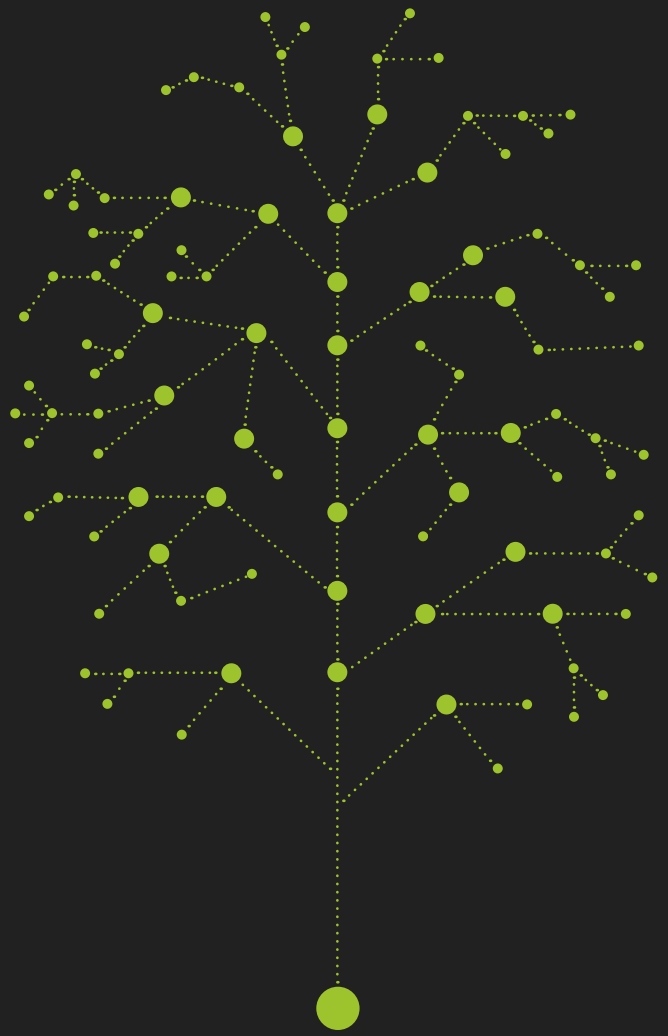

environmental engineering

Geographic Information Systems

Robert Szczepanek

Cracow University of Technology

Kraków 2020

environmental engineering

Geographic Information Systems

Robert Szczepanek

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wydawnictwo@pk.edu.pl
www.wydawnictwo.pk.edu.pl
Correspondence address: ul. Warszawska 24, 31-155 Kraków

Table of Contents

Introduction to GIS

Definition

Geographic Information Systems

Computer framework to capture, store, analyze and visualize spatially related data.

Spatial information, geoinformation

Question

What data or information in the field of environmental engineering has no reference to space?

History of GIS

Year	Event
1963	Canada Geographic Information System
1969	Environmental Science Research Institute ESRI, Intergraph
1972	Landsat 1 satellite
1982	Geographic Resources Analysis Support System GRASS, movie
1994	Open Geospatial Consortium OGC
1997	MapServer
2001	PostGIS
2002	QGIS

GIS today

- Web Services
- Spatial Data Infrastructure (INSPIRE)
- Sensor Web, Internet of Things
- Augmented Reality, water infrastructure application
- Big Data

The scale matters

- GIS (Geographic Information Systems)
- LIS (Land Information System)
- CAD (Computer Aided Design)

Related domains

Geodesy

The earth science of accurately measuring and understanding the Earth's geometric shape, orientation in space, and gravitational field.

source: www.demotywatory.pl

Related domains

Photogrammetry

The science of making measurements from photographs.

source: www.geoforum.pl

Related domains

Cartography

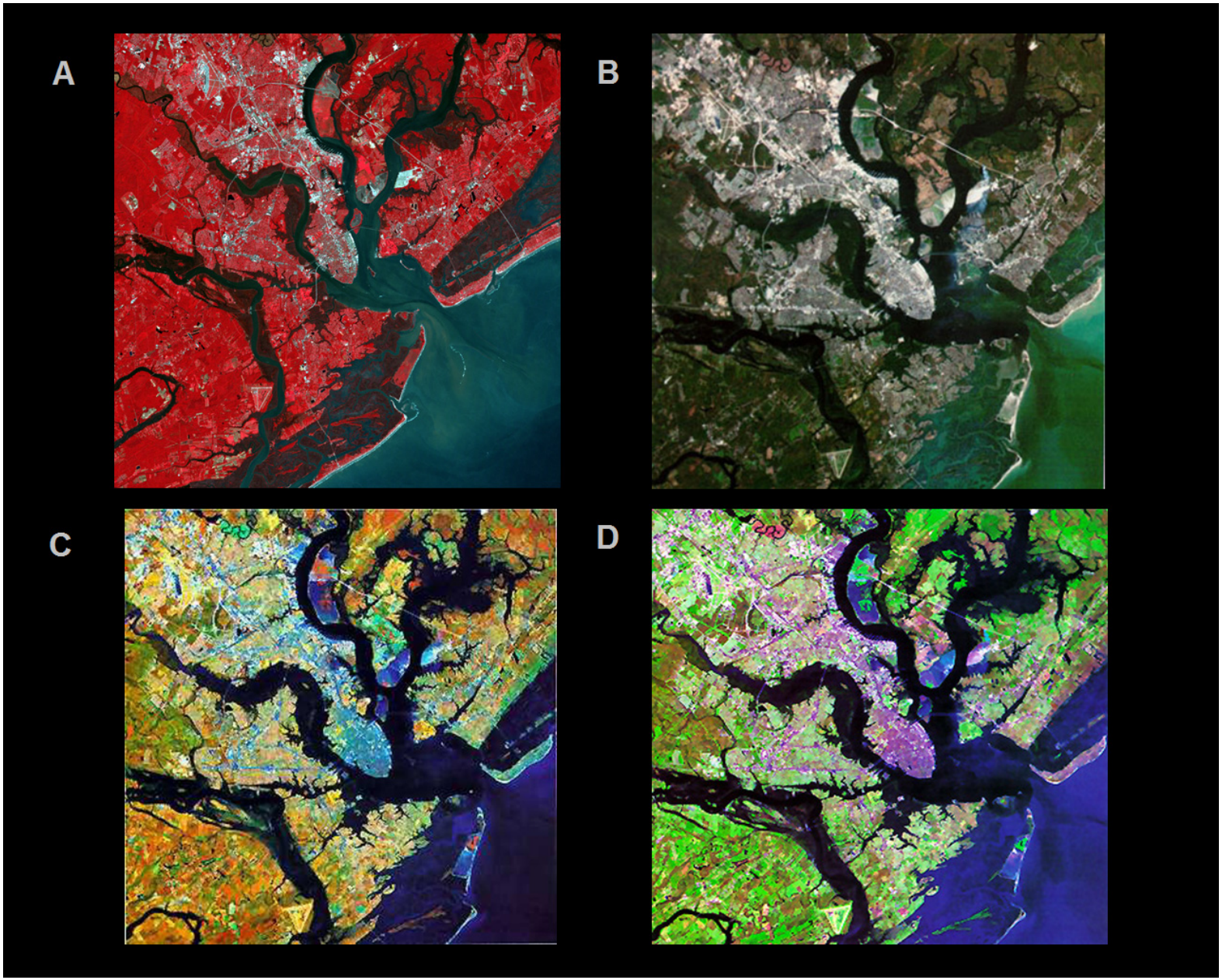
The science or art of making maps.

source: muzeum.wieliczka.pl

Related domains

Remote Sensing

The science of obtaining information about objects from a distance, typically from aircraft or satellites.



source: www.oneonta.edu

Related domains

Global Positioning Systems

- GPS-NAVSTAR – USA
- GLONASS – Russia
- Galileo – Europe (ESA)
- Beidou – China
- IRNSS – India

source: www.solarracing.org

Related domains

Informatics

- Computer programming
- Databases (relational, spatial)
- Computer Graphics
- ...

Components of GIS

- Software
- Data
- Infrastructure
- Users

Question:

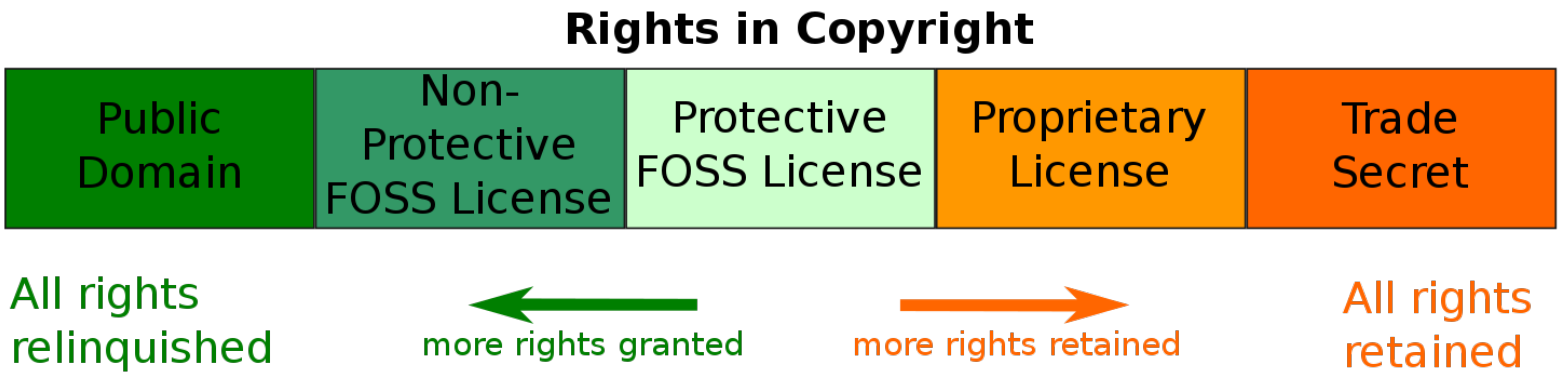
What generates the largest costs?

Popular myths

- Everyone knows about medicine, databases, map creation
- Buying an expensive system will solve all problems
- We have a mess in the data – let's put them in the database
- All data is available for free
- ...

FOSS4G

Licenses classification



source: Wikipedia

FOSS

Free and Open Source Software

Anyone is freely licensed to use, copy, study, and change the software in any way, and the source code is openly shared so that people are encouraged to voluntarily improve the design of the software.

source: https://www.gnu.org/philosophy/free-sw.html

Richard Stallman, Free Software Foundation

source: Wikipedia

The four essential freedoms

A program is free software if the program's users have:

- The freedom to run the program as you wish, for any purpose (freedom 0).
- The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1).
- The freedom to redistribute copies so you can help others (freedom 2).
- The freedom to distribute copies of your modified versions to others (freedom 3).

source: https://www.gnu.org/philosophy/free-sw.html

Is FOSS always free of charge?

No. This is a common misconception about what open source implies, and the concept's implications are not only economic. Open source software programmers can charge money for the open source software they create or to which they contribute. Presently charging users money for software services and support (rather than for the software itself) is more lucrative. This way, their software remains free of charge, and they make money helping others install, use, and troubleshoot it.

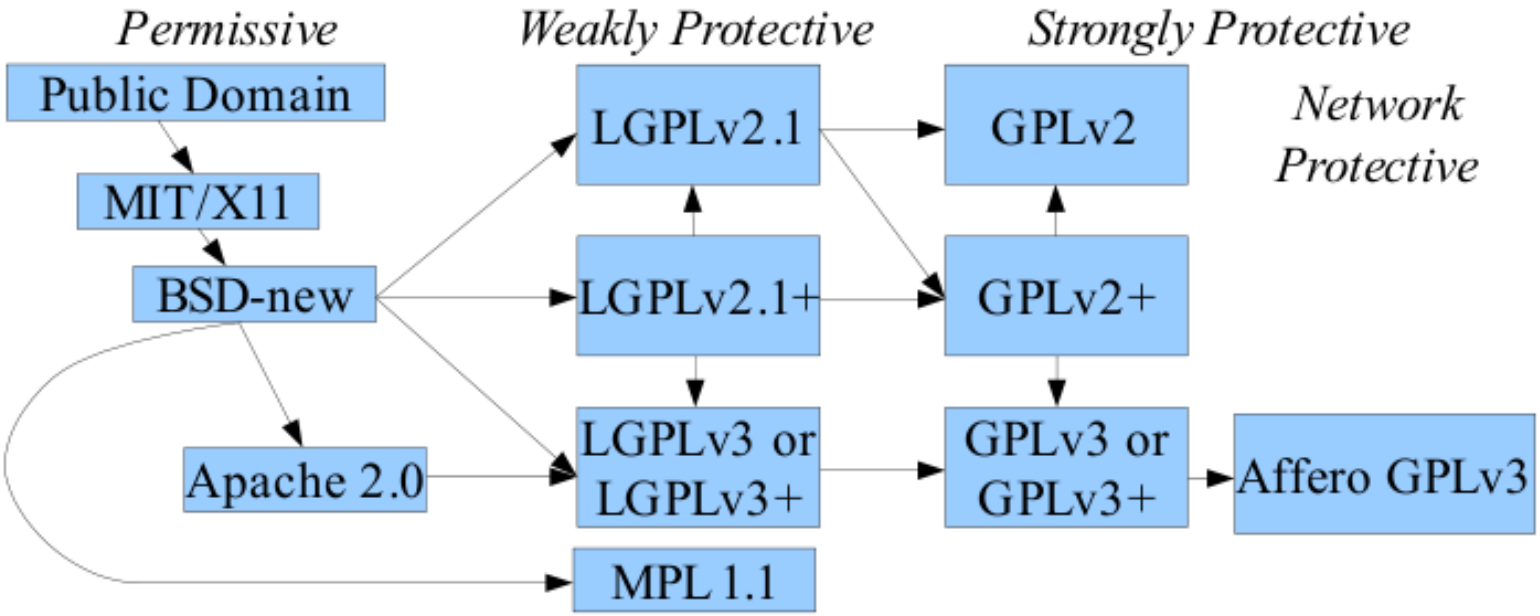
source: https://opensource.com/resources/what-open-source

FOSS licenses

- GNU General Public License (GPL) – probably the most protective one; derivative work must be released under GPL [MySQL, QGIS]
- Mozilla Public License (MPL) – compromise step between strict (GPL) and permissive (MIT) licenses [Mozilla Firefox, Mozilla Thunderbird, LibreOffice]
- MIT – can easily be associated with other licenses, from the GPL to proprietary licenses [jQuery, Atom]
- BSD – [Django, Ruby]

source: https://itsfoss.com/open-source-licenses-explained/

Practical implications



By David A. Wheeler - http://www.dwheeler.com/essays/floss-license-slide.html, CC BY-SA 3.0,

https://commons.wikimedia.org/w/index.php?curid=41060008

Non-standard FOSS licenses

To understand the concept, you should think of free as in *free speech*, not as in *free beer*.
source: The Free Software Foundation

There are plenty of FOSS licensing models:

- Beerware
- Careware
- Postcardware
- WTFPL

There are alternatives

- https://sourceforge.net/directory/os:windows/
- https://alternativeto.net/

FOSS4G

Free and Open Source Software for Geospatial

OSGeo

The Open Source Geospatial Foundation

Because people are the most important, not the equipment!

