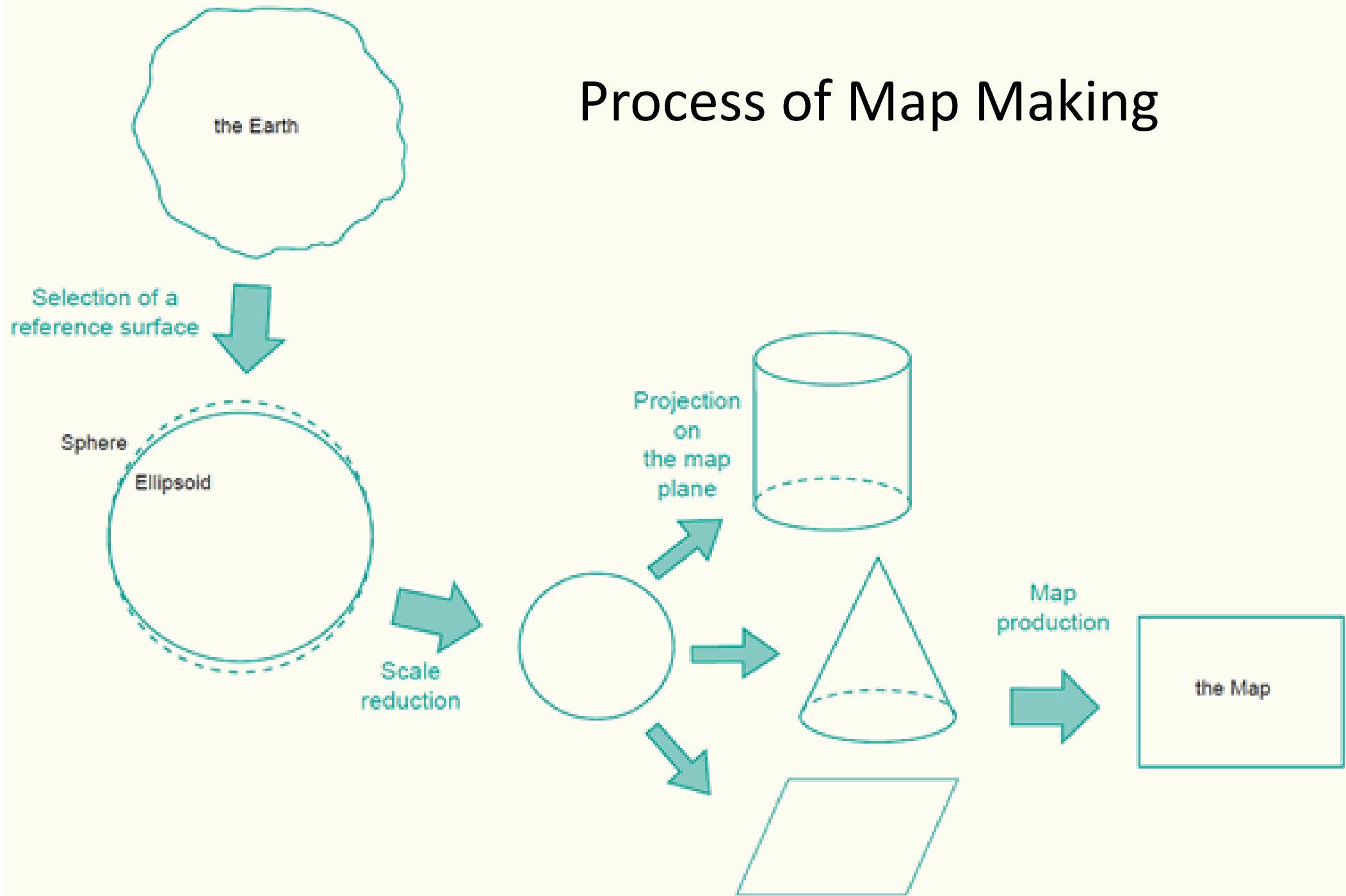


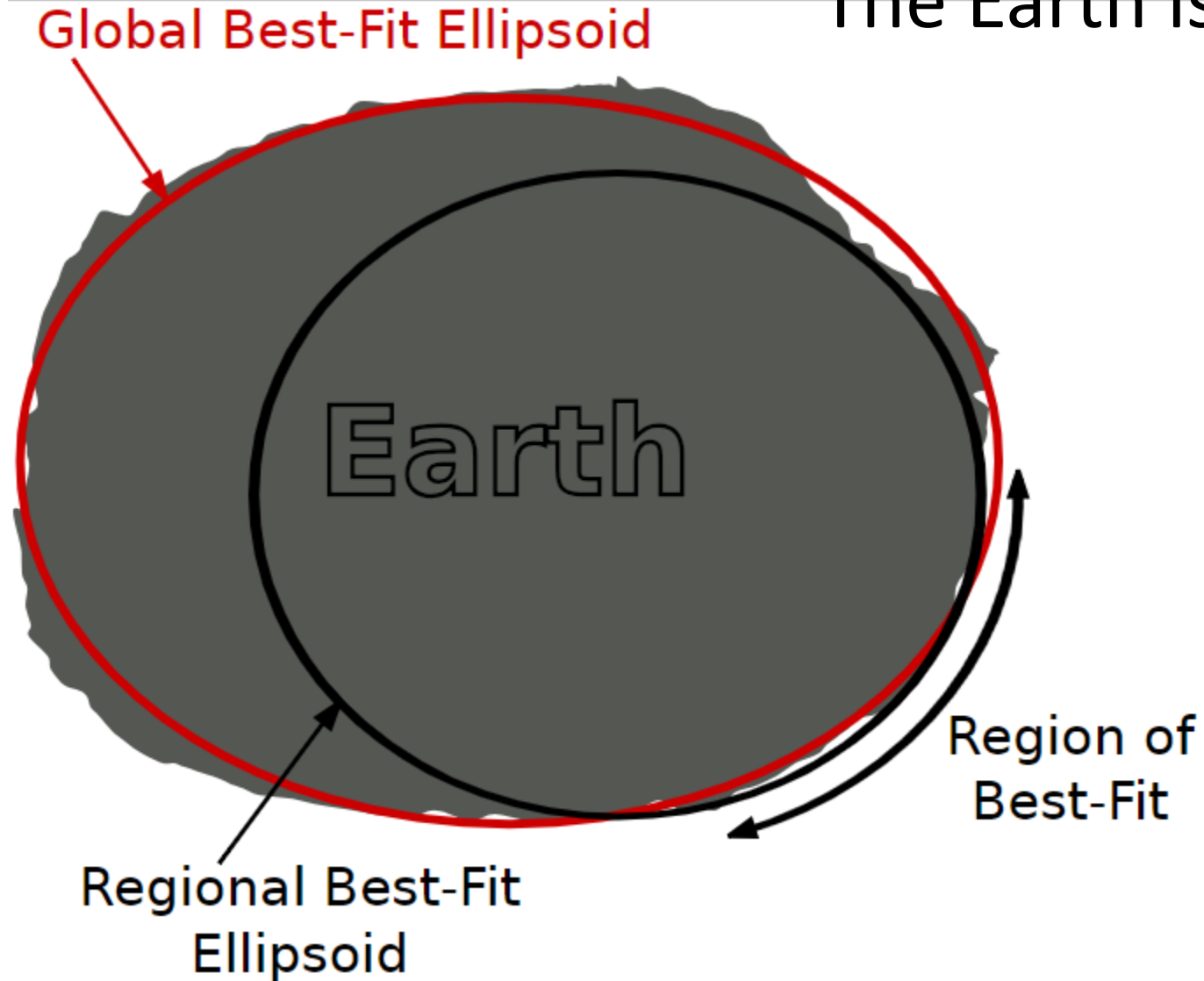
Coordinate Reference Systems

Rolf Becker

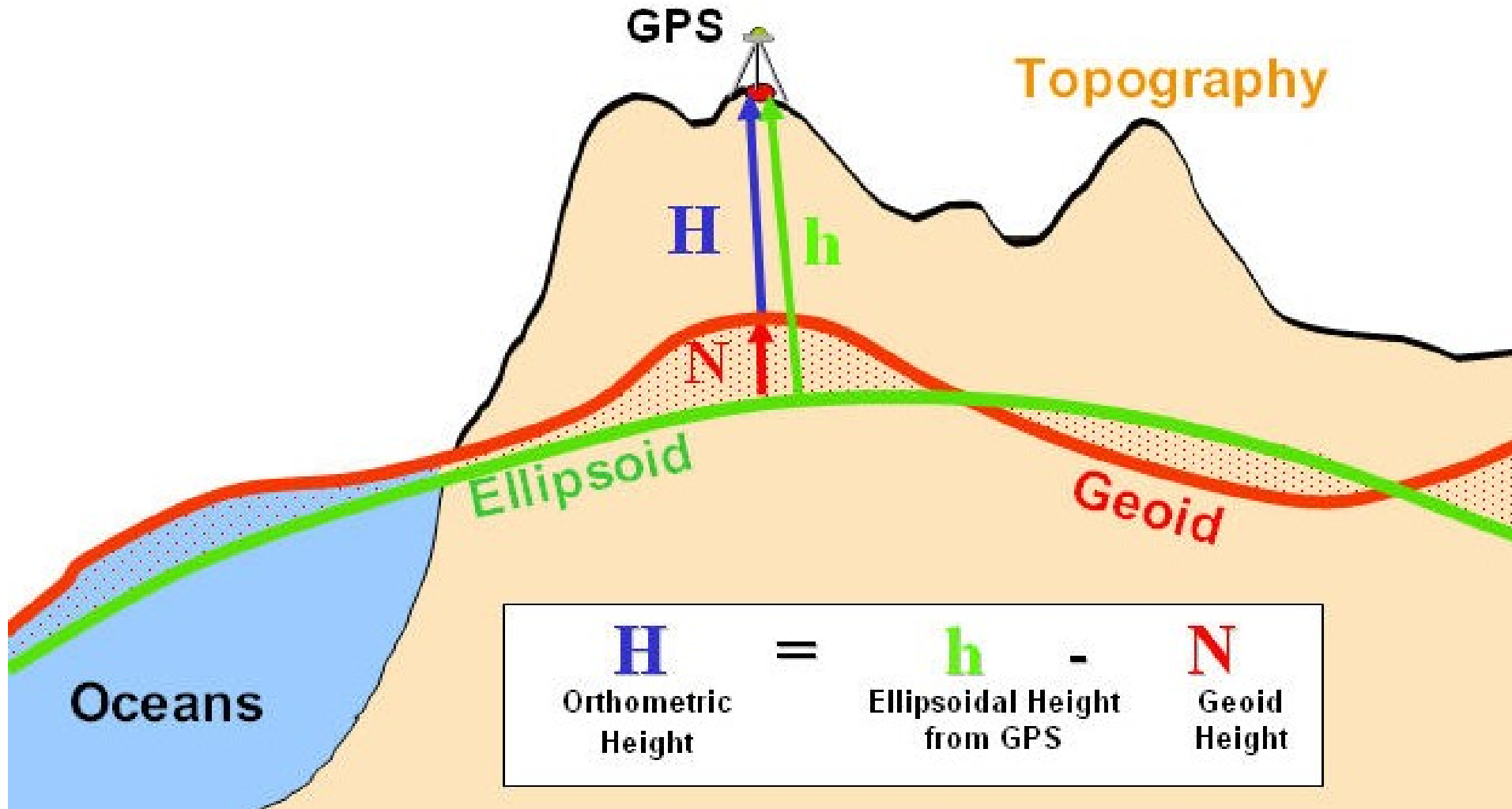
Process of Map Making

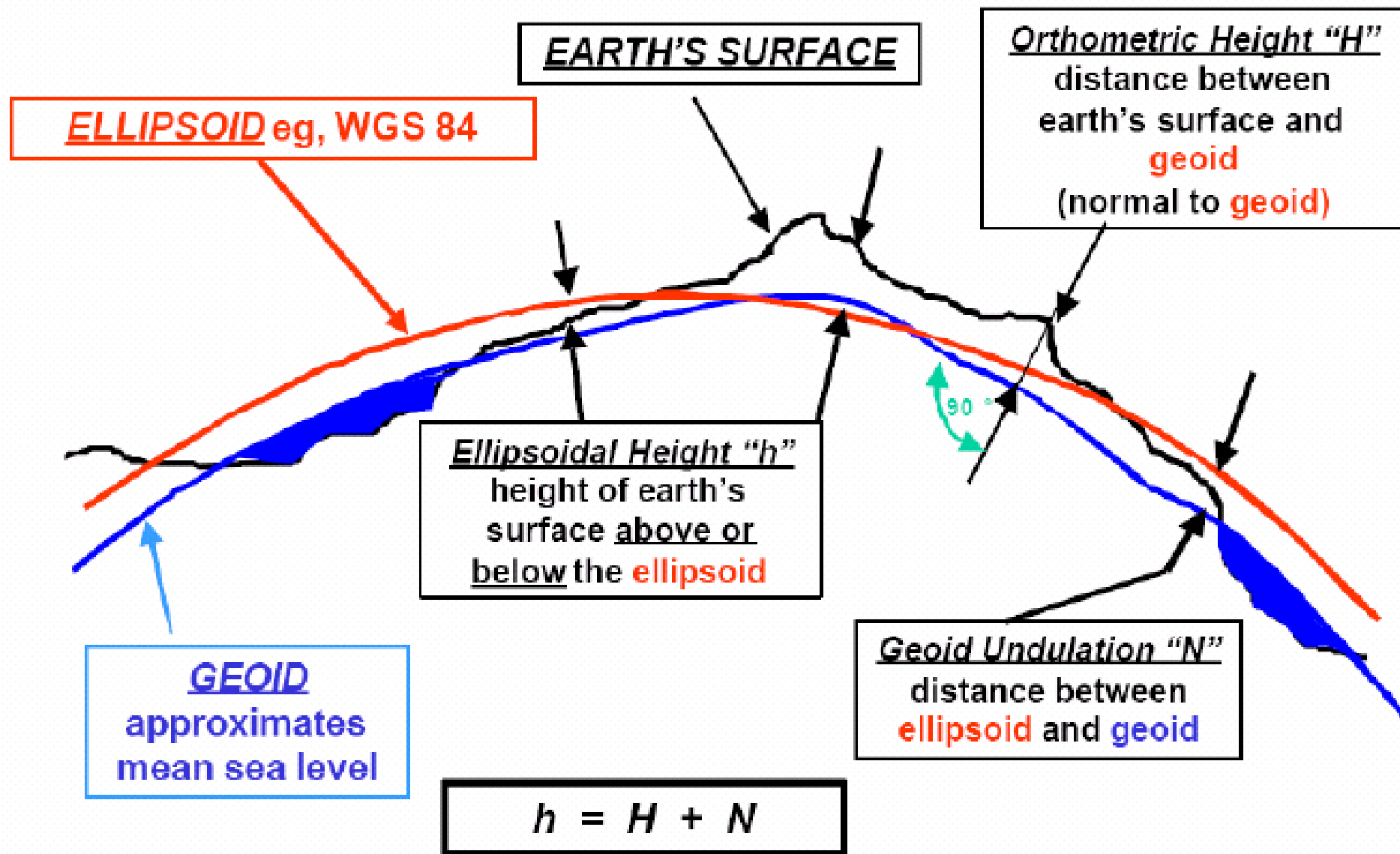


The Earth is a Potato



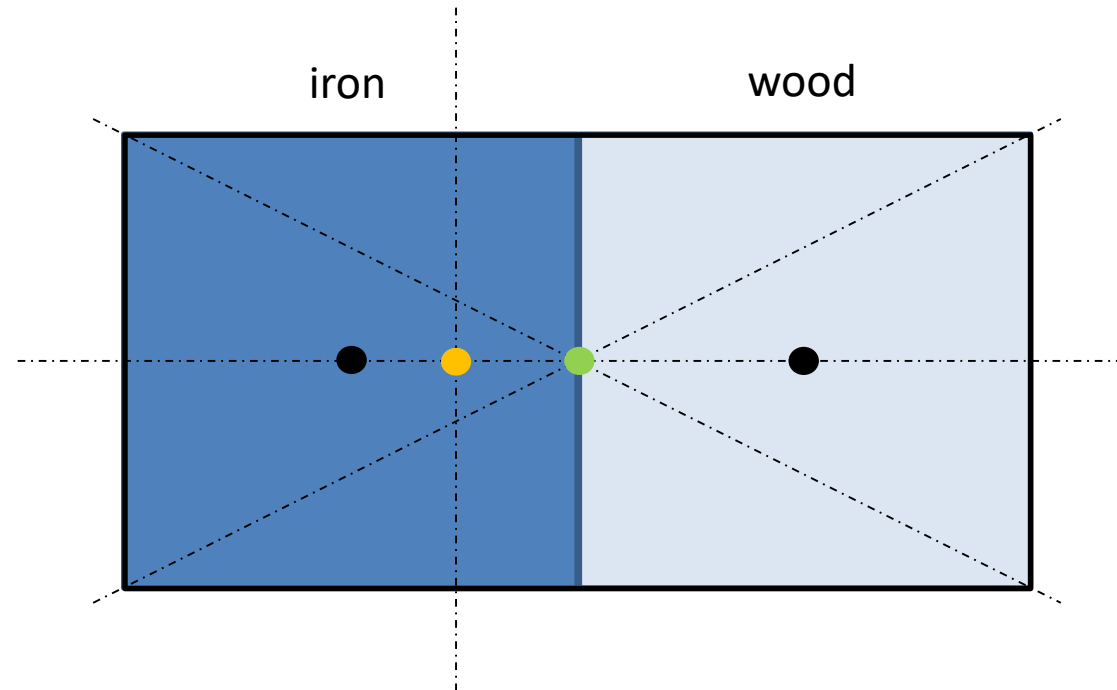
Geoid, Ellipsoid, Topography





Global Ellipsoid: Center?

- Geometric Center (GC): green dot
- Center of Mass (CM), Center of Gravity: yellow dot
- Example: one block made of two materials, half iron, half wood

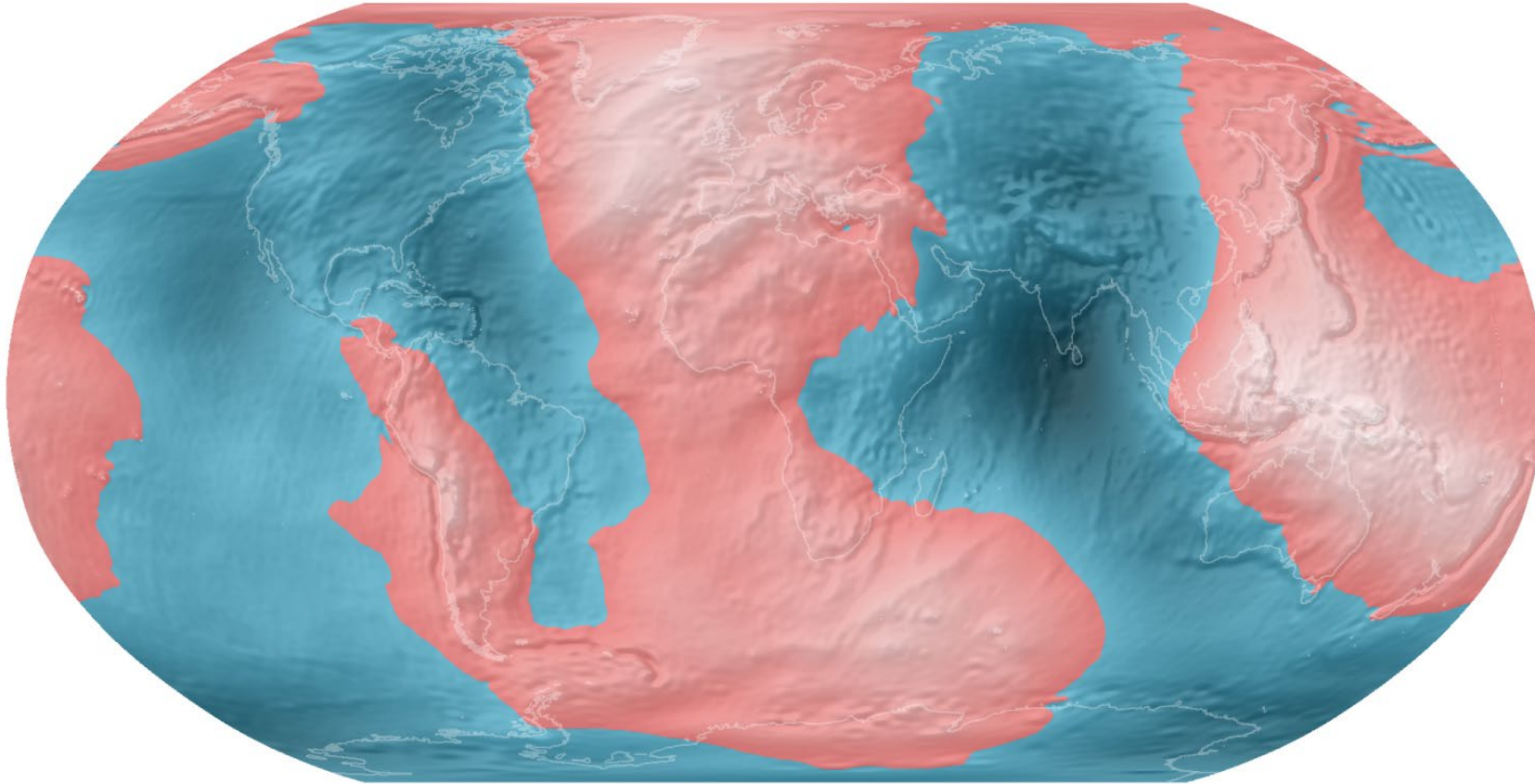


GRS80

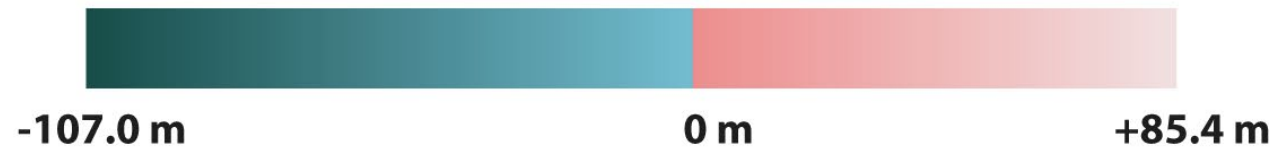
