LUND UNIVERSITY

# Atmospheric chemistry
## Summary

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## Health Effects of Air Pollution in Europe (EU-28)

Source: EEA, "Air Quality in Europe - 2016 Report"

The EEA recently estimated (EEA, 2016) that

the health impacts attributable to exposure to fine particulate matter (**PM2.5**) in the EU-28 were responsible for around

**PM2.5 → 436 000 premature deaths annually**

The health impact of exposure to **$NO_2$** and **$O_3$** concentrations on the EU-population was estimated to be about

**$NO_2$ → 68 000 premature deaths per year**
**$O_3$ → 16 000 premature deaths per year**

European Environment Agency

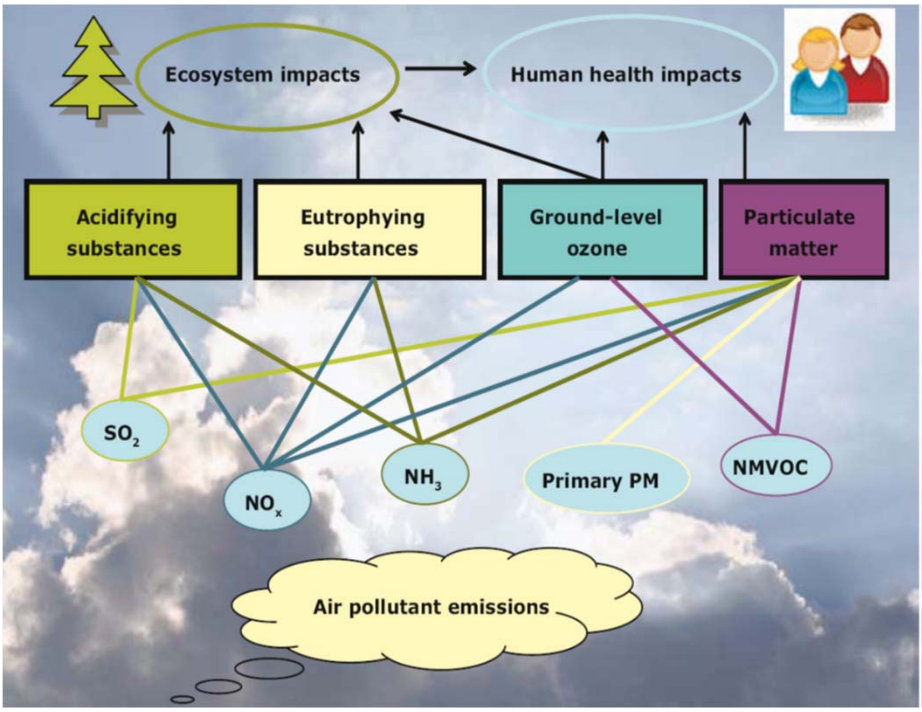
http://www.eea.europa.eu/publications/air-quality-in-europe-2016

## Damage cost of air pollution in Europe (2010) and policy response

Source: " EC, 2013: Impact assessment for new policy package to clean up Europe's air"

- Damage cost of mortality – at least EUR 330 billion 
- Direct economic damage - EUR 15 billion from workdays lost 
- Direct economic damage - EUR 4 billion in healthcare cost 
- Direct economic damage - EUR 3 billion crop yield loss 

European Environment Agency

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# The Convention on Long-Range Transboundary Air Pollution CLRTAP

http://www.unece.org/env/lrtap/welcome.html

Now 51 Parties (countries)

Under UN-ECE

Since 1979 the CLRTAP has addressed some of the major environmental problems of the UNECE region through scientific collaboration and policy negotiation.

The Convention has been extended by **eight protocols** that identify specific measures to be taken by Parties to cut their emissions of air pollutants.

> **8th protocol (Gothenburg):**
> The **1999** Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; 25 Parties.
> Entered into force on 17 May 2005.

