

# The Ozone Story

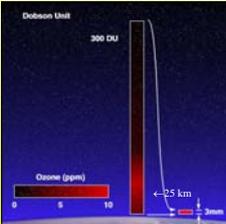
UV C   UV B   UV A   **The Ozone Story**

- ◆ Ozone (O<sub>3</sub>) is highly reactive form of oxygen that is present at concentrations of up to around 12 ppm in the stratosphere [page 448/468/496]
  - ozone has strong absorption in the UV B and some in the IR. The blue sky at dusk is visible evidence of O<sub>3</sub>
  - ozone absorbs harmful UV from the Sun
  - absence of the O<sub>3</sub> layer would be detrimental to life on Earth



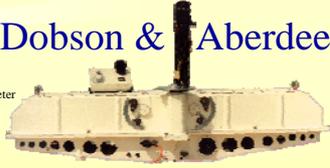
## Where do we find Ozone?

- ◆ 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

The Dobson spectrometer courtesy Met Office

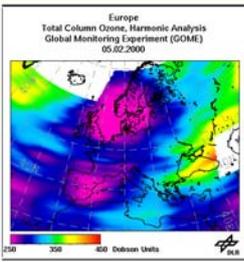



- ◆ Gordon Dobson installed one of his pioneering ozone spectrometers at Aberdeen in 1939
- ◆ Daily observations were made for 5 years from a hut at King's College
- ◆ The motivation was to support World War II meteorology in Britain

← The King's College Met hut ~1940s

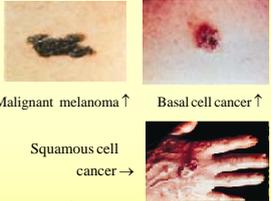
UV C   UV B   UV A   **Is Ozone Beneficial?**

- ◆ 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

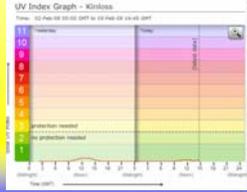
- Solar UV index is a number measuring daily UV radiation in the open
  - 1 unit  $\equiv 40 \text{ J hr}^{-1} \text{ m}^{-2}$  of UV
  - usually 1  $\rightarrow$  5 in the UK



Daily Met Office predictions ↑

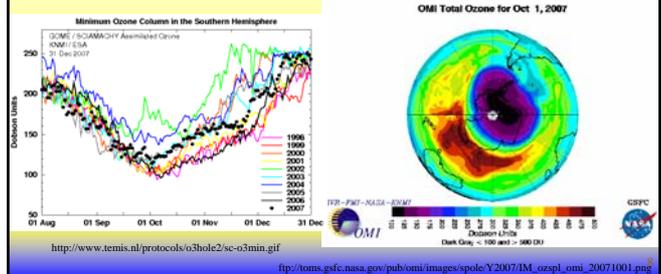
Index	Fair, burns	Fair, tans	Brown	Black
1/2	low	low	low	low
3/4	medium	low	low	low
5	high	medium	low	low
6	very high	medium	medium	low
7	very high	high	medium	medium
8	very high	high	medium	medium
9	very high	high	medium	medium
10	very high	high	high	medium

← Risk of skin damage

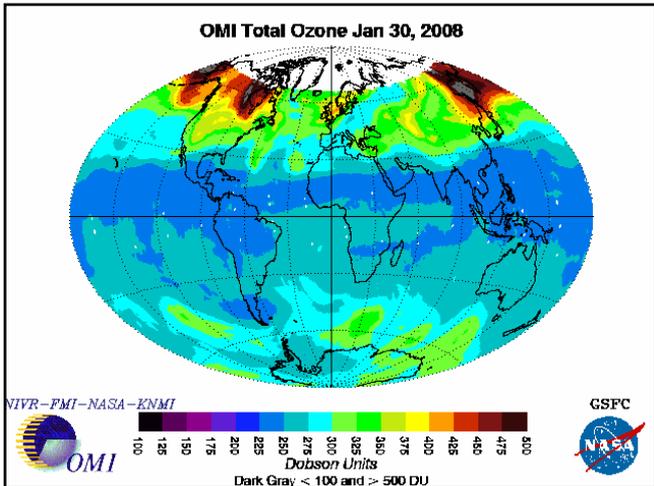


## The "Ozone Hole"

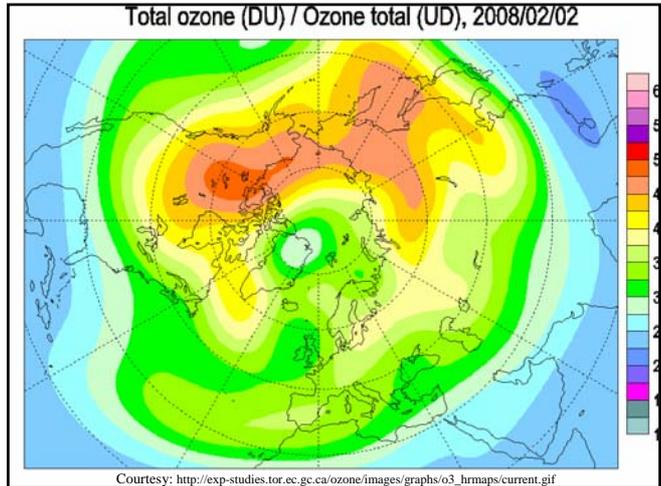
- The ozone hole was identified in 1985
- It isn't a hole, but a thinning that takes place over Antarctica in the early southern hemisphere spring



OMI Total Ozone Jan 30, 2008

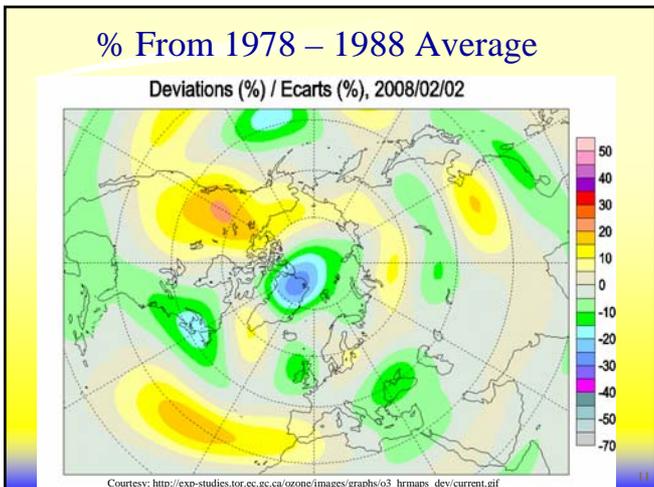


Total ozone (DU) / Ozone total (UD), 2008/02/02

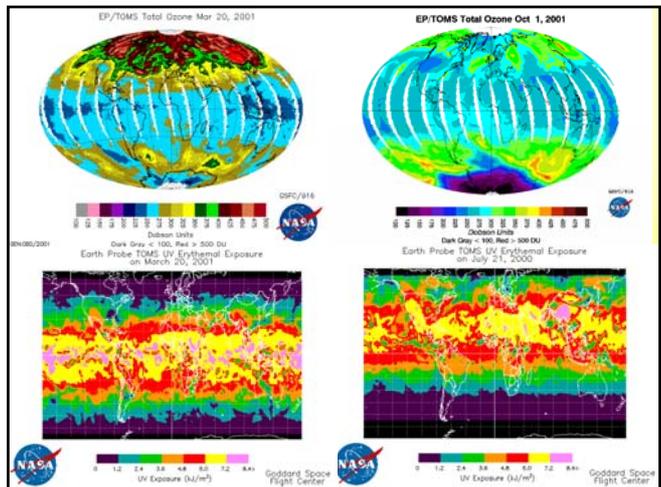


## % From 1978 – 1988 Average

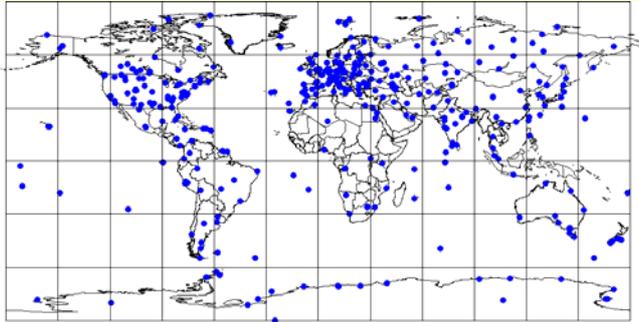
Deviations (%) / Ecartis (%), 2008/02/02



EP/TOMS Total Ozone Mar 20, 2001



## Ground-based Ozone Monitoring Stations

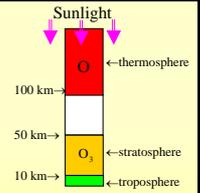


Data from WOUDC

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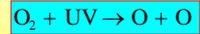


## Ozone Formation



Above 100 km, molecular oxygen ( $O_2$ ) 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** ( $O_2$ ) with **atomic oxygen** (O)

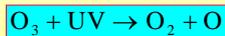


peak concentration of  $O_3$  is at about 25 km

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## UV Ozone Destruction

Ozone absorbs UV and disintegrates in the process



UVB absorption protects us



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## Catalytic Destruction



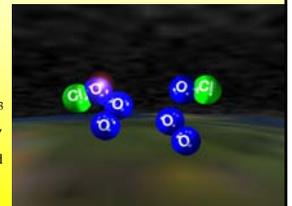
Courtesy: <http://nobelprize.org/chemistry/laureates/1995/>

$O_3$  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"



Courtesy NASA

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## Ozone Destruction by Cl derived from a CFC



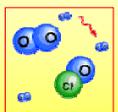
UV strikes CFC ↑



Cl breaks off ↑



Cl strikes  $O_3$  ↑



$O_2$  is formed ↑

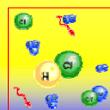
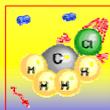


stray O strikes ClO ↑



$O_2$  formed, ↑ Cl released

Eventually the Cl is mopped up by striking a molecule like methane →



← Cl bonds tightly as HCl and is eventually returned to the troposphere

Diagrams courtesy of NASA

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## Why us?

- Ozone holes occur in early spring in both Antarctica and over the Arctic
- 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  $Cl_2$

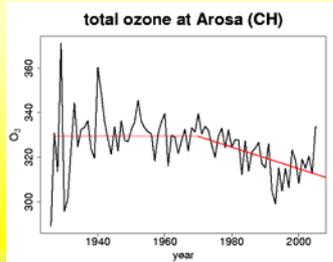
- Spring sunlight decomposes  $Cl_2$  to active atomic Cl
- Catalytic chemistry with the Cl destroys ozone faster than it can be made, making the "hole"



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## 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'

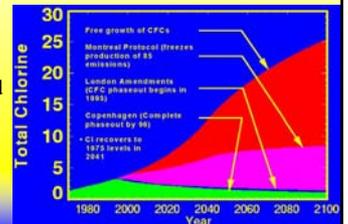


Courtesy: <http://www.iac.ethz.ch/en/research/chemie/tpeter/totozon.html>

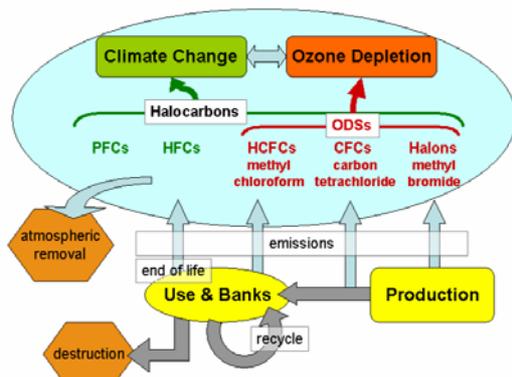
## What's being done?



- 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



Courtesy: <http://www.ipcc.ch/press/SPM.pdf>

## 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]

