

Air Pollution

Part 2

GEOG0170



Air Pollution Lecture 2



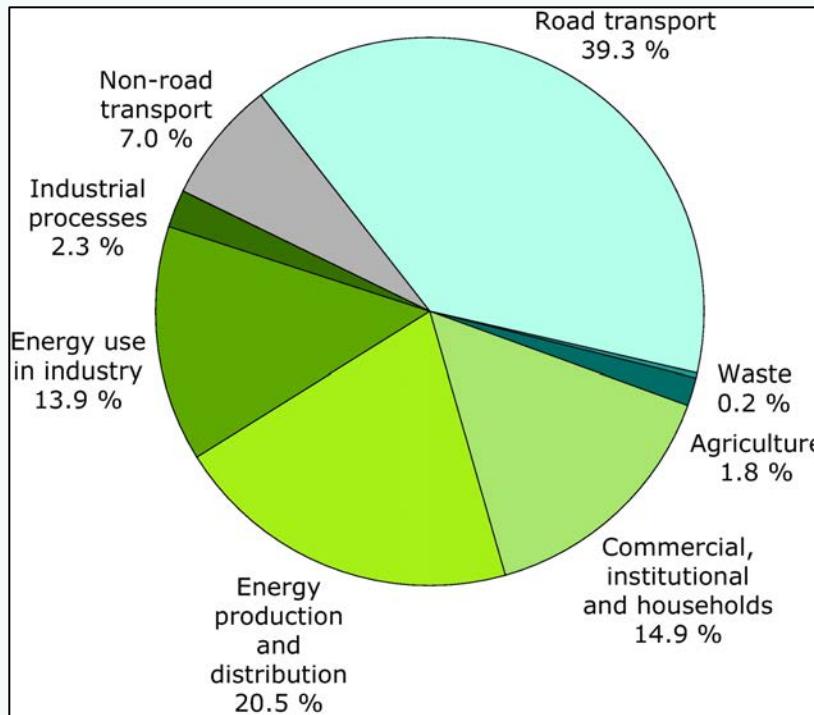
Contents

- Types of air pollution
- Air pollution and weather / meteorology / climate change
- Air pollution impacts
- Air quality policy control measures

Types of Air Pollutants

Nitrogen dioxide (NO_2)

NO_x emissions sources in Europe

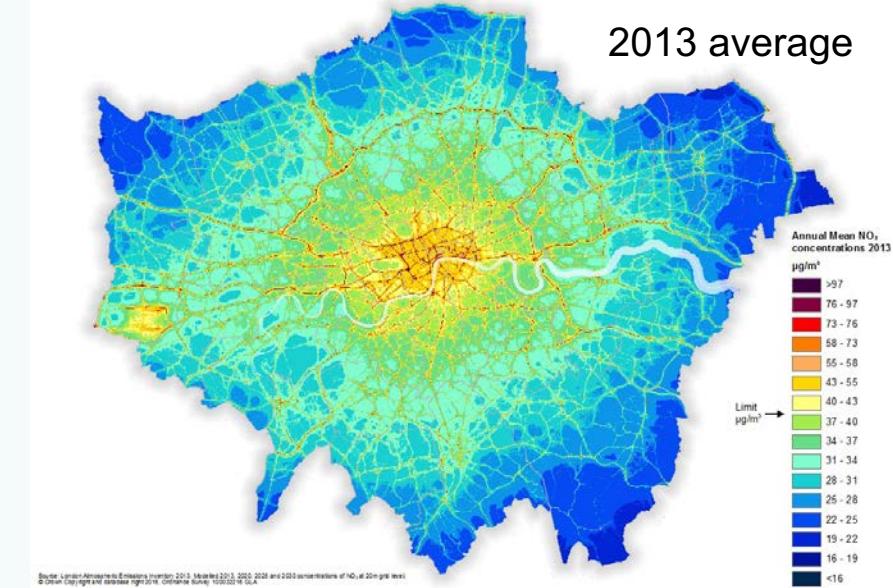


Mostly thermal: conversion of N_2 to NO

Most anthropogenic NO_x emitted as NO

Rapid cycling between NO and NO_2

NO_2 concentrations in London



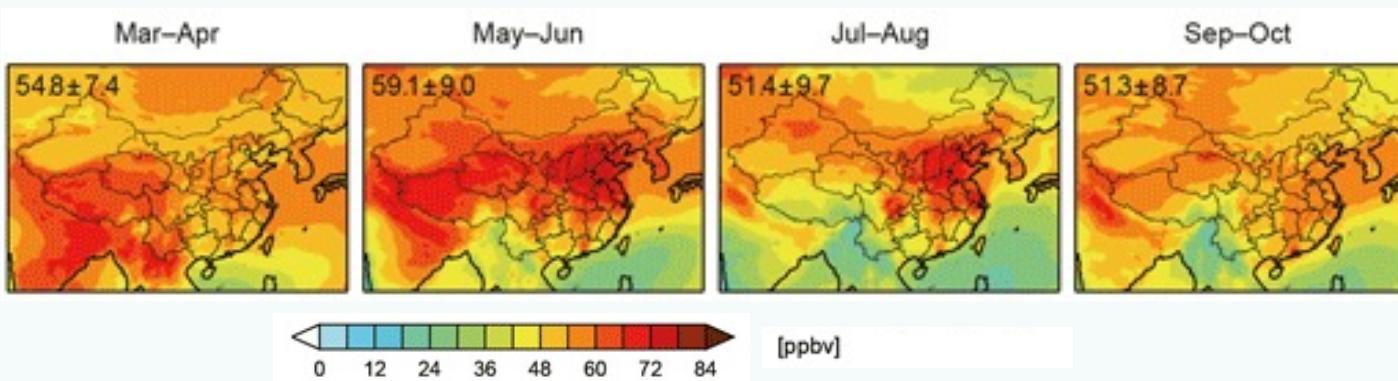
Types of Air Pollutants

Surface ozone (O_3)

Ozone is a secondary pollutant

Requires: Sunlight (photolysis),
 NO_x and either CO or a volatile
organic compound (VOC)

Removal: Dominated by dry
deposition onto vegetation

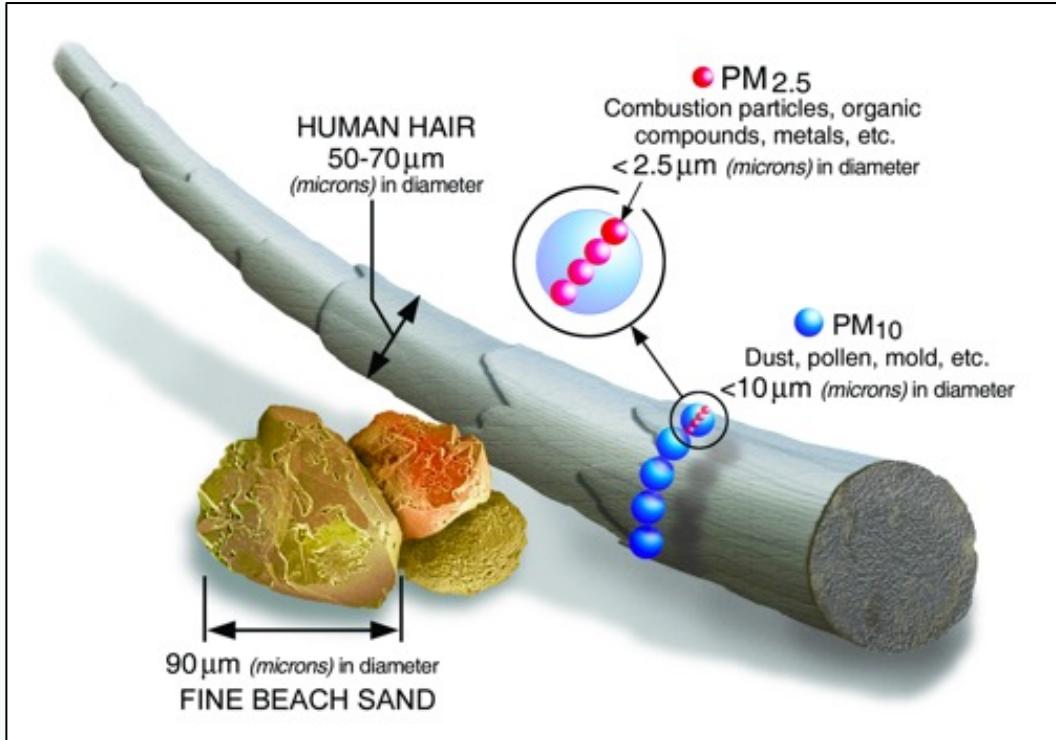


Normally a
seasonal
(spring-summer)
problem

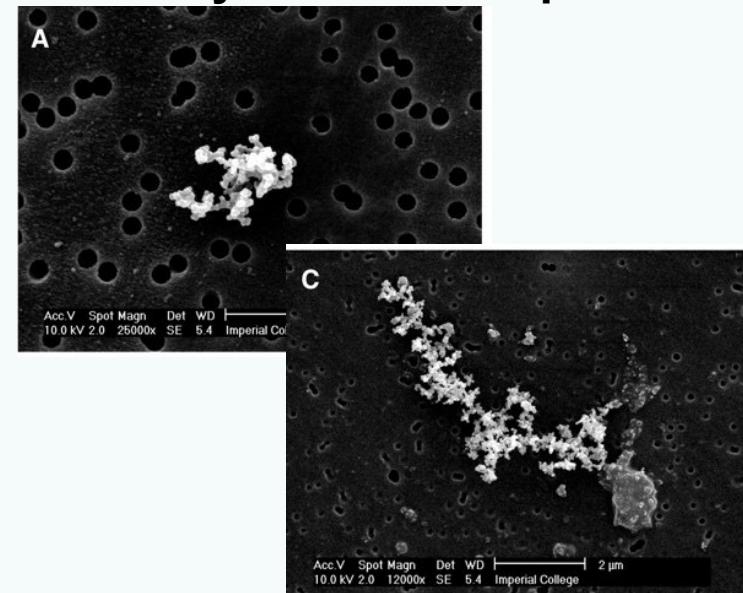
Types of Air Pollutants

Fine particles (PM_{2.5})

Particles suspended in the atmosphere with an aerodynamic diameter < 2.5 microns



Many different shapes

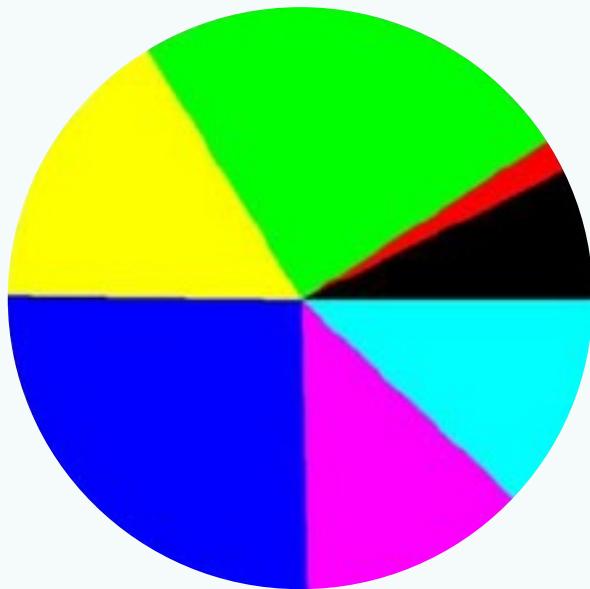


Types of Air Pollutants

Fine particles (PM_{2.5})

