The Current and Future States of the Ozone Layer

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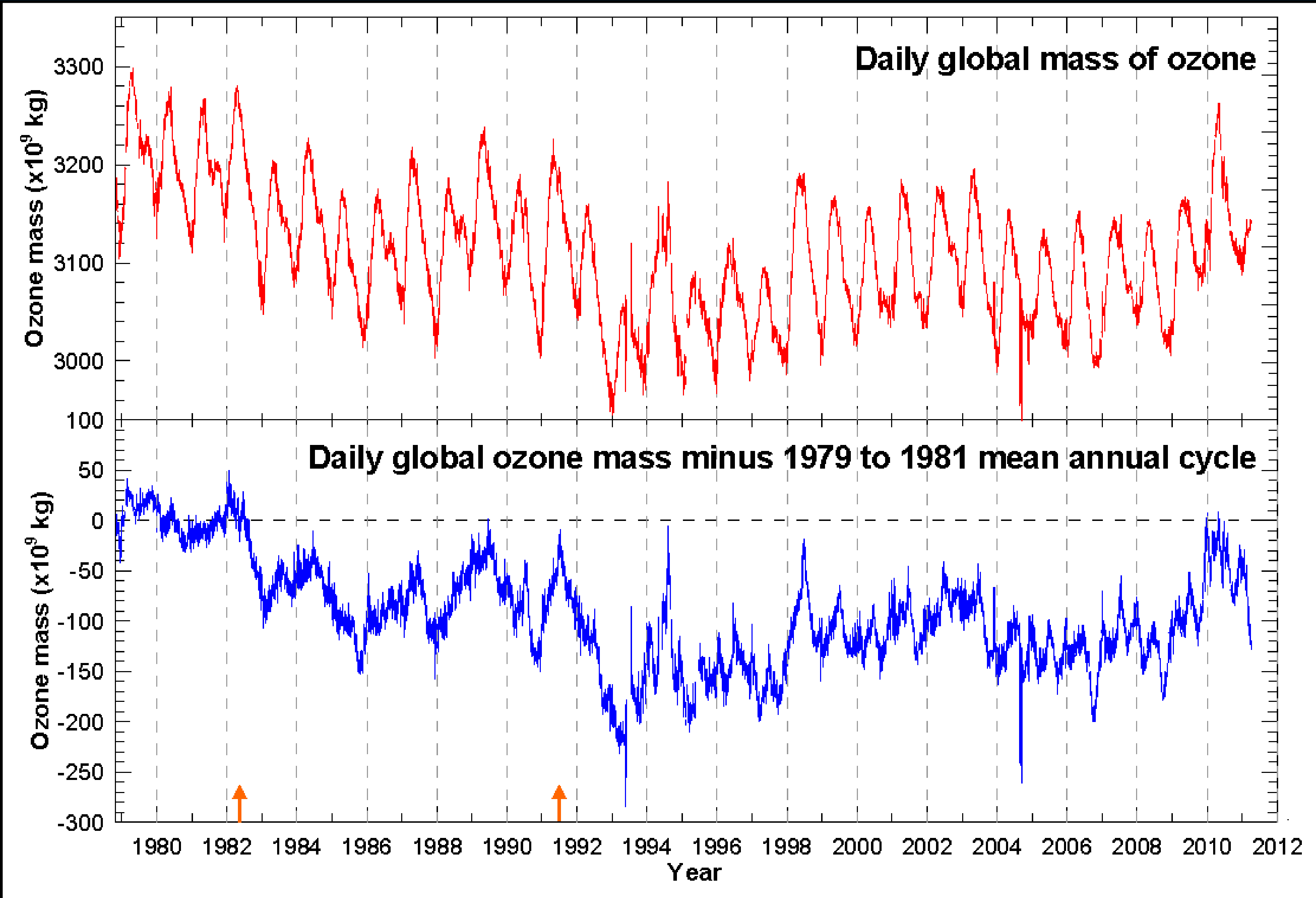
Presented at the 8th Ozone Research Managers Meeting, Geneva, 2-4 May 2011

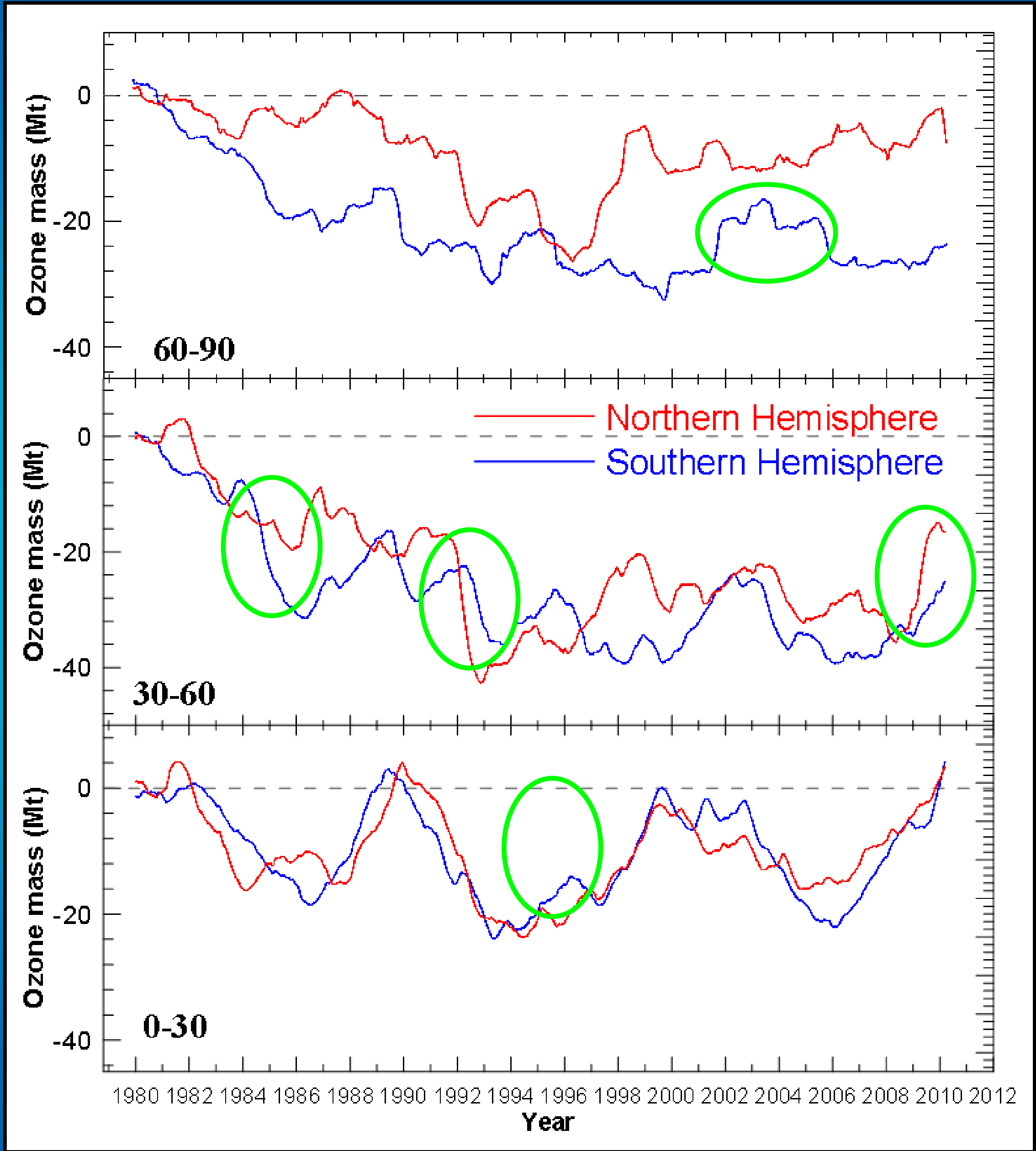
Overview

- A global overview of the state of the ozone layer to date
- The current state of ozone over Antarctica
- The current state of ozone over the Arctic with a special mention of the most recent winter
- An assessment of ozone over mid-latitudes
- Potential future states of the ozone layer through the 21st century
- Potential threats to the ozone layer in the future
- Conclusions

A global overview of the state of the ozone layer



An overview of the state of the ozone layer by zones



2 year running means of ozone mass in 30° latitude zones.

Northern Hemisphere shown in **red** and Southern Hemisphere shown in **blue**.

Note that vertical scales are the same.

Features in the historical ozone distribution

Anomalously high Antarctic ozone in 2002 and 2004: The early years of the 21st century were characterized by large planetary wave forcing of the stratosphere. 2002 experienced a sudden stratospheric warming.

Allen et al. (2003), Unusual stratospheric transport and mixing during the 2002 Antarctic winter, GRL, 30(12), 1599, doi:1510.1029/2003GL017117.

Hoppel et al. (2003), POAM III observations of the anomalous 2002 Antarctic ozone hole, GRL, 30(7), 1394, doi:1310.1029/2003GL016899.

Newman et al. (2005), The Unusual Southern Hemisphere Stratosphere Winter of 2002, J. Atmos. Sci., 62, 614-628.

Downward step in southern midlatitude ozone in 1985: A combination of the particular phasing of the QBO with respect to the annual cycle in wave activity and a minimum in the solar cycle. Happened again in 1997 and 2006.

Bodeker et al. (2007), The 1985 Southern Hemisphere mid-latitude total column ozone anomaly, Atmos. Chem. Phys., 7, 5625–5637.

Features in the historical ozone distribution

Lack of a response of southern midlatitude ozone to the Mt. Pinatubo volcanic eruption: Potential dynamical offset of the Pinatubo signal.

Telford et al. (2009), Reassessment of causes of ozone column variability following the eruption of Mount Pinatubo using a nudged CCM, Atmos. Chem. Phys., 9, 4251–4260.

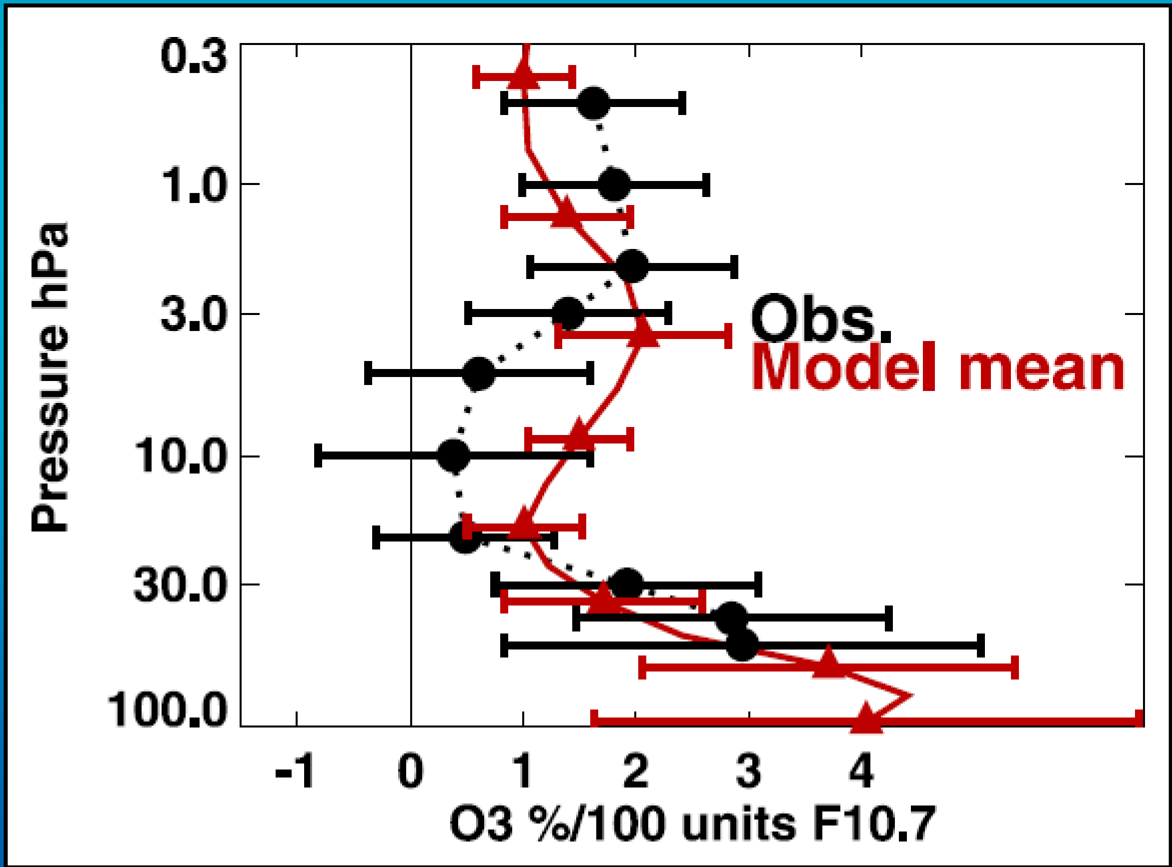
Large positive anomaly in northern midlatitude ozone in recent years: Resulted from unusually pronounced and persistent negative phase of the Arctic Oscillation and North Atlantic Oscillation and easterly wind - shear phase of the QBO.

