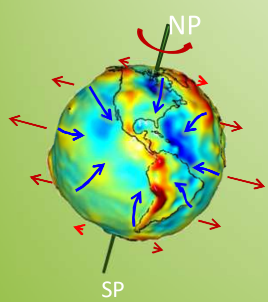
Ground↔Grid - Simple, Right?



Mentoring Mondays

10 March 2025

Jerry Mahun, PLS

Thrice-retired, but still too damn busy

jerry.mahun@gmail.com

https://jerrymahun.com

- I. Earth Models
- II. Spatial Systems
- III. Distortions
- IV. Creating a Grid
- V. State and Regional Coordinate Systems
- VI. Ground and Grid

Grid↔Ground - Simple, Right?

I. Earth Models

I. Earth Models

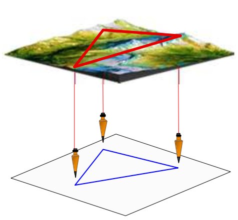
A. Physical Earth - Ground

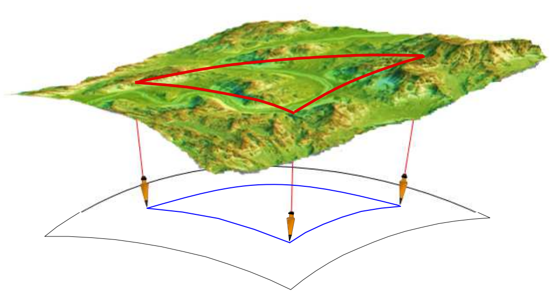
The surface on which we measure.

Not mathematical.

Over small areas, we can assume a flat reference system - plane; simple grid

Over larger areas, must account for earth's shape and dynamics - curved reference





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10 March 2025

I. Earth Models

Mentoring MONDAYS

B. Geoid

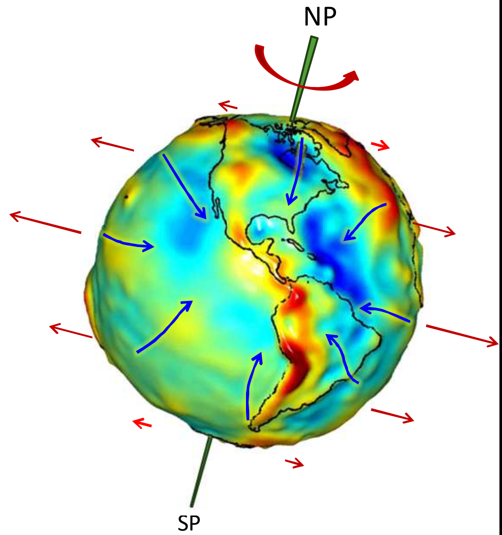
An equipotential surface defined by gravity (in) and centrifugal force (out).

Gravity = f(mass)

Earth: non-homogeneous; mass anomalies

⇨ Lines of gravity are neither parallel nor straight.

Geoid is a lumpy and changing nonmathematical surface.



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10 March 2025

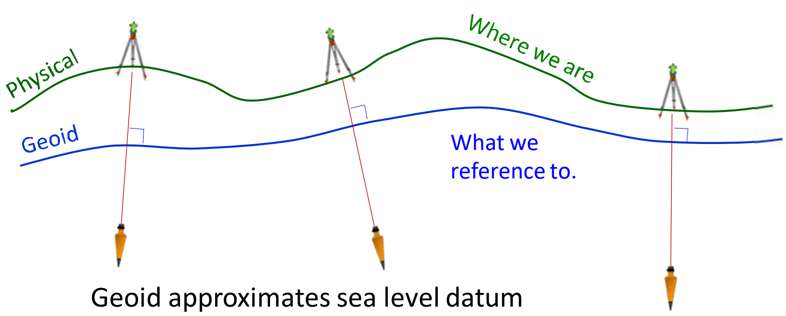
I. Earth Models

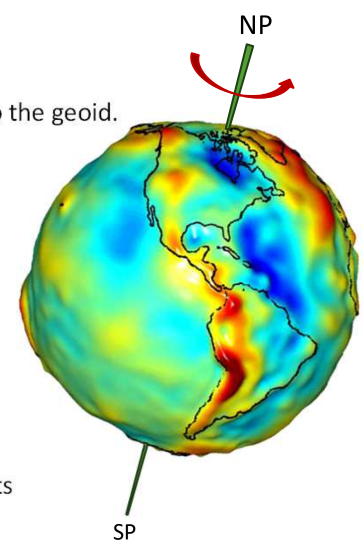
Mentoring MONDAYS

B. Geoid

Gravity is perpendicular to the geoid

Centering a bubble or using a plumb bob orients equipment to the geoid.





Geoid approximates sea level datum

Connected to physical Earth by elevations - orthometric heights

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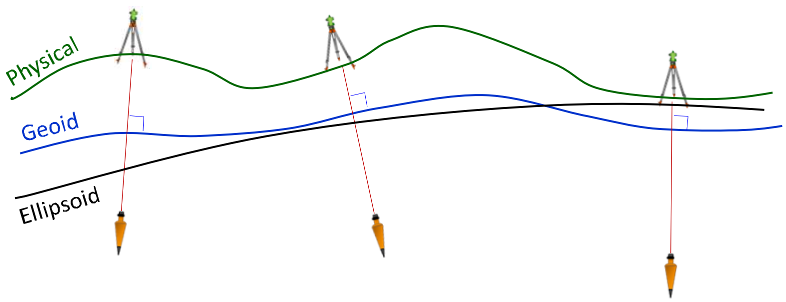
10 March 2025

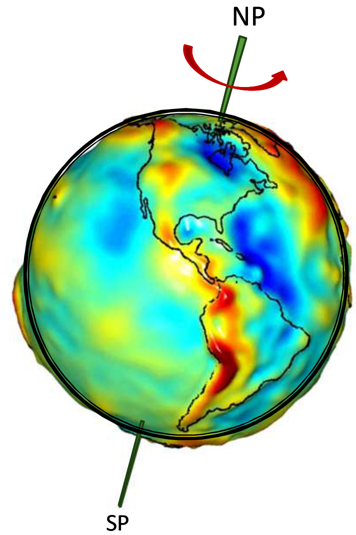
I. Earth Models

C. Ellipsoid

Mathematical 3D surface that is fit to geoid

Doesn't fit exactly; compromises





10 March 2025

I. Earth Models

C. Ellipsoid

Geoid - Ellipsoid fit at a point is a function of Skewness and Vertical separation.

Vertical separation

Heights between the surfaces

H - Orthometric: geoid to ground

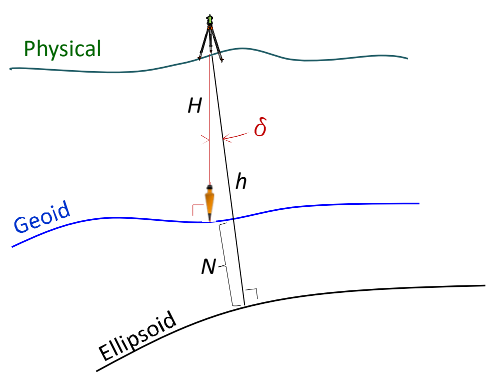
N - Geoid: ellipsoid to geoid

h - Ellipsoidal: ellipsoid to ground

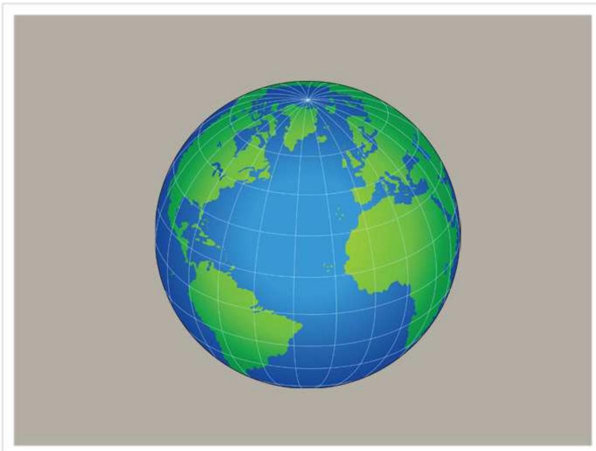
h = H+N

Skewness - Deflection of the vertical, δ

Angle between directions of gravity and ellipsoid *normal*.



