Introduction to GPS

GPS WORKSHOP
February 10, 2011 OSU

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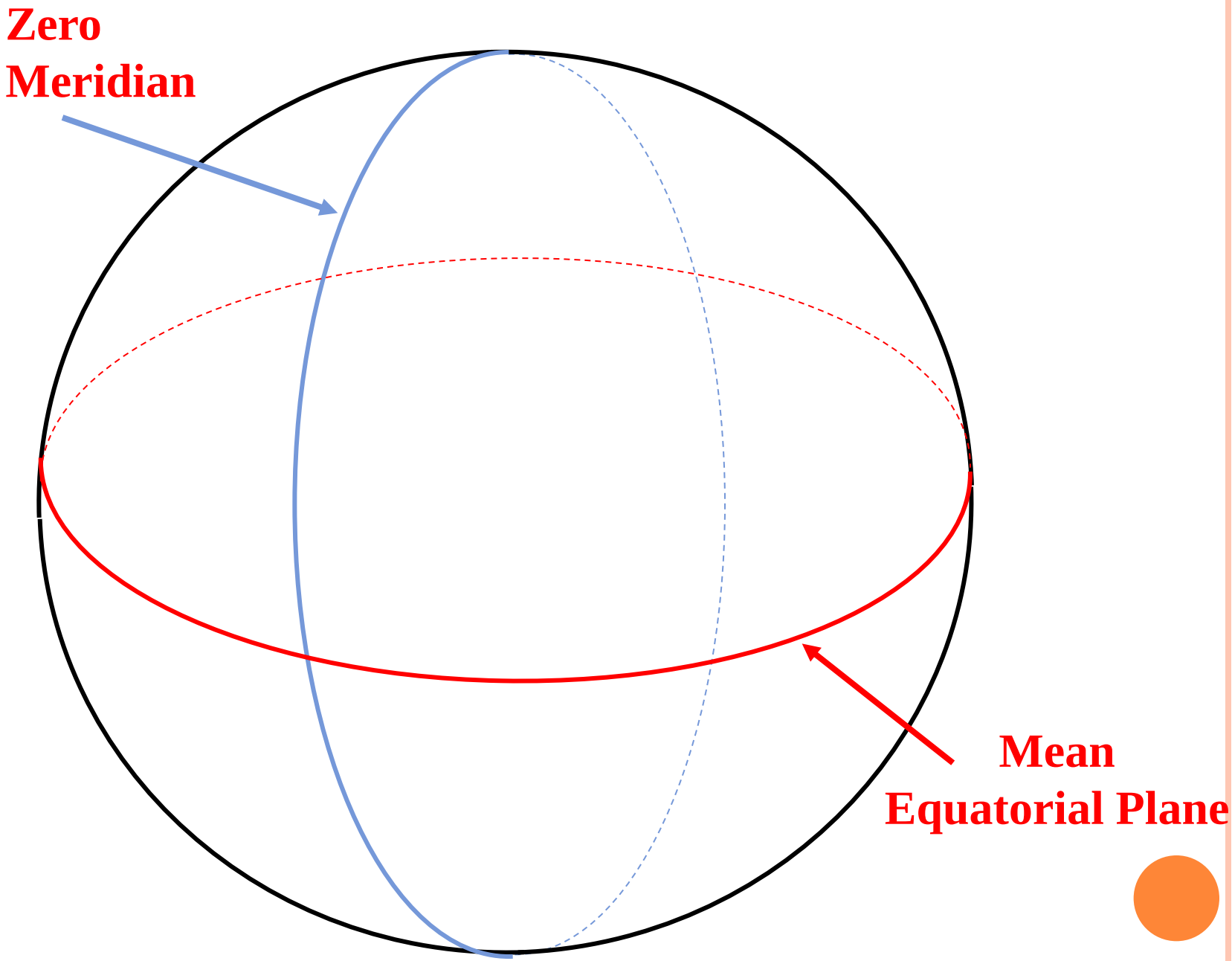
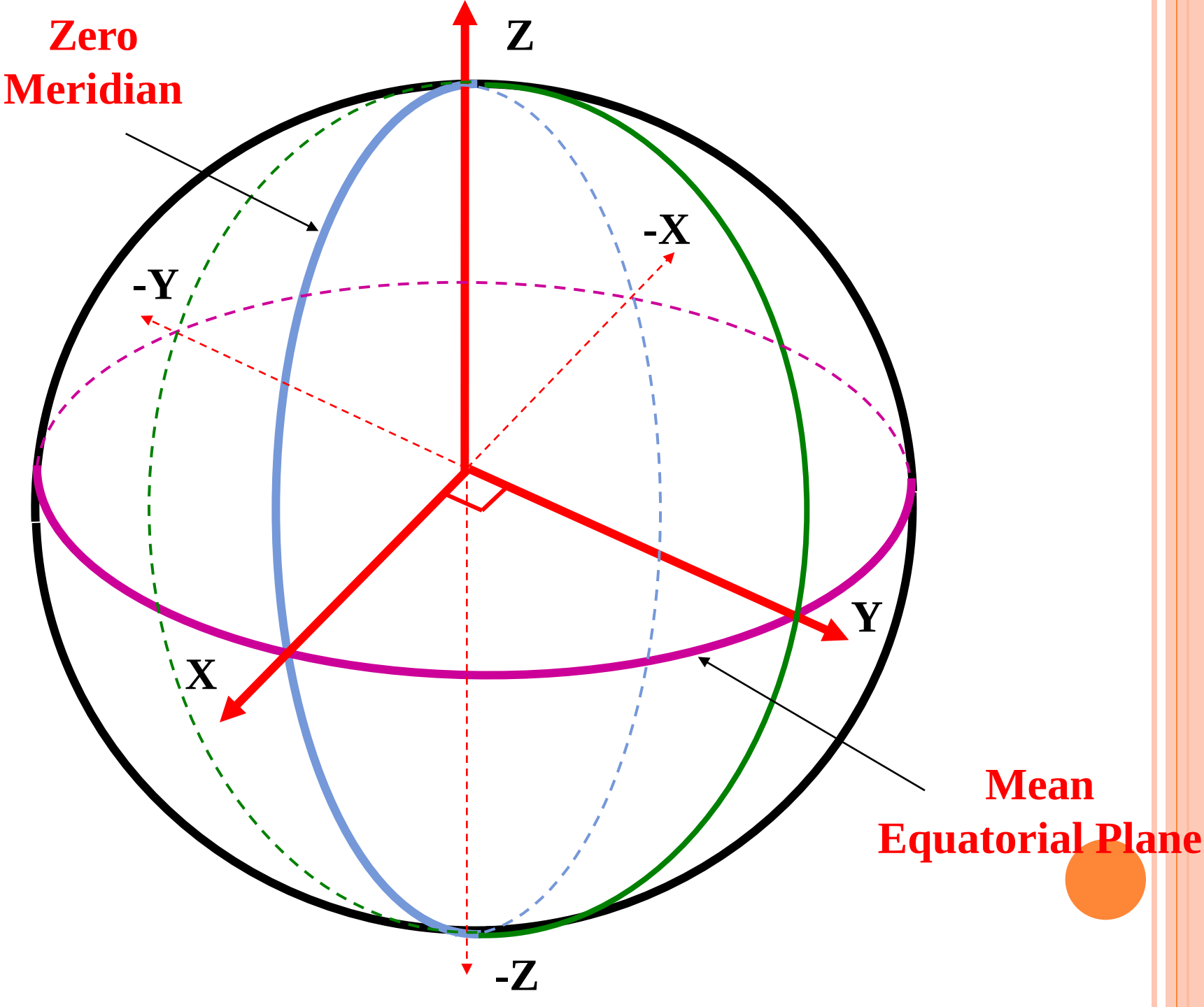
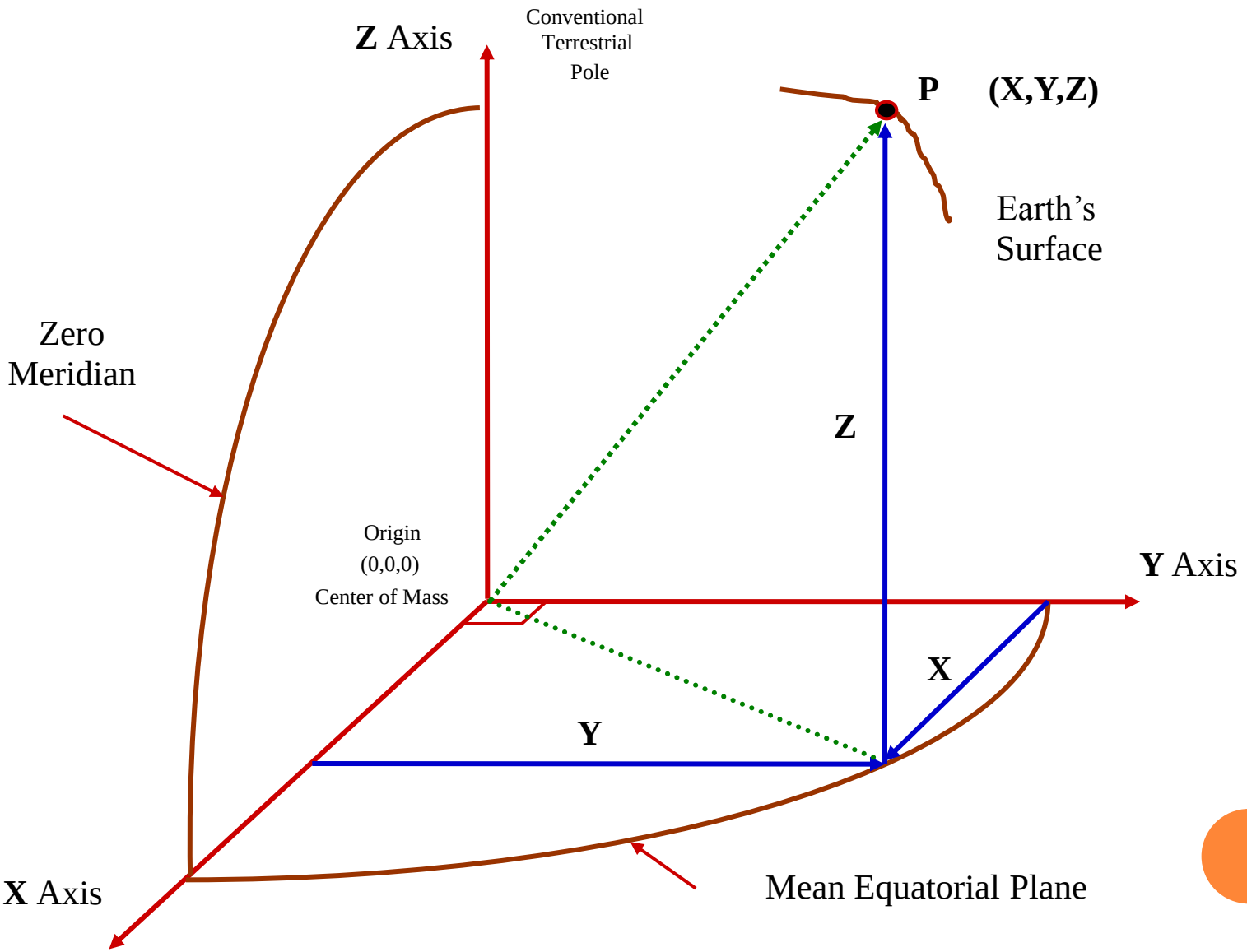
Basic Geodesy

