THE ‘HOLE’ TRUTH:
The role of ozone depletion in Australia’s changing climate

Three speakers prominent in the field of ozone and climate science will be speaking on the relationship between ozone depletion and climate change.

Dr Andrew Klekociuk
Australian Antarctic Division

Leading researcher within Australia’s Antarctic climate monitoring programme, Andrew will speak on formation of the Antarctic ozone hole each spring and will highlight the aspects of climate and meteorology that impact its depth and length.

Dr Paul Fraser
CSIRO Mar & Atmos Res.

A contributor to the IPCC and Montreal Protocol science reports, Paul will speak about the climate change significance of ozone depleting substances and on the impacts of climate change on ozone depletion and recovery.

Prof David Karoly
The University of Melbourne

A lead author to IPCC working groups, David will speak about the influence of ozone destruction and formation on Australia’s regional climate and rainfall patterns.

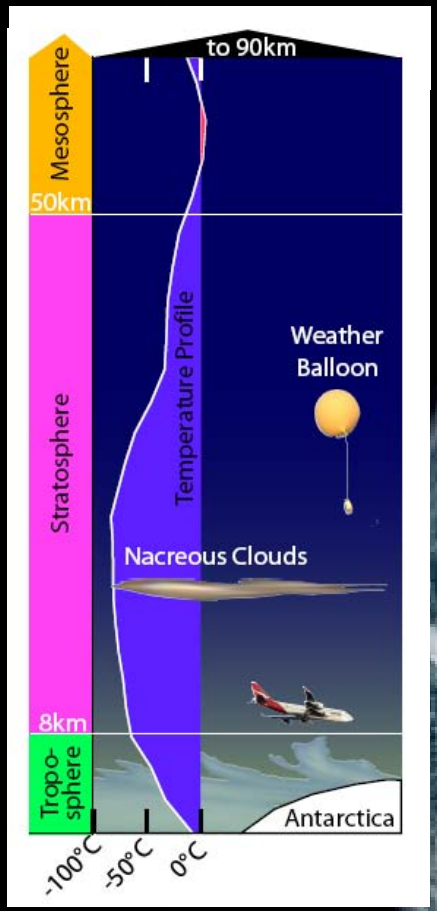
When: 1pm on 1 May 2008
Where: Bunker Theatre in the John Gorton Building, Parkes, Canberra

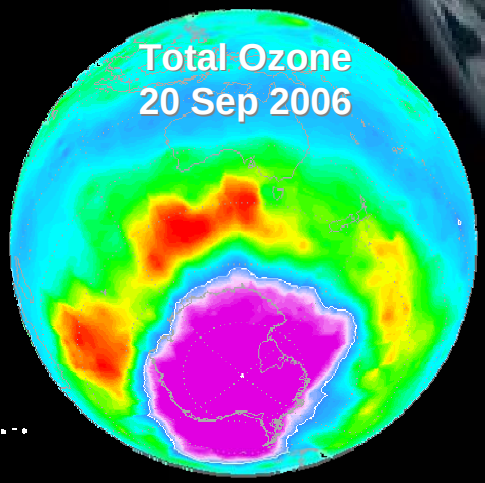
Formation of the Antarctic Ozone Hole

Andrew Klekociuk
Antarctic Climate Program
Australian Antarctic Division

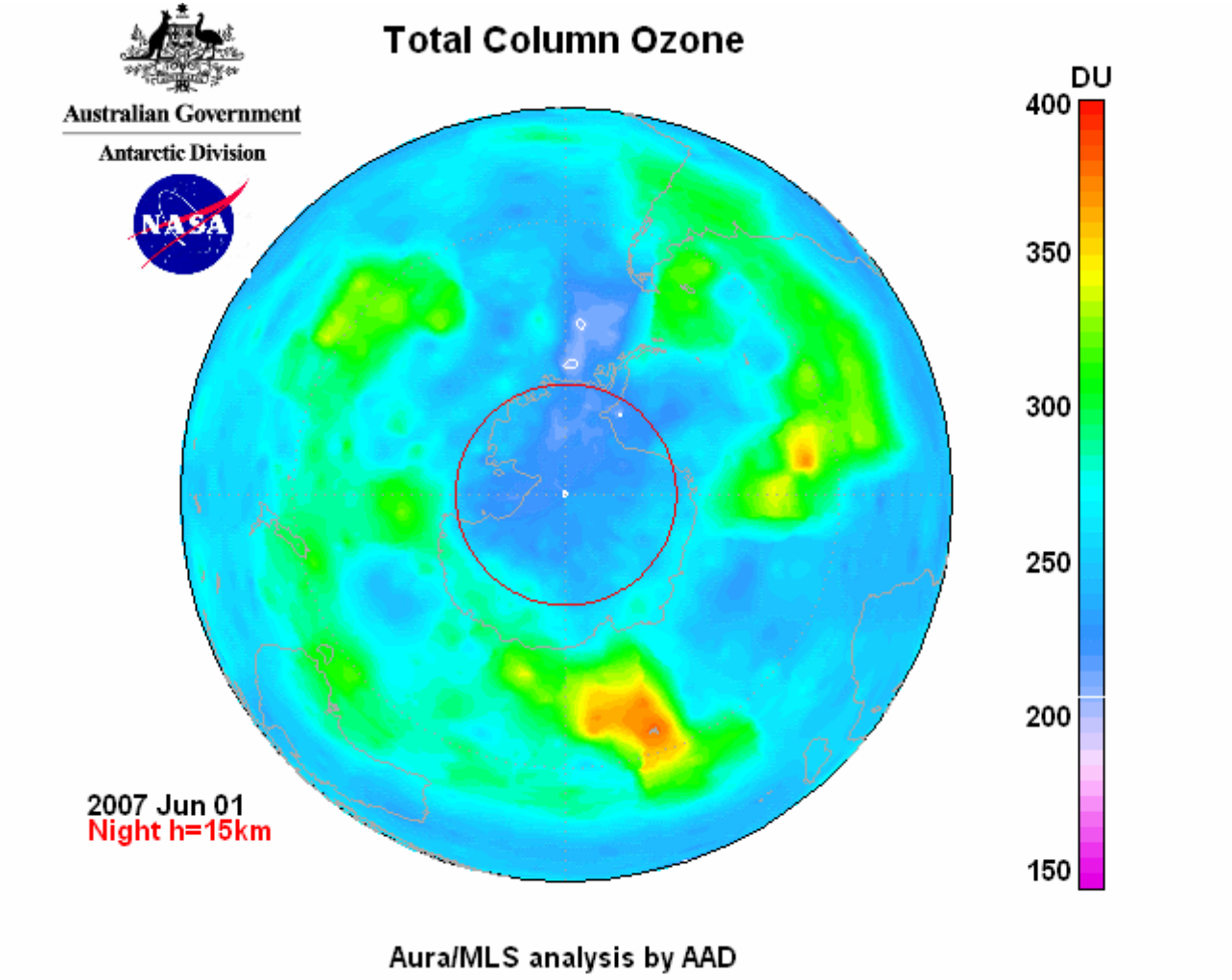
Australian Government
Department of the Environment, Water, Heritage and the Arts
Australian Antarctic Division