10 March 2025



II. Spatial Systems

II. Spatial Systems

Mentoring MONDAYS

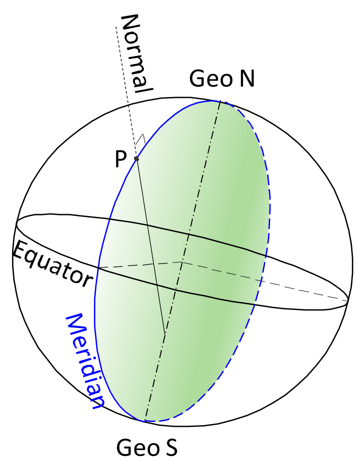
A. Three-Dimensional

1. Geodetic Coordinates

Reference defined by ellipsoid and fit.

NAD 83 - GRS 80 fit to Earth's mass center.

NAD 27 - Clarke 1866 fit to Meades Ranch, KS



Meridian — An elliptical section containing the normal and semi-minor axes. Defines Geodetic N at a point.

Geodetic meridians converge.

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10 March 2025

II. Spatial Systems

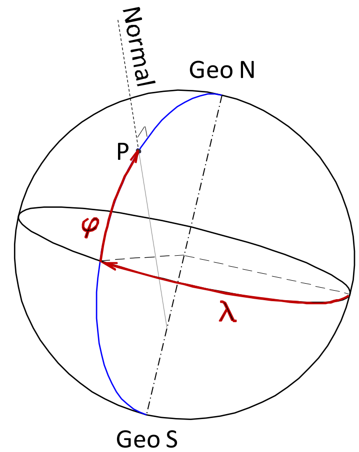
Mentoring MONDAYS

A. Three-Dimensional

1. Geodetic Coordinates

Longitude (λ) - Angle in Equatorial plane
E or W from Greenwich Meridian
0°-180°W; 0°-180°E

Latitude (Φ) - Angle in meridian N or S
of the Equator to the normal
0°-90°N; 0°-90°S



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10 March 2025

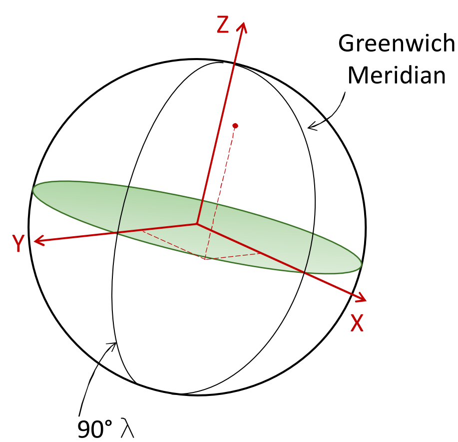
II. Spatial Systems

Mentoring MONDAYS

A. Three-Dimensional

2. Terrestrial Coordinate System - TCS

Three axis rectangular system
Origin at Earth's mass center
Coordinates are linear values



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II. Spatial Systems

B. Two Dimensional

1. Planar

Characteristics

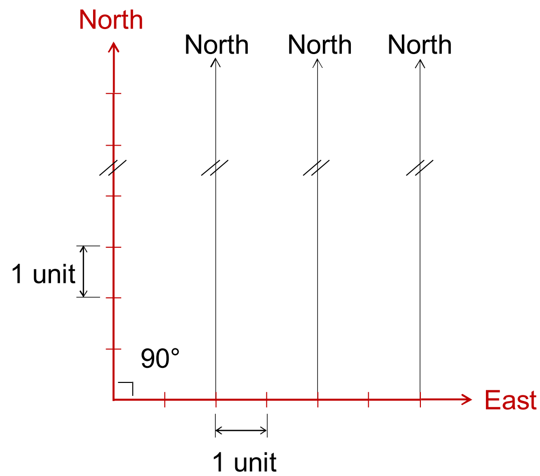
a. Orthogonal

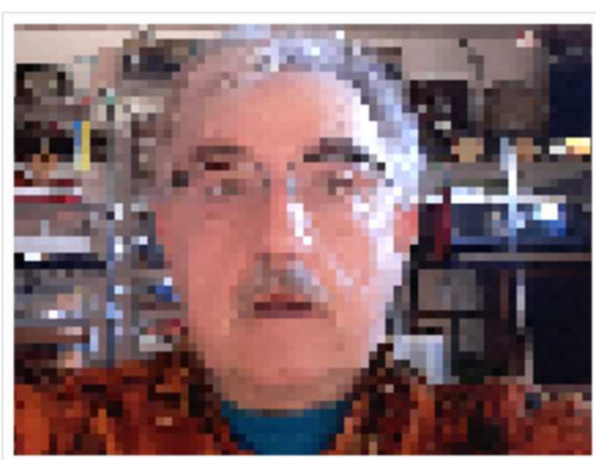
b. Parallel north lines

c. Uniform scale in both directions

Comps are simple.

Disadvantage(s)?





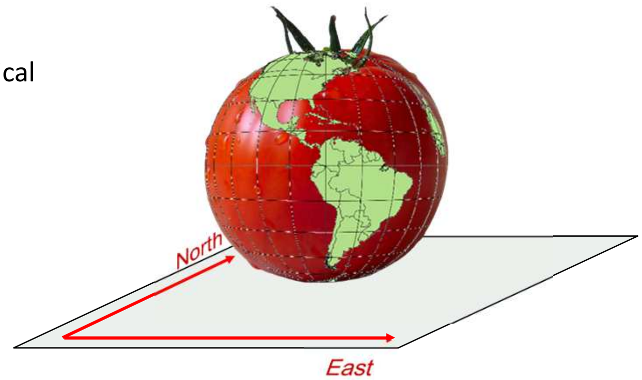
III. Distortions

III. Distortions

A. 3D to 2D

We're on a 3D irregular earth

We want to put it in a 2D mathematical system



III. Distortions

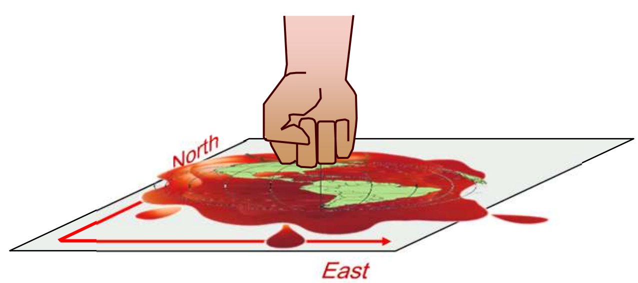
A. 3D to 2D

We're on a 3D irregular earth

We want to put it in a 2D mathematical system

With a direct projection we get a distorted representation.

Different mathematical projections distort different ways.

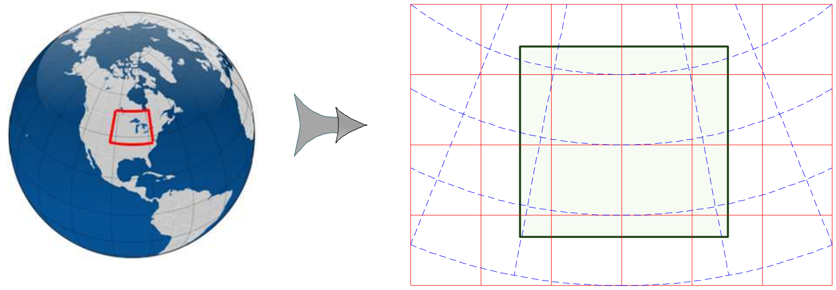


III. Distortions

Mentoring MONDAYS

B. Projection Area

The smaller the area projected, the smaller the distortions.



