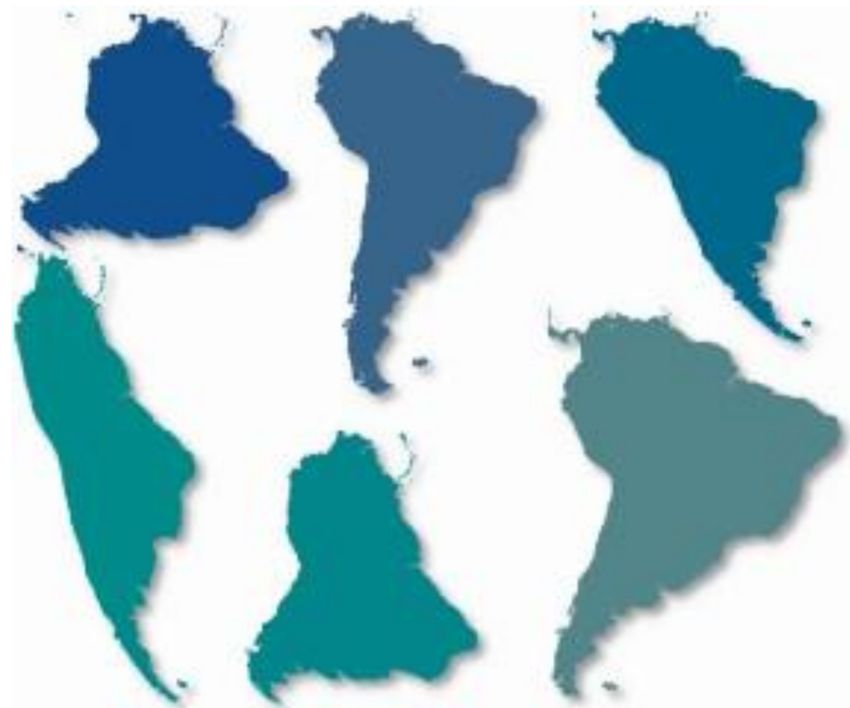
Map projections 1: principles

How can we 'project' a 3D globe onto a 2D display?

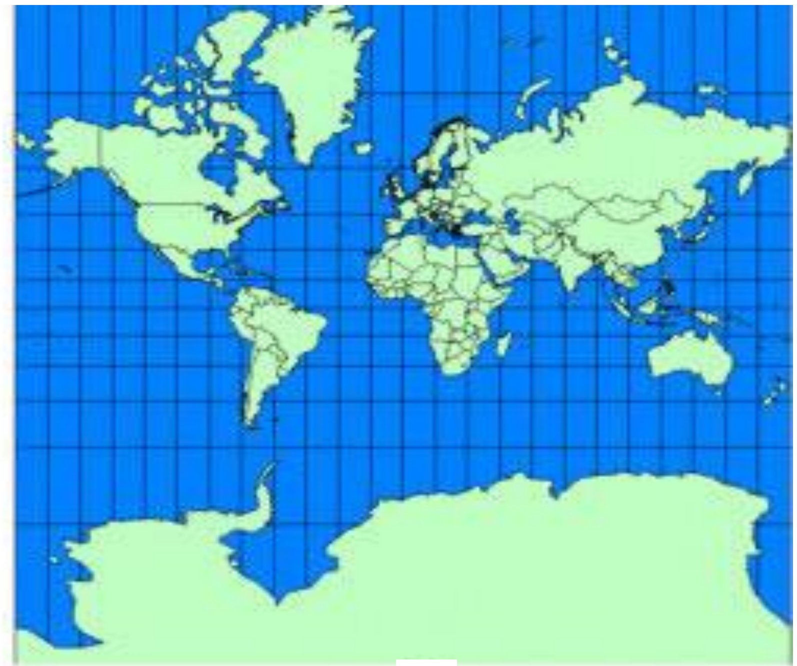
..only a globe maintains all spatial qualities without distortion



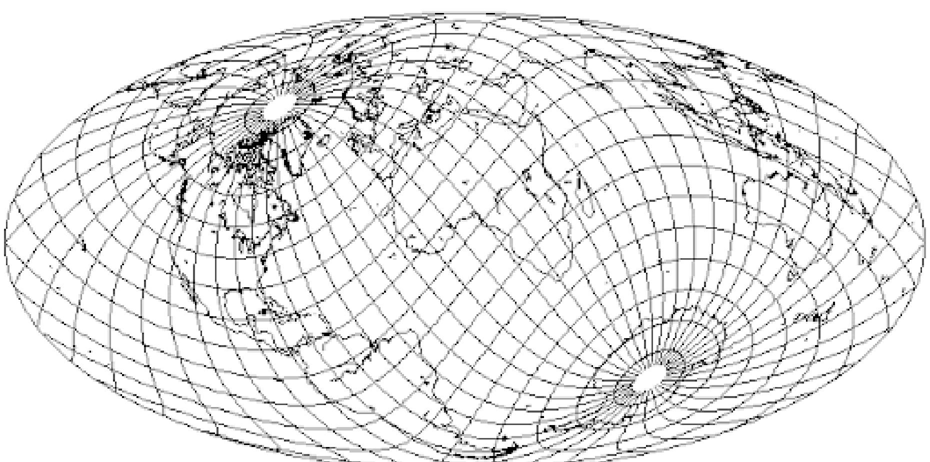
What is a Map Projection?

mathematical expression showing the 3D surface on a 2D map

This process always results in distortion

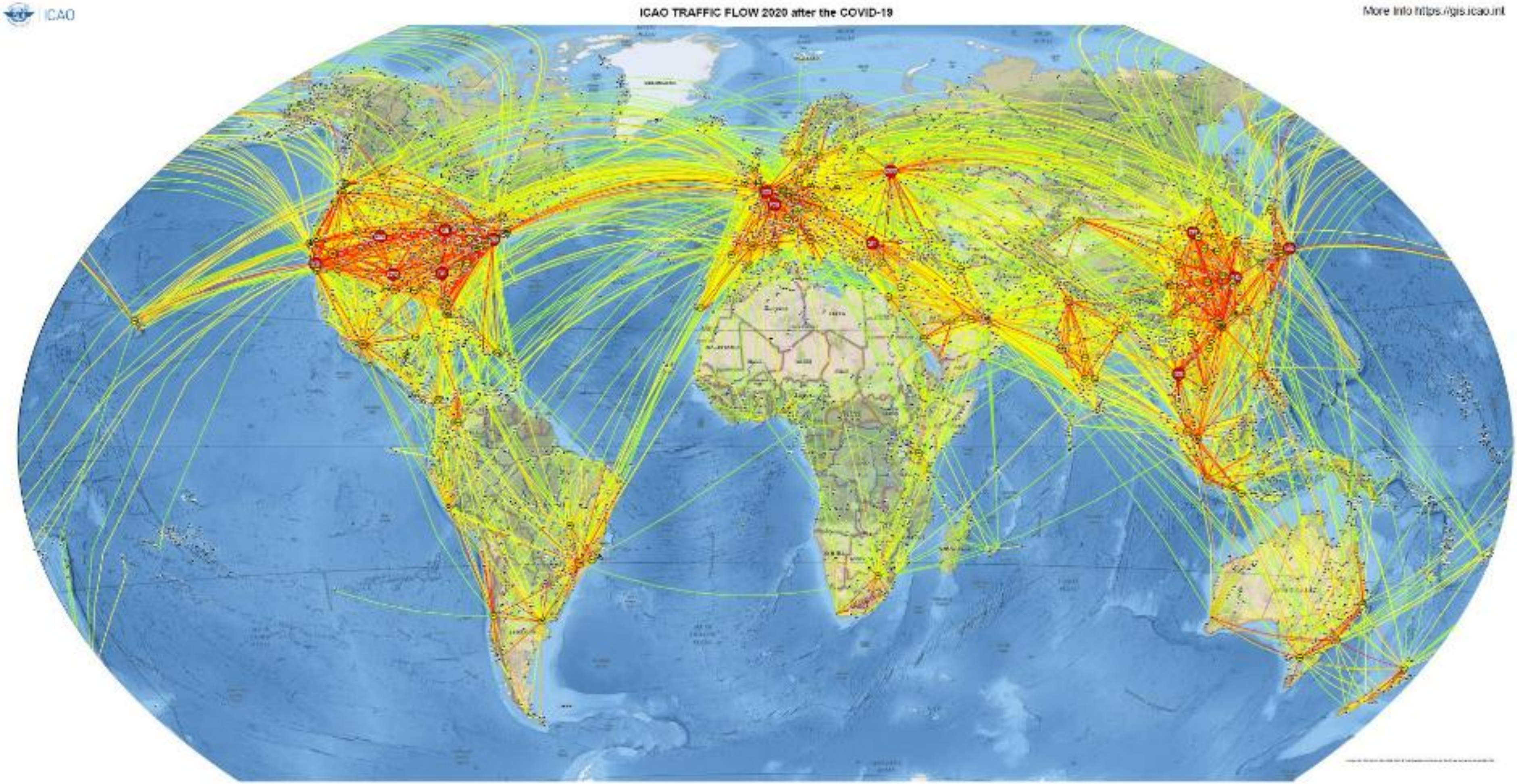


Mercator projection (shape)



Oblique Mollweide   (area)

