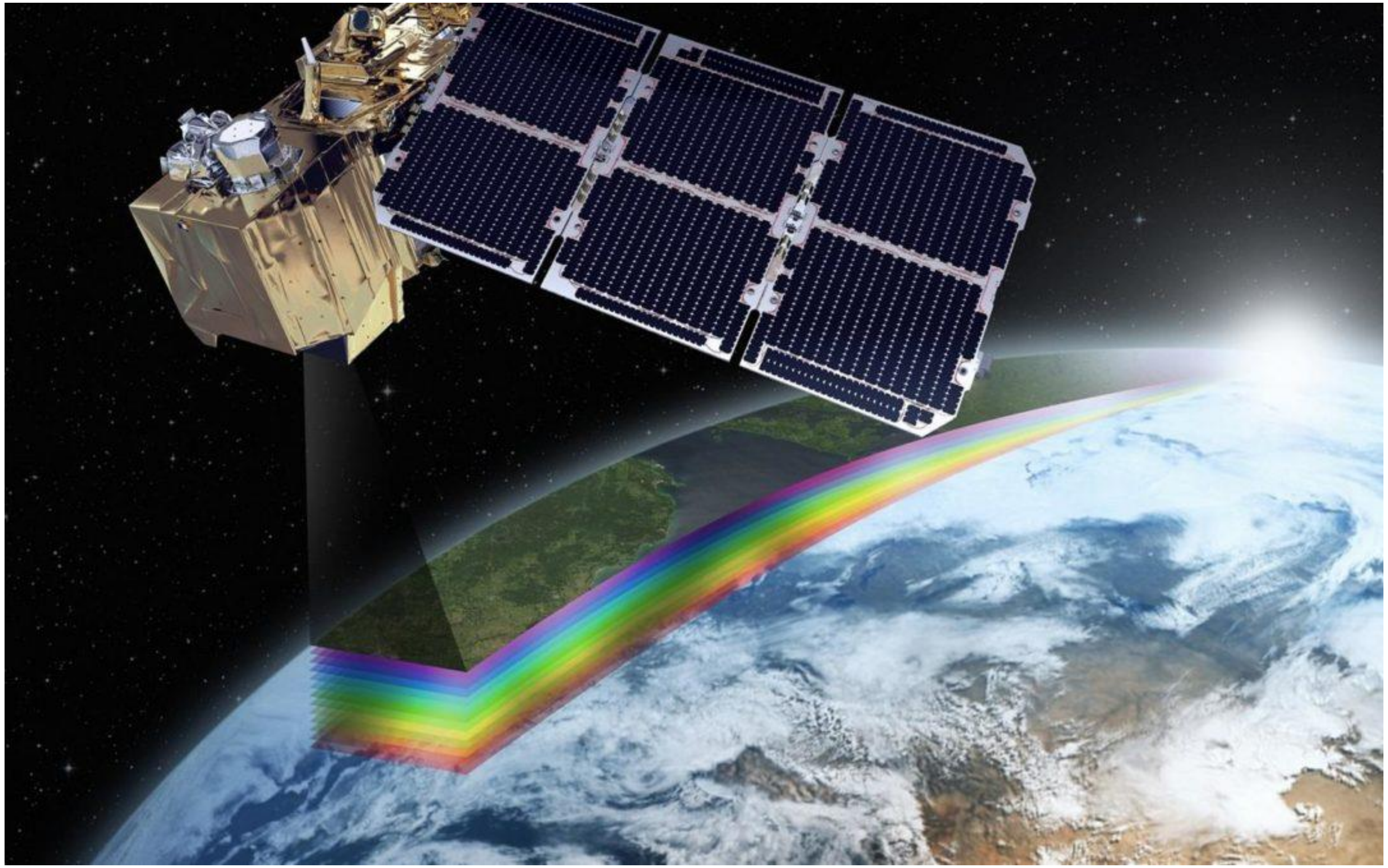
UNIVERSITÀ DEGLI STUDI DI TRIESTE



Course:

Remote Sensing of Global Changes

Dr. Francesco Petruzzellis

PhD student Valentina Olmo

04/10/2022 – Lecture 1 – 8:00 to 9:30
05/10/2022 – Lecture 2 – 11.00 to 13:00

PhD at University of Trieste

Functional traits as a tool to predict invasive potential by alien species in different native communities

2015-2018

2018-2019

Post-doc at University of Trieste

Monitoring water status of vineyards in the Karst area

Post-doc at University of Trieste

Assessing the impact of climate change on plant distribution on the basis of physiological traits

2019-2020

Interreg ITALIA-SLOVENIJA SECAP

2021-2022

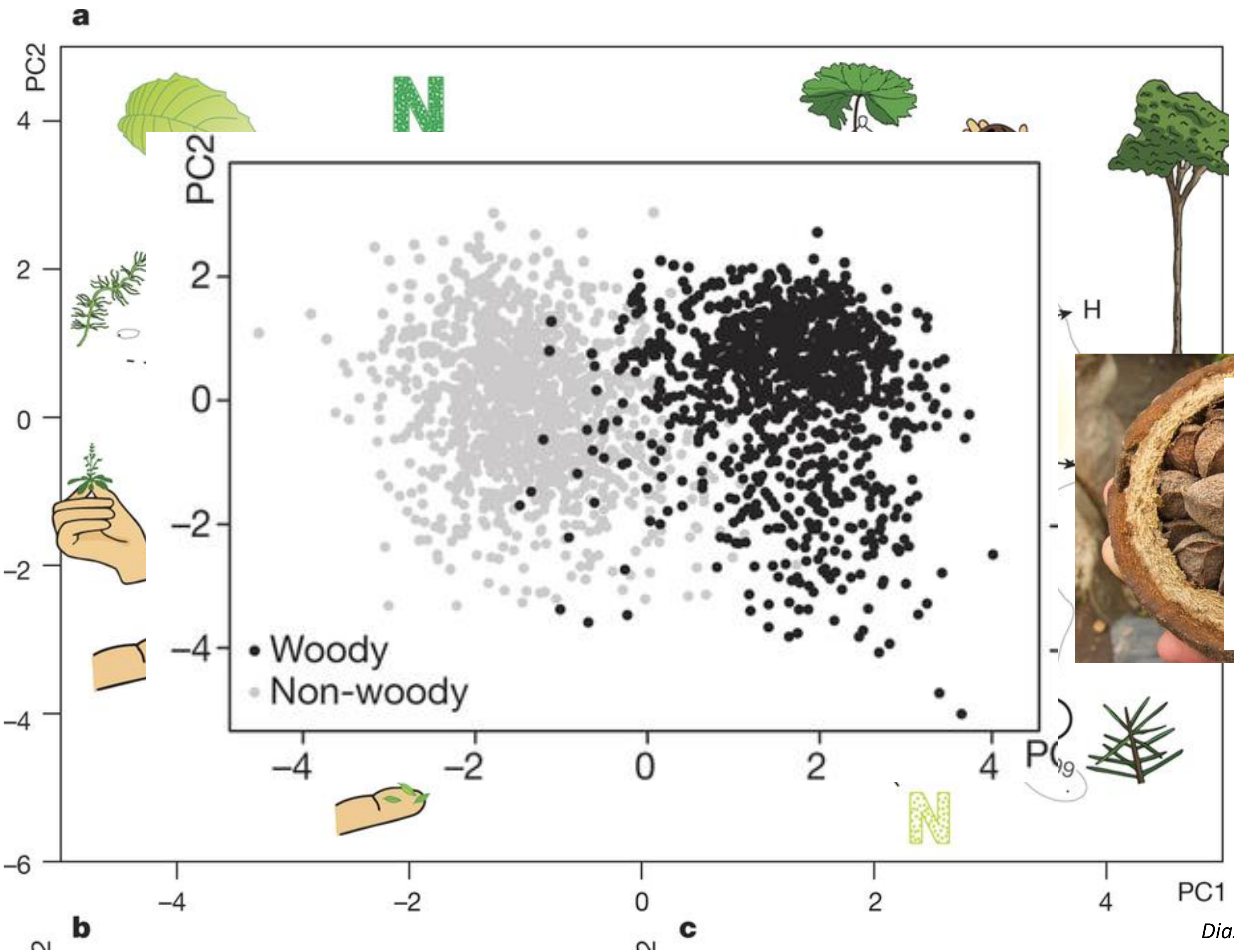
Post-doc at University of Udine

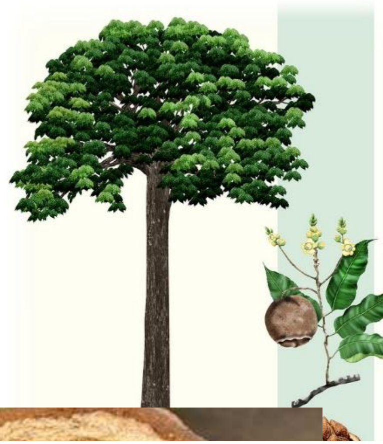
Bioirr: Root hydraulic redistribution as a tool for bio-irrigation in agriculture and forestry”

Researcher at University of Trieste

Towards the definition of Essential Biodiversity Variables by remote sensing for biodiversity monitoring

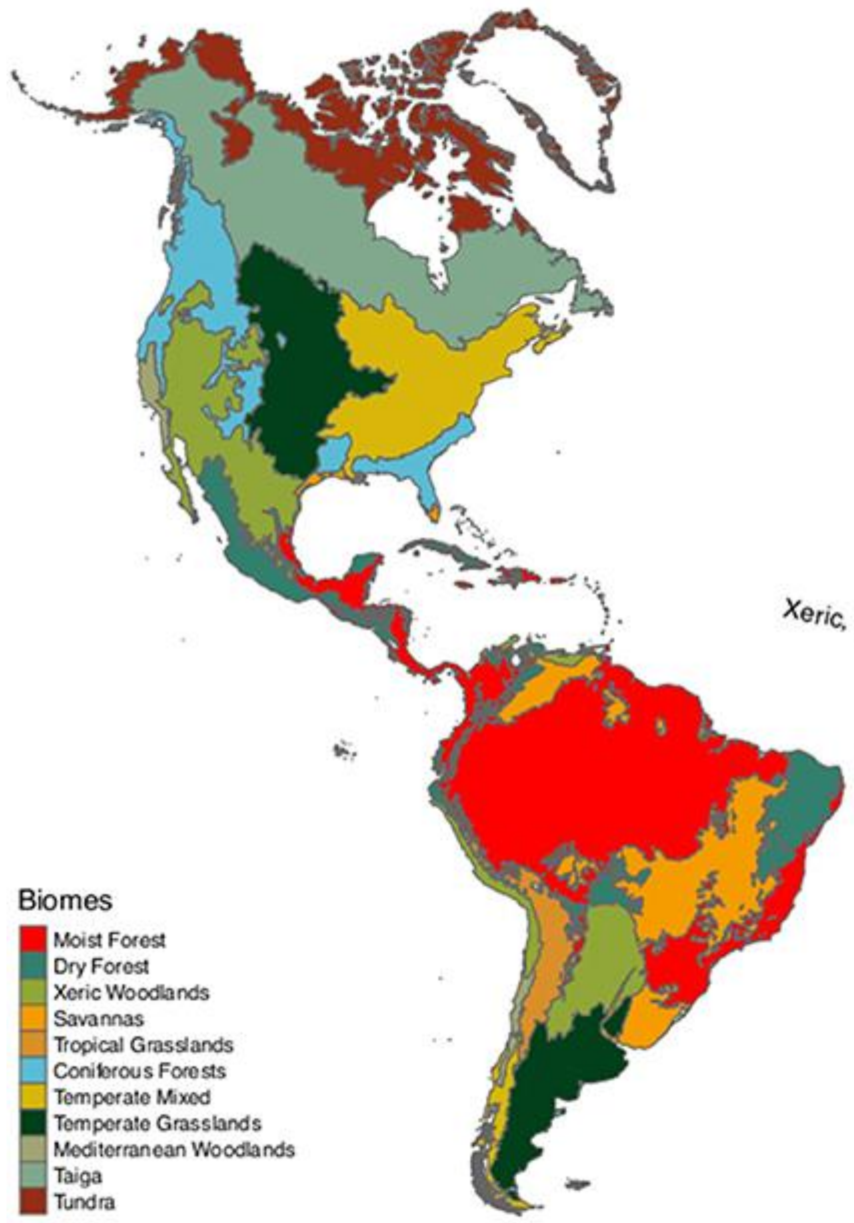
2022-present

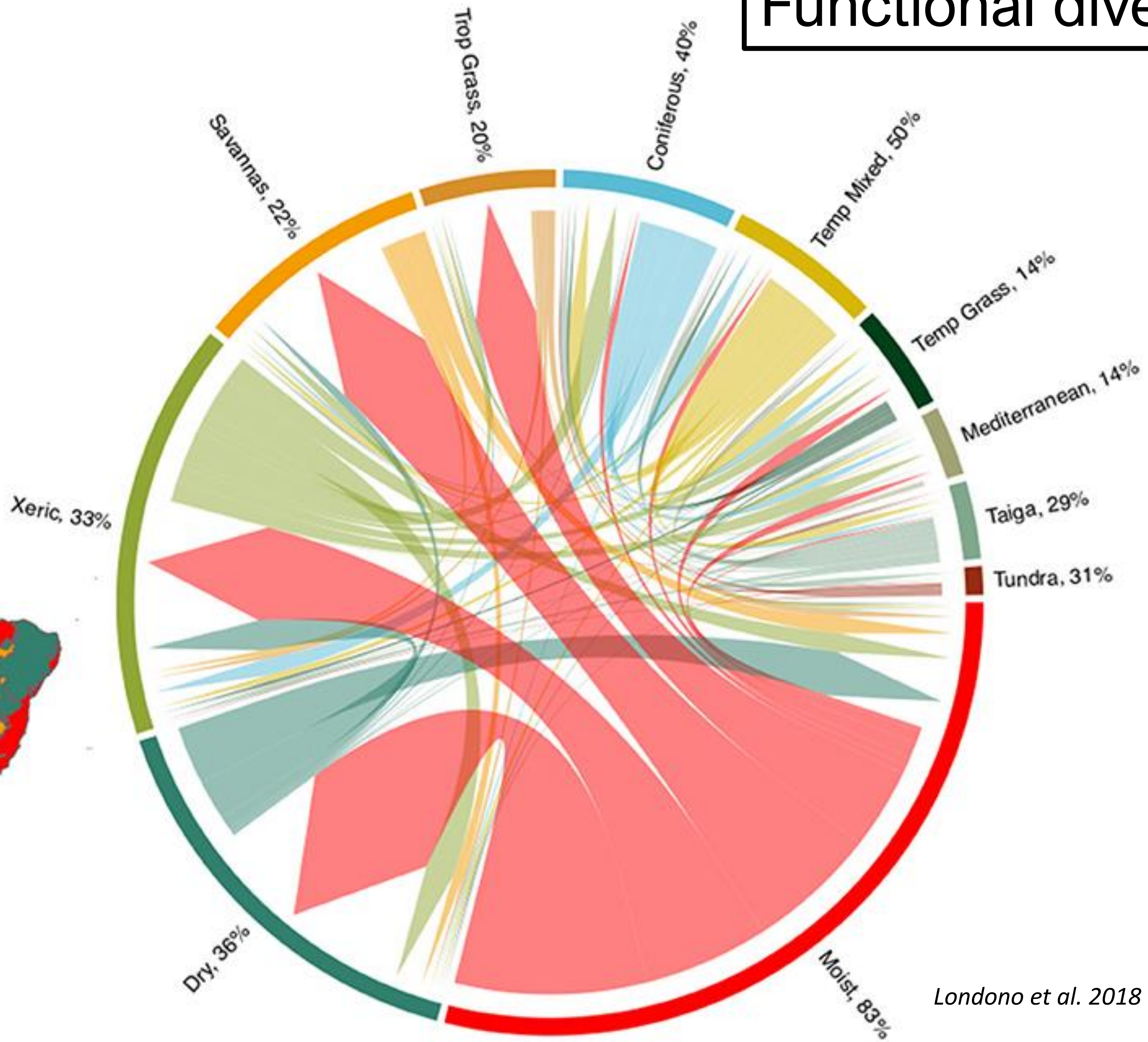




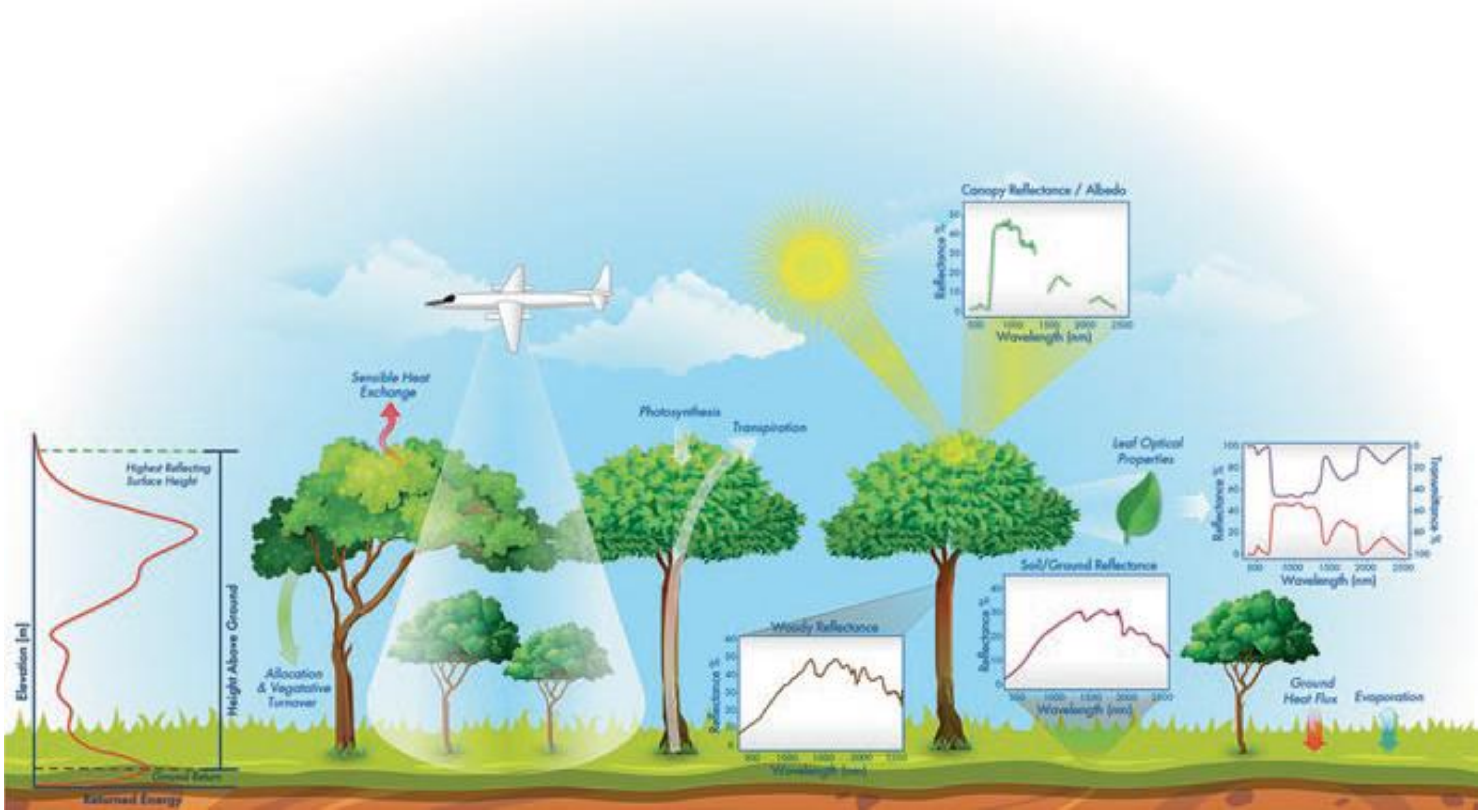
Diaz et al. 2017 Nature

Functional diversity



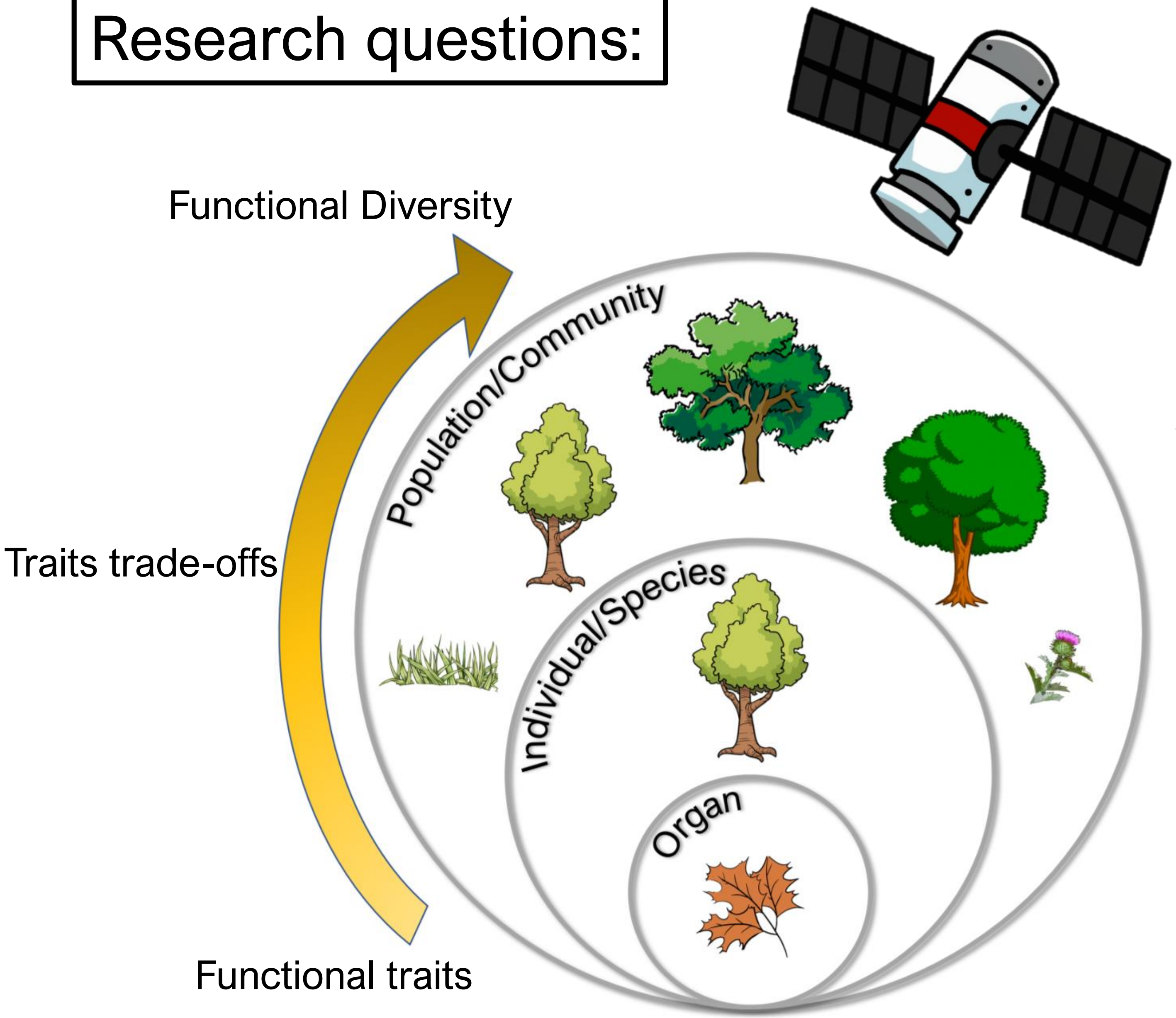


Londono et al. 2018 FEE



Cavender Bares et al. 2020 Remote Sensing of Plant BIodiveristy

Research questions:

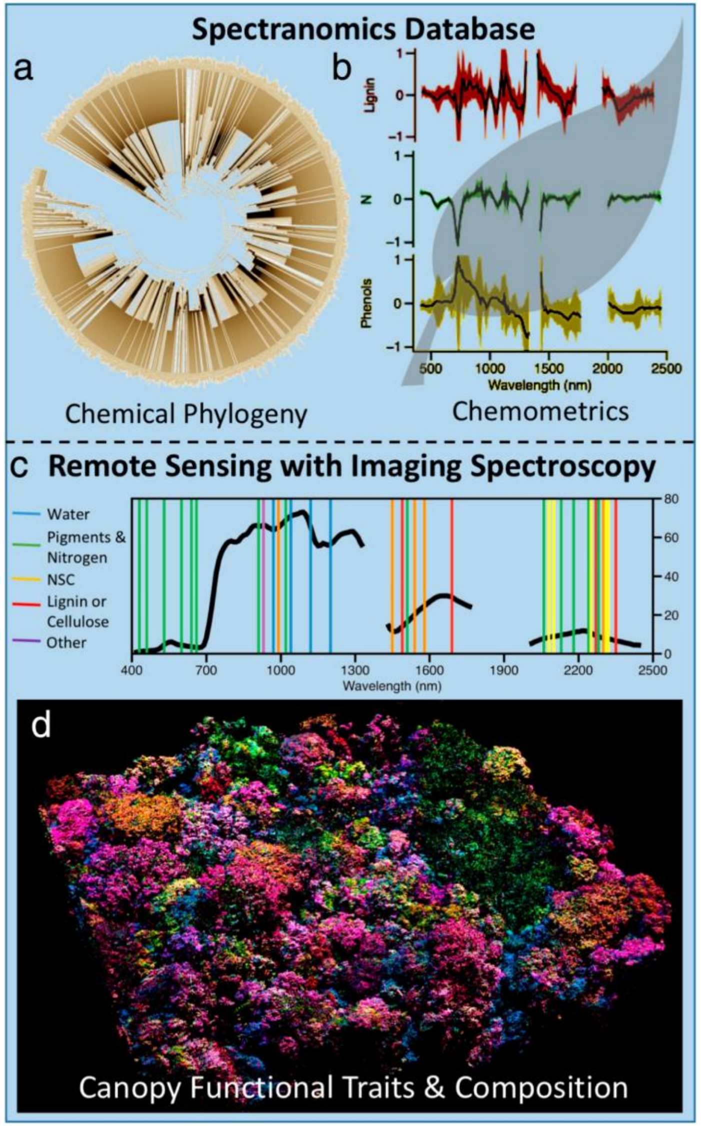


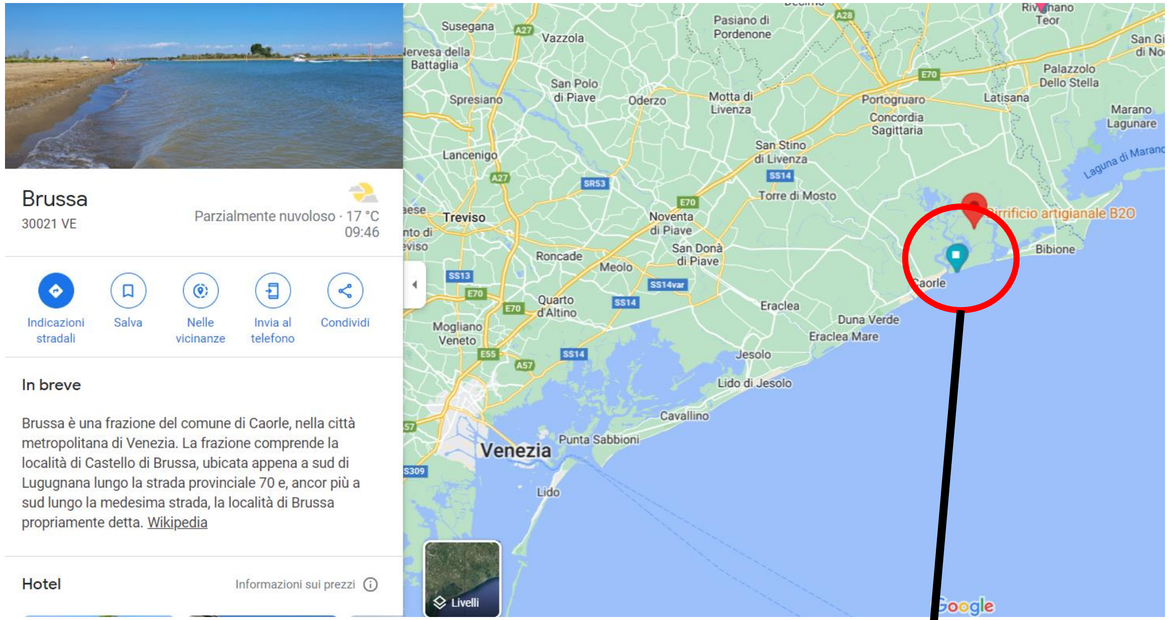
Monitor plant communities by integrating functional trait measurement and Earth Observations (EO):

- Highlighting the relationships between plant traits/functional composition and remotely sensed data.

- Monitoring plant responses to abiotic factors (e.g. drought) in space and time through EO and field data.

Project *a*: Estimating plant biodiversity facets from remote.





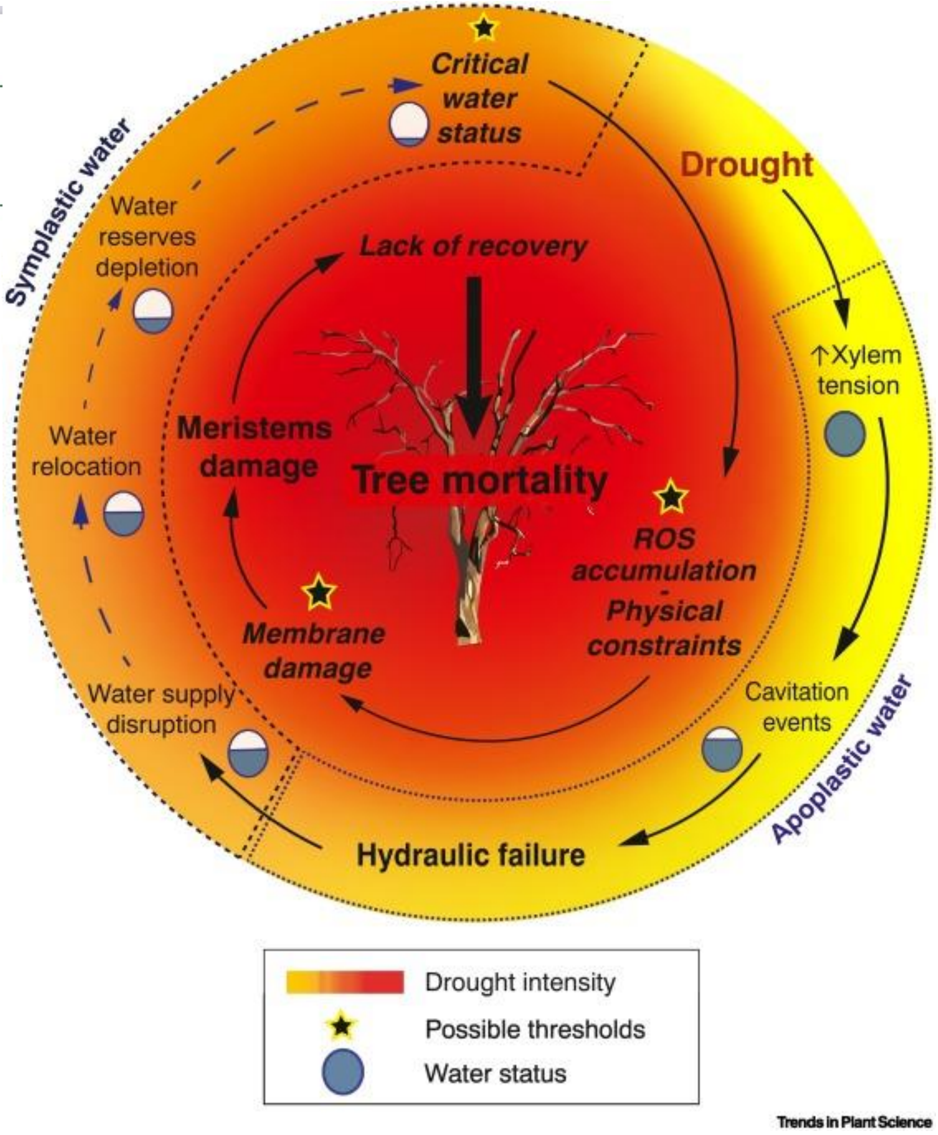
Project *b*: Calibrating models to estimate plant water content from remote.

Forum

Viewpoints

Greater focus on water pools may improve our ability to understand and anticipate drought-induced mortality in plants

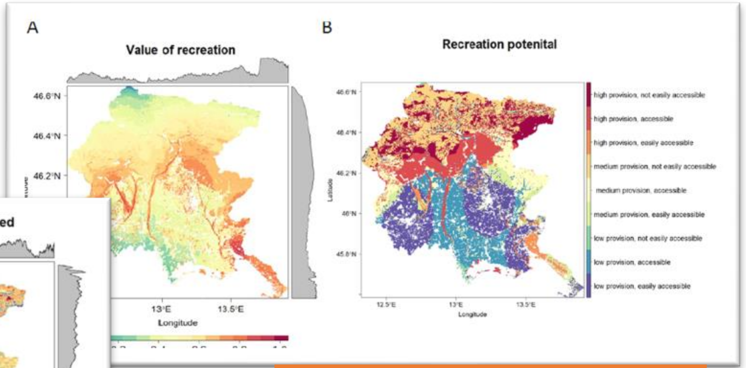
Martinez-Vilalta et al. 2019 New Phytologist

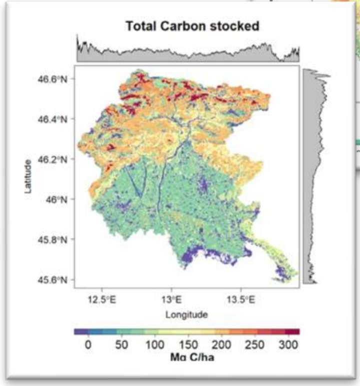


Mantova et al. 2021 Trends In Plant Sciences

Valentina Olmo

PhD student - remote sensing tutor 2022-23





Mapping and quantification of ecosystem services

Bachelor degree in

Biology

UniMi

PhD in

Environmental Life Science

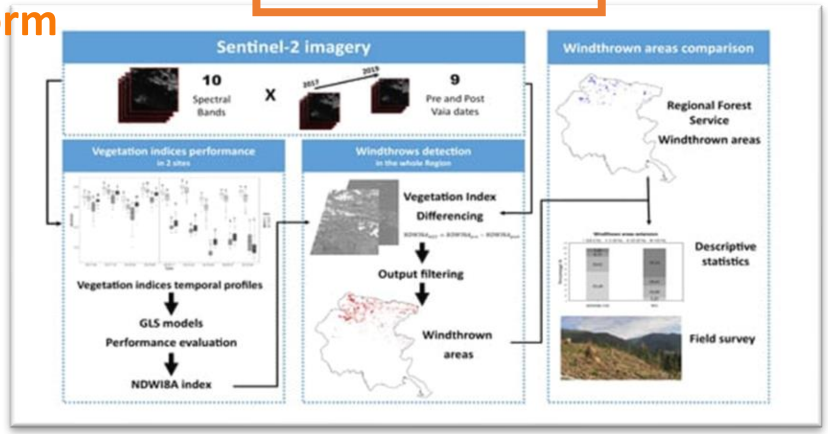
UniTs - Ud

Master degree in

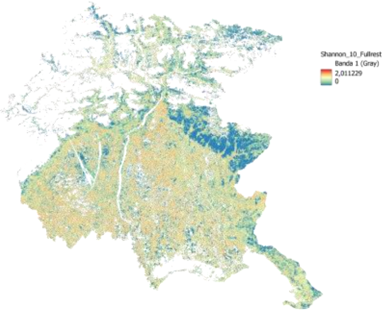
Global change ecology

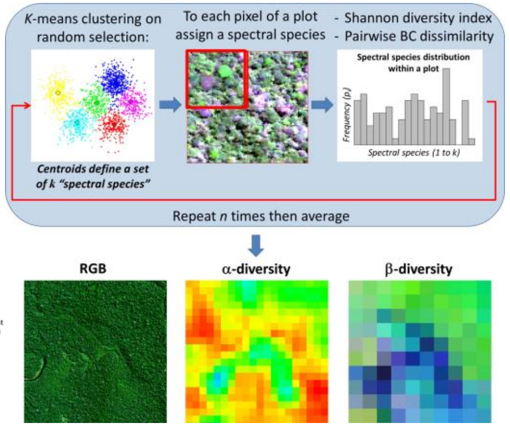
UniTs

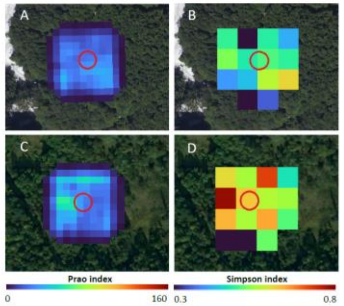
Mapping extreme events: Vaia storm



Mapping plant biodiversity facets from space data







Valentina Olmo
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Via Giorgieri 10, Trieste, Italy
valentina.olmo@phd.units.it

Course outline:

PART 1: Geographic Information Systems (GIS) as tools for managing environmental data. Free and open source GIS software. Computer laboratory exercises.

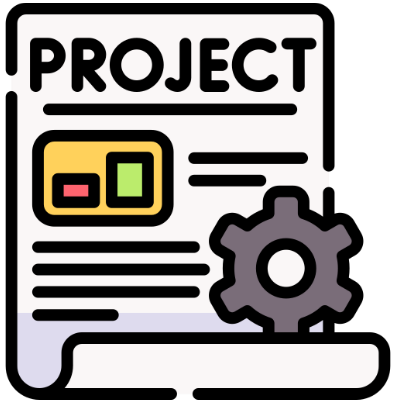
PART 2: Physical principles of remote sensing. Types of satellites and sensors for Earth observation. Satellite data freely downloadable. Spectral data obtained from unmanned aerial vehicle. Acquisition of remotely sensed data. Import in GIS environment and visual interpretation. Computer laboratory exercises.

PART 3: Methodologies for the interpretation and processing of remotely sensed images. Computer laboratory exercises.

PART 4: Remote Sensing of Biodiversity. Relationships between biodiversity facets and remotely sensed data. Computer laboratory exercises. Presentation of group work.

General Information:

- Lectures + Laboratory
- Lectures:
  - Wednesday: 8-11
  - Thursday: 11-13
- Estimated end of the course: 15/12/2022
- Examination: group/individual project + oral



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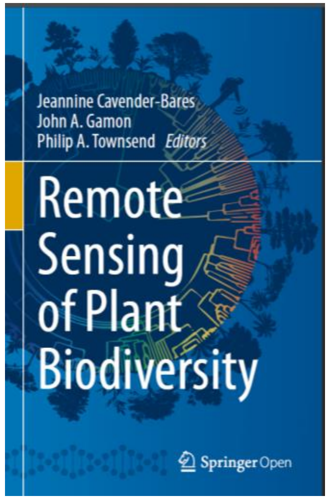
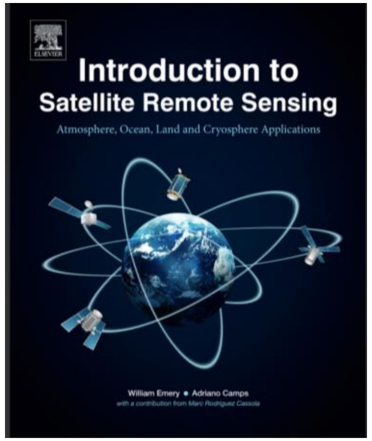
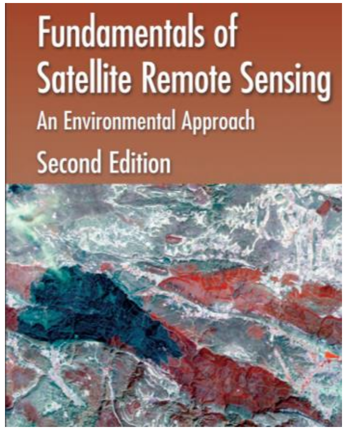
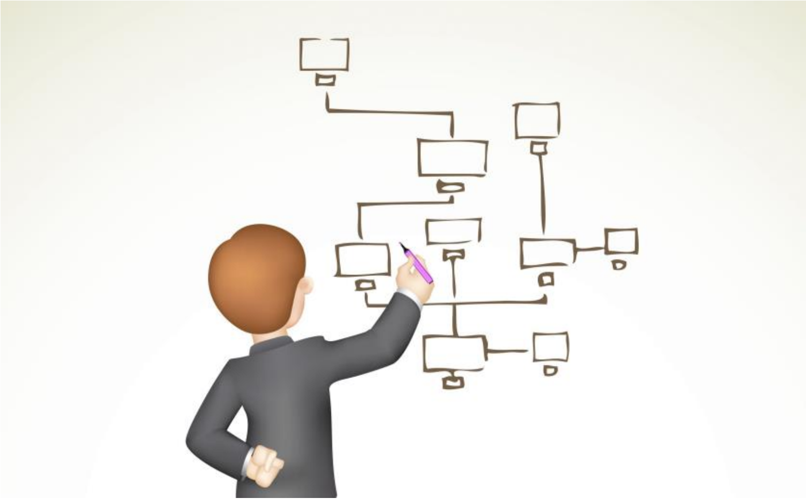