OSGeo projects

- Content Management Systems (GeoNode)
- Metadata Catalogs (GeoNetwork, pycsw)
- Desktop Applications (gvSIG Desktop, QGIS Desktop, GRASS GIS)
- Web Mapping (MapServer, Geomajas, OpenLayers, GeoServer, PyWPS)
- Geospatial Libraries (GDAL/OGR, GEOS, Orfeo ToolBox),
- Spatial Databases (PostGIS)
- Other (OSGeoLive)

source: https://www.osgeo.org/projects/

QGIS project

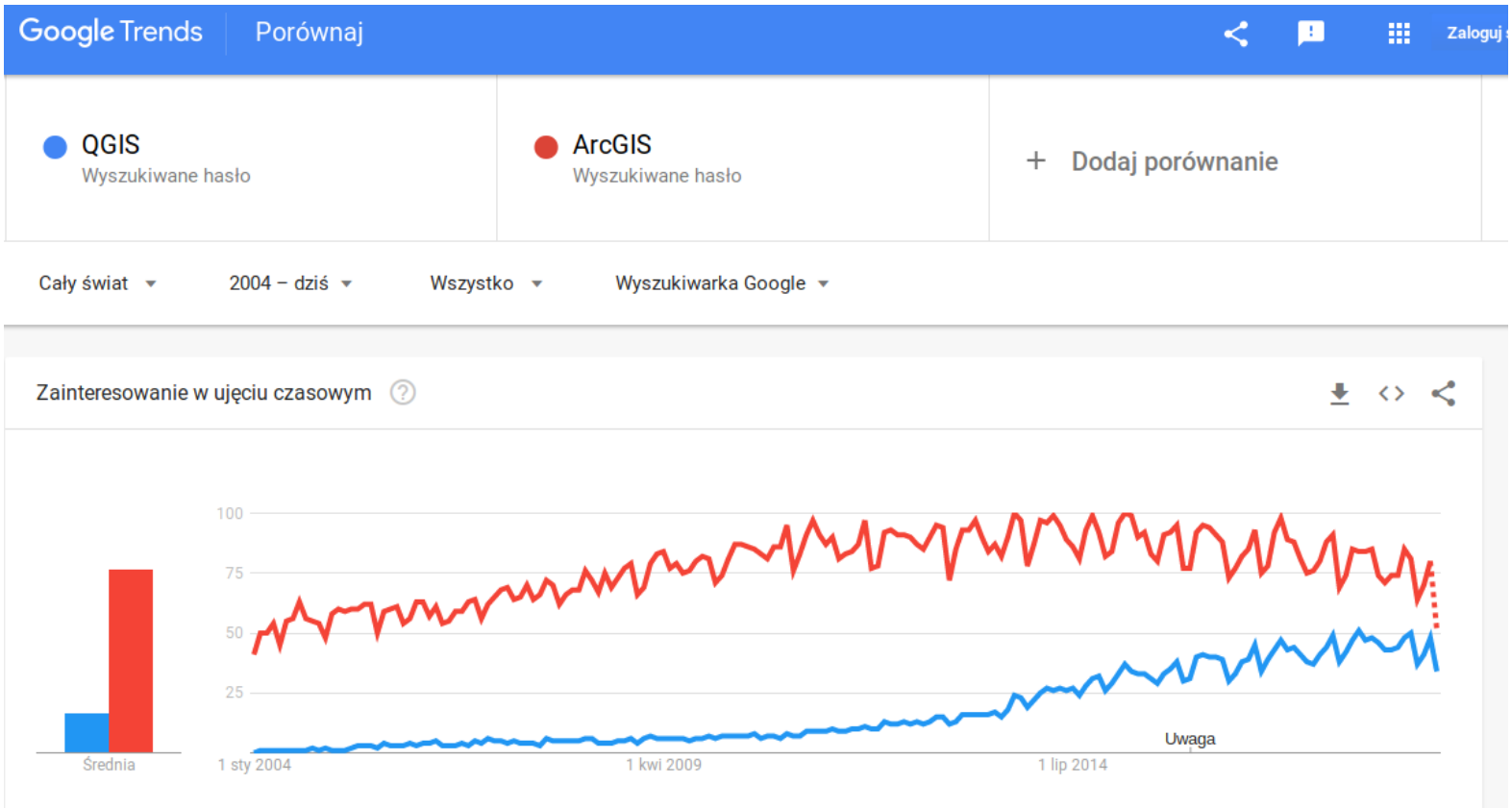
QGIS desktop

One of the most popular GIS desktop systems.
http://www.qgis.org

Gary Sherman, QGIS project

source: www.qgis.org

Google trends for world



source: Google trends

Google trends for France

source: Google trends

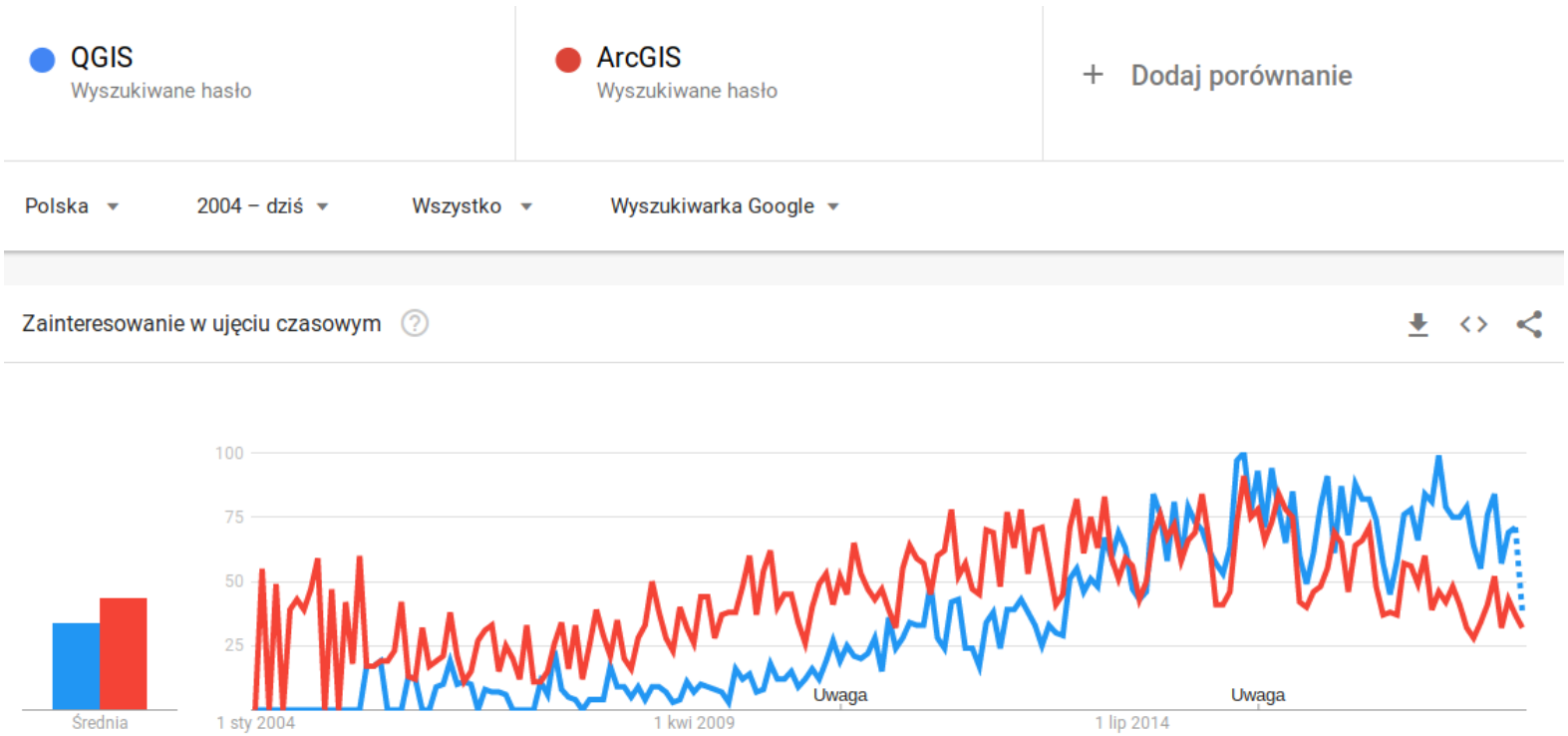
Google trends for Sweden

source: Google trends

Google trends for Germany

source: Google trends

Google trends for Poland



source: Google trends

QGIS project ecosystem

- QGIS Desktop
- QGIS Server
- QGIS Web Client
- QGIS Documentation
- QGIS Tutorials

Public bug tracking and issues reporting

{1} Active Tickets (254 matches)

- List all active tickets by priority.
- Color each row based on priority.
- If a ticket has been accepted, a '*' is appended after the owner's name

Ticket	Summary	Component	Version	Milestone	Type	Owner	Created
#1907	Bad behavior on selection tool when the width or heigth of drag rectangle are equal to 1	MapCanvas	HEAD	Version 1.3.0	patch	nobody	08/30/09
#1906	Set focus on OK button on loading vector layers	GUI	HEAD	Version 1.3.0	patch	nobody	08/30/09
#1905	Relative/Absolute paths are not recalculated on project save	Project Loading / Saving	HEAD	Version 1.3.0	bug	nobody	08/29/09
#1904	GRASS plugin crashes QGIS trying to open location from folder with cyrillics	GRASS	HEAD	Version 1.3.0	bug	rugginoso	08/28/09
#1902	Optionally disable search results dialog in Attribute Table	Build/Install	HEAD	Version 1.3.0	enhancement	nobody	08/27/09
#1900	windows: qgis crashes after closing a GRASS mapset	Data Provider	HEAD	Version 1.3.0	patch	nobody	08/26/09
#1899	Nested Grouping in Layer Tree	Map Legend	HEAD	Version 1.3.0	enhancement	nobody	08/26/09
#1898	Group Transparency/Opacity for Legend Groups	Symbology	HEAD	Version 1.3.0	enhancement	nobody	08/26/09
#1895	File open progress does not update on OS X	Project Loading / Saving	HEAD	Version 1.3.0	bug	nobody	08/25/09
#1894	Opening project file with 2x click or drag to dock icon does not work (OS X)	Project Loading / Saving	HEAD	Version 1.3.0	bug	nobody	08/25/09
#1893	opening data tables widens the main window	Data Provider	HEAD	Version 1.3.0	bug	nobody	08/25/09

http://trac.osgeo.org/qgis/report/1?sort=ticket&asc=1

Public source code

Changes in trunk/qgis/src/app/qgisapp.cpp [11500:11524]

Files: trunk/qgis/src/app/qgisapp.cpp (11 diffs)

Unmodified | Added | Removed | Modified | Copied | Moved

View differences: inline

Show 2 lines around each change

Ignore:

- Blank lines
- Case changes
- White space changes

Update

trunk/qgis/src/app/qgisapp.cpp

r11500	r11524	
2339	2339	*/
2340	2340	
2341		static void openFilesRememberingFilter_(QString const &filterName,
2342		QString const &filters, QStringList & selectedFiles, QString& enc, QString &title)
2343		{
	2341	static bool openFilesRememberingFilter_(QString const &filterName,
	2342	QString const &filters, QStringList & selectedFiles, QString& enc, QString &title,
	2343	bool cancelAll = false)
	2344	{
	2345	
	2346	bool retVal = false;
2344	2347	
2345	2348	bool haveLastUsedFilter = false; // by default, there is no last
...	...	
2366	2369	{
2367	2370	openFileDialog->selectFilter(lastUsedFilter);
	2371	}
	2372	
	2373	// Check if we should add a cancel all button
	2374	if (cancelAll)
	2375	{

QGIS contributors during hackfest in Wrocław

source: http://quantum-gis.pl/czytelnia/hackfest˙2010˙wroclaw

QGIS

https://www.qgis.org
A user friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License.
It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities.
QGIS in nutshell

QGIS install versions

https://www.qgis.org/en/site/forusers/download.html

- OSGeo4W Network Installer
- Standalone (Latest release)
- Standalone LTR (Long term release)

QGIS key features – view data

- Spatially-enabled tables and views using PostGIS, SpatiaLite and MS SQL Spatial, Oracle Spatial, vector formats supported by the installed OGR library, including ESRI shapefiles, MapInfo, SDTS, GML and many more.
- Raster and imagery formats supported by the installed GDAL (Geospatial Data Abstraction Library) library, such as GeoTIFF, ERDAS IMG, ArcInfo ASCII GRID, JPEG, PNG and many more.
- GRASS raster and vector data from GRASS databases (location/mapset).
- Online spatial data served as OGC Web Services, including WMS, WMTS, WCS, WFS, and WFS-T.

QGIS key features – create, edit and manage data

- Digitizing tools for OGR-supported formats
- Ability to create and edit vector layers
- Georeferencer plugin to geocode images
- GPS tools to import and export GPX format
- Support for visualizing and editing OpenStreetMap data
- Ability to create spatial database tables
- Tools for managing vector attribute tables
- Option to save screenshots as georeferenced images

QGIS key features – explore data

- On-the-fly reprojection
- Data-defined vector and raster symbology tools
- Spatial bookmarks
- Identify/select features
- Edit/view/search attributes
- Geoprocessing
- Vector/raster analytical tools

QGIS key features – extend functionality through plugins

- Project repository
- DataPlotly
- Semi-Automatic Classification Plugin

QGIS key features – create traditional and interactive maps

- Map composer
- qgis2web
- Qgis2threejs (Cracow sample)

