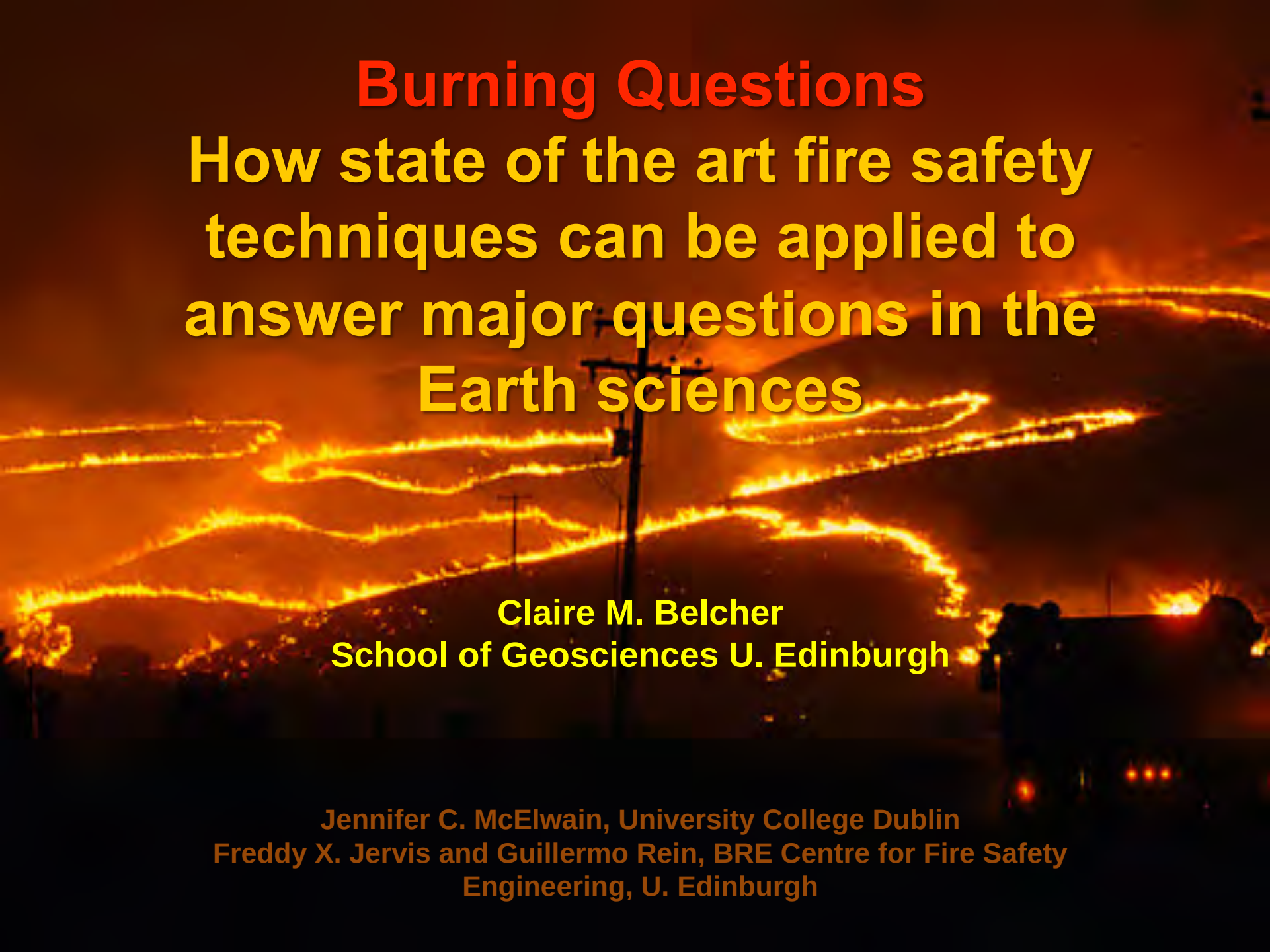


Burning Questions

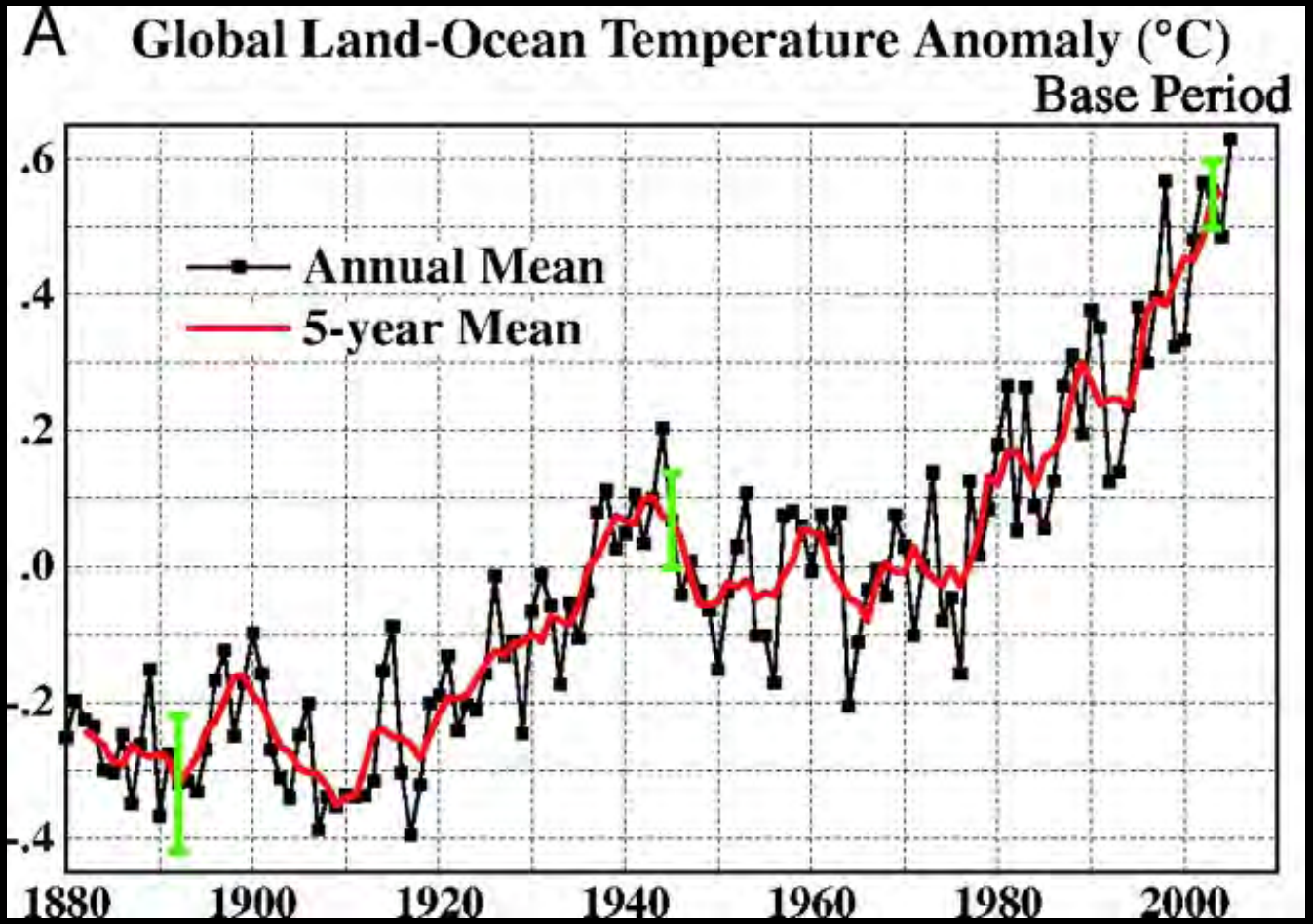
How state of the art fire safety techniques can be applied to answer major questions in the Earth sciences

Claire M. Belcher
School of Geosciences U. Edinburgh

Jennifer C. McElwain, University College Dublin
Freddy X. Jervis and Guillermo Rein, BRE Centre for Fire Safety Engineering, U. Edinburgh

Most significant question being asked of the Earth sciences = How will global warming impact upon our planet?

Global Warming
the Evidence



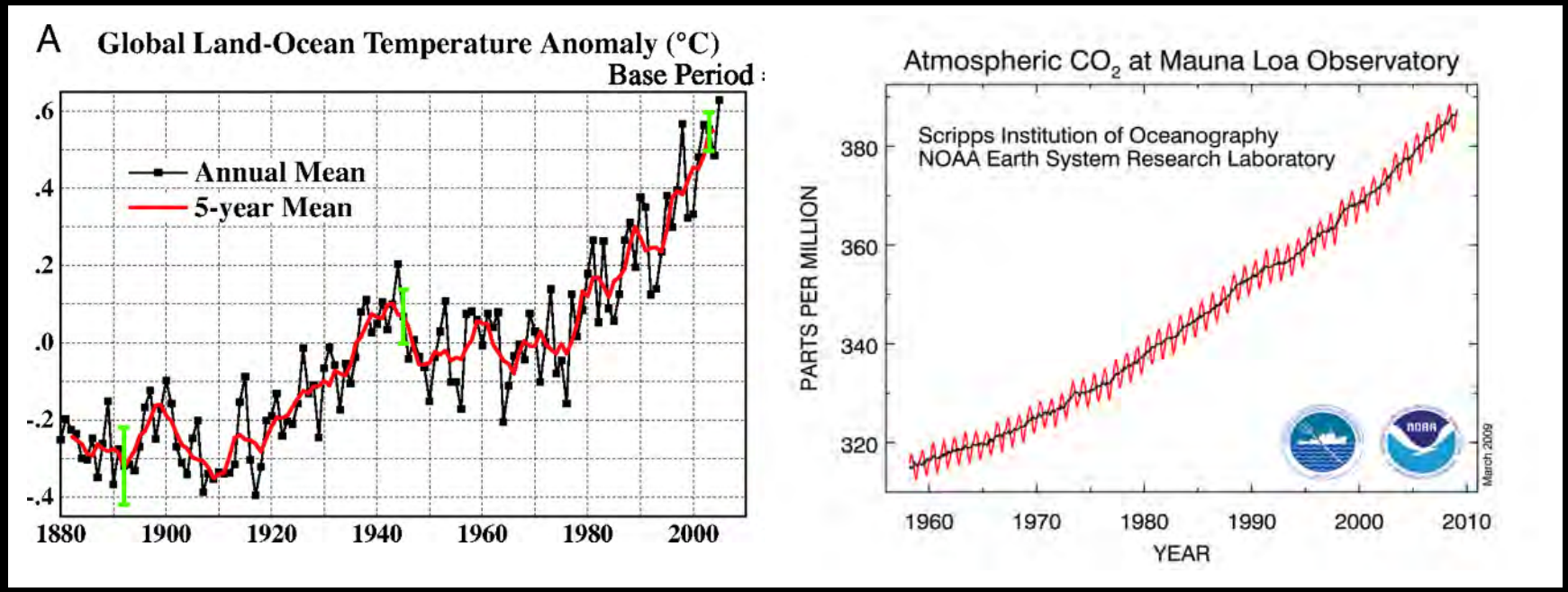
Hansen et al. 2006. PNAS 103.

