

The Southern Hemisphere: Another laboratory for testing ideas (on the rôle of the stratosphere in tropospheric climate)

- Motivation
- The SH annular mode
- The Antarctic ozone hole in 2002
- Discussion



Acknowledgements

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 - Nathan Gillett
 - John Fyfe
 - NASA GSFC, NCEP, NOAA CDC
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 - Simon Grainger, now at BMRC
 - Paul Krummel, CSIRO
- Wenju Cai, who included me as a co-author on his paper



Motivation

- It is difficult to find real world laboratories to test ideas about the large-scale behavior of the atmosphere
- The Southern Hemisphere provides a nearly independent realisation of the atmosphere with the same f , R_e , similar solar radiation but very different lower boundary forcing, with different topography and oceans
- Robust theories of the role of the stratosphere in tropospheric climate should work in the SH just as well as in the NH, and be able to explain observed SH variations



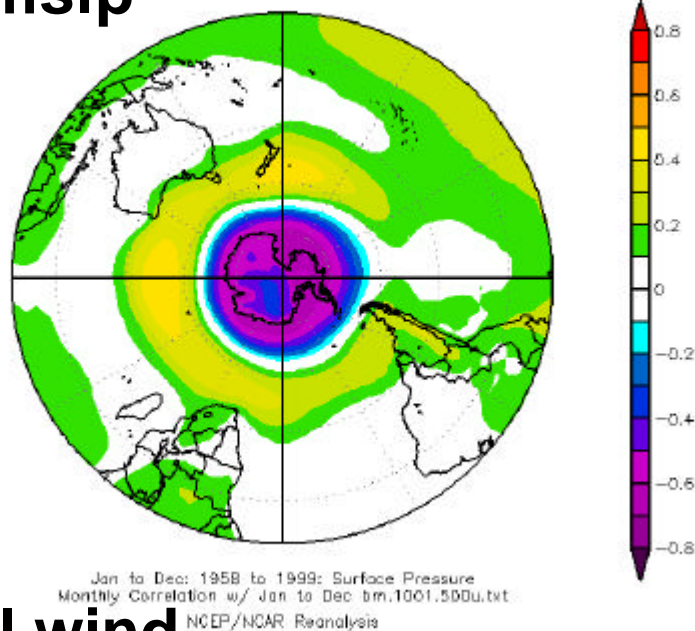
Southern Hemisphere annular mode

- Has been studied since the mid-1980s in the troposphere
- It is the dominant mode of low frequency variations of the SH circulation
- It involves opposite variations of pressure (and geopotential height) between middle and high latitudes, and variations of zonal wind near 60°S
- It occurs on all timescales longer than about 15 days
- It involves coherent variations of transient eddy momentum and heat fluxes

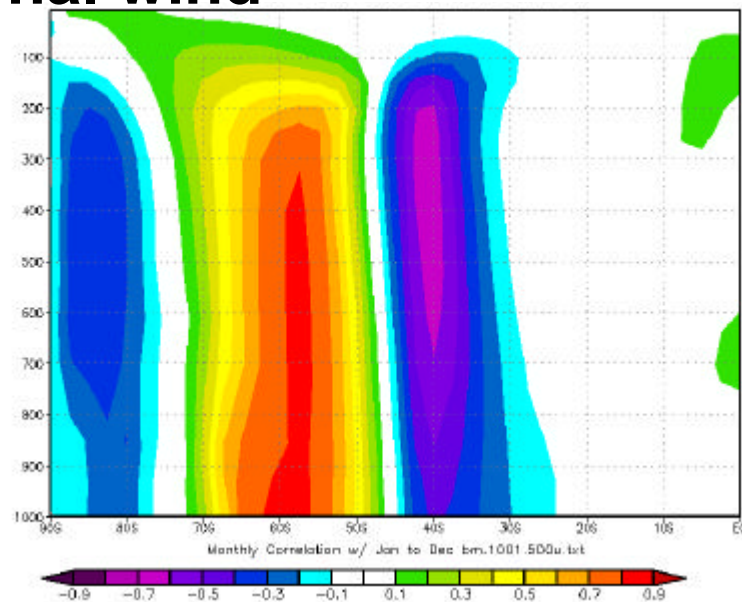


Correlations of monthly variations with [u] 55-65°S

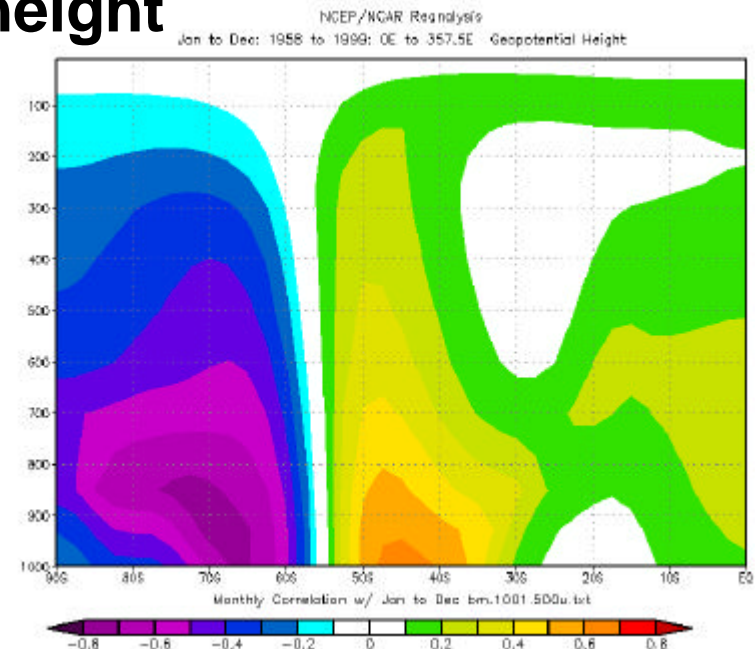
mslp



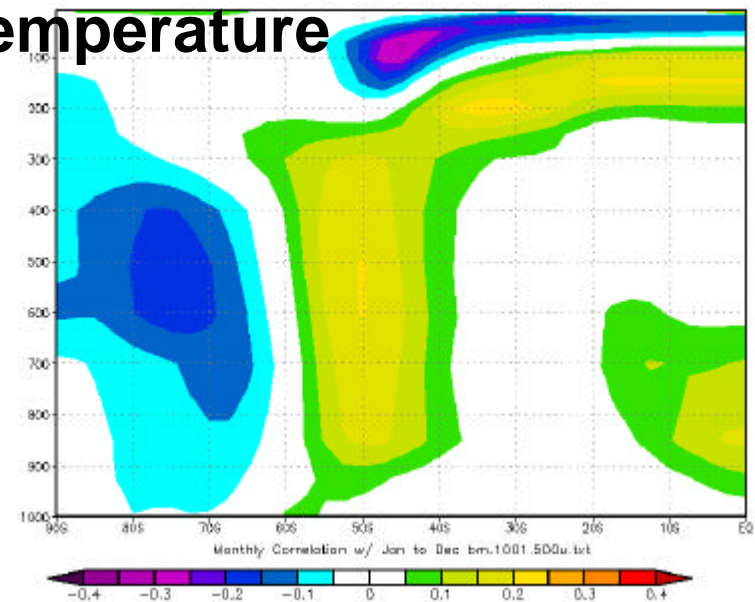
zonal wind



height



temperature



Data sources

- NCEP reanalyses 1958 - 2000, used to generate a high latitude mode index from mean monthly mean zonal wind (55-65°S) and to describe the coherent variations of the SH annular mode
- SH monthly mslp station data from 28 stations, used to generate a high latitude mode index average (30-60°S) - (60-90°S)
- Station-based data used to confirm the NCEP reanalyses