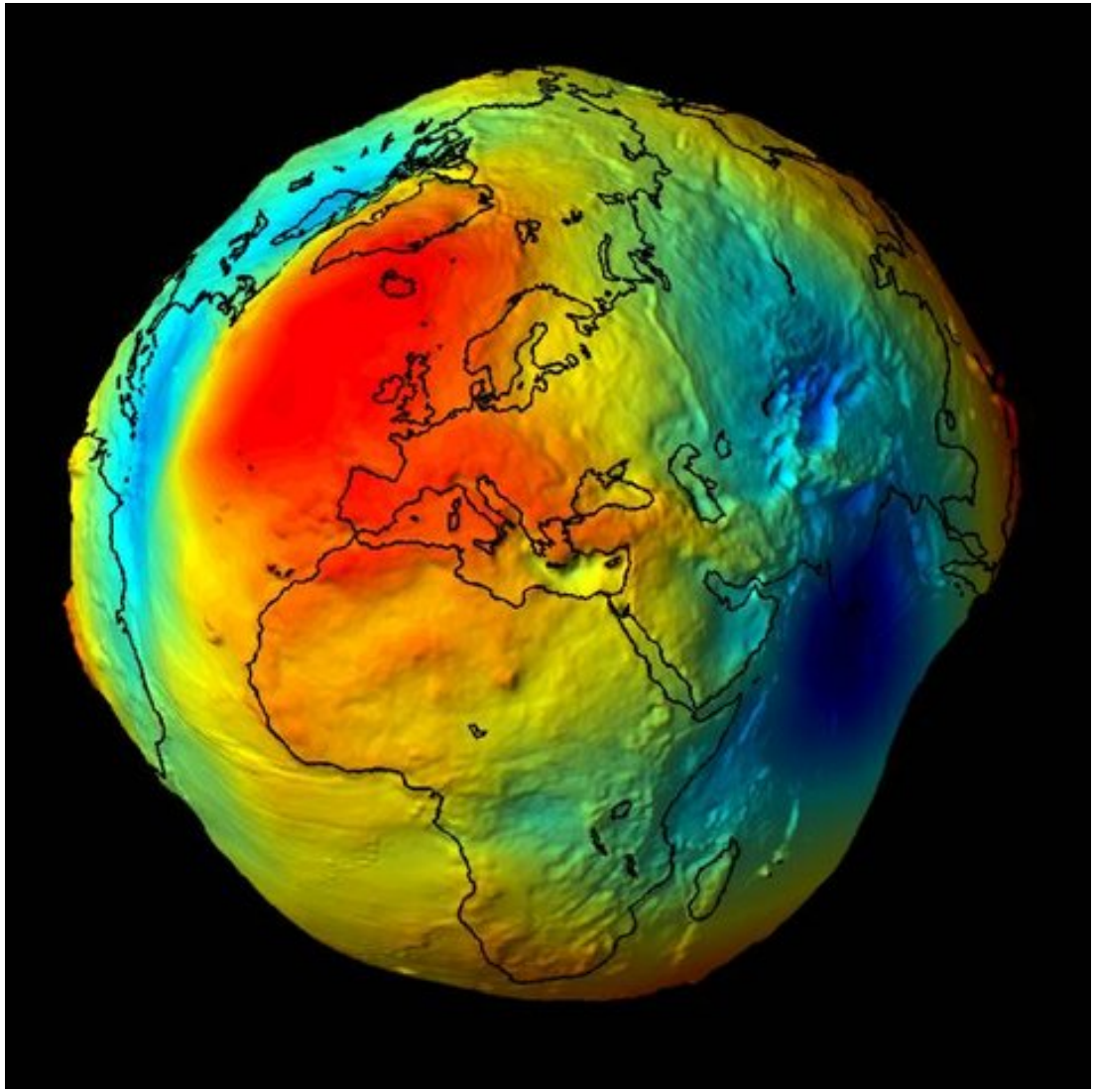
Coordinate reference systems

How to show a 3D object on a flat surface

One method

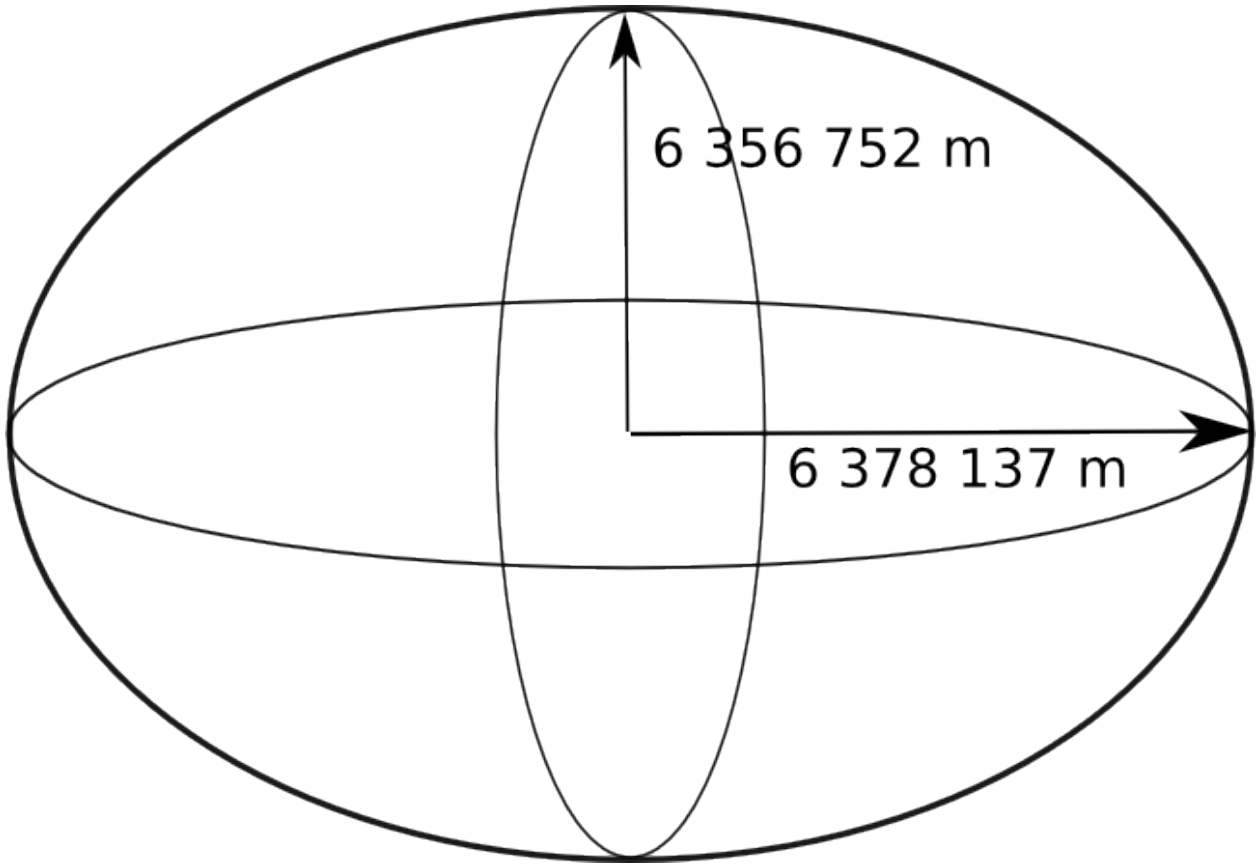
Another method

Geoid

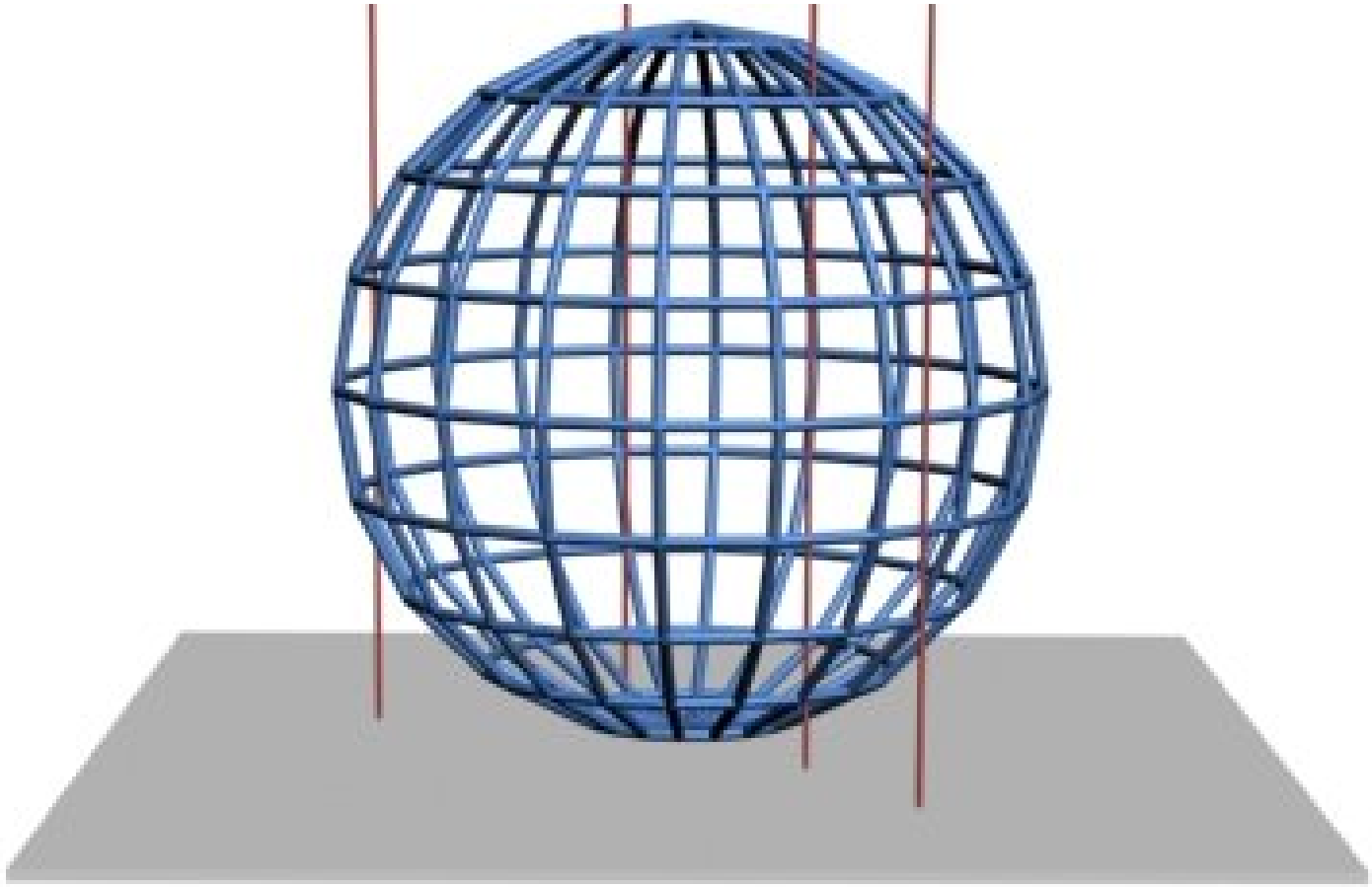


source: https://www.swisstopo.admin.ch

Ellipsoid WGS84 (World Geodetic System)

