8 • SPATIAL DATA AND GEOGRAPHY

Data Visualization and Visual Analytics

TEACHER
Salvatore Rinzivillo

University of Pisa
Department of Computer Science
Course: Visual Analytics
Academic Year: 2026

OBJECTIVE

- To show spatial distribution of data
- To show relative positions of data components
- Thematic maps
  - Mapping to attribute data (quantitative and qualitative) on a map
  - Geometry linked to fixed geographical position

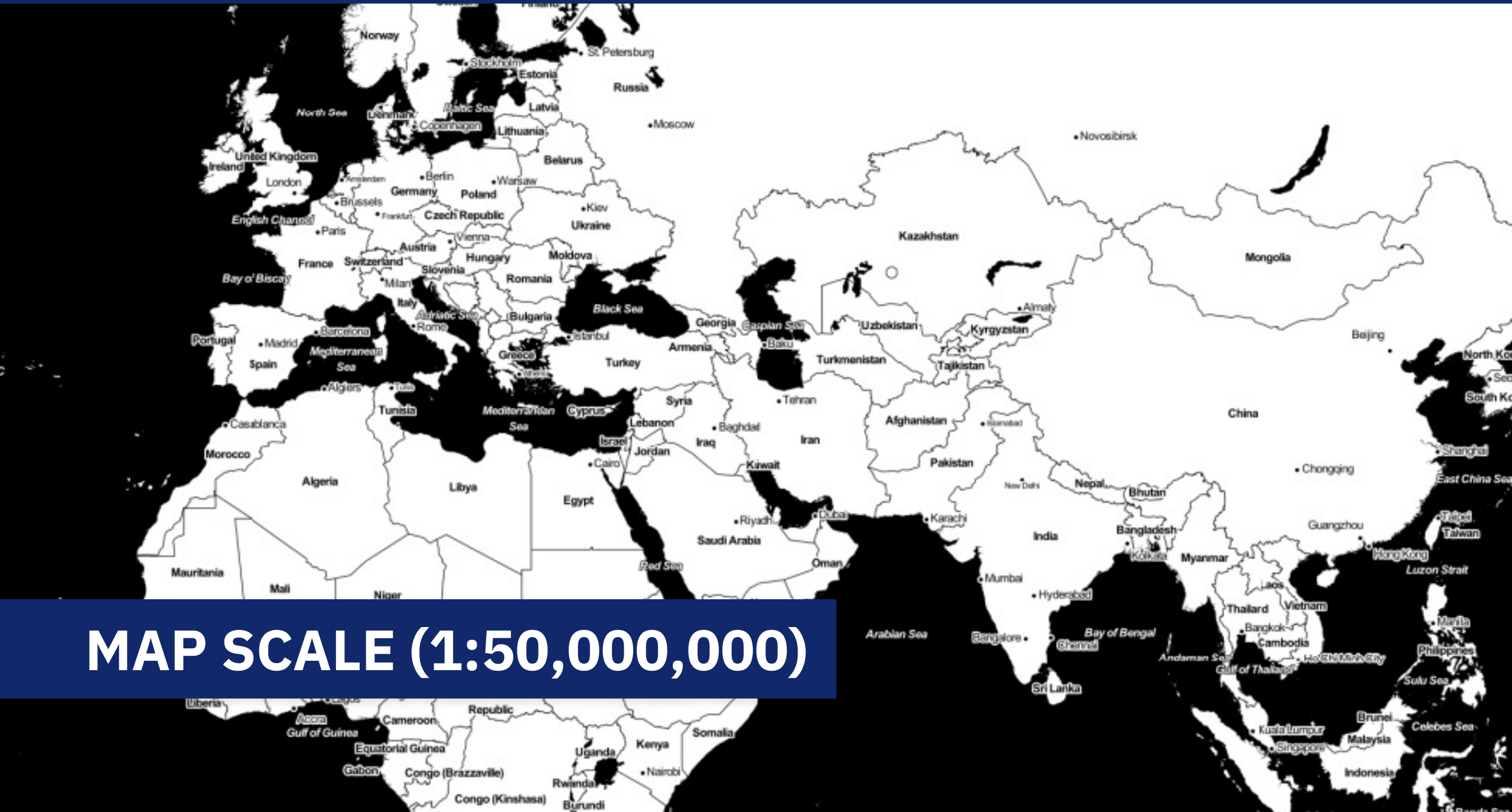
MAP DESIGN

- Projection
  - Map curved 3D objects to a place
- Scale
  - Reduction of a map to the available space
- Symbolization and themes
  - Equivalent to encoding with Visual Variables

