Czech University of Life Sciences Prague

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ECAP Vienna Training Visit 2017

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GIS Fundamentals and Geographic Data Availability for Environmental Applications

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GIS Fundamentals and Geographic Data

- What is GIS ?
- How do we represent Earth ?
- Geographic Data Models

What is GIS?

What is GIS ? Definition….

In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. **data identified according to their location**. Practitioners also regard the total GIS as including operating personnel and the data that go into the system.

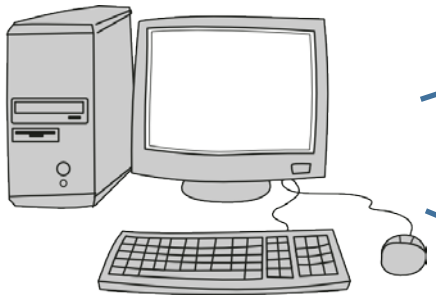
United States Geological Survey definition

A set of tools for collecting, storing, retrieving at will, transforming and displaying **spatial data** from the real world for a particular set of purposes.

P. A. Burrough, 1986

Software and data that enable us to ask and answer questions involving where something is and how that **location relates to other things**.

Nick Santos



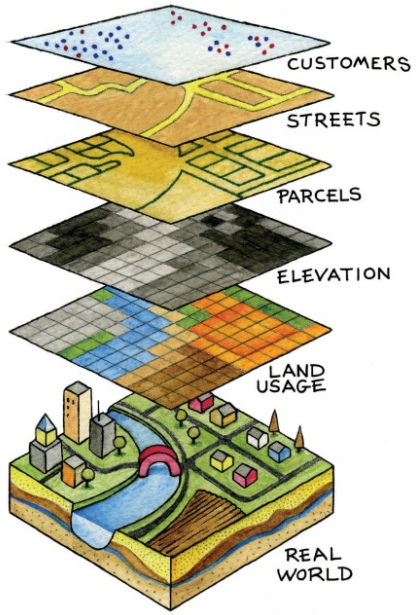
Acquisition

Display

Analysis

Storage

GIS



Geographic Data

Examples:

Solar potential (cadastre): http://www.zonatlas.nl/home/

Species distribution:

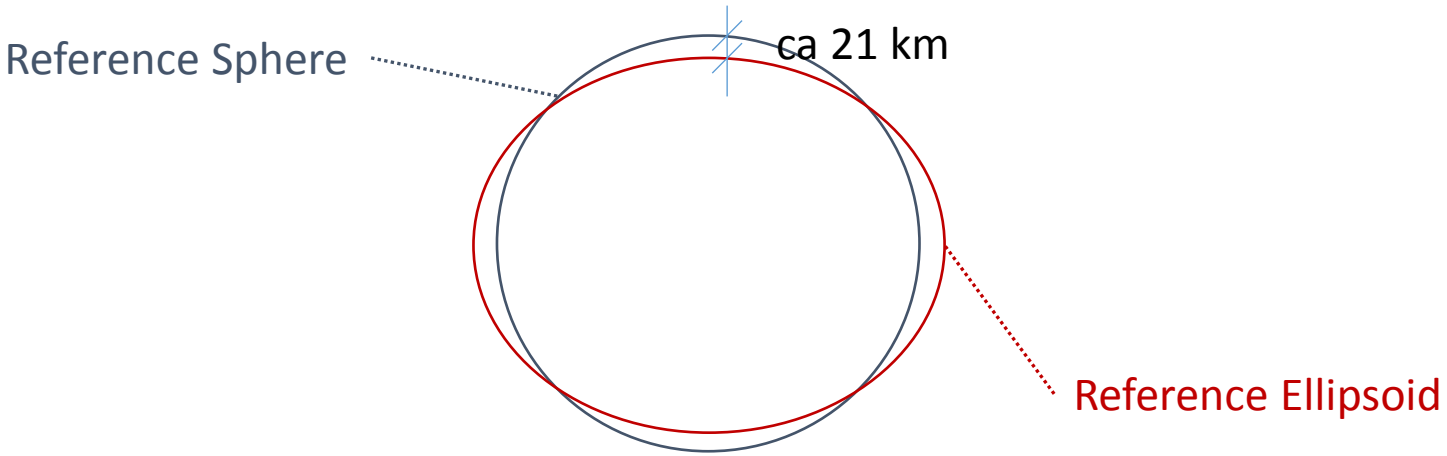
range maps: http://www.iucnredlist.org/search

species occurrences: http://www.iobis.org/ , http://www.gbif.org/

Small-Scale Fisheries: http://toobigtoignore.net/

How do we represent Earth ?

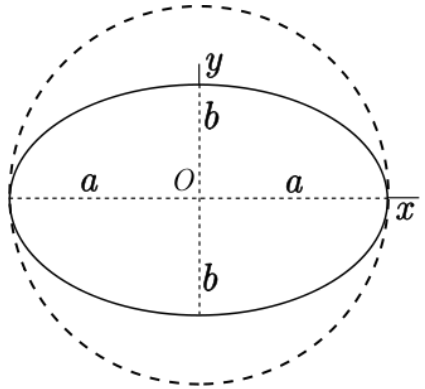
Approximations:



Source: http://www-app2.gfz-potsdam.de/pb1/op/grace/results/grav/g003_eigen-cg01c.html

Reference Ellipsoids

Ellipsoid Parameters:

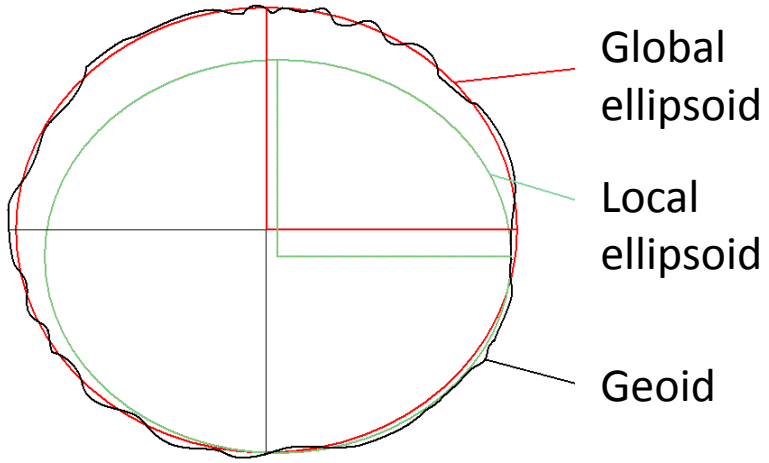


a … semimajor axis
b … semiminor axis

Flattening:

$$f = \frac{a - b}{a}$$

Global vs Local Ellipsoids:



Sources: http://en.wikipedia.org/wiki/Flattening
http://www.socsci.flinders.edu.au/geog/sisl/html/subjects/geog3013/handbook.html

Reference Ellipsoids

Name	Local/ Global	Equatorial axis (m)	Polar axis (m)	Flattening (%)
Airy 1830	Local	6 377 563.40	6 356 256.90	0.3341
Clarke 1866	Local (North America)	6 378 206.40	6 356 583.80	0.3390
Bessel 1841	Local (Europe)	6 377 397.16	6 356 078.97	0.3343
International 1924	Local	6 378 388	6 356 911.90	0.3367
Krassovsky 1940	Local (Soviet union)	6 378 245	6 356 863	0.3352
GRS 1980	**Global**	**6 378 137**	**6 356 752.3**	**0.3353**
WGS 1984	**Global**	**6 378 137**	**6 356 752.31**	**0.3353**
Sphere (6371 km)	Global	6 371 000	6 371 000	0

Source: http://en.wikipedia.org/wiki/Reference_ellipsoid

Geodetic Datum

The spheroid (ellipsoid) defines the size and shape of the earth model, while the datum connects the spheroid (ellipsoid) to the earth's surface.

Local geodetic datum:

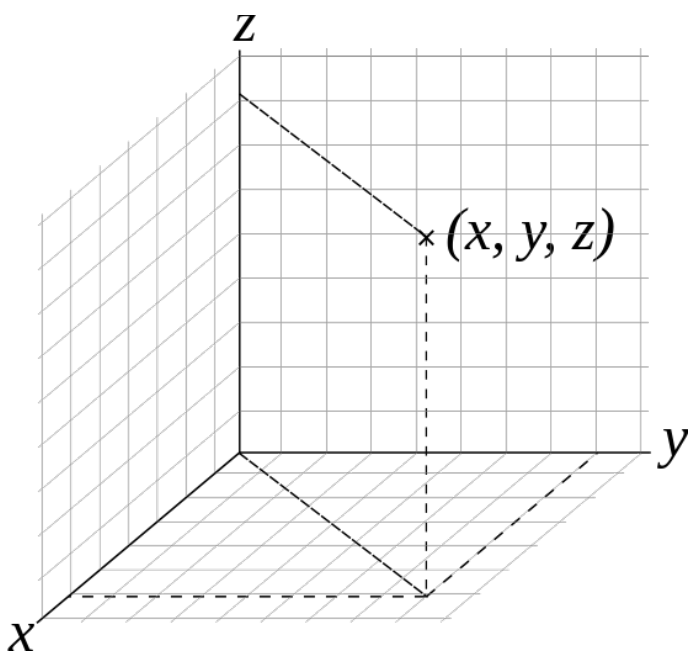
Datum	Ellipsoid
NAD27	Clarke 1866
NAD83	GRS80
ED79	International 1924
Pulkovo 1942 (S-42)	Krassovsky 1940
S-JTSK	Bessel 1841

Global geodetic datum (geocentric):

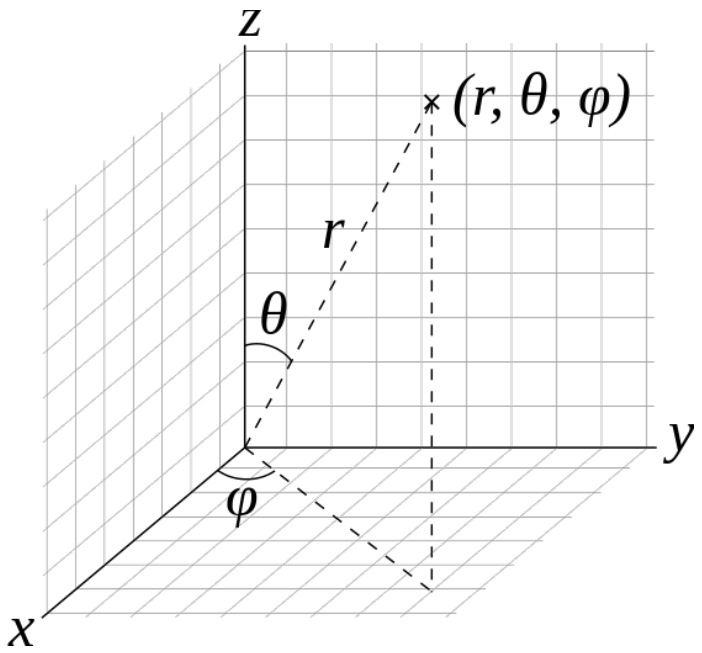
Datum	Ellipsoid
WGS84	WGS84
ITRS	GRS80
ETRS89	GRS80

Coordinate Systems

Cartesian



Spherical



Sources: http://simple.wikipedia.org/wiki/Position http://en.wikipedia.org/wiki/Spherical_coordinate_system

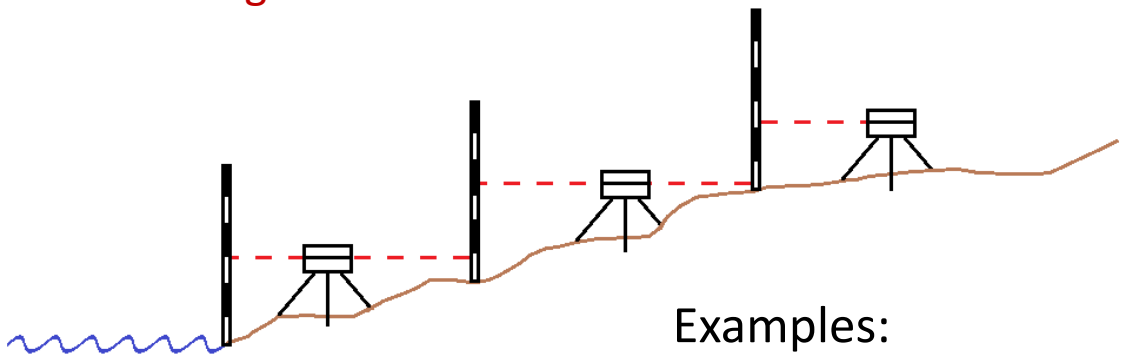
Vertical datum

Vertical Datum

a) Local (“Tidal”) Datums:

- Local sea level (i.e. the tides) measured hourly over years (tide gauges)
- Network of levelling points

Geodetic Levelling:



Examples:

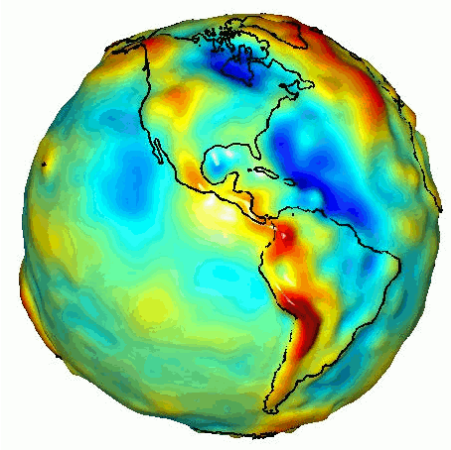
Baltic Sea Level Datum 1977

Ordnance Datum Newlyn

Source: http://kartoweb.itc.nl/geometrics/Reference%20surfaces/refsurf.html

Vertical Datum

Geoid



- Approximation of the **mean sea level**
- Formed by **gravitation** and rotation only (not by tectonics, erosion, tide and currents)
- Equipotential surface in the gravitational field (**plumb line**)
- Base for **heights**, impractical for mapping…

Imaginary surface called the geoid, which is determined by the earth's gravity and approximated by MSL.

