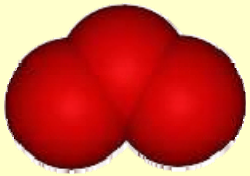
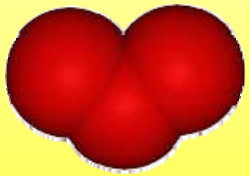



The Ozone Story



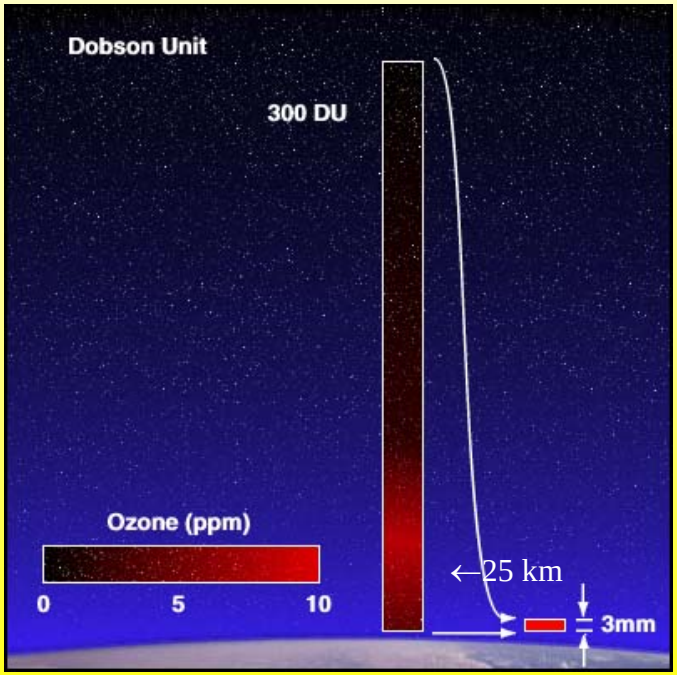

UV C UV B UV A

The Ozone Story

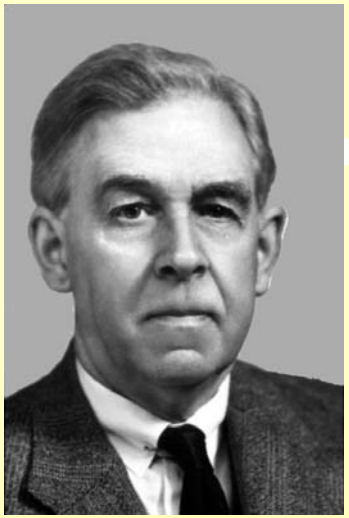
- Ozone (O_3) is highly reactive form of oxygen that is present at concentrations of up to around 12 ppm in the stratosphere [page 448/468/496]
  - ozone has strong absorption in the UV B and some in the IR. The blue sky at dusk is visible evidence of O_3
  - ozone absorbs harmful UV from the Sun
  - absence of the O_3 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

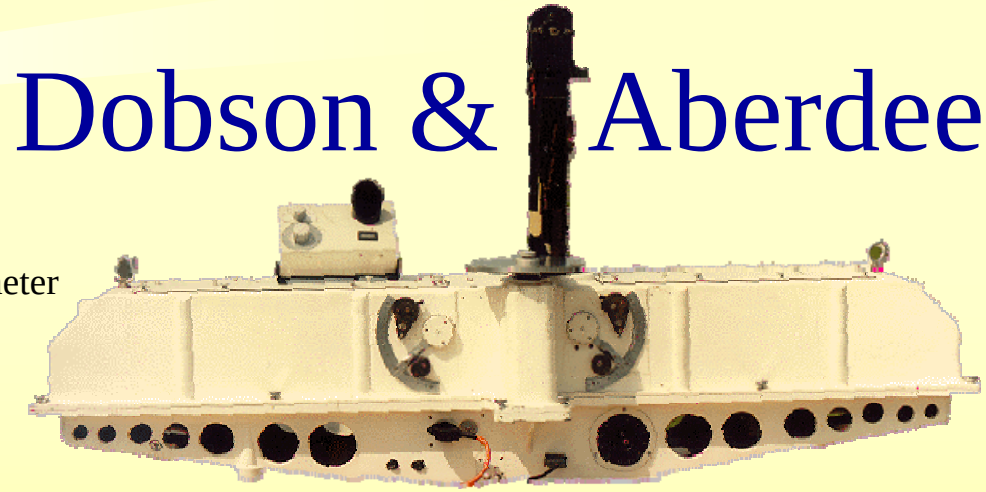


- Lower concentrations of ozone are found nearer the ground



Gordon Dobson & Aberdeen

The Dobson spectrometer
courtesy Met Office



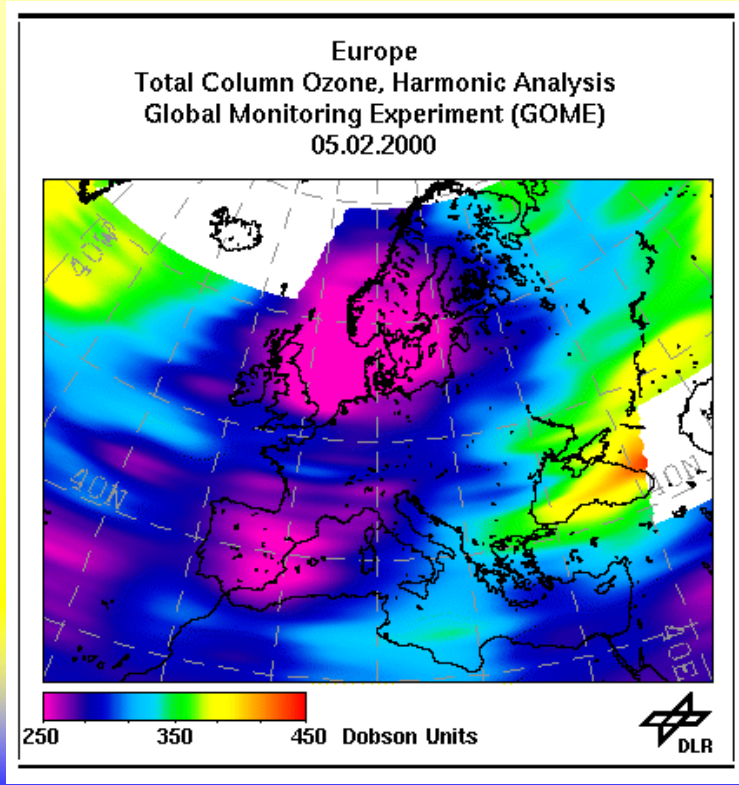
- Gordon Dobson installed one of his pioneering ozone spectrometers at Aberdeen in 1939
- Daily observations were made for 5 years from a hut at King's College
- The motivation was to support World War II meteorology in Britain

← The King's College Met hut ~1940s

UV C UV B UV A

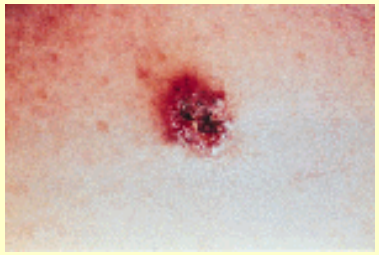
Is Ozone Beneficial?

