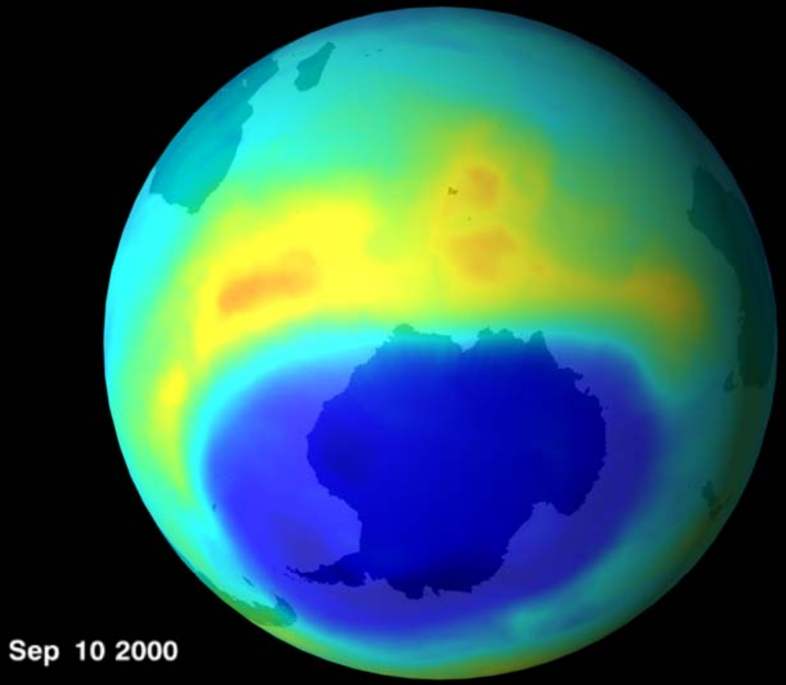
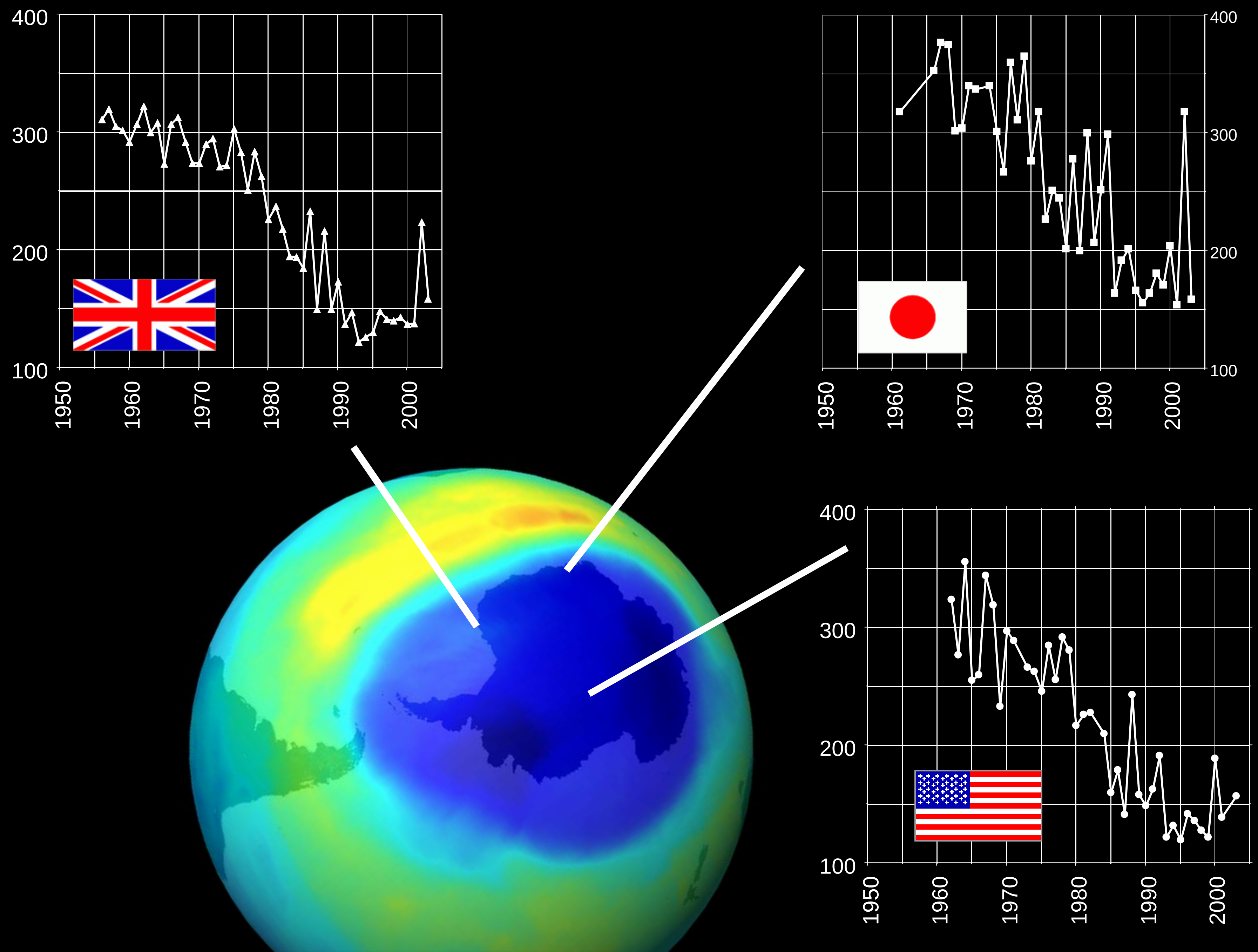
Stratospheric Ozone Linkages to Climate Change, And Wrap-Up

Susan Solomon

1. Antarctic ozone hole: background and downward propagation in the polar regions
2. Tropical changes: new insights into temperature trends

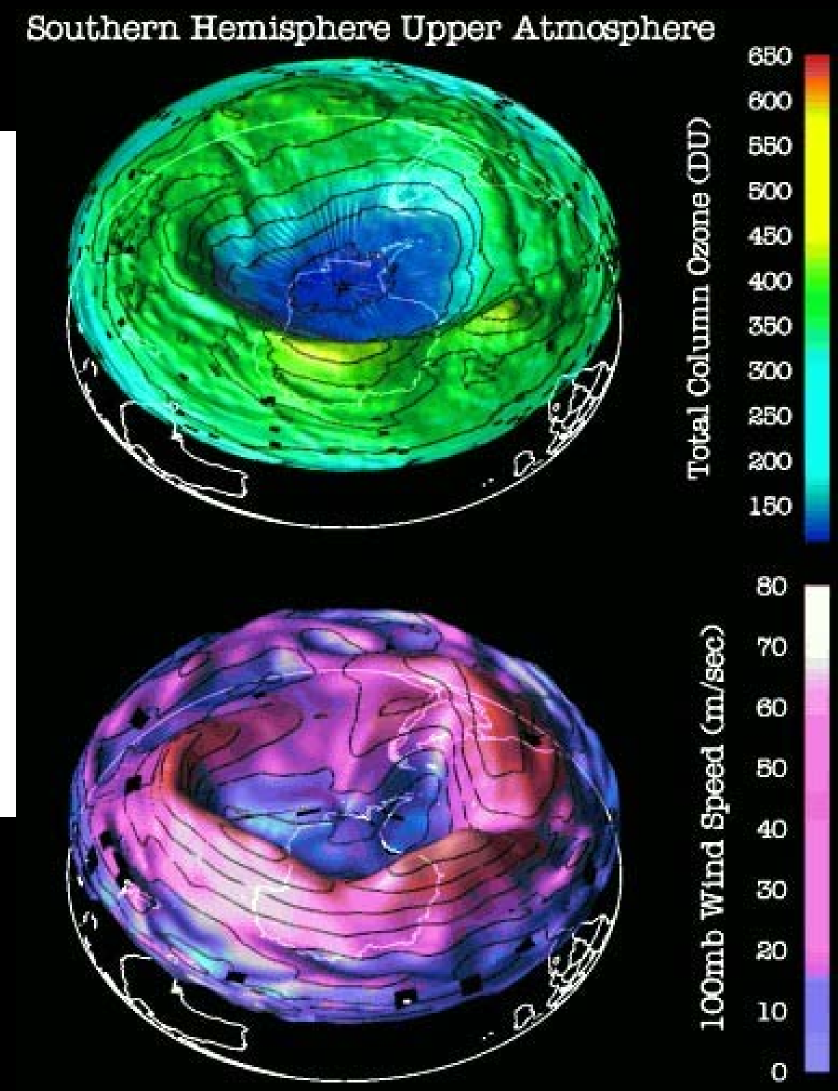
Wrap up: Short review of ESRL future plans for ozone recovery work (across all topics)



