

# Climate Model Tests of the Early Anthropogenic Hypothesis

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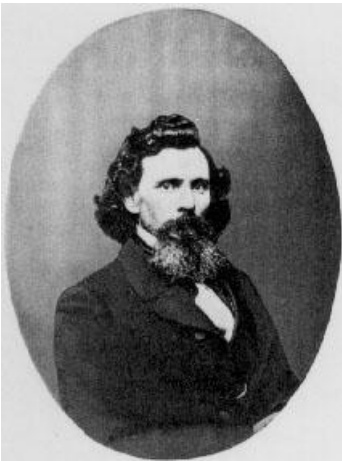


# An Early Anthropocene?

Denton, G., and T. Hughes: “The Arctic Ice Sheet: An Outrageous Hypothesis”

*The Value of Outrageous Geological Hypotheses, Science (1926)*

William Morris Davis



“extolled the value of outrageous geological hypotheses as a means to force reexamination of the convictions of the day”

# A New Outrageous Hypothesis

## news feature

### The hot hand of history

We may not have known we were doing it, but humans have been changing the climate for thousands of years, a new theory suggests. Could our ancestors have saved us from an ice age? Betsy Mason investigates.



Clear cut: did deforestation 8,000 years ago set in motion a pattern of global warming that has since staved off a mini ice age?

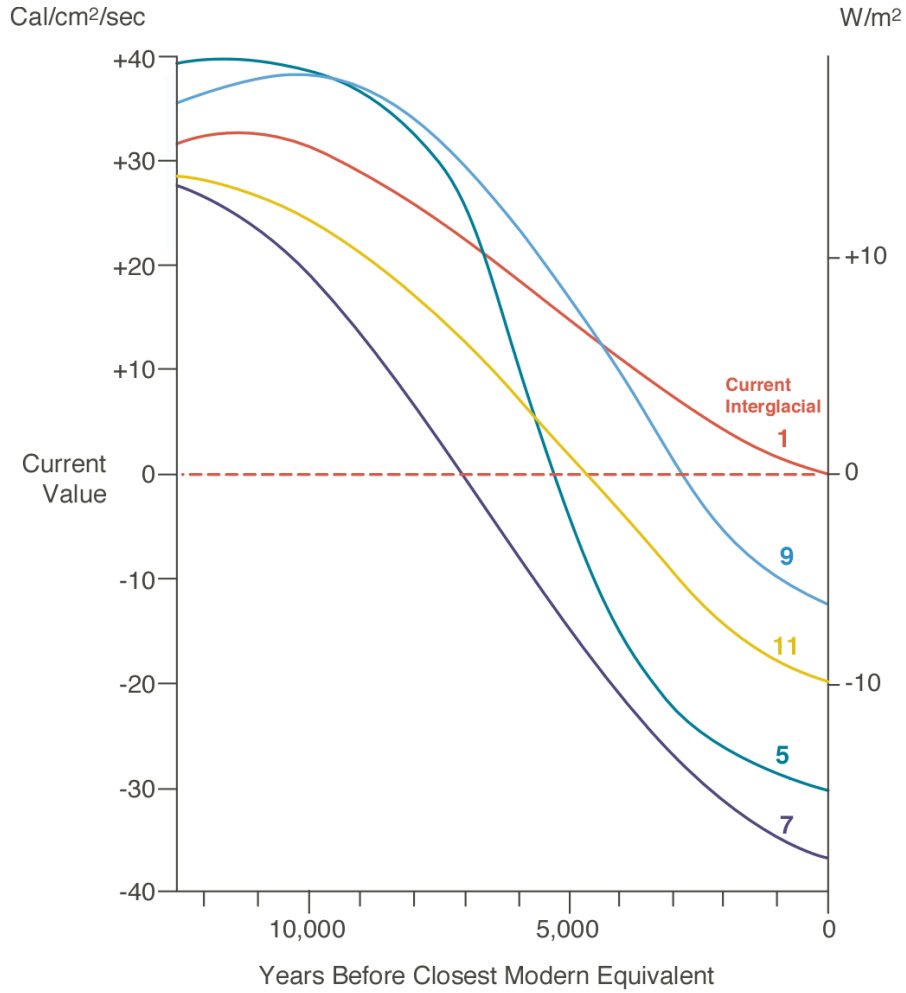
Bill Ruddiman



*Nature*, February 12, 2004

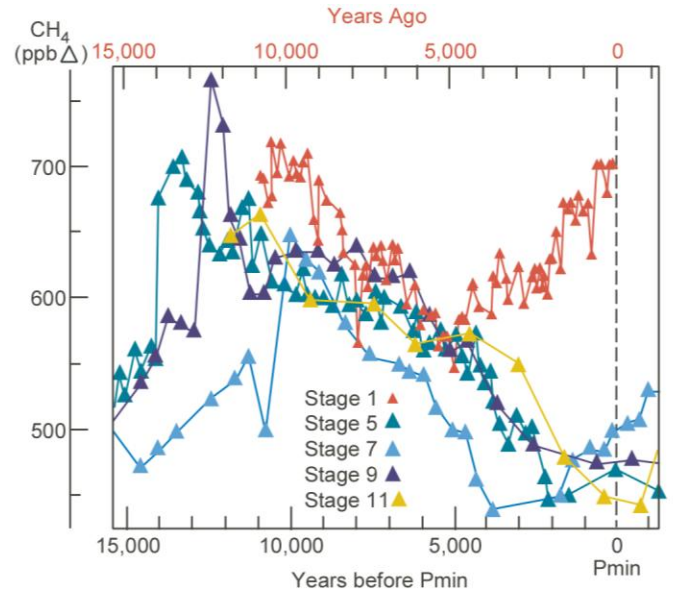
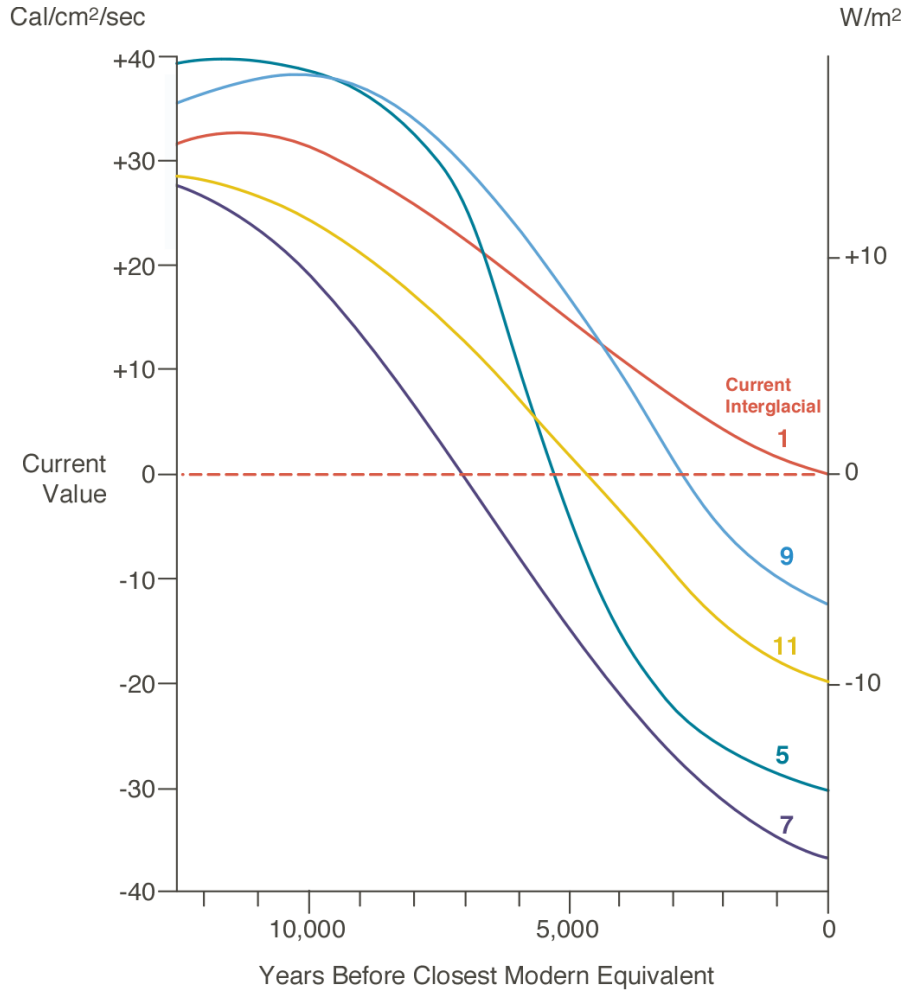
Deforestation -----> Increased atmospheric CO<sub>2</sub> (8,000 years ago)  
Rice Cultivation -----> Increased atmospheric CH<sub>4</sub> (5,000 years ago)