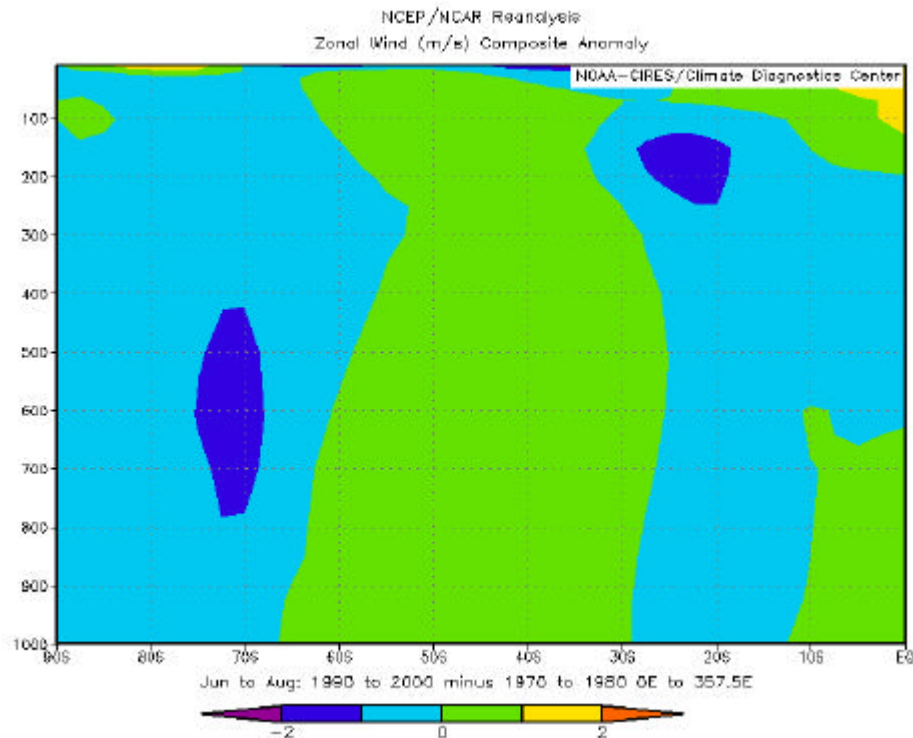
Change in the indices 1958-1999

	DJF	MAM	JJA	SON
Change in [u] 500 (m/s)	2.97	3.51	2.66	1.08
Change in mslp (hPa)	1.90	1.69	2.49	-0.63

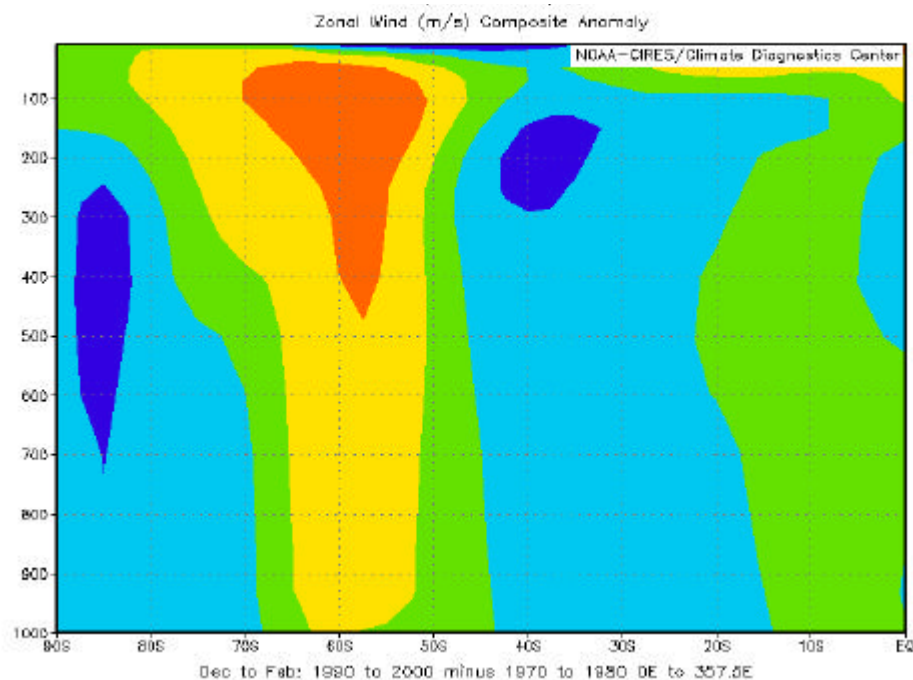


Trends in [u] in SH (1990-2000) - (1970-80)