The aim of the Convention is that Parties shall endeavour to **limit** and, as far as possible, gradually reduce and **prevent air pollution including long-range transboundary air pollution**.

Currently, the Convention's priority activities include review and possible **revision of its most recent protocols**, **implementation** of the Convention and its protocols across the entire UNECE region.



# Will the environmental quality objectives be achieved?

http://miljomal.nu/

| OBJECTIVE | Forecast for 2020 | Trend |
|---|---|---|
| 1. Reduced Climate Impact* | ☹ | ↘ |
| 2. Clean Air | ☹ | → |
| 3. Natural Acidification Only | ☹ | ↗ |
| 4. A Non-Toxic Environment | ☹ | → |
| 5. A Protective Ozone Layer | ☺ | ↗ |
| 6. A Safe Radiation Environment | 😐 | → |
| 7. Zero Eutrophication | ☹ | → |
| 8. Flourishing Lakes and Streams | 😐 | ↗ |
| 9. Good-Quality Groundwater | 😐 | → |
| 10. A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos | ☹ | → |
| 11. Thriving Wetlands | 😐 | ↗ |
| 12. Sustainable Forests | ☹ | → |
| 13. A Varied Agricultural Landscape | 😐 | ↗ |
| 14. A Magnificent Mountain Landscape | 😐 | ↗ |
| 15. A Good Built Environment | ☹ | → |
| 16. A Rich Diversity of Plant and Animal Life | ☹ | → |

* Target year 2050, as a first step

## Chapman mechanism (1930)

The Chapman mechanism for stratospheric ozone

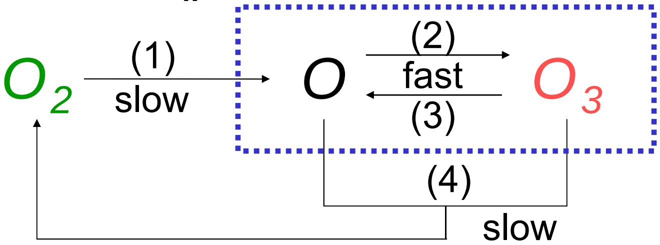
(1) $O_2 + h\nu \rightarrow O + O$ ($\lambda < 240$ nm)

(2) $O + O_2 + M \rightarrow O_3 + M$ (2x) (fast)

(3) $O_3 + h\nu \rightarrow O_2 + O$ (fast, $\lambda < 320$ nm)

