5 Nov. 2018, Berlin, Germany

DYNAMIC PUBLIC LIGHTING - GIS SEMINAR & WORKSHOP

CE452 Dynamic Light | Anna Nowacka, Fabio Remondino

The power of Geographic Information Systems (GIS) for managing dynamic street lighting data

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The Project

Dynamic lighting is an innovative approach to increasing energy efficiency of public lighting and to minimize its negative effects (like light pollution).

The "**Dynamic Light**" project (15 partners from 7 countries) aims to develop dynamic light solutions (strategies, tools, best practices) in order to provide an improved quality of light with energy savings in public space.

The project includes **8 pilot demonstrations**, studies of different public lighting situations and regulations, *geospatial analyses* of existing lighting solutions, analyses and implementation of new technical lighting solutions, offer **trainings** for end users, policy makers and light planners, etc.

More info: https://www.interreg-central.eu/Content.Node/Dynamic-Light.html

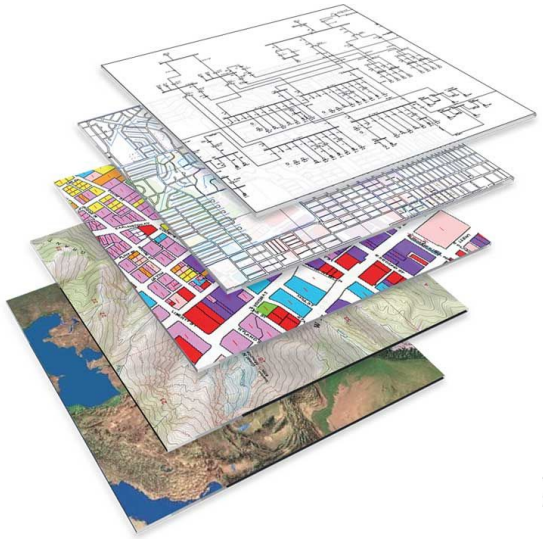
Schedule of the module

14:00 - 15:30: Introductory lecture about GIS

15:30 - 16:00: Installation of QGis and data distribution

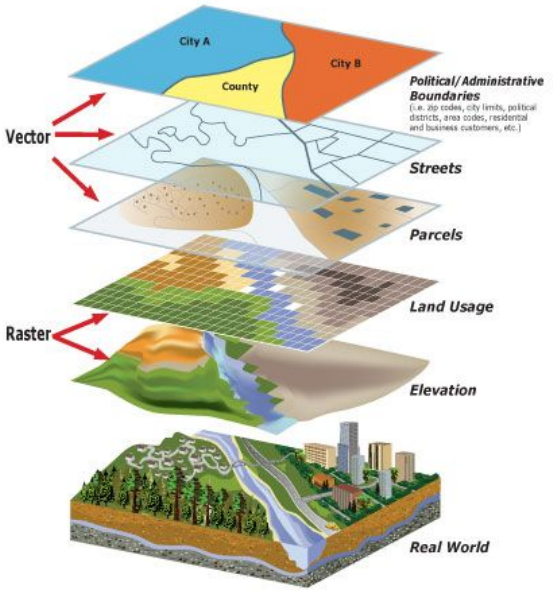
16:00 - 16:30: coffee break

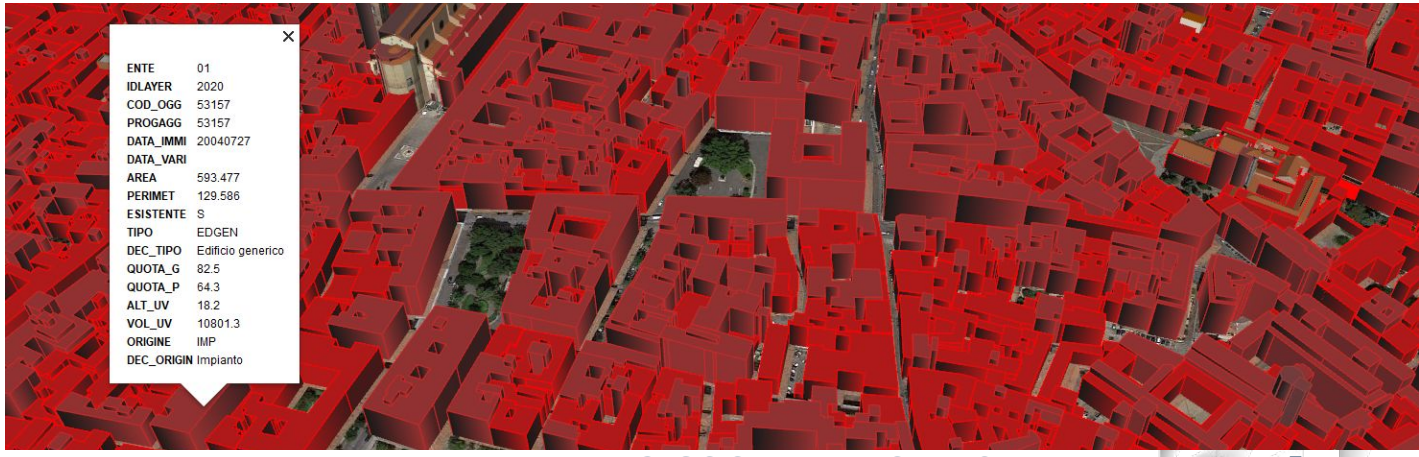
16:30 - 18:00: practical work with QGis



Contents of the GIS Module

- What is a GIS
- Data in GIS
- Data models in GIS
- Data attributes and Databases (DB)
- Coordinate Systems and Map Projections
- Maps in GIS
- 2D vs 3D GIS



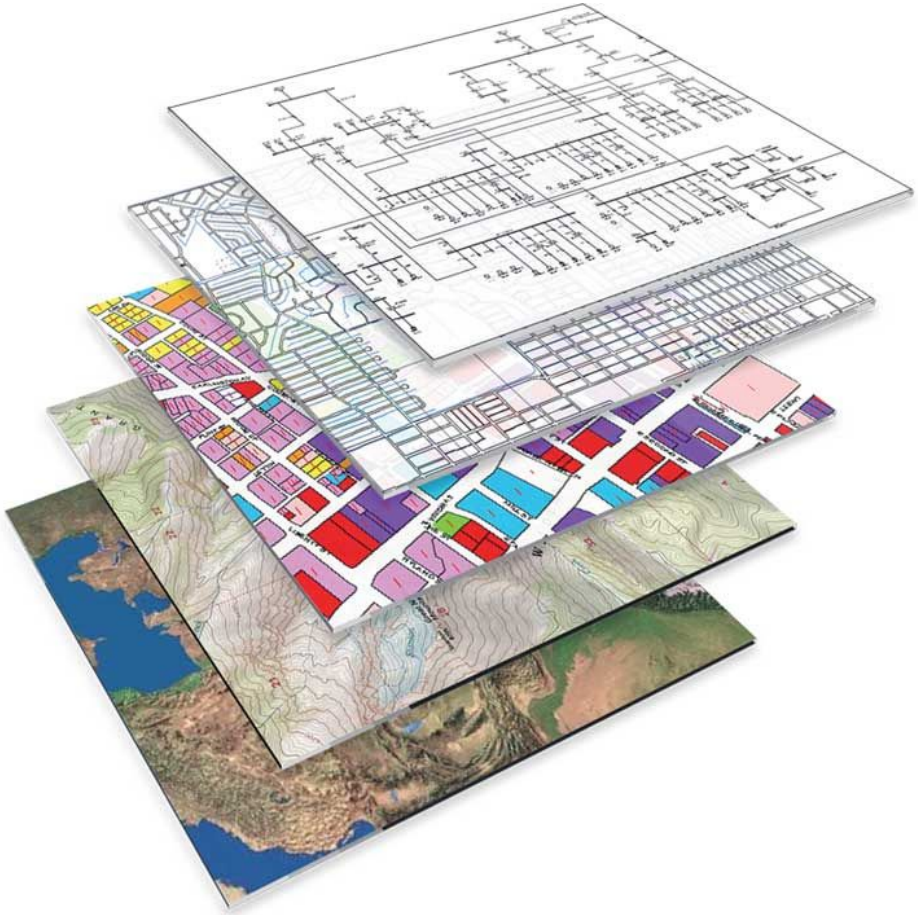



WISDOM
BETTER
DECISIONS

What is Geographic Information System (GIS)

KEYWORDS:

- data
- location(s)
- layers
- visualize
- knowledge
- understand
- wisdom



What is Geographic Information System (GIS)

(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM

-10 °C

2,5 m/s NE

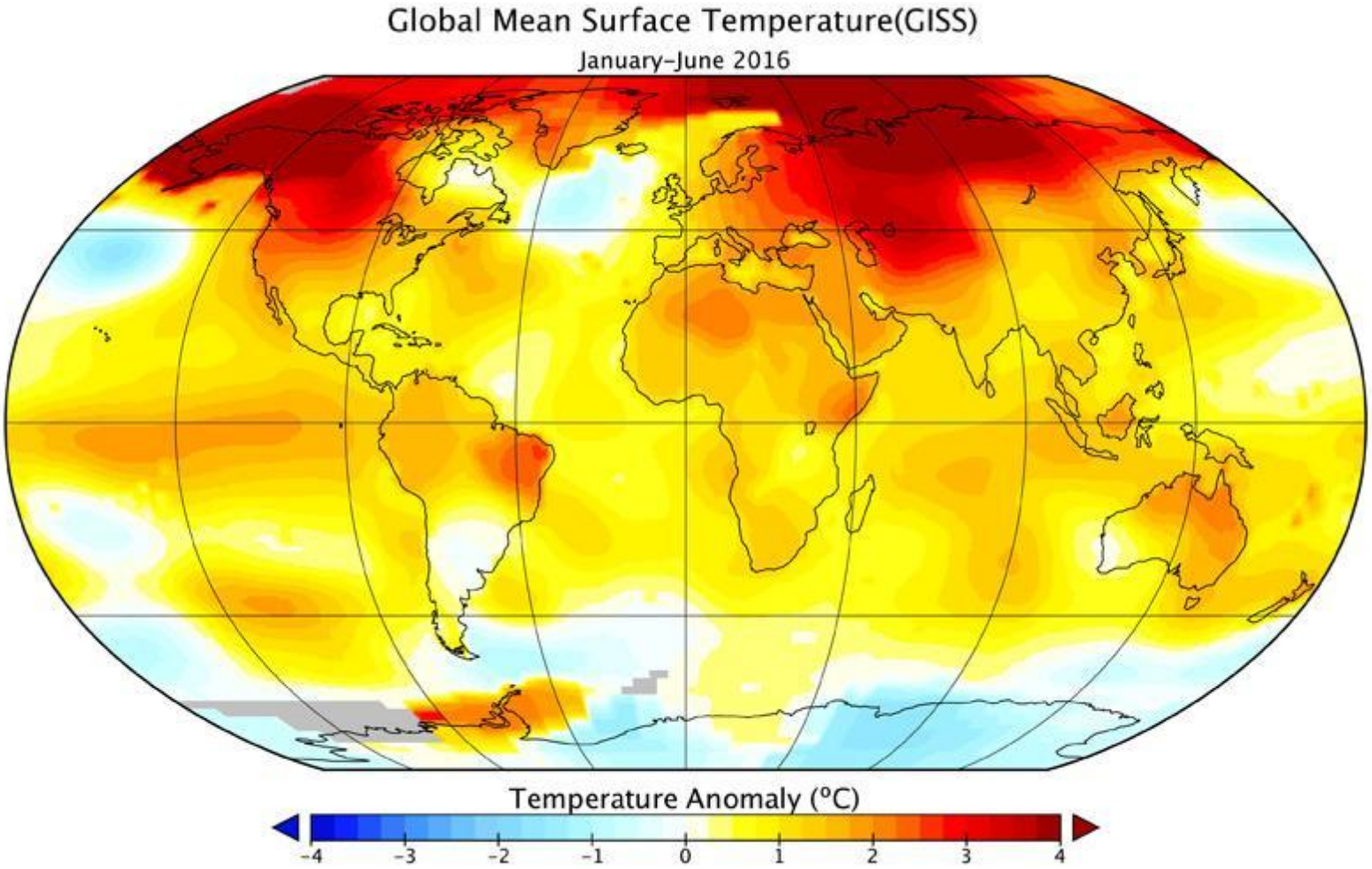
1010 hPa

22.10.2018

(X, Y, Z)

What is Geographic Information System (GIS)

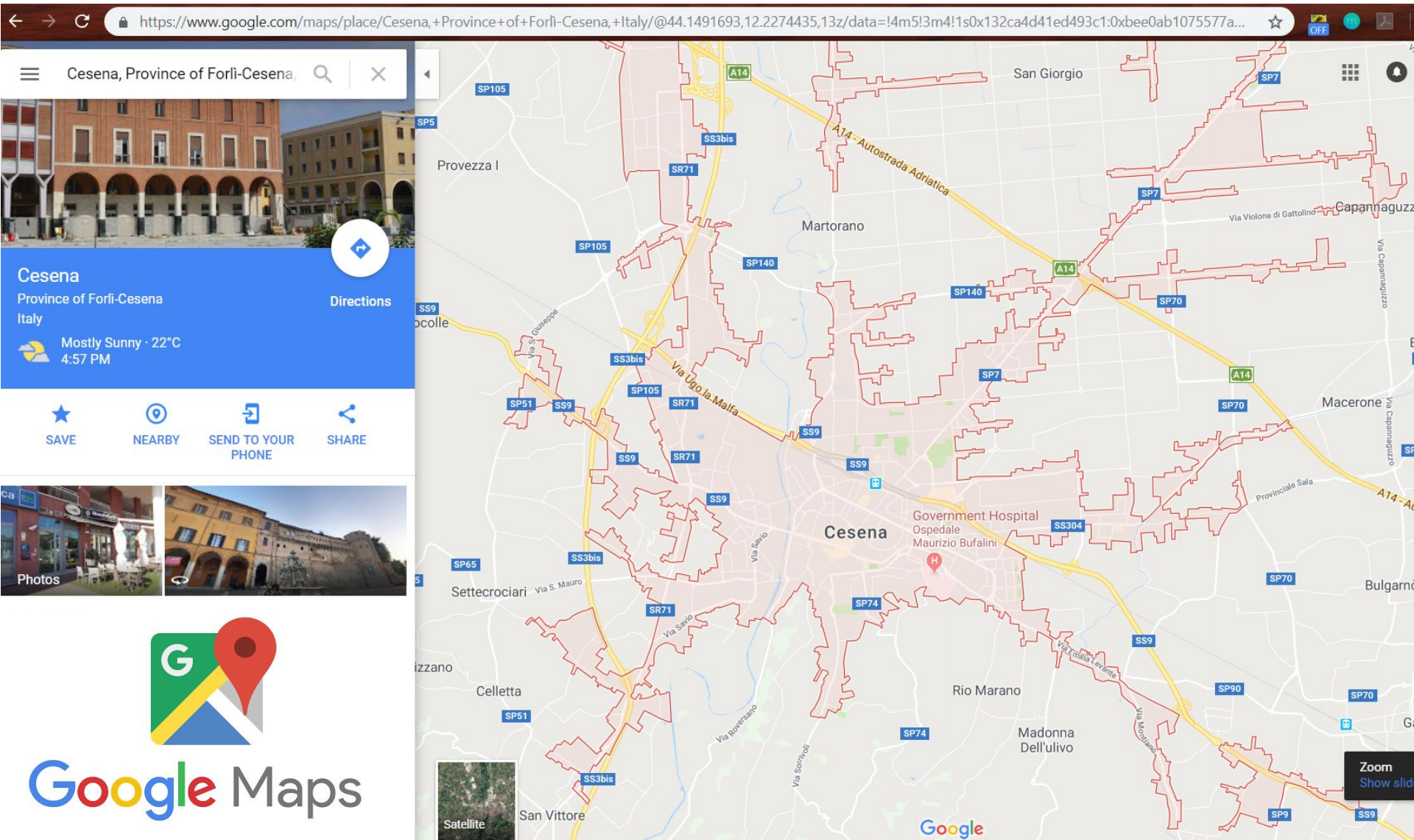
(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM



What is Geographic Information System (GIS)

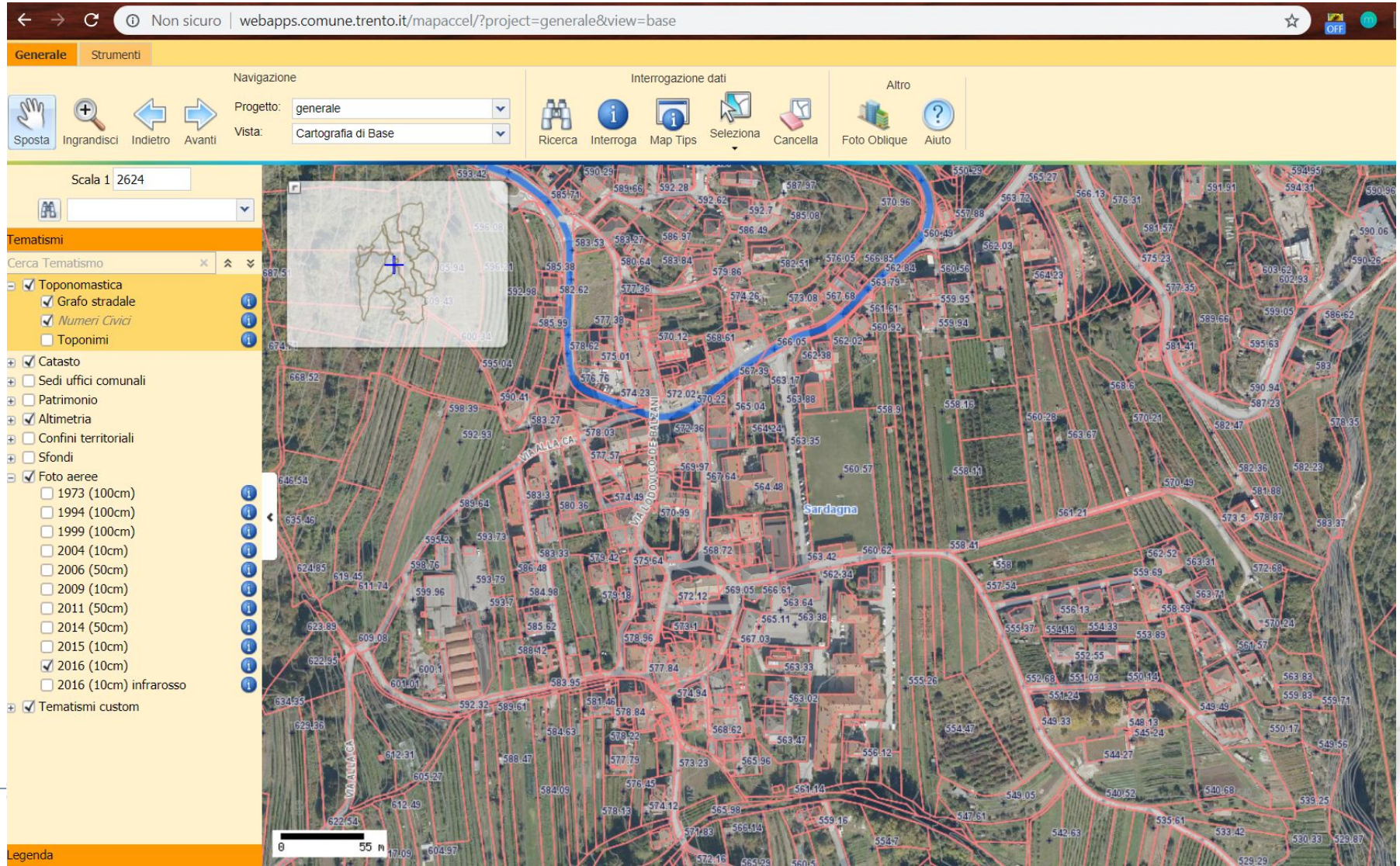
Interreg CENTRAL EUROPE
European Union European Regional Development Fund
Dynamic Light

(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM



What is Geographic Information System (GIS)

(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM

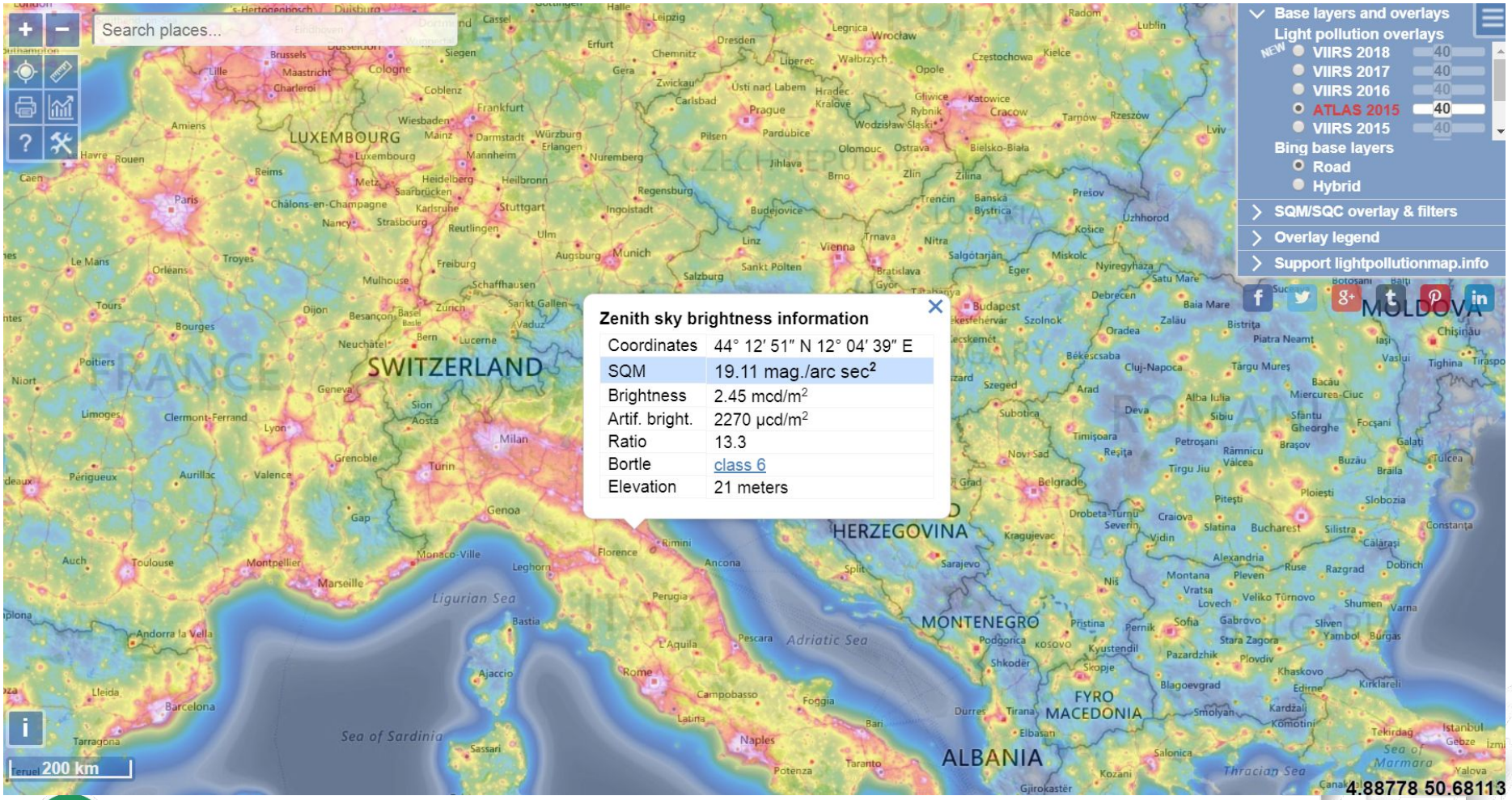


What is Geographic Information System (GIS)

Interreg CENTRAL EUROPE — European Union, European Regional Development Fund

Dynamic Light

(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM



What is Geographic Information System (GIS)