Grid (2D) - Solid red
Geodetic (3D) - Dashed blue

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III. Distortions

Mentoring MONDAYS

C. Distortion Types

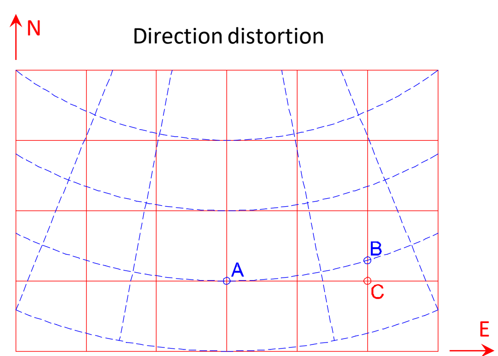
1. Direction
   - 3D meridians converge, 2D Grid do not.
   - 3D E/W lines are curved, 2D Grid are straight.

   No distortion at center of projection

   Increases moving E & W of center

   Direction distortion = f(longitude)
   - Systematic error

Direction distortion



Grid (2D) - Solid red
Geodetic (3D) - Dashed blue

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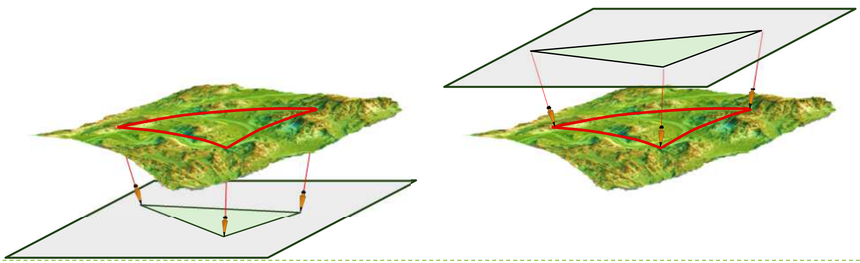
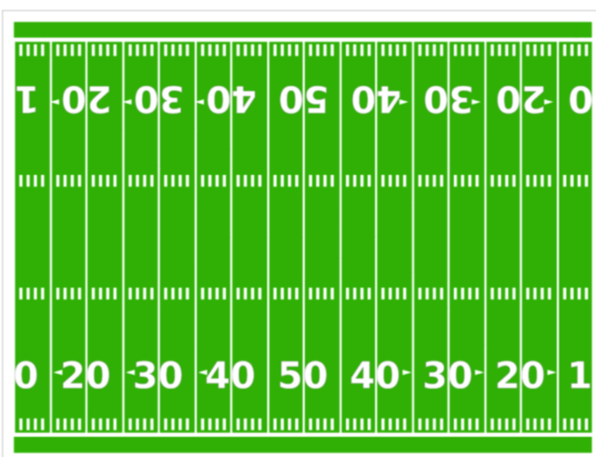
III. Distortions

C. Distortion Types

2. Distance
   - Ground points must be projected vertically to the 2D grid plane.
   - This moves them closer together or further apart, altering distance.
   - Distance distortion = f(heights, grid fit)
     - Systematic error





IV. Creating a Grid

IV. Creating a Grid

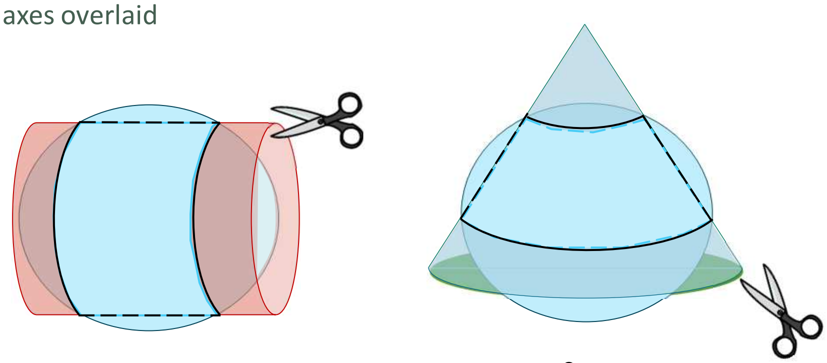
A. Projection Surfaces

Grid is based on a Projection Surface which is fit to Ellipsoid

Points are projected from ellipsoid to surface

Surface is rolled out flat

Coordinate axes overlaid



Cylinder Cone

IV. Creating a Grid

B. Lambert Conic Conformal

Distance distortion

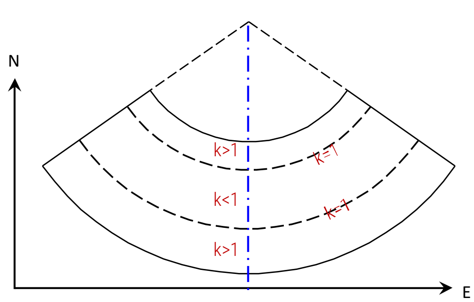
Scale, k, is constant E/W; varies N/S

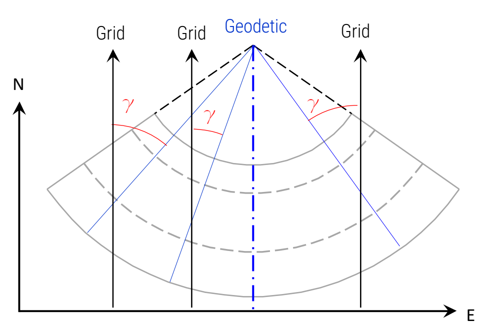
k=f(Latitude)

Direction distortion

Conv, γ, angle between Grid & Geodetic N

γ=f(Longitude)





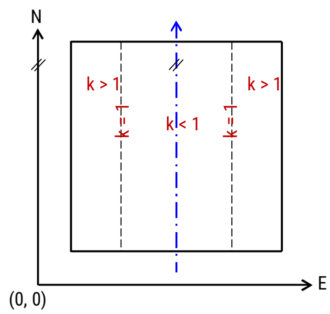
IV. Creating a Grid

C. Mercator Transverse Cylindric

Distance distortion

Scale, k, is constant N/S; varies E/W

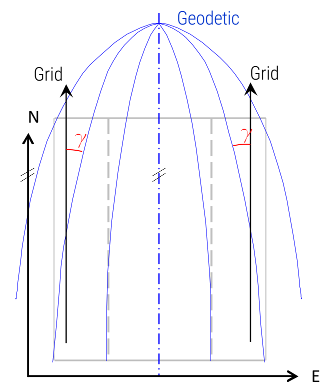
k=f(Longitude)

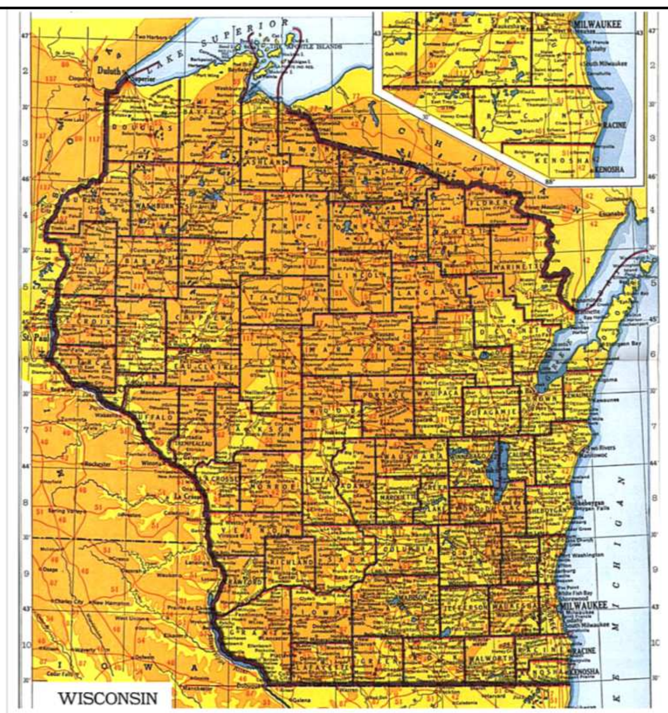


Direction distortion

Conv, γ, angle between Grid & Geodetic N

γ=f(Longitude)