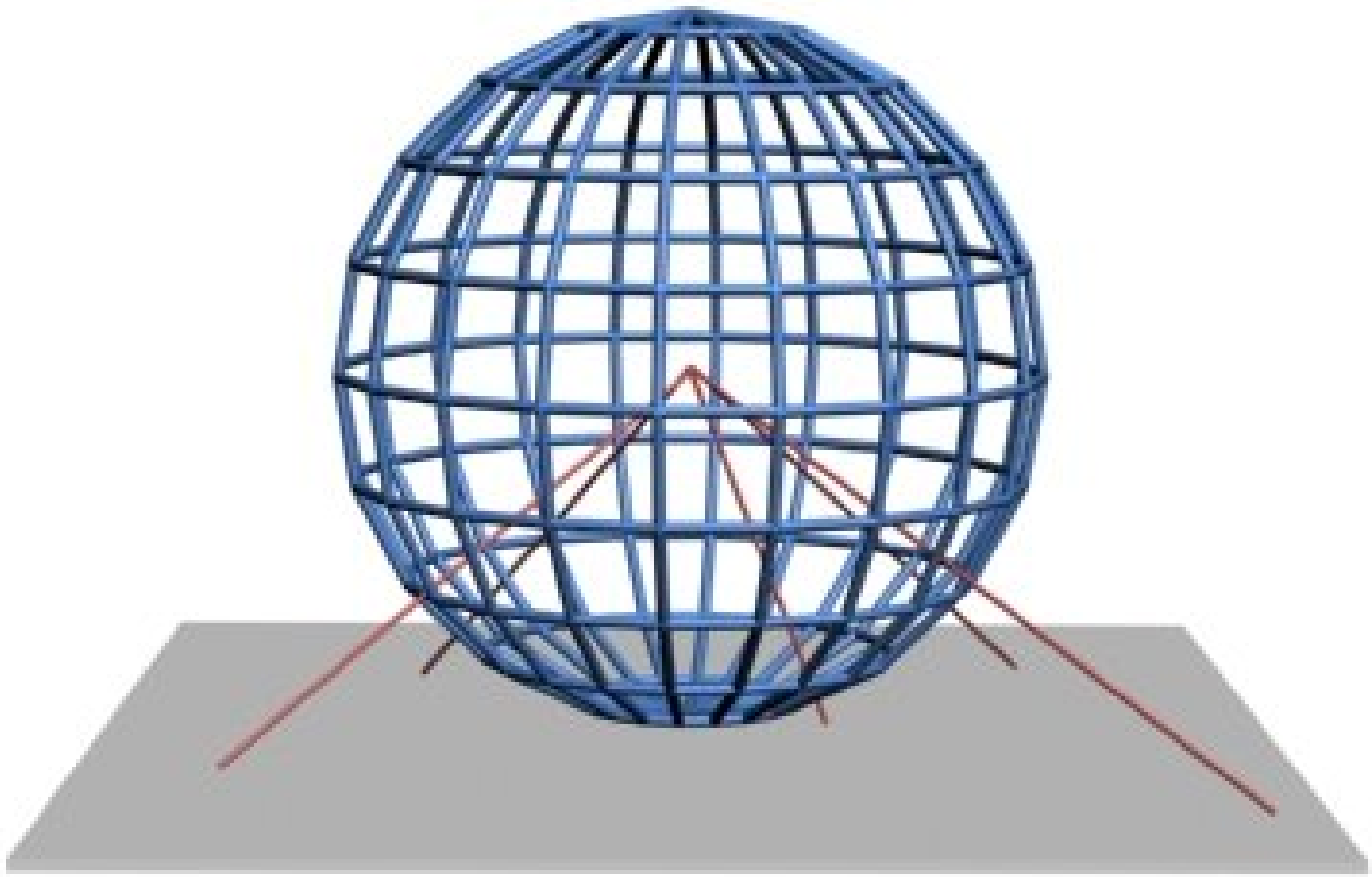


Azimuthal orthographic projection



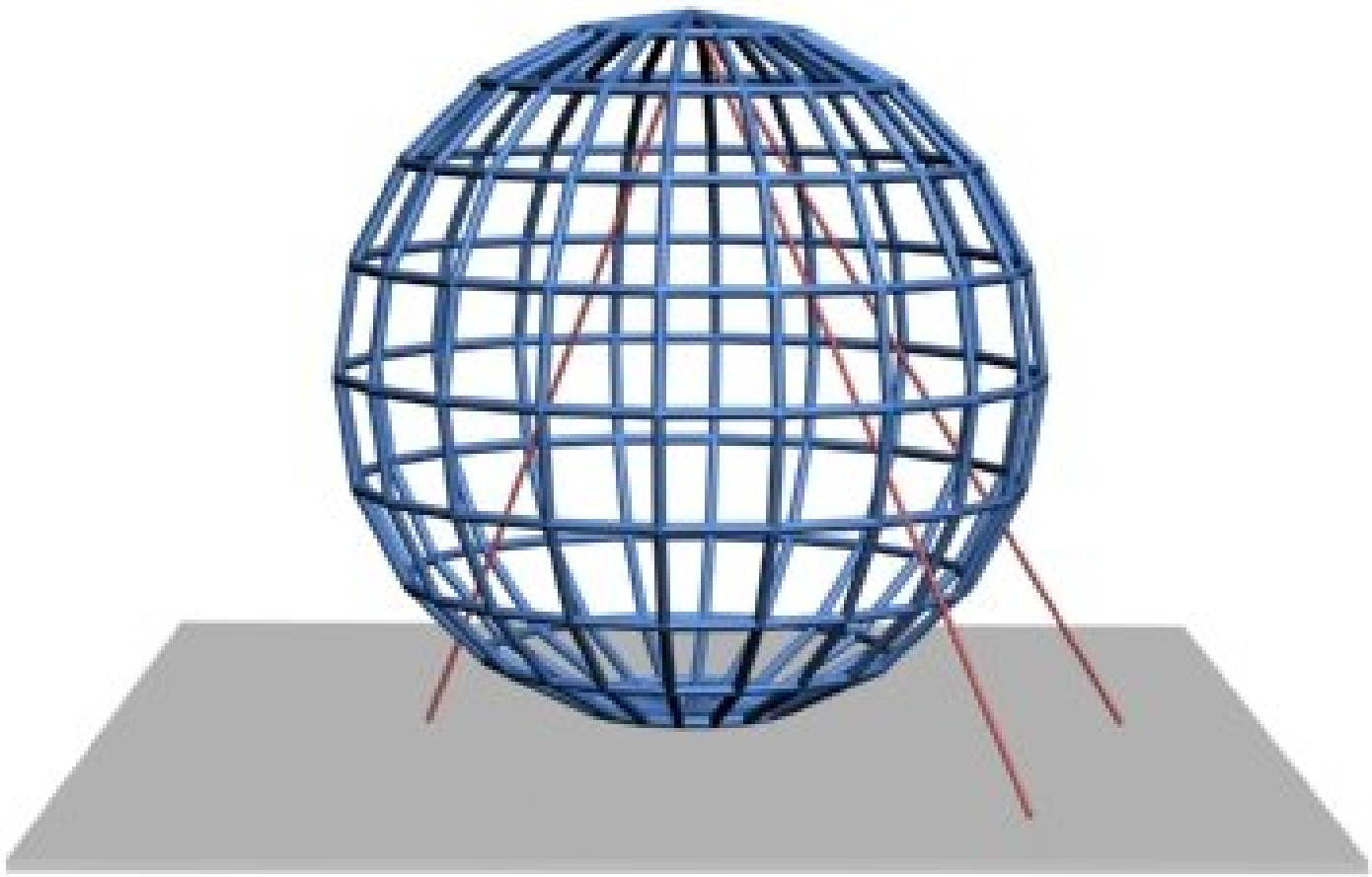
by Traroth

Azimuthal gnomic projection



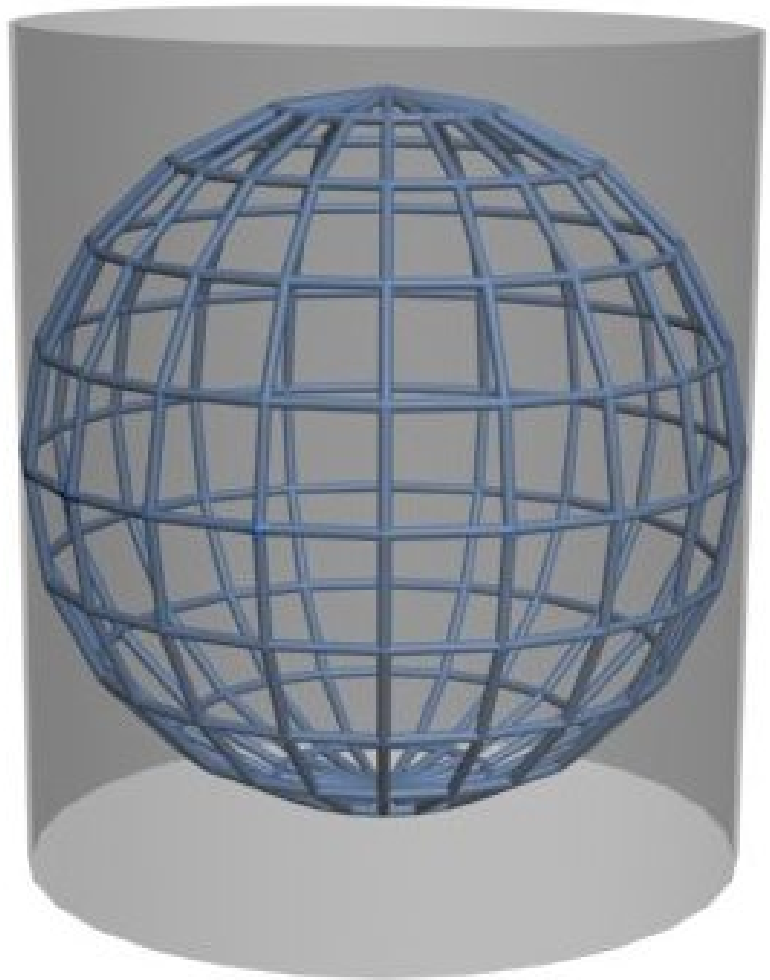
by Traroth

Azimuthal stereographic projection



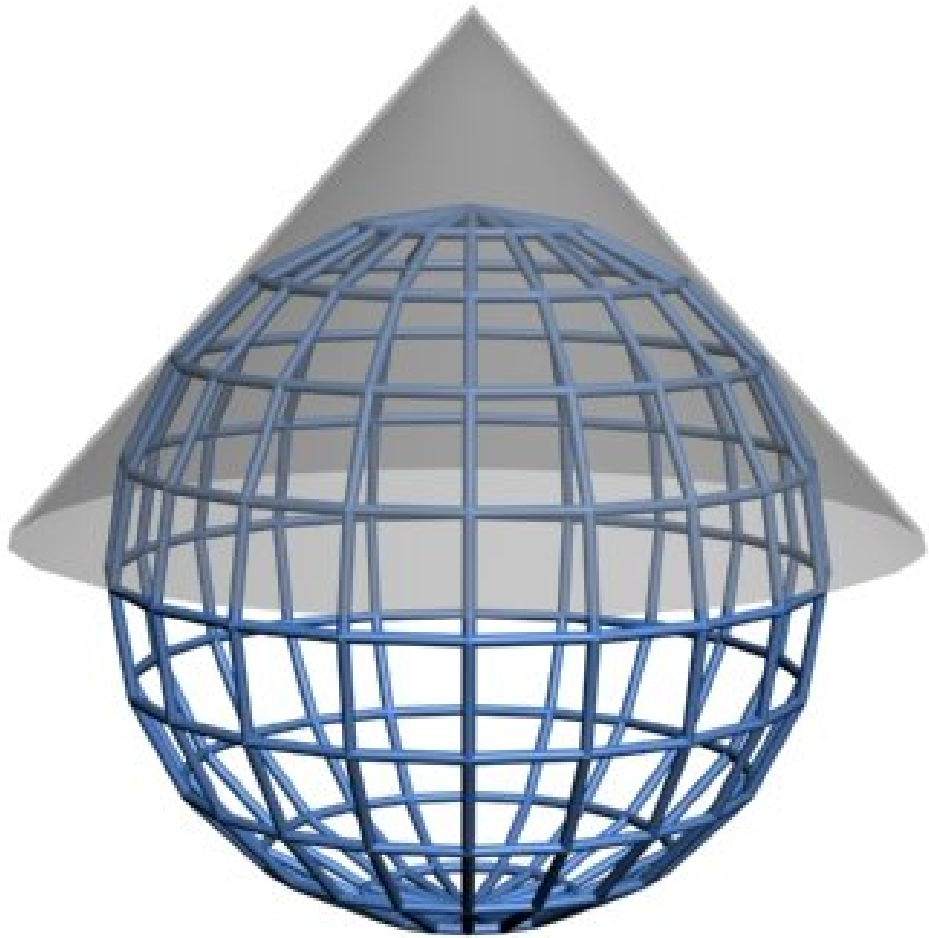
by Traroth

Cylindrical normal projection



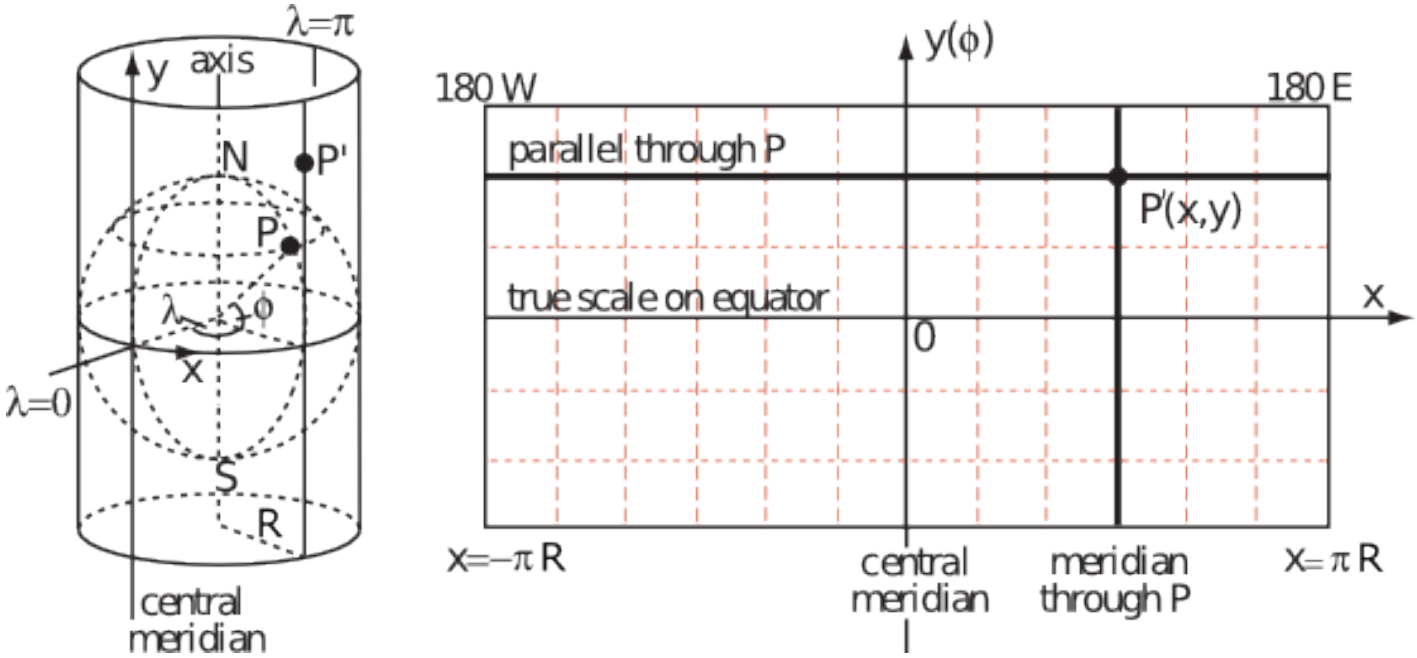
by Traroth

Conic normal projection



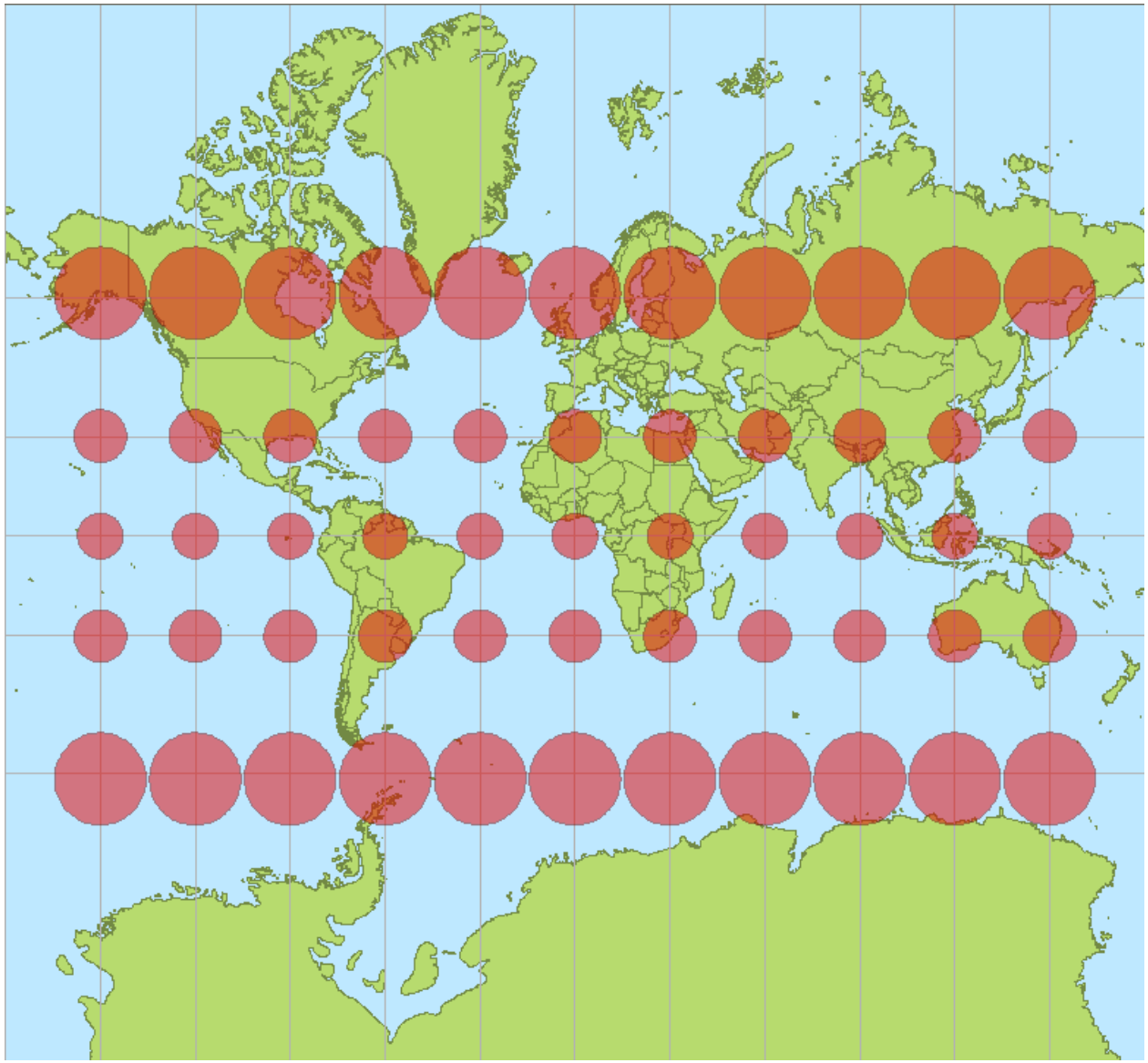
by Traroth

Cylindrical Mercator projection



source: Wikimedia Commons

Mercator projection errors

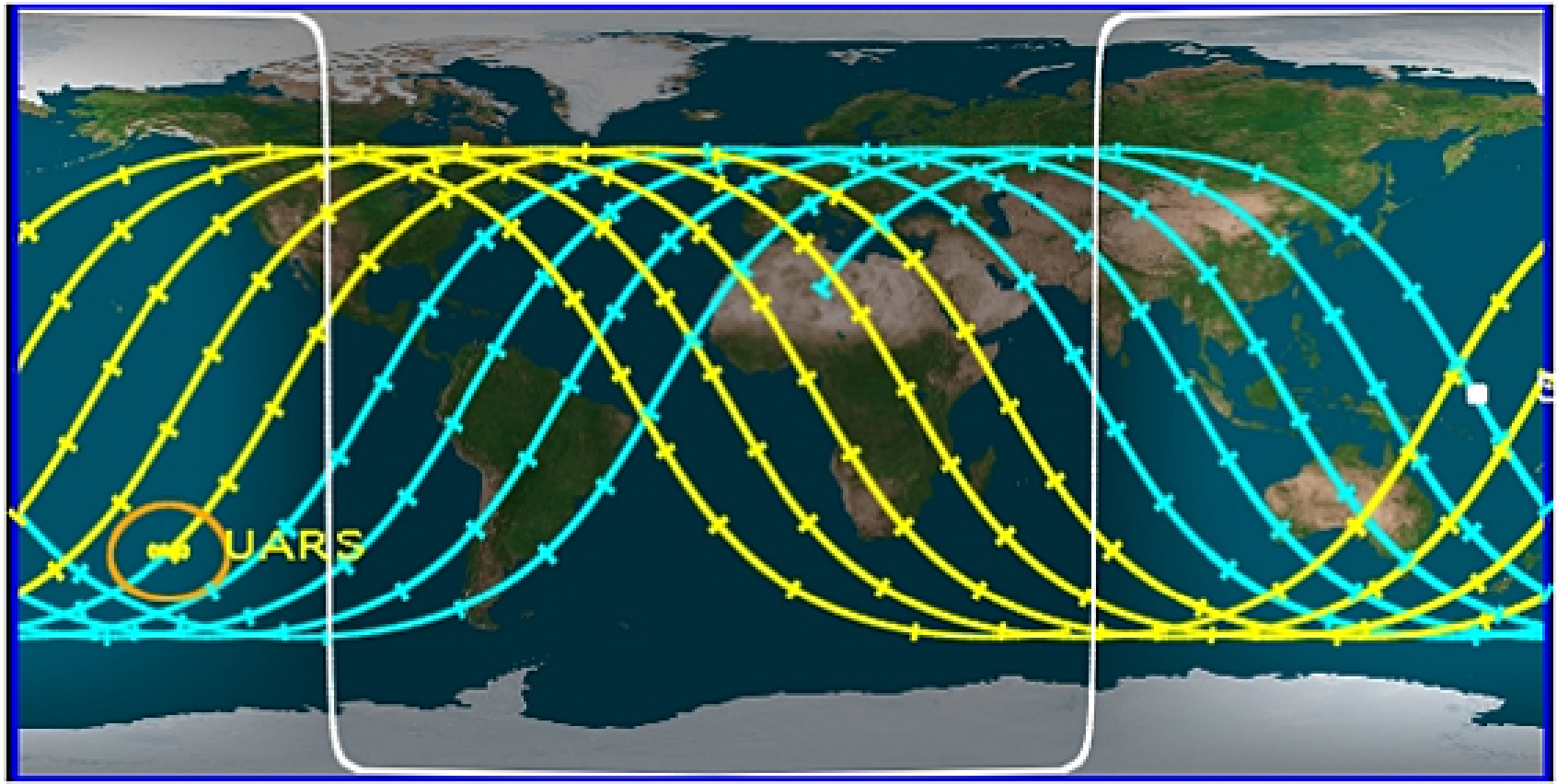


by S.Kühn

Cylindrical Mercator projection

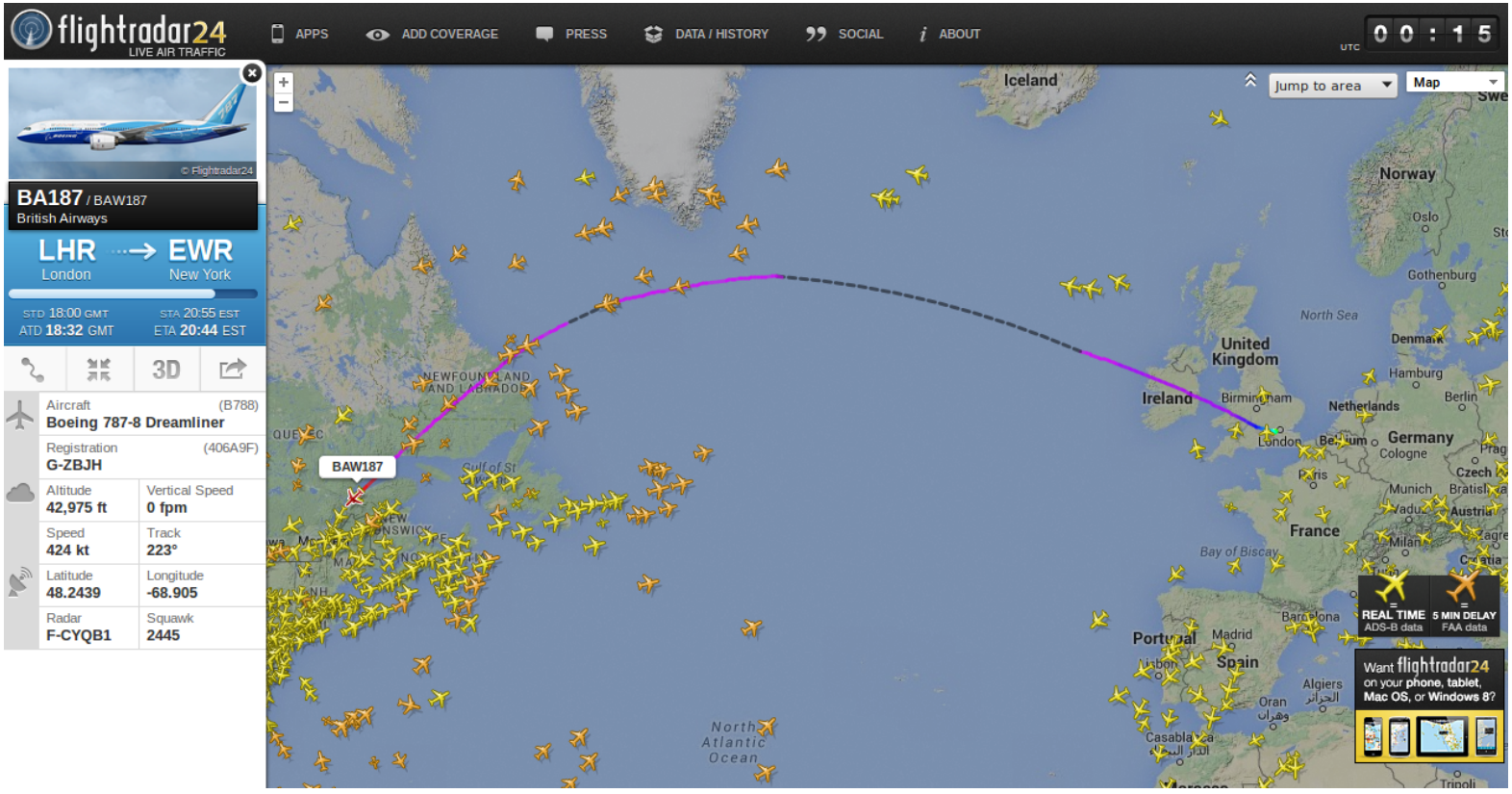
- Bing Maps
- OpenStreetMap
- Google Maps
- Yahoo Maps

Satellite ground path in Mercator projection



source: Center for Orbital and Reentry Debris Studies

Airplane orthodromes in Mercator projection



source: https://www.flightradar24.com

EPSG

European Petroleum Survey Group, Geodetic Parameter Dataset

Structured dataset of Coordinate Reference Systems and Coordinate Transformations.