(4) $O_3 + O \rightarrow 2O_2$

**$O_x$ family** (odd oxygen molecules)



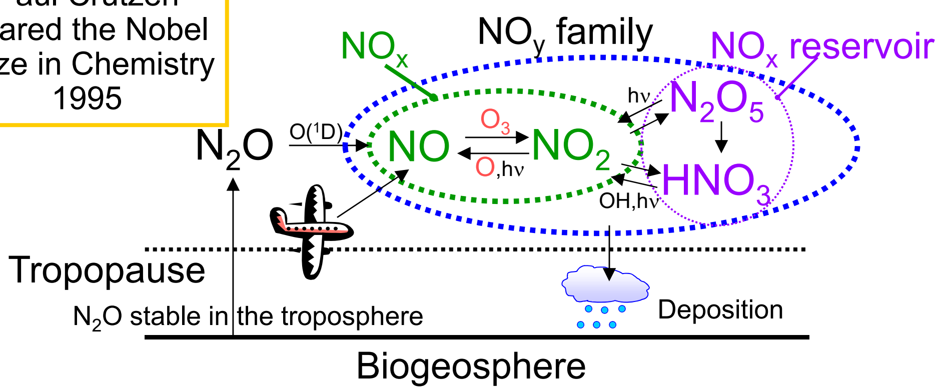



## Catalytic ozone loss – $NO_x$

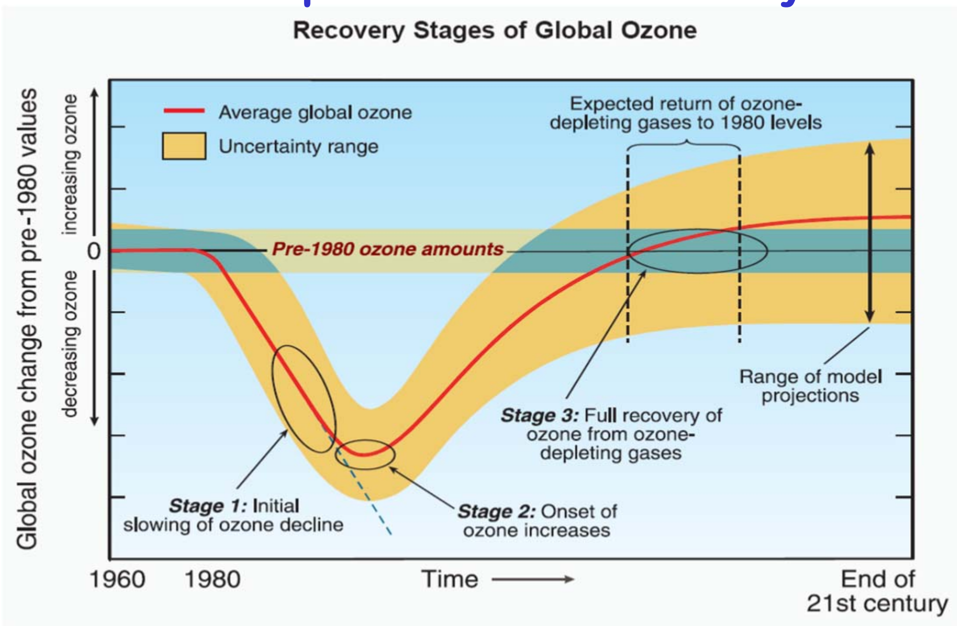
The $O_3$ sinks attributable to $NO_x$ and $HO_x$ are sufficient as complement to the Chapman mechanism to account for the observed natural ozone levels (1970-ies).

Before the discovery of the ozone hole!