Ozone and the Australian Region



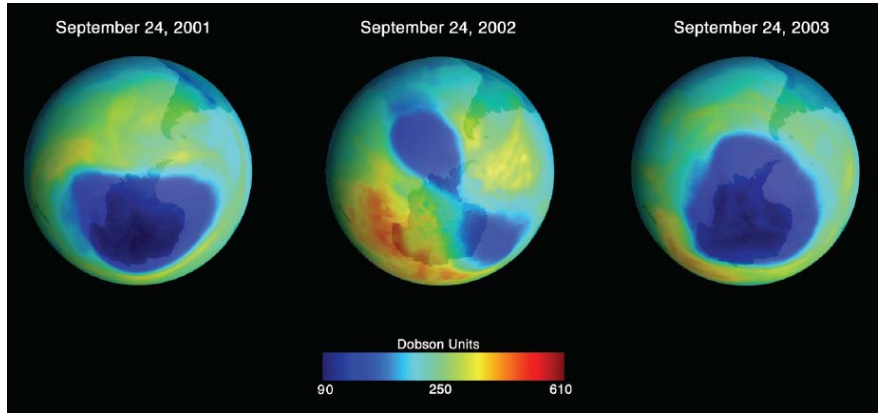


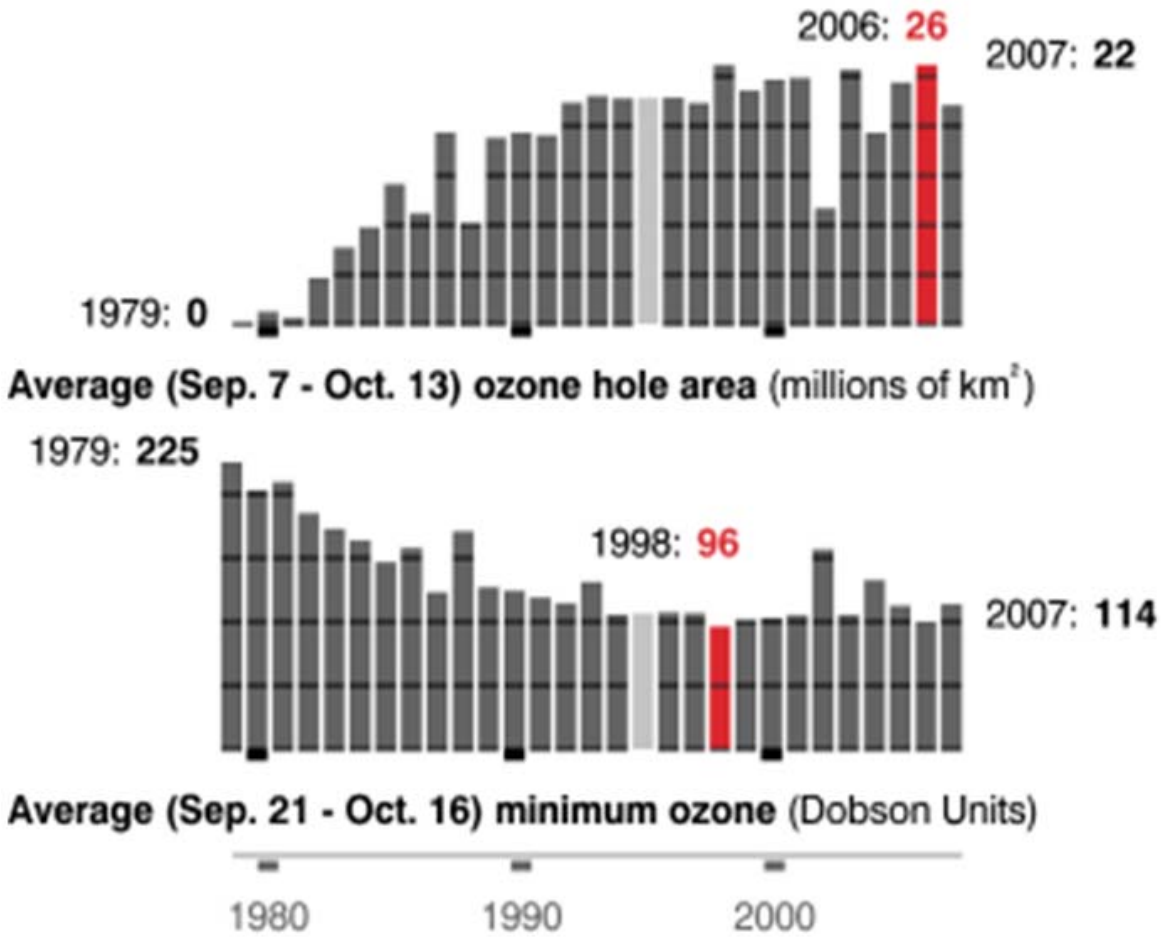
Antarctic Ozone Hole 2007



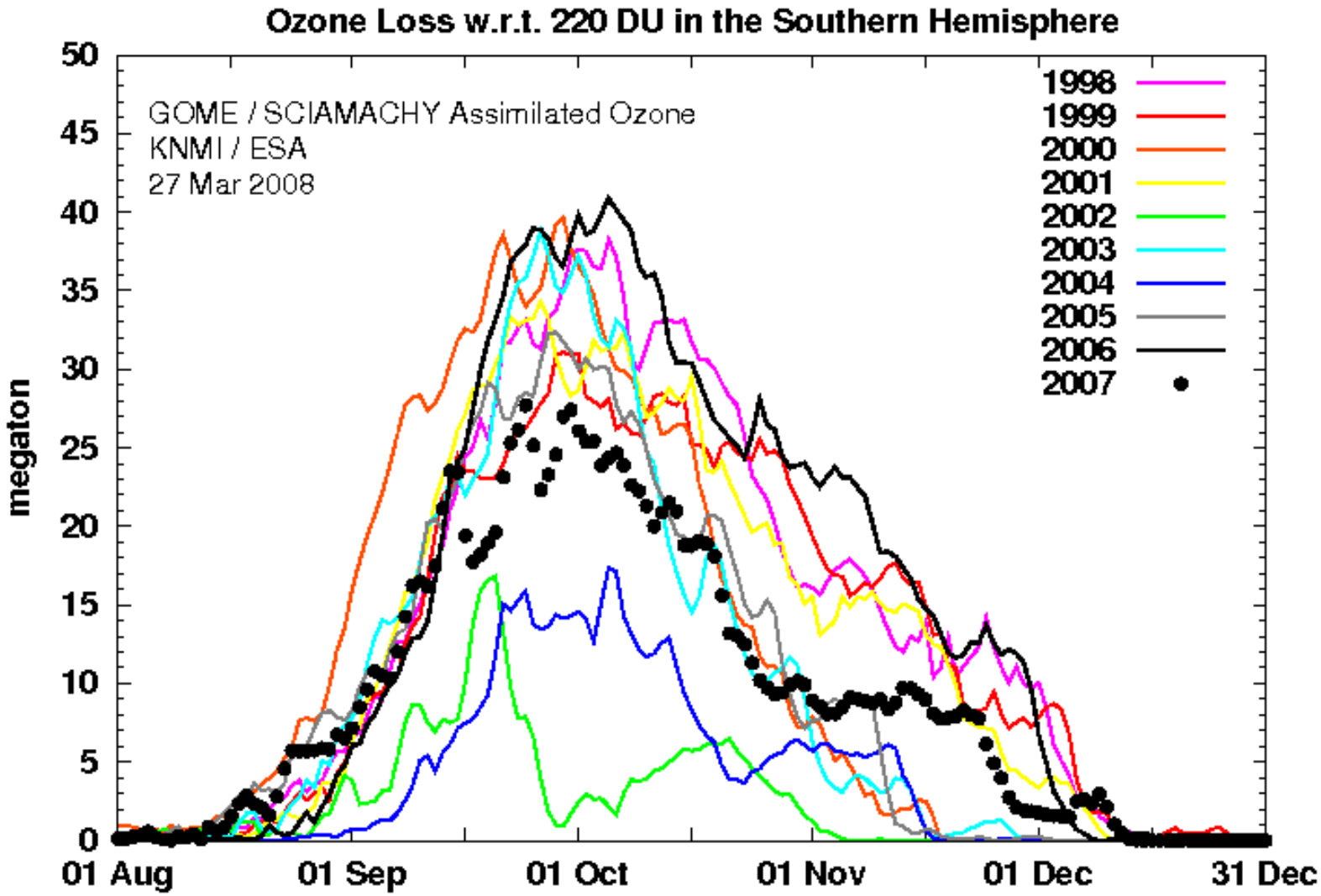
Evolution of the Ozone Hole

http://ozonewatch.gsfc.nasa.gov



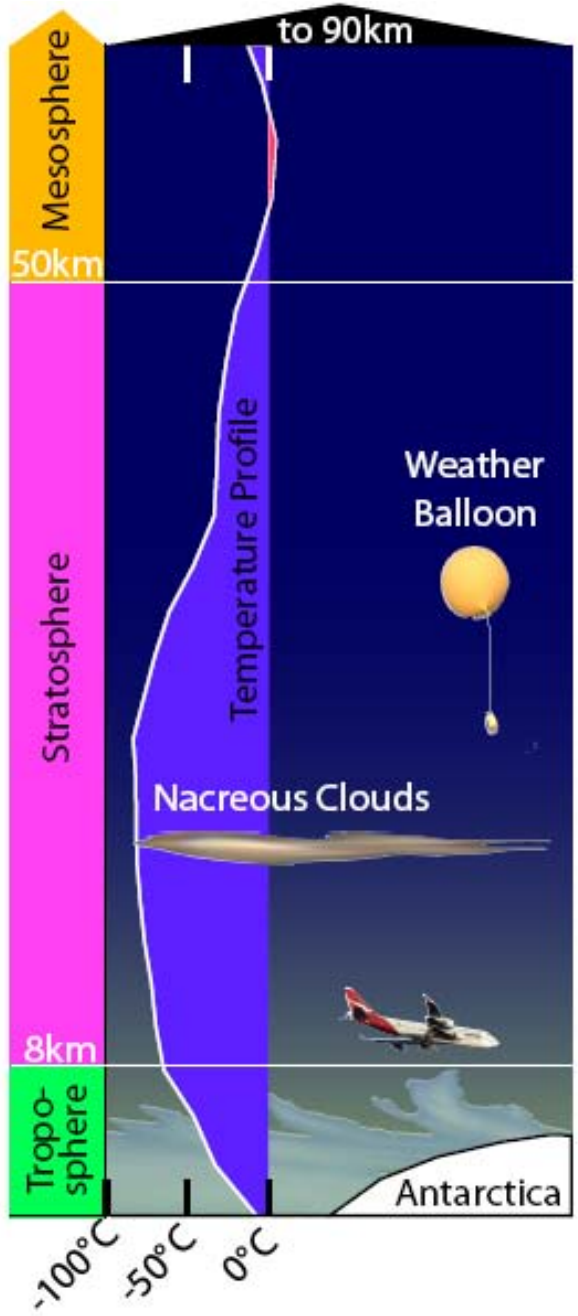


Inter-Annual Variability in Ozone Loss



The Antarctic Ozone Hole : How Does it Form?

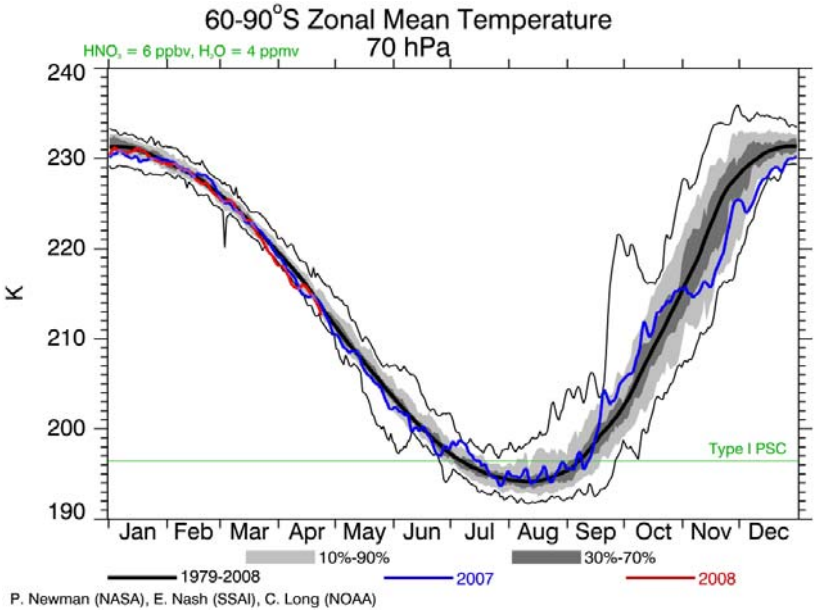
- Recipe for enhanced ozone loss…
  - A cold and stable atmosphere: The Antarctic Polar Vortex
  - Ultraviolet light to break-down chlorofluorocarbons into ‘passive’ halogen compounds (hydrochloric acid, hydrogen bromide).
  - Chemical reactions on icy particles to create ‘active’ halogen compounds (chlorine monoxide, bromine monoxide).
  - Sunlight to release chlorine and bromine, which react with ozone in a catalytic cycle that can be impeded by nitrogen dioxide.



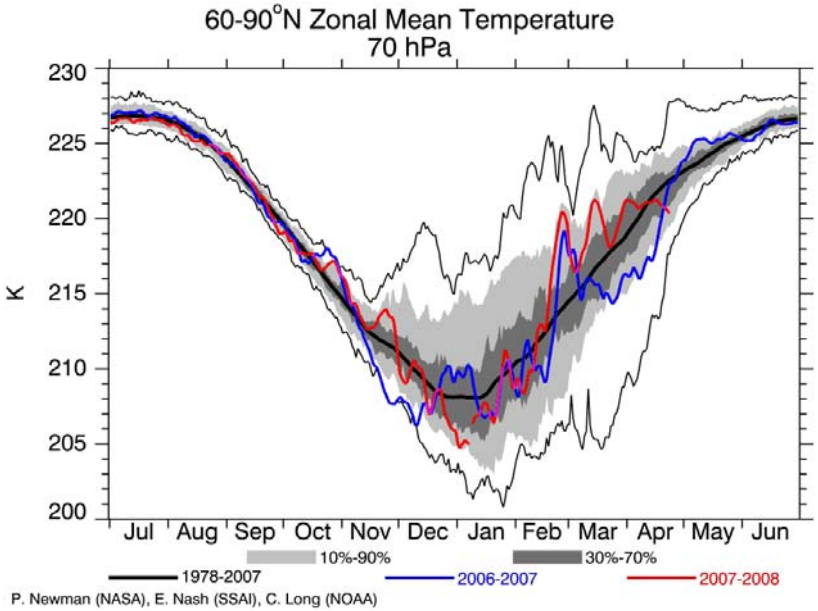
Stratospheric Temperatures

(~16km altitude, lower stratosphere)