- GRS 80, or Geodetic Reference System 1980, is a geodetic reference system consisting of a **global reference ellipsoid** and a **gravity field model**.
- The reference ellipsoid is regular.
- The **geoid** (/ˈdʒiːɔɪd/) is the **shape that the surface of the oceans would take under the influence of Earth's gravity and rotation alone**, in the absence of other influences such as winds and tides.
- Gravitational equipotential surface
- The geoid is irregular.

Deviation of the Geoid from the idealized figure of the Earth

(difference between the EGM96 geoid and the WGS84 reference ellipsoid)



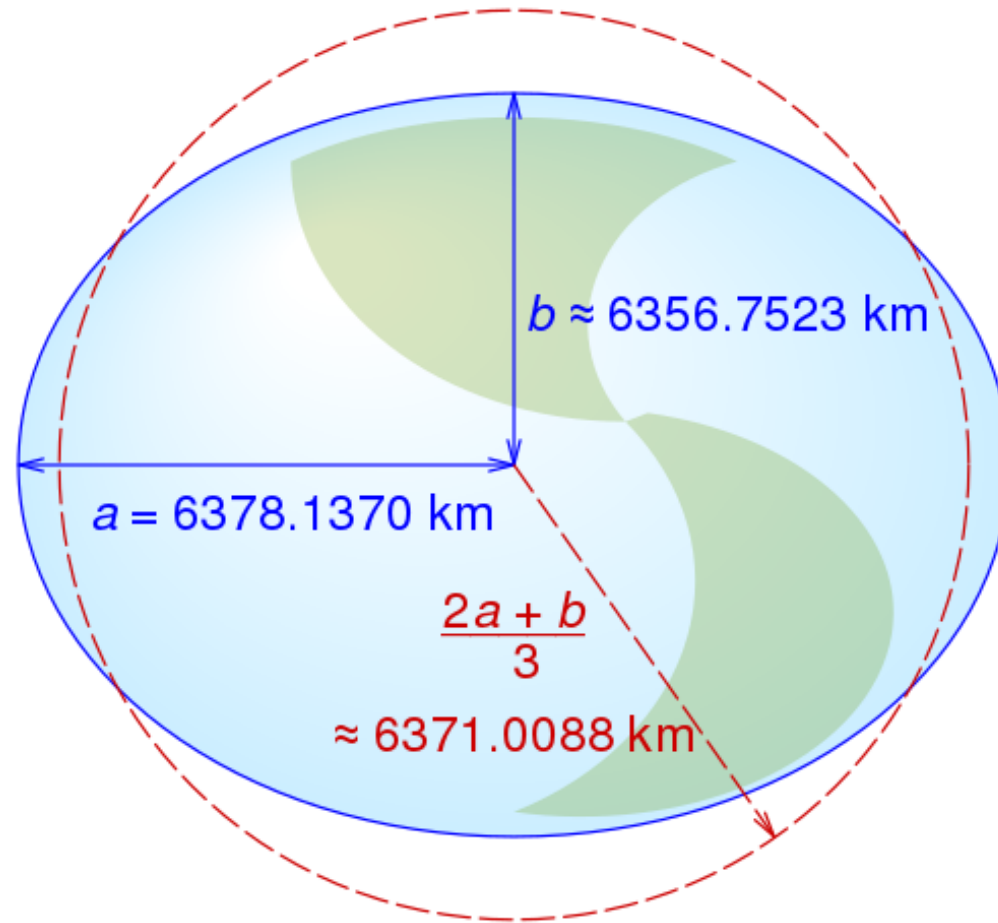
Red areas are above the idealized ellipsoid; blue areas are below.



