

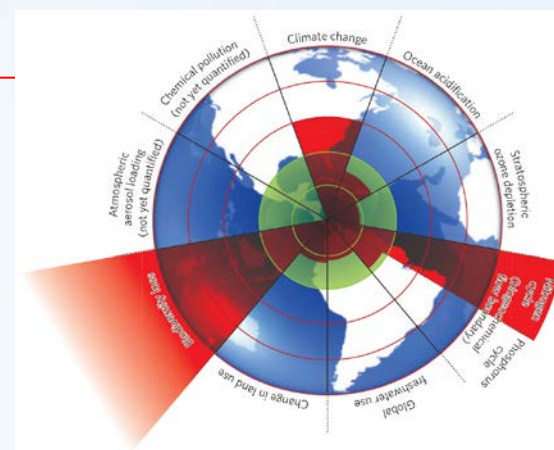
III. Úbytek stratosférického ozónu

Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Stratospheric ozone depletion	Stratospheric O ₃ concentration, DU	Severe and irreversible UV-B radiation effects on human health and ecosystems.	<5% reduction from pre-industrial level of 290 DU (5%–10%)	<ol style="list-style-type: none"> 1. Ample scientific evidence. 2. Threshold well established. 3. Boundary position implicitly agreed and respected.

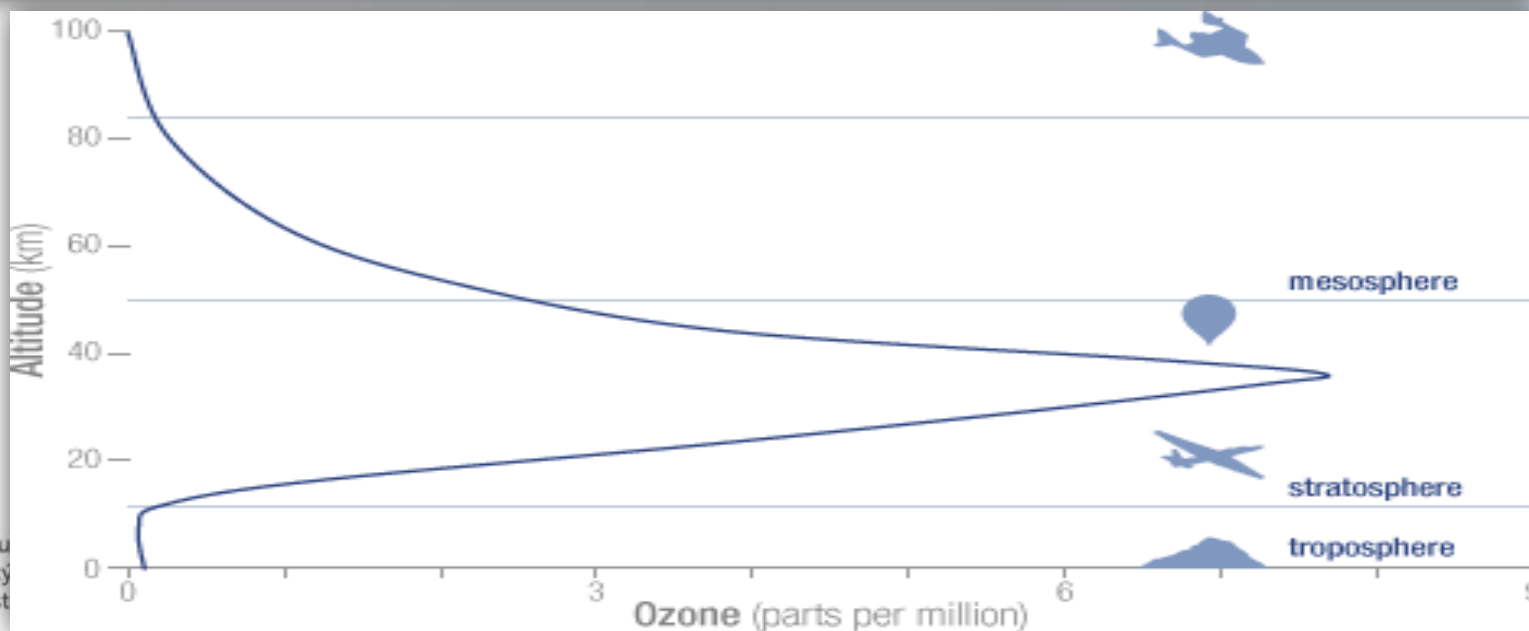
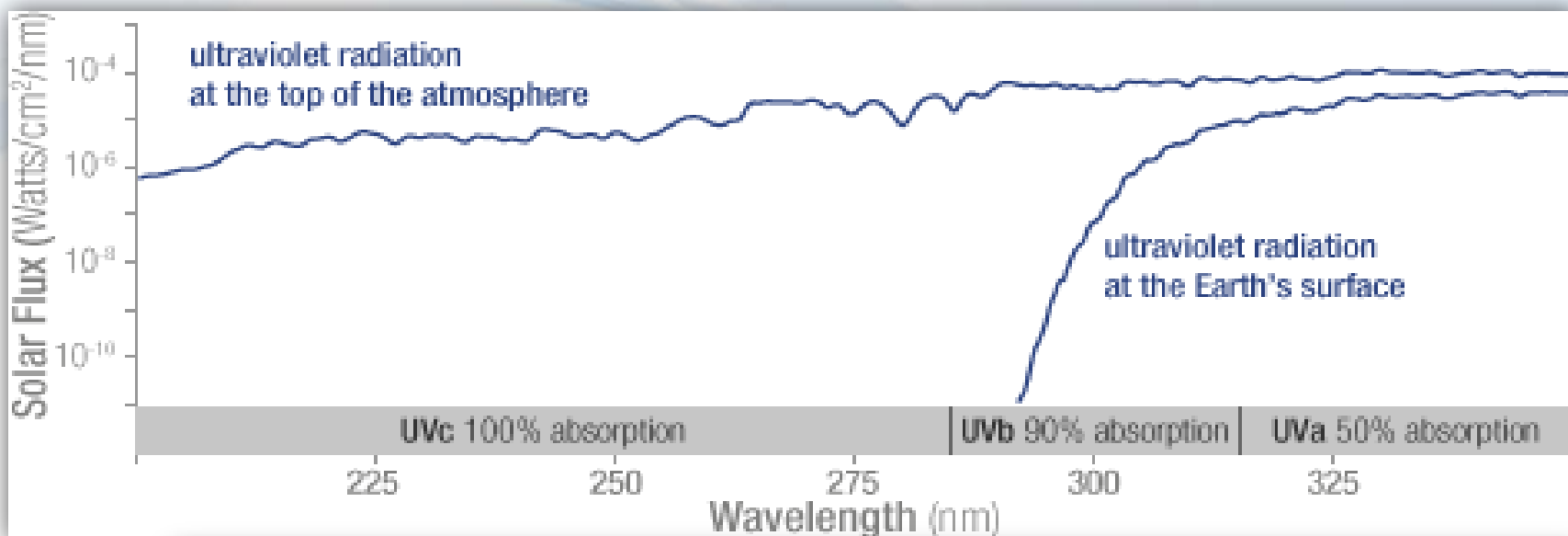
Boundary: Average conc. of stratospheric O₃ no lower than 276 Dobson units

Current level: 283 Dobson units

Diagnosis: Safe, and improving



O₃ – ochrana biosféry před nebezpečným UVB zářením



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 Cl_x 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

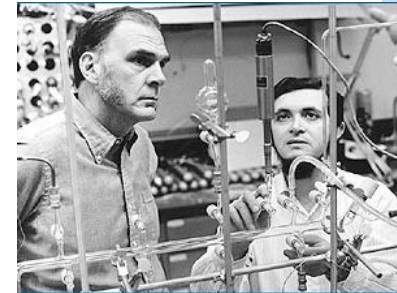
Mario J. Molina & F. S. Rowland

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

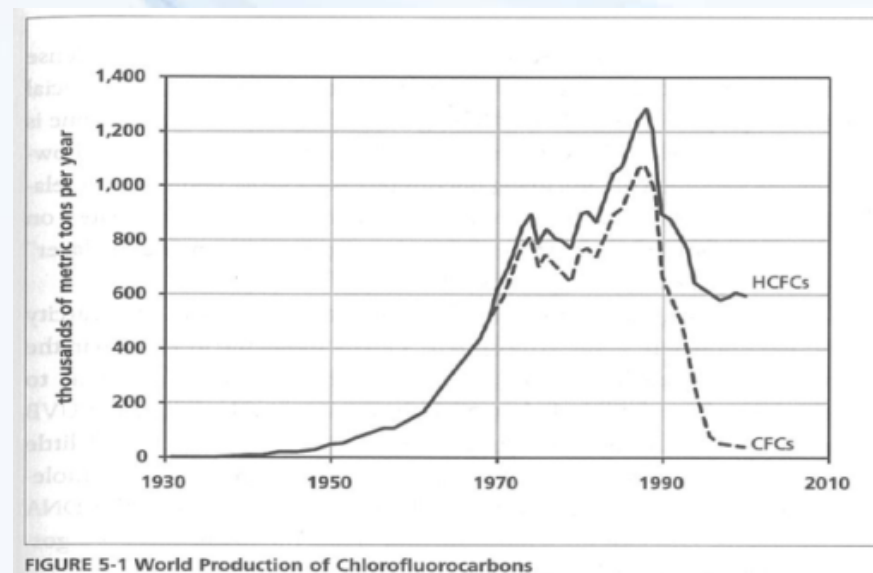
effective rates of vertical diffusion of molecules at these altitudes are also subject to substantial uncertainties. Vertical mixing is frequently modelled through the use of 'eddy' diffusion coefficients^{10,15–18}, which are presumably relatively insensitive to the molecular weight of the diffusing 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



Centrum pro výzkum
toxických látek
v prostředí

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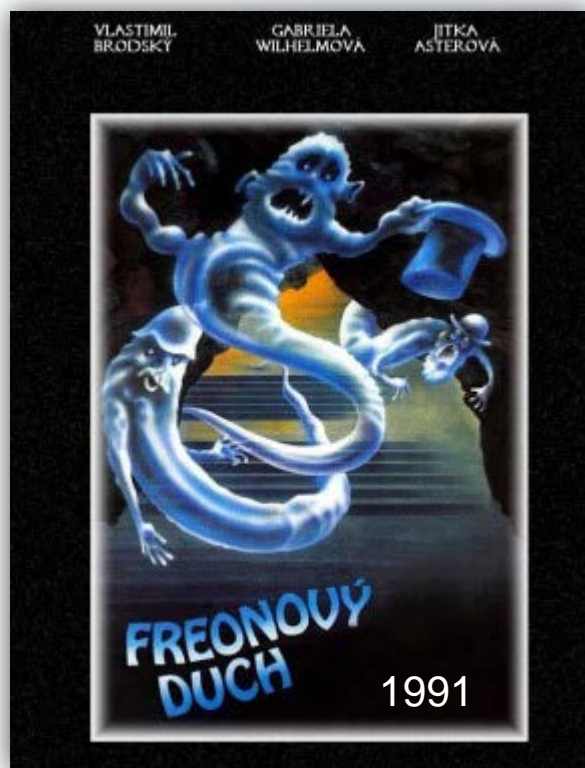


