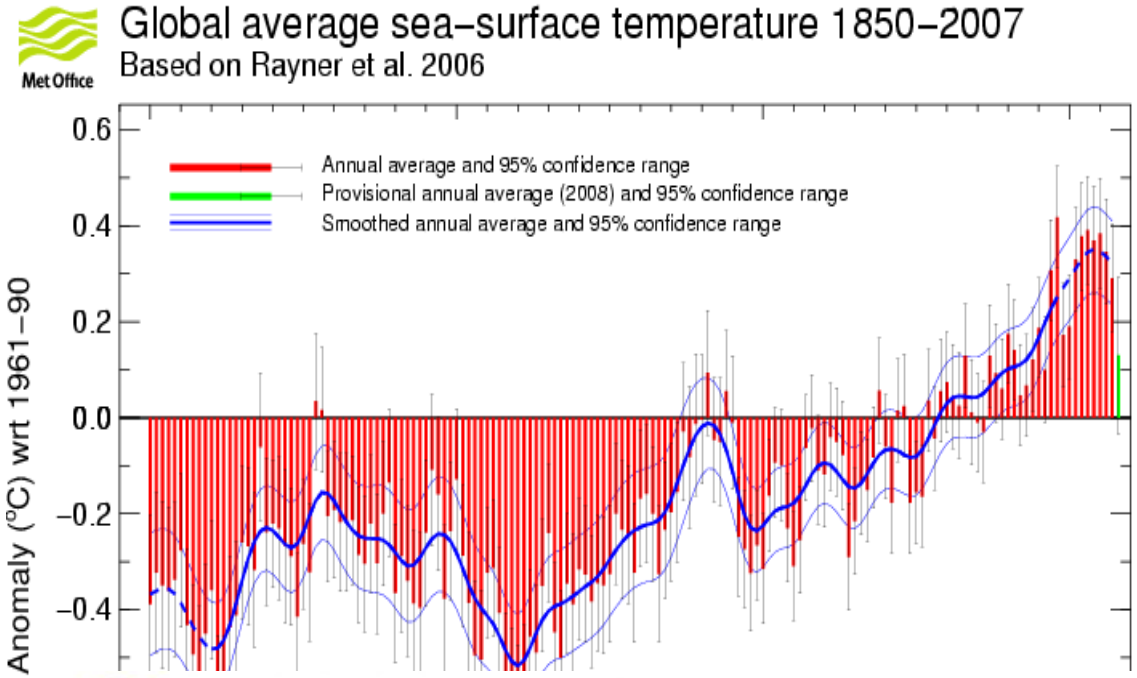
Met Office
Hadley Centre

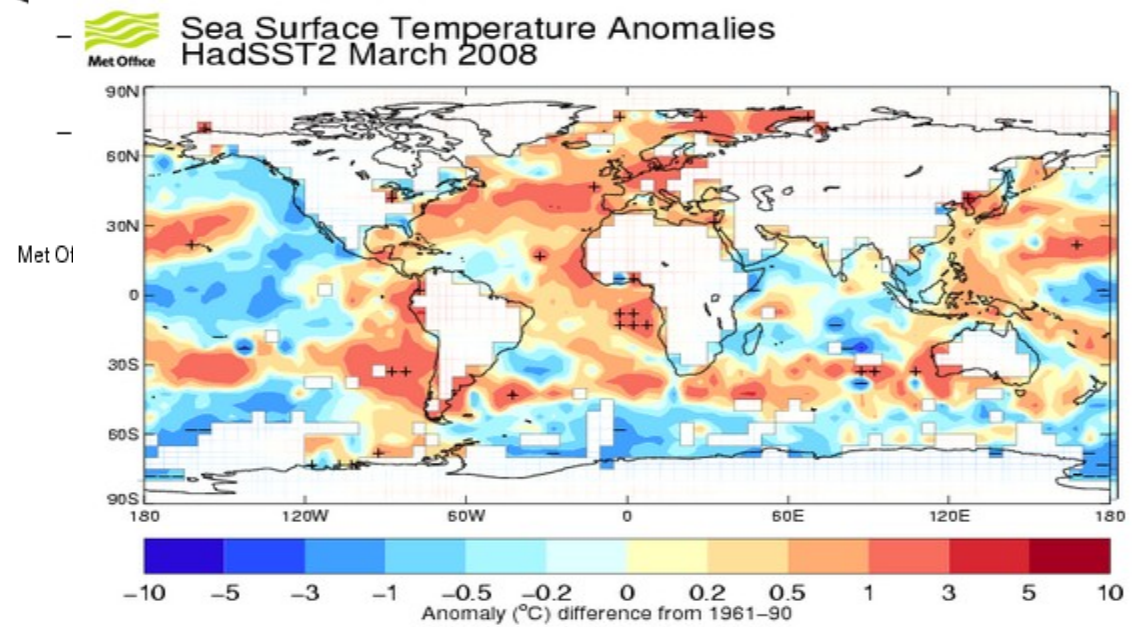
The use of marine data for attribution of climate change and constraining climate predictions

Peter Stott, Climar III, Thursday 8 May 2008

Met Office
Hadley Centre

- The use of marine data to:
- Quantify the contribution of human influence to observed change and variability ?
- Constrain climate predictions ?



