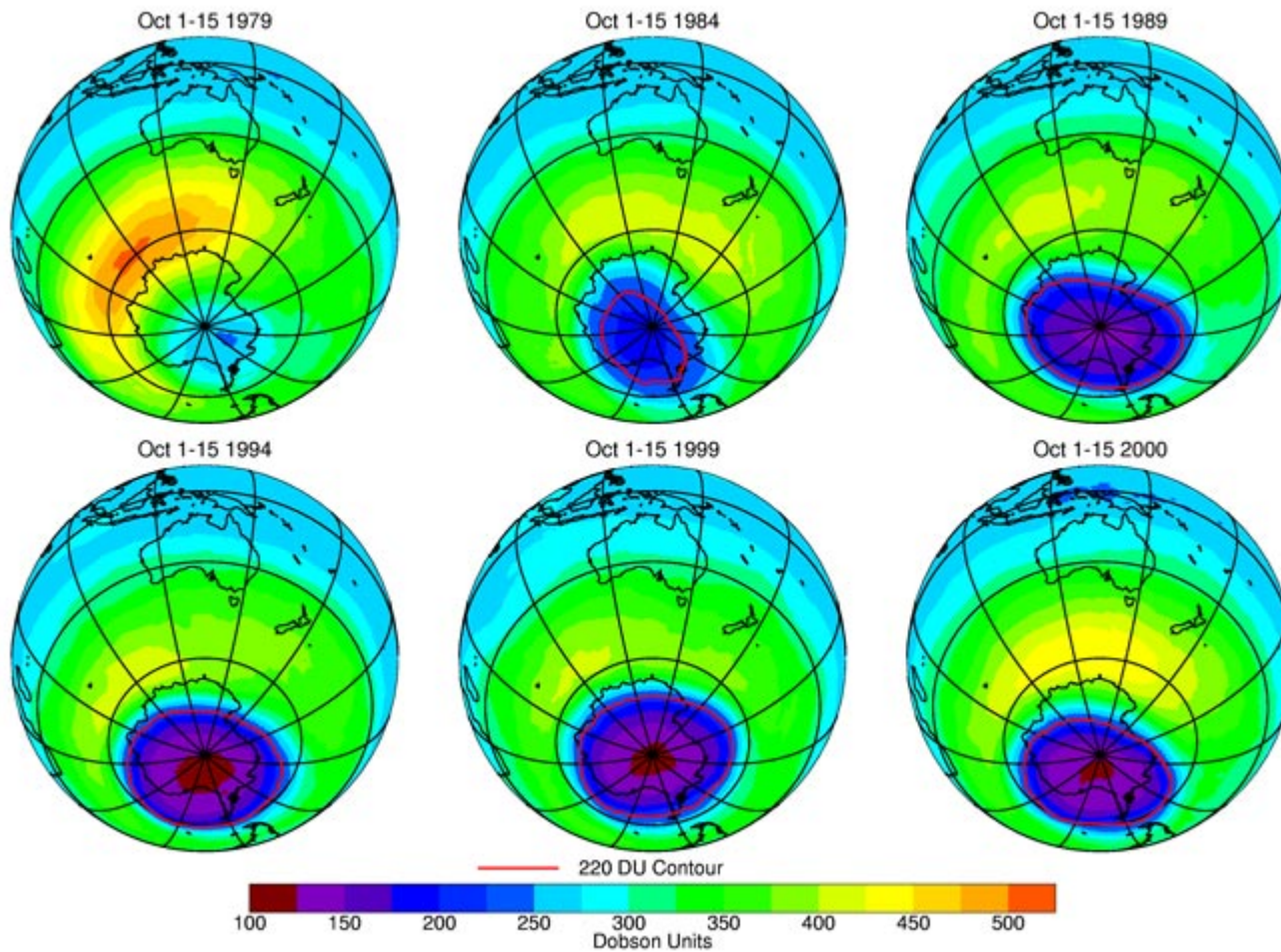
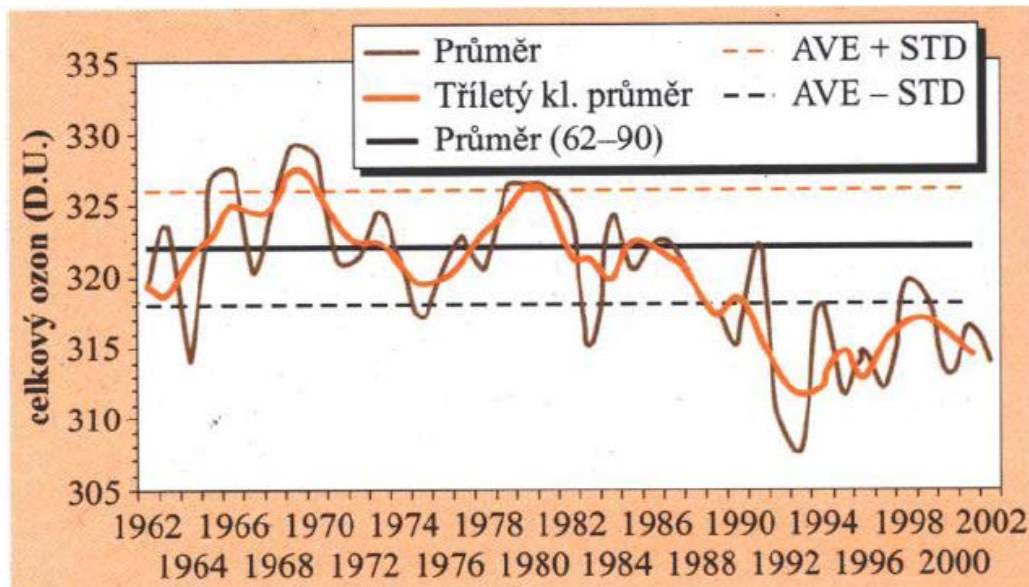
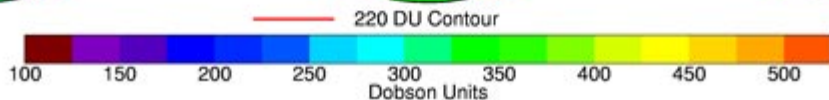
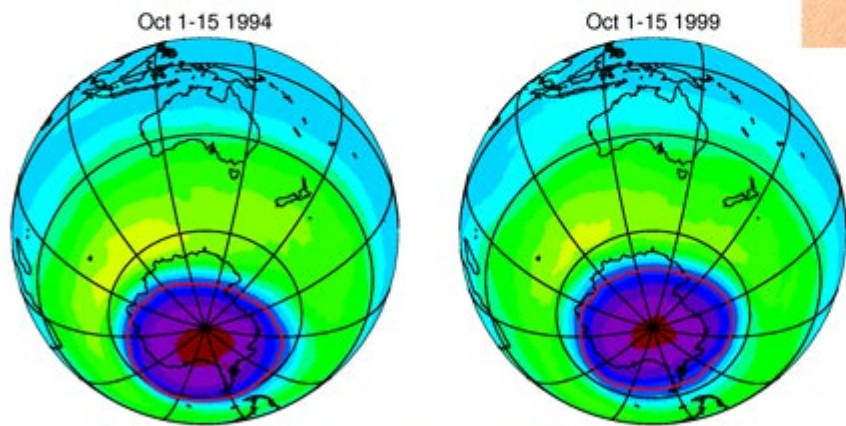
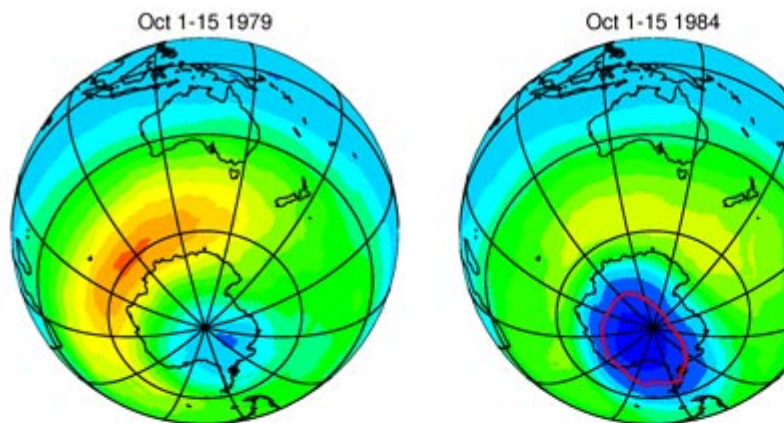


III. Úbytek stratosférického ozónu



III. Úbytek stratosférického ozónu

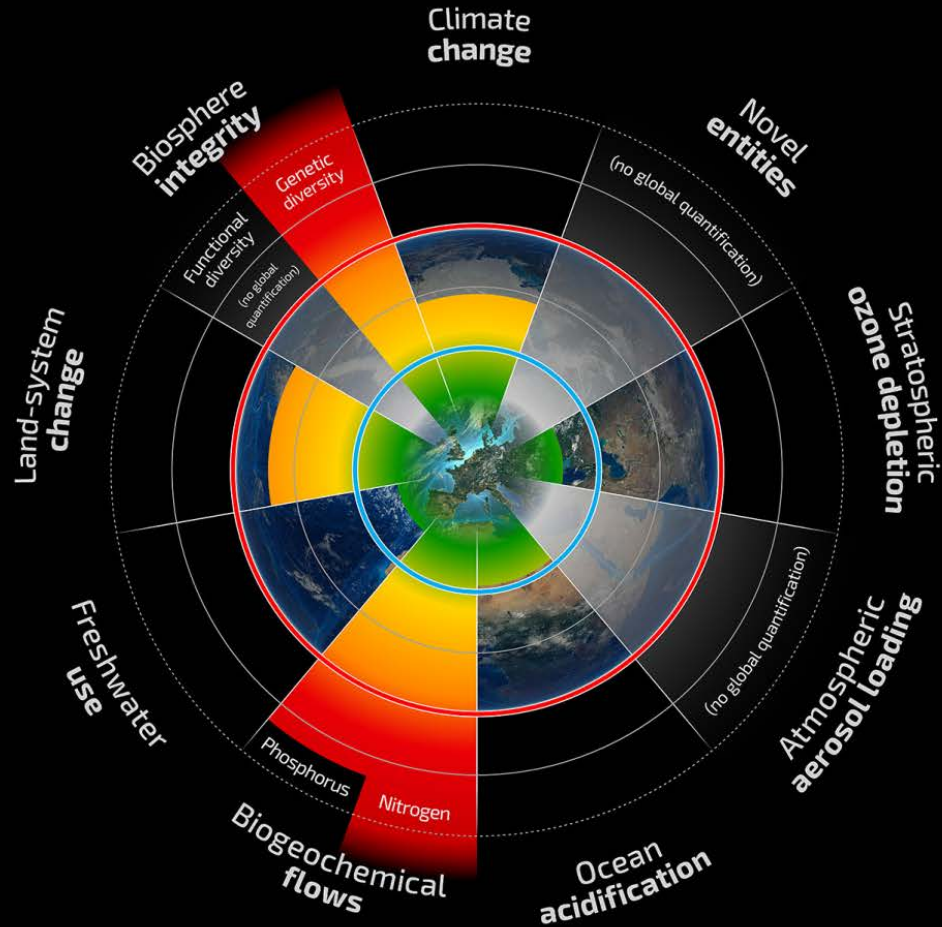
Průměrné množství ozónu, ČR, 1962–2002



Překročení hranic?

Planetary Boundaries

A safe operating space for humanity



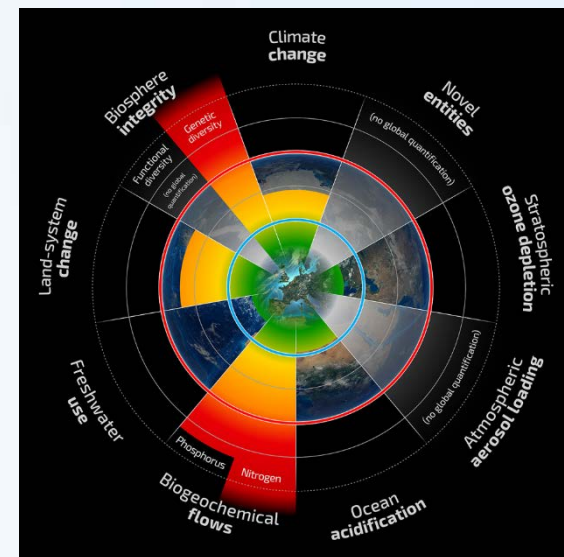
- Beyond zone of uncertainty** (high risk)
- In zone of uncertainty** (increasing risk)
- Below boundary** (safe)
- Boundary not yet quantified**



Centrum pro výzkum
toxických látek
v prostředí

III. Úbytek stratosférického ozónu

Diagnóza



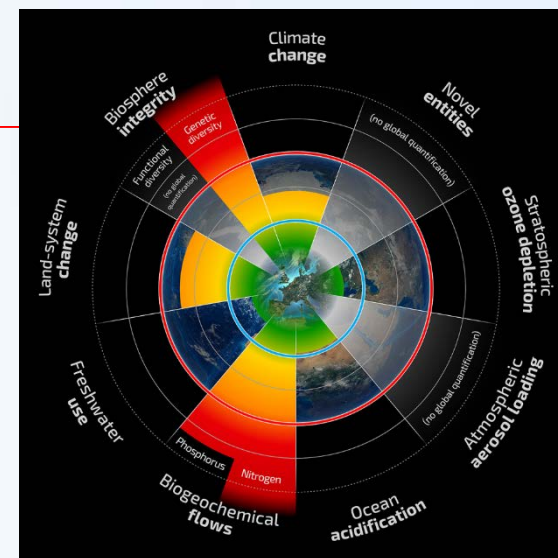
III. Úbytek stratosférického ozónu

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Stratospheric ozone depletion (R2009: same)	Stratospheric O ₃ concentration, DU	<5% reduction from pre-industrial level of 290 DU (5%–10%), assessed by latitude	Only transgressed over Antarctica in Austral spring (~200 DU)

Boundary: Average conc. of stratospheric O₃ no lower than 276 Dobson units

Current level: 283 Dobson units

Diagnosis: Safe, and improving



The Observer: Letní horka způsobují vysoké koncentrace ozónu

14.5.2004 11:14 | PRAHA/LONDÝN (EcoMonitor)

Vědci upozorňují, že by letošní léto mohlo znamenat pro tisíce Britů komplikace. Pravděpodobně budou nuceni nosit ochranné masky nebo zůstat raději doma, aby se vyhnuli škodlivým mlhám plným ozónu, které budou znečišťovat ovzduší v zemi během vln veder.

Víme, reklamy jsou otravné. A respektujeme, že je máte vypnuté :-). Budeme rádi, když nás podpoříte jinak.

PROSÍME, ZVOLTE VÝŠÍ SVÉHO DARU. DĚKUJEME

Částka Kč

Doba trvání daru

Váš e-mail

Darovat

Pro skrytí reklam se prosím přihlašte

Vědci objevili, že horka loni v srpnu způsobila u rostlin a stromů uvolnění chemických látek izoprenů. Ty přispívají k produkci ozónu ve vzduchu. Vědci se domnívají, že ozón zabil loni v létě až 600 lidí. Profesor Alan Thorpe z Centra atmosférických věd k tomu dodává, že teplota dosáhla poprvé v historii Británie hranici 100F, tedy 37,7 °C. Díky globálnímu oteplování budou podobná velká horka stále častější - až desetkrát. Kromě ostatních problémů Británie musí počítat i se zvýšením množství ozónu v přízemní vrstvě atmosféry.

Ozón, který je zvláště nebezpečný pro děti, staré lidi a astmatiky, vzniká když silné sluneční záření rozloží oxidy dusíku, které se uvolňují z výfukových plynů. V posledních letech se situace v Británii při snižování úrovně oxidů dusíku v ovzduší velmi zlepšila. Proto doufala, že má problém pod kontrolou.

