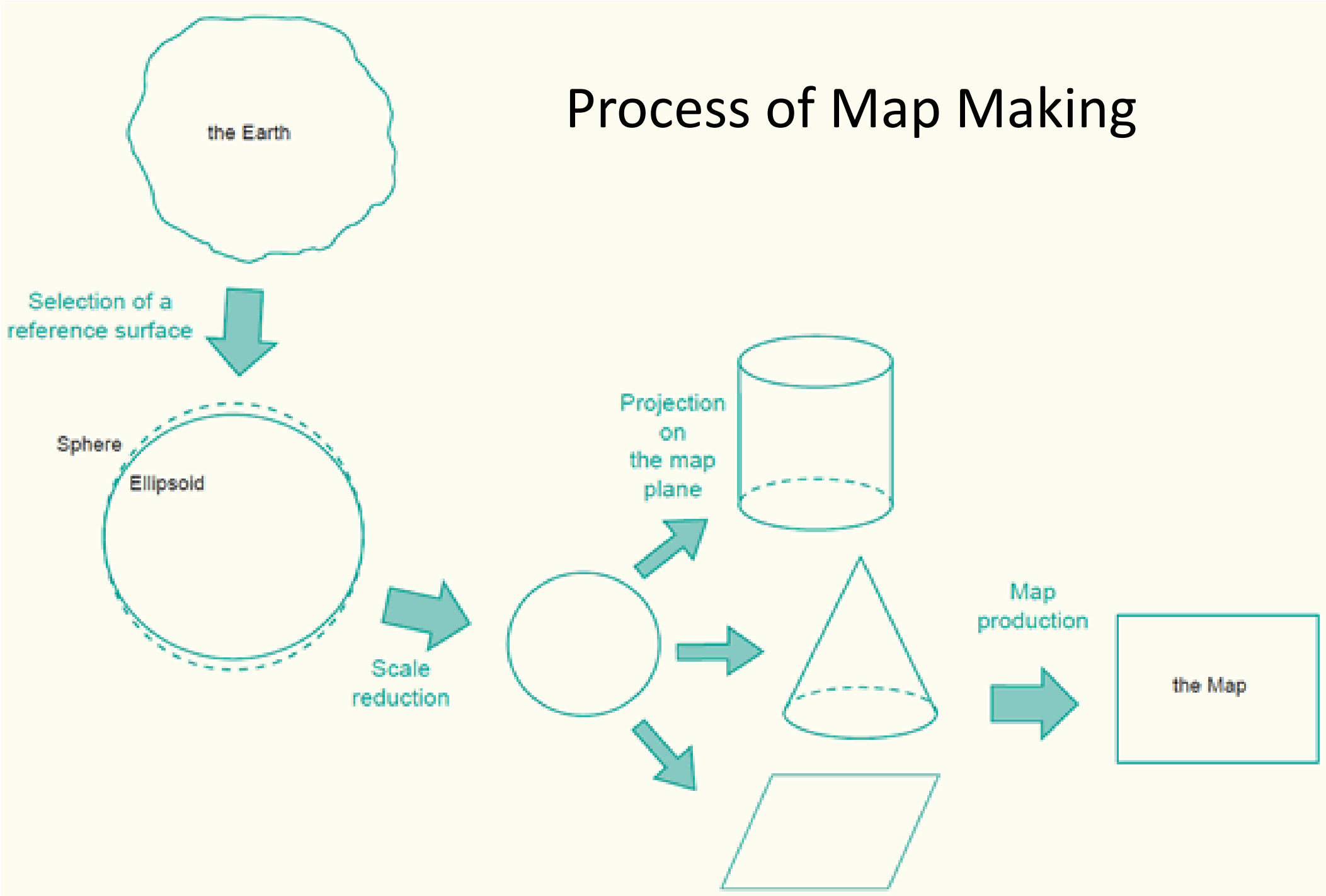
Coordinate Reference Systems

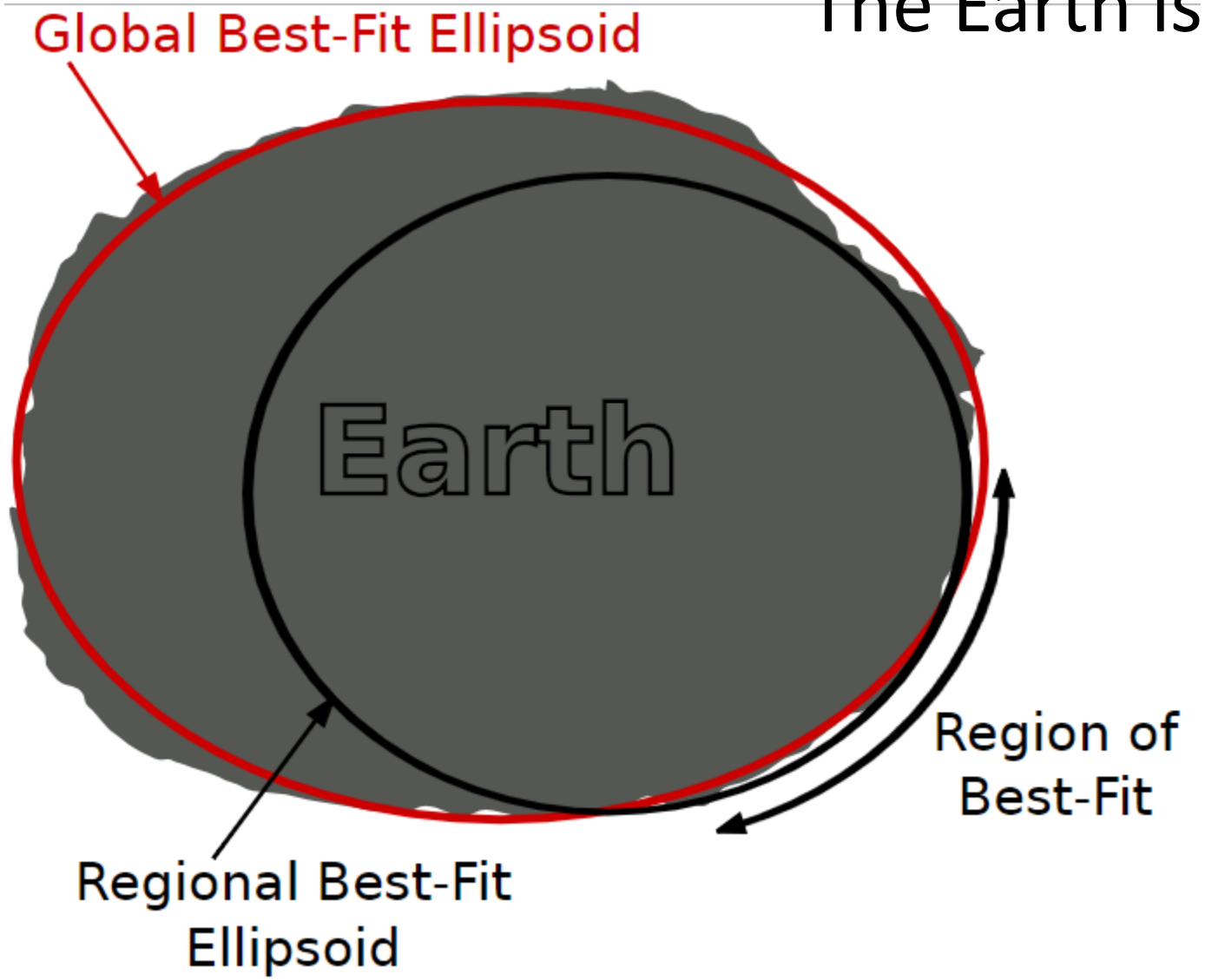
Rolf Becker

Process of Map Making



R. Knippers (2009): Kartoweb. ITC, U Twente
http://kartoweb.itc.nl/geometrics/Introduction/introduction.html

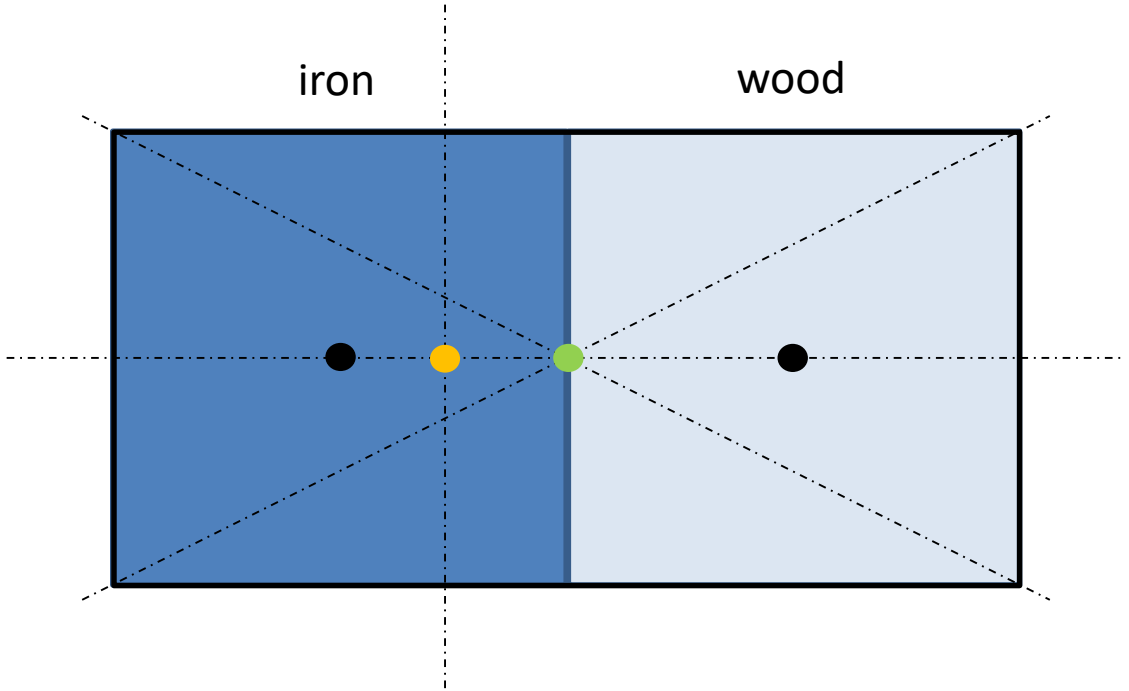
The Earth is a Potato



https://de.wikipedia.org/wiki/Datei:Gloabl_and_Regional_Ellipsoids.svg

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



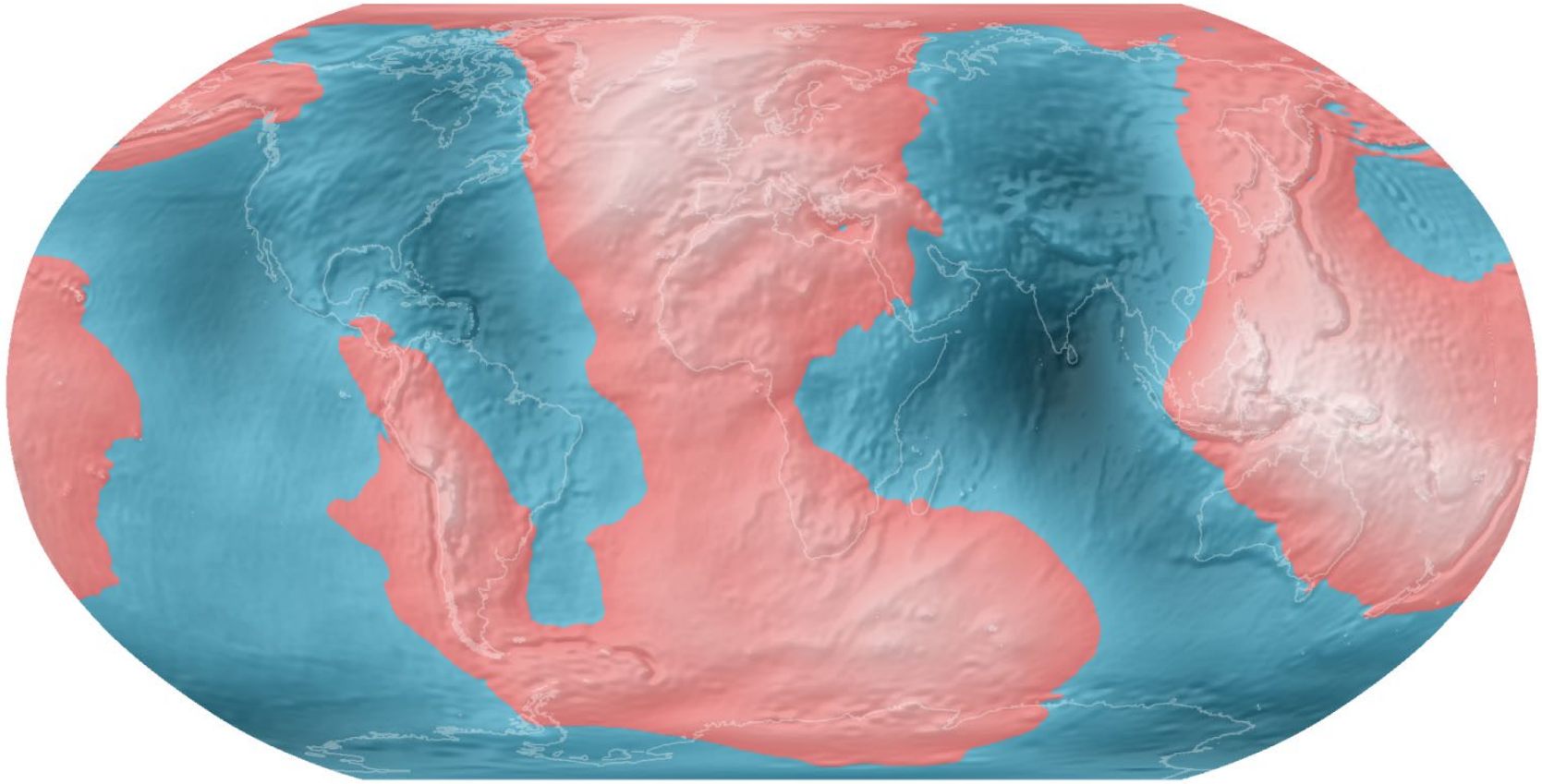
GRS80

- 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.

