

Air Pollution

Part 1

GEOG0170



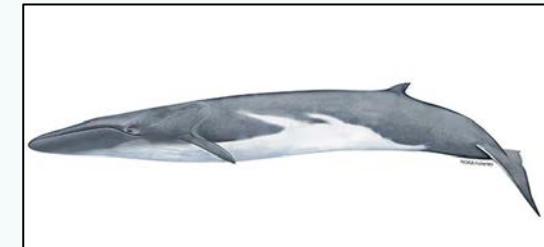
Recent Good News Story



Seeing 1,000 glorious fin whales back from near extinction is a rare glimmer of hope



The Guardian article,
19 Jan 2022



<https://www.theguardian.com/commentisfree/2022/jan/17/glorious-fin-whales-extinction-hope-antarctic-peninsular>

Contents

- Brief history of air pollution awareness
- Overview of relevant concepts and terminology
- Characterization of sources of air pollution
- Atmospheric processing of air pollution

Air Pollution Awareness



Increasing awareness of air pollution over time

Domestic chimneys since 12th century move more air pollution outdoors

Open hearth in centre of room

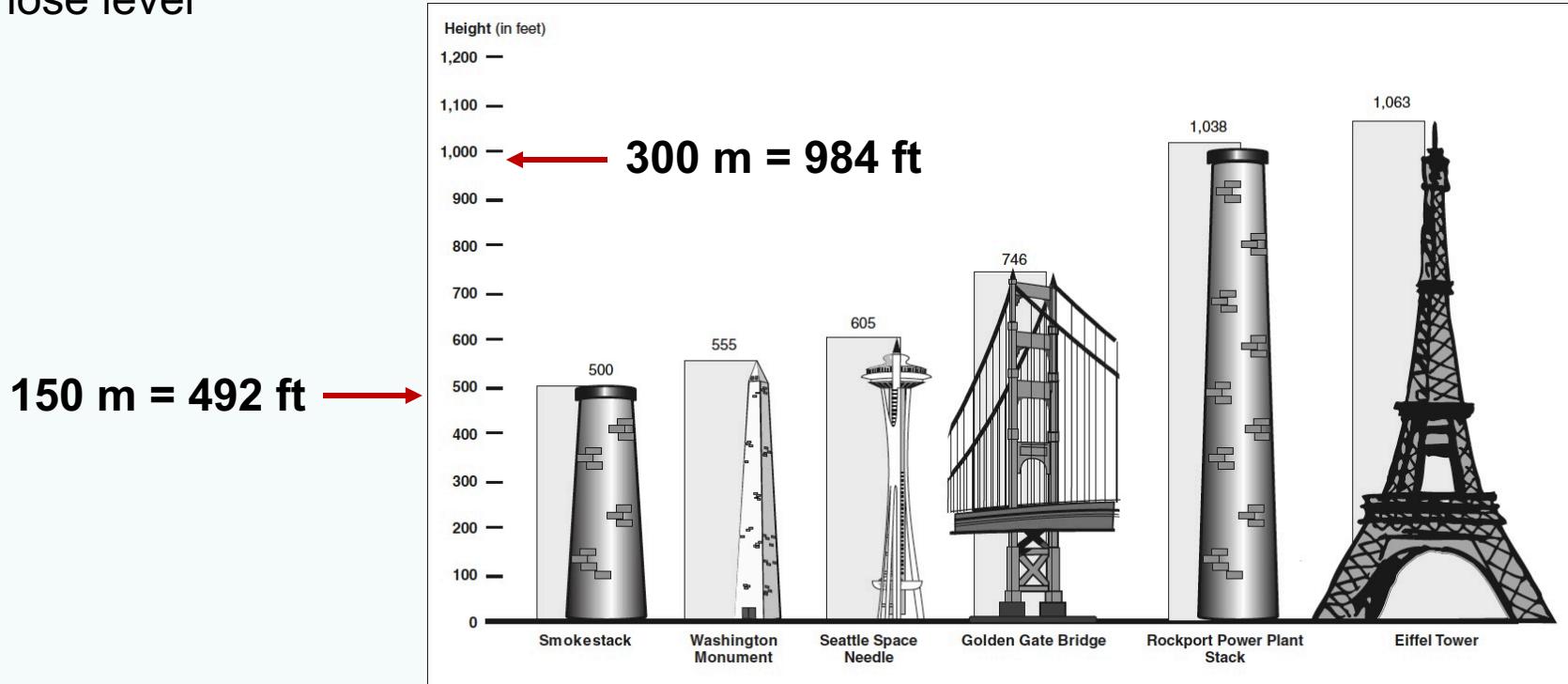


Chimney lots pollution outdoors



Air Pollution Awareness

Increasing height of industrial smokestacks shift plume aloft and pollution away from nose level



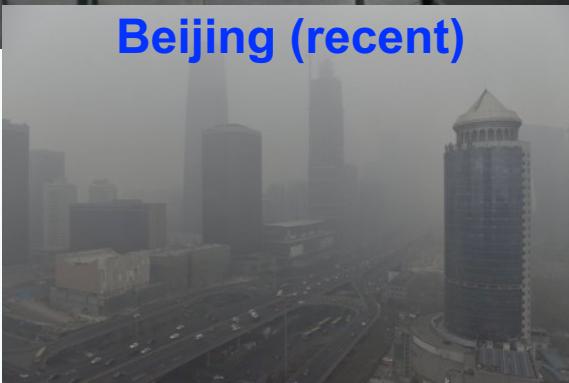
Air Pollution Awareness

City air pollution from London to LA to Beijing to Delhi. Where next?

London landmarks during the smog event of 1952



Beijing (recent)



Los Angeles in 1968



New Delhi (current)



Indoor Air Pollution



Indoor air pollution in work and home environment can also be a large source:
cooking, cleaning and personal care products, new furniture



Disproportionately impacts women and children where people still rely on traditional solid fuels (wood, charcoal, dung)

Outdoor Air Pollution

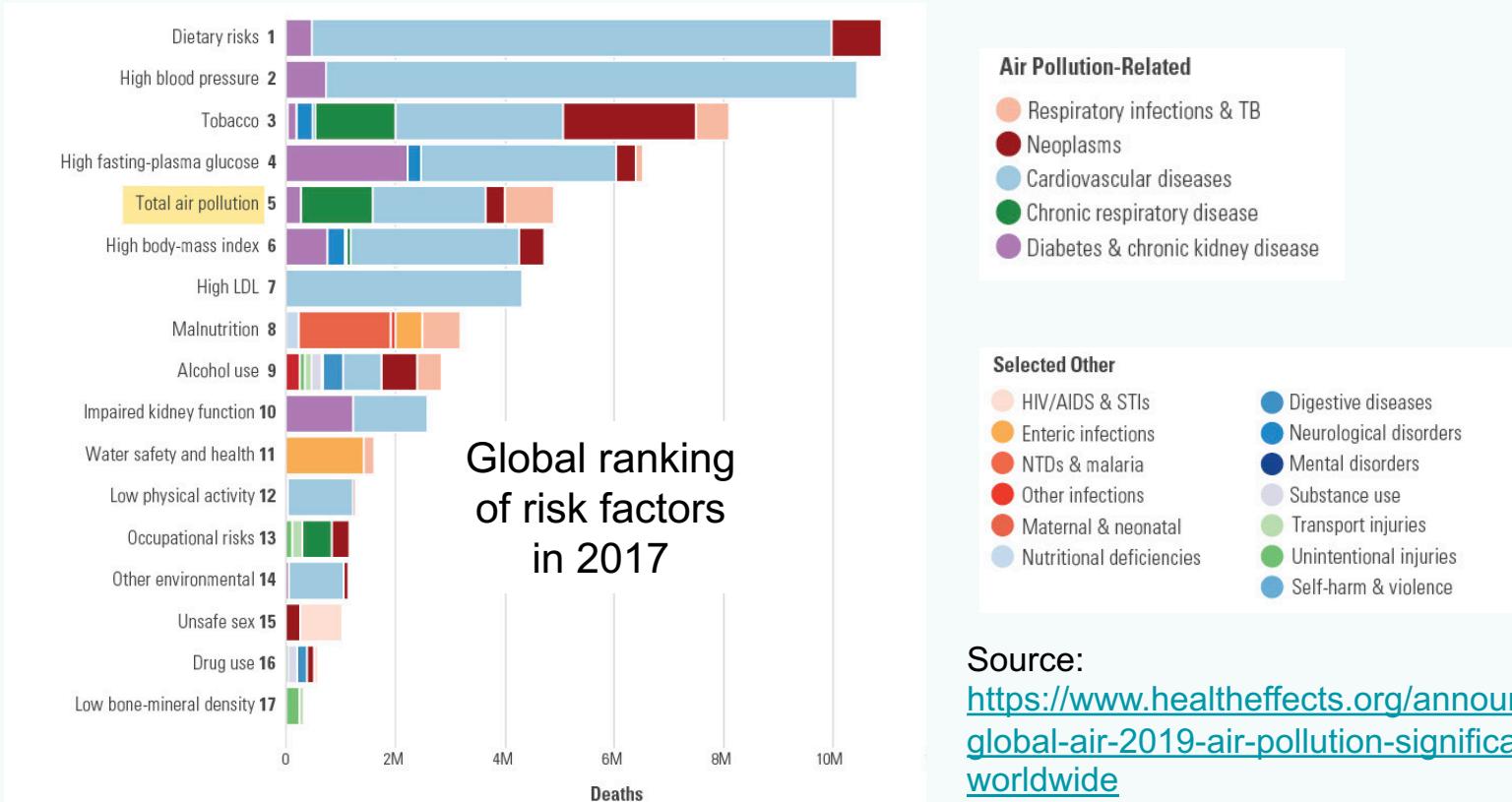
Also called ambient air pollution.



