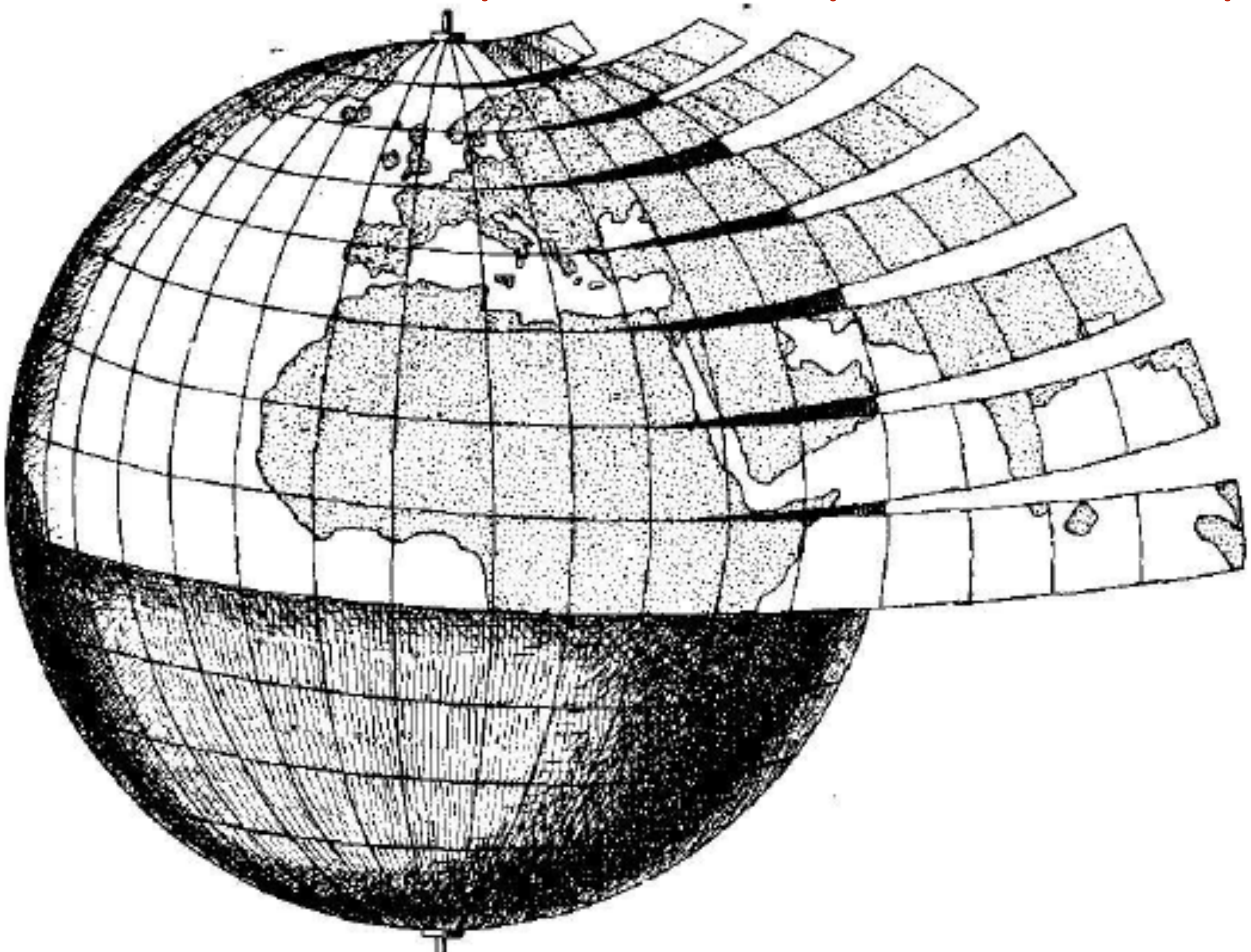
The discovery of the New World by Europeans led to the need for new techniques in cartography, particularly for the systematic representation on a flat surface of the features of a curved surface—generally referred to as a projection (e.g., Mercator projection, cylindrical projection, and Lambert conformal projection).

During the 17th and 18th centuries there was a vast outpouring of printed maps of ever-increasing accuracy and sophistication.

Systematic surveys were undertaken involving triangulation that greatly improved map reliability and precision.

World map by Martin Waldseemüller, 1507.

The Earth is not a geometric shape developable on a plane



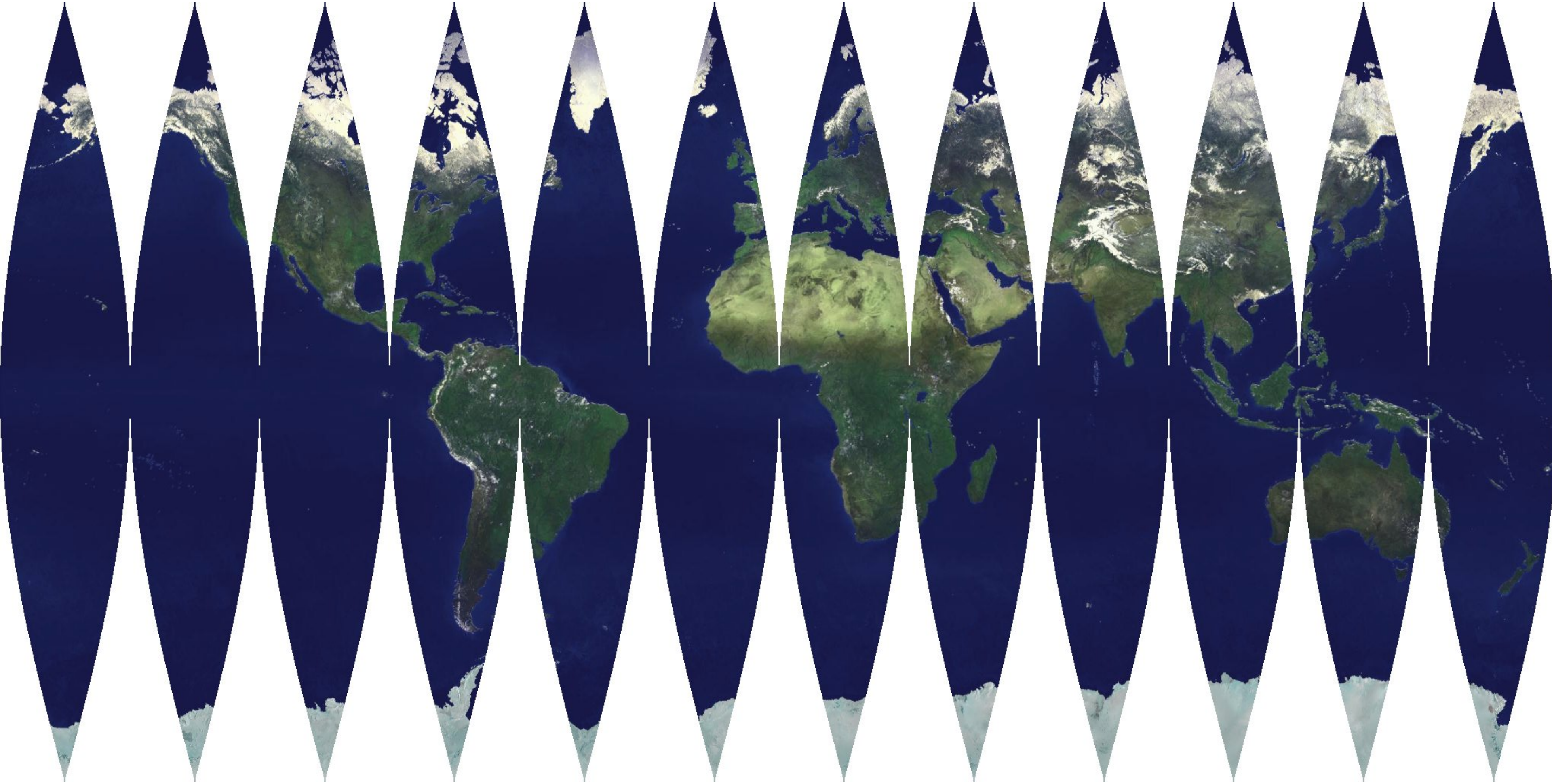
The major problem that occurs in the construction of a map is to represent the surface of a spheroid on a plane, since it is well known how a sphere, or a portion of it, can't be projected onto a plane without deformation.

Globe?

