# Introduction to Geographical Information Systems

*By*


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# Geographical Information Systems (GIS)

- GIS is
  - an organized collection of computer hardware, software, and geographic data designed to efficiently
    - ***capture,***
    - ***store,***
    - ***manipulate (update),***
    - ***analyze and***
    - ***display*** **all forms of geographically referenced information.**
- GIS is
  - a model - it gives a simplified representation of reality
  - a computer-based tools for mapping and analyzing things that exists and events (phenomena) that happen on the earth.


by ESRI

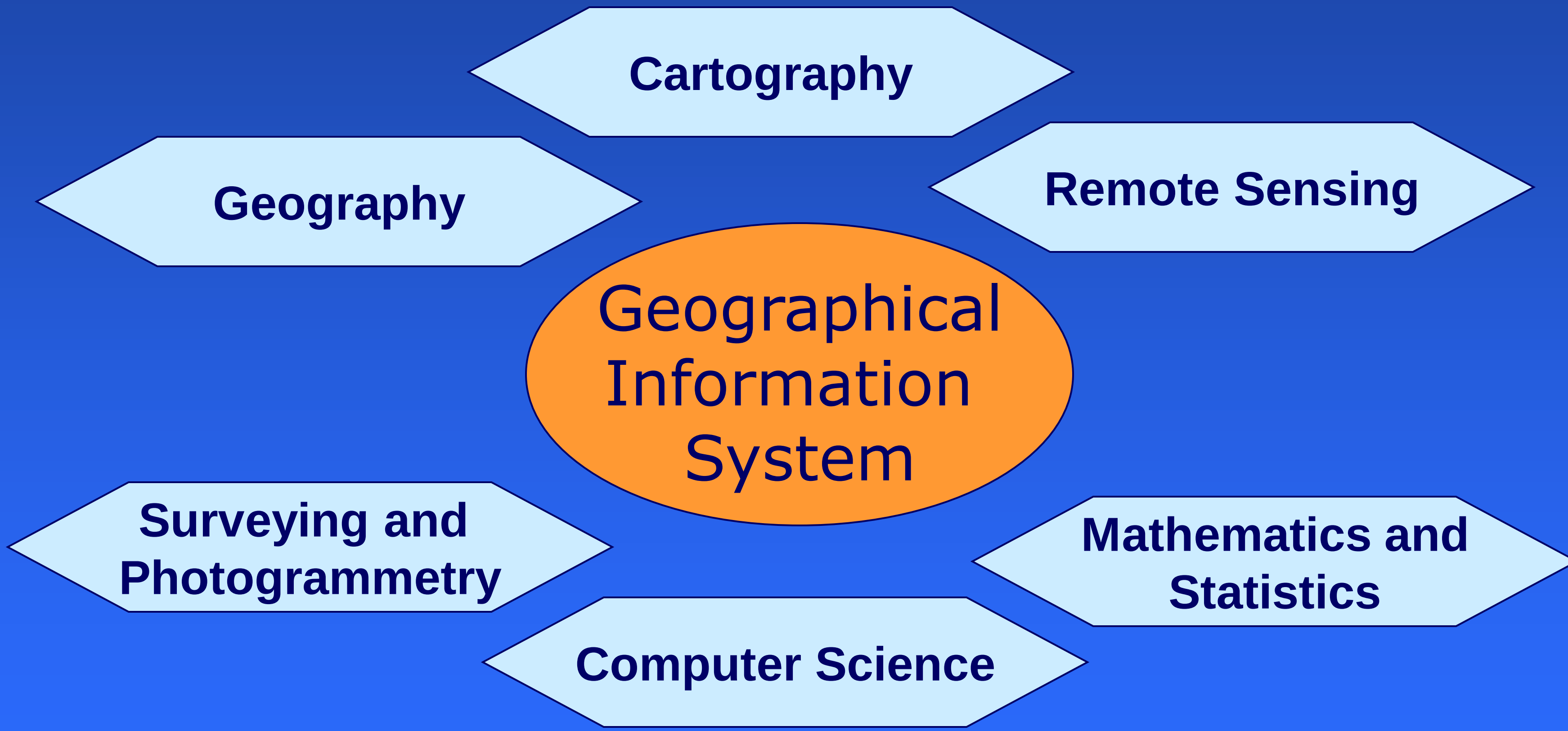
# GIS - What is it good for?

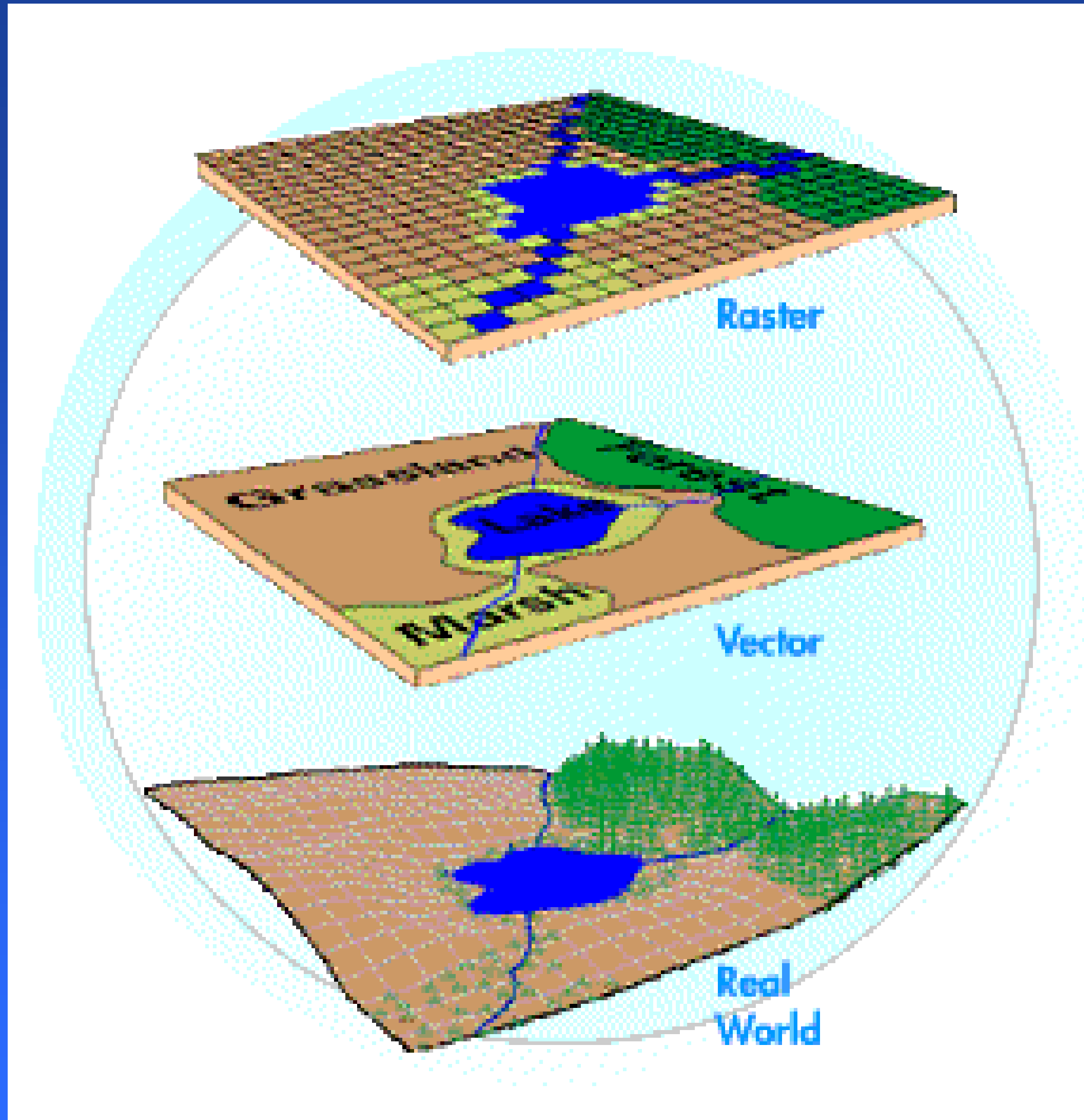
- With GIS we can analyze certain complex scenarios and relationships that would otherwise be very difficult, time consuming, or impractical
- GIS is an useful tool for:
  - monitoring and management of natural resources;
  - integration of spatial (and dynamic) information;
  - determination of relationships (e.g. water availability vs. CWR; water quality vs. population density/presence of waste water treatment plants, etc.);
  - evaluation of alternatives (e.g. when tracing a water distribution network, when developing the cropping pattern);
  - performance of "what if" analysis by projecting data over time and space (decision making);
  - Integration with other modern technologies (GPS, remote sensing, modeling…)

# HISTORY OF GIS

- 550 B.C. - Anassimandro di Mileto - earliest known map of the Mediterranean region
- 120 A.C. - Marino di Tiro - first geographic projection (equidistant cylindrical) - latitude & longitude
- 1137 - first map in raster format (China)
- 1963 - Harvard Laboratory for Computer Graphics and Spatial Analysis starts work on a computer mapping system
- 1966 - CGIS - Canadian GIS - completed in 1971
- 1968 - first GIS Conference
- 1969 - founded ESRI and Intergraph
- 1977-79 - ODYSSEY - first commercial GIS software
- 1980 - first version of Arc/INFO (ESRI)
- 1987 - first version of Map-Info (Microsoft)
- 1987 - first version of IDRISI (Clark University)
- 19 November 1999 - first GIS Day
- 2000 – more than 1 million users & more than $ 7 billion
- 2002 – release of ArcMap GIS v.8.3
- 2004 – release of ArcMap GIS v.9.1 etc.
- QGIS project

# GIS - Related Sciences and Technologies



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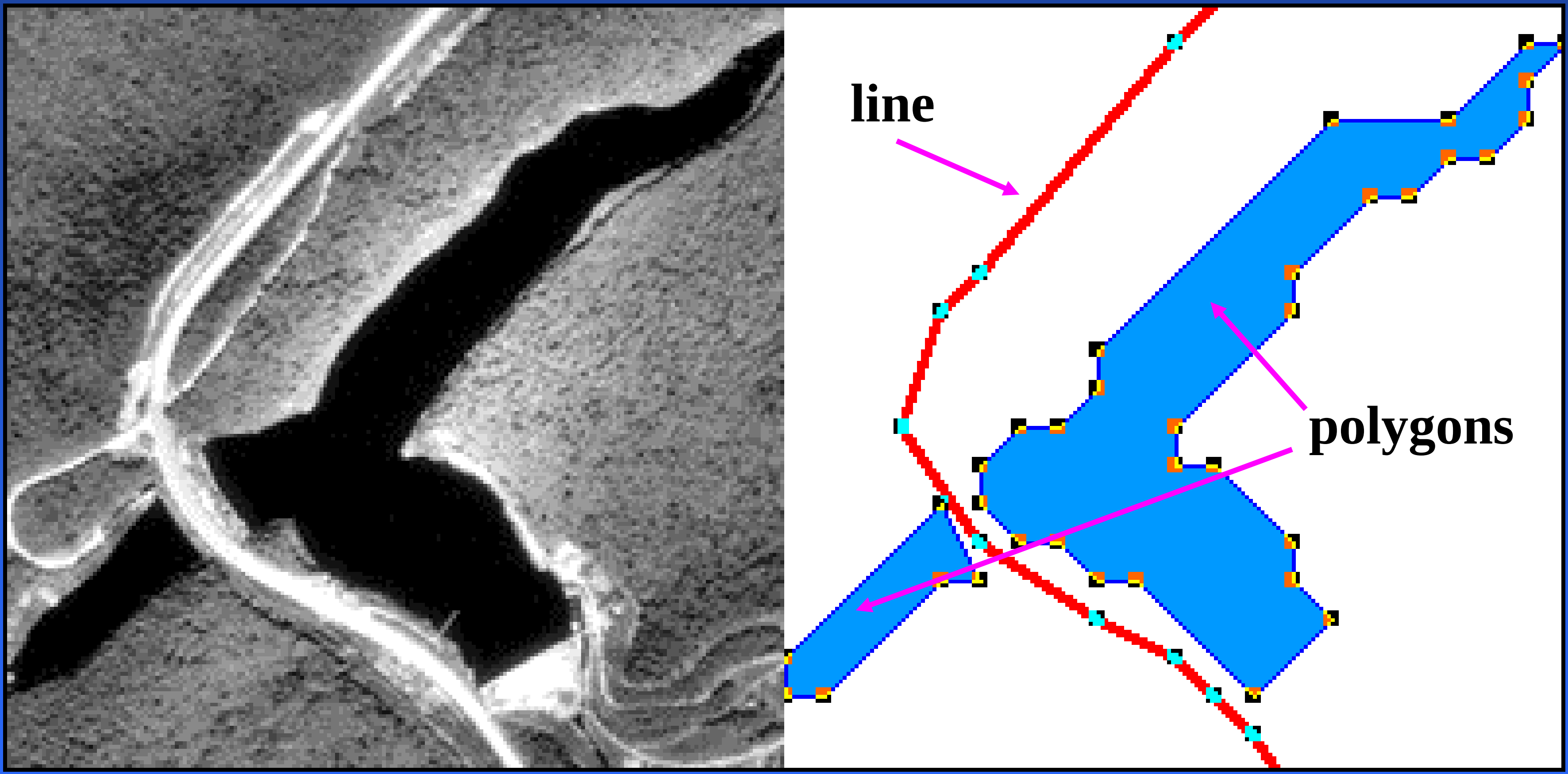
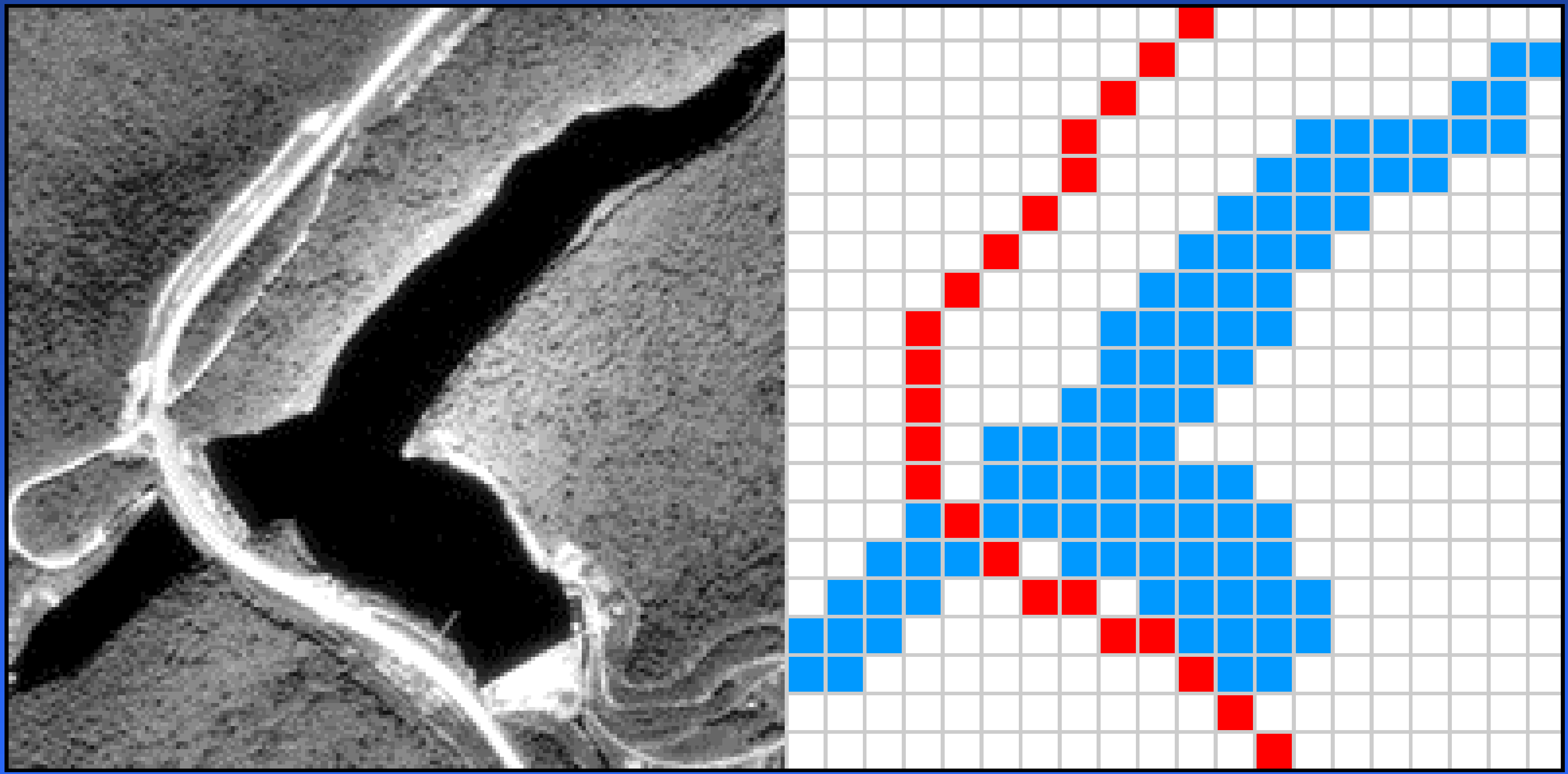
Aerial photo

