General Physical Science

Chapter 19
The Atmosphere

Composition and Structure

- Composition of the atmosphere
  - Mainly N\textsubscript{2} and O\textsubscript{2}
  - Main other constituents: Ar, CO\textsubscript{2}, H\textsubscript{2}O
- Animals consume O\textsubscript{2} and release CO\textsubscript{2}.
- Plants consume CO\textsubscript{2} and release O\textsubscript{2}.
  - Photosynthesis
    - Chlorophyll
    - Over 50% in oceans
- Crepuscular Rays

Composition and Structure

- Gravitational attraction of atmosphere greatest near surface of the Earth.
  - Air density greatest at surface
  - Air pressure greatest at surface
    - Pressure decreases at height increases
  - No clearly defined upper limit
    - ½ of the atmosphere below 7 miles
    - 99% below 19 miles
    - 200 mi above, about 1 molecule/mi\textsuperscript{3}
    - At surface, 112,000,000,000,000,000,000,000,000,000,000,000 molecules in the same volume!
Temperature Variations

• Regions based on change in temperature.
  – Troposphere
    • nearest the Earth
    • Up to about 16 km (10 mi)
    • Temperature decreases as altitude increases
      – About 3.5°F per 1000 ft. (6.5°C per km)
    • Atmospheric conditions constantly changing
      – Weather
    • About 80% of atmosphere
    • At the top - Temperature about 45 - 50°C below zero.

Regions of the Atmosphere

• Stratosphere
  – Troposphere and stratosphere about 99.9% atmospheric mass.
  – Non-uniform increase to about 50 km (30 mi)
• Mesosphere
  – Uniform decrease in temperatures again.
  – 50 km to 80 km (30 mi to 50 mi)
• Thermosphere
  – Temp increases, dependent on Solar activity.

Vertical Structure of the Atmosphere
Ozone and Ion concentrations

- **Ozone (O\textsubscript{3})**
  - Formed by reactions of oxygen
  - \(O\textsubscript{2} + \text{energy} \rightarrow O + O\)
  - \(O + O\textsubscript{2} \rightarrow O\textsubscript{3}\)
- Dissociation energy comes from the Sun.
- Optimum conditions about 30 km (20 mi)
- \(O\textsubscript{3}\) concentration decreases to about 70 km (45 mi)

Ozone

- Region below 75 km known as ozonosphere
  - Roughly corresponds to stratosphere.
  - Formed by reaction of molecular oxygen
    - \(O\textsubscript{2} + \text{energy} \rightarrow O + O; \text{then} O + O\textsubscript{2} \rightarrow O\textsubscript{3}\)
  - Energy for temp increase comes form ozone absorbing uv radiation!
  - Causes \(O + O\textsubscript{2} \rightarrow O\textsubscript{3}\) and \(O + O \rightarrow 2O\textsubscript{2}\)
  - Creates balance of ozone / oxygen in atmosphere.
- Pollutant at the Earth’s surface
  - Also relatively unstable at the surface.

Ozone and Ion Concentrations

- Serves as ‘umbrella’ for uv radiation.
  - Greatly decreases uv radiation that makes it to the surface of the Earth.
- Upper atmosphere:
  - \(N\textsubscript{2} + \text{energy} \rightarrow N\textsubscript{2}^\ast + e\)
  - Ionosphere
  - Made up of 3 layers
**Ionosphere**

- **D layer**
  - Absorbs some lower frequency radio waves
  - Allows higher (AM and FM) frequencies to pass.

- **E and F layer**
  - Reflect AM
  - Allow FM to pass

**Ionosphere**

- Can use for long distance communication.
  - Not as reliable as satellite communication
  - Ionosphere layer will vary with solar activity.