Interreg CENTRAL EUROPE
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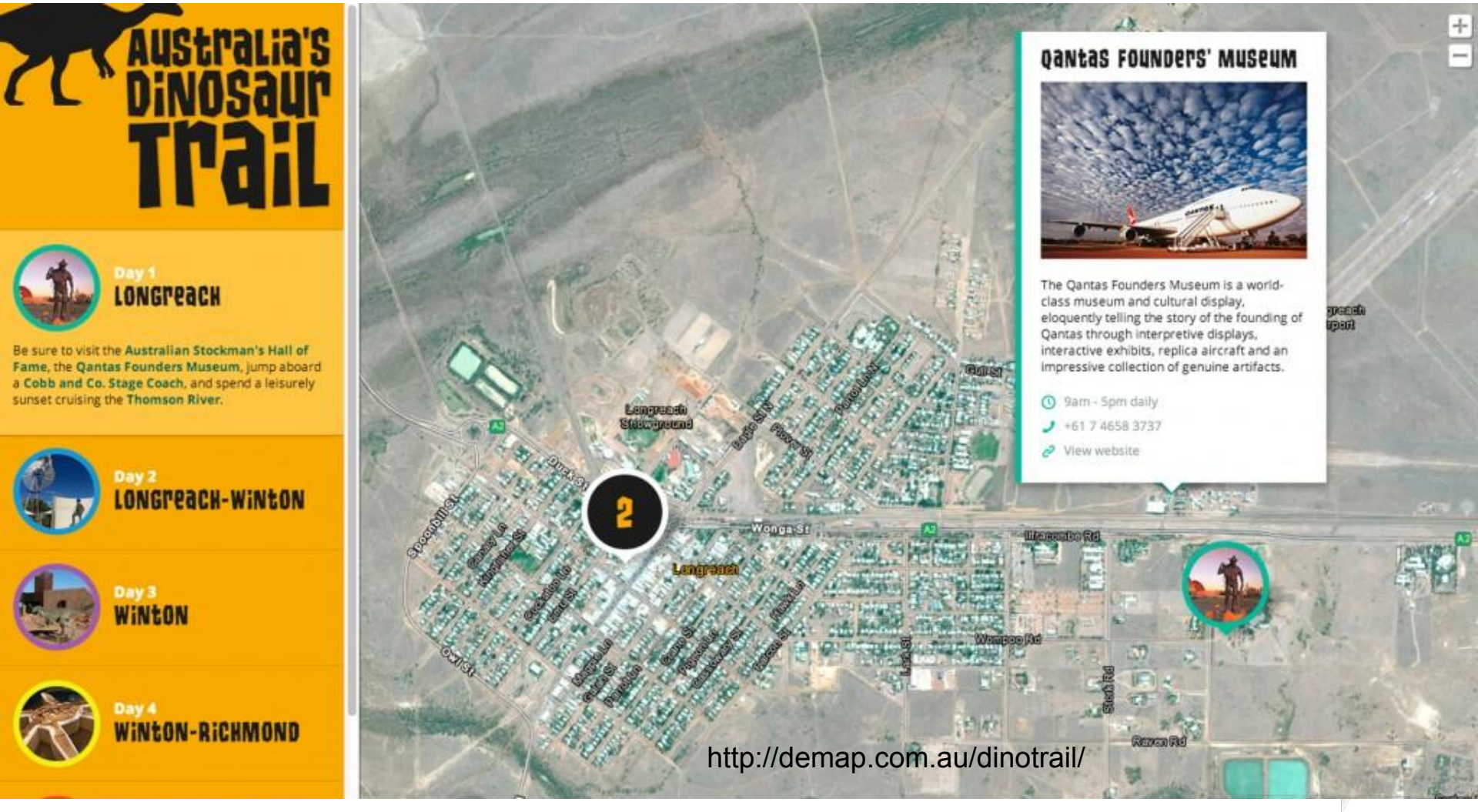
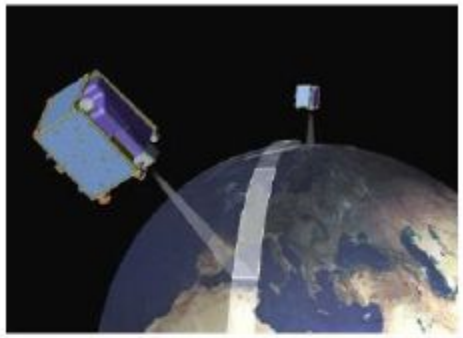
Dynamic Light

(GEO)DATA > INFORMATION > KNOWLEDGE > WISDOM

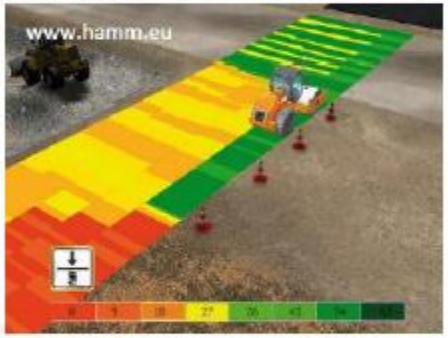


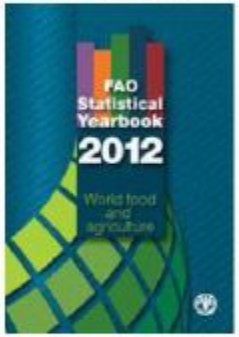
What is Geographic Information System (GIS)

GIS (GEO)DATA SOURCES to create a GIS










Creating a GIS...

Why create your own GIS?

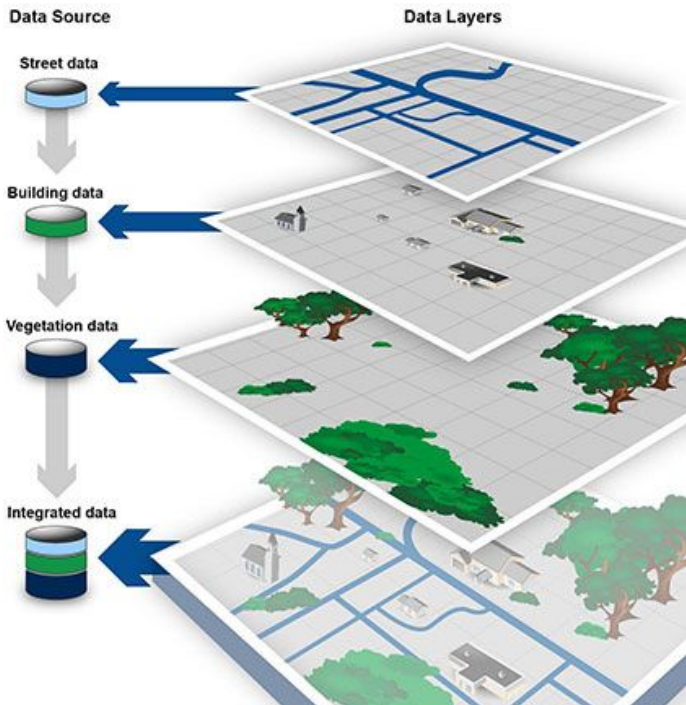
1. Need to organize geospatial data

2. Data you need is on a paper map and needs to be converted to a digital format.

3. Data available is at a different scale than you need.

4. Data need to be accessed /used by multiple people at the same time.

...and many other reasons.



Creating a GIS...

TWO TYPES OF DATA SOURCES

HARDCOPY

DIGITAL

Each of these data sources have their own positive and negative aspects as a way to store / display information.

Creating a GIS...

TWO TYPES OF DATA SOURCES

HARDCOPY

- stable
- does not require hardware/software to use
- portable / tangible
- familiar to many users/audiences
- easily transferable
- not easily updatable

DIGITAL

- stable
- flexible
- easily updatable
- not portable without a device
- requires hardware/software to use them
- may be tied to specific hardware / software that may change over time

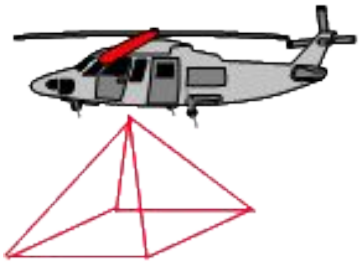
Creating a GIS...

GIS DATA SOURCES

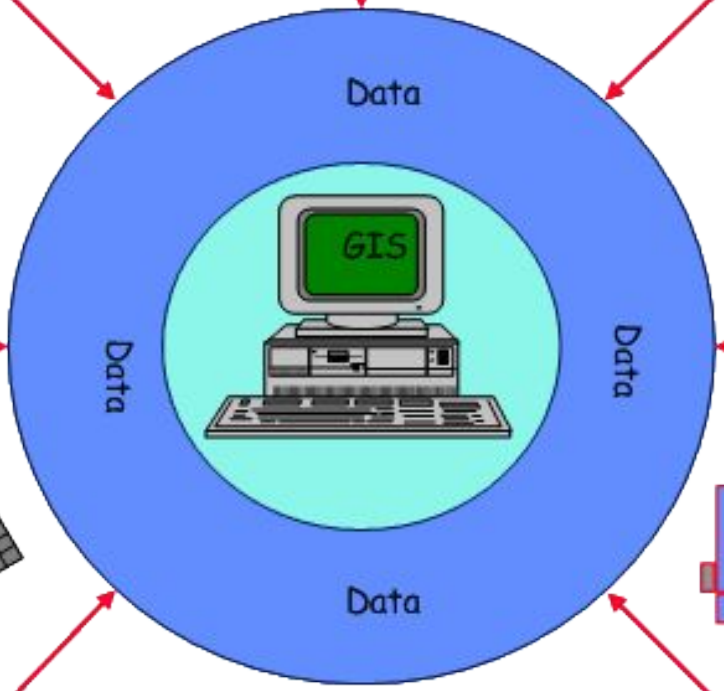
Digital data

Maps and Plans

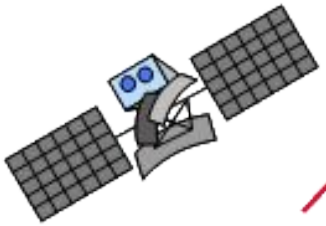
Paper files



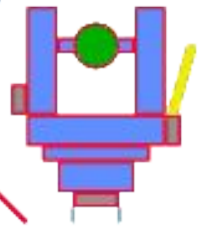
Photogrammetry



Interviews



Remote Sensing



Field survey

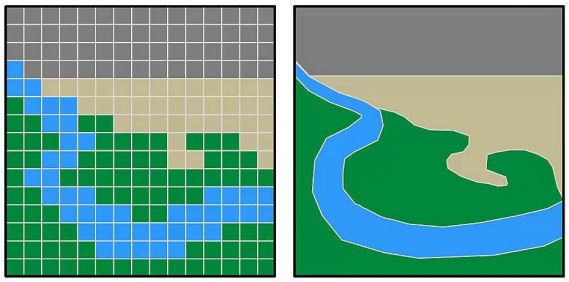
Creating a GIS...

GIS DATA SOURCES

PRIMARY: - geographic data sources which are **collected** (obtained as a result of direct measurements) specifically for use in GIS

SECONDARY: - already **existing** data, e.g. in analogue or digital format
- they are digitized or **processed** into GIS tools and reuse

THE WORLD can be represented in two ways:



RASTER VECTOR

Classification of geographic data for data collection purposes		
	Raster	**Vector**
Primary	- Digital remote sensing images - Digital aerial photographs	- GPS measurements - Survey measurements
Secondary	- Scanned maps of photographs - Digital elevation models from maps	- Topographic maps - Toponymy (placename) databases

Source: Longley et al., 2001. *Geographic Information Systems and Science*, Chichester: Wiley.

Geospatial Data Models

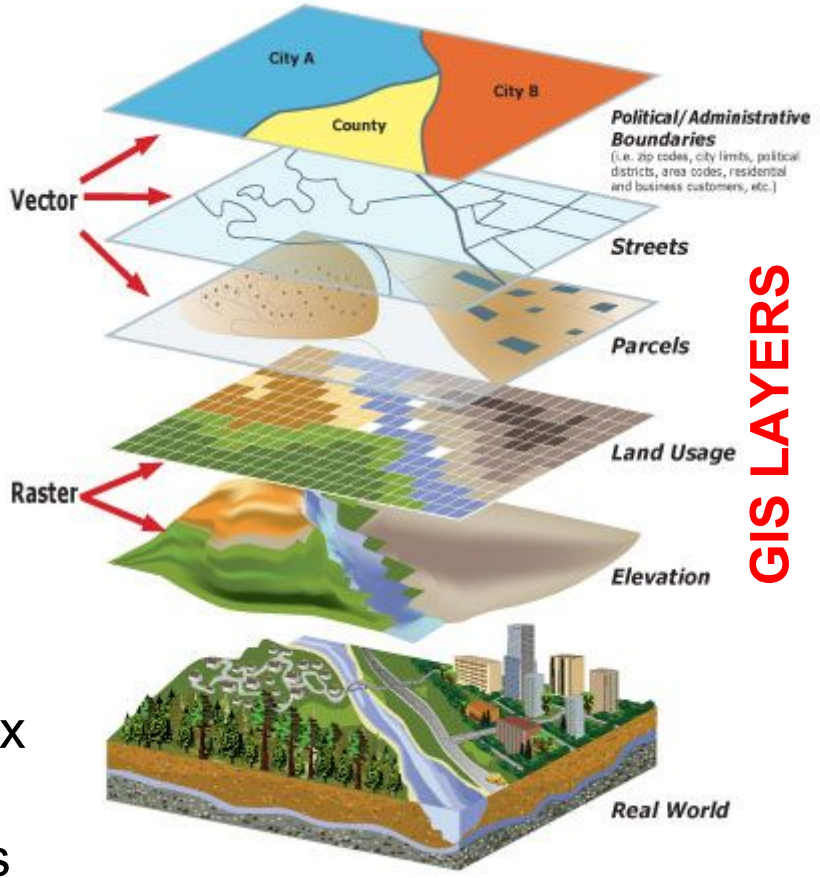
A **data model** is a way of defining and representing **real world surfaces** and characteristics in GIS.

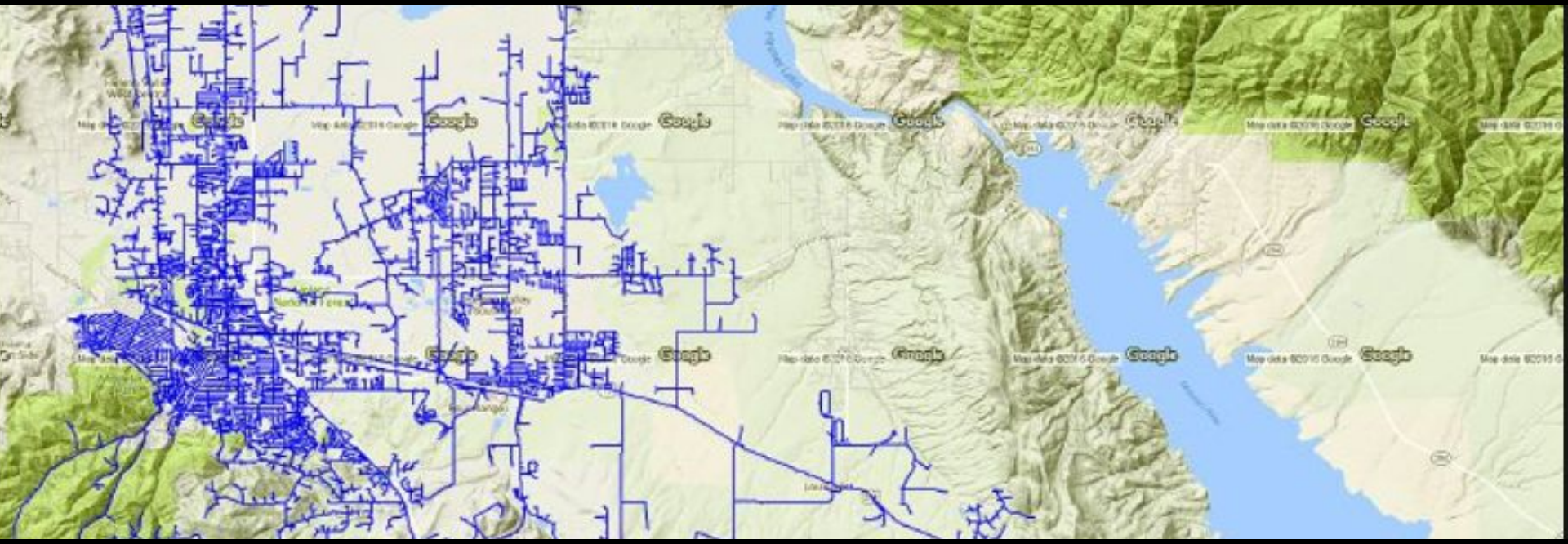
There are **two primary types** of spatial data model:

- **Vector** data represents features as discrete points, lines and polygons
- **Raster** data represents features as a rectangular matrix of square cells (i.e. images)

The modern literature on GIS includes also **other spatial data model**:

- **TIN** data represent surfaces as an approx of reality using connected triangles
- **3D models**, which represents 3D objects using a combination of different primitives





Geospatial Data Models - Vector

Vector data is very common, and is often used to represent **light poles**, **roads** and **boundaries.** They represent geographic features as **points**, **lines**, and **polygons.**

Types of Vector Data

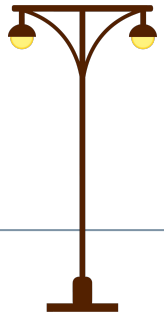
12° 14' 35.34" E, 44° 08' 20.76" N

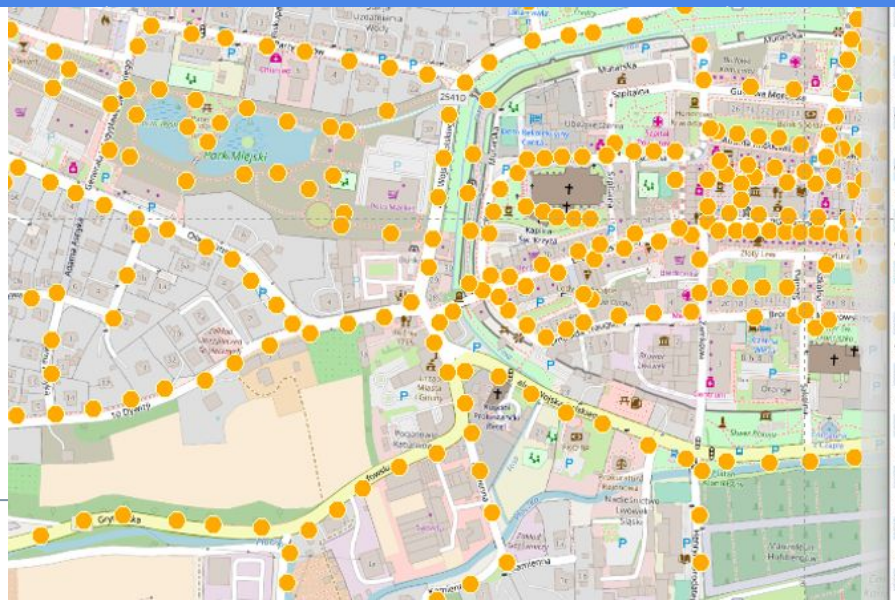
Example: street light poles, pylons, restaurants, etc.

POINTS

- one pair of coordinates defines the location of a point feature

- individual X,Y





oprawa	SGS
moc	100W
mocowanie_	na wierzchooku
szeroko_j	6
typ_lini	kablowa
odlego_su	2
wysoko	8
nawierzch	asfalt
kategoria	droga
wysignikhl	0/1
kat_wysie	5
kat_oprawy	0
chodnik	po obu stronach jezdni
typ_opraw	
numer_lic	
uwagi_dod	
changed	2017-06-30-18-04-36
pictureFo	
pictureNa	
picturePa	
created	2017-06-30-18-01-38
altitude	253.0509
accuracy	12.0

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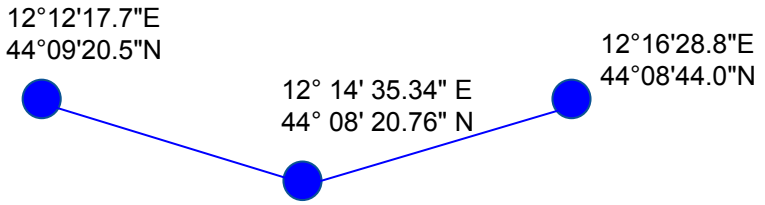
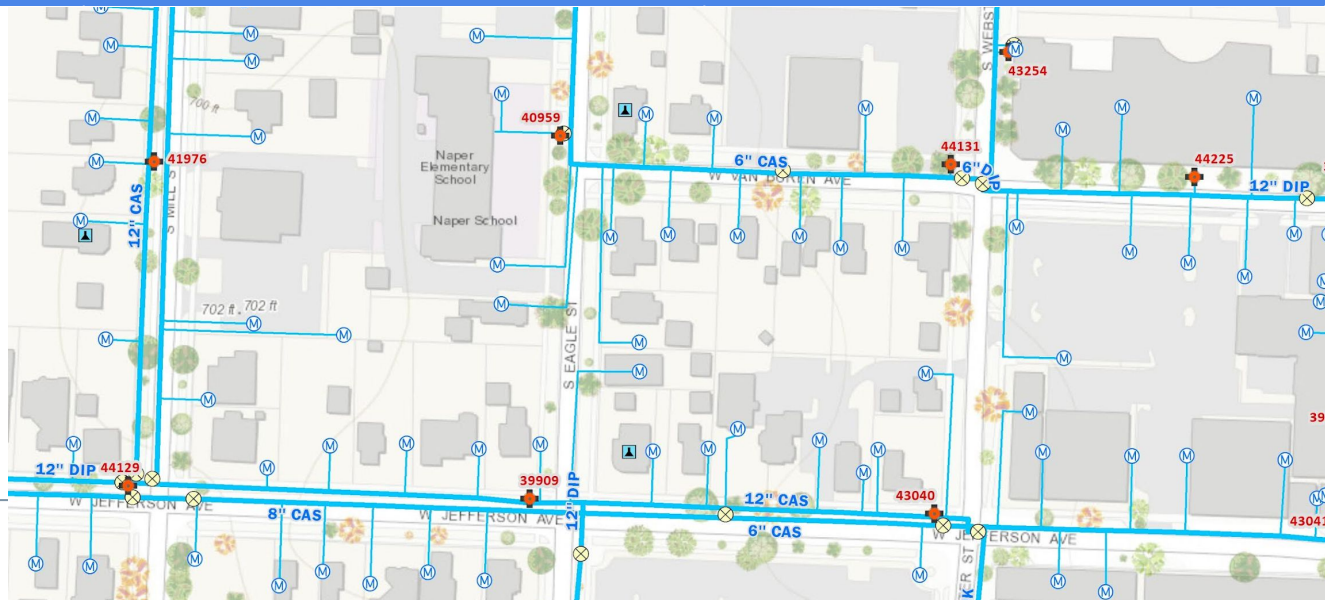


Example: power lines, railways, etc.

POLYLINES

- two or more pairs of coordinates that are connected define a line feature

- a series of connected points actually, a set of series of connected points.



Geospatial Data Models - Vector

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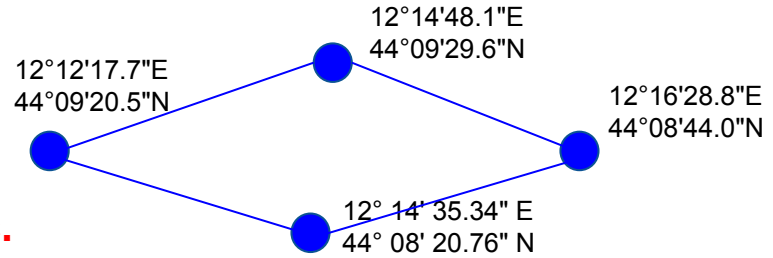


Types of Vector Data

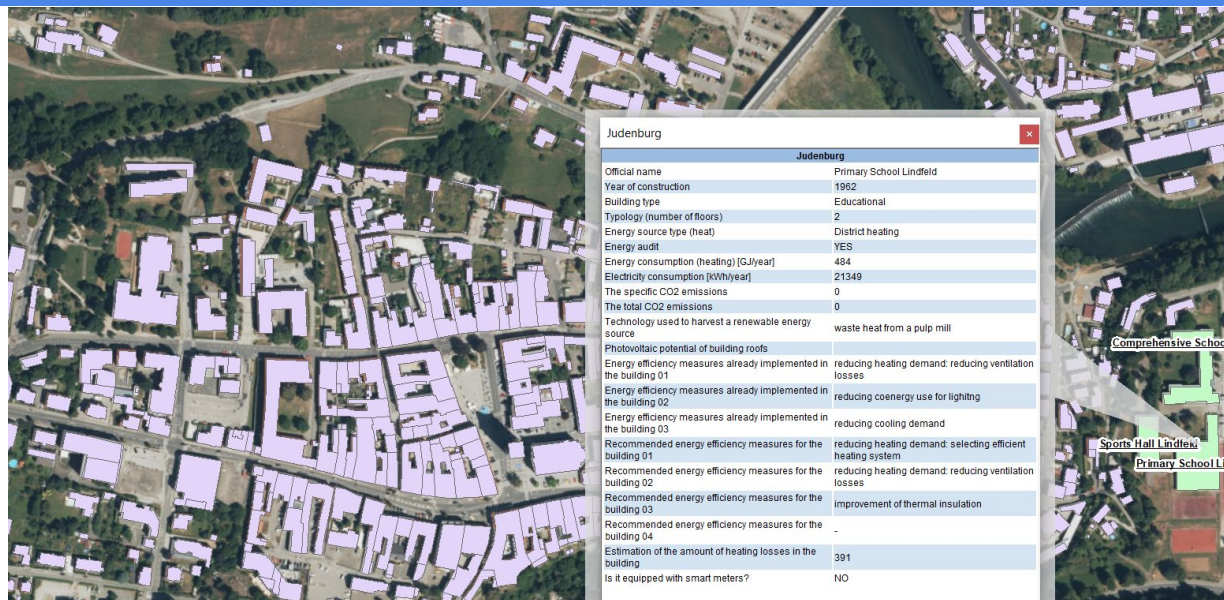
Example: building footprints, green areas, etc.

