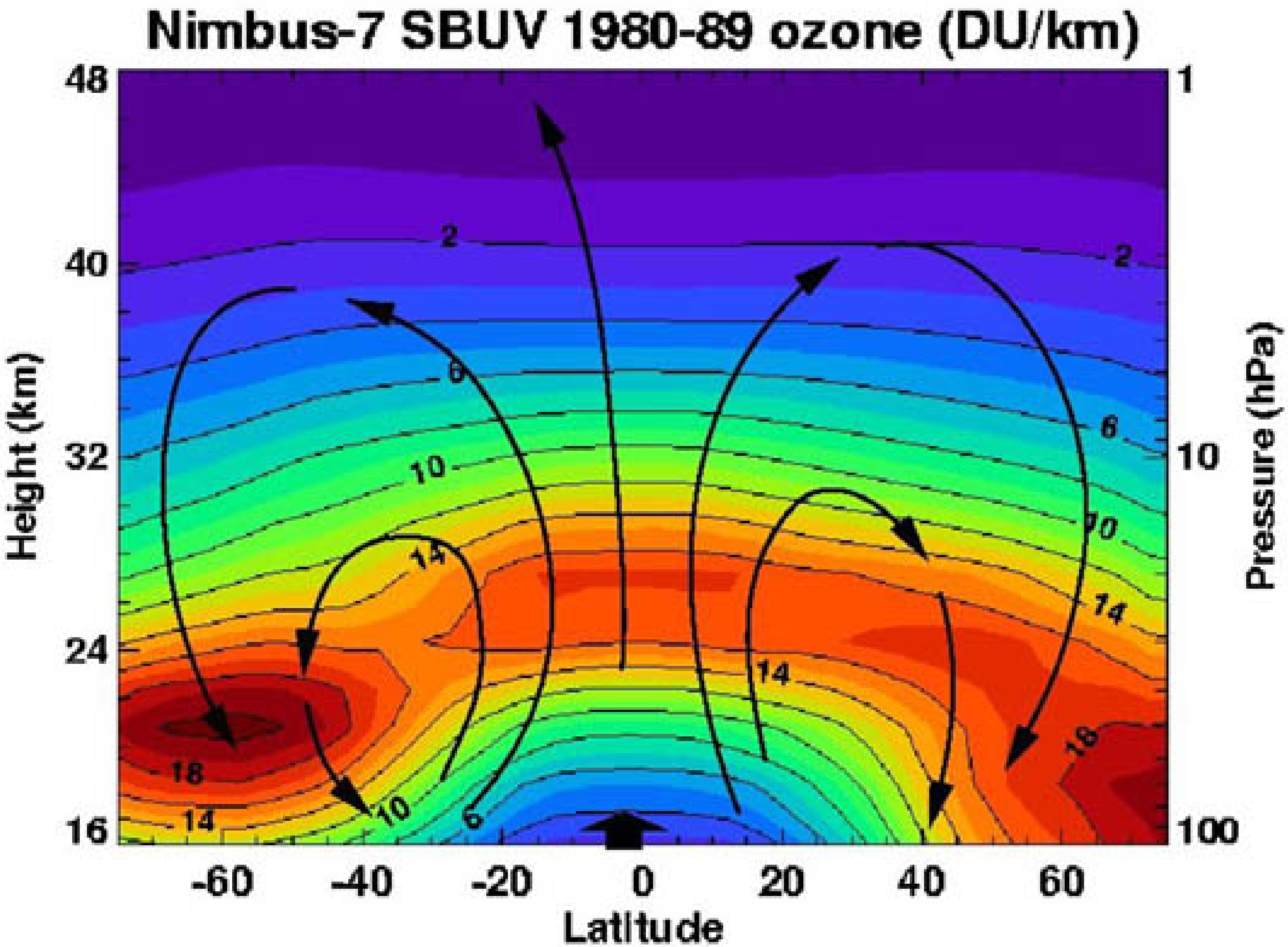
STRATOSPHERIC OZONE: CONCEPTS AND INTERACTIONS WITH CLIMATE

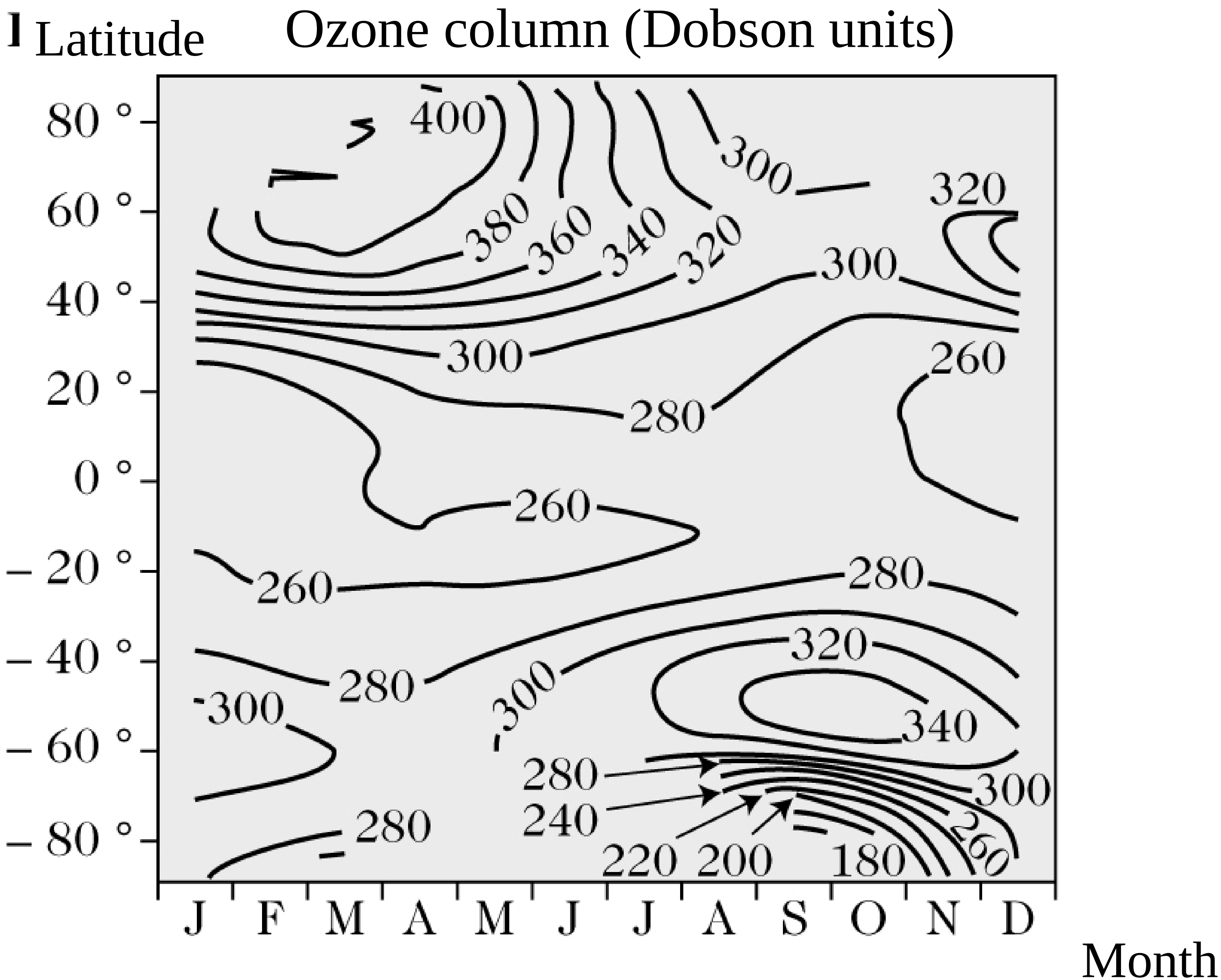
Slimane BEKKI (LATMOS-IPSL)

- Background on Antarctic stratospheric ozone
- Future ozone projections
- Impact on tropospheric climate

