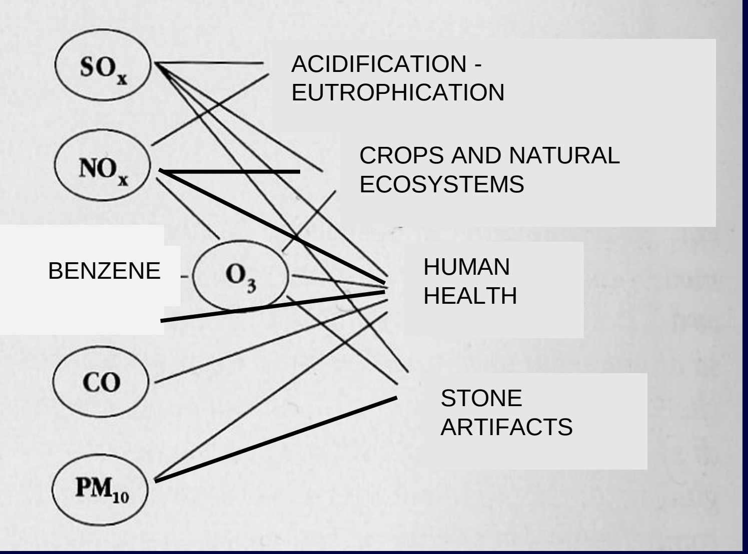


Pollutant	P/S	Process	Origin	by-products	Human health	Environment	
CO	P	incomplete combustion	org. fuels	-	haemoglobine poison	-	
SO_2	P	combustion, metallurgy	fuels containing S	H_2SO_4	variuos	+++	Acid rains
NO_x	P/S	combustion	fuel cont. N + reaction N_2+O_2	HNO_3	variuos, oxidative stress	+++	Acid rains
O_3	S	from NO_x and CO + O_2	NO+O_2 at hv+high temp.	-	Oxidative stress	+++	
Benzene	P	release	green gasoline	-	cancerogenic	+	
PM	P/S	release, phase transformation	wear of materials, combustion	-	Variuos, carrier of dangerous s	+++	

SO_2

The main sulfur dioxide emissions derive from:

- fossil fuel (diesel, fuel oil, kerosene, coal, and wood) combustion plants;
- metallurgical processes (e.g. FeS_2, pyrite; HgS, cinnabar; CuS,);
- production of sulfuric acid (always from the same pyrite…);
- processing of many plastic materials;
- paper industries;
- foundries;
- desulphurisation of natural gases;
- waste incineration.

Basically, by any process based on sulphur-containing compounds.

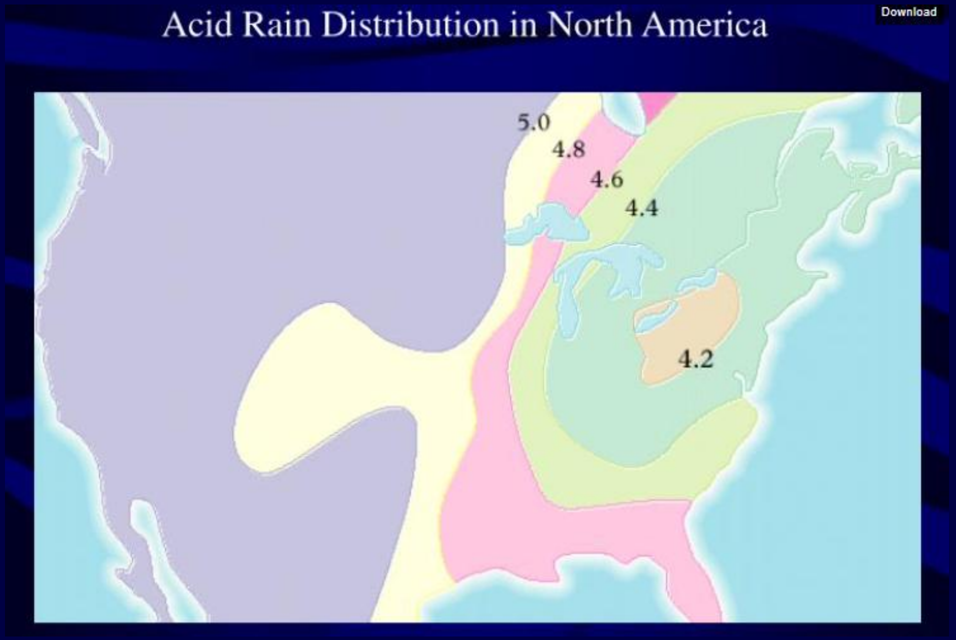
NO_x

Nitrogen oxides derive from forest fires, lightning and various microbiological processes, but above all from anthropogenic processes:

- vehicles that use fossil fuels (both petrol and diesel);
- heating;
- blast furnaces;
- waste incineration.

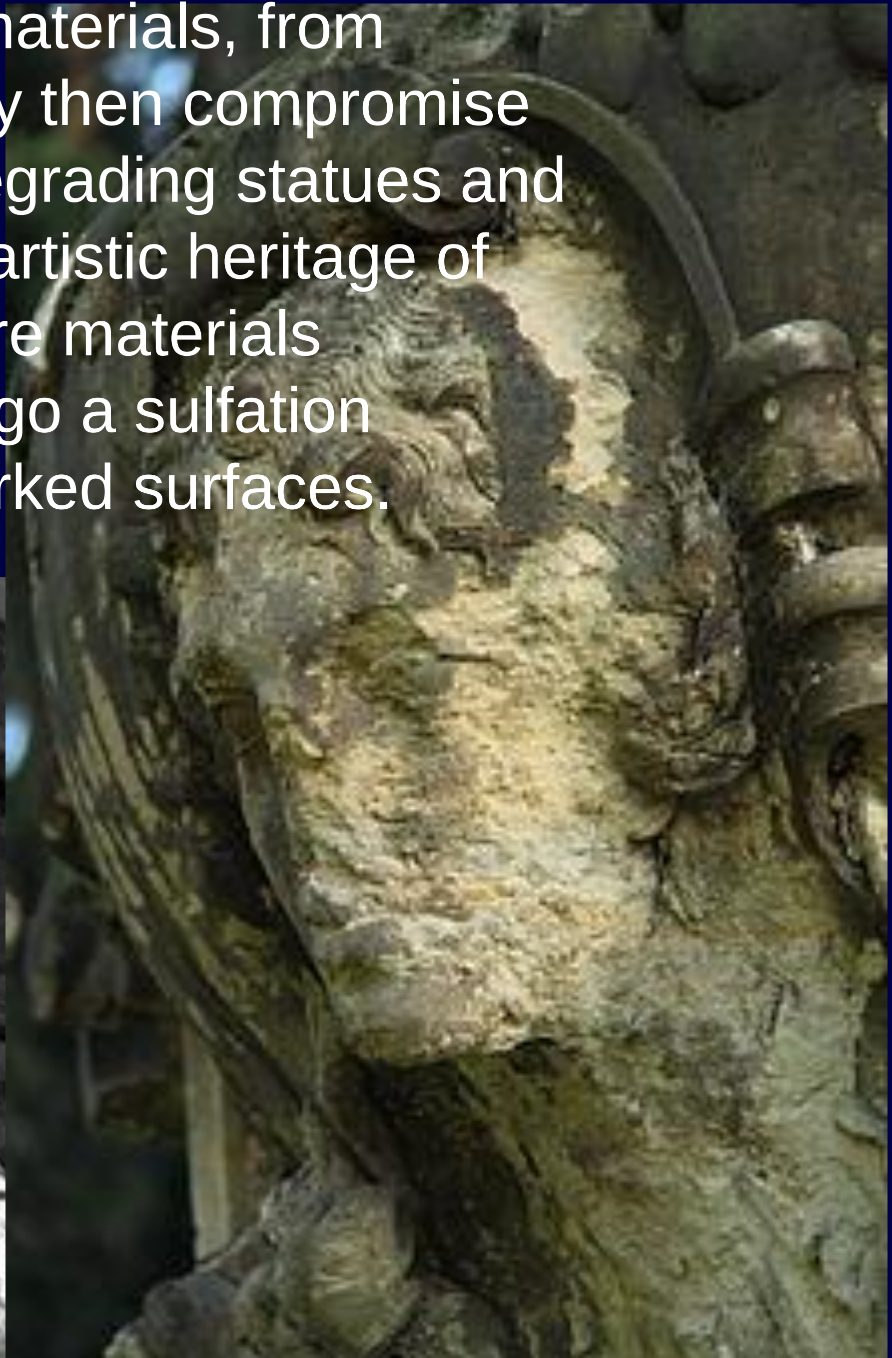
Basically, by any combustion process («thermal nitrogen»), derived by the thermal transformation of the nitrogen of the air, eventually reinforced by the NOx derived by the transformation of the nitrogen-rich compounds present in the fuel («nitrogen fuel»).

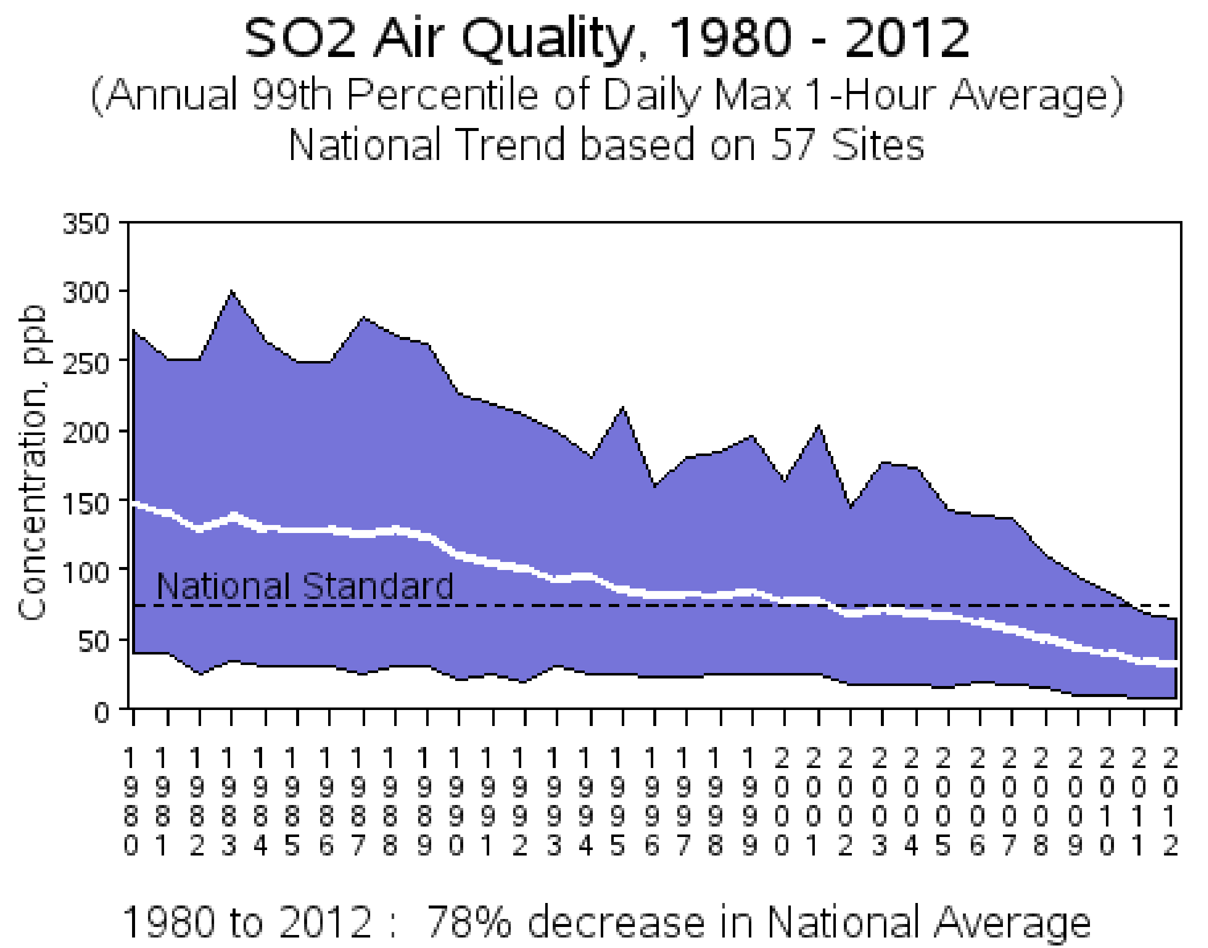
For decades, rain, snow, fog and dew have been recorded in many areas of the planet with pH values significantly lower than normal (pH 5.6), i.e. **between 2.0 and 5.0**.



The acid rains (caused by the reaction of SO_3 and NO_2 with H_2O in the air, forming respectively H_2SO_4 and HNO_3) causes the acidification of water bodies (lakes and watercourses), and forest soils; this causes the solubilization of elements (which were previously insoluble and therefore not bio-available), at toxic concentrations (e.g. Al^{3+}, highly toxic), with dramatic damage to forest vegetation of large regions characterized by acidic soils (e.g. Scandinavia; Tatra Mountains; Black Forest).

Acid rain accelerates the decay of materials, from construction materials to paints; they then compromise the integrity of the lithic surfaces, degrading statues and sculptures, and more generally the artistic heritage of each nation. Particularly sensitive are materials containing carbonates, which undergo a sulfation process, with serious loss of the worked surfaces.





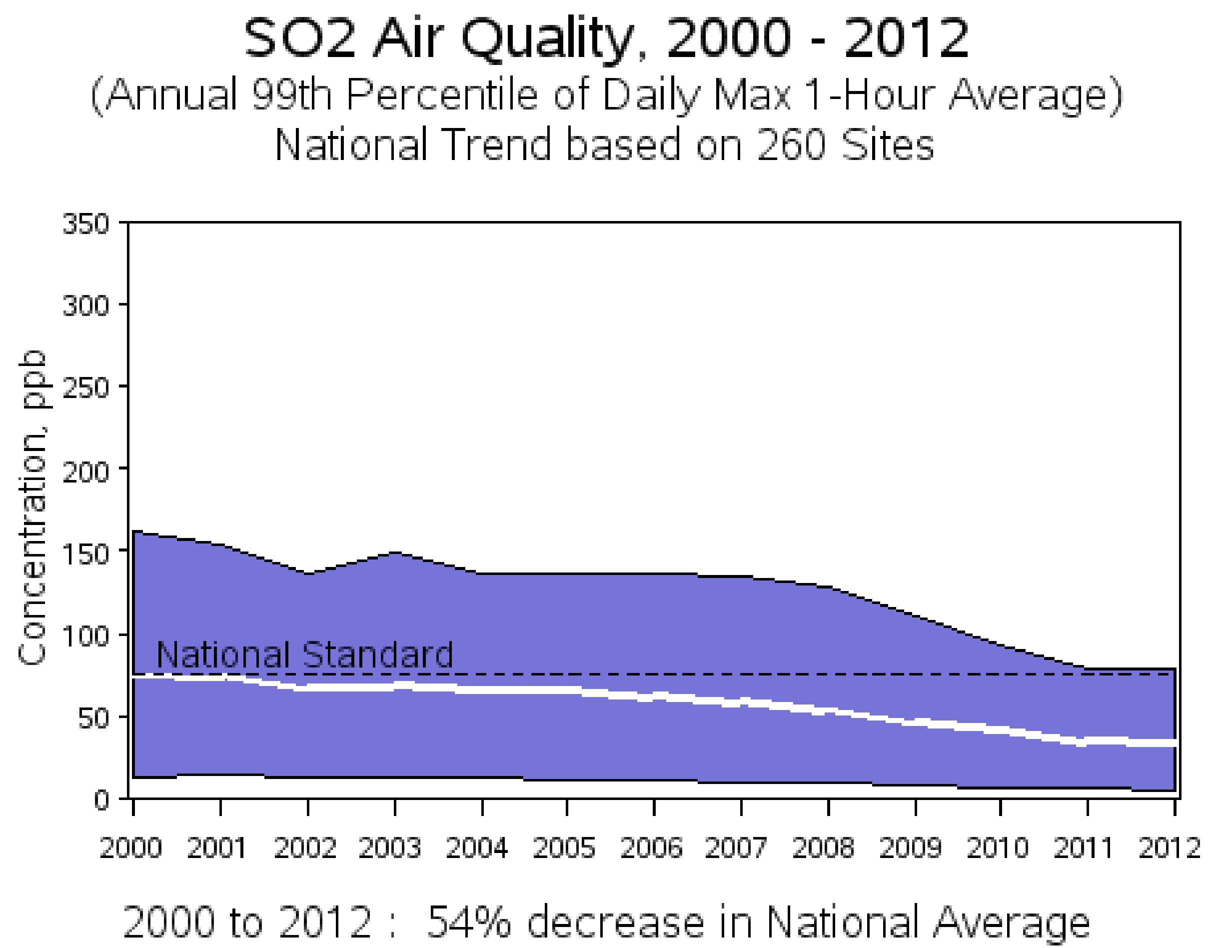
SO2 Air Quality, 1980 - 2012

(Annual 99th Percentile of Daily Max 1-Hour Average)

National Trend based on 57 Sites

1980 to 2012 : 78% decrease in National Average

Data from
EPA, 2014



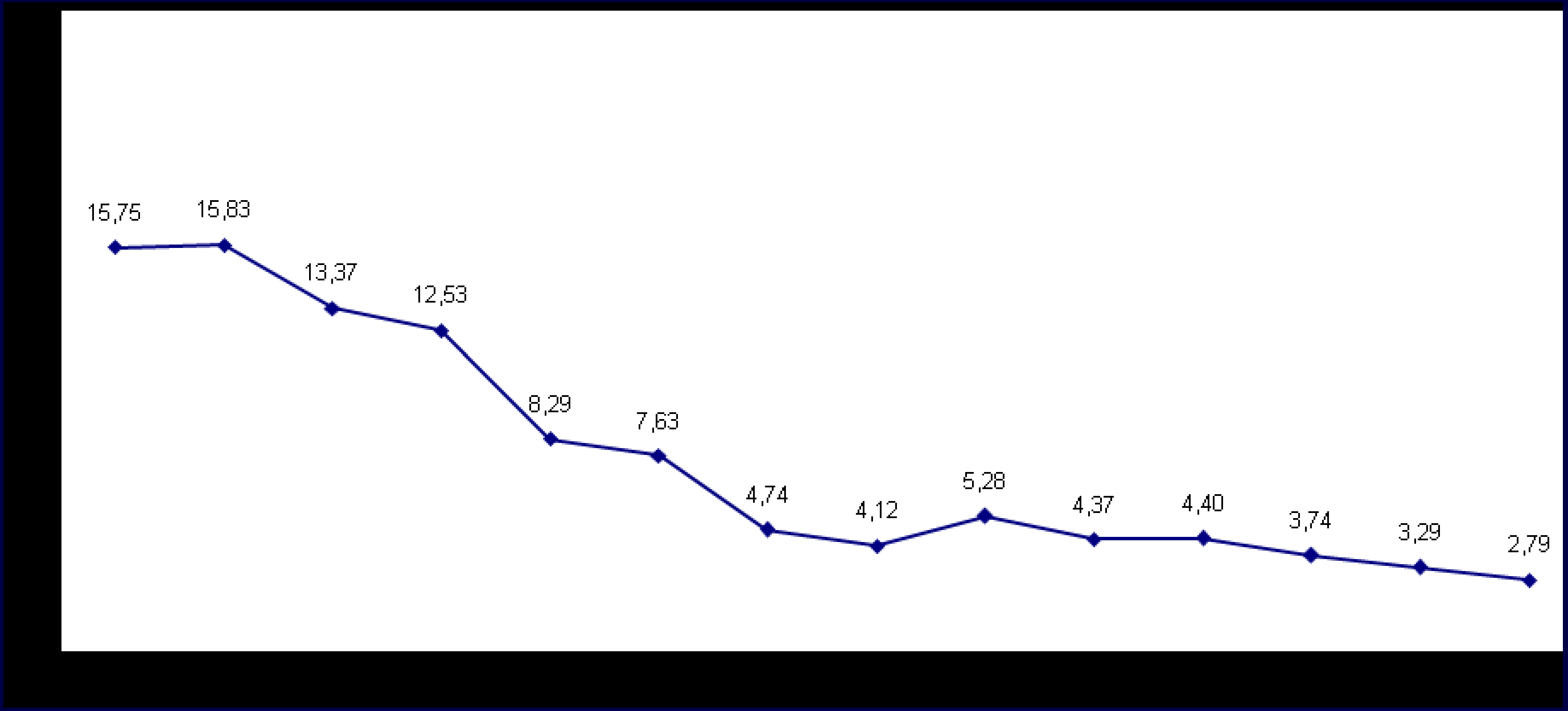
SO2 Air Quality, 2000 - 2012

(Annual 99th Percentile of Daily Max 1-Hour Average)

National Trend based on 260 Sites

2000 to 2012 : 54% decrease in National Average

And Italy?

