SC-407 and MC-226
Introduction to Environmental Studies

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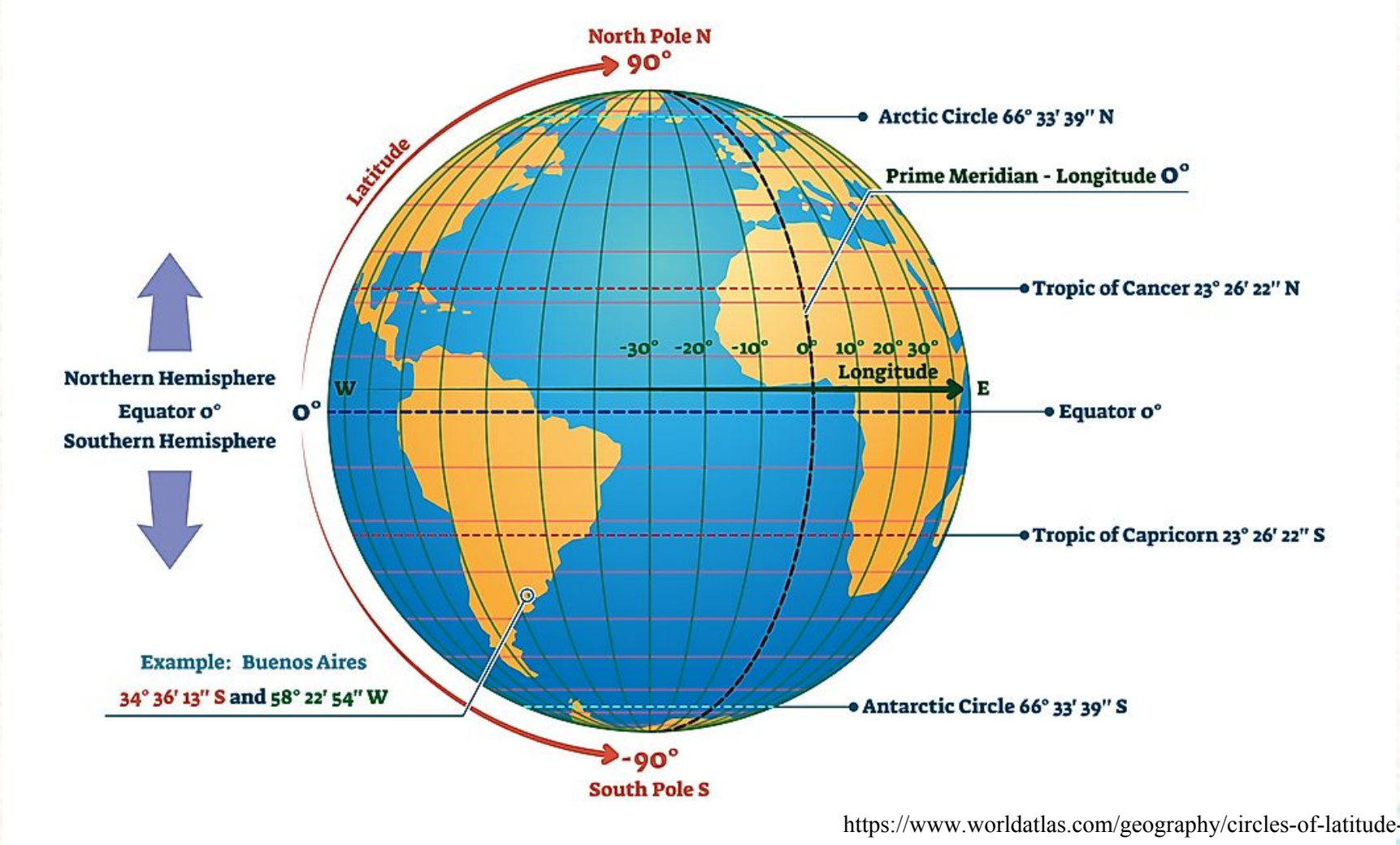
Winter 2024 Semester @ DA-IICT

Overview

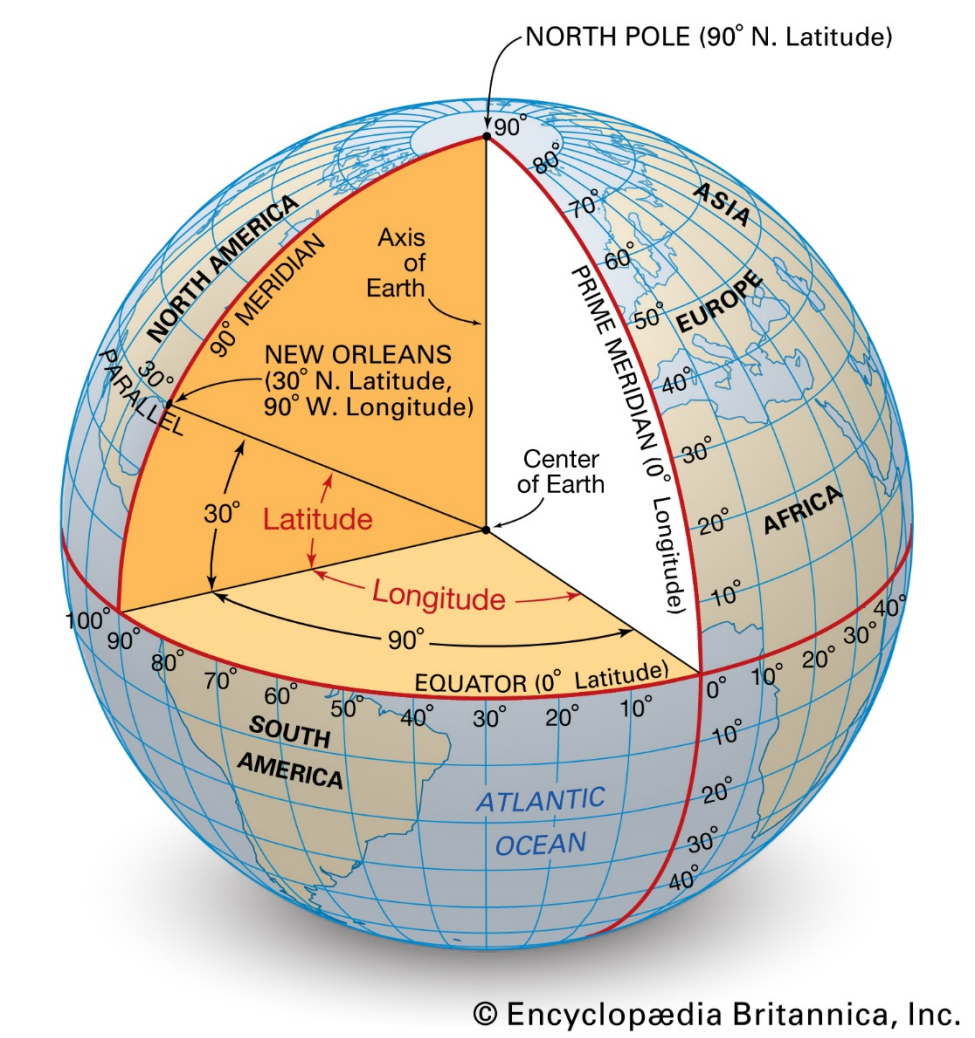
- A detailed look at Earth's Orbit Around the Sun

Longitude and Latitude on the Earth



https://www.worldatlas.com/geography/circles-of-latitude-and-longitude.html

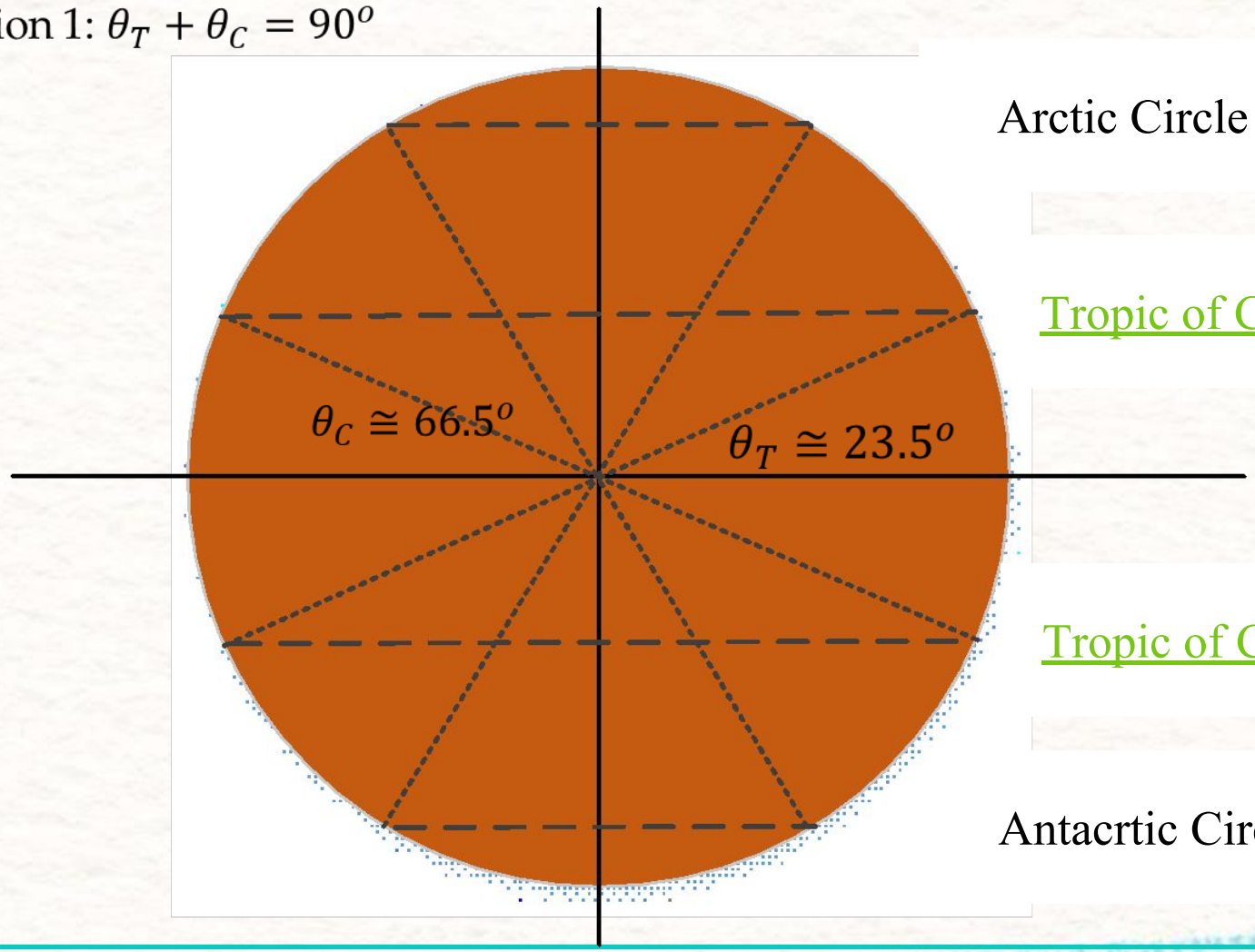
Longitude and Latitude on the Earth



https://www.britannica.com/science/latitude

Four Important Latitudes: $\pm\theta_T \cong \pm 23.5^o; \pm\theta_C \cong \pm 66.5^o$

