

METR/ENVS 113

Lecture 3: Atmospheric Carbon, Nitrogen and Sulfur Cycles

SJSU Fall Semester 2020

Module 1: The Natural, Unpolluted Atmosphere

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From Lecture 1: Composition of Atmosphere

Chemical Species	Concentration	Source
N ₂	78.08%	volcanic, biogenic
O ₂	20.95%	biogenic
H ₂ O (gas)	up to 4% (avg ~2.5%)	volcanic, evaporation
Ar	0.93%	radiogenic
CO ₂	0.037% (370 ppm _v)	volcanic, biogenic, anthropogenic
Ne	18 ppm _v	volcanic (possibly)
He	5.2 ppm _v	radiogenic
Kr	1 ppm _v	radiogenic
CO	50 – 200 ppm _v	biogenic, anthropogenic, photochemical
CH ₄	1.7 ppm _v	biogenic, anthropogenic
NMHC	5 – 20 ppb _v	biogenic, anthropogenic, photochemical
CH ₂ O	0.1 ppb _v	photochemical
N ₂ O	310 ppb _v	biogenic, anthropogenic
NH ₃	0 – 0.5 ppb _v	biogenic, anthropogenic
NO _x	0 – 0.5 ppb _v	biogenic, anthropogenic, lightning
OCS	0.5 ppb _v	volcanic, biogenic, anthropogenic
H ₂ S	0 – 0.5 ppb _v	biogenic, anthropogenic
SO ₂	0.01 – 1 ppb _v	volcanic, anthropogenic, photochemical
DMS	0.01 – 0.1 ppb _v	biogenic

Nitrogen (N₂) and Oxygen (O₂): 99% of Dry Atmosphere
Water Vapor (H₂O): 1 – 4%

Carbon Dioxide (CO₂) – Greenhouse Gas (GHG)

Ar, Ne, He, Kr – “Inert Gases” (non-reactive)

Carbon Monoxide (CO) – From combustion, air pollutant

Methane (CH₄) – Strong GHG

“Non-Methane” Hydrocarbons (NMHC); a class of air pollutants

Ammonia (NH₃) – An air pollutant, industry & agriculture

Nitrogen Oxides (NO_x) – From combustion, an air pollutant

Hydrogen Sulfide (H₂S) – An air pollutant, rotten egg smell

Sulfur Dioxide (SO₂) – From coal combustion, an air pollutant

Nitrogen Dioxide (NO₂)

Unknown city ...



