

Detection and attribution studies of the role of the stratosphere in recent climate changes

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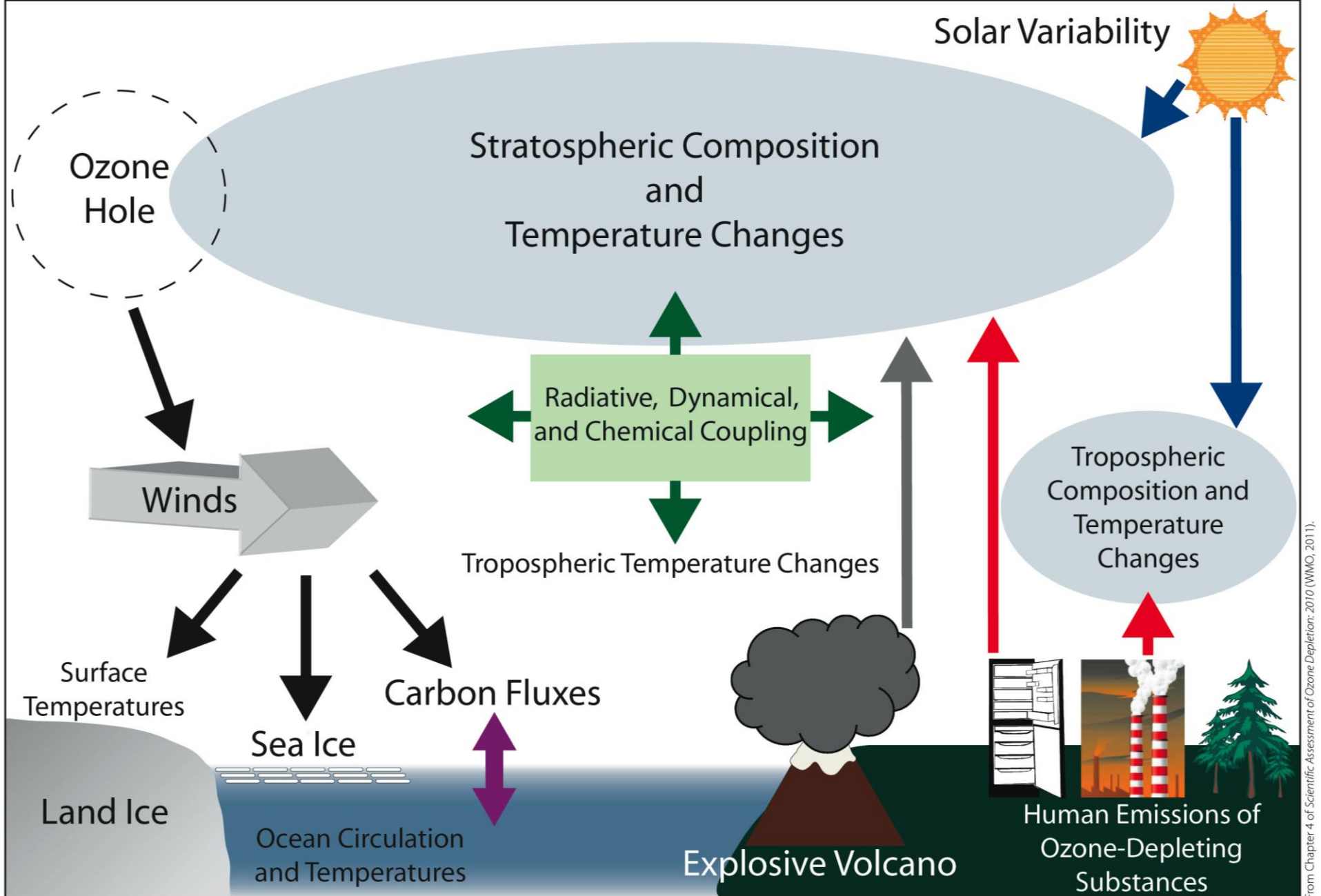
- What is detection and attribution?
- Why use detection and attribution?
- An example: global surface air temperature
- Some stratospheric examples, good & bad

References

IPCC Fifth Assessment Report *Climate Change 2013: The Physical Science Basis*, chapter 10 “Detection and Attribution of Climate Change: from Global to Regional” N Bindoff and P Stott et al. (available from www.ipcc.ch)
and earlier IPCC and ozone assessment reports

Acknowledgements

Numerous colleagues over many years particularly:
Gabi Hegerl, Peter Stott, Dave Thompson, and



From Chapter 4 of Scientific Assessment of Ozone Depletion: 2010 (WMO, 2011).

What is detection and attribution?

Detection of significant observed climate change and attribution of this observed change to one or more causes is a signal-in-noise problem: identifying possible signals in the noise of natural internal climate variations in the chaotic climate system.

Detection is the process of demonstrating that an observed change is significantly different (in a statistical sense) than can be explained by natural internal climate variability.



What is detection and attribution?

Attribution of climate change to specific causes involves statistical analysis and the careful assessment of multiple lines of evidence to demonstrate that the observed changes are:

- unlikely to be due entirely to internal climate variability;
- consistent with the estimated responses to a given combination of anthropogenic and natural forcing; and
- not consistent with alternative, physically plausible explanations of recent climate change

Why use detection and attribution?

- Identify the likely cause or causes of significant observed changes
- Evaluate the performance of models in simulating natural variability and the response to forcings
- Provide greater confidence in model projections of future changes

Requirements of detection and attribution?