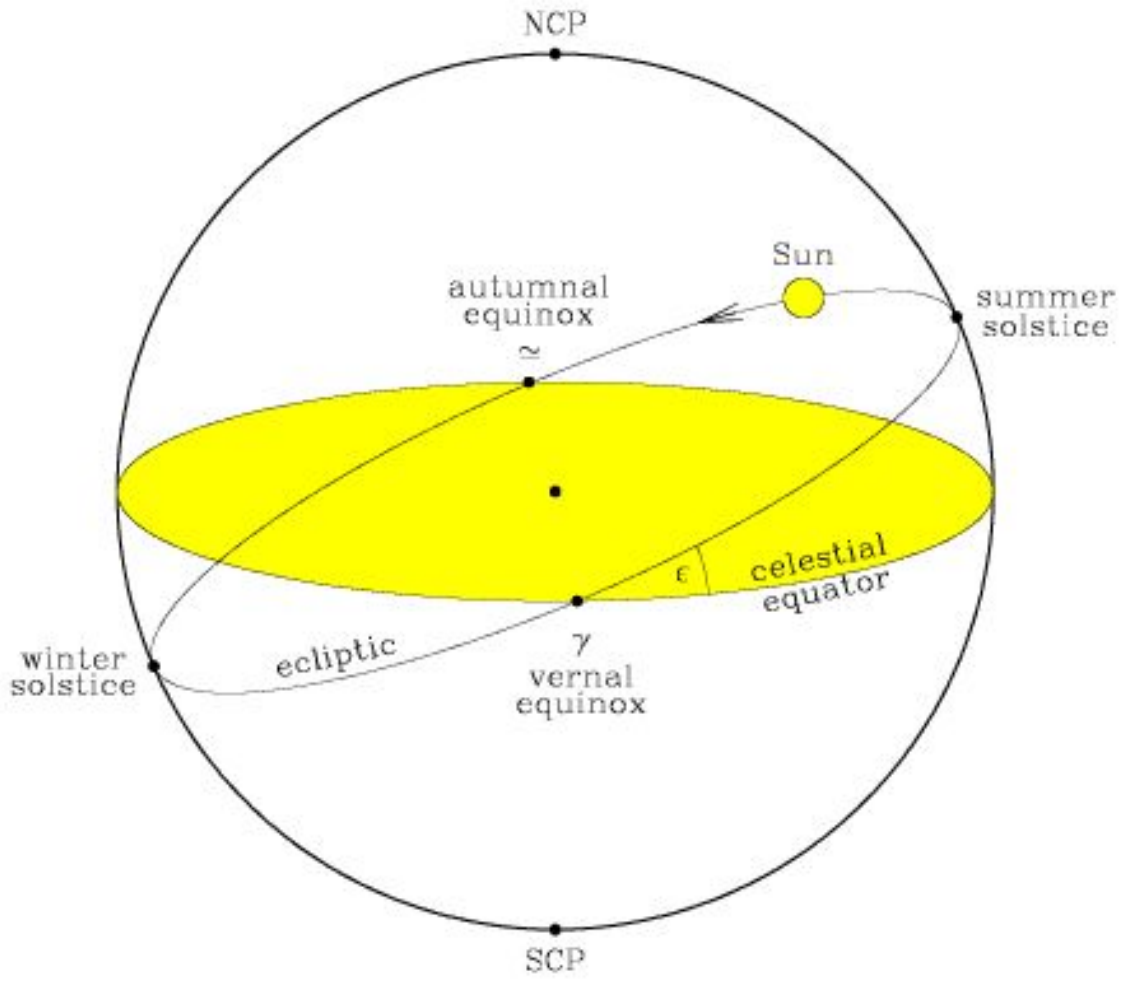
Curious Observation 1: $\theta_T + \theta_C = 90^o$



Some definitions

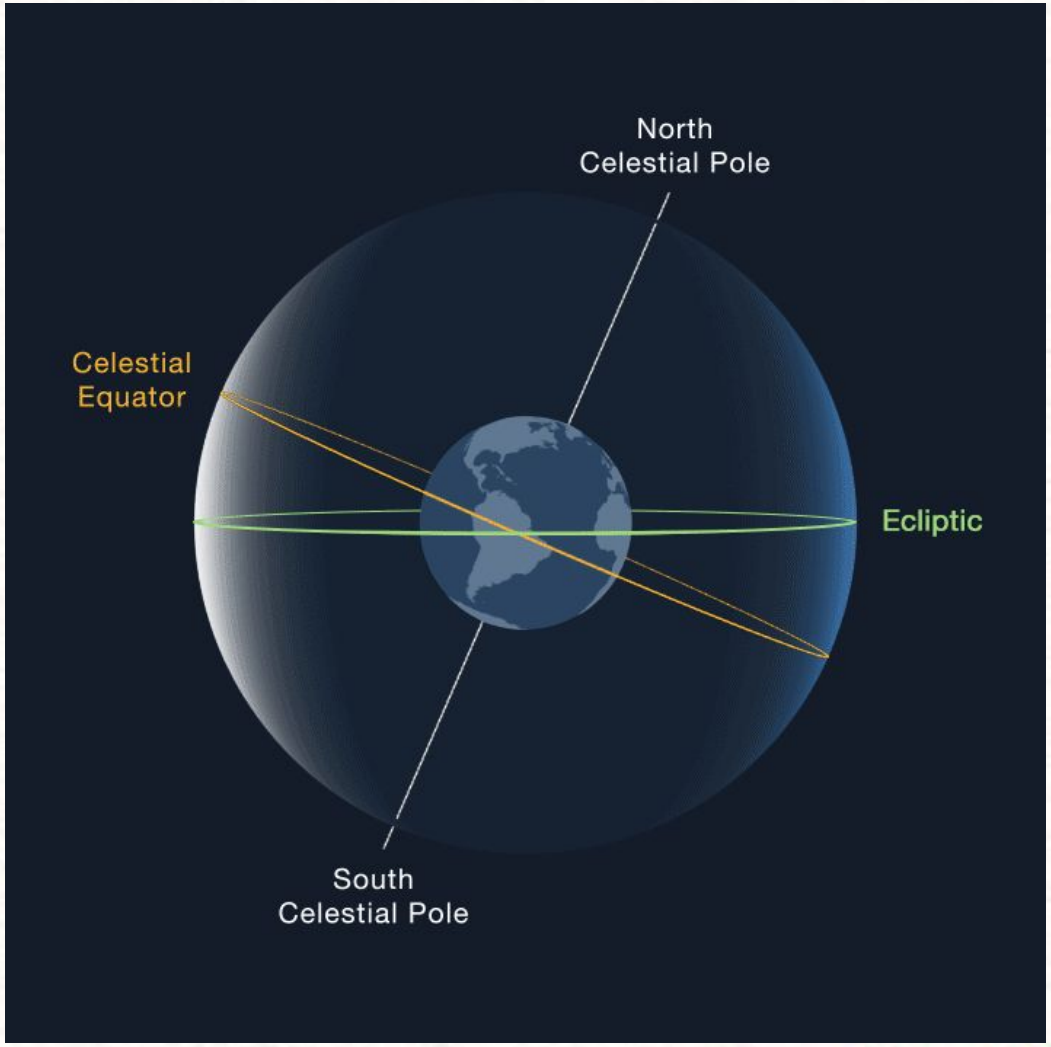
http://astronomy.nmsu.edu/nicole/teaching/astr505/lectures/lecture08/slide02.html

- Celestial Equator, Celestial North Pole (CNP) and Celestial South Pole (CSP)
  - These are extensions of the Earth's equatorial plane, and the Earth's NP and SP in the imaginary sphere in the outer sky surrounding the Earth
- Ecliptic
  - The plane in which the Sun appears to be orbiting around the Earth
- Curious Observation 2:
  - The angle ε between the celestial equator and the ecliptic equals the angle θ_T on the prior slide



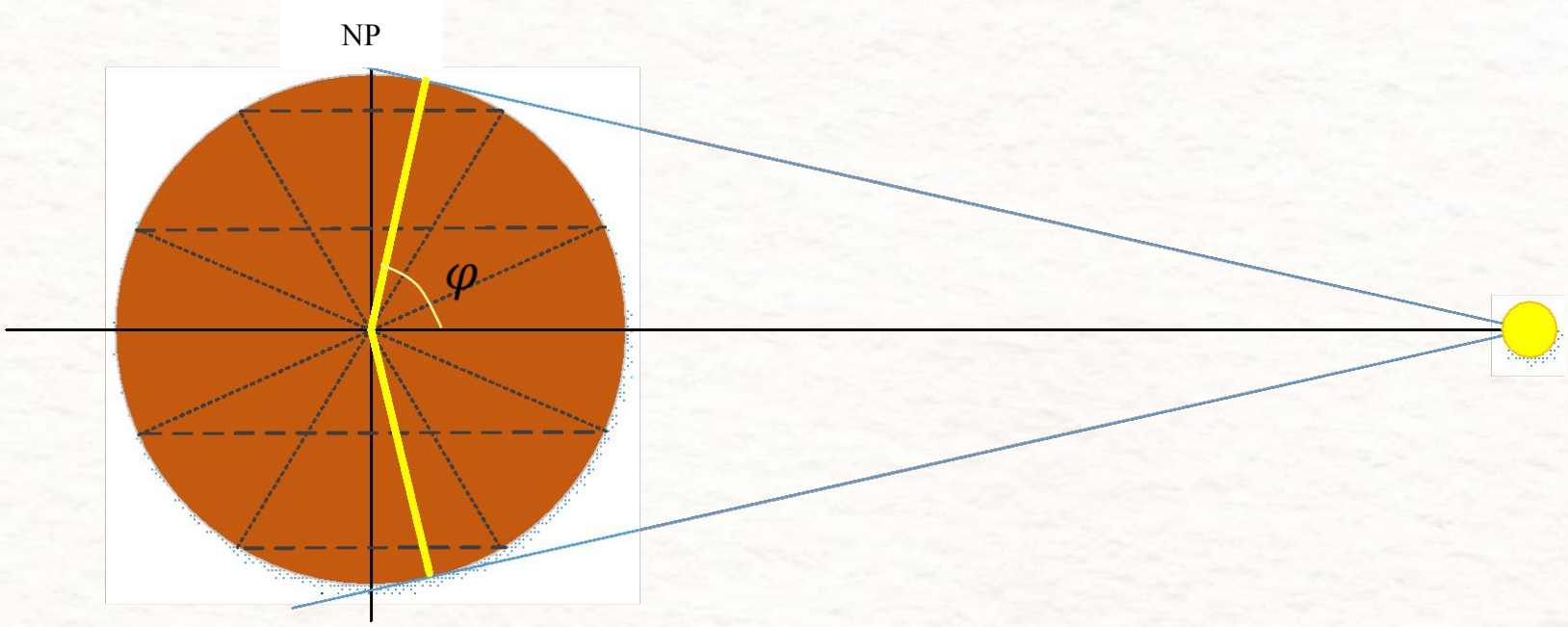
Inclination of the Earth's Axis relative to the Ecliptic