Vector data model



Aerial photo

Raster data model



Regular grid cells


**Bari, Italy**

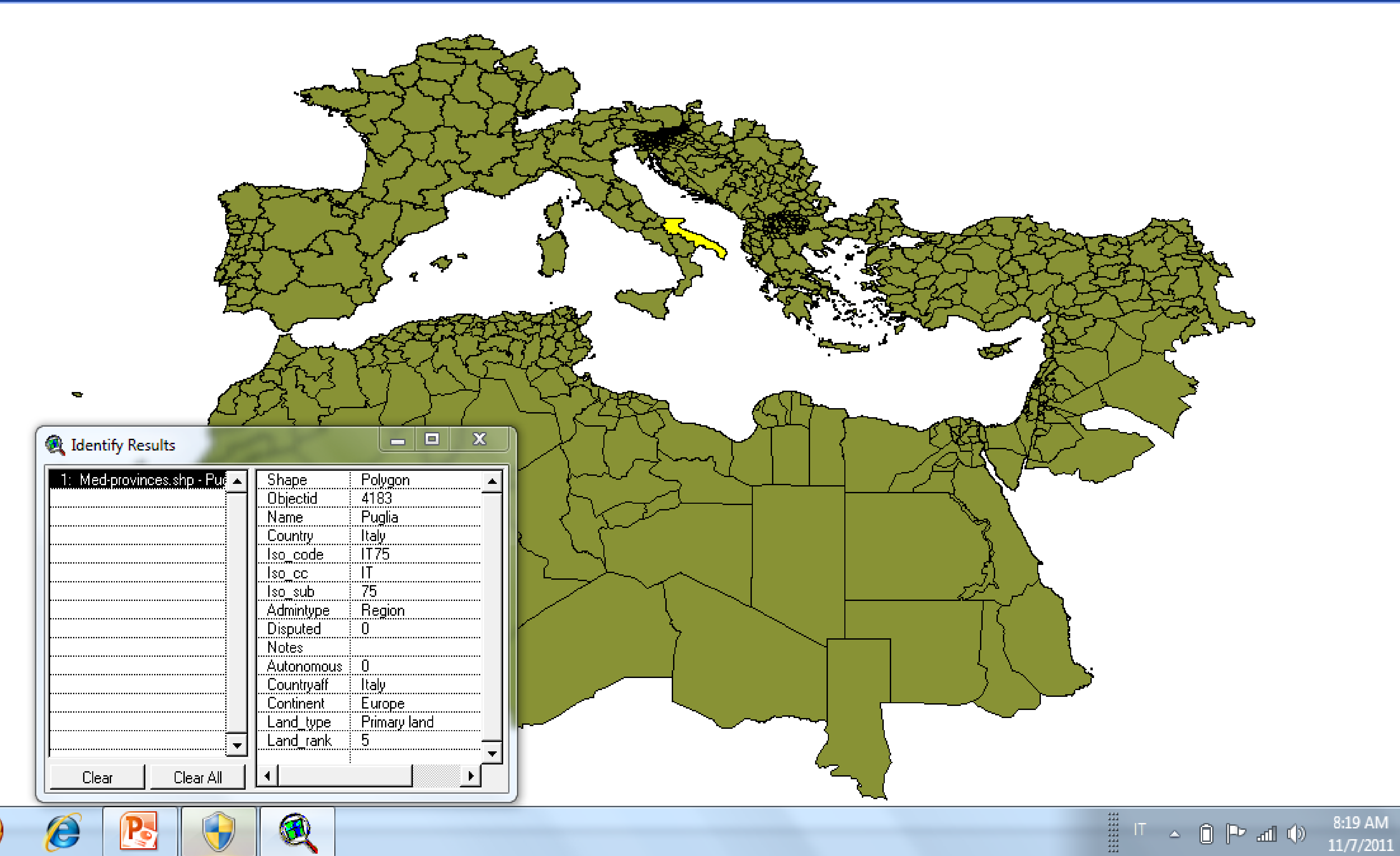
**Vector data model**

**Raster data model**

**CIHEAM-IAMB, Valenzano**

# GIS & Information

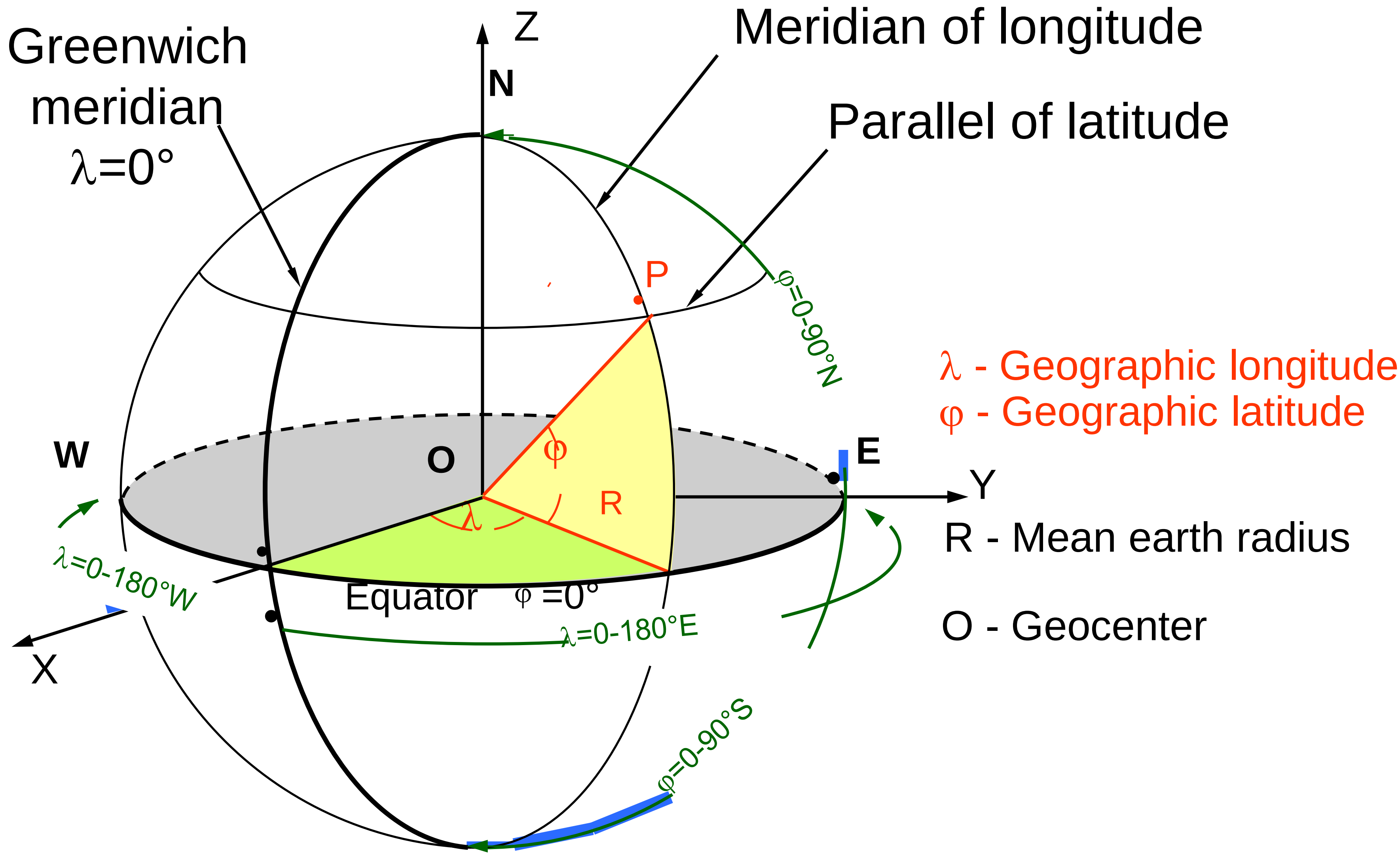
- Three types of information
  - *geometry* - shape of spatial objects
  - *attributes* - description of the spatial objects
  - *topology* - explicit definition of spatial relationships (intersection, connectivity, continuity and contiguity - topological identification of adjacent polygons: left-right of each arc)
- CAD vs. GIS
- Information are integrated trough a physical model based on the relational database structure
- GIS *geo-referentiates* information
  - attributes to each spatial object its real coordinates (as it is in a map)



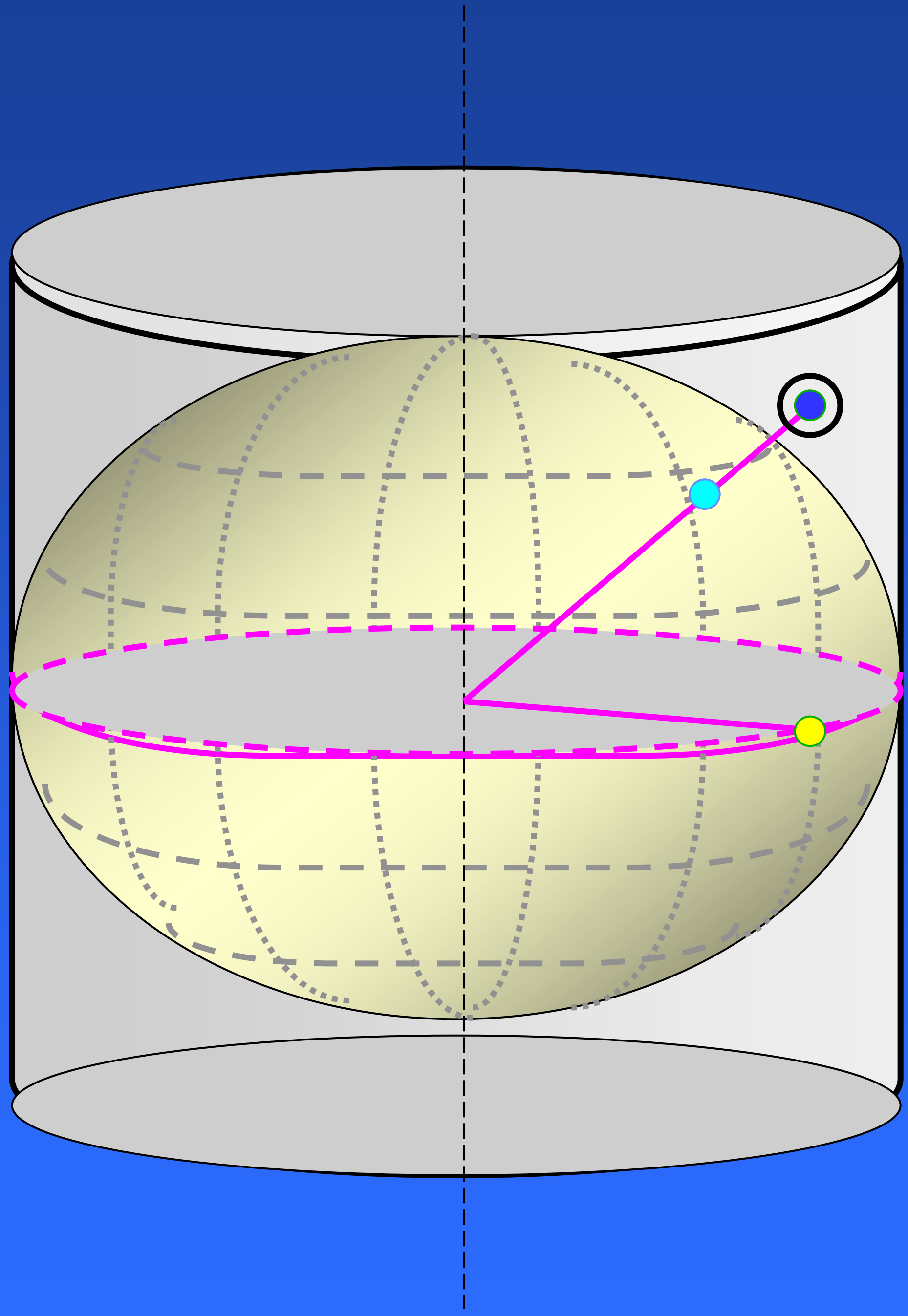
Identify Results
1: Med-provinces.shp - Pu
Shape Polygon
Objectid 4183
Name Puglia
Country Italy
Iso_code IT75
Iso_cc IT
Iso_sub 75
Admintype Region
Disputed 0
Notes
Autonomous 0
Countryaff Italy
Continent Europe
Land_type Primary land
Land_rank 5
Clear
Clear All
IT
8:19 AM
11/7/2011


© 2010 Europa Technologies
Image © 2010 DigitalGlobe
© 2010 Tele Atlas
Data di acquisizione delle immagini: 8 Nov, 2006 41°03'14.30"N 16°52'37.46"E elev 67 m
Alt 513 m
Google

# Latitude and Longitude on a Sphere



# Cylindrical Normal Projection (Mercator)



Project the points starting from the center of the Earth onto a cylinder with the tangency line on the Equator