https://en.wikipedia.org/wiki/GRS_80

Deviation of the Geoid from the idealized figure of the Earth

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

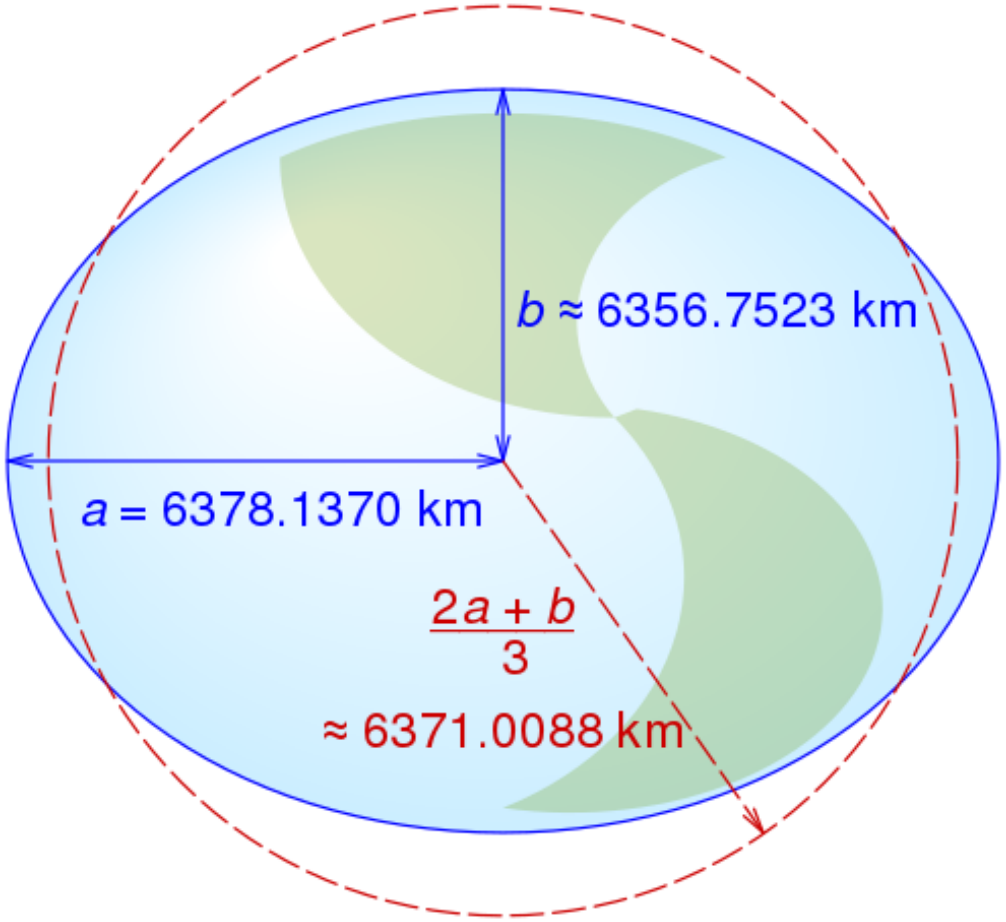


Red areas are above the idealized ellipsoid; blue areas are below.

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. elipsoid differs slightly from GRS80
- Equatorial (a), polar (b) and mean Earth radii as defined in the 1984 World Geodetic System revision (not to scale)

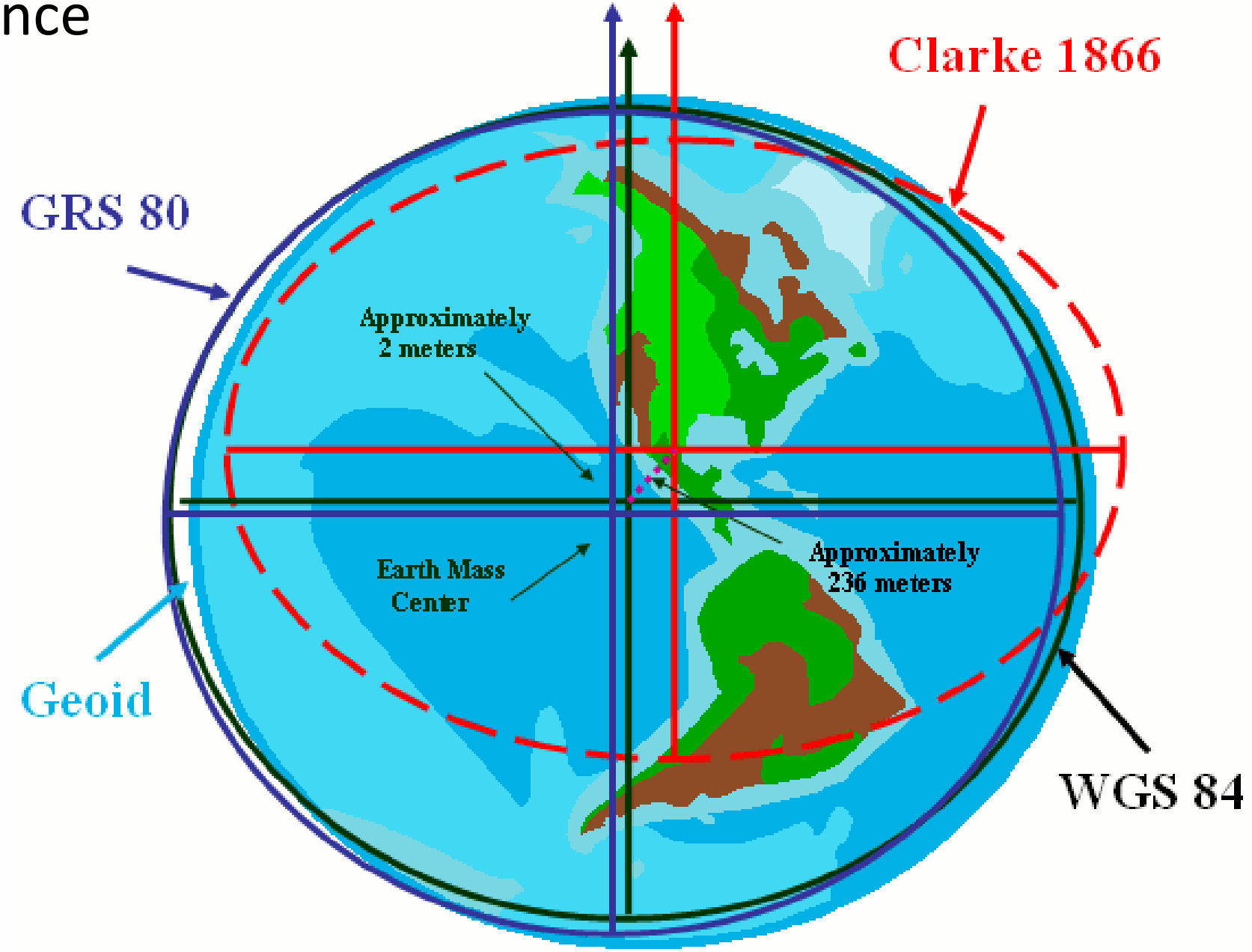


https://commons.wikimedia.org/wiki/File:WGS84_mean_Earth_radius.svg
https://en.wikipedia.org/wiki/World_Geodetic_System#WGS84

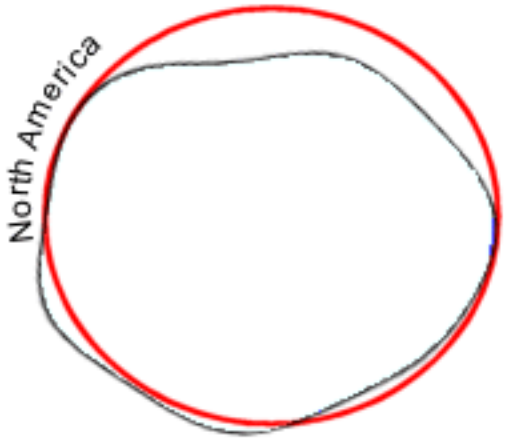
Different Reference Ellipsoids

https://vdatum.noaa.gov/docs/datums.html

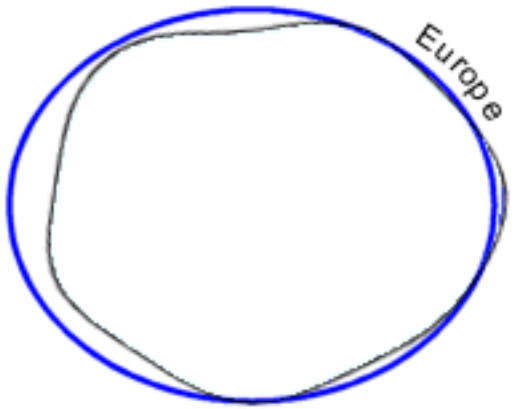
NOAA:
National Oceanic and Atmospheric Agency



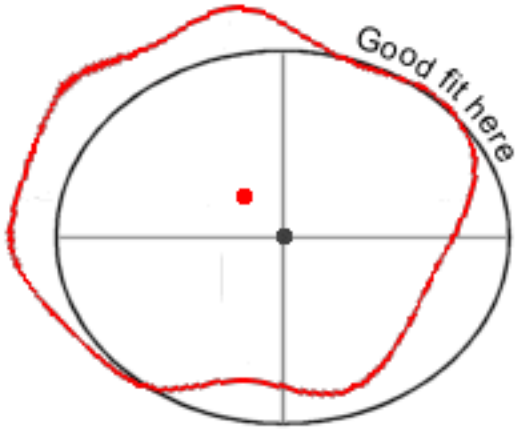
- Ellipsoid approximates geoid locally



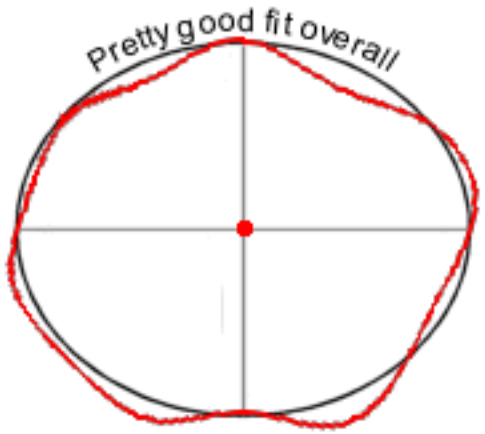
The red ellipsoid fits the geoid well in North America.



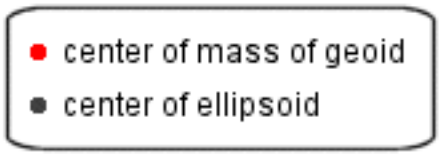
The blue ellipsoid fits the geoid well in Europe.