Global surface temperatures have increased by ~ 0.2ºC per decade over the past 30 years

Global warming is now 0.6°C in the past three decades and 0.8°C in the past century

Carbon Dioxide – The Evidence

Carbon Dioxide vs. Temperature Records

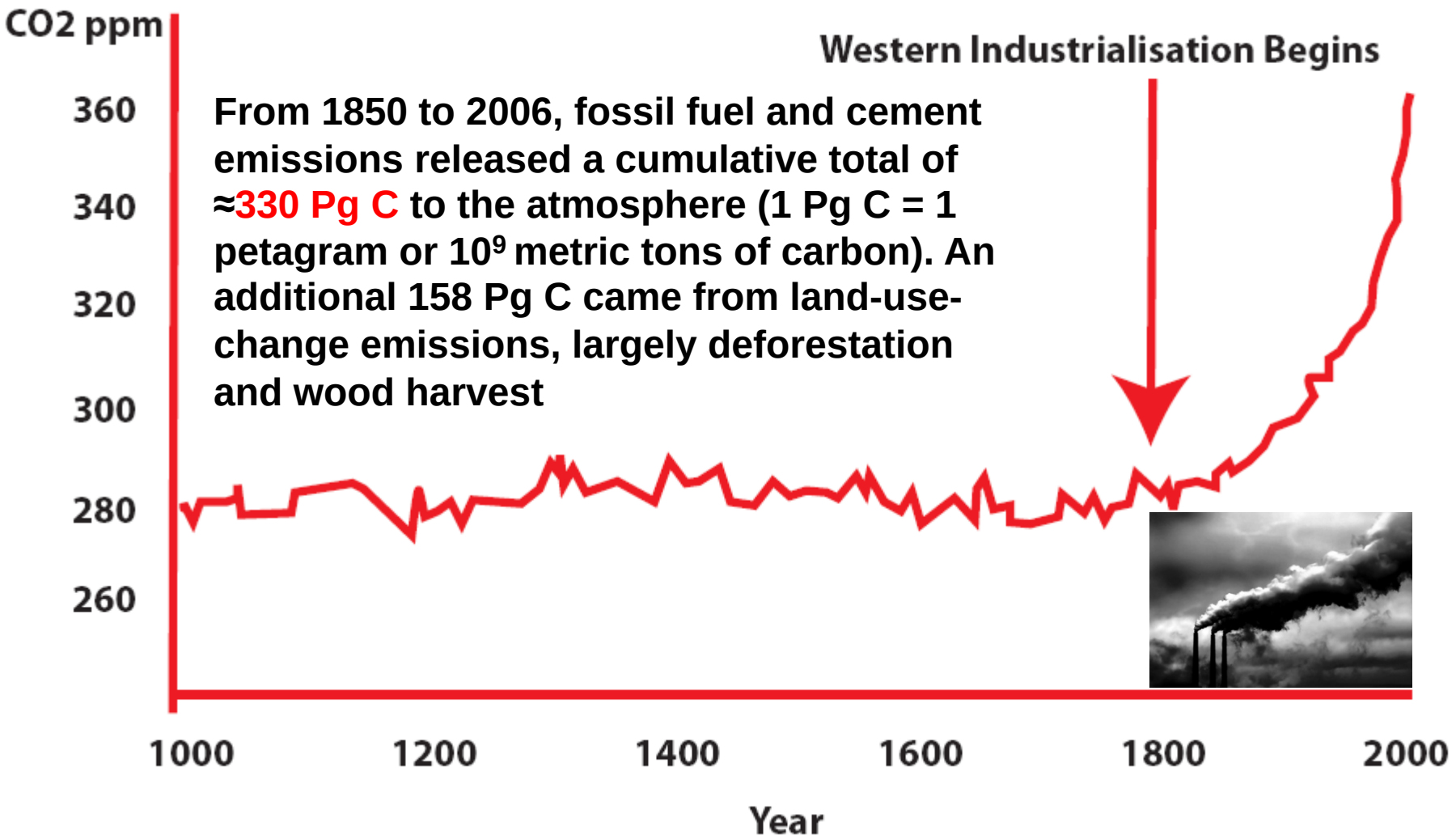


Modified from Hansen et al. 2006, PNAS 103

Surface temperature anomalies relative to 1951–1980 from surface air measurements at meteorological stations and ship and satellite SST measurements compared to carbon dioxide as measured at the Mauna Loa Observatory

Anthropogenic Forcing

Largest Contribution is Carbon Dioxide



Redrawn from IPCC 2003

How does this relate to Fire?

Models predict global warming will cause:

1) 44% increase in forest fires annually in the U.S

2) 61% increase in Canada

3) Prolonged fire seasons in boreal, temperate and Mediterranean regions

Why should we care about forest fire activity?

Risk to Human Life

- Indonesian 1997-98 : huge forest fires due climate-change induced drought.

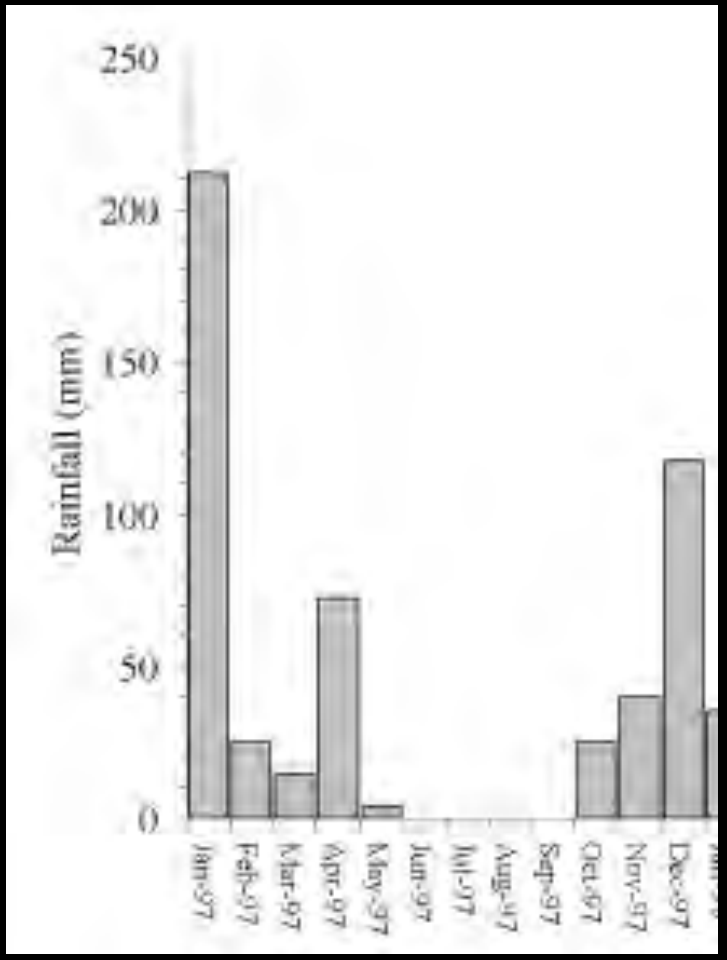
  Cost = $9.3 billion
  $1 billion - adverse health effects of smoke-haze.

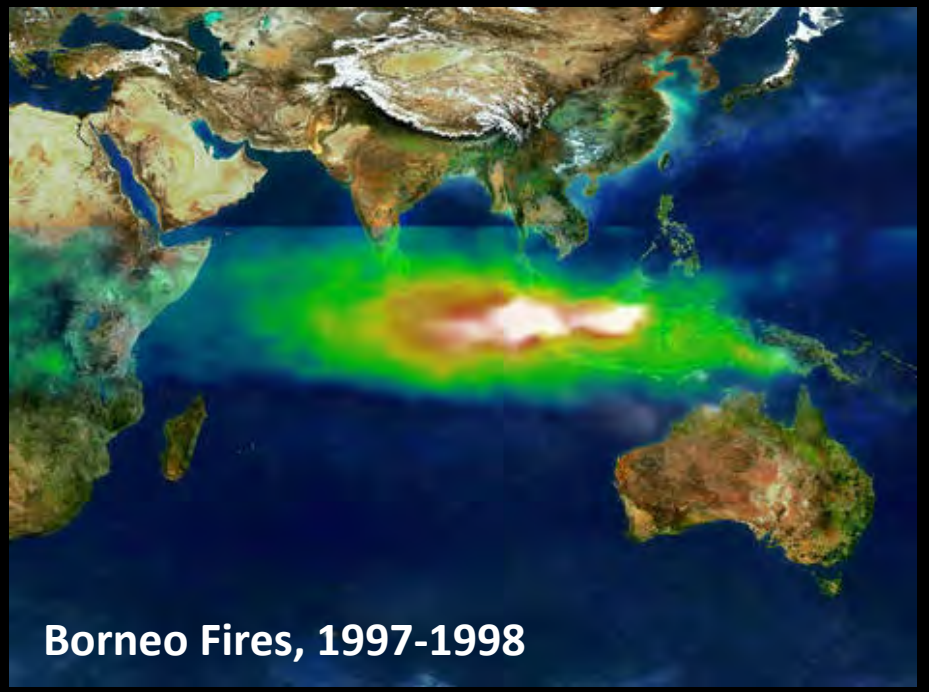
- Same time fires in Latin America - $15 billion

- Australian 2009: fires burned 4500km^2, destroyed 2030 houses, 3500+ structures, displaced 7562 people and killed 173.