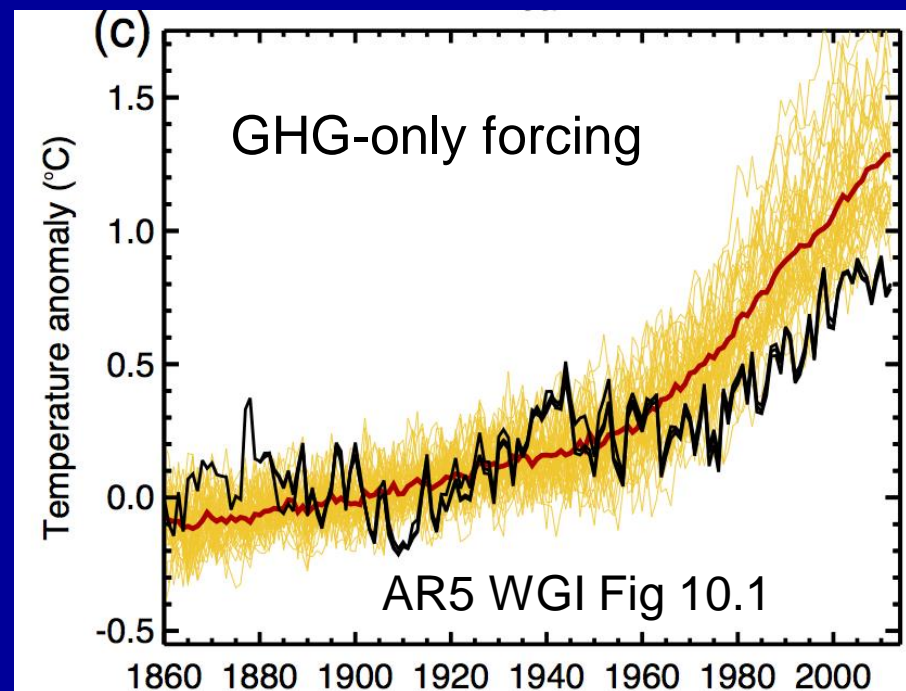
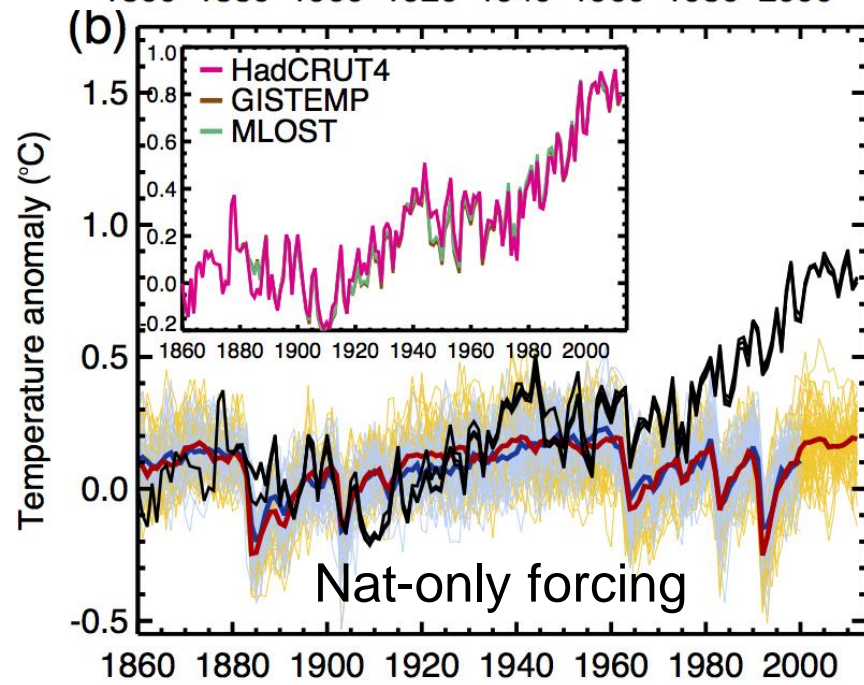
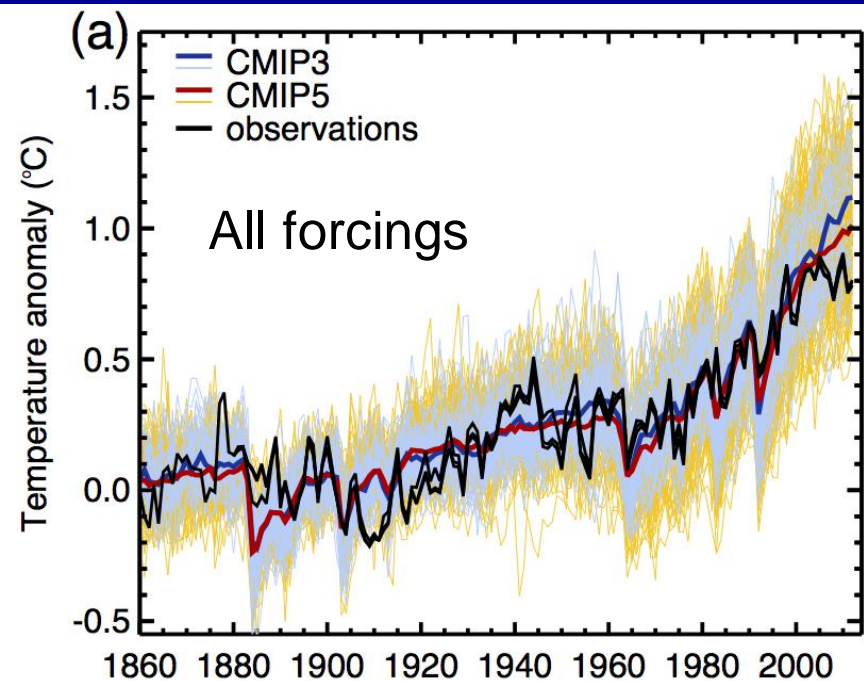
- Variable with high signal-to-noise ratio
- Long observational record
- Long control model simulations and ensembles of forced climate model simulations
- Consistent response to specified forcings between different models – consistent signals
- Separable signals between different forcings
- Statistical analysis methods that enhance signal relative to noise and for identifying signals in observed changes

Fingerprint detection and attribution

- Greater confidence when
 - We are able to separate the contributions to observed change from individual sources
 - Decompose the observed change into space-time patterns from different factors; GHG, aerosols, solar, ozone, internal variability
 - Account for multiple known sources of uncertainty
 - Models and observations agree on the amplitude of the contributions
 - Able to demonstrate that competing explanations are not viable
 - Models simulate similar levels of internal variability as observed

