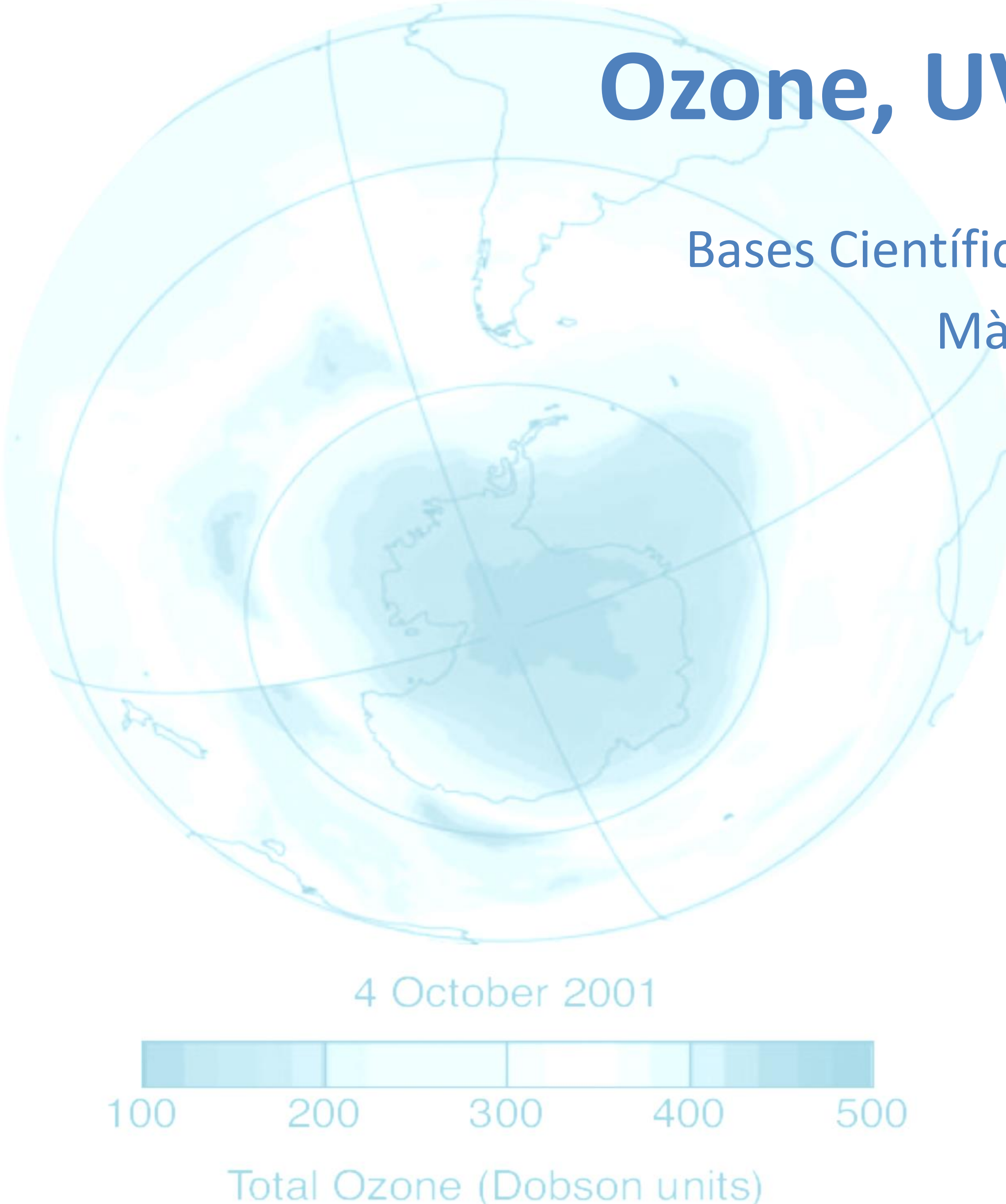
Ozone, UV and effects

Bases Científiques del Canvi Ambiental

Màster en Canvi Ambiental:

Anàlisi i gestió

17/22 desembre 2020



Josep-Abel González

Departament de Física

Universitat de Girona

1

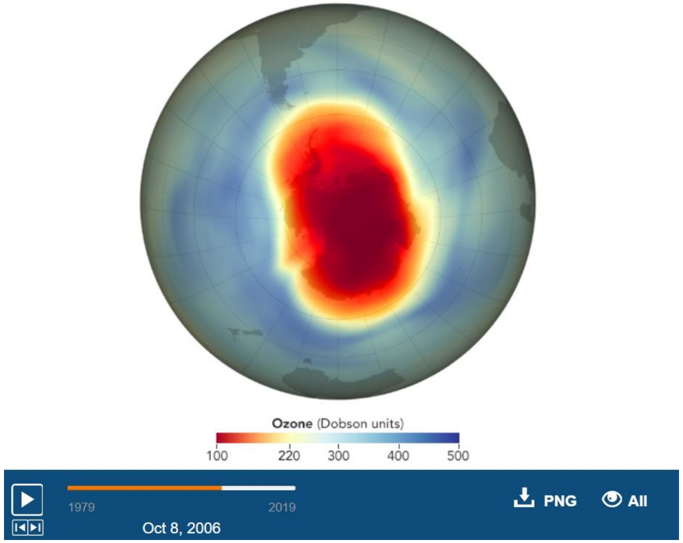
Introduction + references

Summary

There exists in the Earth atmosphere a region with a relatively high concentration of ozone, which has been called the **ozone layer**. This layer protects the Earth surface from the harmful effects of **ultraviolet radiation**. Effects not only in humans, producing skin cancer and cataracts, but in life in general, in ADN, in terrestrial and aquatic ecosystems, in food security, in materials, and even in the climate.

In the early eighties of the last century, scientists discovered that the ozone layer was dramatically thinning every spring in the Antarctic region. This phenomenon came to be known as "**the ozone hole**". Further, it was largely confirmed that the depletion in the ozone layer was caused by **human activities**, with the emission of some very broadly used chemical components (CFC, HCFC) which were reaching the polar stratosphere and were catalyzing some reactions of **destruction of ozone**.

In a very fast response of the international community, boosted by the **Vienna and Montreal protocols**, the emission of the more destructive substances was progressively stopped. This process has been considered as an example of international collaboration giving solutions to a global problem.



But the danger is still far of being conjured. The recovering of the ozone layer to similar amounts to that before the 1980 will not be achieved before the middle decades of the 21st century, … and the 2020 season has shown a very large, deep and persistent ozone hole.

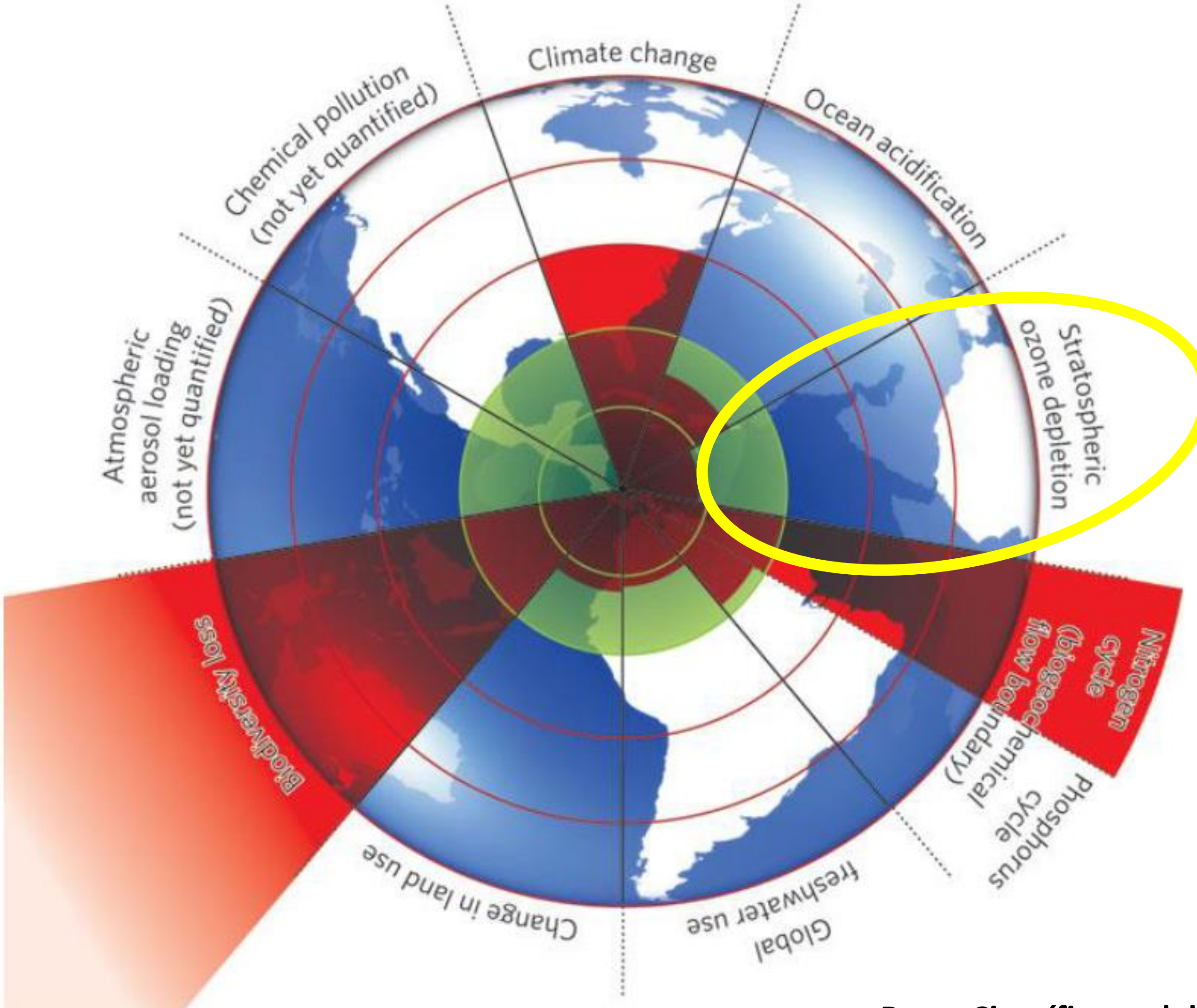
[World of Change: Antarctic Ozone Hole (nasa.gov)]

Alguns fets relacionats amb el canvi global

- During the past 3 centuries human population increased tenfold to 6000 million
- Growth in cattle population to 1400 million (about one cow per average size family).
- Urbanization has even increased tenfold in the past century.
- In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million years.
- The release of SO_2 by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulfide from the oceans
- 30-50% of the land surface has been transformed by human action
- More nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems
- The escape into the atmosphere of NO from fossil fuel and biomass combustion is larger than the natural inputs, giving rise to photochemical ozone formation in extensive regions of the world
- More than half of all accessible fresh water is used by mankind
- Human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests
- Several climatically important "greenhouse' gases have increased in the atmosphere: CO_2 by more than 30% and CH_4 by even more than 100%
- Chlorofluorocarbon gases, which are not toxic at all, have led to the Antarctic 'ozone hole' and which would have destroyed much of the ozone layer if no international regulatory measures to end their production had been taken
- Coastal wetlands are also affected, having resulted in the loss of 50% of the world's mangroves.

CFC

The 9 planetary boundaries

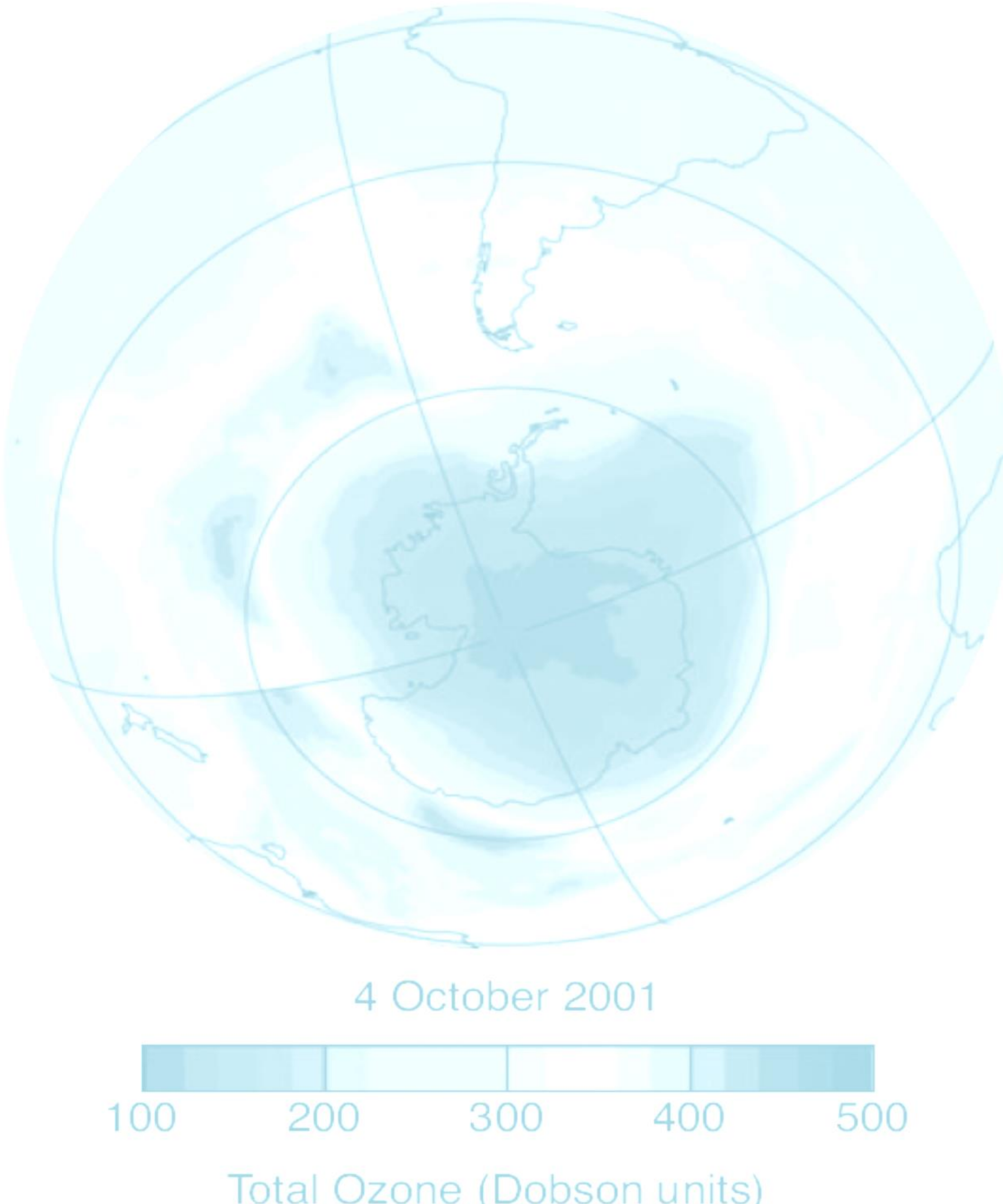


Bases Científiques del Canvi Ambiental

Josep Calbó, UdG

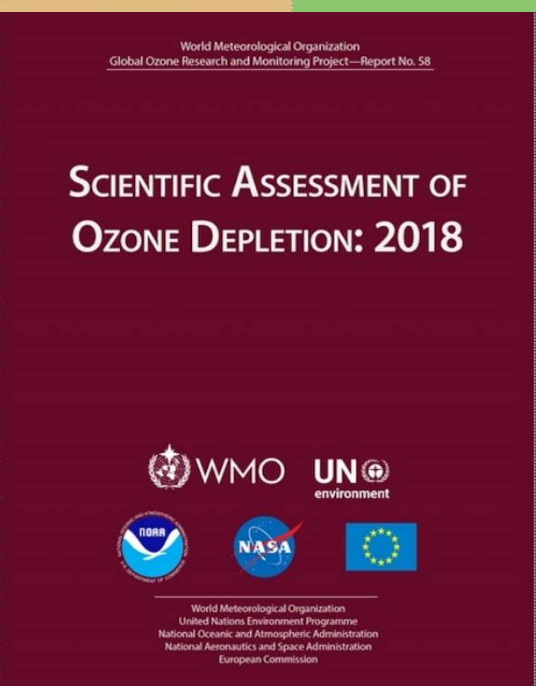
PLANETARY BOUNDARIES

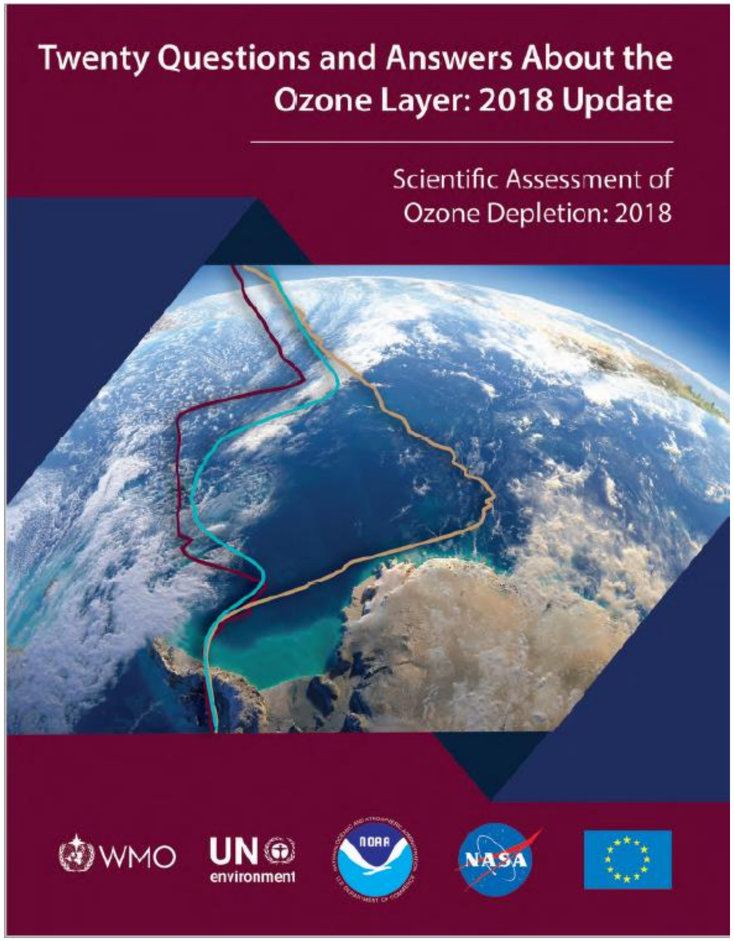
Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5-9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof		To be determined	



References

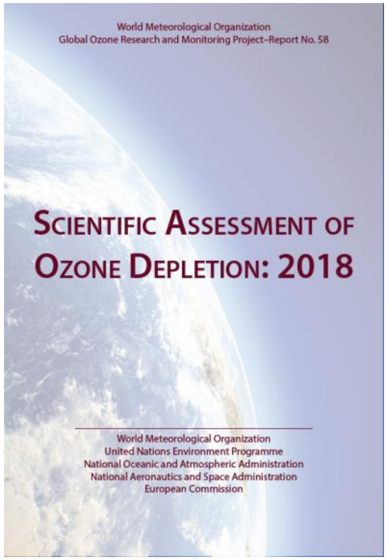
Main references

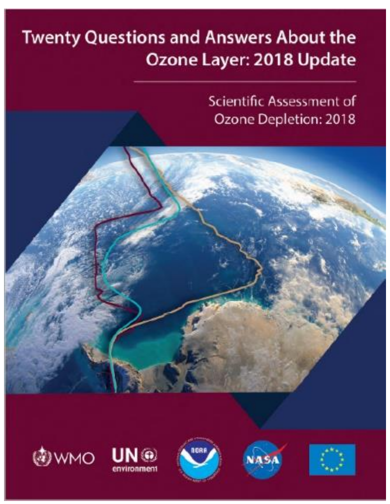




https://www.esrl.noaa.gov/csd/assessments/ozone/2018/
https://www.esrl.noaa.gov/csd/assessments/ozone/2018/executivesummary/

Some documents and papers (available at BCCA Moodle)





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Cite this: *Photochem. Photobiol. Sci.*, 2011, **10**, 182

www.rsc.org/pps

PERSPECTIVE

Ozone depletion and climate change: impacts on UV radiation

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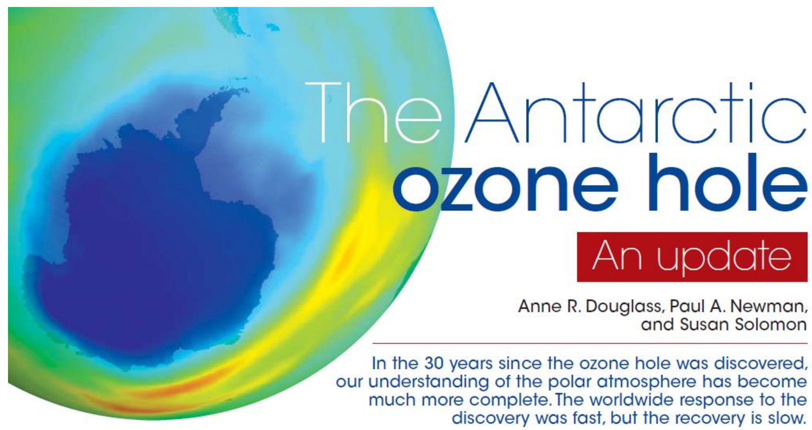
Received 22nd November 2010, Accepted 23rd November 2010
DOI: 10.1039/c0pp90034f



Photochemical & Photobiological Sciences

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Cite this: *Photochem. Photobiol. Sci.*, 2011, **10**, 301

www.rsc.org/pps

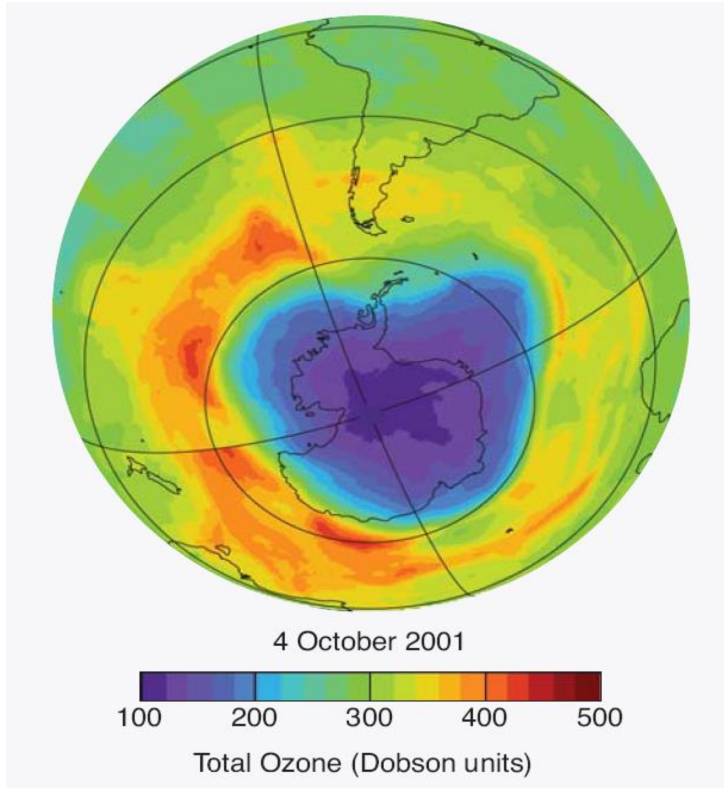
PAPER

Questions and answers about the environmental effects of ozone depletion and its interactions with climate change: 2010 assessment†

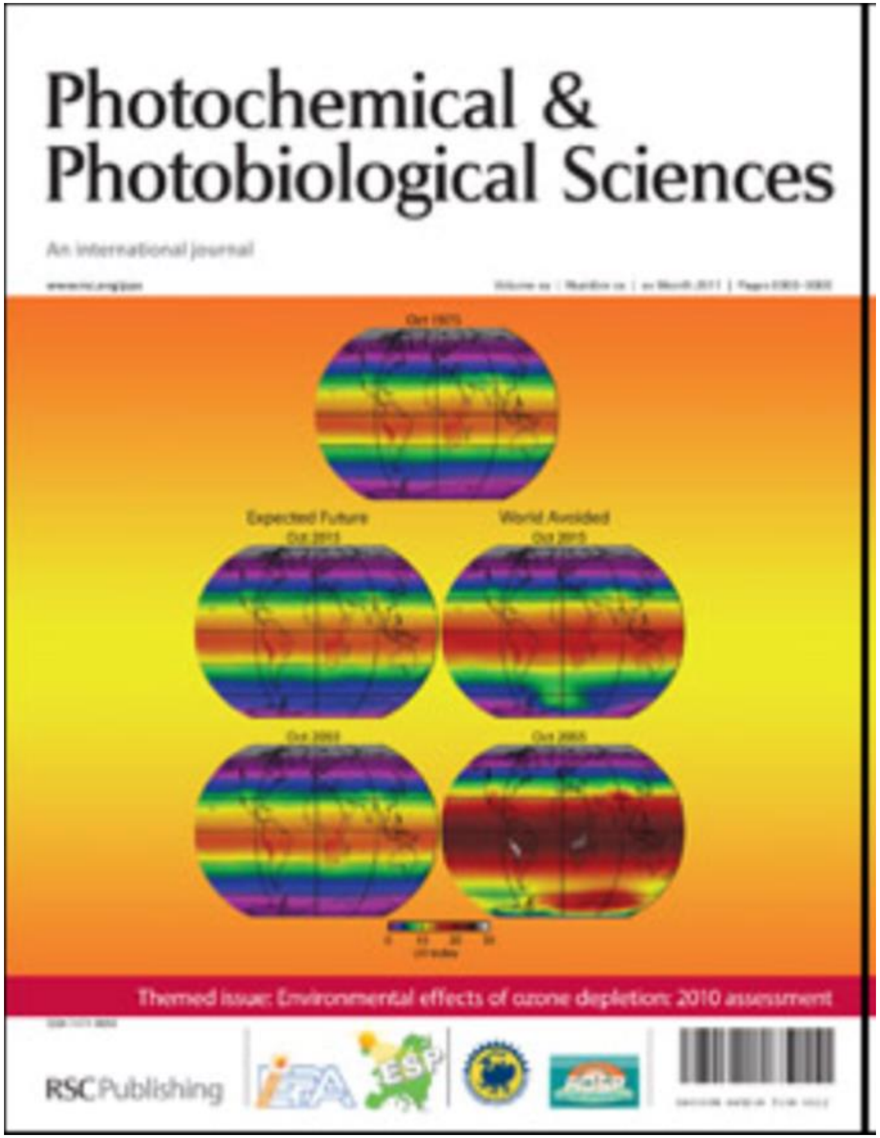
Pieter J. Aucamp,‡[a] Lars Olof Björn‡[b,c] and Robyn Lucas‡[d]

Received 24th November 2010, Accepted 25th November 2010
DOI: 10.1039/c0pp90045a

The ozone hole (some links)



http://ozonewatch.gsfc.nasa.gov/SH.html
http://www.theozonehole.org/
http://www.temis.nl/
http://www.temis.nl/protocols/O3total.html
http://www.temis.nl/protocols/o3hole/



Environmental effects of ozone depletion and its interactions with climate change: 2010 assessment

from the

Environmental Effects Assessment Panel, United Nations Environment Programme (UNEP)

Published in

Photochemical & Photobiological Sciences
issue 2, 2011

More information about the science and effects of ozone depletion?