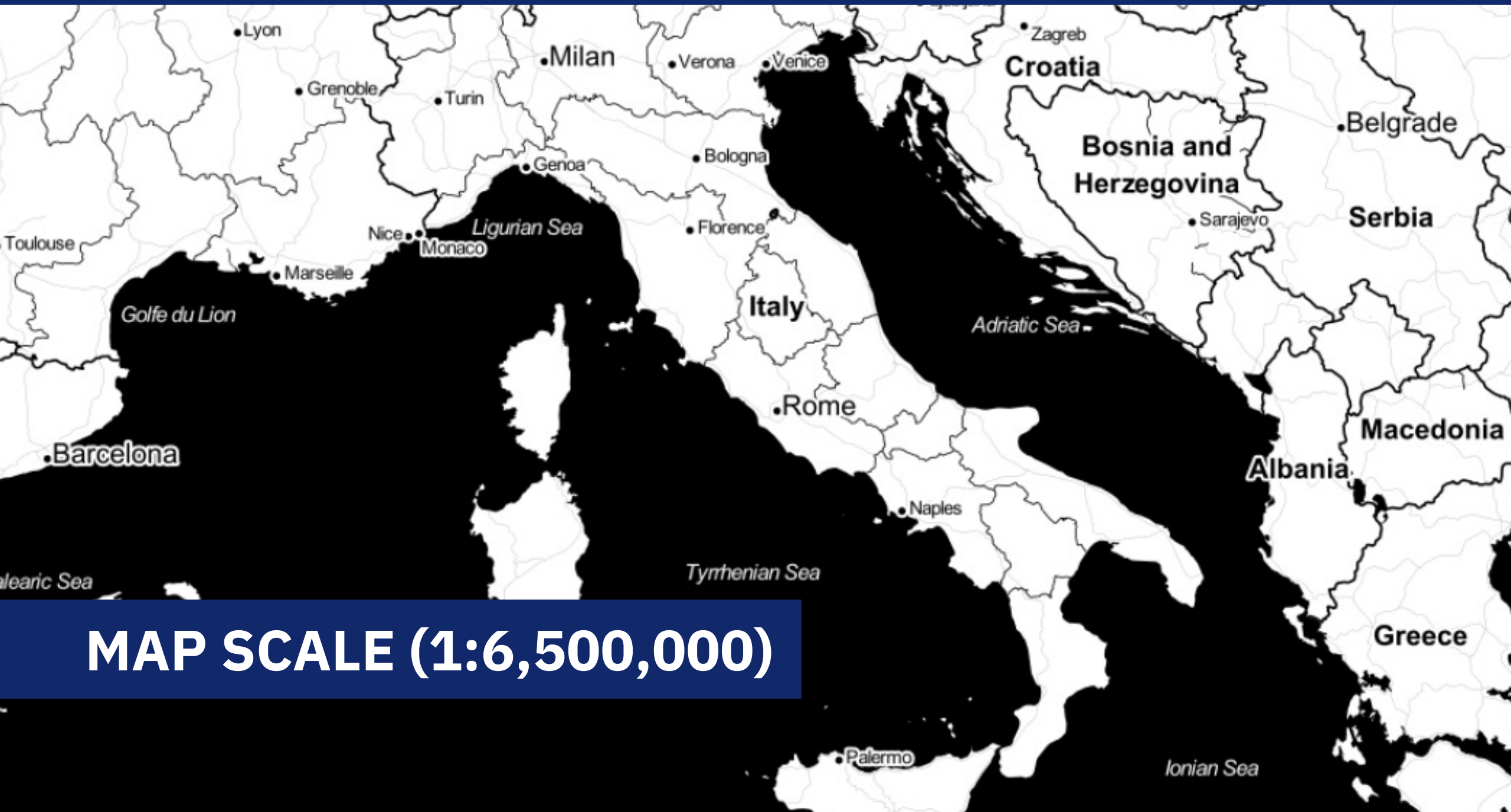
SCALE

MAP SCALE

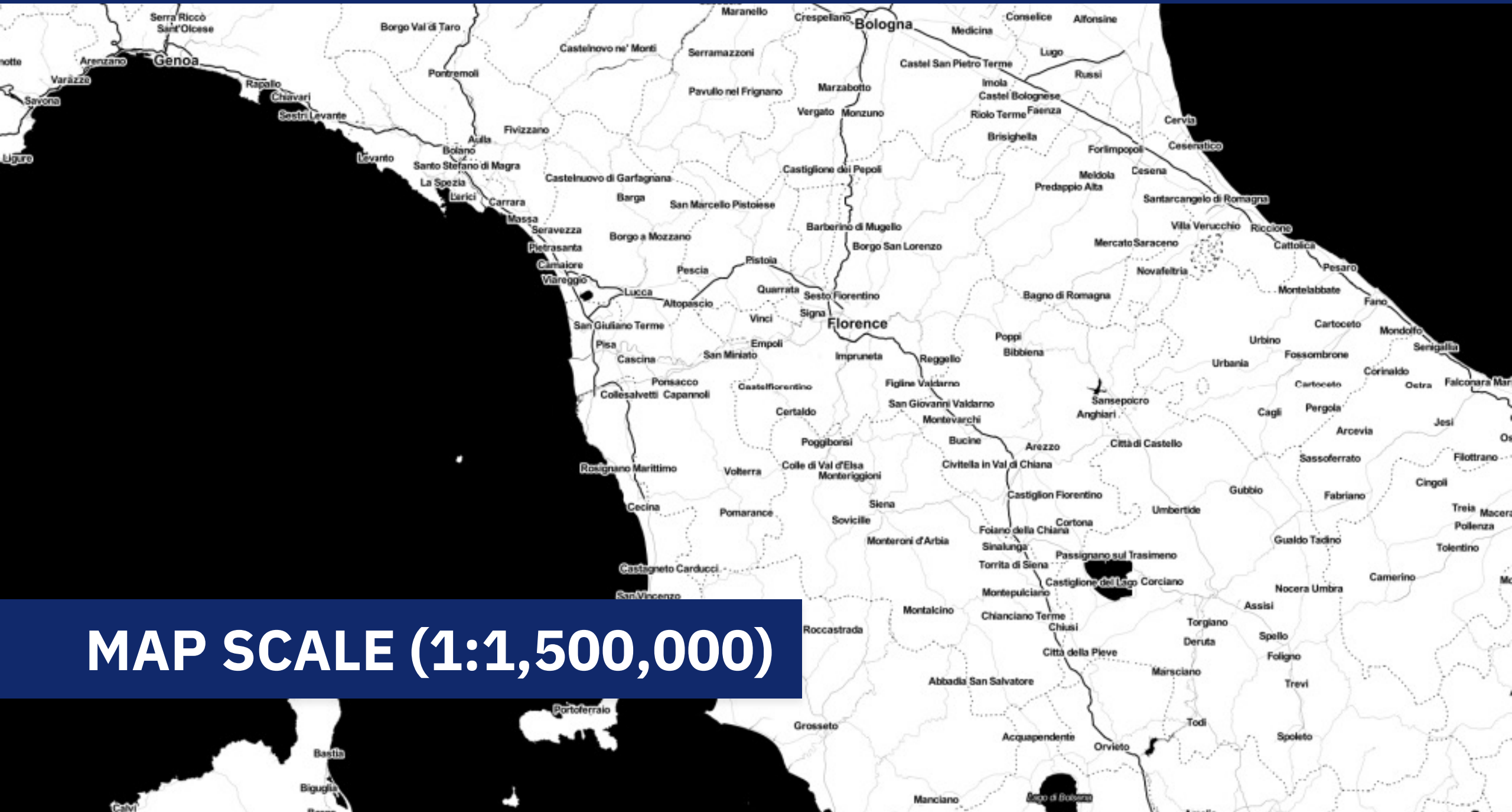
- Defines as the ratio between a distance on the map and the corresponding distance on the Earth
  - Usually expressed as verbal ratio
    - 1:100
    - Distance on the map is always expressed as one
  - The ratio is dimensionless
  - The larger the fraction, the greater the map's details