Why don't planes fly on straight lines – well they do …

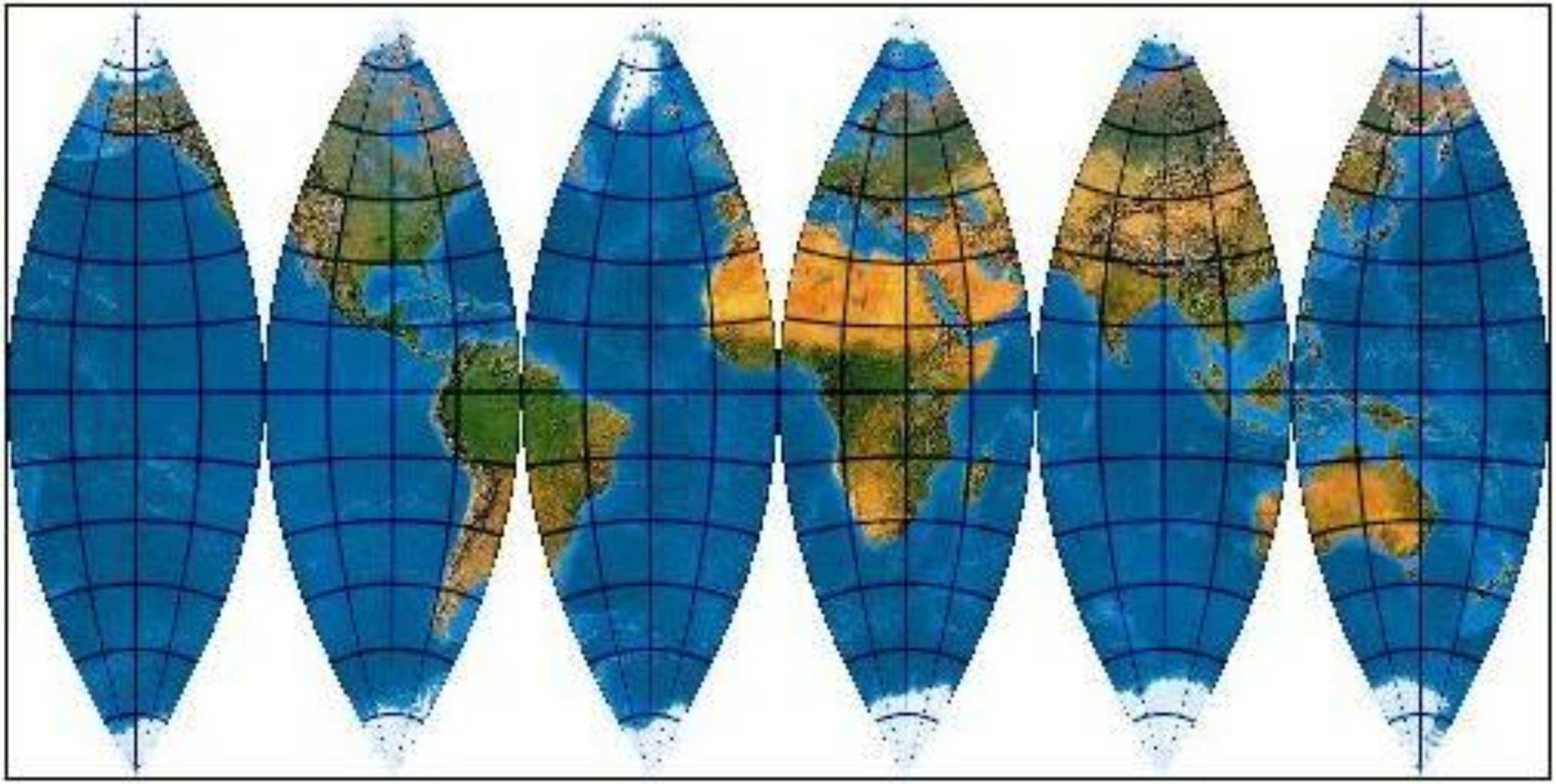


flight routes are 'great circles' … straight line in 3D space – but curves in 2D

The world could be mapped like a bit of orange peel …

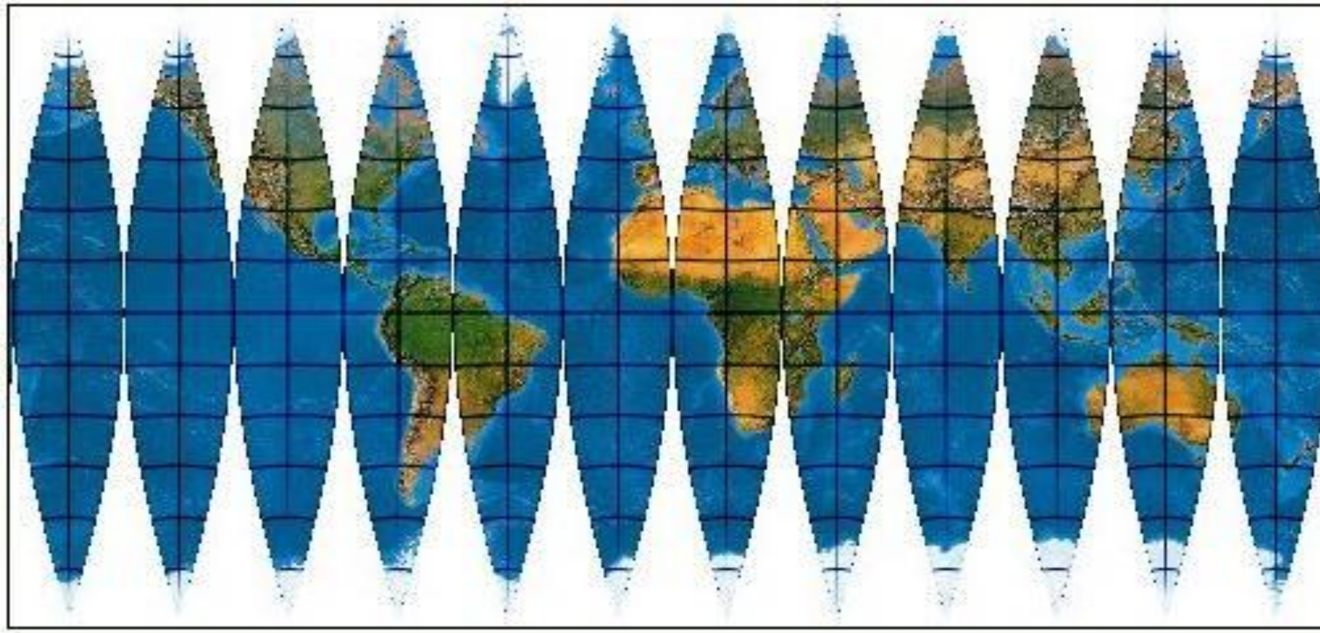
- maybe not a problem locally, but it is for large areas

the strips would still have some curvature
.. and gaps between the strips



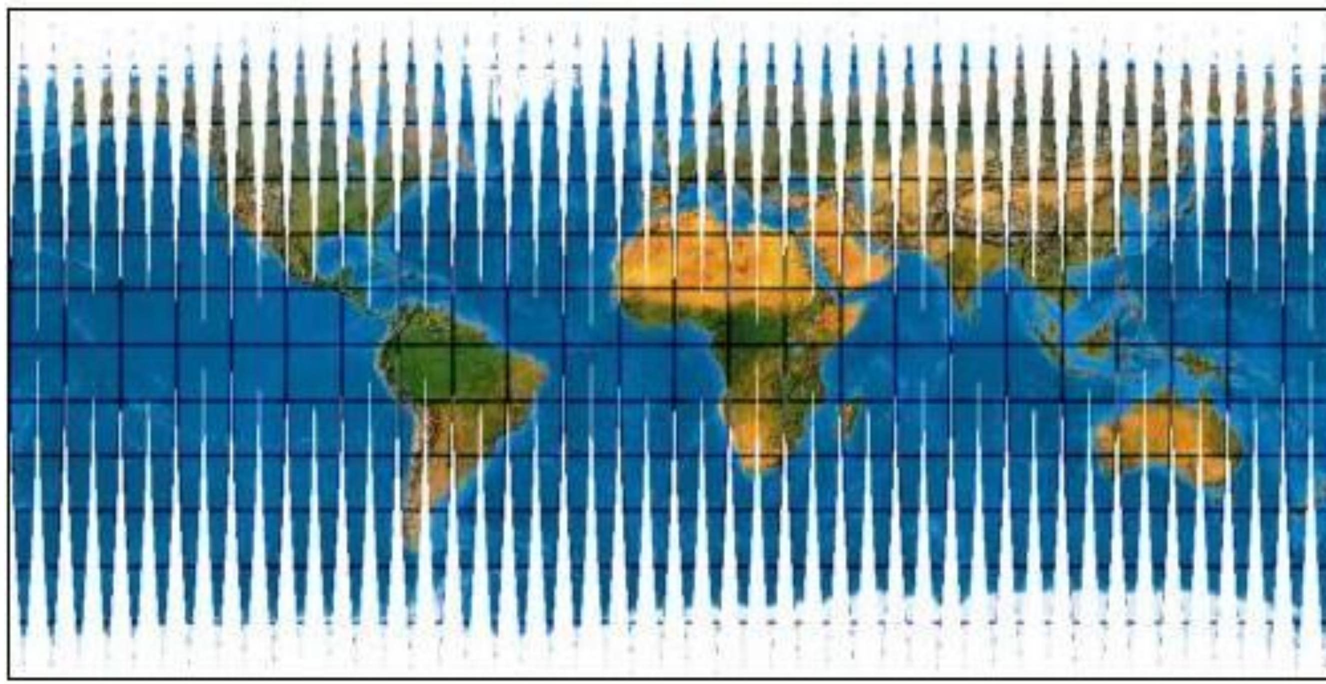
http://boehmwanderkarten.de/kartographie/is_netze_globussegmente.html

12 pieces



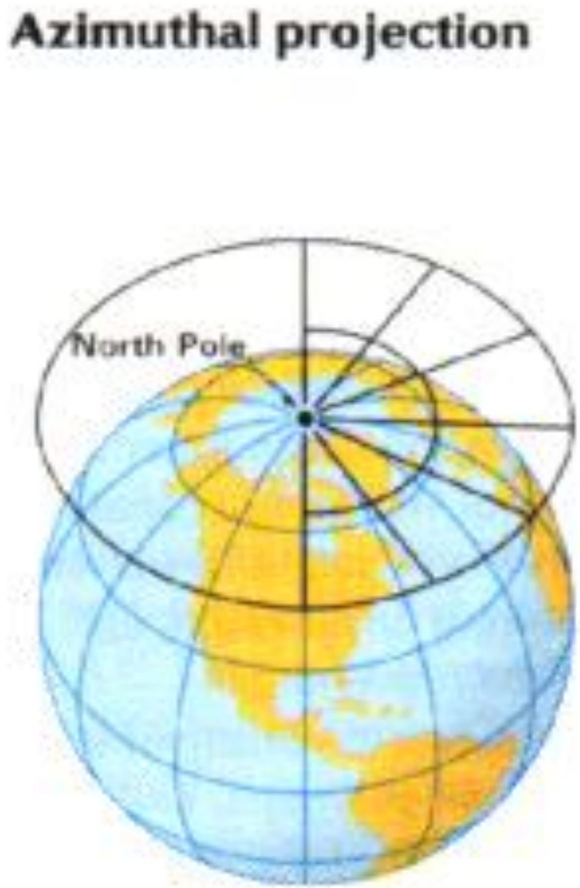
48 pieces

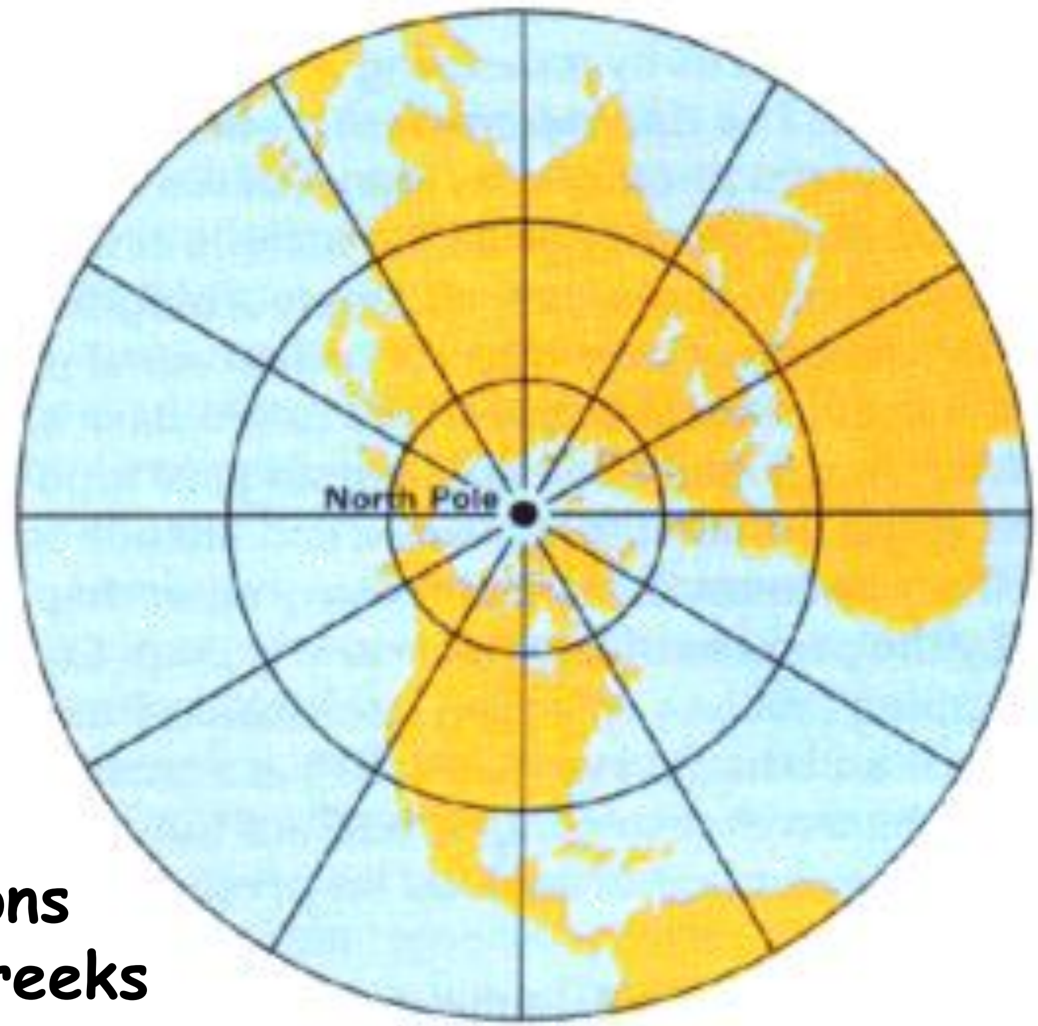
becoming like UTM zones..



