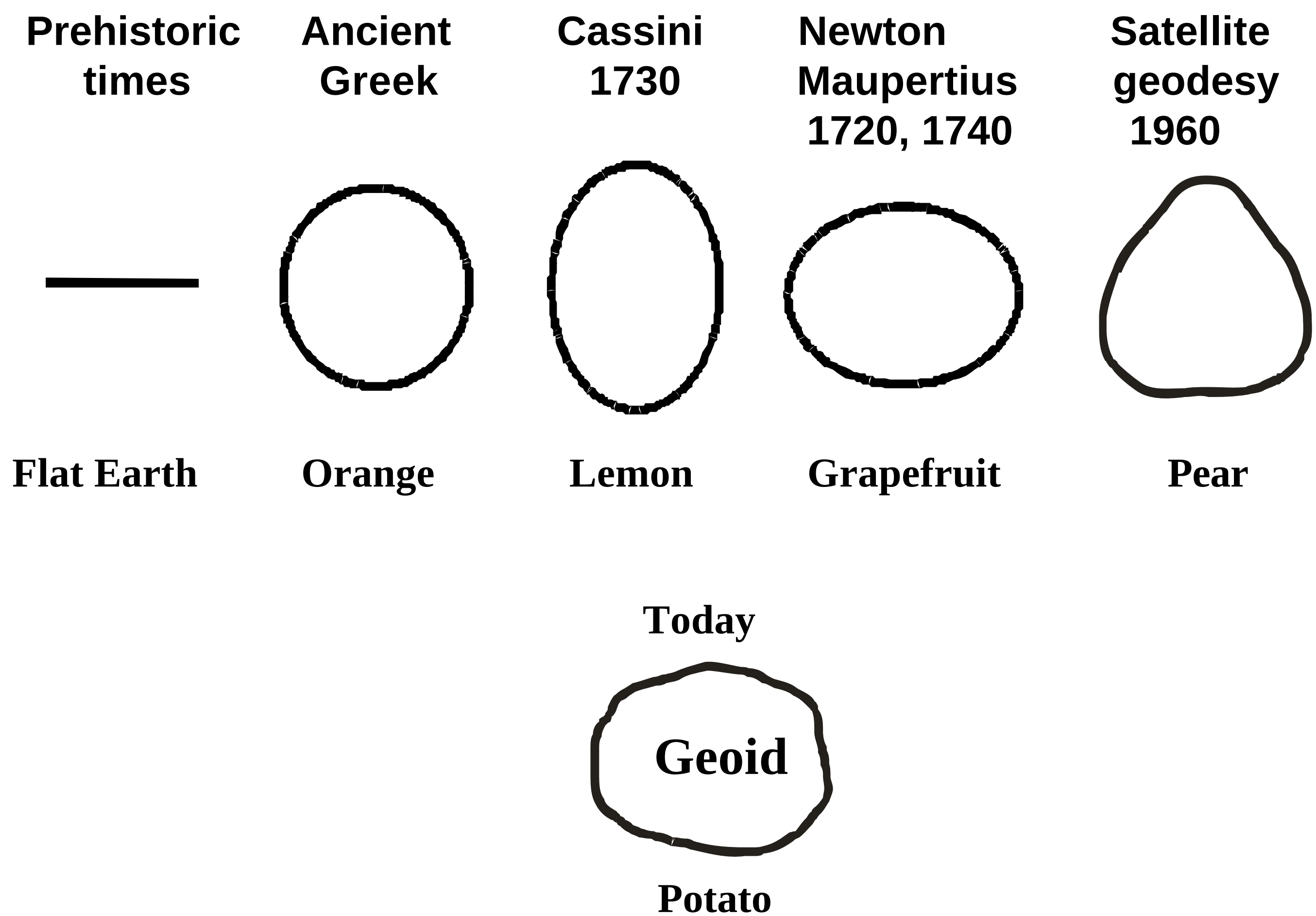
Introducción a Geodesia, Proyecciones, GPS y GIS

Profesor: Gabriel Vargas; Curso: Campo I

Geodesy

The history of the shape of the Earth



The "proof" of the spherical Earth

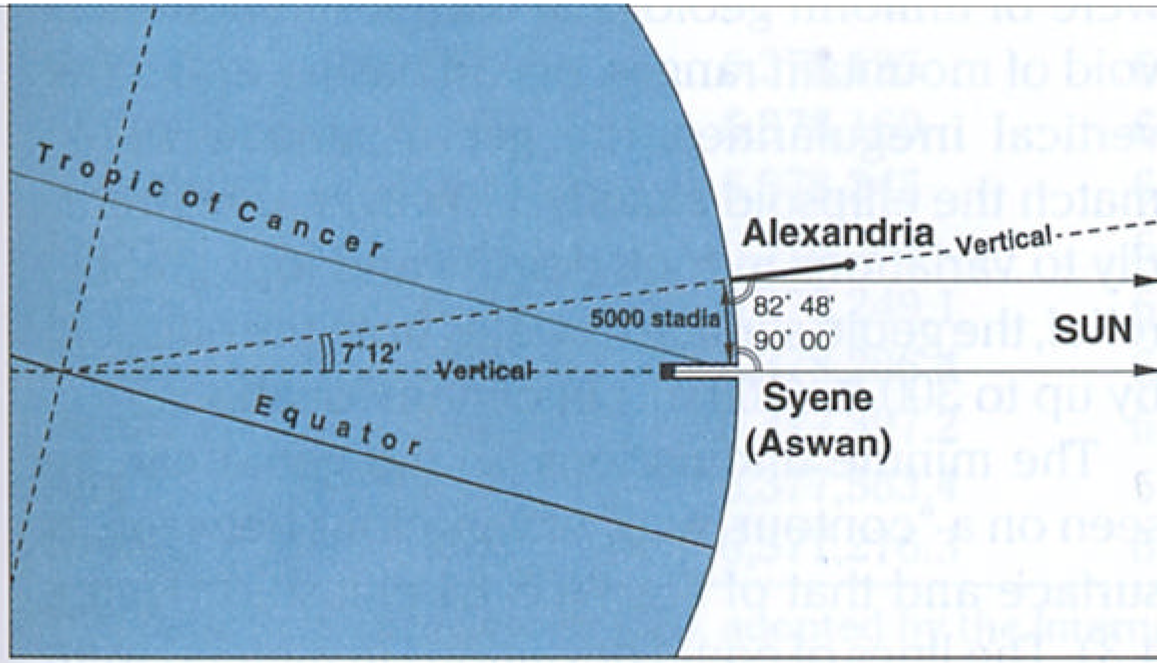
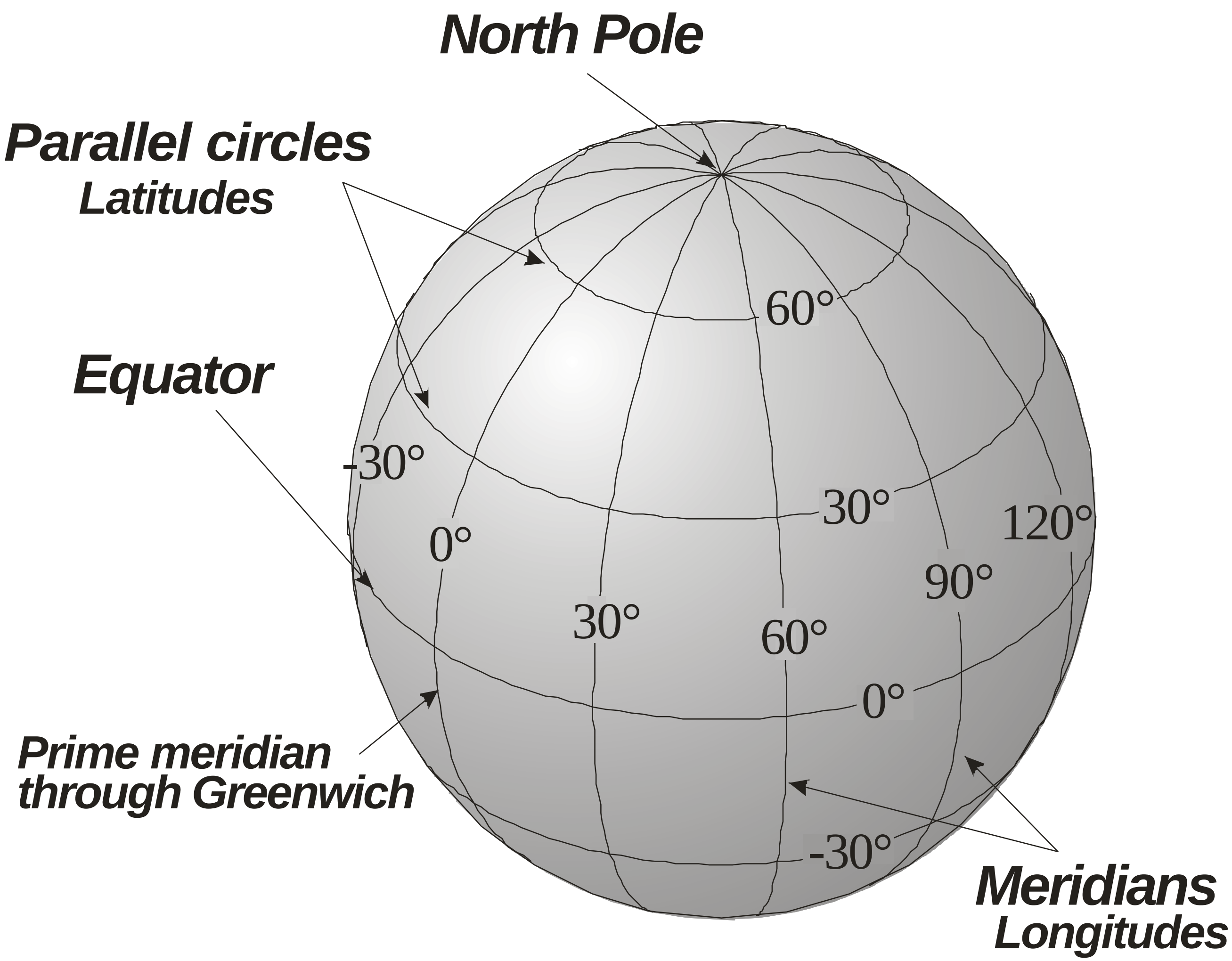


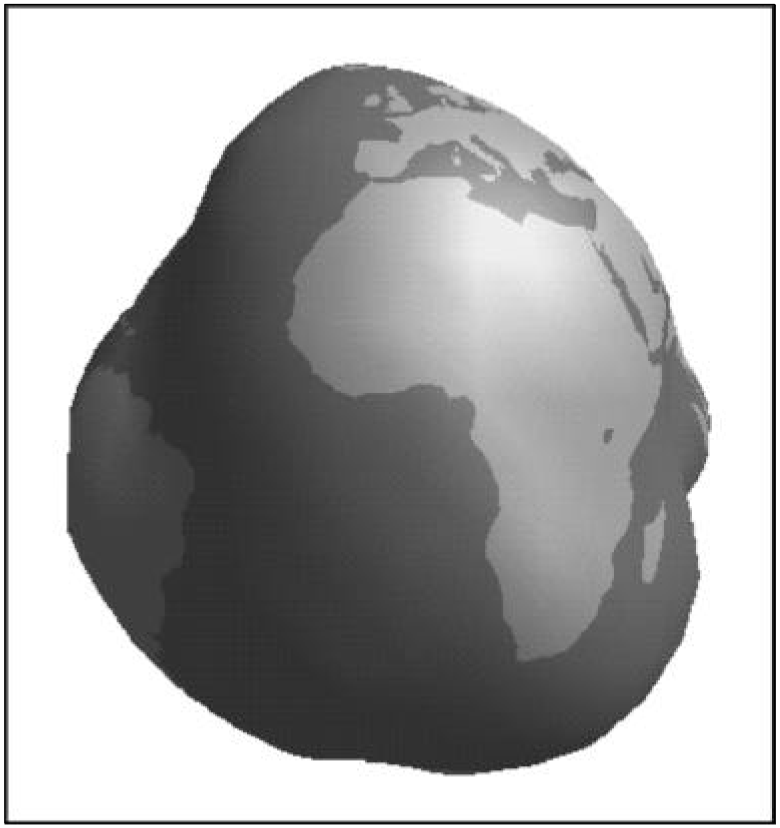
Figure 4.1 The geometrical relationships that Eratosthenes used to calculate the circumference of the earth. See text for explanation.


North Pole
Parallel circles
Latitudes
Equator
Prime meridian
through Greenwich
Meridians
Longitudes
60°
-30°
30°
120°
0°
90°
30°
60°
0°
-30°

	Earth	Distance along a parallel at:		
Time	**rotation**	**Equator**	**30° N/S**	**60° N/S**
24 h	360°	40000 km	34641 km	20000 km
1 h	15°	1667 km	1443 km	833 km
4 min	1°	111.1 km	96.2 km	55.6 km
1 min	15 ´	27.8 km	24.1 km	13.9 km
4 sec	1´	1852 m	1604 m	925 m
1 sec	15 ´´	463 m	401 m	231 m
67 ms	1 ´´	30.8 m	26.7 m	15.4 m
6.7 ms	0.1 ´´	3.1 m	2.7 m	1.5 m
4.32 ms	0.0648 ´´	2.00 m	1.73 m	1 m
667 ?s	0.01 ´´	3.08 dm	2.67 dm	1.54 dm
4.32 ?s	0.0000648 ´´	2.00 mm	1.73 mm	1 mm

The geoid

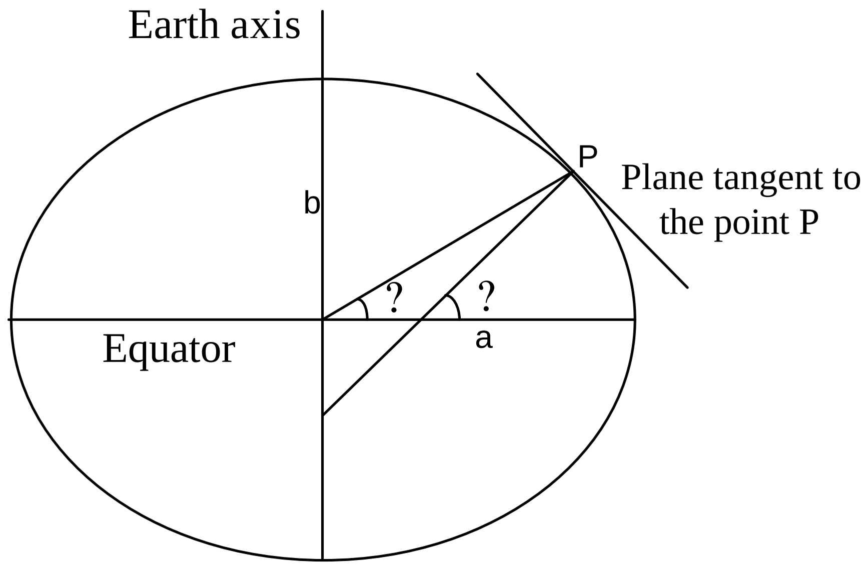
The ”true” shape of the Earth of
equal geopotential = Mean Sea Level



Too complicated surface to project onto a plane for map production.

Use the simpler ellipsoid.