- 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

Malignant melanoma ↑



Basal cell cancer ↑

Squamous cell cancer →

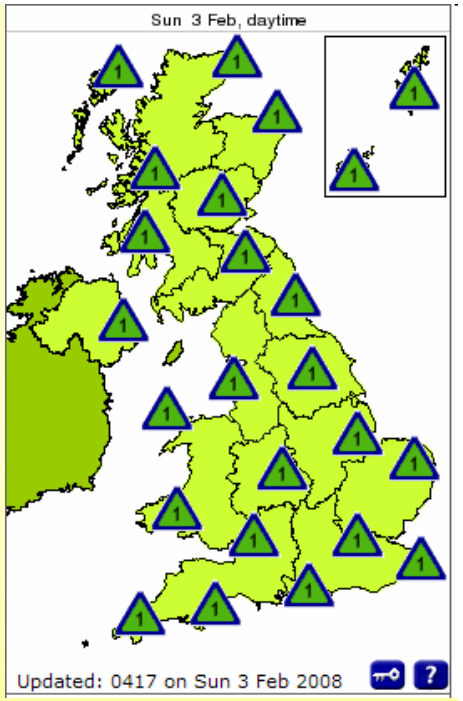
- Absence of the stratospheric ozone shield would be detrimental to life on Earth
- Increased UV B into the lower atmosphere:
  - increased photo-chemical activity in the troposphere
    - more smogs; more pollution generating chemistry taking place on atmospheric particles
  - increased degradation 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

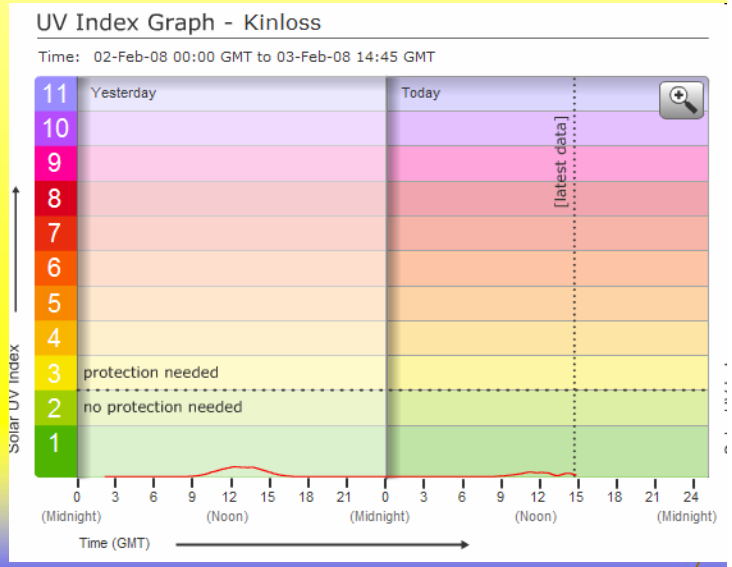
- Solar UV index is a number measuring daily UV radiation in the open
  - 1 unit ≡ 40 J hr^{-1} m^{-2} of UV
  - usually 1 → 5 in the UK