We will focus on **outdoor (ambient)** air pollution.

Outdoor Air Pollution

Today: air pollution is a global leading risk of premature mortality



Source:

<https://www.healtheffects.org/announcements/state-global-air-2019-air-pollution-significant-risk-factor-worldwide>

Outdoor Air Pollution



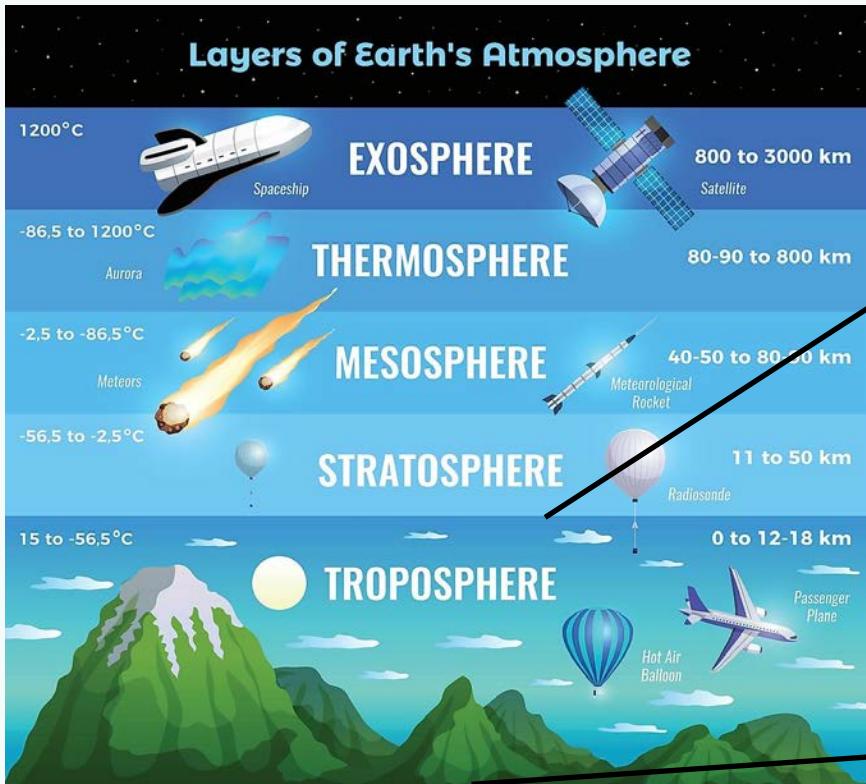
What's the impact of air pollution on health in your home country/province/county?

Use the Global Burden of Disease (GBD) visualization tool to determine the number of premature deaths due to exposure to air pollution in your home country/province/county:

<https://vizhub.healthdata.org/gbd-compare/>

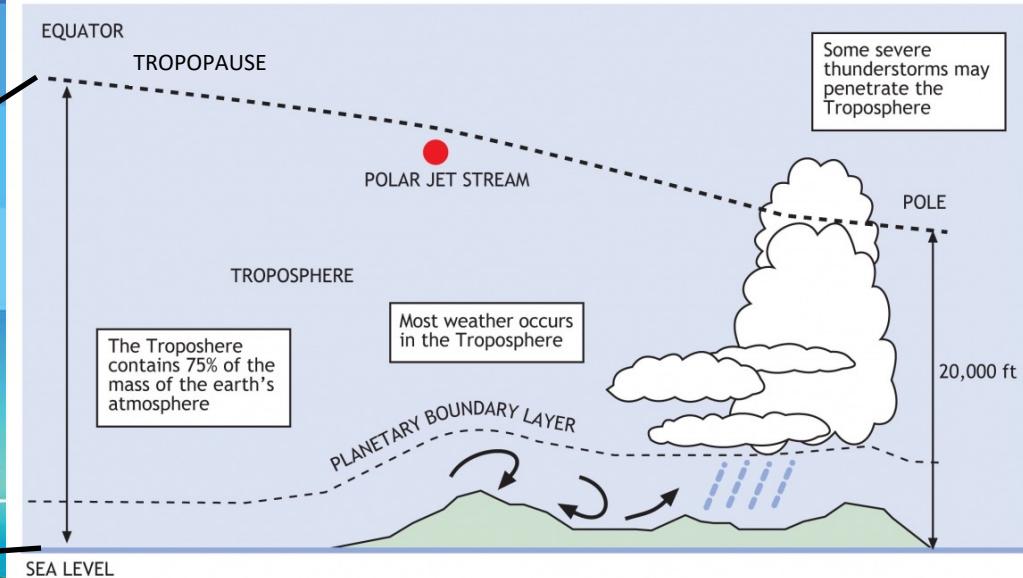
Structure of the Atmosphere

All atmospheric layers



Stratosphere: where the good protective ozone resides

Components of the troposphere



Relevant Concepts & Terminology

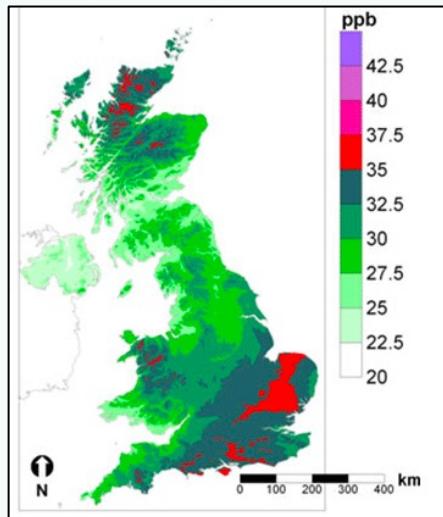


Surface Concentration: abundance at nose level

Volumetric or mixing ratio: m³ compound per m³ air (ppbv or pptv)

