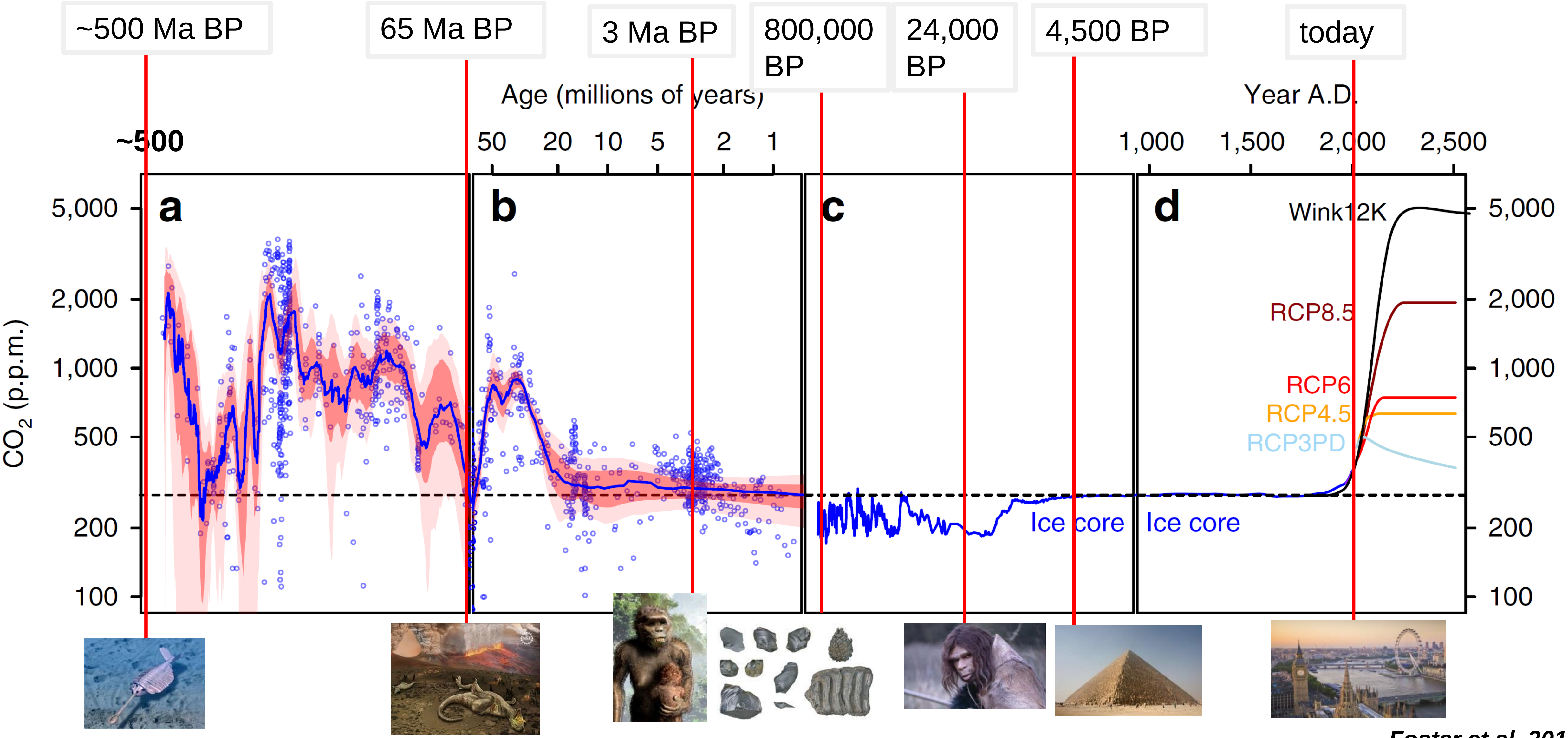

Foster et al, 2017

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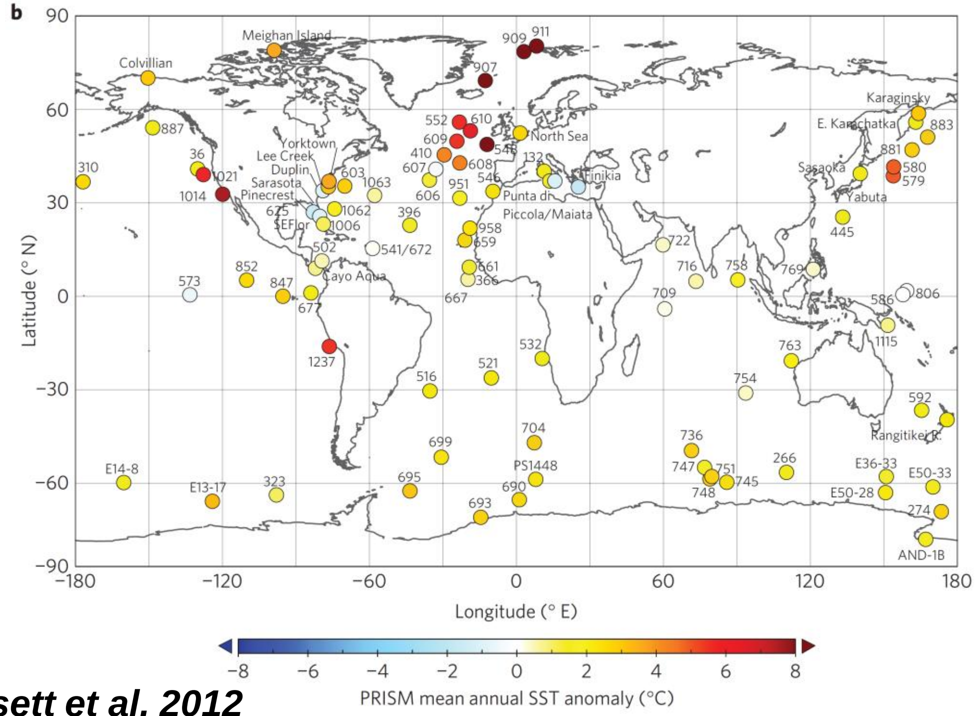
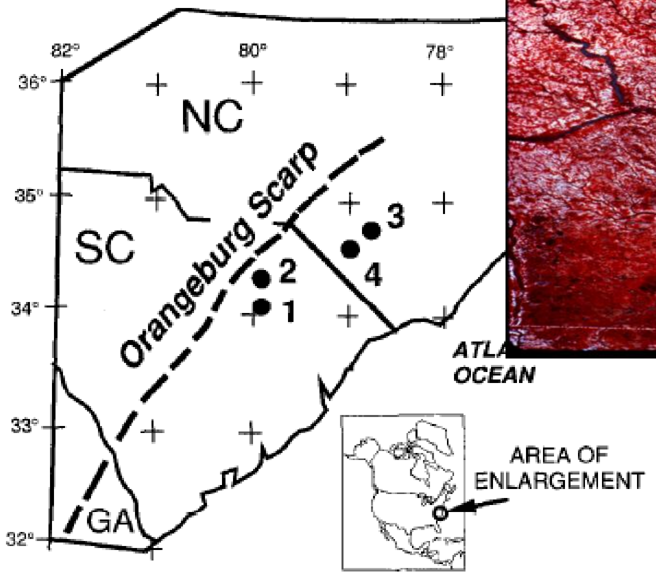
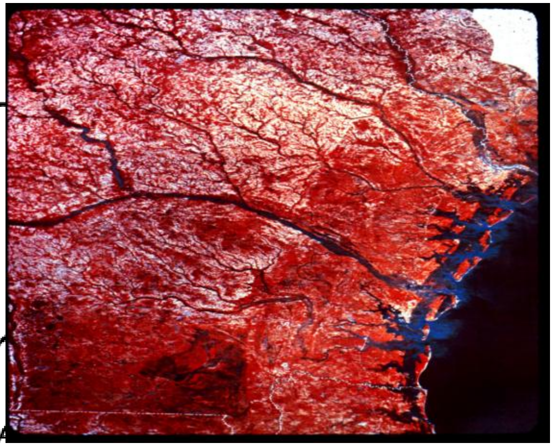