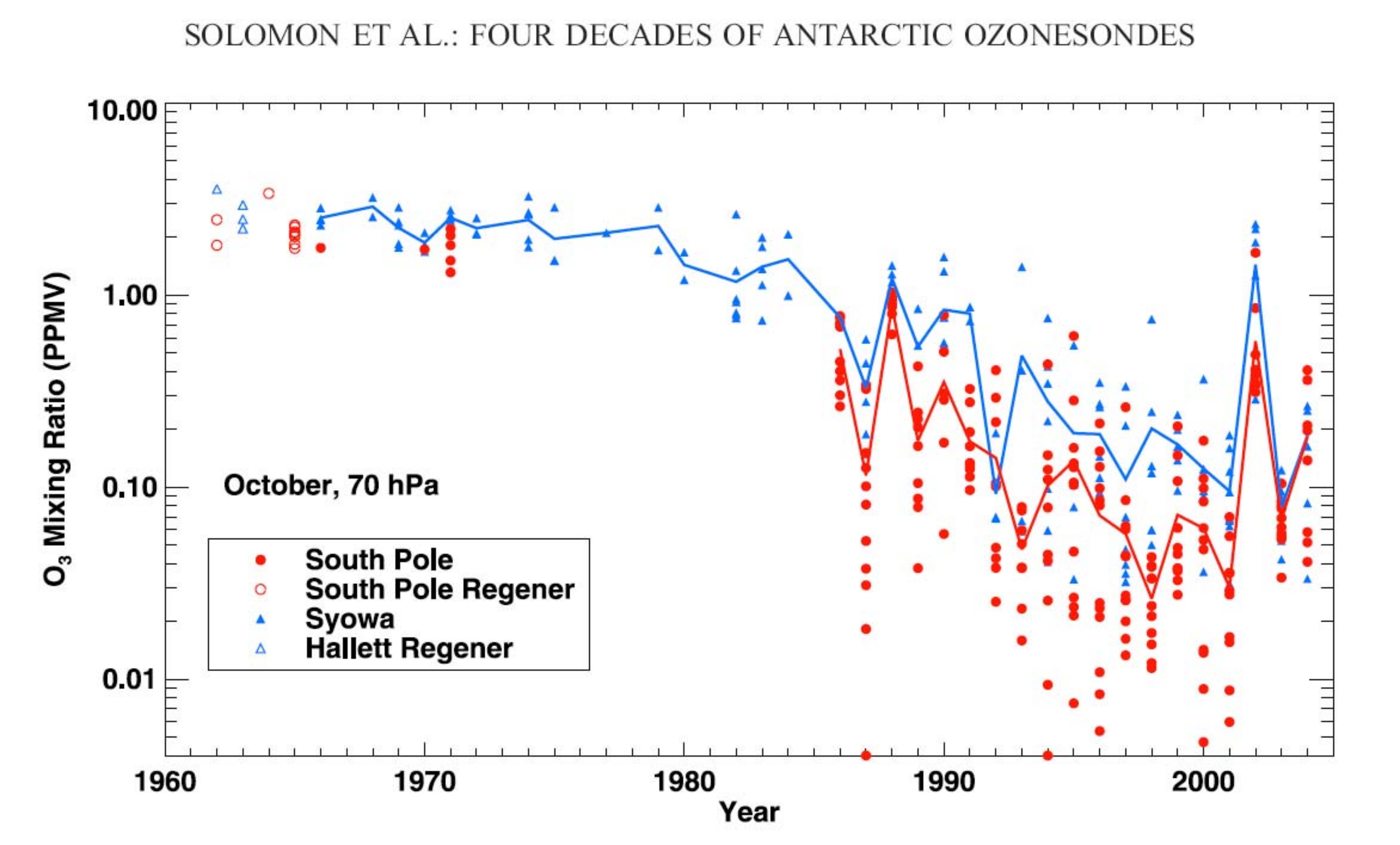

400
300
200
100
1950
1960
1970
1980
1990
2000

Ozone and Climate in the Vortex

A fundamental aspect of temperature, wind, and climate variability in the polar regions



Antarctic Ozone Depletion Is Extreme



South Pole's location deep inside the vortex reveals the most extreme ozone losses.

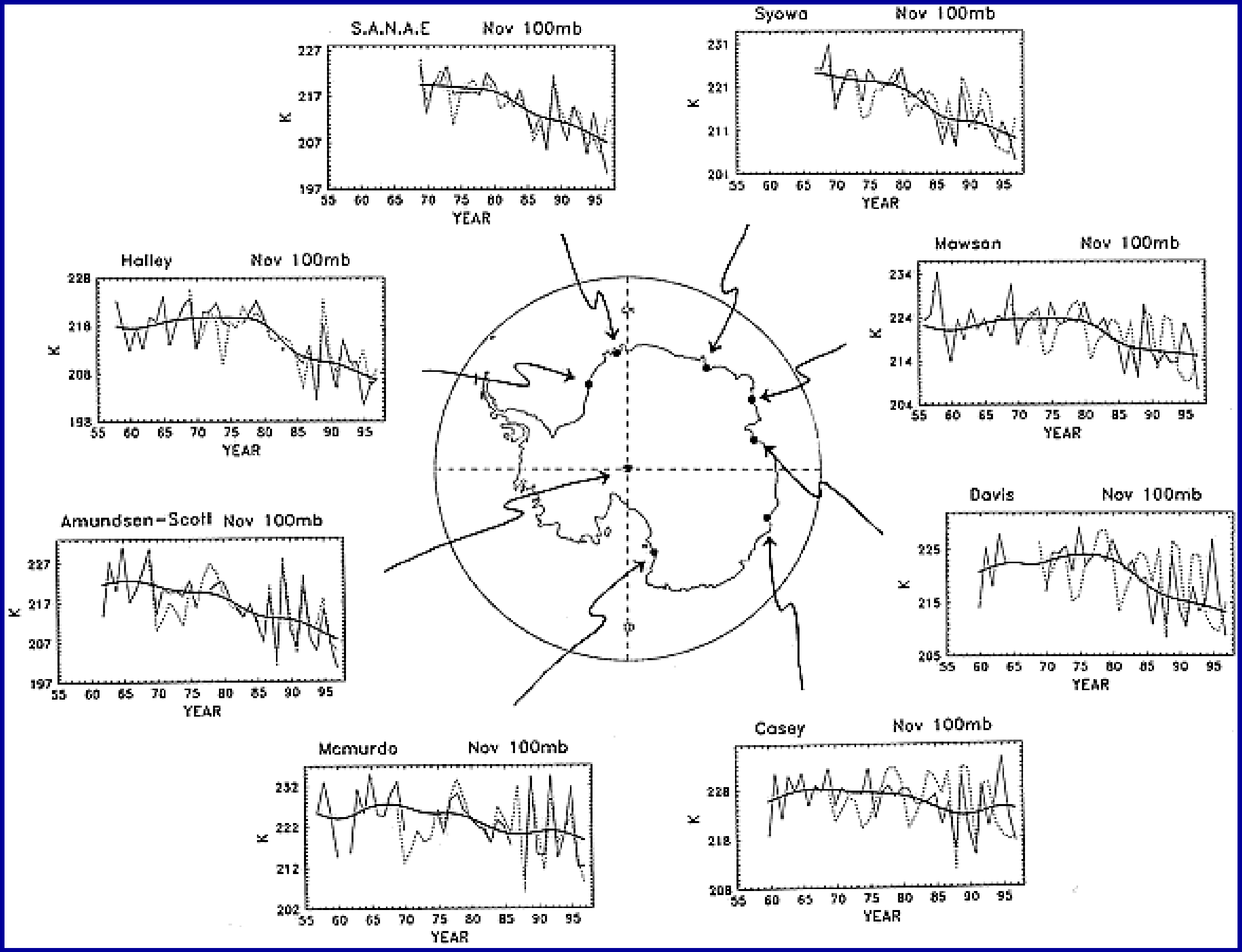
Et Al.: Hofmann, Portmann, Thompson, Sasaki

Ozone Depletion Changes Vortex Dynamics

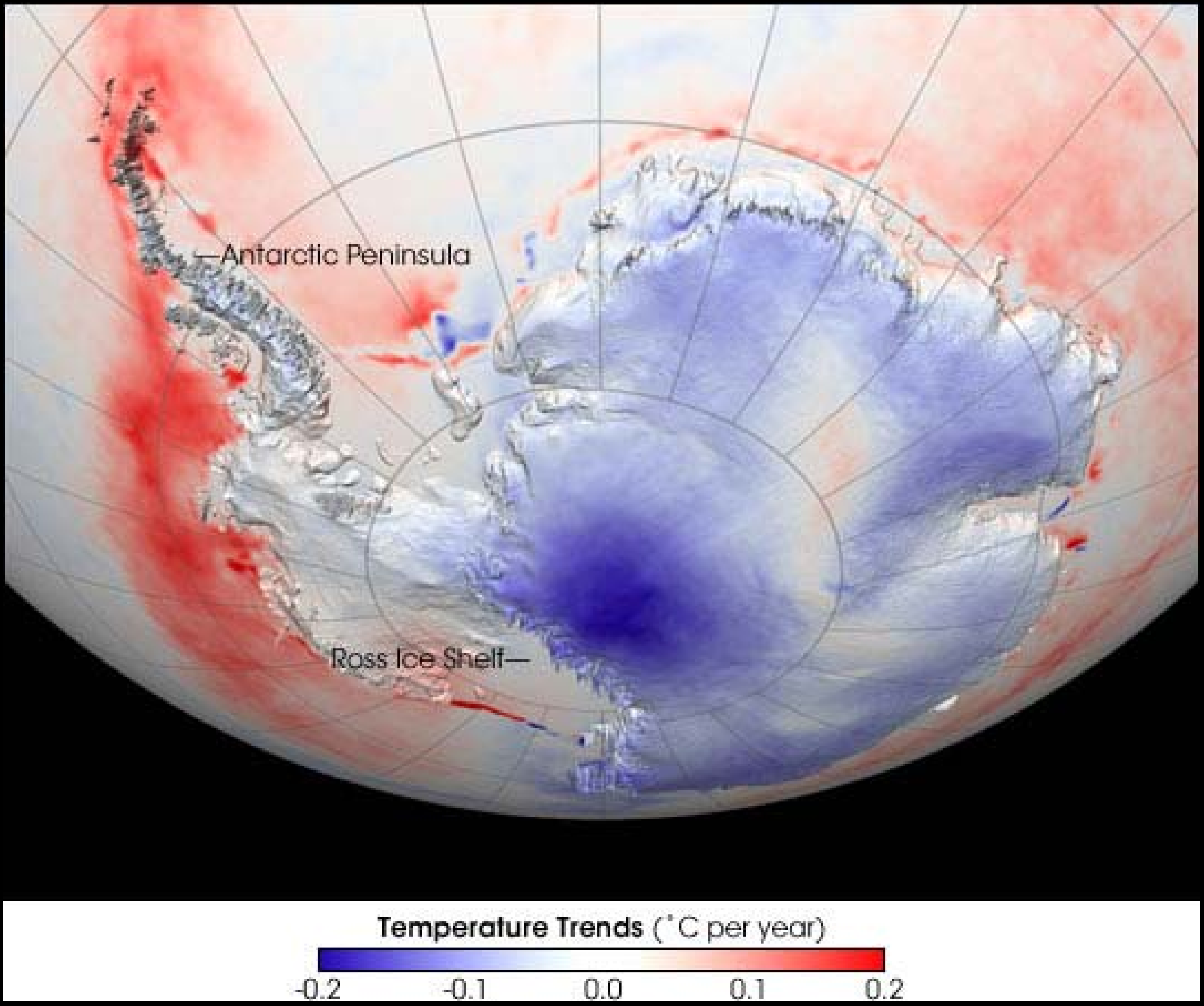
With so much less ozone, the Antarctic stratosphere gets much colder, a change in stratospheric climate.