https://commons.wikimedia.org/wiki/File:Geoid_height_red_blue_averagebw.png

World Geodetic System WGS84 (EPSG:4326)

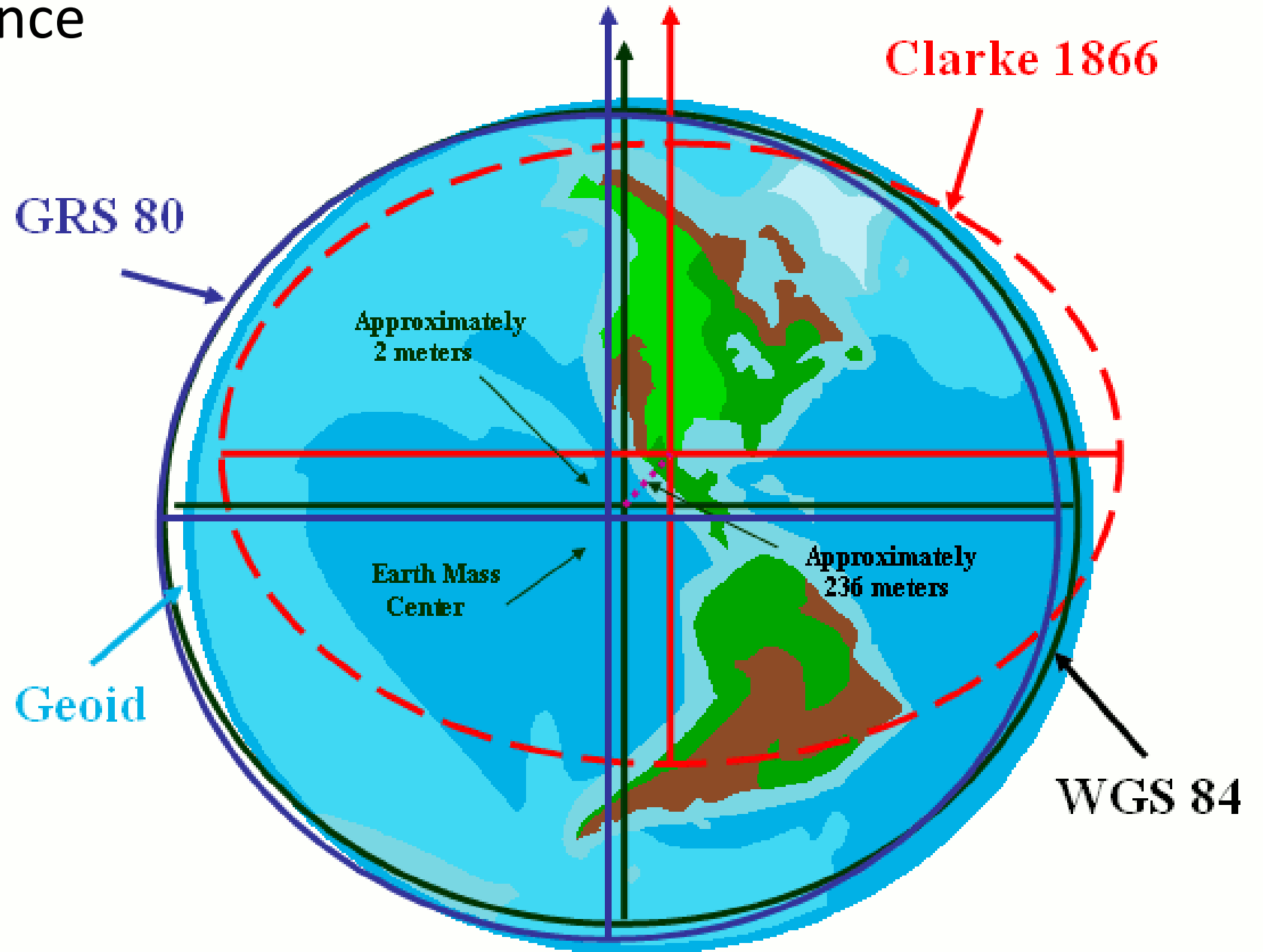
- Used by GPS
- Origin located in Earth's center of mass
- Ref. ellipsoid differs slightly from GRS80
- Equatorial (a), polar (b) and mean Earth radii as defined in the 1984 World Geodetic System revision (not to scale)



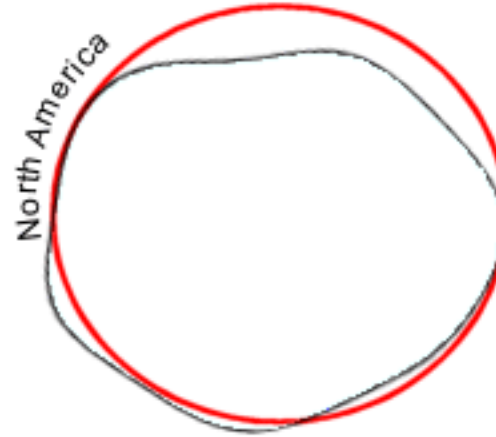
https://commons.wikimedia.org/wiki/File:WGS84_mean_Earth_radius.svg
https://en.wikipedia.org/wiki/World_Geodetic_System#WGS84

Different Reference Ellipsoids

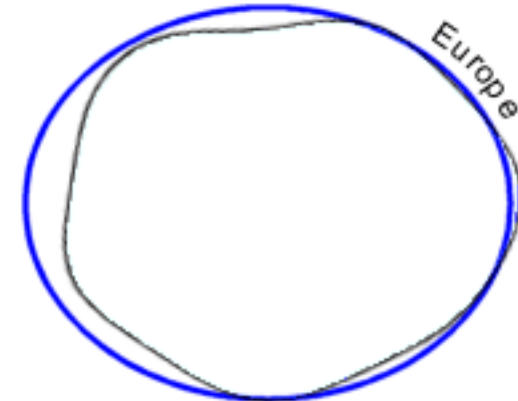
NOAA:
National Oceanic
and Atmospheric
Agency



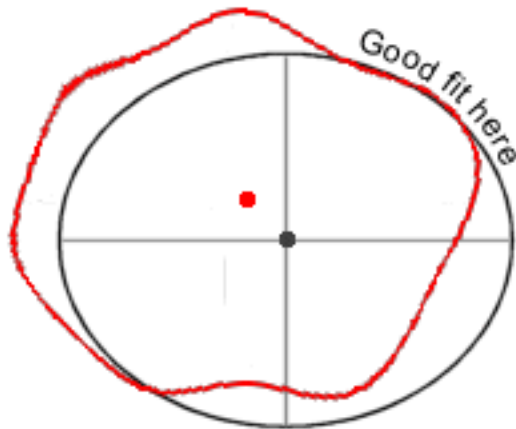
- Ellipsoid approximates geoid locally



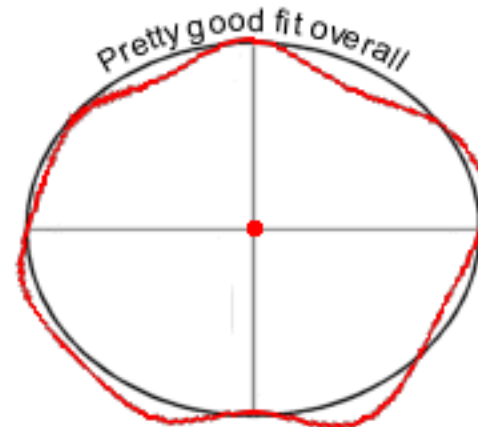
The red ellipsoid fits the geoid well in North America.



The blue ellipsoid fits the geoid well in Europe.



Local datum



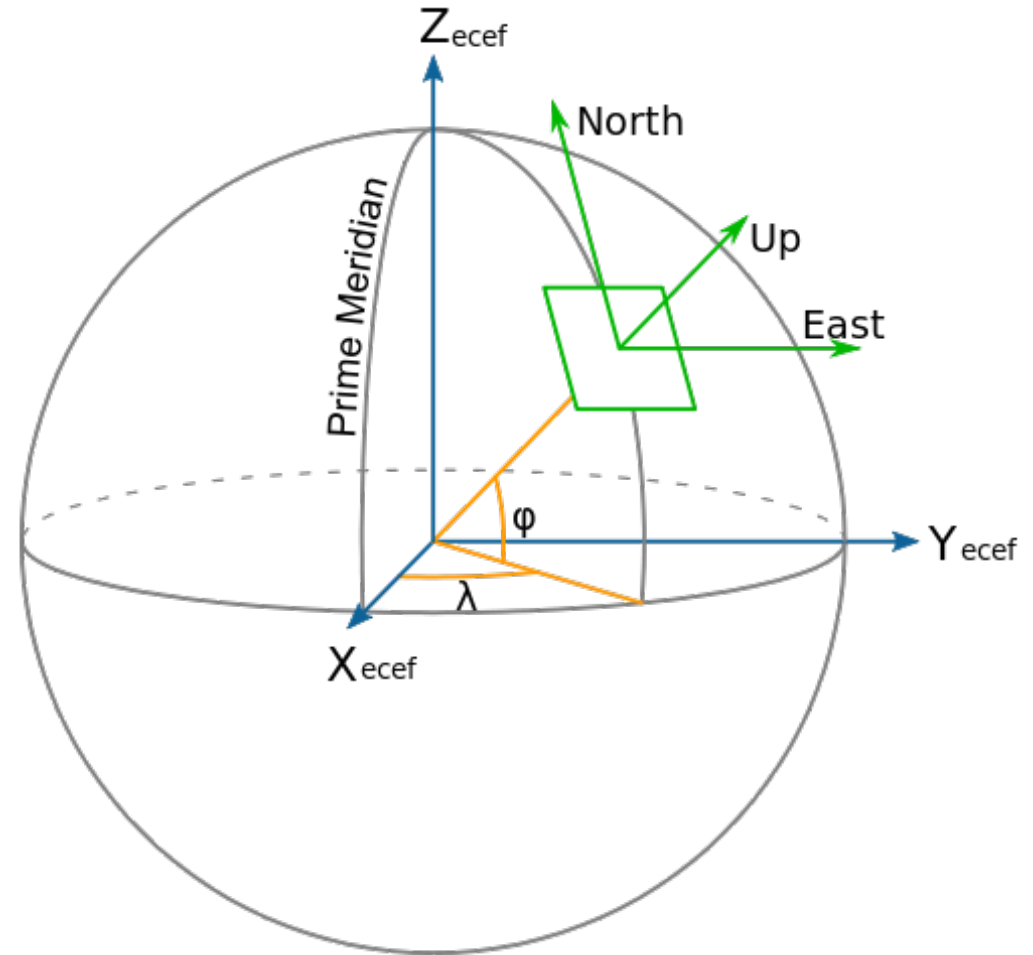
Earth-centered datum

- center of mass of geoid
- center of ellipsoid

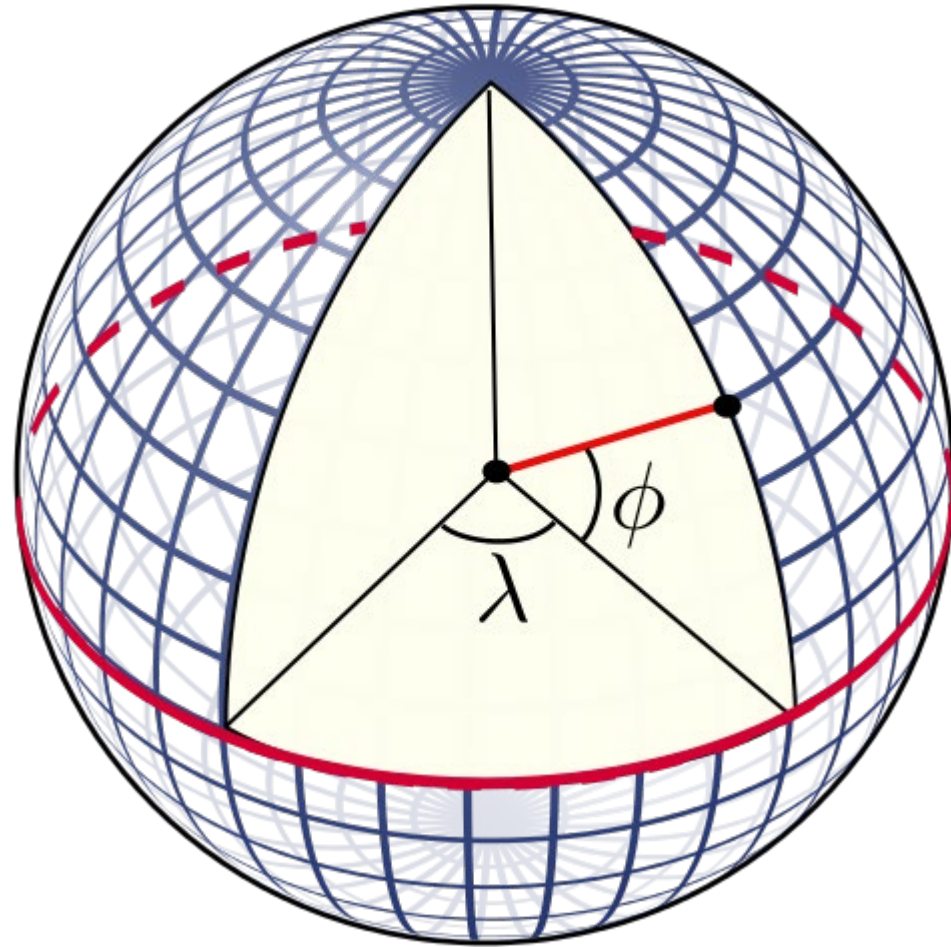
<http://www.geography.hunter.cuny.edu/~jochen/gtech361/lectures/lecture04/concepts/Datums/Components%20of%20a%20datum.htm>