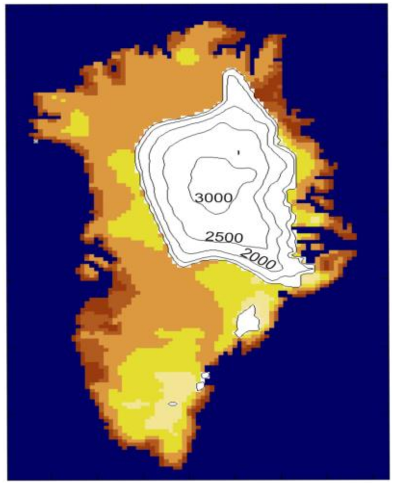
Dowsett et al, 2012

Figure 1. Location of Orangeburg scarp and position of cores and outcrops analyzed for marine microfossils. 1—LB 173, D of Cronin (1988), SC-76 of Cronin (1981), lat 34°19′45″N, long 79°58′00″W; 2—LB 179, K of Cronin (1988), SC-65 of Cronin (1981), 34°01′30″N, 79°59′00″W; 3—Robeson Farm, C of Cronin (1988), NC-27 of Cronin (1981), 34°42′39″N, 78°44′16″W; 4—Lumber River, B of Cronin (1988), NC-21 of Cronin (1981), 34°35′35″N, 78°58′53″W. NC = North Carolina, SC = South Carolina, GA = Georgia.

