

# Abrupt Changes in the Palaeoclimate: *how much do we know?*

What? How? How much? So what?

SCSS seminar March 2013

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PhD students, PostDocs, SFI

# Climate Change and Uncertainty

Disconnect between

Scientific and Public Opinion

over Man-made Global Warming

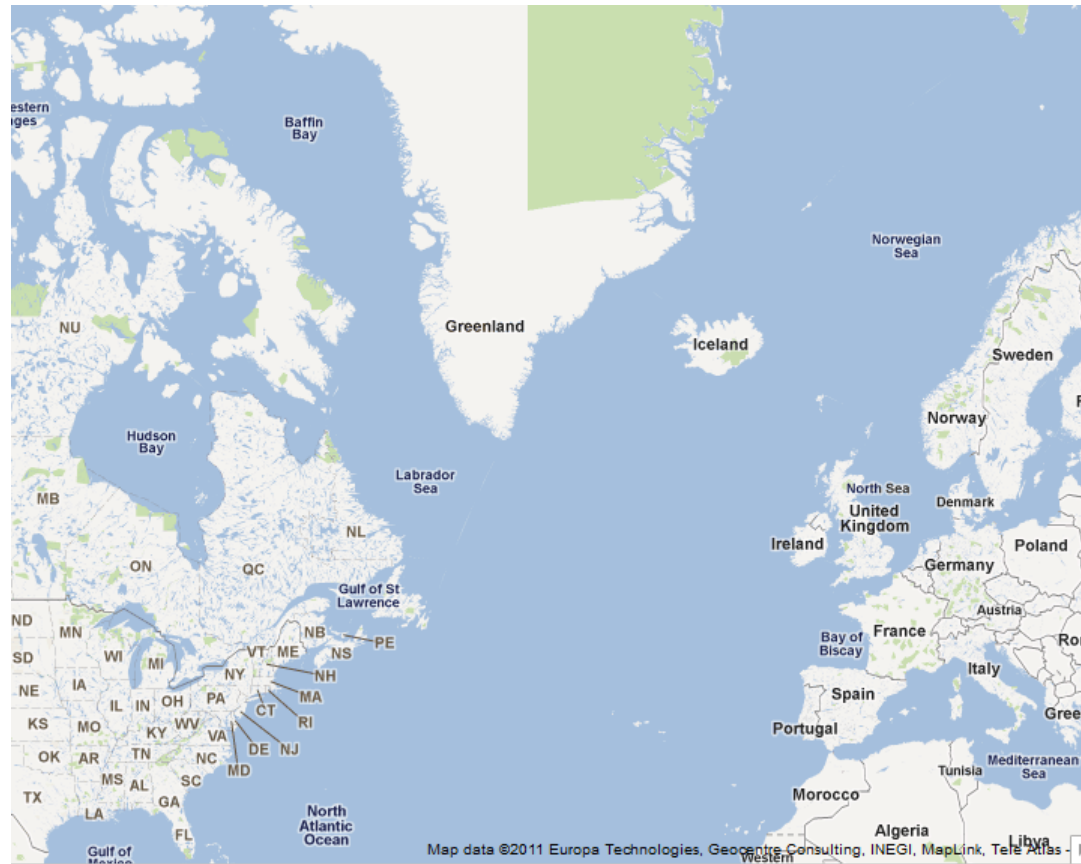
# Science- Abrupt climate change

IPCC WG1 2007

“During the last glacial period, abrupt regional warmings (probably up to 16°C within decades over Greenland) occurred repeatedly over the North Atlantic region”

What do we know about abrupt changes?

**Pitifully little**



# Abrupt change in the climate



NOAA NATIONAL CLIMATIC DATA CENTER  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA Paleoclimatology

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A Paleo Perspective ...  
...on Abrupt Climate Change

## *The Story*

The Beginning	The goal of <i>The Story</i> is to give the reader a background on some physical processes associated with abrupt climate change, as well as the study of past climate variability.
The Story	
The Data	<u><a href="#">Defining abrupt climate change</a></u> This chapter provides a definition and visual analogy for abrupt climate change.
Final Word	
Glossary	<u><a href="#">What are positive feedbacks?</a></u> Positive feedbacks are a key ingredient for abrupt climate change. This chapter defines feedbacks and gives examples of how they operate in the climate system.
References	
Acknowledgements	<u><a href="#">How do scientists study abrupt climate changes of the past?</a></u> This chapter explains how paleoclimate proxies record past climate changes and how ancient materials can be dated.
Site Map	
Contact Us	

What

<http://www.ncdc.noaa.gov/paleo/abrupt/index.html>

# Palaeo-Climature

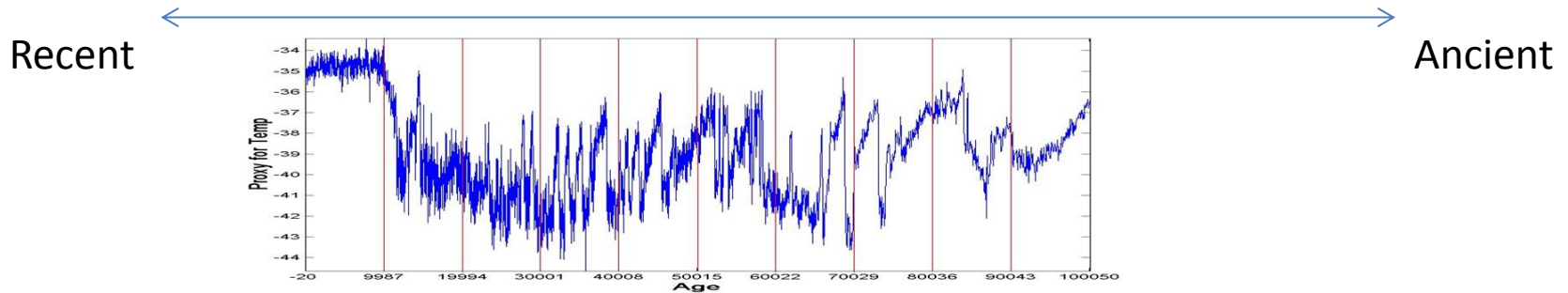
Past 1000 yrs

[http://en.wikipedia.org/wiki/Temperature\\_record\\_of\\_the\\_past\\_1000\\_years](http://en.wikipedia.org/wiki/Temperature_record_of_the_past_1000_years)

Past ~11000 years, Holocene

<http://www.ipcc.ch/ipccreports/tar/wg1/073.htm>

100ka Younger Dryas, Last glacial period/max

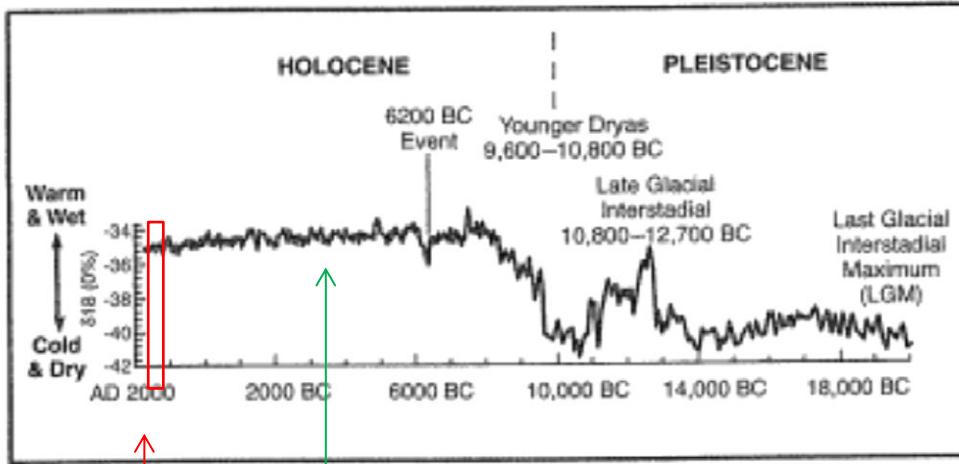


400ka [http://en.wikipedia.org/wiki/Ice\\_core#Ice\\_core\\_data](http://en.wikipedia.org/wiki/Ice_core#Ice_core_data)