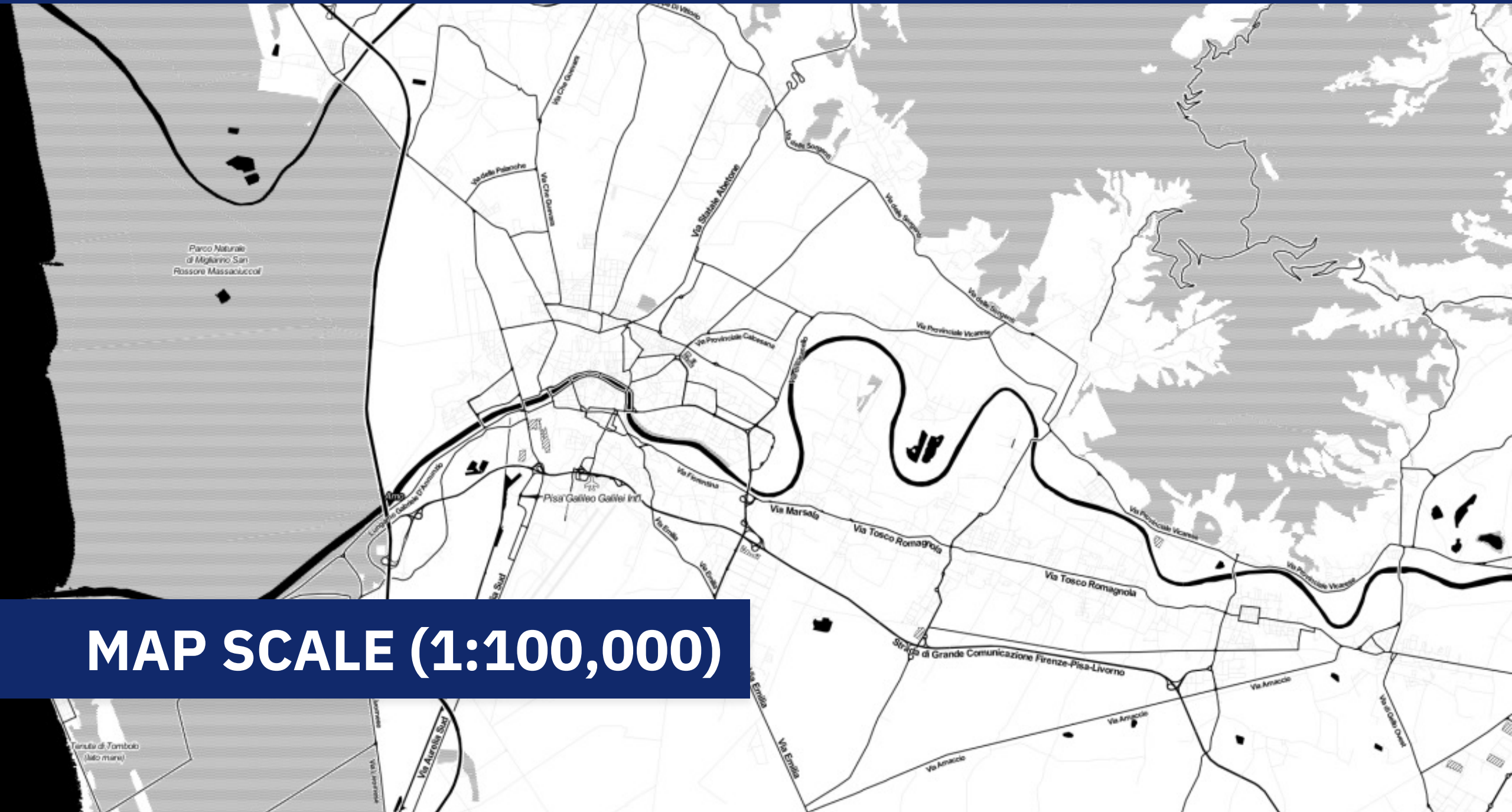
MAP SCALE (1:50,000,000)