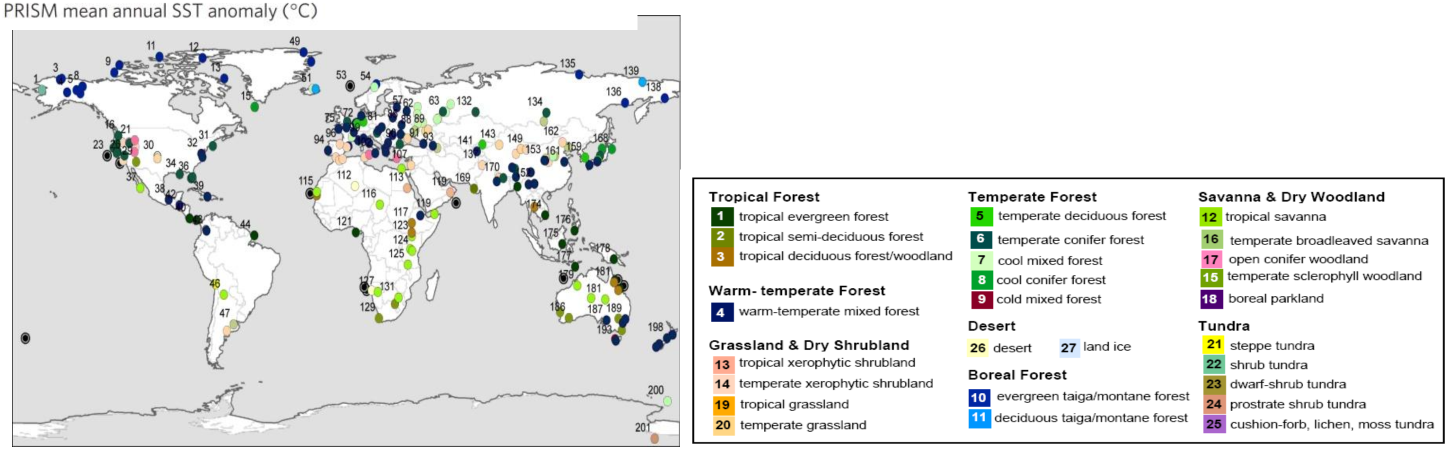




Dowsett et al



Hill et al



Salzmann et al, 2008

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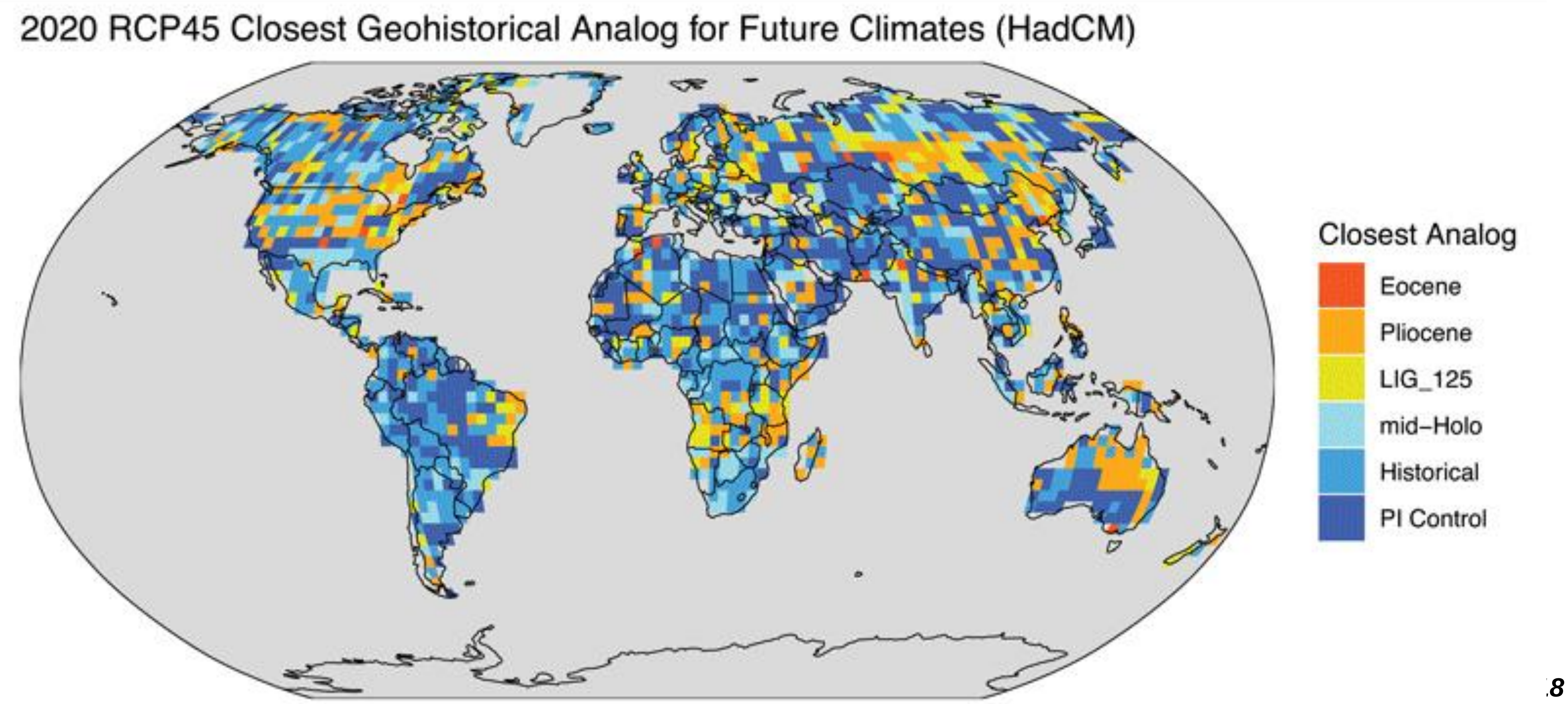

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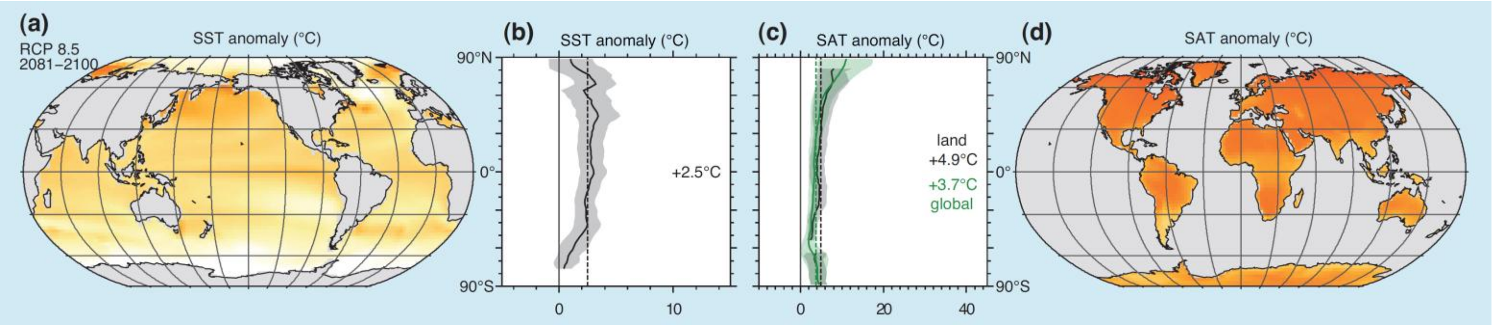

