Meridian Conversion

Mentoring Mondays
11 Dec 2023
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A. Definitions

1. Meridian

A north-south reference line.

"North"

Common Meridians:

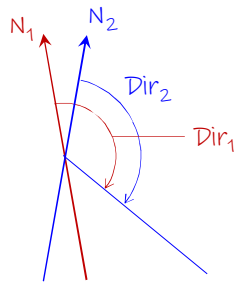
- True
- Geodetic
- Magnetic
- Astronomic
- Grid, Grid, Grid
- Assumed

Some _____, others _____.

- converge, are parallel
- are straight, vary
- are constant, change over time

2. Meridian conversion

Changing a direction from one meridian to another.



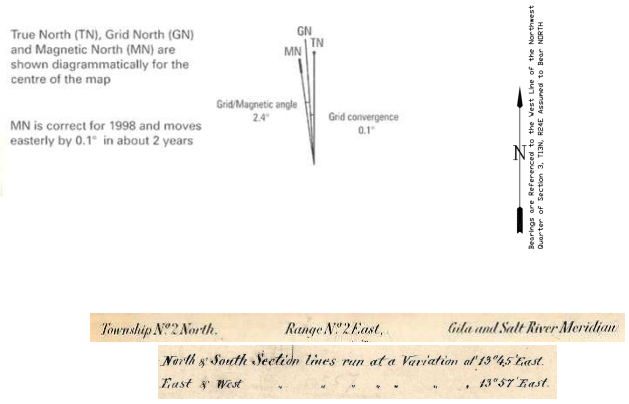
B. Applications

Traditional

- Magnetic ←→ True
- Traverse ←→ Traverse

Contemporary

- Grid ←→ Geodetic
- Grid ←→ Grid



C. Magnetic Conversions

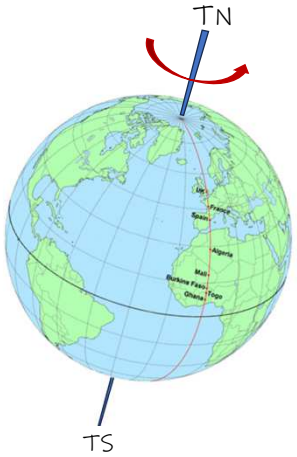
1. True North

Based rotational axis of Earth

Great circle containing observer and Poles

Constant over time.

True meridians converge.



C. Magnetic Conversions

2. Magnetic North

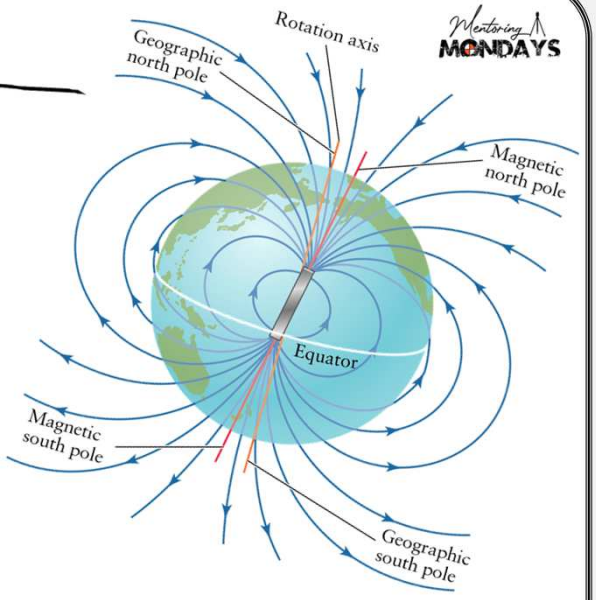
Based on Earth's magnetic fields.

Magnetic meridians converge, but are not straight.

Affected by local attractions.

Magnetic poles move over time.

Movement is not constant.

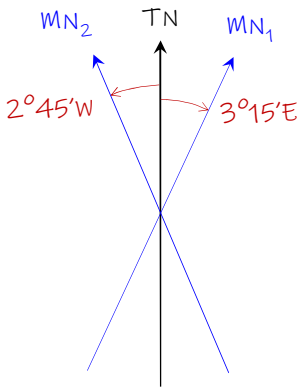


C. Magnetic Conversions

3. Declination, δ

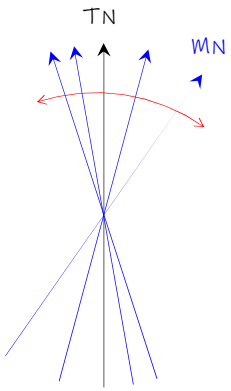
The angle from the true north meridian to the magnetic north meridian at a point.

Measured at the North ends of the meridians.



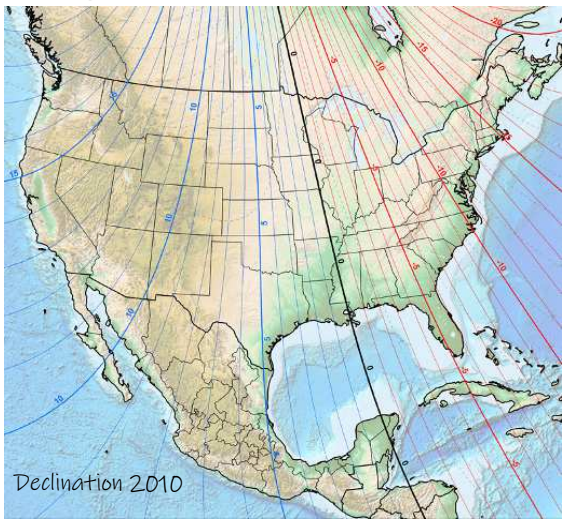
C. Magnetic Conversions

4. Variation
   - Magnetic north moves over time
   - Variation is amount and direction declination changes over time
   - Variation is not constant.
   - While we can record past declinations, it's not easy to predict future declination.



