Atmospheric Chemistry

Lecture 13
Comparison Ozone vs Climate

- Vienna Convention (1985)
- UNFCCC Framework Convention on Climate Change (Bonn, 1992)
- Kyoto Protocol (1997)

Why has one worked so well while the other has not? What do you think?
Some possible reasons for success of Montreal Protocol relative to Kyoto Protocol

• Smoking gun, i.e. ozone hole?
• Availability of replacements?
• CFCs less integral to our society?
• Press coverage?
• Nay-sayers/non-believers?
• IPCC vs Ozone Assessment?
• Regulating emission vs production?
• Nature of the problem (size and time scale of perturbation relative to natural variability)?
• Scare scenarios overplayed?

What else?

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Two-dimensional structure of the stratospheric ozone layer
We put these together into an “Equivalent Effective Stratospheric Chlorine” or EESC

We are here

- HCFC-141B
- CH$_3$CCl$_3$
- HCFC-22
- HALON-1211
- HALON-1301
- CFC-113
- CCl$_4$
- CFC-11
- CH$_3$Br
- CH$_3$Cl
- CFC-12

Atmospheric Chemistry Lecture 13
Total Ozone (60° S - 60° N Area-Weighted Mean)

Du

Year

1980 1990 2000 2010
What else affects the ozone record?

- Seasonal cycle
- 11-year sunspot cycle
- Quasi-biennial oscillation (internal variability with 26-27 month period)
- El Nino Southern oscillation (ENSO)
- Volcanoes
11-Year Sunspot Cycle

Solar cycles - variation with solar latitude and time

Year
Sunspot Number
Solar latitude

Percent of sun's surface and polarity

Modern Maximum
Dalton Minimum
Maunder Minimum
Sunspots are dark areas that are surrounded by bright faculae.

Figure 3. The variation in Earth's monthly mean global surface temperature is shown in the bottom panel by the red symbols. A statistical multiple regression model, shown by the black line, reproduces significant temperature variance by combining variations in solar irradiance (top panel); a secular trend, possibly anthropogenic (second panel); volcanic aerosols (third panel); and a measure of the El Niño Southern Oscillation (fourth panel). ENSO and volcanoes cause changes of 0.2–0.3 K on time scales of months, whereas solar irradiance is associated with a 0.1-K decadal cycle. The irradiance cycle arises from the competing effects of sunspots and bright areas called faculae; the two features are evident in the solar images on the right and produce the effects on daily irradiance shown above.
Solar Irradiance varies over the 11-year cycle; amount of variation is dependent on wavelength

*Total Solar Irradiance varies with the 11-year cycle*

*Stronger variations in the uv than in the visible*

We monitor the solar variations by measuring the 10.7 cm radio wave flux from the sun (f10.7)
How do stratospheric ozone and temperature respond to the solar cycle?

• **Direct heating**
  – $hv + O_2, O_3 \rightarrow T$ increase
  – speeds ozone loss reactions $\rightarrow O_3$ decrease

• **Photolysis**
  – $hv + O_2$ produces $O_3 \rightarrow O_3$ increase
  – More $O_3$, more heating $\rightarrow T$ increase

Same direction for temperature
Opposite direction for ozone
Global Average Response to Solar Variation

Ozone response to heating is much smaller than response to photolysis and in opposite direction.

Temperature response to photolysis is comparable to and is in same direction as response to heating.
Impact of Solar Flux Depends on Wavelength

<table>
<thead>
<tr>
<th>Ratio to Solar Minimum</th>
<th>P (hPa)</th>
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<tbody>
<tr>
<td>0.98</td>
<td>0.1</td>
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<tr>
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<td>1.01</td>
<td>1.02</td>
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<td>1.02</td>
<td>1.03</td>
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</tbody>
</table>

$\lambda < 242$ nm $\Rightarrow$ $J_{O_2}$ and $J_{O_3}$
perturbations: $J_{O_2}$ dominates leading to ozone increase at solar maximum

$\lambda > 242$ nm $\Rightarrow$ $J_{O_3}$
perturbation only: leading to ozone decrease at solar maximum

All $\lambda$ is based on Lean’s breakdown of UV changes for wavelengths $> 242$ nm vs those for wavelengths $< 242$ nm

55°S – 55°N Average

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Fitting the Quasi-Global Data

Year  

Total Ozone (DU)  
270  280  290  300  310
Fit with seasonal cycle removed

60S-60N Area-Weighted Mean

Residual Variance = 2.5