Global mean temperature variations from models and observations

'It is *extremely likely* (>95%) that human activities caused more than half of the observed increase in global mean surface temperature from 1951–2010.' IPCC(2013)

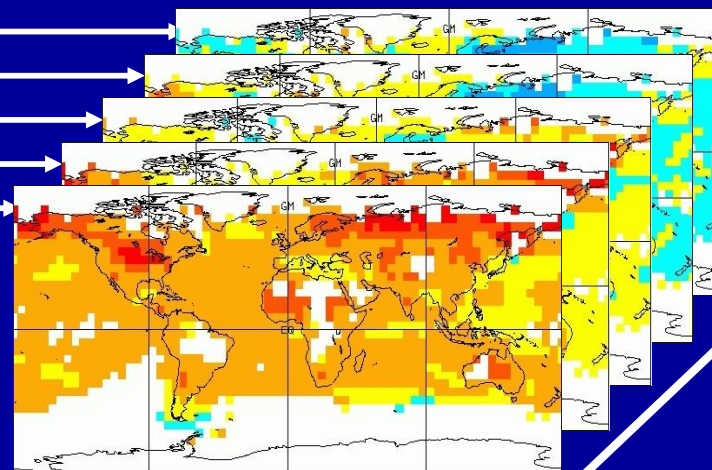
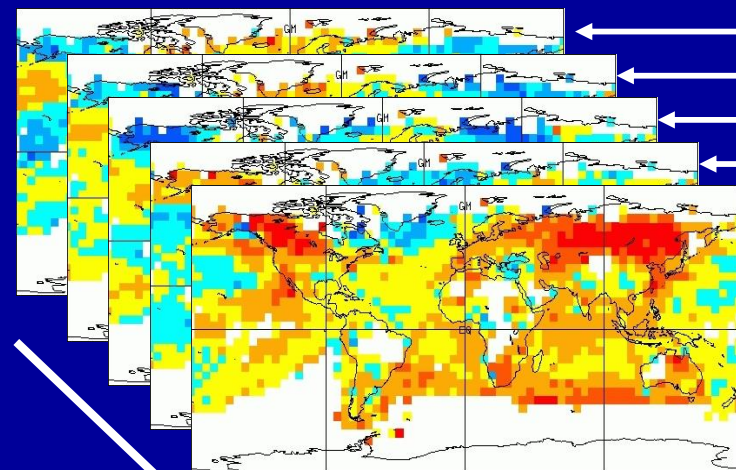


Observations

1951-60

Model

2001-2010



Filtering
and projection
onto reduced
dimension space

Y

X

$$\mathbf{Y} = b\mathbf{X} + e$$

Total least squares regression
in reduced dimension space

**Evaluate
amplitude
estimates**

\hat{b}

\hat{e}

**Evaluate
goodness of
fit**

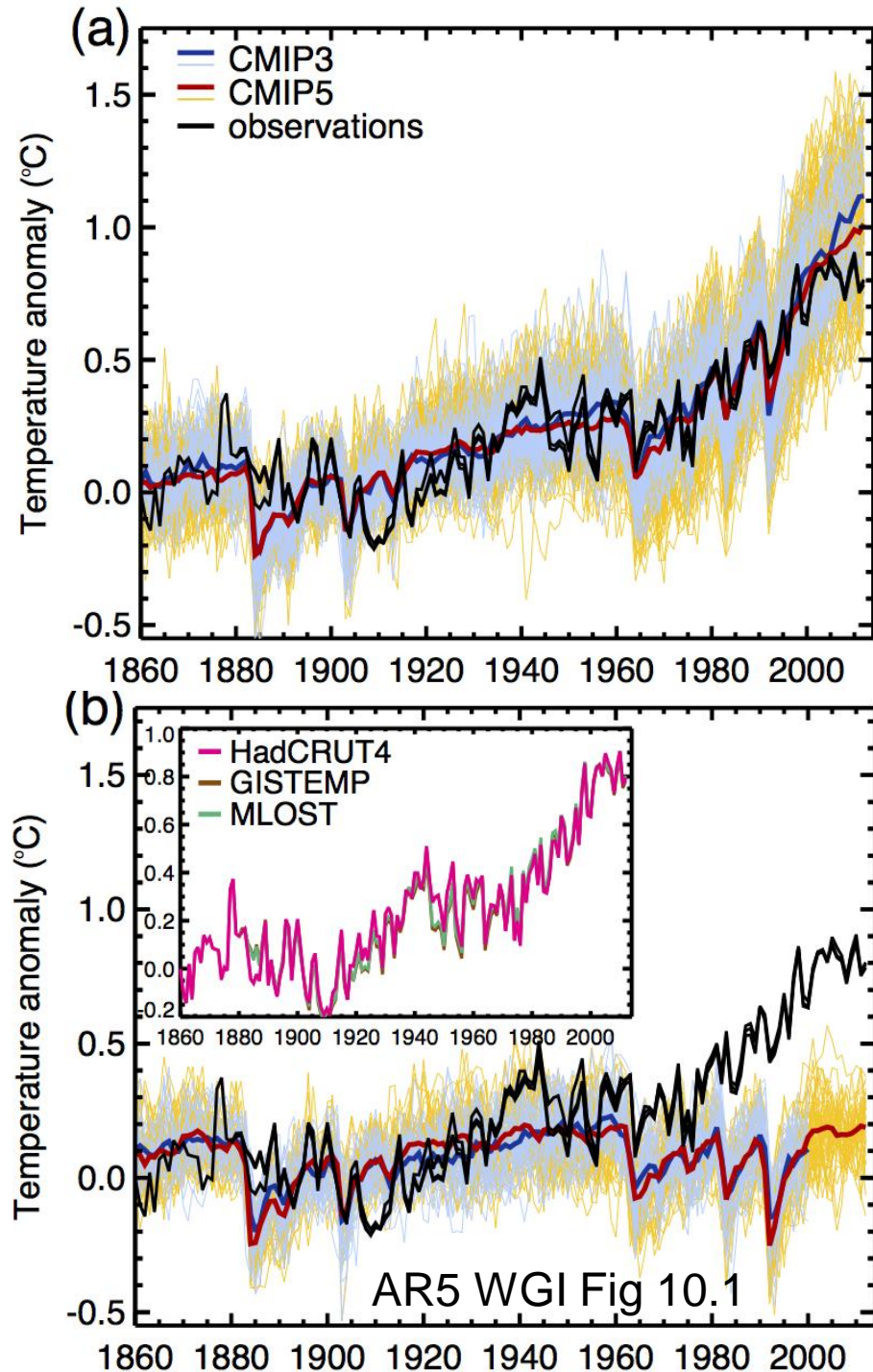
$$\mathbf{Y} = (\mathbf{X} - \hat{\mathbf{i}})\hat{\mathbf{a}} + \hat{\mathbf{a}}$$