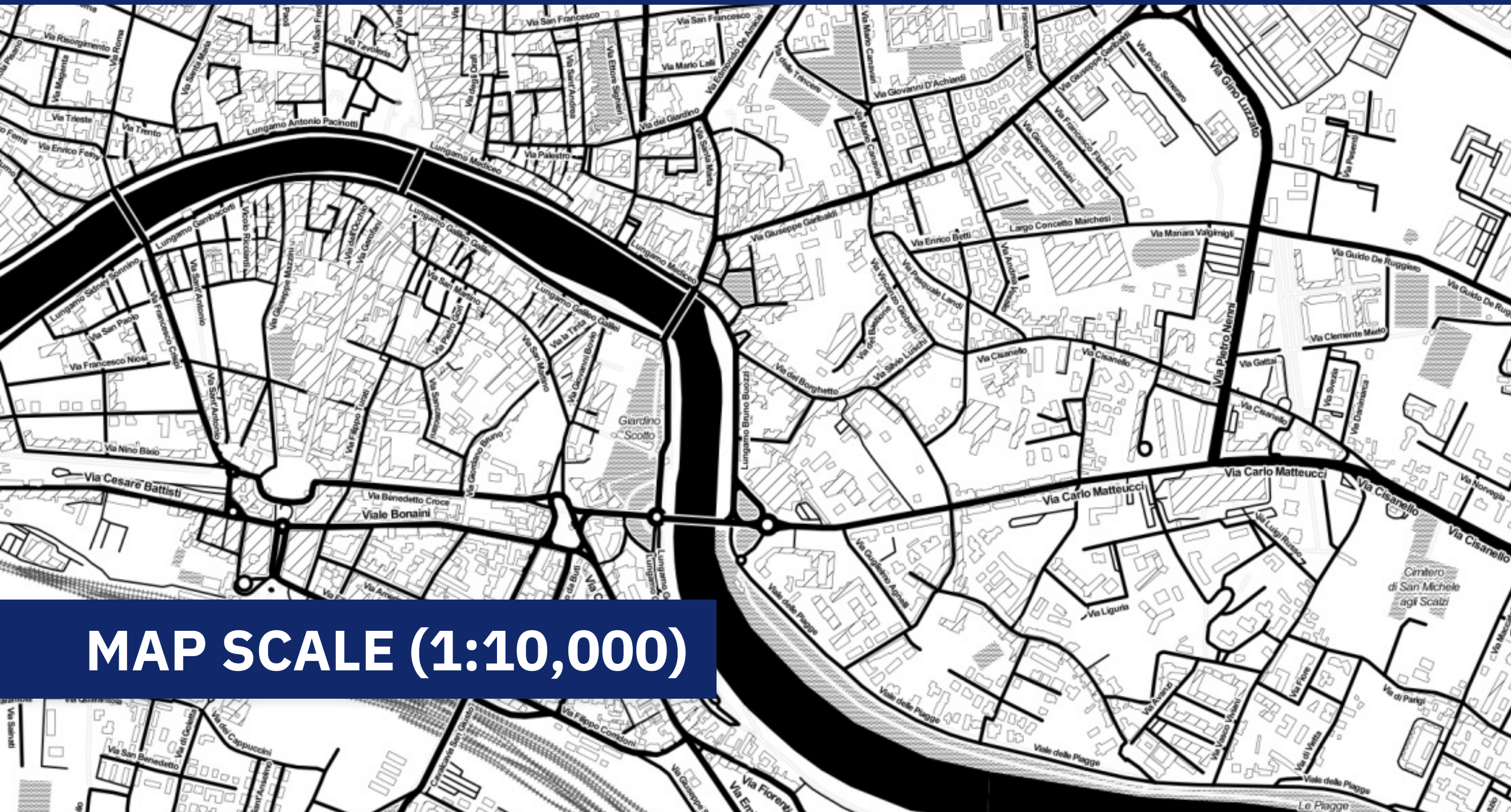
MAP SCALE (1:6,500,000)



MAP SCALE (1:1,500,000)



MAP SCALE (1:100,000)


MAP SCALE (1:10,000)
Via San Francesco
Via Mario Lalli
Via del Giardino
Via Palestro
Lungarno Antonio Pacinotti
Lungarno Medicee
Via Giuseppe Garibaldi
Via Ginio Luzzatto
Via Enrico Betti
Largo Concetto Marchesi
Via Manara Valgimigli
Via Guido De Ruggiero
Via Pietro Nenni
Via Clemente Merlo
Via Gattai
Via Cisanello
Via Carlo Matteucci
Via Nino Bixio
Via Cesare Battisti
Via Benedetto Croce
Viale Bonaini
Giardino Scotto
Lungarno Bruno Buozzi
Via del Borghetto
Via Pasquale Landi
Via Silvio Lucchi
Via Norvegia
Via Liguria
Via Luigi Russo
Cimitero di San Michele agli Scalzi
Viale delle Piagge
Via Filippo Corridoni
Via dei Cappuccini
Via San Benedetto
Via Fiorentina
Via di Parigi
Le Piagge

MAP SCALE (1:1,000)

PROJECTIONS

CARTOGRAPHY AS ART


AFRICVM MARE


OCEANO
SCITHE
EUROPA
MONTI RIPEI
TRACIA
LIBIA
ETIOPI
OCCIDENTALI
ETIOPI
ORIENTALI
OCEANO

THE NEW WORLD

- New challenges for geographers
- Since XVI century new methods to represent geography
- From plane to globe

BASIC COMPONENTS...

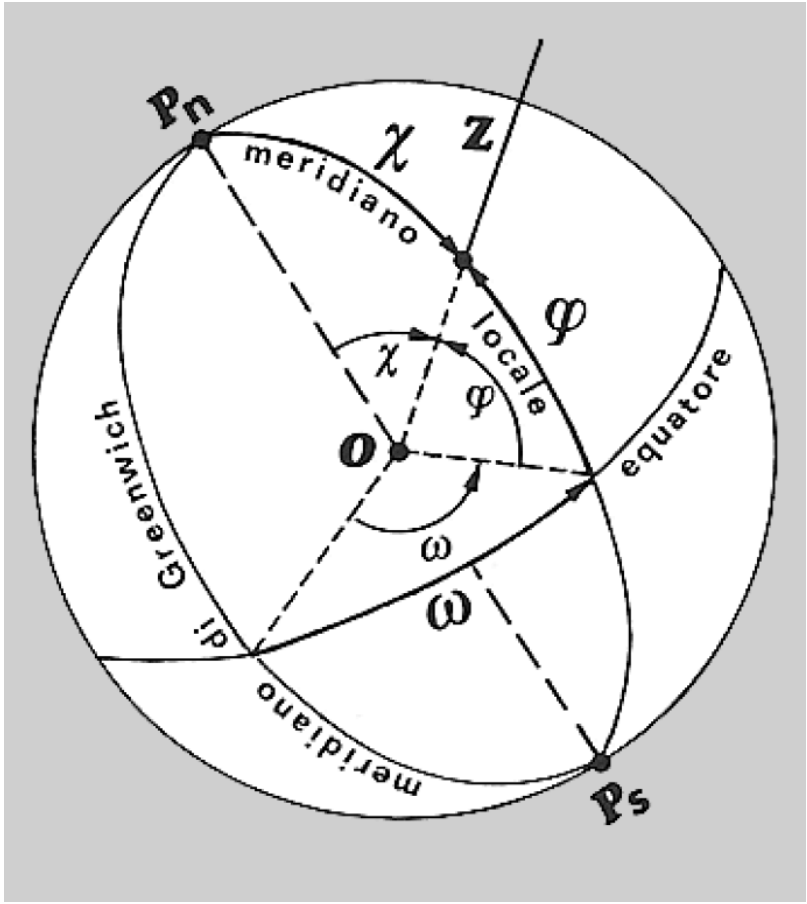
- A reference system
- A set of coordinates

