Climate Change: Using the past to predict the future

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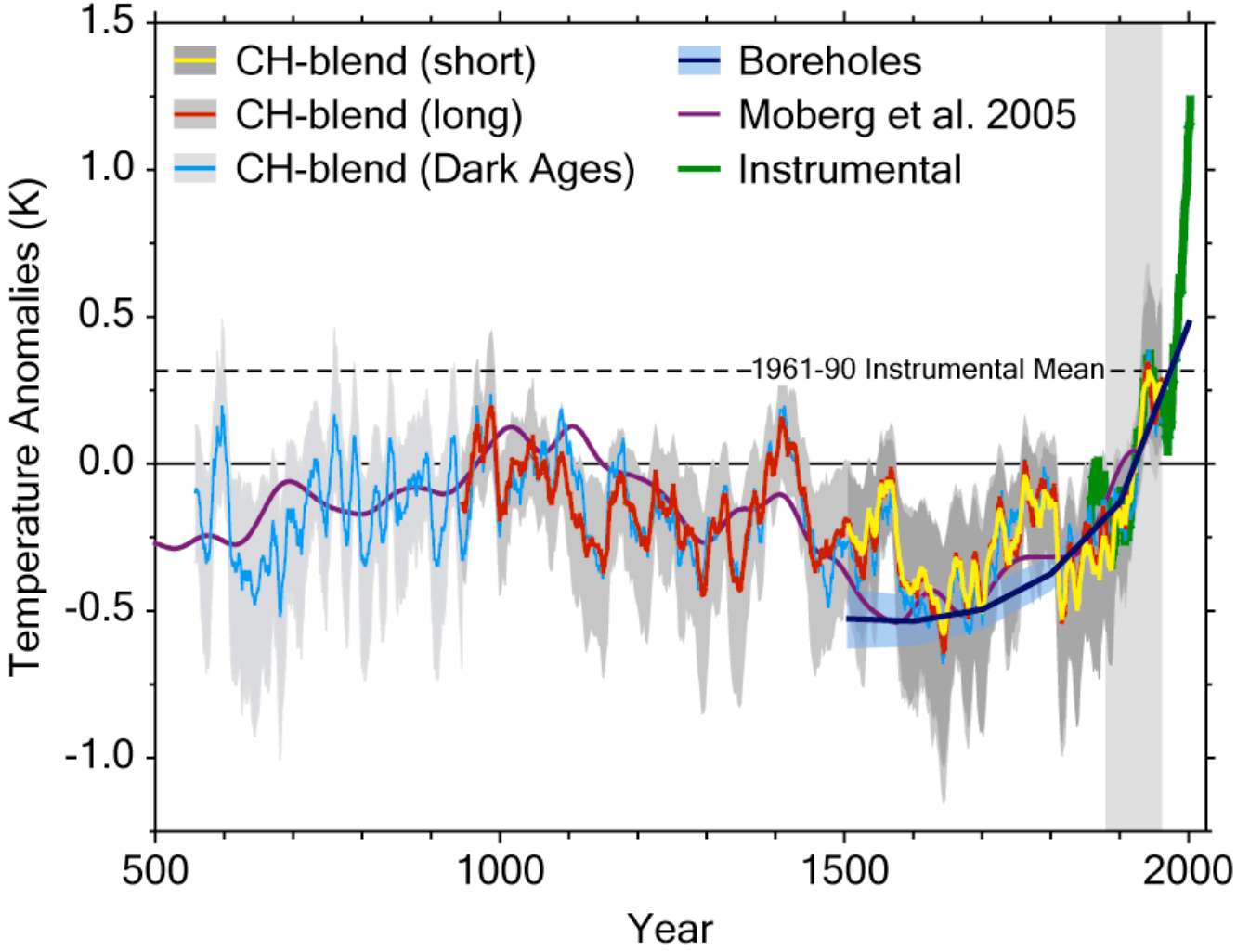
Pieter Bruegel, winter landscape with a bird trap, 1565