# Insolation Trends

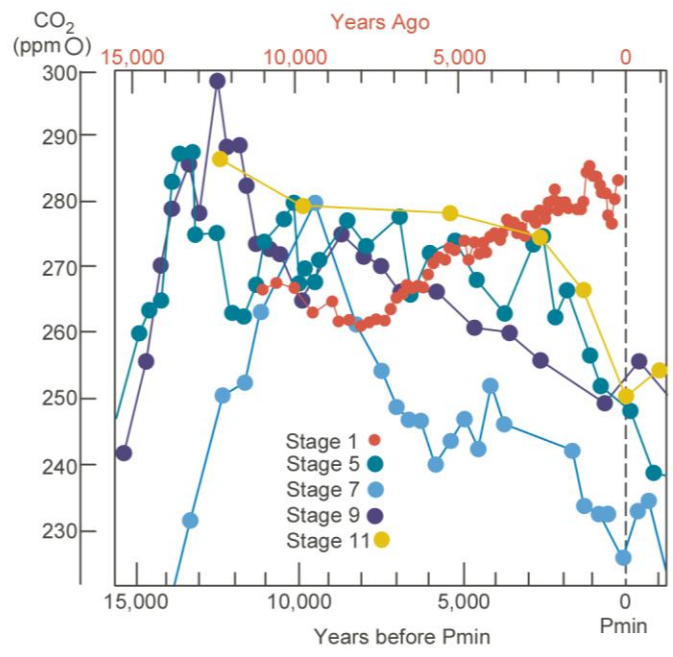




# Insolation Trends



$\text{CH}_4$



$\text{CO}_2$

# Spread of Agriculture

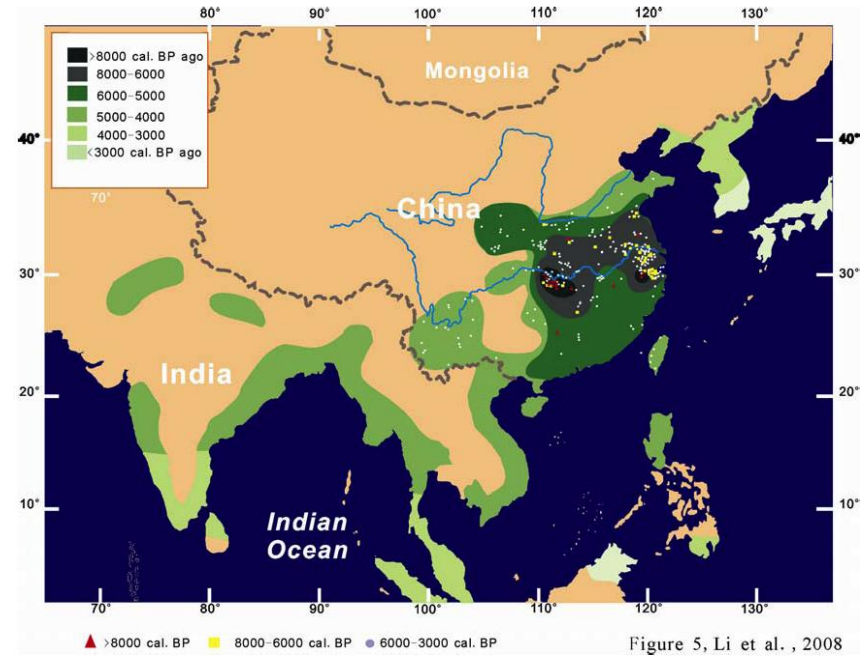
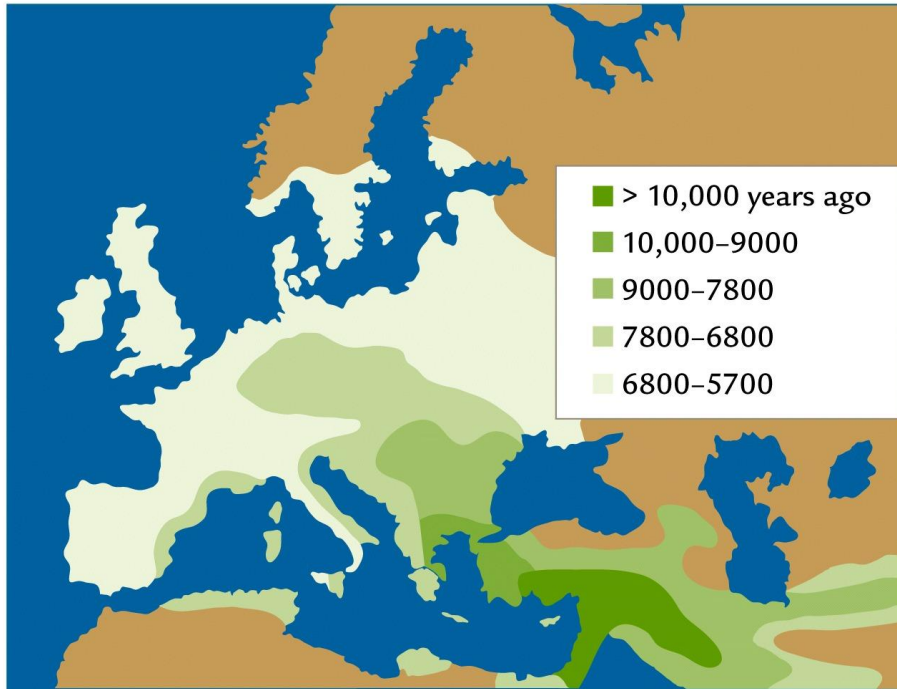