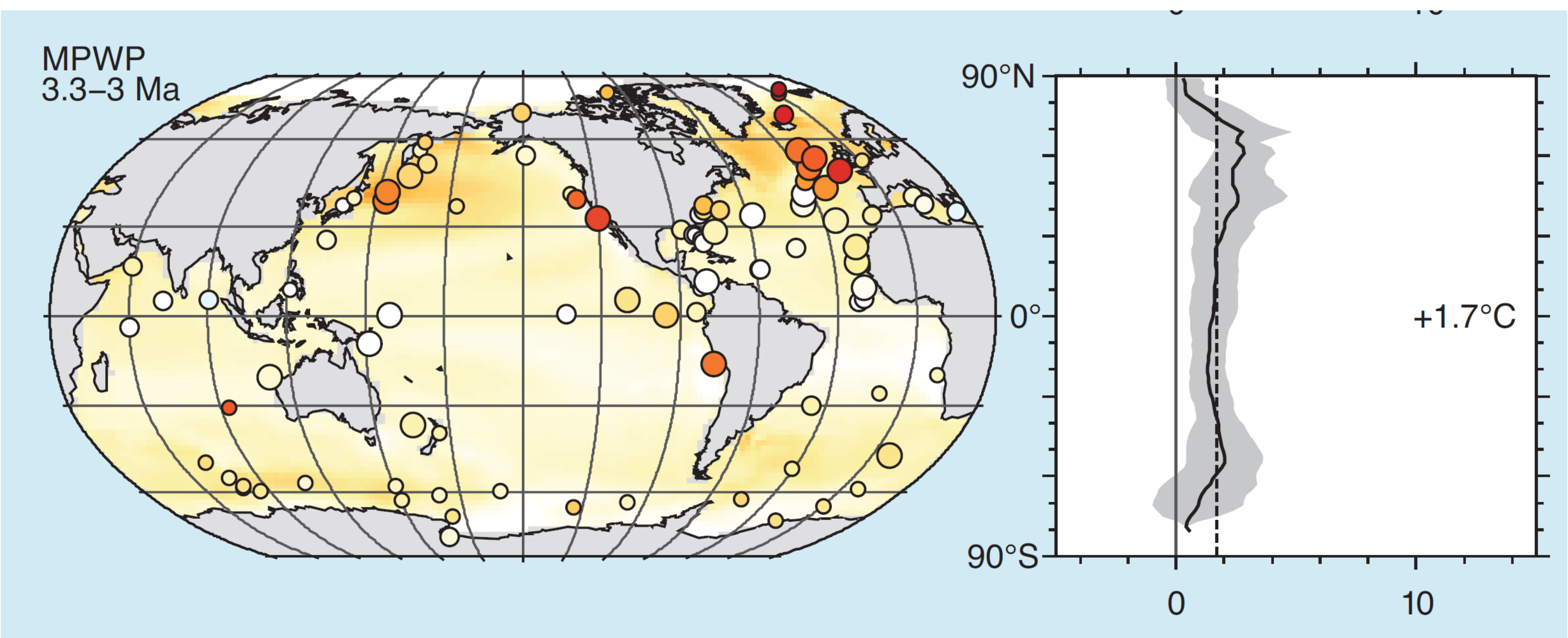

IPCC, 2013

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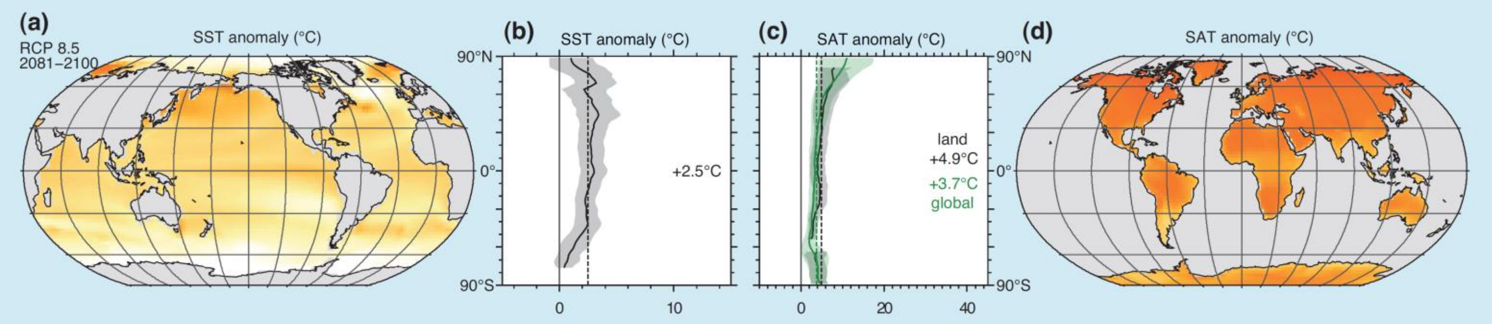
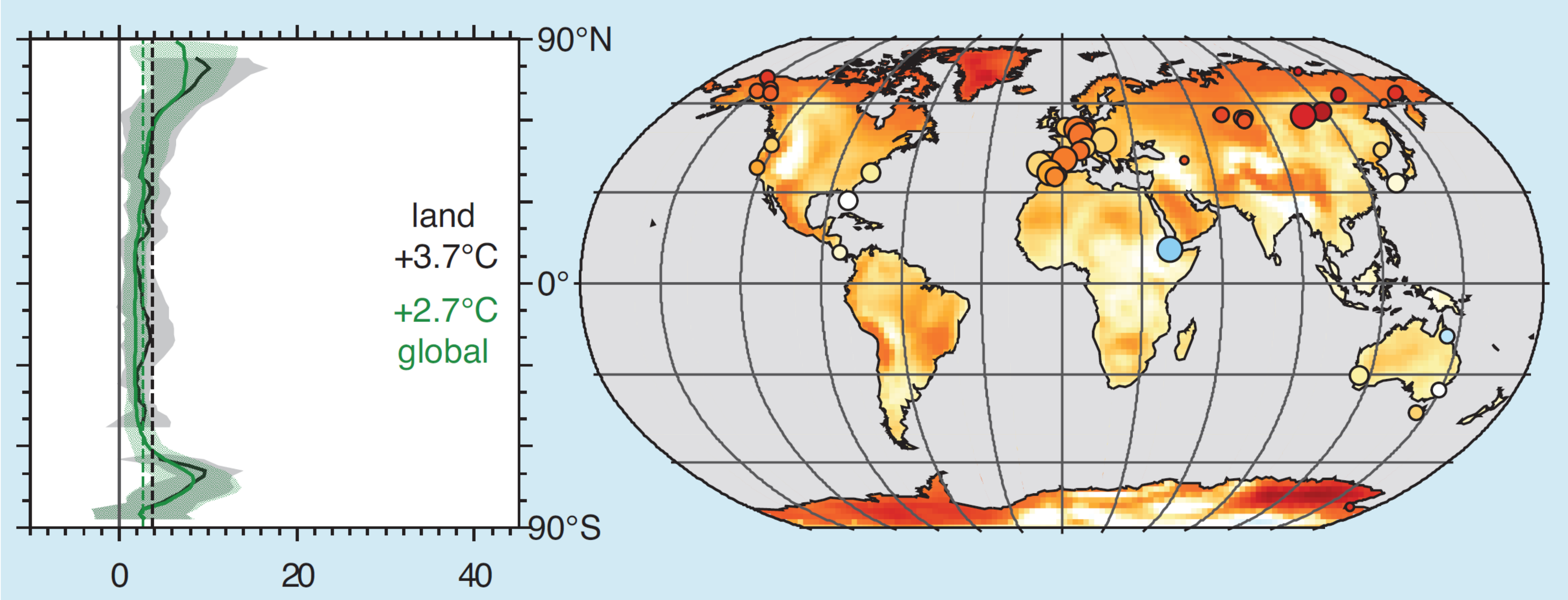




IPCC, 2013

How can the Pliocene inform the future?