Or they can be made by literally 'projecting' the globe onto a map …

Azimuthal (planar) projections





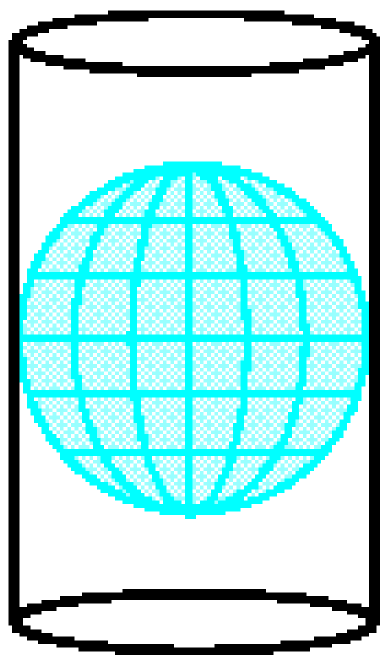
These earliest projections were by the 'ancient' Greeks

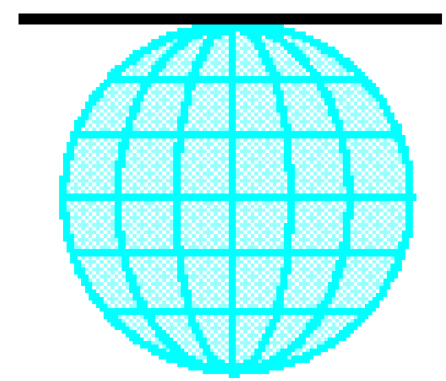
Projection Terms

1. Developable surfaces:

A two dimensional surface onto which the globe is projected

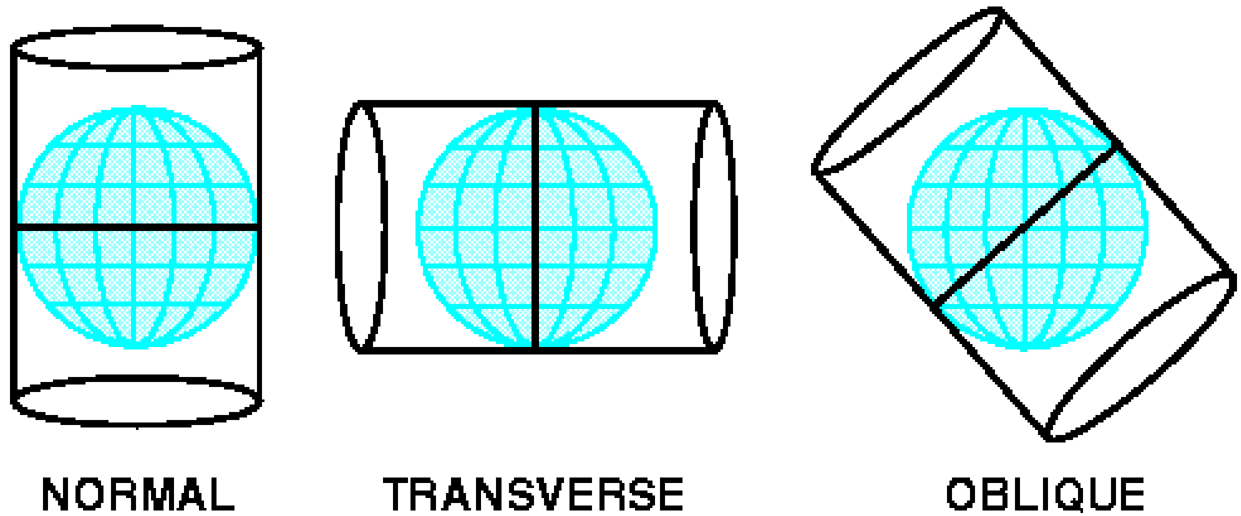
Conic **Cylindrical** **Azimuthal (planar)**





2. Drawing of Projection Orientation

Cylindrical projections:



Planar projections aspects:

3. Scale Factor (SF)

SF = scale at any location /
divided by the 'principal scale'

e.g. if scale = 1:2 million and principal scale = 1:1 million

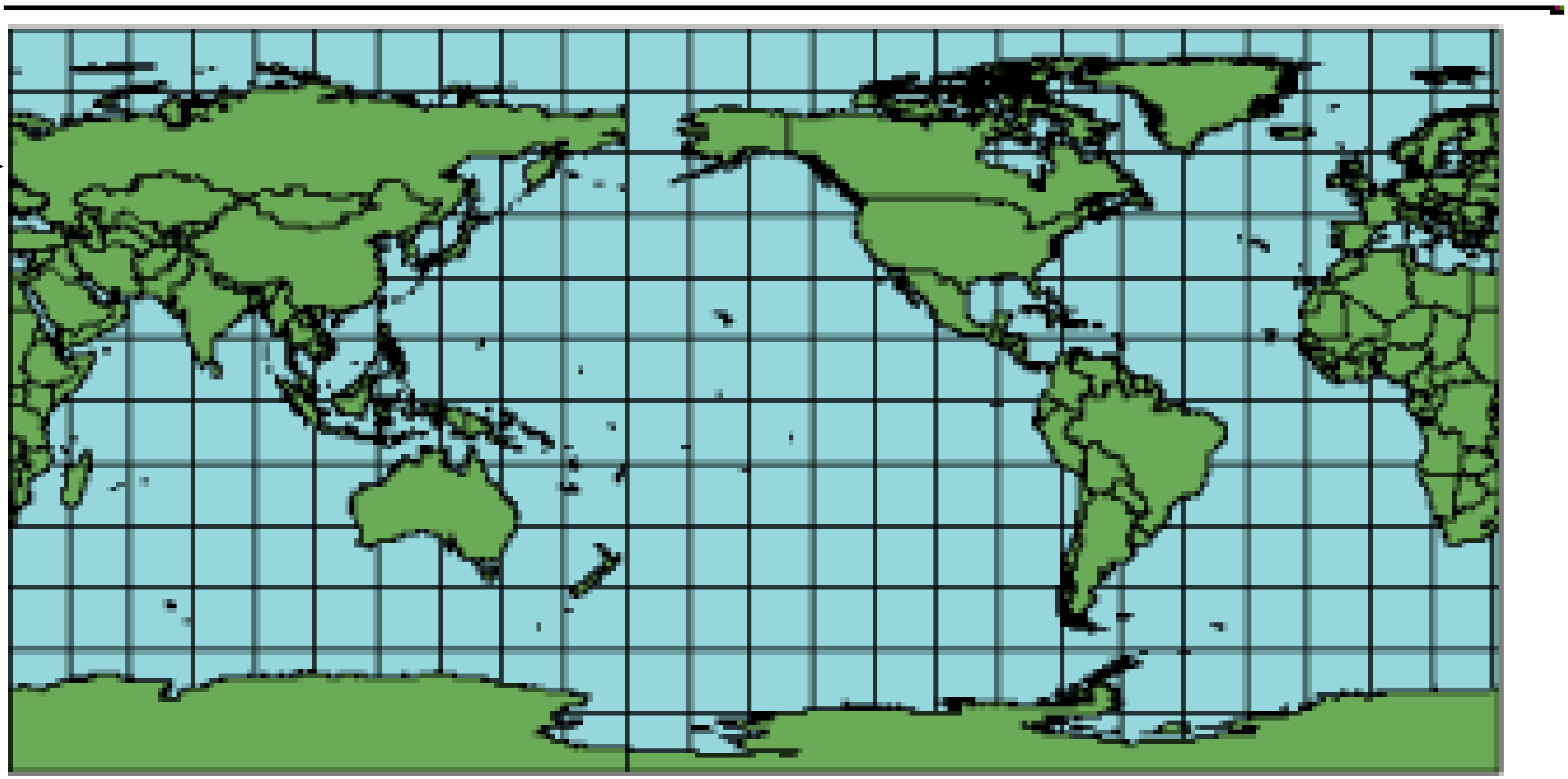
then SF at that point = ½ million divided by 1/1 million
= 1/2 (0.5)

e.g. Canadian NTS maps: ‘scale factor 0.9996 at UTM zone edge’

Example: The Plate Carrée (geographic) projection where every line of latitude is equal in length

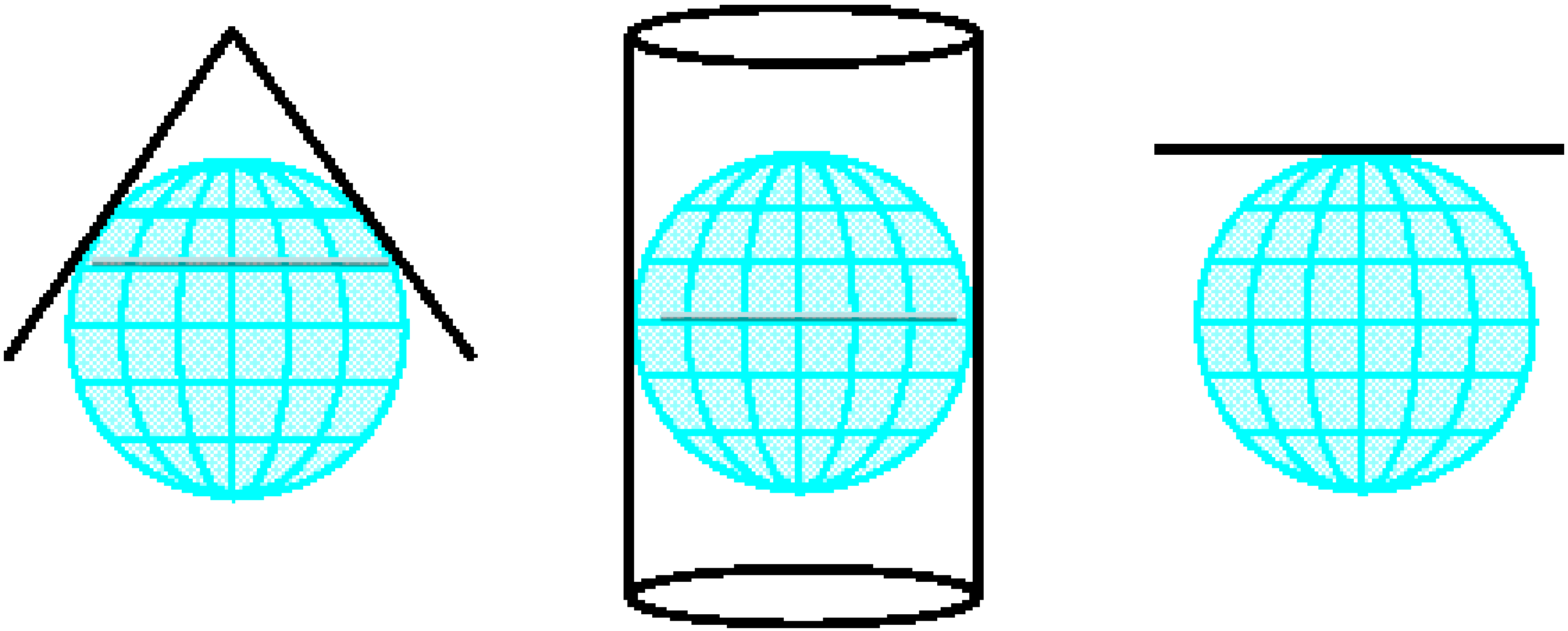
SF along lines of latitude are: equator SF = 1;
at 60°N/S, SF =2 at 90°, SF = ∞ or 'undefined'

90N→
60N →
0→



The SF in the other direction (along meridians) is 1

4. Standard Lines



Distortion increases with distance between the 'globe' and the surface

The standard line has a scale factor = 1

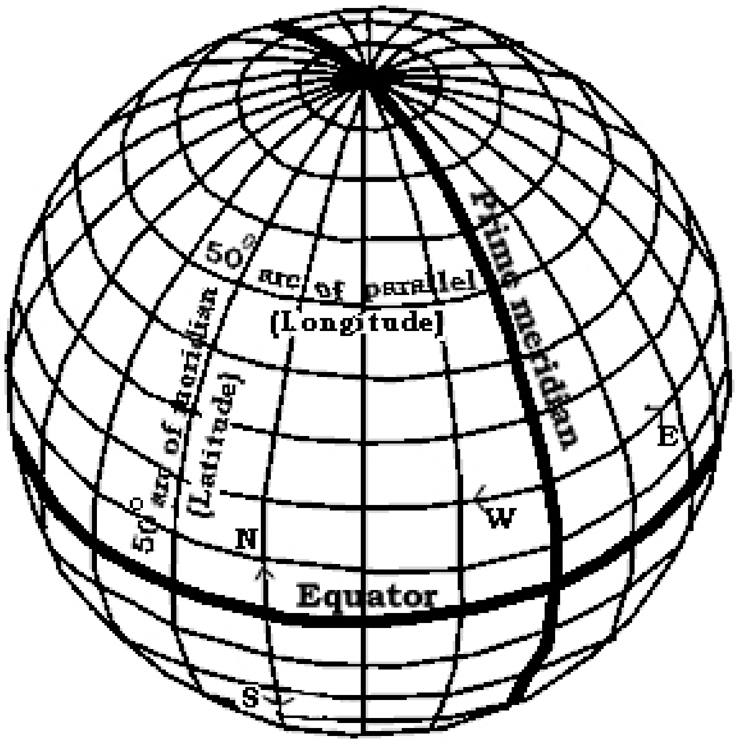
(it is often the line of contact)

5. Distortion: …. compare to the graticule:

➢Lines of latitude are 'parallel' and ~ evenly spaced.

➢Meridians converge at the poles,

(half the distance at 60º N/S).



➢Scale factor is 1 in all directions:

on the globe, but not on any projections..