FIGURE 5-1 World Production of Chlorofluorocarbons



Historie objevů spojených s úbytkem O₃

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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

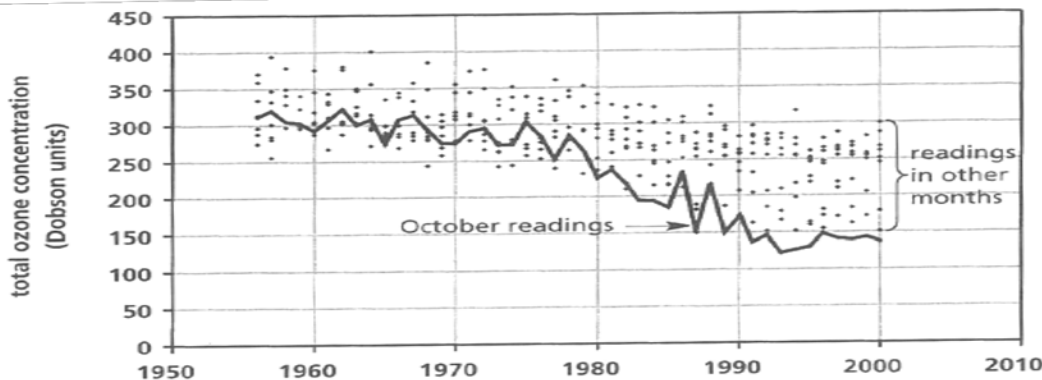


FIGURE 5-4 Ozone Measurements at Halley, Antarctica

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 resulting to the polar stratosphere, could account for

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

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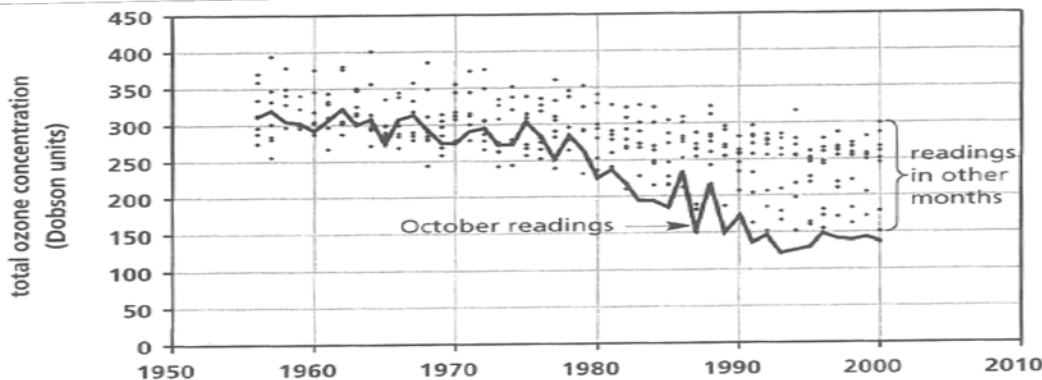


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- po revizi nastavení přístroje zjištěno, že velmi nízké hodnoty přístroj nezapočítával – po zpětném započítání rostoucího množství podlimitních hodnot **díra potvrzena**



Historie objevů spojených s úbytkem O₃

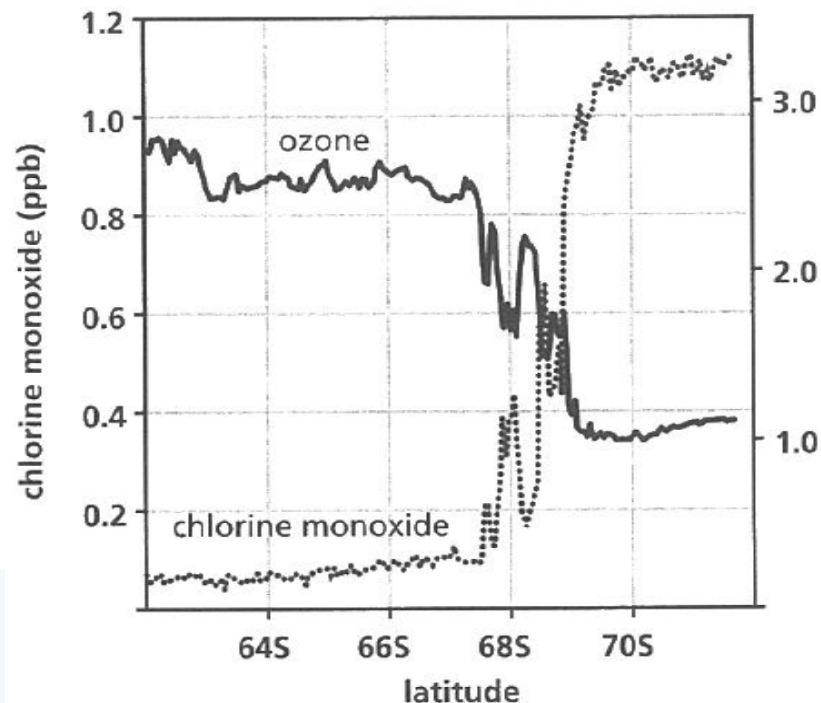
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1987 – potvrzení chlor-ozonové hypotézy – průlet letadlem

ozonovou dírou měřící koncentraci O₃ a ClO

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

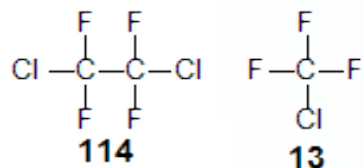
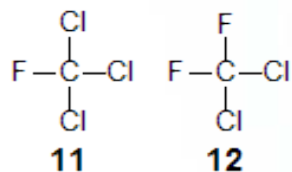


The ozone Hole



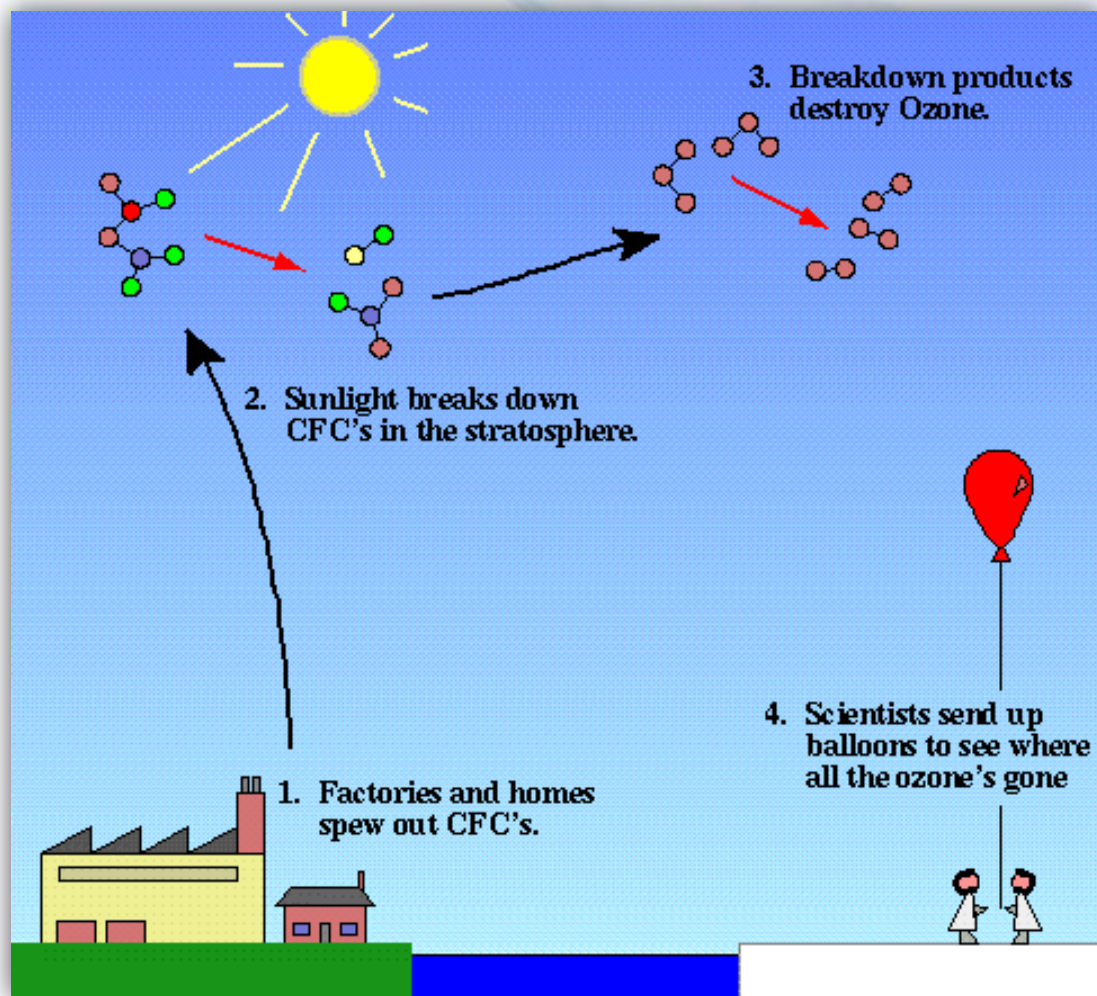
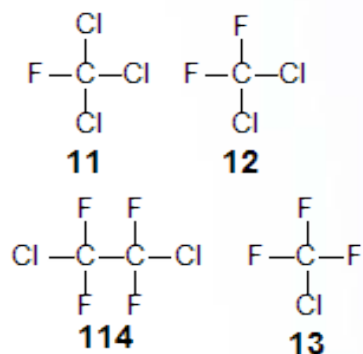
Poškozování ozónové vrstvy země