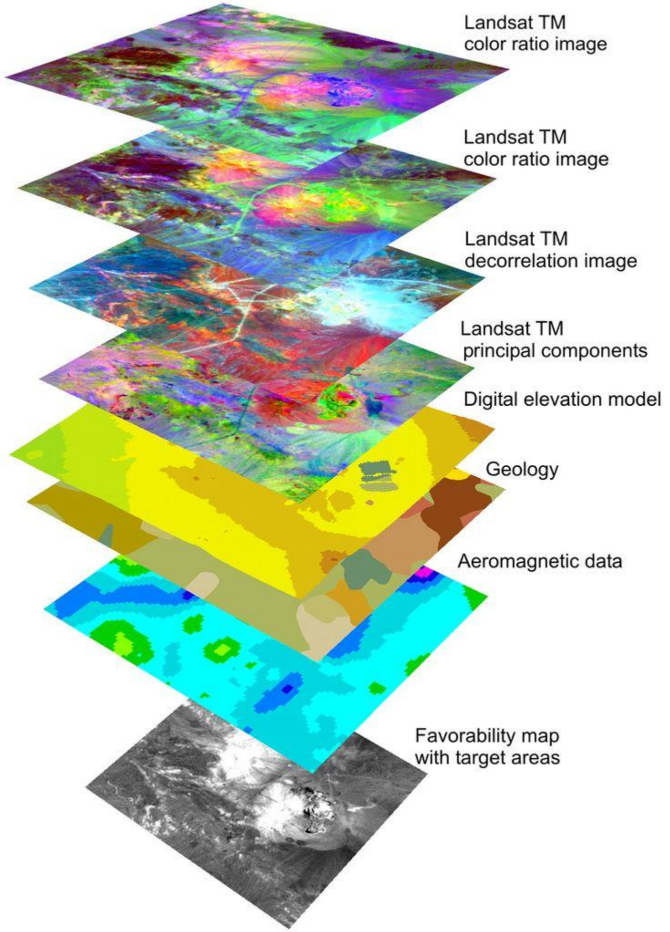




Goal:


WHAT
WHERE
WHEN
WHY




Landsat TM
color ratio image
Landsat TM
color ratio image
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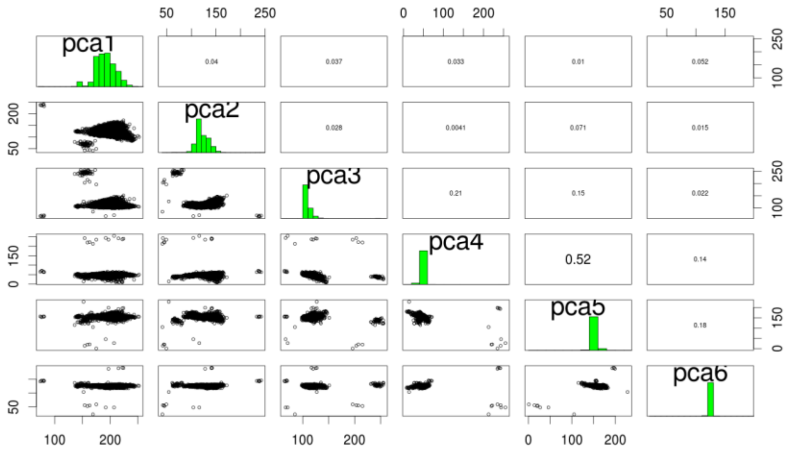
decorrelation image
Landsat TM
principal components
Digital elevation model
Geology
Aeromagnetic data
Favorability map
with target areas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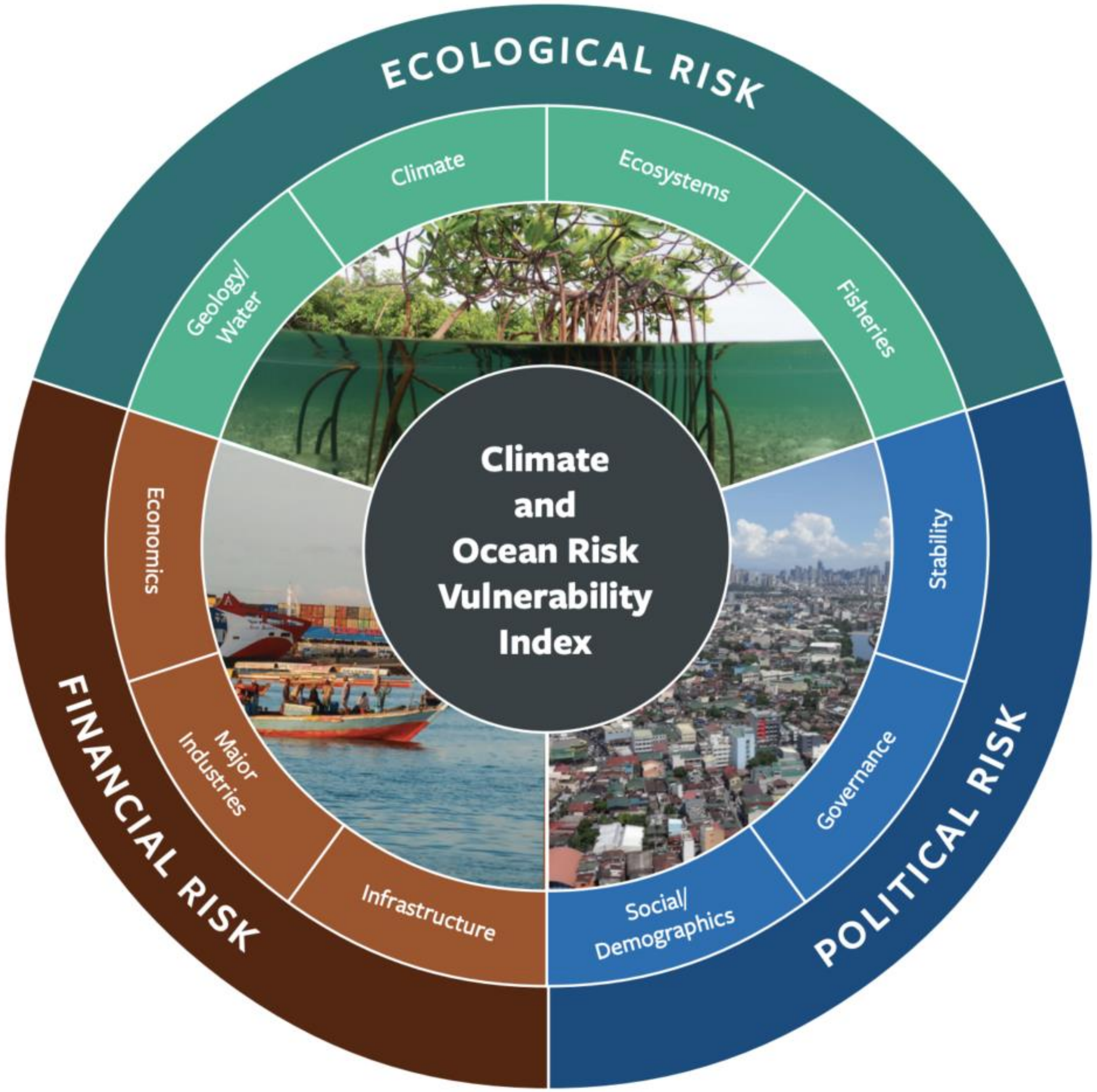
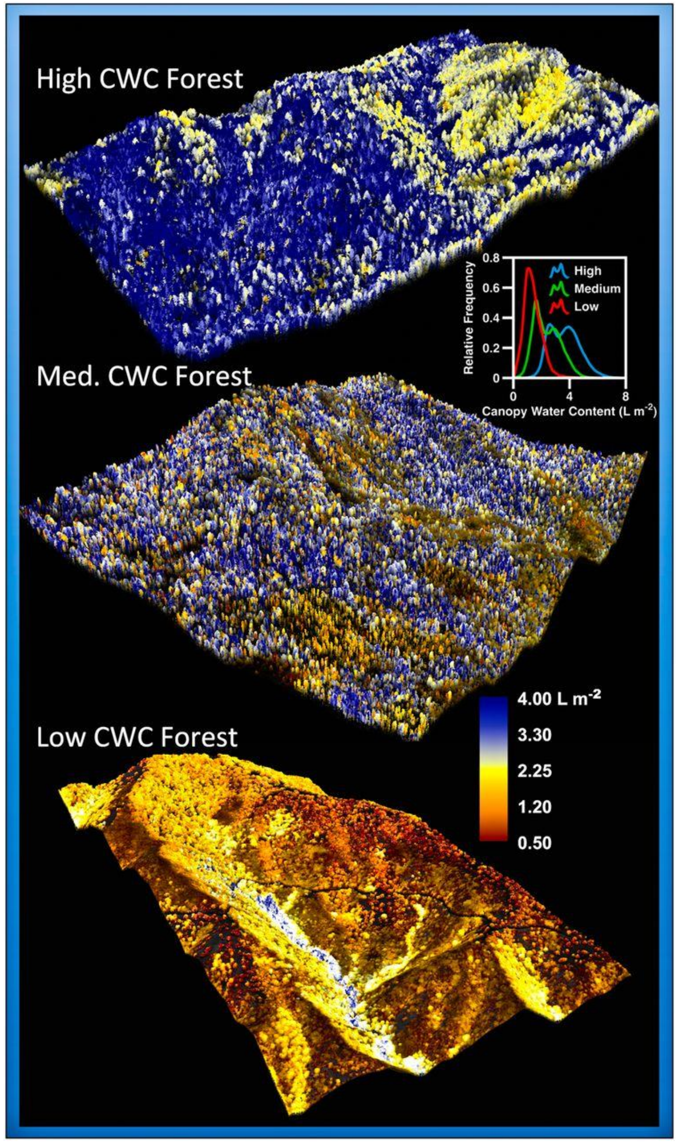


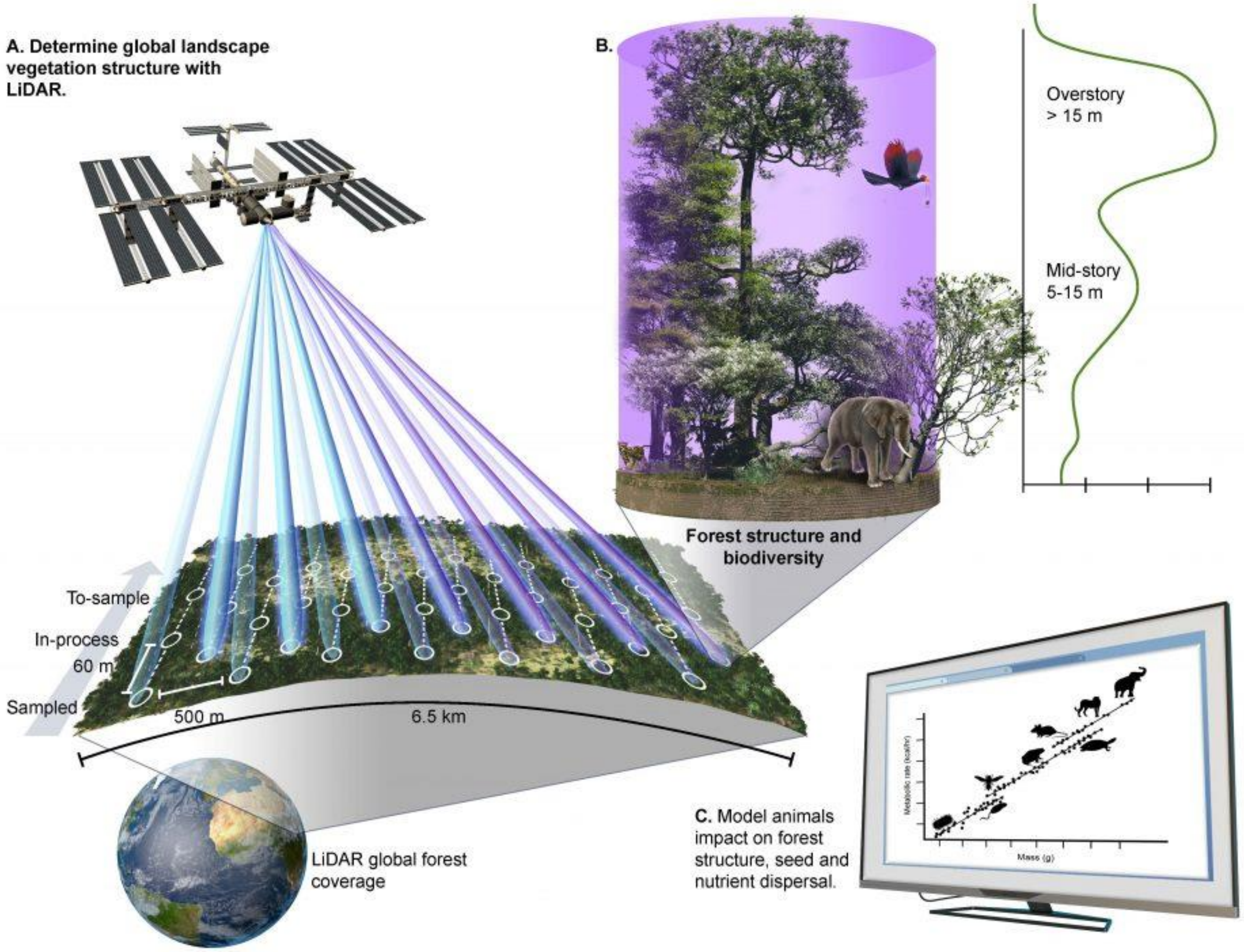
Which will be the effect of climate changes?

How to quantify future global changes and their effects?

Why remote sensing??

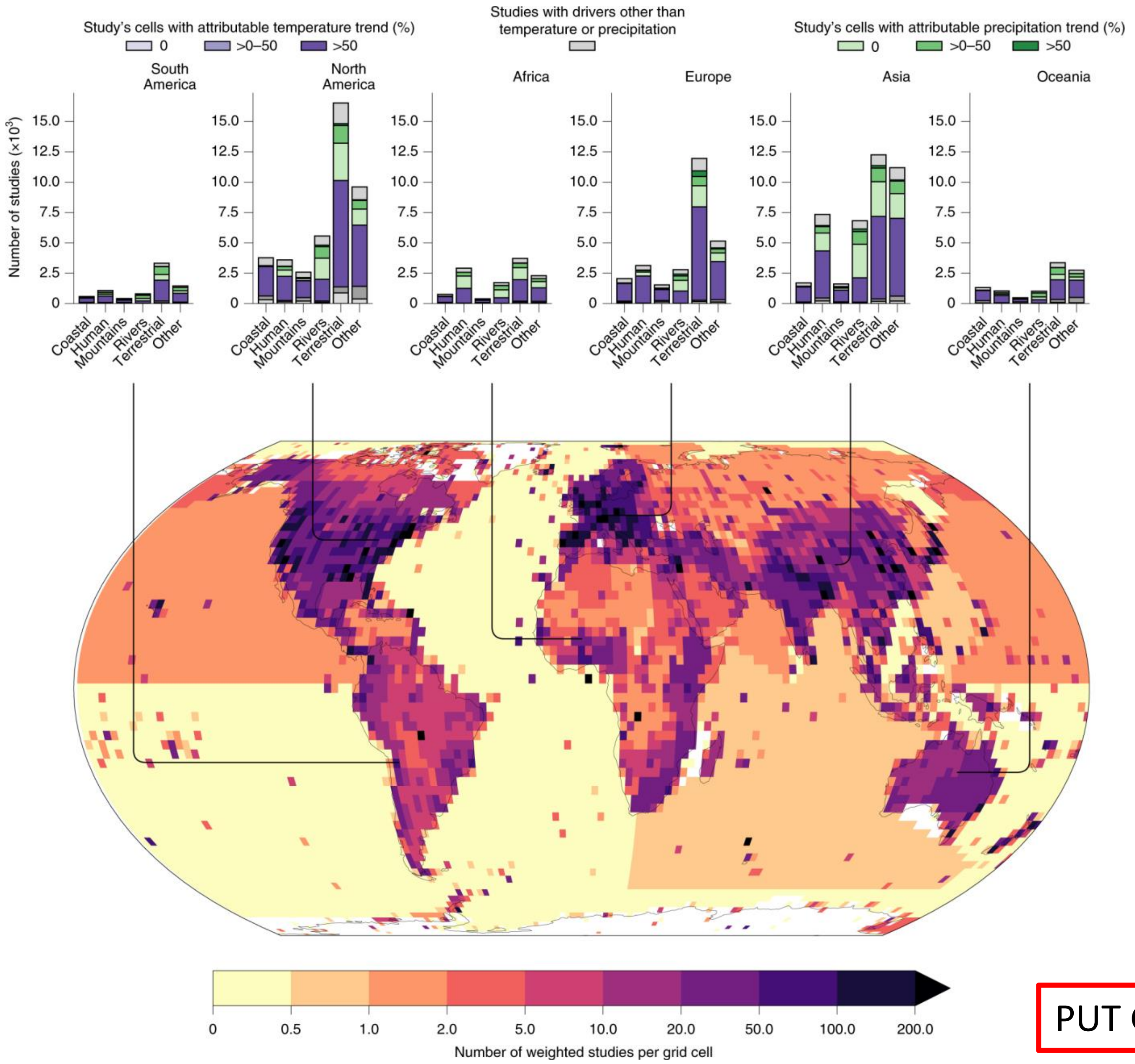


Asner et al. 2015 PNAS



https://news.nau.edu/animals-carbon-cycle/

Why remote sensing??



PUT GLOBAL CHANGES ON A MAP

Part 1

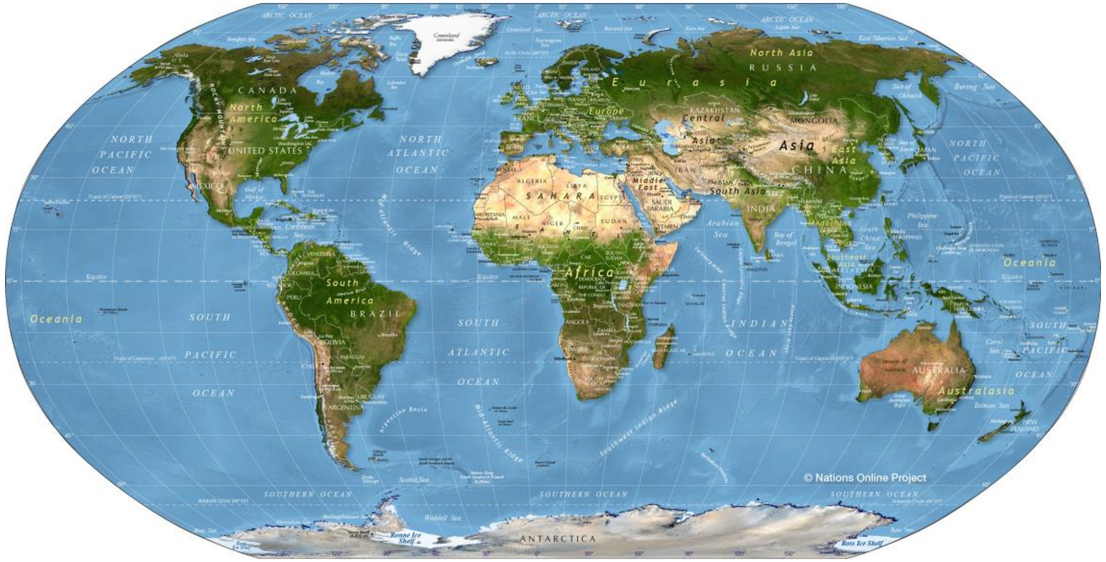
- **Geographic Information Systems (GIS)**
- **Basics of GIS**
- **QGIS Software**

Fundamentals of Cartography

Cartography: is **the science (and art) or representing Earth's surface on a plane.**

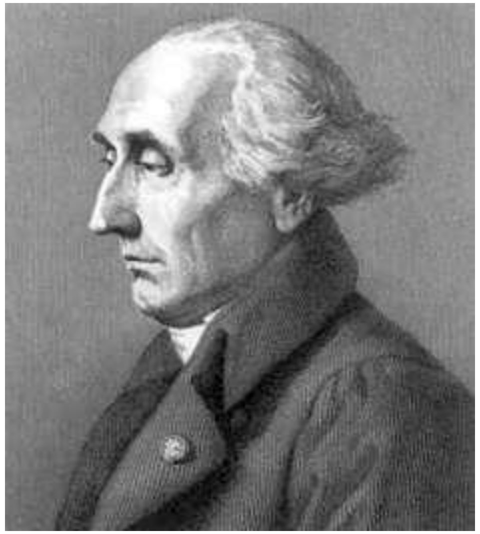
AIM: define the bivariate relationships between Earth's surface and points on a plane using mathematical operations.