These cooling trends are very large…do they propagate down to affect the troposphere and even surface climate?

Links to NOAA's responsibilities and strategic plan in climate variability and change



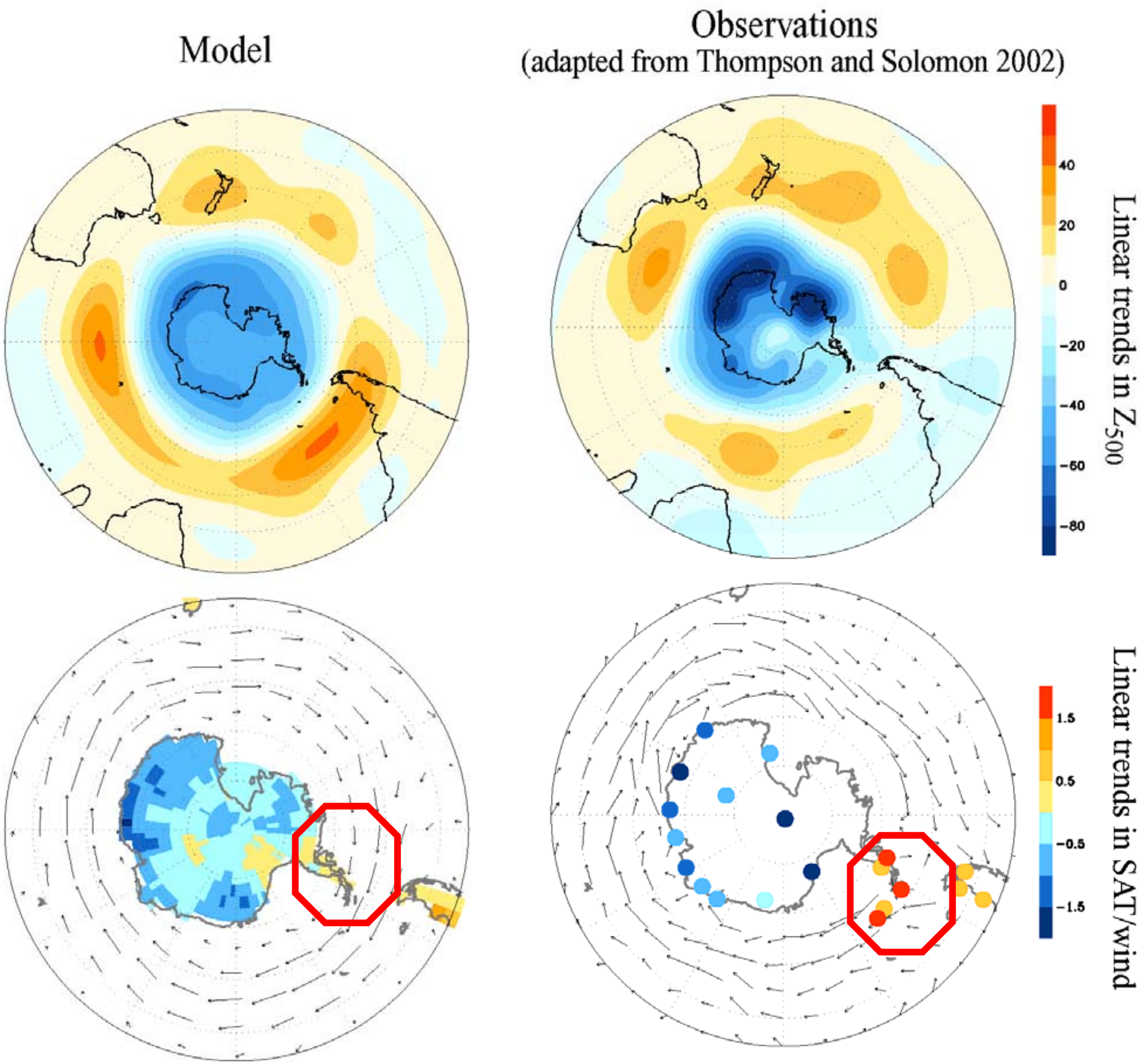
Antarctic Surface Climate: Why So Different from the Rest of the World?



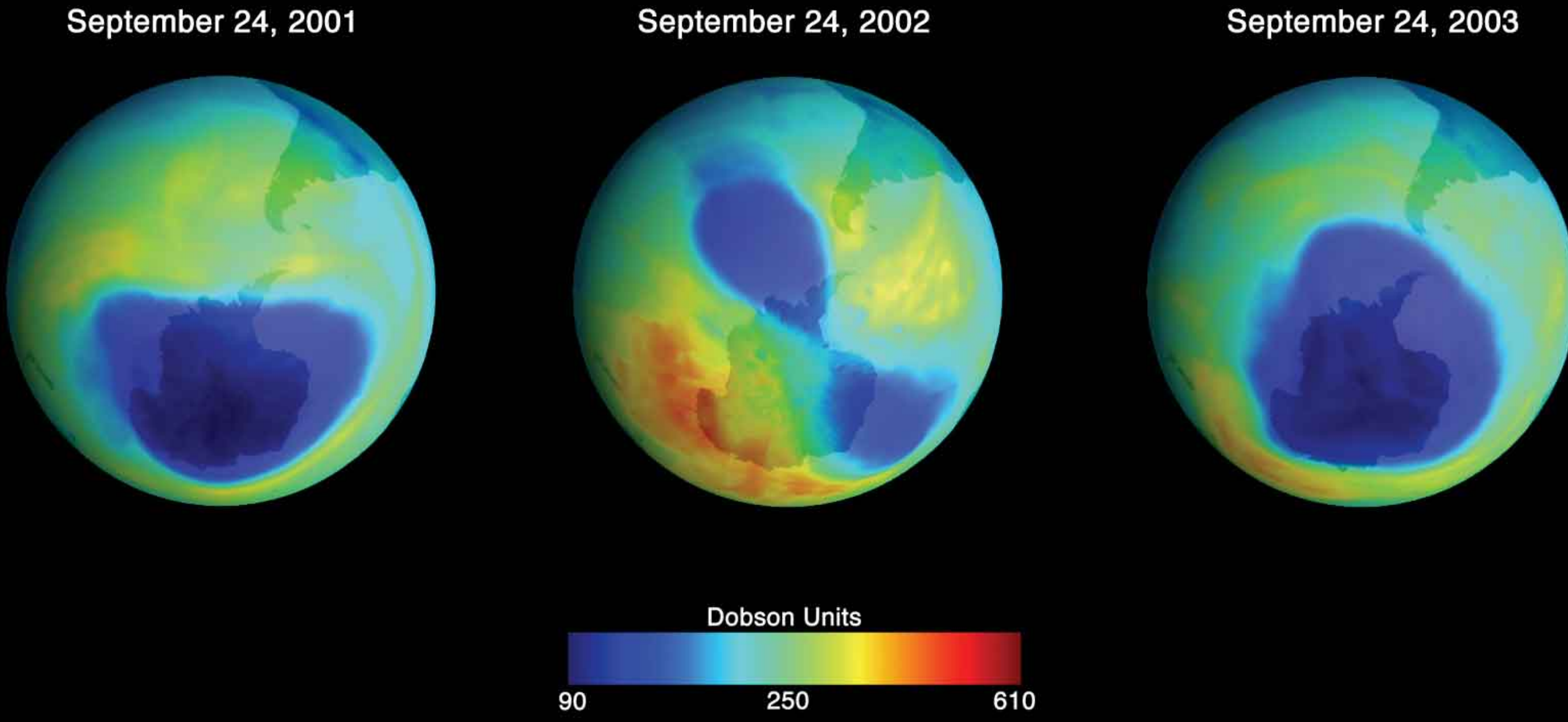
Summer skin temperature trends 1982-2004 from AVHRR

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17257

A New Perspective: Ozone Loss Drives Antarctica's Unusual Surface Climate Change



Variability in the ozone hole



- **Unusual ozone hole in 2002**

Newer: More Ozone Links to Climate Variability and Predictability, in 2002's Special Case