- freony, halony a další určité halogenované látky



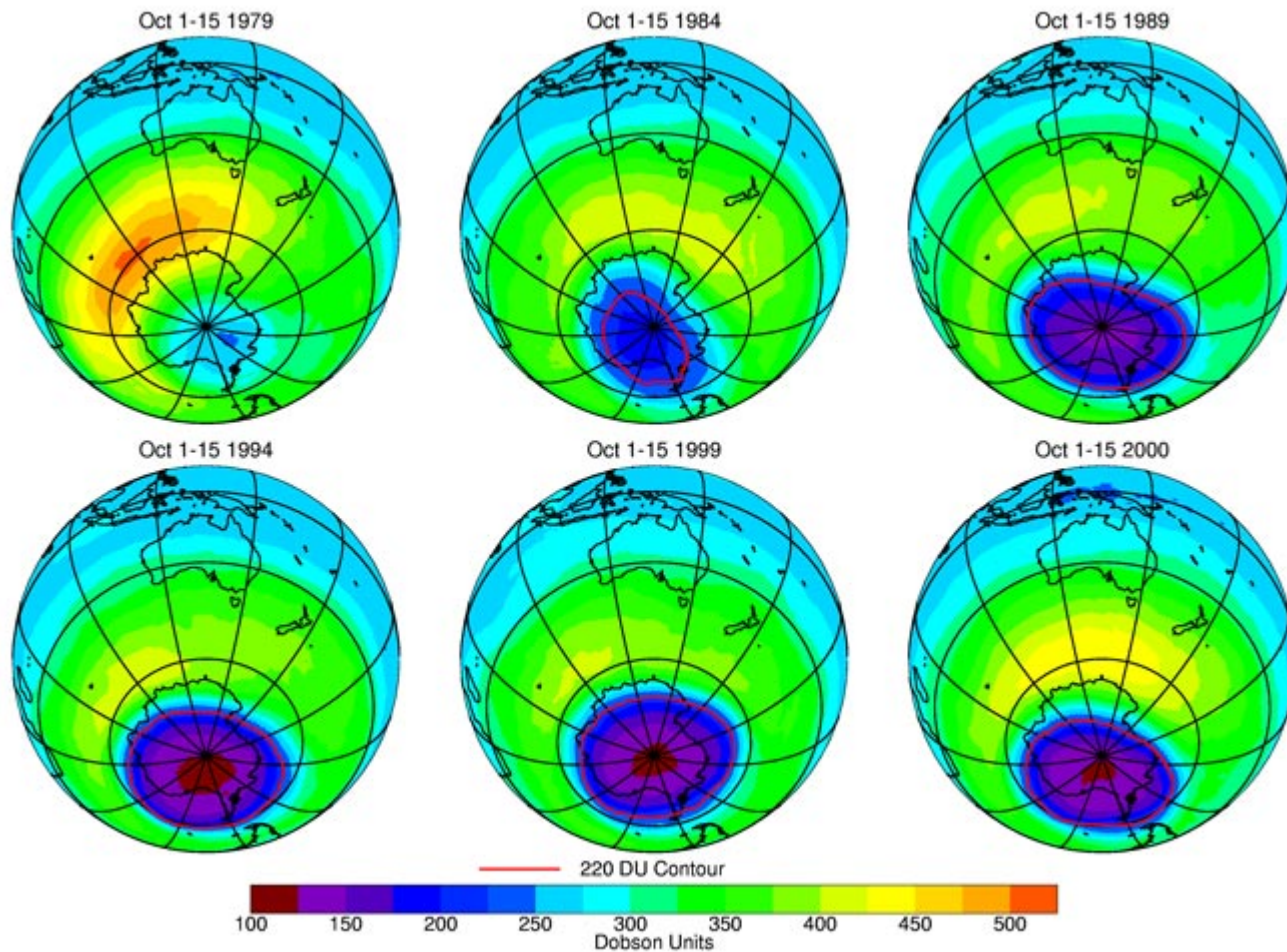
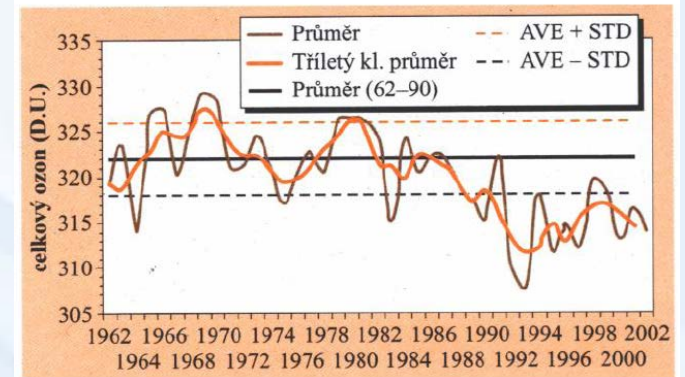
Poškozování ozónové vrstvy země

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

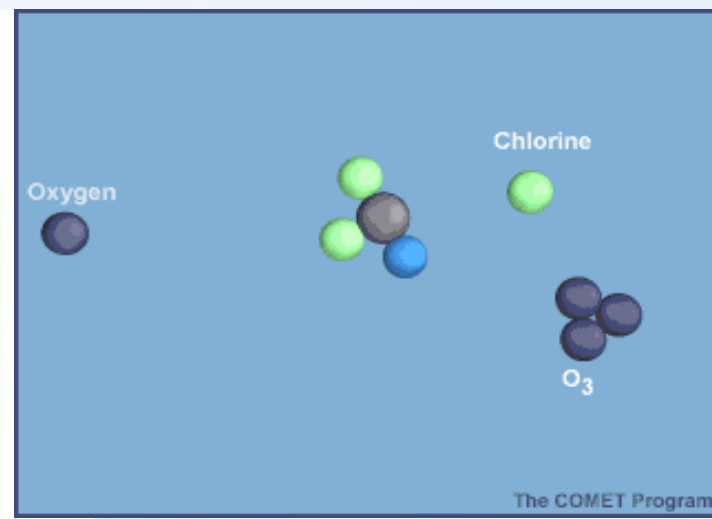
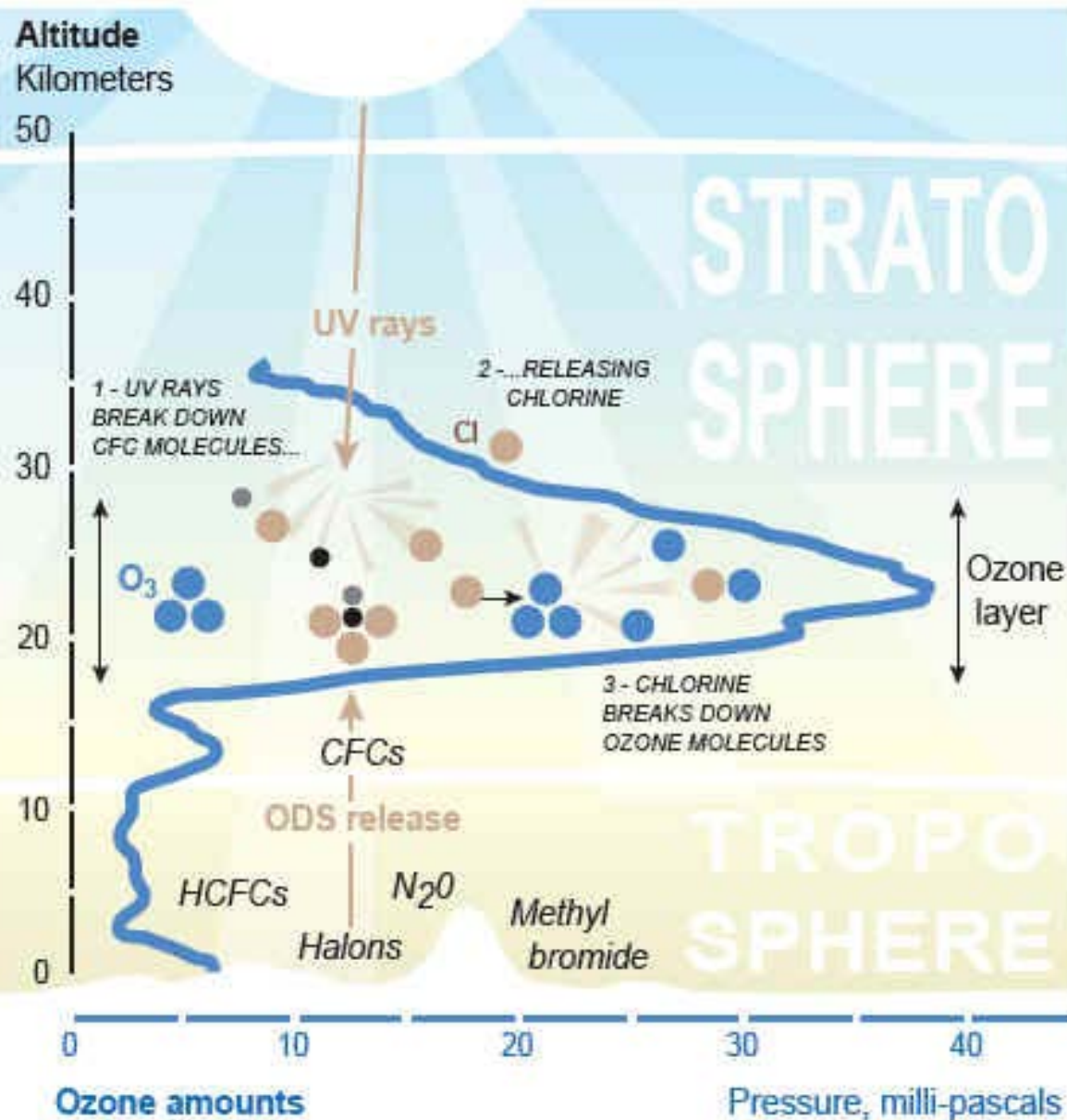