Steinbrecht, W., U. Köhler, H. Claude, M. Weber, J. P. Burrows, and R. J. van der A (2011), Very high ozone columns at northern mid - latitudes in 2010, Geophys. Res. Lett., 38, L06803, doi:06810.01029/02010GL046634.

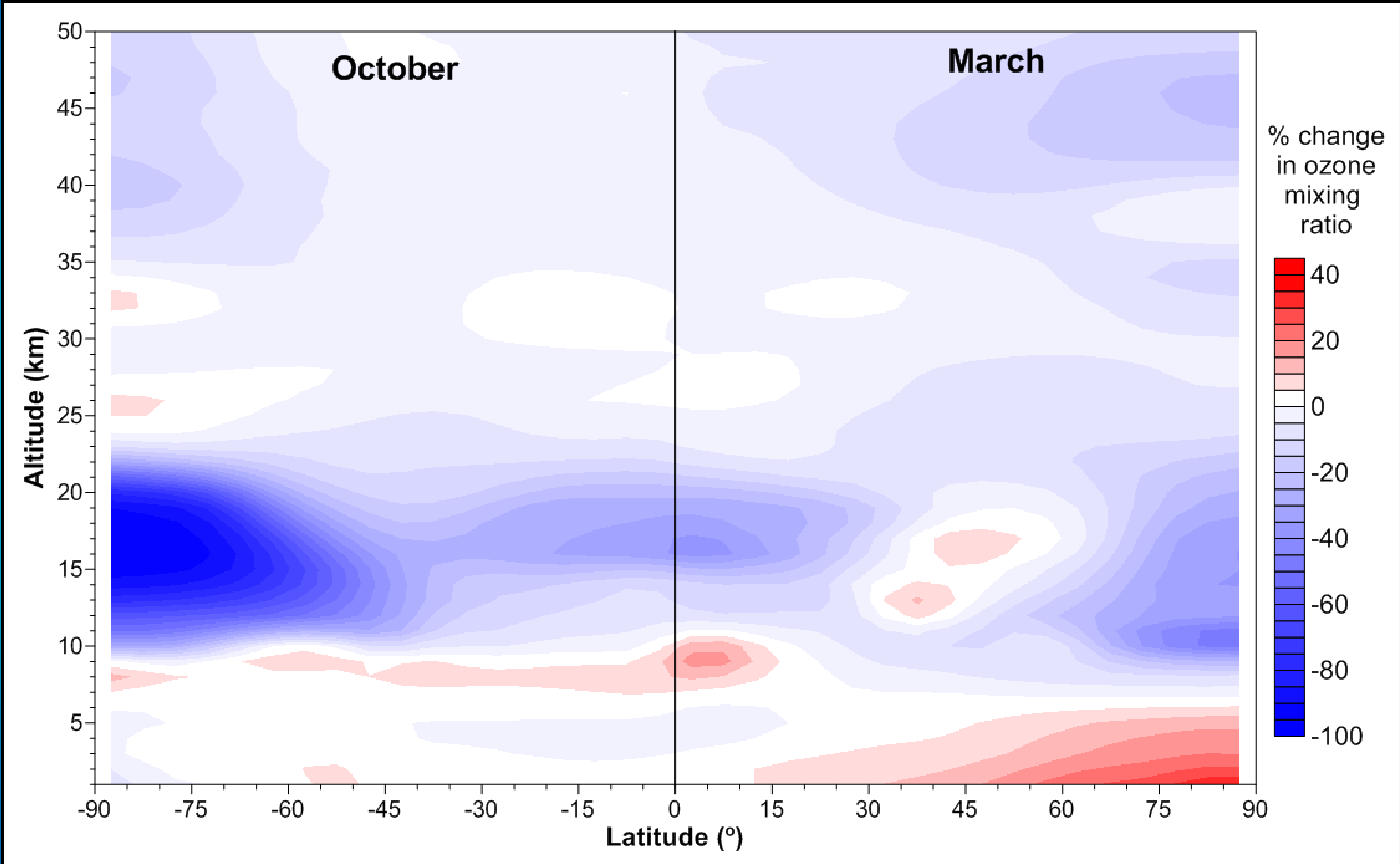
Features in the historical ozone distribution

Solar cycle signal in ozone: Solar cycle modulation of stratospheric ozone is a primary mechanism for amplifying the small effects of top of the atmospheric changes in solar irradiance on climate – primarily by modulating the strength of the Brewer-Dobson circulation. Chemistry-climate models are doing a better job now of simulating these effects.

Austin, J., et al. (2008), Coupled chemistry climate model simulations of the solar cycle in ozone and temperature, J. Geophys. Res., 113, D11306, doi:11310.11029/12007JD009391.



Changes in O_3 mixing ratio from 1979 to 1996



Note the declines in tropical lower stratospheric ozone.

Declines in tropical lower stratospheric ozone

Randel, W. J., and A. M. Thompson (2011), Interannual variability and trends in tropical ozone derived from SAGE II satellite data and SHADOZ ozonesondes, J. Geophys. Res., 116, D07303, doi:07310.01029/02010JD015195.

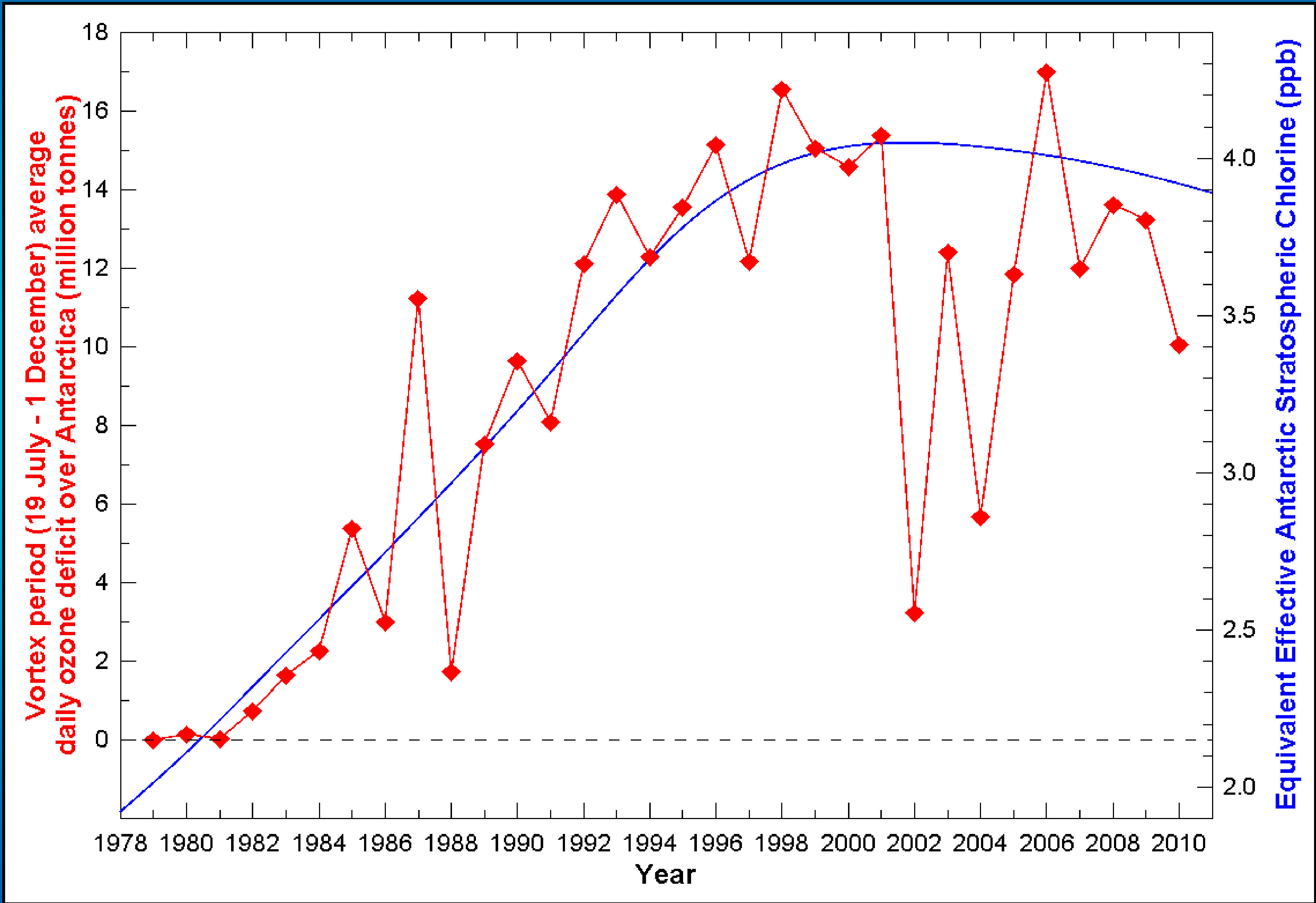
The negative trend is thought to result from increases in upwelling in the tropical lower stratosphere which is turn results from increases in sea-surface temperatures.

Deckert, R., and M. Dameris (2008), Higher tropical SSTs strengthen the tropical upwelling via deep convection, Geophys. Res. Lett., 35, L10813, doi:10810.11029/12008GL033719.

Decreases in ozone in the tropical lower stratosphere have important implications for changes in temperature, also in the tropical upper troposphere.