1. What can we learn from the last millennium?

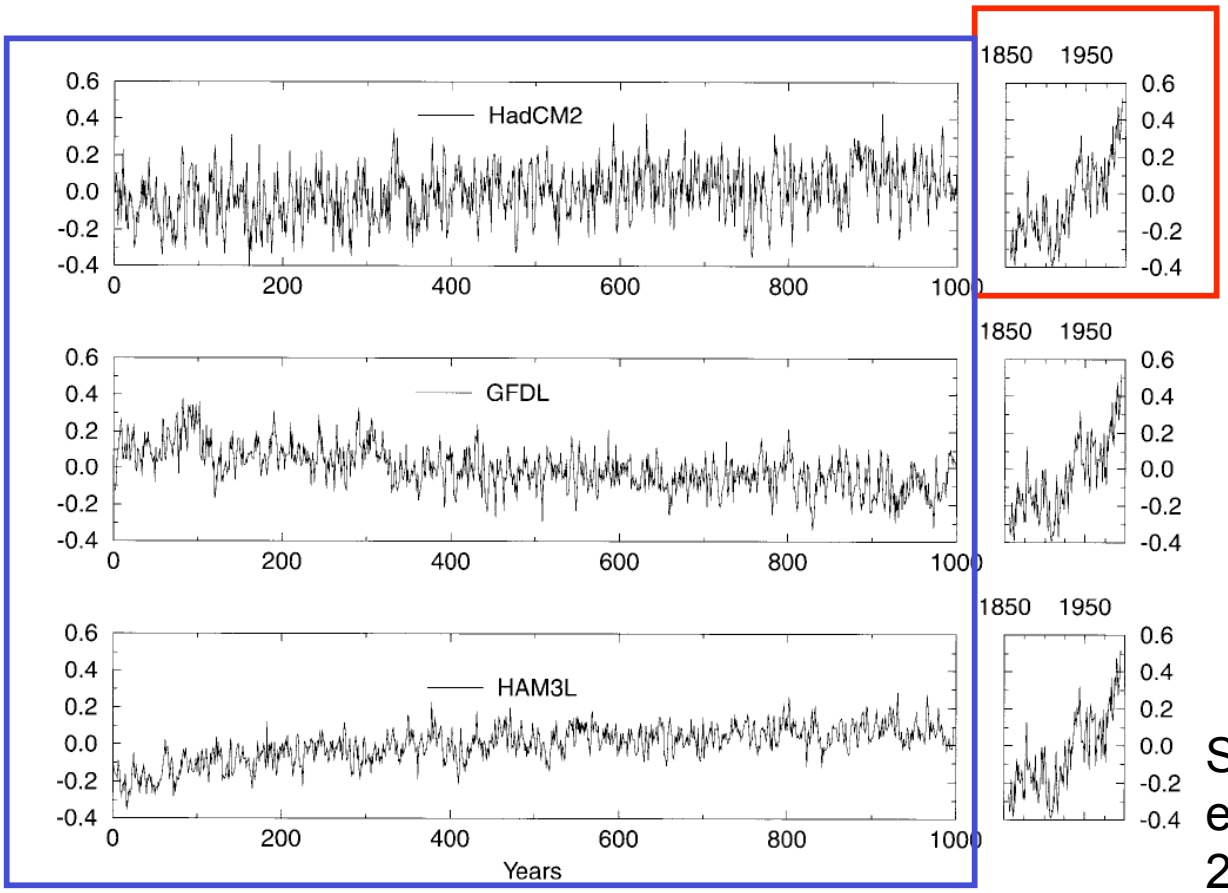


Data: natural archives (treerings, ice cores) and documentary

Decadal NH 30-90N land temperature; Hegerl et al., J Climate, 2007

Why does climate vary?

- **Variability generated within the climate system ('internal')**

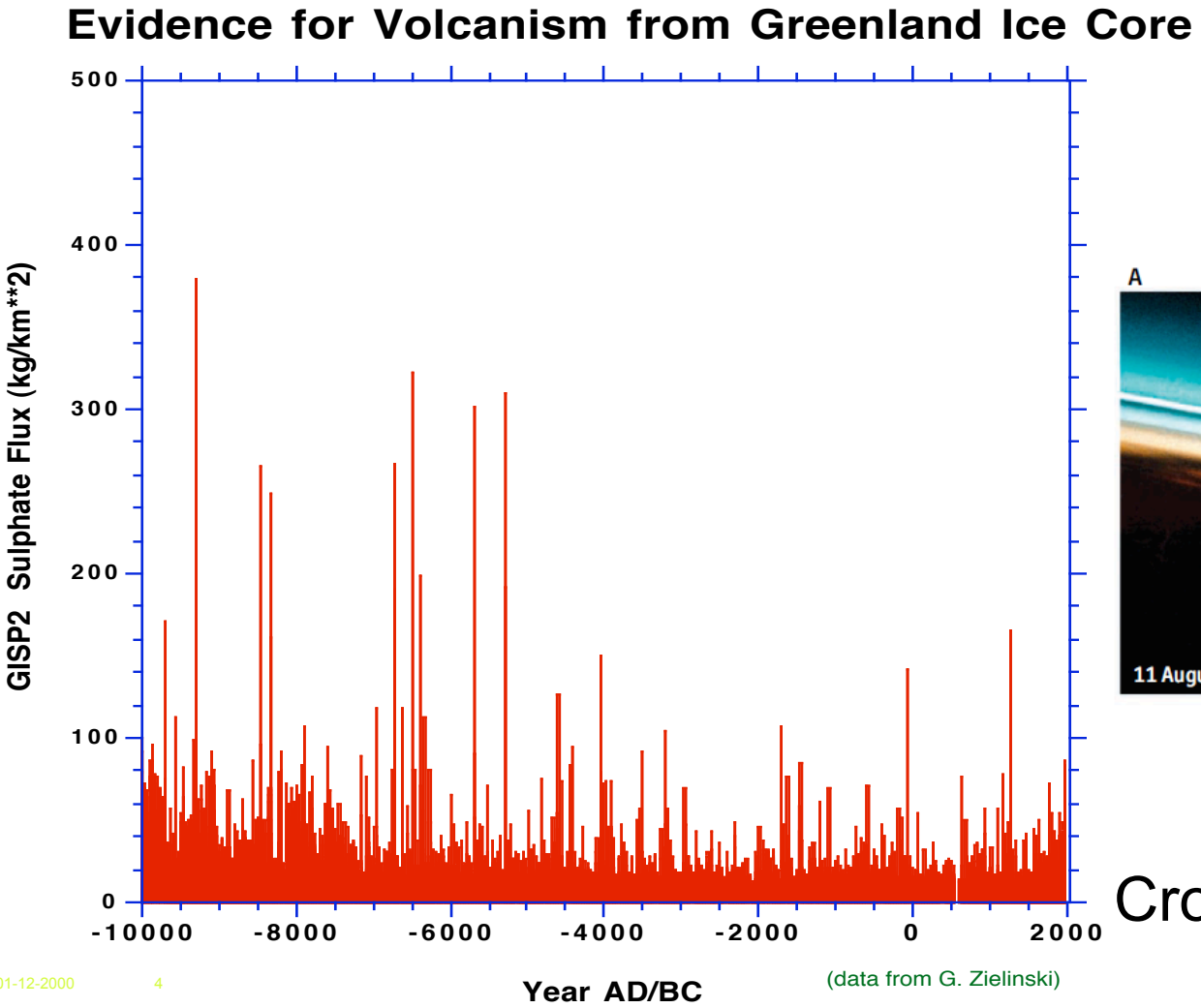


obser vation

Climate models => only small century-scale changes

Stouffer et al 2000

But there are also external influences on climate!