Nejnovější studie, kterou provedl tým Alastaira Lewise z univerzity v Yorku prokázala, že nebezpečí vzniká při vysokých letních teplotách. Vědecký tým doktora Lewise odjel loni do Chelmsfordu, aby zde studoval úroveň ozónu a izoprenu. "Náhodou jsme tam strávili dva velmi horké týdny. To, co jsme objevili, bylo překvapivé. Když teplota překročila 90F a stoupala ke stove, rostliny a stromy ... začaly produkovat rapidně rostoucí množství izoprenu,"

Nejčtenější články

Včely máme rádi. Proč ale nenávidíme vosy?

► Diskuse: 1

Odkud plynou miliardy na ničení přírody? Z daňových rájů

► Diskuse: 3

Dokážou nás zvířata opravdu milovat jako my je?

Na Trutnovsku odhalili pomník věnovaný vyhynulému hořčí jarnímu

Jak se mají polní ptáci v Česku?

Vlny horka. Vcelku zřídka výjev změny klimatu. Zabíjí ale ve velkém

► Diskuse: 4

Vodní eroze snižuje výnos plodin až o 75 %. Jak se jí bránit?

► Diskuse: 1

[Ekolist.cz](#)

G+ Sledovat 184



Historie objevů



Historie objevů spojených s úbytkem O₃

1974

Stratospheric Chlorine: a Possible Sink for Ozone

R. S. STOLARSKI AND R. J. CICERONE

Space Physics Research Laboratory, The University of Michigan, Ann Arbor, Michigan 48105

Received January 18, 1974

This study proposes that the oxides of chlorine, ClO_x, may constitute an important sink for stratospheric ozone. A photochemical scheme is devised which includes two catalytic cycles through which ClO_x destroys odd oxygen. The individual Clx constituents (HCl, Cl, ClO, and OClO) perform analogously to the respective constituents (HNO₃, NO, NO₂, and NO₃) in the NO_x catalytic cycles, but the ozone destruction efficiency is higher for ClO. Our photochemical scheme predicts that ClO is the dominant chlorine

(Reprinted from Nature, Vol. 249, No. 5460, pp. 810-812, June 28, 1974)

Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone

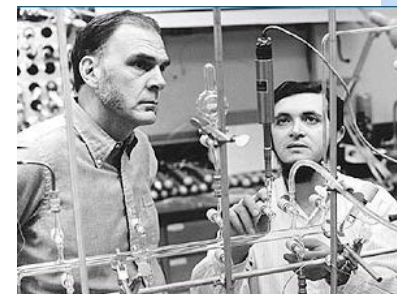
Mario J. Molina & F. S. Rowland

Department of Chemistry, University of California, Irvine, California 92664

Chlorofluoromethanes are being added to the environment in steadily increasing amounts. These compounds are chemically inert and may remain in the atmosphere for 40-150 years, and concentrations can be expected to reach 10 to 30 times present levels. Photodissociation of the chlorofluoromethanes in the stratosphere produces significant amounts of chlorine atoms, and leads to the destruction of atmospheric ozone.

HALOGENATED aliphatic hydrocarbons have been added to the

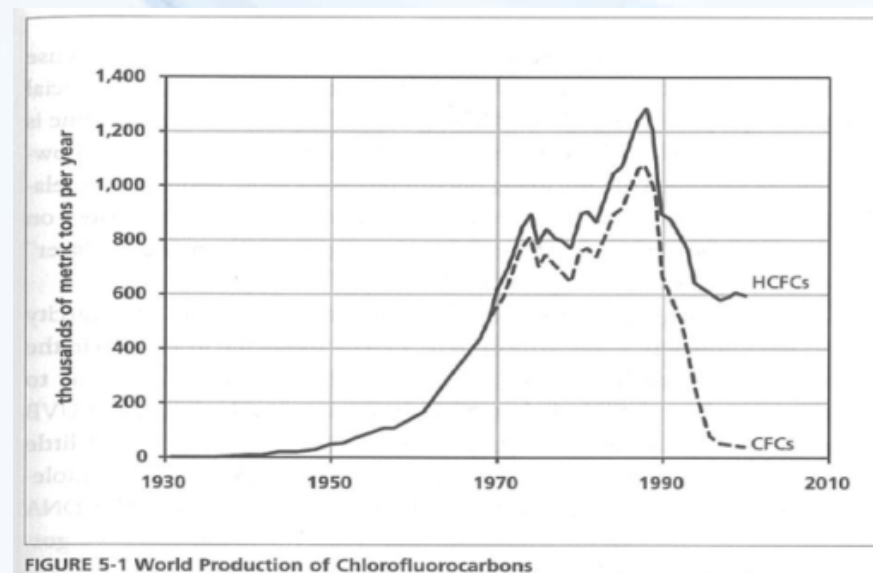
effective rates of vertical diffusion of molecules at these altitudes are also subject to substantial uncertainties. Vertical mixing is frequently modelled through the use of 'eddy' diffusion coefficients^{10,15-18}, which are presumably relatively insensitive to the molecular weight of the diffusing species. Calculated using a time independent one-dimensional vertical diffusion model with eddy diffusion coefficients of magnitude $K \sim (3 \times 10^3) - 10^4 \text{ cm}^2 \text{ s}^{-1}$ at altitudes 20-40 km (refs 10, 15-18), the atmospheric lifetimes of CFC₁₂ and CFC₁₁ fall into the range of 40-150 yr. The time required for approach toward a steady state is thus measured in decades, and the concentrations of chlorofluoromethanes in the atmosphere can be expected to reach



- 1 atom Cl rozloží zhruba 100 000 molekul O₃

Historie objevů spojených s úbytkem O₃

1978 – CFC jako hnací plyn ve sprejích **zakázán** (v USA)
- spotřeba v dalších aplikacích však stále prudce roste



1991



Historie objevů spojených s úbytkem O₃

1978 – CFC jako hnací plyn ve sprejích **zakázán** (v USA)
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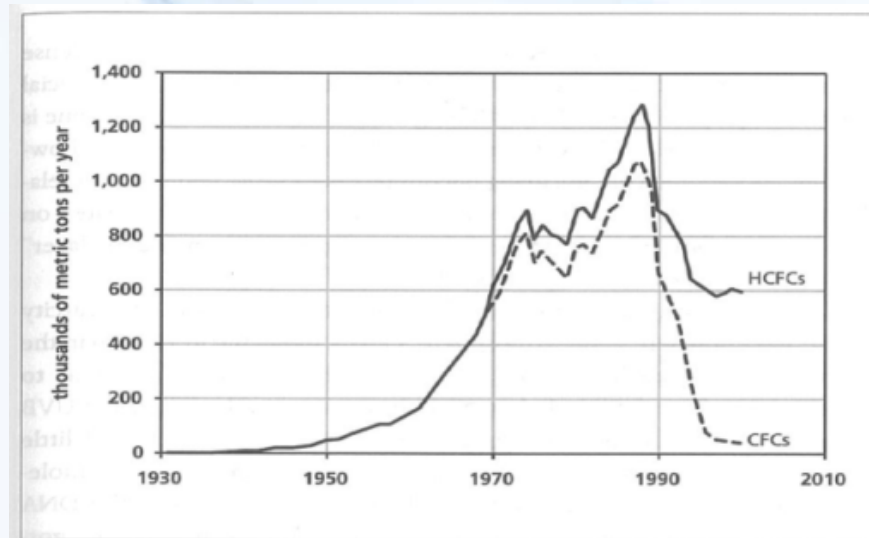
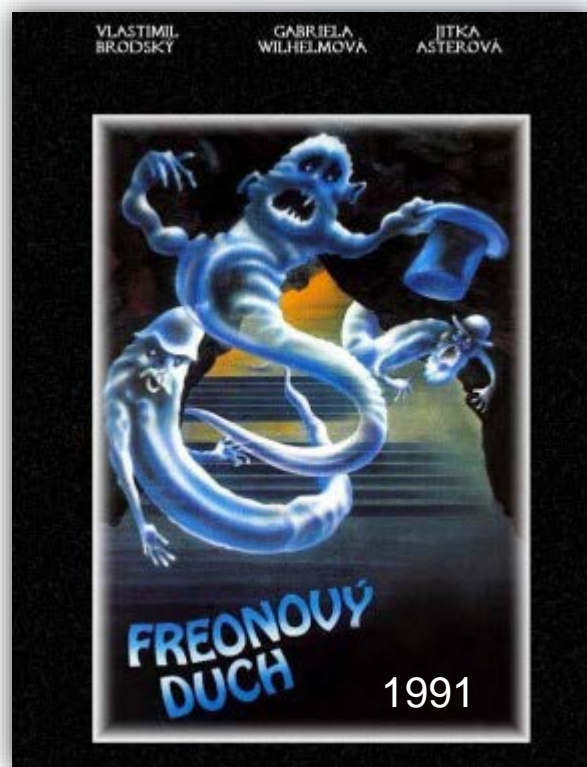


FIGURE 5-1 World Production of Chlorofluorocarbons



Historie objevů spojených s úbytkem O₃

1978 – CFC jako hnací plyn ve sprejích **zakázán** (v USA)

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1984 - V Halley Bay v Antarktidě naměřen **40% úbytek O₃**

- tak dramatickému úbytku nevěřili a hledali způsob ověření

- dramatický pokles ověřen i v další stanici 1000 mil daleko

Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction

J. C. Farman, B. G. Gardiner & J. D. Shanklin

British Antarctic Survey, Natural Environment Research Council,
High Cross, Madingley Road, Cambridge CB3 0ET, UK

Recent attempts^{1,2} to consolidate assessments of the effect of human activities on stratospheric ozone (O₃) using one-dimensional models for 30° N have suggested that perturbations of total O₃ will remain small for at least the next decade. Results from such models are often accepted by default as global estimates³. The inadequacy of this approach is here made evident by observations that the spring values of total O₃ in Antarctica have now fallen considerably. The circulation in the lower stratosphere is apparently unchanged, and possible chemical causes must be considered. We suggest that the very low temperatures which prevail from midwinter until several weeks after the spring equinox make the Antarctic stratosphere uniquely sensitive to growth of inorganic chlorine, Cl_x, primarily by the effect of this growth on the NO₂/NO ratio. This, with the height distribution of UV irradiation peculiar to the polar stratosphere, could account for

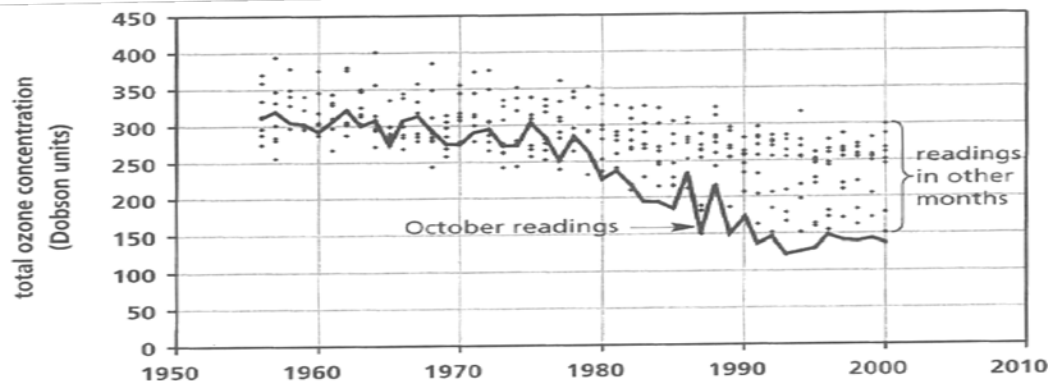


FIGURE 5-4 Ozone Measurements at Halley, Antarctica

Historie objevů spojených s úbytkem O₃

1978 – CFC jako hnací plyn ve sprejích **zakázán** (v USA)
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- tak dramatickému úbytku nevěřili a hledali způsob ověření
- dramatický pokles ověřen i v další stanici 1000 mil daleko

– nezvratný důkaz, že nad sebou likvidujeme ozonový štít???

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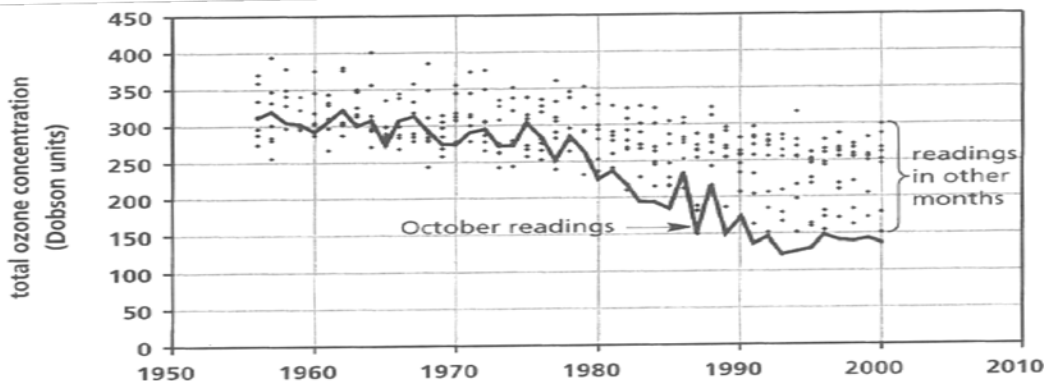


FIGURE 5-4 Ozone Measurements at Halley, Antarctica

Historie objevů spojených s úbytkem O₃

1985 - Nimbus 7 – satelit NASA měřící O₃ od 1978 ale žádnou **díru neeviduje**



Historie objevů spojených s úbytkem O₃

1985 - Nimbus 7 – satelit NASA měřící O₃ od 1978 ale žádnou **díru neeviduje...**

- po revizi nastavení přístroje zjištěno, že velmi nízké hodnoty přístroj nezapočítával – po zpětném započítání rostoucího množství podlimitních hodnot **díra potvrzena**



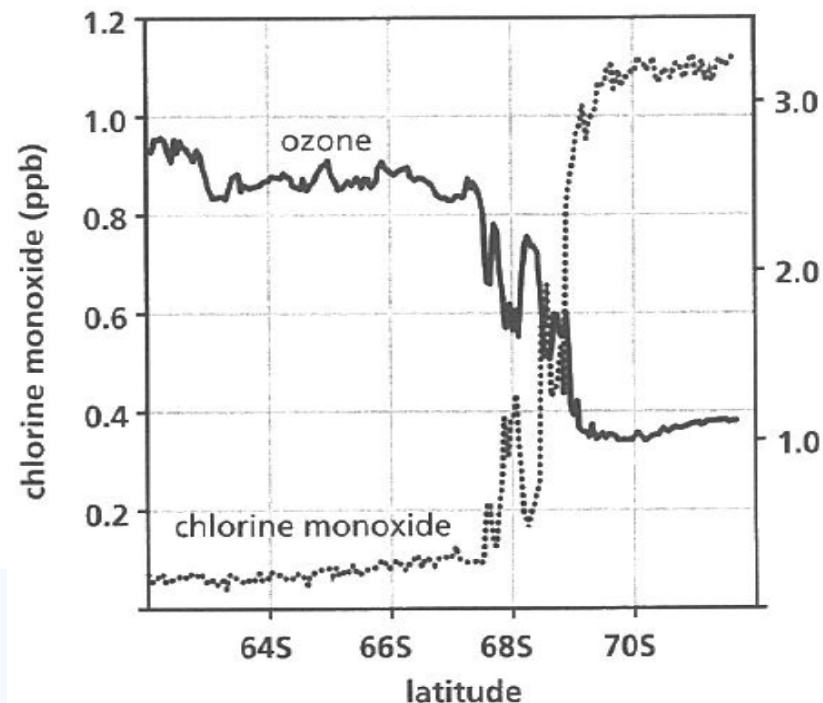
Historie objevů spojených s úbytkem O₃

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1987 – potvrzení chlor-ozonové hypotézy – průlet letadlem ozonovou dírou měřící koncentraci O₃ a ClO