By definition, the geoid describes the irregular shape of the earth and is the true zero surface for measuring elevations.

Previously, there was no way to accurately measure the geoid so it was roughly approximated by MSL. Although for practical purposes, at the coastline the geoid and MSL surfaces are assumed to be essentially the same, at some spots the geoid can actually differ from MSL by several meters.

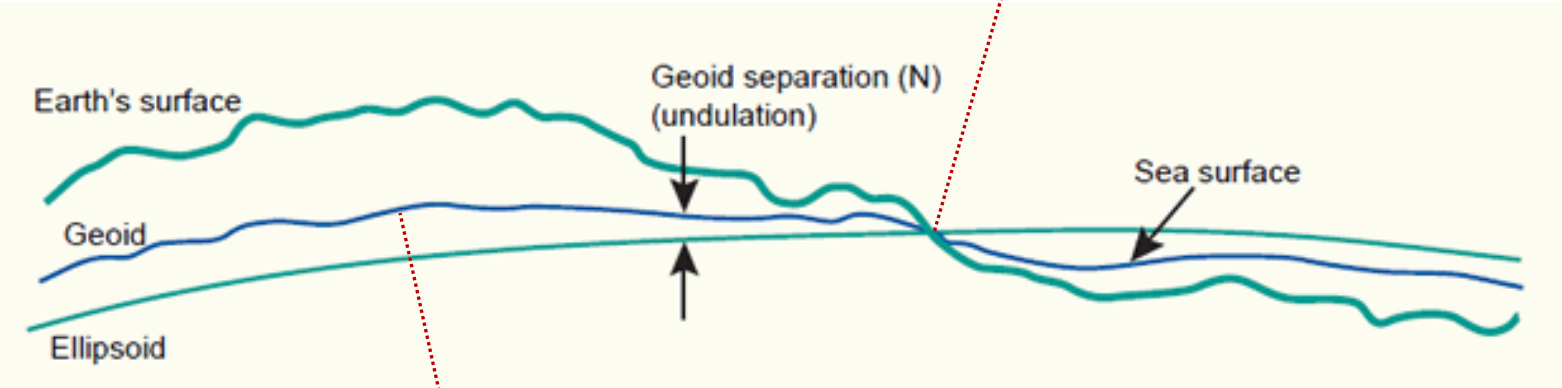
http://www.esri.com/news/arcuser/0703/geoid1of3.html

Vertical Datum

"Height above Mean Sea Level…"

Approximated by:

a) Coastal Measurements
-> Local MSL



b) Gravimetric Measurements
-> Geoid

Source: http://kartoweb.itc.nl/geometrics/Reference%20surfaces/refsurf.html

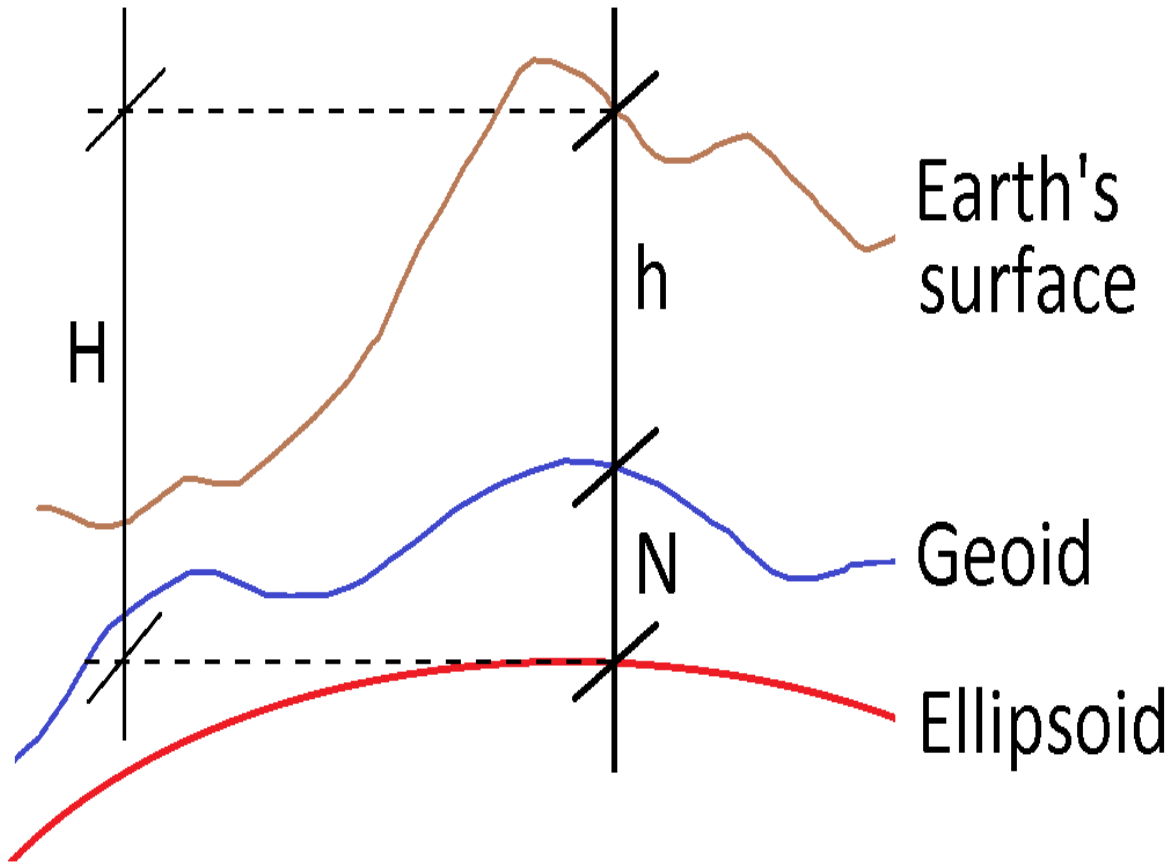
Vertical Datum

H … Ellipsoidical Height

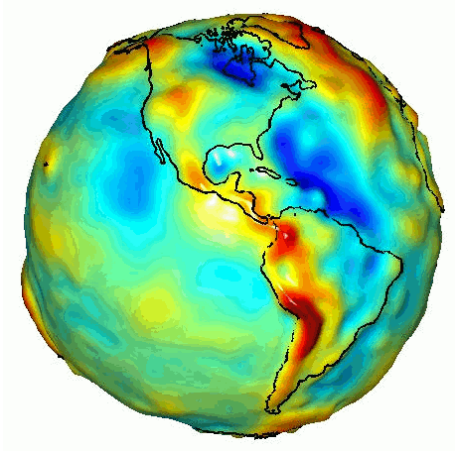
h … Orthometric Height

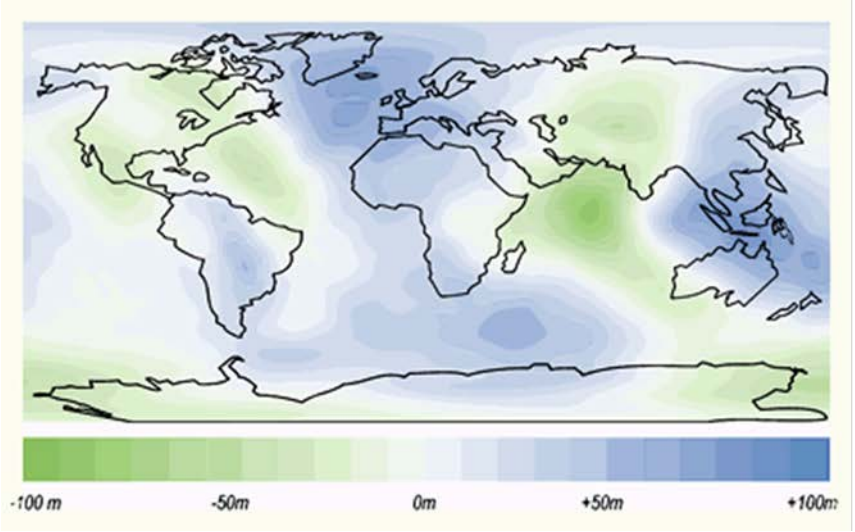
N … Geoid Undulation

h = H – N



Vertical Datum





Geoid undulation (with respect to the WGS84 ellipsoid)

± 100 m

GPS (GNSS) – elipsoidical or orthometric height ?

Coordinate system matters !

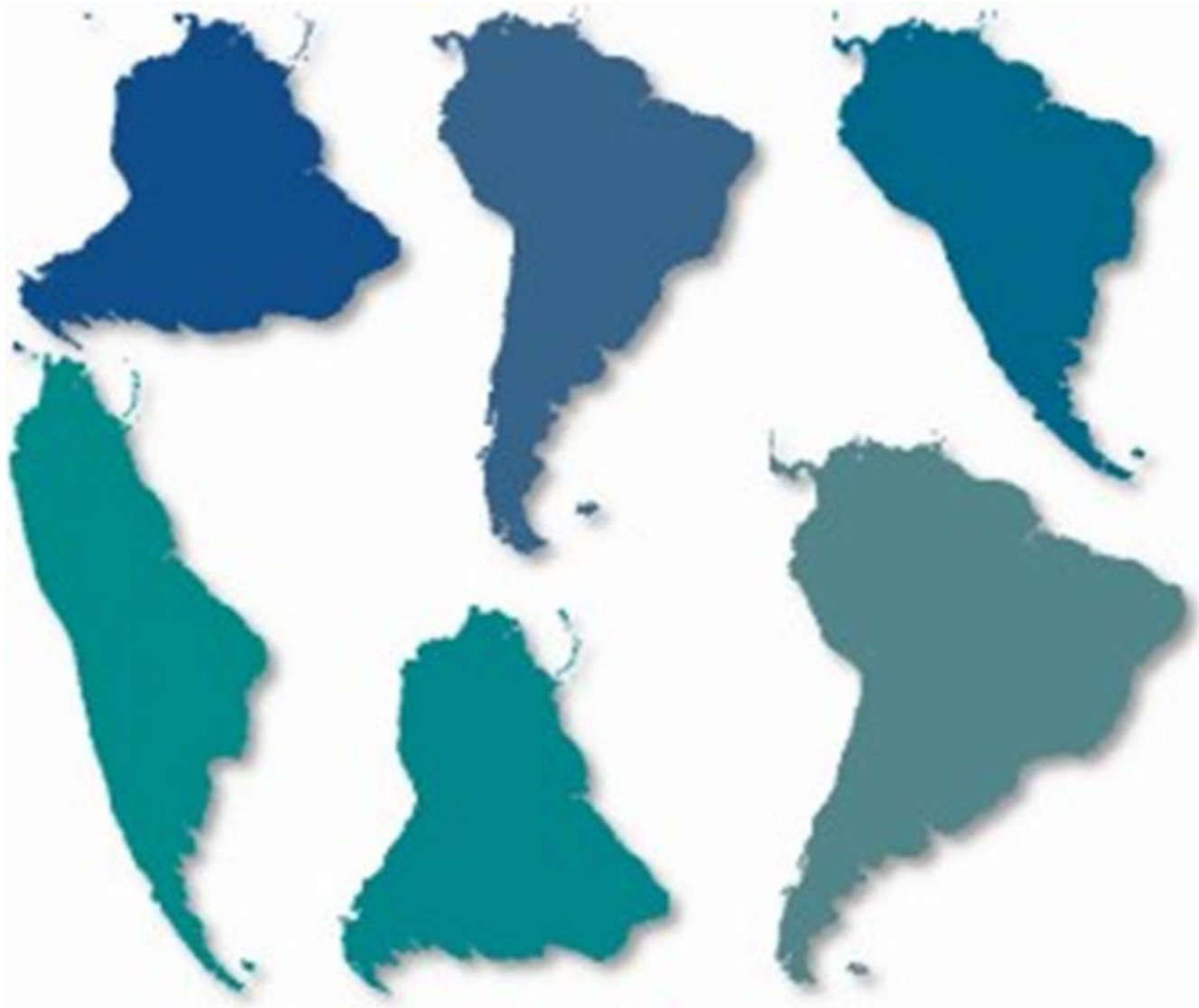
What can go wrong ? Possible consequence of using inconsistent reference systems,….

…,horizontal mismatch

Vertical mismatch,….