  Cost =$1.5 billion's in claims to general insurance industry.

- All these fires are believed to be in part driven by global-warming and highlight our limited understanding of fire, and call into question our capacity for fire control.





Wooster and Strub, 2002, *Global Biogeochem. cycles*, 16

- **Contributed up to 2.8Pg C to the atmosphere**
- **Wildfires accounted for 2/3rds of the variability in the CO_2 growth rate between 1997 and 2001**
- **Wildfires typically contribute 50% as much CO_2 to the atmosphere as fossil fuel combustion**

Fires are a source of CO_2 = Positive feedbacks on global warming

Fire Activity

Global Warming

CO_2

Global Warming May Impact Upon Fire Activity Two Ways

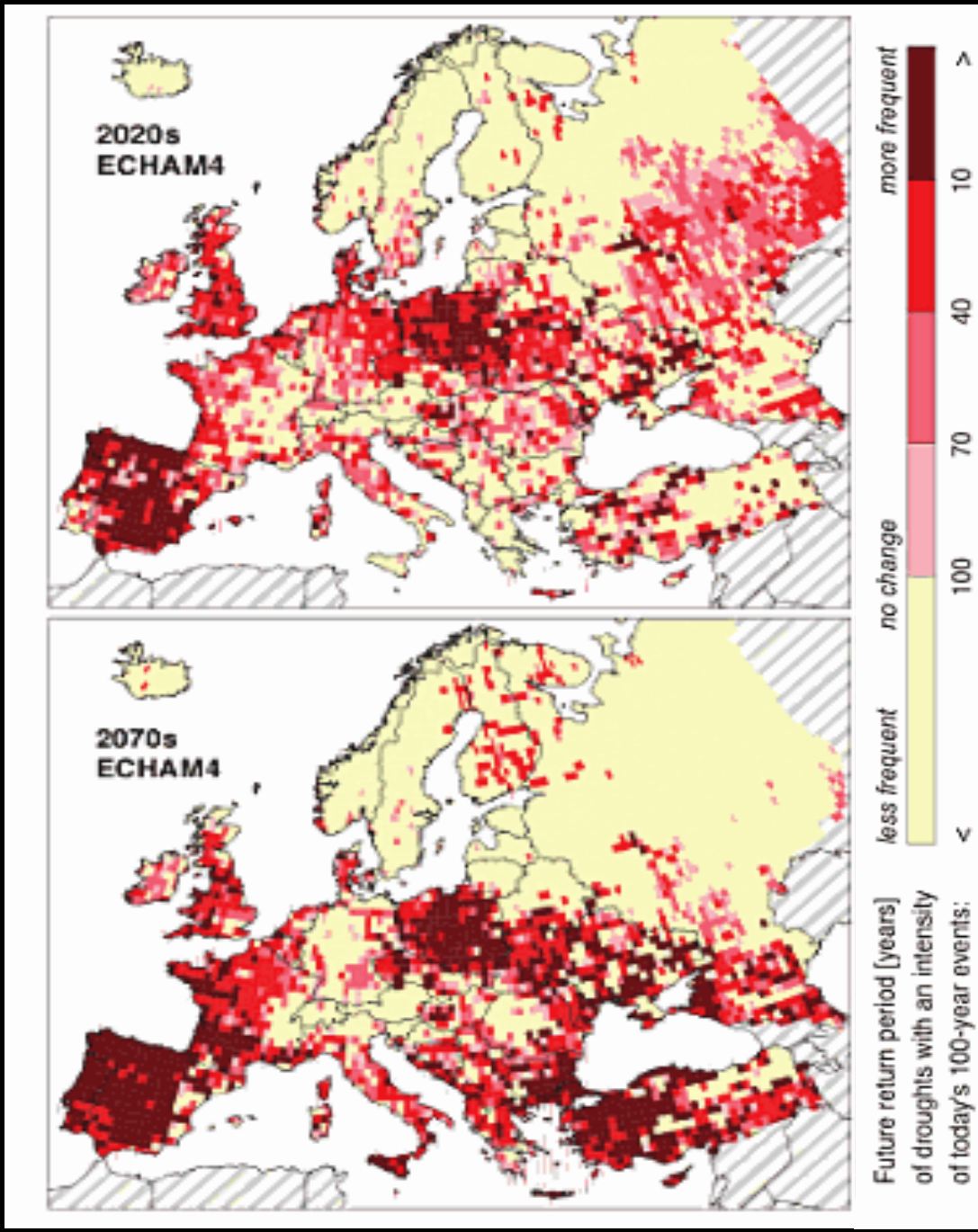
1)By influencing weather patterns and altering the climate in different continents

2)By influencing vegetation – the fuel available for fires

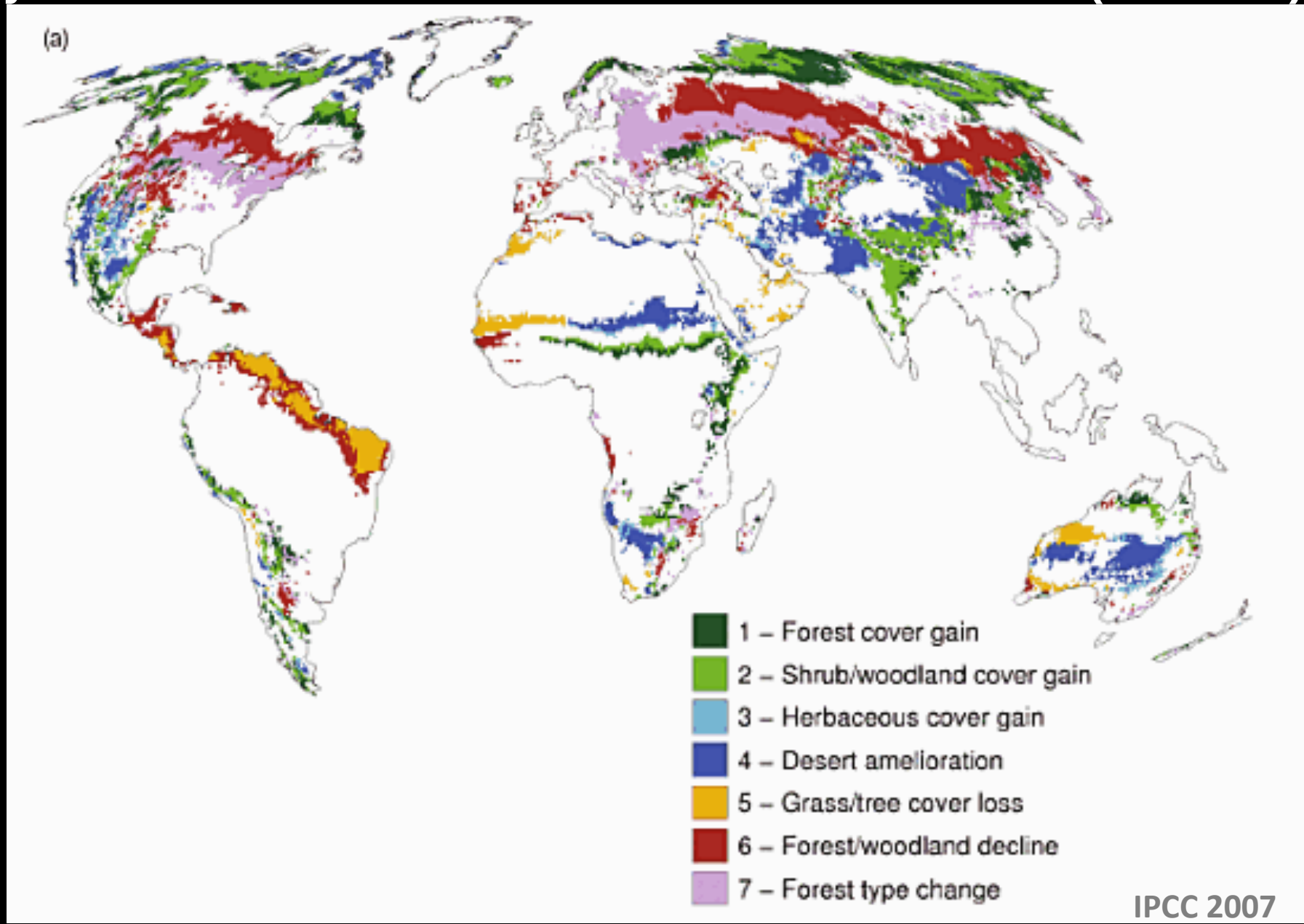
1) Weather and Climate Patterns

Drought intensity estimates for 2020 and 2070

IPCC 2007



2) Vegetation - Projected changes in terrestrial ecosystems by 2100 relative to 2000 based on a climate model (HadCM3)



We can think about fire on two timescales

1)Modern day timescales

i.e. Influence of seasonal variations in vegetation and weather etc.