6. Projection properties: can preserve

- **Shapes or**
- **Areas or**
- **Distances or directions (some but not all)**

….. and never more than one of these

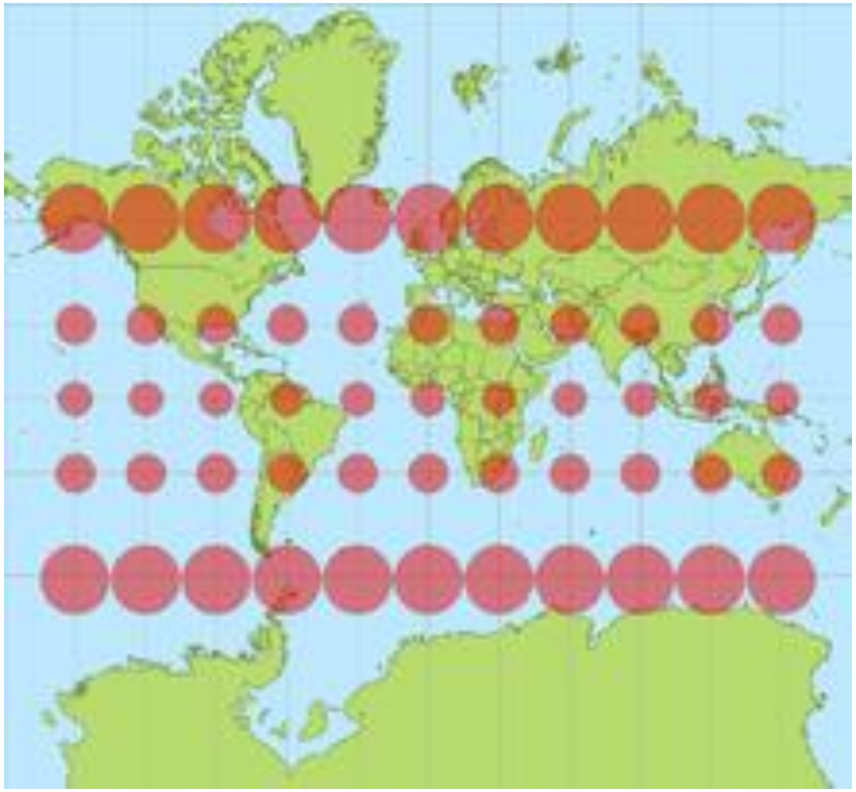
a. Shape

A projection that maintains shape is ‘**conformal**’

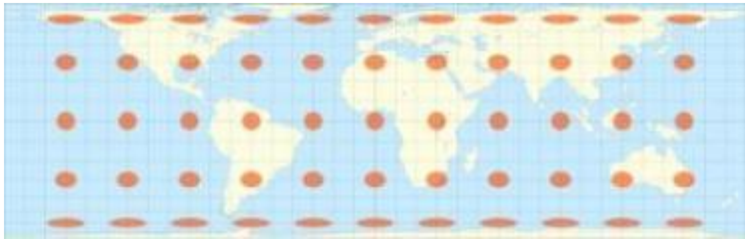
For example a 2x2 square becomes a 1x1 or 4x4 square. Stretching in one direction is **matched** by stretching in the other: that is, the scale factors are equal at a point in the two directions (i.e. there is 'equal-stretching').

Circles (“Tissot’s Indicatrix”) ->

These indicate the relative area compared to a standard area at the equator (the standard line)



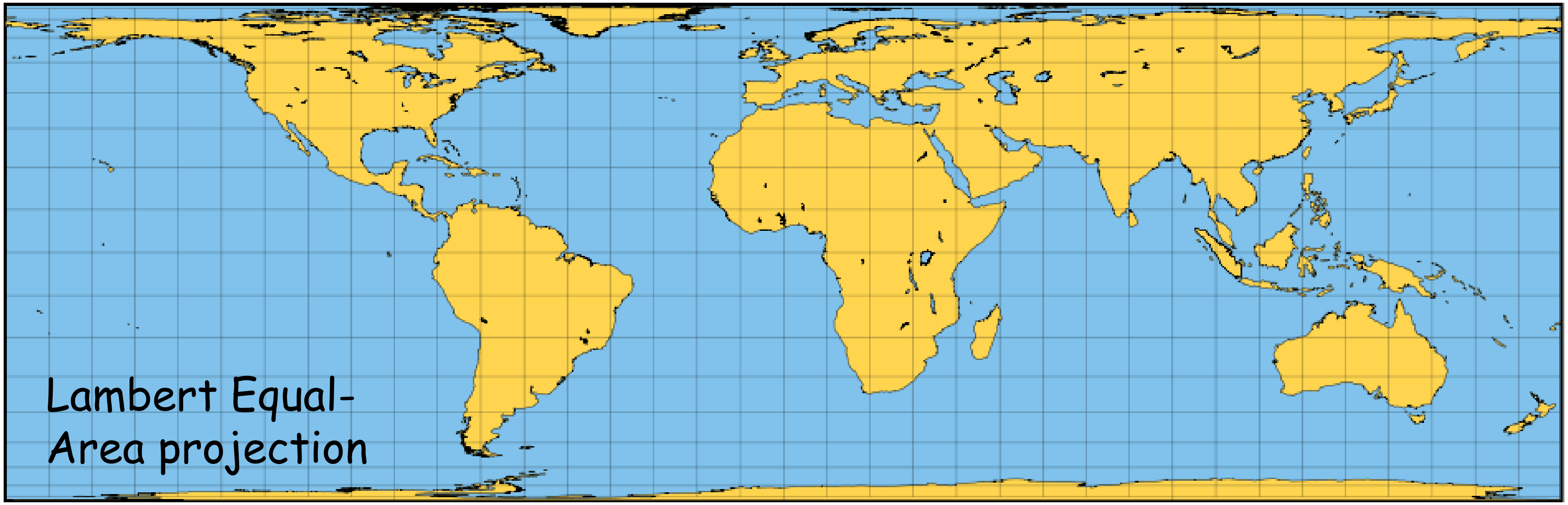
b. Area



A projection that maintains area is **equal area**

This is achieved by sacrificing **shape**: stretching in one direction to counter for earth curvature must be **compensated** by compression in the other.

In other words, the product of the two Scale factors at any point in the two directions (N-S and E-W) = 1.0 (e.g 1 x 1, 2 x 0.5 etc..)



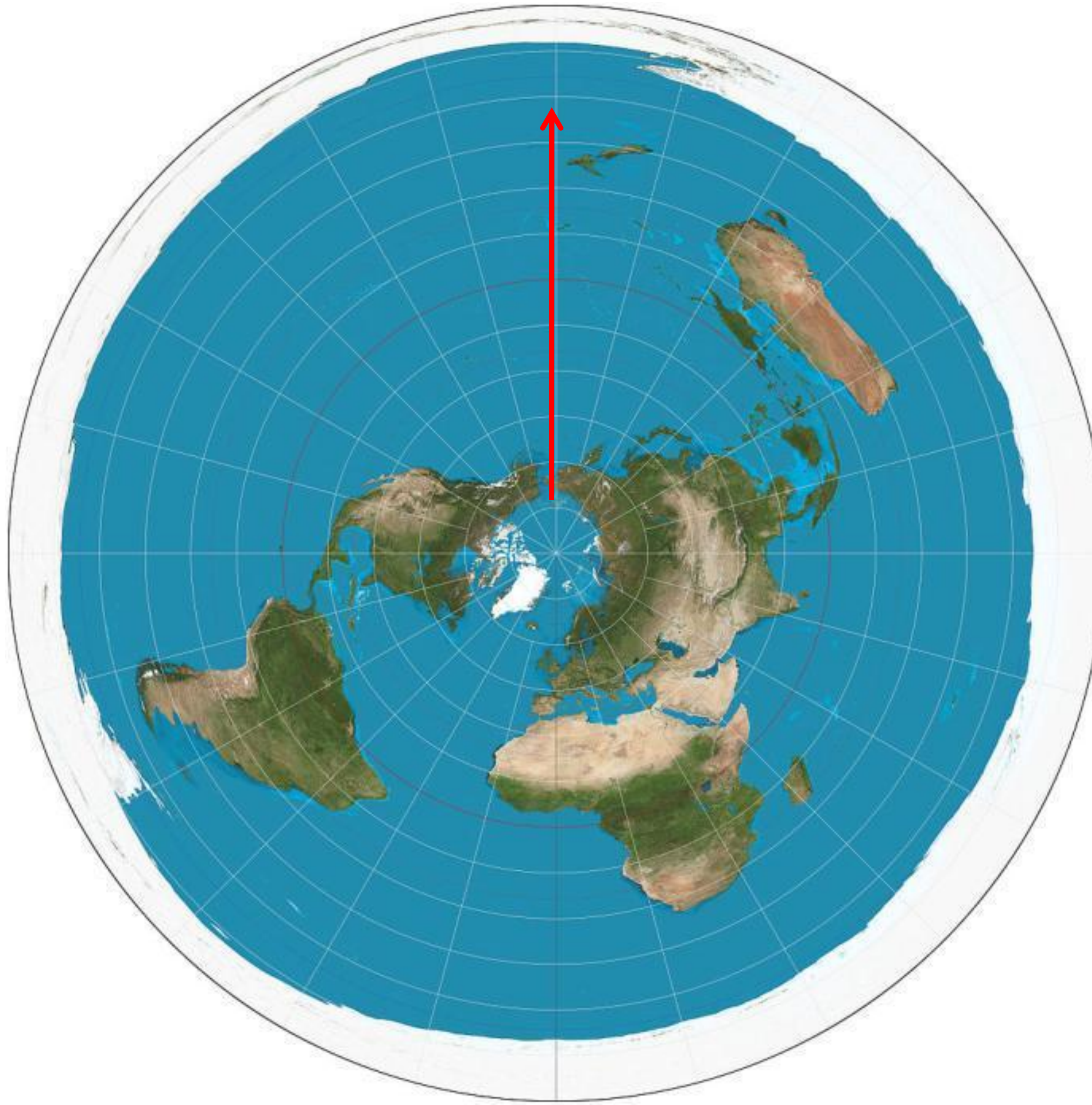
Hence a projection CANNOT preserve both shape AND area

(equal versus compensating stretching)

c.Distance

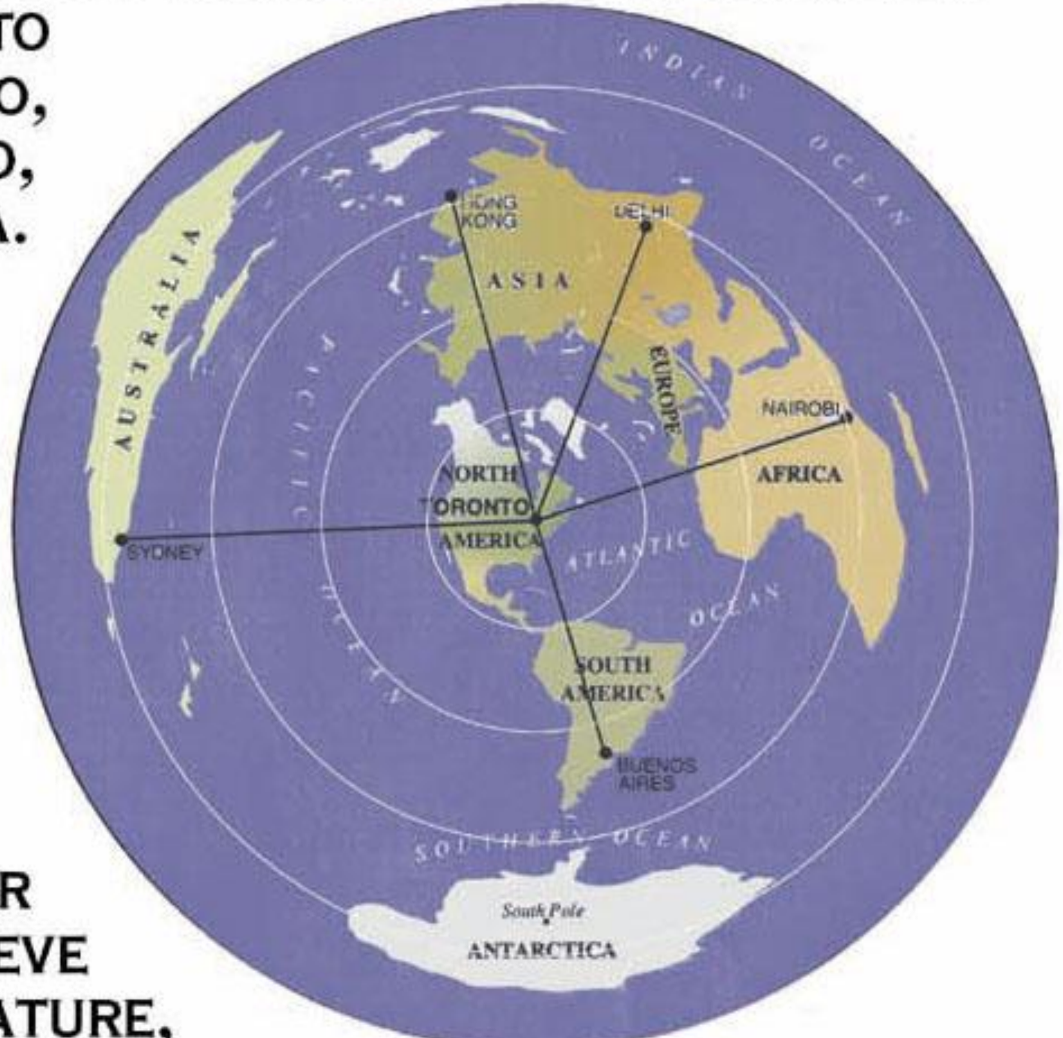
Distances can be correct in one direction from a line or in <u>all directions from a point</u>

In these cases, the projection is '**equidistant**'



Azimuthal equidistant

GUELKE'S EQUIDISTANT PROJECTION TELLS YOU EXACTLY HOW FAR IT IS FROM ANYWHERE ON EARTH TO TORONTO, ONTARIO, CANADA.