What

# The Long Summer - Fagan

Recent ← → Ancient



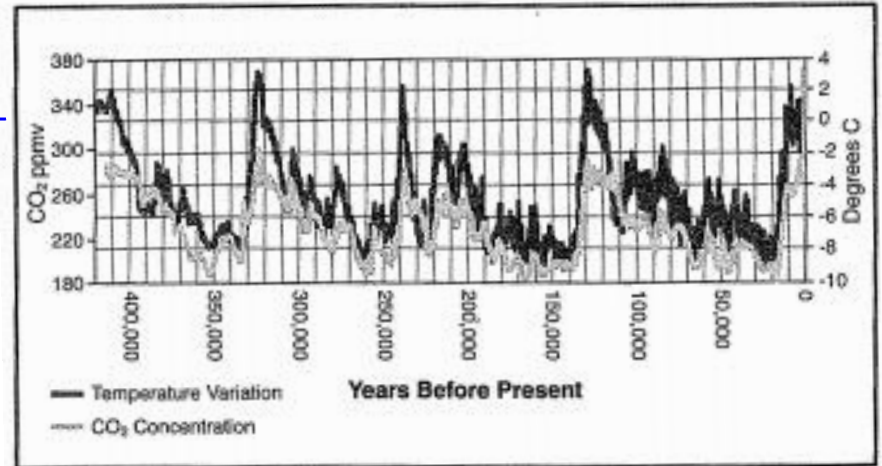
Greenland ice core climatic record extending back to the last glacial maximum (LGM)

End of 'green Sahara'

Little Ace Age

[http://en.wikipedia.org/wiki/North\\_African\\_climate\\_cycles#African\\_Humid\\_Period](http://en.wikipedia.org/wiki/North_African_climate_cycles#African_Humid_Period)  
[http://en.wikipedia.org/wiki/Great\\_Famine\\_of\\_1315%E2%80%931317](http://en.wikipedia.org/wiki/Great_Famine_of_1315%E2%80%931317)

Diagrams reproduced from Fagan

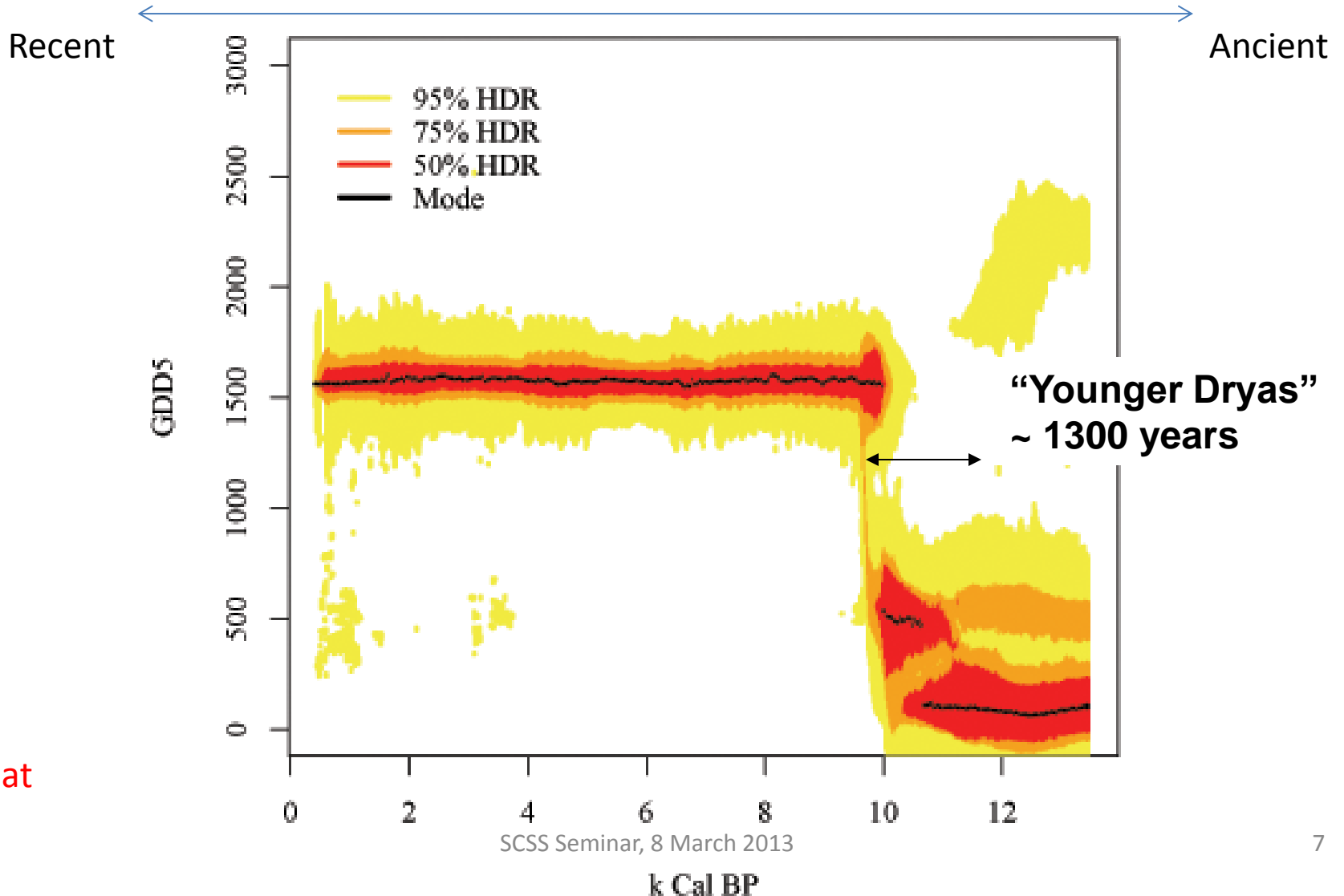


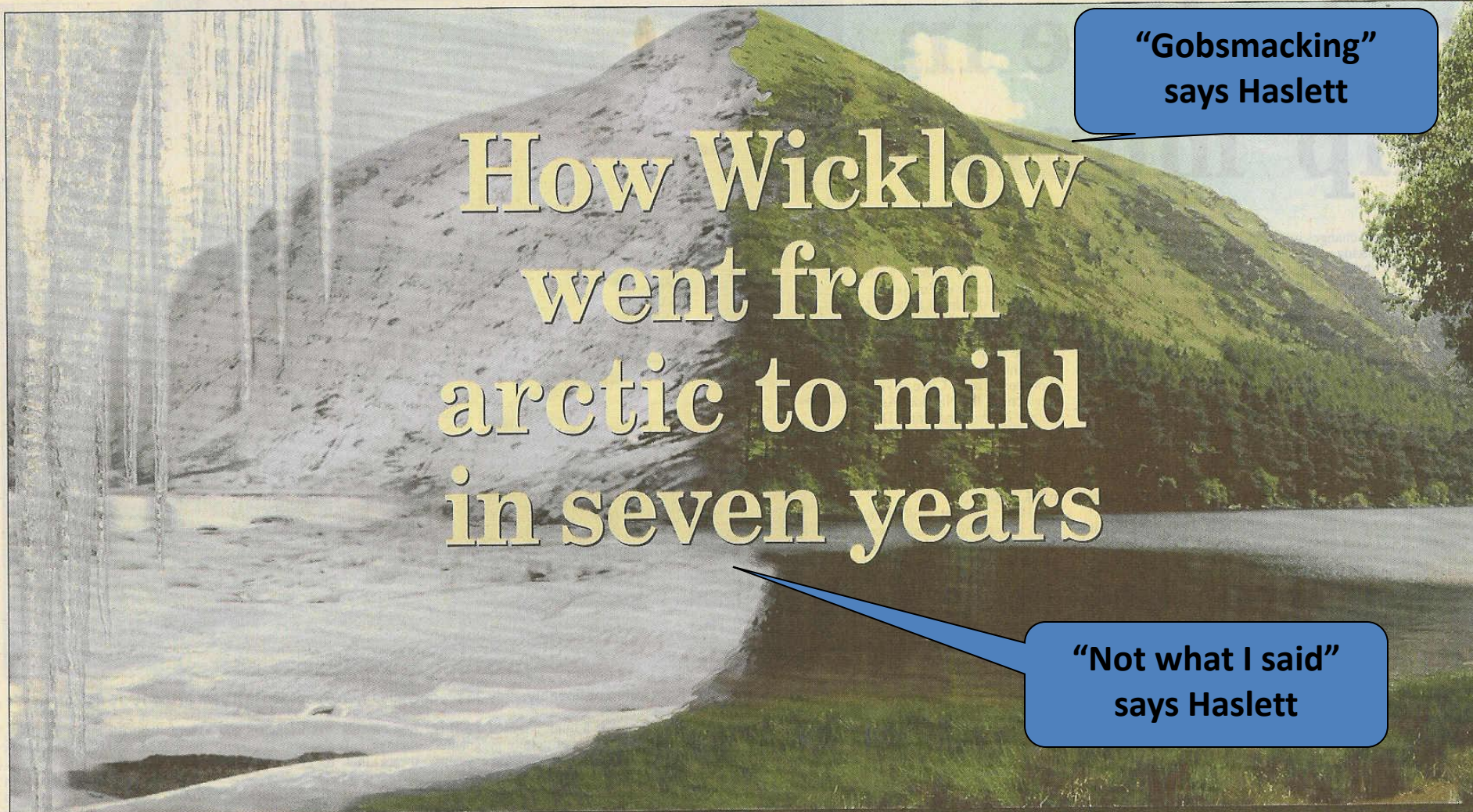
Climatic fluctuations over the past 420,000 years, as revealed in the Vostok ice core, Antarctica