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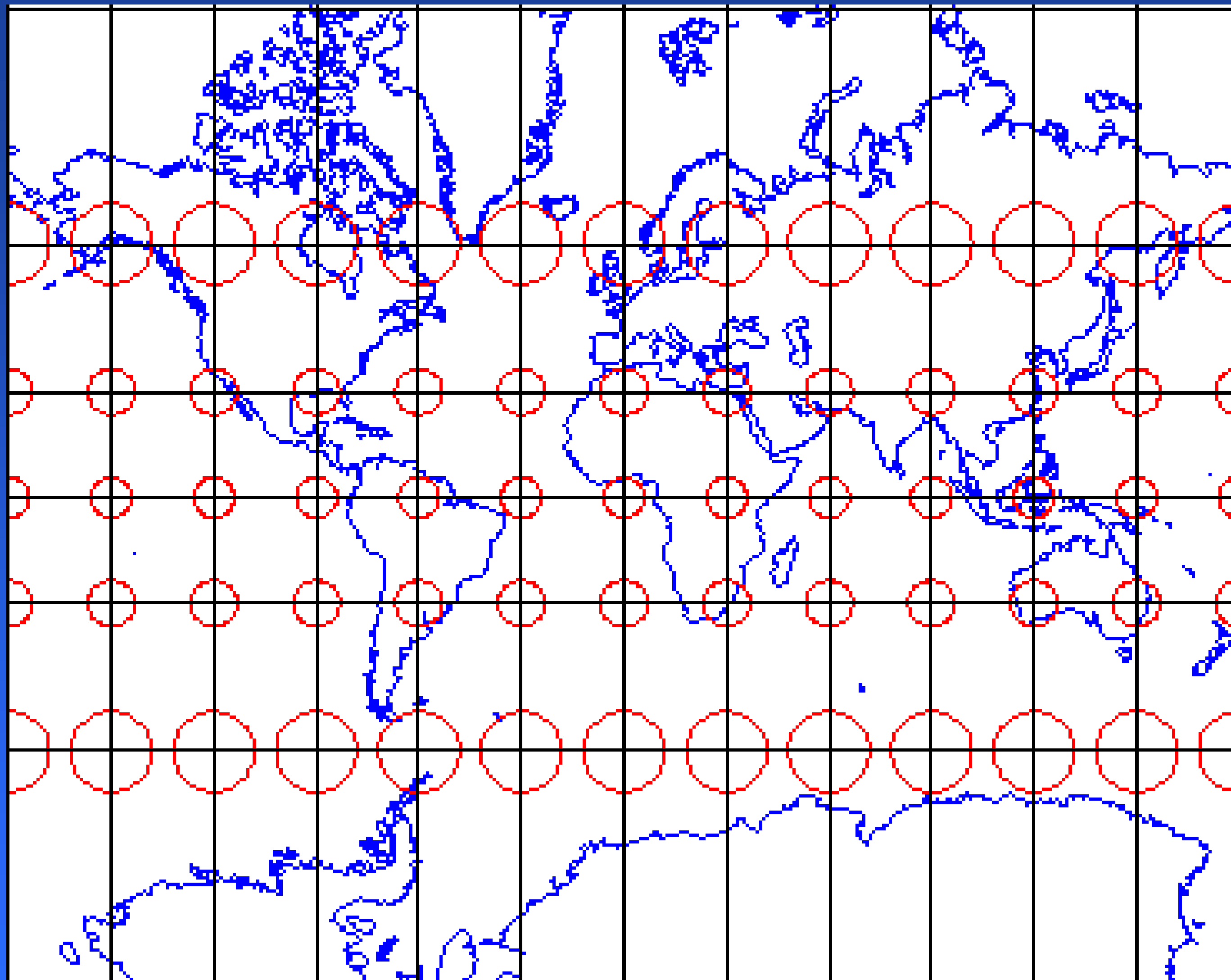

**Mercator projection of the world**

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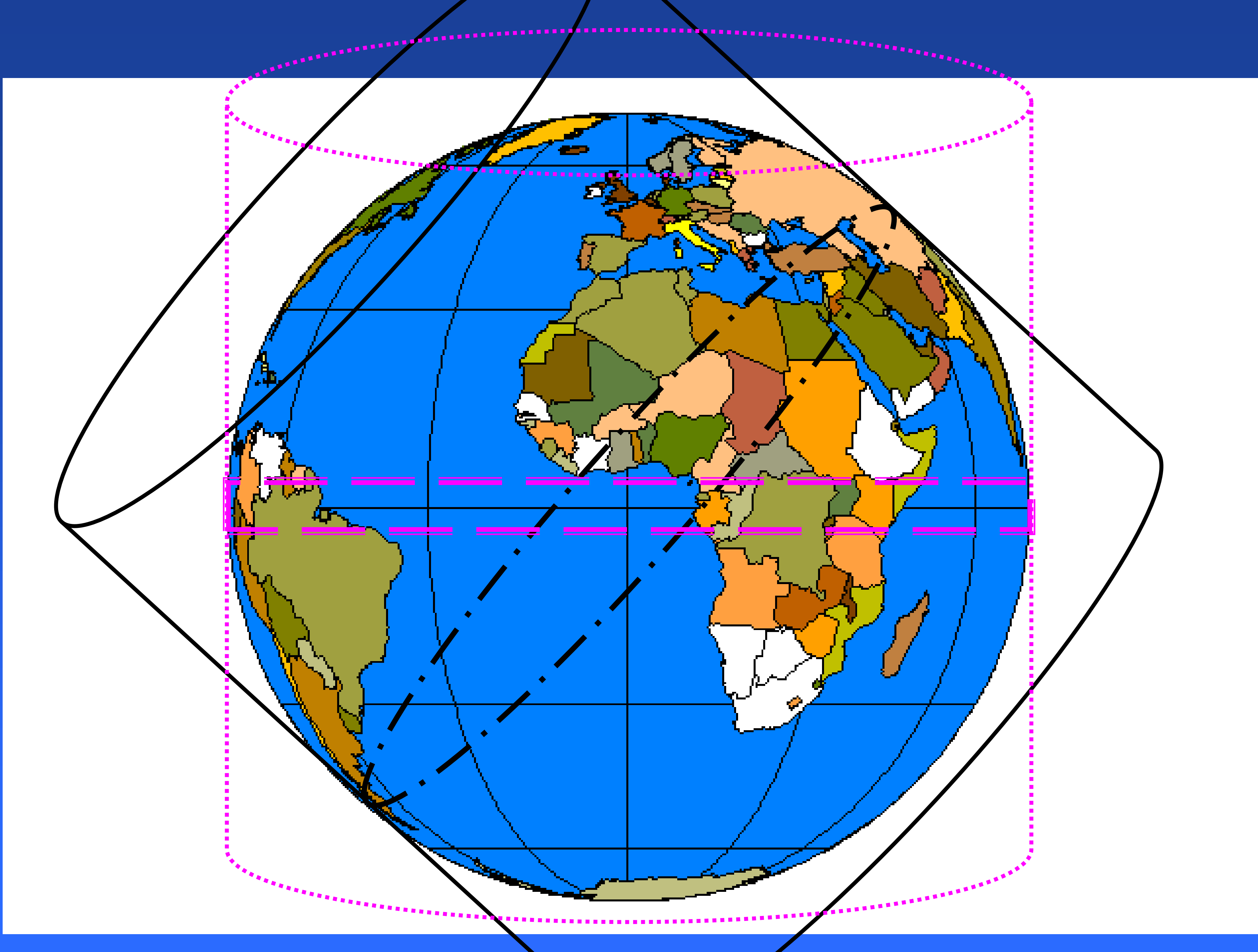
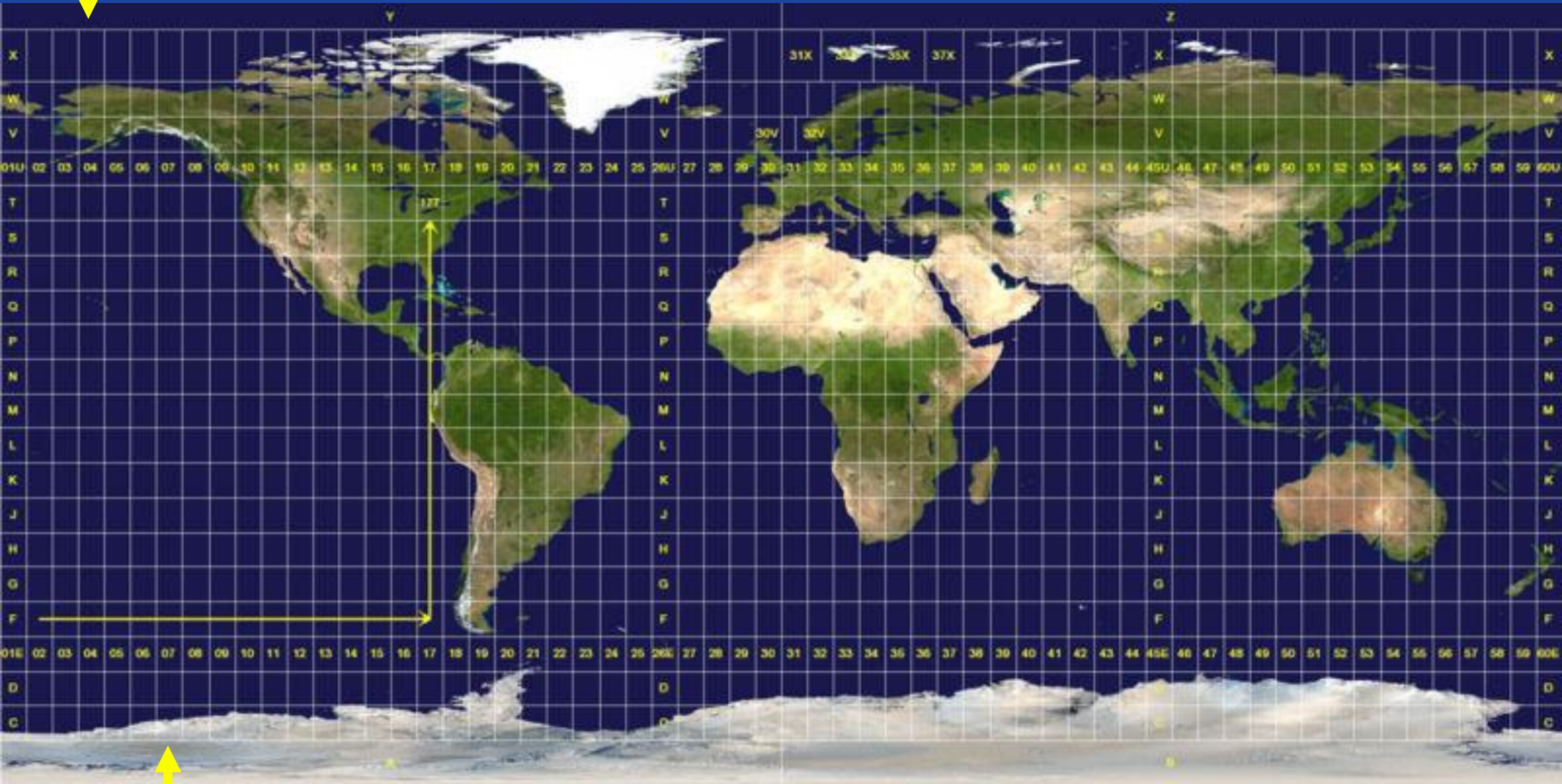


# Universal Transverse Mercator Coordinate System

84°N

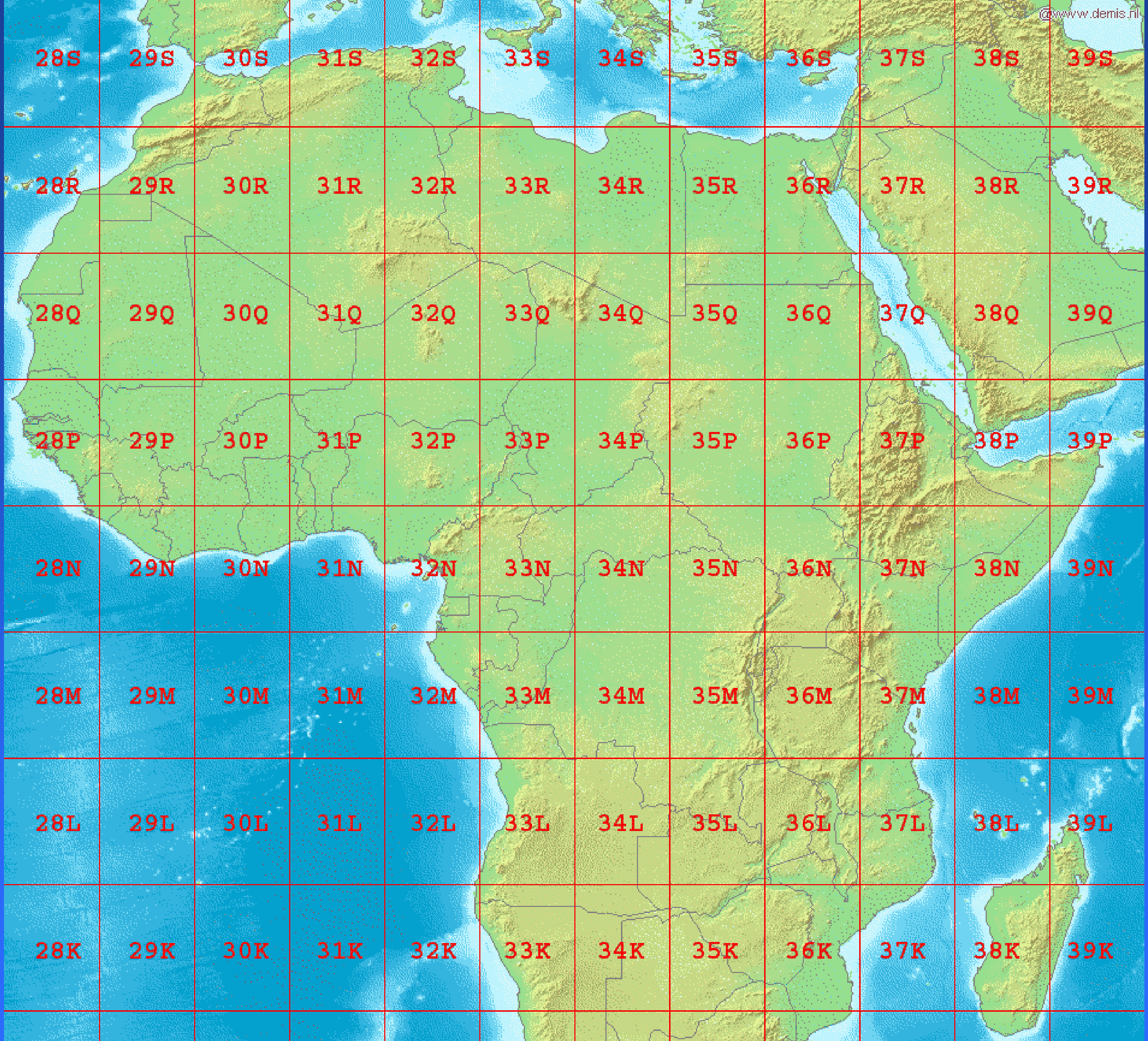



80°S

8°

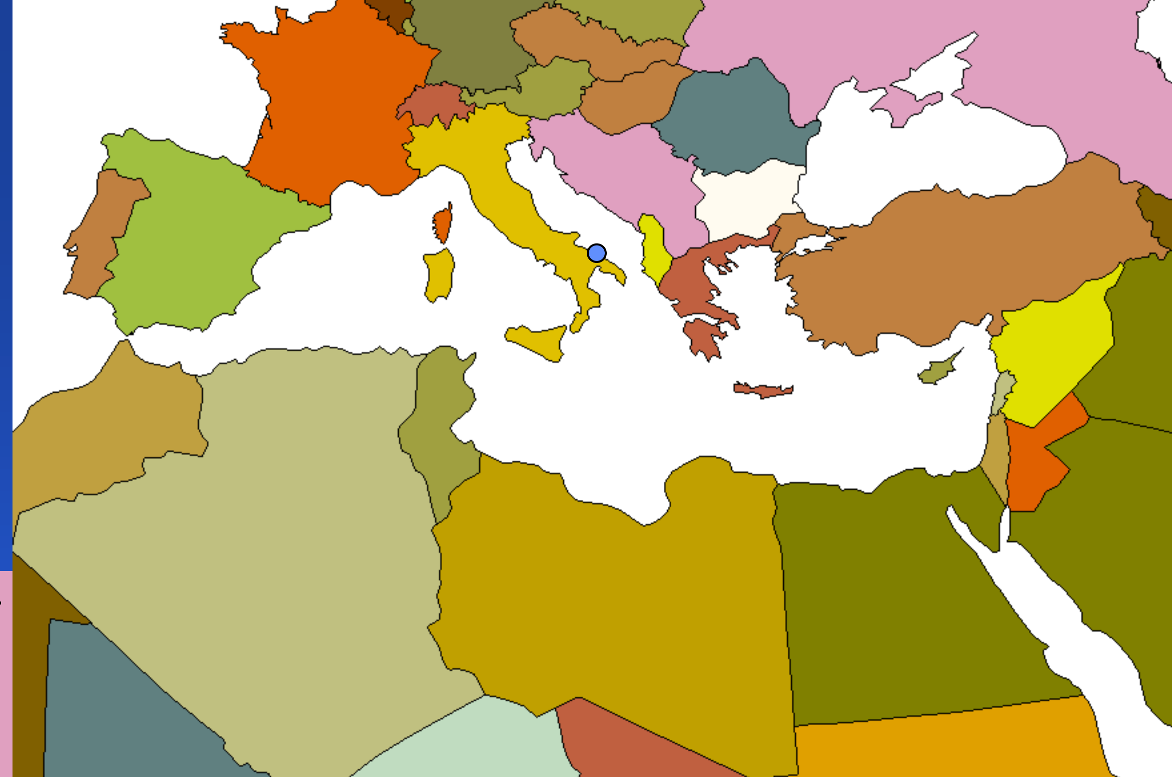
6°

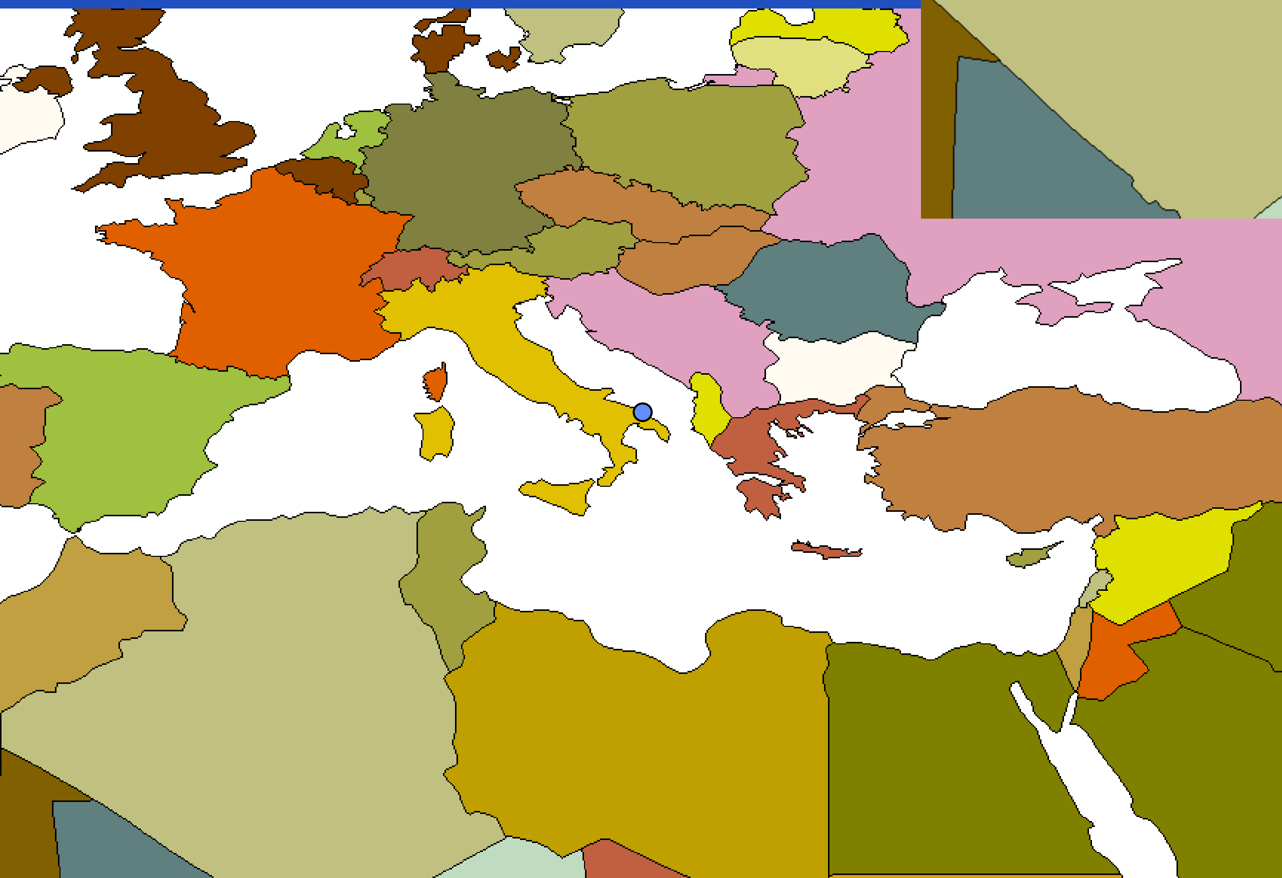

@www.demis.nl
29W 30W 31W 32W 33W 34W 35W 36W 37W 38W
29V 30V 31V 32V 33V 34V 35V 36V 37V 38V
29U 30U 31U 32U 33U 34U 35U 36U 37U 38U
29T 30T 31T 32T 33T 34T 35T 36T 37T 38T
29S 30S 31S 32S 33S 34S 35S 36S 37S 38S


©www.demis.nl
28S 29S 30S 31S 32S 33S 34S 35S 36S 37S 38S 39S
28R 29R 30R 31R 32R 33R 34R 35R 36R 37R 38R 39R
28Q 29Q 30Q 31Q 32Q 33Q 34Q 35Q 36Q 37Q 38Q 39Q
28P 29P 30P 31P 32P 33P 34P 35P 36P 37P 38P 39P
28N 29N 30N 31N 32N 33N 34N 35N 36N 37N 38N 39N
28M 29M 30M 31M 32M 33M 34M 35M 36M 37M 38M 39M
28L 29L 30L 31L 32L 33L 34L 35L 36L 37L 38L 39L
28K 29K 30K 31K 32K 33K 34K 35K 36K 37K 38K 39K

**Mediterranean region** – UTM projection, zone 33

IAMB $\begin{cases} X = \quad 657{,}921.8 \text{ m} \\ Y = 4{,}546{,}581.4 \text{ m} \end{cases}$





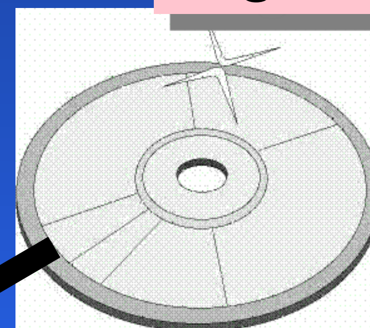
**Mediterranean region** – the projection of the world – geographic coordinates

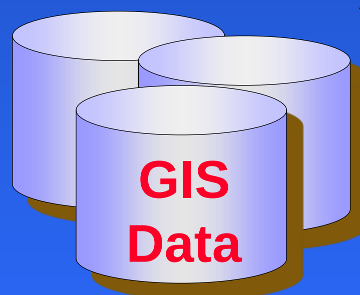
IAMB $\begin{cases} \text{Long} = 16°52'45'' \text{ E} \\ \text{Lat} = 41°3'16'' \text{ N} \end{cases}$

# Sources of Input information

## Hardcopy maps

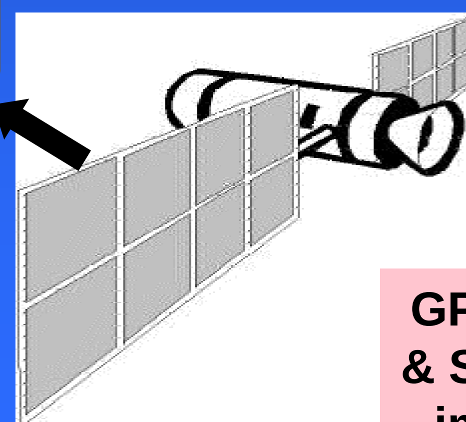

## Digital data





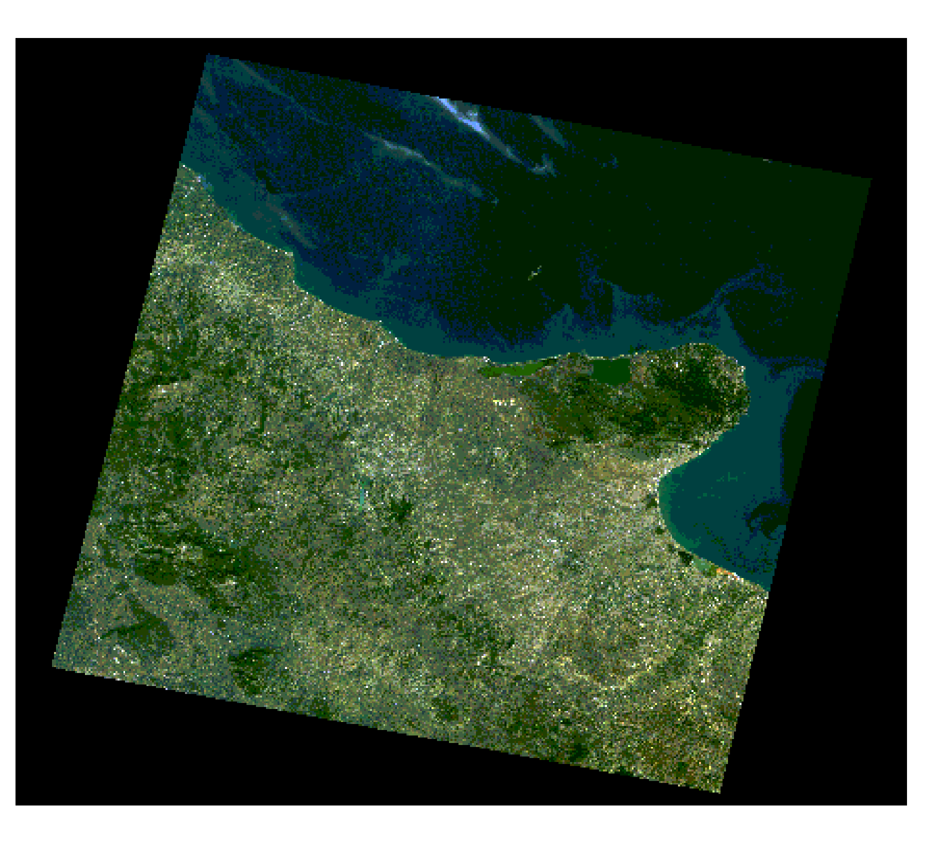

## Coordinates

```
480585.5, 3769234.6
483194.1, 3768432.3
485285.8, 3768391.2
484327.4, 3768565.9
483874.7, 3769823.0
```

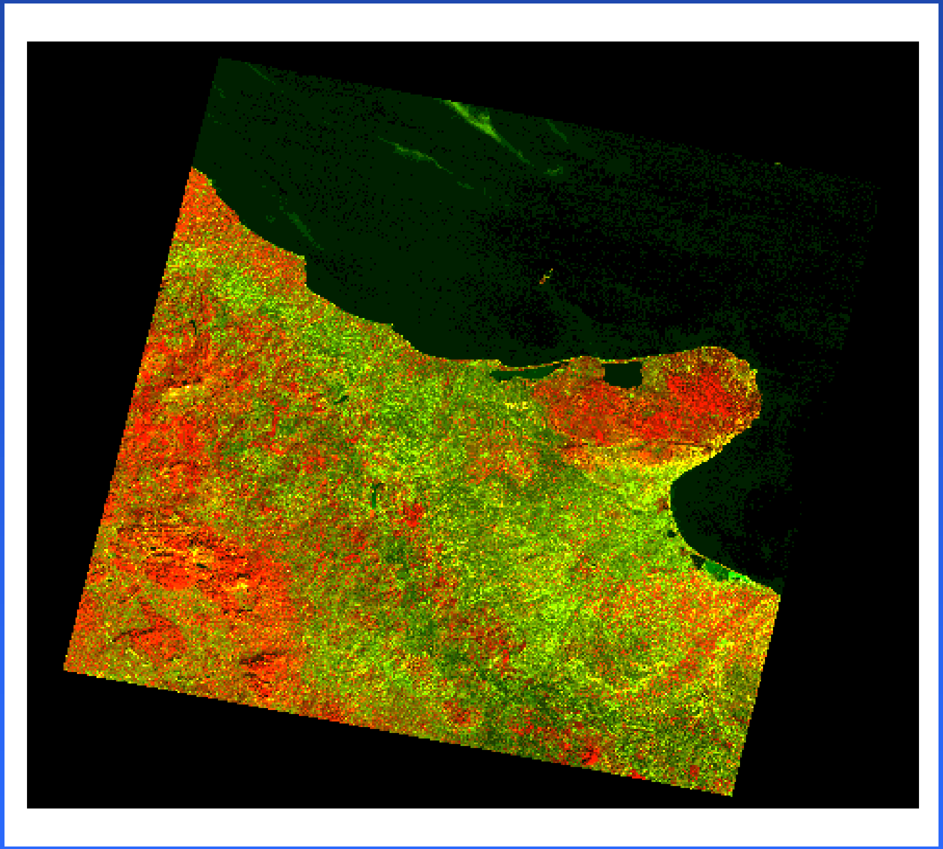


## GPS data & Satellite images

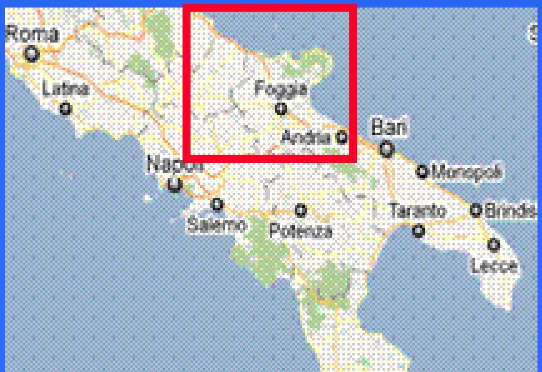
# Landsat Image of the Northern part of the Apulia Region



True-color composite image



False-color composite image

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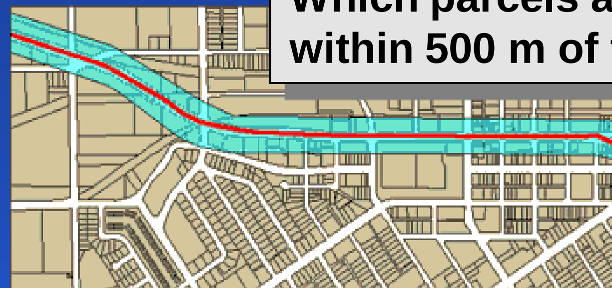
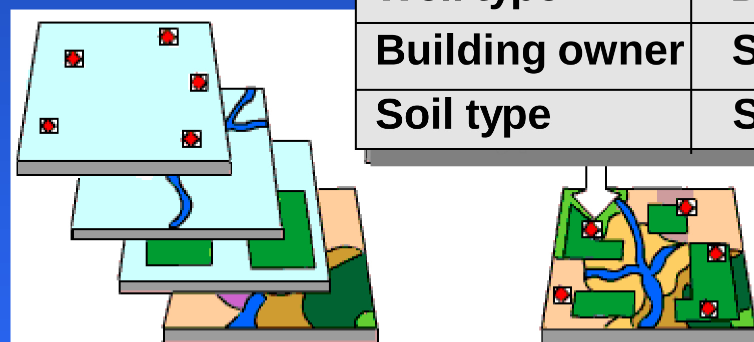
# Examples of data analysis

**Proximity**

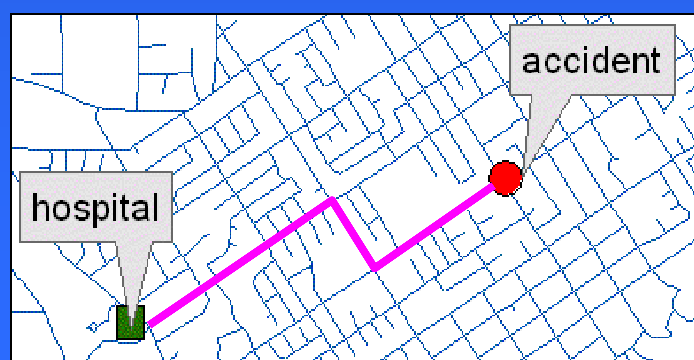



**Overlay**

| | |
|---|---|
| Well type | Drilled |
| Building owner | Smith |
| Soil type | Sandy |



**Network**

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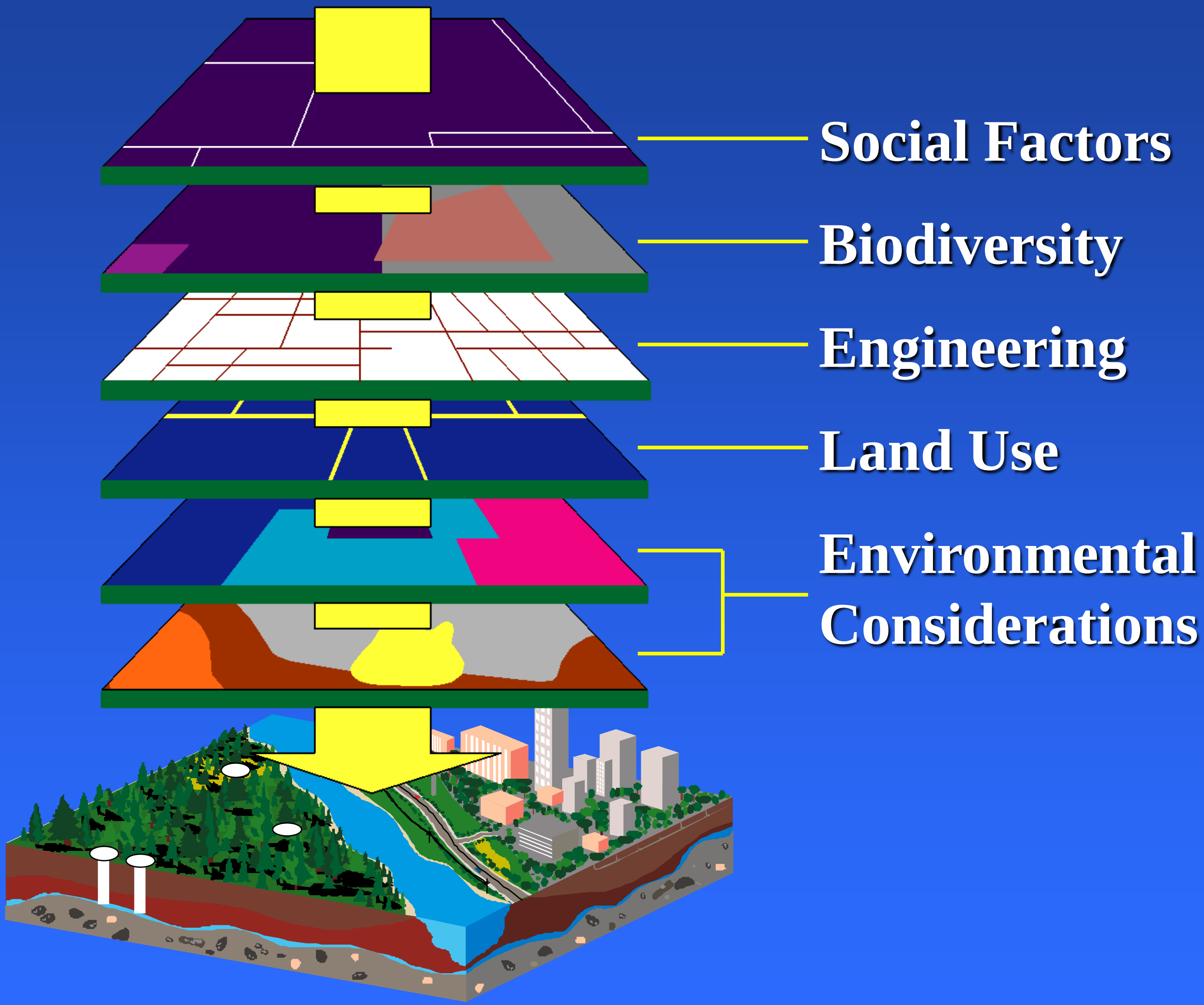
# Measuring and Integrating the Parts...




## ...Means Seeing the Whole

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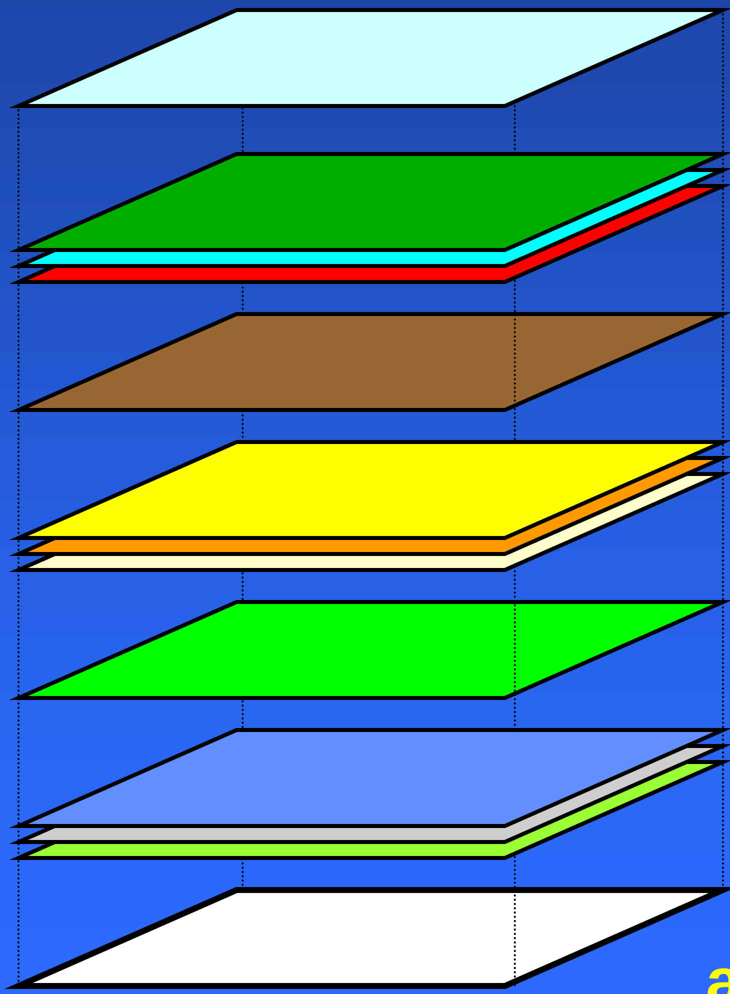
# Agro-ecological Database



Administrative map

Climatic maps

Soil map

Topographic maps

Land-use map

Productivity maps (modelling outputs)

**Final map agro-ecological database**

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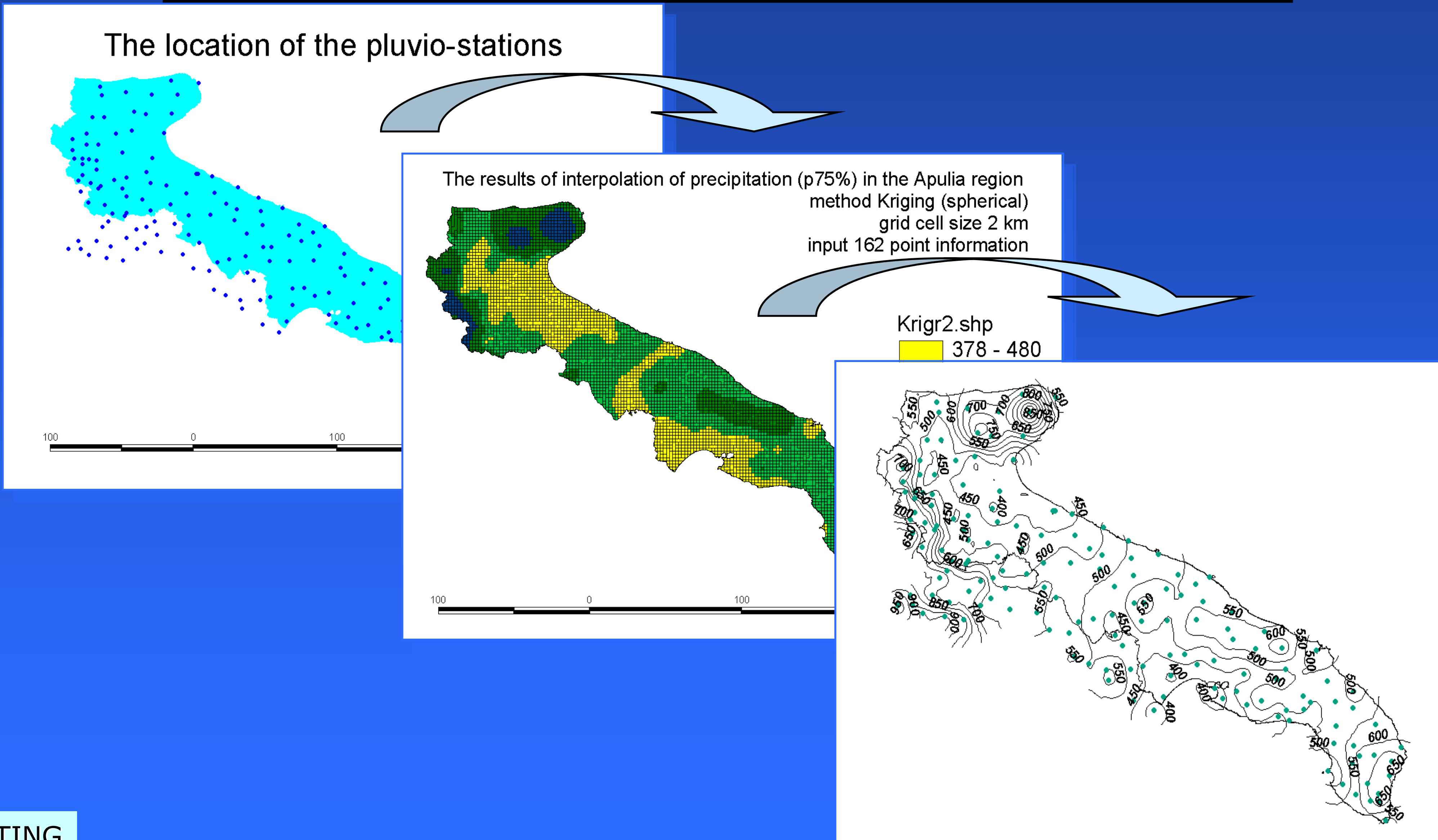
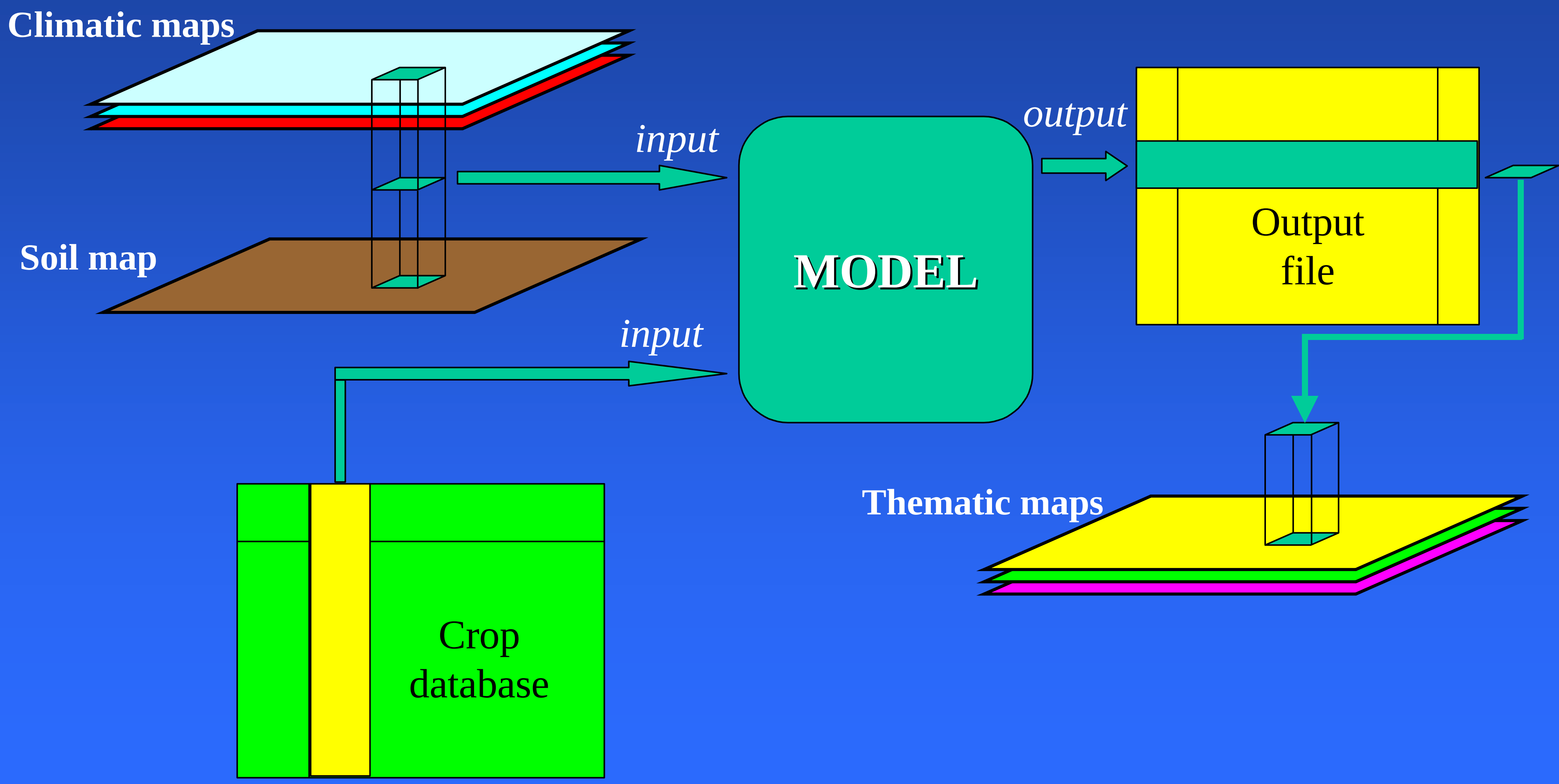
# GIS creates new information

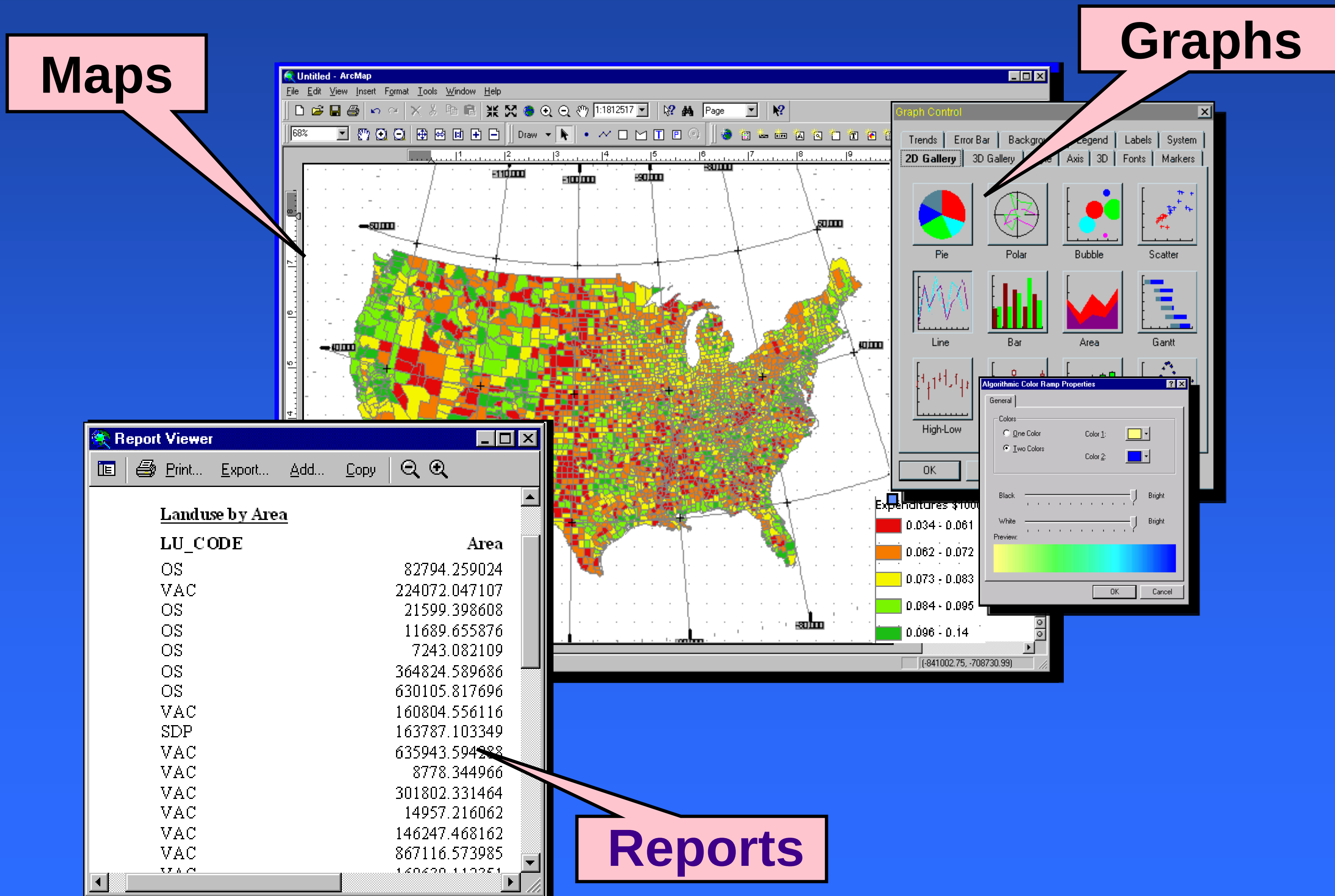


# Flowchart of data for crop modeling




*Adapted after Steduto, Todorovic et al. 1999*

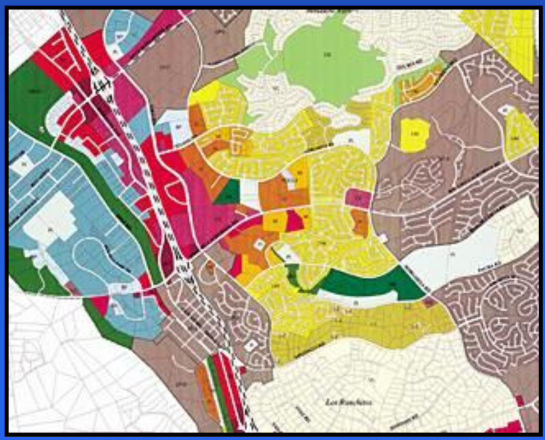
# Data display in GIS



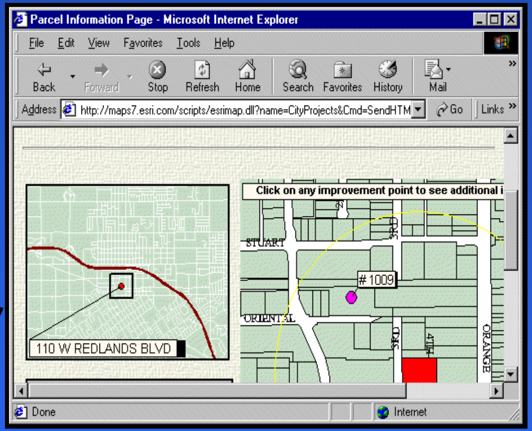

by ESRI

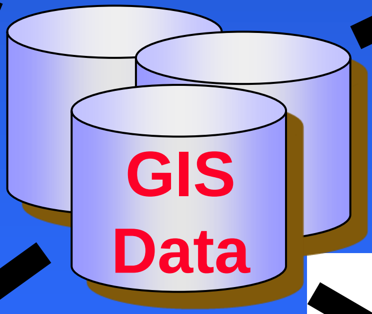
# OUTPUTS of GIS analyses

Paper map (printed)



Internet




Image

Bari.jpg

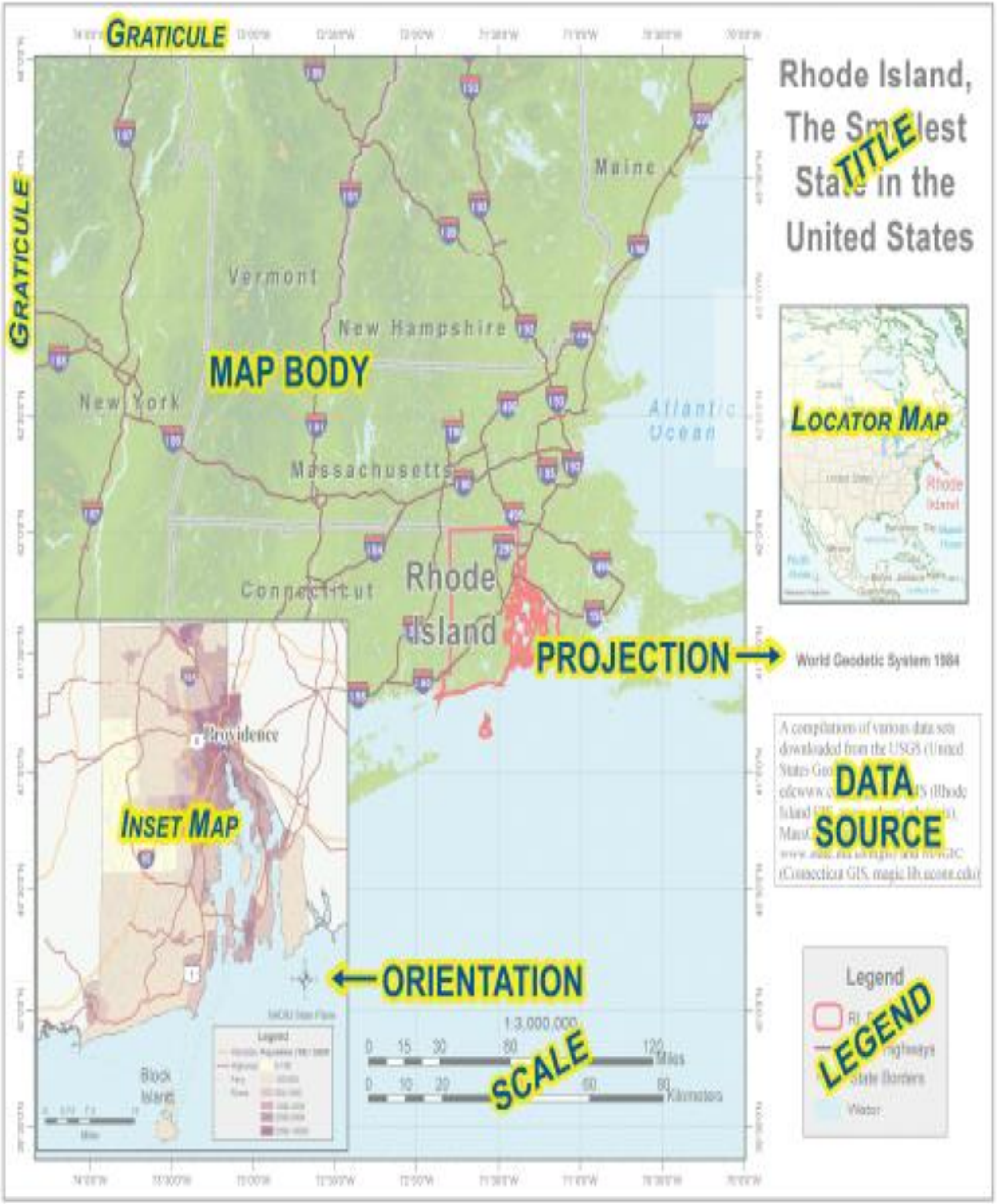
Document

Bari.mxd

by ESRI

# Basic mapping principles

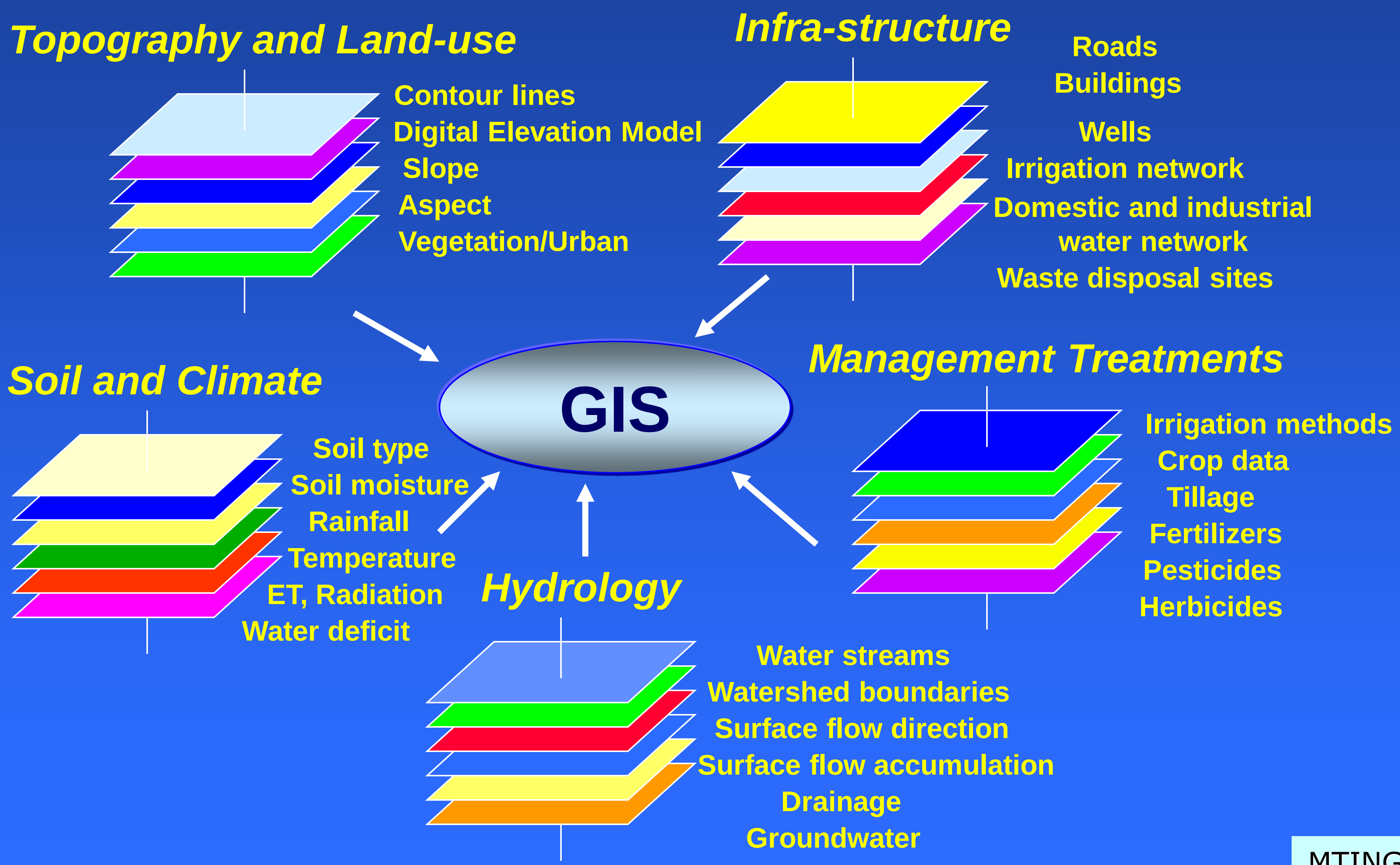
- **Purpose:** using two or more maps – each focused on a single message – is recommended
- **Audience:** few persons or millions of people
- **Size, scale and media**
- **Focus:** where the map reader should first focus (cool - blue, green and gray – and warm – red, yellow, black – colors)
- **Integrity and cross validation of data**
- **Balance of map elements:** map body, title, scale, projection, legend, etc.
- **Completeness of information**




# Data presentation: Map elements diagram

by ESRI

# GIS Applications in Irrigated Agriculture

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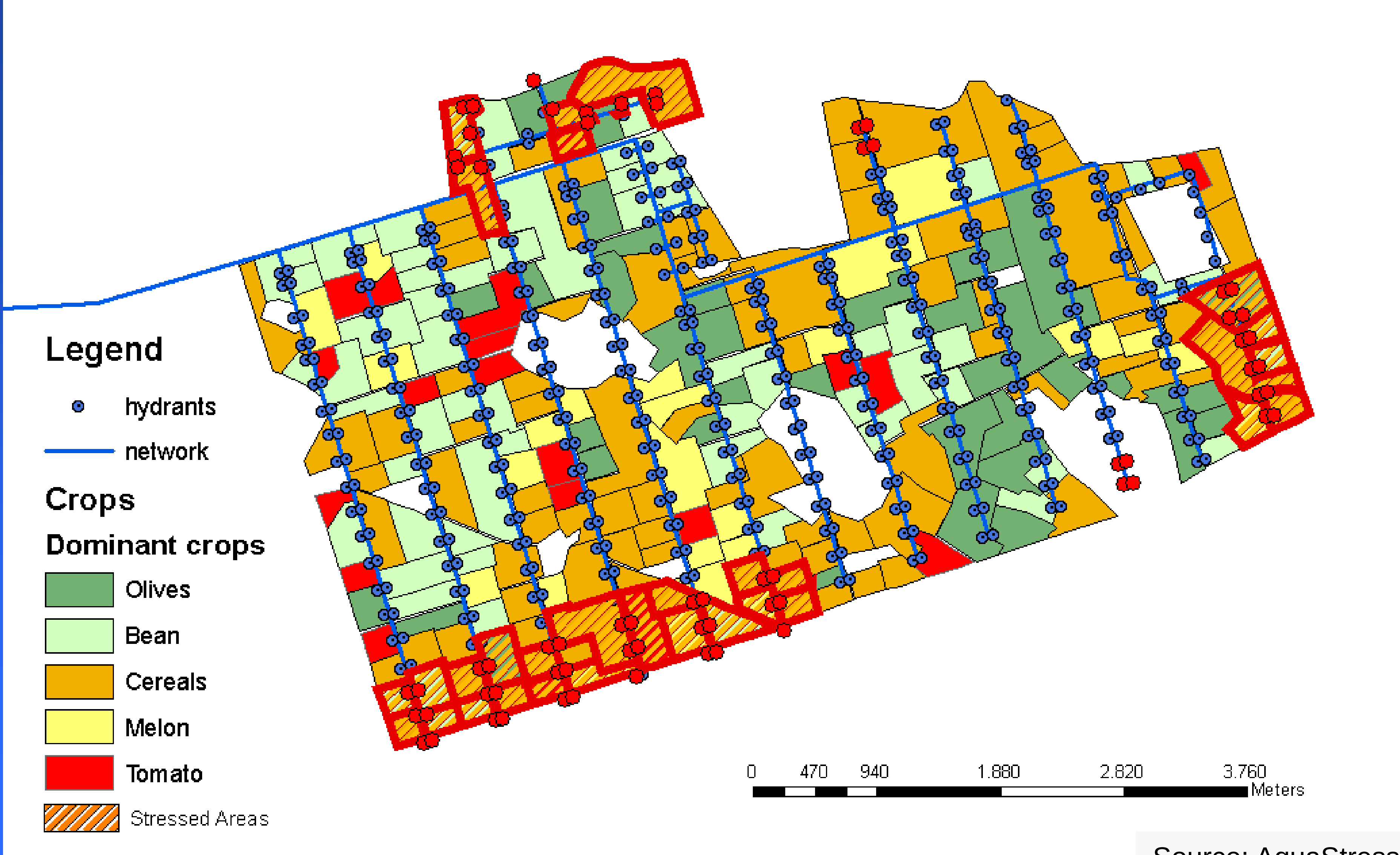
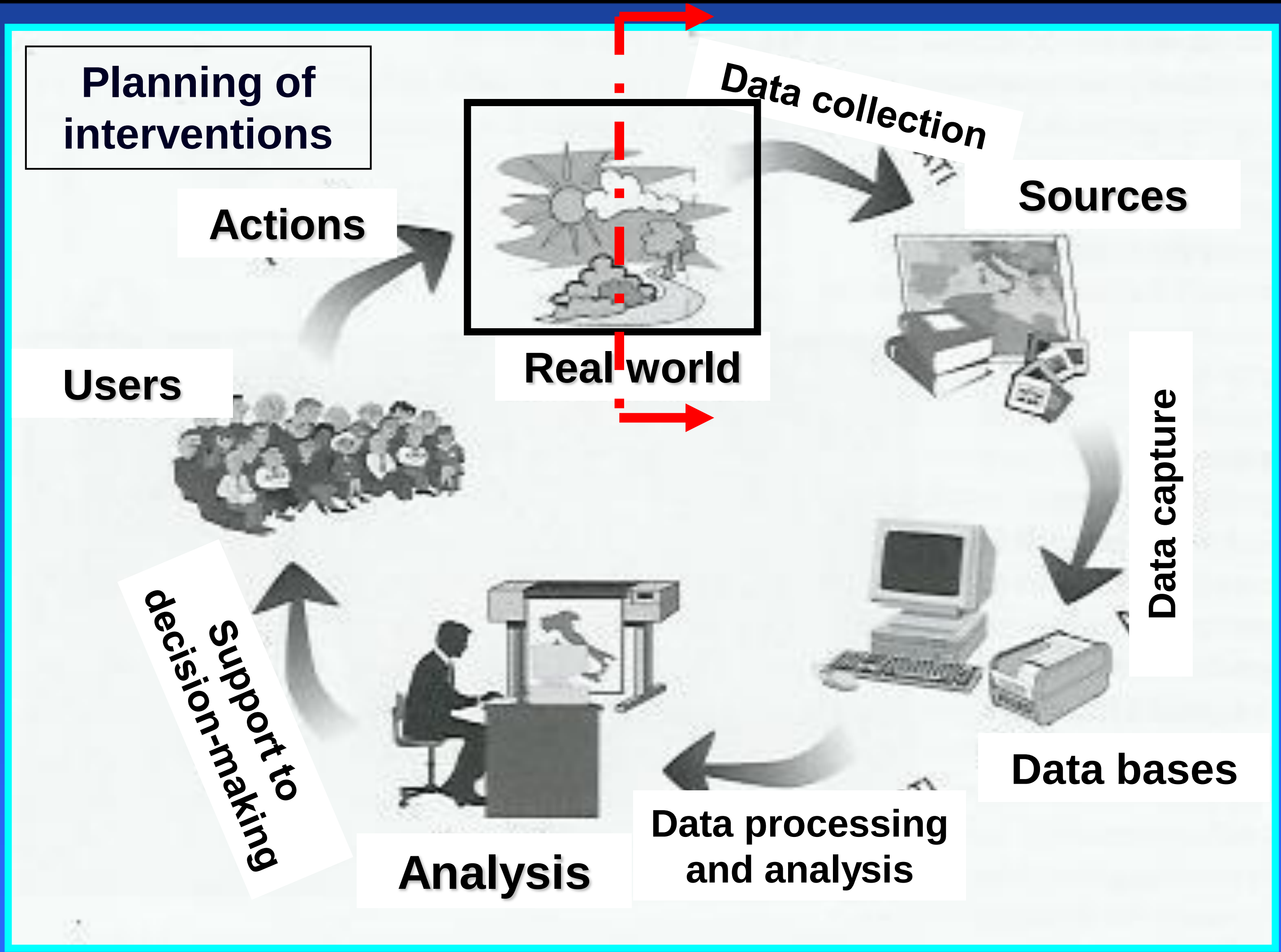
*Example of application in Tunisia (Chebika region, Merguellil watershed): integration of agronomic and engineering aspects of water management and GIS*




Source: AquaStress, 2009

# The decision-making process




**As a whole, a Geographic Information System is a tool including specific functions to acquire, handle, store, process and return geo-referenced data and provides a relevant role in decision making processes**

# GIS & Precision Farming Cycle

# Use of GIS in Italian Ministerial Offices

*Presidenza del Consiglio dei Ministri*

- Dipartimento per i Servizi Tecnici Nazionali
  - Servizio Geologico Nazionale
  - Servizio Sismico Nazionale
  - Servizio Nazionale Dighe
  - Servizio Idrografico e Mareografico Nazionale
- Dipartimento per il Coordinamento della Protezione Civile

*Ministero del Ambiente*

- Servizio Inquinamento Atmosferico Acustico e per le Industrie a Rischio
- Servizio Conservazione Natura
- Agenzia Nazionale per la Protezione dell'Ambiente

*Ministero della Difesa*

*Ministero per le Politiche Agricole*

- Sistema Informativo Agricolo Nazionale (SIAN)
- Sistema Informativo della Montagna
- Azienda di Stato per gli Interventi nel Mercato Agricolo (AIMA)

*Ministero per i Beni e le Attività Culturali*

- Istituto Centrale per i Beni Archeologici, Architettonici, Artistici e Storici
  - Istituto Centrale per il Catalogo e la Documentazione
  - Istituto Centrale per il Restauro
- Ufficio Centrale Beni Ambientali e Paesaggistici

*Ministero delle Finanze*

*ISTAT*

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# GIS vs. traditional cartography

*Advantages:*

- Maintains data consistency and reduces data redundancy
- Integrates information from different sources
- Facilitates spatial analyses and retrieval of information
- It is a dynamic system - facilitates update of information
- Reduces time and cost for creating of maps
- Creates easily thematic maps for various uses
- Produces specific maps (3D, contours) easily
- Uses explicit procedures for DB development and analyses
- Allows graduated level of generalization of information
- Allows interaction with other software (models, statistics, etc.) and IT (remote sensing, GPS, etc.)

*Disadvantage: difficulties to produce high-quality printed maps - technical and cost problems*

# Benefits and limitations in using information modeling in water-related issues

## Benefits +

- Large amount of variables
- Control of the structure and organization of variables
- Standardization of data
- Promote interdisciplinary approach
- Fast elaboration & update of data
- Use of different spatial scales
- Use of simple/complex models
- Possibility to concatenate the models
- Possibility to integrate models, GIS, RS, monitoring network, audio & video information
- Spatial visualization of inputs, outputs, scenarios, monitoring...

## Limitations -

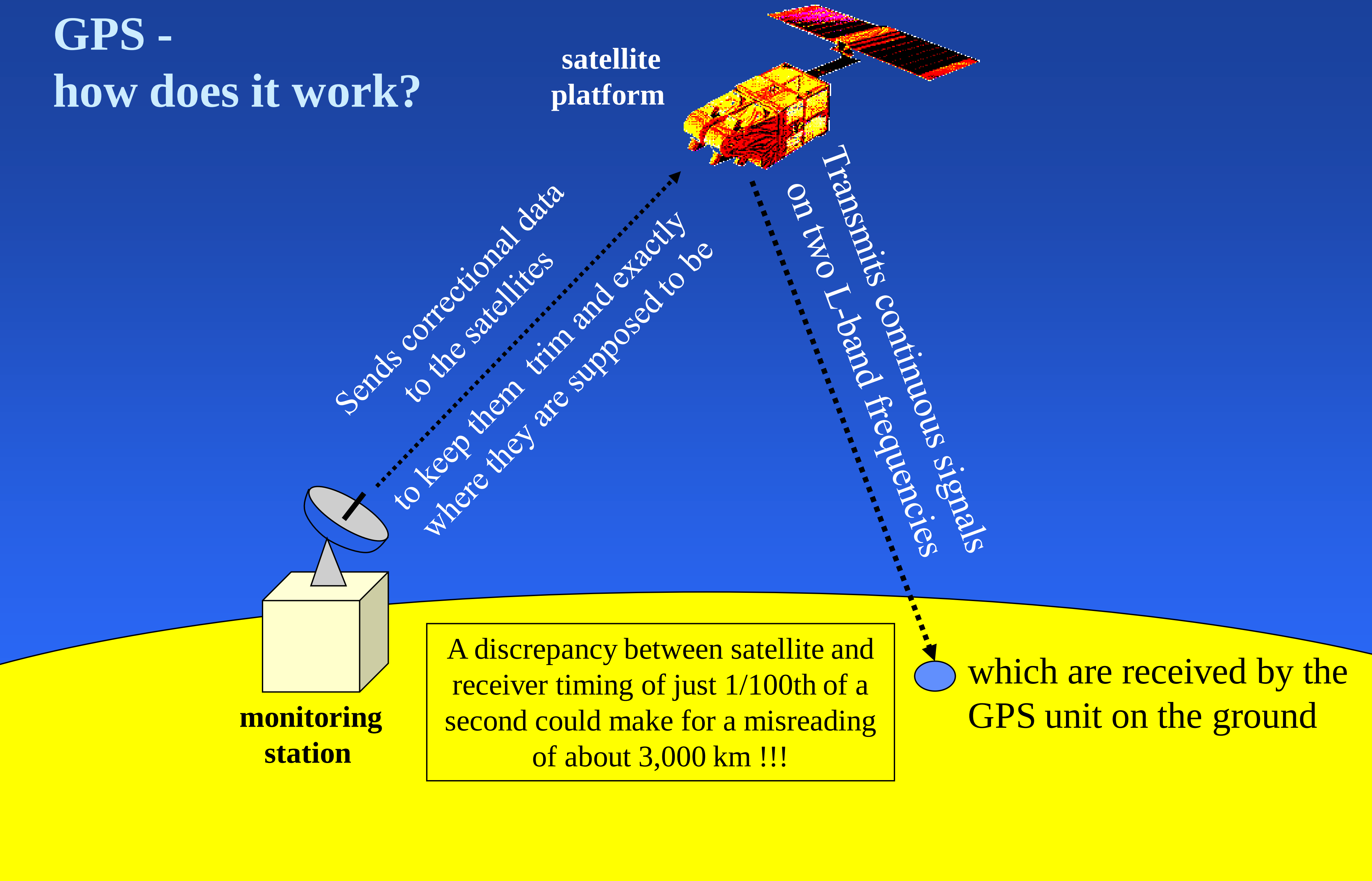
- DB development time-consuming and costly, requires significant live-ware
- Model is a "black box" for non-expert users
- Trend to accept the results of modeling without validation and with non sufficient quantity of data
- Lack of on-field experiences - Non eliminate on-field work (errors)
- Useful for relative comparisons and not for absolute
- There is no unique criteria for validation of models, spatial modeling applications, classification of RS images...