There are several websites that contain information on ozone, UV radiation, environmental effects and related topics. The sites mentioned below belong to dependable organizations and contain reliable information. Most of these sites contain links to other sources of information.

United Nations Environmental Program UNEP http://www.ozone.unep.org
World Meteorological Organization WMO http://www.wmo.ch
World Health Oganization WHO http://www.who.int
International Panel on Climate Change IPCC http://www.ipcc.ch
National Oceanic and Atmospheric Administration NOAA
http://www.noaa.gov/climate.html
Environmental Protection Agency EPA https://www.epa.gov/ozone-layer-protection
National Aeronautics and Spatial Agency NASA http://ozonewatch.gsfc.nasa.gov
National Institute for Water and Atmosphric Research (New Zealand) NIWA
http://www.niwascience.co.nz
World Ozone and Ultraviolet Radiation Data Center WOUDC http://www.woudc.org
Environment Canada http://www.ec.gc.ca

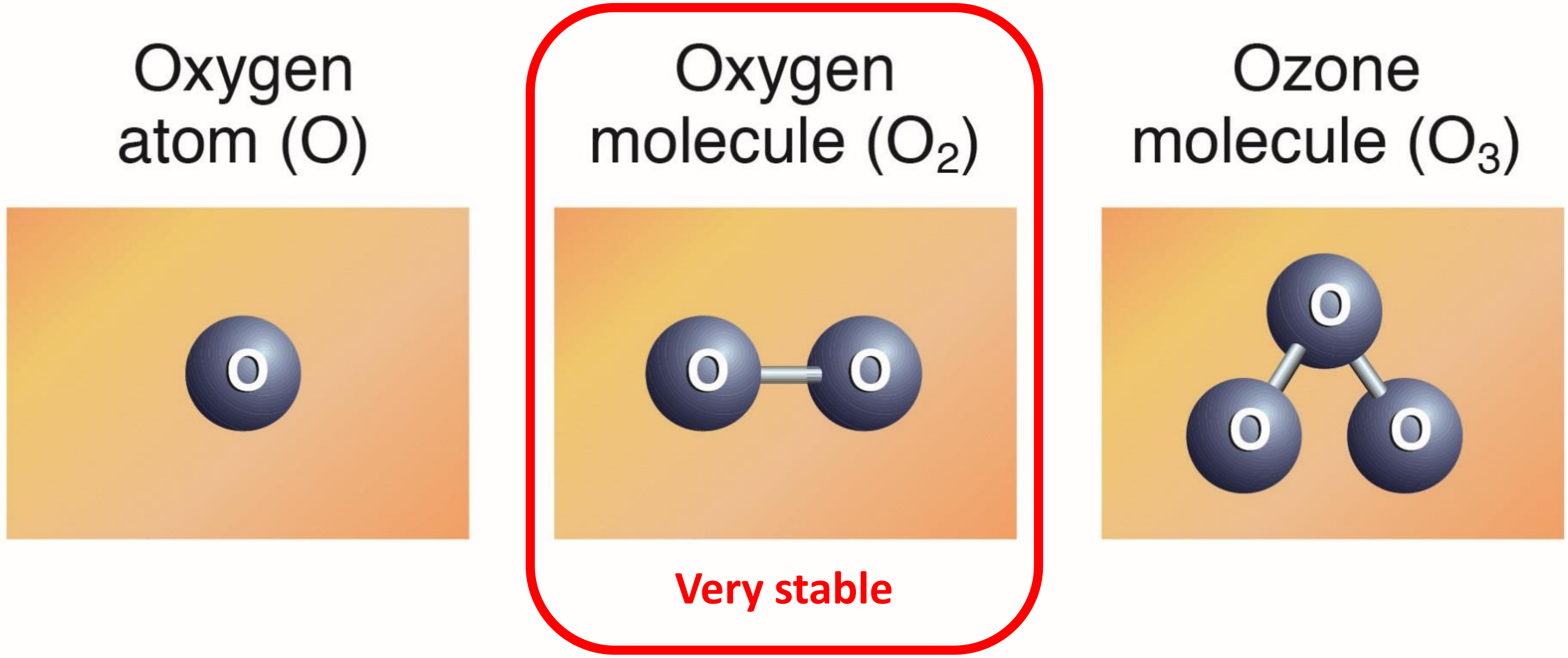
UVI forecast

METEOCAT http://www.meteo.cat/prediccio/uvi
AEMET http://www.aemet.es/es/eltiempo/prediccion/radiacionuv

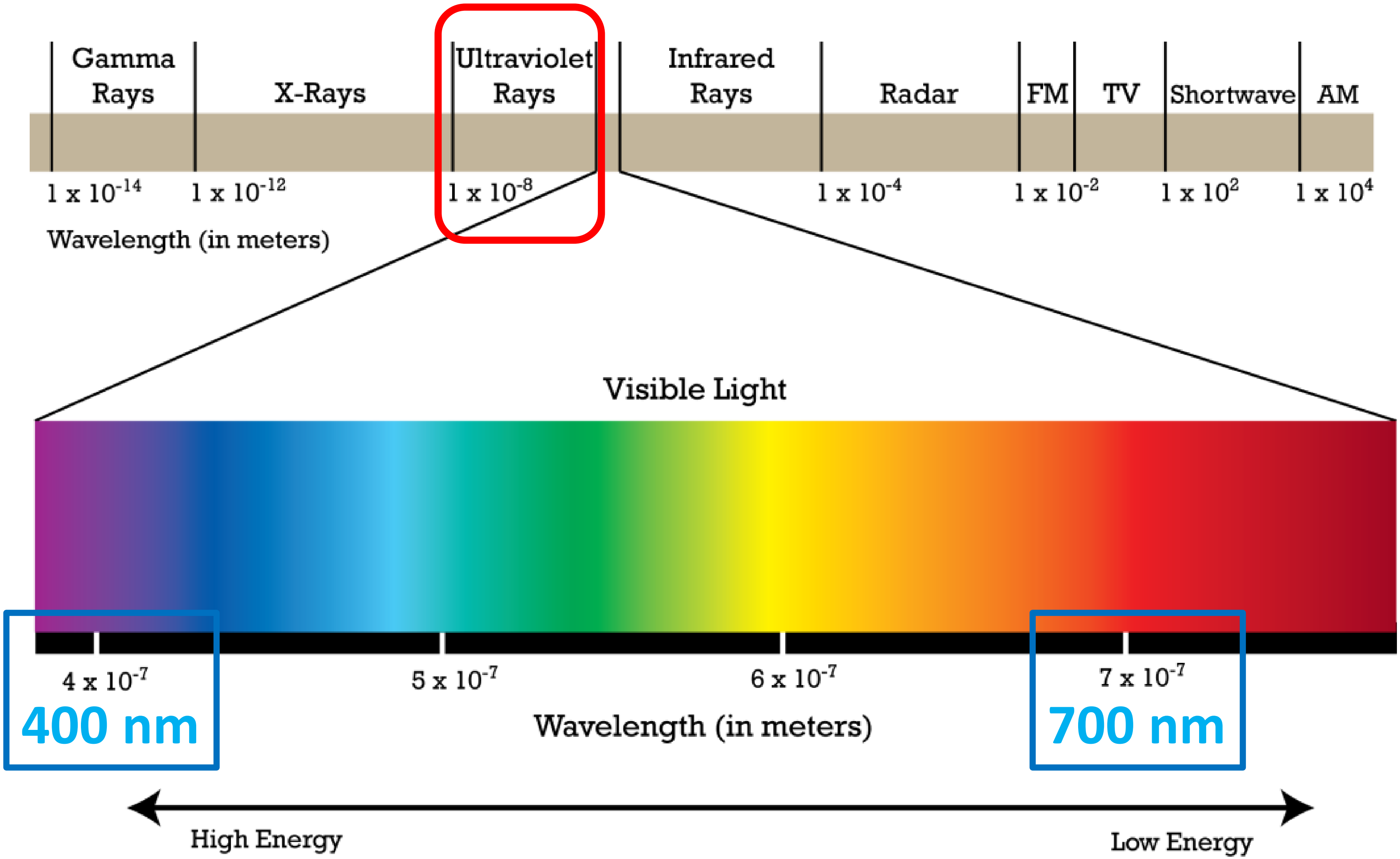
2

The ozone layer

Ozone

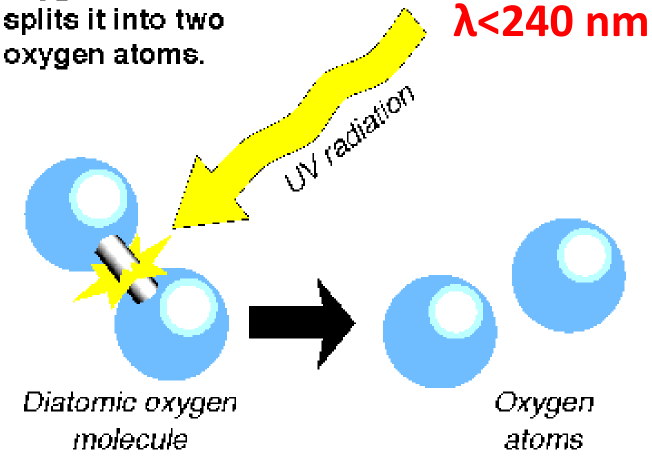

Oxygen atom (O)
O
Oxygen molecule (O_2)
O
O
Very stable
Ozone molecule (O_3)
O
O
O

UV and VIS radiation

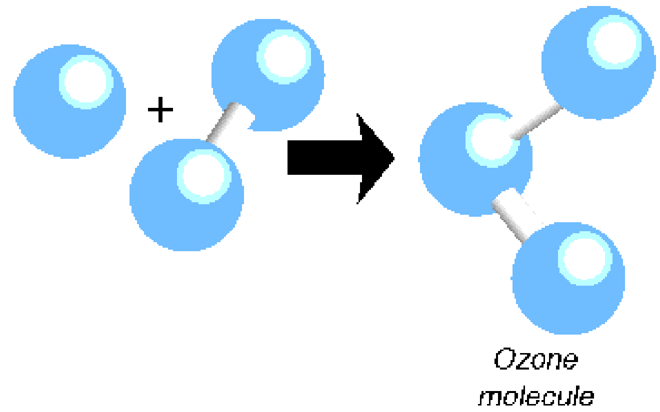


Natural Ozone Production in the Stratosphere

Ultraviolet radiation from the sun strikes a diatomic oxygen molecule and splits it into two oxygen atoms.

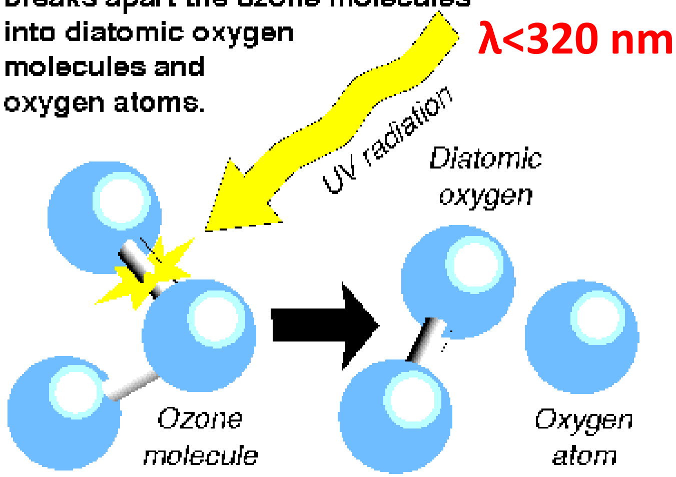


The free oxygen atoms react with diatomic oxygen molecules to form ozone.

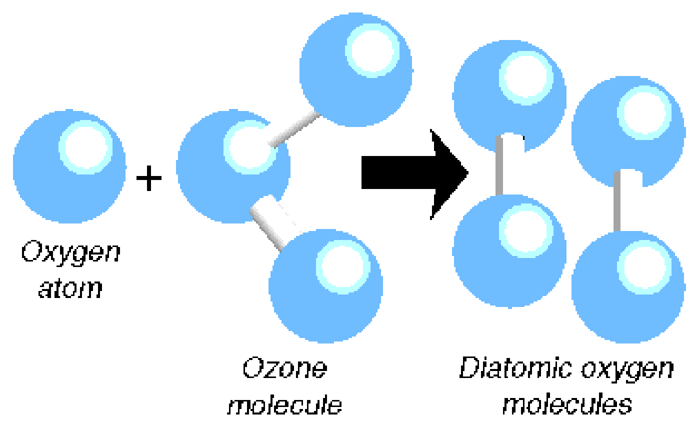


Natural Ozone Destruction in the Stratosphere

Ozone absorbs ultraviolet light in the range of 290-320 nanometers. This solar energy breaks apart the ozone molecules into diatomic oxygen molecules and oxygen atoms.



The free oxygen atom can react with an ozone molecule and form two molecules of diatomic oxygen.



Ozone generation/destruction (natural)

$$O_2 + \text{UV}_{(\lambda<240nm)} \rightarrow O + O$$

$$O + O_2 \rightarrow O_3$$

$$O + O_2 \rightarrow O_3$$

$$O_3 + \text{UV}_{(\lambda<320nm)} \rightarrow O + O_2$$

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

Balance

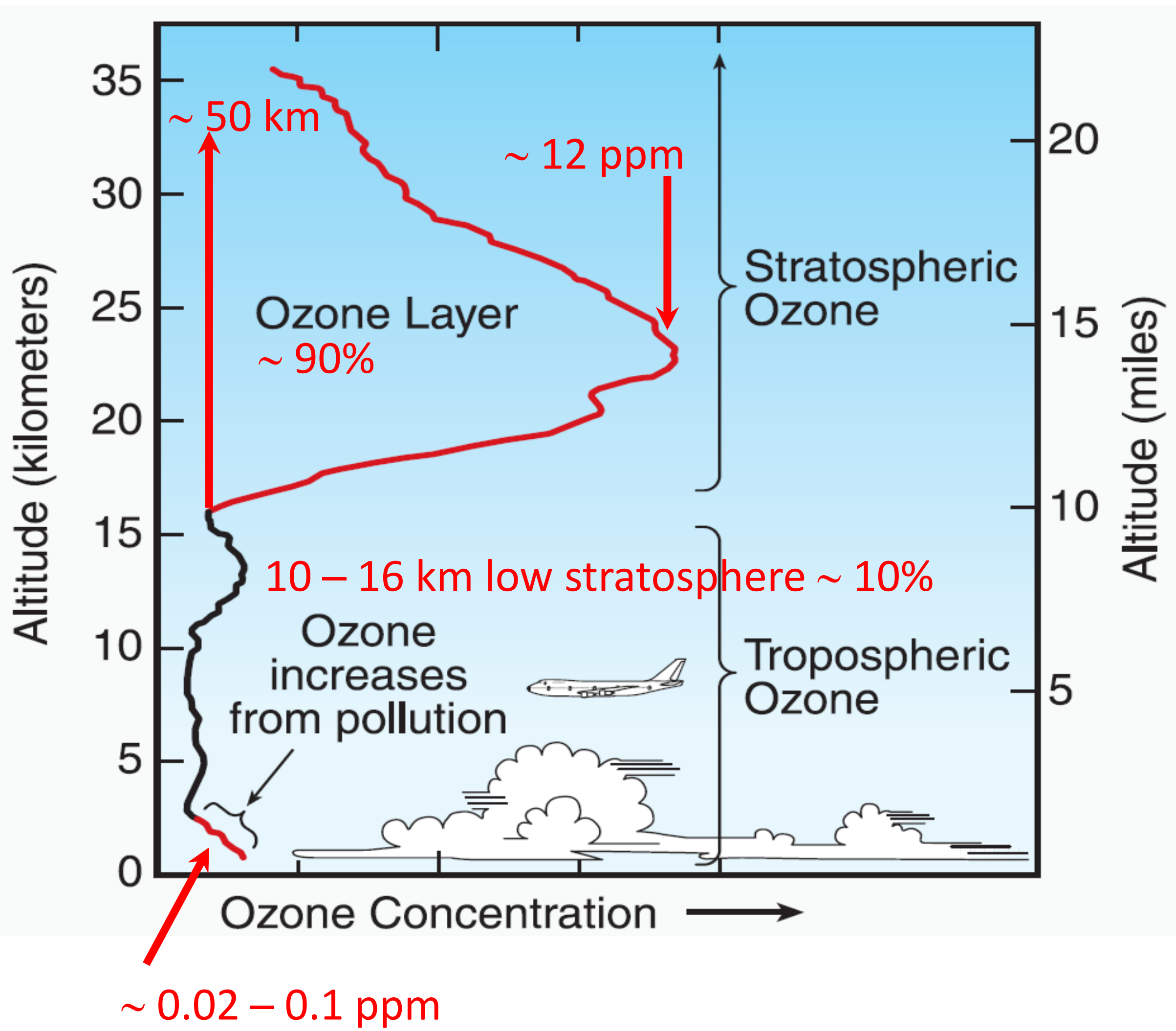
$$3O_2 + \text{UV}_{(\lambda<240nm)} \rightarrow 2O_3$$

$$2O_3 + \text{UV}_{(\lambda<320nm)} \rightarrow 3O_2$$

Ozone concentration at any point and time depends on the **equilibrium** between **production** and **destruction**, in turn depends on **UV levels** and **T** (meteorology)

Ozone in the atmosphere

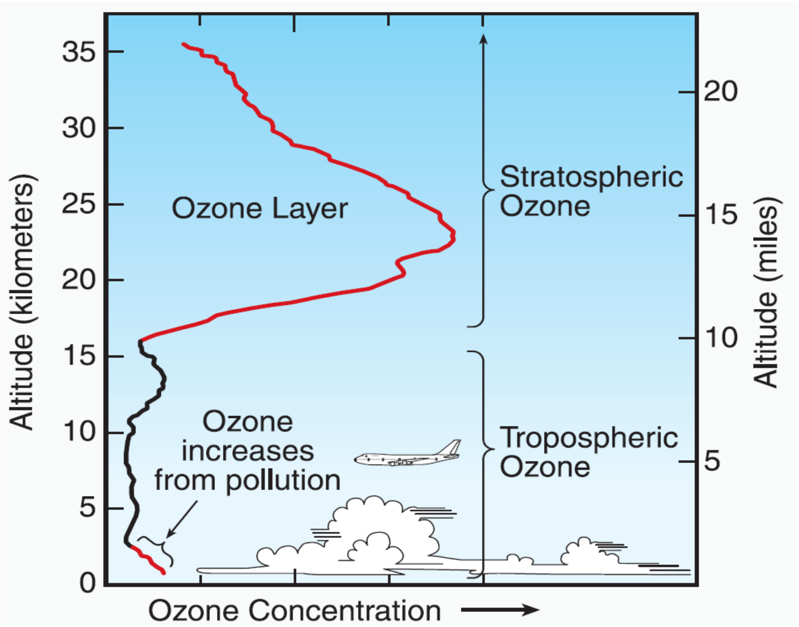
Air = $N_2 + O_2$ + … + ozone

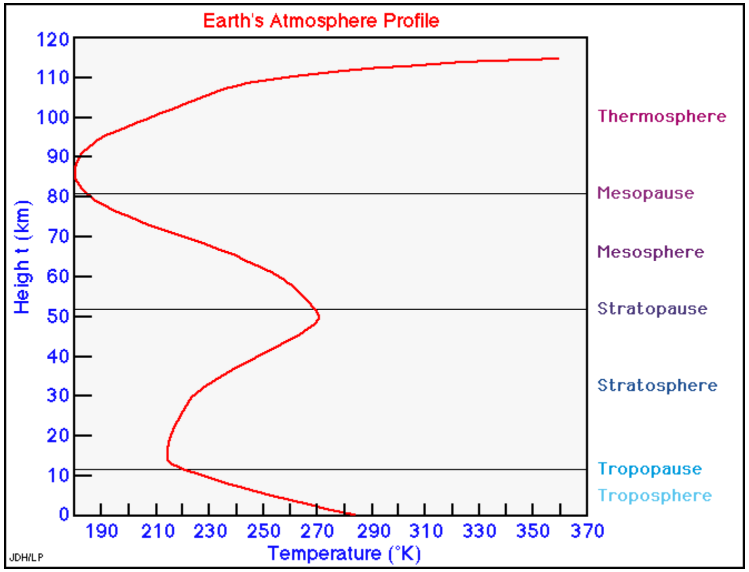


Total Ozone Column (TOC)

- Dobson Units (1DU=10µm STP=2.69×10^{20} mollecules/m^2)
- About 300 DU (3 mm STP), but it depends on latitude, season and atmospheric processes.