Local datum



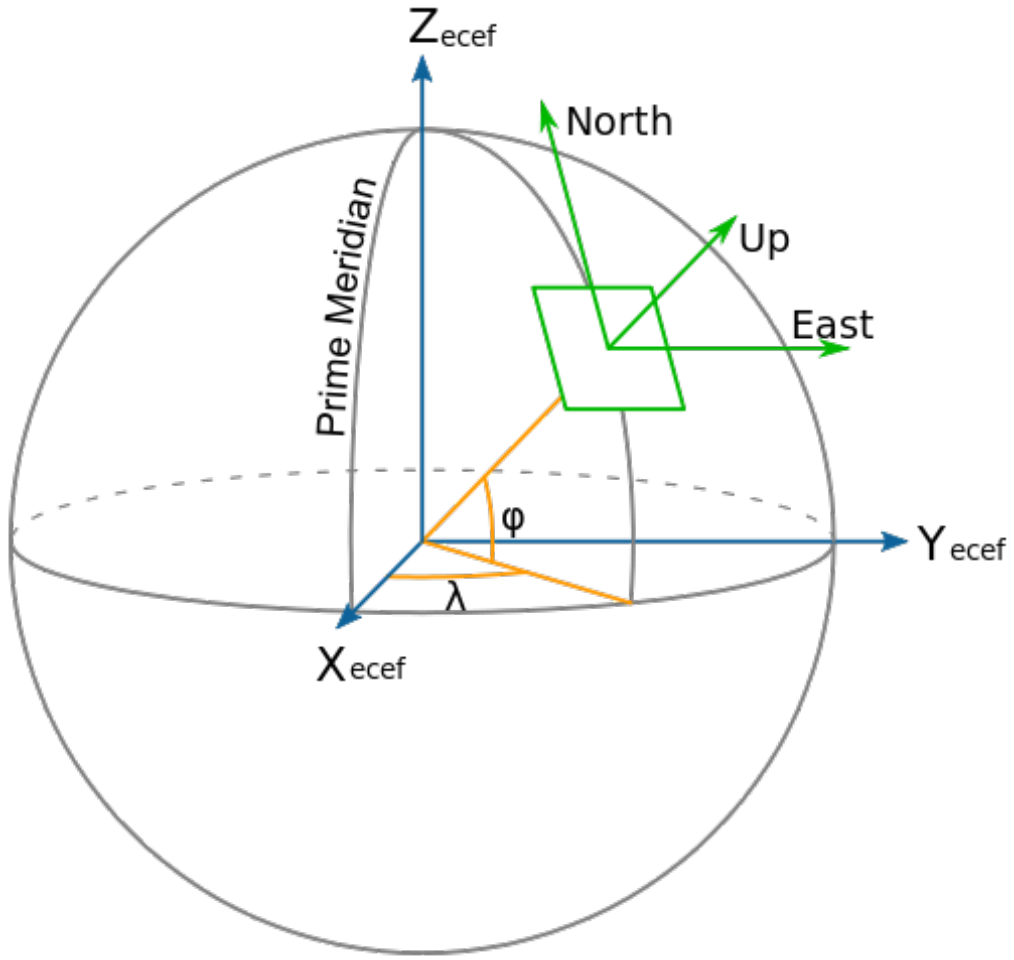
Earth-centered datum



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

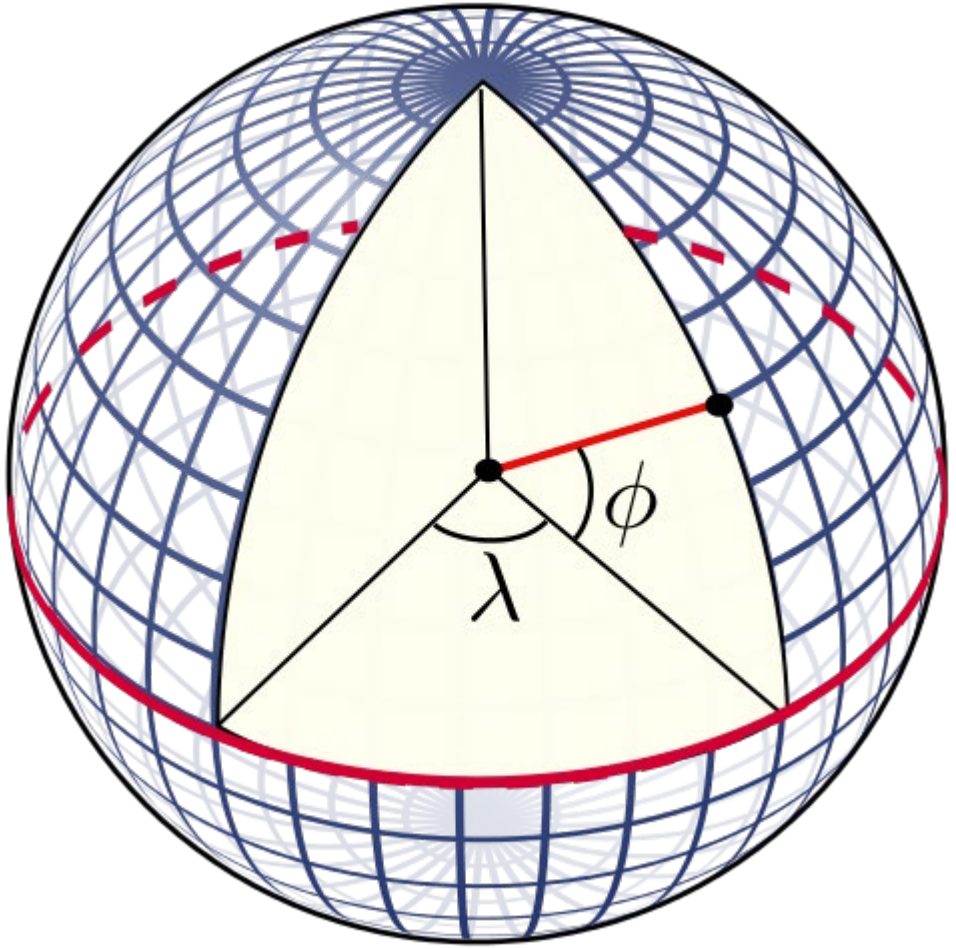
WGS 84: Latitude, Longitude (lat, lon)

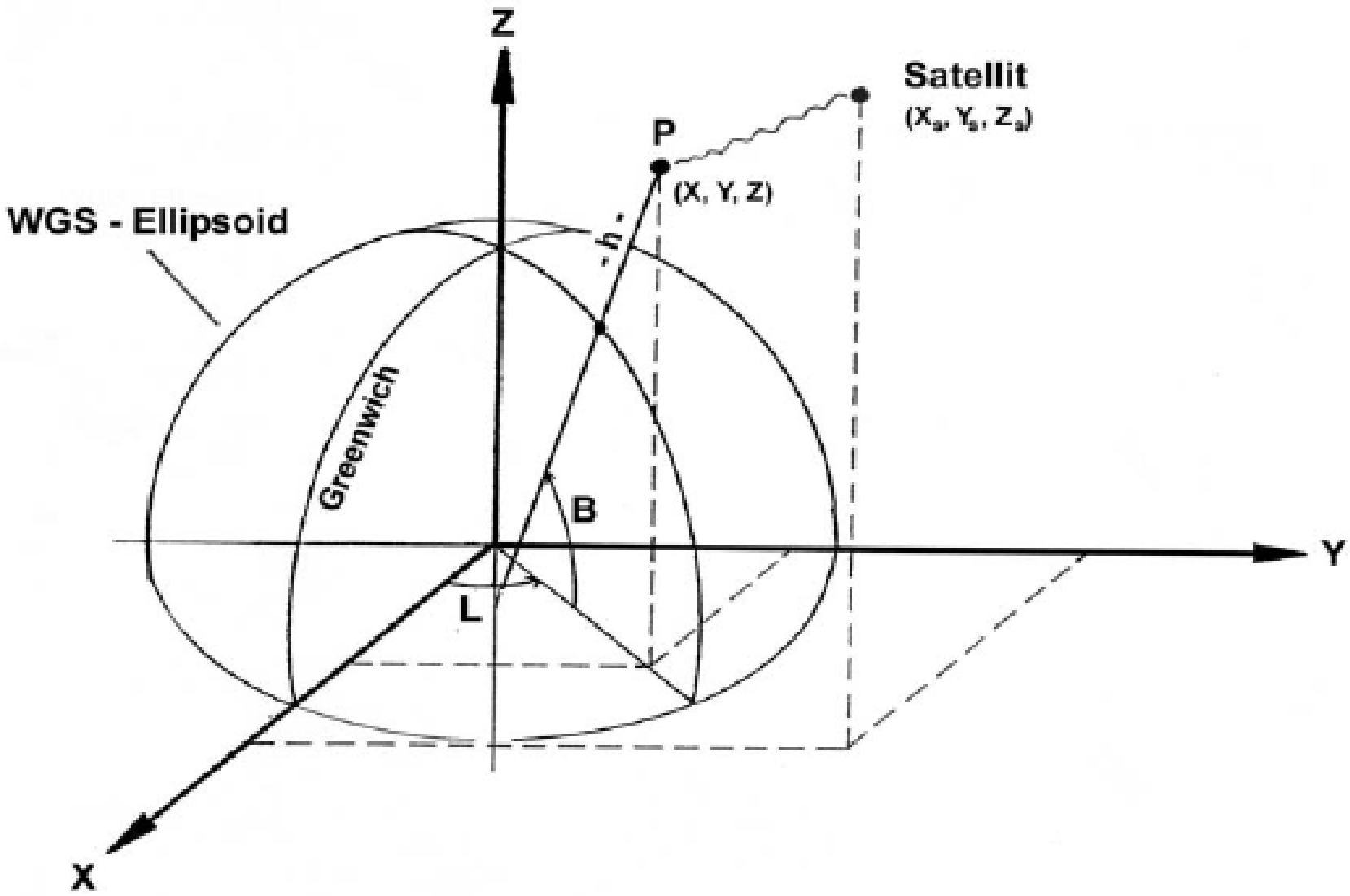
- Prime Meridian: λ = 0° (approx. Greenwich)
- Latitude (Breite) φ, ϕ : measured from equator, North +, South -
- Logitude (Länge) λ : measured from PM, East + , West -



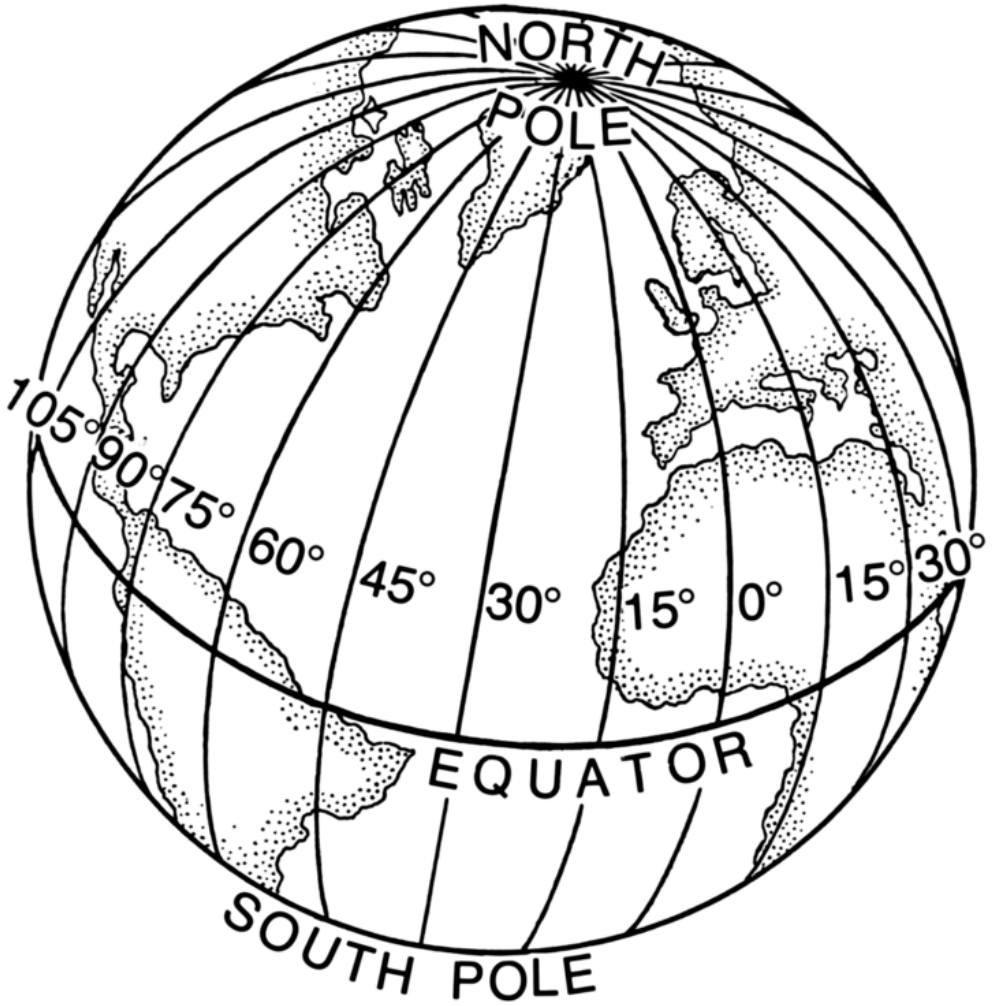
https://commons.wikimedia.org/wiki/File:ECEF_ENU_Longitude_Latitude_relationships.svg