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

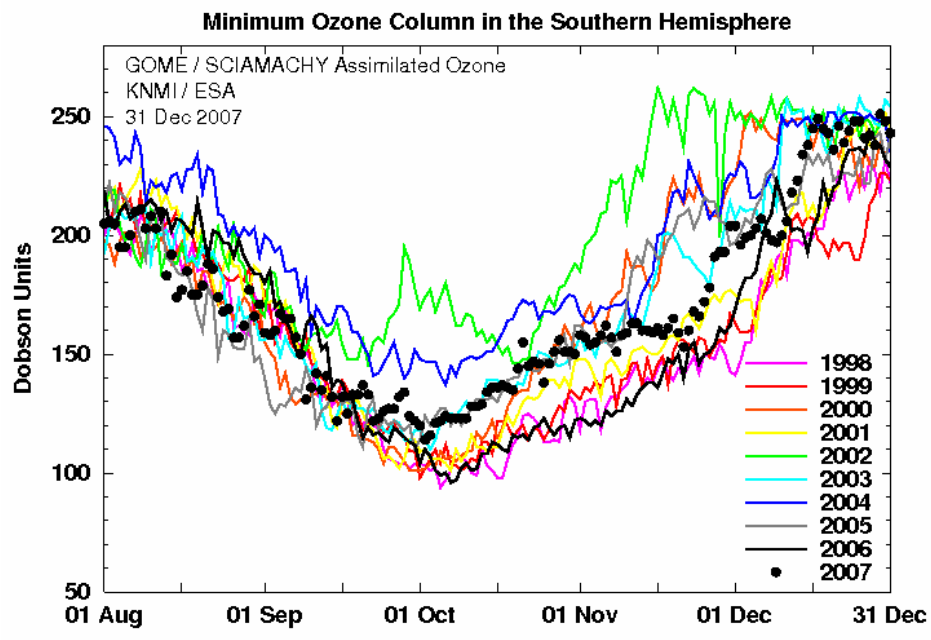


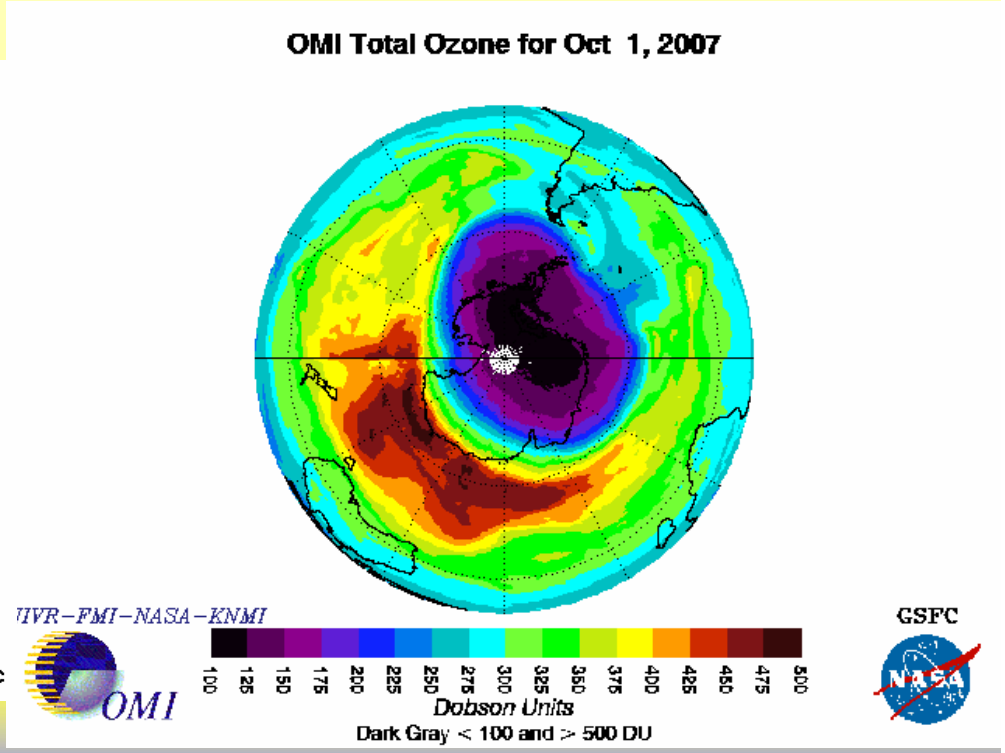
Daily Met Office predictions ↑



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

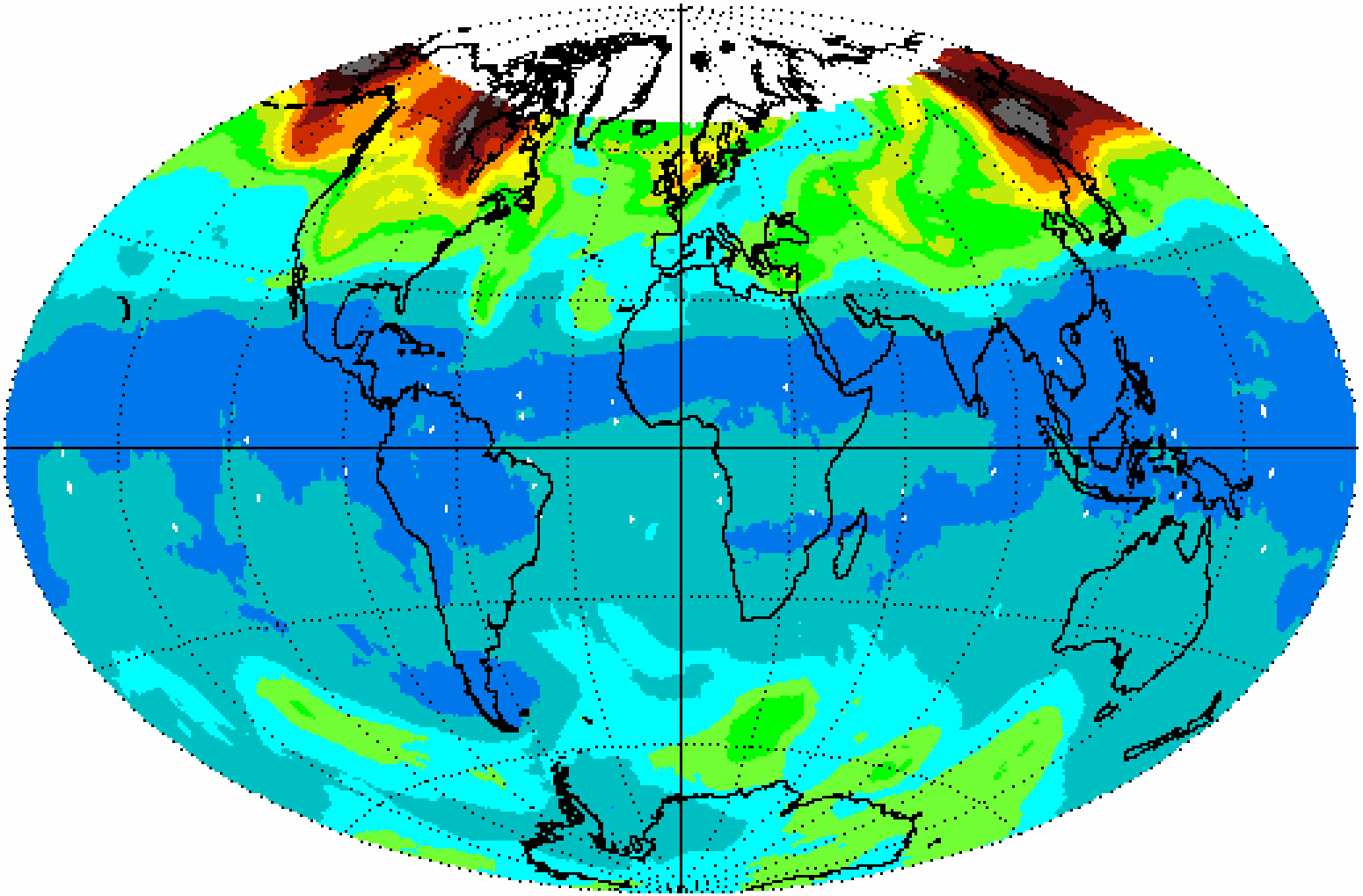




http://www.temis.nl/protocols/o3hole2/sc-o3min.gif

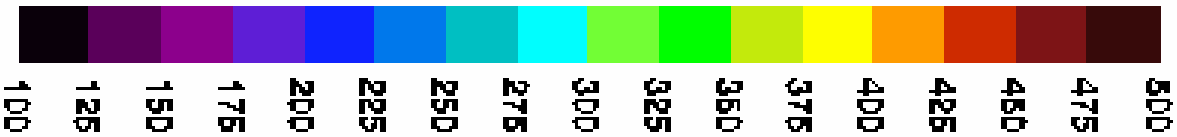
ftp://toms.gsfc.nasa.gov/pub/omi/images/spole/Y2007/IM_ozspl_omi_20071001.png