https://solarsystem.nasa.gov/basics/chapter2-2/



Sun as a Point Source
Along the Earth's Equatorial Plane

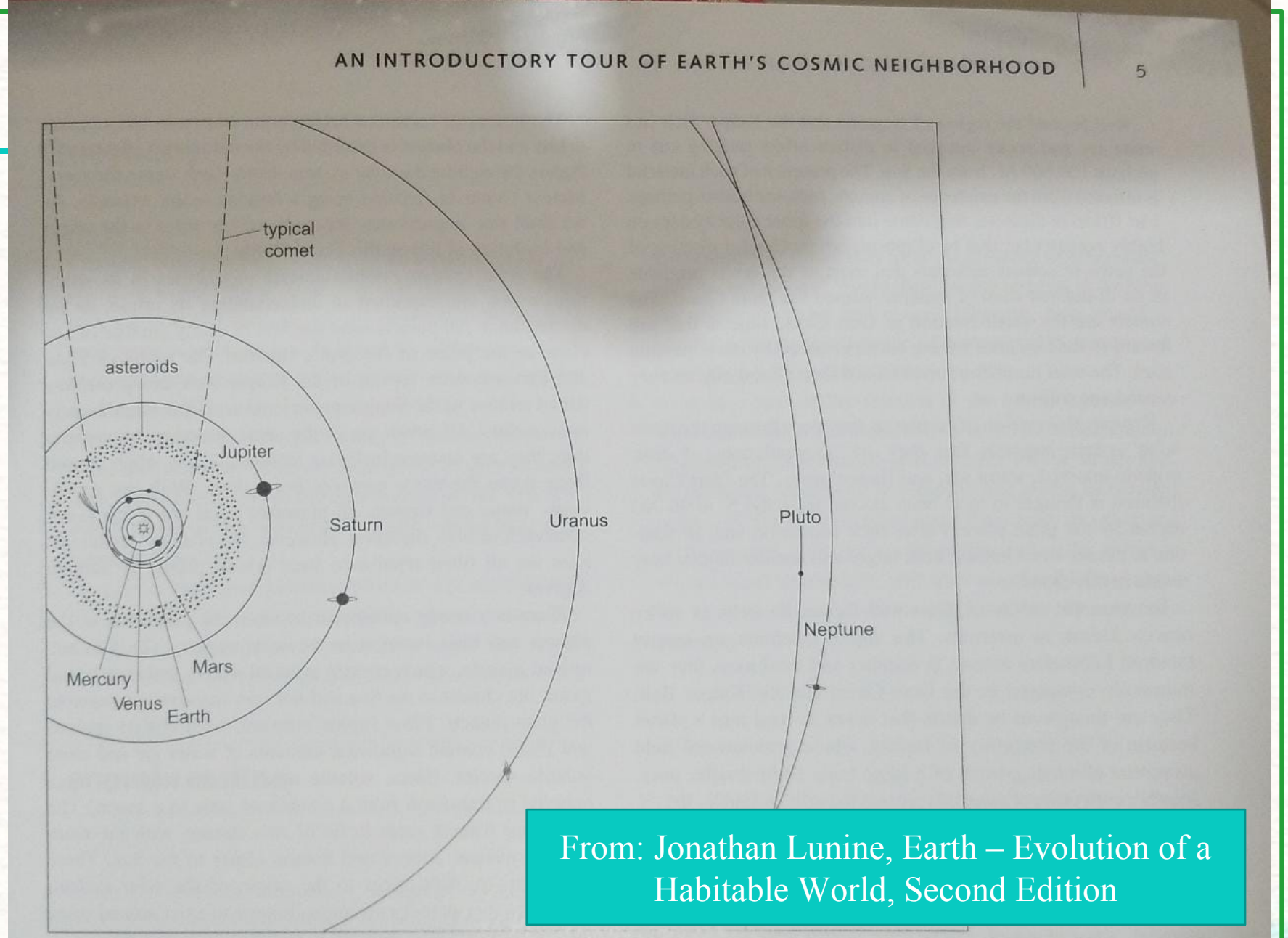
- Let the Earth's radius be denoted as R_e ($\cong$ 6371 km) and the distance from the Earth Center to the Sun be approximated as $n \times R_e$
- Determine the angle φ relative to the equator where there is day



Sun as a Point Source
Along the Earth's Equatorial Plane

- Asymptotic analysis:
  - $\cos\varphi = \frac{R_e}{nR_e} = \frac{1}{n} \to 0,$
  - Thus, as $n \to \infty$, $\cos\varphi \to 0$ and $\varphi \to 90^o$
- Specific calculation:
  - $R_e = 6371\ km$
  - Distance to the Sun $\approx$ 150 million km
  - $n \approx 23500$ and $\cos\varphi = \frac{1}{n} = 4 \times 10^{-5}$
  - Therefore, $\varphi \to 89.99^o$
- Sun's radius: ~7 lakh km (~110 times larger than the Earth's radius)
- The animation on the next slide is (almost) true-to-the-scale
  - The radius of the Earth's orbit is reduced by half ($n = 11750$) and Earth's radius is increased five-fold (33000 km) since otherwise the Earth becomes such a tiny dot that it becomes very difficult to spot it

Solar System

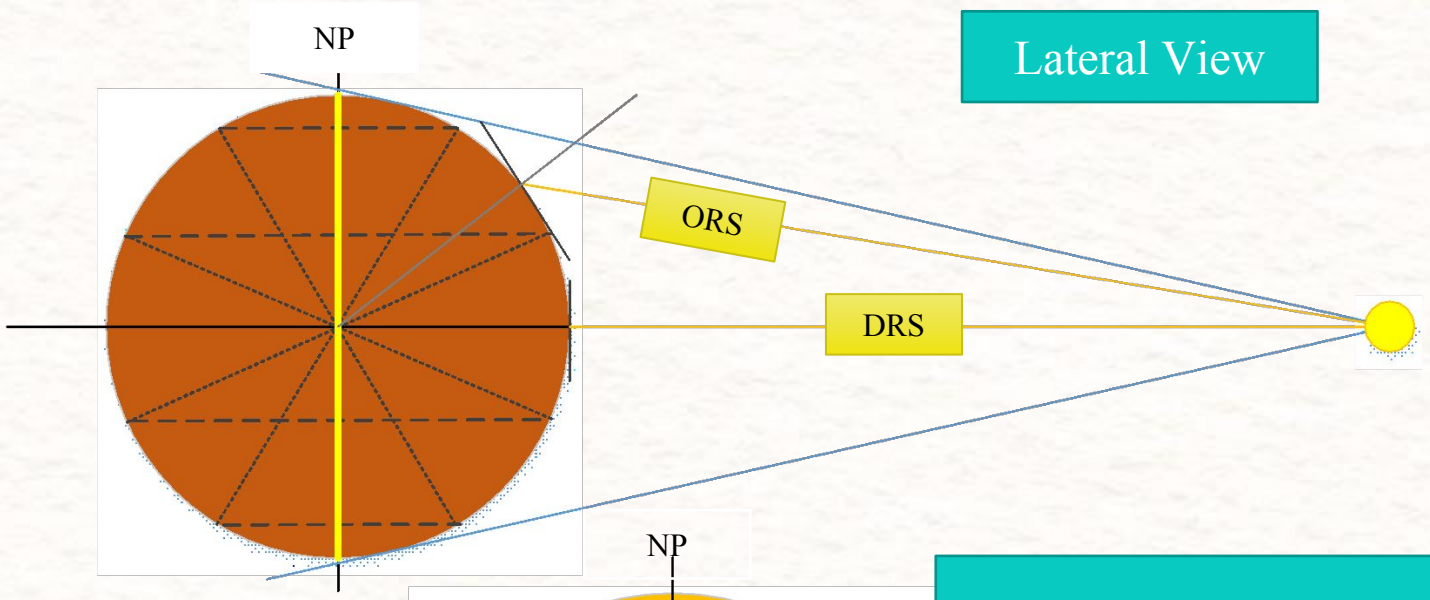


From: Jonathan Lunine, Earth – Evolution of a Habitable World, Second Edition

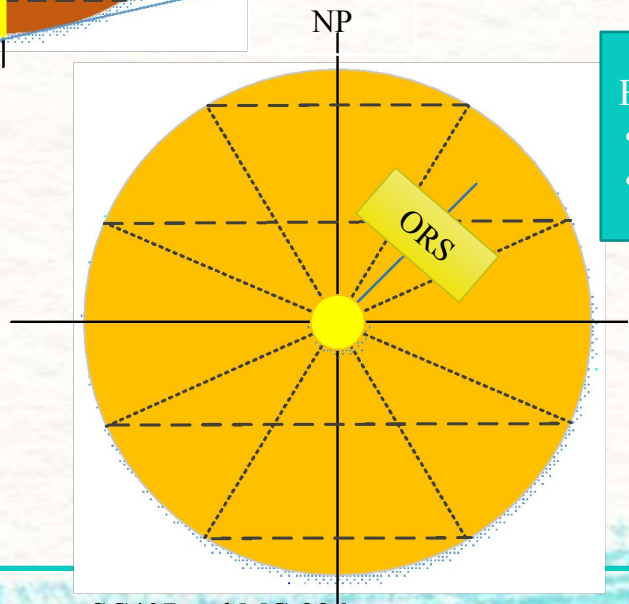
Figure 1.2 Schematic map of our solar system, showing the ... but not of the bodies themselves. Note the small scale of the orbits of terrestrial planets compared to the vast realm of the ... are the Kuiper Belt beginning just beyond Neptune's orbit and the Oort cloud of comets much further out.