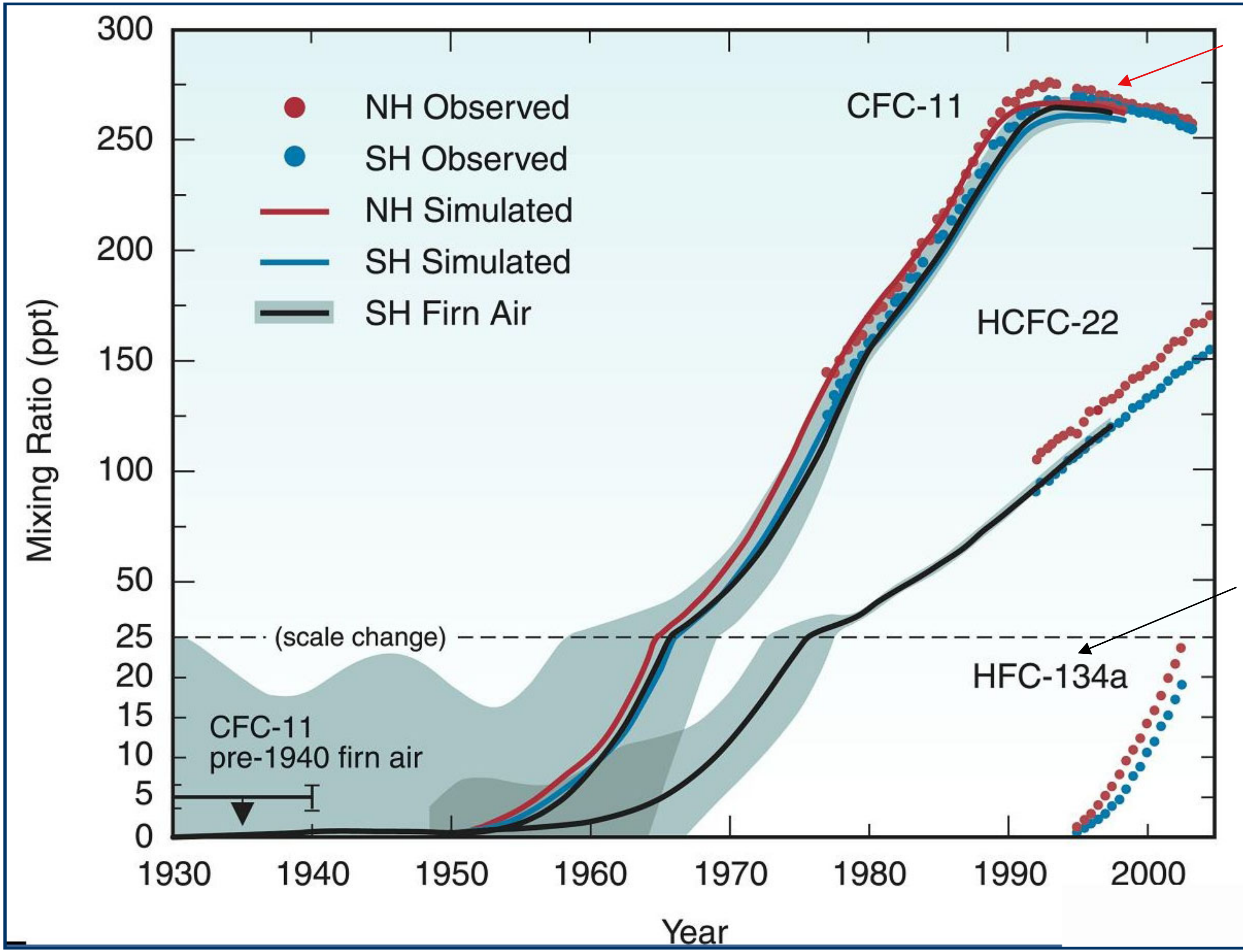
OZONE GLOBAL DISTRIBUTION



Stratospheric circulation driven by tropospheric wave forcing

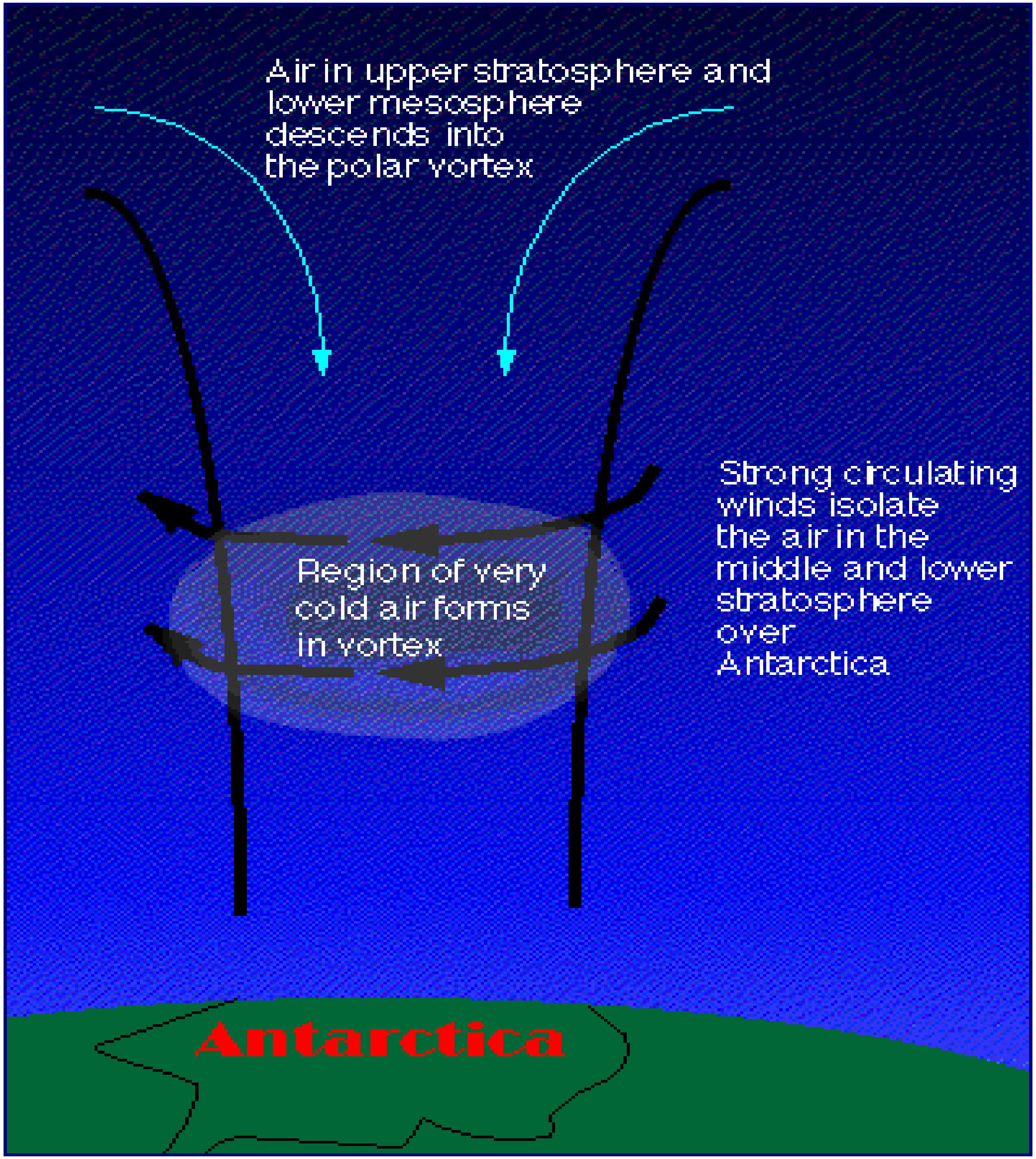


Latitude
Ozone column (Dobson units)
80 °
60 °
40 °
20 °
0 °
– 20 °
– 40 °
– 60 °
– 80 °
400
380
360
340
320
300
320
300
300
260
280
260
260
280
320
300
280
340
300
280
240
280
220 200
180
260
300
J F M A M J J A S O N D
Month