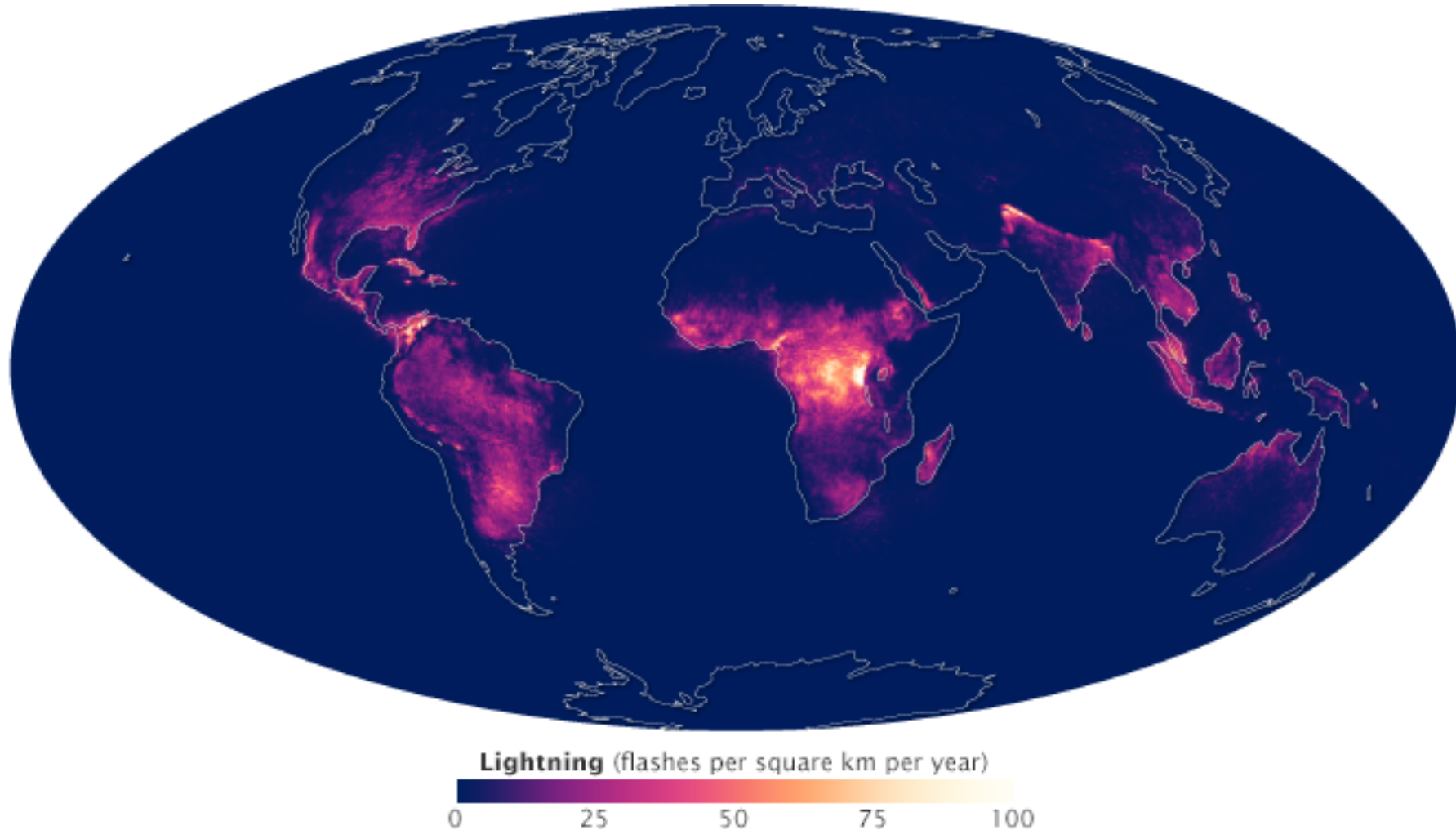
Los Angeles



NO₂ absorbs violet/blue sunlight, remaining colors filter through ... brownish

A natural source of NO₂: Lightning Strokes

(1995 – 2011, flashes per square km per year)