- http://www.epsg.org/
- http://www.epsg-registry.org/

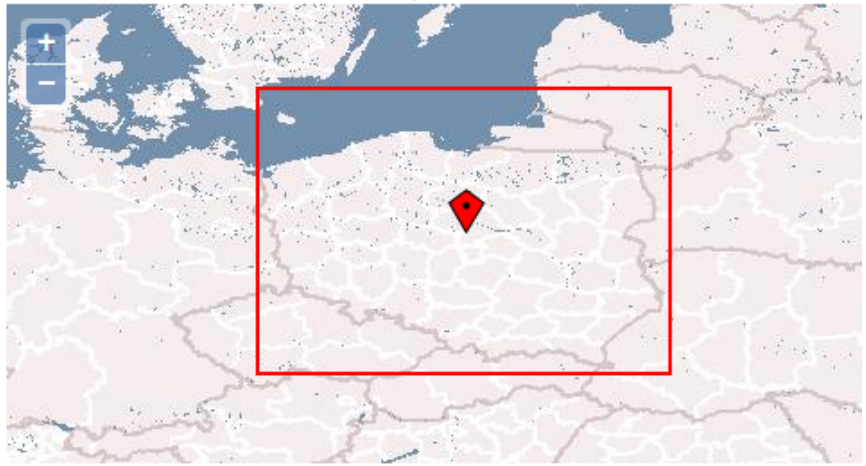
EPSG:2180

ETRS89 / Poland CS92 (Google it)

- **WGS84 Bounds**: 14.1400, 49.0300, 24.1600, 55.9500
- **Projected Bounds**: 144907.1658, 140544.7241, 877004.0070, 910679.6817
- **Scope**: Medium and small scale topographic mapping (1:10,000 and smaller).
- **Last Revised**: Feb. 2, 2007
- **Area**: Poland

- Well Known Text as HTML
- Human-Readable OGC WKT
- Proj4
- OGC WKT
- JSON
- GML
- ESRI WKT
- .PRJ File
- USGS
- MapServer Mapfile | Python
- Mapnik XML | Python
- GeoServer
- PostGIS spatial_ref_sys INSERT statement
- Proj4js format

Input Coordinates: 19.2919921875, 52.3388671875 Output Coordinates: 519887.719724, 497028.877499



http://spatialreference.org/ref/epsg/etrs89-poland-cs92/

OGC Well Known Text

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GEOGCS["ETRS89",
DATUM["European_Terrestrial_Reference_System_1989",
SPHEROID["GRS 1980",6378137,298.257222101,
AUTHORITY["EPSG","7019"]],
AUTHORITY["EPSG","6258"]],
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AUTHORITY["EPSG","4258"]],
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PARAMETER["central_meridian",19],
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PARAMETER["false_northing",-5300000],
AUTHORITY["EPSG","2180"],
AXIS["y",EAST],
AXIS["x",NORTH]]
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PROJ.4