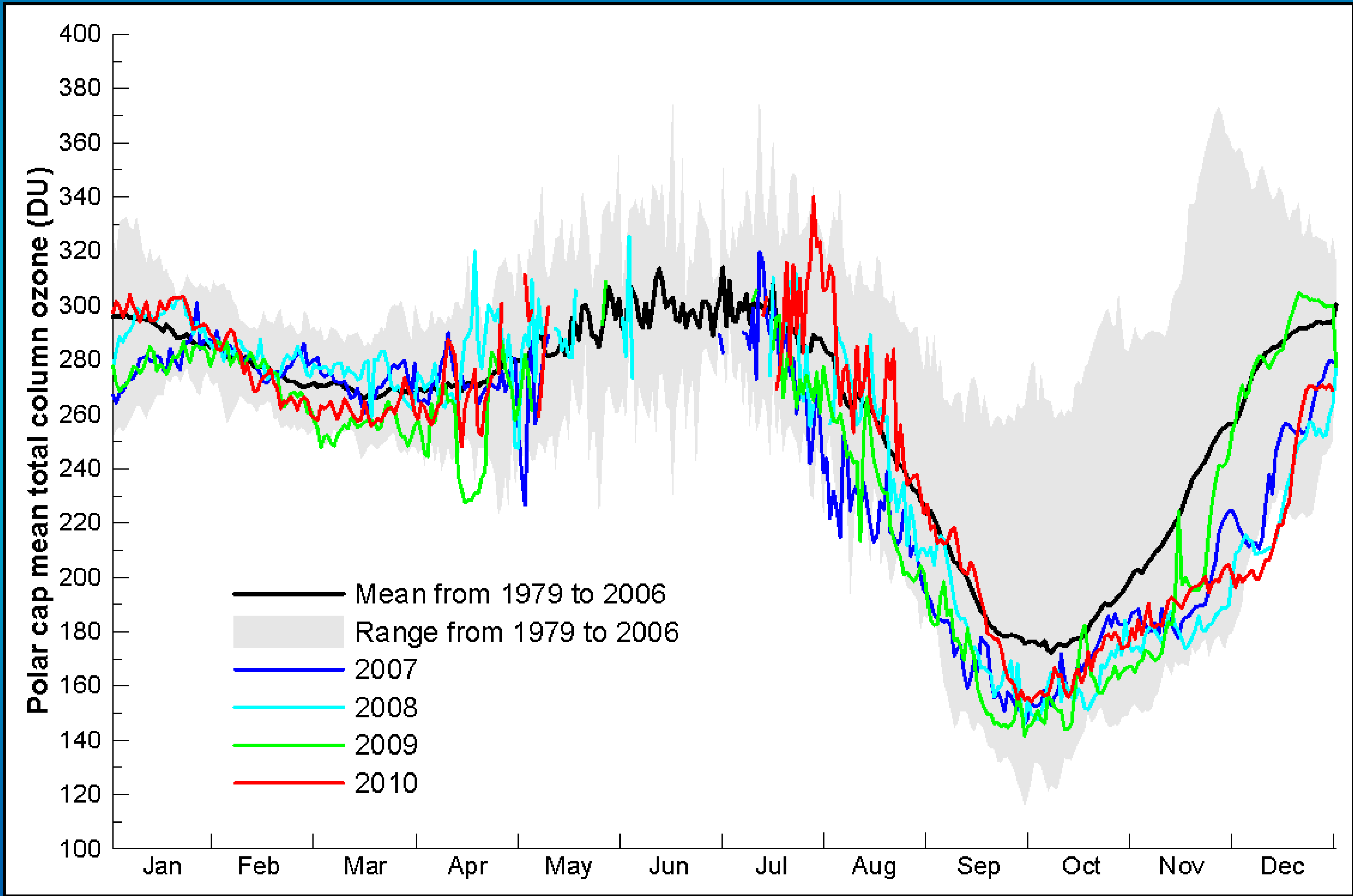
Forster, P. M., G. E. Bodeker, R. Schofield, S. Solomon, and D. W. J. Thompson (2007), Effects of ozone cooling in the tropical lower stratosphere and upper troposphere, Geophys. Res. Lett., 34, L23813, doi:23810.21029/22007GL031994.

The current state of ozone over Antarctica



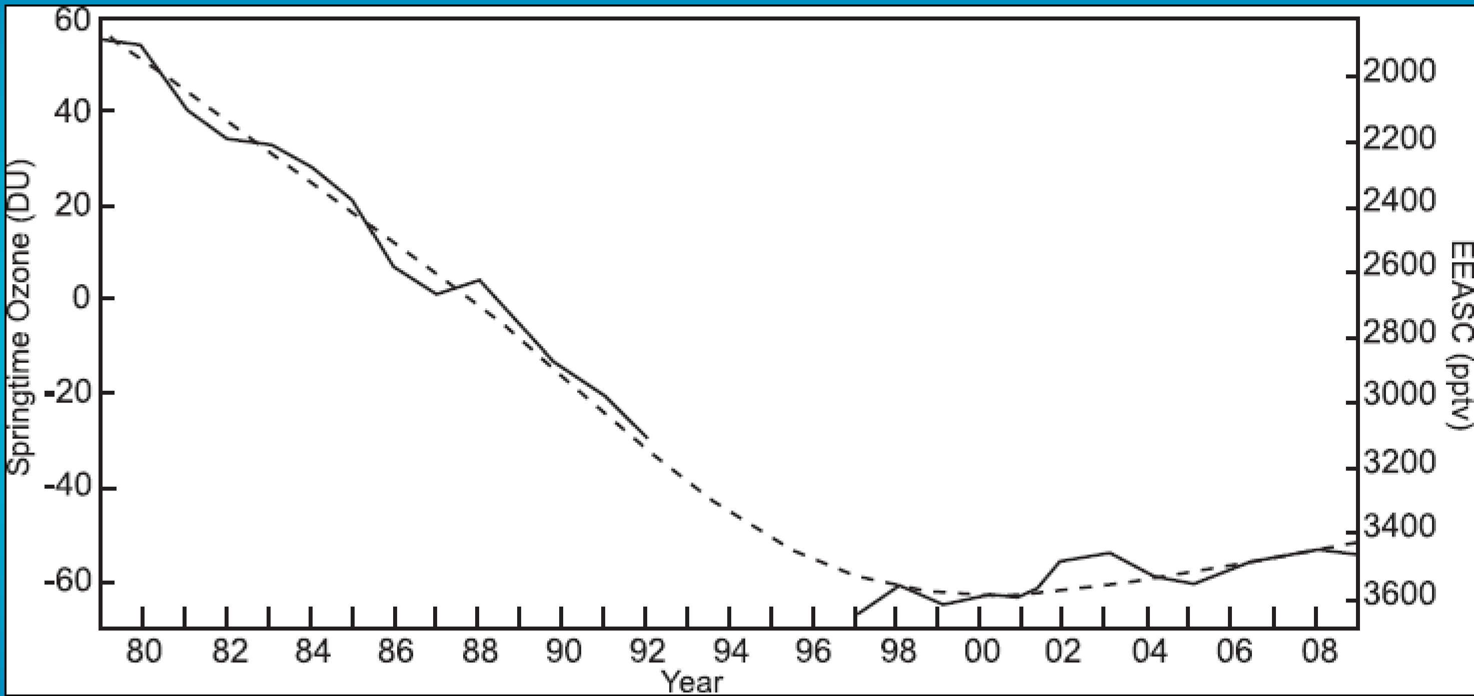
The current state of ozone over Antarctica

Daily polar cap mean (75°S to 90°S eqlat) total column ozone



Is the Antarctic ozone layer responding to the Montreal Protocol as expected?

Salby, M., E. Titova, and L. Deschamps (2011), Rebound of Antarctic ozone, Geophys. Res. Lett., in press.

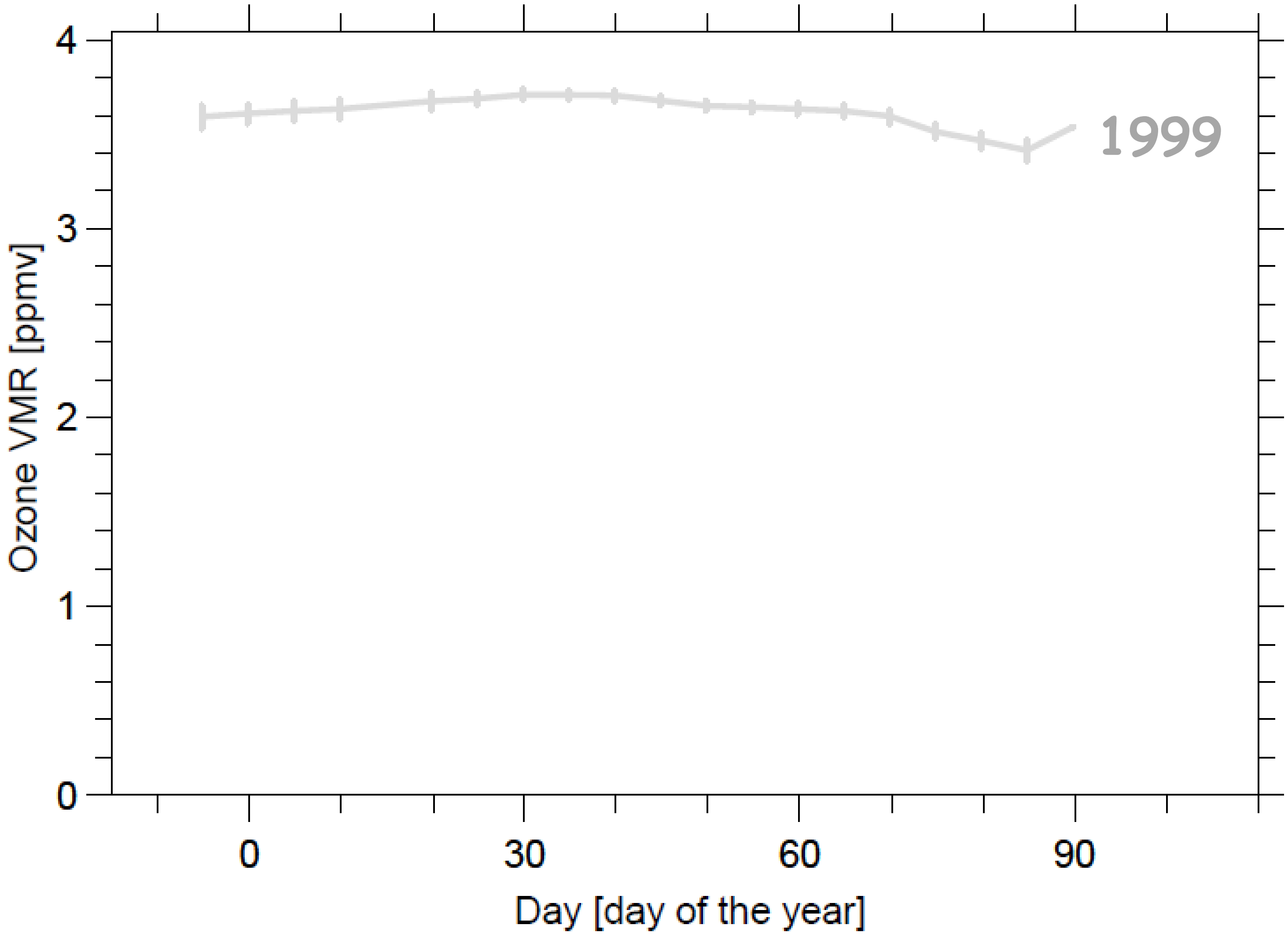


However, uncertainties remain around the age-of-air in the Antarctic stratosphere and hence the exact shape of EEASC and correlations of metrics of dynamical variability do not provide the quantitative assessment needed.