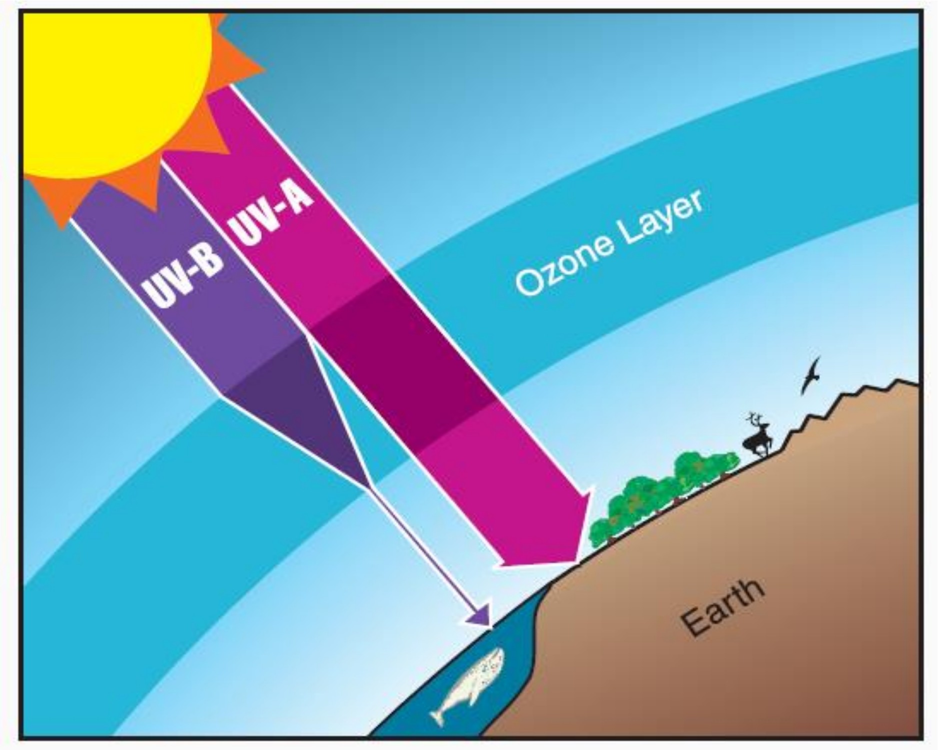
Main effects of the atmospheric ozone: heating





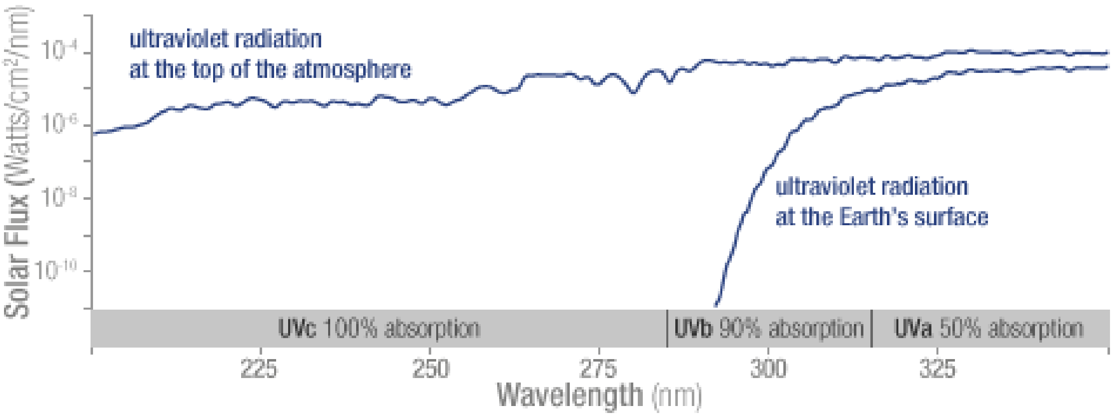
HEATING

Main effects of the atmospheric ozone : filtering

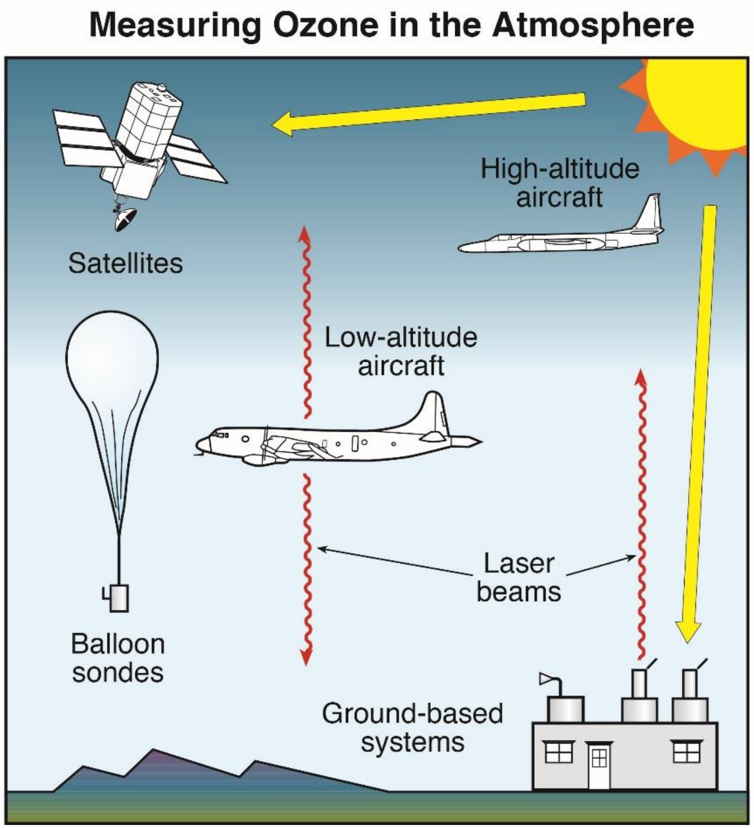


FILTERING

UVC 200-280 nm
UVB 280-315 nm
UVA 315-400 nm



The measurement of the atmospheric ozone



Dobson spectrophotometer at Boulder (Colorado)

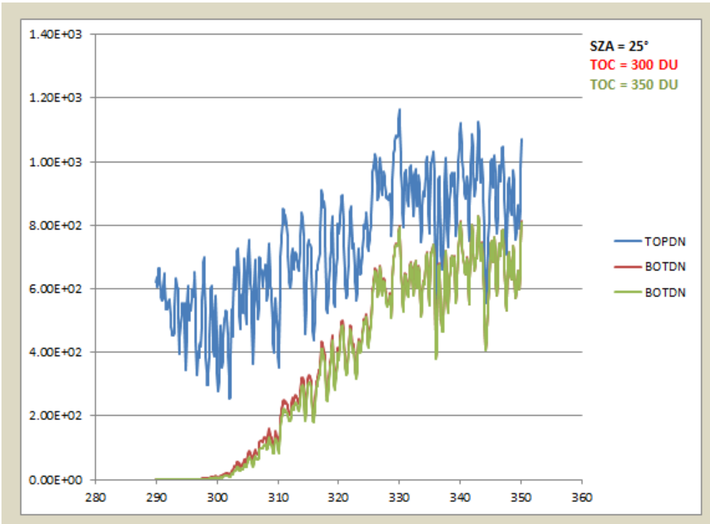
~ 50 in operation

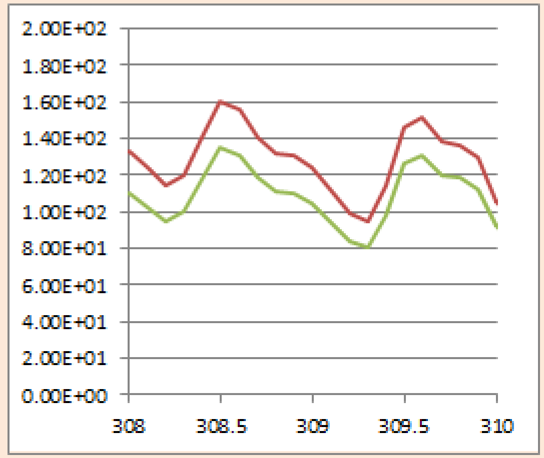
Standard: No. 83

At the British Antarctic Survey 1984: No. 31 + No. 51

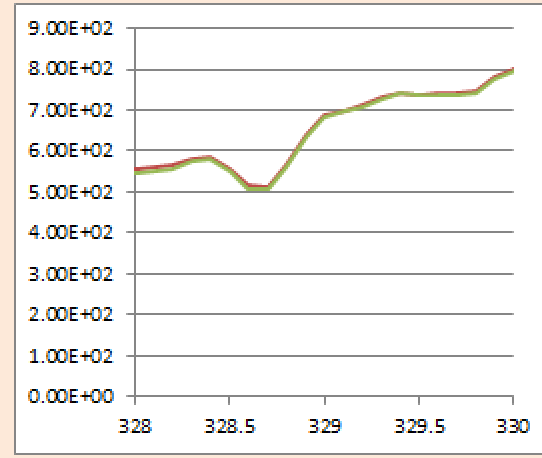
Brewer spectrophotometer

The measurement of the atmospheric ozone





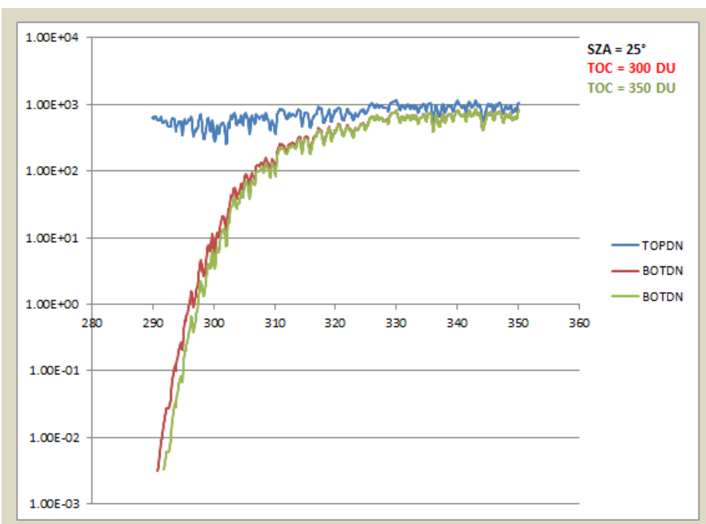
Downward irradiance at 308.8 nm



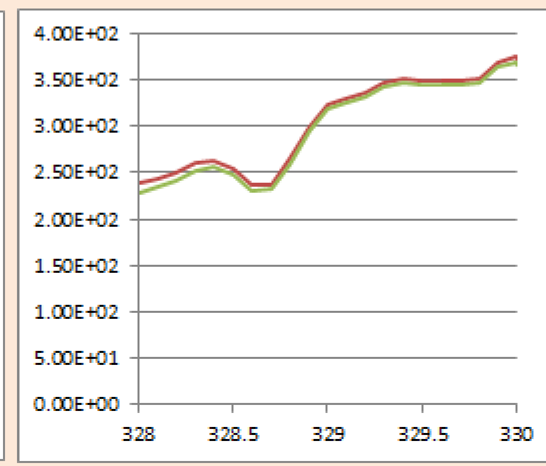
Downward irradiance at 329.1 nm

Units: W/m²/µm

ground: absorption/transmission



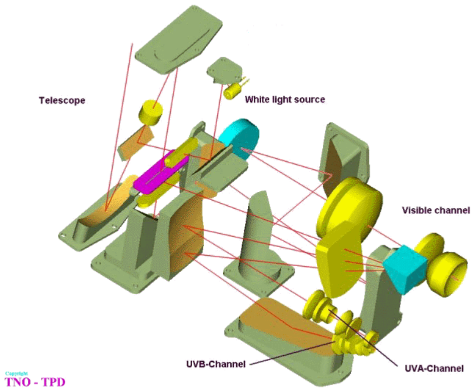
Upward irradiance at 308.8 nm

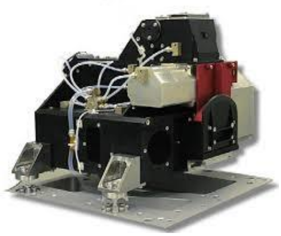


Upward irradiance at 329.1 nm

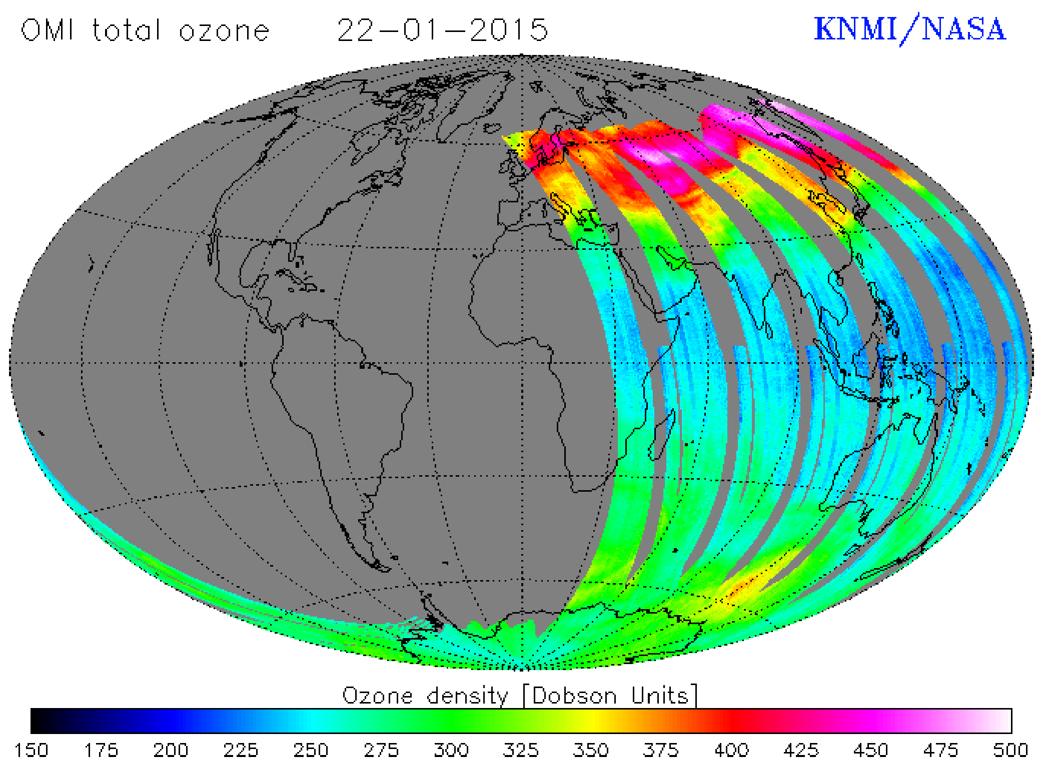
top: reflection

The measurement of the atmospheric ozone





TOMS: Total Ozone Mapping Spectrometer
OMI: Ozone Monitoring Instrument



1979–1993
TOMS instrument onboard the NASA/NOAA Nimbus-7 satellite.

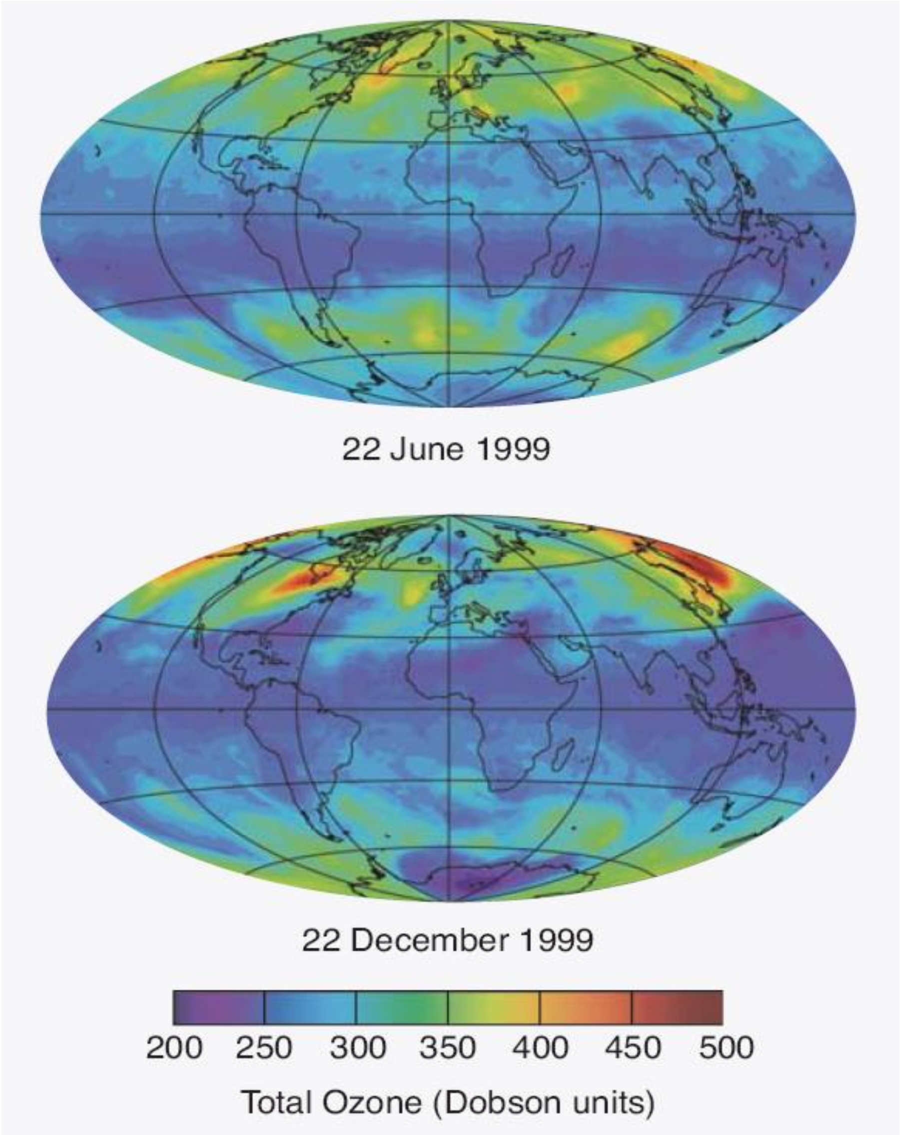
1993–1994
TOMS instrument on the Soviet-built Meteor-3 satellite.

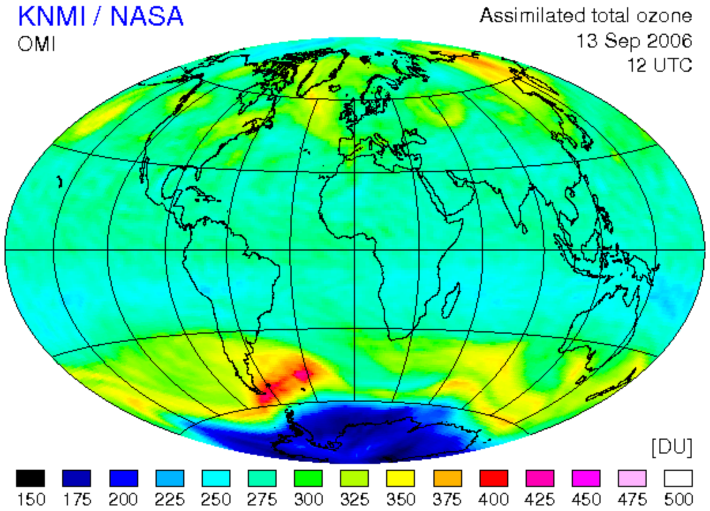
1996–October 2004
TOMS instrument on the NASA Earth Probe satellite.

November 2004 - now
OMI (KNMI) instrument onboard the NASA Aura satellite.

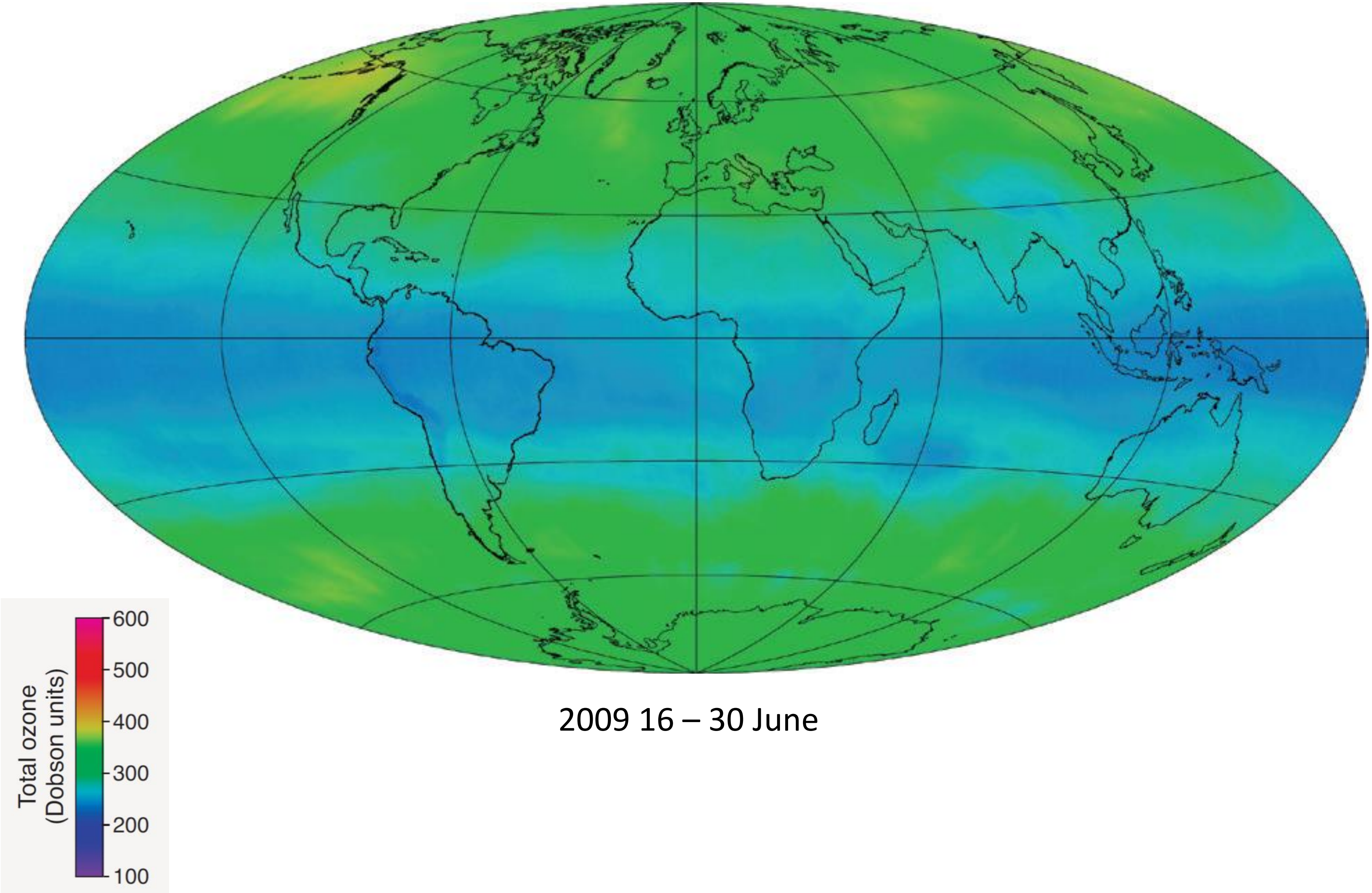
http://www.temis.nl/protocols/O3total.html
http://www.temis.nl/protocols/o3field/data/omi/forecast/today_wd.gif