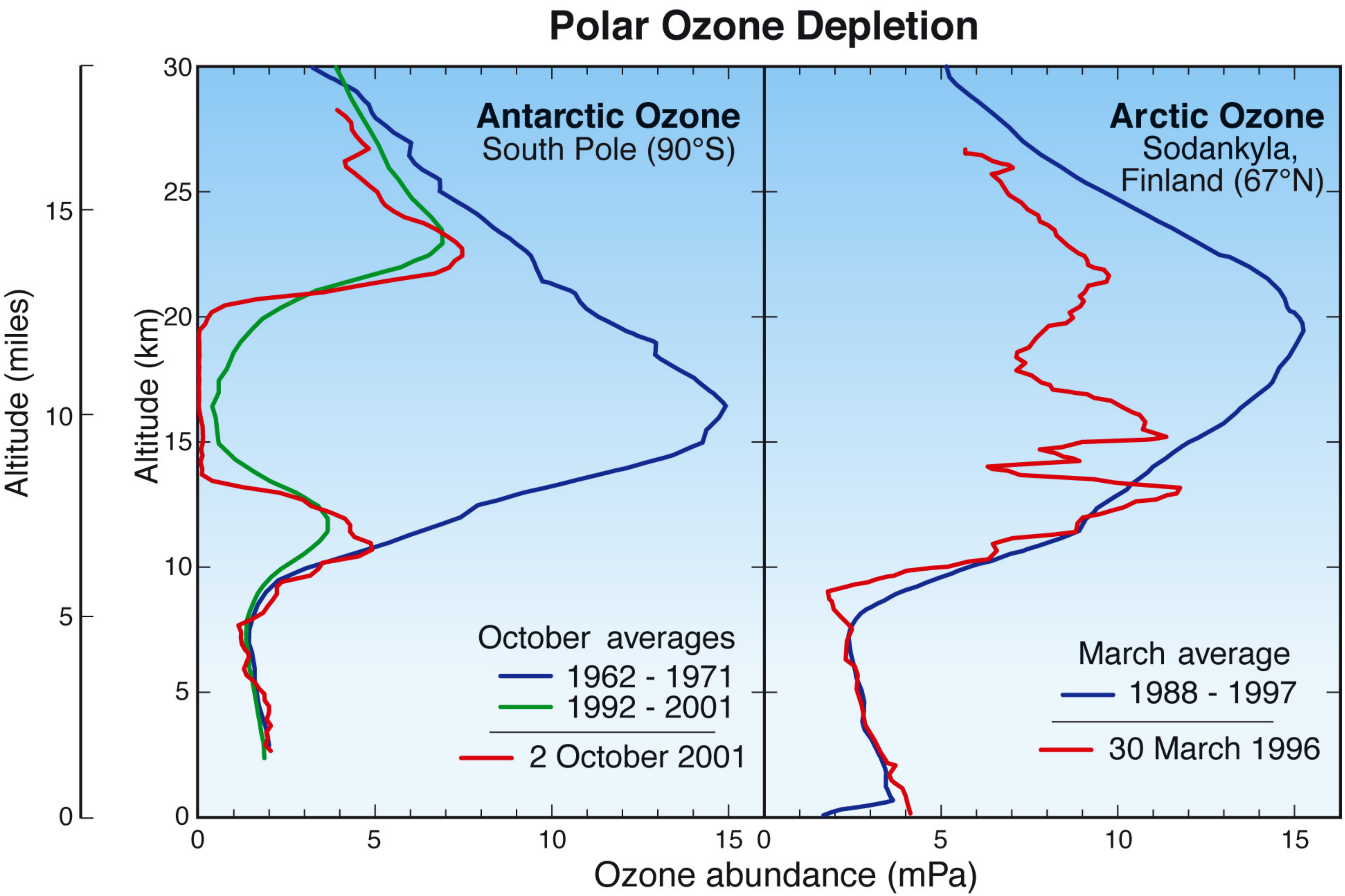


Protocols are working

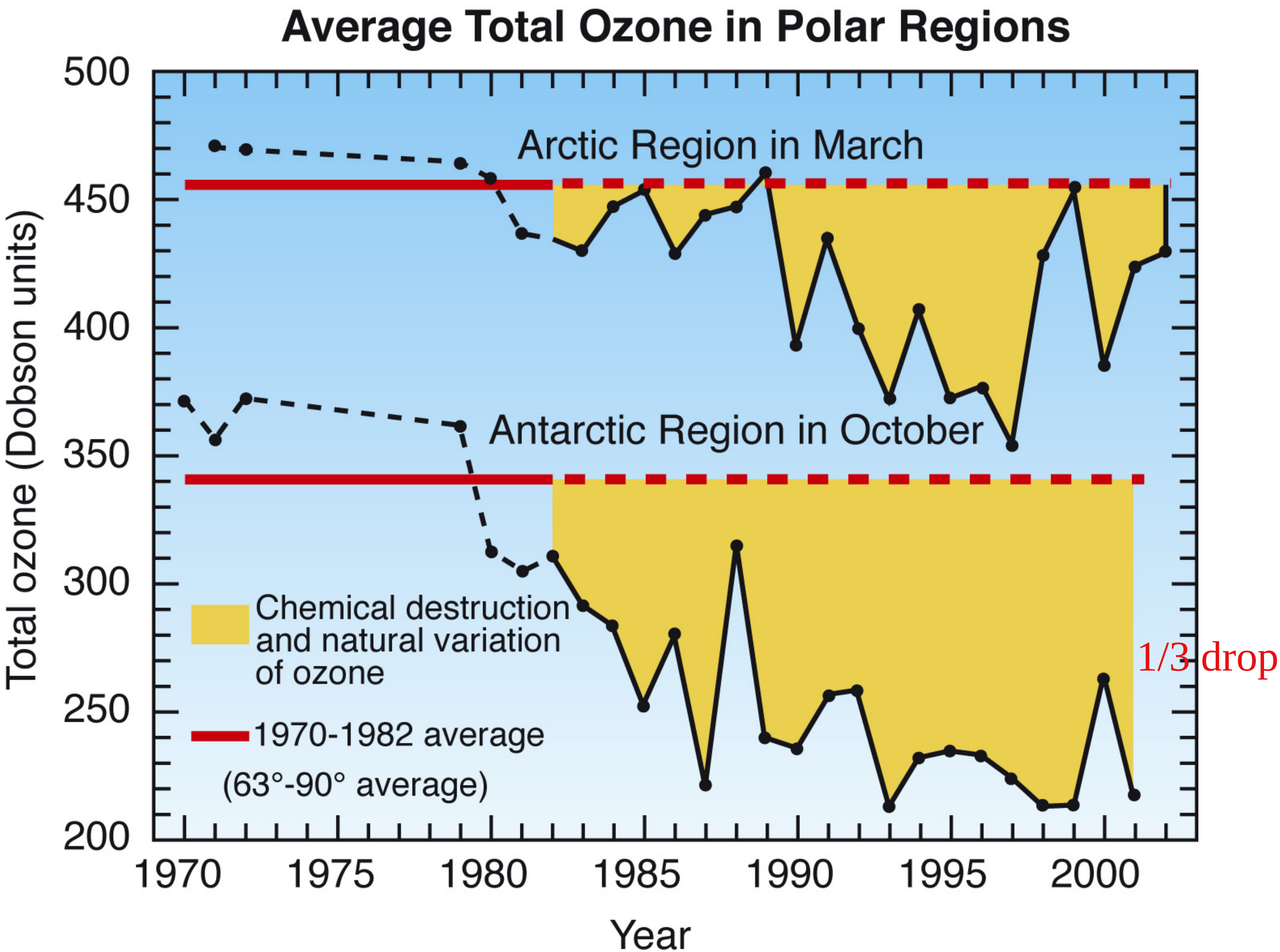
products of replacement



very cold and isolated polar vortex where the chemistry is perturbed (ClO increase, O_3 depletion)

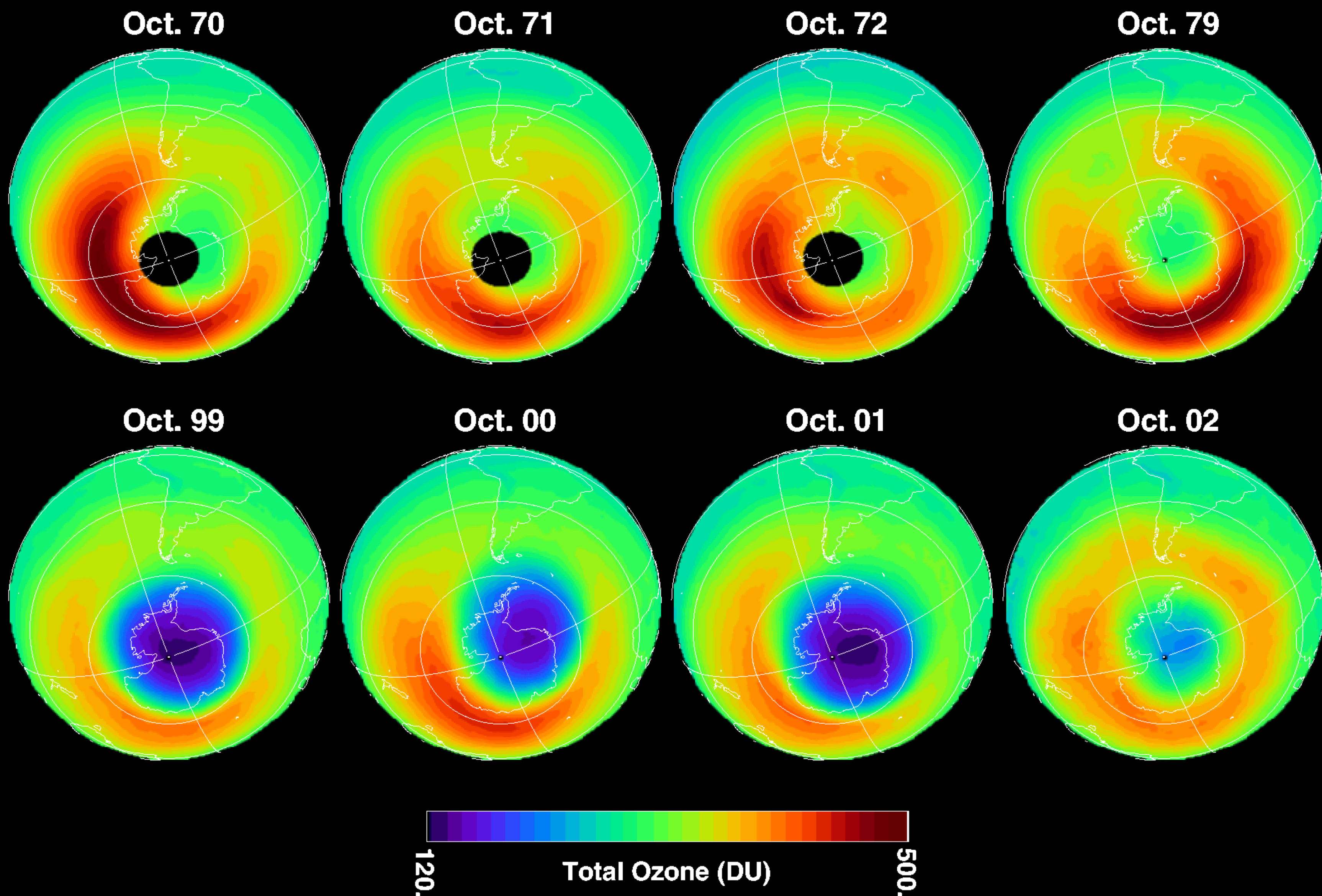


Polar Ozone Depletion
Antarctic Ozone
South Pole (90°S)
Arctic Ozone
Sodankyla, Finland (67°N)
October averages
1962 - 1971
1992 - 2001
2 October 2001
March average
1988 - 1997
30 March 1996
Altitude (miles)
Altitude (km)
Ozone abundance (mPa)
0
5
10
15
20
25
30



Average Total Ozone in Polar Regions
Total ozone (Dobson units)
500
450
400
350
300
250
200
Arctic Region in March
Antarctic Region in October
Chemical destruction and natural variation of ozone
1970-1982 average
(63°-90° average)
1970
1975
1980
1985
1990
1995
2000
Year
1/3 drop

