Applied Geomorphology

Lecture 4: Total Station & GPS Survey Methods

Total Station

- Electronic version of Alidade
- Accurate to ±3 ppm horizontal & vertical
  - $3x10^{-6}$ (5000 feet) = 0.2 inches

Total Station Advantages over the Alidade

- Calculations are processed internally so there are no post data collection calculations to process
- Accuracy is much better than alidade, and it is not shot distance dependent
- Results are stored in a data collector computer that can display results graphically
- Each individual ray shot can take as little as a few seconds to take- many more stations can be collected per day as compared to the alidade and plane table method

Total Station Disadvantages

- No plane table for sketching contours and/or contacts on a geologic map
- It may take 30 minutes to an hour to set up (level) the instrument before data can be collected
- Battery life on data collector computer can limit length of daily surveys

Total Station Surveys

- The initial XY coordinate system of the instrument is random- it must be calibrated to conform to geographic or magnetic north
- A “backsight” target is established north of the starting station position to calibrate coordinate system
- If two benchmarks or former station positions have known coordinates the relative positions can be used to calibrate coordinate system
- Because of the range and accuracy of the total station one instrument station may be sufficient for entire survey project

Integrating Pocket Transit & Total Station Surveys

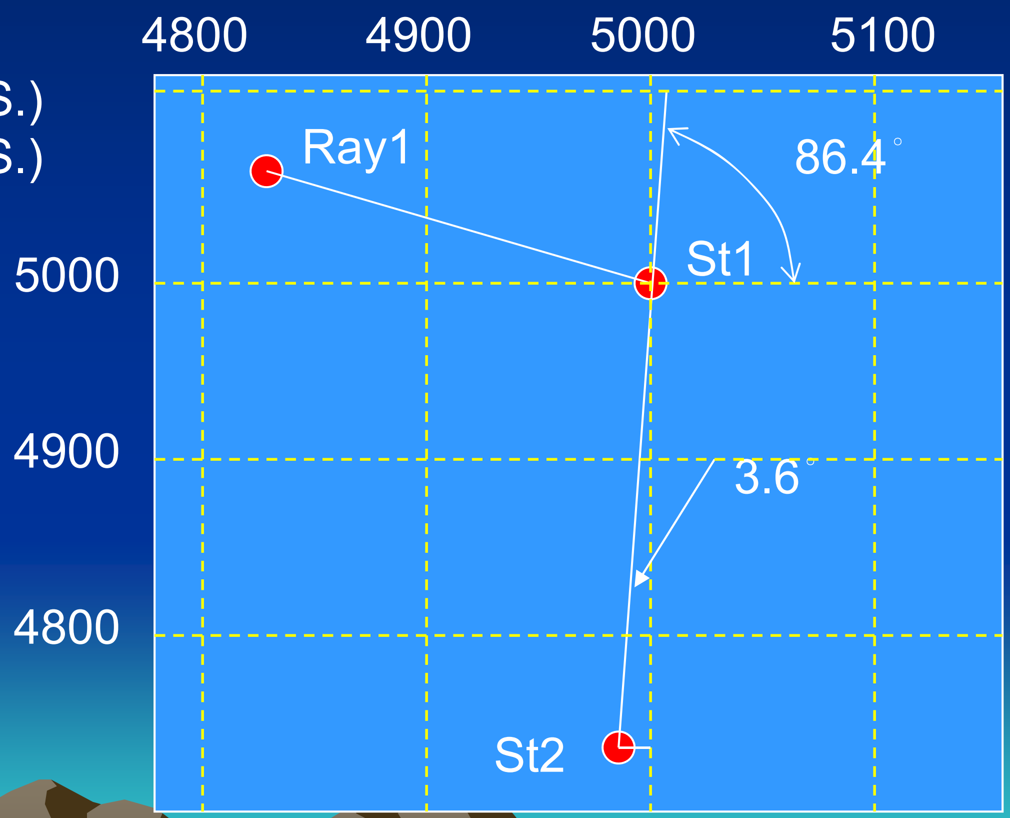
- To integrate a Transit survey with T.S. data you must “grid” the transit points based on the XY coordinates of two known points.
- Once grid lines are established on the alidade map each data point is read off as if the map were a sheet of graph paper.