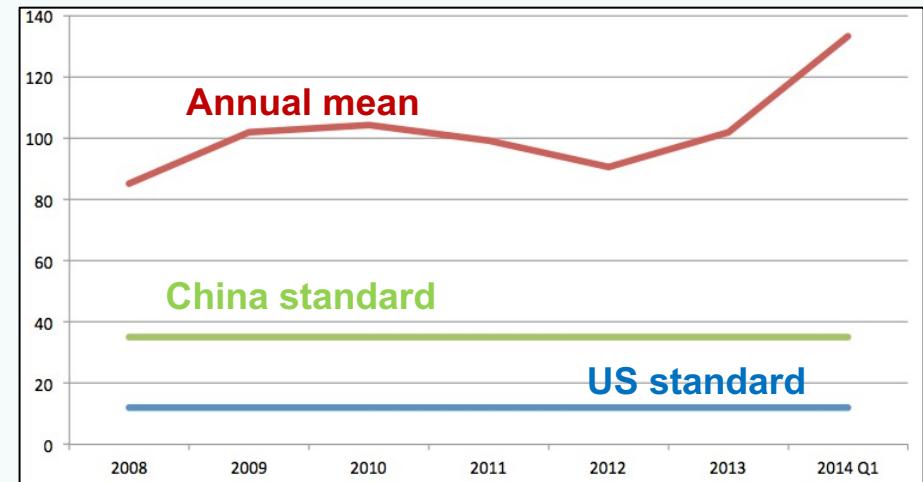
Mass concentration: mass per volume air (μg m⁻³)

Surface ozone in the UK



Source: http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Fine particles (PM_{2.5}) in μg m⁻³ in Beijing

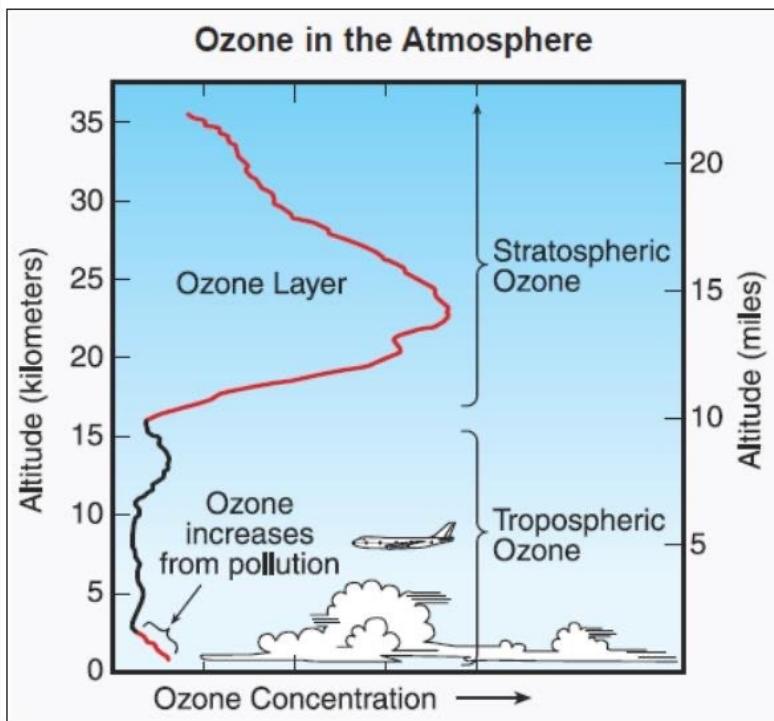


Source: <http://www.livefrombeijing.com/>

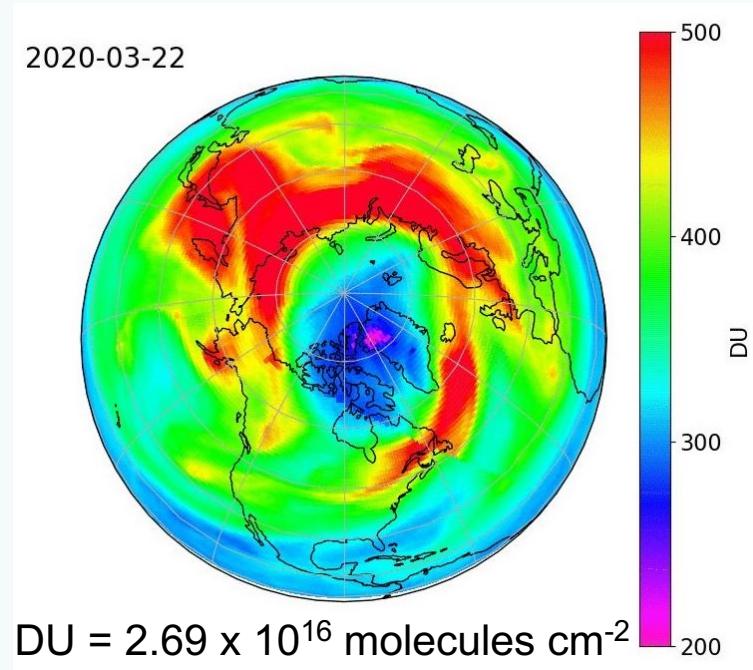
Relevant Concepts & Terminology

UCL

Column Concentration: abundance throughout atmospheric column



Total ozone column



Number of molecules in a column of air in units of molecules / cm²

Relevant Concepts & Terminology



Pollutant state: gas or aerosol (particle, particulate matter)

Many sources (like fires) include a mix of both

NO_x gas

CO gas

NH_3 gas

Non-methane
volatile organic
compound
(NMVOC) gases



Soot or black carbon (BC) particles

Organic carbon (OC) particles

Relevant Concepts & Terminology

UCL

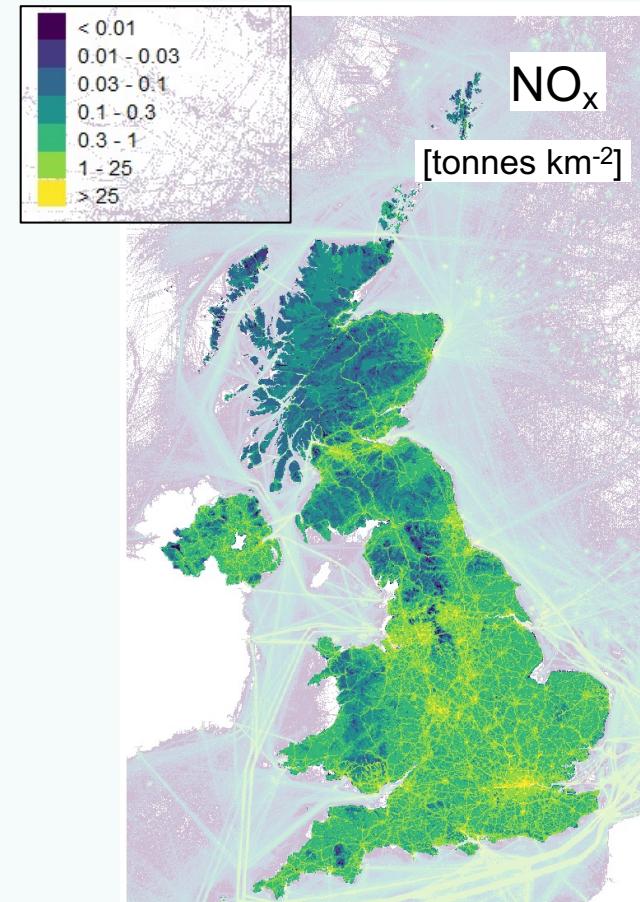
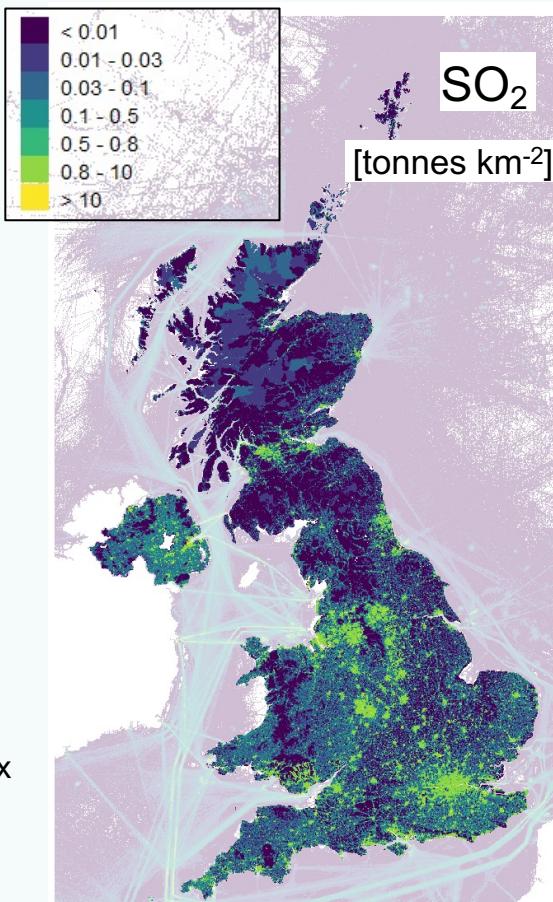
Emissions:

Rate of release of compound into the atmosphere by a source

In units of amount per unit area per unit time

Such as:

$\text{kg SO}_2 \text{ m}^{-2} \text{ s}^{-1}$ for SO_2
 $\text{molecules N m}^{-2} \text{ s}^{-1}$ for NO_x



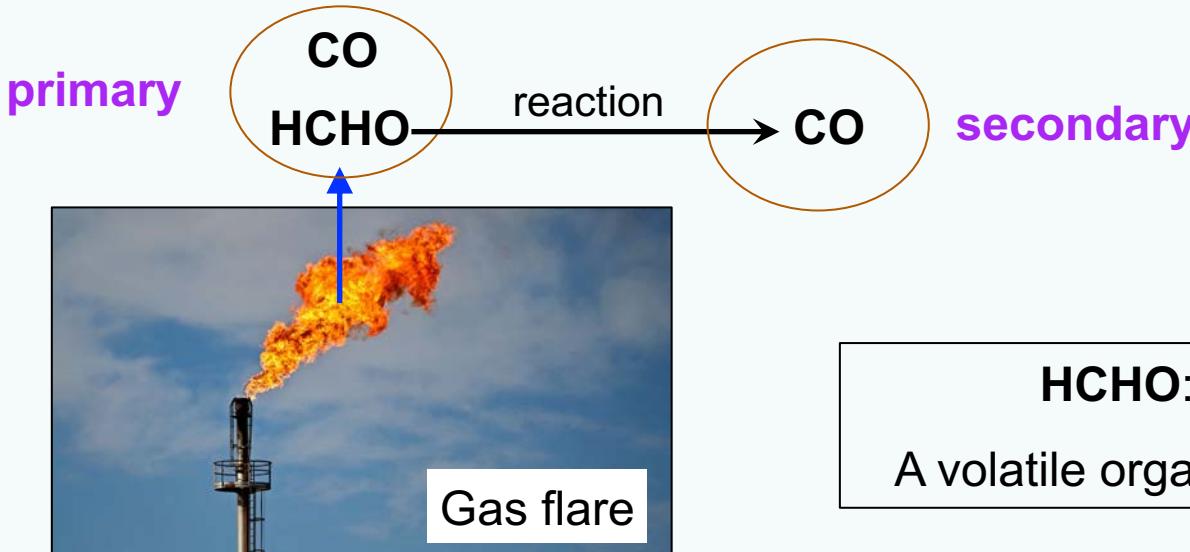
Relevant Concepts & Terminology



Source types: primary versus secondary

Primary: Formed at the source (emitted)

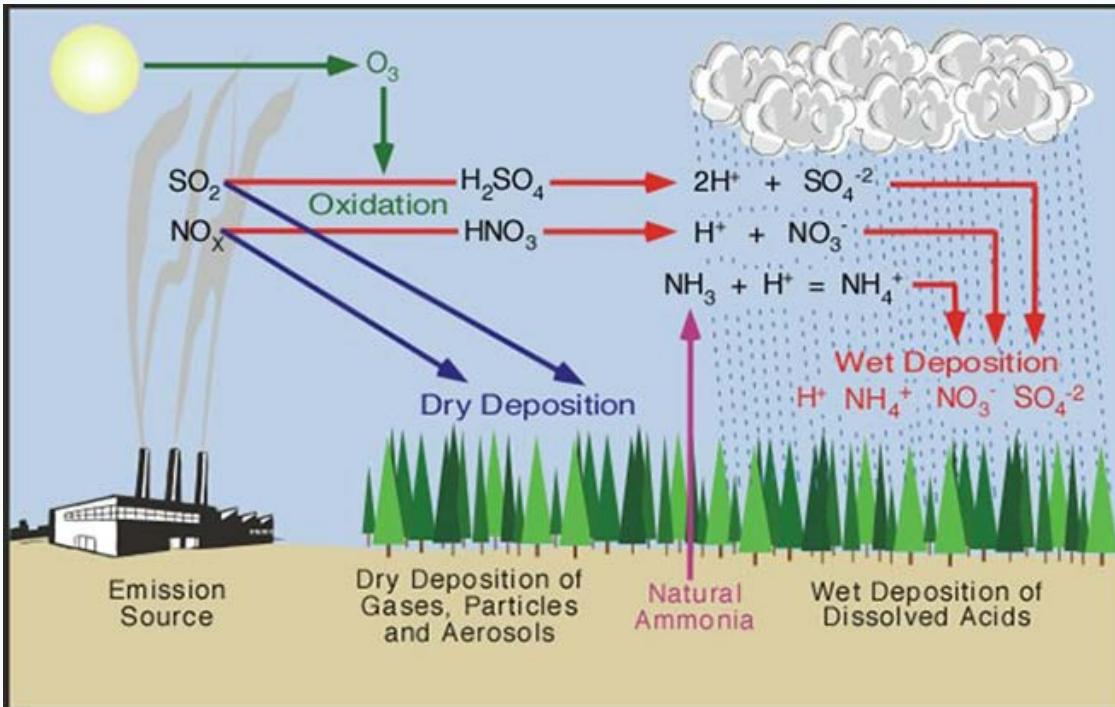
Secondary: Formed from chemical reaction in the atmosphere



Relevant Concepts & Terminology

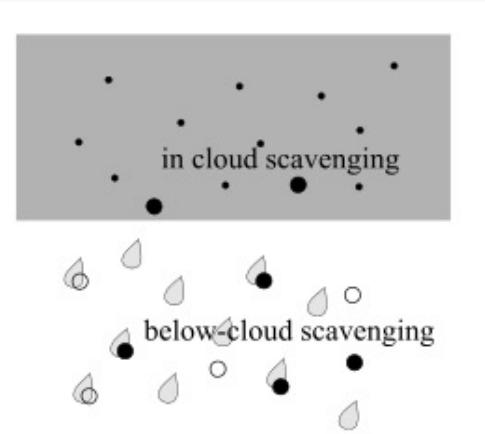
UCL

Dry and wet deposition



Dry deposition: settles on a surface

Wet deposition: scavenging when rain falls or when clouds form during convection



Terminal fate of air pollutant

Relevant Concepts & Terminology



Chemical changes: photolysis (sunlight), oxidation (oxidizer), thermal decomposition (temperature)

Whiteboard examples of:

- photolysis of formaldehyde (HCHO)
- oxidation of carbon monoxide (CO)
- thermal decomposition of peroxyacetyl nitrate (PAN)

Relevant Concepts & Terminology



Residence time or lifetime: how long a compound stays in the atmosphere

Two approaches to determine this:

1. If at steady state: ratio of concentration to loss or source rate
2. If not at steady state: time to reach 37% of original amount (1/e or e-folding time)