REFERENCE SYSTEM

- Univocally determine a position in 3D (2D+1D)
- Need for a simple model:
  - Mathematically tractable: surface
  - Link to physical world
- Typical surfaces:
  - Sphere
  - Ellipsoid (spheroid)
  - Geoid

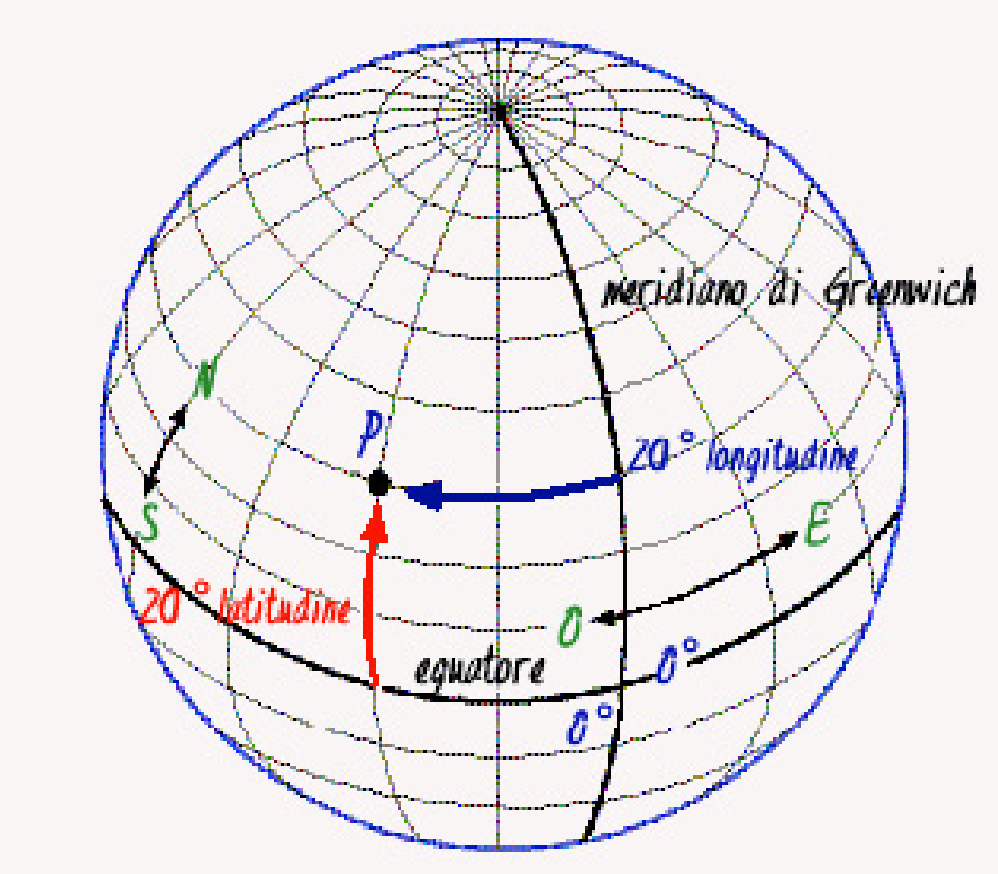
COORDINATE (2D+1D)

- Position relative to the reference system
- Angular coordinates
  - Longitude
  - Latitude
- Altitude as offset from the reference point



LATITUDE AND LONGITUDE

- Latitude: angular distance from equator
- Longitude: angular distance from central meridian