What

# Ireland - growing season - pollen

Sluggan Moss





# How Wicklow went from arctic to mild in seven years

“Gobsmacking”  
says Haslett

“Not what I said”  
says Haslett

Rapid climate shifts have occurred before, but while previous studies indicate the warming of the last ice age could have taken decades, the Glendalough study narrows it down to a mere seven years



# The Little Ice Age

.. during the period from 1315–1317, Western Europe witnessed a combination of rainy autumns, cold springs, and wet summers that led to crop failures and a dramatic slowdown in urban expansion.....the last major locust invasion (1338), the “millennium flood” (1342), and the coldest summer of the millennium in 1347. From 1347 to 1350 the “Black Death” devastated populations...In the same period, agricultural land was abandoned and forests increased.....

.....The clustering of extreme events in the 14th century fundamentally undermined the social order and was a key factor in a major wave of anti-Semitic pogroms and systematic discrimination.

[Costanza et al, incl Leemans 2007;](#)

see also [http://en.wikipedia.org/wiki/Great\\_Famine\\_of\\_1315%E2%80%931317](http://en.wikipedia.org/wiki/Great_Famine_of_1315%E2%80%931317)

What

# Stability in the climate

- The long summer : how climate changed civilization, Fagan, Brian (2004), Granta
- Collapse : how societies choose to fail or survive, Diamond, Jared (2006) Penguin
- Was Agriculture Impossible during the Pleistocene but Mandatory during the Holocene? A Climate Change Hypothesis Richerson, Boyd, Bettinger *American Antiquity*, 2001
- Climate stability and the development of agricultural societies Feynman, Ruzmaikin, *Climatic Change* (2007)

What/why?

# What? How? How much? So what?

- What is the palaeoclimate?
- How do we know anything?
- How *much* do we *know* – about  
*past abrupt change?*
- So what? How to discuss uncertainty.

# Theory: General Circulation Models

Systems of differential equations based on the basic laws of physics, fluid motion, and chemistry. ... *Equilibrium*

- Atmospheric models calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions with neighbouring points.

*linked with*

- Ocean climate models
- Cryosphere models
- Biosphere models
- *Anthroposphere*

*Volcanoes*  
*Meteor strikes*  
*Disease*  
...

How?

# Data: Climate Stability

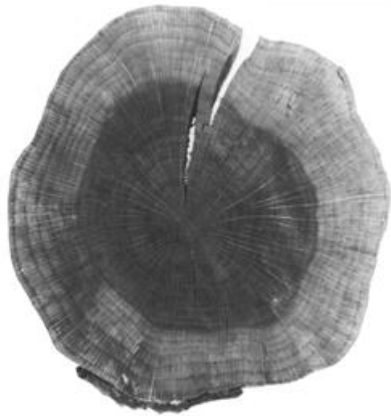
- [Evidence for general instability of past climate from a 250-kyr ice-core record](#)

W Dansgaard, SJ Johnsen, HB Clausen... - Nature, 1993 –  
RECENT results<sup>1, 2</sup> from two **ice** cores drilled in central Greenland have revealed large, abrupt **climate** changes of at least regional extent during the late stages of the last glaciation, suggesting that **climate** in the North Atlantic region is able to reorganize itself ...

How?

# Proxies

high-temporal  
resolution



Oak tree

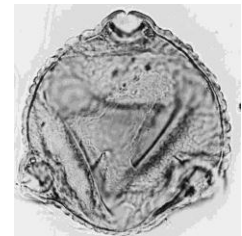
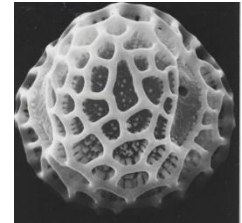
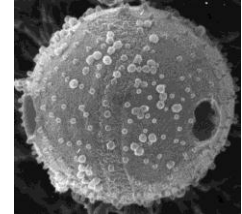


GISP ice



Sediment

low-temp  
resolution



Pollen

How?