Much work done on - flammability of individual ecosystems over daily and seasonal timescales

2) Long term multi-million year timescales

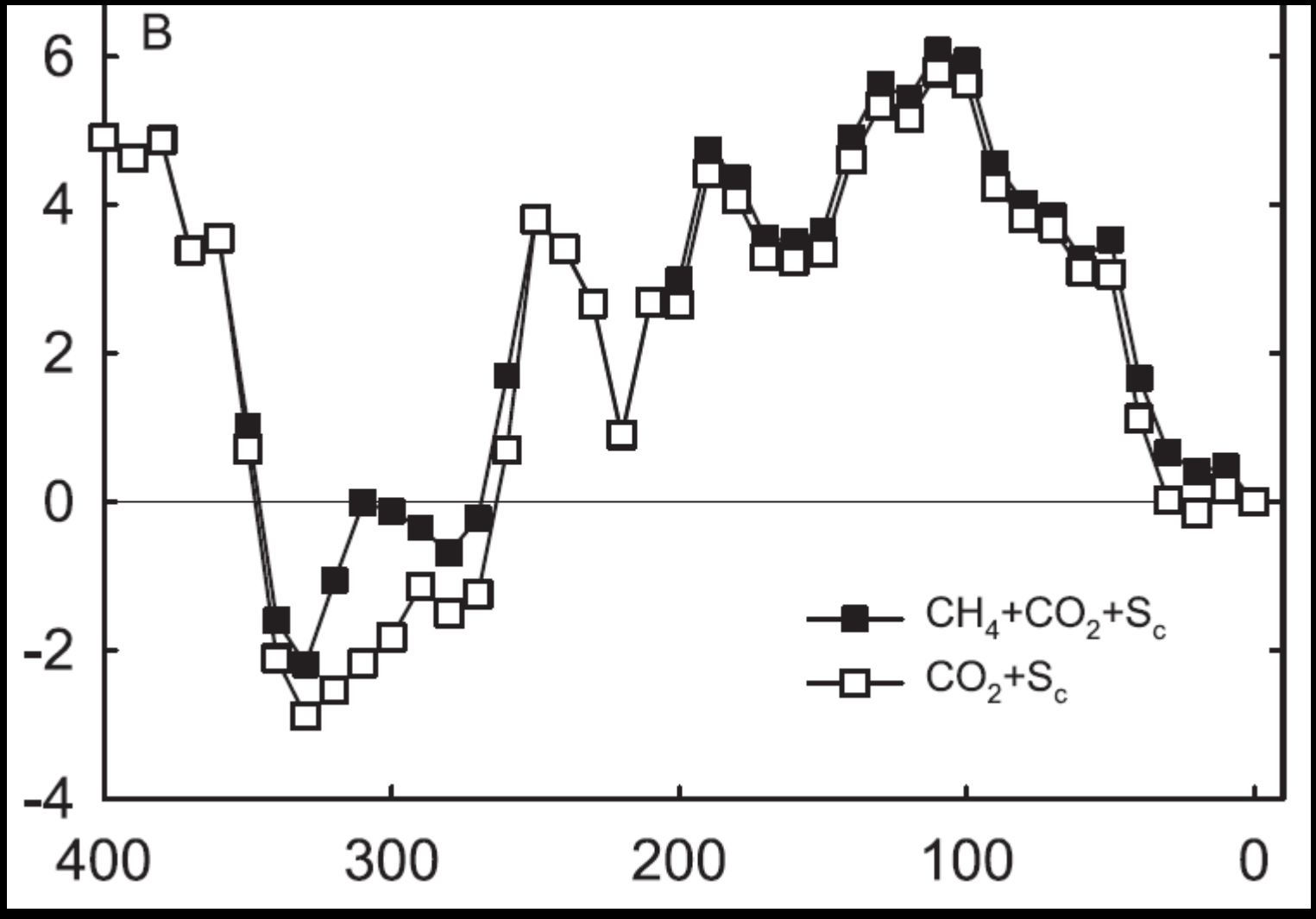
Limited work and understanding of Earth's ancient flammability and how it has varied in response to climate change

My interest =

Have past global warming events altered vegetation composition and if so how has this impacted upon the flammability of our planet?

Have there been major changes in global temperature throughout Earth's history?

Estimated Changes in Global Temperature for the Past 400 Million Years of Earth History

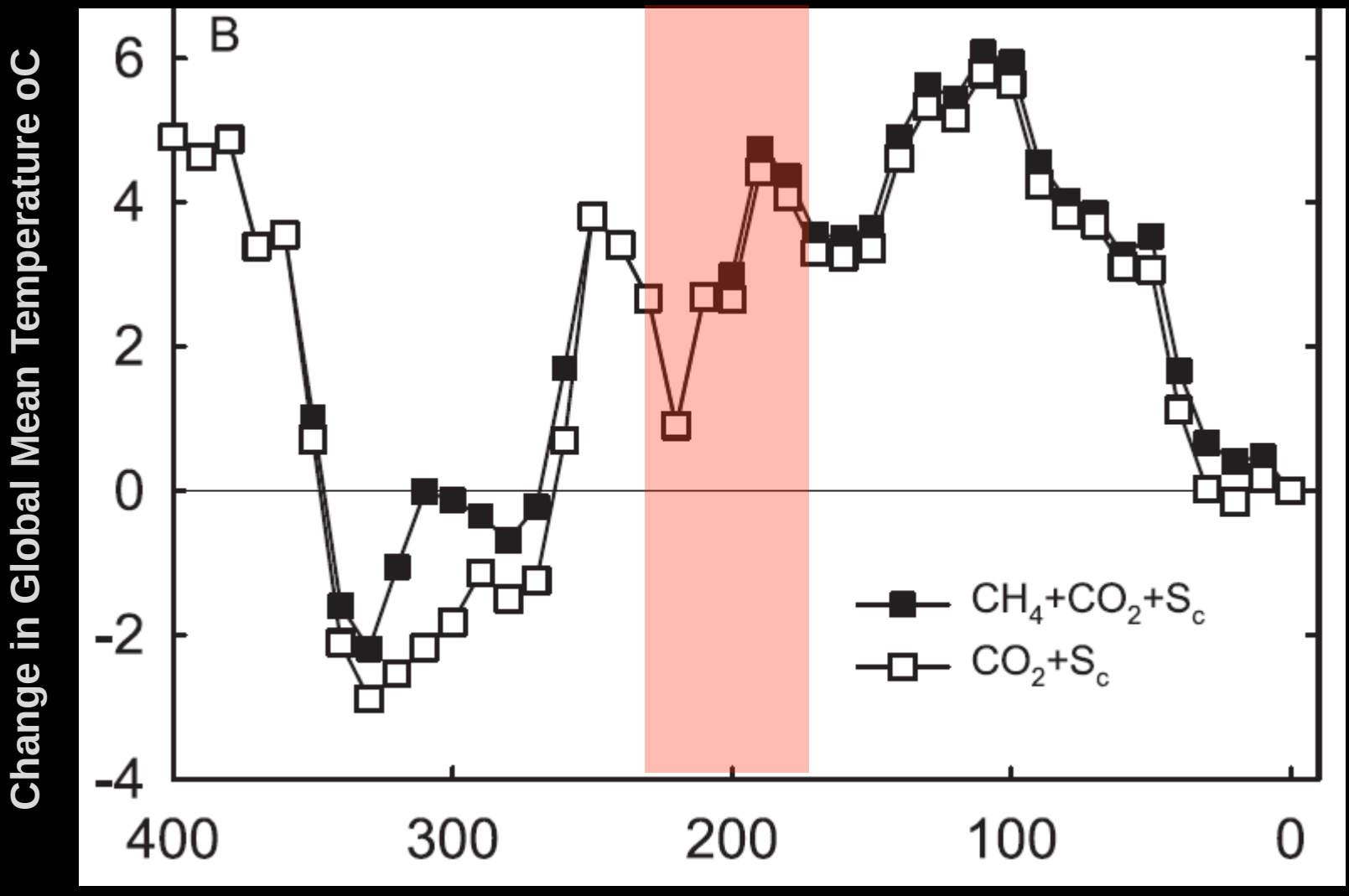


Beerling et al., 2009. J. Am. Sci. 309.

Have there been major changes in global temperature throughout Earth's history?