Ozone column (DU) from TOMS satellite



FUTURE OZONE AT NH MID-LATITUDES

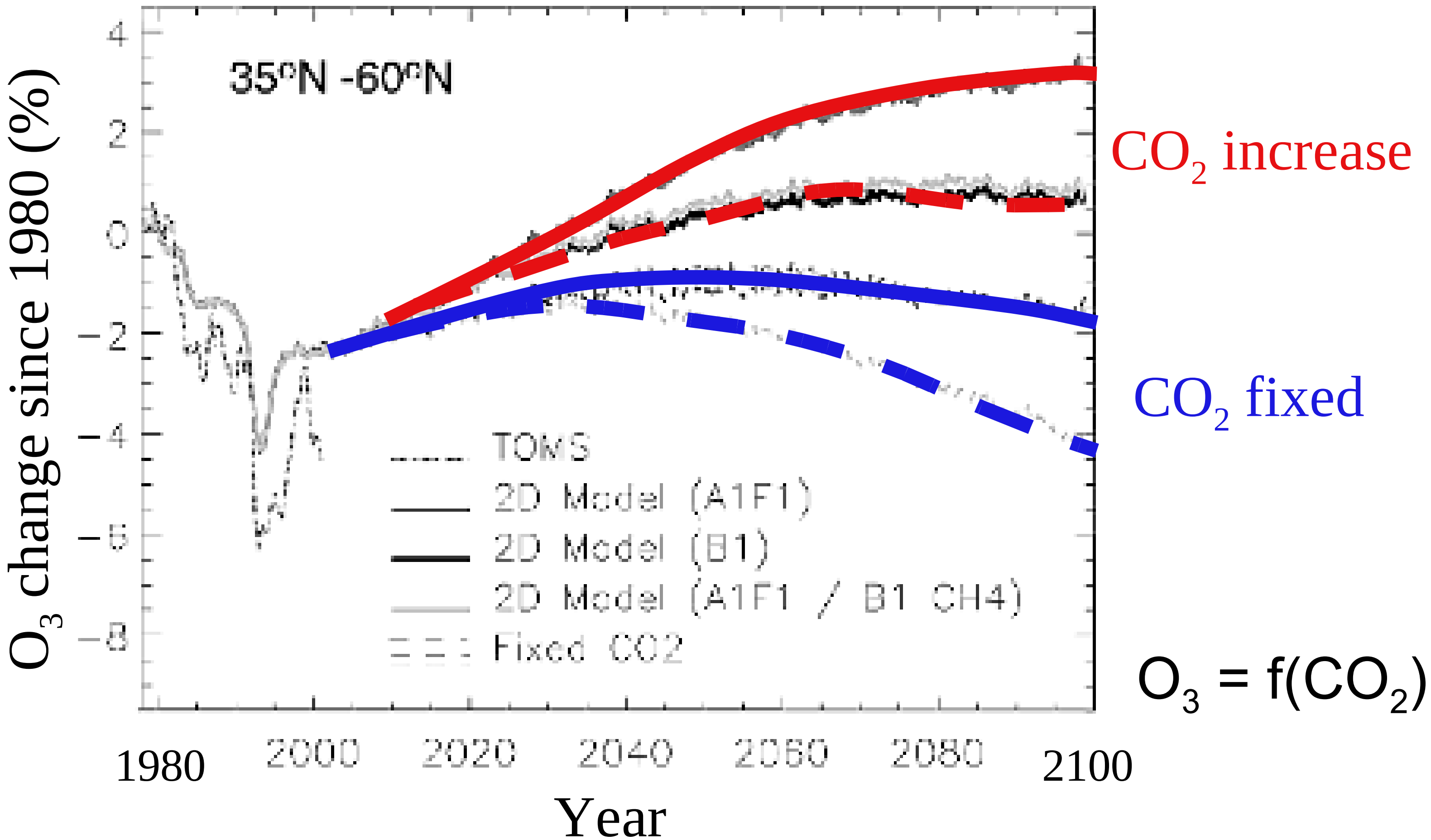
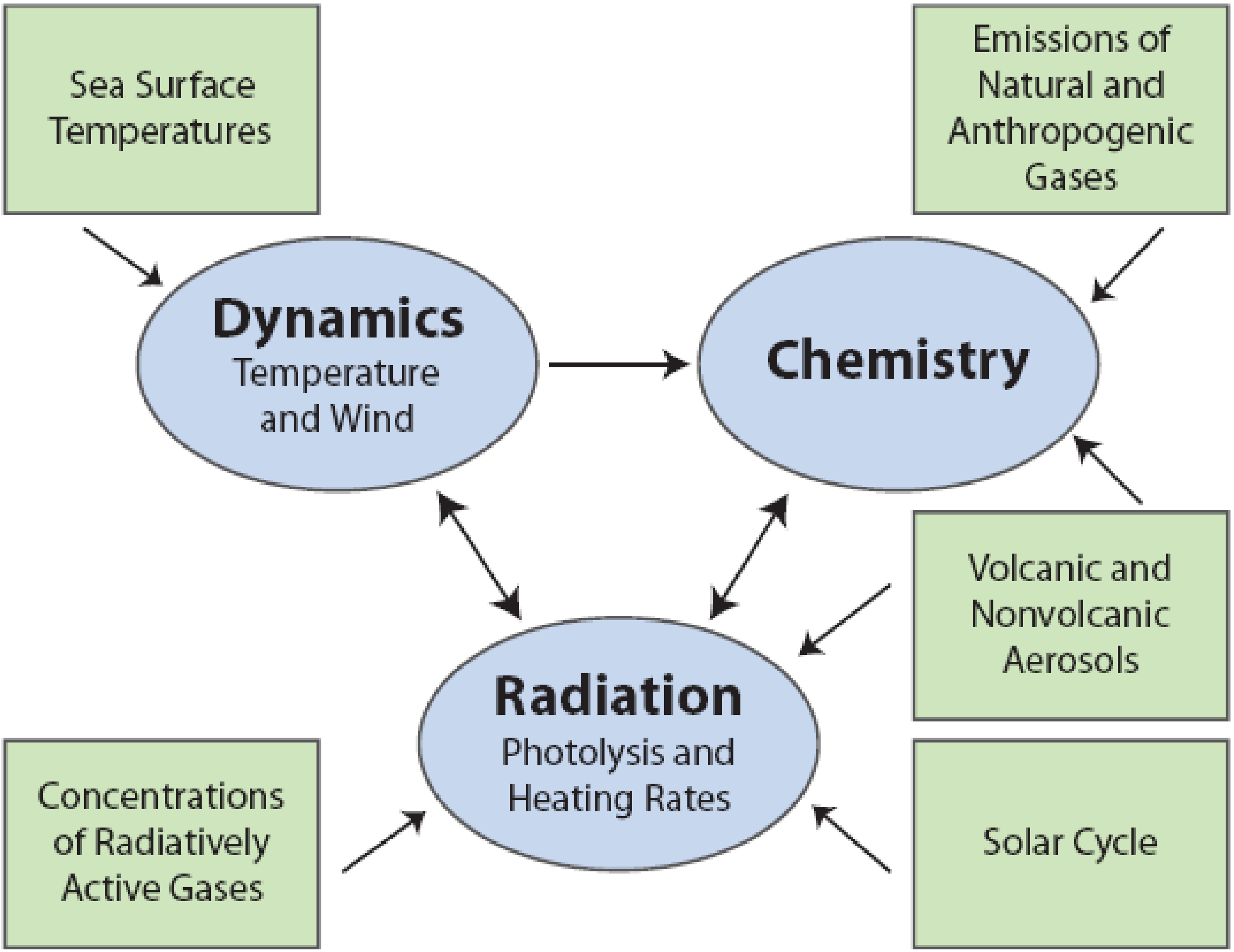


Figure 6-9: Variation in northern hemisphere mid-latitude total column ozone (% change since 1980). Results of six 2D model runs are shown with (solid lines) and without (dashed lines) stratospheric cooling due to CO_2 increases. Also shown are observed past changes from satellite data. From Chipperfield and Feng (2003).