In this light, it is the process for MAPs creation and analysis



Fundamentals of Cartography

MAP: is a drawing representing Earth surface or a part of it on a plane (Lagrange, 1720)



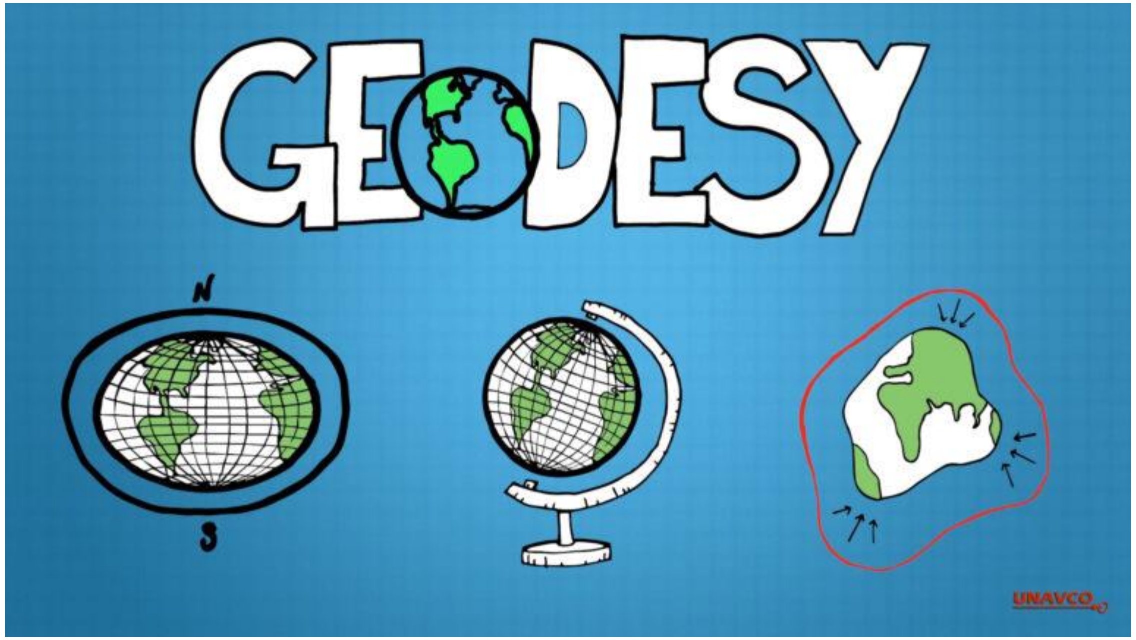
Associazione Italiana Cartografia (1950): " a Map is a symbolic representation of the geographic reality, representing selected features or characteristics, resulting from the creative effort of its author, and is useful when spatial relationships are of primary relevance"

Cartography: is **the discipline dealing with art, science and technology of making and using Maps**

1. GEODESY

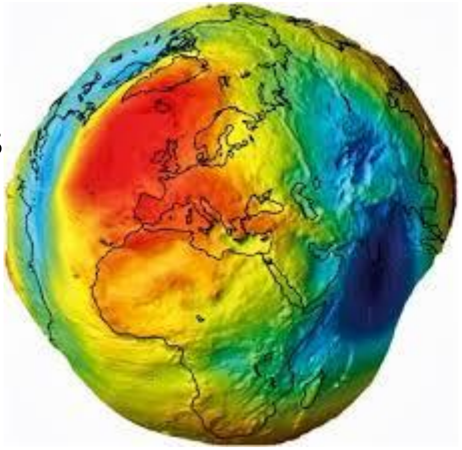
Is the science that:

- **Studies Earth's SHAPE and DIMENSION**
- **Describes these elements in a simplified way using specific mathematical models**
- **Analyses the errors derived form Earth's shape approximation**



Earth looks like this…

…but actually is like this



Sciences related to Cartography

2. TOPOGRAPHY

Is the science that:

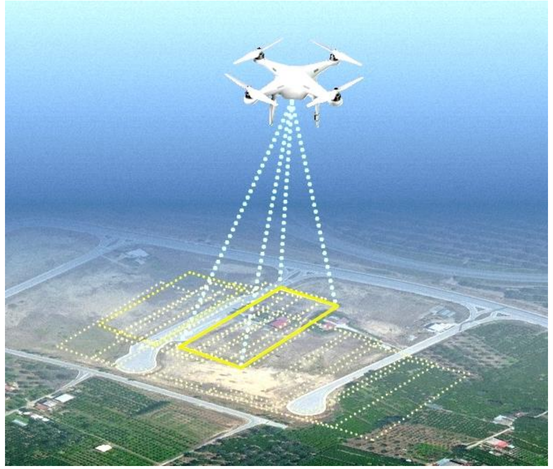
- **Locates the exact position of the objects on Earth surface**

- **Measures the relative position of the objects on Earth surface**

3. PHOTOGRAMMETRY

Is the science that:

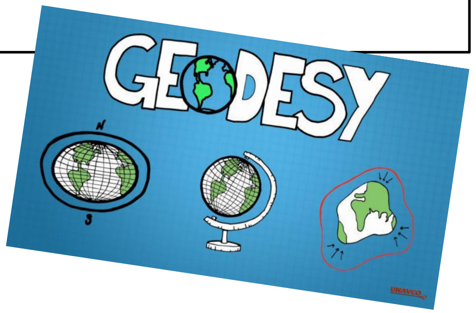
- **Locates the exact position of the objects on Earth surface using aerial photographs**



How to represent Earth complex surface?

Cartographic projections:

- Definition of the mathematical rules that could be used to represent Earth surface (which is curve) on a Cartesian plane
- Study and Evaluation of the deformations introduced by cartographic projections



Equatorial radius (a)	6378.4 km
Polar radius (b)	6356.9 km
Difference/Flattening (a-b)	21.5 km
Compression ([a-b]/a)	1/297
Equatorial circumference	40075.6 km
Meridian length	40008.9 km
Area	509950.414 km^2
Volume	1083000000 km^3
Everest	8882 m
Emden deep	-10793 m

First problem: Earth shape

First approximation = sphere

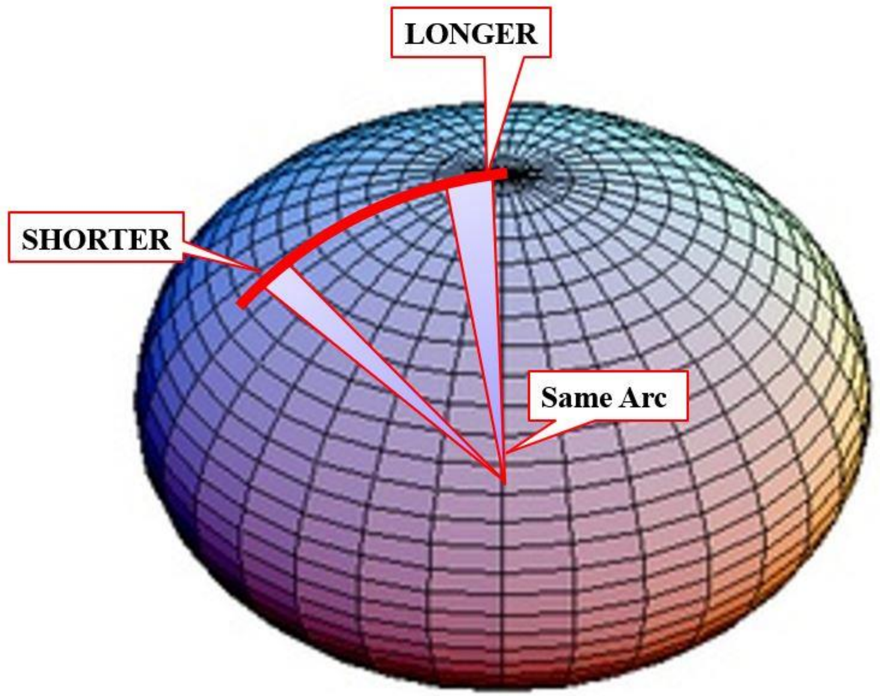
The first demonstration of a sphere-like shape was given by Eratostene of Cirene (III b.C.) and then after oceanic journeys in XVI century (e.g. Magellano)

BUT

Earth is not a perfect sphere:
- **Compressed at the poles**
- **Swollen at the equator**

} Centrifuge effect due to Earth rotation; Gravitational forces and translation

First problem: Earth shape



- Among regular solids, the ELLIPSOID is the best approximation of earth shape

- **Equatorial diameter > Polar diameter**

- Eccentricity = (equatorial diameter – polar diameter)/equatorial diameter

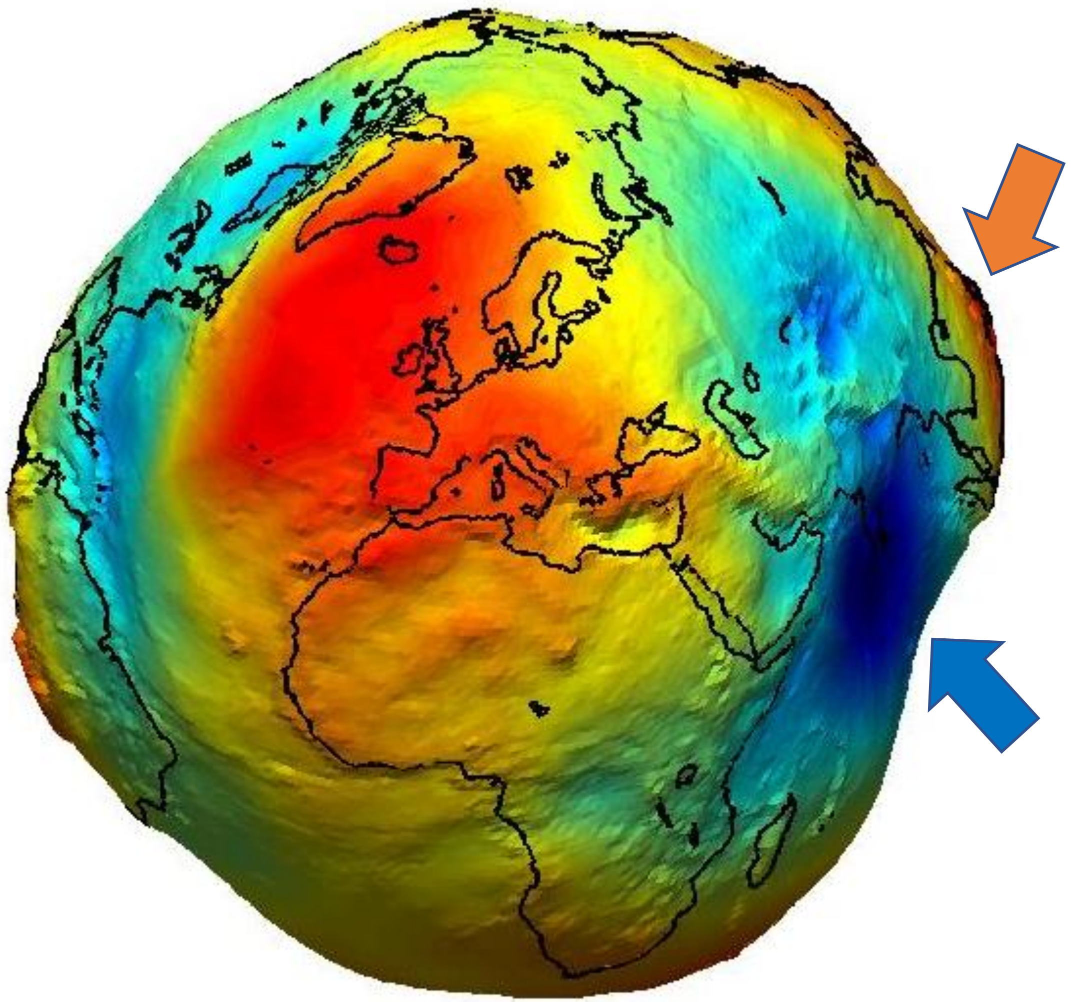
Earth is a GEOID

- Geoid is the best approximation of Earth, but it is not possible to describe it geometrically

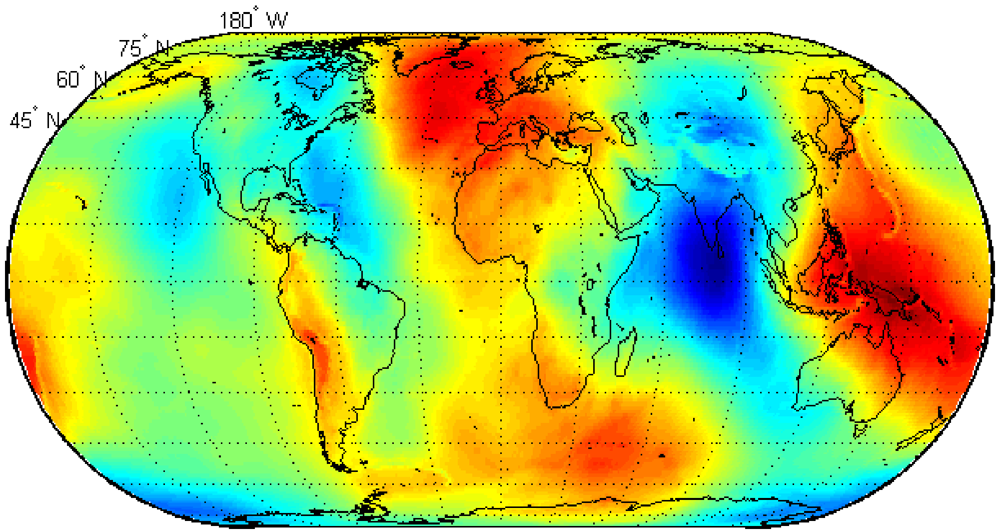
- **GEOID = defined as the equipotential surface of Earth's gravitational field**

- **Another def = the surface of equal gravitational potential of a hypothetical ocean at rest**

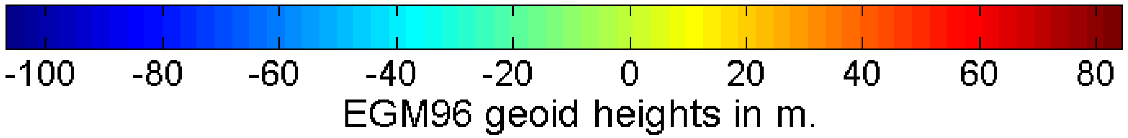
- The shape of the geoid is influenced by mass distribution, since mountains attracts the geoid's surface upward and deeps/abysses attracts it downward



Earth is a GEOID



Deviations of the Geoid from the idealized figure of the Earth

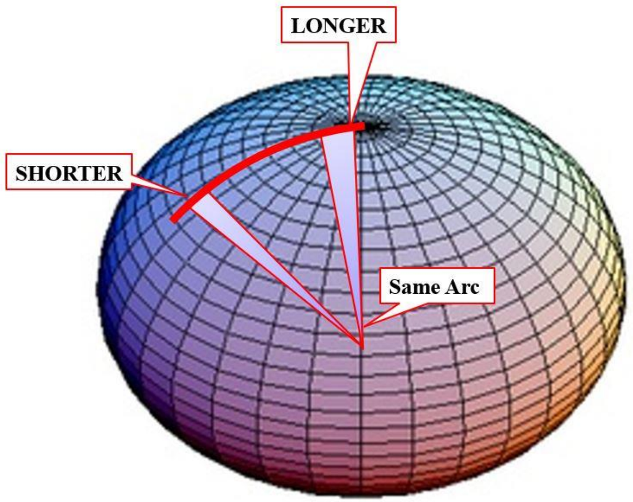


It is possible to study the GEOID and **MEASURE the errors** (ondulations) with respect to the surface that better estimates geoid's surface.

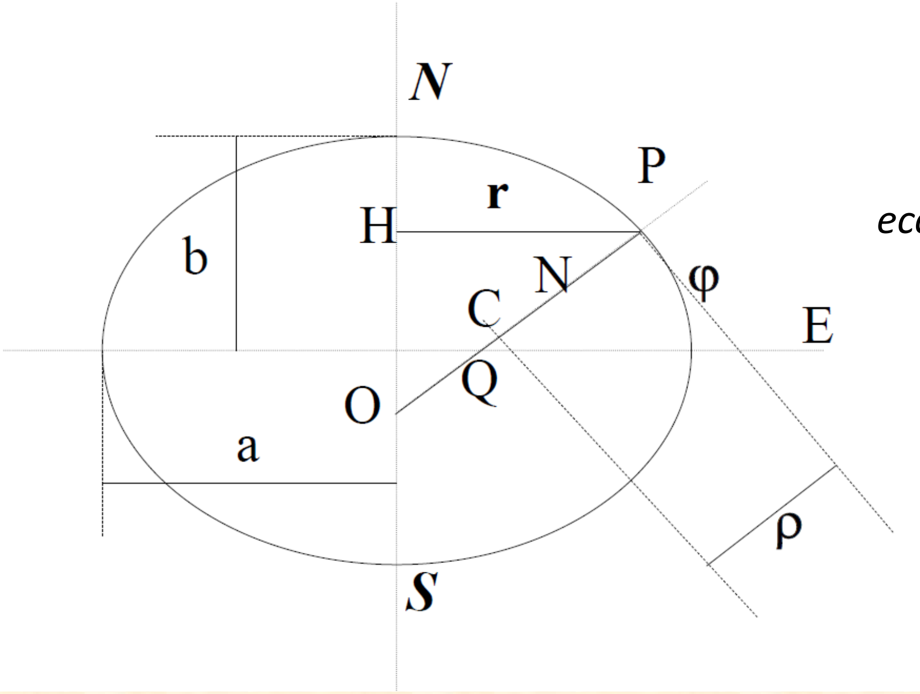
↓

ERRORS between the geoid and the ROTATION ELLIPSOID, by means of geophysical and gravimetric measures (such as EGM96 in the picture above)

ROTATION ELLIPSOID



- It is the best estimation of Earth surface that could be described geometrically and mathematically
- It represents the REFERENCE SURFACE for cartographic representation



Equations describing the ELLIPSOID:

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

$$\alpha=\frac{a-b}{a}$$ *Compression factor / Flattening*

eccentricity

$$\mathrm{e}=\sqrt{\frac{a^2-b^2}{a^2}}$$

$$r=\frac{a\cos\varphi}{\sqrt{1-\mathrm{e}^2 sen^2\varphi}}$$

Radius of altitude parallel

$$N=\frac{a}{\sqrt{1-\mathrm{e}^2 sen^2\varphi}}$$

Major radius

$$\rho=\frac{a(1-\mathrm{e}^2)}{\sqrt{(1-\mathrm{e}^2 sen^2\varphi)^3}}$$

Minor radius

ROTATION ELLIPSOID

Name	Year	Semi-Major Axis (Equator Radius)	Semi-Minor Axis (Polar Radius)	Users
Clarke	1866	6,378,206.4 m	6,356,583.8 m	North America
International (Hayford) Ellipsoid	1924	6,378,388.0 m	6,356,911.9 m	Most of the World
WGS72	1972	6,378,135.0 m	6,356,750.5 m	NASA
GRS80	1980	6,378,137.0 m	6,356,752.3 m	Worldwide
WGS84	1984	6,378,137.0 m	6,356,752.3 m	Current Worldwide

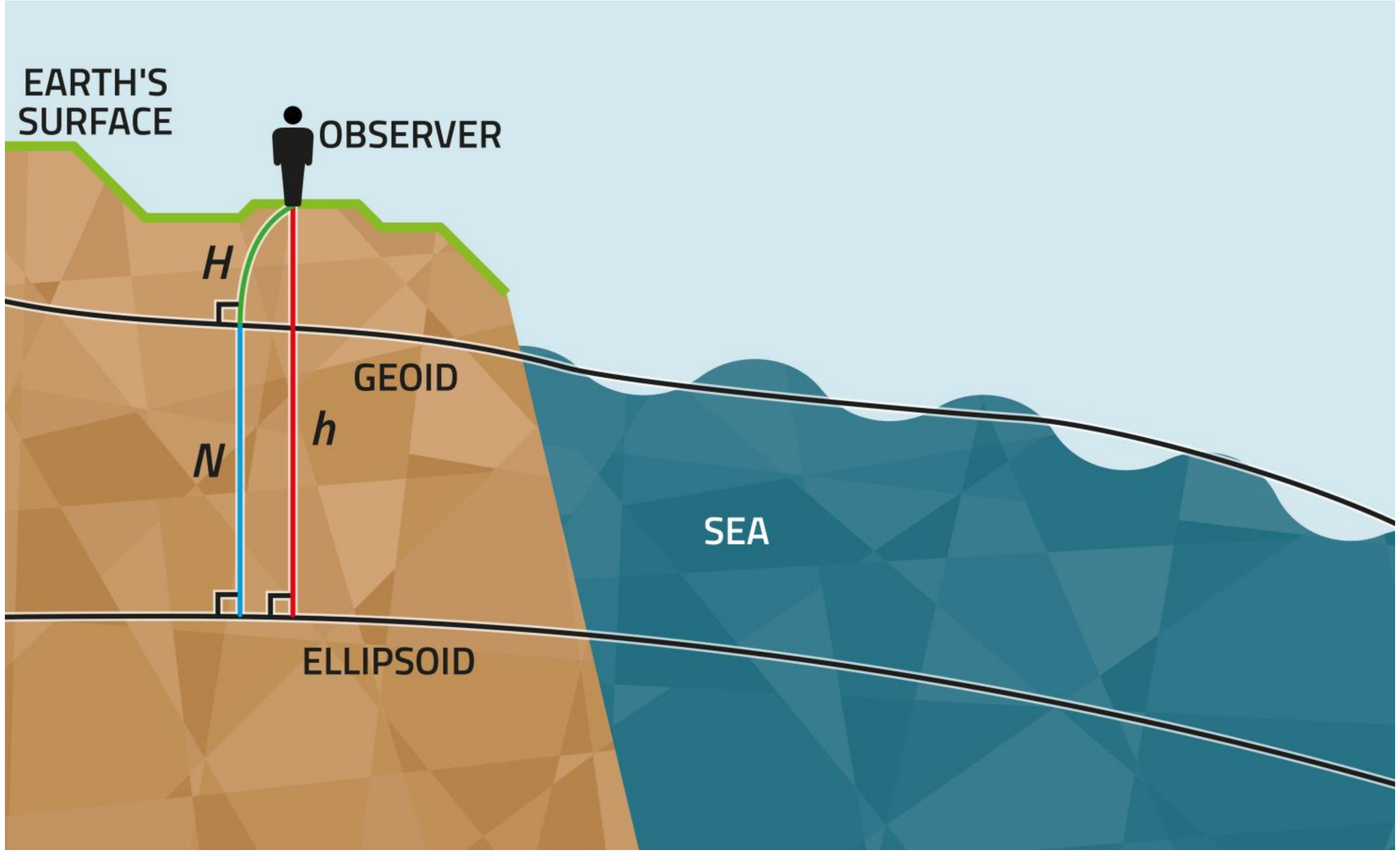
ROTATION ELLIPSOID

Different surfaces generated during the process of Earth projection:

1. **GEOIDIC SURFACE**: the one perceived studying gravitational forces

2. **ELLIPSOID SURFACE**: mathematical approximation of Earth’s surface

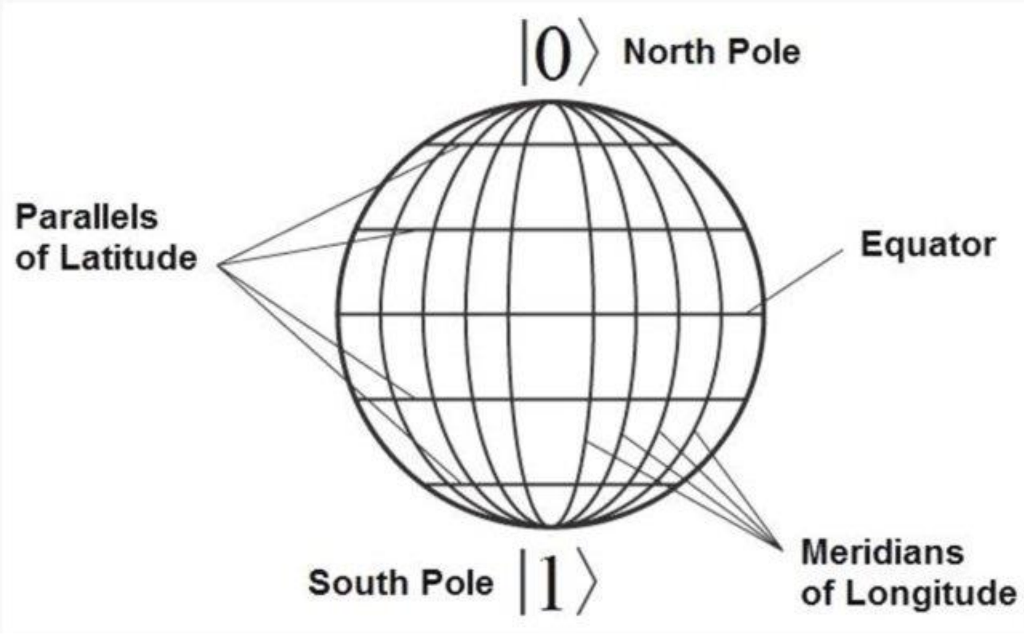
3. **TOPOGRAPHIC SURFACE**: what we see



POSITIONING OBJECTS on the map

On the basis of mathematical rules for Earth's surface approximation, it is possible to locate objects.

The system is a **COORDINATE SYSTEM**, which allows to define the bivariate relationships between the points on Earth's surface and the points on the map.



POLES: intersection points between earth rotation axis and Earth surface

MERIDIAN: all the maximum semicircumferences passing through each pole

PARALLEL: all the circumferences perpendicular to Earth's axis

MERIDIANS AND PARALLELS FORM A GRID → GEOGRAPHIC COORDINATES

POSITIONING OBJECTS on the map

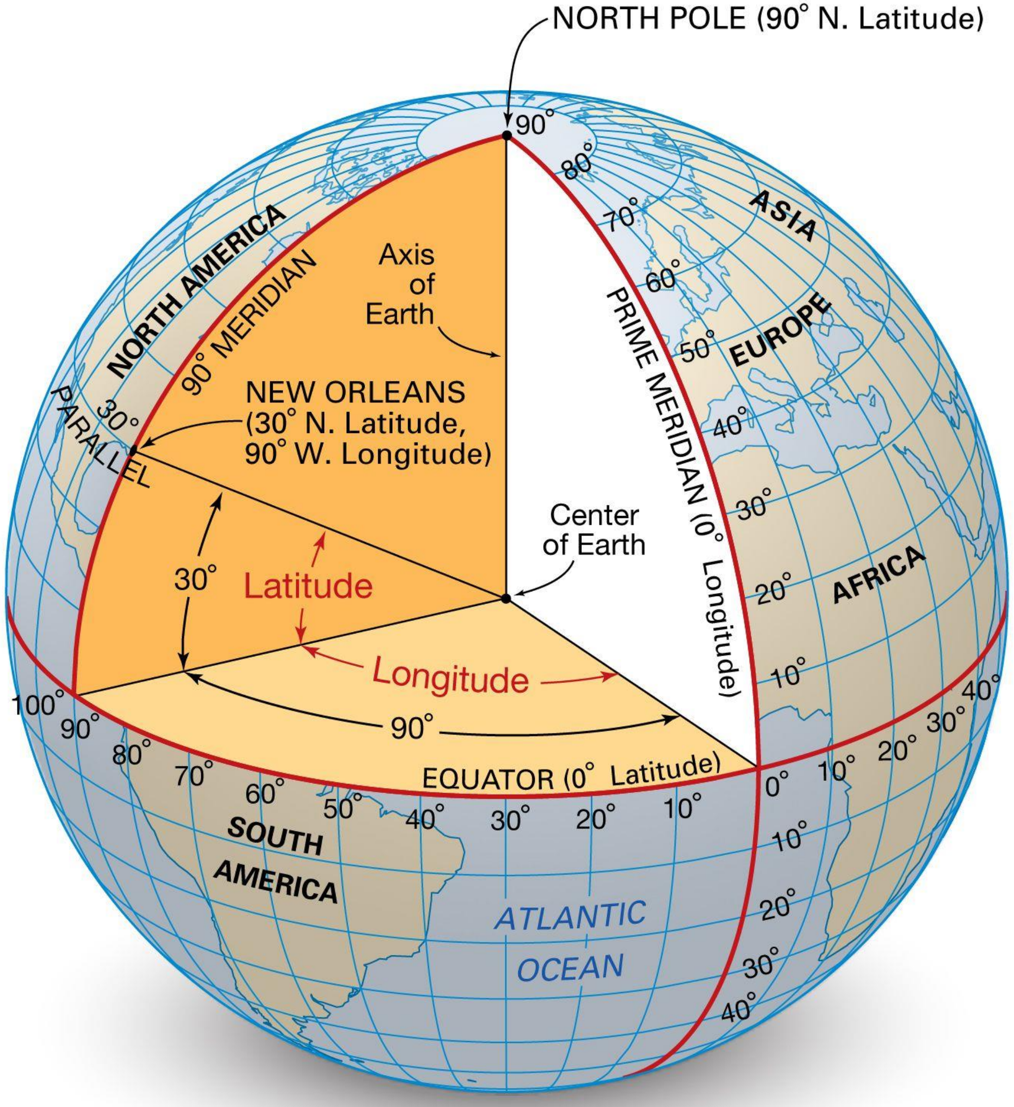
GEOGRAPHIC COORDINATES:

LATITUDE:

- angular value between a point and the Equator
- Generally indicated with letter phi (ϕ) and range from 0° (equator) to 90° (north or south pole)

LONGITUDE:

- angular value between a point and the reference meridian
- Generally indicated with letter lambda (λ) and range from 0° to 180° (east or west) with respect to Greenwich meridian



REFERENCE SYSTEM (SR or DATUM)

Coordinates' values are not universally valid but can change according to different paramters

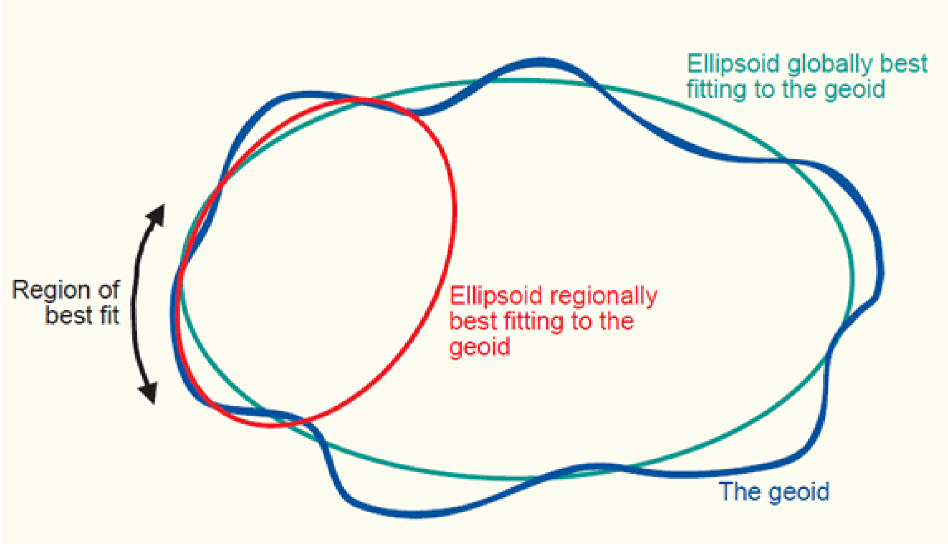
REFERENCE SYSTEM (SR or DATUM): is defined as the RULES AND MEASURES THAT ALLOWS TO DEFINE UNEQUIVOCALLY THE POSITION OF A POINT ON EARTH'S SURFACE

A datum is a simplified model of the Earth surface.

Datum is defined by:

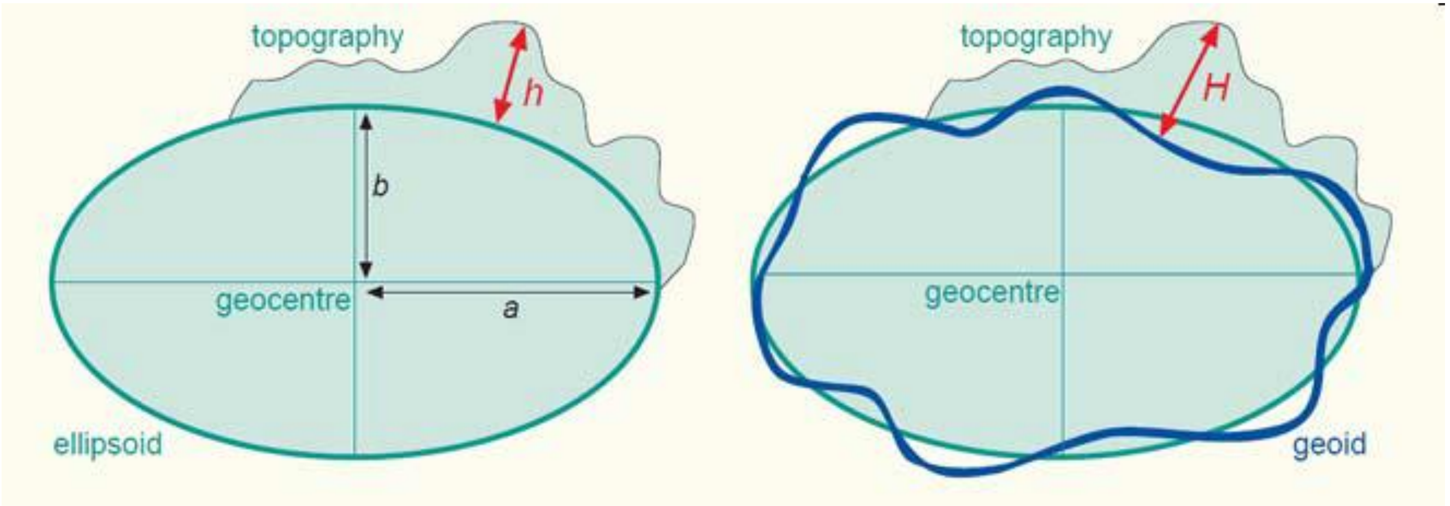
- **ELLIPSOID TYPE**, which change according to the relationship between major and minor semiaxis
- **ELLIPSOID POSITION AND ORIENTATION** with reference to the Geoid
- **Geodetic Control Network Points**

ELLIPSOID POSITION AND ORIENTATION

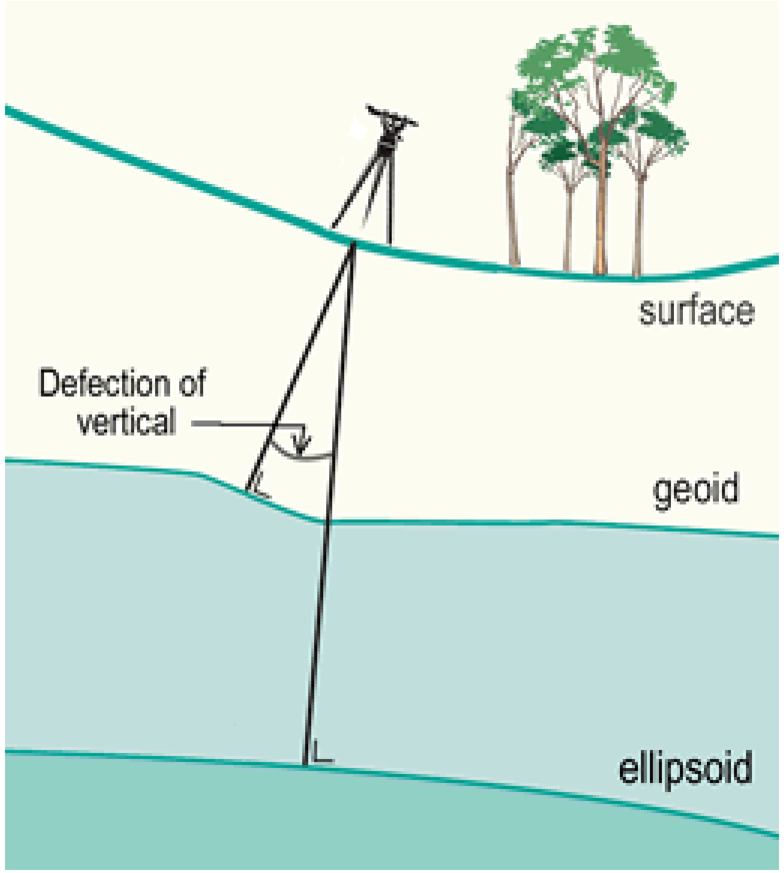


Depending on positioning, a SR can be:

1. **LOCAL**: geographic coordinates have very high accuracy and precision, but are valid only for limited areas
2. **GLOBAL**: geographic coordinates have similar accuracy and precision on a global scale



ELLIPSOID POSITION AND ORIENTATION



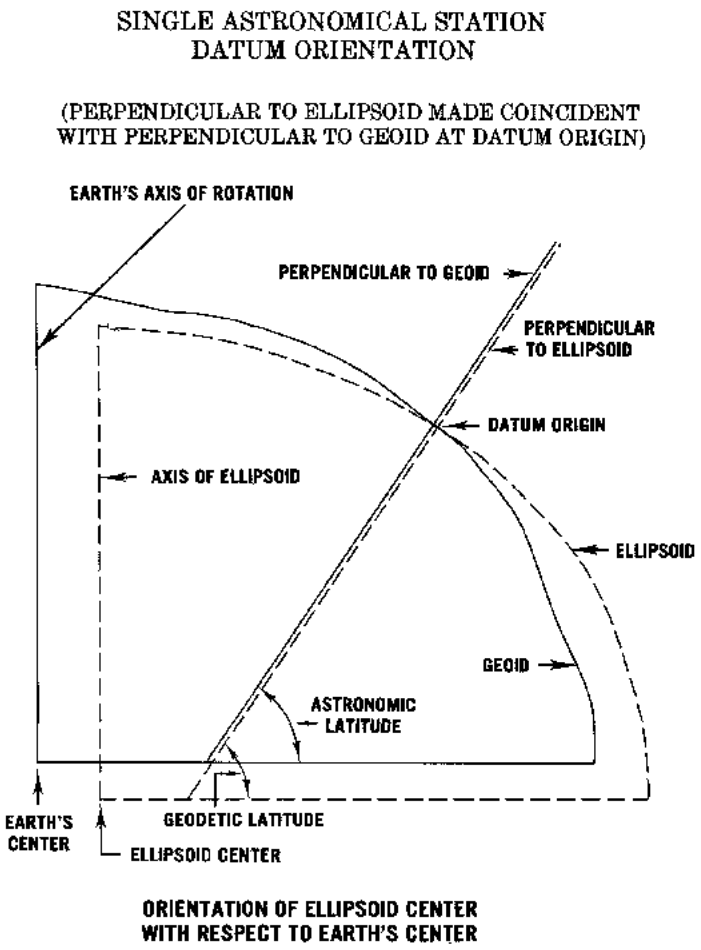
Given an object on Earth’s surface, the Geoid vertical is different from the Ellipsoid vertical

α angle = DEFECTION OF VERTICAL

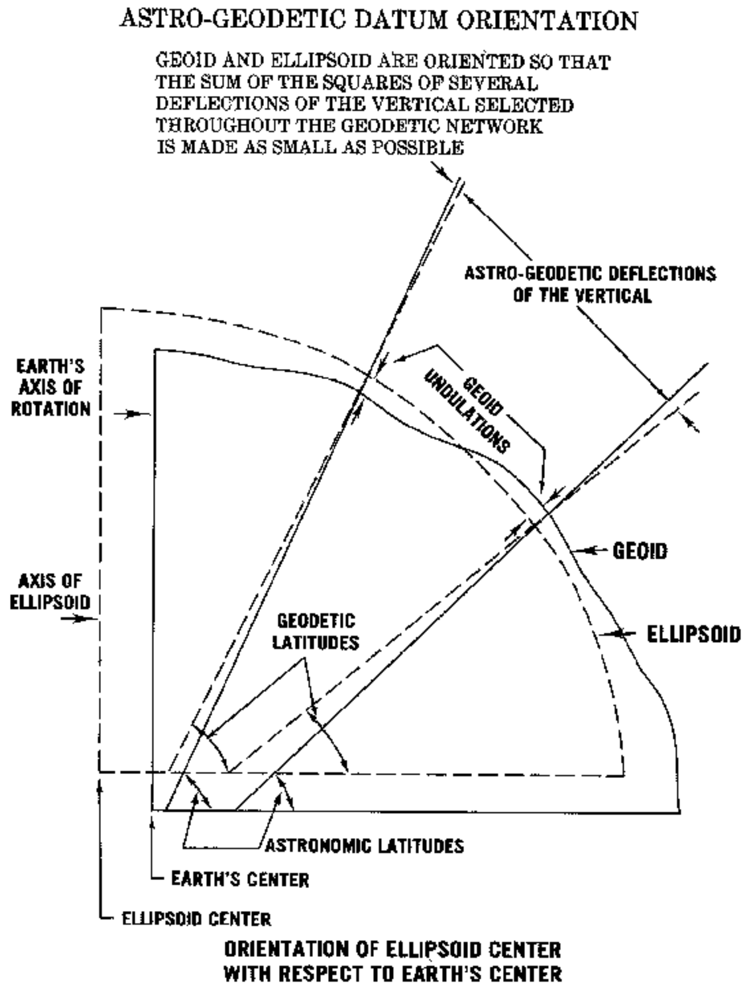
It ranges from 0-10” in planes and 20-50” in mountains

LOCAL ELLIPSOID POSITION AND ORIENTATION

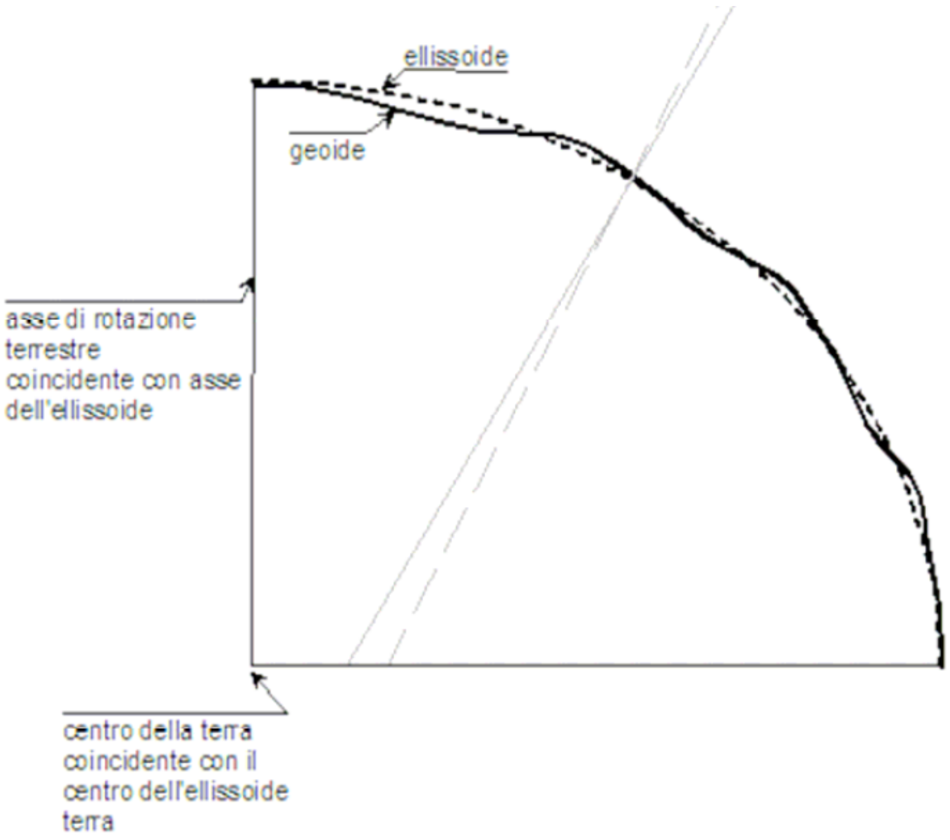
Strong/Robust orientation



Medium/Weak orientation



GEOCENTRIC ELLIPSOID POSITION AND ORIENTATION



GEOCENTRIC ELLIPSOID:
Ellipsoid is oriented in order that ellipsoide's central is equivalent to the Geoid's mass centre.