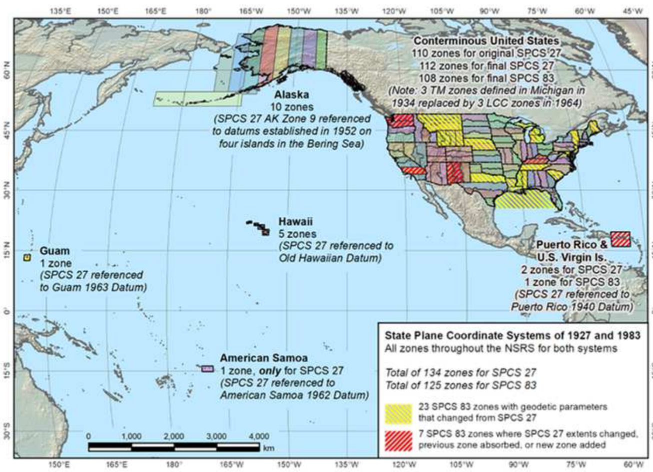


V. State and Regional Coordinate Systems

V. State and Regional Coordinate Systems

A. Traditional

1. State Plane Coordinate (SPC) system



Developed by C&GS in 1934

Max distortion: 1/10,000

ellipsoid to grid

Updated on NAD 83

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10 March 2025

V. State and Regional Coordinate Systems

A. Traditional

2. Universal Transverse Mercator (UTM) system

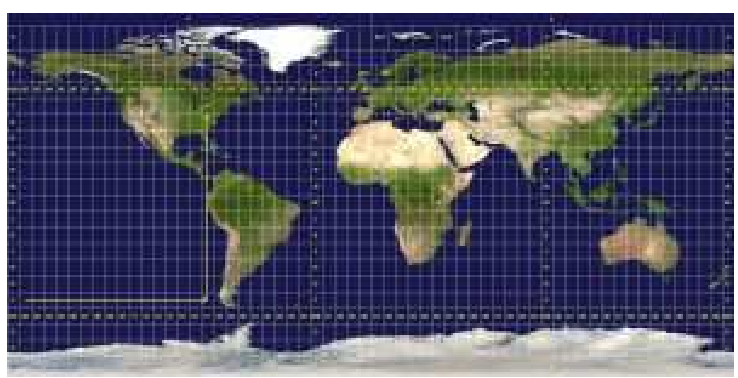
Developed by DMA

6° wide zones - global coverage

Max distortion: 1/2,500

ellipsoid to grid

Updated on NAD 83



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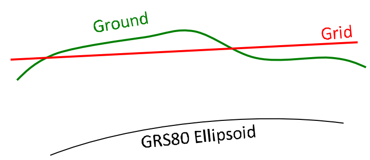
V. State and Regional Coordinate Systems

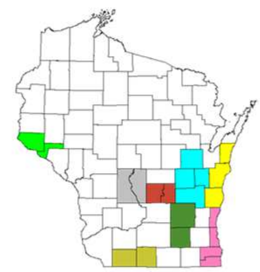
B. Low Distortion Projection (LDP)

Minimizes distortions by

- Fitting grid closed to ground
- Covering smaller area



How low are distortions?



Projection	Cylindric & Conic
Zones	58
Max Distortion (**ground** to grid)	urban: 1/50,000 rural: 1/30,000

V. State and Regional Coordinate Systems

B. Low Distortion Projection (LDP)

NAD 83 - based

- IL is developing County Systems

Most States will have LDPs when new datum is adopted.

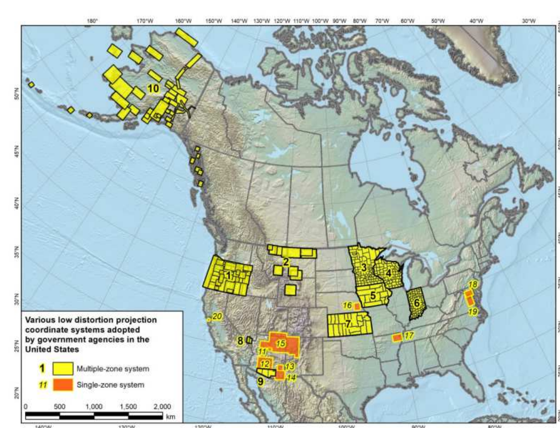


Figure 7. Examples of U.S. LDP coordinate systems (see Table 2 for additional information).

VI. Ground and Grid

What's the beef?

VI. Ground and Grid

A. Distortion Compensation

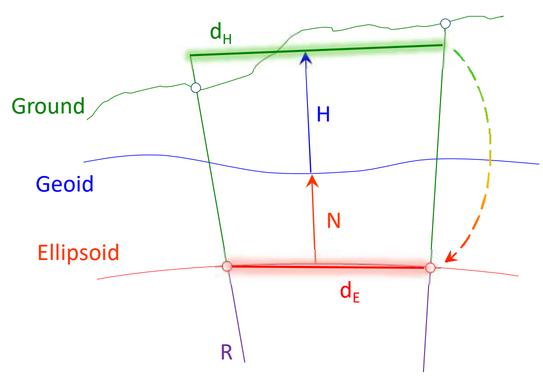
1. Distance - Two steps

a. Ground to ellipsoid: EF

$$EF = \frac{R}{R+H+N}$$

$$d_E = d_H \times EF$$

d_H	Horizontal ground distance
d_E	Ellipsoidal (geodetic) distance
EF	Elevation Factor
R	Mean earth radius
H	Orthometric ht (elev)
N	Geoid height
k	Scale factor



R = 20,902,000 ft = 6,371,000 m (approx.)

VI. Ground and Grid

A. Distortion Compensation

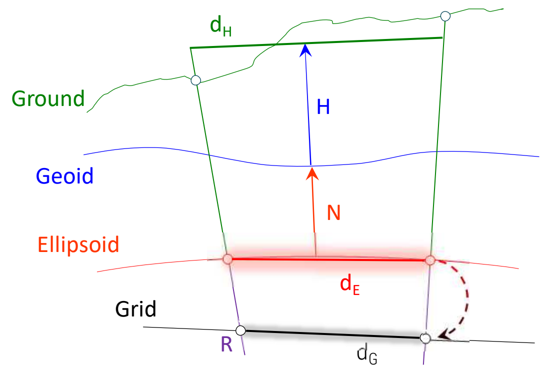
1. Distance - Two steps

a. Ground to ellipsoid: EF

b. Ellipsoidal to grid: k

$d_G = d_E \times k$

d_G	Grid distance
d_E	Ellipsoidal (geodetic) distance
k	Grid scale factor



VI. Ground and Grid

A. Distortion Compensation

1. Distance - Two steps

a. Ground to ellipsoid: EF

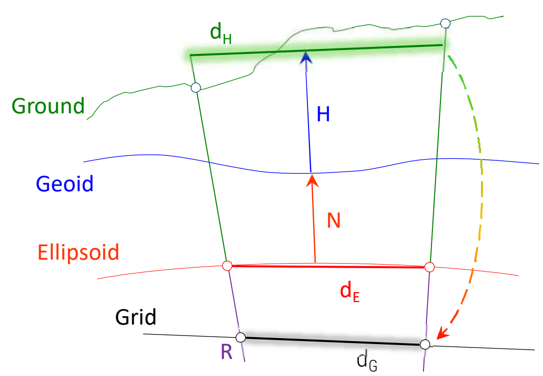
b. Ellipsoidal to grid: k

or

c. Combined factor: CF

$CF = EF \times k$

$d_G = d_H \times CF$



VI. Ground and Grid

A. Distortion Compensation

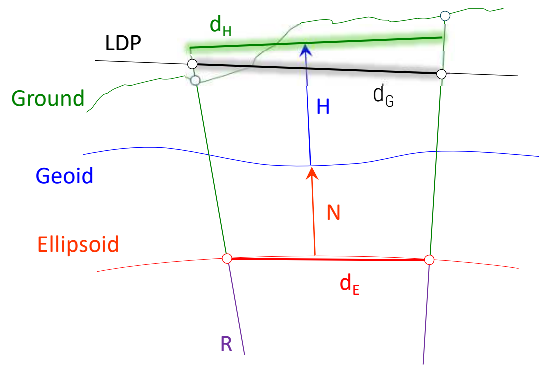
1. Distance

c. LDP

Because a LDP grid is near-ground level, there may be no discernible difference between ground and grid distances.