# GLOBAL POSITIONING SYSTEMS

# Global Positioning Systems (GPS)

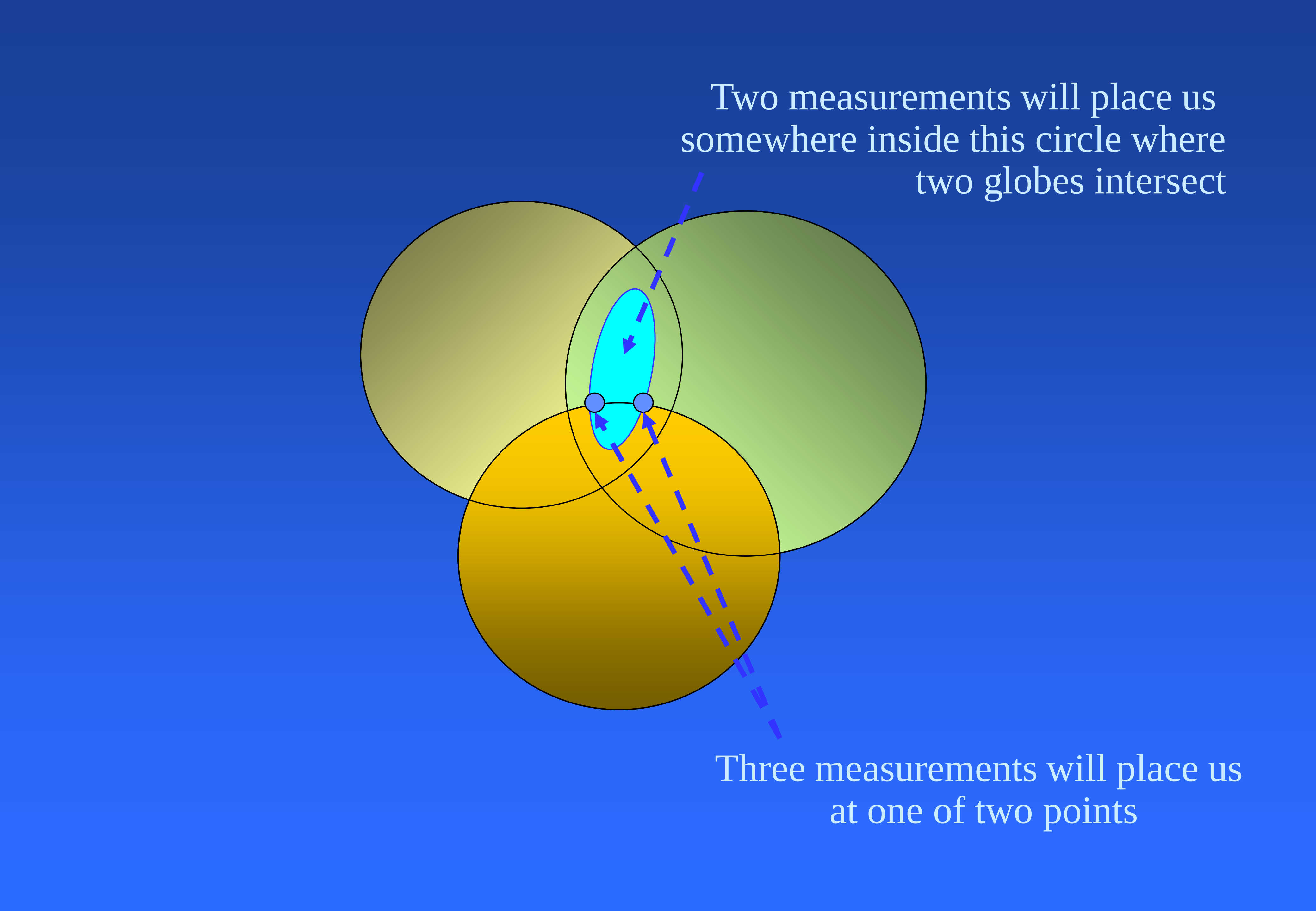
- **Definition:**
  - GPS are the space-based radio positioning systems that provide 24-hours three dimensional position, velocity and time information to suitable equipped users anywhere on or near the surface of the Earth.
- **Principles:**
  - GPS is a constellation of 24 (+some spares) orbiting satellites NAVSTAR (12-hours orbits at an altitude of 20,200 km) - open for use by anyone without charge, 5 monitoring stations and individual receivers
  - 6 orbital planes (4 satellites in each), equally spaced (60° apart), and inclined at about 55° with respect to the equatorial plane
  - The orbital paths of the satellites were designed so that any point of the Earth's surface has at least four of the satellites available above the local horizon at any time.
  - Each satellite continuously transmits a time and location signal
  - GPS receivers process the satellite's signal from as few as three of satellites (a process known as trilateration) and calculates a position in geographic coordinates (and in a user-specified coordinate and projection system).

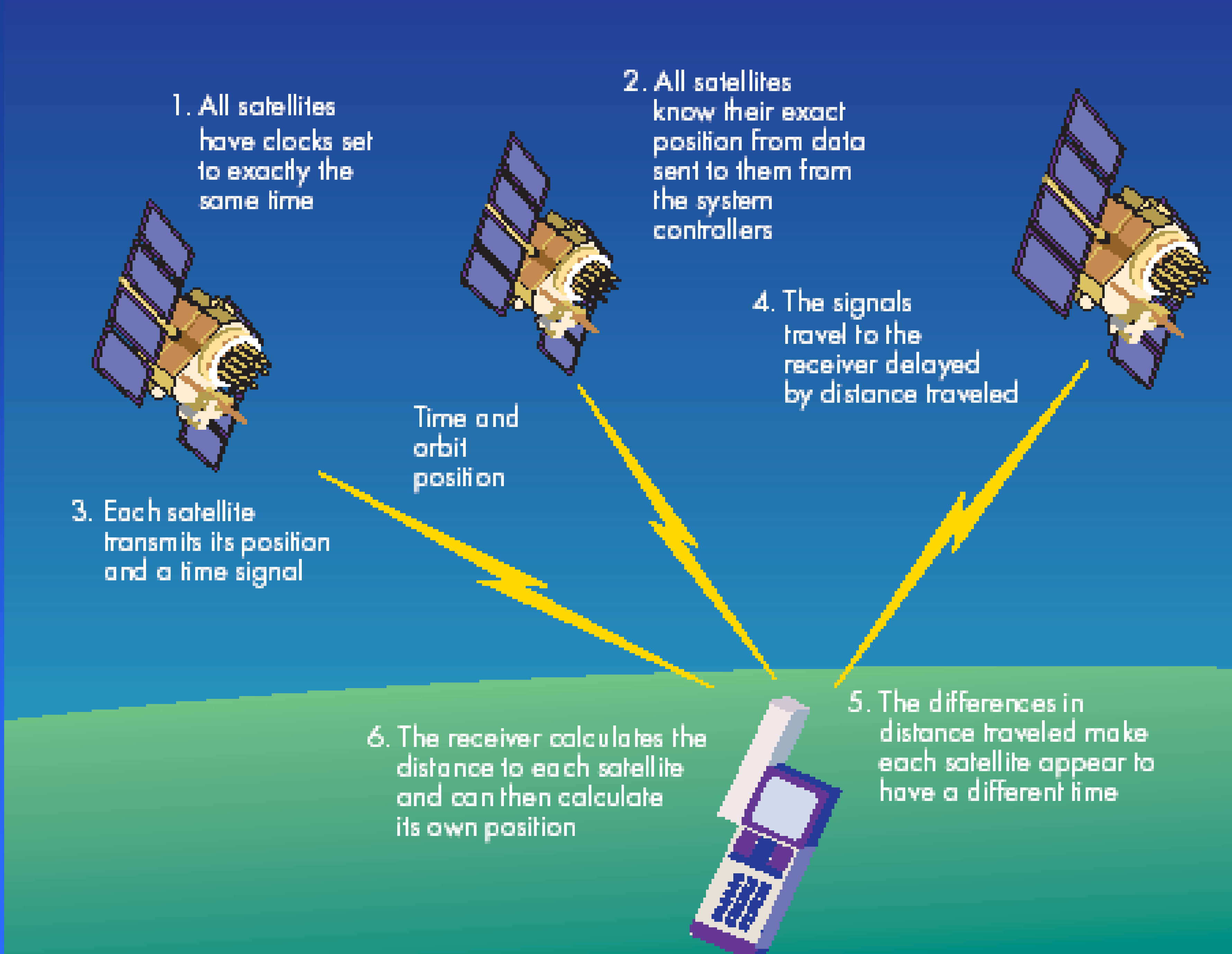
# GPS - how does it work?



# How the GPS works?

- How can a GPS knows how far it is from a satellite?
  - GPS measures the time to calculate the distance: distance = time * velocity
  - velocity is constant (speed of light) - the receiver needs to know only how long it took for the signal to travel from the satellite to the GPS receiver on the ground.
  - To accomplish this, each GPS satellite is equipped with a so-called “atomic” clock and GPS receivers with quartz clocks - the receiver’s clock is automatically adjusted by the satellites.
  - GPS measures the difference between the time signal left the satellite and the time receiver got it.
- Why GPS needs the signal from three (four) satellites?
  - the first reading puts the location somewhere on the globe
  - the second narrows the possibilities to the circle where the two globes intersects
  - the third gives enough information to calculate the location as one of two points
  - the fourth satellite is necessary if our location is above the surface of the Earth (e.g. in an aircraft)


Two measurements will place us somewhere inside this circle where two globes intersect
Three measurements will place us at one of two points

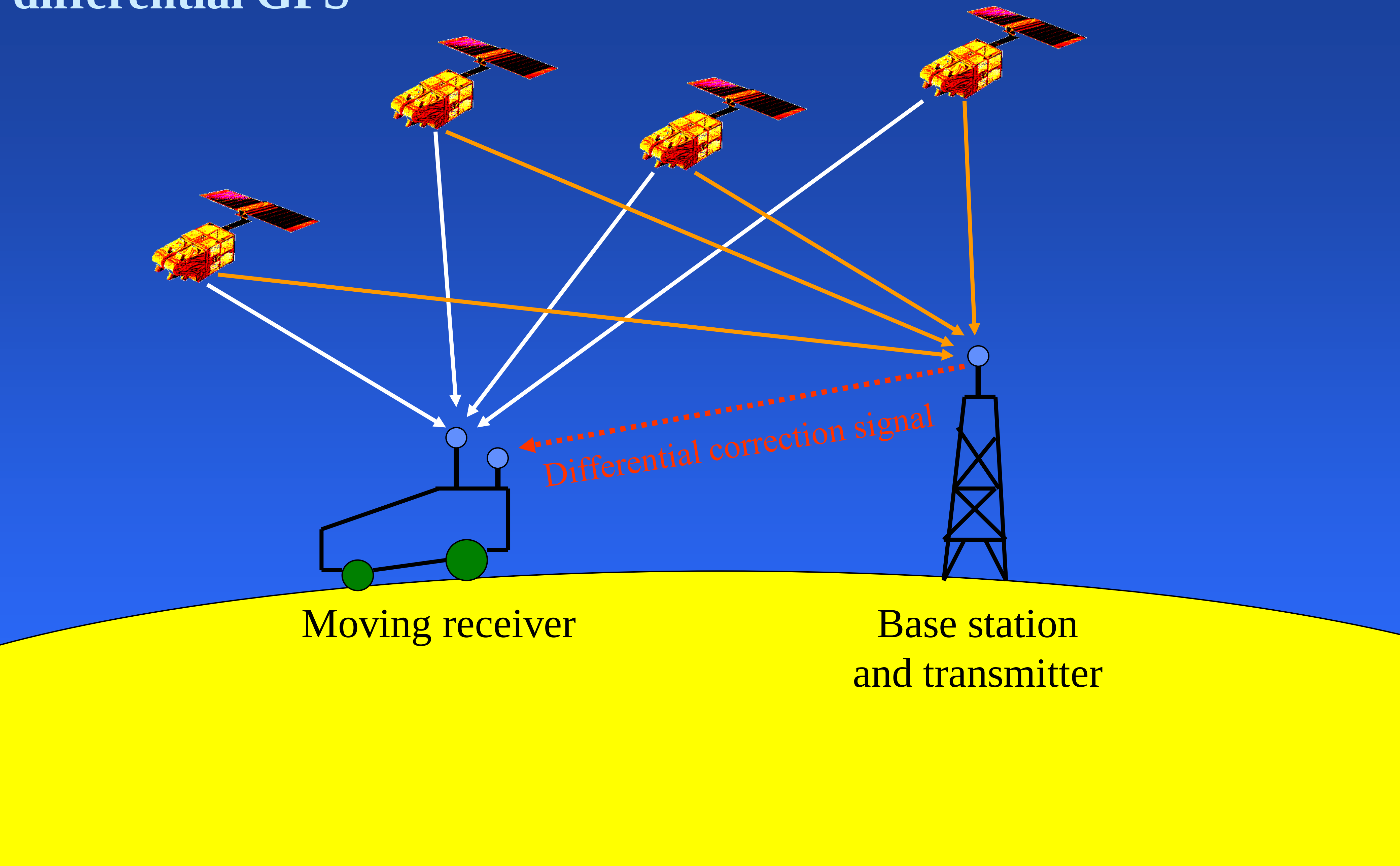



Source: Aerospace coorporation, 2003

# Global Positioning Systems (GPS)

- Errors:
  - random error - associated with atmospheric variation and equipment reliability - is addressed by collecting a large sample of data (points) at the same location and averaging them..
  - systematic error - result of Selective Availability - is avoidable or reduced by using two GPS receivers, i.e. differential GPS (radio link between the reference receiver at known location - base station and the rover receiver at the field)
- How to choose a GPS?
  - The user should determine the level of acceptable error and purchase the equipment and software supporting those parameters.
  - stand-alone GPS - with an error between 5 and 50 m - US$ 200-500
  - Geodetic quality GPS units - with an accuracy of few mm – between US$10,000 and US$75,000

# Real-time differential GPS



# Global Positioning Systems (GPS)

- Applications:
  - **large scale application in surveying and topography mapping may result in more than 50% cost saving and more than 75% time saving in respect to the use of traditional methods**
  - **use in rectification and geometric correction of satellite images - high accurate coordinates of Ground Control Points (GCP)**
  - **use in the control of the results of classification of satellite images**
  - **in agriculture, along with specialized GIS-based software and on-field sensors - use in field monitoring of soil type and soil moisture, crop height, density and productivity, fertilizer use, pesticides and herbicides application etc.**
  - **in water resources - flow and water quality measurements, water distribution network (pipelines) digitalization, wells and hydrants locations, etc.**
- Limitations
  - **cannot be effectively used if receiver does not have a clear view of sky (signals can be blocked by buildings, trees or dense canopy, and the earth itself)**

# GPS-GIS Integration: the work flowchart
# Planning, implementation and evaluation