Geodetic basis

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Reference systems and frames

- **The reference system** is a set of recommendations, findings and constants and models necessary to define the origin, the scale, the orientation of the coordinate system axes and their variability over time
- **The reference frame** is a practical implementation of the reference system. It is defined by a set of physical points with precisely determined coordinates in a system defined in the definition of the reference system
- **The coordinate system** determines the manner of assigning a set of numerical values (coordinates of a point) to the position of a point in space in relation to the axis of this system

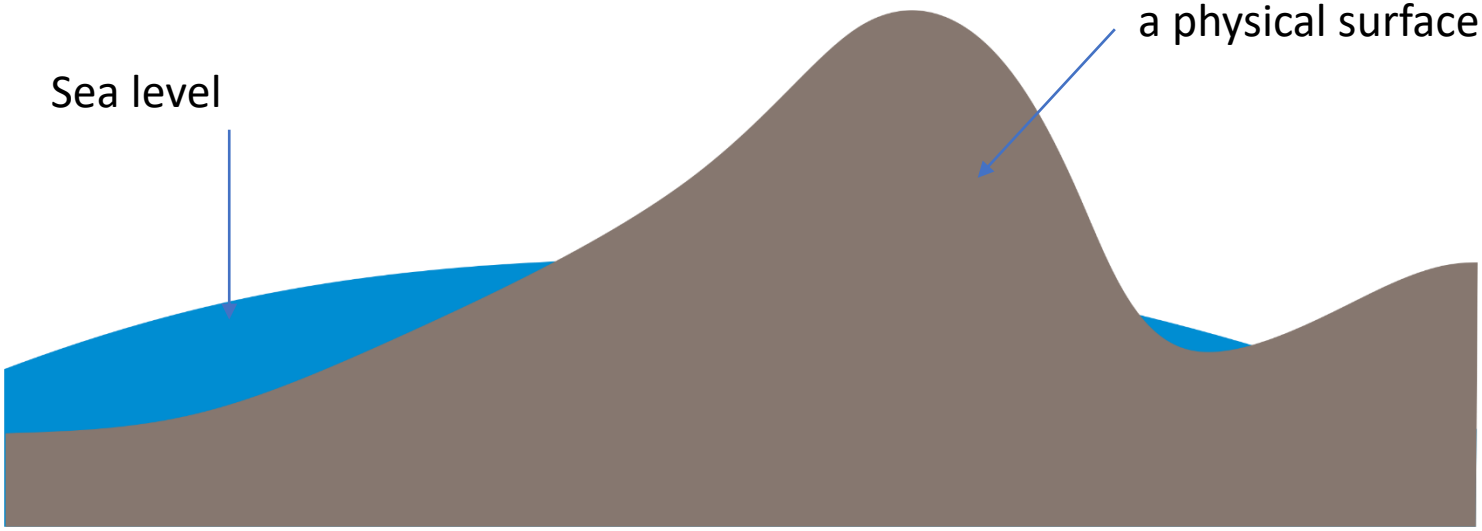
Models of the Earth

Flat Earth

Globe

Reference surfaces

- The physical surface of the Earth is very complicated and has complex shapes.
- For these reasons, a certain level has been set, to which the measurements of the surface of the Earth relate.
- This level of reference was taken to the level of seas and oceans with the full balance of the water masses contained therein



The geoid

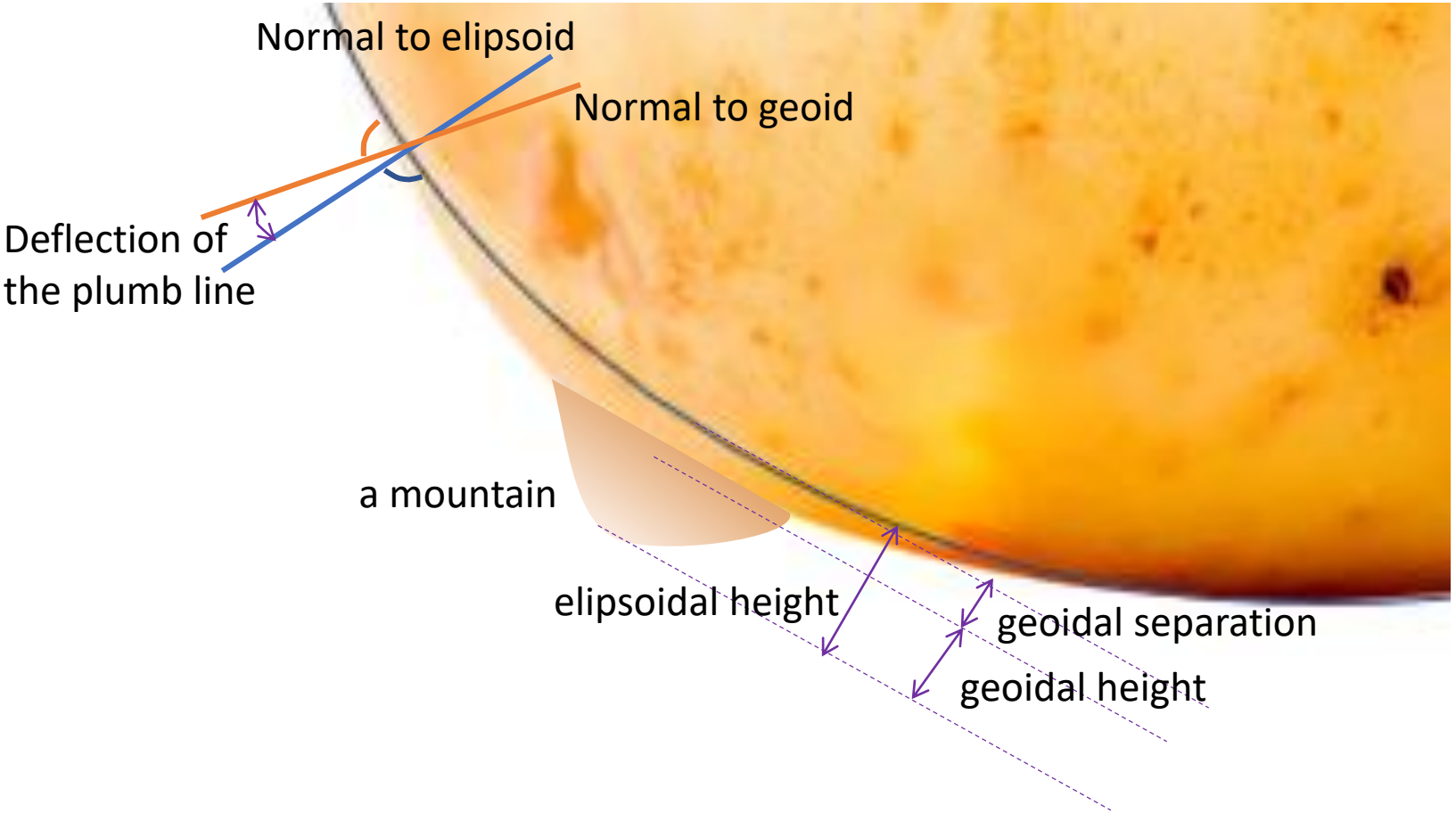
the equipotential surface of the Earth's gravity field which best fits, in a least squares sense, global mean sea level

The Elipsoid

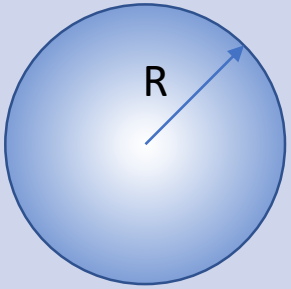
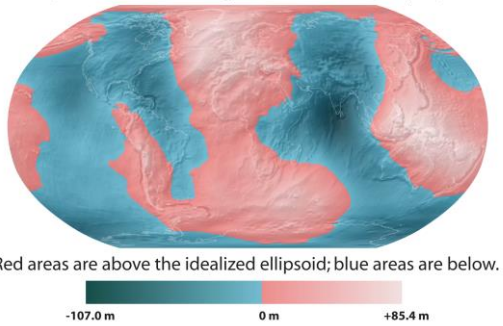
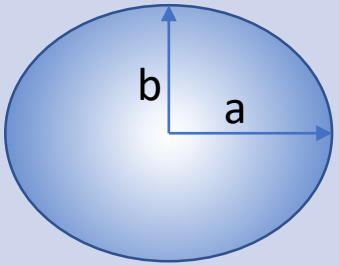
In geodesy, a reference ellipsoid is a mathematically-defined surface that approximates the shape of the Earth.
It is a closed surface, formed from the rotation of an ellipse around its small axis

The Elipsoid vs the geoid

Due to asymmetrical mass circumstances in the earth, gravity has an irregular course, which will render the geoid useless for a precise calculation surface for determination of points



Reference surfaces

Globe	Geoid	Ellipsoid
		
R = 6371000 m		a = 6 378 137 m
		b = 6 356 752,3142 m
		f = 1/298,257223563
		e = 0,081819

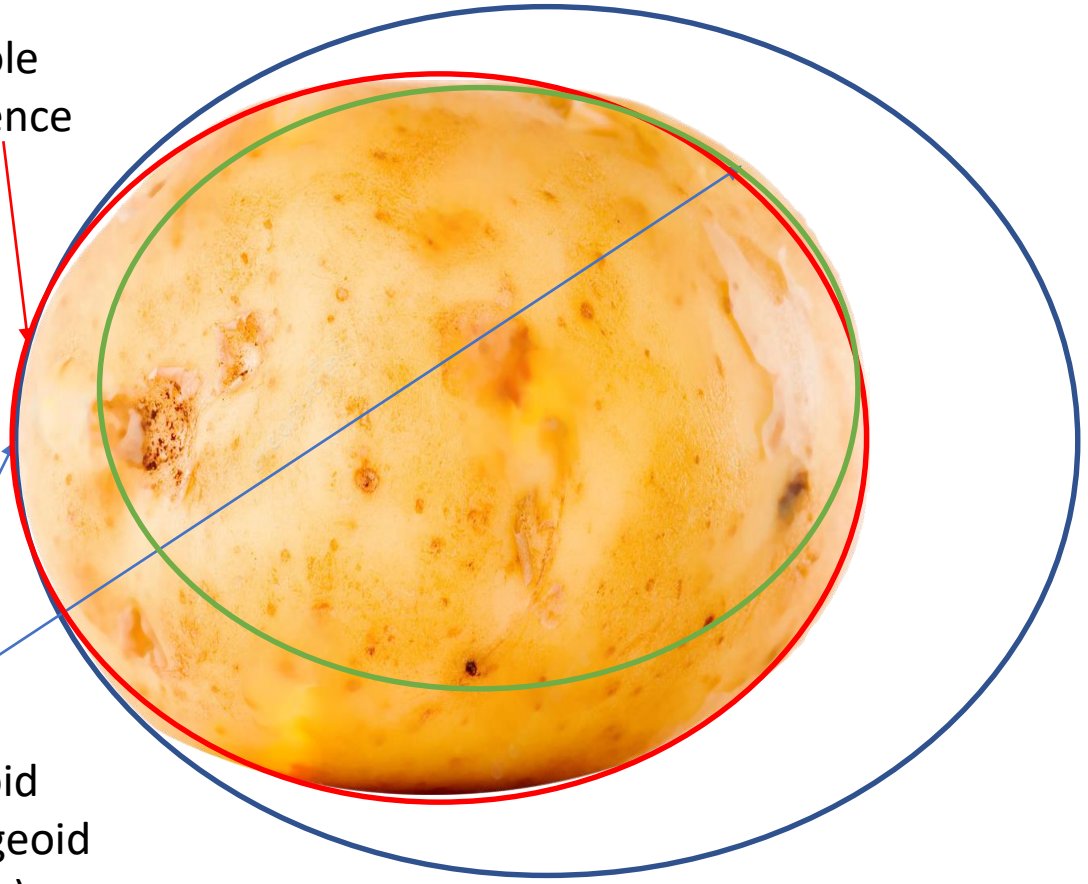
Where:
R = mean earth radius
a – semi major axe
b – semi minor axe

f – $flattening$ $\quad f = \frac{a-b}{a}$

e – $eccentricity$ $\quad e = \sqrt{\frac{a^2-b^2}{a^2}}$

Reference ellipsoids: local and global

The best fit for the whole geoid => a global reference ellipsoid i.e. WGS84



Areas where the ellipsoid matches very well the geoid (local reference systems)