ARCTIC OCEAN
GREENLAND (Kalaallit Nunaat) (Denmark)
CANADA
UNITED STATES OF AMERICA
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
SOUTH PACIFIC OCEAN
INDIAN OCEAN
SOUTHERN OCEAN
ANTARCTICA
RUSSIAN FEDERATION
KAZAKHSTAN
MONGOLIA
CHINA
INDIA
JAPAN
AUSTRALIA
NEW ZEALAND
BRAZIL
ARGENTINA
MEXICO
ALGERIA
LIBYA
EGYPT
SOUTH AFRICA
THE WORLD
MERCATOR PROJECTION
0 miles 1000 2000 3000 miles
scale at the Equator
©Academia Maps, GeoAtlas®

Projections



GAME

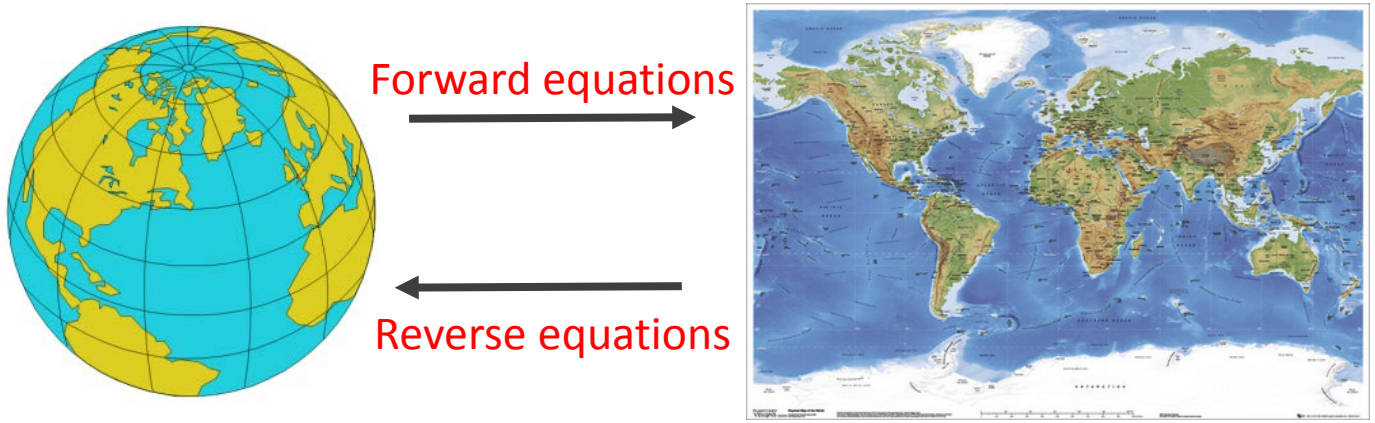
	Astana
	Prague
51° 30‘ N	Vancouver
51° 10‘ N	New York
50° 05‘ N	
49° 15‘ N	London
48° 12‘ N	Rome
41° 53‘ N	Tashkent
41° 17‘ N	Vienna
40° 40‘ N	

https://en.wikipedia.org/wiki/List_of_cities_by_latitude


Same Latitude Cities
in black: north hemisphere cities
in blue: south hemisphere cities
Massimo Pietrobon
capitan-mas-ideas.blogspot.com
Arkhangelsk
Anchorage
St.Petersburg
Magadan
Churchill
Krasnoyarsk
Yekaterinburg
Ushuaya
Novosibirsk
Punta Arenas
Edmonton
Petropavlovsk-
-Kamchatskly
Irkutsk
Saskatoon
Astana
Winnipeg
Vancouver
Calgary
Volgograd
Khabarovsk
Ulaan Bataar
Atyrau
Seattle
Quebec
Harbin
Urumqi
Halifax
Montreal
Toronto
Vladivostok
Boston
Chicago
Buffalo
Puerto Montt
Tashkent
New York
Wellington
Pyongyang
Pekin
Las Vegas
Tokyo

Map Projections

Mathematical equations used to transform latitude and longitude coordinates to plane (X, Y) coordinates.



Source: http://www.posters.cz/plakaty/planetary-visions-psychical-map-of-the-world-v13251

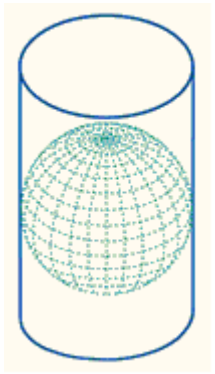
Projection Class and Case:

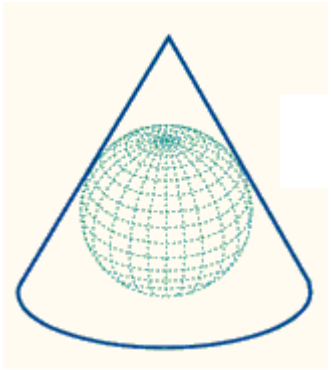
Class:

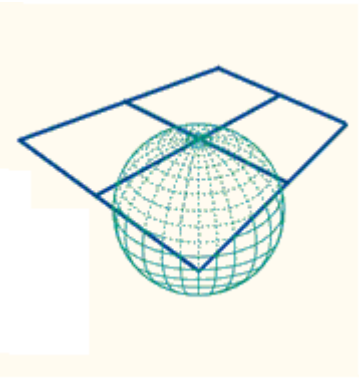
Cylindrical | Conical | Azimuthal

Case:

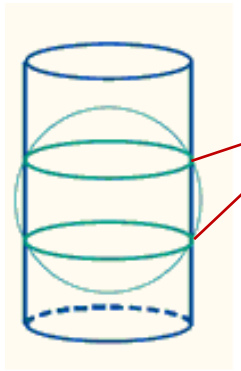
Tangent



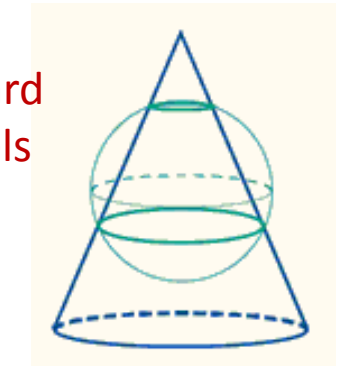


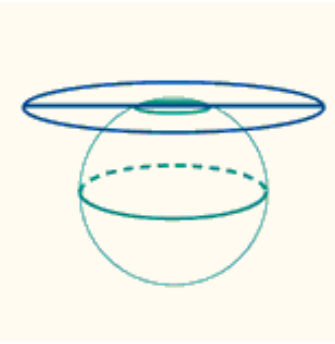


Secant



Standard parallels

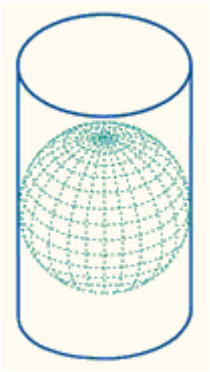




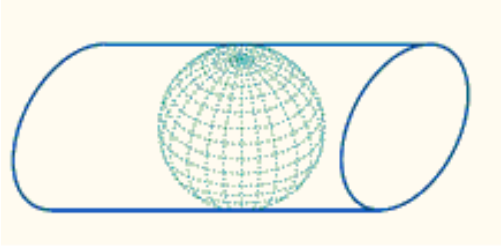
Source: http://kartoweb.itc.nl/geometrics/Map%20projections/mappro.html

Projection Aspect:

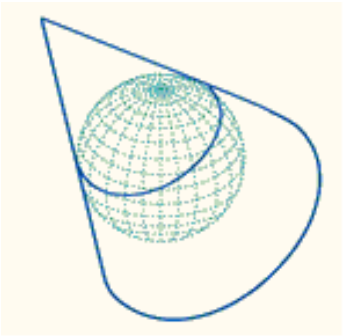
Normal aspect



Transverse aspect



Oblique aspect

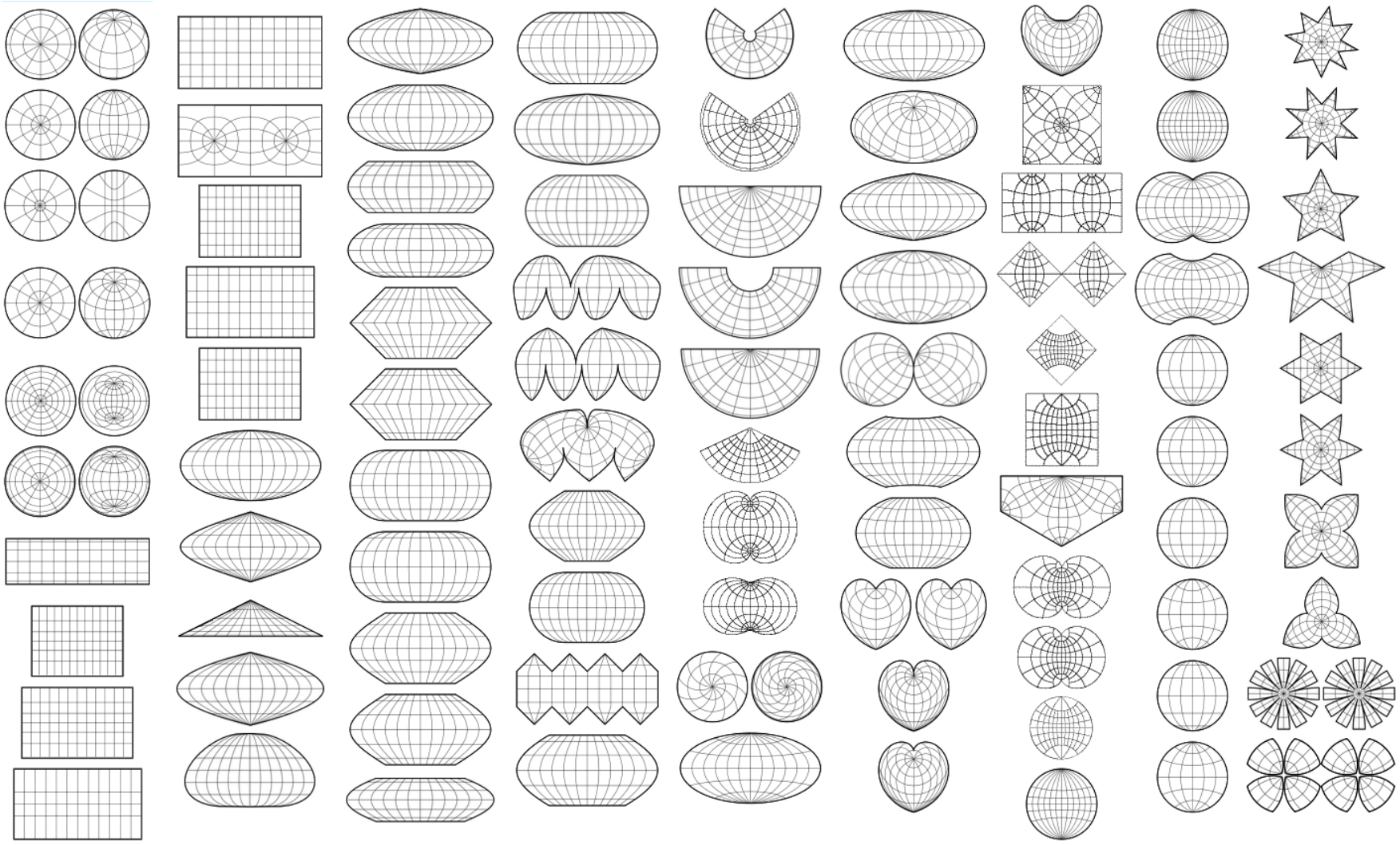


Distortion properties:

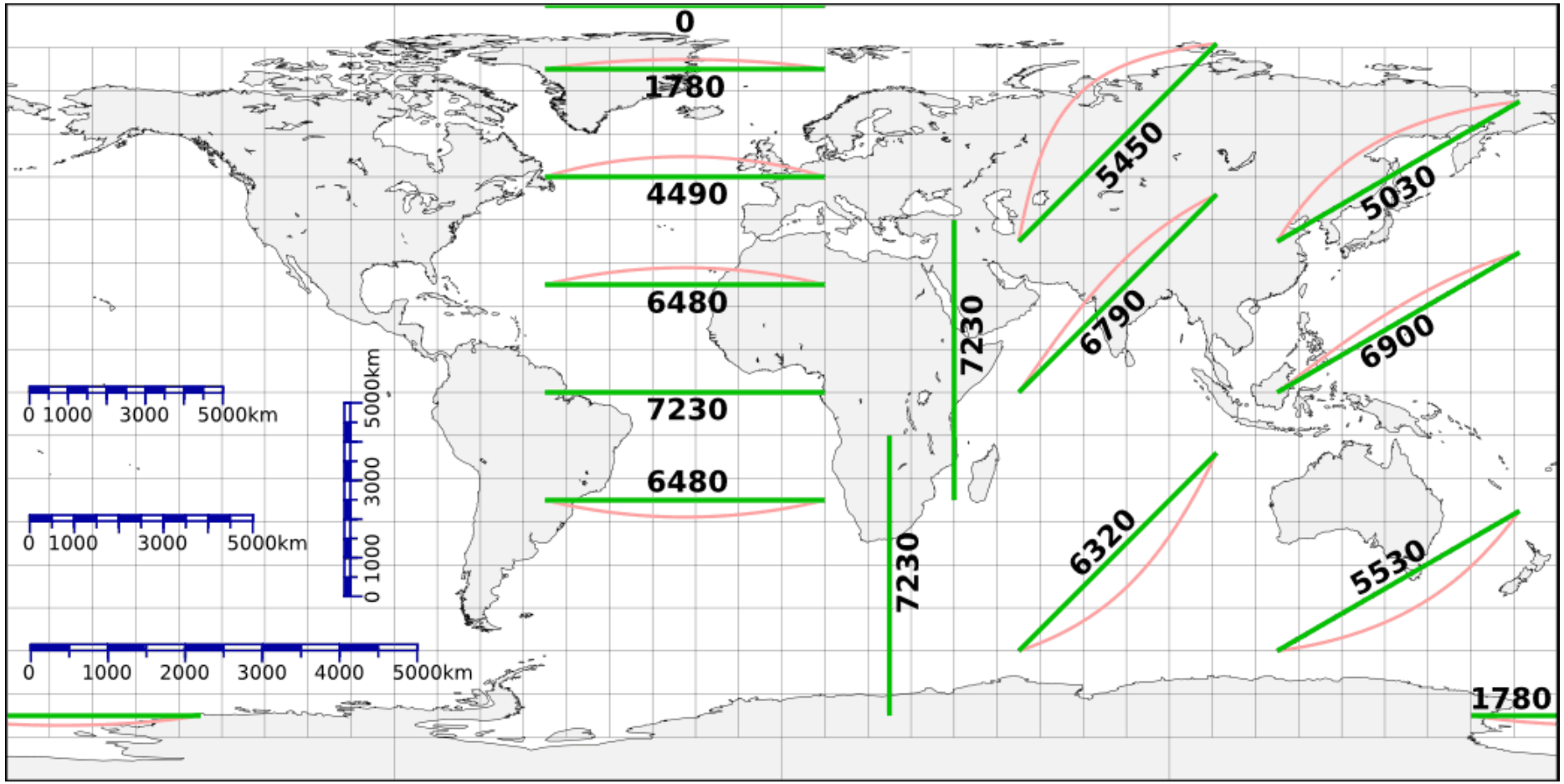
- Equal-area (equivalent) projections
- Conformal (orthomorphic) projections
- Equidistant projections
- Compromise projections

Source: http://kartoweb.itc.nl/geometrics/Map%20projections/mappro.html

Map Projections Gallery:



Source: http://www.progonos.com/furuti/MapProj/Normal/ProjTbl/projTbl.html



Equidistant cylindrical map showing distances (km) between lines connected by identical (in the map) lines. Each graphic scale is only valid along its own parallel. Only the vertical scale is valid anywhere, and none of the four is valid if rotated.

Mercator Projection

- Conformal cylindrical projection

- Gerhard Kremer (Gerardus Mercator), 1569
- Usage: Navigation, Google Maps

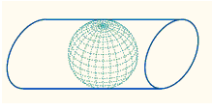
Source: http://www.progonos.com/furuti/MapProj/Normal/ProjNav/projNav.html#Mercator

Mercator puzzle:

https://bramus.github.io/mercator-puzzle-redux/

Transverse Mercator Projection

- Transverse conformal cylindrical projection

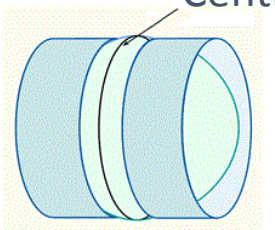


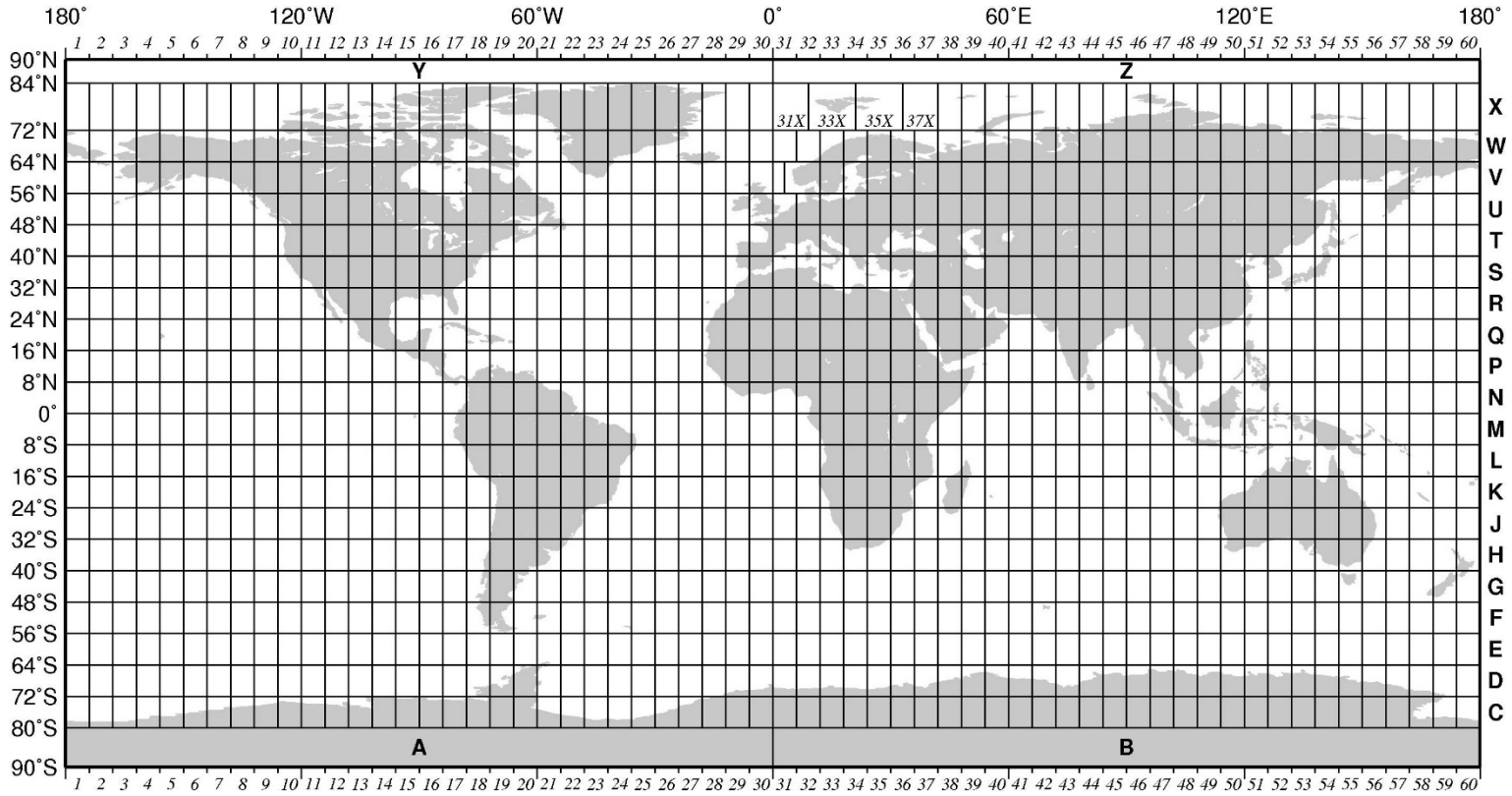
- Sphere: Lambert, 1772
- Ellipsoid: Gauss, ca. 1822, Krüger, ca. 1912
- Also known as **Gauss-Krüger projection**
- Usage: Large-scale mapping

Source: http://www.progonos.com/furuti/MapProj/Normal/ProjNav/projNav.html#Mercator

Universal Transverse Mercator system

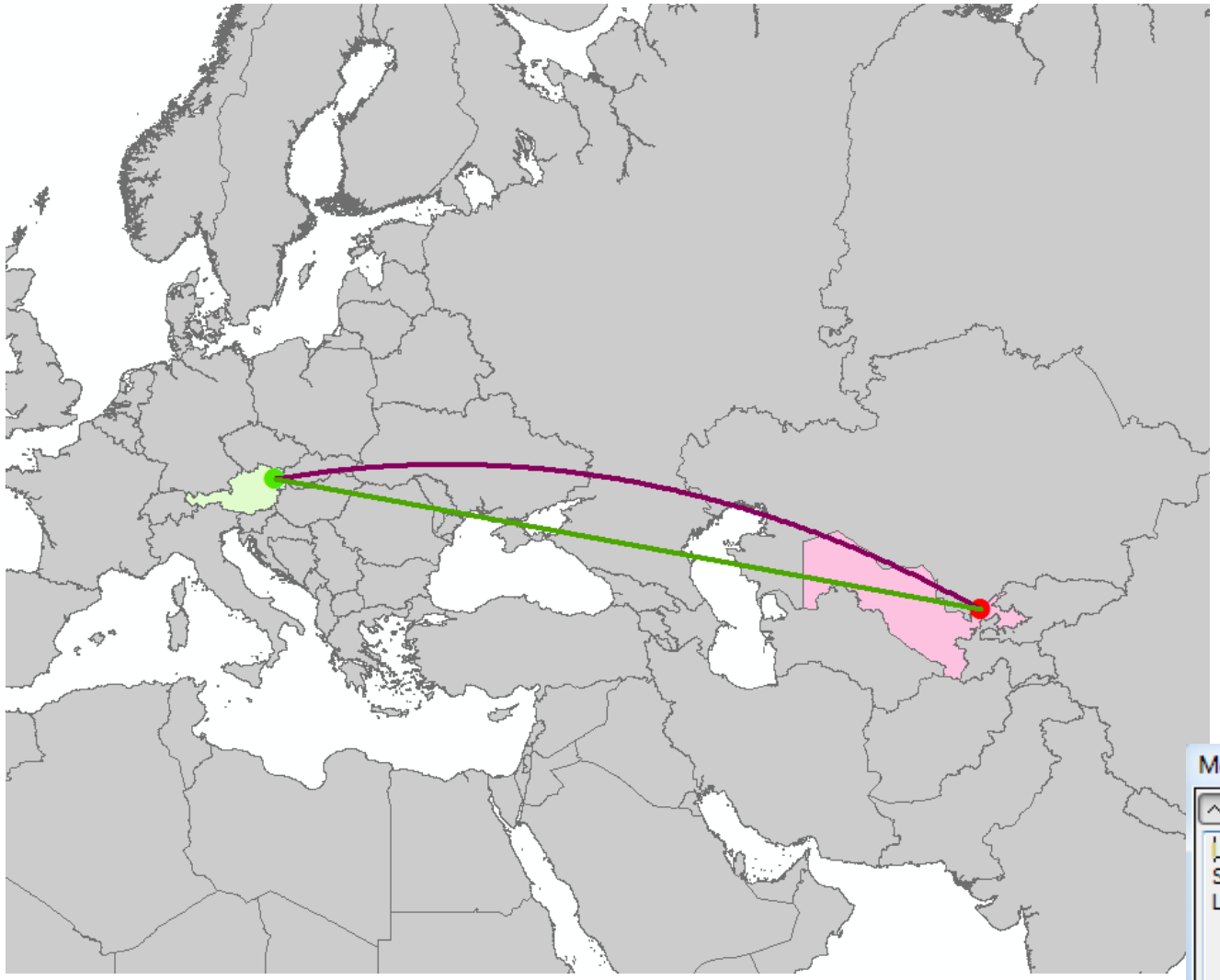
- NATO 1947
- 60 Transverse Mercator projections
- 60 zones (each 6° width)





Source: http://tabs2.gerg.tamu.edu/gmt/GMT_Docs/node108.html

- What is the distance („great circle“) from Tashkent to Vienna ?
  - 4 172 km



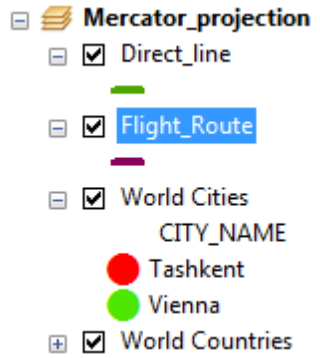


Table - Flight_Route

Flight_Route

FID	Shape *	Id	Length
0	Polyline	0	6122054

0 (0 out of 1 Selected)