The global distribution



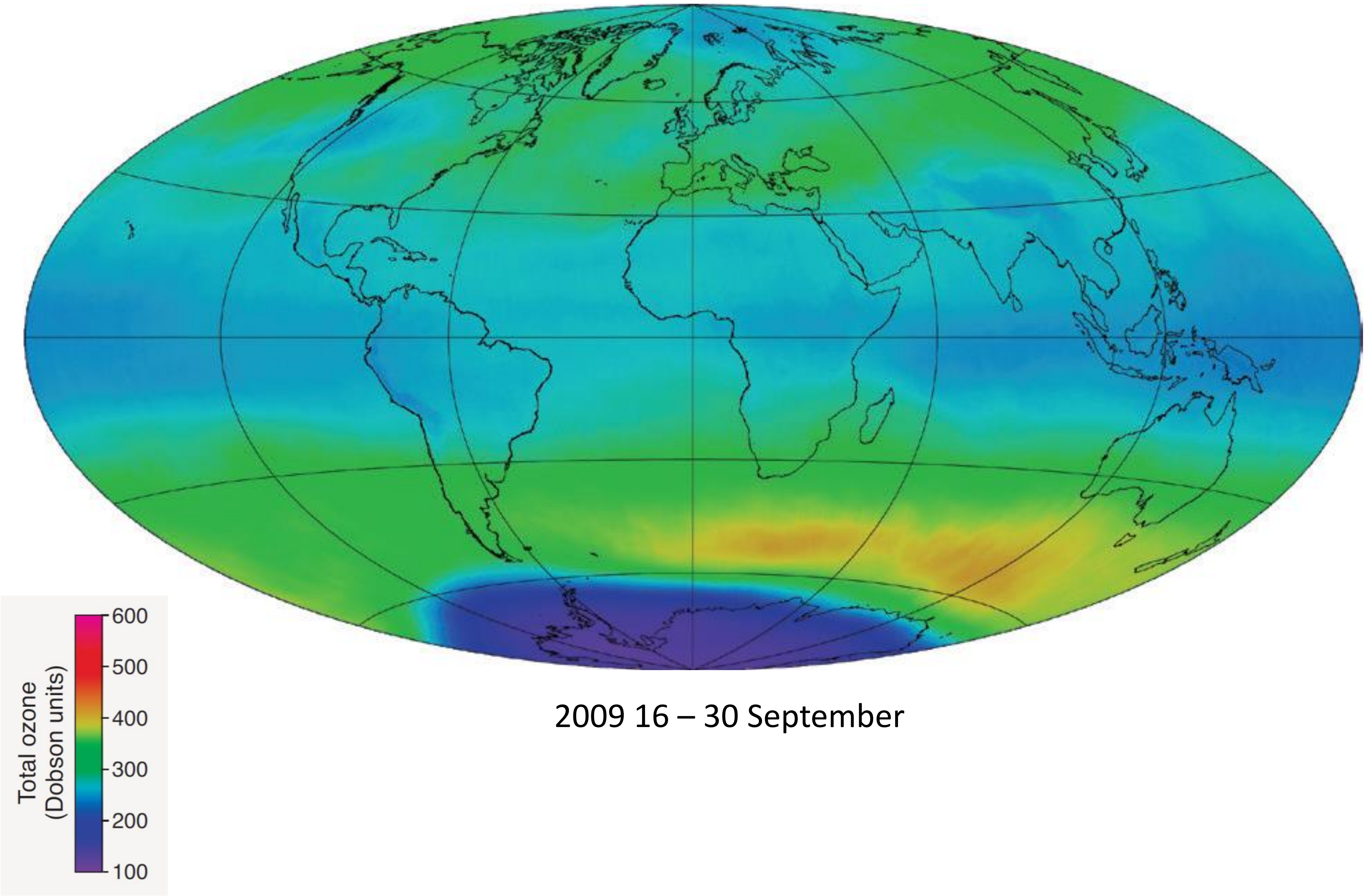


The seasonal evolution



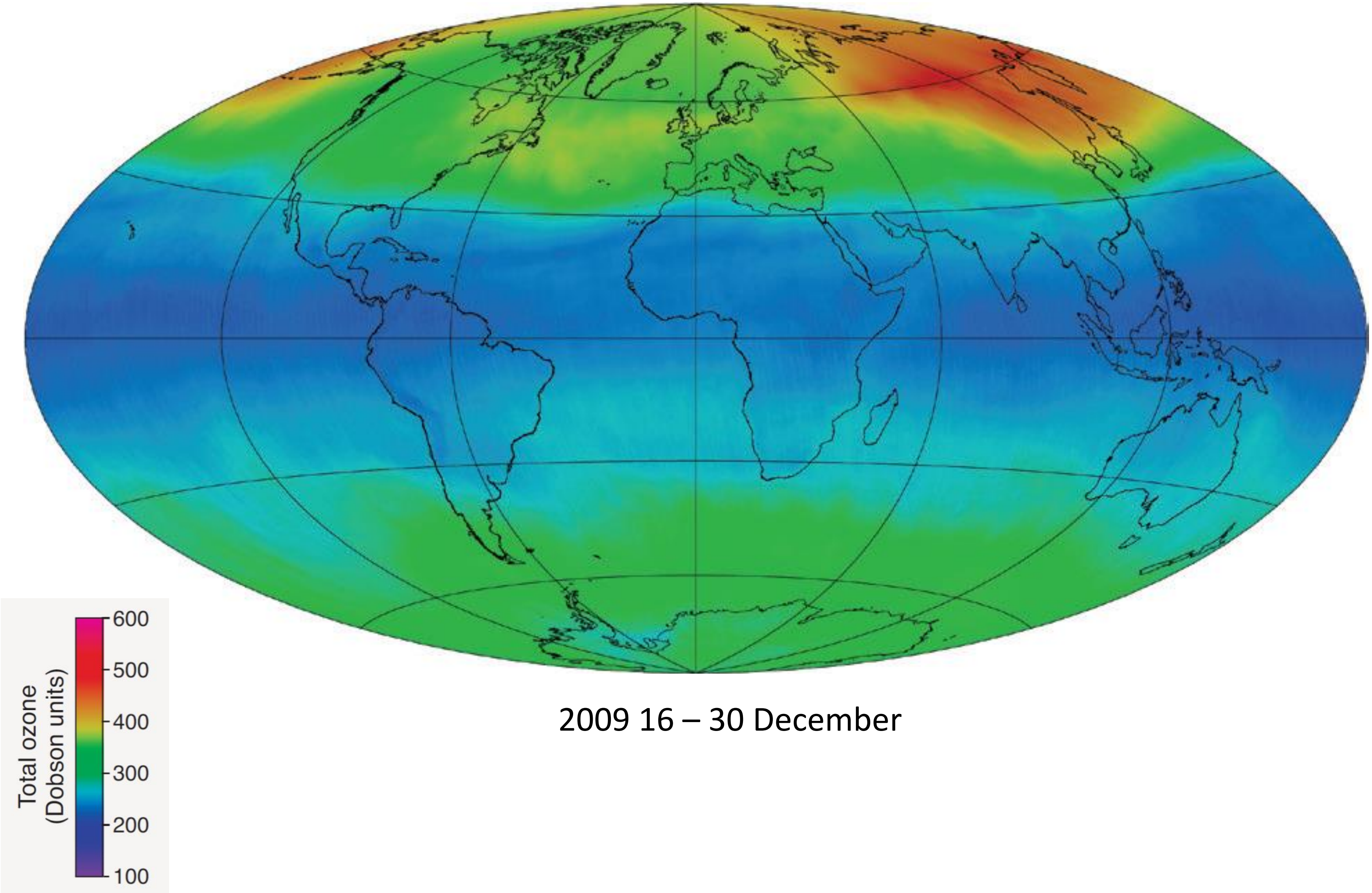
2009 16 – 30 June

The seasonal evolution



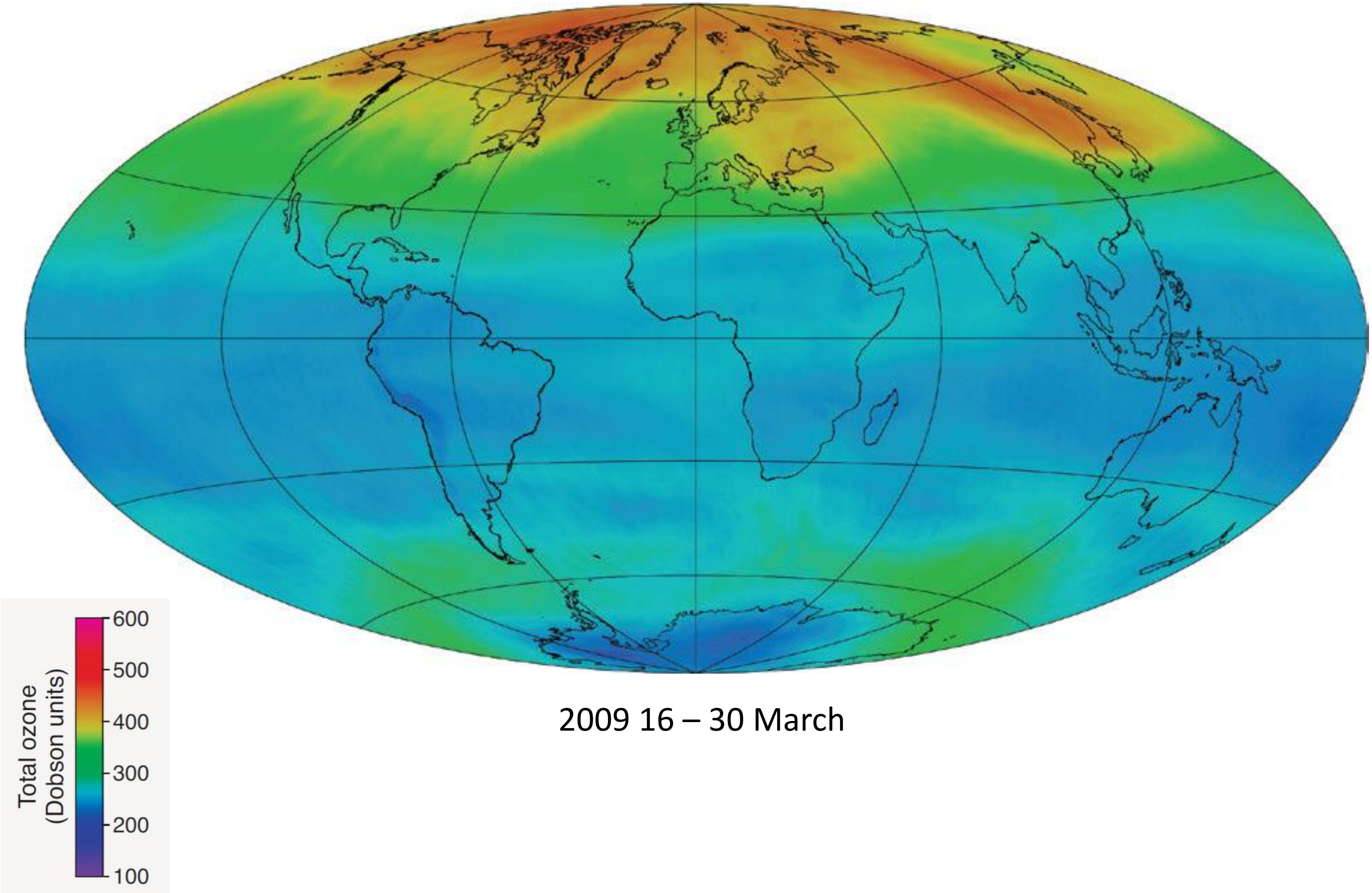
2009 16 – 30 September

The seasonal evolution



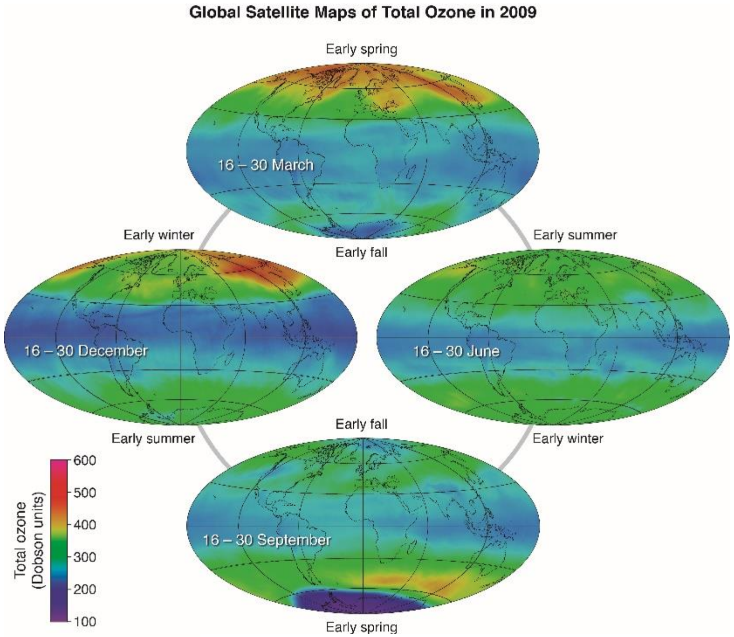
2009 16 – 30 December

The seasonal evolution



2009 16 – 30 March

The seasonal evolution



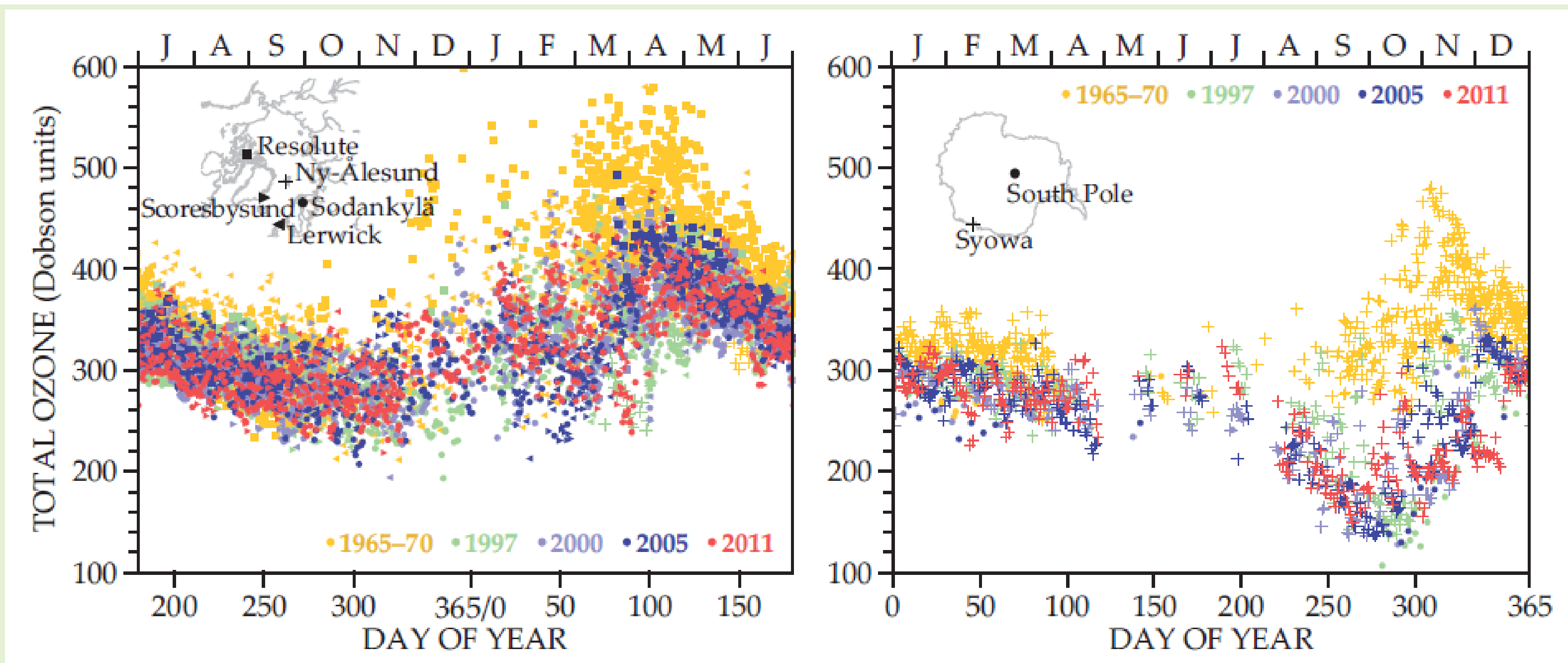


Fig. 4. Douglass et al (2014)

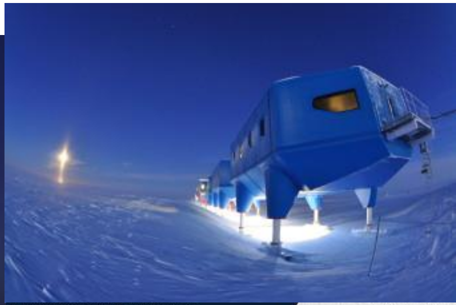
3

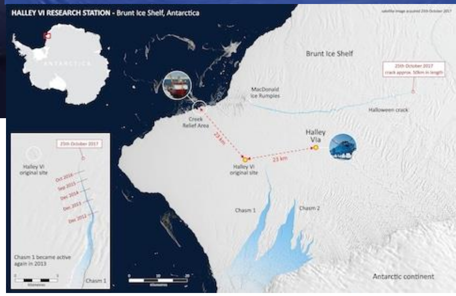
The ozone hole

Discovering of the Ozone Hole

- In the early 1970s, Crutzen, Molina and Rowland alert about CFCs stability and growing source and concentrations of stratospheric chlorine
- The first decreases in Antarctic total ozone were observed in the early 1980s over research stations located on the Antarctic continent (ground-based Dobson spectrophotometers).
- Unusual low total ozone column during the late winter/early spring months of September, October, and November, compared with previous observations made as early as 1957.
- The early published reports came from the British Antarctic Survey and the Japan Meteorological Agency; more widely known in the international community after three scientists from the British Antarctic Survey published them in the journal *Nature* in 1985.
- Satellite measurements confirmed the austral spring ozone depletion and further showed that in each late winter/early spring, the depletion extended over a large region near the South Pole.
- The term "ozone hole" came about from satellite images of total ozone that showed very low values encircling the Antarctic continent each spring.

Farman , Gardiner, and Shanklin
(British Antarctic Survey)





http://www.telegraph.co.uk/science/2017/10/31/halloween-crack-forces-british-antarctic-survey-abandon-research/

The chlorine role

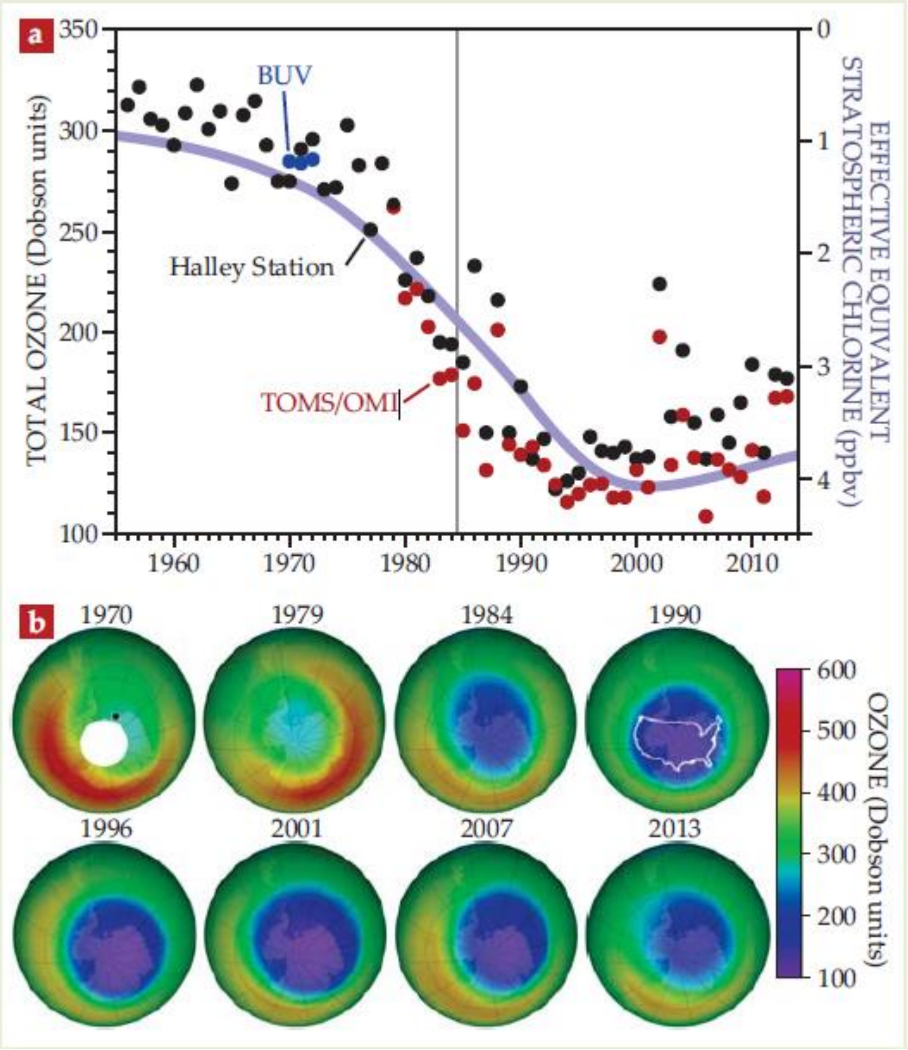
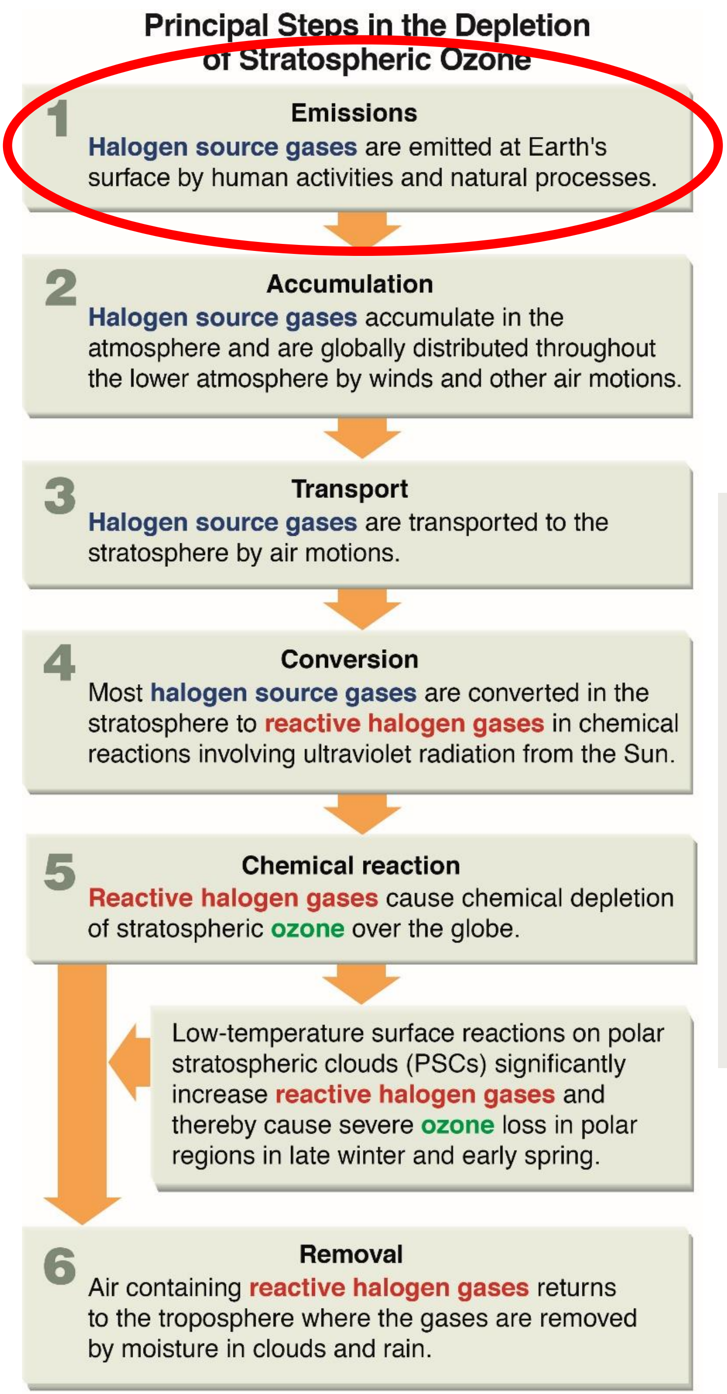
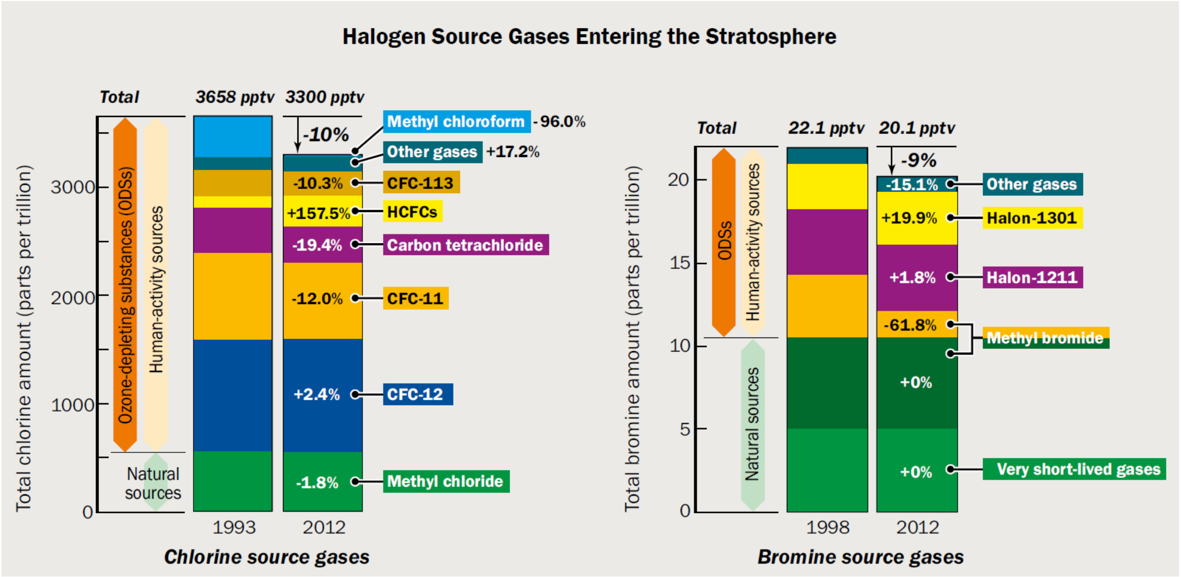


Fig. 1. Douglass et al (2014)

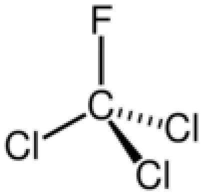


Depletion of Stratospheric Ozone.