JJA

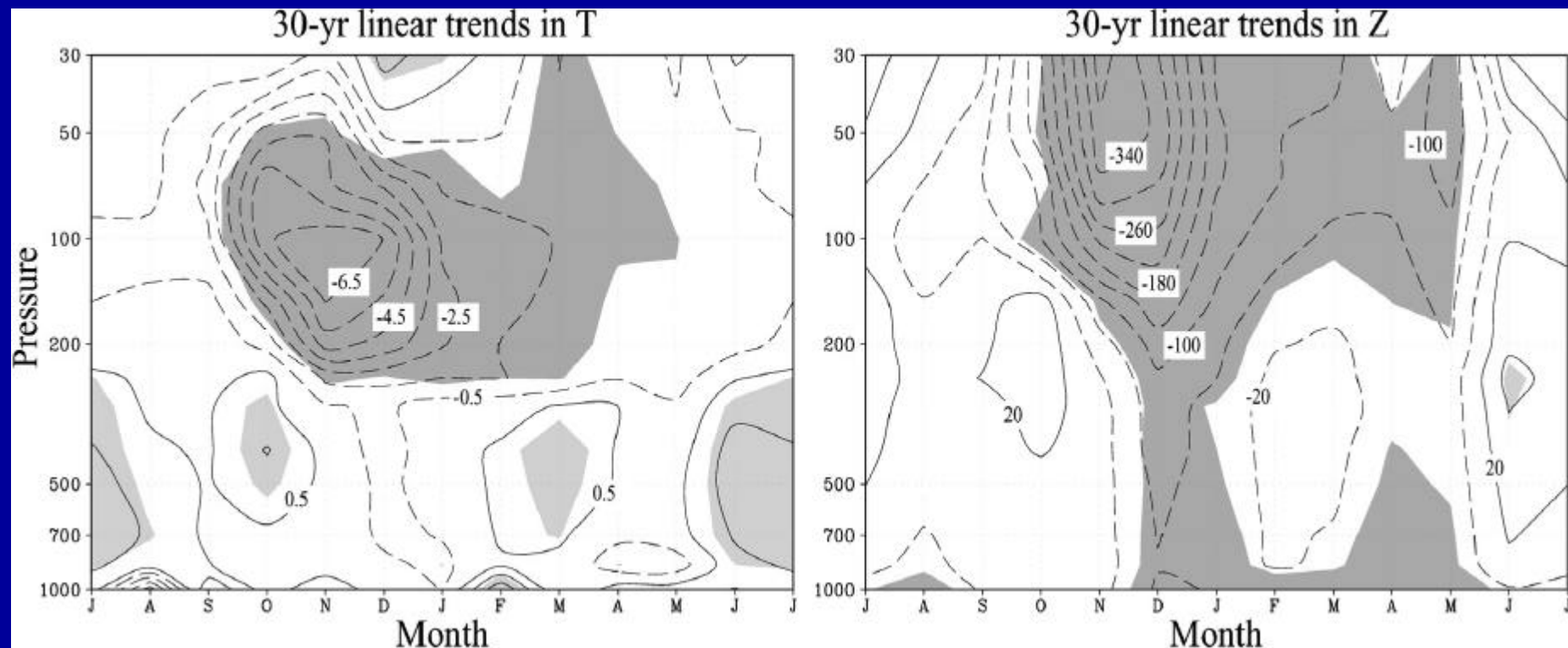


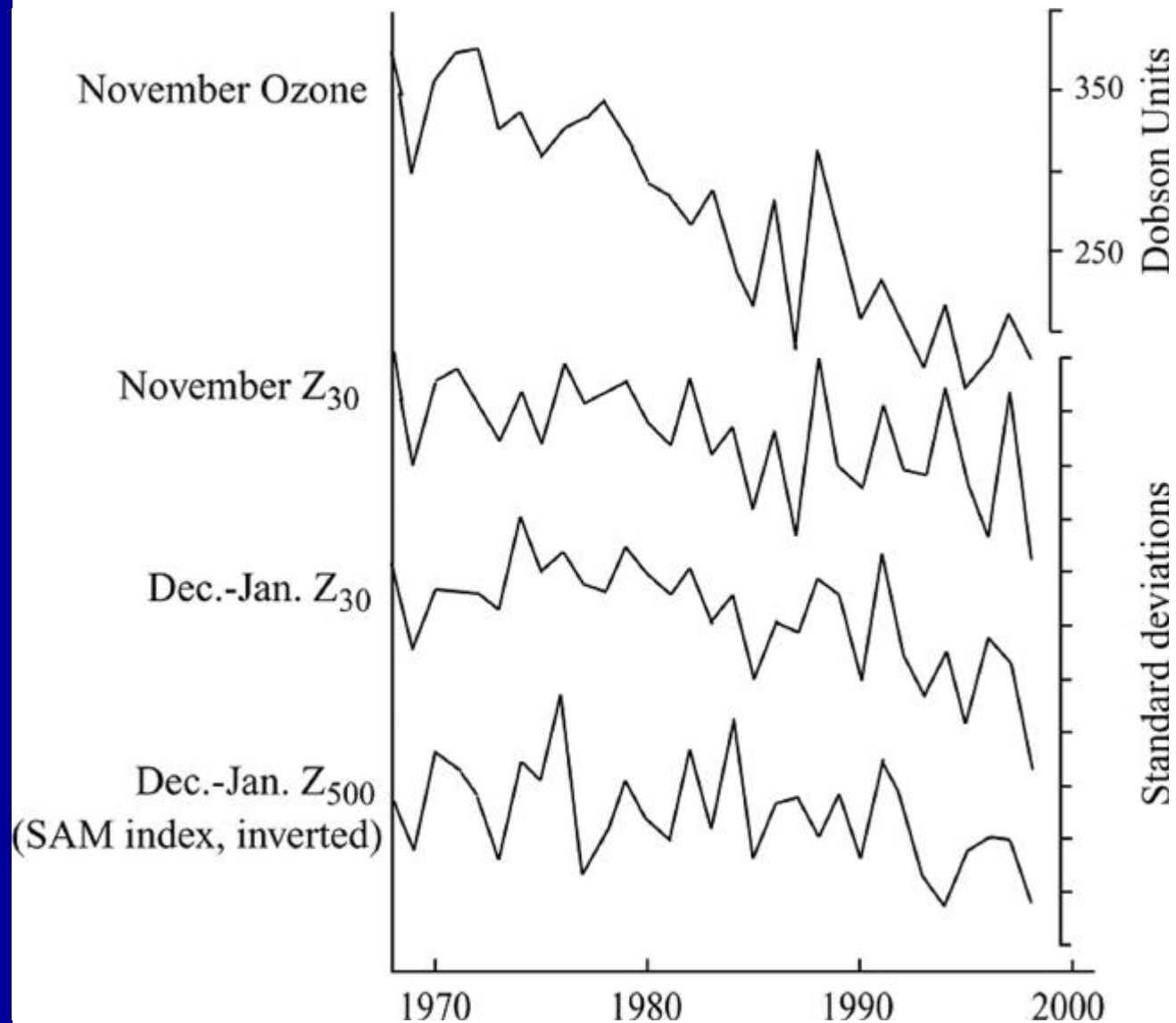
DJF



Trends over Antarctica

30-year (1969-98) linear trends in temperature and height for Antarctic radiosonde stations
(from Thompson and Solomon, 2002)

