

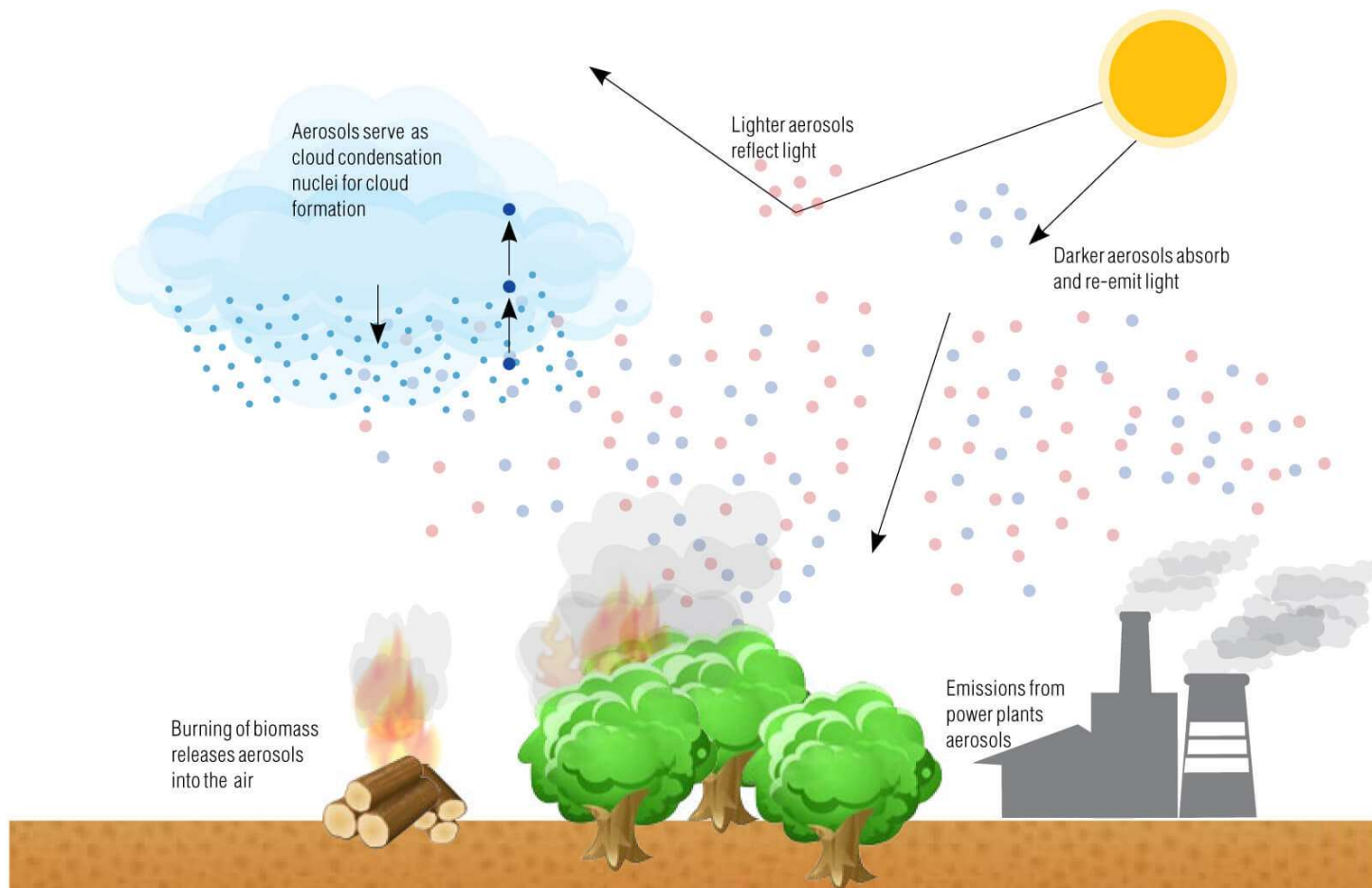
# Climate Change And Its Implications (CCI)