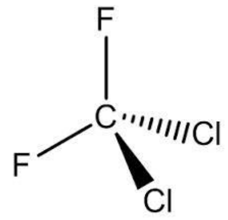
CFC-11

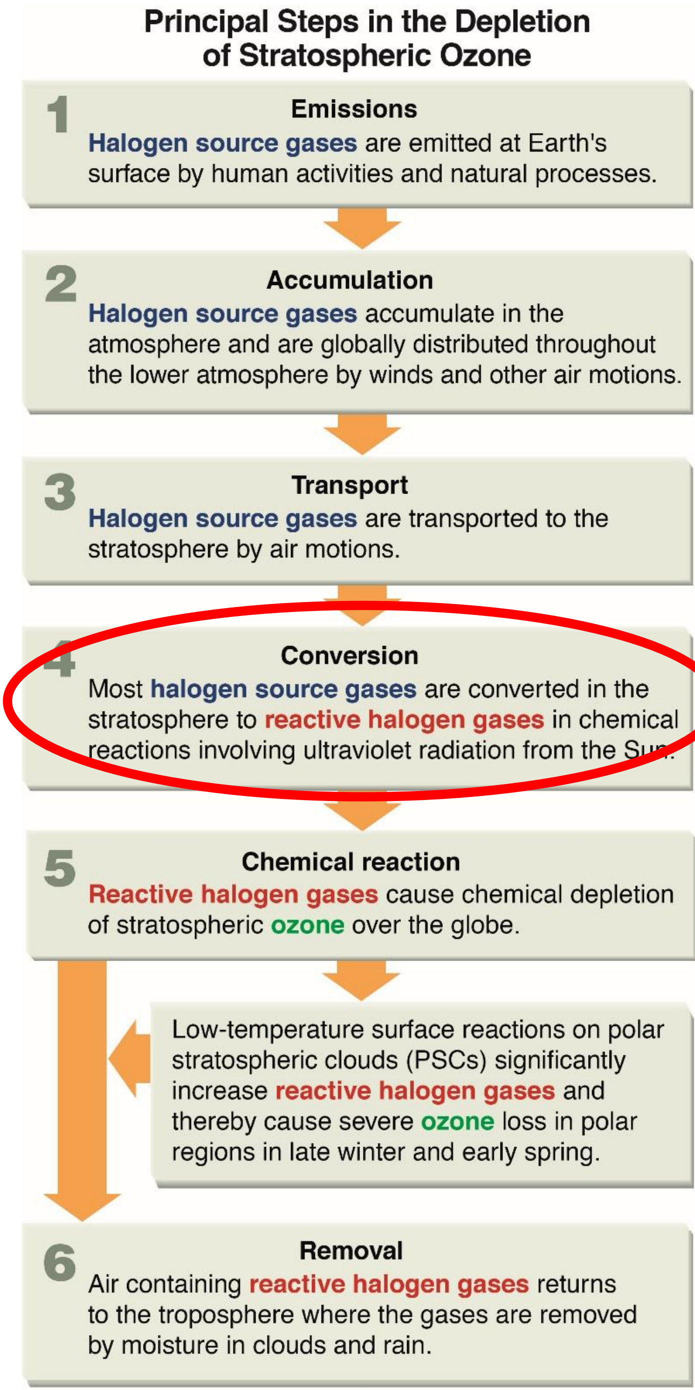
52 yr life

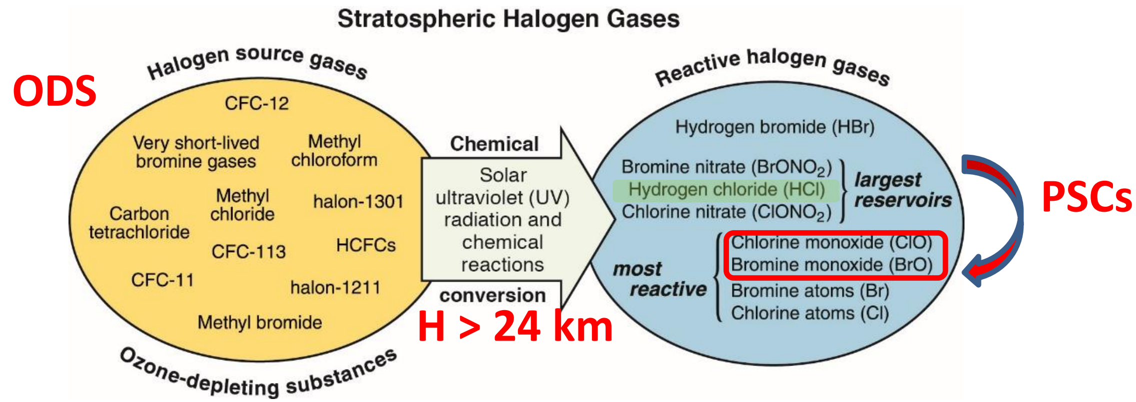


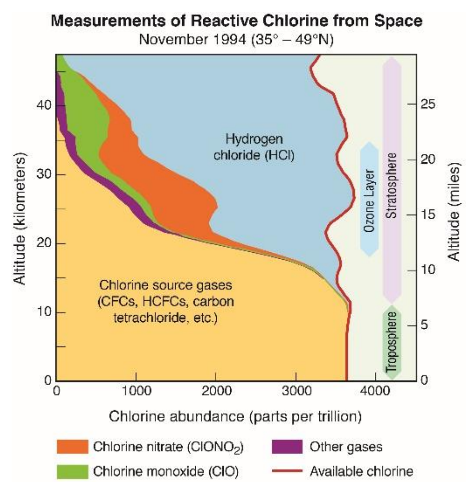
CFC-12

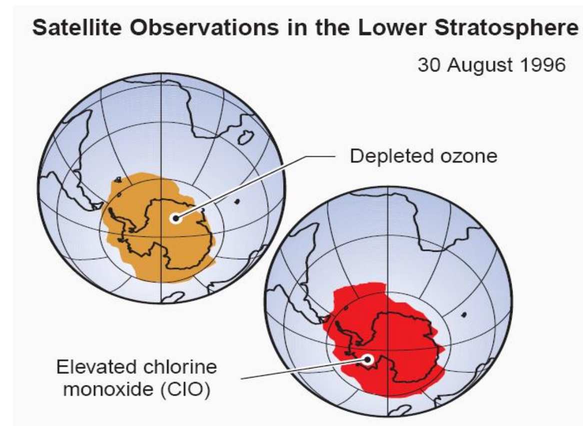
102 yr life

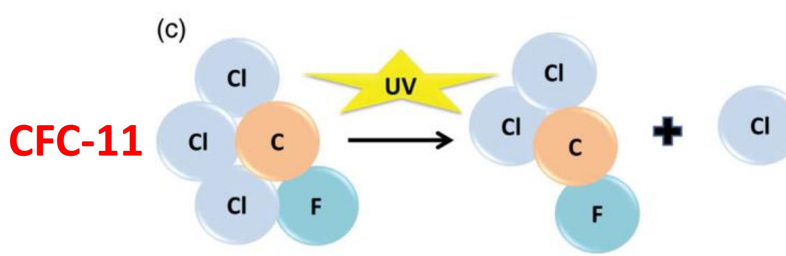



Principal Steps in the Depletion of Stratospheric Ozone
1
Emissions
Halogen source gases are emitted at Earth's surface by human activities and natural processes.
2
Accumulation
Halogen source gases accumulate in the atmosphere and are globally distributed throughout the lower atmosphere by winds and other air motions.
3
Transport
Halogen source gases are transported to the stratosphere by air motions.
4
Conversion
Most halogen source gases are converted in the stratosphere to reactive halogen gases in chemical reactions involving ultraviolet radiation from the Sun.
5
Chemical reaction
Reactive halogen gases cause chemical depletion of stratospheric ozone over the globe.
Low-temperature surface reactions on polar stratospheric clouds (PSCs) significantly increase reactive halogen gases and thereby cause severe ozone loss in polar regions in late winter and early spring.
6
Removal
Air containing reactive halogen gases returns to the troposphere where the gases are removed by moisture in clouds and rain.


Stratospheric Halogen Gases
ODS
Halogen source gases
CFC-12
Very short-lived bromine gases
Methyl chloroform
Methyl chloride
Carbon tetrachloride
halon-1301
CFC-113
HCFCs
CFC-11
halon-1211
Methyl bromide
Ozone-depleting substances
Chemical
Solar ultraviolet (UV) radiation and chemical reactions
conversion
H > 24 km
Reactive halogen gases
Hydrogen bromide (HBr)
Bromine nitrate ($BrONO_2$)
Hydrogen chloride (HCl)
Chlorine nitrate ($ClONO_2$)
largest reservoirs
most reactive
Chlorine monoxide (ClO)
Bromine monoxide (BrO)
Bromine atoms (Br)
Chlorine atoms (Cl)
PSCs


Measurements of Reactive Chlorine from Space
November 1994 (35° – 49°N)
Altitude (kilometers)
Altitude (miles)
Hydrogen chloride (HCl)
Chlorine source gases (CFCs, HCFCs, carbon tetrachloride, etc.)
Ozone Layer
Stratosphere
Troposphere
0
1000
2000
3000
4000
Chlorine abundance (parts per trillion)
Chlorine nitrate ($ClONO_2$)
Chlorine monoxide (ClO)
Other gases
Available chlorine


Satellite Observations in the Lower Stratosphere
30 August 1996
Depleted ozone
Elevated chlorine monoxide (ClO)


(c)
CFC-11
Cl
Cl
C
Cl
F
UV
Cl
Cl
C
F
Cl

Principal Steps in the Depletion of Stratospheric Ozone

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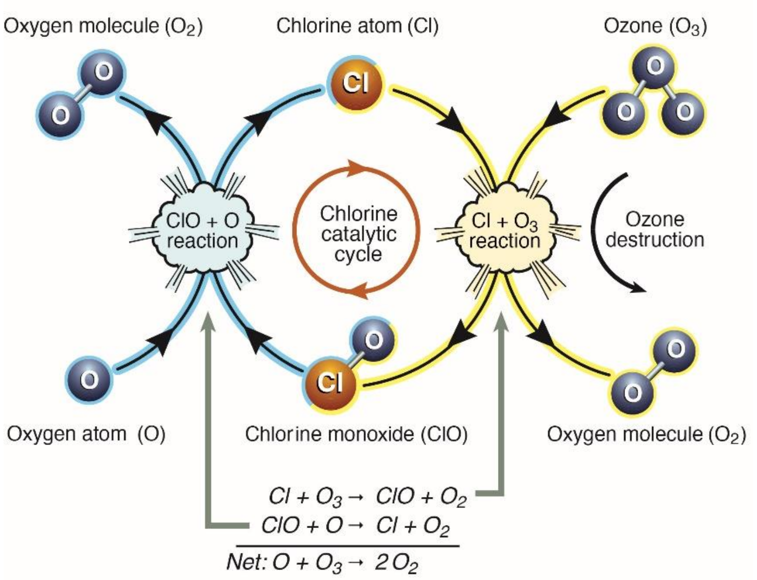
6 Removal
Air containing reactive halogen gases returns to the troposphere where the gases are removed by moisture in clouds and rain.

Ozone Destruction Cycle 1



10^3–10^5 cycles before deactivation !!!

Ozone Destruction Cycles in Polar Regions

Cycle 2

$ClO + ClO \rightarrow (ClO)_2$

$(ClO)_2 + \text{sunlight} \rightarrow ClOO + Cl$

$ClOO \rightarrow Cl + O_2$

$2(Cl + O_3 \rightarrow ClO + O_2)$

Net: $2O_3 \rightarrow 3O_2$

Cycle 3

$ClO + BrO \rightarrow Cl + Br + O_2$

or $\left(\begin{array}{l} ClO + BrO \rightarrow BrCl + O_2 \\ BrCl + \text{sunlight} \rightarrow Cl + Br \end{array} \right)$

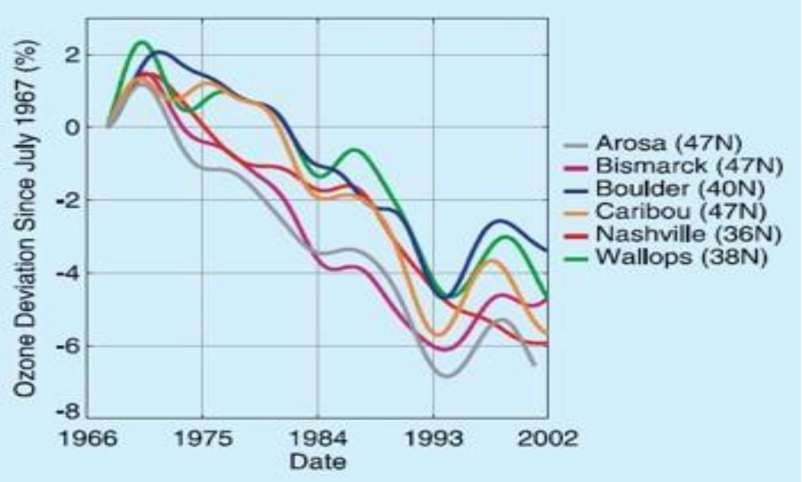
$Cl + O_3 \rightarrow ClO + O_2$

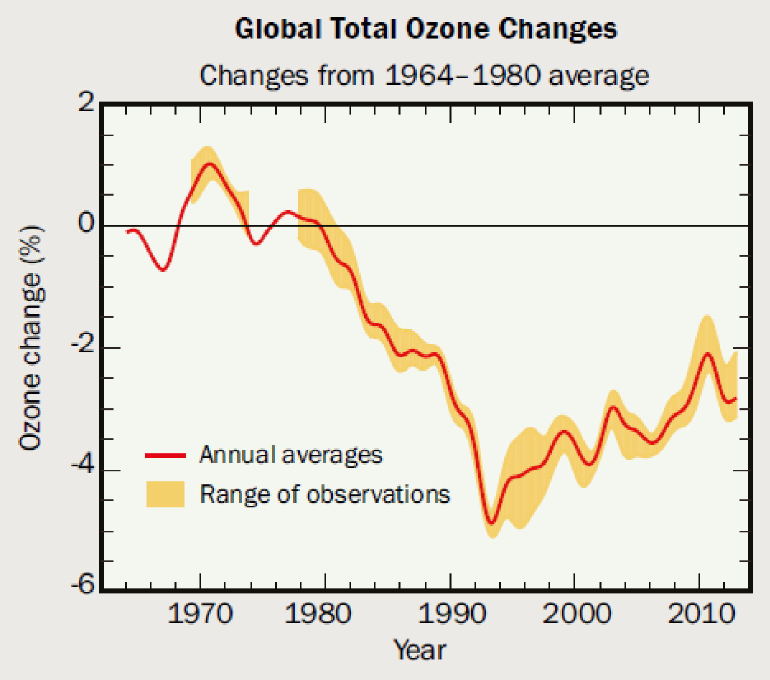
$Br + O_3 \rightarrow BrO + O_2$

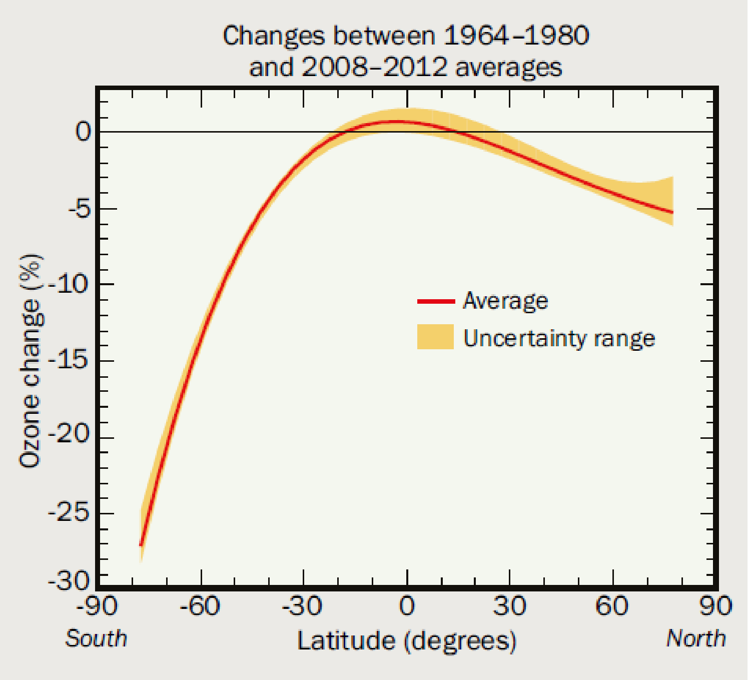
Net: $2O_3 \rightarrow 3O_2$

No O needed → no UV needed !

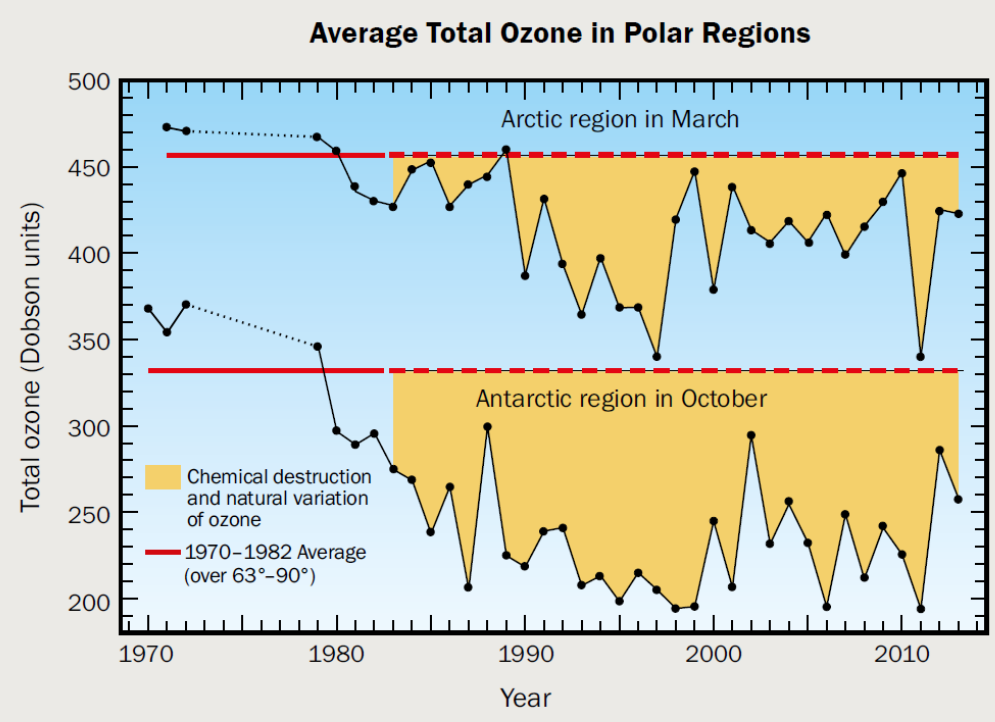
The global depletion

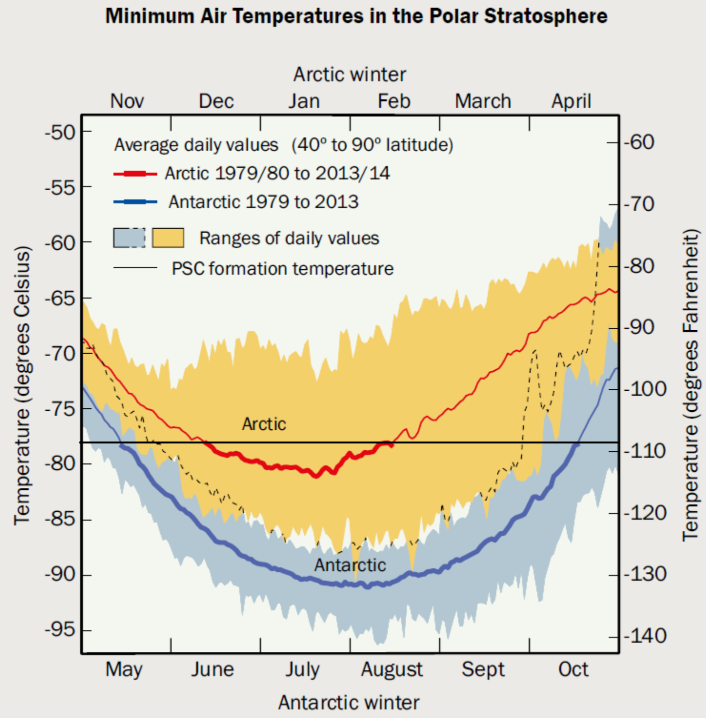




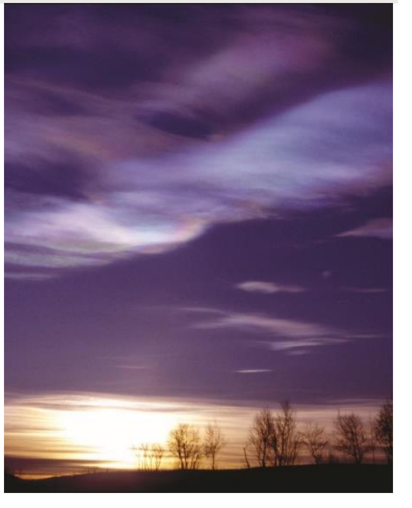


Arctic vs Antarctic hole





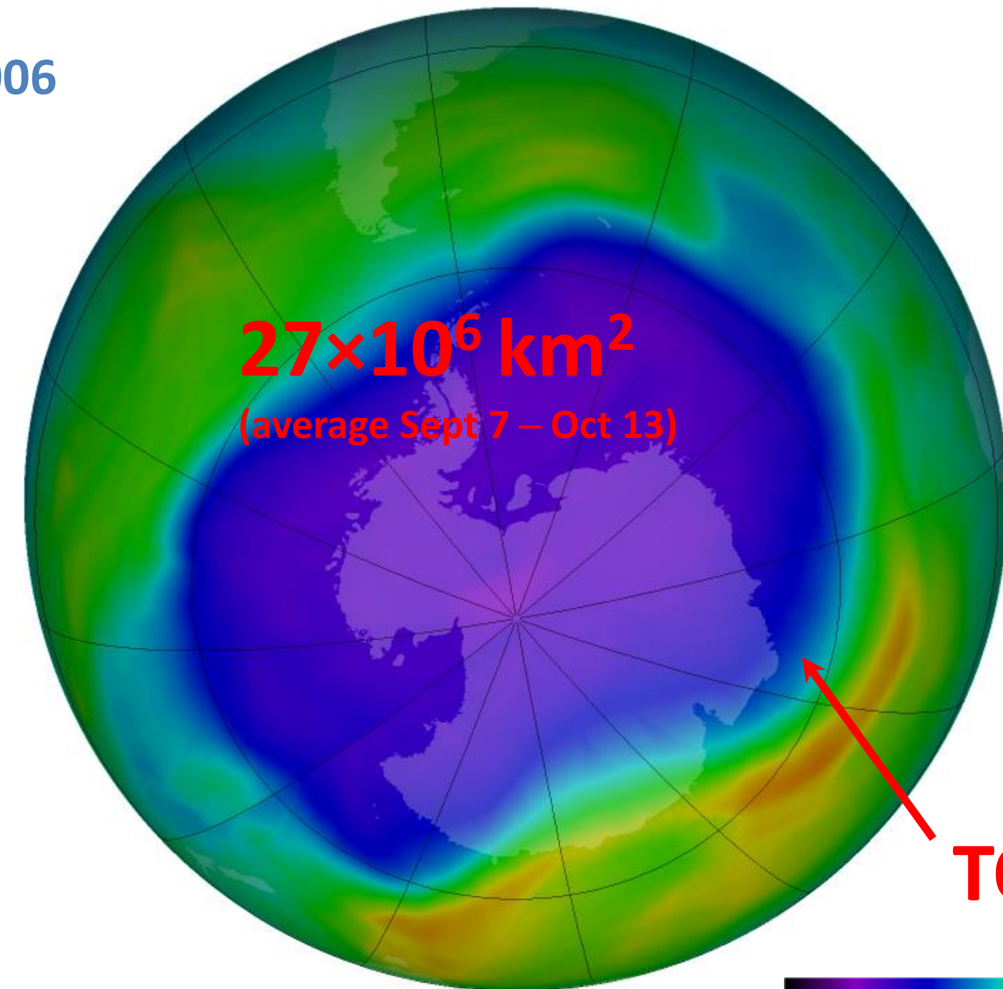
- **Isolation**: The Antarctic polar winter leads to the formation of the polar vortex which isolates the air within it.
- **Formation of PSC:** Cold temperatures form inside the vortex; cold enough for the formation of Polar Stratospheric Clouds (PSCs). As the vortex air is isolated, the cold temperatures and the PSCs persist.
- **Activation:** Once the PSCs form, heterogeneous reactions take place and convert the inactive chlorine and bromine reservoirs to more active forms of chlorine and bromine.
- **Catalytic destruction:** No ozone loss occurs until sunlight returns to the air inside the polar vortex and allows the production of active chlorine and initiates the catalytic ozone destruction cycles.