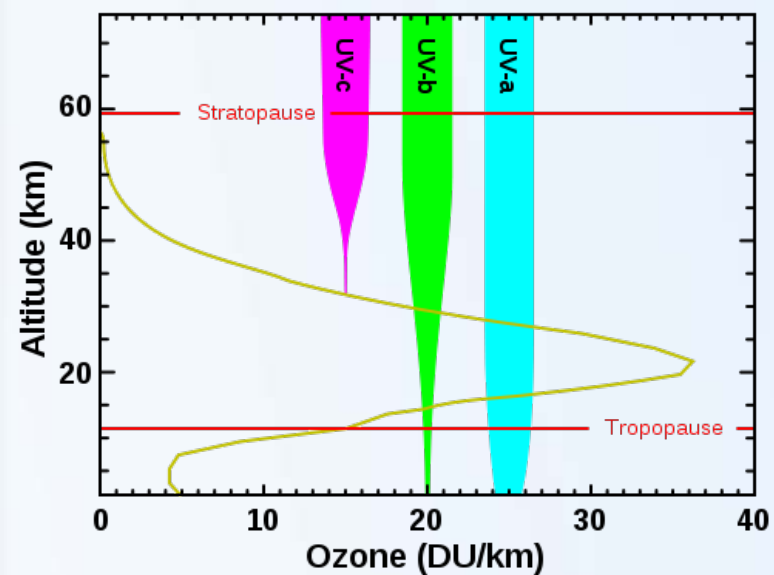
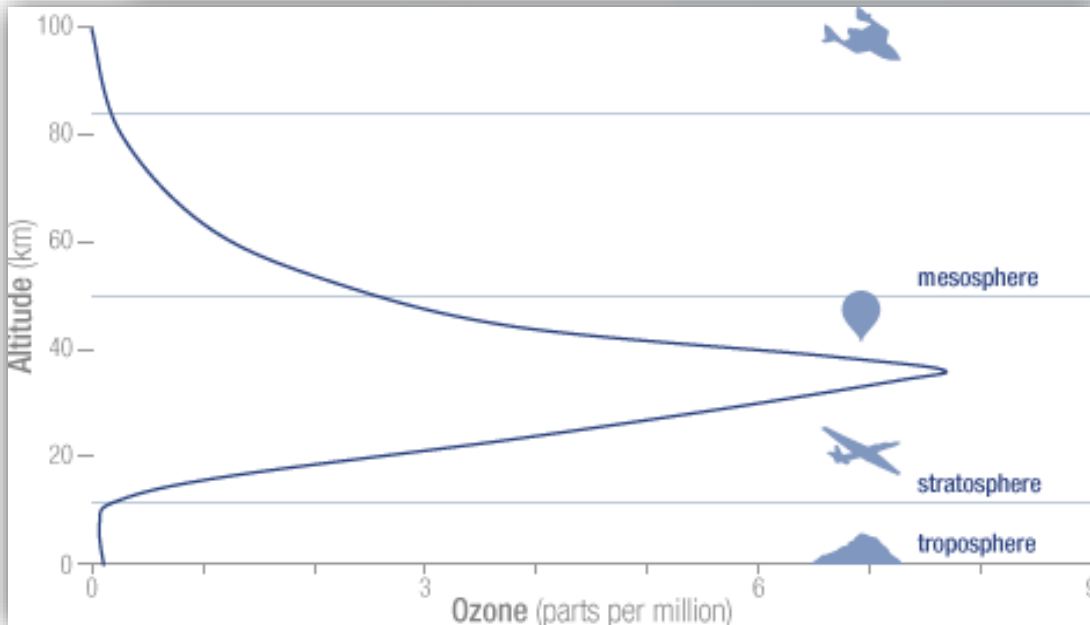
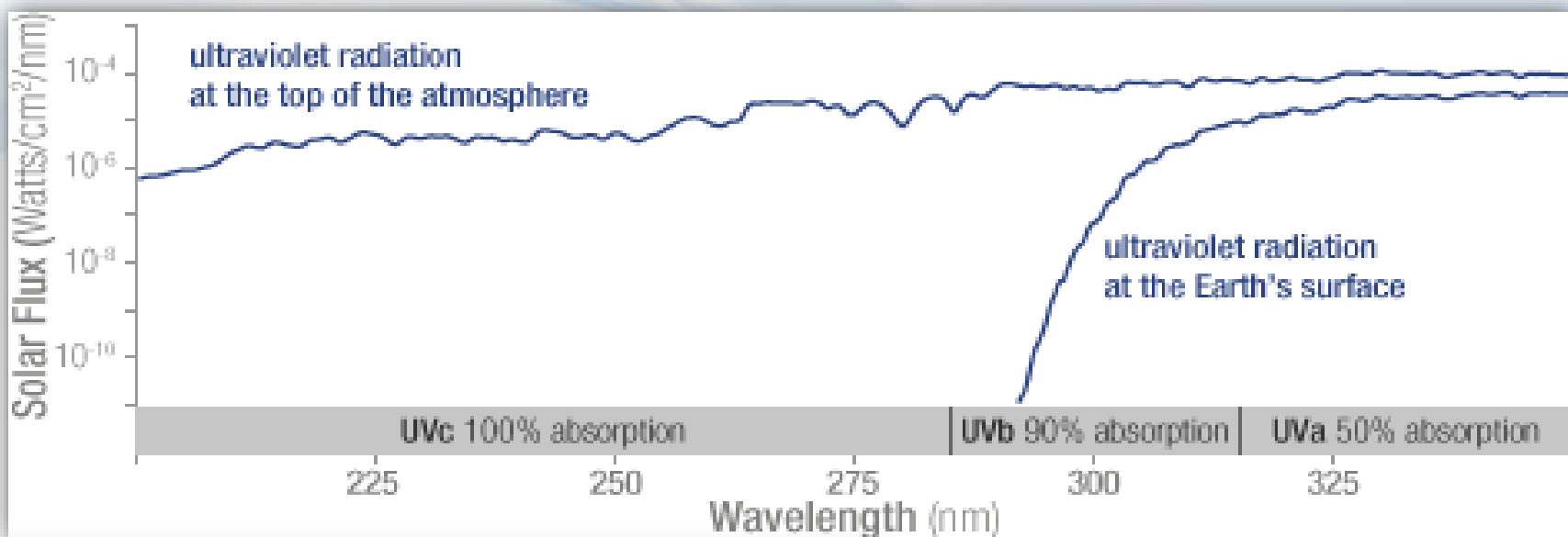
- silná **korelace** mezi koncentrací obou měřených látek



Fyzikální základ jevu

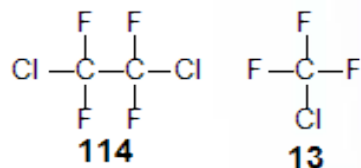
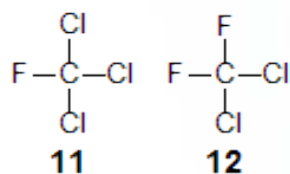


O₃ – ochrana biosféry před nebezpečným UVB zářením



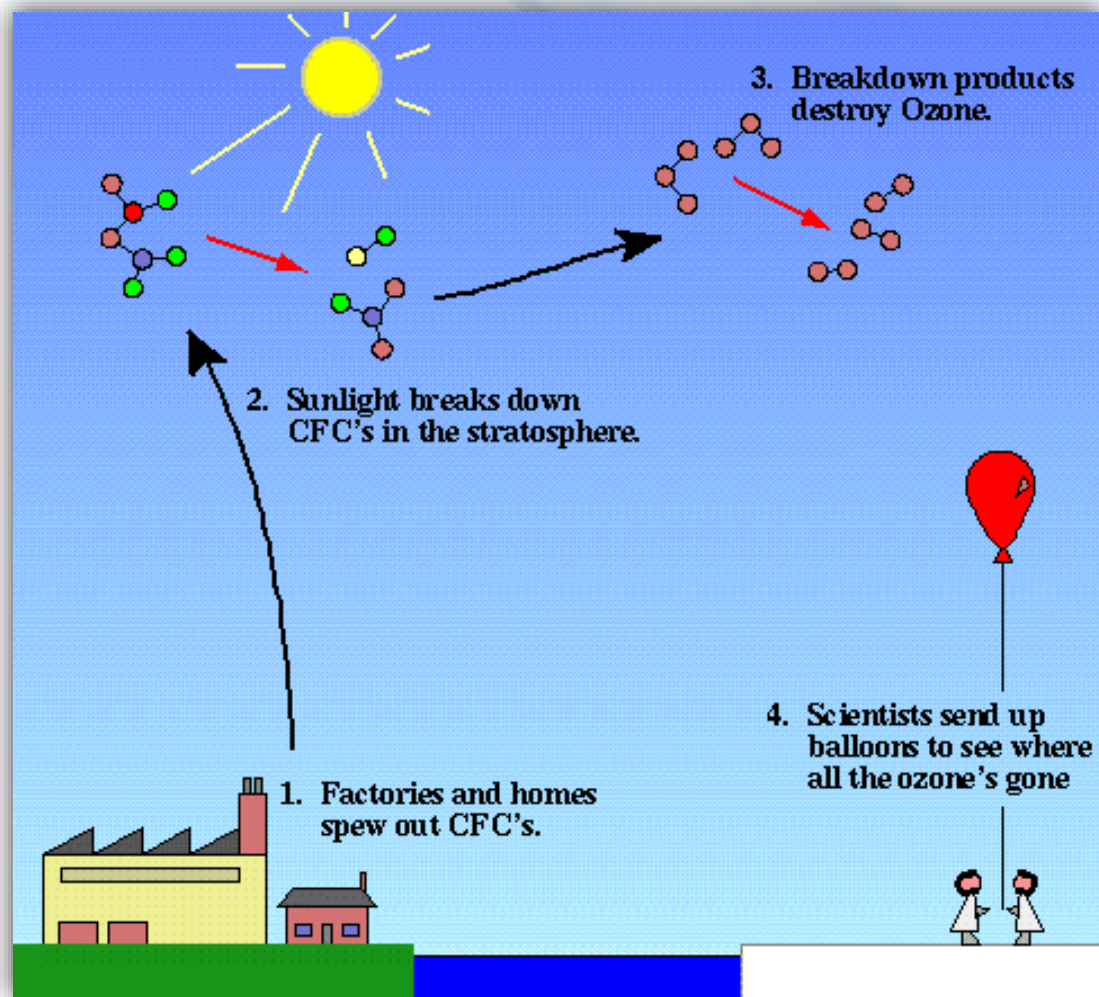
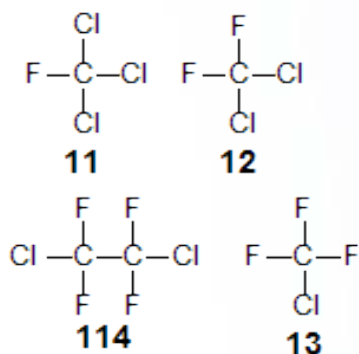
Poškozování ozónové vrstvy země

- freony, halony a další určité halogenované látky



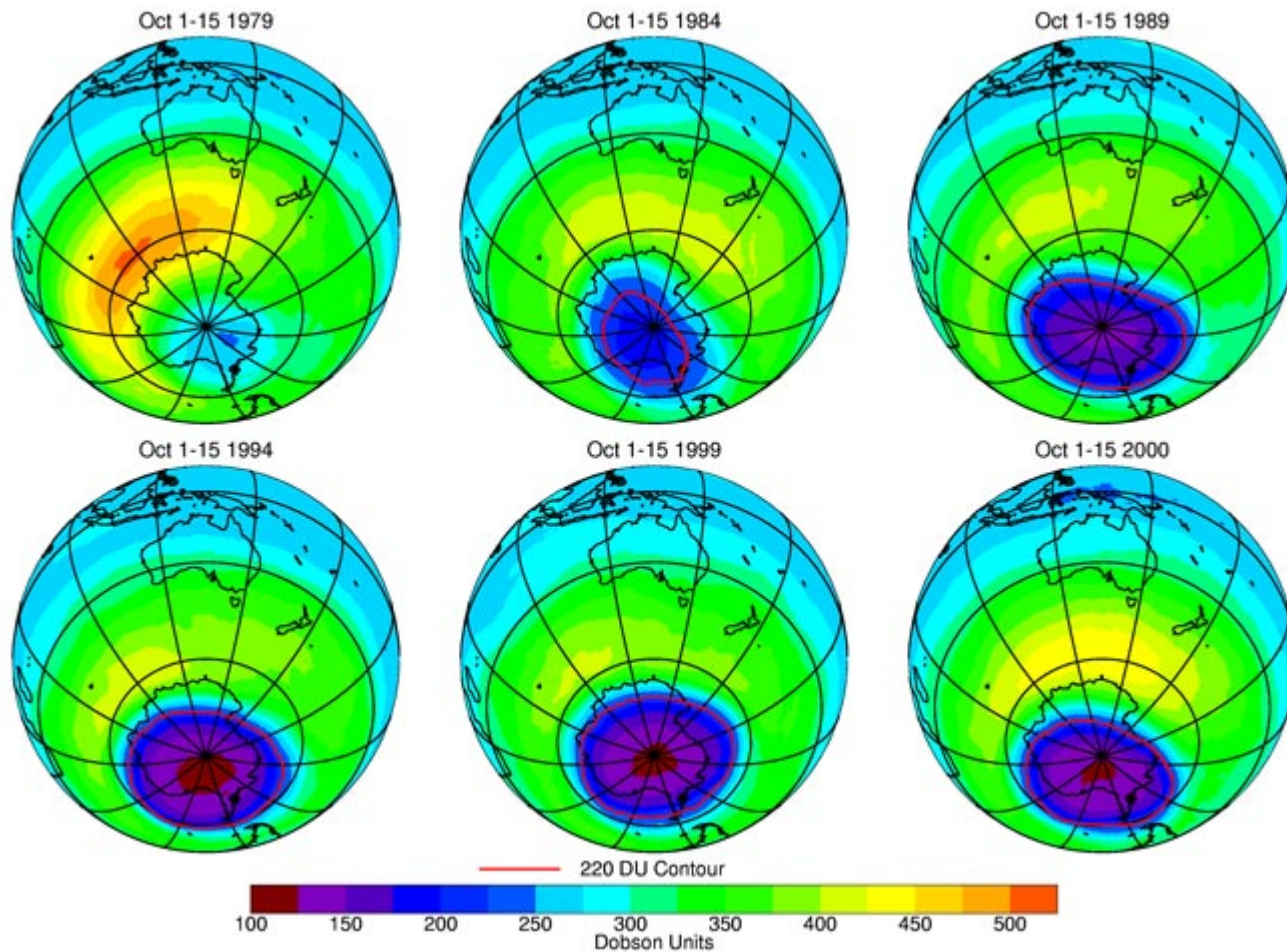
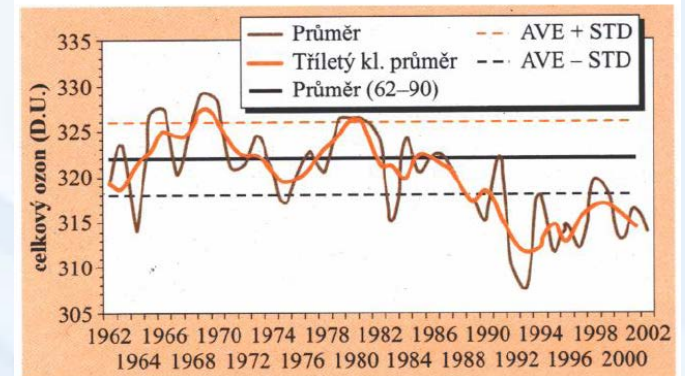
Poškozování ozónové vrstvy země

- freony, halony a další určité halogenované látky
- freony - netoxické, inertní, nízkovroucí kapaliny, výborné izolanty