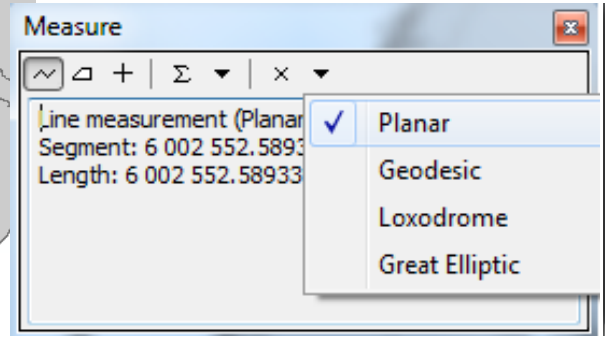
Flight_Route

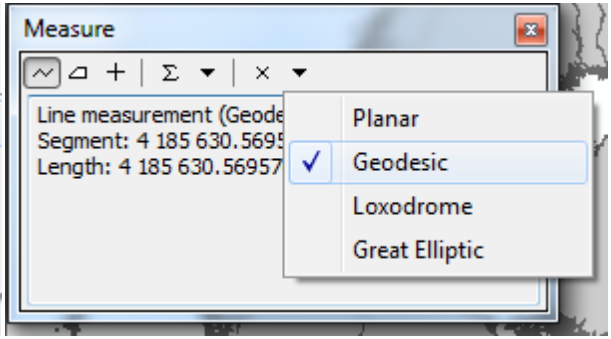
Direct_line

FID	Shape *	Id	Length
0	Polyline	0	6002553

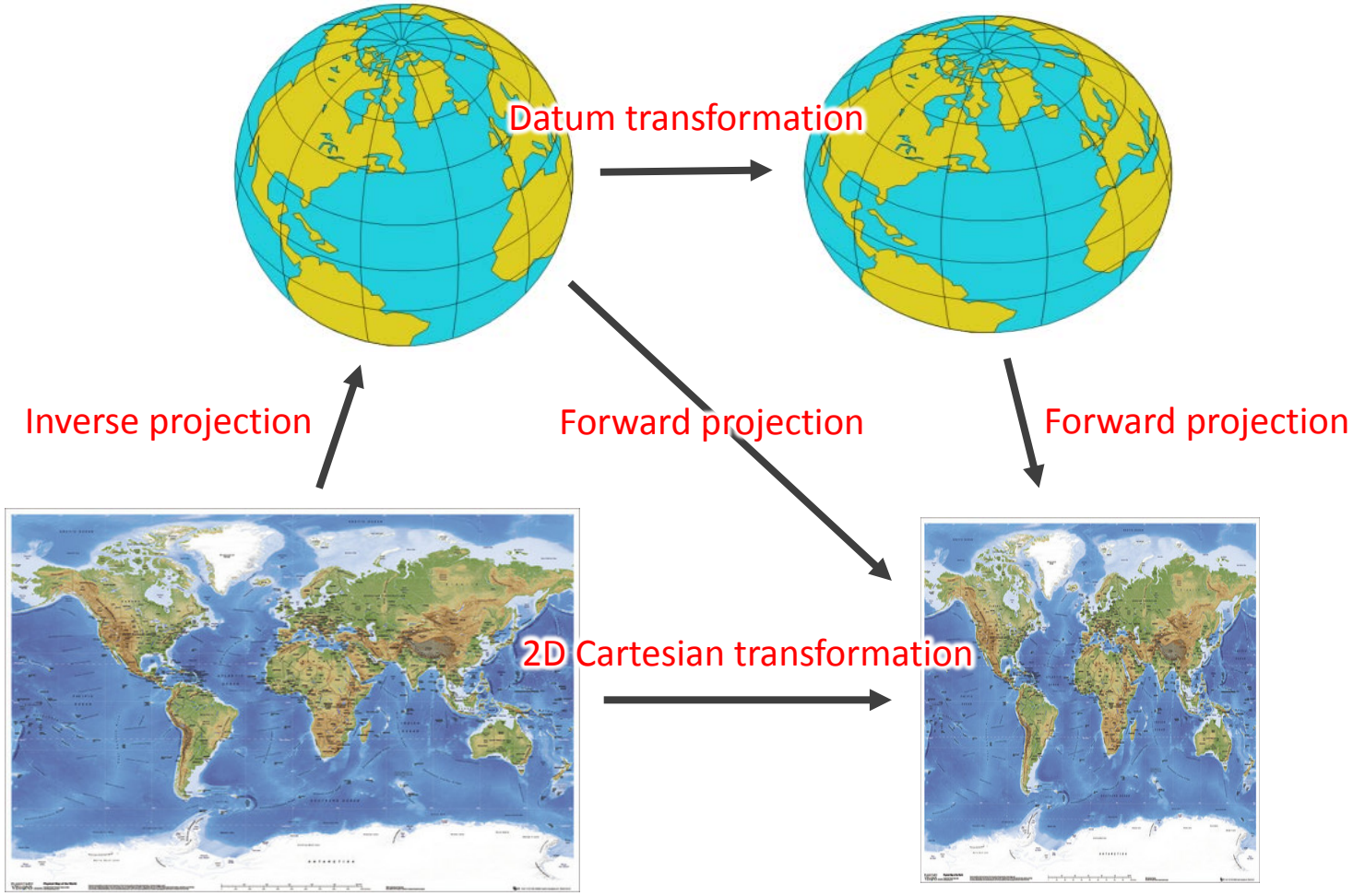
1 (0 out of 1 Selected)

Direct_line





Coordinate transformations



Source: http://www.posters.cz/plakaty/planetary-visions-psychical-map-of-the-world-v13251

Study materials

Reference surfaces:
http://kartoweb.itc.nl/geometrics/index.html

Map projections:
http://www.progonos.com/furuti/MapProj/Normal/TOC/cartTOC.html

https://www.arcgis.com/apps/MapJournal/index.html?appid=31484c80dba54a058369dfb8e9ced549

Geographic Data Models

GIS as Representation of Real World

World is extremely complex,…

…,revealing more detail the closer one looks !

Coastline paradox,….

- How long is coastline of Great Britain ?
- The **coastline paradox** is the counterintuitive observation that the coastline of a landmass does not have a well-defined length.
- The length of the coastline depends on the method used to measure it.
- When we represent the real world we necessarily simplify it.

An example of the coastline paradox. If the coastline of Great Britain is measured using units 100 km (62 mi) long, then the length of the coastline is approximately 2,800 km (1,700 mi). With 50 km (31 mi) units, the total length is approximately 3,400 km (2,100 mi), approximately 600 km (370 mi) longer.

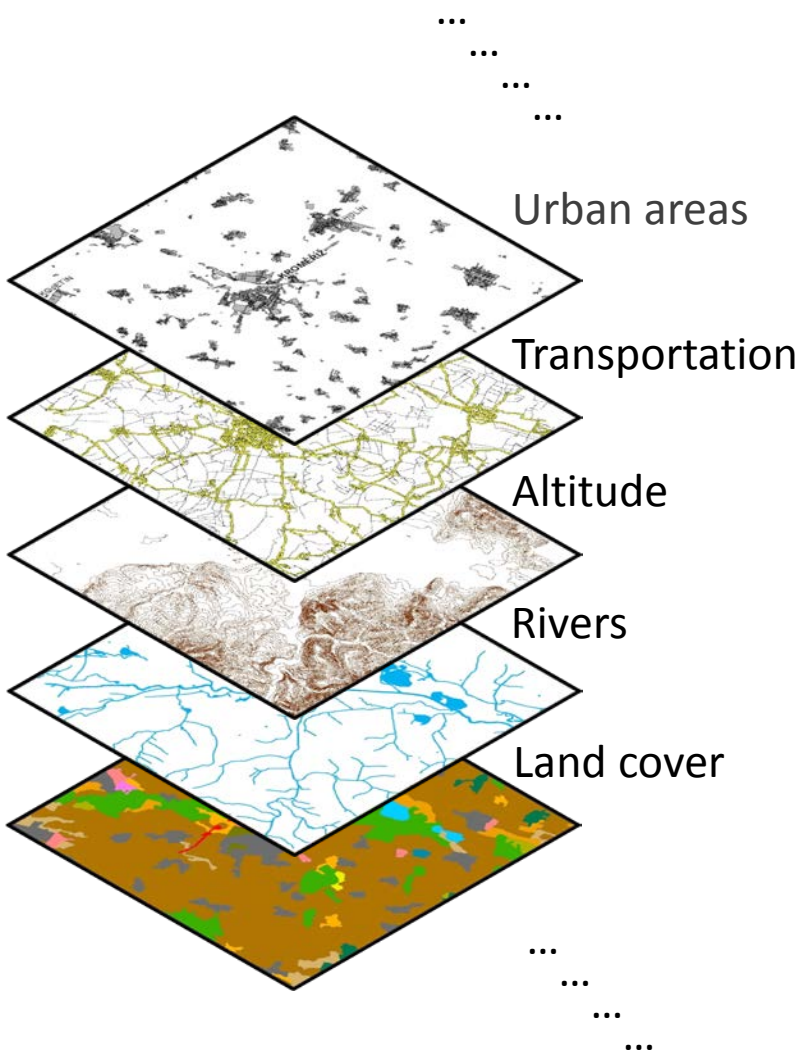
https://en.wikipedia.org/wiki/Coastline_paradox

Have to make choices about:

- What to represent
- At what level of detail - What is building or lake and what is not
- Over what time period – Changes will be probably more frequent in slum than in Prague (will they?)

and How to represent it ?

What is the world made of?
What to represent ?

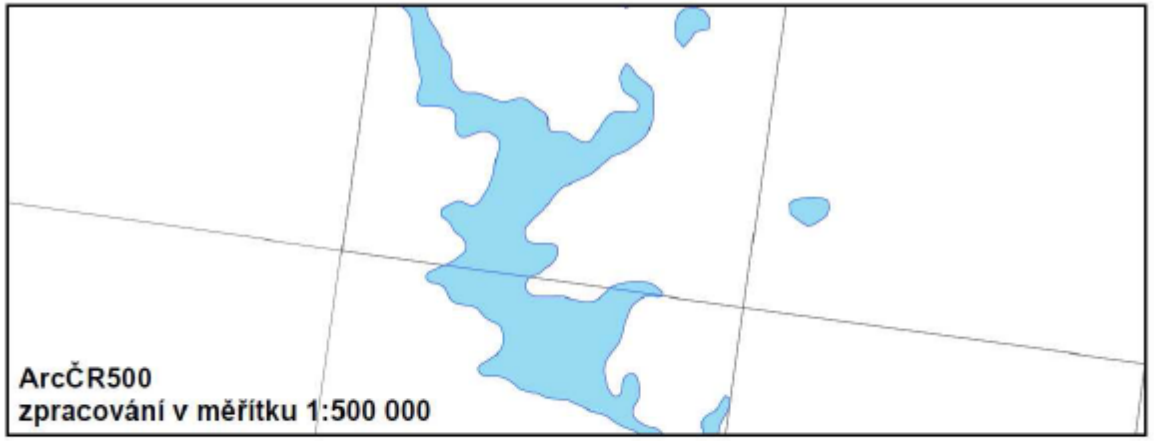


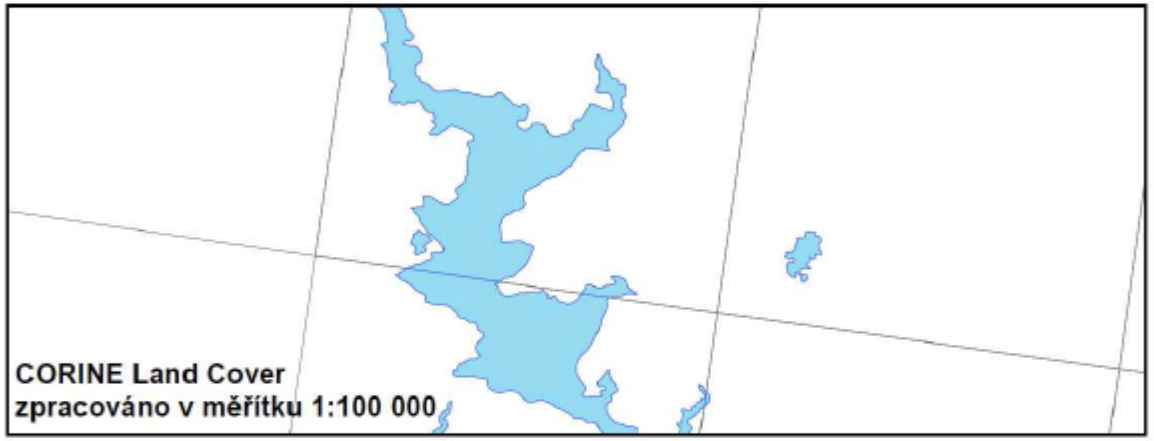
What to represent?

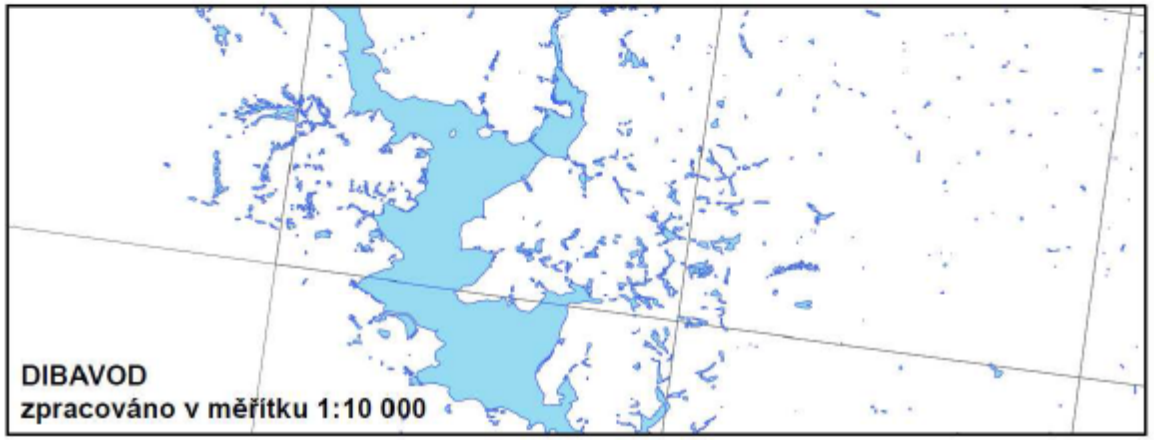
What is in the picture ?
And would you define this object ?

In what level of detail ?
and over what time period ?

Practical example







REPORT

High-Resolution Global Maps of 21st-Century Forest Cover Change

M. C. Hansen[1,*], P. V. Potapov[1], R. Moore[2], M. Hancher[2], S. A. Turubanova[1], A. Tyukavina[1], D. Thau[2], S. V. Stehman[3], S. J. Goetz[4], T. R. Loveland[5], A. Kommareddy[6], A. Egorov[6], L. Chini[1], C. O. Justice[1], J. R. G. Townshend[1]

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TECHNICAL COMMENTS

Comment on "High-resolution global maps of 21st-century forest cover change"

Robert Tropek[1,2,*], Ondřej Sedláček[3], Jan Beck[1], Petr Keil[4,5], Zuzana Musilová[6], Irena Šímová[3,5], David Storch[3,5]

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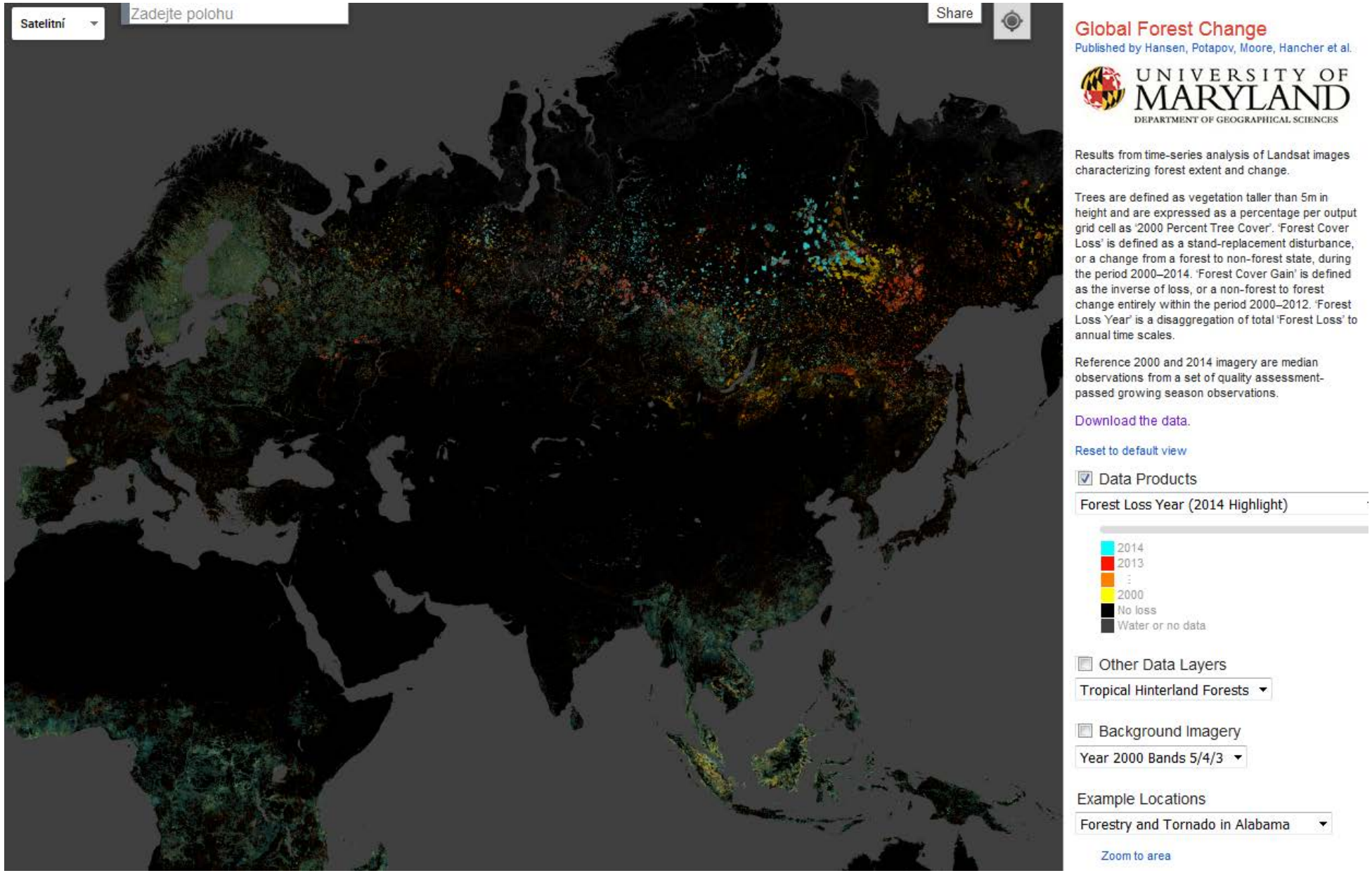
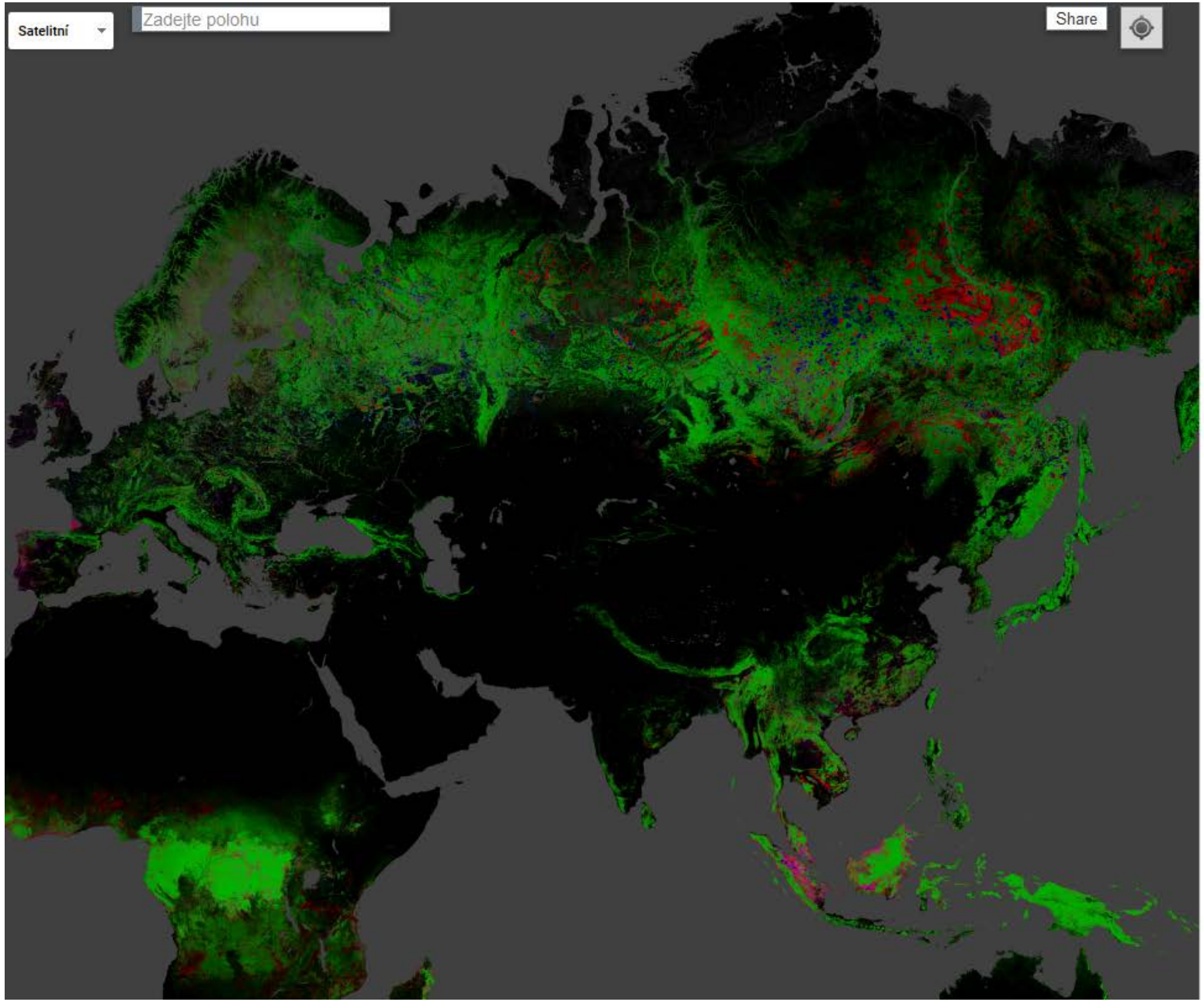
Vol. 344, Issue 6187, pp. 981
DOI: 10.1126/science.1248753

Data link: http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html

- https://earthenginepartners.appspot.com/science-2013-global-forest





Global Forest Change

Published by Hansen, Potapov, Moore, Hancher et al.

UNIVERSITY OF MARYLAND
DEPARTMENT OF GEOGRAPHICAL SCIENCES

Results from time-series analysis of Landsat images characterizing forest extent and change.

Trees are defined as vegetation taller than 5m in height and are expressed as a percentage per output grid cell as '2000 Percent Tree Cover'. 'Forest Cover Loss' is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000–2014. 'Forest Cover Gain' is defined as the inverse of loss, or a non-forest to forest change entirely within the period 2000–2012. 'Forest Loss Year' is a disaggregation of total 'Forest Loss' to annual time scales.

Reference 2000 and 2014 imagery are median observations from a set of quality assessment-passed growing season observations.

Download the data.

Reset to default view

Data Products

Loss/Extent/Gain (Red/Green/Blue)

Legend

- Forest Loss 2000–2013
- Forest Gain 2000–2012
- Both Loss and Gain
- Forest Extent

Other Data Layers

Tropical Hinterland Forests

Background Imagery

Year 2000 Bands 5/4/3

Example Locations

Forestry and Tornado in Alabama

Zoom to area

The trail of destruction from the April 27 2011

TECHNICAL COMMENTS

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Robert Tropek[1,2,*], Ondřej Sedláček[3], Jan Beck[1], Petr Keil[4,5], Zuzana Musilová[6], Irena Šímová[3,5], David Storch[3,5]

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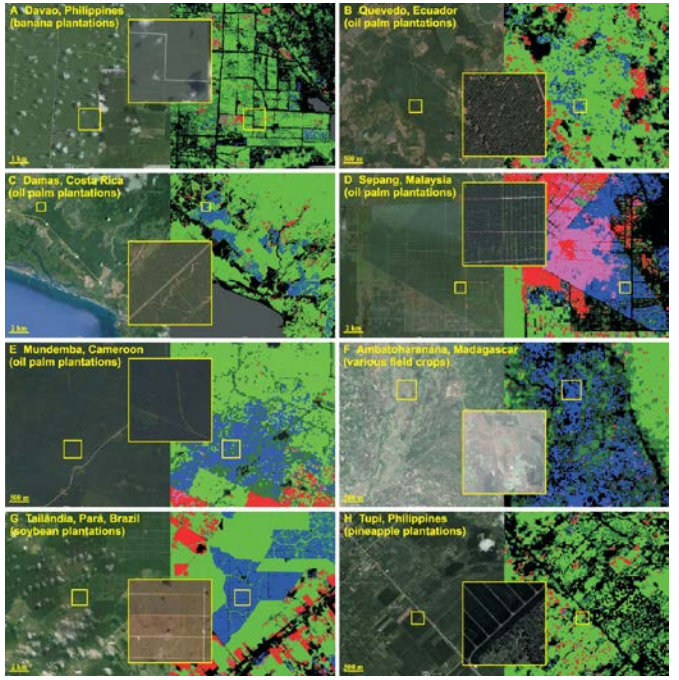


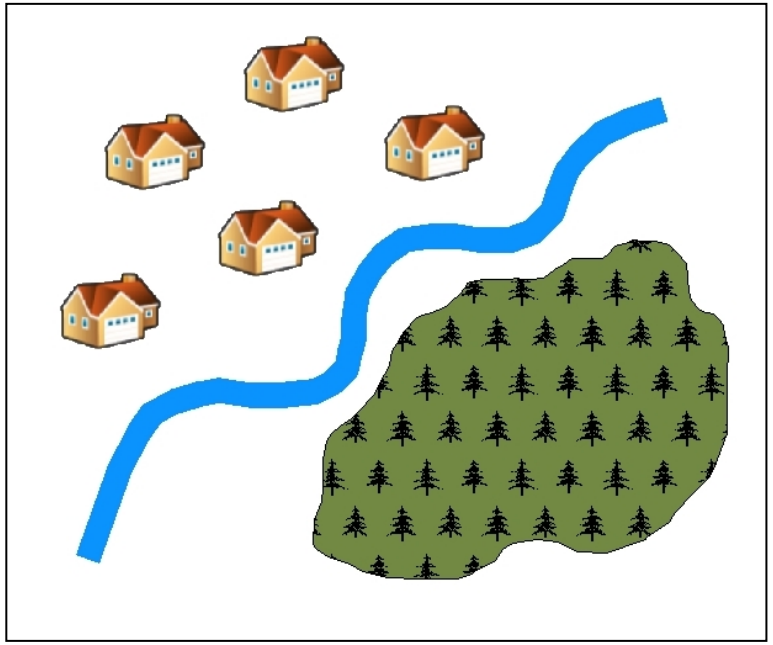
We express serious concerns about the appropriateness of the product for these purposes.