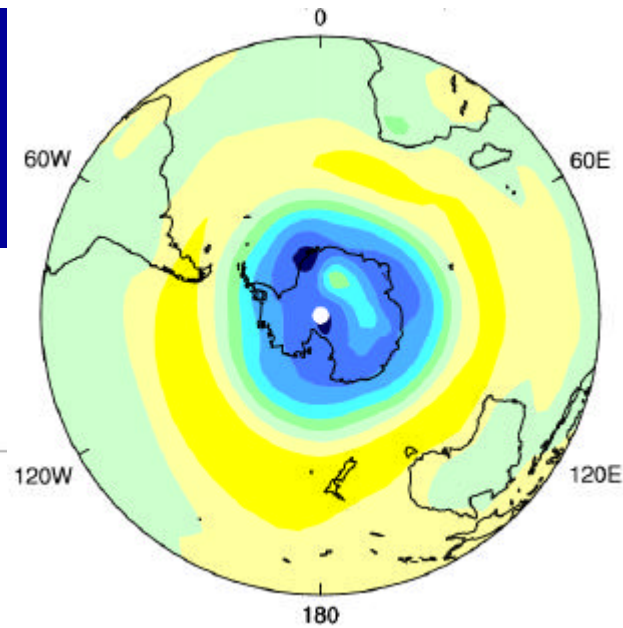
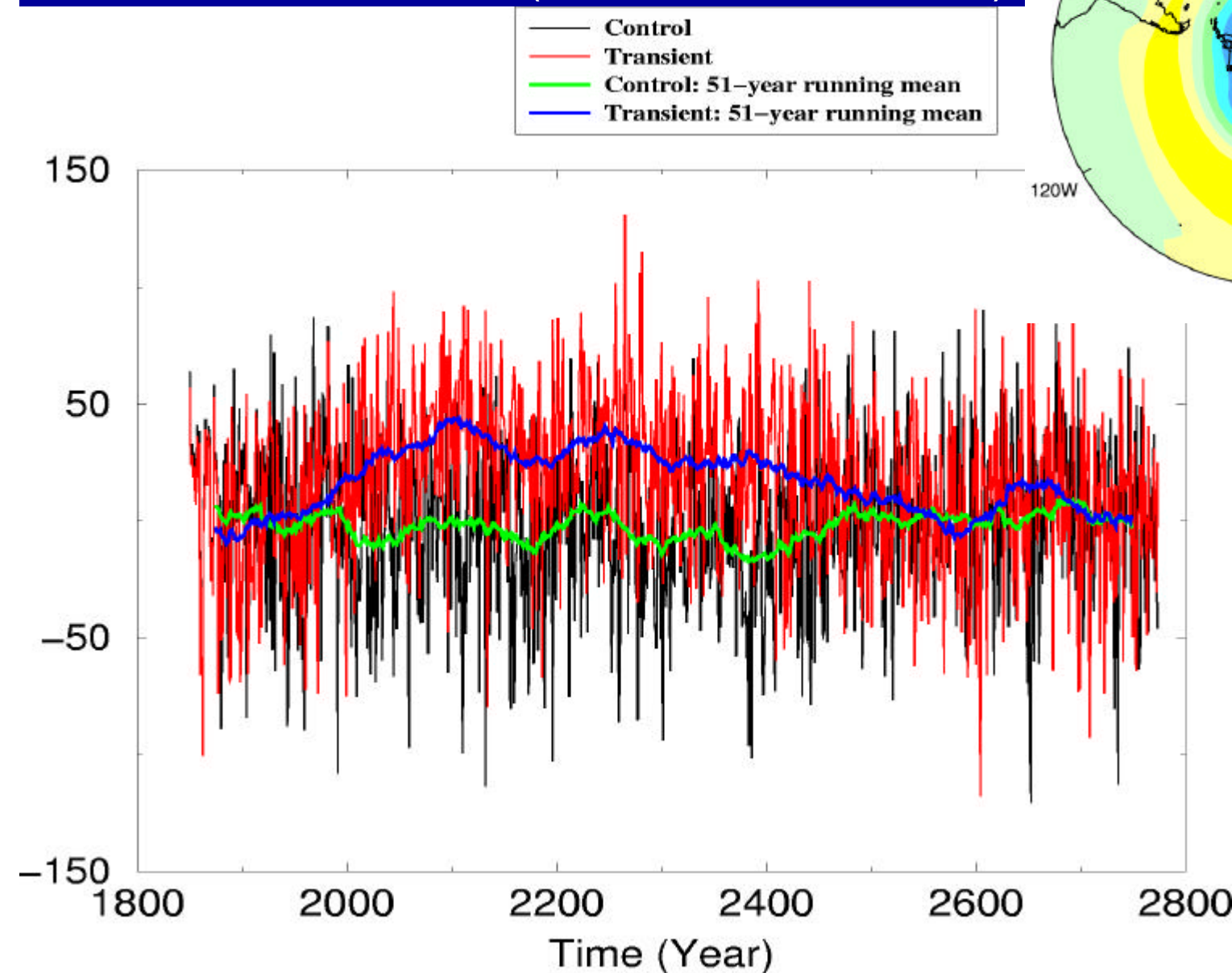




Variations in SH high latitudes in the stratosphere and troposphere (from Thompson and Solomon, 2002)



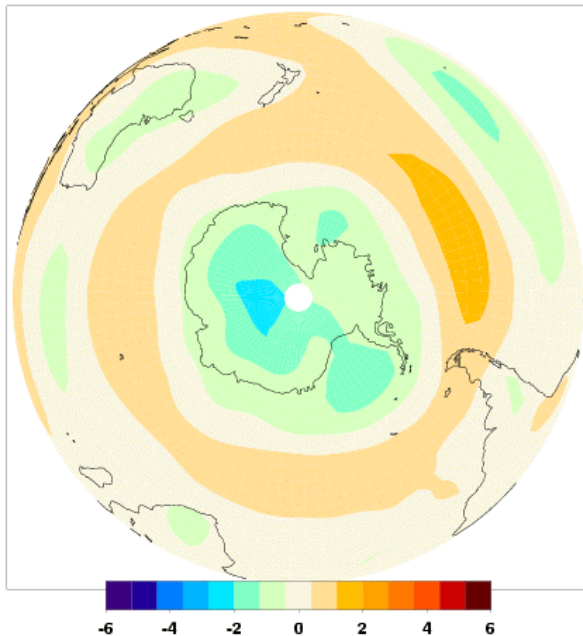
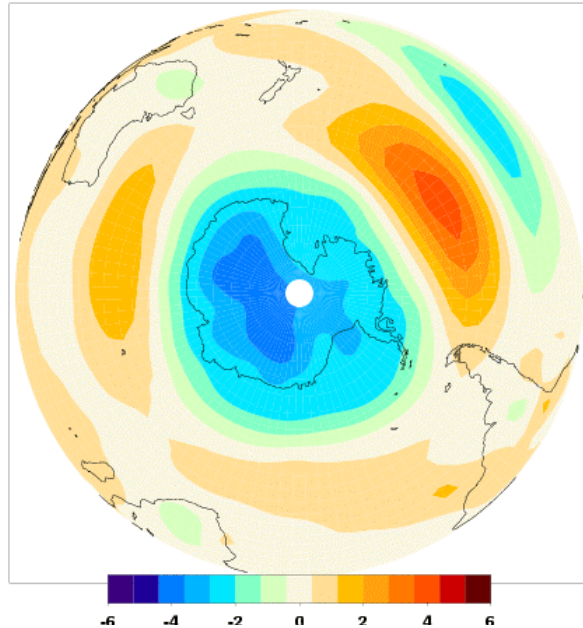
CSIRO climate model simulated SH annular mode (from Cai et al, 2003)



Trends in the
SH annular
mode in
transient
greenhouse
runs reverse
when the forcing
stabilises