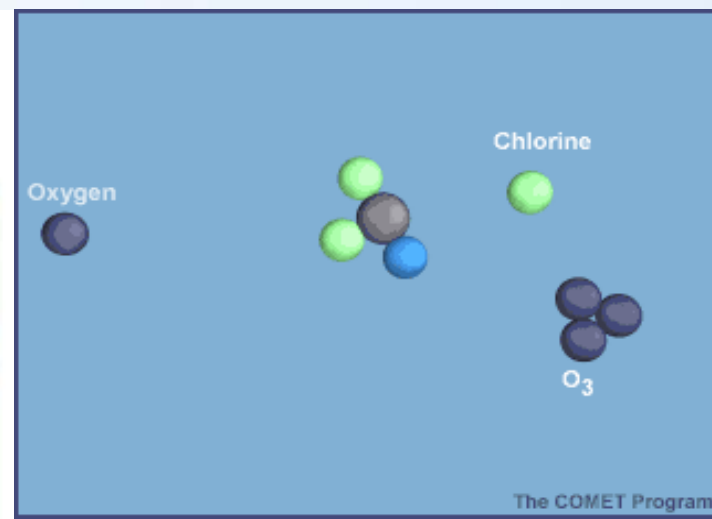
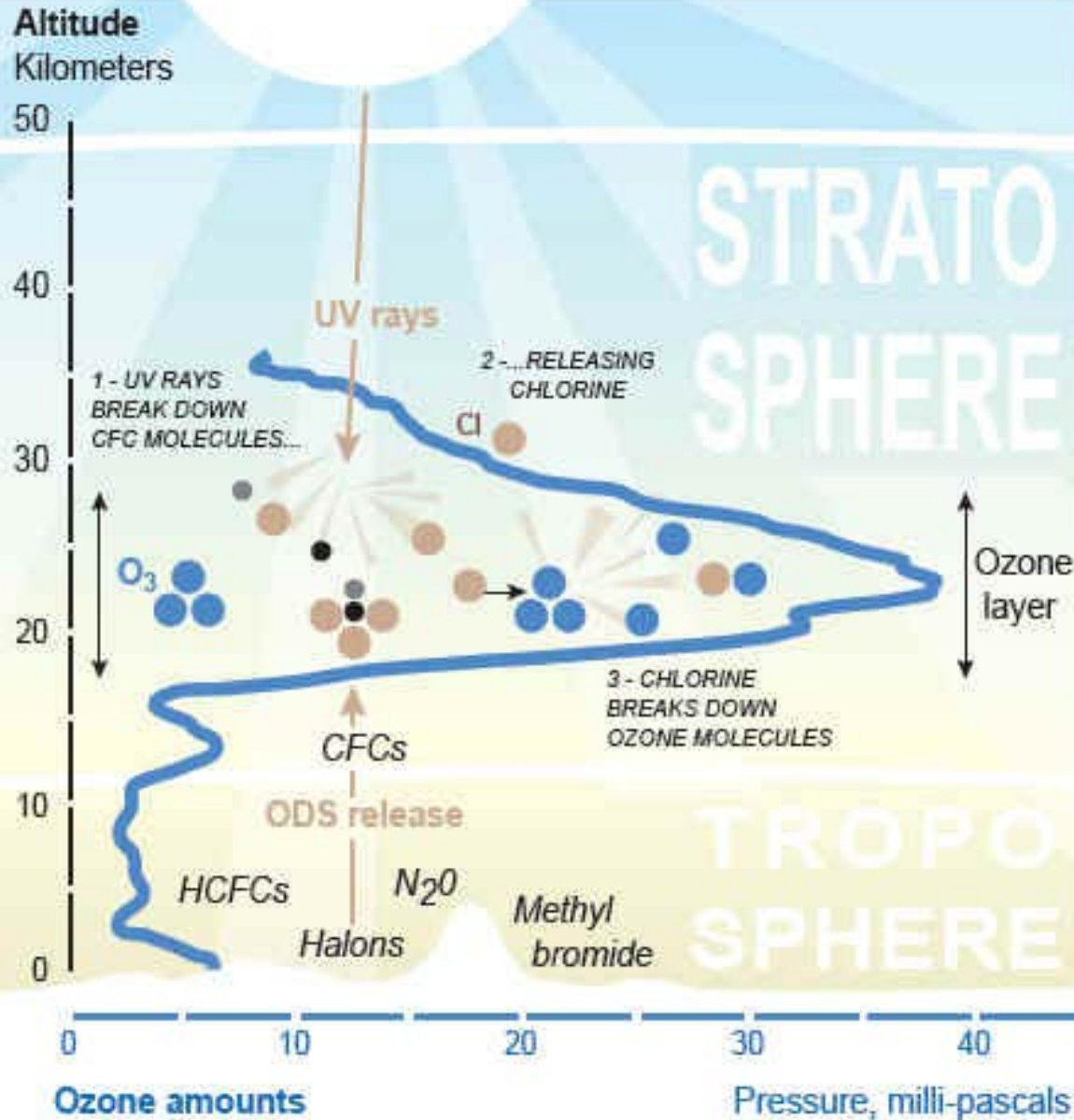


Ozónová díra

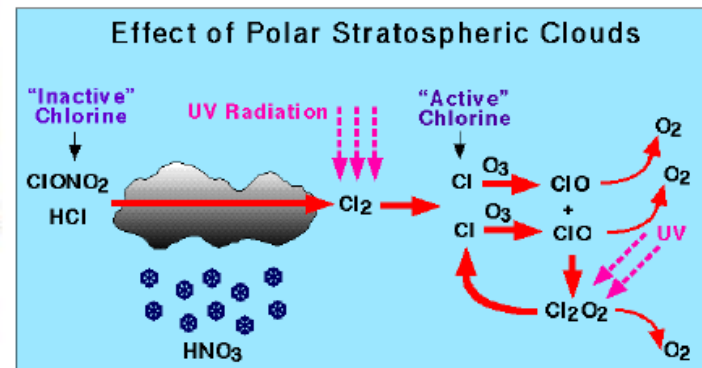
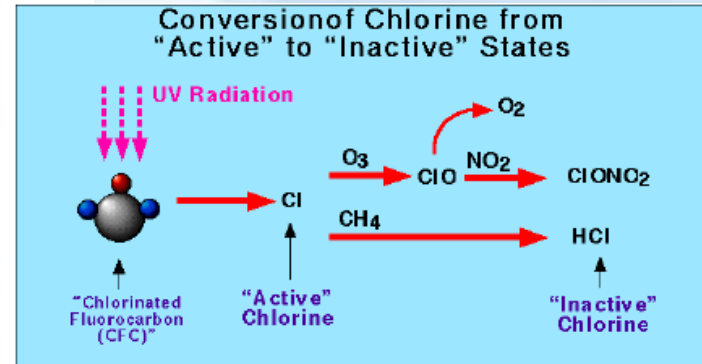
- výrazný úbytek ozónu především nad **polárními** oblastmi



CHEMICAL OZONE DESTRUCTION PROCESS IN THE STRATOSPHERE



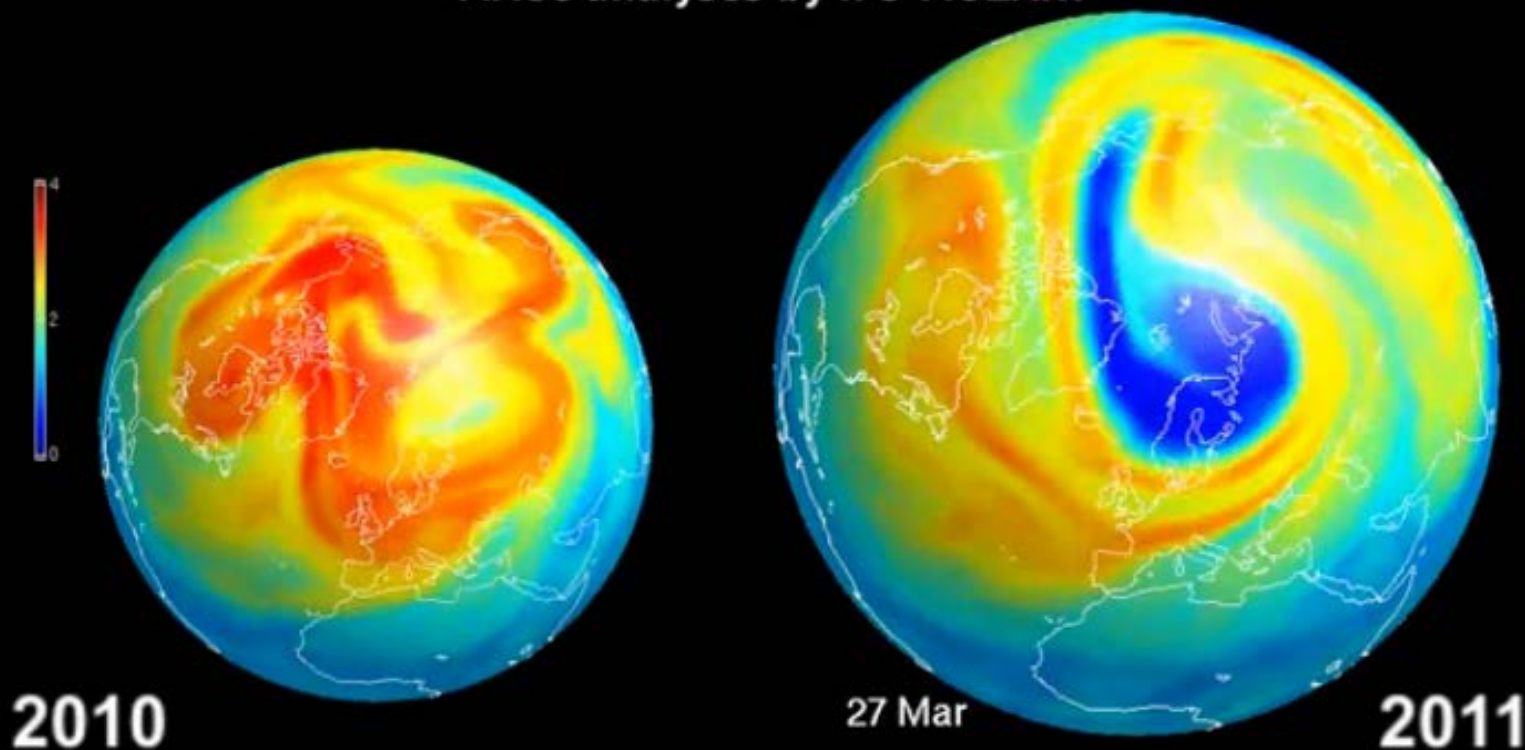
Proč nad póly?



Úbytek stratosférického O₃ nad Arktidou

Stratospheric ozone

Mixing ratio (ppmv) at 470K
MACC analyses by IFS-MOZART



www.gmes-atmosphere.eu

MACC
Monitoring atmospheric
composition & climate

ECMWF

JÜLICH
FORSCHUNGSCENTRUM

aeronomie.be

0:16

Důsledky úbytku O_3

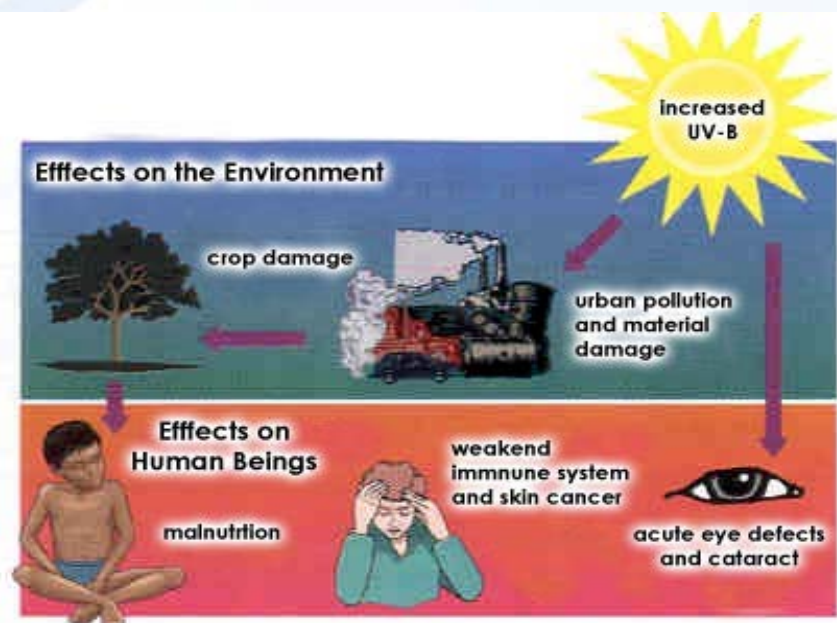


The ozone Hole



Důsledky úbytku strat. O₃

1% ↓ konc. O₃ ≈ 2% ↑ intenzity UVB ≈ 4% ↑ rizika rakov. kůže



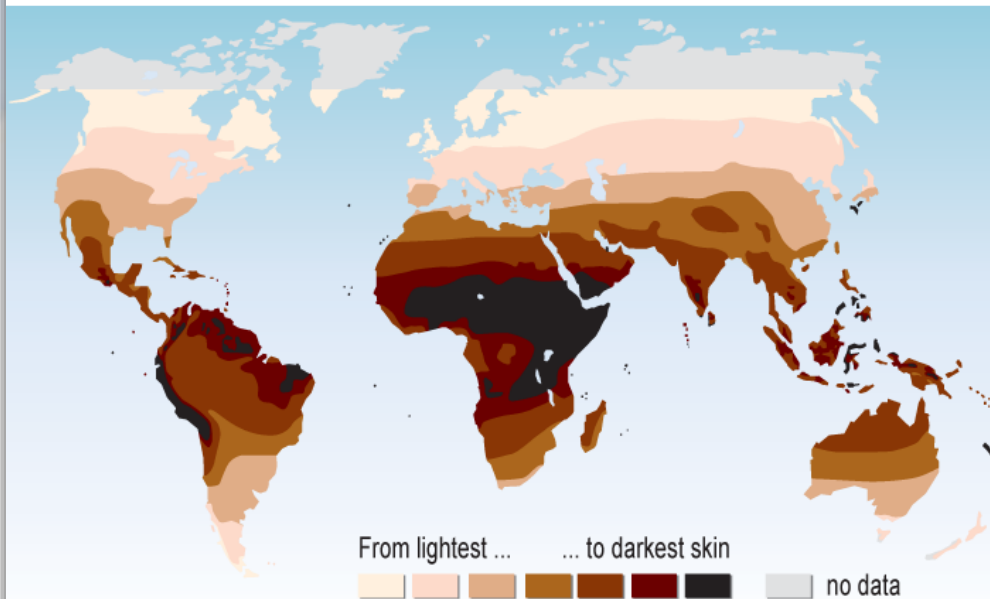
- většina melanomů vzniká na **osluněné části kůže**
- nejčastější výskyt u Australanů



VULNERABILITIES

Skin colour map (indigenous people)

