Sunrise Sunset Seasonal Markers

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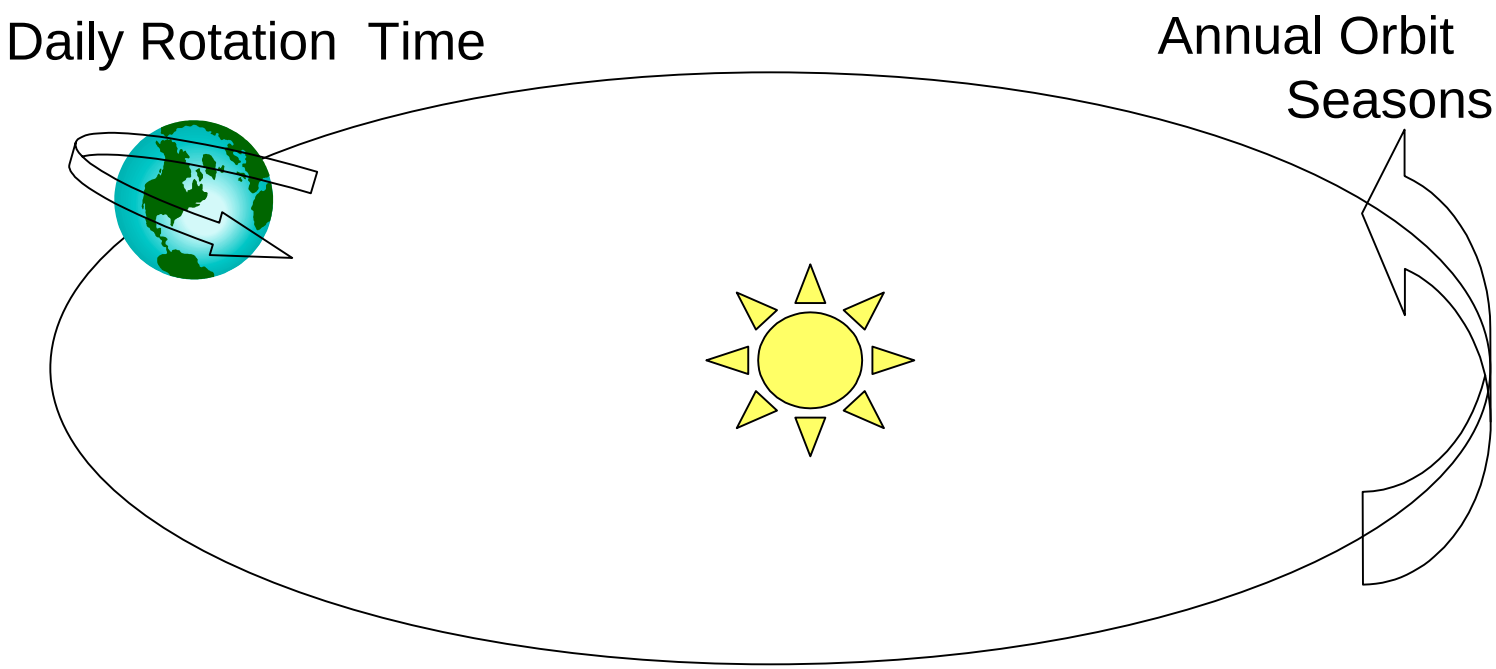
Mike DeAmicis-Roberts

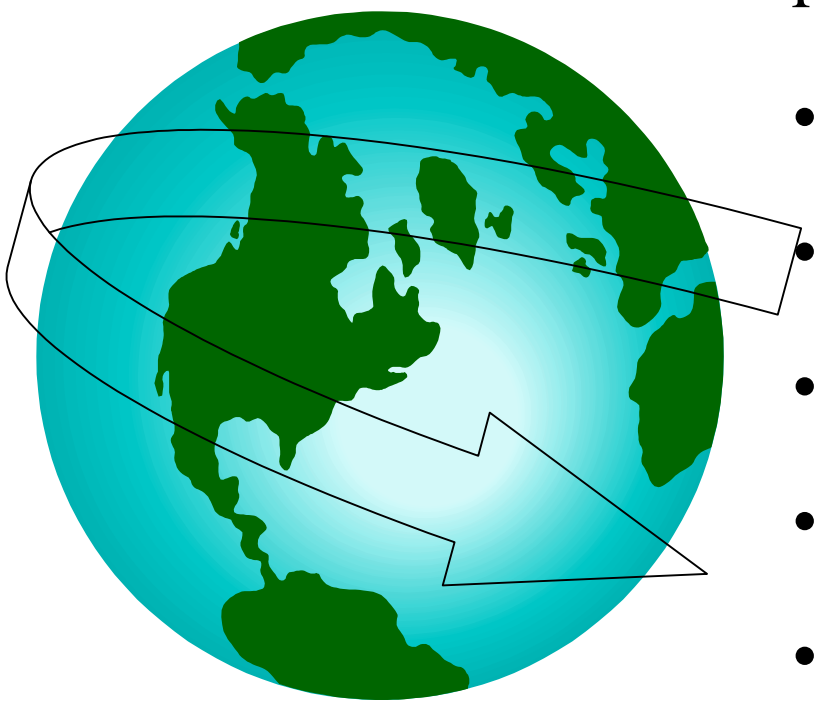
NASS Tucson 2002

Solar Cycles



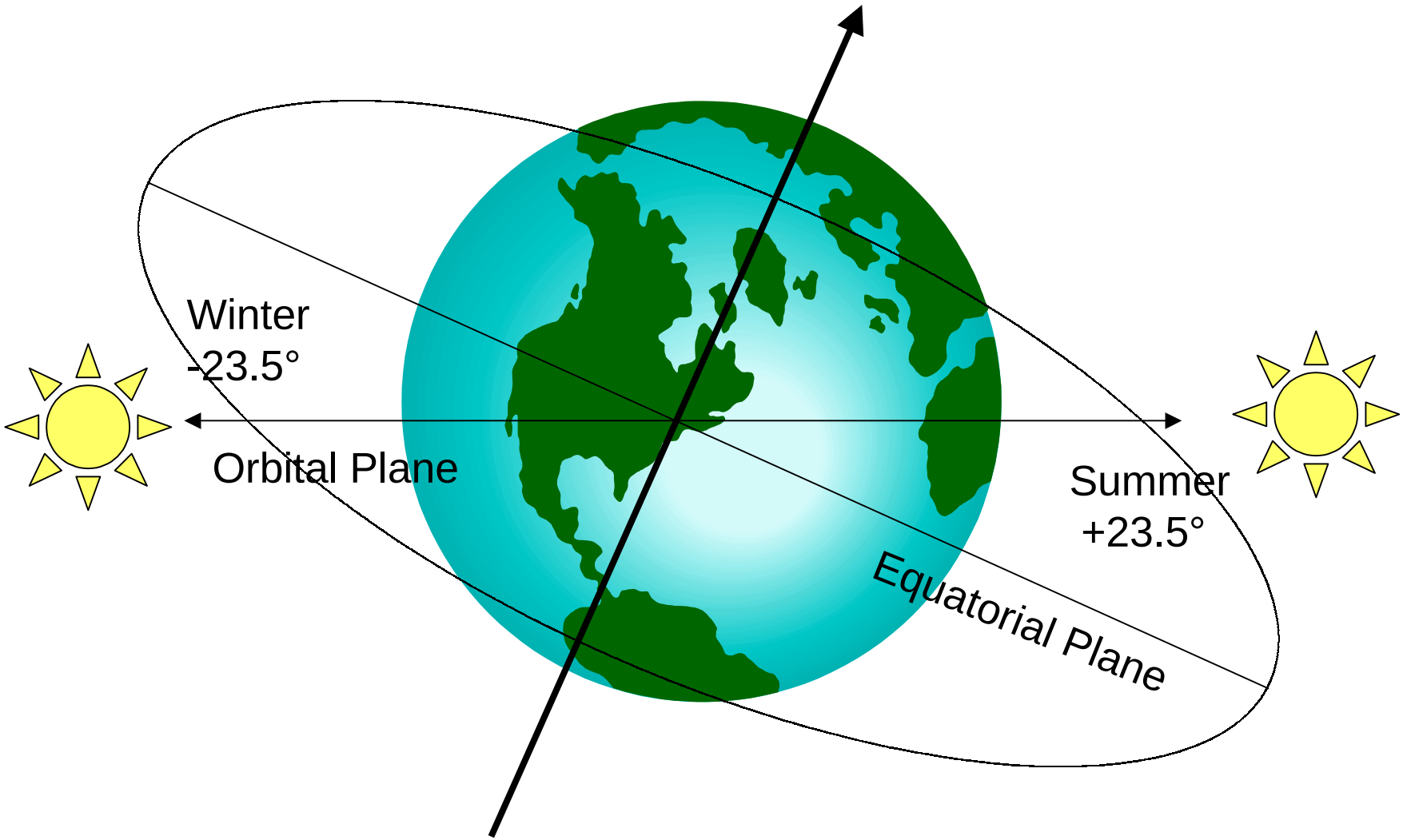
Walking Shadow Designs

Earth's Rotation and Time

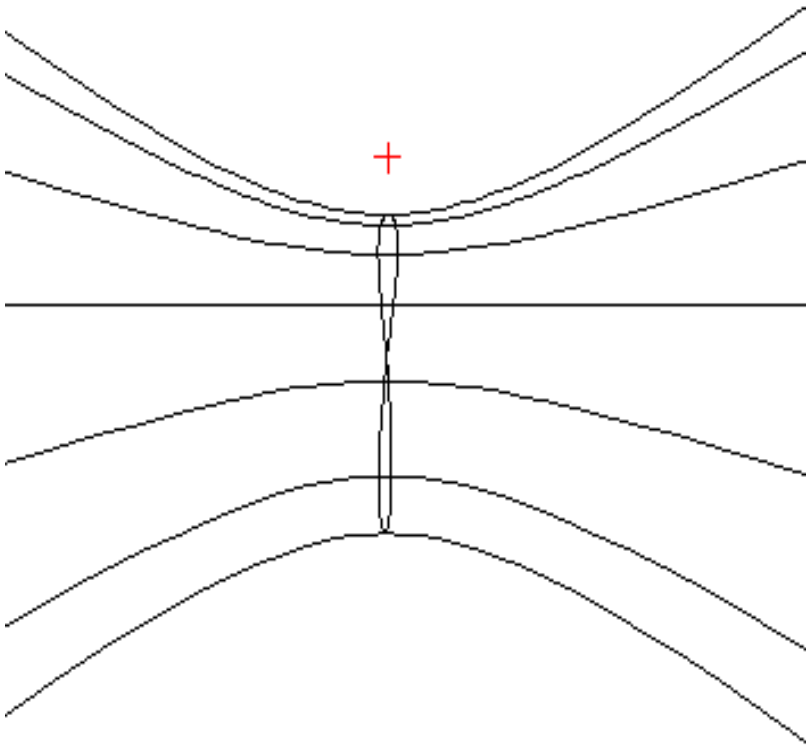


- Sun's position, Earth's rotation is the essence of time
- 1 day, 24 hours, 360°
- Time Angle 15°/Hour
- Shadow on sundial tells time
- Time from Noon / Midnight
- Time from Sunrise Sunset