Mixtures of primary and secondary chemicals

Pie chart of relative mass contribution of individual components

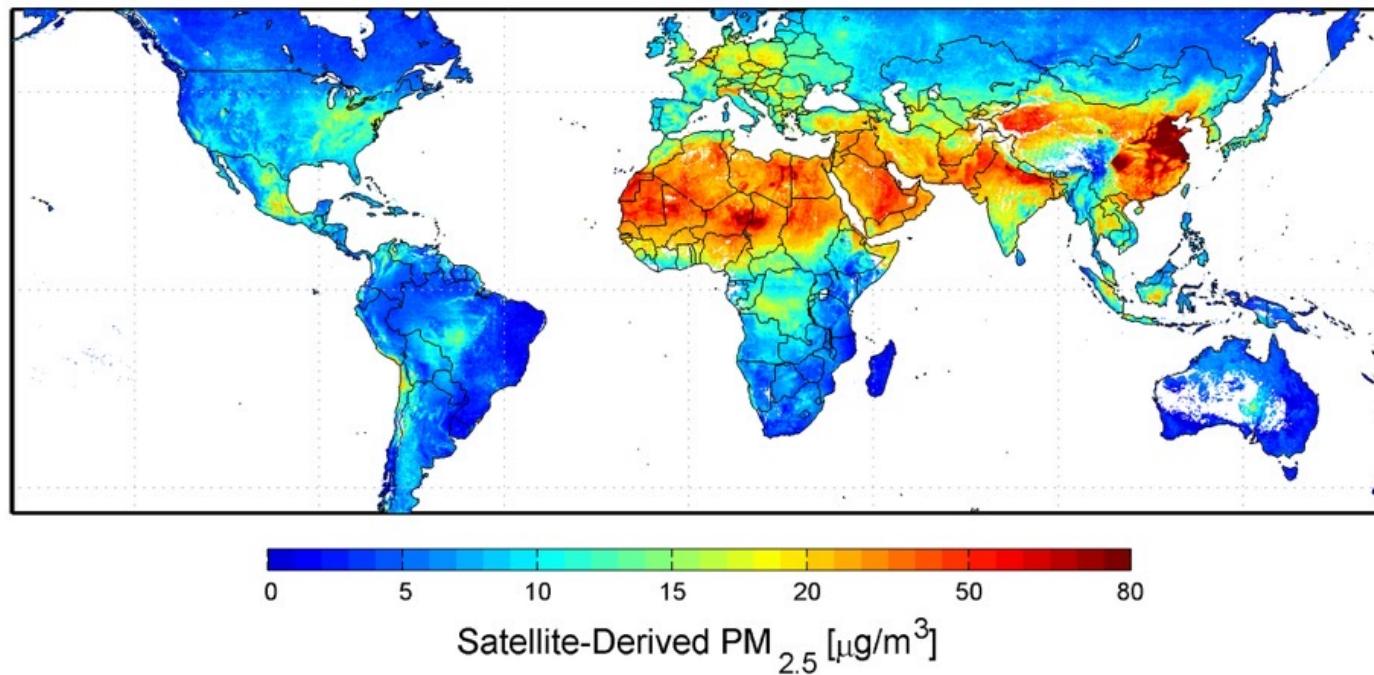


Black carbon	primary
Sulfate	
Nitrate	
Ammonium	
Other inorganics	primary
Organic aerosols	primary+secondary
Dust	primary

Types of Air Pollutants

Fine particles (PM_{2.5})

Global distribution of annual average PM_{2.5}



Source: van Donkelaar et al., EHP [2010]

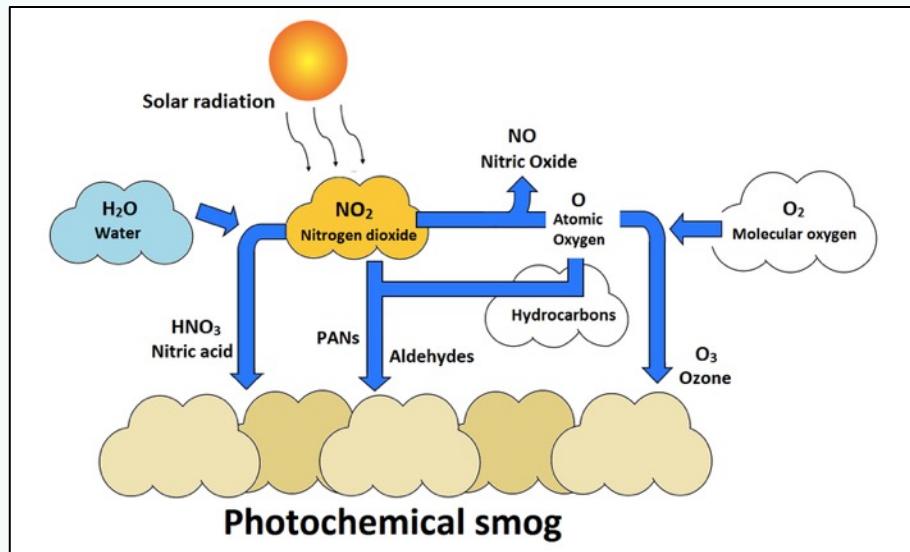
Smog

Hazy pollution layer of high levels of very reactive pollutants

Cause: Photochemical reactions of very large sources of VOCs, NO_x , SO_2 .

Impacts: health, visibility, infrastructure (buildings), ecosystems (acid rain)

London Smog



PAN: peroxyacetyl nitrate; **aldehydes:** VOCs

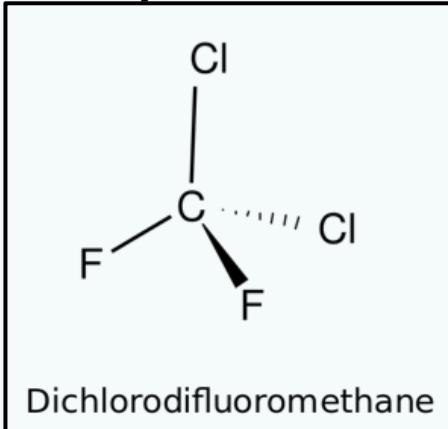
Types of Air Pollutants

Ozone depleting substances (ODS)

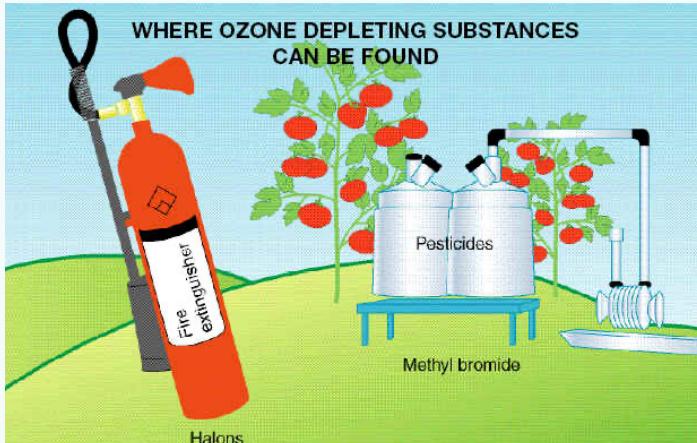
Effect: Long-lived gases that deplete ozone in the stratosphere (10-50 km)

Sources: fridges, air conditioners, spray cans, insulation material

Example of an ODS



Cl: chlorine
F: fluorine



Types of Air Pollutants

Persistent Organic Pollutants (POPs)

Long-lived organic compounds

Transported long distances

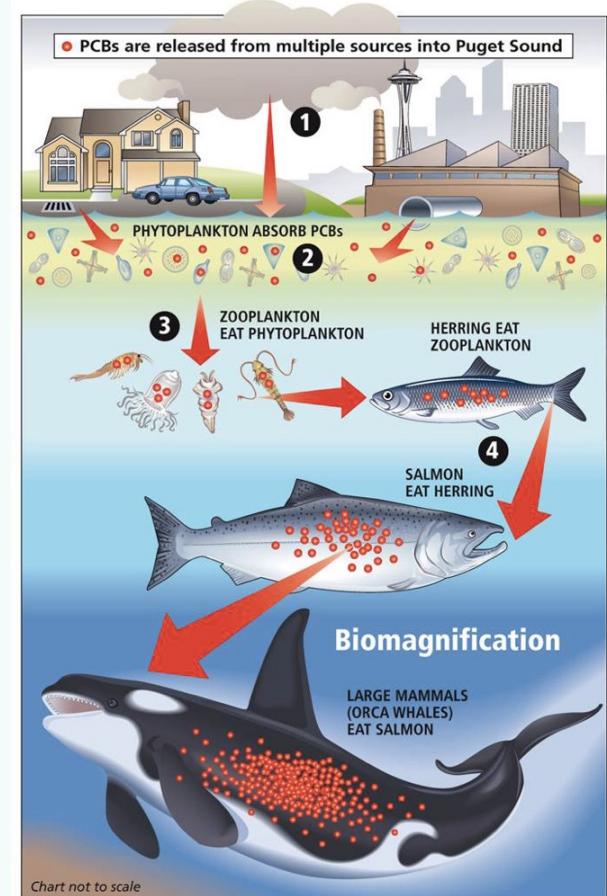
Bioaccumulate / biomagnify

Sources: industry, wood burning, wildfires, pesticides, pharmaceuticals

Kinds:

Polychlorinated biphenyls (PCBs) Polycyclic aromatic hydrocarbons (PAHs)

Effects: developmental defects, chronic disease, death, cancer, endocrine disruptors.