Paul Crutzen shared the Nobel prize in Chemistry 1995



# Stratospheric ozone - Recovery

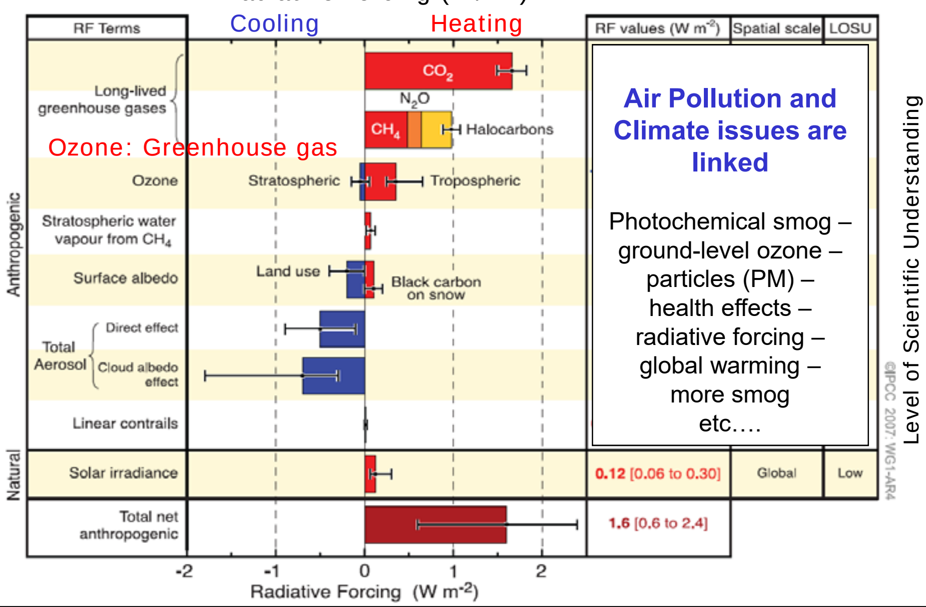


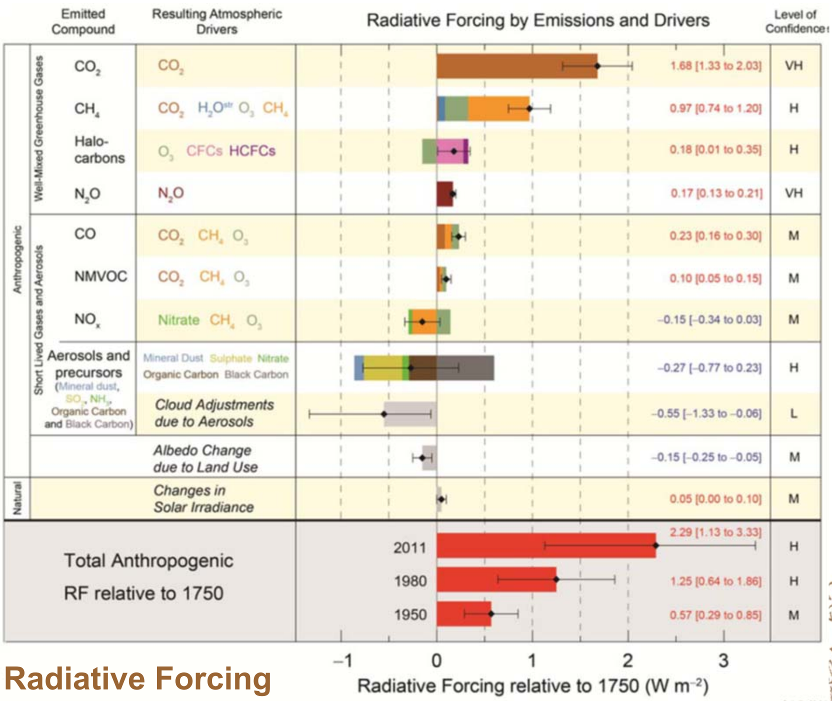



# Intergovernmental Panel on Climate Change

4th Assessment Report 2007

Radiative Forcing (W/m$^2$)



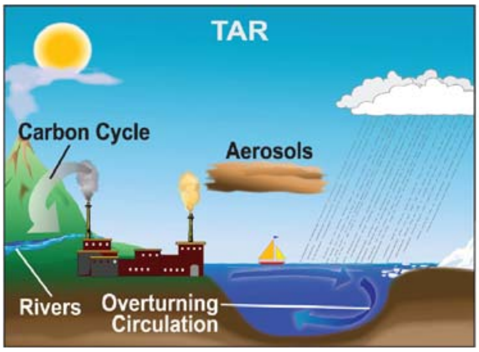


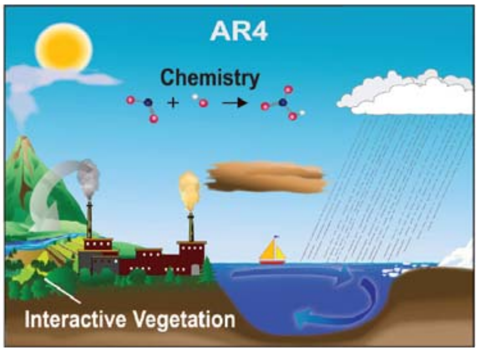

## Radiative Forcing

# History of Climate Modelling

Aerosols and atmospheric chemistry has only recently been introduced in global climate models.