It is the best for global cartography

It is less accurate and precise but the cartography produced is based on the same reference system.

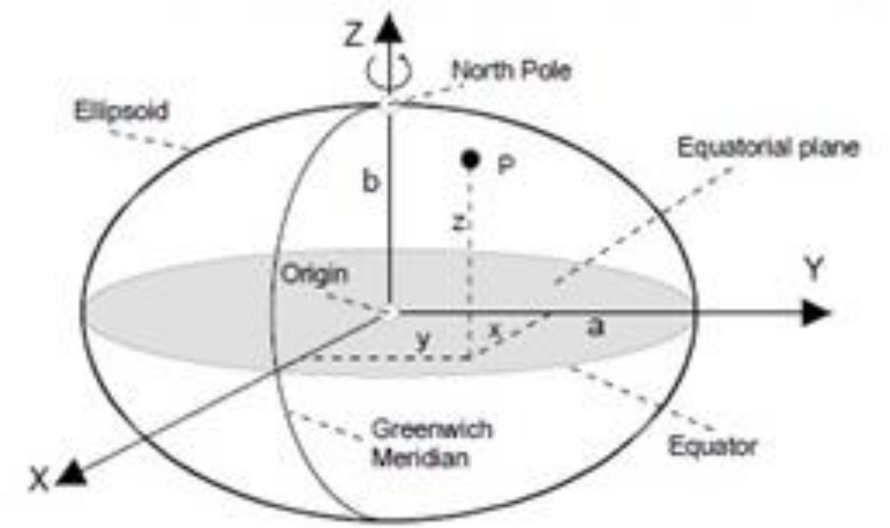
REFERENCE SYSTEMS USED IN ITALY

SR	Ellipsoid	Orientation
Sistema "Roma ante 1940" e catastale	Bessel	Genova, Roma, Castanea delle Furie
Sistema nazionale Roma 1940	International	Strong, Monte Mario
European System Datum 1950	International	Weak, Postdam
Global World Geodetic System 1984	Geocentric	/
Dynamical system ITRS and ETRS	Geocentric, permanent stations with variable coordinates	/

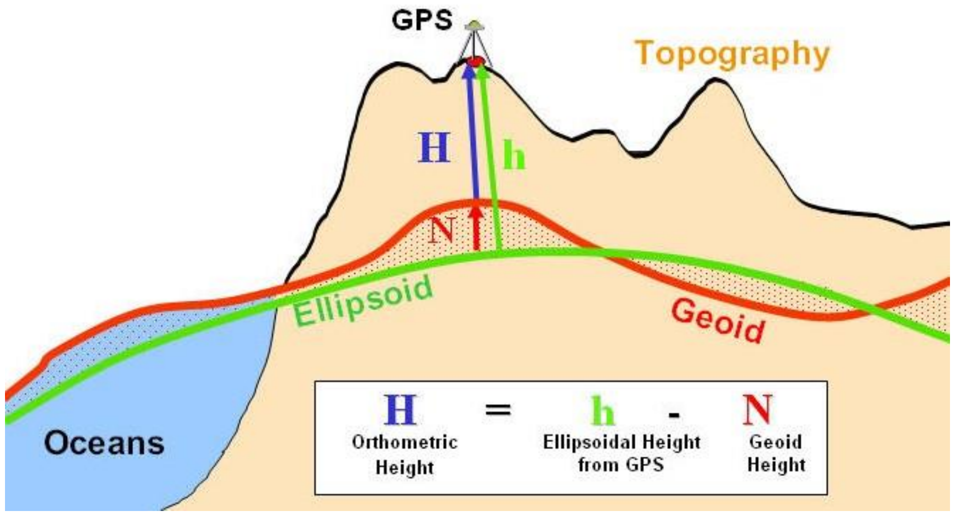
SR WGS 84

- The WGS 84 coordinate system is geocentrically positioned with respect to the centre of the Earth. For this reason, it is called ECEF (Earth Centered, Earth Fixed)

- WGS 84 is a three-dimensional, right handed, Cartesian coordinate system with its original coordinate point at the centre of mass of an ellipsoid



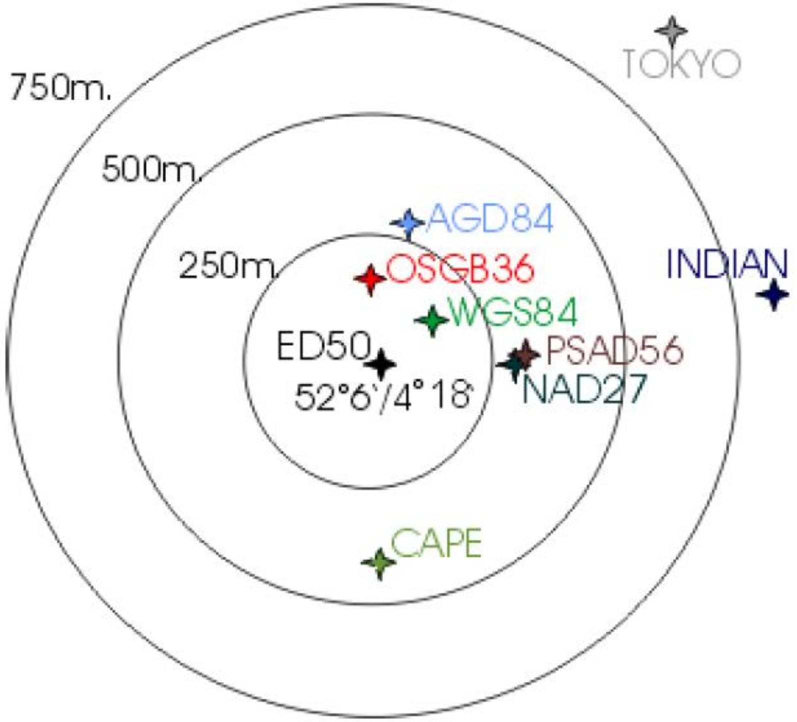
Parameter of WGS 84 Reference Ellipsoid		
Semi major axis (a), km	Semi minor axis (b), m	Flattening (1:…)
6,378,137	6,356,752	298.26



No agreement between Geoid's and Ellipsoid's altitude
→ ERROR ESTIMATIONS (ondulations)

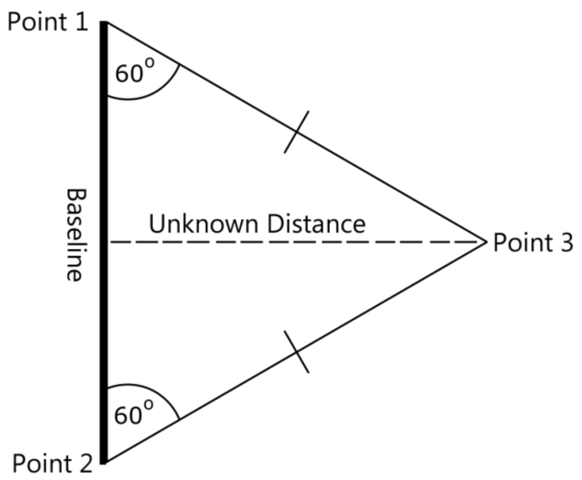
SR WGS 84

Knowing the reference system or datum used in GIS applications is fundamental, since the coordinates of a point on Earth surface can change accordingly to the SR used.



Geodetic Control Network Points

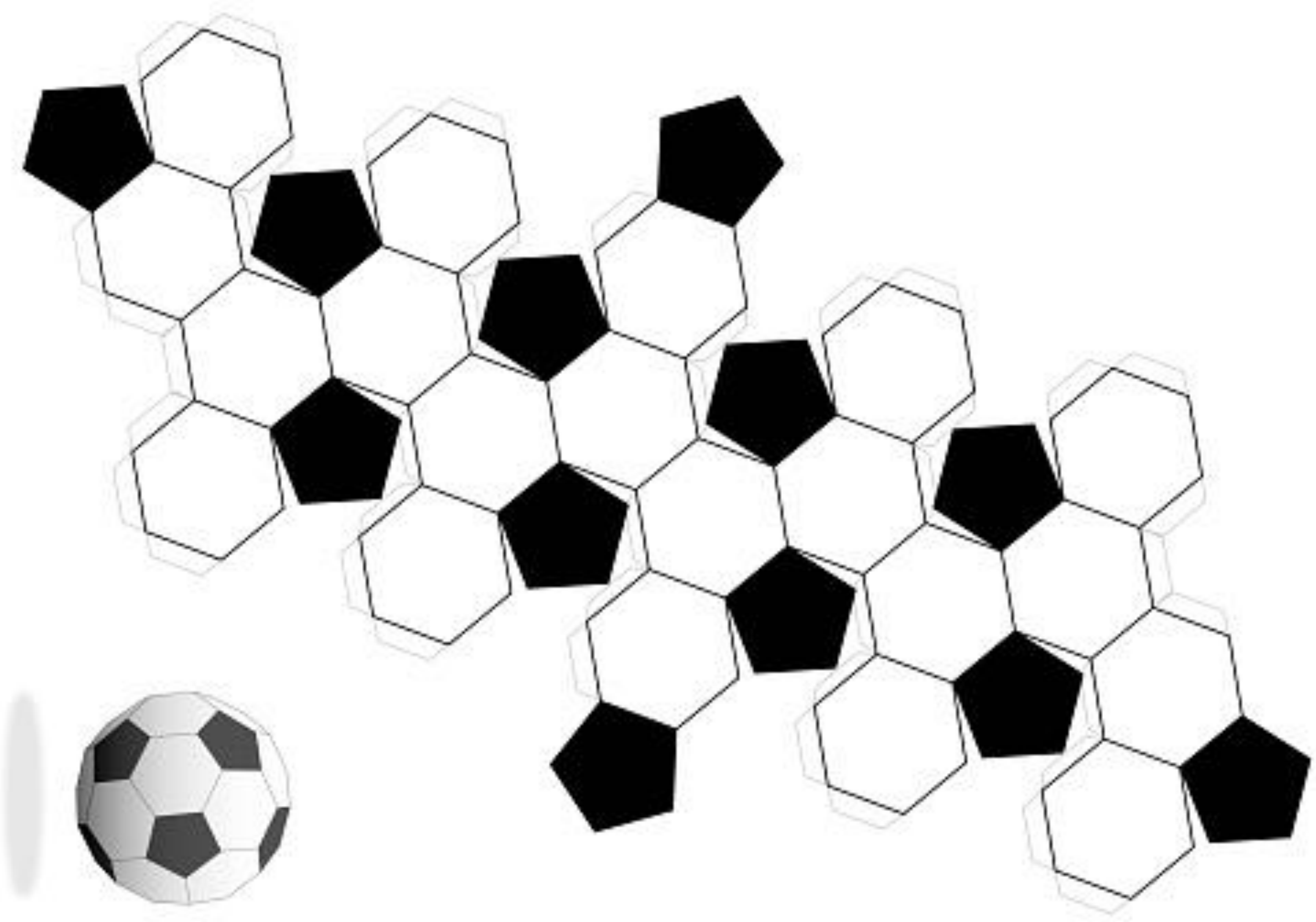
- For cartographic purposes, it is necessary to define the exact position of some reference points that could be easily located.
- The network of these point = Geodetic Control Network points
- Based on the position of known points, is it possible to locate objects by means of the **TRIANGULATION** process. It is defined as the **mathematical process that allows the determination of a location of a point by measuring the angles from known points to the object**. The object is fixed as a third point of a triangle with known side and two angles.



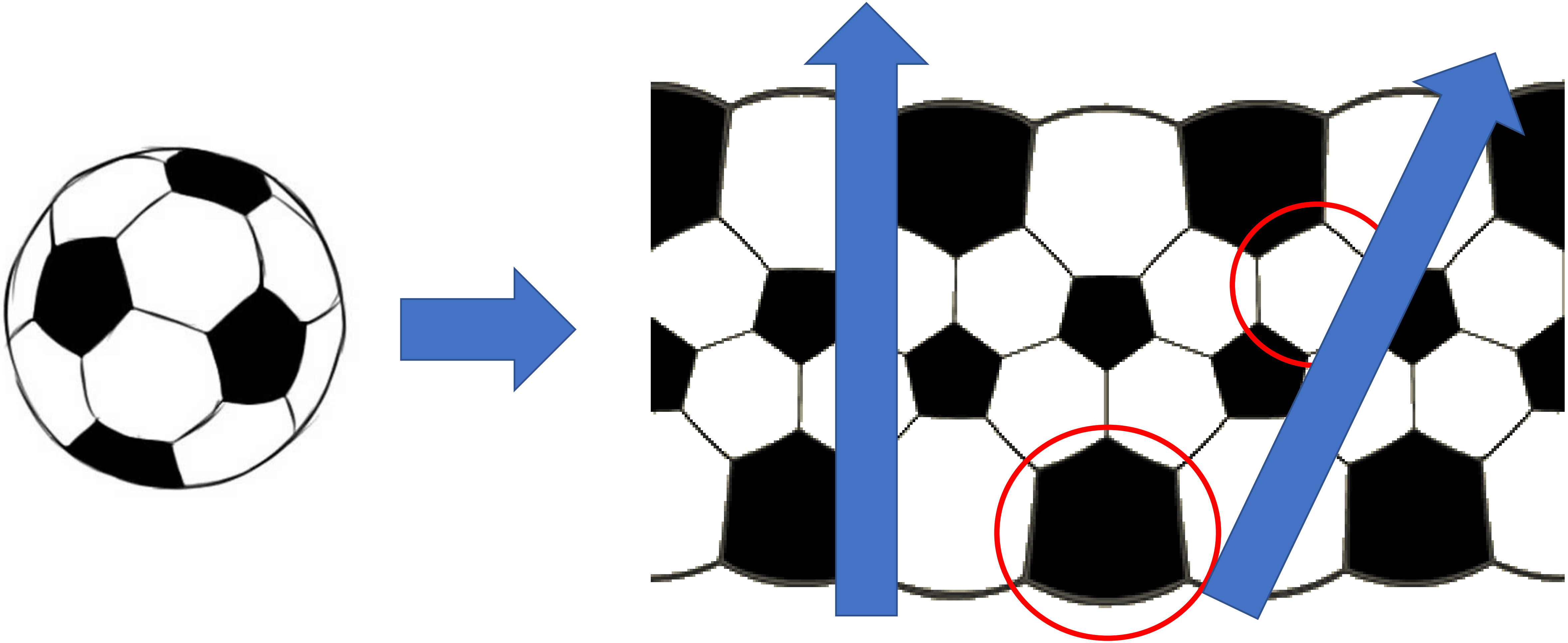
CARTOGRAPHIC PROJECTIONS

How to represent Earth surface (which is curve) in two dimensions on a Map?

CARTOGRAPHIC PROJECTIONS



CARTOGRAPHIC PROJECTIONS



CARTOGRAPHIC PROJECTIONS

How to represent Earth surface (which is curve) in two dimensions on a Map?

PROJECTION: defined as the mathematical processes to visualize an ellipsoid an a plane.

The process of projecting Earth surface on a map causes **DEFORMATION** of the objects on it.

A projection is defined by couple of equations:

- $x = f(\phi,\lambda)$
- $y = (\phi,\lambda)$

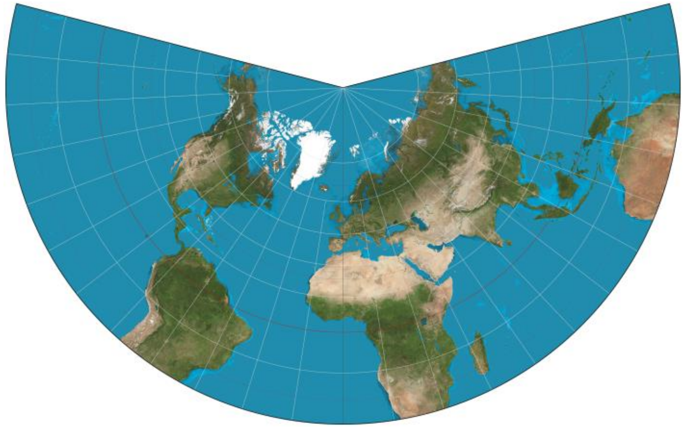
Where ϕ and λ are the geographical coordinates of a object on Earth surface, and x and y are the related coordinates on a Cartesian plane

Cartography aims at finding the best representation of all or part of Earth's surface by minimizing the deformations created during the projection processes.

CARTOGRAPHIC PROJECTIONS

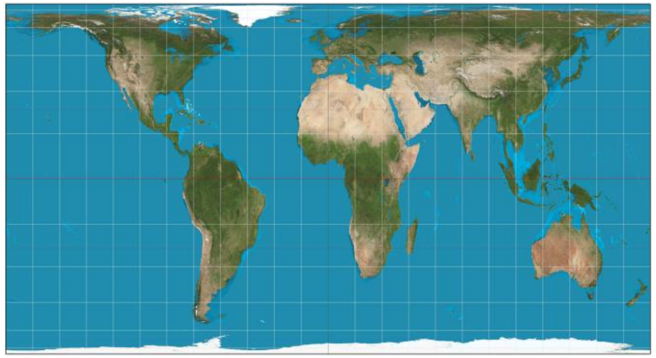
https://mangomap.com/

TYPE of PROJECTIONS



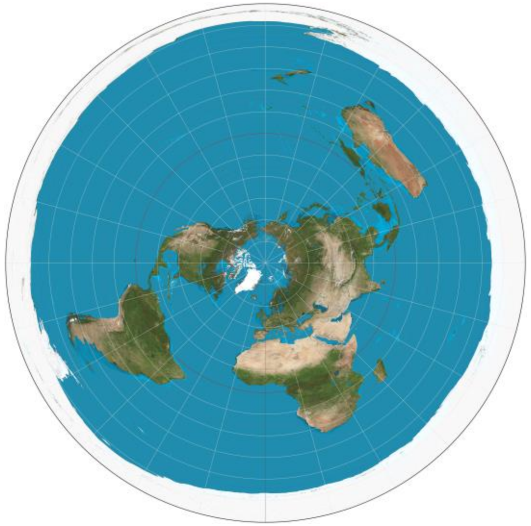
CONFORMAL PROJECTIONS

The value of the angles are preserved when projecting Earth's surface on a plane



EQUIVALENT PROJECTIONS

The area of the objects are the same when projected on the plane.