• **Observations** represented in a dimension-reduced space

- Typically filtered
 - Spatially (to retain large scales)
 - Temporally (to retain decadal variability - 5-10 decades)
 - Projected onto low-order space-time EOFs

• **Signals** estimated from

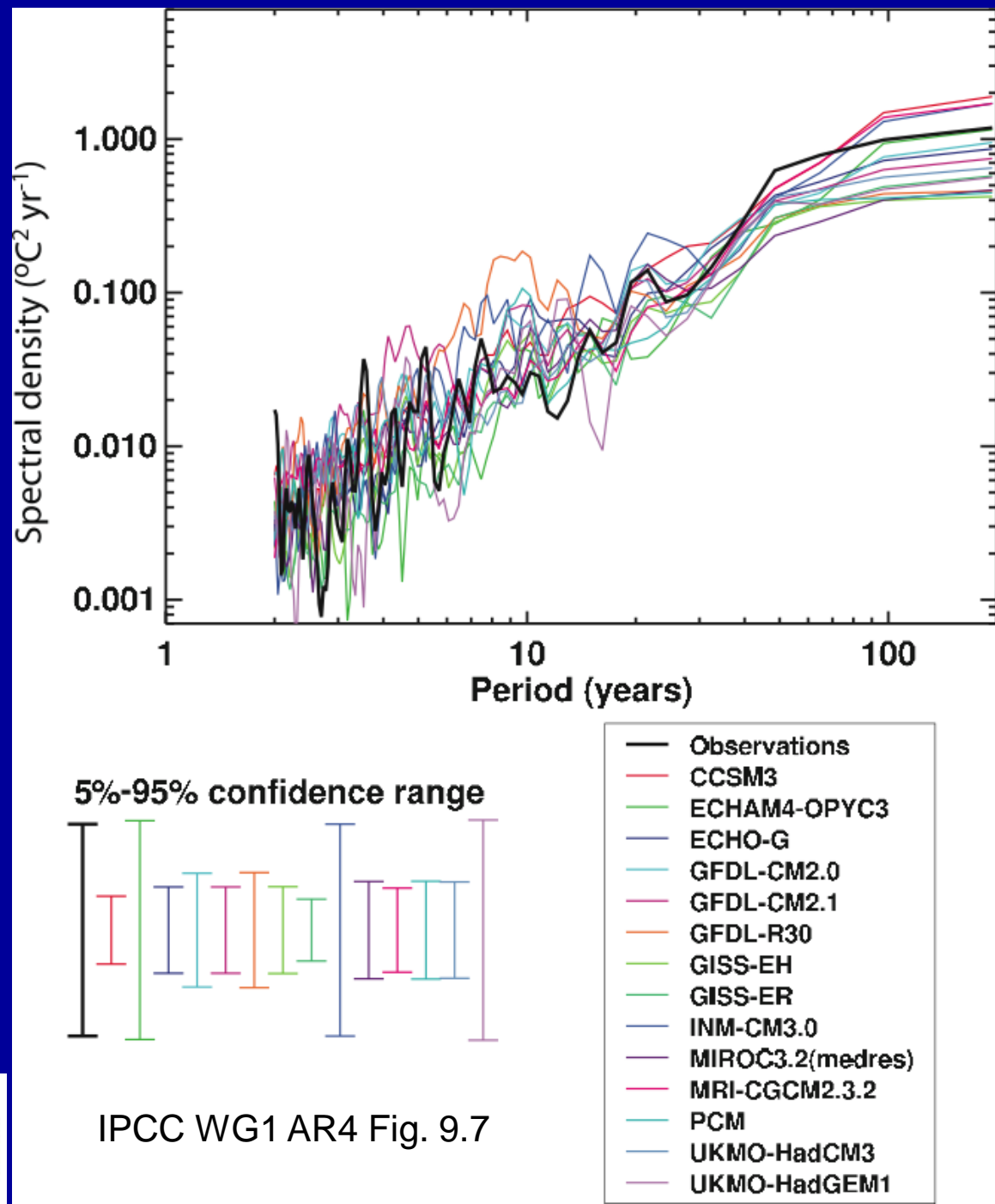
- Multi-model ensembles of 20th century simulations
 - With different combinations of external forcings
 - Anthropogenic (GHG, aerosols, etc)
 - Natural (Volcanic, solar)
 - Multiple models, ensemble sizes from 1-9 runs
 - Assume linearity of response



We think models adequately represent internal surface temperature variability on global scales ...