Pinatubo aerosols as seen from the space shuttle A

Crowley

Krakatau, 1883 (Robock

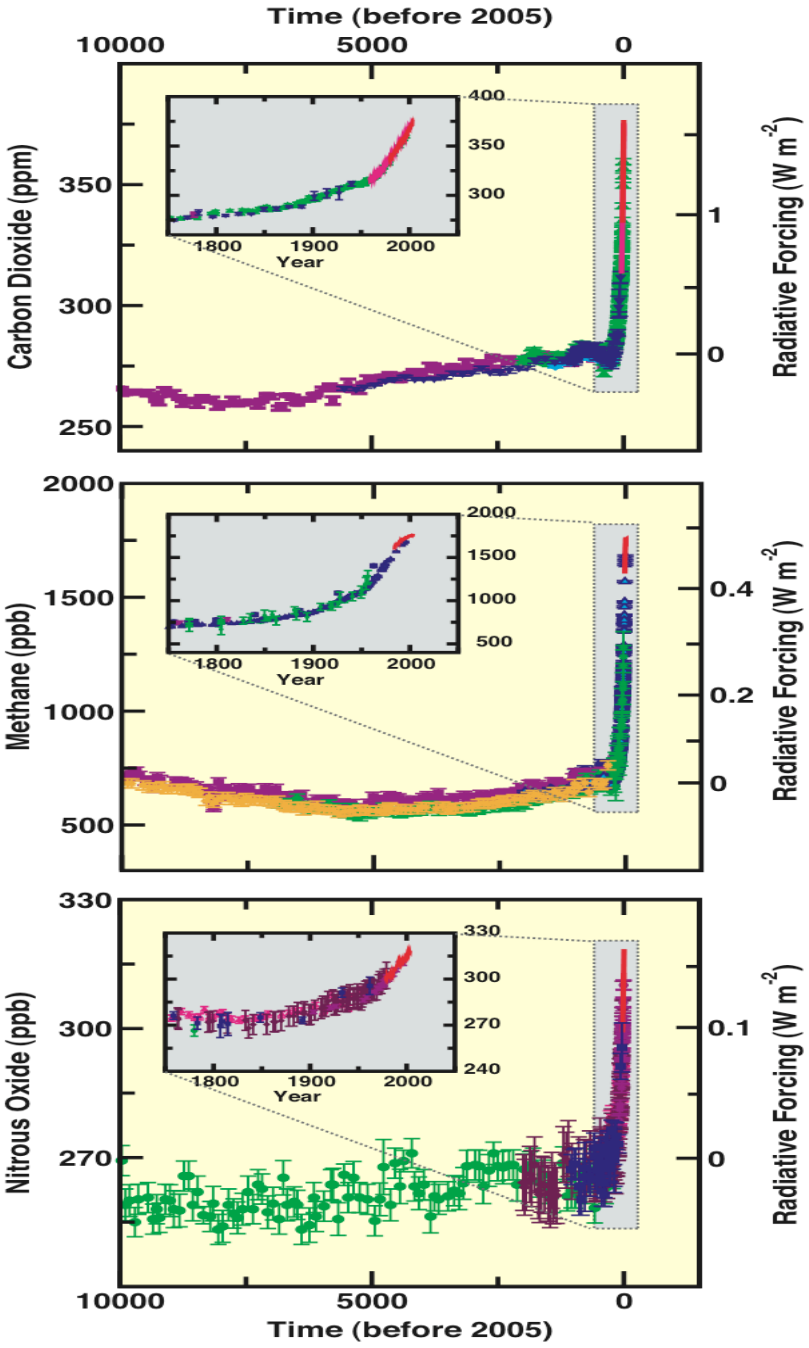
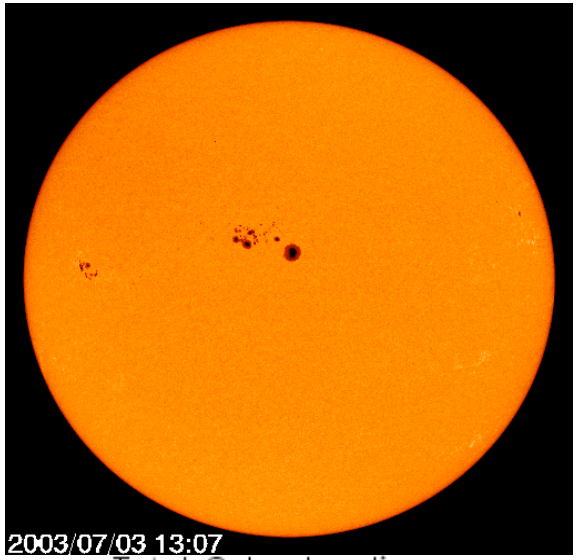
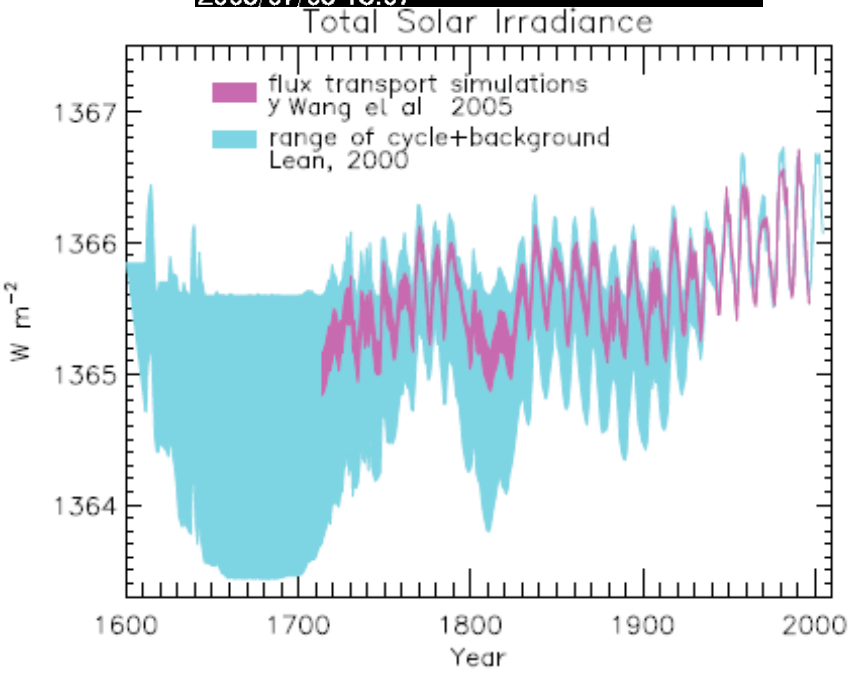