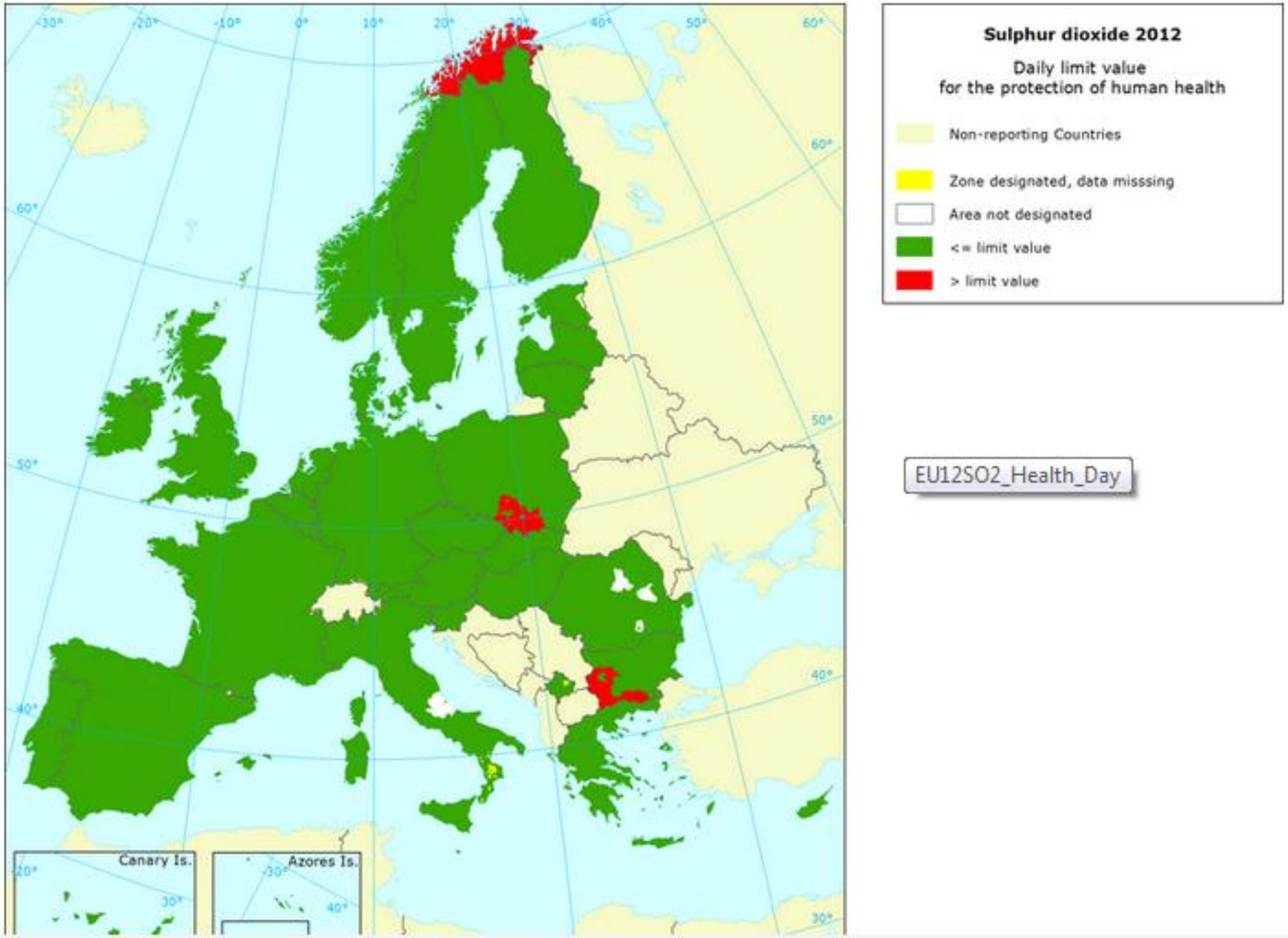


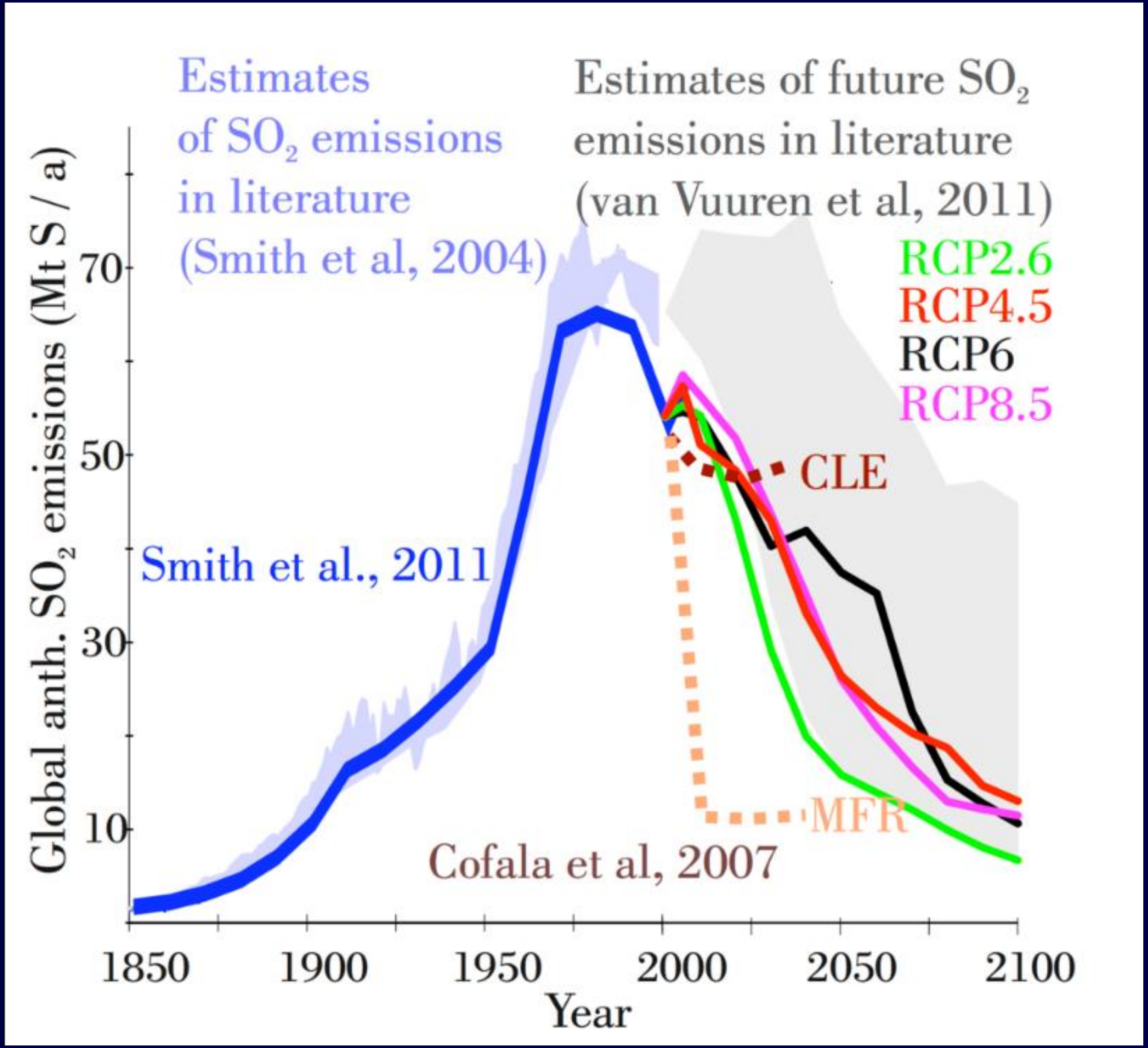
Trend of SO_2 concentration (average daily values, mg m^{-3}) in the period 1995-2008 in the city of Udine (NE Italy) [data from: Padovani & Polato, 2010].

This improvement resulted from:

- flue-gas desulfurization, a technology that enables SO_2 to be chemically bound in power plants burning sulfur-containing coal or oil. Most gypsum sold in Europe comes from flue-gas desulfurization, and thus the material used for producing drywall (“cartongesso”);
- increase in the use of methane, in industrial processes and in building heating systems;
- Strong taxation of sulphur-rich coal, oil or other fossil fuels.

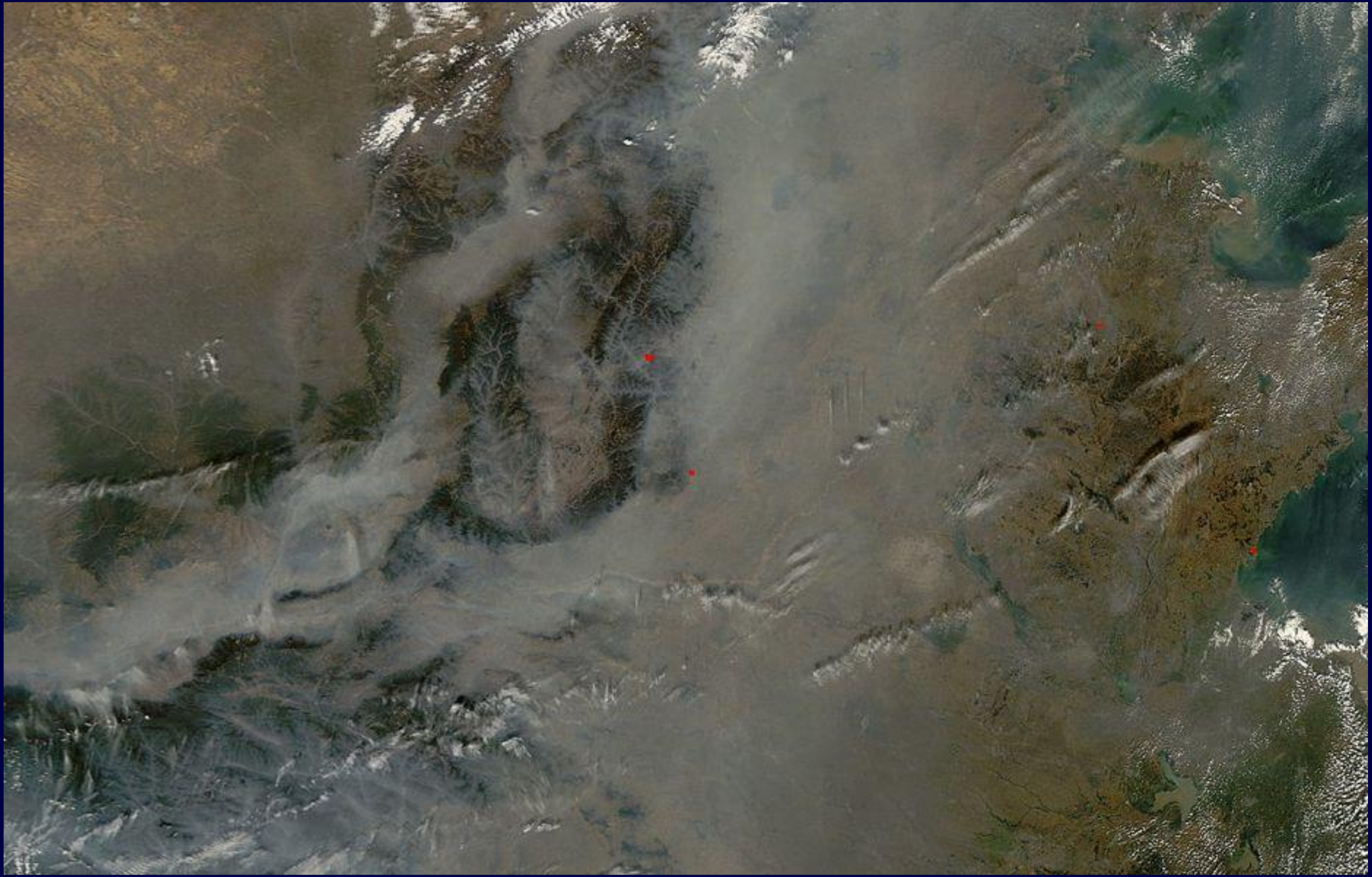
In the air quality directive (2008/EC/50) the EU has set two limit values for sulphur dioxide (SO2) for the protection of human health: the SO2 hourly mean value may not exceed 350 micrograms per cubic metre (µg/m3) more than 24 times in a year and the SO2 daily mean value may not exceed 125 micrograms per cubic metre (µg/m3) more than 3 times in a year.





A collection of estimates of past and future anthropogenic global sulphur dioxide emissions.

As of 2006, China was the world's largest sulfur dioxide polluter, with 2015 emissions estimated to be 25,490,000 short tons (23.1 Mt). This amount represents a 27% increase since 2000 and is roughly comparable with U.S. emissions in 1980.

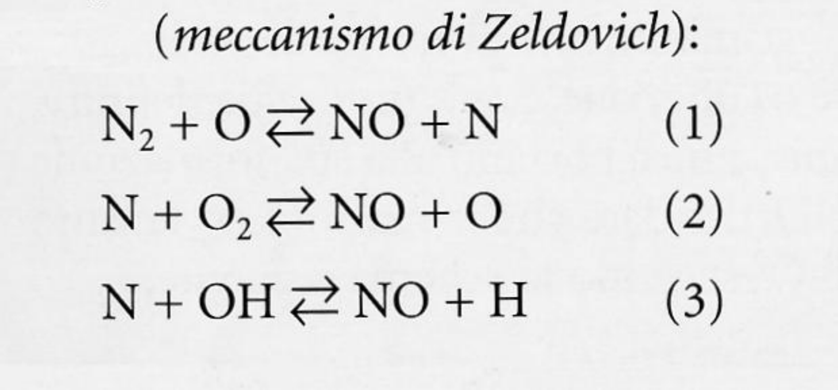


“Super smog” is often engulfing a large swath of northern China. Apparently, the haze is dense enough to be spotted from space. In October 2022, NASA's Terra Satellite captured this image of smog engulfing China, because of a combination of weather conditions and an increase in the burning of coal for homes and municipal heating systems.

Smog over Northern India. acquired February 5, 2006.
A pale band of haze hangs along the front of the Himalaya .

For NO_x, the situation is less positive.

NO_x include a family of compounds:
NO, NO_2 (also as N_2O_4), N_2O, N_2O_3, N_2O_5

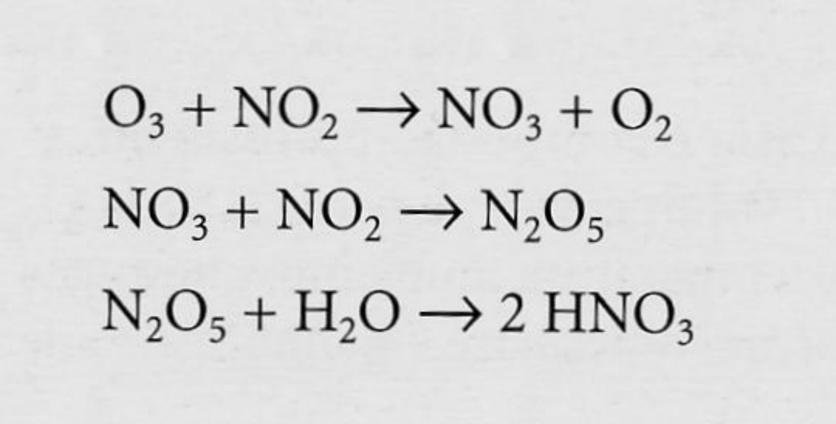


(*meccanismo di Zeldovich*):

$$N_2 + O \rightleftarrows NO + N \quad (1)$$

$$N + O_2 \rightleftarrows NO + O \quad (2)$$

$$N + OH \rightleftarrows NO + H \quad (3)$$

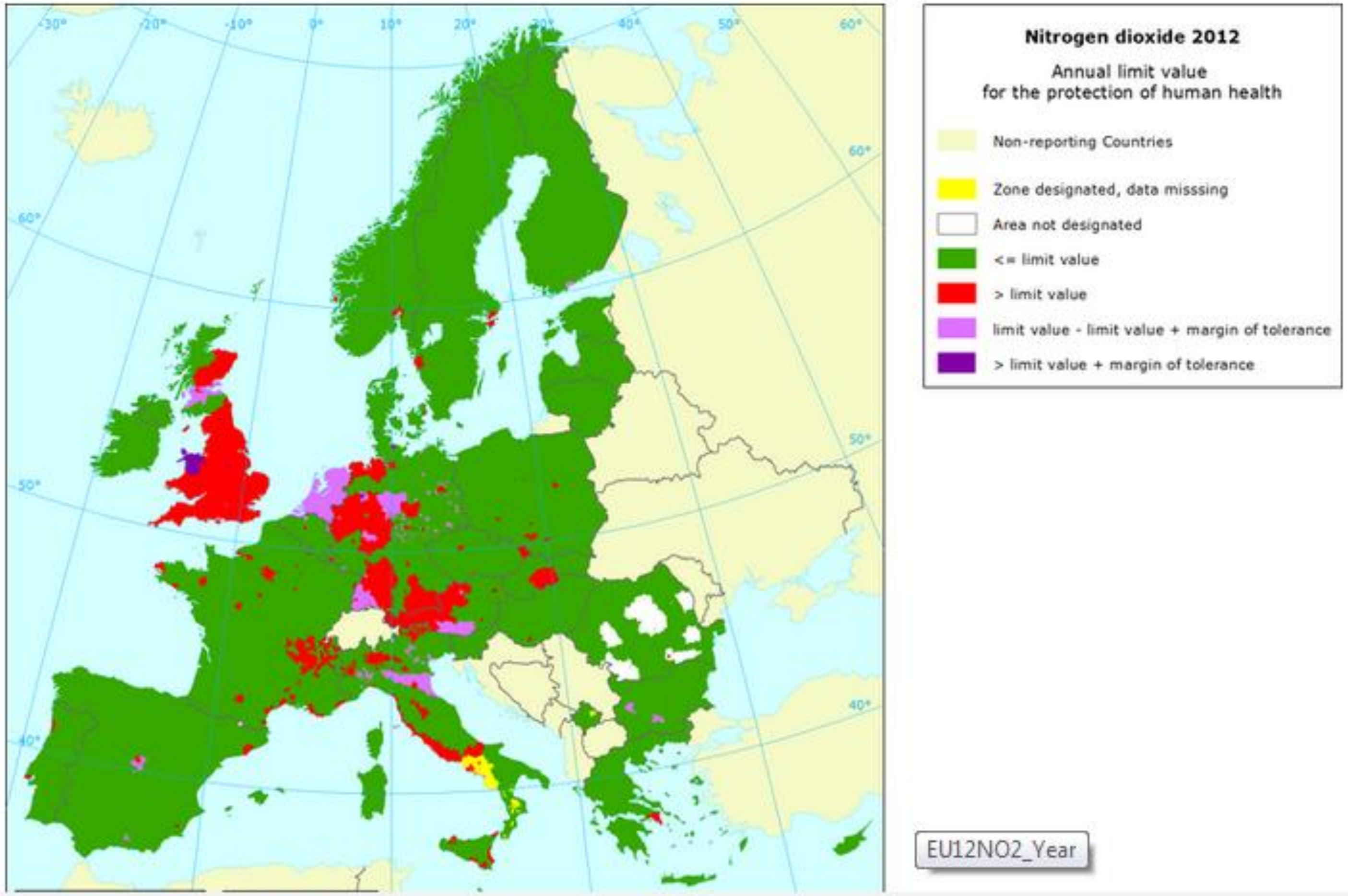


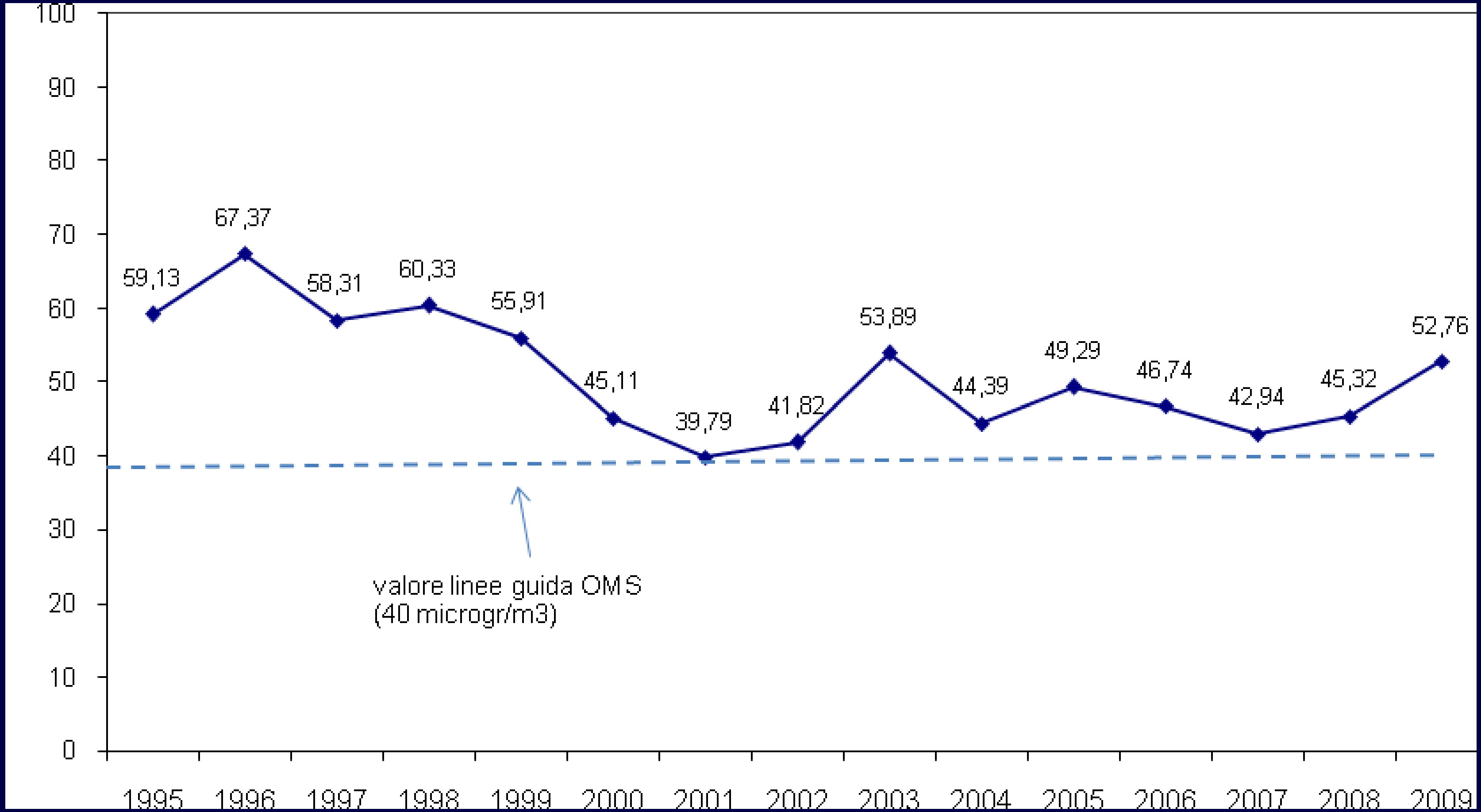
$$O_3 + NO_2 \rightarrow NO_3 + O_2$$

$$NO_3 + NO_2 \rightarrow N_2O_5$$

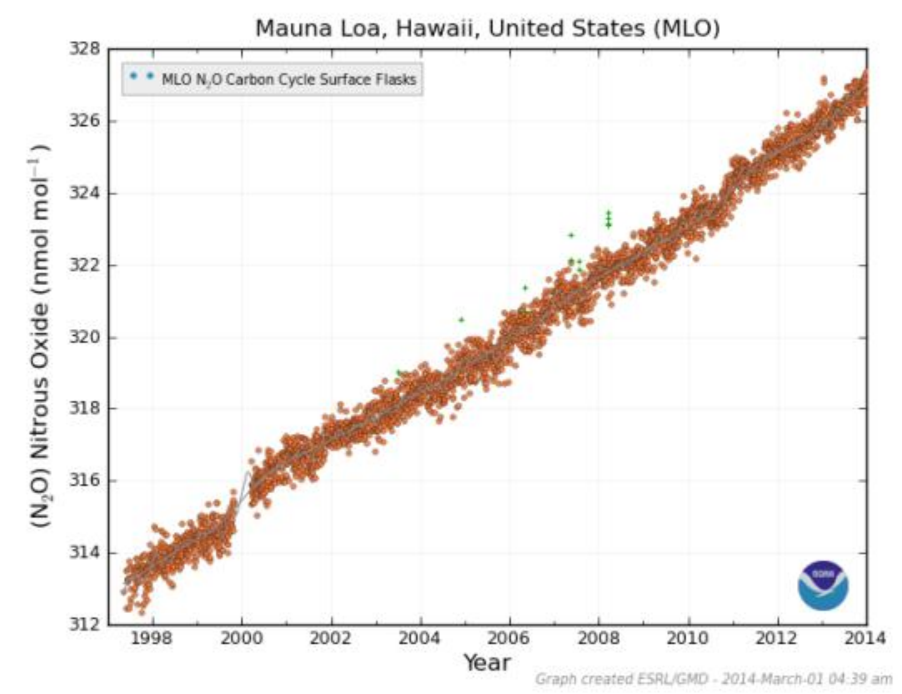
$$N_2O_5 + H_2O \rightarrow 2\ HNO_3$$

In the air quality directive (2008/EC/50) the EU has set two limit values for nitrogen dioxide (NO2) for the protection of human health: the NO2 hourly mean value may not exceed 200 micrograms per cubic metre (µg/m3) more than 18 times in a year and the NO2 annual mean value may not exceed 40 micrograms per cubic metre (µg/m3). These limit values come into force for concentrations measured from 1.1.2010 so during 2009 a margin of tolerance equal to an annual mean value of 42 micrograms per cubic metre (µg/m3) is still in place.

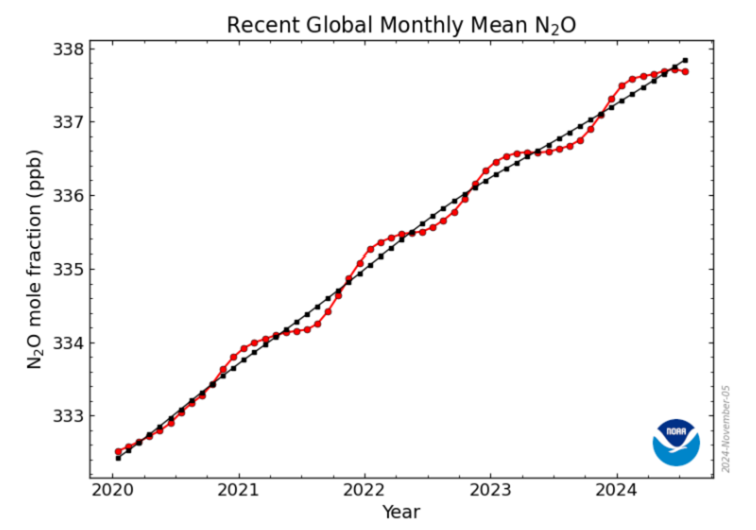




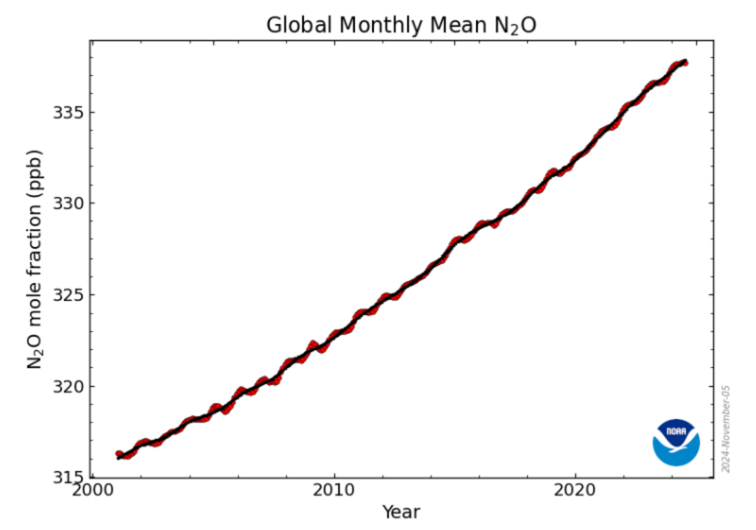
Trend of NO_2 concentration (average daily values, mg m^{-3}) in the period 1995-2008 in the city of Udine (NE Italy) [data from: Padovani & Polato, 2010].



Mauna Loa, Hawaii, United States (MLO)
MLO N$_2$O Carbon Cycle Surface Flasks
(N$_2$O) Nitrous Oxide (nmol mol^{-1})
328
326
324
322
320
318
316
314
312
1998
2000
2002
2004
2006
2008
2010
2012
2014
Year
Graph created ESRL/GMD - 2014-March-01 04:39 am

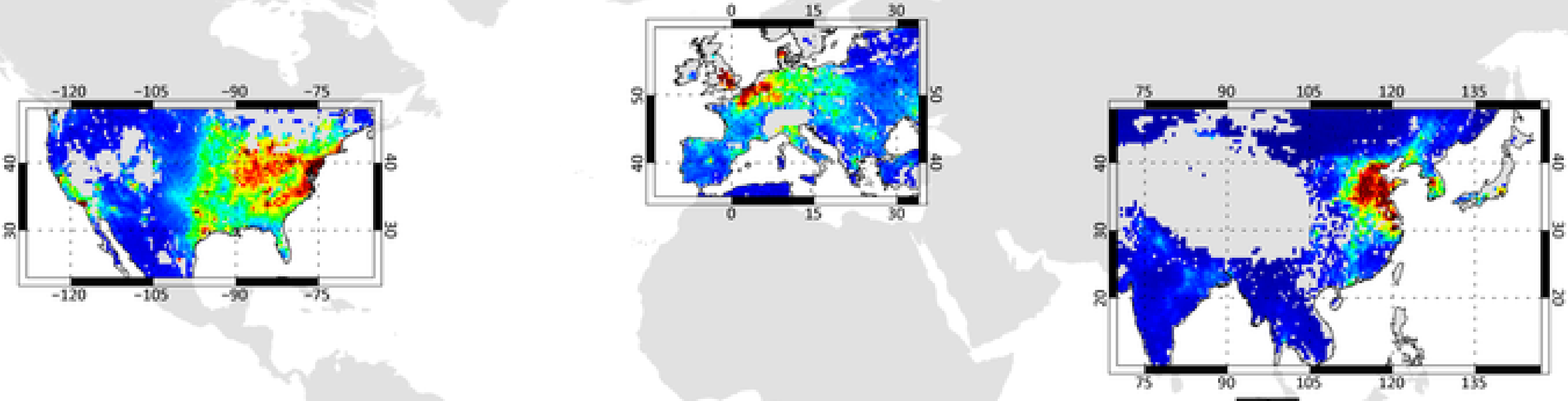


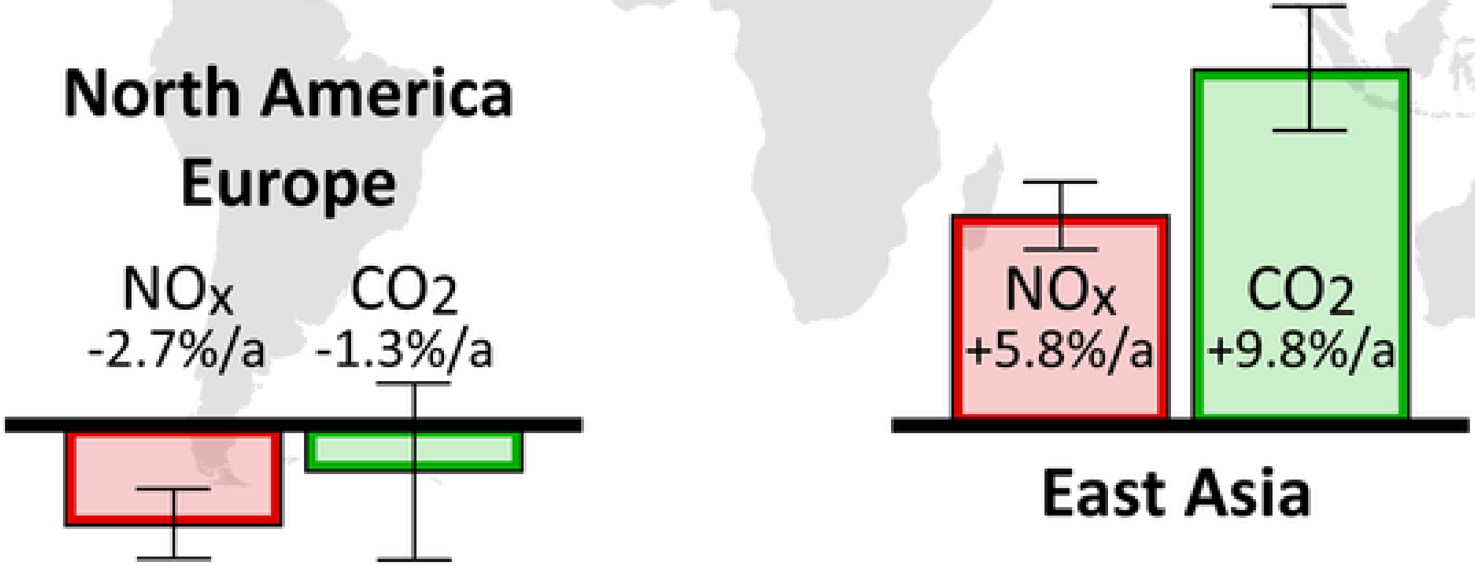
Recent Global Monthly Mean N$_2$O
N$_2$O mole fraction (ppb)
338
337
336
335
334
333
2020
2021
2022
2023
2024
Year
2024-November-05



Global Monthly Mean N$_2$O
N$_2$O mole fraction (ppb)
335
330
325
320
315
2000
2010
2020
Year
2024-November-05

Satellite derived trends of anthropogenic NO_x and CO_2 emissions





North America

Europe

NO_x -2.7%/a

CO_2 -1.3%/a

NO_x +5.8%/a

CO_2 +9.8%/a

East Asia

Reuter et al., 2014 (Nature Geoscience)

maximilian.reuter@iup.physik.uni-bremen.de

An important reminder:

NO_x represent the most important oxidized components of nitrogen, but there is another component that is causing even more serious problems, especially for valuable ecosystems, and it is the reduced component, the most frequent representative of which is the ammonium ion, NH_4^+.

It is a pollutant of amphoteric origin, both primary (e.g. from a source: animal excrement) and secondary (i.e. formed in the atmosphere due to reductive processes from NO_x).

The ammonium NH_4^+ is never measured by our automated recording gauges. The most important source is animal farming (pigs, cows, poultry, rabbits).

The environmental enrichment in NH_4^+ actually represents a case of eutrophication (=excessive availability of an otherwise limiting element, in this case nitrogen), which is causing particularly serious problems especially for some valuable oligotrophic ecosystems, and for entire groups of organisms, determining for example a significant change in the lichen flora of entire countries (e.g. Holland; in Italy: Po Valley).

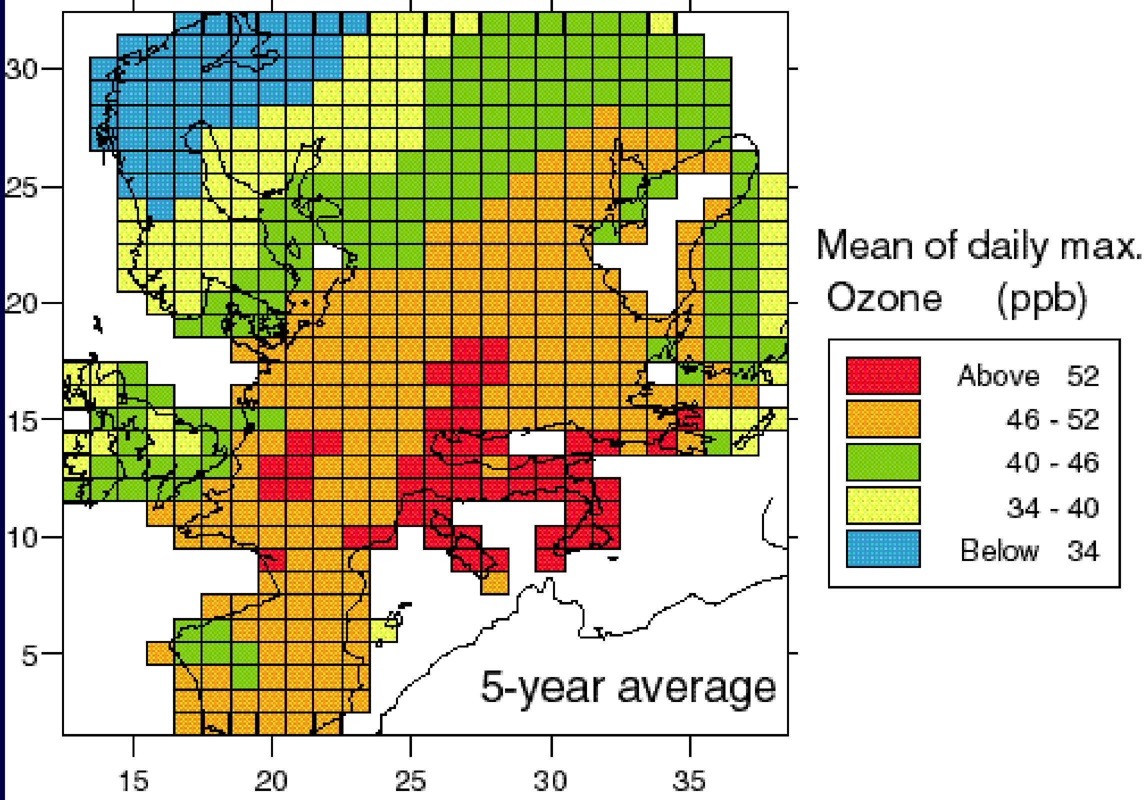
Coastal dune environments (photo on the left) are among the environments most affected by environmental eutrophication, together with moors (photo on the right)

NO_x are related to the formation – at specifc conditions – of an important secondary pollutan, ozone (O_3). Together with organic pollutants, they form the so-called «photochemical smog» or «Los Angeles smog», in contrast to the «London smog», caused by SO_2 plus particulate matter, PM.