Integrating Transit & T.S. Surveys

- Campus Map Example using stations 1 & 2

St1 = 5000, 5000 (measured w/ T.S.)
St2 = 4984, 4744 (measured w/ T.S.)
$\Delta x = 16$, $\Delta y = 256$
Tan $\alpha = \Delta x / \Delta y = 16/256$
$\alpha = 3.6^\circ$

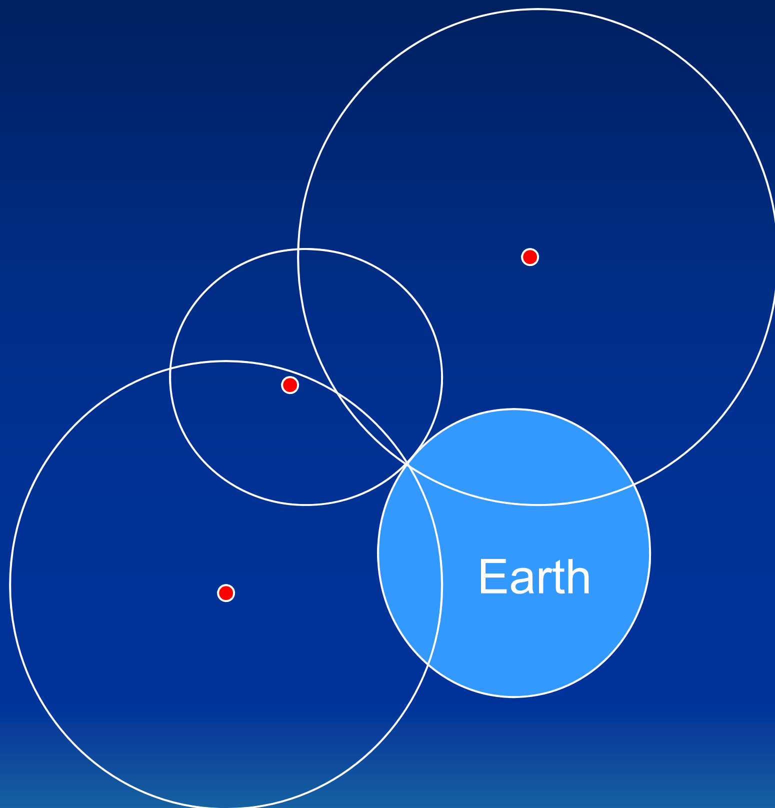
Ray1 = 4819, 5067
(interpolated from grid)



GPS Surveys

- Global Positioning System
- Constellation of 24 satellites orbiting at 50,000 km altitude
- At a given point on the earth at least 4 satellites can be tracked by receiver simultaneously
- 3 satellites plus the earth define a range of possible positions; the 4th satellite timing is used to arrive at a consistent position

Earth- GPS Satellite Geometry



GPS Satellite Characteristics

- Contain a very accurate atomic clock
- Orbit at a high altitude so that no friction with the atmosphere is possible, resulting in a very predictable orbit
- Broadcast signal contains the position of the satellite, and the time the signal was broadcast
- Satellites are maintained by the Military and NASA

GPS Error Sources

- SA: selective availability
- Atmospheric heterogeneity
- Clock Error
- Multipath Error (largest source of error)
- PDOP: position dilution of precision
- Because of satellite geometry z accuracy is usually 1.5 to 2 times that of horizontal map accuracy

GPS Receiver Types

- Autonomous
  - Hand held receivers with built-in antenna ($150 - $500)
  - Receiver and external antenna (usually as a backpack or harness) combo ($500 - $5,000)
- Base Station (Survey Grade; Real-Time Kinetic) ($20,000 to $50,000)
  - Receiver and PDA data collector
  - Base station receiver with differential correction beacon broadcast

Typical GPS Accuracy

- Low-end autonomous: 5m (with differential beacon)
- High-end autonomous: 2m (with differential beacon)
- RTK: 1cm

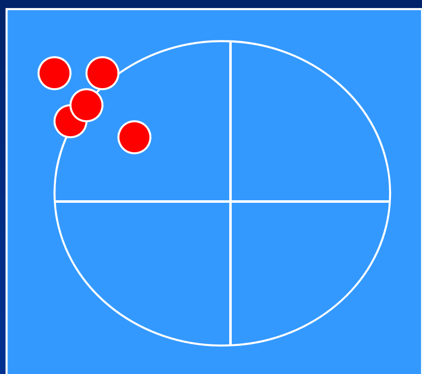
Differential Correction Beacons

- A GPS receiver is permanently fixed at a known benchmark
- A correction factor that accounts for the differential between the actual and calculated position is continually broadcast on the FM radio band from the benchmark
- In theory any errors generated by PDOP or atmospheric conditions can be eliminated by a GPS receiver that applies the correction factor
- Multipath errors are not eliminated by differential beacons (DGPS)

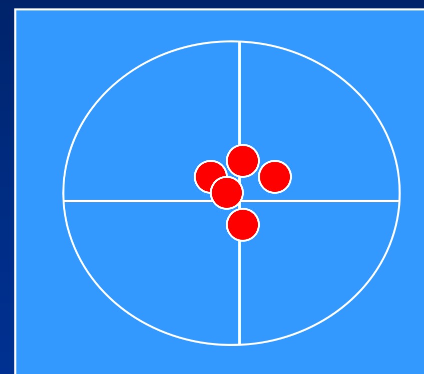
GPS Accuracy & Precision

- Precision is the reproducibility of the measurement
- Accuracy is how close the measured position is to the actual location