Fig. IPCC SPM-1

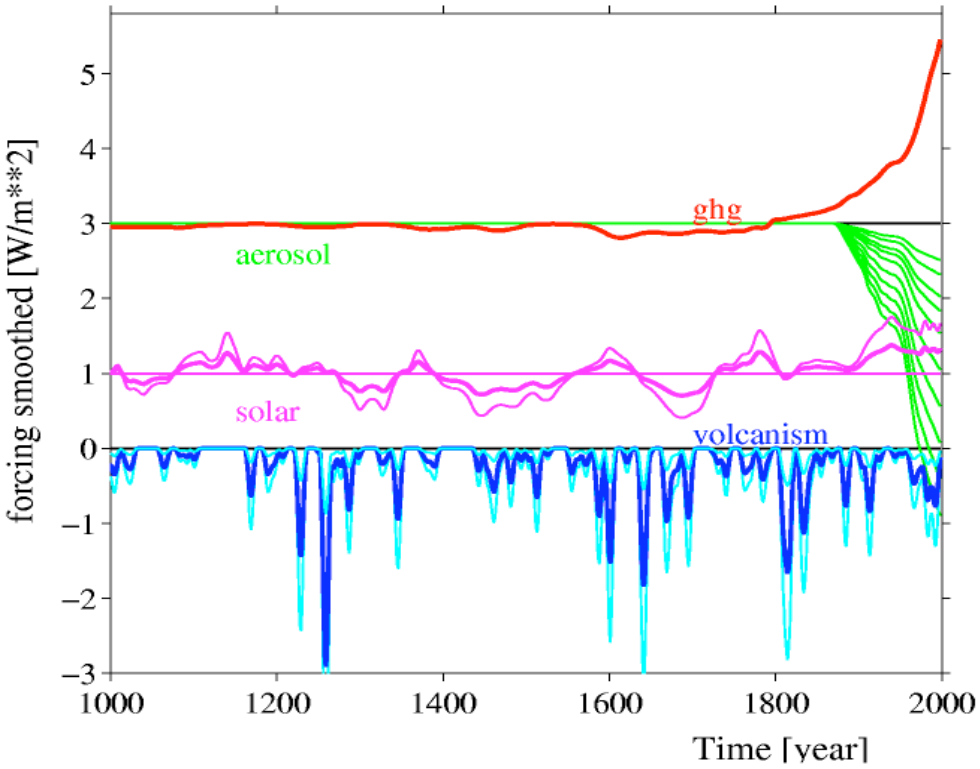
Greenhouse gases increased

Solar forcing changed





Climate forcing over the last millennium



Northern Hemispheric 30-90N mean radiative forcing (decadally smoothed) from Crowley

Attribution:

- **What caused climate variations**
- **Use fingerprints f_i for climate response to forcings**
- **Either 1 fingerprint for all combined f or several indiv. f_i**

Multiple regression:

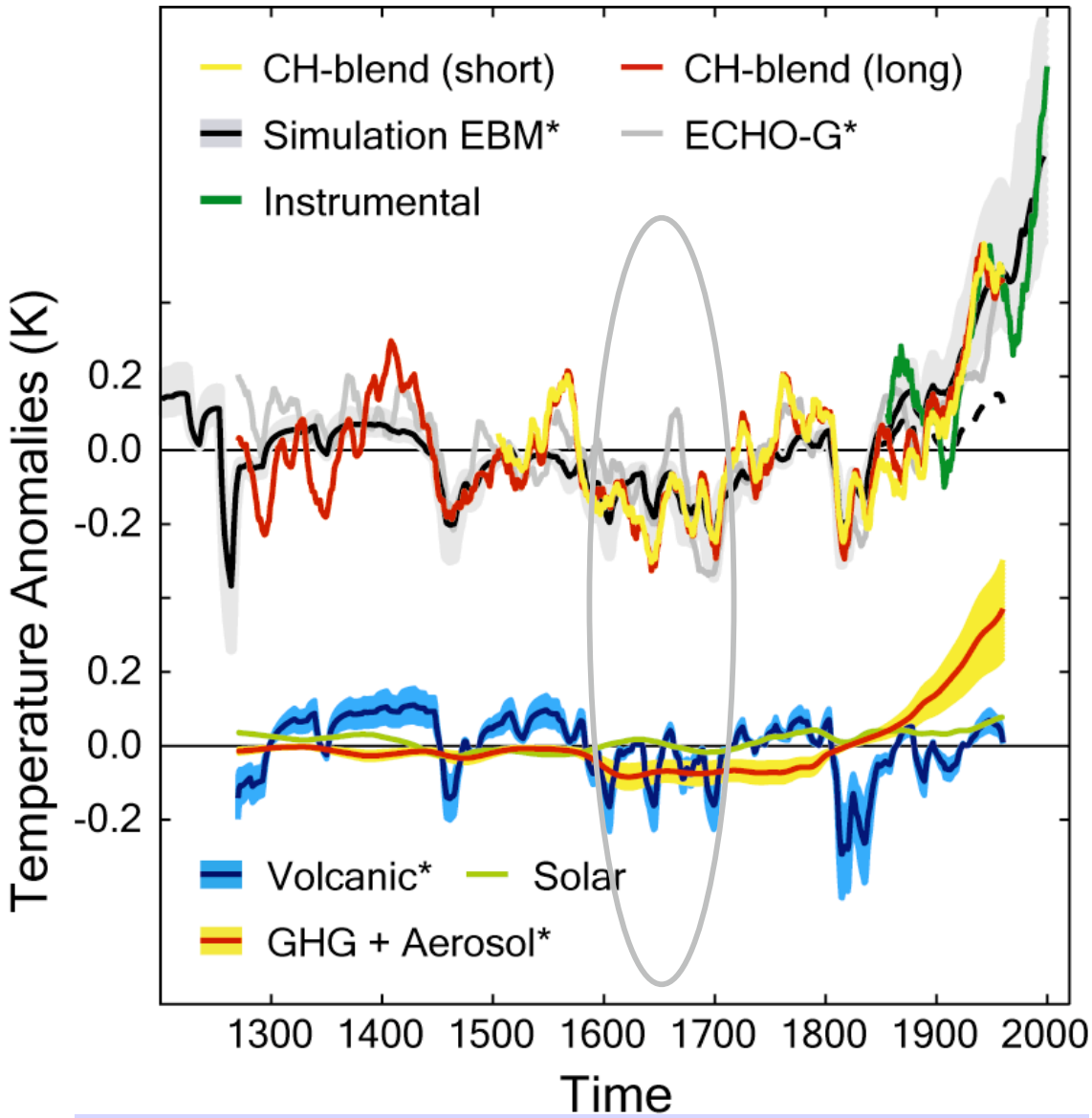
$$T_{proxy}(t) = \sum_{forcings} a_i f_i(t) + noise$$

Result (similar for other recons)

Fingerprint of all forcings combined compared to climate models

Contribution from invididual forcings

Errorbars: how much could fit be misestimated because of climate variability?