**Dr. Raji P**

**Lecture-6**



# Aerosols

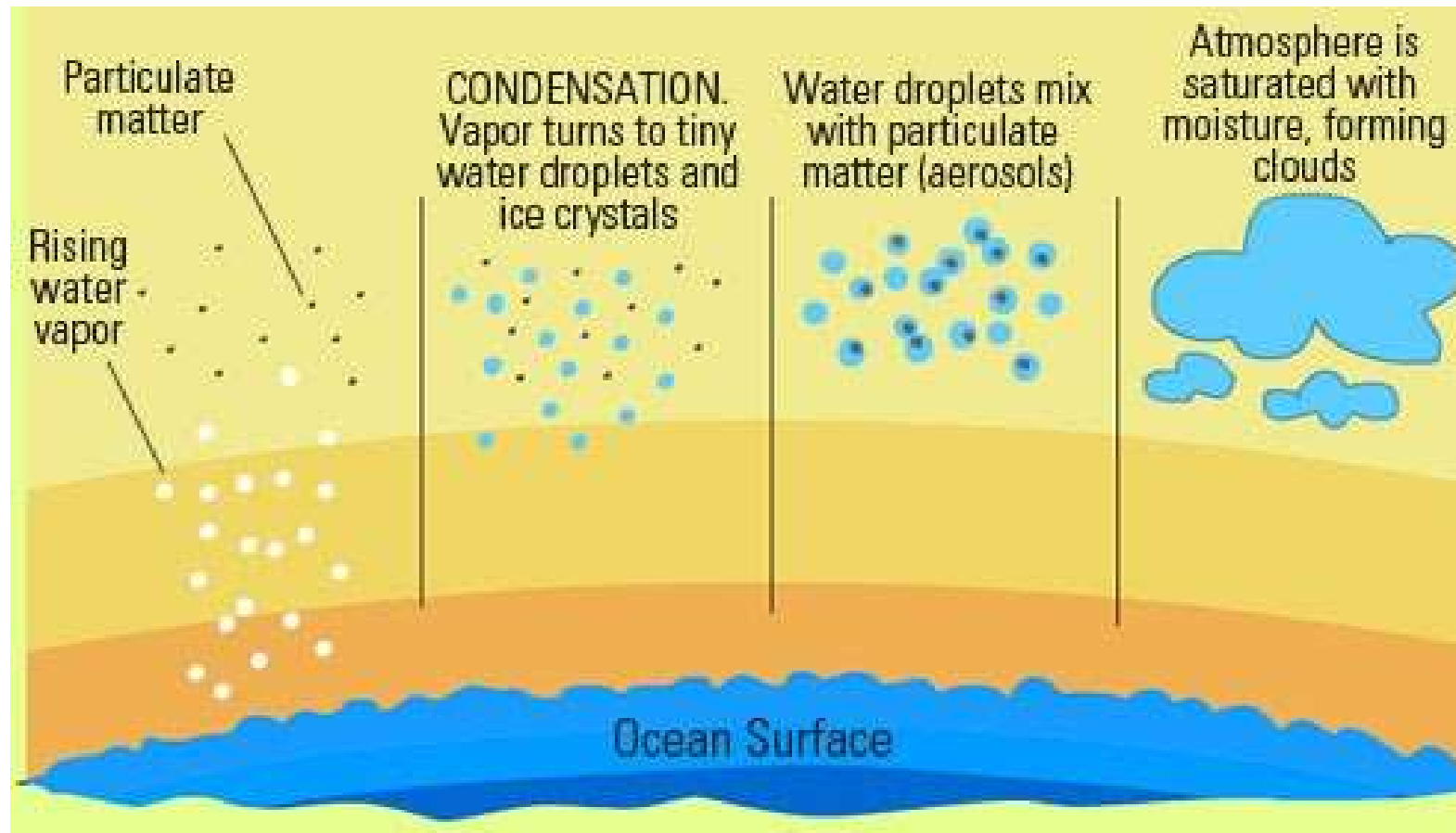


## What are aerosols?

- Aerosols/particulates are microscopic particles of solid or liquid matter suspended in the air/gas
- Aerosols occur in both the troposphere and the stratosphere, but there are considerable differences in the size ranges, chemical nature and sources of the aerosols
- Aerosol is to be stable for few seconds to several months
- Aerosol includes particles size: 0.002 to more than 100 $\mu$ m

How aerosols are useful?