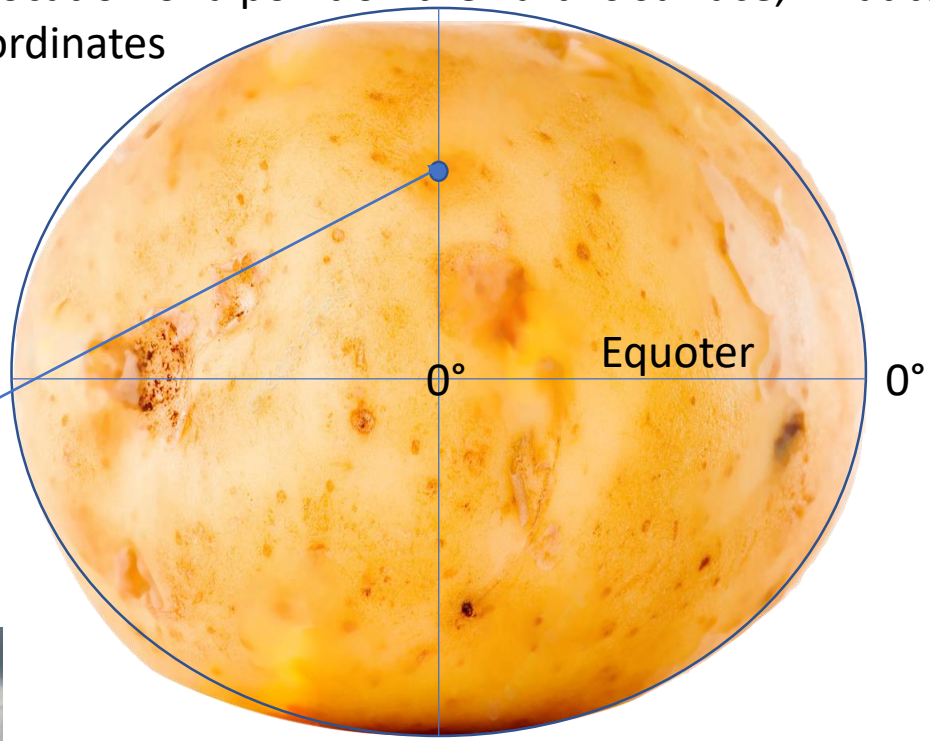
∞

Reference ellipsoids

Nazwa	Duża półoś (m)	Mała półoś (m)	Odwrotność spłaszczenia
Modified Everest (Malaya) Revised Kertau	6 377 304,063	6 356 103,038993	300,801699969
Timbalai	6 377 298,56	6 356 097,55	300,801639166
Sferoida Everesta	6 377 301,243	6 356 100,228	300,801694993
Maupertuis (1738)	6 397 300	6 363 806,283	191
Delambre (1810}	6 376 985,0		308 6465
Everest (1830)	6 377 276,345	6 356 075,413	300,801697979
Airy (1830)	6 377 563,396	6 356 256,909	299,3249646
Bessel (1841)	6 377 397,155	6 356 078,963	299,1528128
Clarke (1866)	6 378 206,4	6 356 583,8	294,9786982
Clarke (1880)	6 378 249,145	6 356 514,870	293,465
Helmert (1906)	6 378 200	6 356 818,17	298,3
Hayford (1910)	6 378 388	6 356 911,946	297
Międzynarodowa (Hayford 1924)	6 378 388	6 356 911,946	297
NAD 27	6 378 206,4	6 356 583,800	294,978698208
Krassowski (1940)	6 378 245	6 356 863,019	298,3
WGS-66 (1966)	6 378 145	6 356 759,769	298,25
Australian National (1966)	6 378 160	6 356 774,719	298,25
Nowa Międzynarodowa (1967)	6 378 157,5	6 356 772,2	298,24961539
GRS-67 (1967)	6 378 160	6 356 774,516	298,247167427
Południowo-Amerykańska (1969)	6 378 160	6 356 774,719	298,25
WGS-72 (1972)	6 378 135	6 356 750,52	298,26
GRS 80 (1979)	6 378 137	6 356 752,3141	298,257222101
NAD 83	6 378 137	6 356 752,3	298,257024899
WGS-84 (1984)	6 378 137	6 356 752,3142	298,257223563
IERS (1989)	6 378 136	6 356 751,302	298,257
Sfera (6371 km)	6 371 000	6 371 000	∞

The Datum

A geodetic reference frame. In surveying and geodesy, a datum is a set of reference points on the Earth's surface, and (often) an associated model of the shape of the Earth (reference ellipsoid) used to define a geographic coordinate system. Horizontal datums are used to describe the location of a point on the Earth's surface, in latitude and longitude or other appropriate coordinates



Greenwich meridian - 0°
The Royal Observatory

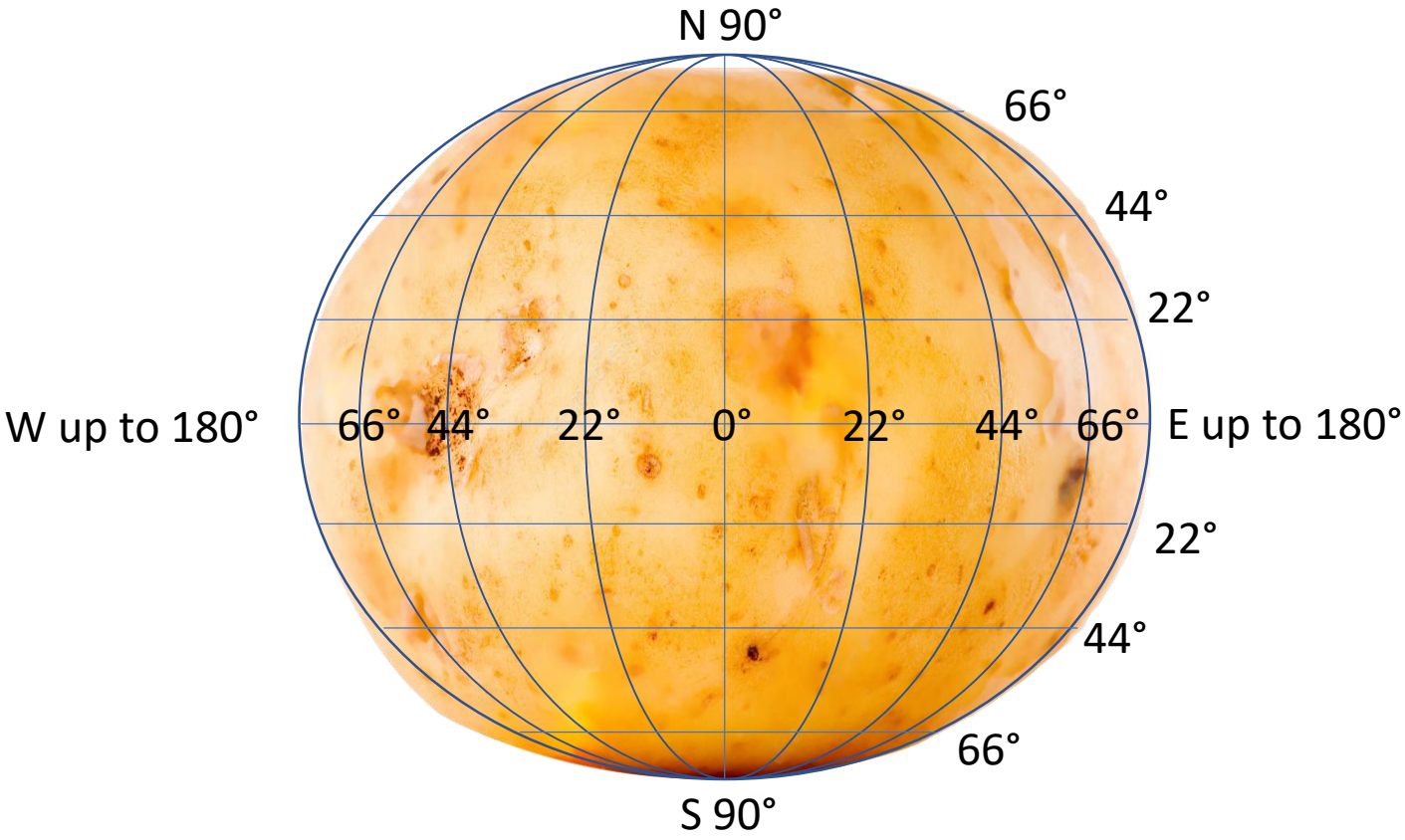
Co-ordinates

- Terrestrial co-ordinates
  - They have a fixed position connected to the Earth's crust and rotate with it
  - The origin lies in or near the Earth's center of gravity (geocentric system), or lies on the Earth's Surface (topocentric system)
  - Describes position on / near the Earth's surface
- Celestial co-ordinates
  - Connected to the solar system, applied to define co-ordinates for celestial bodies
  - Orbit co-ordinates used to describe position of satellites in orbit around the Earth

Terrestrial co-ordinates

- Geographical co-ordinates
  - based on angular measurements
  - North – South direction – latitude +/- 90°
  - East – West direction – longitude +/- 180°
- Cartesian co-ordinates
  - based on triaxial (x, y, z) right-hand system
  - Used to fix position on an ellipsoid's surface
  - Usual uses meters as a unit