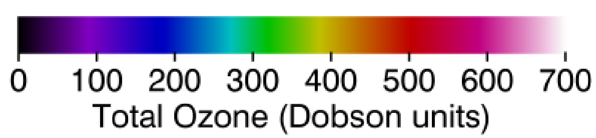


Gas	Atmospheric Lifetime (years)	Global Emissions in 2012 (Kt/yr)[a]	Ozone Depletion Potential (ODP)[c]	Global Warming Potential (GWP)[c]
Halogen source gases				
Chlorine gases[e]				
CFC-11	52	46–68	1	5160
CFC-12	102	16–64	0.73	10300
CFC-113	93	0–7	0.81	6080
Carbon tetrachloride (CCl_4)	26	40–74	0.72	1730
HCFCs	1–18	400–528	0.01–0.10	800–2070
Methyl chloroform (CH_3CCl_3)	5	0–5	0.14	153
Methyl chloride (CH_3Cl)	0.9	2707	0.015	11
Very short-lived Cl-containing gases	less than 0.5	[b]	[b, d] very low	[b] less than 1
Bromine gases				
Halon-1301	72	1.4–2	15.2	6670
Halon-1211	16	0.3–9.3	6.9	1750
Methyl bromide (CH_3Br)	0.8	85	0.57	2
Very short-lived Br-containing gases (e.g., $CHBr_3$)	less than 0.5	[b] 260–1080	[b, d] very low	[b] very low
Hydrofluorocarbons (HFCs)				
HFC-134a	14	144–215	0	1360
HFC-23	228	11–14	0	12500
HFC-143a	51	20–25	0	5080
HFC-125	31	31–47	0	3450
HFC-152a	1.6	40–66	0	148
HFC-32	5.4	12–30	0	700

The largest ozone hole

24 September 2006

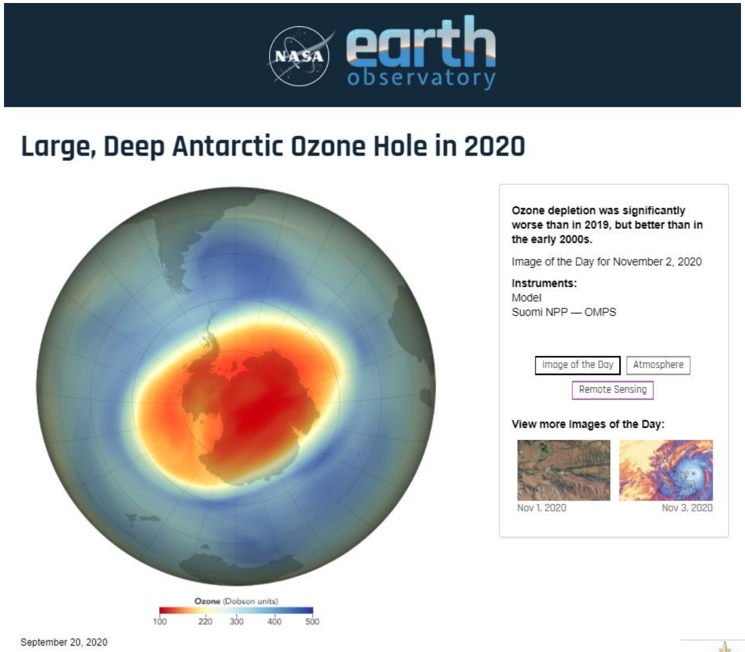




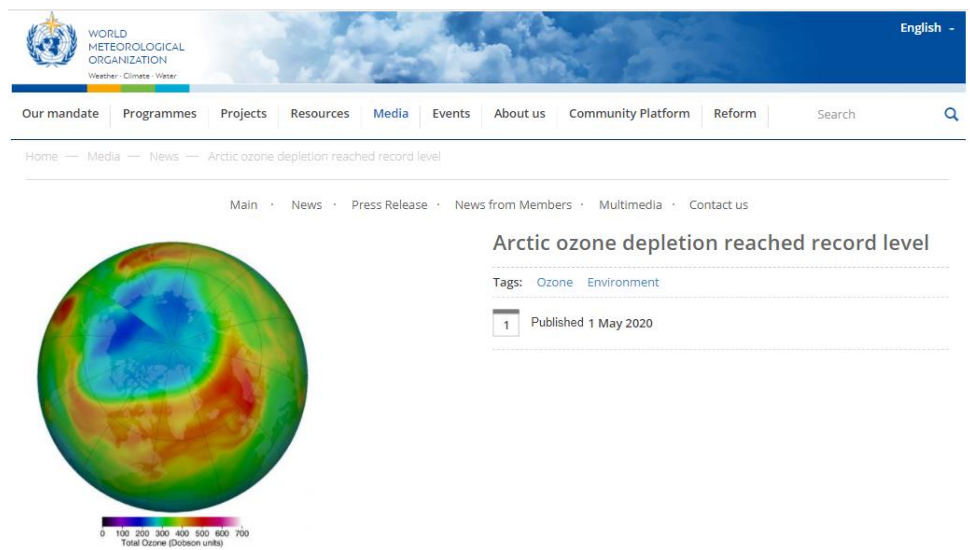
False-color view of total ozone over the Antarctic pole. The purple and blue colors are for low ozone, and the yellows and reds are for high ozone.

http://earthobservatory.nasa.gov/Features/WorldOfChange/ozone.php

2020 NEWS

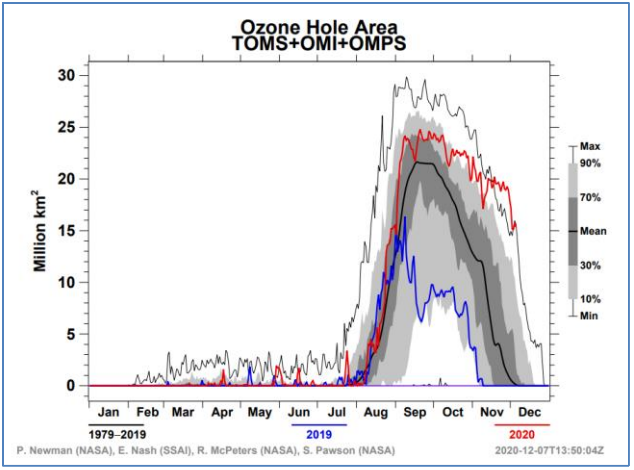


[Large, Deep Antarctic Ozone Hole in 2020 (nasa.gov)]



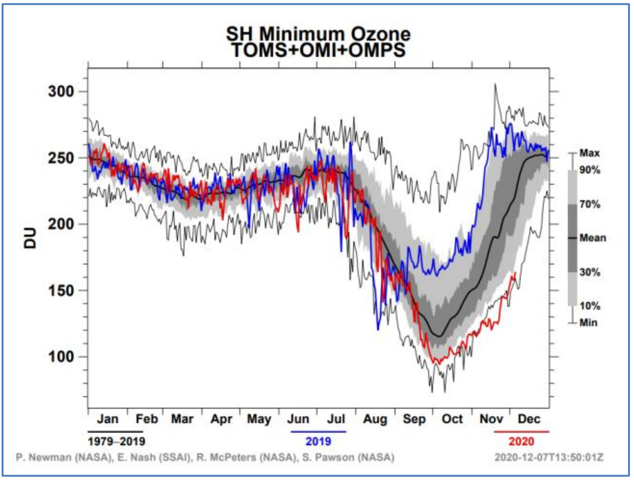
[Arctic ozone depletion reached record level | World Meteorological Organization (wmo.int)]

Ozone hole quantification



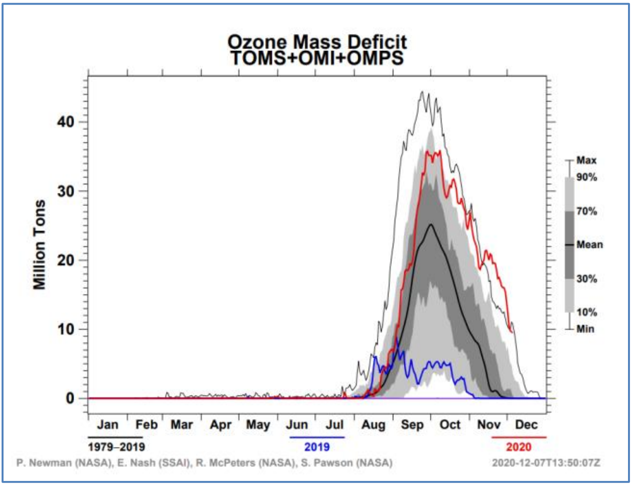
Measure 1: The size of the ozone hole is the area on the globe in million square km with ozone column below 220 DU.

https://ozonewatch.gsfc.nasa.gov/meteorology/figures/ozone/to3areas_2020_toms+omi+omps.pdf



Measure 2: The depth of the ozone hole is the lowest ozone column value in Dobson Units (DU) for latitudes below 30°S.

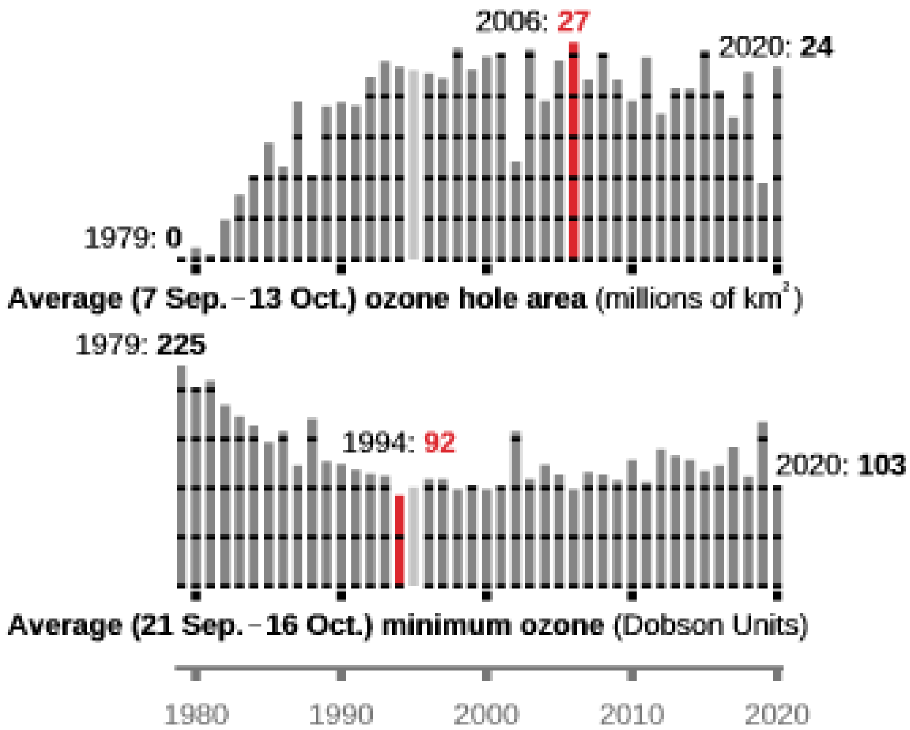
https://ozonewatch.gsfc.nasa.gov/meteorology/figures/ozone/to3mins_2020_toms+omi+omps.pdf



Measure 3: The ozone loss (mass deficit) is the amount of ozone in megaton necessary to fill the ozone hole to 220 DU over the whole area

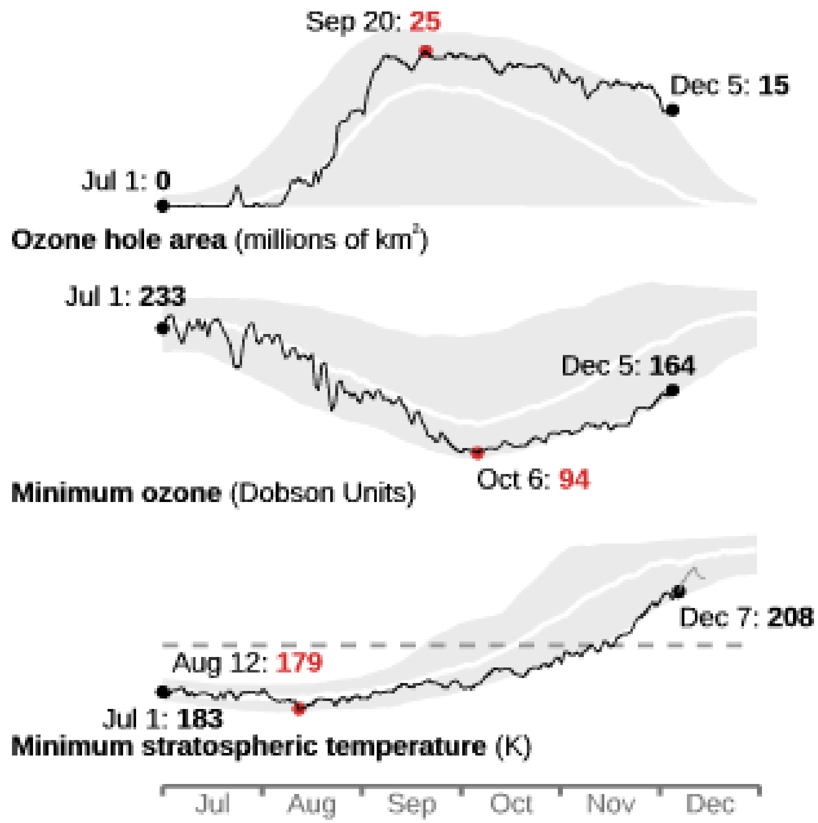
https://ozonewatch.gsfc.nasa.gov/meteorology/figures/ozone/omds_2020_toms+omi+omps.pdf

Annual records



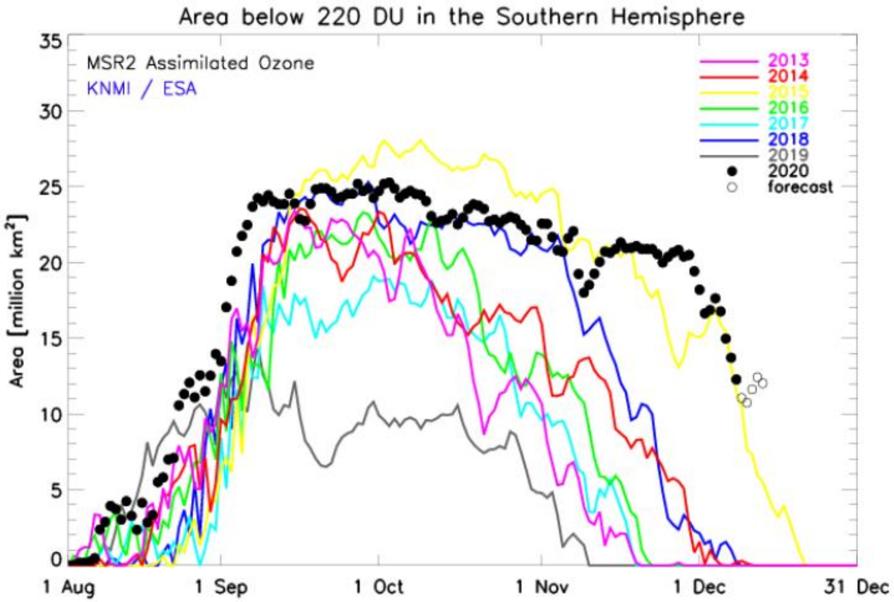
Note: No data were acquired during the 1995 season

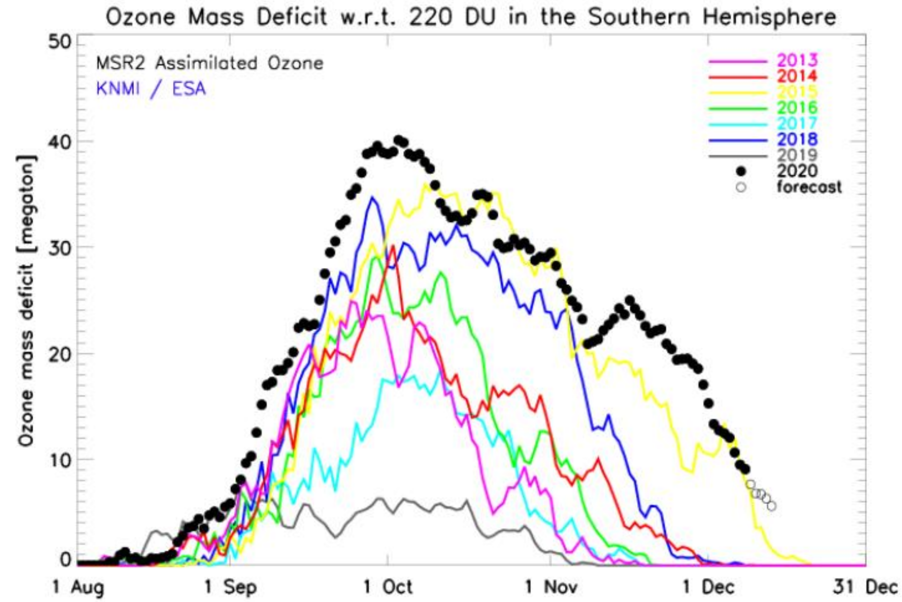
2020 Season



[NASA Ozone Watch: Latest status of ozone](https://ozonewatch.gsfc.nasa.gov/): https://ozonewatch.gsfc.nasa.gov/

Last years

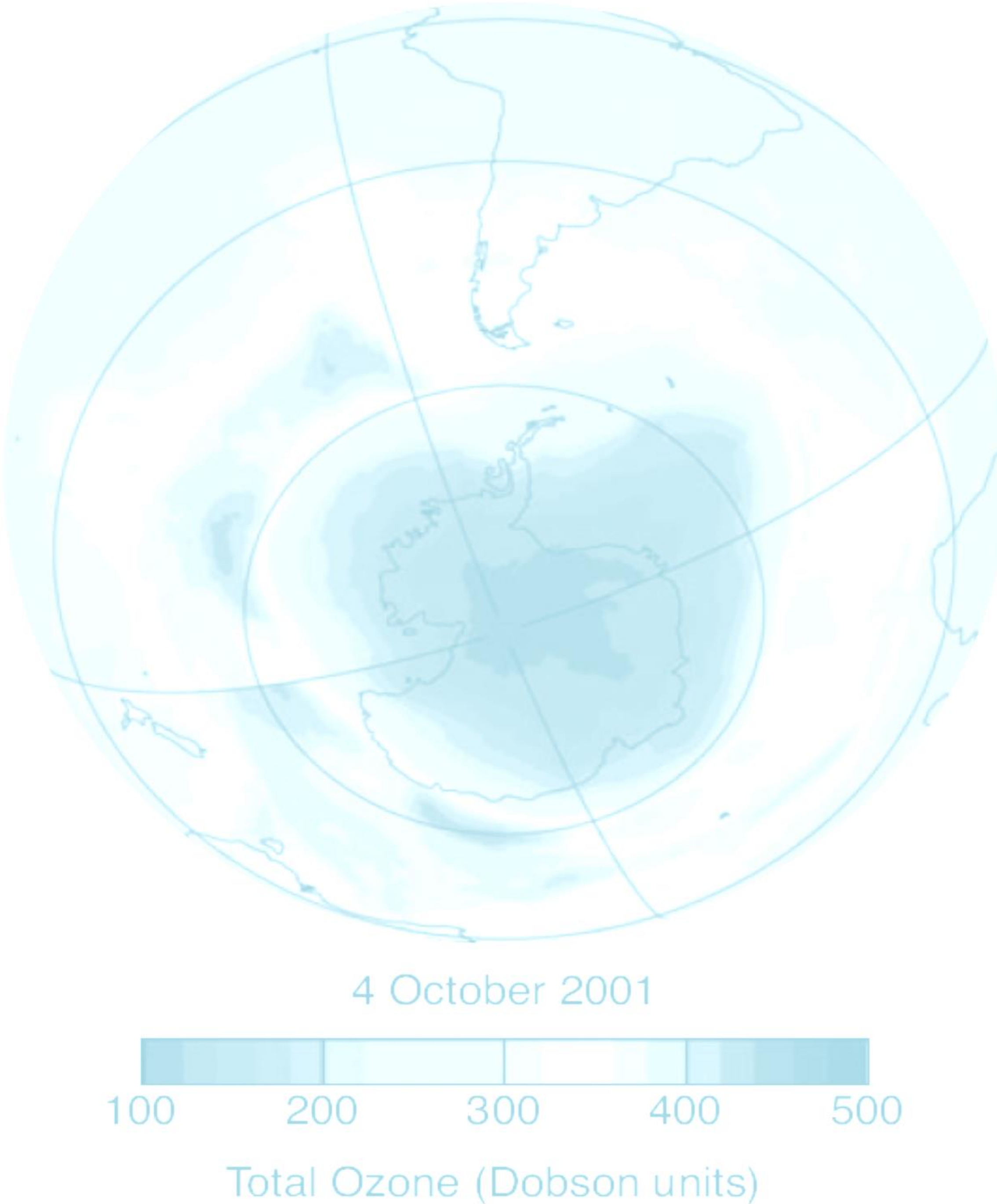




KNMI

Ronald van der A, Bas Mijling

http://www.temis.nl/protocols/o3hole/o3_history.php



4
Effects of UV

Effects

HUMANS
Skin
Immune system
Eyes

NATURAL TERRESTRIAL ECOSYSTEMS, CROPS, FORESTS

AQUATIC LIFE

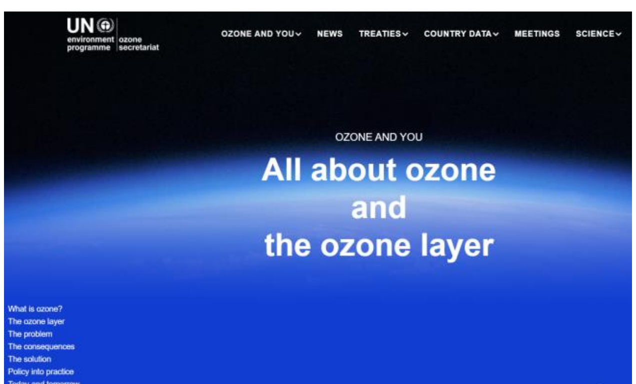
ENVIRONMENTAL PROCESSES AND SYSTEMS

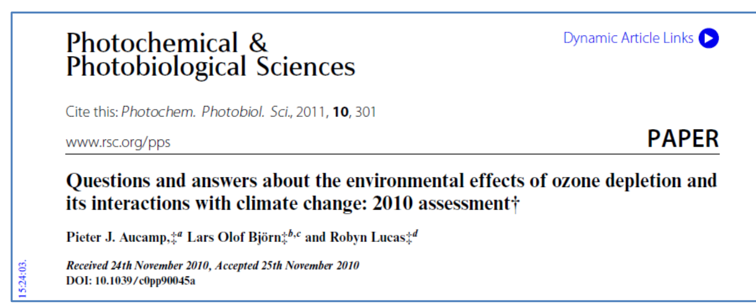
FOOD SECURITY

AIR QUALITY

MATERIALS

RADIATION AUGMENTATION FACTOR

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www.rsc.org/pps

PAPER

Questions and answers about the environmental effects of ozone depletion and its interactions with climate change: 2010 assessment†

Pieter J. Aucamp,‡[a] Lars Olof Björn‡[b,c] and Robyn Lucas‡[d]

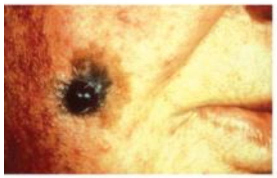
Received 24th November 2010, Accepted 25th November 2010
DOI: 10.1039/c0pp90045a

[Ozone and You | Ozone Secretariat (unep.org)]

Adverse effects of exposure to solar UV-B radiation on human skin

Solar UV-B exposure is the major environmental risk factor in skin cancers

Squamous cell carcinoma



Cutaneous melanoma

Basal cell carcinoma

Examples of the 3 major types of skin cancer. (Photograph supplied by ProfessorM. Norval, University of Edinburgh, Scotland, UK.)

Acute overexposure of the skin to solar UV radiation causes sunburn; chronic sunlight exposure can lead to the development of skin cancers.

- Sunburn (acute)   UVI = 10 → 15 min
- Chronic exposure + sunburn episodes → skin cancers
- Non-melanoma
  - Basal cell carcinoma
  - Squamuous cell carcinoma
- Cutaneous melanoma
  - Increasing in many countries
  - Higher incidence in fair-skinned individuals and for age > 20 yr

Effects on the immune system (IS)

The immune system can be suppressed by exposure of the skin and eyes to UV-B radiation leading to reduced immune responses to infectious agents and skin cancers, but a potentially beneficial effect for some autoimmune diseases.

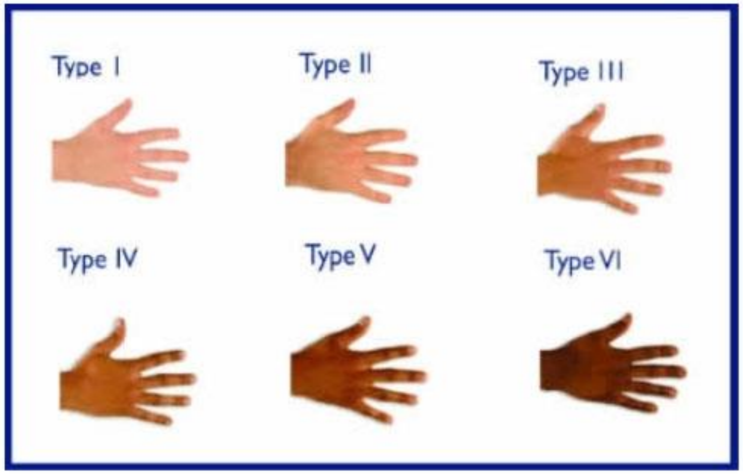
Cold sores caused by reactivation of latent herpes simplex virus following exposure to solar UV-B radiation. (Photograph supplied by Professor M. Norval, University of Edinburgh, Scotland, UK).