- Lat: N – S
- Lon: E – W




Z
Satellit
(X_s, Y_s, Z_s)
P
(X, Y, Z)
WGS - Ellipsoid
h
Greenwich
B
L
Y
X

Longitude



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

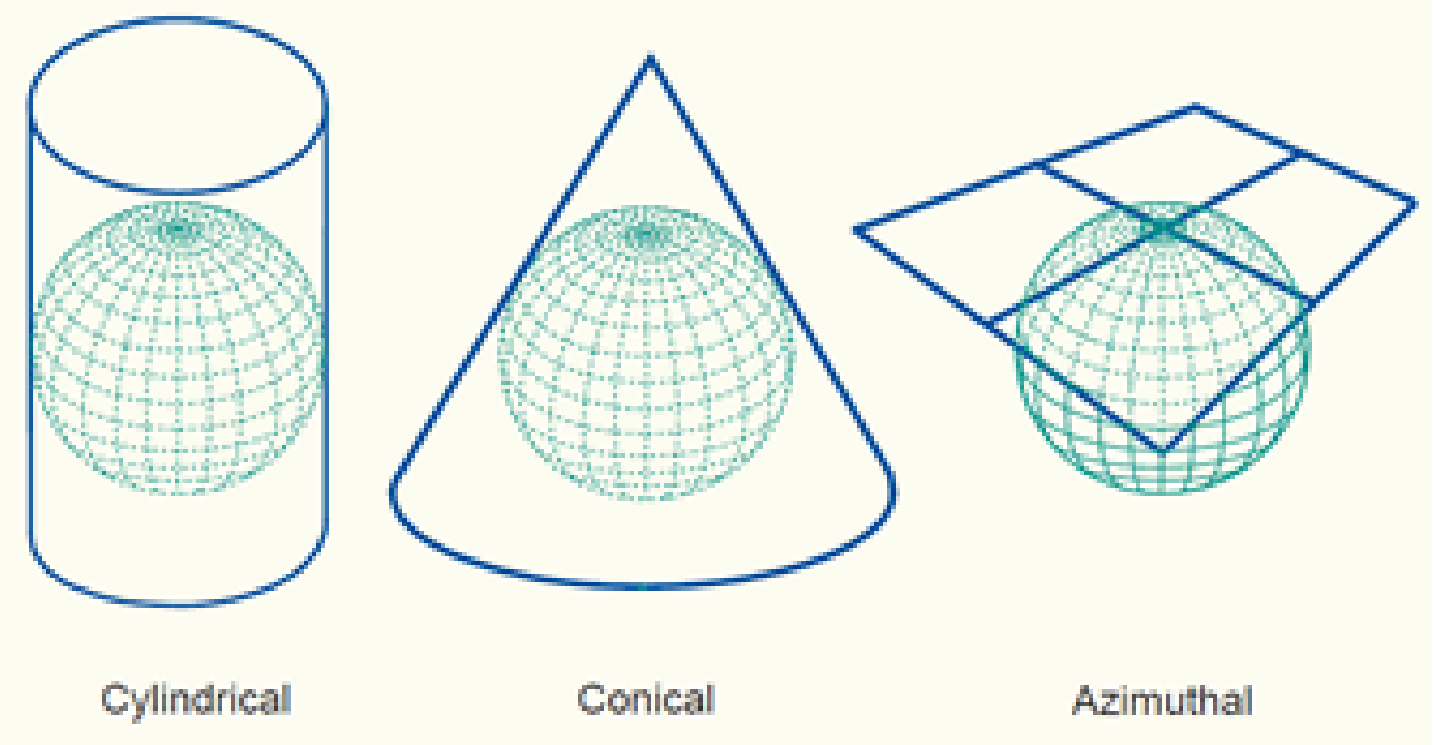
Which city?

- 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&params=51.5_N_6.5333333333333_E_region:DE-NW_type:city(37346)