POLYGONS

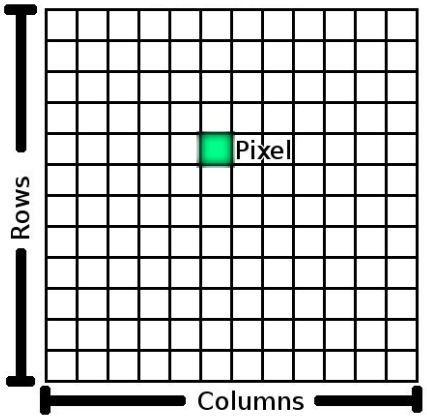
- multiple pairs of coordinates that are connected and closed define a polygon feature.

- a series of connected points that loop back to the first point

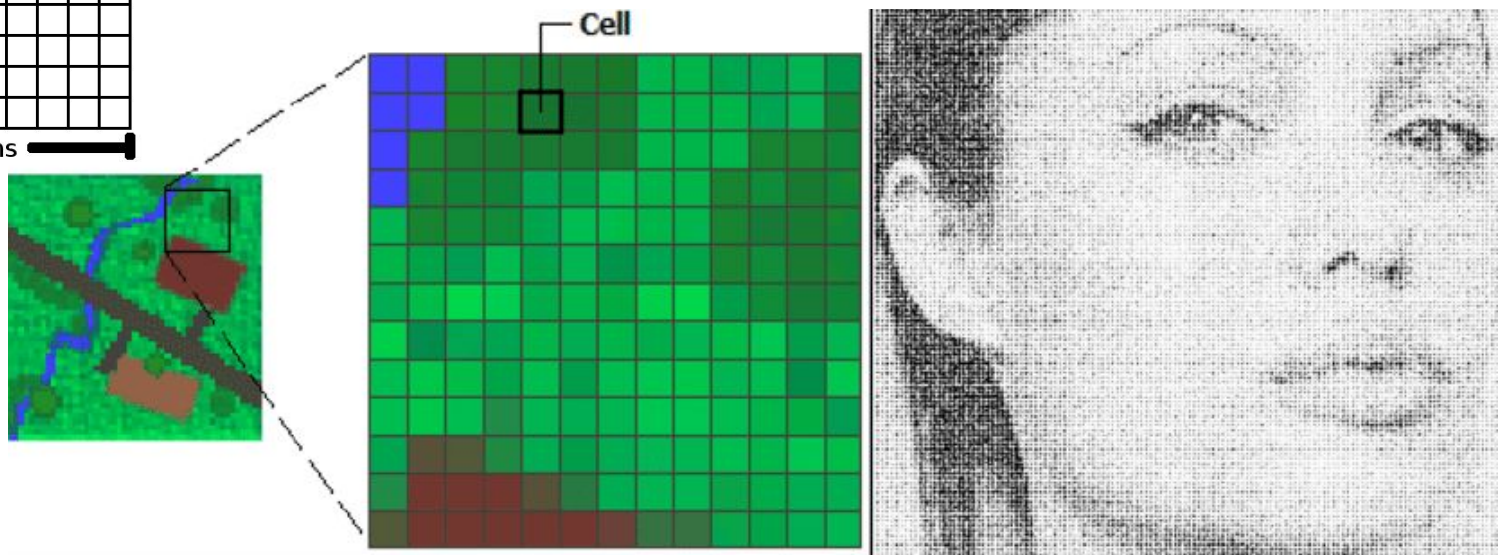
- the beginning and ending coordinates for a polygon are the same.



Geospatial Data Models - Raster



Raster data models **represent surfaces** as a **matrix of cells or pixels that are organized into rows and columns (or a grid).**

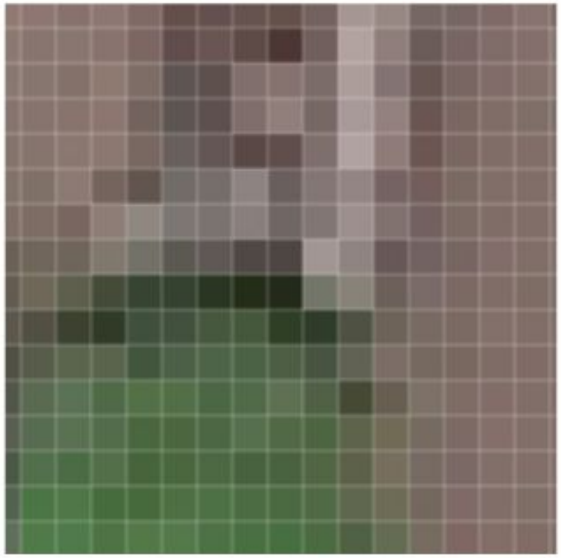


Each cell/pixel **contains a value representing data** (e.g. information such as temperature, height, PV potential, etc.).

Raster's are: orthophotos, satellite imagery or even scanned maps.

Geospatial Data Models - Raster

All raster images are made up of up of thousands (or millions) of individual "picture elements" or pixels.

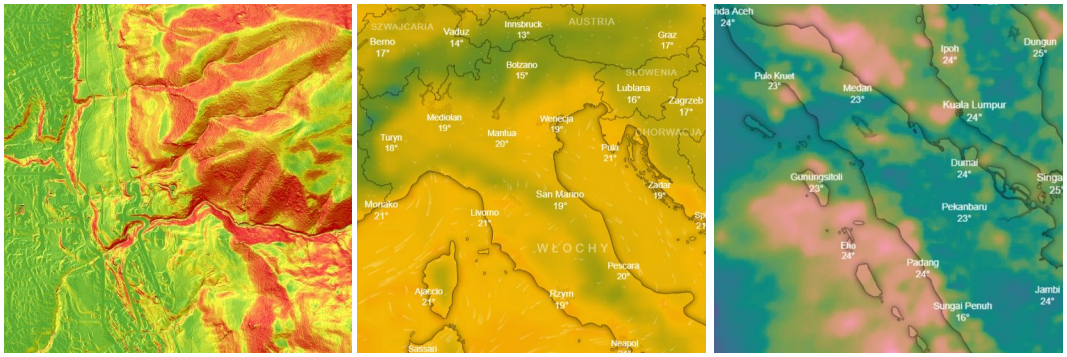


http://gsp.humboldt.edu

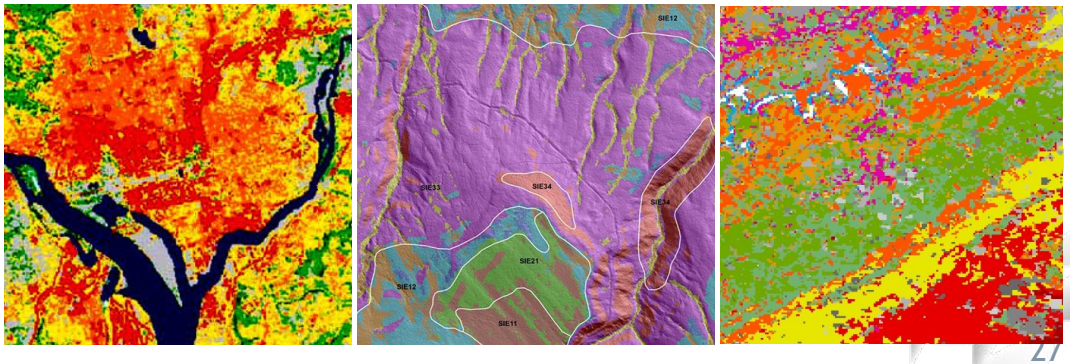
Types of Raster Data

Rasters can represent a wide variety of data.
The data can be **continuous** or **categorical**

- **Continuous Data:**
  - Elevation
  - Temperatures
  - Rainfall



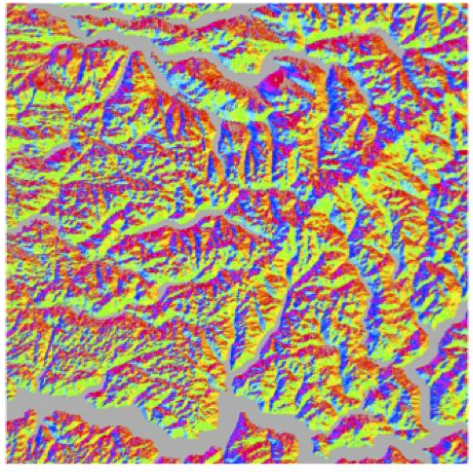
- **Categorical Data:**
  - Land Cover Type
  - Soil Type
  - Vegetation Type



Geospatial Data Models - Raster

Digital Elevation Model (DEM) representing the heights of a territory, at a certain resolution (e.g. 1m). This is a primary data source

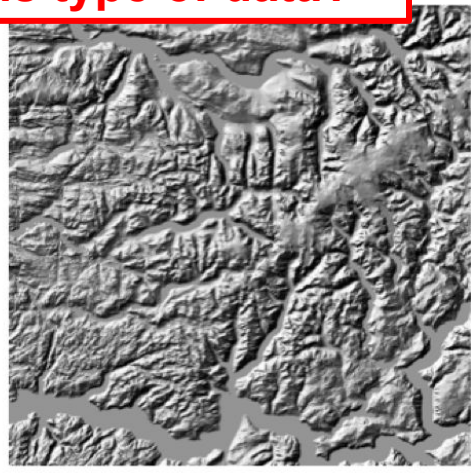
What can you do with this type of data?

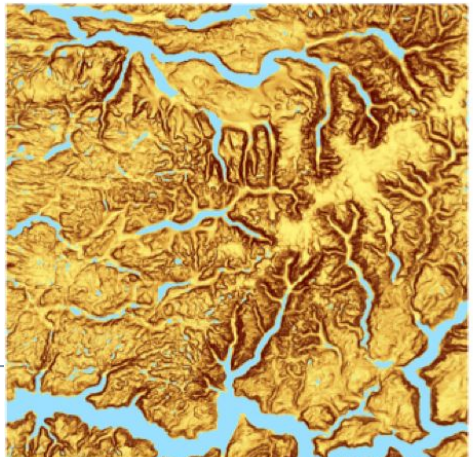


Aspect Map

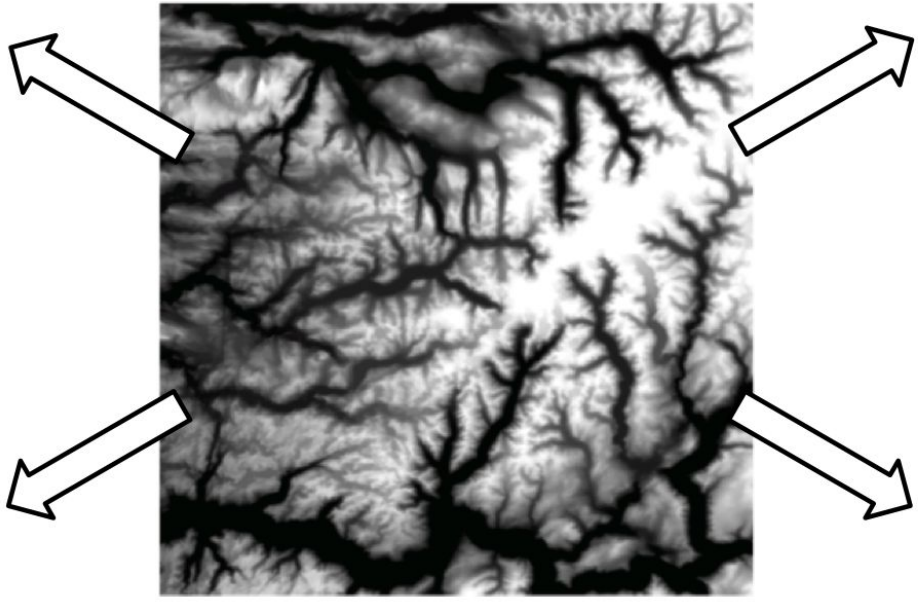
Digital Elevation Model (DEM)

Hillshade





Slope Map

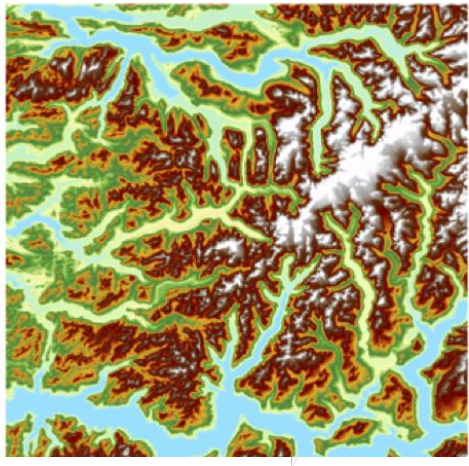


(Sognefjord, Norway -- 50 m)

source: data.kartverket.no / 50-m-utm-33

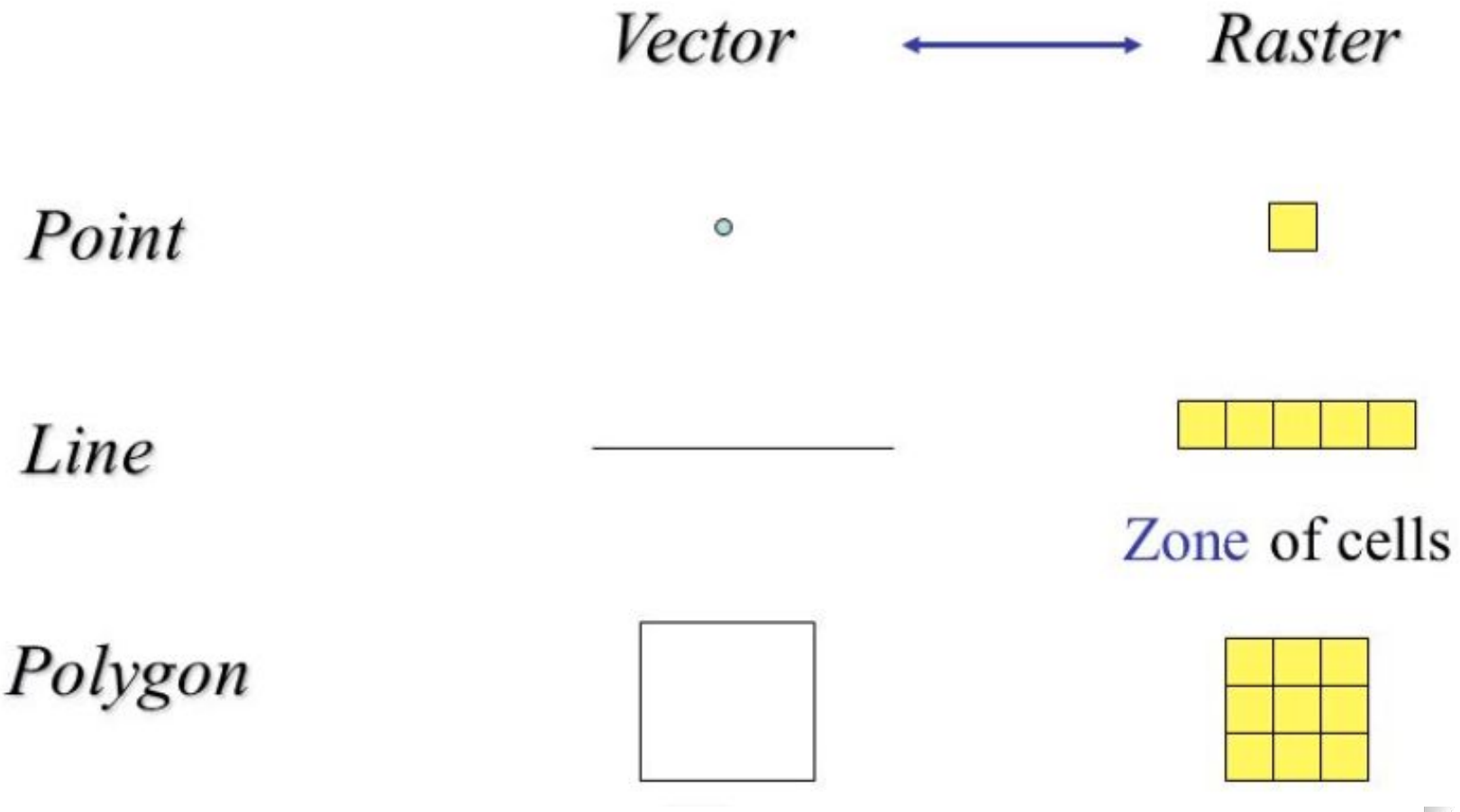
Hillshade

Elevation Tinted



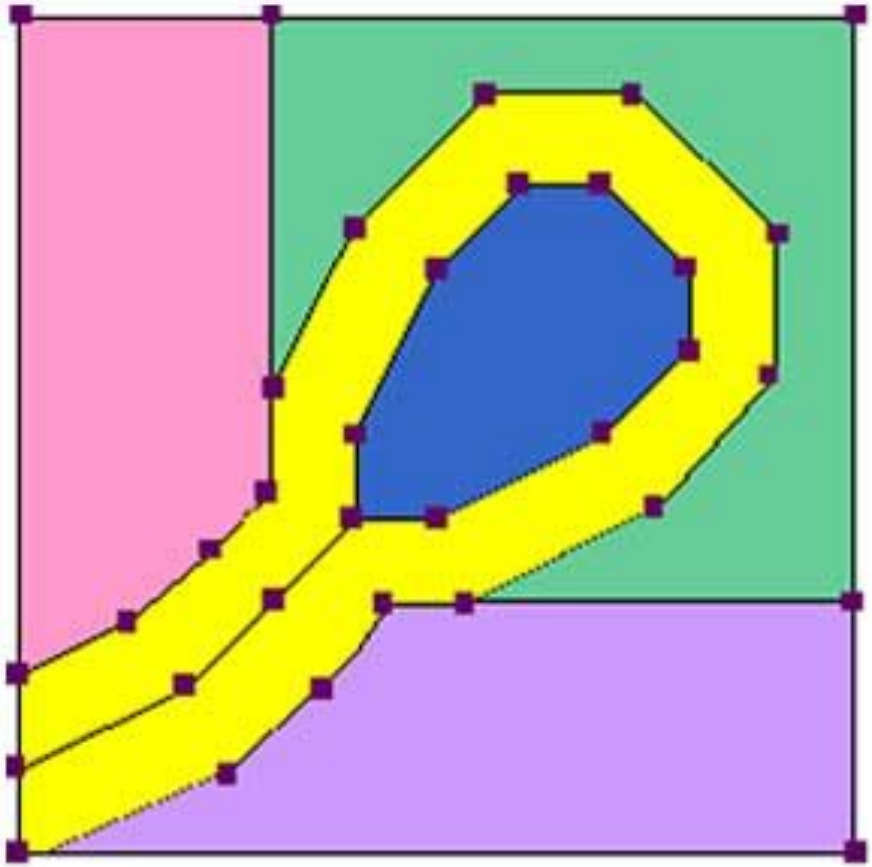
Geospatial Data Models - Vector vs Raster

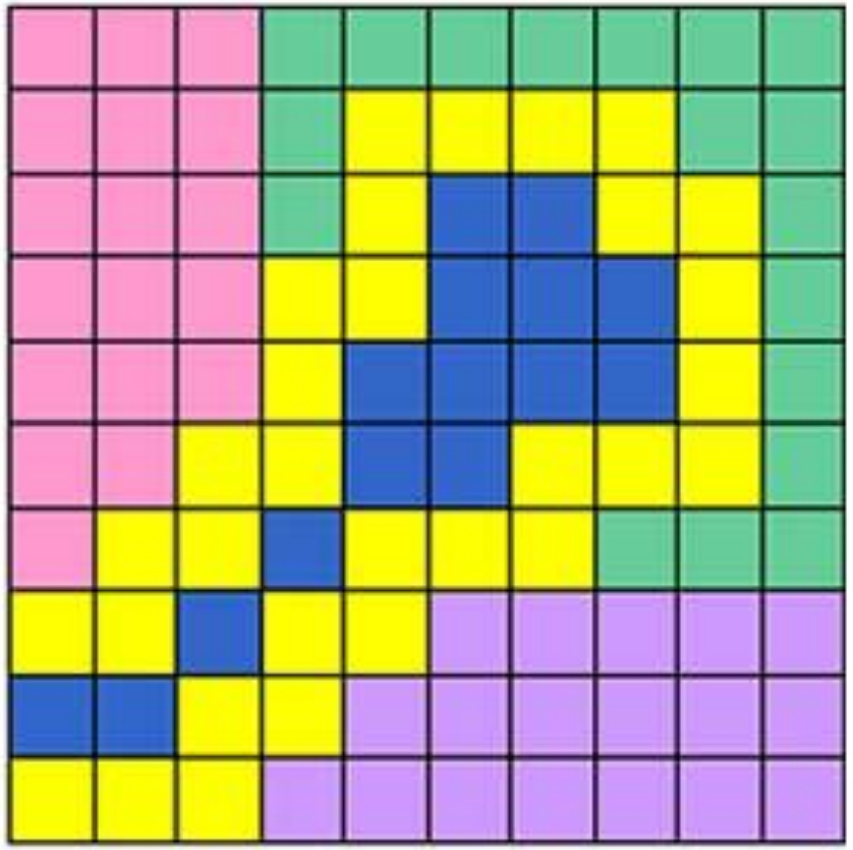
Raster data are described by a cell grid, one value per cell



Geospatial Data Models - Vector vs Raster

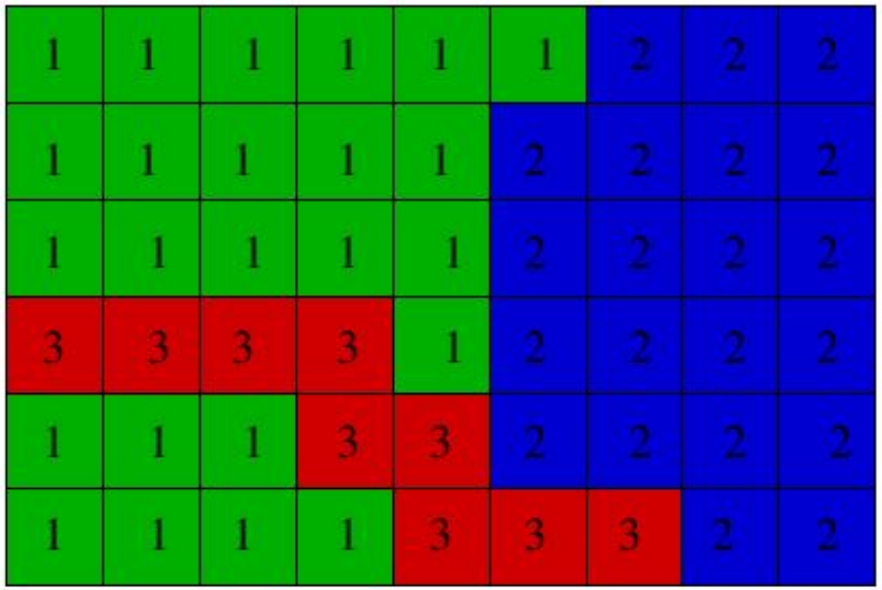
which one is vector and which one is raster?