Direct Ray of Sun (DRS) versus Oblique Ray of Sun (ORS)

- DRS reaches a point on the earth from directly overhead, i.e., the DRS arrives at an elevation angle of 90^o relative to the tangential plane at a given location on the Earth
  - The DRS, if extended, would reach the center of the Earth
  - The DRS does not generate a shadow
- The elevation angle at which the ORS reaches a location on the earth is less than 90^o
  - When the Sun is located on the Celestial Equator, the highest elevation angle at which the Sun appears in the sky at a latitude of θ is equal to _____ degrees



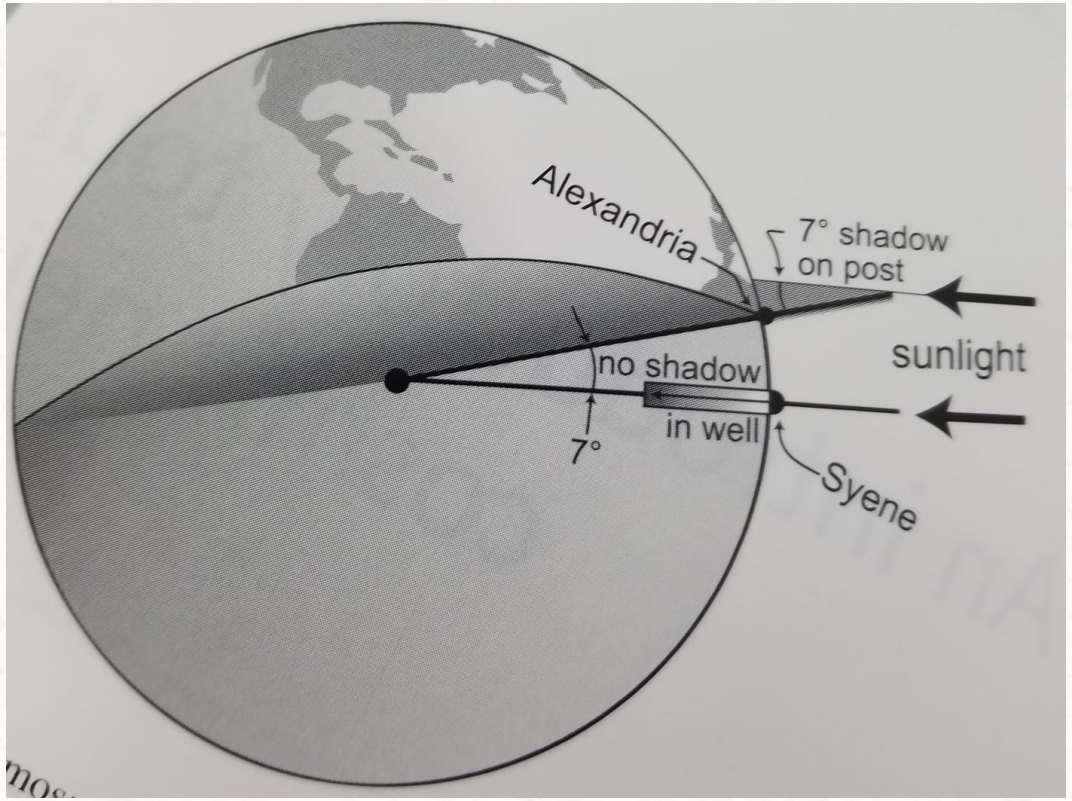
Lateral View



From Sun's Point of View
- DRS is hidden
- An example ORS is shown

An Early Application of the DRS and the ORS

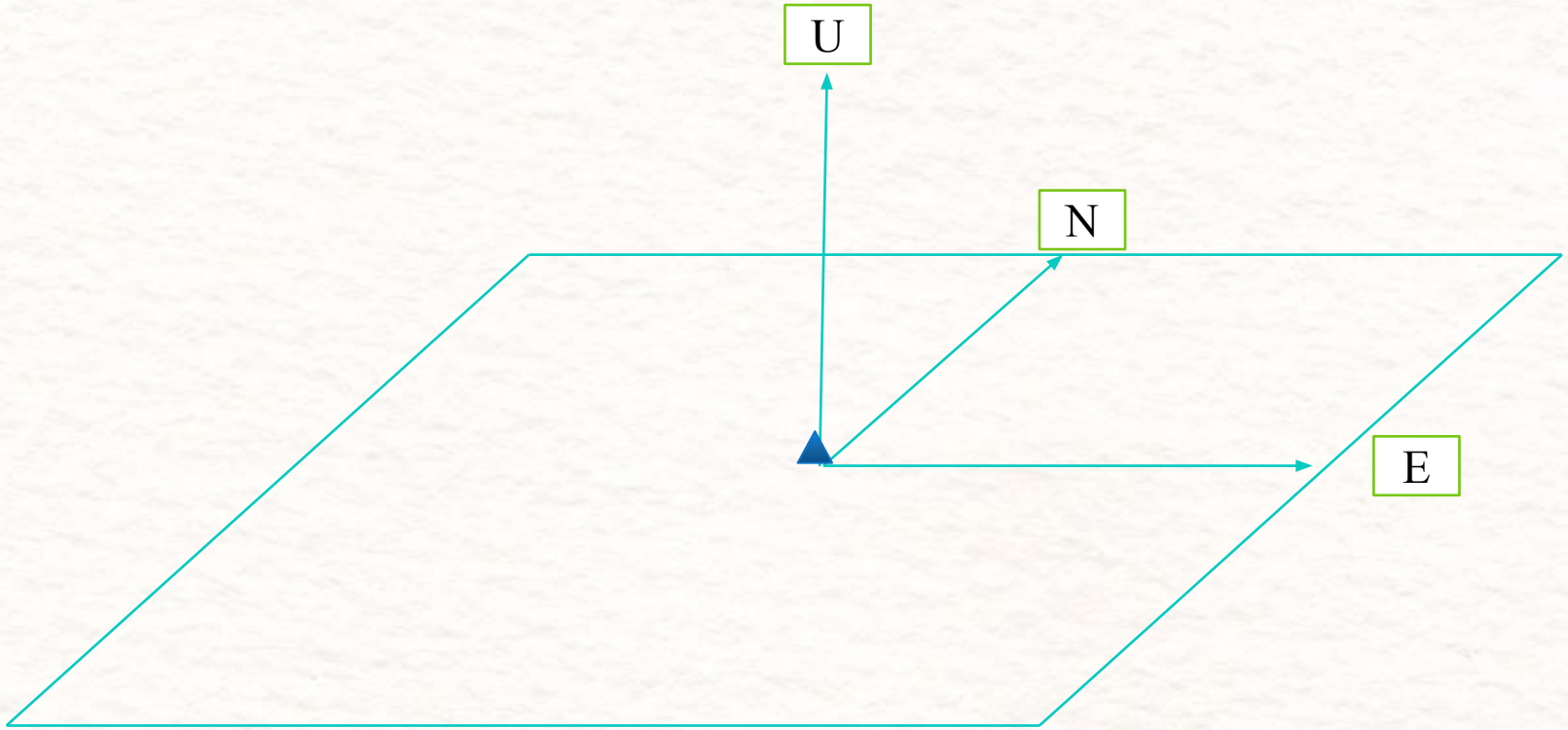
- Eratosthenes in the third century BC (about 2300 years ago) determined the size of the Earth
- The Sun was directly overhead at noon at a site in Syene (now Aswan) in Egypt and no shadow was visible of an object hanging on the top of a vertical well shaft
- Eratosthenes lived in Alexandria, the same longitude but at a higher latitude and there he could see that the Sun cast a shadow at noon
- He measured the size of a shadow of a obelisk (tower) of known height at Alexandria the same time and the same day that no shadow could be seen at Syene
- He calculated that these two places must be separated by 7.2^o in latitude (at the Earth's center)
- He deduced that the Earth's circumference must be $\frac{360^o}{7.2^o} \times d$, where $d = 918$ km is the distance between Syene and Alexandria. This gives the Earth's circumference as 46000 km which is just 12% too large



From: Jonathan Lunine, Earth – Evolution of a Habitable World, Second Edition

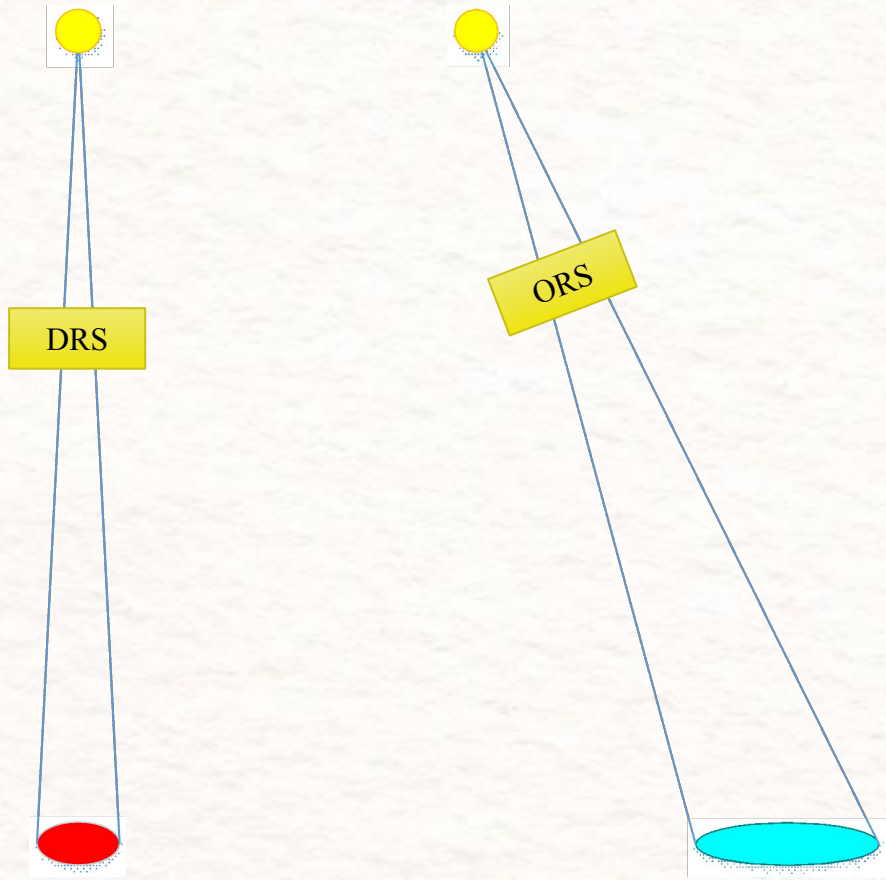
Sun’s Appearance in the Sky

- East-North-Up (ENU) coordinate system



Energy Transfer by the Rays of Sun and the Weather Seasons on the Earth

- Both the DRS and the ORS leave the Sun carrying the same amount of energy
- However, the DRS remains focused on the surface of the Earth and transfers a high packet of energy
- The ORS gets spread over a larger area on the Earth surface, and so the energy transferred per unit area on the Earth's surface is smaller compared to the DRS
- This is the reason for the faster variation of the temperature over 24 hours in a day, and also for a slower variation of the weather over 12 months in a year