DJF

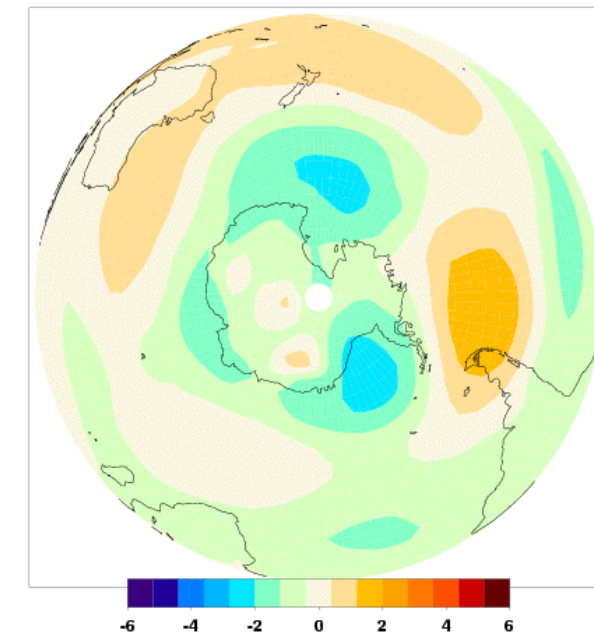
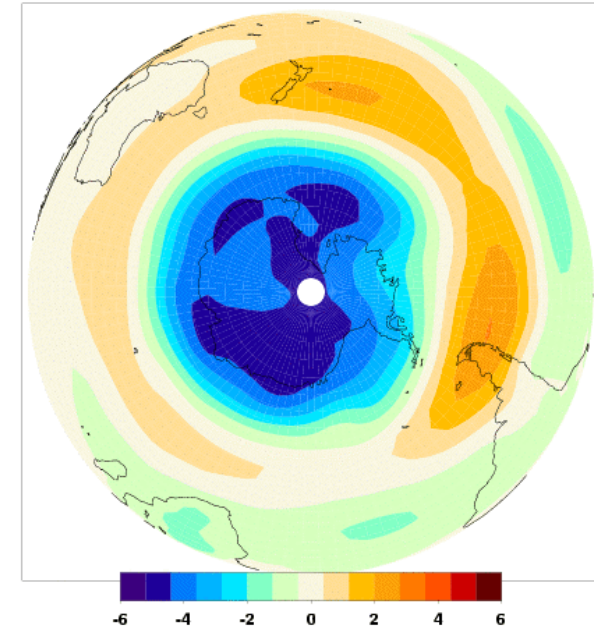


2000 to 2100
SLP change in
transient
greenhouse
climate change
expts with CCC
models

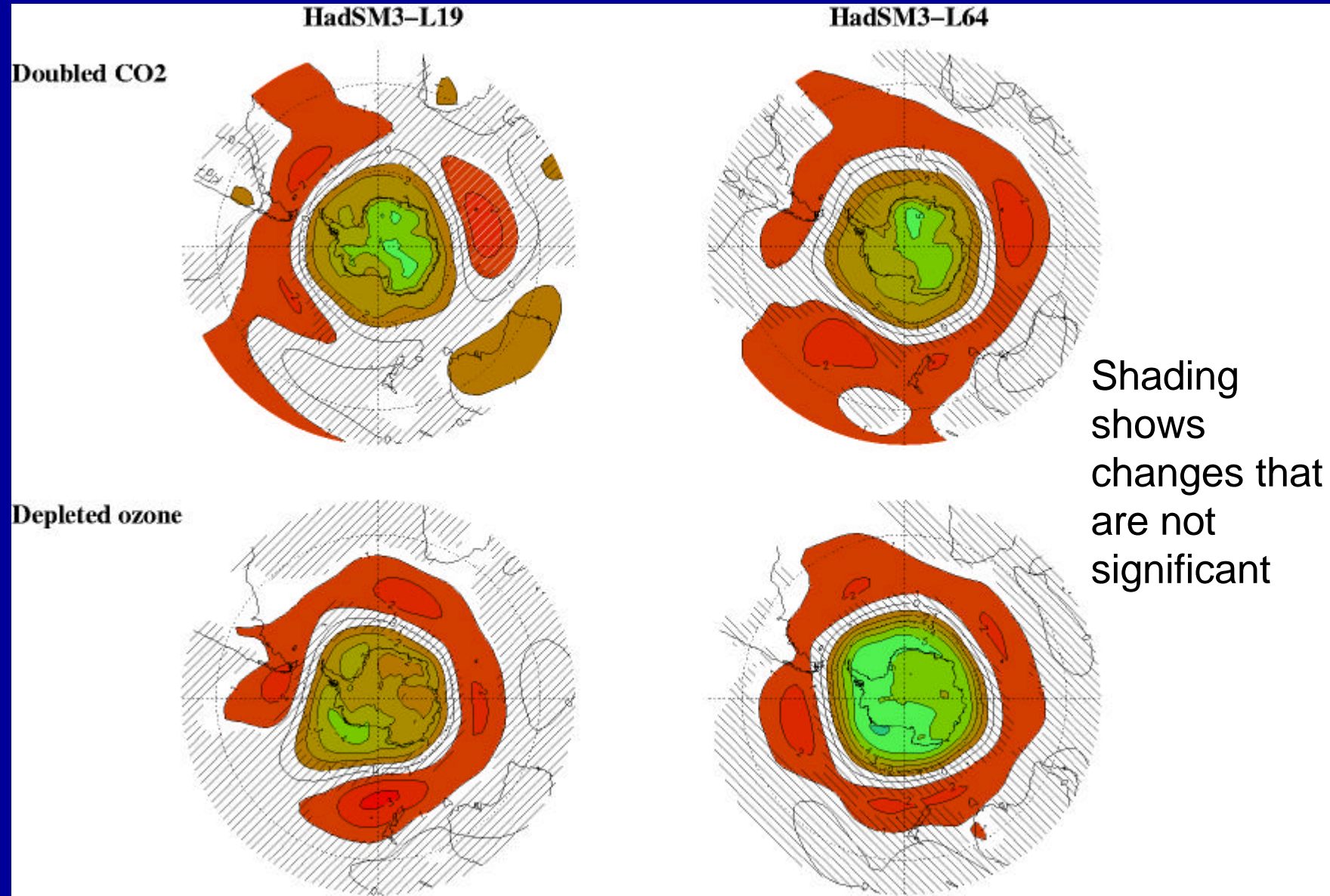
Model 1

Model 2
(from Fyfe et
al, 1999)

JJA



MSLP changes due to CO₂ forcing or ozone forcing in Hadley Centre climate models (from Gillett et al, 2002)