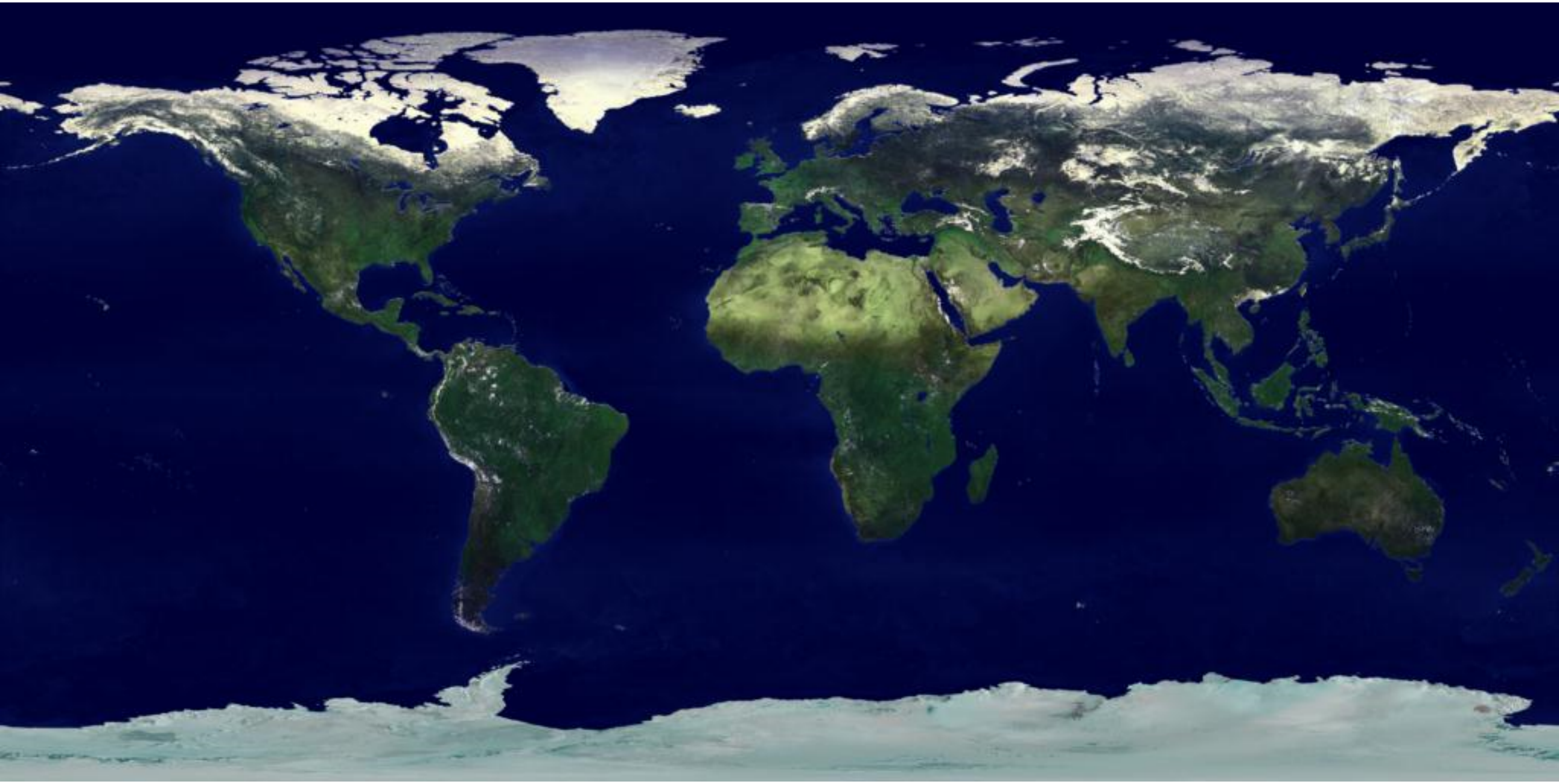
The particular shape of the earth implies that it can be accurately represented only on a globe, obviously small size.

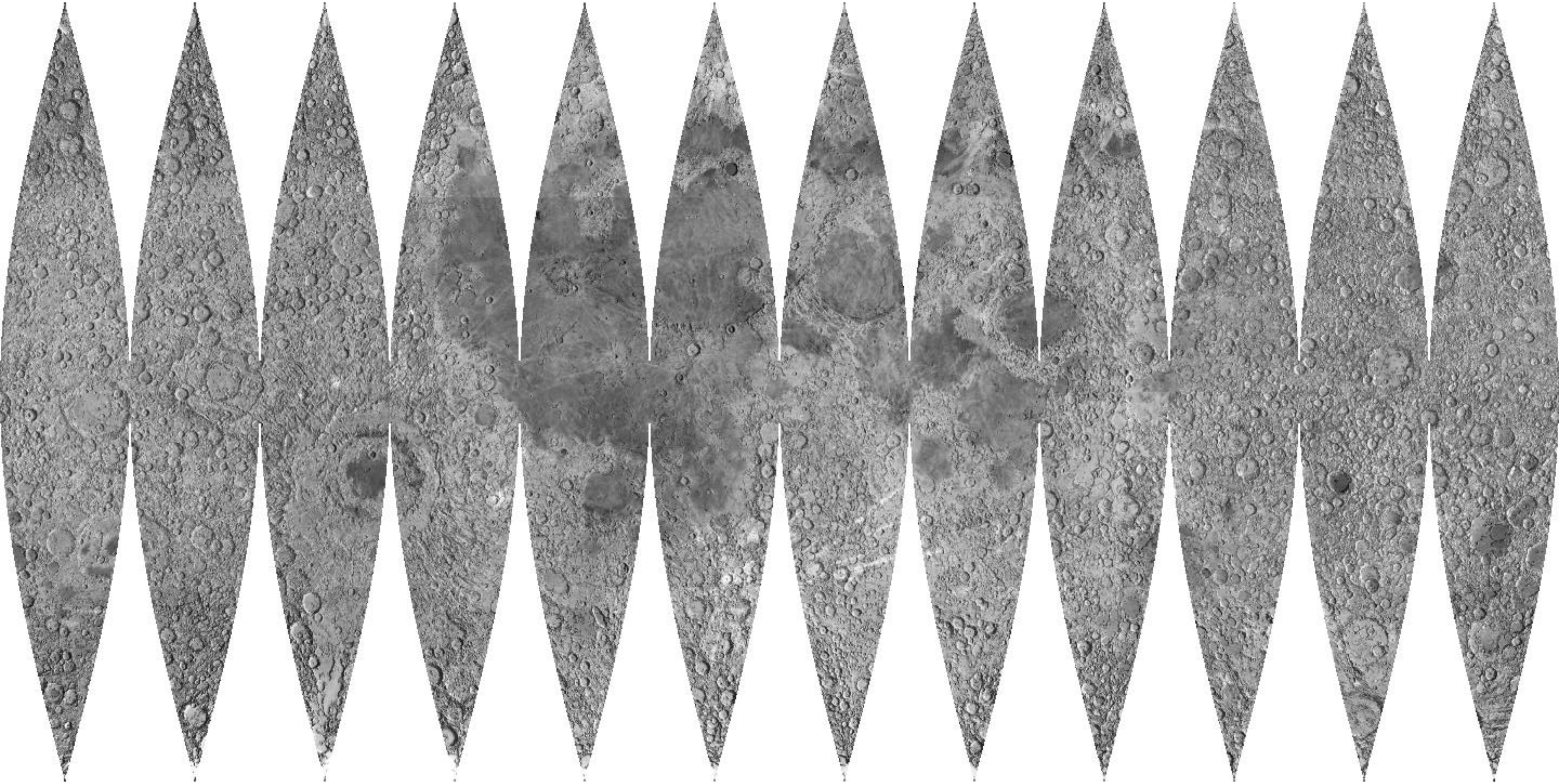
On a globe, you can restore exactly the parallels and meridians that allow us to determine the position of any point on Earth's surface.