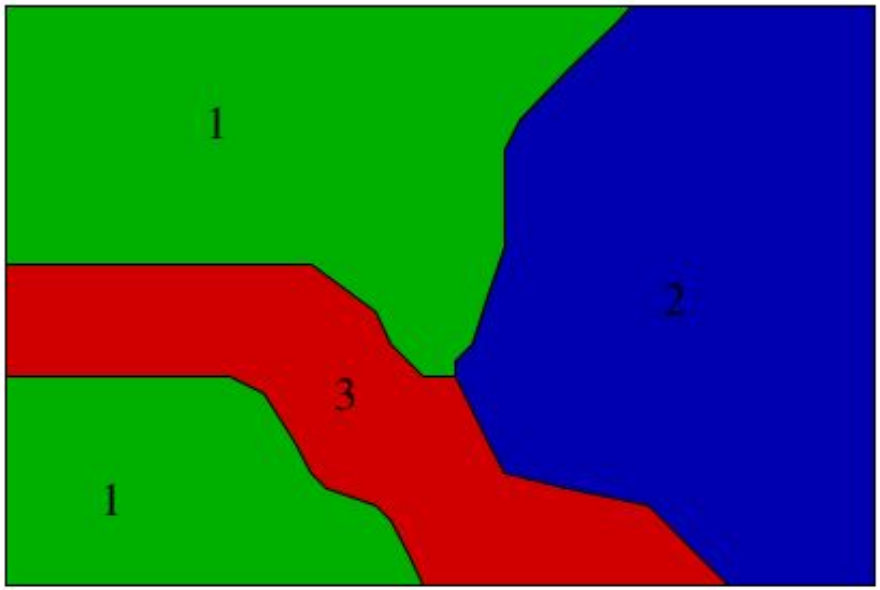


Geospatial Data Models - Vector vs Raster

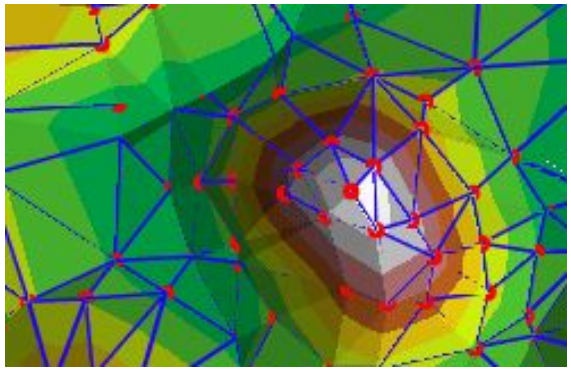
which one is vector and which one is raster?



1 = greenland 2 = water

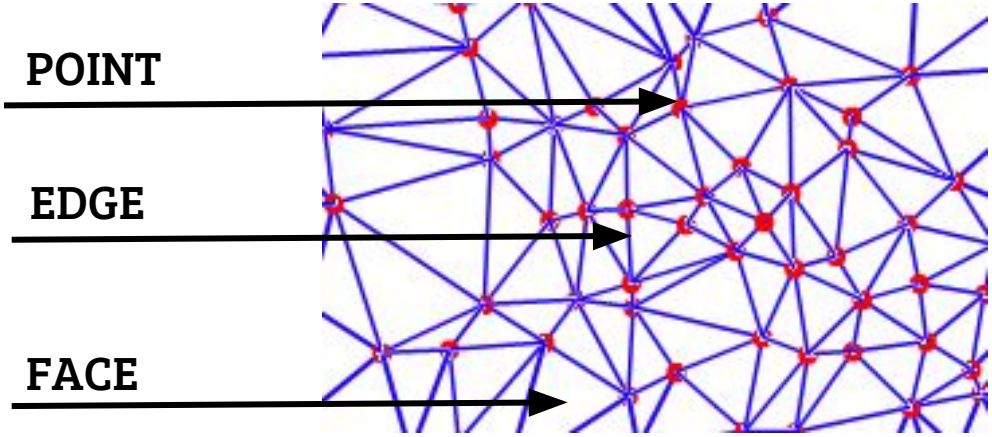


3 = urban area



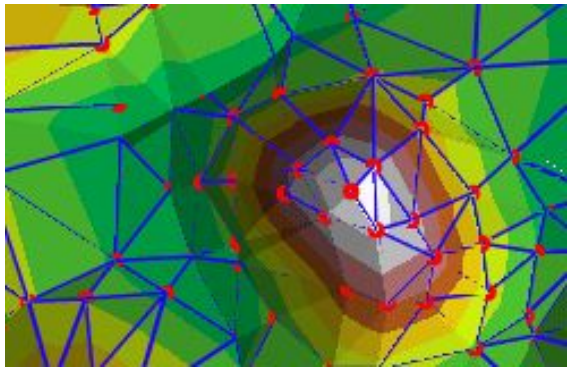
TIN (*Triangulated Irregular Network*) is a network of triangles connected together to create a 2.5D surface where the triangles in this network are not crossing.

Anatomy of a TIN



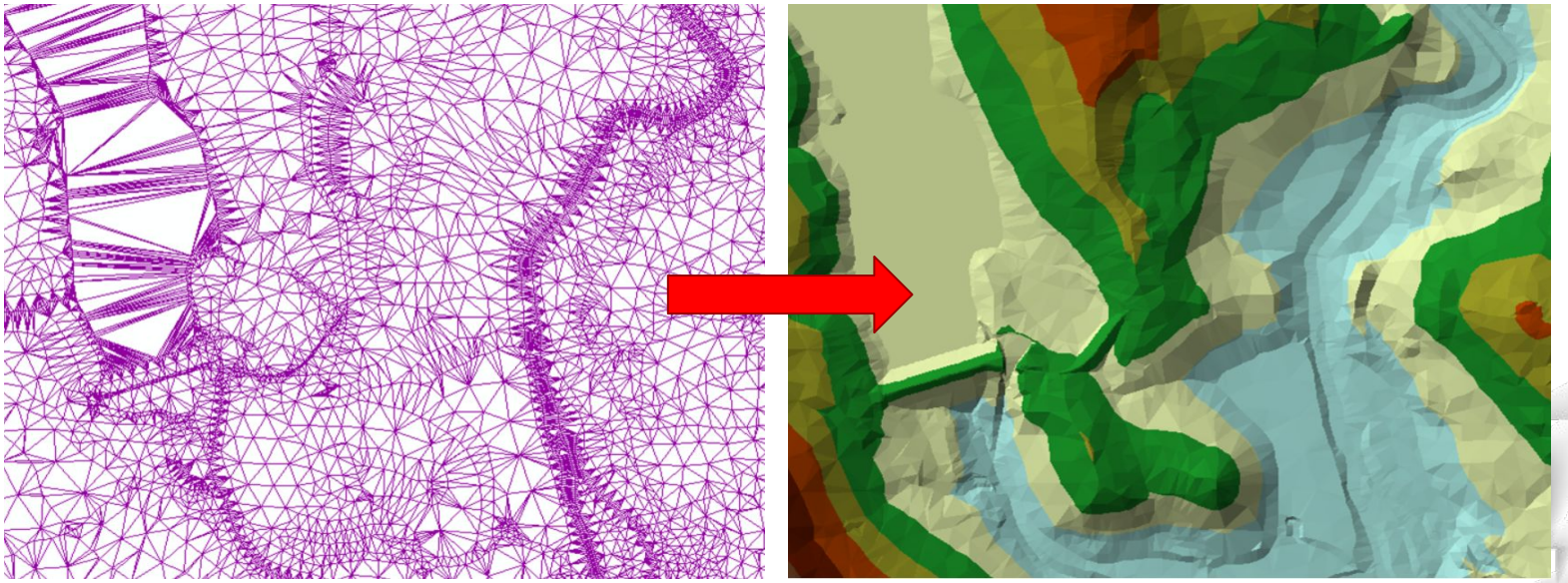
- **TIN:**
  - more complex than rasters
  - easily represent geometric and density changes with smoother transitions wrt rasters

Geospatial Data Models - TIN Data Models

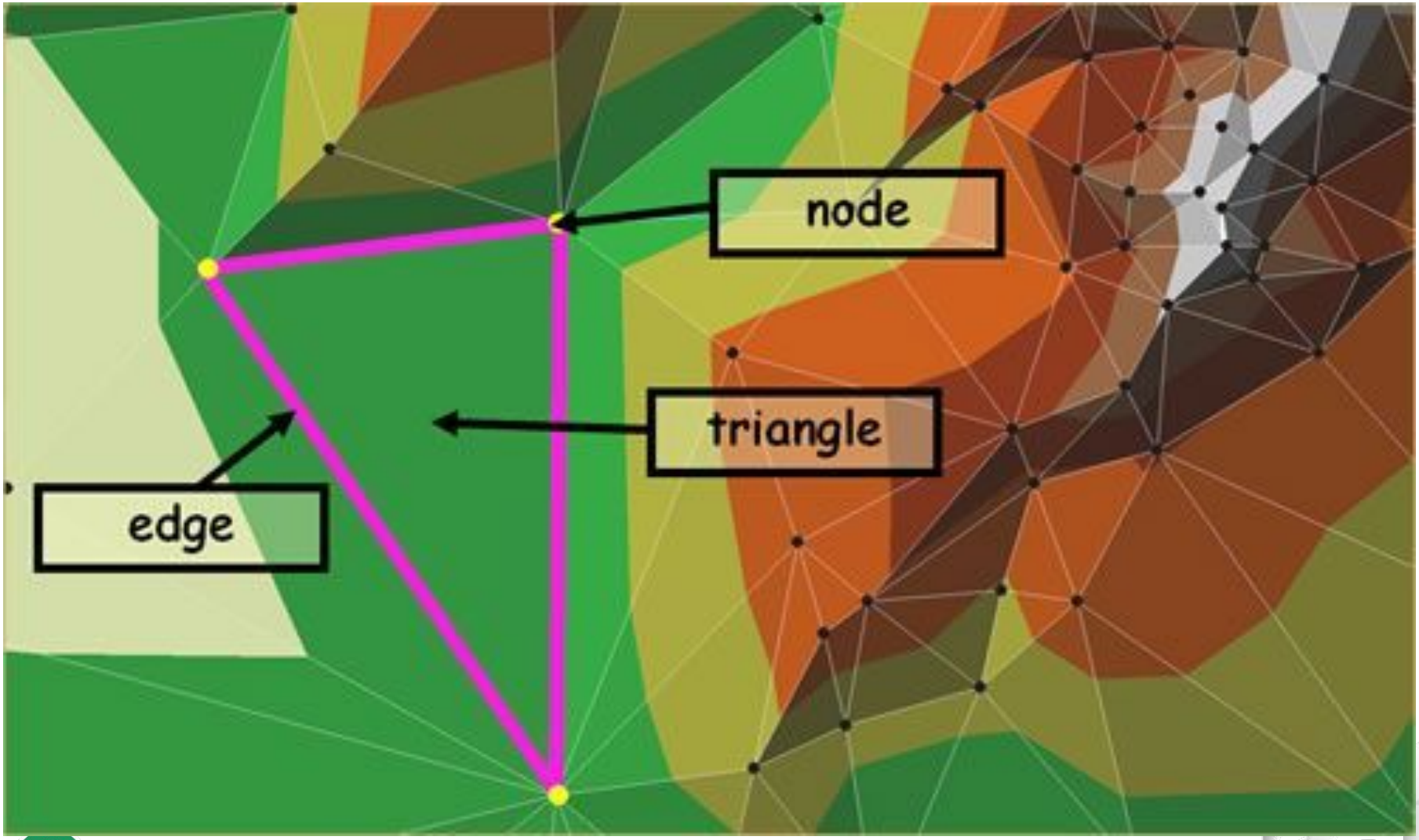


TIN (*Triangulated Irregular Network*) is a network of triangles connected together to create a 2.5D surface where the triangles in this network are not crossing.

Applying Colors based on the **elevation value**, help understand what TIN is representing.



Geospatial Data Models - TIN Data Models



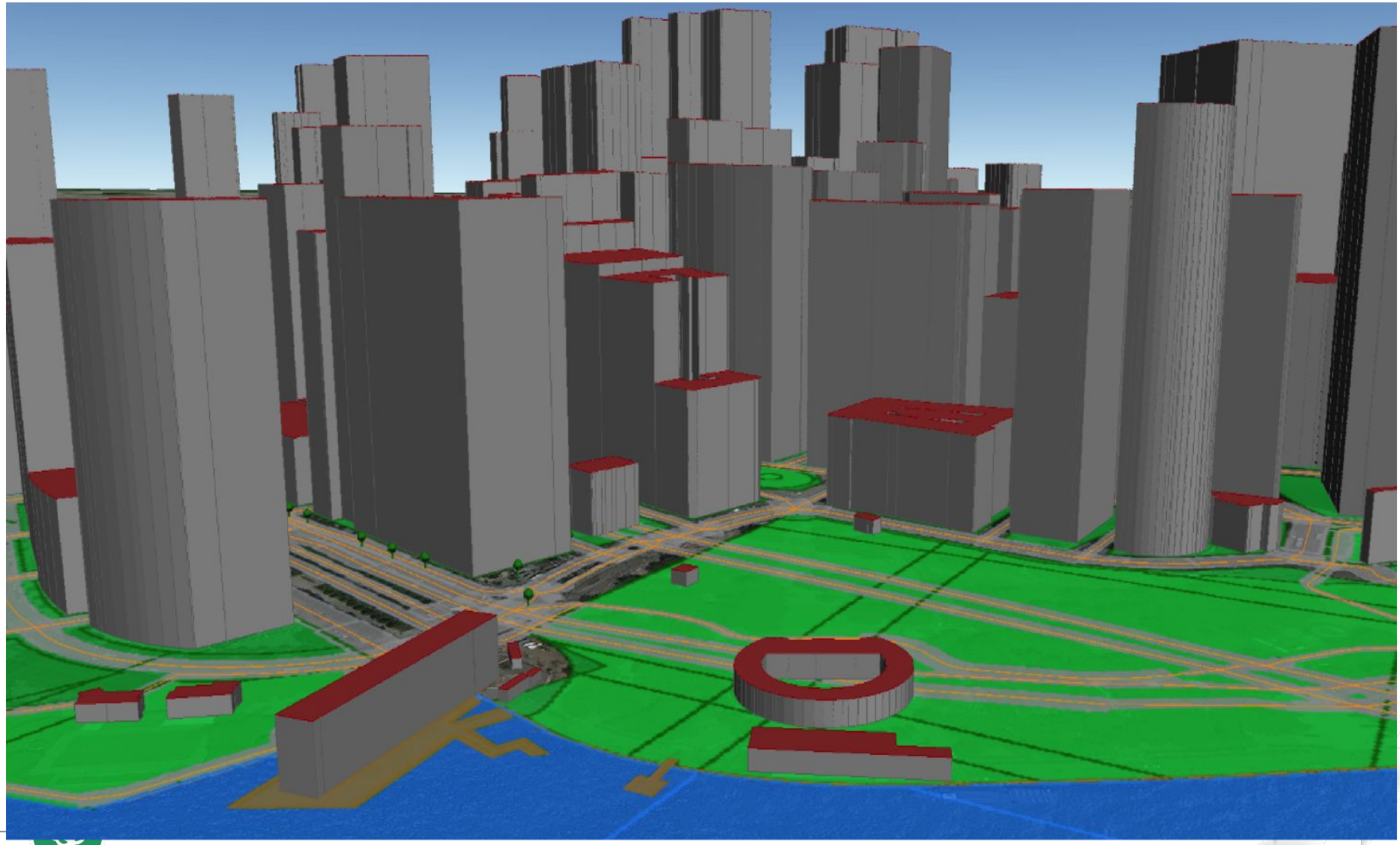
Geospatial Data Models - 3D Models

3D data model use a combination of geometric primitives to represent reality with 3D object. Attributes include positions, shape and size, beside textual and numerical information.

3D objects includes various geometric primitives and can be represented using different models, among:

- 3DFDS (Format Data Structure): the basis objects of the model are Body, Surface, Line and Point while the geometric elements are Node, Arc, Edge and Face.
- SSM (Simplified Spatial Model): it includes two geometric elements (Nodes and Face) and four basic objects (Point, Line, Surface and Body)
- UDM (Urban Data Model): it has four basic objects (Point, Line, Surface, Body) and two geometric elements (Node and Face)
- 3DTIN, OCTREE, CityGML, etc.

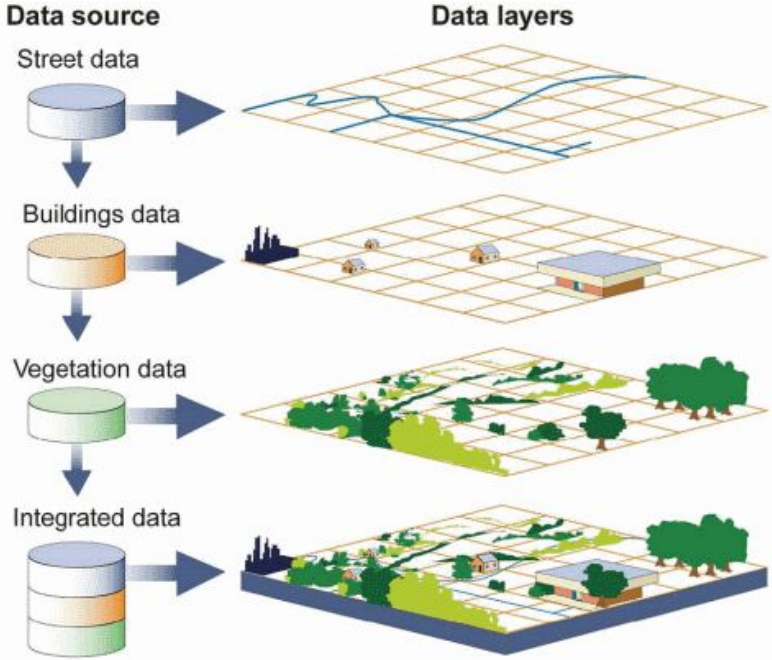
Geospatial Data Models - 3D Models

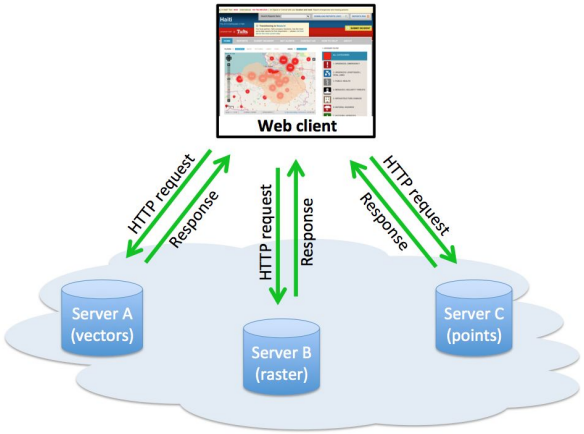


Geospatial Data Models - Offline vs Online

Data can be loaded and visualized into GIS environment from:

- local hard-disc of your computer
- a remote server thru specific protocols:
  - **WMS** (Web Map Service) which provides georeferenced map images,
  - **WFS** (Web Feature Service) which provide vector data
  - **WCS** (Web Coverage Service) which provides raster data.



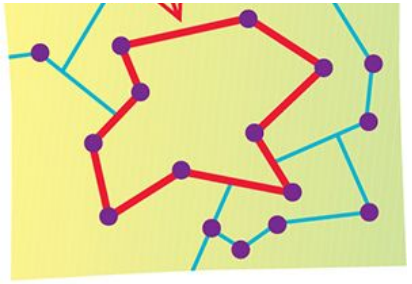


Geospatial Data Models - Object & Attributes

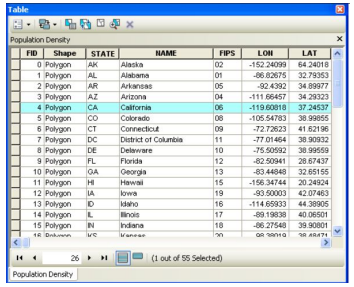
A geospatial data model is composed of two parts:

OBJECT and ATTRIBUTES

Object



Attributes

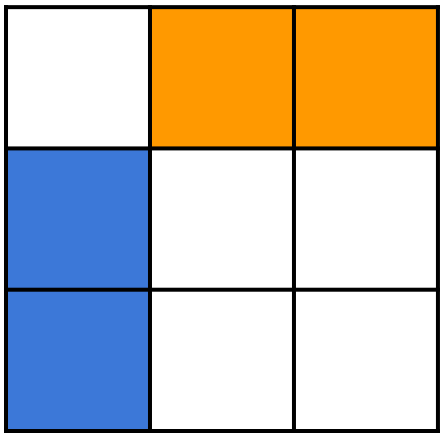


The object stores the geometry of the spatial phenomena that we are representing / modeling (e.g. a polygon a vector, a point, a raster).

The attribute stores the descriptive information related to the object part of the geospatial data model.

Reality

Geospatial Data Models - Attributes



Attributes are the non-spatial characteristics that describe spatial entities; are commonly arranged in tables.

Row = 1 entity of the what we are representing (e.g. a light pole in a street)

Column = 1 attribute (e.g. the height of the pole)

	xcoord	ycoord	ID	ID_pole	switchboar	fixtures
1	15.691667000000...	51.117381000000...	punkt 362	362	Bielanka SO-1	1
2	15.691115999999...	51.117297000000...	punkt 363	363	Bielanka SO-1	1
3	15.695456000000...	51.116553000000...	punkt 360	360	Bielanka SO-B	1
4	15.689043000000...	51.117167000000...	punkt 366	366	Bielanka SO-B	1
5	15.696315999999...	51.116475999999...	punkt 359	359	Bielanka SO-B	1
6	15.692712999999...	51.116998000000...	punkt 361	361	Bielanka SO-B	1

Attribute data are stored in a row x column table

Geospatial Data Models - Attributes

Attributes can be split into **four different categories**:

- **nominal** provides descriptive information about the object such as: color, city name, plant type, etc; **may also be** images, movies, sounds.

Geospatial Data Models - Attributes

- **ordinal** attributes imply a **ranking** or **order** based on their values. Can be **descriptive text**, or **numerical**
  e.g. **high / low / medium** or **100 / 50 / 1**

In either case, these ordinal attributes allow us to specify **rank only**, and not scale.

Example: ranking the taste of the potato chips on a scale from **1- 10.**

- **interval** attributes imply a **rank order** and **magnitude** or **scale** and use numbers, however those numbers do not have a natural zero.

Example: calendar dates, temperatures in Celsius or Fahrenheit.

- **ratio** attribute implies **both rank order** and **magnitude** about a natural zero. Uses numerical attributes and addition, subtraction, multiplication, and division makes sense, as the values are absolute from a natural zero.

Example: monetary quantities, age, mass, length, rainfall.

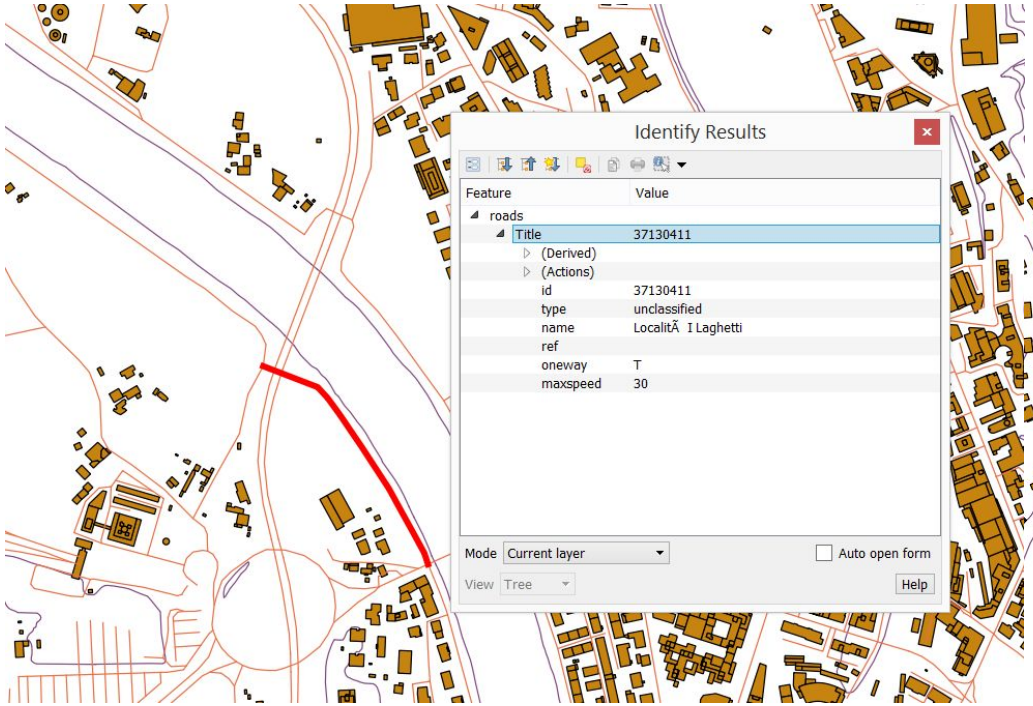
Geospatial Data Models - Attributes

Attributes can be stored using **different type of representations:**

- **integer** is a **whole number**, such as the **number one**, the **number 2458**, and the **number -54**. Integers can be used for **mathematical calculations**, however, any resulting fraction of a whole number will be **rounded, or truncated.**
- **float or real** data type holds a **decimal number** such as the number 1.452, the number 254,783.1, or -845.157.
- **text or string** data type contains **characters** such as character “A”, the characters “GIS”, the characters “125 Main St.”, or the number “9”.
- **data** data type holds t**ime and date information** such as 12/10/2010, or 10/12/10, or **December 10, 2010.**
- **binary large object (BLOB)** a collection of binary data stored as a single entity. Blobs are typically **images**, **audio** or other **multimedia objects**.