- Chromophores → cascade of events affecting IS
- → Induce lymphocytes T regulatory cells
- Increase symptoms and duration of disease caused by infection
- Reduce immunization and effectiveness of vaccination
- Triggers the reactivation of latent virus
- Inmunosuppresion → interacts with papillomavirus and basal/squamous cell carcinomas
- Benefits for some autoimmune diseases

The erythemal effect in different skins

Table 9b Skin types

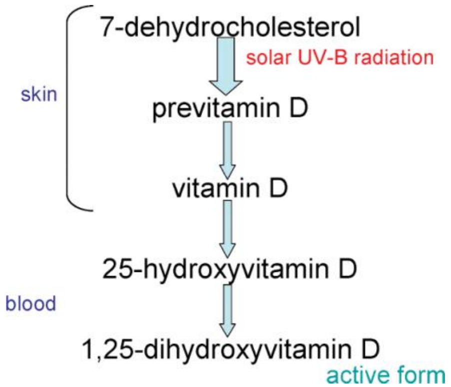
Phototype/ethnicity	UV sensitivity	Sunburn/tan
I/White Caucasian	Extremely sensitive	Always burns, never tans
II/White Caucasian	Very sensitive	Burns readily, tans slowly and with difficulty
III/White Caucasian	Moderately sensitive	Can burn after high exposure, tans slowly
IV/White Caucasian, often south Mediterranean	Relatively tolerant	Burns rarely, tans easily
V/Brown, Asian/Middle Eastern	Variable	Can burn easily, difficult to assess as pigment is already present
VI/Black, Afro-Caribbean	Relatively insensitive	Rarely burns



UV Index	Skin Type: I and II	III and IV	V	VI
1, 2	low	low	low	low
3, 4	medium	low	low	low
5	high	medium	low	low
6	high	medium	medium	low
7, 8, 9	very high	high	medium	medium
[illegible]	very high	high	high	medium

… but we need some UV doses

A major benefit to human health of exposure to UV-B radiation is the production of vitamin D.



Simplified metabolic pathway leading to the active form of vitamin D (1,25-dihydroxyvitamin D).

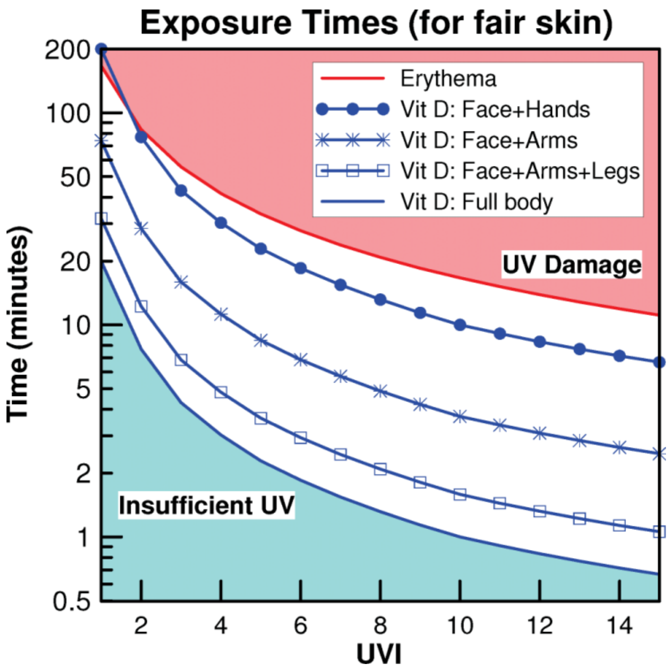
- Food (oily fish, eggs) only provides 10% of needs
- Synthesis is more difficult for dark skin and old individuals

How much time should I spend in the sun in order to produce sufficient vitamin D but avoid sunburn and minimise the risk of skin cancer?

There is no short and simple answer to this question but some guidance is given in the table and the figure

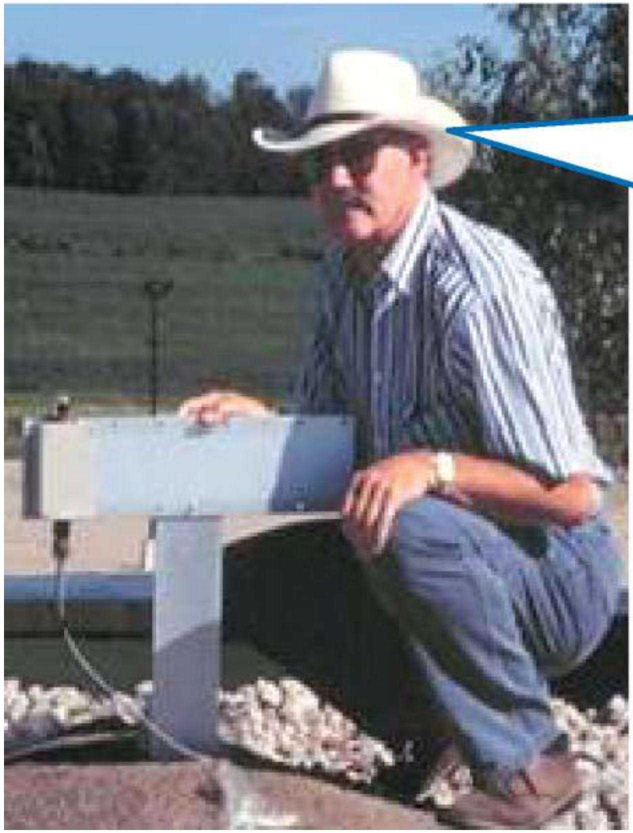
Table 9g Estimates of daily variations in sunburning UV radiation and in the UV radiation needed to make vitamin D at mid-latitudes (from R. L. McKenzie, J. B. Liley and L. O. Björn, UV radiation: balancing risks and benefits, *Photochem. Photobiol.*, 2009, **85**, 88–98)

	Minutes to sunburn	Minutes for sufficient vitamin D, full body exposure	Minutes for sufficient vitamin D, 10% body exposure
Mid-latitude, summer, UV Index 12	15	1	10
Mid-latitude, winter, UV Index 1	180	20	200
Tropics, UV Index 16	10	<1	7



How can I protect myself from the adverse effects of solar UV-B radiation on the skin?

Many protective strategies against excessive exposure to sunlight have been developed, particularly to avoid sunburn.

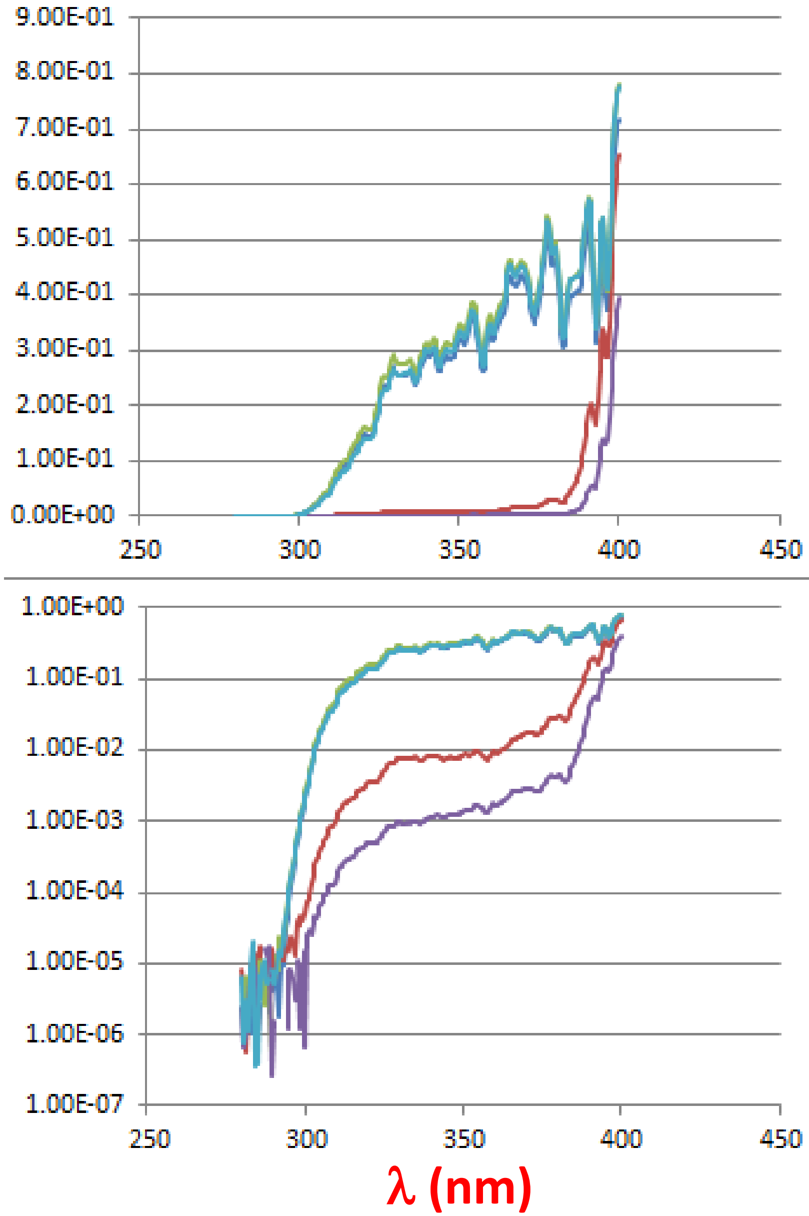


Note the wide brimmed hat, wrap-around glasses and textile clothes. The face and exposed arms should be protected by the use of the correct sunscreen.

Wearing the correct clothing and the use of sunscreen can protect against UV radiation.

(Photograph supplied by Dr A. Cullen, University of Waterloo, Canada.)

When the atmosphere is not enough...



Natural

SPF15

SPF50

Measured global horizontal UV

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Note the wide brimmed hat, wrap-around glasses and textile clothes. The face and exposed arms should be protected by the use of the correct sunscreen.

Wearing the correct clothing and the use of sunscreen can protect against UV radiation.

(Photograph supplied by Dr A. Cullen, University of Waterloo, Canada.)

Effects of exposure to solar UV radiation on the human eye, and, how can the eye be protected?

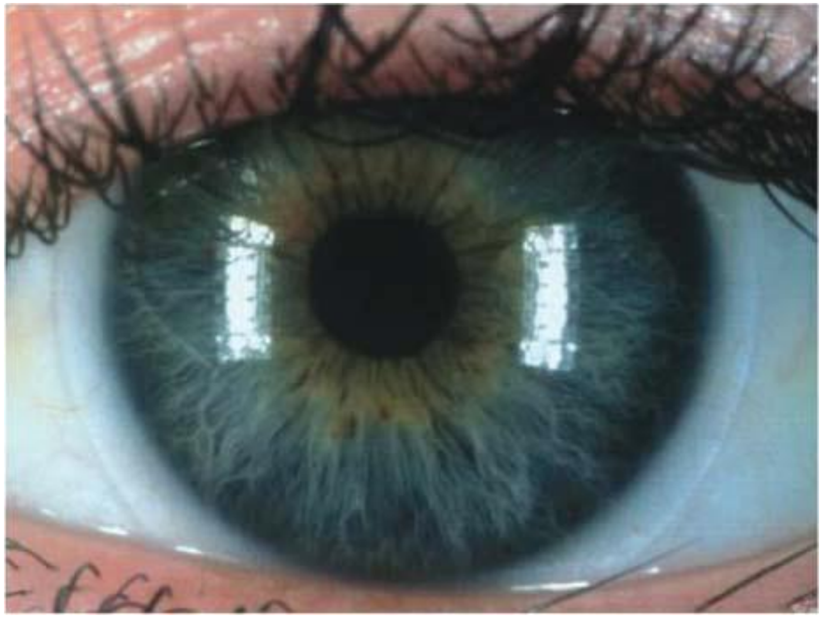


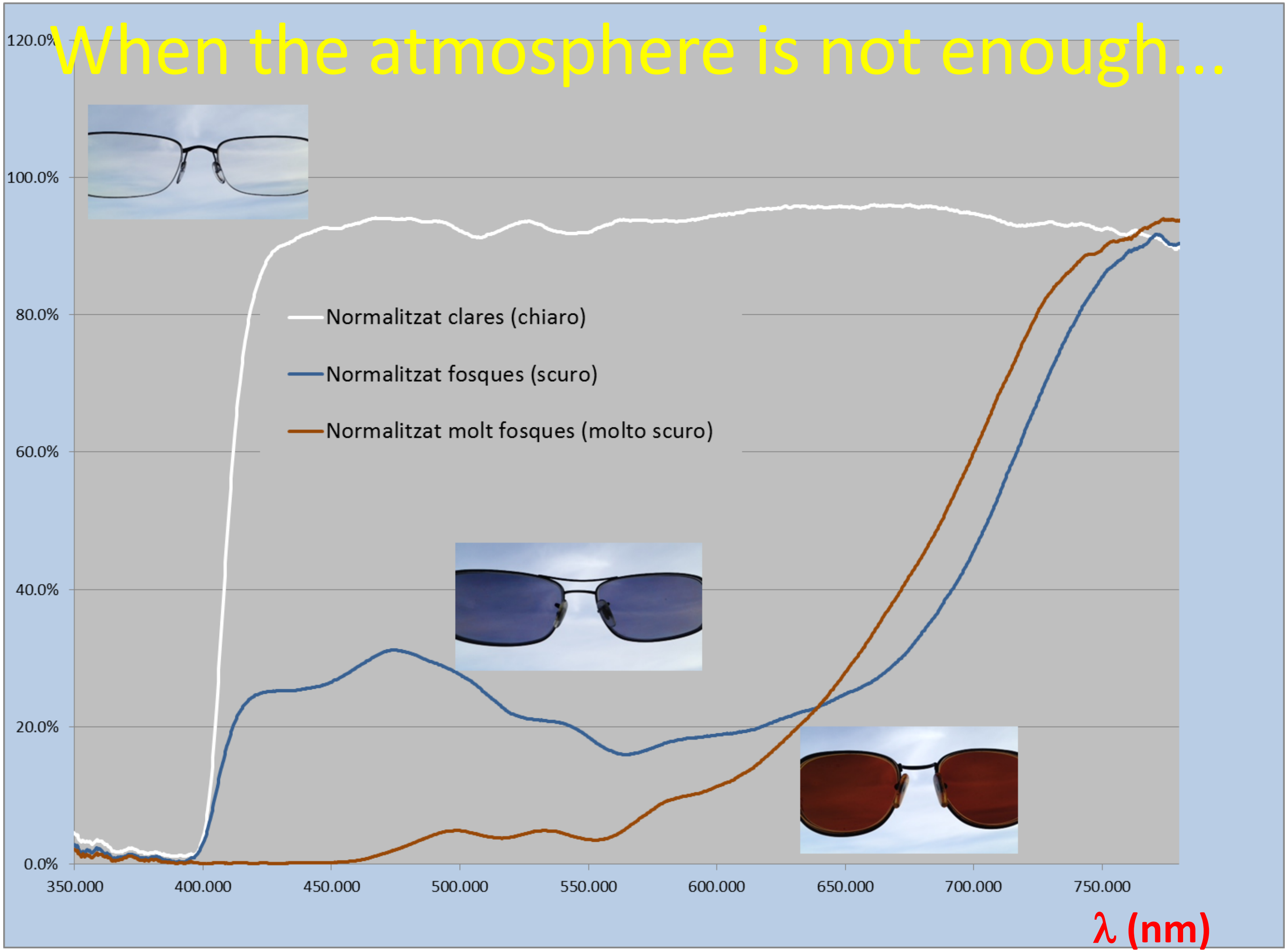
Figure. Soft UV radiation-absorbing contact lens covering the entire cornea.

(Photograph provided by Dr A. Cullen, University of Waterloo, Canada.)

The effects of UV radiation on the eye can be almost immediate (acute), occurring several hours after a short, intense exposure.

They can also be long-term (chronic), following exposure of the eye to levels of UV radiation below those required for the acute effects but occurring repeatedly over a long period of time.

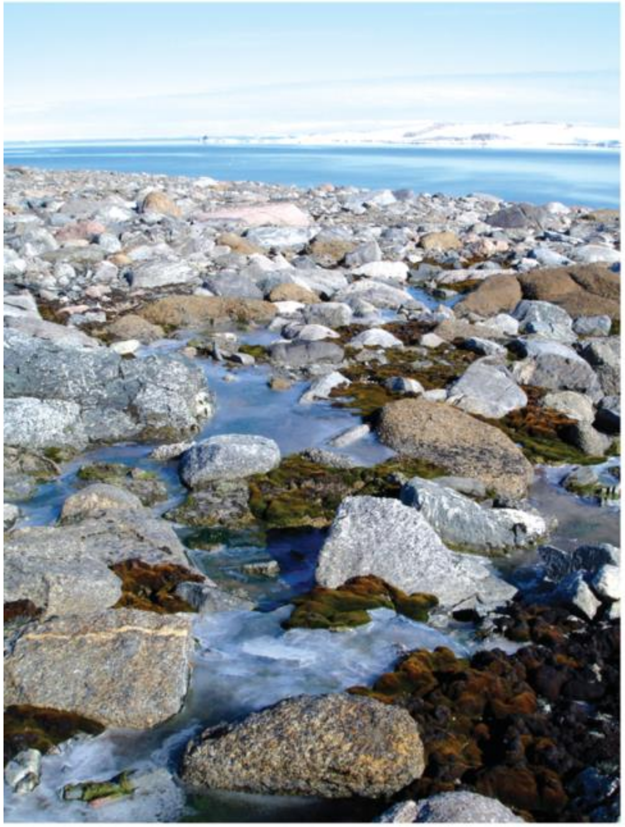
The commonest acute effect, photokeratitis (snow blindness), leaves few or no permanent effects, whereas cataract due to chronic exposure is irreversible and ultimately leads to severe loss of vision requiring surgery.



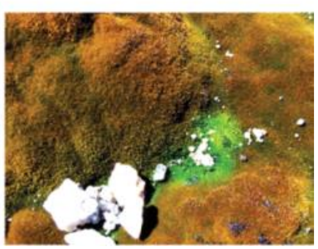
UV400 ✓

Measured UV transmission

A



B

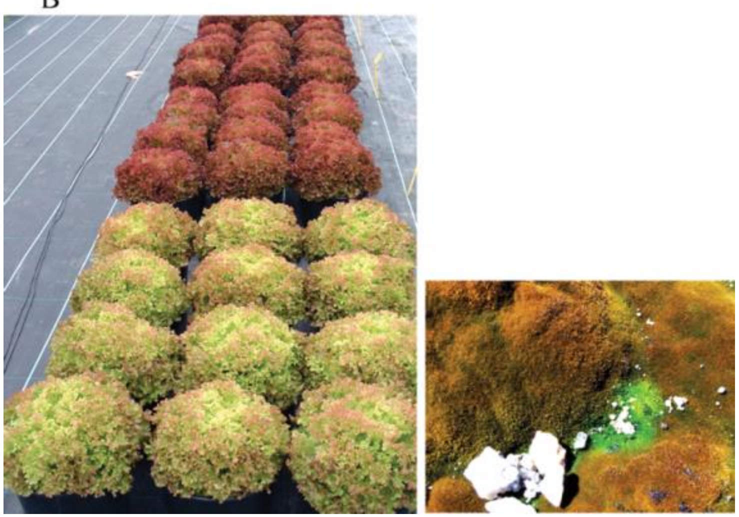


Impacts of UV-B radiation on natural terrestrial ecosystems, crops and forests

- **Wide range of responses in terrestrial organisms**
  - Vital biomolecules (DNA, proteins, lipids) are sensible to UV
  - Animals can move to avoid UV-B radiation
  - Most plants (including crop and forest species) have mechanisms that provide some UV shielding: synthesis of compounds sunscreen, increasing thickness of leaves
  - Mechanisms for repairing DNA
  - Protective molecules are important in our food: colours, flavours, antioxidants, fiber
- **Ecosystem level**
  - Effects on palatability and decomposition
  - Insects → reduce consumption of plants
  - Leaf decomposition and recycling of nutrients → soil fertility
  - Microbes in the soil
  - Consequences for future carbon sequestration?
- **Detrimental effects on crops and wild plants**
  - 6% less growth in affected areas (spent in protection material)
  - Accumulative effects in crops → evolution could be fast enough?

A

B



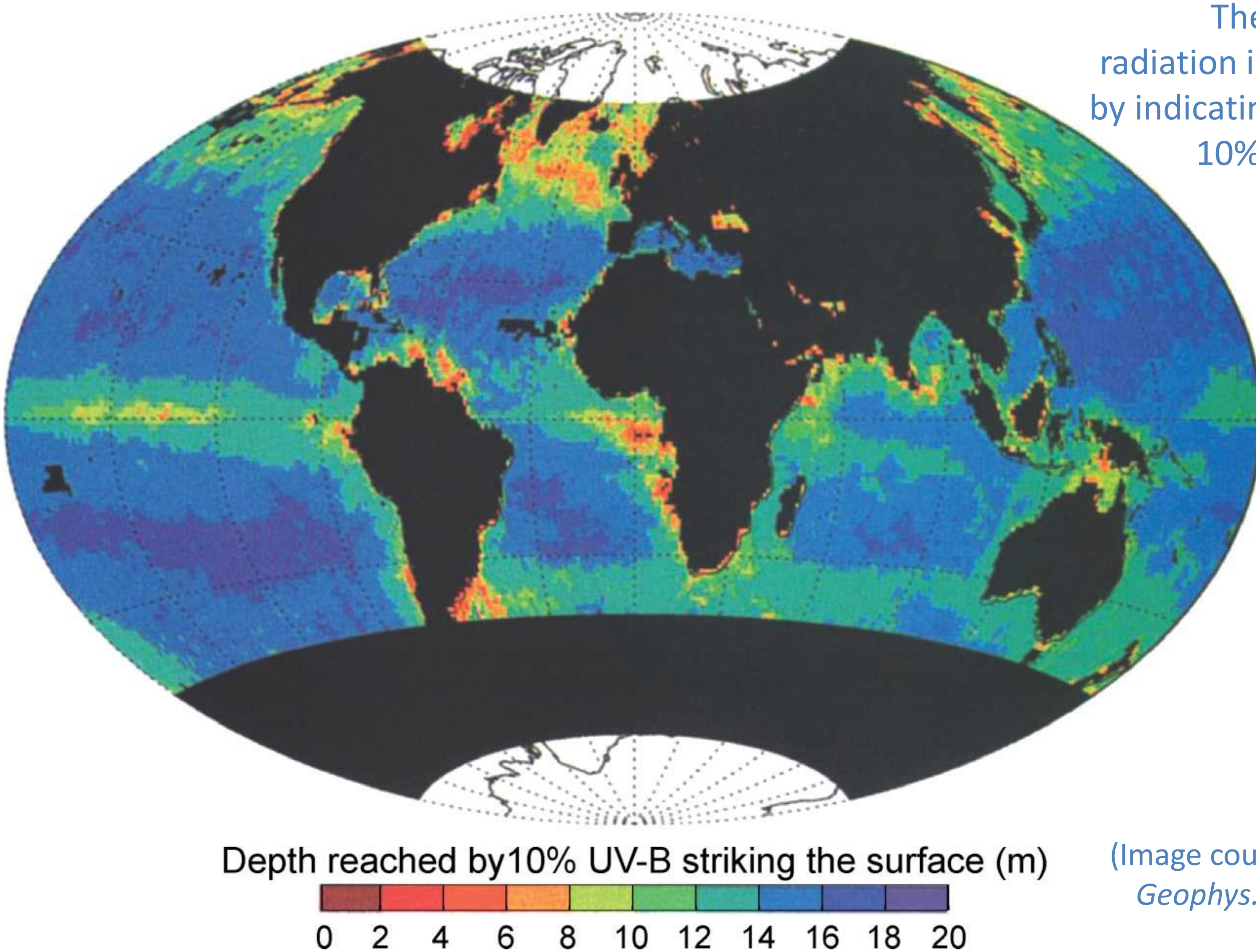
A: Impacts of UV-B radiation on terrestrial ecosystems. Ozone depletion has led to higher UV fluxes over Antarctica with negative effects on some species of Antarctic plants, such as the mosses seen growing along this icy stream.

B: Other examples of protective molecules produced by plants in response to UV radiation include the red pigments seen in lettuces (left panel), while those shielded from UV are mostly green. Similarly, Antarctic mosses (right panel) shielded by small stones are green (centre), while the plants around them produce protective red pigments. These protective compounds can be important components of our foods.

(Image of lettuce: Professor N. Paul, University of Lancaster, UK; others: Professor S. Robinson, University of Wollongong, Australia.)

Does exposure to UV-B radiation affect aquatic life?

UV-B radiation can penetrate to ecologically significant depths in the clearest natural waters and have an effect on the aquatic life.

