Visualizing Environmental Science

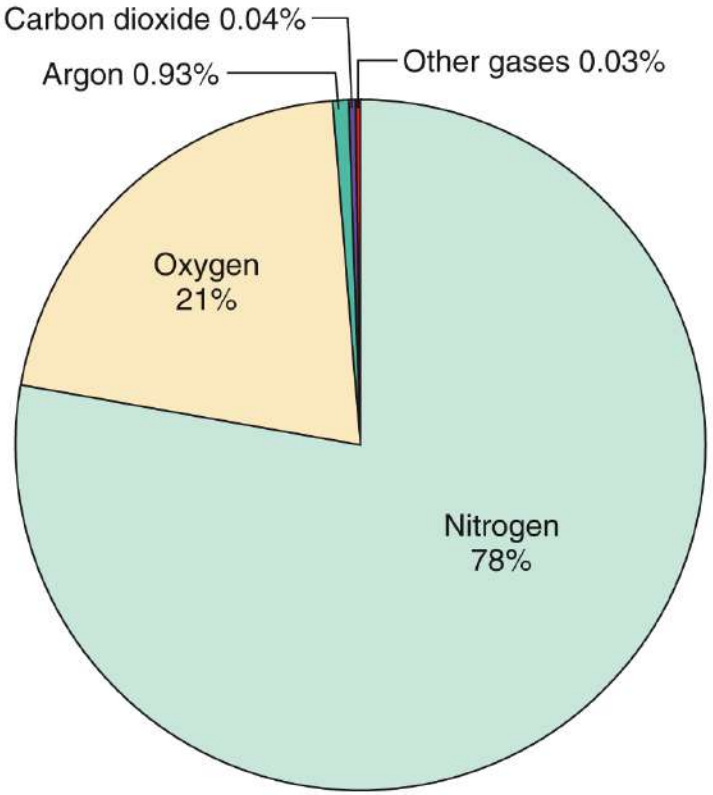
Air and Air Pollution

Chapter 8

Norbert Rosing/National Geographic Creative

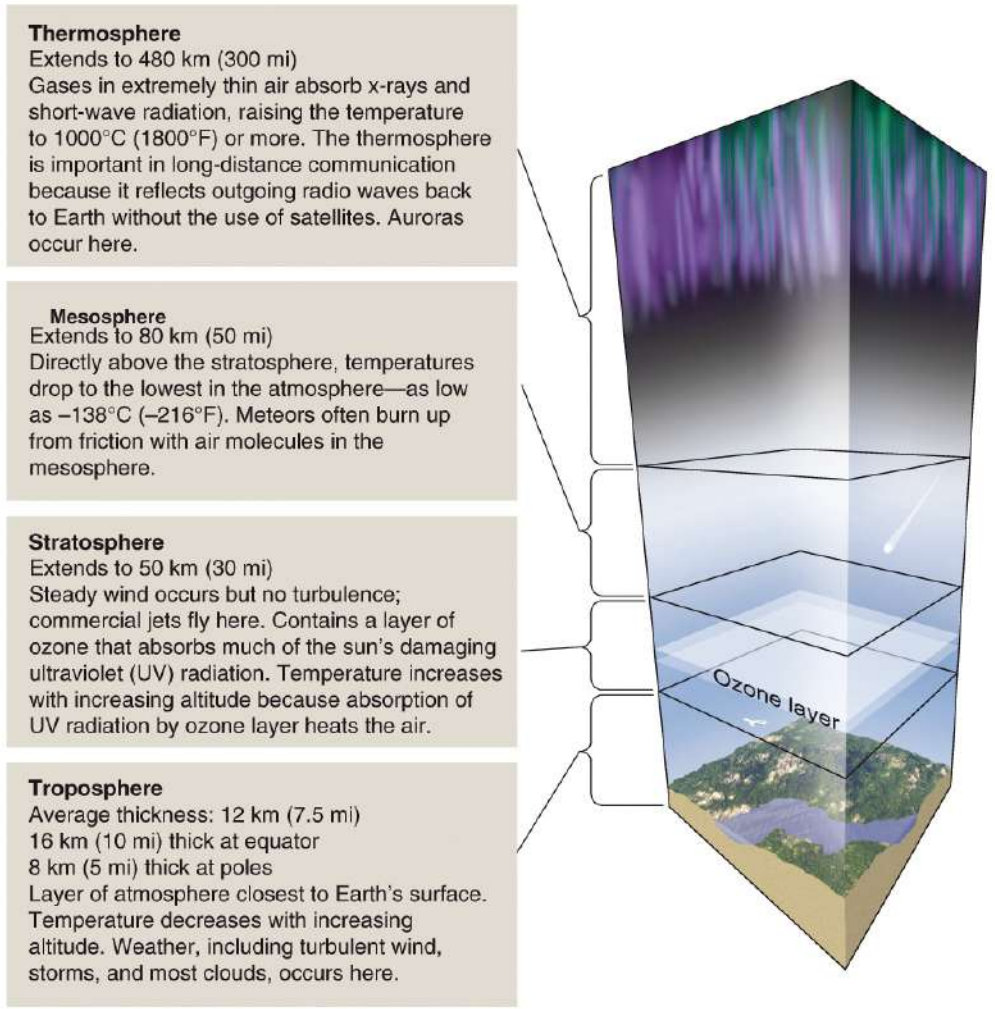
The Atmosphere

- Atmosphere
  - Gaseous envelope surrounding Earth
- Composed of:
  - 78% nitrogen
  - 21% oxygen
  - 0.04% carbon dioxide
  - 0.93% argon
  - 0.03% other gases
  - Water vapor and trace amounts of air pollutants
- The atmosphere becomes less dense as it extends outward into space



The Atmosphere

- The atmosphere is composed of four concentric layers
  - Troposphere
  - Stratosphere
  - Mesosphere
  - Thermosphere
- These layers vary in altitude and temperature, depending on latitude and season