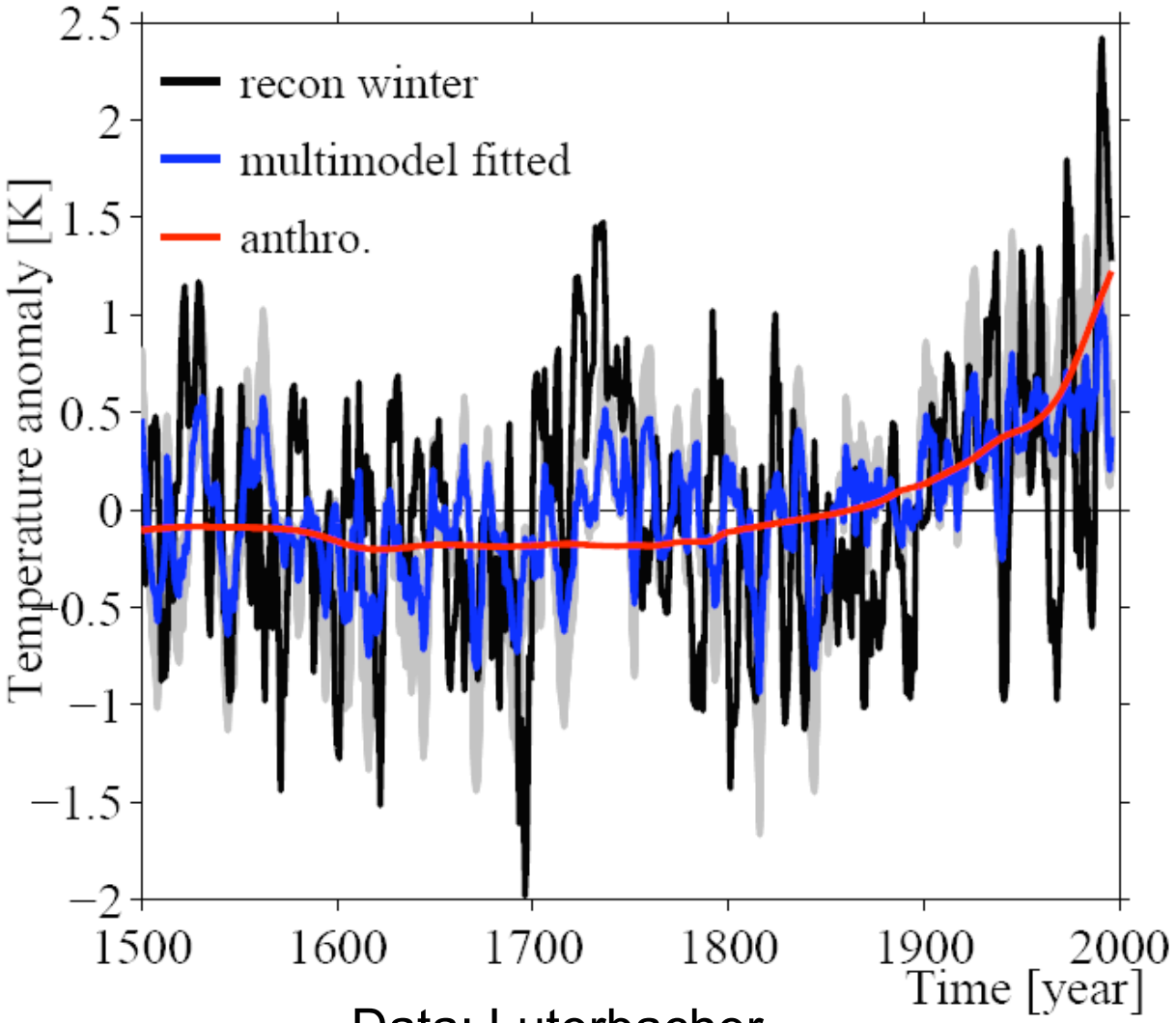


⇒Substantial influence by external forcing

⇒Volcanism, CO_2 and maybe solar radiation influenced the LIA

A similar result holds for European winter temperatures

- Reconstruction (5-yr sm)
- Multimodel fingerprint (average of three climate model simulations), scaled with uncertainty
- Understanding regional changes is an important frontier!



Data: Luterbacher

Similar results for other reconstructions and model runs

- A similar result is obtained for other reconstructions
- Last millennium variability is 'very unlikely' result of variability generated within climate system alone