Antarctic

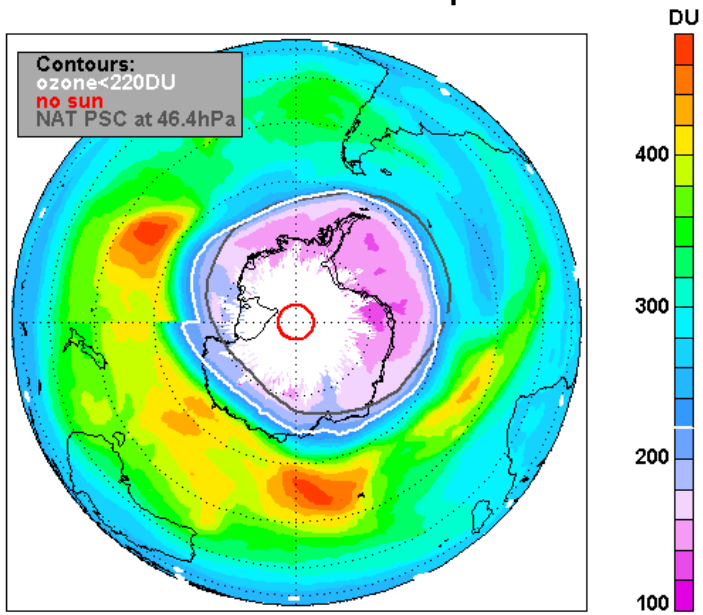


Arctic

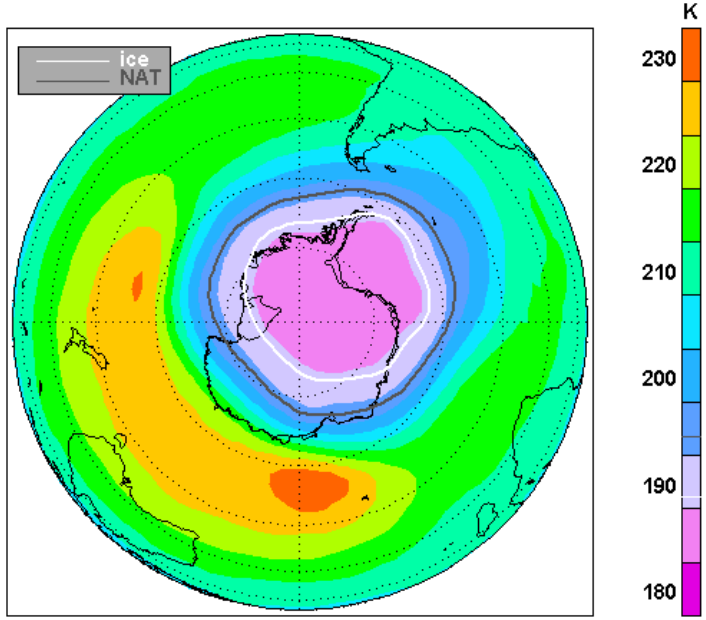


The Antarctic Polar Vortex

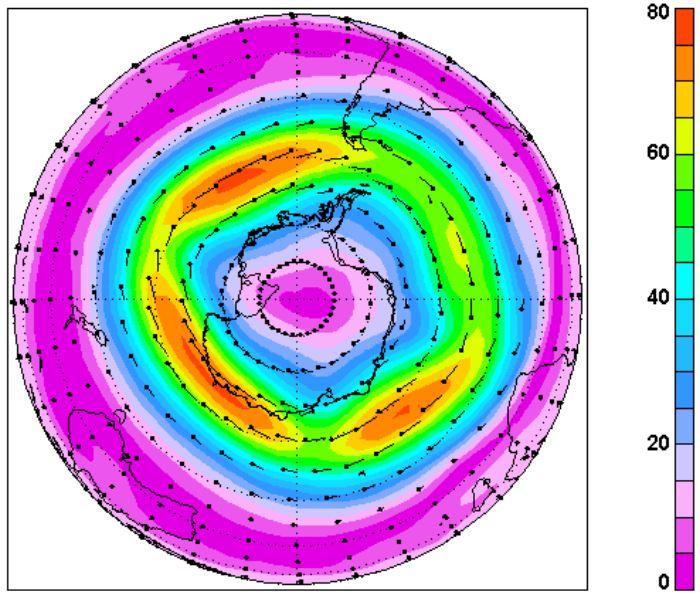
OMI Column Ozone 2007 Sep 12



UKMO Temperature 2007 Sep 12 12UT, 46.4hPa (20.3km)



UKMO Wind Speed 2007 Sep 12 12UT, 46.4hPa (20.3km)

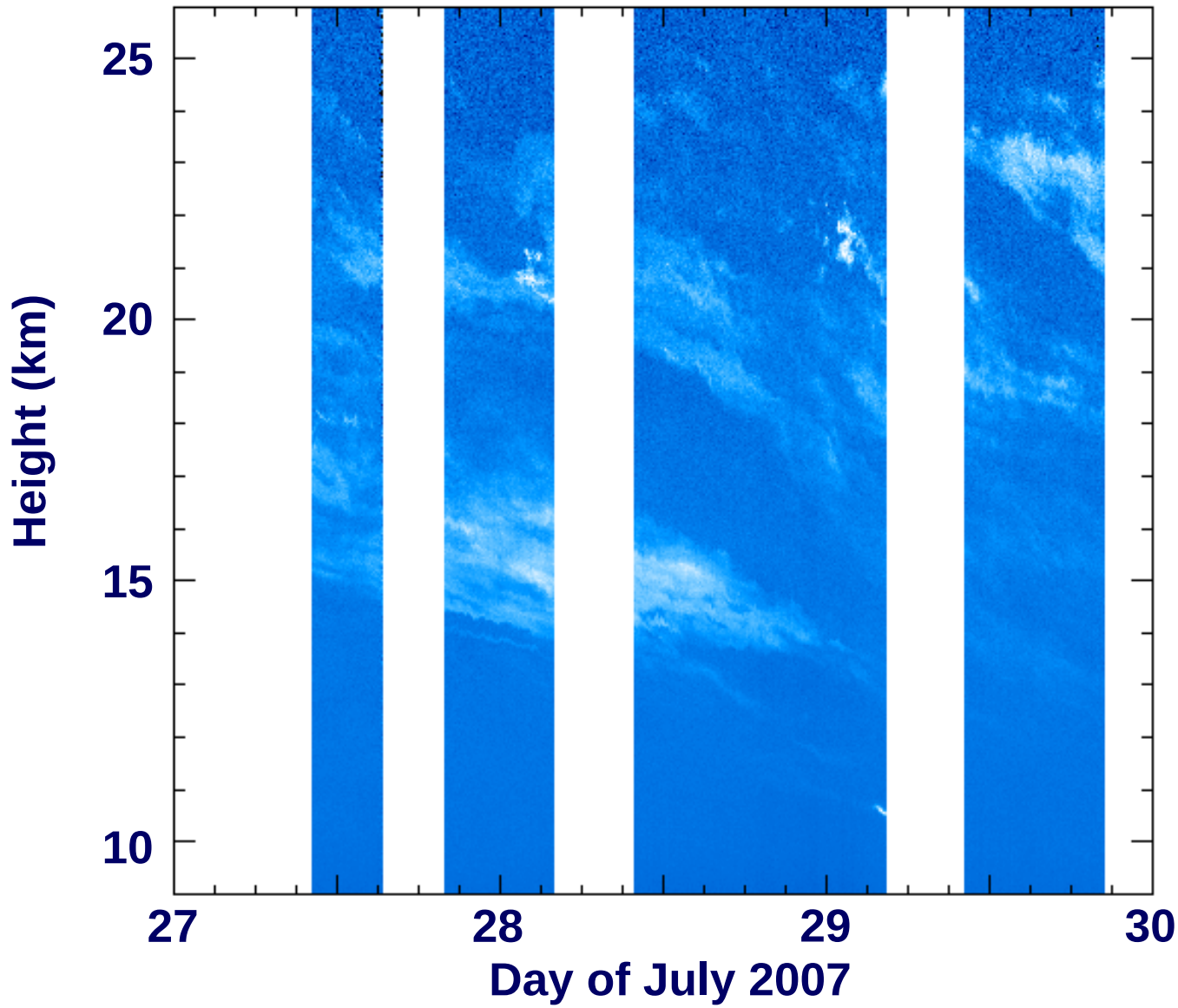


Nacreous (Polar Stratospheric) Clouds

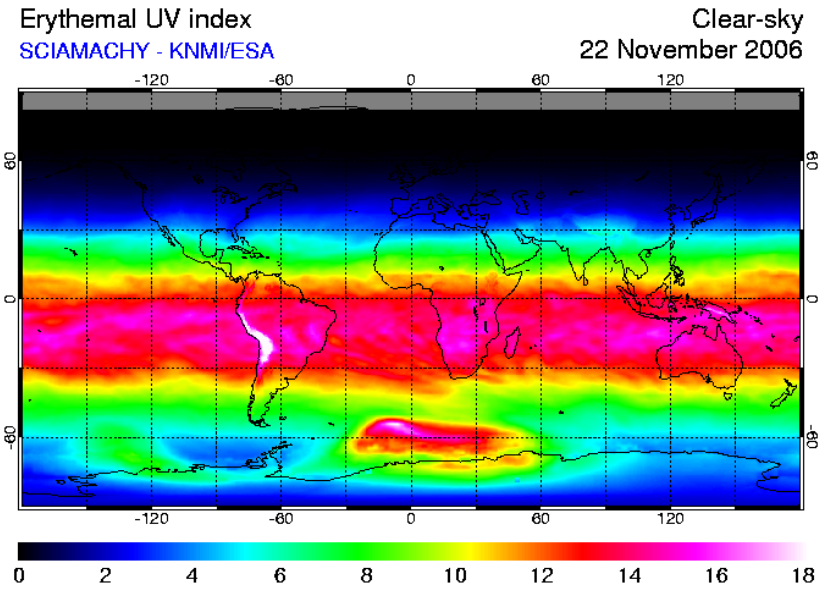
Visual Observations at Mawson, Antarctica

Polar Stratospheric Clouds

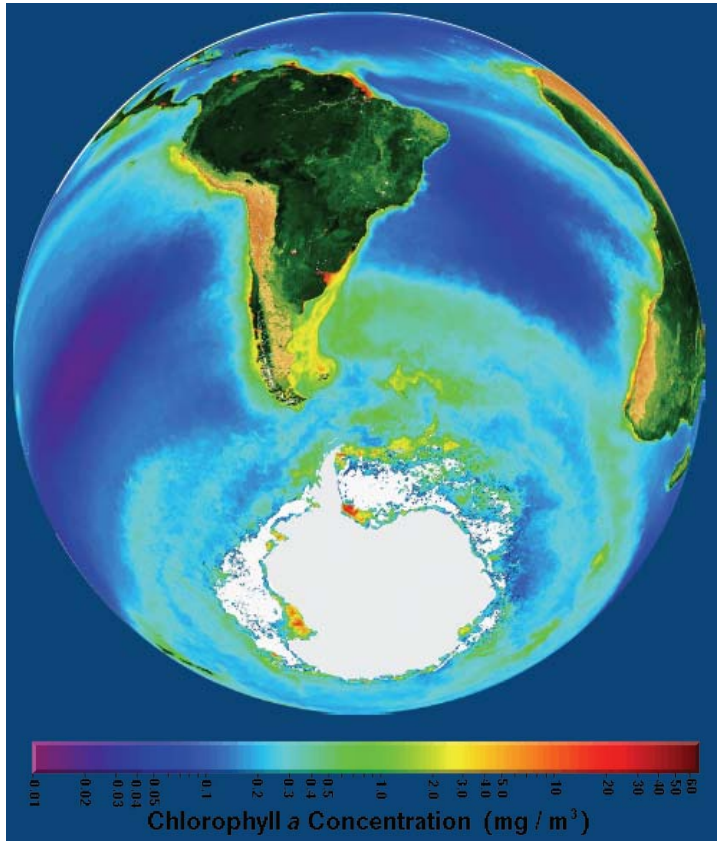
Lidar Measurements at Davis, Antarctica



Ozone Hole and Ultraviolet Radiation



Ultraviolet Index



Chlorophyll Concentration

Future Outlook

- Stratospheric Ozone Depleting Substances (ODS) declining
- Recovery by ~2060, influenced by climate change and ODS mitigation
- Next 5-10 years: variation in Ozone Hole size dictated by meteorology

Thanks to the Australian Ozone Science Group,
and thank you for listening!