Ozónová díra

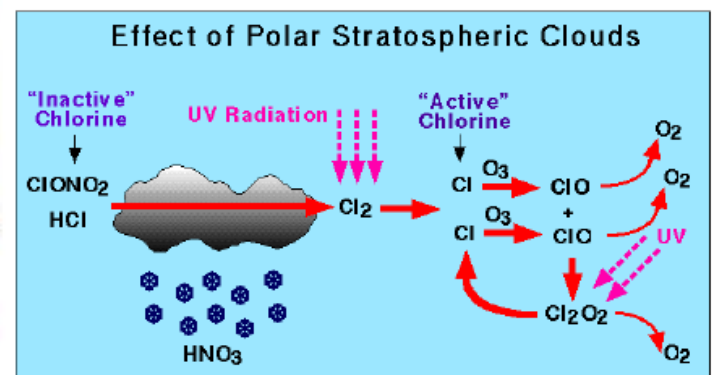
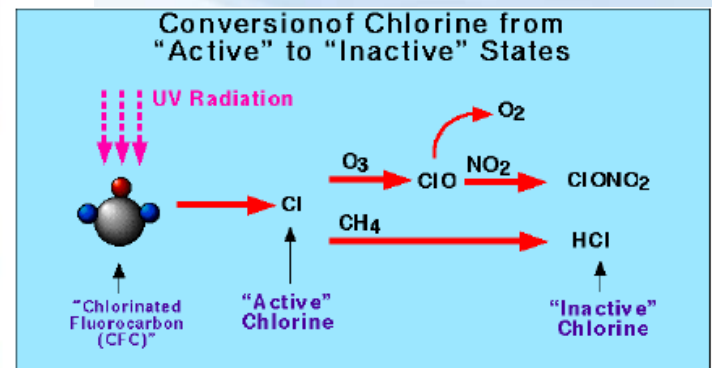
- výrazný úbytek ozónu především nad **polárními** oblastmi



CHEMICAL OZONE DESTRUCTION PROCESS IN THE STRATOSPHERE



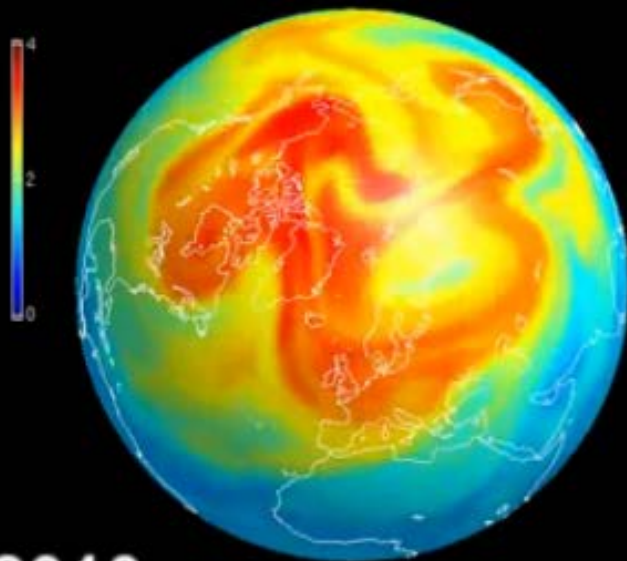
Proč nad póly?



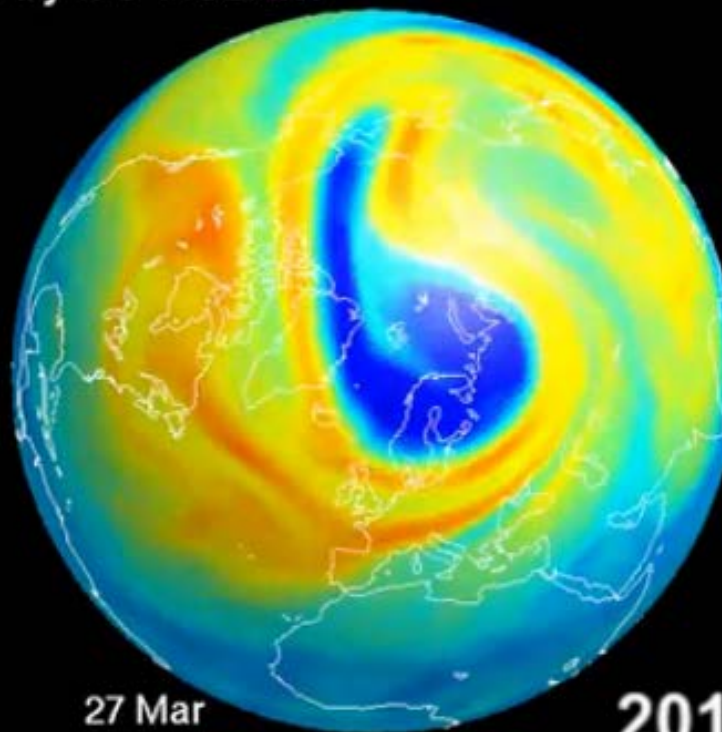
Úbytek stratosférického O₃ nad Arktidou

Stratospheric ozone

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



2010



27 Mar

2011



www.gmes-atmosphere.eu

MACC
Monitoring atmospheric
composition & climate

ECMWF

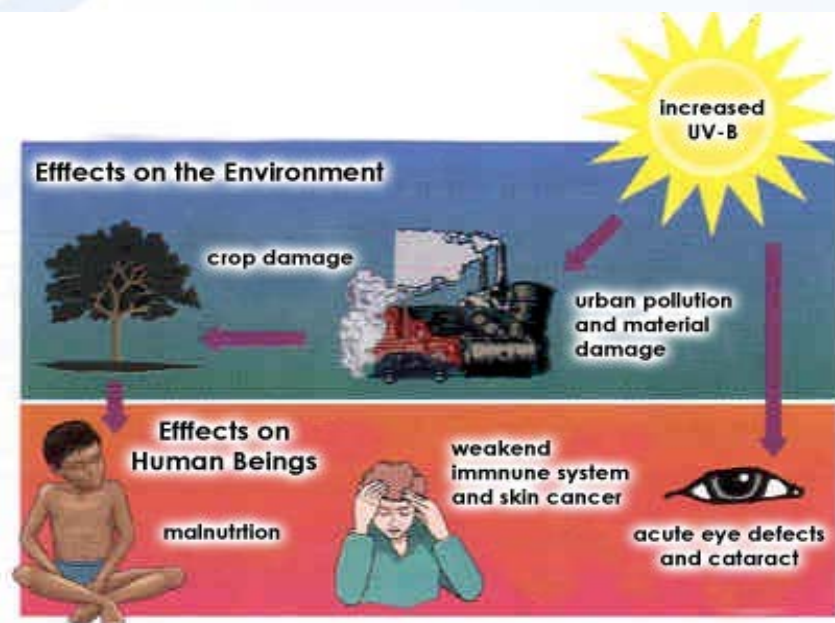
JÜLICH
FORSCHUNGSCENTRUM

aeronomie.be

0:16

Důsledky úbytku strat. O₃

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



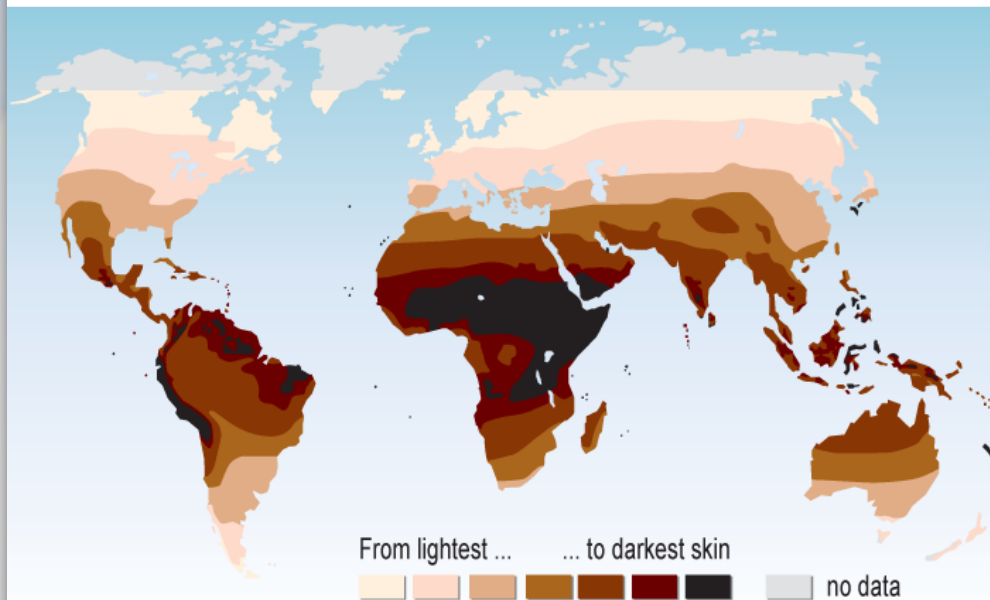
- většina melanomů vzniká na **osluněné části kůže**
- nejčastější výskyt u Australanů



VULNERABILITIES

Skin colour map (indigenous people)

Predicted from multiple environmental factors



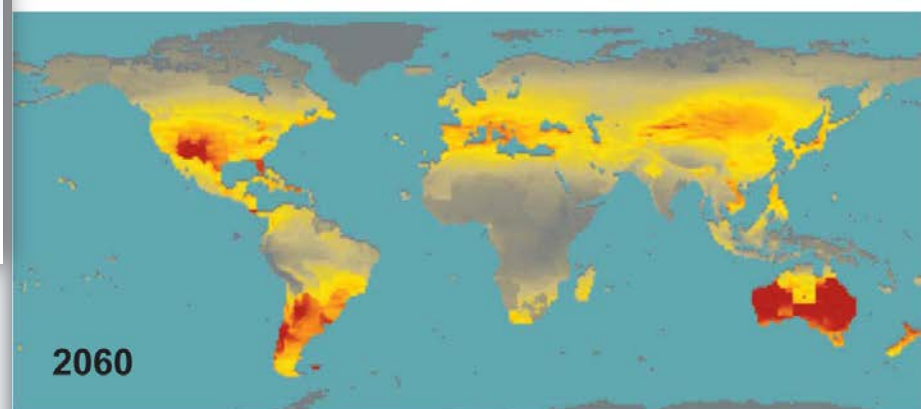
Source: Chaplin G.®, *Geographic Distribution of Environmental Factors Influencing Human Skin Coloration*, American Journal of Physical Anthropology 125:292–302, 2004; map updated in 2007.



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.

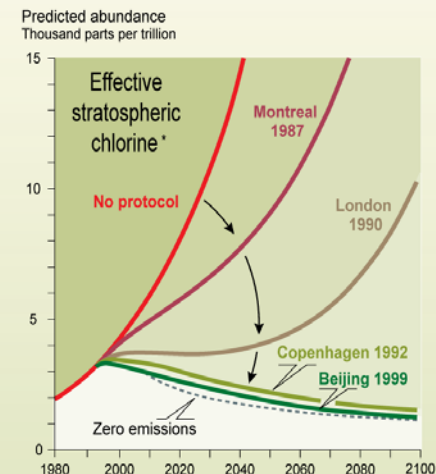


Řešení a důsledky

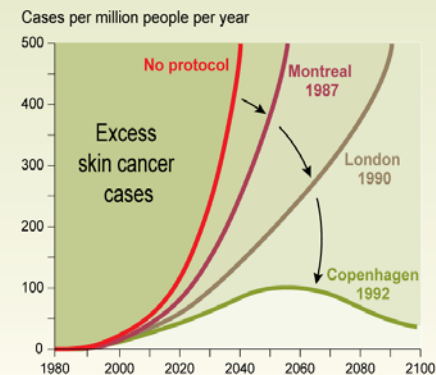
1985 – Vídeňská smlouva na ochranu O₃ vrstvy

1987 – Montrealský protokol + další dodatky

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



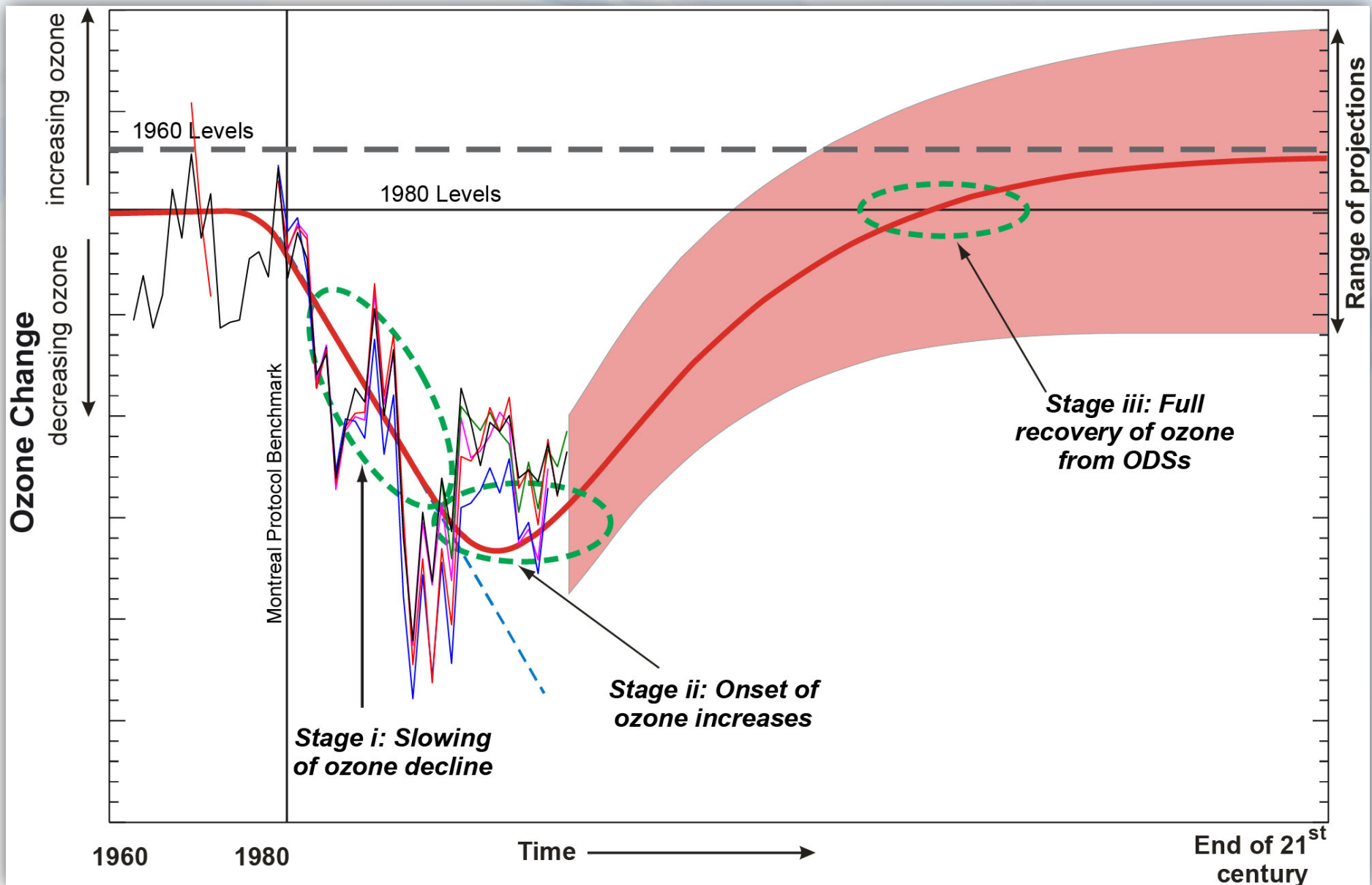
* Chlorine and bromine are the molecules responsible for ozone depletion.
"Effective chlorine" is a way to measure the destructive potential of all ODS gases emitted in the stratosphere.



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

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

The Nobel Prize in Chemistry 1995



Paul J.
Crutzen

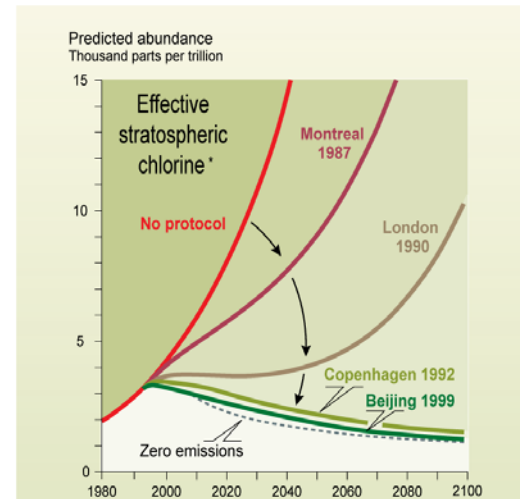


Mario J.
Molina

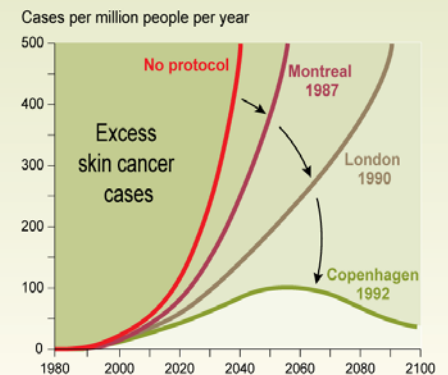


F. Sherwood
Rowland

*„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
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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

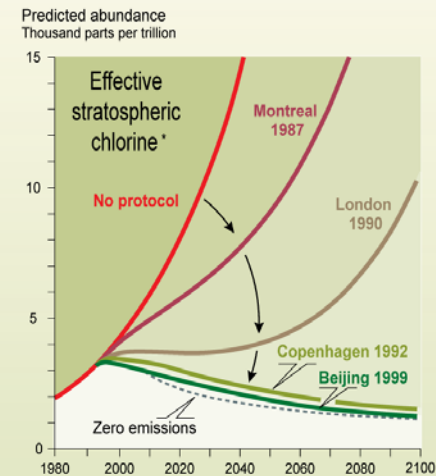
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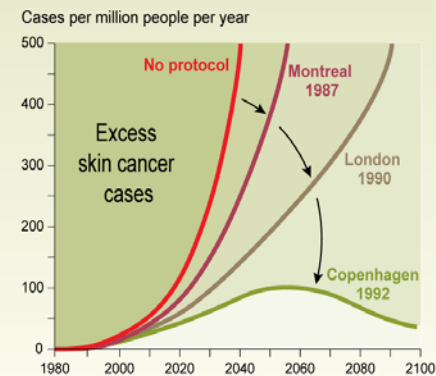
Náklady opuštění CFC

- 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



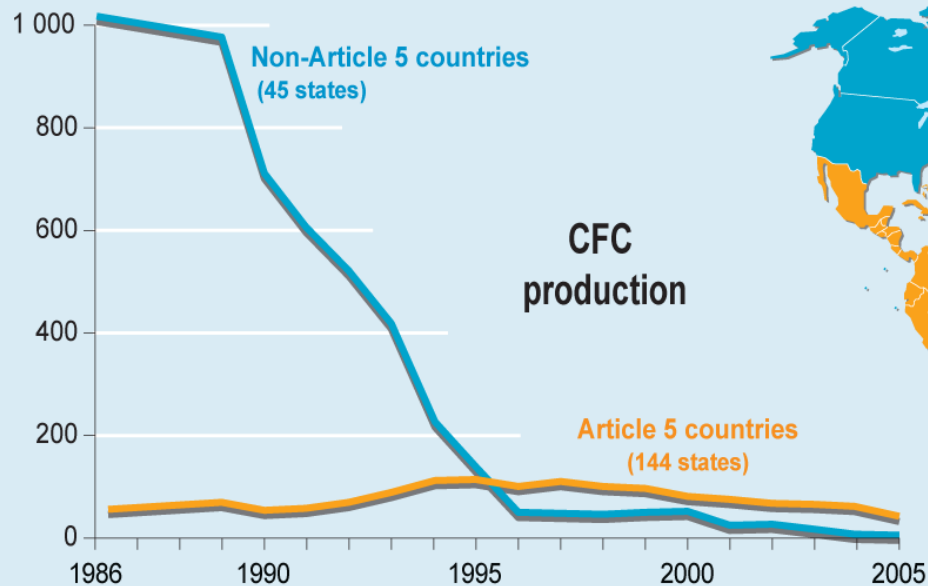
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Source: Twenty Questions and Answers about the Ozone Layer: 2006 Update, Lead Author: D.W. Fahey, Panel Review Meeting for the 2006 ozone assessment.

Společná, ale diferencovaná zodpovědnost

Thousand Ozone Depleting Potential Tonnes (ODP Tonnes)*



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



Source: United Nations Environment Programme Ozone Secretariat

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**

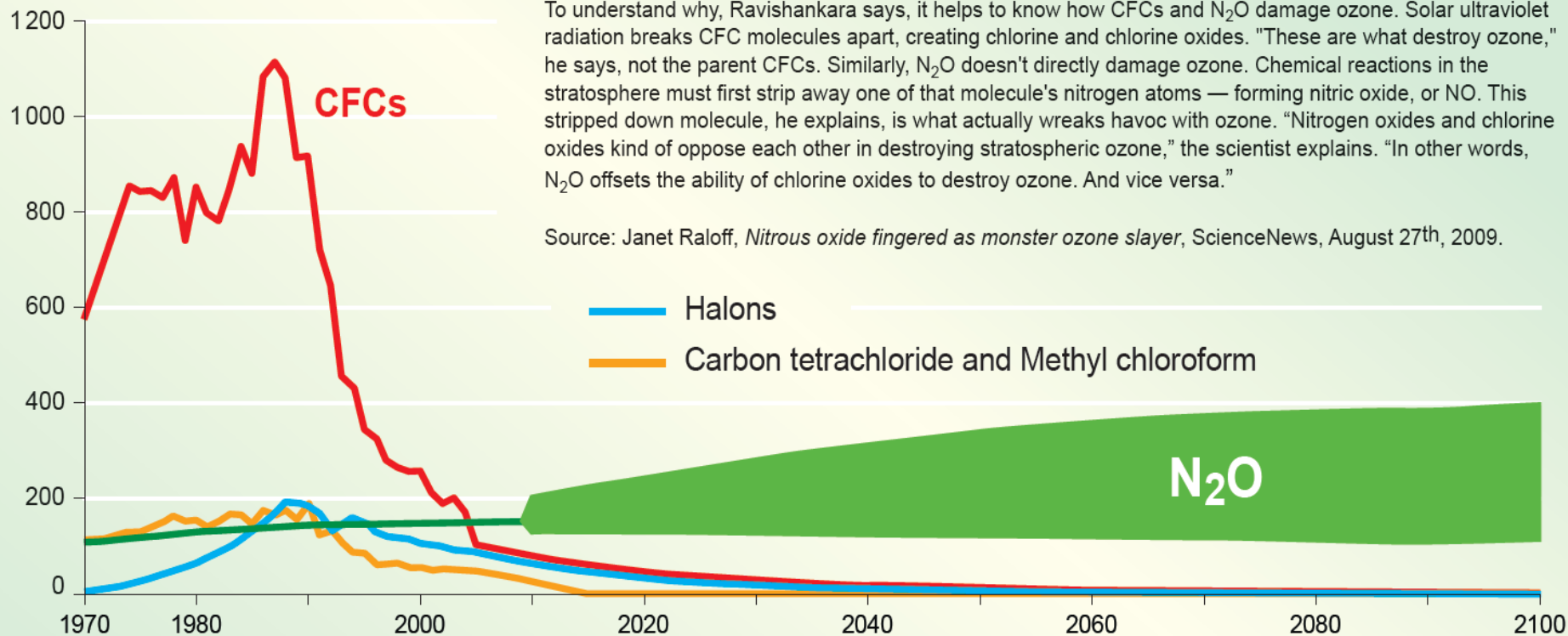


Aktuální problém – N₂O

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.



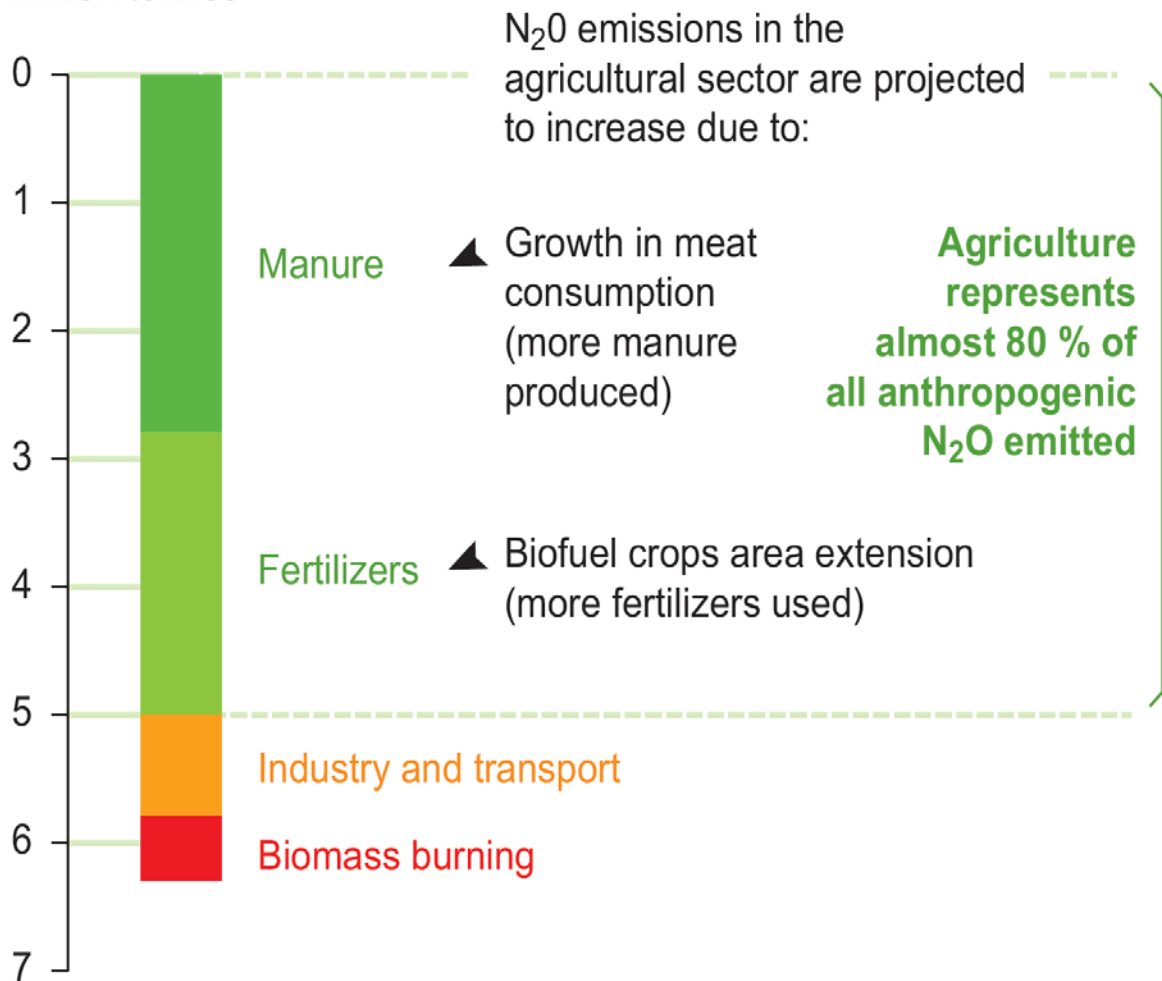
Centrum pro výzkum
toxických látek
v prostředí

Aktuální problém – N₂O



Nitrous oxide anthropogenic emissions

Million tonnes

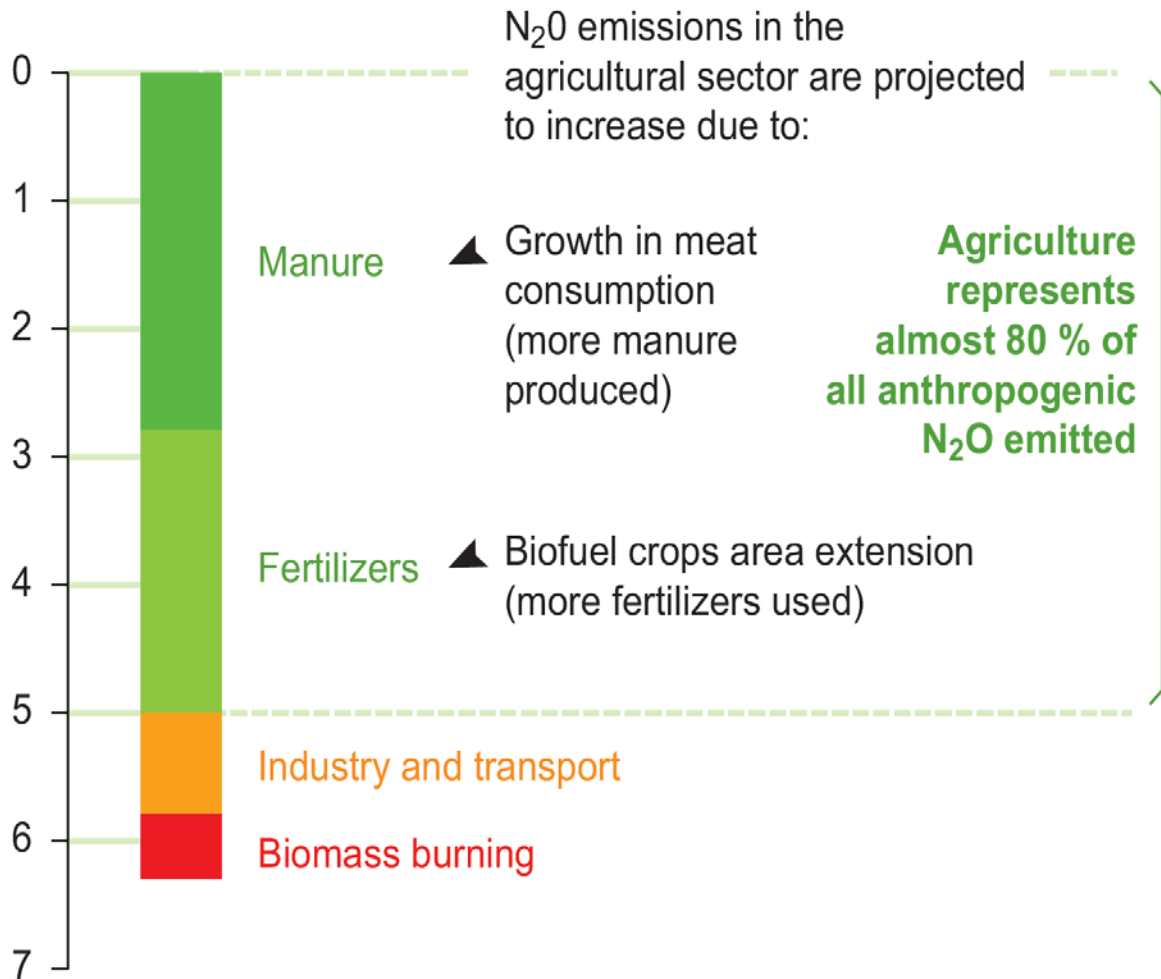


Source: Eric A. Davidson, *The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860*, Nature Geoscience, August 2009.

Aktuální problém – N₂O

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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

⁴Mount Pleasant, SC, USA

⁵School of Geosciences, University of Edinburgh, Edinburgh, UK

⁶Austrian Research Centers – ARC, Vienna, Austria

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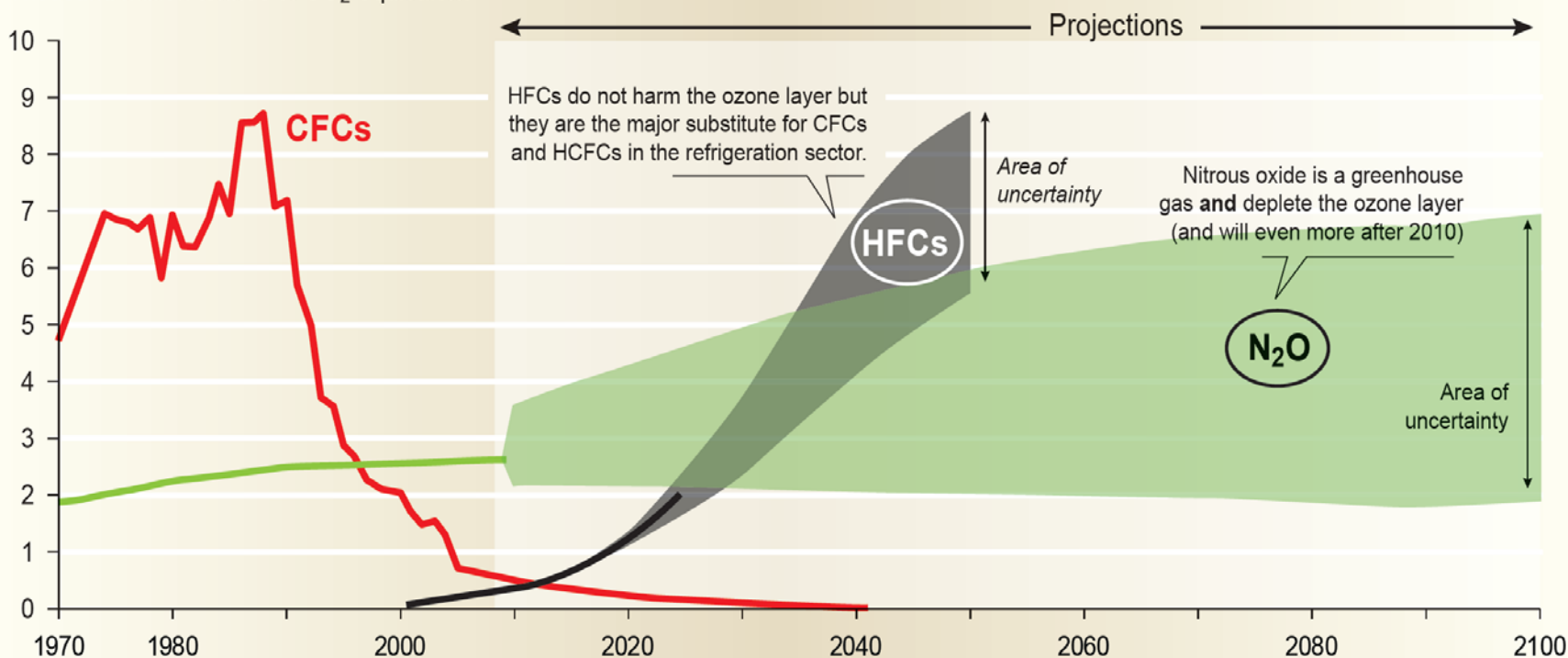
Correspondence to: P. J. Crutzen (crutzen@mpch-mainz.mpg.de)

Globální oteplování x úbytek stratosférického ozónu

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

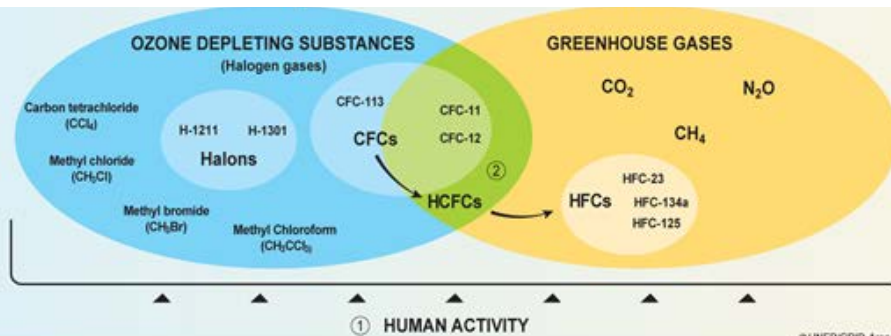
Selected greenhouse gases emissions

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.



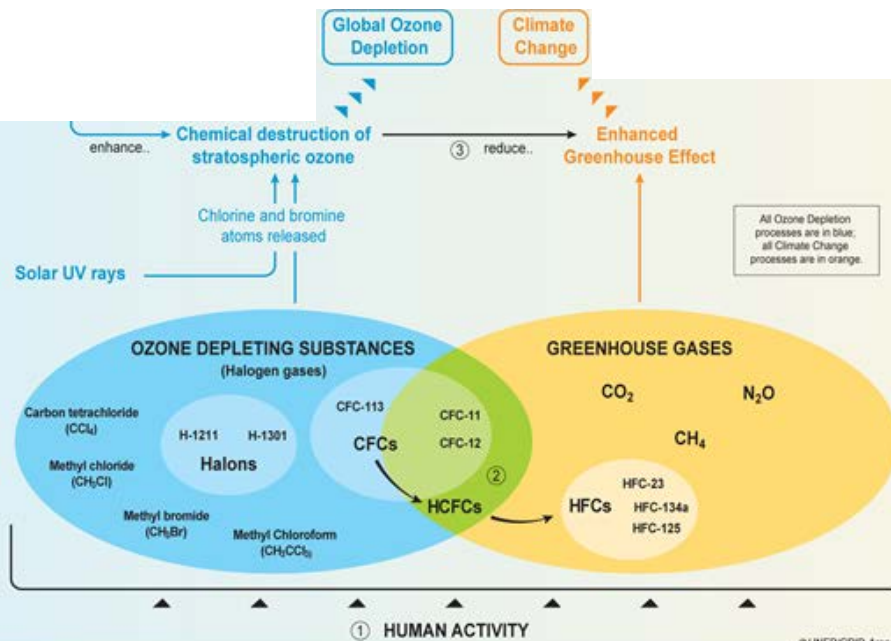


© UNEP/GRID-Arendal

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.

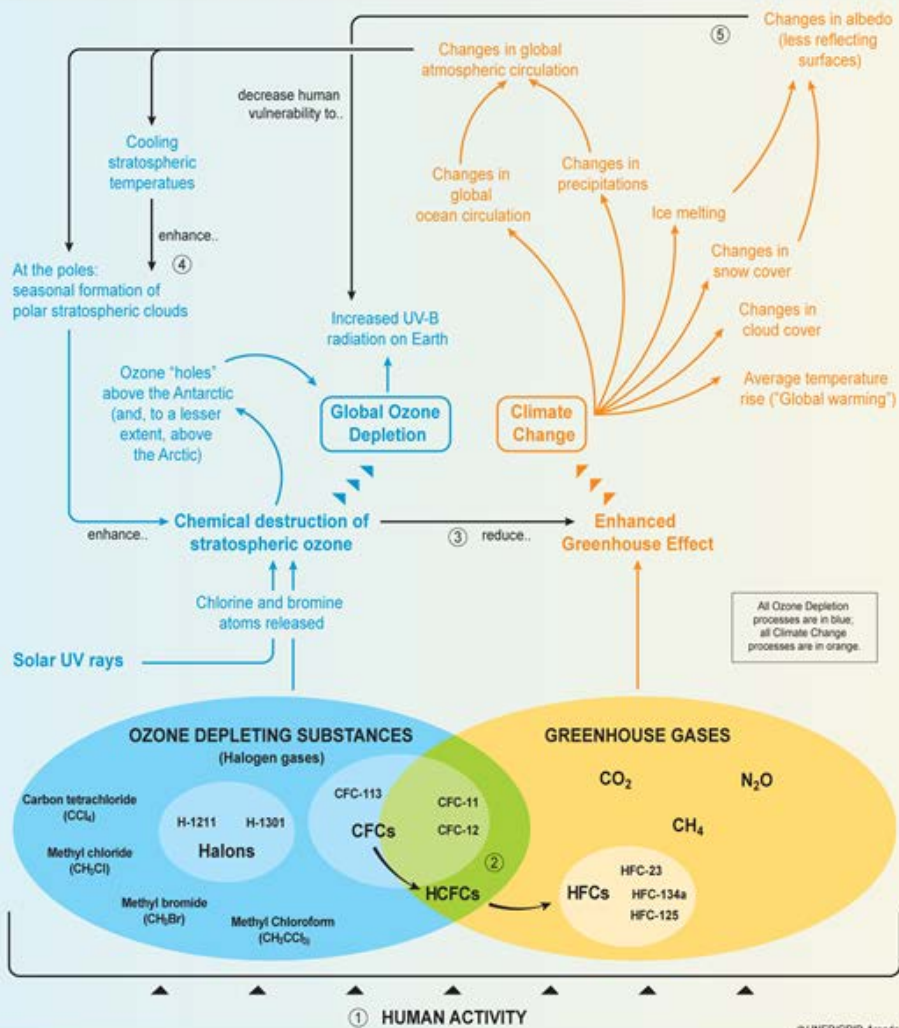




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IV. Okyselování oceánů

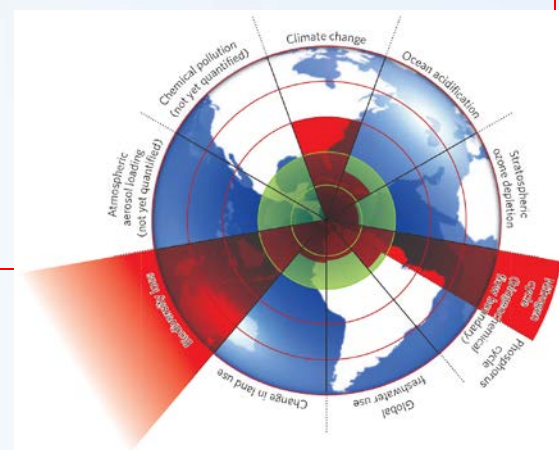
Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	Conversion of coral reefs to algal-dominated systems. Regional elimination of some aragonite- and high-magnesium calcite-forming marine biota Slow variable affecting marine carbon sink.	Sustain $\geq 80\%$ of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability ($\geq 80\% - \geq 70\%$)	<ol style="list-style-type: none"> 1. Geophysical processes well known. 2. Threshold likely. 3. Boundary position uncertain due to unclear ecosystem response.

Boundary: Global average aragonite "saturation ratio" no lower than 2.75:1

Pre-industrial level: 3.44:1

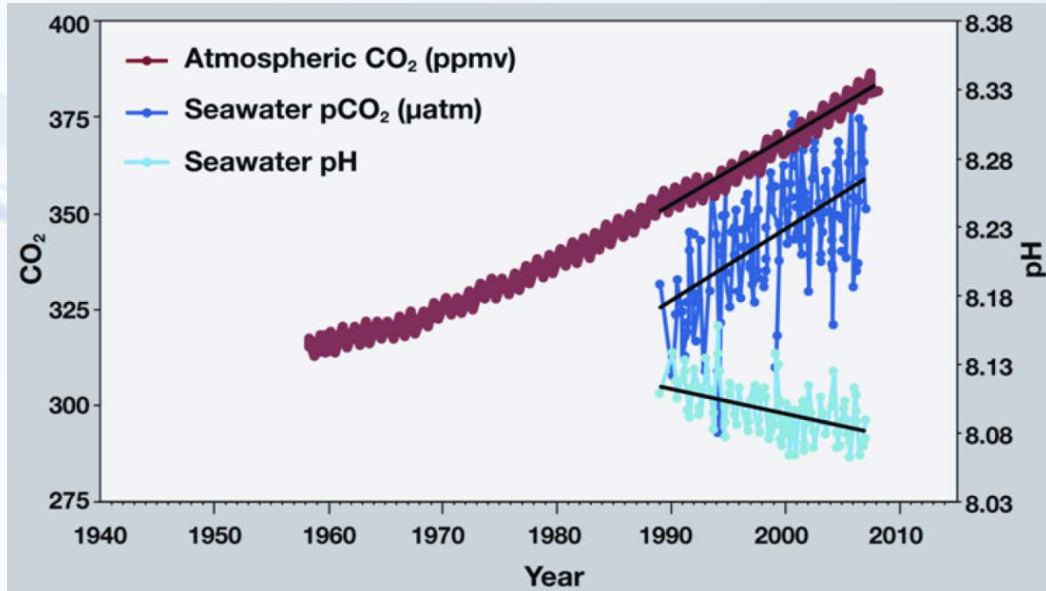
Current level: 2.90:1

Diagnosis: Safe for now, but some oceans will cross threshold by mid-century



Okyselování oceánů

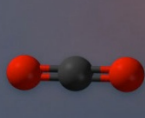
- čím je způsobené?



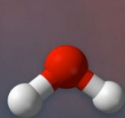
OCEAN ACIDIFICATION

HOW WILL CHANGES IN OCEAN CHEMISTRY AFFECT MARINE LIFE?

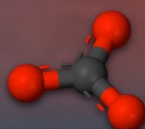
CO₂ absorbed from the atmosphere



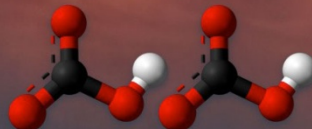
carbon dioxide



water

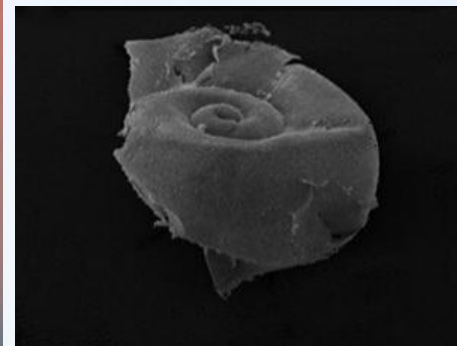


carbonate ion

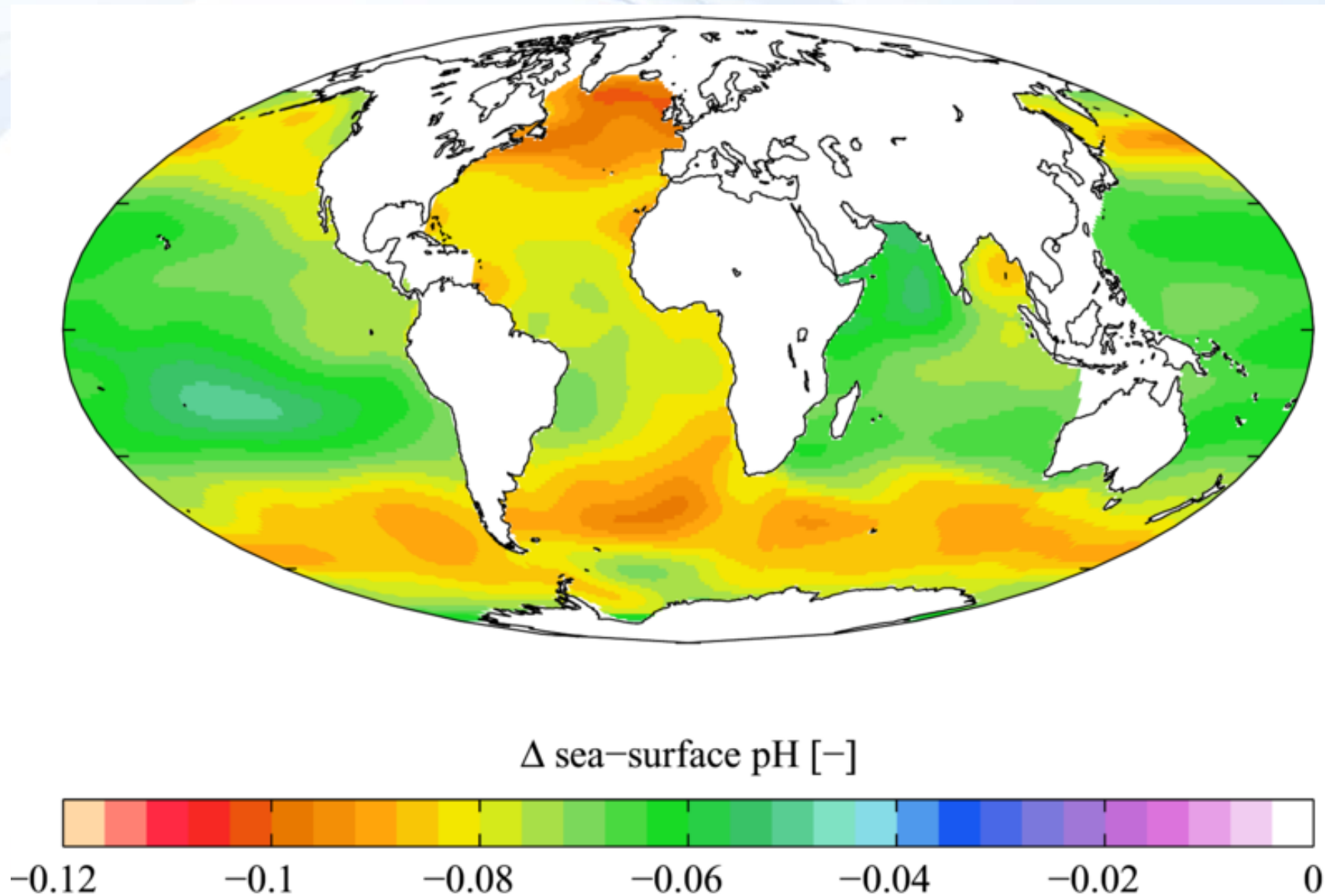


2 bicarbonate ions

consumption of carbonate ions impedes calcification



Změna pH oceánů 1700-2000

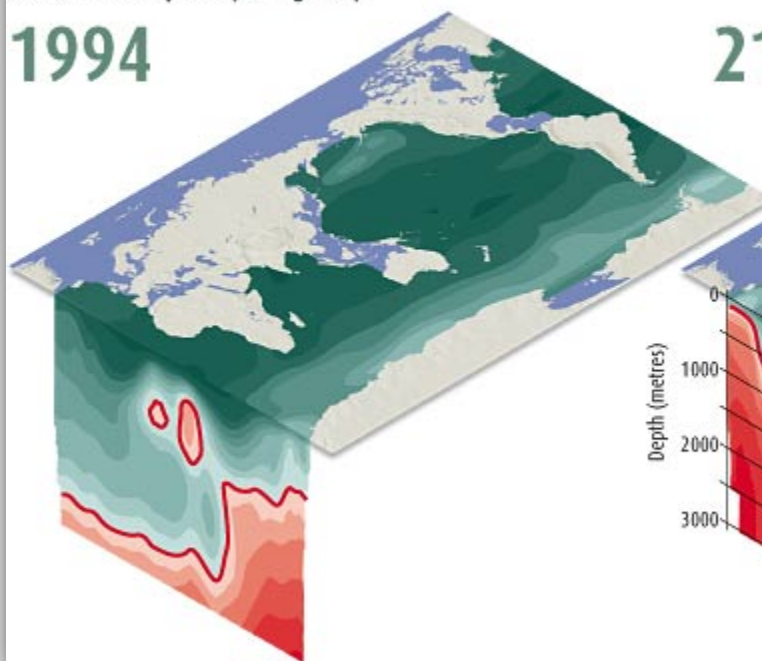


Změna pH oceánů - 3D rozvrstvení

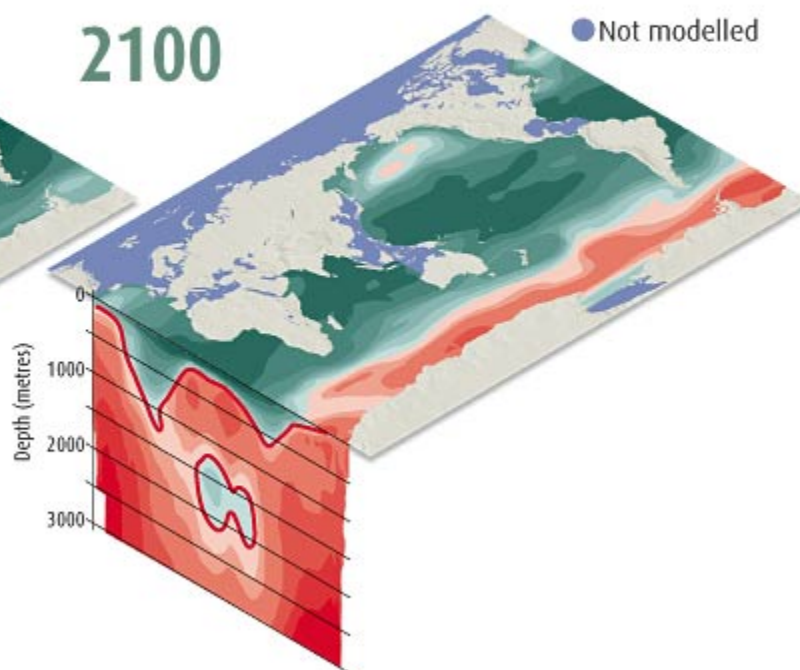
SHELL HELL

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

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his hoard of Nazi art

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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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