# Science: from pollen to climate

## Changing pollen composition

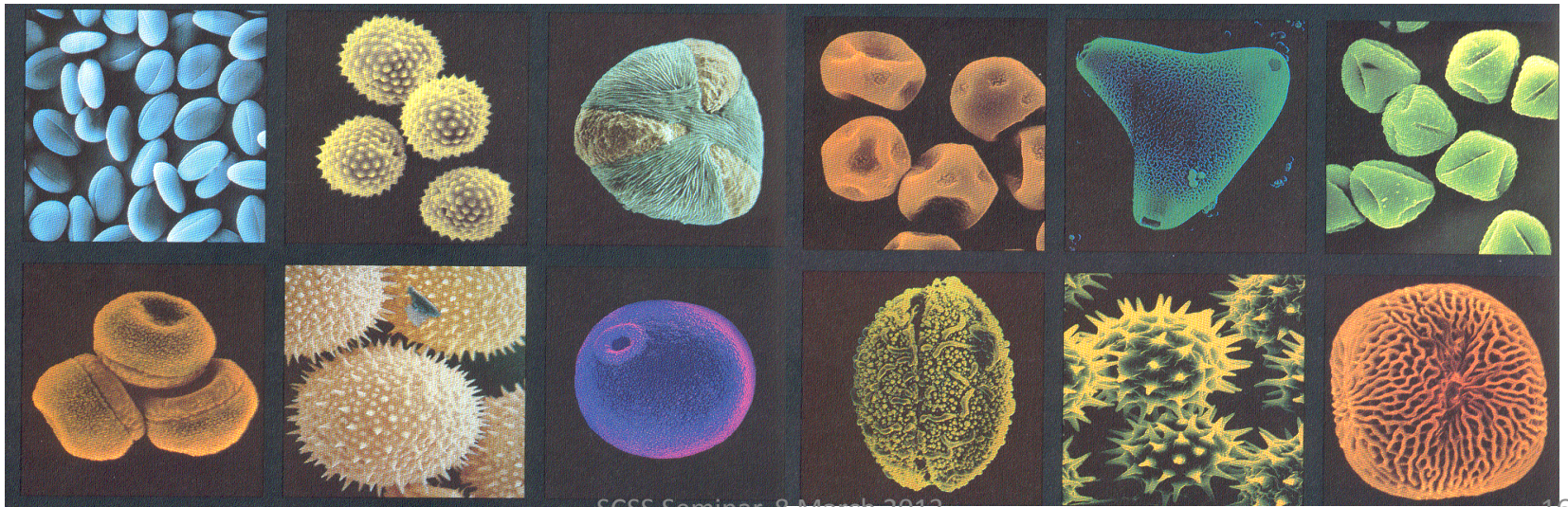
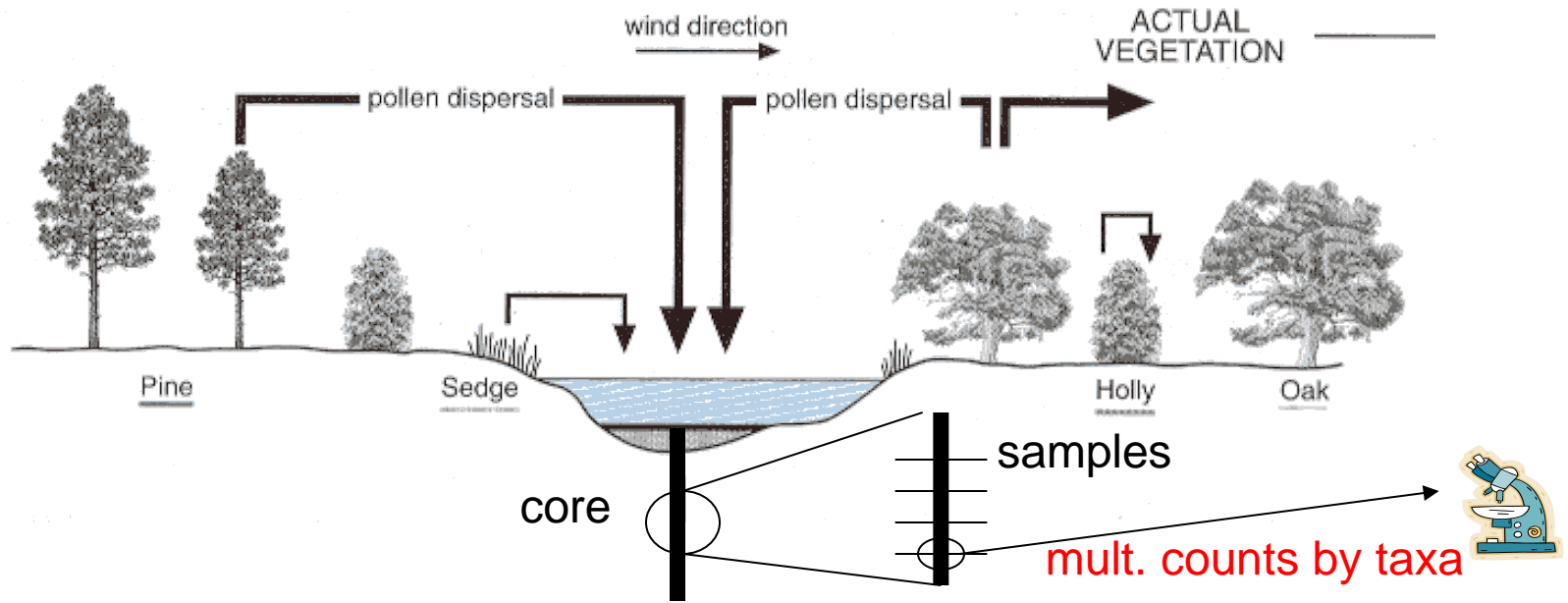
- Reflects changing vegetation, which
- Reflects changing climate
  - GDD5 Growing Deg Days  $> 5^{\circ}$
  - other climate summaries

## Thus

- Can reconstruct climate quantitatively
- Can *reduce uncertainty* about past climate

How?

# Science: from pollen to climate



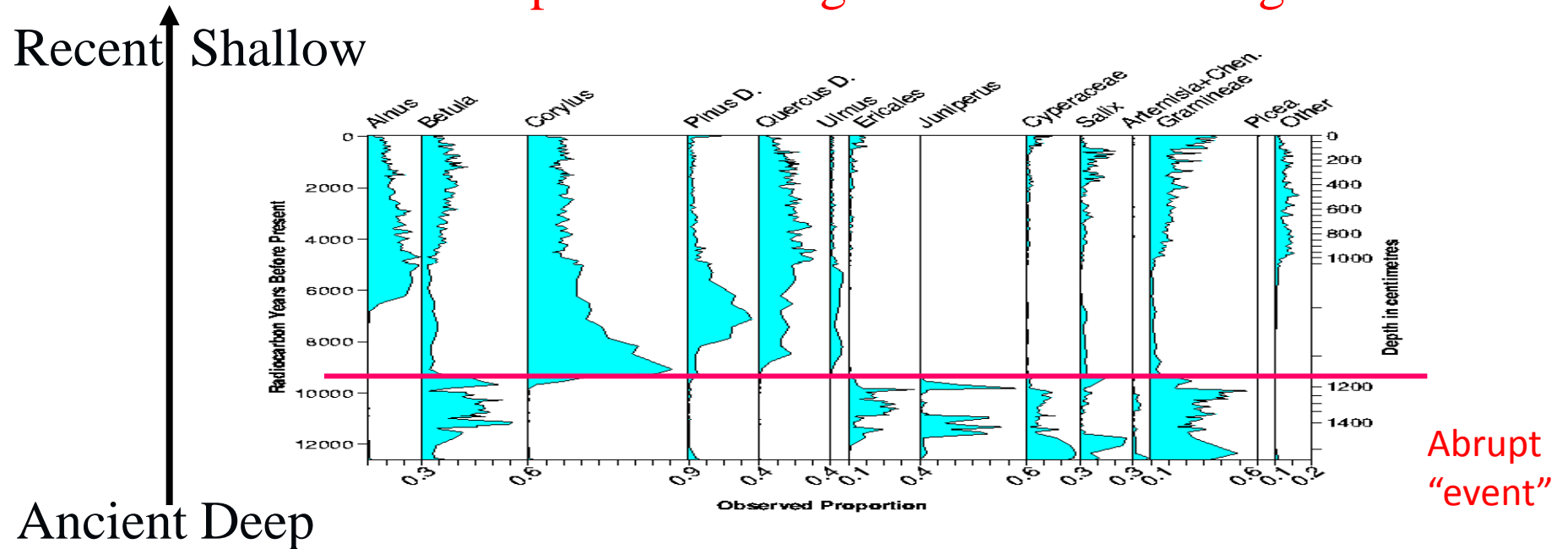
How?



# Changing pollen composition

Observed pollen proportions vs  $^{14}\text{C}$  y BP – sum to 1

Pollen composition changes  $\Rightarrow$  Climate changes



How?

# Modern Training Data

Sluggan Moss  
Glendalough

Hypothesis

Modern analogue

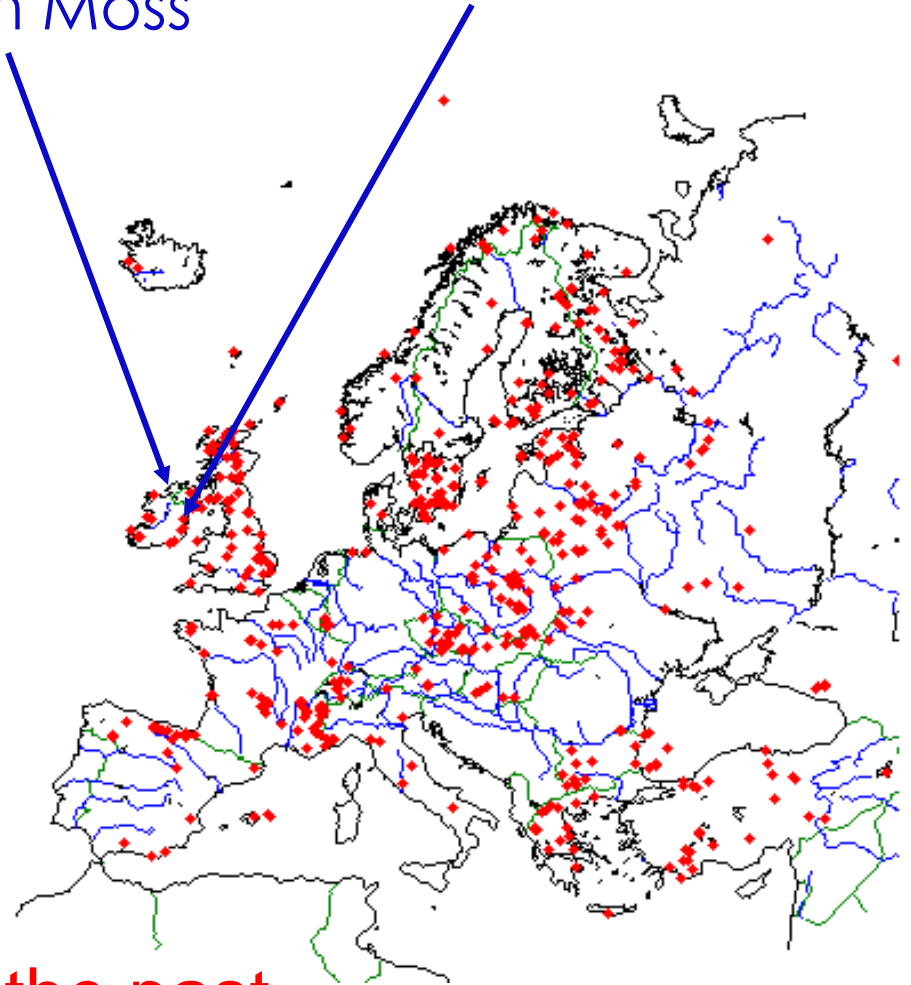
Climate at

Glendalough 8,000 yearsBP

“like”

Somewhere right now

The present is a model for the past



# Dates

- Lamination
  - Tree Rings (Dendrochronology)
  - Ice-cores, stalactites, coral, some sediment
- Stable Isotopes
  - Radio-carbon
- Depth
  - Most sediments

BC

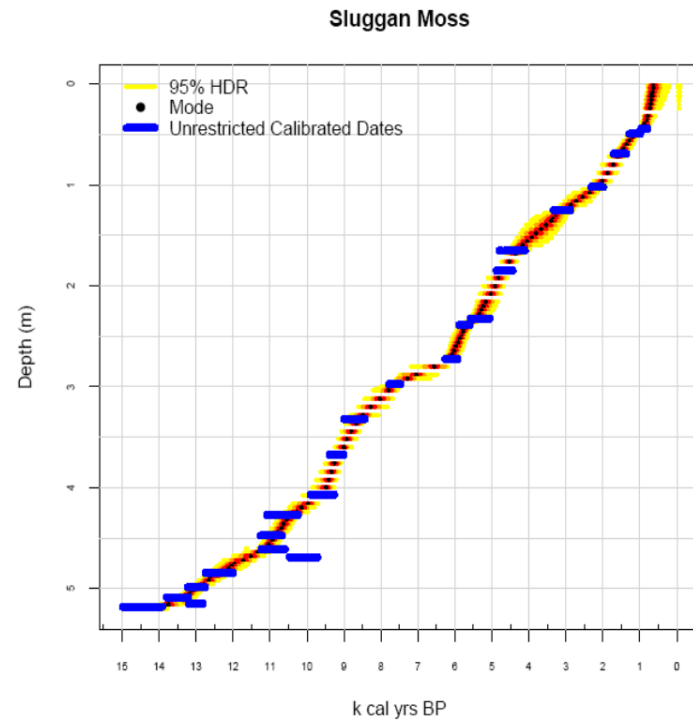
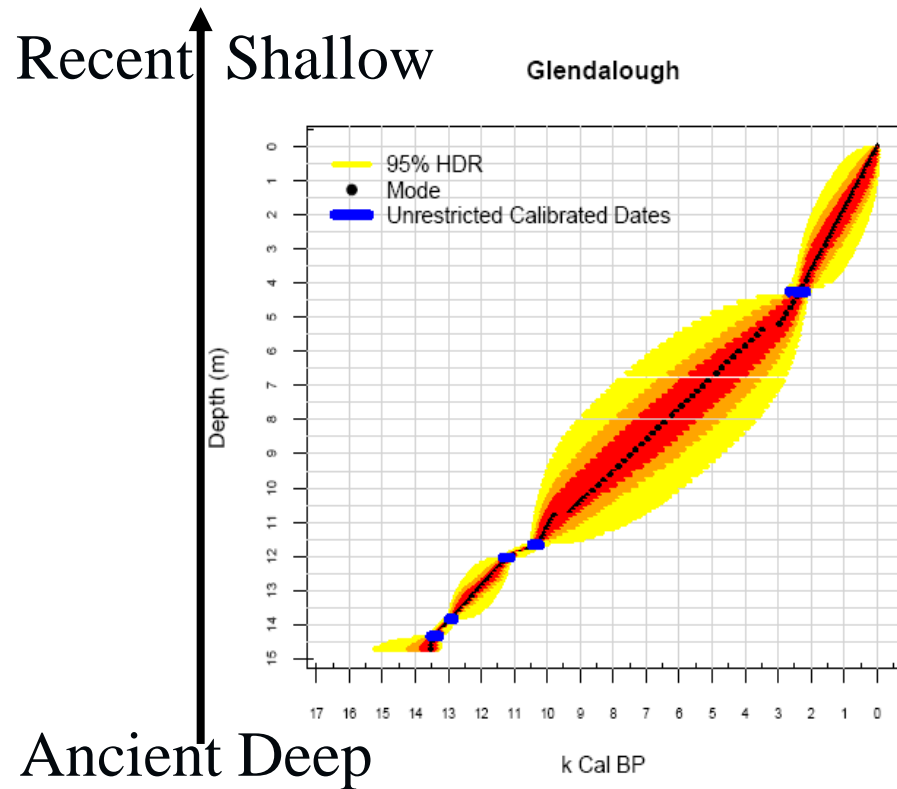
BCE

BP

“High resolution”

How?

# Uncertainties: Radio Dating



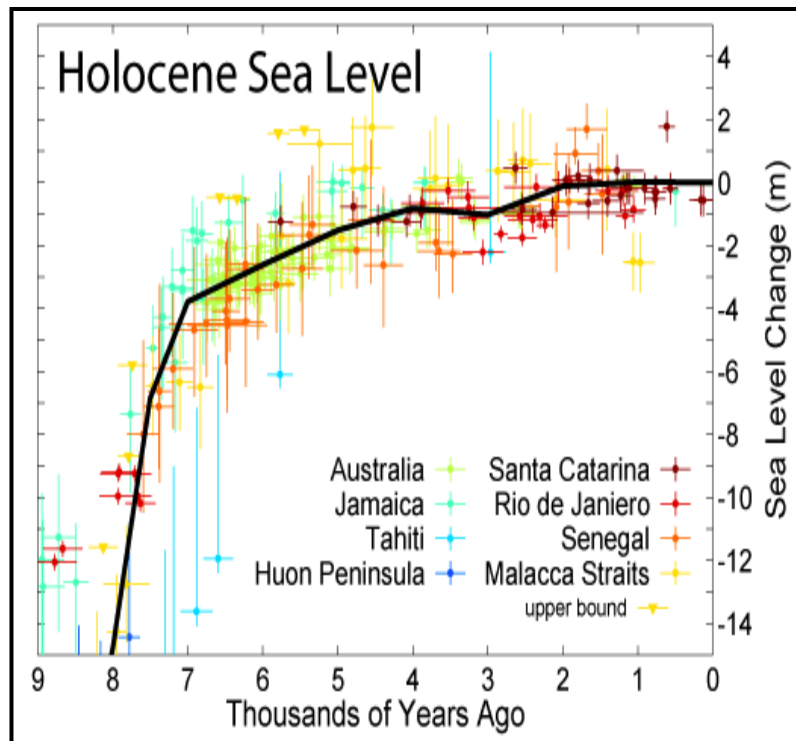
CPGchron v 0.1

How much?

# Stating Uncertainties

Ancient

Recent



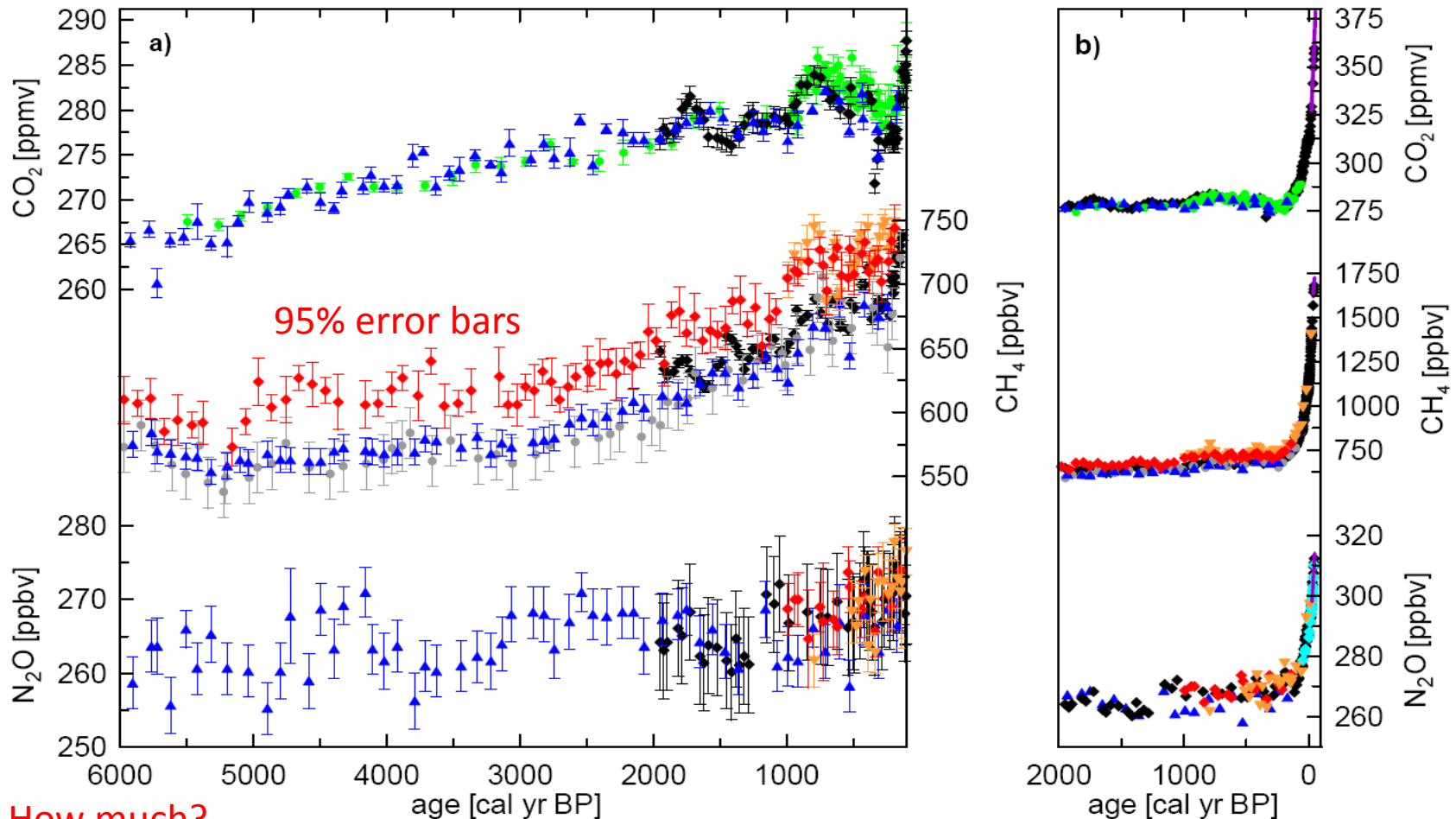
How much?

# What Do Scientists Do (About uncertainty)?

Ancient

$\text{CO}_2$ ,  $\text{CH}_4$  and  $\text{N}_2\text{O}$  (6000 years)

Recent



How much?

# Uncertainty Fusion

- Many indirect sources of information
- Proxies
  - Different spatial/temporal supports
- Forward Theory
  - Changing “Climate”
  - Proxy Data
  - Many sources of uncertainty
- Backward Inversion

$$C = \{C(s, t)\}$$

$$Y = \{Y(s_i, t_i); i = 1, \dots, n\}$$

$$Y = F(C, \theta) \quad \text{Data gen model}$$

$$\Rightarrow \pi(C | Y) = \int \pi(C, \theta | Y) d\theta$$

How much?

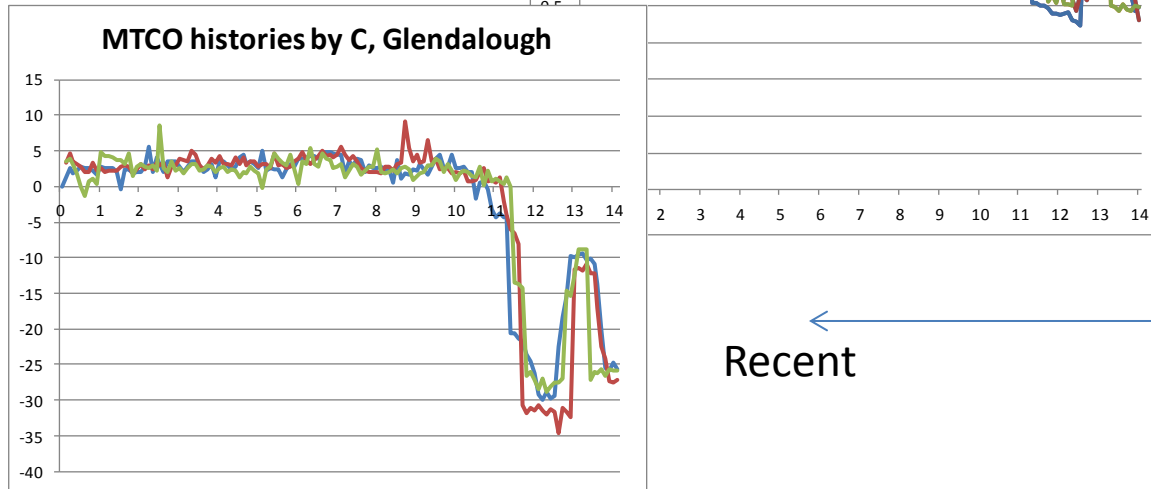
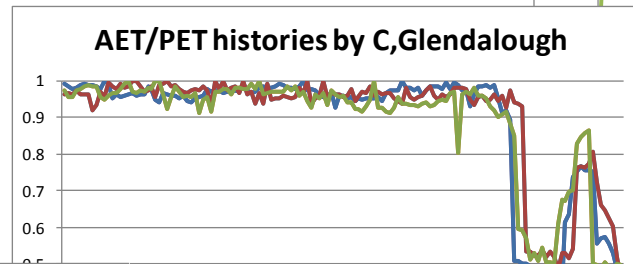
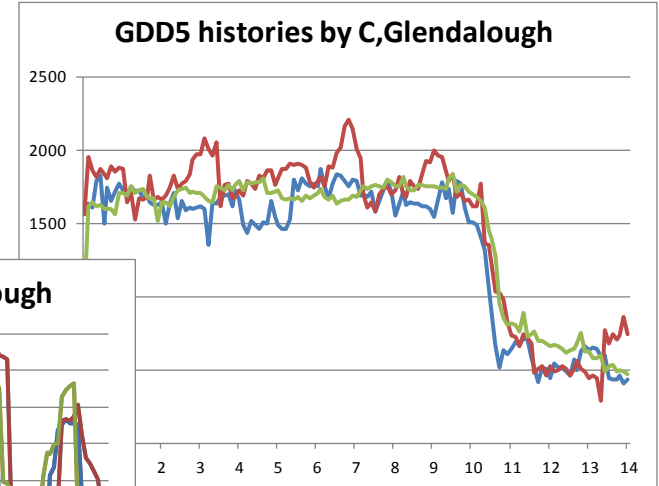
# Integrating Uncertainties: Samples

$$\pi(C|Y) = \int \pi(C, \theta|Y) d\theta$$

$$c_m = \{C(s, t)\}$$

*Sampled histories*

- all consistent with data
- all equally likely



← Recent → Ancient

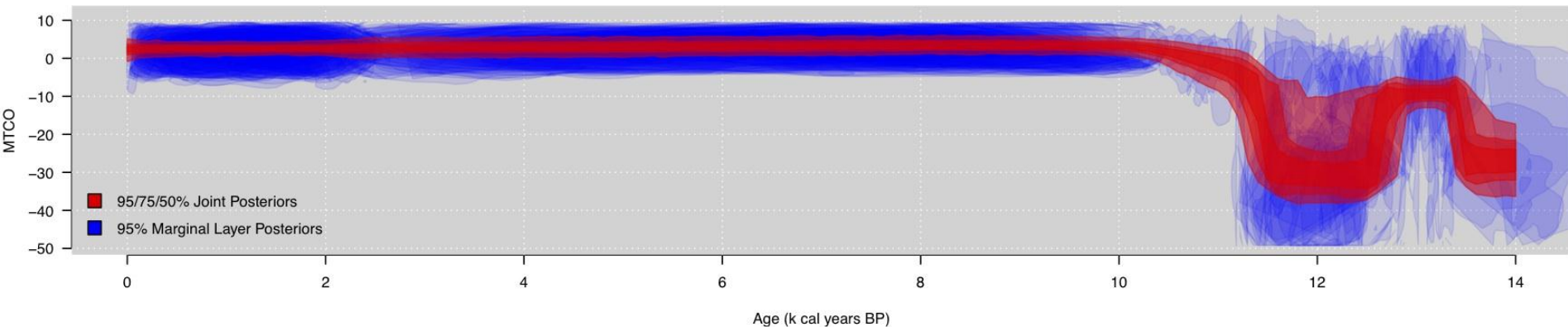
How much?



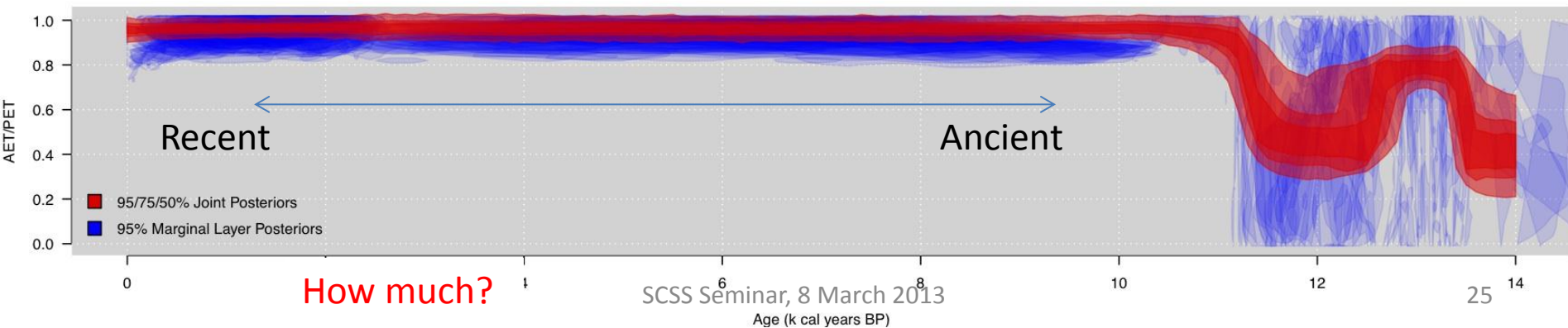
# Summarising Uncertain Histories



Glendalough: MTCO

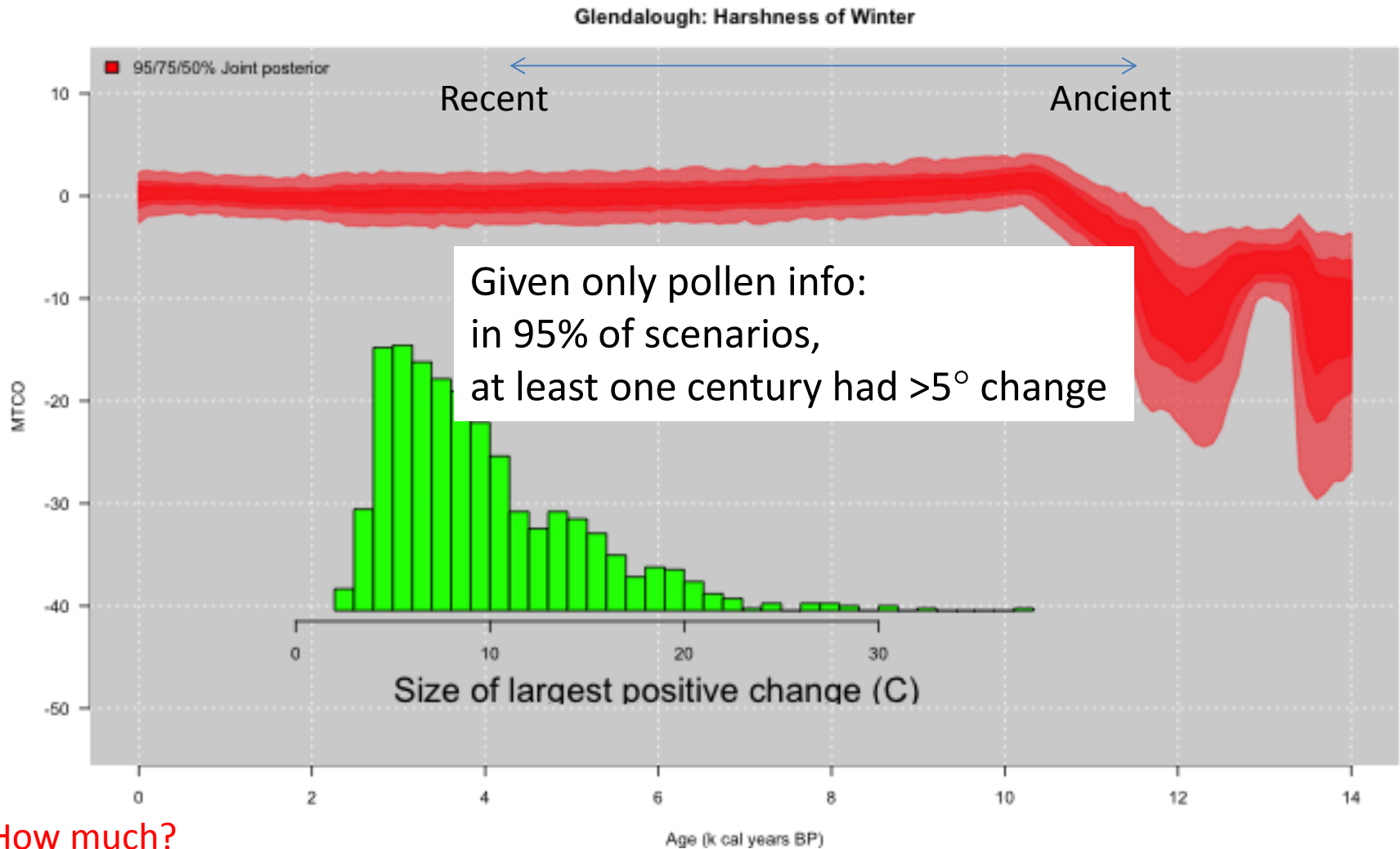


Glendalough: AET/PET



# Summarising Uncertain Histories

Alternative set of summaries of histories 'Abrupt change orientation'



How much?