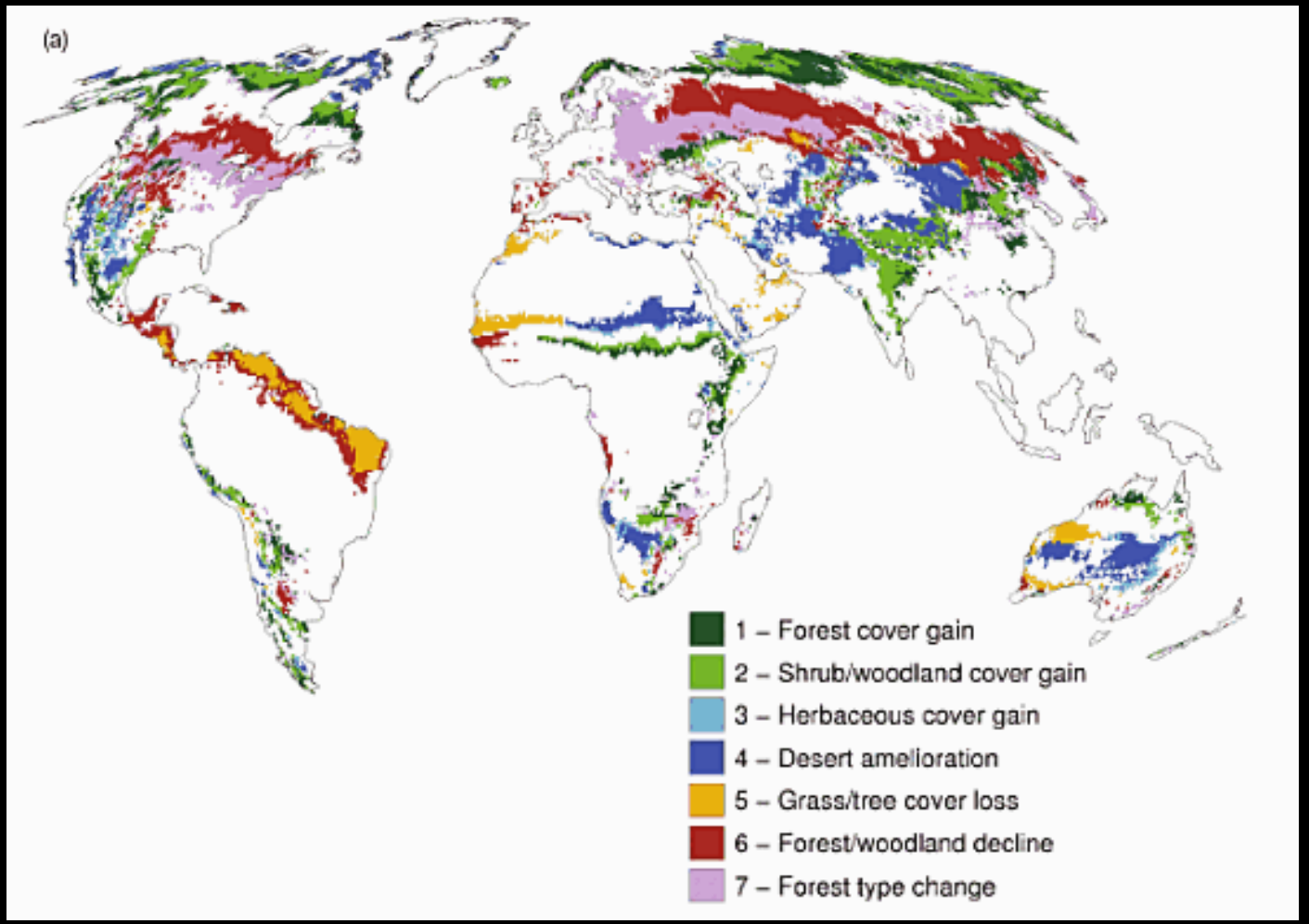
YES

The Triassic-Jurassic Boundary Global Warming Event – 200 Million Years Ago



Beerling et al., 2009. J. Am. Sci. 309.

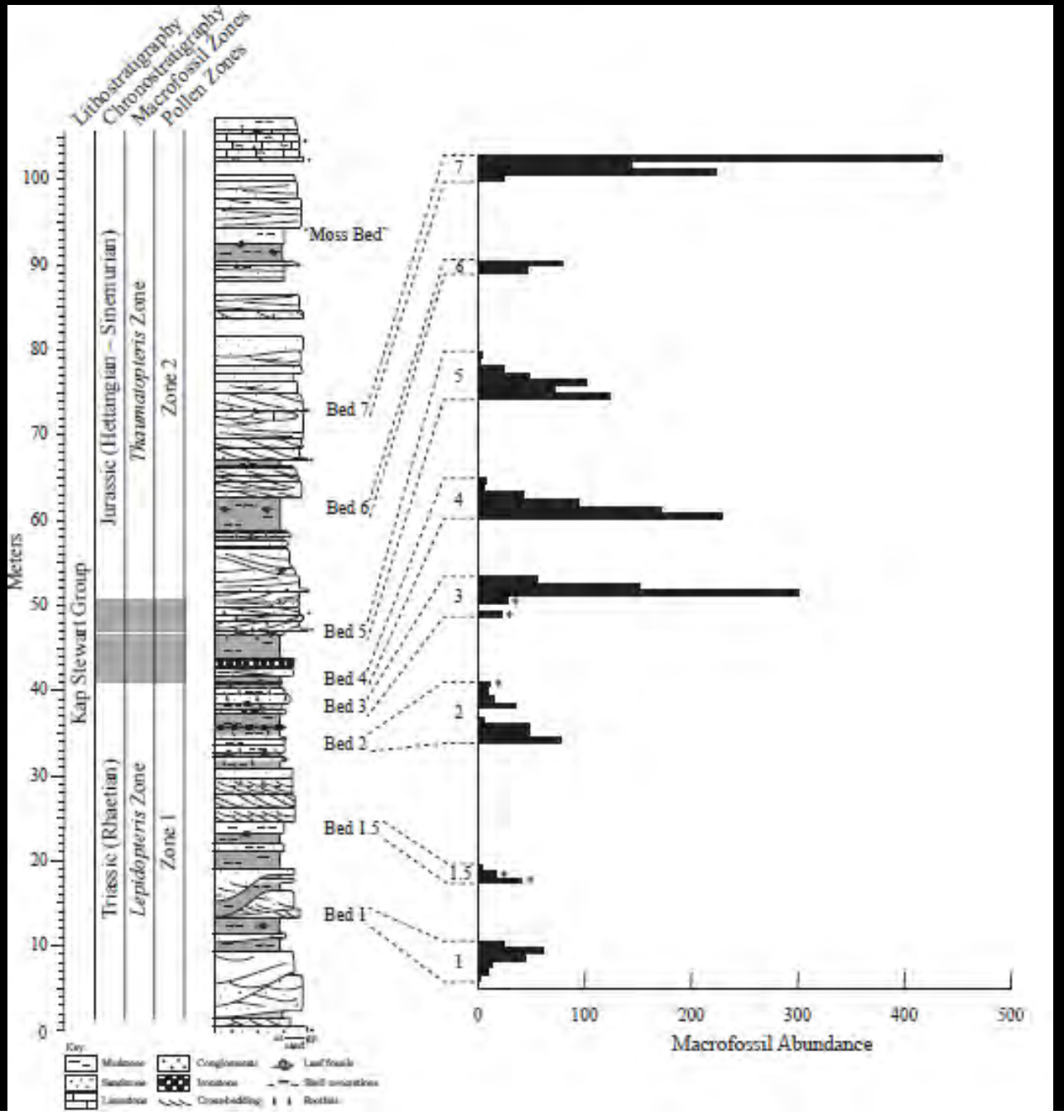
Did the Triassic-Jurassic boundary global warming event cause changes in Earth's forests?



East Greenland 200 Million years ago

Collected over 4000 plant fossils from Triassic-Jurassic boundary age rocks in E. Greenland