**Ionospheric Effects**

- *Aurora Borealis*
  - Northern lights
  - Recombination of ions with electrons
  - Directed by Earth’s magnetic field
  - *Aurora Australis*
Composition and Structure

• Learning Goals
  – Identify the composition of air.
  – Describe how the atmosphere is divided into regions.
• Questions: 1 - 6
• Exercises: 1, 3

Atmospheric Energy Content

• Sun
  – Main source of energy
  – Insolation
    • incoming solar radiation
  – Earth is tilted and orbits the Sun.
    • leads to uneven distribution of insolation
    • Seasons
  – Only about 50% of insolation reaches the surface.

Atmospheric Energy Content

• The atmosphere is primarily heated by the Earth!
  – About 1/3 (33%) of the insolation reflected back into space
    • Albedo
      • Values in Table 19.2
  – Scattering
    • Rayleigh scattering
      • Wavelength dependent (1/λ^4)
      • Longer wavelength - less scattering
      • Blue Sky/Red Sunsets!
Atmospheric Energy Content

• About 15% absorbed by ozone
• About 50% to the surface
  – This energy then heats the atmosphere
  – 3 processes
    • Absorption of re-radiation
    • Latent heat of condensation
    • Convection

Atmospheric Energy Content

• Absorption of re-radiation
  – Wavelength dependent on temperature
  – Earth radiates in the long infrared wavelengths
  – Absorbed by water vapor and CO₂.
    • Water most important
  – Leads to the ‘Greenhouse Effect’

The Greenhouse Effect
Atmospheric Energy Content

- Latent heat of condensation
  - Earth’s surface about 70% water
  - Heat to surface causes evaporation
  - Evaporated water condenses
    - Rain, fog, clouds, dew, etc…
- Convection
  - Air near surface heated
  - Rises

Atmospheric Energy Content

- Learning Goals
  - Describe how insolation is distributed in the atmosphere.
  - Explain why the sky is blue and sunsets are red.
  - Describe the greenhouse effect and its impact on Earth’s temperature.
- Questions: 7-12
Atmospheric Measurements and Observations

• We measure 5 fundamental properties of the atmosphere.
  – Temperature
  – Pressure
  – Humidity
  – Wind Speed and Direction
  – Precipitation

Atmospheric Measurements

• Temperature
  – Measure air temperature
  – Do not want direct heating of the thermometer
  • Measure ‘in the shade’

• Pressure
  – Force per area
  – ‘Standard’ pressure 14.7 lb/in²
    • Due to the weight of the atmosphere

Pressure

• Galileo
  – Trying to get water to top of building using vacuum
    • Same principle as a straw
    • Could only get water about 10 m

• Torricelli
  – Discovered mercury would be lifted only a given distance in an evacuated tube.
Barometer

- Device for measuring pressure
- Height of column dependent on the density of the liquid
  - Water higher than Hg
  - Water less dense than Hg

Types of Barometers

- Aneroid
  - pointer driven by a metal diaphragm.
- Liquid
  - measure height of column.
- Altimeter
  - Aneroid barometer to determine altitude

Pressure

- Typical Measurements (standard pressure)
  - $1.013 \times 10^5$ N / m² (SI units)
  - atmospheres (1 atm)
  - millimeters of mercury (760 mm Hg)
  - inches of mercury (29.92 in Hg)
  - pounds per square inch (14.7 psi)
  - bar (1.013 bar)
  - millibar (1013 mb)
Pressure Changes

- Ears most sensitive
  - Inner ear does not equalize pressure as quickly as outer ear.
  - Things to help inner ear
    • Chewing
    • Valsalva
- Many airplanes are pressurized
  - Pressure differential
  - Typical airliner pressurized to an altitude of 8,000 ft.

Humidity

- Measurement of the amount of water vapor in the air
- Absolute
  - mass of water per unit volume
  - 4.5 grains / ft³
- Relative
  - Ratio of how much is there to how much could be there

Relative Humidity

- Dependent on temperature
  - Can be saturated with water vapor
  - Dewpoint
- Psychrometer
  - Uses dry bulb and wet bulb
  - Temp difference due to evaporation
  - Table I - Appendix VIII
Heat Index
- Body is cooled by evaporation of sweat
- The higher the relative humidity, the slower the evaporation.