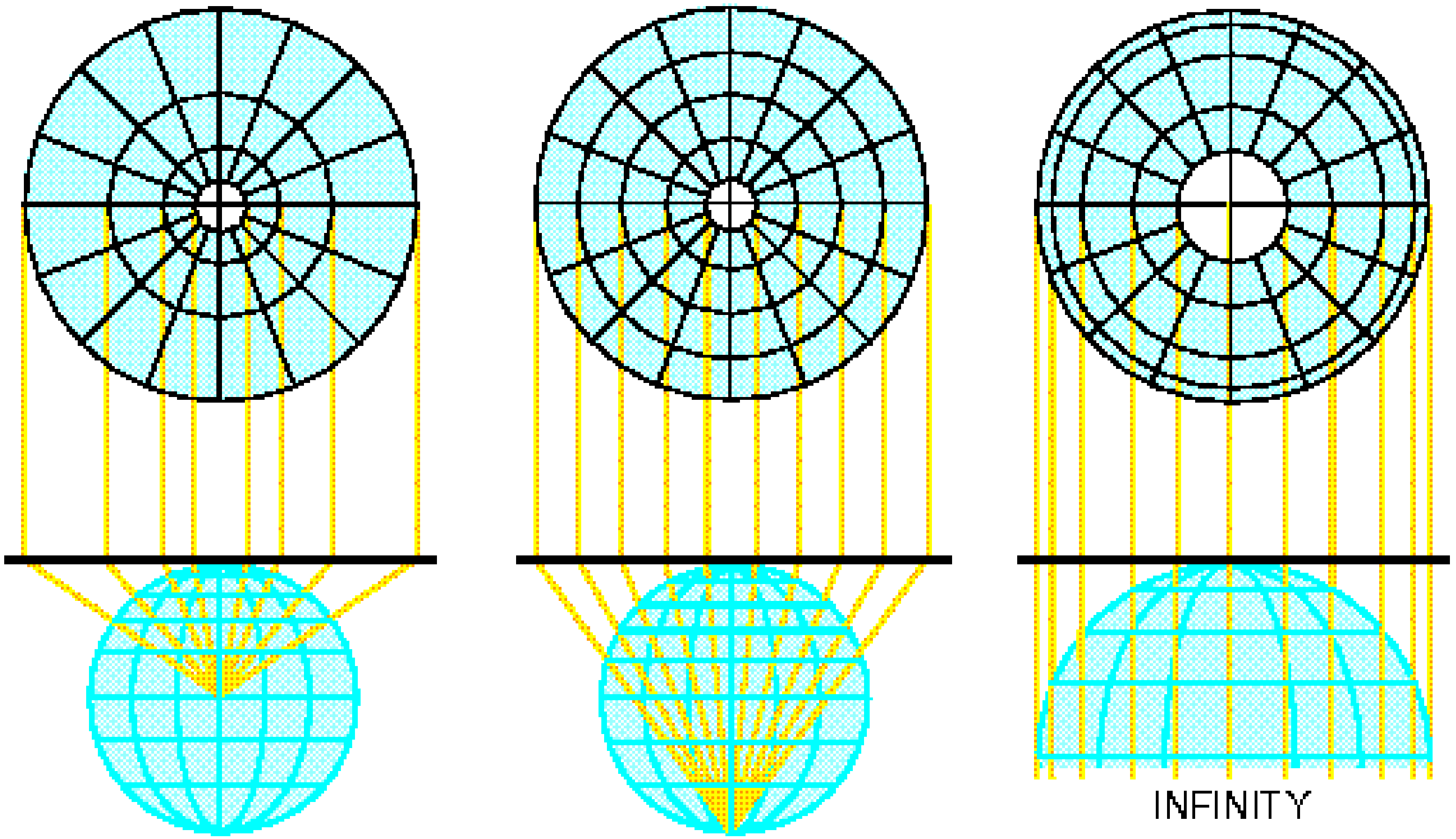


IN ORDER TO ACHIEVE THIS FEATURE, YOU NEED TO SACRIFICE SOME SHAPES AND SIZES.

www.diversophy.com/guelke.htm

Projection groups (based on the developable surface)

I. Azimuthal projections



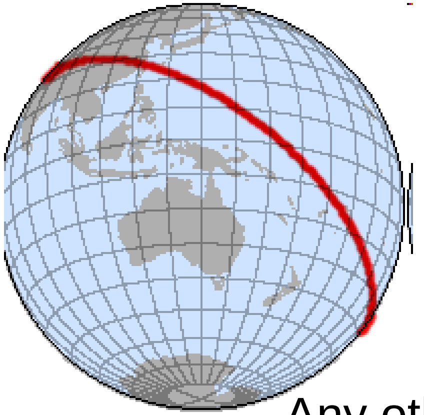
GNOMONIC	STEREOGRAPHIC	ORTHOGRAPHIC
Great circles= straight lines	Conformal (shape)	'View from space'
Thales 500BC	Ptolemy 125BC	Hipparchus 150BC

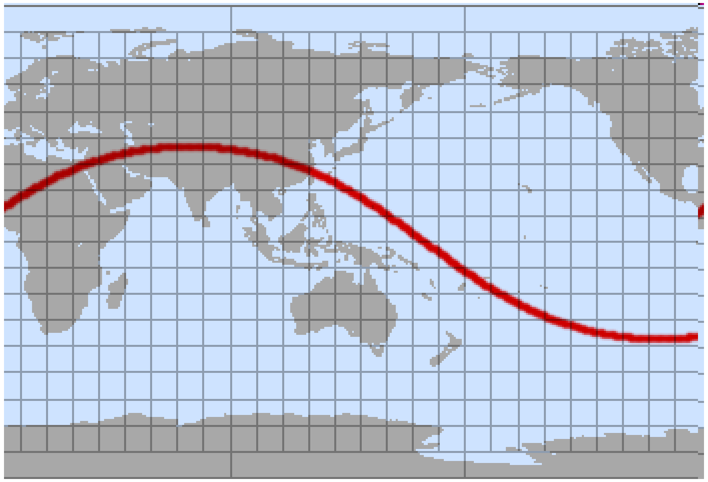
Gnomonic projection

Probably the world's oldest map projection – 6th century BC

Of all projections, only the **gnomonic** retains all great circles as straight lines

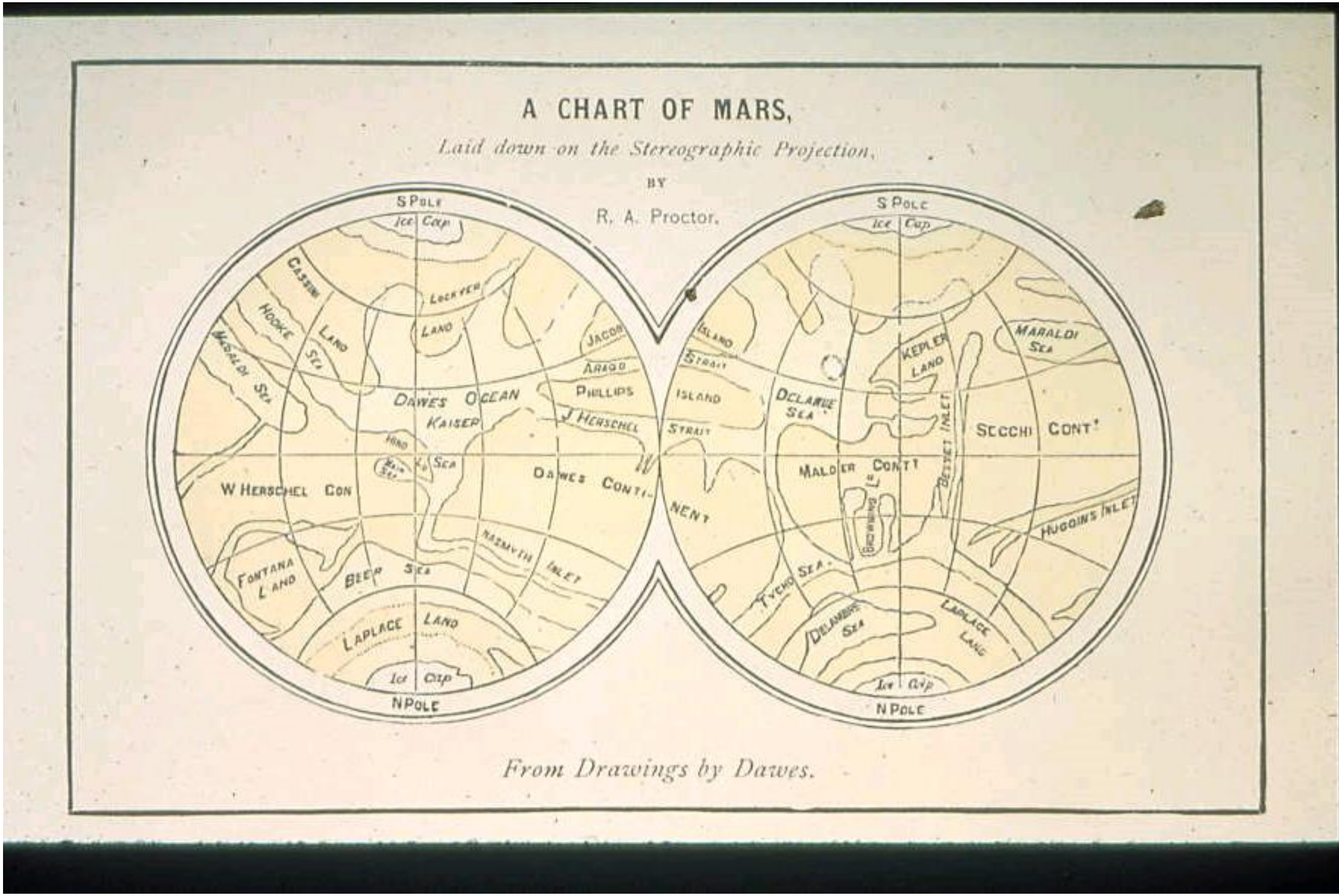
(but cannot show one entire hemisphere)





Any other projection e.g..Equidistant rectangular projection

First map of Mars, 1867- equatorial stereographic

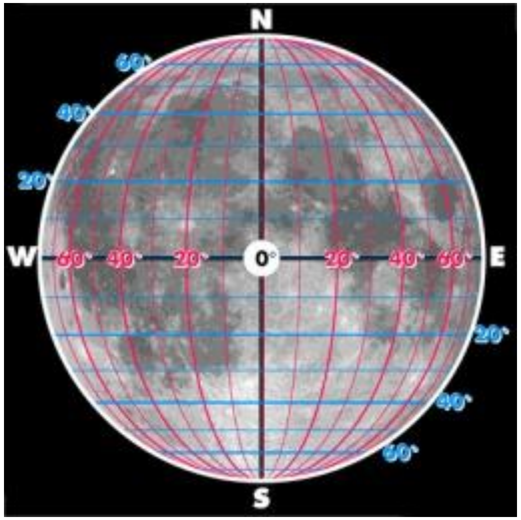


Dark / light = land / 'sea' ..