# Abrupt Climate Change

Int Panel on Climate Change WG1 2007

“During the last glacial period, abrupt regional warmings (*probably* up to 16°C within decades over Greenland) occurred repeatedly over the North Atlantic region”

*Prediction is difficult, especially about.....*

So what?

# Climate Change and Uncertainty

## Disconnect between Scientific and Public Opinion over Man-made Global Warming

- Roles of Scientists
- Place of Uncertainty
- Media
- Public Opinion

## Climate Science: Rapid Response Team

<http://www.climaterapidresponse.org/resources.php>

So what?

# Uncertainty

- Studying Uncertainty
- Communicating
- Scientist to Scientist
- Science to Public

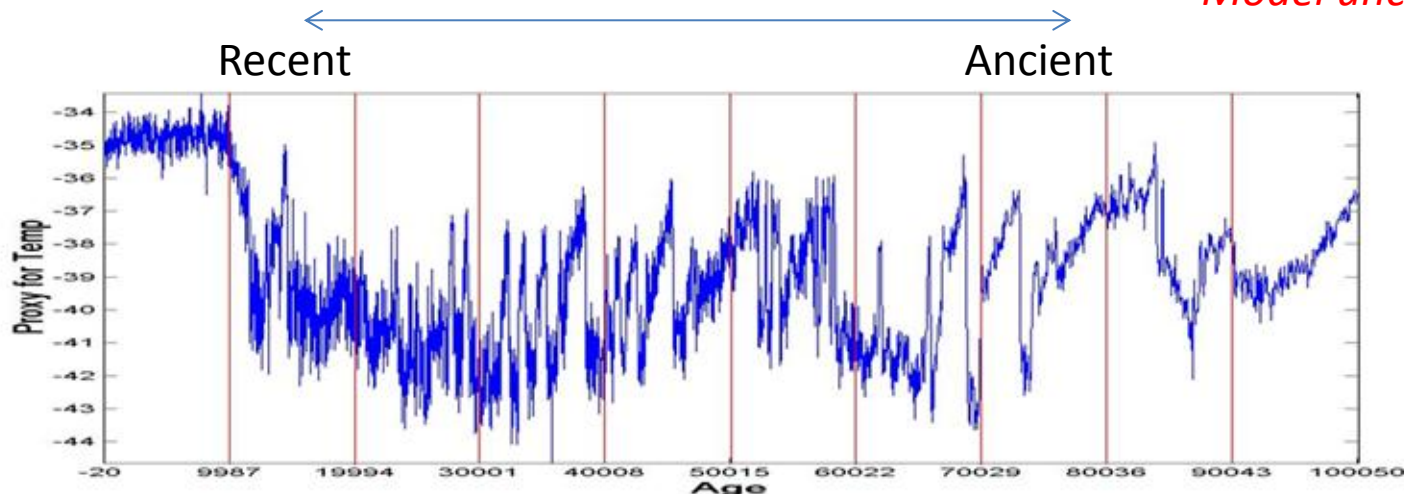
The modelling *of uncertainty*  
*Does computed uncertainty in  
some specific aspect of climate  
Change?  
Smoothly?  
In space and time?*

So what?

# Studying Past Uncertainty

- Partially Observed Stochastic System
- Posterior  $\propto$  Likelihood  $\times$  Prior
  - Freq small changes; occasional very large changes
- Monte Carlo

*Random variation*  
*Model uncertainty*



So what?

# Studying Future Climate Change

## Objective

- To use science
  - to reduce uncertainty about
  - future climate change
- Stochastic models
- Priors & baseline
- Monte Carlo replications

So what?

# Studying Future Climate Change

- Linked GCMs
  - Dynamic Systems: non-linear, with “feedback”
  - Finite element, **deterministic**
  - Steady State/ Equilibrium
  - IPCC “uncertainty guidelines”
- Poss Abrupt (Regional) Changes
  - Monsoon failures      India, W Africa
  - Amazon die back
  - Ice sheet collapse      Greenland, W Antarctica
  - ??

Super-computers  
Budget Priorities  
Emulators  
Tipping points

So what?



# Communicating Uncertainty

- Scientist to Scientist

- “Not even scientists understand [probability]”

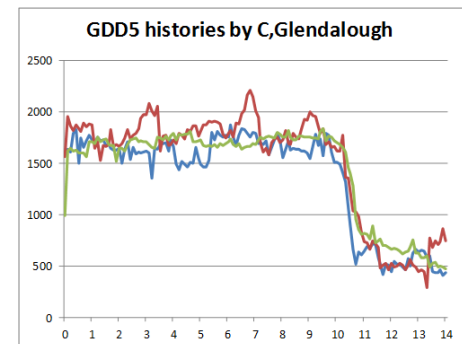
Leemans

- “The probability is high that the probability is high that [..our children will see disruptive change]”

Goldstein

- Publish multiple space-time histories

- or code that generates them

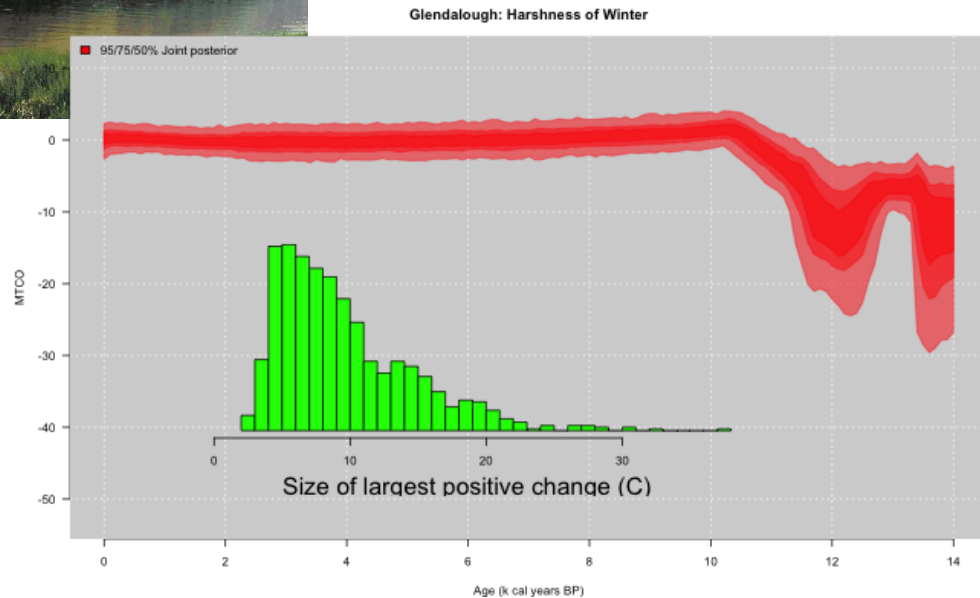


So what?

# Communicating Uncertainty



*Compare and contrast*



So what?

# Thinking about Uncertainty

Should we worry about *future* abrupt change?

Lenton, T.M. (2011).

[2 °C or not 2 °C? That is the climate question.](#) *Nature*

Early warning of climate tipping points. *Nature Climate Change*

Revolutions that made the Earth, OUP

So what?

# Disasters

Sir John Houghton - critical role in establishing the IPCC  
roundly condemned ... scary propaganda ...to frighten  
the public ...

"Unless we announce disasters, no one will listen," Sir  
John was supposed to have said in 1994.

...iconic smoking gun of the climate sceptic community.

...1.77 million web links

November 2006 article in Australia's [The Daily Telegraph](#), journalist [Piers Akerman](#)  
[myths-tales-lies-quotes/](#)

# Thinking about Uncertainty

- Kahneman, Taleb
  - Fallacy of the narrative
  - Blindness to extremes
  - Ignore baseline risk WYSIATI\*
  - Focus on immediate perceivable future
  - Confirmation bias

So what?

\*What you see is all there is

# Abrupt Climate Change in the past

- Evidence
  - Uncertainty
  - “Abrupt”
  - Regional
- So what?
  - How to discuss uncertainty and risk for future
  - Discuss the baseline
  - Climate change – a disaster or a challenge?