# Cloud formation



- Aerosols have important consequences for global climate, ecosystem processes, and human health
- Aerosols affect the earth-atmosphere radiation budget and leads to
  - ✓ Direct effects - scattering and absorption of solar radiation
  - ✓ Indirect effects - changes in cloud characteristics



Dust



Fog



Mist



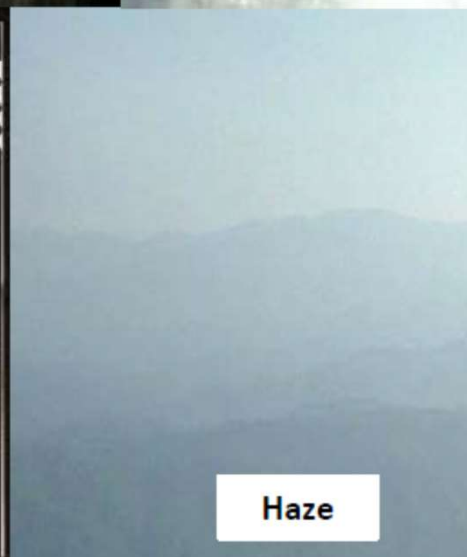
Cloud Droplets



Smog



Smoke



Haze



## Forms of aerosols

**Dust:** Solid particles formed by mechanical breakage of parent materials or crushing (size  $>1\mu\text{m}$ )

**Fumes:** Particles formed by condensation or chemical reaction ( $<1\mu\text{m}$ )

**Fog:** Suspension of water droplets (2 to 15  $\mu\text{m}$ )

**Mist:** Suspension of droplets and they affect visibility  $>1\text{ km}$  ( $<0.5\text{ }\mu\text{m}$ )

**Smog:** Consists of solid and liquid particles formed by the presence of sunlight and vapour (0.3-1.0  $\mu\text{m}$ )

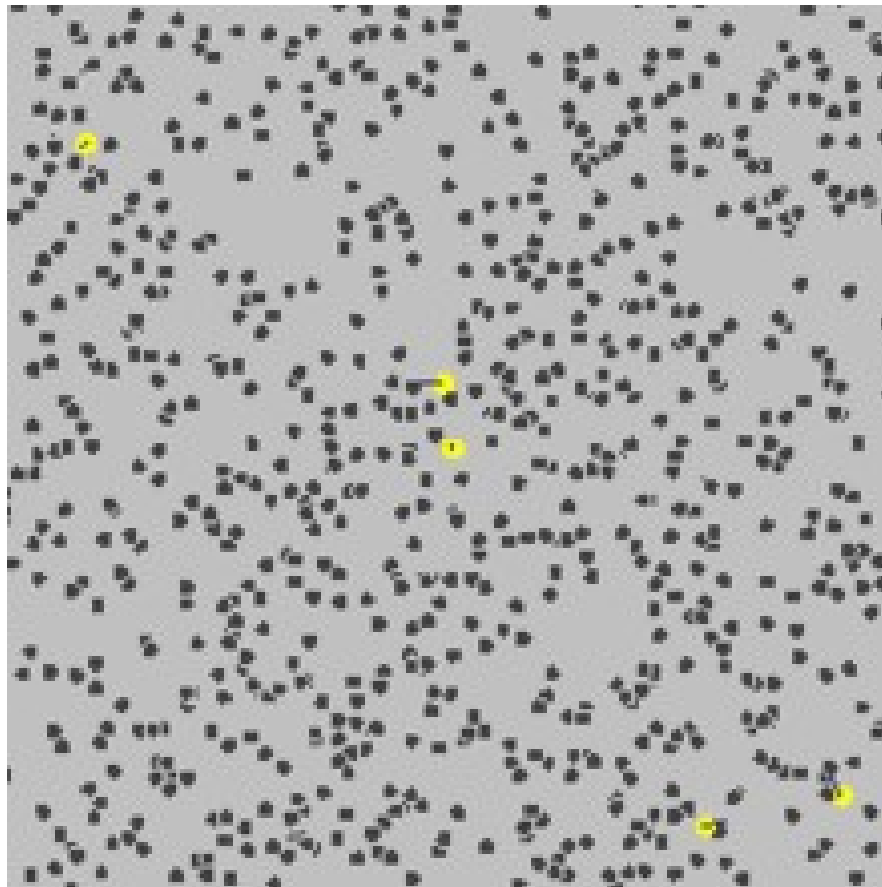
**Smoke:** Visible aerosol from incomplete combustion ( $<1\mu\text{m}$ )