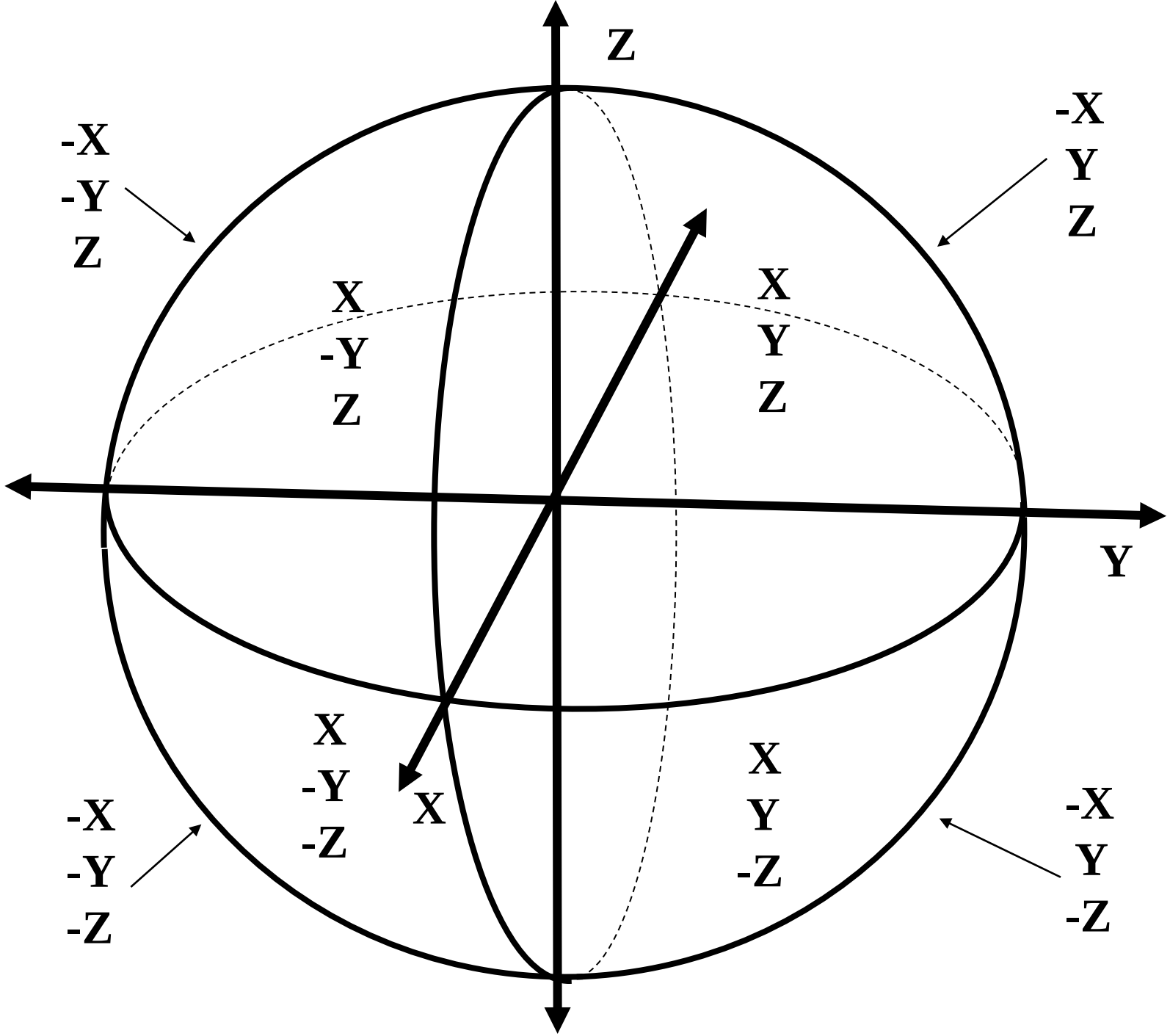
- Irregular, Spherical Shaped Earth
- Geodetic Coordinate Systems
  - Rectangular X, Y, and Z Coordinates
  - Curvilinear Latitude, Longitude, and Ellipsoid Height
- Height Relationships
- Horizontal Datums
  - International Terrestrial Reference Frame (ITRF)
  - North American Datum of 1983 (NAD83)


Zero
Meridian
Mean
Equatorial Plane


Zero
Meridian
Z
-X
-Y
Y
X
-Z
Mean
Equatorial Plane

Earth-Centered-Earth-Fixed (ECEF) Coordinates Rectangular System




Z
-X
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-X
-Y
-Z
-X
Y
-Z

X, Y, and Z Coordinates

- Pros
  - True 3-dimensional coordinates
  - “Universal” format for exchanging spatial information
  - GPS base system
  - Already using (background in software)
  - Available on NGS Data Sheets
- Cons
  - Large unwieldy numbers
  - Negative numbers (quadrants)
  - No visual association
  - Z is not height value

First station : 4S9 B (AA7997)

X = -2424190.8349 m
Y = -3791941.3772 m
Z = 4504340.1907 m

Second station : 4S9 D (AA7999)