Types of Air Pollutants

Heavy Metals

Desirable properties:

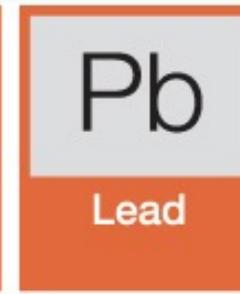
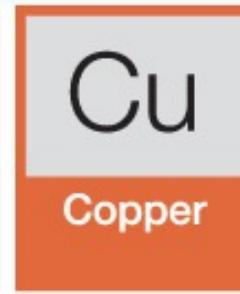
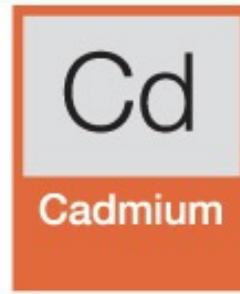
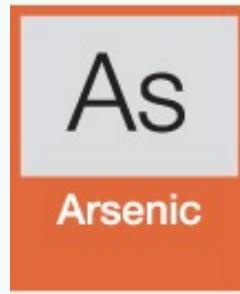
Lustre (shine)

Conduct electricity

Non-degradable

Malleable: reformed into thin sheets

Ductile: drawn into wires



Sources: forestry, mining, fossil fuel combustion, waste incineration, smelting, metallurgical industries

Target vital organs:

As → liver (hepatotoxic)

Hg/Pb → brain (neurotoxic)

Cd → kidney/lungs (nephrotoxic/pulmonotoxic)

Air Pollution and Weather



Clouds affect photolysis

Rain washes the atmosphere

Temperature affects reaction rates and thermally unstable pollutants

Wind speed and direction disperses pollution



Air Pollution and Weather



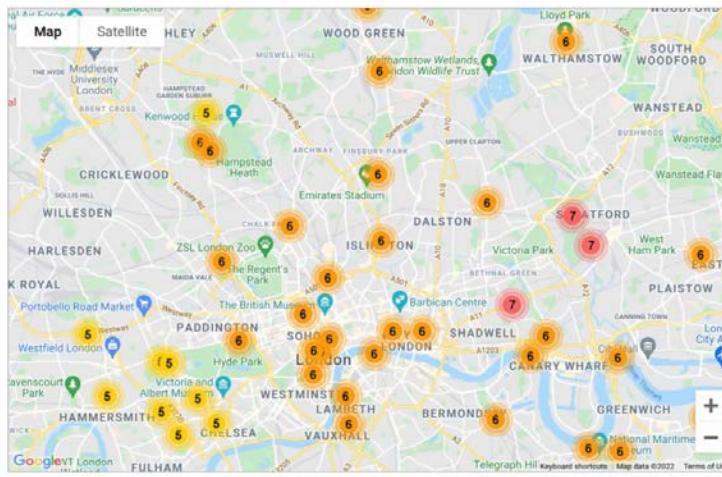
Calm and mild conditions contributed to poor air quality in London last week Friday

Pollution forecast near London

Issued at Thursday (13th January 2022). Provided by the Met Office.

Enter your location or postcode:

Today 11th Jan Wed 12th Jan Thu 13th Jan Fri 14th Jan Sat 15th Jan



<https://uk-air.defra.gov.uk/forecasting/>

Londoners told to reduce physical activity on Friday due to pollution



The Guardian, 13 Jan 2022

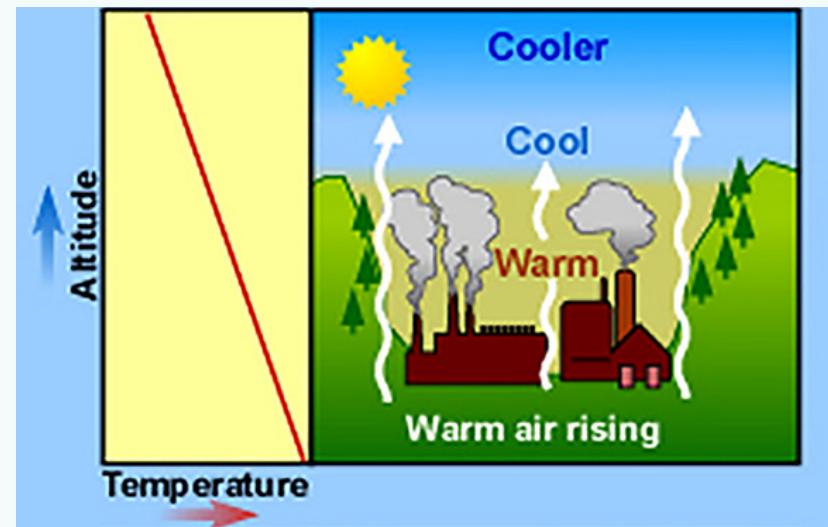
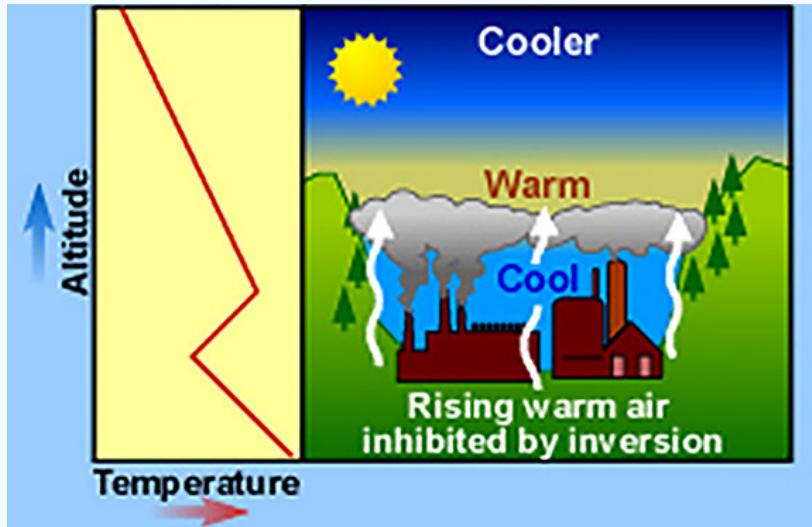


<https://waqi.info/>

Air Pollution and Meteorology



Temperature Inversion



Stable conditions, prevents mixing, promotes accumulation of pollution

Occurs over cities in valleys

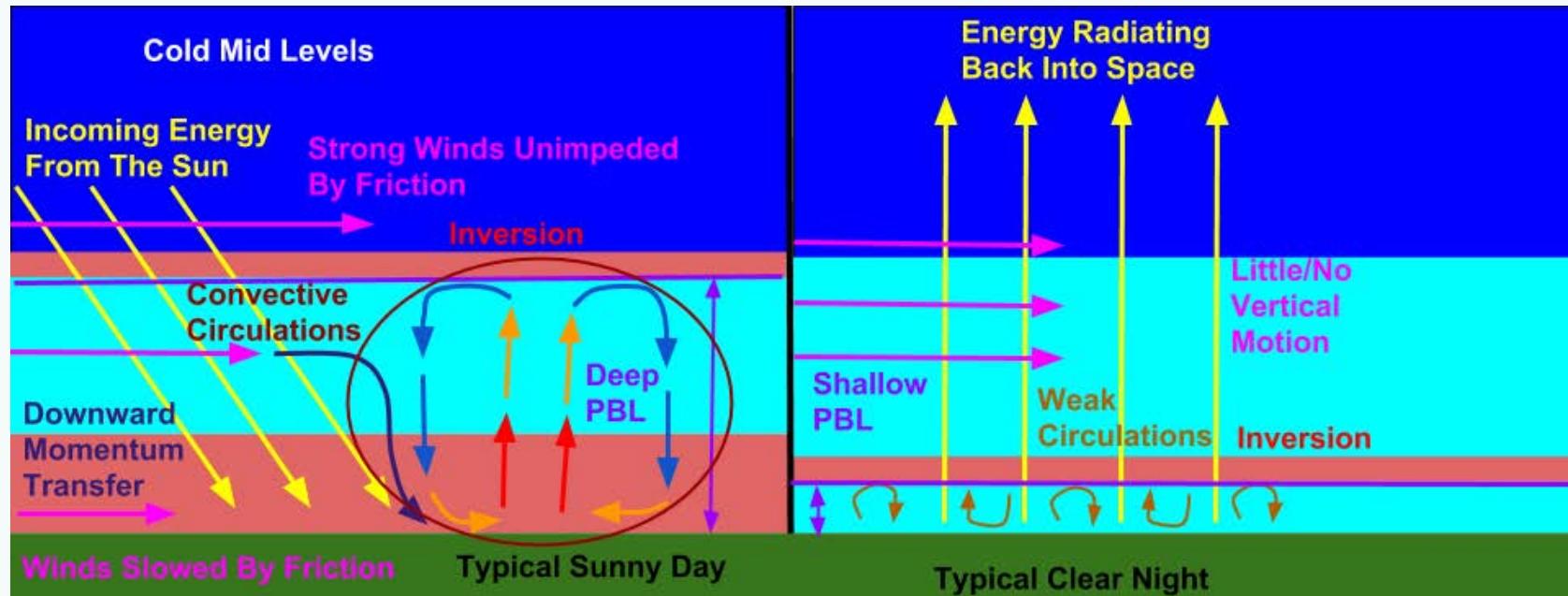
Air Pollution and Meteorology



Planetary Boundary Layer (PBL)

Layer 100 m to 3 km above Earth's surface where pollution is well mixed

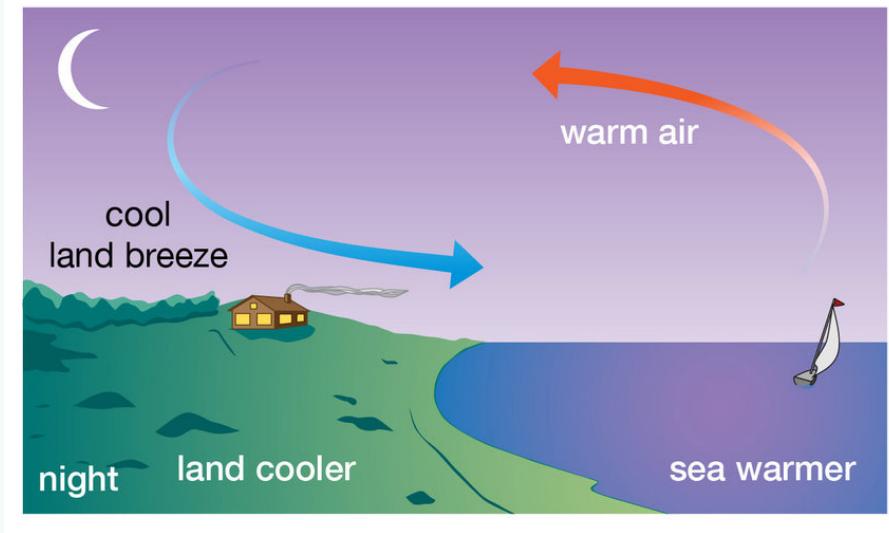
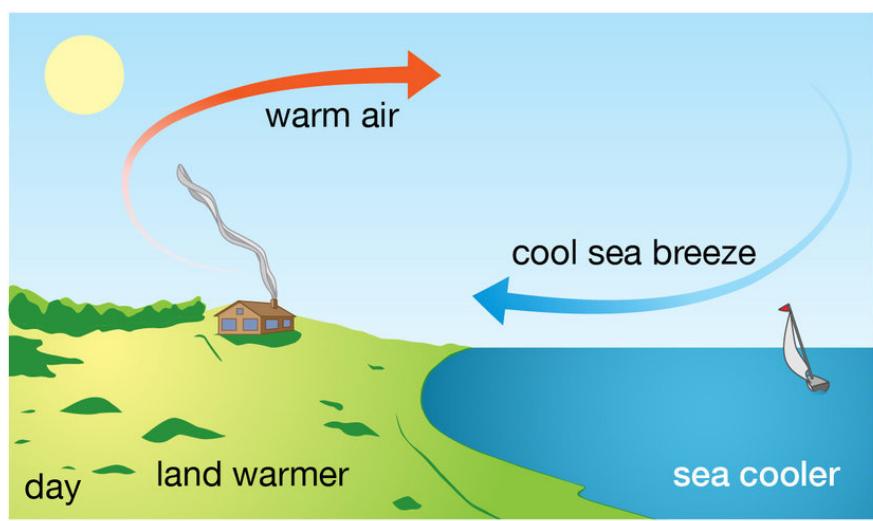
Height depends on surface warming (warmer → deeper PBL → dilutes pollution)