Solar Orbit and Seasons



Sundials as Seasonal Markers

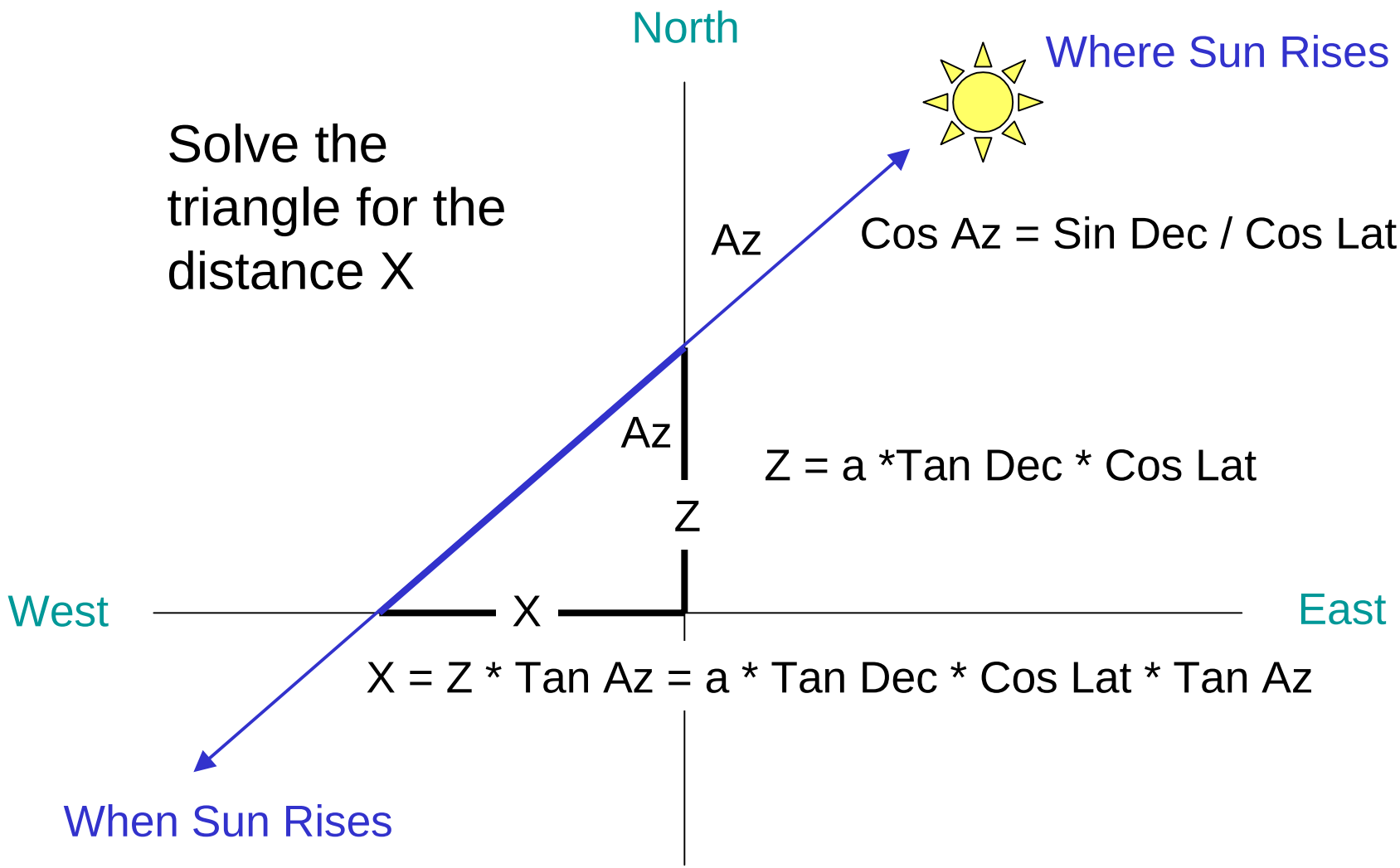


- Mike's first good question
- *"Can a sundial be used to follow the sun through the seasons?"* Yes!
- Solstices and equinoxes
- Declination Lines
- Analemmatic Zodiac Table
- Sunrise/set Azimuth
- Analemma: EQT vs Dec

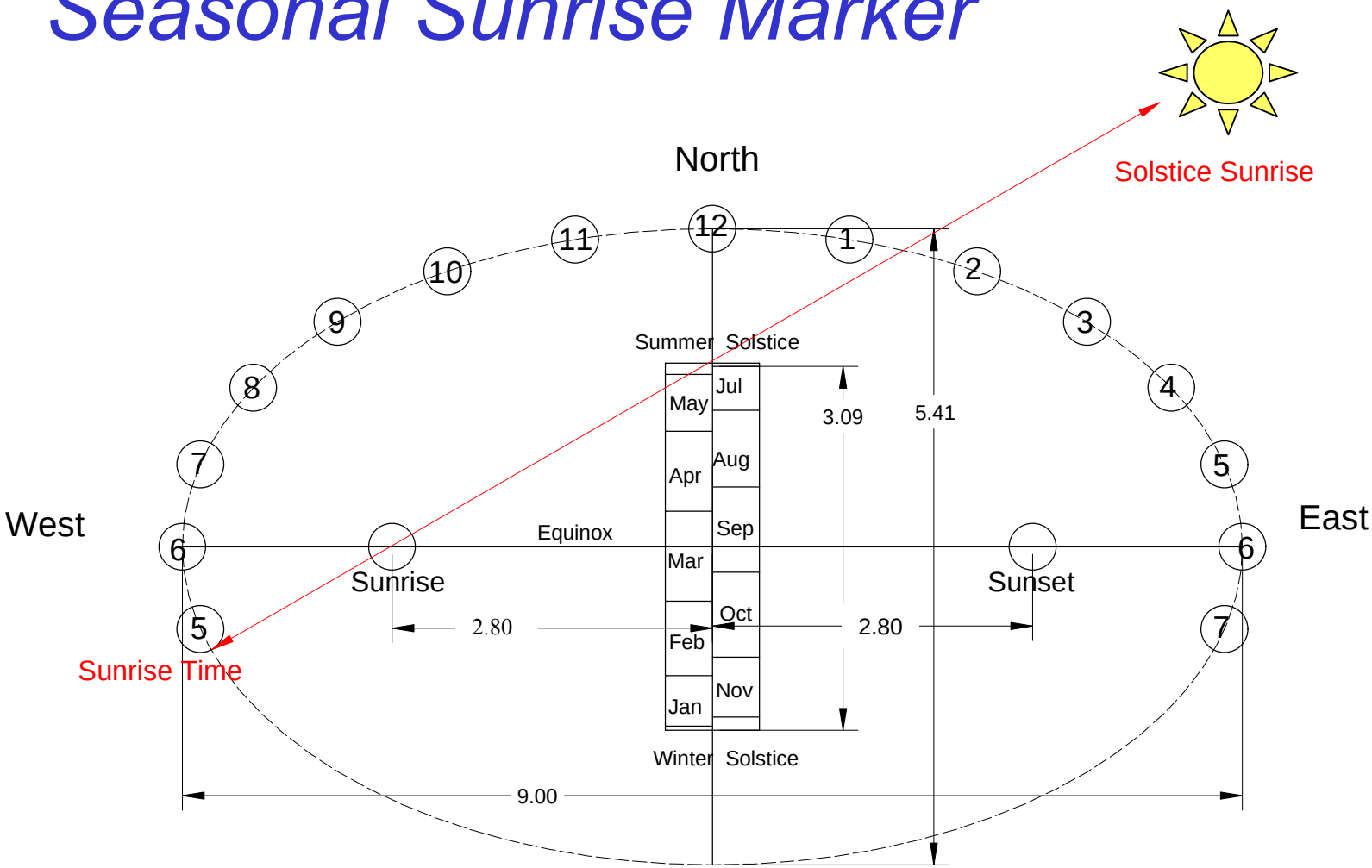
Analemmatic Seasonal Markers

- Mike's second good question.
- *"Is there a point in an analemmatic sundial that can be used with the Zodiac date line to show where the sun rises?"*
- Solve the triangle for the marker position
- Zodiac date line Z= a *Tan Dec * Cos Lat
- Sunrise Azimuth Cos Az = Sin Dec / Cos Lat