The main problem lies in Hansen *et al*.'s definition of forest as "**all vegetation taller than 5m in height**"

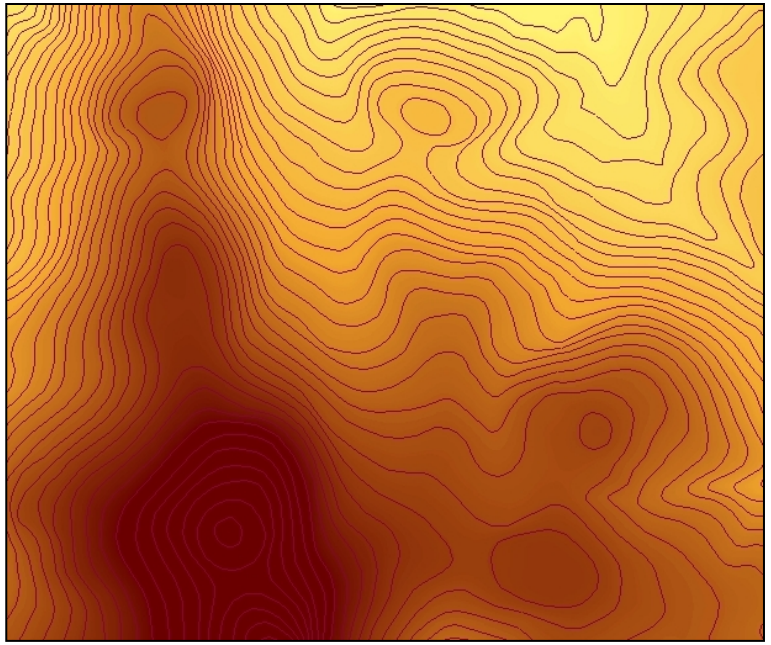
Such a structural definition includes types of plantations that have already replaced substantial parts of tropical (and also extratropical) forests. Monocultures of oil palm, rubber, or *Eucalyptus* are recognized as some of the biggest threats to tropical biodiversity, and their expansion into forest systems continues at an alarming rate. Although these plantations are technically "forests" in the definition above, they do not provide the benefits of forest vegetation as enumerated by the authors—i.e., "ecosystem services, including biodiversity richness, climate regulation, carbon storage, and water supplies". Classifying plantations as forests confuses an endangered habitat with its greatest threats and thus underestimates real forest loss.

Geographical phenomena

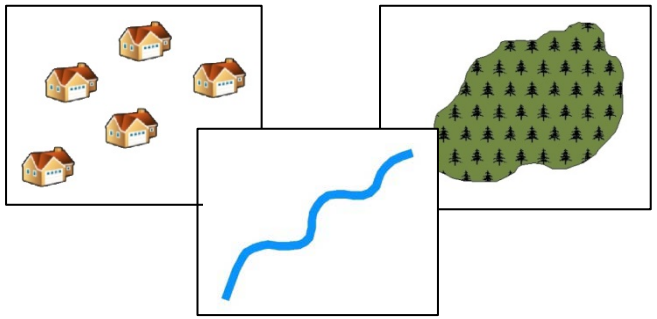
Discrete objects

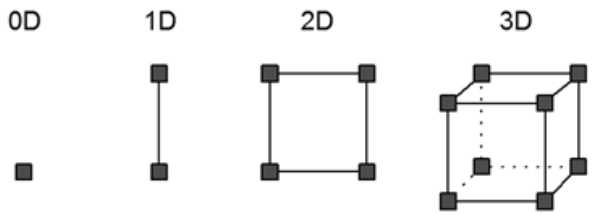


Continuous fields



Discrete objects





In this view, the world is **empty**, except where it is occupied by object with well-defined boundaries.

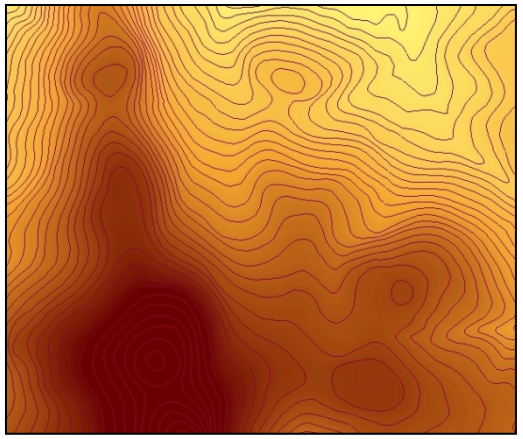
Geographic objects are identified by their dimensionality (0D, 1D, 2D, 3D).

Dimension depeds on level of detail.

(In which dimension would you represent tree?)

Continuous fields

In this view the geographic world can be described by a number of variables, each measurable at **any point** on the Earth‘s surface and changing in value across the surface.



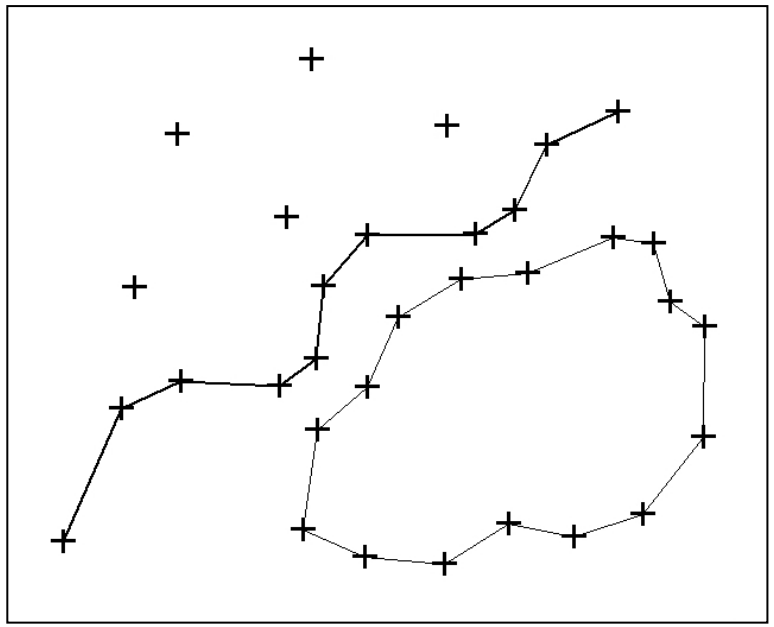
Continuous fields, can be distinguished by what varies and how smoothly.

No borders of objects,…

Data models

Geographic data

Vector data model

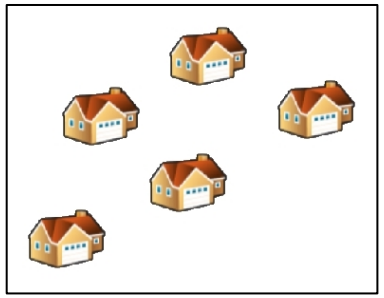


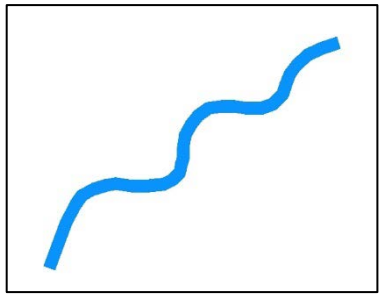
Raster data model

817,46	841,01	846,45	828,13	808,56	800,6	799,14	793,76	783,53	779,14	788,45
825,54	849,07	856,01	840,68	822,53	813,59	809,73	803,39	794,2	789,01	792,82
833,48	857,48	867,36	854,39	837,35	828,28	824,26	819,18	810,98	804,91	803,03
842,89	865,91	877,55	867,29	852,27	843,79	841,14	837,86	831,94	826,39	820,41
852,58	873,76	885,15	879,52	867,79	858,64	856,02	854,67	852,41	848,07	839,19
863,15	885,22	898,68	897,39	886,6	873,54	868,35	867,7	867,6	862,7	851,3
872,62	895,87	912,86	916,03	903,52	886,45	877,64	875,69	874,72	868,07	856,97
877,82	900,92	920,86	929,23	914,96	894,2	881,04	879,52	877,5	870,49	861,17
880,79	901,01	921,24	934,68	918,6	892,4	873,73	870,78	874,1	870,38	864,88

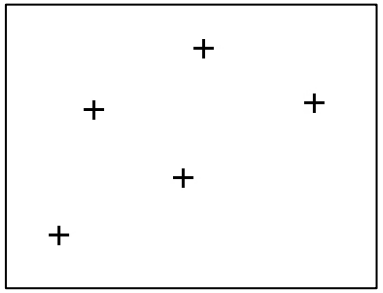
Discrete objects' representation

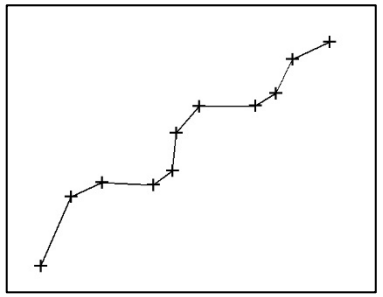
World

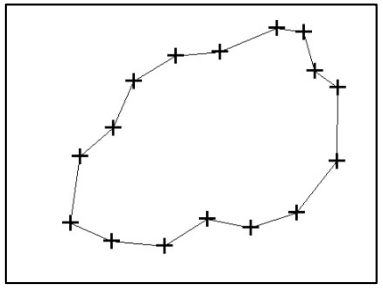




Vector model







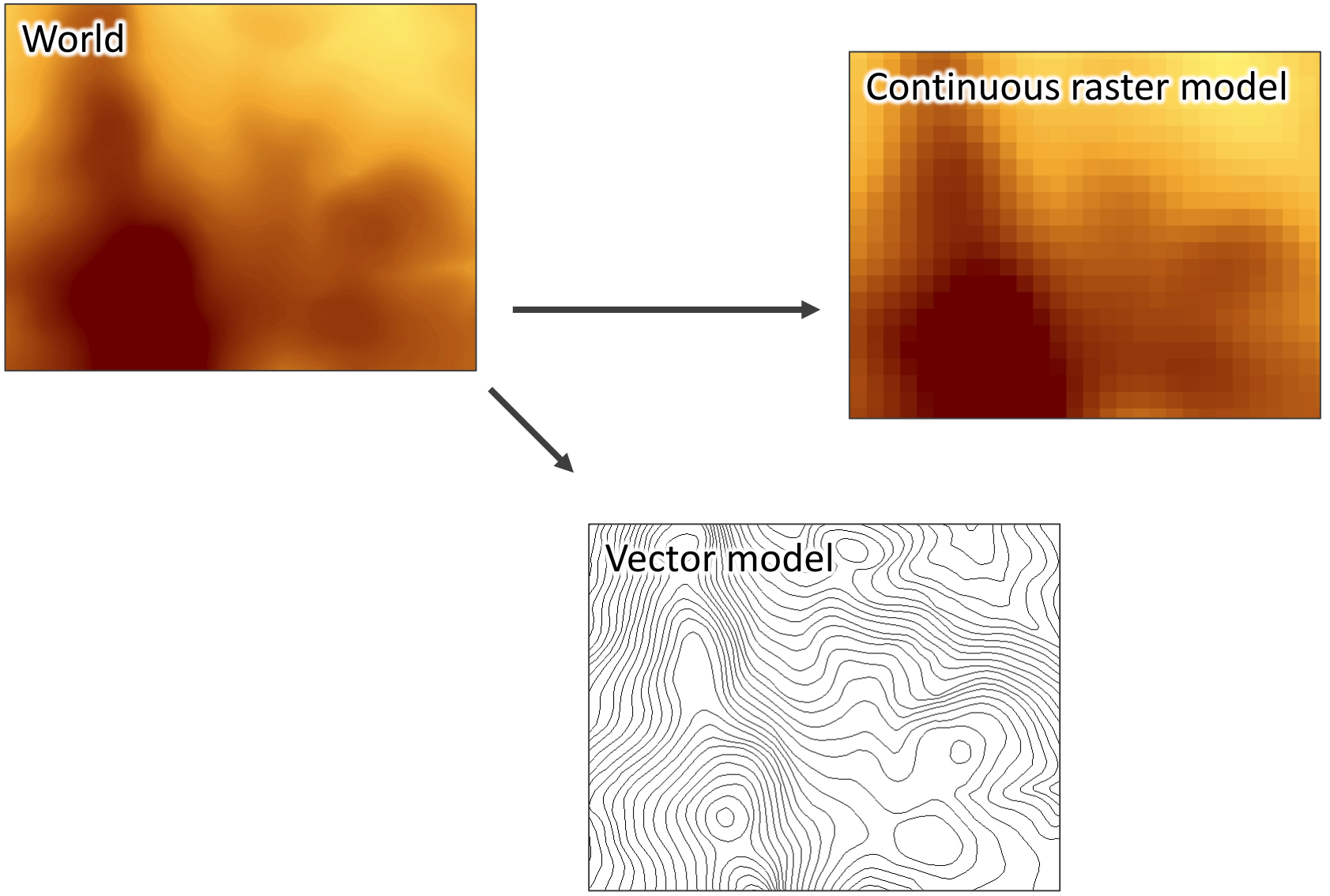
Raster model

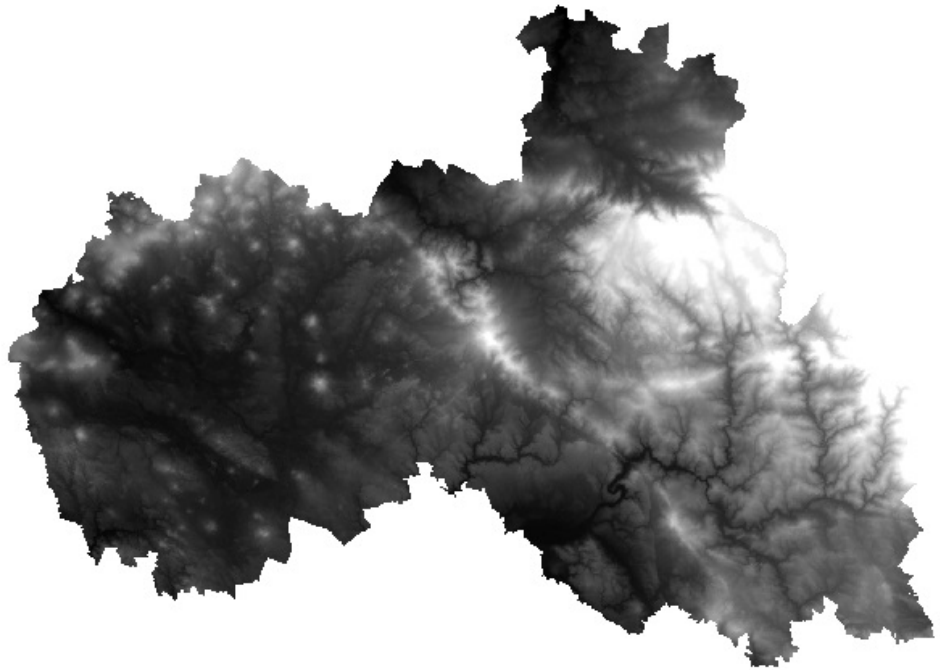
0	0	0	0	5	0	0	0
0	0	0	0	0	0	0	4
0	3	0	0	0	0	0	0
0	0	0	2	0	0	0	0
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0