Air Pollution and Meteorology



Sea breeze



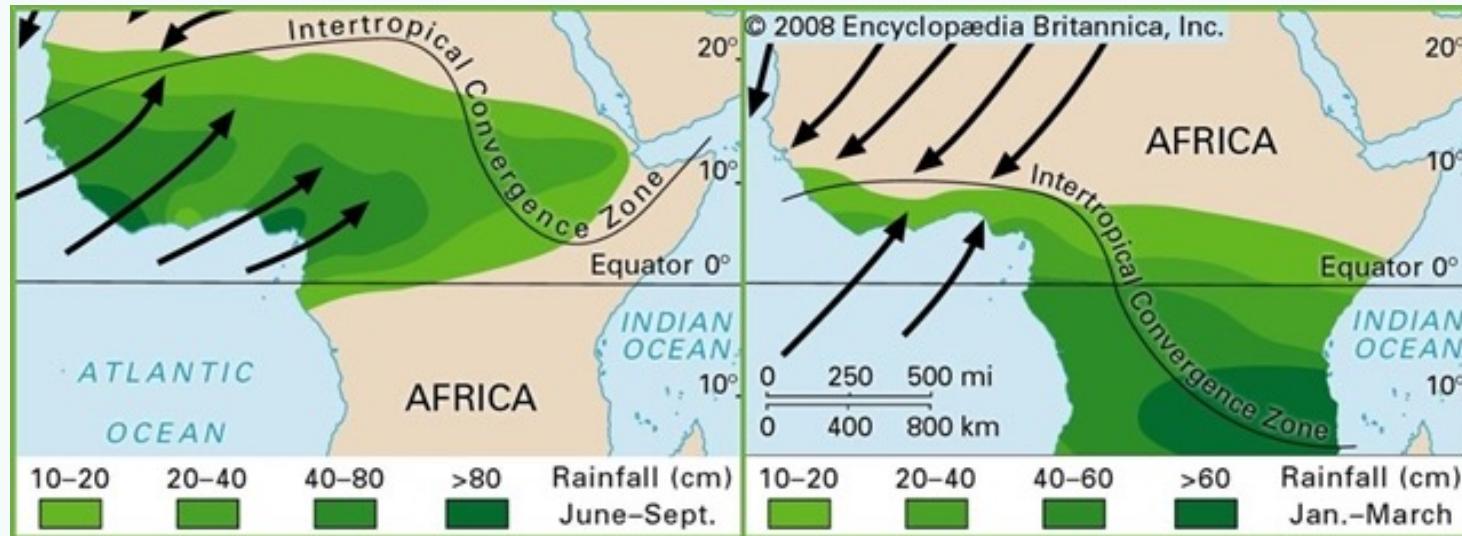
Land heats and cools faster than ocean

Daytime: hot air ascends over land and descends over ocean; opposite at night

Contributes to poor air quality in coastal cities (LA)

Air Pollution and Meteorology

Monsoon



Extreme wet and dry seasons

Dry season: conditions ideal for fires and stable conditions (buildup of pollution)

Wet season: Particulate and other pollution efficiently removed from atmosphere

Air Pollution and Climate Change

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Many impacts of climate change on air pollution

Most distinct is desertification (increase dust emissions) and extreme weather (more dry biomass to burn)

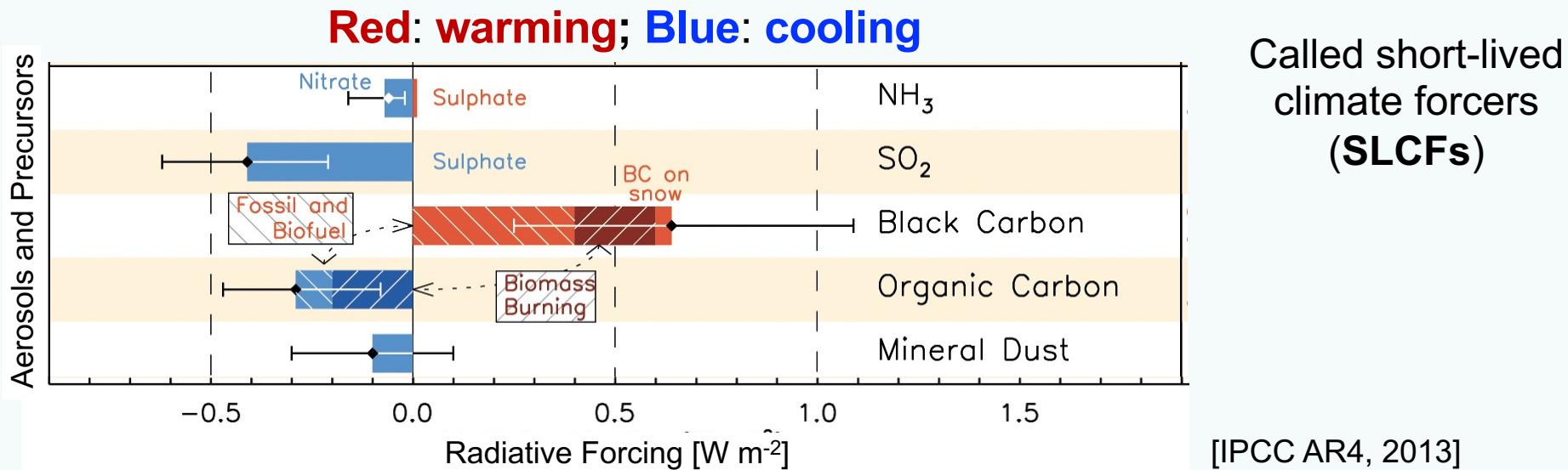


Air Pollution Impacts

On Climate

Air pollutants are also greenhouse gases (ozone in the troposphere) and efficient at absorbing (BC) and reflecting (sulfate, nitrate, ammonium aerosols) radiation

Radiative forcing: change in energy (heat) balance of the Earth [W m^{-2}]

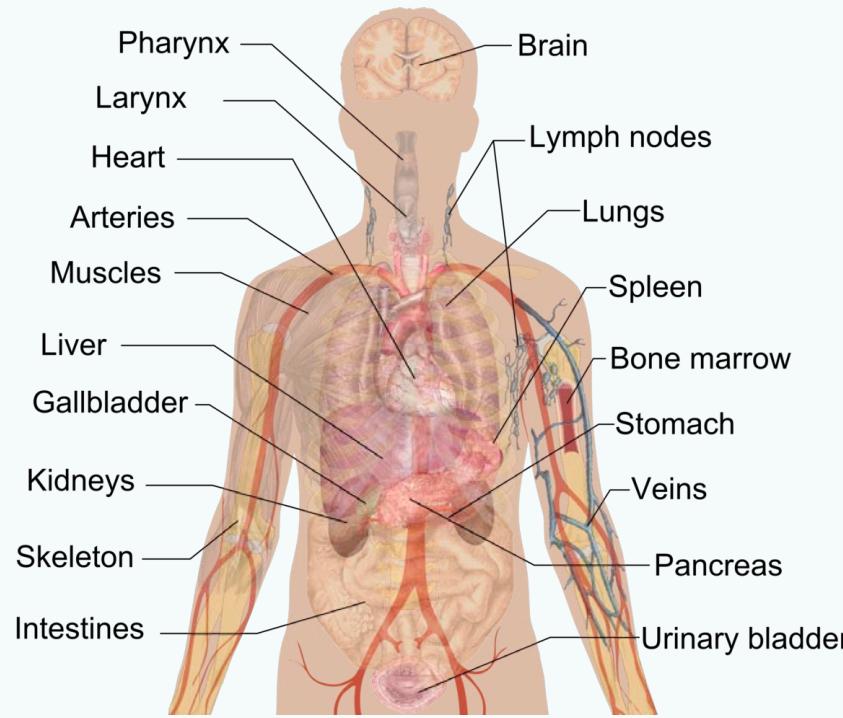


Air Pollution Impacts

On Human Health

Every organ in our body may be susceptible to its deleterious effects

Internal organs

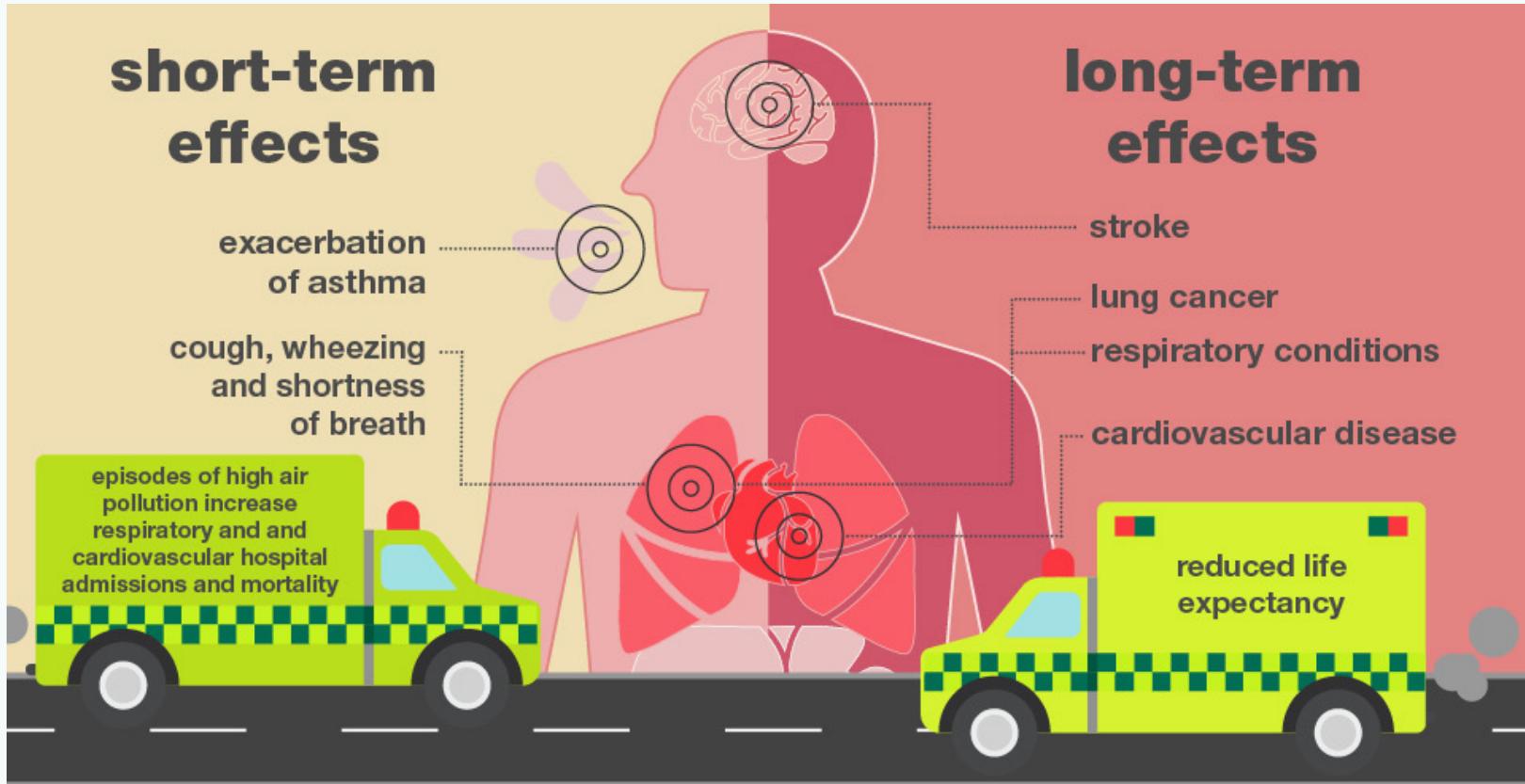


Interactive report:

<https://www.theguardian.com/environment/ng-interactive/2019/may/17/air-pollution-may-be-damaging-every-organ-and-cell-in-the-body-finds-global-review>

Air Pollution Impacts

On Human Health



Air Pollution Impacts

On Human Health

It is estimated that **long-term exposure to man-made air pollution in the UK** has an annual effect equivalent to:



**28,000 to
36,000
deaths**

Over the following 18 years a **1 µg/m³ reduction in fine particulate air pollution in England** could prevent around:



50,900 cases
of coronary heart disease



16,500 strokes

9,300 cases of asthma

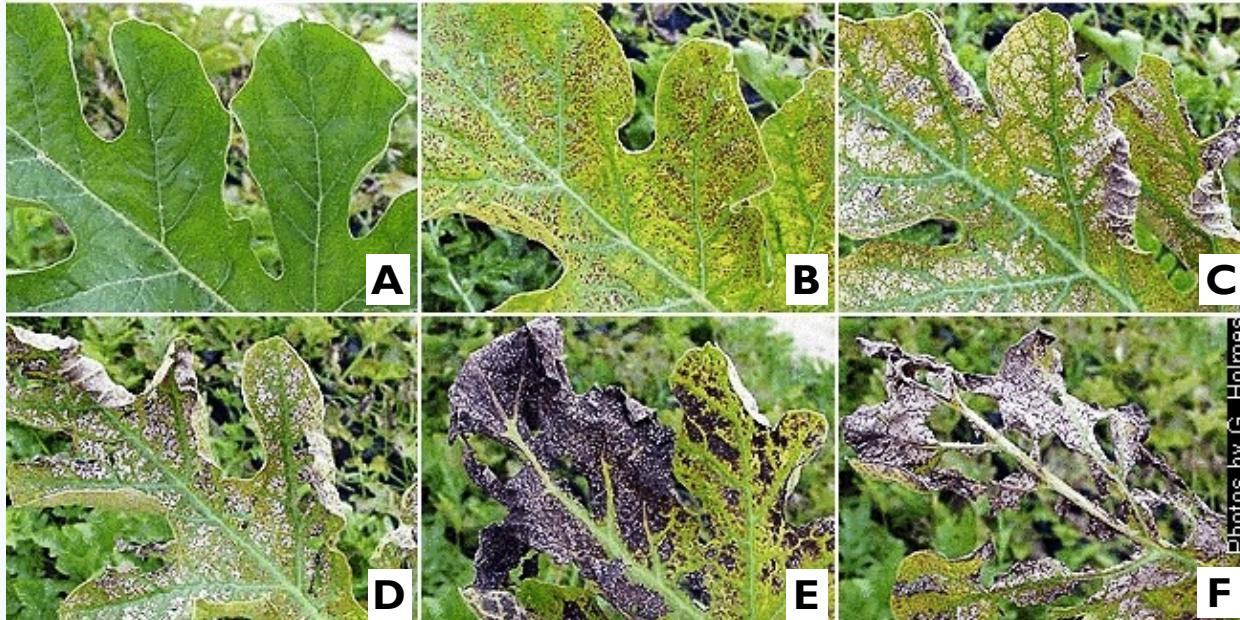
4,200 lung cancers

Air Pollution Impacts

On Food Security

Progression of ozone damage (A=none to F=severe) on watermelon foliage

Damage occurs at
 $O_3 > 40 \text{ ppb}$



Not all crops impacted. Ranges from very sensitive (**soybean**), moderately sensitive (**rice/maize**), no damage (**barley**).

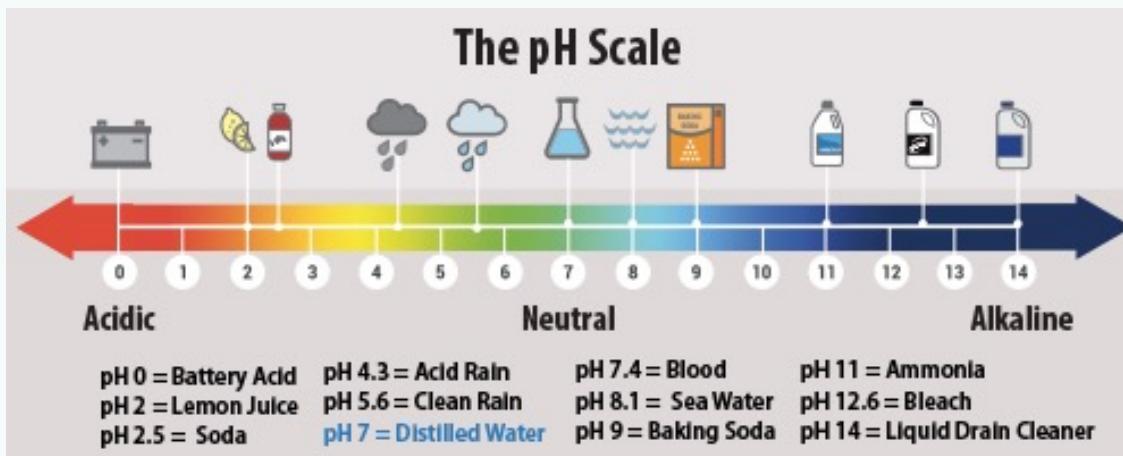
Air Pollution Impacts

On Ecosystem Vitality

Acid rain ($\text{pH} < 5.6$)

Wet and dry deposition of acidic **sulfate** and **nitrate** aerosols

Affects terrestrial and aquatic ecosystems and infrastructure, leads to leaching of soil nutrients, solubilizes harmful metals