Analemmatic Seasonal Markers



Seasonal Sunrise Marker



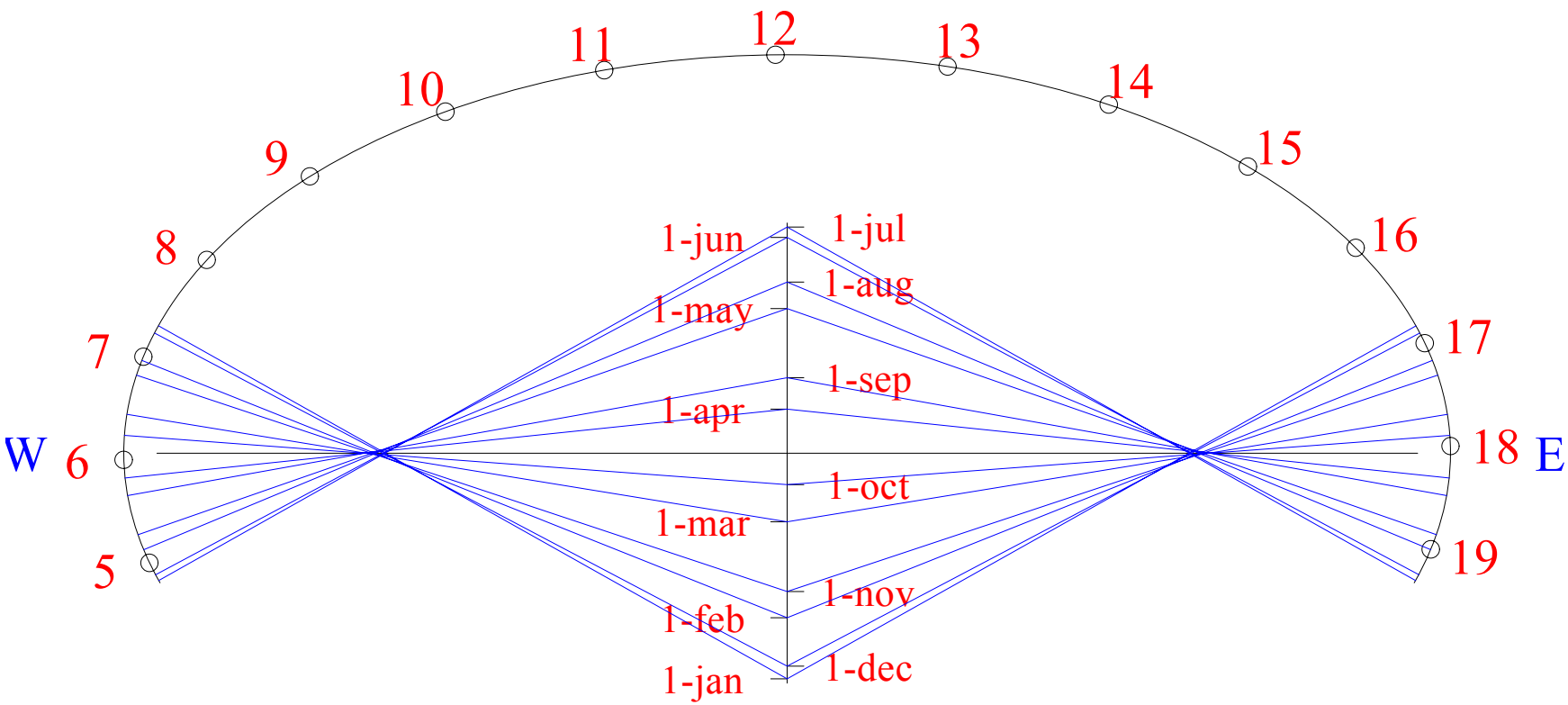
Stand on Marker, sight over date to see where the sun rises
Stand on Date, sight over marker to see when the sun sets


Test Layout


Stand on the Date, sight over the
Marker for the time of sunset

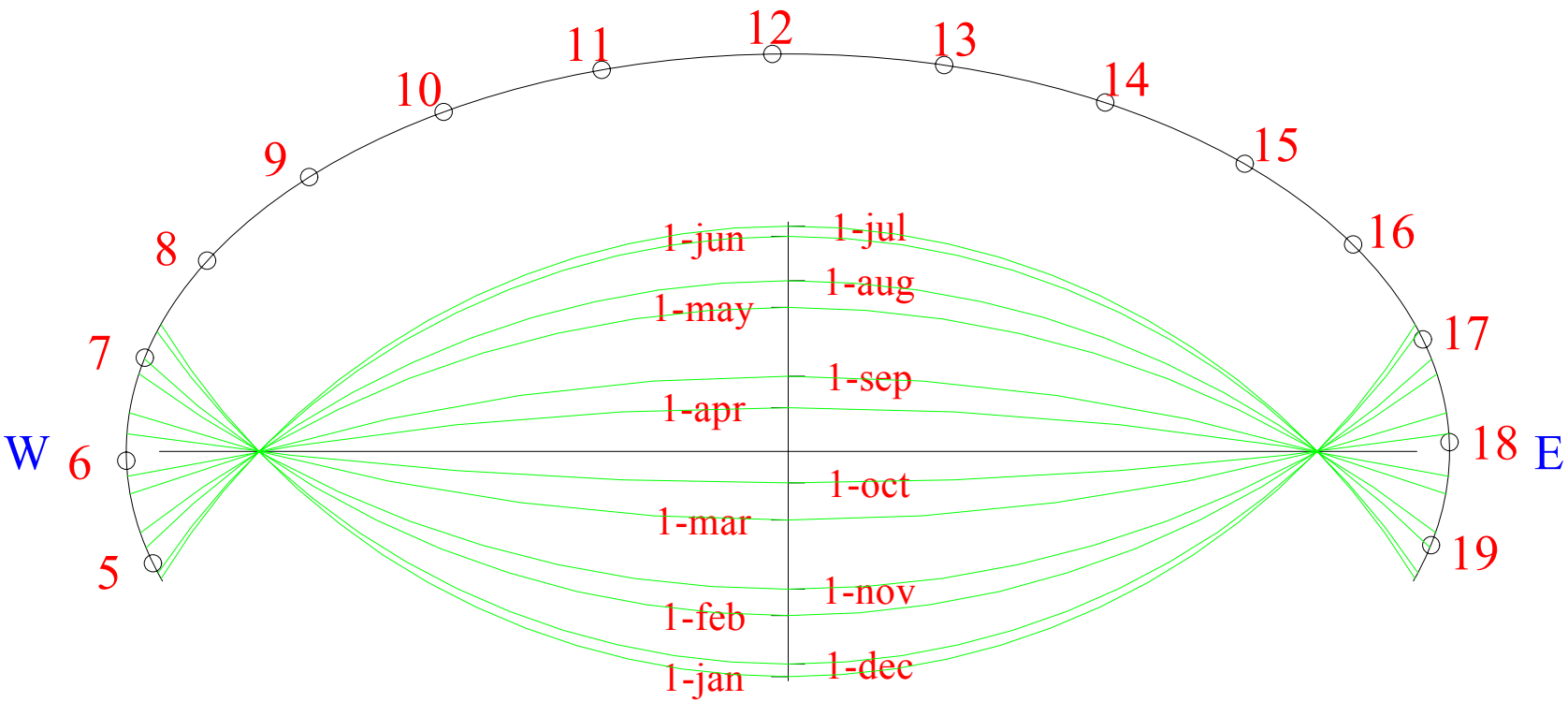
Stand on
the Marker,
sight over
the Date,
to see where
the sun sets

Seasonal Sunrise/set Markers



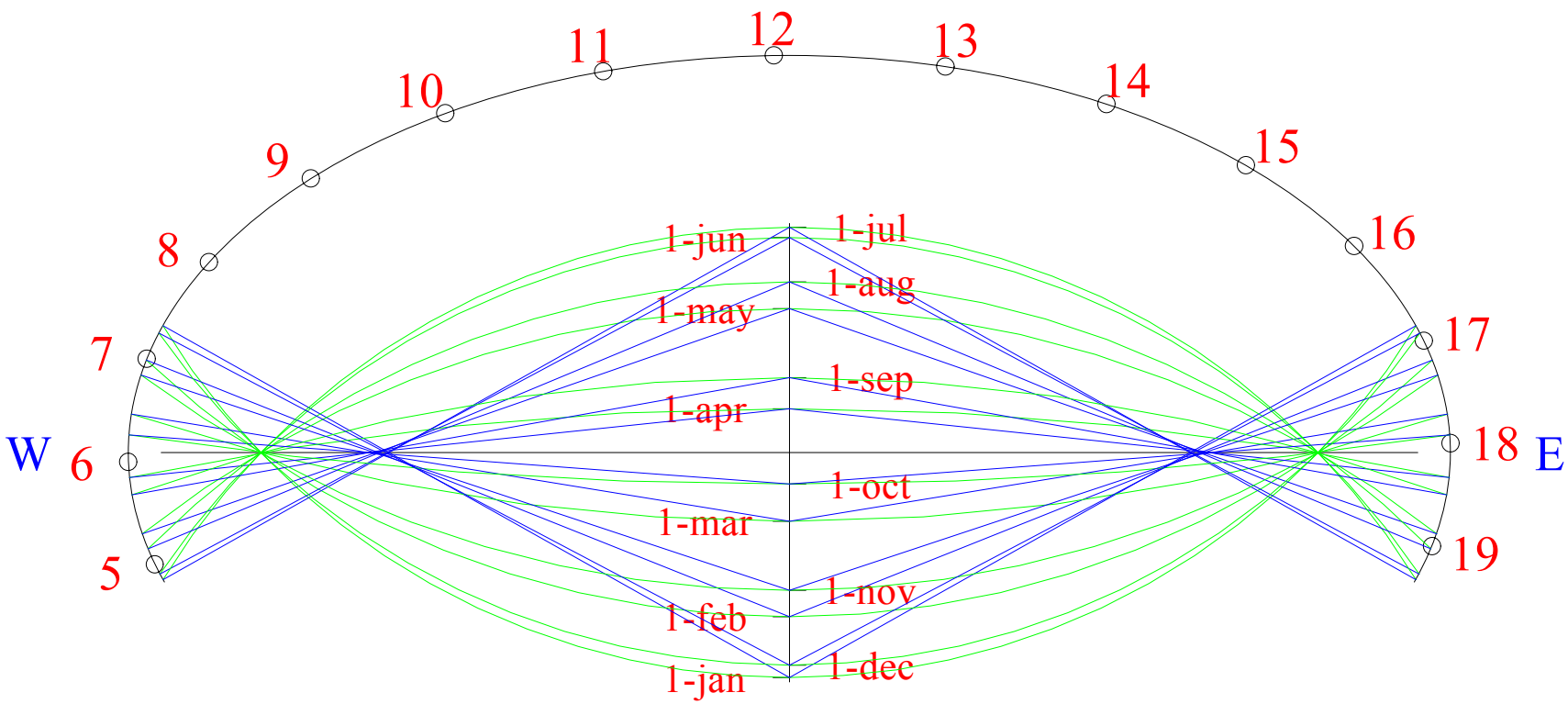
Mike's good question leads to a brilliant idea!
Seasonal Markers converge almost to a point