- Past climates allow us to **quantify** key metrics such as climate sensitivity.

“Climate Sensitivity”

- ➢ **Equilibrium global mean near-surface air temperature increase given a doubling of atmospheric CO_2**

- ➢ **High-profile metric because with it, we can answer questions such as:**
    - ***“I want to limit warming to 1.5 ^{o}C; what CO_2 concentration is allowed ”***
    - ***“I think CO_2 concentrations will reach 1200 ppmv by the year 2100, what will the warming be? ”***
    - ***[also an input to many economic and impact models]***

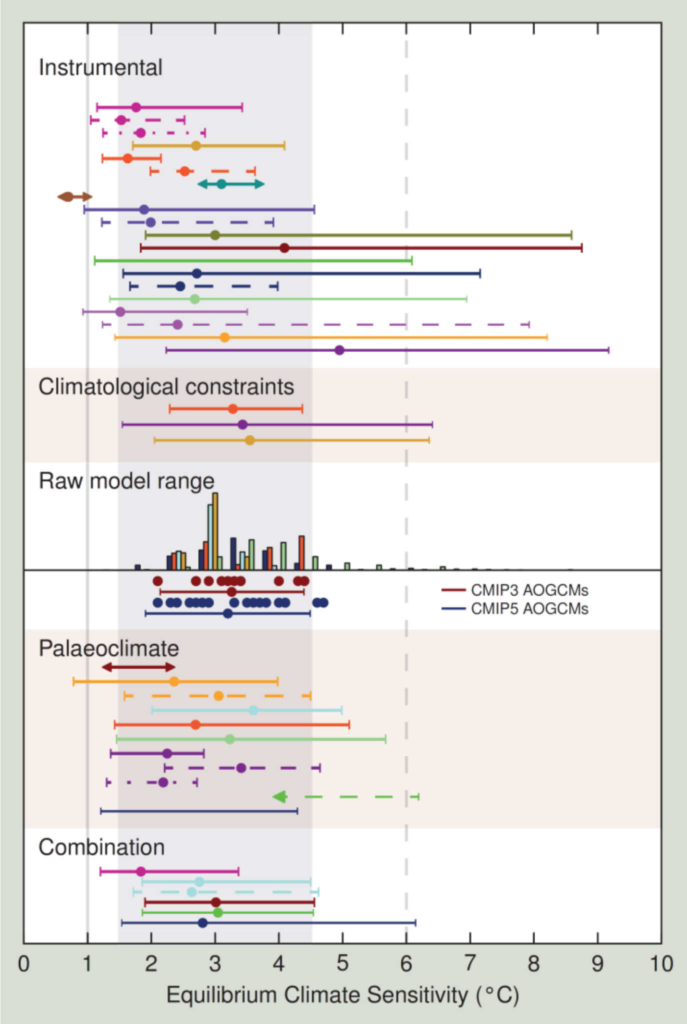
Climate Sensitivity

Publication	Equilibrium sensitivity to CO_2 doubling	Remarks
(Arrhenius, 1896a)	5-6°C	2-D (zonal and vertical) radiative transfer model
(Hulburt 1931)	4°C	Unnoticed until 1960s due to general rejection of CO_2 theory; Callendar unaware of Hulburt's work until about 1942
(Callendar 1938)	1.5°C	1-D radiative transfer model; CO_2 doubling not mentioned in text, but appears in graph; no convection
(Callendar 1949)	2.1°C	Revised version of his 1938 calculations; CO_2 doubling explicitly mentioned
(Plass 1956b)	3.8°C	1-D radiative transfer model; no convection or water vapor feedback
(Möller 1963)	1.5-9.6°C	1-D surface energy balance model; combined H20 and CO_2 absorption reduces overall warming, but water vapor feedback produces "almost arbitrary temperature changes"
(Conservation Foundation 1963)	2.0°C cloudy; 3.8°C clear-sky	Consensus statement by E Ericksson, G Plass, C Keeling, others
(Manabe and Wetherald 1967)	2.4°C	1-D radiative-convective model; humidity and cloudiness levels strongly influence CO_2 effects
(Manabe 1970)	1.9°C	Revised version of Manabe & Wetherald 1967 1-D radiative-convective model; sensitivity is for "average" cloudiness
(Rasool and Schneider 1971)	0.8°C	1-D radiation balance model with fixed relative humidity and cloudiness
(Manabe and Wetherald 1975)	2.9°C	First use of a GCM to simulate effects of CO_2 doubling; coupled OAGCM with highly idealized land and ocean

Huge effort to characterise this number….

And IPCC….

IPCC Assessment Report	"Likely" Range [°C]	Best Estimate [°C]
FAR (1990)	1.5 – 4.5	2.5
SAR (1995)	1.5 – 4.5	2.5
TAR (2001)	1.5 – 4.5	2.5
AR4 (2007)	2.0 – 4.5	3.0
AR5 (2013)	1.5 – 4.5	Not given
AR6 (2021?)	??	??