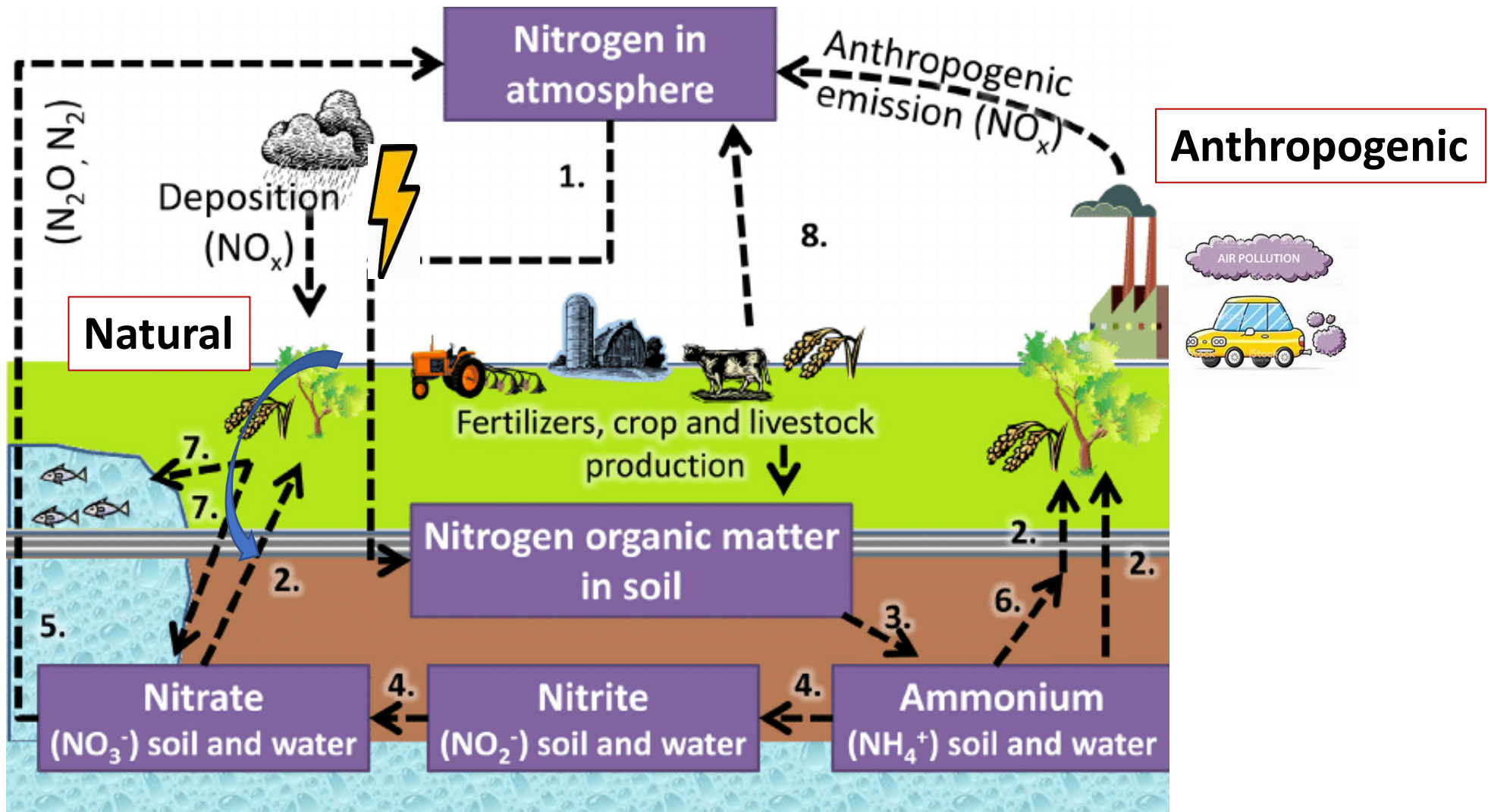


Outline

- Nitrogen Cycle
- Sulfur Cycle
- Carbon Cycle
- Natural, Background Concentration Levels (absent air pollution)

Nitrogen Cycle

Atmosphere
(primarily N₂)