**Cloud:** Visible aerosol with defined boundaries

**Haze:** Visibility reducing aerosol with fine suspended particles (0.02 to 0.06  $\mu\text{m}$ )

- Aerosol concentration varies from place to place, and also varies with height
- The total concentration of aerosol particles in the lower atmosphere is maximum near the surface and it decreases with height (altitude)

# Brownian coagulation



- Most aerosol particles are much smaller than cloud droplets and can be influenced easily by the constant bombardment of air molecules and perform random motions called **Brownian motion**
- Brownian motion is especially pronounced for particles  $<0.5 \mu\text{m}$  because of their small size, and they can collide and coagulate to form larger particles

# **Aging of aerosols**

# Types of aerosols based on source

Primary: They directly reaches to the atmosphere (wind action, burning etc)

Secondary: Forms from the atmosphere itself- Gas to particle conversion (GPC) and drop to particle conversion (DPC)

Major sources of aerosols from the Earth surface



# Dust storms

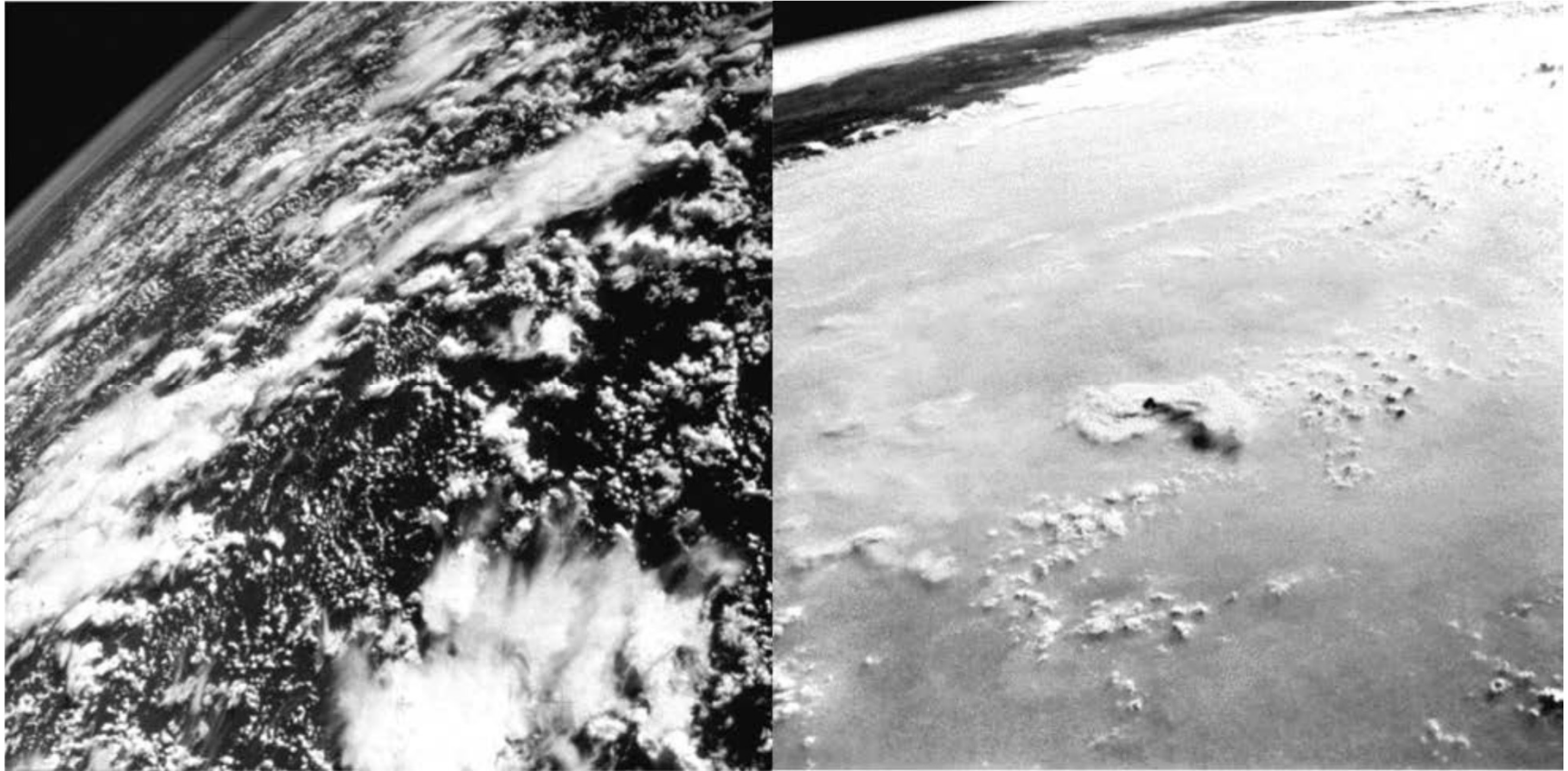


- A dust storm (sandstorm) is a meteorological phenomenon common in arid and semi-arid regions
- Dusts can travel thousands of kilometers and inject a huge number of aerosol particles into the atmosphere
- Clay particles such as  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{MgO}$

# Biomass burning



- Natural or man-made fires that destroy large areas of forests and other vegetated surfaces – Biomass burning
- Large-scale biomass burning can cause significant changes in **local albedo** (will increase)



Satellite images of the Amazon basin area during (left) a day with no biomass burning and (right) a day with massive biomass burning (Source: NASA)

- The air became opaque due to strong reflection of sunlight by fire-produced aerosol particles
- The local albedo will increase dramatically

- Biomass burning particles are efficient cloud condensation nuclei and hence they have great impact on the global climate process through their cloud formation ability
- Biomass burning particles can travel a long range, and thus may have a far greater impact on the global climate