Figure 5, Li et al. , 2008

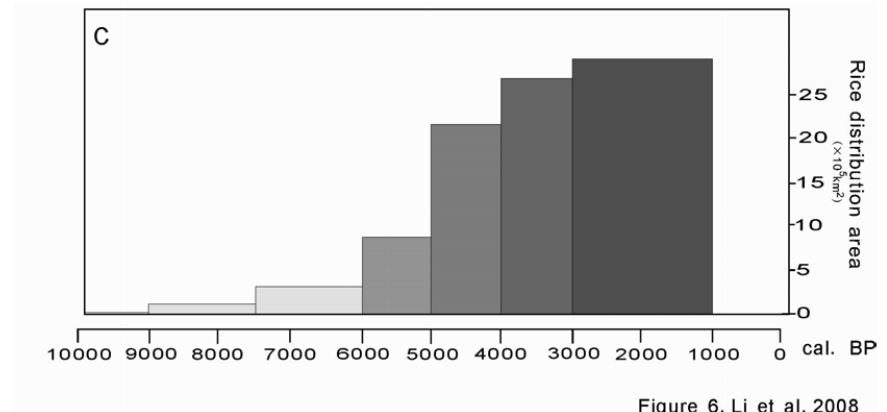
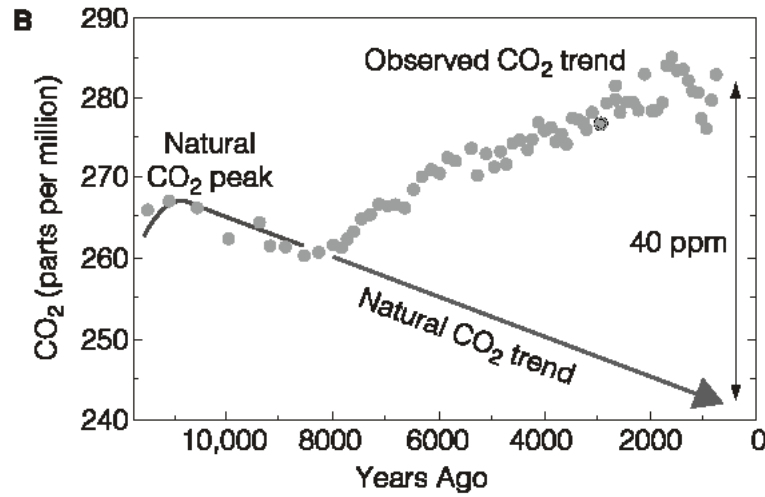
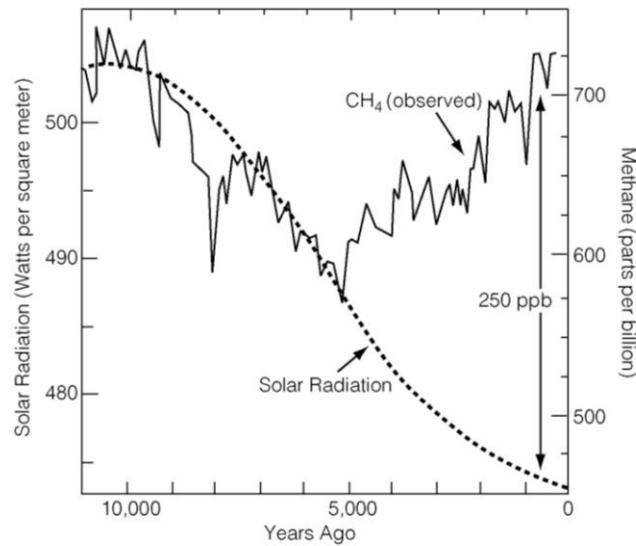


Figure 6, Li et al. 2008



280 ppm pre-industrial CO<sub>2</sub>

240 ppm CO<sub>2</sub> naturally



700 ppb pre-industrial CH<sub>4</sub>

450 ppb CH<sub>4</sub> naturally

ANTHROPOGENIC  
EMISSIONS

~10 ppm CO<sub>2</sub>  
~200 ppb CH<sub>4</sub>



EFFECTS ON CLIMATE SYSTEM

Warmer  
Holocene  
Climate

Warmer  
Deep Ocean



CO<sub>2</sub> FEEDBACKS

Additional  
CO<sub>2</sub>

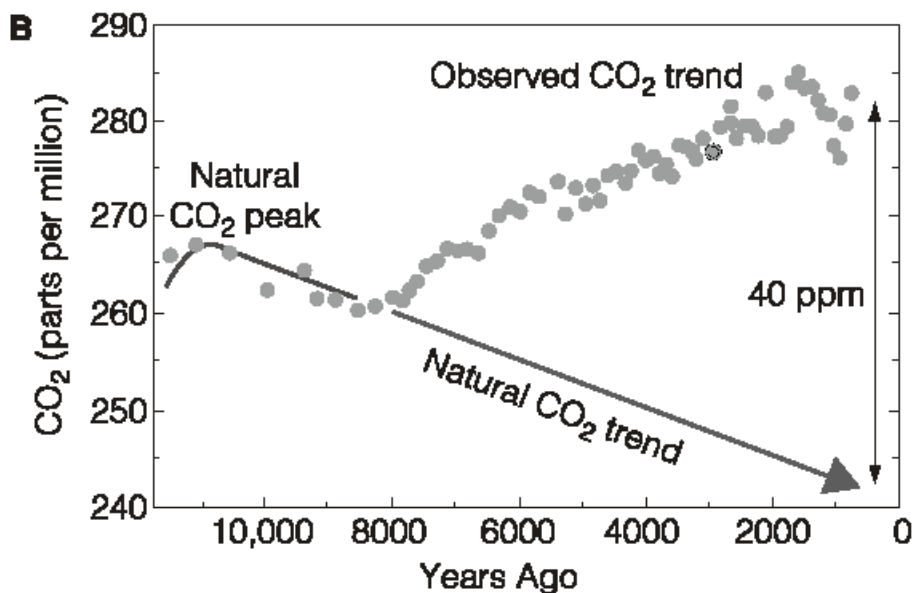
Warmer  
Southern Ocean  
(Sea ice,  
stratification,  
westerlies axis)