The Triassic-Jurassic Boundary in East Greenland

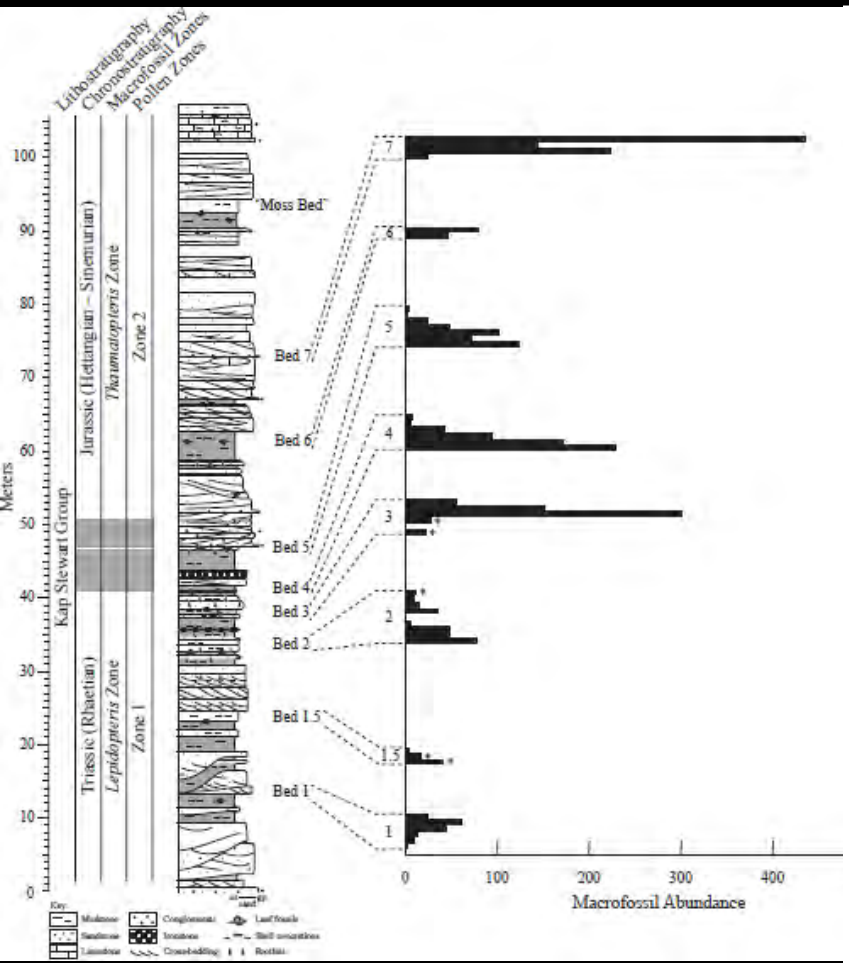


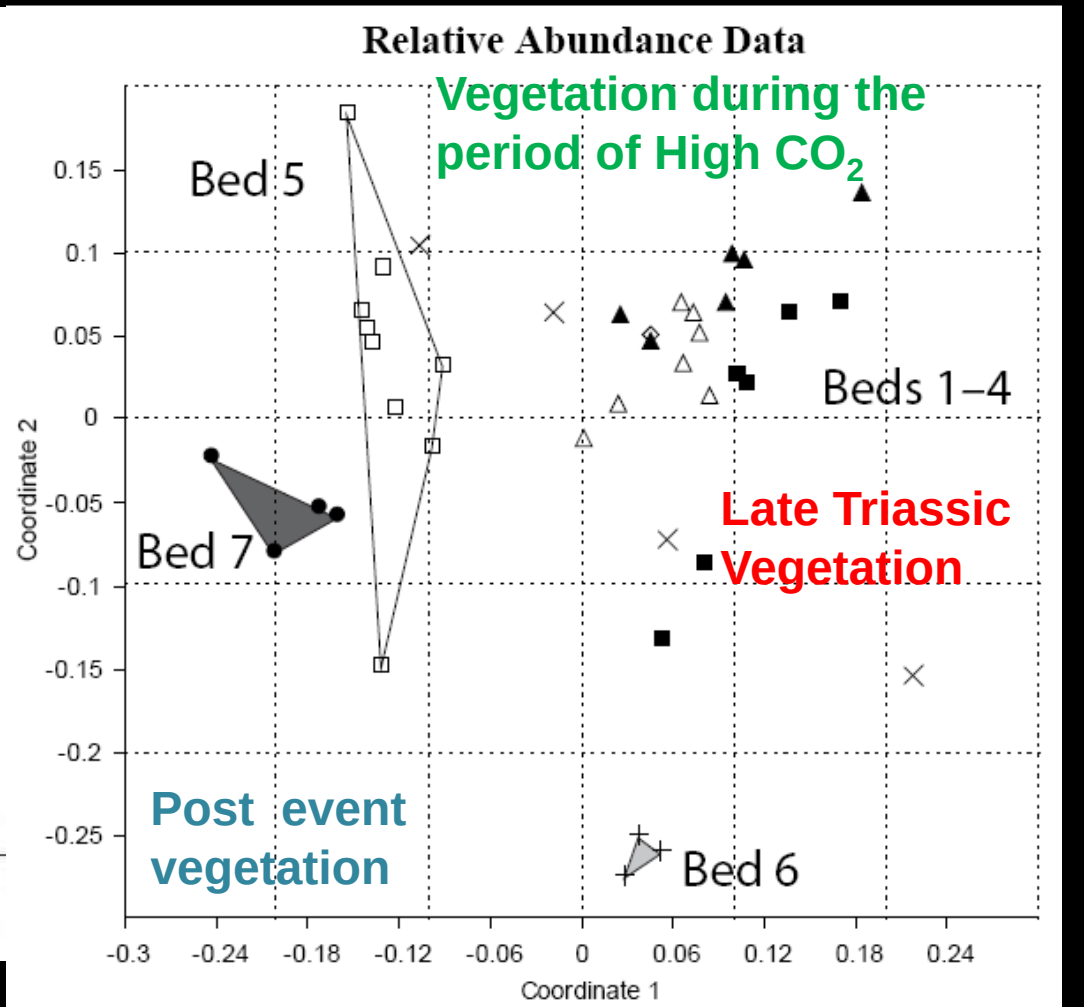
pCO_2 from McElwain et al., 1999, Science 285

0 1000 2000

Atmospheric pCO_2 ppm

Evidence for Climate Induced Compositional Change in Vegetation Across the Tr-J Global Warming Event

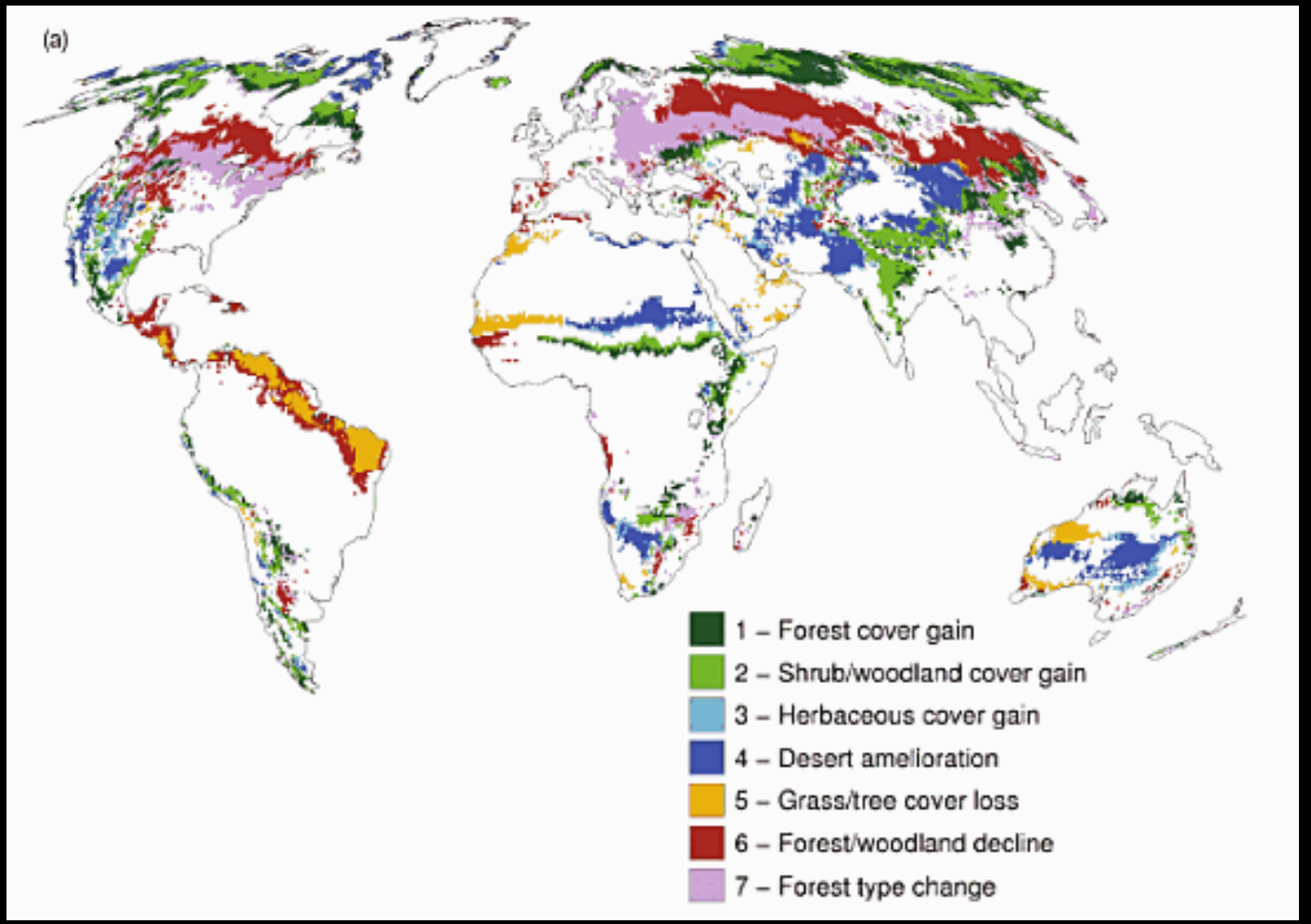




Mander et al., (2010) PNAS

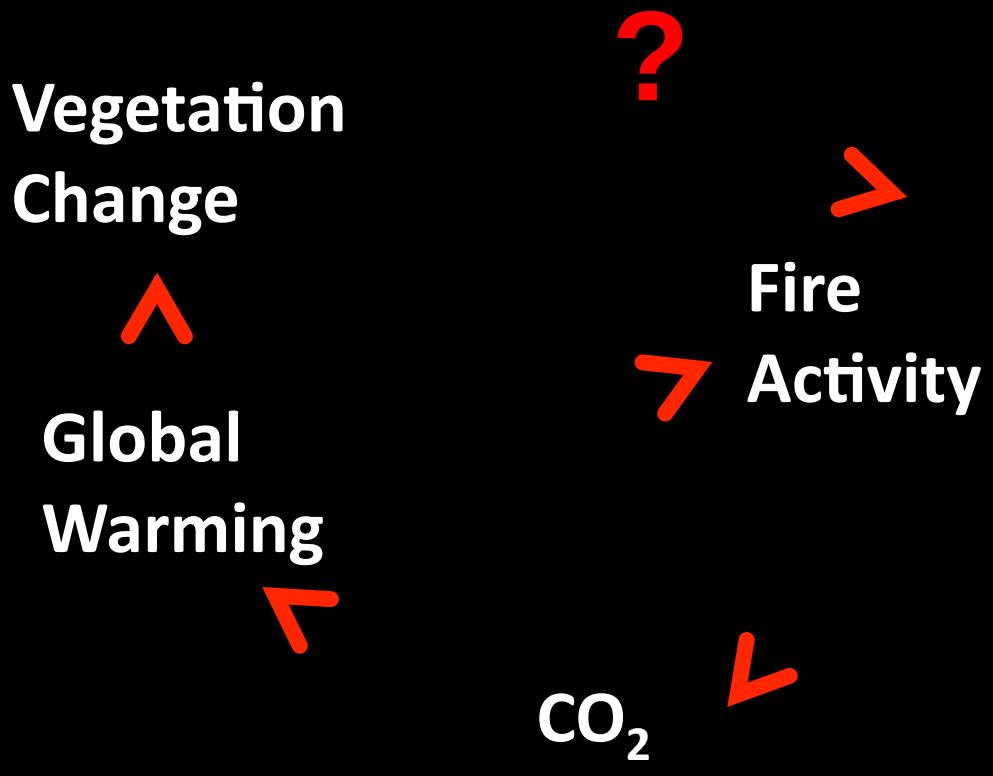
Different types of plants grew before, during and after the global warming event

Did the Triassic-Jurassic boundary global warming event cause changes in Earth's forests?



YES

Might these climate-driven changes in vegetation influence fire activity?