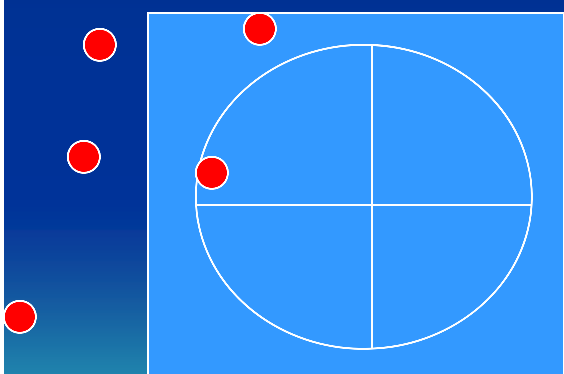
Concept of Precision & Accuracy



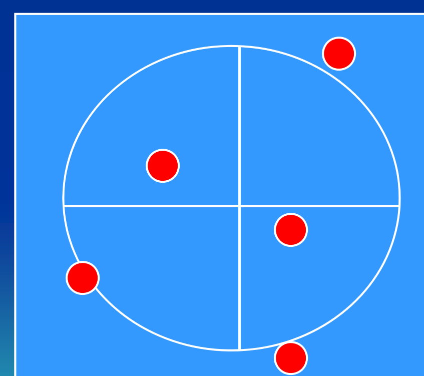
Good precision,
Poor accuracy



Good precision,
Good accuracy

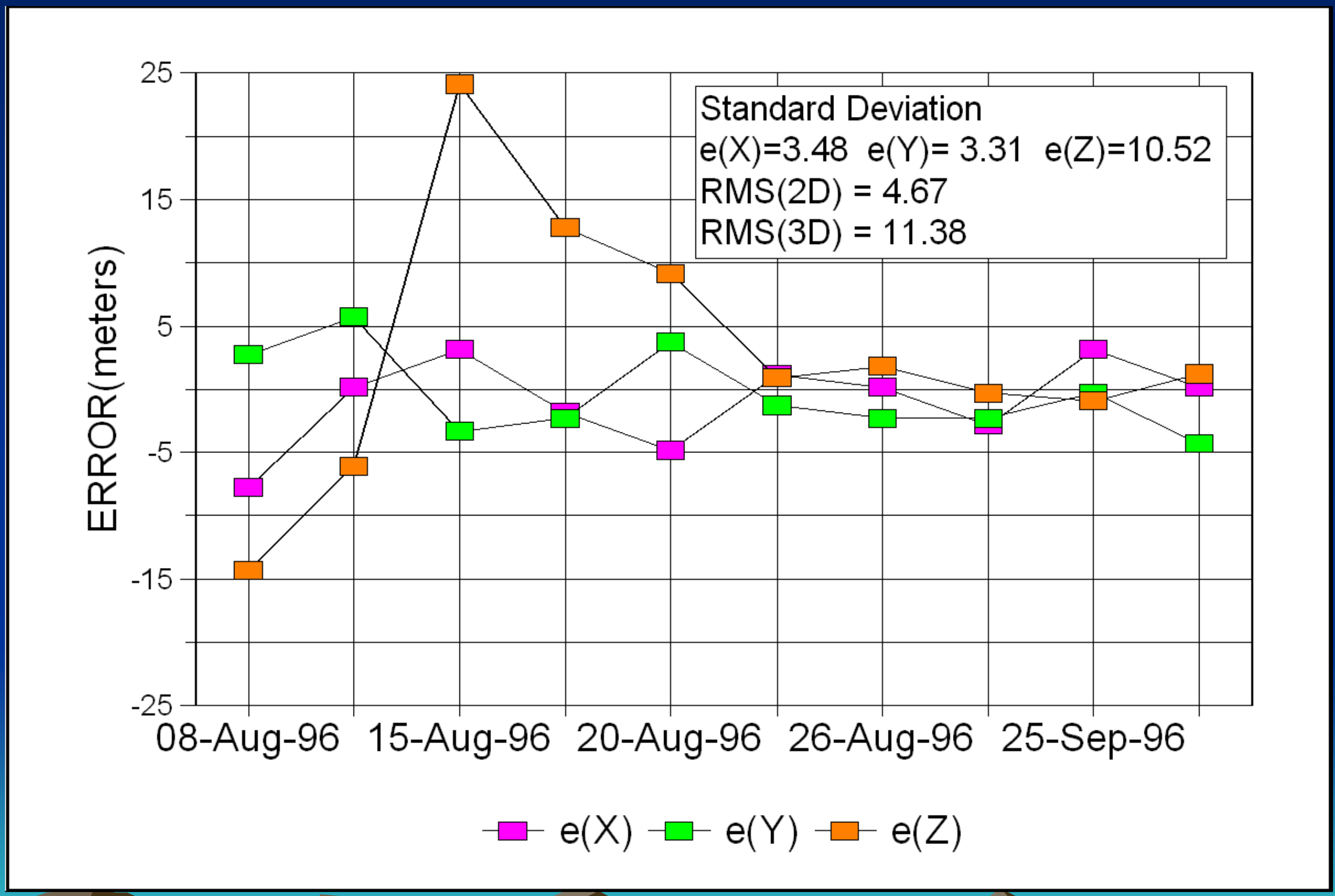


Poor precision,
Poor accuracy



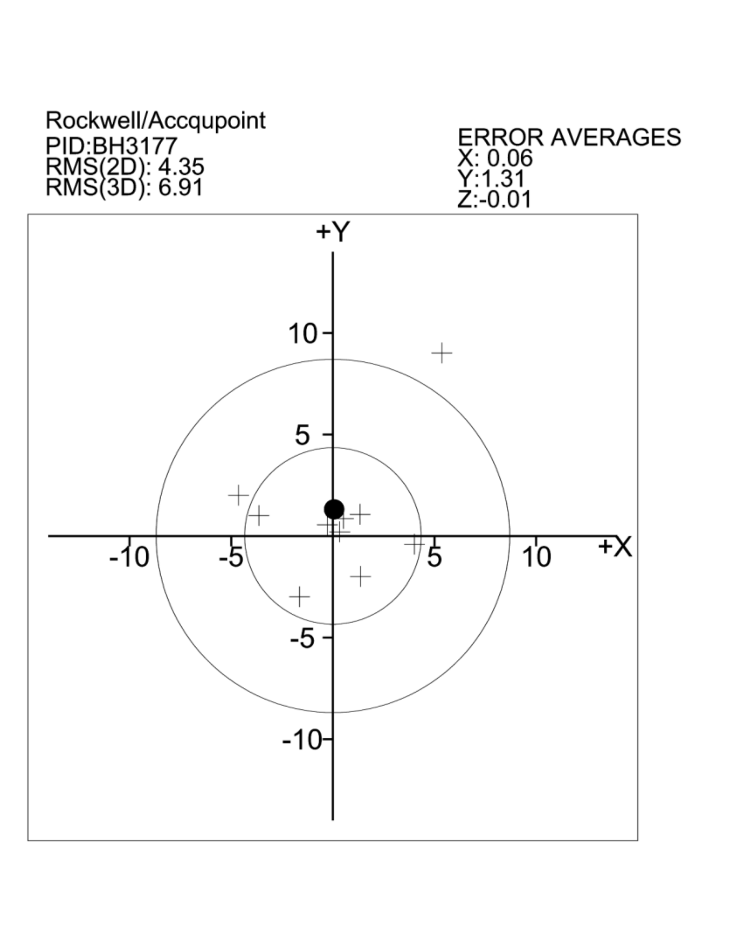
Poor precision,
Good accuracy

Accuracy & Precision cont.



GPS RMS Values

- RMS: root mean square
- RMS = Σ(d)/N where d = distance from actual position



Celestial Observations

- Certain astronomical observations may indicate true geographic north (i.e. celestial pole)