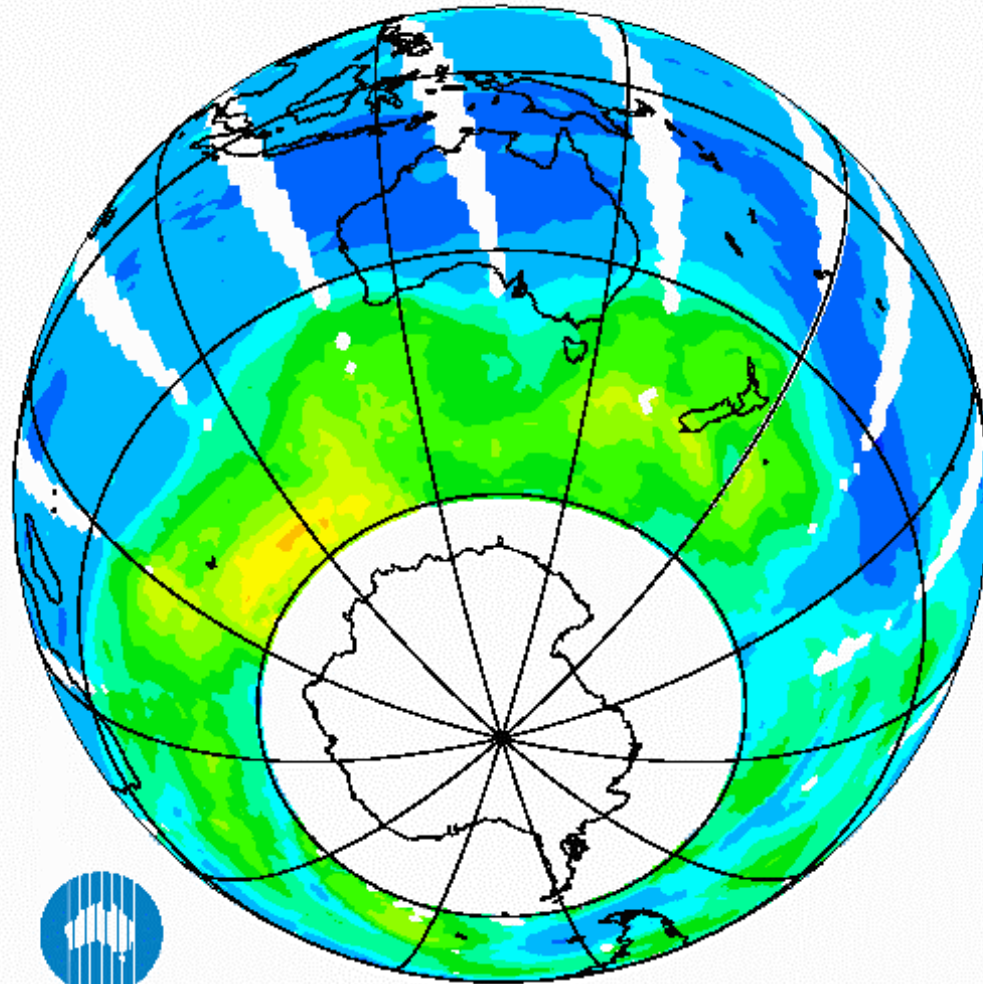


Summary (so far)

- Southern Hemisphere annular mode in monthly variability occurs in all seasons
 - Link to stratosphere is not essential
- Recent observed trend in SH annular mode has seasonal variations but occurs in all seasons
 - Link to stratosphere is not essential
- Model simulations with greenhouse gas forcing can simulate trend in SH annular mode
 - Link to stratosphere is not essential
- Stratospheric link to SH troposphere is possible (response to ozone forcing) but likely to occur only at specific times of year



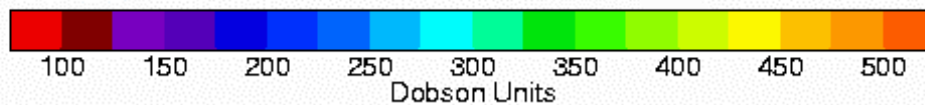
TOMS Ozone Jul 1, 2002 - Min: 242 DU; ~Area: $0.0 \times 10^6 \text{ km}^2$



CSIRO

Data from NASA GSFC Code 916

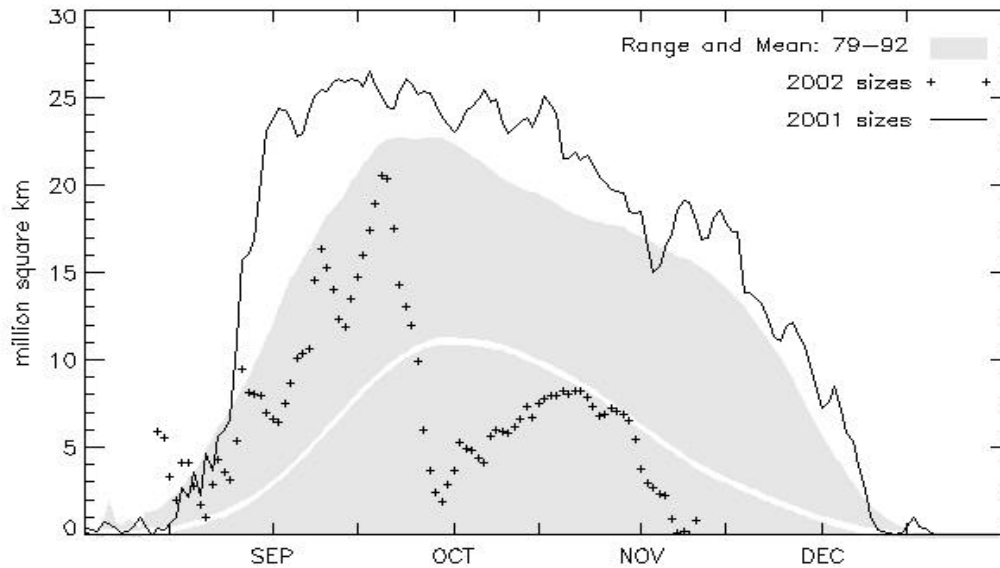
— 220 DU Contour



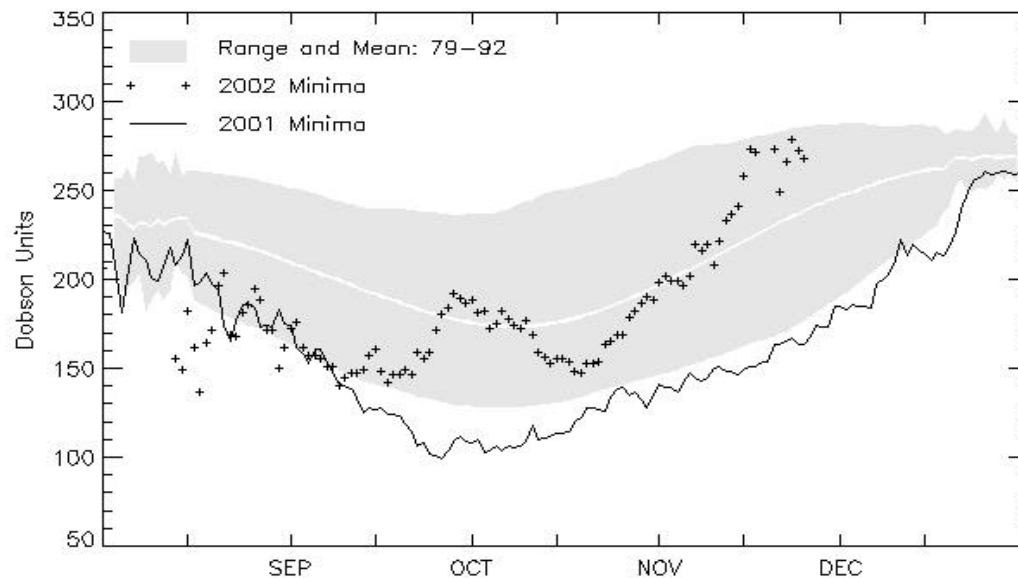
Evolution of the Antarctic ozone hole in 2002