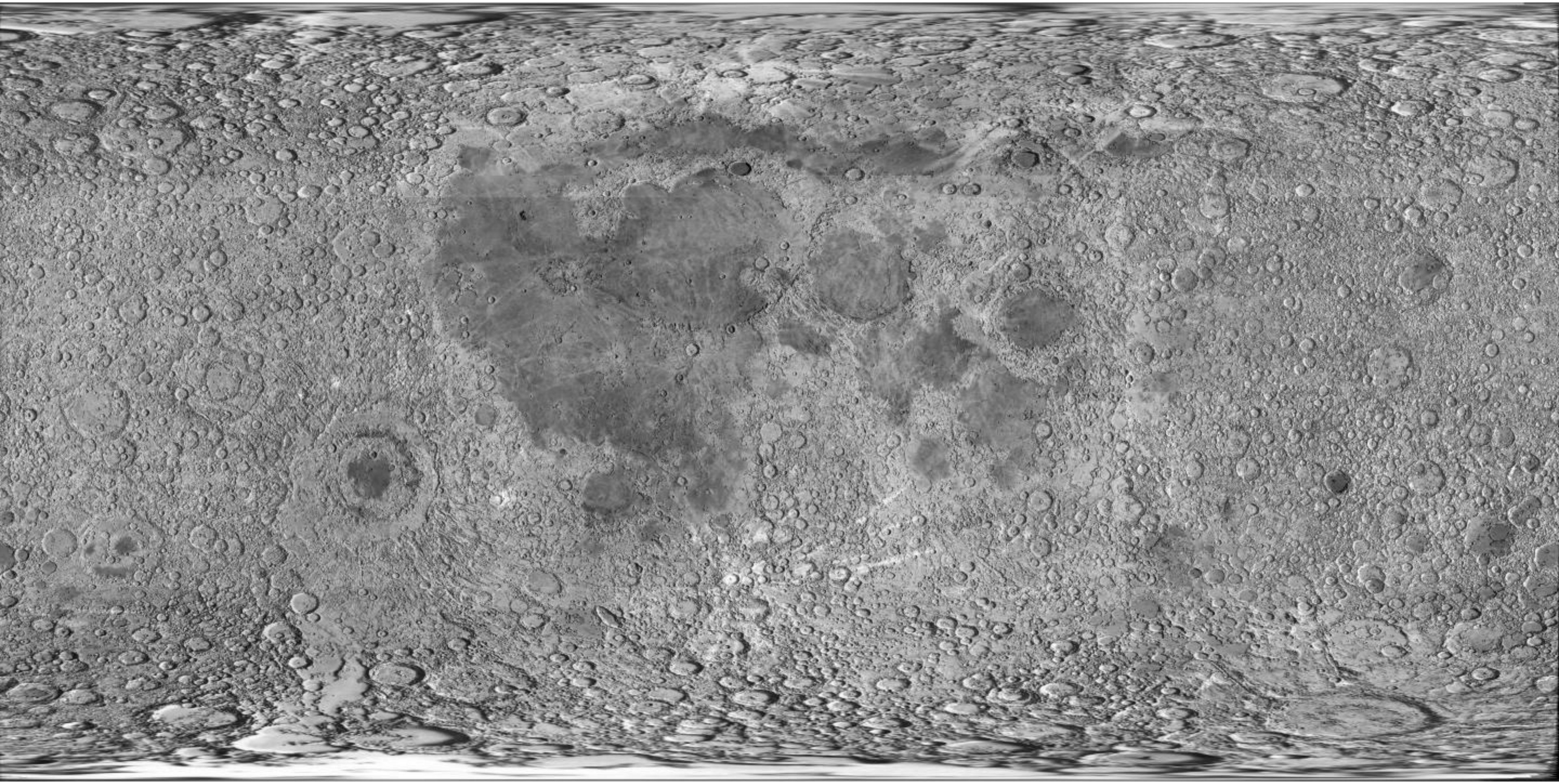
Circolo artico
E 90°
N50°
E 70°
W 50°
E 50°
W 30°
E 30°
W 10°
Meridiano zero
E 10°
N30°
Tropico del Cancro
Image NASA
Image © 2008 TerraMetrics
Image © 2008 DigitalGlobe
10°37'35.09" O
7886.62 km



36







The 3 conditions we need

- **Equidistance**. The parallels and meridians with their intersection make spherical segments and trapezes; the degrees of longitude and latitude will be reduced according o the scale ratio, so the distances between points on the surface will remain unchanged and reduced in the same scale ratio.
- **Conformality.** The angle between meridians and parallels is kept unchanged. As there is no angular deformation, and true angles are maintained, angular measurements can be made from conformal projections
- **Equivalence.** Equal area or equivalent maps maintain true relationships of areas. That is, at a given scale, for every part, as well as the whole, map area is proportional to the corresponding area on the Earth.

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… cannot be achieved togheter

- The globe is the only way to represent the earth without distorting one or more of the above-mentioned metric properties. Globes have the advantage of being true to metric properties and able to provide a true picture of spatial relationships on the earth's surface. The disadvantages of the globe are that it is impractical to make large-scale maps with it, it is difficult to measure on a globe, one can't see the whole world at once and it is difficult to handle and transport a globe around (unlike a folding map).
- The flat map has the disadvantage of always distorting one or more of the metric properties and it is more difficult to get a true picture of the spatial relationships between objects. Flat maps have numerous advantages however; it is not practical to make large or even medium scale globes, it is easier to measure on a flat map, easy to carry around, and one can see the whole world at once.

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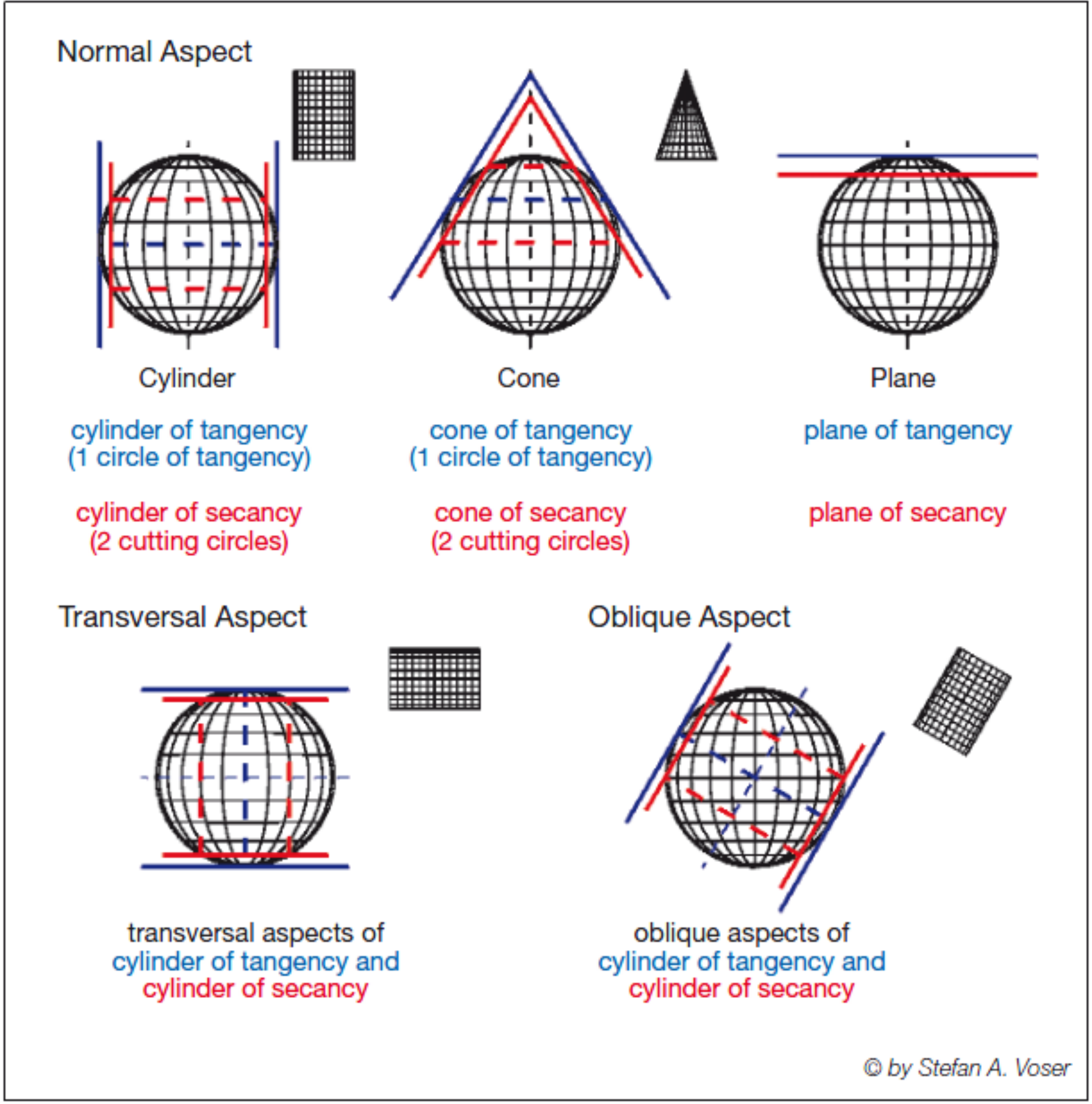
- Scale in particular is effected by the choice between using a globe vs. a plane. Only a globe can have a constant scale throughout the entire map surface and the scale for flat maps will vary from point to point and may also vary in different directions from a single point (as in Azimuthal maps). The scale for a flat map can only be true along one or two lines or points (tangent or secant points/lines). The 'scale factor' is therefore used to measure the difference between the idealized scale and the actual scale at a particular point on the map.