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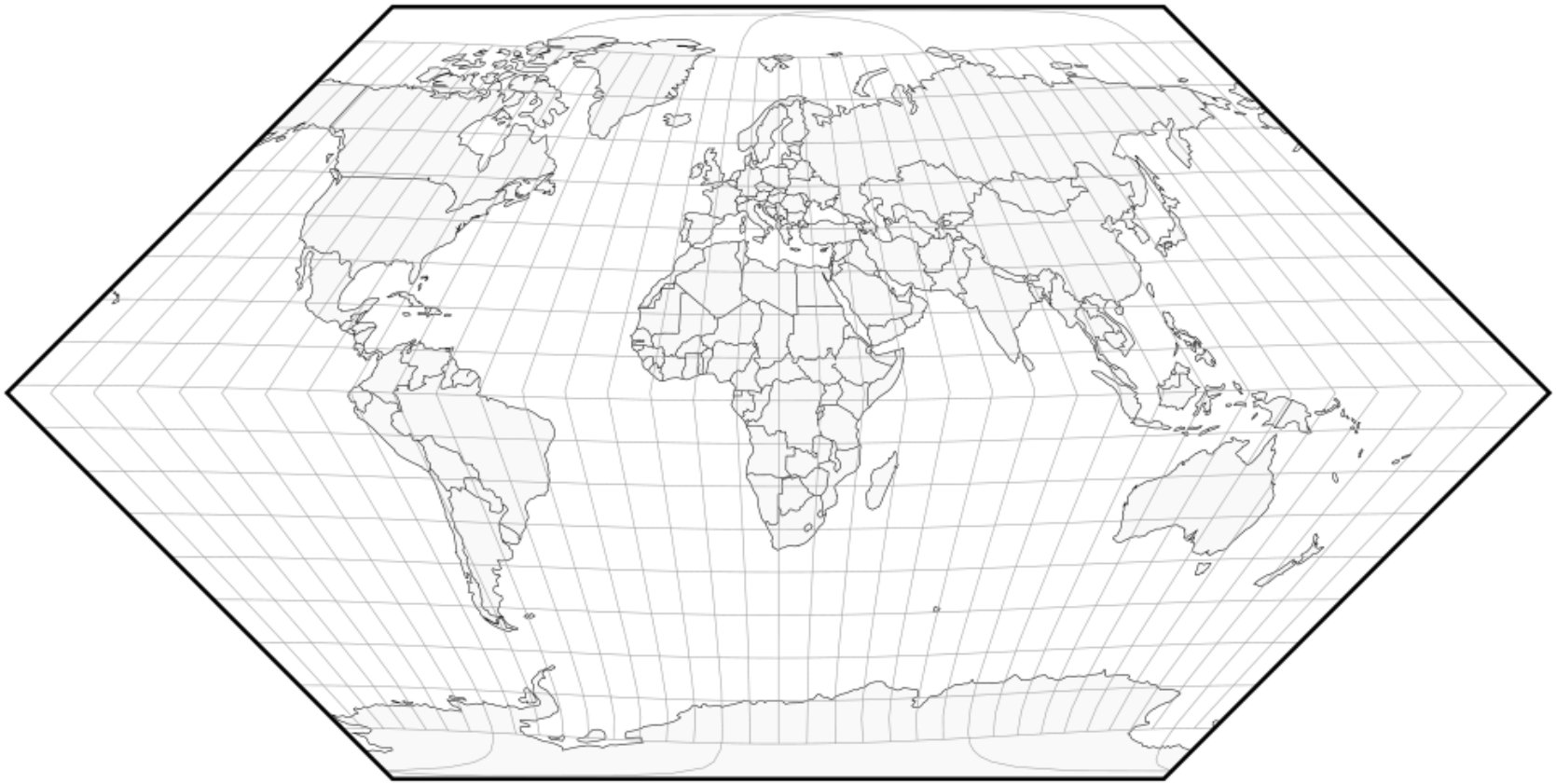
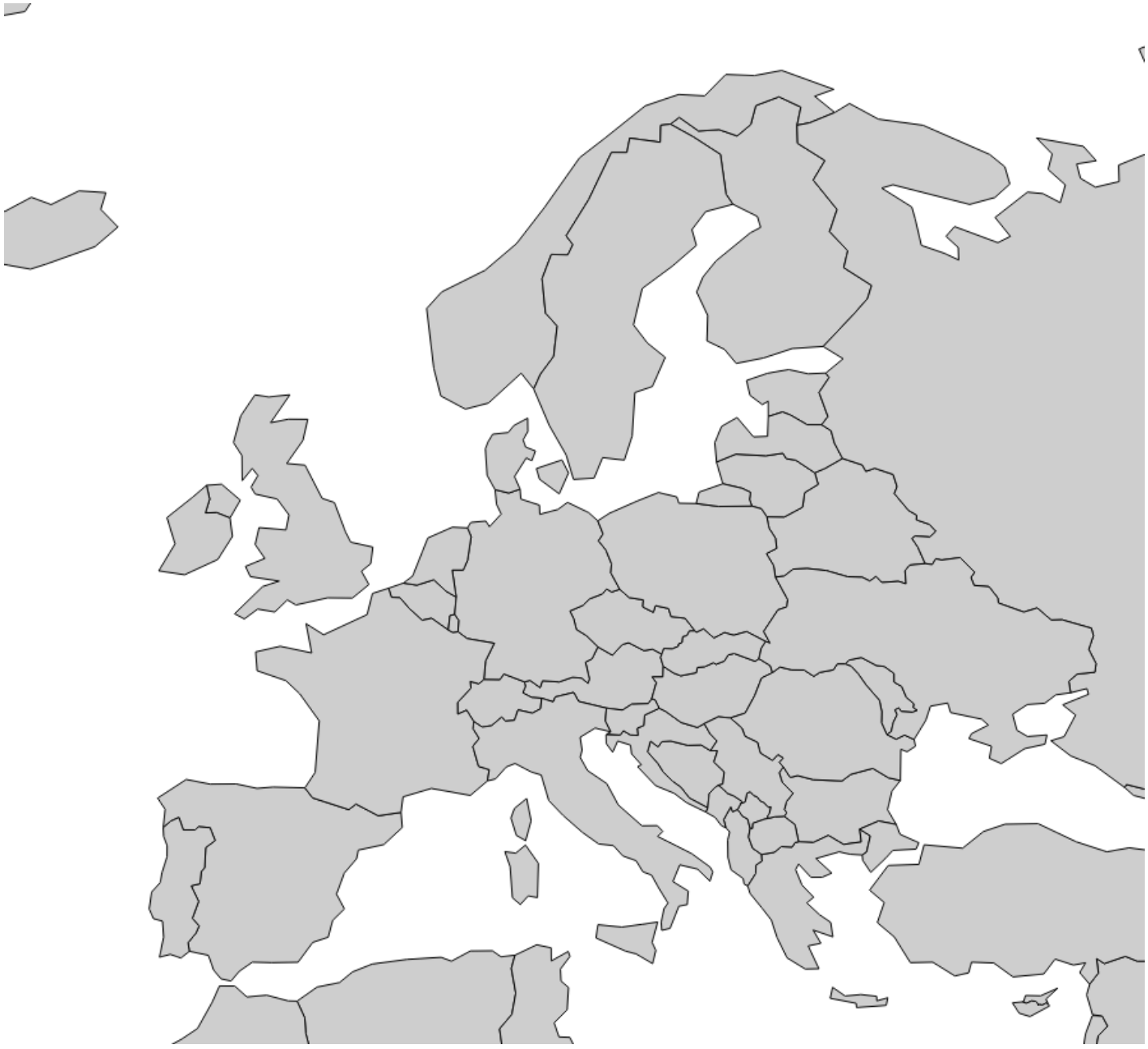
+proj=tmerc +lat_0=0 +lon_0=19 +k=0.9993 +x_0=500000 +y_0=-5300000
+ellps=GRS80 +units=m +no_defs
```

- C library (bindings to JavaScript, PHP, Python, VB)
- MIT license
- proj.osgeo.org



Eckert I



Eckert I; EPSG: 54015

Eckert II; EPSG: 54014

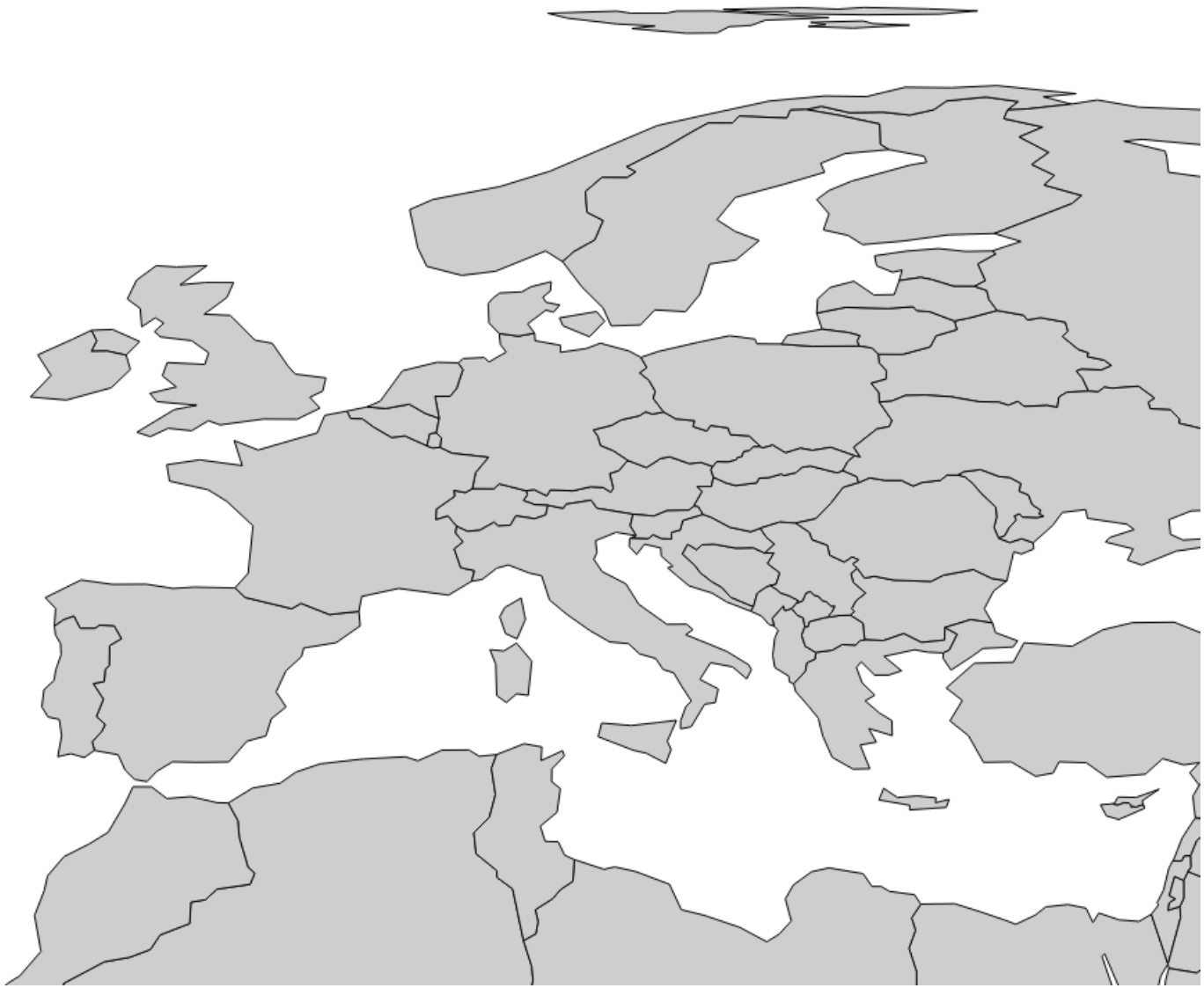
Eckert III; EPSG: 54013

Eckert IV

Eckert IV; EPSG: 54012

Eckert V; EPSG: 54011

Eckert VI; EPSG: 54010



Equal Area Cylindrical; EPSG: 3975

Europe Equidistant Conic; EPSG: 102031

NAD27/North Texas; EPSG: 32037

WGS 84

World Geodetic System (WGS).
Global coordinate reference system for use in cartography, geodesy, and satellite navigation including GPS.

EPSG: 4326

WGS 84; EPSG: 4326

Web Mercator

Projection used in many popular web mapping applications (Google/Bing/OpenStreetMap/etc). More information.

EPSG: 3857, 900913

Universal Transverse Mercator (UTM)

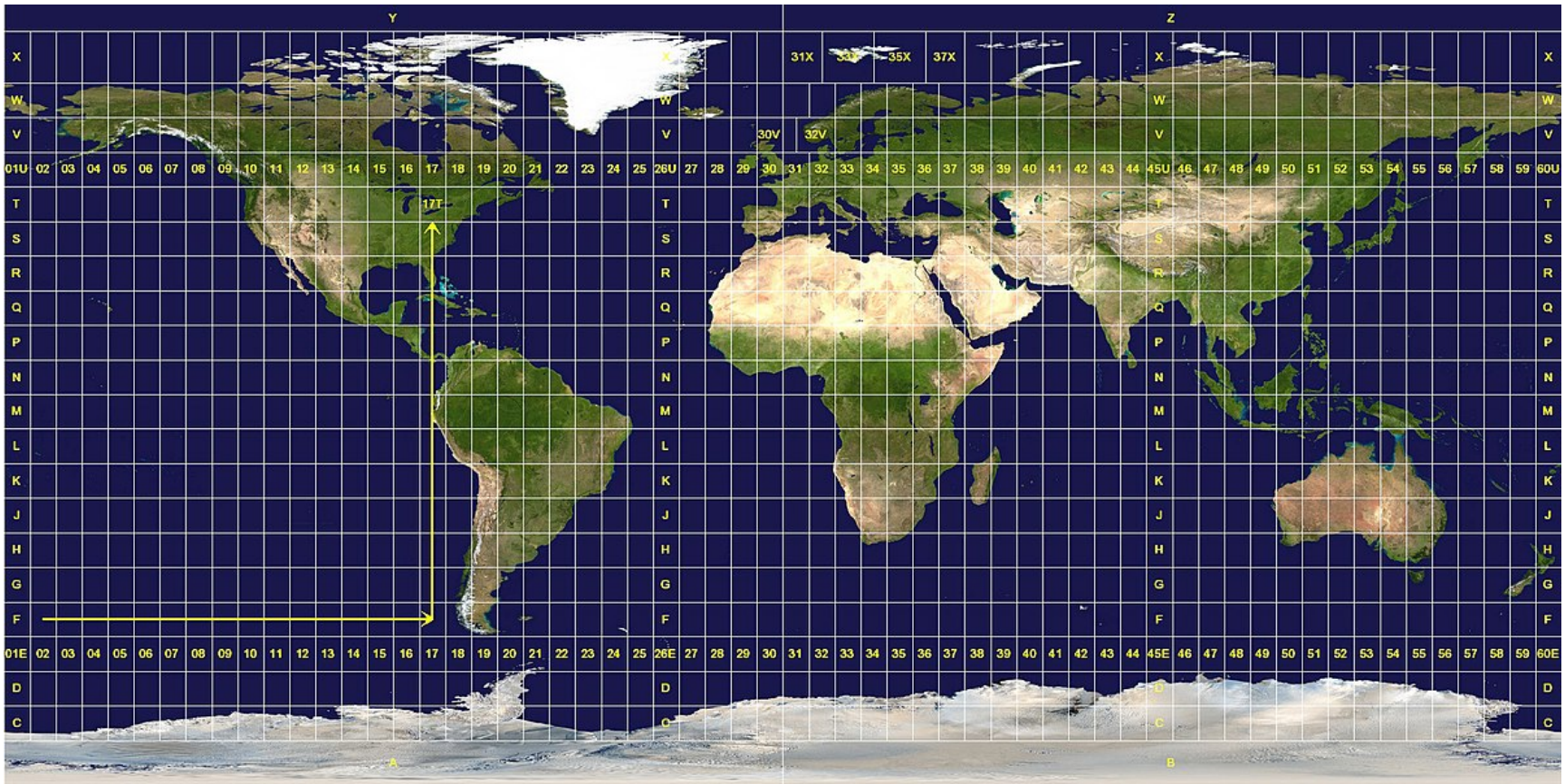
Projected coordinate reference system with its origin on the equator at a specific Longitude. To avoid too much distortion, the world is divided into **60 equal zones** that are all **6 degrees** wide.

UTM zone 33N

UTM zone 33S

EPSG: 32633, 32733

UTM zones

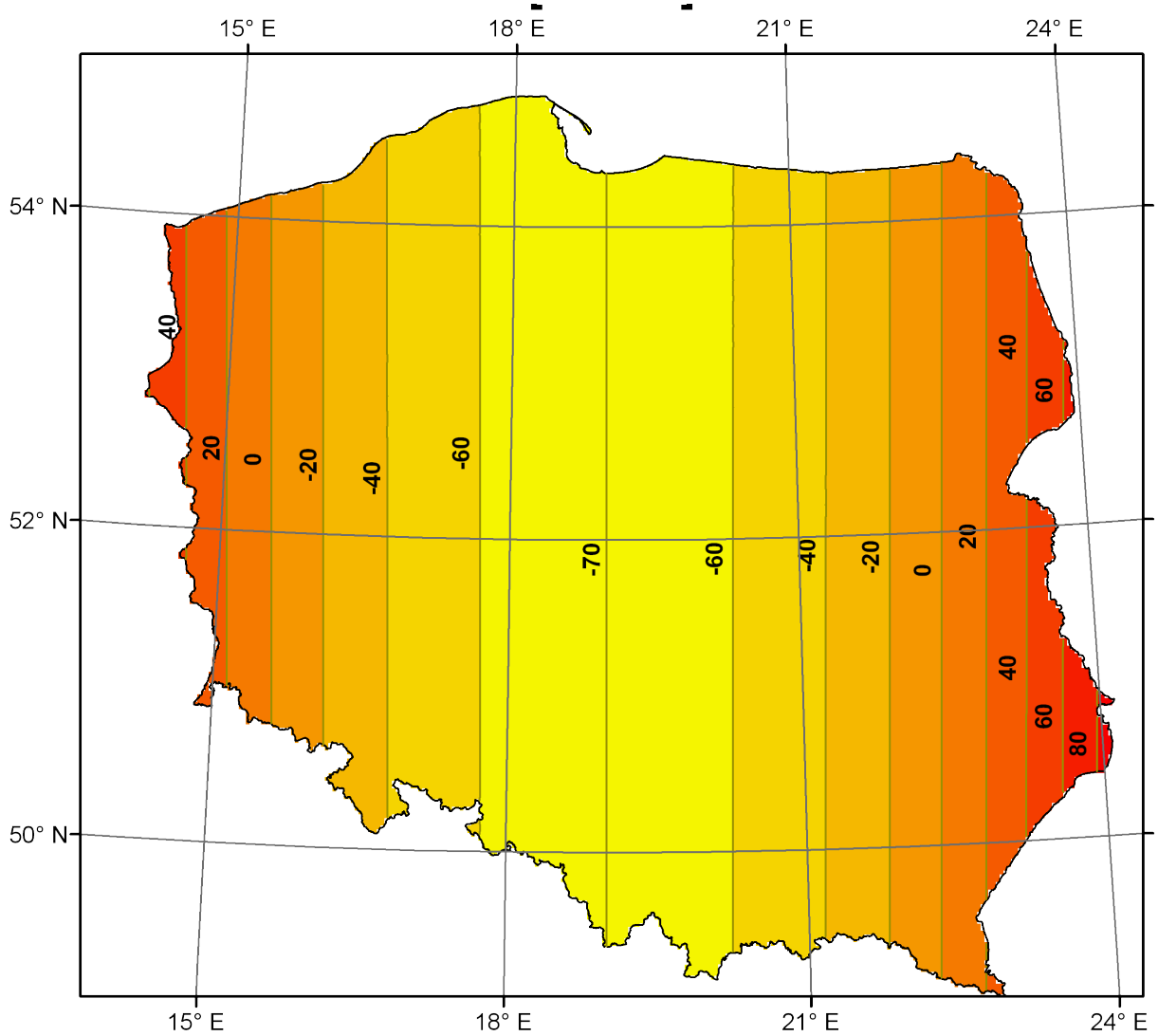