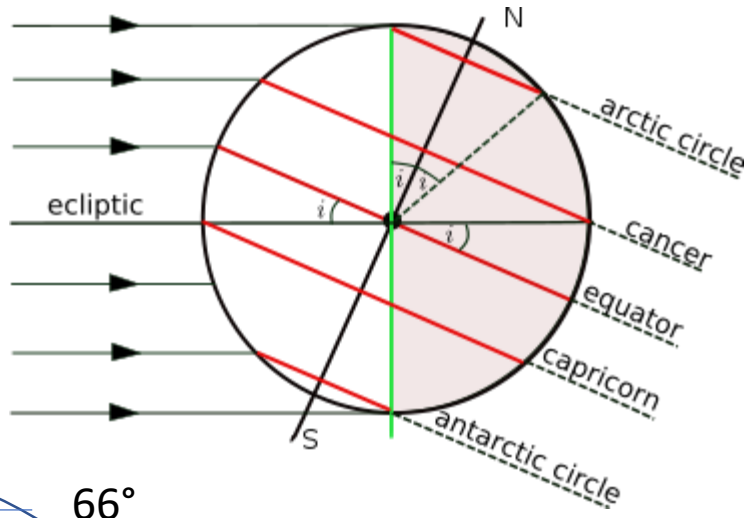
Geographical co-ordinates

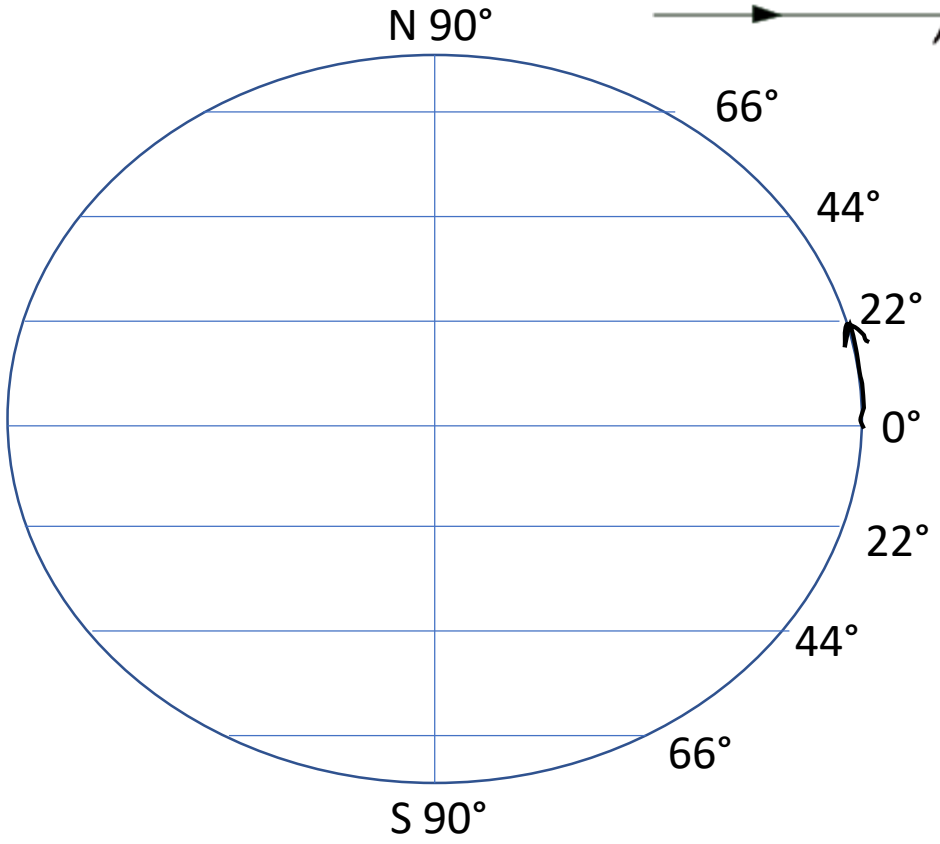


The latitude – from 0°, on the equator, up to +90° to the North and up to -90° to the South

The longitude – from 0° meridian, which goes through the Greenwich Observatory, up to +180° to the East and up to -180° to the West

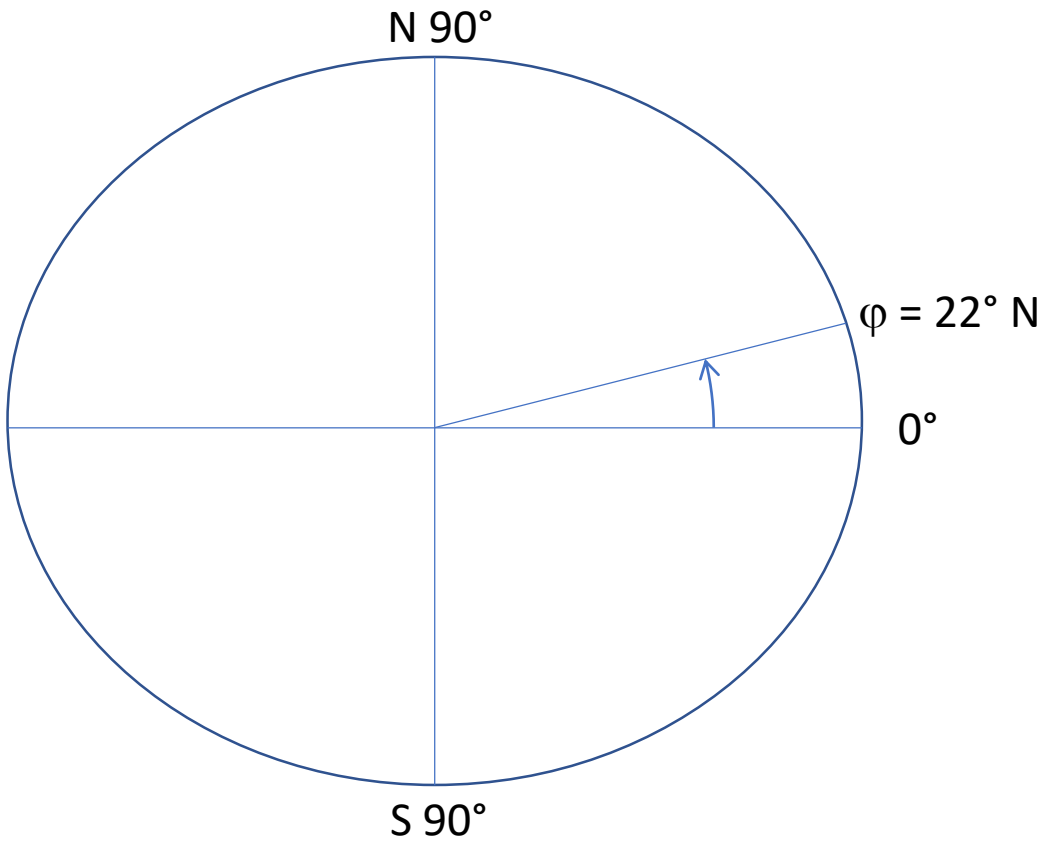
Latitude





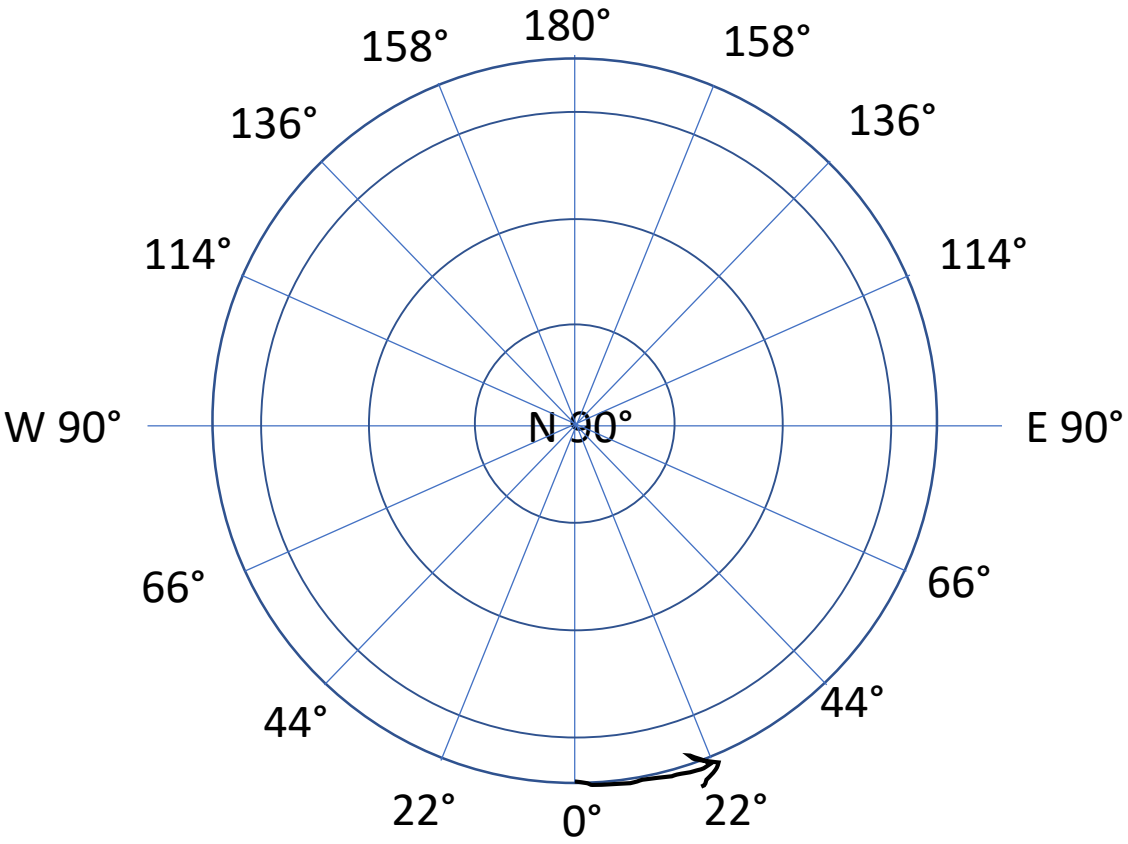
The length of the meridian arc, which is expressed in an angular measure from the equator to a parallel passing through a given point on N or on S to max. 90 °

