A note on possible effects of the unexpected increase in global CFC-11 to ozone profiles

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Motivation


• LOTUS Phase 2: 2019-2020

Need to attribute trends to halogen chemistry vs other sources of variability (e.g. GHGs, dynamics), which was not attempted in LOTUS phase 1.

• Montzka et al. (2018) results on increased global CFC-11 emissions.
Outline

• Data sources and model simulations

• Stratospheric ozone trends from observations and model comparisons at individual lidar stations

• Effect of halogen chemistry on stratospheric ozone trends studies with Chemical Transport Model (CTM) simulations

• Effect of increased CFC-11 on future ozone profile trends studies with Chemistry Climate Model (CCM) simulations
Long-term LIDAR ozone data at 5 stations (1998-2016) residing in the northern mid-latitudes, the tropics and the southern mid-latitudes.

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elevation</th>
<th>Starting years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hohenpeissenberg</td>
<td>47.8 °N</td>
<td>11.0 °E</td>
<td>975 m</td>
<td>1987</td>
</tr>
<tr>
<td>Haute Provence</td>
<td>43.9 °N</td>
<td>5.7 °E</td>
<td>674 m</td>
<td>1985</td>
</tr>
<tr>
<td>Table Mountain</td>
<td>34.4 °N</td>
<td>117.7 °W</td>
<td>2200 m</td>
<td>1992</td>
</tr>
<tr>
<td>Mauna Loa</td>
<td>19.5 °N</td>
<td>155.6 °W</td>
<td>3405 m</td>
<td>1993</td>
</tr>
<tr>
<td>Lauder</td>
<td>45.0 °S</td>
<td>169.7 °E</td>
<td>370 m</td>
<td>1994</td>
</tr>
</tbody>
</table>

SBUV v8.6 satellite overpass ozone data at 5 lidar stations (1998-2016, total and profile)

Natural proxies considered to affect ozone variability:
- Quasi Biennial Oscillation (QBO), Solar flux (F10.7), El Nino Southern Oscillation (ENSO), Arctic Oscillation/Antarctic Oscillation (AO/AAO),
- Tropopause pressure (from NCEP reanalysis), Aerosol Optical Depth (AOD)

Trends are derived after removing seasonal and other natural variability.
Model simulations

- Ozone simulations with the **Chemical Transport Model** (Oslo CTM3) (period 1998-2016)
  
  Two runs performed:
  
  a) run with full chemistry
  
  b) run with halogens fixed at 1998 levels

- Ozone simulations with the coupled **Chemistry Climate Model** (CCM) EMAC (period 2002-2050)
  
  Two runs performed:
  
  a) Reference run: Free-running simulation where CFC-11 declines by about 50% until 2050
  
  b) Sensitivity run with CFC-11 fixed at 2002 levels, i.e. no CFC-11 decline (Dameris et al., ACPD, 2019)
Sampling Issues: Consistency of Zonal Mean Trends to Single Location Trends (LOTUS phase 1)

Compare trends from SBUV MOD overpass to trends in relevant 5° zonal average at five lidar stations: LDR=Lauder; MLO=Mauna Loa; TBL=Table Mountain; OHP=Haute Provence; HP=Hohenpeissenberg).

Adapted from Figure 7 of Zerefos et al., ACP, 2018
Current Study: Stratospheric ozone trends (observed and modelled) at individual lidar stations

- Model runs indicate an increase in ozone in the upper stratosphere above 7 hPa and a decrease in the lower stratosphere between 30 and 100 hPa.
- Very good agreement with SBUV (v8.6) satellite data.
Oslo chemical transport model (CTM3) data correlate well both with Lidar measurements and SBUV observations.

<table>
<thead>
<tr>
<th>Layers</th>
<th>Model vs SBUV</th>
<th>Model vs Lidar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-7hPa</td>
<td>0.70*</td>
<td>0.49*</td>
</tr>
<tr>
<td>7-30hPa</td>
<td>0.81*</td>
<td>0.78*</td>
</tr>
<tr>
<td>30-100hPa</td>
<td>0.70*</td>
<td>0.54*</td>
</tr>
</tbody>
</table>

* 99.9% confidence level
Oslo chemical transport model (CTM3) data (1998-2016)

Two runs performed:
a) run with full chemistry
b) run with constant halogens at 1998 levels

Difference in trends between the two runs is 0.5% per decade in the upper and lower stratosphere, and almost zero in the middle stratosphere.

CTM3 indicates that the reduction of halogens after 1997 explains about 55% of the upward trend in the upper stratospheric ozone (1-7 hPa), and about 24% in the lower stratospheric ozone (30-100 hPa).
Current Study: Total ozone and tropopause pressure trends at individual lidar stations

- Opposing trends in the vertical distribution resulted to insignificant trends in total ozone after 1997.
- Reanalysis data from NCEP reveal insignificant trends in tropopause pressures as well.
A Chemistry-Climate Model (CCM) study is performed, investigating the consequences of a constant CFC-11 surface mixing ratio for stratospheric ozone in future.

Two runs performed:
- a) Reference run: Free-running simulation where CFC-11 declines by 50% from 2002 to 2050
- b) Sensitivity run with CFC-11 fixed at 2002 levels, i.e. no decline

The total column ozone is in particular affected in both polar regions in winter and spring.
Current Study: Effect of CFC-11 on profile/total column ozone trends

**5 STATIONS MEAN**
- **REFERENCE RUN**
- **CONSTANT CFC-11 RUN**

**5° ZONAL MEANS**
- **REFERENCE RUN**
- **CONSTANT CFC-11 RUN**

**1-7 hPa**
- Ozone anomalies (%)

**7-30 hPa**
- Ozone anomalies (%)

**30-100 hPa**
- Ozone anomalies (%)

**Total column**
- Ozone anomalies (%)

**2000** **2010** **2020** **2030** **2040** **2050**
Current Study: Effect of CFC-11 on profile/total column ozone trends

Arctic (70-90°N)  
- REFERENCE RUN
- CONSTANT CFC-11 RUN

Winter (JFM mean)

1-7 hPa

7-30 hPa

30-100 hPa

Total column

Antarctic (70-90°S)  
- REFERENCE RUN
- CONSTANT CFC-11 RUN

Winter/Spring (ASO mean)

1-7 hPa

7-30 hPa

30-100 hPa

Total column
Summary

• It is confirmed from observations (lidar, SBUV) that we do not see yet a signal in ozone profiles following the increase of CFC-11 emissions since 2012.

• We expect the effect of Halogens reduction to be maximized at 1-7 hPa at lidar stations, as shown by chemical transport model simulations since 1998.

• We expect the effect of increased CFC-11 to be clearly seen after 2040 particularly in the poles, as shown by chemical climate model simulations.
Acknowledgements

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