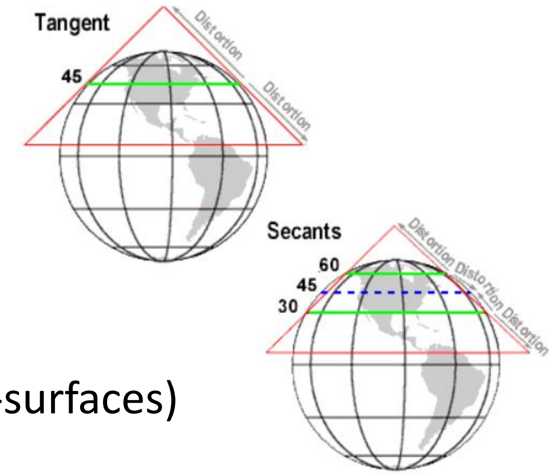
EQUIDISTANT PROJECTIONS

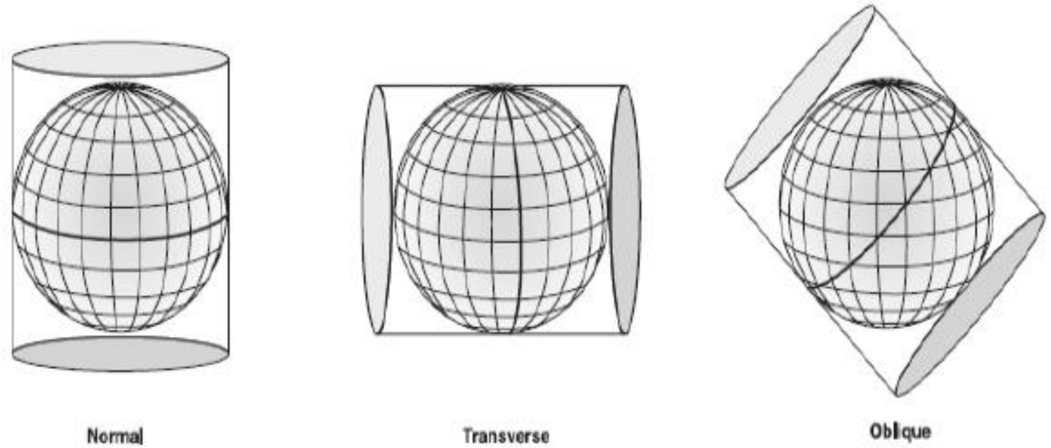
The scale along one or more lines, or from one or two points to all other points on the map are maintained. The distance between the center point of the map and any other point is correct with an equidistant projection.

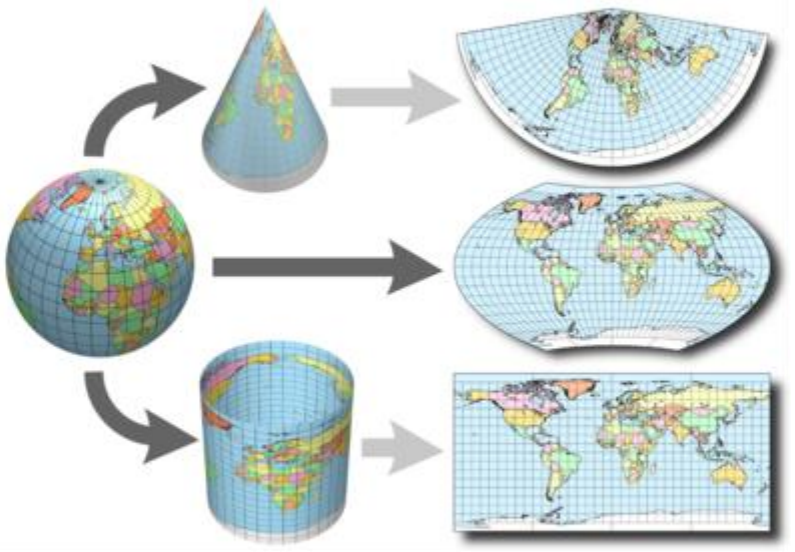
CLASSIFICATION

Projections are classified according to:

- **Projection's surface** (plane, conic, cylindrical)
- **Orientation of the projection's surface (direct, transverse, oblique)**
- **Position of projection surface** with respect to the Earth's surface (tangent, secant, multi-surfaces)
- **Position of the hypothetical light source** that generates the projection (point of view) with respect to Earth's globe
- **Geometrical or Mathematical model** used by the projection







FOCUS on…

Direct cylindrical projections:

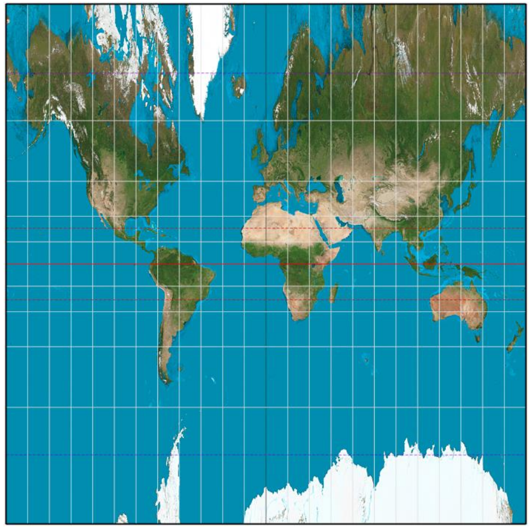
- Meridians and parallels intersect creating an rectangular reticulate

- Different cylindrical projections differs in the space between the rectangles:

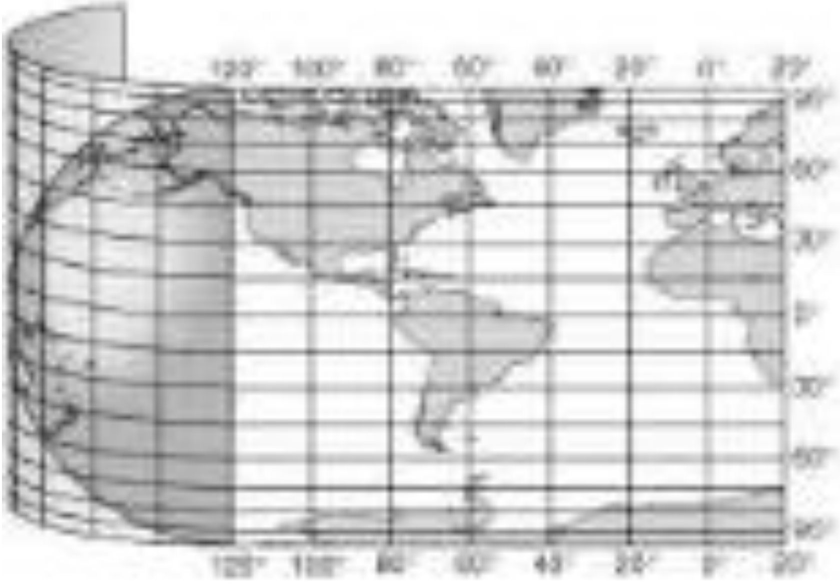
1. **Real cylindrical projections**:
   - Parallels are denser towards the poles
   - Space between meridians is constant
   - Distances and shapes are exaggerated in the east-west direction

2. **Central cylindrical projections**:
   - Parallels are less dense towards the pole
   - Distances and shapes are exaggerated in the north-south directio

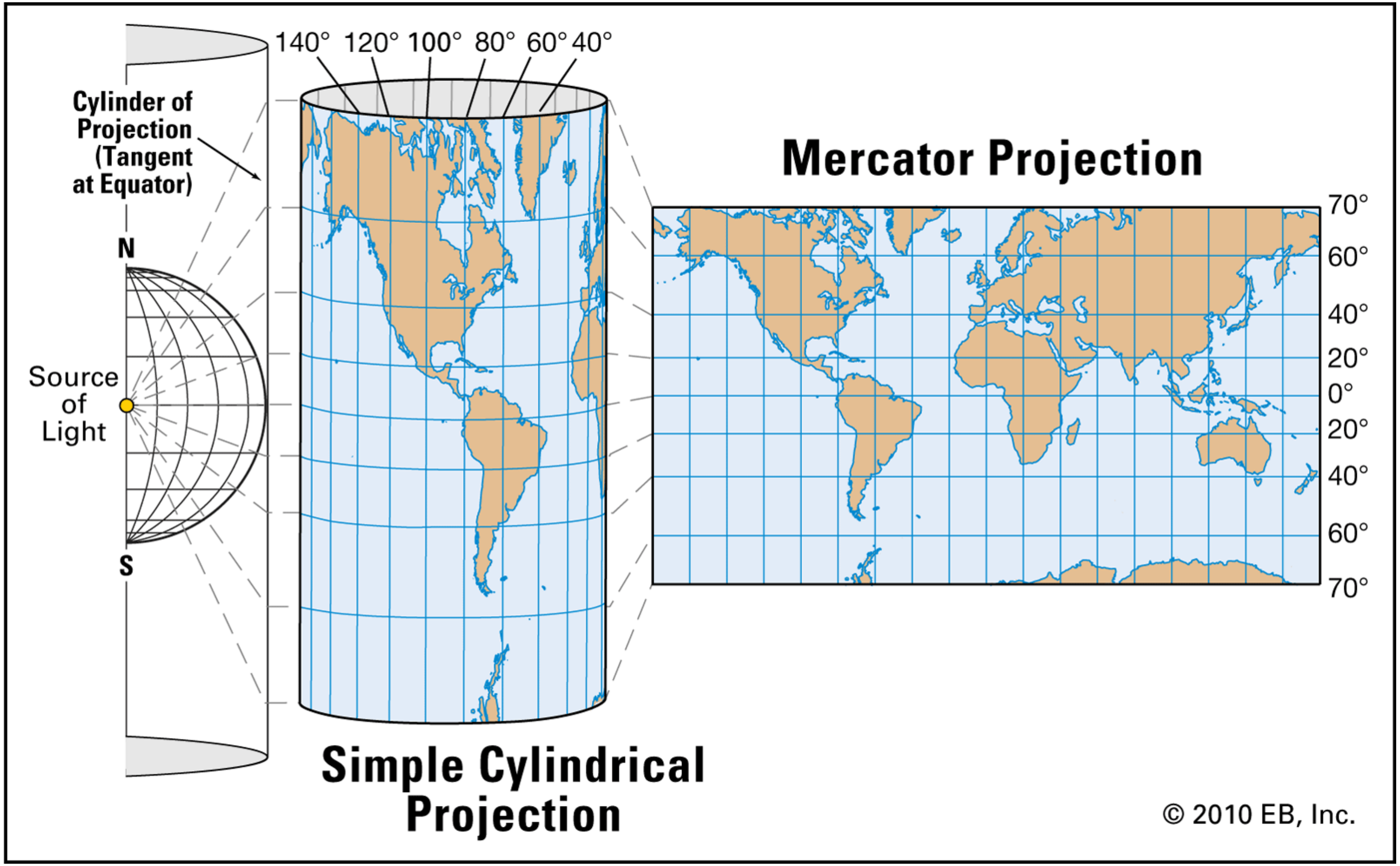
3. **Mercator cylindric projection**:
   - Distances between parallels is calculated through mathematical operations in order to create north-south distortion which compensate east-west one



Central cylindrical projection



FOCUS on…

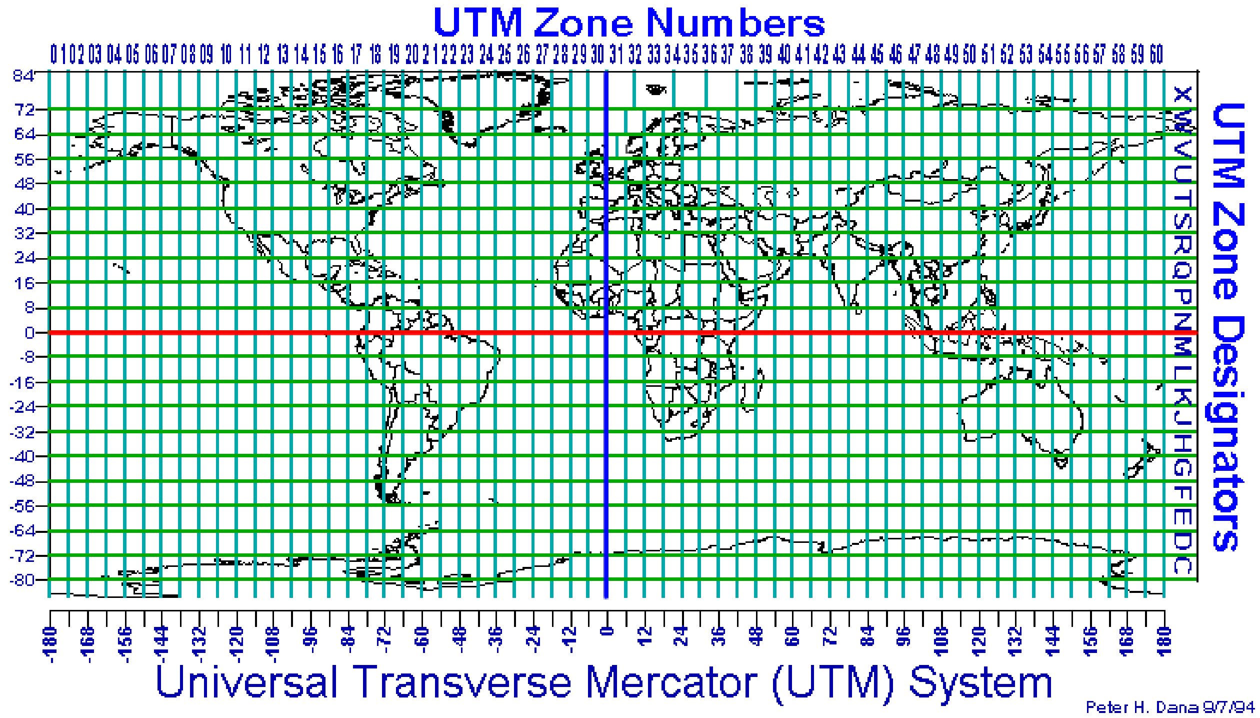


140°
120°
100°
80°
60°
40°
Cylinder of Projection (Tangent at Equator)
N
Source of Light
S
Mercator Projection
70°
60°
40°
20°
0°
20°
40°
60°
70°
Simple Cylindrical Projection
© 2010 EB, Inc.

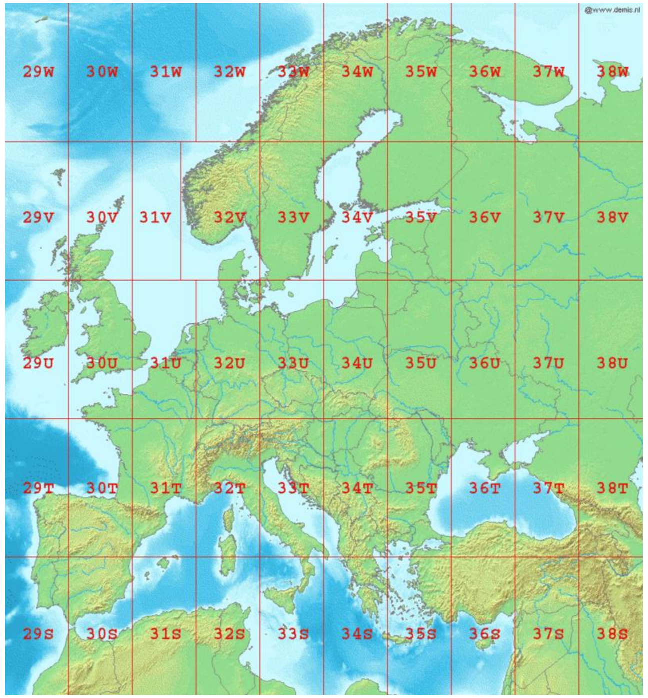
How to reduce deformations?

Introduction of FUSES = portion of the reference ellipsoid with different size

UTM = Universal Transverse Mercator



- Earth is divided in 60 fuses (each 6°) and in 20 bands (from X to C)
- The intersection between fuses and bands = ZONE, identified by the number of the fuse + the letter of the band (e.g. 32S)



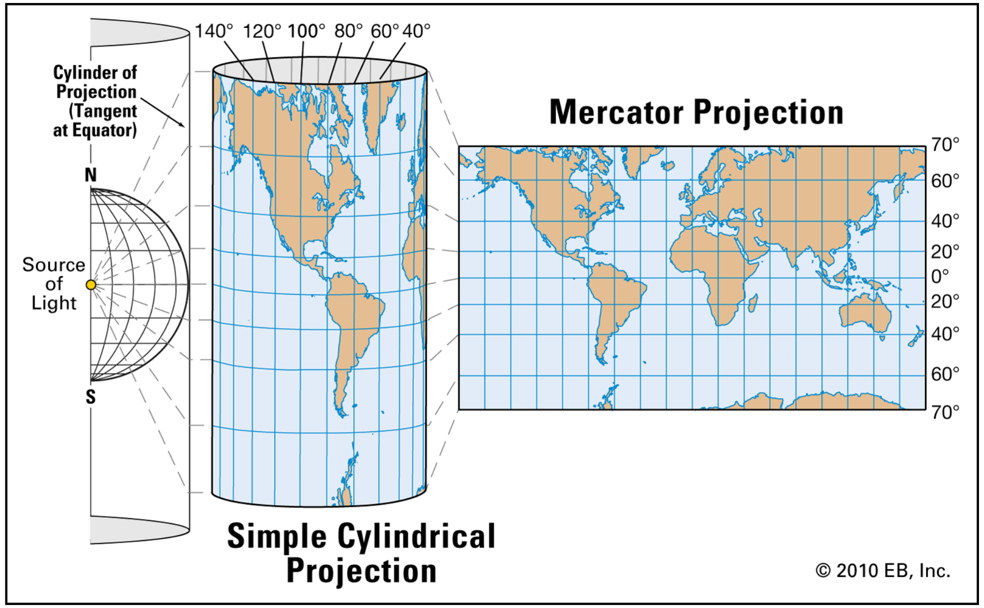
How to reduce deformations?

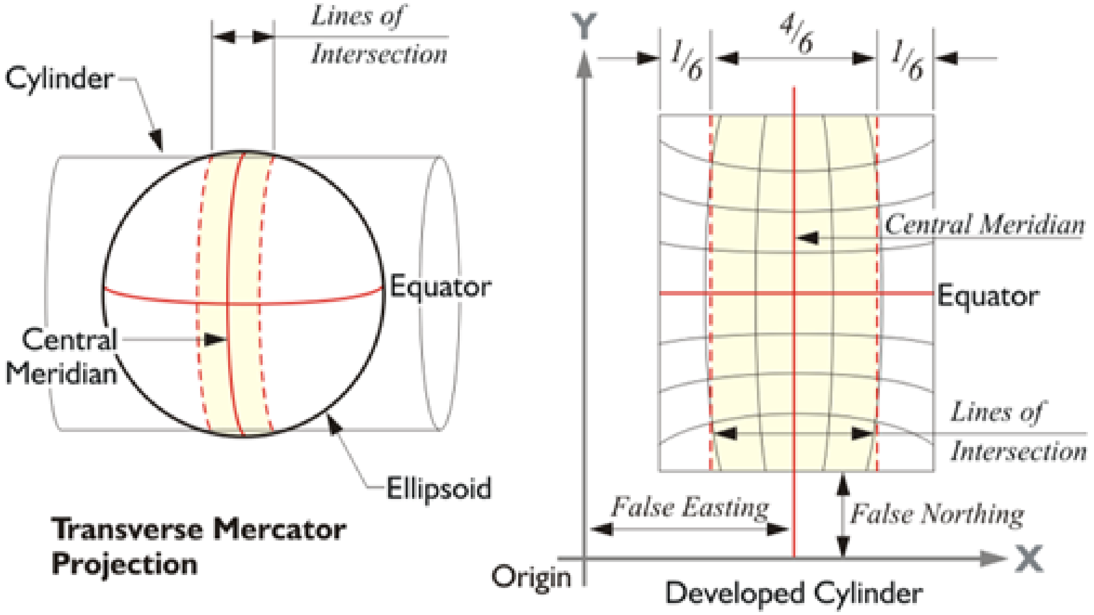
In this type of projections:

- The minimal deformation obtained during the projection is obtained near the meridian of the ellipsoid tangent to the cylinder

- In other words, DISTORSION ARE HIGHER FAR FROM THE PROJECTION POINT

- For this reason, the cylinder is rotated in order to re-project the ellipsoid at the meridian of the fuse closest to the study area



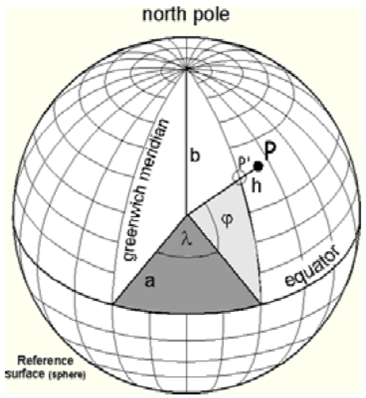


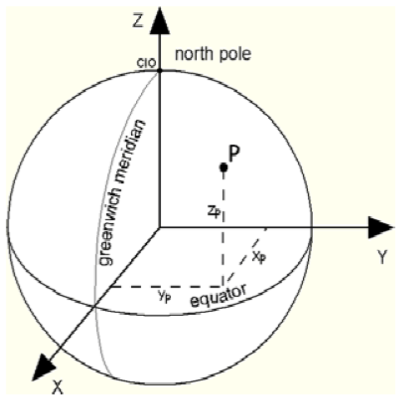
COORDINATES

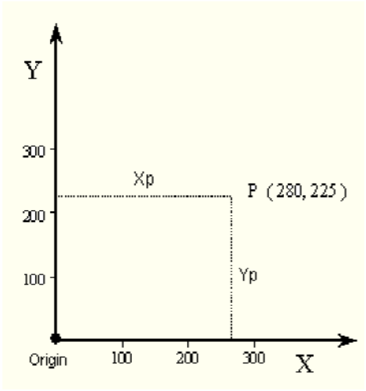
1. **<u>Geographic coordinates:</u>**
   λ and ϕ (latitude and longitude) are measured in angular values