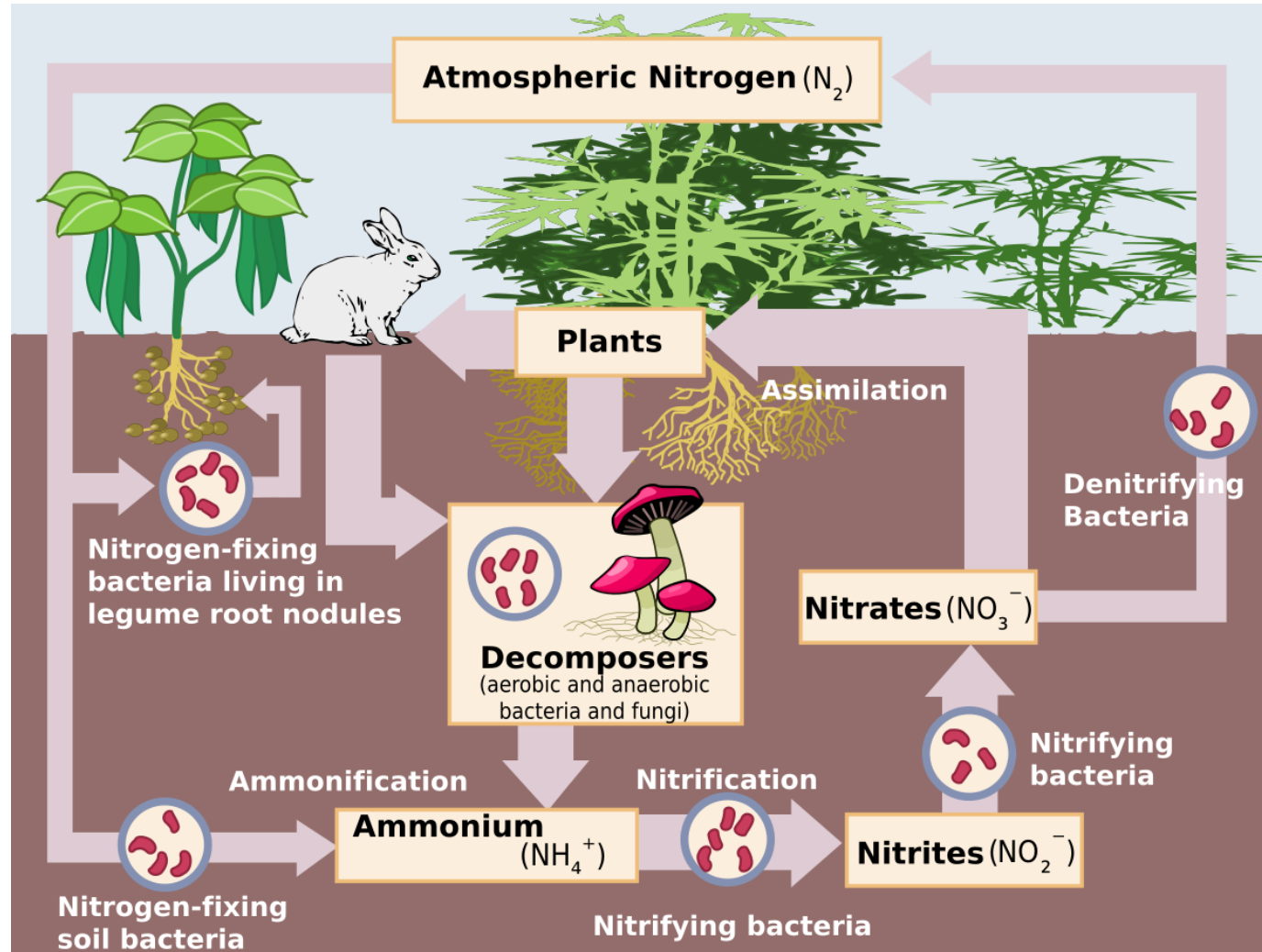
Soil / Earth / Plants

("Fixated" nitrogen, bio-available)

(nitric acid (HNO₃), ammonia (NH₃), nitrites, nitrates, ammonium ions for plant uptake)