TFE.6, Figure 1 | Probability density functions, distributions and ranges for equilibrium climate sensitivity, based on Figure 10.20b plus climatological constraints shown in IPCC AR4 (Box AR4 10.2 Figure 1), and results from CMIP5 (Table 9.5). The grey shaded range marks the *likely* 1.5°C to 4.5°C range, grey solid line the *extremely unlikely* less than 1°C, the grey dashed line the *very unlikely* greater than 6°C. See Figure 10.20b and Chapter 10 Supplementary Material for full caption and details. {Box 12.2, Figure 1}

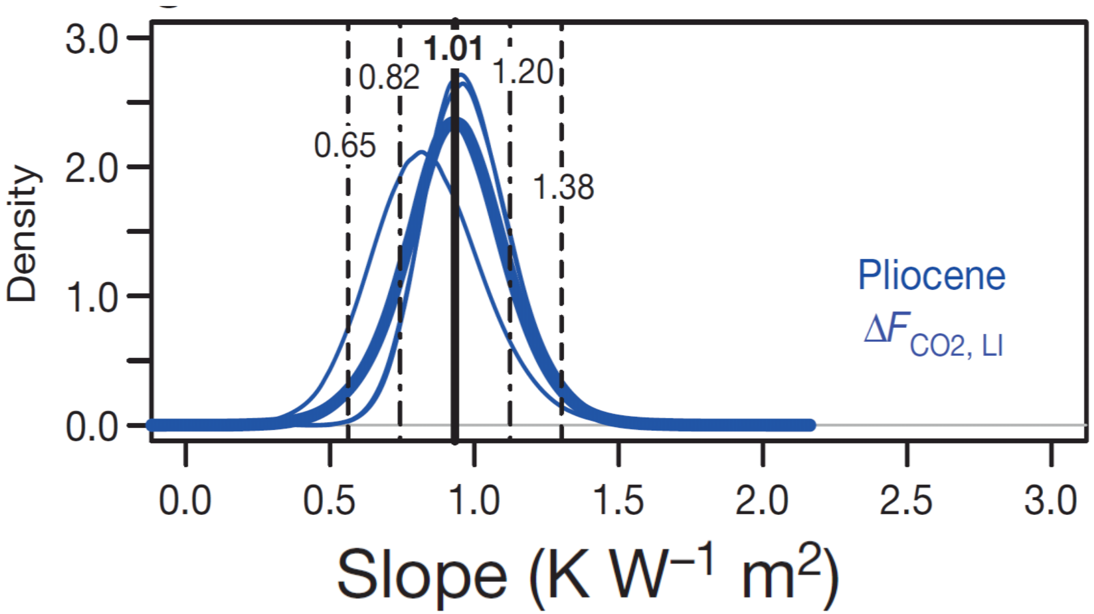
IPCC, 2013

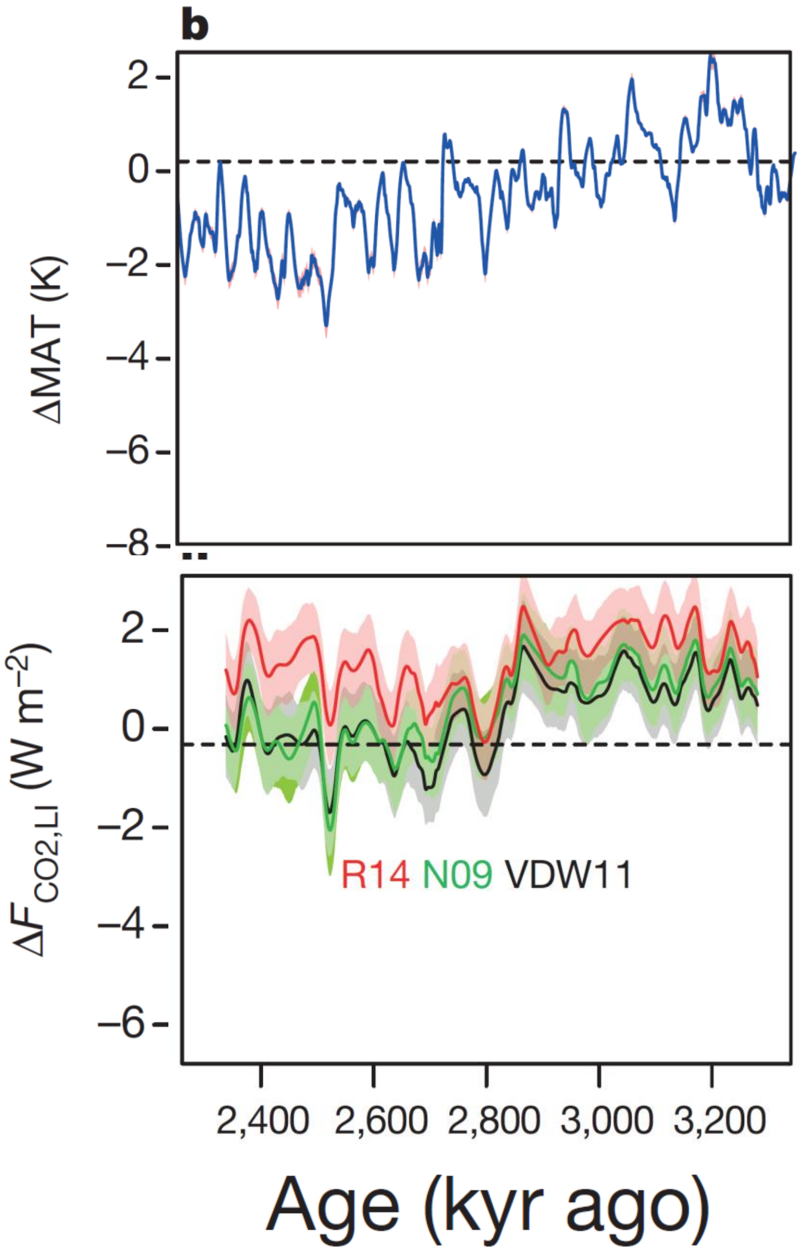
Climate Sensitivity

(1) Direct estimates

Estimate CO_2 concentrations of the Pliocene, and estimate global mean temperature, we can estimate Climate Sensitivity. Potentially very powerful!