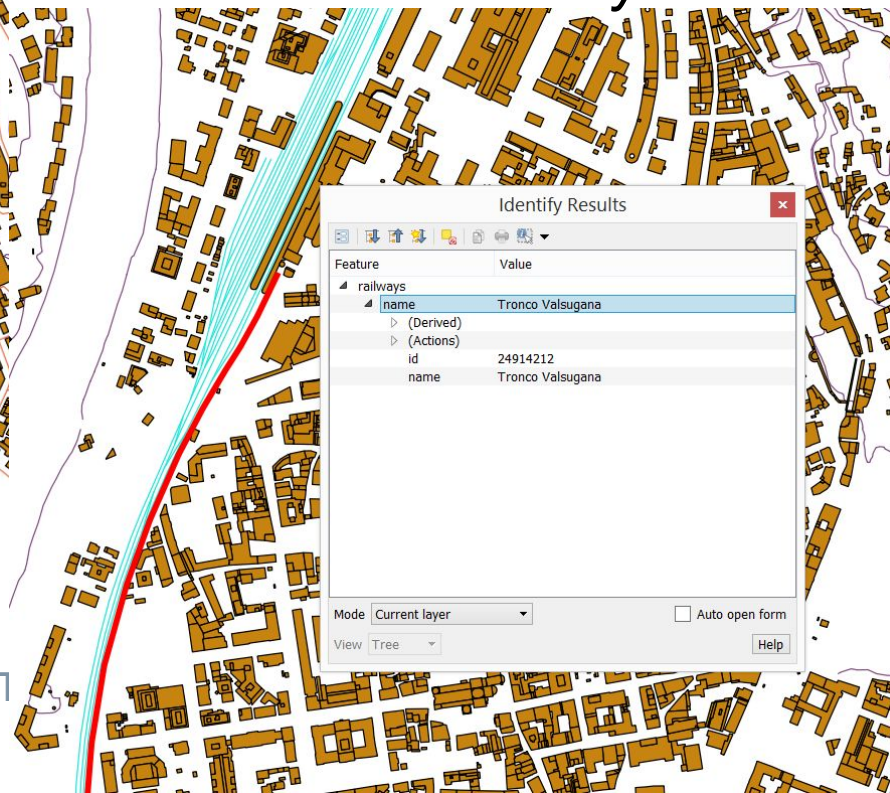
Geospatial Data Models - Attributes vs Databases

- A database is a collection of attribute tables
  - streets, railways and bike paths are vector data (type = polylines) with different attributes



streets

railways



Geospatial Data Models - Attributes vs Databases

- A database management system (DBMS) is an information system that people use to store, update and analyze non-geographic databases sharing a common attribute

Parcels feature class

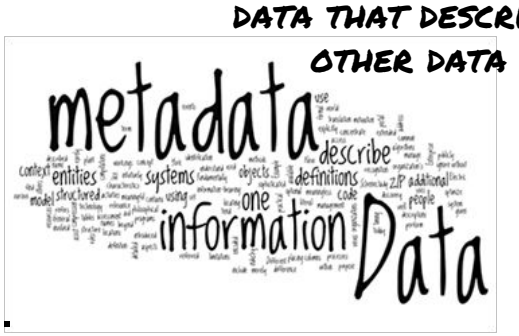
Shape	ID	PIN	Area	Addr	Code
	1	334-1626-001	7,342	341 Cherry Ct.	SFR
	2	334-1626-002	8,020	343 Cherry Ct.	UND
	3	334-1626-003	10,031	345 Cherry Ct.	SFR
	4	334-1626-004	9,254	347 Cherry Ct.	SFR
	5	334-1626-005	8,856	348 Cherry Ct.	UND
	6	334-1626-006	9,975	346 Cherry Ct.	SFR
	7	334-1626-007	8,230	344 Cherry Ct.	SFR
	8	334-1626-008	8,645	342 Cherry Ct.	SFR

Related ownership table

PIN	Owner	Acq.Date	Assessed	TaxStat
334-1626-001	G. Hall	1995/10/20	$115,500.00	02
334-1626-002	H. L Holmes	1993/10/06	$24,375.00	01
334-1626-003	W. Rodgers	1980/09/24	$175,500.00	02
334-1626-004	J. Williamson	1974/09/20	$135,750.00	02
334-1626-005	P. Goodman	1966/06/06	$30,350.00	02
334-1626-006	K. Staley	1942/10/24	$120,750.00	02
334-1626-007	J. Dormandy	1996/01/27	$110,650.00	01
334-1626-008	S. Gooley	2000/05/31	$145,750.00	02

Geospatial Data Models - Metadata

The **meta-DATA:**



- is an **identity card** of data,
- is the **documentation** of data,
- defines **who, what, when, where, why** and **how**.

- How, when, where, and by whom the data was collected.
- Availability and distribution information.
- Its projection, scale, resolution and accuracy.
- Its reliability with regard to some standard.

Why use and create metadata?

- To help organize and maintain an organization's spatial data.
- To provide information to other organizations to facilitate data sharing and transfer.
- To document the history of a spatial data set.

Geospatial Data Models - Metadata

Government authorities, businesses and citizens need
to easily share and use spatial data for making the right decisions about our environment and well-being in a timely manner

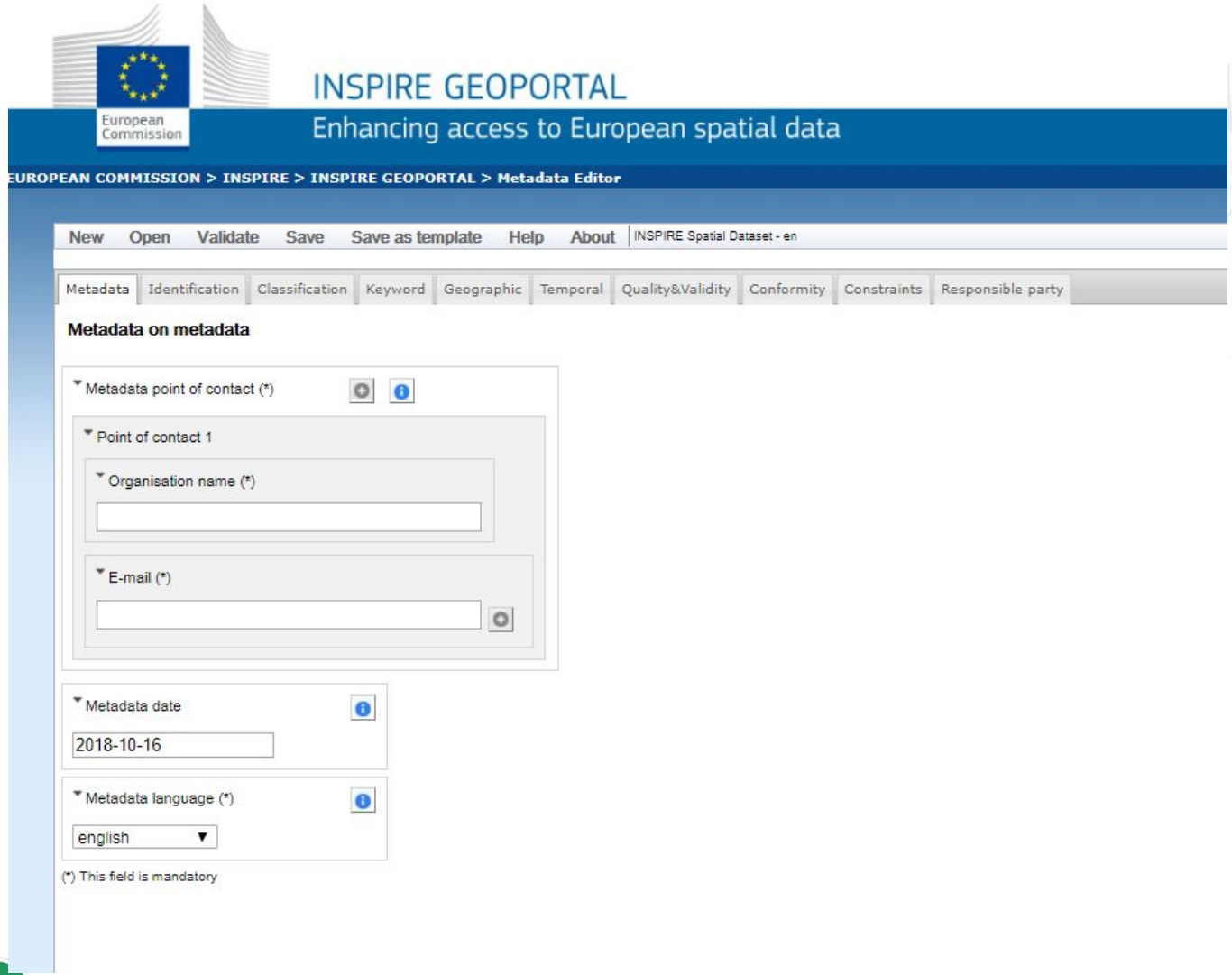
The **Infrastructure** for **Spatial Information in Europe (INSPIRE)** is a European Directive 2007/2/EC of 25/04/2007

Its goal is for an Internet-accessible infrastructure of technologies and permissions to tie European geospatial information producers and users together into a single geospatial information-sharing community to improve decision making and operations in service of a productive and sustainable Europe.

INSPIRE METADATA

INSPIRE hosts a **metadata catalog.**

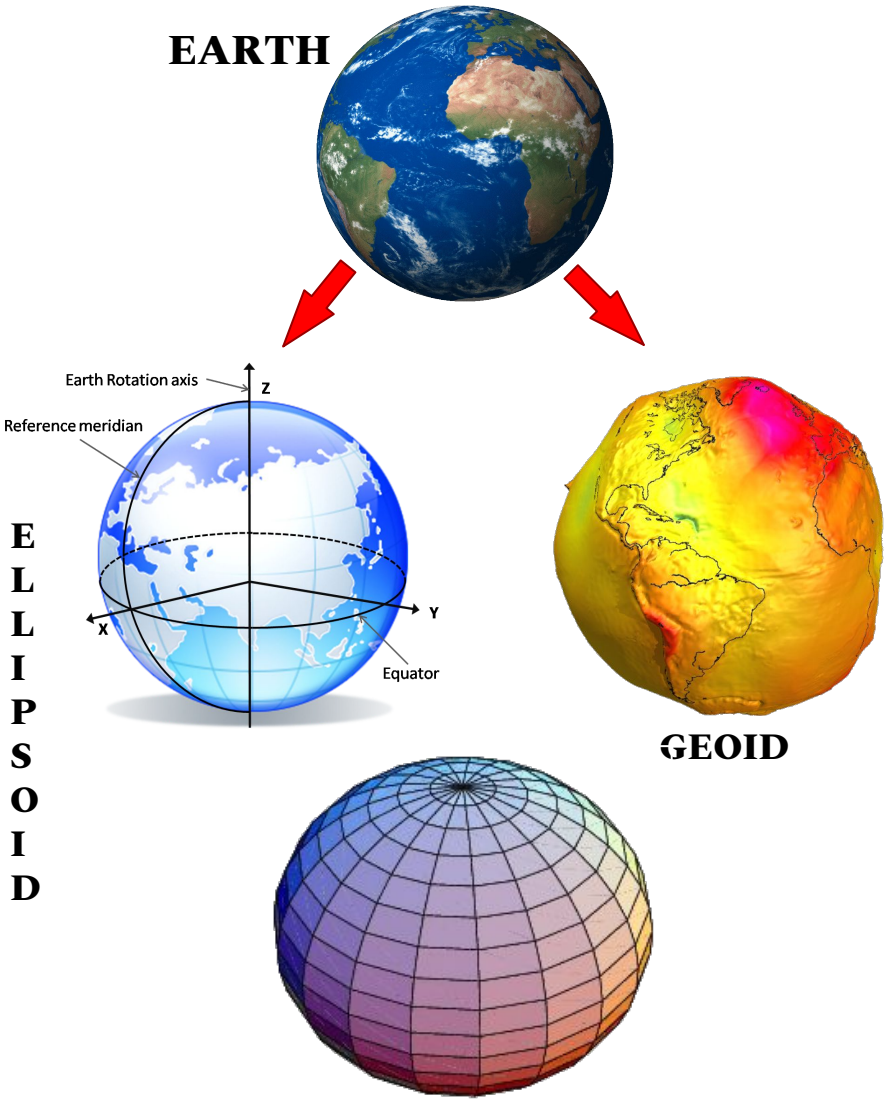
Geospatial Data Models - INSPIRE - Metadata



Coordinate Systems and Map Projections

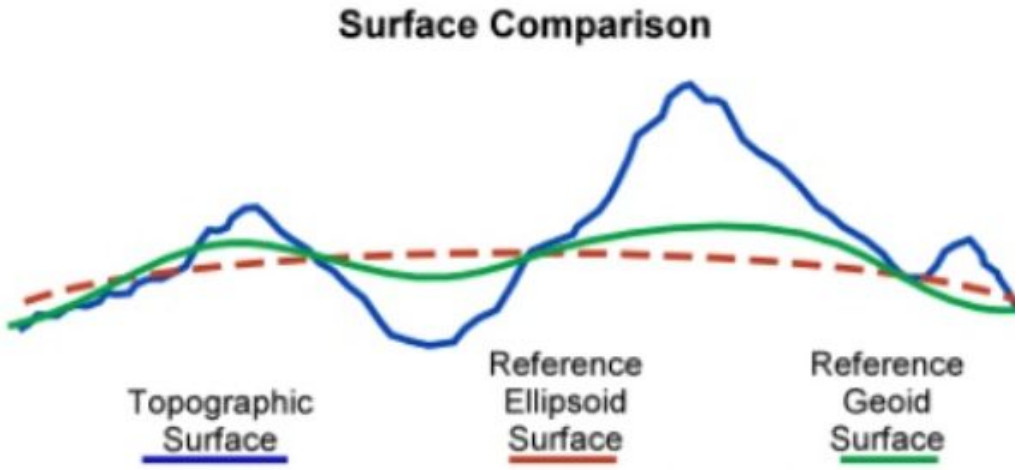
Interreg CENTRAL EUROPE European Union European Regional Development Fund
Dynamic Light

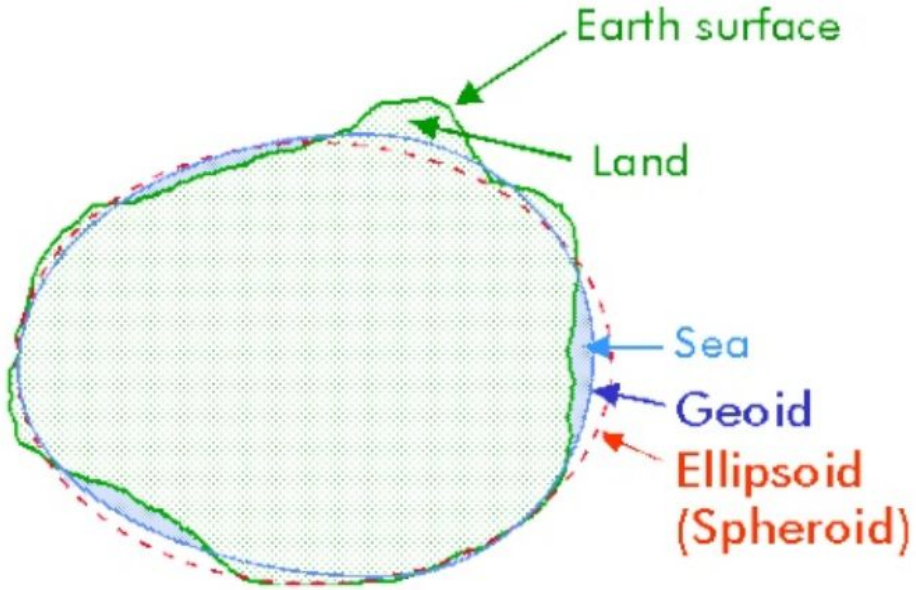
EARTH AND ITS SHAPE



- Earth is almost a sphere, **slightly flattened at the poles** and somehow **fat at the equator.**
- So, mathematically, the Earth is **not a sphere.**
- Mathematical regular shape: **Ellipsoid** i.e. a geometrical figure which would be obtained by rotating an ellipse about its **shorter axis**.
- Mathematical idealized and irregular representation: **Geoid**, i.e. a surface whose shape results from the uneven distribution of mass within and on the surface of Earth. Geoid is smoother than Earth's physical surface.

ELLIPSOID VS GEOID



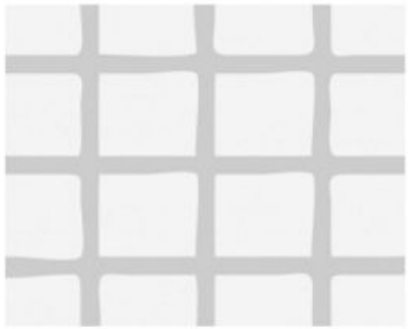


- The **reference ellipsoid** surface (a map of average sea level).
- The **reference geoid** surface- in continental areas, the reference geoid can be estimated as the level that would be taken by the surface of the sea in a set of criss-crossing canals stretching across the land from coast to coast. (a mean sea level surface).
- The **real surface** of the Earth (the ground) also called the **topographic** surface.

Coordinate Systems and Map Projections

To uniquely identify a point on Earth, we need to define a **coordinate system.** It lets us define where a location is in space.
In GIS, there are many types of coordinate systems, of which the two most used are **geographic (3D)** and **projected (2D)**.

Geographic (3D)



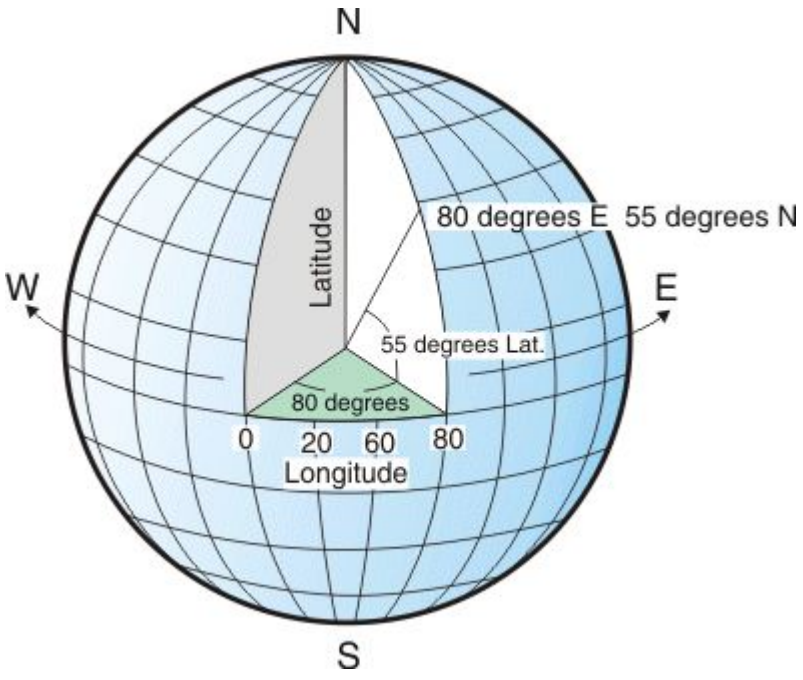
Projected (2D)

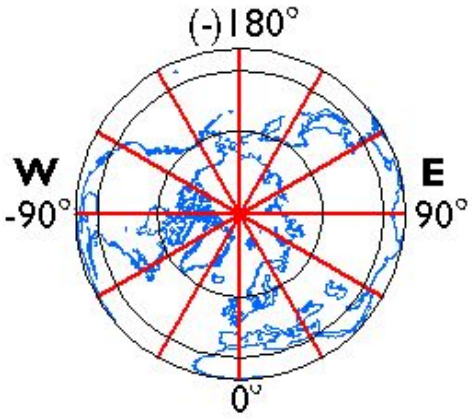
https://communityhub.esriuk.com

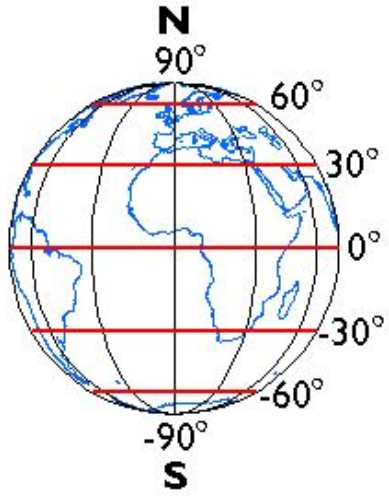
Geographic Coordinate System - uses **latitude** and **longitude** to represent the x, y position in space

Map Projection (Rectangular Coordinate System) - the transformation of the Earth's spheroid (real world) to flat surface (abstraction)

Geographic Coordinate System (GCS) uses a three-dimensional spherical surface to define locations on the earth. It defines a real world point on a 3 dimensional digital surface using 3 coordinates.





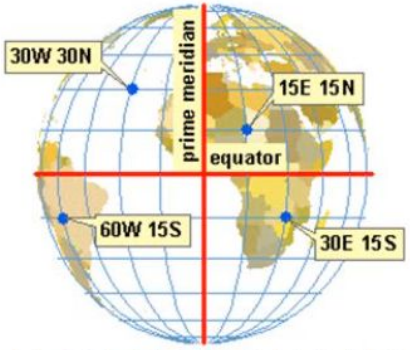


Longitude → **Meridians**

Latitude → **Parallels**

Among the most used GCS, we have the **WGS84** (World Geodetic Survey 1984), also used for GPS measurements.