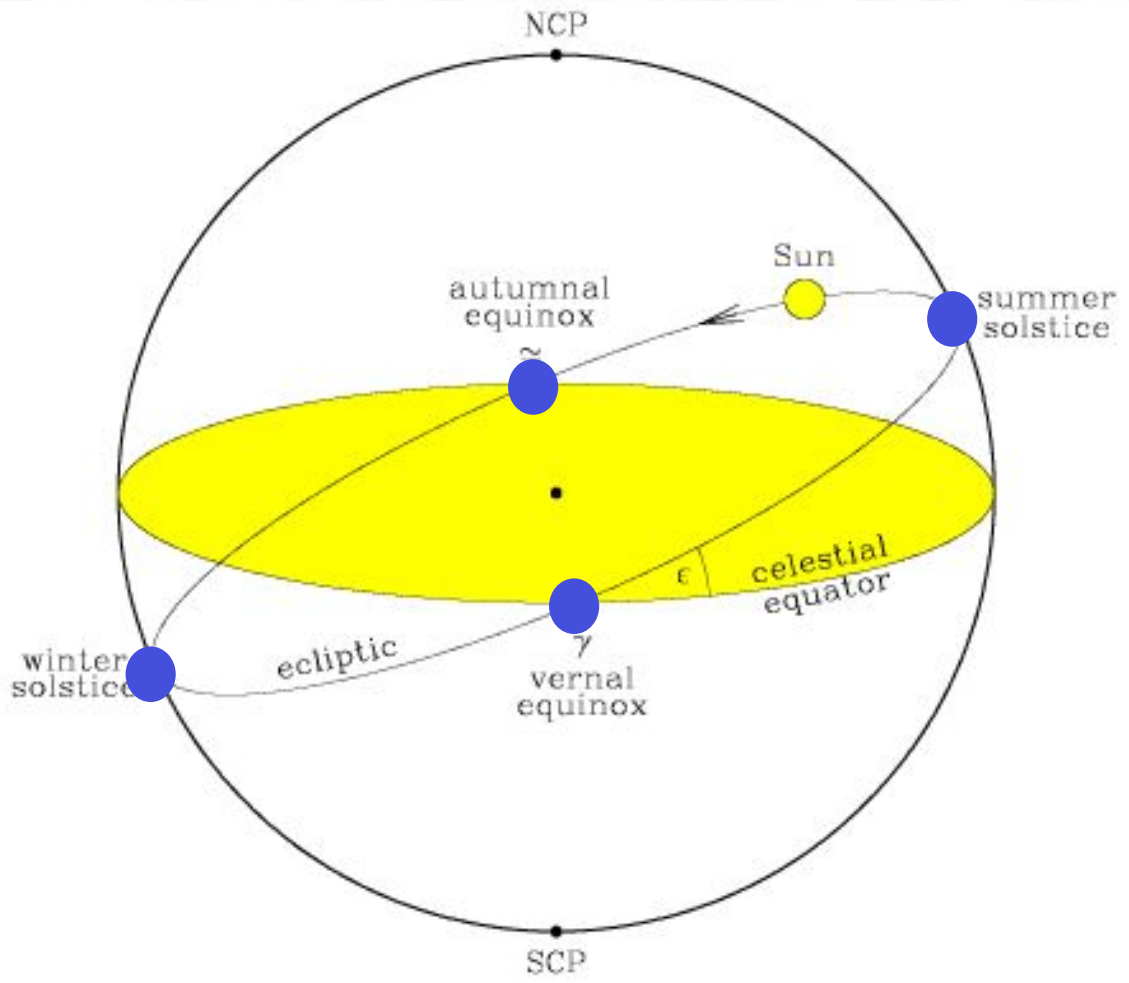
Energy Transfer by the Rays of Sun and the Weather
Seasons on the Earth

- https://en.wikipedia.org/wiki/Effect_of_Sun_angle_on_climate
- https://www.washingtonpost.com/weather/2019/09/23/how-understanding-sun-angles-clarifies-character-seasons-their-weather

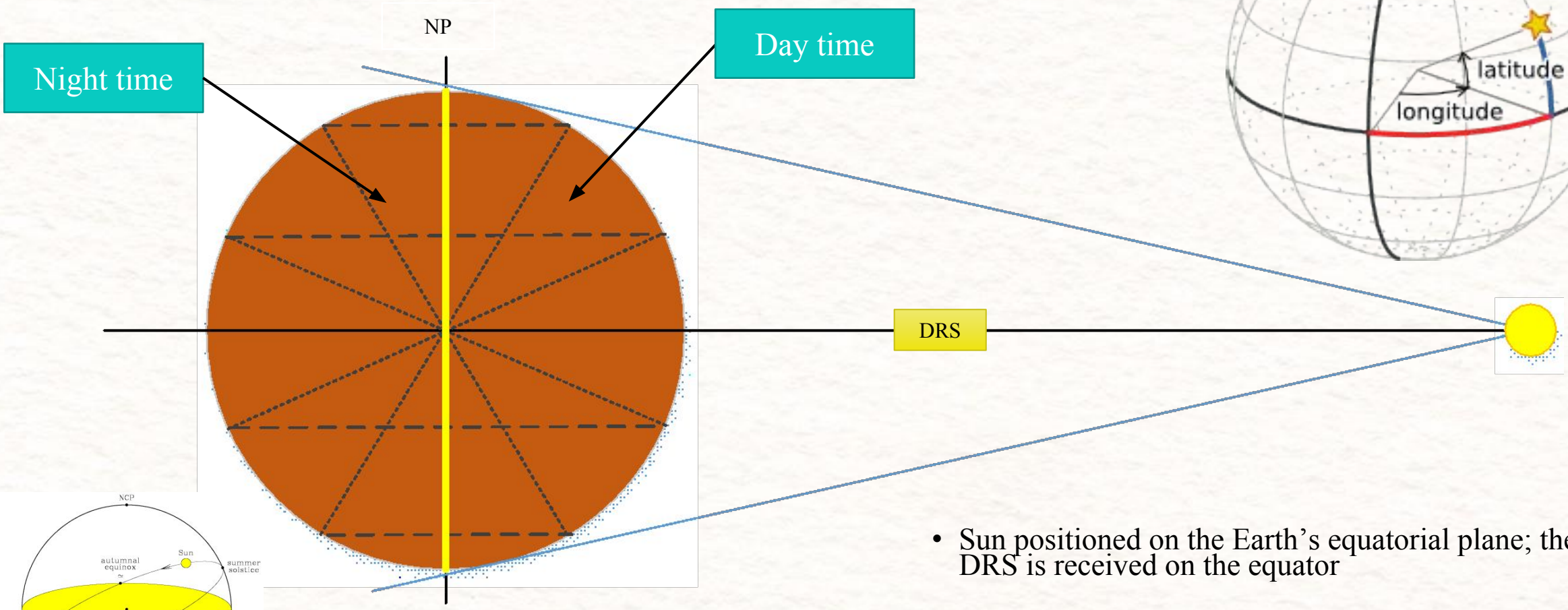
Several Other Effects that Determine the Weather and the Temperature

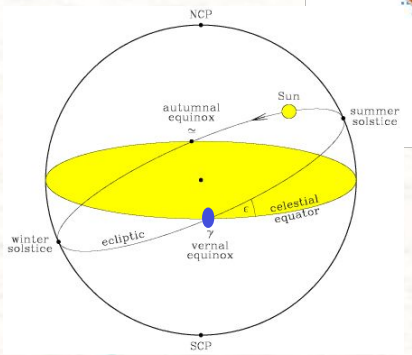
- Solar Irradiance: https://en.wikipedia.org/wiki/Solar_irradiance
- Albedo: https://en.wikipedia.org/wiki/Albedo
- Effect of oceans and wind currents in regulating the temperature on the Earth: http://www.ces.fau.edu/nasa/module-3/why-does-temperature-vary/land-and-water.php

Four Days in a Year – Three Months Apart



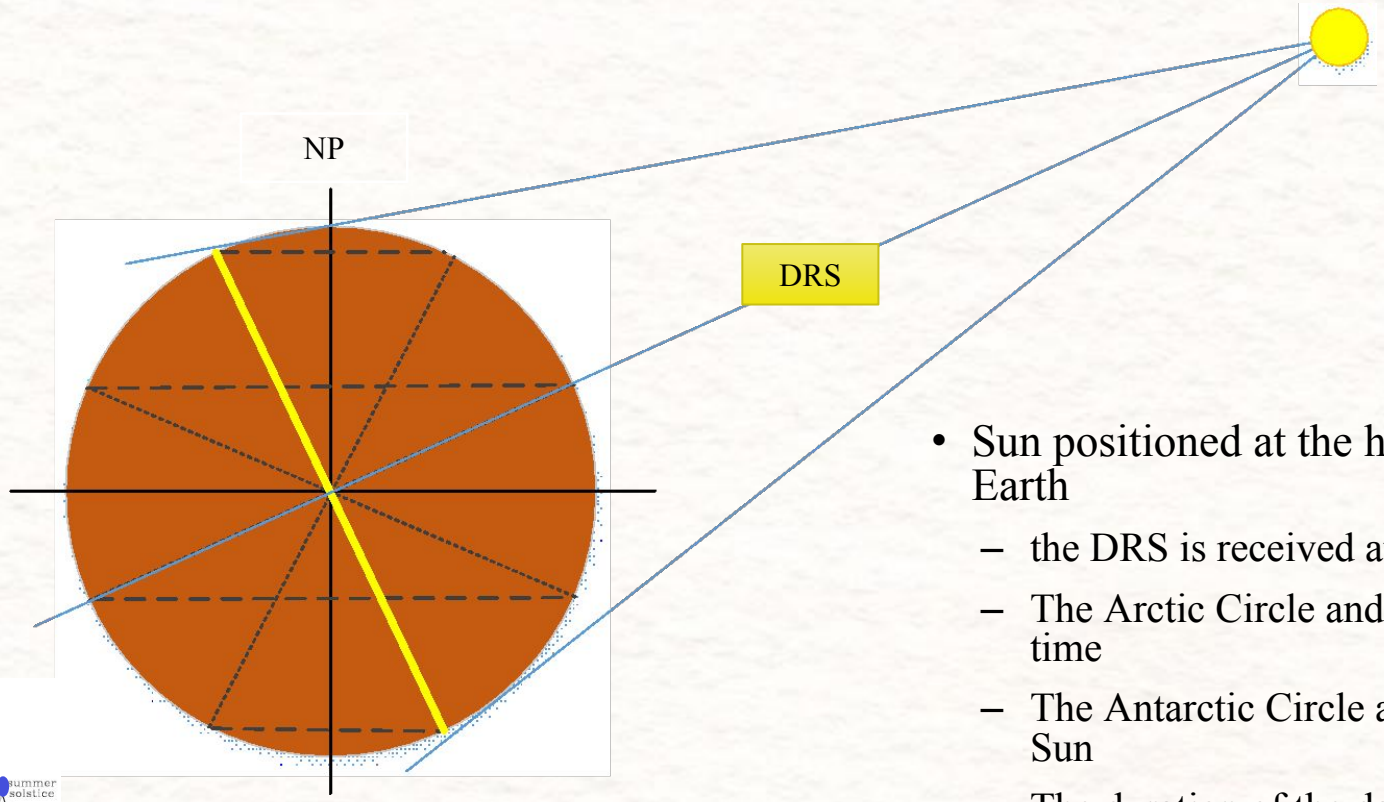
Vernal Equinox: 21st March

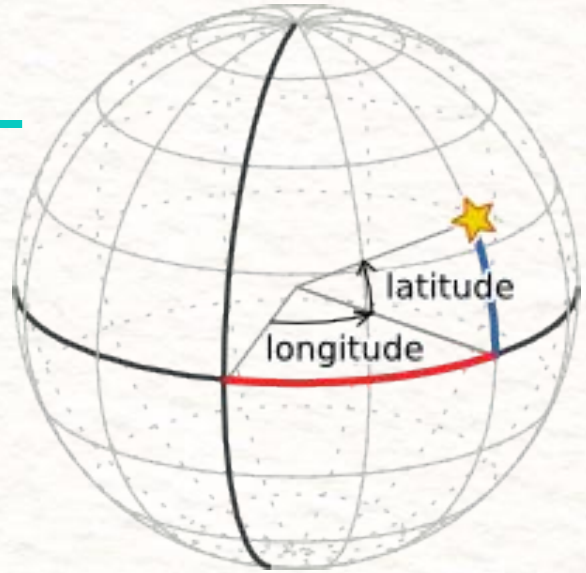


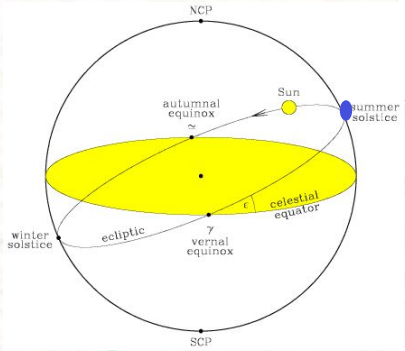


- Sun positioned on the Earth's equatorial plane; the DRS is received on the equator
- The length of the day and the night are equal irrespective of the latitude
- Happens on or around 21st March