"likely" range 3.05-4.35 °C





Martinez-Boti et al, 2015

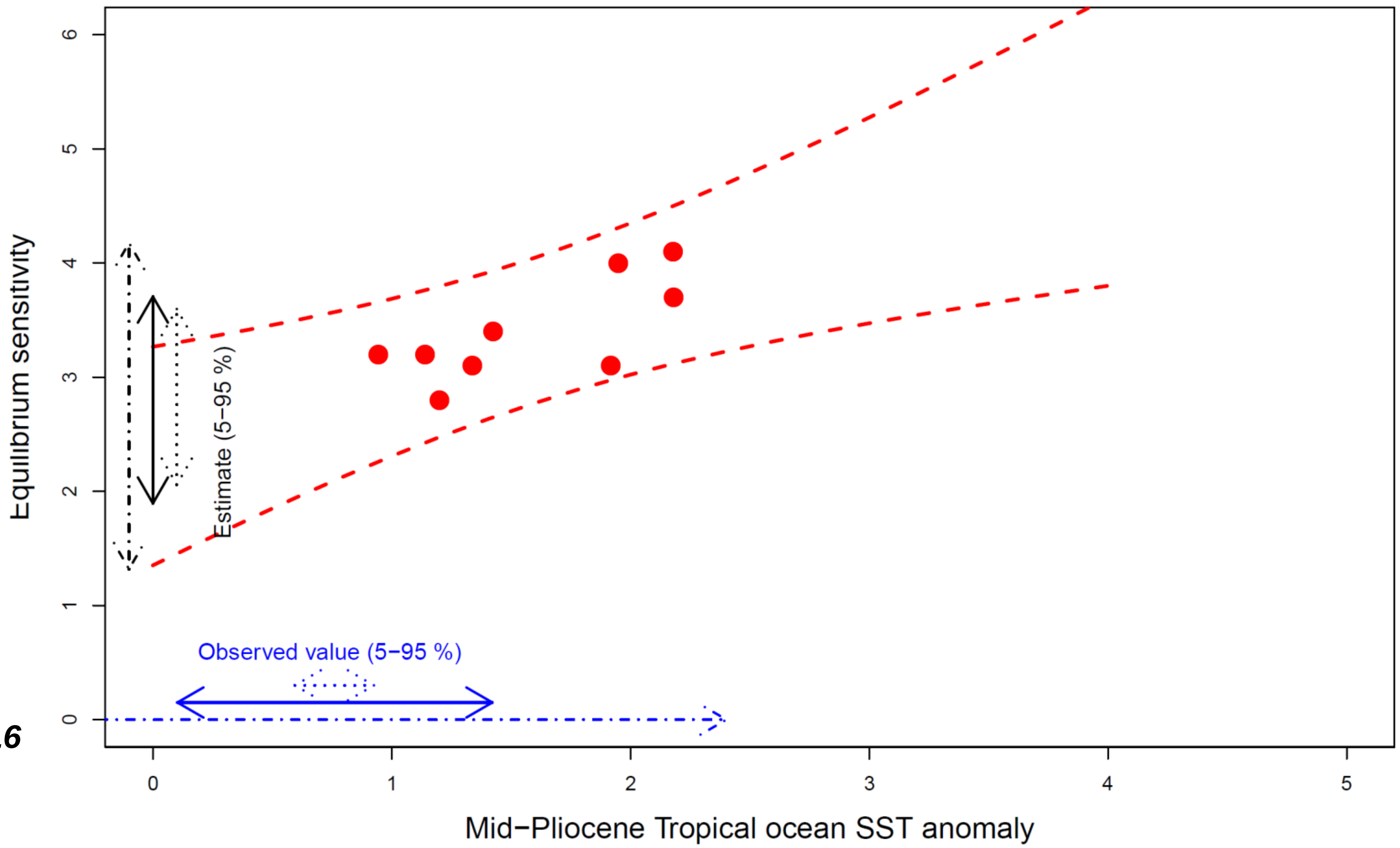
Climate Sensitivity

(2) Emergent constraints

"likely" range 2.35-3.25 ^oC

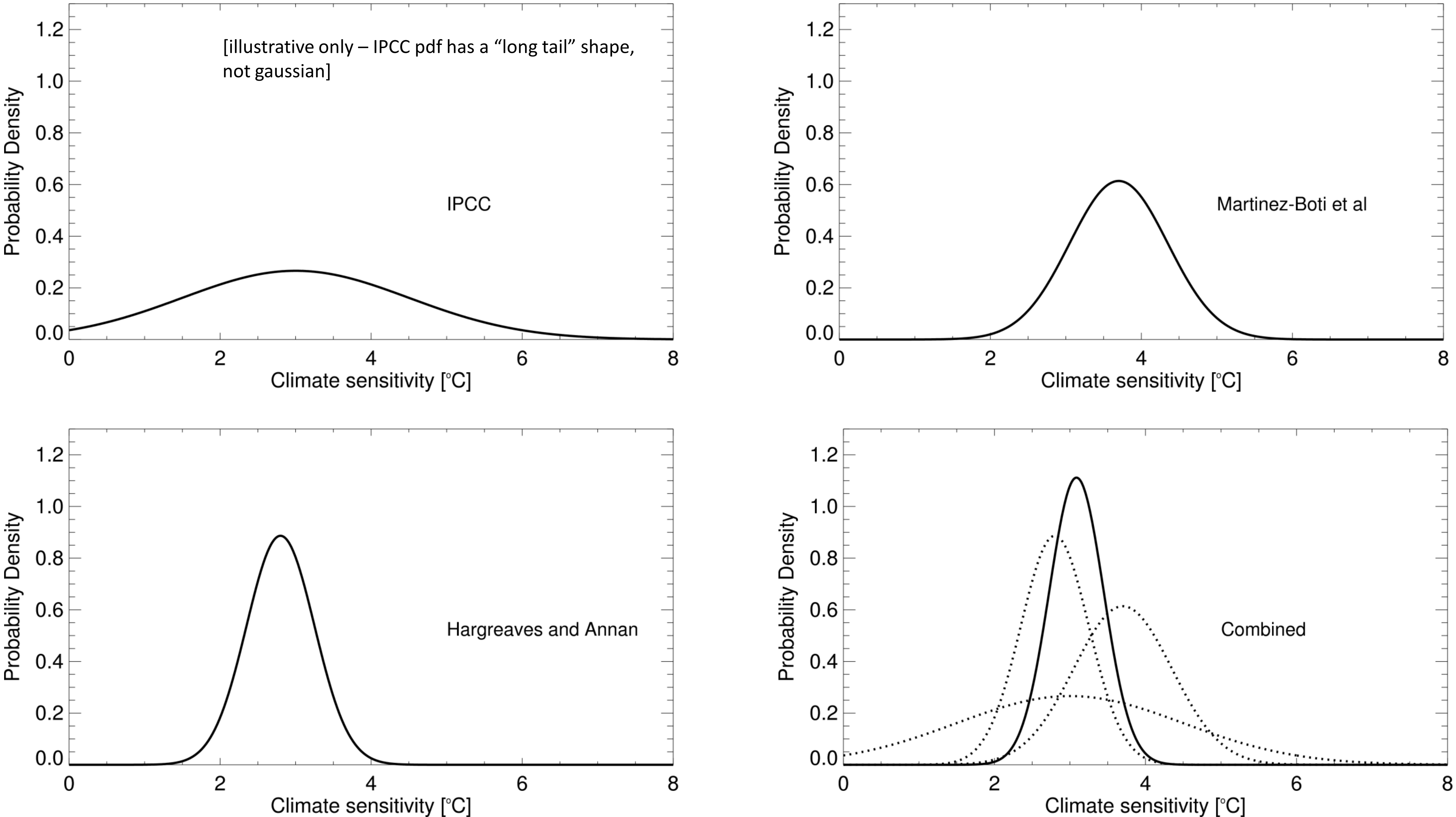
Carry out multiple Pliocene simulations with different models, and multiple future simulations with the same models.