Coordinate Systems and Map Projections



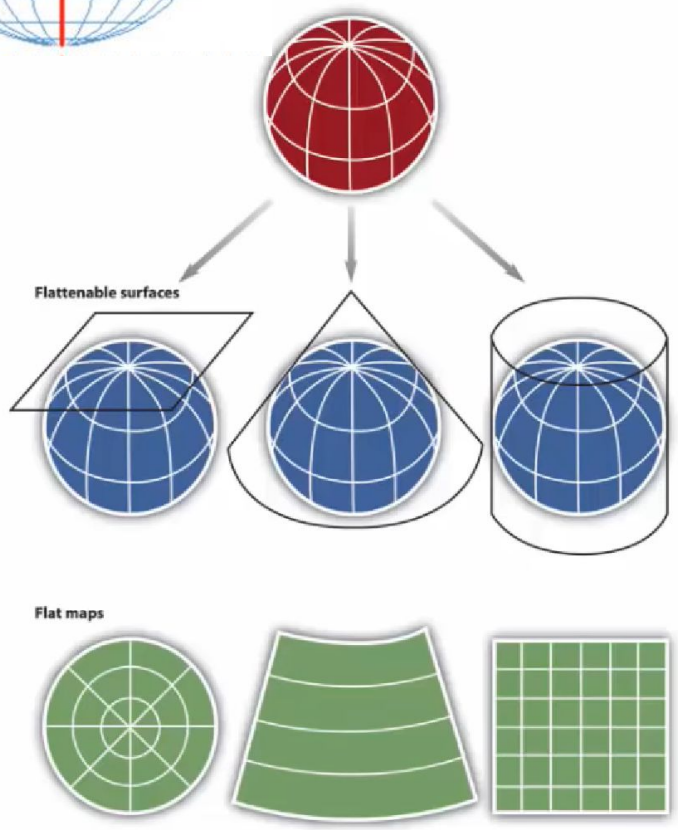
FROM Geographic Coordinate System

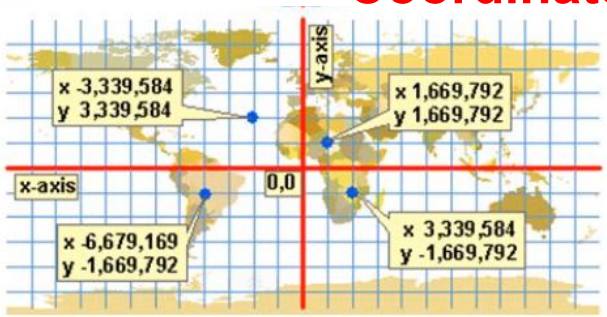
...we need a mathematical process to transform features **from one (spherical(surface onto another (planar) surface…** this is called

MAP PROJECTION

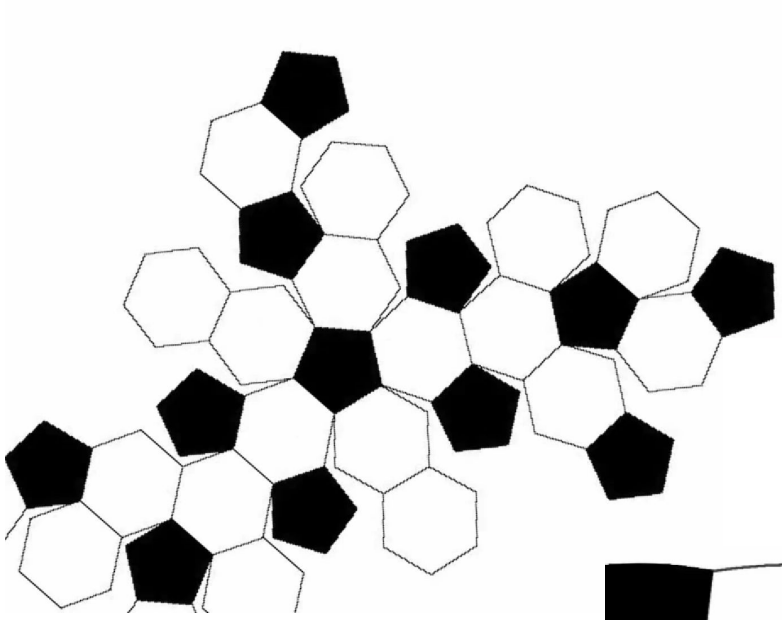
TO Plane/Rectangular Coordinate System

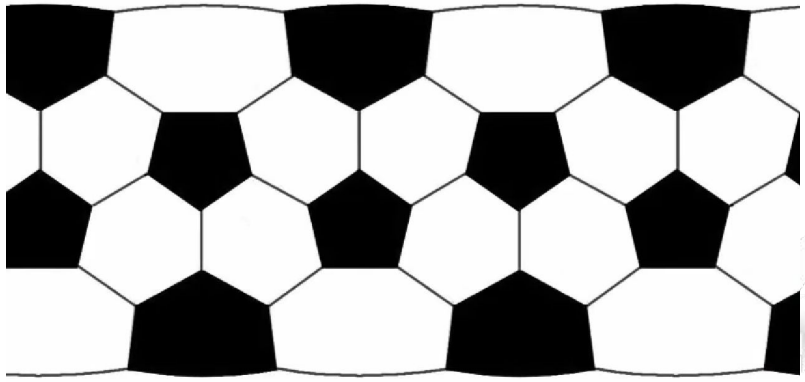
TRANSFORMATION





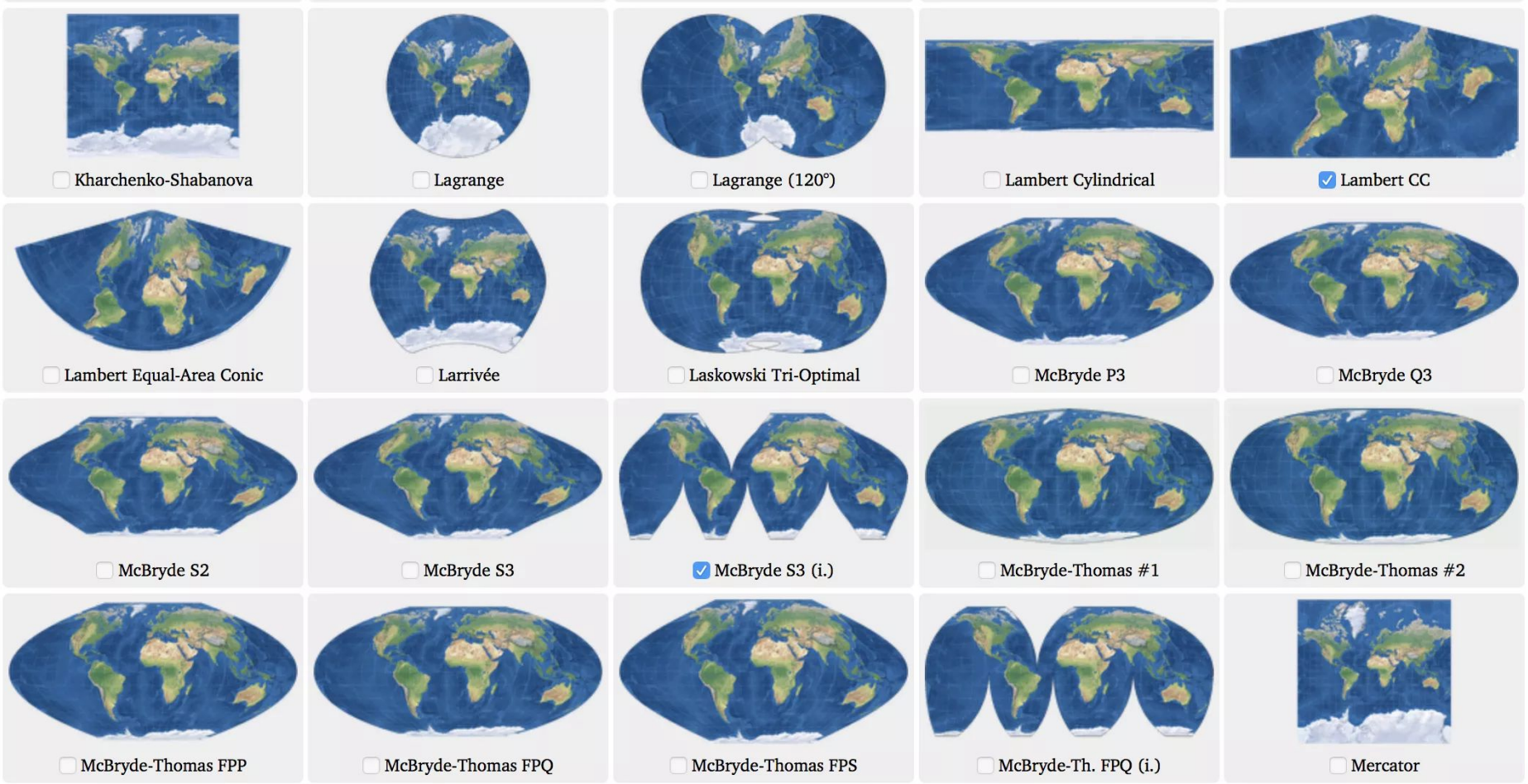
TRANSFORMATION - EXAMPLE



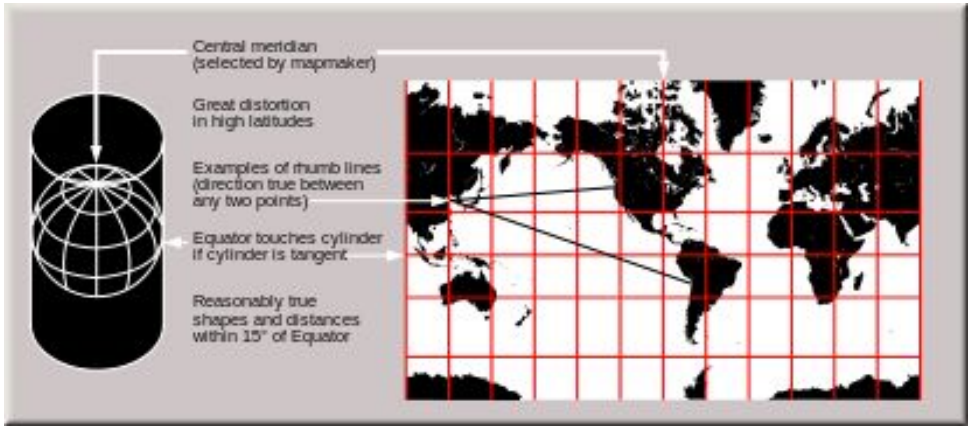


Coordinate Systems and Map Projections

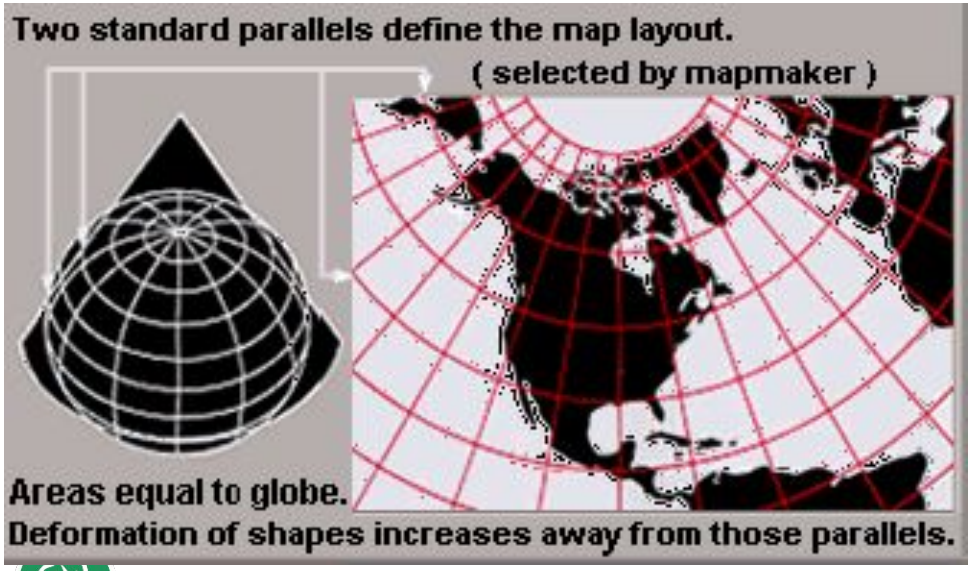
A map projection is based on **projection surface** (e.g. cylinder, cone, etc.) and **some assumptions** (e.g. same areas, same distances, same scale, etc.)



Coordinate Systems and Map Projections



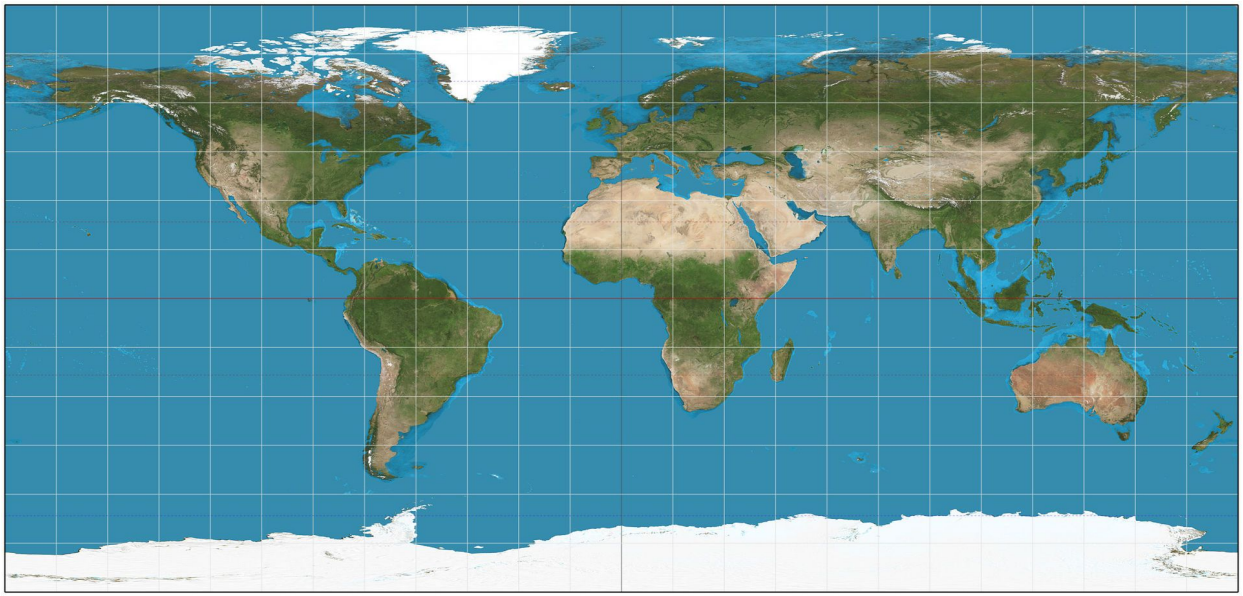
Cylindrical projection



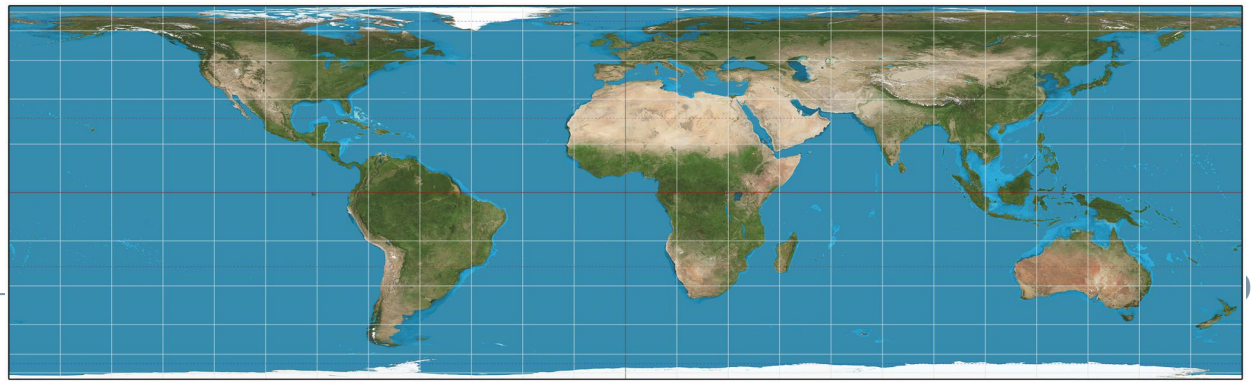
Conic projection

Coordinate Systems and Map Projections

Assumptions, i.e. preservation of some metric properties: conformal (preserve angles and scale), equal-area (preserve area measure, generally distorting shapes), equidistant (distances), etc.



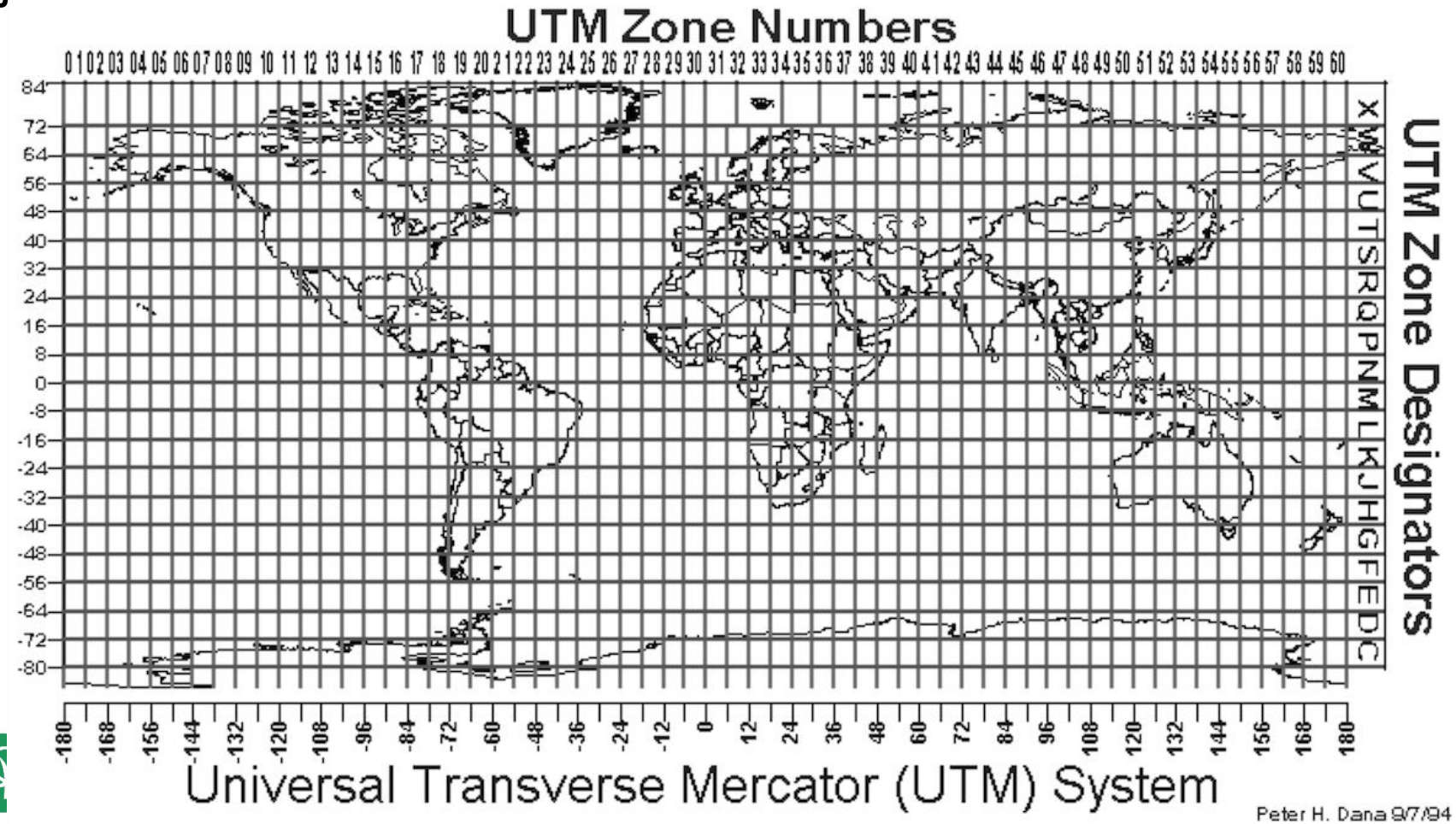
Cylindrical equidistant



Cylindrical equal-area

Coordinate Systems and Map Projections

Plane coordinate system most frequently used: UTM (Universal Transverse Mercator), i.e. a conformal cylindrical projection



MAPS in GIS

http://fastcashtransaction.com/content/img

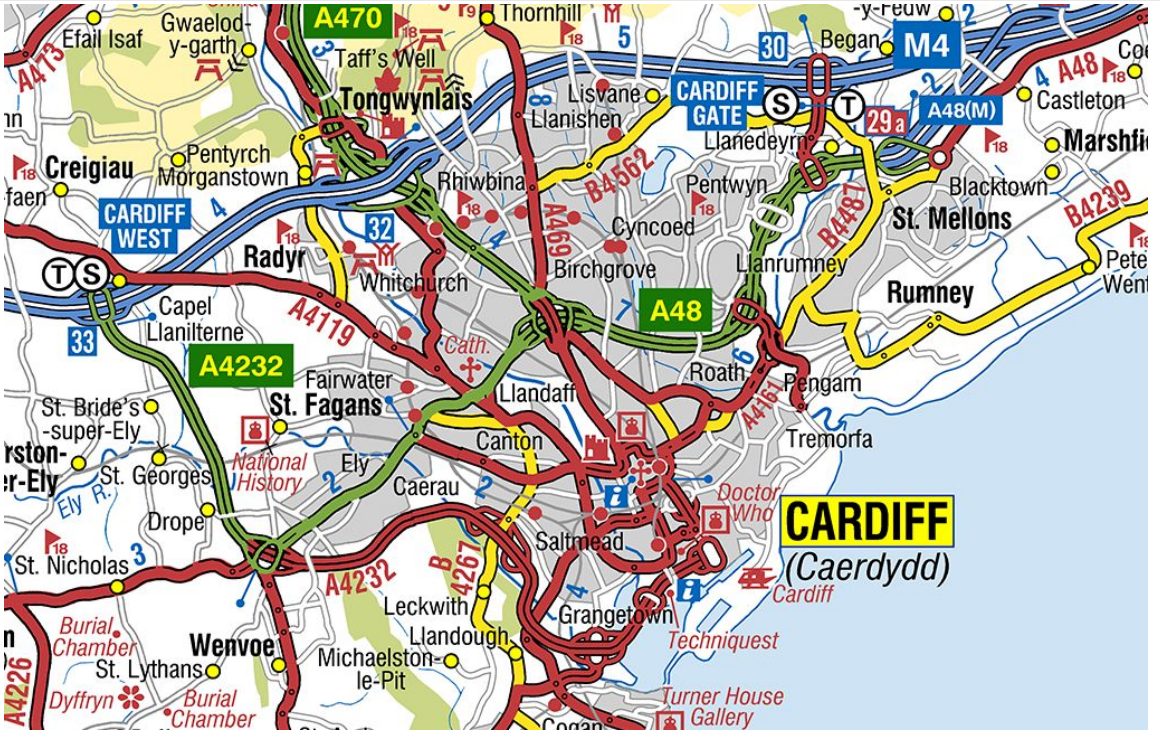
Generally there are two kinds of maps: **reference maps** and **thematic maps.**

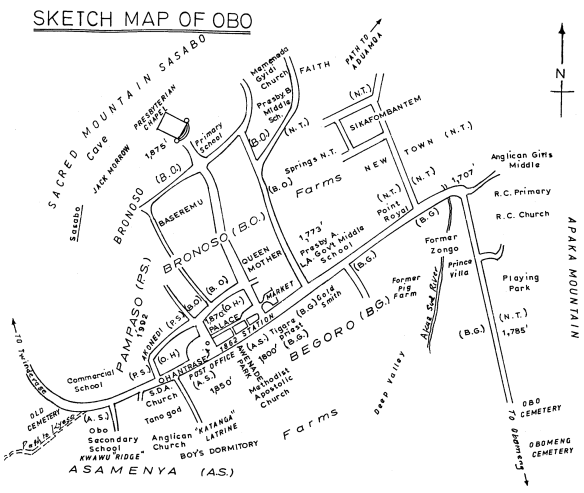
General Reference Maps:

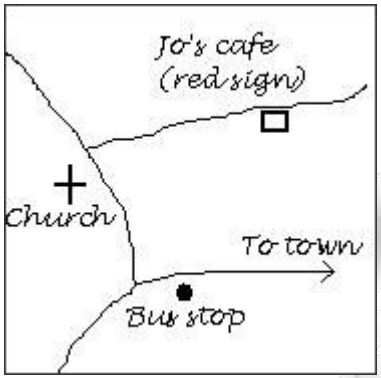
- A highly generalized map type designed to show general spatial properties of features.
- Examples are **world maps, road maps, atlas maps**, etc.