Forest damage



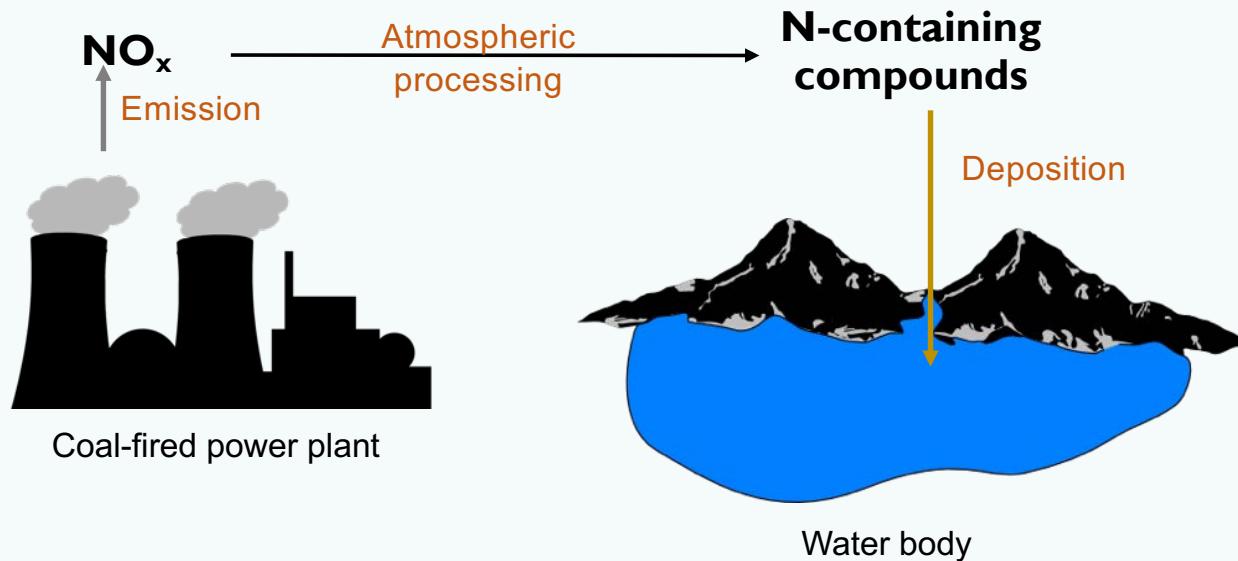
Air Pollution Impacts

On Ecosystem Vitality

Excessive enrichment of nutrients in terrestrial and aquatic ecosystems

From wet and dry deposition of nitrogen from NO_x and NH_3 emissions

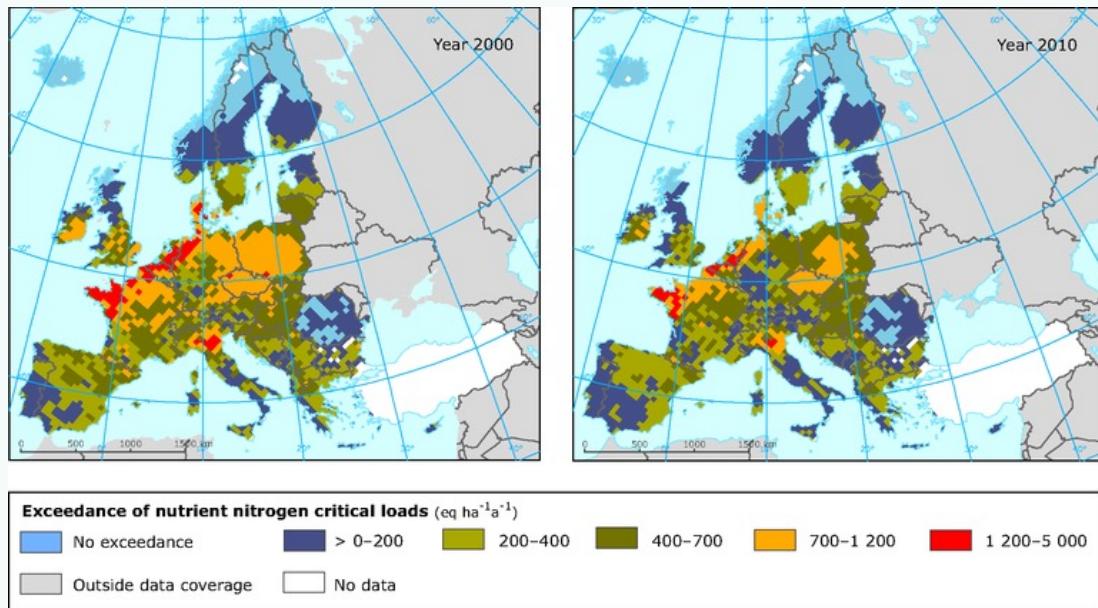
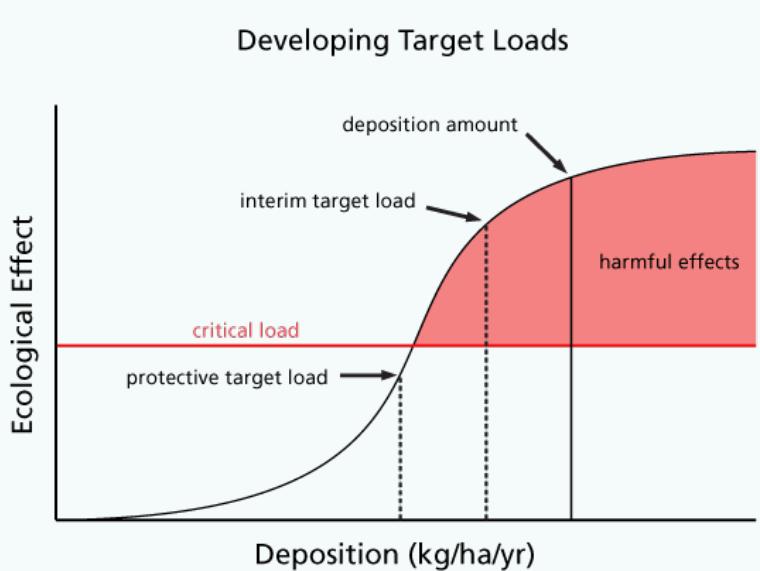
Decreased biodiversity, changes species composition, leads to eutrophication



Air Pollution Impacts

On Ecosystem Vitality

Assess by measuring critical loads (point at which input of nutrients becomes harmful)

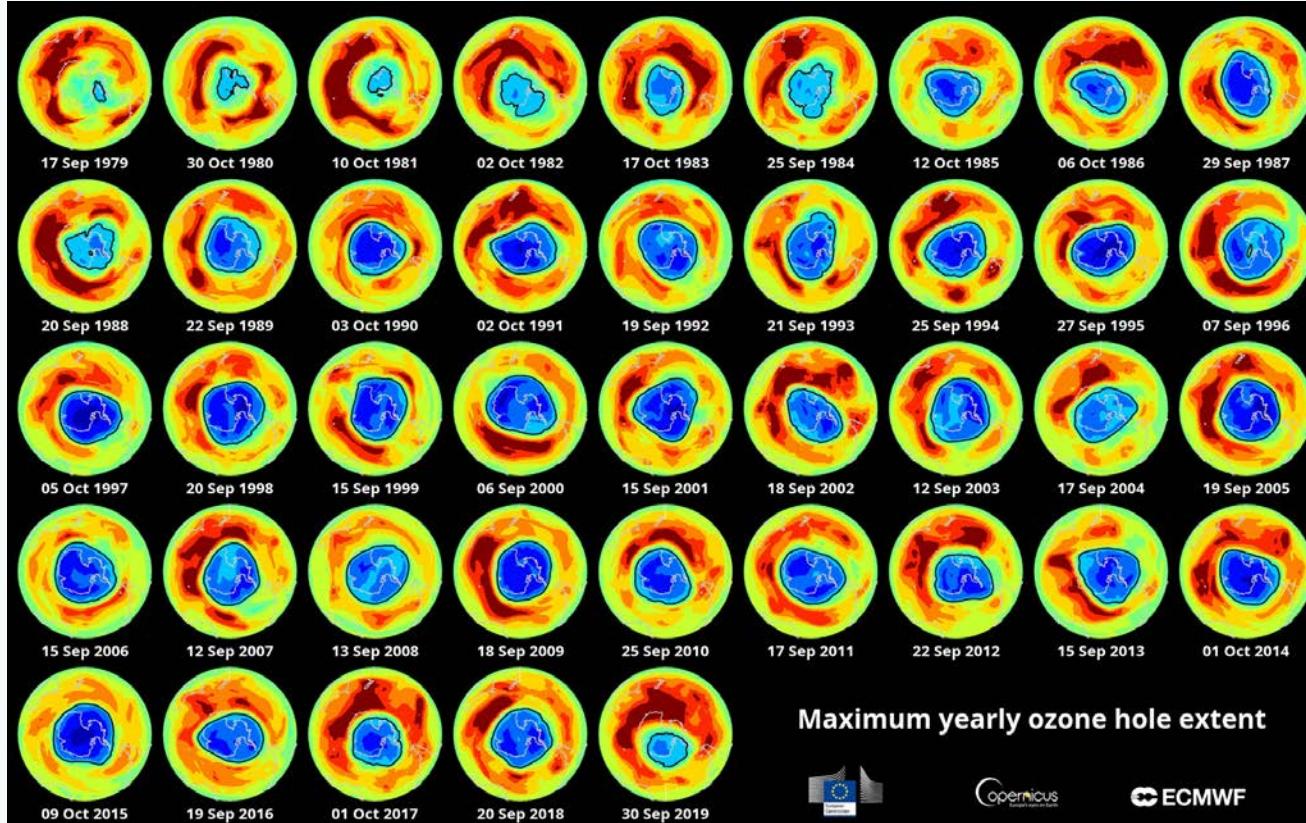


Air Pollution Impacts



On the Protective Ozone Layer

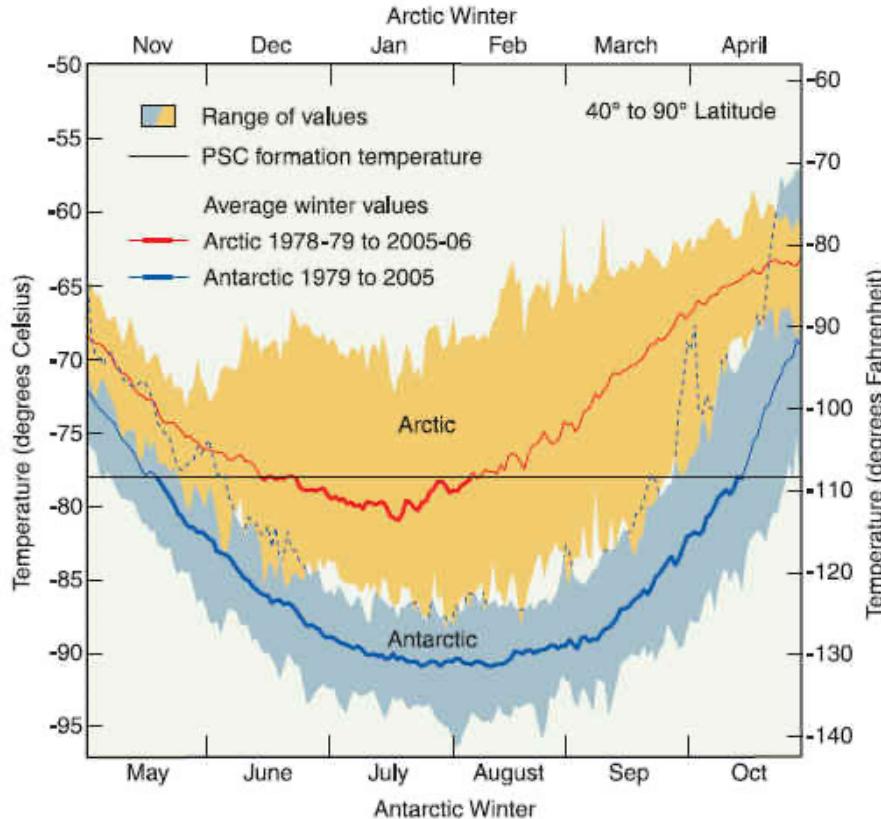
1979



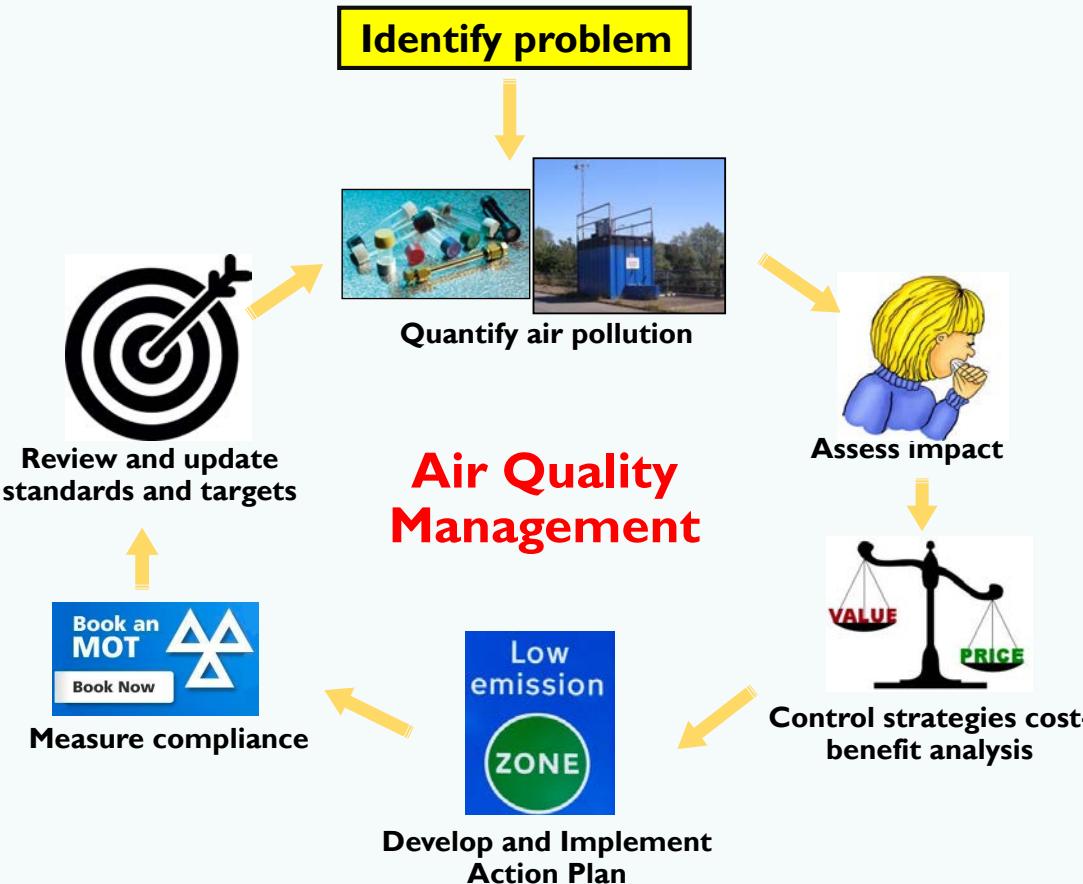
Air Pollution Impacts

On the Ozone Layer

Minimum Air temperatures in the Polar Lower Stratosphere



Policy Control Measures



Policy Control Measures

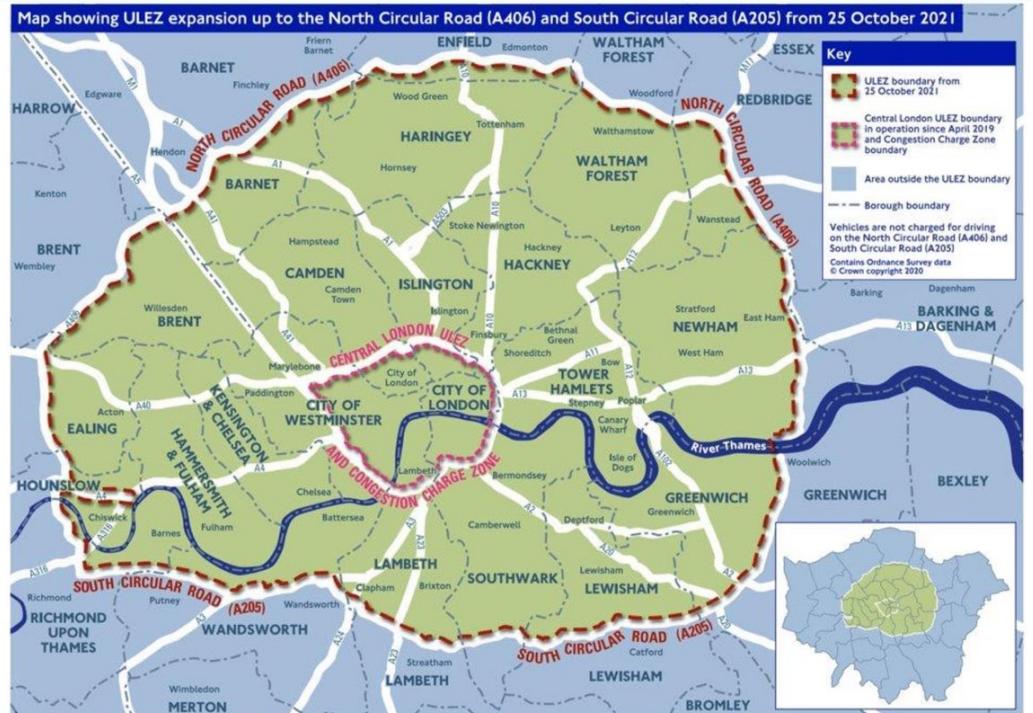


Emission controls at **local** level

Smoke control areas



Low Emission Zones



Policy Control Measures



Emission controls at **national** level

Vehicles in the UK need to meet Euro 6 emissions standards (implemented 2014)

Pollutant	Emission Standard (grams per km)	
	Petrol	Diesel
CO	1.0	0.50
NO _x	0.06	0.08
Particles	0.005	0.005



Description	Limits	Actual Value	
Fast Idle Test			Pass
RPM	2500 - 3000 RPM	Manual Check	Pass
CO	<= 0.2 %	0.06 %	Pass
HC	<= 200 PPM	68 PPM	Pass
Lambda	0.97 - 1.03	1.00	Pass
Natural Idle Test			Pass
RPM	450 - 1500 RPM	Manual Check	Pass
CO	<= 0.3 %	0.05 %	Pass
Overall Result:		Exhaust Emissions Test	Passed



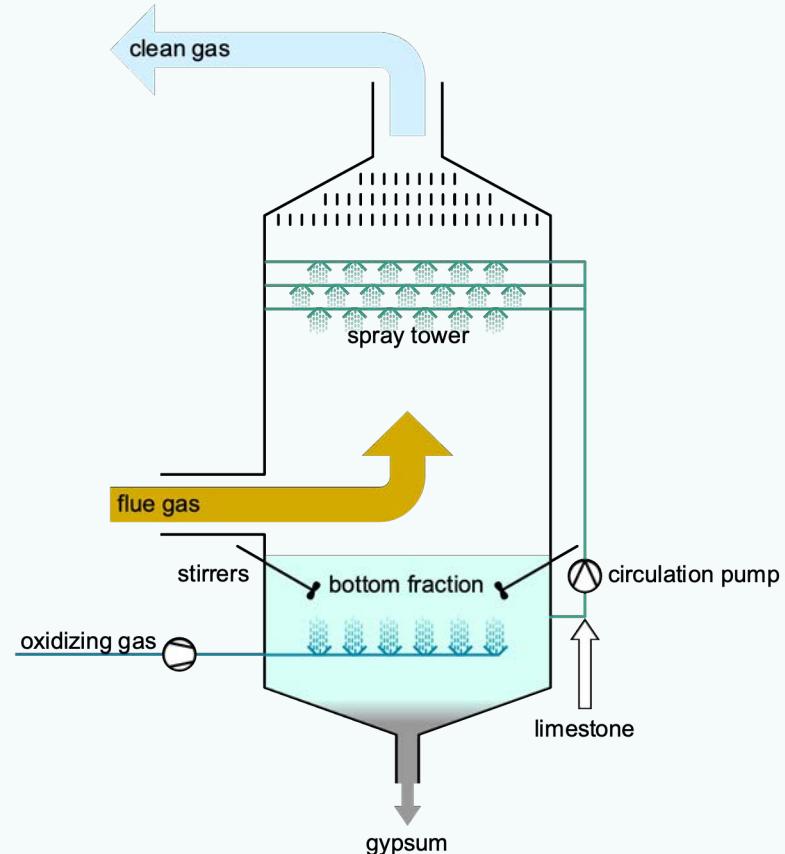
Policy Control Measures

Emission controls at **national** level

Emission control technology: scrubbers for power plants

Flue gas desulfurization: remove SO_2 from effluent gas from fossil fuel power plants

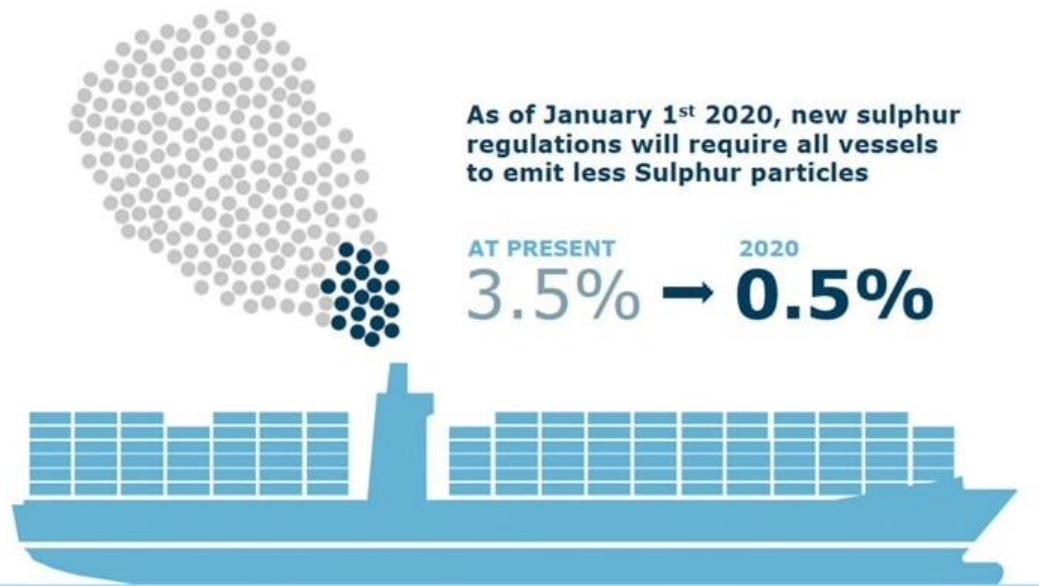
Prevent acid rain and particulate pollution



Policy Control Measures

Emission controls at **international** level

IMO 2020 Regulations



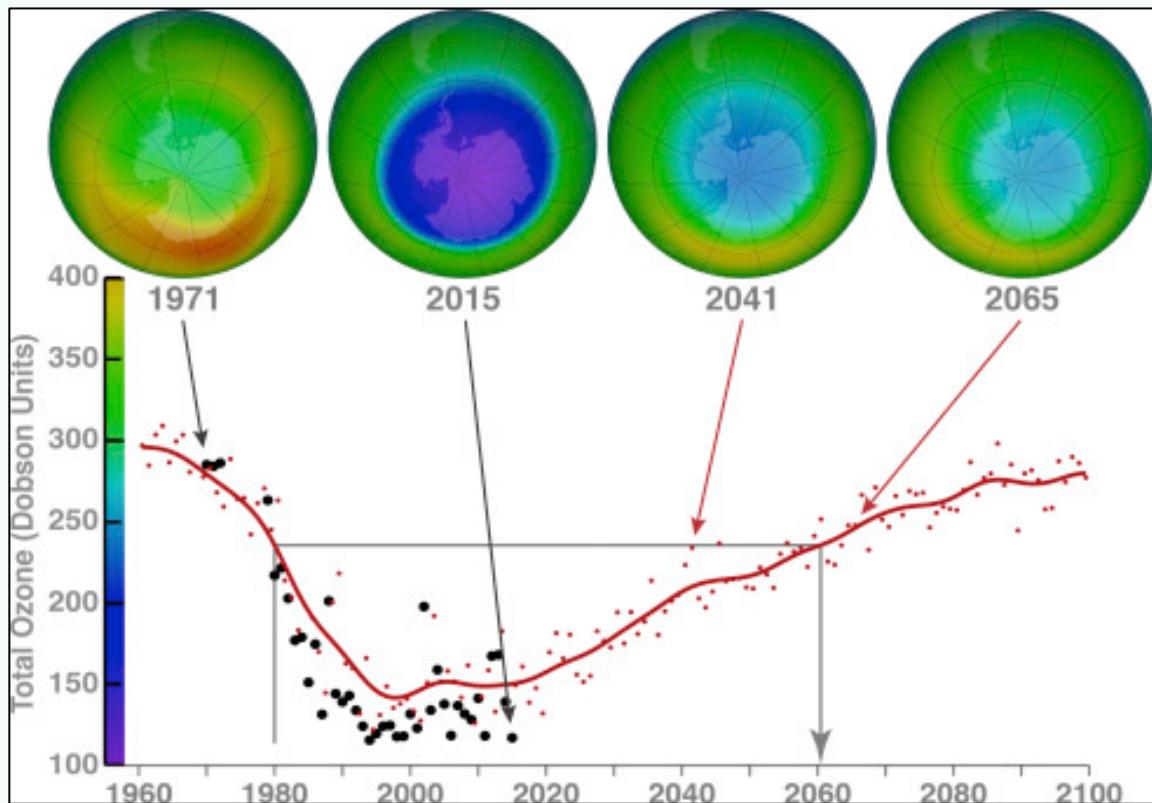
As of January 1st 2020, new sulphur regulations will require all vessels to emit less Sulphur particles