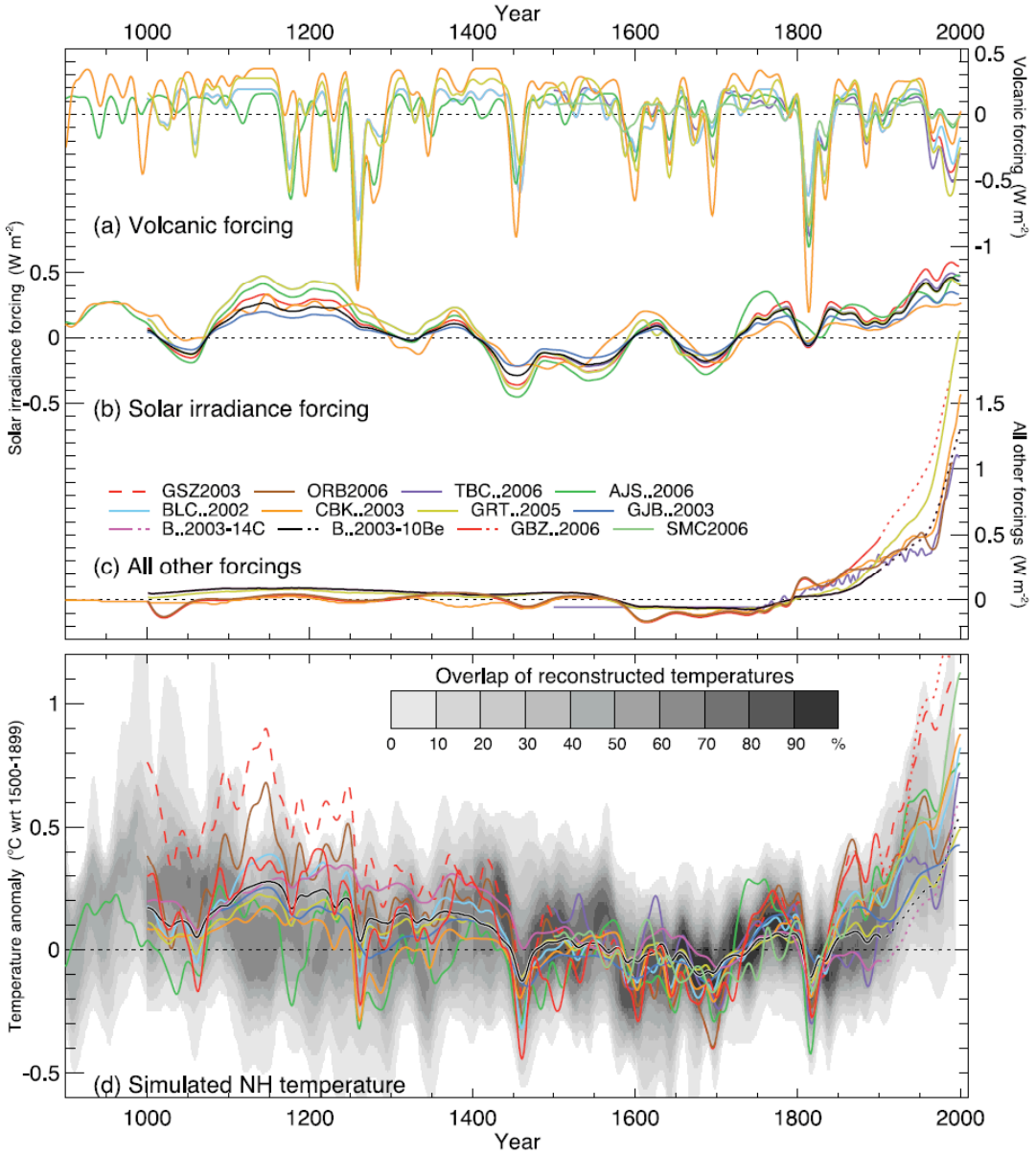


Fig. IPCC 6.13

Does this tell anything about future warming?

- Last millennium hemispheric temperatures are influenced by external forcing
- The strength of that response can provide information about the sensitivity of the climate system to external changes in its radiative budget
- The Equilibrium climate sensitivity is a measure of this: global mean warming in response to sustained doubling of CO2.

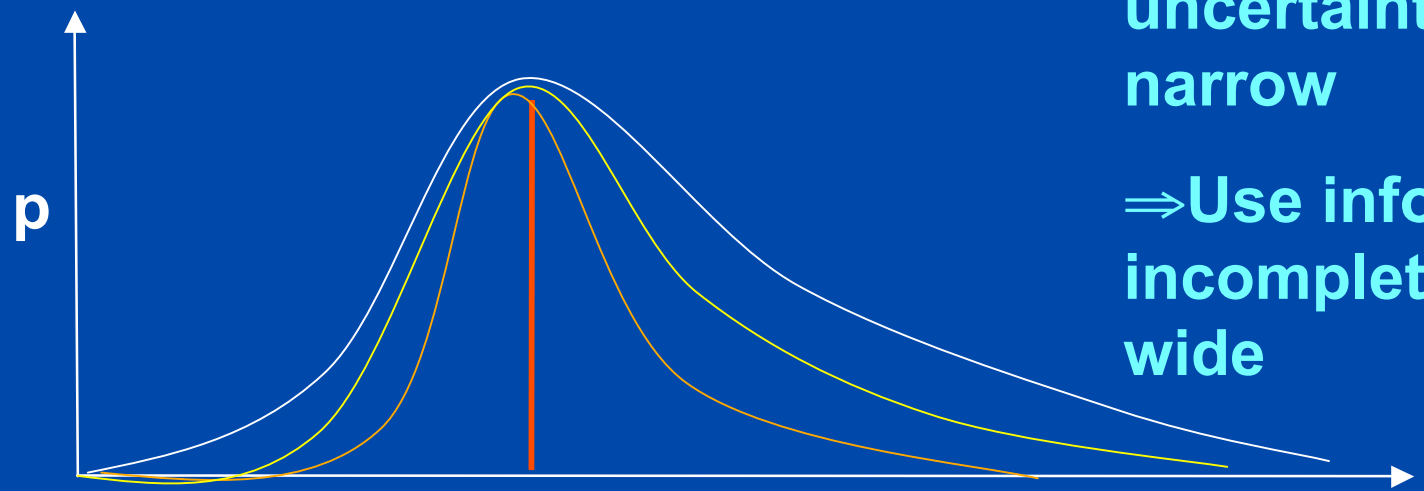
What climate sensitivity yields a good simulation of past 700 years?