X = -2423846.1436 m
Y = -3791974.1790 m
Z = 4504497.0132 m

$$\begin{aligned} & 4504340.1907\ \text{m} \\ -\ & 4504497.0132\ \text{m} \\ \hline \Delta Z = & -156.8225\ \text{m} \end{aligned}$$

```
First station : 4S9 B (AA7997)
  X =   -2424190.8349    LAT =  45 12 58.08108
North
  Y =   -3791941.3772    LON = 122 35 26.91721
West
  Z =    4504340.1907    EHT =    55.3900

Second station : 4S9 D (AA7999)
  X =   -2423846.1436    LAT =  45 13  5.29248
North
  Y =   -3791974.1790    LON = 122 35 12.79711
West
  Z =    4504497.0132    EHT =    55.3900

  Delta height =       .0000
  Ellipsoidal distance  =       380.1037
  Mark to mark distance =       380.1070
  Forward azimuth from north =  54  8 48.0080
  Back azimuth from north    = 234  8 58.0302
  DX =        344.6913     DN =       222.6334
  DY =        -32.8017     DE =       308.0840
  DZ =        156.8226     DU =         -.0113
```

First station : 4S9 B (AA7997)

X = -2424190.8349 m

Y = -3791941.3772 m

Z = 4504340.1907 m

Second station : LUCAS (AA5138)

X = -2635459.0293 m

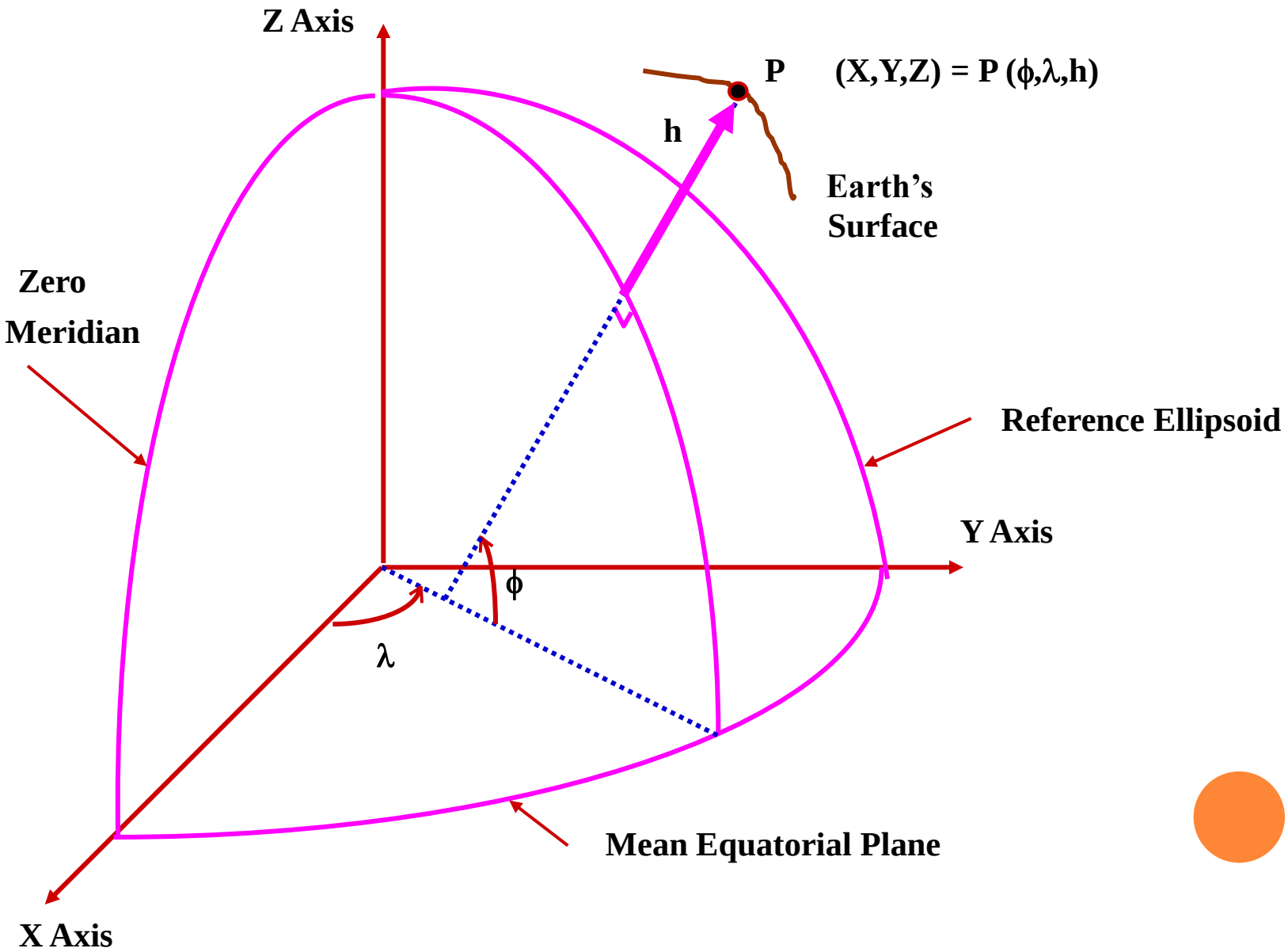
Y = -3898579.2630 m

Z = 4291000.1711 m

$$\begin{aligned} & 4504340.1907 \text{ m} \\ - & \underline{4291000.1711 \text{ m}} \\ \Delta Z = & \quad 213{,}340.0196 \text{ m} \end{aligned}$$

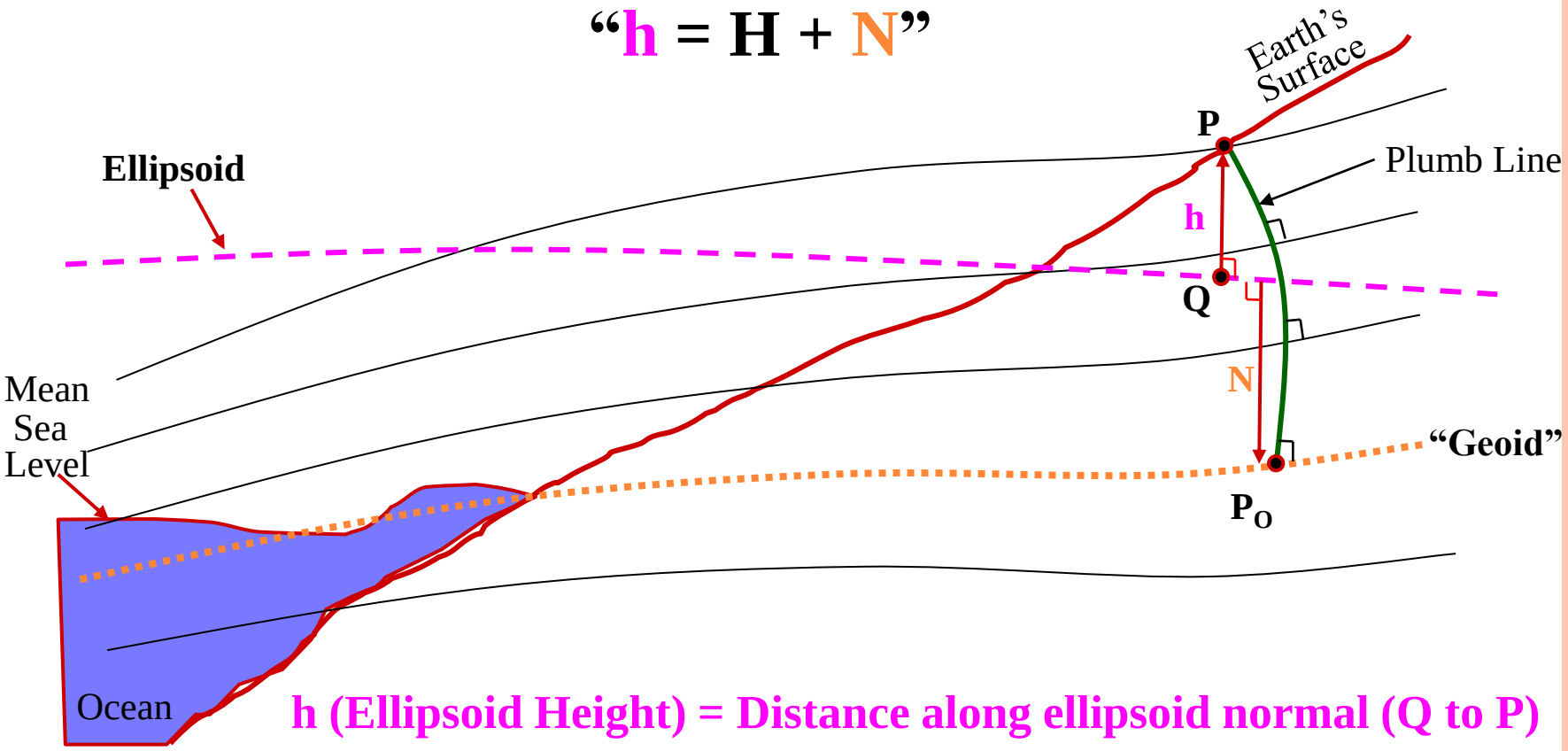
```
First station : 4S9 B (AA7997)
  X =   -2424190.8349     LAT =  45 12 58.08108
North
  Y =   -3791941.3772     LON = 122 35 26.91721
West
  Z =    4504340.1907     EHT =     55.3900

Second station : LUCAS (AA5138)
  X =   -2635459.0293     LAT =  42 33  6.80355
North
  Y =   -3898579.2630     LON = 124  3 32.00235
West
  Z =    4291000.1711     EHT =     55.3900

  Delta height =       .0000
  Ellipsoidal distance  =   318652.2632
  Mark to mark distance =   318621.8019
  Forward azimuth from north = 202 14 28.2192
  Back azimuth from north    =  21 13 23.4971
  DX =   -211268.1945     DN =   -294823.6561
  DY =   -106637.8858     DE =   -120562.6833
  DZ =   -213340.0196     DU =     -7968.9306
```