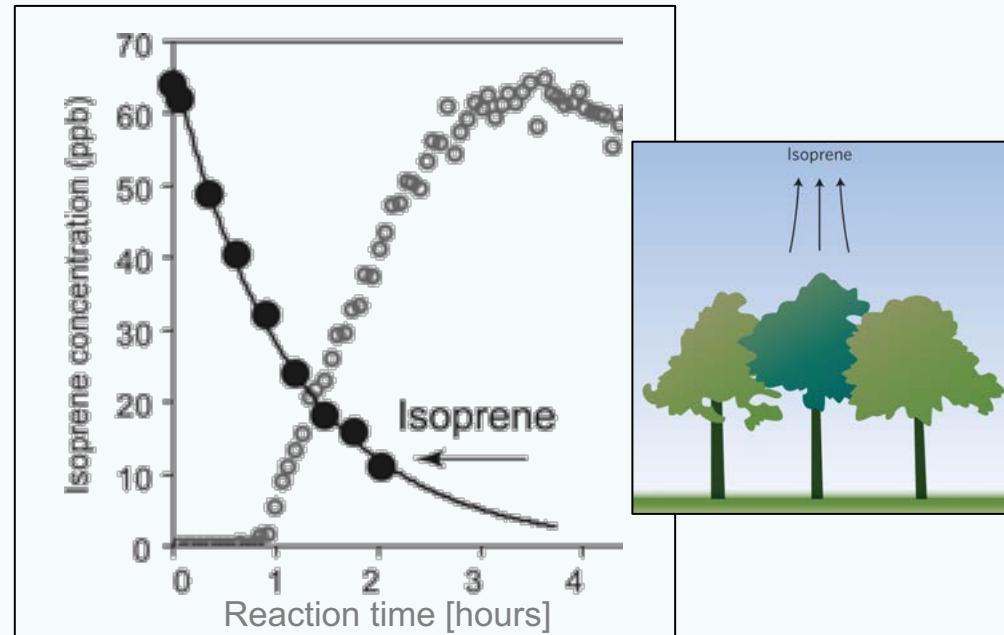
Important for assessing impact

NO₂: < 1 hour

CO: 2 months

PM_{2.5}: a day to 2 weeks

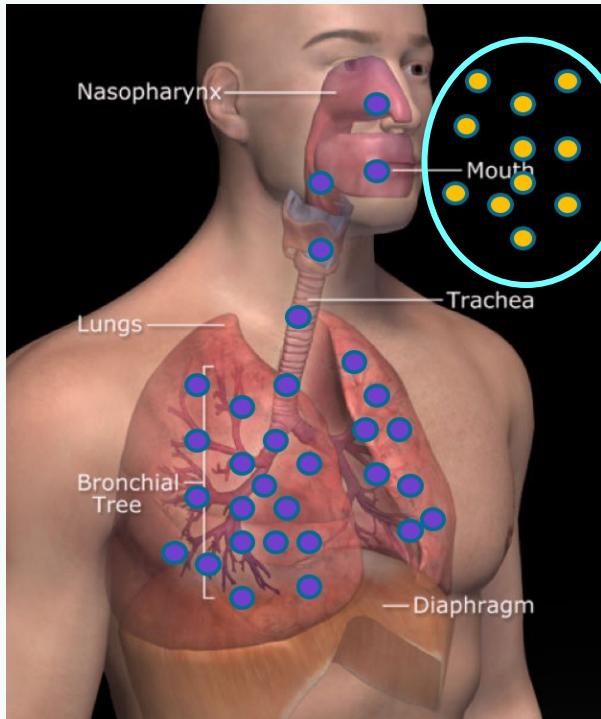
Benzene: weeks



Relevant Concepts & Terminology



Exposure: Pollution in contact with a target population.



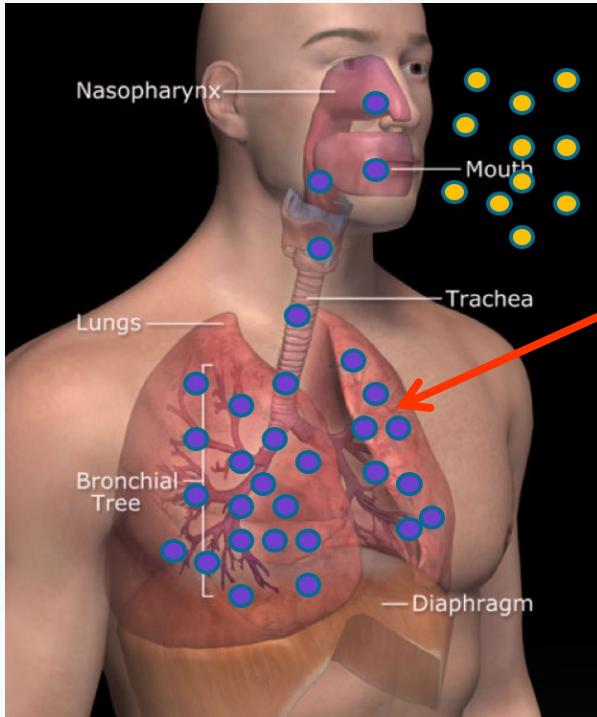
Personal exposure

Typically what's measured in health studies

Relevant Concepts & Terminology



Dose: amount of pollutant inhaled / ingested
(e.g. μg benzene inhaled per day or $\mu\text{g day}^{-1}$).



Lung Dose

Ideally what we want to relate air pollution to health effects

Relevant Concepts & Terminology

Air quality index (AQI): Measure of the quality of air (unitless)

Calculation and guidance varies from one location to the next.

UK calculation:

Index	Ozone, Running 8 hourly mean ($\mu\text{g}/\text{m}^3$)	Nitrogen Dioxide, Hourly mean ($\mu\text{g}/\text{m}^3$)	Sulphur Dioxide, 15 minute mean ($\mu\text{g}/\text{m}^3$)	PM _{2.5} Particles, 24 hour mean ($\mu\text{g}/\text{m}^3$)	PM ₁₀ Particles, 24 hour mean ($\mu\text{g}/\text{m}^3$)
1	0–33	0–67	0–88	0–11	0–16
2	34–66	68–134	89–177	12–23	17–33
3	67–100	135–200	178–266	24–35	34–50
4	101–120	201–267	267–354	36–41	51–58
5	121–140	268–334	355–443	42–47	59–66
6	141–160	335–400	444–532	48–53	67–75
7	161–187	401–467	533–710	54–58	76–83
8	188–213	468–534	711–887	59–64	84–91
9	214–240	535–600	888–1064	65–70	92–100
10	≥ 241	≥ 601	≥ 1065	≥ 71	≥ 101

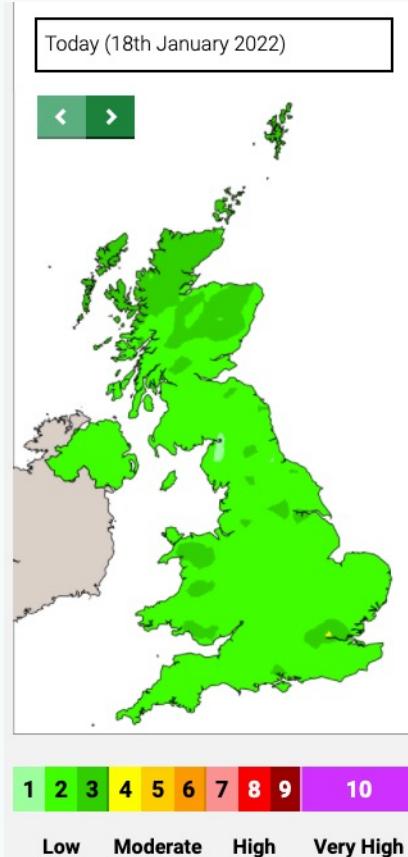
Relevant Concepts & Terminology

UK guidance:

Air pollution banding	Value	Health messages for At-risk individuals
Low	1-3	Enjoy your usual outdoor activities.
Moderate	4-6	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.
High	7-9	Adults and children with lung problems, and adults with heart problems, should reduce strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also reduce physical exertion.
Very High	10	Adults and children with lung problems, adults with heart problems, and older people, should avoid strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.