Flammability in Modern Ecosystems

Flammable plants

- Relatively low moisture contents

- Fine plant parts with a fuel to air ratio optimized to propagate fire

Less flammable plants

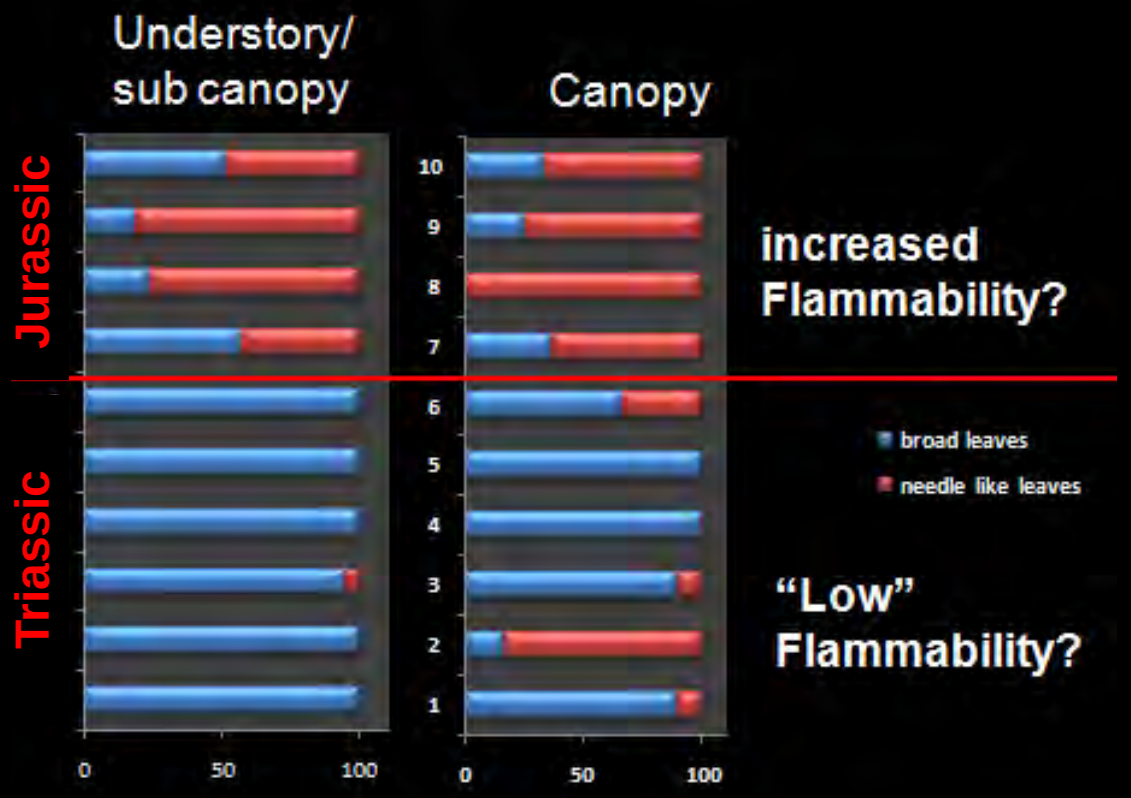
- High moisture contents

- Relatively coarse dimensions

(see Bond and van Wilgen, 1996)

Could Morphological Changes in the Vegetation Alter Ecosystem Flammability?

Changes in Leaf Morphology Across the Triassic-Jurassic Boundary Event



Data from - Belcher et al., 2010. Nature Geoscience, 3.

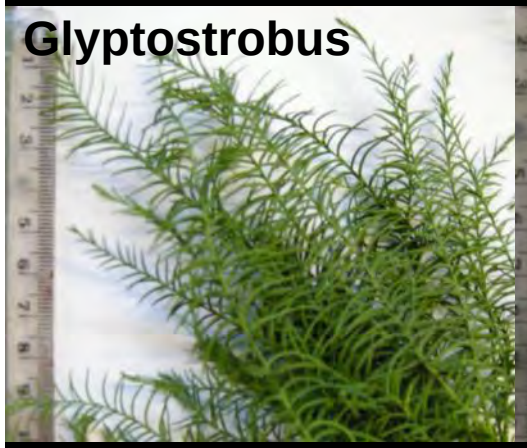
Shift from broad to narrow leaves

Expect an increase in fire activity?

Does changing plant morphology influence flammability?

Are narrow leaves more flammable than broad leaves?

Testing Leaf Flammability



6 genera were selected:

Metasequoia glyptostroboides	**Narrow leaved**
Glyptostrobus pensilis	**Narrow leaved**
Wollemia nobilis	**"Slim" broad leaved**
Afrocarpus sp.	**"Slim" broad leaved**
Agathis australis	**Broad leaved**
Nageia nagi	**Broad leaved**

Fire Propagation Apparatus

Fire Propagation Apparatus (FPA) BRE Centre for Fire Safety Engineering, The University of Edinburgh

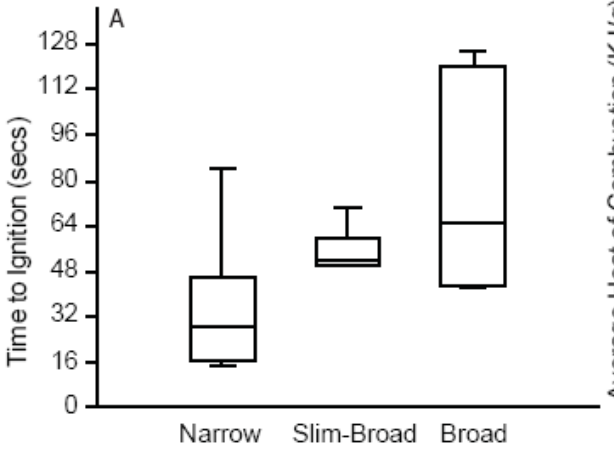
Approx. equal volumes of plant material were combusted in each sample

Three samples of each genera were ignited

Flaming Ignition of Wollemi Pine

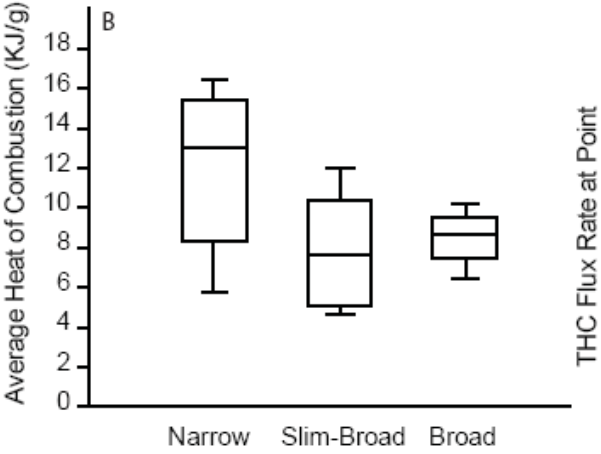
Does Leaf Morphology Alter Flammability?

Time to Ignition



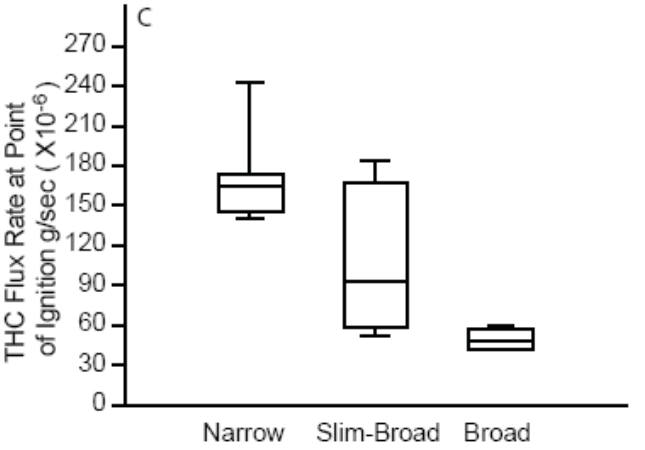
kw = 5.208 *p* = 0.02248

Average Heat of Combustion



kw = 2.94 *p* = 0.08641

Total Hydrocarbon Flux Rate at Point of Ignition



kw = 6 *p* = 0.0143

Narrow leaves ignite faster than broad leaves

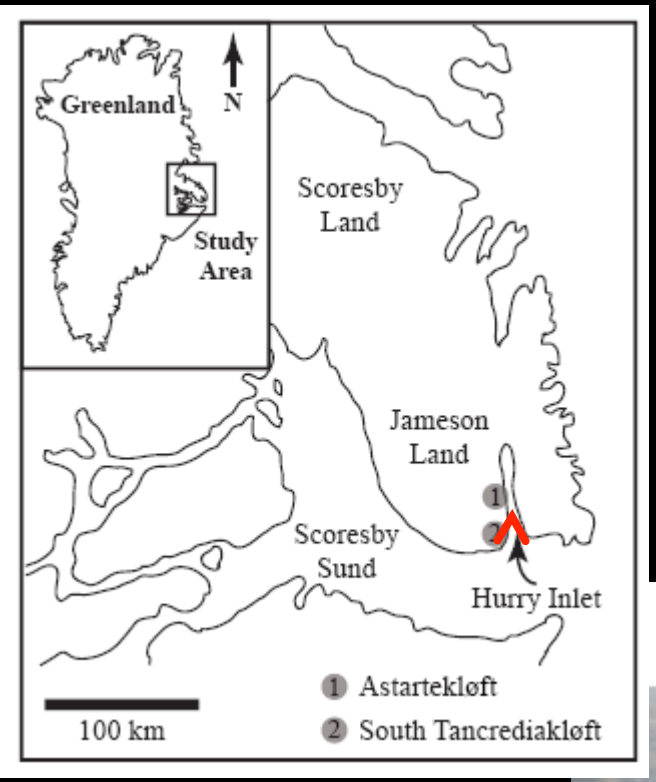
Narrow leaves burn hotter quicker

Narrow leaves release volatile gases more rapidly than broad leaves

Belcher et al., 2010. Nature Geoscience, 3.