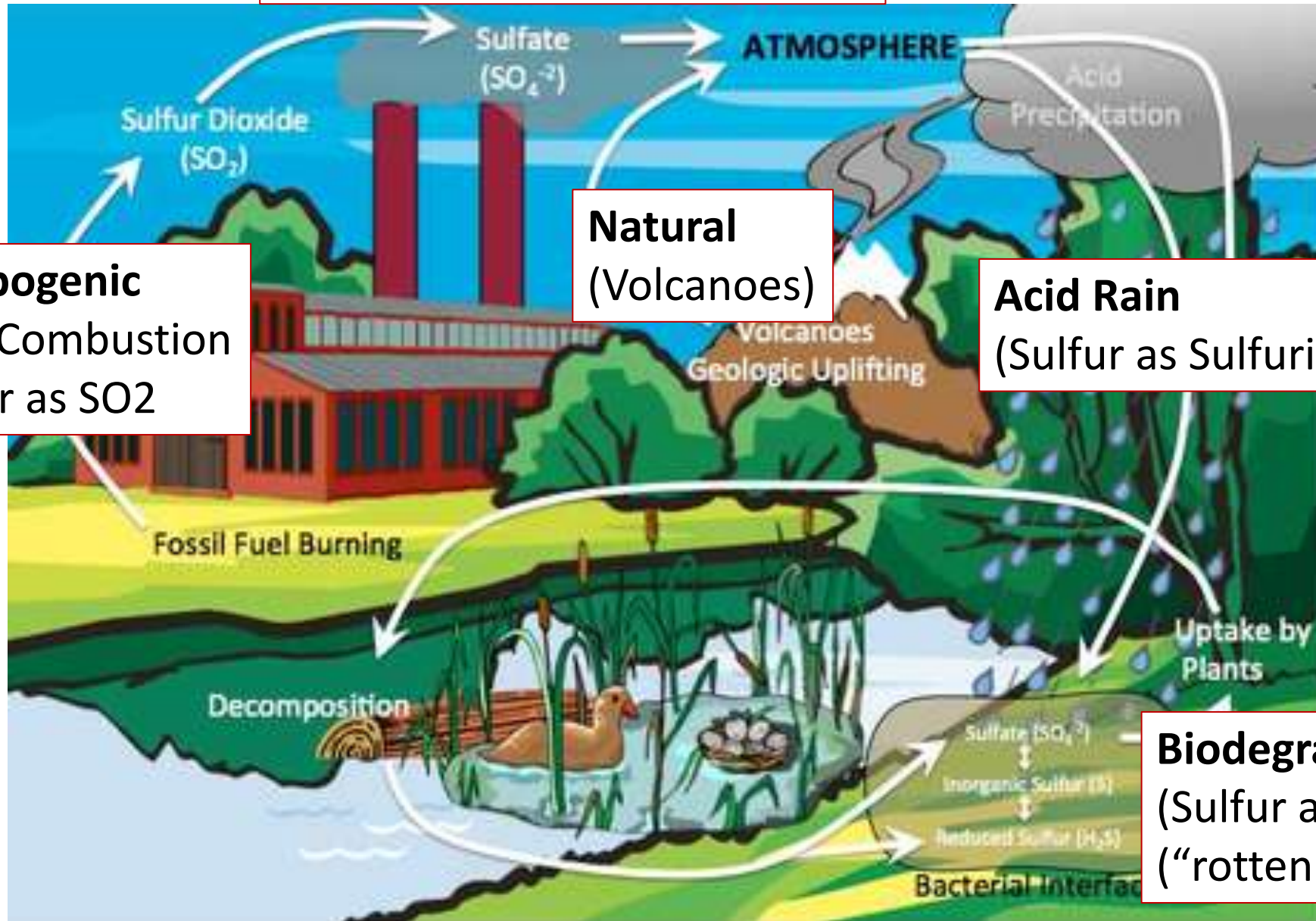
Nitrogen Fixation (2)

(Fixed Nitrogen -> Nitrogen Ionic Compounds for Plant Uptake)
(NO_2 & HNO_3 -> Nitrites, Nitrates, Ammonium)