Ozone Depletion, Ozone Depleting Substances & their Replacements: Roles in Climate Change

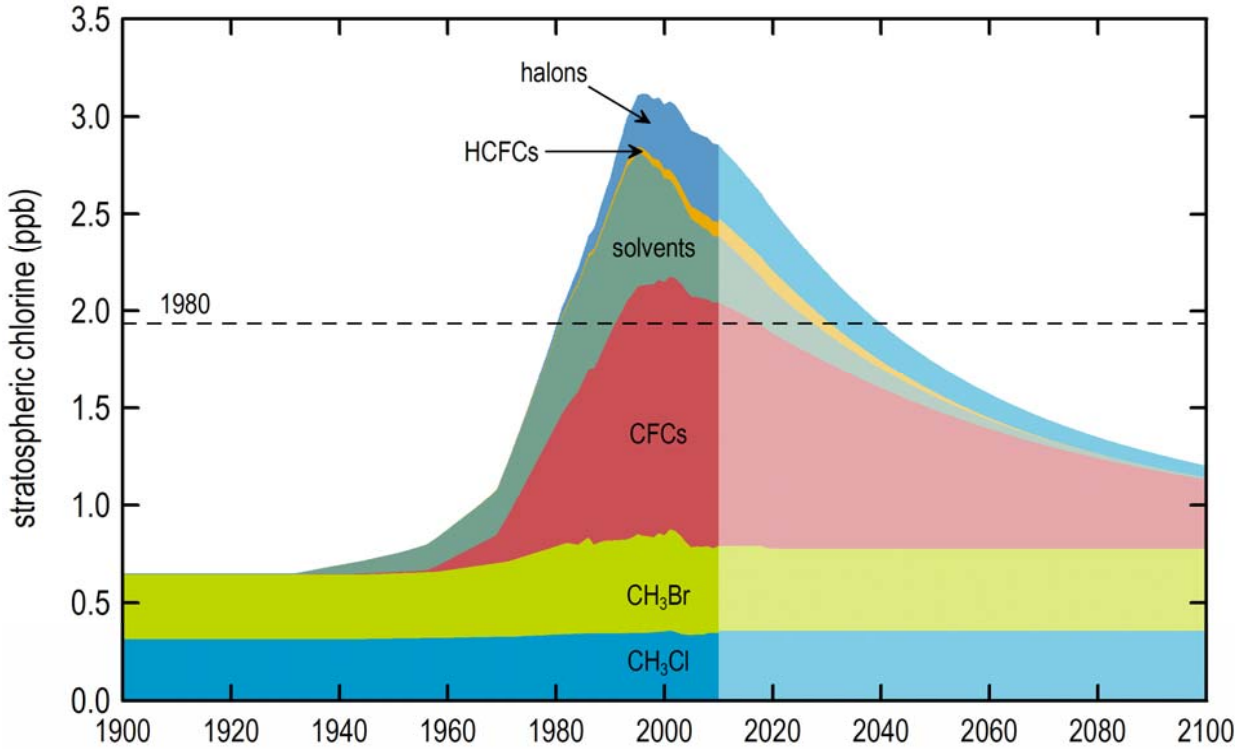
Paul Fraser & Paul Krummel
Centre for Australian Weather & Climate Research
CSIRO Marine & Atmospheric Research

www.csiro.au

Australian Government
Bureau of Meteorology

CSIRO

Ozone Depleting Substances & the Montreal Protocol



- the Montreal Protocol is a major ‘success story’
- stratospheric ‘chlorine’ (=EESC) peaked mid-1990s
- all ODSs now declining
  - biggest contributors to decline: methyl chloroform and methyl bromide (short-lived ODSs)
  - except HCFCs (3% of stratospheric chlorine, growing at 4%/yr) & halons (stopped growing)
- stratospheric ‘chlorine’ now declining by 0.8% per year
- should return to 1980 levels (when ozone losses became significant) by 2040

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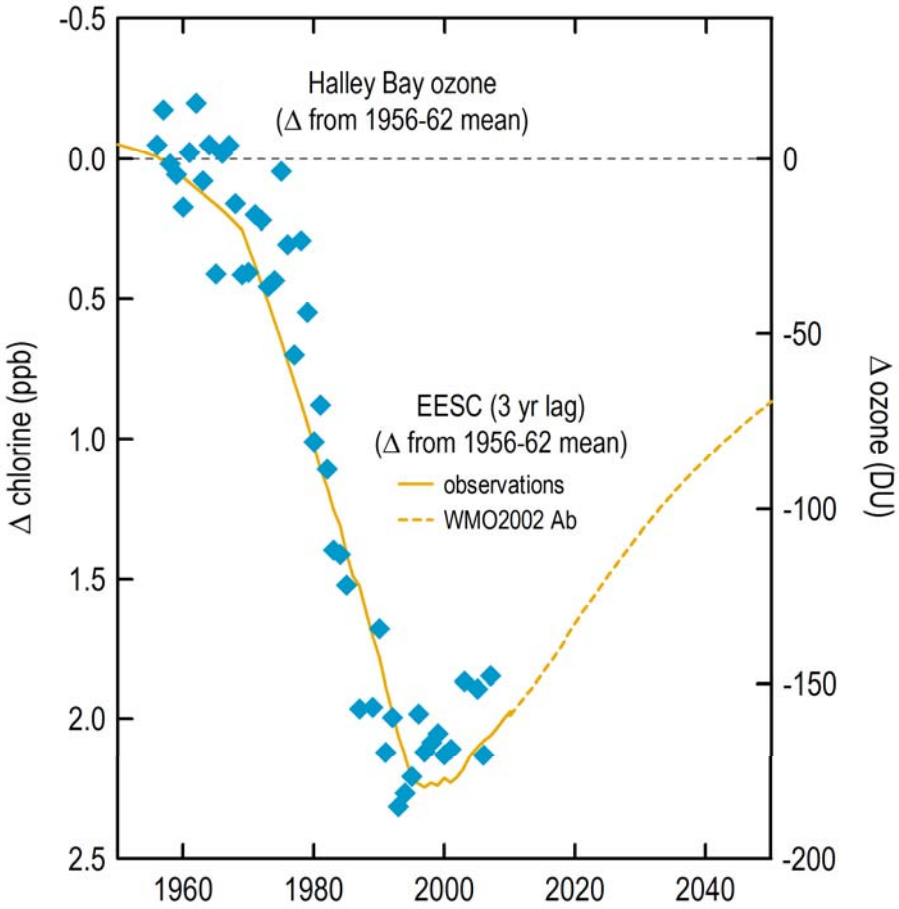
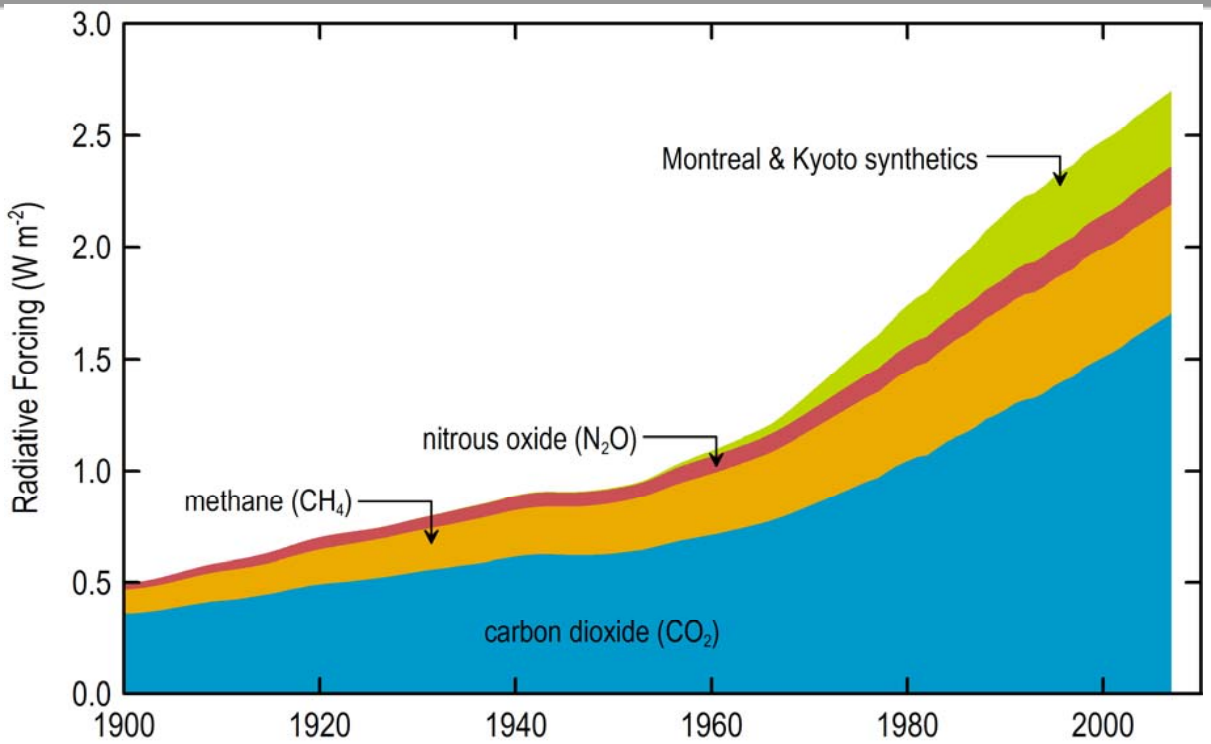
Stratospheric ‘chlorine’ & impact on Antarctic ozone



- strong correlation between changes in Halley Bay column ozone and stratospheric chlorine
- if correlation remains robust, Halley Bay ozone should return to 1980 levels by 2050
- the Montreal Protocol is working as intended

Climate impact of Montreal & Kyoto Protocol synthetic gases



- MP (CFCs etc) and KP (HFCs etc) synthetics are important GHGs
- how important? - radiative forcing compares of the climate impact of GHGs
- since pre-industrial times (1750)
  - CO_2 – 63%, CH_4 – 18%, N_2O – 6%
  - MP & KP synthetics – 13%
- in addition to protecting ozone, the Montreal Protocol is an important climate change agreement