MAPS in GIS

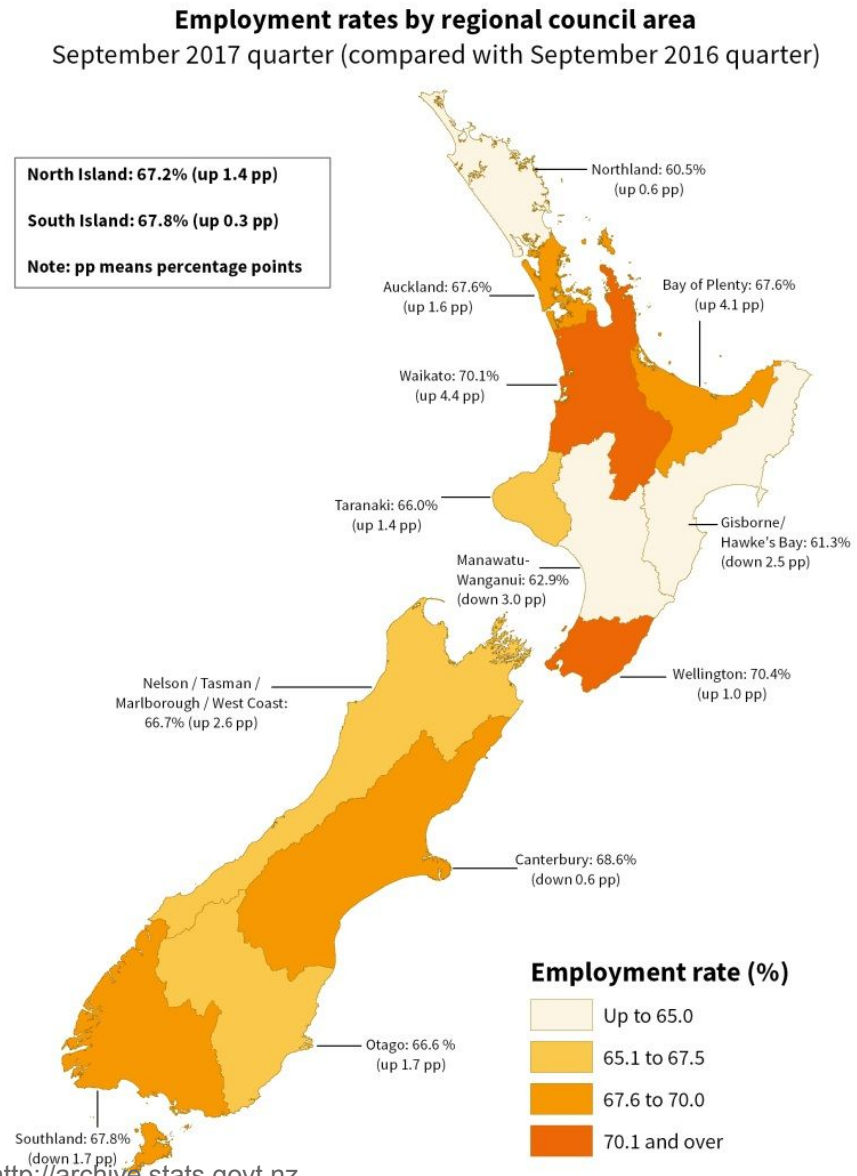
http://fastcashtransaction.com/content/img







MAPS in GIS

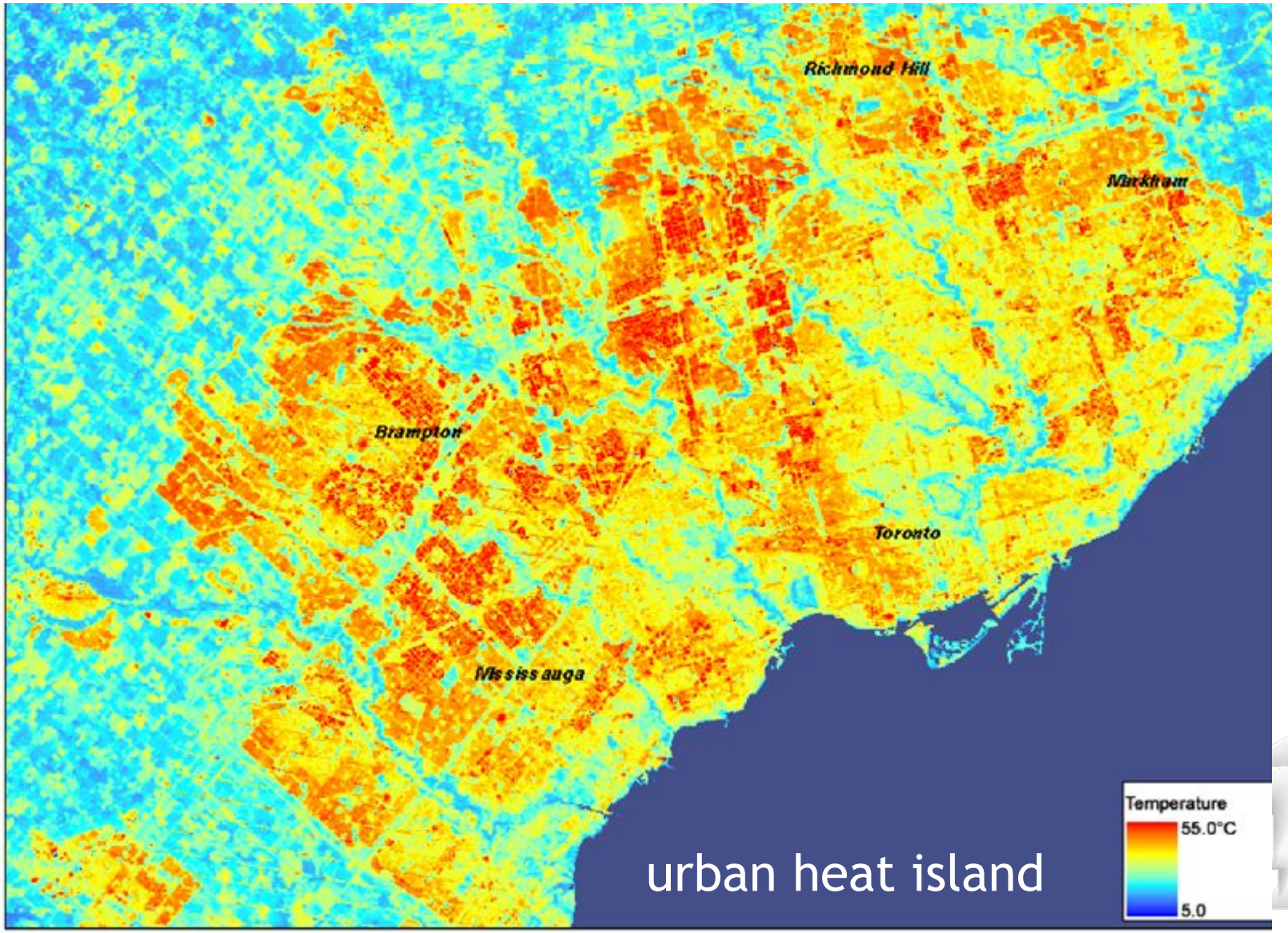


Generally there are two kinds of maps: **reference maps** and **thematic maps.**

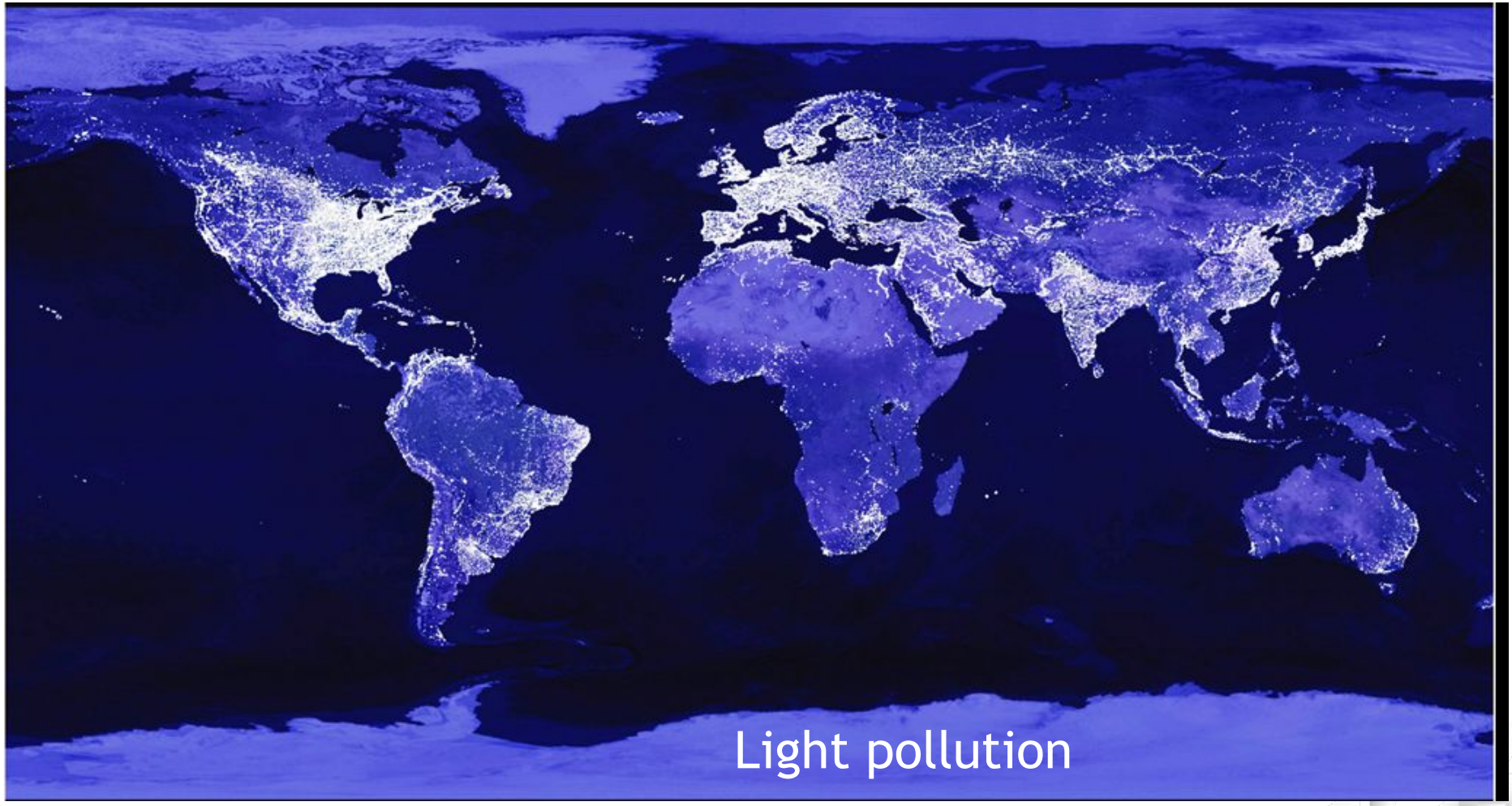
Thematic Maps:

- A thematic map shows georeferenced data, numeric or character, by **colors** or **symbols**.
- **Specific data** displayed in this manner is referred to as a **theme.**
- Different types of thematic maps, useful for showing different types of thematic variables.
- Obtained "**manipulating**" attributes of layers
- Examples are dot, isoline, choropleth or cartogram.

MAPS in GIS

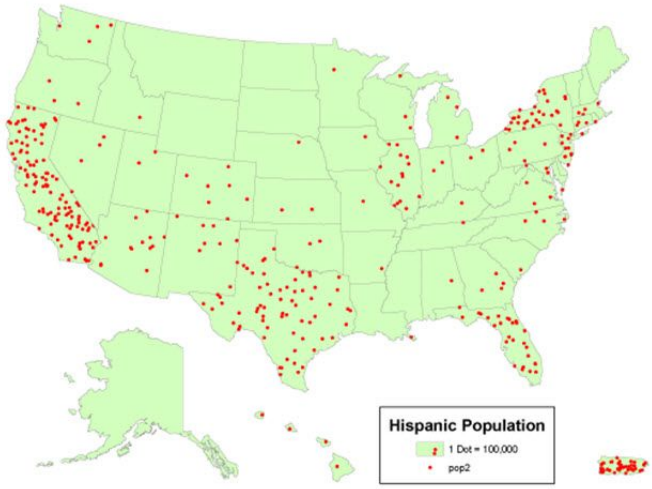

Richmond Hill
Markham
Brampton
Toronto
Mississauga
Temperature
55.0°C
5.0
urban heat island

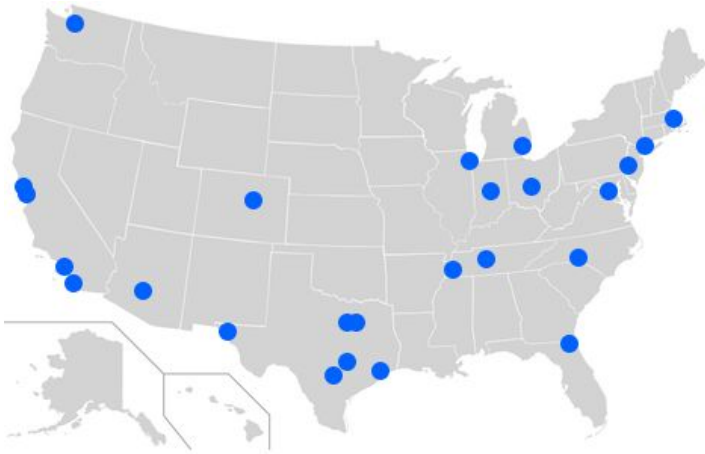
MAPS in GIS



MAPS in GIS

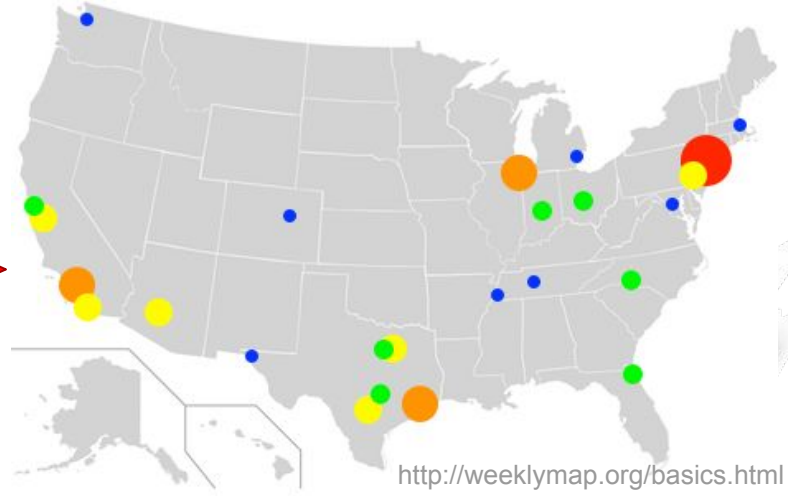
Dot, isoline, choropleth or cartogram maps





- The dots represent the **frequency of some variable.**

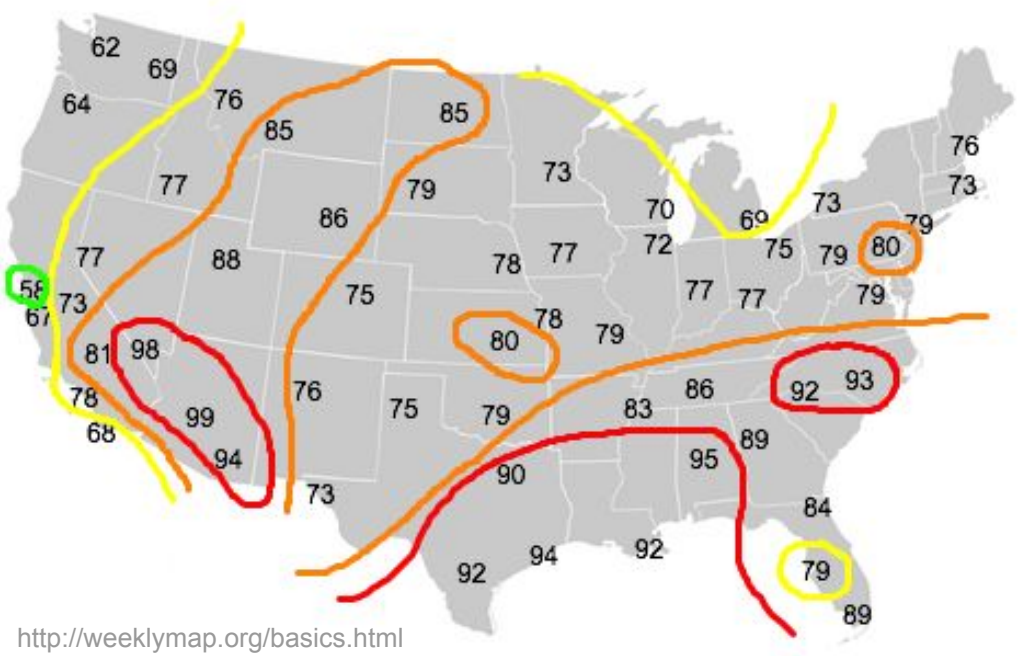
Dot maps can be unsatisfying, however, because they depict all data with dots of the same size. An alternative method is to use a **proportional symbol map**, which uses larger dots for data points of larger size.



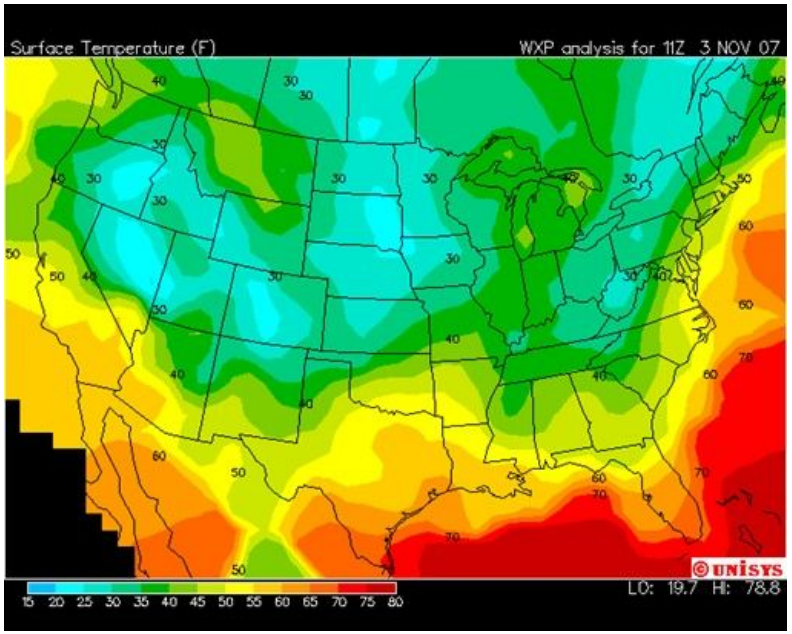
http://weeklymap.org/basics.html

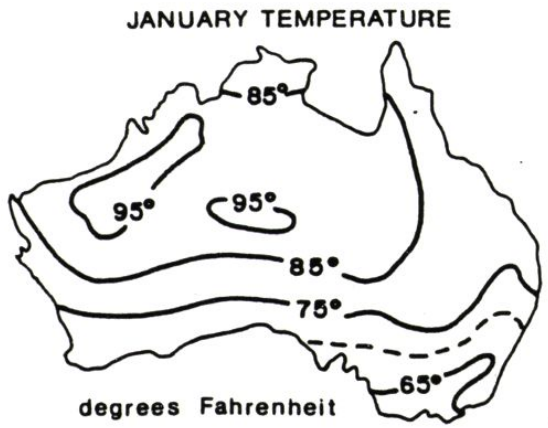
MAPS in GIS

Dot, **isoline**, choropleth or cartogram maps



http://weeklymap.org/basics.html

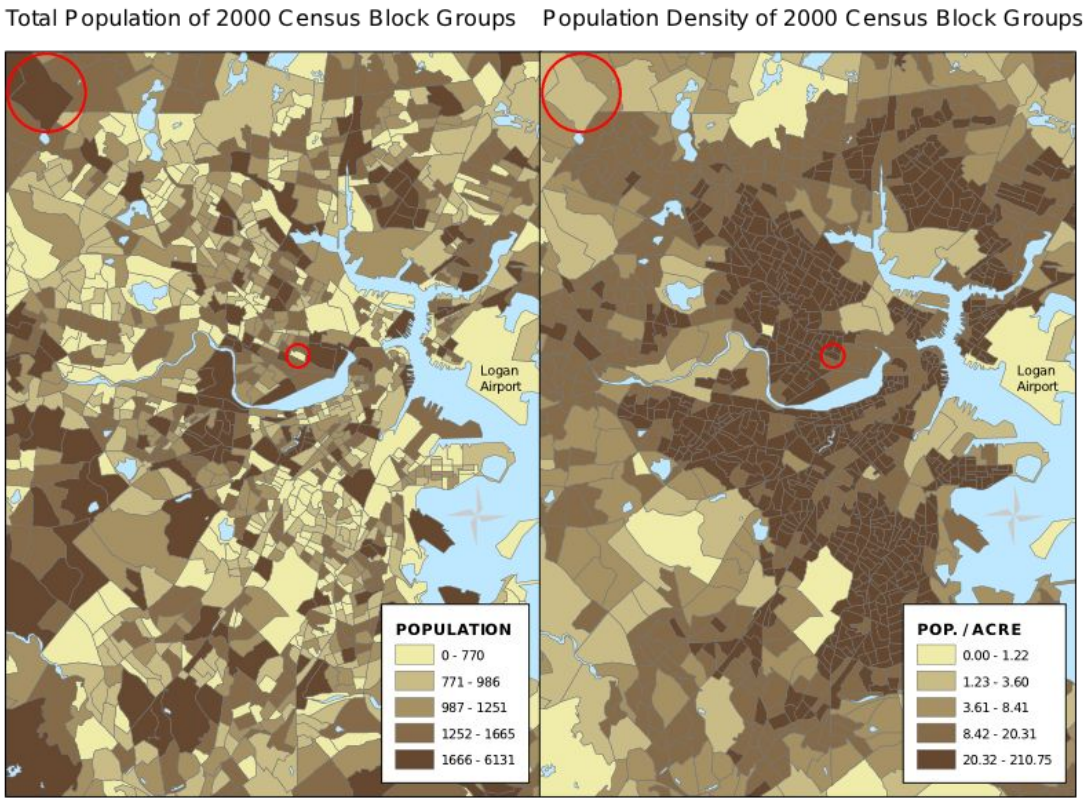


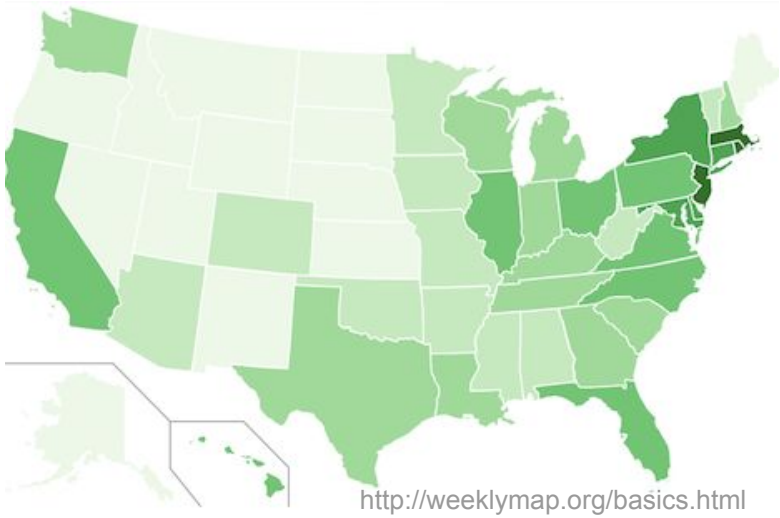


- connects points of equal value, e.g a map showing temperature (isotherms), equal altitude (contour map), barometric pressure (isobars), etc.

MAPS in GIS

Dot, isoline, **choropleth** or cartogram maps

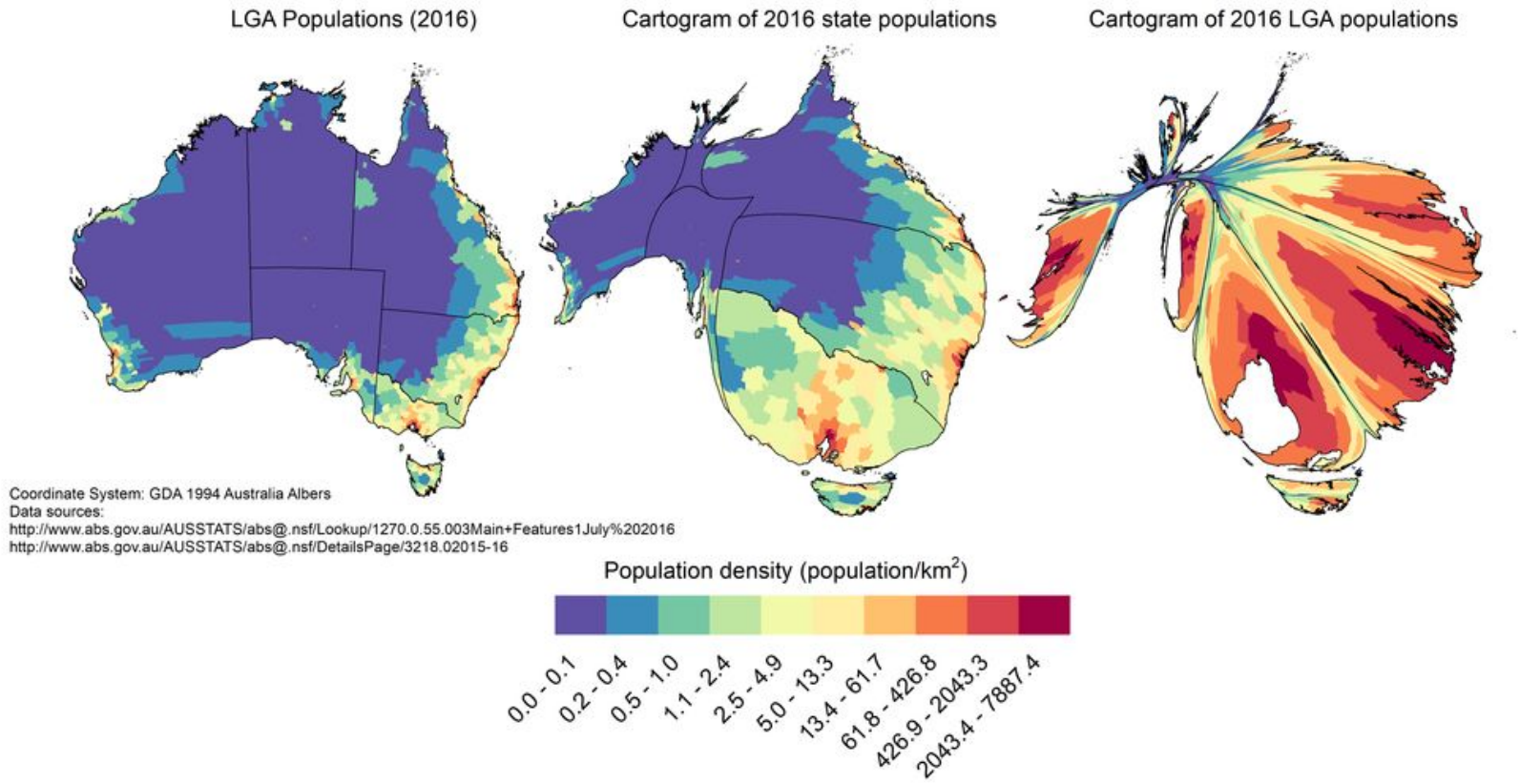




- Represents a **single** georeferenced **variable.**
- Shows variations over **discrete** regions.