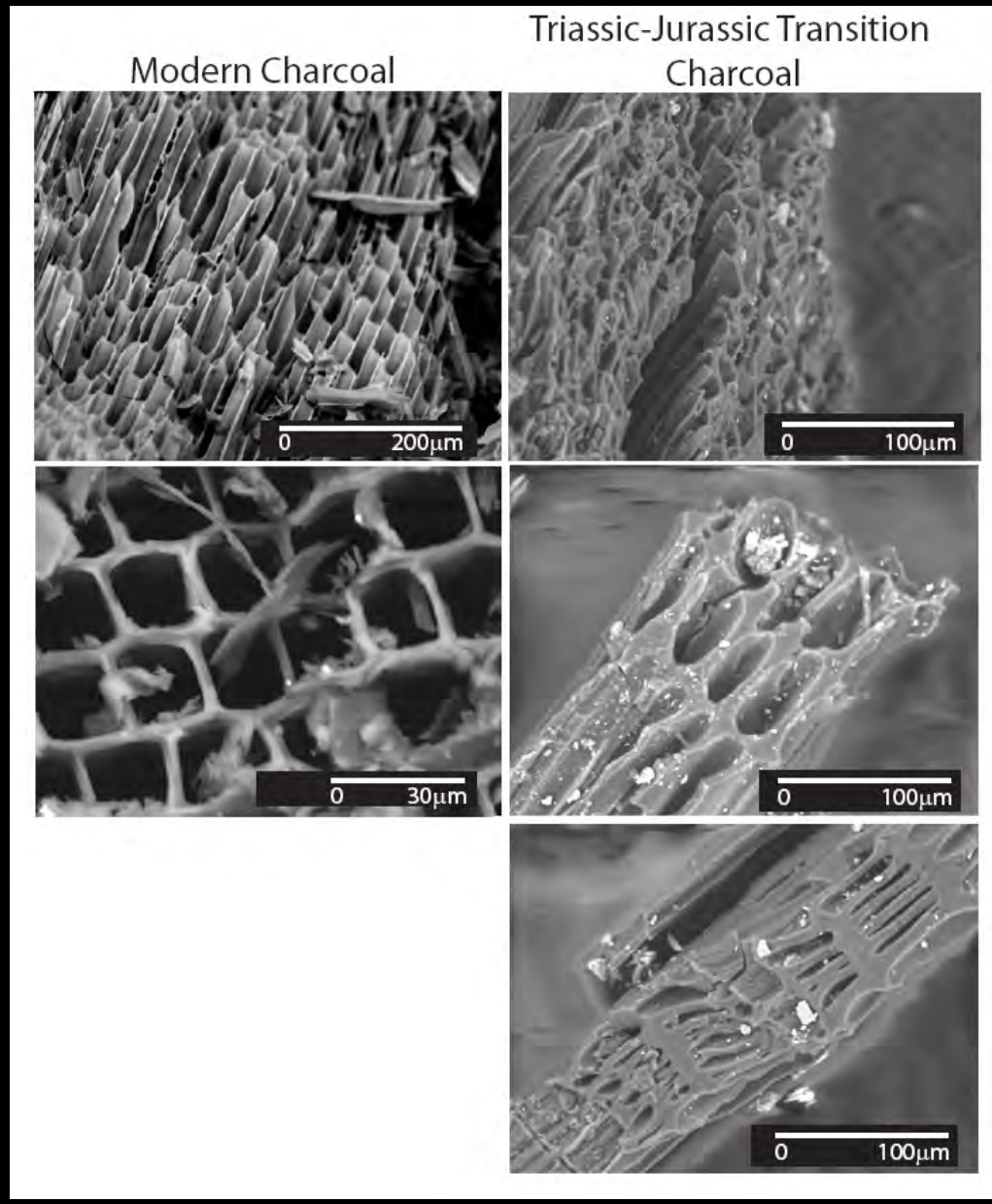
Changes in the types of plants e.g. a shift from broad leaved - narrow leaved dominated floras can influence ecosystems flammability

Searching for Evidence of Fossil Fire

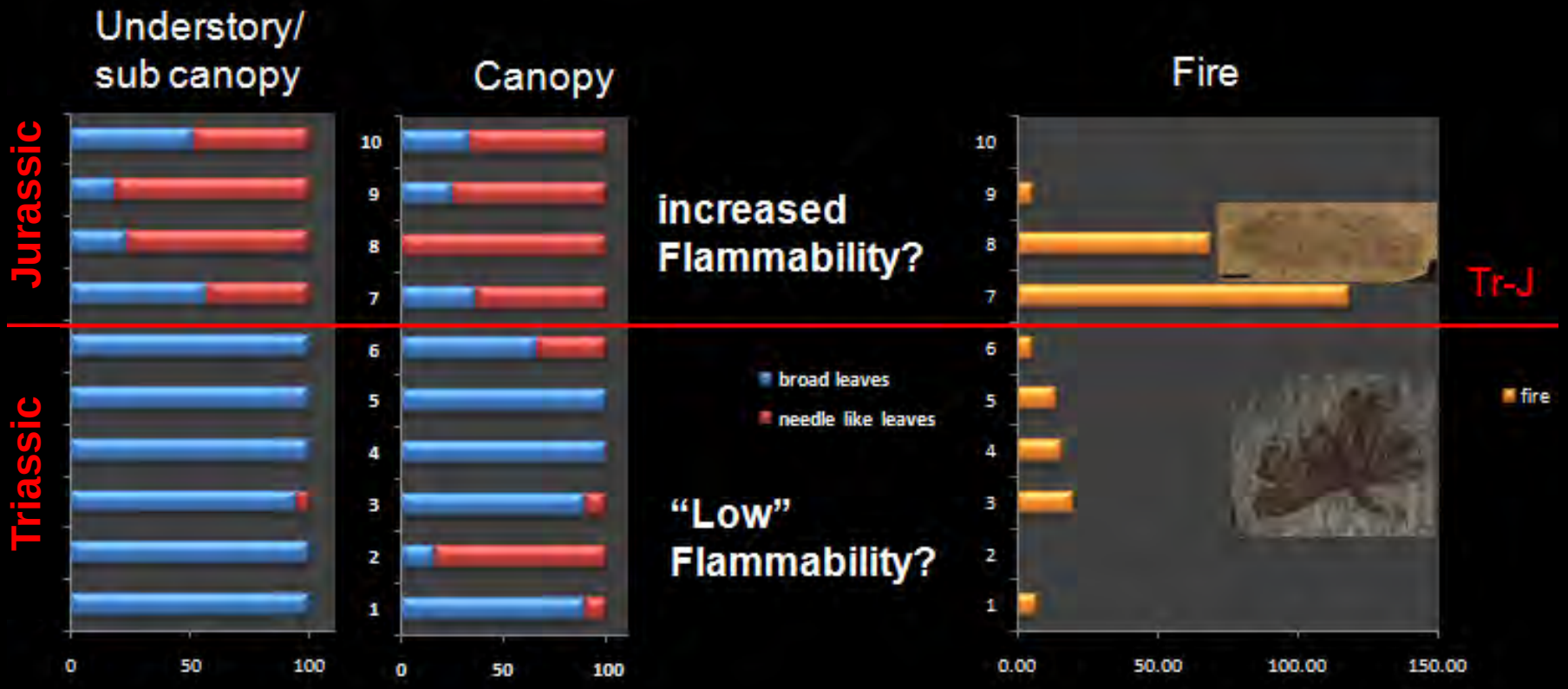


Astartekløft, Jameson Land, East Greenland

Quantified the abundance of fossil charcoal from the rocks that span the Triassic-Jurassic event in E. Greenland



Was There a Change in Fire Activity Across the Tr-J Boundary?



Belcher et al., 2010. Nature Geoscience, 3.

5 fold increase in fire activity associated with the shift from a broad leaved dominated flora to a narrow leaved flora

Changes in the potential flammability of the vegetation across this ancient natural global warming event provided a positive feedback on fire potential

LA October 2009

This highlights the potential of future climate driven vegetation change to fuel future fire activity

Acknowledgments

Funding from EU Marie Curie

UCD Seed Fund

BRE CENTRE *for* FIRE SAFETY ENGINEERING
UNIVERSITY *of* EDINBURGH

Philip Thomas - The Royal Botanic Gardens Edinburgh

Read more at: http://clairembelcher.carbonmade.com/

Fire and Storm Activity Under Increased CO_2

- The main ignition source of natural fires is lightning

- There are over 8 million strikes a day under modern atmospheric conditions

Letters to Nature

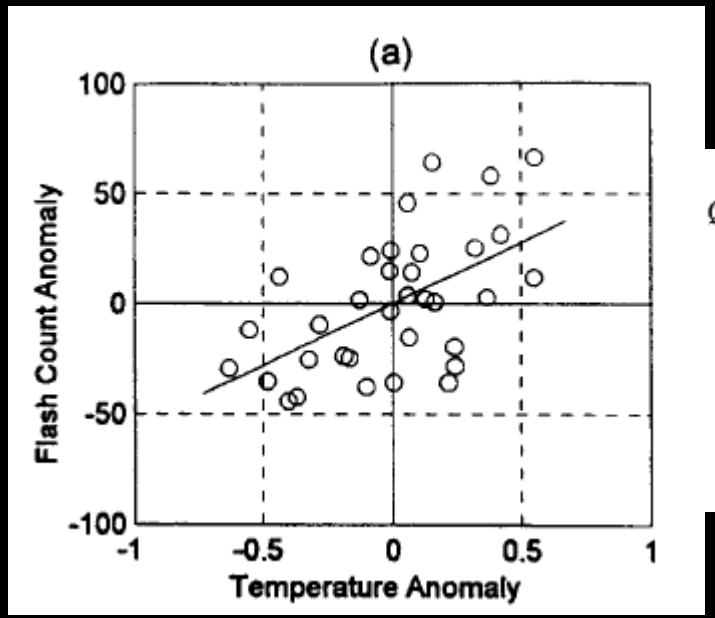
Nature **406**, 290-293 (20 July 2000) | doi:10.1038/35018543; Received 6 April 2000; Accepted 19 May 2000

Evidence for a link between global lightning activity and upper tropospheric water vapour

Colin Price

1. Department of Geophysics and Planetary Sciences, Tel Aviv University , Levanon Road, Ramat Aviv 69978, Israel

Global lightning activity is predicted to increase as global temperature increases



Q. J. R. Meteorol. Soc. (1999), **125**, pp. 893–903

Lightning activity as an indicator of climate change

By N. REEVE and R. TOUMI*
Imperial College, UK

(Received 29 June 1998; revised 16 October 1998)

Number of N. Hemisphere lightning flashes as a function of temperature