C. Magnetic Conversions

5. Isogonic Chart
   - Map of declination at a specific time
     - Isogonic line
       - line of equal declination
     - Agonic line
       - line of 0° declination
   - Historic Magnetic Declination
     - https://www.ncei.noaa.gov/maps/historical_declination/



C. Magnetic Conversions

6. Behavior

True North does not move over time.

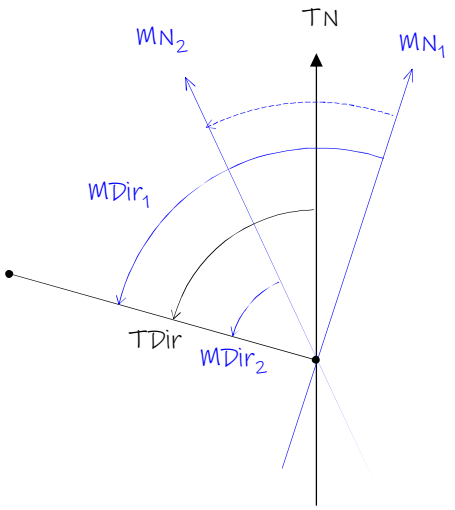
The line whose direction is measured does not move over time.

Only Magnetic North moves over time.

That means:

A line's true direction *does not* change.

A line's magnetic direction *does* change.



C. Magnetic Conversions

7. Computations

Problem (1) [Assign #2]

The magnetic bearing of line AB in 1885 was recorded as N58°45'E and the declination was 5°20' E.

What is the true bearing of the line?

Build the sketch in pieces.

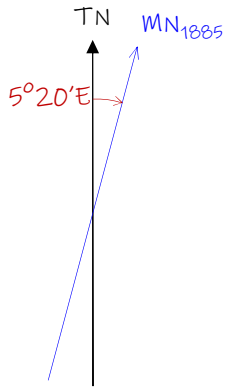
C. Magnetic Conversions

7. Computations

Problem (1) [Assign #2]

The magnetic bearing of line AB in 1885 was recorded as N58°45'E and the declination was 5°20' E.
What is the true bearing of the line?

Build the sketch in pieces.
Add the declination & magnetic meridian.



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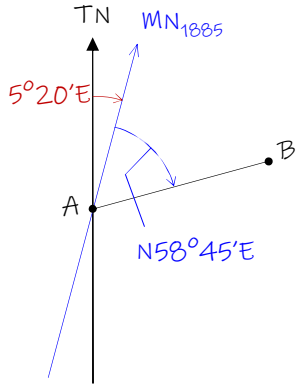
Add the declination & magnetic meridian.
Then the line and magnetic bearing.



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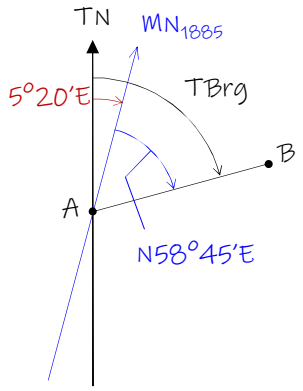
Add the declination & magnetic meridian.
Then the line and magnetic bearing.
And finally label the true bearing.



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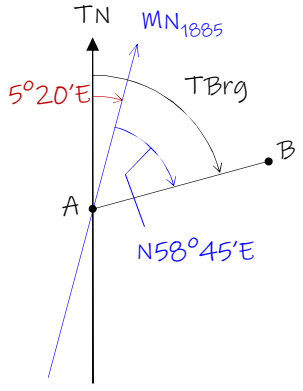

Angle = 5°20'+58°45' = 64°05'
→ TBrg = N 64°05' W

C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

Problem (2) [Assign #3]

The magnetic bearing of line PQ in 1925 was recorded as S86°35'W. The present true bearing of the line is S79°50'W. What was the declination in 1925?

C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

Problem (2) [Assign #3]

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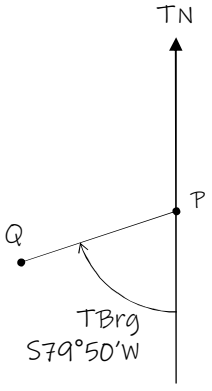
Add the line with its true bearing.



C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

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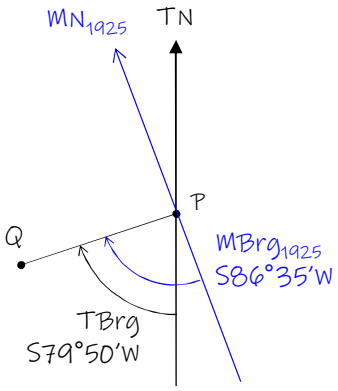
The magnetic bearing of line PQ in 1925 was recorded as S86°35'W. The present true bearing of the line is S79°50'W. What was the declination in 1925?

Add the line with its true bearing. Using the 1925 magnetic bearing, add the magnetic meridian.



C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

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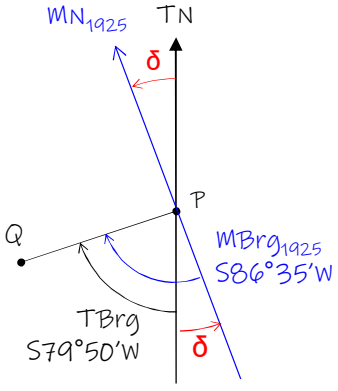
Add the line with its true bearing. Using the 1925 magnetic bearing, add the magnetic meridian.

$\delta = 86°35' - 79°50' = 6°45'$

$\delta = 6°45'W$



C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

Problem (3) [Assign #4]

The magnetic bearing of line ST in 1963 was recorded as N38°55'W. The present magnetic bearing of the line is N31°50'W and declination is 3°20'W.

(1) What is the true bearing of the line?

(2) What was the declination in 1963?

C. Magnetic Conversions

Mentoring MONDAYS

7. Computations

Problem (3) [Assign #4]

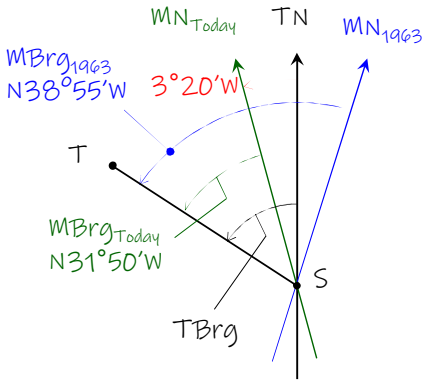
The magnetic bearing of line ST in 1963 was recorded as N38°55'W. The present magnetic bearing of the line is N31°50'W and declination is 3°20'W.

(1) What is the true bearing of the line?

TBrg = N 35°10' W

(2) What was the declination in 1963?

δ_{1963} = 3°45' E



C. Magnetic Conversions

7. Computations

Problem (4) [Assign #5]

In 1890:

Mag brg of AB = S30°50'E

Mag brg of BC = N85°30'E

Decl = 3°00'E

In 1960:

Mag brg AB = S21°10'E

Mag brg BC = ?

C. Magnetic Conversions

7. Computations

Problem (4) [Assign #5]

In 1890:

Mag brg of AB = S30°50'E

Mag brg of BC = N85°30'E

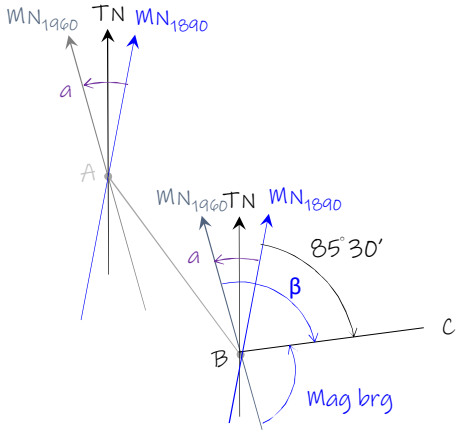
Decl = 3°00'E

In 1960:

Mag brg AB = S21°10'E

Mag brg BC = ?

Mag brg = S84°50'E



D. Traverse to Traverse Conversion

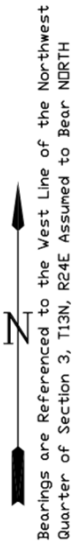
Mentoring MONDAYS

Often, when computing a traverse, the direction of one line is assumed

- If the relationship between assumed north and true north can be determined then the true directions of the traverse lines can be computed.

This can also be done when two surveyors use two different assumed directions for adjacent surveys.

- If the surveys share a line, then one survey can be rotated into the other.

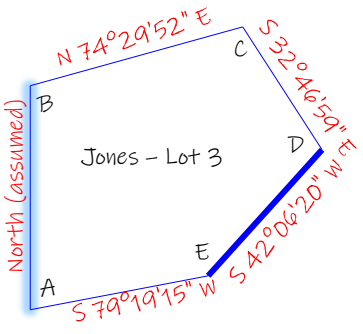


D. Traverse to Traverse Conversion

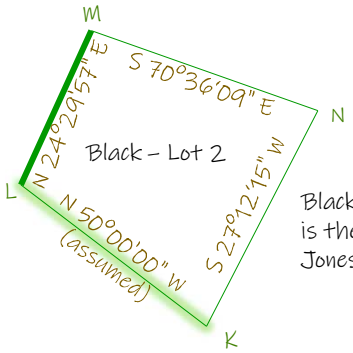
Mentoring MONDAYS

[Assign #6]

Surveyor Jones surveyed Lot 3. He assumed the direction of one line (AB) as due North. The resulting directions around the Lot are:



Surveyor Black surveyed Lot 2 next door. She assumed the direction of one line (KL) as N50°00'00"W. The resulting directions around the Lot are:



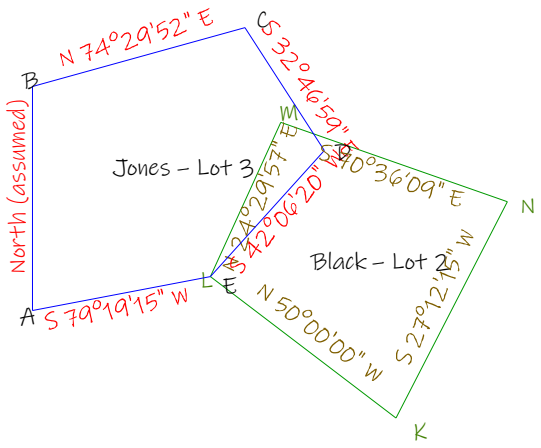
Black's line ML is the same as Jones' line DE.

D. Traverse to Traverse Conversion

[Assign #6]

Pick one end of the common line as a pivot point.

Rotate one survey into the other.



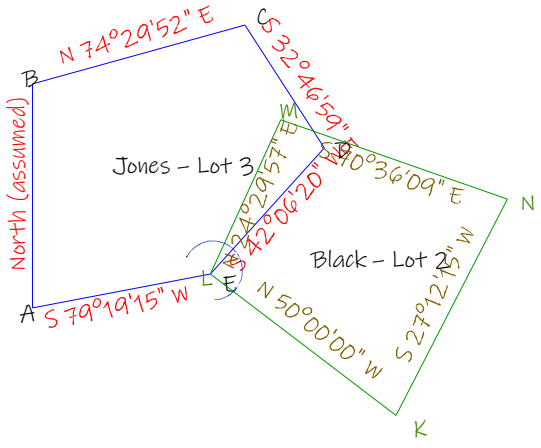
D. Traverse to Traverse Conversion

[Assign #6]

Pick one end of the common line as a pivot point.

Rotate one survey into the other.

To rotate Jones' survey into Black's...



D. Traverse to Traverse Conversion

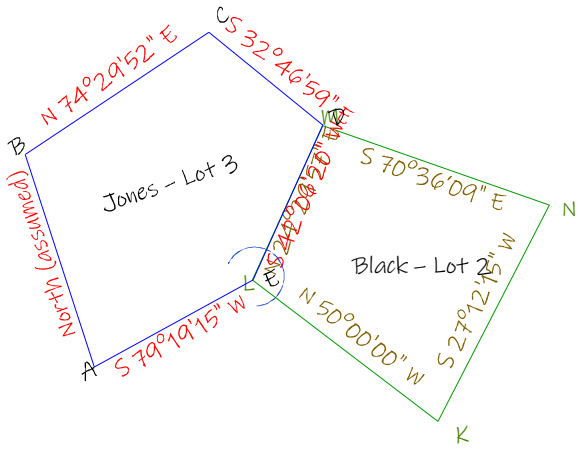
[Assign #6]

Pick one end of the common line as a pivot point.

Rotate one survey into the other.

To rotate Jones' survey into Black's...

42°06'20"-24°29'57" =
17°36'23" ccw



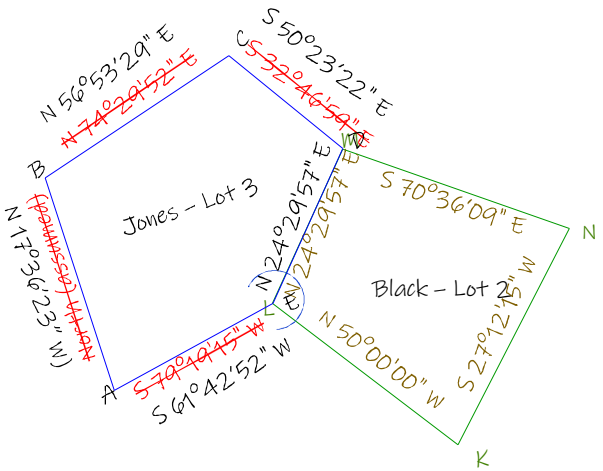
D. Traverse to Traverse Conversion

[Assign #6]

Each of Jones' bearings changes by 17°36'23"

- Depending on quadrant, the bearing angle may increase or decrease.

Pivoting Jones' survey around the other point would result in the same bearings.



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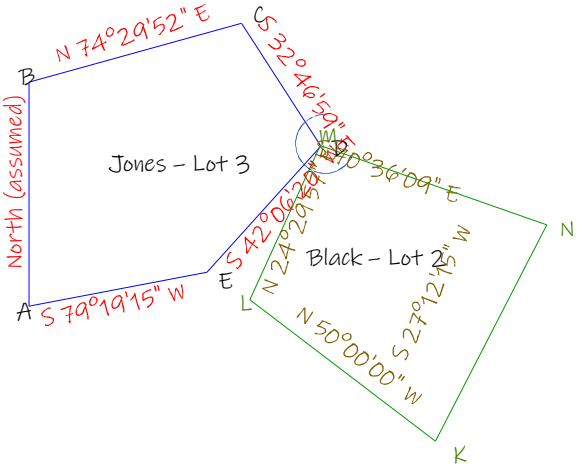
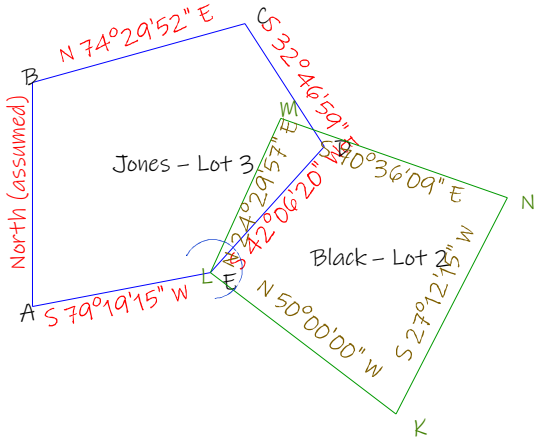




E. Grid and Geodetic Conversions

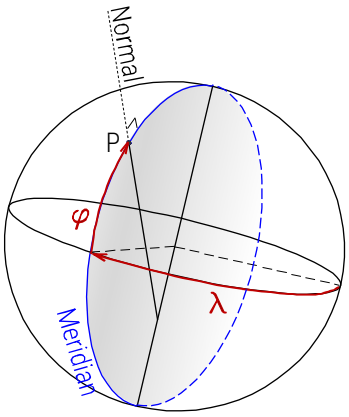
1. Geodetic North

Geodetic north is defined by the reference ellipsoid and its fit.

NAD 83 uses GRS 80 which is closely fit to Earth's mass center.

Normal	A line from the observer's position, P, perpendicular to the ellipsoid
Meridian	An elliptical section containing the normal and semi-minor axes.

Geodetic meridians converge.



E. Grid and Geodetic Conversions

2. Grid North

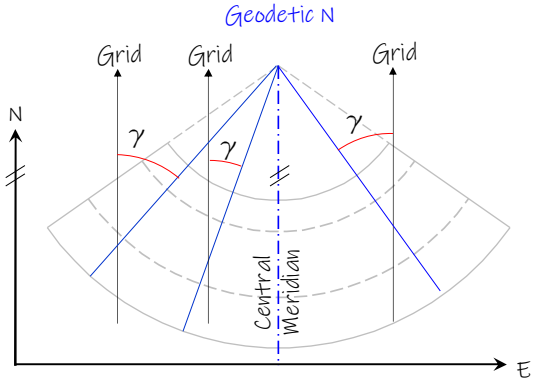
A function of the projection & its fit.
Grid north meridians are parallel

a. Cone: Lambert Conic

Convergence, γ, is angle between Grid and Geodetic North.

γ=0° at CM, magnitude increases moving E or W

Direction behavior



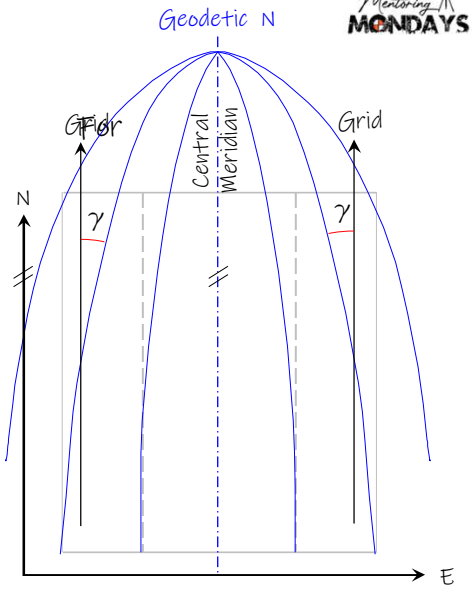
E. Grid and Geodetic Conversions

2. Grid North

b. Cylinder: Transverse Mercator

γ=0° at CM, magnitude increases moving E or W

Some change moving N or S but, except for UTM, the zones are generally small so the effect is negligible.



E. Grid and Geodetic Conversions

2. Grid North

c. Converting

γ is :

positive East of the CM

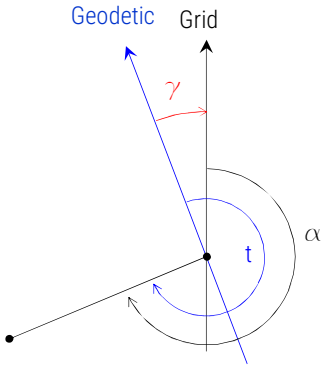
negative West of the CM

$t = \alpha - \gamma$

t Grid azimuth

α Geodetic azimuth

γ Convergence



E. Grid and Geodetic Conversions

3. Where do we get convergence?

NGS Survey Mark Datasheet

```
NJ0866  DESIGNATION -  PLATTEVILLE
NJ0866                      *CURRENT SURVEY CONTROL
NJ0866  ______________________________________________________________
NJ0866* NAD 83(1996) POSITION- 42 44 07.57581(N) 090 28 43.06363(W)   ADJUSTED
NJ0866* NAVD 88 ORTHO HEIGHT -   303.    (meters)      994.    (feet) SCALED
NJ0866  ______________________________________________________________
NJ0866  GEOID HEIGHT    -        -32.860 (meters)                     GEOID18
NJ0866  LAPLACE CORR    -         -1.72  (seconds)                    DEFLEC18
NJ0866  HORZ ORDER      -  FIRST
NJ0866
NJ0866. The following values were computed from the NAD 83(1996) position.
NJ0866
NJ0866;                      North         East      Units Scale Factor Converg.
NJ0866;SPC WI S      -    81,813.433   560,805.351   MT  0.99999958   -0 19 43.9
NJ0866;SPC WI S      -   268,416.24  1,839,908.89   sFT  0.99999958   -0 19 43.9
NJ0866;UTM  15       - 4,734,519.181   706,397.710   MT  1.00012413   +1 42 41.9
NJ0866
NJ0866!              -  Elev Factor  x  Scale Factor =   Combined Factor
NJ0866!SPC WI S      -   0.99995765  x   0.99999958  =   0.99995723
NJ0866!UTM  15       -   0.99995765  x   1.00012413  =   1.00008177
NJ0866
NJ0866:                  Primary Azimuth Mark                    Grid Az
NJ0866:SPC WI S      -  PLATTEVILLE AZ MK                       202 04 40.3
NJ0866:UTM  15       -  PLATTEVILLE AZ MK                       200 02 14.5
```

E. Grid and Geodetic Conversions

3. Where do we get convergence?

Software

NGS – NCAT; online conversion

Others – most surveying software that supports grid systems can compute (and apply) convergence.

NAD_83_Conbersion.xlsm – Excel spreadsheet at jerrymahun.com

Shows all the Direct and Inverse calculations.

Lambert Conformal Conic

State/Zone	WI South	Code 4803
Units	Survey Ft	
	3.28083333	conversion

Direct Conversion			Inverse Conversion	
Lat (φ)	42.4407575810	d.ms	N	184,406.690 Survey Ft
Long (λ)	90.284306363	d.ms	E	1,706,443.560 Survey Ft
N	268,416.2372	Survey Ft	Lat (φ)	+42°30'06.328065"
E	1,839,908.8893	Survey Ft	Long (λ)	+90°58'18.201301"
Conv (γ)	-0°19'43.923"	Conv	Conv (γ)	-0°40'03.625"
Scale (k)	0.99999 9576	Scale	Scale (k)	1.00005 4733

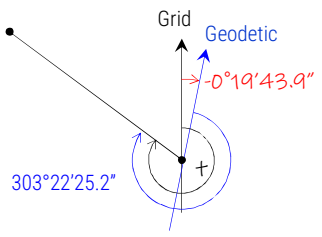
E. Grid and Geodetic Conversions

4. Example [Assign #7a]

At point *Platteville*:

SPC S Zone γ = -0°19'43.9"

What is the grid azimuth in the WIS SPC S Zone from Platteville to Lancaster Co Courthouse Dome?



	PID	Reference Object	Distance	Geod. Az dddmmss.s
NJ0866	NJ0870	PLATTEVILLE ST MARYS CH SPIRE	170.514 METERS	00413
NJ0866	NJ0869	PLATTEVILLE FIRST CONG CH	25.341 METERS	03206
NJ0866	NJ0867	PLATTEVILLE ST PAULS LUTH CH	APPROX. 0.6 KM	1001100.3
NJ0866	NJ0859	CUBA CITY MUNICIPAL TANK	APPROX.14.9 KM	1641538.5
NJ0866	NJ0860	CUBA CITY CHURCH SPIRE	APPROX.14.7 KM	1645646.9
NJ0866	CJ1868	PLATTEVILLE RM 1	27.267 METERS	19528
NJ0866	CJ1867	PLATTEVILLE AZ MK		2014456.4
NJ0866	NJ0930	DICKEYSVILLE HOLY GHOST CHURCH	APPROX.15.3 KM	2183355.3
NJ0866	NJ0871	PLATTEVILLE PIONEER S T C STK	APPROX. 0.6 KM	2585500.0
NJ0866	CJ1869	PLATTEVILLE RM 2	27.094 METERS	28637
NJ0866	NJ0872	PLATTEVILLE WATER WORKS TANK	231.429 METERS	30005
NJ0866	NJ0921	LANCASTER ST CLEMENTS CATH CH	APPROX.22.8 KM	3030447.2
NJ0866	NJ0922	LANCASTER CO COURTHOUSE DOME	APPROX.22.7 KM	3032252.0

E. Grid and Geodetic Conversions

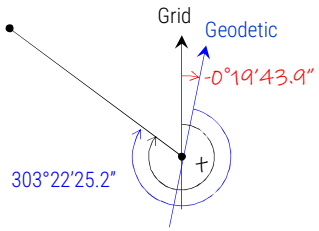
4. Example [Assign #7a]

At point *Platteville*:

SPC S Zone γ = -0°19'43.9"

α = 303°22'52.0"

$t = \alpha - \gamma$ = 303°22'52.0" – (-0°19'43.9") = **303°42'35.9"**




```
NJ0866|-------------------------------------------------------------------|
NJ0866| PID    Reference Object                    Distance      Geod. Az  |
NJ0866|                                                          dddmmss.s |
NJ0866| NJ0870 PLATTEVILLE ST MARYS CH SPIRE     170.514 METERS 00413     |
NJ0866| NJ0869 PLATTEVILLE FIRST CONG CH          25.341 METERS 03206     |
NJ0866| NJ0867 PLATTEVILLE ST PAULS LUTH CH      APPROX. 0.6 KM 1001100.3 |
NJ0866| NJ0859 CUBA CITY MUNICIPAL TANK          APPROX.14.9 KM 1641538.5 |
NJ0866| NJ0860 CUBA CITY CHURCH SPIRE            APPROX.14.7 KM 1645646.9 |
NJ0866| CJ1868 PLATTEVILLE RM 1                    27.267 METERS 19528     |
NJ0866| CJ1867 PLATTEVILLE AZ MK                                  2014456.4 |
NJ0866| NJ0930 DICKEYSVILLE HOLY GHOST CHURCH    APPROX.15.3 KM 2183355.3 |
NJ0866| NJ0871 PLATTEVILLE PIONEER S T C STK     APPROX. 0.6 KM 2585500.0 |
NJ0866| CJ1869 PLATTEVILLE RM 2                    27.094 METERS 28637     |
NJ0866| NJ0872 PLATTEVILLE WATER WORKS TANK       231.429 METERS 30005     |
NJ0866| NJ0921 LANCASTER ST CLEMENTS CATH CH     APPROX.22.8 KM 3030447.2 |
NJ0866| NJ0922 LANCASTER CO COURTHOUSE DOME      APPROX.22.7 KM 3032252.0 |
NJ0866|-------------------------------------------------------------------|
```

E. Grid and Geodetic Conversions

5. Grid to Grid [Assign #7b]

Sometimes we need to convert a direction from one grid system to another.

To do so we need the convergence at the point for both systems.

At point *Platteville*:

```
NJ0866;                      North          East      Units Scale Factor Converg.
NJ0866;SPC WI S      -    81,813.433   560,805.351    MT  0.99999958   -0 19 43.9
NJ0866;SPC WI S      -   268,416.24  1,839,908.89    sFT  0.99999958   -0 19 43.9
NJ0866;UTM  15       - 4,734,519.181   706,397.710    MT  1.00012413   +1 42 41.9
NJ0866
```

Wis South SPC grid az = 135°18'25". What is UTM Zone 15 grid az?

$t = \alpha - \gamma \rightarrow \alpha = t_{SPC} + \gamma_{SPC}$

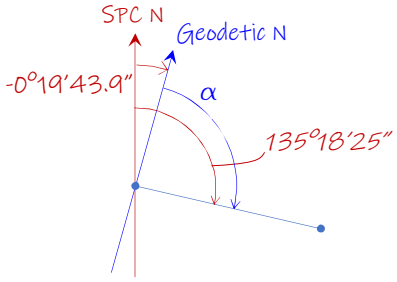
$t_{UTM} = \alpha - \gamma_{UTM} = (t_{SPC} + \gamma_{SPC}) - \gamma_{UTM} = (135°18'25" + [-0°19'43.9"]) - (+1°42'41.9")$

$= \underline{133°15'59.2"}$

E. Grid and Geodetic Conversions

5. Grid to Grid [Assign #7b]

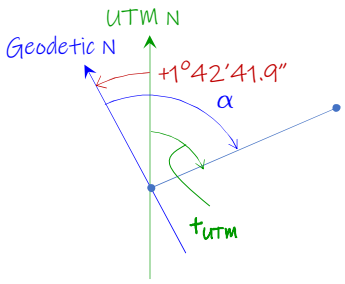
Draw a sketch:



$t = \alpha - \gamma \rightarrow \alpha = t - \gamma$

$\alpha = 135°18'25" + (-0°19'43.9")$

$= 134°58'41.1"$



$t = \alpha - \gamma$

$t_{UTM} = 134°58'41.1" - (+1°42'41.9")$

$= \underline{133°15'59.2"}$

F. PLSS Corner Restoration Using Grid Coordinates

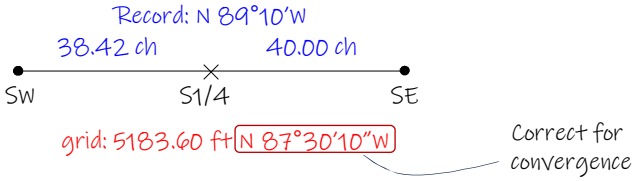
1. Cardinal Equivalents

Direction basis for PLSS is True Meridian.

If working in SPC or UTM, must convert Grid to True directions.

2009 Manual treats Geodetic and True the same, which isn't *technically* true, but close enough.

To determine cardinal equivalents using grid directions, apply the convergence.



G. Trivia: Astronomic

1. Background

In traditional control surveys, directions were determined using astronomic observations. Observing stars, typically Polaris.

Wild T-4 theodolite, used exclusively for star observations.
0.1" circle resolution H, 0.05" est,
Only 439 produced. **Weight: 220 lbs**

Wild T-3theodolite, used for star observations and triangulation.
0.2" circle resolution; 0.1" estimation

Kern DKM3 used for star observations and triangulation.
0.5" circle resolution; 0.1" estimation

G. Trivia: Astronomic

1. Background

FGCC 1984 Standards

3.2 Triangulation

Triangulation is a measurement system comprised of joined or overlapping triangles of angular observations supported by occasional distance and astronomic observations. Triangulation is used to extend horizontal control.

Network Geometry

Order Class	*First*	*Second I*	*Second II*	*Third I*	*Third II*
Station spacing not less than (km)	15	10	5	0.5	0.5
Average minimum distance angle† of figures not less than	40°	35°	30°	30°	25°
Minimum distance angle† of all figures not less than	30°	25°	25°	20°	20°
Base line spacing not more than (triangles)	5	10	12	15	15
Astronomic azimuth spacing not more than (triangles)	8	10	10	12	15

† Distance angle is angle opposite the side through which distance is propagated.

Instrumentation

Only properly maintained theodolites are adequate for observing directions and azimuths for triangulation. Only precisely marked targets, mounted stably on tripods or supported towers, should be employed. The target should have a clearly defined center, resolvable at the minimum control spacing. Optical plummets or collimators are required to ensure that the theodolites and targets are centered over the marks. Microwave-type electronic distance measurement (EDM) equipment is not sufficiently accurate for measuring higher-order base lines.

Order Class	*First*	*Second I*	*Second II*	*Third I*	*Third II*
Theodolite, least count	0.2"	0.2"	1.0"	1.0"	1.0"

G. Trivia: Astronomic

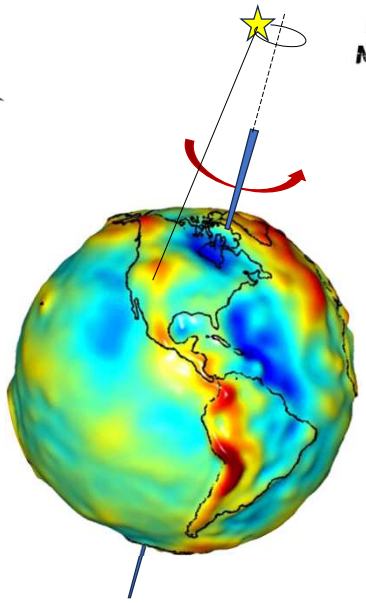
2. Astronomic North

"...the positive direction of a line tangent to the (gravity) equipotential surface at the observer." ... ???

NGS Geodetic Glossary

Observation of celestial body to determine location of astronomic north.

Instrument is oriented to the geoid, which is irregular.



G. Trivia: Astronomic

2. Astronomic North

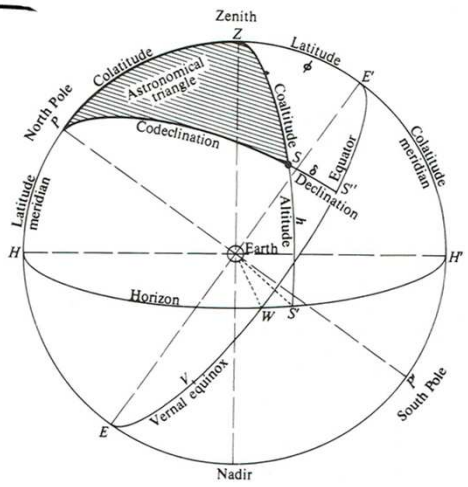
A star is observed at night.

- Horiz & vert angles measured.
- Time of obs recorded.

Ephemeris used to determine star position at obs time.

Star and instrument positions are used to calculate where astronomic (celestial) north is.

- PZS triangle

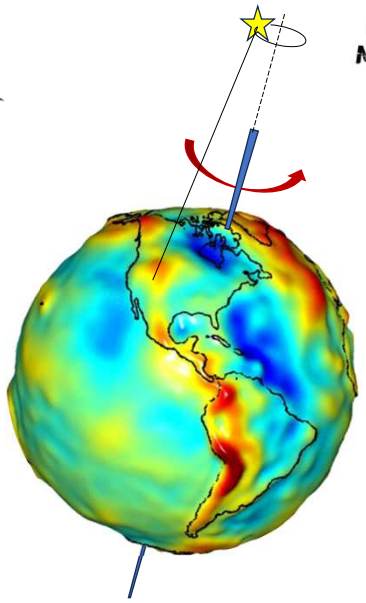


Celestial Sphere

G. Trivia: Astronomic

2. Astronomic North

Astronomic meridians converge
but
Because geoid is irregular so are the meridians.



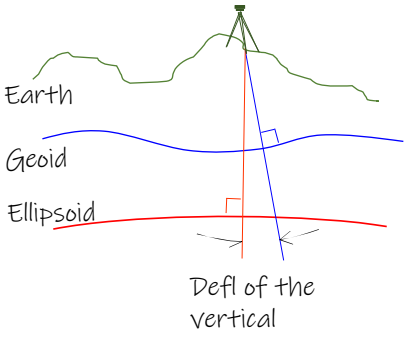
G. Trivia: Astronomic

3. Deflection of the Vertical

The difference between
- direction of gravity
- ellipsoid normal

at instrument location.

Skewness of ellipsoid-geoid fit.



G. Trivia: Astronomic

Mentoring MONDAYS

4. LaPlace Correction

A component of the deflection of the vertical used to correct an astronomic direction to a geodetic one.

[Assign #8]

$$\alpha_A - \alpha_G = (\lambda_A - \lambda_G)\sin\varphi_G$$

α_A - astronomic direction
α_G - geodetic direction
λ_A – astronomic longitude
λ_G – geodetic longitude
φ_G – geodetic latitude
$(\lambda_A - \lambda_G)\sin\varphi_G$ – LaPLace correction

Astronomic values are referenced to geoid.

Geodetic values are referenced to ellipsoid.

G. Trivia: Astronomic

Mentoring MONDAYS

4. LaPlace Correction

Where do we get the LaPlace correction?

Survey Mark Datasheet

```
NJ0866  DESIGNATION -  PLATTEVILLE
NJ0866                        *CURRENT SURVEY CONTROL
NJ0866
NJ0866* NAD 83(1996) POSITION- 42 44 07.57581(N) 090 28 43.06363(W)   ADJUSTED
NJ0866* NAVD 88 ORTHO HEIGHT -   303.     (meters)       994.     (feet) SCALED
NJ0866
NJ0866  GEOID HEIGHT     -        -32.860 (meters)                      GEOID18
NJ0866  LAPLACE CORR     -         -1.72  (seconds)                     DEFLEC18
NJ0866  HORZ ORDER       -  FIRST
```

NGS software: DEFLCxx

xx latest year.

Depends on geoid model

G. Trivia: Astronomic

Mentoring MONDAYS

4. LaPlace Correction

Will you ever use the LaPlace correction?
Probably not, but it's interesting trivia you can use to impress your friends.