ESCI 241 - Meteorology
Lesson 4 – Seasons

EARTH'S ORBIT

- **Earth's orbit is elliptical**
  - **Eccentricity = 0.0167**
  - **Period = 365.25463 days**
  - **Average Earth-Sun distance is 93,000,000 miles**
  - **Earth is closest to sun near January 4th (perihelion, about 91,000,000 miles)**
  - **Earth is farthest from sun near July 4th (aphelion, about 94,000,000 miles)**
  - **Earth's axis of rotation is tilted 23.5° with respect to the plane of orbit**

ANGLES OF IMPORTANCE

- ***Latitude*** **(ϕ)– the angle between a position on the Earth's surface, the center of the Earth, and the plane of the equator**
  - **Latitude varies from +90° at the North Pole to –90° at the South Pole**
- ***Declination*** **(δ)– the angle between the sun, the center of the Earth, and the plane of the equator (the latitude over which the sun is directly overhead)**
  - **Declination varies from +23.5° at the Summer Solstice to –23.5° at the Winter Solstice**
  - **Declination can be estimated by**

$$\delta = \pm 23.5° \sin\left(|N|°\right) \qquad \textbf{(1)}$$

where *N* is the number of days to the nearest Equinox (either forward or backwards).

    - **The + sign is used for dates between the March and September equinoxes, while the – sign is used for dates between the September and March equinoxes.**
- ***Sun angle*** **(ψ)– the angle between the Sun, a position on the surface of the Earth, and a plane tangent to the Earth at that position**
  - **Sun angle is negative between sunset and sunrise**
  - **Sun angle is maximum at local noon**

- **The sun angle at any time of day is found by**

$$\sin\psi = \sin\phi\sin\delta - \cos\phi\cos\delta\cos\left(15°t_{\text{UTC}} - \lambda\right) \quad \textbf{(2)}$$

  where λ is West longitude and t_{UTC} is the decimal hours in Universal Time.

- **The noon sun angle (ψ_{noon}) is found by**

$$\psi_{noon} = 90° + \delta - \phi \quad \textbf{(3)}$$

- **The sun angle should always fall in the range of $-90° \le \psi \le 90°$. If either (2) or (3) yield a number that is outside of this range then the number should either subtracted (if positive) or added (if negative) to 180°.**
- **Solar zenith angle (Φ) – the angle between the Sun, a position on the surface of the Earth, and the local vertical at that position**

$$\Phi = 90° - \psi \text{ .} \quad \textbf{(4)}$$

SEASONS

- **Because the Earth's axis is tilted, the declination angle changes throughout the year**
- **The change in the declination is responsible for the differing amount of heat received at the surface of the Earth, and results in the seasons.**
  - **The ratio of energy flux from a tilted beam to that of a direct beam is**

$$E_{tilted} / E_{direct} = \sin\psi \quad \textbf{(5)}$$

  - **A direct beam will have more energy flux than a tilted beam**
  - **Sun angle is lowest in winter, so less energy is absorbed per unit area**
    At low sun angles, the Sun's rays must also penetrate more of the atmosphere, resulting in more absorption, so less energy reaches the surface.
- **The change in declination also results in longer days and shorter nights in the summer hemisphere.**
  - **Ground receives energy over a longer time period in summer than in winter.**
- **Solstices and Equinoxes**
  - **Equinoxes occur when declination is zero**
    - **Occur near March 20 (Vernal) and September 22 (Autumnal)**
  - **Solstices occur when declination is a maximum or minimum**

- **Summer solstice occurs when declination is +23.5°**
  - **Sun directly over 23.5°N latitude (Tropic of Cancer)**
  - **Occurs near June 21**
- **Winter solstice occurs when declination is –23.5°**
  - **Sun directly over 23.5°S latitude (Tropic of Capricorn)**
  - **Occurs near December 21**

- ***Astronomical seasons* are defined in terms of solstices and equinoxes**
  - **Spring – begins at vernal equinox**
  - **Summer – begins at summer solstice**
  - **Autumn – begins at autumnal equinox**
  - **Winter – begins at winter solstice**
- ***Meteorological seasons* are defined in terms of the hottest and coldest months**
  - **Spring – March, April, and May**
  - **Summer – June, July, and August**
  - **Autumn – September, October, and November**
  - **Winter – December, January, and February**

EXERICSES

1. **What is the noon sun angel in Olathe, KS (38.9° N, 94.8° W) on November 4th?**

2. **What is the sun angle in Olathe, KS at 2:38 p.m. Central Standard Time (CST) on November 4th?**