- The two most common objects used in surveying are the Sun and Polaris- but other stars can also be used.
- Data relating to positions of the Sun, stars or planets are termed “ephemeris” tables.

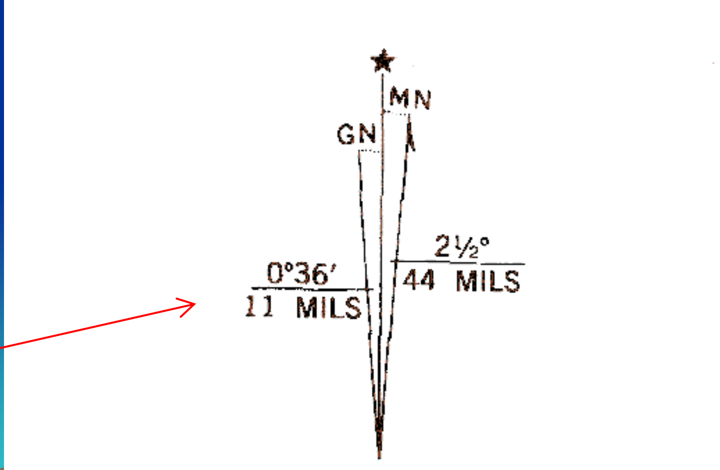
Why use Celestial Observations?

- Magnetic compasses can be affected by variations in the Earth’s magnetic field.
- Published magnetic declinations may be out-of-date.
- Internet resources may be inaccessible in remote areas.
- Celestial observations are at worst less than 1 degree error; at best within a few seconds accuracy.

