SCI-123 Spring 2026

Key Concepts - Unit One

1. **Atmospheric Composition, Variables, & Structure**
    - Earth's atmospheric evolution
    - atmospheric parcel
    - atmospheric composition
        - permanent gases
            - nitrogen (N_2)
            - oxygen (O_2)
        - variables constituents
            - water vapor (H_2O)
            - carbon dioxide (CO_2)
            - ozone (O_3)
            - aerosols (dust, sea salt, smoke, volcano ash)
            - pollutants (NO_2, CO, hydrocarbons, SO_2)
    - hydrologic cycle
    - well-mixed atmosphere
    - T = air temperature, ρ = density (mass/volume), and P = pressure (force/area)
    - Ideal Gas Law
    - mixing ratio (MR or W)
    - potential temperature (θ)
    - vertical profile of temperature in the troposphere and stratosphere
    - lapse rate (6.5 °C/km on average) of atmospheric temperature in the troposphere
    - air density and air pressure as a function of elevation z
2. **Energy Forms & Transfers**
    - energy forms
        - thermal energy (molecular motion - parcel temperature)
        - kinetic energy (parcel motion)
        - potential energy (parcel vertical location)
    - specific heat (heat capacity)
    - latent heat (H_2O phase change)
        - melting $\leftrightarrow$ freezing
        - evaporation $\leftrightarrow$ condensation
        - sublimation $\leftrightarrow$ deposition
    - energy transfer mechanisms
        - conduction
        - convection (atmospheric thermals)
        - latent heat transfer
        - electromagnetic radiation (EMR)
    - radiation (EMR)
        - duality model : wave and particle (photons)
        - blackbody radiators (dense masses) - continuous wavelength spectrum
            - wavelength maximum as a function of blackbody temperature T : **Wien's Law** $\lambda_{max} = 2890/T$

        * total energy (all wavelengths) per area per time emitted as a function of blackbody temperature T :
          Stefan-Boltzmann Law $E = \sigma T^4$
    - selective absorbers (thin gases) - discrete wavelength spectrum - **Kirchhoff's Law**
- earth-atmosphere annual energy balance
    - solar constant
    - earth's albedo
    - greenhouse effect - enhanced greenhouse effect
    - atmospheric window
    - latitudinal dependence

3. **Seasonal and Daily Temperatures**

- Earth-Sun relationship - long and short cycles
    - orbit shape (eccentricity) - $100{,}000^+$ year periodicity
    - axis tilt and wobble (obliquity and recession) - 41,000- and 26,000-year periodicity, respectively
    - day of the year when the Earth is closest to the sun - 20,000 year periodicity
    - Earth's orbit - 365.25 day periodicity (tilt causes the seasons)
    - Earth's rotation - 24 hour periodicity
- temperature controls - climatic (average or long-term)
    - latitude
    - land - water distribution
    - ocean currents
    - altitude
- temperature control - short-term
    - cloud cover
    - wind speed
    - mixing ratio
    - warm/cold advection

4. **Atmospheric Forces & Winds**

- Newton's laws of motion
    - mass, acceleration, and forces
    - atmospheric forces
        * pressure gradient (PG)
        * Coriolis (Co)
        * centripetal (imbalance of PG and Co)
        * friction (f)
        * gravity (g)
        * buoyancy (gravity related, due to differences in parcel densities)
- resultant horizontal motion (winds)
    - geostrophic wind - in terms of pressure gradient or height gradient (reference state)
    - gradient wind
        * sub-geostrophic
        * super-geostrophic
    - surface wind (friction layer or planetary boundary layer)
- vertical motion
    - hydrostatic balance (reference state)
- horizontal and vertical wind connections
    - sub-geostrophic $\leftrightarrow$ super-geostrophic
    - adjacent low and high pressure centers