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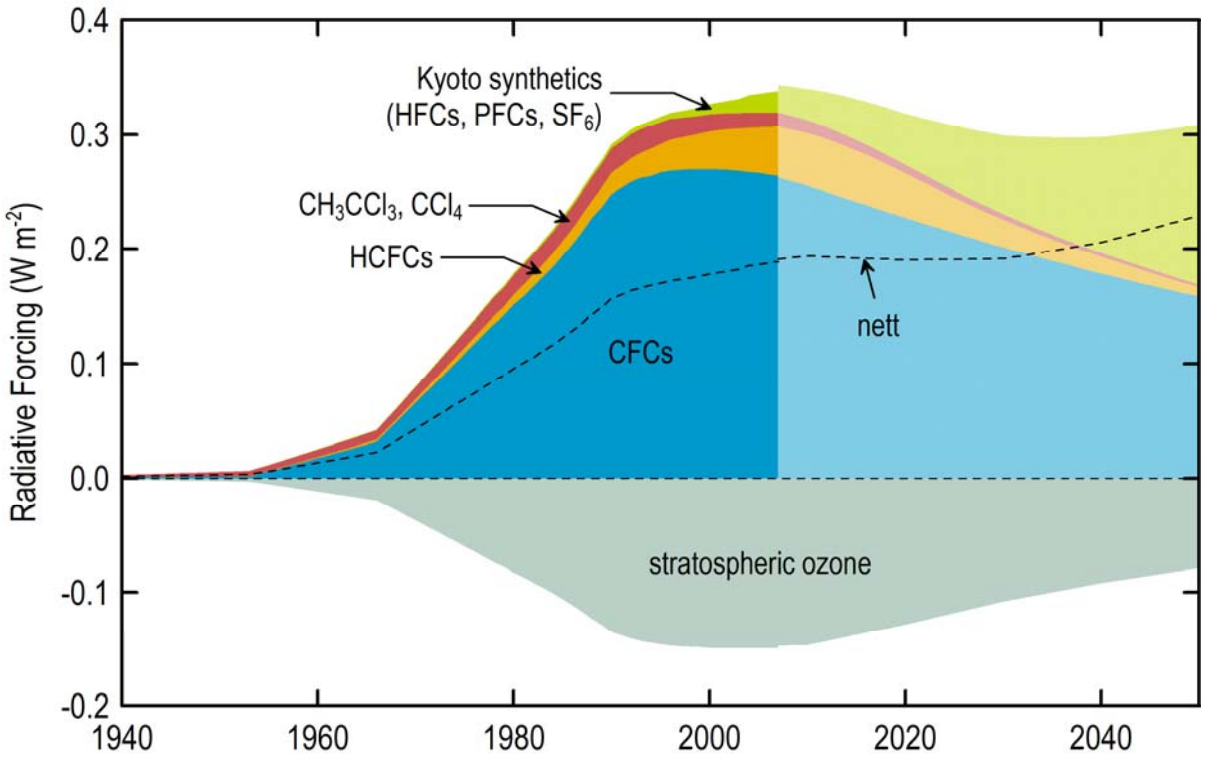
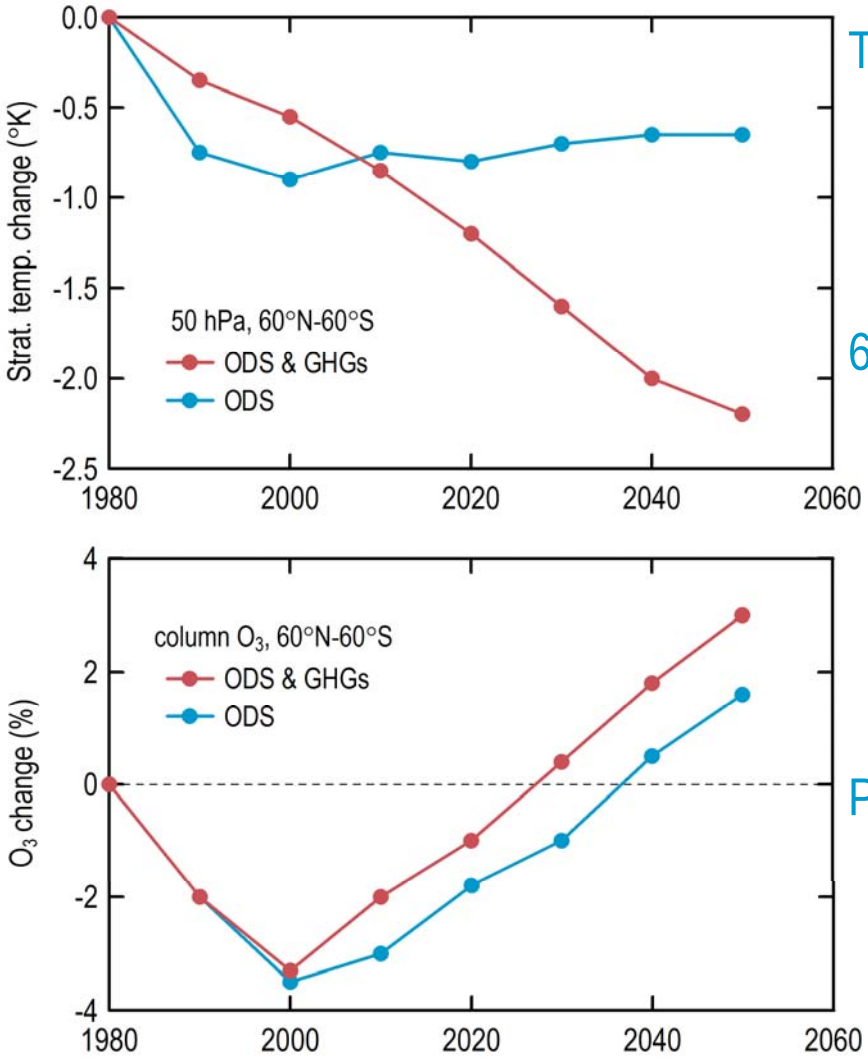
Total climate impact: MP & KP synthetics & stratospheric ozone changes



- radiative forcing due to MP & KP synthetics grew strongly until 1990, now peaked
- will decline until 2030, then grow again in 2040 (MP decreases v. KP increases)
- 45% of climate impact of MP & KP synthetics negated by stratospheric O_3 changes
- taking O_3 changes into account, net radiative forcing static until 2030, then starts to grow again

Climate change impacts on ozone: coupled chemistry-climate models (WMO 2007)



Temperature changes (60°N-60°S)

- ODS only: constant (-0.7°K) relative to 1980
- ODS + GHGs (CO_2, CH_4, N_2O, KP): steady decline to -2.2°K by 2050

60°N-60°S (mid-latitude) ozone changes

- ODS only: O_3 recovery by 2040
- ODS + GHGs: O_3 recovery 10-15 years earlier
  - gas-phase destruction of ozone slowed at lower stratospheric temperatures
  - despite increased ozone loss due to higher CH_4 (H_2O, OH) & N_2O (NO_x)

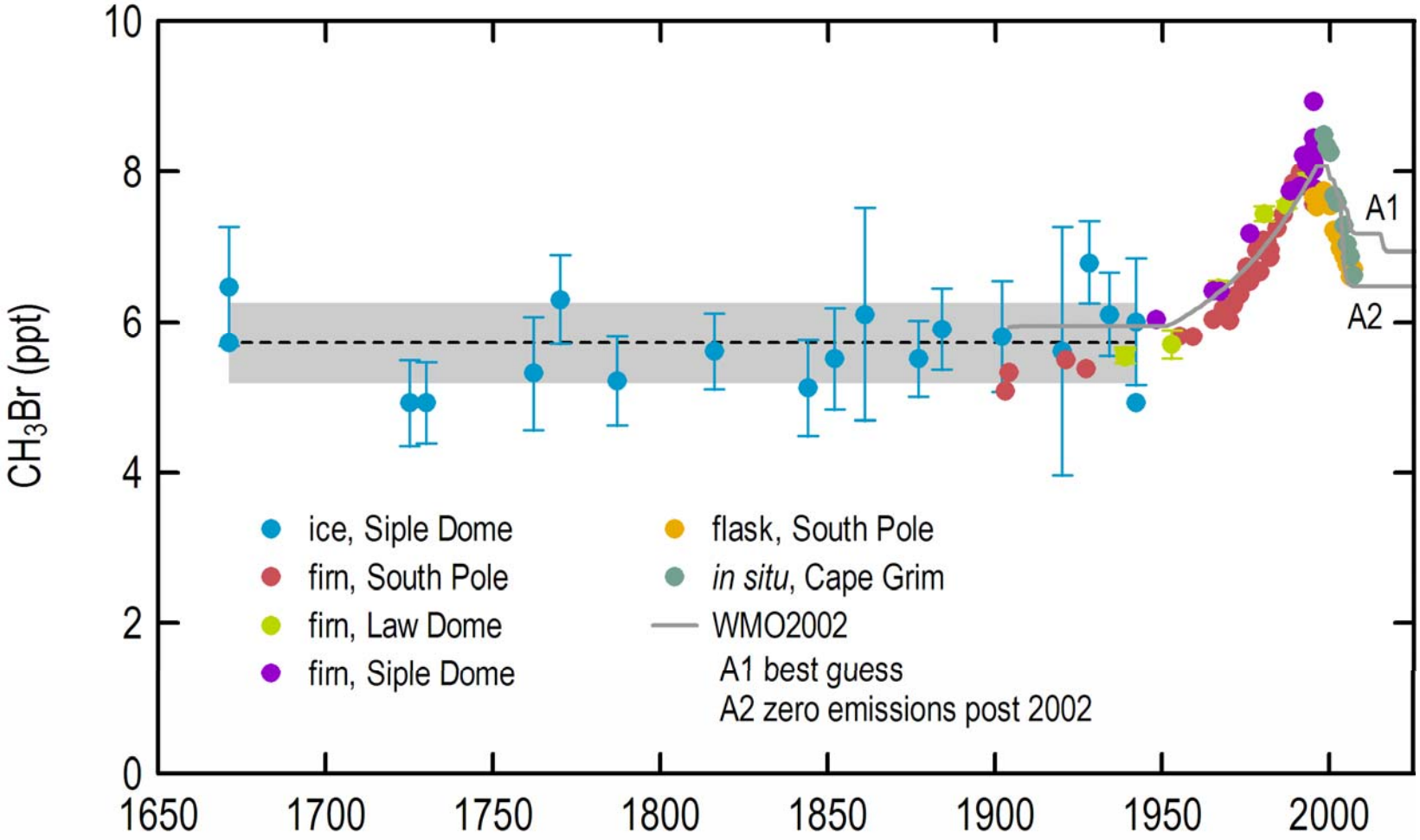
Polar ozone changes

- O_3 recovery by 2060, GHGs have no significant impact
  - heterogeneous-phase (on PSCs) ozone destruction not temperature dependent

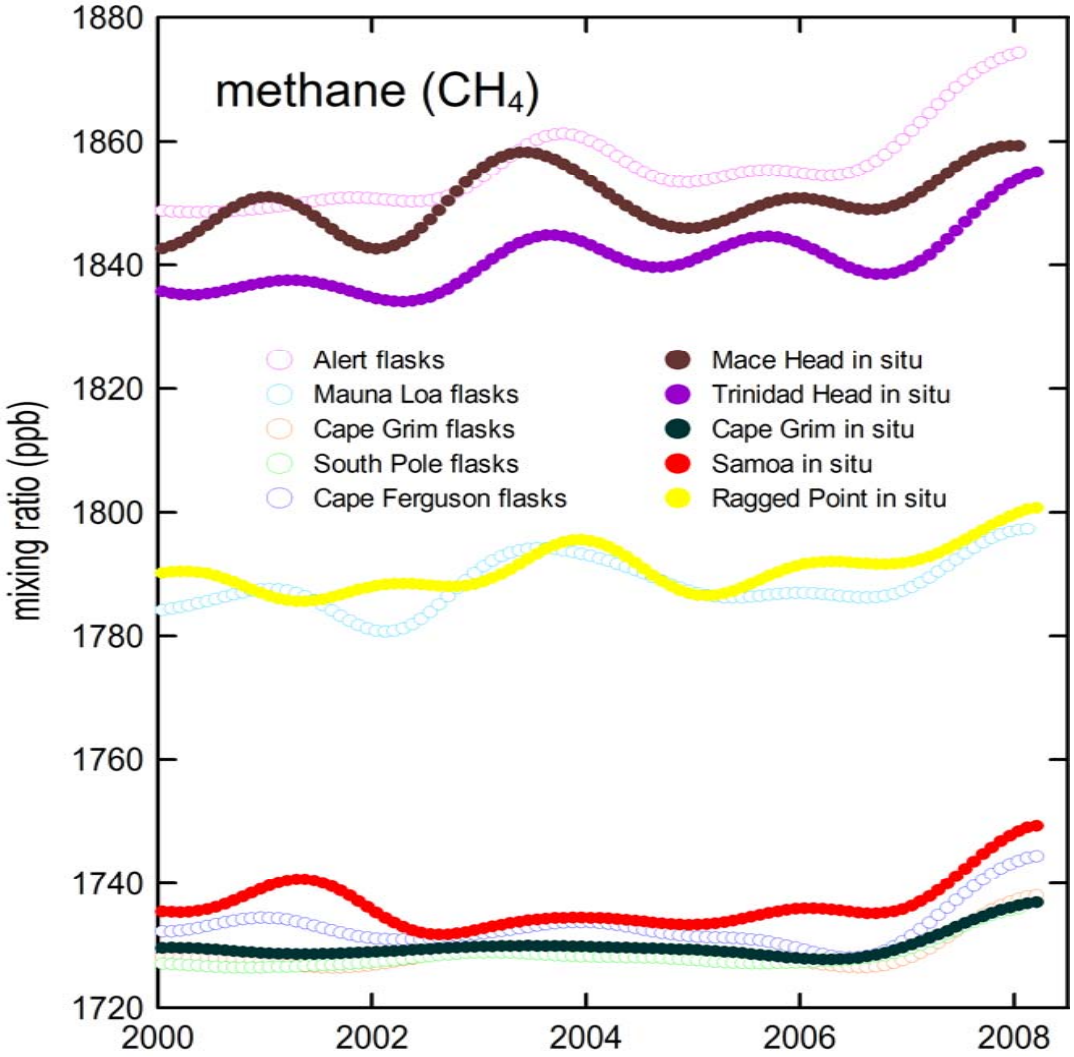
Conclusions

- Montreal & Kyoto Protocol synthetics (CFCs, HFCs etc) have accounted for about 13% of climate change since pre-industrial times
- the climate impact MP & KP synthetics grew strongly until 1990, now peaked (MP decline v. KP increase)…
- …and almost half (45%) of climate impact of MP/KP synthetics negated by stratospheric ozone changes
- however, the climate impact of KP synthetics will grow strongly after 2040, when MP synthetics have declined and ozone depletion has ceased
- stratospheric 'chlorine' now declining by 0.8% per year, will return to 1980 levels by 2040: however ozone recovery may be impacted by climate change
- mid-latitude ozone changes
  - ODS only: O_3 recovery possible by 2040
  - ODS + GHGs: O_3 recovery possible 10-15 years earlier (i.e. as early as 2025)
  - if correct, we are more than half way down the path to ozone recovery
- polar ozone changes
  - O_3 recovery by 2060, GHGs have no significant impact