Method: Make very many simulations with a simple model varying sensitivity and ocean heat uptake

- Find best fit simulation; estimate probability that others are same or better fit given uncertainty

1. Estimating equilibrium climate sensitivity

- Simulate observed climate change not with a single best fit, but a large ensemble of model simulations with different sensitivities
- Determine probability of models in agreement with data, given: internal variability, uncertainty in data, uncertainty in model



⇒Miss uncertainties: too narrow

⇒Use information incompletely: too wide

Estimated PDF for climate sensitivity

Response small ~ climate variability

Larger amplitude

Smaller forcing

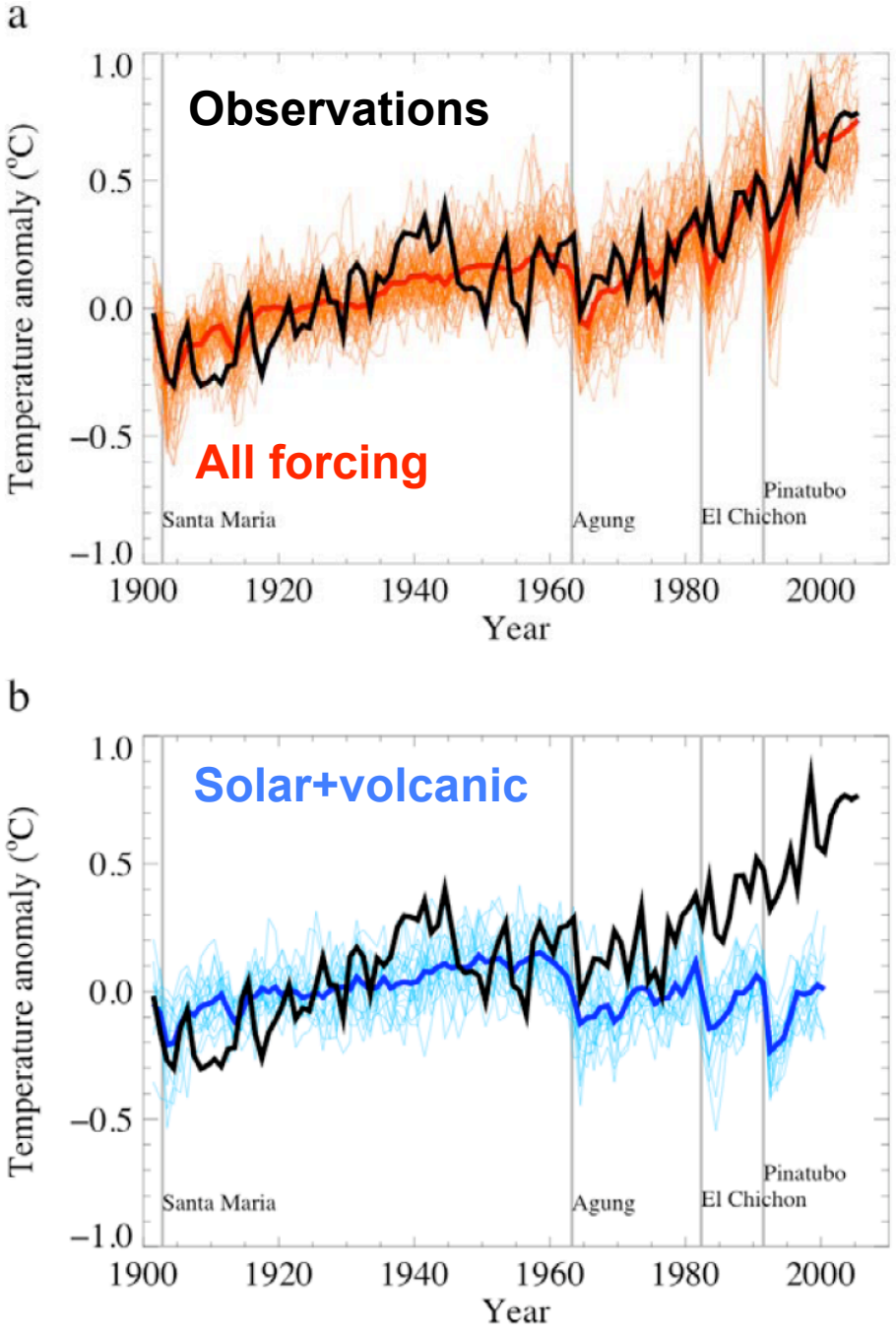
Nonlinear relationship sensitivity – volcanic cooling

2. What can we learn from the 20th century?

Simple illustration

Attribution: Apply fingerprint method again

Use space-time information; apply signal-to-noise optimizing metric



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Attribution yields estimates (with errorbars) of warming caused by external forcing