Rotational ellipsoid, spheroid



a = semi major axis

b = semi minor axis

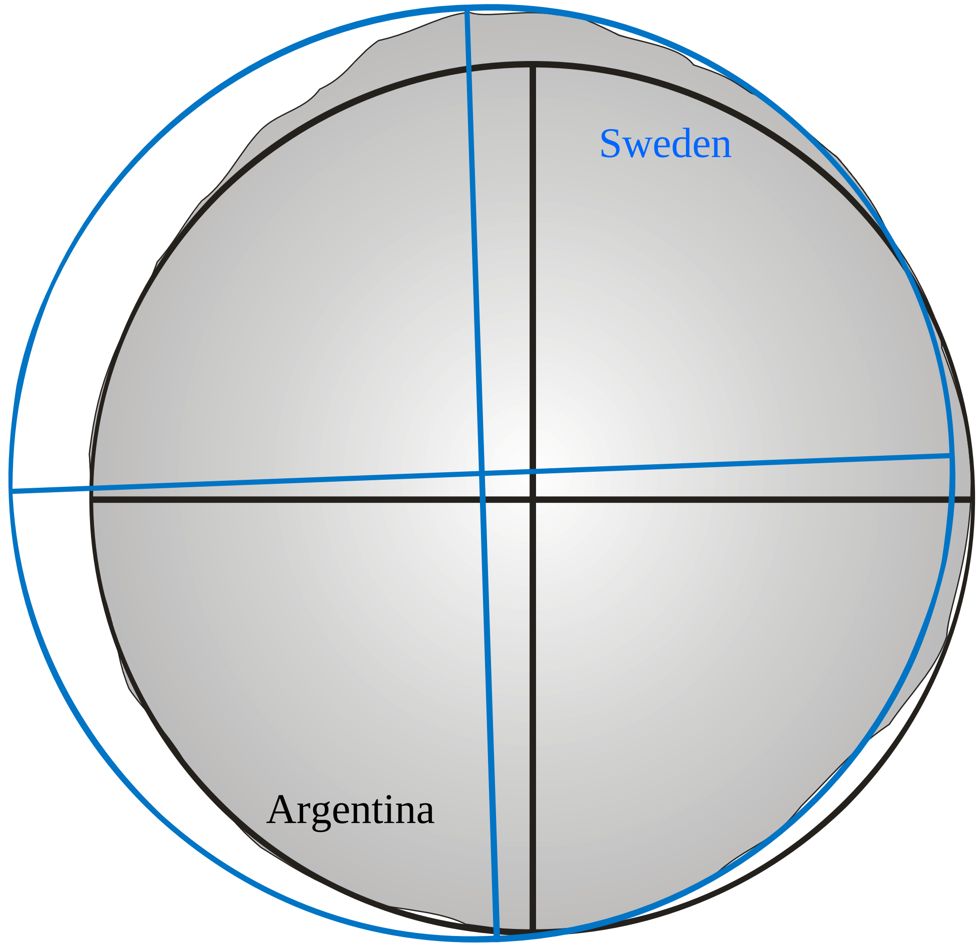
? = geodetic latitude

? = geocentric latitude

Calculations on the ellipsoid

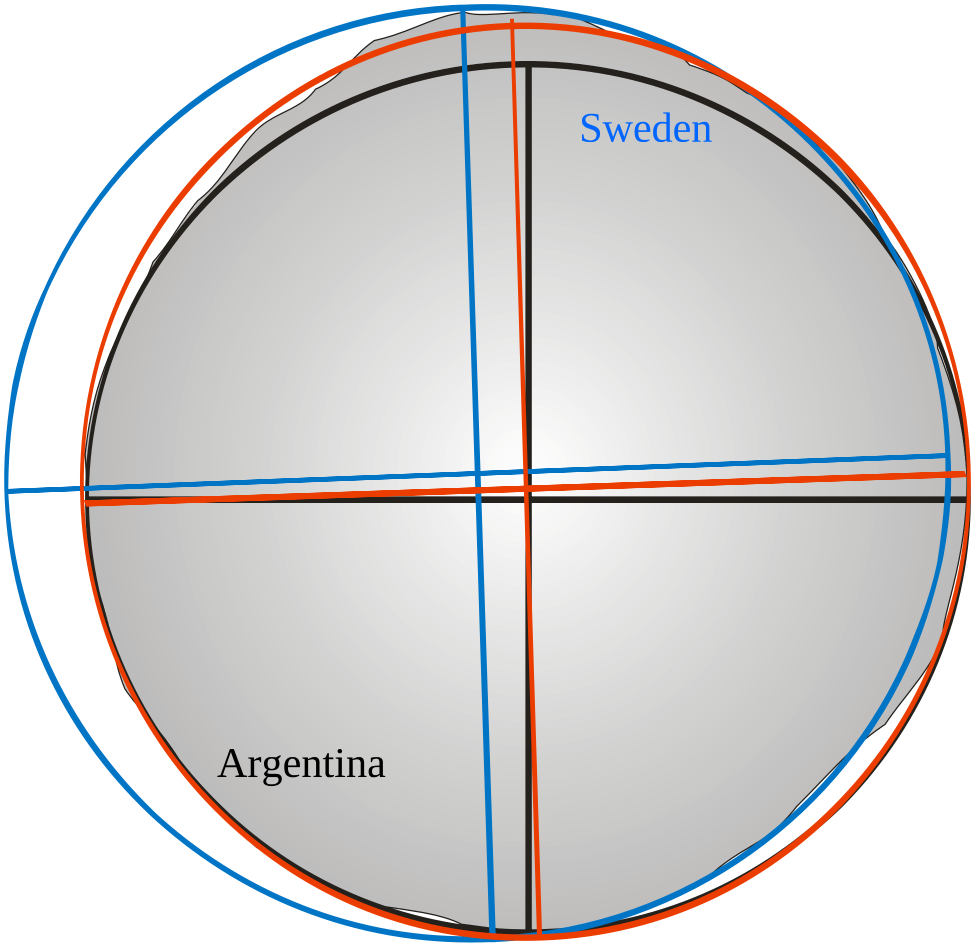
Semi major axis:	**a**
Flattening:	**f = (a - b) / a**
Semi minor axis:	**b**
1:st eccentricity quadrate:	$e^2 = (a^2 - b^2) / a^2$
2:nd eccentricity quadrate:	$e'^2 = (a^2 - b^2) / b^2$
Radius of curvature at the pole:	$c = a^2 / b$
Radius of curvature in the meridian	$M = \dfrac{a(1 ? e^2)}{\left(\sqrt{1 ? e^2 \sin^2 ?}\right)^3}$
Radius of curvature in the prime vertical	$N' = \dfrac{a}{\sqrt{1 ? e^2 \sin^2 ?}}$
Mean radius of curvature	$r = \sqrt{MN?} = \dfrac{a\sqrt{1 ? e^2}}{\left(\sqrt{1 ? e^2 \sin^2 ?}\right)^2}$

Two solutions of the problem of how to fit an ellipsoid onto the irregular geoid.



Global solution = Geodetic datum WGS84

Fits as good as possible over the entire Geoid



A geodetic datum =

one ellipsoid of a specified size and shape (defined by **a** and **f**) and how that ellipsoid is placed into the geoid (position and orientation).

Selected Reference Ellipsoids

Ellipse	Semi-Major Axis (meters)	1/Flattening
Airy 1830	6377563.396	299.3249646
Bessel 1841	6377397.155	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest 1830	6377276.345	300.8017
Fischer 1960 (Mercury)	6378166.0	298.3
Fischer 1968	6378150.0	298.3
G R S 1967	6378160.0	298.247167427
G R S 1975	6378140.0	298.257
G R S 1980	6378137.0	298.257222101
Hough 1956	6378270.0	297.0
International	6378388.0	297.0
Krassovsky 1940	6378245.0	298.3
South American 1969	6378160.0	298.25
WGS 60	6378165.0	298.3
WGS 66	6378145.0	298.25
WGS 72	6378135.0	298.26
WGS 84	6378137.0	298.257223563

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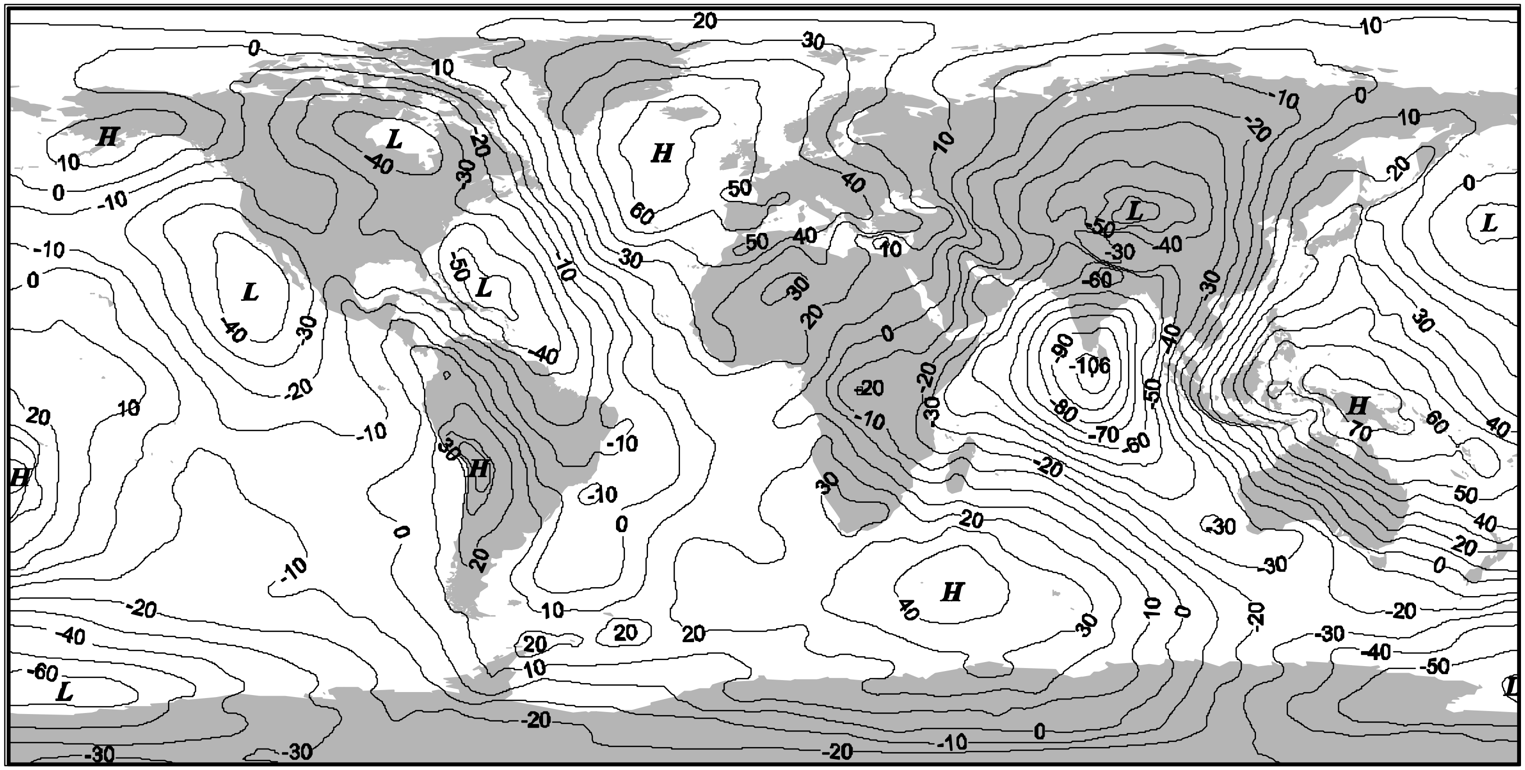
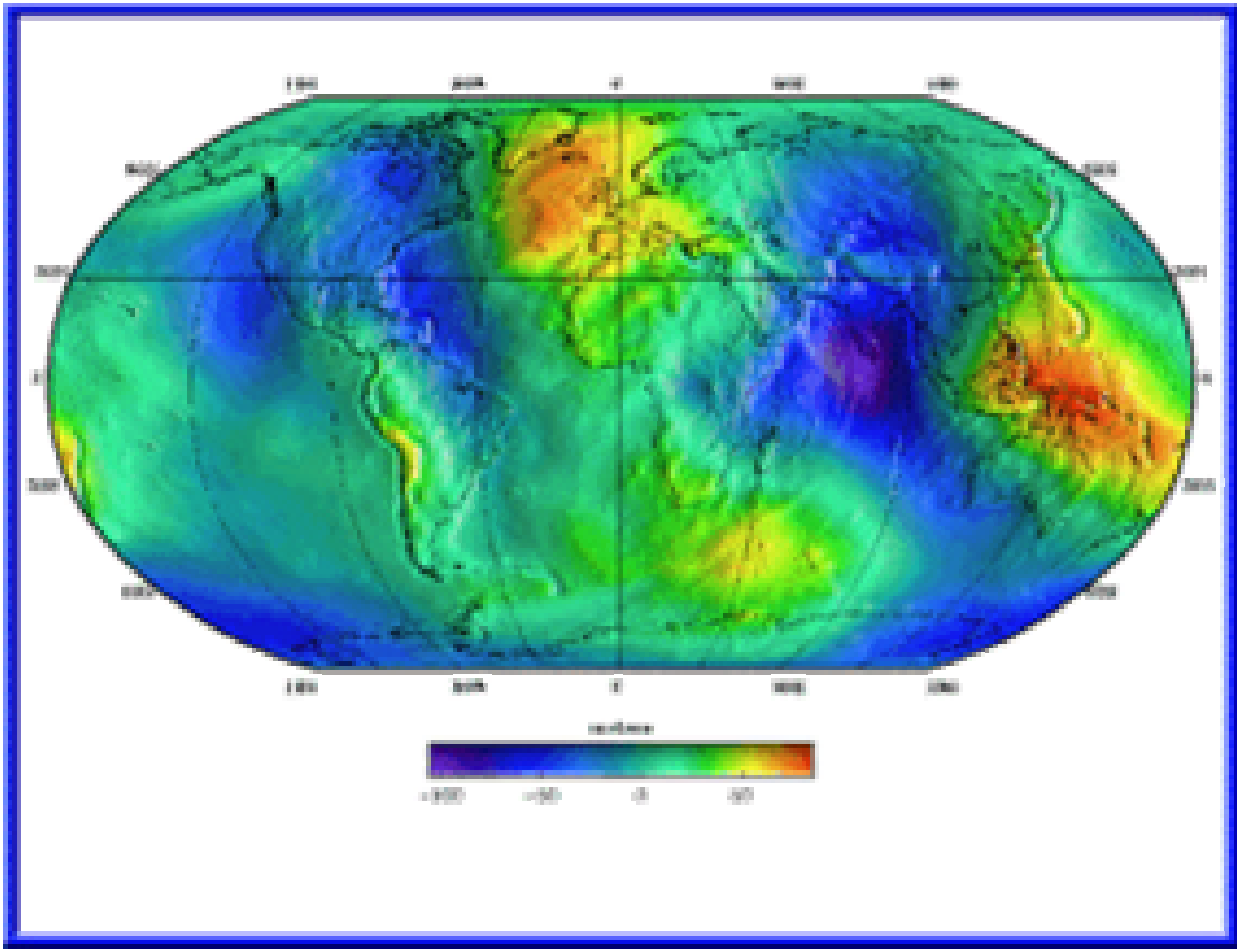
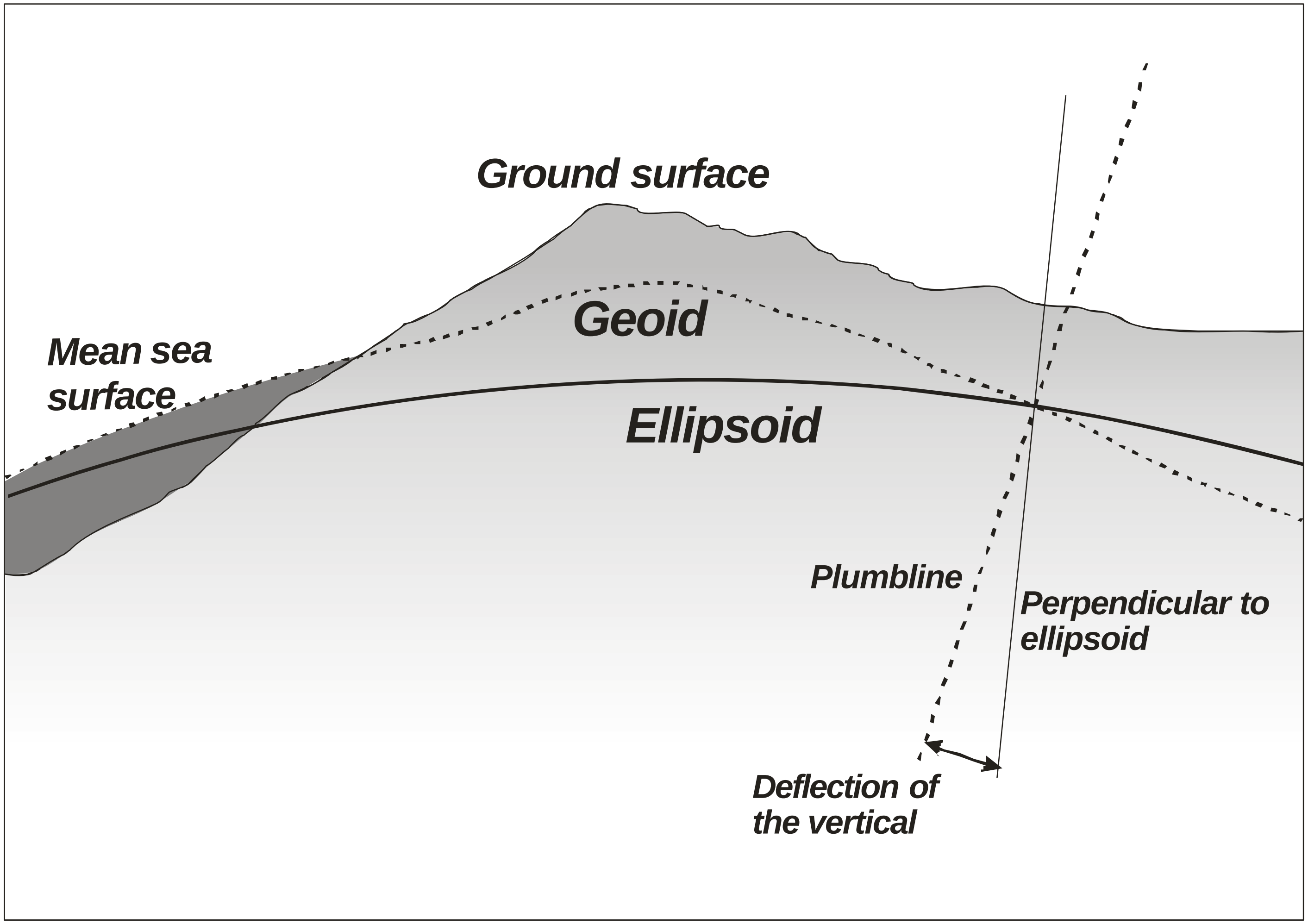