Variability of observed and simulated annual global mean surface temperature (1901-2005)

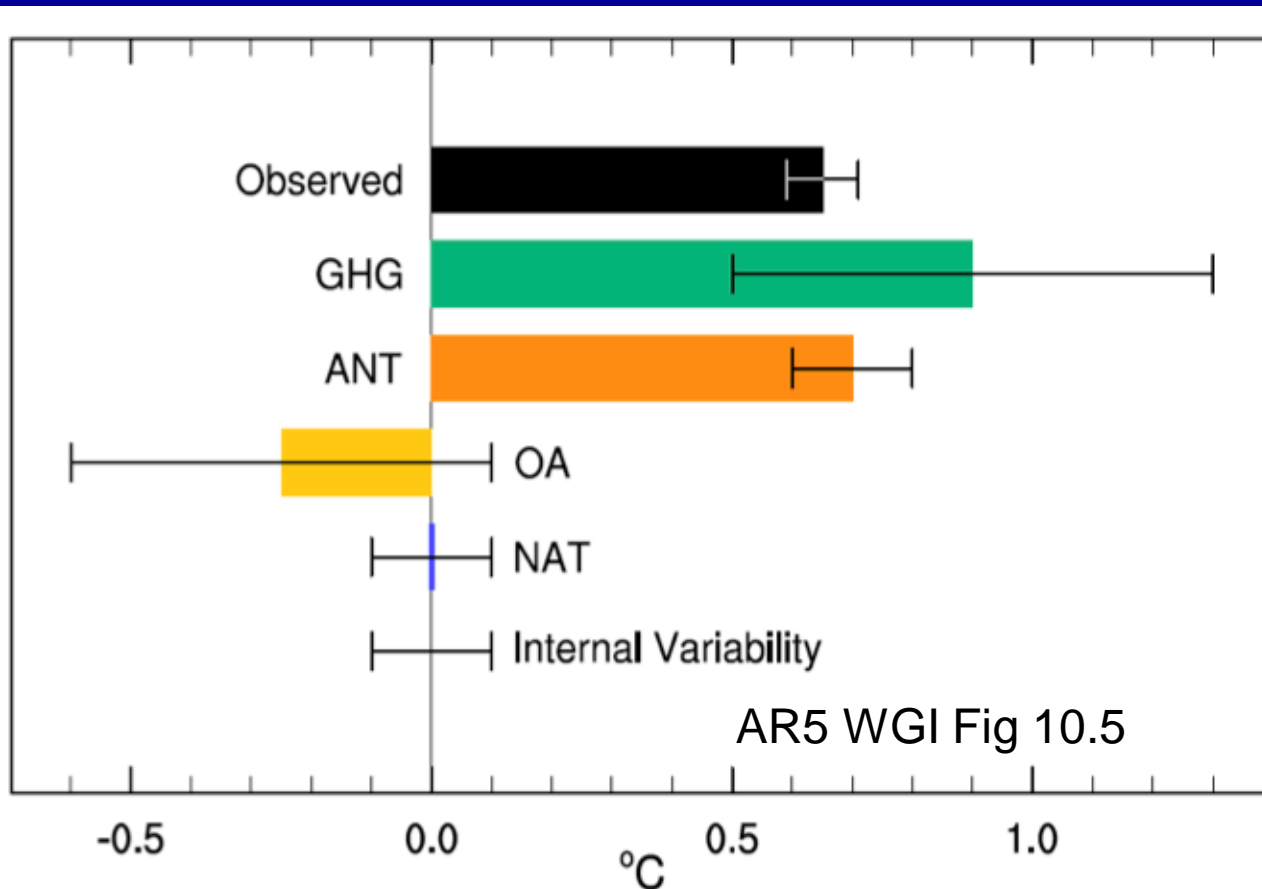
ALL forcings
58 simulations
14 models



IPCC WG1 AR4 Fig. 9.7

‘It is *extremely likely* (>95%) that human activities caused more than half of the observed increase in global mean surface temperature from 1951–2010.’ IPCC(2013)

Estimated contribution from different forcings to observed global mean temperature change 1951-2010