# Will aerosol travel from Tropics to Antarctica?

- Biomass burning particles have been collected in Antarctica and their origin is in central Brazil (Amazon basin), a tropical region (Fiebig et al., 2009)
- Detection of aerosols in Antarctica From Long-Range Transport of the Australian Wildfires in 2009 (Jumelet et al., 2020)
- Tropical biomass burning particles, and whatever climatic implications they have, can reach the polar regions in a short time

# Volcanic activity



Eruption of Mt. Pinatubo, Philippines on 12 June 1991

- The volcanic eruption was a near-vertical one and the plumes reached the stratosphere (up to 24 km)
- They inject directly into the atmosphere not only aerosol particles but a large amount of other gases as well
- The most abundant volcanic gas turns out to be water vapor, followed by  $\text{CO}_2$  and  $\text{SO}_2$
- Among these gases,  $\text{SO}_2$  is the precursor for the formation of sulfate aerosols

- In the Mt. Pinatubo eruption,  $\text{SO}_2$  injection is estimated at more than  $2 \times 10^7$  tons
- Pure sulfates and nitrates reflect nearly all radiation they encounter, **cooling the atmosphere**
- **Black carbon** absorbs radiation readily, **warming** the atmosphere but also shading the surface



# Human industrial activity



- Aerosol particles from by burning fuels (wood, coal, etc.) to obtain energy-produces smoke
- The most conspicuous particle sources due to industry are the thick smoke coming out of numerous tall stacks in the world's industrial complexes
- The most common outputs from these stacks are **sulfates** and **black carbon**
- $\text{SO}_2$  produced by burning fossil fuels is a common precursor that usually ends up as sulfate particles through DPC or GPC



- Another familiar aerosol production due to human activity is the photochemical **smog in big cities**
- This is mainly due to high automobile traffic volumes that produce large amounts of nitrogen oxides, which, in the presence of sunlight, produce ozone, several radicals, and some stable products

# Ocean surface process

## Ocean surface process



- Aerosol particles produced over the ocean surface are largely NaCl particles, smaller amounts of  $K^+$ ,  $Mg^{2+}$ ,  $CO_3^{2-}$  ; and  $SO_4^{2-}$ , organic and biological materials
- The production of sea salt particles is due to the bubble burst mechanism (also called sea spray mechanism)