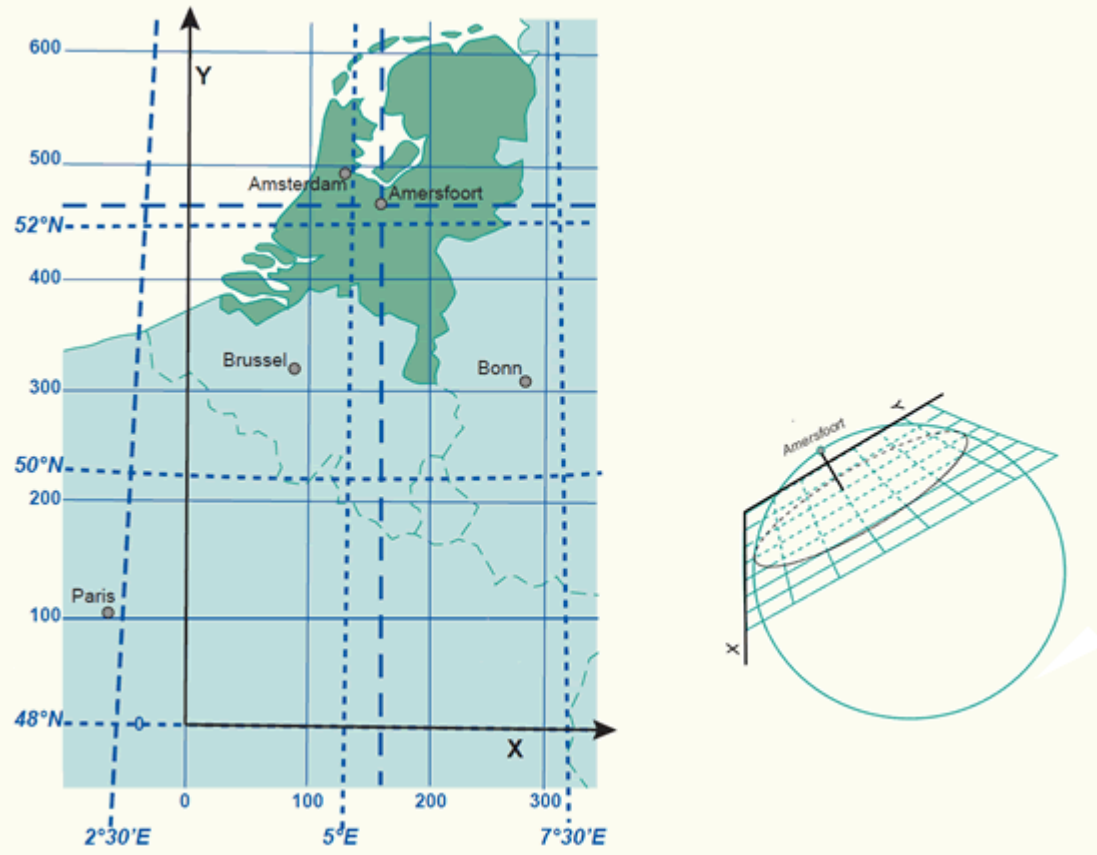
Map Projections

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



http://kartoweb.itc.nl/geometrics/Introduction/introduction.html

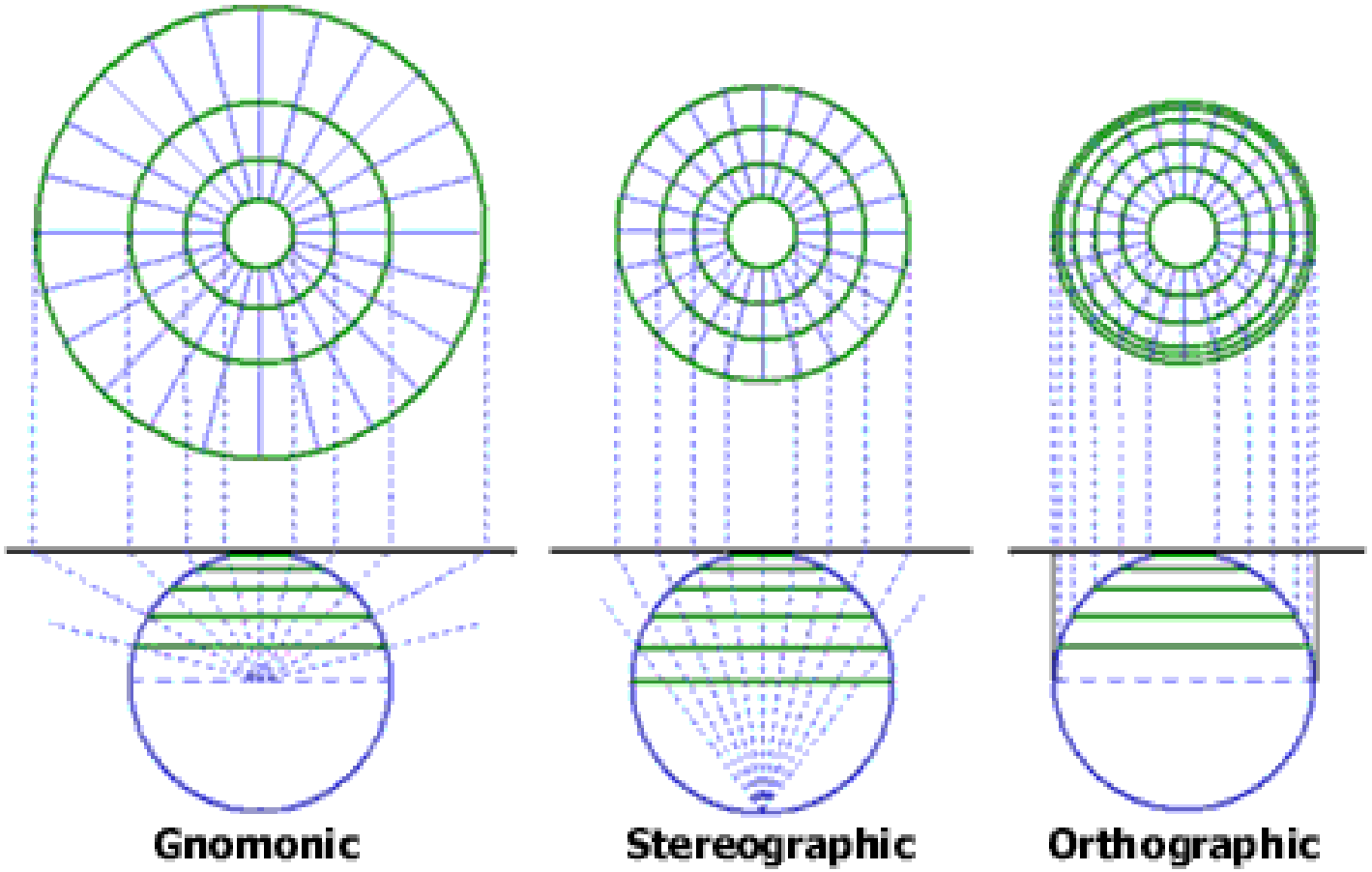
Map Projections



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

http://kartoweb.itc.nl/geometrics/Introduction/introduction.html

Different Azimuthal Projections



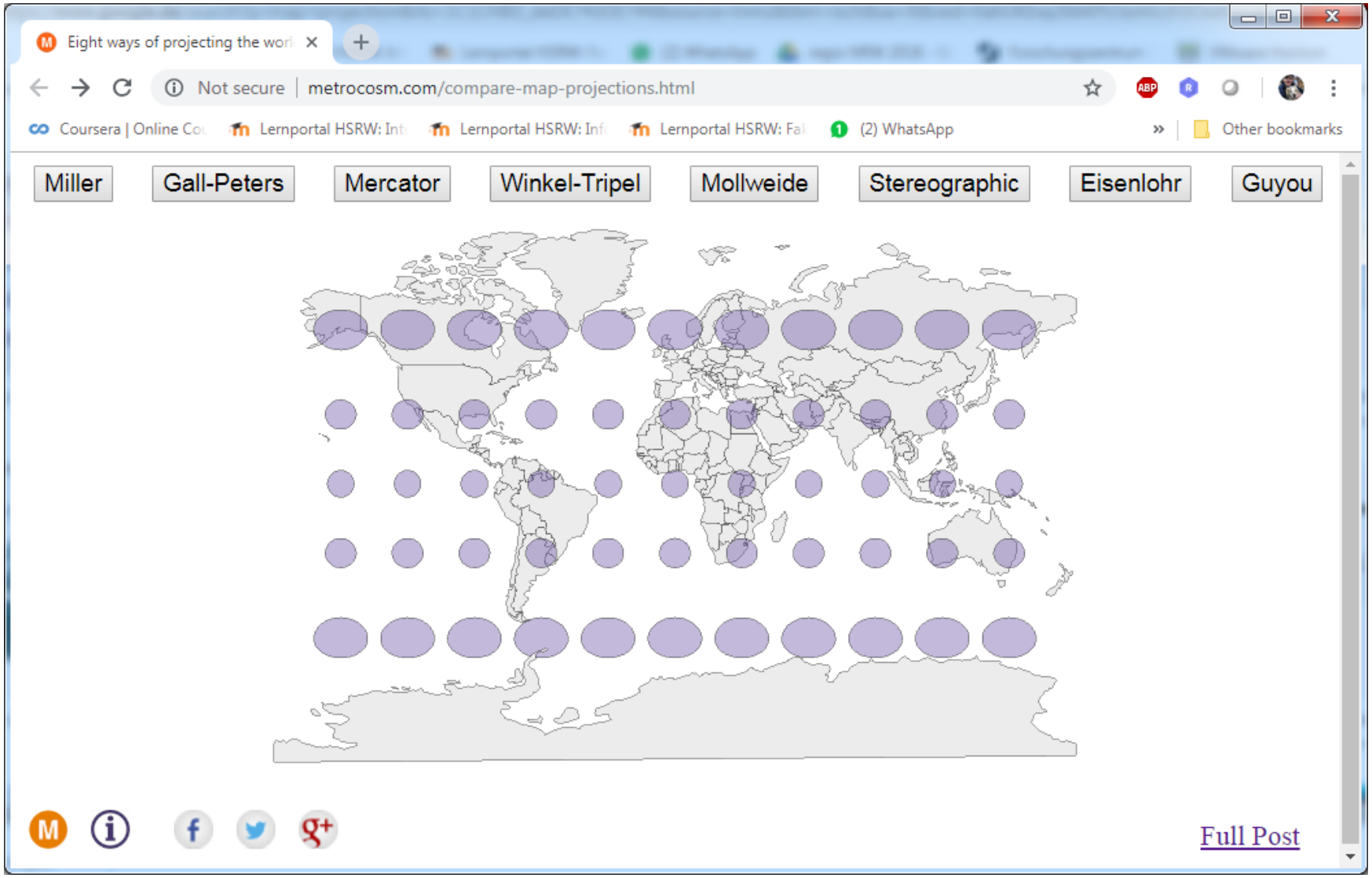
http://www.geo.hunter.cuny.edu/~jochen/gtech201/lectures/lec6concepts/Map%20coordinate%20systems/Perspective.htm

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.

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

Map Projection - Tissot‘s Indicatrices

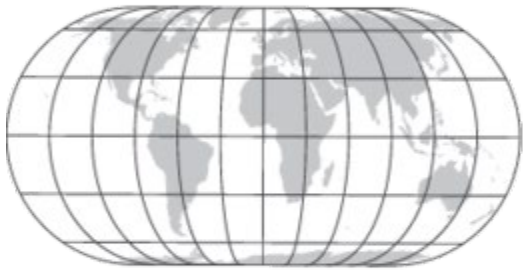


http://metrocosm.com/compare-map-projections.html

Robinson

Plate Carrée

Winkel Tripel

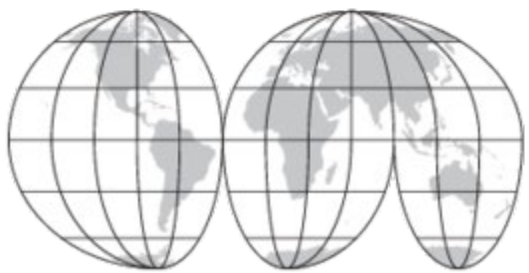


Eckert IV

Mollweide

Mercator

Wagner VII

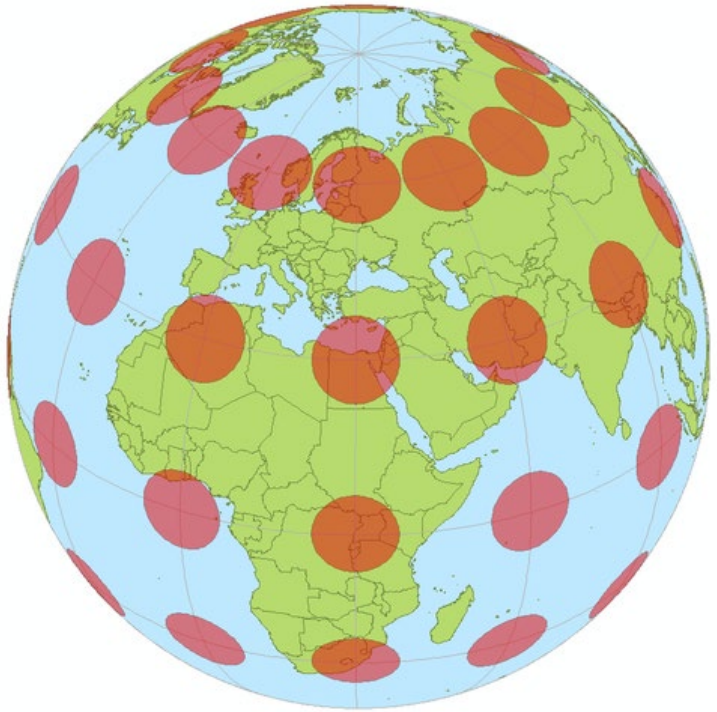


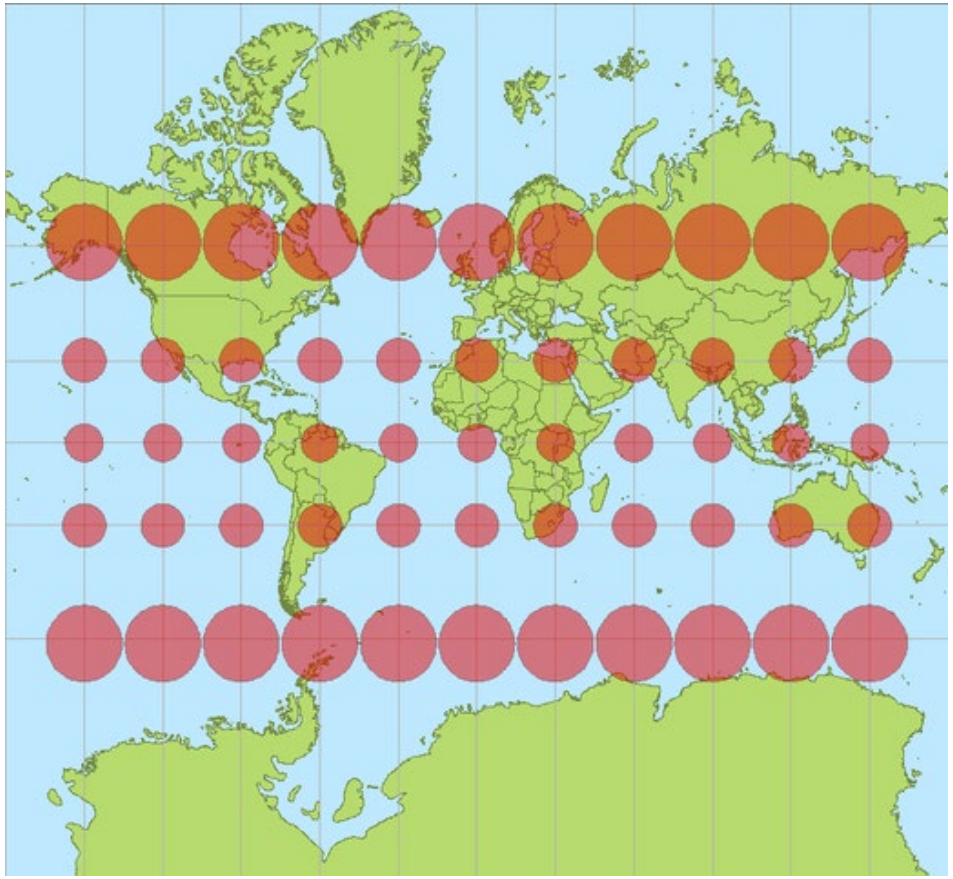
Interrupted Mollweide

Goode Homolosine

https://www.researchgate.net/publication/273517879_User_preferences_for_world_map_projections

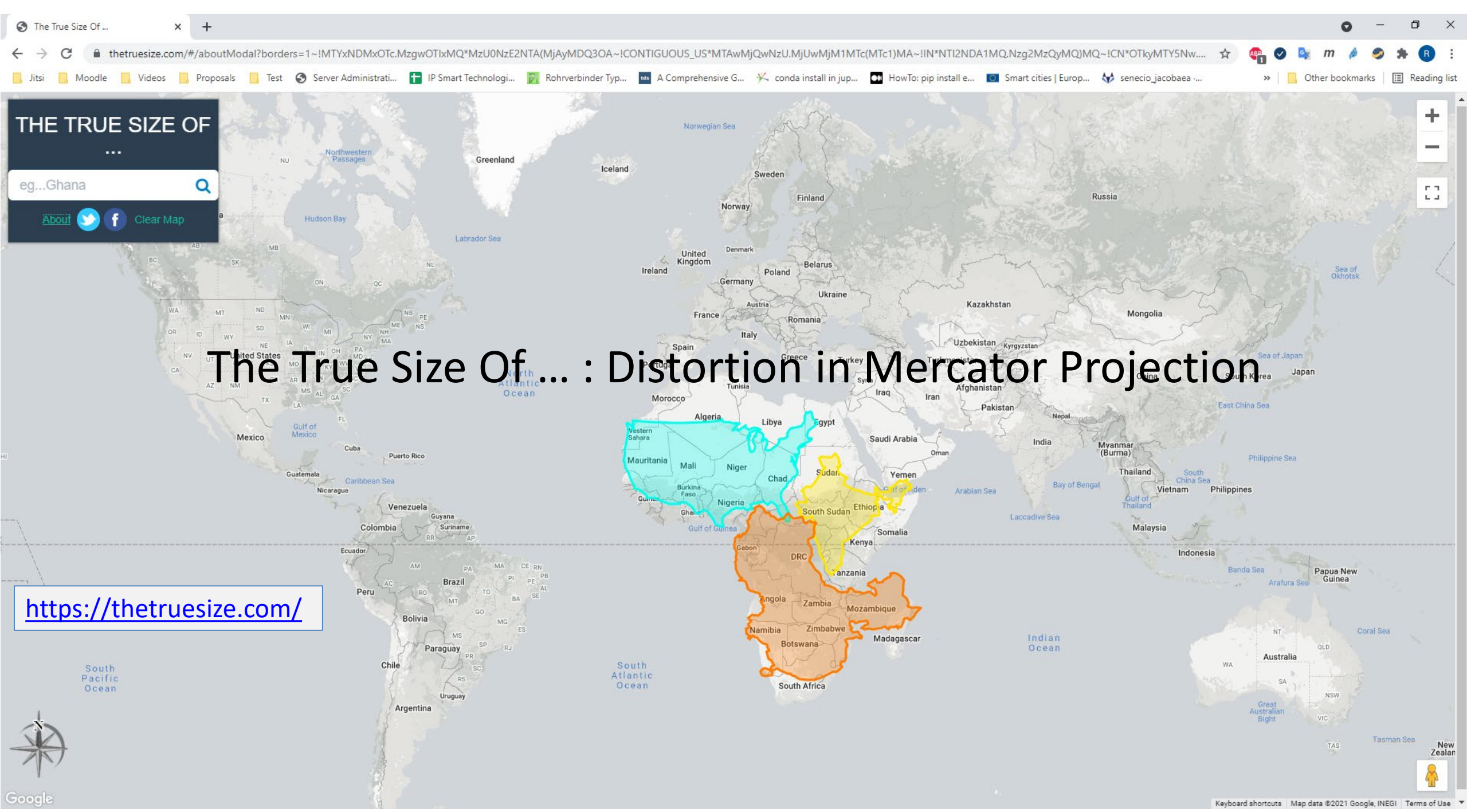
Mecator Projection



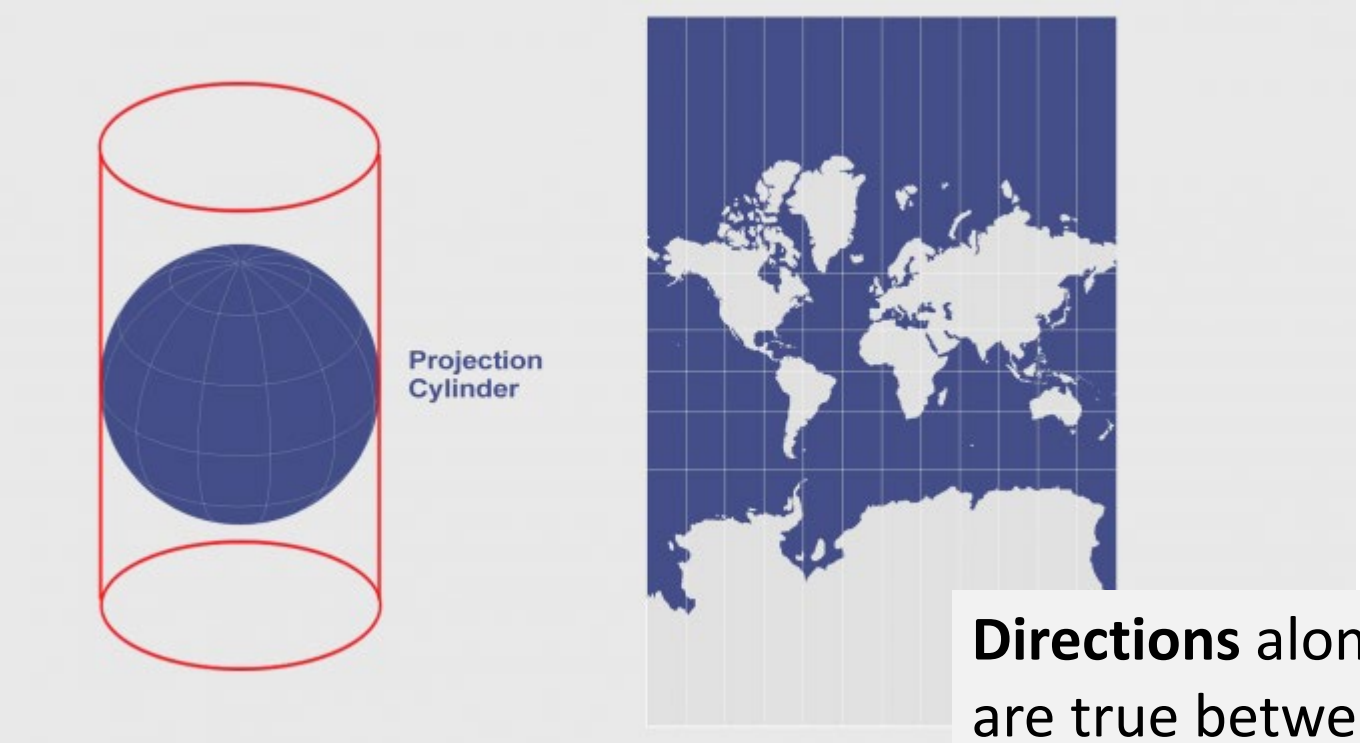


Red Dots:
Tissot‘s Indicatrix / Indicatrices

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


THE TRUE SIZE OF
...
eg...Ghana
About
Clear Map
The True Size Of... : Distortion in Mercator Projection
https://thetruesize.com/
Google

Mercator Projection

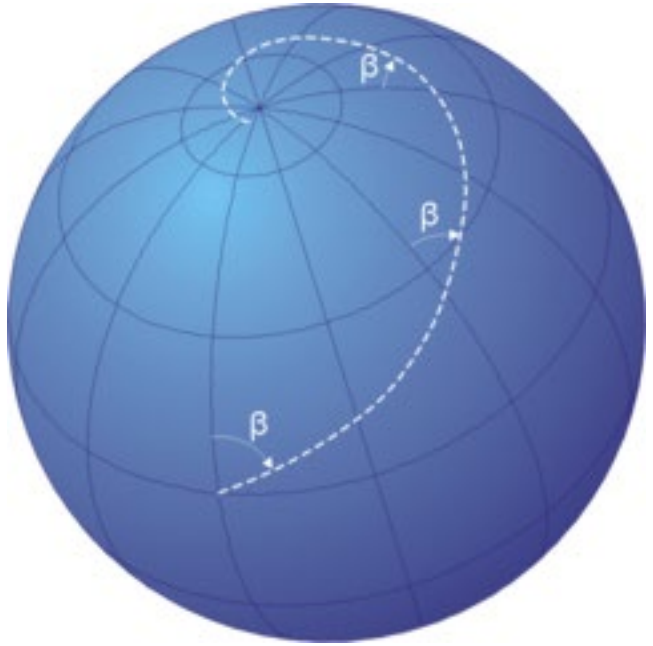


Directions along a Rhumb line are true between any two points on a map. **Distances** are true only along the Equator. Although it has a **conformal** property, areas are greatly distorted increasing size at poles.

https://gisgeography.com/cylindrical-projection/

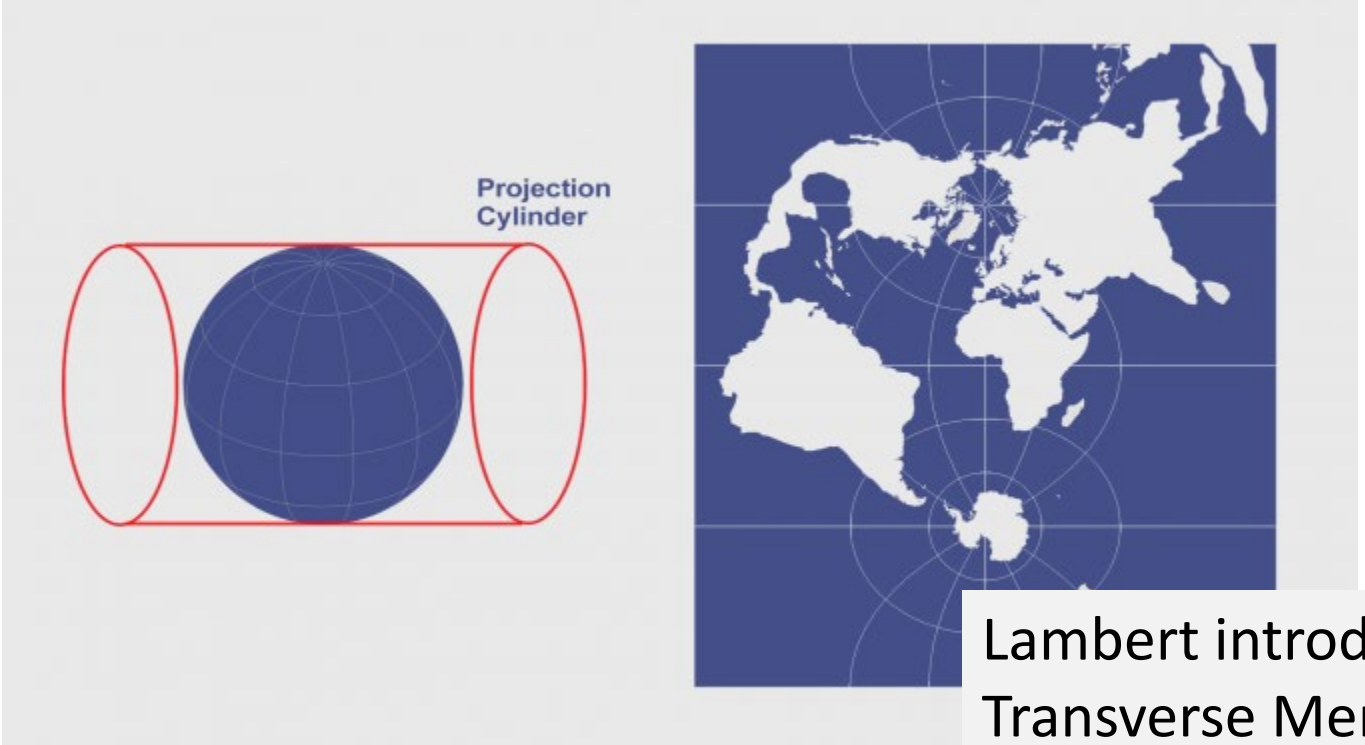
Rhumb Line

- 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.



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

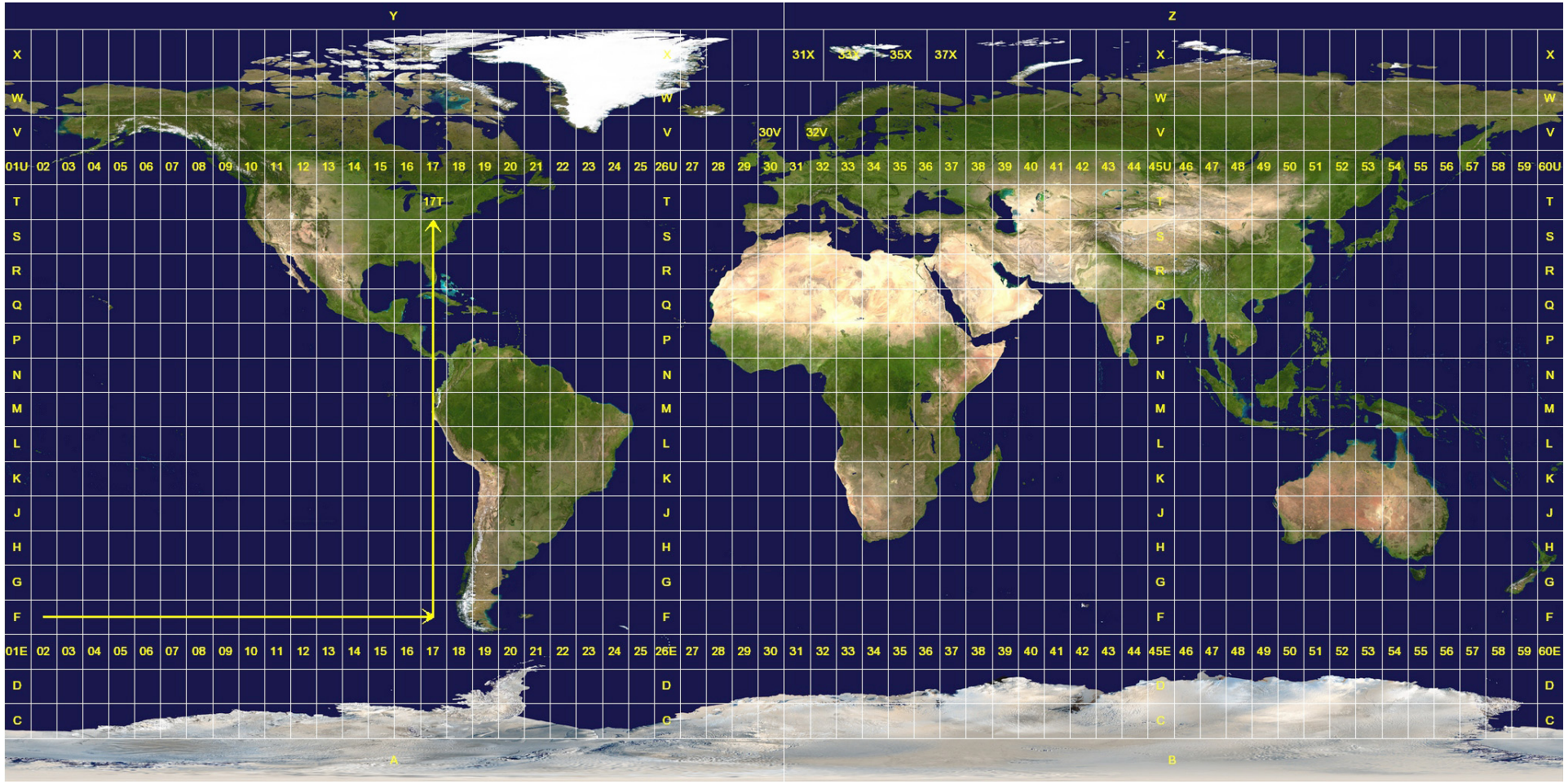
Tranverse Mercator Projection



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.

https://gisgeography.com/cylindrical-projection/

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 Terrestial 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

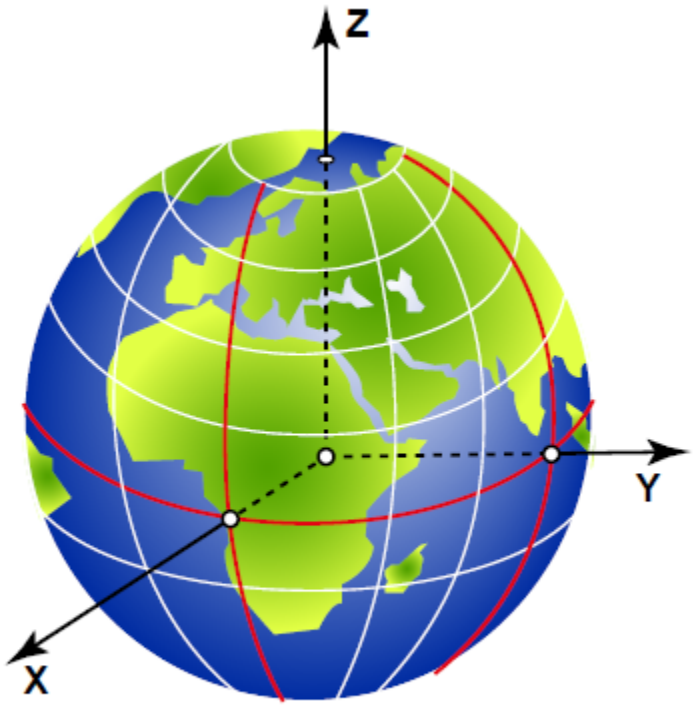


Abb. 1: Dreidimensionales kartesisches geozentrisches Koordinatensystem

https://www.bezreg-koeln.nrw.de/brk_internet/publikationen/abteilung07/pub_geobasis_etrs89.pdf

Nordrhein-Westfalen: ETRS89 / UTM

UTM projection strip 32

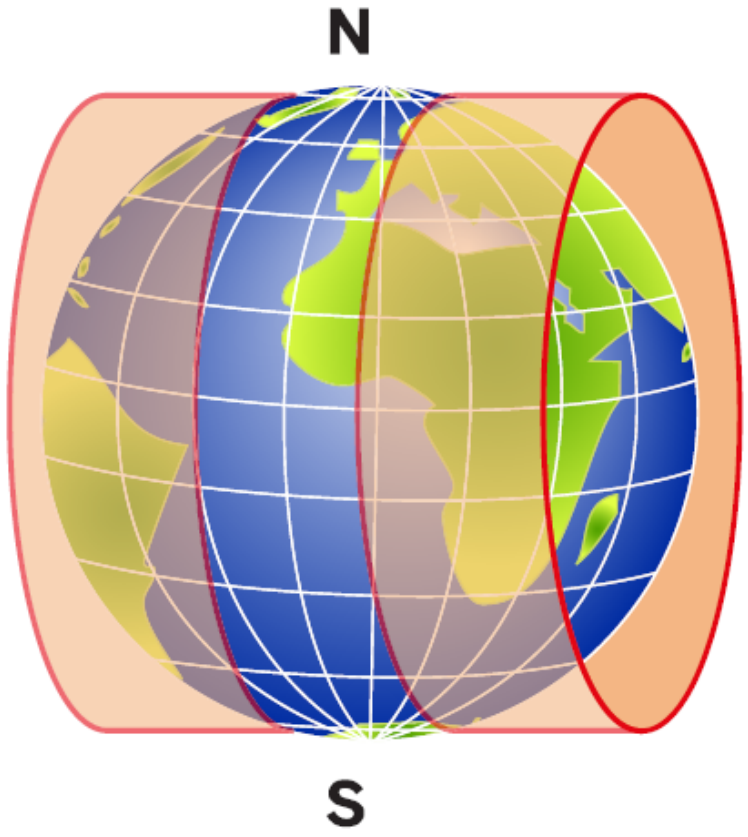


Abb. 2: Schnittzylinder der UTM-Abbildung

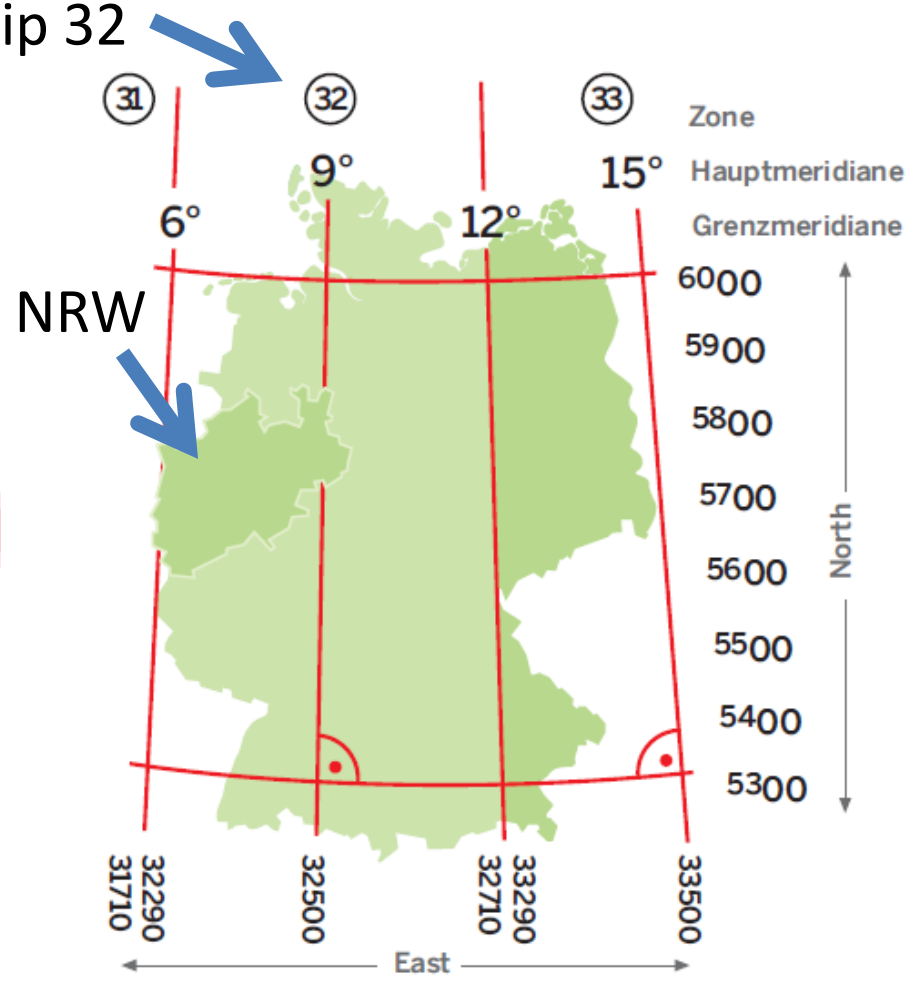
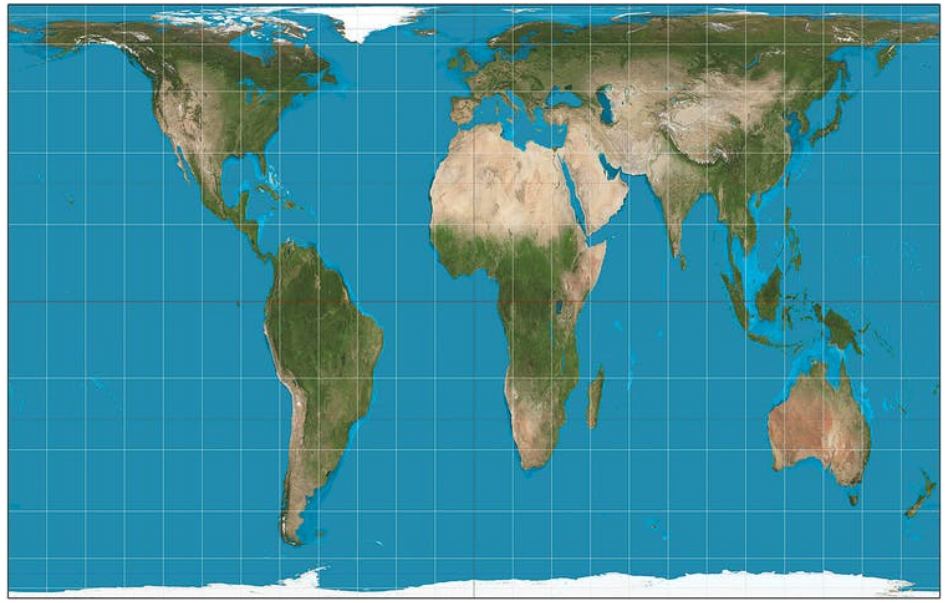


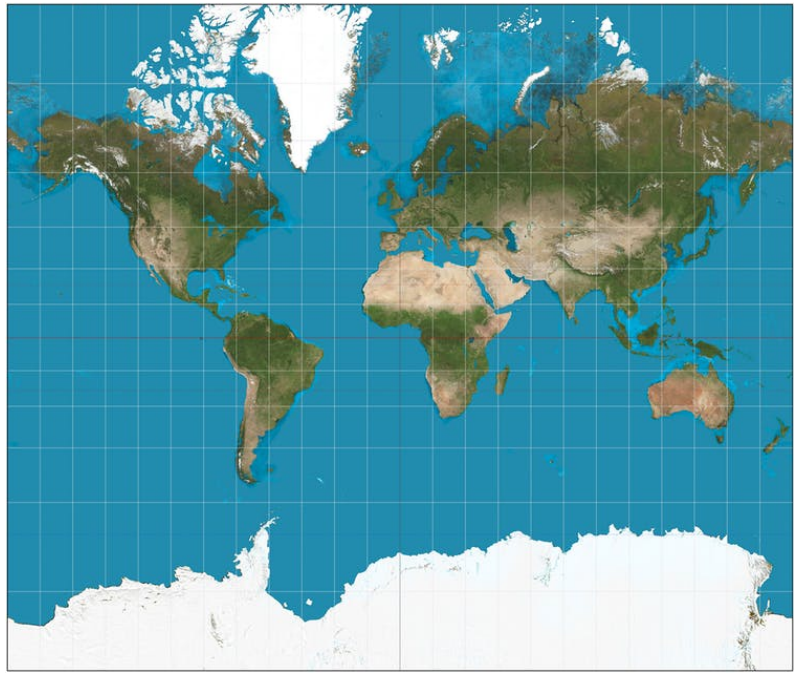
Abb. 3: Die Lage von NRW in der UTM-Zone 32

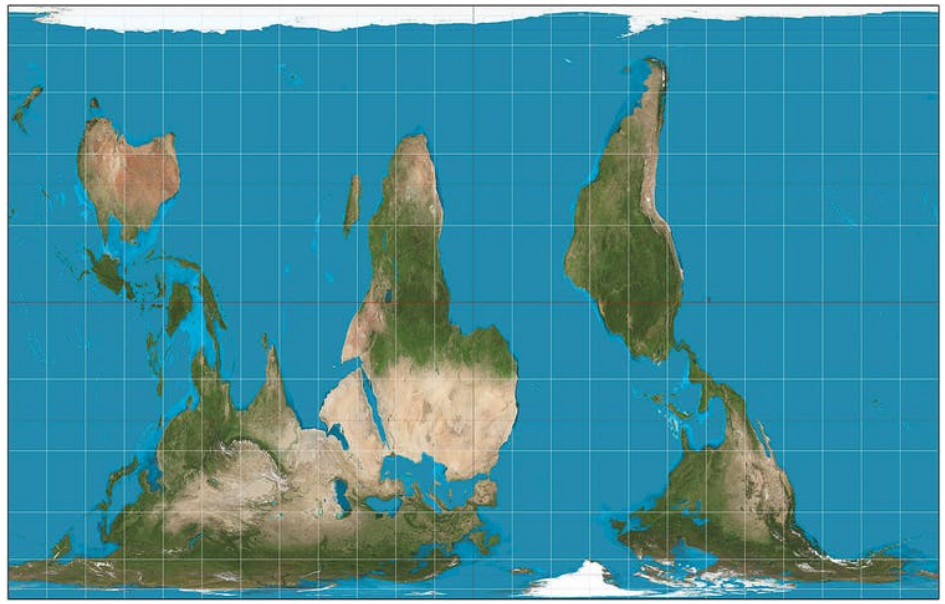
https://www.bezreg-koeln.nrw.de/brk_internet/publikationen/abteilung07/pub_geobasis_etrs89.pdf