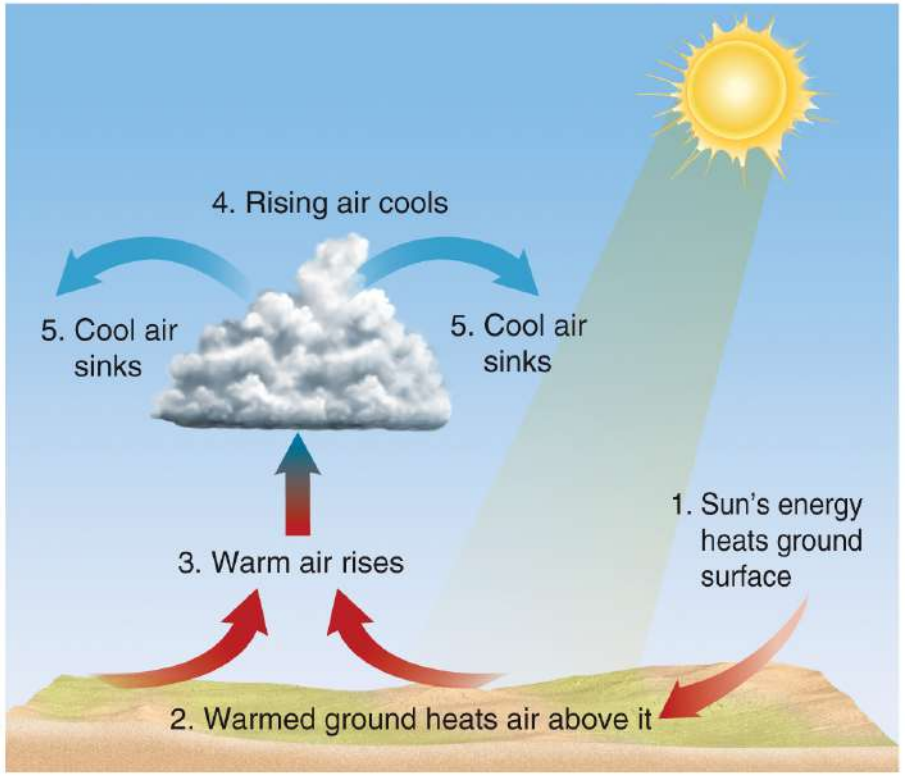


The Atmosphere

- The atmosphere performs several *ecosystem services*
  - Protects Earth from most radiation from the sun and space
    - Ultraviolet (UV)
    - X-rays
    - Cosmic rays
    - —Without this atmospheric radiation shield, life as we know it would cease to exist
  - Naturally occurring greenhouse gases absorb some reradiated heat
    - Keeps surface temperature within habitable range for life to exist
  - Atmosphere is modified and partially maintained by living organisms
    - Photosynthesis contributes O_2 , cellular respiration CO_2

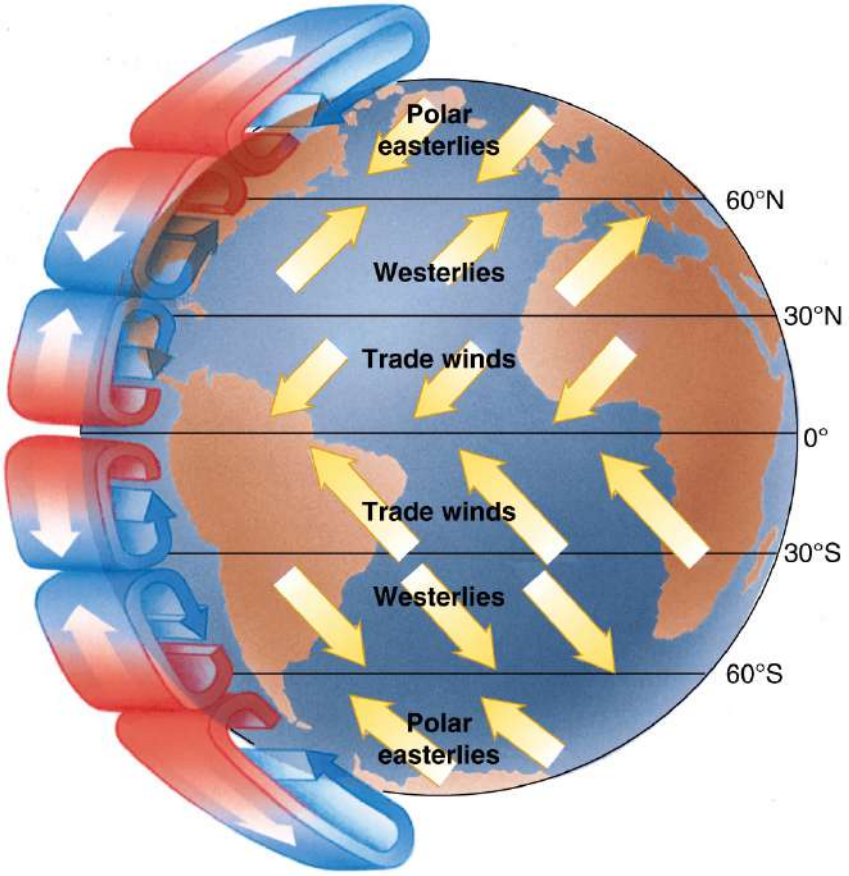
Atmospheric Circulation

- Variation in solar energy reaching the earth creates temperature differences that drive atmospheric circulation
- In *atmospheric convection*, solar heating of the ground causes the air to warm, producing an updraft of this less dense, warm air
- The convection process ultimately causes air currents, which mix warmer with cooler parts of the atmosphere