Fer De Vries's Day Circles



Fer de Vries "hor_analem3.bas" Delta Cad macro shows the exact solution, Day or Lambert's Circles through the date line and ellipse focus points to the time of sunrise/set

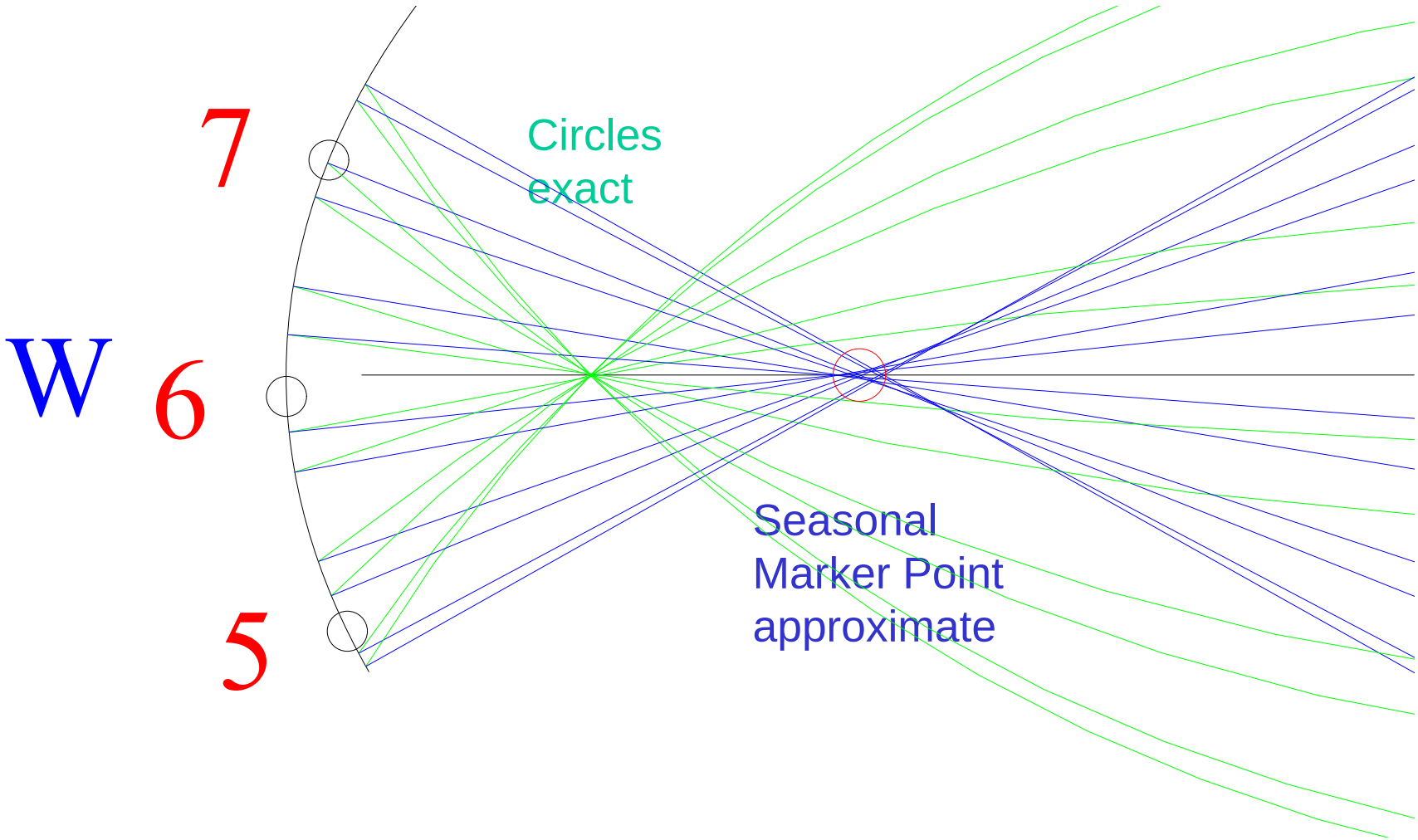
Seasonal Markers and Lambert's Circles



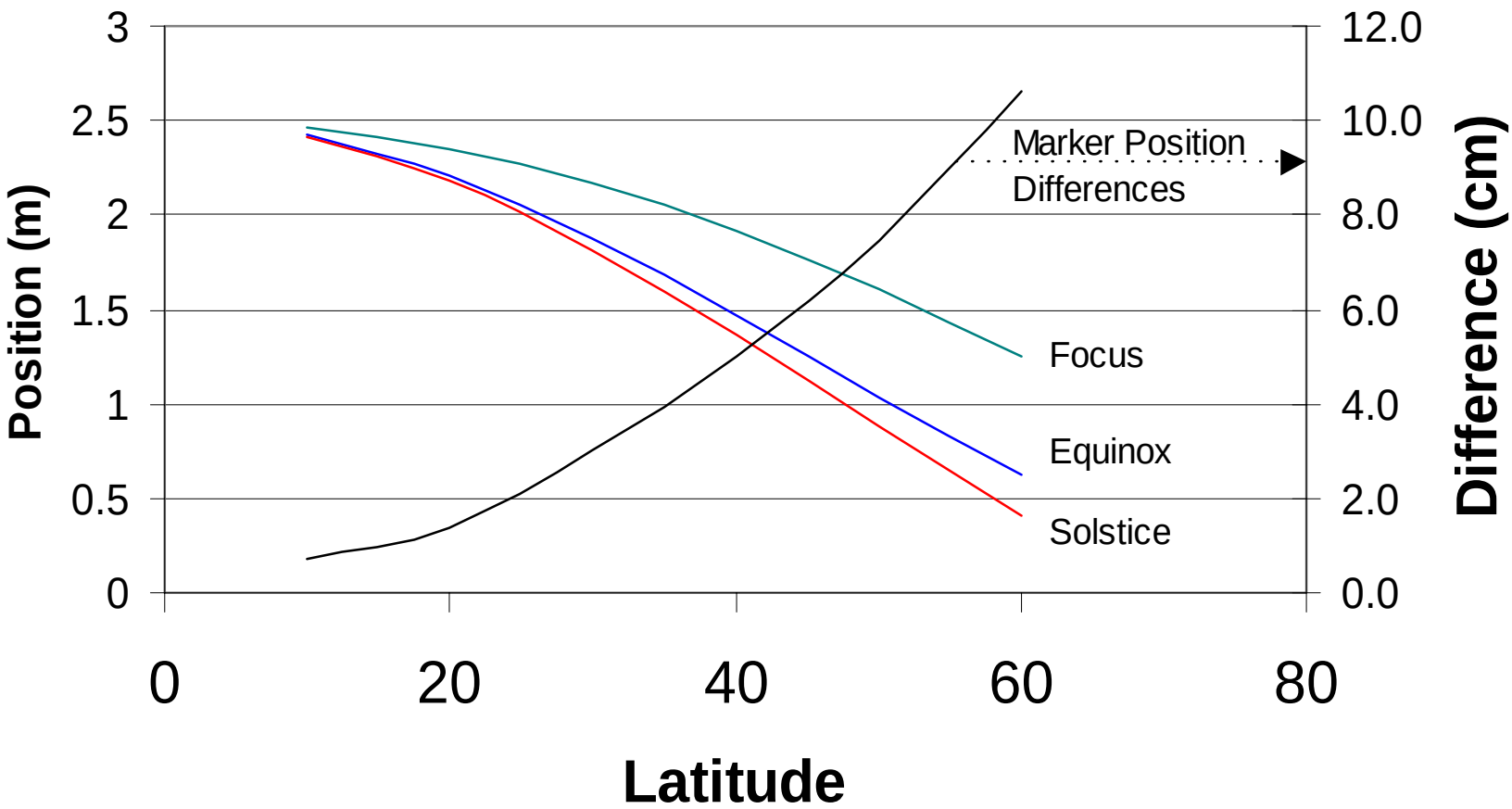
Seasonal Markers are not the ellipse focus points