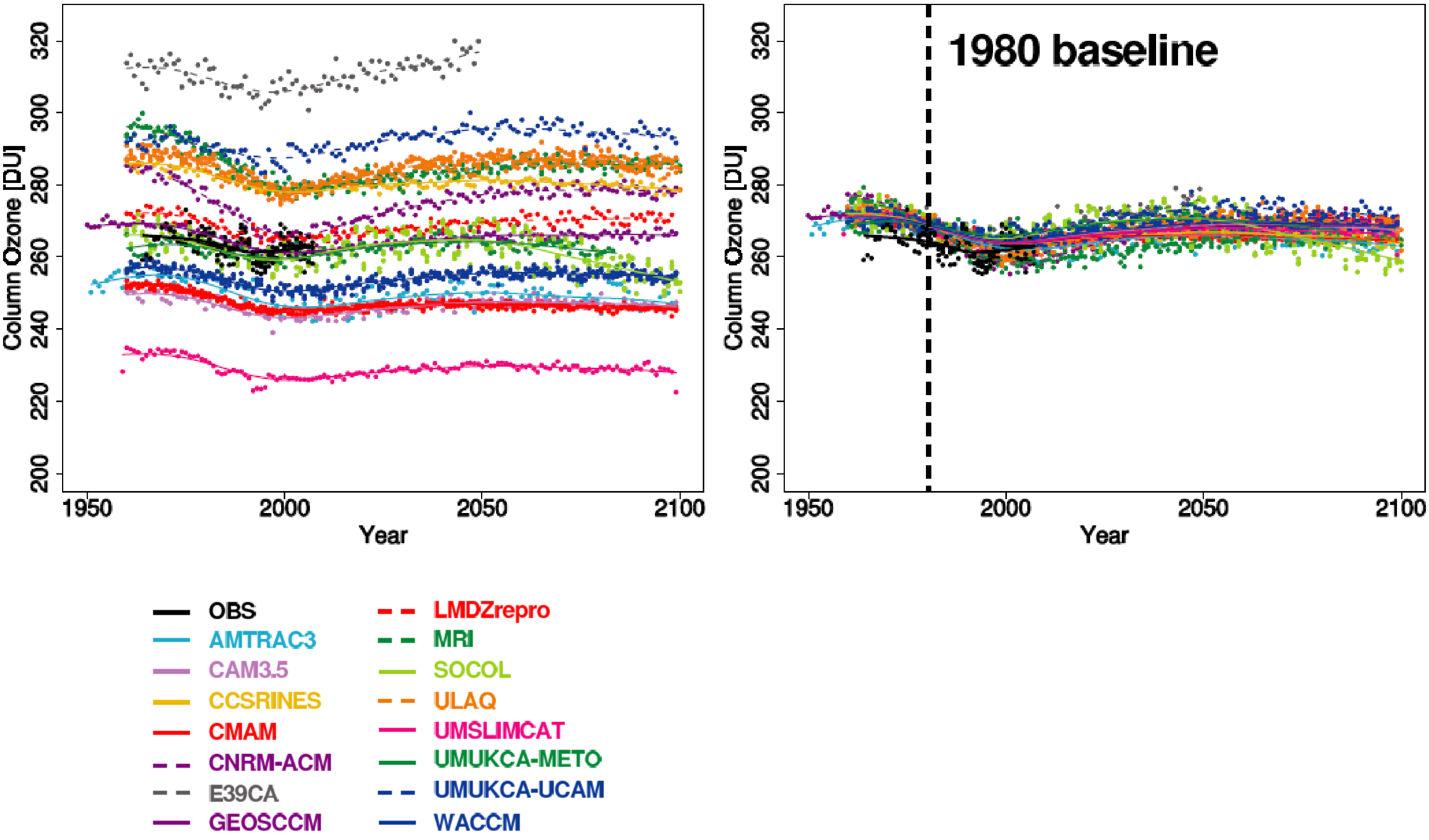
SCHEMATIC OF A CHEMISTRY-CLIMATE MODEL



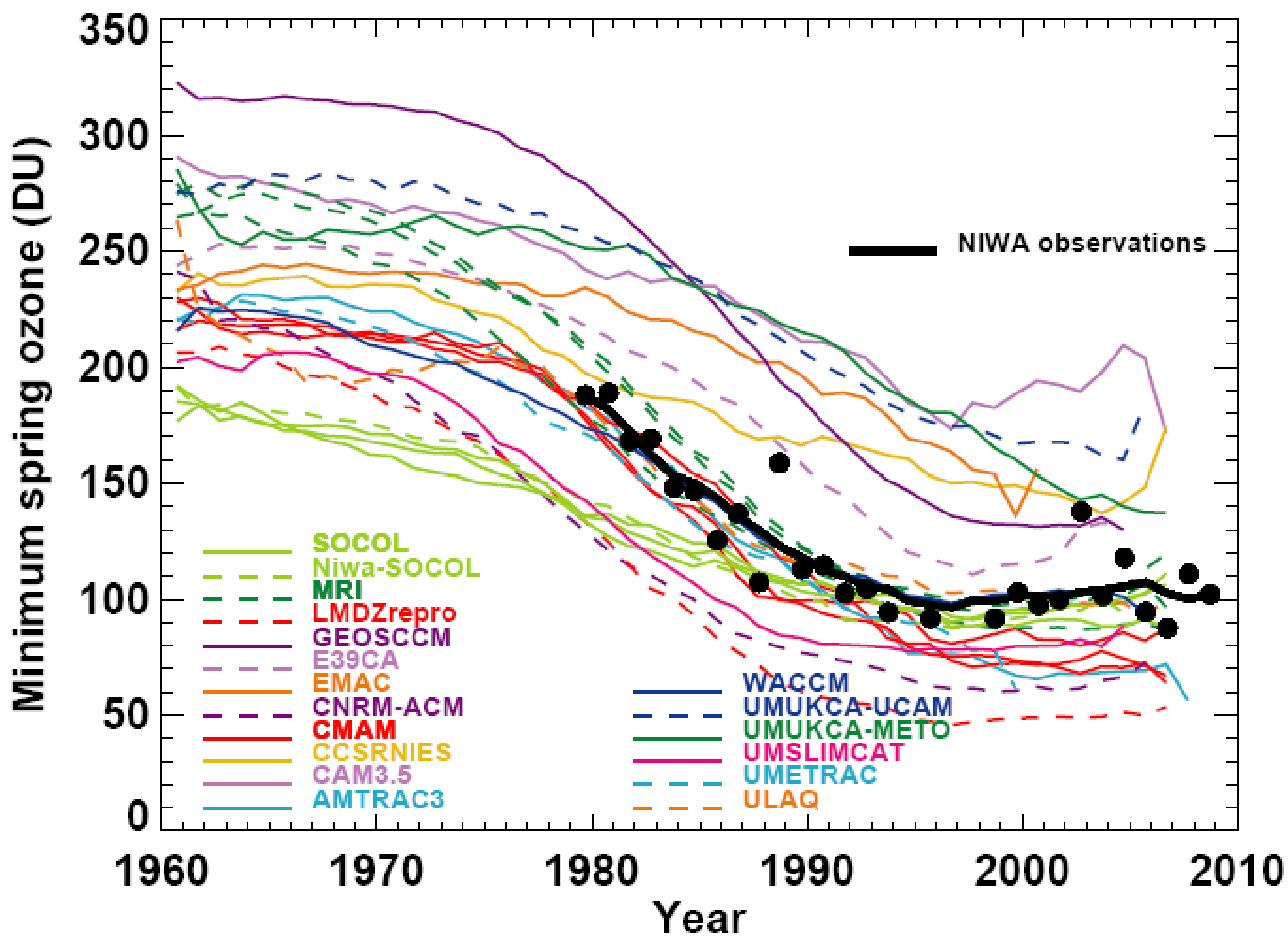
List of CCMs and their origins

CCM	Full name	Institution
AMTRAC3	Atmospheric Model with TRansport and Chemistry 3	NOAA, Boulder, USA
CAM3.5	Community Atmosphere Model 3.5	NCAR, Boulder, USA
CCSRNIES	Center for Climate Systems Research / National Institute for Environmental Studies	Tsukuba, Japan
CMAM	Canadian Middle Atmosphere Model	Environment Canada, Victoria, and U. Toronto, Canada
CNRM-ACM	Centre National de Recherche Météorologique - ARPEGE-Climat coupled MOCAGE	MétéoFrance, Toulouse, France
E39CA	ECHAM4.L39(DLR)/CHEM/-ATTILA	DLR, Oberpfaffenhofen, Germany
EMAC	ECHAM5 Middle-Atmosphere with Chemistry	MPI-Chemistry, Mainz and DLR, Oberpfaffenhofen, Germany
GEOSCCM	Goddard Earth Observing System - Chemistry-Climate Model	NASA GSFC, Greenbelt, USA
LMDZrepro	Laboratoire de Météorologie Dynamique Zoom - REPROBUS	LMDz, Paris, France
MRI	Meteorological Research Institute	JMA, Tsukuba, Japan
Niwa-SOCOL	National Institute of Water and Atmospheric Research - Solar-Climate-Ozone Links	Lauder, New Zealand
SOCOL	Solar-Climate-Ozone Links	PMOD/WRC, Davos, and ETH Zürich, Switzerland
ULAQ	Università degli Studi L'Aquila	Italy
UMSLIMCAT	Unified Model - SLIMCAT	U. Leeds, UK
UMETRAC	Unified Model with Eulerian Transport and Atmospheric Chemistry	NIWA, Lauder, NZ
UMUKCA-METO	Unified Model / U. K. Chemistry Aerosol Community Model - MetOffice	Exeter, UK
UMUKCA-UCAM	Unified Model / U. K. Chemistry Aerosol Community Model - U. Cambridge	UK, and NIWA, Lauder, NZ
WACCM	Whole-Atmosphere Chemistry-Climate Model	NCAR, Boulder, USA

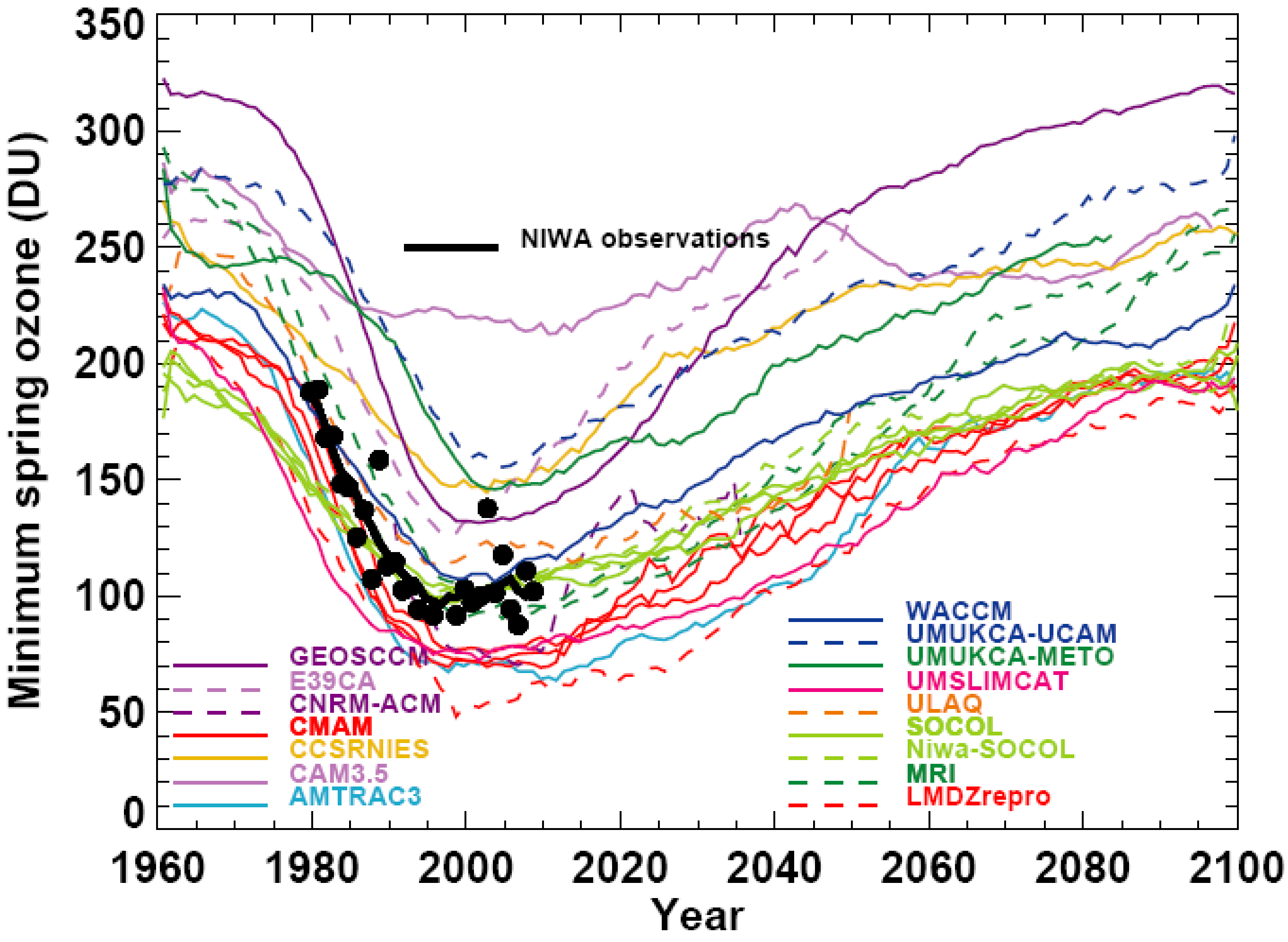
Annual Column O_3 25°S–25°N



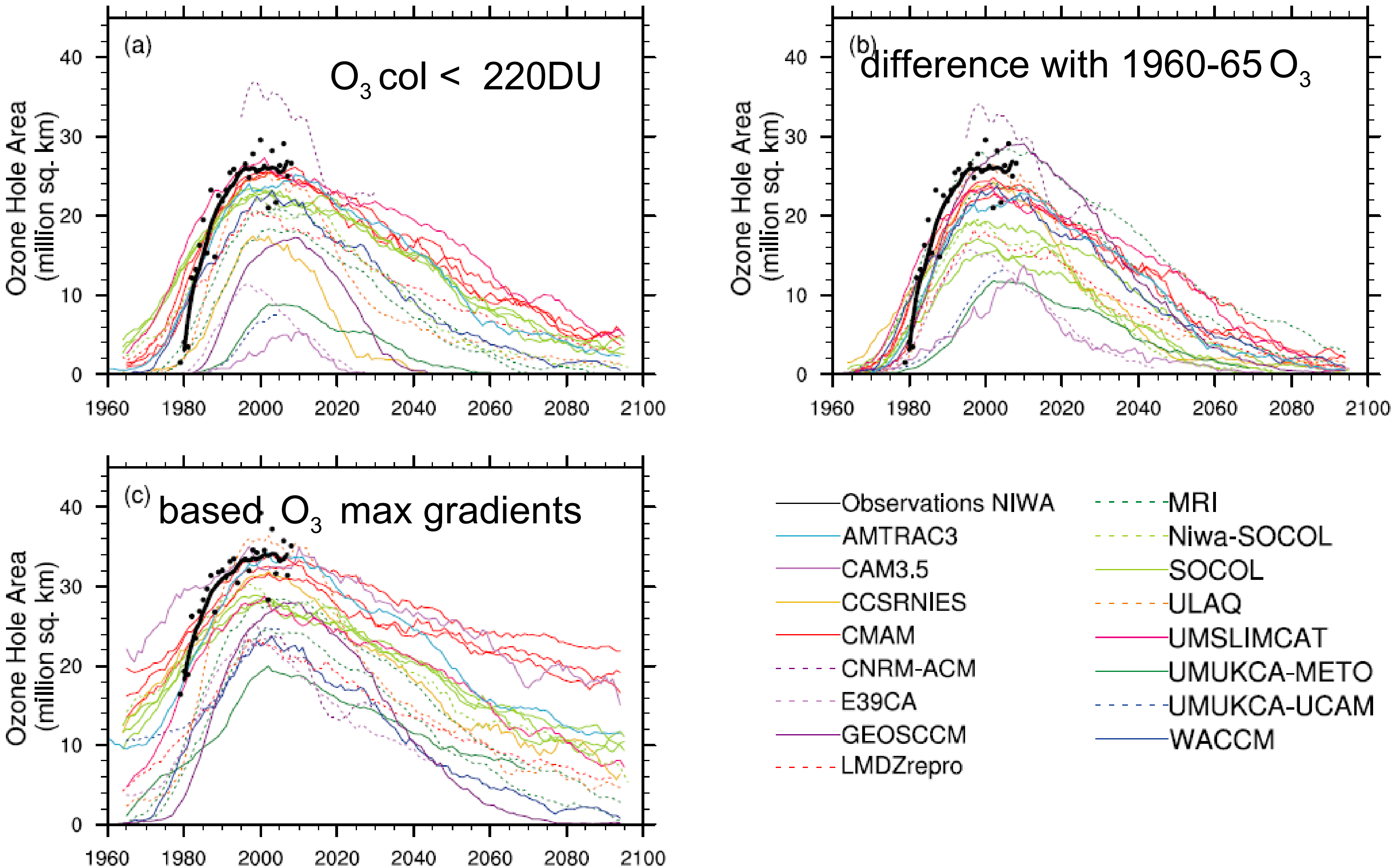
SIMULATED AND OBSERVED MINIMUM ANTARCTIC OZONE COLUMN (1960-2009)