Map projects

- Map projects are one of the fundamental concepts of geography and cartography. Selecting the right map projection is one of the important first considerations for accurate GIS analysis.
- The problem with projections (and the reason why there are so many types) is that it is very difficult to represent the curved 3D surface of the Earth on a flat 2D surface of a map; some distortion is bound to occur.

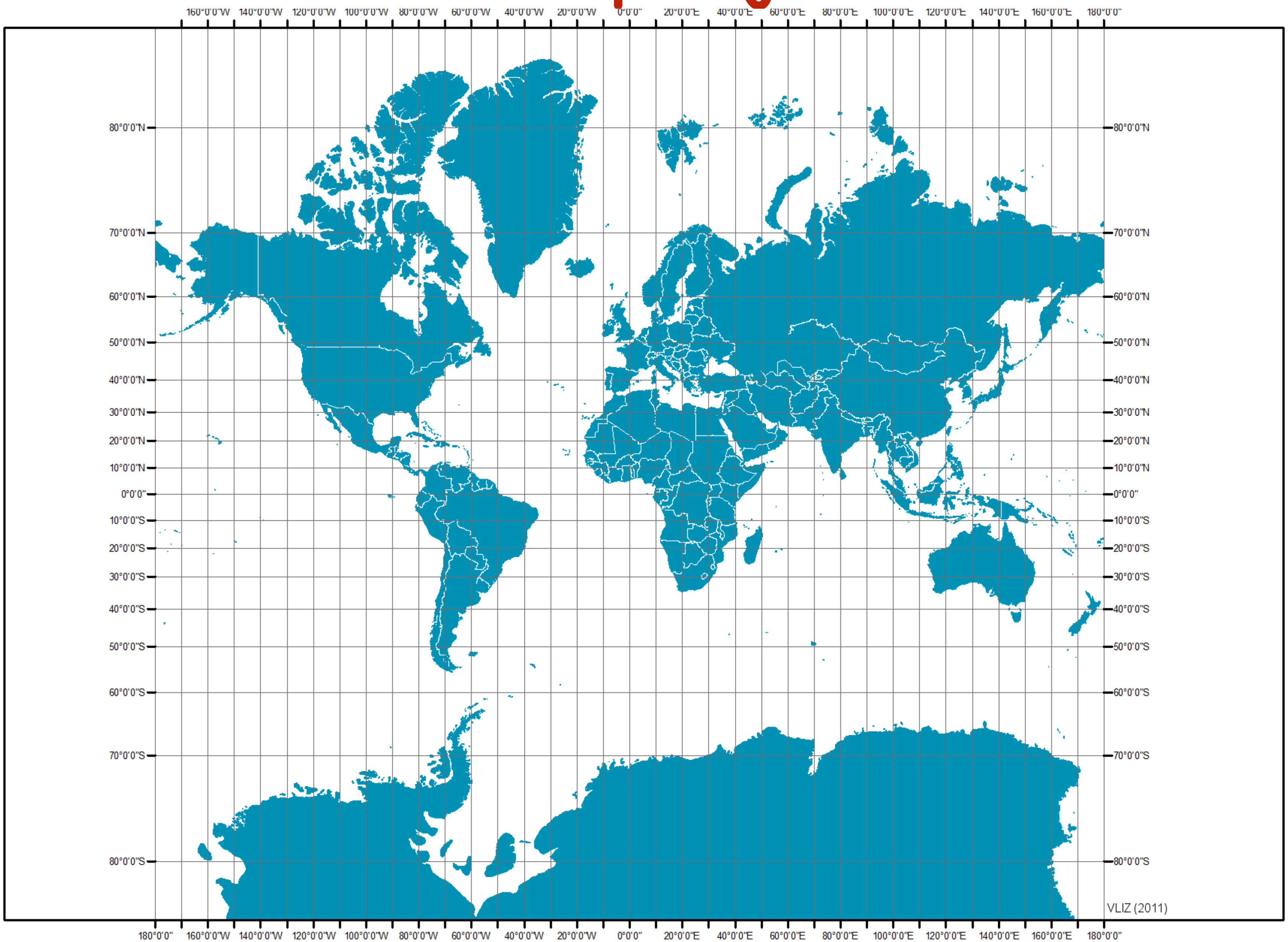
- Many geographers through the ages have tried to solve the distortion problem through various map projections
- A number of map projections have been used throughout history and deciding which projection to use is largely based on what is being mapped. Each projection has its tradeoffs and some are better at depicting the Polar Regions while others are better at depicting mid latitude areas. The scale of the map is also an important consideration as some projections are useful for small areas such as cities and counties while other projects are better for large areas such as continents or world maps.

- Further considerations regarding choosing which map projection to use are the complexity of the mathematical functions that transform the coordinates from the curved surface of the earth to a flat plane. With the popularity of GIS software and robust computer hardware, these calculations are now primarily done by computer but without this convenience most mapmakers choose suitable projections with simpler mathematical equations.

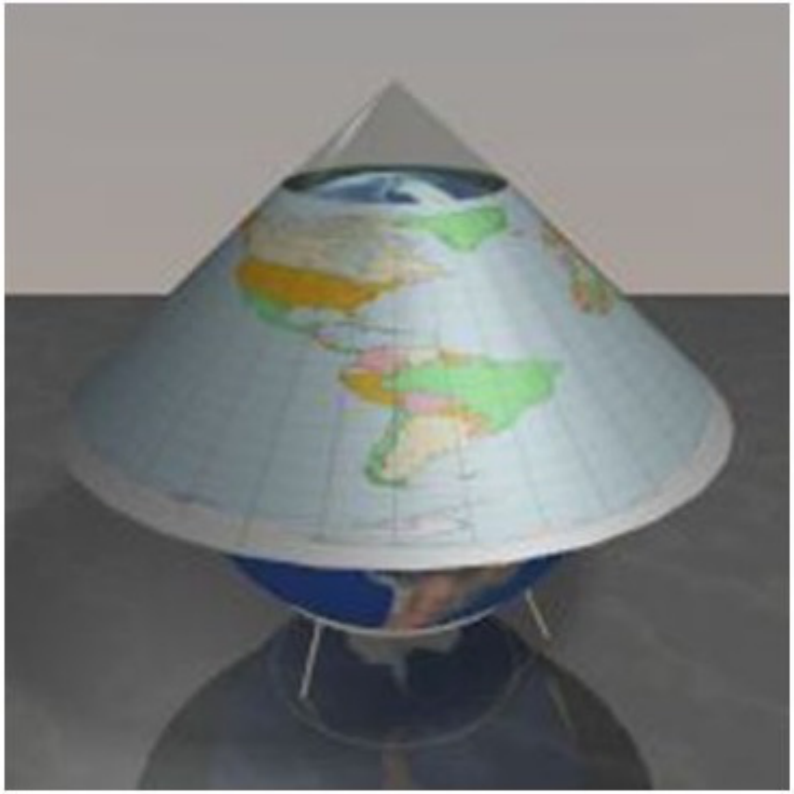


Normal Aspect
Cylinder
cylinder of tangency
(1 circle of tangency)
cylinder of secancy
(2 cutting circles)
Cone
cone of tangency
(1 circle of tangency)
cone of secancy
(2 cutting circles)
Plane
plane of tangency
plane of secancy
Transversal Aspect
transversal aspects of
cylinder of tangency and
cylinder of secancy
Oblique Aspect
oblique aspects of
cylinder of tangency and
cylinder of secancy
© by Stefan A. Voser