Summer Solstice: 21st June

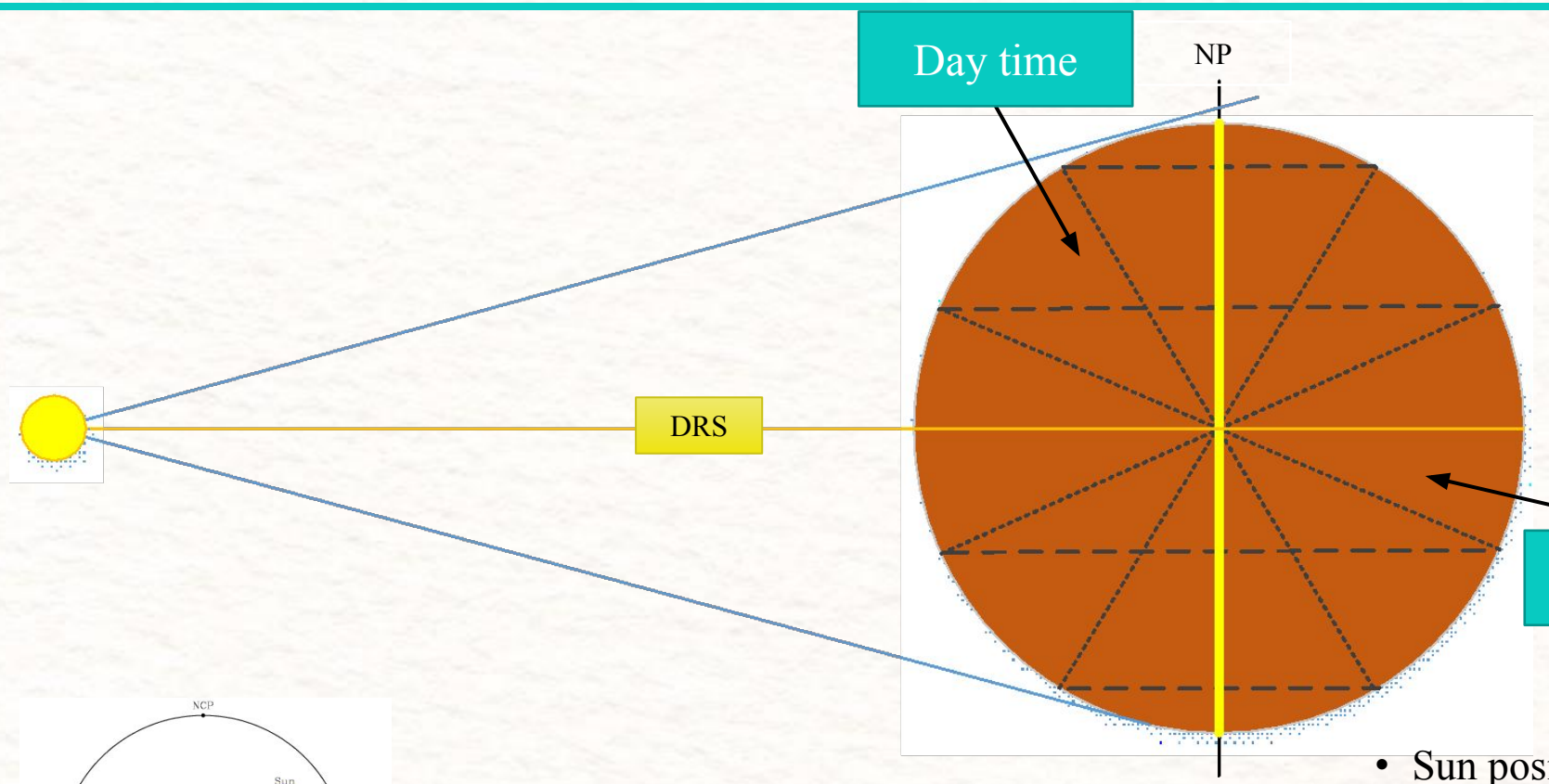


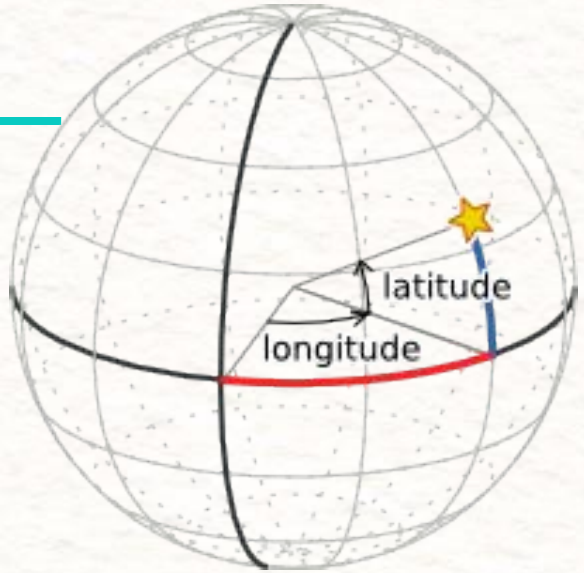


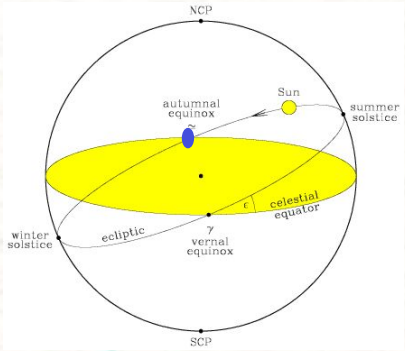


- Sun positioned at the highest point on its orbit around the Earth
  - the DRS is received at the Tropic of Cancer
  - The Arctic Circle and its northern region never have night time
  - The Antarctic Circle and the southern region never see the Sun
  - The duration of the day is longest in the northern hemisphere and shortest in the southern hemisphere
- Happens on one day in a year – 21st June (Summer Solstice for the Northern Hemisphere)

Autumn Equinox: 21st September

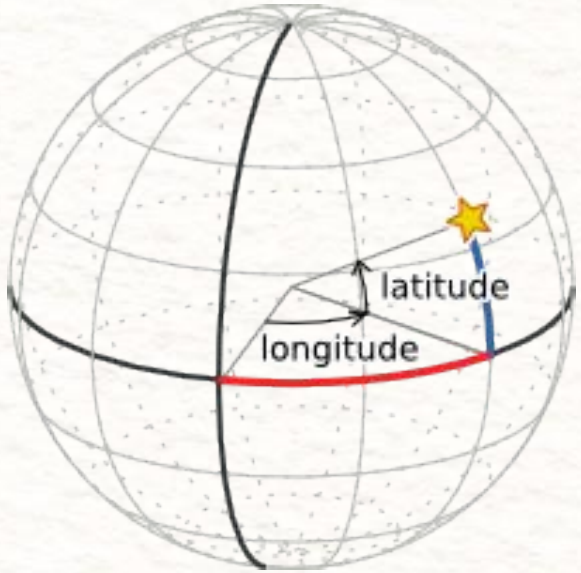


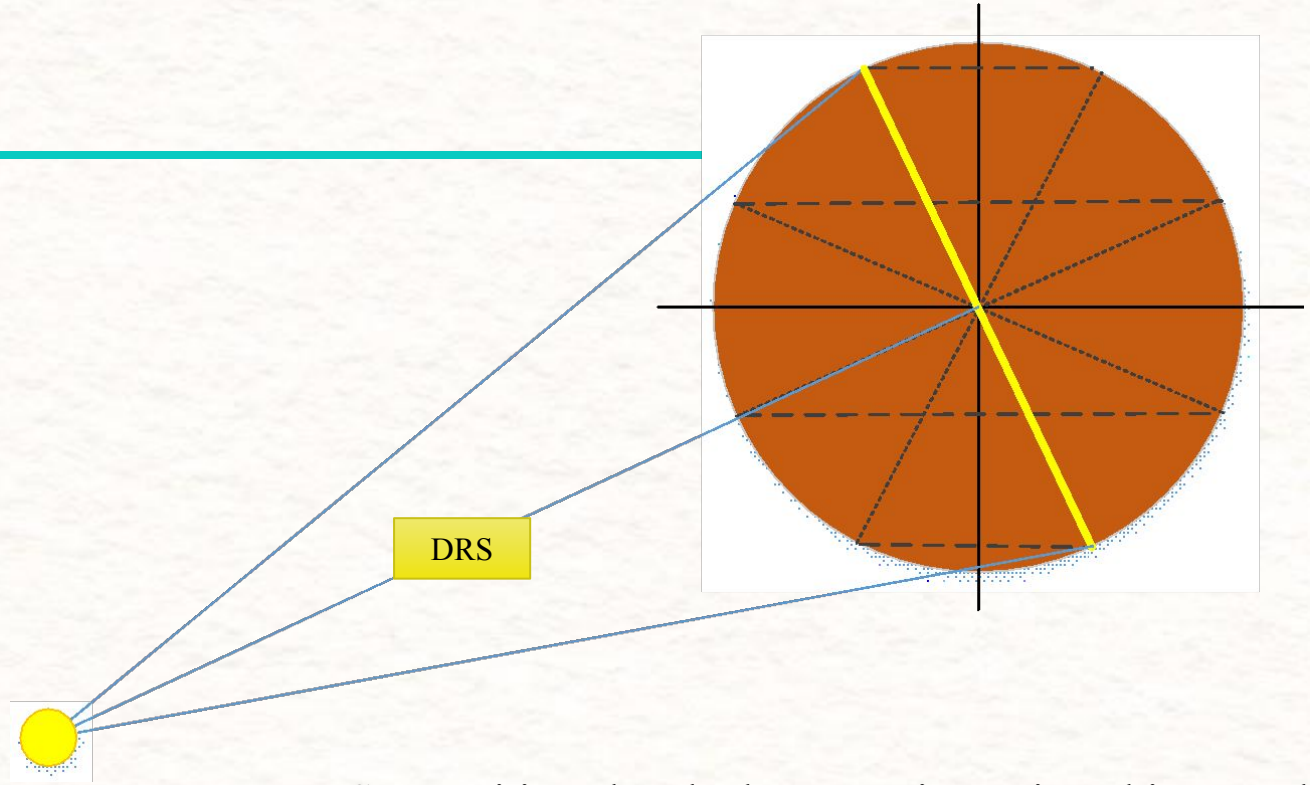


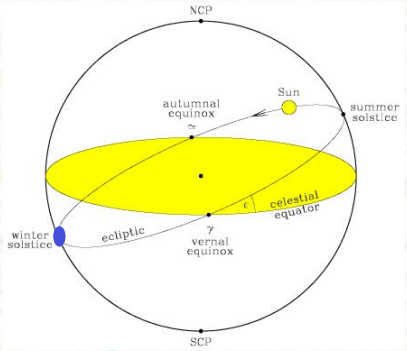


- Sun positioned on the Earth's equatorial plane; the DRS is received on the equator
- The length of the day and the night are equal irrespective of the latitude
- Happens on or around the 21st September

Winter Solstice

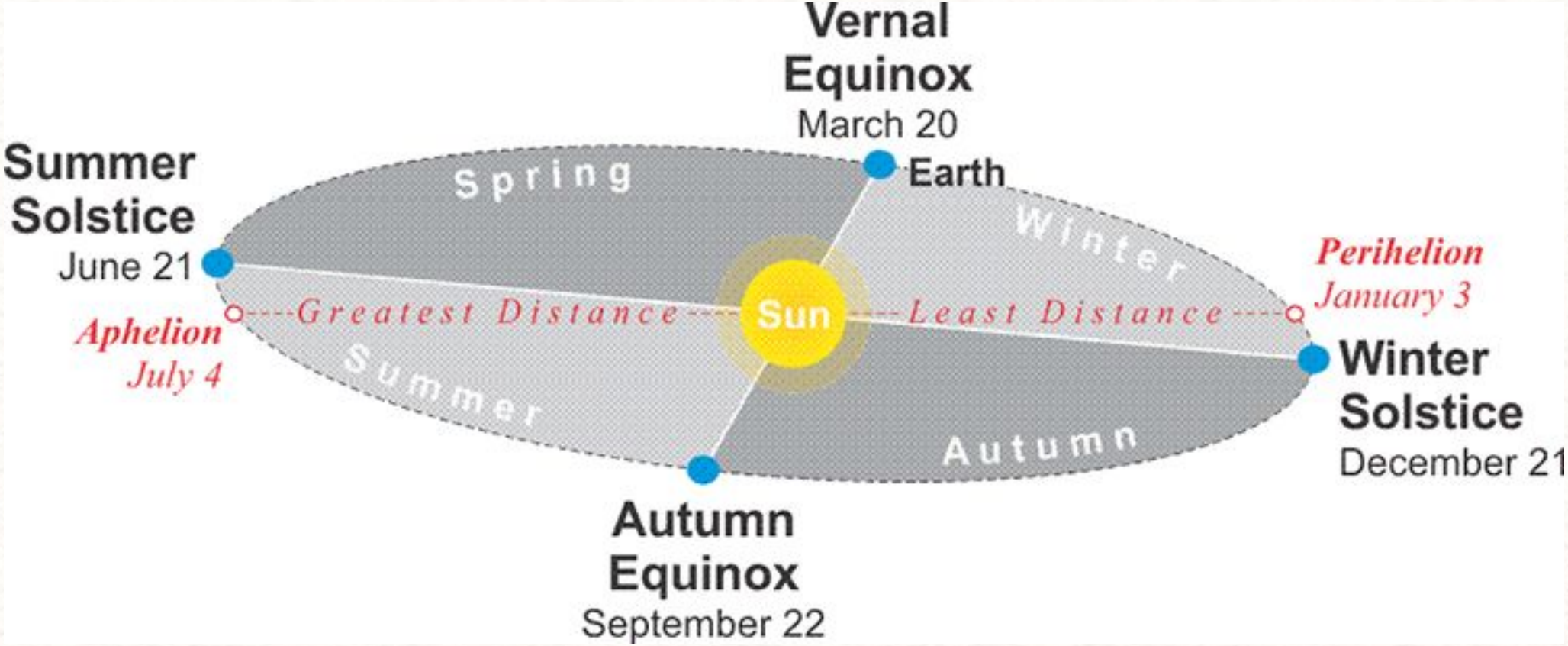






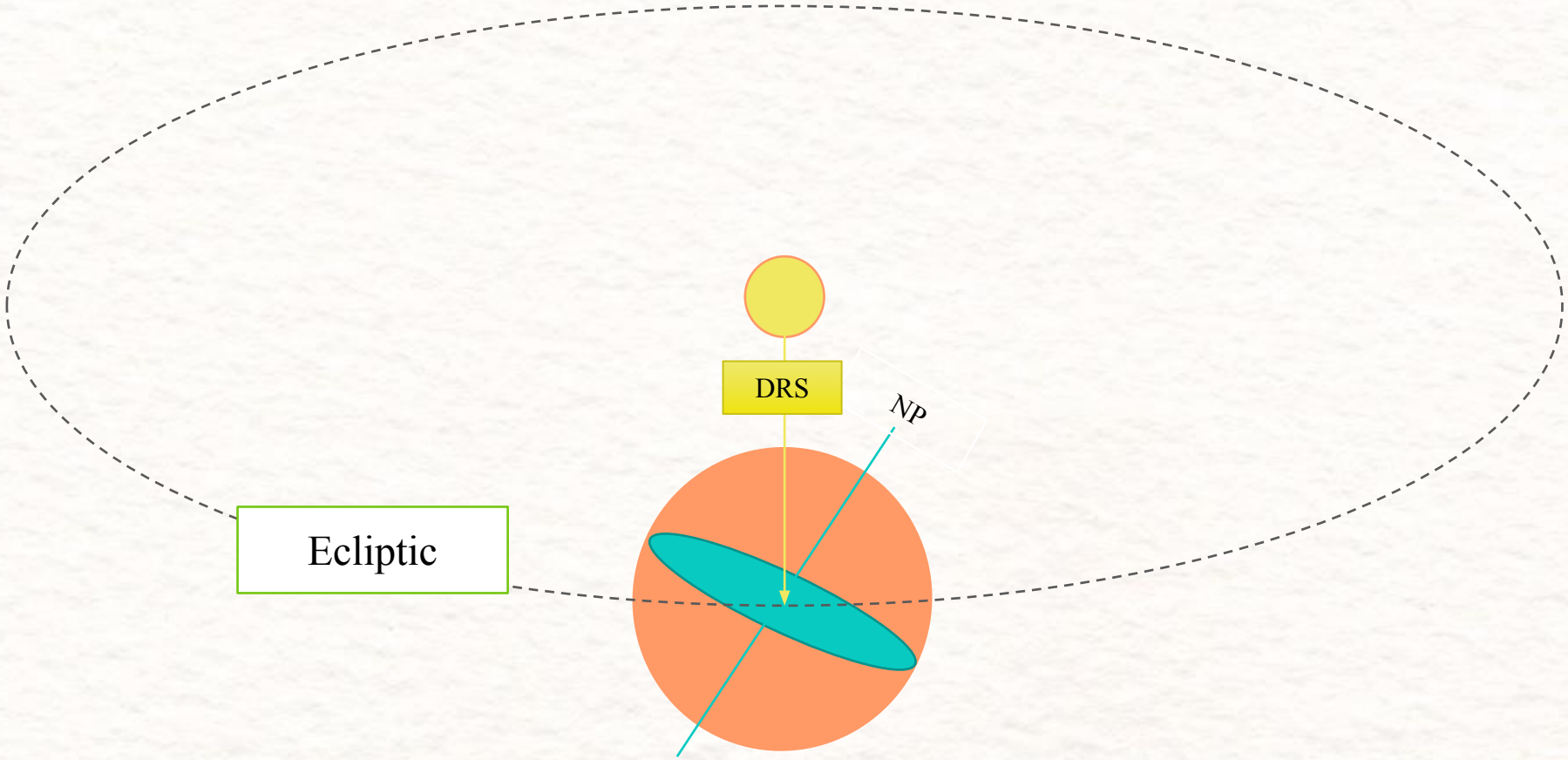
- Sun positioned at the lowest point on its orbit around the Earth;
  - The DRS is received at the Tropic of Capricorn
  - The Arctic Circle and above have 24 hours of night
  - The Antarctic Circle and below have 24 hours of sunshine
  - The duration of the day is longest in the southern hemisphere and shortest in the northern hemisphere
- Happens on one day in a year – 21st December (Winter Solstice for the Northern Hemisphere)