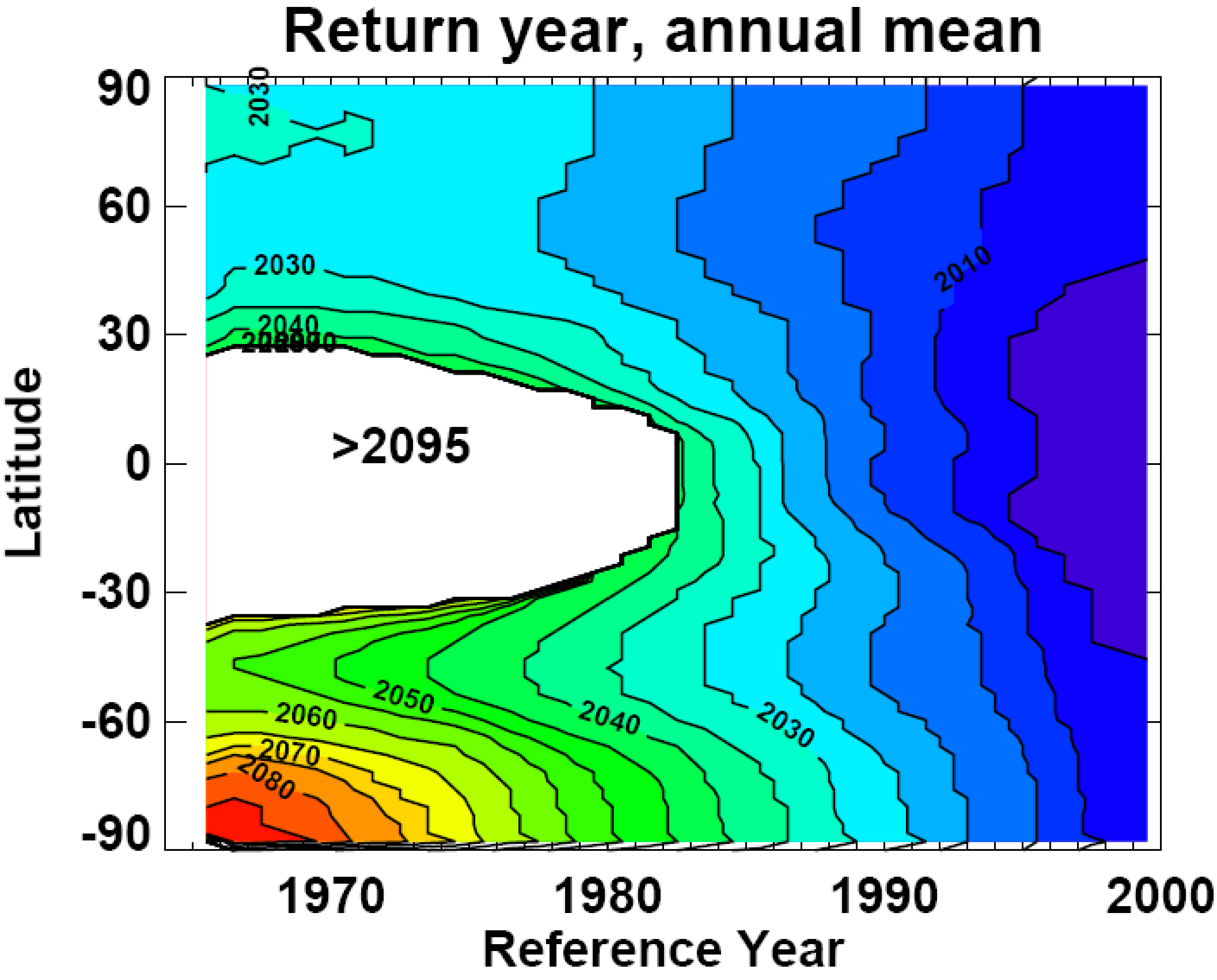


SIMULATED AND OBSERVED MINIMUM ANTARCTIC OZONE COLUMN (1960-2009)