Mercator projection

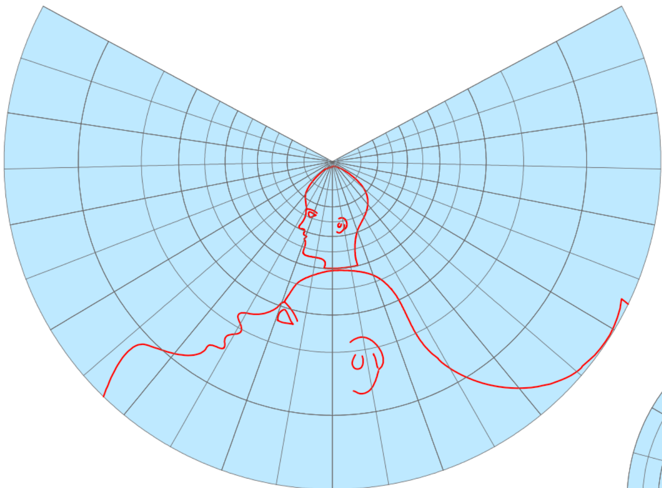


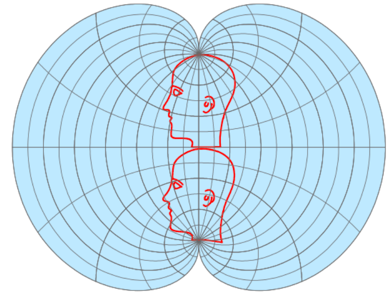
Lambert Conformal Conic Projection

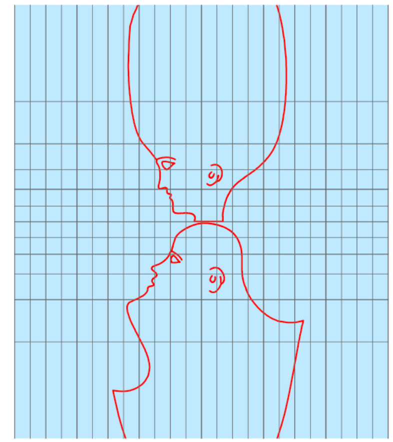


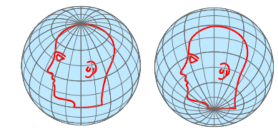
The World Aeronautical Chart (WAC) and the Visual Navigation Chart (VNC) are Lambert Conformal Conic Projections.

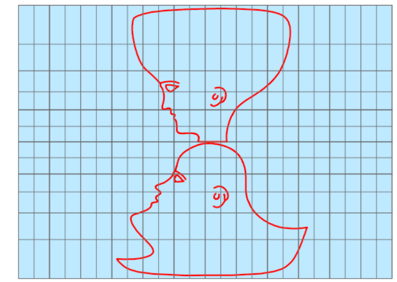
Distortion On Map Projections
Using Gedymin Profiles

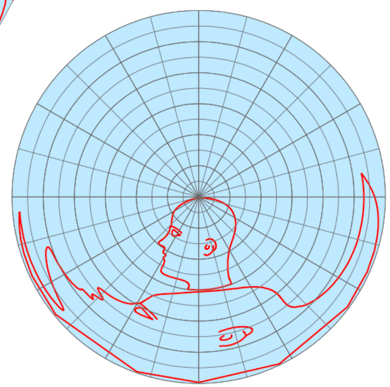

Lambert Conformal Conic

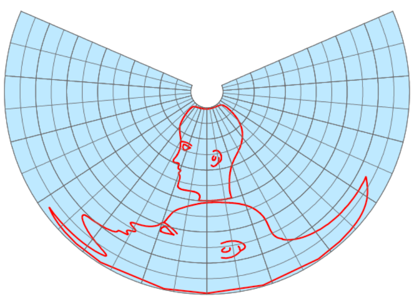

Polyconic

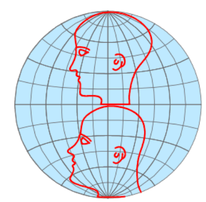

Mercator


Oblique Orthographic: Non-Distorted Profiles

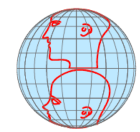

Miller 1

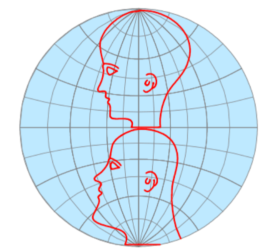

Polar Azimuthal Equidistant

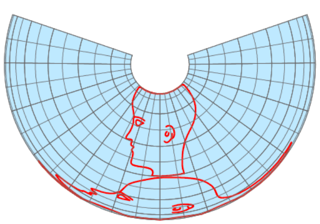

Equidistant Conic

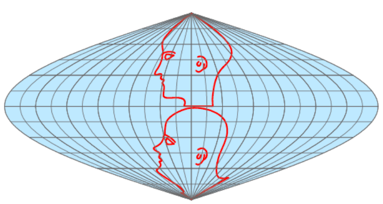

Azimuthal Equidistant

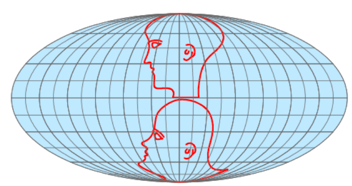

Azimuthal Equal-area

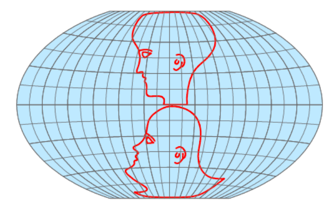

Orthographic

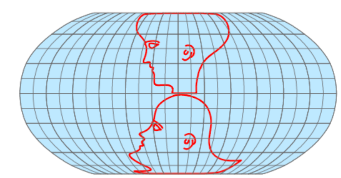

Stereographic


Albers Equal-area Conic


Sinusoidal

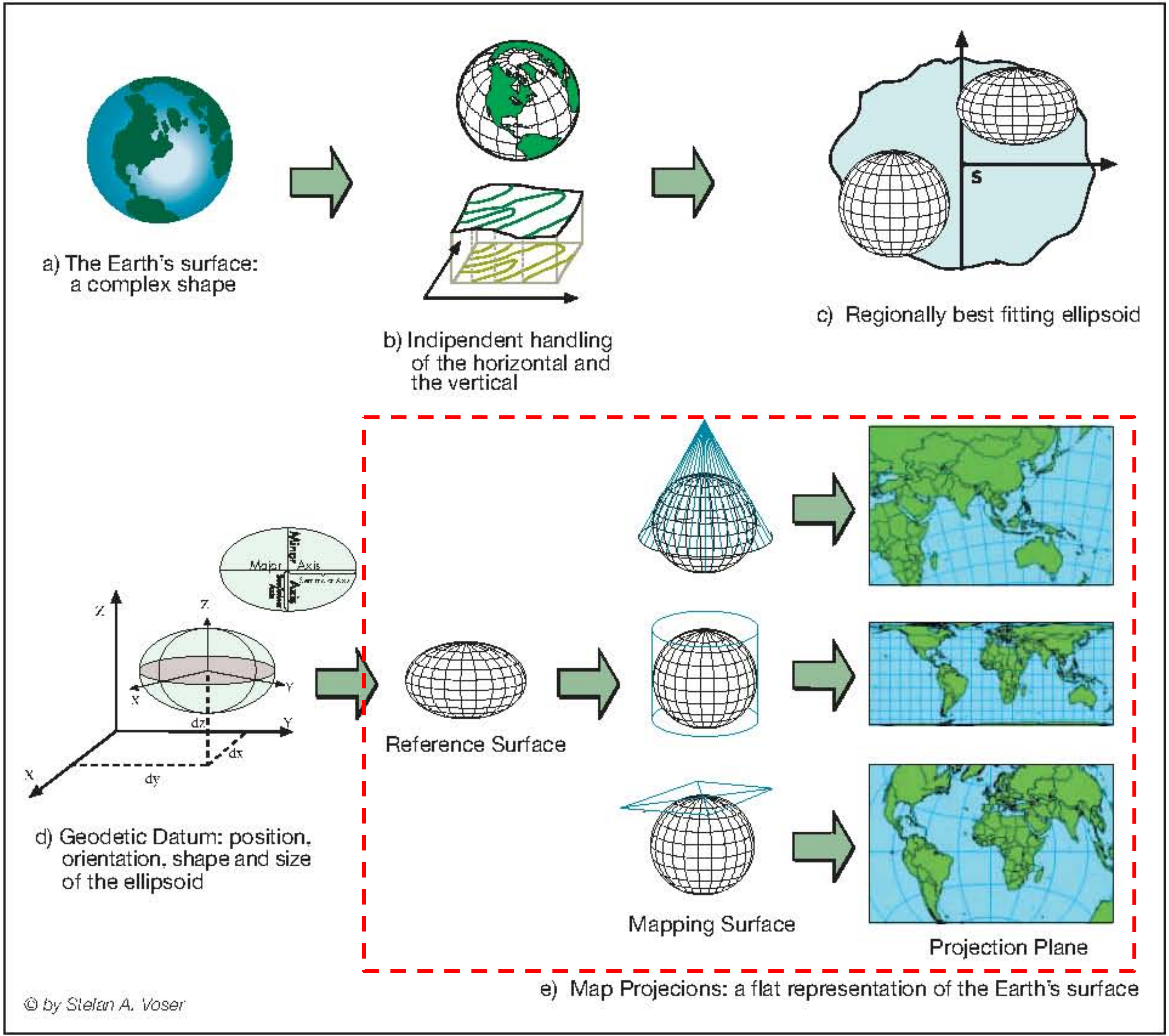

Mollweide


Winkel tripel


Robinson

Reference:
Gedymin, A.V. [Гедымин, А.В.], 1946, *Kartografiya*: Moscow, Gos. Ucheb.-Pedagog. Izd-vo, 180 p. [Russian. 2nd ed., 1952.]
Tobler, W.R., 1964, *Geographical coordinate computations*: Part I, General considerations; Part II, Finite map projection distortions: Ann Arbor, Mich., University of Michigan, Dept. of Geography, Technical Reports no. 2 and 3, ONR Task No. 389-137.