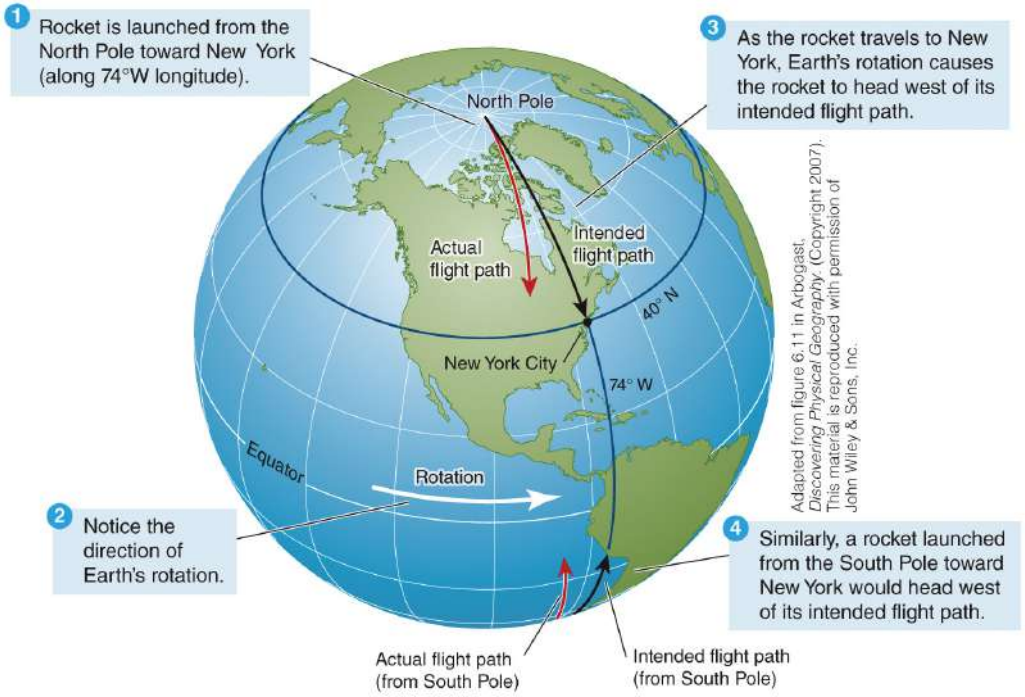
Atmospheric Circulation

- *Atmospheric circulation* transports heat from the equator to the poles
- Greatest solar energy input is at the equator
- Air travels towards the poles, cools and descends at 30 degrees latitude
- At higher latitudes, pattern of air circulation is complex



Atmospheric Circulation

- Winds
  - Smaller scale horizontal atmosphere movements that result from changes in atmospheric pressure and the planet's rotation
- There are three prevailing winds that blow continually
  - Polar easterlies: Winds near the poles
  - Westerlies: Middle latitude winds
  - Trade winds: Tropical winds



The Coriolis effect:

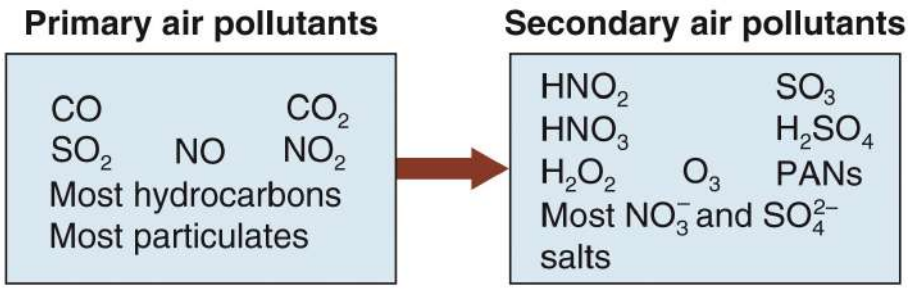
Winds and ocean currents are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere

Types and Sources of Air Pollution

- Air pollution
  - Various chemicals (gases, liquids, solids) present in the atmosphere in harmful levels
  - Can be from natural sources (smoke from forest fires; volcanic emissions), or anthropogenic (combustion or industrial byproducts, amongst others)
- Two main categories of air pollutants
  - Primary air pollutants
    - Harmful chemicals that are released directly from a source into the atmosphere
  - Secondary air pollutants
    - Chemicals that form in the atmosphere when primary air pollutants react chemically with one another or with natural components of the atmosphere

Types and Sources of Air Pollution

- Air pollution
  - Primary air pollutants:
    - Carbon oxides
    - Nitrogen oxides
    - Sulfur dioxide
    - Particulate matter
    - Hydrocarbons
  - Secondary air pollutants:
    - Ozone
    - Sulfur trioxide
    - Some acids



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Major Classes of Air Pollutants

- **Particulate matter**
  - Dusts and mists, solid and liquid particles suspended in the atmosphere
  - Includes soil particles, soot, lead, asbestos, microorganisms, and sulfuric acid droplets
  - Some particulate matter has toxic or carcinogenic effects
  - Can corrode metals and erode buildings
  - Scatters and absorbs sunlight
  - Microscopic particles more dangerous than larger particles since they are inhaled more deeply into lungs

Pollutant	Category	Characteristics
Dust particles	Primary	Solid particles
Lead (Pb)	Primary	Solid particles
Sulfuric acid (H_2SO_4)	Secondary	Liquid droplets

Major Classes of Air Pollutants

- **Nitrogen oxides** (NO_x)
  - Gases produced when N and O interact during combustion
  - Aggravate asthma
  - Involved in the production of photochemical smog and acid deposition
  - Associated with global warming and ozone depletion in the stratosphere
  - Corrode metals

Pollutant	Category	Characteristics
Nitrogen dioxide (NO_2)	Primary	Reddish-brown gas
Nitric oxide (NO)	Primary	Colorless gas

- **Sulfur oxides**
  - Result from chemical interaction of S and O
  - Major role in acid deposition
  - Damage stone, corrode metals
  - Respiratory tract irritant

Pollutant	Category	Characteristics
Sulfur dioxide (SO_2)	Primary	Colorless gas with strong odor
Sulfur trioxide (SO_3)	Secondary	Reactive colorless gas

Major Classes of Air Pollutants

- **Carbon oxides**
  - Carbon monoxide (CO) poisonous
  - Colorless, odorless, tasteless
  - Reduces the blood's ability to carry oxygen
  - Carbon dioxide (CO_2) associated with climate change

Pollutant	Category	Characteristics
Carbon monoxide (CO)	Primary	Colorless, odorless gas
Carbon dioxide (CO_2)	Primary	Colorless, odorless gas

- **Hydrocarbons**
  - Diverse group of organic compounds
  - Variety of health effects, depending on the individual chemical
  - Many are respiratory tract irritants and carcinogenic
  - Most contribute to photochemical smog
  - Methane linked to global warming

Pollutant	Category	Characteristics
Methane (CH_4)	Primary	Colorless, odorless gas
Benzene (C_6H_6)	Primary	Liquid with sweet smell

Major Classes of Air Pollutants

- **Ozone**
  - Stratospheric ozone essential to protect Earth's surface from high levels of UV radiation
  - Ground-level (tropospheric) ozone considered a pollutant
  - Photochemical smog
  - Respiratory irritant
  - Contributes to plant and forest decline

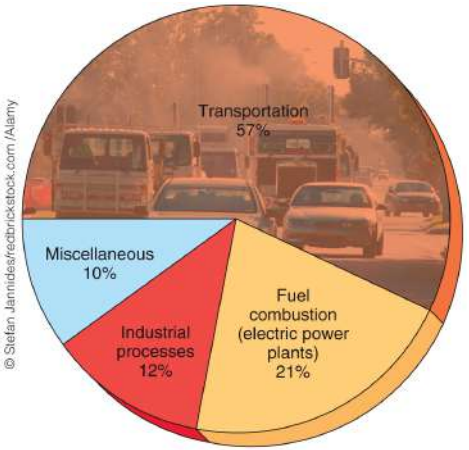
Pollutant	Category	Characteristics
Ozone (O_3)	Secondary	Pale blue gas with irritating odor