The formation of ozone takes place when there are specific environmental conditions:

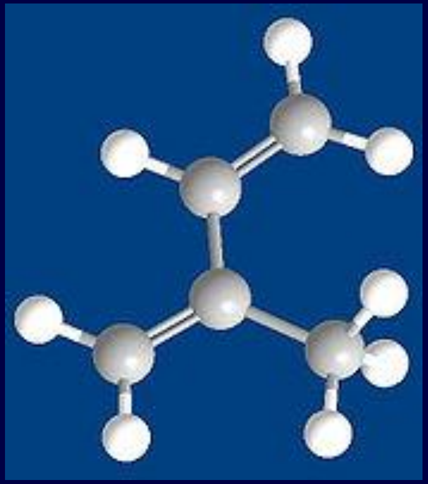
- High solar irradiation (ultraviolet light is high)
- High temperatures
- High concentration of NO_2
- High concentration of Volatile Organic Compounds («VOC»)

Cities located in peri-Mediterranean geographical areas are the ideal candidates for the development of episodes of acute ozone pollution, especially in summer, in the central hours of the day, in the presence of low wind speed.



VOCs constitute a group of organic compounds that evaporate rapidly in the air under normal pressure and temperature conditions. This group includes benzene, ethanol, isoprene, and trichloroethane, and mixtures such as gasoline and turpentine.

Their presence in the air is mainly due to the incomplete combustion of fossil fuels and plant materials, and to the evaporation of solvents and fuels.



VOCs are also produced by plants, by the volatilization of terpens and terpenoids, biomolecules made up of multiples of the isoprene unit (left) with a linear, cyclic or mixed structure, possibly modified to carry hydroxyl, carbonyl and amino functional groups (terpenoids).

Terpenes are well-known molecules such as menthol, limonene, geraniol, isoprenol, camphor. They are produced by many plants, being the main components of resins (1) and essential oils produced by specialized glands (2), with many adaptive functions, from defense against insects and animals, to that against bacteria and fungi.

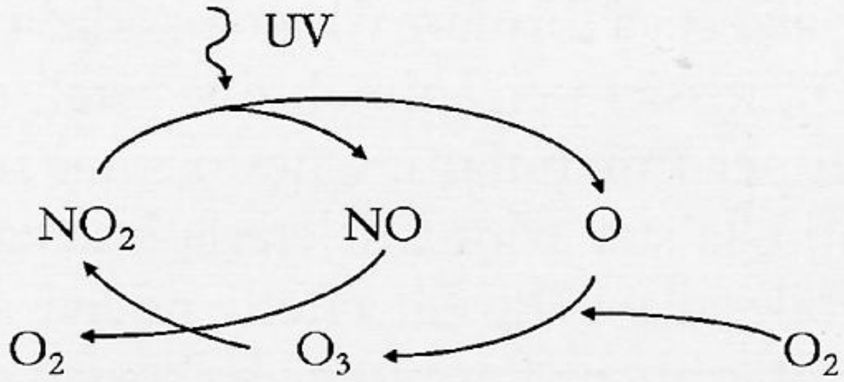
Eucalyptus, conifers and Mediterranean scrub plants release significant quantities of VOC, but also apparently harmless species such as oaks do the same.

Natural emissions of VOC are generally widespread in large areas, on the contrary, man-made emissions are concentrated in well-defined areas. VOCs are in fact among the main components of emissions in urban areas, although they are rarely measured by automatic recording gauges, with the exception of benzene.

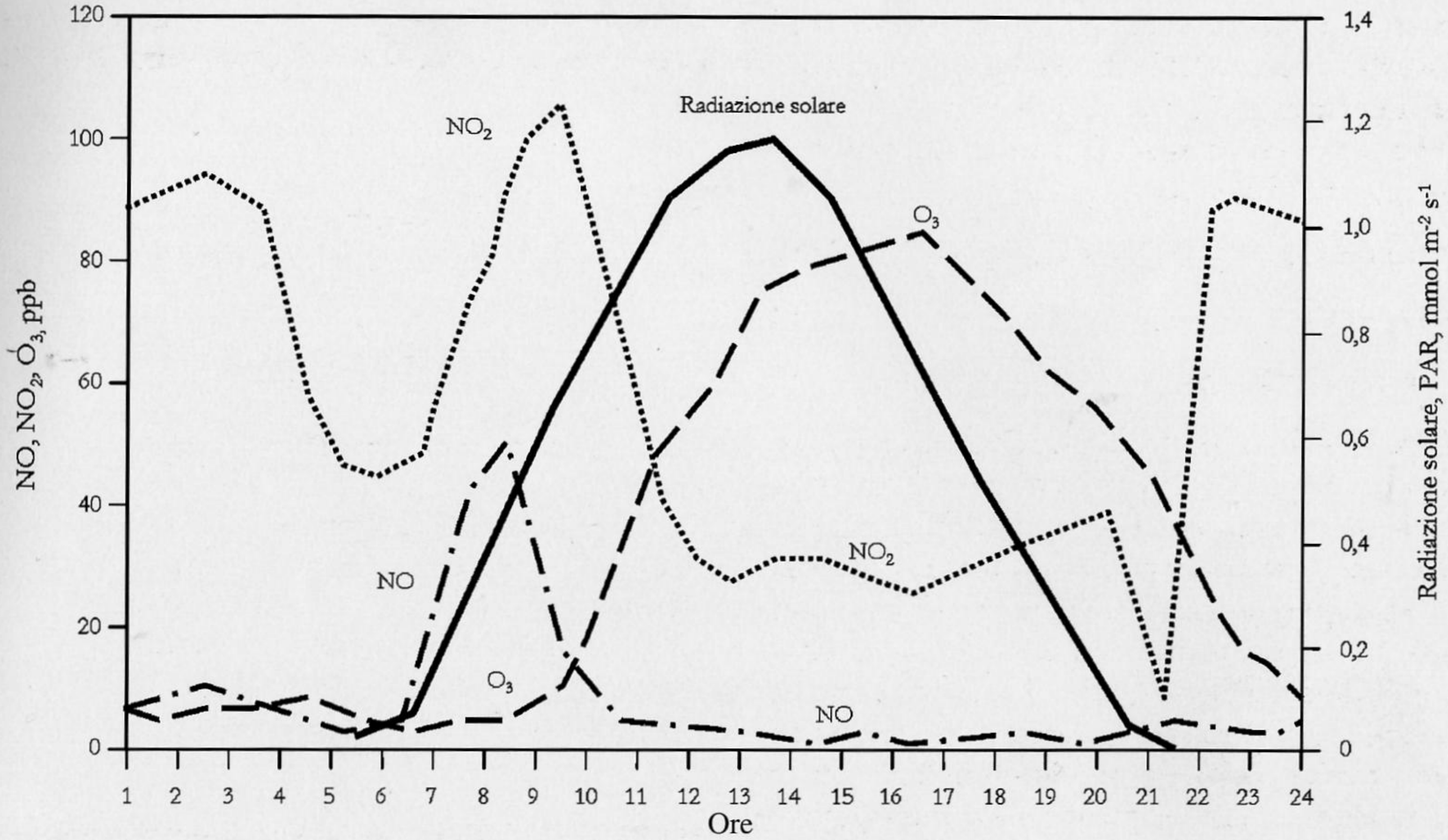

(1)


(2)

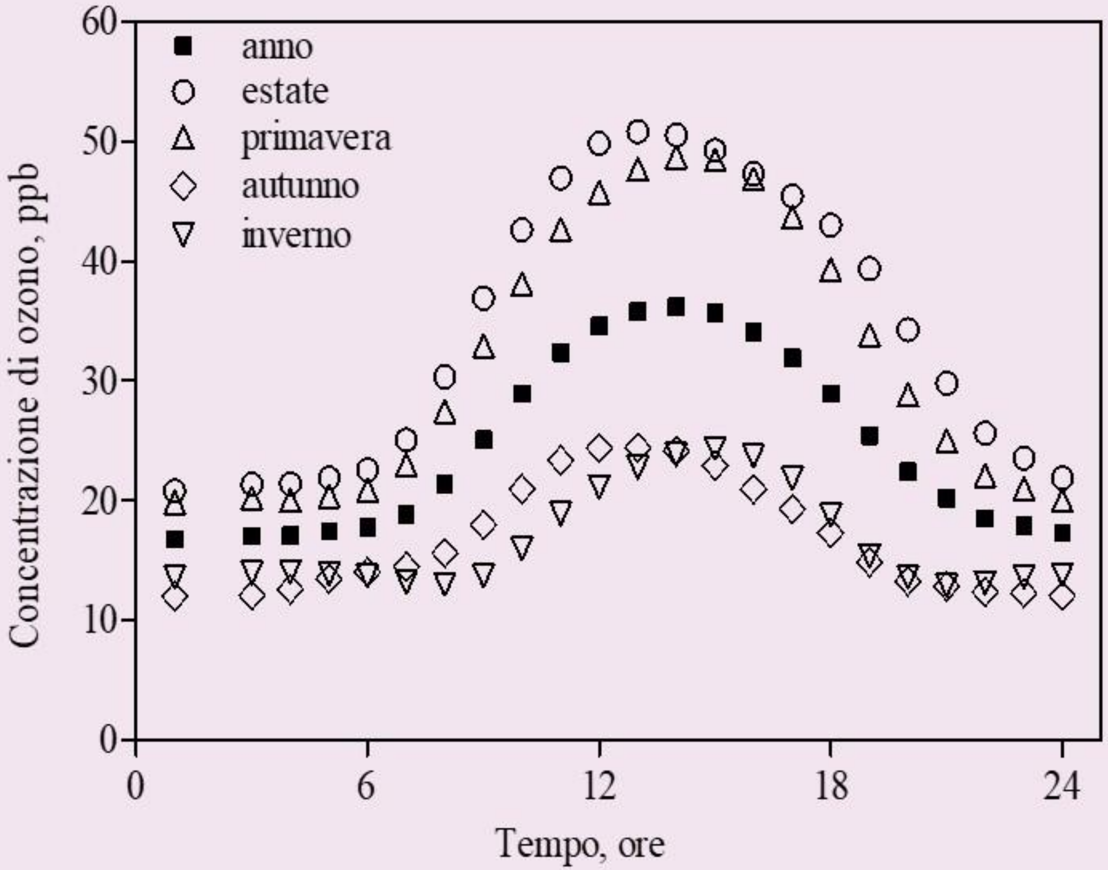
Normal cycle



«ill» cycle

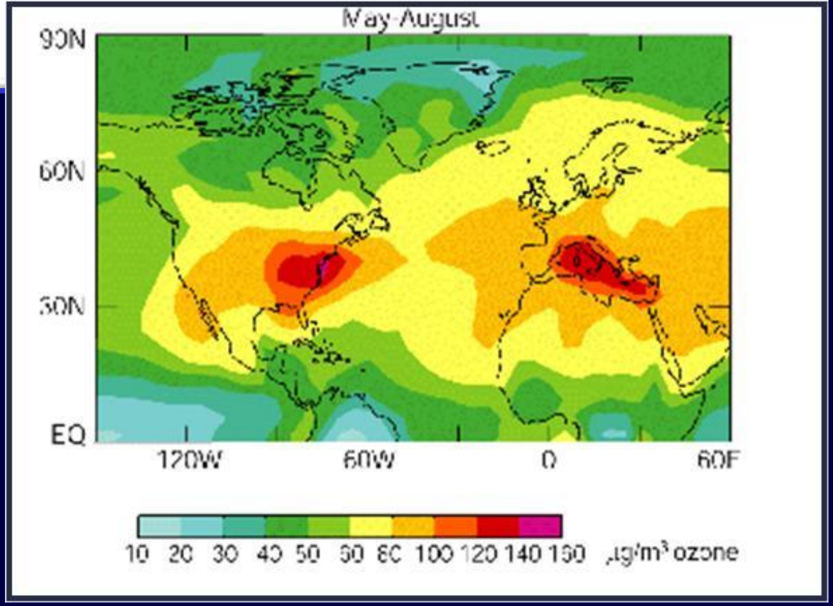


Tipico profilo circadiano, in relazione alla radiazione solare, degli inquinanti ossidanti secondari (ossidi di azoto e ozono) in atmosfera urbana in condizioni di *smog fotochimico*

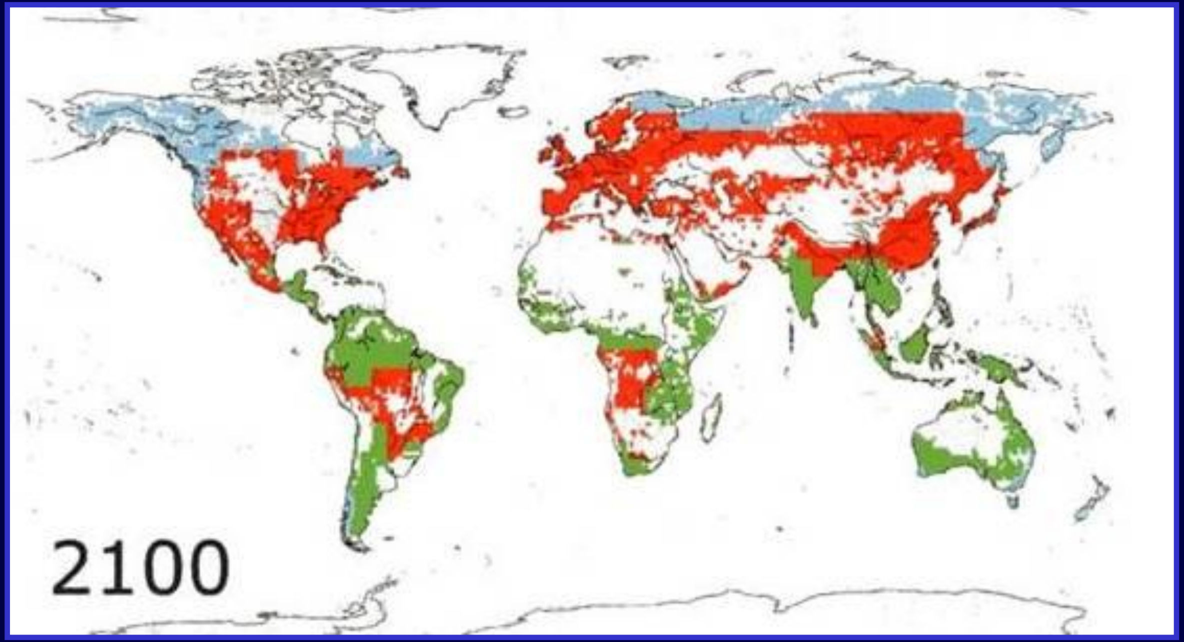


■ anno
○ estate
△ primavera
◇ autunno
▽ inverno
Concentrazione di ozono, ppb
0
10
20
30
40
50
60
Tempo, ore
0
6
12
18
24

Geographic distribution of ozone



TODAY



The effects of ozone on human health

It is estimated that around 21,000 premature deaths per year are associated with ozone levels exceeding 70 μg/m^3 in the 25-country Europe.

It is also estimated that the slight decrease in ozone, expected as a result of new legislation and policies on climate change carried out by EU, reduced premature mortality by only 600 cases per year, between 2000 and 2020.

Source: Public Health Epidemiology Portal
organized by the National Center for Disease Prevention and Health Promotion of the Istituto Superiore di Sanità

- oxidations of polyunsaturated fatty acids in lipids (lipid peroxidation)
- oxidations of amino acids in proteins
- oxidative deactivation of specific enzymes by oxidation of co-factors
- damage of DNA or RNA

Recent epidemiological studies have confirmed that ozone is associated with acute and adverse health effects, both in terms of morbidity and mortality. Chronic exposure to ozone causes significant changes in the airways at the level of the bronchioles. The reversibility of this type of injury is a point that still needs to be clarified.

The available investigations substantiate long-term effects of ozone on the functionality of the airways and on asthma. Repeated ozone exposures to the developing lungs of children can lead to a reduction in lung function as adults.

Furthermore, exposure to ozone can accelerate the natural aging process of lung function.

Ozone has a high redox potential

F: 2.87 V; **OH•**: 2.86 V; **O**: 2.42 V; **O_3**: 2.07 V; **H_2O_2**: 1,78 V; **Cl**: 1.36 V; **ClO_2**: 1.27 V; **O_2**: 1,23 V)

It dissolves readily in water, eventually forming **Reactive Oxygen Species** (ROS):

Radicale superossido **O_2^-**

Perossido di idrogeno **H_2O_2**

Radicale ossidrile **OH**

Ossigeno singoletto **$^1O_2$**

A last remark. Not all ozone is bad…

- in the stratosphere (25-40 km high) where it plays a fundamental role by absorbing high-energy ultraviolet rays (λ<290 nm) of solar radiation (“ozone hole”);
- in the troposphere (<25 km) as a consequence of: a) descent from other layers of the atmosphere due to particular weather conditions; b) lightning or electrical discharges; c) as a secondary pollutant, of natural and/or anthropogenic origin.
- We use it to sterilize drinkable water in our aqueducts or in specific therapies.