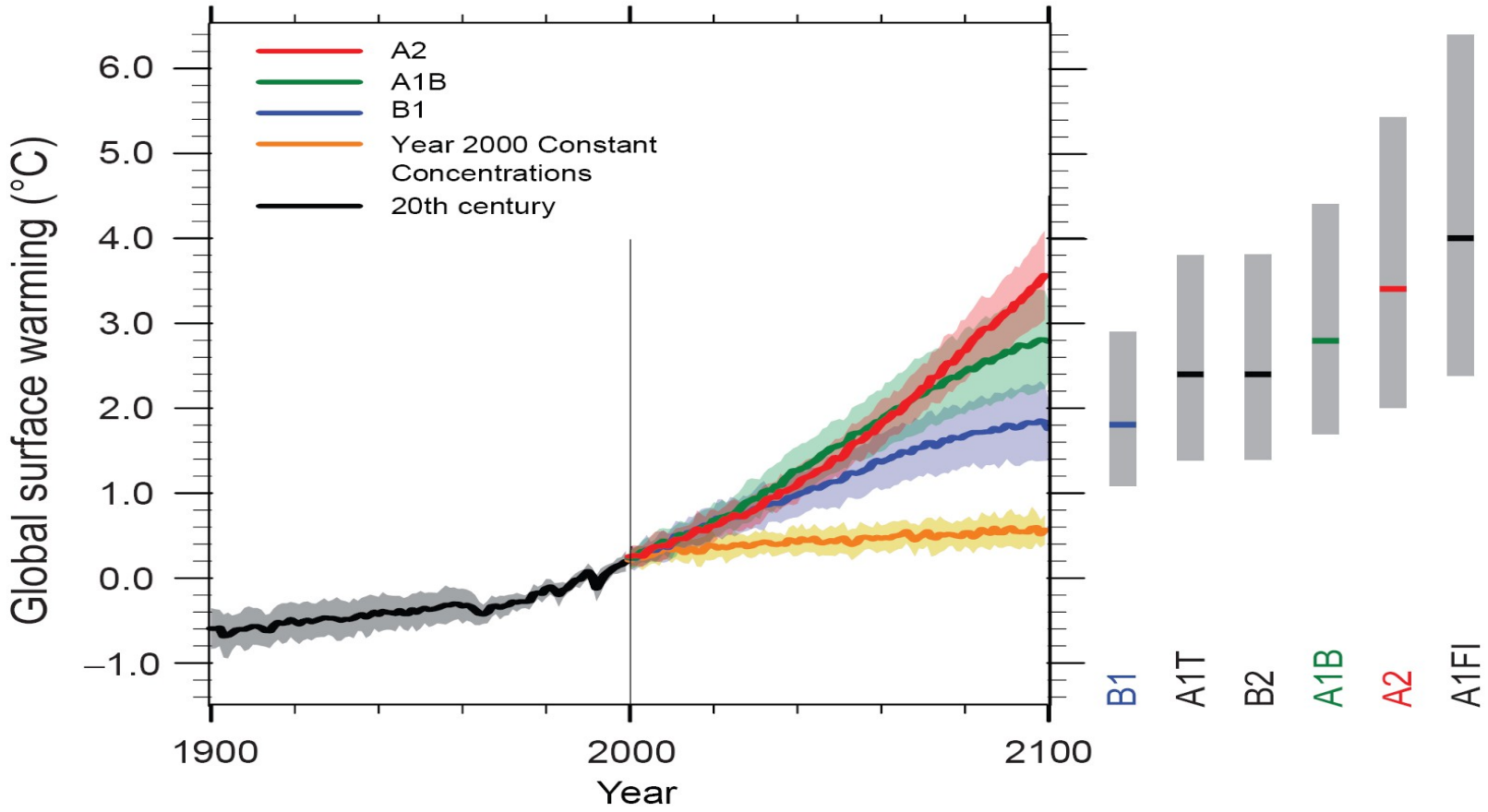


www.hadobs.org

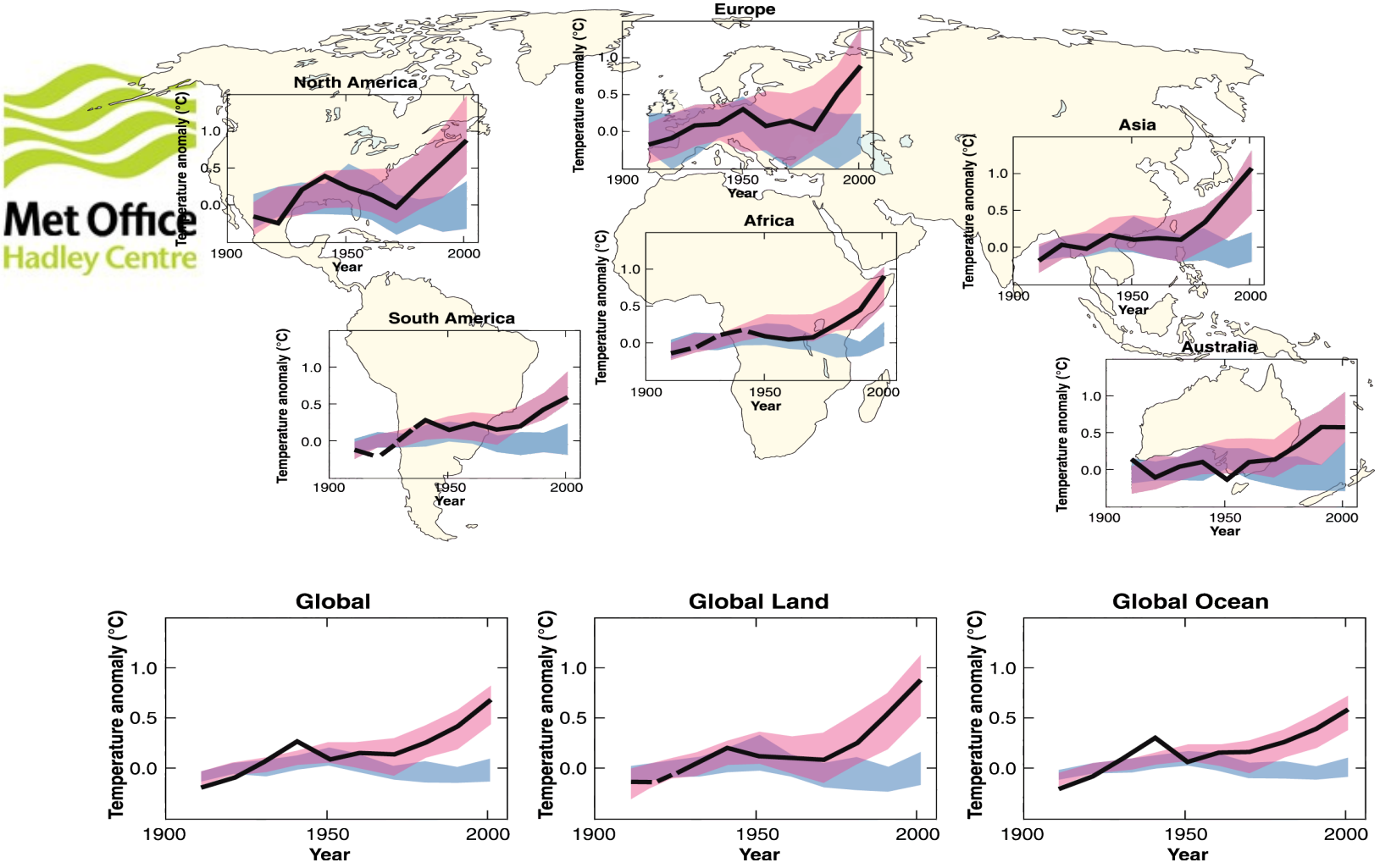
Contents

- AR4 : Observational constraints on future global warming
- Evidence for climate models having too great a deep ocean heat uptake and a tendency to underestimate transient climate response
- Attribution of ocean heat content changes
  - Do models underestimate observed variability ?
- Attribution of sea surface temperature changes
  - Atlantic and Pacific cyclogenesis regions
  - Observational uncertainty
- Can we attribute individual weather events ?
  - Attributable SSTs
- Salinity changes

IPCC AR4 provided uncertainty ranges of future global mean warming based on likelihood weighting of climate models derived from observations



Knutti et al, 2008 In press

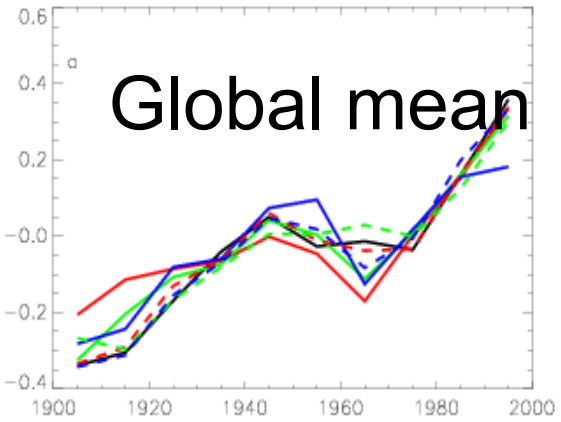


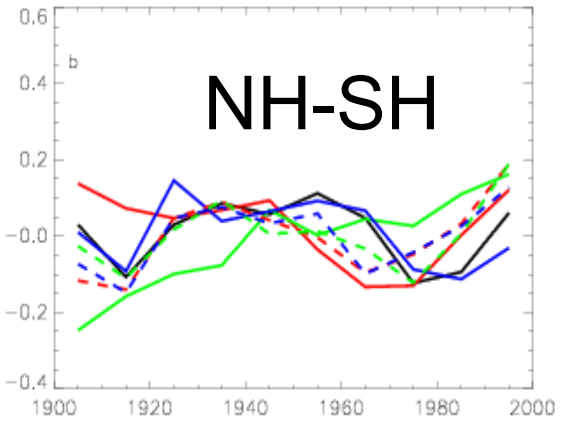
Most global warming *very likely* due to increase in anthropogenic GHG concentrations

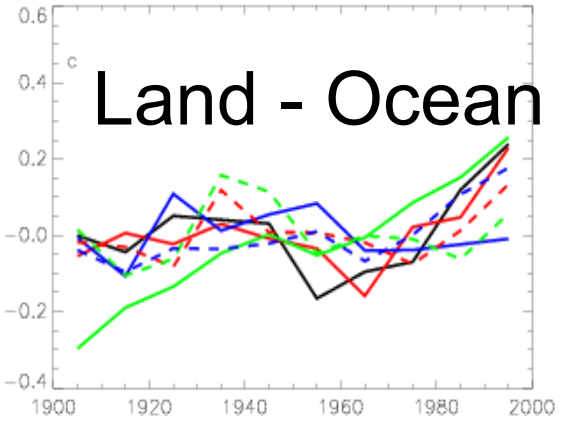
Likely anthropogenic warming on continental scale

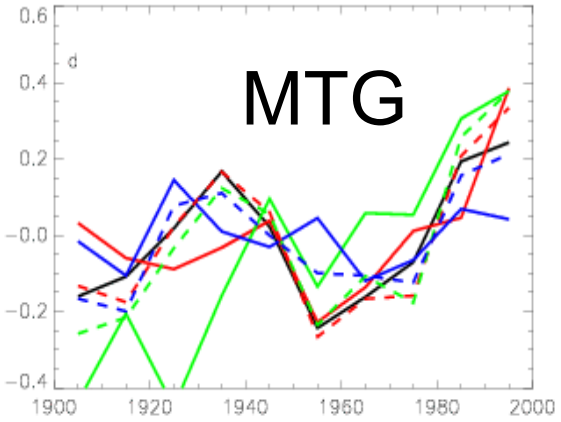
Optimal detection determines scaling of responses to individual forcings that are consistent with observed record

$$\text{Obs} = \beta_{GHG}\,GHG + \beta_{SUL}\,SUL + \beta_{NAT}\,NAT + \text{Noise}$$