Additional  
CO<sub>2</sub>



# Difference Between Natural and Pre-Industrial CO<sub>2</sub>



~25%: direct agricultural carbon emissions  
(land clearance)

~25%: reduced ocean CO<sub>2</sub> solubility  
(warmer ocean)

~50%: enhanced S. Ocean CO<sub>2</sub> outgassing  
(sea ice, winds, stratification)

# Testing Hypothesis with 3 Climate Model Simulations

## T42 Resolution

1. CAM3: Atmosphere/Mixed-Layer Ocean (CAM3+MLO): “NOANTHRO”
2. CAM3 + Interactive Vegetation (CAM3+MLO+VEG): “NOANTHRO\_VEG”
3. CCSM3: Fully Coupled (includes deep ocean but fixed vegetation)

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Modern Control: Recent Greenhouse Gases (355 ppm CO<sub>2</sub>, 1700 CH<sub>4</sub>)

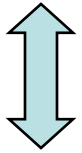
LOWGHG: “Natural” Present-Day Gases (240 ppm CO<sub>2</sub>, 450 ppb CH<sub>4</sub>)

Pre-Industrial: Pre-industrial Gases (280 ppm CO<sub>2</sub>, 700 ppb CH<sub>4</sub>)

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Total anthropogenic influence (industrialization, early farming)

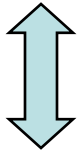
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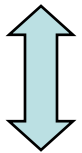
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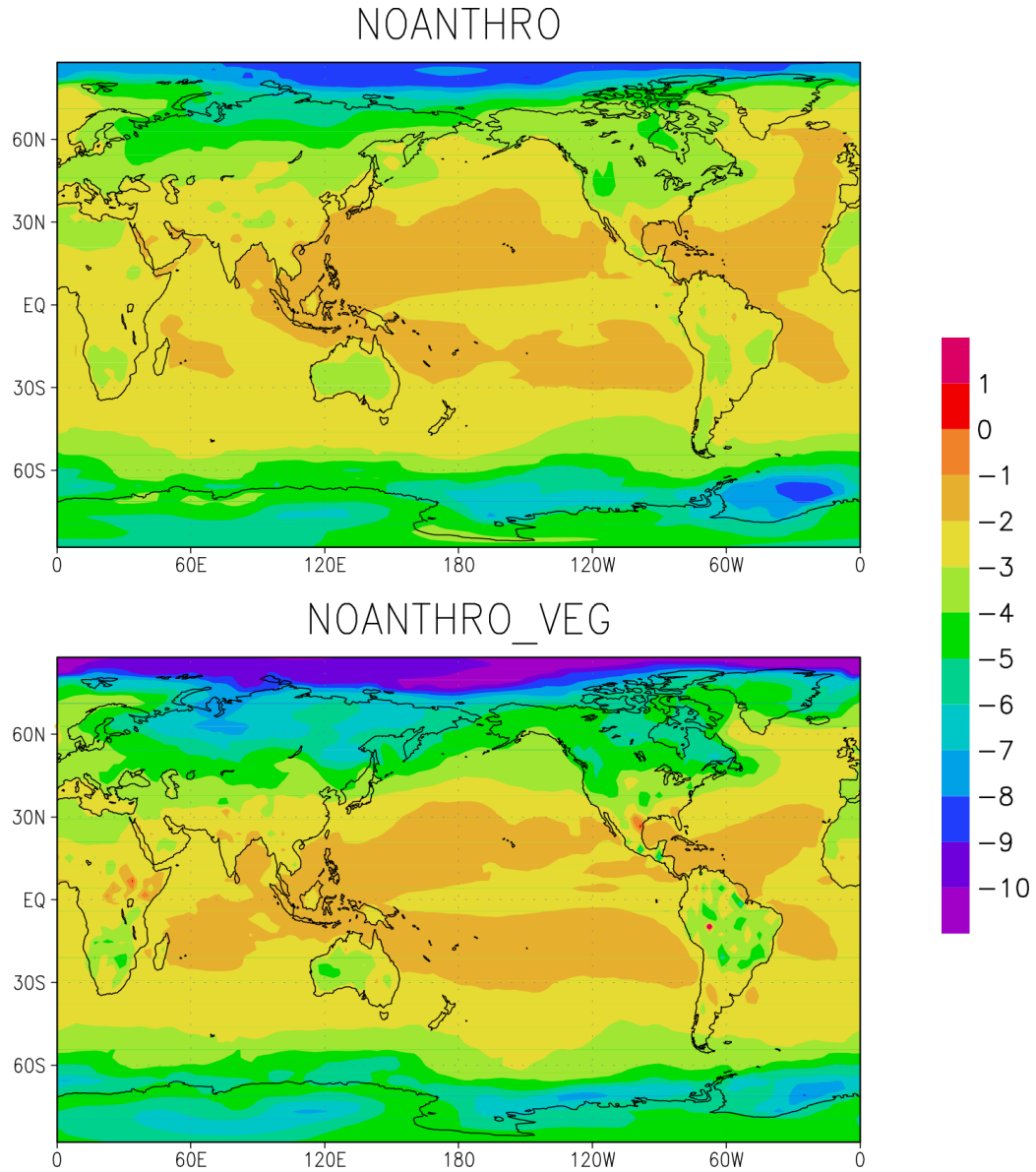


Anthropogenic influence of early farming only

Pre-Industrial: Pre-industrial Gases (280 ppm CO<sub>2</sub>, 700 ppb CH<sub>4</sub>)



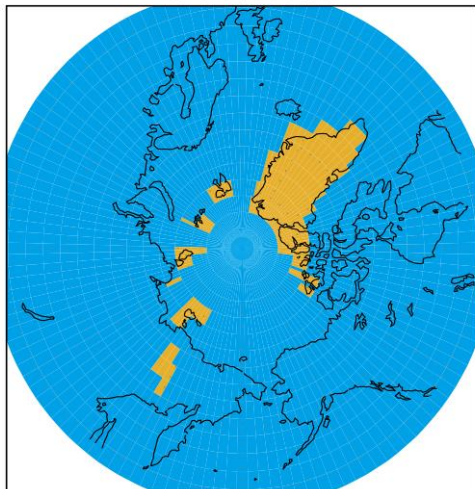
# Temperature Change under “Natural” GHG Forcing