Photomosaic 1960 (pre-NASA): Orthographic projection

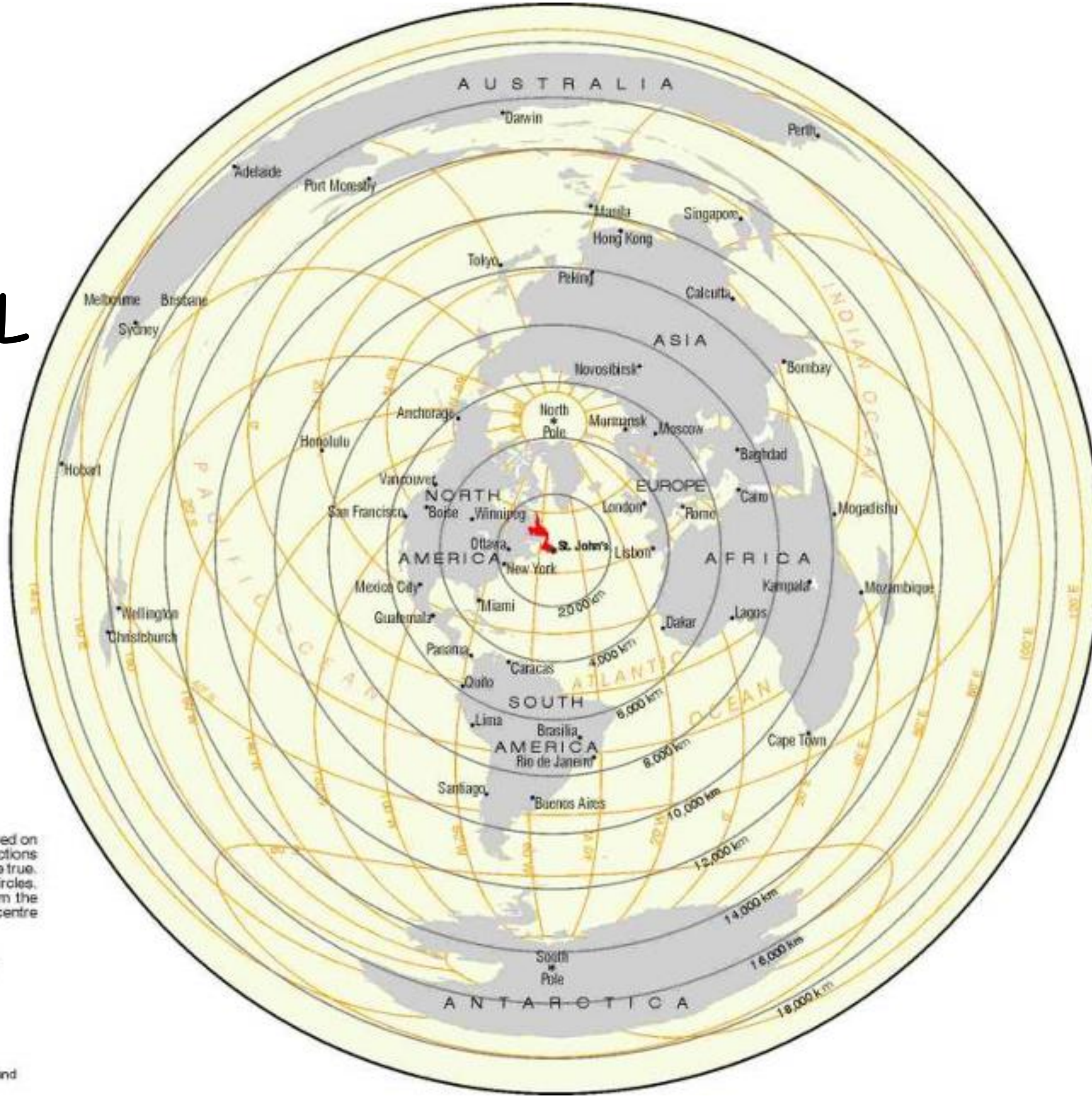
Like Earth, longitude zero is arbitrary – a feature is chosen

The Prime Meridian of the Moon lies in the middle of the face of the moon visible from Earth.



Azimuthal equidistant

centred on St. John's, NL



This is an AZIMUTHAL EQUIDISTANT PROJECTION centred on St. John's, Newfoundland. Only distances and directions measured along straight lines radiating from the centre are true. All straight lines passing through St. John's are great circles. Deformation of the earth surface increases outward from the centre and measurements taken other than through the centre are inaccurate.

SCALE along any straight line through the centre

1000 0 2000 4000
Kilometres

1000 0 1000 2000 3000 4000
Miles

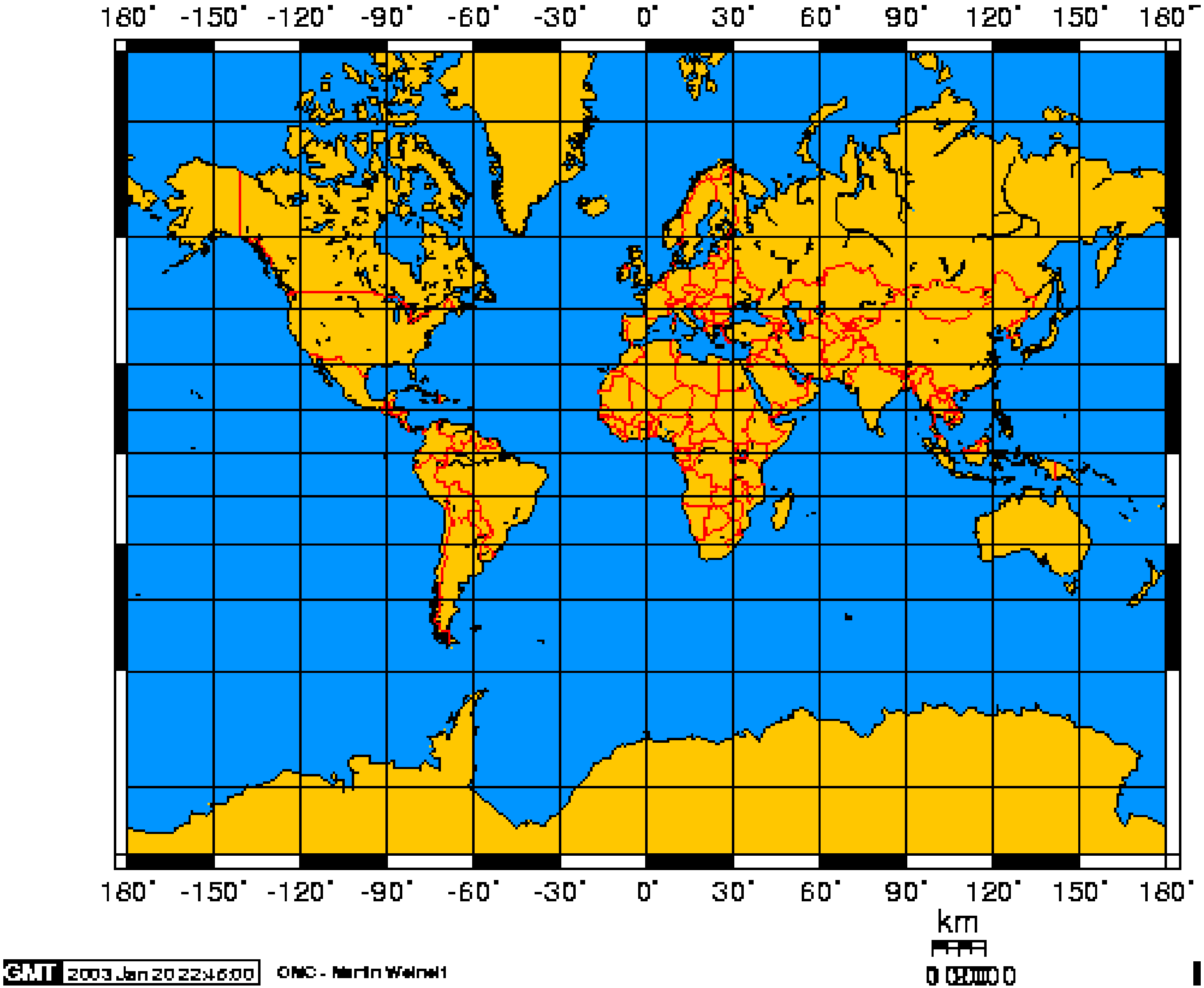
Projections of the sphere like the azimuthal equidistant projection have been co-opted as images of the flat Earth model depicting Antarctica as an ice wall surrounding a disk-shaped Earth.

The FLAT EARTH SOCIETY

II. Cylindrical Projections **16th century**

for early world maps … they fill a rectangular shape

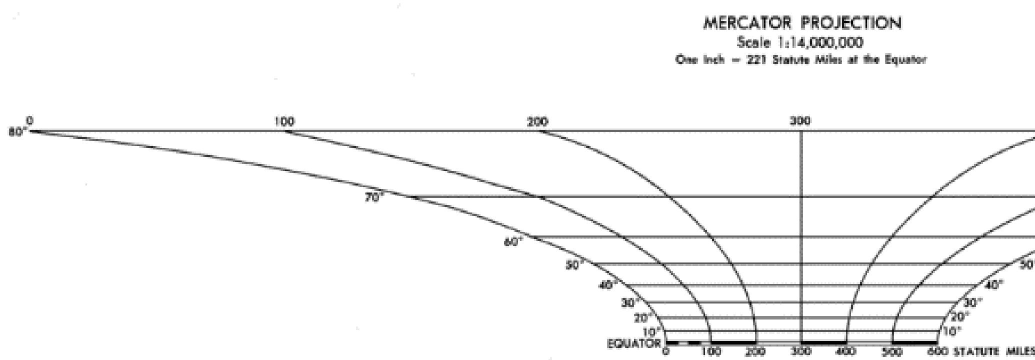
Mercator's Projection 1569 – conformal = shape/direction preserving



All ‘straight lines’ have constant compass bearings = ‘Rhumb lines’

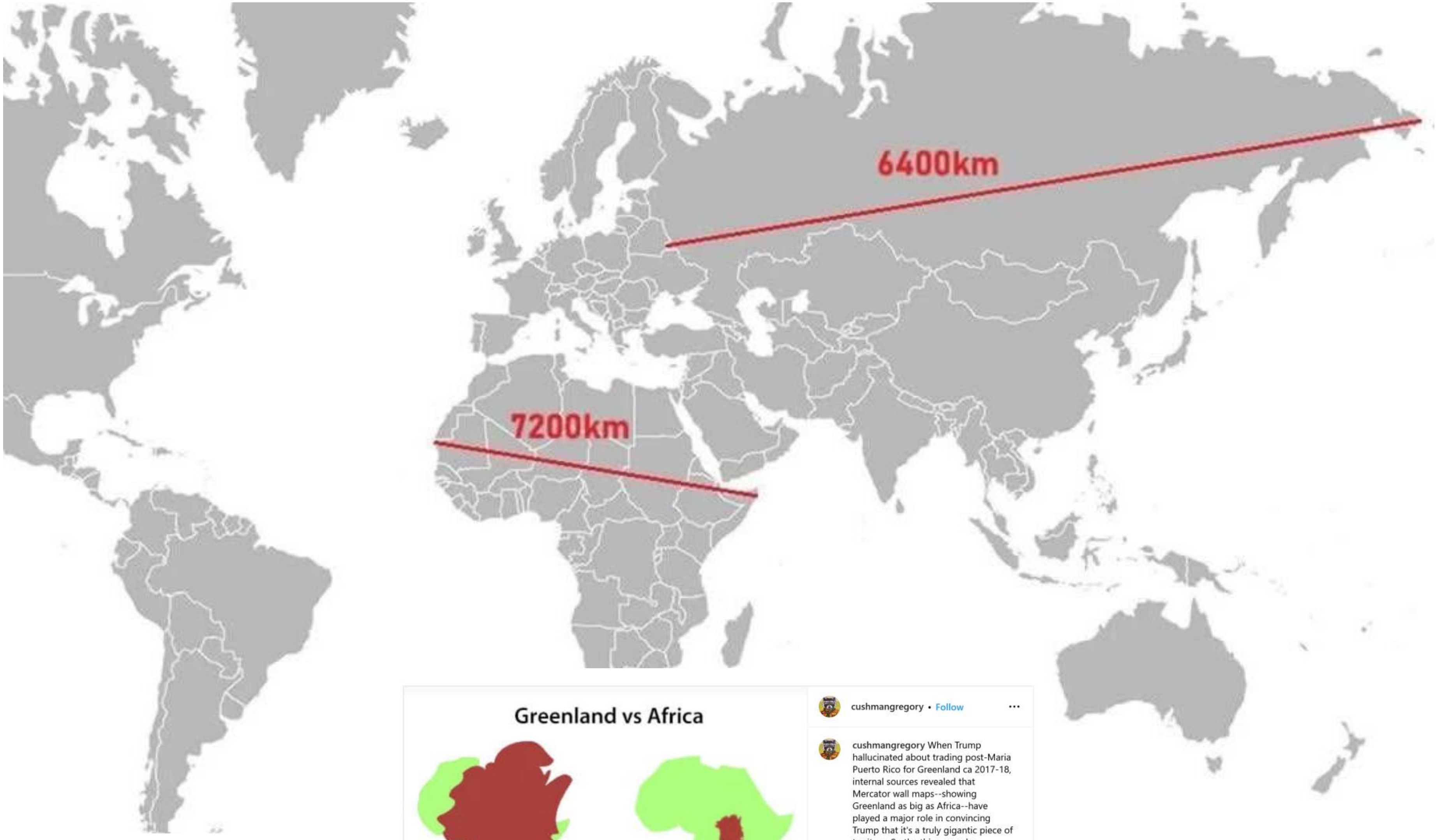
…. but the dashed line (great circle) is the shortest route