GPS - Derived Ellipsoid Heights
Curvilinear System



Ellipsoid, Geoid, and Orthometric Heights

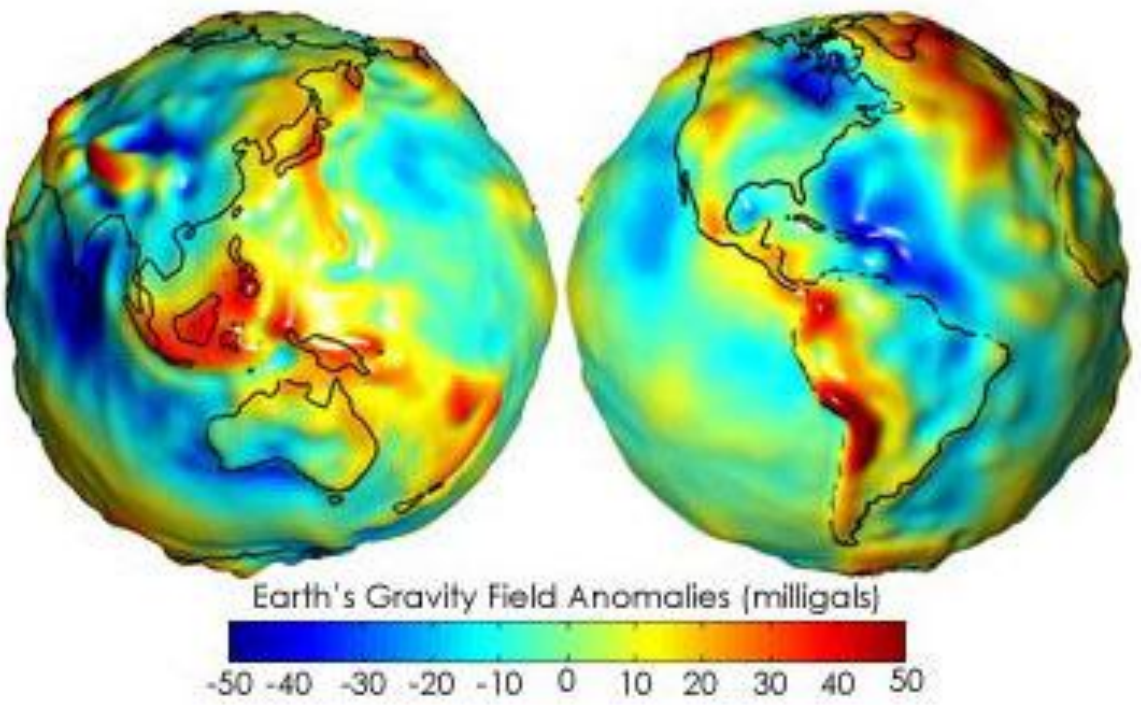
"h = H + N"



h (Ellipsoid Height) = Distance along ellipsoid normal (Q to P)

N (Geoid Height) = Distance along ellipsoid normal (Q to P_O)

H (Orthometric Height) = Distance along plumb line (P_O to P)



Source: Wikipedia

High Resolution Geoid Models

- G96SSS
  - 1.8 million gravity measurements (marine, land, altimetry)
  - 30 second DTED updated with Canadian Rockies data
  - Earth Gravity Model of 1996 (EGM96)
  - 2 min x 2 min spacing
  - International Terrestrial Reference Frame ITRF94 (1996.0)

High Resolution Geoid Models

- GEOID96
  - Begin with G96SSS model
  - 2951 GPS/Level Bench Marks (NAD83/NAVD88)
  - Converts NAD83 (86) into NAVD 88
  - Relative to non-geocentric GRS-80 ellipsoid

High Resolution Geoid Models

G99SSS (Scientific Model)

- 2.6 million terrestrial, ship, and altimetric gravity measurements
- 30 arc second Digital Elevation Data
- 3 arc second DEM for the Northwest USA
  - Decimated from 1 arc second NGSDEM99
- Earth Gravity Model of 1996 (EGM96)
- Computed on 1 x 1 arc minute grid spacing
- GRS-80 ellipsoid centered at ITRF97 origin

High Resolution Geoid Models

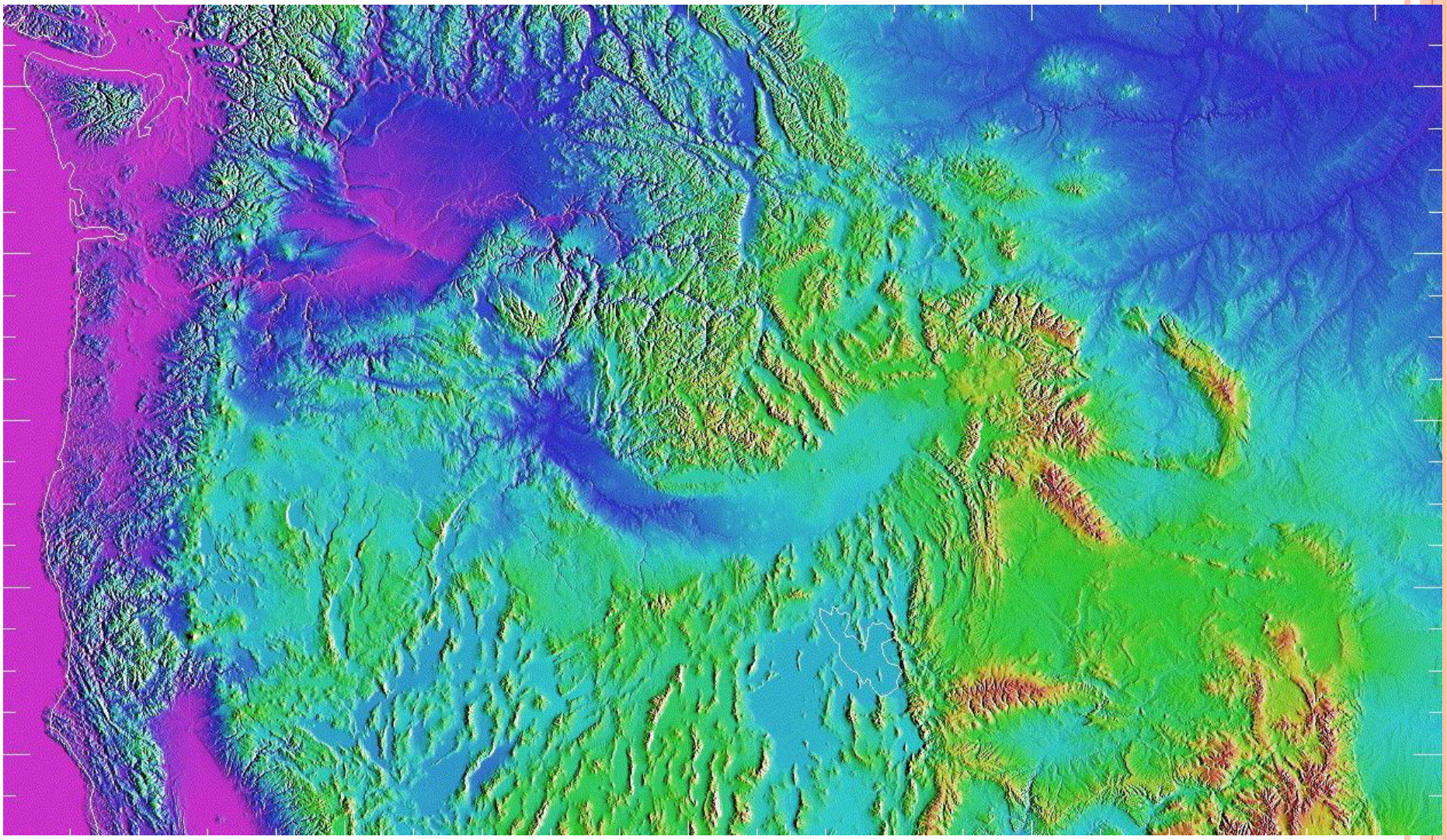
GEOID99

- Begin with G99SSS model
  - 6169 NAD83 GPS heights on NAVD88 leveled benchmarks
  - Determine national bias and trend relative to GPS/benchmarks
  - Create grid to model local (state-wide) remaining differences
  - ITRF97/NAD83 transformation
  - Compute and remove conversion surface from G99SSS