Circles are the exact solution; marker points are linear approximations

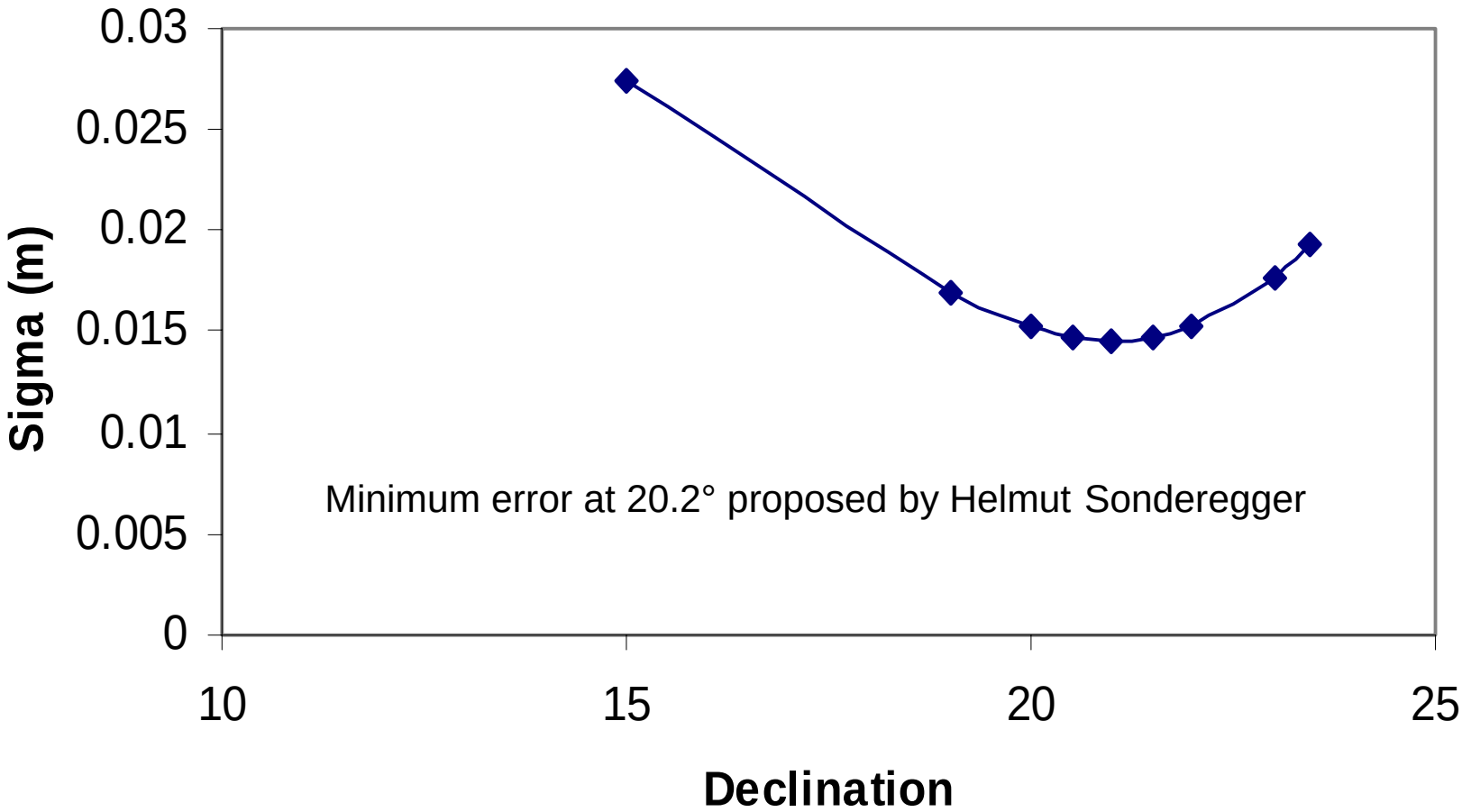
Seasonal Markers and Lambert's Circles



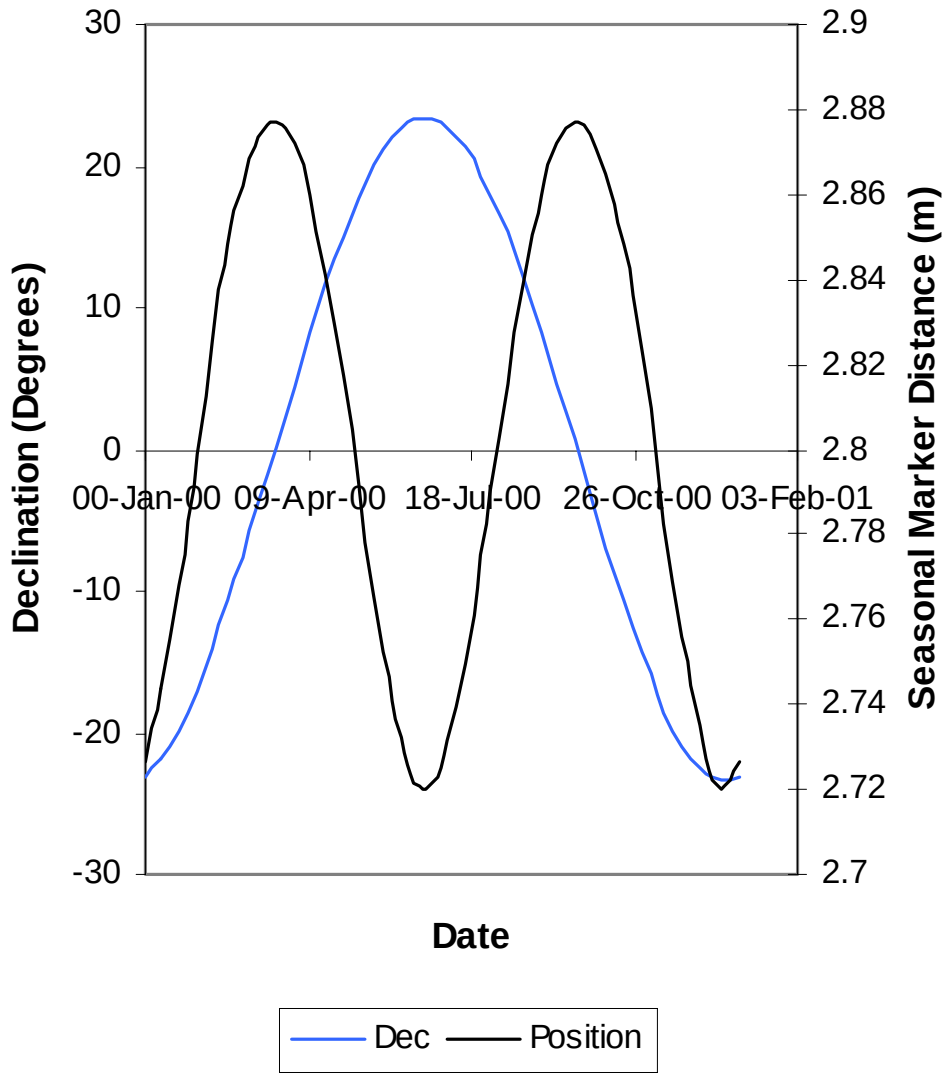
Seasonal Marker Error



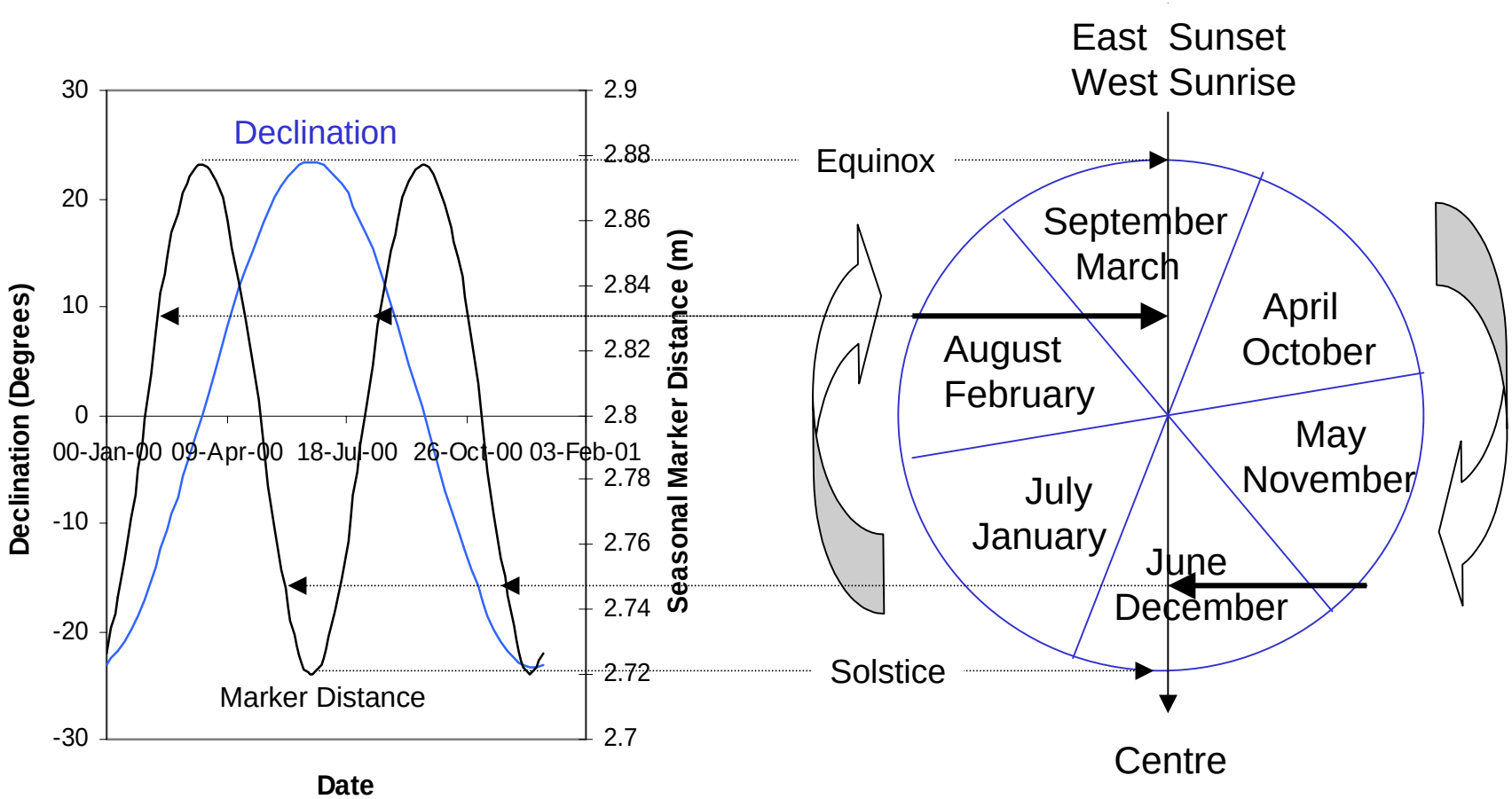
Seasonal Marker Error Analysis



Periodic Error in Marker Distance

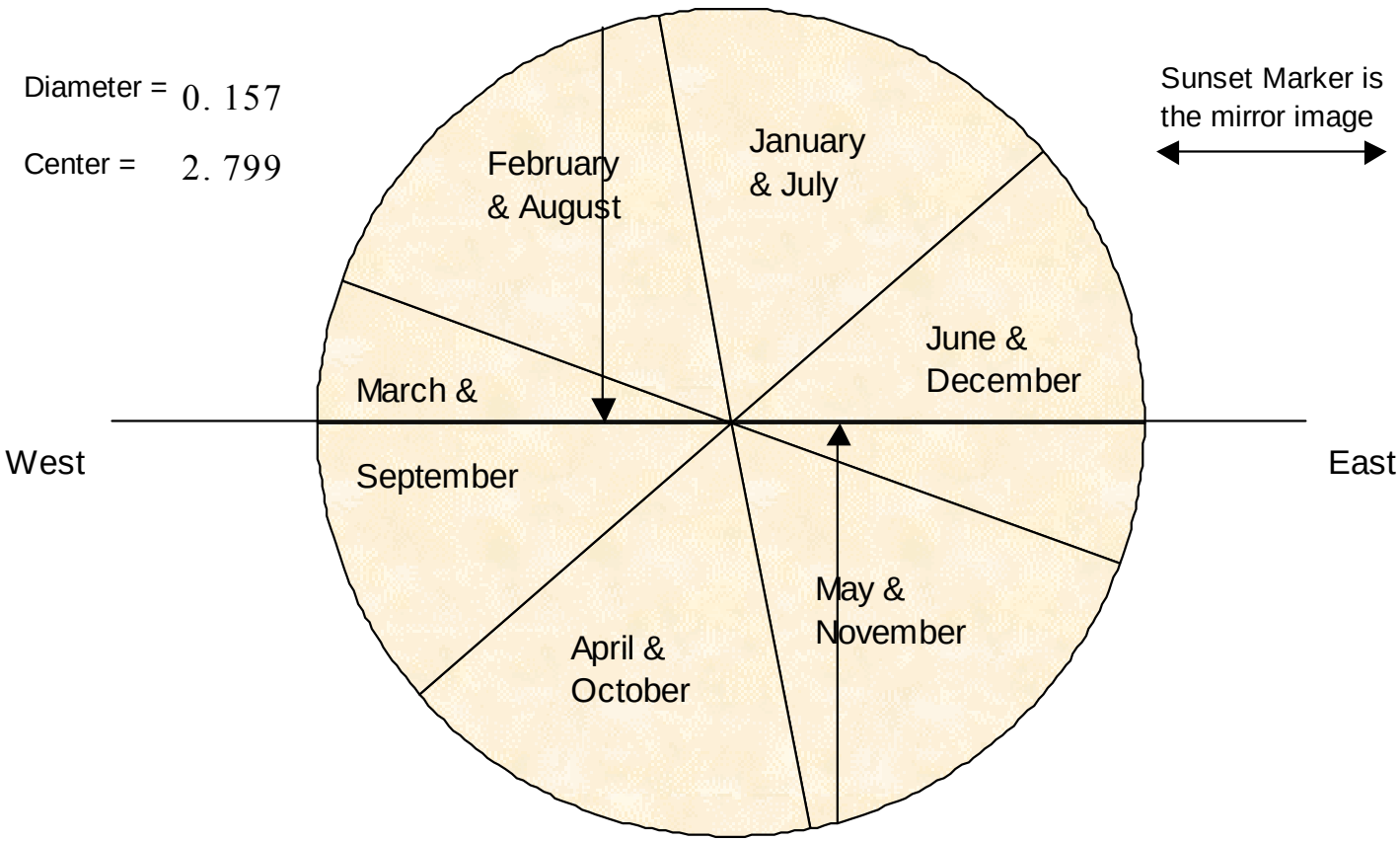


Periodic Error Correction Epicycle



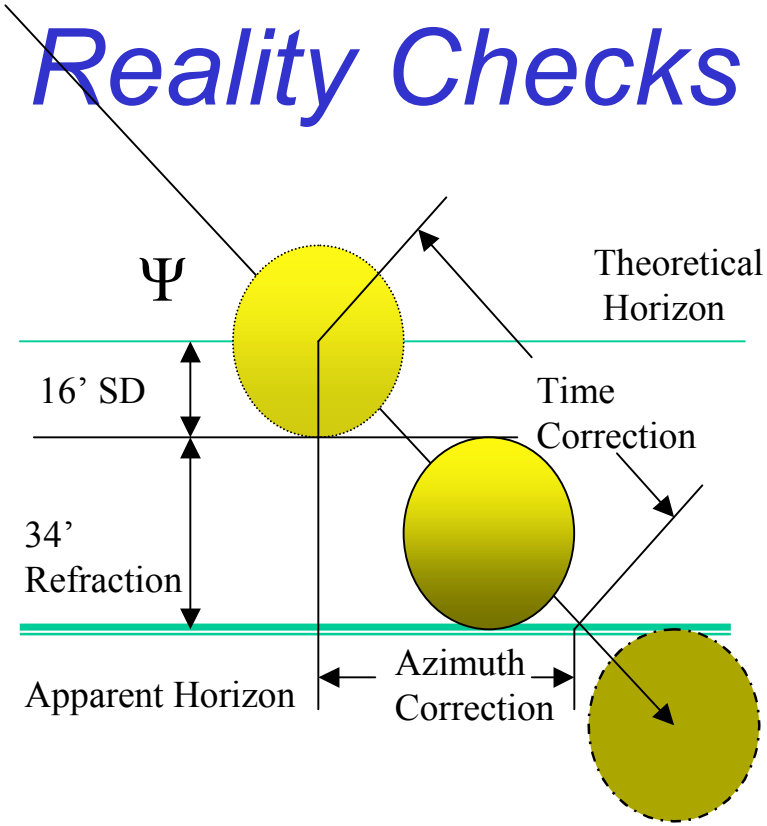
Going around the epicycle, twice per year, generates the sine curve. Drop a perpendicular from the date on the circumference to the axis to find the exact marker position

Correction Epicycle



From the date on the circumference, drop a perpendicular to the axis to establish the precise date marker

Reality Checks for Sunset Path



- Horizon Corrections
  - Semidiameter 16'
  - Refraction 34'
- Time Correction
  - 50' x 4 / Sin Ψ
- Azimuth Correction
  - 50' x Cos Ψ

Mike's Seasonal Marker Dial

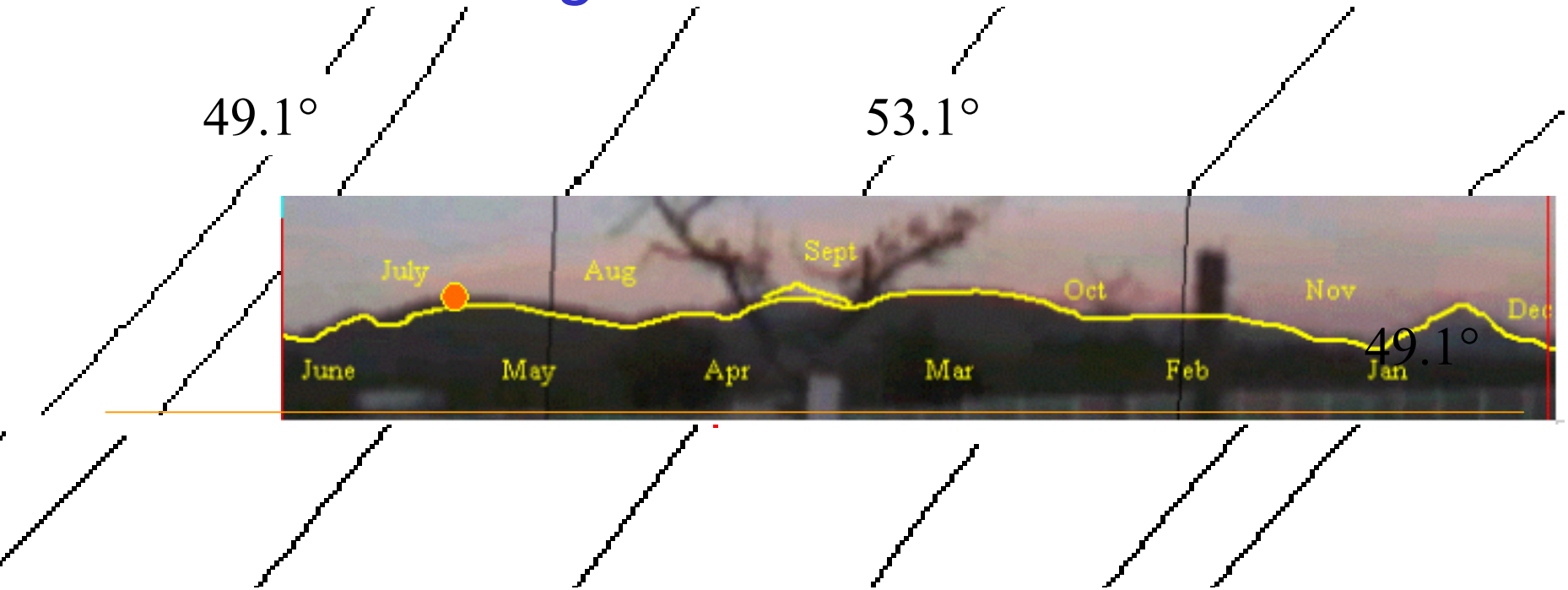
- Seasonal Marker +/- 2.8 m for 4.5m dial at Wild X Ranch: Lat 36.92, Long 121.35
- Correction epicycle diameter is 15.7 cm
- Seasonal Marker distances:
  - Equinox +/- 2.877m
  - Solstices +/- 2.72 m

Walking Shadow Designs

Seasonal Marker Offset

- Mike's third good question.
- *"Can you offset the seasonal marker to correct for the real horizon?"* Yes, but….
- Azimuth shift depends on altitude of real horizon and path of the rising sun Ψ where
- Cos Ψ =Sin Lat / Cos Dec
- Azimuth Shift AzS = Alt / Tan Ψ
- Offset is always to the north but distance depends on sunrise geometry. It is not constant for constant horizon altitude and azimuth shift