Air pollution banding	Value	Health messages for General population
Low	1-3	Enjoy your usual outdoor activities.
Moderate	4-6	Enjoy your usual outdoor activities.
High	7-9	Anyone experiencing discomfort such as sore eyes, cough or sore throat should consider reducing activity, particularly outdoors.
Very High	10	Reduce physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

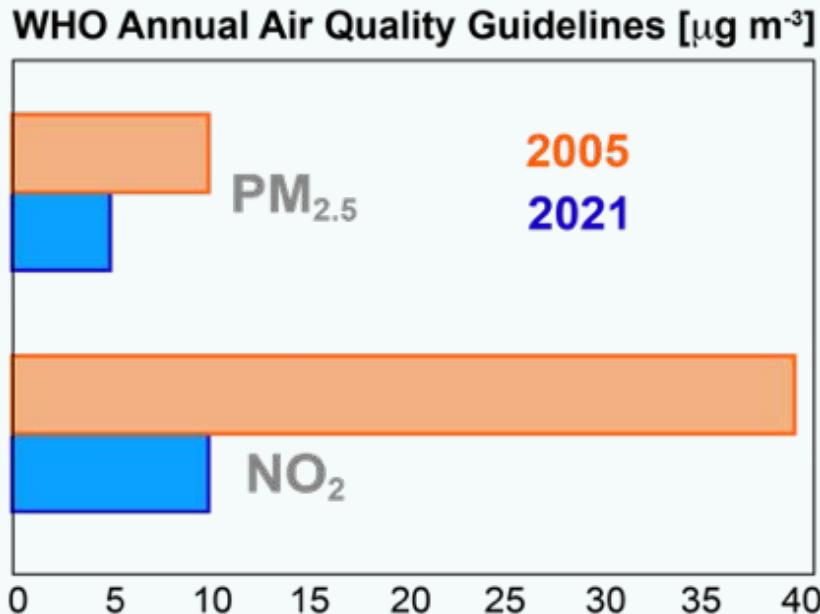
Approaches and guidance for other countries:
https://en.wikipedia.org/wiki/Air_quality_index



Relevant Concepts & Terminology

Air quality guidelines: values offered by reputable organization of experts

World Health Organization (WHO) publishes guidelines informed by research



New guidelines: <https://apps.who.int/iris/handle/10665/345329>



Source: WHO Facebook page

Relevant Concepts & Terminology

Air quality standards: regulated/enforced by local, national or regional authority
Standards often trade-off between what's necessary and what's feasible

UK air quality standards

National air quality objectives and European Directive limit and target values for the protection of human health							
Pollutant	Applies	Objective	Concentration measured as ¹⁰	Date to be achieved by and maintained thereafter	European obligations	Date to be achieved by and maintained thereafter	New or existing
Particles (PM _{2.5}) Exposure Reduction	UK (except Scotland)	25µg.m ⁻³	annual mean	2020	Target value 25µg.m ⁻³ ¹²	2010	New (European obligations still under negotiation)
	Scotland	12µg.m ⁻³		2020	Limit value 25µg.m ⁻³	2015	
	UK urban areas	Target of 15% reduction in concentrations at urban background ¹¹		Between 2010 and 2020	Target of 20% reduction in concentrations at urban background	Between 2010 and 2020	
Nitrogen dioxide	UK	200µg.m ⁻³ not to be exceeded more than 18 times a year	1 hour mean	31 December 2005	200µg.m ⁻³ not to be exceeded more than 18 times a year	1 January 2010	Retain existing
	UK	40µg.m ⁻³	annual mean	31 December 2005	40µg.m ⁻³	1 January 2010	
Ozone	UK	100µg.m ⁻³ not to be exceeded more than 10 times a year	8 hour mean	31 December 2005	Target of 120µg.m ⁻³ not to be exceeded more than 25 times a year averaged over 3 years	31 December 2010	Retain existing