Latitude



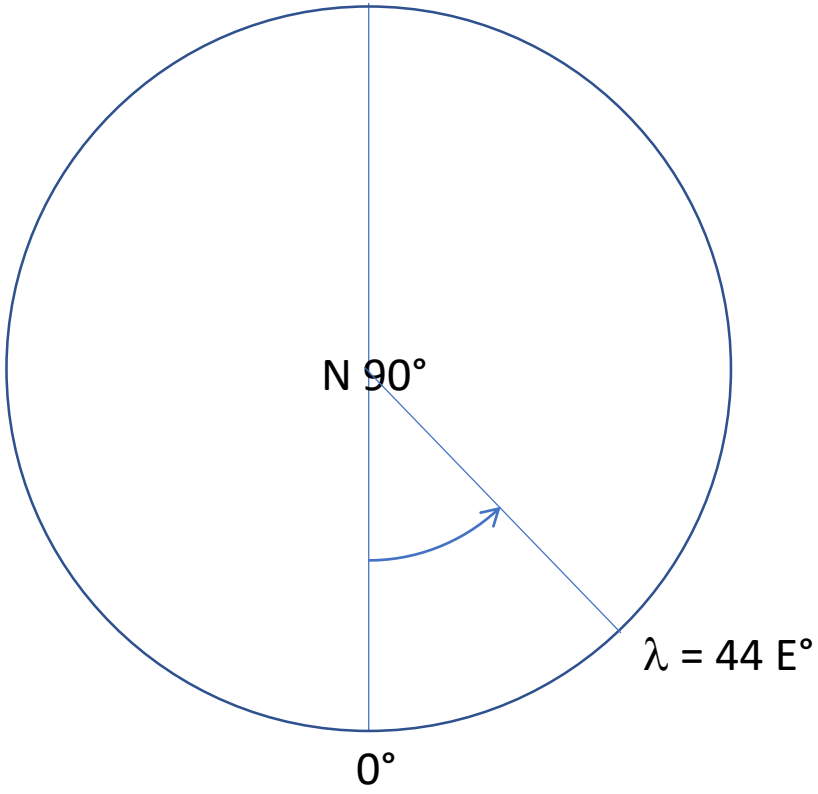
The angle between the equator's plane and a line drawn from the center of the Earth and passing through a given point; on N or on S to maximum 90°

Longitude



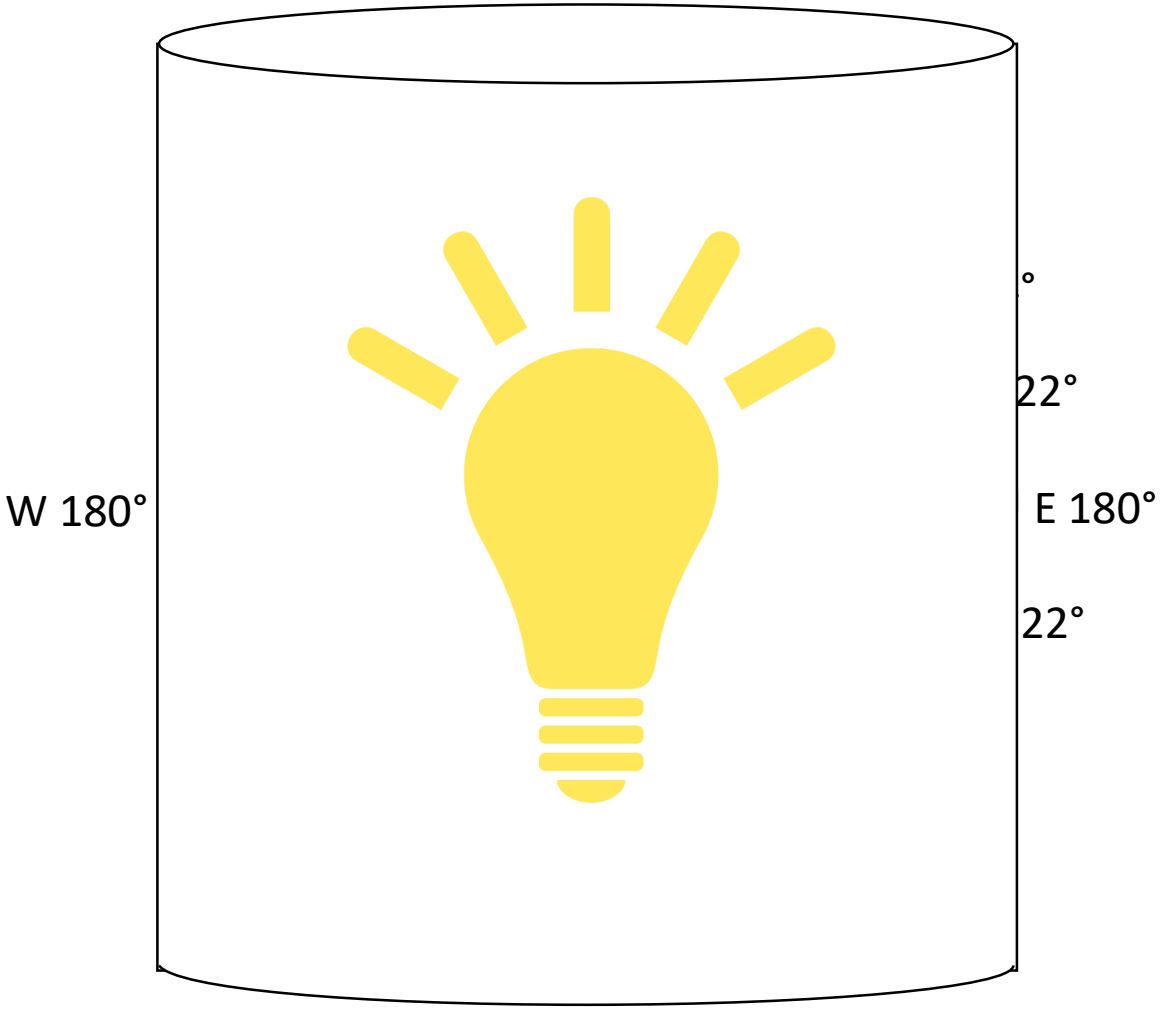
The length of the equator arc, which is expressed in degrees, counted from the meridian 0 ° to a meridian passing through a given point on E or on W up to max 180°

Longitude

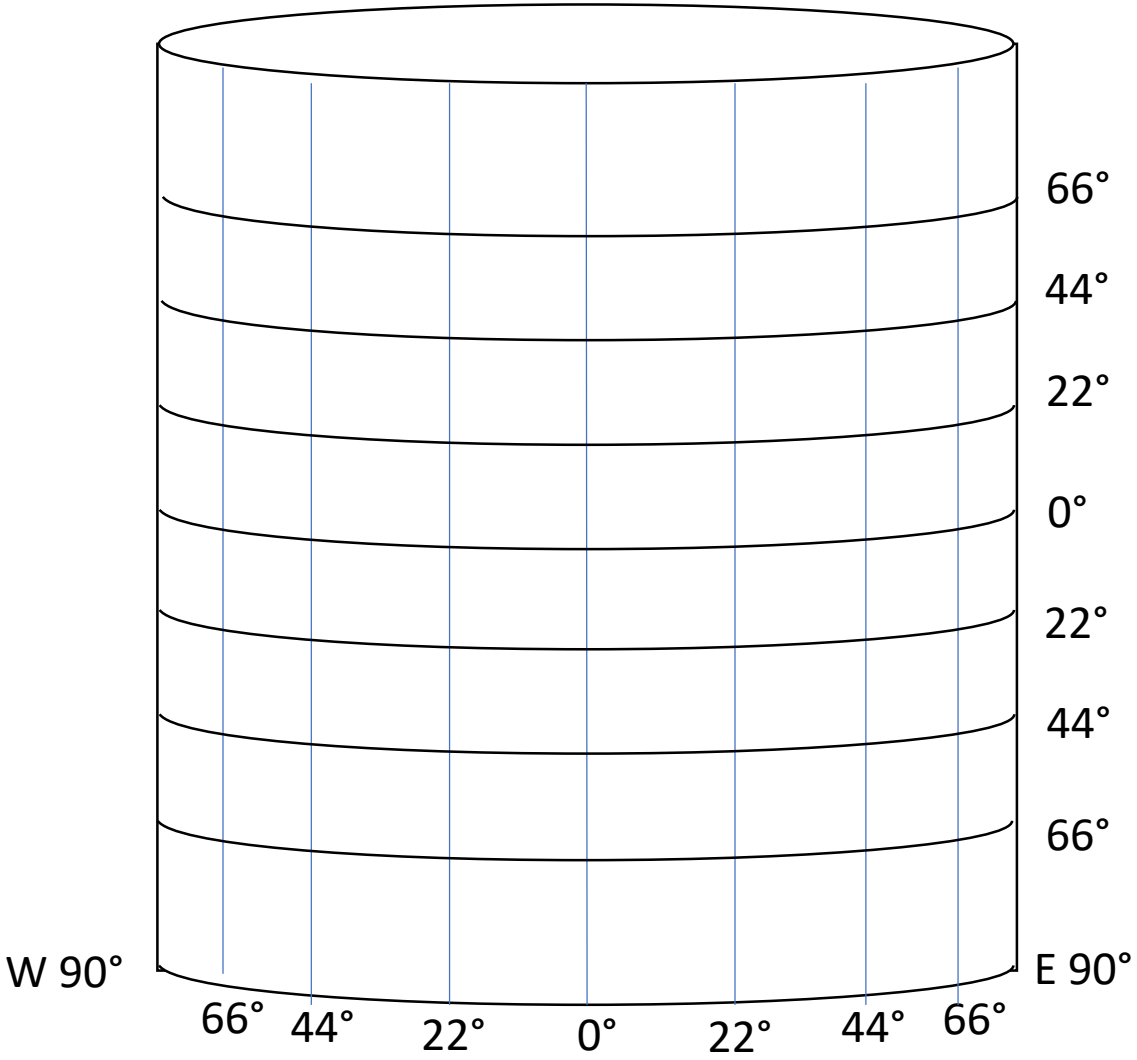


the angle between the 0° meridian's semi-plane and a meridian's semi plane passing through a given point on E or on W up to max 180°

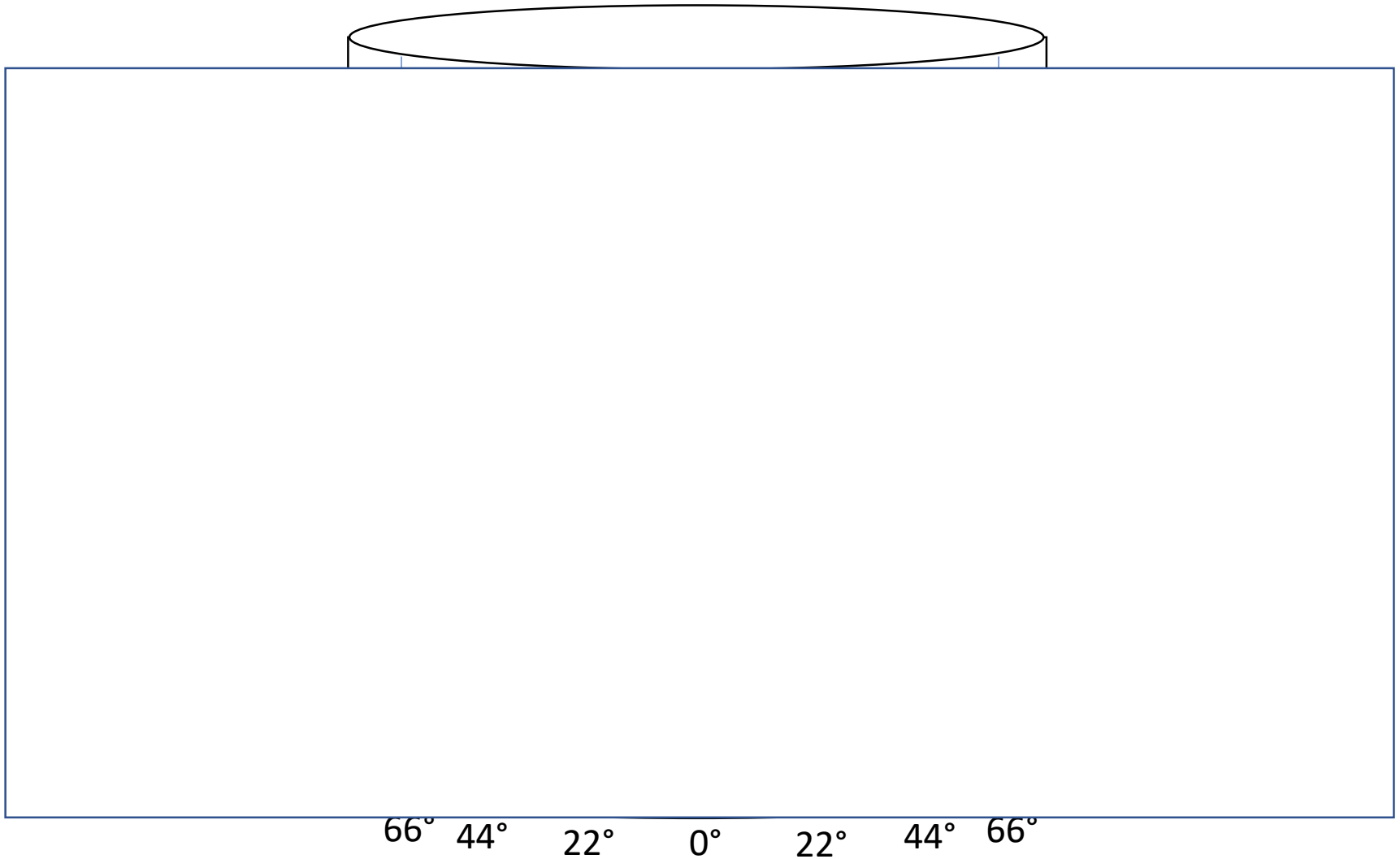
Mercator’s projection



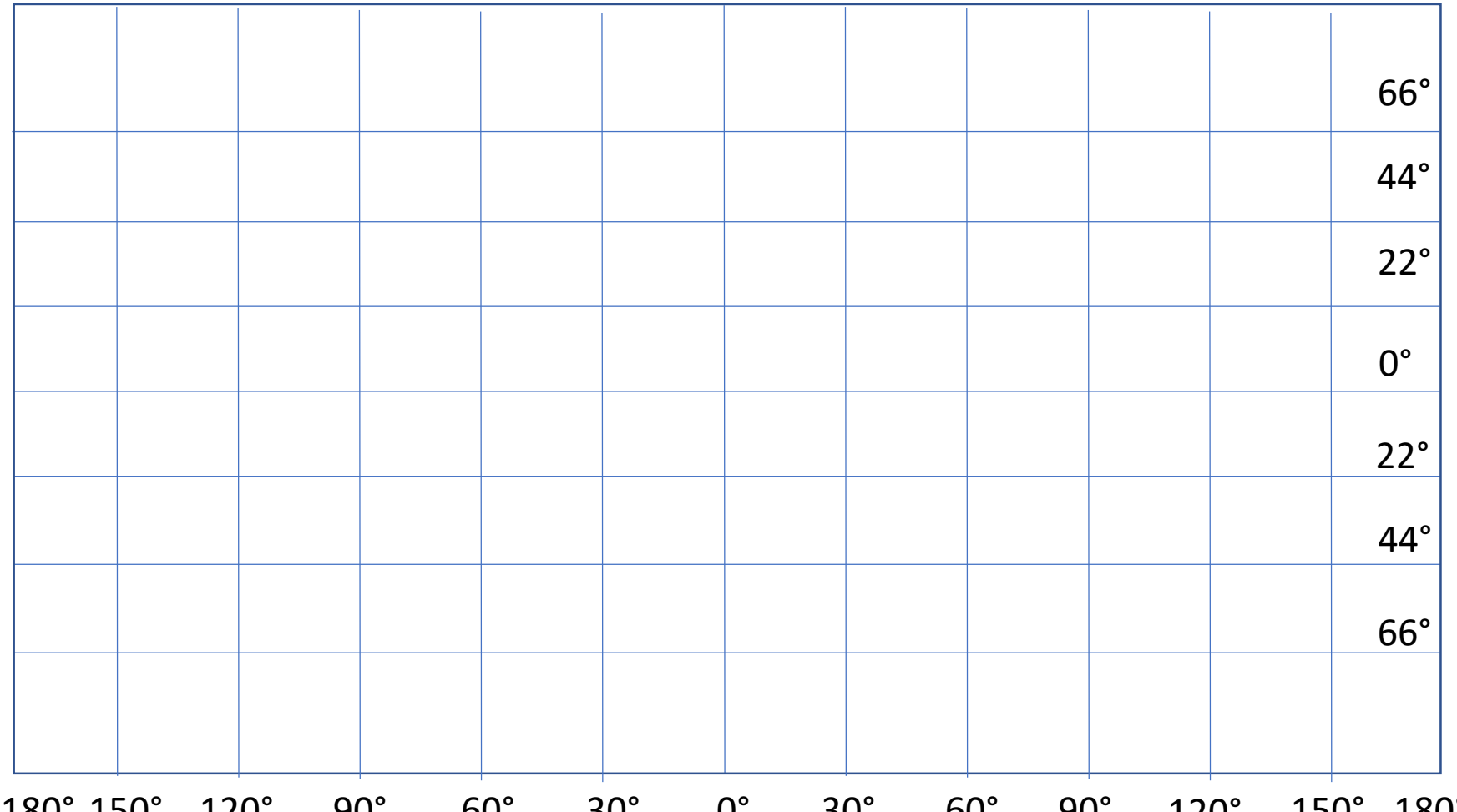
Odwzorowanie Mercatora



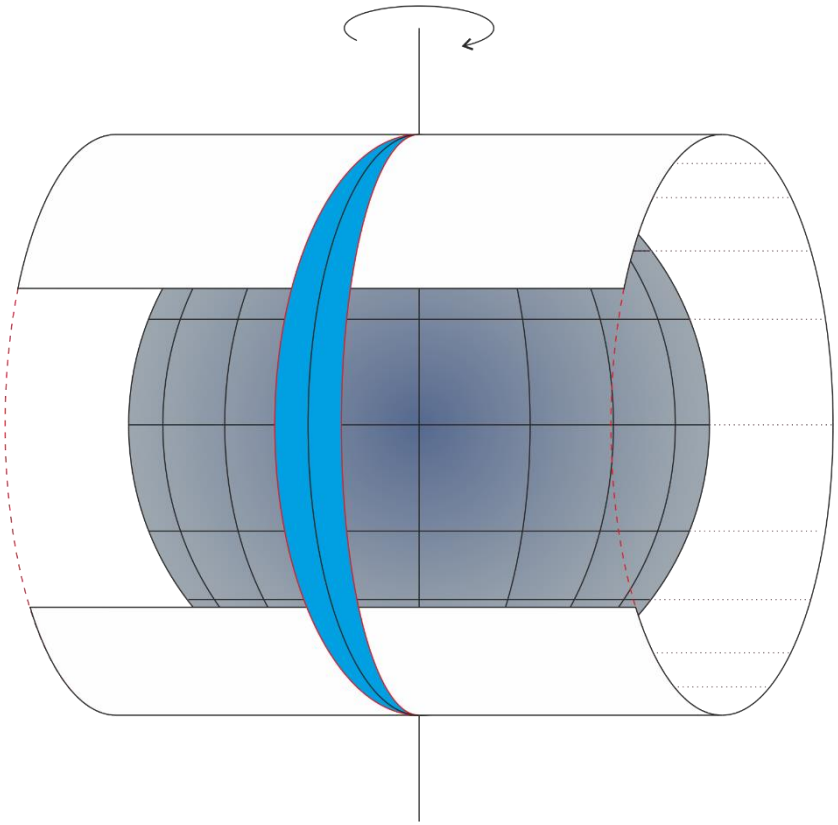
Odwzorowanie Mercatora



Odwzorowanie Mercatora

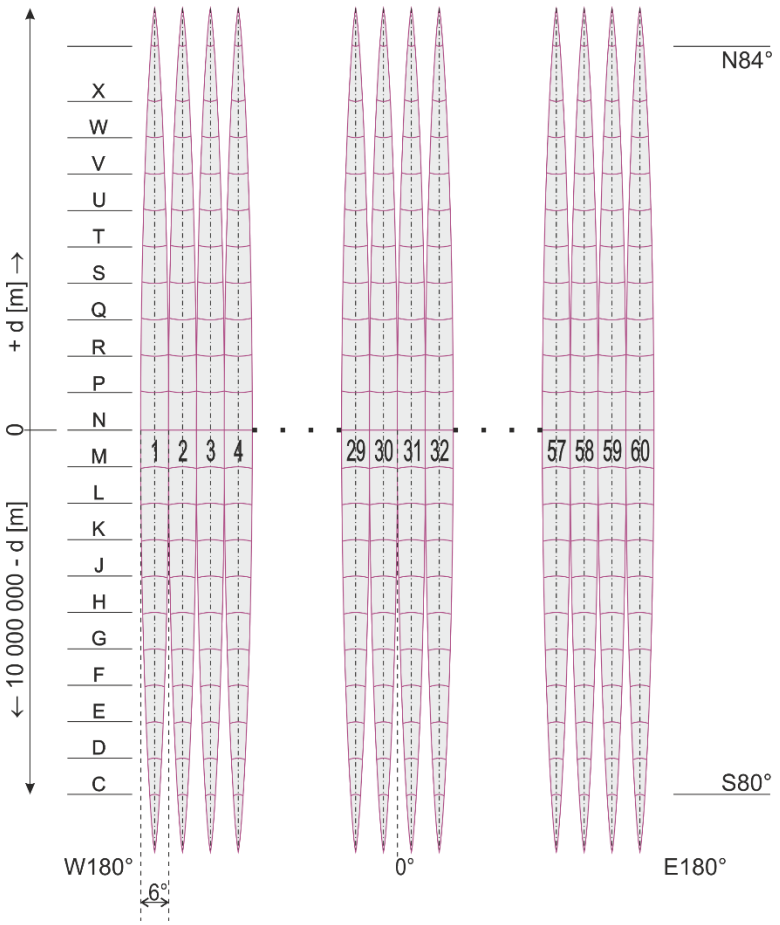


Universal Tranversal Mercator UTM



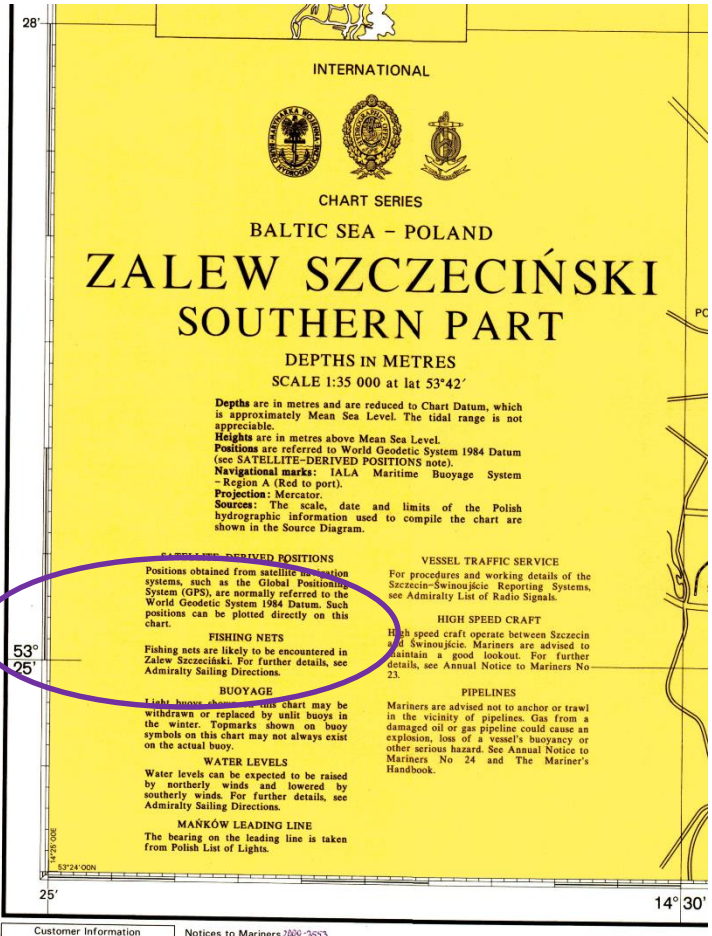
- The tangency meridian (central) is selected every 6 degree of longitude, which gives 60 zones (6 degrees wide)
- The first zone: W180 – W174
- The zone is divided into 20 belts from C to X (except I and O) along latitude
- Every belts is 8 degrees of latitude, except X which is equal 12 degrees

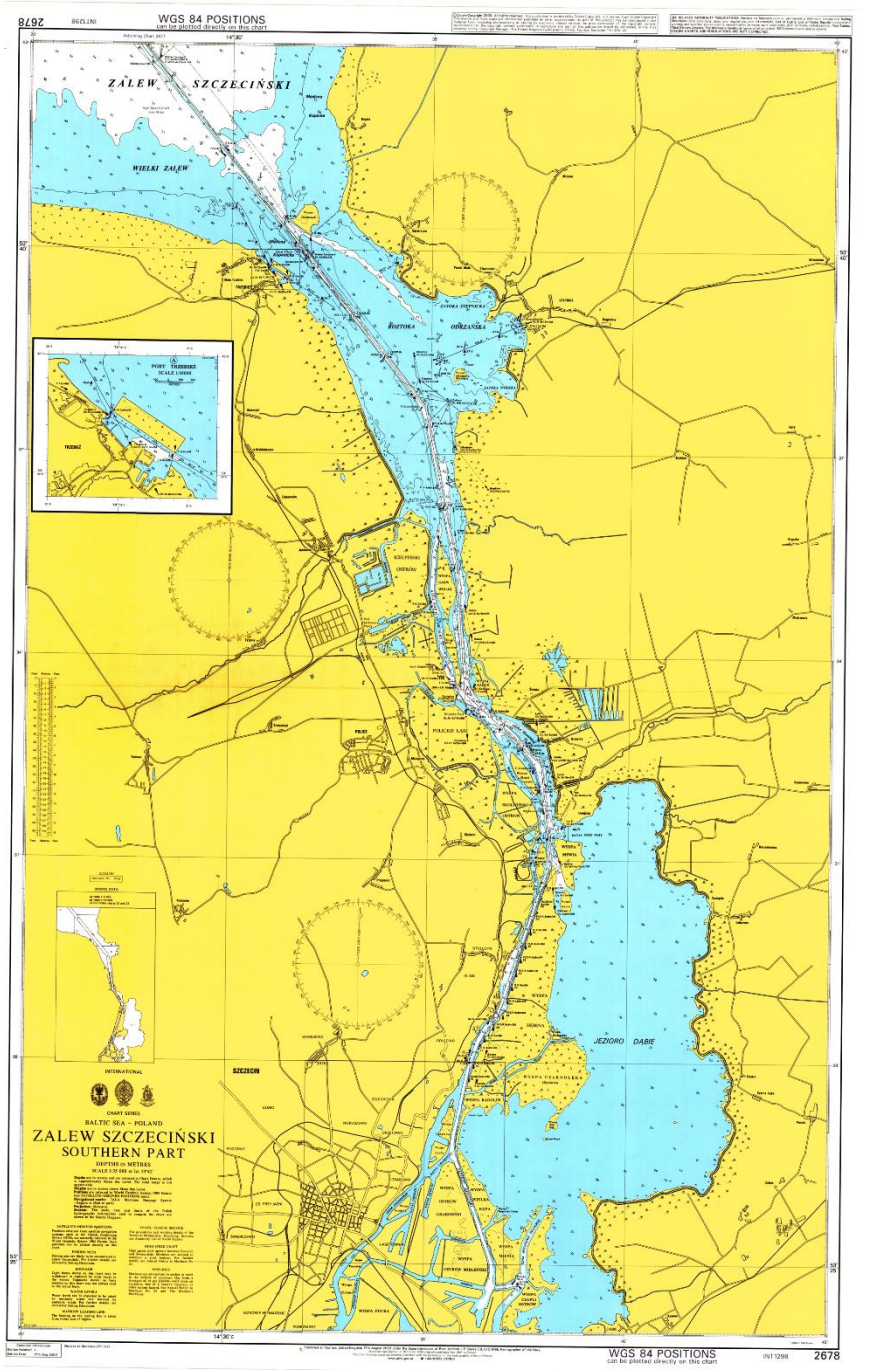
UTM: northing, easting



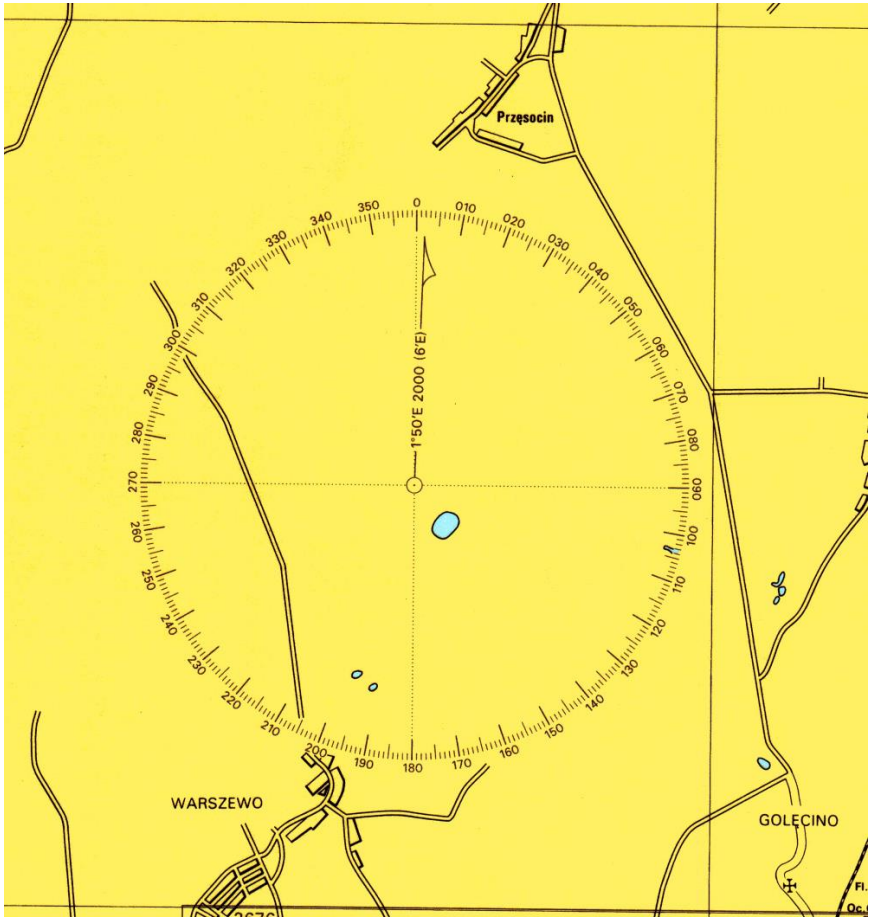
- North hemisphere – distance in meters, from the equator to North (up to N84)
- South hemisphere – 10 million minus distance [m] from the equator to South (up to S80); “false northing”
- Easting – distance [m] from the central meridian of the zone + 500 000 m; „false easting”
- Positive values of coordnates

Navigation Chart





Directions on the chart



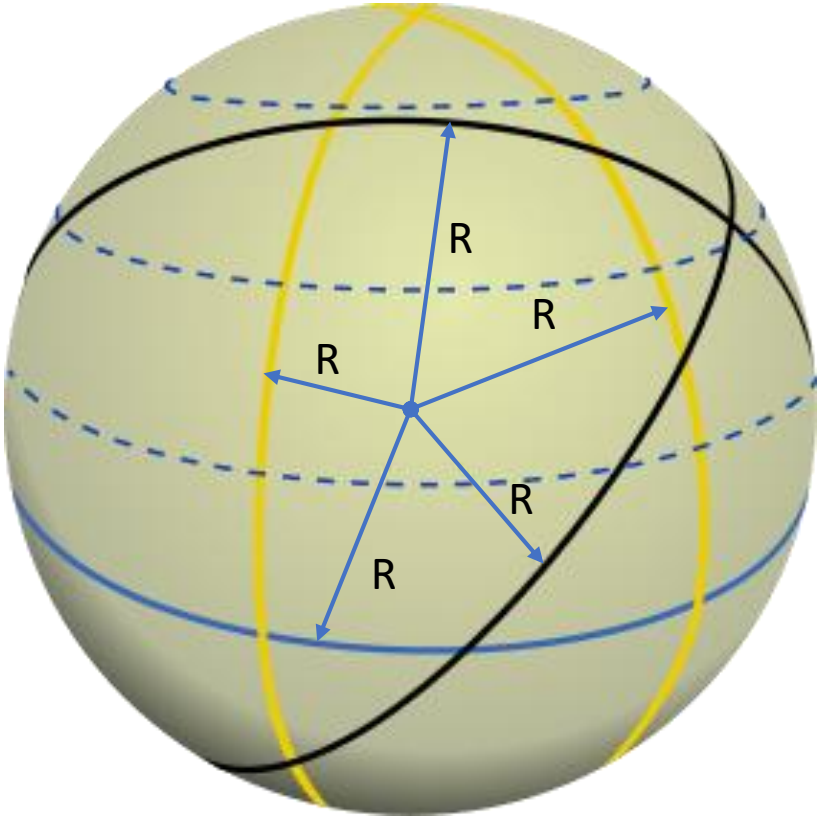
Nautical miles

- *Nautical mile NM* – (*International Nautical Mile* – INM) – it is a distance unit used in marine navigation and aviation
- It is the arc length of the Earth meridian corresponding to one minute of an angle on a great circle
- In fact, due to the shape of the globe (Geoid), the arc length of 1 minute angle, varies depending on the latitude, therefore the average length was assumed

Nautical mile

- 1 NM → 1’
  1 NM = 40 000 km / (360° × 60’) =
  1851,852 m ≈ 1 852 m
- 1 NM = 10 cables

Great circle– the largest circle, which can be put into a globe. Its diameter is equal to the diameter of the sphere, and the plane of the circle divides the globe into two symmetrical halves, called hemispheres.
It is a trace of the plane on the sphere that passes through center of the globe.