source: Wikipedia

Local, Polish CRS

Two projected Coordinate Reference Systems used in Poland at different scales.

EPSG: 2180, error distribution [cm/km]

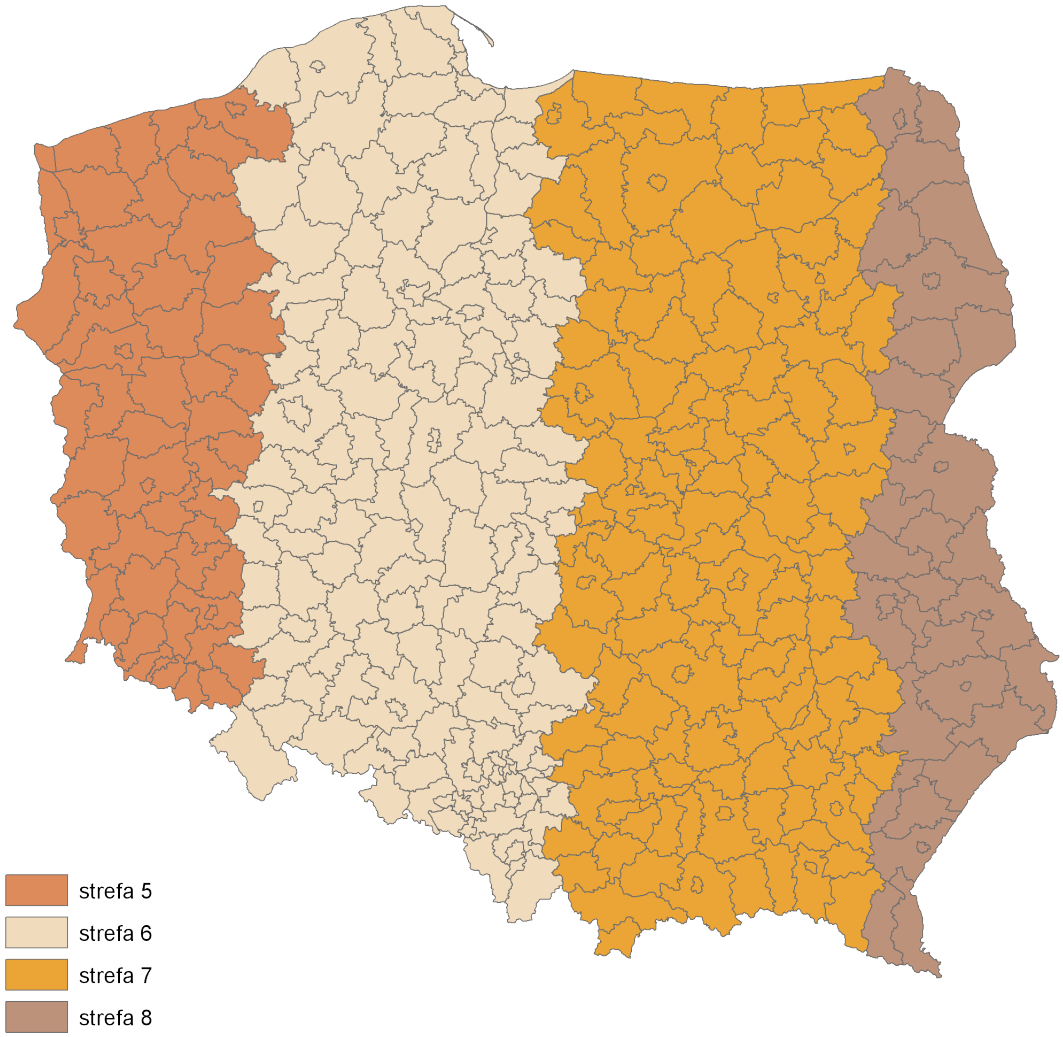


source: Wikipedia

ETRS89/Poland CS92; EPSG: 2180

Zonal projected reference system for Poland

Max. error below 7 cm/km



source: Wikipedia

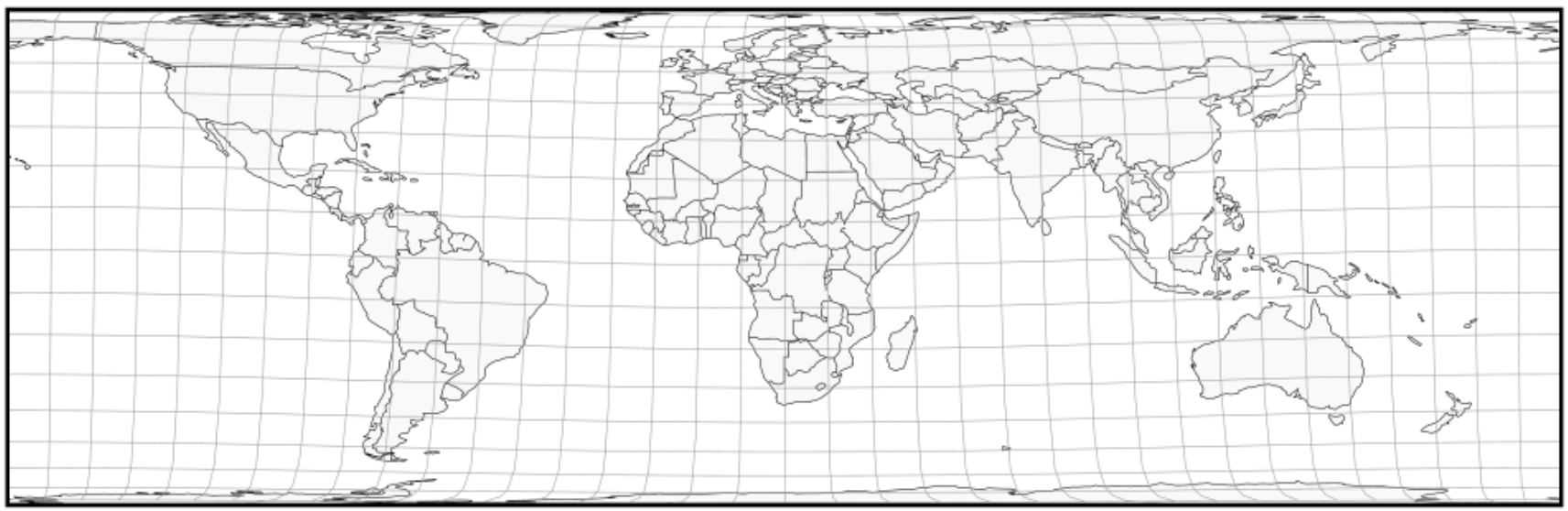
ETRS89/Poland CS2000 zone 6; EPSG: 2177

ETRS-LAEA

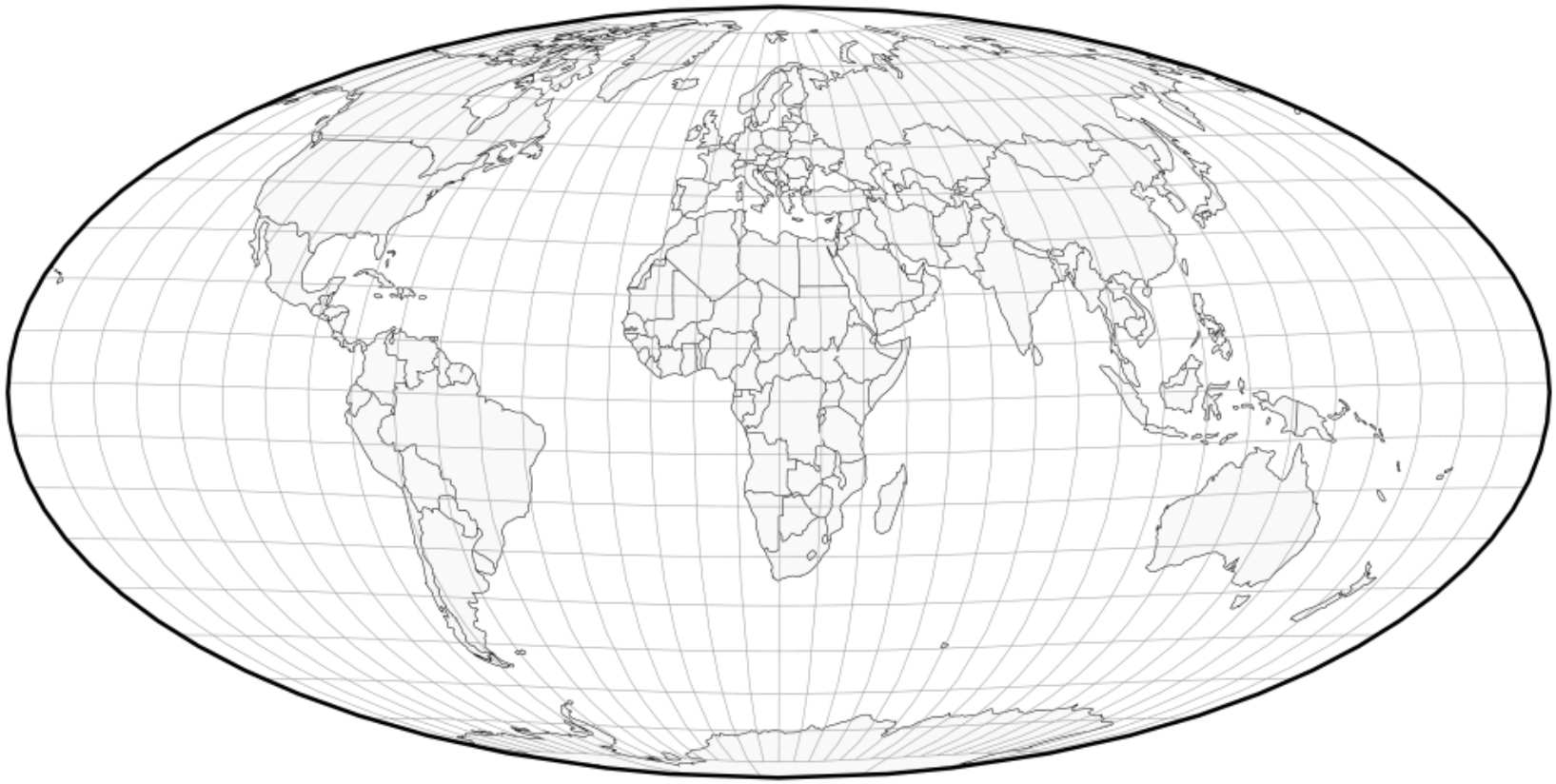
Single CRS for all Europe. Used for statistical mapping at all scales and other purposes where true area representation is required.

EPSG: 3035

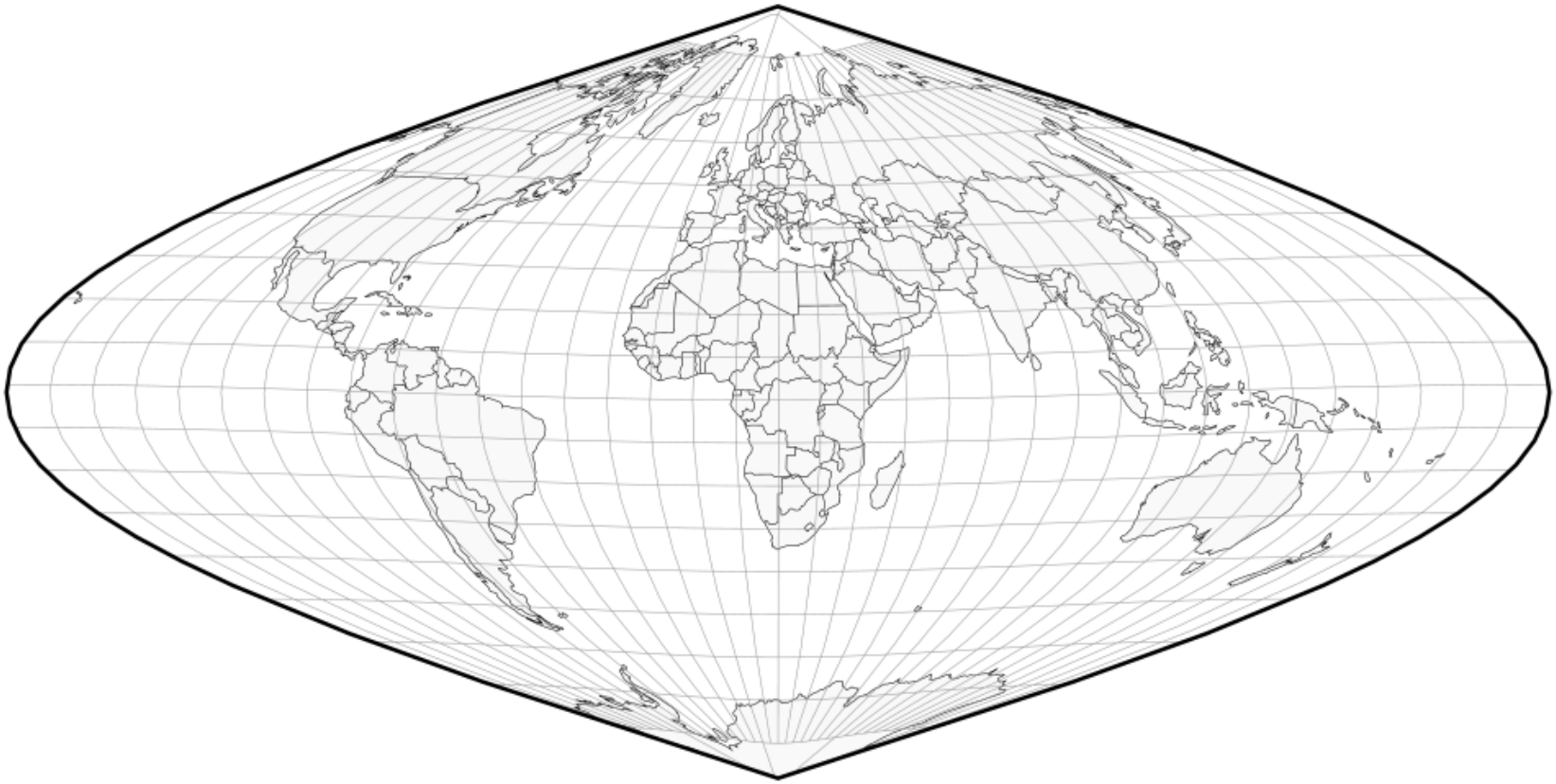
Lambert Equal Area



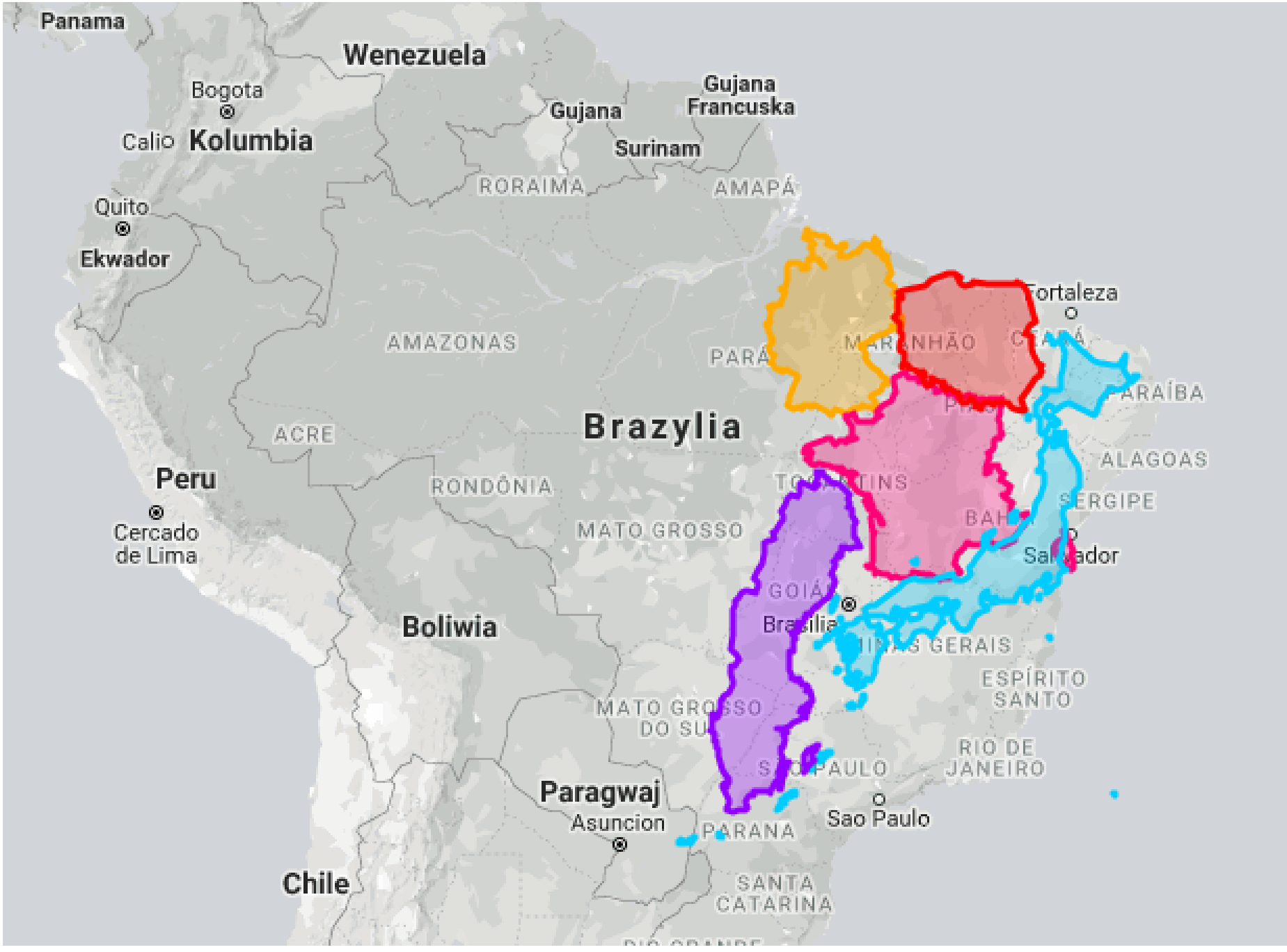
Lambert Azimuthal Equal Area;
European Terrestrial Reference System
ETRS89/ETRS-LAEA; EPSG: 3035



Mollweide

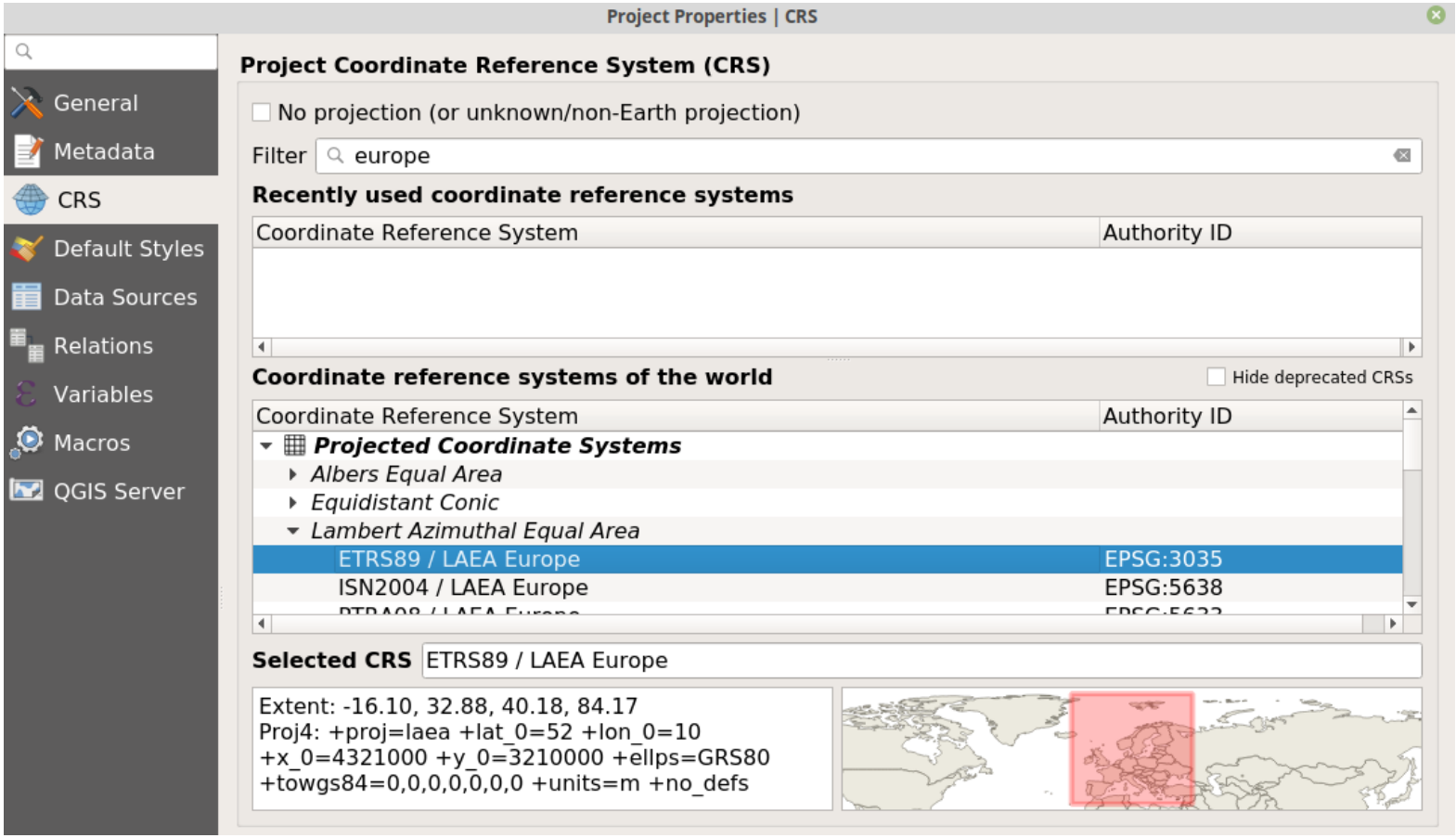


Sinusoidal



https://thetruesize.com

CRS in QGIS


Project Properties | CRS
General
Metadata
CRS
Default Styles
Data Sources
Relations
Variables
Macros
QGIS Server
Project Coordinate Reference System (CRS)
No projection (or unknown/non-Earth projection)
Filter
europe
Recently used coordinate reference systems
Coordinate Reference System
Authority ID
Coordinate reference systems of the world
Hide deprecated CRSs
Coordinate Reference System