Pollution Sources

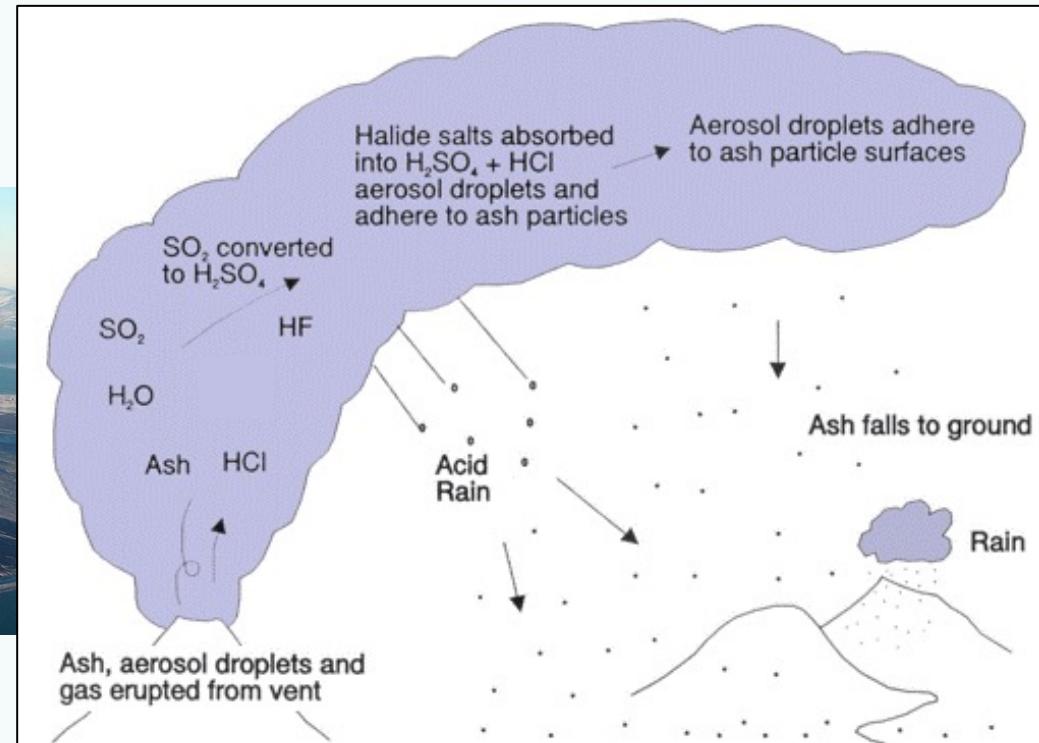
Natural

Volcanoes



Gases: SO_2 , HCl, HF

Aerosols: ash particles

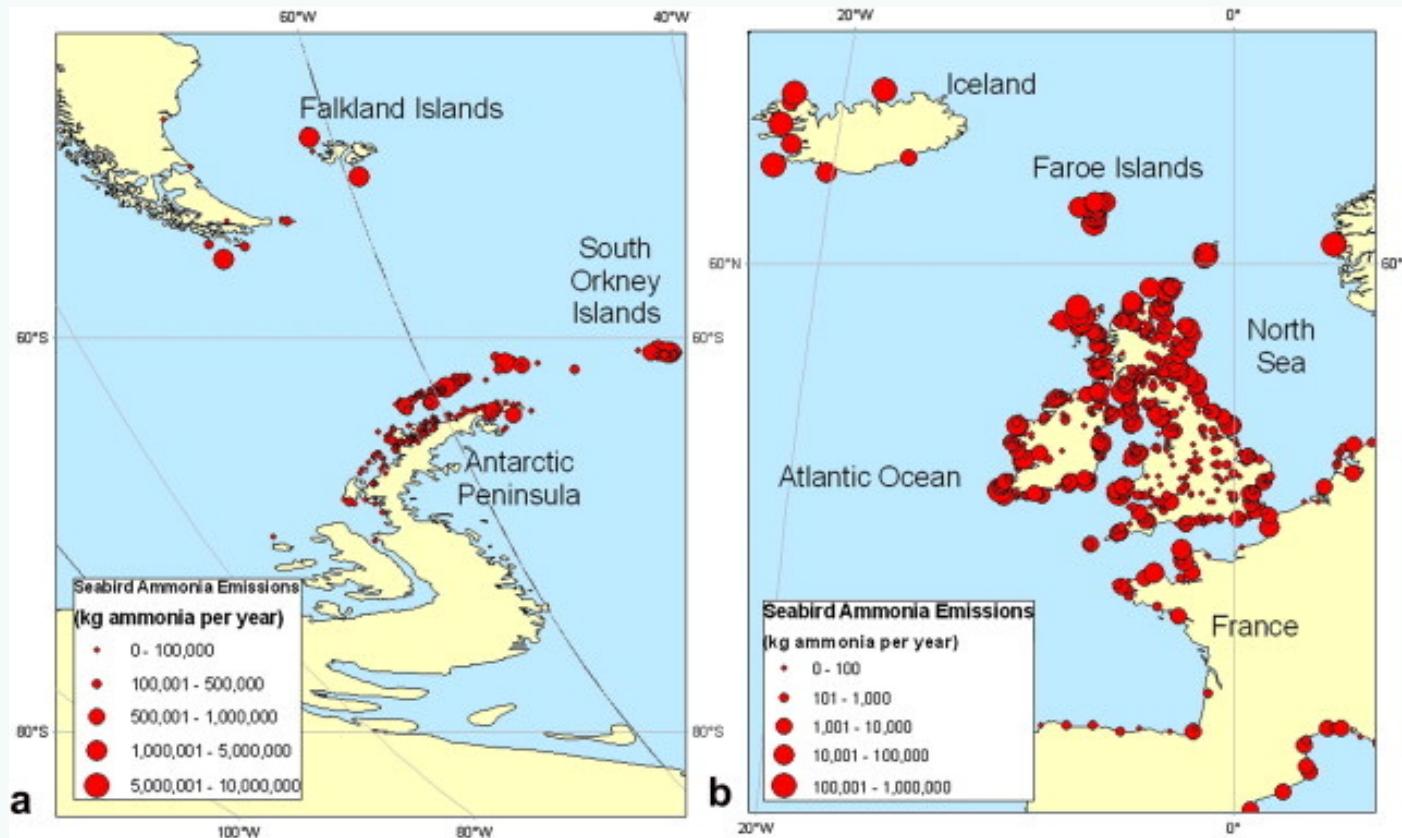


Pollution Sources

Natural

Seabirds

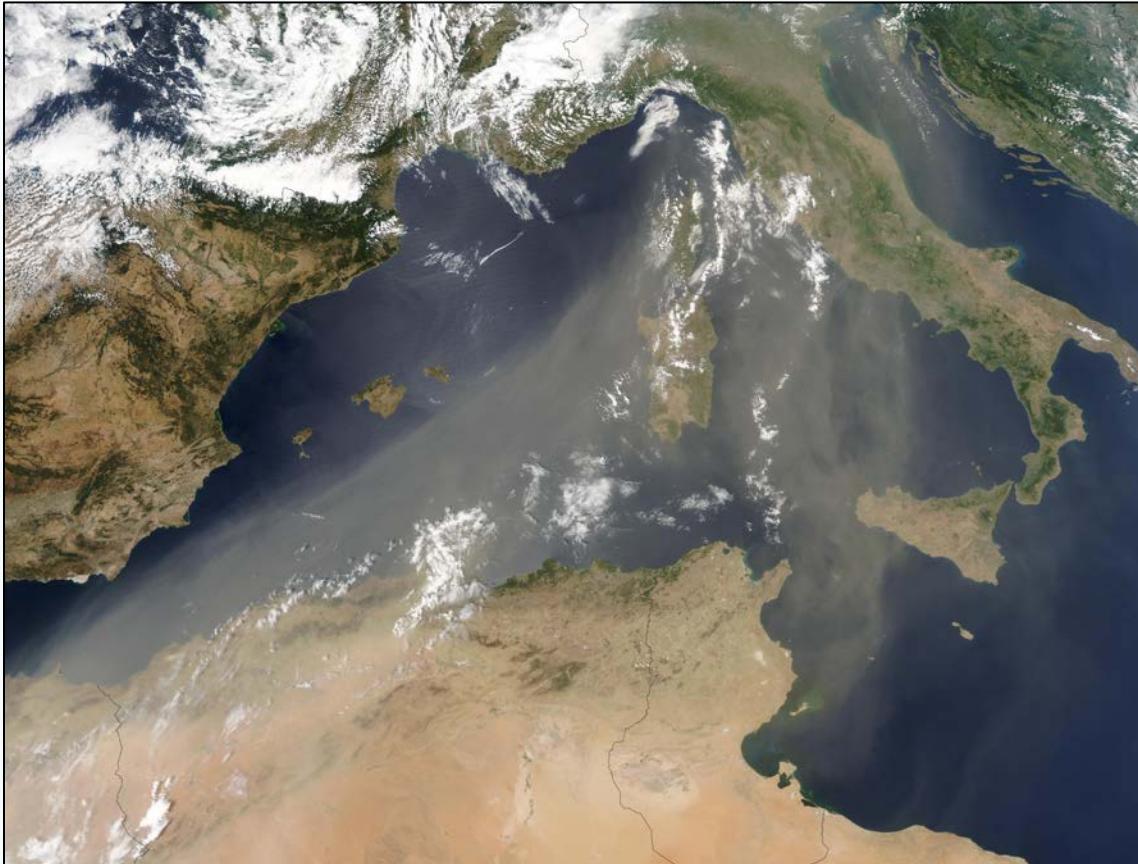
Gas: NH₃



Pollution Sources

Natural

Desert dust

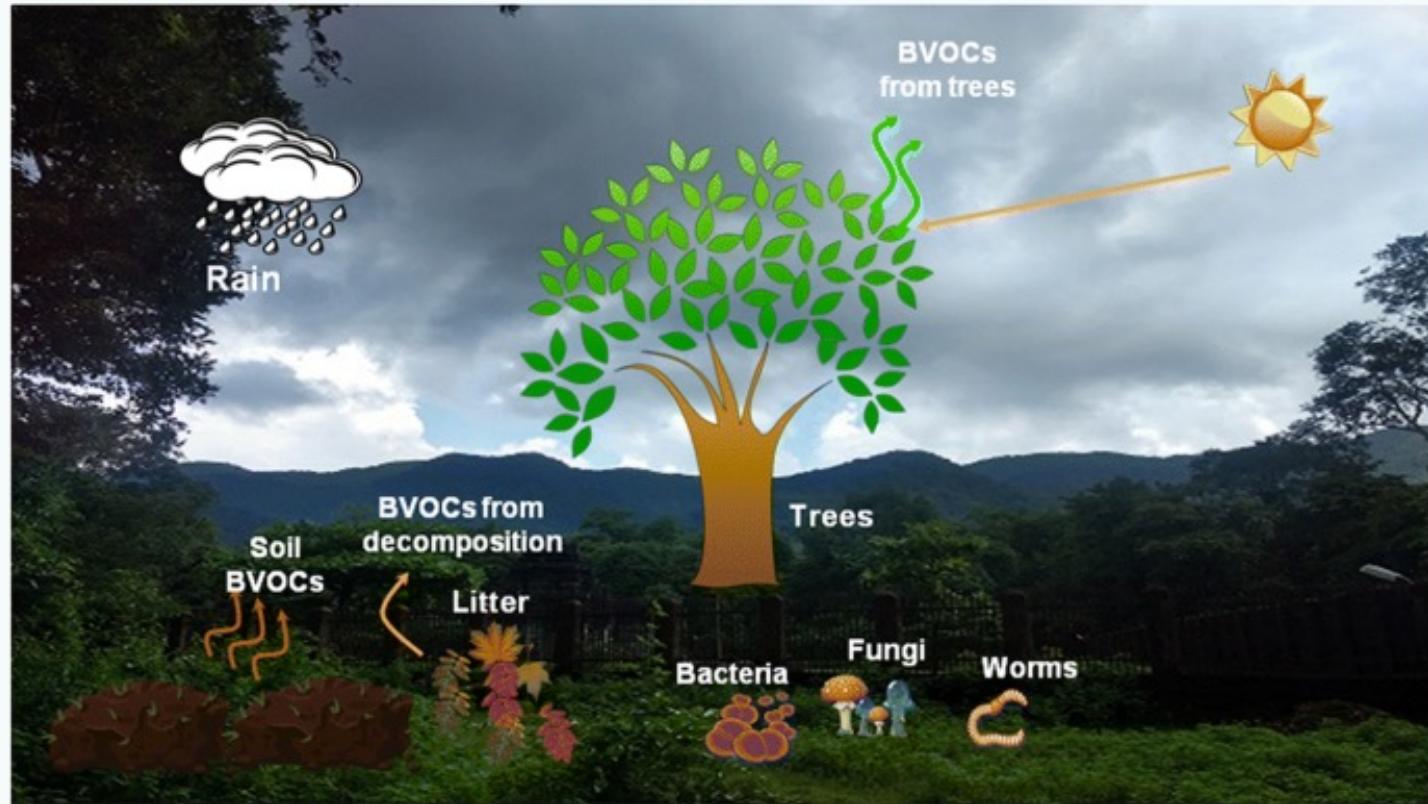


Pollution Sources

Natural

Vegetation

BVOCs:
Biogenic volatile
organic
compounds



Pollution Sources

Anthropogenic

Electricity generation:
Coal, natural gas, wood,
waste, diesel, crude oil



Pollution Sources

Anthropogenic

On- and off-road transportation



Electric cars shift pollution from exhaust to non-exhaust
(tire abrasion, break ware)