Sulfur Cycle

Formation of sulfate particles



Anthropogenic

- Coal Combustion
- Sulfur as SO_2

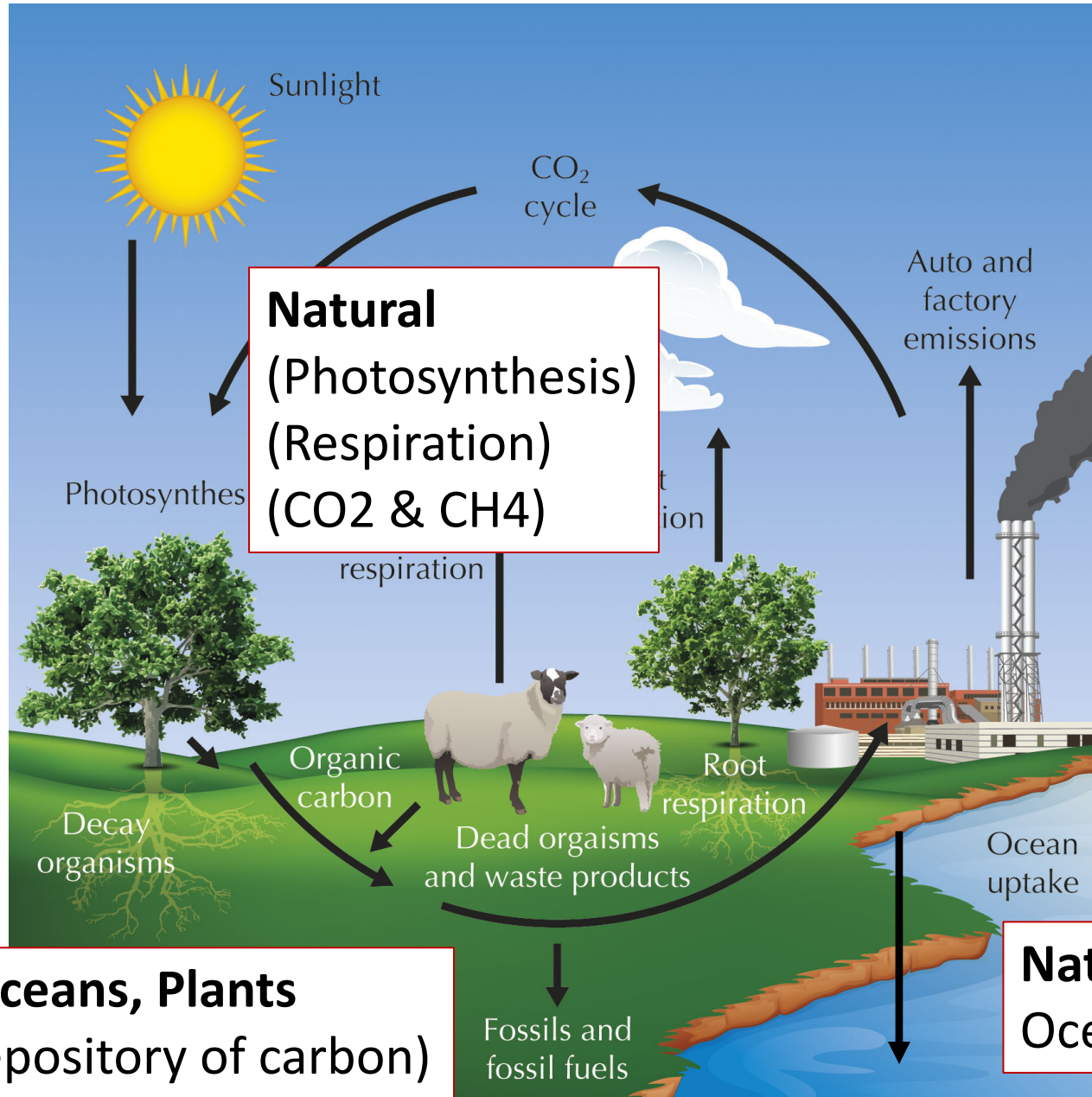
Natural (Volcanoes)

Acid Rain

(Sulfur as Sulfuric Acid, H_2SO_4)

Biodegradation
(Sulfur as H_2S)
("rotten egg smell")