Geoid undulation (meters). EGM96 (USGS)

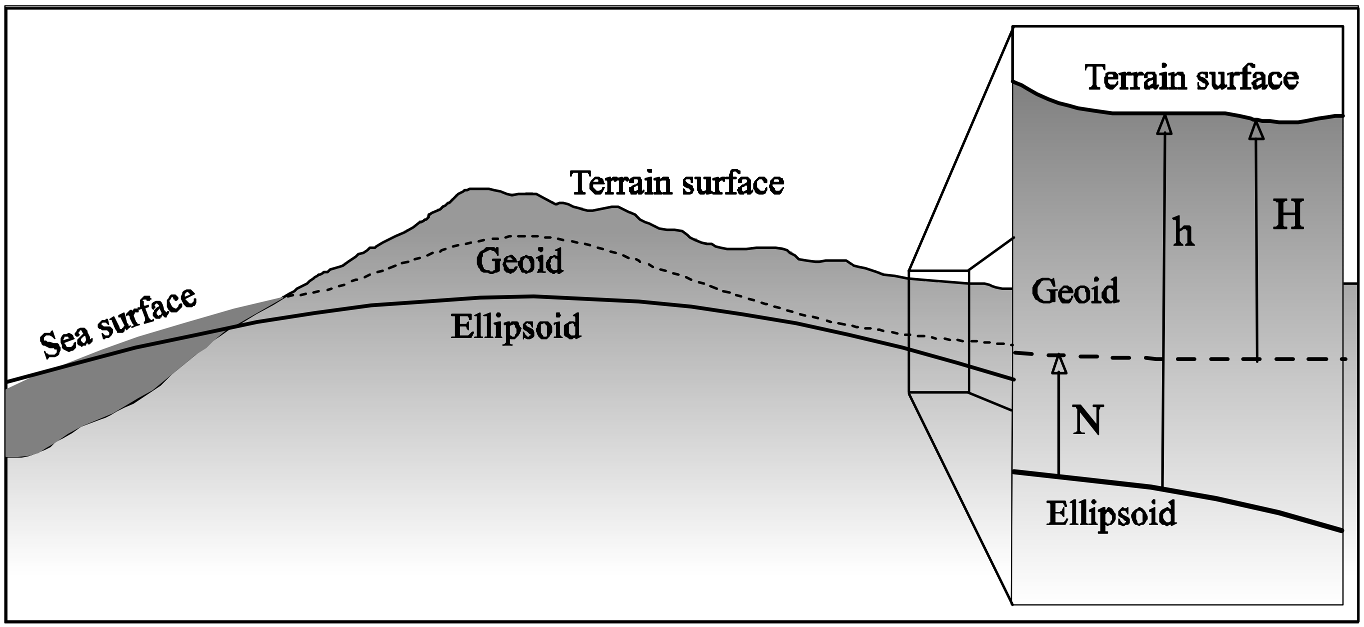
The geoid surface relative the WGS84 ellipsoid and datum

Geoid height relative WGS84 (-105m - +75m)




Ground surface
Geoid
Mean sea surface
Ellipsoid
Plumbline
Perpendicular to ellipsoid
Deflection of the vertical

Orthometric height (H) = height above mean sea level
Geoid surface is the reference for orthometric height



H = h – N

Orthometric height = Ellipsoid height – Geoid height

Map projections

”The problem of flattening a Grapefruit
onto a plane”

The used model of the Earth is an ellipsoid
The map is a flat paper

Projection types:

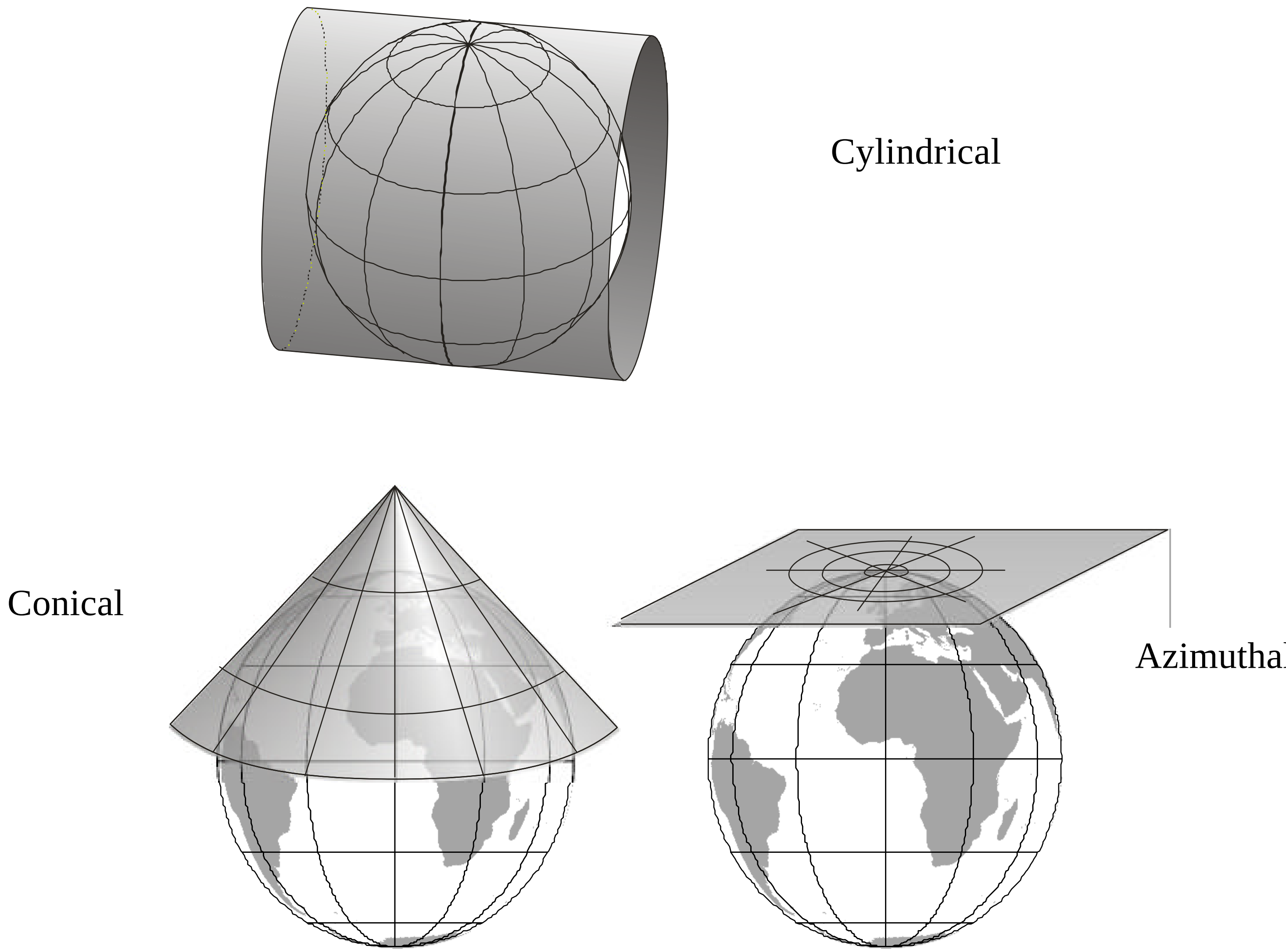
- Cylindrical
- Conical
- Azimuthal, Planar

Construction methods:

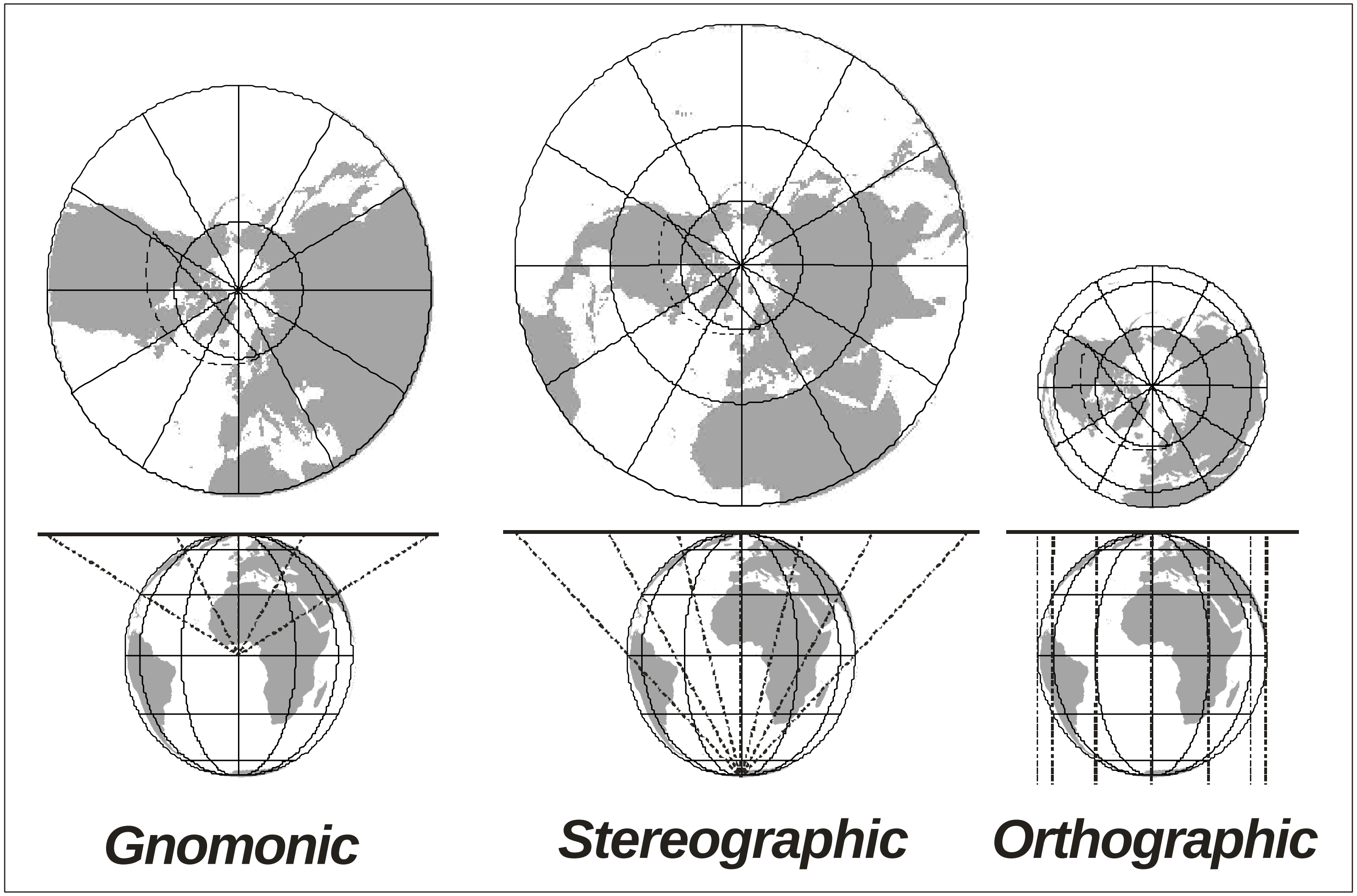
- Perspective
  - Using different projection points
    - Gnomonic (centre of globe)
    - Stereographic (opposite point)
    - Orthographic (at infinite distance)
- Non perspective, Mathematical

Properties:

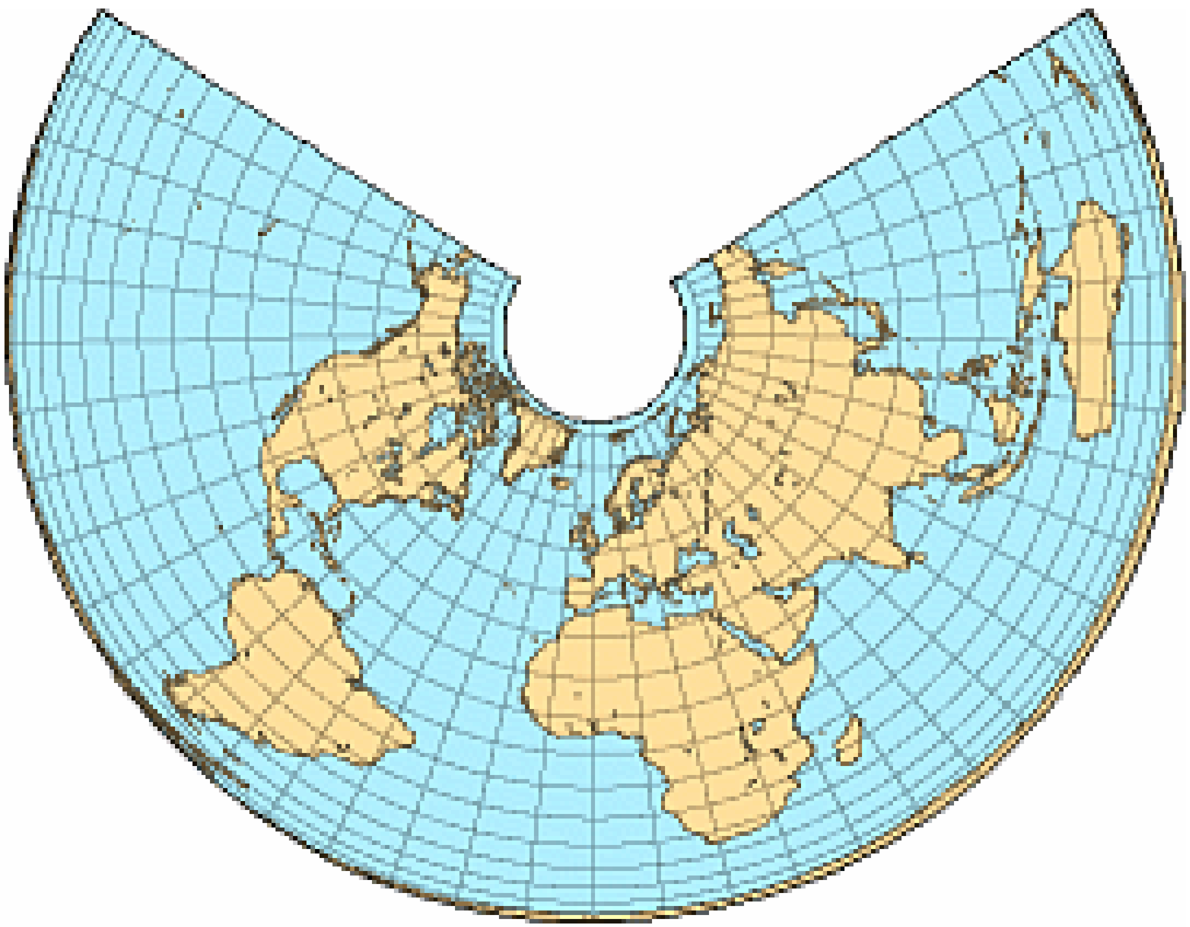
- Equal area
- Equidistant (along certain directions)
- Conformal (locally), True direction


Cylindrical
Conical
Azimuthal

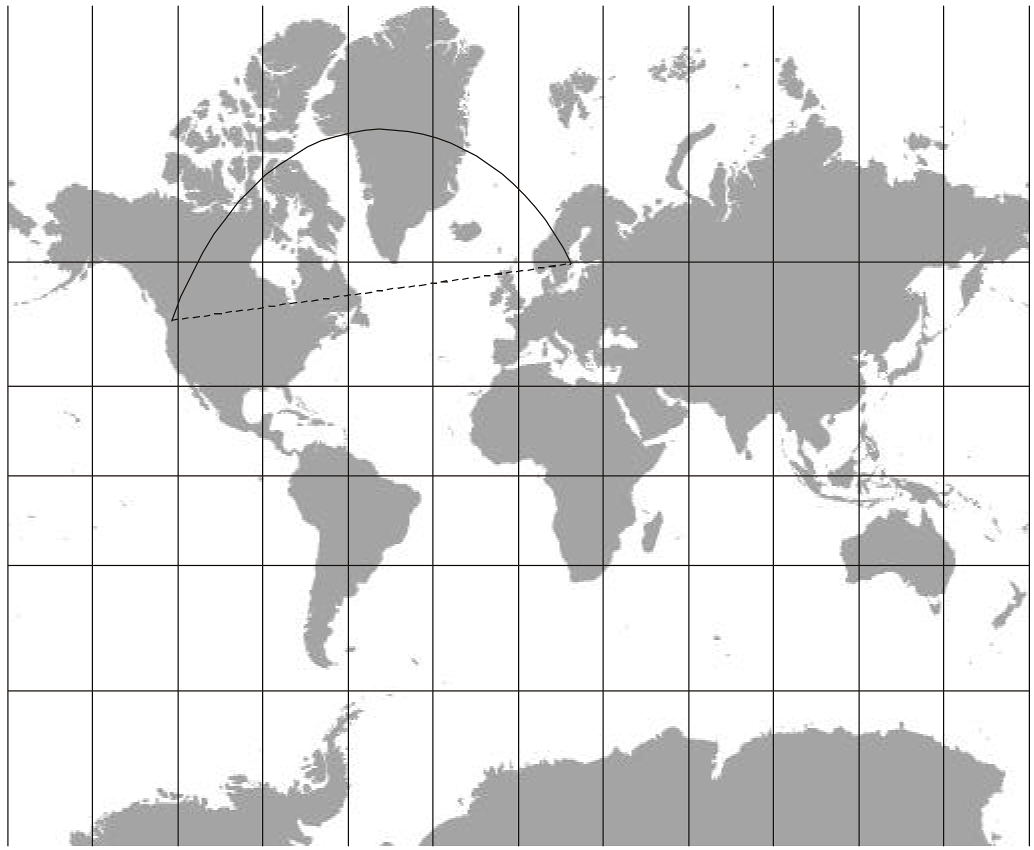
Examples of projections of azimuthal type



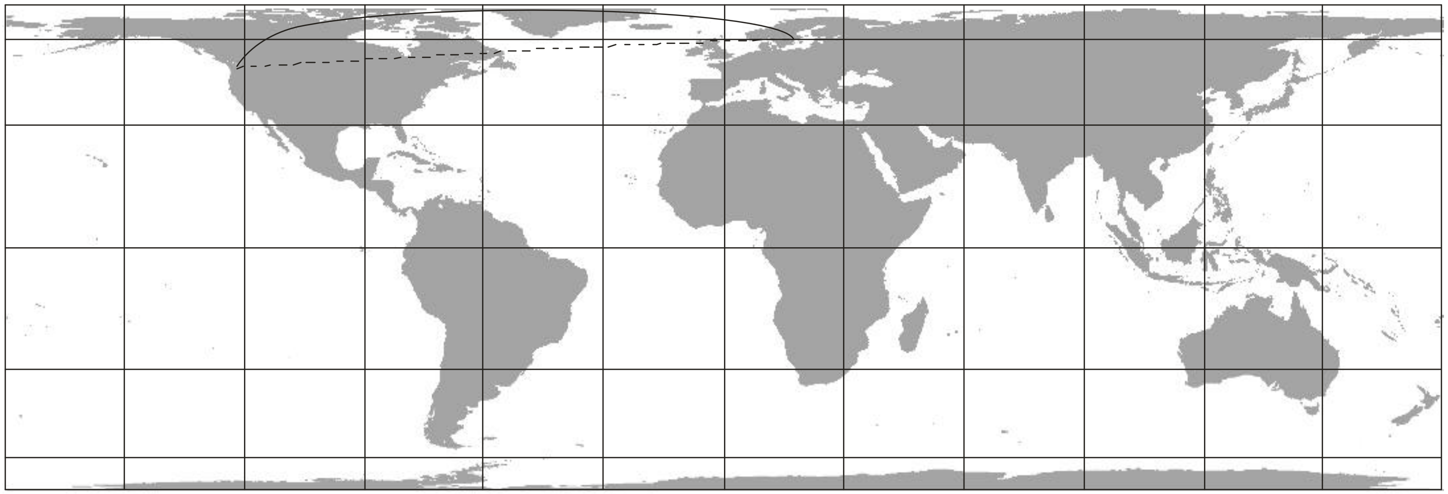
Example of a conical map projection



Albers Equal-Area projection

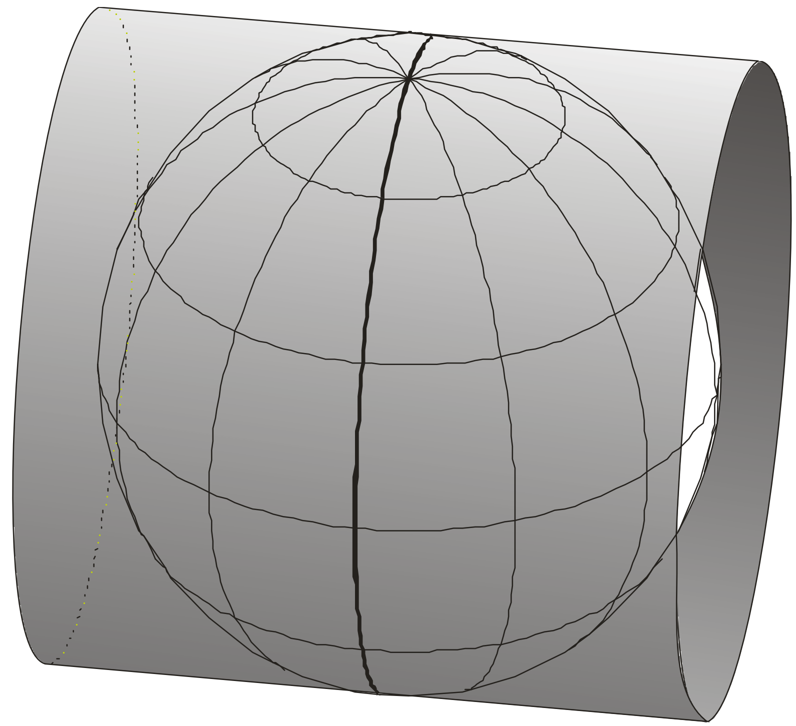


Mercator Projection, Gerardus Mercator 1569
Normal cylindrical, conformal,
rhumb lines are straight lines



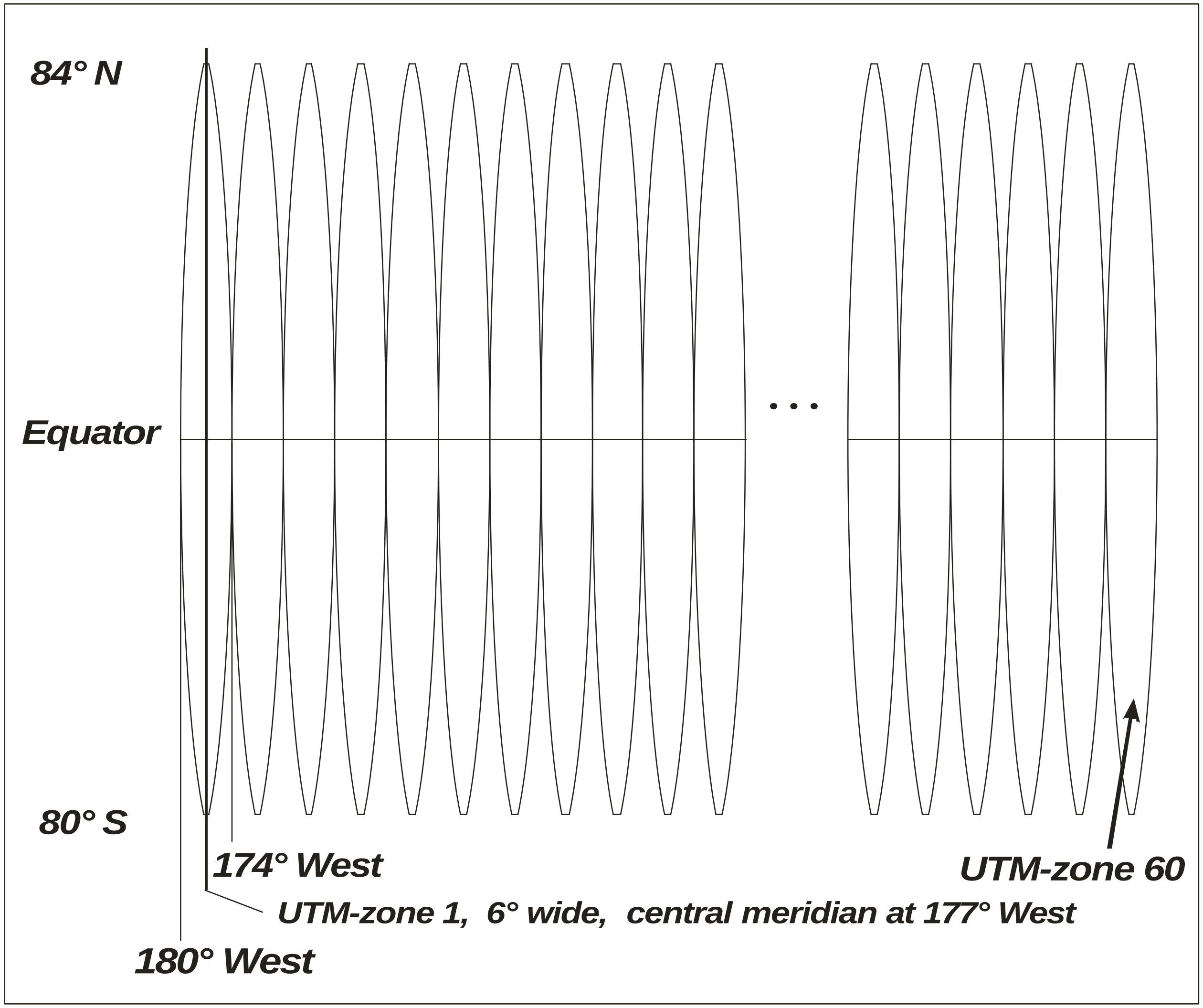
Lamberts Cylindrical Equal Area
Equal Area property

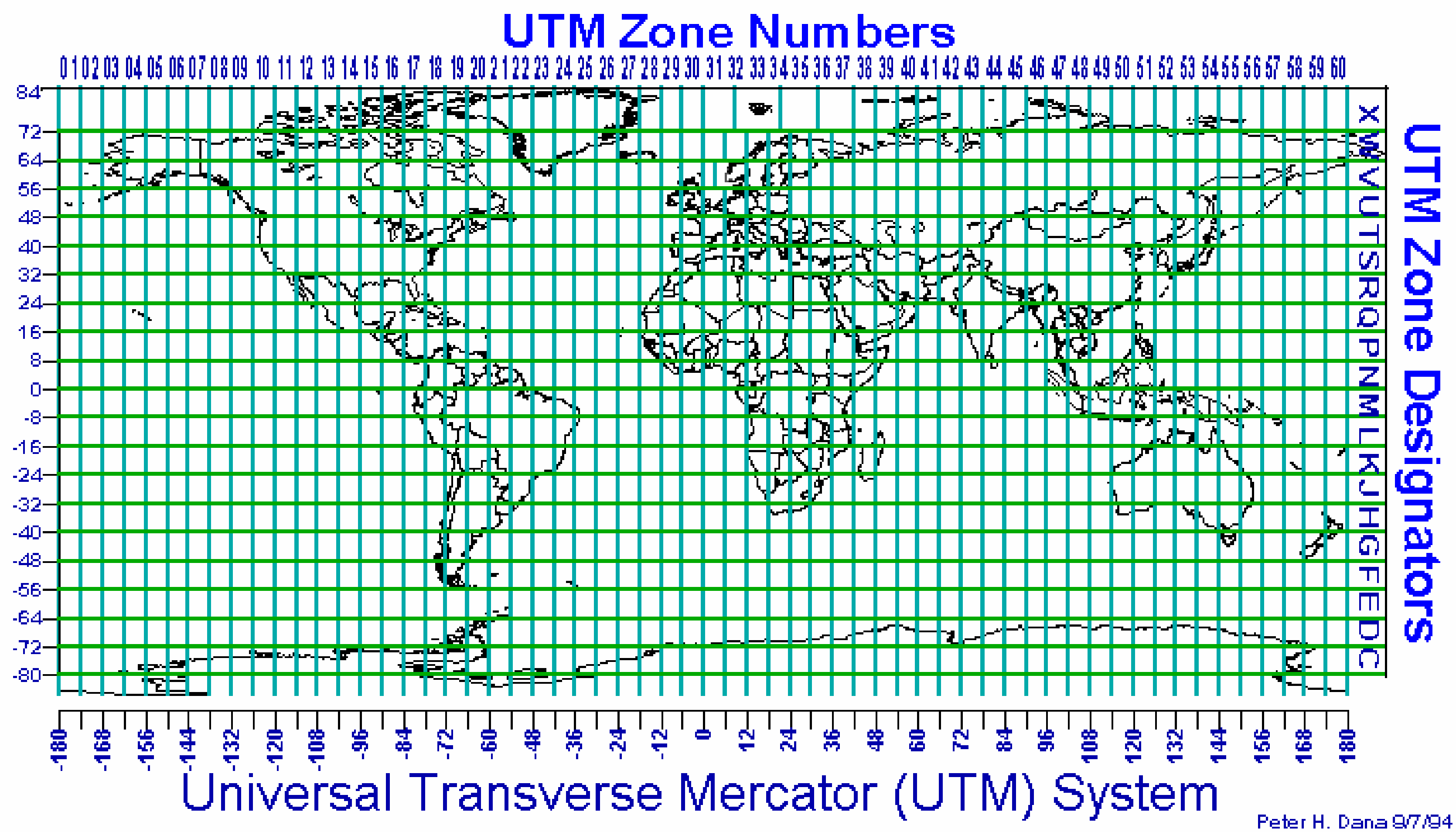
Transverse Mercator projection



- Cylindrical and transverse
- Other name is Gauss-Kreuger projection
- Conformal properties
- Define a central meridian for the projection
- Define latitude of origin (e.g. Equator)
- Define a scale factor at central meridian
- Define a false Easting and a false Northing
- Choose an ellipsoid
- Choose a geodetic datum

The UTM system, Universal Tranverse Mercator, 60 projections.
All are Transverse Mercator with some parameters specified.

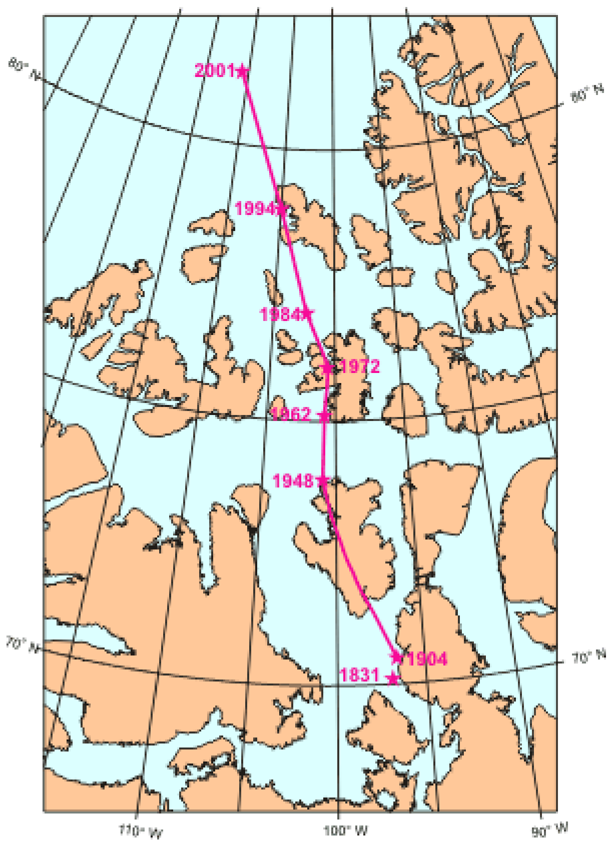



UTM Zone Numbers
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
84 72 64 56 48 40 32 24 16 8 0 -8 -16 -24 -32 -40 -48 -56 -64 -72 -80
X W V U T S R Q P N M L K J H G F E D C
UTM Zone Designators
-180 -168 -156 -144 -132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
Universal Transverse Mercator (UTM) System
Peter H. Dana 9/7/94

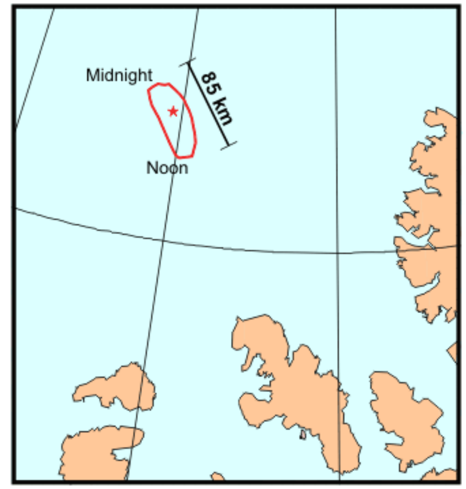
Projection parameters for the UTM system:

- Central meridian = One of the 60 predefined depending on the position in longitude (177°W, 171°W, 165°W, …., 177°E).
- Each projection is valid ±3° from the central meridian to form one 6° wide zone.
- Latitude of origin = The Equator (0°N).
- Scale factor at central meridian = 0.9996.
- False Easting = 500 000 meter.
- False Northing = 0 meter if north of the equator, or
  10 000 000 meter if south of the equator.
- Ellipsoid = Not specified.
- Geodetic datum = Not specified.

Magnetic North Pole positions 1831 – 2001 in Arctic Canada



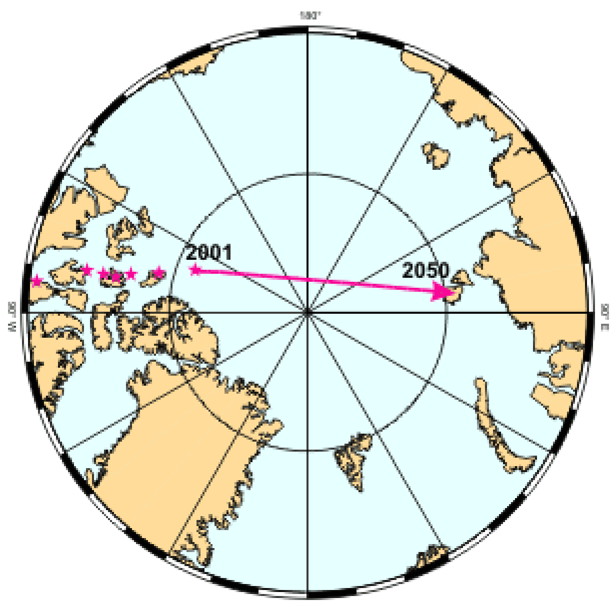
Daily variations

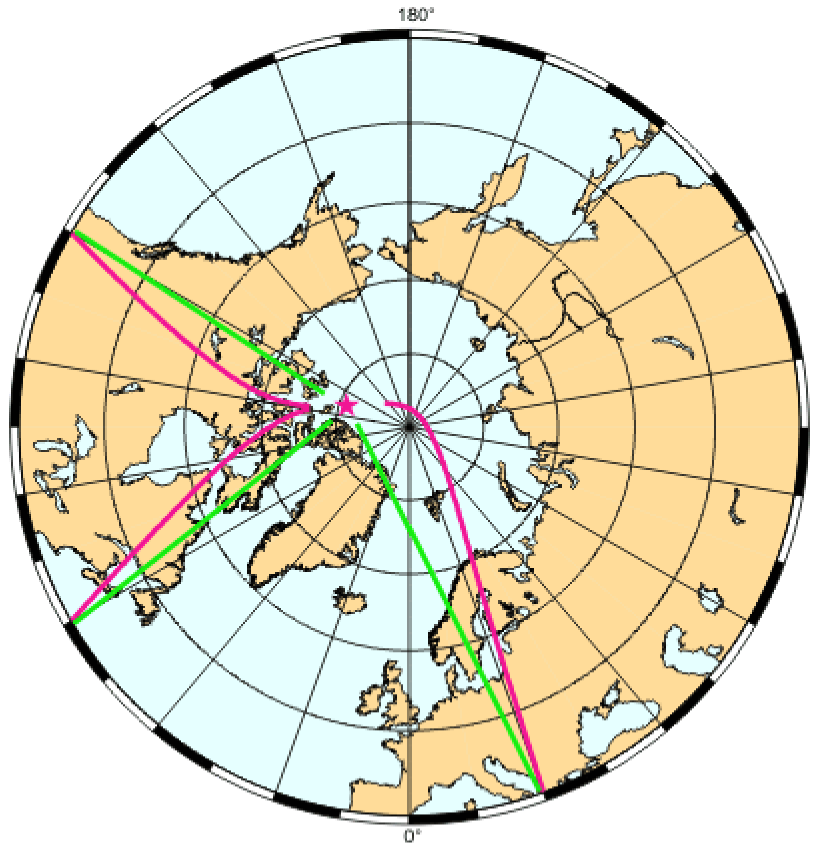


Magnetic North Pole Predictions. App. motion rate is 45 kms per year and increasing.

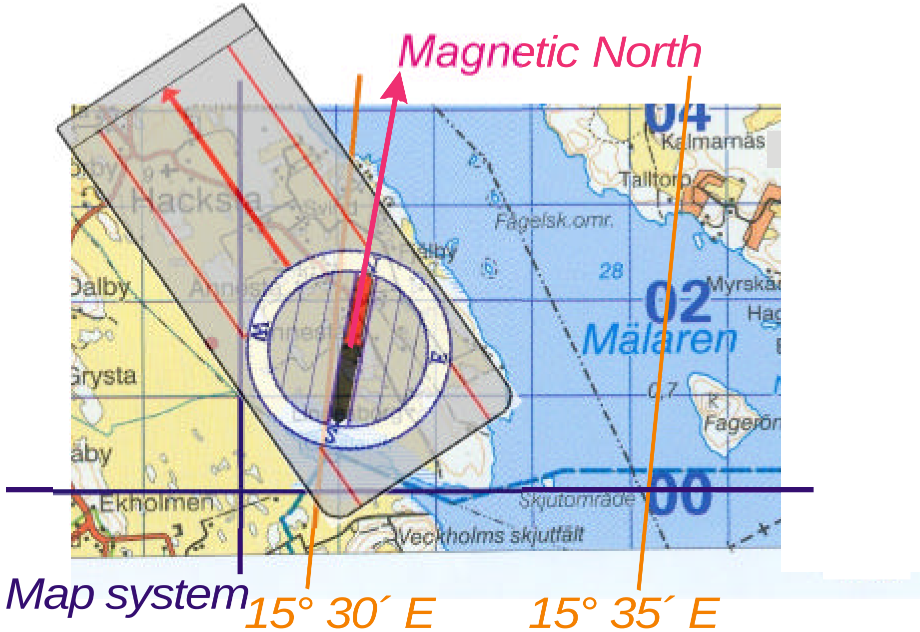
Year	Latitude (°N)	Longitude (°W)	
2001	81.3	110.8	
2002	81.6	111.6	P
2003	82.0	112.4	P
2004	82.3	113.4	P
2005	82.7	114.4	P

At current speed of motion
the Magnetic North Pole
will be in Sibiria 2050

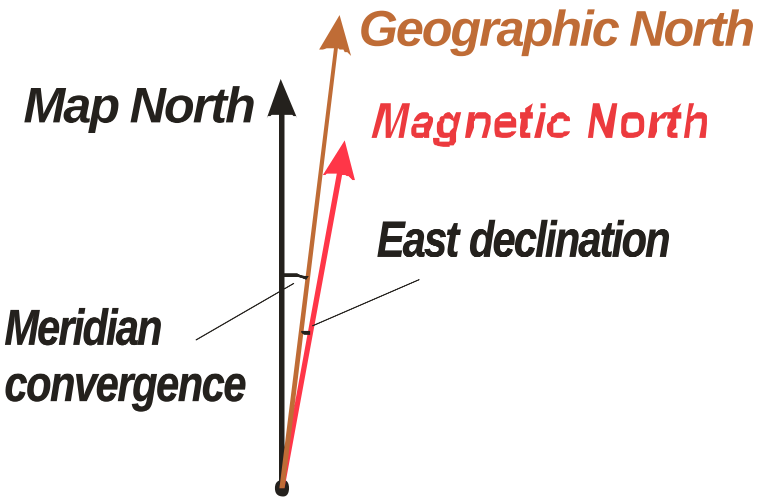




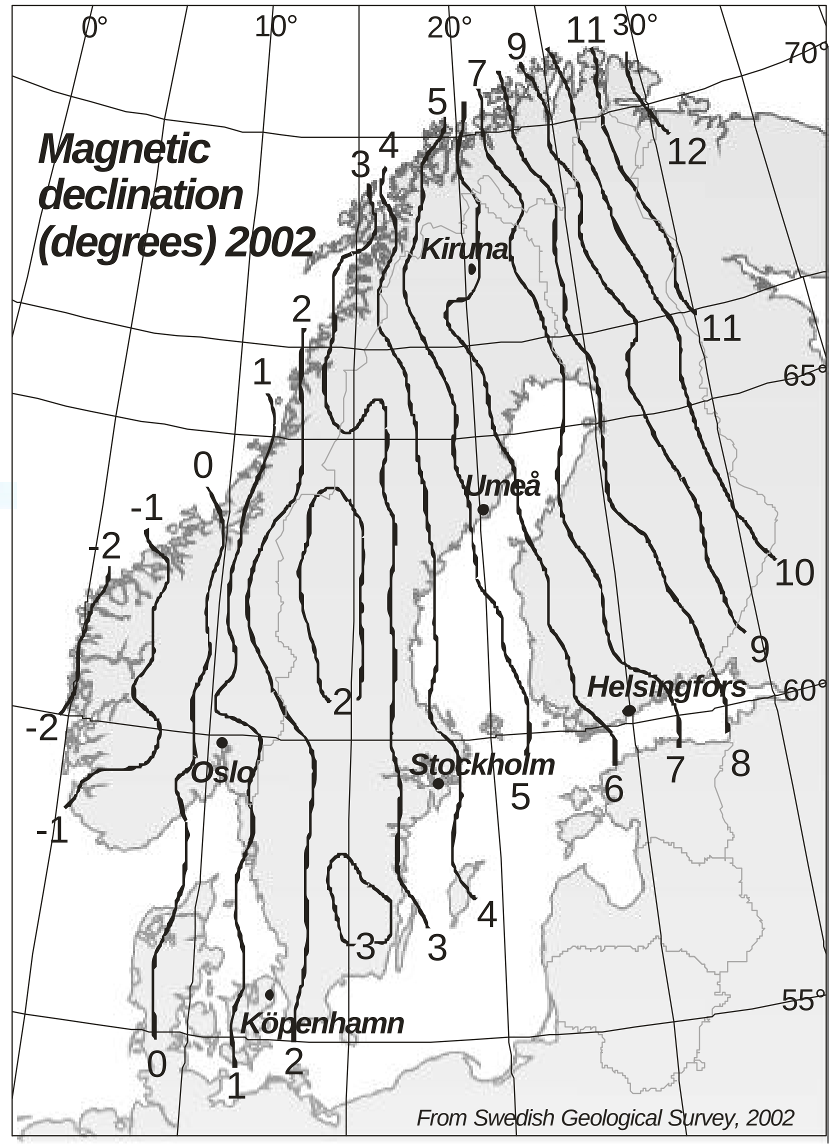
The magnetic field lines [red]
(magnetic meridians) do not
go the shortest way as great circles
[green] towards the MNP.



Magnetic North
Kalmarnäs
Talltorp
Fågelsk.omr.
Mälaren
Myrskär
Fageron
Hacksta
Dalby
Grysta
Ekholmen
Skjutområde
Veckholms skjutfält
Map system
15° 30´ E
15° 35´ E



Geographic North
Map North
Magnetic North
East declination
Meridian convergence

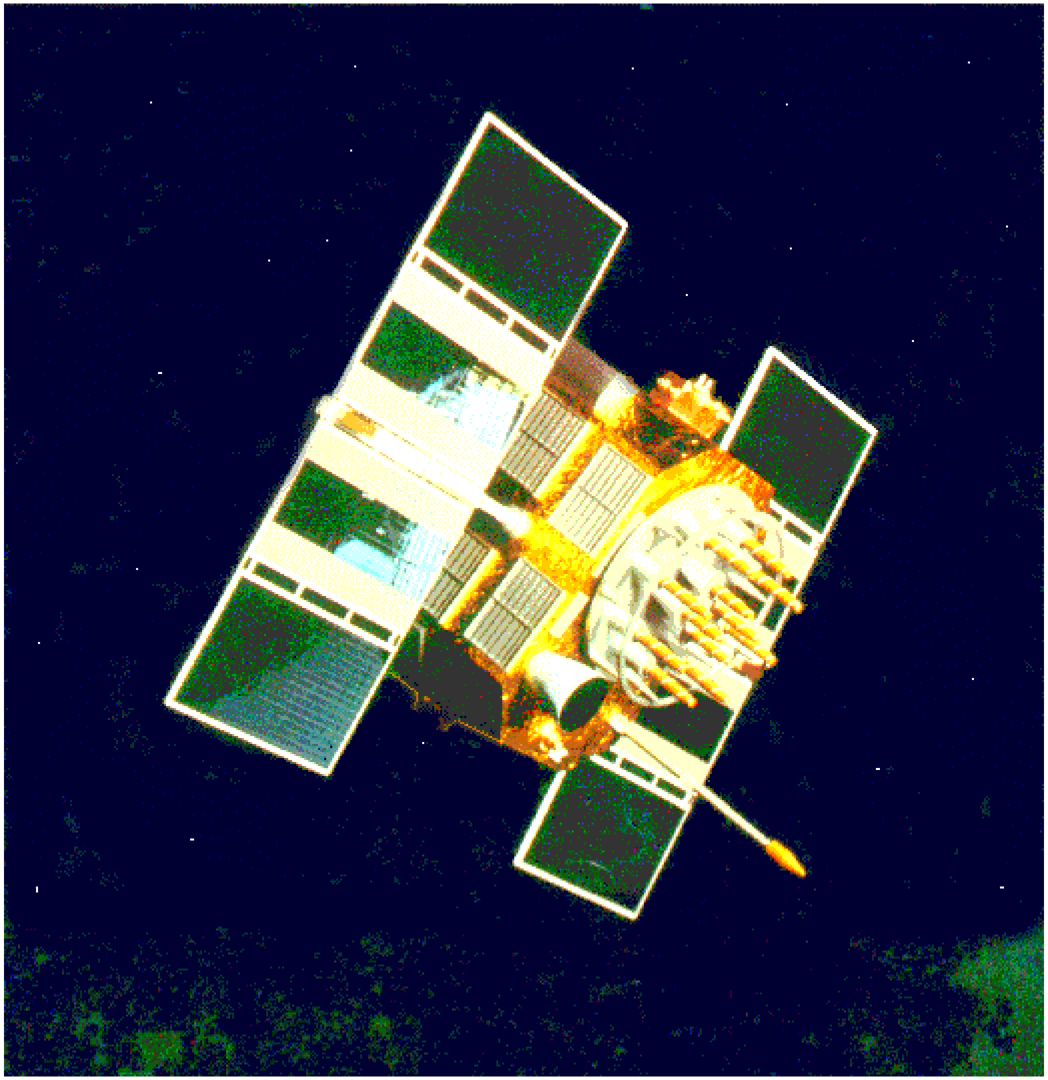


Magnetic declination (degrees) 2002
0°
10°
20°
30°
70°
65°
60°
55°
Kiruna
Umeå
Helsingfors
Oslo
Stockholm
Köpenhamn
From Swedish Geological Survey, 2002

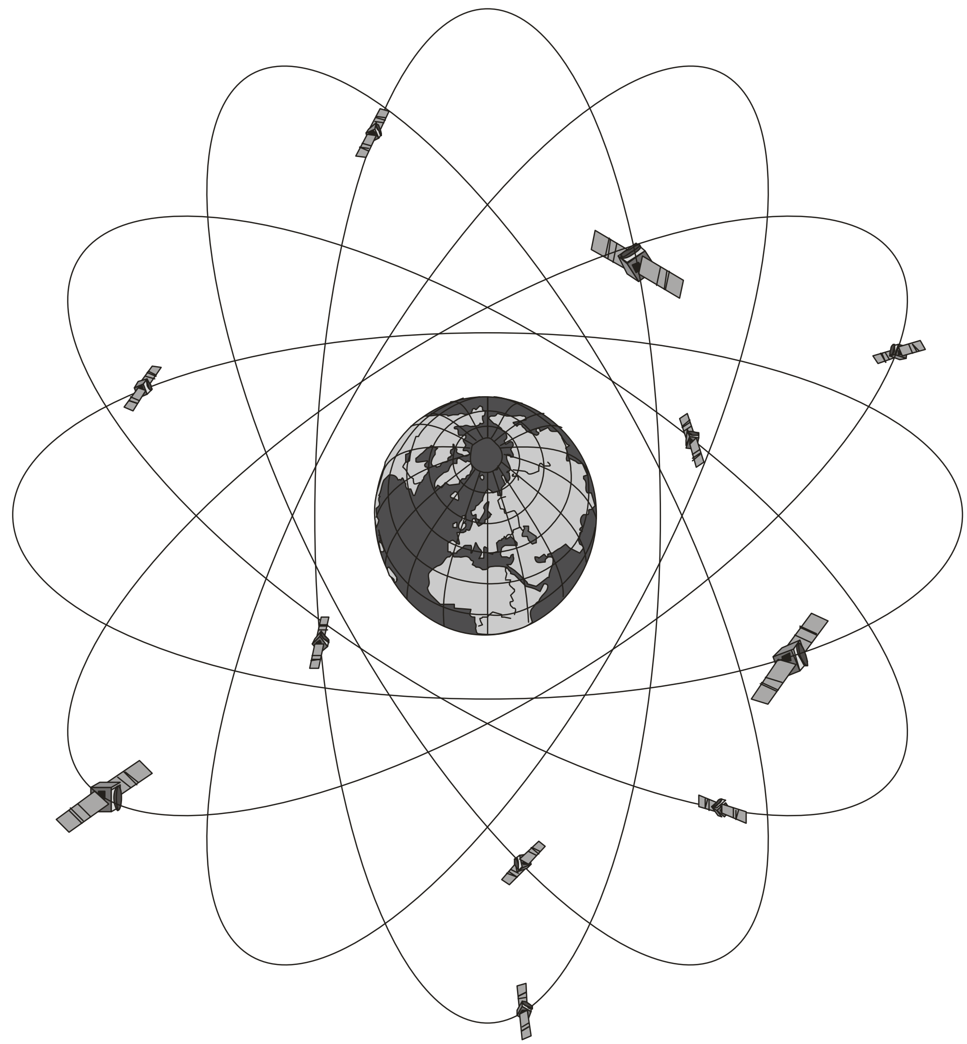
GPS navigation system

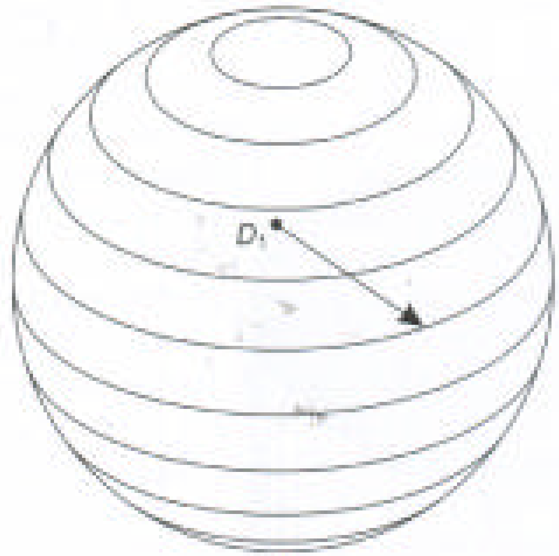
American defense has initiated
It is **costly** – but free to use for everyone
Development started 1978
Was decleared operational 1995
SA was shut off April 2000
Has been a tremendouos success
Used worldwide for navigation and positioning

A 700 kg heavy GPS satellite

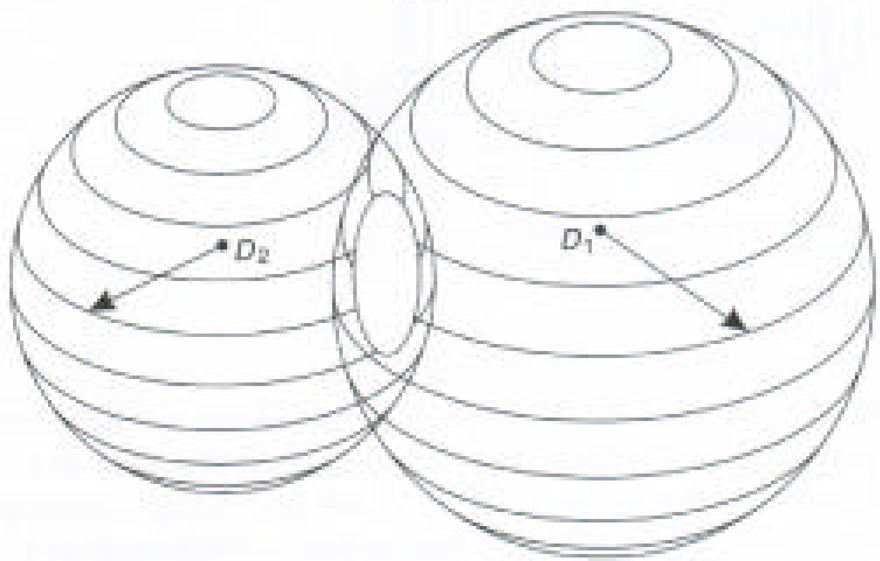


The GPS system has up to 32 active satellites,
6 orbital planes, 20 200 kms above the Earth, 12 hour orbits.



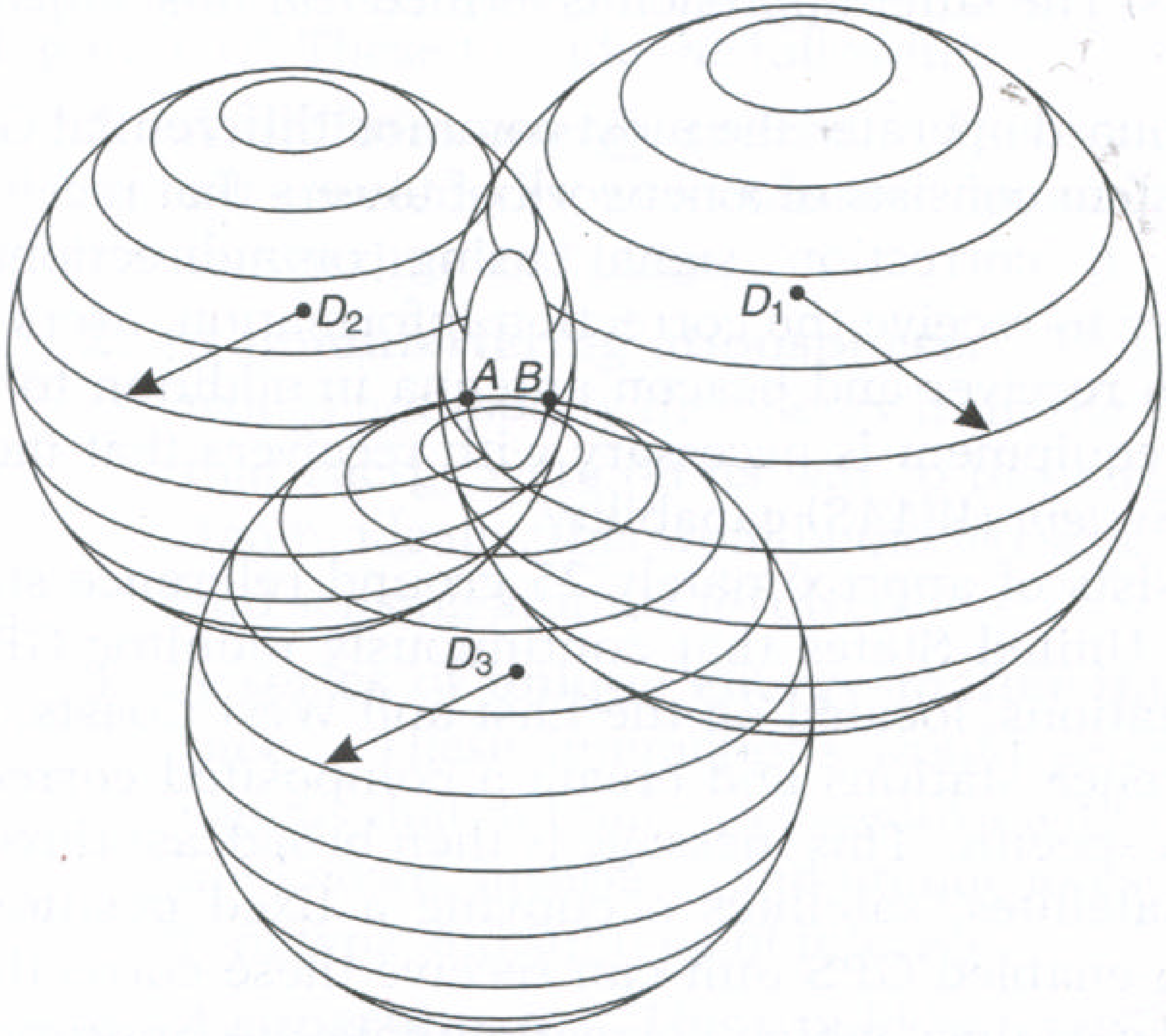


(a)



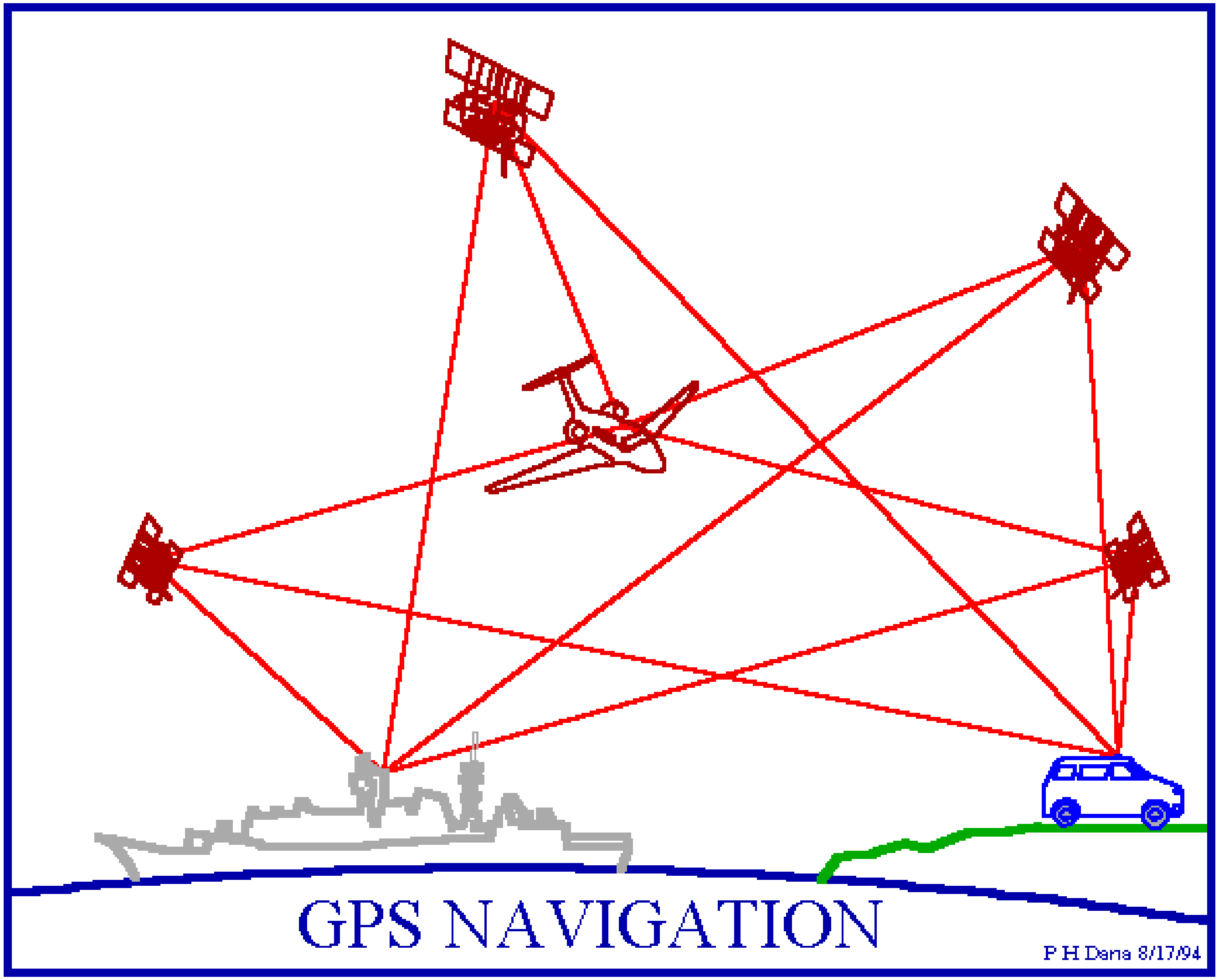
(b)

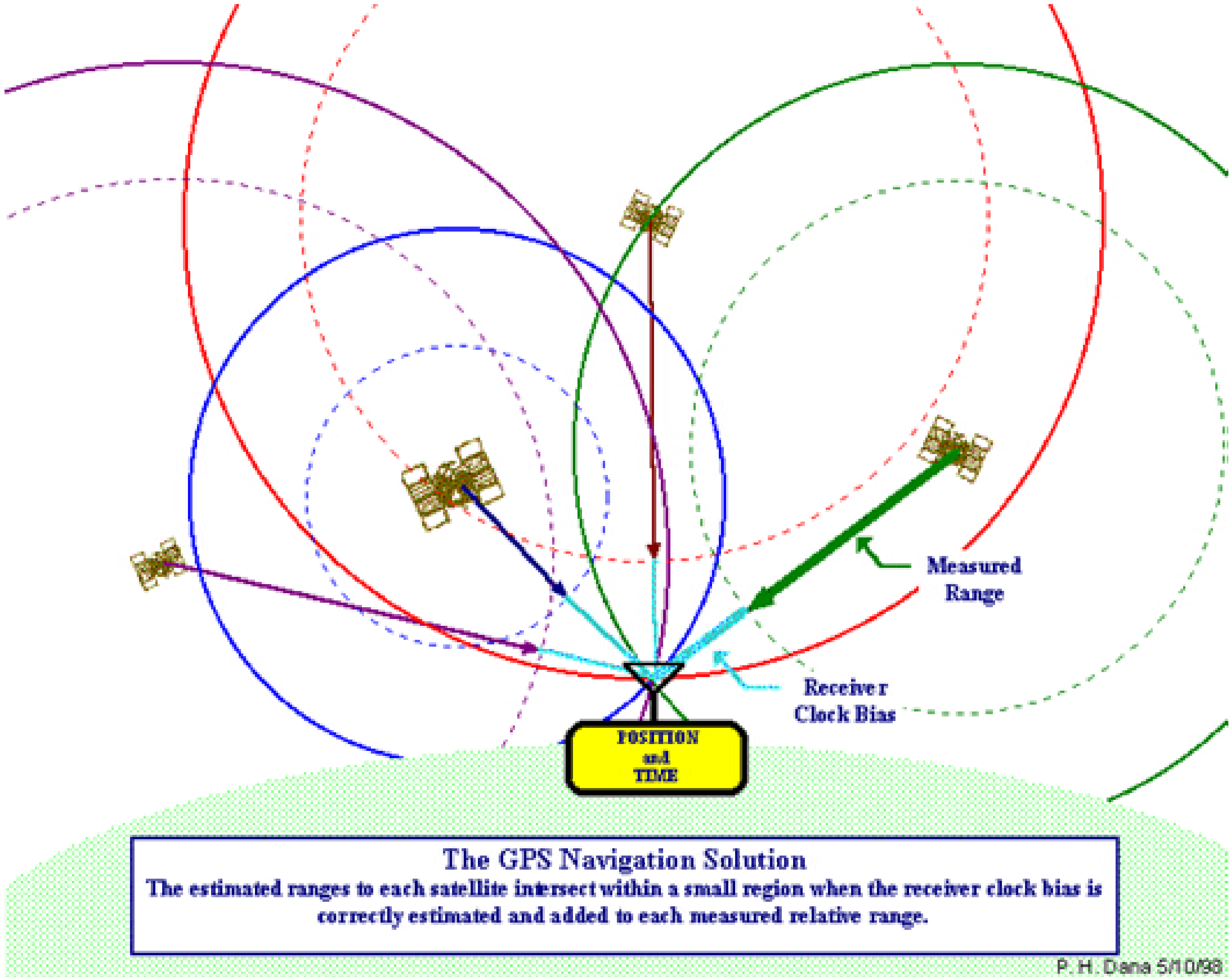
Figure 1.17 Principle of satellite ranging: (a) distance measurement from one satellite establishes position on a sphere; (b) distance measurement from two satellites establishes a circle of intersection of two spheres; (c) distance measurement from three satellites narrows position to only two possibilities.



(c)

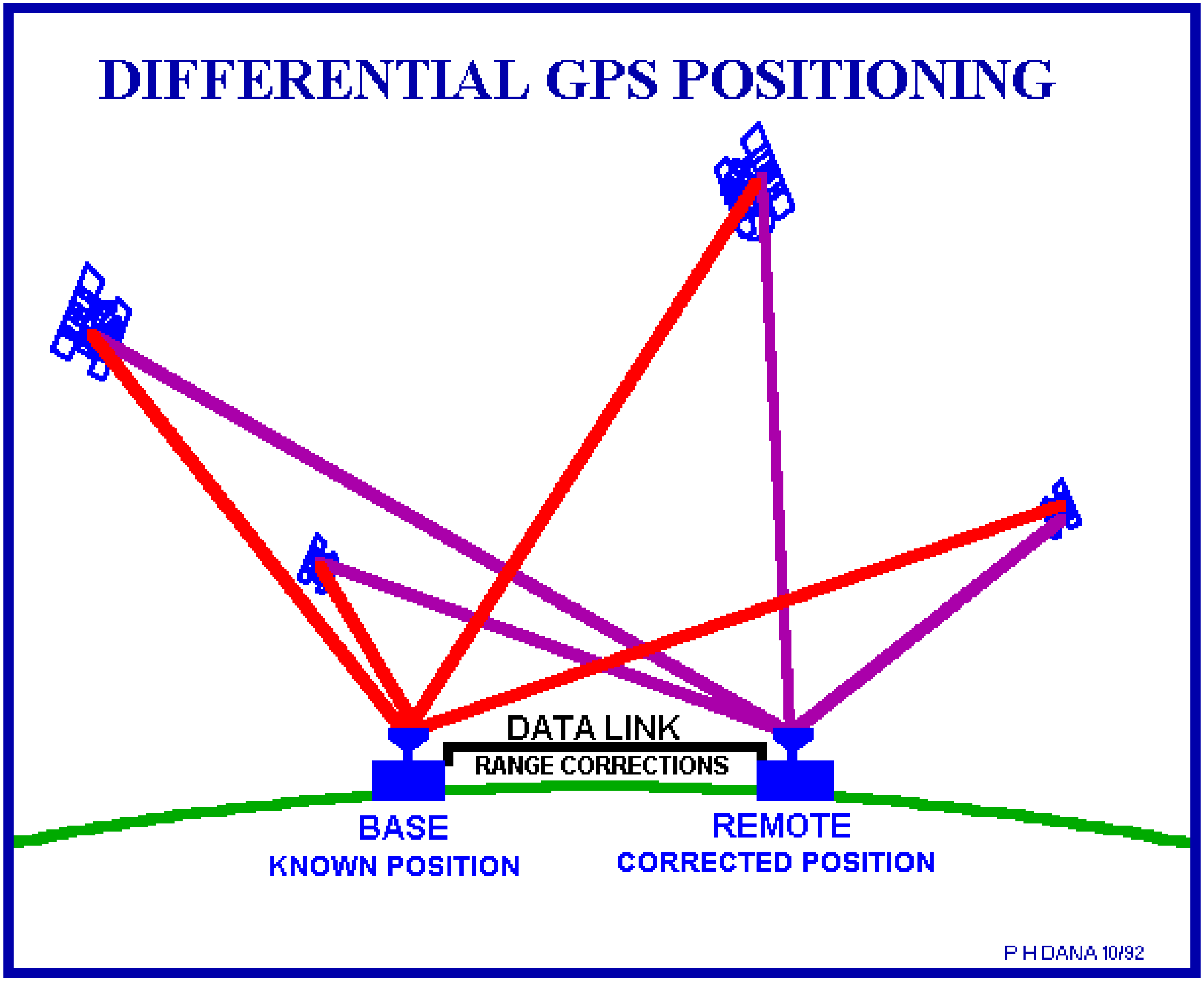
Figure 1.17 *(Continued)*

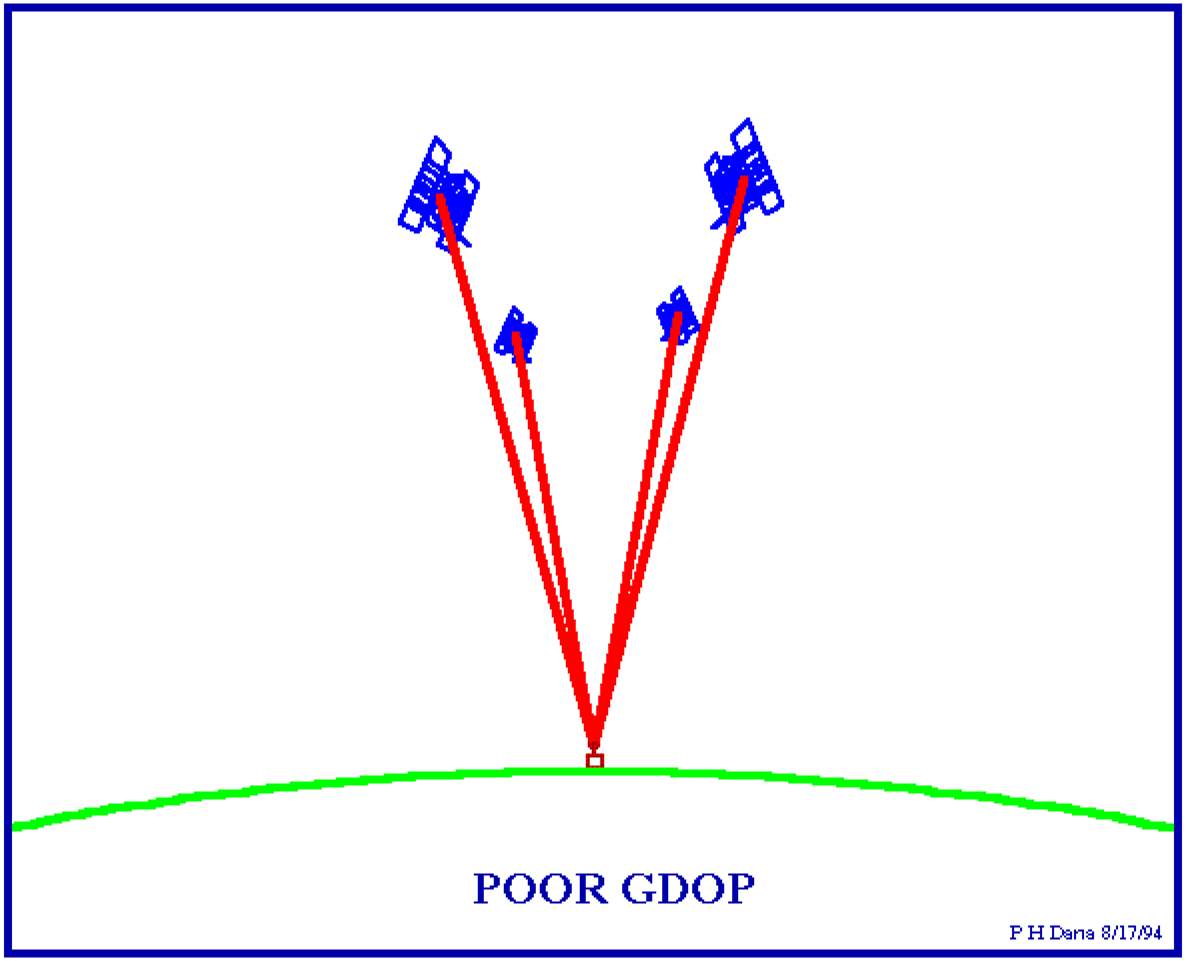

GPS NAVIGATION
P H Dana 8/17/94

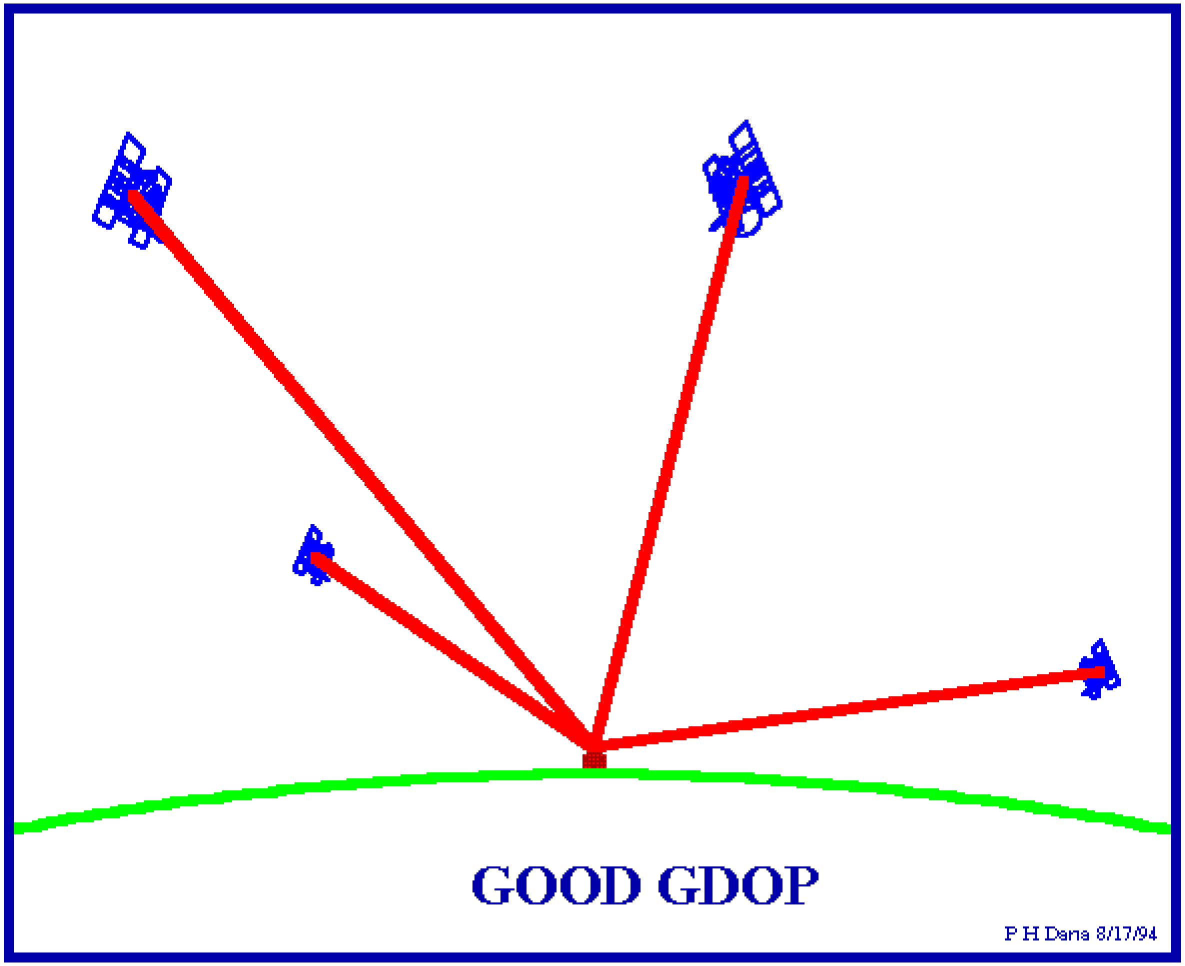


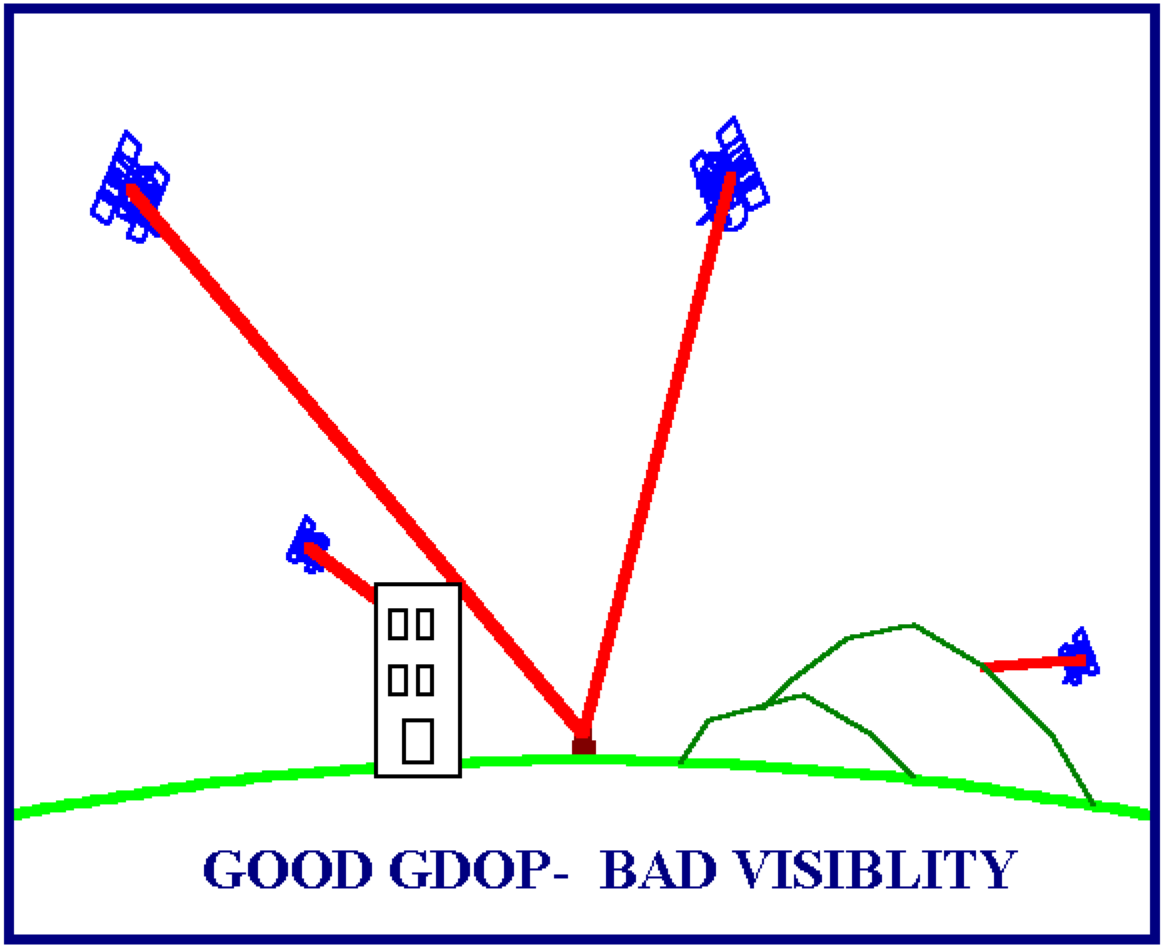
The GPS Navigation Solution

The estimated ranges to each satellite intersect within a small region when the receiver clock bias is correctly estimated and added to each measured relative range.


DIFFERENTIAL GPS POSITIONING
DATA LINK
RANGE CORRECTIONS
BASE
KNOWN POSITION
REMOTE
CORRECTED POSITION
P H DANA 10/92


POOR GDOP
P H Dana 8/17/94


GOOD GDOP
P H Dana 8/17/94


GOOD GDOP- BAD VISIBLITY

The accuracy of a GPS for navigation

- All modern GPS:es should have an accuracy of 15 meter or better
- If you pay US$ 30 000 you can get centimeter precision

The accuracy can be lost because of these things:

Bad reception, bad satellite constallation, obscured sky view
can make position impossible.

SA disturbance of the time for all non-american military
50 – 150 meter of error (semi-random).

Readings in wrong geodetic datum
Up to 800 meter error (systematic).

Simplified geodetic conversion model
Up to 50 meter error (systematic in local areas).

From remote sensing data to GIS

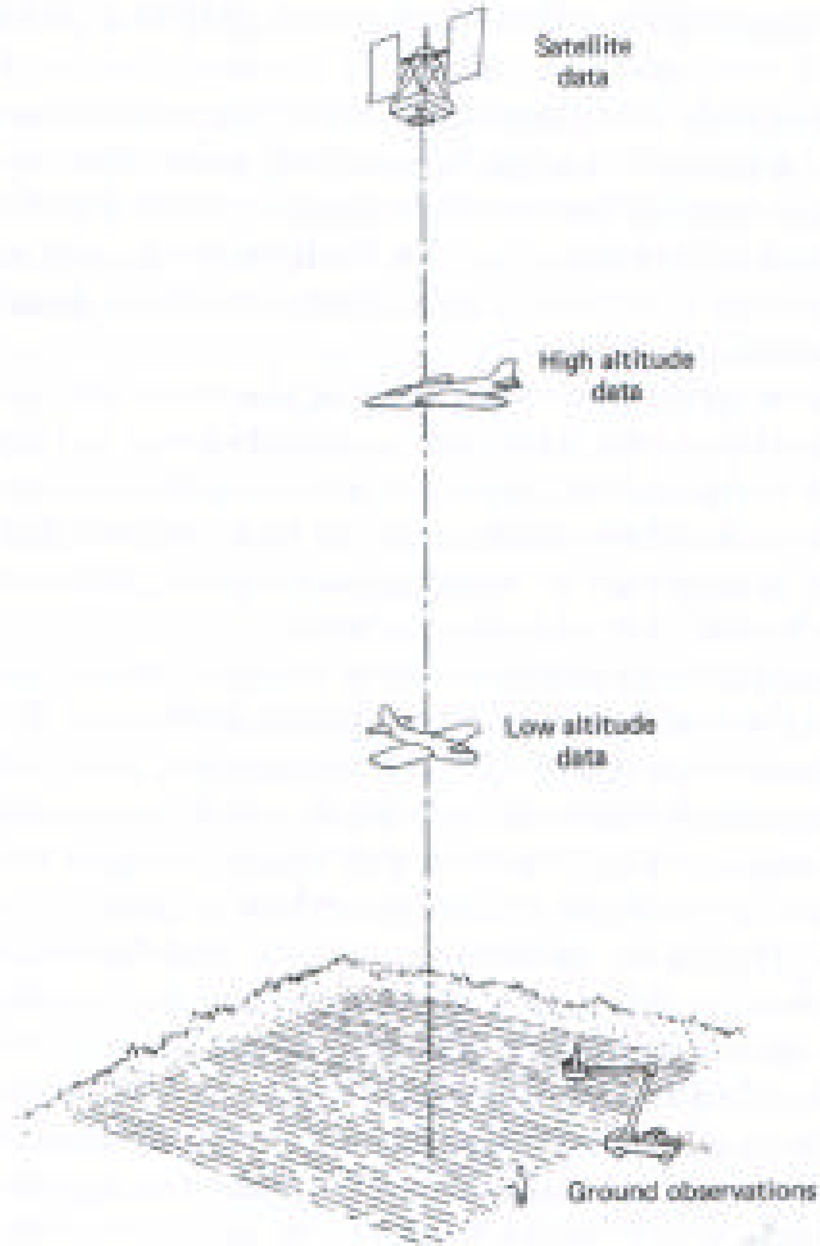


Figure 1.21 Multistage remote sensing concept.

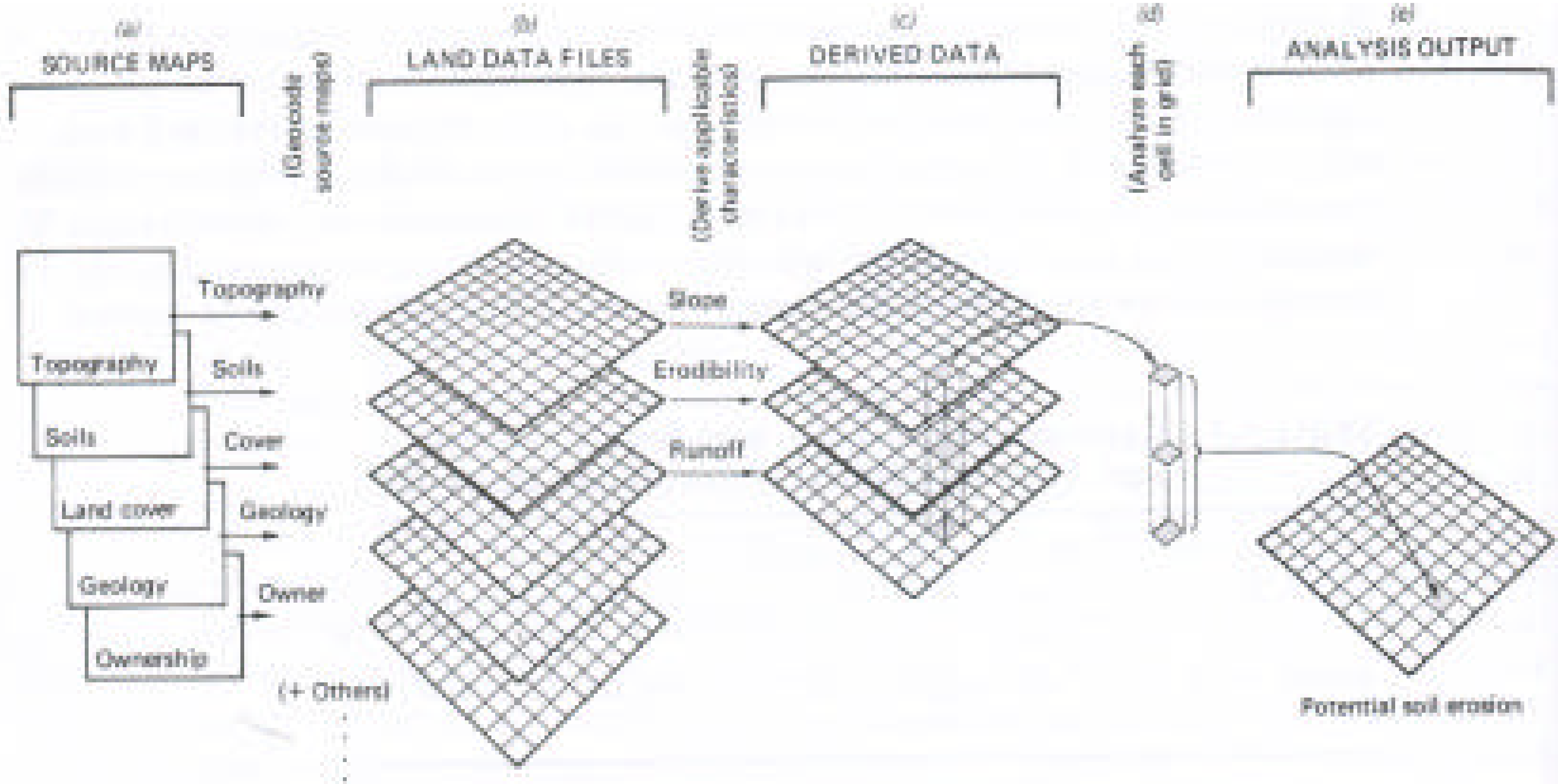


Figure 1.22 GIS analysis procedure for studying potential soil erosion.

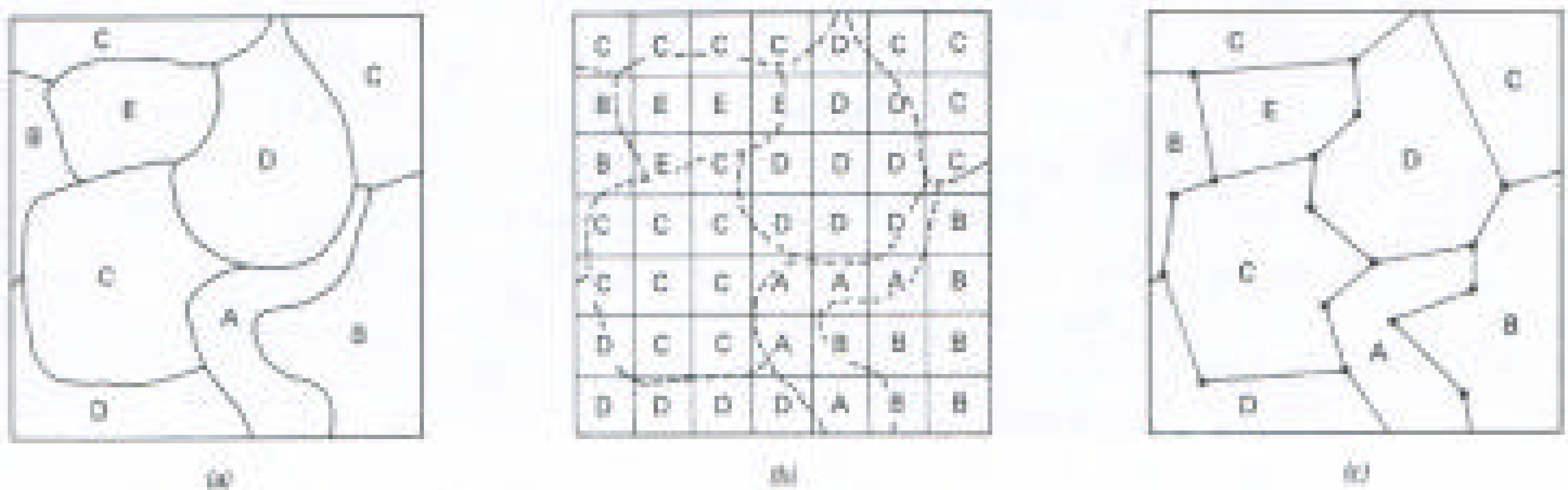


Figure 1.23 Raster versus vector data formats: (a) original line map, (b) raster format, and (c) vector format.