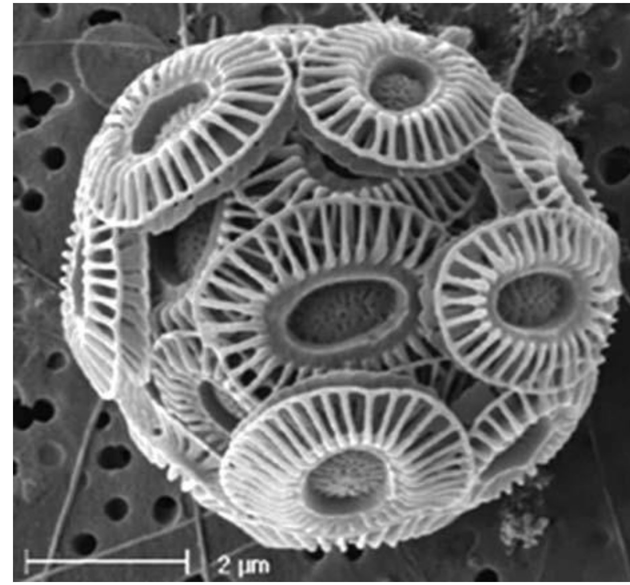


The penetration of UV-B radiation into the global oceans by indicating the depth to which 10% of surface irradiance penetrates.

(Image courtesy of Vasilkov *et al.*, *J. Geophys. Res. Oceans*, 2001, **106**, 205–227.)

UV effects on aquatic life?

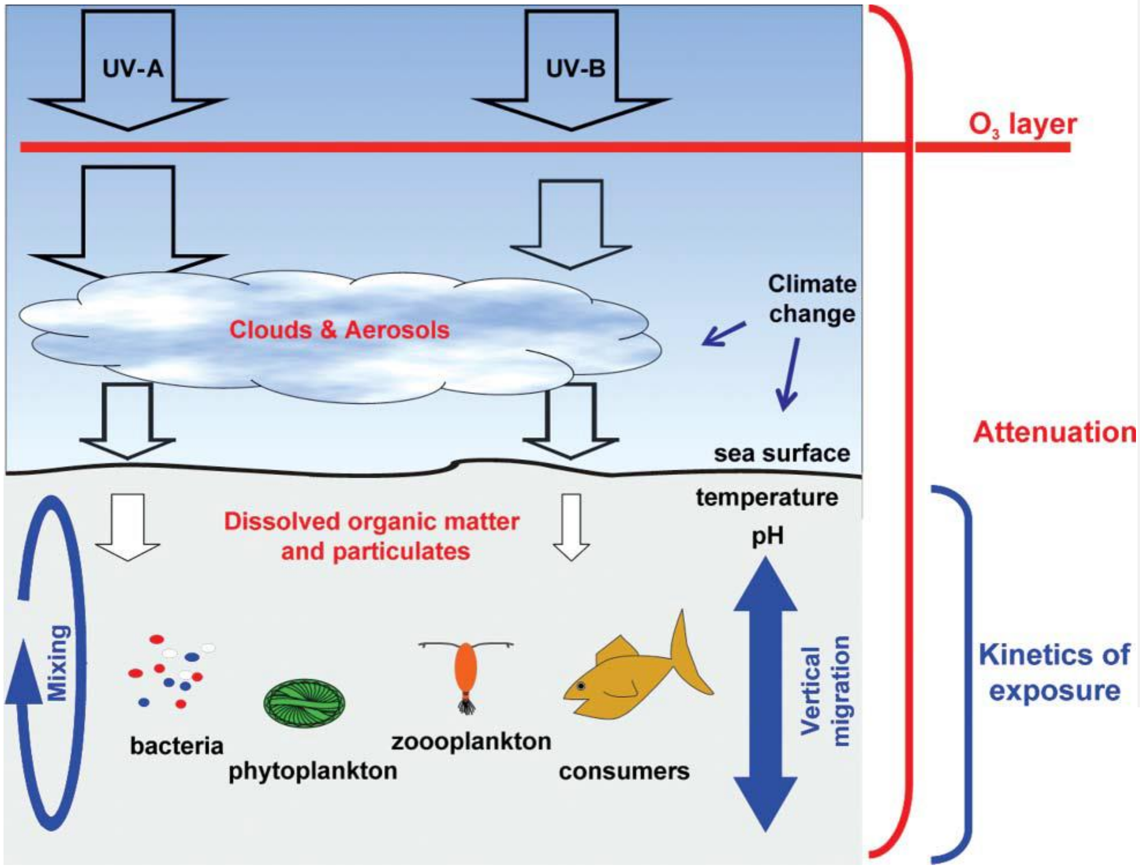
- **Aquatic organisms like light**
  - Phytoplancton → support photosynthesis
  - Detrimental effects on organisms near surface: plants, phytoplancton, fish eggs and larvae, zooplancton, and other consumers
  - Adult fish are well protected → deep water
- **Detrimental effects have been shown on many species**
  - Worsened by environmental pollution
- **Ecosystem level → less studied**
  - biodiversity,
  - interaction between trophic levels
- **Climate change effects**
  - Depth distribution
  - Water transparency
  - Seaweeds have ecologic/economic importance
  - Climate driven changes may exceed adaptative capacity to UV changes



Scanning electron micrograph of the phytoplankton coccolithophore, *Emiliania huxleyi*, covered with coccoliths. (Photograph courtesy of Kunshan Gao, Xiamen, China.)

Several marine organisms protect themselves from solar UVB radiation by producing a calcified outer layer; the increasing acidification of lakes and marine habitats impairs this calcification process.

Does climate change alter the effect of UV radiation on aquatic ecosystems?



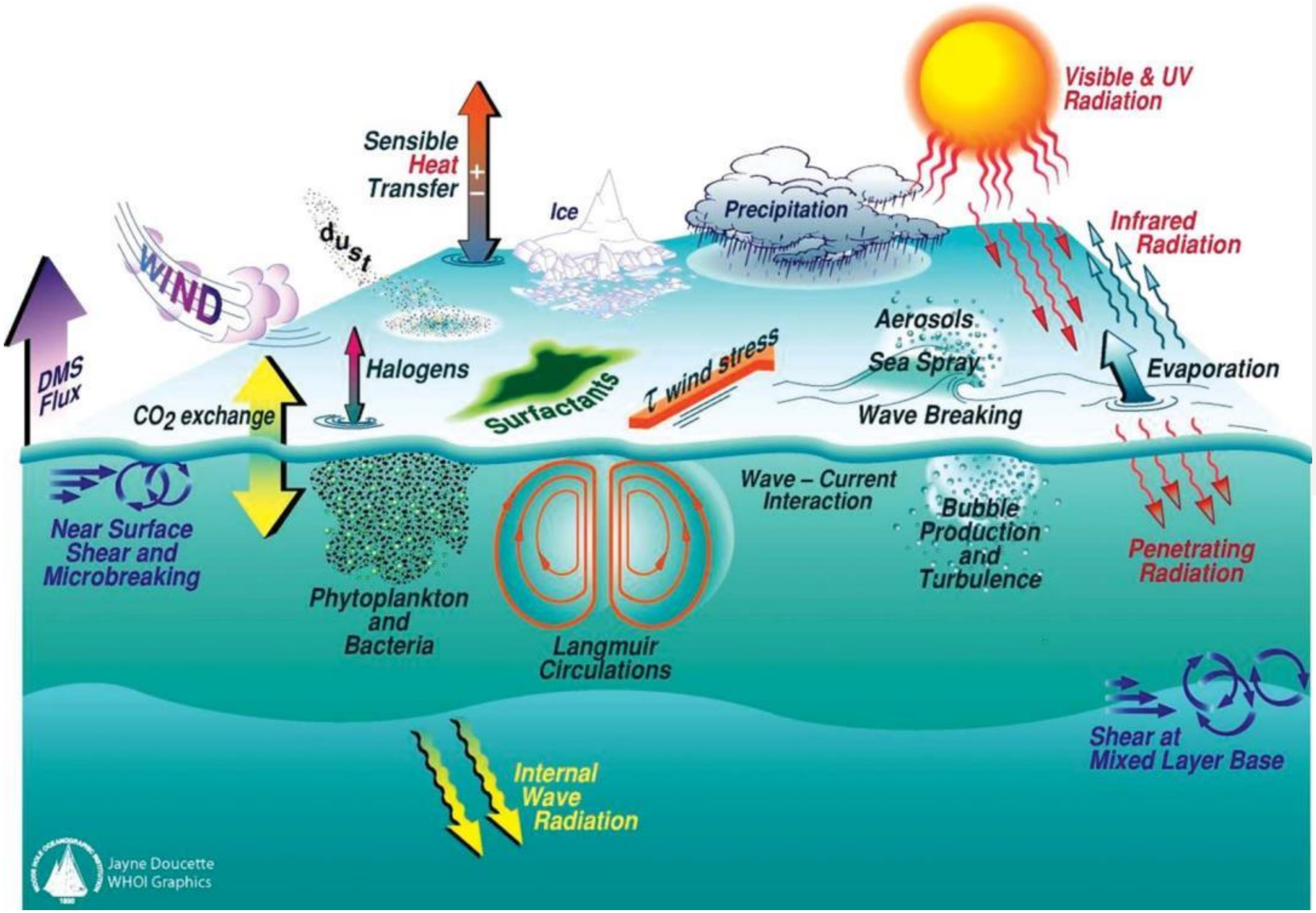
Climate change will influence various aspects of how UV-B radiation affects aquatic ecosystems, such as through changes in temperature and sea-level, shifts in the timing and extent of sea-ice cover, changes in the wave climate, ocean circulation and salinity, and alterations in the stratification of the water column.

Main factors affecting the quantity and quality of UV radiation received by aquatic organisms.

(Diagram modified from Gonçalves *et al.*, *Ecología Austral.*, 2010, **20**, 129–153.)

What effects does the depletion of ozone have on environmental processes and cycles?

Changes in UV-B radiation cause complex alterations to atmospheric chemistry, and thus affect the entire biosphere, with consequences for all organisms on Earth, including humans.

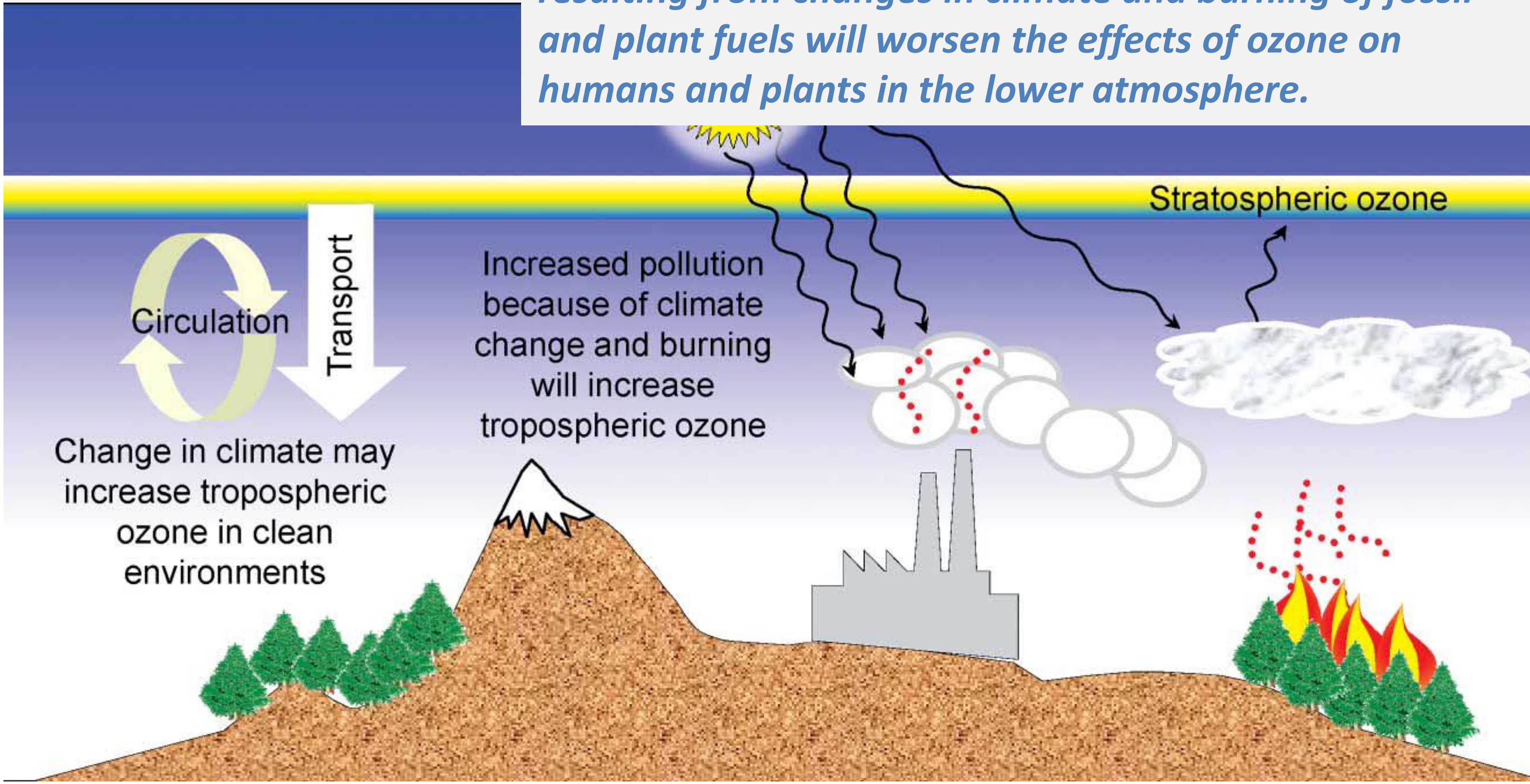


Interactions between environmental processes and cycles.

(Figure provided by the US Surface Ocean Lower Atmosphere Study (SOLAS) and the Woods Hole Oceanographic Institute (WHOI).)

What is the effect of the interaction between UV-B radiation, climate change, and human activity on air pollution?

Pollutants emitted by human activities can reduce UV-B radiation near the surface, while particles may lead to enhancement by scattering. These processes decrease some exposures to UV radiation while enhancing others. ***Interactions between UV radiation and pollutants resulting from changes in climate and burning of fossil and plant fuels will worsen the effects of ozone on humans and plants in the lower atmosphere.***



Processes that influence the concentration of ozone at different altitudes in the atmosphere.
(Illustration provided by Professor K. Solomon, University of Guelph, Canada.)

Effects on air quality

1 The impacts of air pollution on human health and the environment will be directly influenced by future changes in climate, emissions of pollutants, and stratospheric ozone

2 Numerical models predict that future changes in UV radiation and climate will modify the trends and geographic distribution of **hydroxyl radicals**, thus affecting urban and regional photochemical smog formation, as well as the abundance of several greenhouse gases

3 Photochemically produced **tropospheric ozone** is projected to increase over the next 20–40 years in certain regions of low and middle latitudes because of interactions of emissions, chemical processes, and climate change

4 **Aerosols** composed of organic substances have a major role for climate and air quality, and contribute a large uncertainty to the energy budget of the atmosphere

5 The decomposition of **substitutes for ozone-depleting substances** can lead to a range of chemical species, however with little relevance expected for human health and the environment are judged to be negligible.

Can the increased temperature due to global warming increase the deleterious effects of UV-B radiation on plastics and wood products used outdoors?

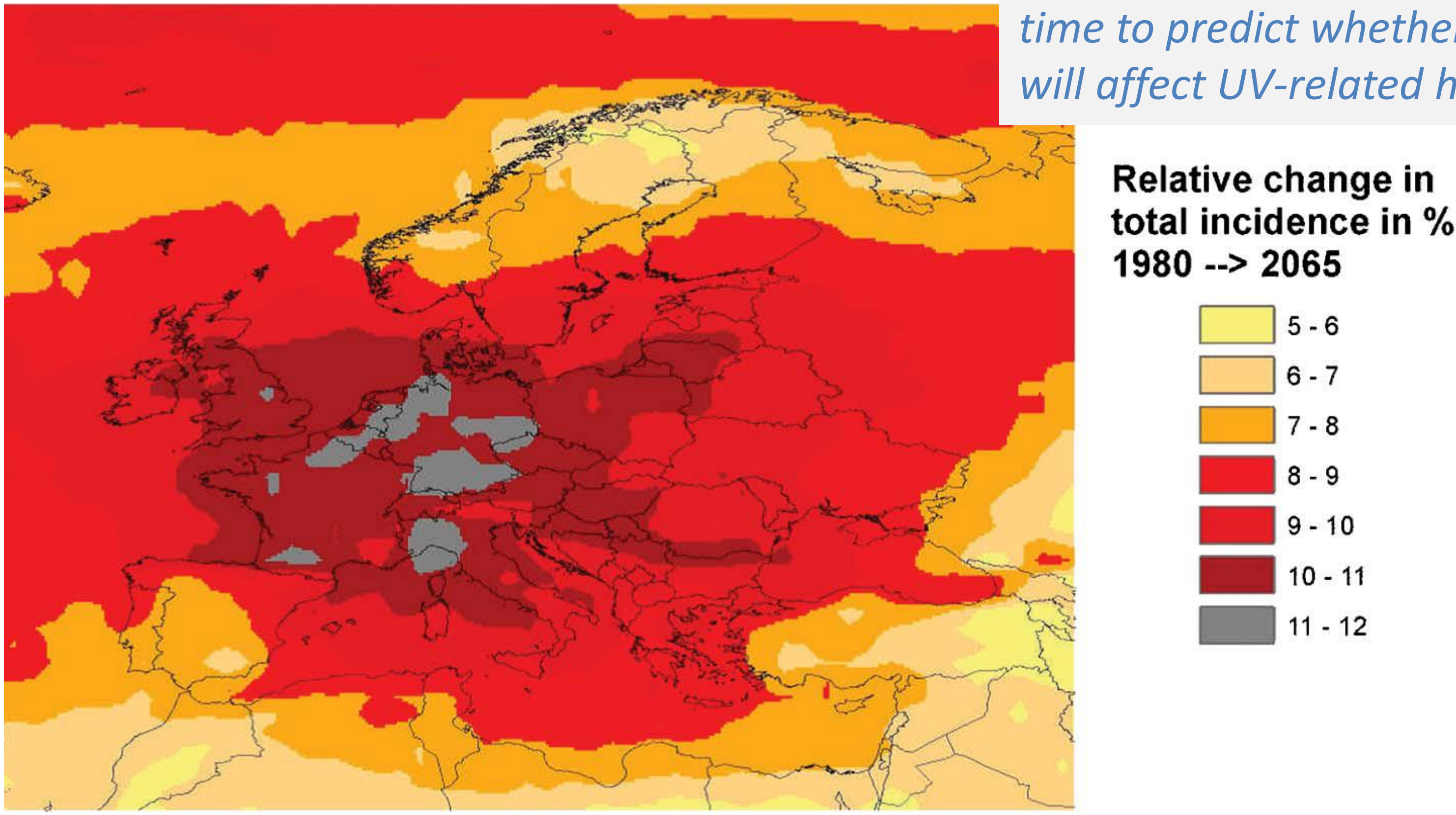
Yes, climate change can have a detrimental effect on plastics and wood products used outdoors.

Table 11 Solar UV radiation, temperature, and several environmental factors affect the degradation of materials in outdoor environments. Legend: ++++ very susceptible, +++ moderately susceptible, ++ susceptible, + likely to be susceptible (from Dr A. Andrady, North Carolina State University, USA)

	UV-B radiation	Temperature	Humidity	Pollutants
Plastics	++++	+++	+	+
Wood	+++	++	++++	+

Will global climate change alter the effects of UV radiation on human health?

While there are clear concerns about the health effects of global climate change through, for example, increasing temperatures and changes in the distribution of some vector-borne diseases, it is not possible at the present time to predict whether climate change will affect UV-related health issues.



The predicted relative change in total skin cancer incidence from 1980 to 2065 in Europe.

(From Fig. 5.16, Relative change in total skin cancer incidence from 1980 to 2065 for the A1 scenario, based on the AMOUR2.0 assessment model, RIVM in http://www.rivm.nl/bibliotheek/rapporten/610002001.html.)

Próximo día: 22 diciembre

Revisar por encima el apartado 4, efectos de la UV

Probar el QUICK TUV CALCULATOR

NCAR UCAR | National Center for Atmospheric Research
Atmospheric Chemistry Observations & Modeling

Search

- Modeling
- Master Mechanism
- TUV
- WRF-Chem

QUICK TUV CALCULATOR

This web page runs the *5.3* version of the TUV model. You can run the model for a specified latitude, longitude and time (input option 1), or for a given solar zenith angle (input option 2). In either case, you must also specify the additional parameters in the second column. Also, you may select to print out the photolysis rates and/or the solar actinic flux spectrum at a given altitude above the surface (output option 1), or the erythemal UV and/or solar irradiance at that altitude (output option 2). For any problem, or to send comments, email TUV administrators.

Wavelength

Start:	End:	Increments:
280	420	140

◉ **INPUT OPTION 1**

LATITUDE (deg): 41.962
LONGITUDE (deg): 2.829
DATE (YYYYMMDD): 20201222
TIME (hh:mm:ss, GMT): 12:00:00

○ **INPUT OPTION 2**

SOLAR ZENITH ANGLE (deg): 0

OTHER INPUT PARAMETERS

OVERHEAD OZONE COLUMN (du): 300
SURFACE ALBEDO (0-1): 0.1
GROUND ELEVATION (km asl): 0.115
MEASUREM. ALTITUDE (km asl): 0.115

Clouds

Opt. Depth:	Base:	Top:
0.00	4.00	5.00

Aerosols

Opt. Depth:	S-S Alb:	Alpha:
0.235	0.990	1.000

Sunlight

Direct beam:	Diffuse down:	Diffuse up:
1.0	1.0	0.0

○ **OUTPUT OPTION 1**
(for Atmospheric Science)

☐ MOLECULAR PHOTOLYSIS FREQUENCIES (s-1)
☐ ACTINIC FLUX, SPECTRAL (quanta s-1 cm-2 nm-1)

◉ **OUTPUT OPTION 2**
(for Biology)

☑ IRRADIANCE, WEIGHTED (W m-2)
☐ IRRADIANCE, SPECTRAL (W m-2 nm-1)

RADIATION TRANSFER MODEL

◉ Pseudo-spherical 2 streams (faster, less accurate)
○ Pseudo-spherical discrete ordinate 4 streams (slower, more accurate)

GO!

RESET

ACOM: Quick TUV (ucar.edu)

INPUT

```
INPUT PARAMETERS:

RADIATION SCHEME:              2  streams

w-grid:          141    280.0000        420.0000
equally spaced z-grid
z-grid:           81   0.1150000        80.00000
 measurement point: index            1  altitude=   0.1150000
idate =      20201222  esfact(1) =     1.033511
air temperature: USSA, 1976
air concentrations: USSA, 1976
ozone profile: USSA, 1976
DATAE1/SUN/susim_hi.flx
DATAE1/SUN/atlas3_1994_317_a.dat
DATAE1/SUN/neckel.flx
DATAE1/SUN/sao2010.solref.converted
aerosols:  Elterman (1968) continental profile
lat=    41.96200       long=     2.829000       ut=    12.00000
solar zenith angle =      65.45741
```

OUTPUT

```
WEIGHTED IRRADIANCES (W m-2)
 (with normalized action spectra)

   1 UV-B, 280-315 nm                              2.495E-01
   2 UV-B*, 280-320 nm                             6.210E-01
   3 UV-A, 315-400 nm                              1.998E+01
   4 vis+, > 400 nm                                9.861E+00
   5 Gaussian, 305 nm, 10 nm FWHM                  8.346E-03
   6 Gaussian, 320 nm, 10 nm FWHM                  9.890E-02
   7 Gaussian, 340 nm, 10 nm FWHM                  2.093E-01
   8 Gaussian, 380 nm, 10 nm FWHM                  2.853E-01
   9 RB Meter, model 501                           7.091E-02
  10 Eppley UV Photometer                          1.662E+01
  11 PAR, 400-700 nm, umol m-2 s-1                 3.381E+01
  12 Exponential decay, 14 nm/10                   9.514E-02
  13 DNA damage, in vitro (Setlow, 1974)           3.820E-04
  14 SCUP-mice (de Gruijl et al., 1993)            3.714E-02
  15 SCUP-human (de Gruijl and van der Leun,       7.763E-02
  16 Standard human erythema (Webb et al., 20      3.471E-02
  17 UV index (WMO, 1994; Webb et al., 2011)       1.388E+00
  18 Erythema, humans (Anders et al., 1995)        1.143E-04
  19 Occupational TLV (ACGIH, 1992)                7.328E-03
  20 Phytoplankton (Boucher et al., 1994)          8.007E-04
  21 Phytoplankton, phaeo (Cullen et al., 199      4.537E-04
  22 Phytoplankton, proro (Cullen et al., 199      3.843E-04
  23 Cataract, pig (Oriowo et al., 2001)           1.020E-01
  24 Plant damage (Caldwell, 1971)                 2.063E-02
  25 Plant damage,Flint&Caldwell,2003,orig.        2.775E-01
  26 Plant damage,Flint&Caldwell,2003,ext390       4.236E-01
  27 Previtamin-D3 (CIE 2006)                      4.807E-02
  28 NMSC (CIE 2006)                               7.120E-02
  29 Ebola virus inactivation                      1.208E-01
```

×40

… SARS CoV-2 virus