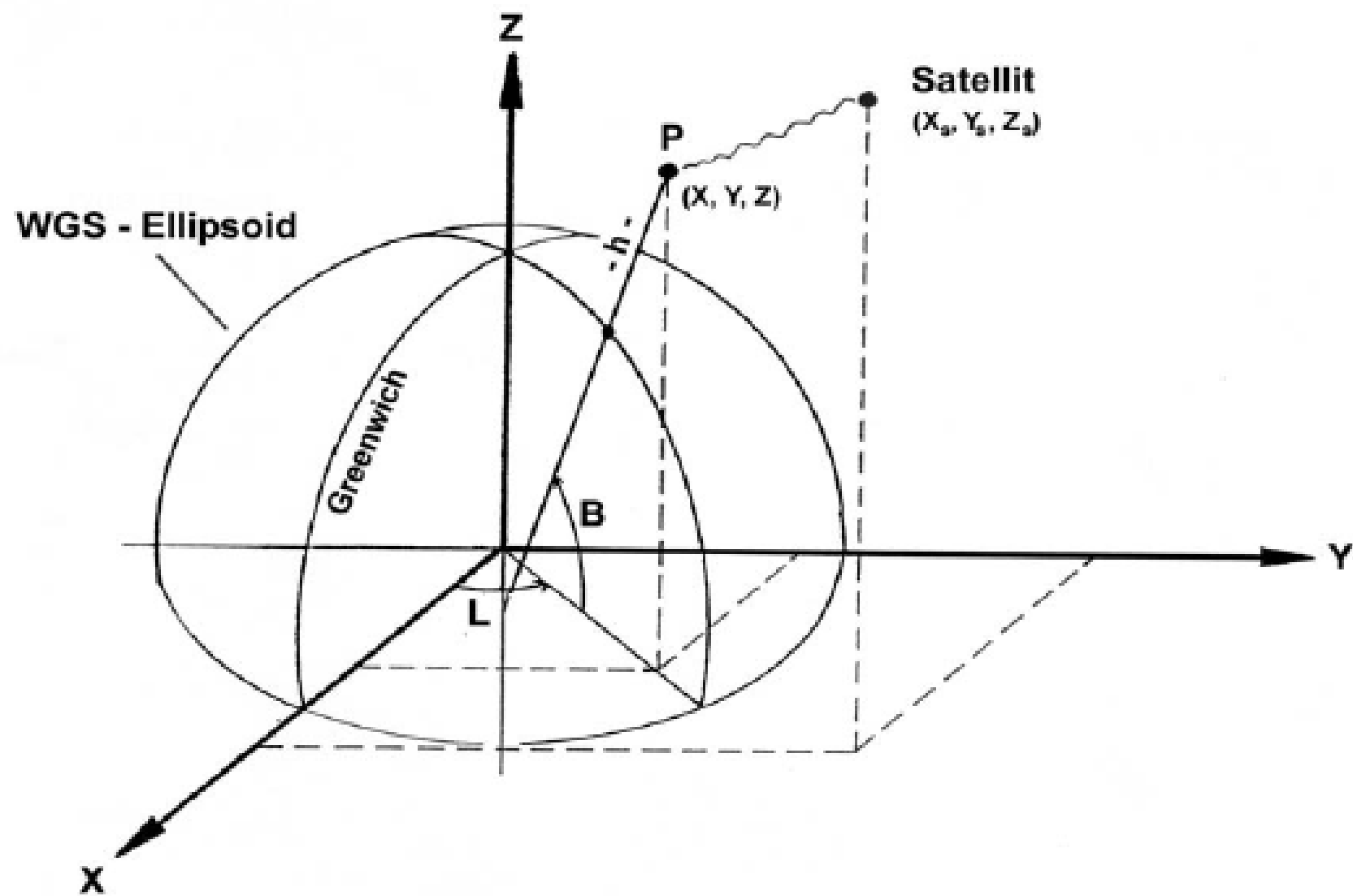
WGS 84: Latitude, Longitude (lat, lon)

- Prime Meridian: $\lambda = 0^\circ$ (approx. Greenwich)
- Latitude (Breite) φ , ϕ : measured from equator, North +, South -
- Longitude (Länge) λ : measured from PM, East +, West -

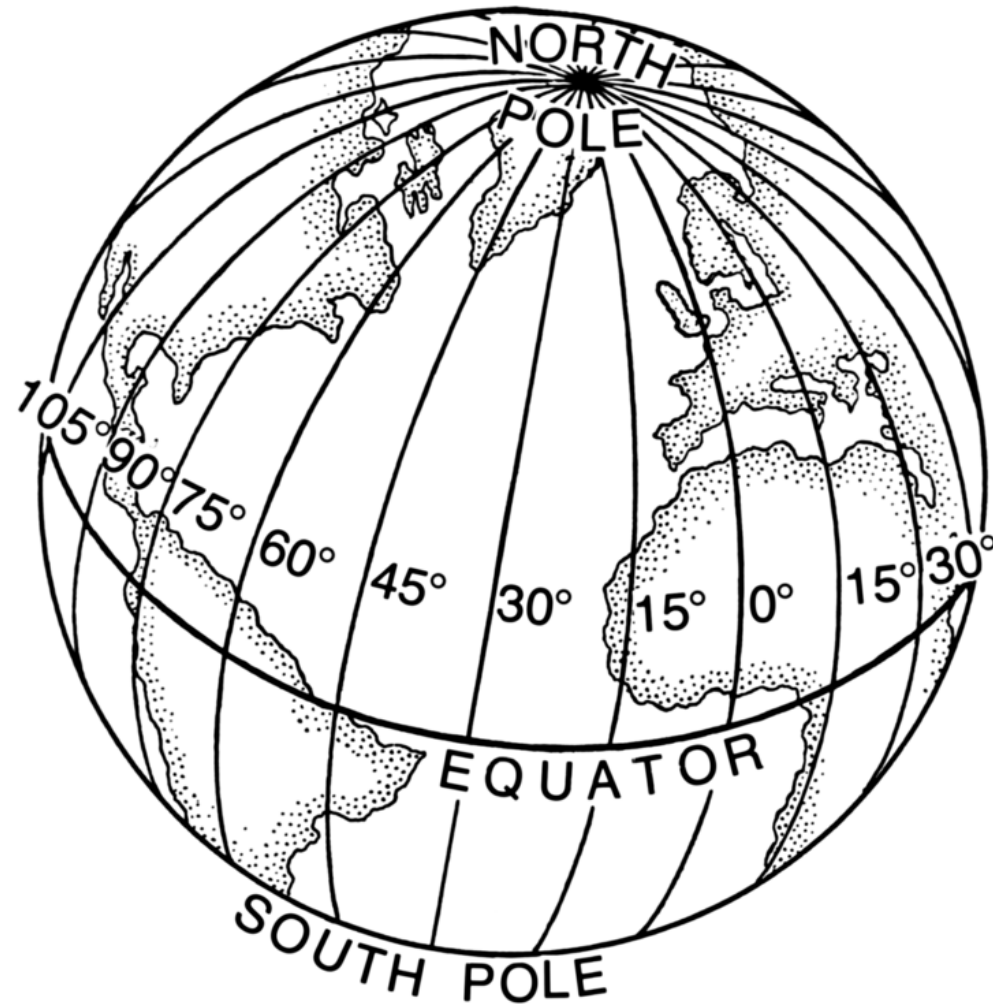


- Lat: N – S
- Lon: E – W





Longitude



[https://commons.wikimedia.org/wiki/File:Longitude_\(PSF\).png](https://commons.wikimedia.org/wiki/File:Longitude_(PSF).png)

Metropolis

Kamp-Lintfort:

- WGS84: 51° 30' 0" N 6° 32' 0" E
- WGS84: 51.5° 6.533333°
- UTM: 32U 328794 5708314

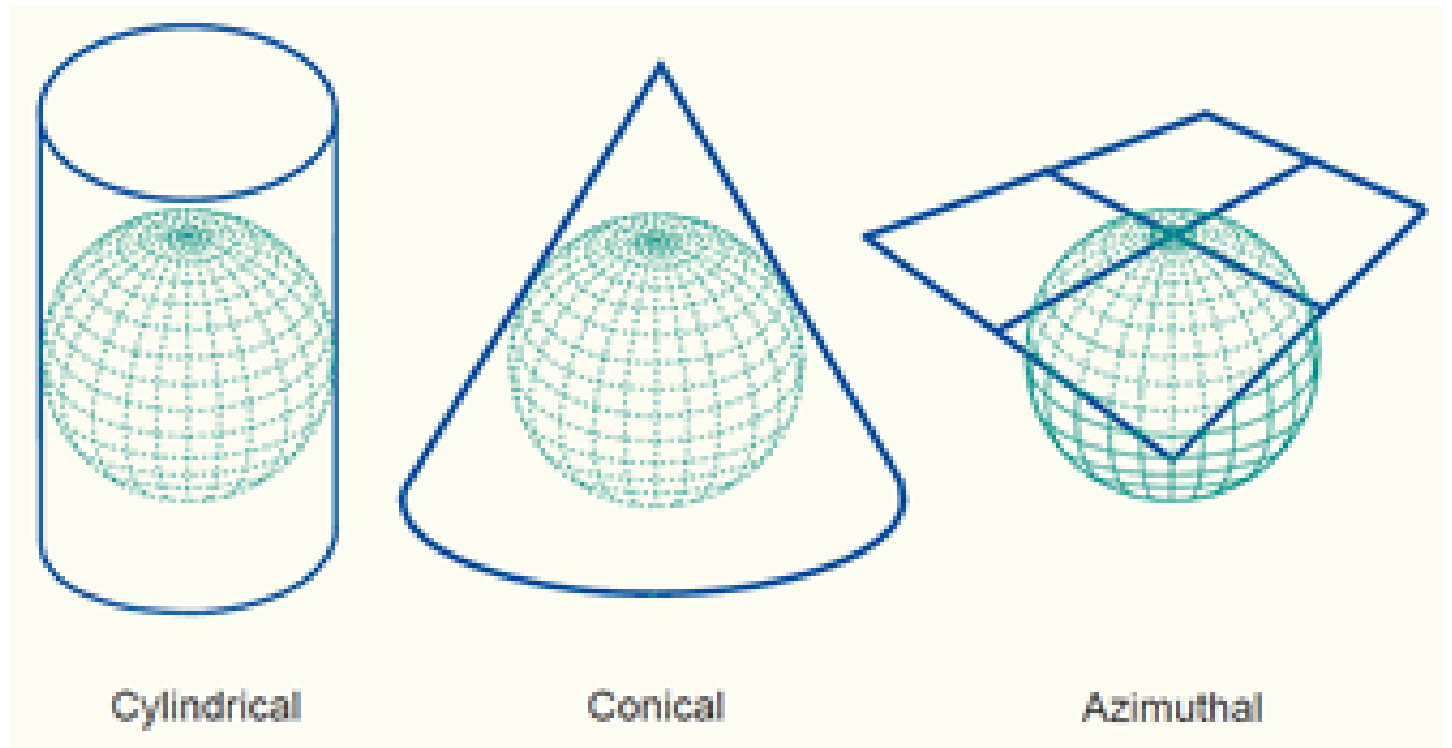
Which city?