OMI Total Ozone Jan 30, 2008



NIVR – FMI – NASA – KNMI

OMI

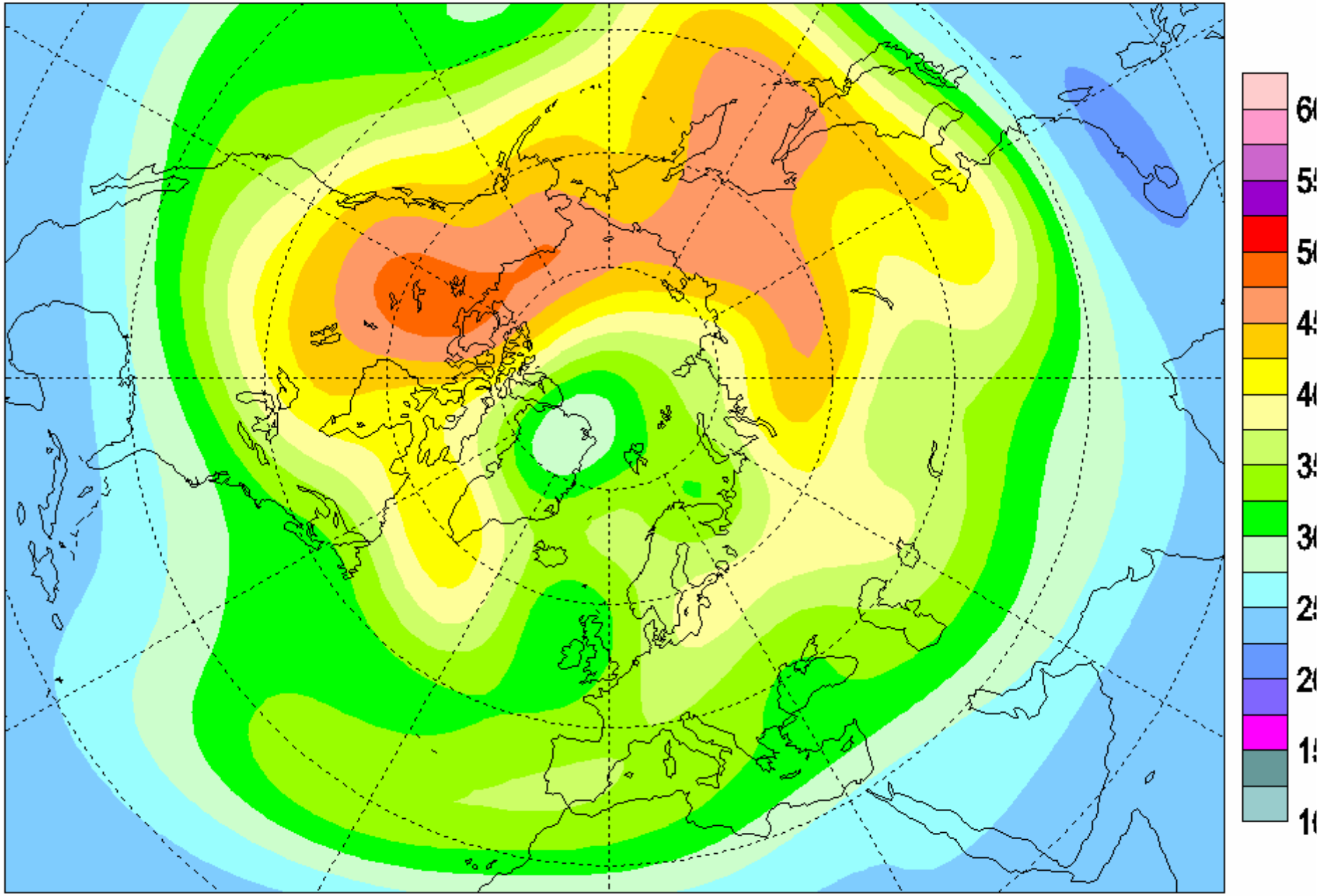


Dobson Units

Dark Gray < 100 and > 500 DU

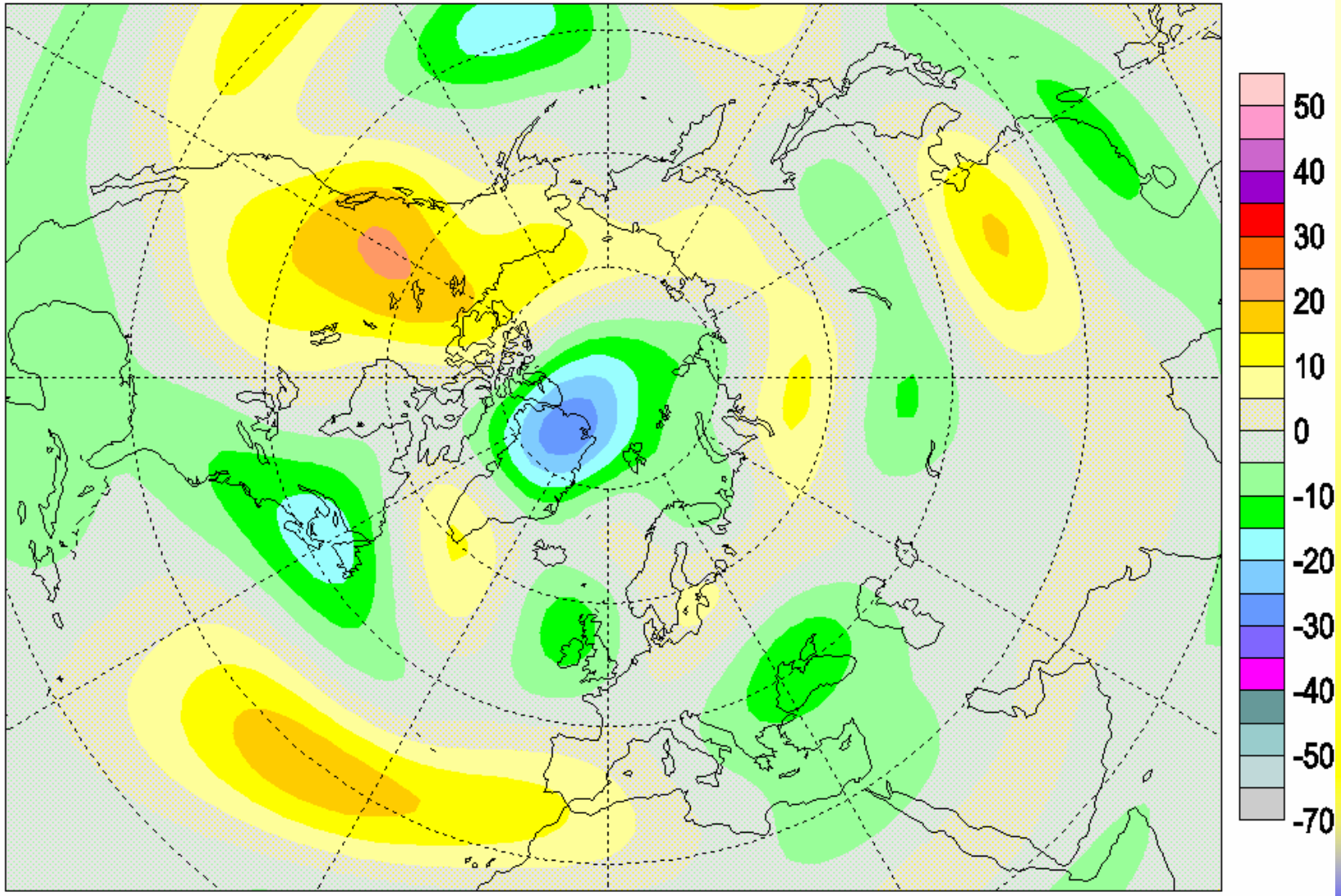
GSFC

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



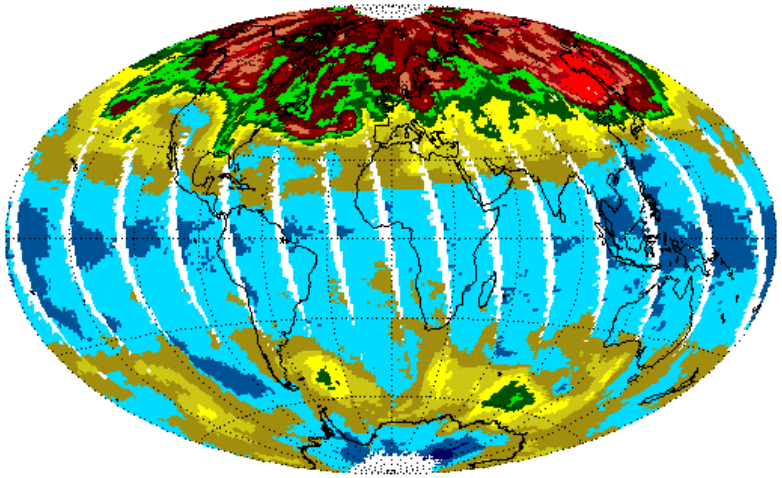
Courtesy: http://exp-studies.tor.ec.gc.ca/ozone/images/graphs/o3_hrmaps/current.gif

% From 1978 – 1988 Average



Courtesy: http://exp-studies.tor.ec.gc.ca/ozone/images/graphs/o3_hrmaps_dev/current.gif