- **Hazardous air pollutants (HAPs) (air toxics)**
  - Chlorine, formaldehyde, etc.
  - Health risks to people who live and work around chemical factories and incinerators

Pollutant	Category	Characteristics
Chlorine (Cl_2)	Primary	Yellow-green gas
Formaldehyde	Primary	Colorless gas with pungent odor

Sources of Outdoor Air Pollution

- Air pollution can be naturally generated as well as by humans
  - Volcanoes
  - Plants
- The two main human sources of primary air pollutants are:
  - Transportation (mobile sources)
    - Cars, trucks, construction equipment
  - Power plants (stationary sources)
    - Burning coal responsible for most of these emissions
  - Top three industrial sources are chemical, metal, and paper industries
  - Agricultural forest burning activities also significant around the world



Effects of Air Pollution

- Air pollution
  - Injures organisms
  - Reduces visibility
  - Corrodes materials
    - Metals, plastics, rubber, fabrics
  - Harms the respiratory tract, and can worsen existing medical conditions
  - Reduces crop productivity
  - Involved in acid deposition, global warming, and stratospheric ozone depletion

Air Pollution and Human Health

- Air pollution
  - Low level exposure leads to eye irritation and respiratory tract inflammation
  - Suppresses the immune system
  - May lead to development of chronic respiratory disease
    - Emphysema
    - Chronic Bronchitis

Health effects of several major air pollutants • Table 8.1

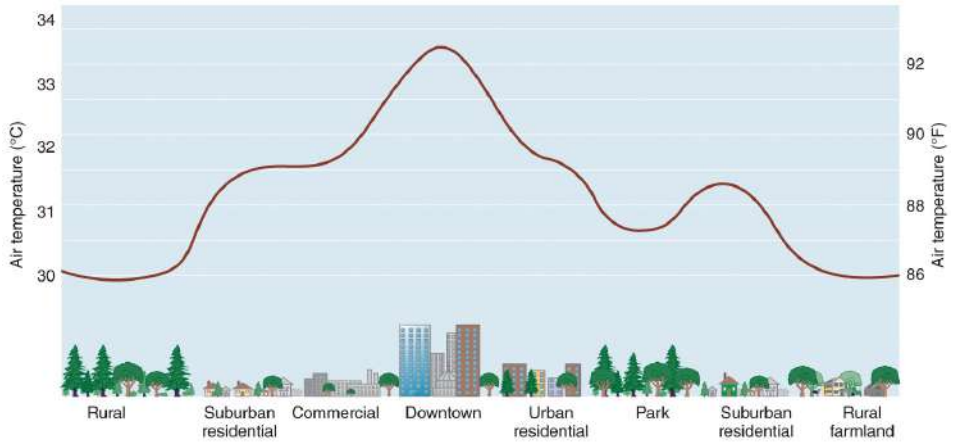
Pollutant	Source	Effects
Particulate matter	Industries, motor vehicles	Aggravates respiratory illnesses; long-term exposure may cause chronic conditions such as bronchitis
Sulfur oxides	Electric power plants, industries	Irritate respiratory tract; same effects as particulates
Nitrogen oxides	Motor vehicles, industries, heavily fertilized farmland	Irritate respiratory tract; aggravate respiratory conditions such as asthma and chronic bronchitis
Carbon monoxide	Motor vehicles, industries	Reduces blood's ability to transport oxygen; causes headache and fatigue at low levels; causes mental impairment or death at high levels
Ozone	Formed in atmosphere (secondary air pollutant)	Irritates eyes; irritates respiratory tract; produces chest discomfort; aggravates respiratory conditions such as asthma and chronic bronchitis