Diablo Range Horizon at Wild X Ranch

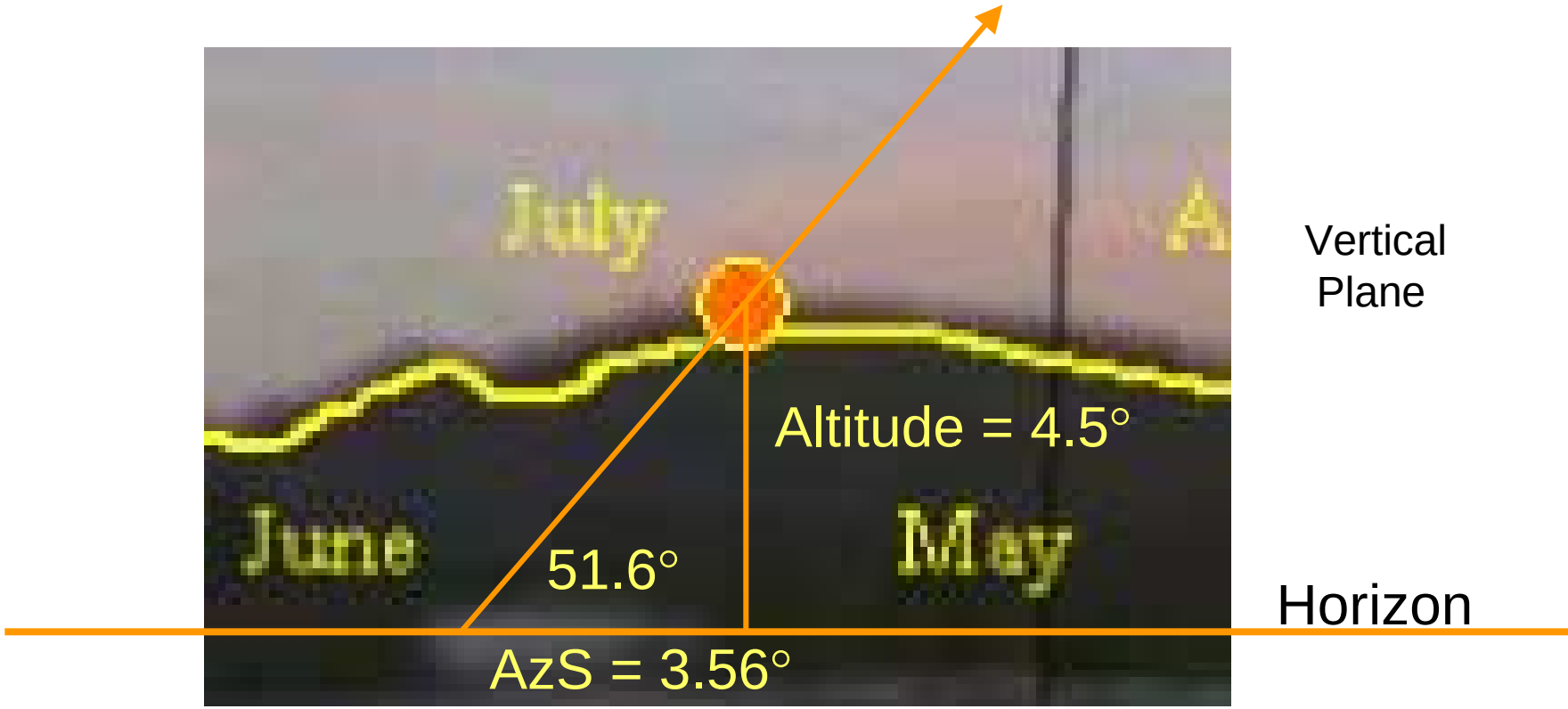


Approximate path Ψ of rising sun at different times of the year

Angle with horizon Ψ varies from 49.1 to 53.1 and 51.6 on 30 April

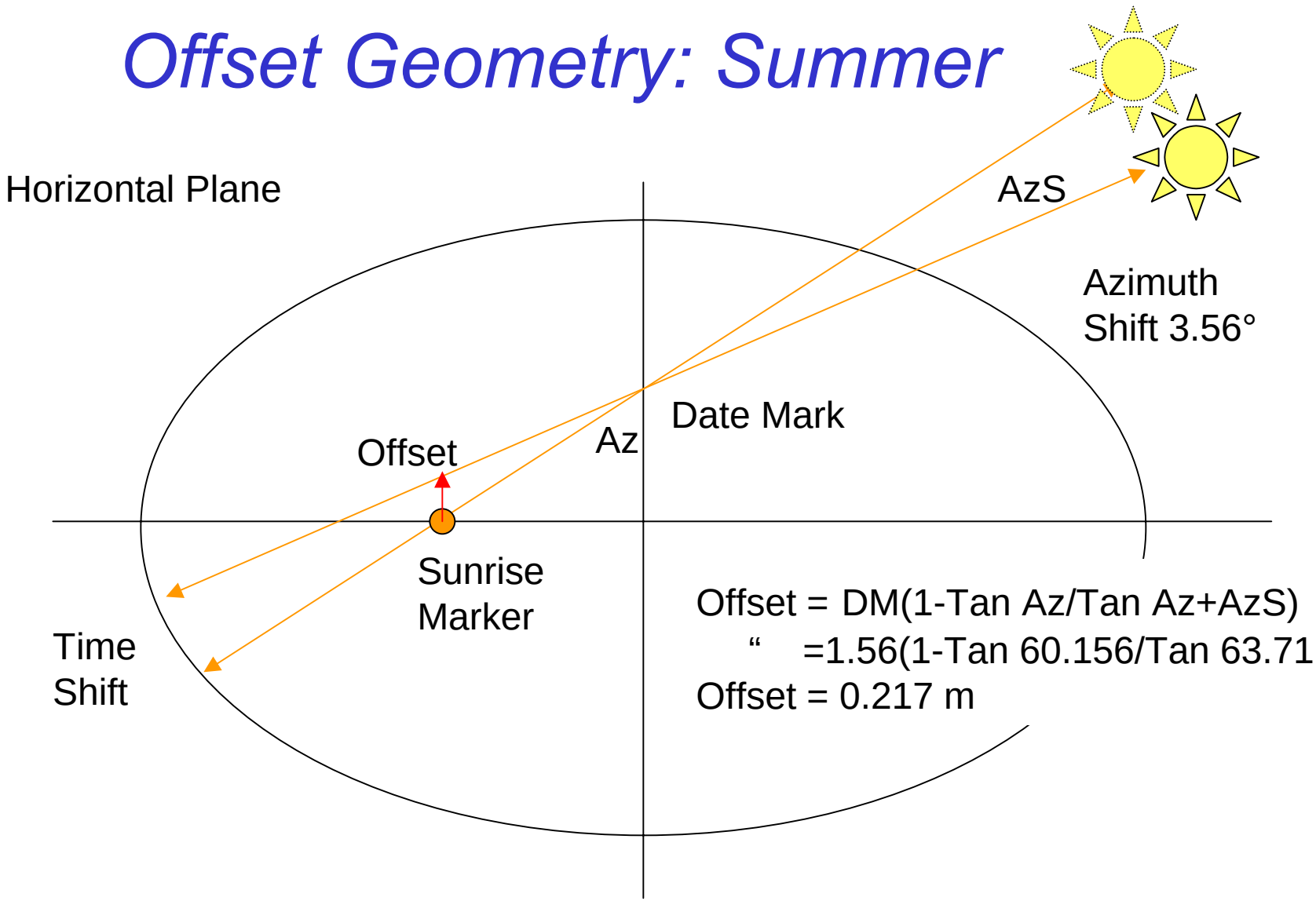
Walking Shadow Designs

Sunrise Geometry

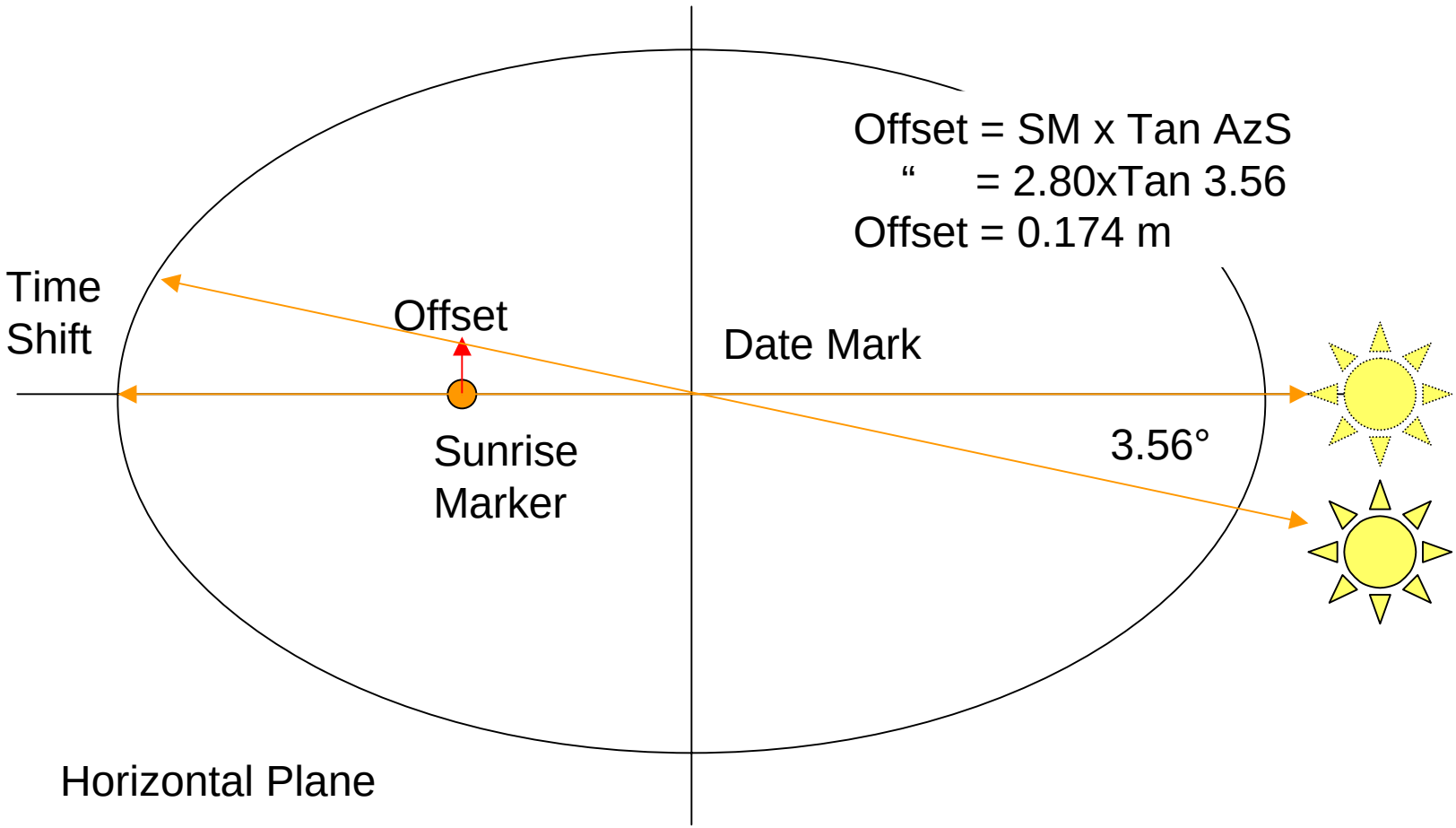


Altitude at 6:40:40 on 30 April is 4.5°
Azimuth shift from sunrise is 3.56° (4.5/Tan 51.6)