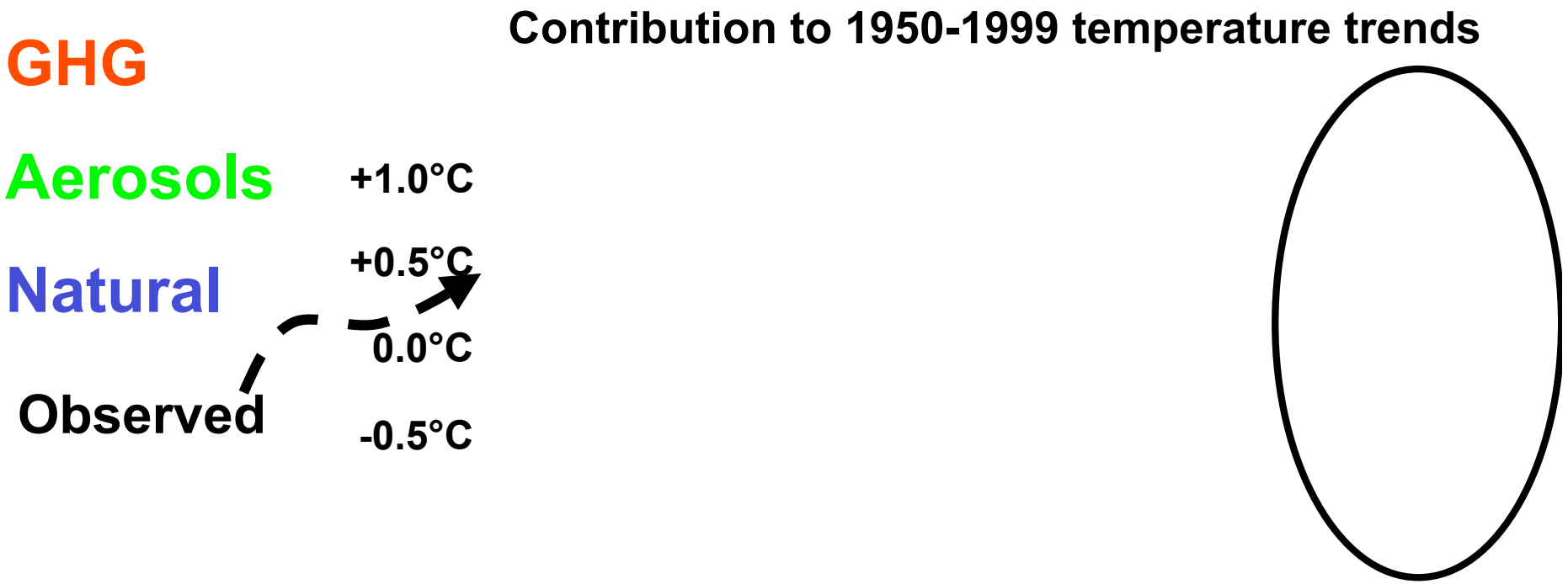


Fig. 9.9c

Anthropogenic greenhouse gas increases *very likely* caused most of the observed warming since mid-20th century

20th century also yields an estimate of climate sensitivity as do other periods/lines of research

How to move on in sensitivity?

-Each line of evidence yields low sensitivity unlikely => climate change will not be small

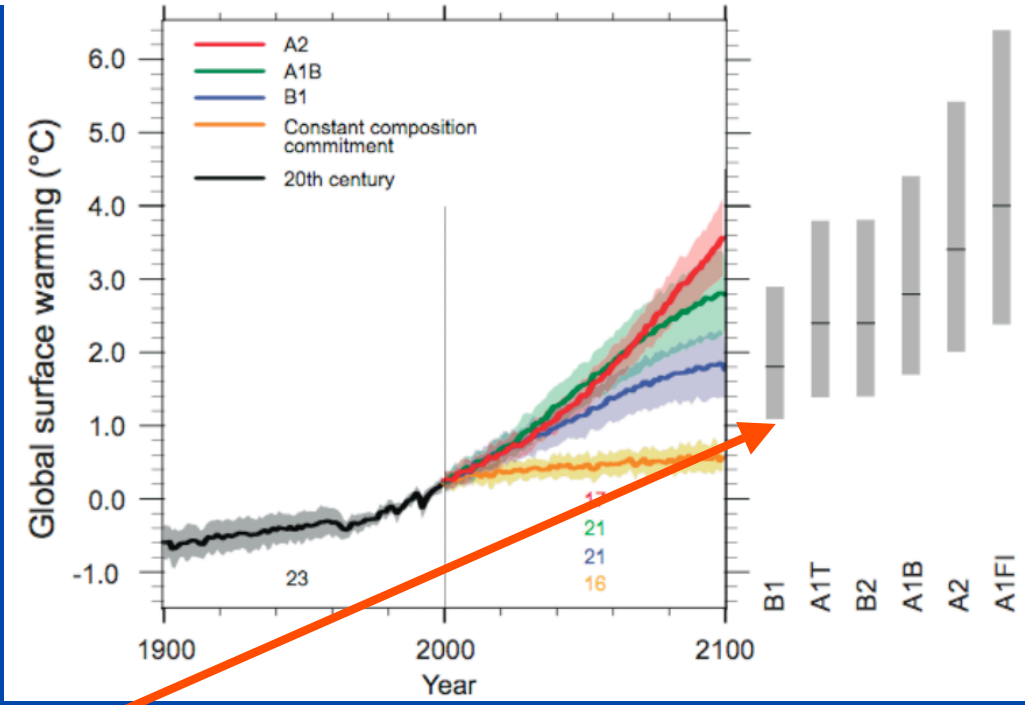
-The combined evidence is stronger than each individual line

-IPCC 'very likely' > 1.5°C, likely range 2-4.5°C

Hegerl et al. 06

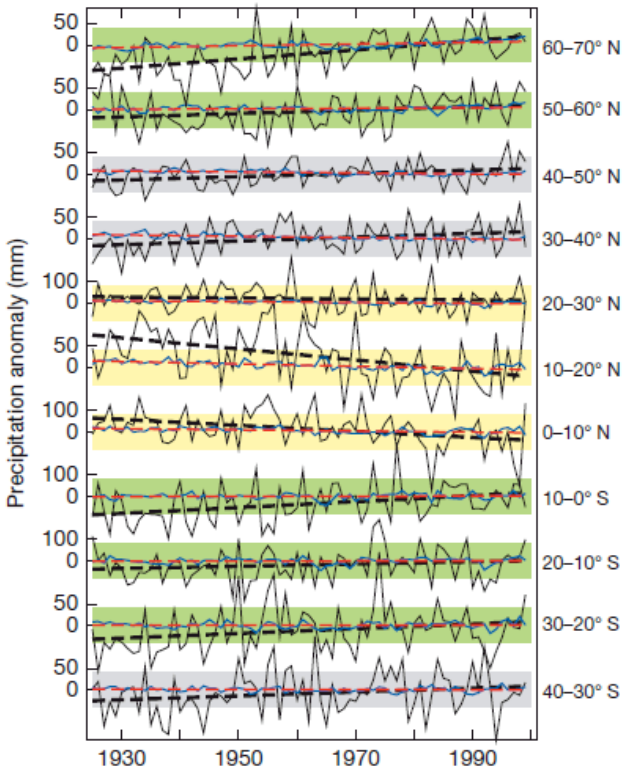
Results have been used to quantify predictions

- Predictions: Raw climate model simulations
- Adjusting predictions and quantifying their uncertainty
- This will become more important in the future, and more feasible
- It is based more on the rate of warming at present than equilibrium sensitivity



Climate change predictions in IPCC report

Precipitation – do predictions need adjustment?



From Zhang et al., 2007

Observed changes show pattern of precipitation changes that is expected to intensify in the future

Conclusions

- Climate varied in the past, but we increasingly understand why
- Predictions have made use of that information
- Hot areas: understanding precipitation and regional changes
- We have used climate in the past for predictions, and increasingly will!