It became known as the “Navigator’s friend”

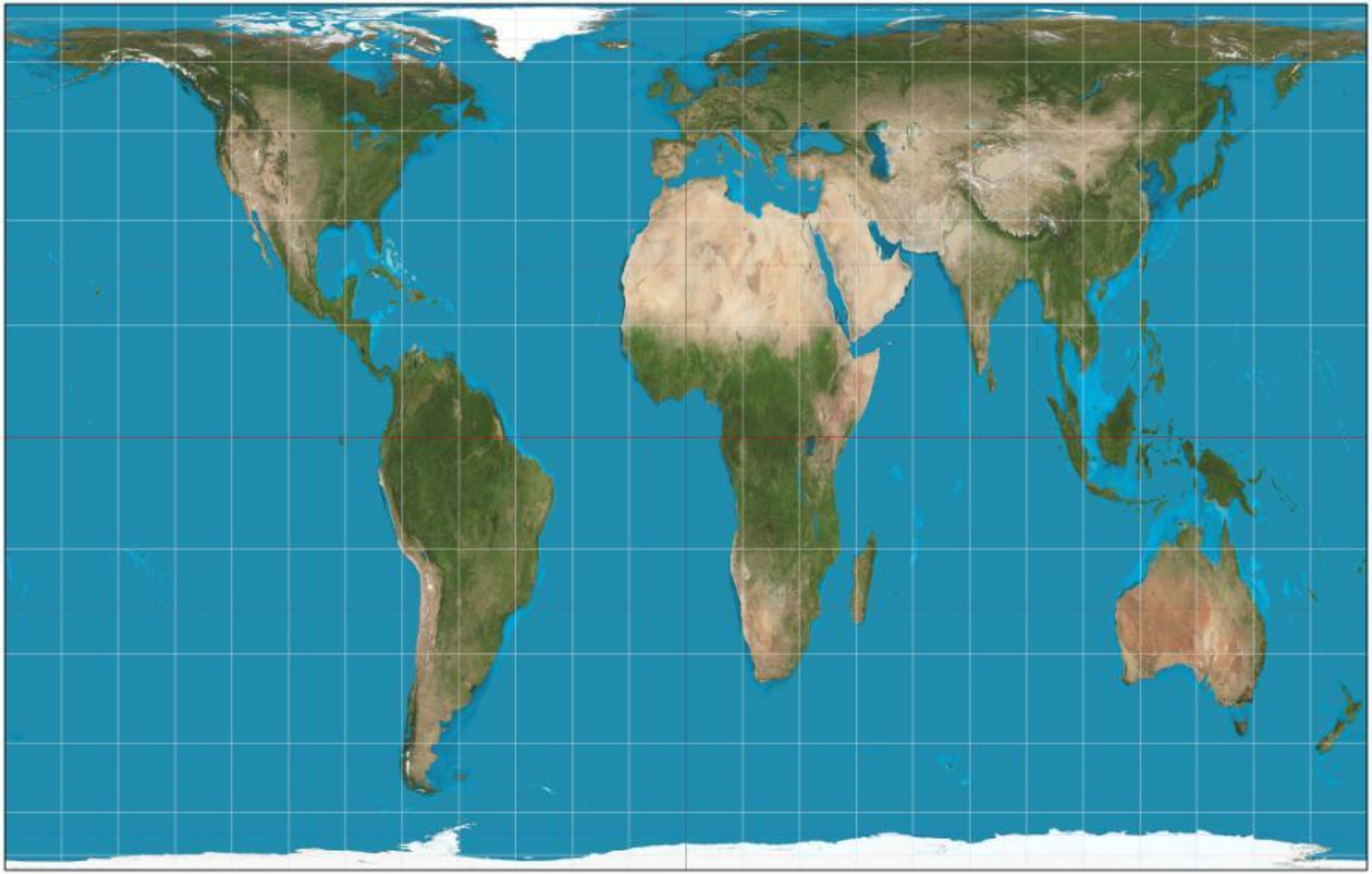


Scale bar –
scale increases away
from the equator

Mercator projection – distortion of distances and areas

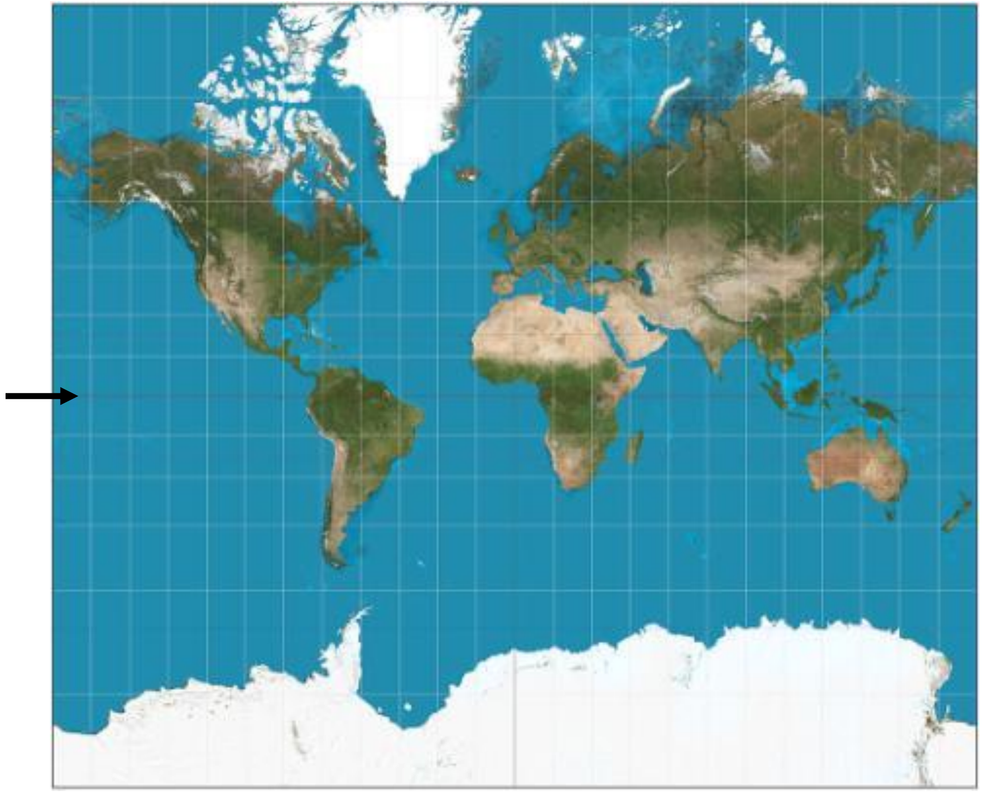


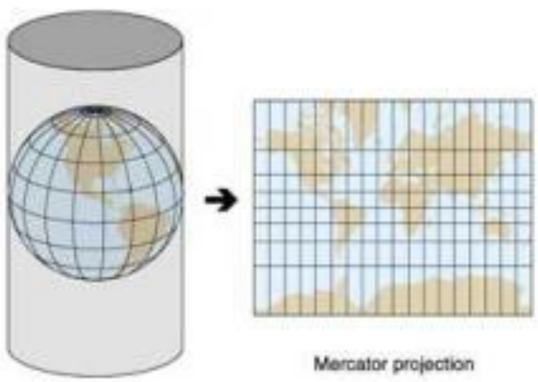
Gall (1885) -> Gall-Peters projection (1972) – equal-area

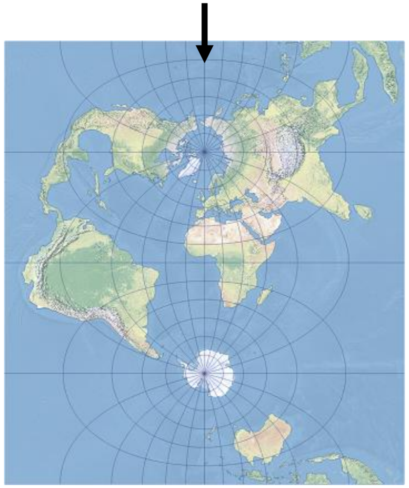


Corrects for area distortion of Mercator, but impacts shape

Mercator (1569) 'normal'   Transverse Mercator (1772)







The TM projection is the basis for the (Universal) **UTM** system
- a SYSTEM of 60 TM projections

Minimal distortion at a chosen longitude
- Adopted by Canada after WWII, from the US Army / German Wehrmacht

III. Conic projections – 18th century

The cone opens along a line of longitude

Latitude lines are curved sections of a circle

Longitude like ‘spokes’ of a wheel

Can have 1 or 2 standard lines (parallels)

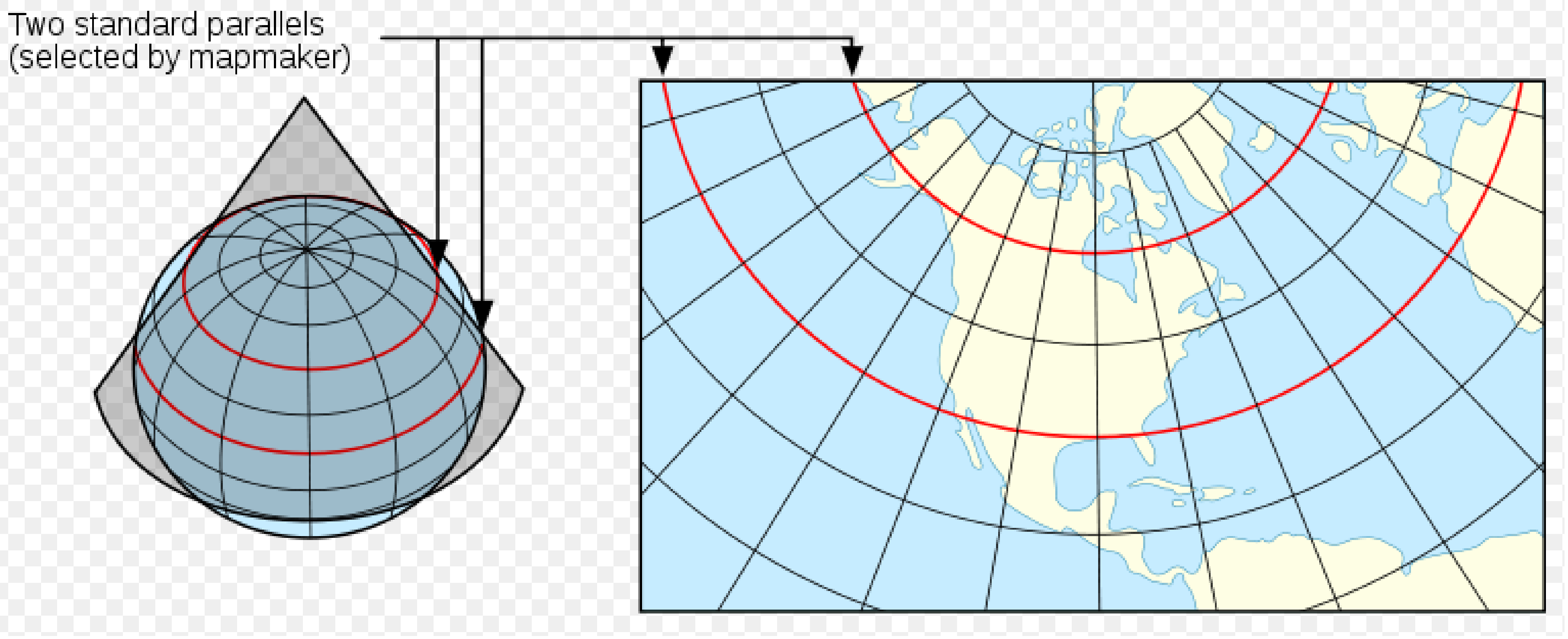
CONIC projections … are all 'normal orientation'

(e.g. Albers)

They can be varied by :