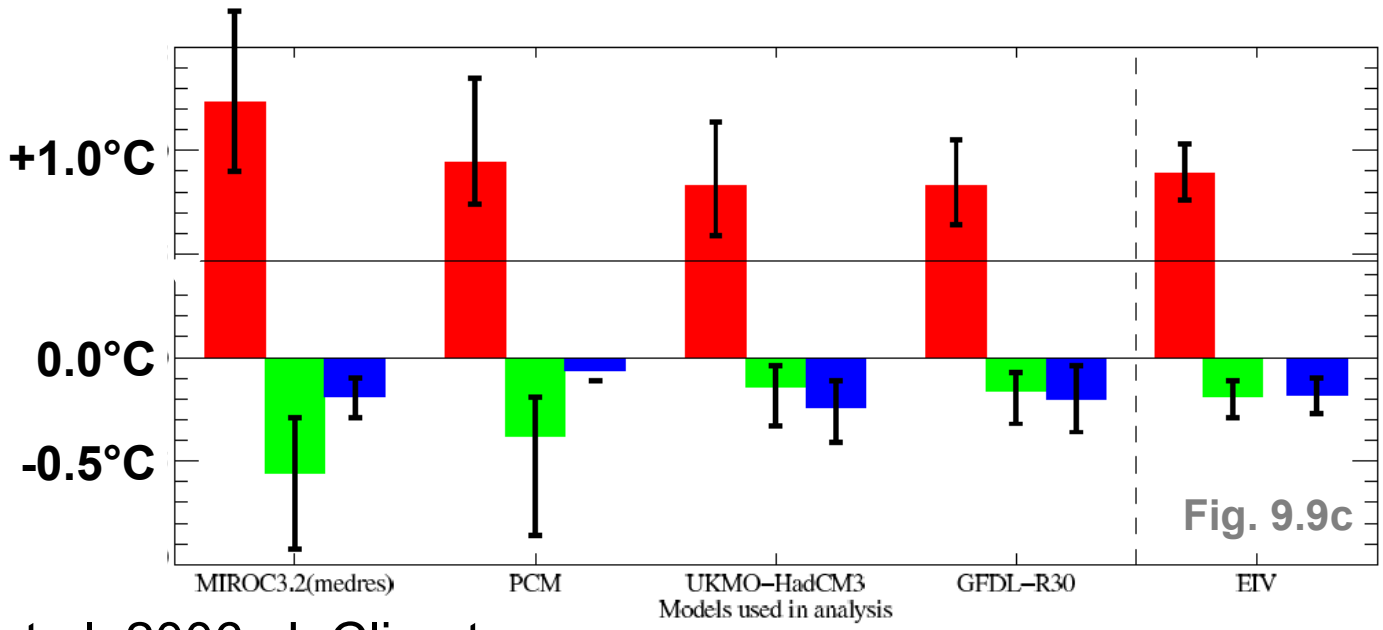
Attribution : quantifying contributions

GHG

Aerosols

Natural

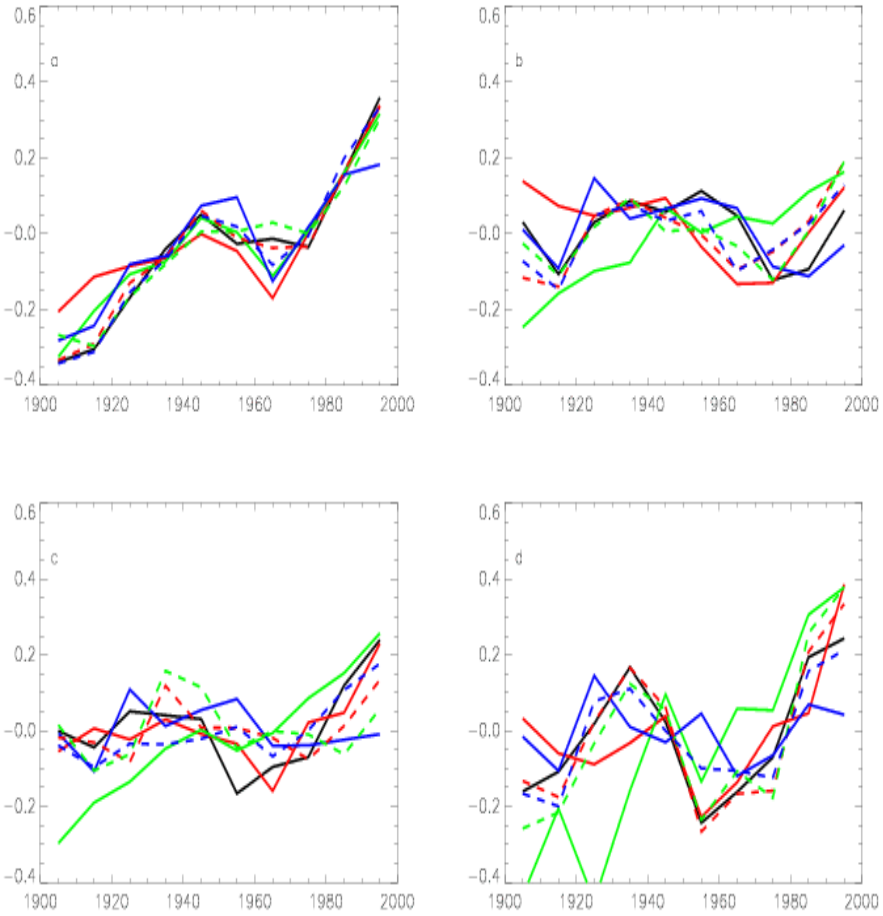
Observed

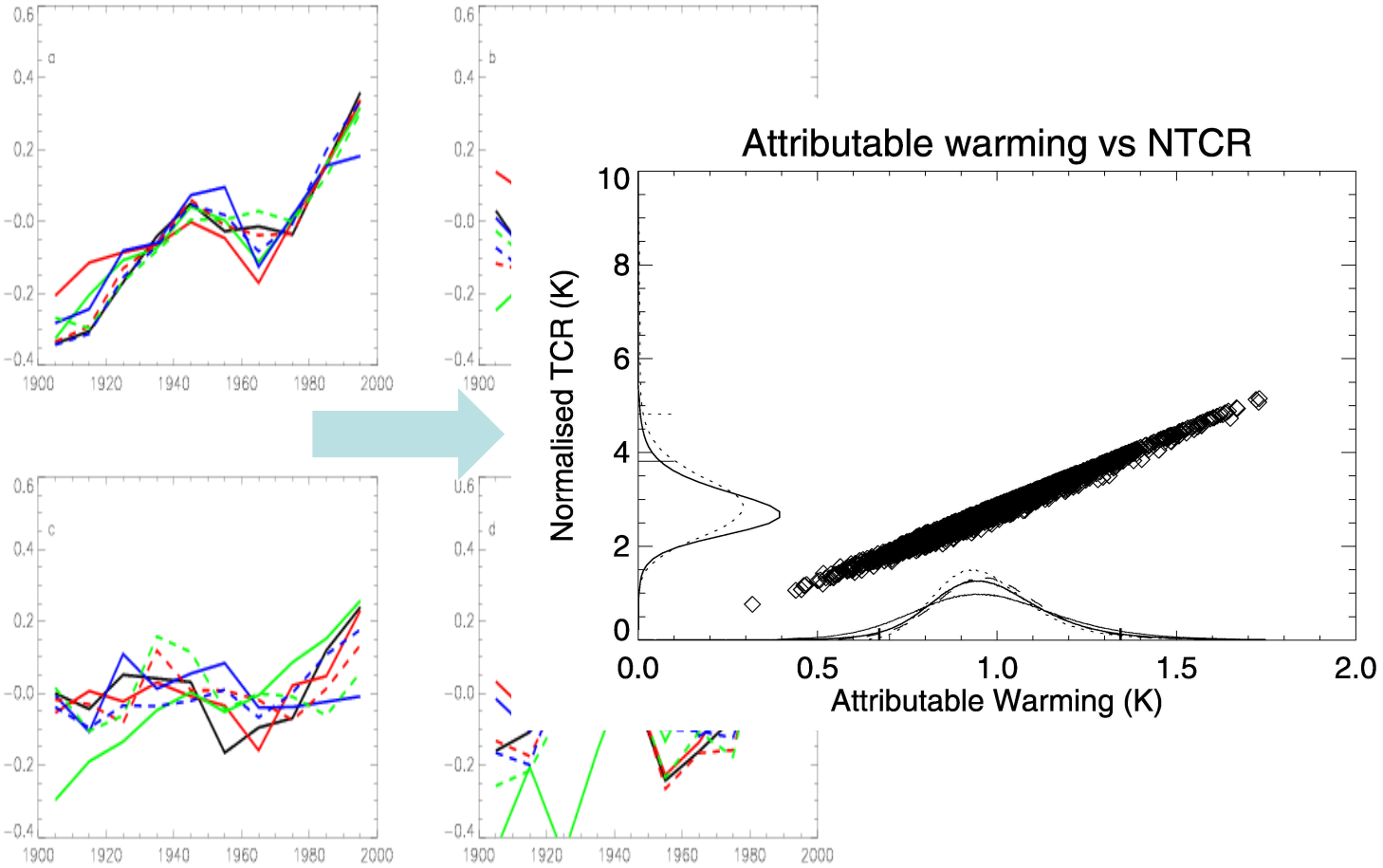


See Stott, Mitchell et al, 2006, J. Climate

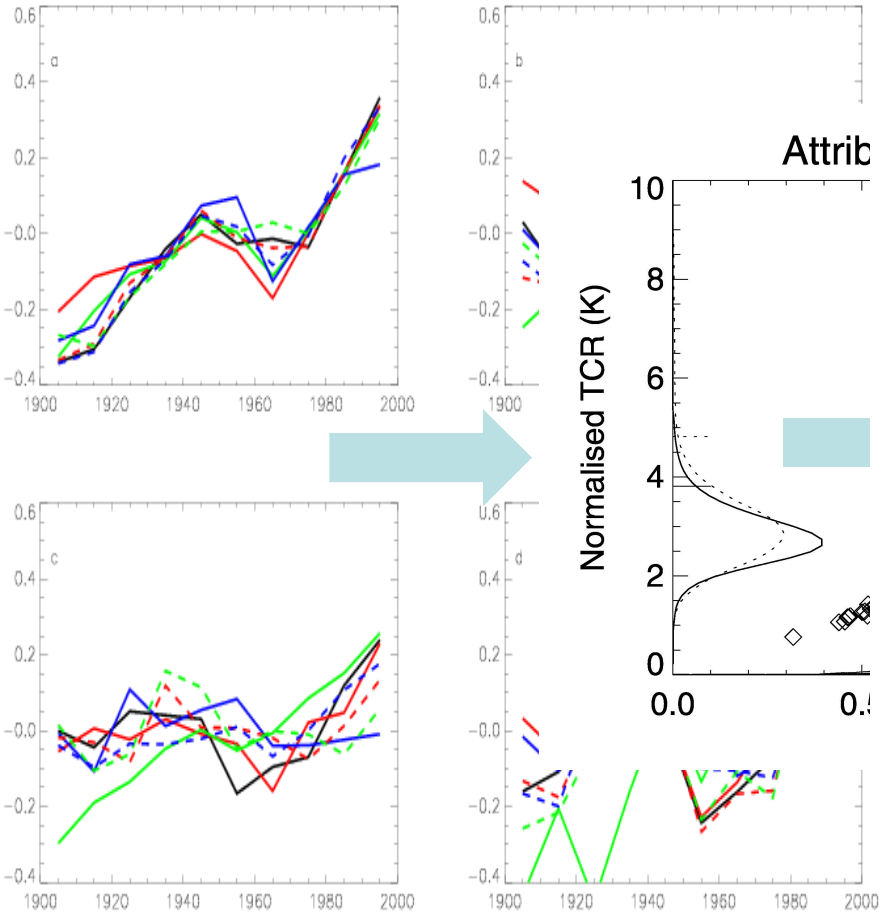
- It is likely that increases in greenhouse gas concentrations would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some of the warming that would otherwise have taken place.

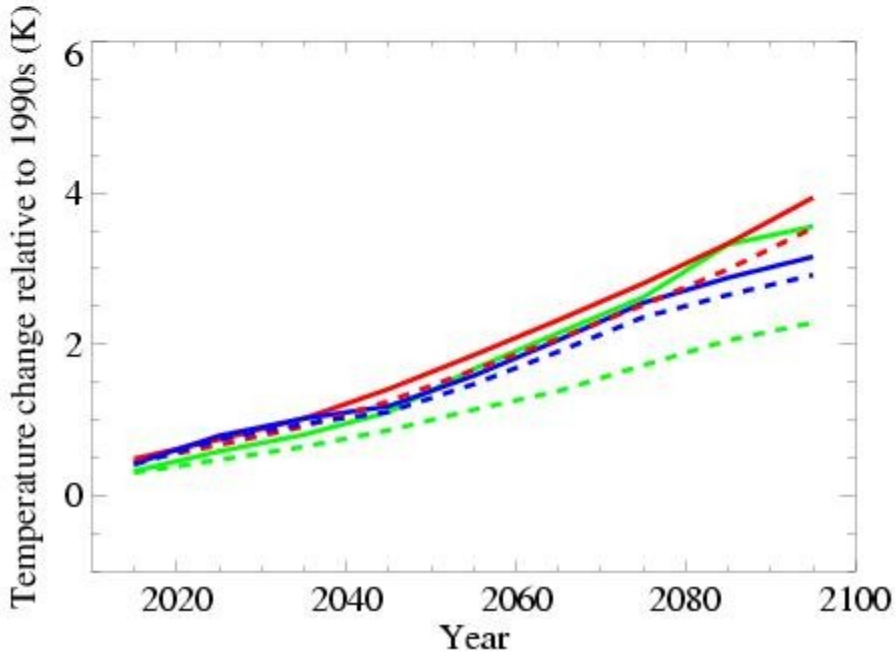
Warming attributable to anthropogenic greenhouse gases is strongly related to transient climate response to future greenhouse gas increases



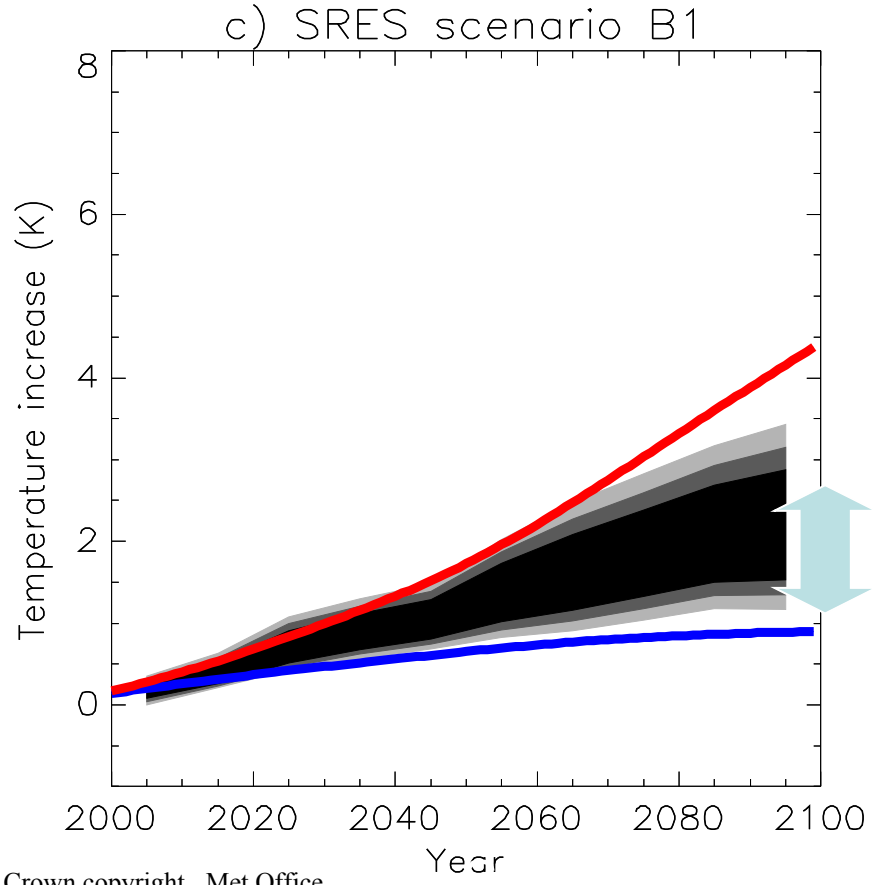


Met Office
Hadley Centre





Observationally constrained uncertainties in global mean temperature are narrower than implied by uncertainties in aerosol forcing but wider than AR4 ensemble of opportunity



Red curve : future warming rates implied by large present day aerosol cooling.

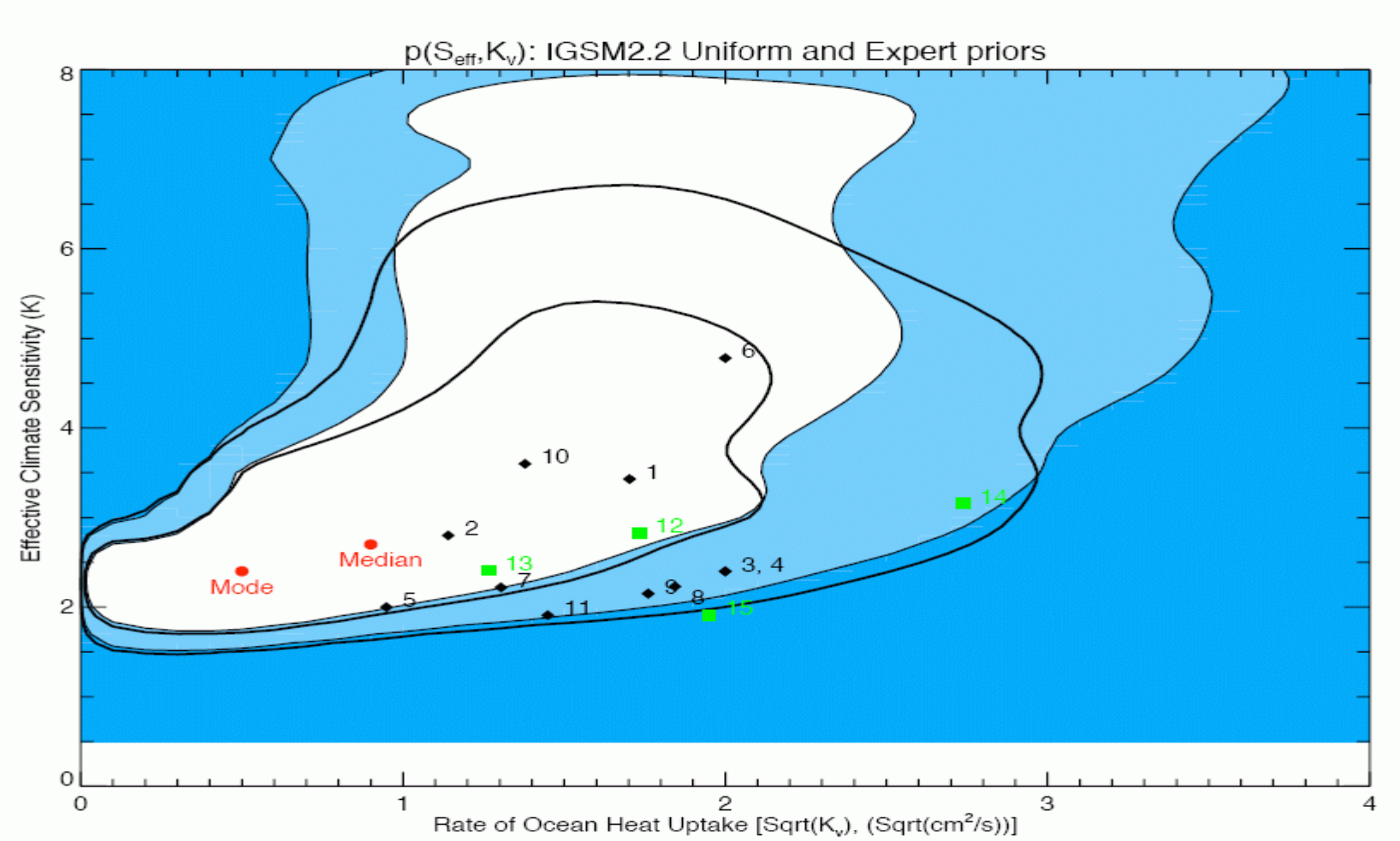
Blue curve : future warming rates implied by zero present day aerosol cooling.

- Andreae et al, Nature, 2005.
- Stott and Forest, 2007 Phil. Trans. Roy. Soc.; Stott et al, Tellus, 2007.

Met Office Hadley Centre

Evidence for models' rate of deep-ocean heat uptake greater than the observed implying a bias in the predictions.

Forest et al, 2008; Stott and Forest, 2007.

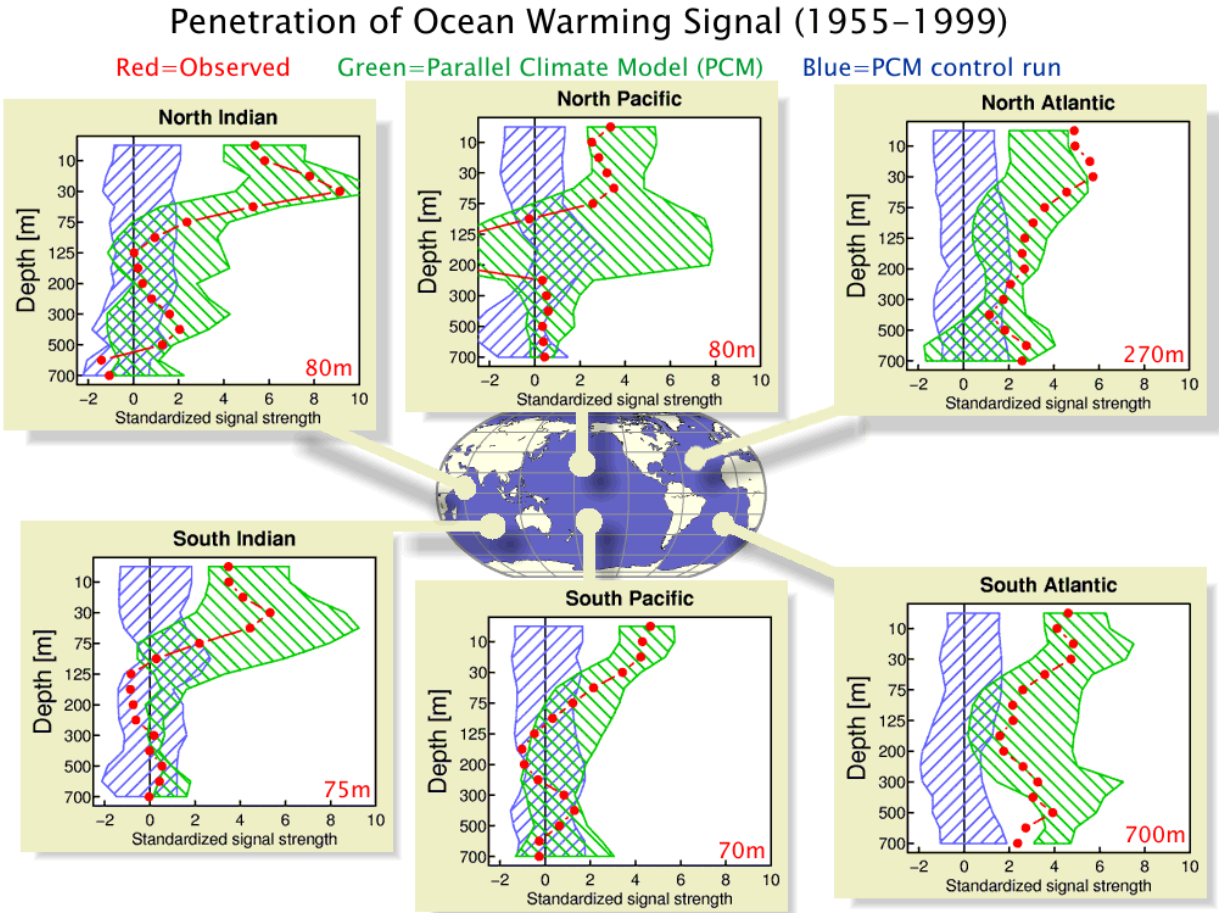


Human-induced warming of the ocean has been detected

Natural internal variability (blue range)

Observations (red circles)

Simulations including anthropogenic factors (green range)



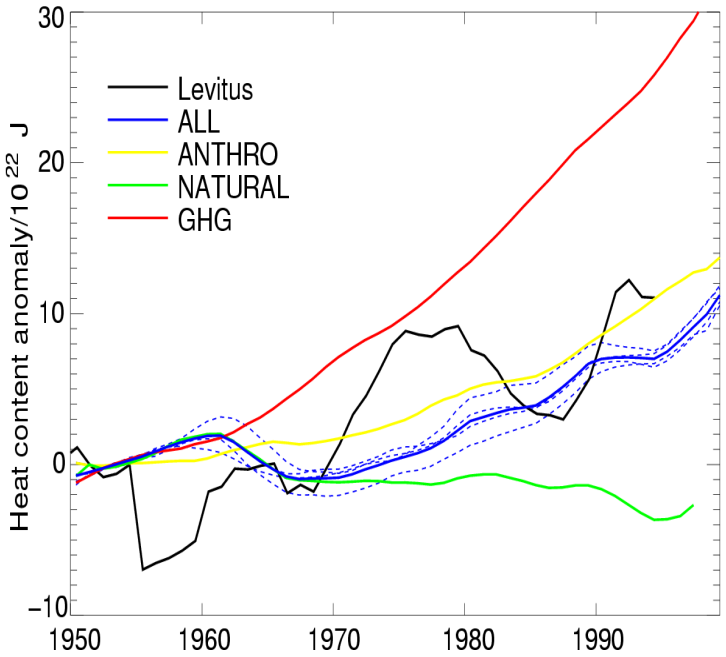
Penetration of Human-Induced Warming into the World's Oceans

Tim P. Barnett,[1*] David W. Pierce,[1] Krishna M. AchutaRao,[2] Peter J. Gleckler,[2] Benjamin D. Santer,[2] Jonathan M. Gregory,[3] Warren M. Washington[4]

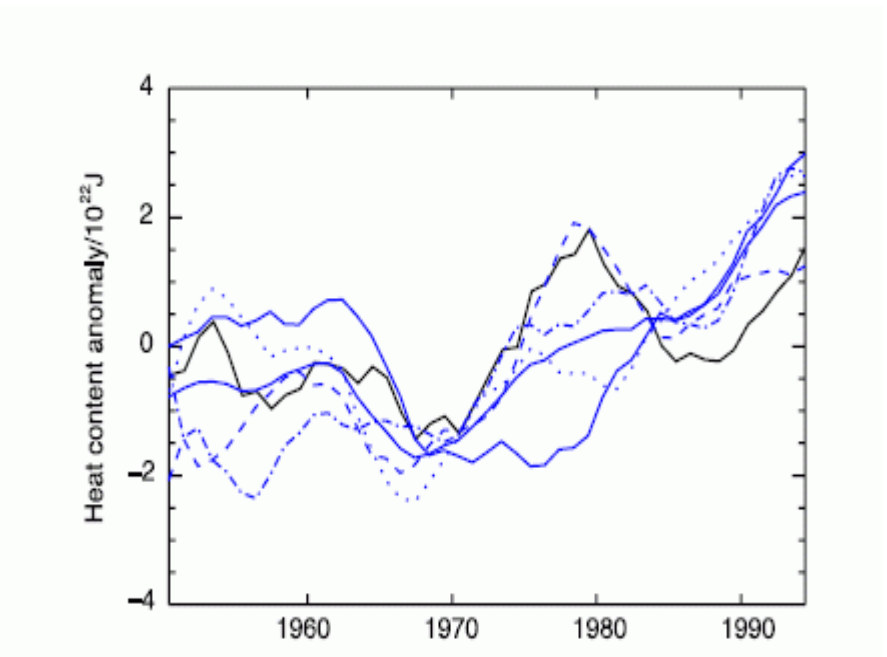
Barnett *et al.*, *Science* (2005)

Levitus et al (2005) dataset

Confidence in attribution of ocean heat content changes undermined by apparent poor simulation of variability



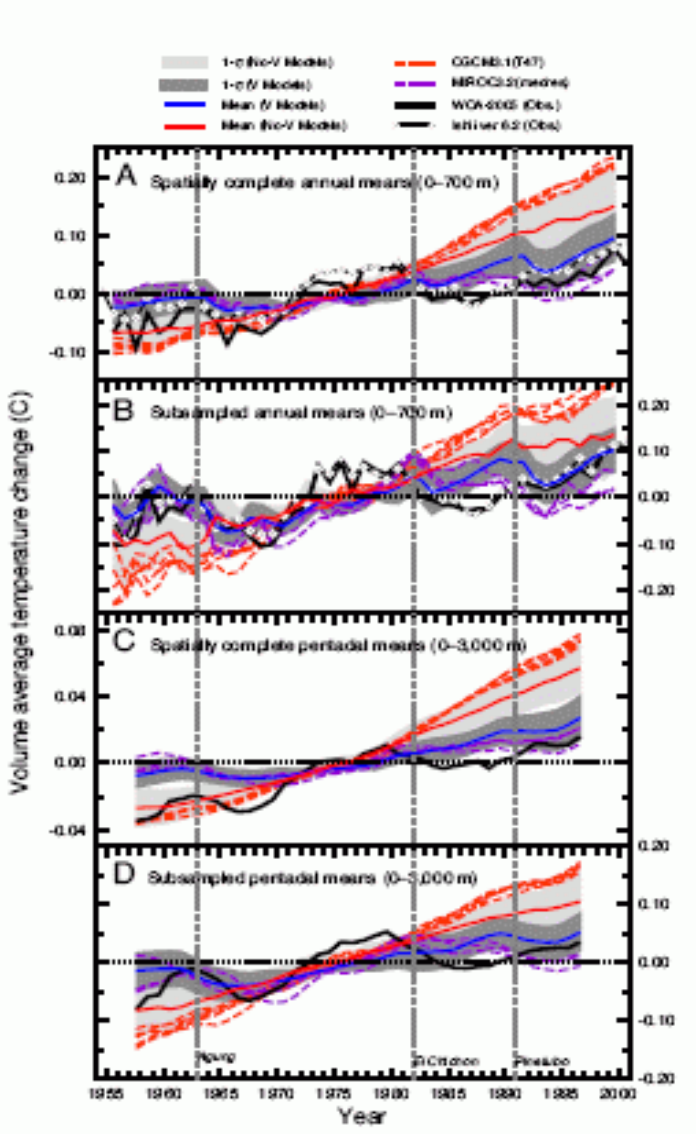
Global ocean

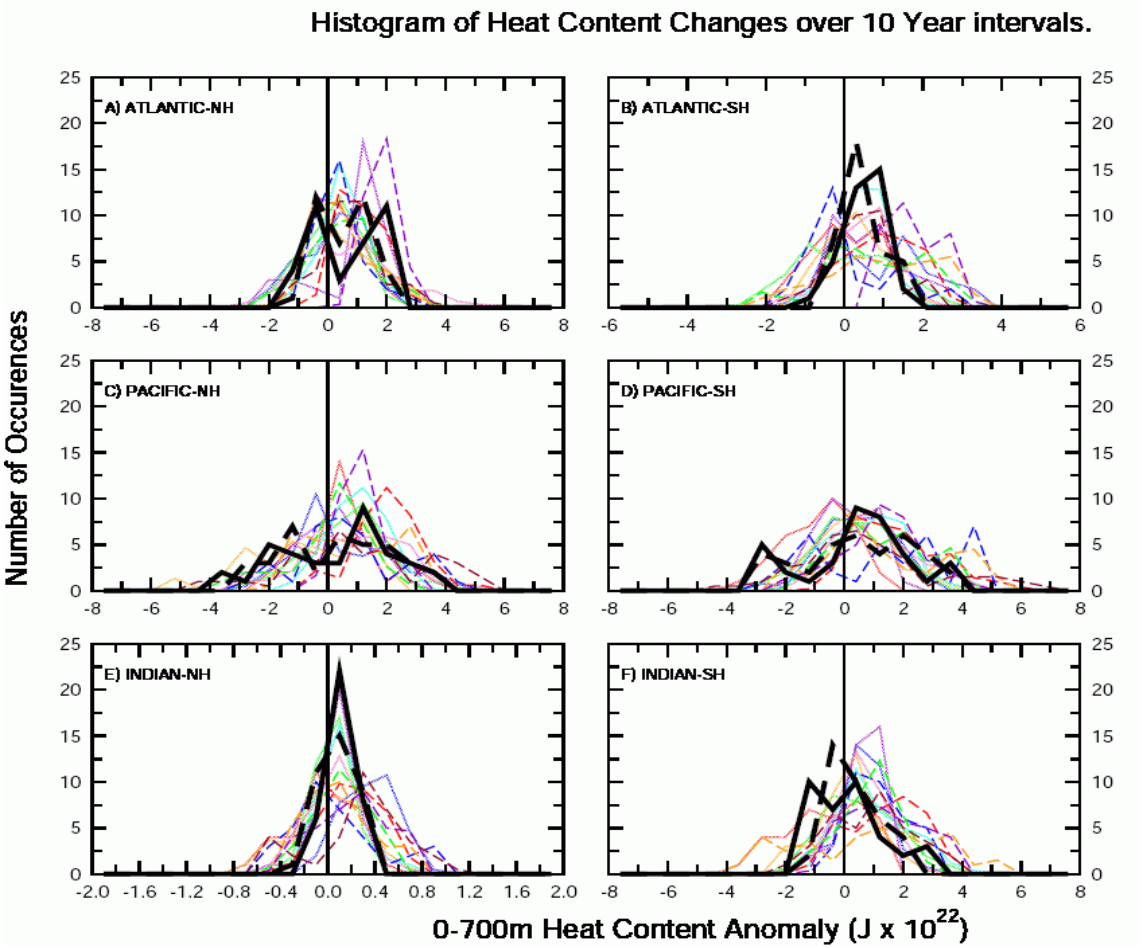


Upper Atlantic ocean

Gregory et al, GRL,2004

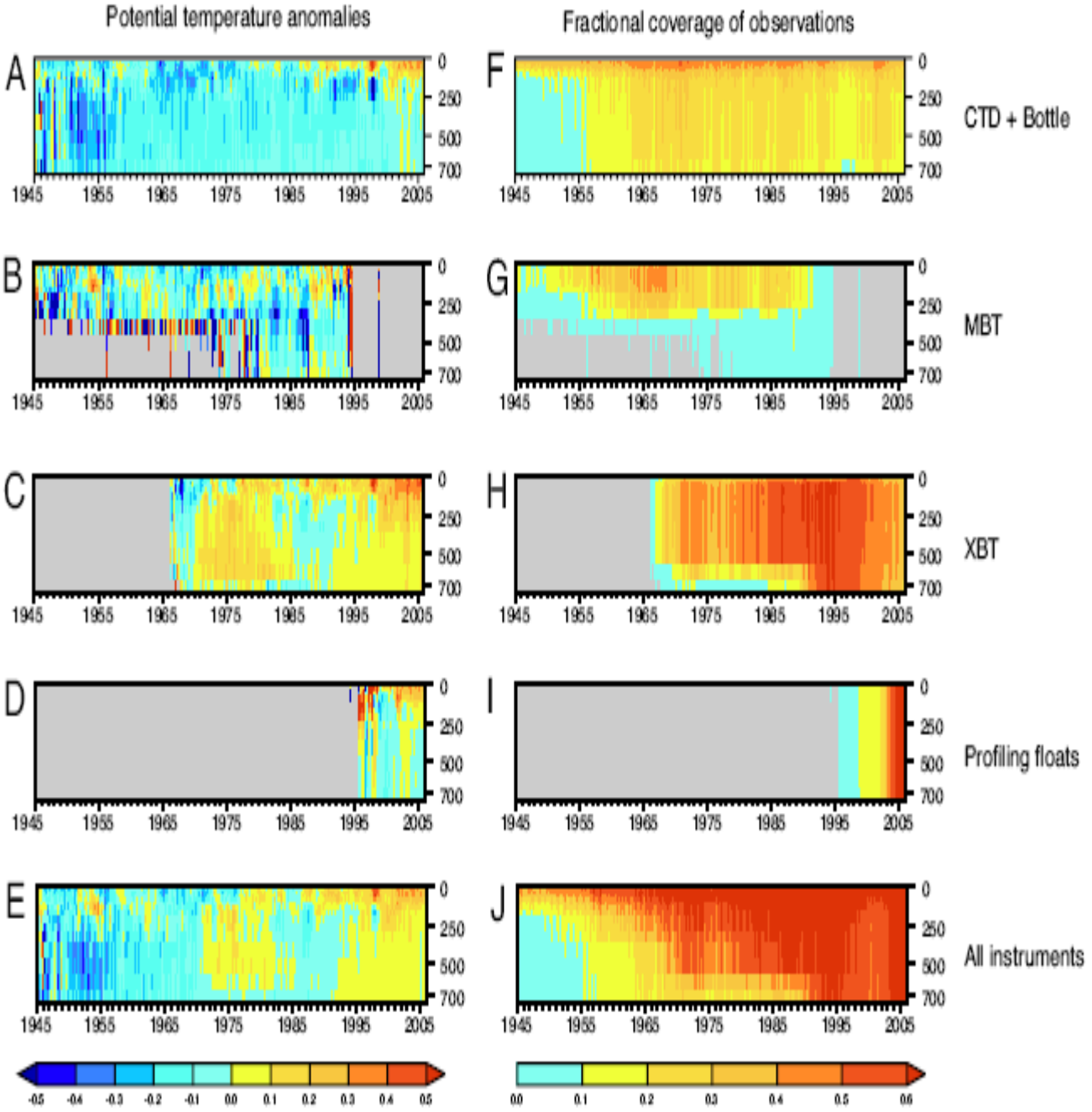
Model-data discrepancies largely accounted for by coverage changes and instrumentation and including volcanic eruptions – AchutaRao et al PNAS, 2007





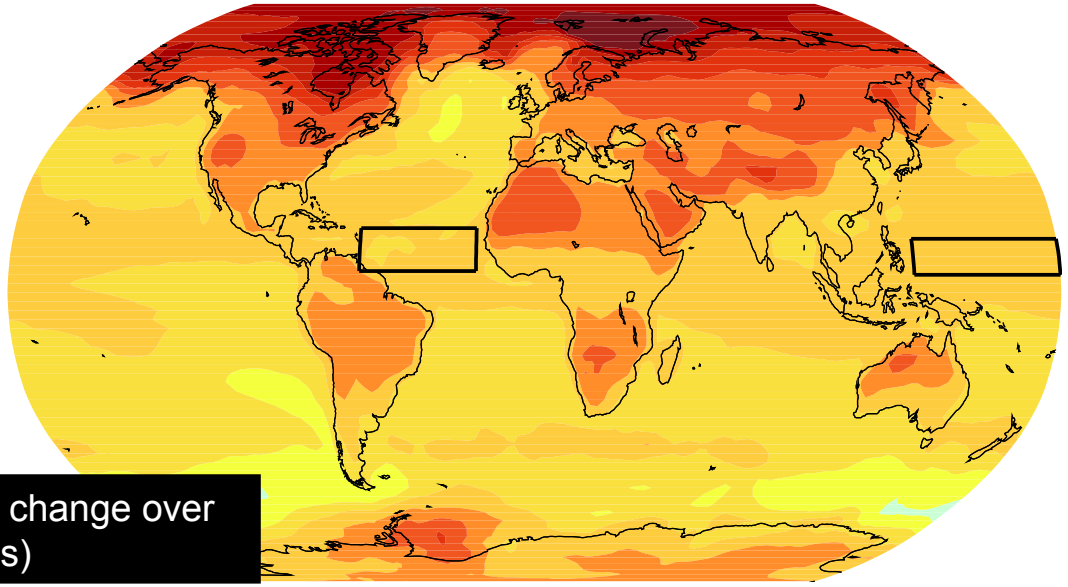
Met Office
Hadley Centre

Complex interplay of biases in different instruments AcutaRao et al, PNAS, 2007



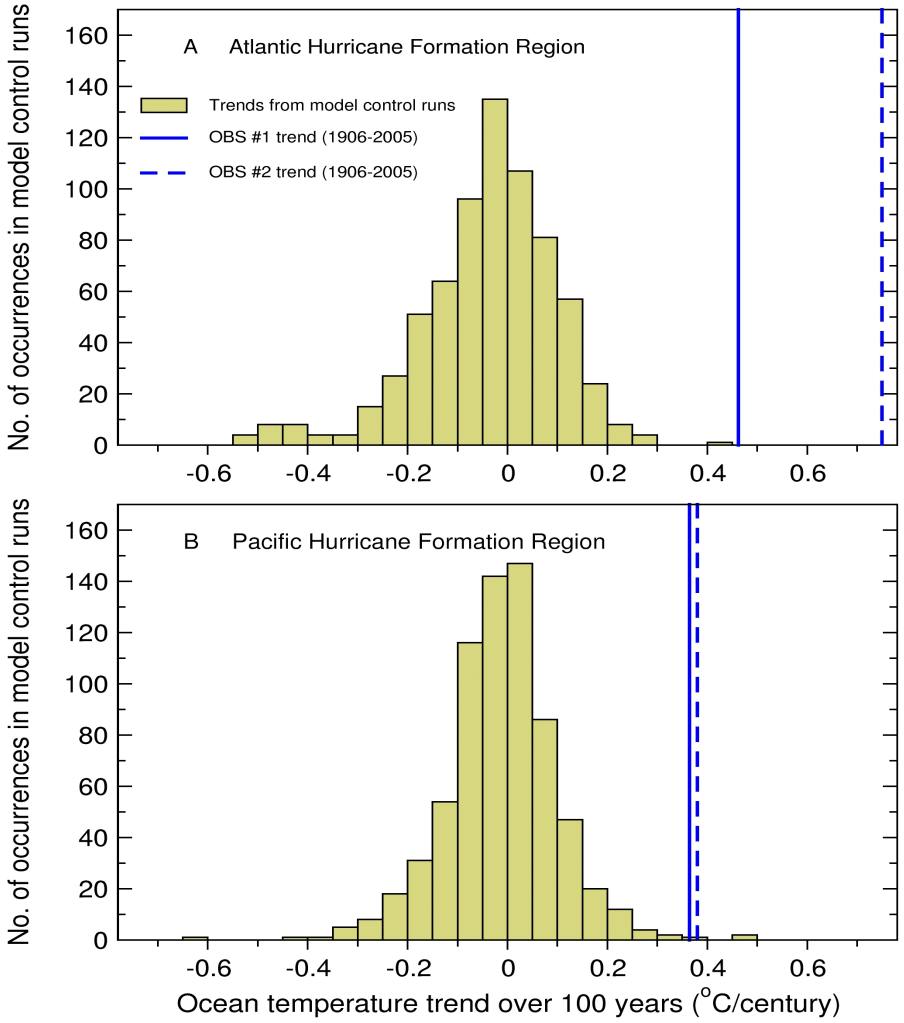
Sea surface temperature changes : Detection and attribution of temperature changes in Atlantic and Pacific hurricane formation regions

Santer et al, PNAS, 2006



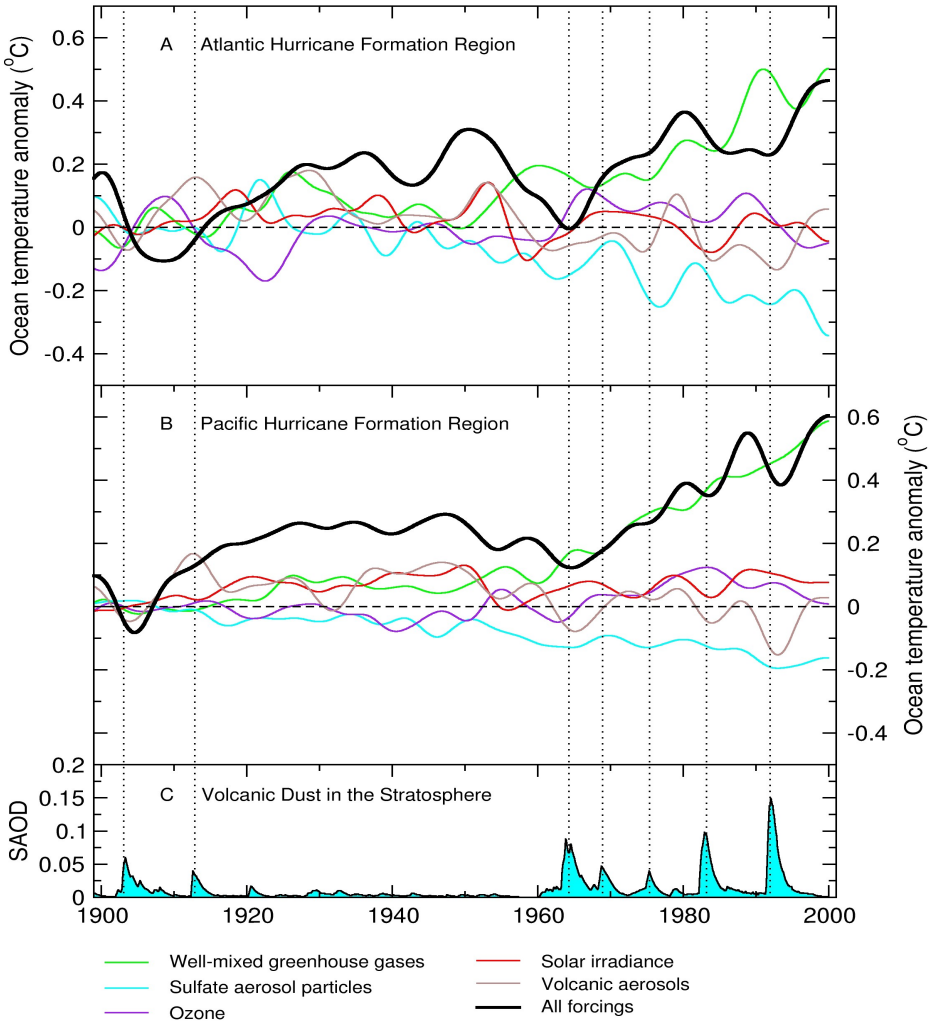
Model average temperature change over 1950-99 (°Celsius)

“Climate noise” cannot explain observed 20th-century trends in ocean surface temperatures



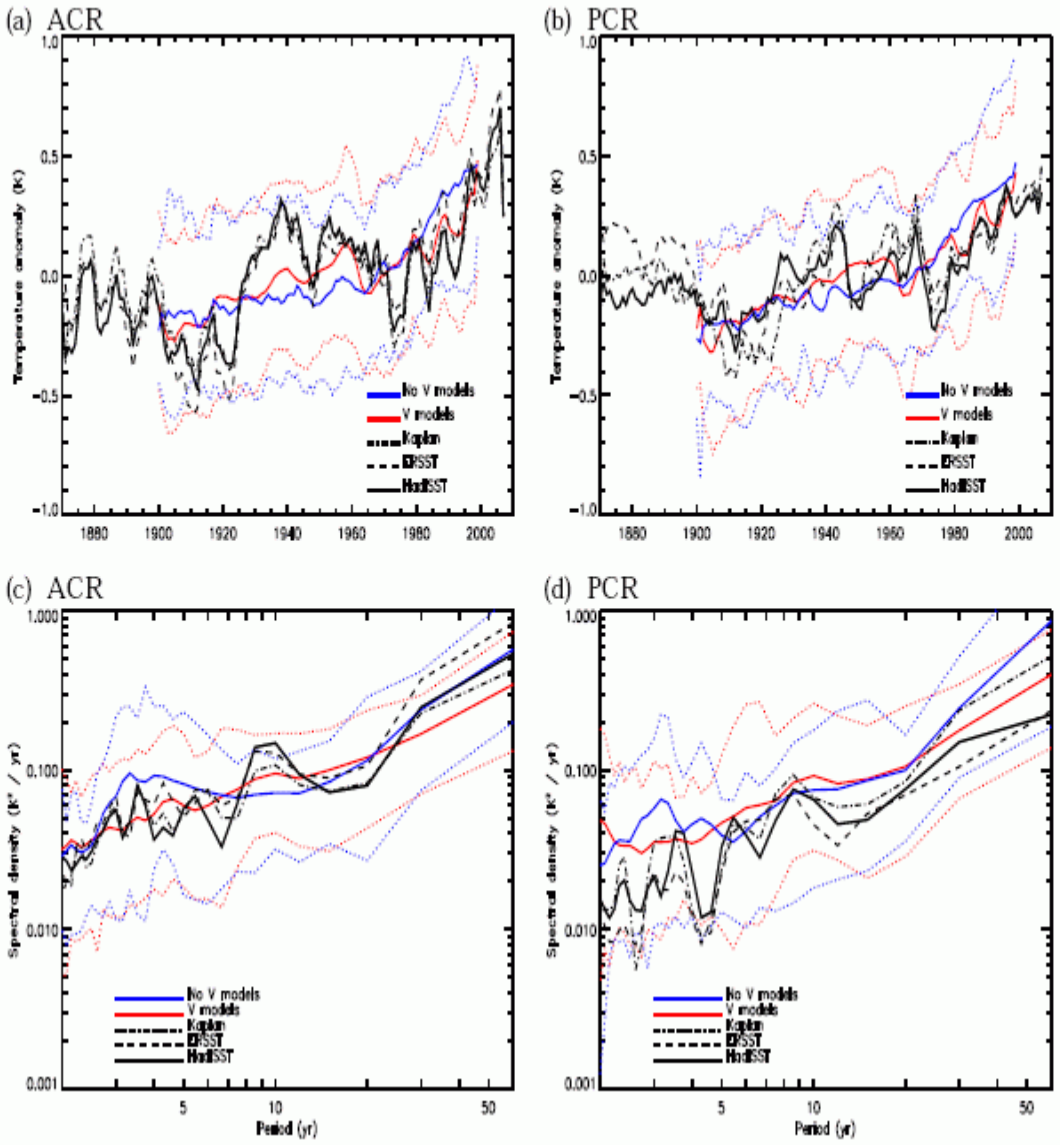
Santer *et al.*, *PNAS* (2006)

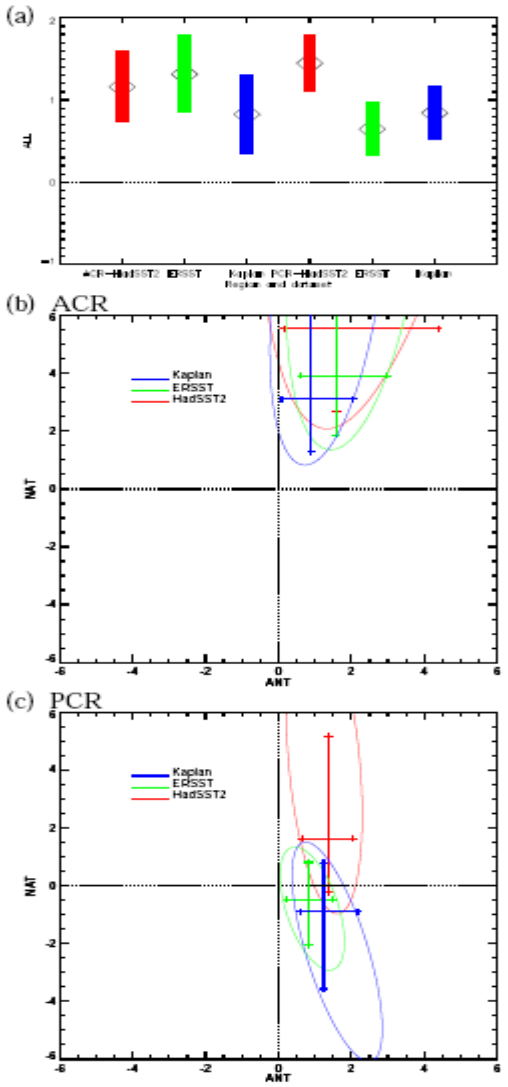
Greenhouse gases are probably the main cause of ocean temperature increases in hurricane formation regions



Santer *et al.*, *PNAS* (2006)

Optimal detection finds significant human influence on ACR and PCR SSTs
Gillett, Stott, Santer GRL, 2008 In press

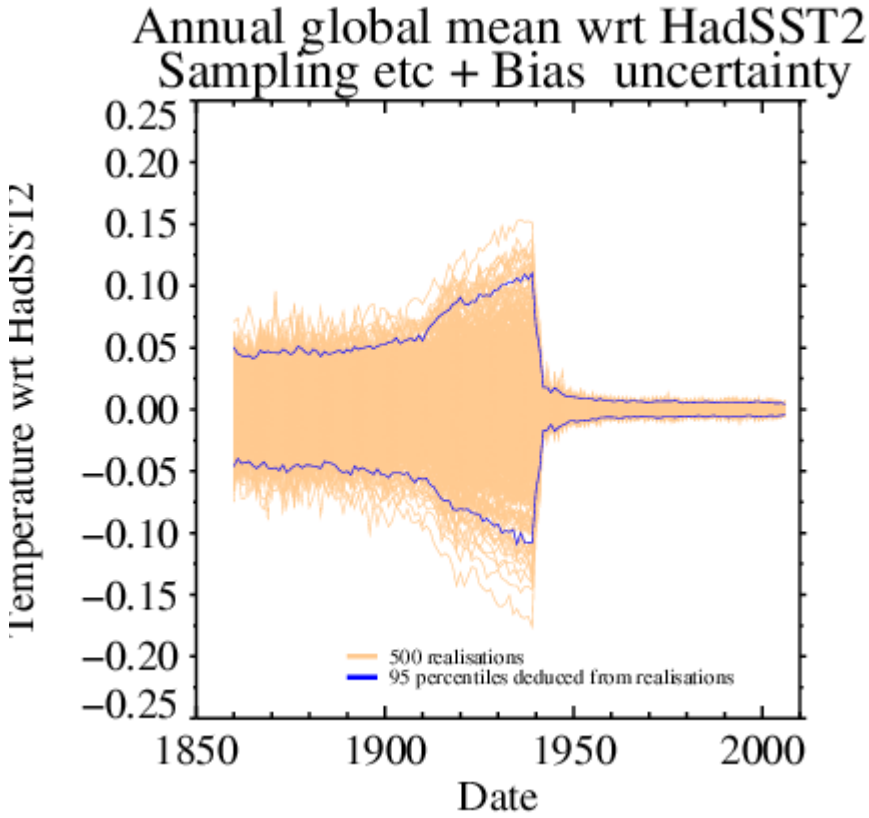




What about observational uncertainty in SSTs ?

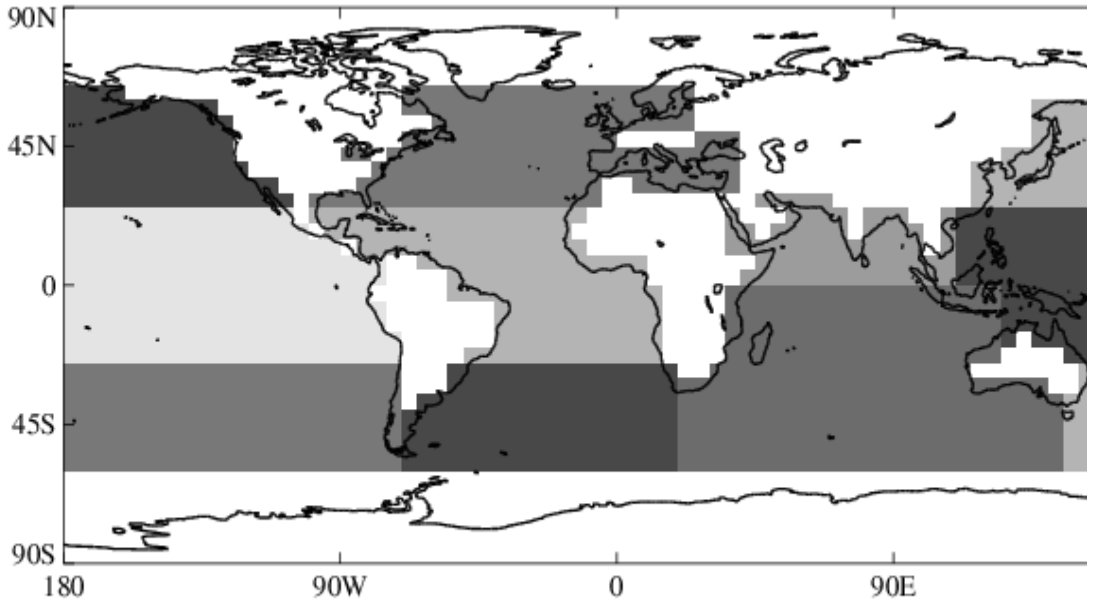
Rayner et al, 2006

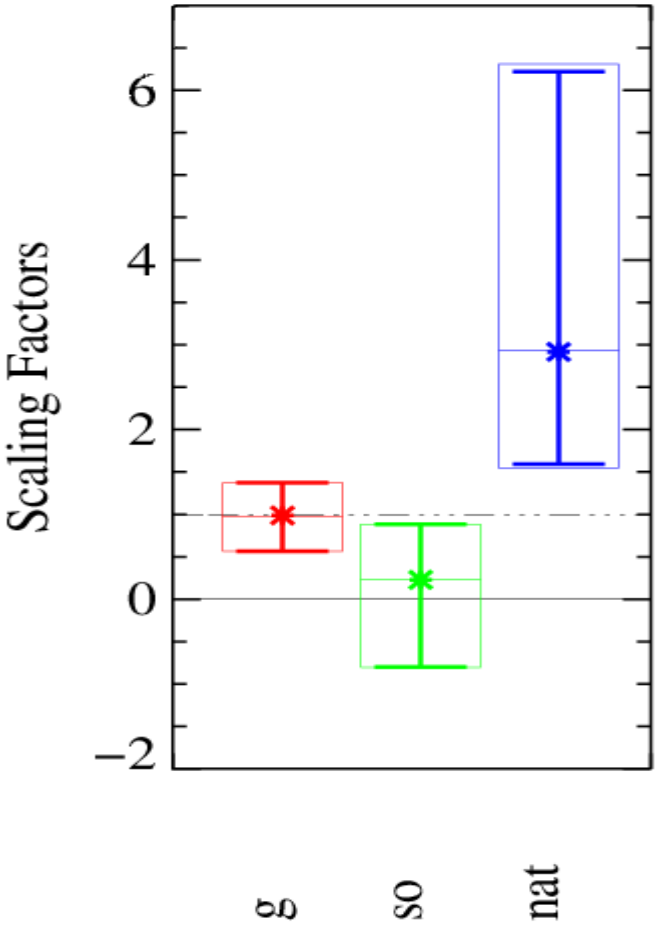
- Measurement and grid-box sampling errors
- Biases
  - Fast/slow boats
  - Modelled heat loss from wooden and canvas buckets
  - Proportions of wooden and canvass buckets



Gareth Jones

Human influence detected on SSTs worldwide with little sensitivity to observational uncertainties on global scale. Gareth Jones, In Prep.





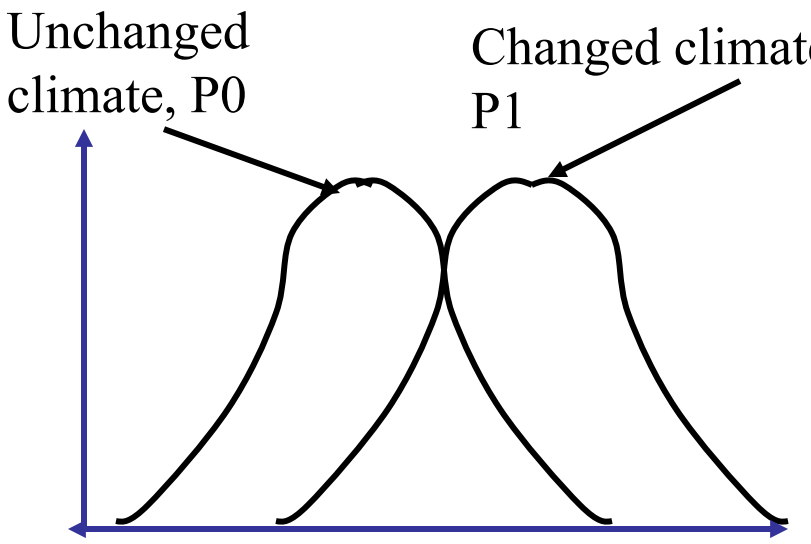
At present, conflicting advice is being received by the general public about whether extreme events are anthropogenically or naturally caused

The July 2007 floods in Gloucestershire, England

"It's official: the heavier rainfall in Britain is being caused by climate change."
Independent, 23rd July, 2007

"But Jim Dale, a risk meteorologist at British Weather Services, says it's down to bad luck, not global warming."
BBC News Website, 23rd July, 2007