The current state of ozone over the Arctic

This material from Markus Rex (AWI) and is preliminary

Average ozone inside vortex @ eQ=465K



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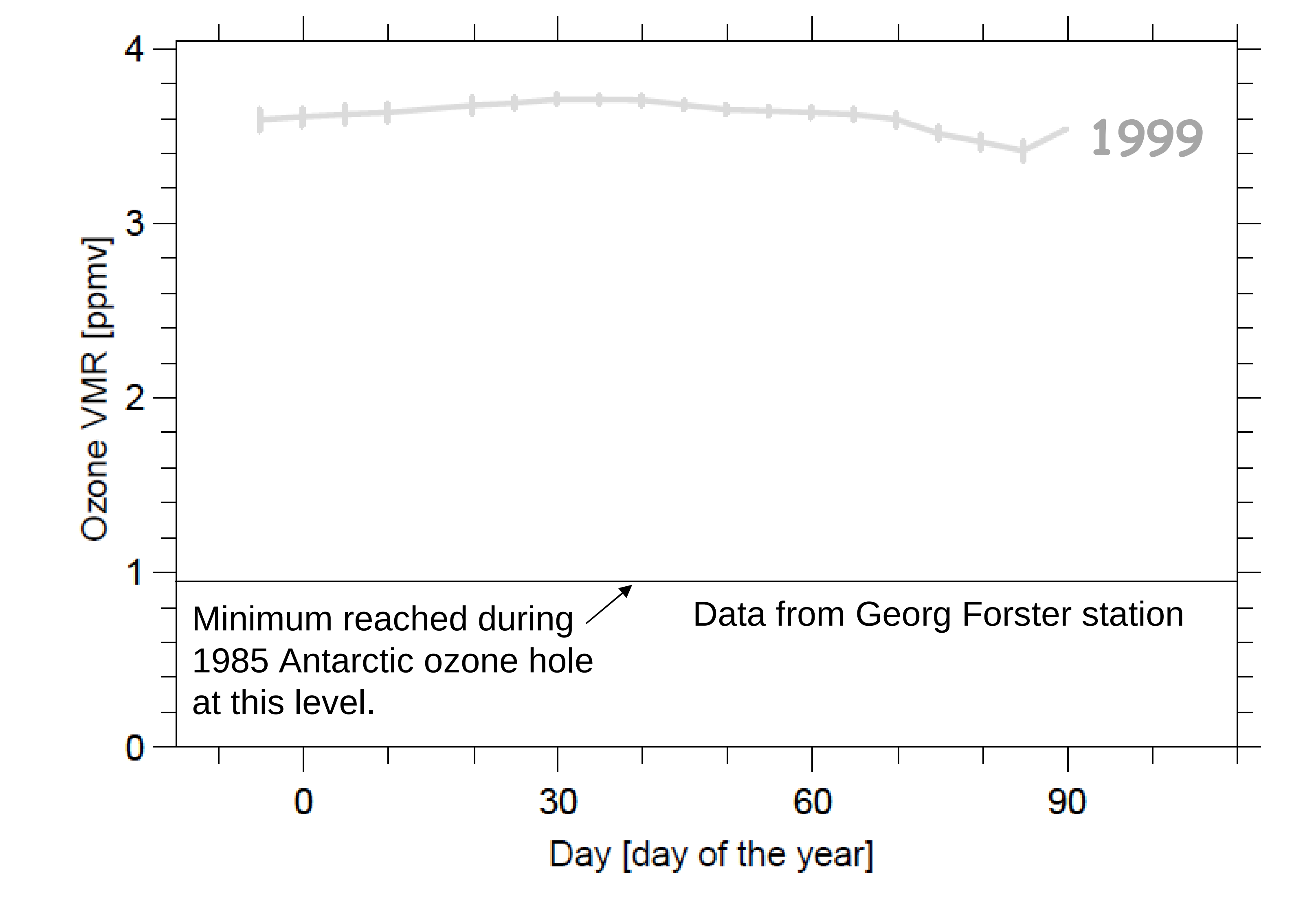

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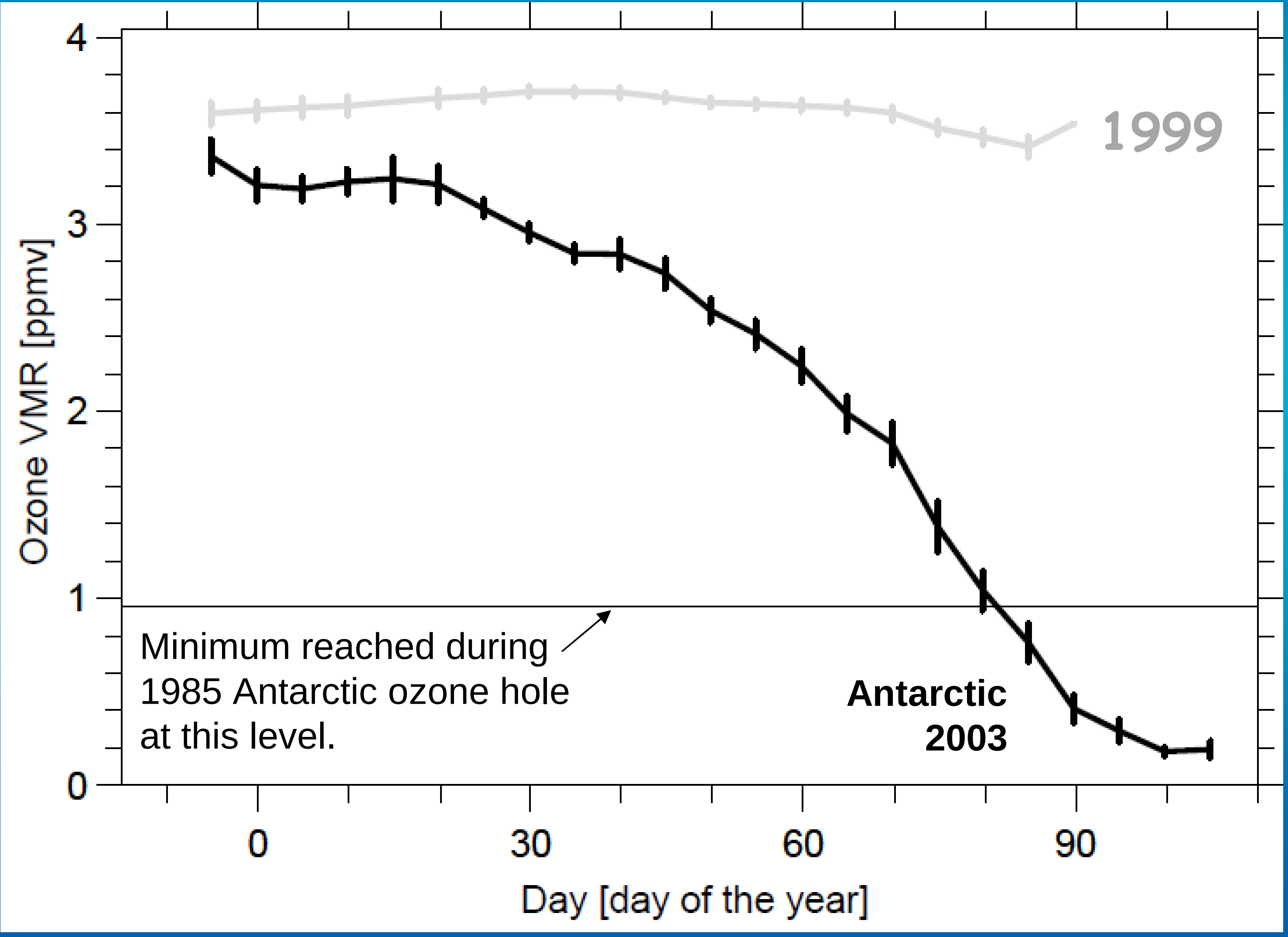

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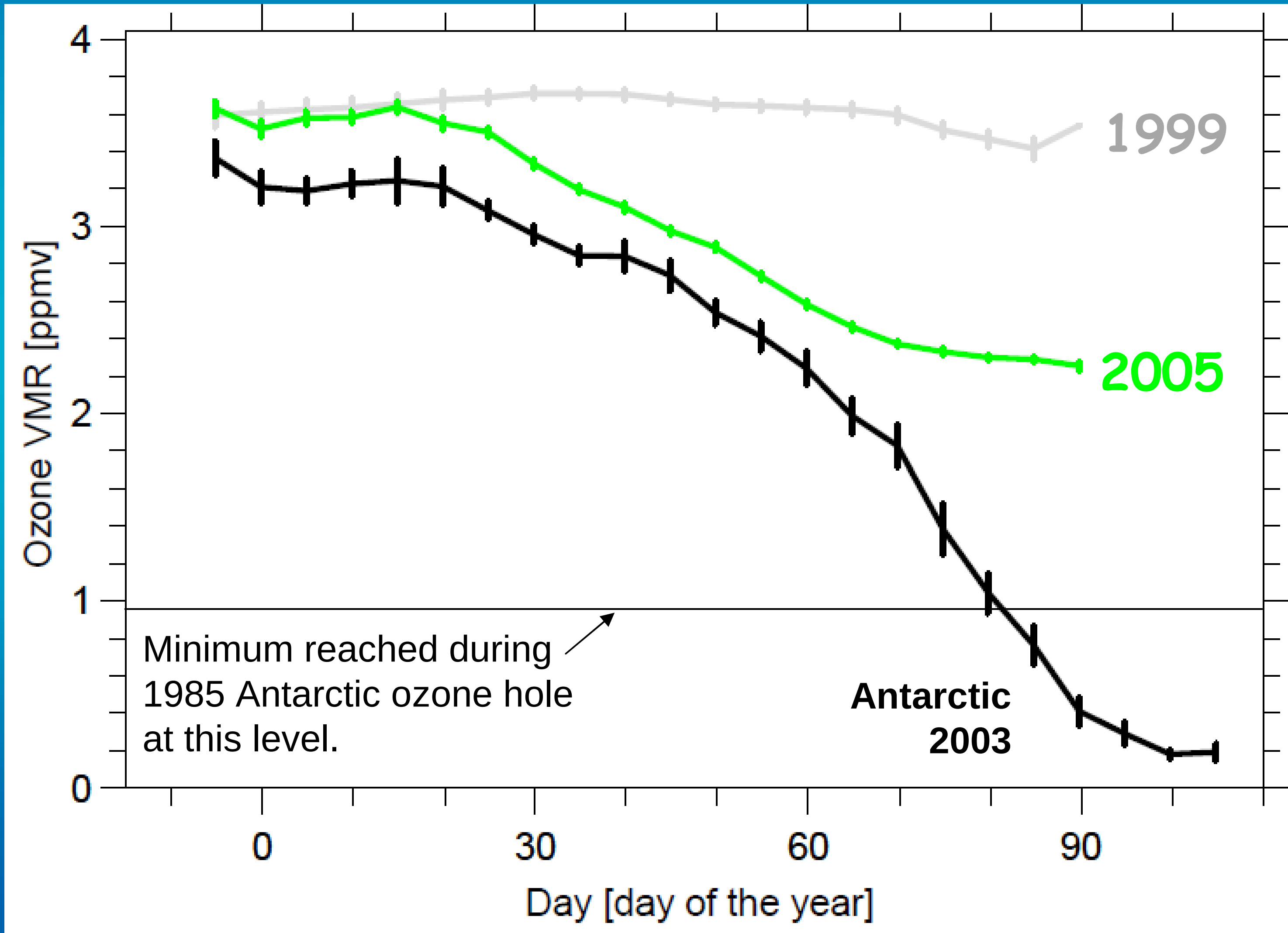