Global methyl bromide: latest results



Global methane: on the rise again



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Thank you

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Stratospheric ozone depletion and Australian climate change

Prof David Karoly, University of Melbourne

Summary

- Ozone depletion has played a role in recent Australian climate change, together with increasing greenhouse gases
- There will be competing influences from ozone recovery and increasing greenhouse gases on future climate change
- Australia does not have a world-class capability to model stratospheric ozone and its influences on Australian climate

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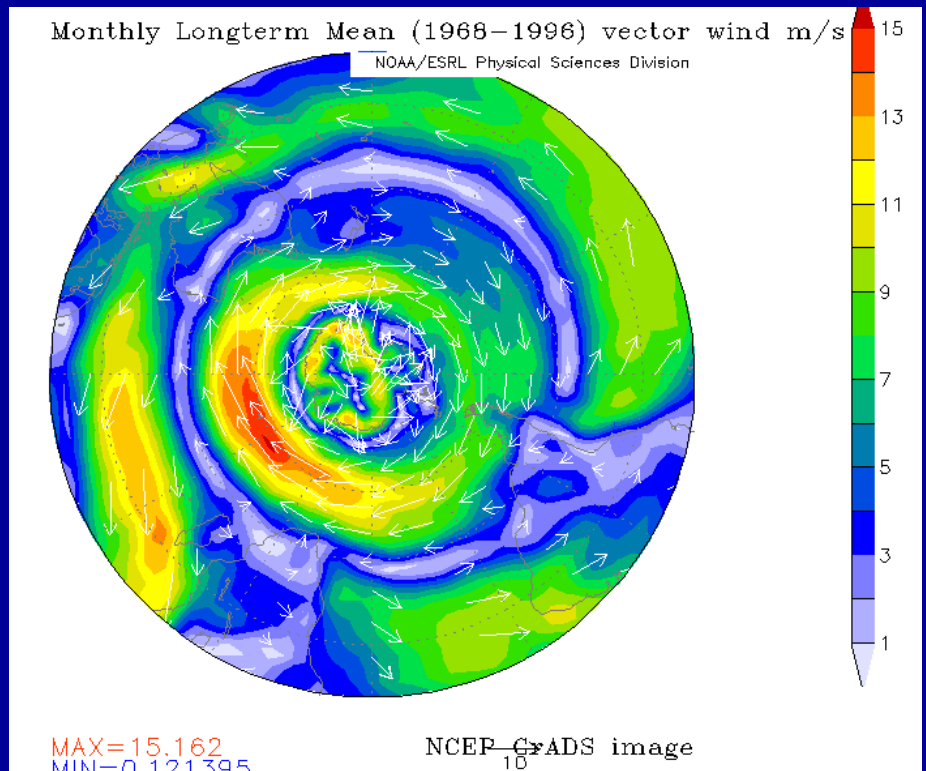
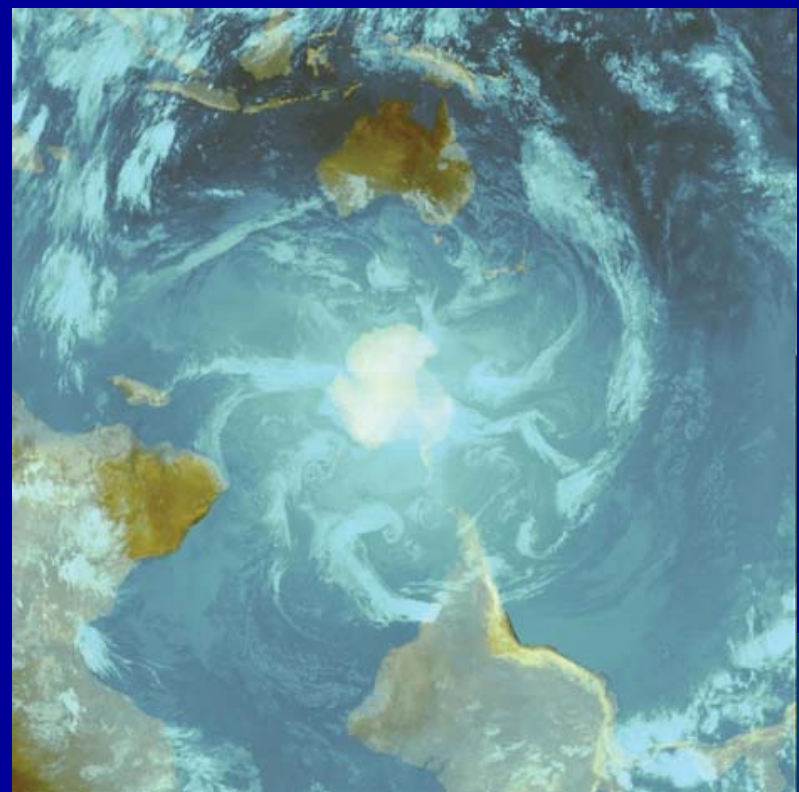
Southern Hemisphere storm track

- The Southern Hemisphere has a band of strong westerly winds from 45 - 65°S from the surface into the stratosphere (where it is called the polar vortex)
- This is associated with the main storm track, with weather systems that bring rain to southern Australia

JJA wind vectors

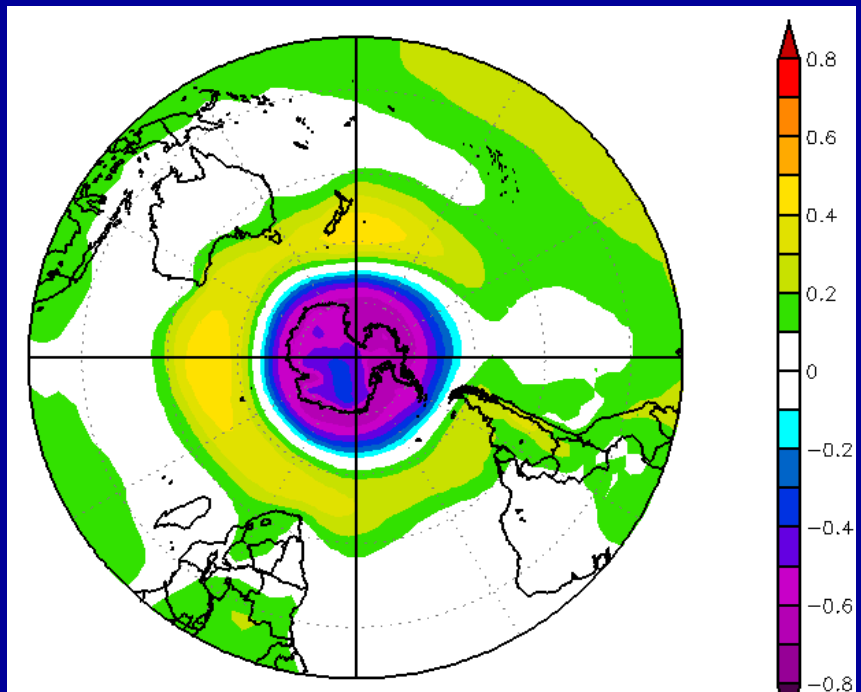


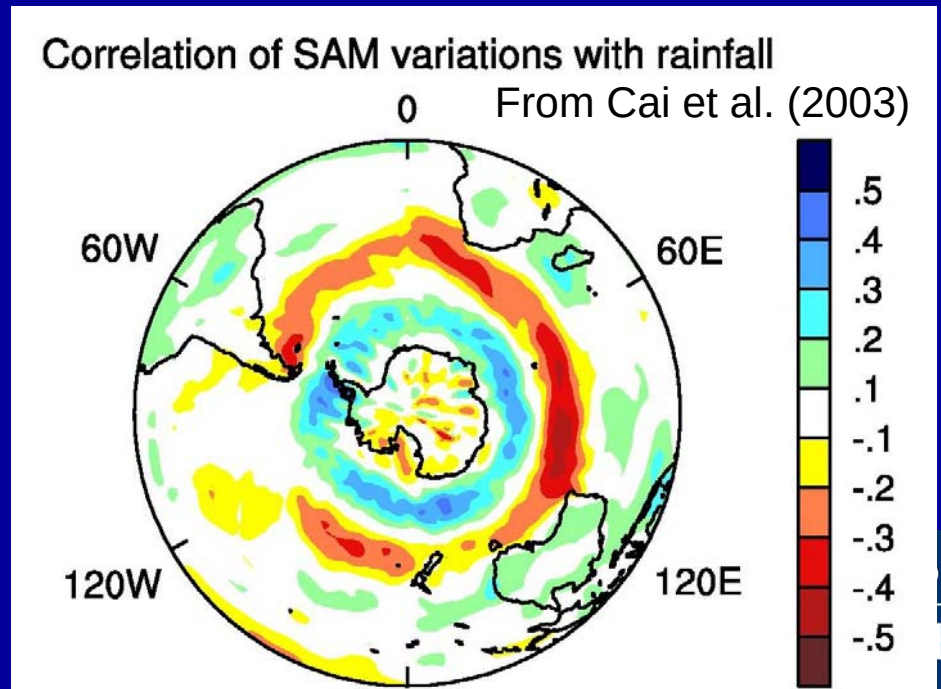


Southern Hemisphere annular mode

- Variations of the strength and location of the westerly jet and storm track are the dominant mode of variability of the SH high latitude circulation, called the SH annular mode (SAM)
- The SAM involves variations of the strength of the polar vortex near 60ºS, opposite variations of pressure between middle and high latitudes, and shifts in the storm track