High Resolution Geoid Models

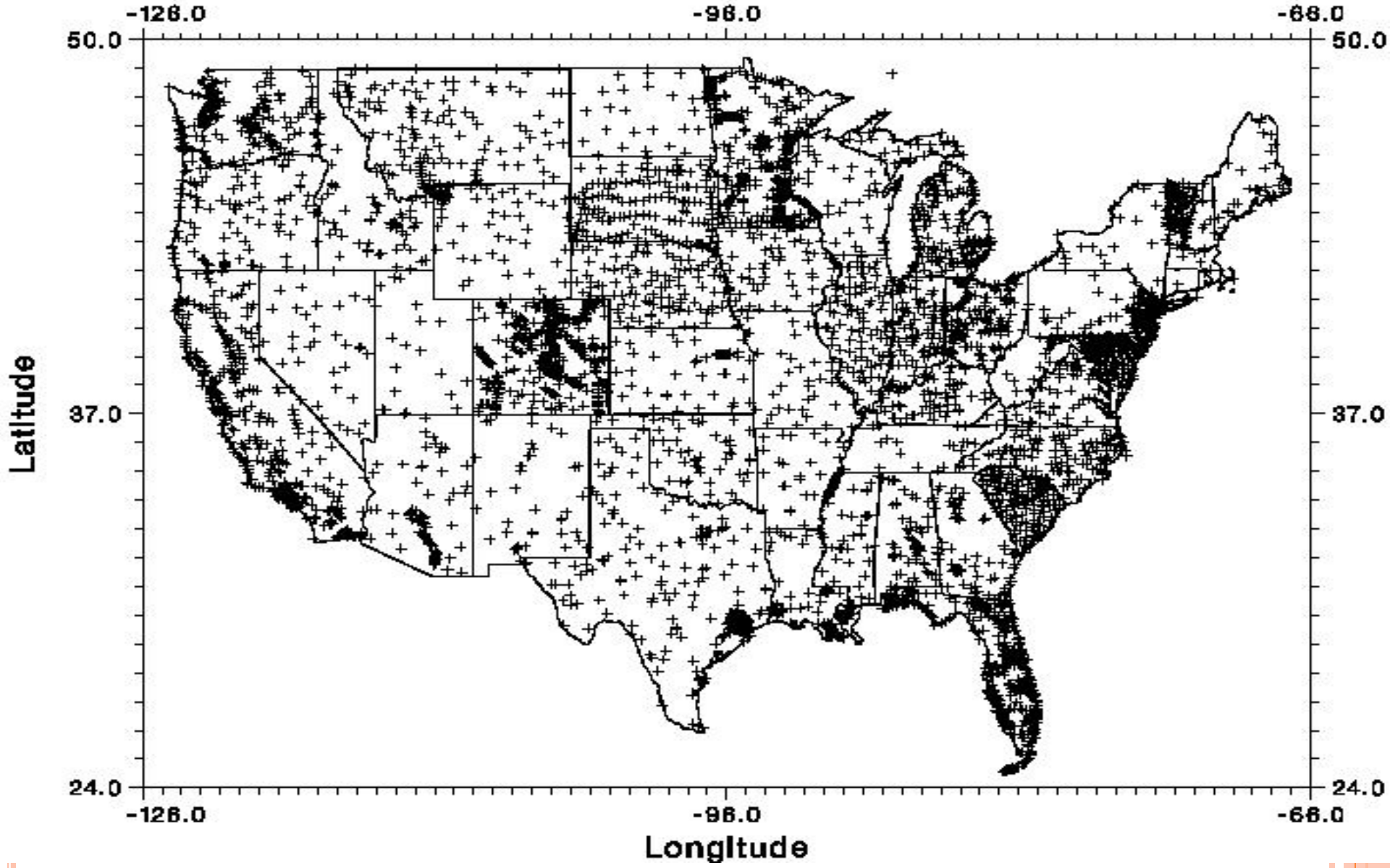
GEOID99

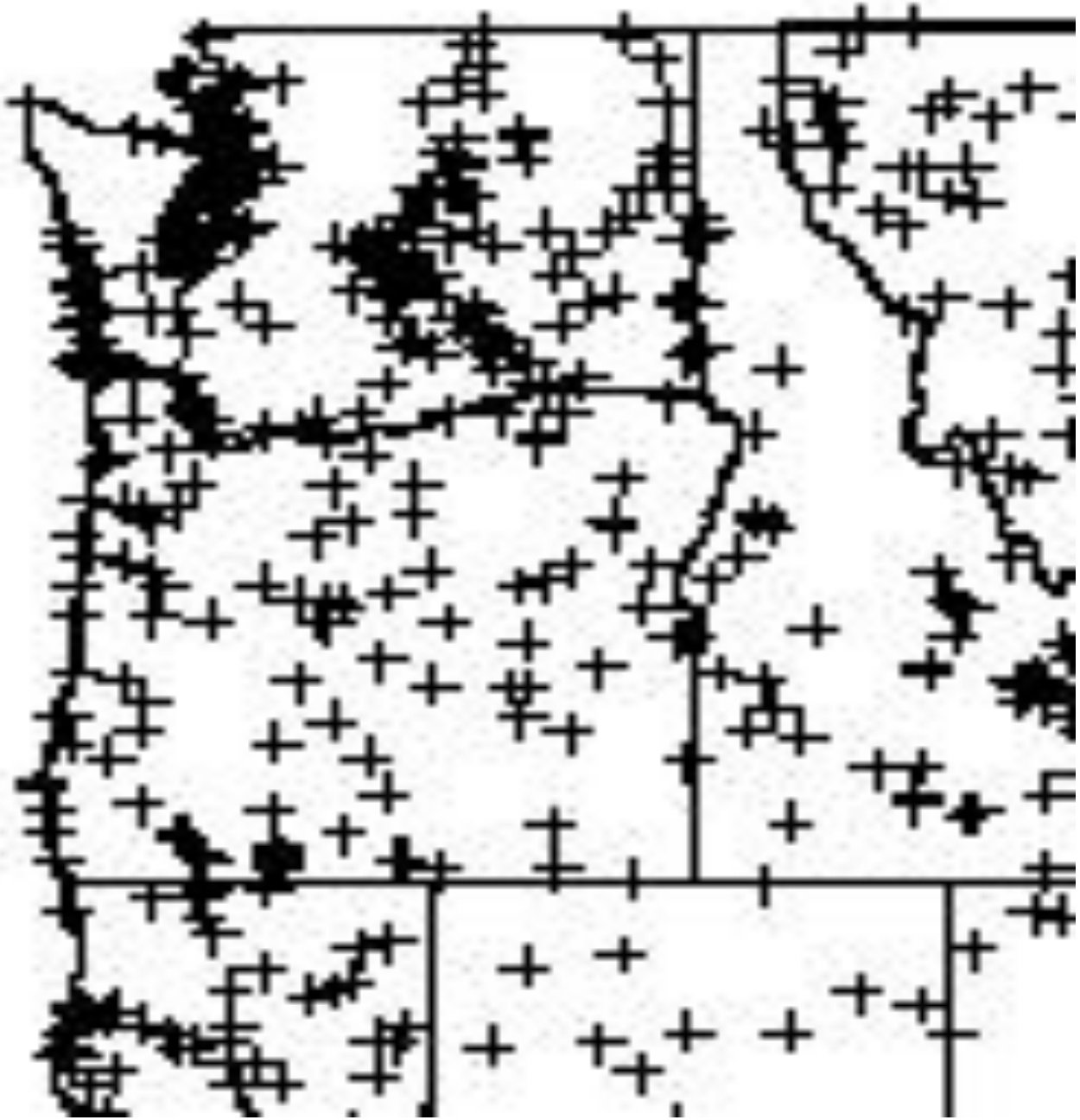
- Relative to non-geocentric GRS-80 ellipsoid
- 4.6 cm RMS nationally when compared to BM data
- RMS ≈16% improvement over GEOID96



NGSDEM99 is a 1 x 1 arc-second Digital Elevation Model (DEM) of the Northwest United States, covering the region 39 - 49N latitude, and 234 - 265E longitude.