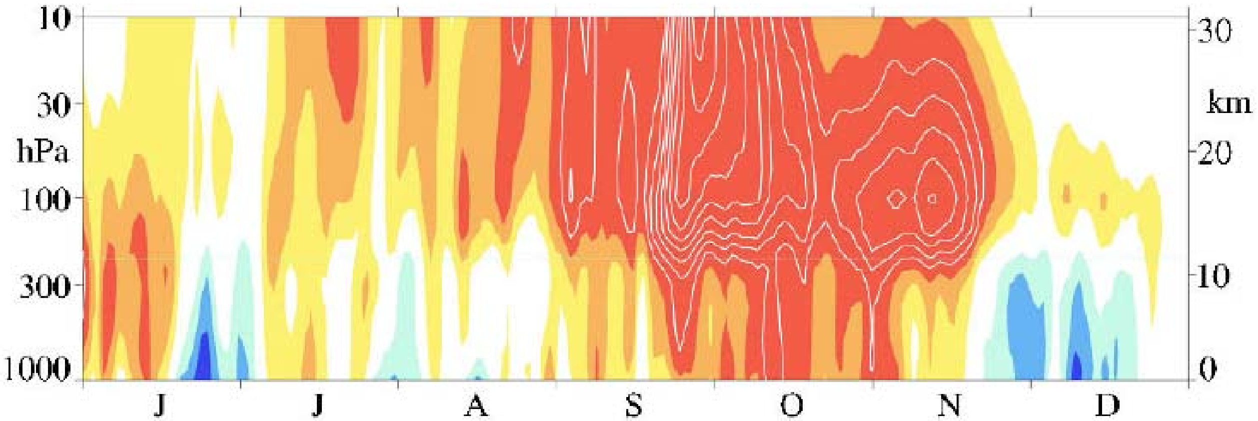


FIG. 7. Values of the SAM index during 2002. Contours are drawn at 0.5 std dev. Shading is drawn for values exceeding ±0.5 std dev. Red shading denotes positive values in the SAM index (weaker-than-normal zonal flow along 60°S).

Thompson, Baldwin, Solomon, 2005

Newer: More Ozone Links to Climate Variability and Predictability, in 2002's Special Case

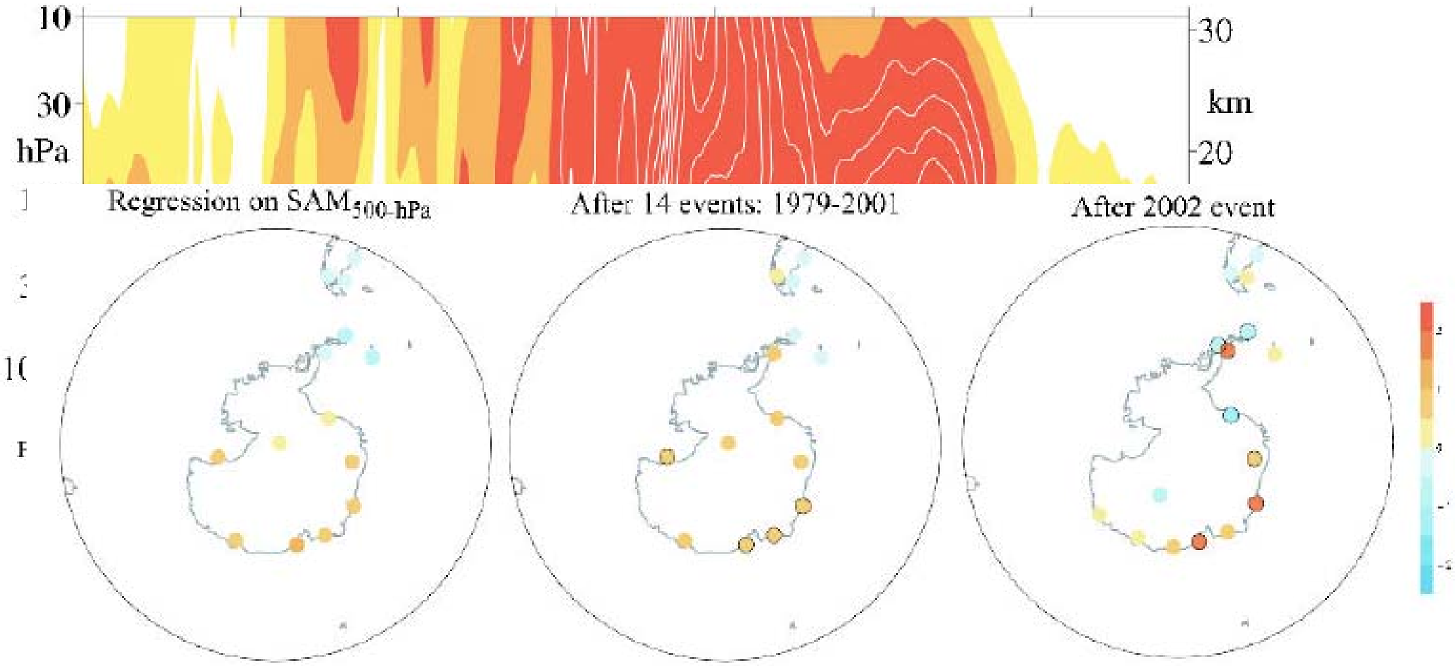
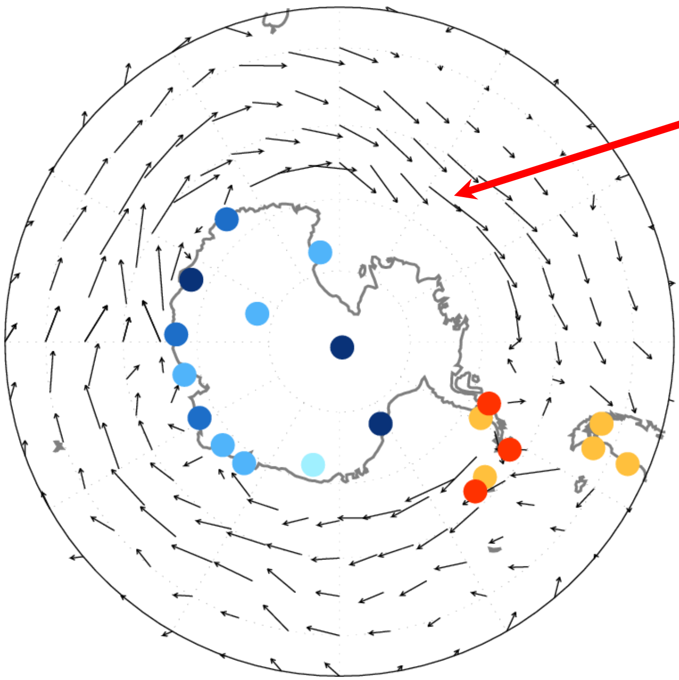


FIG. 5. As in Fig. 4, but for surface temperature anomalies. (middle and right) Composite differences during the 2-month period starting the first day of the first month following the onset of the weak and strong events listed in Table 1. Units are °C. Circles with black outlines denote regions where the results exceed (middle) the 95% confidence level and (right) 1 std dev about the climatological mean.

Record high surface temperatures (-27C at the end of October, 2002 on the plateau)

Thompson, Baldwin, Solomon, 2005

Key Couplings: Winds And Ozone, and Climate Variability and Change



Stronger avg westerlies

Links to Australian drought?

Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

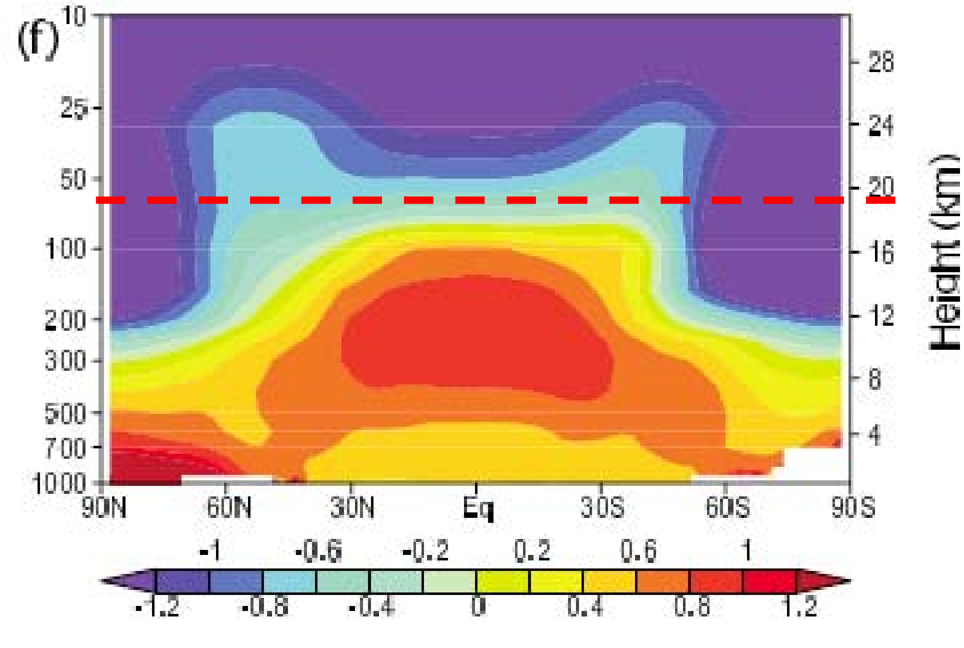
Corinne Le Quéré,[1,2,3]* Christian Rödenbeck,[1] Erik T. Buitenhuis,[1,2] Thomas J. Conway,[4] Ray Langenfelds,[5] Antony Gomez,[6] Casper Labuschagne,[7] Michel Ramonet,[8] Takakiyo Nakazawa,[9] Nicolas Metzl,[10] Nathan Gillett,[11] Martin Heimann[1]

Based on observed atmospheric carbon dioxide (CO_2) concentration and an inverse method, we estimate that the Southern Ocean sink of CO_2 has weakened between 1981 and 2004 by 0.08 petagrams of carbon per year per decade relative to the trend expected from the large increase in atmospheric CO_2. We attribute this weakening to the observed increase in Southern Ocean winds resulting from human activities, which is projected to continue in the future. Consequences include a reduction of the efficiency of the Southern Ocean sink of CO_2 in the short term (about 25 years) and possibly a higher level of stabilization of atmospheric CO_2 on a multicentury time scale.

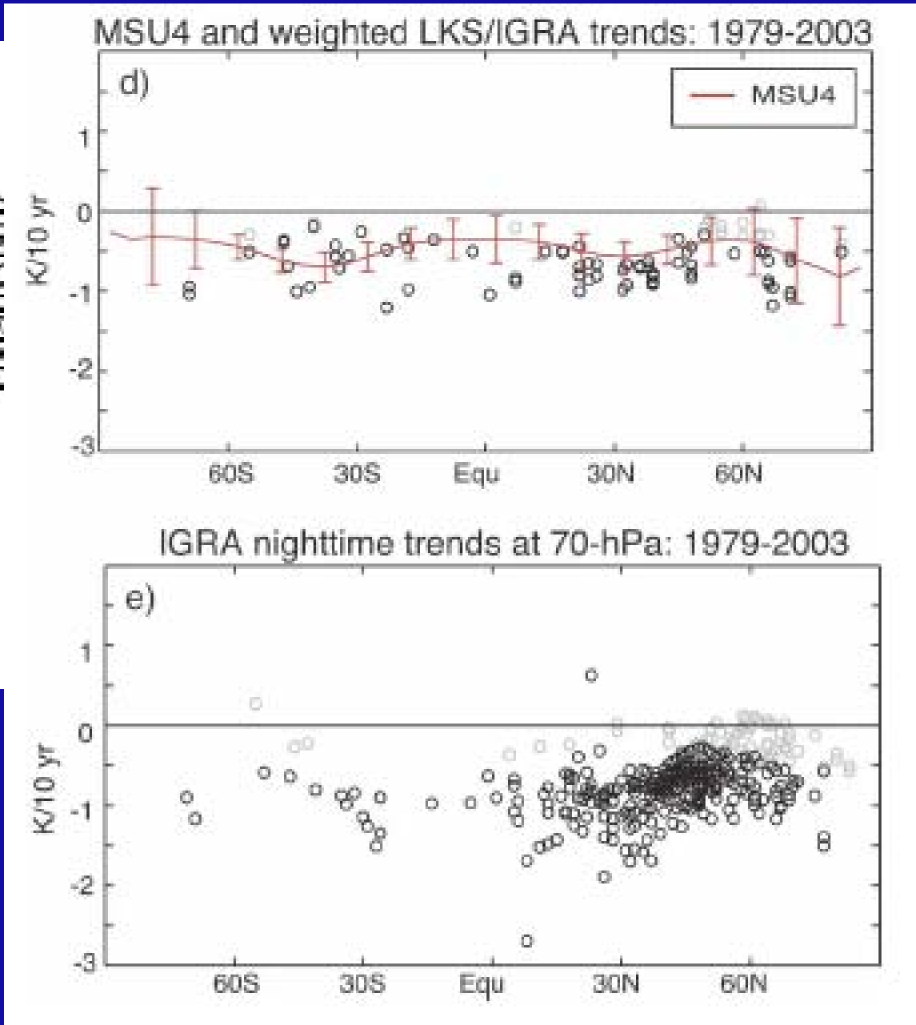
Linkage (a controversial one) to the carbon cycle?

Newer: Global Temperature Trends

Typical GCM [from ch 9, IPCC (2007)]: very little cooling in the tropical lower strat



Observations at 70 mbar [Thompson and Solomon, 2005]: tropical cooling comparable to higher latitudes!

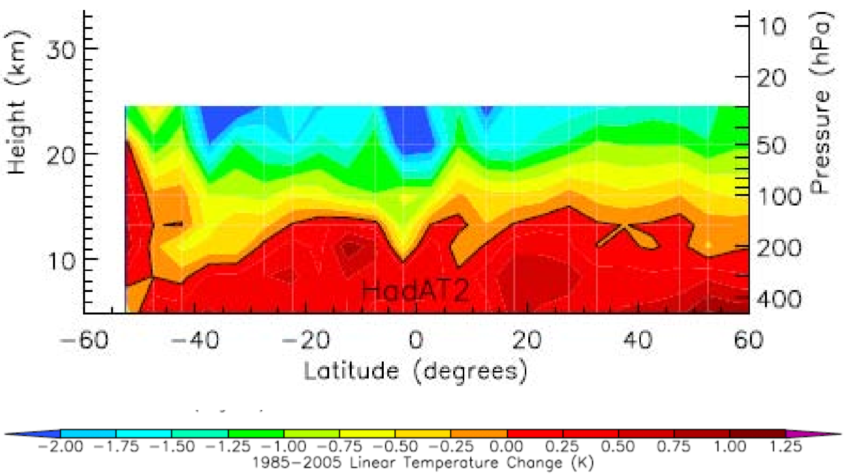


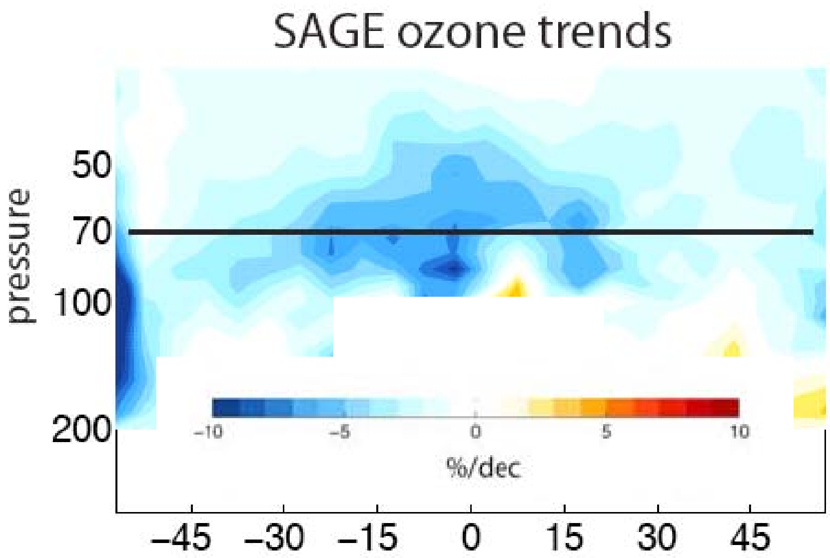
- TS 2005 showed how MSU agrees with radiosondes (including nightime).
- Tropical cooling very likely real - why is this happening?

Newest: Ozone and Temperature Near the Tropical Tropopause

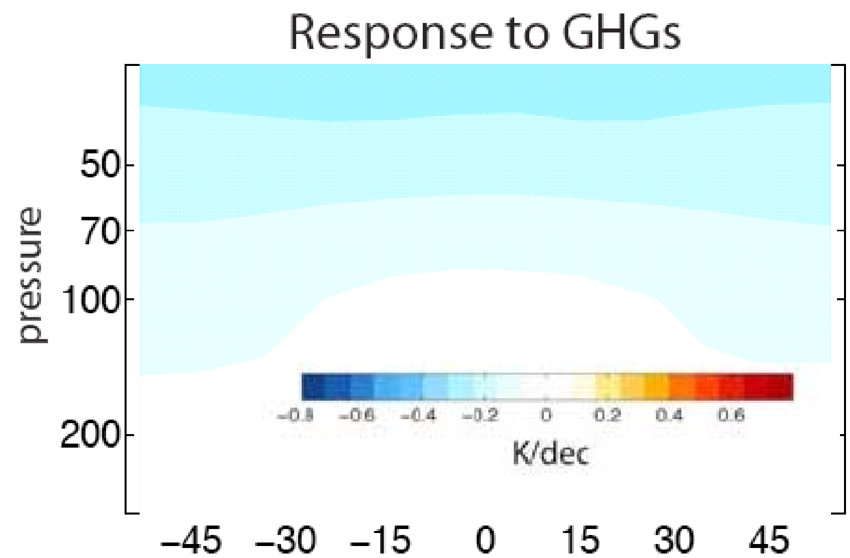
Observations

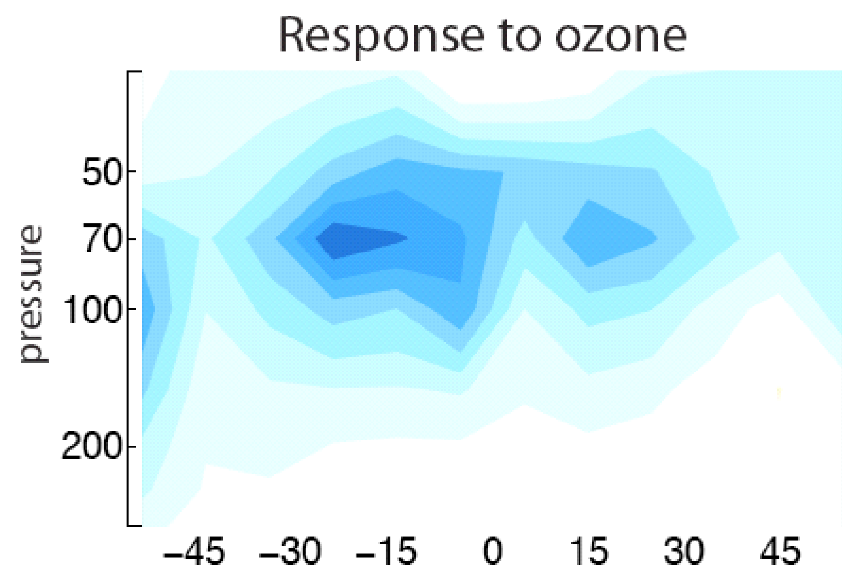
HADAT2 Obsvd T Trend





RT Model

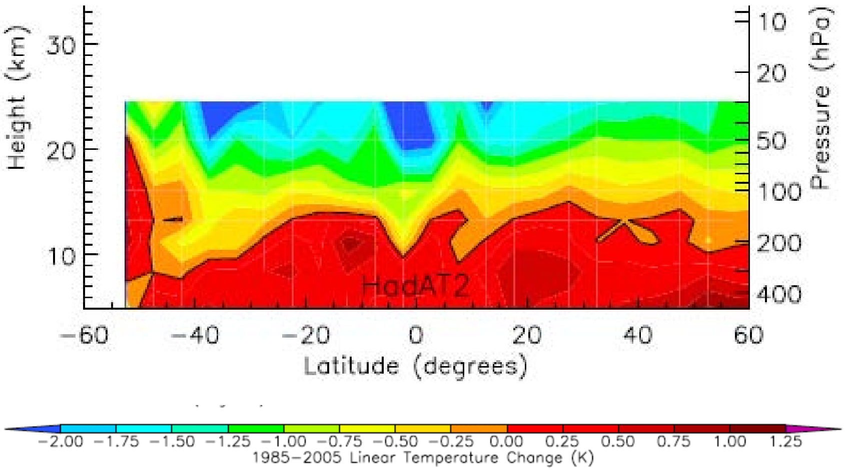




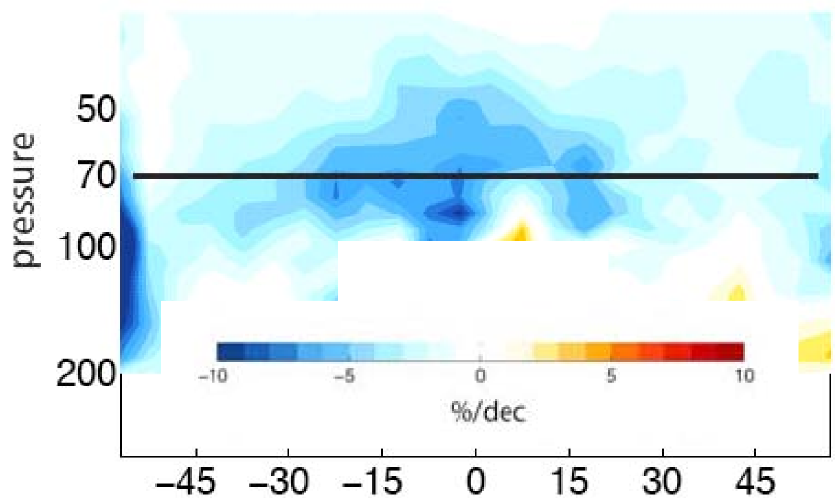
Newest: Ozone and Temperature Near the Tropical Tropopause

Observations

HADAT2 Obsvd T Trend

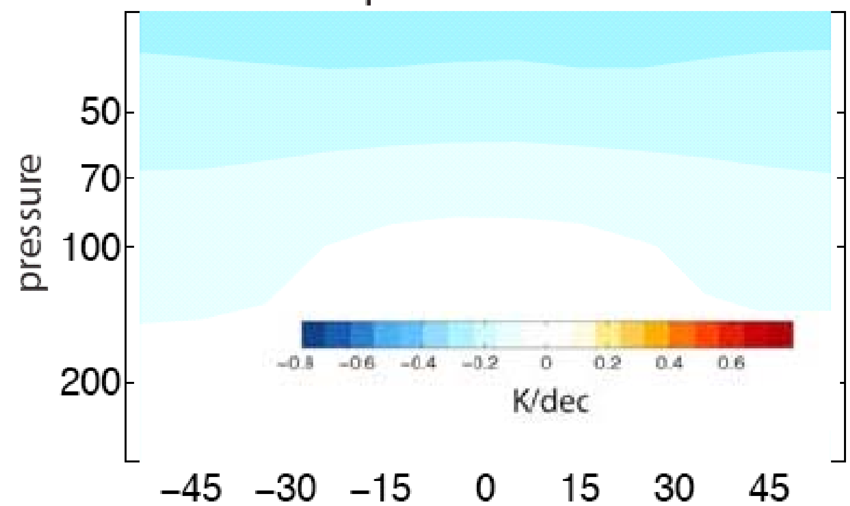


SAGE ozone trends

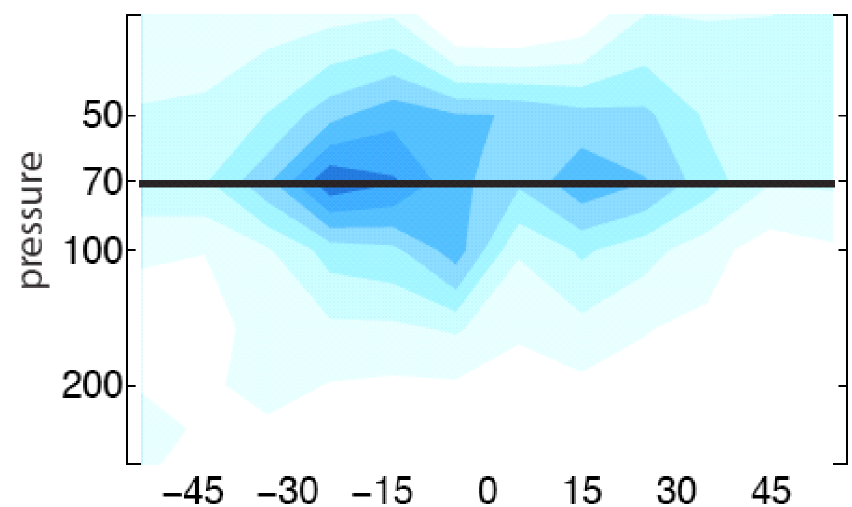


RT Model

Response to GHGs



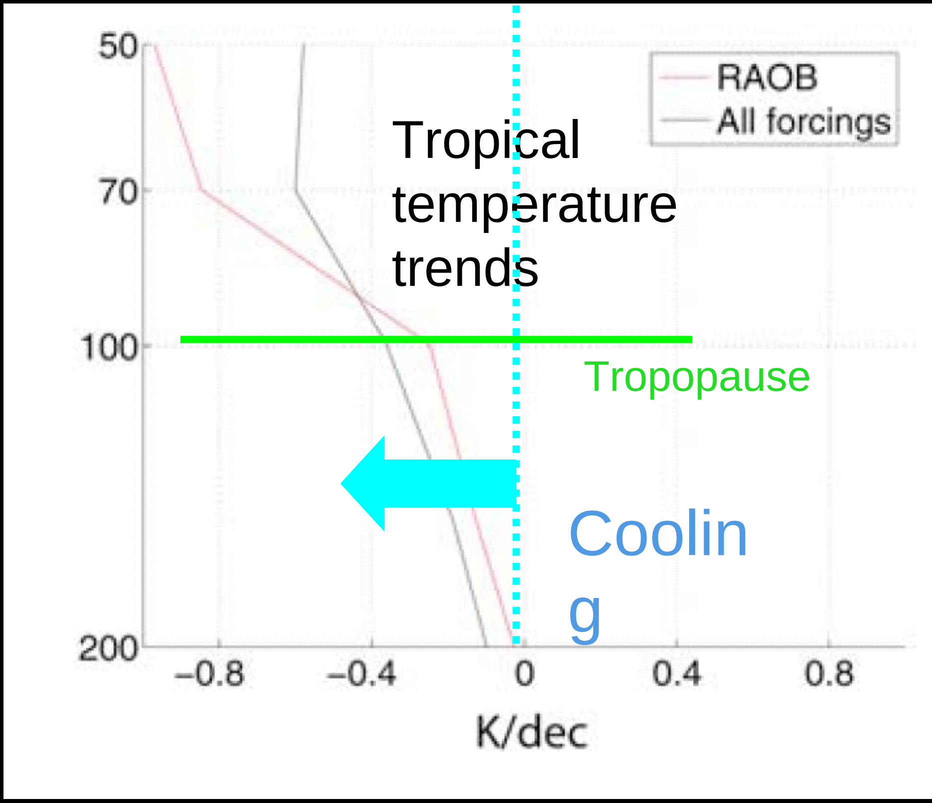
Response to ozone above 70 hPa



Newest: Ozone and Temperature Near the Tropical Tropopause

- Improved analysis of ozone trends, radiative model. Explained tropical cooling at 50-70 mbar is due at least in part to local ozone losses there.

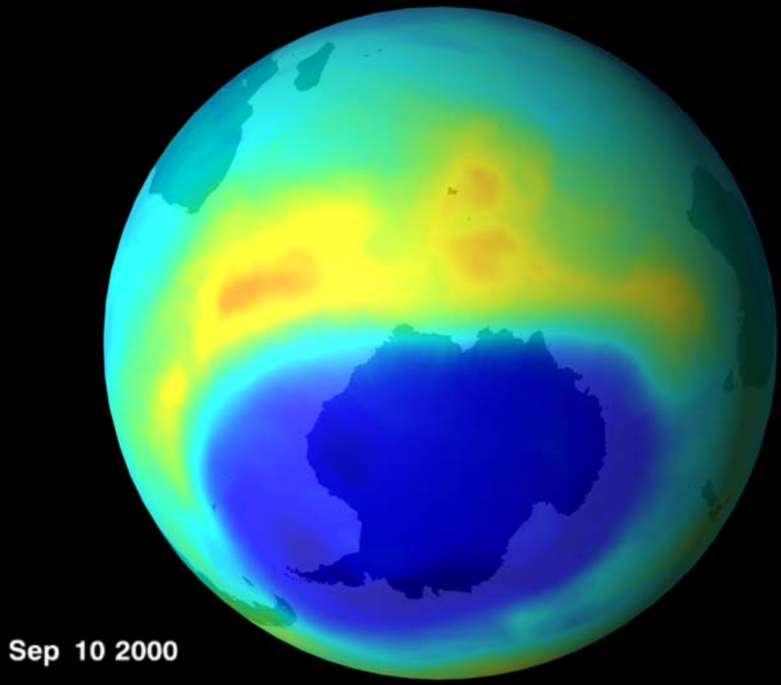
- Also: Cooling at lower levels ‘long distance’ (through downwelling longwave changes), affects model/data comparison in lower stratosphere and even the uppermost troposphere (about 200-70 mbar)



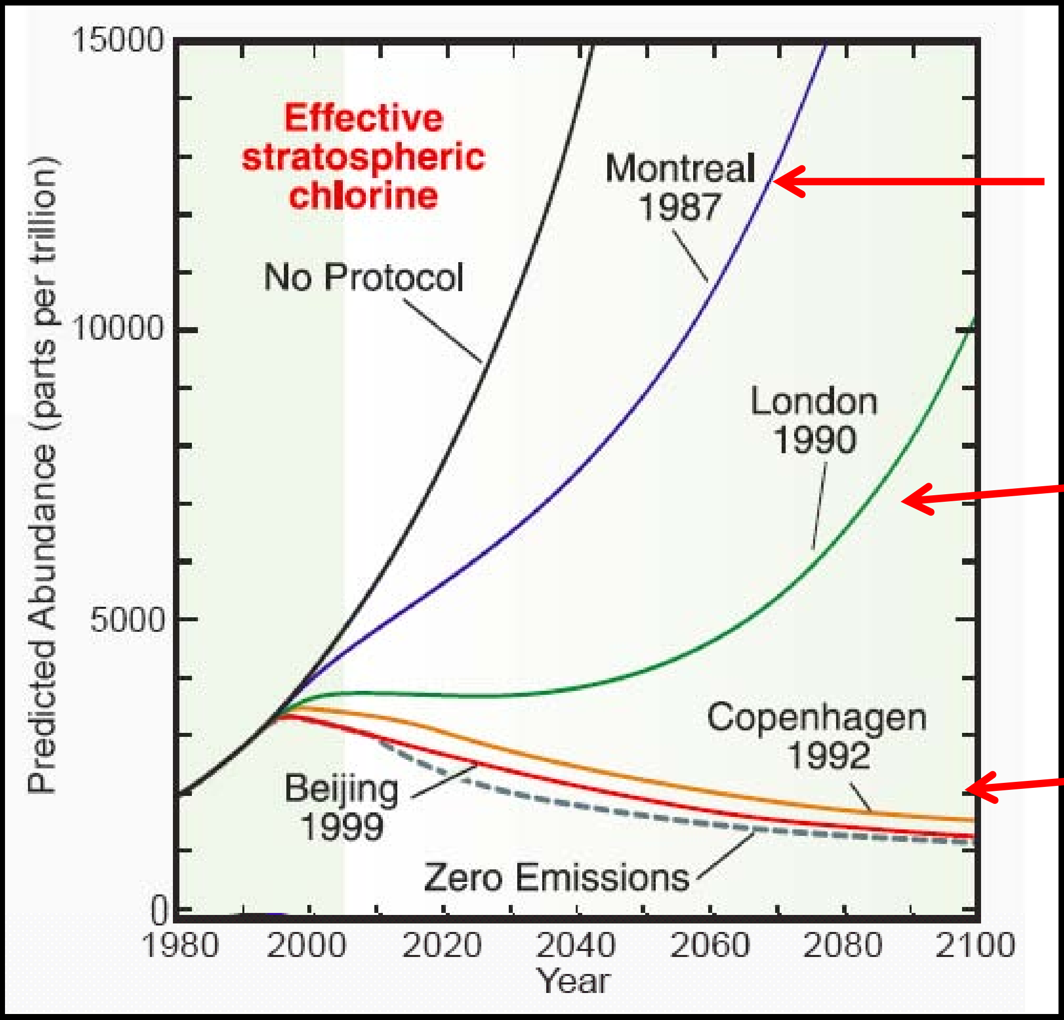
Forster et al., GRL, 2007.

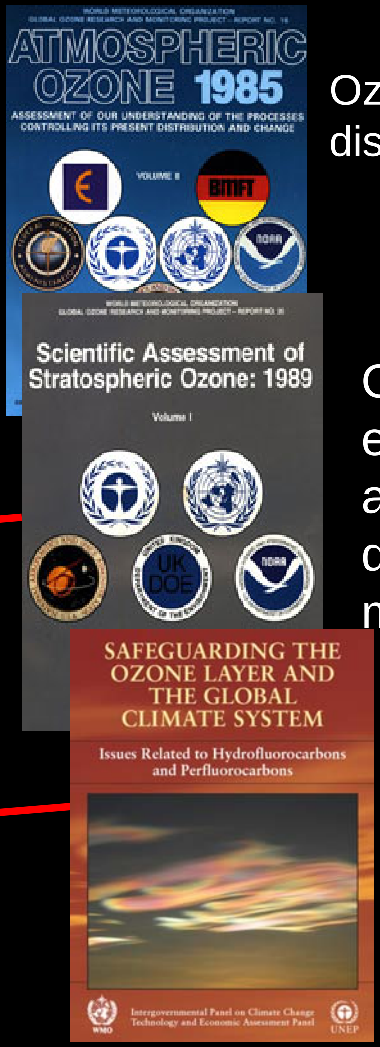
- Key result: Help for the long-standing tropical vertical profile temperature comparison controversy

Short Summary of ESRL-wide Future Plans on Stratospheric Ozone Recovery



Ozone Science Assessments and Policy





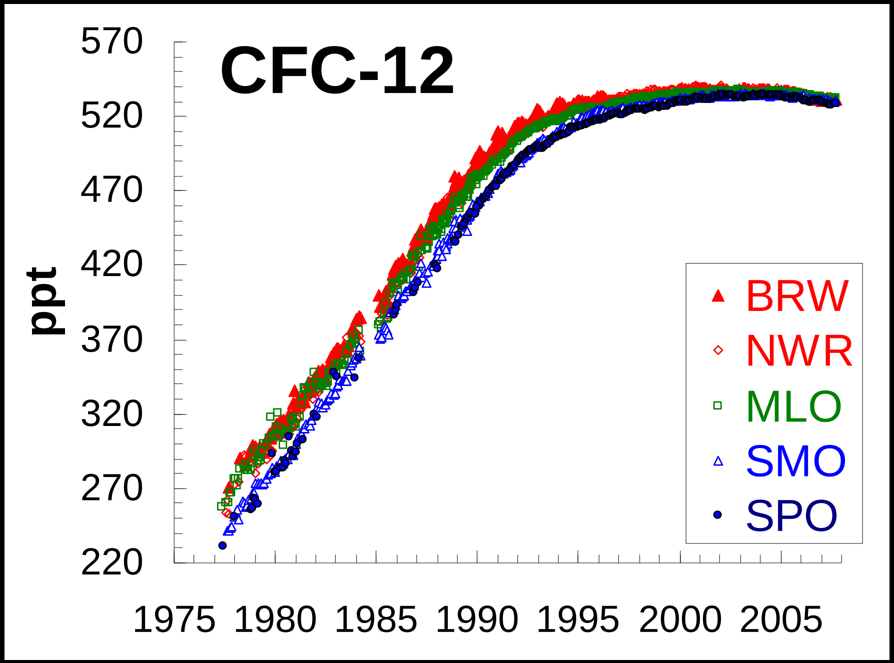
Ozone hole discovered

Ozone hole explained; also depletion in mid-lats

HCFC accelerated phaseout; climate coupling

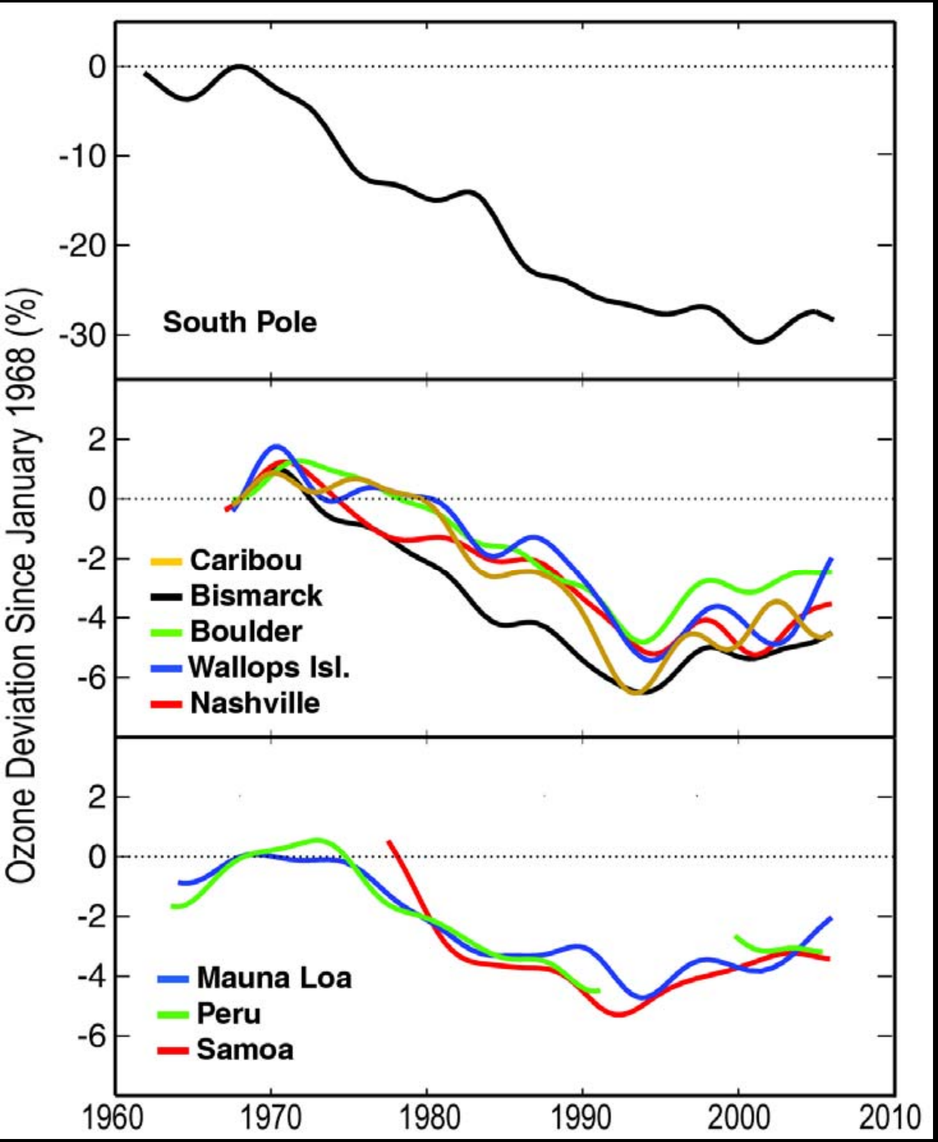
Our goal: Continue to make major contributions to the future science and policy needs in stratospheric ozone.

Future Changes in Trace Gases: Measurements and Analysis



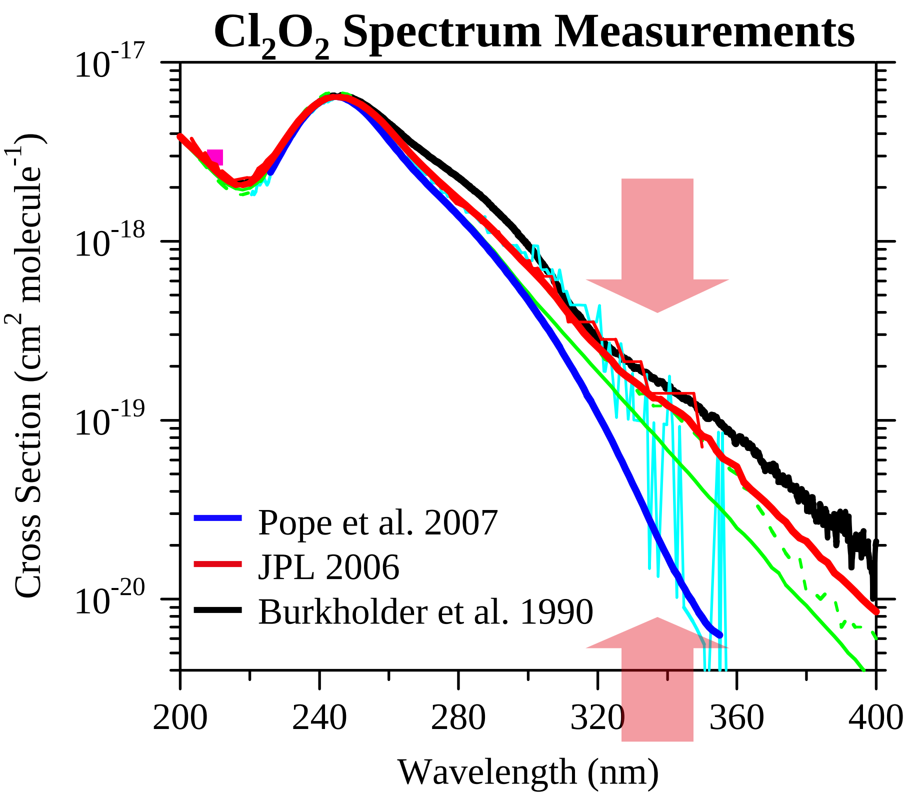
- Are ODSs declining in a way that will ensure the recovery of ozone (is the Montreal Protocol still effective)? Role of banks of CFCs? Halons?
- When will HCFC emissions begin to decline in light of the new phase-out schedules?
- How are the suite of halocarbons affecting global warming?
- How significant are natural fluxes of halogenated gases vs regulated, long-lived gases?
- Could use of shorter-lived, non-regulated gases influence atmospheric halogen amounts and trends?

Future Changes in Ozone: Measurements and Analysis



- When will the Antarctic ozone hole recover?
- What are the processes causing the tropical ozone trends? (nb., there is a clear need for process studies, e.g. WB-57).
- When will clear signs of recovery be detectable at mid-latitudes?
- How important are dynamical changes in the stratosphere in driving ozone losses?

Future Laboratory Studies



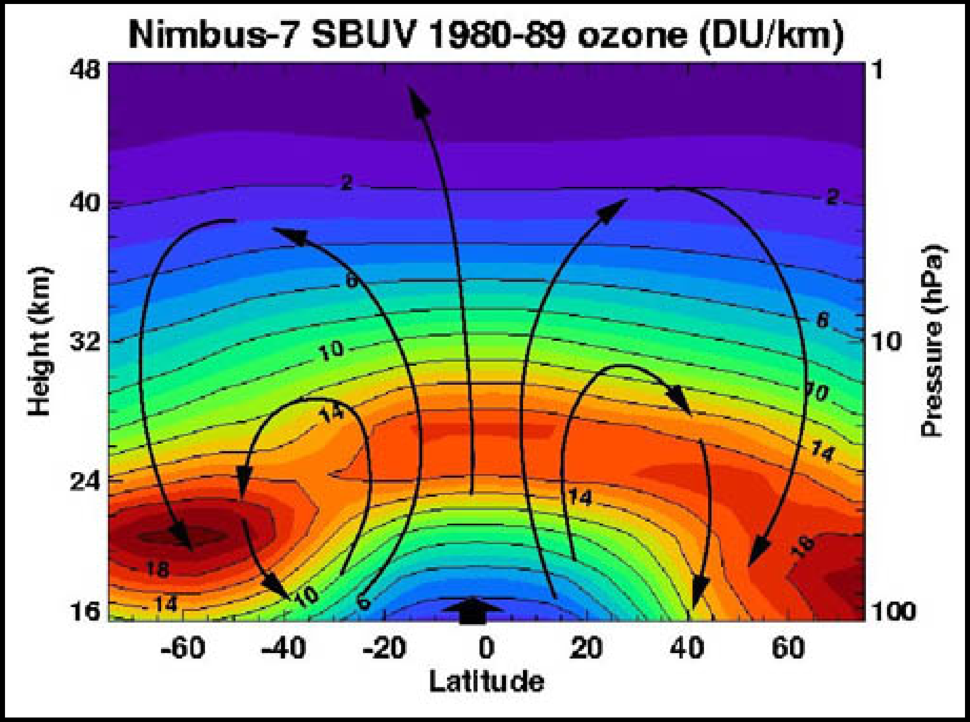
- What are the choices among replacement options?

[Evaluate ozone- and climate-friendliness of potential ODS substitutes and their degradation products]

- How well do we understand polar ozone loss chemistry?

[Resolve Cl_2O_2 photochemistry issues and reduce uncertainties in halogen chemistry, through time-resolved absorption measurements of ClO and Cl_2O_2 following the pulsed laser photolytic formation of ClO at low T /high P]

Ozone Linkages to Climate Change



- How well do we understand ozone's negative radiative forcing?

- How do changes in ozone influence SH climate change and climatic variables such as ice shelves/sea ice? Australian drought? What seasons?
- How do ozone-related variables (e.g., stratospheric dehydration) affect SH climate?
- Role of ozone in NH circulation changes (NAO)?
- Links of ozone to polar climate predictability on interannual and interdecadal time scales?
- How important is ozone cooling in driving temperature changes of the tropical uppermost troposphere?

Closing Remarks about Future Plans

Why ESRL, and Why? We have helped to provide key science underpinning the Montreal Protocol and its amendments and adjustments - but there is much still to be done.

What? Measurements and analysis of changes in ozone-relevant trace gases as well as ozone profiles and column abundances, key laboratory studies, numerical modelling, interpretation of processes, and linkages to climate change.

Who? Joint work between the two ESRL divisions, CSD and GMD, with both senior staff and a cadre of top younger people, with key outside collaborations. This continues a long heritage of shared efforts.

What else? Continuing strong connections to assessments.