Pressure variations due to the SAM

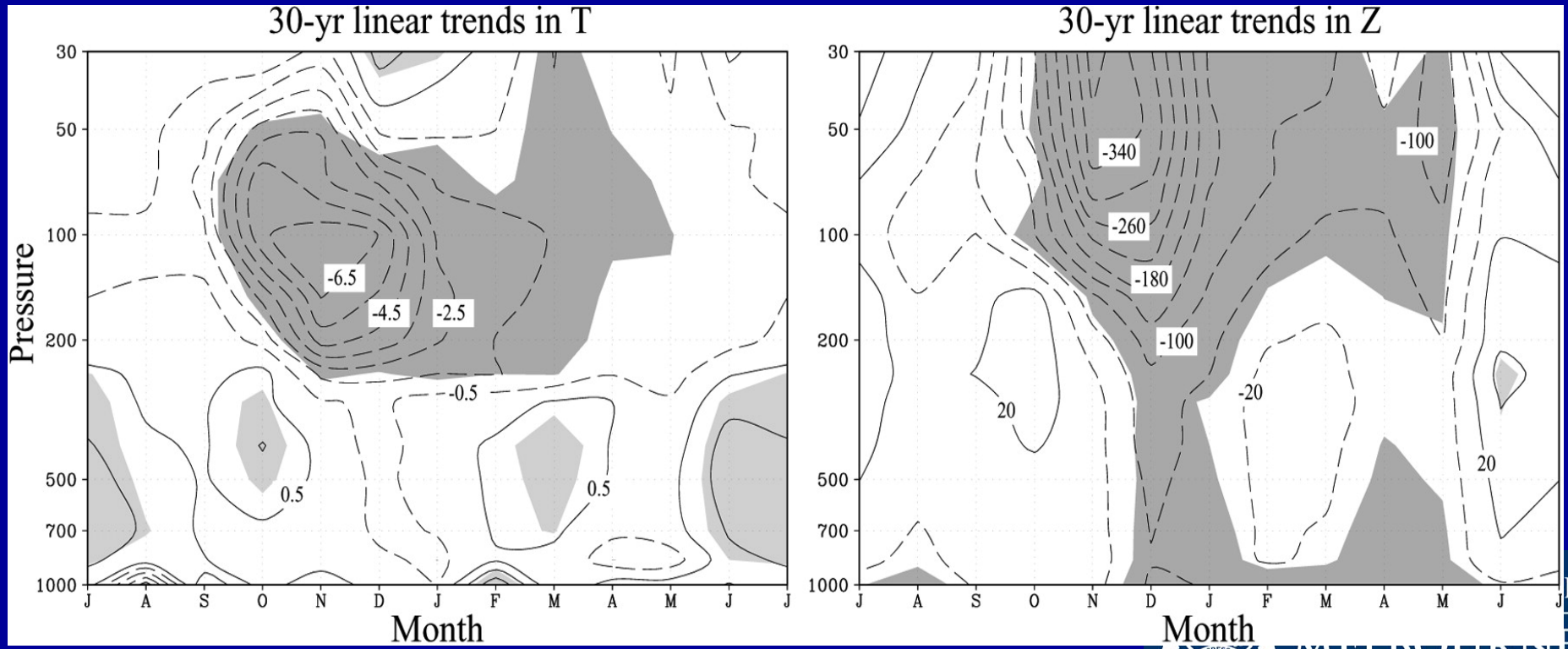




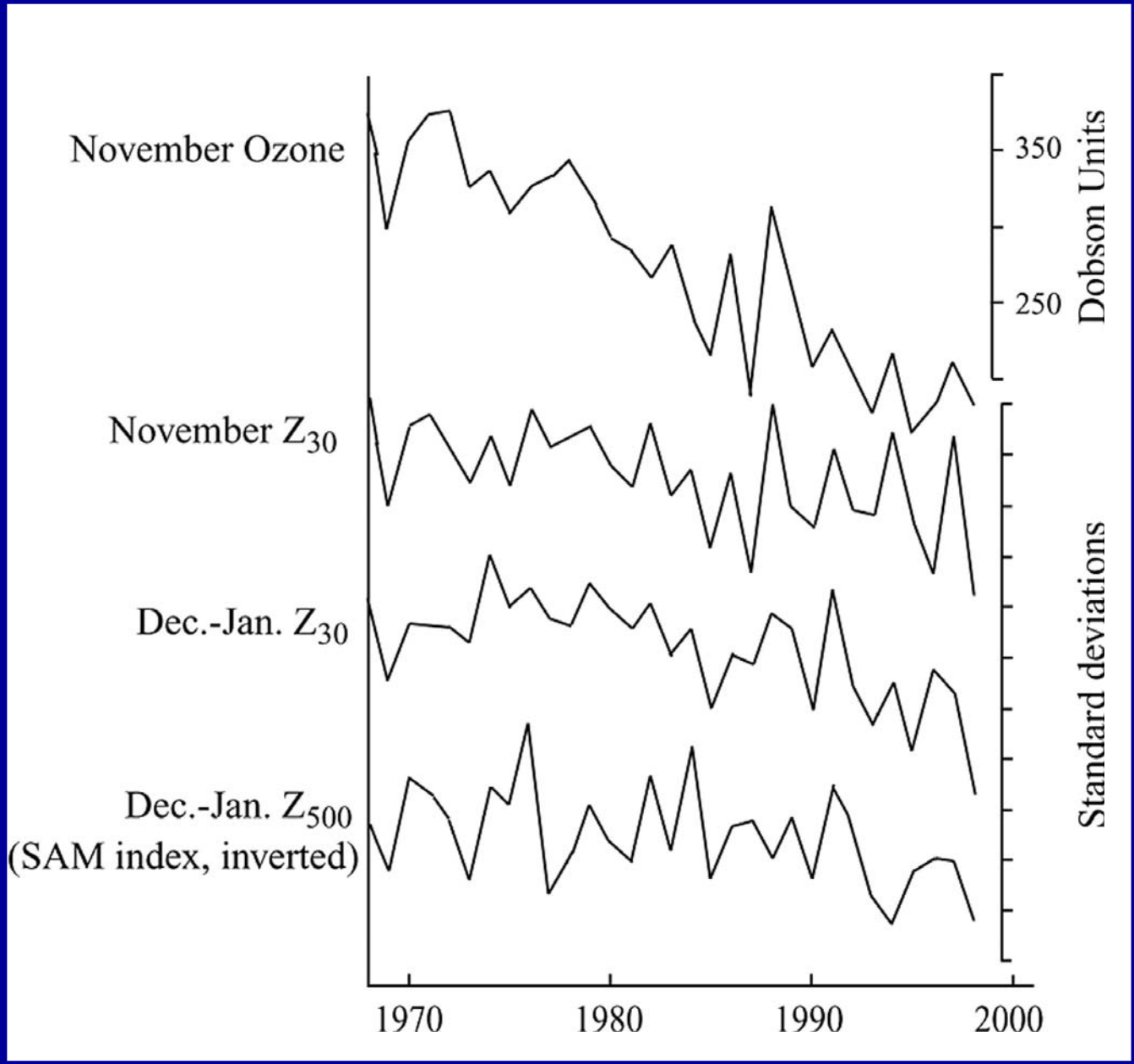
Trends over Antarctica
Response to ozone forcing?

30-year (1969-98) linear trends in temperature and height averaged over Antarctica (from Thompson and Solomon, 2002)

Temperature trends



Trends over Antarctica



Variations in SH high latitudes in the stratosphere and troposphere (from Thompson and Solomon, 2002)

Gillett and Thompson (2003) show that the modelled SH high latitude response to Antarctic ozone depletion is very similar to observed.

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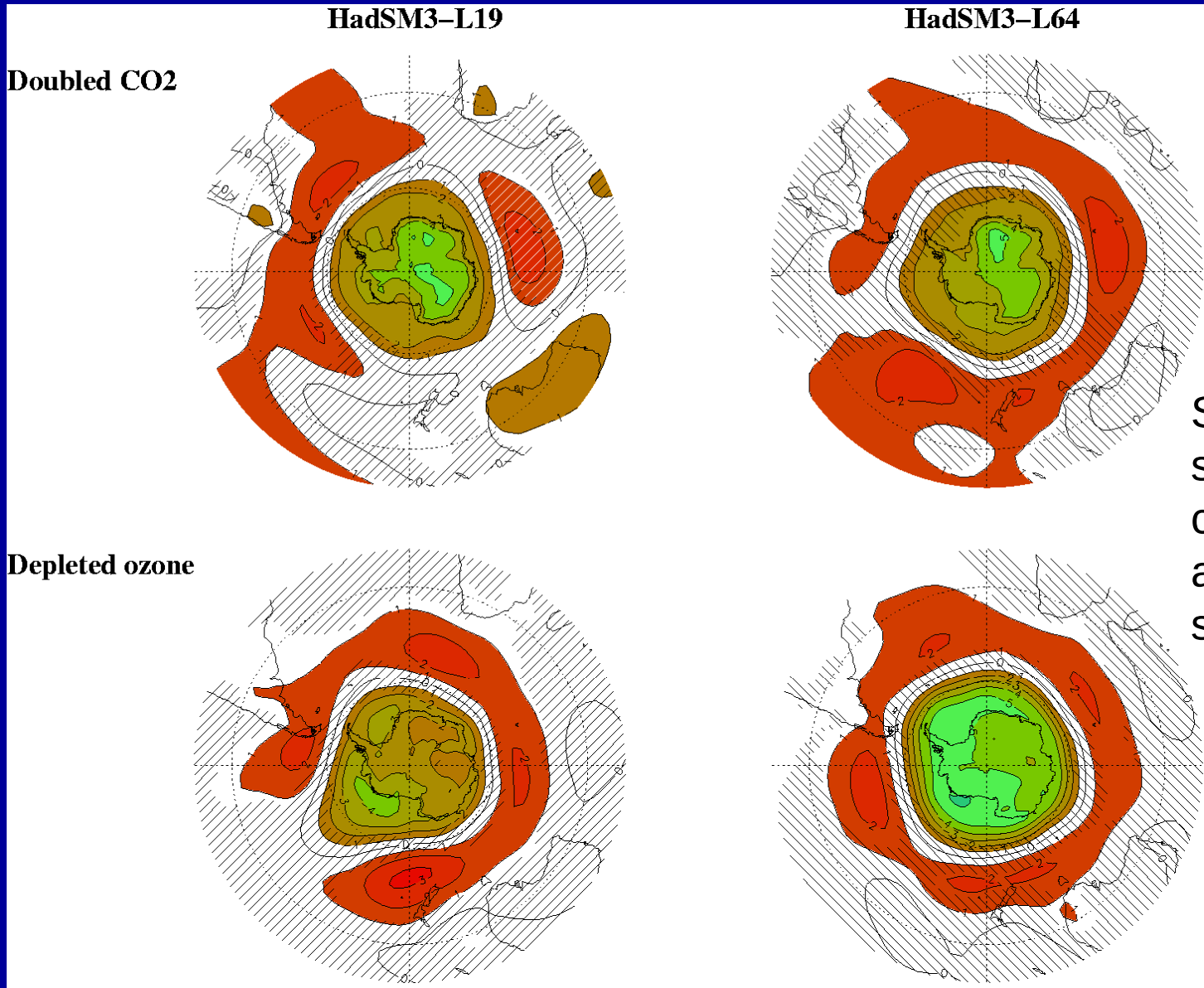
Pressure changes due to CO_2 forcing or ozone forcing in Hadley Centre climate models (from Gillett et al, 2002)

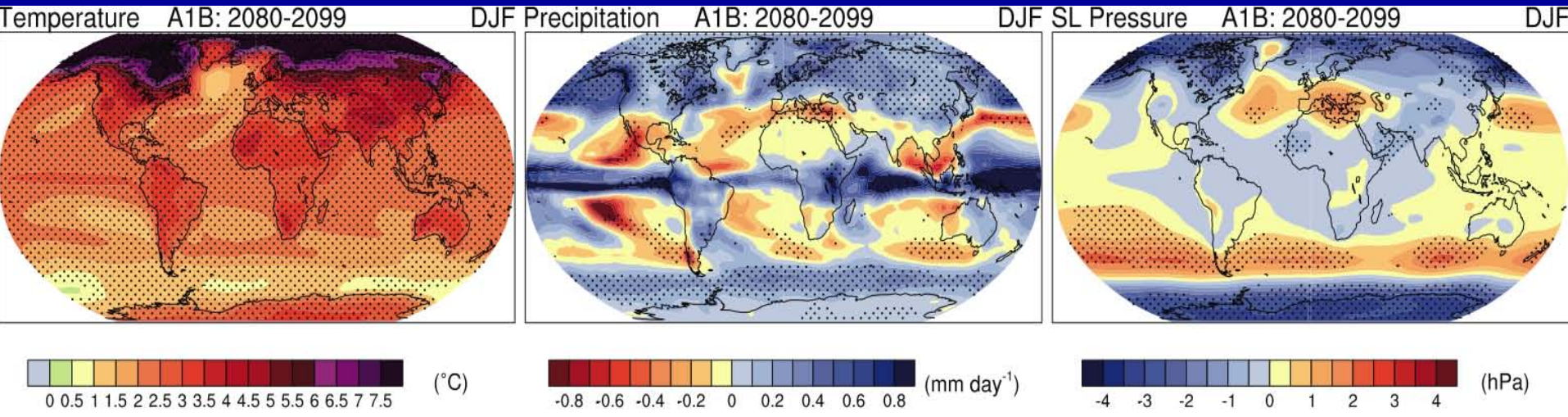


Shading shows changes that are **not** significant

Projections of climate change

Ensemble mean multi-model climate change projections for Dec-Feb for 2080-99 from IPCC AR4.

Models include increasing greenhouse gases and aerosols. Some models also include projected ozone changes



From IPCC AR4 (2007)

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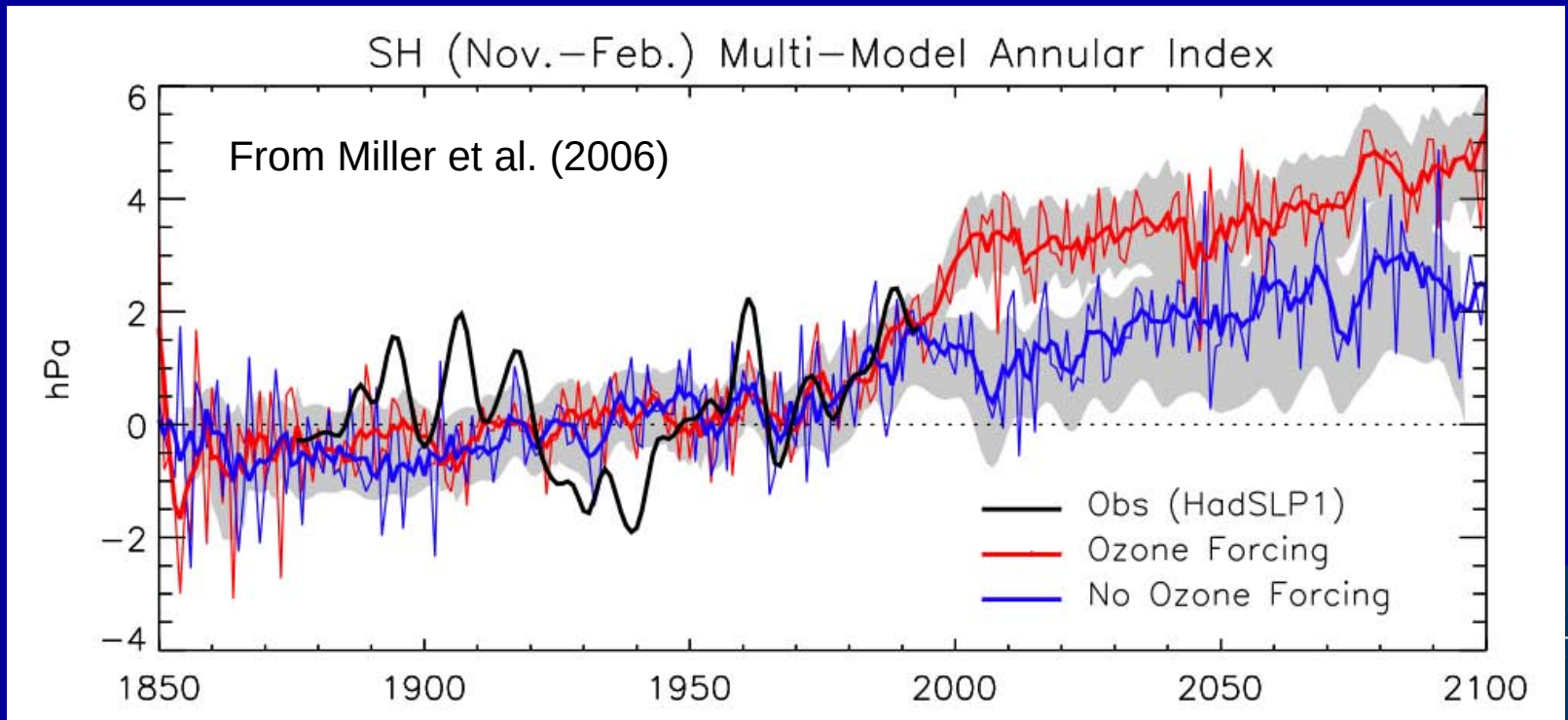
Projections of climate change

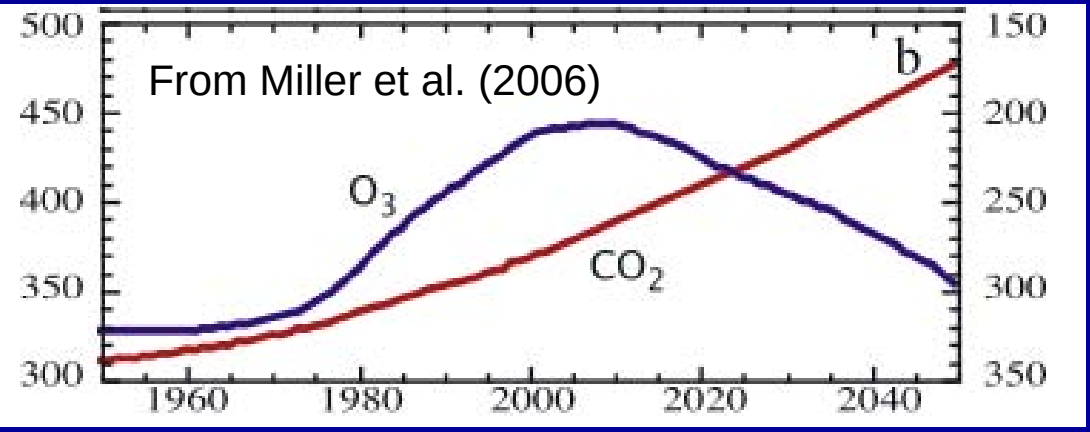
The observed increasing trend in the SAM is simulated better in models that include both increasing greenhouse gases and stratospheric ozone depletion.

The largest differences in SAM variations are from 1990 to 2010, the period of lowest Antarctic ozone.

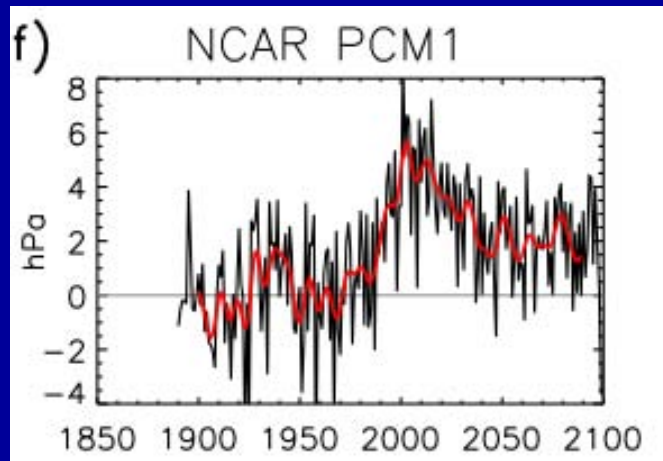


Competing influences

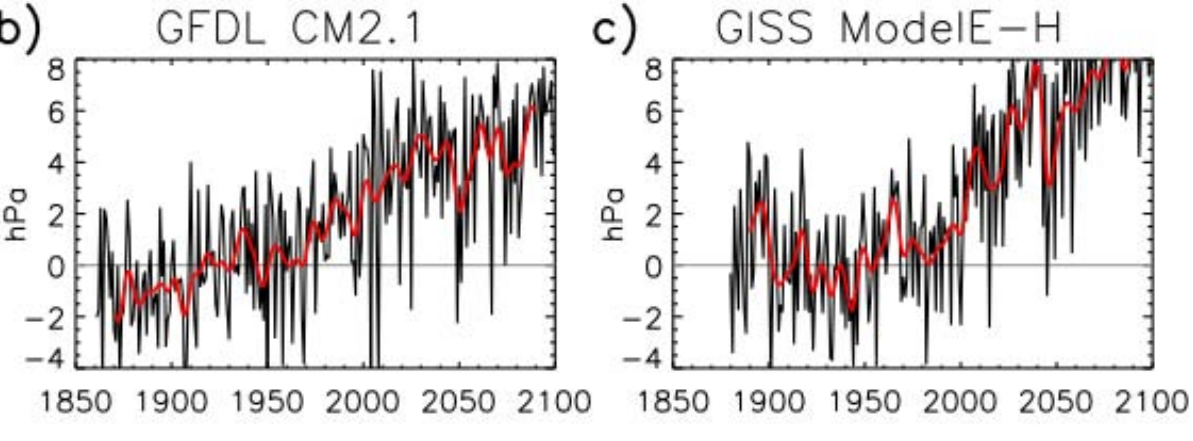
Future greenhouse gases and ozone

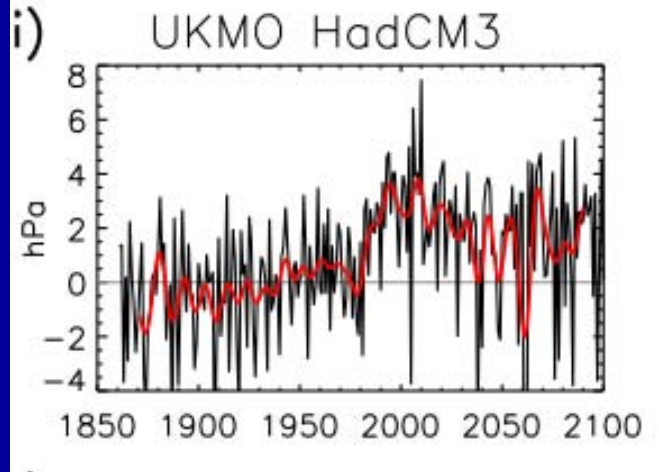


Model NDJF SAM for increasing ghgs and ozone depletion and recovery



Model NDJF SAM for increasing ghgs and ozone depletion but no recovery





Modelling ozone-climate interactions

- The Australian climate model simulations used in the IPCC AR4 did not include ozone depletion
- Centre for Australian Weather and Climate Research (CAWCR), together with Australian university groups, is developing the next generation Australian climate model, ACCESS (Australian Community Climate and Earth System Simulator)
- A long-term goal (beyond 2010) is for ACCESS to simulate coupled ozone-climate interactions
- Inadequate resources are available for coupled ozone-climate modelling

Summary

- Ozone depletion has played a role in recent Southern Hemisphere climate change, together with increasing greenhouse gases, contributing to a southward shift of the storm track and rainfall decreases in southern Australia
- There will be competing influences from ozone recovery and increasing greenhouse gases on future climate change
- Australia does not have a world-class capability to model stratospheric ozone and its influences on Australian climate