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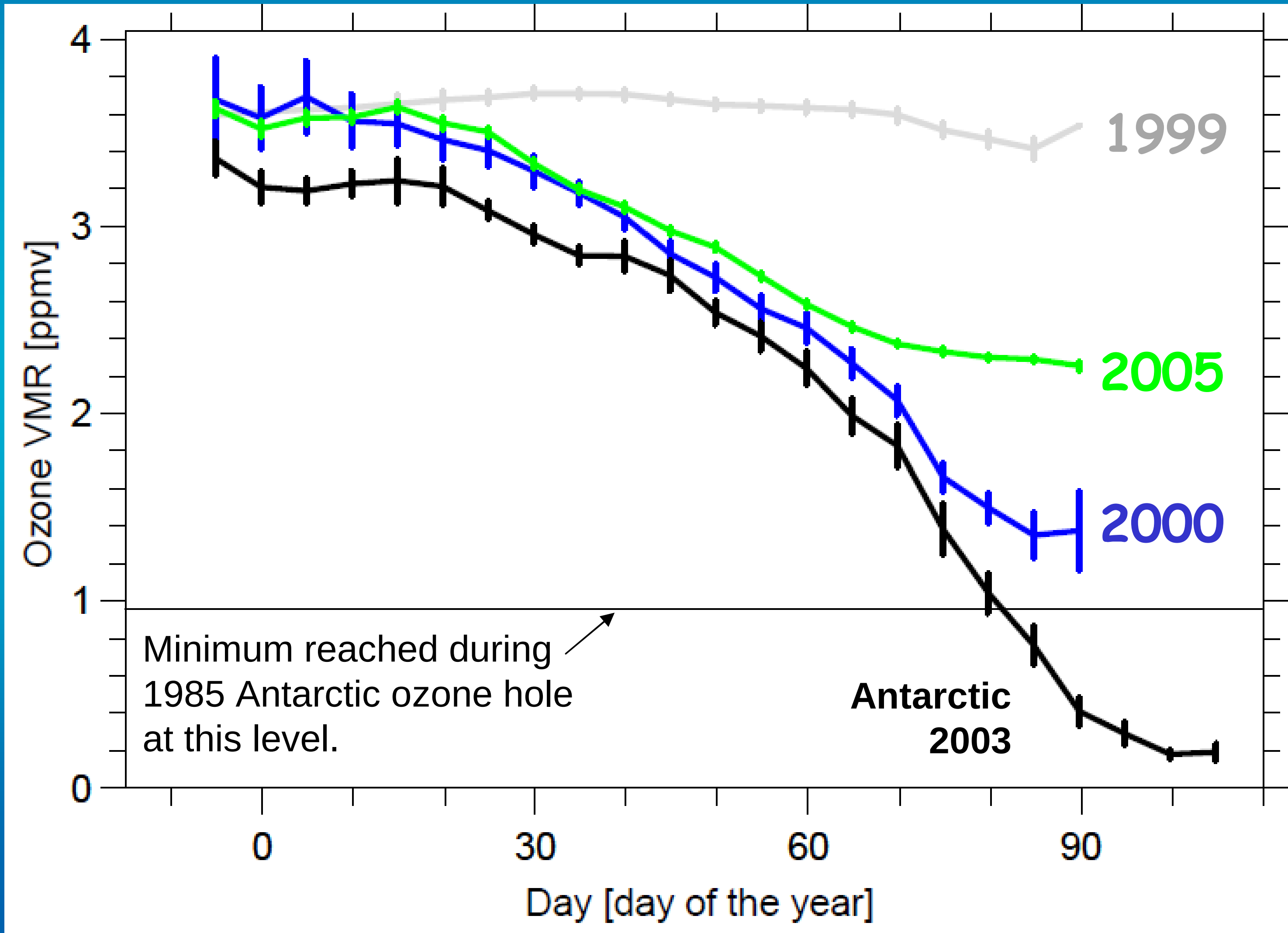

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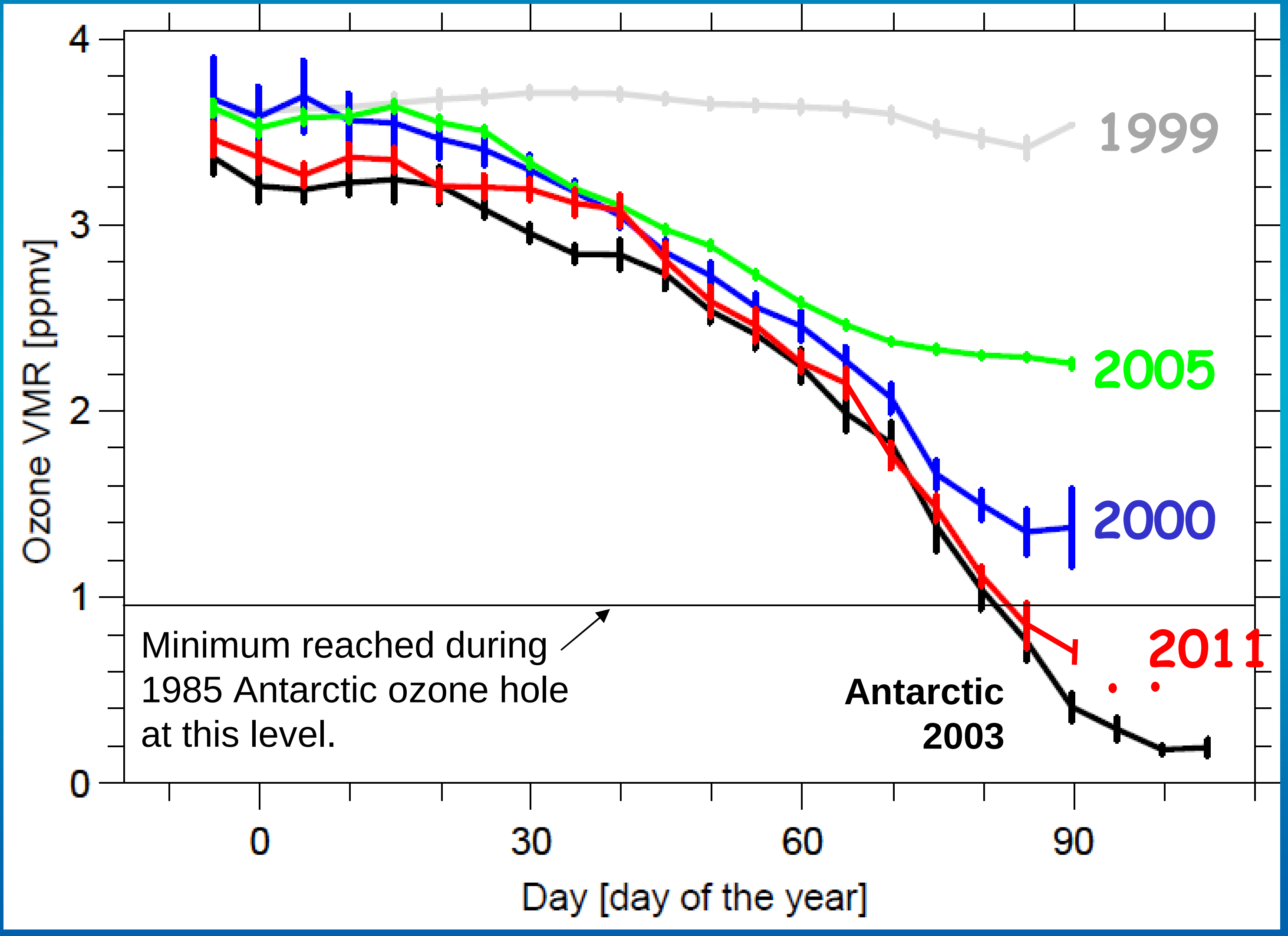
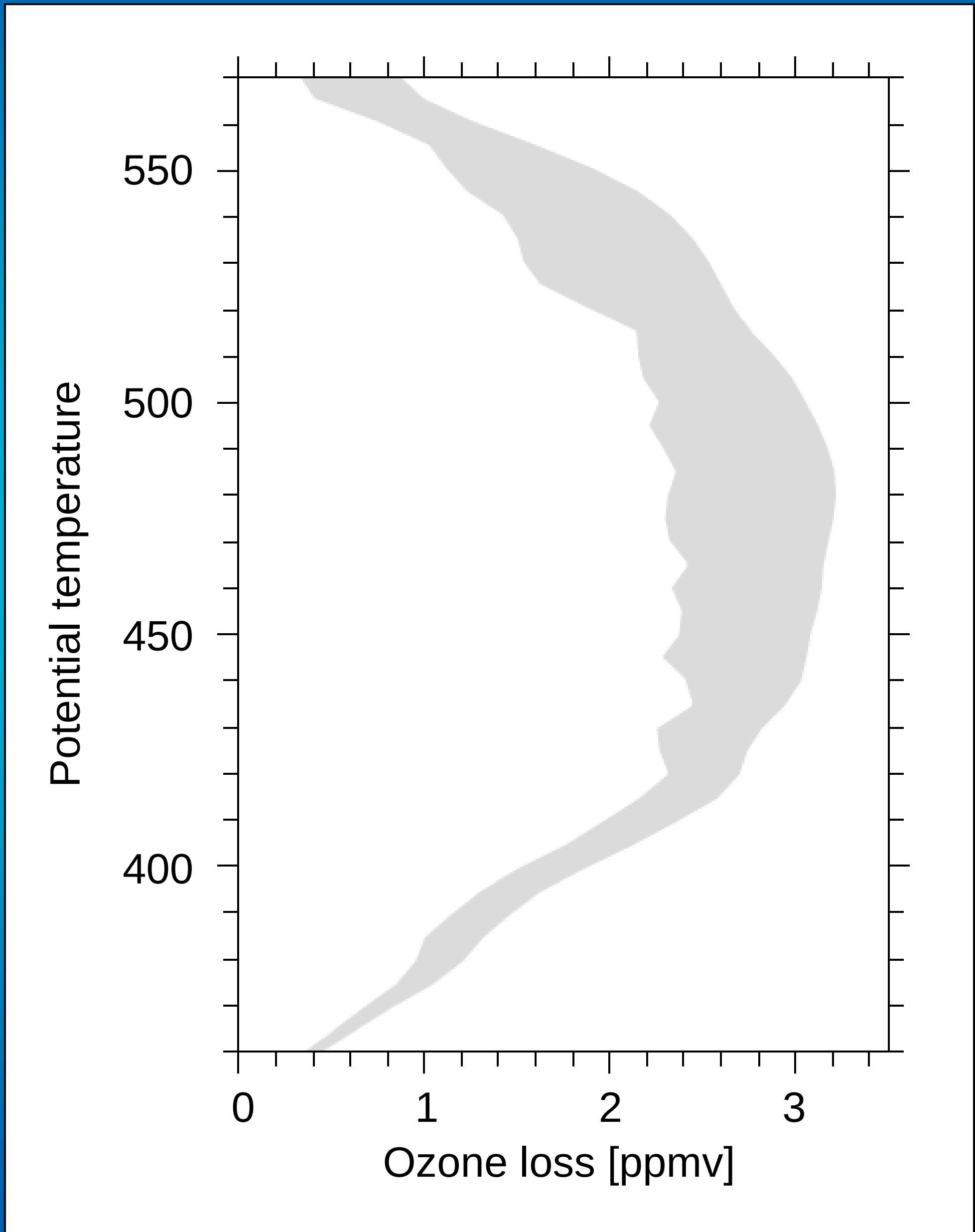