Pollution Sources

Anthropogenic

Agriculture



Largest source of gaseous ammonia (NH_3) from fertilizers and dairy and beef cattle

Pollution Sources

Anthropogenic

Household heating
and cooking



Large contributor to ambient pollution in countries with low access to electricity (women and children most impacted)

Pollution Sources

Anthropogenic

Recreational activities



Fireworks emit gases (chlorine or Cl), particles, and toxic metals (Pb, Cr, Mn, Ni)

Pollution Sources

Natural/Anthropogenic

Wildfires, agricultural burning



Smoke includes many types of particles and gases

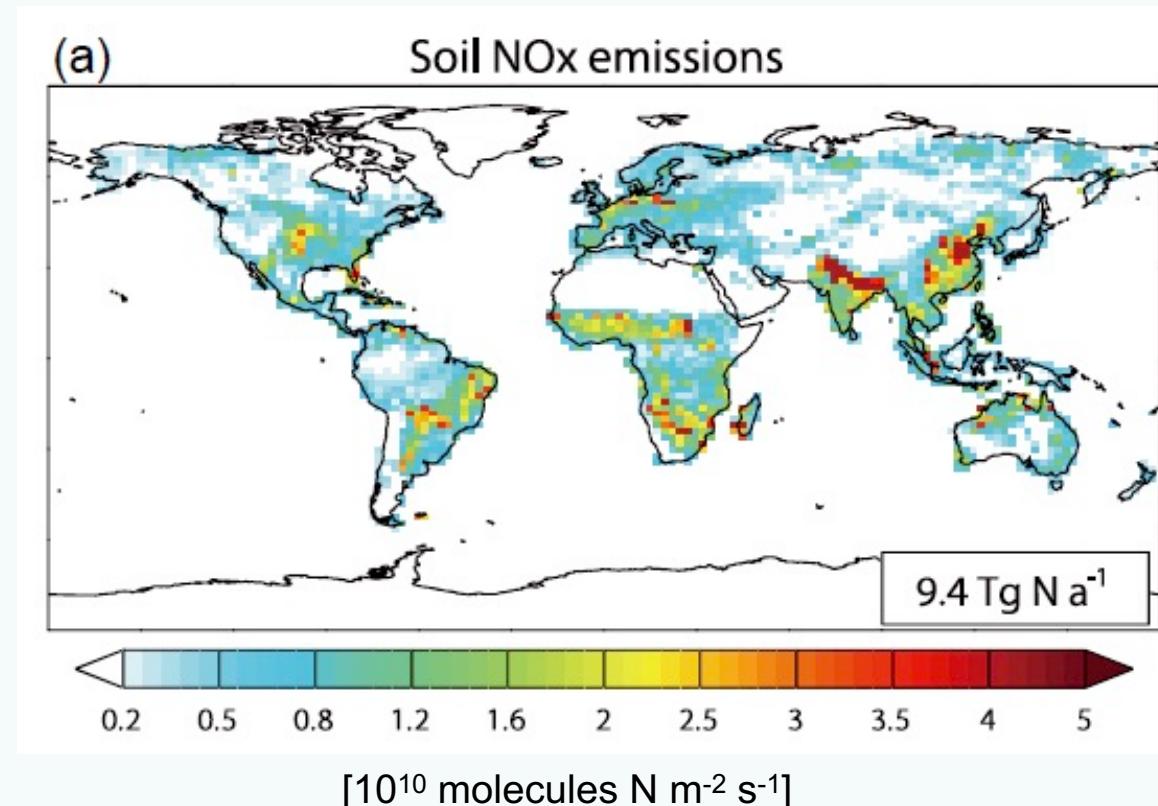


Pollution Sources

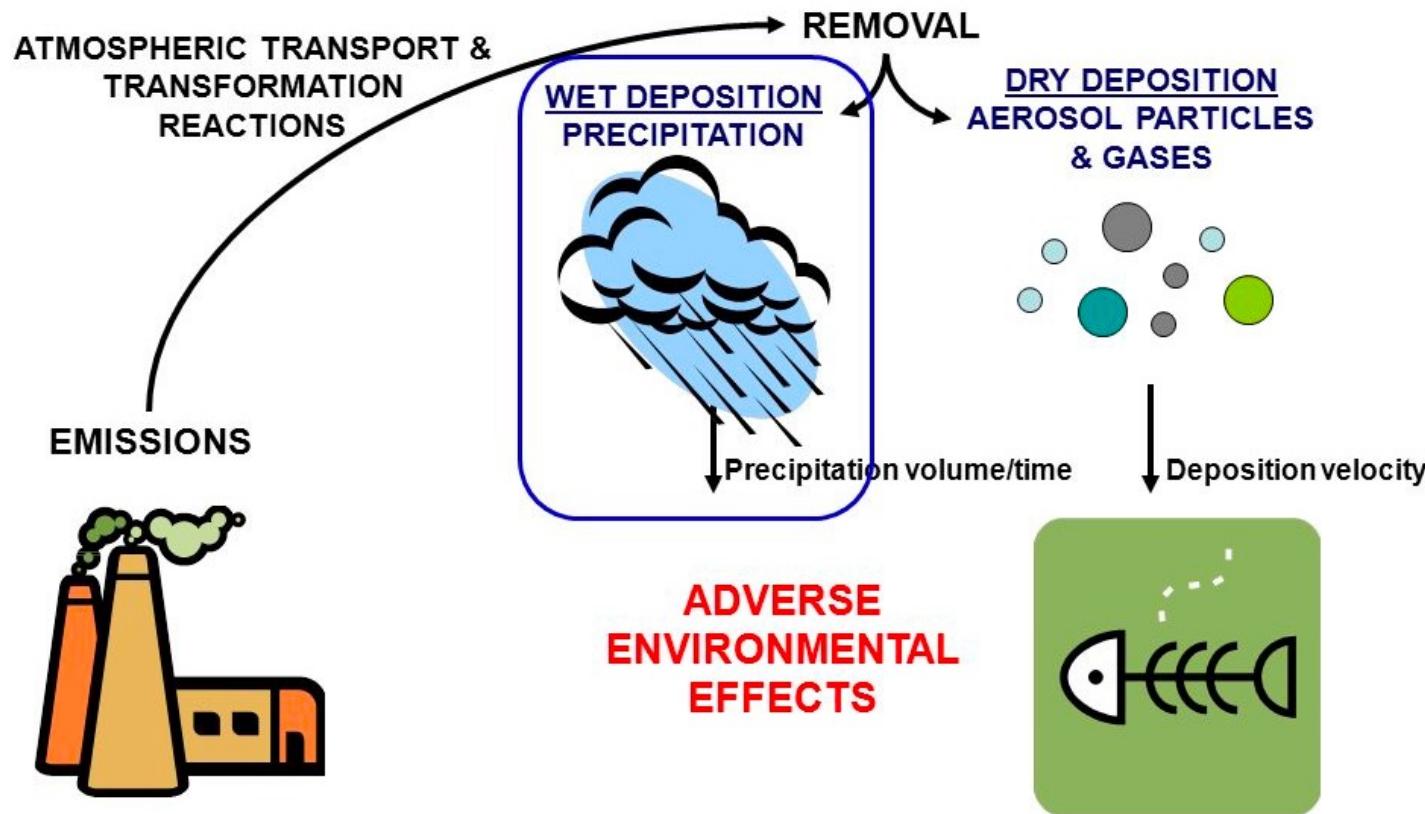
Natural/Anthropogenic

Soils

NO_x
(Nitrogen oxides =
 $\text{NO} + \text{NO}_2$)



Pollution Evolution



Pollution Evolution



Whiteboard example of how ammonia (NH_3) evolves in the atmosphere