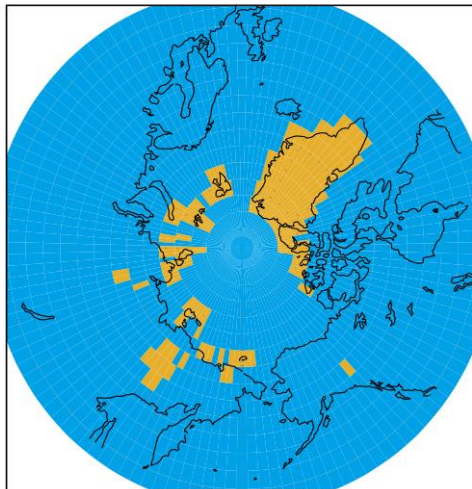
2.75-3.0°C Global Cooling

# Permanent Snow Cover

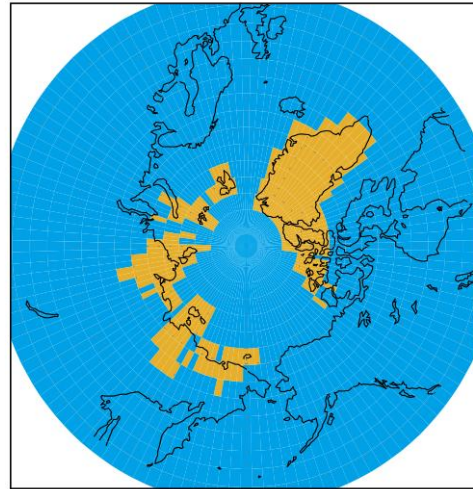
CONTROL



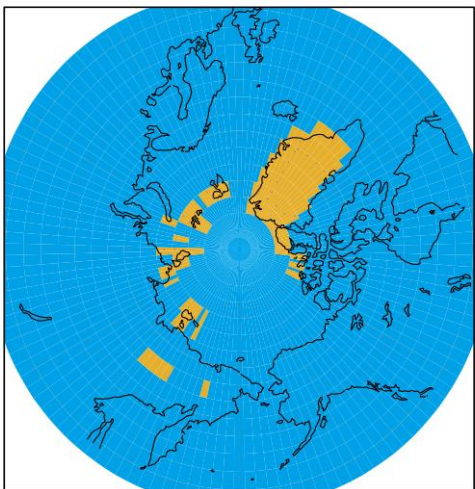
PREIND



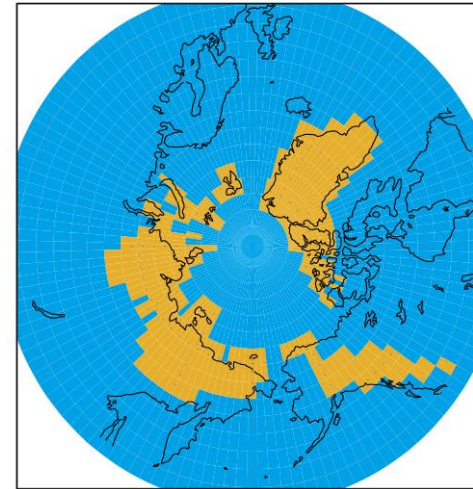
NOANTHRO



CONTROL\_VEG

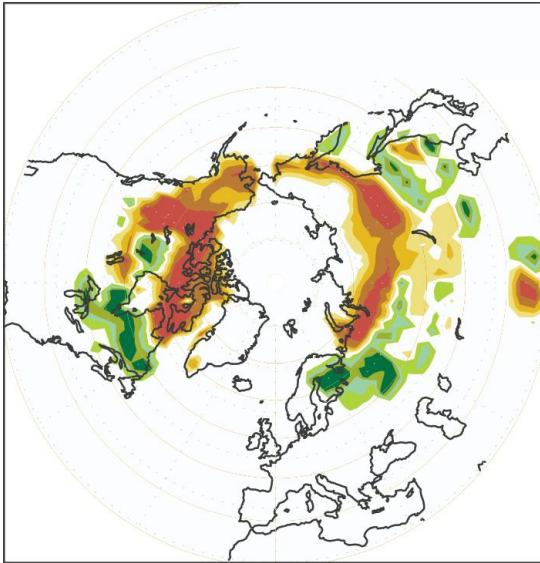


NOANTHRO\_VEG

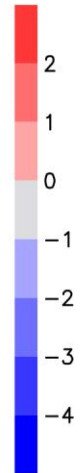
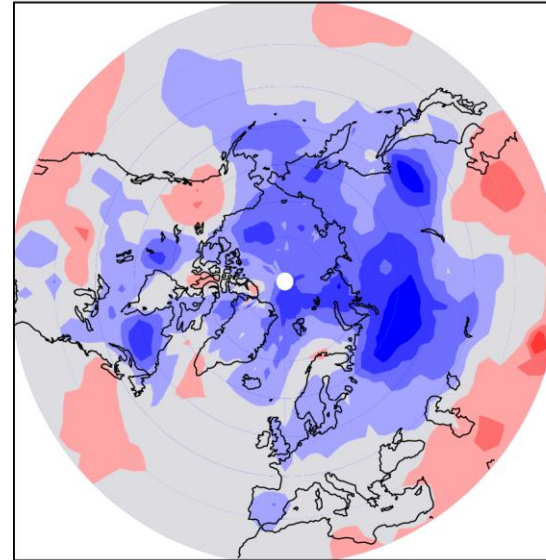


# Vegetation Feedbacks

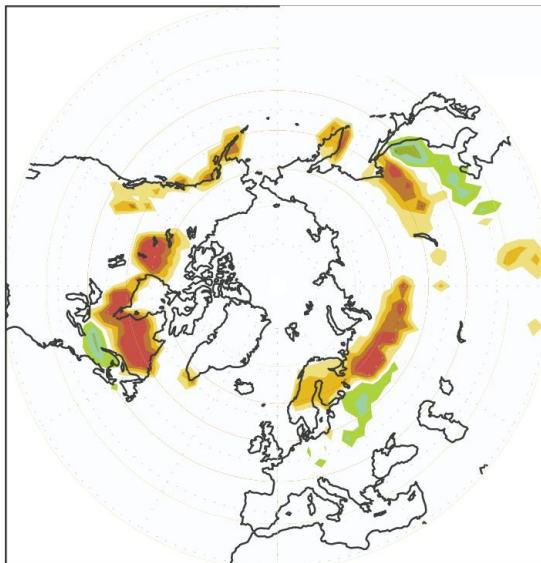
Change in Tundra (%)



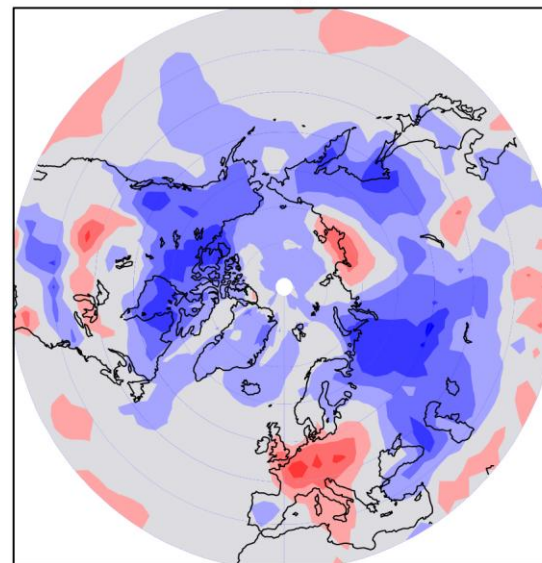
MAM TS NOANTHRO\_VEG-NOANTHRO



Change in Boreal Forest (%)