Carbon Cycle



Anthropogenic Fossil Fuel Combustion

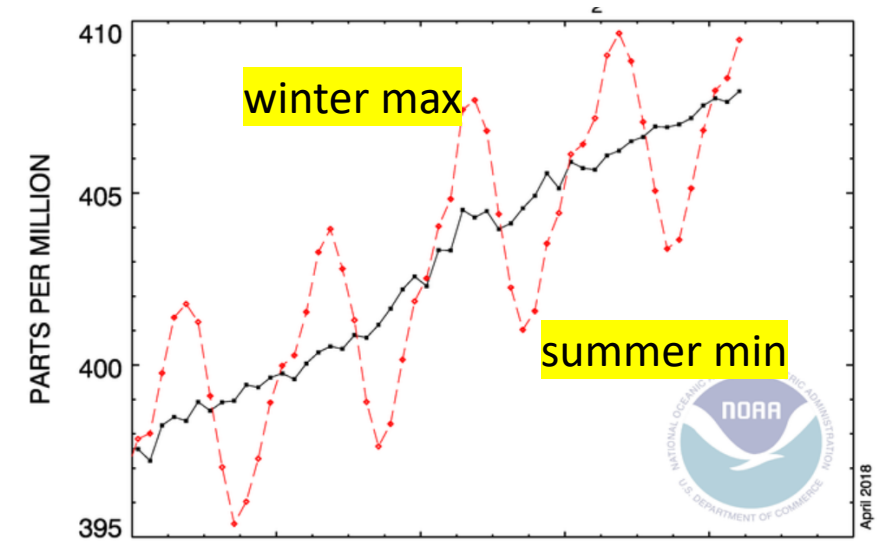
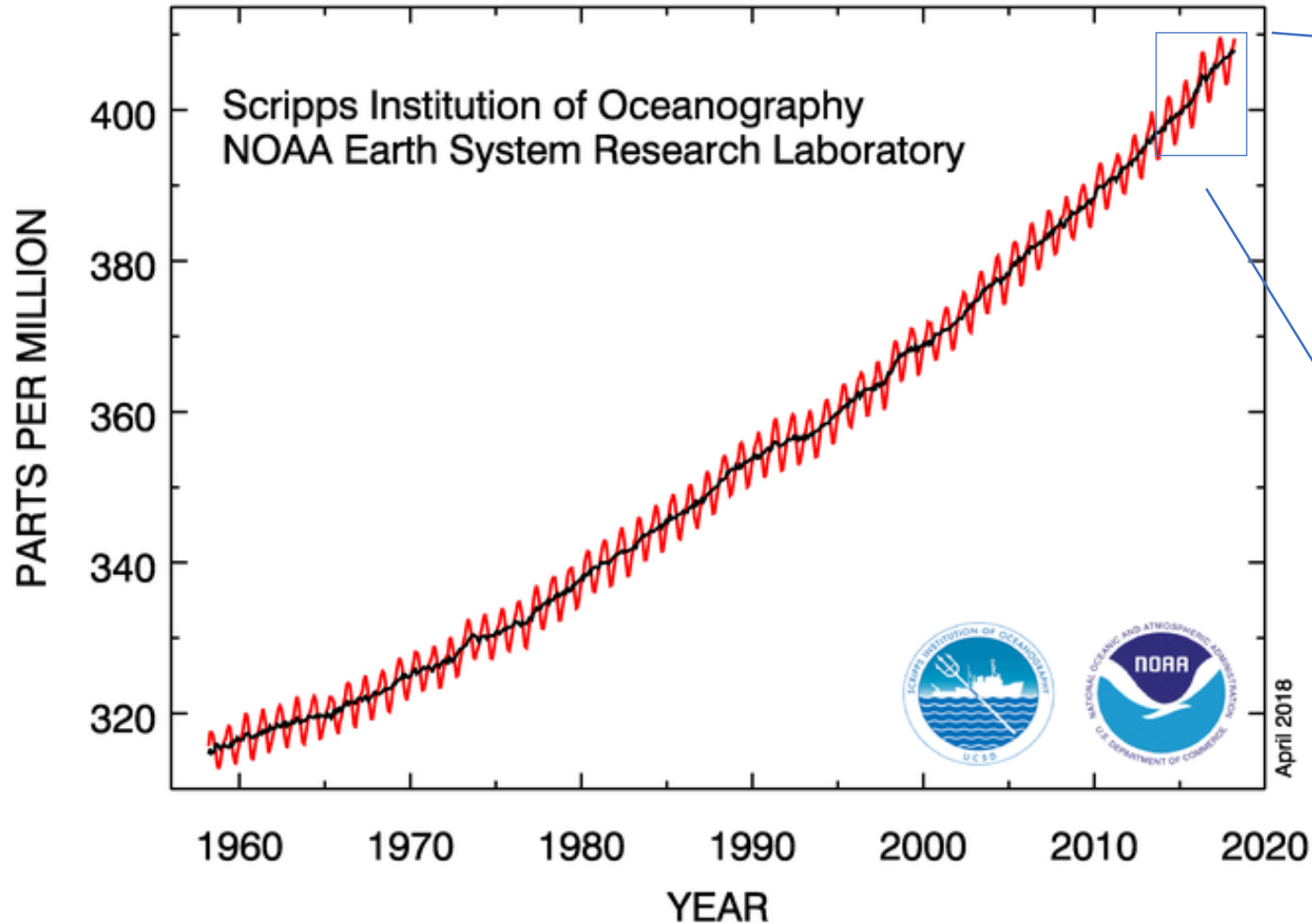
- Carbon released to air mainly as Carbon Dioxide - CO₂
- Other compounds:
 - Carbon Monoxide (CO)
 - Smoke Particles
 - Hydrocarbon Gases