Calculation of the changing risk of extreme events



FAR = 1 – P0/P1

If the risk of a particular event has doubled as result of human influence

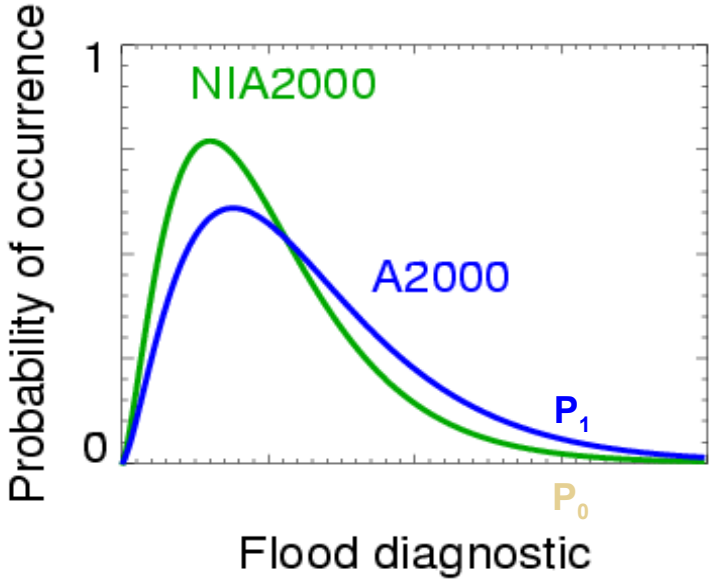
FAR = 1 - 1/2 = 0.5

Half the events can be blamed on human influence

Human influence has loaded the dice

See Allen, Nature, 2003, 421, 891-892

Stott et al, Nature, 2004



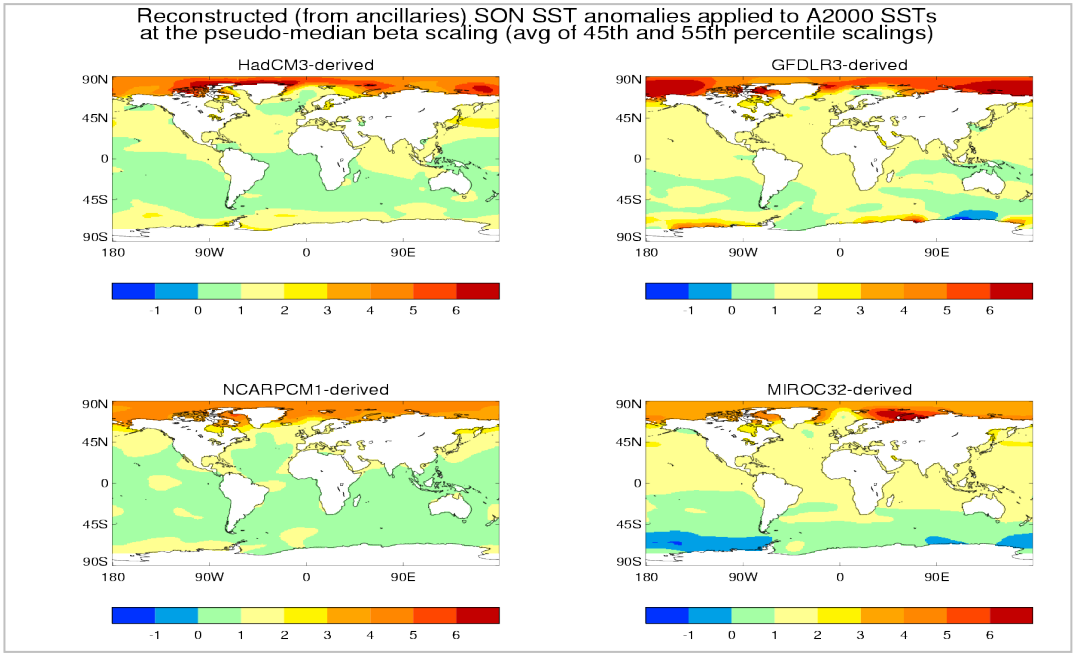
- To construct NIA2000 climate, remove 4 different patterns of estimated GHG attributable SST warming

- Taken from a conventional optimal detection study

  (Stott et al 2006 for

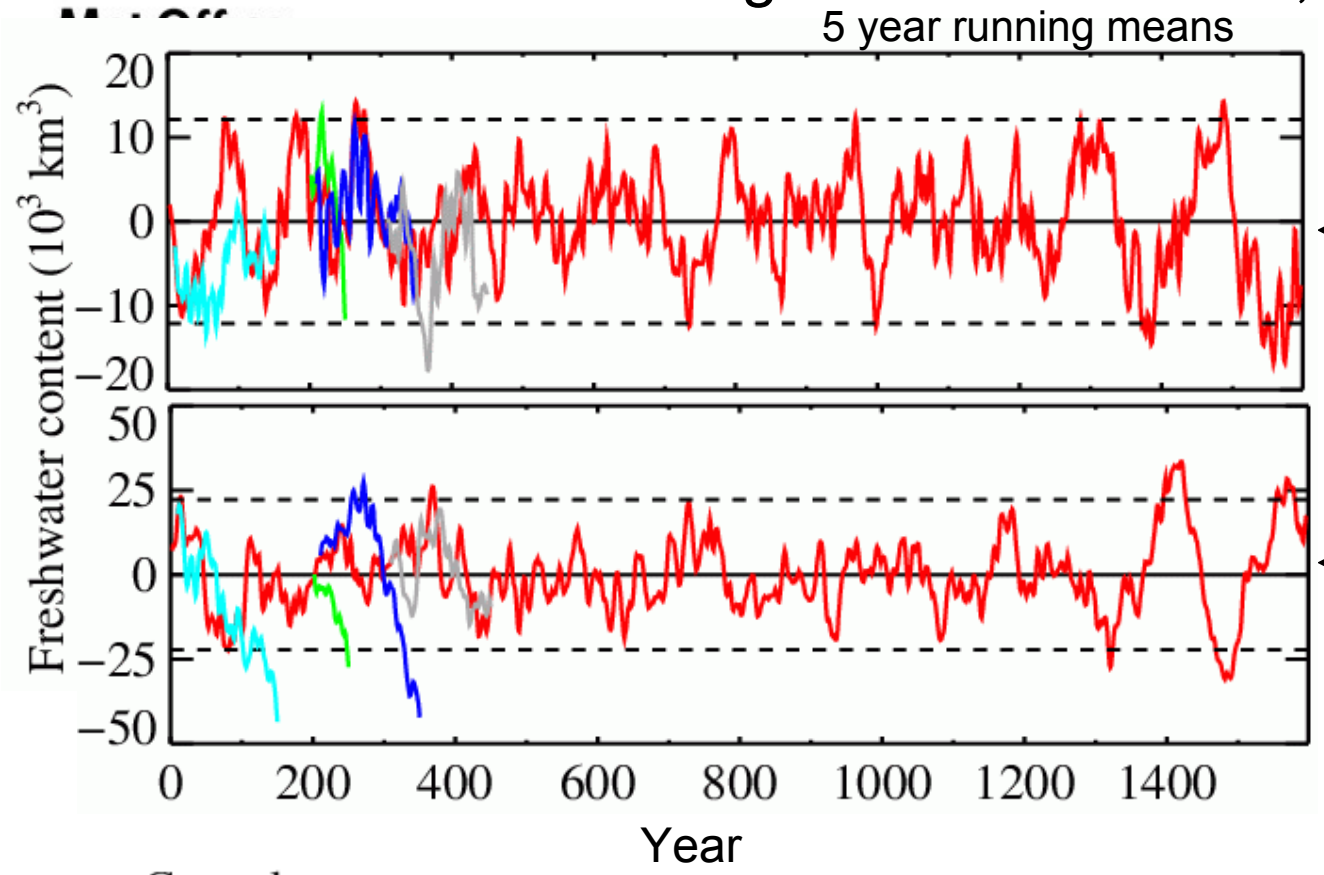
  HadCM3, GFDLR30, NCARPCM1, MIROC3.2)

- Effectively generates 4 NIA2000-sub climates



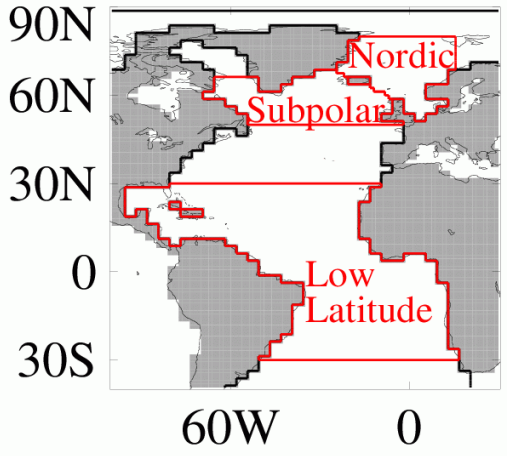
Pall et al, In prep

Roles of internal variability and external forcing in HadCM3 simulated large-scale Atlantic freshwater content changes. Pardaens et al, 2008



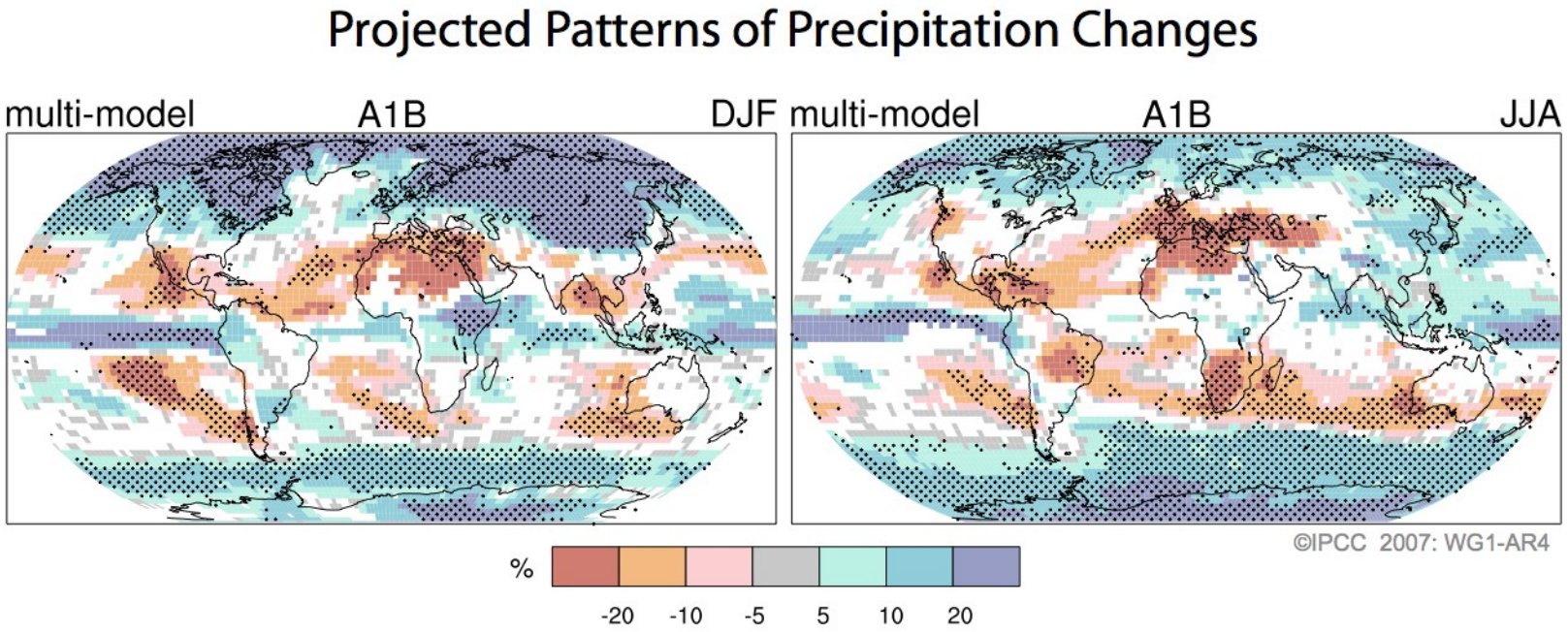
Subpolar plus Nordic Seas

Low Latitude



External forcing signal generally evident in low-latitude Atlantic freshwater content but not obvious in northern Atlantic.

IPCC AR4 projection of precipitation changes



Drying of the sub-tropics and increases at high latitudes and near the equator.

Summary

- Importance of marine data for constraining climate predictions
  - Transient Climate Response
- Ocean heat content
  - Evidence for models having too much ocean heat uptake
  - Discrepancy between modelled and observed variability ?
    - Sampling, data biases, volcanic eruptions
- Sea surface temperatures
  - Attributable changes linked to hurricane formation
  - Link between SST changes and probability of extreme weather events
- Salinity
  - Evidence for attributable increases at low latitudes
  - Links to hydrological cycle