Ozone loss profiles

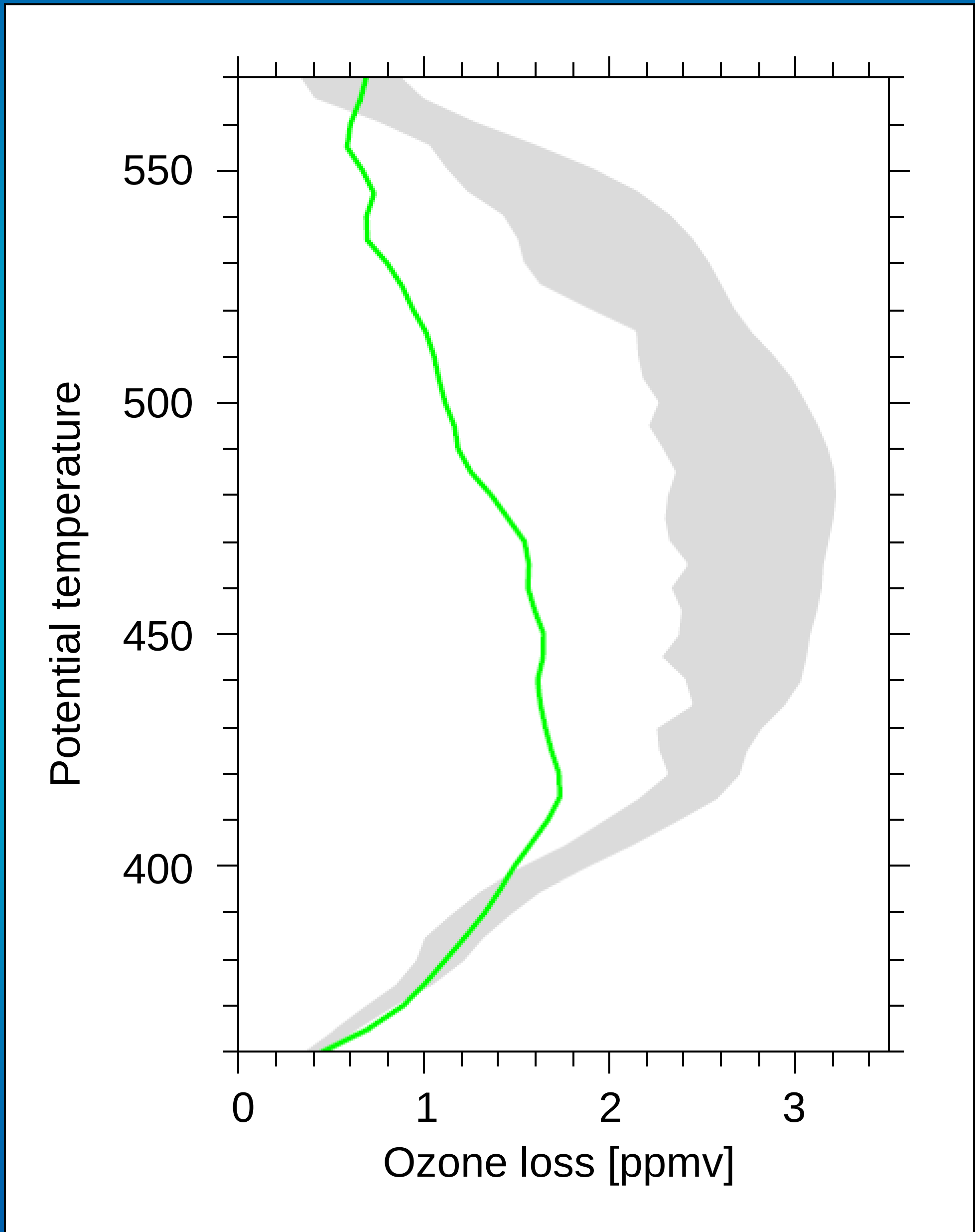


This material from Markus Rex (AWI) and is preliminary

Antarctic:

Ozone hole range (indicated by 1985 & 2003)

Ozone loss profiles



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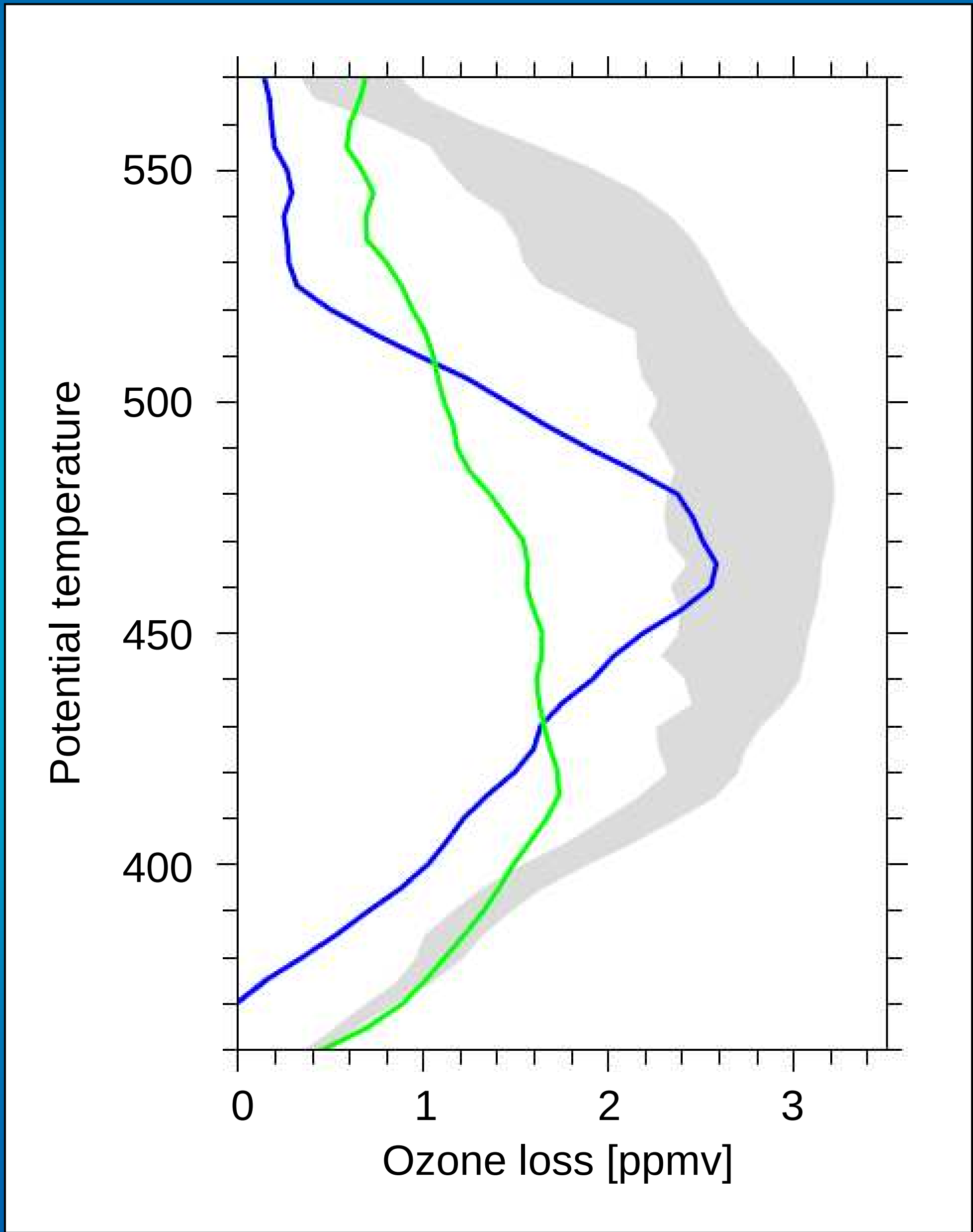
Antarctic:

Ozone hole range (indicated by 1985 & 2003)

Arctic:

2005

Ozone loss profiles



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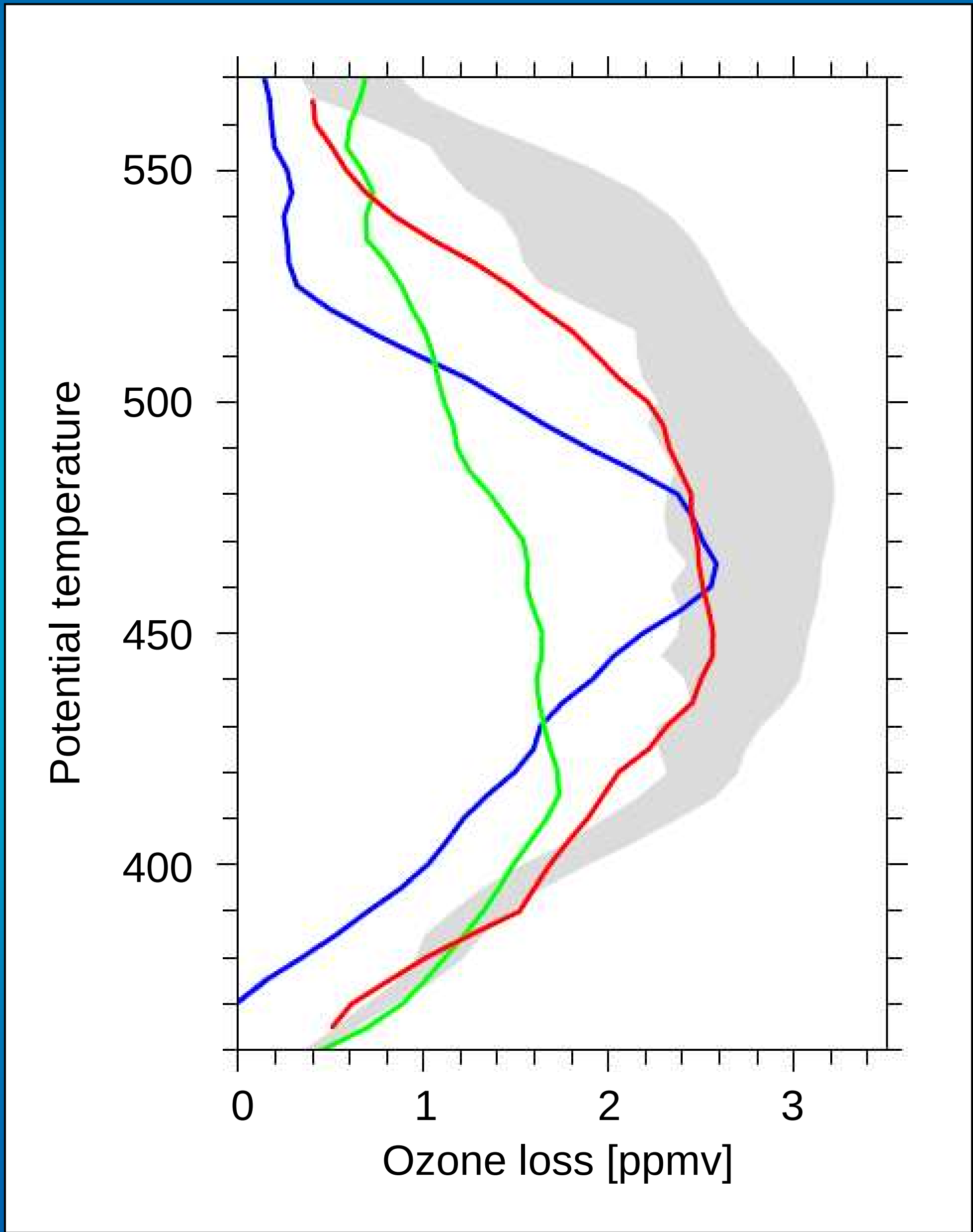


This material from Markus Rex (AWI) and is preliminary

Antarctic:

Ozone hole range (indicated by 1985 & 2003)

Arctic:

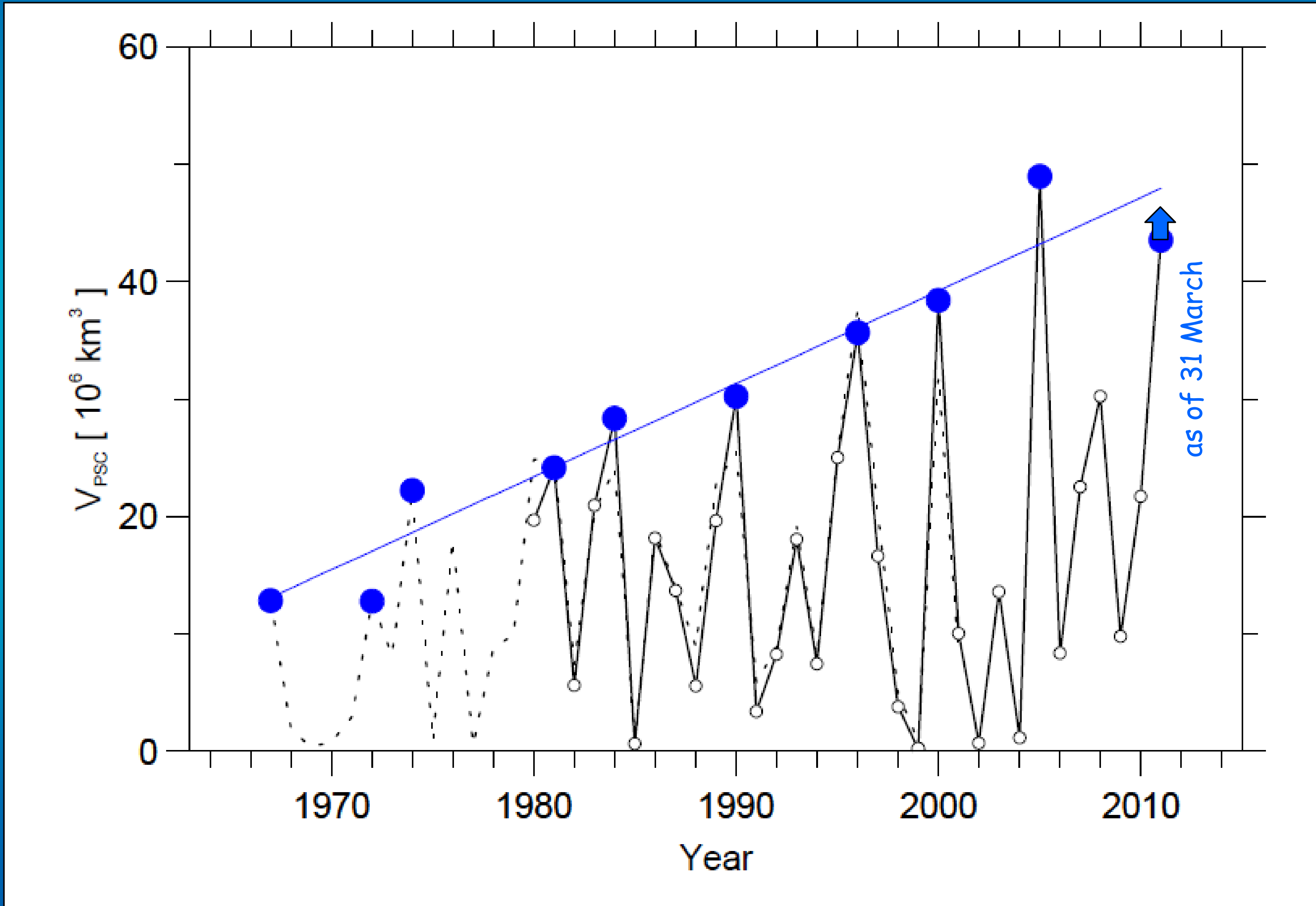
2000

2005

2011 (as of March 31)

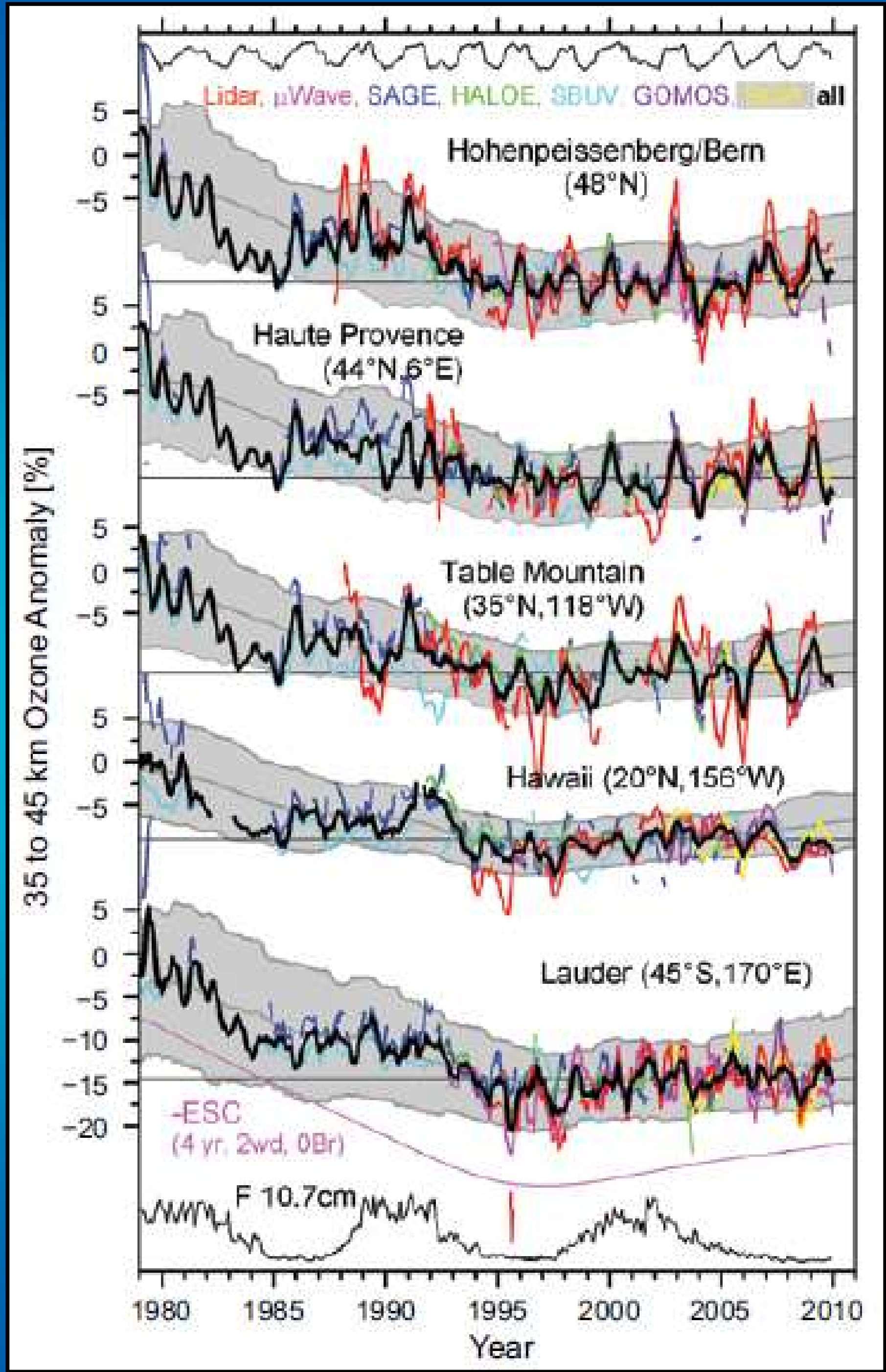
Long-term evolution of Arctic V_{PSC}

This material from Markus Rex (AWI) and is preliminary



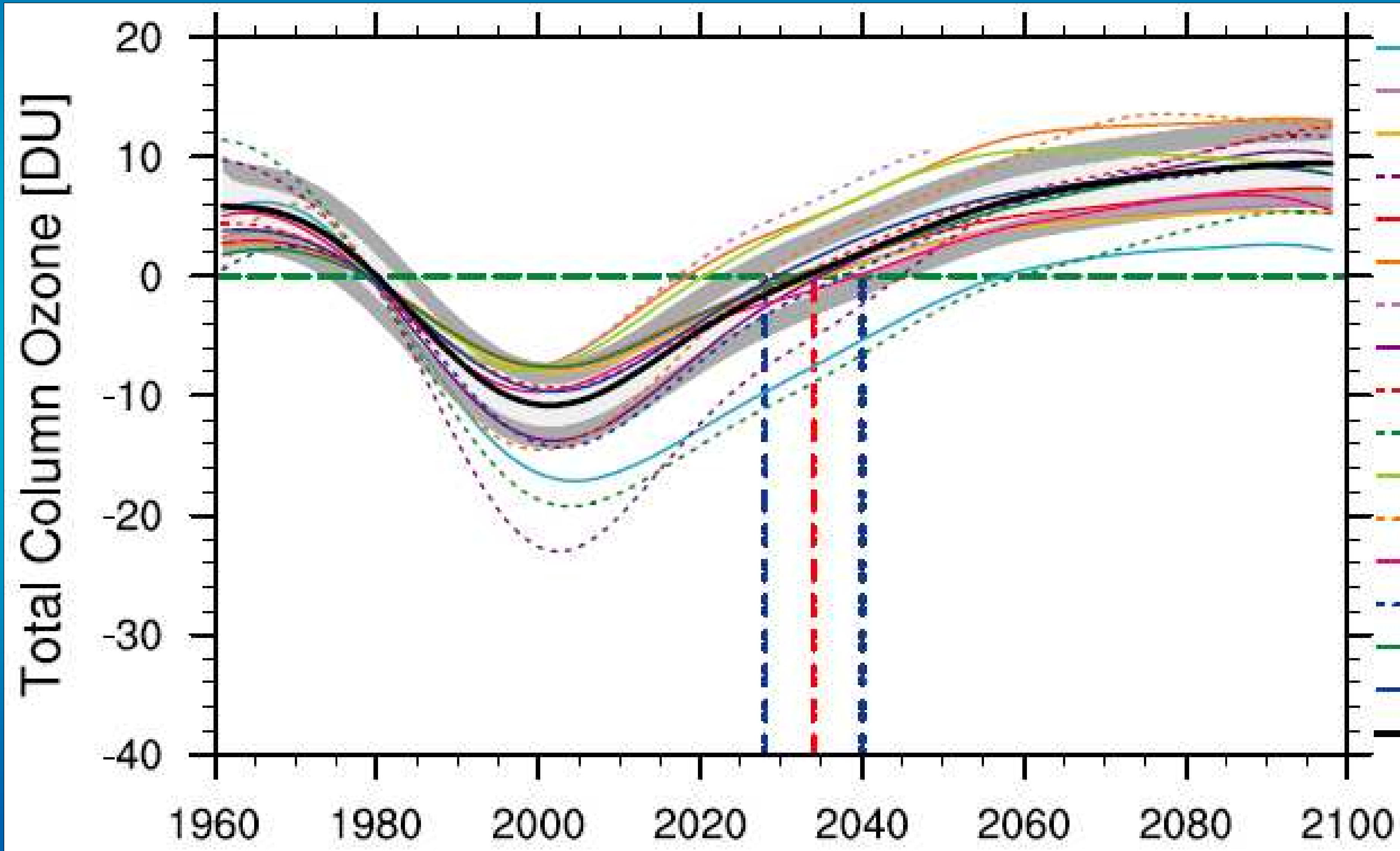
An assessment of ozone over mid-latitudes

- A number of different ground- and satellite-based instruments confirm that ozone in the mid-latitude upper stratosphere is no longer decreasing.
- Chemistry-climate model simulations of mid-latitude upper stratosphere ozone changes over the past 3 decades are consistent with observations.
- Maintaining long-term ground-based measurement time series is very important.



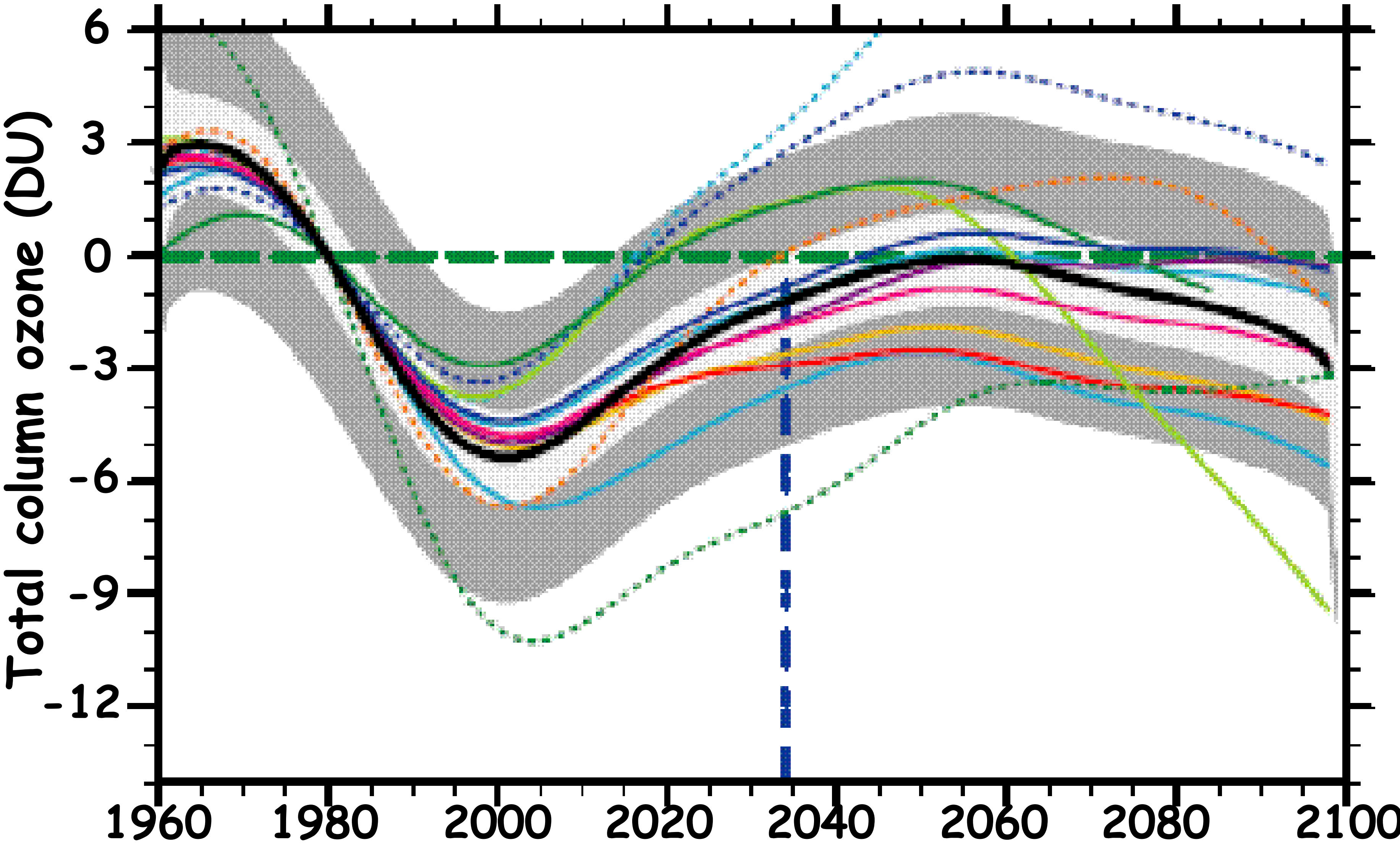
Potential future states of the ozone layer

Projected changes in global mean total column ozone using chemistry-climate models from SPARC CCMVal2 activity.



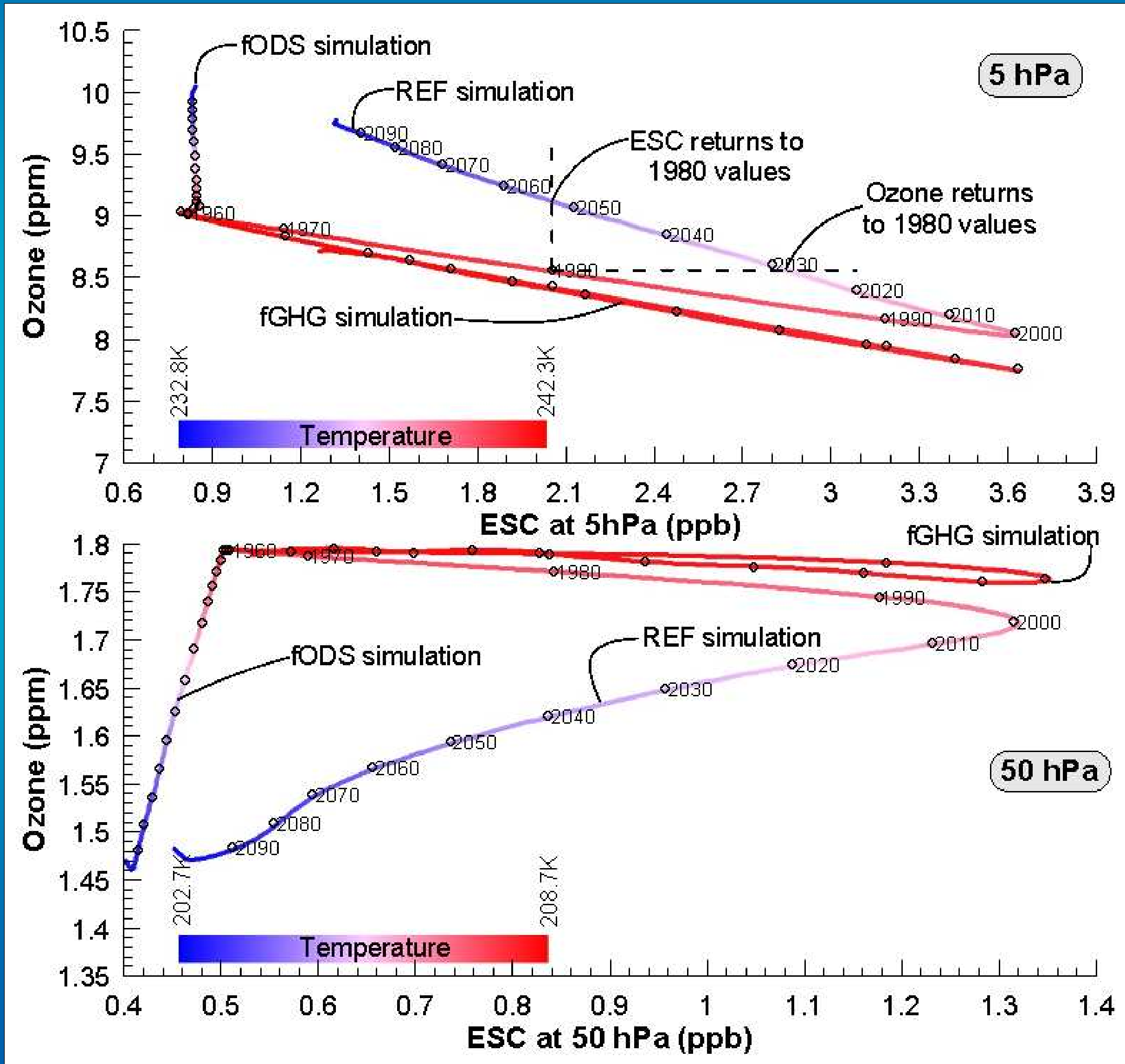
Potential future states of the ozone layer

Projected changes in tropical total column ozone



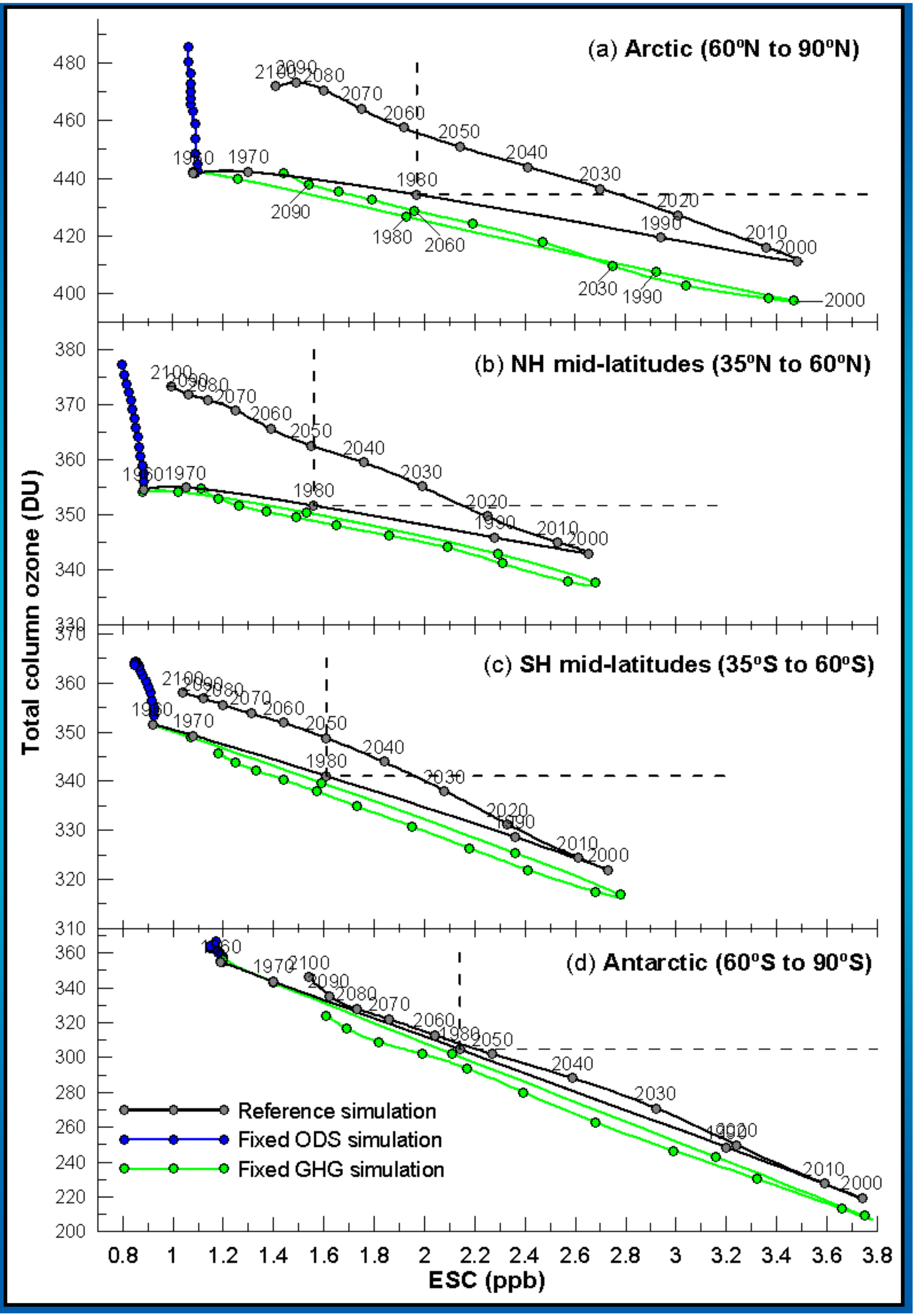
What's going on in the tropics? The influence of changes in climate

Increases in greenhouse gases (GHGs) cause tropical upper stratospheric ozone to increase by cooling the stratosphere but cause tropical lower stratospheric ozone to decrease, particularly in the latter half of the century, by strengthening meridional circulation.



The future of extra-tropical ozone

- The elevation of northern hemisphere extra-tropical total column ozone as a result of GHG increases is greater in the northern hemisphere than in the southern hemisphere. As a result, northern middle and high latitude ozone returns to 1980 values earlier than in the southern hemisphere
- Projected ozone changes over Antarctica show little sensitivity to GHGs.



Potential threats to the ozone layer in the future

- Geoengineering by sulfate aerosol injection: Proposed schemes involve the injection of ~2Tg of sulfur per year into the stratosphere. This cools surface climate in much the same way as occurred following the Mt. Pinatubo eruption. But recall the response of ozone to Mt. Pinatubo. Increases in atmospheric sulfate aerosol loading will also change the ratio of diffuse to direct radiation. This will affect plant photosynthesis. Not much, if any, research has been done on the direct effects of proposed geoengineering schemes on the surface UV environment.

- Increased emissions of brominated very-short-lived substances: Proposed kelp farms to use algae as a CO_2 sink would enhance marine emissions of bromine containing compounds in the region where their transport to the stratosphere is most efficient.

Conclusions

- The Montreal Protocol has been effective in reducing halogen concentrations in the stratosphere and ozone throughout most of the stratosphere is no longer decreasing. In some regions ozone is now increasing.
- The low ozone values observed in the Arctic stratosphere in 2011 are not an indication that the Montreal Protocol is failing. Rather, they result from anomalously low temperatures in the stratosphere.
- Interpretations of recent changes in ozone must be done in the context of changes in dynamics.
- Chemistry-climate models are improving in their ability to capture important stratosphere↔climate interactions.
- Increases in GHG concentrations will speed the return of ozone to historical levels through most of the stratosphere.