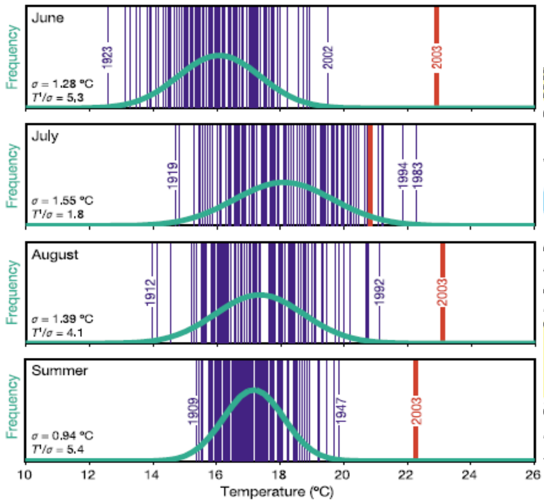
Still very crude representations.



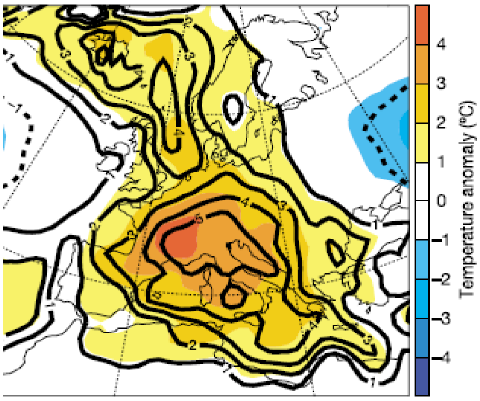



## Heat Wave in Central Europe Summer 2003

**Switzerland**
Summer temperatures (monthly)
1864–2003

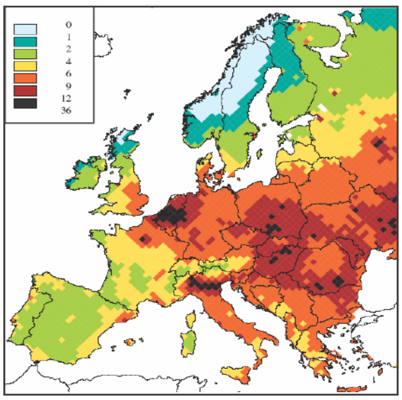



**Deviations from average temperatures 1961-90 (June, July, August)**
*Colour scale*: Temperature deviations in oC
*Contoures*: Standard devations