why all maps are wrong



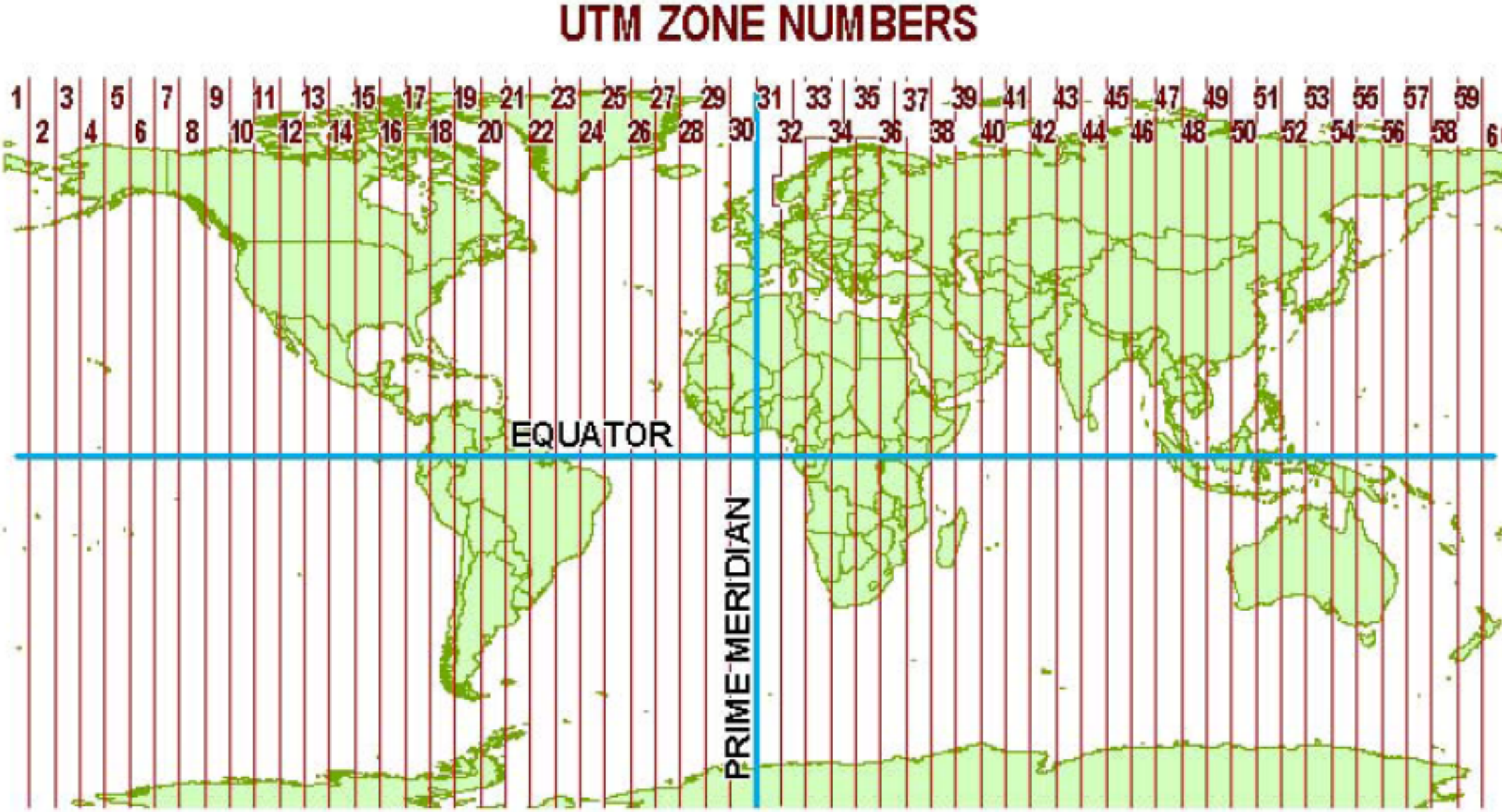
a) The Earth's surface: a complex shape
b) Indipendent handling of the horizontal and the vertical
s
c) Regionally best fitting ellipsoid
Minor Axis
Major Axis
Z
X
Y
dz
dx
dy
d) Geodetic Datum: position, orientation, shape and size of the ellipsoid
Reference Surface
Mapping Surface
Projection Plane
e) Map Projecions: a flat representation of the Earth's surface
© by Stefan A. Voser

Transverse Mercator Projection

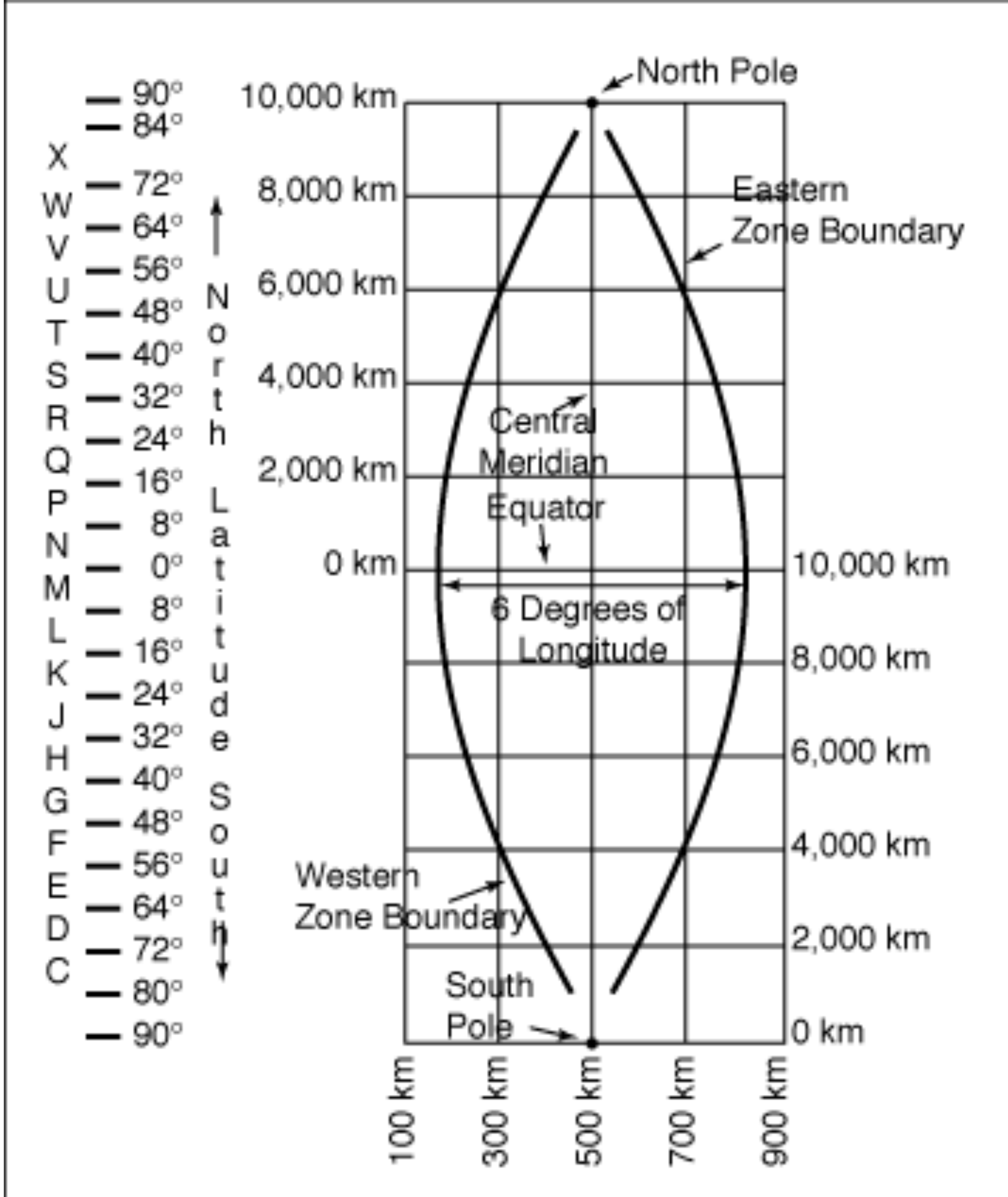
- Central meridian is selected by the map maker and touches the cylinder.
- Maps using the projection can show the whole Earth, but directions, distances, and areas are reasonably accurate only within 15° of the central meridian.