EP/TOMS Total Ozone Mar 20, 2001



GSFC/916

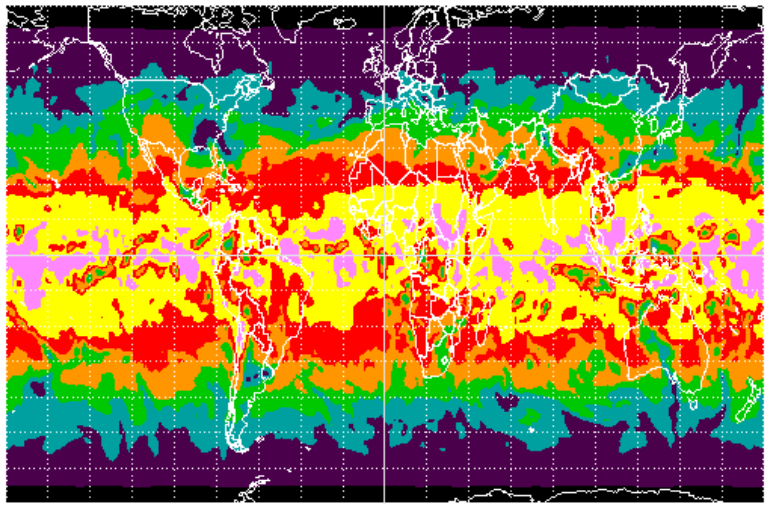
100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Dobson Units

Dark Gray < 100, Red > 500 DU

GEN:080/2001

Earth Probe TOMS UV Erythemal Exposure
on March 20, 2001

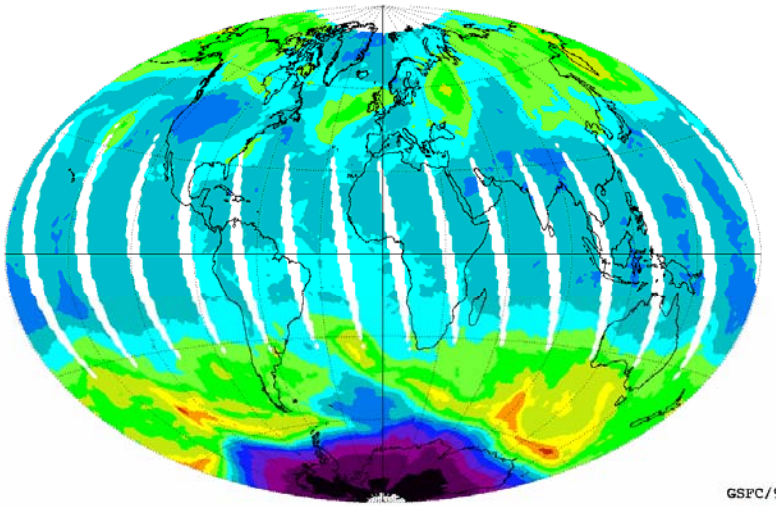


0 1.2 2.4 3.6 4.8 6.0 7.2 8.4>

UV Exposure (kJ/m^2)

Goddard Space
Flight Center

EP/TOMS Total Ozone Oct 1, 2001



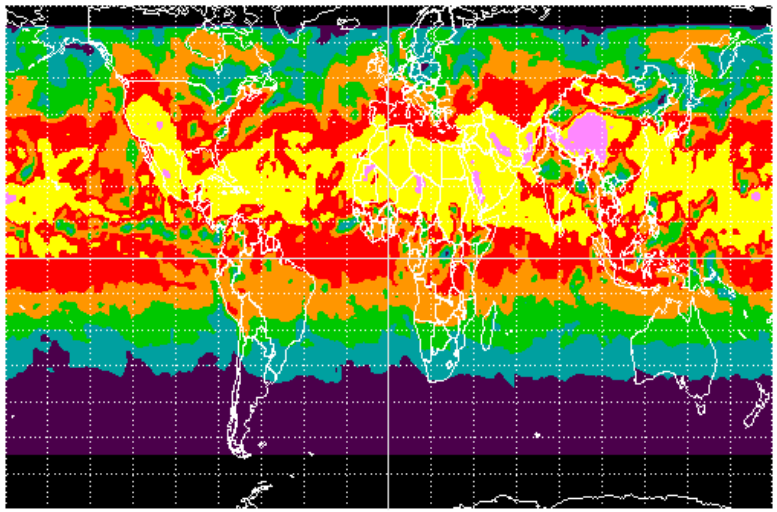
GSFC/916

100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500

Dobson Units

Dark Gray < 100, Red > 500 DU

Earth Probe TOMS UV Erythemal Exposure
on July 21, 2000

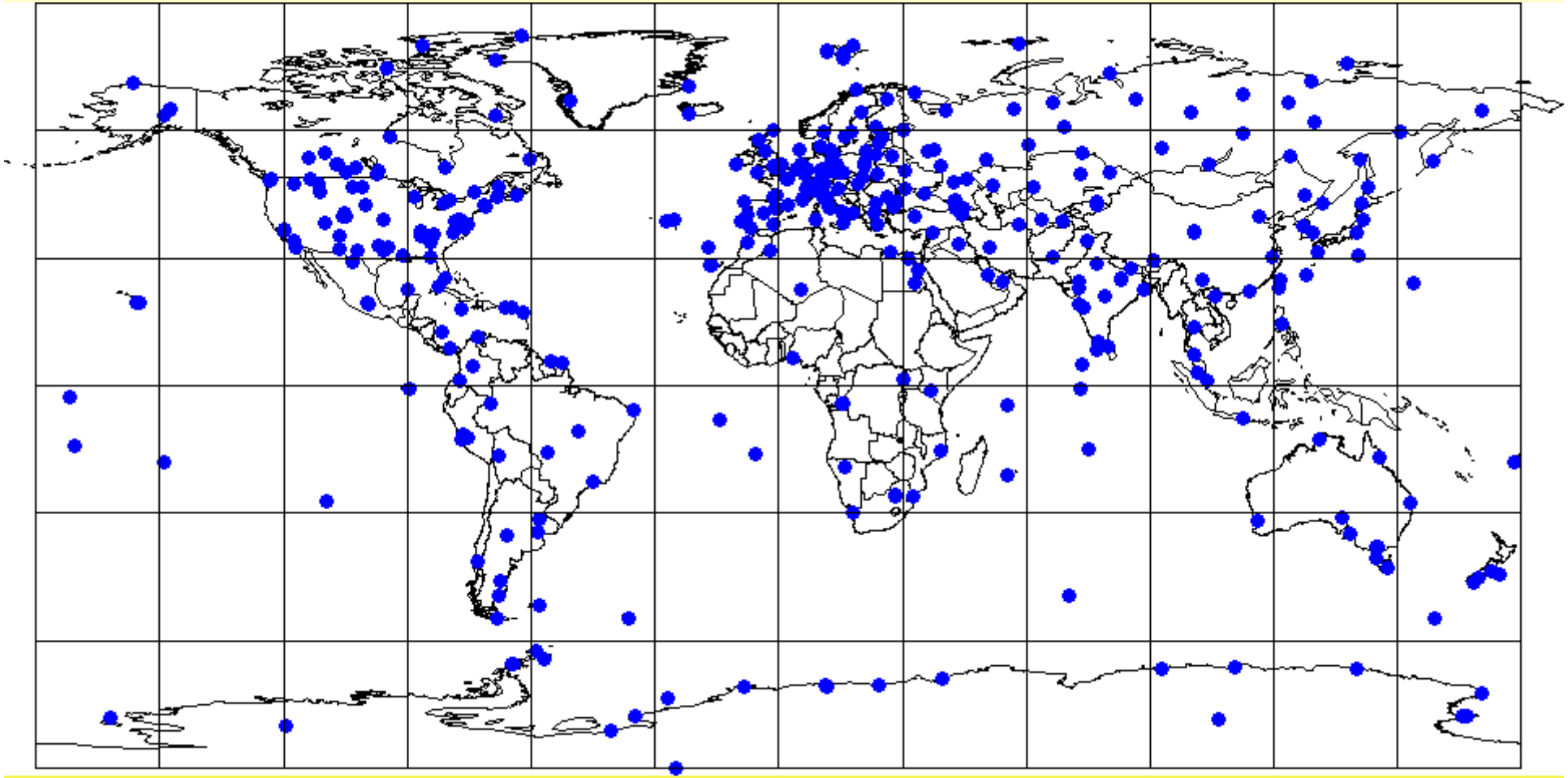


0 1.2 2.4 3.6 4.8 6.0 7.2 8.4>

UV Exposure (kJ/m^2)

