Stratospheric Ozone Linkages to Climate Change, And Wrap-Up

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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)
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
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

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
Record high surface temperatures (-27°C at the end of October, 2002 on the plateau)
Key Couplings: Winds And Ozone, and Climate Variability and Change

Stronger avg westerlies

Links to Australian drought?

Saturation of the Southern Ocean CO₂ Sink Due to Recent Climate Change

Corinne Le Quéré, Christian Rödenbeck, Erik T. Buitenhuis, Thomas J. Conway, Ray Langenfelds, Antony Gomez, Casper Labuschagne, Michel Ramonet, Takakiyo Nakazawa, Nicolas Metzl, Nathan Gillett, Martin Heimann

Based on observed atmospheric carbon dioxide (CO₂) concentration and an inverse method, we estimate that the Southern Ocean sink of CO₂ 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 CO₂. 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 CO₂ in the short term (about 25 years) and possibly a higher level of stabilization of atmospheric CO₂ on a multicentury time scale.
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 nighttime).
- Tropical cooling very likely real - why is this happening?
Newest: Ozone and Temperature Near the Tropical Tropopause

Observations
HADAT2 Obsvd T Trend

RT Model
Response to GHGs

SAGE ozone trends

Response to ozone
Newest: Ozone and Temperature Near the Tropical Tropopause

Observations
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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)

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

Forster et al., GRL, 2007.
Short Summary of ESRL-wide Future Plans on Stratospheric Ozone Recovery
Ozone Science Assessments and Policy

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

Ozone hole discovered

Ozone hole explained; also depletion in mid-lats

HCFC accelerated phaseout; climate coupling
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?

- Could use of shorter-lived, non-regulated gases influence atmospheric halogen amounts and trends?

- How significant are natural fluxes of halogenated gases vs regulated, long-lived gases?
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 Cl₂O₂ photochemistry issues and reduce uncertainties in halogen chemistry, through time-resolved absorption measurements of ClO and Cl₂O₂ following the pulsed laser photolytic formation of ClO at low T/high P]
Ozone Linkages to Climate Change

- 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?

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