Daily Estimates of Ozone Hole Area



Daily Minima in Southern Hemisphere



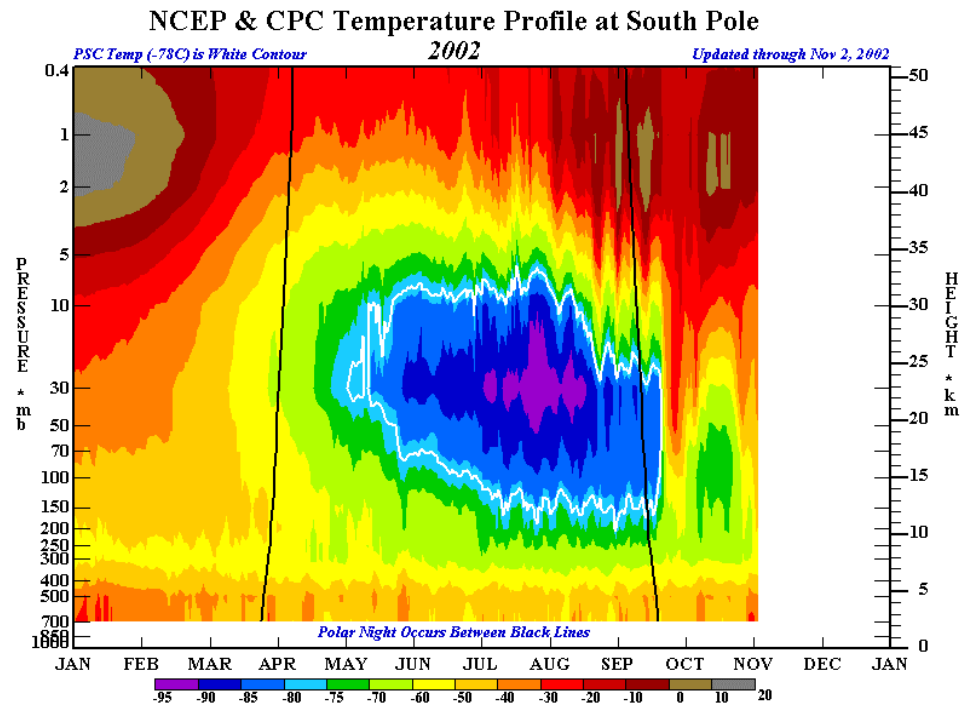
Evolution of the
ozone hole in 2002

Ozone hole area

Minimum column
ozone

From NASA

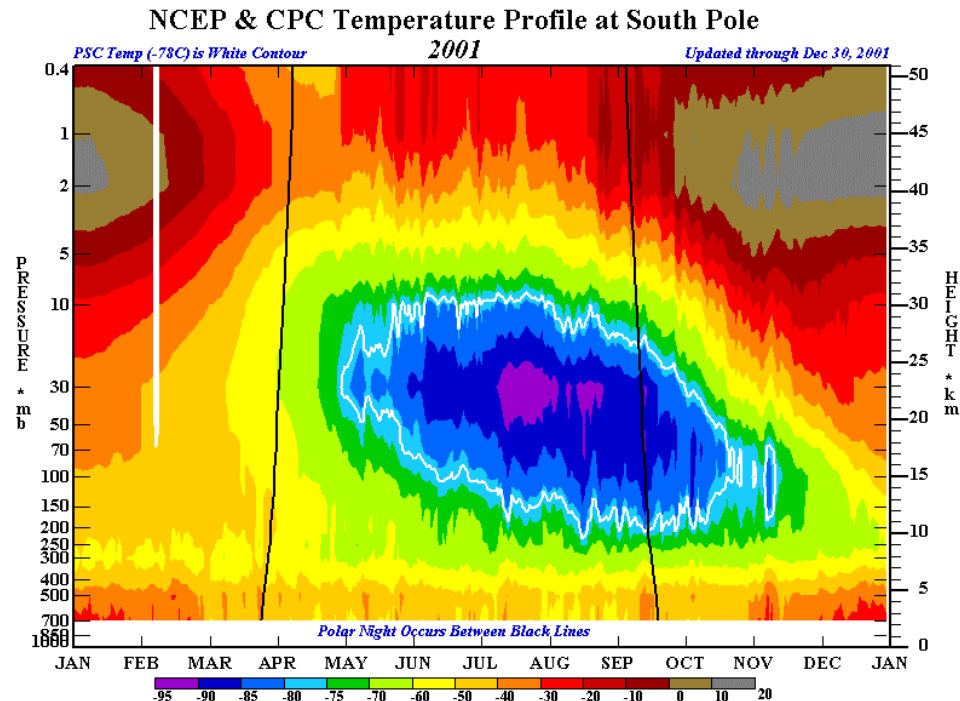




Temperature variations at the South Pole

2002

Note the stratospheric sudden warming late in September

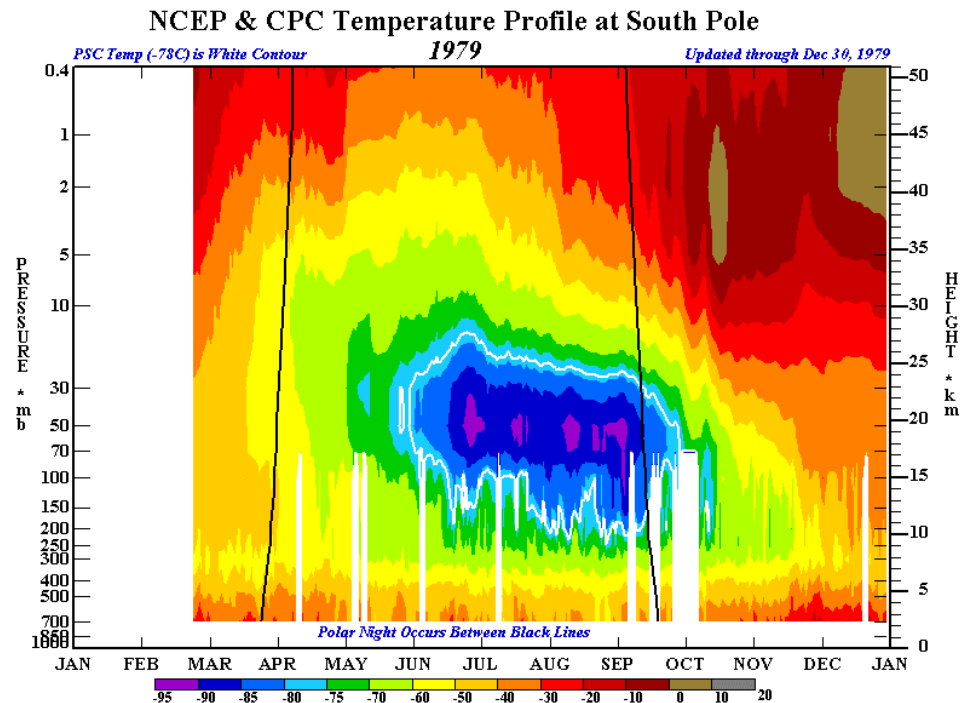


2001

The cold polar temperatures last until early November

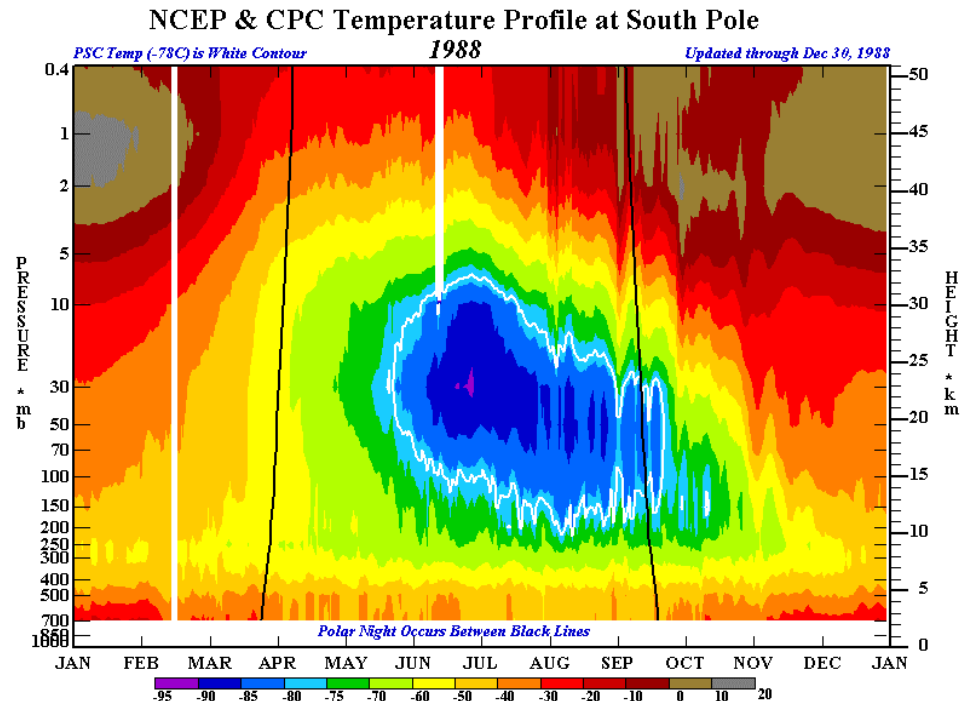
The white contour shows PSC temps (-78C)





Temperature variations at the South Pole

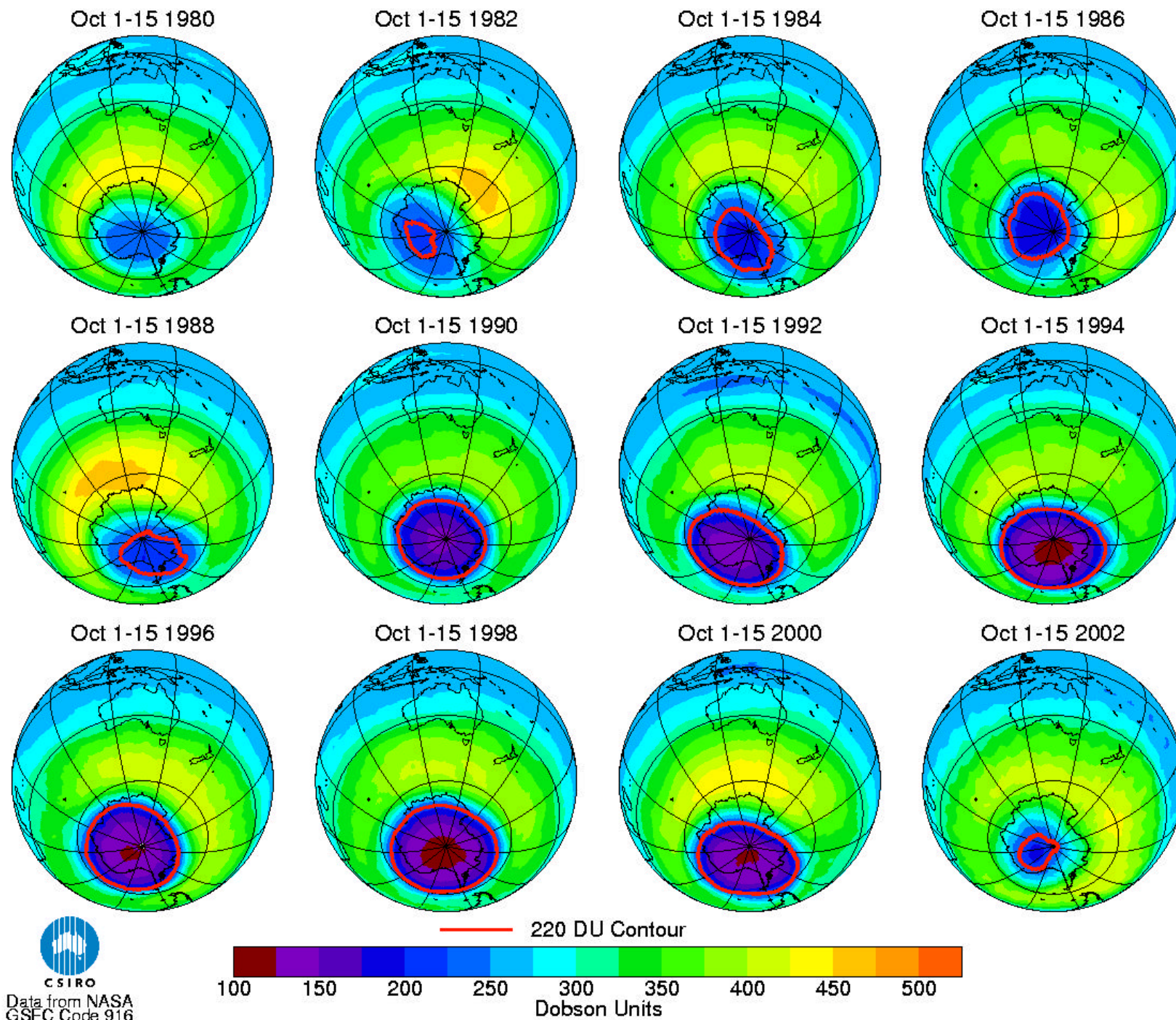
1979



1988

The white contour shows
PSC temps (-78C)





The Antarctic ozone hole in 2002

- The splitting of the ozone hole on 24 Sept was unprecedented
- This was associated with a stratospheric major sudden warming, which has never been observed in the SH before
- The sudden warming appears to be associated with much larger than normal planetary wave activity propagating from the SH troposphere into the stratosphere from July till September



Discussion

- There has been a small increasing trend in the SH annular mode index over the last 40 years
- Climate models forced by increasing greenhouse gases or by decreasing stratospheric ozone usually show a trend in the SH annular mode
- The seasonality of the trend may help to unravel its causes
- There was a sudden warming in the SH stratosphere in 2002, probably opposite to expectations from the trend in the annular mode
- Any theory of links between the stratosphere and the troposphere needs to be able to explain these events