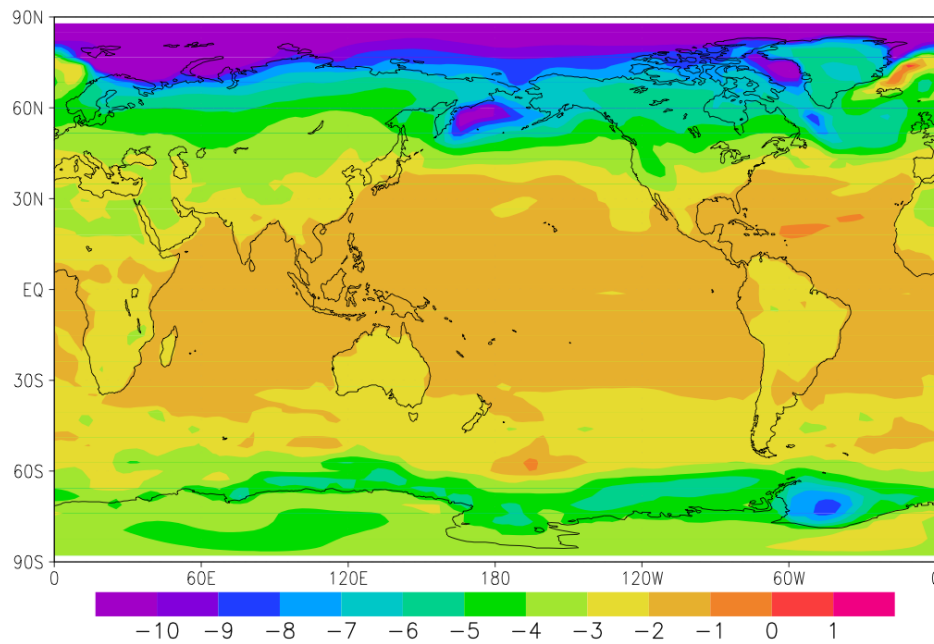
JJA TS NOANTHRO\_VEG-NOANTHRO





# Annual Temperature Change

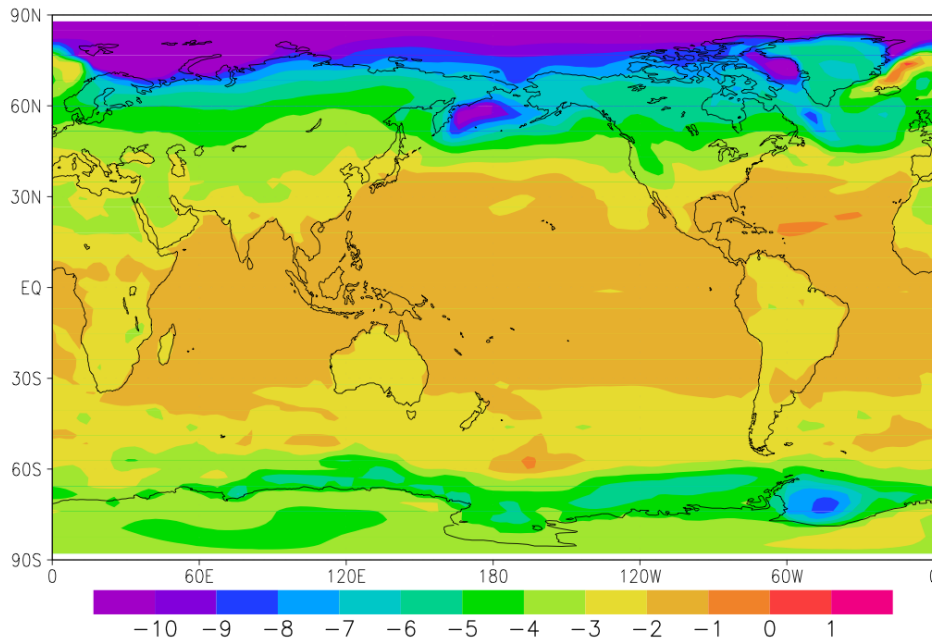
Fully Coupled CCSM3



2.8°C Global Cooling

# Annual Temperature Change

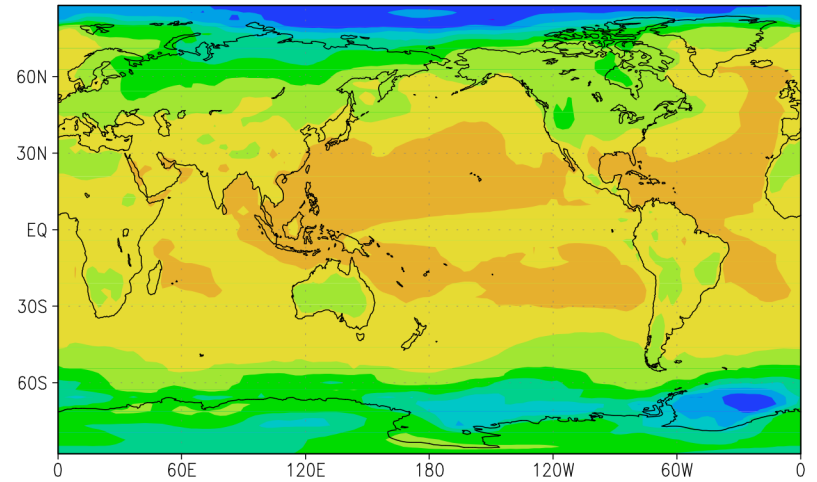
Fully Coupled CCSM3



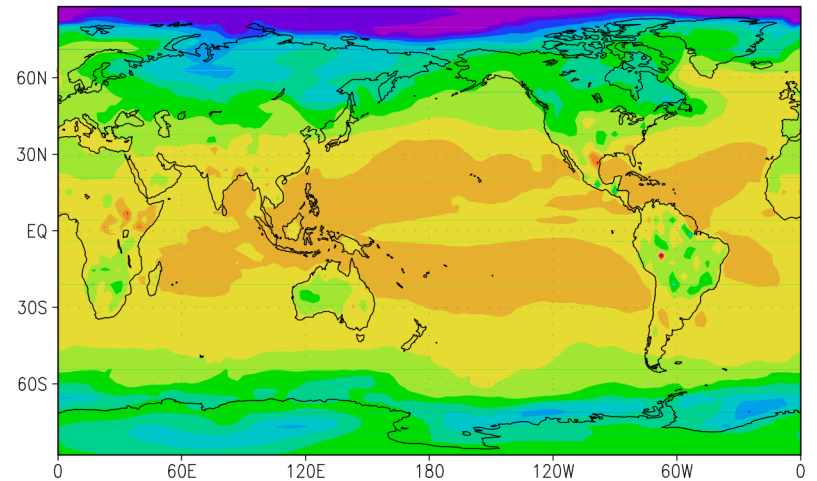
2.8°C Global Cooling

CAM3-SOM

NOANTHRO



NOANTHRO\_VEG



2.75-3.0°C Global Cooling



# Permanent Snow Cover

Fully Coupled CCSM3

CONTROL

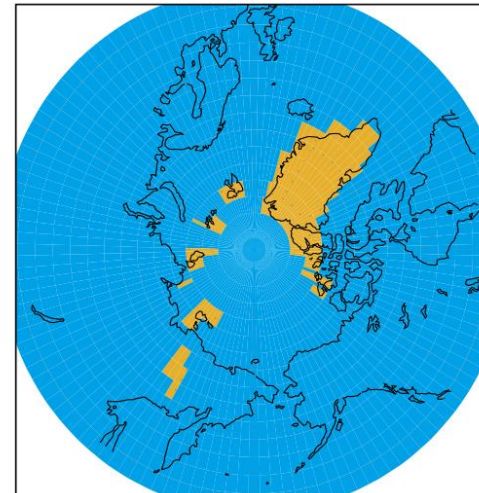


LOWGHG

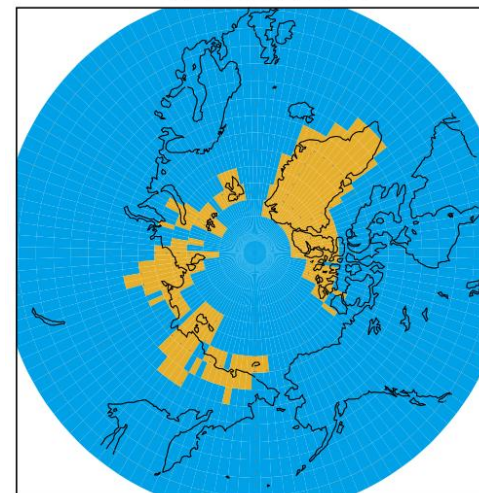


CAM3-SOM

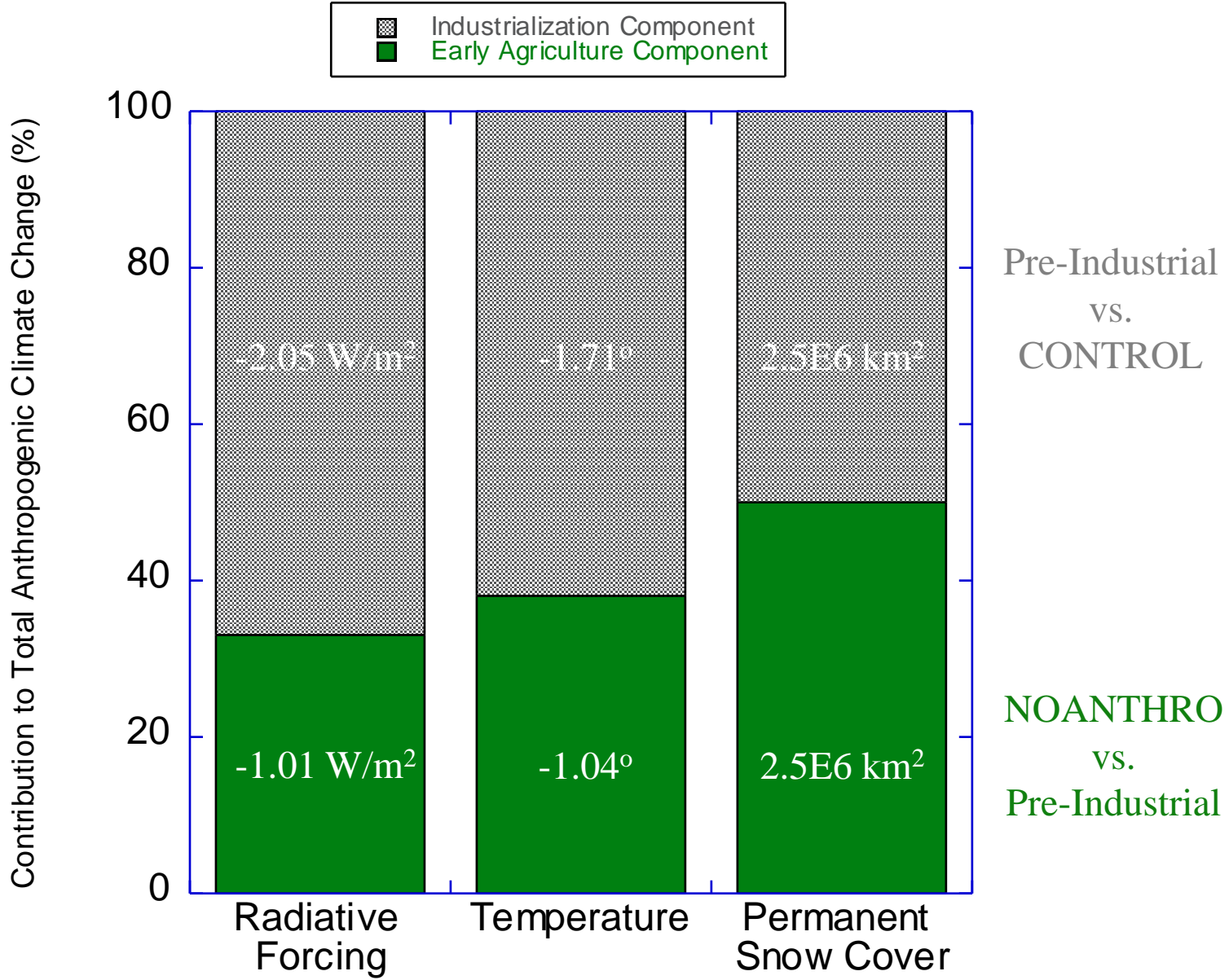
CONTROL



NOANTHRO



NOANTHRO  
Minus  
CONTROL



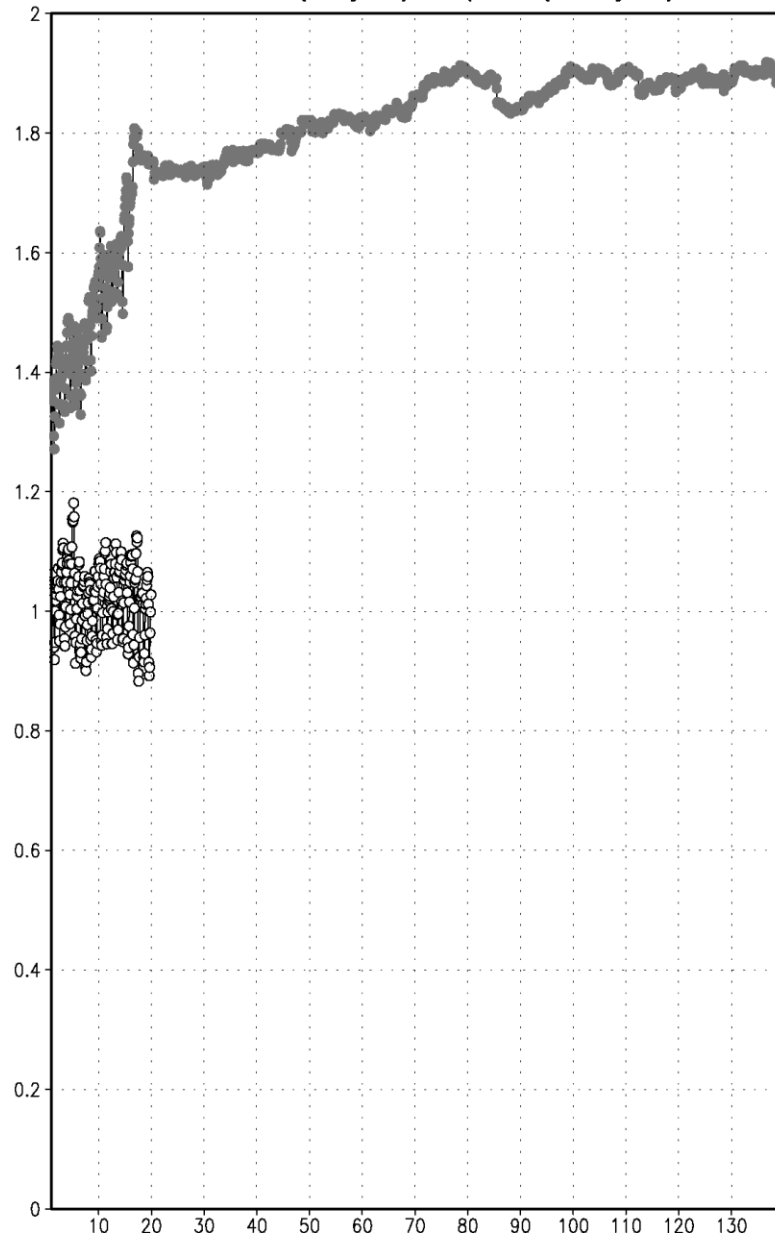
# Conclusions

- Ruddiman's early anthropogenic hypothesis is outrageous
- Holocene GHG trends are very unusual compared with recent interglacials
- Model evidence suggests a climate nearly 3°C cooler than present in the absence of ancient agriculture and modern industrialization