2. **<u>Cartesian coordinates</u>** (X, Y and Z) are geocentric with respect to a specific datum

3. **<u>Projected coordinates</u>**:
   - Are the most used one in GIS applications
   - Plane coordinates (E and N): points on Earth's surface are re-projected using algorithms that convert geographical coordinates in a cartesian system
   - Expressed in metres



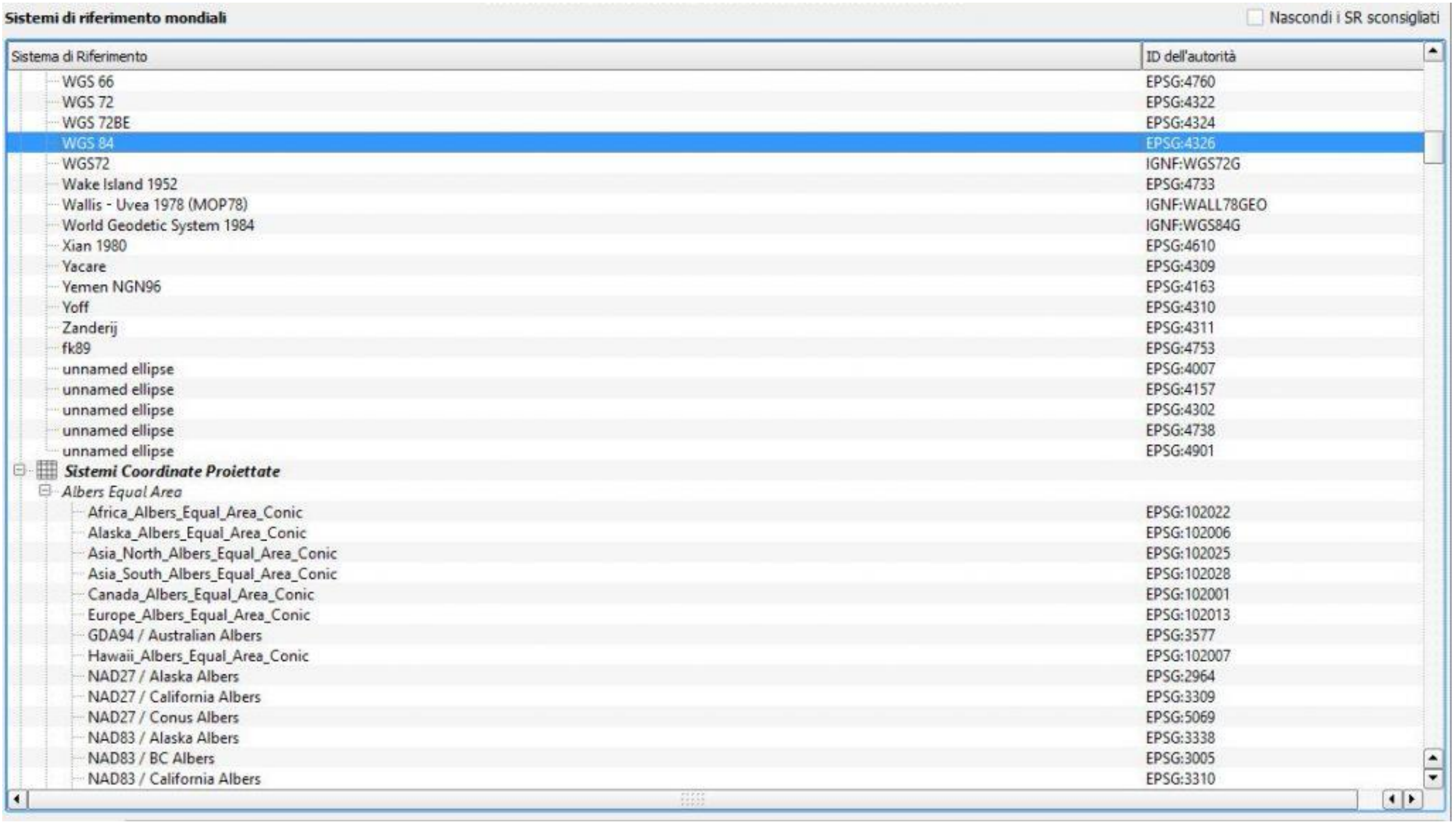




EPSG REGISTER

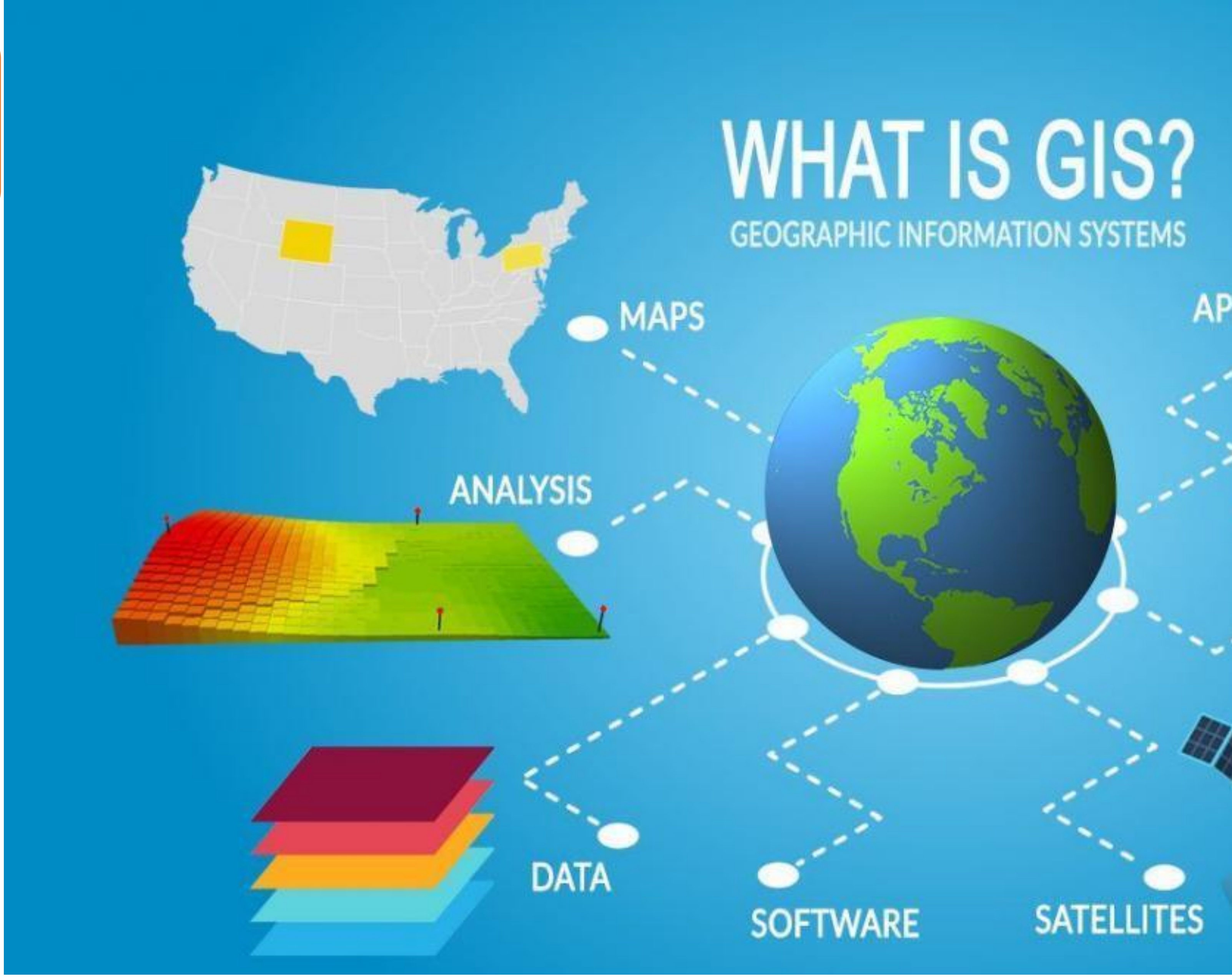
EPSG = European Petroleum Survey Group

It is a register containing all the reference systems (SR) which are identified by a number



Part 1

- **Geographic Information Systems (GIS)**
- **Basics of GIS**
- **QGIS Software**



GIS

GIS = Geographic Information Systems

DEFINITION:
GIS are defined as the combination of Hardware, Software, Human Resources and Procedures aiming at CAPTURE, MANAGE and ANALYSE spatially referenced data.

Main processess:

- Create Geographic Data (GD)
- Manage GD
- Analyse GD
- Display GD on a map

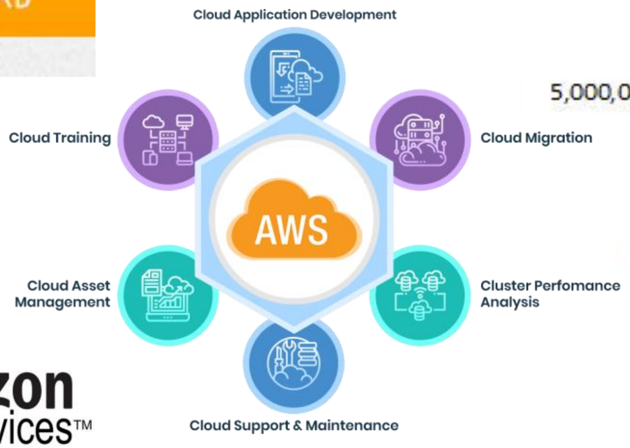
What to do with GIS?

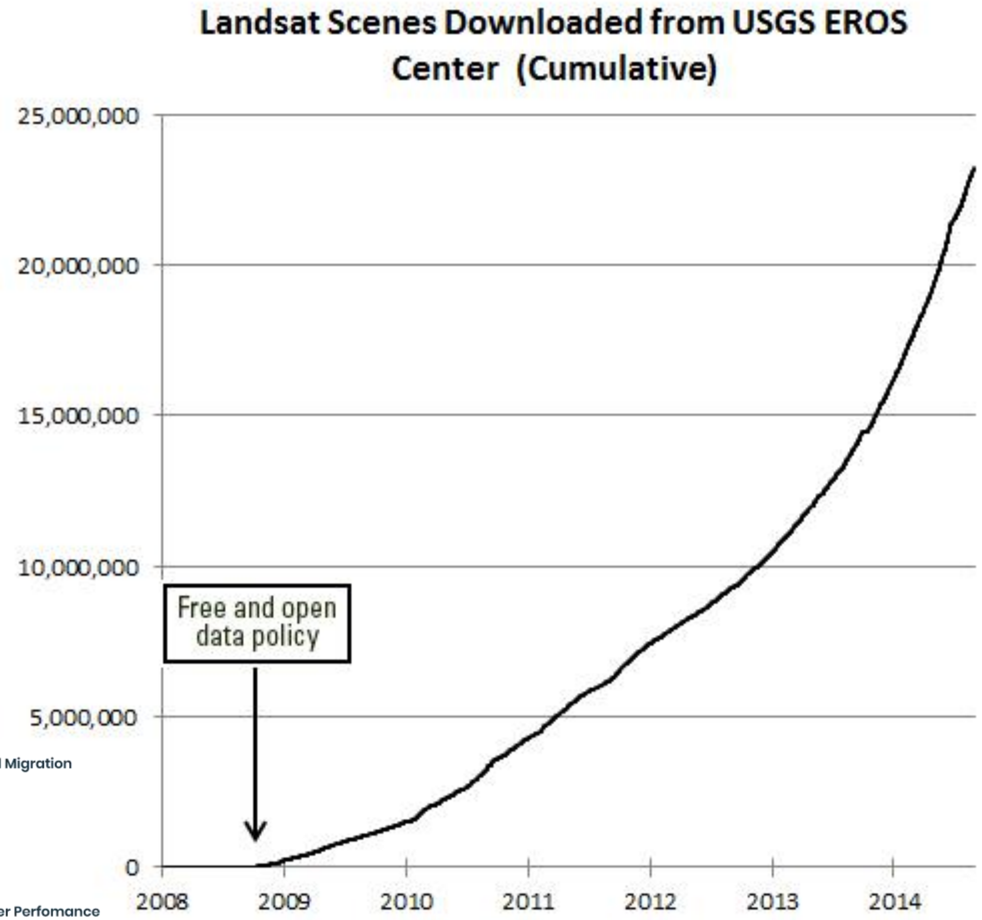
- Identify problems on a landscape level
- Monitoring changes
- Provide information to managing and responding to events
- Performing forecasting
- Analyse TRENDS

Open Data

<u>Open data: free access</u>

<u>Open source: free software</u>





GIS

Components:

1. **MAPS**
    - geographic containers for data = **layers**
    - Can be virtually shared

2. **DATA – GEODATA**
    - Data that are associated to the map
    - Alphanumeric information (es. imagery, feature, basemaps) linked to a spreadsheet

3. **ANALYSIS – SPATIAL ANALYSIS**
    - Mathematical and statistical operations that could be implemented to answer specific questions

4. **APPLICATIONS**
    - Bringing GIS to everyone (mobile app, web app, dekstop app)

Type of GIS data

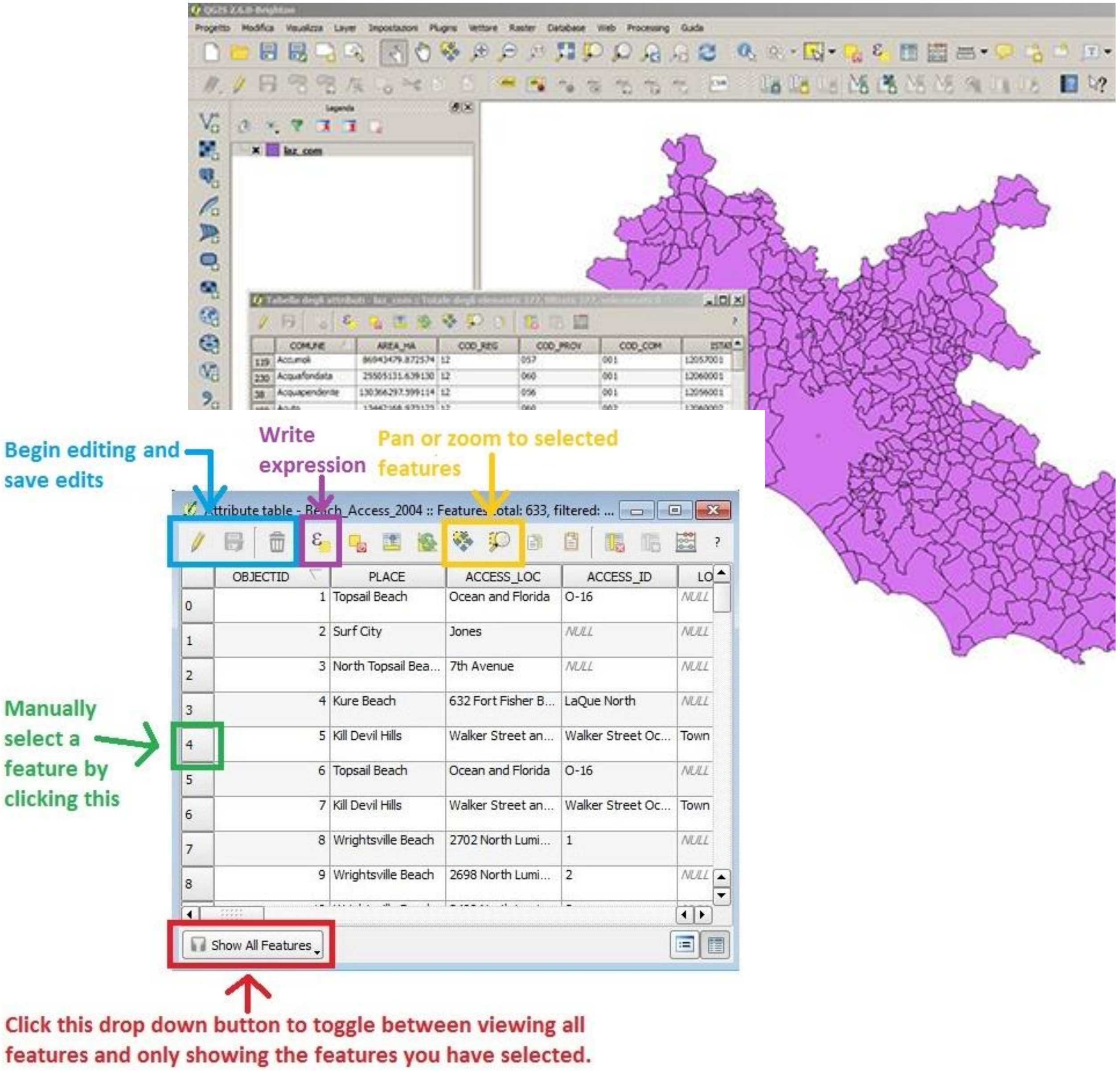
Vector:
It is an element on a map (like a point, a line or a polygon) with associated alphanumeric information

It means that a spreadsheet is associated to the map, where

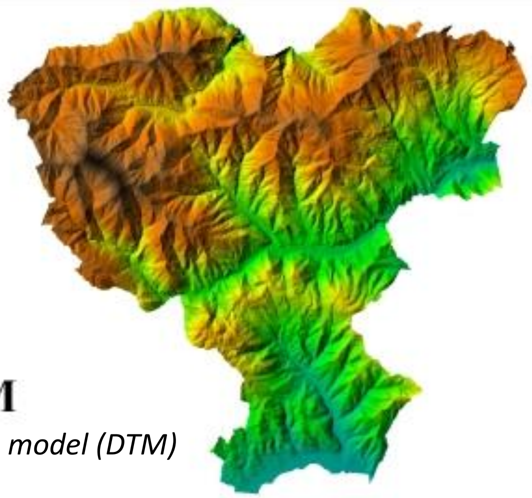
lines = geographic elements
columns = information type

Vectors are not single file:

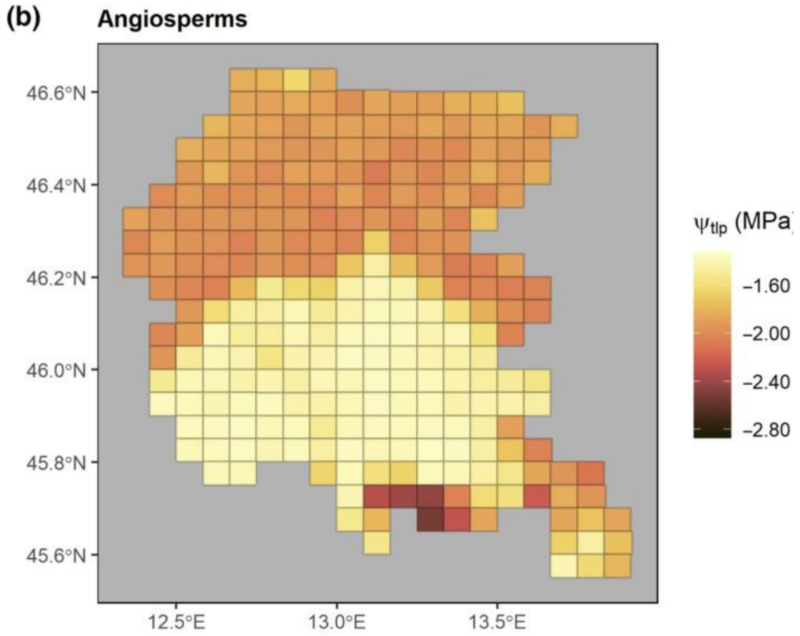
- .shp = file with the geometries
- .shx = file with geometry's index
- .dbf = database with alphanumeric is associated to the geometries in the .shp fle



Type of GIS data



Digital terrain model (DTM)



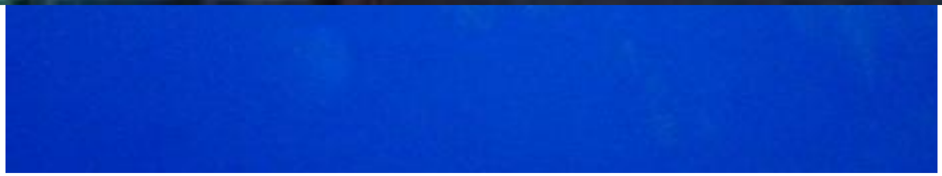
Raster:

It visualises localities and stores geographical data using a quadrat cell matrix.

A number is associated to each cell

Raster files are bigger (in terms of digital memory) than vector's one

Each cell has the same spatial extent, and the lower the area of each cell, the higher the resolution is




I've seen things
you people wouldn't believe.