GPS/BMs for GEOID99 (6169 points)

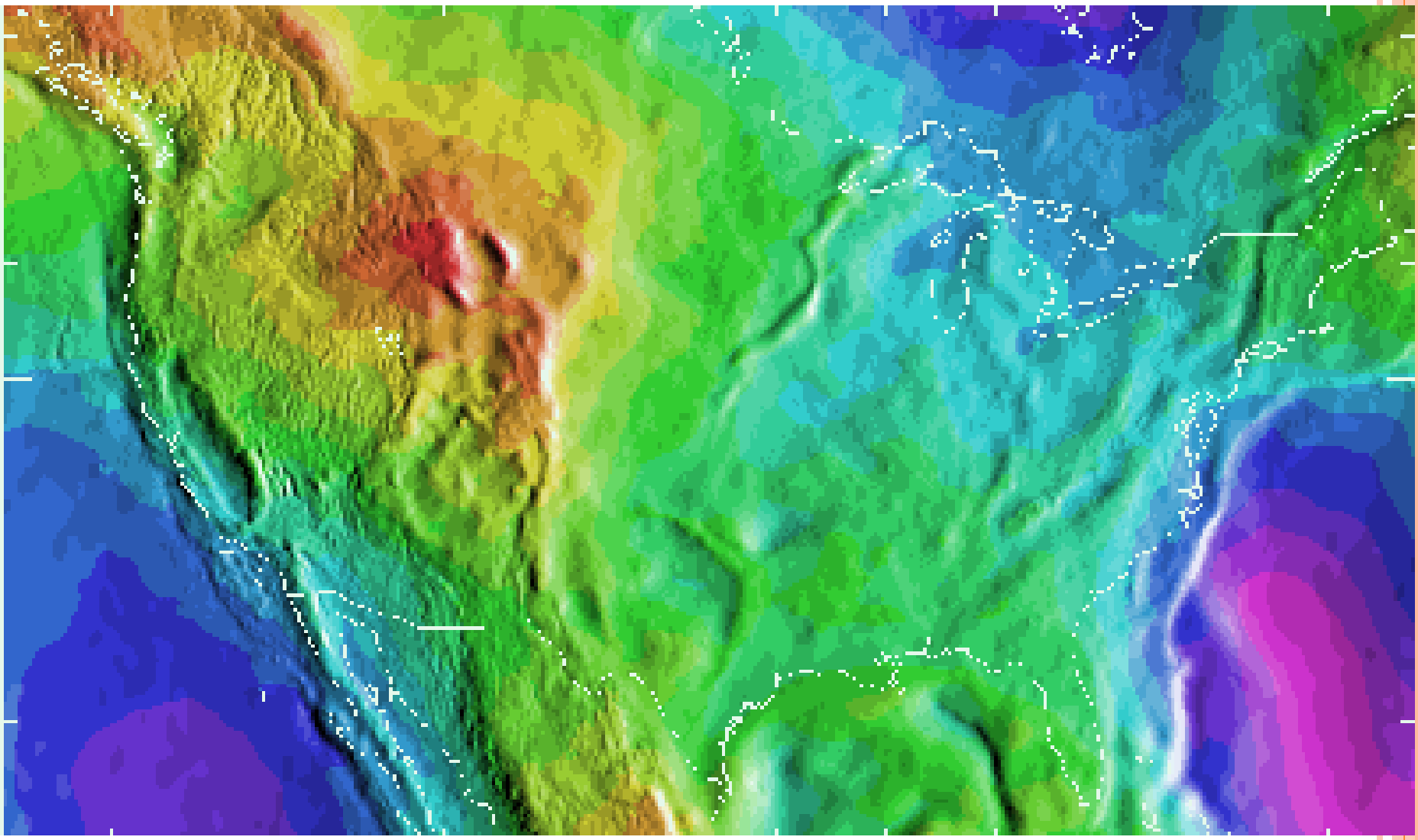




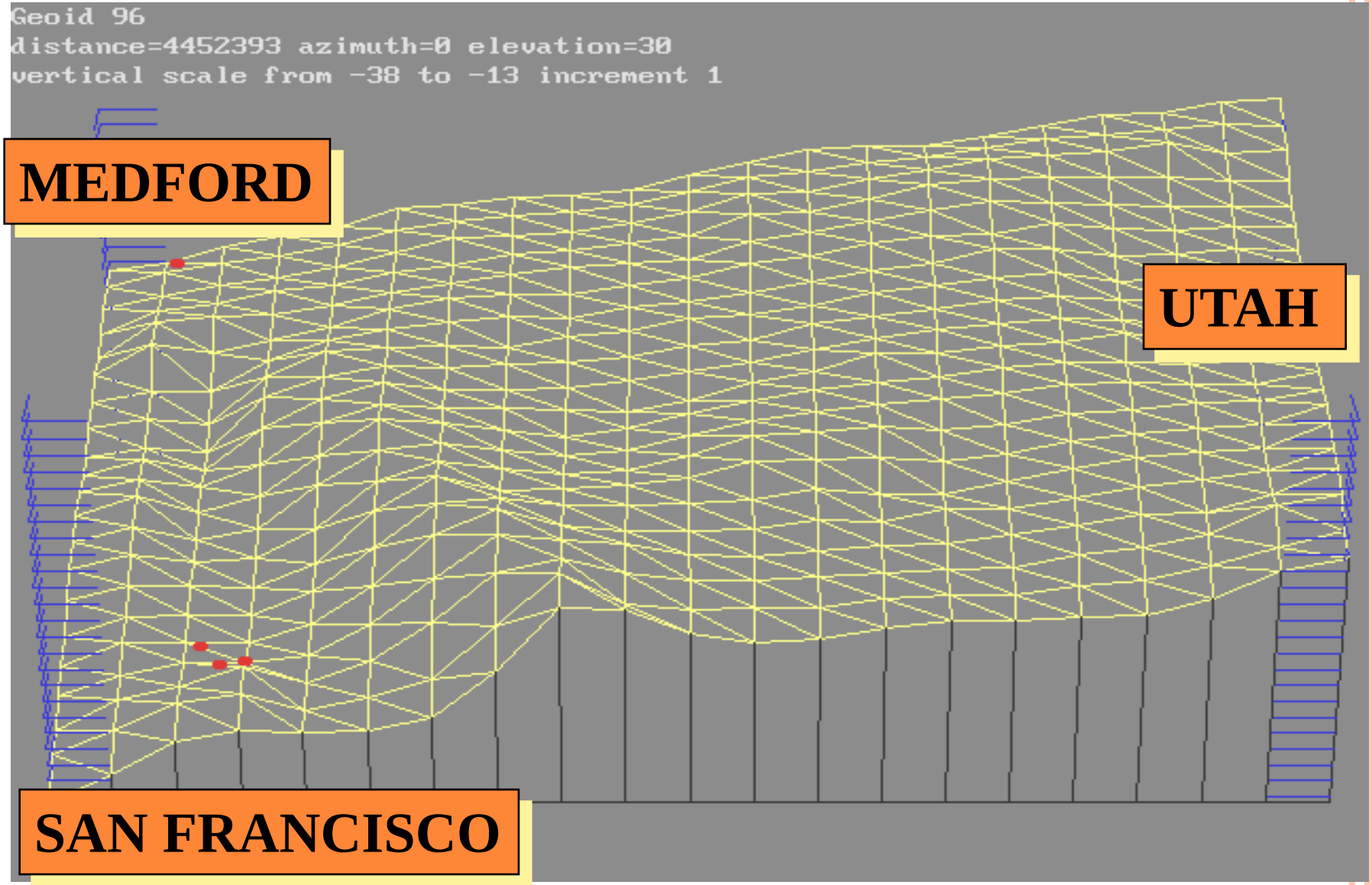
GPS / NAVD88
Bench Marks
for GEOID99

94 for Oregon

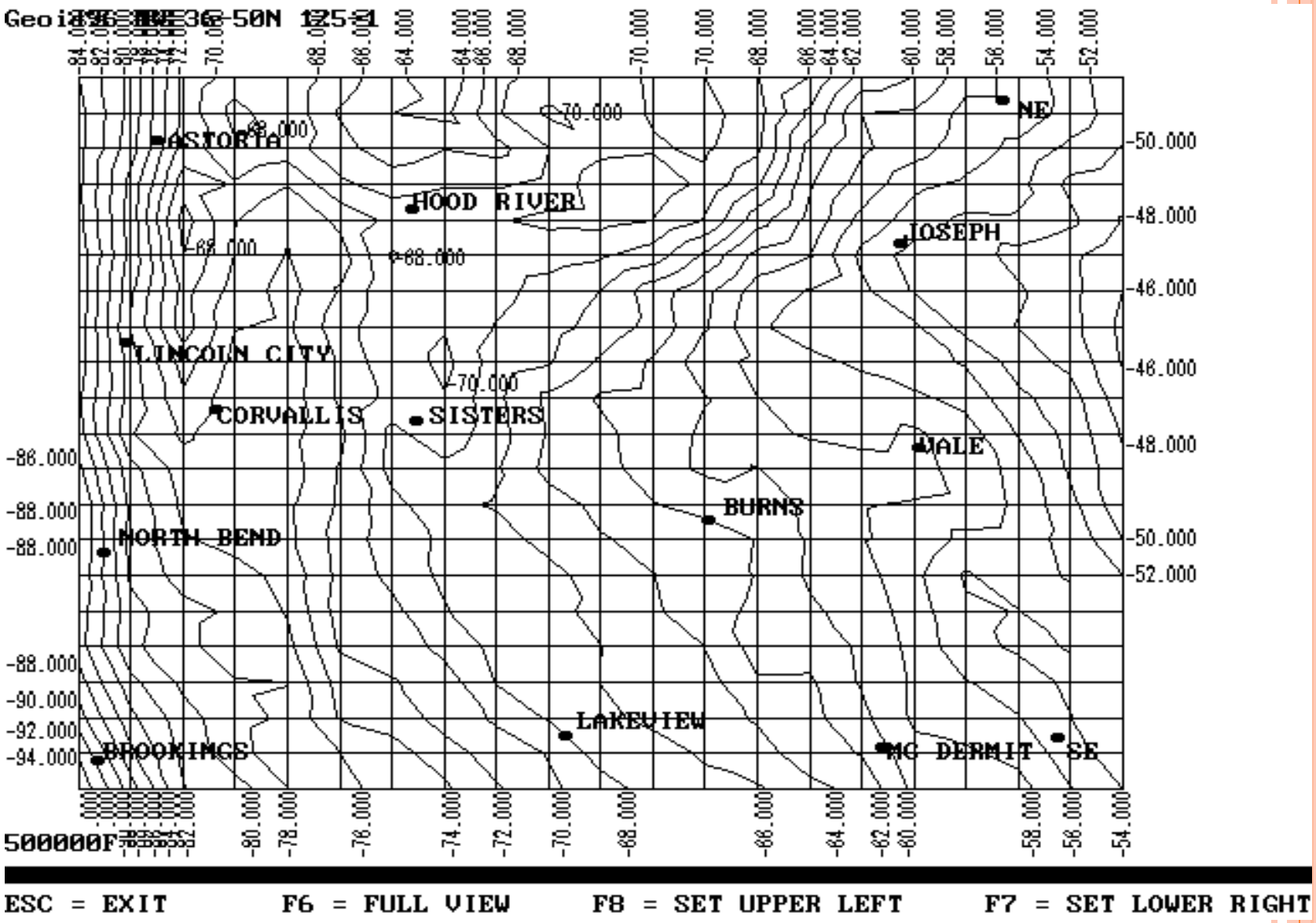
GEOID99



