Chapter 3: Introduction to the Atmosphere

I. Size of Earth’s Atmosphere
   A. air
      1. air: a mixture of gases, mainly nitrogen and oxygen
      2. pure air is invisible; gases in it are colorless, odorless, and tasteless
   B. the atmosphere
      1. the atmosphere completely surrounds Earth, to which it is held by
         gravitational attraction, out to 6,000 miles
      2. > 50\% of mass of atmosphere within 3.8 miles of sea level; 98\% within
         16 mi.
      3. atmosphere extends downward into crevices in rocks and soil

II. Composition of the Atmosphere
   A. Permanent Gases
      1. Nitrogen and Oxygen
         a. nitrogen
            1) 78\% volume of dry air
            2) added by decay and burning of organic matter, volcanic eruptions,
               and chemical breakdown of certain rocks
         b. oxygen
            1) 21\% volume of dry air
            2) produced by vegetation
         c. argon = 0.943\%
         d. trace gases: neon, helium, methane, krypton, hydrogen
         e. atmospheric concentration does not change
         f. minimal effect on weather and climate
   B. Variable Gases
      sparse but highly variable atmospheric quantities; significant influence on
      weather and climate
      1. Water Vapor
         a. determines humidity of atmosphere
         b. 0 – 4\% of total volume
            1) highest in air overlying warm, moist surfaces, such as tropical
               oceans
            2) lowest over deserts and in polar regions
            3) listed as a variable gas, but it is variable in location, not in time
            4) total amount in atmosphere as a whole remains virtually constant
         c. significant influence on weather and climate
            1) source of all clouds and precipitation
            2) impacts heating and cooling processes
      2. Carbon Dioxide (CO\textsubscript{2})
         a. 390 ppm (parts per million)
         b. concentration increasing (2 ppm per year), result of increased
            burning of fossil fuels
         c. significant influence on weather and climate
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1) **absorbs infrared radiation**
2) increase concentration → **global climate change**

3. **Ozone** (O₃)
   a. a minor but vital gas
   b. concentrated in ozone layer (9-30 miles above Earth’s surface)
   c. **absorbs ultraviolet** radiation
   d. increasing concentrations of CO, SO₂, NO₂ and various hydrocarbons from automobile and factory emissions

C. **Particulates**
   1. **particulates/aerosols**: solid and liquid particles in the atmosphere
      a. natural sources: volcanic ash, windblown soil and pollen grains, wildfire smoke, salt spray
      b. human sources: industrial and auto emissions, smoke and soot
   2. influence on weather and climate
      a. **hygroscopic**: water vapor condenses around condensation nuclei → cloud formation
      b. **absorb or reflect sunlight** → decrease solar energy reaching earth

III. Vertical Structure of the Atmosphere
A. **Thermal Layers** (Fig 3-5)
   1. lower portion of the atmosphere is the zone in which most weather phenomena occur
   2. –pause: boundary between layers
   3. **Troposphere**
      a. sea level – 11 miles
      b. zone of vertical mixing and turbulence
      c. depth varies
         1) deepest over tropical regions (11 mi.); shallowest over poles (5 mi.)
         2) deeper in summer than winter
      d. **tropopause**: top of the troposphere
   4. **Stratosphere**
      a. 11 miles – 30 miles
      b. zone of layered/stratified/stagnant condition w/o vertical mixing
      c. **stratopause**: top of stratosphere
   5. Upper Thermal Layers
      a. **mesosphere**
         1) 30 miles – 50 miles
         2) **mesopause**: top of mesosphere
      b. **thermosphere**
         1) 50 miles and up
         2) merges gradually with exosphere
      c. **exosphere**
   6. Temperature Patterns in the Atmosphere
      a. air temperature changes with altitude
      b. sea level average global temperature = 59° F
      c. **troposphere**:
1) air temperature decreases with increasing altitude (to -71° F at tropopause)
2) heat source at ground level: solar energy absorbed by Earth’s surface
d. tropopause: temperature remains constant
e. stratosphere:
   1) air temperature increases with increasing altitude
   2) heat source: ozone layer where ozone absorbs ultraviolet radiation and warms the atmosphere
f. mesosphere: air temperature decreases with increasing altitude
g. air temperature reaches minimum at top of the mesosphere; ~ 50 miles
h. thermosphere:
   1) air temperature increases with increasing altitude
   2) heat source: splitting and heating of atoms and molecules that absorb ultraviolet radiation
i. essentially all weather phenomena occur in the troposphere

B. Pressure
1. atmospheric pressure: the force exerted by the atmosphere on a surface; weight of overlying air
2. atmospheric pressure is normally highest at sea level and decreases rapidly with increasing altitude
   a. lower layers of atmosphere are compressed by the air above
   b. atmospheric pressure decreases upward at a decreasing rate:
      1) most of the mass of the atmosphere is found relatively close to the ground
      2) 50% gas molecules lie below 3.5 miles; 90% below 10 miles

C. Composition
1. homosphere
   a. sea level – 50 miles
   b. principal gases uniformly distributed
2. heterosphere
   a. beyond 50 miles
   b. gases layered in accordance with their molecular masses from heaviest to lightest: nitrogen, oxygen, helium, hydrogen
3. water vapor
   a. diminishes with increasing altitude
   b. >10 miles atmosphere so cold, any moisture already frozen → no clouds
4. ozonosphere
   a. 9-30 miles in the stratosphere
   b. concentration of ozone relative to other gases is at its maximum
5. ionosphere
   a. deep layer of electrically charged molecules and atoms
   b. middle-upper mesosphere and lower thermosphere
   c. aids long-distance communication by reflecting radio waves
   d. auroral displays – northern lights
IV. Human-induced Atmospheric Change