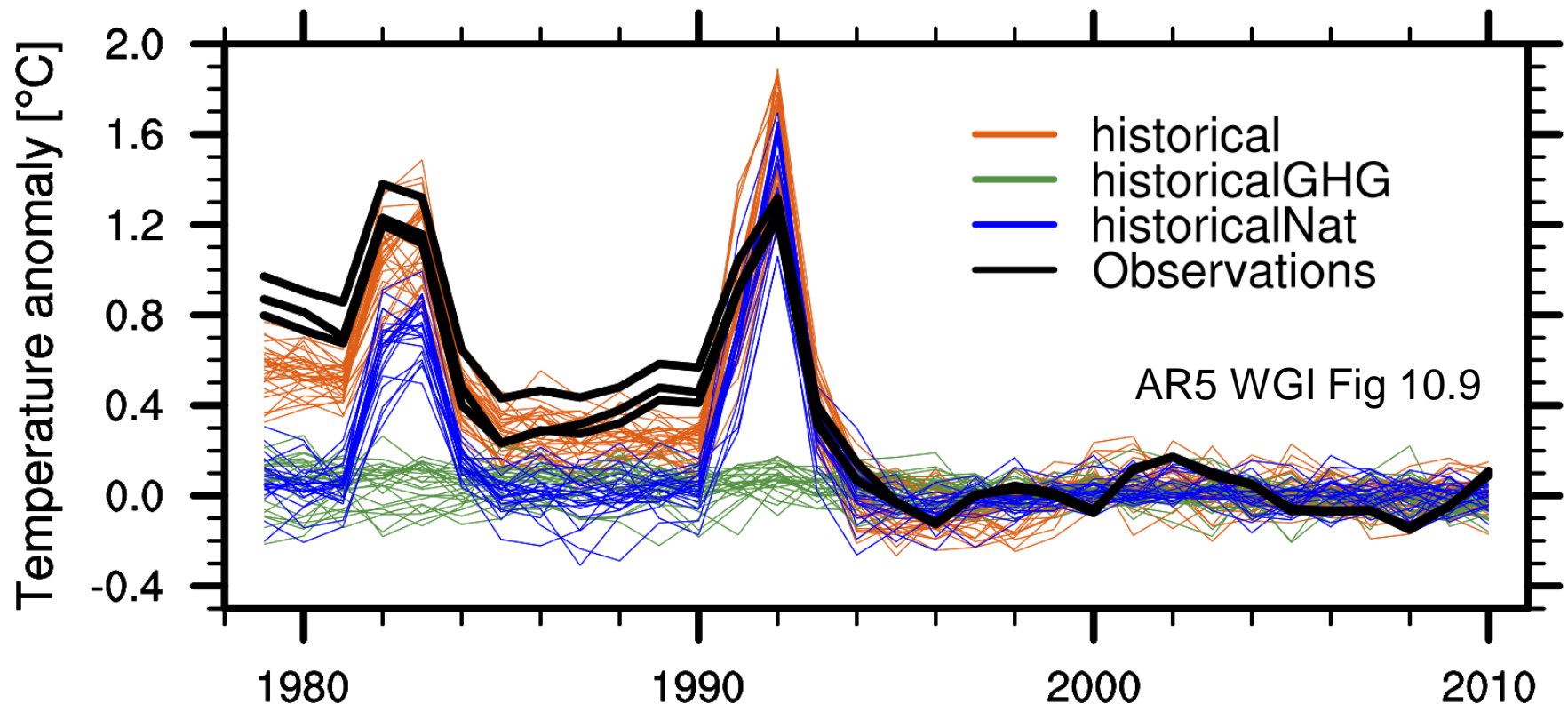


Lower stratospheric temperature trends

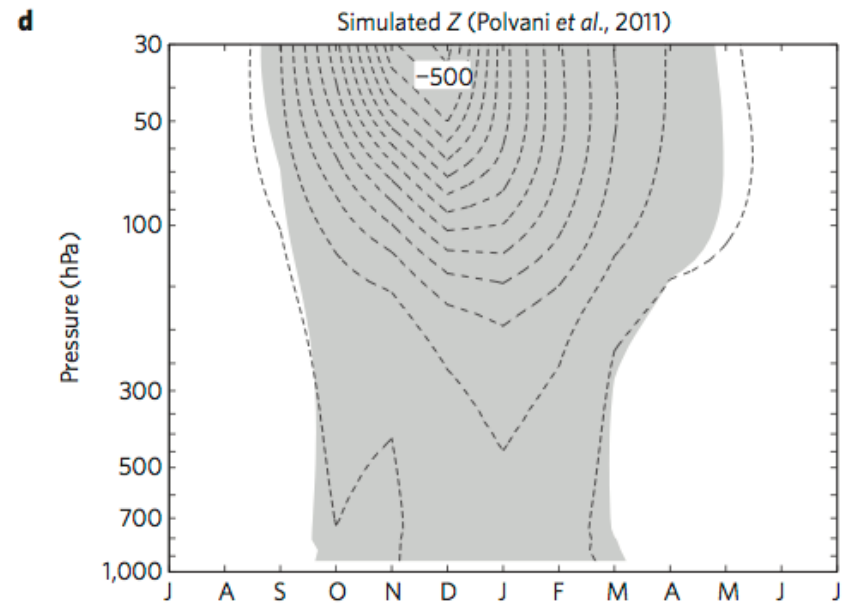
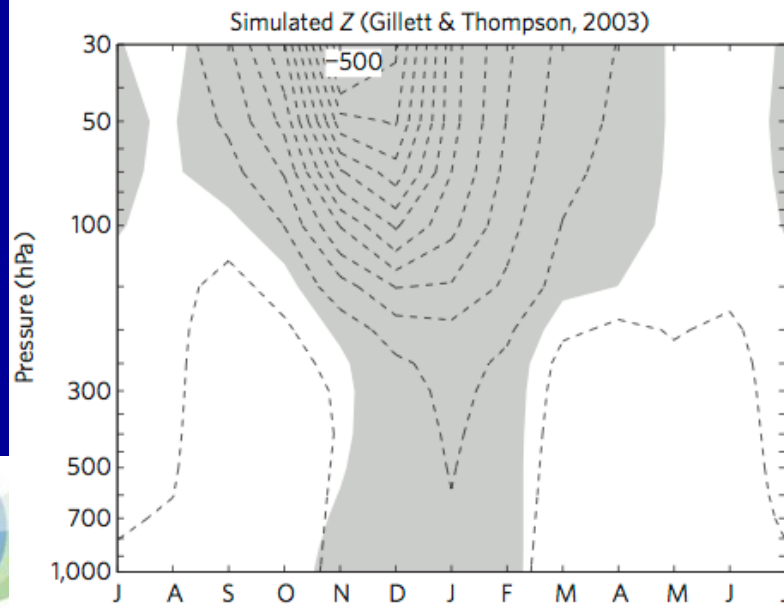
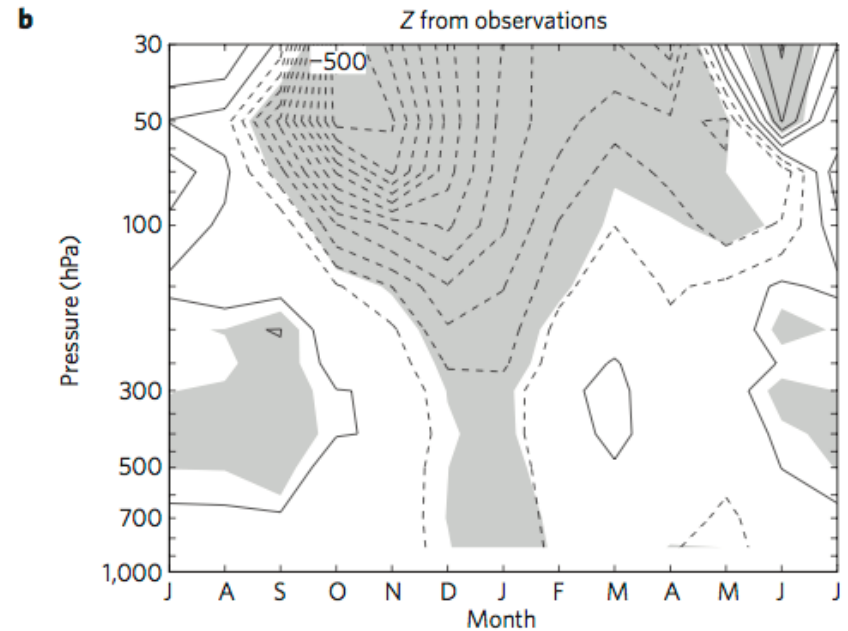
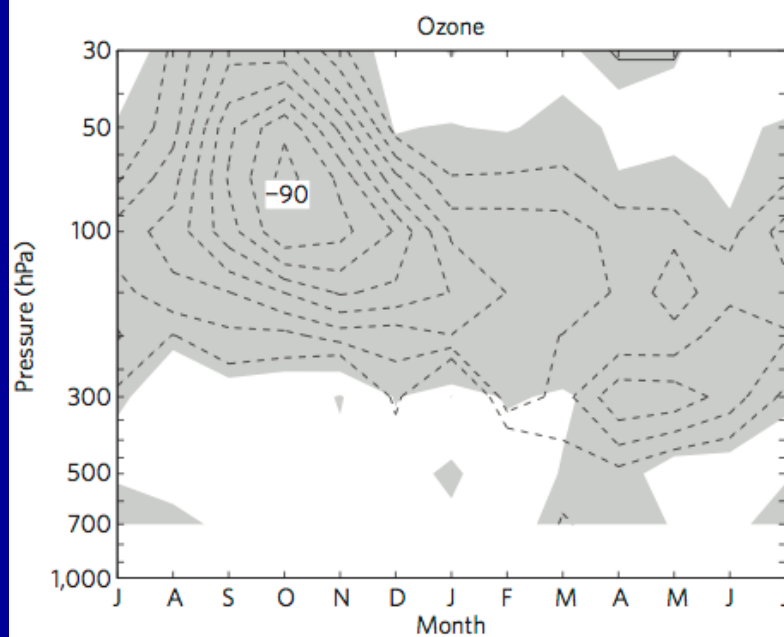
HistoricalGHG simulations cannot explain observed changes