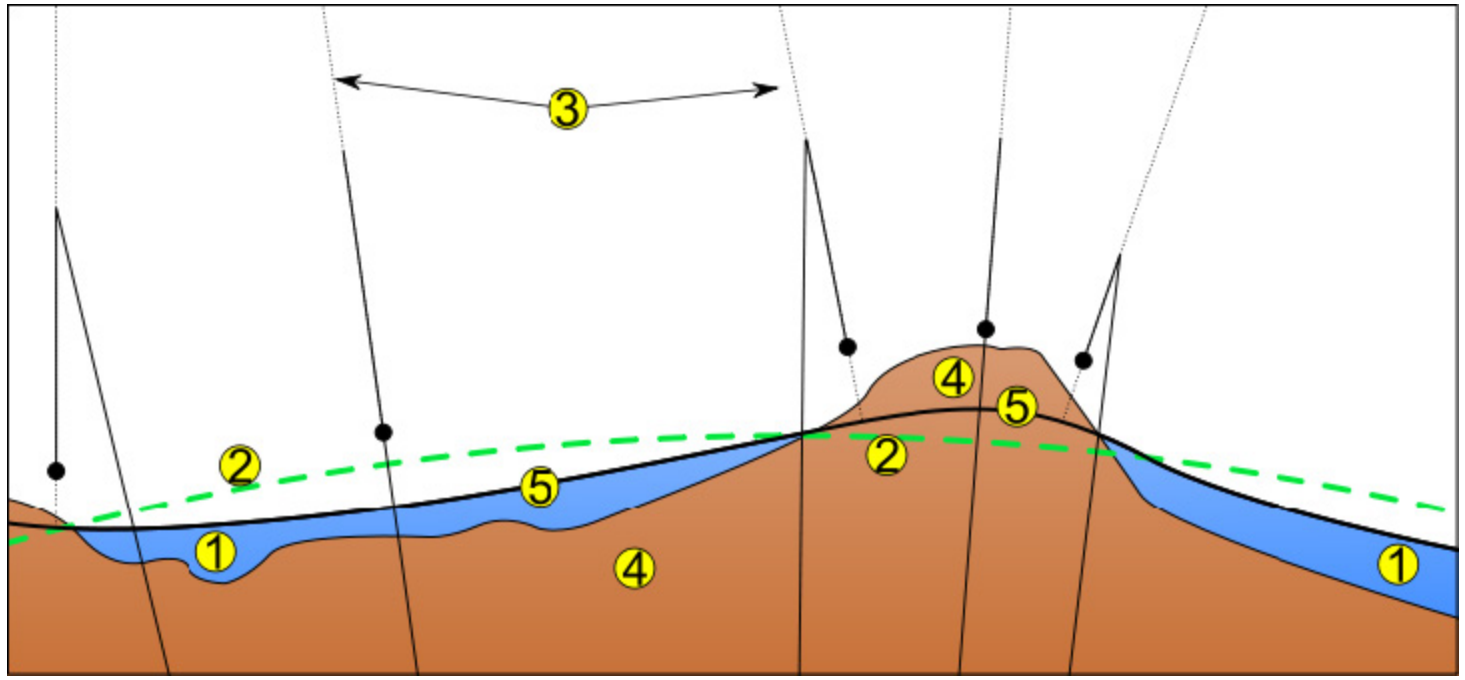


WHICH REFERENCE SYSTEM?

- Earth present a complex surface, results of gravity, magnetical forces and different densities
- Mathematic representation is very complex

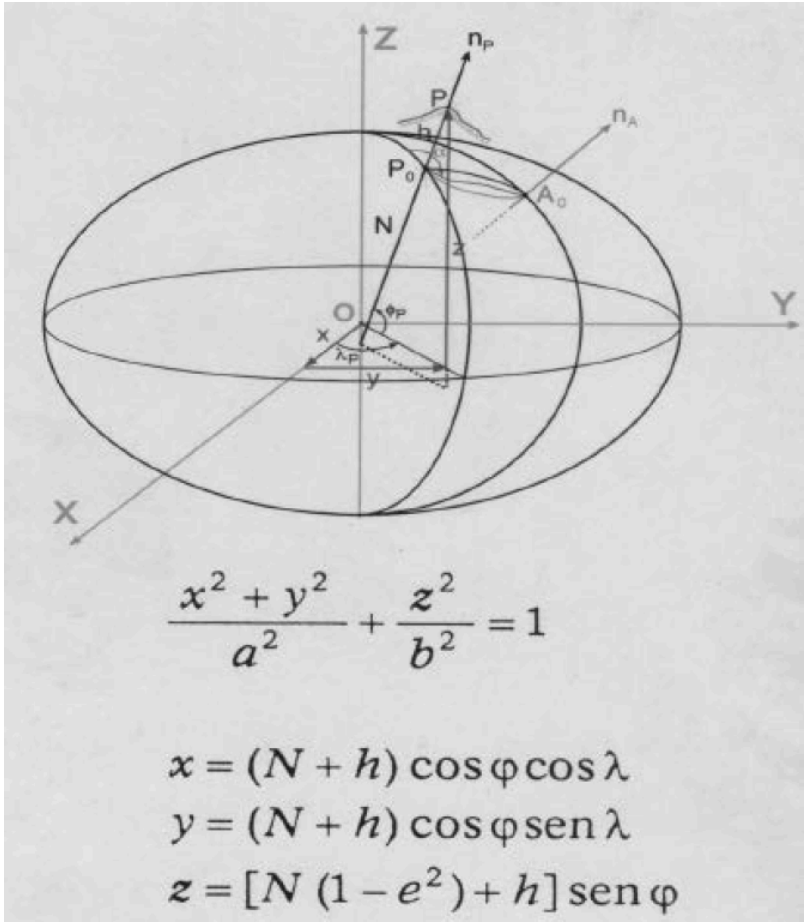
GEOID

- Geoid: surface where gravity is constant in each point
- Average surface of seas



WHICH REFERENCE SYSTEM?

- Ellipsoid: clear and easy mathematic definition
- Easy to define a position of a point in the space
- Low differences with the real geoid (~40m)