Natural Background Concentrations in Air

(Current-Day, remote Areas ... away from major air pollution sources)

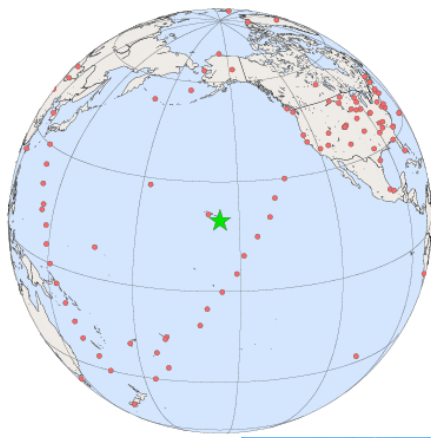
Pollutant	Natural Background Concentrations	Source
Carbon Dioxide (CO ₂)	410 ppm	Mauna Loa (Hawaii) https://www.esrl.noaa.gov/gmd/ccgg/trends/
Carbon Monoxide (CO)	50 – 120 ppb	http://www.euro.who.int/_data/assets/pdf_file/0020/123059/AQG2ndEd_5_5carbonmonoxide.PDF
Nitrogen Dioxide (NO ₂)	0.2 – 5 ppb	http://www.euro.who.int/_data/assets/pdf_file/0017/123083/AQG2ndEd_7_1nitrogendioxide.pdf
Sulfur Dioxide (SO ₂)	< 1 ppb	http://www.temis.nl/products/so2.html

Atmospheric CO₂ at Mauna Loa Observatory



CO₂ drops in spring; lowest value in summer
Photosynthetic CO₂ removal from atmosphere during spring and summer plant growing season

CO₂ rises in fall; highest value in winter
Plant growing season ends, plant respiration and biomass decay releases CO₂ to air.



Mauna Loa Observatory

North Slope
Of Mauna Loa
Volcano.

~ 11,000 ft ASL

Atmospheric CO₂ measurements
since mid- 1950s

<https://www.esrl.noaa.gov/gmd/ccgg/trends/>