Grid Surveys vs. Celestial

- Remember that because of map projection distortion grid systems (UTM, SPCS, etc.) do not align with lines of latitude and longitude.
- Resection to GPS UTM coordinates will align with the grid but not geographic north.

Springhill, AL 1:24k
1982



UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Celestial Geometry

- Geographic north pole is the point where the Earth’s rotational axis penetrates the surface.
- The extension of the rotation axis into space is the celestial pole (i.e. the rotational axis)
- The celestial pole projects into the sky at an angle above the north/south horizon equal to the latitude of the observer.

Sun Observations with Total Station

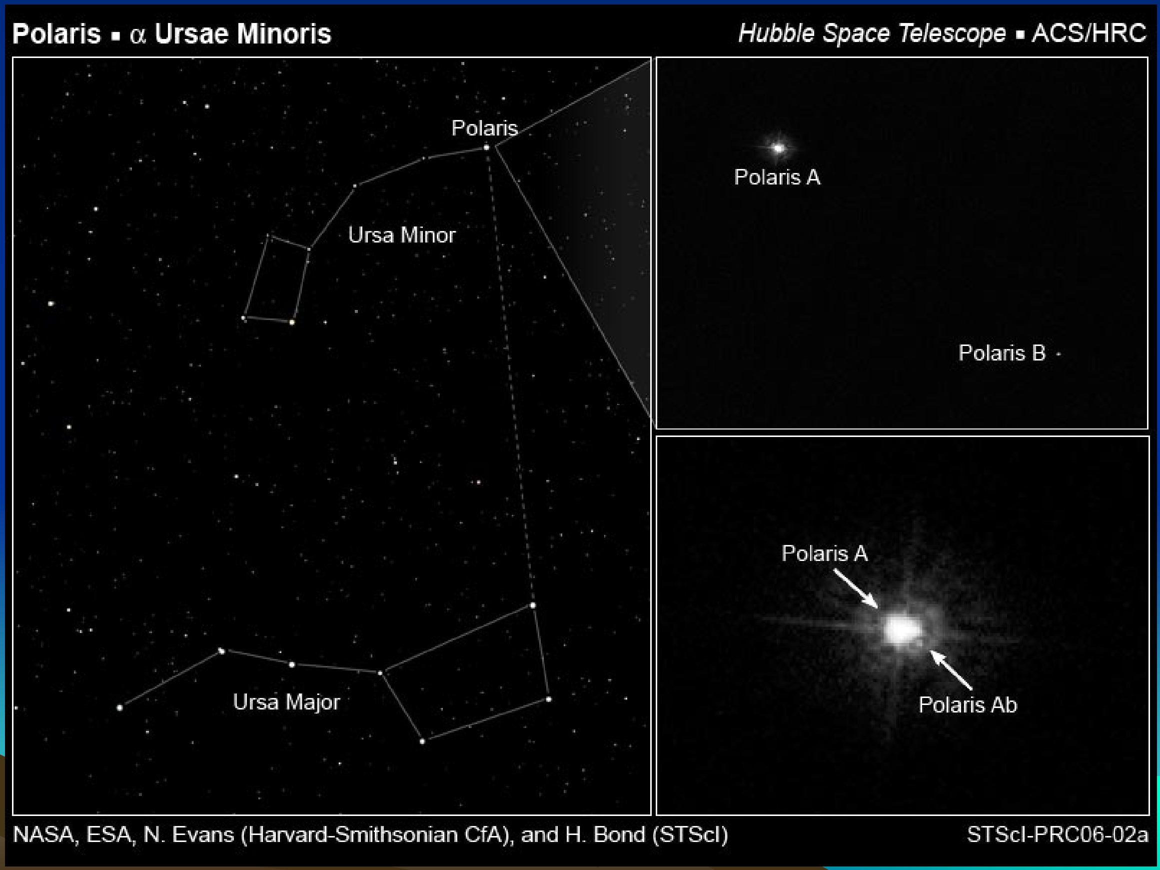
- With advanced survey software, a sun filter, and precise time from a GPS the Sun's ephemeris data can be used to calculate the true geographic azimuth.
- Because of the Sun's disk size and its rapid transit velocity the measurement suffers from error +/- 5 seconds or more.
- The method's advantage is that it is possible in daytime.

Polaris Observations

- Polaris is a magnitude 2 star that is within 40 minutes of the celestial pole.
- Aligning a total station with Polaris at any random time of night guarantees an accuracy of < 1 degree: perfectly acceptable for a pocket transit.
- Waiting for one of the “elongation” or “culmination” special times allows for accuarcy of a few seconds or better.

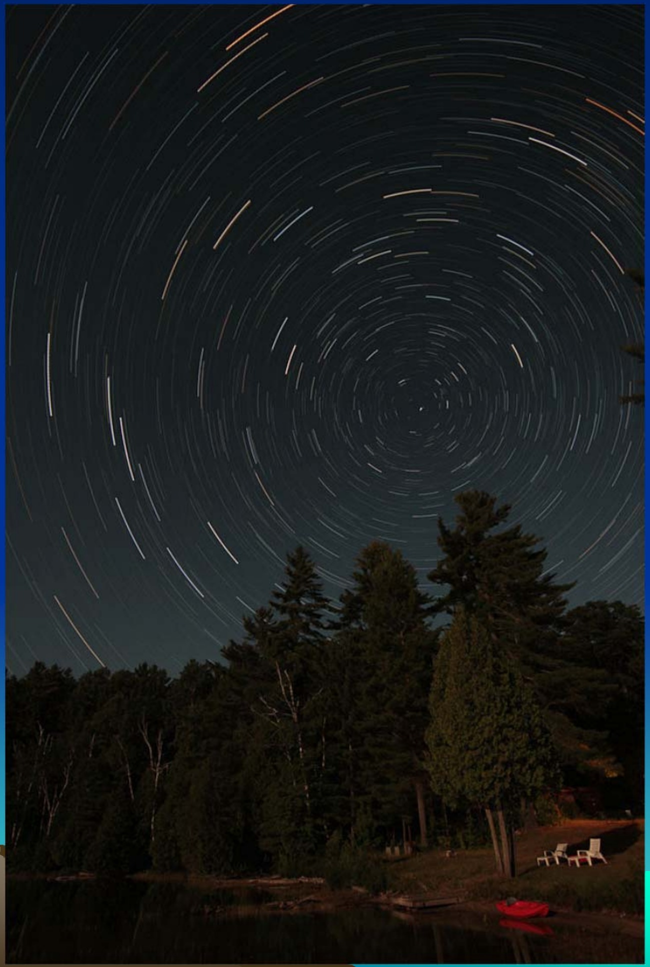
Finding Polaris (Northern Hemisphere)

- Polaris is the last star in the handle of the little dipper.
- The last 2 stars in the big dipper cup point to Polaris.



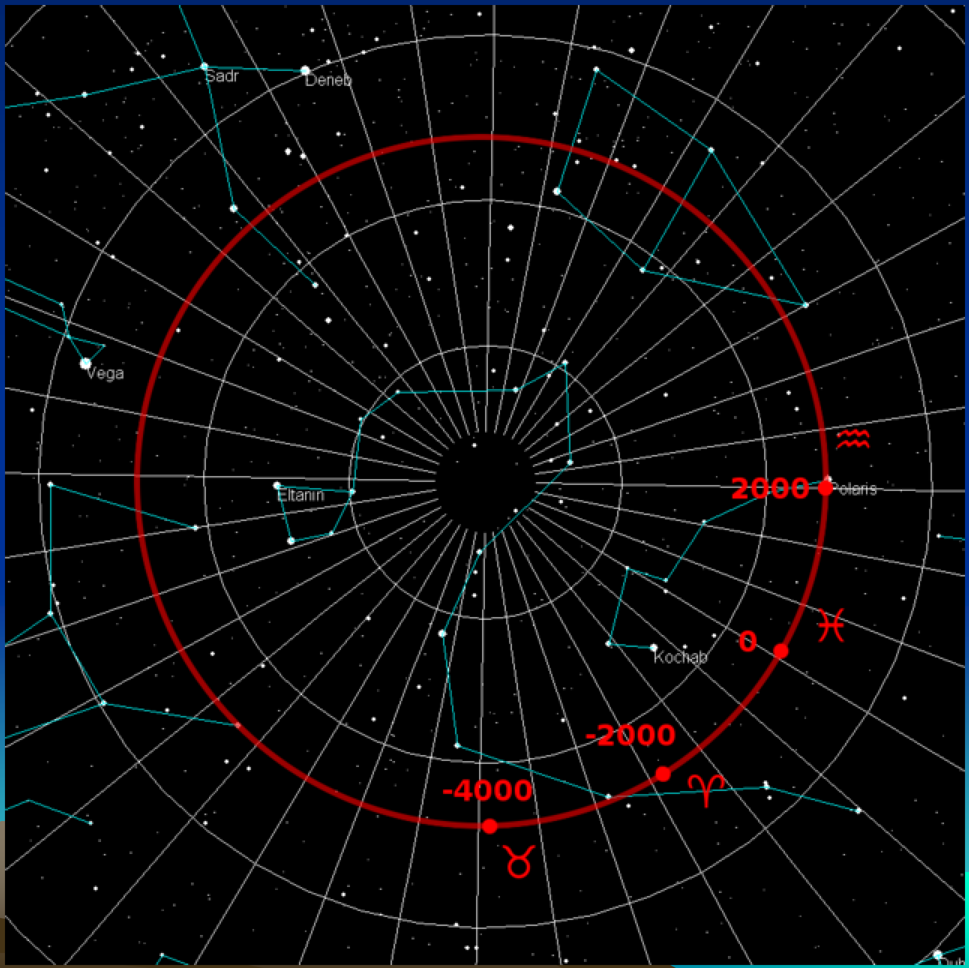
Rotation of Stars around Polaris

- Because Polaris is essentially in line with the celestial pole other stars will rotate around it in a small circle path.



Earth’s Precession

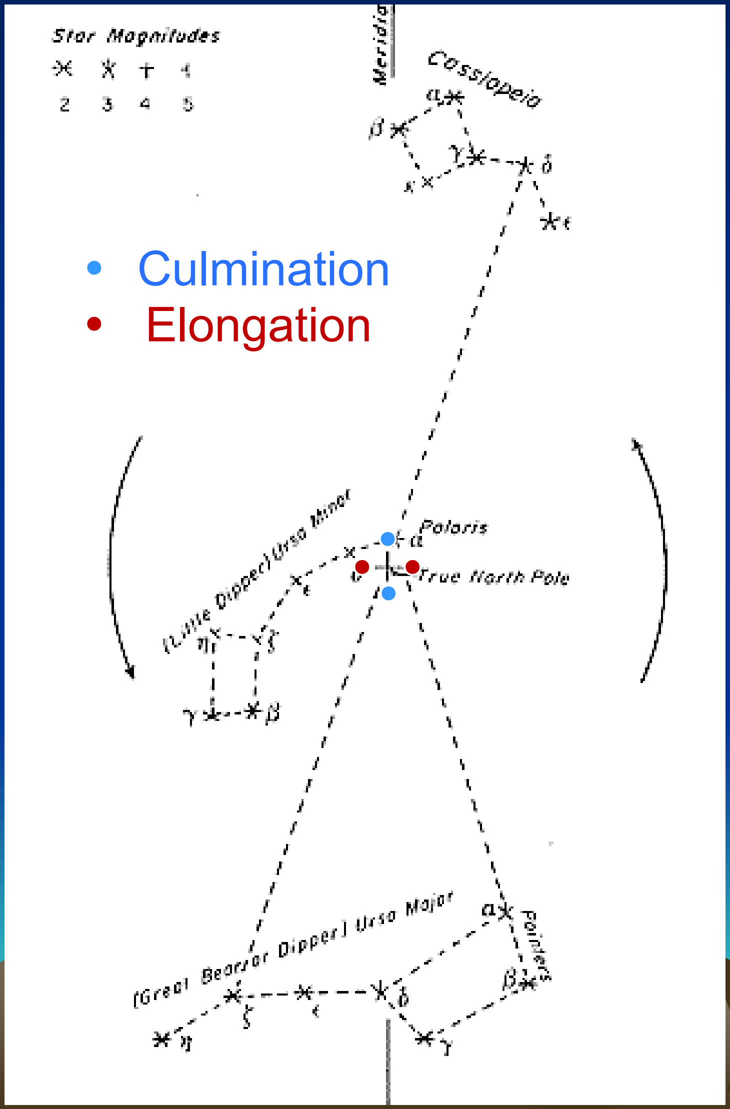
- The Earth “wobbles” like a spinning top = Precession.
- On a 20,000 year cycle the rotational axis rotates 360 degrees.



Polaris Culmination Points

- A line connecting the next to last stars in the “handles” of the Big Dipper and Cassiopia will be vertical at the upper or lower culmination point.
- At culmination Polaris is perfectly aligned with geographic north.

Polaris Culmination Geometry



Polaris Ephemeris

October 2014 Sun and Polaris Ephemeris

January | February | March | April | May | June | July | August | September | **October** | November | December

2014 Date	SUN Declination (d m s)	GHA (d m s)	Eq o Time (m s)	Semi-Di (m s)	Polaris Declination (d m s)	Polaris GHA (d m s)	TUC (h m s)
Oct 1 WE	- 3 04 21.7	182 32 15.0	+10 09.00	15 58.4	89 19 22.12	326 38 10.6	2 13 05.4
Oct 2 TH	- 3 27 37.1	182 37 05.2	+10 28.34	15 58.6	89 19 22.46	327 36 57.6	2 09 10.9
Oct 3 FR	- 3 50 50.1	182 41 51.1	+10 47.41	15 58.9	89 19 22.81	328 35 46.5	2 05 16.3
Oct 4 SA	- 4 14 00.4	182 46 32.6	+11 06.17	15 59.2	89 19 23.15	329 34 37.2	2 01 21.6
Oct 5 SU	- 4 37 07.5	182 51 09.1	+11 24.61	15 59.5	89 19 23.49	330 33 29.6	1 57 26.7
Oct 6 MO	- 5 00 11.2	182 55 40.5	+11 42.70	15 59.8	89 19 23.82	331 32 22.9	1 53 31.8
Oct 7 TU	- 5 23 11.0	183 00 06.4	+12 00.42	16 00.0	89 19 24.12	332 31 16.2	1 49 36.9
Oct 8 WE	- 5 46 06.7	183 04 26.3	+12 17.75	16 00.3	89 19 24.41	333 30 08.7	1 45 42.1
Oct 9 TH	- 6 08 58.0	183 08 39.9	+12 34.66	16 00.6	89 19 24.69	334 28 59.8	1 41 47.3
Oct 10 FR	- 6 31 44.4	183 12 46.9	+12 51.13	16 00.9	89 19 24.98	335 27 49.6	1 37 52.6
Oct 11 SA	- 6 54 25.7	183 16 46.9	+13 07.13	16 01.1	89 19 25.28	336 26 38.7	1 33 58.0
Oct 12 SU	- 7 17 01.5	183 20 39.5	+13 22.63	16 01.4	89 19 25.60	337 25 27.6	1 30 03.4
Oct 13 MO	- 7 39 31.4	183 24 24.5	+13 37.63	16 01.7	89 19 25.93	338 24 17.3	1 26 08.7
Oct 14 TU	- 8 01 55.1	183 28 01.4	+13 52.10	16 02.0	89 19 26.29	339 23 08.0	1 22 14.0
Oct 15 WE	- 8 24 12.1	183 31 30.1	+14 06.01	16 02.2	89 19 26.65	340 22 00.3	1 18 19.1
Oct 16 TH	- 8 46 22.2	183 34 50.3	+14 19.35	16 02.5	89 19 27.01	341 20 54.1	1 14 24.2
Oct 17 FR	- 9 08 24.8	183 38 01.6	+14 32.11	16 02.8	89 19 27.38	342 19 49.4	1 10 29.1
Oct 18 SA	- 9 30 19.7	183 41 03.9	+14 44.26	16 03.0	89 19 27.74	343 18 45.8	1 06 34.0
Oct 19 SU	- 9 52 06.3	183 43 56.9	+14 55.79	16 03.3	89 19 28.09	344 17 43.2	1 02 38.8
Oct 20 MO	-10 13 44.4	183 46 40.3	+15 06.68	16 03.6	89 19 28.43	345 16 41.2	0 58 43.6
Oct 21 TU	-10 35 13.6	183 49 13.9	+15 16.93	16 03.8	89 19 28.76	346 15 39.2	0 54 48.4
Oct 22 WE	-10 56 33.4	183 51 37.6	+15 26.51	16 04.1	89 19 29.08	347 14 36.9	0 50 53.2
Oct 23 TH	-11 17 43.4	183 53 51.2	+15 35.41	16 04.4	89 19 29.40	348 13 34.0	0 46 58.0
Oct 24 FR	-11 38 43.2	183 55 54.4	+15 43.63	16 04.6	89 19 29.72	349 12 30.3	0 43 02.9
Oct 25 SA	-11 59 32.4	183 57 47.1	+15 51.14	16 04.9	89 19 30.04	350 11 25.9	0 39 07.8

Culmination Times

- Upper culmination is published in table form for UTC (prime meridian) time.
- The time of upper/lower culmination is when Polaris is exactly on zero azimuth.
- The time for each upper/lower culmination is the same for every time zone.
- The time of the culmination must be corrected within a time zone for the offset within the 15 degrees.

Making a Polaris Observation with the Total Station

- Occupy a known point at dusk and level instrument.
- Focus on a distant object (moon, clouds, etc.)
- When sufficiently dark find Polaris in the Little Dipper and align crosshair on star. “zero set” the instrument to align with geographic north.
- Rack the scope down to set a stake at a convenient distance from the occupied point. A headlamp can be used to illuminate the crosshair.
- The occupied instrument point and stake now are aligned with true north. If you wait until a culmination time the accuracy will be within a few seconds.
- The next day a tape can be pulled between the points. A pocket transit declination can be set by aligning the edge with the tape and using the declination screw to set “0”.

Other Stars

- Stars will rotate around the celestial pole in small circle paths. The rotational “cone axis” is the celestial pole.
- Certain statistical best-fit cone algorithms can be used to find the axis with several observations of a star separated by several hours time.
- Aligning the horizontal angle with the calculated cone axis angle and “zero set” will align the instrument with true north.
- Note that angles from horizontal up to a star position (i.e. declination) are equal to 90 – VA.

Lecture Test 1 Review

- Take home test
- Contour problem: from spot elevations
- Closed traverse: plot from data; adjust error
- Topographic profile: calculate V.E.
- Hand-Level/Height calculation problem
- ArcGIS contour problem: Grid given data and generate contours
- Relational fraction (RF) problems
- Map Coordinate systems (UTM, LOGS, SPCS, Lat-Long): find map features given coordinates and vice versa.