Most of the time, this reduction can be ignored for LDP grids.

$CF = EF \times k \approx 1.0$



VI. Ground and Grid

A. Distortion Compensation

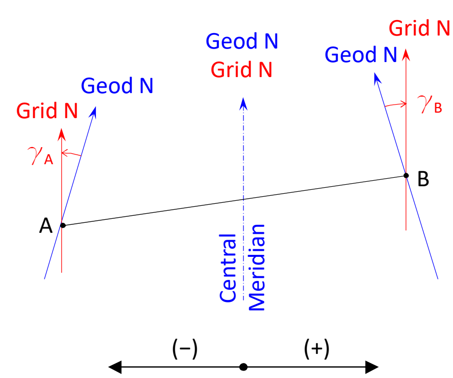
2. Direction

The convergence angle, γ, is **from** Geodetic N **to** Grid N

It is positive (cw) East of the CM, negative (ccw) West of the CM

To convert Geodetic direction to Grid:

Grid Az = Geodetic Az - γ



VI. Ground and Grid

B. Reduction Elements

Where do we get the ortho and geoid heights, scale, & conv angle?

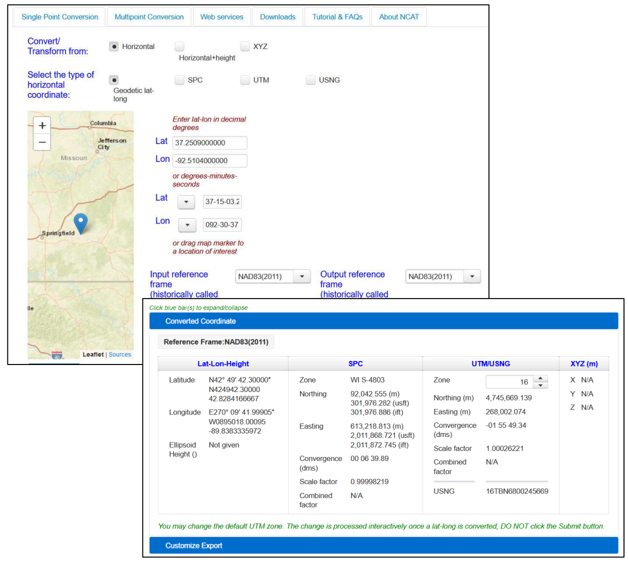
NGS software (*Geodetic Tool Kit*):

NCAT[1]

GEOIDXX

Ortho heights from USGS topoquads

[1]*NCAT* does not currently support local LDPs. When NATRF2022 is adopted, *NCAT* will include NGS-accepted LDPs.



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VI. Ground and Grid

B. Reduction Elements

NSRS Datasheet

```
DESIGNATION -  JERRY
 PID        -  NH0936

* NAD 83(2011) POSITION- 42 54 24.02215(N) 089 43 53.76413(W)   ADJUSTED
* NAD 83(2011) ELLIP HT-    324.836 (meters)        (06/27/12)   ADJUSTED
* NAD 83(2011) EPOCH   -  2010.00
* NAVD 88 ORTHO HEIGHT -     358.6    (meters)     1177.     (feet)  VERTCON

 GEOID HEIGHT    -          -33.902  (meters)                     GEOID18
 NAD 83(2011) X  -      21,919.631  (meters)                      COMP
 NAD 83(2011) Y  - -4,679,204.603  (meters)                       COMP
 NAD 83(2011) Z  -   4,320,134.562  (meters)                      COMP
 LAPLACE CORR    -            -0.36  (seconds)                    DEFLEC18

                      North         East     Units Scale Factor Converg.
SPC WI S      -   100,758.292    621,917.891    MT  0.99996957   +0 11 03.9
SPC WI S      -   330,571.16   2,040,408.95    sFT  0.99996957   +0 11 03.9
UTM  16       - 4,754,071.382    277,008.712    MT  1.00021177   -1 51 37.6

              -  Elev Factor  x  Scale Factor =   Combined Factor
SPC WI S      -   0.99994906  x   0.99996957  =   0.99991863
UTM  16       -   0.99994906  x   1.00021177  =   1.00016082
```

At *Jerry*'s elevation

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10 March 2025

VI. Ground and Grid

C. Variations

1. Elevation factor, EF

$$EF = \frac{R}{R + H + N}$$

N doesn't change much so can generally use a single value over the project area.

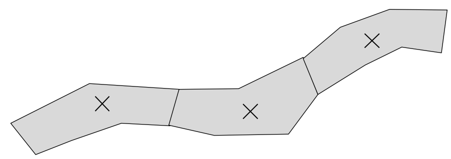
Depending on terrain, H can be:

- project area average – use for all lines
- computed average for each line

2. Grid scale, k

For relatively small projects, a single value at project center could be used.

Larger/longer projects would require applying different k in different areas.



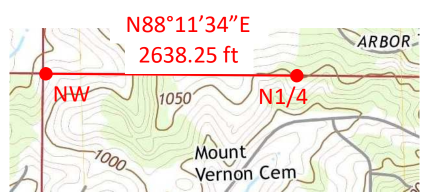
SPC/UTM - use approx. lat & long with *NCAT* to determine k.

VI. Ground and Grid

D. SPC Example

N Quarter line NW1/4 of S34 T5N R7E 4PM

Determine WI SPC South zone grid dist & brng from NW to N1/4



From topoquad

NW elev: 960 ft

N1/4 elev: 1050 ft

Approx position of NW corner is:

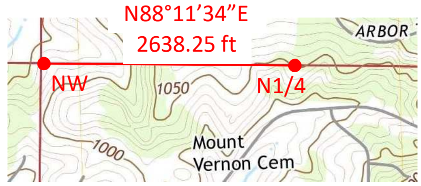
- 42°57.5' Lat
- 89°39.75' Long

VI. Ground and Grid

D. SPC Example

N Quarter line NW1/4 of S34 T5N R7E 4PM

Determine WI SPC South zone grid dist & brng from NW to N1/4



From topoquad

NW elev: 960 ft

N1/4 elev: 1050 ft

Approx position of NW corner is:

42°57.5' Lat
89°39.75' Long

From *NCAT*

k = 0.99996 224

γ = +0°13'54.8"

From *GEOID18*

N = -34.046 m

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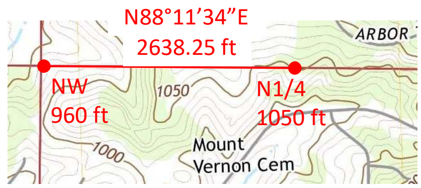
10 March 2025

VI. Ground and Grid

D. SPC Example

1. Distance

a. Ground to ellipsoid



$$H = \frac{960 + 1050}{2} = 1005$$

$$EF = \frac{20,902,000}{20,902,000 + 1005 + (-111.7)}$$

$$= 0.99995\ 7264$$

$$d_E = 2638.25 ft \times 0.99995\ 7264 = 2638.137 ft$$

R = **20,902,000 ft**

From *NCAT*

k = 0.99996 224

γ = +0°13'54.8"