A: angle of the cone B: 1 or 2 standard lines

Distortions are less between the parallels versus outside them



IV. Pseudo-cylindrical Projections

-19th century (and 20th) – mostly equal-area (to show thematic data)

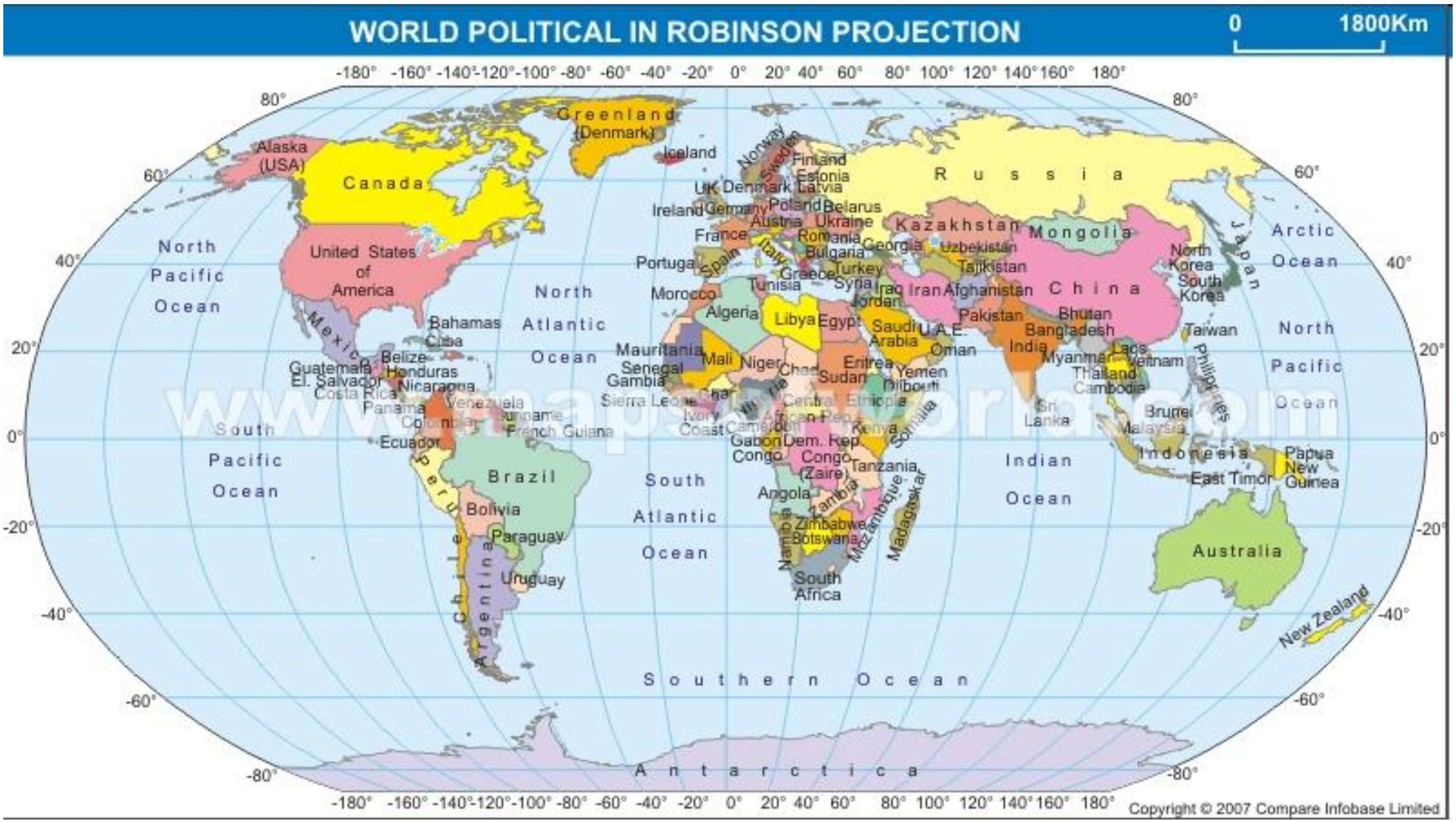
These are geometrically constructed (not perspective). Parallels are equally spaced but more proportional to their real length to minimize overall distortion.

Mollweide, 1805

Equal area for mapping global distributions

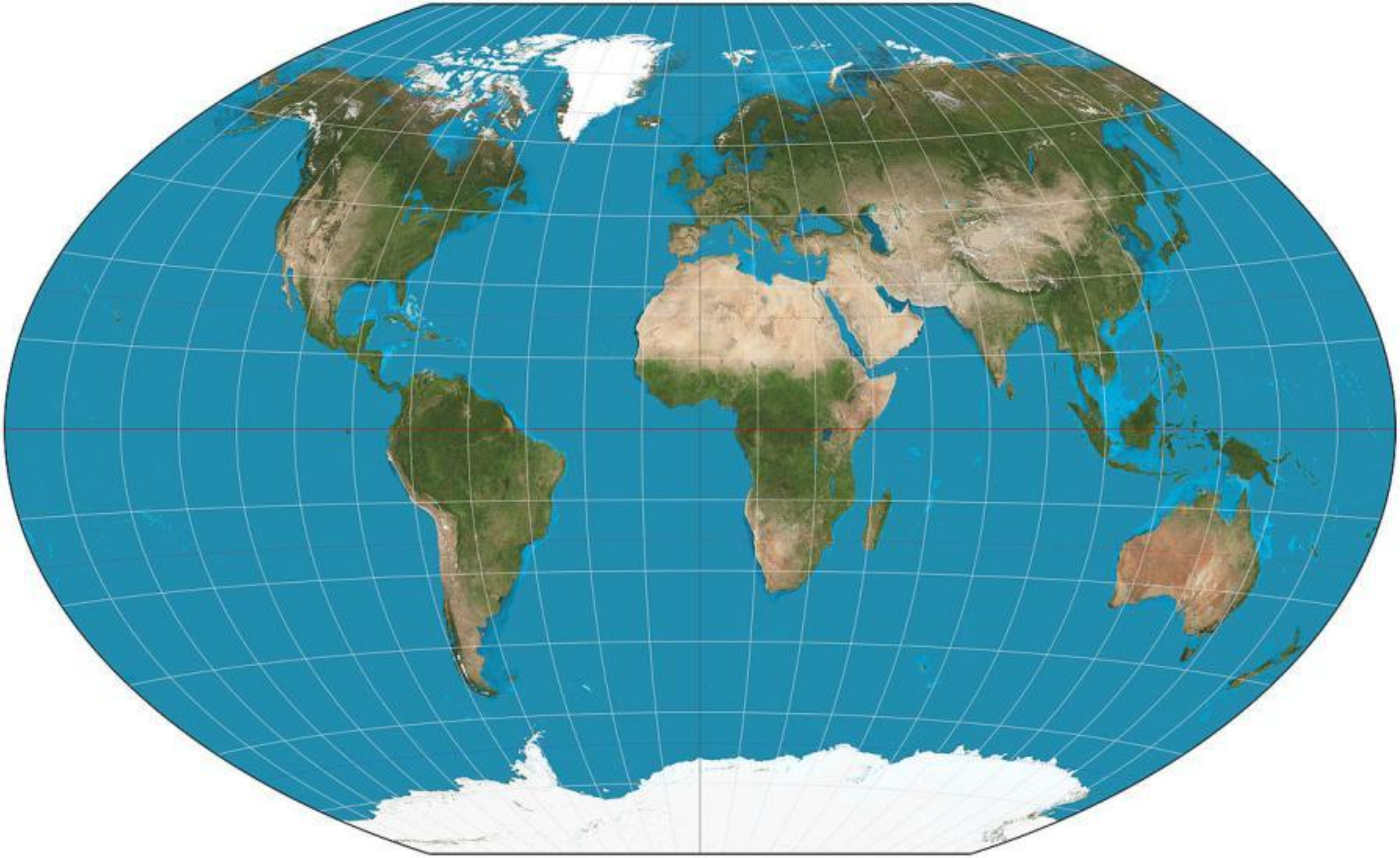
Robinson projection (1963) adopted by National Geographic 1988

Poles drawn as lines to create better shapes, projection is equal area



http://www.mapsofworld.com/projection-maps/robinson/world-political-light.html

Winkel tripel (Winkel III) by Oswald Winkel in 1921, adopted by National Geographic in 1998. The name *Tripel* refers to Winkel's goal of minimizing three kinds of distortion: area, shape (direction), and distance.

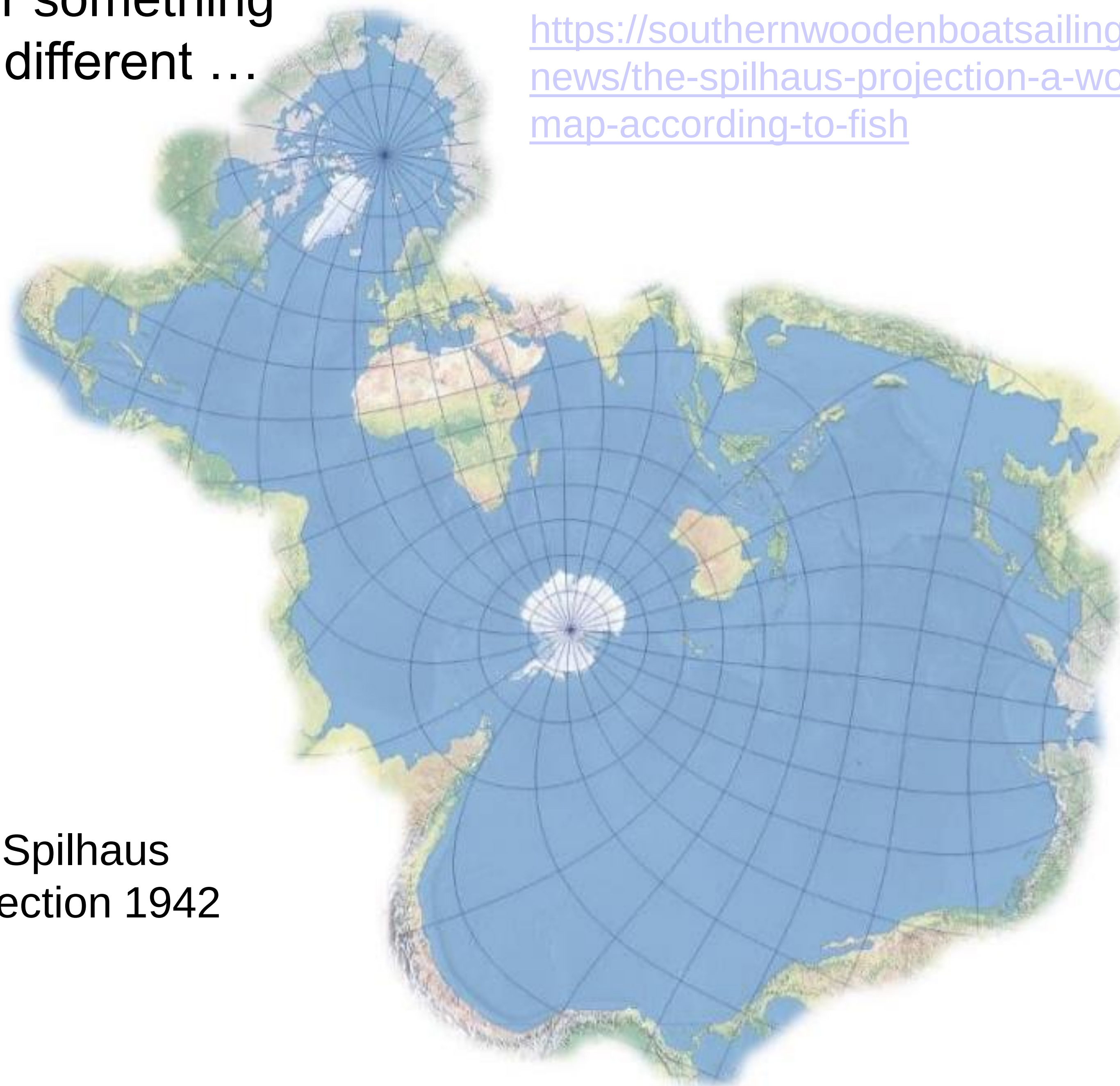


IVa. Interrupted pseudo-cylindrical (e.g. Goode's, 1923)

Minimum overall distortion and equal area – common in world atlases

And now for something completely different …

https://southernwoodenboatsailing.com/news/the-spilhaus-projection-a-world-map-according-to-fish



Dr. Athelstan Spilhaus
Spilhaus projection 1942

Map projections websites:

https://gisgeography.com/map-projections

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

Cordiform projection

Map humour: The Moocator Projection

Thursday: projections in GIS / the digital world

Quiz3 to follow: