The Ozone Story
Ozone (O₃) is a highly reactive form of oxygen that is present at concentrations of up to around 12 ppm in the stratosphere. Ozone has strong absorption in the UV B and some in the IR. The blue sky at dusk is visible evidence of O₃.

- Ozone absorbs harmful UV from the Sun.
- Absence of the O₃ layer would be detrimental to life on Earth.
Where do we find Ozone?

- Mainly in the stratosphere
  - maximum ozone concentration is at a height of about 25 km and is ~12 ppm
- The ozone column is measured in ‘Dobson Units’ (DU)
  - 100 DU is equivalent to a slab of gas 1 mm thick at ground level at 0°C
  - typical values are 300 DU
- Lower concentrations of ozone are found nearer the ground
Gordon Dobson & Aberdeen

- Gordon Dobson installed one of his pioneering ozone spectrometers at Aberdeen in 1939
- Daily observations were made for 5 years from a hut at King’s College
- The motivation was to support World War II meteorology in Britain

The Dobson spectrometer courtesy Met Office

← The King’s College Met hut ~1940s
Ozone has strong absorption in the damaging ultraviolet (UV B) region and some in the infra-red
- stratospheric ozone acts as the main sunscreen to the world

Stratospheric ozone is responsible for the warming of the stratosphere
- this in turn puts a cap on atmospheric circulation of the weather at a height of ~ 10 km in our latitudes

Low level ozone is harmful and encourages pollution related atmospheric chemistry
**Effects of Ozone Reduction**

- **Absence of the stratospheric ozone shield would be detrimental to life on Earth**
  - Increased UV B into the lower atmosphere:
    - increased photo-chemical activity in the troposphere
      - more smogs; more pollution generating chemistry taking place on atmospheric particles
    - increased degradation of natural and artificial polymers in buildings and other constructions
    - increased UV irradiation of animals, plants and phytoplankton
      - increased sun-burn, skin cancer, cataracts; depressed immune system
  - Cooling of the stratosphere
Solar UV Index

Solar UV index is a number measuring daily UV radiation in the open

- 1 unit ≡ 40 J hr\(^{-1}\) m\(^{-2}\) of UV
- usually 1 → 5 in the UK

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Daily Met Office predictions ↑

← Risk of skin damage
The "Ozone Hole"

- The ozone hole was identified in 1985
- It isn’t a hole, but a thinning that takes place over Antarctica in the early southern hemisphere spring

http://www.temis.nl/protocols/o3hole2/sc-o3min.gif
Total ozone (DU) / Ozone total (UD), 2008/02/02

Courtesy: http://exp-studies.tor.ec.gc.ca/ozone/images/graphs/o3_hrmaps/current.gif
% From 1978 – 1988 Average

Deviations (%) / Écart (%) 2008/02/02

Courtesy: http://exp-studies.tor.ec.gc.ca/ozone/images/graphs/o3_hrmaps_dev/current.gif
Ground-based Ozone Monitoring Stations

Data from WOUDC
Above 100 km, molecular oxygen (O₂) strongly absorbs very energetic UV C and is broken into atomic oxygen (O)

- fresh O fed into the top of the stratosphere

Ozone forms naturally in the stratosphere from a combination of molecular oxygen (O₂) with atomic oxygen (O)

- peak concentration of O₃ is at about 25 km
UV Ozone Destruction

- Ozone absorbs UV and disintegrates in the process
  \[ \text{O}_3 + \text{UV} \rightarrow \text{O}_2 + \text{O} \]

- UVB absorption protects us
O$_3$ can be destroyed chemically

- collision with more O$_3$ or O
- by catalytic reactions using NO, Cl and other radicals that leave these unchanged
  - one Cl atom can destroy 100,000 O$_3$

1995 Nobel Prize for Chemistry

- Paul Crutzen, Mario Molina & Sherwood Rowland
- “in atmospheric chemistry, particularly concerning the formation and decomposition of ozone”
Ozone Destruction by Cl derived from a CFC

1. UV strikes CFC $\uparrow$
2. Cl breaks off $\uparrow$
3. Cl strikes $O_3$ $\uparrow$
4. $O_2$ is formed $\uparrow$
5. Stray O strikes ClO $\uparrow$
6. $O_2$ formed, $\uparrow$ Cl released

Eventually the Cl is mopped up by striking a molecule like methane $\rightarrow$

$\leftarrow$ Cl bonds tightly as HCl and is eventually returned to the troposphere.
Ozone holes occur in early spring in both Antarctica and over the Artic

Very cold polar air is isolated by global circulation patterns

Over the sunless winters, Polar Stratospheric Clouds (PSCs) form and persist

The PSCs act as surfaces on which chemical reactions take place that convert inactive Cl compounds to molecular Cl₂

Spring sunlight decomposes Cl₂ to active atomic Cl

Catalytic chemistry with the Cl destroys ozone faster than it can be made, making the “hole”
Long-term Trend

- The longest series of ozone measurements in the world is from Arosa in Switzerland
  - you can see the range of natural fluctuations
  - the decline from 1975 ~2000 in ozone is about 3% per decade
  - Ozone depletion is not just about the ‘ozone hole’

What’s being done?

- The Montreal agreement of 1987 and 5 further amendments is reducing the world-wide production of ozone destroying chemicals
- Recent ozone holes are still quite deep
- Ozone depletion over the world is thought likely to get worse for several years yet
An overview of ODS

Halocarbons

Climate Change ↔ Ozone Depletion

PFCs  HFCs

HCFCs
methyl chloroform

CFCs
carbon tetrachloride

Halons
methyl bromide

atmospheric removal

Use & Banks

Production

destruction

end of life

emissions

recycle

What can we do?

- Don’t believe everything you read!
- Don’t junk your old fridge
- Vote for sympathetic policies
- Spend less time in the sun

← Greenpeace goes rather far!
Weather & Climate

- Weather is the daily values of:
  - wind [page 15/16]
  - sunshine & cloud cover
  - air temperature
  - air pressure
  - humidity
  - precipitation
  - visibility

- Climate is the weather over decades: average and variation
Weather Affects our Lives

- Weather affects
  - clothing
  - wind-chill, frostbite, heat-stroke…
  - social customs, past-times…
  - pollution accumulation
  - health and well-being…

- Climate affects
  - landscape
  - crops
  - architecture…[pp 18-21/20-23/20-23]