Goddard Space
Flight Center

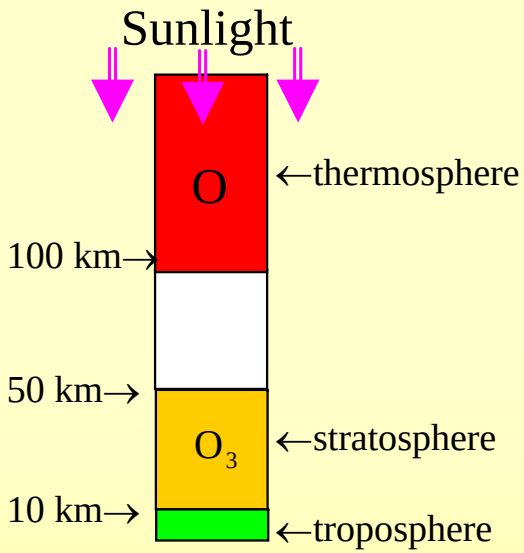
Ground-based Ozone Monitoring Stations



Data from WOUDC

O_3

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

$$O_2 + UV \rightarrow O + O$$

- Ozone forms naturally in the stratosphere from a combination of **molecular oxygen** (O_2) with **atomic oxygen** (O)

$$O_2 + O + Mol = O_3 + Mol$$

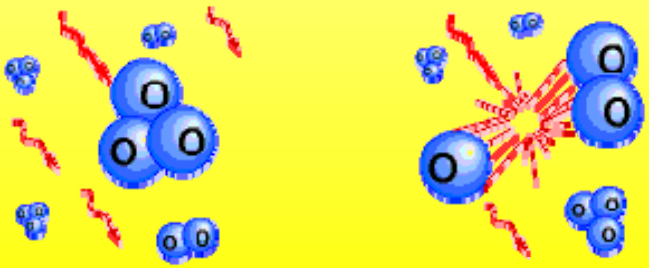
  - peak concentration of O_3 is at about 25 km

UV Ozone Destruction

- Ozone absorbs UV and disintegrates in the process

$$O_3 + UV \rightarrow O_2 + O$$

  - UVB absorption protects us



Catalytic Destruction

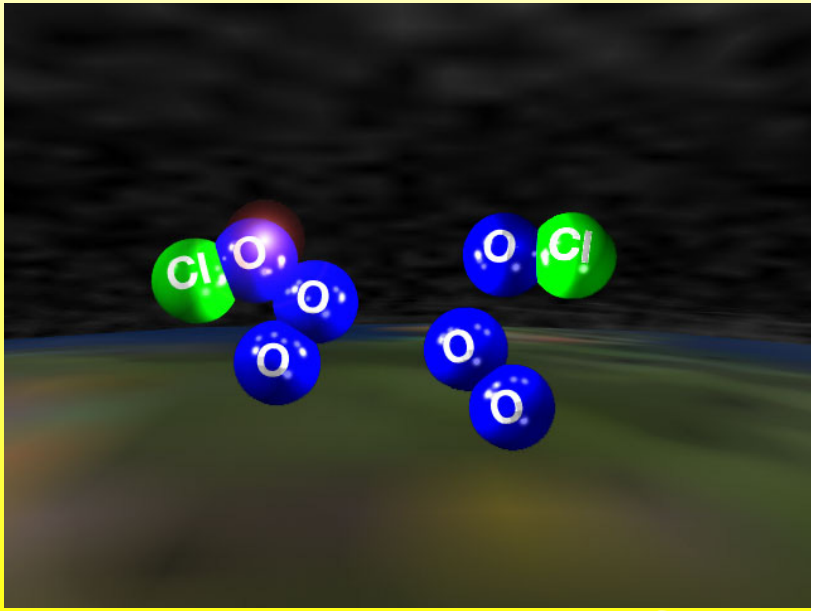

Crutzen


Molina


Rowland

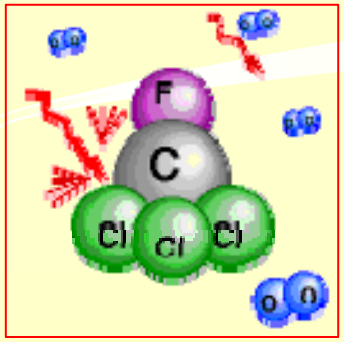
Courtesy: http://nobelprize.org/chemistry/laureates/1995/

- 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"

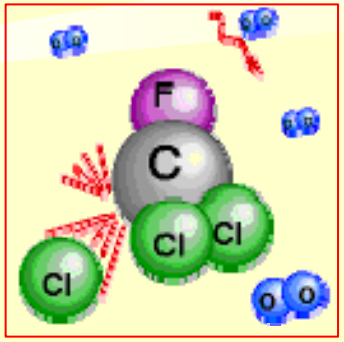


Courtesy NASA

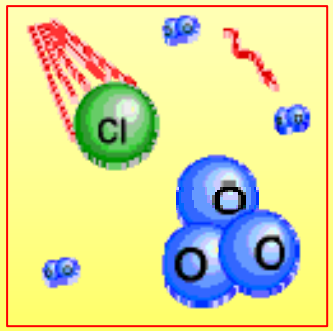
Ozone Destruction by Cl derived from a CFC



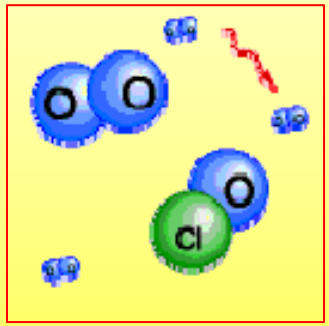
UV strikes CFC ↑



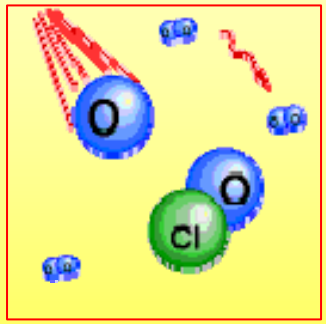
Cl breaks off ↑



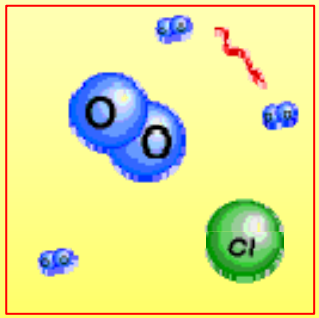
Cl strikes O_3 ↑



O_2 is formed ↑

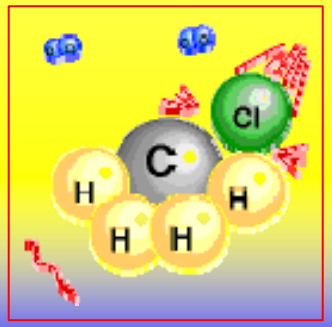


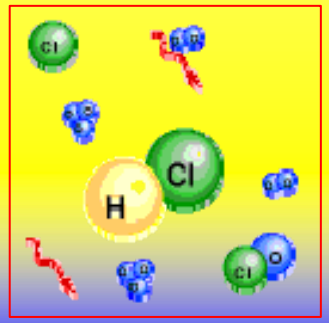
stray O strikes ClO ↑



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

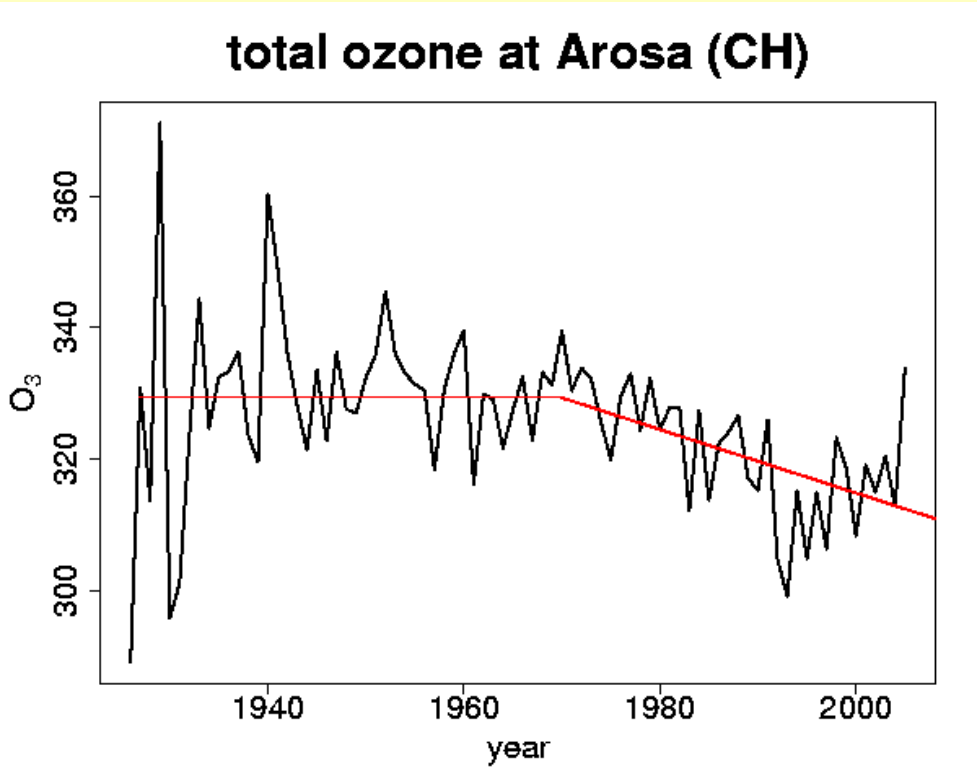
Why us?

- 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 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”

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'

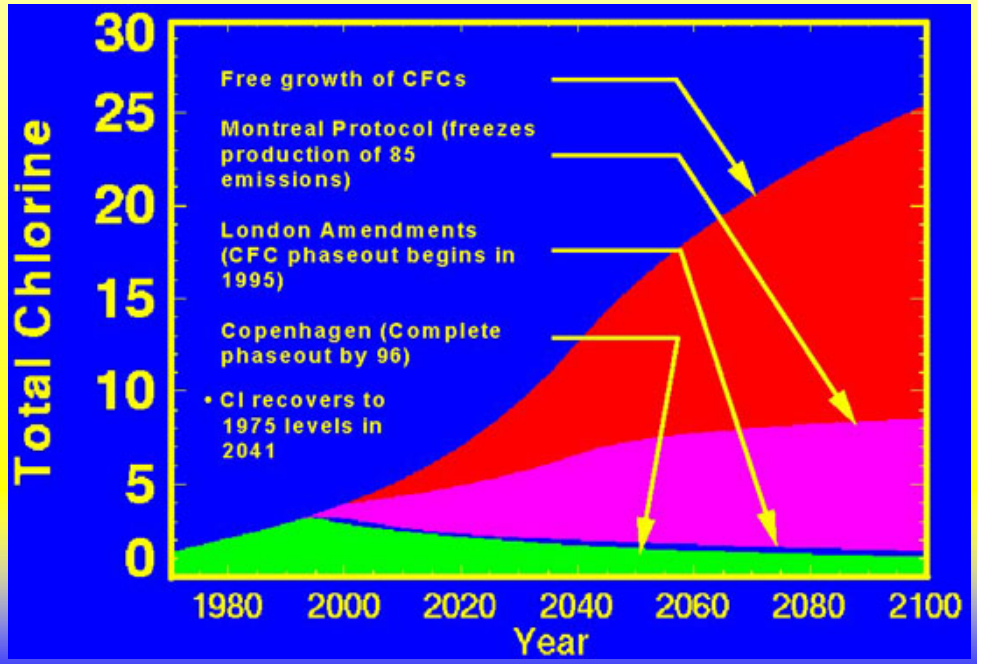


Courtesy: http://www.iac.ethz.ch/en/research/chemie/tpeter/totozon.html

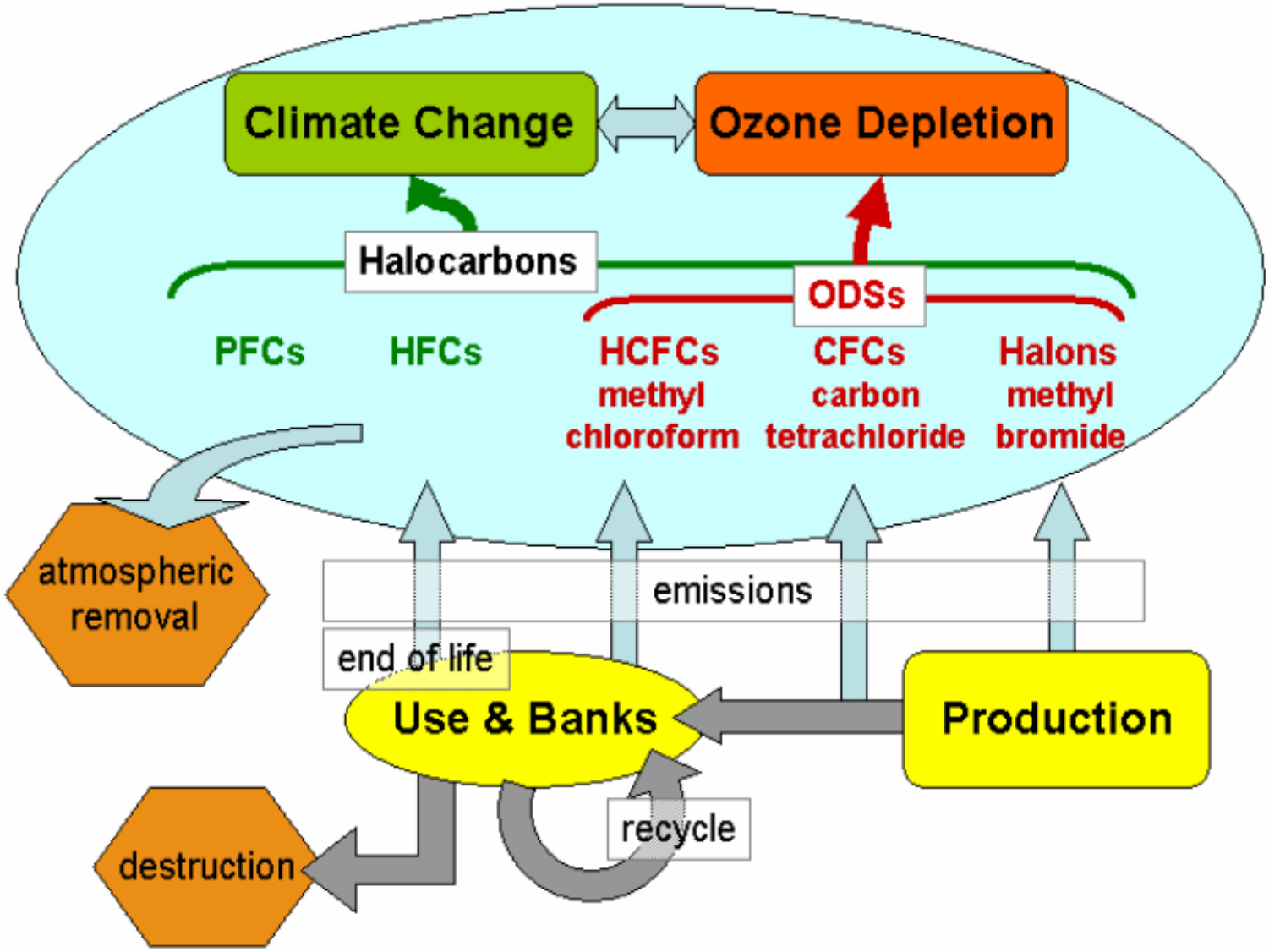
What's being done?

United Nations Environment Programme
Programme des Nations Unies pour l'environnement
UNEP
The Ozone Secretariat

- 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!

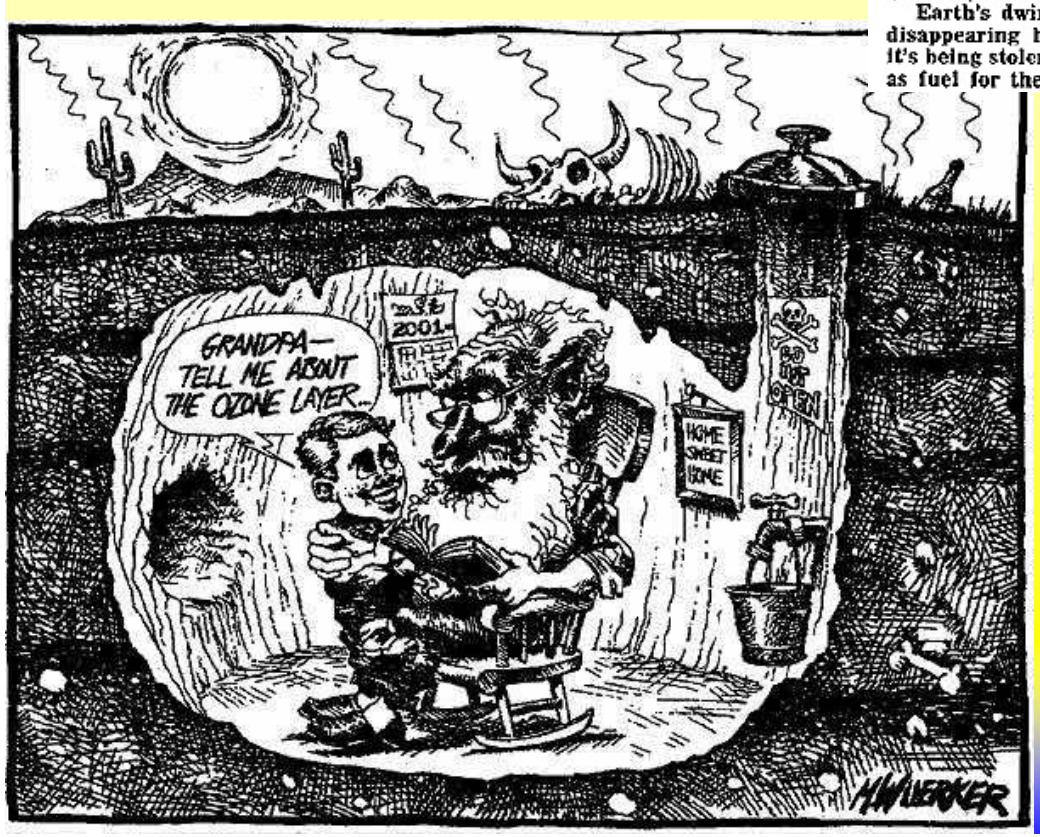

Top scientist's SHOCKING REVELATION:

UFOs ARE STEALING EARTH'S OZONE

. . . & using it as FUEL for their starships!

By BEATRICE DEXTER

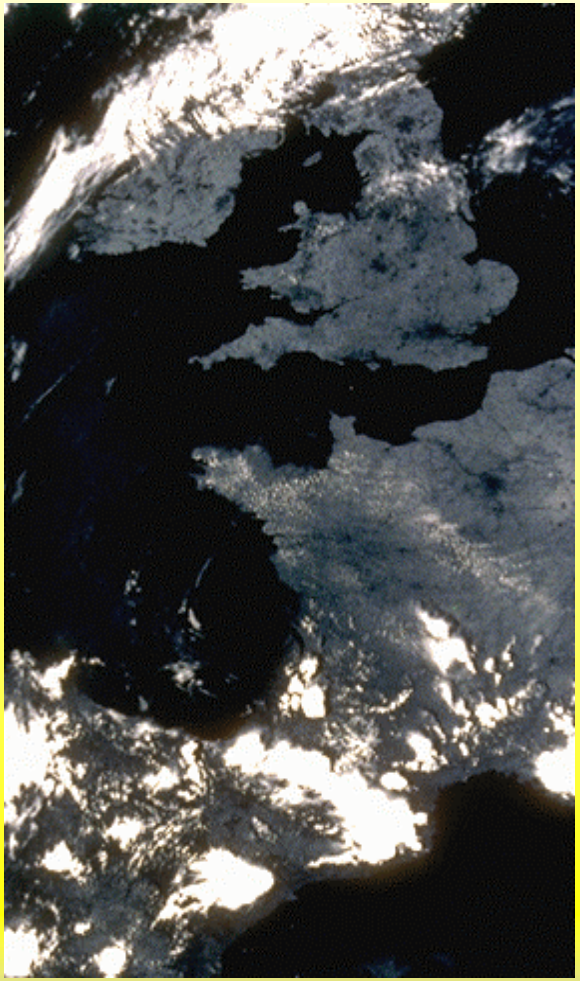
Earth's dwindling ozone layer isn't disappearing because of pollution — it's being stolen by space aliens for use as fuel for their starships!



- 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]