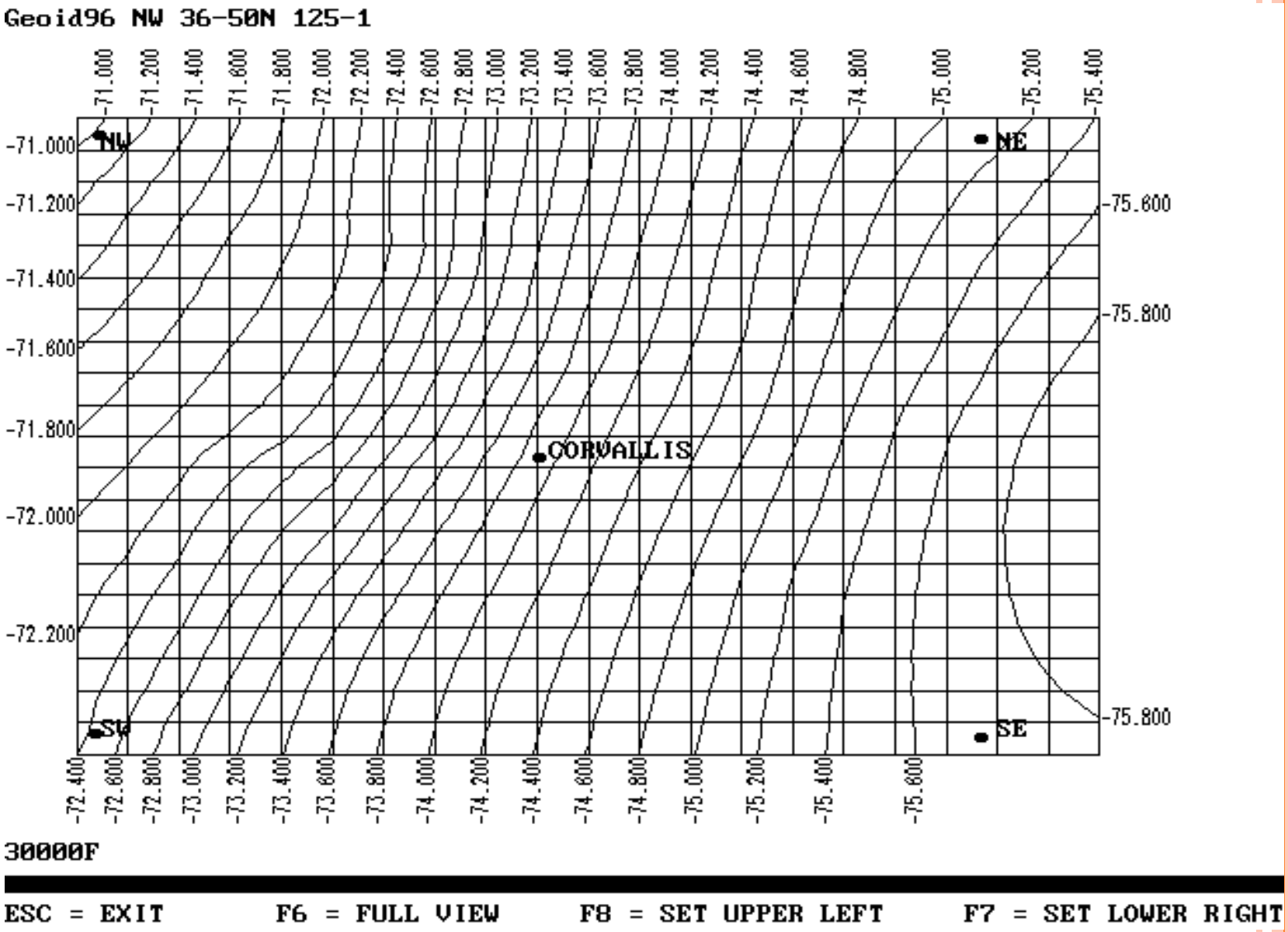
For the conterminous United States (CONUS), GEOID99 heights range from a low of -50.97 meters (magenta) in the Atlantic Ocean to a high of 3.23 meters (red) in the Labrador Strait.