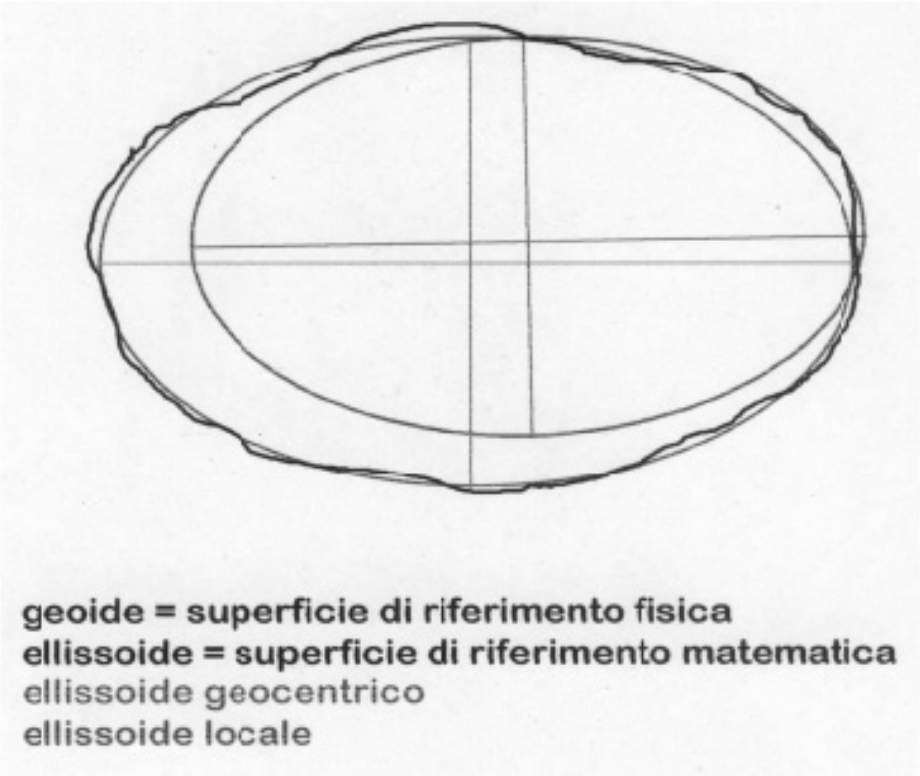


$$\frac{x^2 + y^2}{a^2} + \frac{z^2}{b^2} = 1$$

$$x = (N + h)\cos\varphi\cos\lambda$$
$$y = (N + h)\cos\varphi\,\mathrm{sen}\,\lambda$$
$$z = [N\,(1 - e^2) + h]\,\mathrm{sen}\,\varphi$$

DATUM

- An ellipsoid is univocally determined by 8 parameters (named Datum)
  - 2 shape parameted:
    - Equatorial radius
    - Polar radius
  - 6 parameters for position and orientation



WHICH DATUM?

- Diffusion of GPS systems: WGS84 (World Geodetic System 1984)
- Many local cartograph systems use local defined datum
  - In Europe, datum ED50 (European Datum 1950, Ellissoide di Hayford) is largely used
- All datum can be mapped/translated to WGS84

PROJECTIONS

- Cartographic projections maps coordinates from the ellipsoid to the plane
- A direct mapping is not feasible without introducing deformations
- Families of mapping that preserve:
  - Angles (conformal projection)
  - Surfaces (equal area projection)
  - Minimizing both

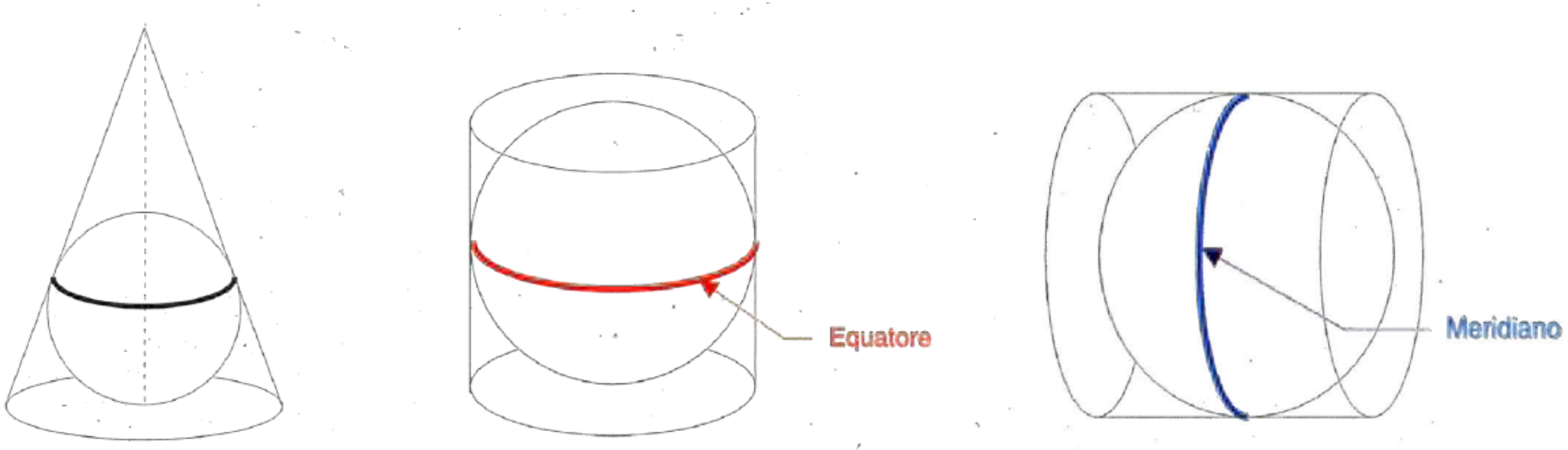
PROJECTIONS

- Each projection assume a precise datum
- For example, UTM projection uses datum WGS84 and ED50

PROJECTIONS

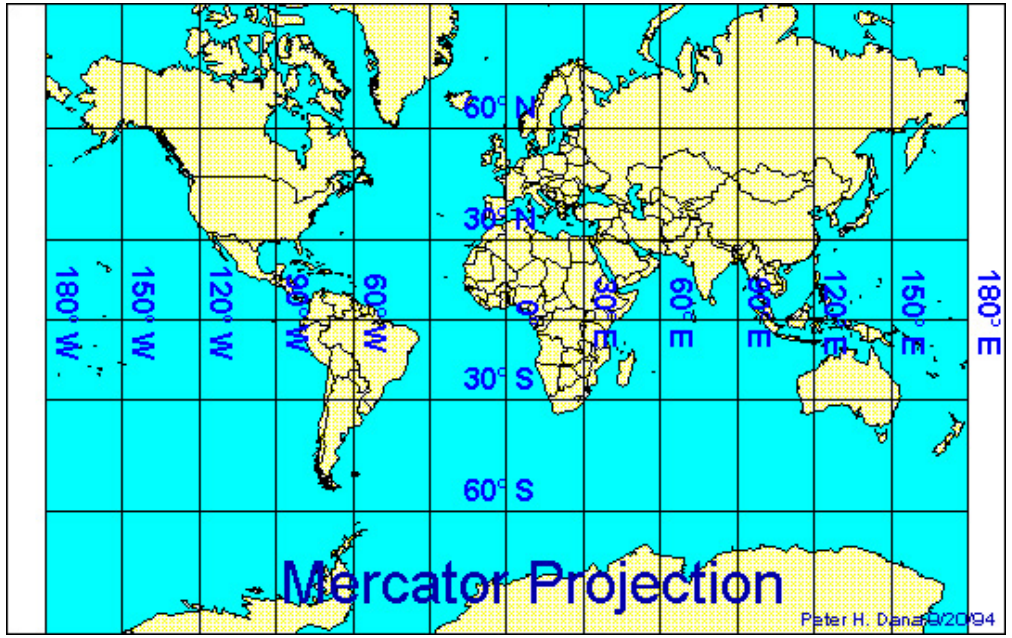
Three different types

- Azimuthal: projection plane is tangent to a point on the earth
- Conic: points are projected on a cone
- Cylindrical: points are projected ona cylinder