MAPS in GIS

Dot, isoline, choropleth or **cartogram** maps



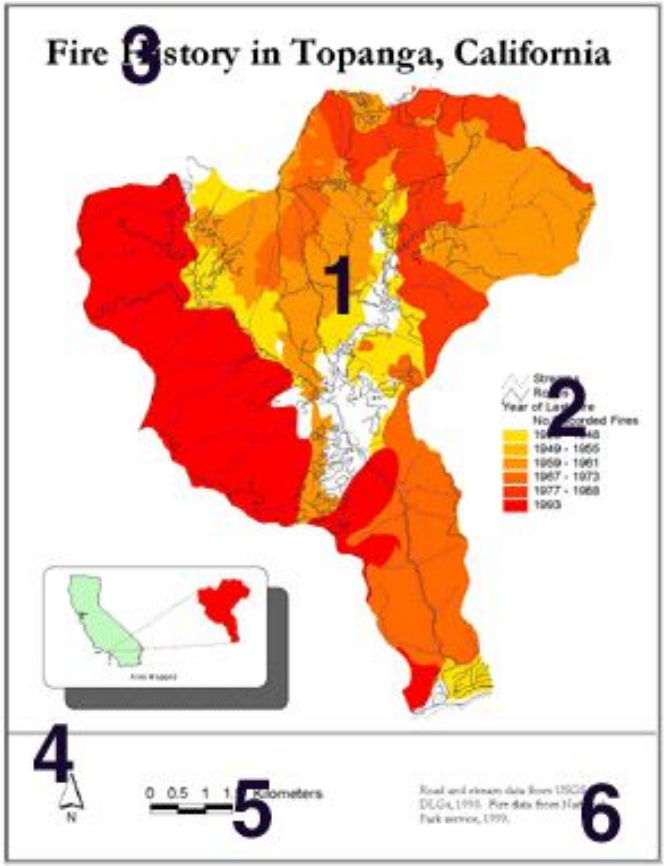
- a map with statistical information is shown in **diagrammatic form**.
- Cartogram - is a map in which statistics are **represented by distorting** the **size of each part of the map to reflect the magnitude of a statistical variable (Visualization with Exaggeration)**.

Design of a Map

When designing GIS maps, you have complete control in manipulating the map components.

There are several map components:

1. **Data Frame -** is the portion of the map that displays the data layers
2. **Legend** - should make the map contents clear
3. **Title** - should be dominant in size
4. **Directional Indicator** - north arrow
5. **Scale**
6. **Citation -** constitutes the metadata of the map



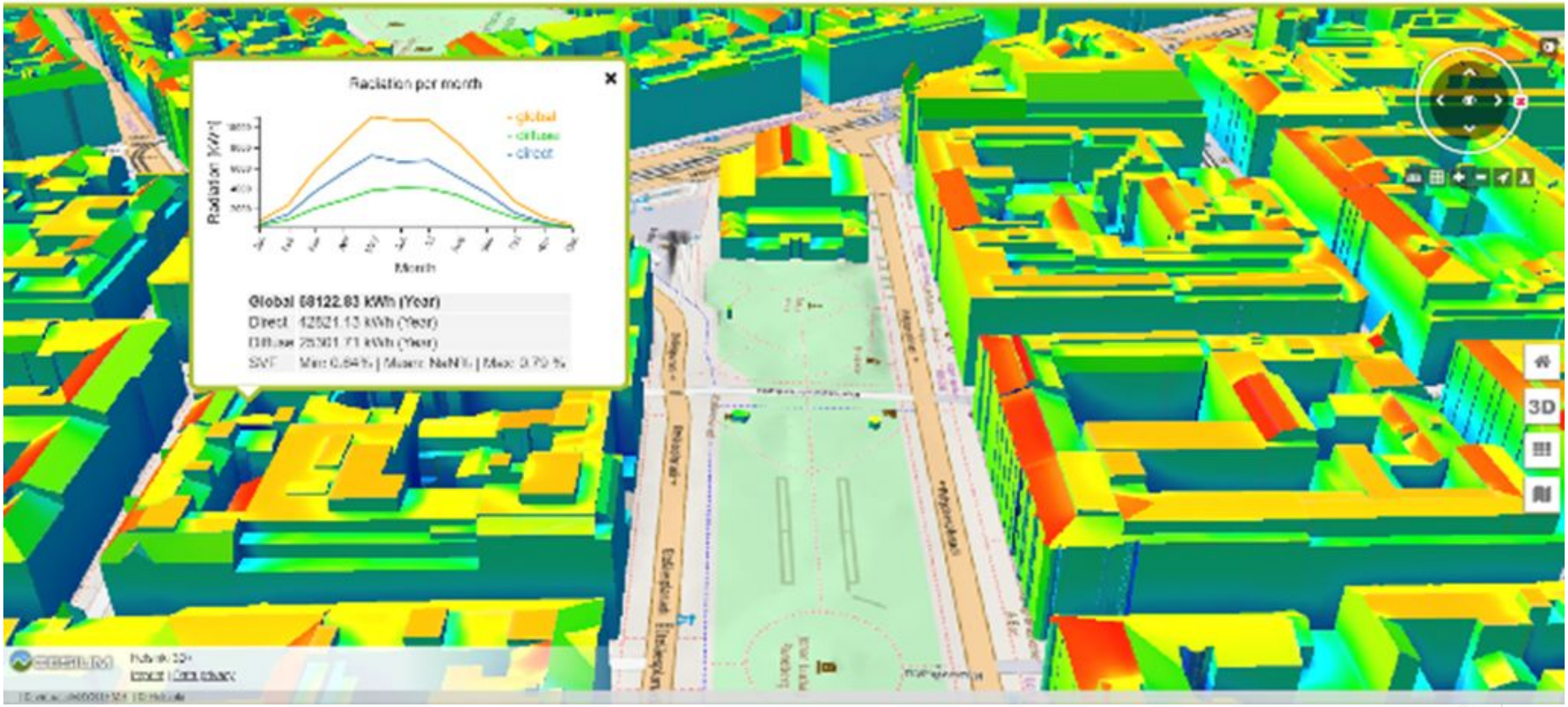
Supplementary Information:

- **Labels -** attribute or ancillary information directly placed on the map

2D GIS vs 3D GIS

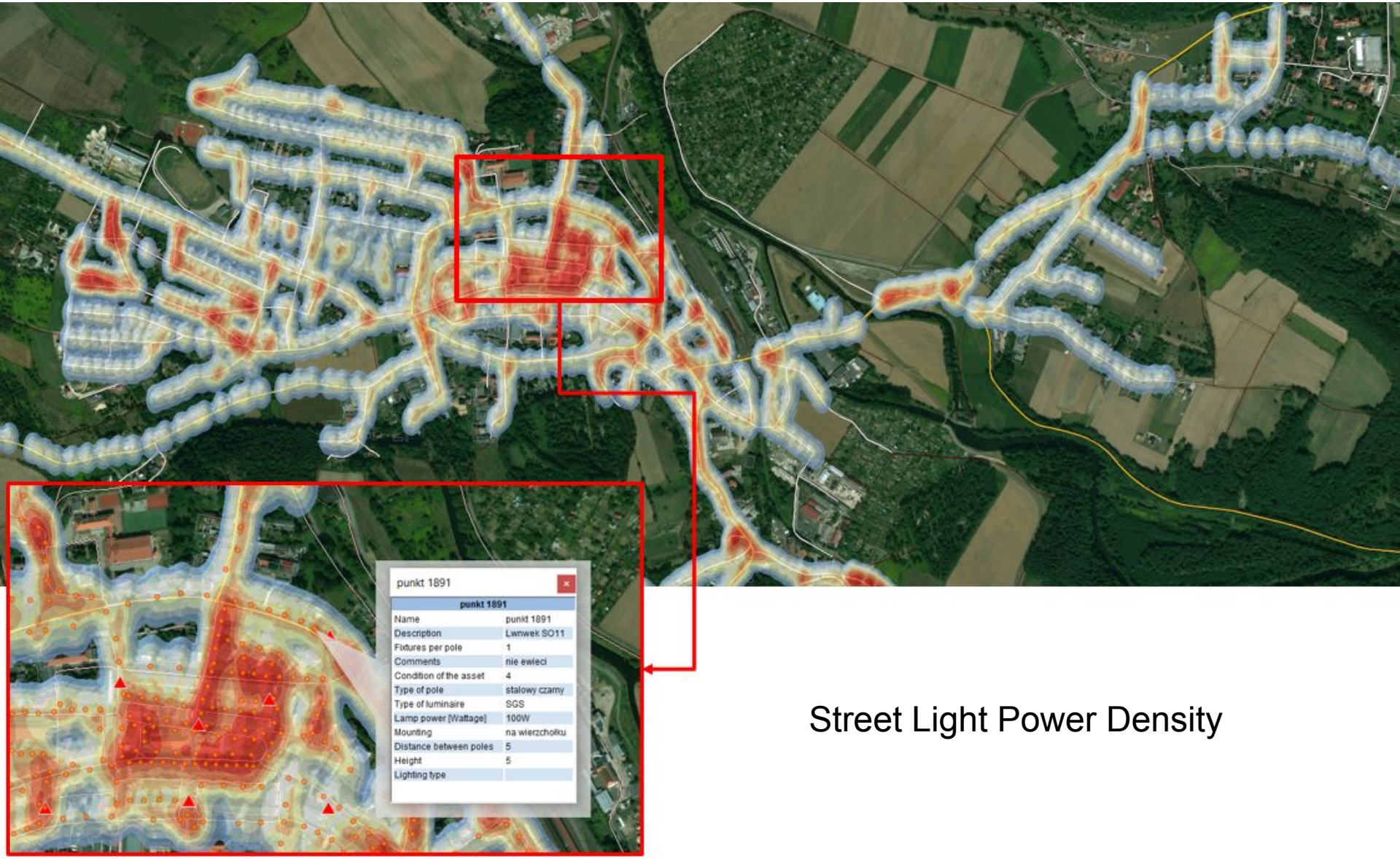
https://www.businesslocationcenter.de/en/berlin-economic-atlas

2D GIS vs 3D GIS



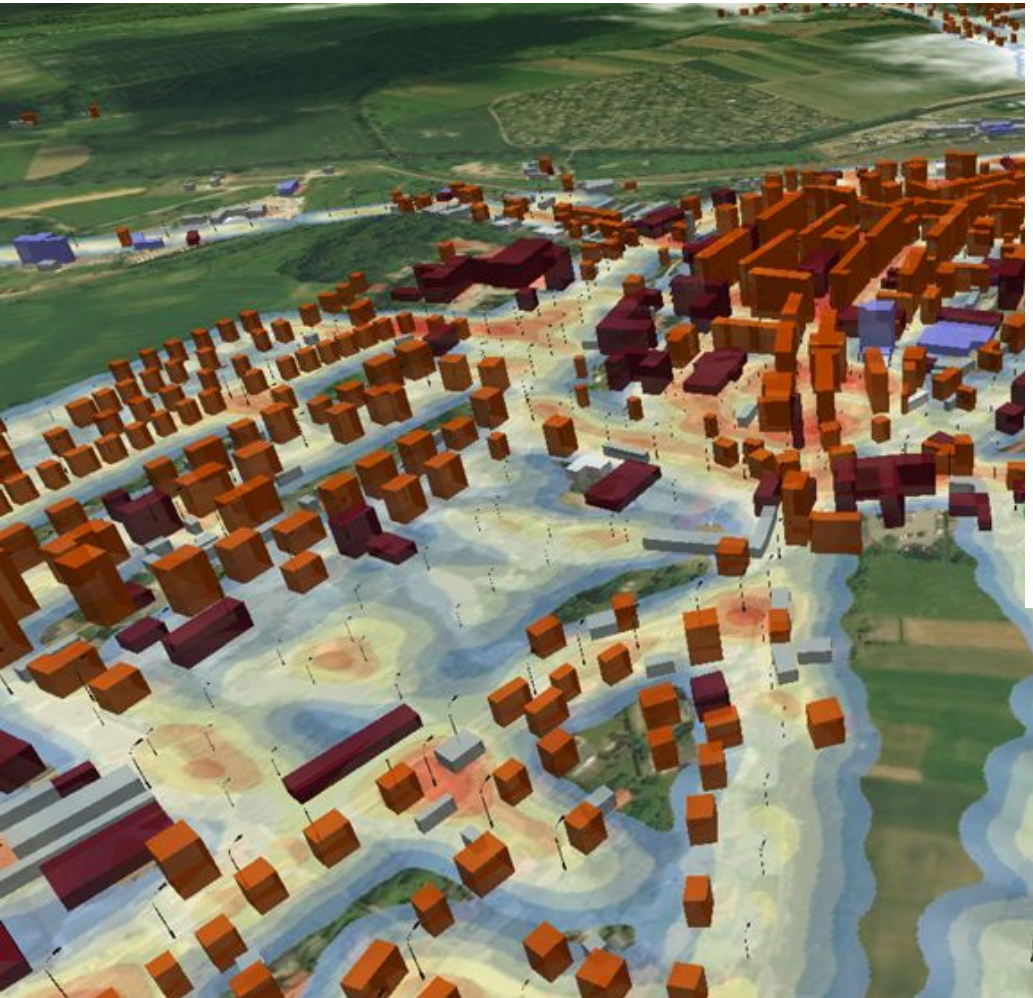
https://kartta.hel.fi/3d/

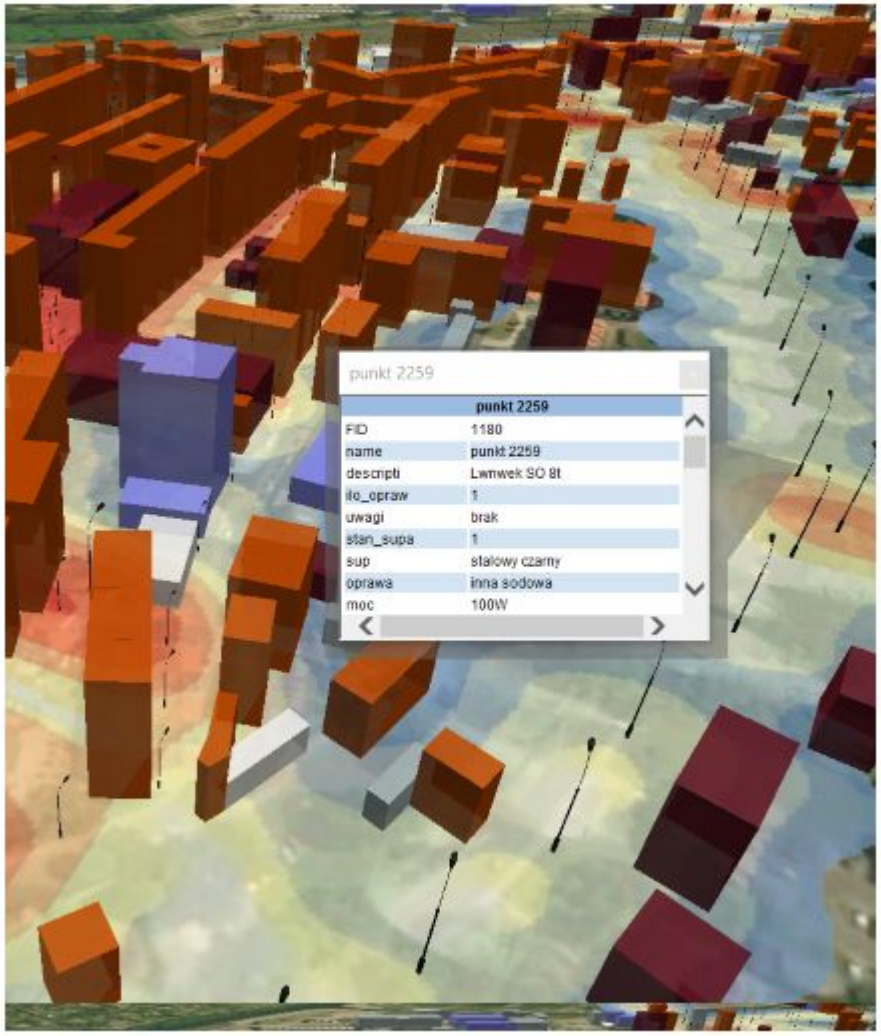
2D GIS vs 3D GIS

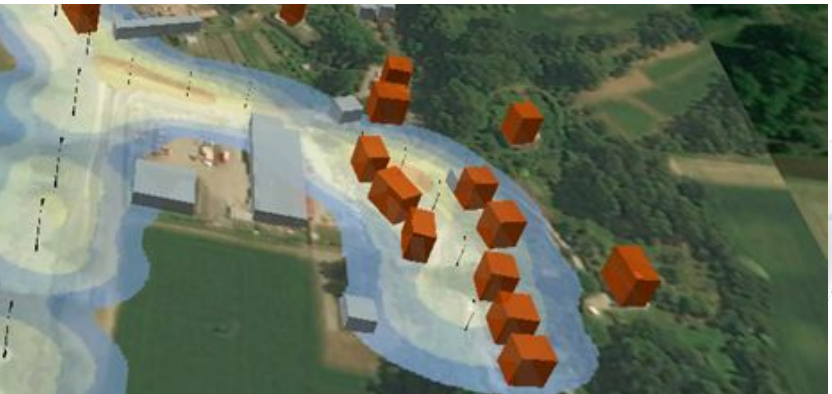


Street Light Power Density

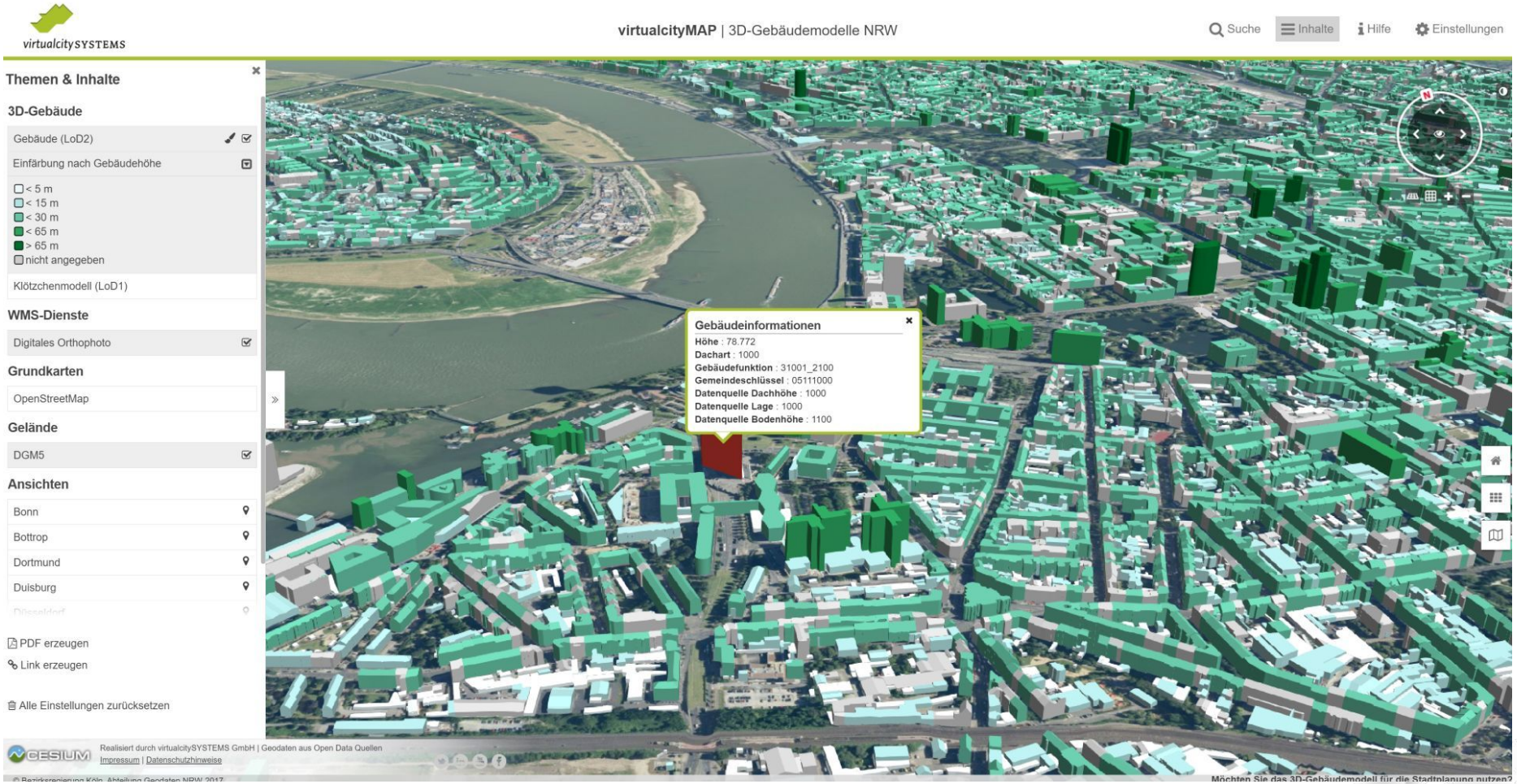
2D GIS vs 3D GIS





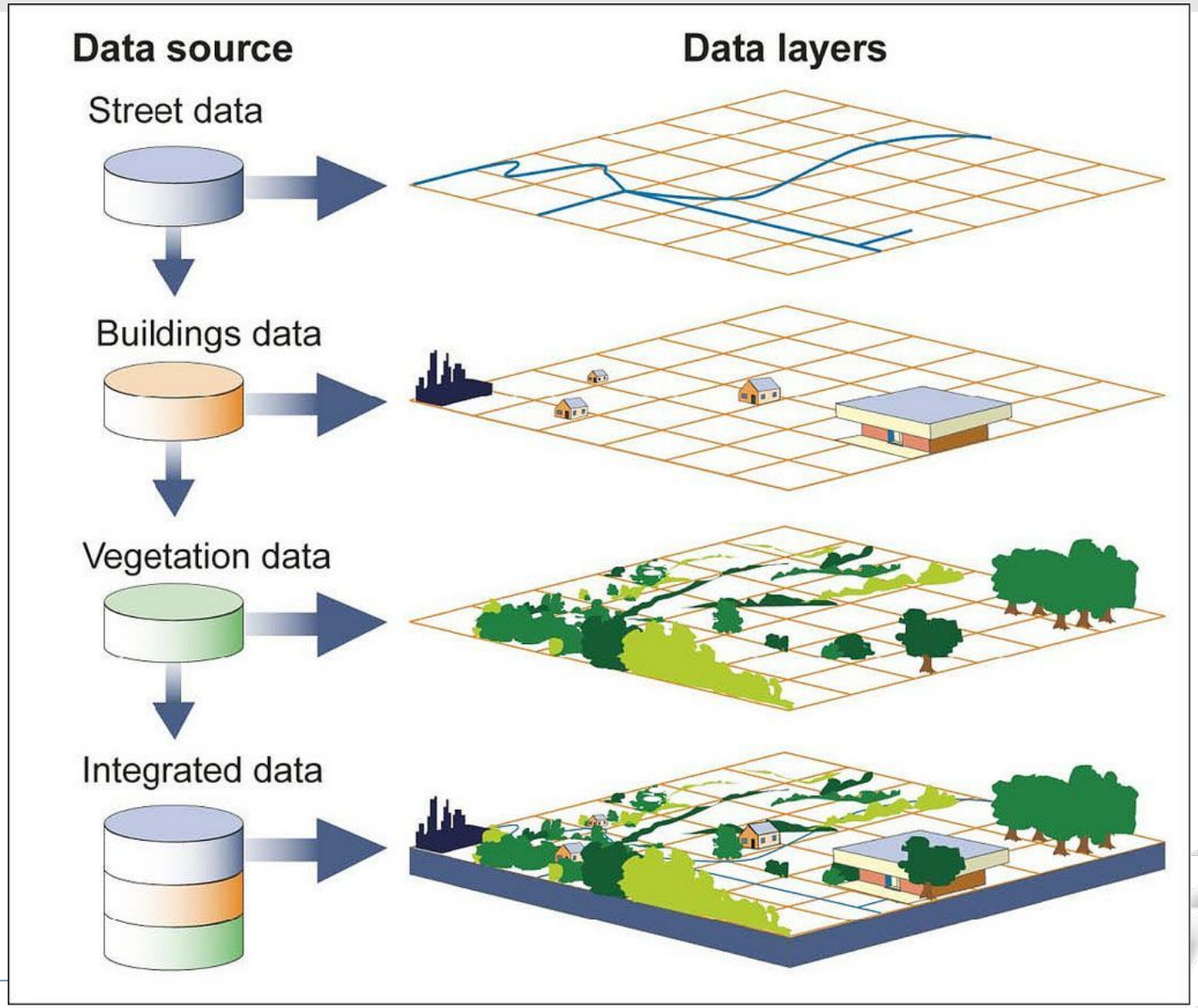


2D GIS vs 3D GIS



https://berlin.virtualcitymap.de/?lang=en

SUMMARY



Source: GAO.

Installation of QGis & data distribution

https://www.qgis.org