- The sea surface is constantly subject to winds, air is trapped in the surface layer to form bubbles
- Some of these droplets eventually evaporate to leave dry sea salt particles that may be carried up higher by winds

# Biogenic aerosol

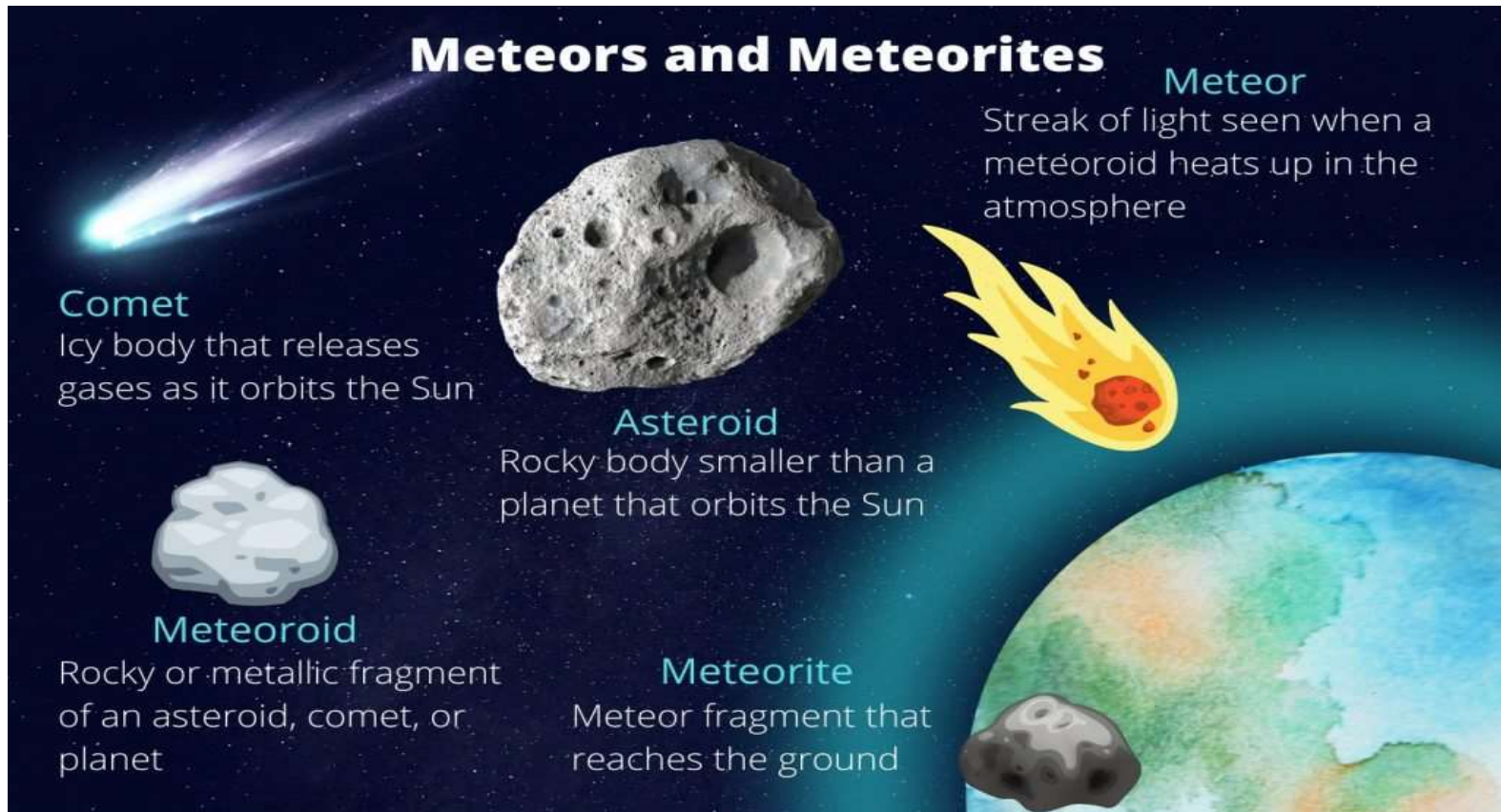
- Aerosol particles are produced by biological systems during their life cycle and plants are the main source of these biogenic aerosols
- Pollens released by the flowers of various plants are spread in the air during pollination to become aerosol particles
- They are typically about 10  $\mu\text{m}$  or larger in size
- Some of these biogenic aerosol particles may serve as efficient nuclei for condensation and freezing