MERCATOR PROJECTION

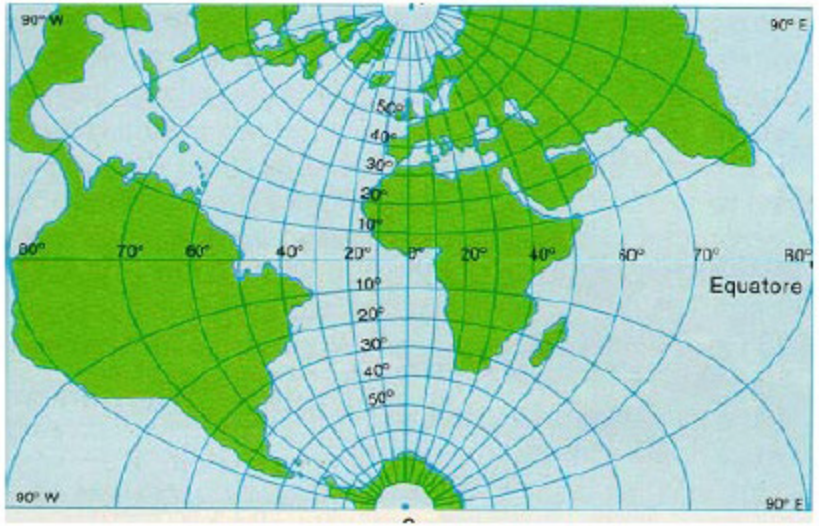
- Cylindrical projections
- Cylinder tangent to equator
- Meridians are paralled
- Low distortion for tropical zones



UTM

(UNIVERSAL TRANSVERSE MERCATOR)

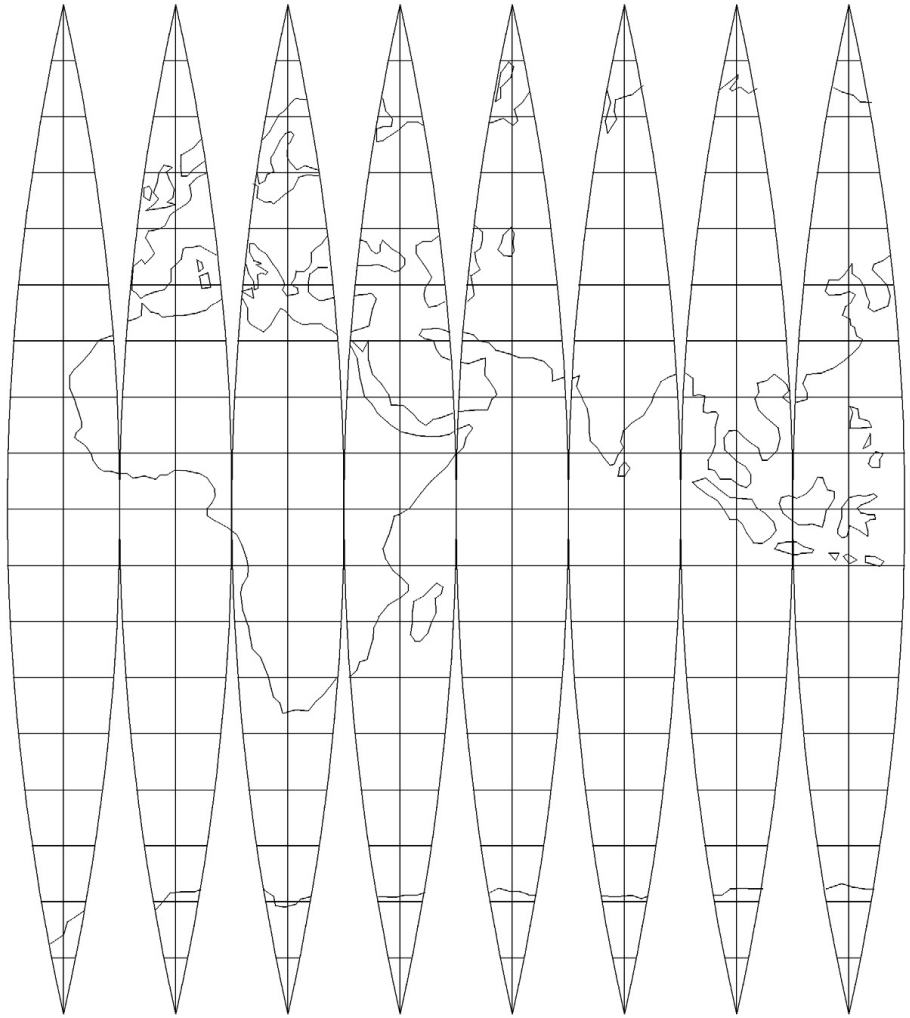
- Transverse Mercator Projection
- Cylinder tangent to one of the meridians
- Low deformation around the reference meridian



UTM PROJECTION

- Minimize distortion
  - Each projection is limited to a zone of 6 degrees
  - Central meridian is contracted by 0.9996
  - To ensure positive coordinates, each zone has a false easting origin at 500000 m on the east of central meridian
  - Projection is limited to latitudes between -80 N and +80 N

UTM ZONES



UTM ZONES IN ITALY

- Italy is covered by zones 32, 33 e 34