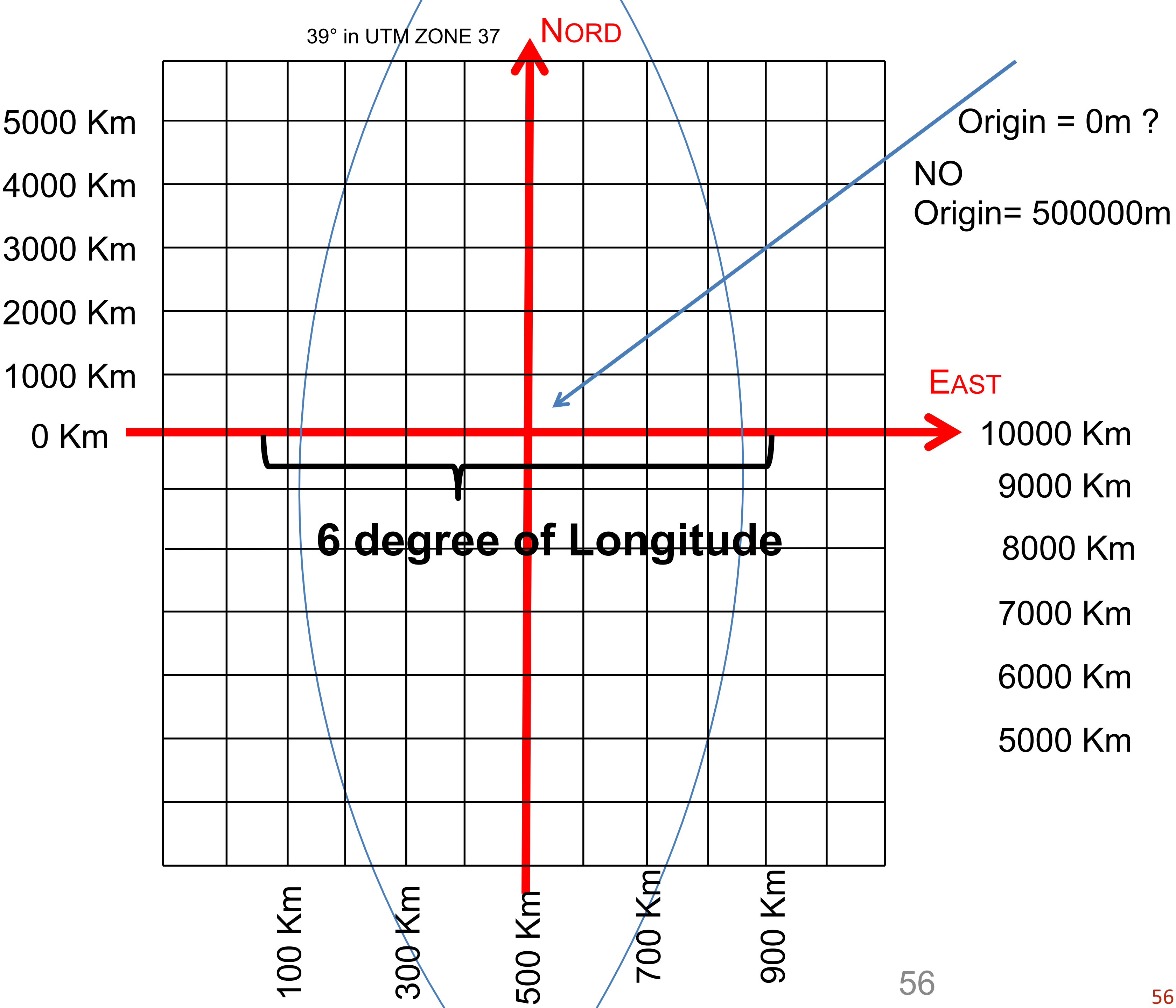
UTM Zones

- World is divided into 60 zones.
- Each zone is 6° of longitude wide.
- Zones are numbered 1 to 60, starting at 180° and progressing to the east.


UTM ZONE NUMBERS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
EQUATOR
PRIME MERIDIAN

UTM Zone Details

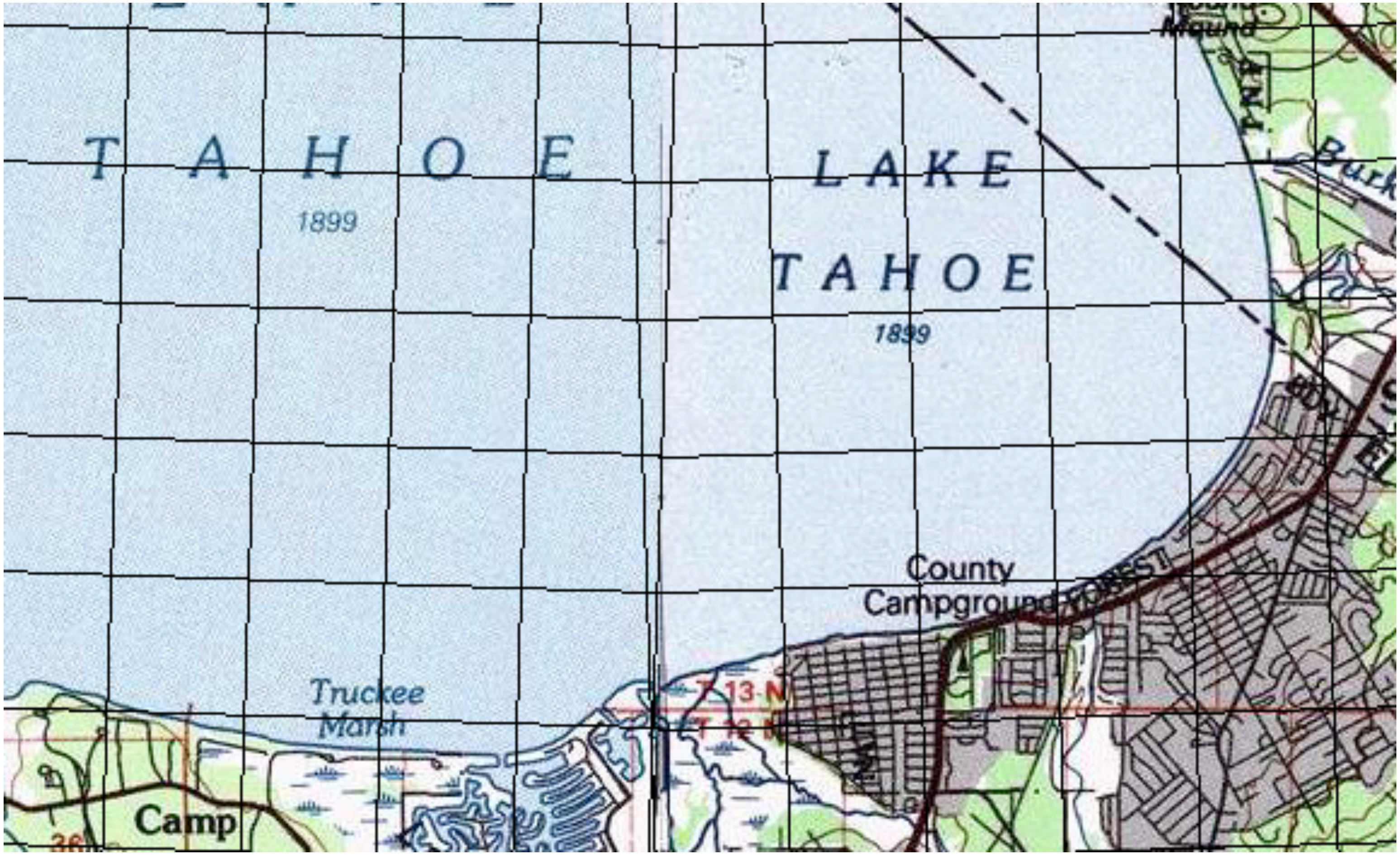




39° in UTM ZONE 37
NORD
Origin = 0m ?
NO
Origin= 500000m
EAST
5000 Km
4000 Km
3000 Km
2000 Km
1000 Km
0 Km
10000 Km
9000 Km
8000 Km
7000 Km
6000 Km
5000 Km
6 degree of Longitude
100 Km
300 Km
500 Km
700 Km
900 Km

56

Boundary between UTM zones



UTM cartesian coordinate

• X coordinate, called East, has a value of 500,000m on the Central Meridian of each zone.
• Y coordinate, called Nord, has a value of 0m on the Equator for the Emisphere North, a value of 10.000.000.m on the Equator per the South Emisphere.