- About 40% of the total artificial anthropogenic warming is early agricultural
- Improved physics (interactive veg and dynamical ocean) enhances response

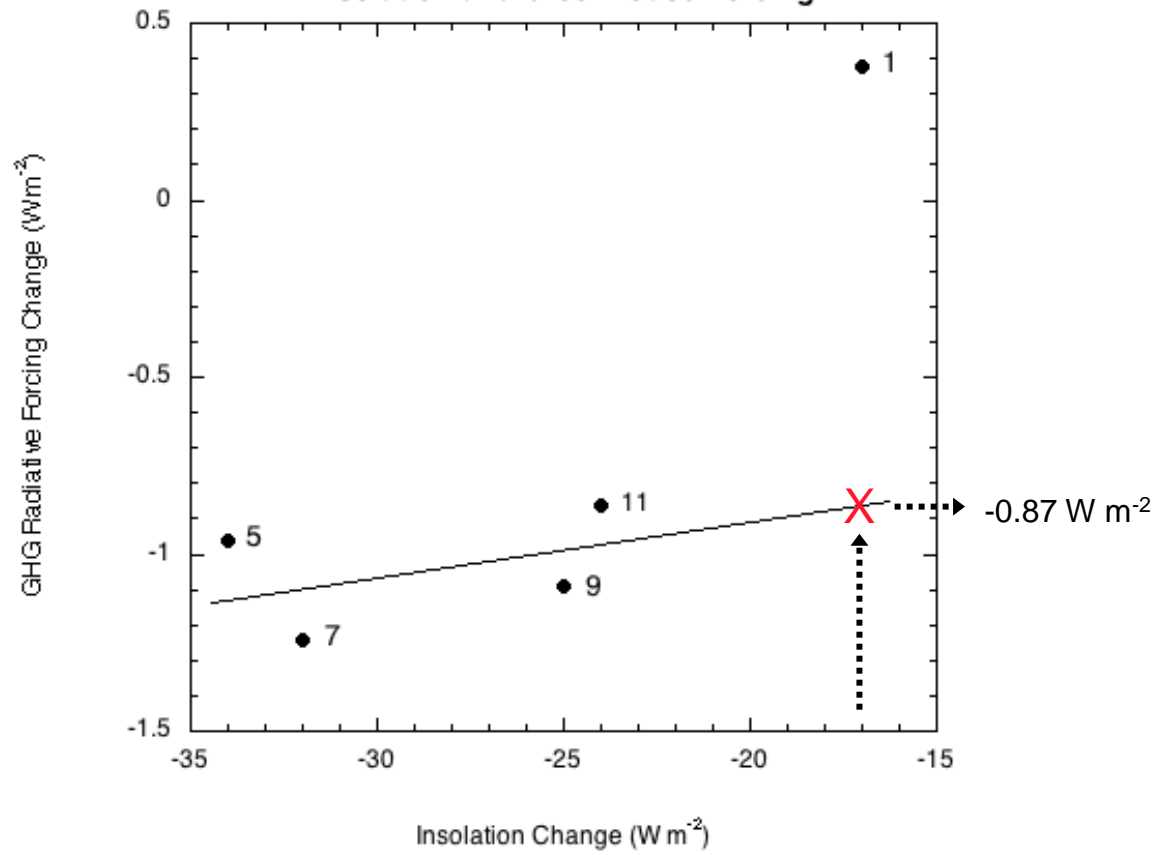
Future work: 1. Higher resolution runs (T85), 2. Plant CO<sub>2</sub> physiology,  
3. Coupled carbon cycle in CCSM4

Special session at AGU Fall Meeting

Snow Depth (m) Ellesmere Is. (77N,76W)  
Control (19yrs), Spin1(139yrs)



**Amplitude of Interglacial Variations in  
Insolation and Greenhouse Forcing**





# EMIC Simulation of Eemian and Holocene