- WGS84: 40° 42' 46" N 74° 0' 21" W
- WGS84: 40.712778° -74.005833°
- UTM: 18T 583973 4507349

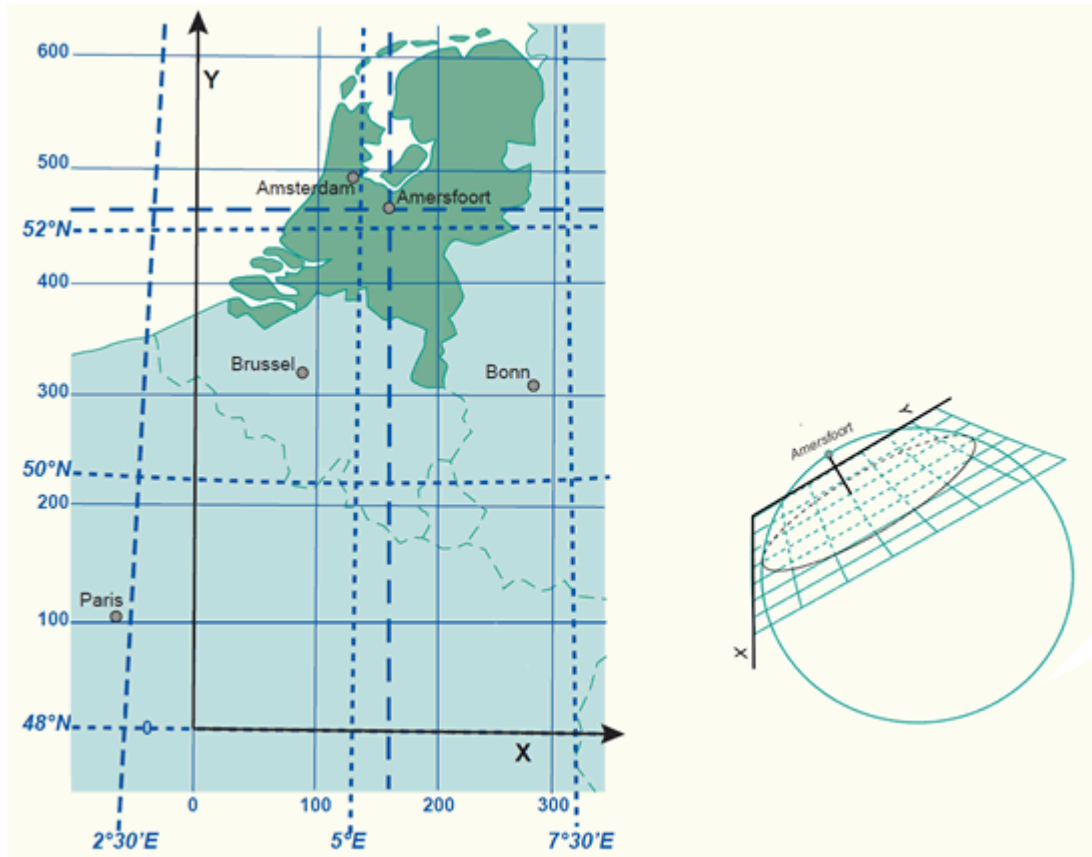
[https://tools.wmflabs.org/geohack/geohack.php?pagename=Kamp-Lintfort&language=de¶ms=51.5 N 6.533333333333333 E region:DE-NW type:city\(37346\)](https://tools.wmflabs.org/geohack/geohack.php?pagename=Kamp-Lintfort&language=de¶ms=51.5 N 6.533333333333333 E region:DE-NW type:city(37346))

Map Projections

- Geographic coordinates:
lat, lon (radius)
- Cartesian coordinates:
x, y (z)
- Mostly optimized
locally!

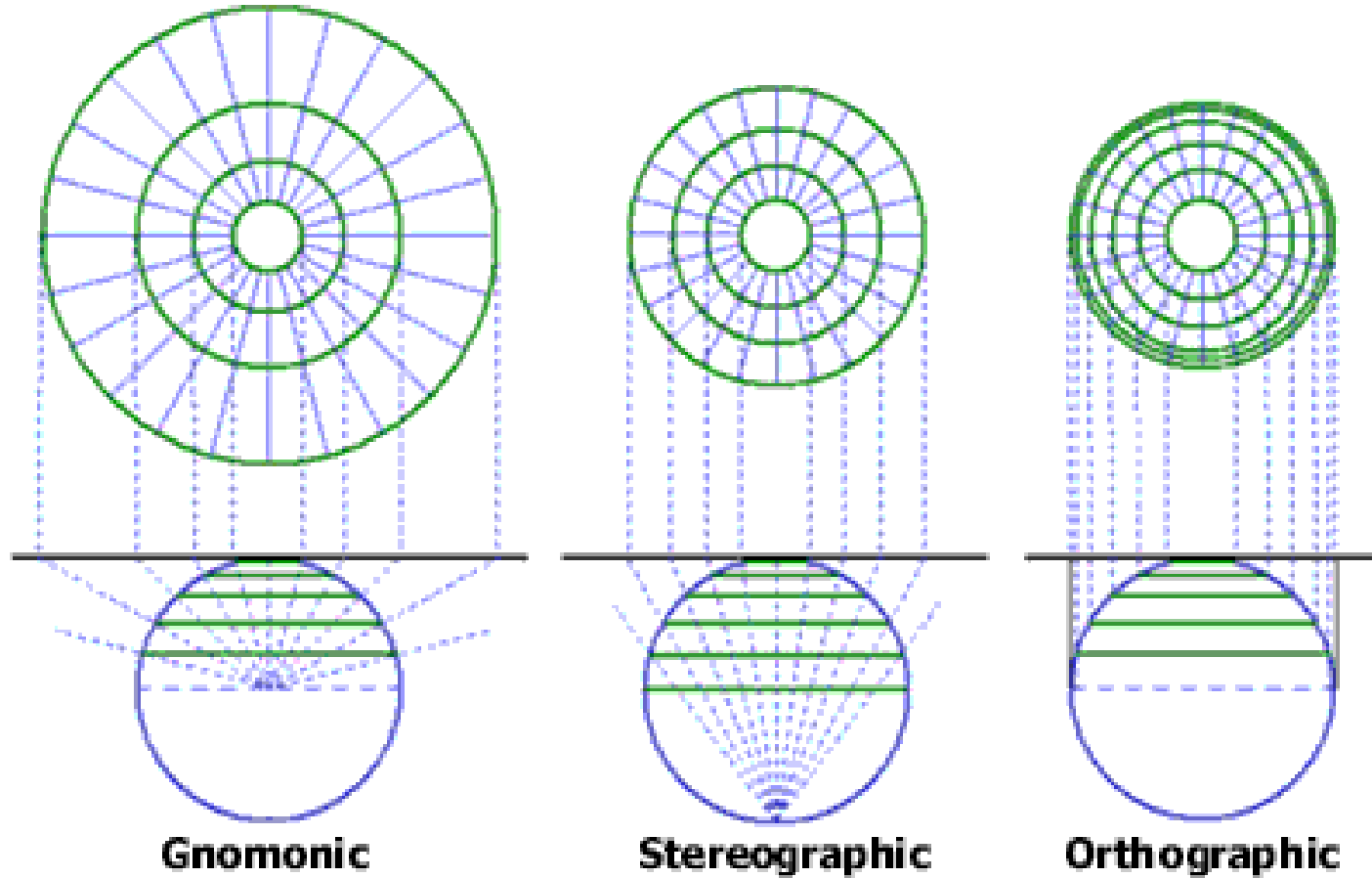


Map Projections



The coordinate system of the Netherlands is derived from an oblique azimuthal stereographic projection.

Different Azimuthal Projections

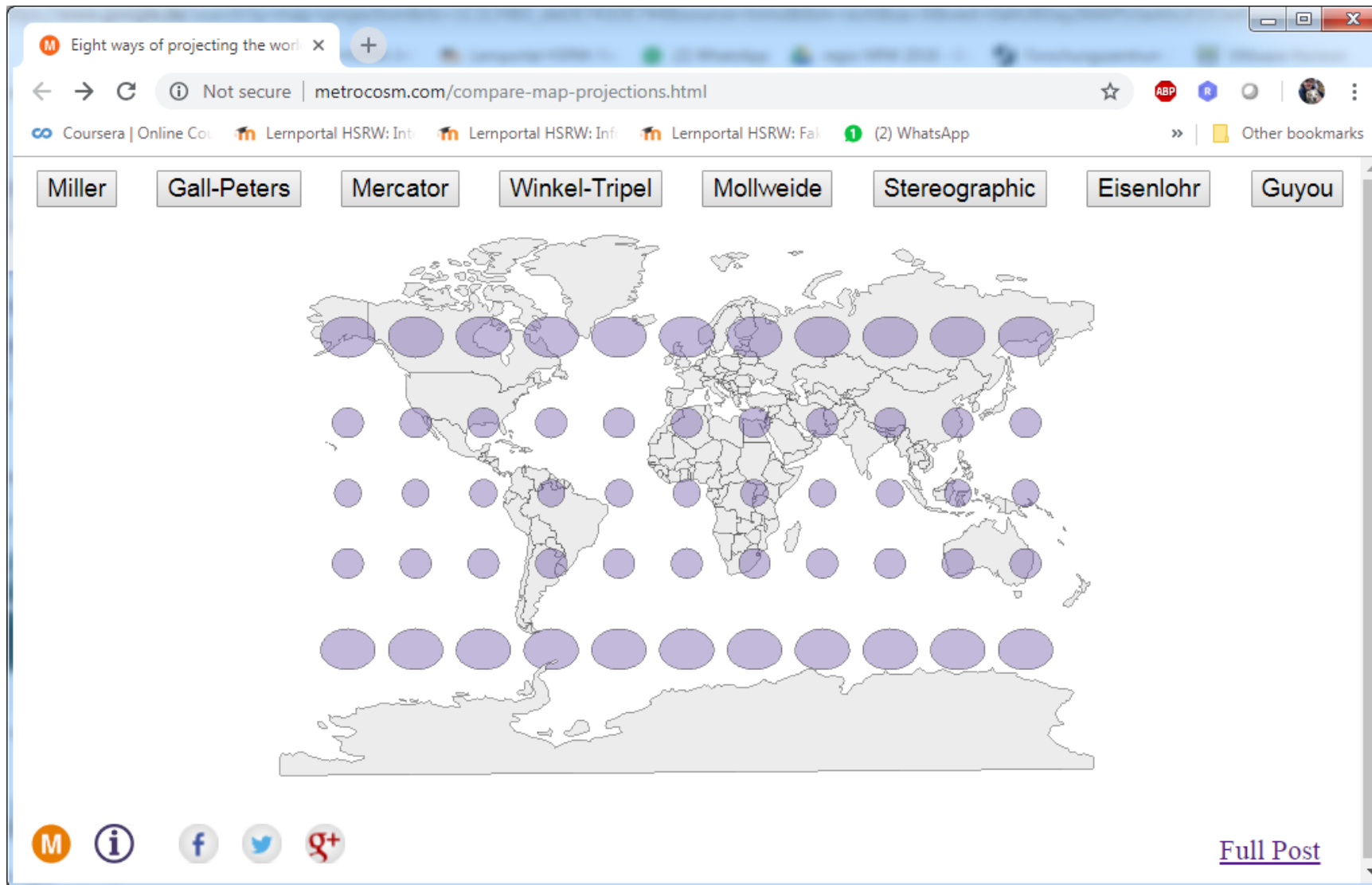


<http://www.geo.hunter.cuny.edu/~jochen/gtech201/lectures/lec6concepts/Map%20coordinate%20systems/Perspective.htm>

Projection Invariants (what is preserved)

- Preserving direction (azimuthal or zenithal), a trait possible only from one or two points to every other point
- **Preserving shape locally (conformal or orthomorphic)**
- Preserving area (equal-area or equiareal or equivalent or authalic)
- Preserving distance (equidistant), a trait possible only between one or two points and every other point
- Preserving shortest route, a trait preserved only by the gnomonic projection
- Because the sphere is not a developable surface, it is impossible to construct a map projection that is both equal-area and conformal.

Map Projection - Tissot's Indicatrices



<http://metrocosm.com/compare-map-projections.html>



Robinson



Plate Carrée



Winkel Tripel



Eckert IV



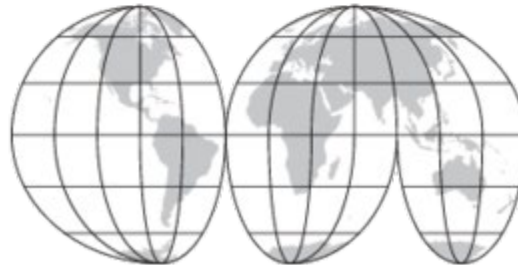
Mollweide



Mercator



Wagner VII

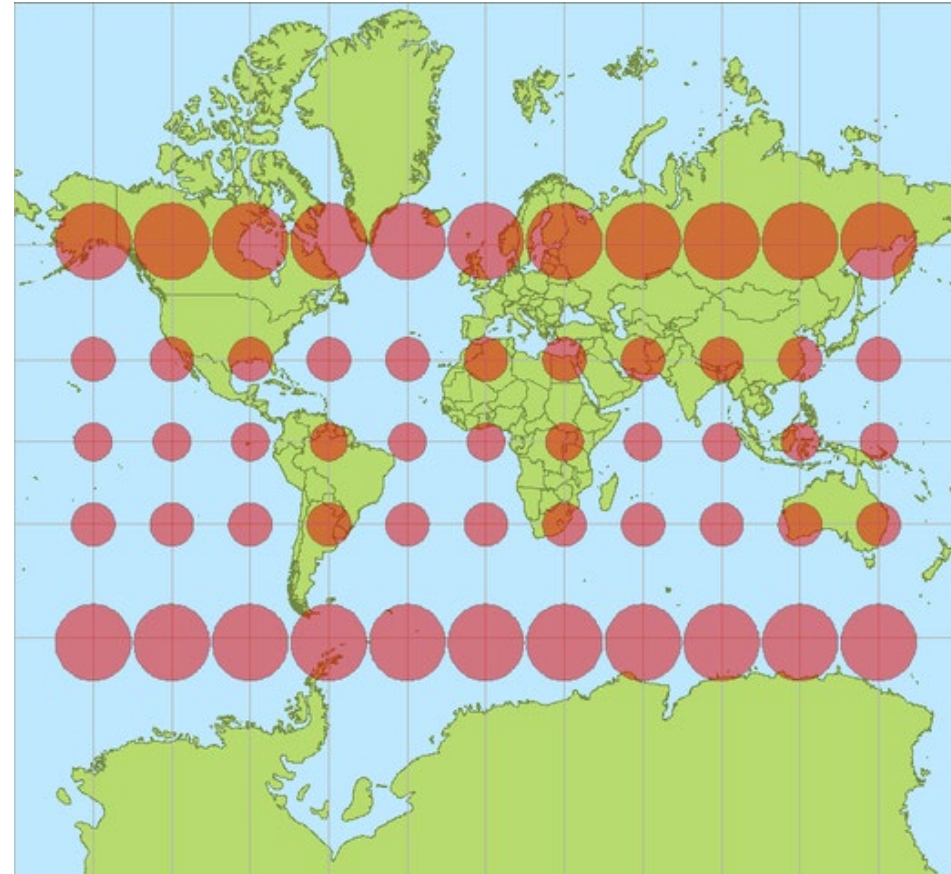
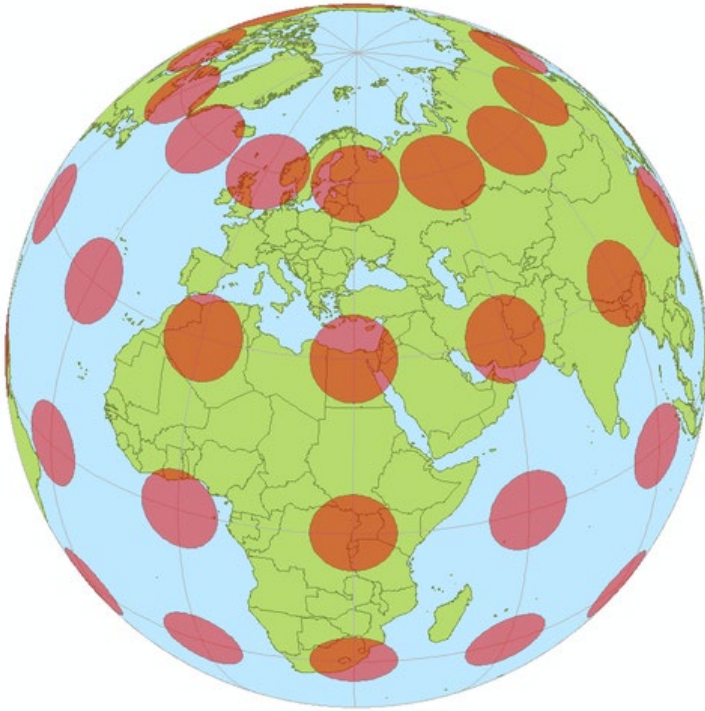


Interrupted Mollweide



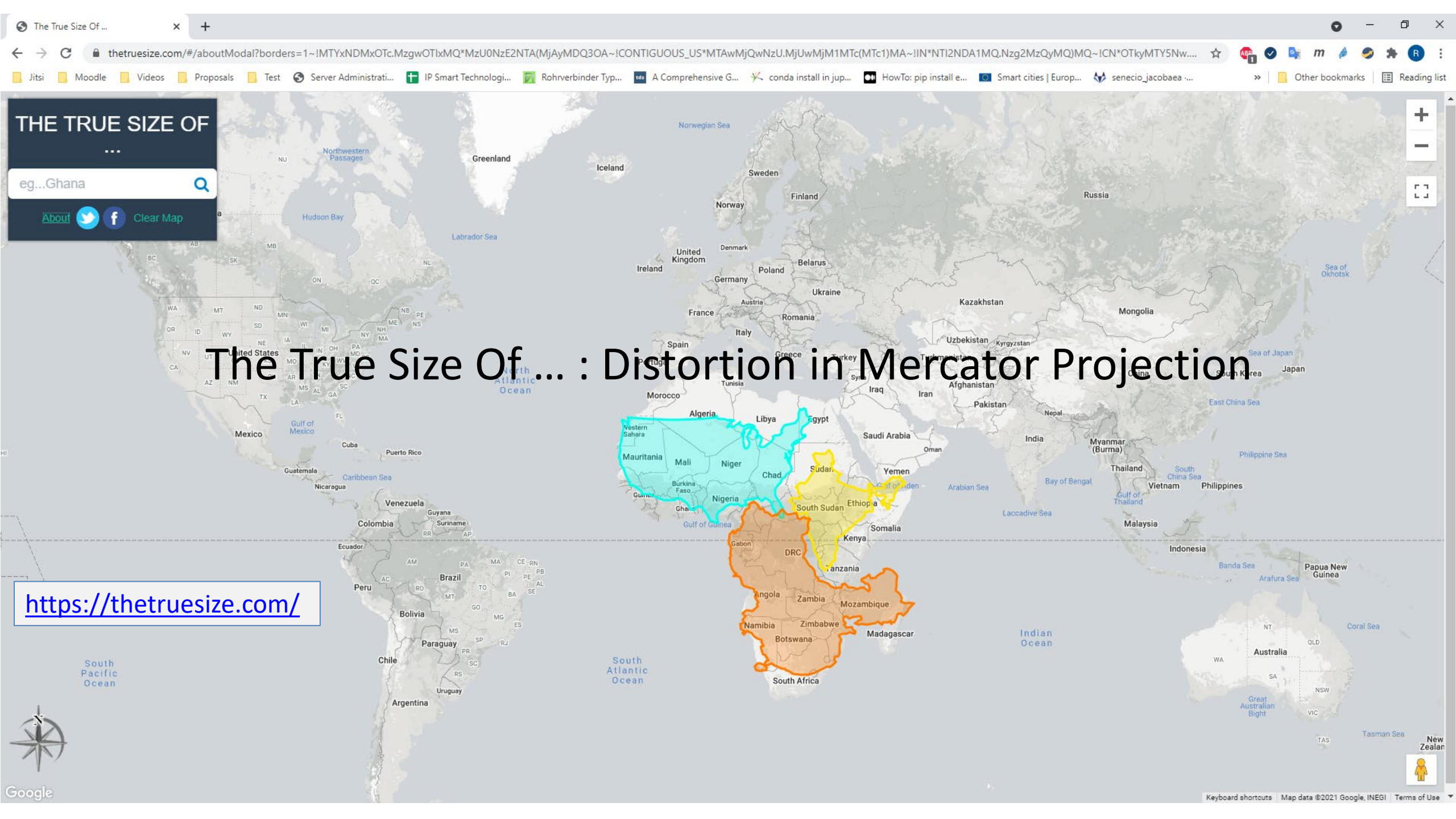
Goode Homolosine

Mercator Projection

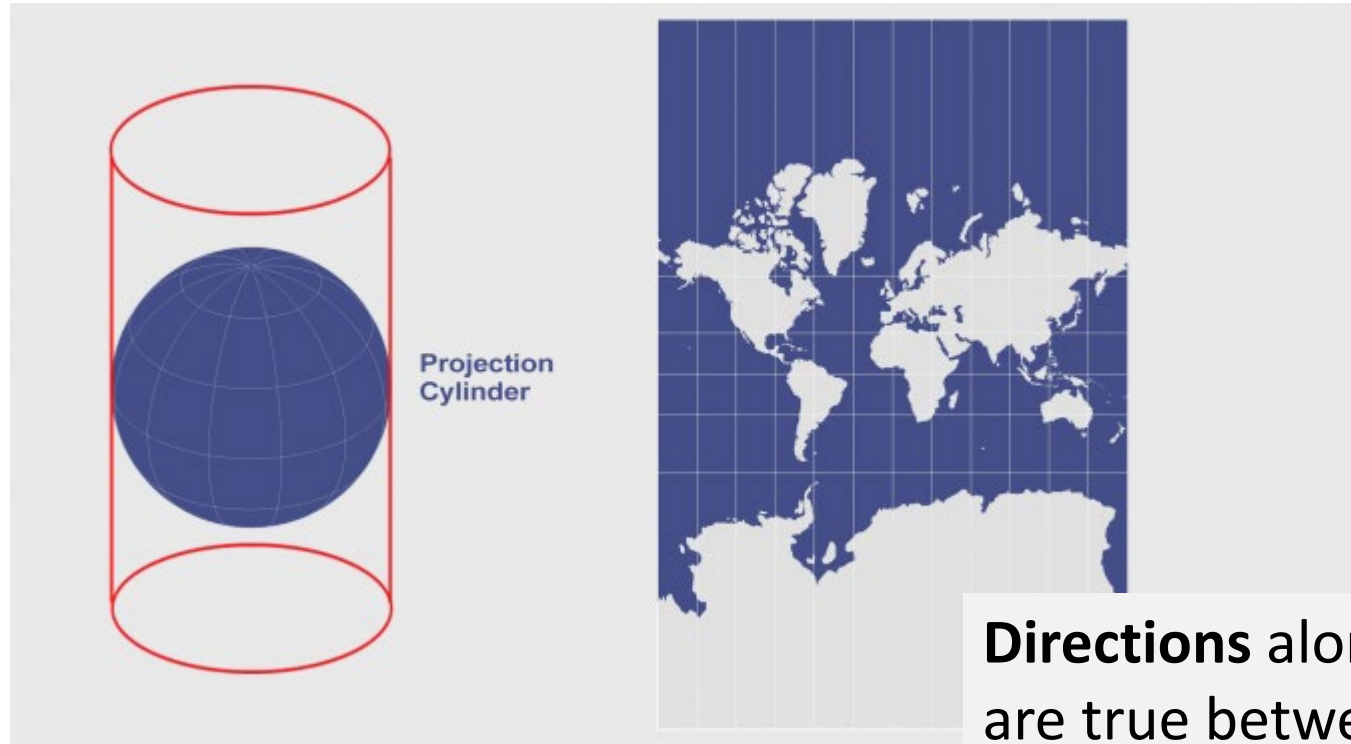


Red Dots:
Tissot's Indicatrix / Indicatrices

<https://de.wikipedia.org/wiki/Mercator-Projektion>



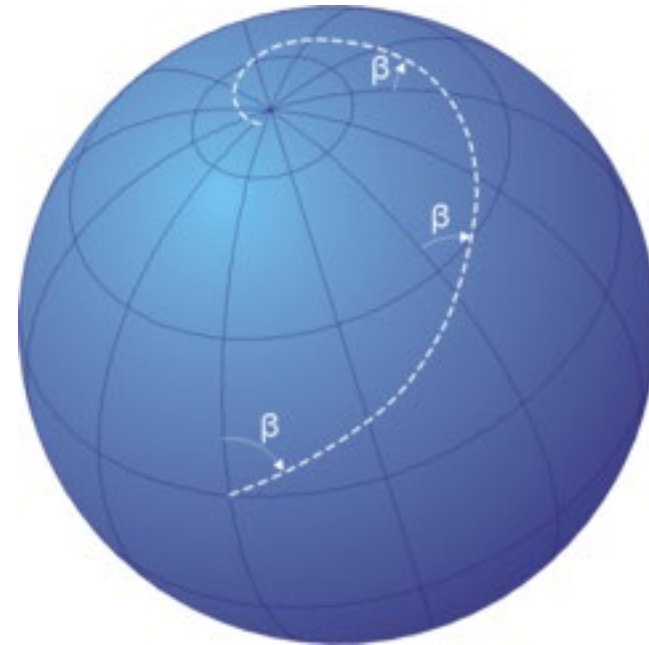
Mercator Projection



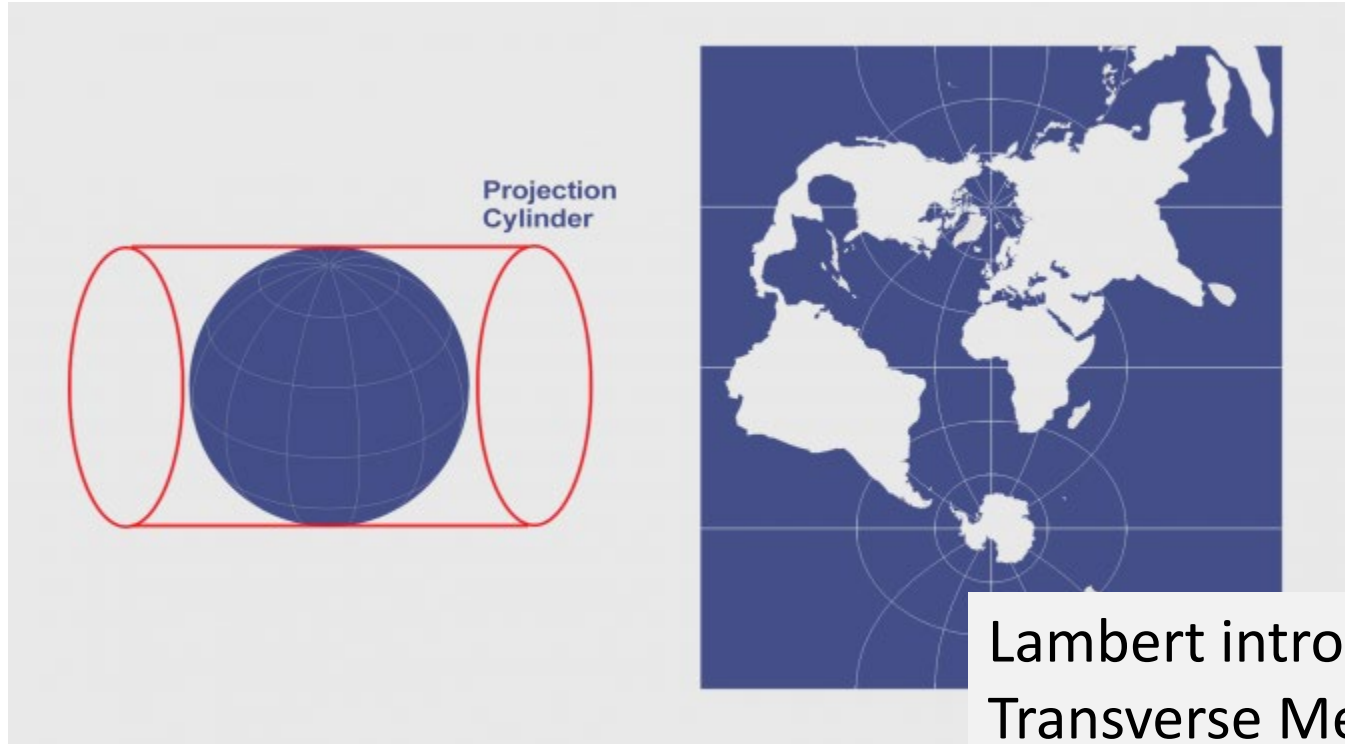
Directions along a Rhumb line are true between any two points on a map. **Distances** are true only along the Equator. Although it has a **conformal** property, areas are greatly distorted increasing size at poles.

Rhumb Line

- In navigation, a rhumb line, rhumb, (/rʌm/) or loxodrome is an arc crossing all meridians of longitude at the same angle, that is, a path with constant bearing as measured relative to true or magnetic north.

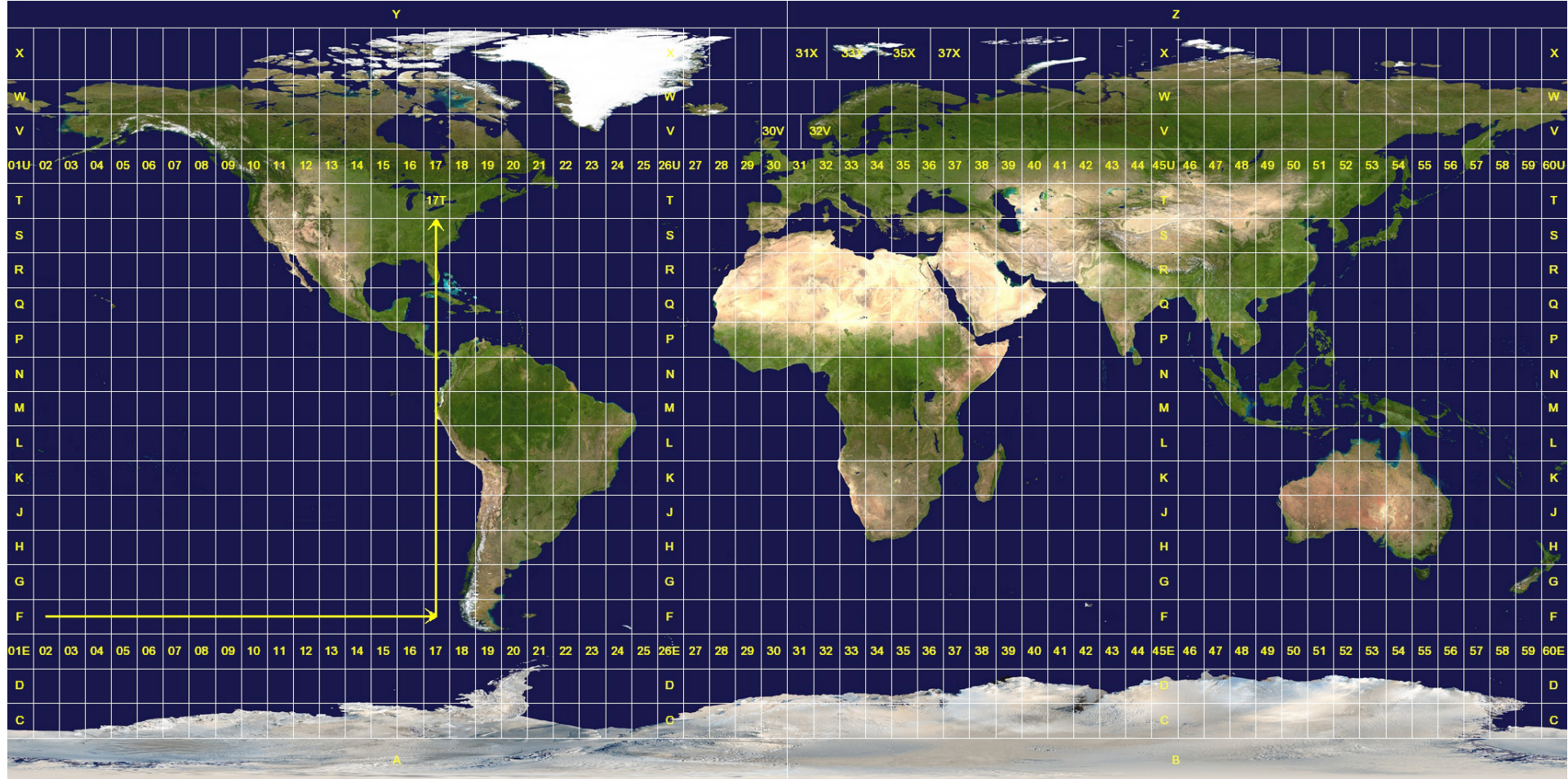


Tranverse Mercator Projection



Lambert introduced the Transverse Mercator in 1772. It uses a horizontally oriented cylinder tangent to a Meridian. This is particular useful for mapping large areas that are mainly north-south in extent.

Universal Transverse Mercator (UTM): Conformal Projection



https://en.wikipedia.org/wiki/Universal_Transverse_Mercator_coordinate_system

Nordrhein-Westfalen: ETRS89 / UTM, Realisation of WGS84

- ETRS89: European Terrestrial Reference System

Bezugssystem	Europäisch terrestrisches Referenzsystem 1989
Bezugsfläche	GRS80-Ellipsoid, Große Halbachse a : 6 378 137 m und Abplattung f : 1 : 298, 257 222 101
Datum/Lagerung	Fundamentalstationen des ITRS zum Zeitpunkt Januar 1989
Abbildung	Universale Transversale Mercatorabbildung (UTM)
Projektion	Schnittzylinder - siehe Abb. 2
Meridianstreifensystem	6° breite Meridianstreifen (Zonen)
Hauptmeridian	nicht längentreu, Maßstabsfaktor 0,9996
Netzgrundlage	ETRS89

Tab. 1: Wesentliche Merkmale von ETRS89/UTM

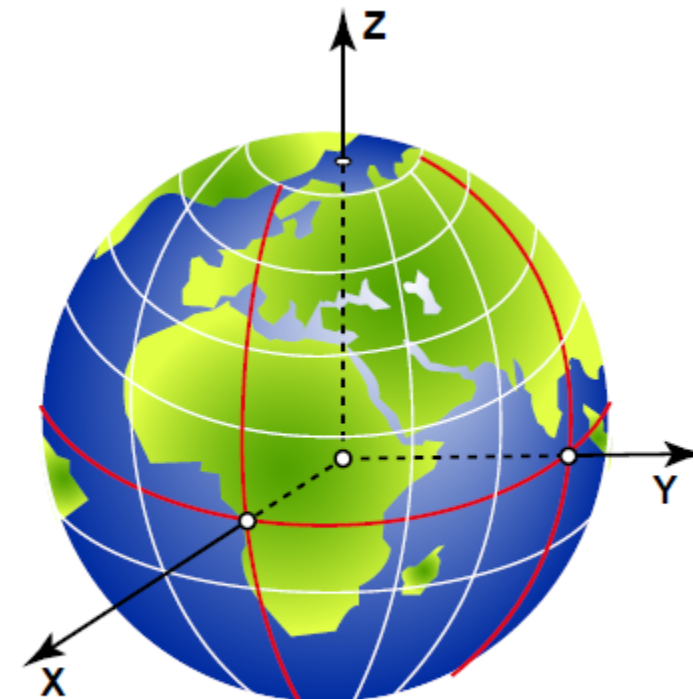


Abb. 1: Dreidimensionales kartesisches geozentrisches Koordinatensystem

https://www.bezreg-koeln.nrw.de/brk_internet/publikationen/abteilung07/pub_geobasis_etr89.pdf

Nordrhein-Westfalen: ETRS89 / UTM

UTM projection strip 32

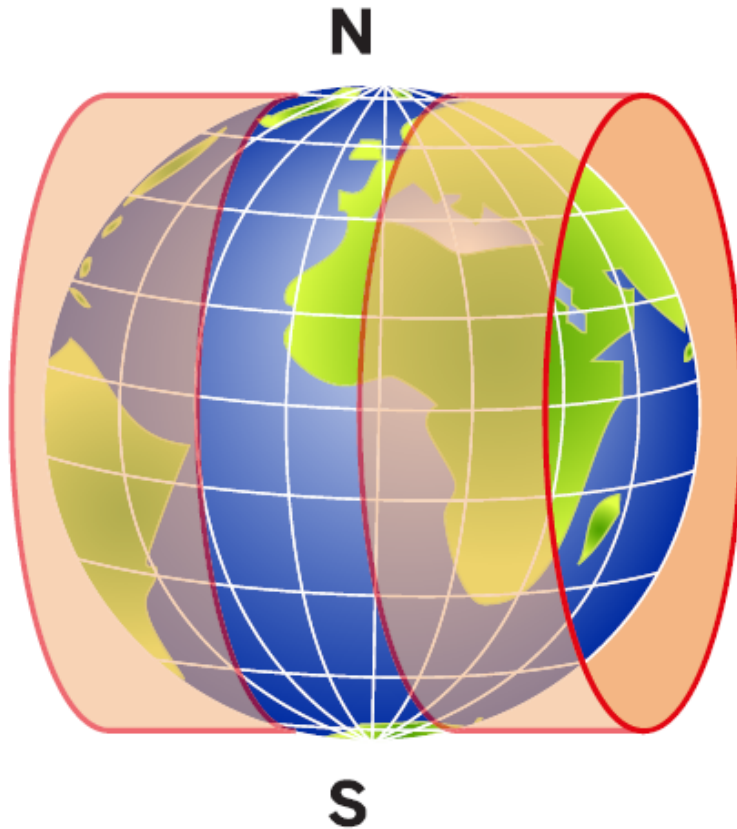


Abb. 2: Schnitzzylinder der UTM-Abbildung

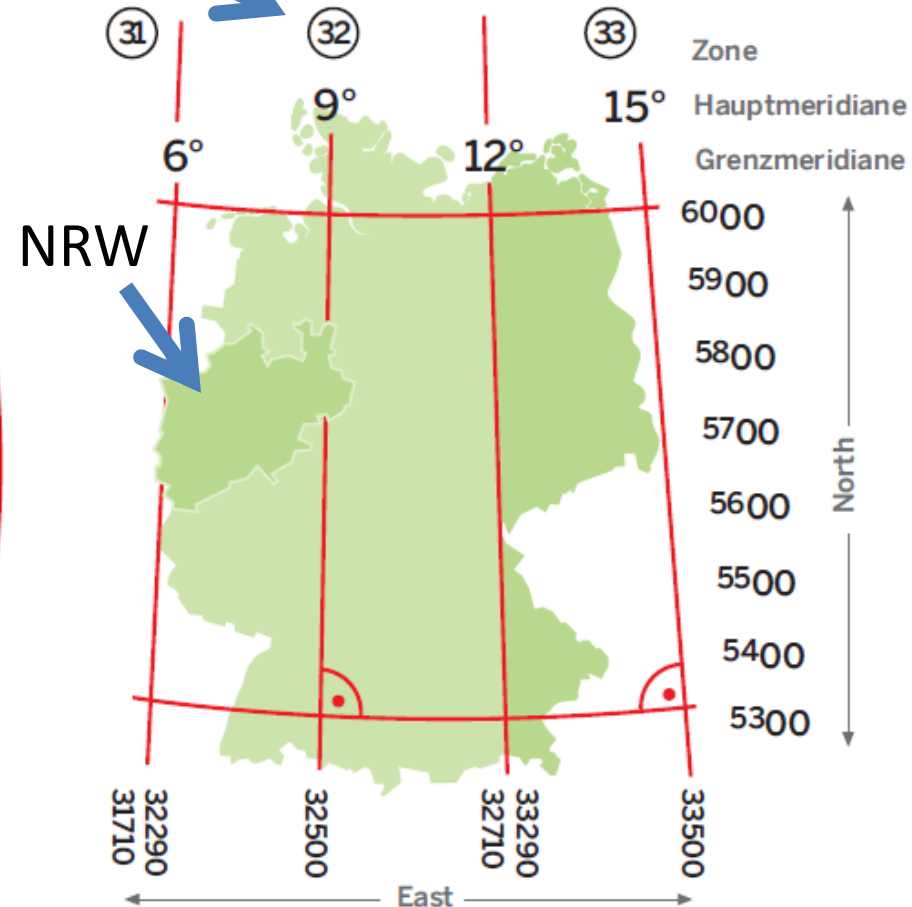
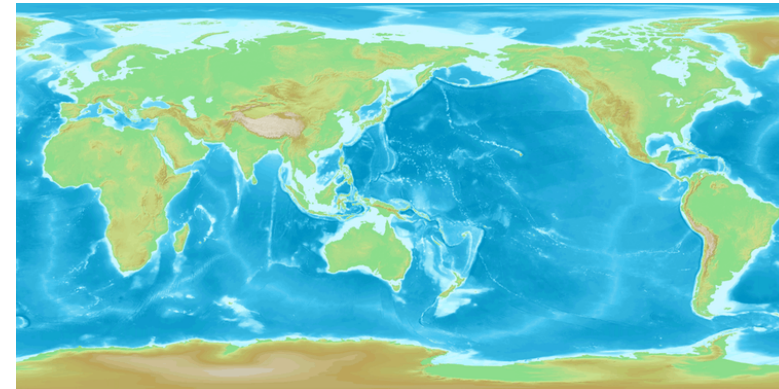
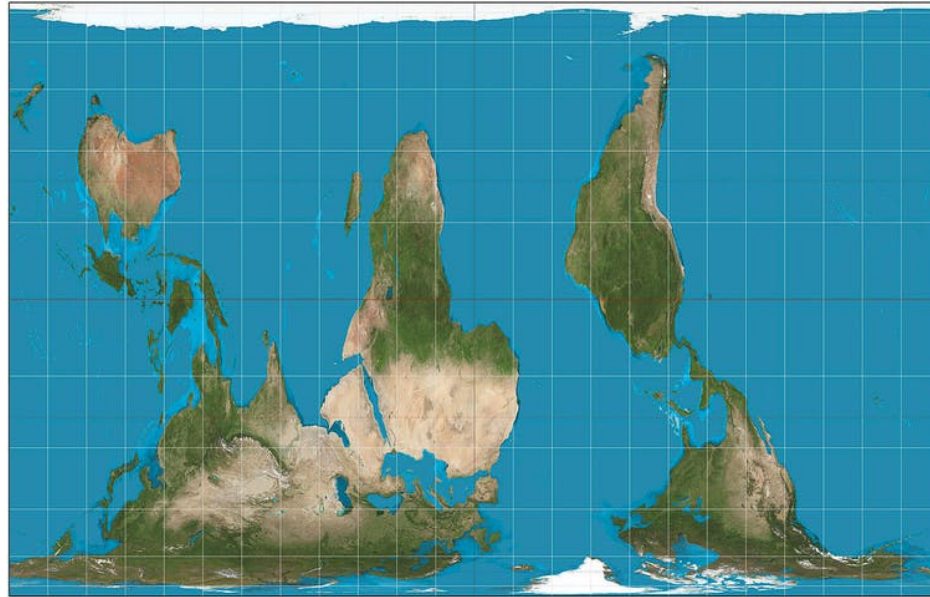
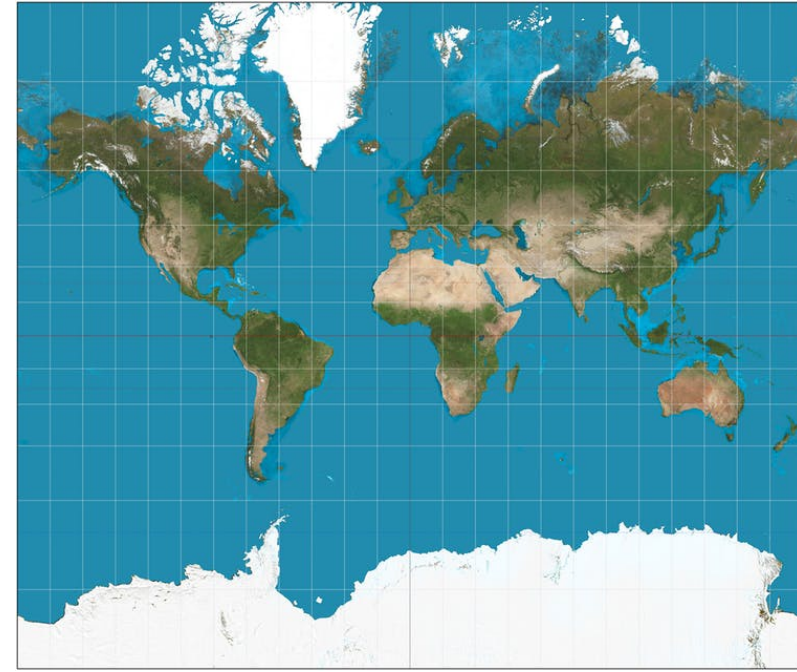
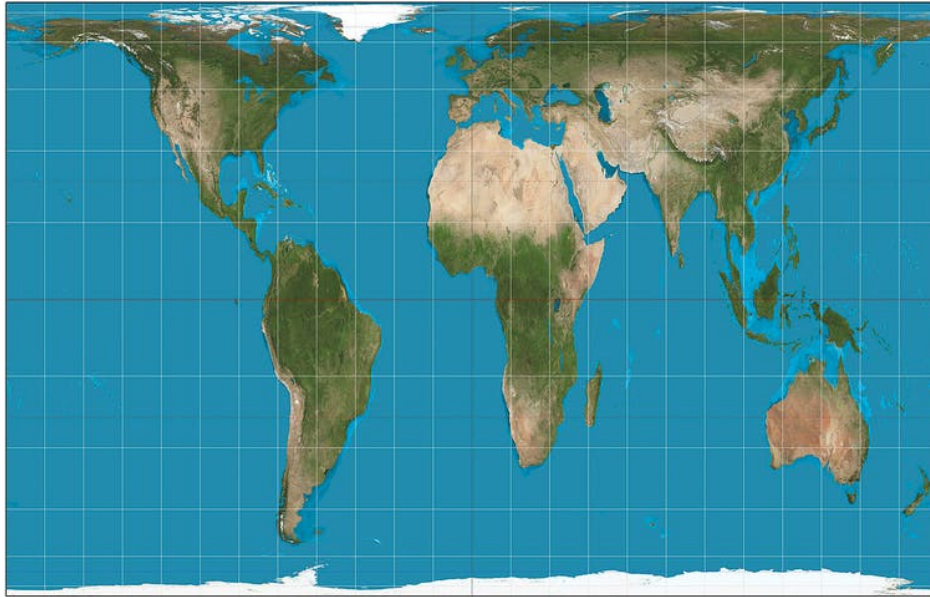


Abb. 3: Die Lage von NRW in der UTM-Zone 32

https://www.bezreg-koeln.nrw.de/brk_internet/publikationen/abteilung07/pub_geobasis_etr89.pdf

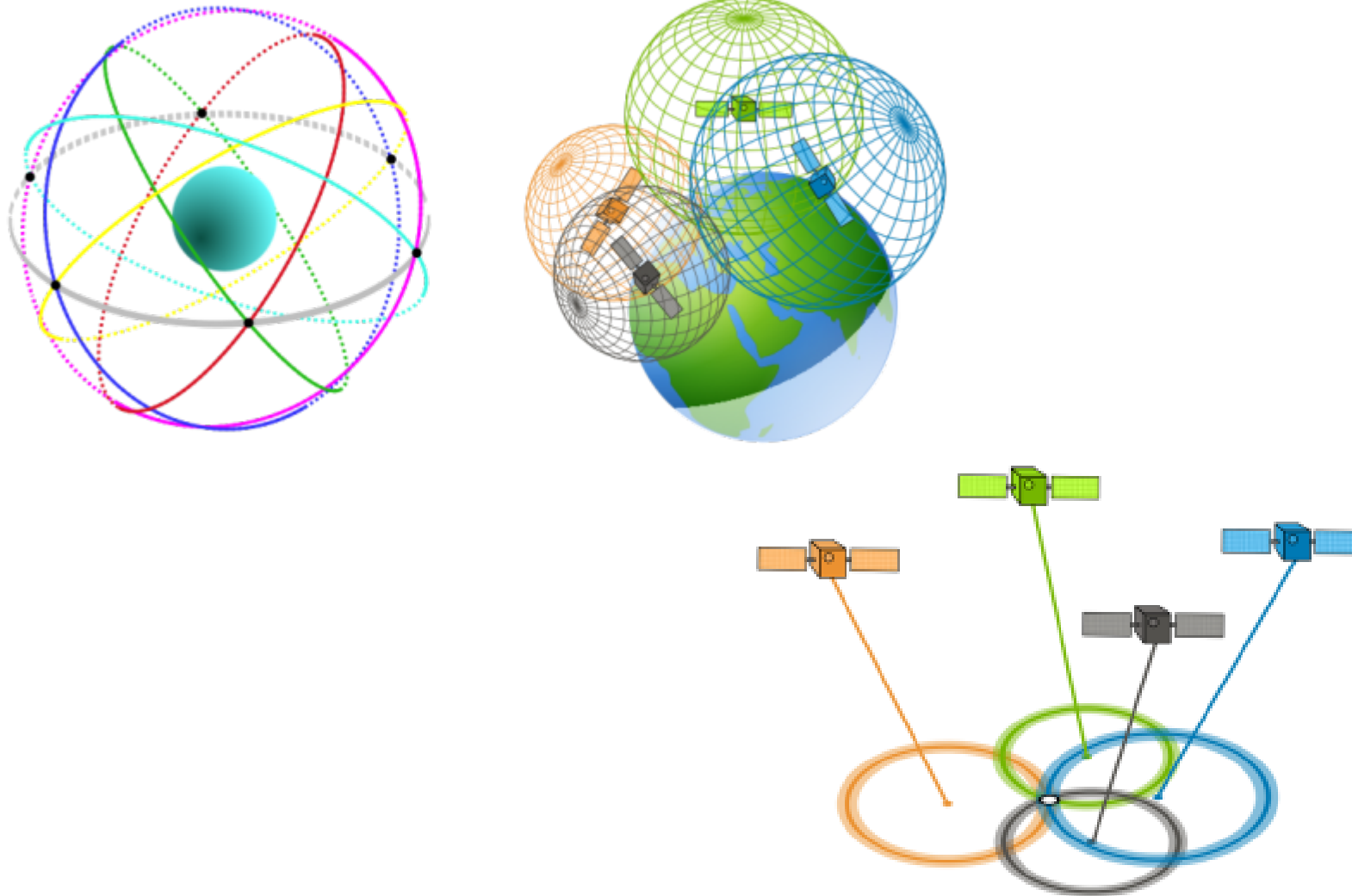
EPSG: Unique ID for CRS

- EPSG: European Petroleum Survey Group Geodesy
- Provides a unique numeric key for all registered CRS
- **EPSG:4326** -> WGS84 (GPS coord.), <https://epsg.io/4326>
- **EPSG:25832** -> ETRS89 / UTM zone 32N, <https://epsg.io/25832>
 - Ka-Li coord: 327896.29, 5710585.12
- **EPSG:4647** -> ETRS89 / UTM zone 32N (zE-N), <https://epsg.io/4647>
 - Ka-Li coord: **32**327896.29, 5710585.12
 - Remarks: Variant of ETRS89 / UTM zone 32N (CRS code 25832) in which **easting has zone prefix**.
- **EPSG:3857** -> WGS 84 / Pseudo-Mercator, <https://epsg.io/3857>
 - Spherical Mercator, Google Maps, OpenStreetMap, Bing, ArcGIS, ESRI



<http://theconversation.com/five-maps-that-will-change-how-you-see-the-world-74967>

WGS 84: GPS Trilateration



<https://gisgeography.com/wgs84-world-geodetic-system/>