As other pollutans, but more than other pollutants, ozone can heavily affect crops and plants in general. Actually, the first studies concerning environmental ozone were requested in the 50s’ of last century by Californain farmers, who observed damage to their crops: salad plants, and orange trees. In those years, California knew an economic boom, vehicular traffic increased exponentially, and the same farmers, to control freezing temperatures (which damage orange trees) were used to burn tires in the field: a perfect combination of factors to increase ozone formation…

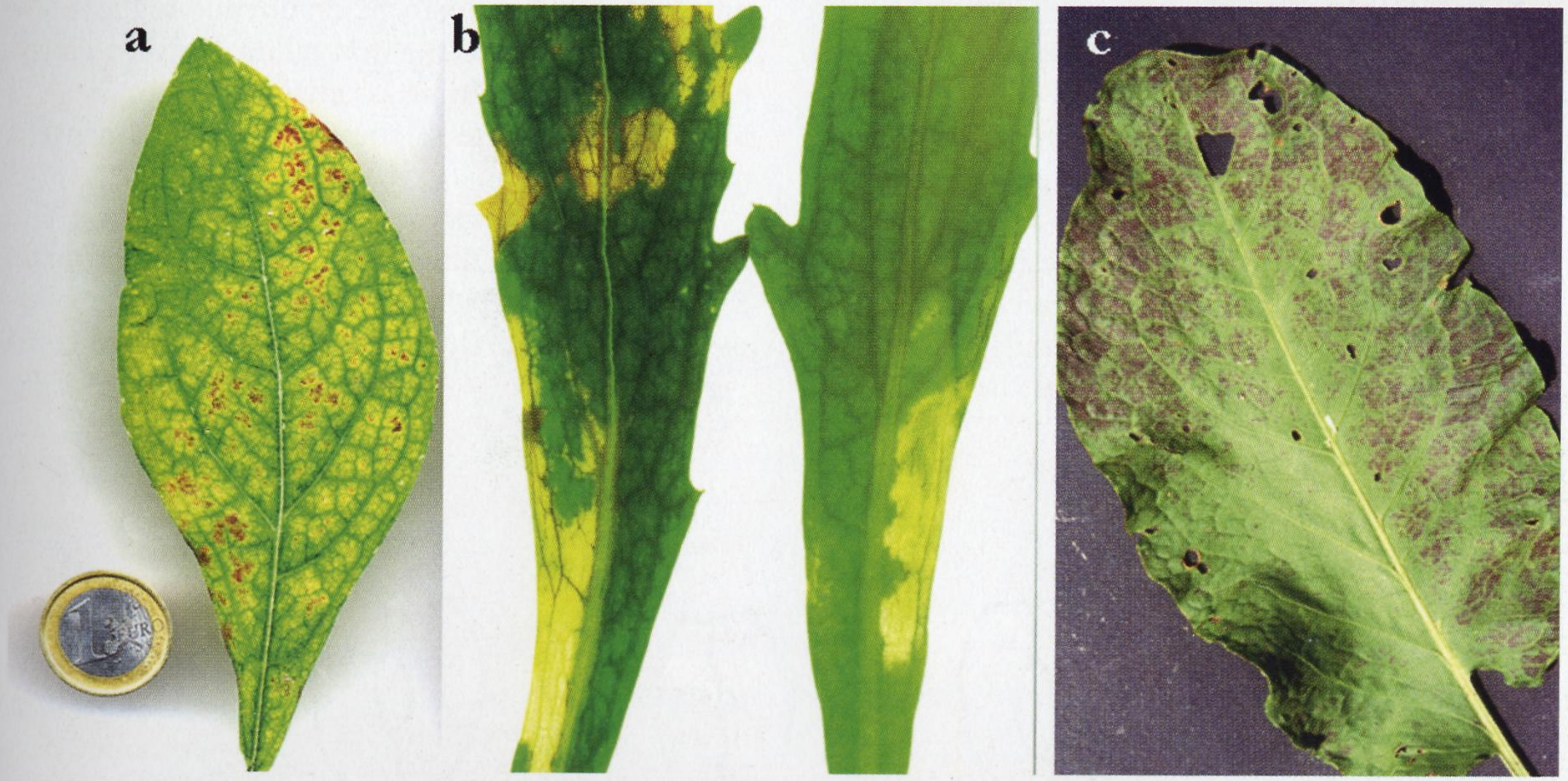
DAMAGES CAUSED BY OZONE IN PLANTS

Anatomical, biochemical and physiological variations, characteristic of the natural aging processes of the plant.

THE MOST EVIDENT SYMPTOMS: Chlorosis, necrosis and leaf abcission

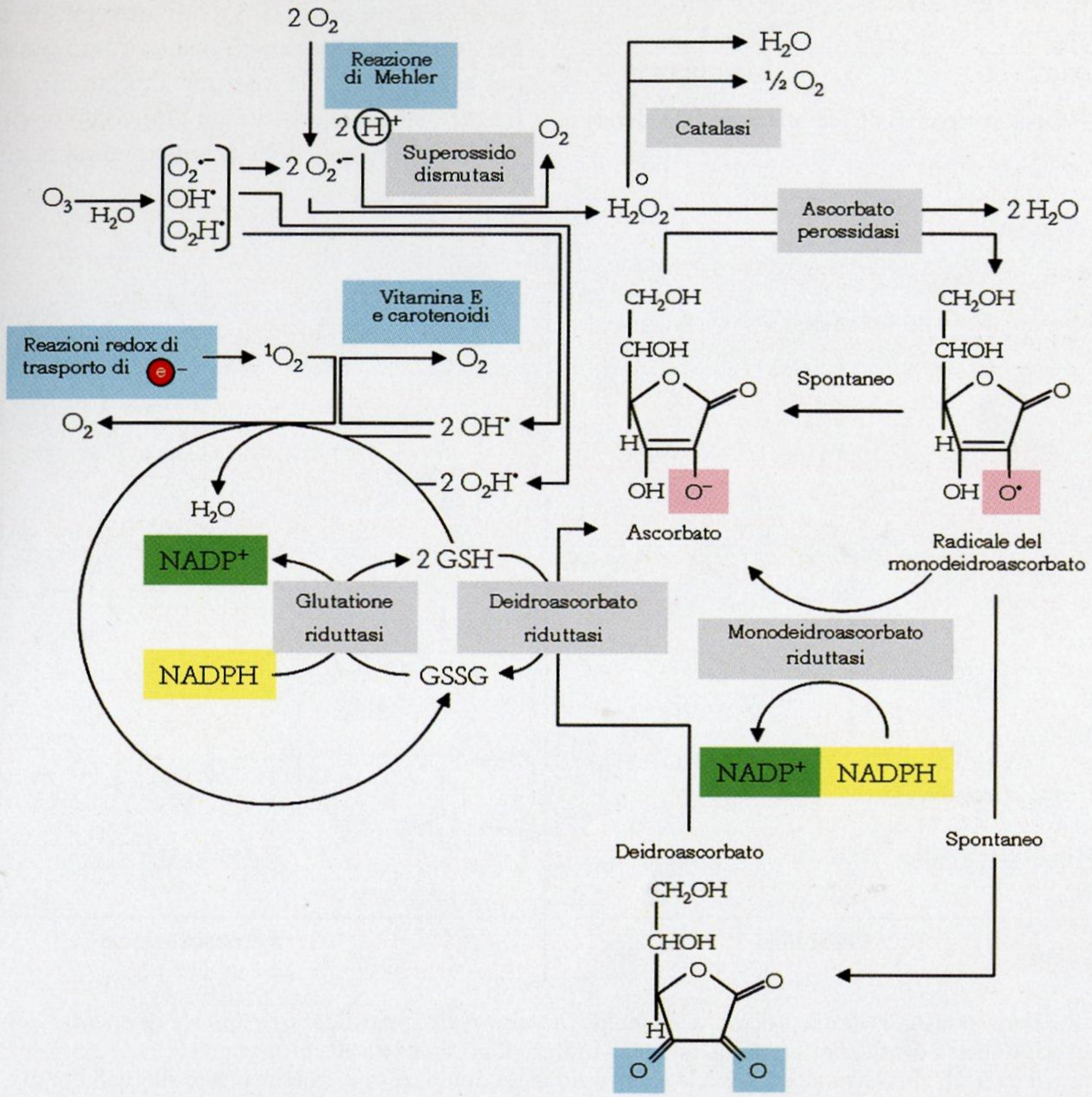
SUBLIMINAL SYMPTOMS: Decreased photosynthetic activity, reduced productivity and development, premature senescence

Overall, this is a symptomatic picture typical of natural processes of plant senescence. Therefore, the authors speak of OZONE-DEPENDENT STRESS SYNDROME or OZONE ACCELERATED SENESCENCE



Sintomi indotti dall'esposizione all'ozono su *Centaurea jacea* (**a**), *Conyza bonariensis* (**b**) e *Rumex* sp. (**c**)

“Halliwell/Foyer/Asada cycle”



Vie enzimatiche e non di difesa antiossidante nei sistemi vegetali. (Elaborato da Bray *et al.*, 2003). I radicali superossido ($O_2^{\cdot -}$) sono eliminati dalla superossido dismutasi (SOD) in una reazione che produce perossido di idrogeno (H_2O_2). Questo è consumato, attraverso la conversione a ossigeno e acqua, dalla catalasi, o a sola acqua, attraverso l'ossidazione dell'ascorbato. Quest'ultimo, a sua volta, è rigenerato attraverso due meccanismi: (**a**) riduzione enzimatica di monodeidroascorbato nei plastidi; (**b**) il monodeidroascorbato è spontaneamente dismutato a deidroascorbato e reagisce con il glutatione (GSH) a dare ascorbato e glutatione ossidato (GSSG) in una reazione catalizzata dalla deidroascorbato riduttasi. GSSG è ridotto dalla glutatione riduttasi, che richiede consumo di nicotinamide adenin dinucletide fosfato ridotto (NADPH). L'ossigeno singoletto e gli ioni ossidrilici sono eliminati nella via del glutatione. L'azione tossica dell'ossigeno singoletto e degli ioni ossidrilici viene contrastata dagli antiossidanti non enzimatici, quali carotenoidi e vitamina E (vedi Tabella 16)

Eliminating O_3 and ozone-derived ROS – is the task of low molecular weight organic molecules, such as the tripeptide GLUTATHIONE (GSH), ASCORBATE, TOCOPHEROLS, present at cytoplasmatic level, and specific enzymes.

The ability to cope with ROS depends on:

- quantity of constituent anti-ROS molecules, in particular the GSH (reduced) – GSSG (oxidized) couple;
- presence of constitutively expressed enzymes;
- ability to mobilize reducing power (NADPH), which must allow the "work" of reduction of oxidized molecules by the specific enzymes.

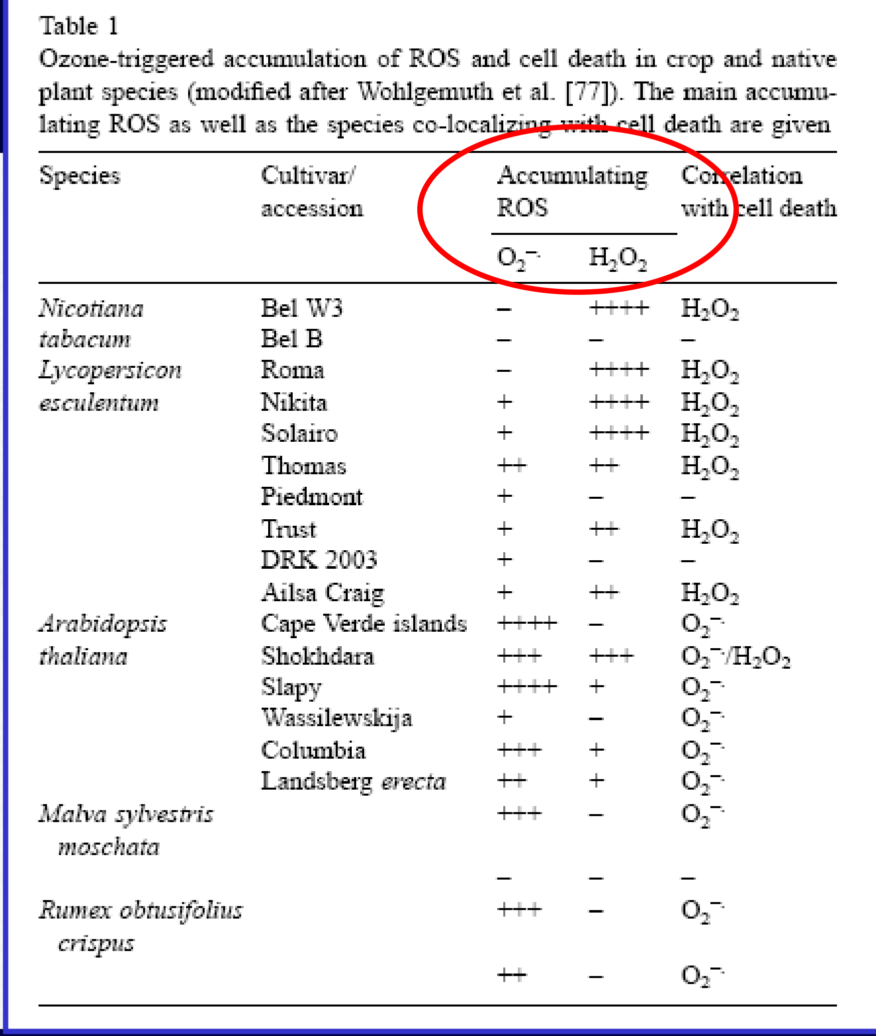


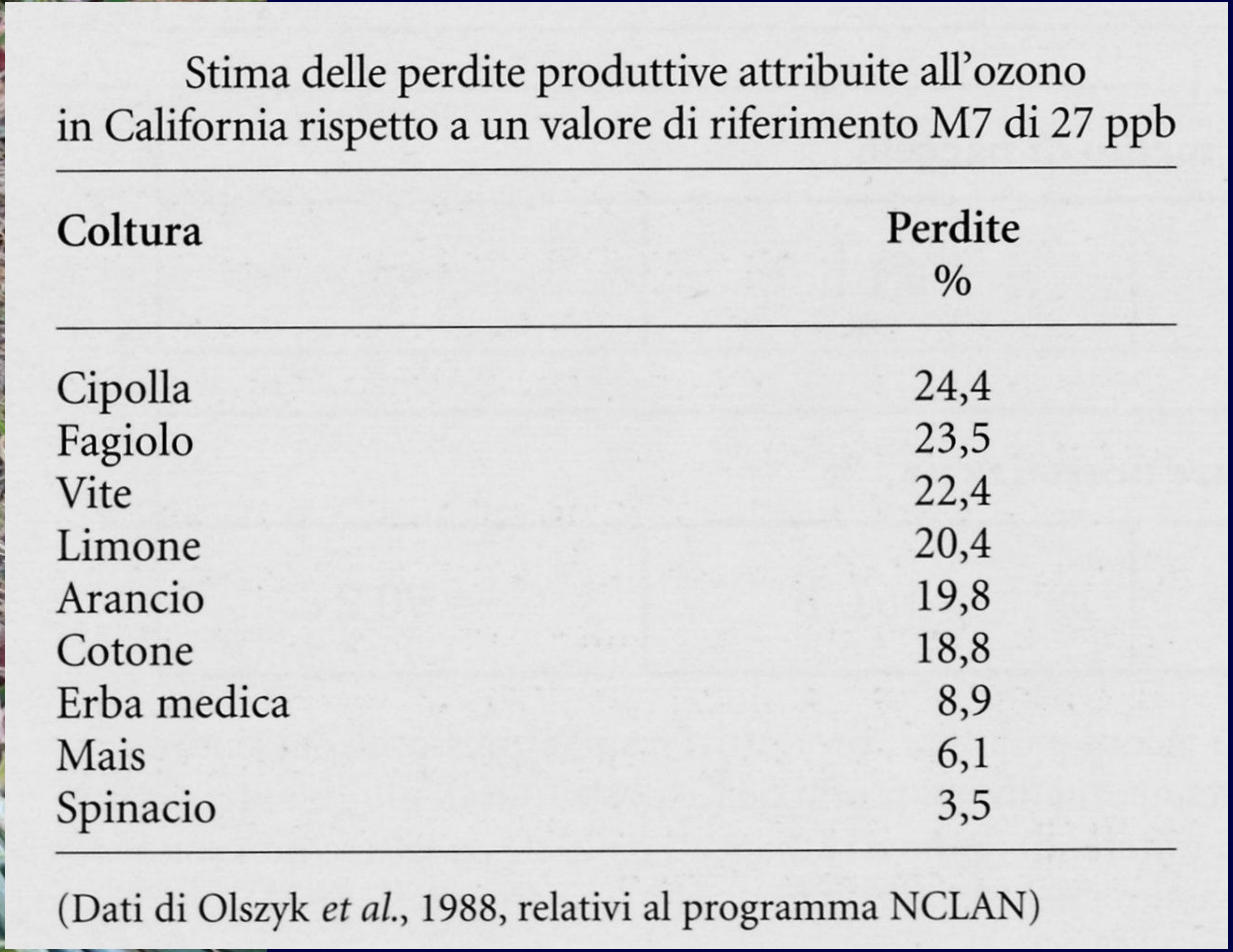
Table 1

Ozone-triggered accumulation of ROS and cell death in crop and native plant species (modified after Wohlgemuth et al. [77]). The main accumulating ROS as well as the species co-localizing with cell death are given

Species	Cultivar/ accession	Accumulating ROS		Correlation with cell death
		$O_2^{-\cdot}$	H_2O_2	
Nicotiana	Bel W3	–	++++	H_2O_2
tabacum	Bel B	–	–	–
Lycopersicon	Roma	–	++++	H_2O_2
esculentum	Nikita	+	++++	H_2O_2
	Solairo	+	++++	H_2O_2
	Thomas	++	++	H_2O_2
	Piedmont	+	–	–
	Trust	+	++	H_2O_2
	DRK 2003	+	–	–
	Ailsa Craig	+	++	H_2O_2
Arabidopsis	Cape Verde islands	++++	–	$O_2^{-\cdot}$
thaliana	Shokhdara	+++	+++	$O_2^{-\cdot}/H_2O_2$
	Slapy	++++	+	$O_2^{-\cdot}$
	Wassilewskija	+	–	$O_2^{-\cdot}$
	Columbia	+++	+	$O_2^{-\cdot}$
	Landsberg *erecta*	++	+	$O_2^{-\cdot}$
Malva sylvestris		+++	–	$O_2^{-\cdot}$
moschata				
		–	–	–
Rumex obtusifolius		+++	–	$O_2^{-\cdot}$
crispus				
		++	–	$O_2^{-\cdot}$

Plant cultivars may have very different behaviour when exposed to the same concentration of ozone, differing in their capability to face high intracellular content of ROS.

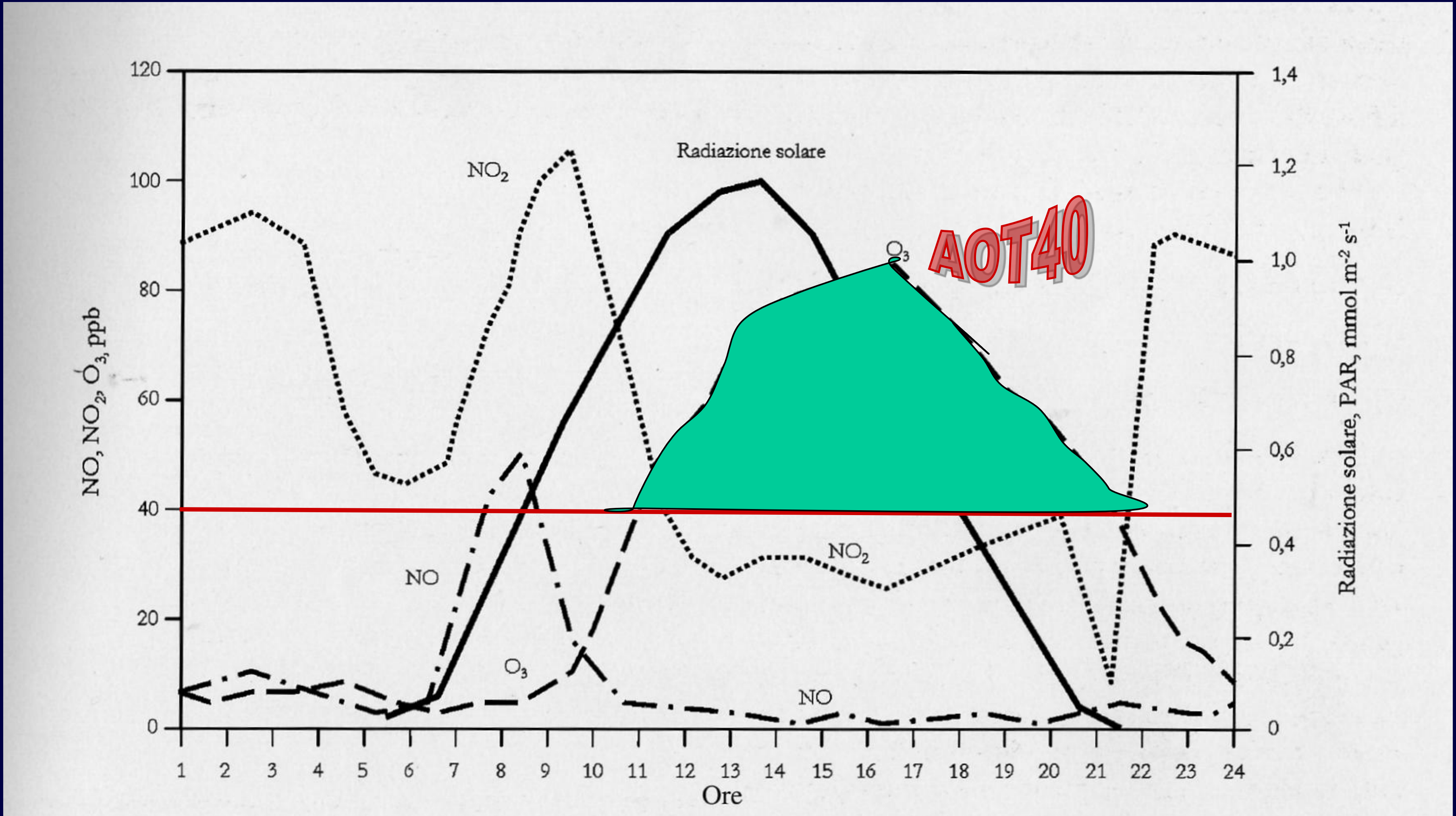
Langebartels *et al*., 2002. Plant Physiol. Biochem. 40: 567