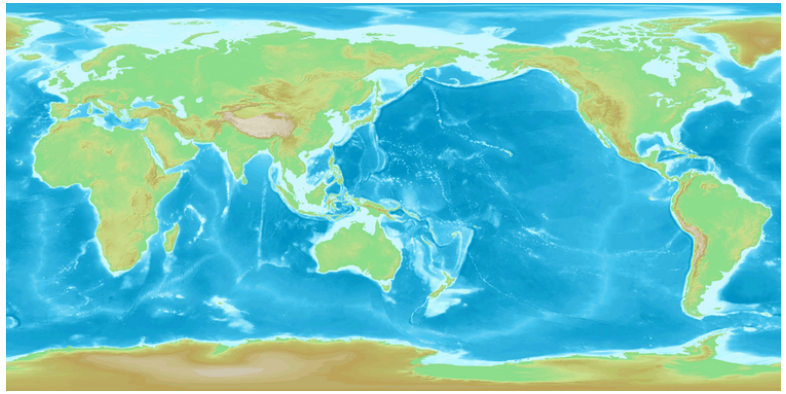
EPSG: Unique ID for CRS

- 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



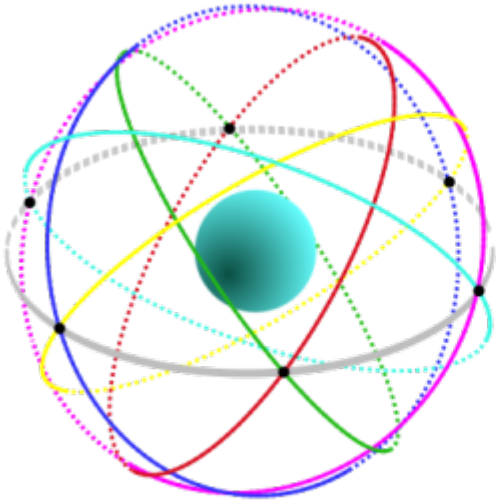


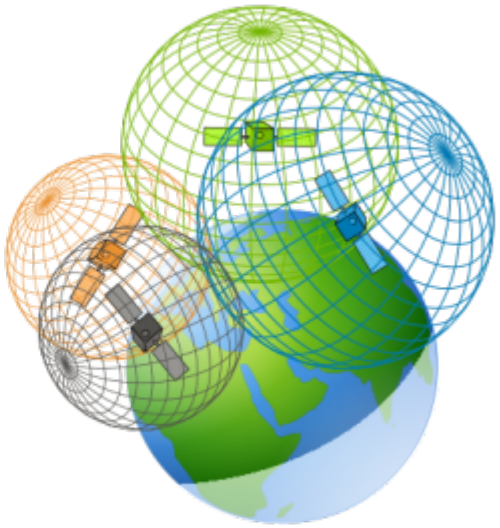


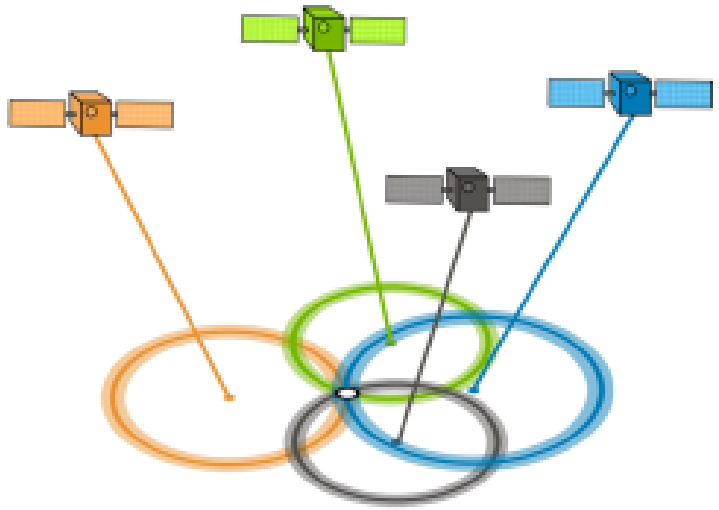


http://theconversation.com/five-maps-that-will-change-how-you-see-the-world-74967

WGS 84: GPS Trilateration

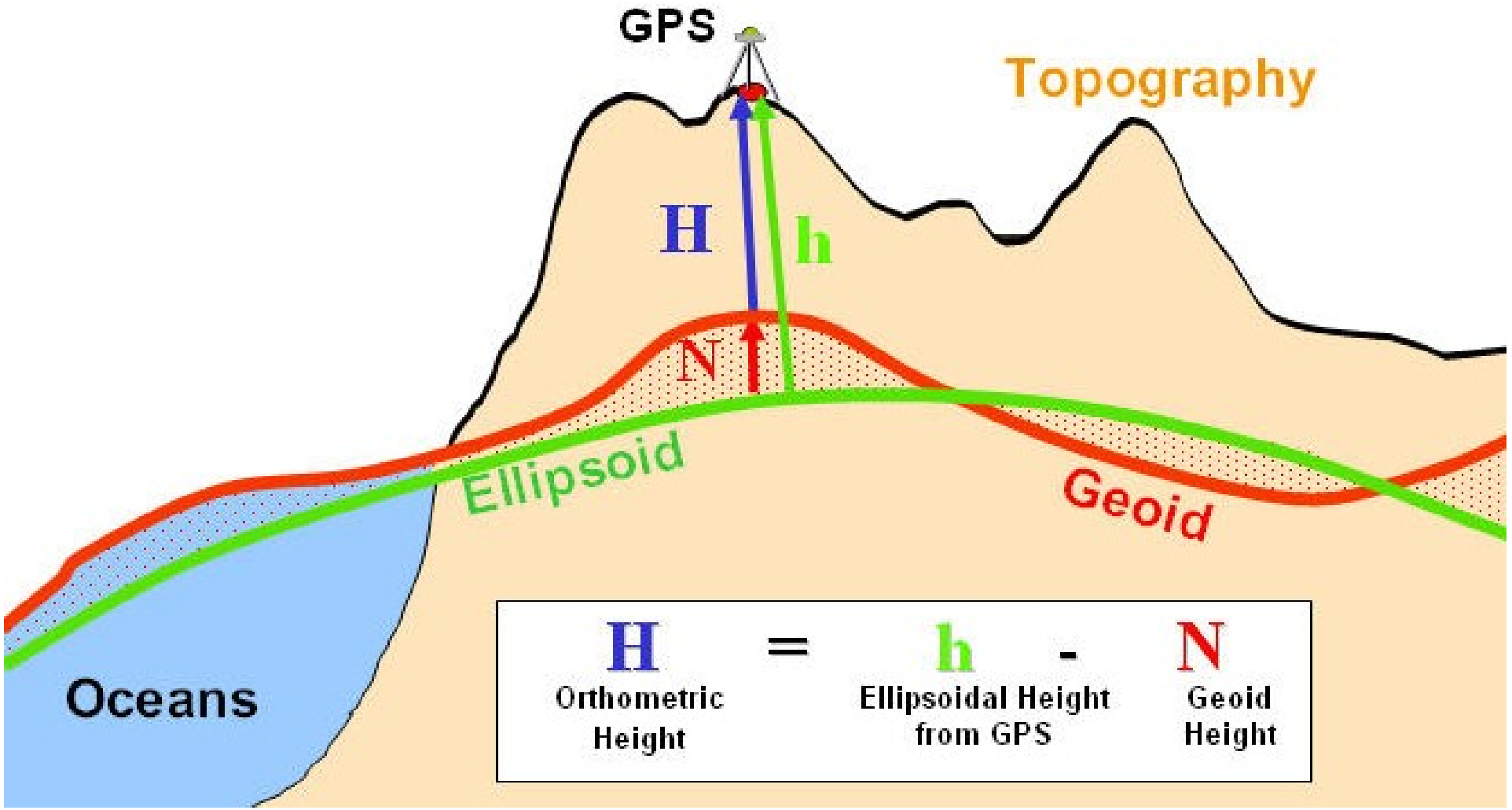




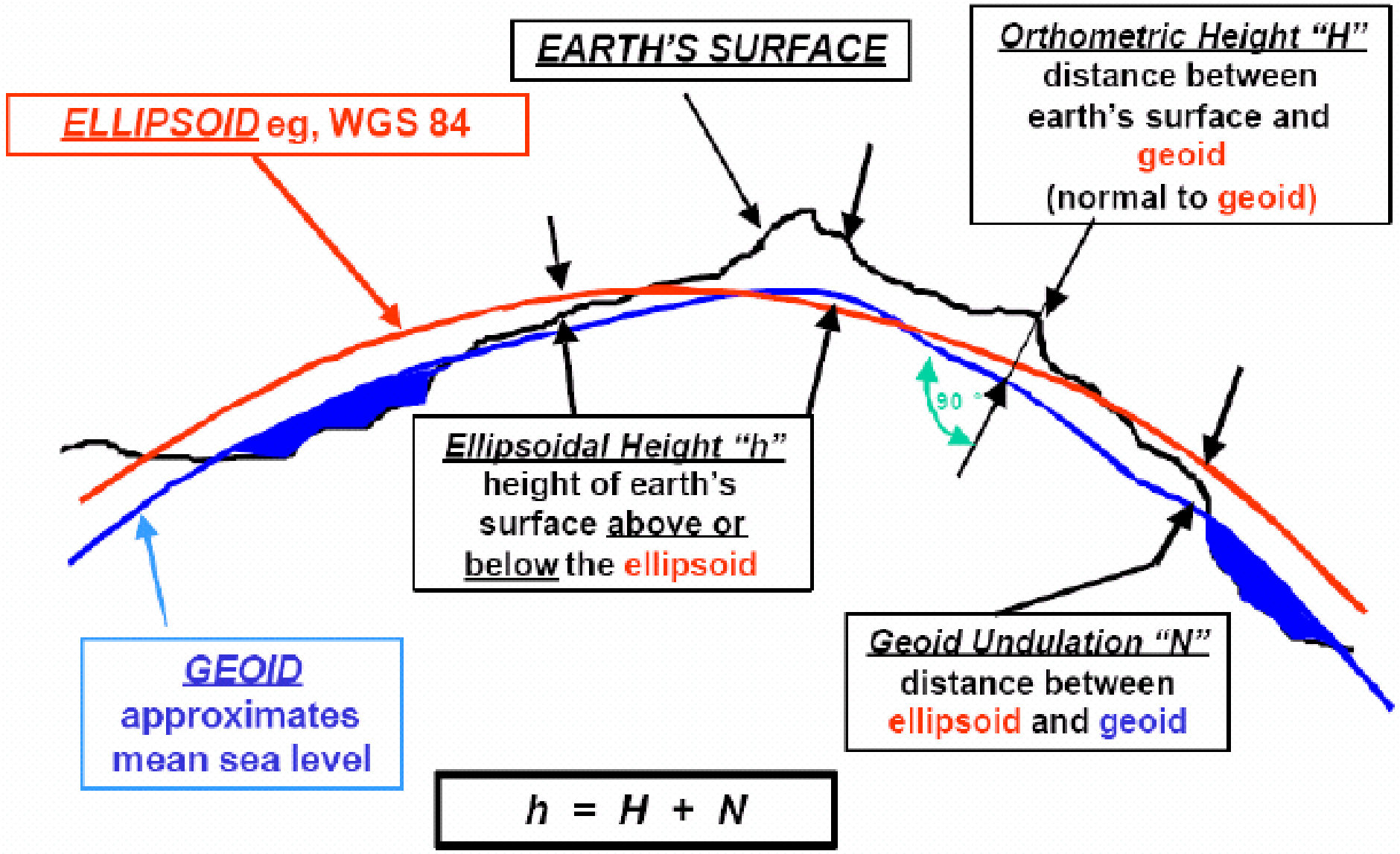


https://gisgeography.com/wgs84-world-geodetic-system/

Geoid, Ellipsoid, Topography



https://gis.stackexchange.com/questions/80533/which-of-egm96-geoid-or-wgs84-ellipsoid-fits-the-earth-better



https://nptel.ac.in/courses/105104100/lectureB_8/B_8_8coordinate.htm