HistoricalNat (volc) explains warming in 1982 and 1991

Historical (all forcings) gives best fit, role of ozone decreases



Observed and simulated changes over Antarctica



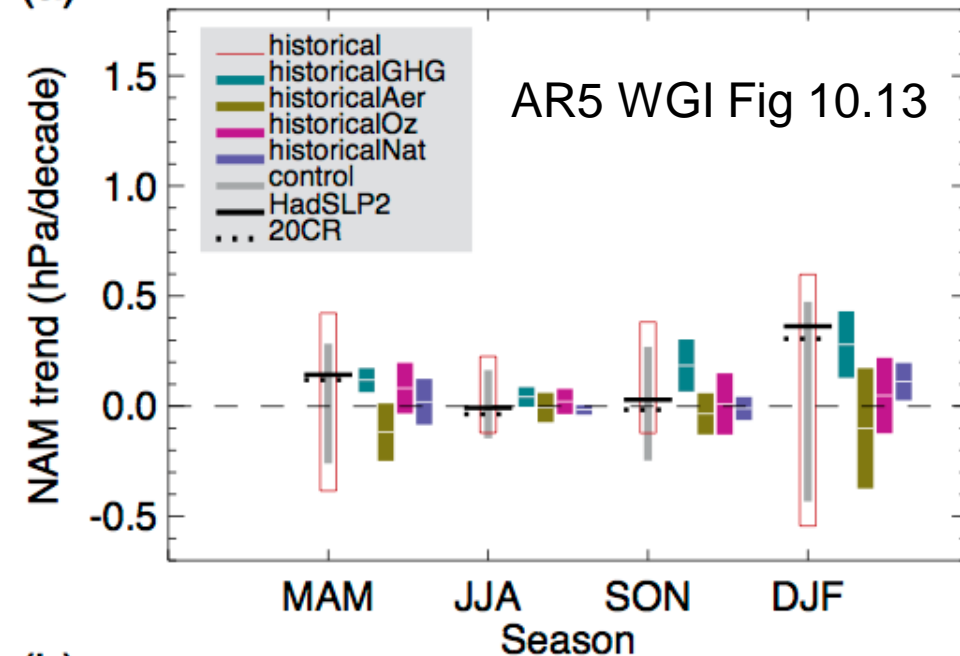
Tropospheric circulation changes

Simulated and observed trends in annular modes in NH and SH over 1951-2010

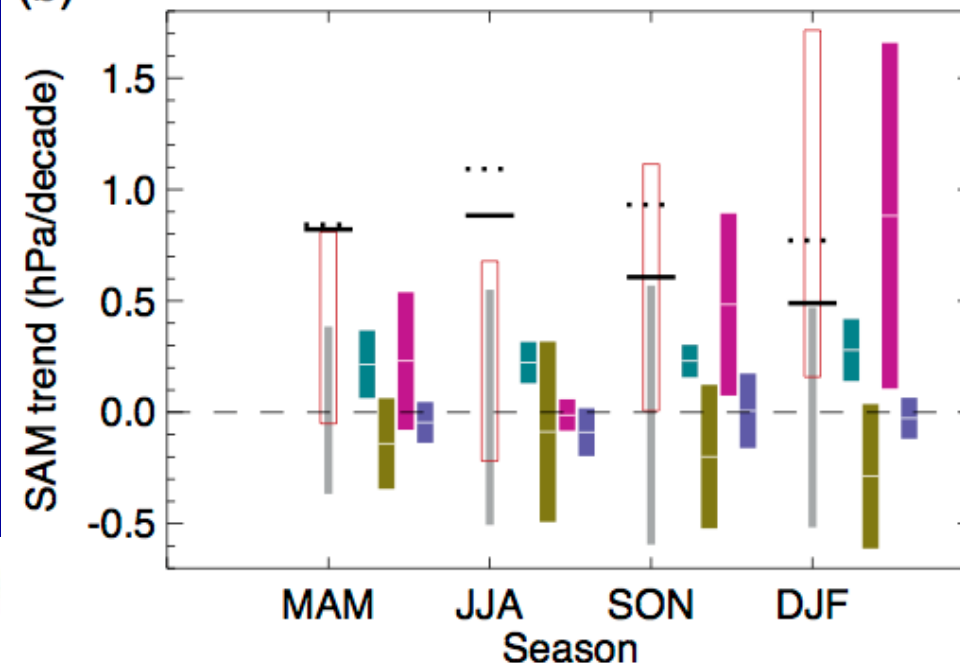
No significant trends in NH in any season