Is there a relationship between the ability of models to correctly predict the past, and their climate sensitivity in the future?



Hargreaves and Annan, 2016

Climate Sensitivity



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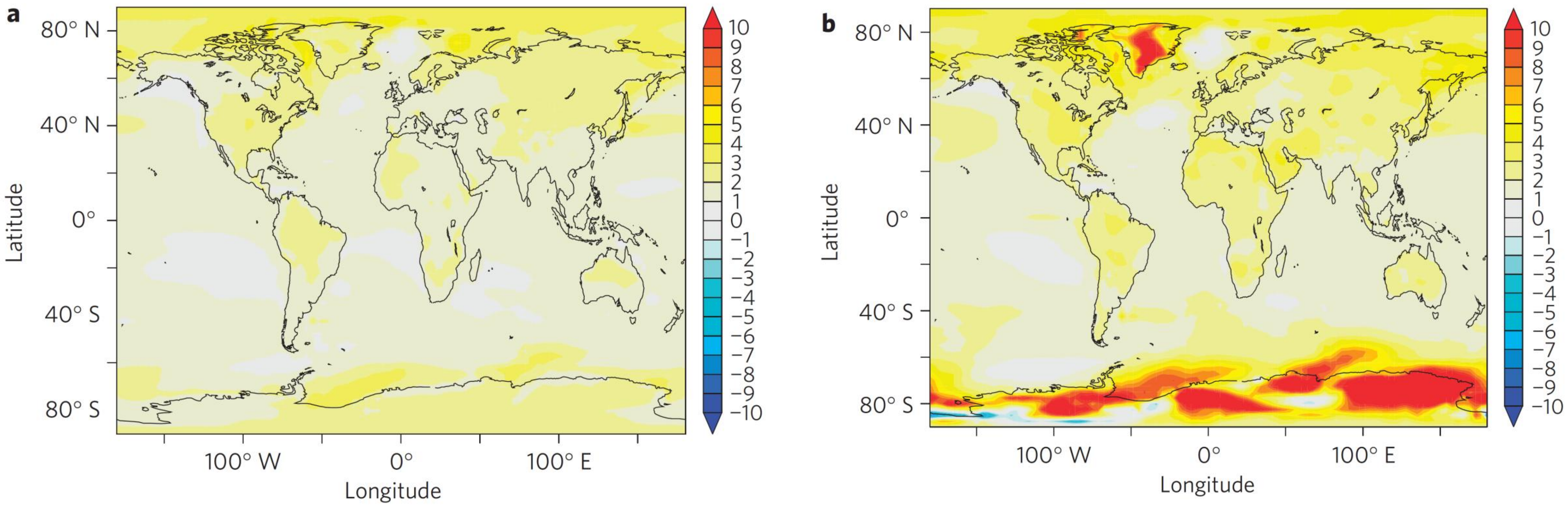


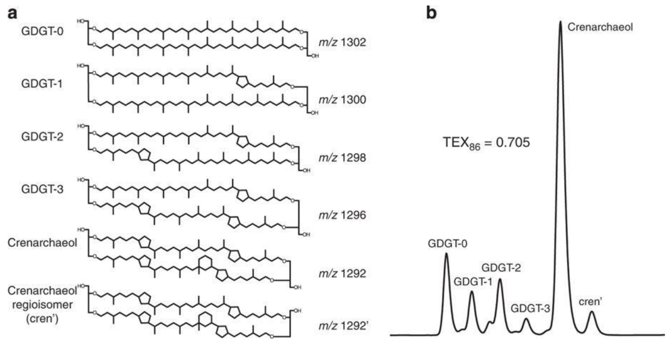
Long-term feedbacks associated with vegetation and ice increase climate sensitivity by ~50% on "long" timescales.

Lunt et al, 2010

Ways forward

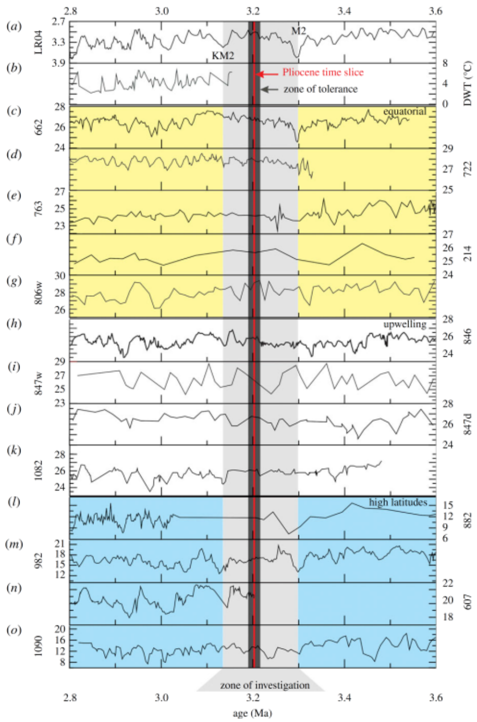
- ➢ Move towards a smaller window of time in the Pliocene

- ➢ More independent geological data



- ➢ Better models

- ➢ More robust statistics for model-data comparisons



Haywood et al, 2013