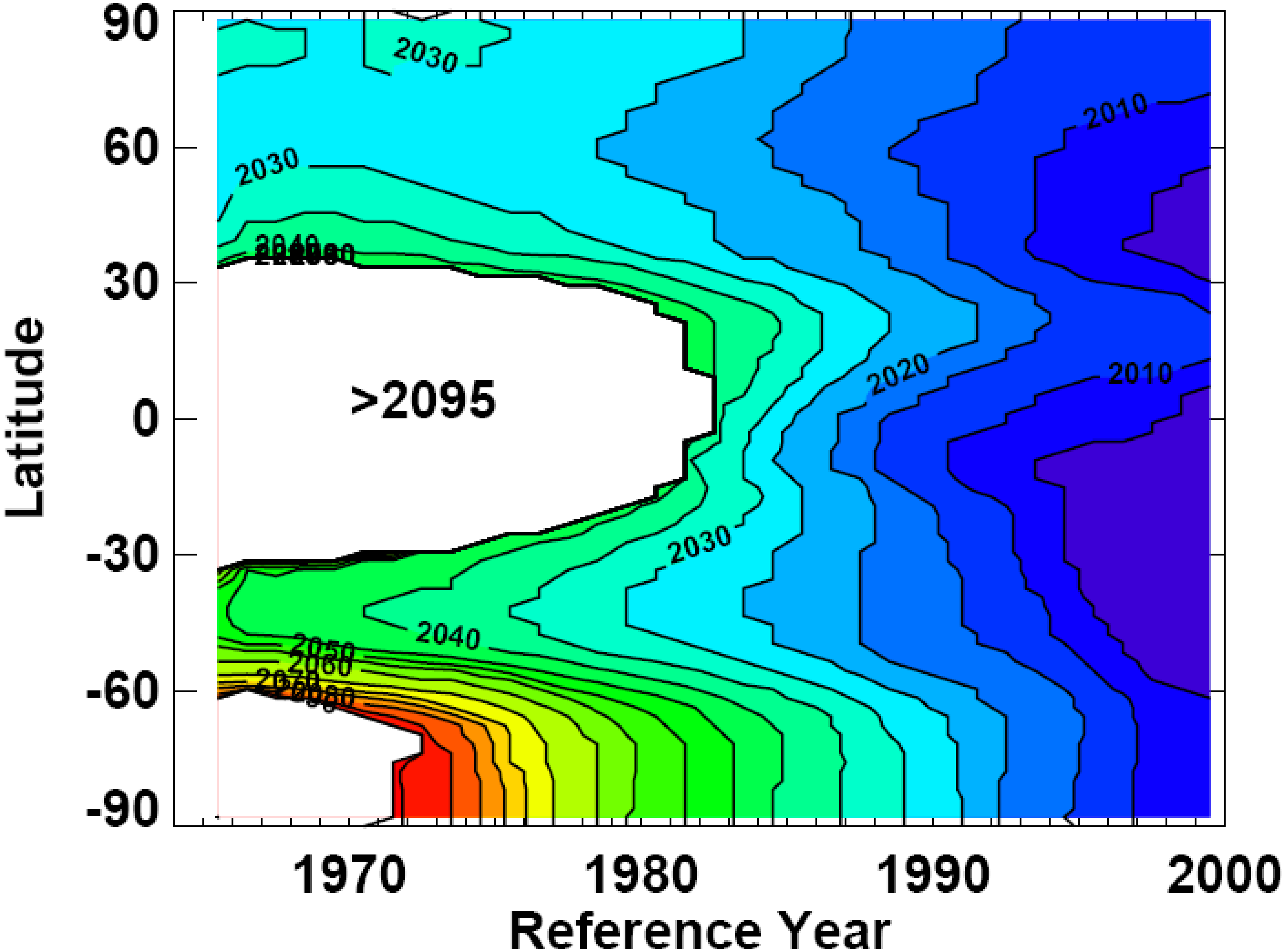
SIMULATED AND OBSERVED OZONE HOLE AREAS





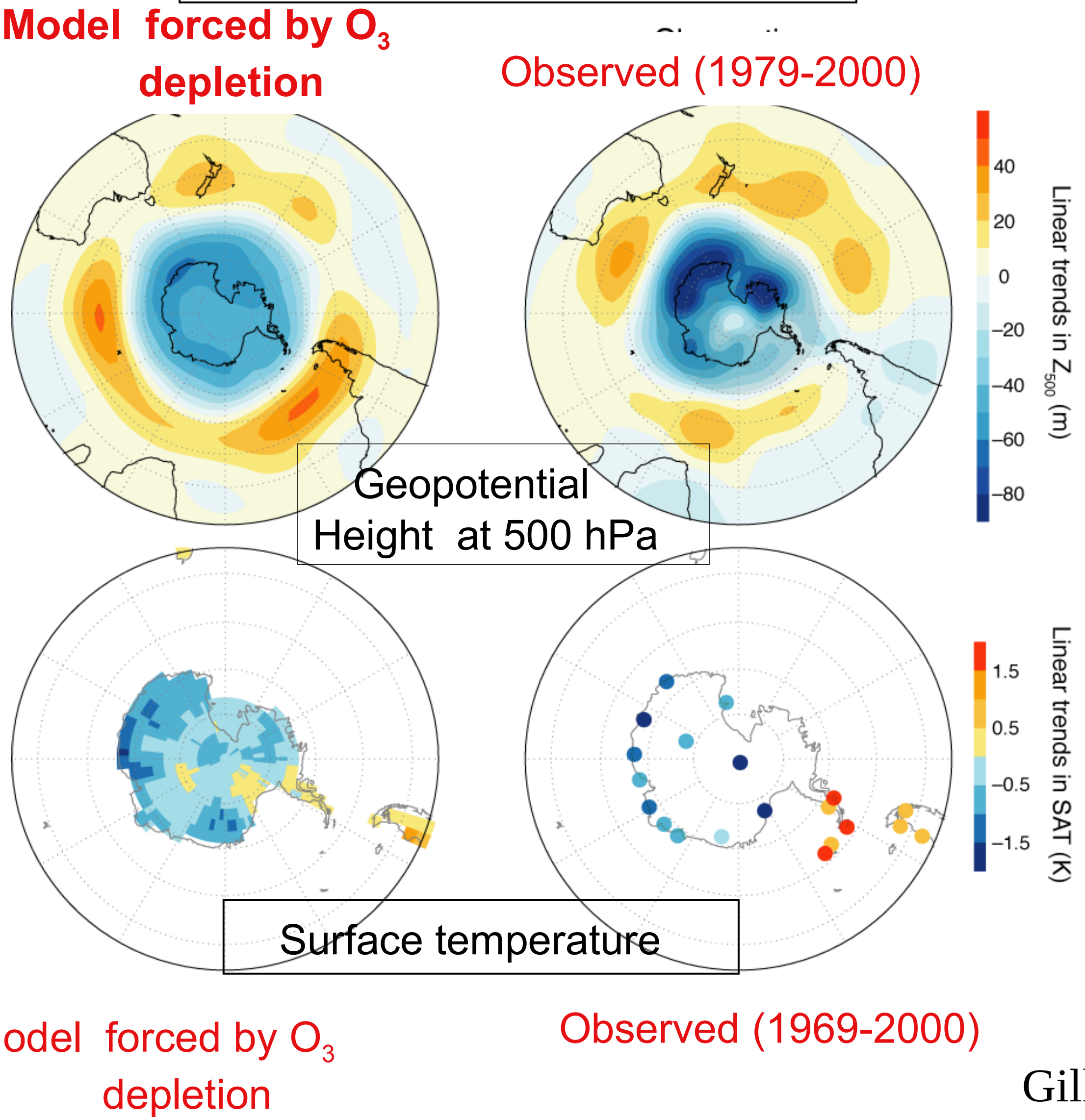
Return year, annual mean
Latitude
90
60
30
0
-30
-60
-90
1970
1980
1990
2000
Reference Year
>2095
2010
2030
2040
2050
2060
2070
2080

Return Year, Sept-Nov



Impact of ‘O_3 hole’ on tropospheric climate: climate model forced with polar O_3 depletion (all other forcings cste)

December-May trend



Similar features in observations and model :

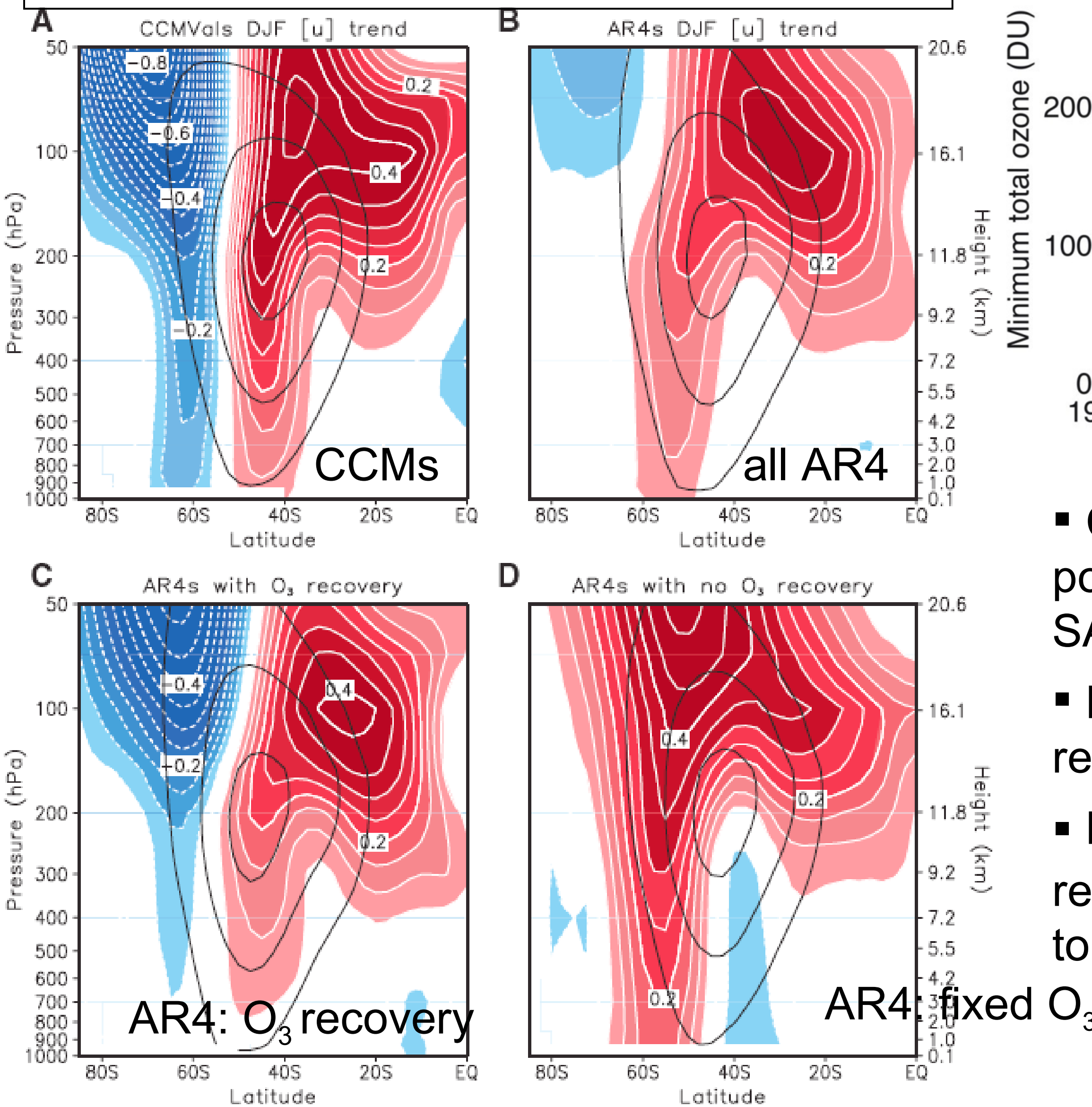
- Falling geopotential heights poleward of 60°S and rising geopotential heights in the middle latitudes
- Significant surface cooling over most of Antarctica butg warming over Antarctic Peninsula & Patagonia
- Intensification of surface westerly flow at around 50°S to 60°S (not shown).

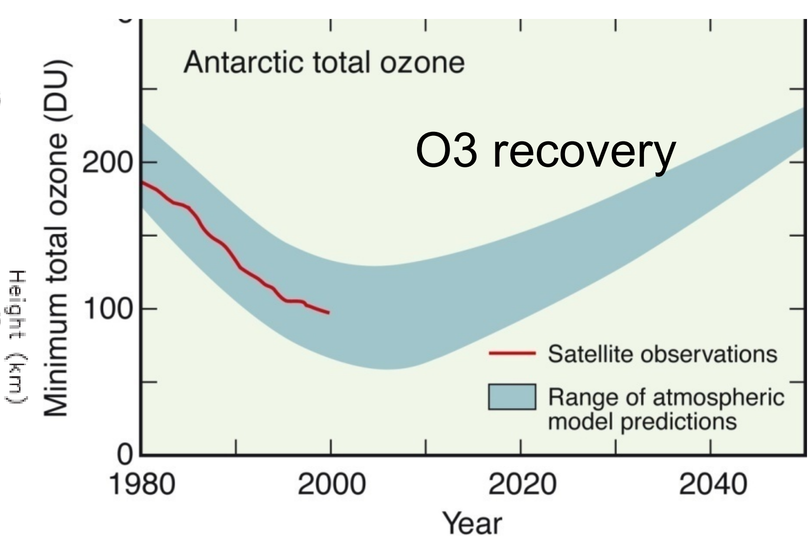
-> O_3 hole may have impacted Antarctic surface climate

Gillett & Thompson, Science, 2003

Future Polar Jet:
CCMs versus AR4 models (with/without ozone recovery)