Atmospheric Measurements
- Wind speed
  - anemometer
- Wind direction
  - wind vane
- Precipitation
  - Rain gauge
  - Snow
    - melted to determine moisture content

Weather Observations
- Radar
  - Reflected radio waves
- Doppler Radar
  - Reflected radio waves with measurement of Doppler shift
  - Increased awareness of tornado
- Airport
  - Windshear
Weather Observations

- Weather Satellites
  - GOES
    - Geostationary Orbiting Environmental Satellites
    - Continuous coverage of the Earth's surface
  - Images often combined with radar/Doppler radar images to get a picture of the weather.
Atmospheric Measurements and Observations

• Learning Goals
  – Identify some important atmospheric measurements and the instruments used to make them.
  – Demonstrate how the relative humidity may be found from psychrometric readings.
  – Distinguish between conventional and Doppler radar.
• Questions: 13 - 19
• Exercises: 5 – 11 odd

Air Motion

• Wind
  – Horizontal movement of air.
• Air currents
  – Vertical movement of air
    • updrafts and downdrafts
• 2 main causes for air movement
  – Gravity
  – Pressure changes due to temperature variations.

Air Motion

• Gravity
  – Vertically downward movement of air
  – Constant presence
    • can be overridden by other forces
• Variations in temperature
  – Governed by the Gas Laws (Chap. 11)
    • Pressure is directly proportional to temperature.
    • Aerosol can in a fire
Air Motion

• Variation in Temperature
  – Variation in pressure leads to an unbalanced force
  – Air moves from high pressure to low pressure

• Isobars
  – Regions of the same pressure
  – Wind flow is ideally perpendicular to the isobars

Convection Cycle

• Thermal circulation of air
• Sea Breeze
• Land Breeze
  – Note name describes where wind comes from.
  – North wind - comes from the North

Secondary Forces

• Coriolis
  – Due to the rotation of the Earth
  – Pseudoforce
    • Only appears to occur because our frame of reference is moving!
  – Northern Hemisphere - objects are deflected to the right
  – Southern Hemisphere - deflection to the left
Secondary Forces

- Coriolis effect leads to the direction of circulation around Highs and Lows.
  - Low circulation is counterclockwise (NH)
    - cyclonic
  - High circulation is clockwise (NH)
    - anticyclonic

Secondary Forces

- Friction
  - Most prevalent near surface
  - Upper level winds normally stronger than surface winds!
- General Weather Patterns
- Jet Stream
  - Upper level wind more than 55 mph.
Air Motion

• Learning Goals
  – Identify the forces involved in air motion.
  – Analyze some local winds and Earth’s general circulation pattern.
• Questions: 20 - 24

Clouds

• Buoyant masses of visible moisture
  – Water
  – Ice
• Cloud classification categories
  – Shape
  – Appearance
  – Altitude

Cloud Types - Cirrus
Cloud Types

- Cumulus

- Stratus

- Nimbus (Stratocumulus and Cumulonimbus)
Clouds

• Height
  – High
  – Middle
  – Low
  – Extensive Vertical Development
• The text (560 - 562) has explanations and additional photographs of common cloud types.

Clouds

• Cloud Formation
  – Condensation
  – Occurs at the dew point
• Cooling
  – Warm air mass contacts a cold air mass
  – Vertical movement
    • Formed by rising
    • Shaped by upper level winds

Clouds

• Vertical Formation
  – Warm air rises (unstable)
  – Cools
  – Reaches dew point
  – When temp of rising air equals surroundings, no more rise (stable)
  – Wind shapes the cloud
Clouds

• Learning Goals
  – Explain how clouds are described and classified.
  – Describe how clouds are formed.
• Questions: 25 – 28
• Key Terms; Matching, Multiple Choice, and Fill-in-the-Blank Questions; Visual Connection and Applying your Knowledge

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