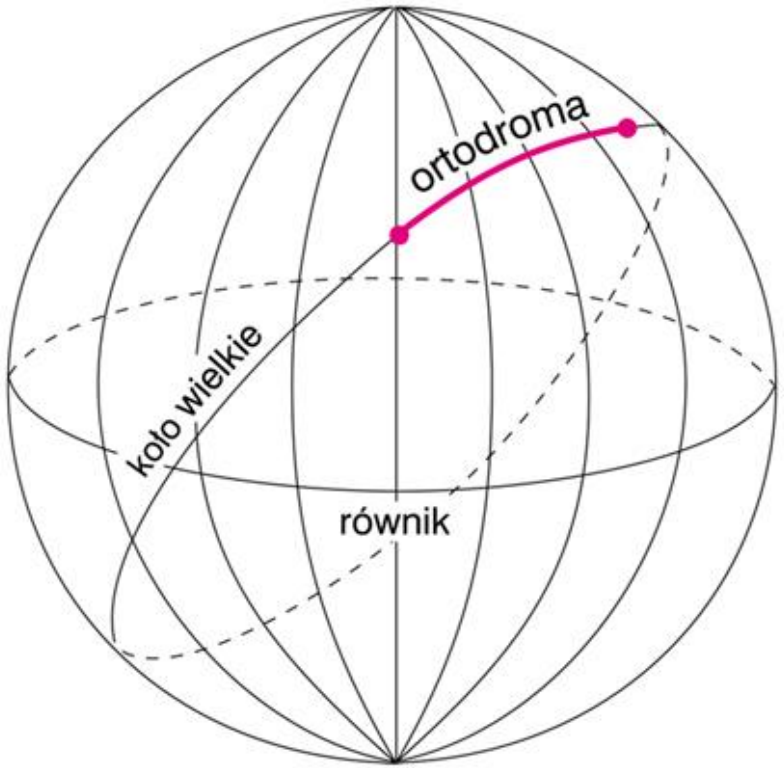


Ortodroma / great circle / gc

orthodroma [gr]:

- the shortest line connecting 2 points on the surface of the ball
- it is the arc of a great circle passing through the given 2 points;
- on the globe orthodroma crosses meridians at different angles.

GC (or similar see manual) on receiver's display means that the navigation is on the orthodromic: a distance is calculated on great circle and a bearing is an initial orthodromic angle



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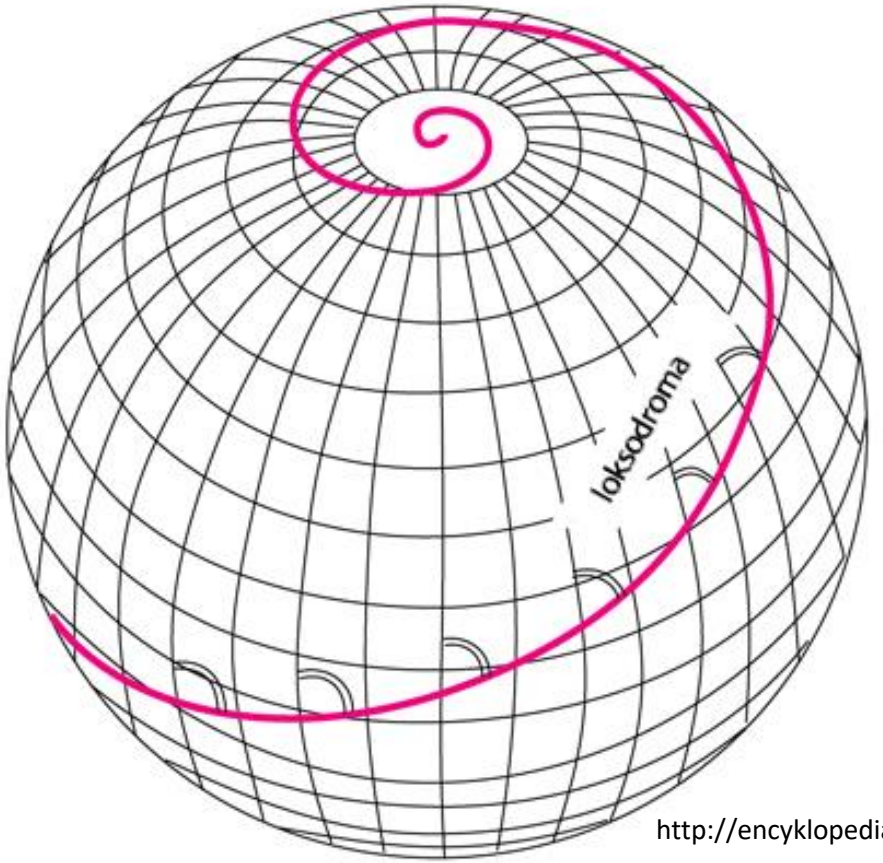
Loxodrome / rhumb line / rl

loxodrome [gr.]:

- a line on the surface of the sphere that cuts all meridians at a constant angle α;
- when α is an acute or obtuse angle (α ≠ 0 °, 90 °, 180 °), then it has a spiral shape with an asymptotic point on the pole;
- on the chart in the Mercator projection loxodrome is a straight line, which is used in navigation (road after loxodrome means a route at a fixed course);
- the term l. was introduced by Snellius (1624).



http://encyklopedia.pwn.pl/

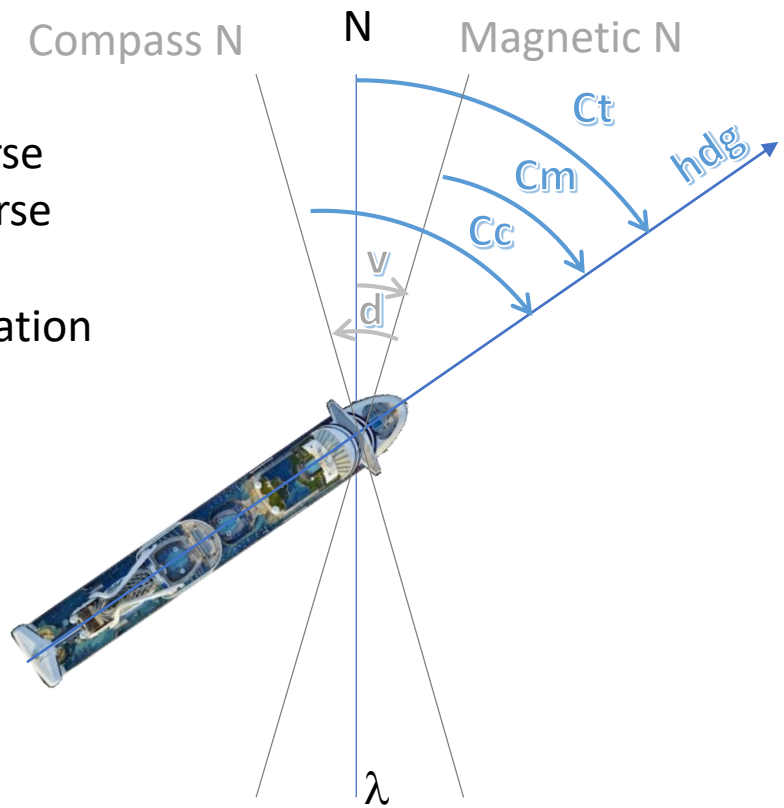
RL (or similar see manual) on receiver's display means that the navigation is on the rhumb line: a distance is calculated on rhumb line and a bearing is a bearing to a destination

Heading

Heading (hdg) – where the bow is directed in relations to North

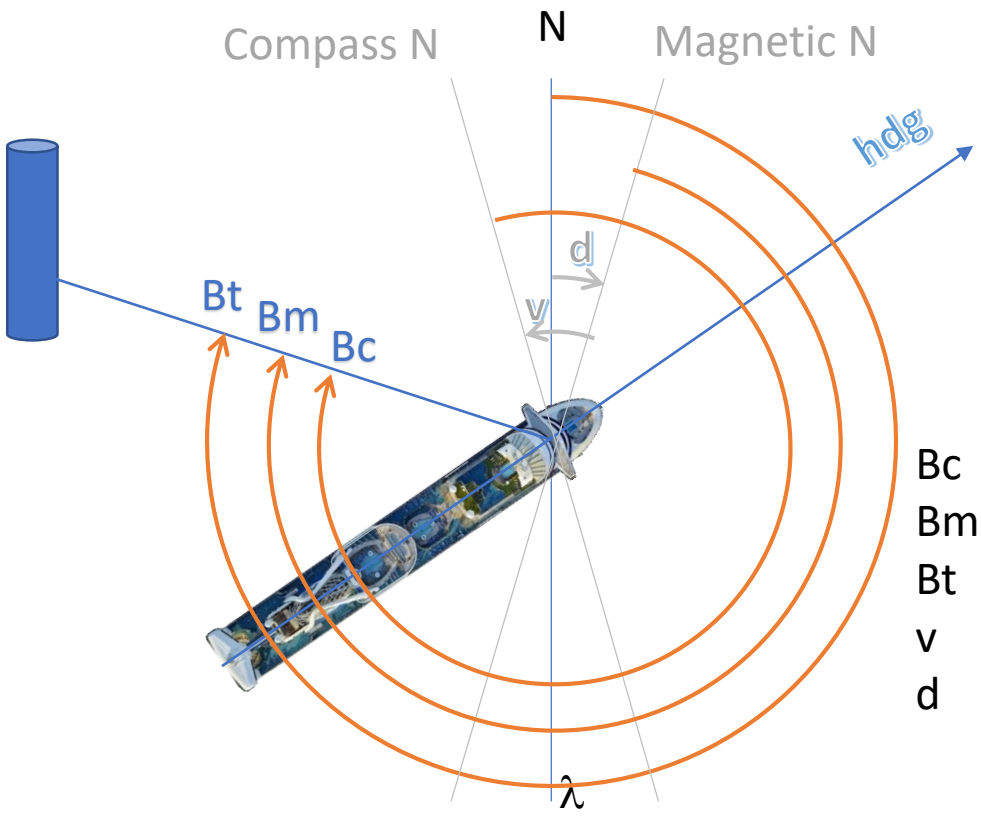
the angle between the northern part of the local meridian and the bow part of the ship's symmetry axis
It depends on which reference line is taken into consideration:

Cc – Compass course
Cm – Magnetic course
Ct – True course
v – magnetic variation
d – deviation



Bearings

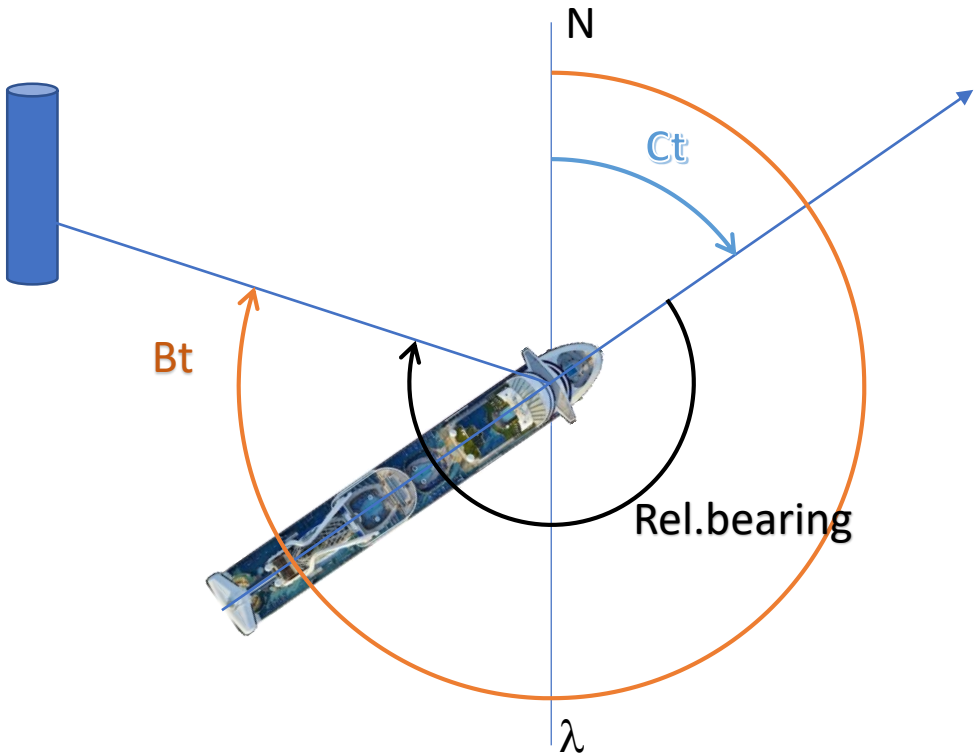
True bearing (bearing) – the angle between the northern part of the local meridian and the line drawn from the observer to an object (target)



Bc – Compass bearing
Bm – Magnetic bearing
Bt – True bearing
v – magnetic variation
d – deviation

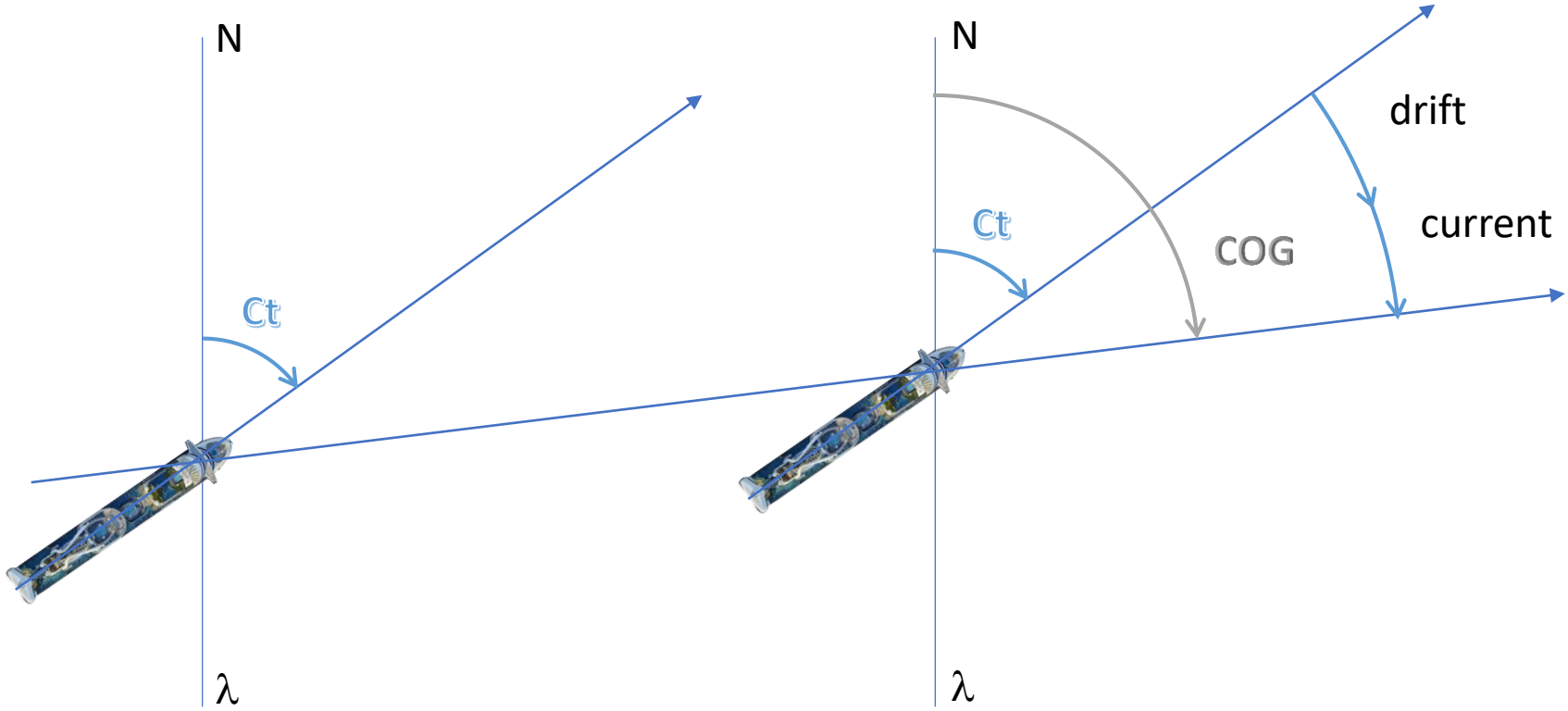
Relative bearing

Relative bearing (rel.bearing) - the angle between the bow part of the ship's symmetry axis and the line drawn from the observer to a object (target)



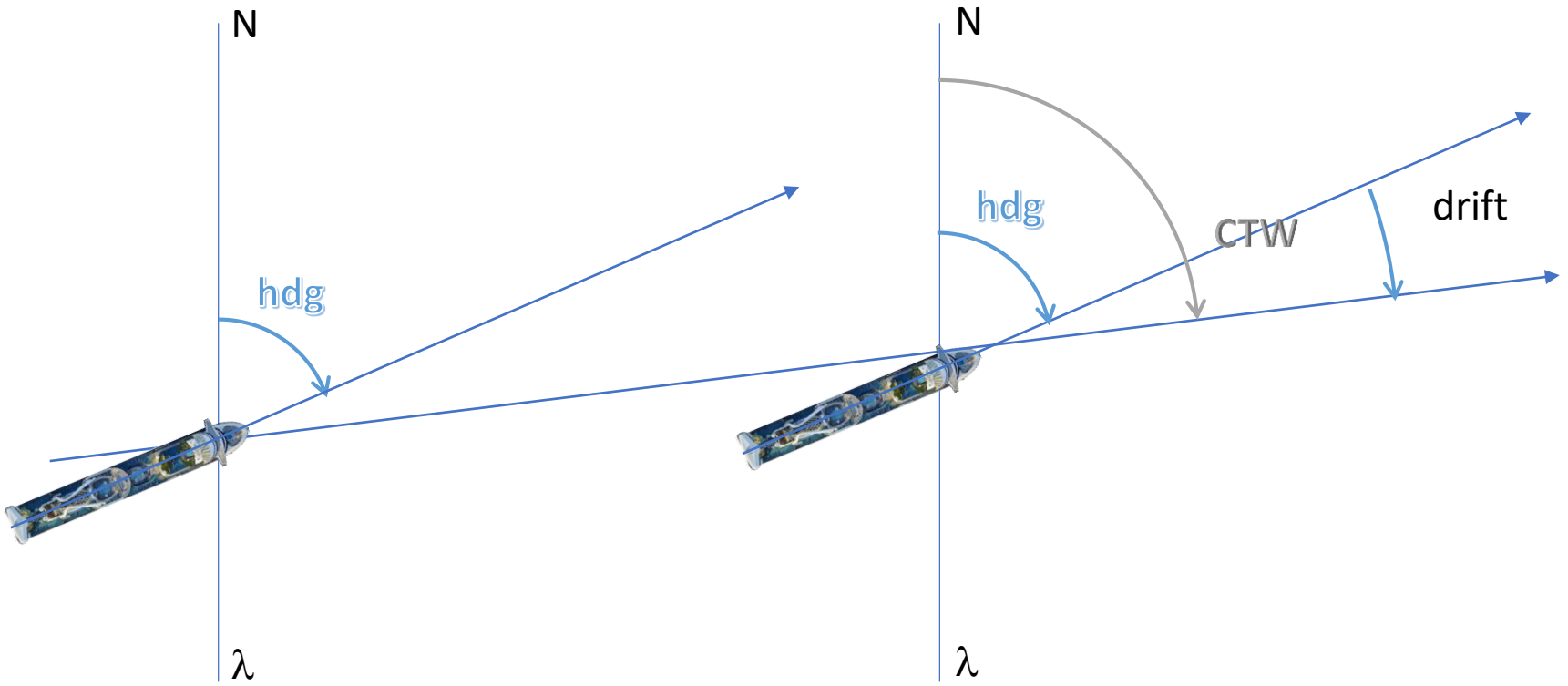
COG

Course over ground - the angle between the northern part of the meridian and the path of the vessel movement in relation to the a bottom (Earth)



CTW

Course through the water - movement in relation to the water (heading is corrected for the wind)



The end