2000-2050 summer trend in Zonal Wind

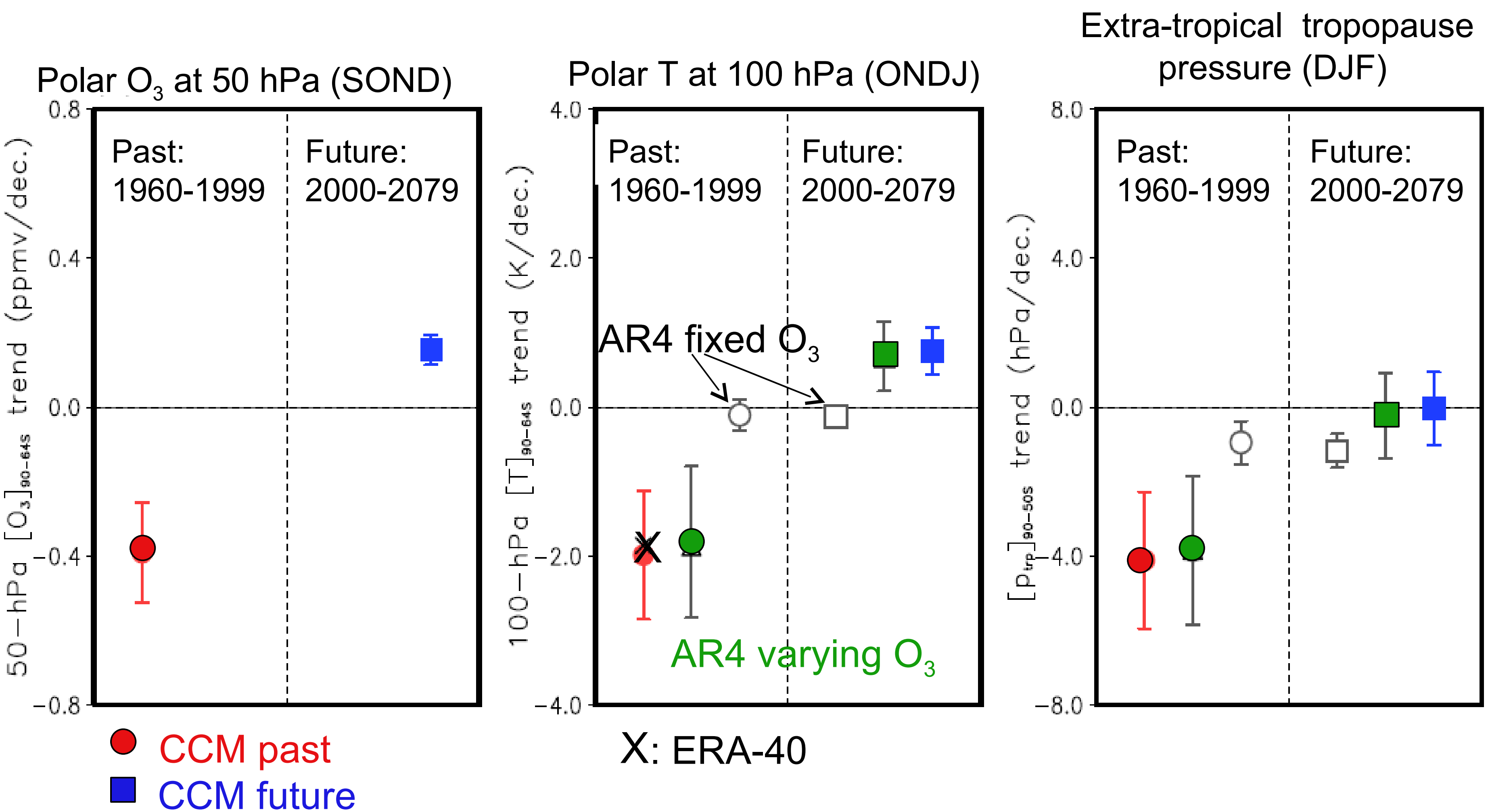




- CCMs: deceleration on the poleward side of jet (decrease in SAM).
- Multi-AR4 mean: opposite response
- But AR4 models with O_3 recovery are closer to CCMs than to AR4 models with fixed O_3.

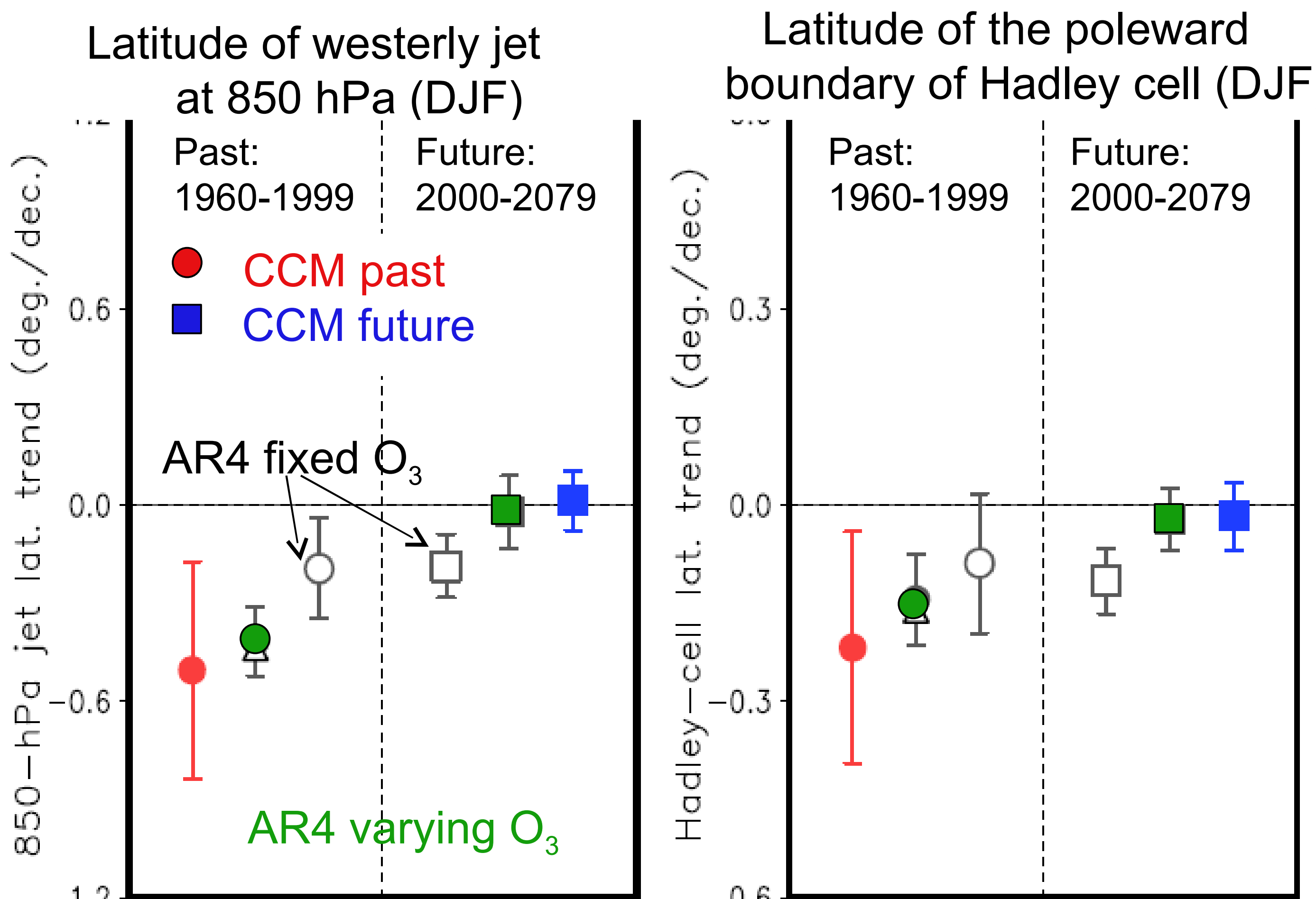
Son et al., Science, 2008

Past et future SH lower stratosphere :
Trends in CCMs versus AR4 (with/without ozone varying)



- CCMs and AR4 varying O_3 models give similar results
- AR4 fixed O_3 models give completely different results

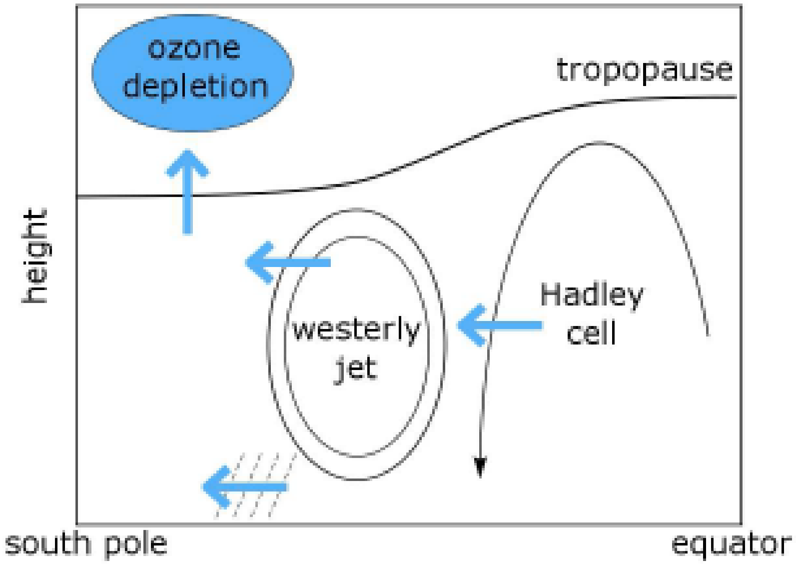
Past et future SH troposphere : Trends in CCMs versus AR4 (with/without ozone varying)

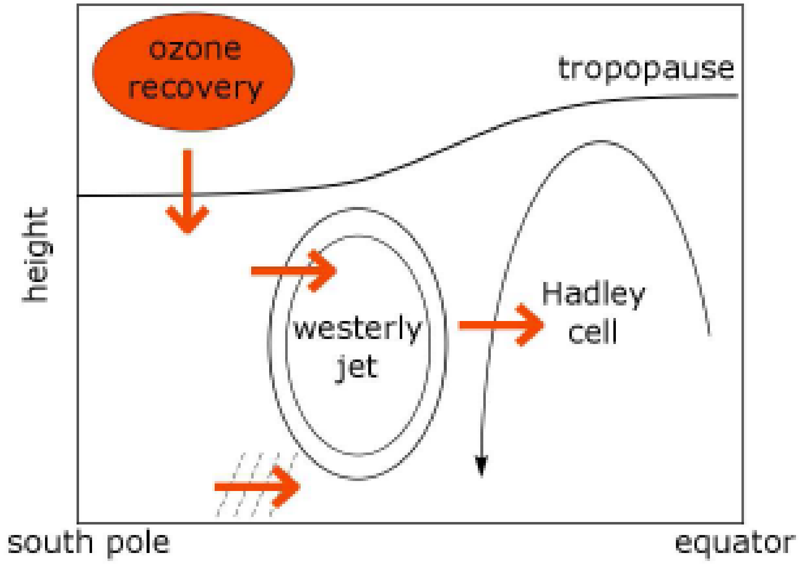


- CCMs and AR4 varying O_3 models give similar results
- AR4 fixed O_3 models give different results

'O_3 hole' affects SH troposheric climate (->IPCC)

IMPACT OF SOLAR VARIABILITY ON SSTs





Son et al, 2010

MESSAGES

- Ozone = f(CFCs, GHGs)
- Important for Antarctic climate, but difficult to predict