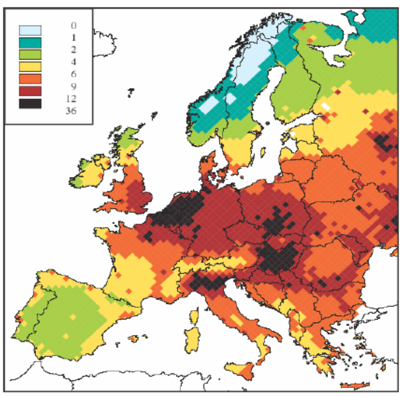



## Inter-annual Meteorological Variability
## **Loss in life expectancy** (days) **due to PM2.5**

Meteorology 2000

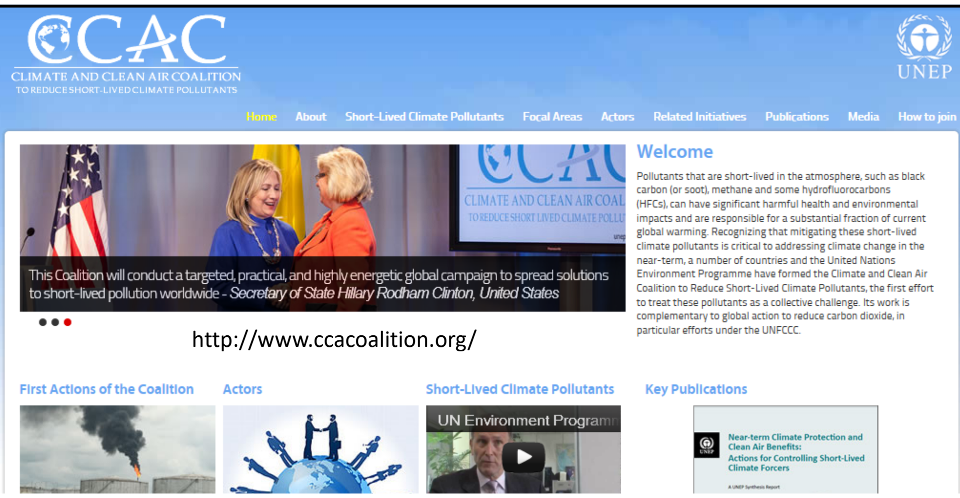



Meteorology 2003




Loss in statistical life expectancy that can be attributed to the anthropogenic contributions to PM2.5 (in months).

Strong coupling between climate and health effects
Here aerosol particles (PM2.5).



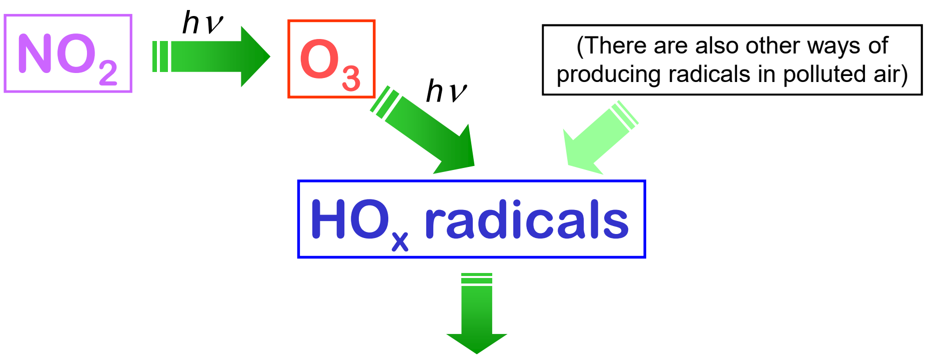

**CCAC – Climate and Clean Air Coalition**

Short-lived Climate Pollutants (SLCP)

http://www.smhi.se/slcp

## The troposphere is an oxidizing medium

*$NO_2$* and solar radiation controls the production of *$O_3$* , which in turn controls the production of *$HO_X$* radicals, which in turn controls the oxidizing capacity of the troposphere and the lifetime of trace gases.




# Oxidizing capacity of the troposphere

## Filtering of UV by stratospheric ozone

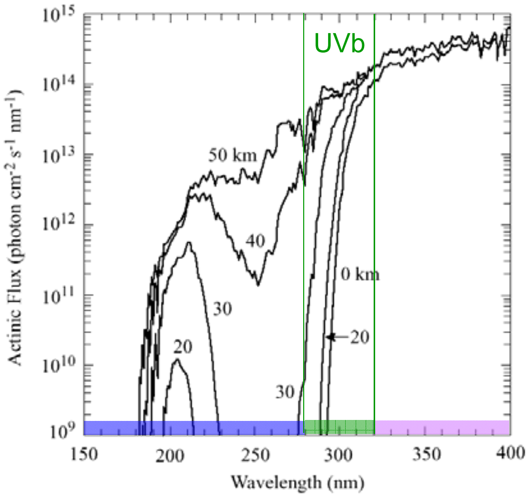
UVc (200 < λ < 280 nm)

$O_2$ photolysis: λ < 240 nm

UVb (280 < λ < 320 nm)

$O_3$ photolysis: λ < 320 nm

UVa (320 < λ < 400 nm)






## Production of the hydroxyl radical OH

Production of $O(^1D)$ occurs in a narrow wavelength band between 300-320 nm.