Significant trends in most seasons in SH, ozone forcing main contributor in SON and DJF, uncertain forcing in JJA

(a)



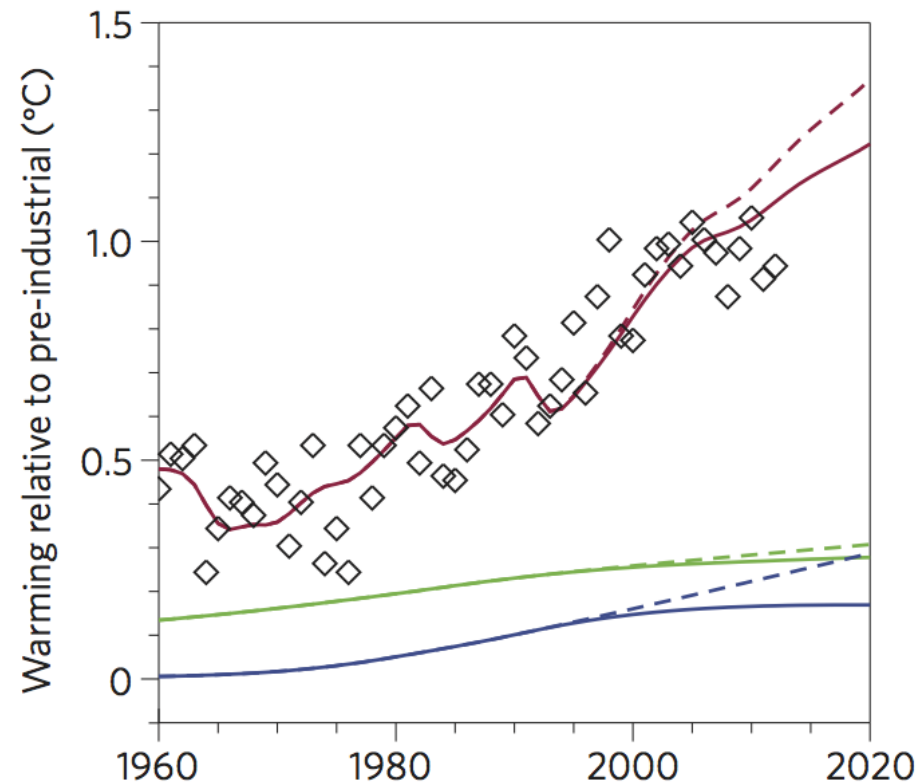
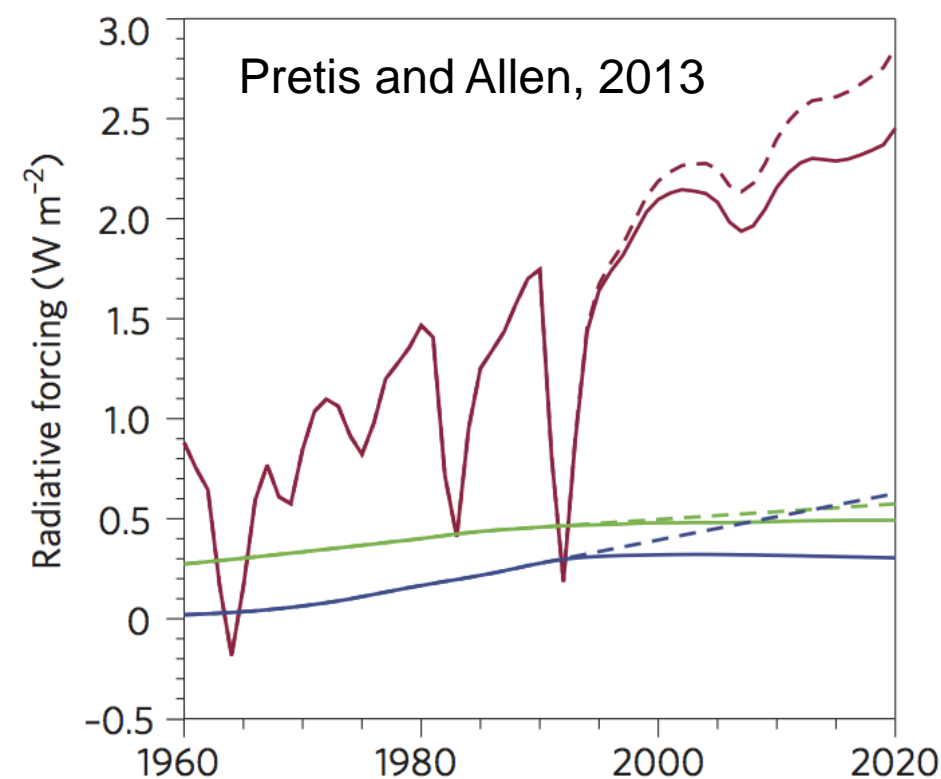
(b)



Montreal Protocol and global warming hiatus

Estrada et al (2013) 'Our statistical analysis suggests that the reduction in the emissions of ozone-depleting substances under the Montreal Protocol (blue), as well as a reduction in methane emissions (green), contributed to the lower rate of warming since the 1990s'

Role of natural variability? Other forcing factors?



Conclusions

- Detection and attribution studies have allowed the quantification of the anthropogenic contribution to observed changes in global mean temperature
- Observed changes in lower stratospheric temperature and springtime SH tropospheric zonal wind have been attributed to stratospheric ozone depletion
- Limitations of observational and modelling datasets and large internal variability make attribution of stratospheric changes difficult