Earth's Orbit Around the Sun

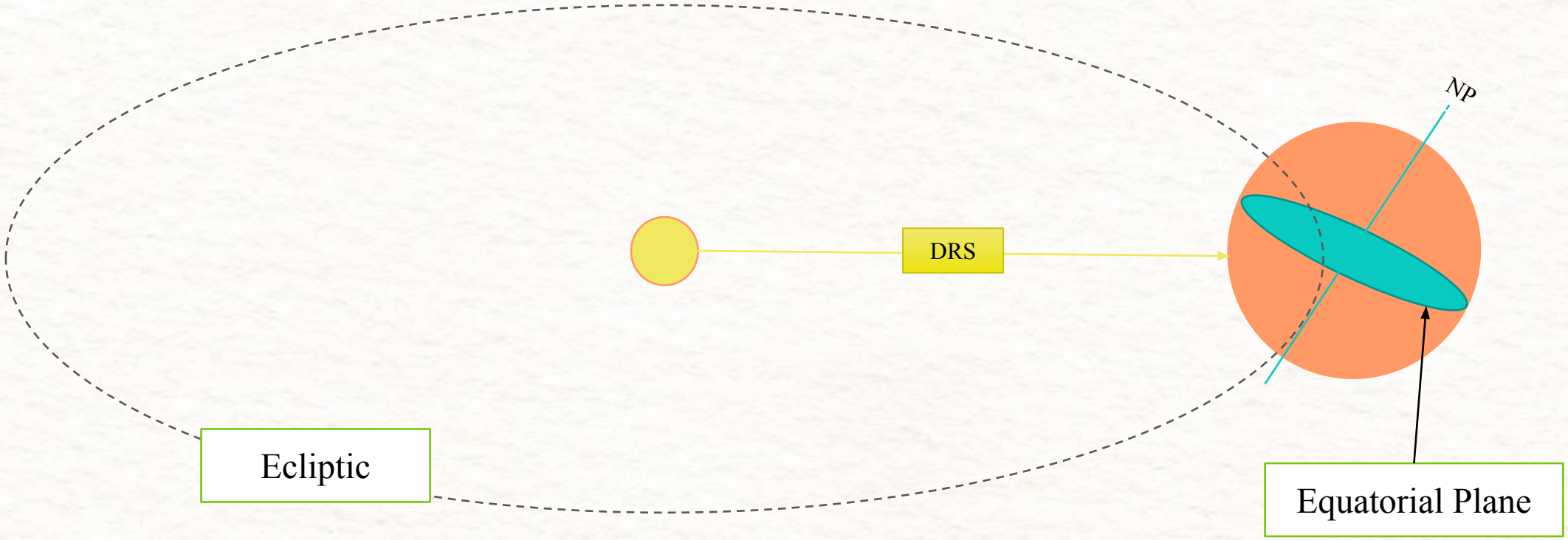


https://www.e-education.psu.edu/geog862

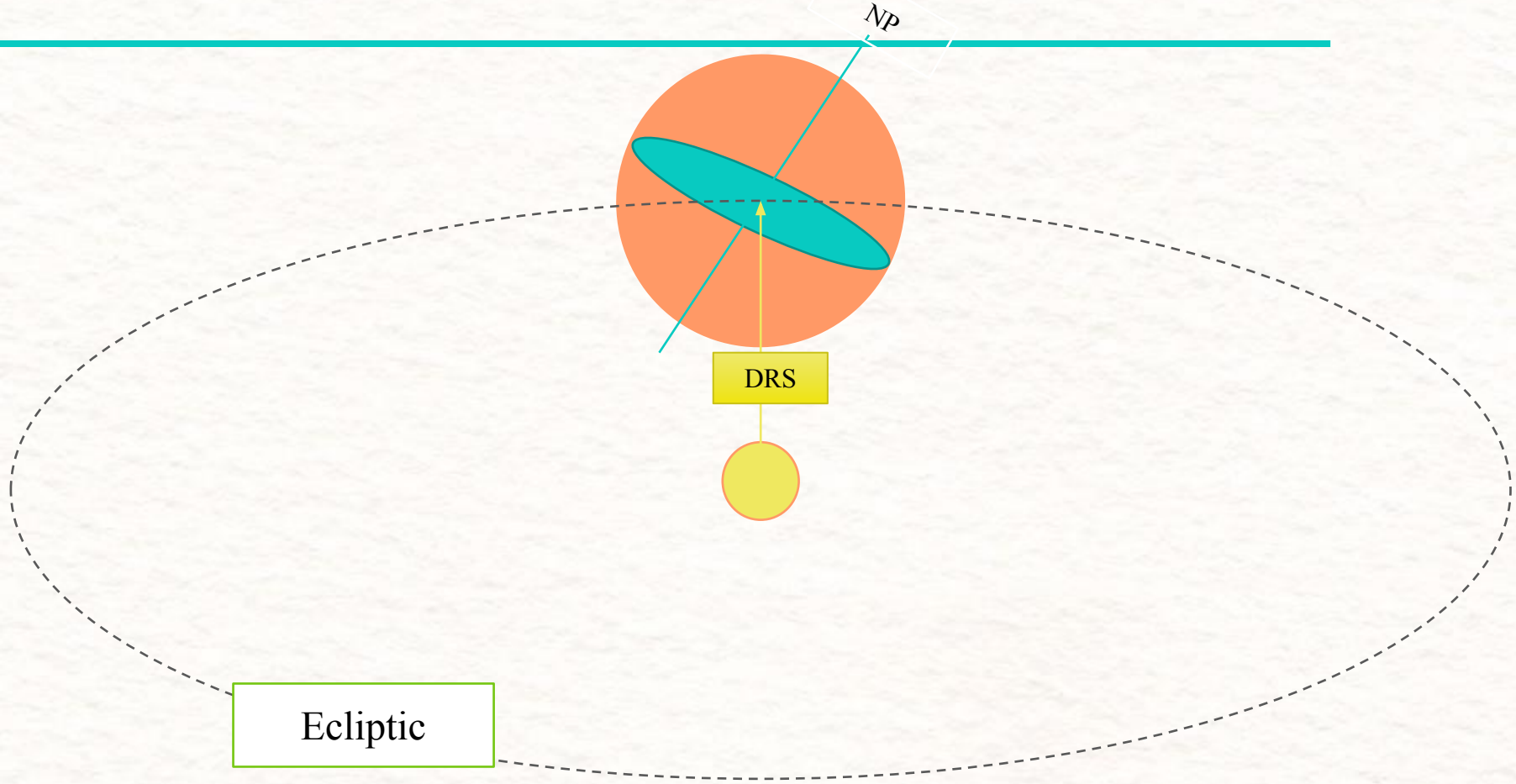
An Alternate View of Autumnal Equinox



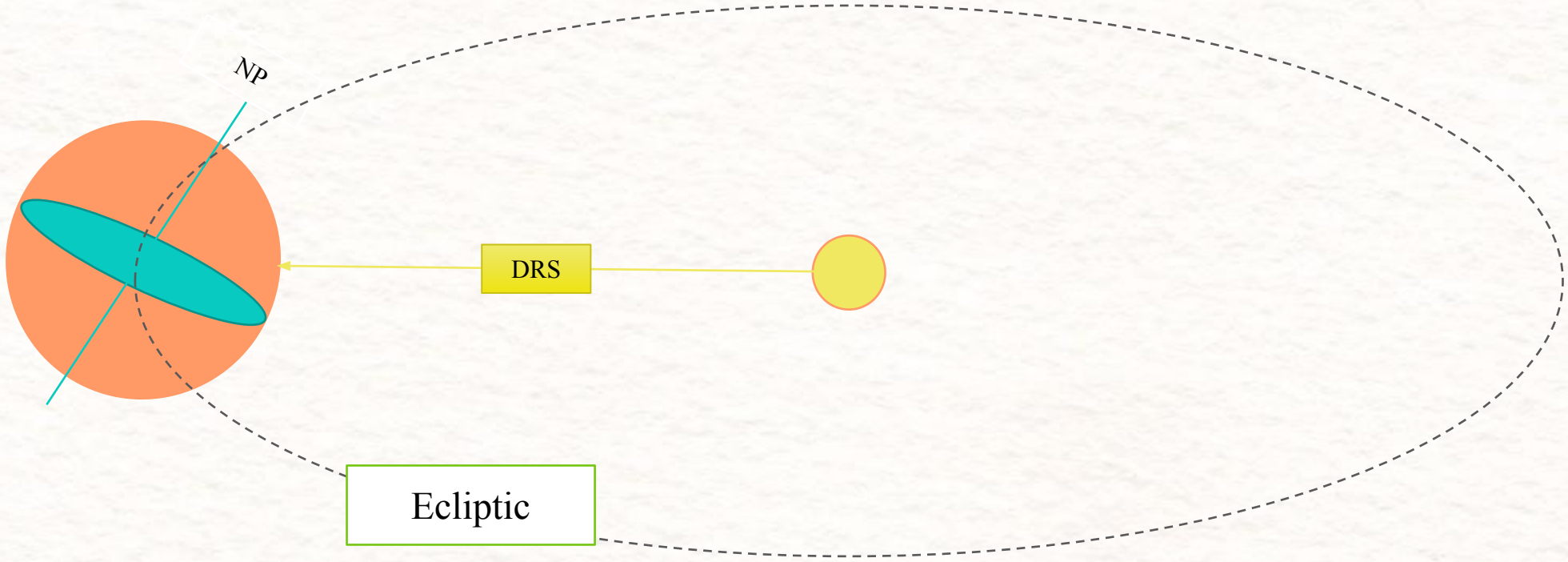
An Alternate View of Winter Solstice



An Alternate View of Spring Equinox



An Alternate View of Summer Solstice



https://www.youtube.com/watch?v=gfnuZjAcx00

https://www.youtube.com/watch?v=tX3Y5bzNDiU

Phases of the Moon

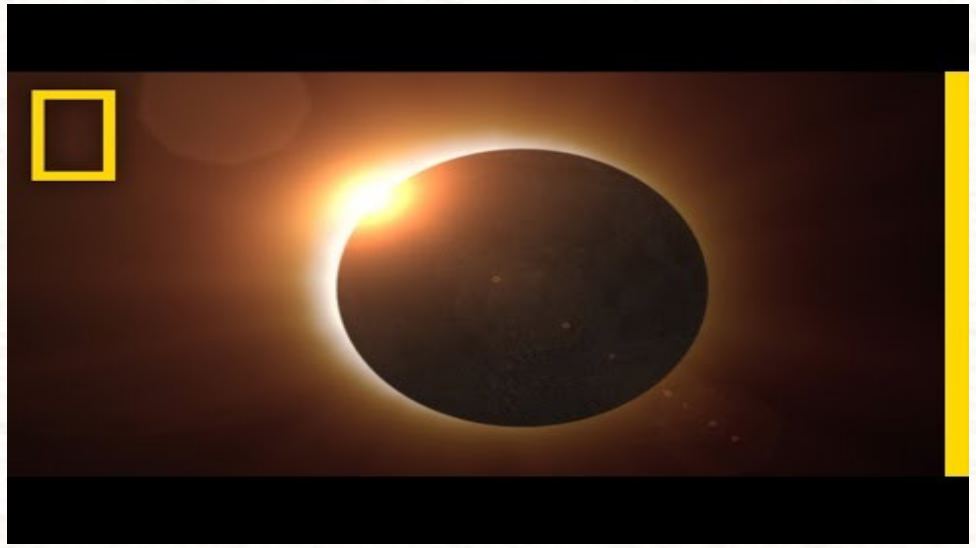
- Phases of the Moon: https://www.youtube.com/watch?v=wz01pTvuMa0

Lunar Eclipse

- Lunar Eclipse: https://www.youtube.com/watch?v=VW2xRR75lKE

Solar Eclipse

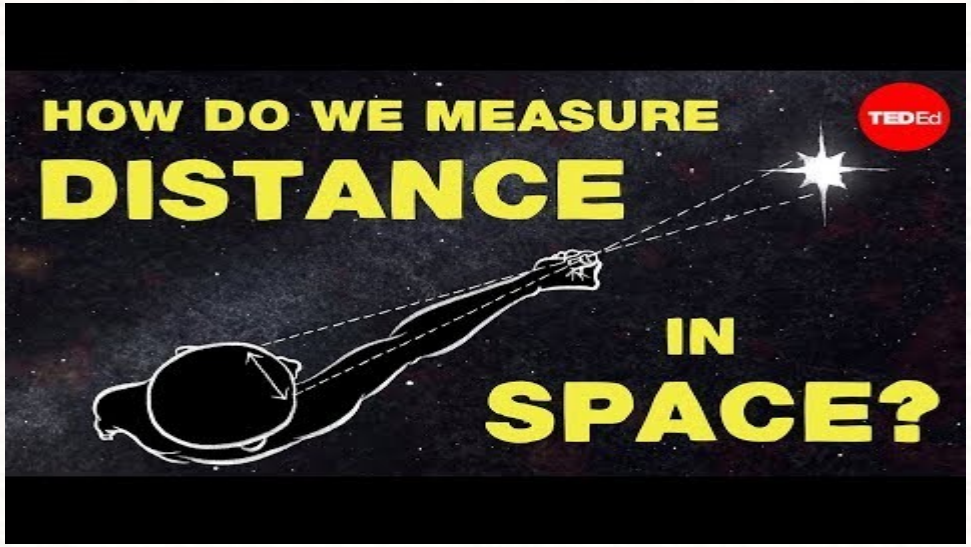
- https://www.youtube.com/watch?v=cxrLRbkOwKs



- https://www.atlasobscura.com/articles/eclipse-maps-halley-18th-century-astronomy?utm_source=pocket-newtab-en-intl

Astronomical Distance Measurement

https://www.youtube.com/watch?v=Op3AYaJc0Xw



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