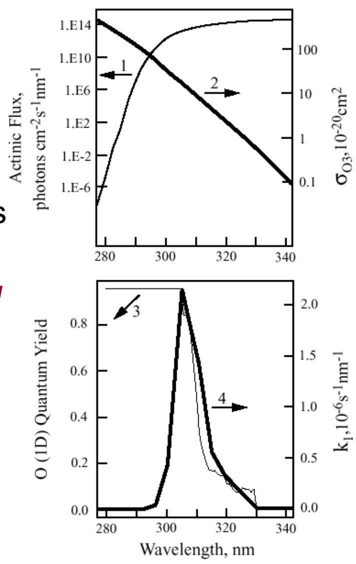
**Tropospheric ozone is both good and bad.**

**Ozone is needed** to produce *OH* radicals via

$O_3 + h\nu \rightarrow O_2 + O(^1D)$ and $O(^1D) + H_2O \rightarrow 2OH$

*OH* is essential for the **oxidizing capacity of the troposphere** and the **lifetime of trace gases**.

**High levels of ozone are dangerous to humans, plants and and materials.**



## Photostationary equlibrium for ozone

In a **sunlit atmosphere with** $NO$ **and** $NO_2$ **but without hydrocarbons:**

(11.11) $NO_2 + h\nu \rightarrow NO + O$ ($\lambda$< 420 nm)
(10.2) $O + O_2 + M \rightarrow O_3 + M$ (only way to produce $O_3$)
(11.14) $NO + O_3 \rightarrow NO_2 + O_2$

Net reaction:

$$NO_2 + O_2 \overset{h\nu}{\Leftrightarrow} NO + O_3$$

A **photostationary equilibrium** exists.

More sun light ($\lambda$< 420 nm) gives more ozone $O_3$.

$NO$ consumes ozone. In the vicinity of strong sources of $NO$, then $O_3$ is titrated out and can be entirely depleted (e.g. close to a smoke stack or the tail pipe of a car.)



## Shifting the equilibrium towards more ozone

**Hydrocarbons are needed to shift the equilibrium** to the right, that is towards a **higher ozone production**.

**Hydrocarbons consume** $NO$ (by producing peroxyl radicals $HO_2$ and $RO_2$, which in turn react with $NO$).

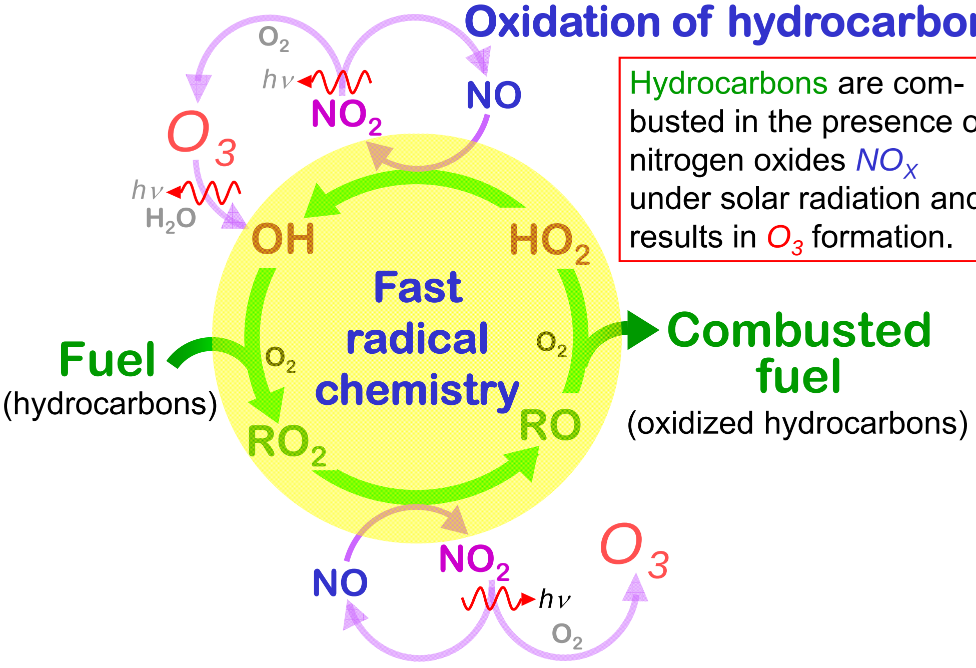
**More sun light** ($\lambda$< 420 nm) **gives more ozone** $O_3$.