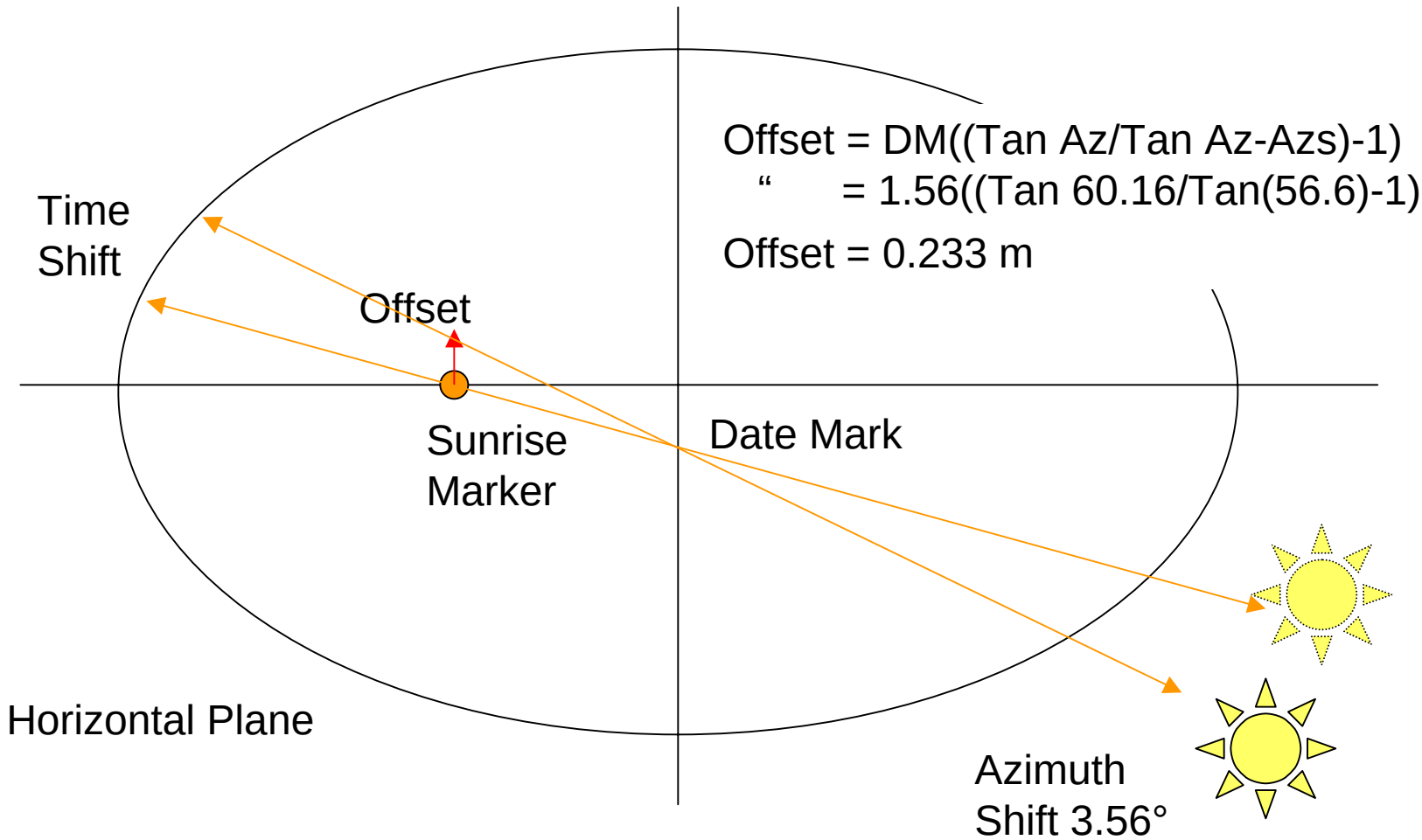
Offset Geometry: Summer



Offset Geometry: Equinox



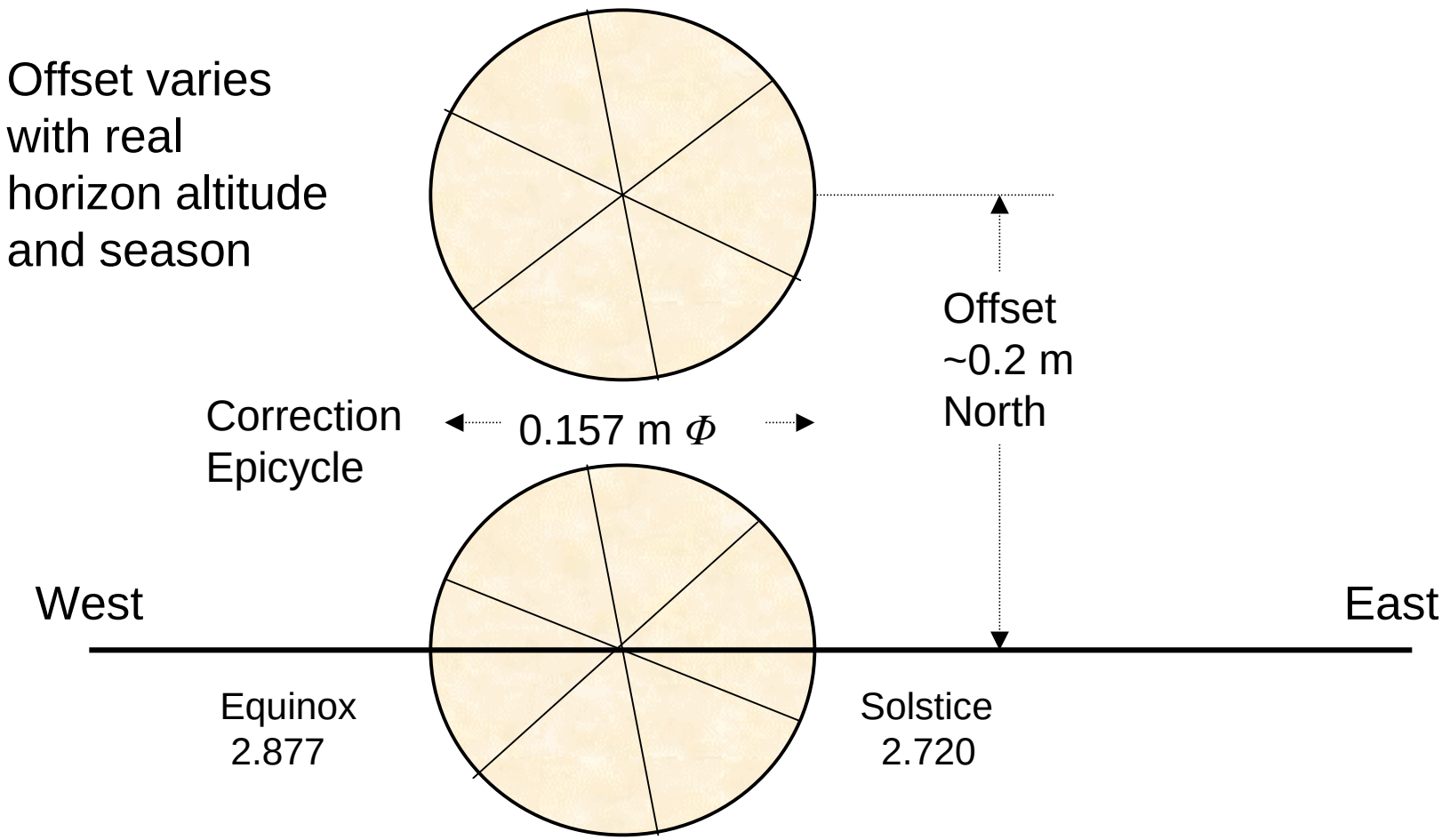
Offset Geometry: Winter



Seasonal Marker Offset

- Offset can *approximately* correct for the real horizon
- Offset north is ~ 20 cm or 8” to correct for the Diablo range east of Wild X ranch
- Horizon altitude is more near the equinox as the Diablo Range is closer
- This may correct somewhat for the lower offset distance near the equinox

Sunrise Marker Offset




Skeptic's Test

Conclusions

- Seasonal Markers are an excellent addition to analemmatic sundials
- Seasonal Markers show when and where the sun rises and sets throughout the year
- Markers are linear approximations
- Errors increase with latitude
- Exact solutions are available with the correction epicycle, but not necessary
- Offsets to correct for the horizon are possible, but not necessary

Assistance

Acknowledgements

- Daniel Roth's "Sundial Mailing List"
- Mike DeAmicis Roberts "good questions"
- Fer De Vries "Delta Cad macros & day circles"
- Helmut Sonderegger "spreadsheet improvements and error analysis"

- References: Roger's tool box
  - "How Long is My Shadow" NASS 99 RTB
  - "Analemmatic Sundial Design Spreadsheet" RTB & HS
  - "Sunrise Phenomenon" NASS 99 RTB
  - "Hor_analem3SME.bas by Fer De Vries, & RTB