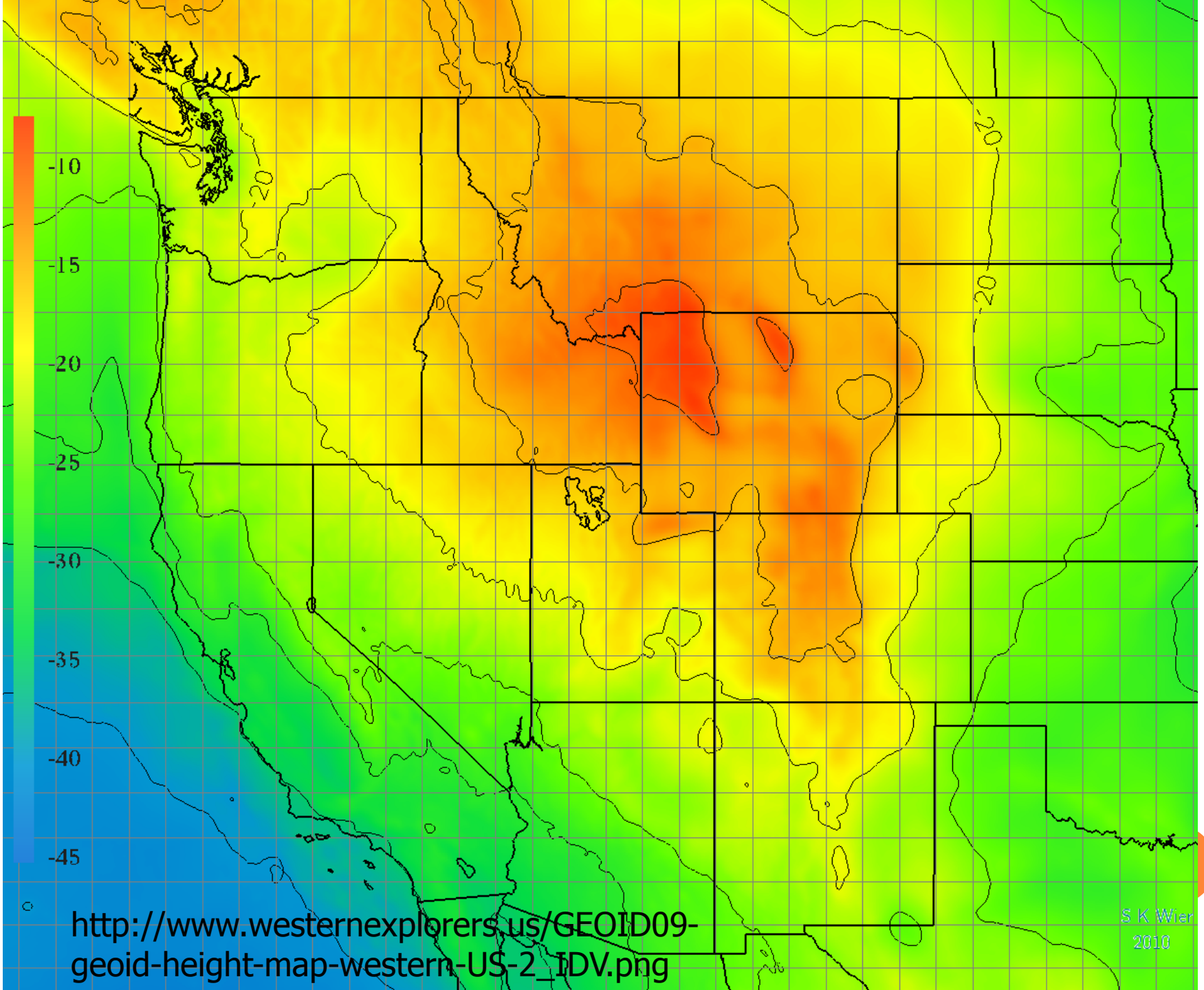

Geoid 96
distance=4452393 azimuth=0 elevation=30
vertical scale from -38 to -13 increment 1
MEDFORD
UTAH
SAN FRANCISCO

GEOID UNDERLYING OREGON



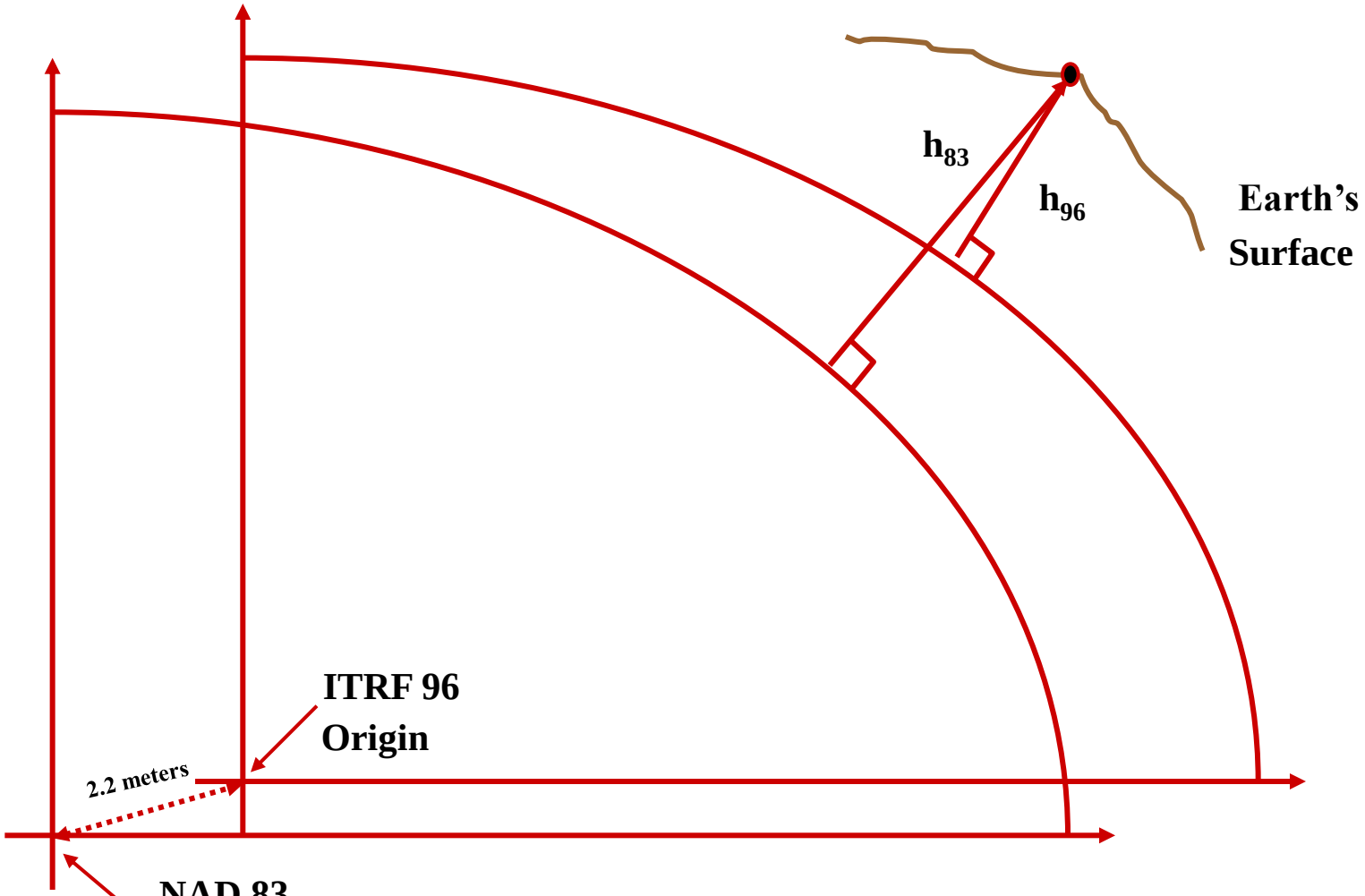
GEOID UNDERLYING CORVALLIS





http://www.westernexplorers.us/GEOID09-geoid-height-map-western-US-2_IDV.png

Simplified Concept of ITRF 96 vs. NAD 83



Identically shaped ellipsoids WGS-80
a = 6,378,137.000 meters (semi-major axis)
1/f = 298.25722210088 (flattening)

Common ellipsoids in surveying

- WGS-84 (Datum = WGS-84)
  - a = 6378137.000 b = 6356752.3142
    1/f = 298.2572235630
- GRS-80 (Datum = NAD83)
  - a = 6378137.000 b = 6356752.3141
  - 1/f = 298.2572221010
- Clarke 1866 (Datum = NAD27)
  - a = 6378206.400 b = 6356583.800
  - 1/f = 294.9786982000
- NOTE SIMILARITY BETWEEN WGS-84 AND GRS-80

Questions ?