Stima delle perdite produttive attribuite all'ozono
in California rispetto a un valore di riferimento M7 di 27 ppb

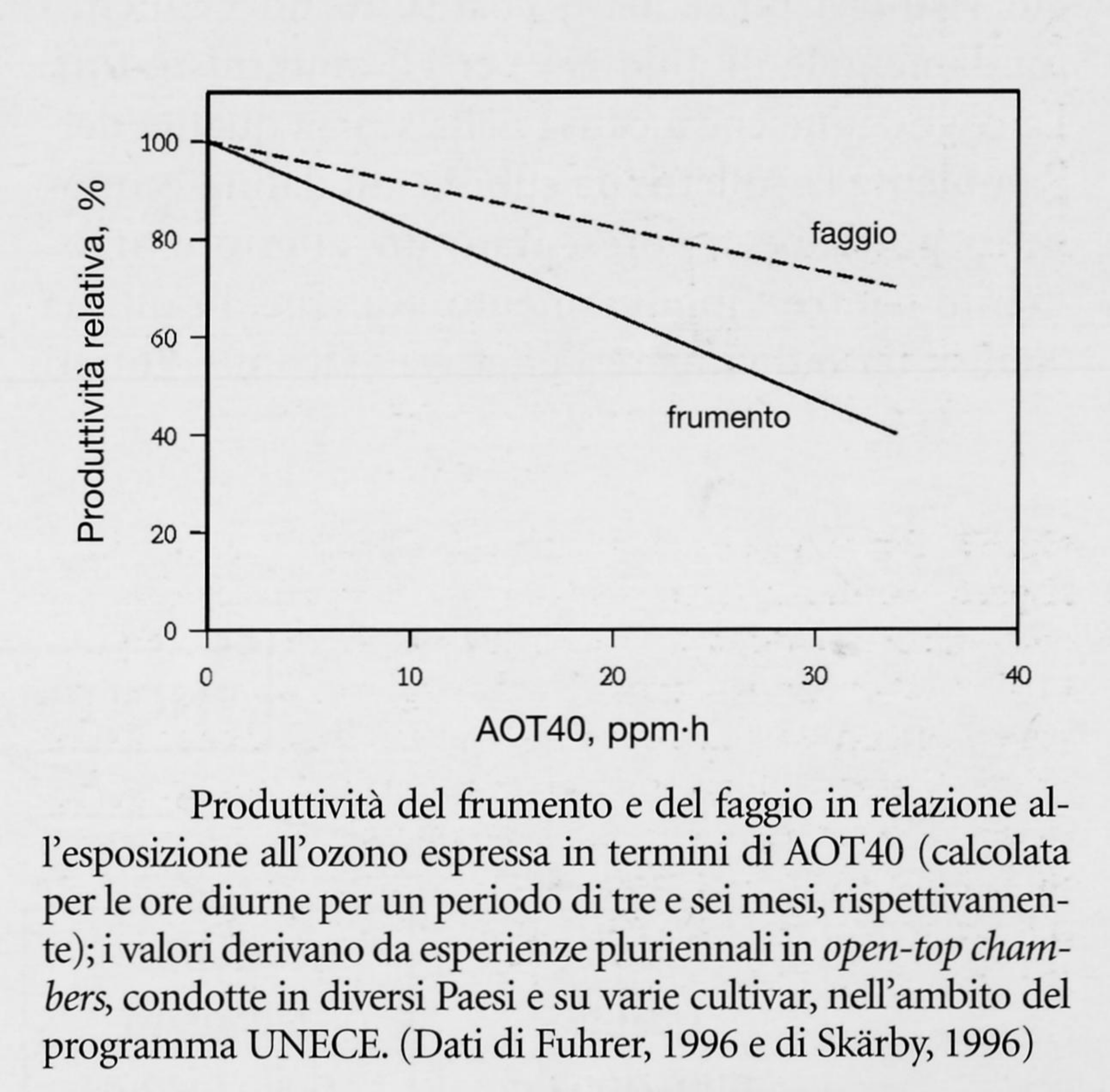
Coltura	**Perdite %**
Cipolla	24,4
Fagiolo	23,5
Vite	22,4
Limone	20,4
Arancio	19,8
Cotone	18,8
Erba medica	8,9
Mais	6,1
Spinacio	3,5

(Dati di Olszyk *et al.*, 1988, relativi al programma NCLAN)

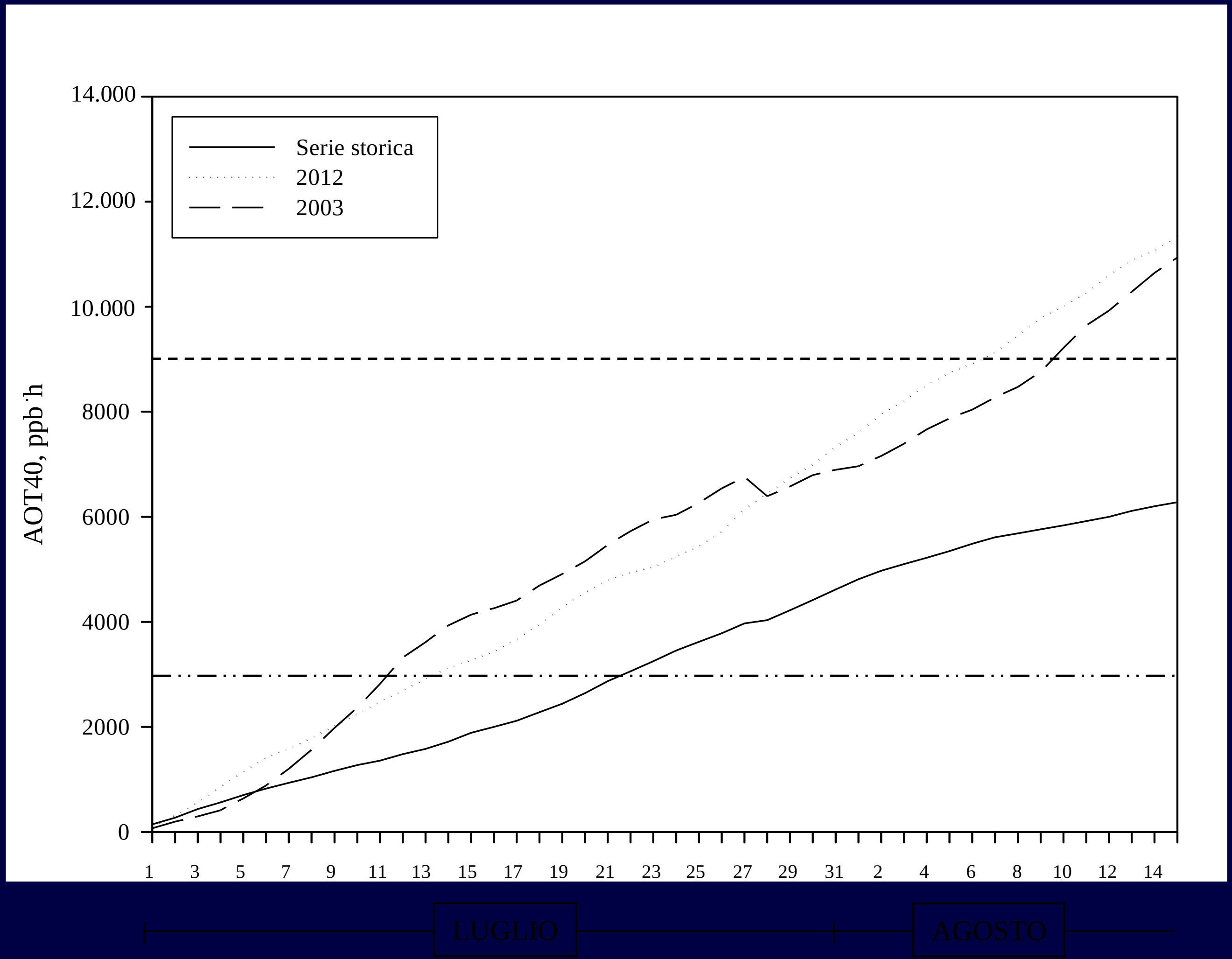


Tipico profilo circadiano, in relazione alla radiazione solare, degli inquinanti ossidanti secondari (ossidi di azoto e ozono) in atmosfera urbana in condizioni di *smog fotochimico*

AOT40 (Accumulated exposure Over a Threshold of 40 ppb) corresponds to the integral of the curve that interpolates concentration values > 40 parts per billion, ppb (=80 µg/m^3) in a certain time interval, using the hourly values recorded daily between 8:00 and 20:00, local time



Produttività del frumento e del faggio in relazione all'esposizione all'ozono espressa in termini di AOT40 (calcolata per le ore diurne per un periodo di tre e sei mesi, rispettivamente); i valori derivano da esperienze pluriennali in *open-top chambers*, condotte in diversi Paesi e su varie cultivar, nell'ambito del programma UNECE. (Dati di Fuhrer, 1996 e di Skärby, 1996)



In summer 2021, the AOT40 (Accumulated exposure Over Threshold of 40 ppb) reached an average of 24,139 ppb h (range 6,718-41,433) (Pisa, Tuscany).

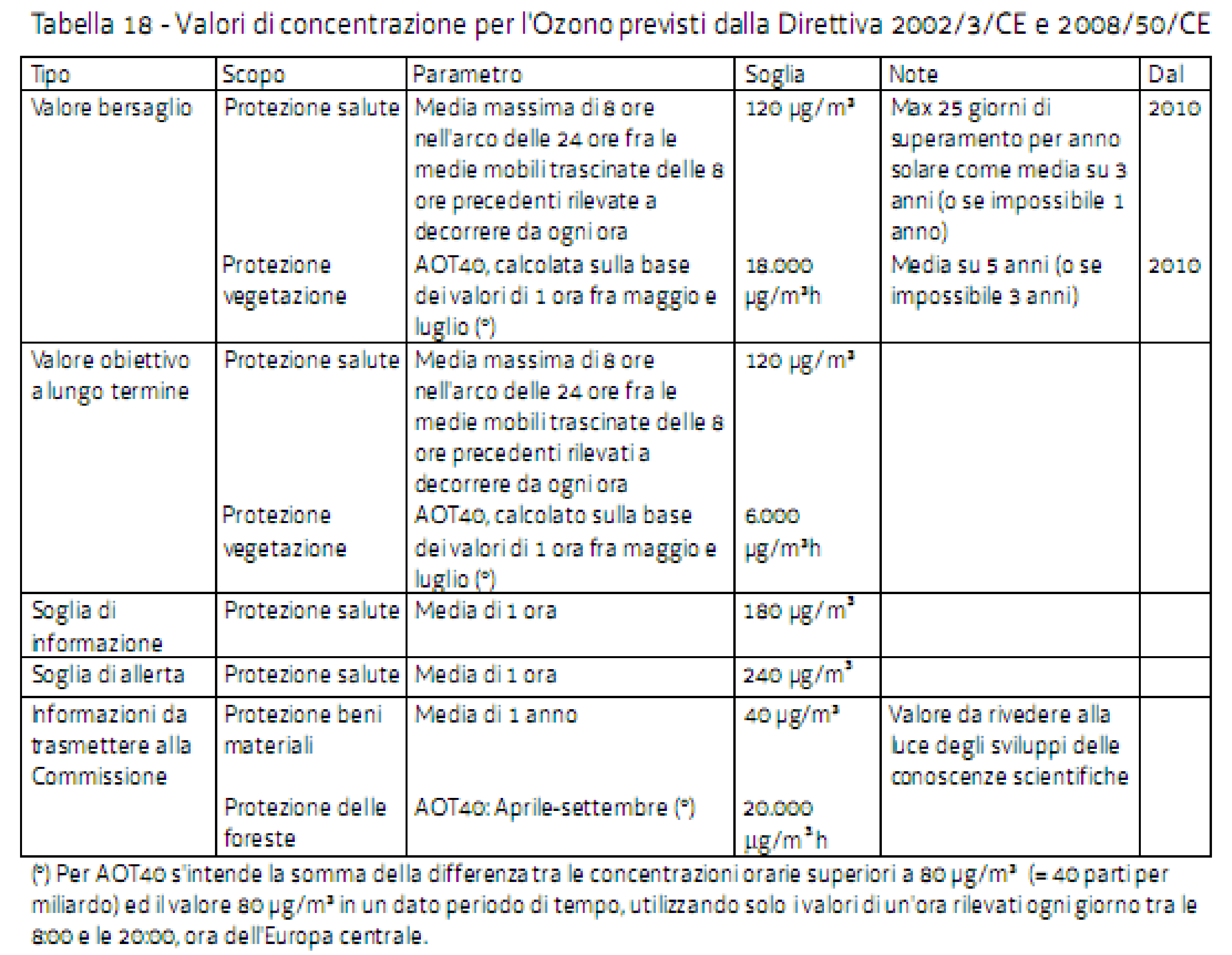


Tabella 18 - Valori di concentrazione per l'Ozono previsti dalla Direttiva 2002/3/CE e 2008/50/CE

Tipo	Scopo	Parametro	Soglia	Note	Dal
Valore bersaglio	Protezione salute	Media massima di 8 ore nell'arco delle 24 ore fra le medie mobili trascinate delle 8 ore precedenti rilevate a decorrere da ogni ora	120 $\mu g/m^3$	Max 25 giorni di superamento per anno solare come media su 3 anni (o se impossibile 1 anno)	2010
	Protezione vegetazione	AOT40, calcolata sulla base dei valori di 1 ora fra maggio e luglio (*)	18.000 $\mu g/m^3h$	Media su 5 anni (o se impossibile 3 anni)	2010
Valore obiettivo a lungo termine	Protezione salute	Media massima di 8 ore nell'arco delle 24 ore fra le medie mobili trascinate delle 8 ore precedenti rilevati a decorrere da ogni ora	120 $\mu g/m^3$		
	Protezione vegetazione	AOT40, calcolato sulla base dei valori di 1 ora fra maggio e luglio (*)	6.000 $\mu g/m^3h$		
Soglia di informazione	Protezione salute	Media di 1 ora	180 $\mu g/m^3$		
Soglia di allerta	Protezione salute	Media di 1 ora	240 $\mu g/m^3$		
Informazioni da trasmettere alla Commissione	Protezione beni materiali	Media di 1 anno	40 $\mu g/m^3$	Valore da rivedere alla luce degli sviluppi delle conoscenze scientifiche	
	Protezione delle foreste	AOT40: Aprile-settembre (*)	20.000 $\mu g/m^3h$		

(*) Per AOT40 s'intende la somma della differenza tra le concentrazioni orarie superiori a 80 $\mu g/m^3$ (= 40 parti per miliardo) ed il valore 80 $\mu g/m^3$ in un dato periodo di tempo, utilizzando solo i valori di un'ora rilevati ogni giorno tra le 8:00 e le 20:00, ora dell'Europa centrale.

Continuous measurements become mandatory in areas and agglomerations in which the long-term objective has been exceeded for at least one of the last five years. The Directive also indicates the criteria for placing the measuring points for ozone (O_3) concentrations. In at least 50% of the points, there must be simultaneous measurement of NO_x. Very often the measuring points coincide with the automated recording gauges of other pollutants. The problem, however, derives from the fact that ozone is a classic secondary pollutant: it is not strictly associated with specific sources, indeed often the most monitored areas (e.g. cities) are those which do not present absolute peaks, because the presence of NO in traces determines its possible consumption, while others where VOCs of natural origin are present can suffer from very high concentrations, but the absence of detection units makes the problem underestimated.

Therefore, peri-urban and remote environments are much more threatened, where the population density is fortunately lower, but unfortunately they are not covered by direct chemical-physical measurements.

De facto, also in the case of ozone our territory is covered by virtual data, based on models that use a few measuring points, many imaginific data (e.g. those of VOC), and more robust meteorological data, such as temperatures and UV radiation …

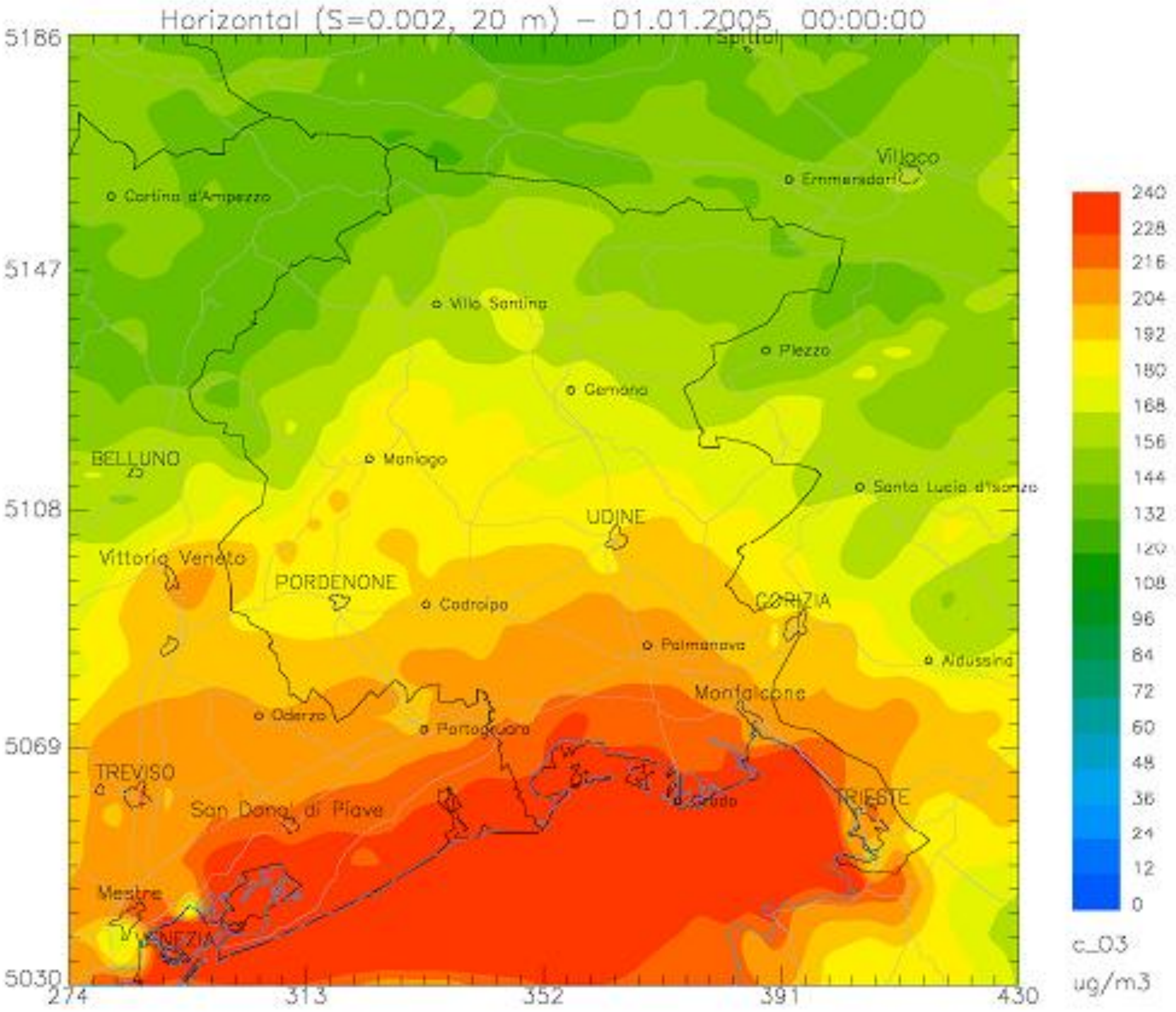
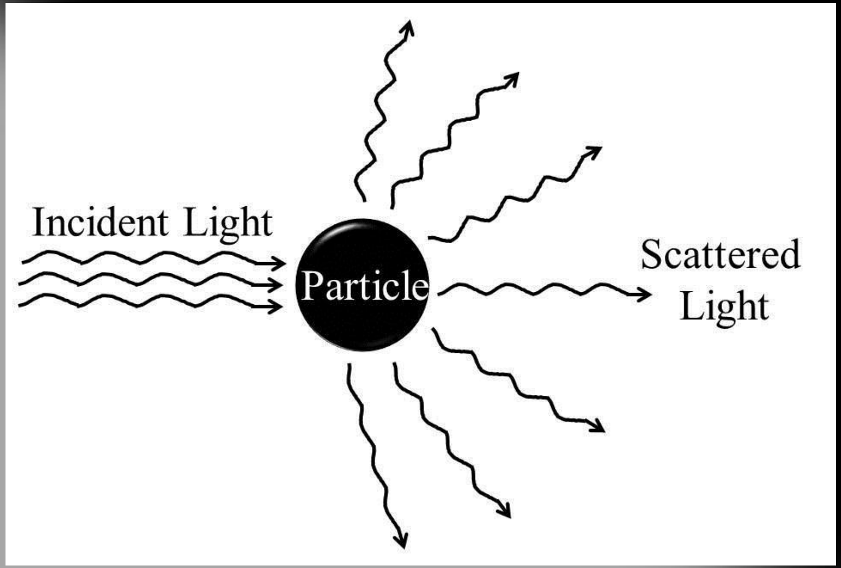


Figura 67: Distribuzione spaziale dei massimi annuali della concentrazione di ozono. L'inventario delle emissioni regionali e la meteorologia di riferimento sono relativi all'anno 2005.