Air Pollution Impacts

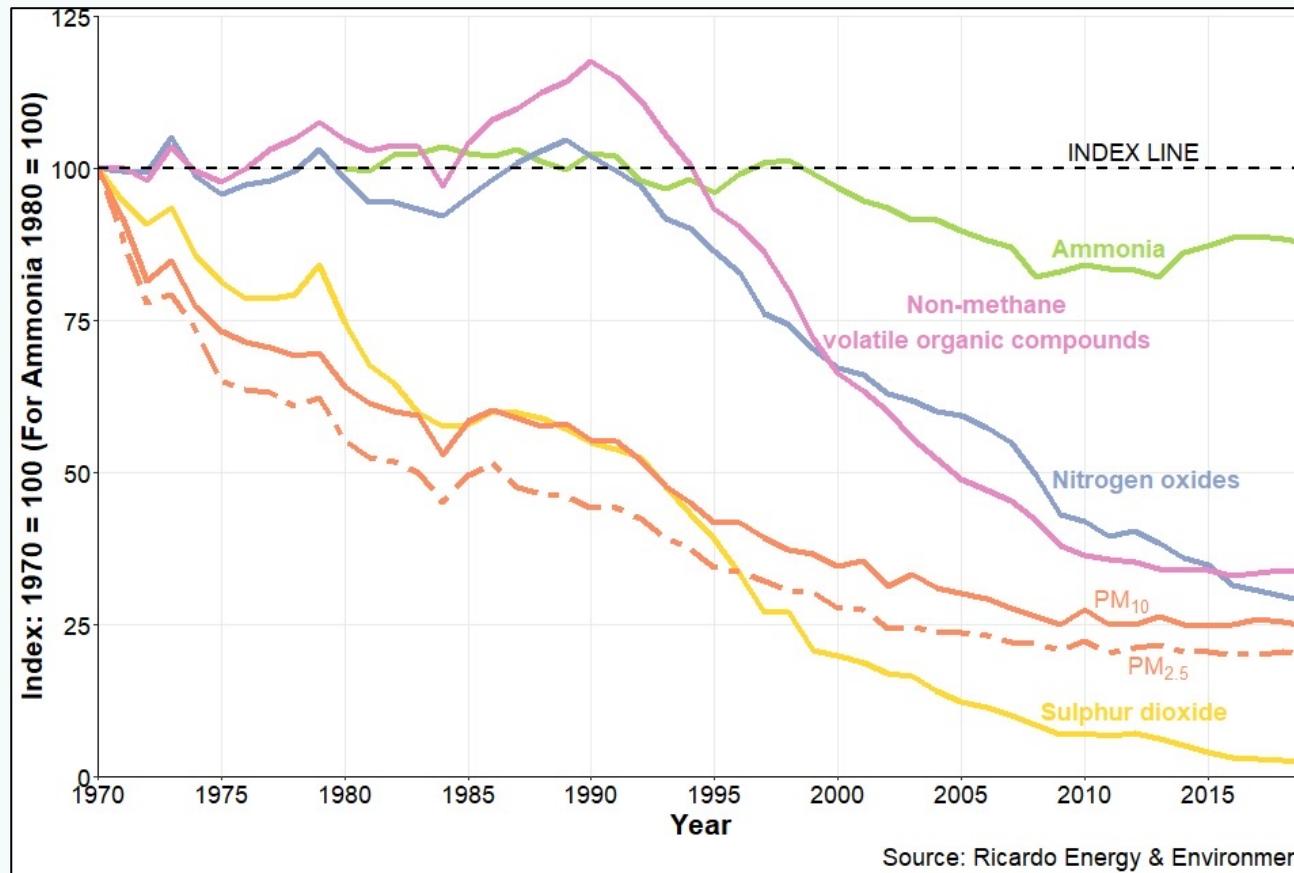
Emission controls at **international** level

Montreal Protocol:

International treaty that led to the successful phase-out of CFCs



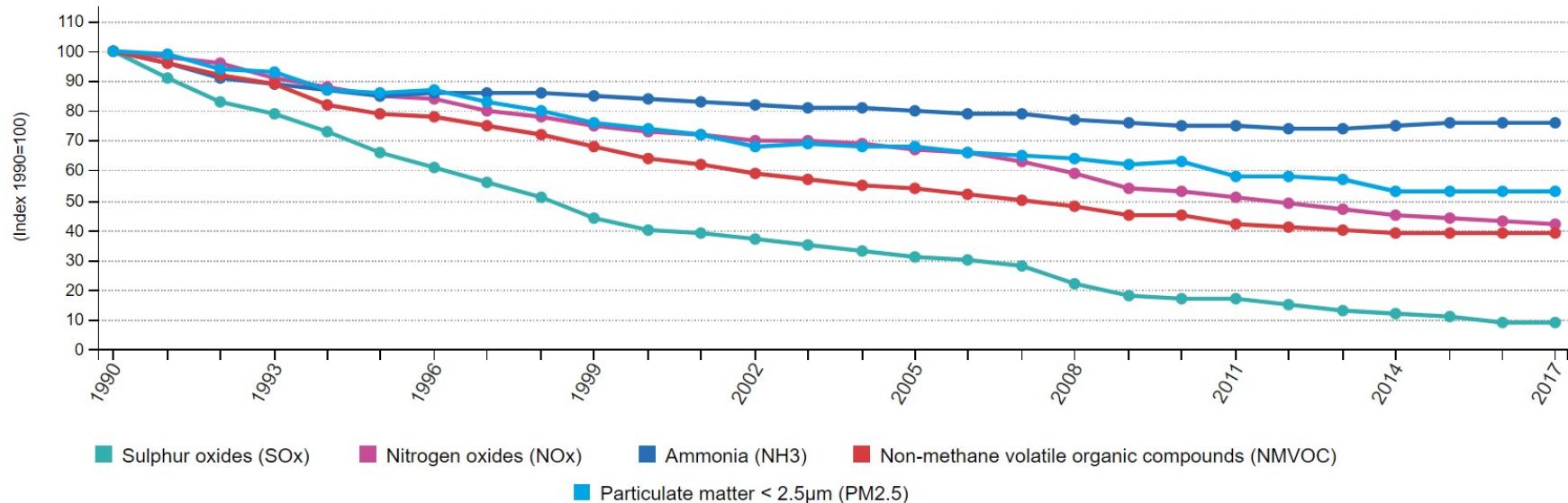
Decline in emissions in UK



Decline in emissions in Europe



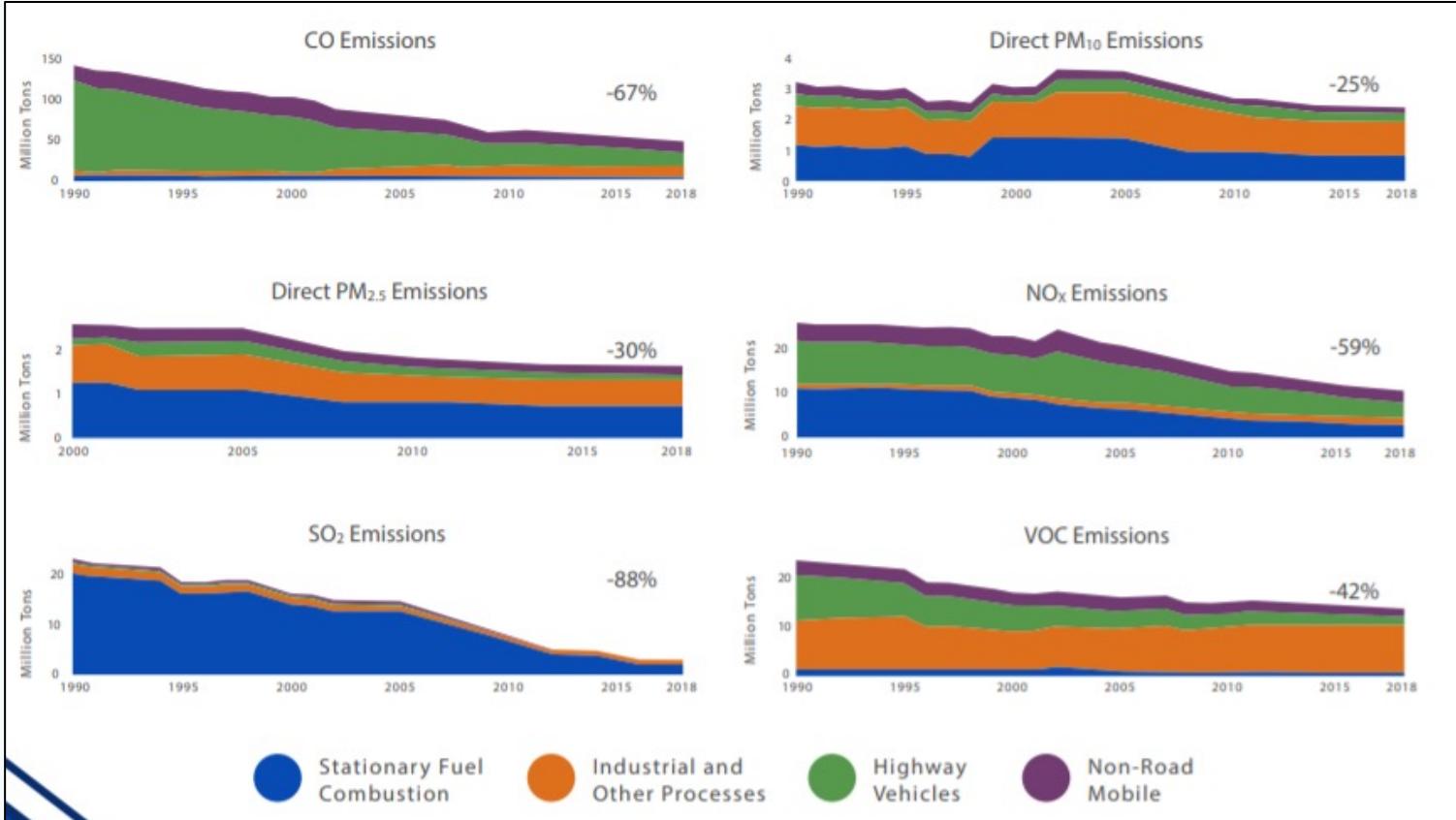
Emissions of air pollutants, EU-28, 1990-2017



Source: European Environment Agency (online data code: env_air_emis)

eurostat 

Decline in emissions in the US



Other Resources



- Interactive health statistics map: <https://vizhub.healthdata.org/gbd-compare/>
- <https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution>
- WHO report: <https://apps.who.int/iris/handle/10665/345329>
- Air quality news and information site: <https://airqualitynews.com/>
- Climate air and climate coalition: <https://www.ccacoalition.org/en>
- EEA summary on the impact of air pollution on health:
<https://www.eea.europa.eu/themes/air/health-impacts-of-air-pollution>

Seminar Activity for Week 3



Air pollution data exercise

Visible on Moodle under “Assessments” section.

Due by 4 Feb

Submit upload link will be active from 2 Feb

Next Lecture: Biodiversity Loss

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