A. Depletion of the Ozone Layer
1. ozone (O\textsubscript{3}) in the stratosphere
   a. naturally produced in the \textbf{stratosphere} 
   b. \textbf{absorbs} harmful \textbf{ultraviolet radiation} (UV-C and UV-B)
2. ozone in the troposphere
   a. produced in the \textbf{troposphere} through human activities
3. The “Hole” in the Ozone Layer
   a. human cause
      1) use of \textbf{CFCs} (chlorofluorocarbons) in refrigeration, foam and plastic manufacturing, and aerosol sprays
      2) when CFCs are exposed to ultraviolet radiation in the ozonosphere, chlorine is released and breaks down O\textsubscript{3} into O and O\textsubscript{2}
   b. results in thinning of stratospheric ozone layer, especially in the polar regions, and increased levels of UV radiation at ground level
   a. US and other countries banned CFCs in aerosol sprays in 1978
   b. industrial world banned all CFC production in 1996
   c. goal: end production in developing countries by 2010
   d. ozone layer will not recover immediately because reservoir of CFC in atmosphere may persist 50-100 years

B. People and the Environment: The UV Index
1. ranges from (low ultraviolet radiation exposure risk) 1 – 11\textsuperscript{+} (high)
2. in US based on forecast levels of ozone, cloud cover, and elevation
3. generally the lower the concentration of stratospheric ozone and clearer the skies, the greater the level of harmful UV radiation

C. Air Pollution
1. intro
   a. natural sources: wildfires, ash from volcanic eruptions, windblown dust, pollen, salt
   b. humans have dramatically increased the frequency and magnitude of atmospheric pollutants
      1) greatest air pollution problems are associated with cities
      2) air pollution greatly intensified with Industrial Revolution
2. Primary and Secondary Pollutants
   a. primary pollutants: contaminants released directly into the air – particulates, sulfur compounds, nitrogen compounds, carbon oxides and hydrocarbons
   b. secondary pollutants: form as a consequence of chemical reactions or other processes in the atmosphere, such as photochemical smog
3. Particulates (or aerosols)
   a. tiny solid or liquid droplets suspended in the air
   b. many associated health hazards are greatest when particulates are small (<2.5 micrometers)
4. Carbon Monoxide (CO)
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5. Sulfur Compounds
   a. natural sources: volcanoes and hydrothermal vents
   b. human source: burning of fossil fuels such as coal and petroleum
   c. secondary pollutants → acid rain

6. Nitrogen Compounds
   a. forms through combustion that takes place at high temperatures and pressures – such as automobile engine
   b. reacts in sunlight to form smog

7. Photochemical Smog
   a. major contributors: nitrogen dioxide and hydrocarbons (VOC: volatile organic compounds) that result from incomplete burning of fuels such as gasoline
   b. ozone, formed when nitrogen compounds break down, is the main component
   c. particularly severe when high-pressure (anticyclonic) conditions prevail that result in little surface wind flow and temperature inversions

8. Consequences of Anthropogenic Air Pollution
   a. ozone exposure causes 20% of all summer hospital cases involving respiratory illness
   b. increasingly stringent EPA emission standards have resulted in a decline in the US in emission of all pollutants except nitrogen oxides and ozone

V. Weather and Climate
   A. Intro
      1. **weather**: short term atmospheric conditions for a given time in a specific area
      2. **climate**: aggregate of day-to-day weather conditions over a long period of time, normally at least 3 decades
         a. encompasses average characteristics as well as variations and extremes
      3. “climate is what you expect; weather is what you get”
   B. The Elements of Weather and Climate
      1. temperature
      2. moisture content
      3. pressure
      4. wind
   C. The Controls of Weather and Climate: certain semi-permanent attributes of our planet
      1. **Latitude**
         a. basic distribution of heat over Earth is first and foremost a function of latitude
         b. latitude influences the element **temperature**
c. overall **latitude is the most fundamental control of climate**

2. Distribution of Land and Water  
   a. **oceans heat and cool more slowly** and to a lesser degree than landmasses; maritime areas experience milder temperatures than continental areas in both summer and winter  
   b. **oceans greater source of atmospheric moisture**; maritime climates normally more humid than continental climates  
   c. uneven land/water distribution is **prominent control of moisture content and temperature**

3. General Circulation of the Atmosphere  
   a. atmosphere in constant motion  
   b. major, semi-permanent pattern of **wind and pressure systems greatly influence most elements** of weather and climate

4. General Circulation of the Oceans  
   a. broad general pattern of currents  
   b. currents assist in **heat transfer** by moving warm water poleward along eastern coasts of continents and cool water equatorward along western coasts of continents

5. Altitude  
   a. **temperature, pressure, and moisture generally decrease upward in the troposphere**

6. Topographic Barriers (mountains)  
   a. divert wind flows  
   b. variations in **windward and leeward climates**

7. Storms  
   a. some storms are prominent and frequent enough to affect climate as well as weather

D. The Coriolis Effect  
1. **all freely moving objects on Earth’s surface or in Earth’s atmosphere appear to drift sideways as a result of Earth’s rotation**  
   a. can significantly influence long-range movements  
   b. basics of the Coriolis effect  
      a. objects appear to deflect **to the right in the northern hemisphere, to the left in the southern hemisphere**  
      b. apparent deflection **strongest at the poles; decreases progressively toward the equator where there is zero deflection**  
      c. **fast moving objects deflected more than slower ones**  
      d. influences **direction only; speed not influenced**  
   c. Coriolis impact on climate:  
      a. all **winds** are affected  
      b. **ocean currents** are deflected  
         1) → cold water upwelling along continental coastlines  
   d. does not affect water draining out of bathtub