PARTICULATE MATTER, PM



PARTICULATE MATTER – AEROSOL

Particolate matter, **suspended particolate sospeso**, **dust**, **total suspended matter (TSM),** are terms identifying the heterogeneous group of solid or liquid substances suspended in air. They consist in fibers, carbon particles, minerals, liquid and solid pollutants, and an important fraction is given by biological materials of different origin, from spores and pollen grains to fragments of cuticle or tissue.

In general, the smaller and lighter a particle is, the longer it will stay in the air.

- Larger particles (greater than 10 µm in diameter) tend to settle to the ground by gravity in a matter of hours.

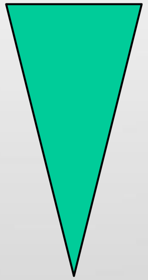
- Particles of 10 µm have a half-life of c. 1 week.

- The smallest particles (less than 1 micrometer) can stay in the atmosphere for weeks and are removed by precipitation.

Important: in a single rain event, the rain of the first minutes is always more «dirty» than at the end…

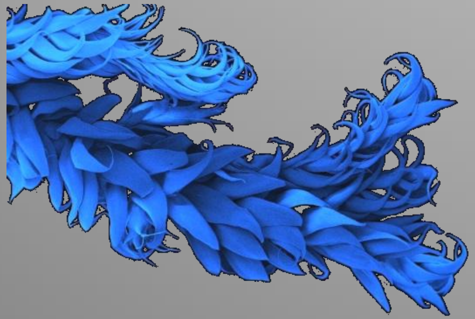
In the raindrops, some particles can dissolve, more or less readily, in function of:

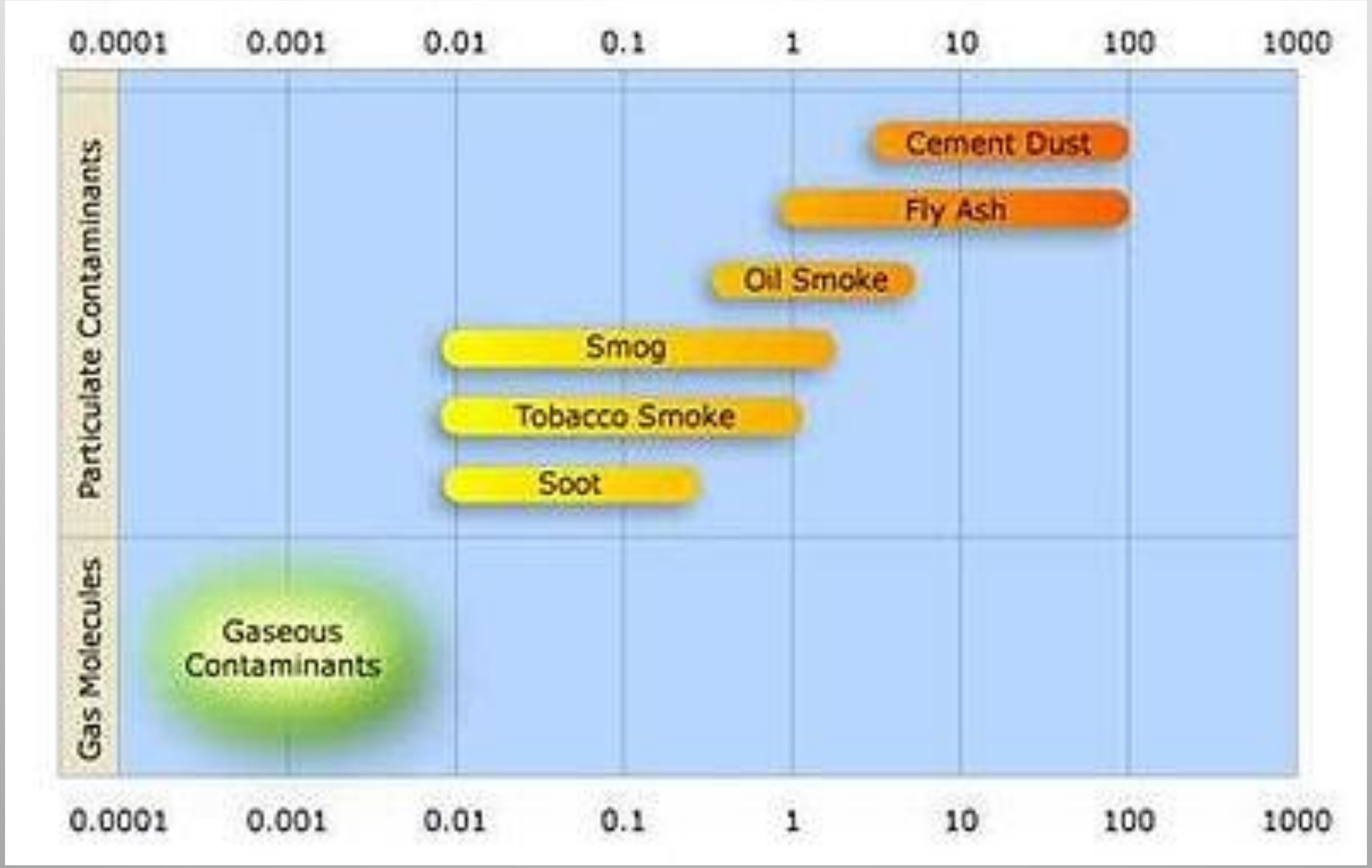
- their chemical nature;
- pH of the rain;
- air temperature.



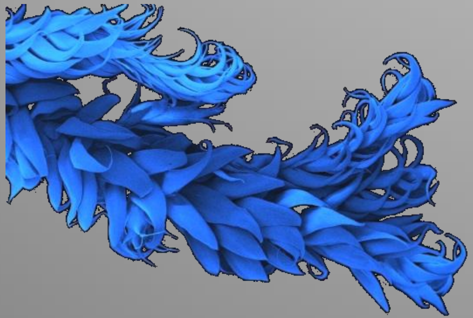
The raindrops can thus be enriched in specific ions and hydrophilic substances.

Hydrophobic substances are eventually limited to the surface of the raindrops or remain entrapped in the particulate matter transported by the raindrops.

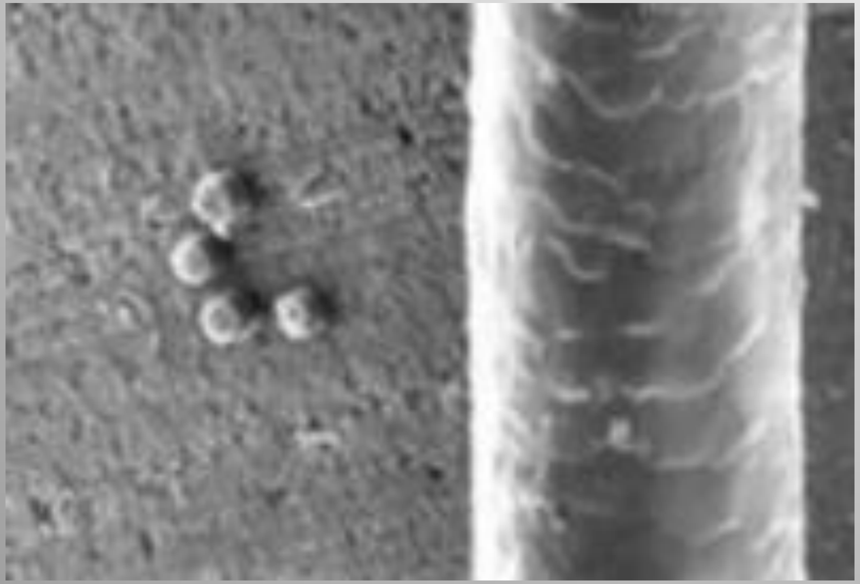



0.0001
0.001
0.01
0.1
1
10
100
1000
Particulate Contaminants
Cement Dust
Fly Ash
Oil Smoke
Smog
Tobacco Smoke
Soot
Gas Molecules
Gaseous Contaminants
0.0001
0.001
0.01
0.1
1
10
100
1000

µm



EQUIVALENT AERODYNAMIC DIAMETER



All the particles are compared in terms of their Equivalent aerodynamic diameter.

They are grouped together if they have the same aerodynamic behavior (in particular sedimentation speed and ability to diffuse within filters of certain dimensions) of a spherical particle of a certain diameter having unit density (1 g/cm^3) in the same conditions of temperature, pressure and relative humidity.

E.g.: PM10 group together all the particles, (independently from their actual size, mass and composition) which behave aerodynamically as a spherical particle of 10 µm in diameter and unit density

PRIMARY PARTICULATE MATTER

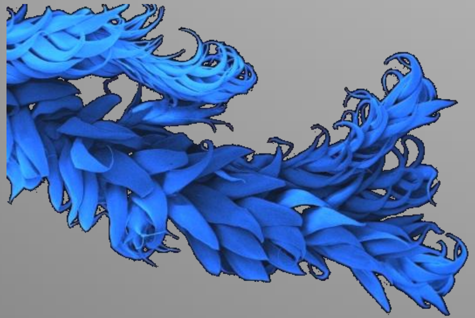
it is directly released in solid and/or liquid form.

SECONDARY PARTICULATE MATTER

It forms in the atmosphere as a result of chemaical-physical transformation of other compounds:

- oxidized compounds of primary gases - SO_x and NO_x are oxidized to the correponding strong acids, H_2SO_4 and HNO_3, with highly reactivity towards mineral compounds.

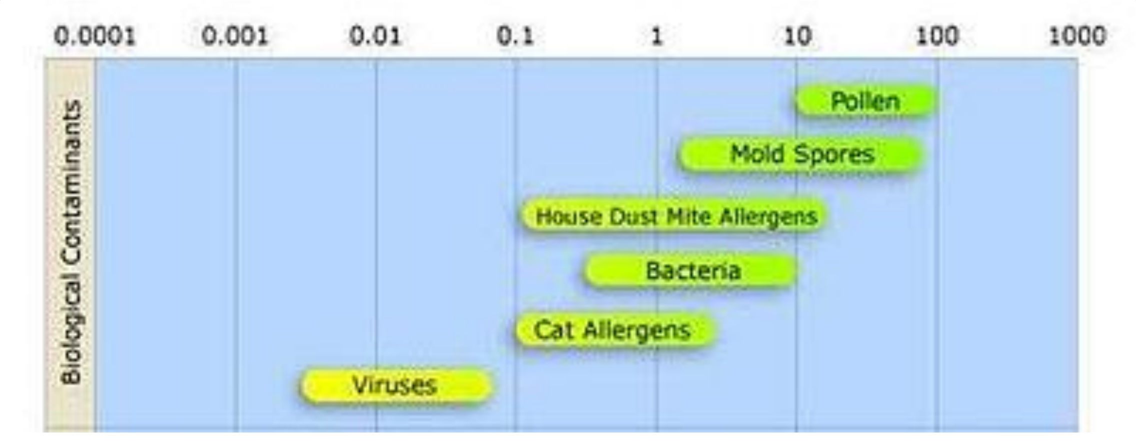
- oxidized organic matter – volatile organic compounds (VOC) are easily oxidized in the athmosphere, and modified.



Sources of atmospheric particulate matter

NATURAL SOURCES – A large fraction (c. 90%) of particulates circulating into the atmosphere is of natural origin, deriving from volcanoes, dust storms, forest and grassland fires, living vegetation, sea spray and soil erosion.

LIVING VEGETATION – es. spores, pollen grains, fragments derived from wind abrasion of the enormous surface formed by the forest canopies, released organic substances.



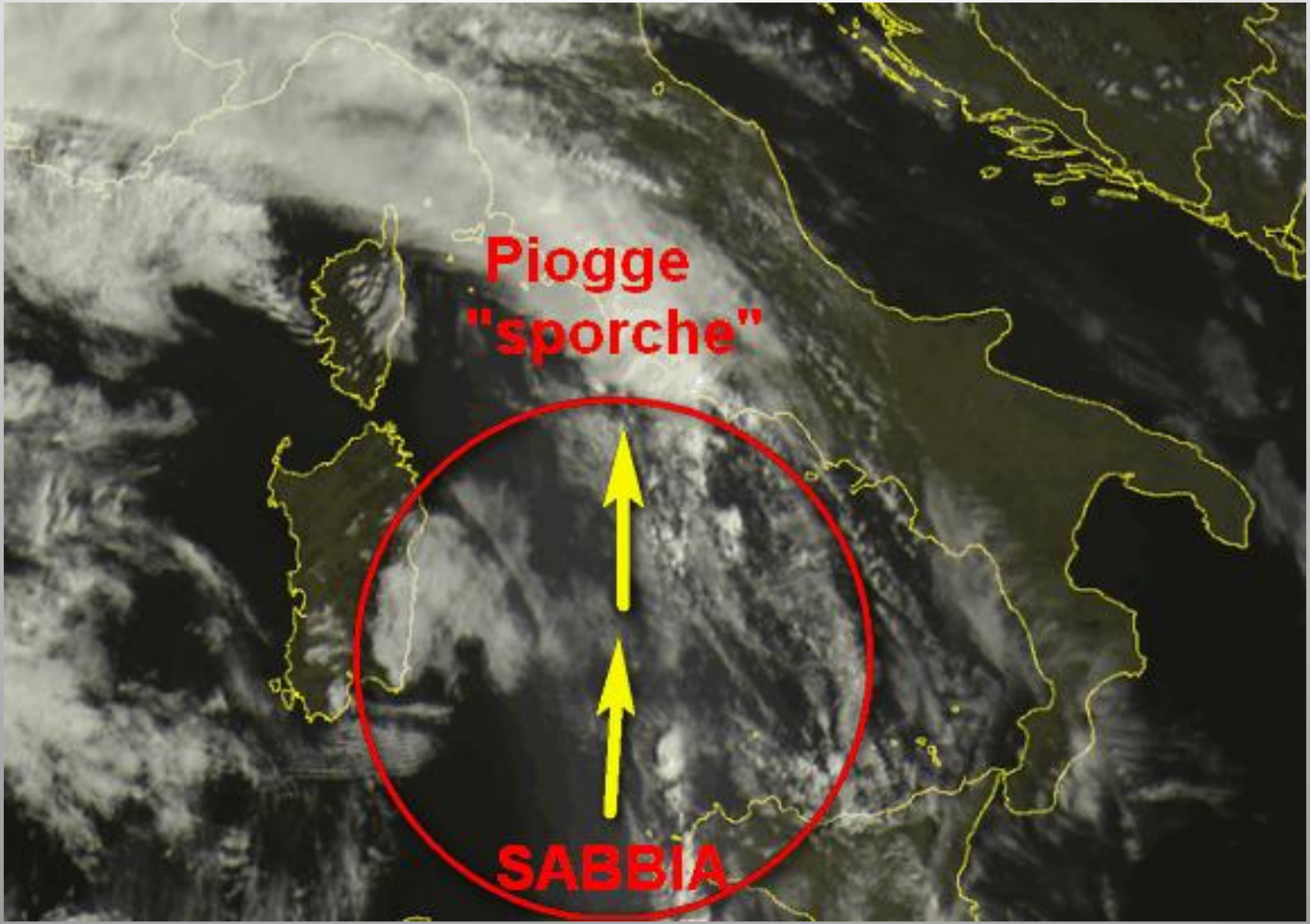
SALT SPRAY from the oceans is the overwhelmingly most common form of particulate in the atmosphere. Consisting of NaCl, it can also contains Mg, S, Ca, K, I, and organic compounds (es. sulphur-compounds derived from the realese of phytoplankton). It derives from the sea spray vaporized by the wild. The sea aerosol does not absorb sun light.

SOIL EROSION

SOIL EROSION

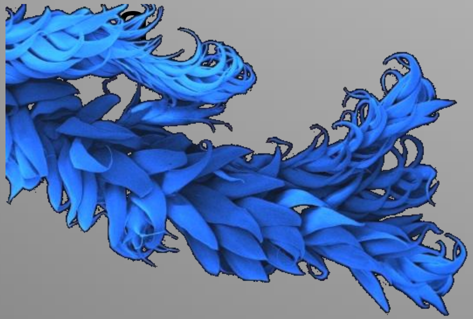
A recent study published in the Geophysical Research Letters analysed the data provided by the NASA Calypso probe. For the first time, the 'cloud' of dust and sand that migrates from Africa to South America every year has been quantified and mapped in three dimensions.

Every year the winds and therefore the high-altitude currents tear 182 million tons of sand and dust from Sahara, the largest desert in the world: 27 million of them, every year, are deposited in the Amazon basin. Saharan dust is rich in phosphorus, an essential nutrient for plants. The supply from the Sahara helps the rainforest to supplement the phosphorus that is lost and not absorbed due to torrential rains.


Piogge
"sporche"
SABBIA

Atmospheric aerosols originating from the suspension of minerals constituting the soil and therefore deriving from the earth's crust, are often mineral oxides, carbonates, sulphates and silicates (MINERAL POWDERS).

These dusts absorb sunlight and therefore also play an important role in climate change.



The plant cover strongly contains the wind erosion of the substrates: its removal determines a strong erosive risk. Our agriculture should consider this…

Anthropogenic aerosols — those made by human activities — currently account for about **10 percent** of the total mass of aerosols in our atmosphere.