Urban Air Pollution

- Air pollution in an urban area is referred to as smog or industrial smog (worse in the winter)
- Photochemical smog is a brown-orange haze formed by chemical reactions involving sunlight, nitrogen oxides, and hydrocarbons
  - Photochemical smog was first noted in Los Angeles in the 1940s
  - Photochemical smog development requires solar energy
    - Worse in the summer months
  - Ozone is a principal component of photochemical smog
  - Results in eye irritation, aggravates respiratory illness, and harms plant tissue
  - Sources include car exhaust, dry cleaners, and bakeries

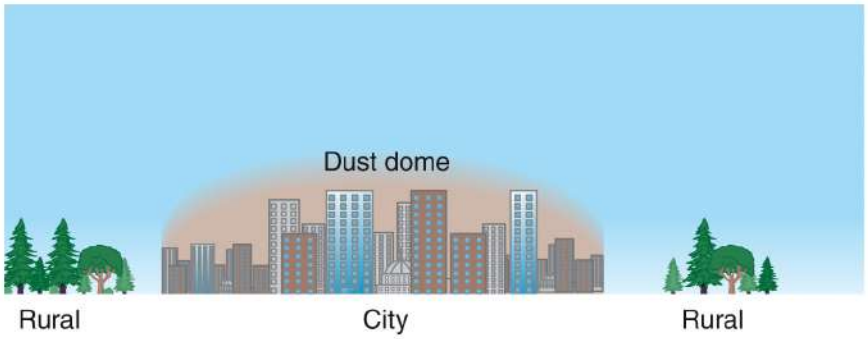
Urban Heat Islands and Dust Domes

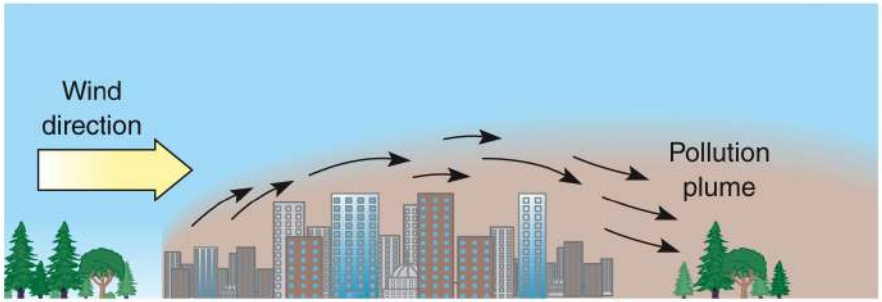
- Urban heat islands
  - Heat from sunlight heated streets, rooftops, and parking lots, radiates into the atmosphere at night
  - Heat from human activities is highly concentrated in urban areas
  - These pockets of heat in urban areas surrounded by cooler rural and suburban areas, are called heat islands



Urban Heat Islands and Dust Domes

- Urban heat islands encourage the formation of a dome of heated air that surrounds an urban area
  - This contributes to the buildup of air pollutants, especially particulate matter
- If wind speeds increase, the polluted air spreads over rural areas
- Cities in valleys are highly susceptible to buildup of pollutants on low wind days
- Increased number of thunderstorms in summer associated with urban heat islands





Case Study: Curbing Air Pollution in Chattanooga

- Chattanooga, Tennessee was determined to have the worst air pollution in the U.S. in 1960s
  - So polluted, car headlights were necessary during the day
  - Surrounding mountains kept the pollutants produced within the city from dispersing
- After the CAA of 1970, the city established an air pollution control board to enforce regulations, and today the air is clean
- Chattanooga now has lower than federal standard required levels for all seven EPA-regulated air pollutants
- In early 2000s, Chattanooga continued to move toward sustainability
- By 2015, it earned a top rating by the Tennessee Valley Authority's "Sustainable Communities“ program and recognition as a "Bicycle Friendly Community”