0	0	0	0	0	0	1	1
0	0	0	0	1	1	1	0
0	0	0	1	1	0	0	0
0	1	1	1	0	0	0	0
1	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0

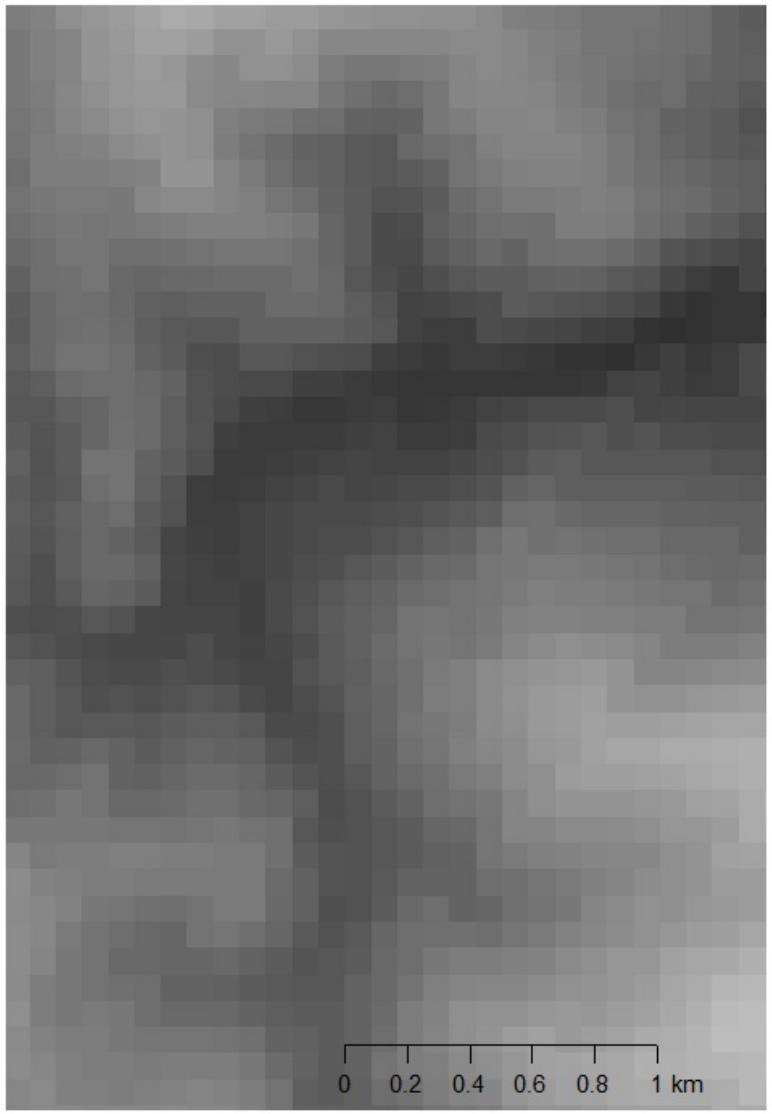
0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	0
0	0	1	1	1	1	1	0
0	0	1	1	1	1	1	0
0	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0

Continuous field representation

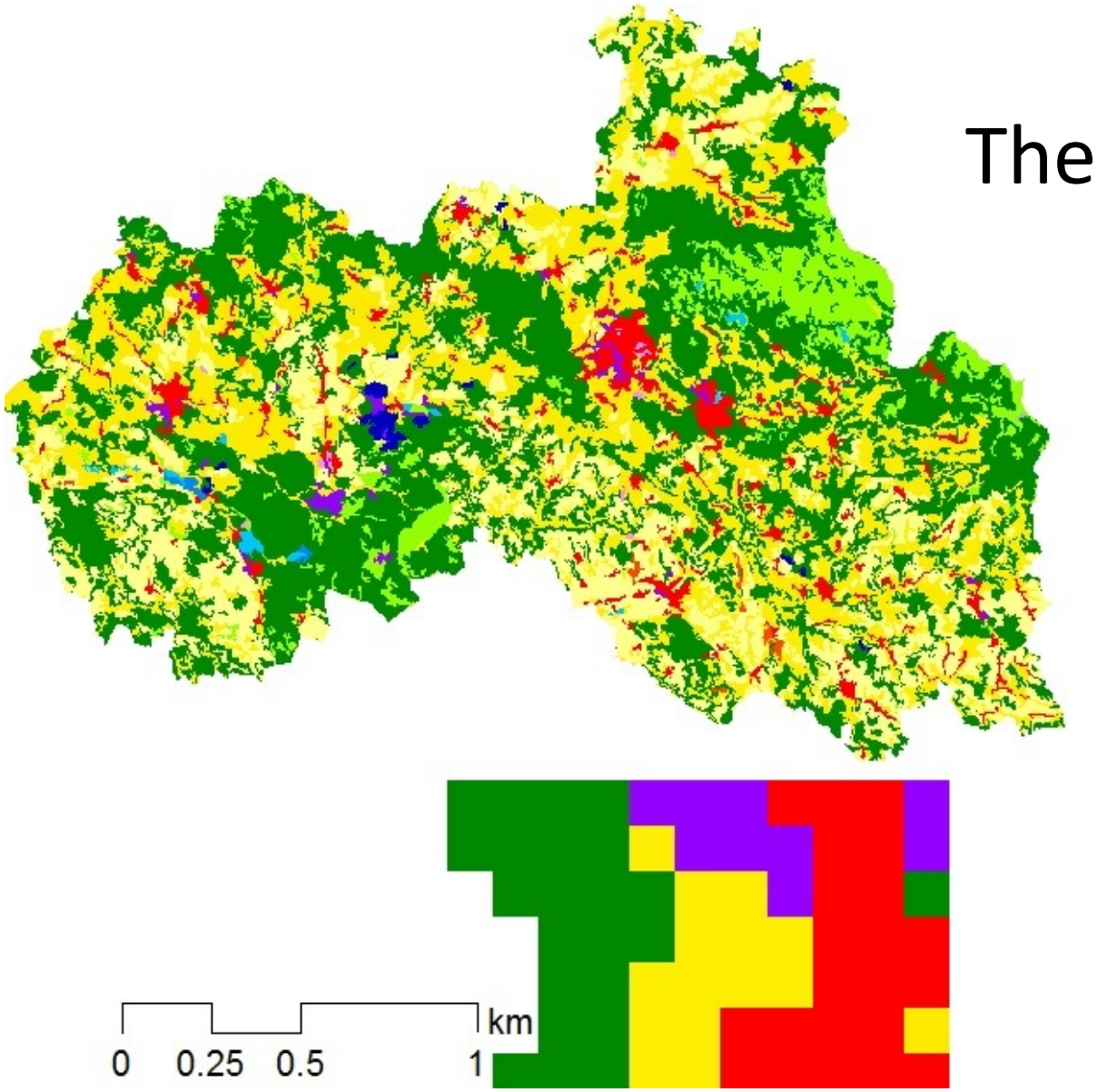




Continuous raster

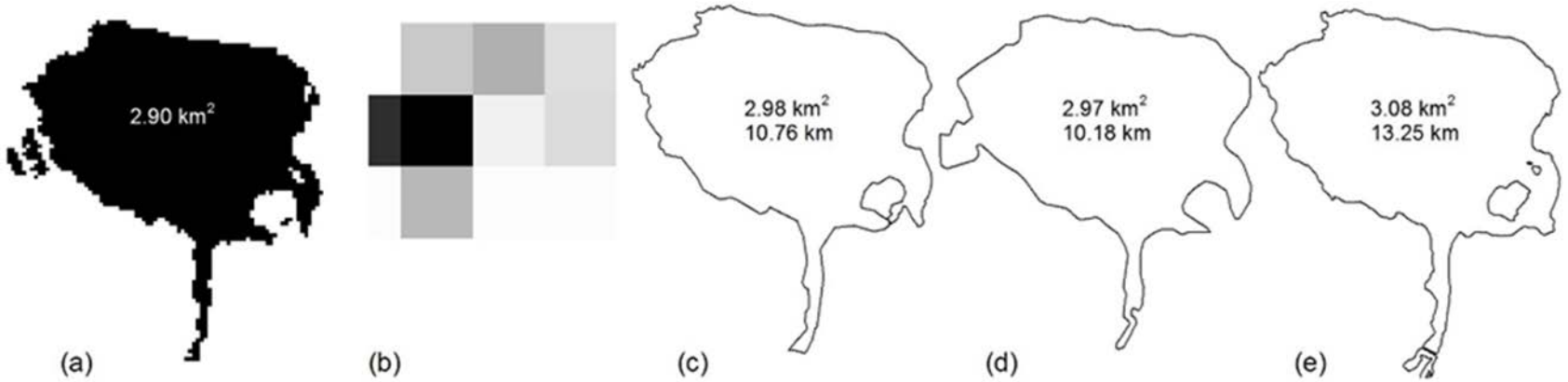


Thematic raster

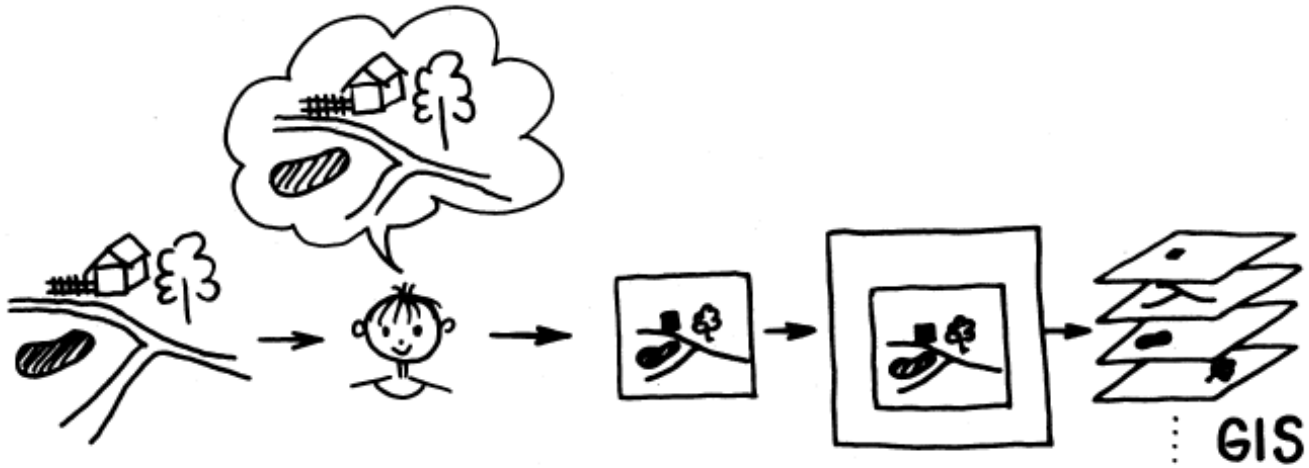


- Which representation (data model) is more accurate (or allow better accuracy):

vector or raster ?



GIS (Geographical Information Systems) incorporates graphical features with tabular data **in order to assess real world problems**



Geographic Information Science is research both *on* and *with* GIS. "*the generic issues that surround the use of GIS technology, impede its successful implementation, or emerge from an understanding of its potential capabilities.*"

(Goodchild, 1992)

GIS is not a reality – thought so, can have serious consequences !

Geographic Data Availability for Environmental Applications