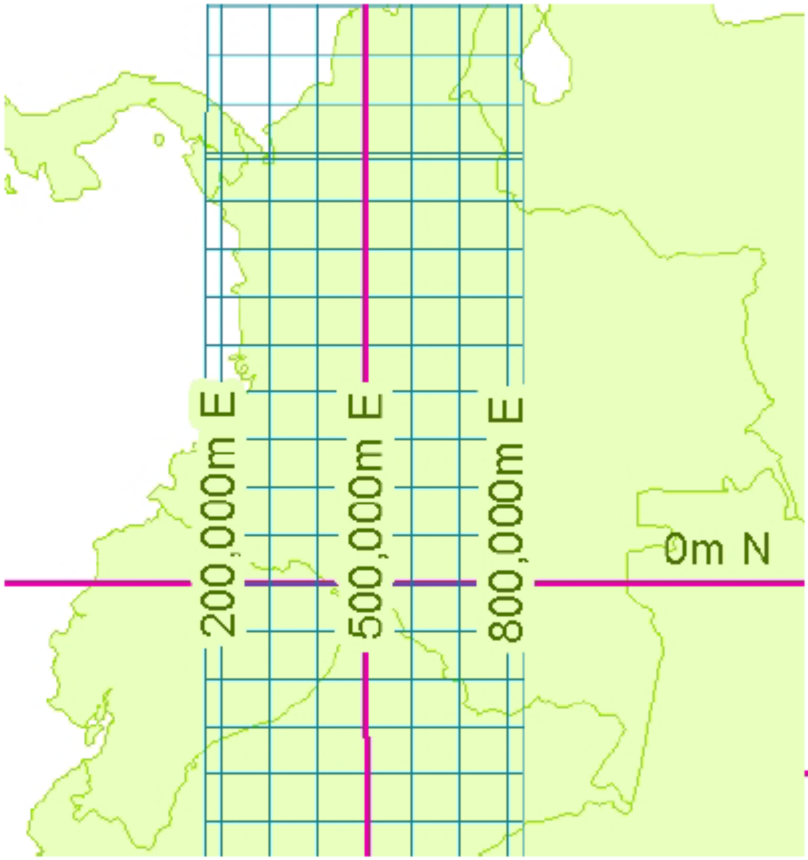


Figura 1 Valori Est

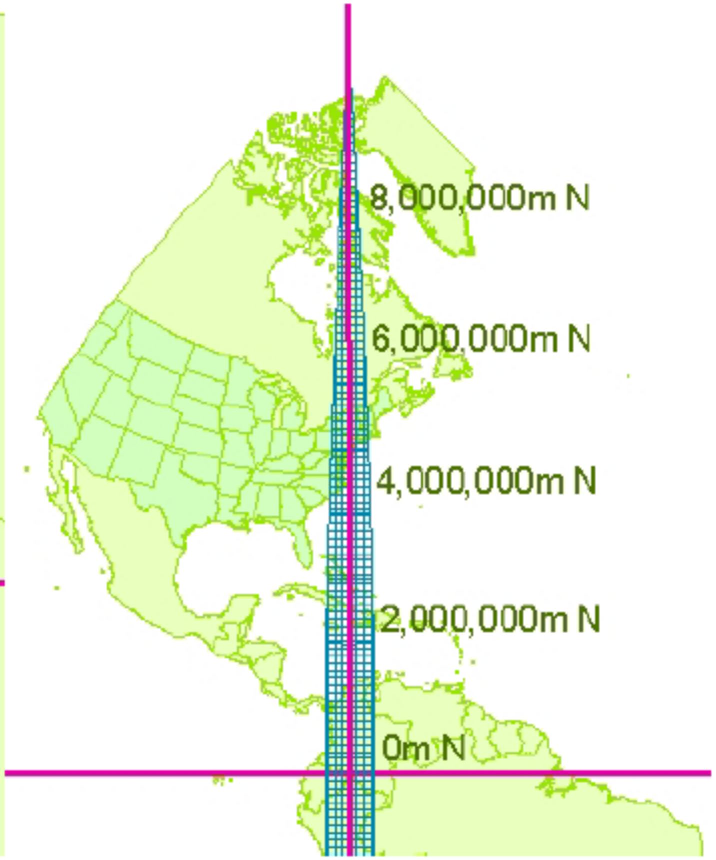


Figura 2 Valori Nord

Example

Geographic Coordinates:

45° 12’ 24” Latitude N

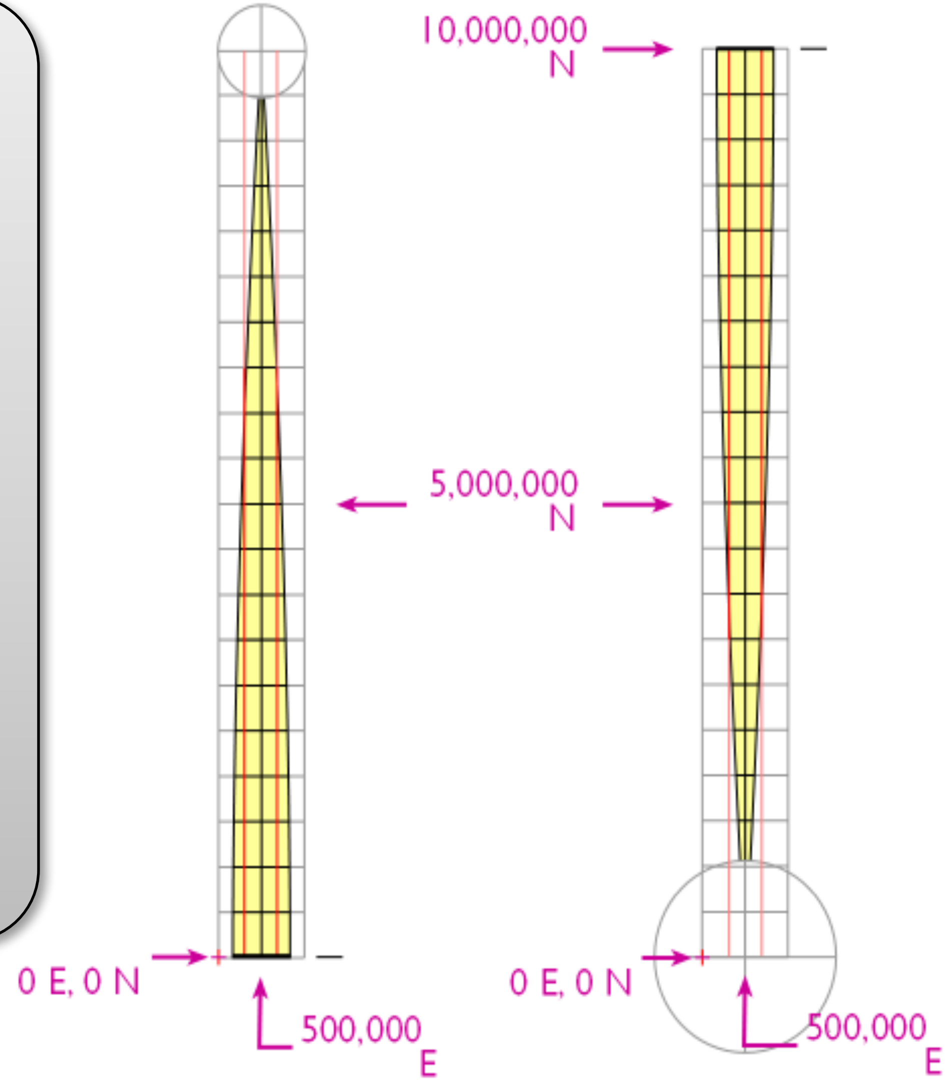
11° 45’ 57” Longitude E

Cartesian Coordinates

5009630.69 N

717204.3 E

Zone 32 North Emisphere



Emisfero Nord

Emisfero Sud

Modern cartography largely involves the use of aerial and, increasingly, satellite imaging as a base for any desired map or chart.

The procedures for translating photographic data into maps are governed by the principles of photogrammetry and yield a degree of accuracy previously unattainable.

The remarkable improvements in satellite imaging since the late 20th century and the general availability on the Internet of satellite images have made possible the creation of Google Map and Google Earth and other databases that are widely available online.