From *GEOID18*

N = -34.046 m = **-111.7 ft**

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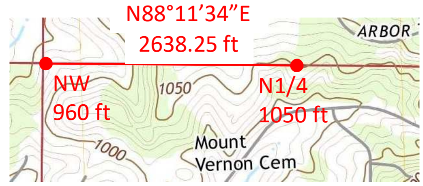
10 March 2025

VI. Ground and Grid

Mentoring MONDAYS

D. SPC Example



1. Distance

a. Ground to ellipsoid

$$H = \frac{960 + 1050}{2} = 1005$$

$$EF = \frac{20,902,000}{20,902,000 + 1005 + (-111.7)}$$

$$= 0.99995\ 7264$$

$$d_E = 2638.25 ft \times 0.99995\ 7264 = 2638.137 ft$$

b. Ellipsoid to grid

$$d_G = d_E \times k$$

$$d_G = 2638.137 ft \times 0.99996\ 224 = \underline{2638.037\ ft}$$

R = 20,902,000 ft

From *NCAT*

k = **0.99996 224**

γ = +0°13'54.8"

From *GEOID18*

N = -34.046 m = -111.7 ft

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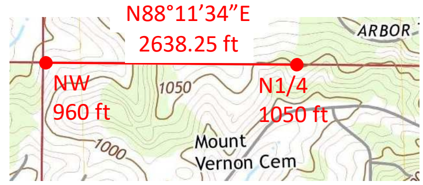
10 March 2025

VI. Ground and Grid

Mentoring MONDAYS

D. SPC Example



1. Distance

a. Ground to ellipsoid

$$H = \frac{960 + 1050}{2} = 1005$$

$$EF = \frac{20,902,000}{20,902,000 + 1005 + (-111.7)}$$

$$= 0.99995\ 7264$$

$$d_E = 2638.25 ft \times 0.99995\ 7264 = 2638.137 ft$$

b. Ellipsoid to grid

$$d_G = d_E \times k$$

$$d_G = 2638.137 ft \times 0.99996\ 224 = \underline{2638.037\ ft}$$

Distortion

$$diff = 2638.25 - 2638.037 = 0.213$$

$$2638.25 / 0.213 = 12386.2$$

$$distortion:\ 1/12,400$$

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10 March 2025

VI. Ground and Grid

Mentoring MONDAYS

D. SPC Example

2. Direction

Convert bearing to azimuth

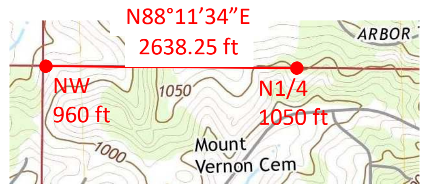
$$Az = 88°11'34''$$

Convert to Grid Az

$$Grid\ Az = 88°11'34'' - (+0°13'55'')$$
$$= 87°57'39''$$

Convert to bearing

$$Grid\ Brg = \underline{N87°57'39''E}$$



From *NCAT*

k = 0.99996 224

γ = **+0°13'54.8"**

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10 March 2025

VI. Ground and Grid

Mentoring MONDAYS

E. Low Distortion Projections

1. Reduction Elements

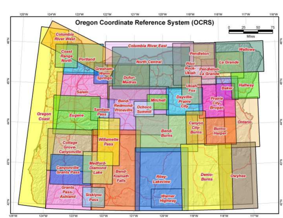
LDPs are not supported by *NCAT*, how to get N, convergence, and scale?

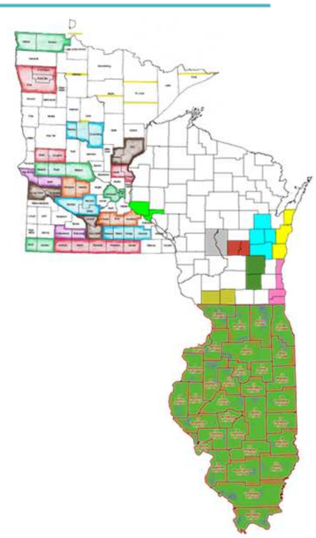
N: Use *GEOIDXX*, but need geodetic coordinates.

γ and k: ?

Need LDP-specific software.

Some surveying and mapping software have support for LDPs, including Wisconsin's.





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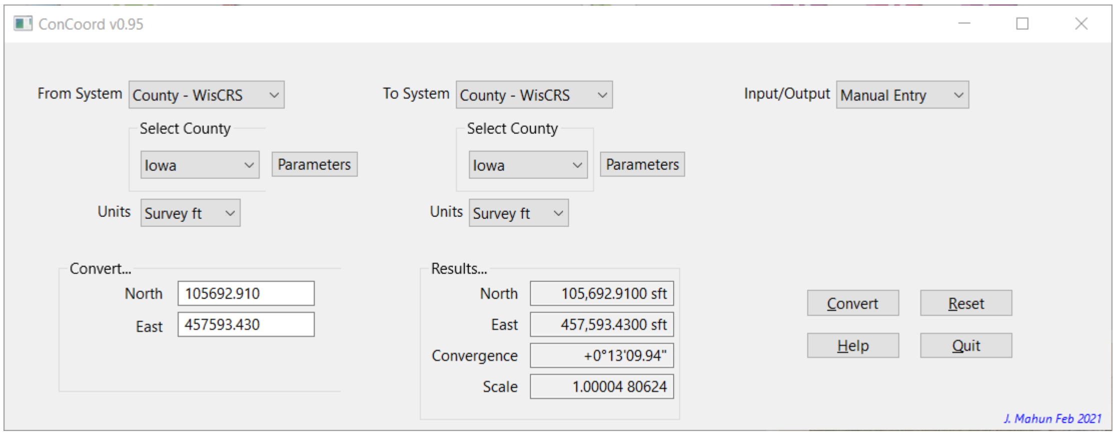
10 March 2025

VI. Ground and Grid

E. Low Distortion Projections

2. *WisCRS: ConCoord v0.95* At https://jerrymahun.com



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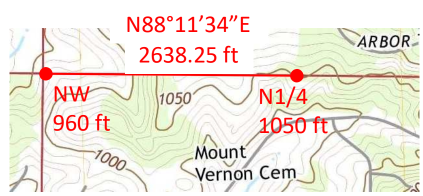
VI. Ground and Grid

F. WisCRS Example

N Quarter line NW1/4 of S34 T5N R7E 4PM

Determine Dane Co Coord Sys grid dist & brng from NW to N1/4



From topoquad

- NW elev: 960 ft
- N1/4 elev: 1050 ft
- Approx position of NW corner is:
  - 42°57.5' Lat
  - 89°39.75' Long

R = 20,902,000 ft

From *ConCoord*

- k = 1.00004 03535
- γ = -0°09'50.7"

From *GEOID18*

- N = -34.046 m = -111.7 ft

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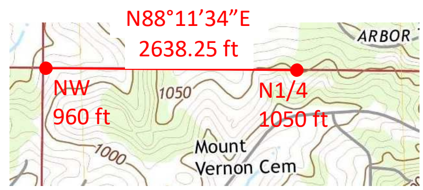
VI. Ground and Grid

F. WisCRS Example

1. Distance



$$H = \frac{1177 + 1050}{2} = 1113.5$$

$$EF = \frac{20902000}{20902000 + 1113.5 + (-111.2)}$$

$$= 0.999952050$$

$$CF = 0.99995\ 2050 \times 1.00004\ 03535$$

$$= 0.99999\ 2401$$

$$d_G = 2638.25ft \times 0.99999\ 2401 = 2638.230\ ft$$

Distance distortion?

$$diff = 2638.25 - 2638.230 = 0.02$$

$$2638.25 / 0.02 = 131913$$

$$distortion:\ 1/131,900$$

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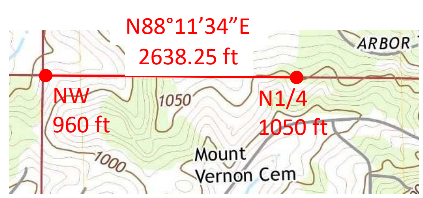
VI. Ground and Grid

F. WisCRS Example

2. Direction



Convert bearing to azimuth

$$Az = 88°11'34''$$

Convert to Grid Az

$$Grid\ Az = 88°11'34'' - (-0°09'51'')$$

$$= 88°21'25''$$

Convert to bearing

$$Grid\ Brg = \underline{N88°21'25''E}$$

R = 20,902,000 ft

From *ConCoord*

k = 1.00004 03535

γ = -0°09'50.7"

From *GEOID18*

N = -34.046 m = -111.7 ft

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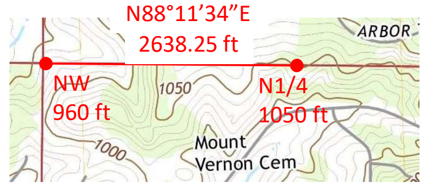
VI. Ground and Grid

Mentoring MONDAYS

G. SPC vs WisCRS Example



	Dist	Brng
Ground	2638.25	N 88°11'34"E
SPC	2638.037	N 87°57'39"E
WiCRS	2638.230	N 88°21'25"E

VI. Ground and Grid

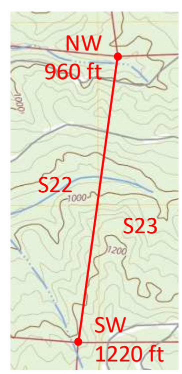
Mentoring MONDAYS

H. Inverse Calculation

NW and SW corners of
S23 T5N R6W Willamette Mer, Oregon

Oregon N SPC coordinates

Compute ground distance and geodetic bearing from SW to NW cor.



	North, ift	East, ift
NW	830,037.35	7,464,463.50
SW	824,978.10	7,463,529.96
Elevations from topoquad		

VI. Ground and Grid

Mentoring MONDAYS

H. Inverse Calculation

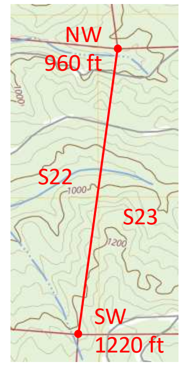
NW and SW corners of
S23 T5N R6W Willamette Mer, Oregon

Oregon N SPC coordinates

Compute ground distance and geodetic bearing from SW to NW cor.

From *NCAT* & *Geoid18*

	Conv, g	Scale, k	N, ft
NW	-02°03'19.5"	0.99997 7693	-21.010
SW	-02°03'27.0"	0.99997 4573	-21.021



	North, ift	East, ift
NW	830,037.35	7,464,463.50
SW	824,978.10	7,463,529.96
Elevations from topoquad		

VI. Ground and Grid

Mentoring MONDAYS

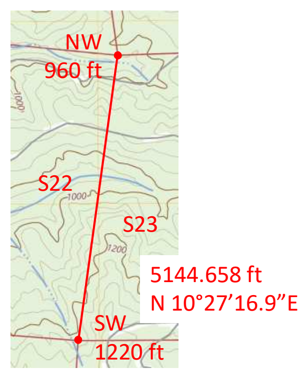
H. Inverse Calculation

Grid comps

$$dN = 830,037.35 - 824,978.10 = 5059.250$$
$$dE = 7,464,463.50 - 7,463,529.96 = 933.540$$

$$\underline{d_{Grid} = \sqrt{5059.25^2 + 933.54^2} = 5144.658\ ift}$$

$$\alpha = \tan^{-1}\left[\frac{933.540}{5059.250}\right] = 10°27'16.9''$$
$$\underline{Brng_{Grid} = N10°27'16.9''E}$$



	North, ift	East, ift
NW	830,037.35	7,464,463.50
SW	824,978.10	7,463,529.96
Elevations from topoquad		

VI. Ground and Grid

Mentoring MONDAYS

H. Inverse Calculation

Distance

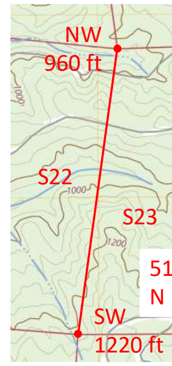
1. Grid to ellipsoid

use average scale factor

$$k = \frac{0.99997\ 7693 + 0.99997\ 4573}{2} = 0.99997\ 6133$$

$$d_G = d_E \times k \Rightarrow d_E = \frac{d_G}{k} = \frac{5144.658}{0.99997\ 6133}$$

$$d_E = 5144.7071$$



	Conv, g	Scale, k	N, ft
NW	-02°03'19.5"	0.99997 7693	-21.010
SW	-02°03'27.0"	0.99997 4573	-21.021

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VI. Ground and Grid

Mentoring MONDAYS

H. Inverse Calculation

Distance

2. Ellipsoid to Ground

use average geoid height.

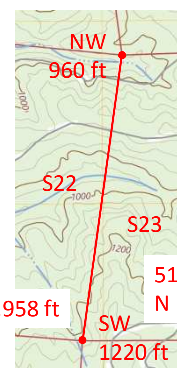
$$N = \frac{-21.010m + (-21.021m)}{2} \times \frac{39.37\ in}{1\ m} \times \frac{1\ ft}{12\ in} = -68.9\ ft$$

$$H = \frac{960\ ft + 1220\ ft}{2} = 1090\ ft$$

$$d_E = d_H \times CF \Rightarrow d_H = \frac{d_E}{CF}$$

$$= 5144.7071 \times \frac{20,902,000 + 1090 - 68.9}{20,902,000}$$

$$= 5144.958\ ft$$



	Conv, g	Scale, k	N, ft
NW	-02°03'19.5"	0.99997 7693	-21.010
SW	-02°03'27.0"	0.99997 4573	-21.021

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VI. Ground and Grid

Mentoring MONDAYS

H. Inverse Calculation

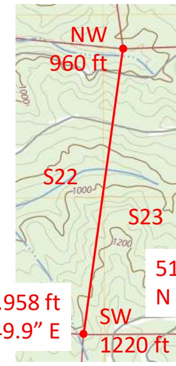
Direction

$$\text{Grid Az} = \text{Geodetic Az} - \gamma$$

$$\Rightarrow \text{Geodetic Az} = \text{Grid Az} - \gamma$$

$$= 10°27'16.9'' - (2°03'27.0'')$$

$$= 8°23'49.9''$$



	Conv, g	Scale, k	N, ft
NW	-02°03'19.5"	0.99997 7693	-21.010
SW	-02°03'27.0"	0.99997 4573	-21.021

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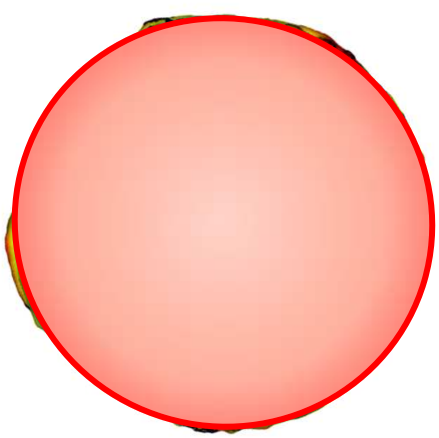


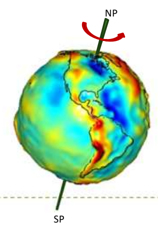
VII. Geodetic and True

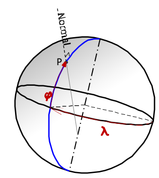
VII. Geodetic and True

A. True Direction

Manual of Surveying Instructions 2009

2-3 The direction of each line of the public land surveys is determined with reference to the true meridian as defined by the axis of the earth's rotation. The true meridian is a line along a meridian of longitude. Historically, determination of the true meridian has been based upon direct astronomic observation at the point of record and, thus, an astronomic meridian. The value of the angular difference between the astronomic and geodetic direction, caused by the deflection of the vertical, relates the astronomic meridian to the geodetic meridian, as properly aligned with the axis of the earth's rotation.





VII. Geodetic and True

B. Deflection of the Vertical

1. Definition

Angle between gravity and ellipsoidal normal

Normal: perpendicular to ellipsoid

Can be divided into N-S and E-W components.

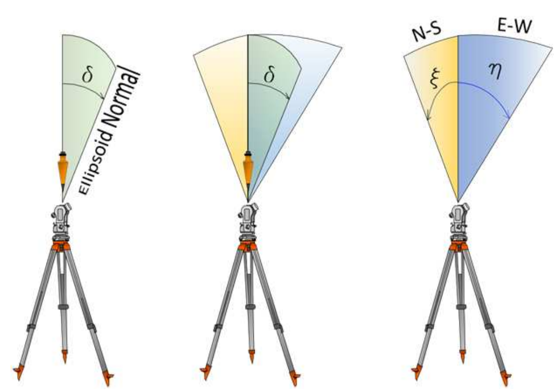
Affect Latitude and Longitude

Astronomic Lat/Long

vs

Geodetic Lat/Long

Relates measurement setup to ellipsoid.



VII. Geodetic and True

Mentoring MONDAYS

B. Deflection of the Vertical

2. LaPlace Correction

Deflection of the vertical defines the Astronomic meridian.

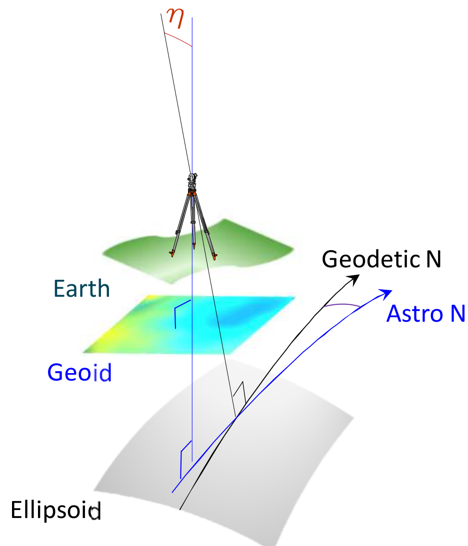
LaPlace correction: angle between Geodetic and Astronomic meridians at a measurement location.

$$Az_G = Az_A + \eta \tan(\phi_G)$$

$$LaPlace\ corr'n:\ \eta \tan(\phi_G)$$

How big is the LaPlace corr'n?

Where do we get it?



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VII. Geodetic and True

Mentoring MONDAYS

B. Deflection of the Vertical

2. LaPlace Correction

NSRS Datasheet

```
DESIGNATION -  JERRY
PID         -  NH0936
___________________________________________________________________________
* NAD 83(2011) POSITION- 42 54 24.02215(N) 089 43 53.76413(W)   ADJUSTED
* NAD 83(2011) ELLIP HT-   324.836 (meters)        (06/27/12)   ADJUSTED
* NAD 83(2011) EPOCH   -  2010.00
* NAVD 88 ORTHO HEIGHT -   358.6   (meters)     1177.    (feet) VERTCON
___________________________________________________________________________
 GEOID HEIGHT    -         -33.902 (meters)                    GEOID18
 NAD 83(2011) X  -      21,919.631 (meters)                    COMP
 NAD 83(2011) Y  -  -4,679,204.603 (meters)                    COMP
 NAD 83(2011) Z  -   4,320,134.562 (meters)                    COMP
 LAPLACE CORR    -           -0.36  (seconds)                  DEFLEC18
```

Not very much, huh?

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VII. Geodetic and True

Mentoring MONDAYS

B. Deflection of the Vertical

2. LaPlace Correction

NSRS Datasheet

Located in SW Utah

```
FBN          -  This is a Federal Base Network Control Station.
DESIGNATION -  MONROE
PID          -  AA3697
 ______________________________________________________________________
* NAD 83(2011) POSITION- 38 37 44.99765(N) 112 07 45.20549(W)   ADJUSTED
* NAD 83(2011) ELLIP HT-  1618.966 (meters)         (06/27/12)   ADJUSTED
* NAD 83(2011) EPOCH    -  2010.00
* NAVD 88 ORTHO HEIGHT -  1637.9   (meters)      5374.     (feet) GPS OBS
______________________________________________________________________
 NAVD 88 orthometric height was determined with geoid model     GEOID09
 GEOID HEIGHT    -         -18.898  (meters)                     GEOID09
 GEOID HEIGHT    -         -18.881  (meters)                     GEOID18
 NAD 83(2011) X  - -1,879,866.007  (meters)                      COMP
 NAD 83(2011) Y  - -4,622,786.178  (meters)                      COMP
 NAD 83(2011) Z  -  3,961,251.322  (meters)                      COMP
 LAPLACE CORR    -           8.73  (seconds)                     DEFLEC18
```

How about now?

VII. Geodetic and True

Mentoring MONDAYS

A. Determining True Direction

2. LaPlace Correction

NGS *DEFLEC18* online program.

Computation of DEFLEC18 deflection of the vertical

A DEFLEC18 deflection of the vertical can be computed for a specific geographic location or for a **file of input points**. Position coordinates should be in the appropriate North American Datum of 1983 (NAD 83) reference frame.

DEFLEC18 will compute deflections for the following geographic areas:

Area	Ellipsoid Reference Frame	Vertical Datum	Latitude		Longitude	
			Min	Max	Min	Max
Conterminous United States	NAD83 (2011)	NAVD88	24N	58N	60W	130W
Puerto Rico/U.S. Virgin Islands	NAD83 (2011)	PRVD02 and VIVD09	15N	21N	64W	69W

Compute a DEFLEC18 deflection of the vertical for a single location:

The formats below may be used for entering latitude and longitude. Degrees, minutes, and seconds must be separated by spaces. (Note that commas are not valid for DEFLEC18 computations.)

Degrees, minutes, and decimal seconds Latitude Example: 35 55 19.0221 Longitude Example: 97 55 40.2351	Degrees, minutes, and integer seconds Latitude Example: 35 55 19 Longitude Example: 97 55 40
Degrees and decimal minutes Latitude Example: 35 55.3453	Degrees and integer minutes Latitude Example: 35 55
Decimal degrees. Latitude Example: 35.9320	Integer degrees. Latitude Example: 35

Enter Latitude:

Enter Longitude: West East

Perform DEFLEC18 Computation for a single location | Clear Input

VII. Geodetic and True

Mentoring MONDAYS

A. Determining True Direction

2. LaPlace Correction

NGS *DEFLEC18* online program.

Computation of DEFLEC18 deflection of the vertical

A DEFLEC18 deflection of the vertical can be computed for a specific geographic location or for a **file of input points**. Position coordinates should be in the appropriate North American Datum of 1983 (NAD 83) reference frame.

DEFLEC18 will compute deflections for the following geographic areas:

Area	Ellipsoid Reference Frame	Vertical Datum	Latitude Min	Latitude Max	Longitude Min	Longitude Max

Output from DEFLEC18

```
Station Name          latitude          longitude          Xi       Eta      Hor_Lap
                      dd mm ss.sssss ddd mm ss.sssss  arc-sec  arc-sec  arc-sec
USER LOCATION         45 55 10.00000 103 05 30.00000     0.64     6.31    -6.51
```

conds

Degrees, minutes, and decimal seconds
Latitude Example: 35 55 19.0221
Longitude Example: 97 55 40.2351

Degrees, minutes, and integer seconds
Latitude Example: 35 55 19
Longitude Example: 97 55 40

Degrees and integer minutes
Latitude Example: 35 55

Integer degrees.
Latitude Example: 35

Enter Longitude: West East

Perform DEFLEC18 Computation for a single location | Clear Input

Remember:
PLSS proportioning based on true meridian.
Surveyor:
May need to apply LaPlace corr'n.

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10 March 2025

I. Earth Models
II. Spatial Systems
III. Distortions
IV. Creating a Grid
V. State and Regional Coordinate Systems
VI. Ground and Grid
VII. Geodetic and True

Grid⬌Ground - Simple, Right?