- Measurements in the Amazon basin by Pöschl et al. (2010) showed that sub-micrometer biogenic aerosol particles are the main cloud condensation nuclei during the wet season in contrast to the dry season, when the biomass burning particles dominate the condensation



# Natural Sources - Extraterrestrial sources



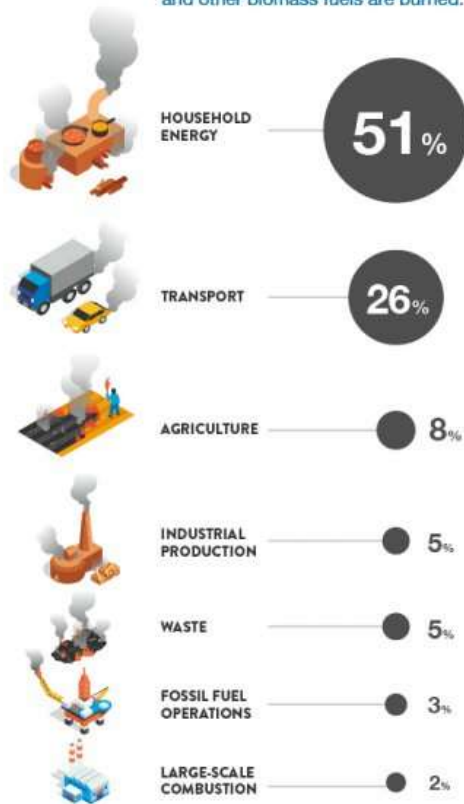
- The Earth's atmosphere is constantly bombarded by meteoroids, which are basically rocks of various sizes
- Some are larger than a few centimeters but most are probably just of dust particle size
- These rocks are widely distributed in the interplanetary space in the Solar System and are attracted to the Earth by the gravitational force if their orbits happen to intercept that of the Earth
- Meteoric aerosols are known to contain elements such as Fe, Si, Mg, S, Ca, Ni, Al, Cr, Mn, Cl, K, Ti, and Co

Black carbon

# BLACK CARBON (BC)

## SOURCES

Black carbon is one of many particles and gases that are emitted when diesel, coal, and other biomass fuels are burned.



Black carbon, or soot, is part of fine particulate air pollution ( $PM_{2.5}$ ) and contributes to climate change.

## IMPACTS

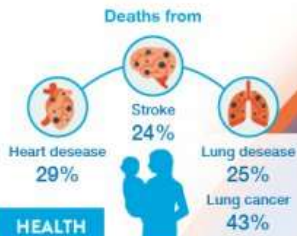
### CLIMATE



Absorbs sunlight and converts it to heat

### LIFETIME IN ATMOSPHERE: UP TO 2 WEEKS

Since black carbon does not last long in the atmosphere, efforts to reduce it will bring immediate benefits for the climate and human health.



### HEALTH

7 million pollution-related deaths every year

### WEATHER

- Prevents clouds from being formed
- Alters regional weather patterns and rainfall

### SNOW & ICE

Accelerates the melting of snow and ice

### AGRICULTURE & ECOSYSTEMS

- Reduces sunlight
- Affects plant health and productivity

- Aerosol BC is released from the incomplete combustion of fossil fuels, bio-fuels and biomass
- It exerts considerable influence on regional precipitation and surface cooling, northern hemispheric tropical expansion, Arabian Sea tropical cyclones and the hydrological cycle in general
- Among aerosol chemical constituents, black carbon (BC) is the most potent climate forcing agent ~65% of that of CO<sub>2</sub>

- India is the 2<sup>nd</sup> largest emitter of BC in the world, with emissions projected to rise steadily in the coming decades
- Unlike developed economies (USA, UK and Europe) where aerosol BC is predominantly sourced from on-road and off-road diesel engines
- Indian BC emissions are from low efficiency combustion of domestic fuels followed by industrial emissions