Predicted from multiple environmental factors



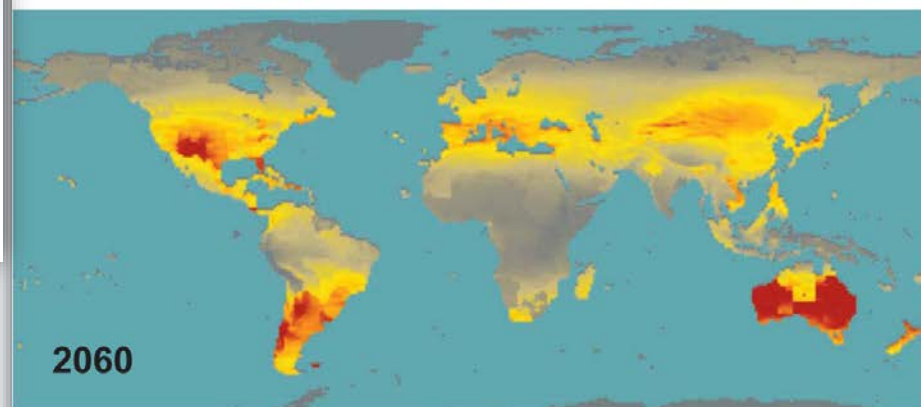
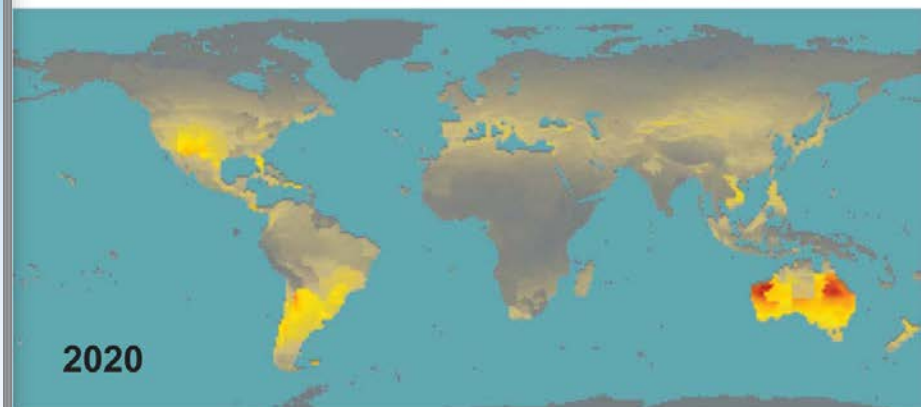
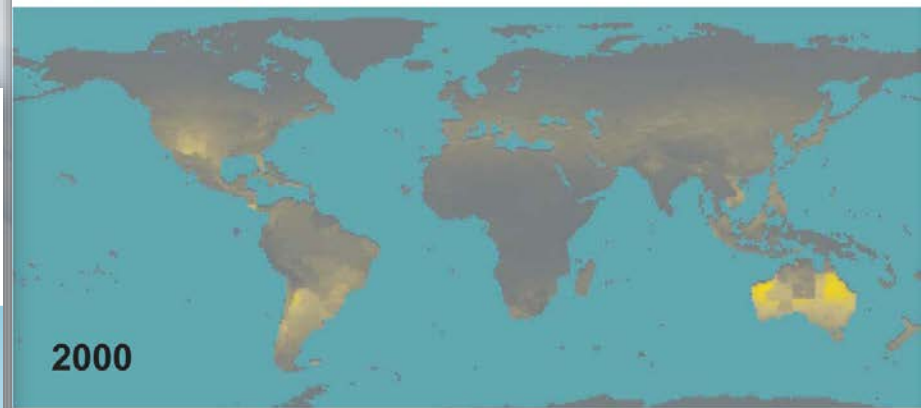
Source: Chaplin G.®, *Geographic Distribution of Environmental Factors Influencing Human Skin Coloration*, American Journal of Physical Anthropology 125:292–302, 2004; map updated in 2007.



Centrum pro výzkum
toxických látek
v prostředí

Number of extra skin cancer cases related to UV radiation

Per million inhabitants per year



Source: Dutch National Institute for Public Health and the Environment (RIVM), Laboratory for Radiation Research (www.rivm.nl/milieuStoffen/straling/zomertherma_uv/), 2007



Dopad zvýšené UVB radiace na plodiny

Possible changes in plant characteristics

- Reduced **photosynthesis**
- Reduced **water-use efficiency**
- Enhanced **drought stress sensitivity**
- Reduced **leaf area**
- Reduced **leaf conductance**
- Modified **flowering**
(either inhibited or stimulated)
- Reduced **dry matter production**

Consequences

Enhanced plant fragility

Growth limitation

Yield reduction

Selected sensitive crops

Rice

Oats

Sorghum

Soybeans

Beans

NB: Summary conclusions from artificial exposure studies.

Source: modified from Krupa and Kickert (1989) by Runeckles and Krupa (1994) in: Fakhri Bazzaz, Wim Sombroek, *Global Climate Change and Agricultural Production*, FAO, Rome, 1996.



Ozonová díra

- možná řešení?

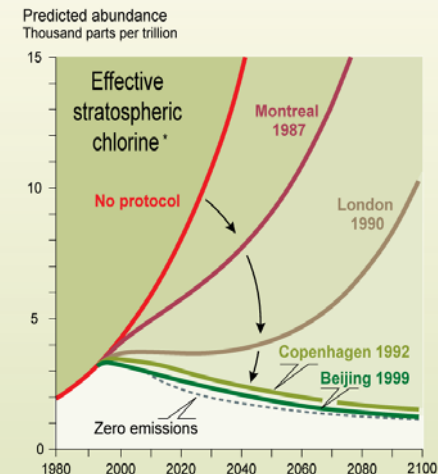


Řešení a důsledky

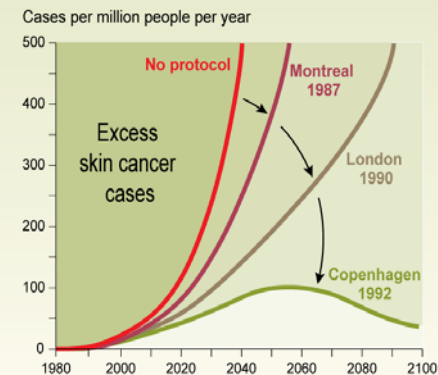
1985 – Vídeňská smlouva na ochranu O₃ vrstvy

1987 – Montrealský protokol + další dodatky

THE EFFECTS OF THE MONTREAL PROTOCOL AMENDMENTS
AND THEIR PHASE-OUT SCHEDULES



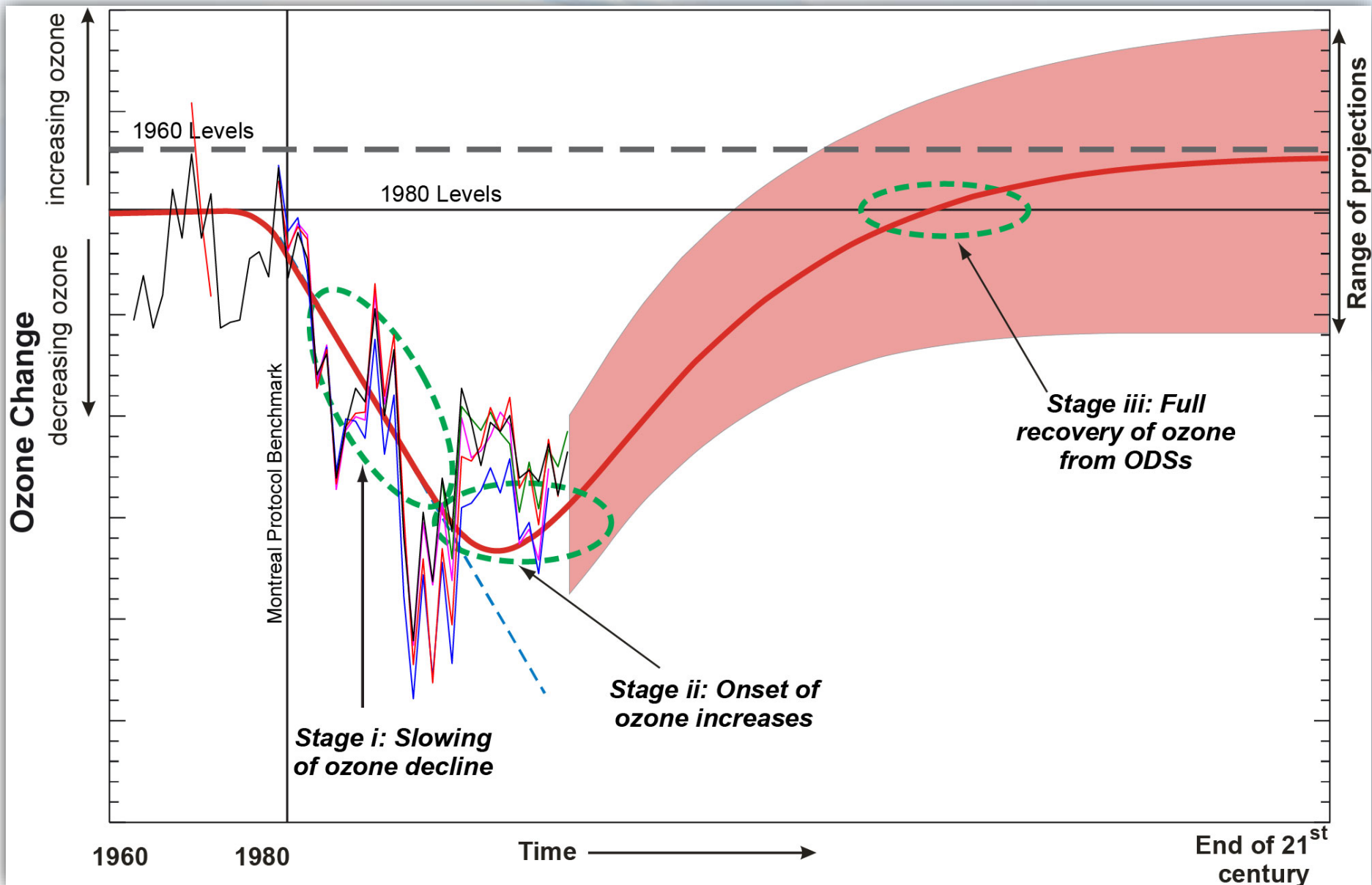
* Chlorine and bromine are the molecules responsible for ozone depletion.
"Effective chlorine" is a way to measure the destructive potential of all ODS
gases emitted in the stratosphere.



Source: *Twenty Questions and Answers about the Ozone Layer: 2006 Update*,
Lead Author: D.W. Fahey, Panel Review Meeting for the 2006 ozone assessment.



Časová prodleva – ozón a jeho obnova



Řešení a důsledky

1985 – Vídeňská smlouva na ochranu O₃ vrstvy

1987 – Montrealský protokol + další dodatky

THE EFFECTS OF THE MONTREAL PROTOCOL AMENDMENTS
AND THEIR PHASE-OUT SCHEDULES

The Nobel Prize in Chemistry 1995



Paul J.
Crutzen

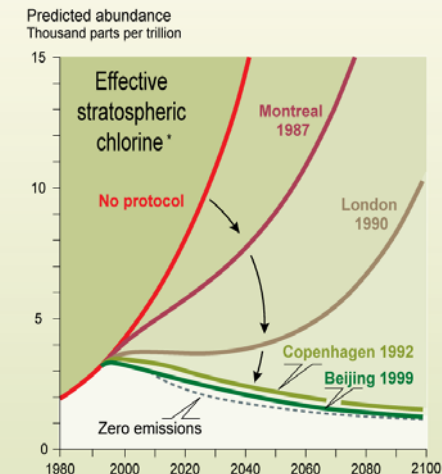


Mario J.
Molina

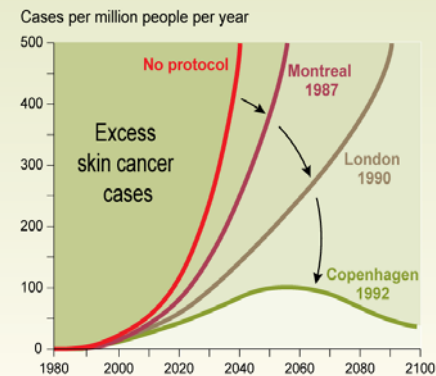


F. Sherwood
Rowland

„for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.“



* Chlorine and bromine are the molecules responsible for ozone depletion.
* Effective chlorine* is a way to measure the destructive potential of all ODS gases emitted in the stratosphere.



Source: Twenty Questions and Answers about the Ozone Layer: 2006 Update, Lead Author: D.W. Fahey, Panel Review Meeting for the 2006 ozone assessment.

Řešení a důsledky

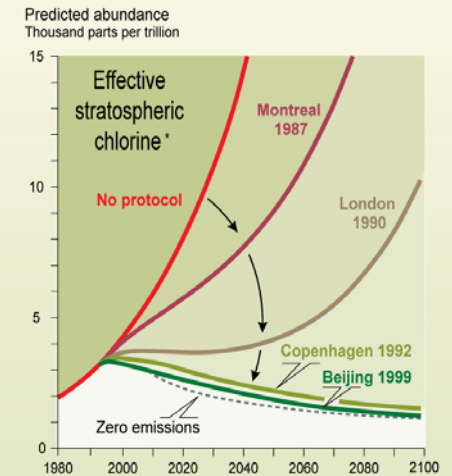
1985 – Vídeňská smlouva na ochranu O₃ vrstvy

1987 – Montrealský protokol + další dodatky

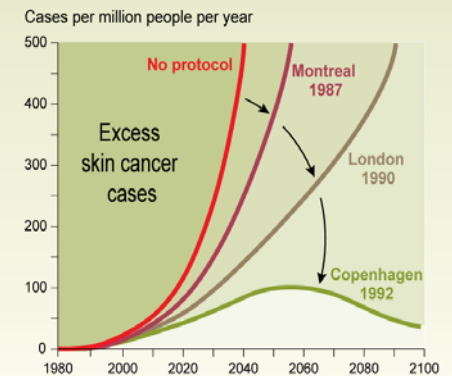
Náklady opuštění CFC

- 1988-2000 - pokles produkce na desetinu
- celkové **náklady** zhruba 40 miliard \$
- ke ztrátám **zaměstnání** nedošlo
- 1/3 snížení prostou **úsporou**
- nahrazování CFC snadnější, často i za snížení nákladů (náhrady levnější)
- **nové HFC** v autech navýšily cenu o 50-150 \$ (předpovězeno 1000-1500 \$)
- CH₃Br pro **sterilizaci** půd nahrazen např. střídáním plodin
- CH₃Br pro **fumigaci** skladů nahrazen CO₂

THE EFFECTS OF THE MONTREAL PROTOCOL AMENDMENTS AND THEIR PHASE-OUT SCHEDULES



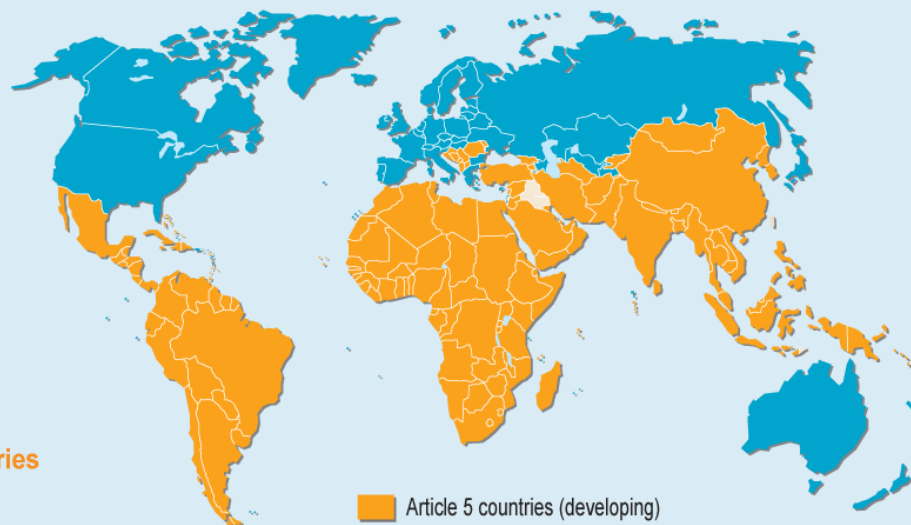
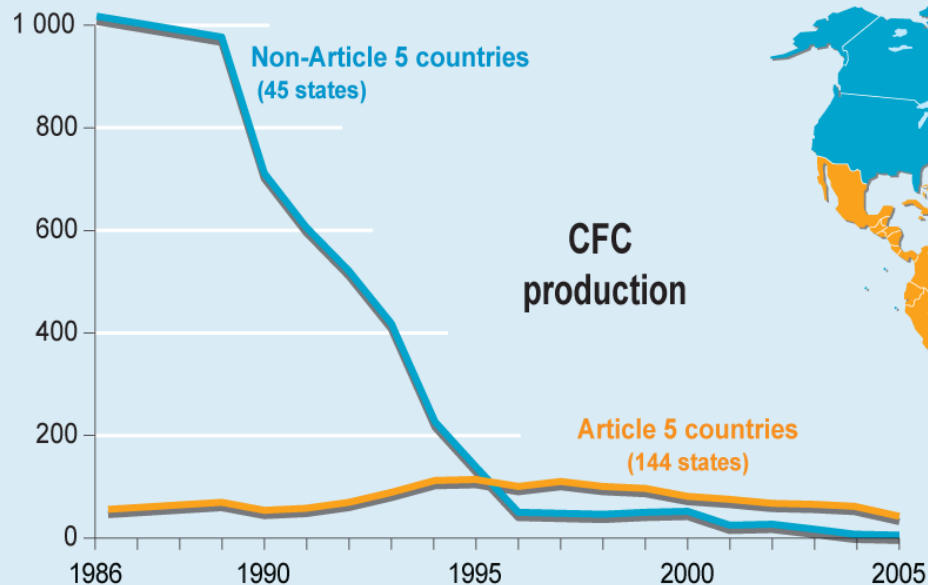
* Chlorine and bromine are the molecules responsible for ozone depletion. "Effective chlorine" is a way to measure the destructive potential of all ODS gases emitted in the stratosphere.



Source: Twenty Questions and Answers about the Ozone Layer: 2006 Update, Lead Author: D.W. Fahey, Panel Review Meeting for the 2006 ozone assessment.

Společná, ale diferencovaná zodpovědnost

Thousand Ozone Depleting Potential Tonnes (ODP Tonnes)*



- Article 5 countries (developing)
- Non-Article 5 countries (industrialized)
- Countries that did not ratify the Montreal Protocol (not on the map: San Marino, Vatican, Andorra)

* Tonnes multiplied by the ozone depleting potential of the considered gas.

Source: United Nations Environment Programme Ozone Secretariat



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Ponaučení z úspěšného řešení globálního problému

- spolupráce zúčastněných aktérů:
- vědecké objevy a monitoring – **upozornění na problém**
- UNEP – **mezinárodní koordinátor politických opatření**
- environmentální aktivisté vyvíjející **tlak na řešení problému**
- uvědomění konzumenti nakupující dle **env. informovanosti**
- techničtí experti vyvíjející **technologie šetrné k ŽP**
- flexibilní a **zodpovědný průmysl**

NEWS

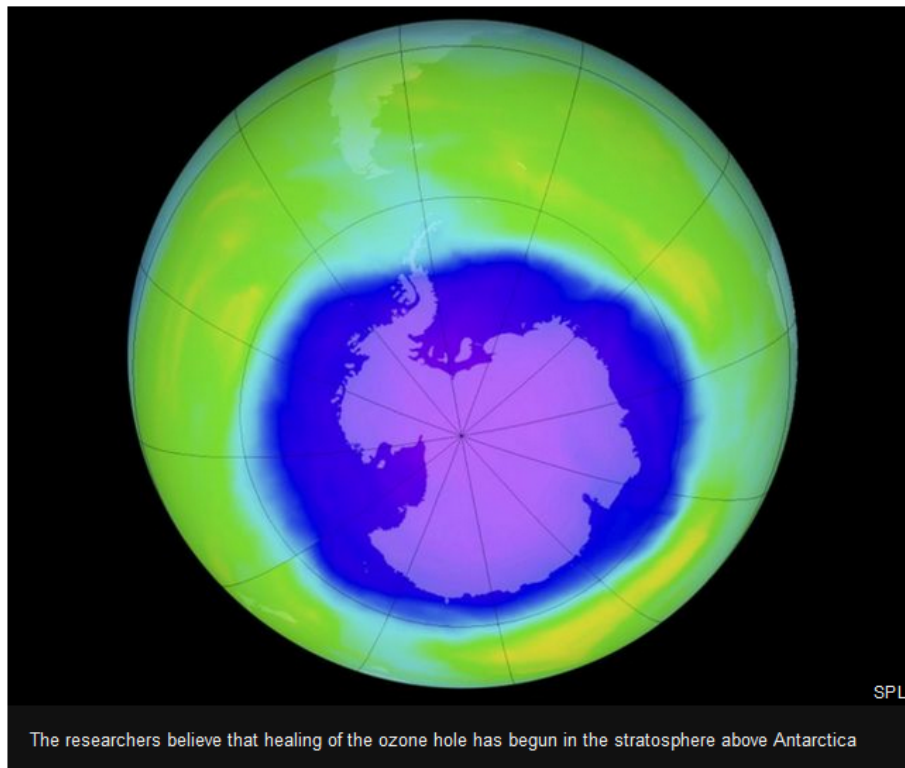
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'Healing' detected in Antarctic ozone hole

By Matt McGrath
Environment correspondent

🕒 30 June 2016 | [Science & Environment](#)

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The researchers believe that healing of the ozone hole has begun in the stratosphere above Antarctica

Researchers say they have found the first clear evidence that the thinning in the ozone layer above Antarctica is starting to heal.



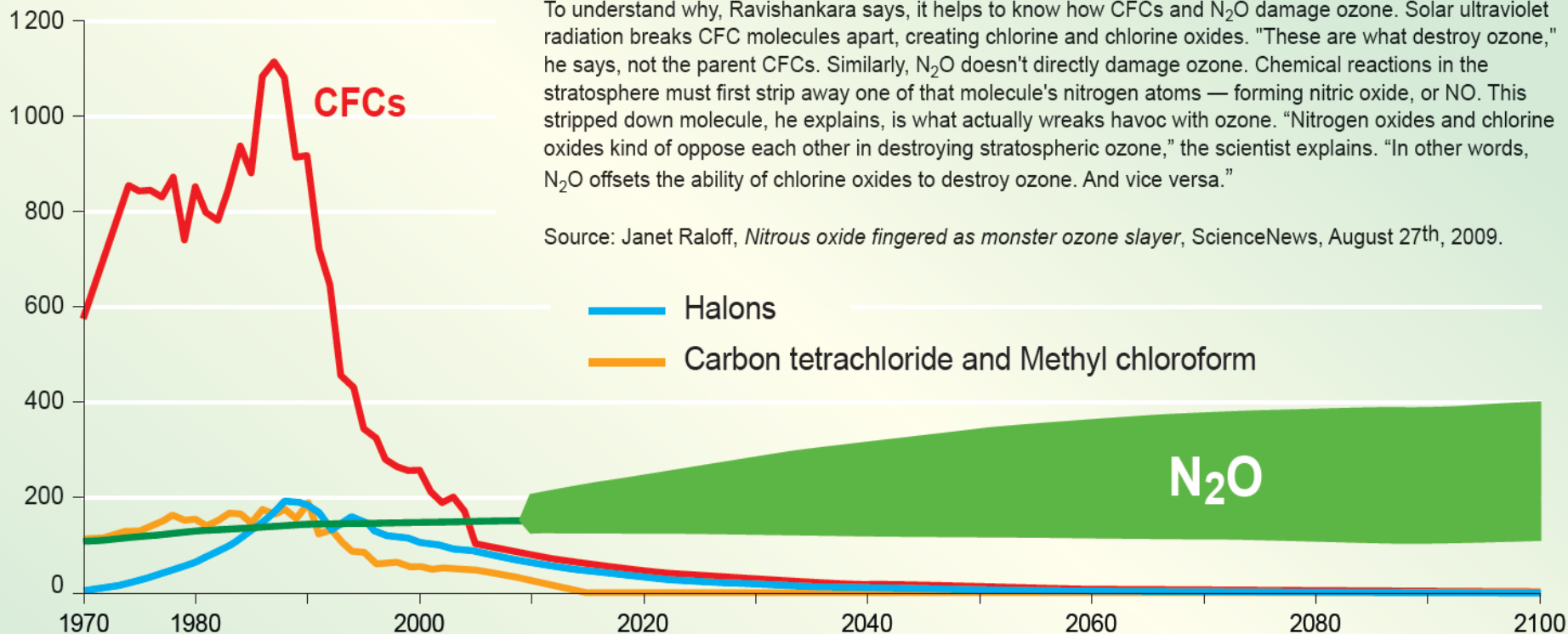
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Aktuální problém – N₂O

NITROUS OXIDE: A MAJOR CULPRIT AFTER 2010

Emissions

Thousand ODP Tonnes



“We have calculated the **ozone-depleting potential of N₂O to be roughly 50 percent larger** when chlorine levels return to the year-1960 level”

To understand why, Ravishankara says, it helps to know how CFCs and N₂O damage ozone. Solar ultraviolet radiation breaks CFC molecules apart, creating chlorine and chlorine oxides. “These are what destroy ozone,” he says, not the parent CFCs. Similarly, N₂O doesn’t directly damage ozone. Chemical reactions in the stratosphere must first strip away one of that molecule’s nitrogen atoms — forming nitric oxide, or NO. This stripped down molecule, he explains, is what actually wreaks havoc with ozone. “Nitrogen oxides and chlorine oxides kind of oppose each other in destroying stratospheric ozone,” the scientist explains. “In other words, N₂O offsets the ability of chlorine oxides to destroy ozone. And vice versa.”

Source: Janet Raloff, *Nitrous oxide fingered as monster ozone slayer*, ScienceNews, August 27th, 2009.

* Tonnes multiplied by the ozone depleting potential of the considered gas.

Source: A. R. Ravishankara, John S. Daniel, Robert W. Portmann, *Nitrous oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century*, Science, August 2009.



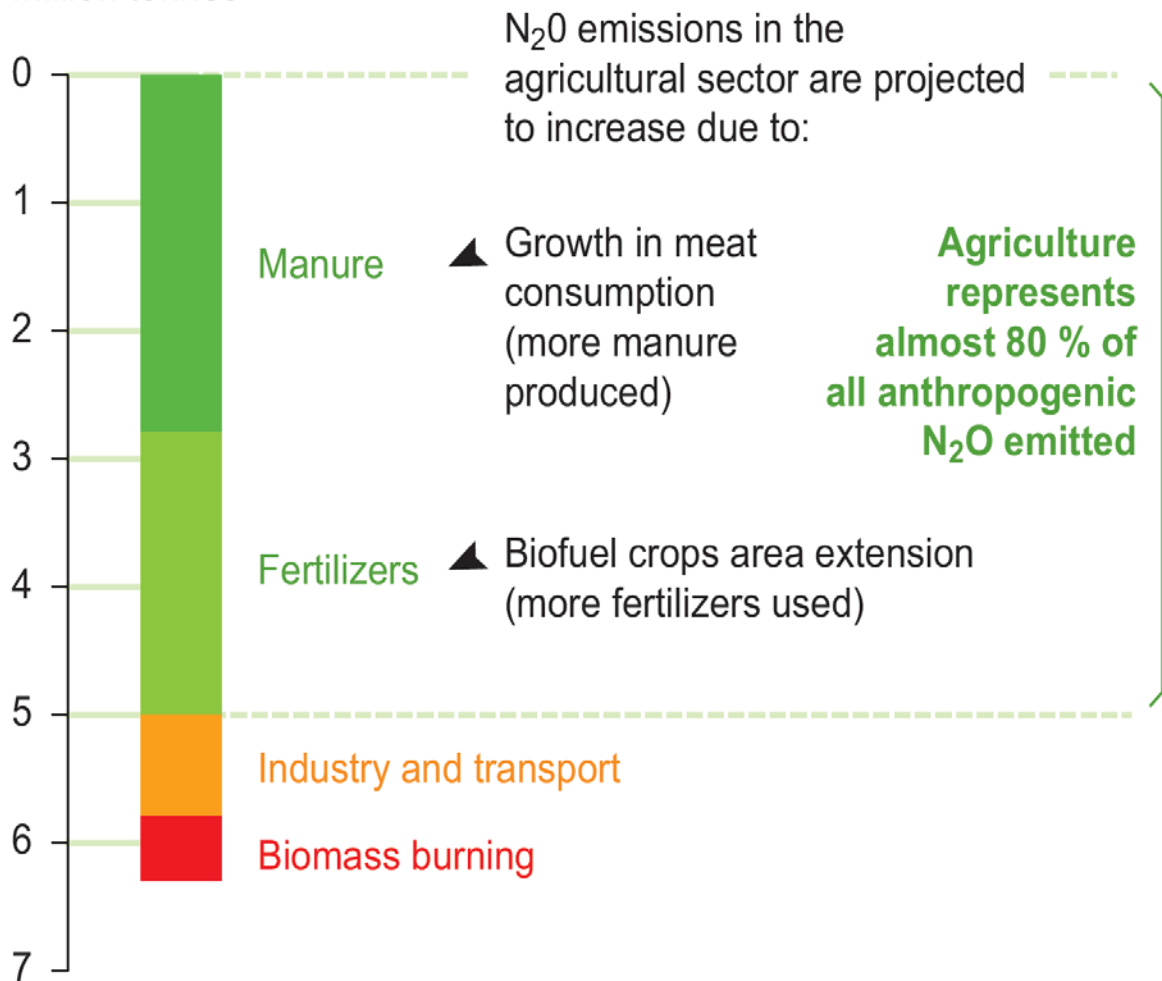
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Aktuální problém – N₂O



Nitrous oxide anthropogenic emissions

Million tonnes



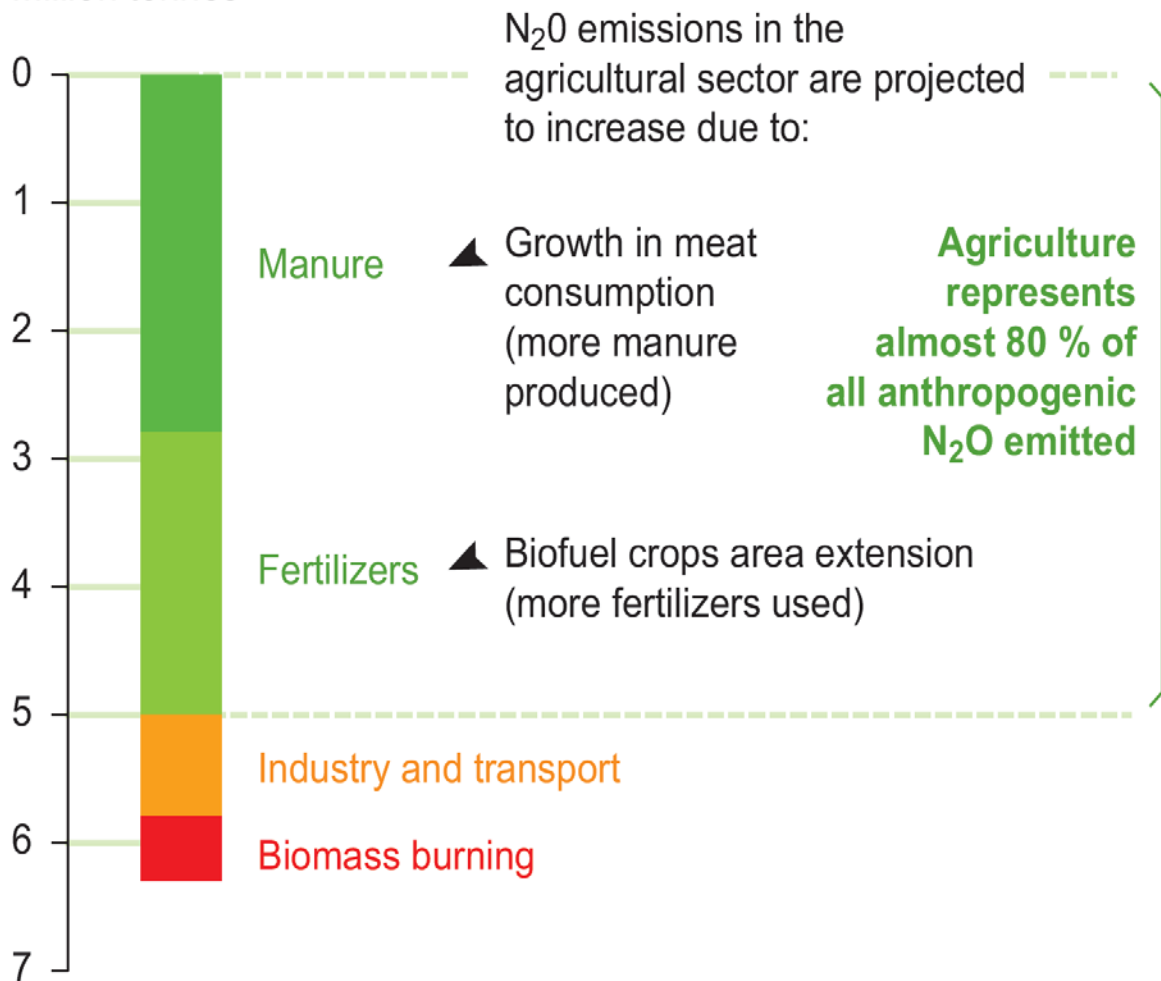
Source: Eric A. Davidson, *The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860*, Nature Geoscience, August 2009.

Aktuální problém – N₂O



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Million tonnes



Atmos. Chem. Phys. Discuss., 7, 11191–11205, 2007
www.atmos-chem-phys-discuss.net/7/11191/2007/
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N₂O release from agro-biofuel production negates global warming reduction by replacing fossil fuels

P. J. Crutzen^{1,2,3}, A. R. Mosier⁴, K. A. Smith⁵, and W. Winiwarter^{3,6}

¹Max Planck Institute for Chemistry, Department of Atmospheric Chemistry, Mainz, Germany

²Scripps Institution of Oceanography, University of California, La Jolla, USA

³International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

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Received: 28 June 2007 – Accepted: 19 July 2007 – Published: 1 August 2007

Correspondence to: P. J. Crutzen (crutzen@mpch-mainz.mpg.de)

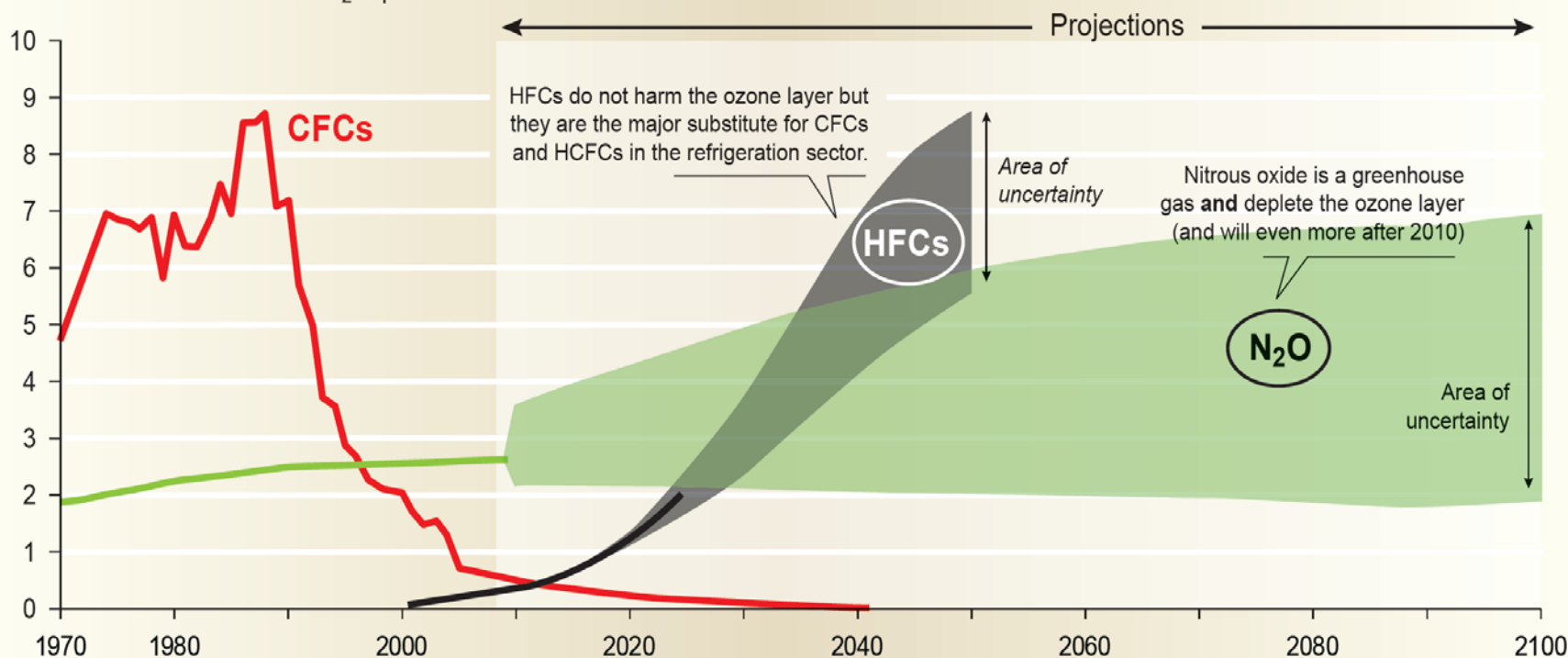
Source: Eric A. Davidson, *The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860*, Nature Geoscience, August 2009.

Globální oteplování x úbytek stratosférického ozónu

HFC AND N₂O: TWO CLIMATE ENEMIES RELATED TO THE OZONE LAYER

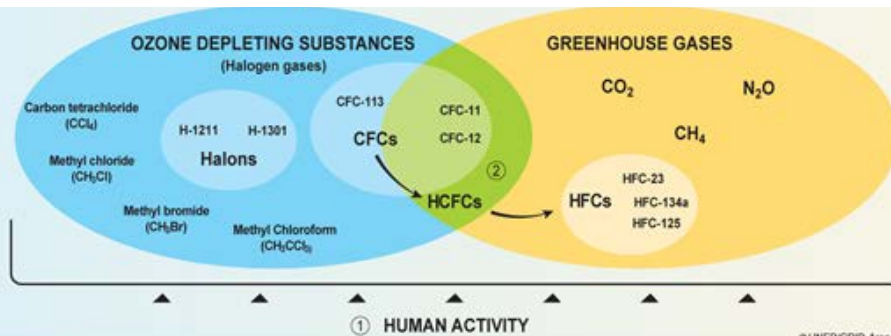
Selected greenhouse gases emissions

Thousand million tonnes of CO₂-equivalent



Source: A. R. Ravishankara, John S. Daniel, Robert W. Portmann, *Nitrous oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century*, Science, August 2009.

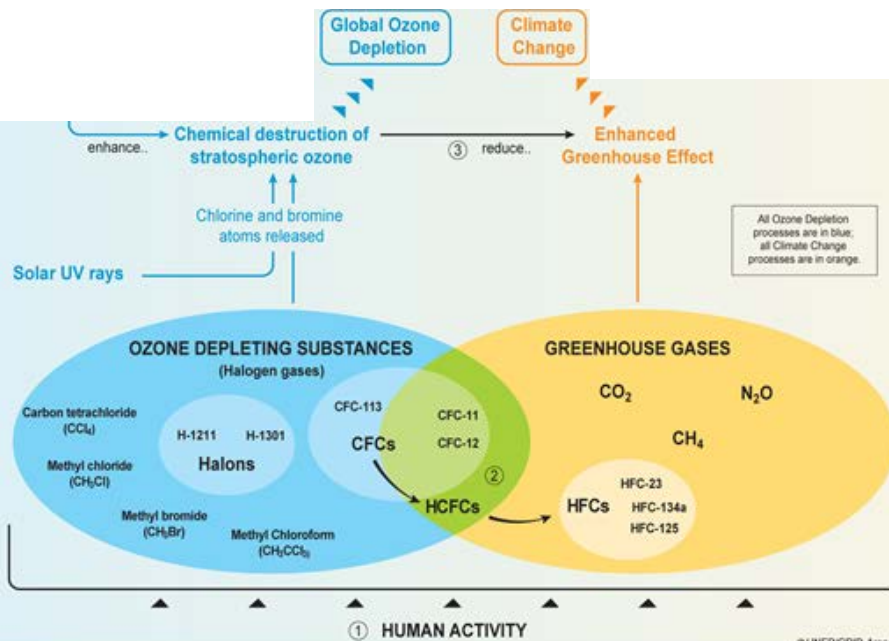




Ozone depletion and climate change are two distinct problems but as they both modify global cycles, they cannot be totally separated. There are still many uncertainties concerning the relations between the two processes. Several links have been identified, in particular:

- ① Both processes are due to human-induced emissions.
- ② Many ozone depleting substances are also greenhouse gases, like CFC-11 and CFC12. HFCs, promoted to substitute CFCs, are sometimes stronger greenhouse gases than the CFCs they are replacing, but do not deplete the ozone layer. This fact is taken into account in the negotiations and decisions in both the Montreal and the Kyoto Protocol.
- ③ Ozone itself is a greenhouse gas. Therefore, its destruction in the stratosphere indirectly helps to cool the climate, but only to a small extent.
- ④ The global change in atmospheric circulation could be the cause of the recently observed cooling of stratospheric temperature. These low temperatures drive the formation of polar stratospheric clouds above the poles in the winter, greatly enhancing chemical ozone destruction and the formation of the "hole".
- ⑤ Human vulnerability to UV-B radiation is related to the albedo. The global warming context reduces white surfaces that are more likely to harm us.



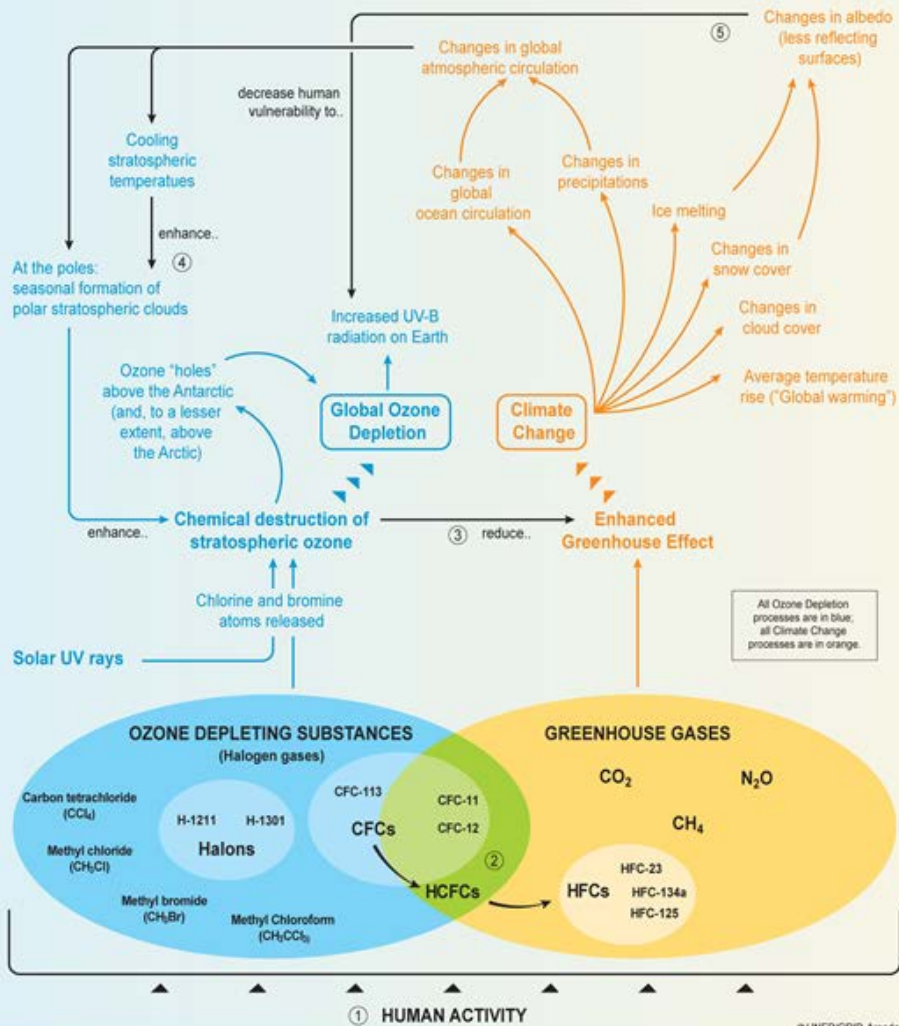


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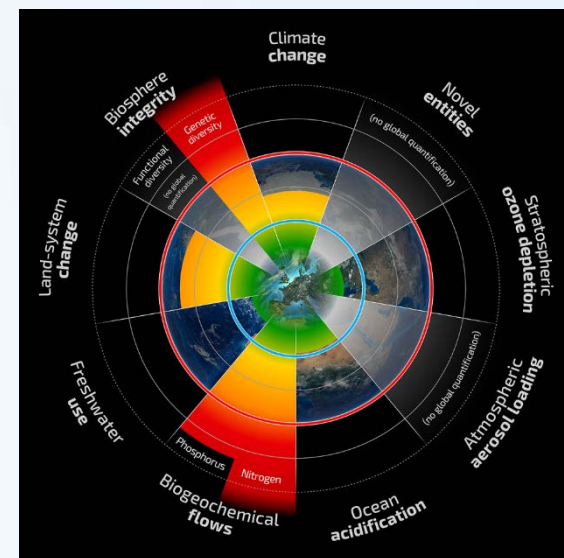
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IV. Okyselování oceánů

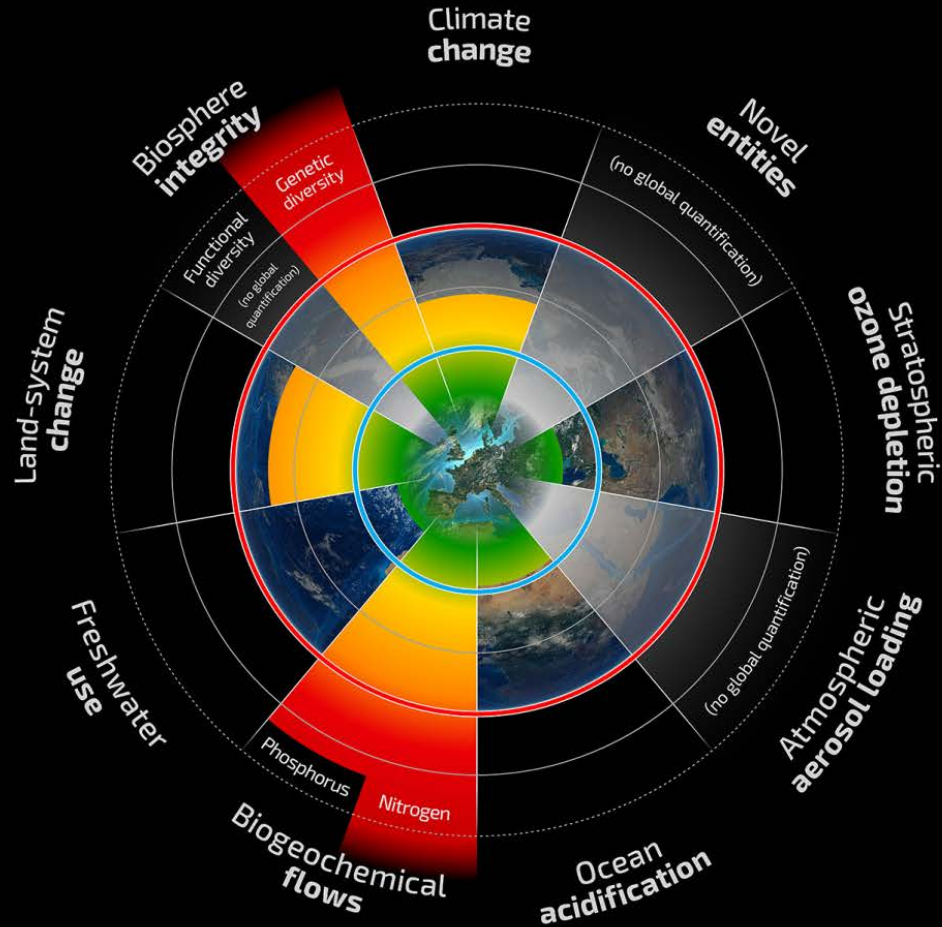
Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Ocean acidification (R2009: same)	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	$\geq 80\%$ of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability ($\geq 80\%$ – $\geq 70\%$)	$\sim 64\%$ of the pre-industrial aragonite saturation state



Překročení hranic?

Planetary Boundaries

A safe operating space for humanity



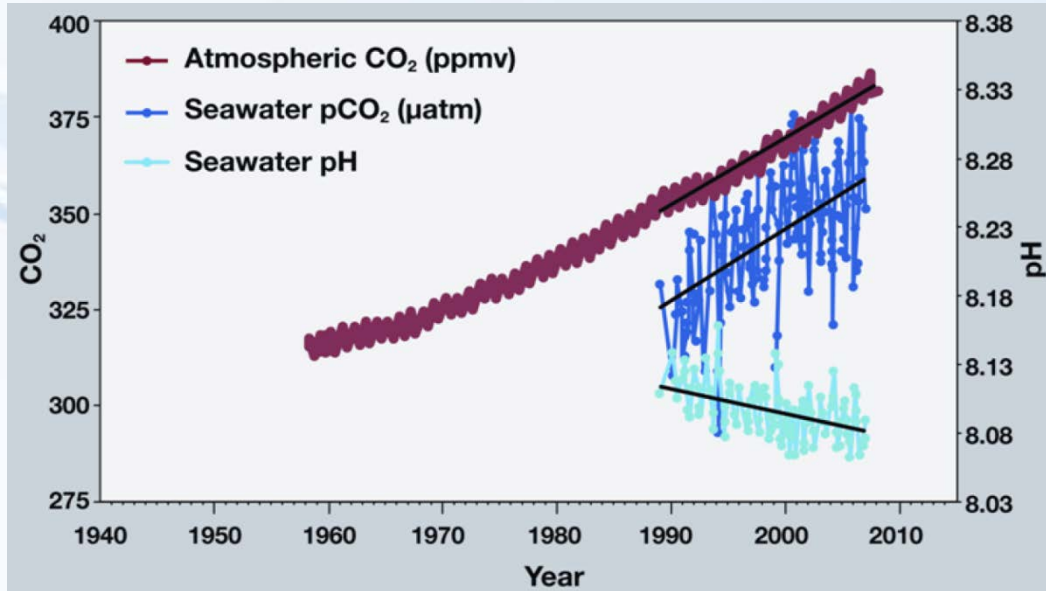
- Beyond zone of uncertainty (high risk)
- In zone of uncertainty (increasing risk)
- Below boundary (safe)
- Boundary not yet quantified



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Okyselování oceánů

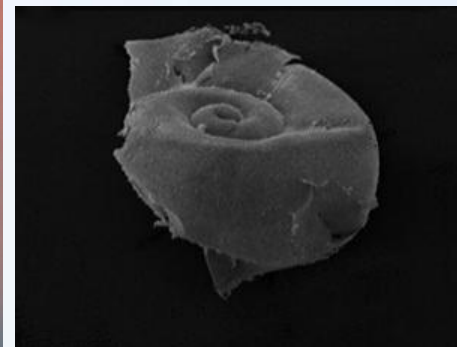
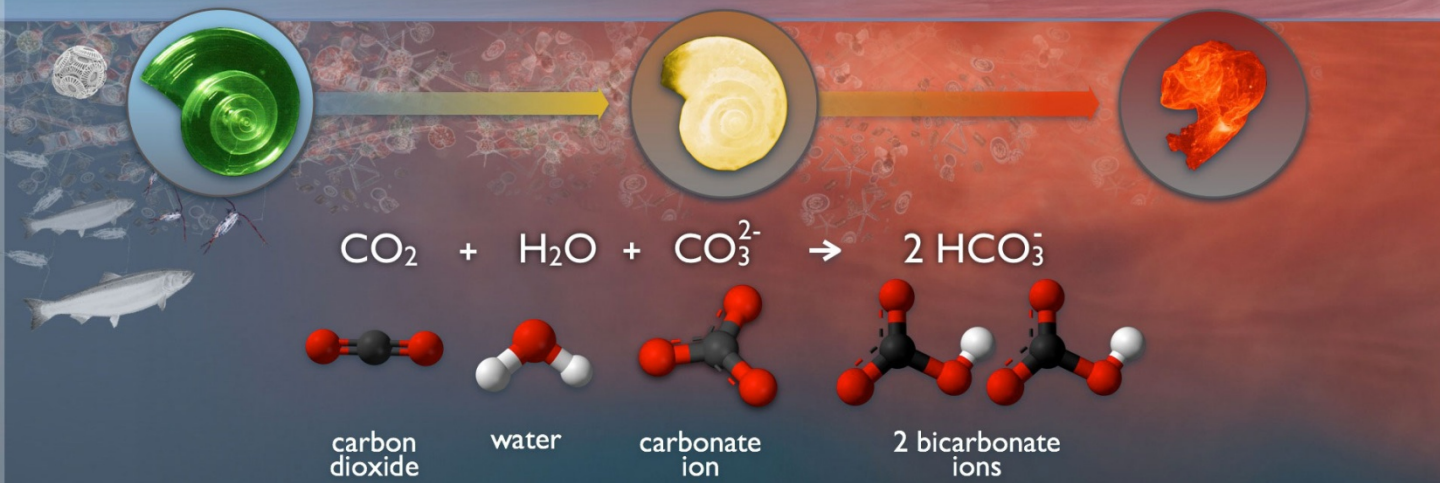
- čím je způsobené?



OCEAN ACIDIFICATION

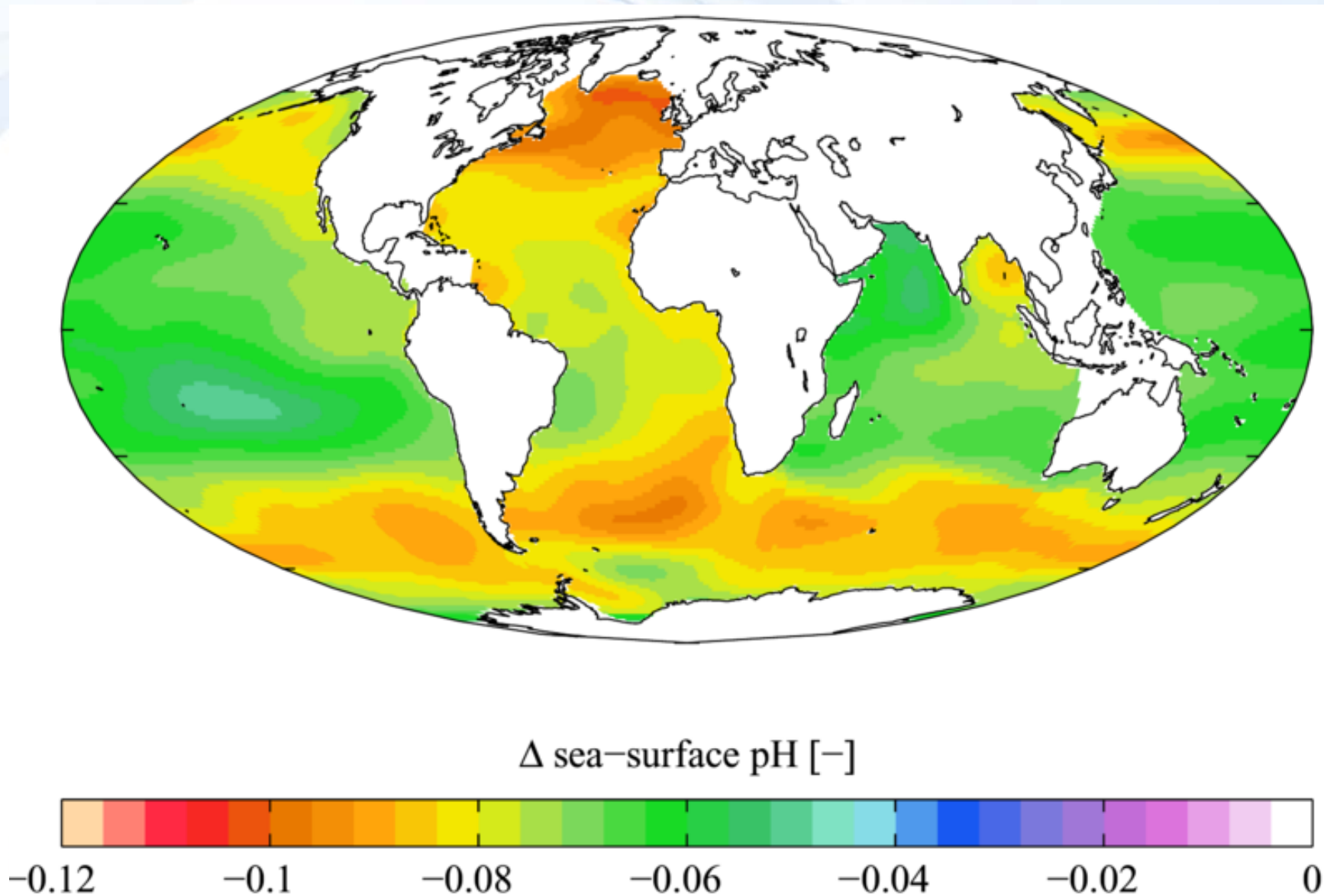
HOW WILL CHANGES IN OCEAN CHEMISTRY AFFECT MARINE LIFE?

CO₂ absorbed from the atmosphere



consumption of carbonate ions impedes calcification

Změna pH oceánů 1700-2000

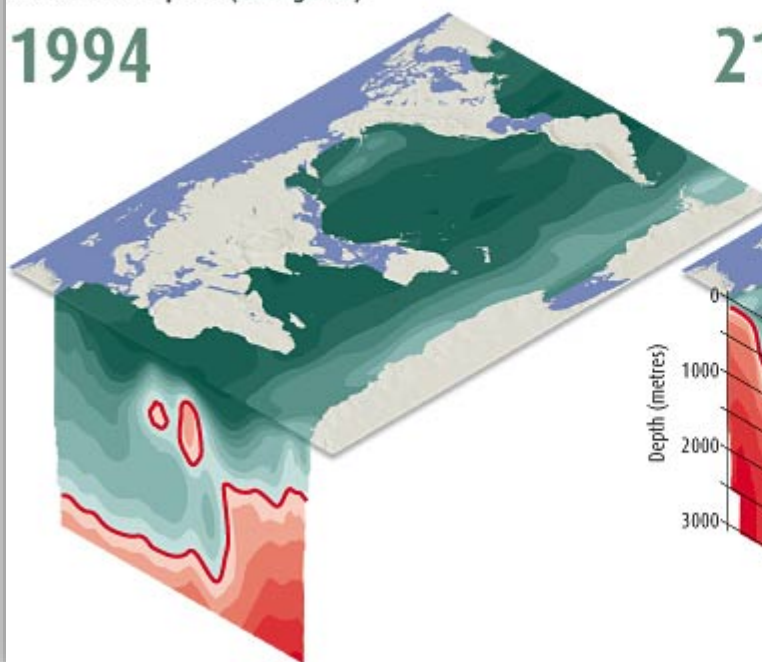


Změna pH oceánů - 3D rozvrstvení

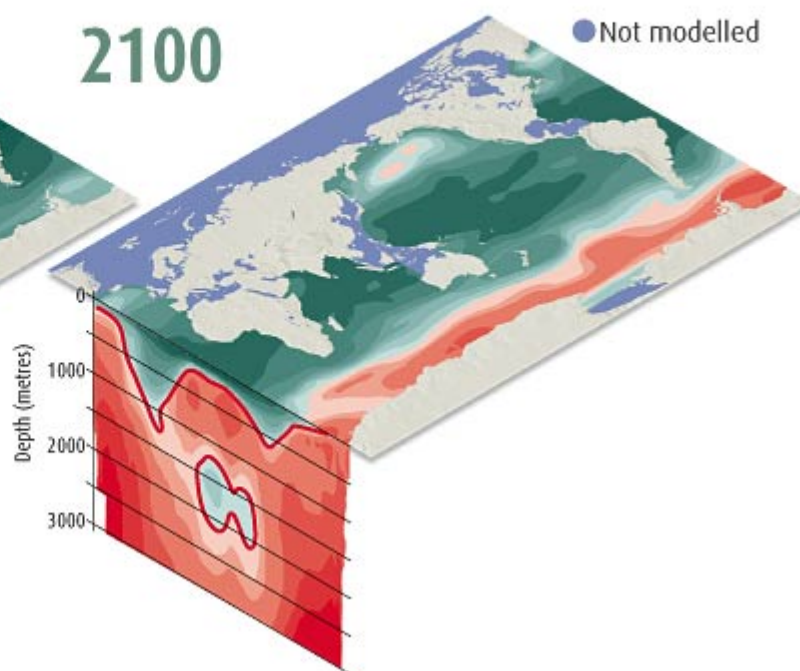
SHELL HELL

Many creatures make their shells or skeletons from a form of calcium carbonate called aragonite. This is possible because, apart from the deepest waters, most seawater is supersaturated with carbonate ions (green areas). As CO₂ levels rise, the saturation horizon will move upwards and even some surface water will become undersaturated (red). Tropical corals thrive in water three or four times past the saturation point (dark green)

1994



2100



SOURCE: ORR 2005



„Přírodní laboratoř“

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Natural lab shows sea's acid path

By Richard Black

Environment correspondent, BBC News website



Scientists study conditions at the bottom of the Mediterranean Sea

Natural carbon dioxide vents on the sea floor are showing scientists how carbon emissions will affect marine life.

Dissolved CO₂ makes water more acidic, and around the vents, researchers saw a fall in species numbers, and snails with their

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26 March 2014 Last updated at 23:03 GMT

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How climate change will acidify the oceans

By Roger Harrabin

BBC environment analyst, Normanby Island



Off the remote eastern tip of Papua New Guinea a natural phenomenon offers an alarming glimpse into the future of the oceans, as increasing concentrations of CO₂ in the atmosphere make sea water more acidic.

Streams of volcanic CO₂ bubbles emerge from deep under the seabed here, like a giant jacuzzi.

As the bubbles of carbon dioxide dissolve into the water, carbonic acid is

In today's
Magazine

One lonely man and
his hoard of Nazi art

Malaysia plane: 10
questions that are
still unresolved

Kombinace antropogenních změn oceánů

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The oceans are heating, acidifying and choking

› 19:58 04 October 2013 by [Fred Pearce](#)

› For similar stories, visit the [Climate Change](#) Topic Guide

We know the oceans are warming. We know they are acidifying. And now, to cap it all, it turns out they are suffocating, too. A new health check on the state of the oceans warns that they will have lost as much as 7 per cent of their oxygen by the end of the century.

The cascade of chemical and biological changes now under way could see coral reefs irreversibly destroyed in 50 to 100 years, with marine ecosystems increasingly taken over by [jellyfish](#) and toxic algal blooms.

The [review](#) is a repeat of a study two years ago by the [International Programme on the State of the Ocean \(IPSO\)](#), a coalition of scientists. It concludes that things have become worse since the first study.

"The health of the oceans is spiralling downwards far more rapidly than we had thought, exposing organisms to intolerable and unpredictable evolutionary pressure," says [Alex Rogers](#) at the University of Oxford, the scientific director of IPSO.

Deadly trio

Rogers describes a "deadly trio" of linked global threats. The first is global warming: surface sea water has been [warming](#) almost as fast as the atmosphere. The second is [acidification](#) – a result of the water absorbing ever more CO₂ from the atmosphere. The third is [deoxygenation](#).

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Getting harder to breathe underwater (Image: [Incredible Features/Barcroft Media](#))

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