$$NO_2 + O_2 \overset{h\nu}{\Leftrightarrow} NO + O_3$$

**Prerequisites for high ozone levels:**

- **Sun light** ($\lambda$< 420 nm)
- **Hydrocarbons**
- **Nitrogen oxides** ($NO_X$)

## Oxidation of hydrocarbons

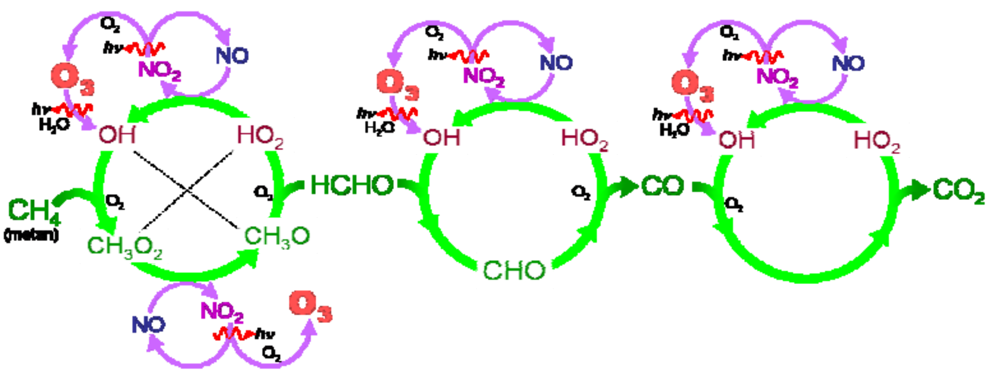



Hydrocarbons are com-busted in the presence of nitrogen oxides $NO_X$ under solar radiation and results in $O_3$ formation.

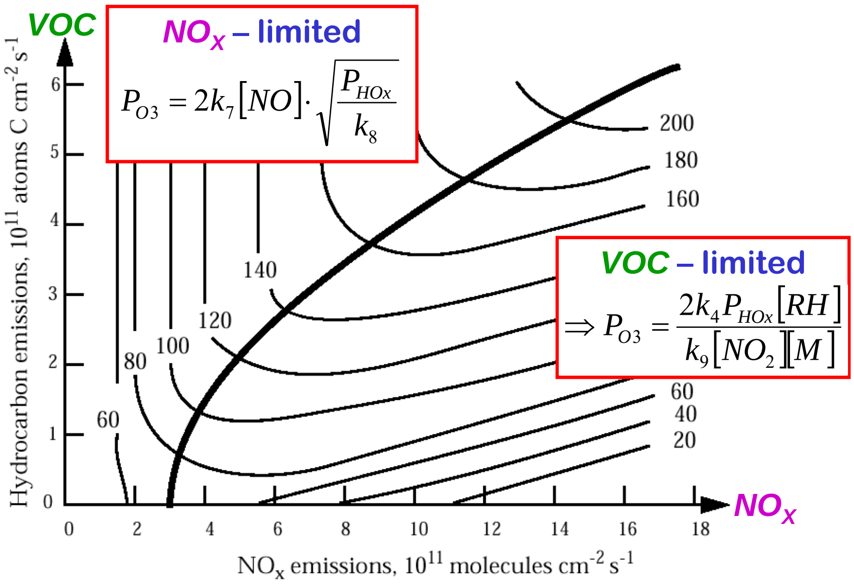


$CH_4 \rightarrow HCHO \rightarrow CO \rightarrow CO_2$

methane C(-IV) → formaldehyde C(0) → carbon monoxide C(II) → $CO_2$ C(IV)



## Regimes for ozone production






## Hemispheric background levels of ground-level ozone have increased by ~5 ppb per decade the last 20-30 years.

Data from the station Mace Head on the west coast of Ireland.