ANTHROPOGENIC SOURCES are:

- the burning processes (e.g. fossil fuels in vehicles, power plants, blast furnaces; domestic heating);
- wear and tear of mechanisms in movement;
- various industrial processes, such as cement production, mining, agricultural work;
- Resuspension of dust particles due to vehicle traffic.

Anthropic sources in FVG: Some estimates

Vehicular traffic: **28%**;
Industry: **12,4%** (combustion) + **6,4%** (other processes);
Domestic heating: **44,5%**;
Sea and air transport: **4%**
Agricolture, from nitrogen fertilizers (NH_3, N_2O, NO_X): **2%**;
Energy production: **3%**.

These percentages are based on regional data collected in 2005.

The particulate matter of anthropic origin is characterized by heterogeneous but particular compositions.

Thus what derives from mechanical wear phenomena will reflect the special composition of the materials that have worn out, for example:

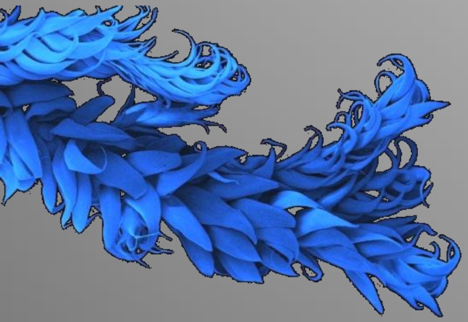
- the styrene-butadiene copolymer of our tires;
- the bituminous conglomerate of the asphalt of our roads;
- special alloys "doped" with hard steels for moving mechanisms;
- the brake pads of our cars.

The particles from combustion processes will be composed of both combusted derivatives and unburned fractions, and will be particularly rich in Polycyclic Aromatic Hydrocarbons (PAHs) and classes of similar organic compounds (e.g. chlorinated molecules due to the presence of Cl in combustibles when not in the combustion air).

Particulate matter emissions are highly regulated in most industrialized countries.

Due to environmental concerns, most industries are required to operate some kind of dust collection system to control particulate emissions.

These systems include inertial collectors (cyclone collectors), fabric filter collectors (bag-houses), wet scrubbers, and electrostatic precipitators.



PM effects from the Earth’s point of view

Atmospheric aerosols affect the climate of the Earth by changing the amount of incoming solar radiation and outgoing terrestrial long wave radiation retained in the Earth's system.

The aerosol climate effects are the biggest source of uncertainty in future climate predictions.

The Intergovernmental Panel on Climate Change, Third Assessment Report, says: *While the radiative forcing due to greenhouses gases may be determined to a reasonably high degree of accuracy... the uncertainties relating to aerosol radiative forcings remain large, and rely to a large extent on the estimates from global modelling studies that are difficult to verify at the present time*.

Effects on the human health

Increased levels of fine particles in the air as a result of *anthropogenic* particulate air pollution «*is consistently and independently related to the most serious effects for human health*».

The large number of deaths and other health problems associated with particulate pollution was first demonstrated in the early 1970s and has been reproduced many times since.

The effects of inhaling particulate matter that have been widely studied in humans and animals now include asthma, lung cancer, cardiovascular issues, respiratory diseases, birth defects, and premature death.

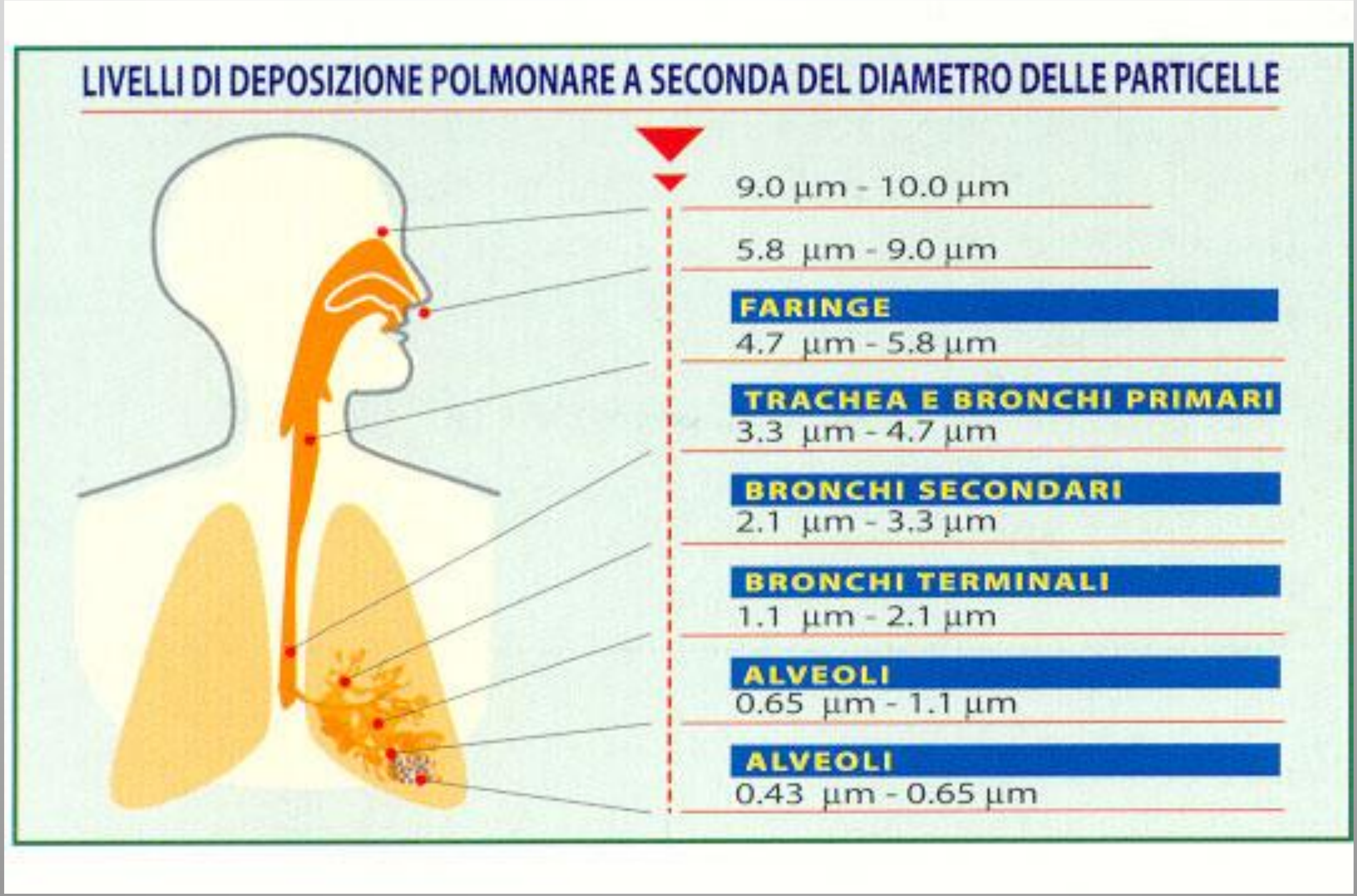
PM pollution is estimated to cause 22,000-52,000 deaths per year in the United States (from 2000) and 200,000 deaths per year in Europe.

The size of the particle is a main determinant of where in the respiratory tract the particle will come to rest when inhaled.

Larger particles are generally filtered in the nose and throat via cilia and mucus, but particulate matter smaller than about 10 micrometers, referred to as PM_{10}, can penetrate the deepest part of the lungs such as the bronchioles or alveoli, causing health problems.

The 10 micrometer size does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies.

Similarly, particles smaller than 2.5 micrometers, *PM2.5*, tend to penetrate into the gas exchange regions of the lung, and very small particles (< 100 nanometers) may pass through the lungs to affect other organs.



LIVELLI DI DEPOSIZIONE POLMONARE A SECONDA DEL DIAMETRO DELLE PARTICELLE

9.0 µm - 10.0 µm

5.8 µm - 9.0 µm

FARINGE

4.7 µm - 5.8 µm

TRACHEA E BRONCHI PRIMARI

3.3 µm - 4.7 µm

BRONCHI SECONDARI

2.1 µm - 3.3 µm

BRONCHI TERMINALI

1.1 µm - 2.1 µm

ALVEOLI

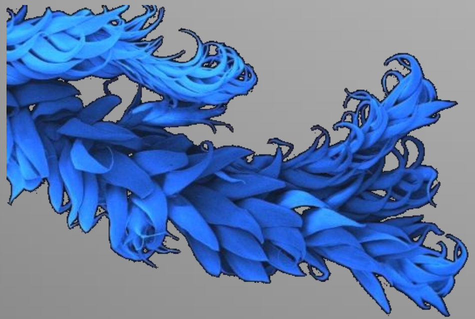
0.65 µm - 1.1 µm

ALVEOLI

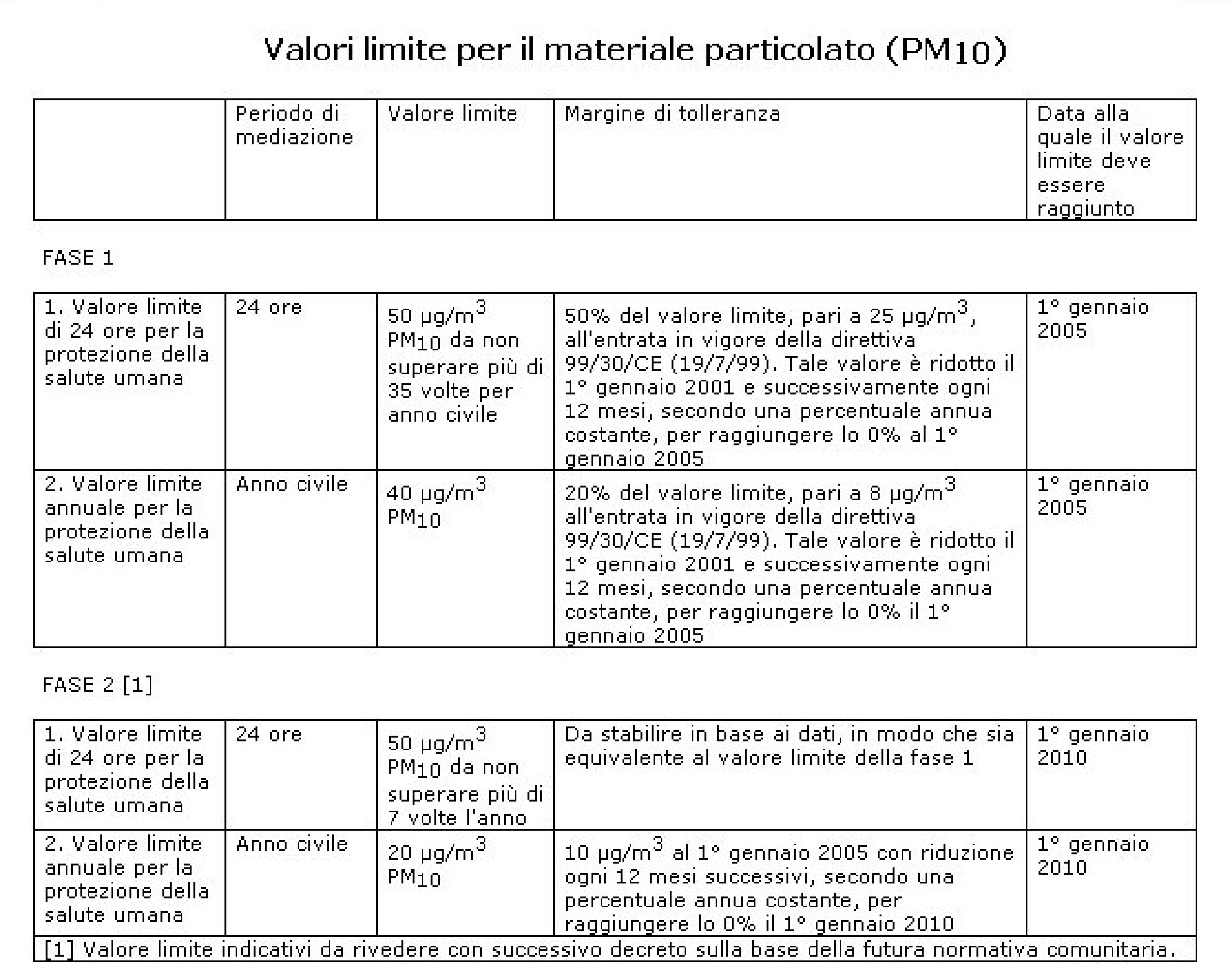
0.43 µm - 0.65 µm

The composition of the particles has rarely been studied in detail, due to the scarcity of information. Intuitively, a K silicate grain is less dangerous than a Cd containing fine particle, but the coat formed by condensed substances on the surface of the particle may be detrimental.

Any information regarding DPM and the atmosphere, flora, height, and distance from major sources would be useful to determine health effects.



Dir. 1999/30/CE; D.M. 2-4-2002 n. 60



Valori limite per il materiale particolato (PM_{10})

	Periodo di mediazione	Valore limite	Margine di tolleranza	Data alla quale il valore limite deve essere raggiunto
FASE 1				
1. Valore limite di 24 ore per la protezione della salute umana	24 ore	50 $\mu g/m^3$ PM_{10} da non superare più di 35 volte per anno civile	50% del valore limite, pari a 25 $\mu g/m^3$, all'entrata in vigore della direttiva 99/30/CE (19/7/99). Tale valore è ridotto il 1° gennaio 2001 e successivamente ogni 12 mesi, secondo una percentuale annua costante, per raggiungere lo 0% al 1° gennaio 2005	1° gennaio 2005
2. Valore limite annuale per la protezione della salute umana	Anno civile	40 $\mu g/m^3$ PM_{10}	20% del valore limite, pari a 8 $\mu g/m^3$ all'entrata in vigore della direttiva 99/30/CE (19/7/99). Tale valore è ridotto il 1° gennaio 2001 e successivamente ogni 12 mesi, secondo una percentuale annua costante, per raggiungere lo 0% il 1° gennaio 2005	1° gennaio 2005
FASE 2 [1]				
1. Valore limite di 24 ore per la protezione della salute umana	24 ore	50 $\mu g/m^3$ PM_{10} da non superare più di 7 volte l'anno	Da stabilire in base ai dati, in modo che sia equivalente al valore limite della fase 1	1° gennaio 2010
2. Valore limite annuale per la protezione della salute umana	Anno civile	20 $\mu g/m^3$ PM_{10}	10 $\mu g/m^3$ al 1° gennaio 2005 con riduzione ogni 12 mesi successivi, secondo una percentuale annua costante, per raggiungere lo 0% il 1° gennaio 2010	1° gennaio 2010

[1] Valore limite indicativi da rivedere con successivo decreto sulla base della futura normativa comunitaria.

Monitoraggio

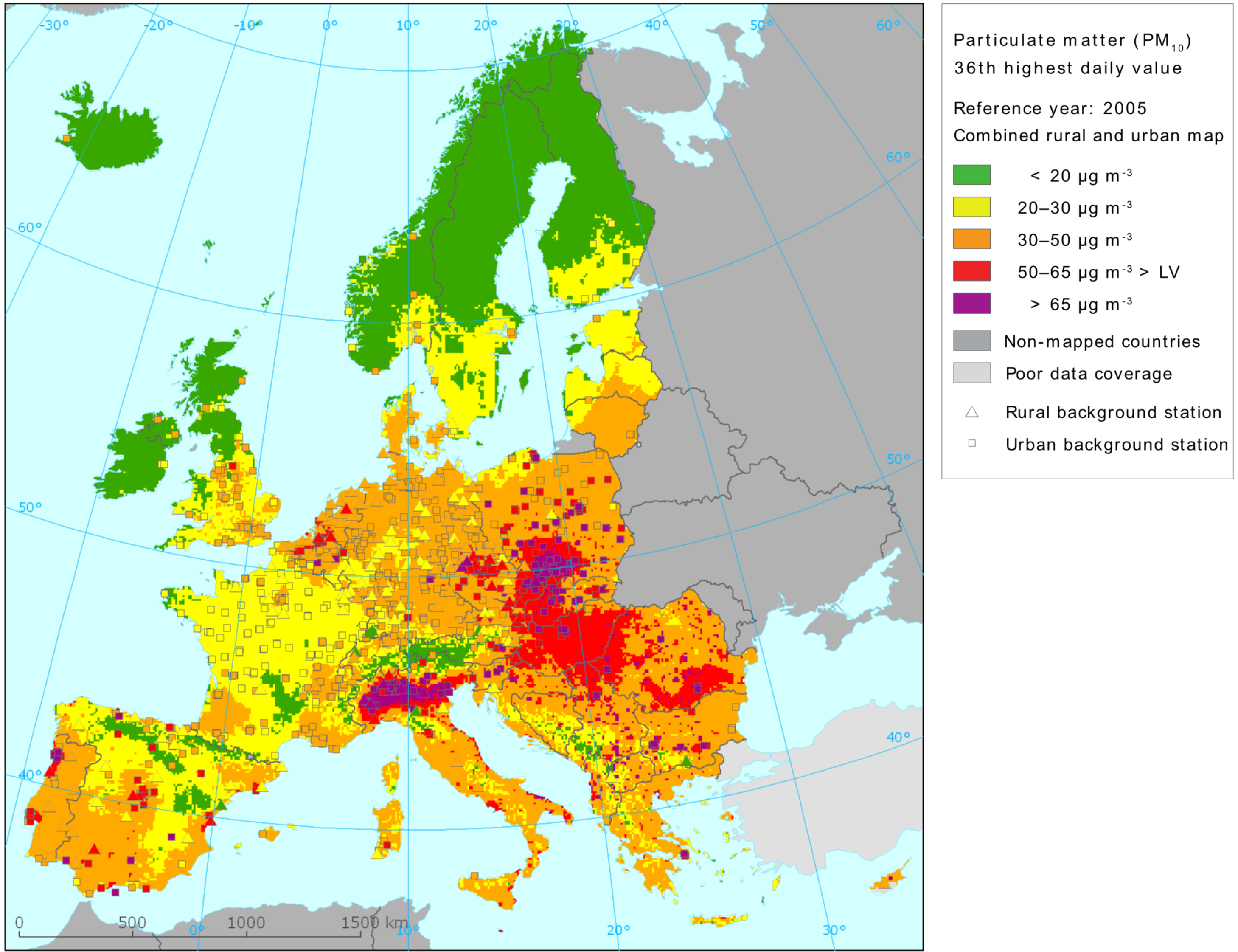
Tabella 13 - Valori di concentrazione del particolato sospeso con diametro inferiore a 10 micron previsti dalla Direttiva 2008/50/CE

Tipo	Scopo	Parametro	Soglia	Note	Dal
Valore limite (v.l.)	Protezione salute	Media giornaliera	$50\ \mu g/m^3$	Max 35 super. anno	
	Protezione salute	Media annuale	$40\ \mu g/m^3$		
Soglia di valutazione superiore	Protezione salute	Media giornaliera	$35\ \mu g/m^3$ (70% del v.l.)	Max 35 super. anno	
	Protezione salute	Media annuale	28 µg/m3 (70% del v.l.)		
Soglia di valutazione inferiore	Protezione salute	Media giornaliera	$25\ \mu g/m^3$ (50% del v.l.)	Max 35 super. anno	
	Protezione salute	Media annuale	$20\ \mu g/m^3$ (50% del v.l.)		

Level below which measurements can be combined with modeling techniques.

Level below which it is possible to use only modeling or objective estimation techniques.

Anthropogenic sources may generate quite different aerosols also in terms of element composition.



http://www.eea.europa.eu/publications/spatial-assessment-of-pm10-and-ozone-concentrations-in-europe-2005-1/at_download/file