Authority ID
Projected Coordinate Systems
Albers Equal Area
Equidistant Conic
Lambert Azimuthal Equal Area
ETRS89 / LAEA Europe
EPSG:3035
ISN2004 / LAEA Europe
EPSG:5638
Selected CRS
ETRS89 / LAEA Europe
Extent: -16.10, 32.88, 40.18, 84.17
Proj4: +proj=laea +lat_0=52 +lon_0=10
+x_0=4321000 +y_0=3210000 +ellps=GRS80
+towgs84=0,0,0,0,0,0,0 +units=m +no_defs

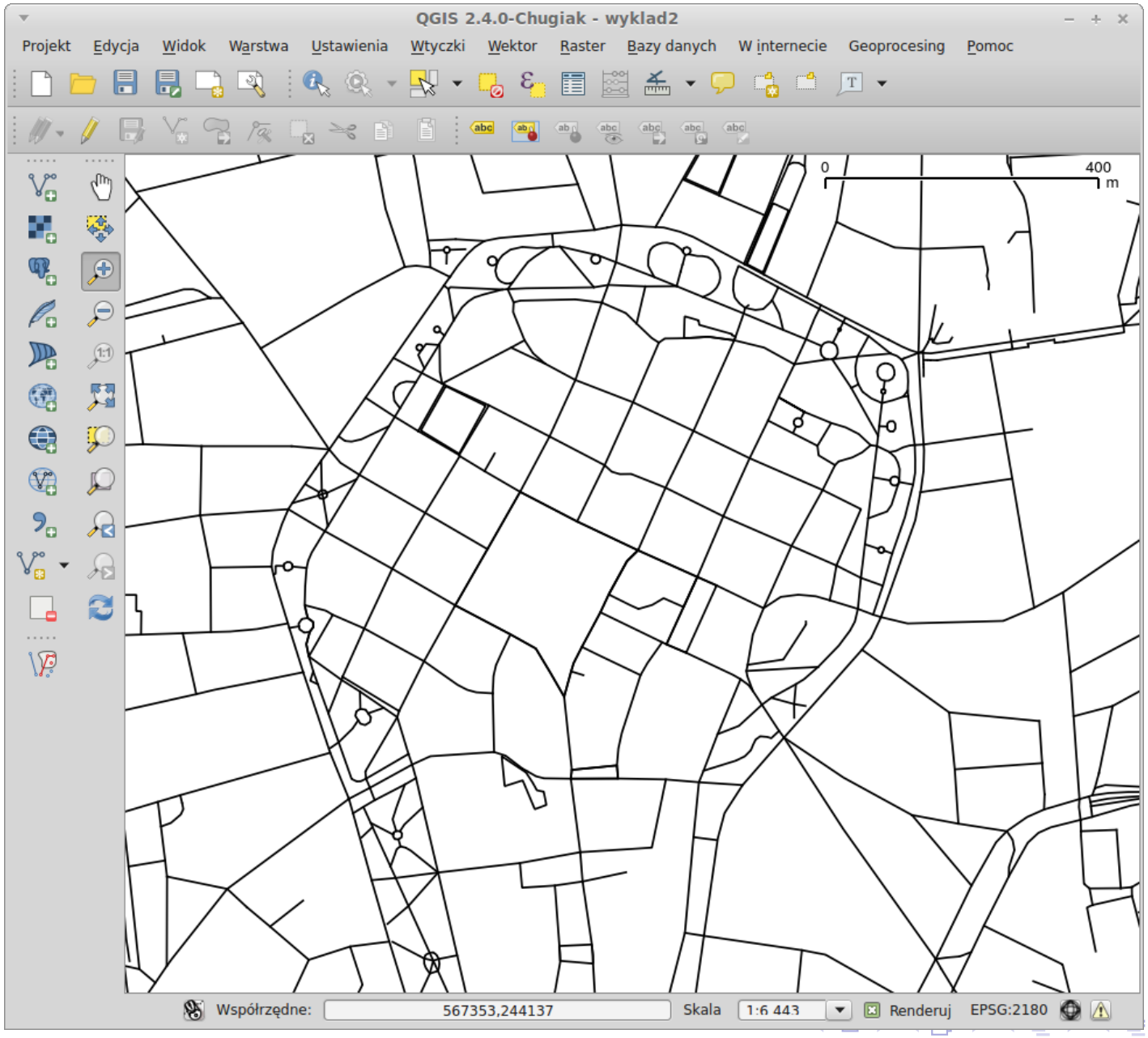
CRS in QGIS

- On-the-fly projection
- Order of reading layers is important
- No projection

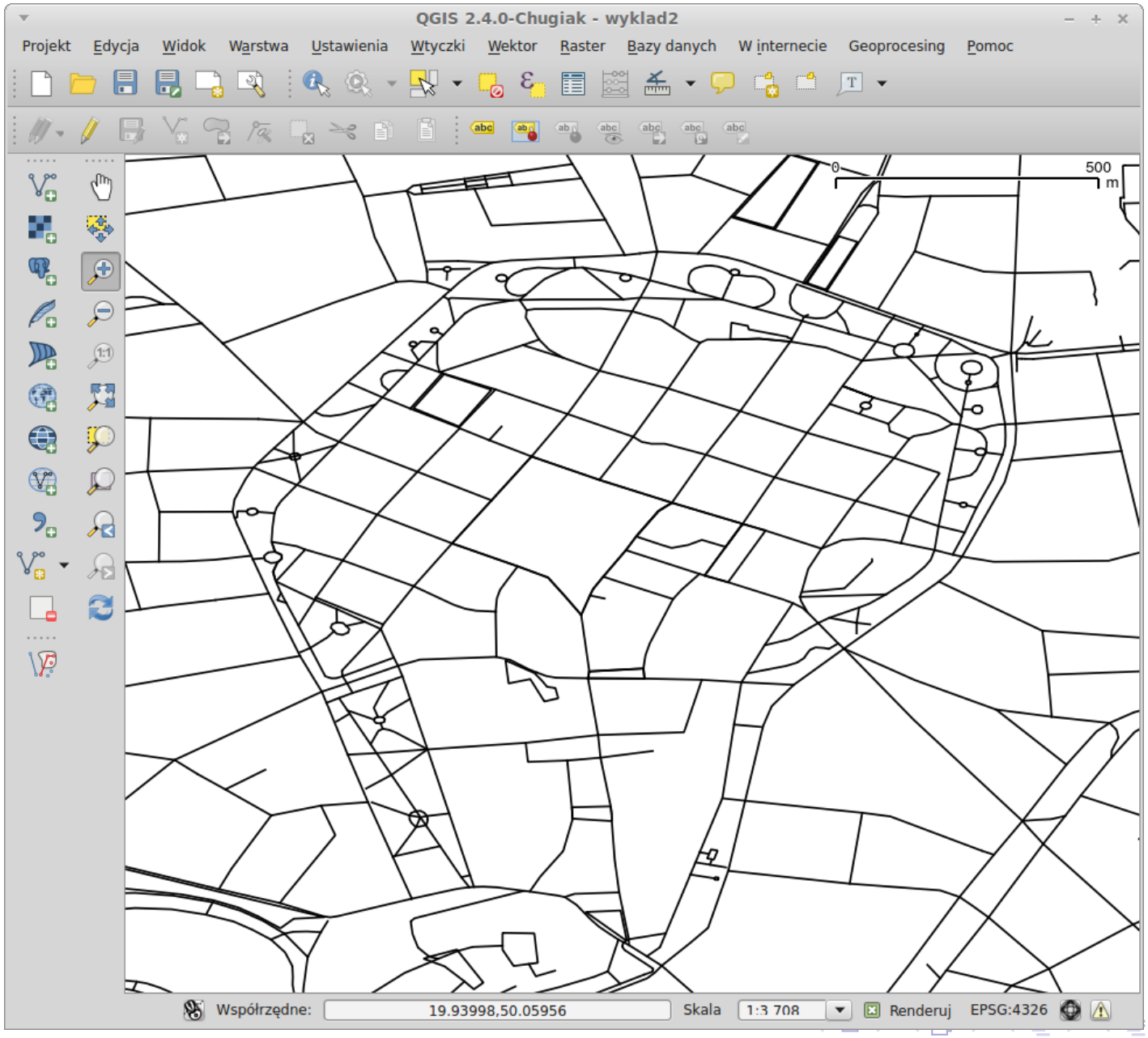
To change CRS in QGIS

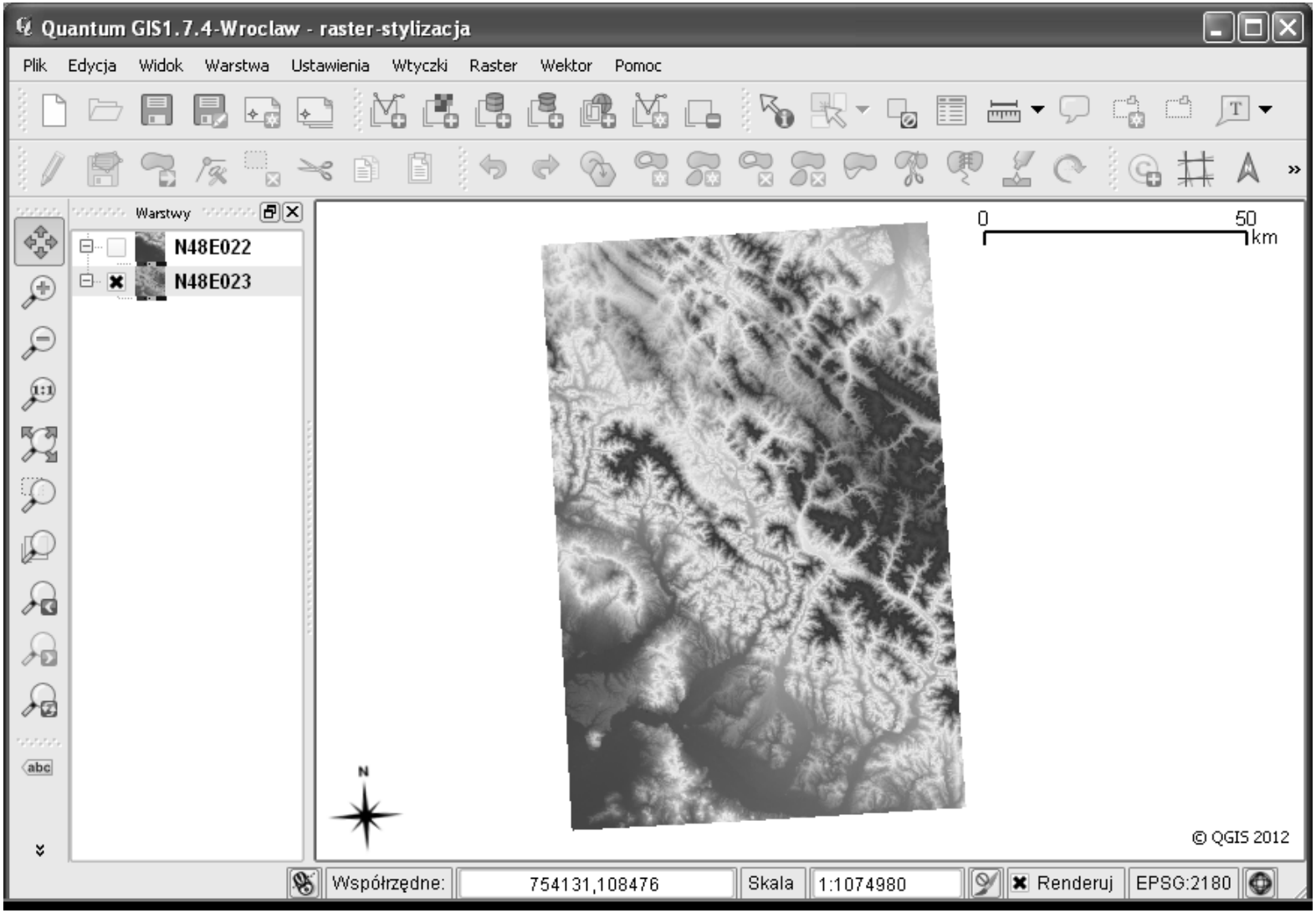
- Load a layer
- Layer : Save as .. OR Export : Save Features as ..
- Change CRS

How to recognize CRS – Sample 1



How to recognize CRS – Sample 2



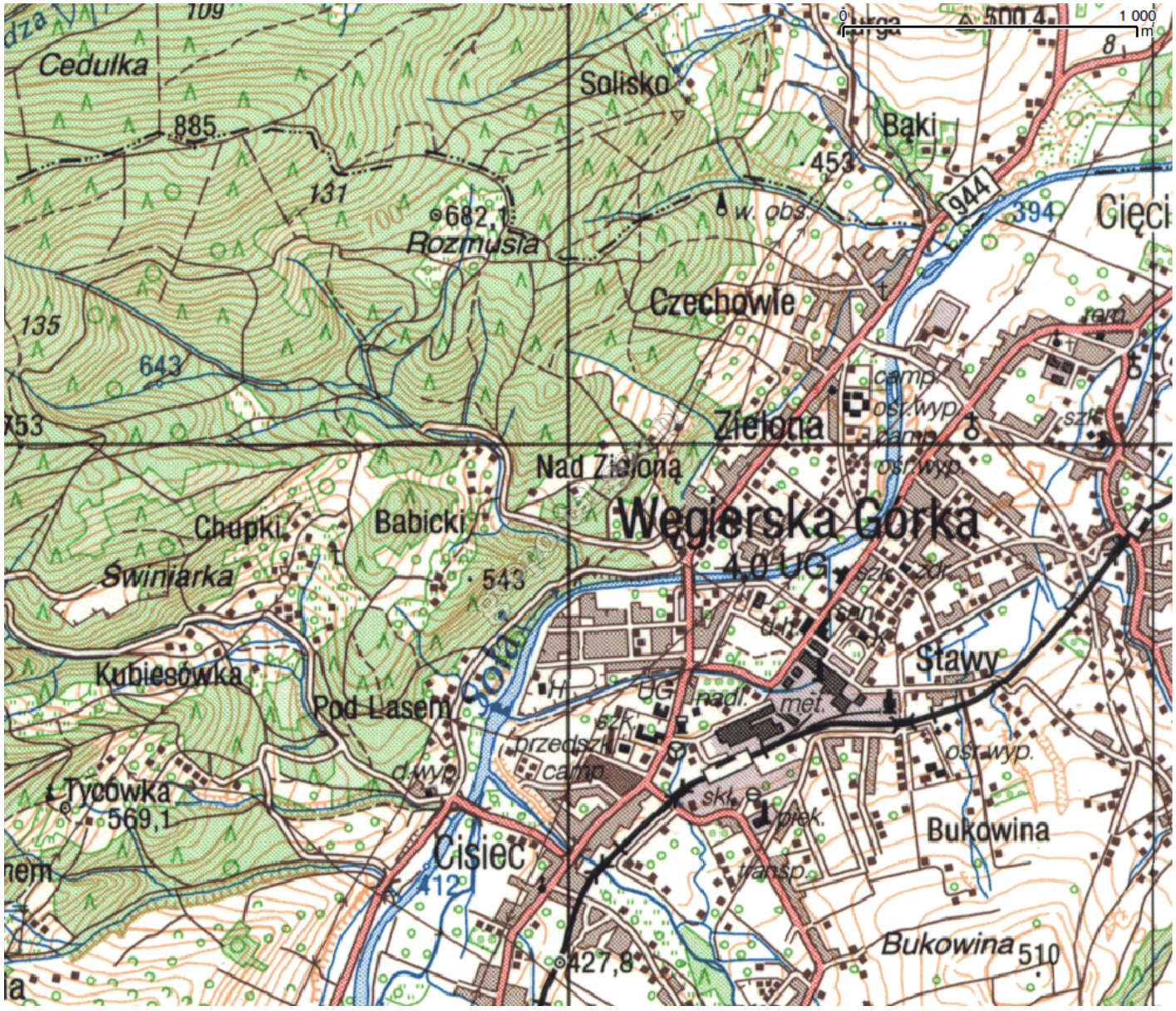

Quantum GIS1.7.4-Wroclaw - raster-stylizacja
Plik
Edycja
Widok
Warstwa
Ustawienia
Wtyczki
Raster
Wektor
Pomoc
Warstwy
N48E022
N48E023
0
50
km
N
© QGIS 2012
Współrzędne:
754131,108476
Skala
1:1074980
Renderuj
EPSG:2180

Data models

What is a map?

A simplification of a complex world at a certain scale.

source: geoportal.gov.pl

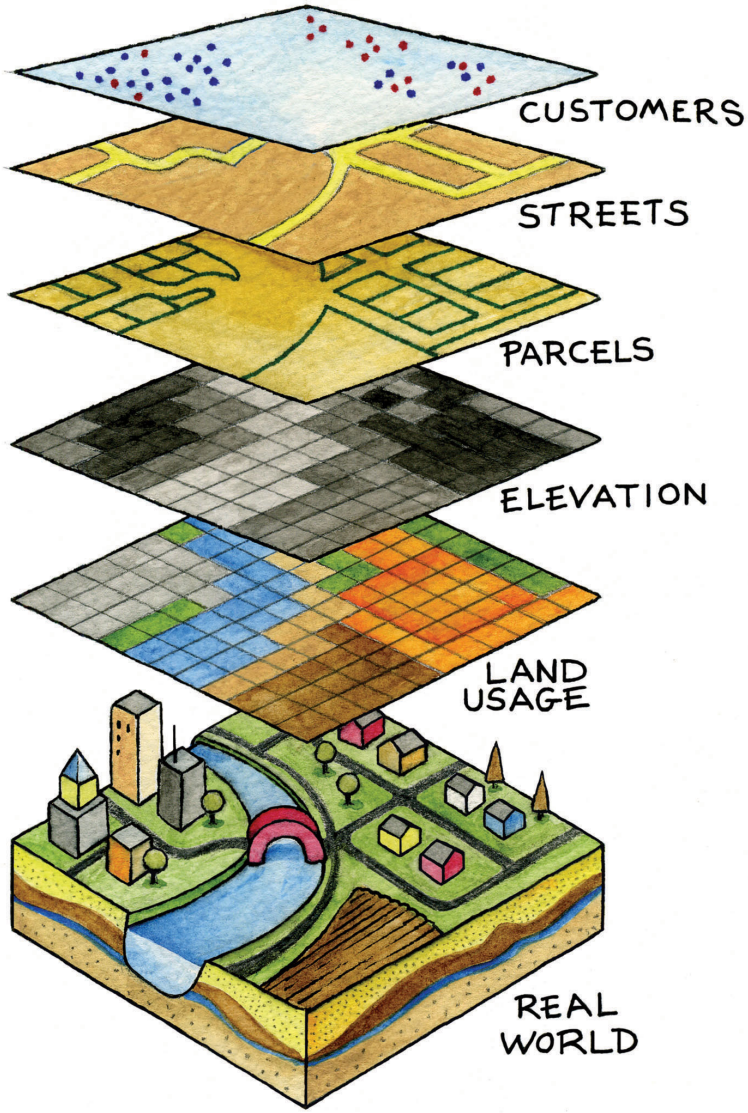


source: geoportal.gov.pl

How to save spatial data

Decomposition

Division of real-world entities (roads, buildings, landuse) into uniform themes (layers).



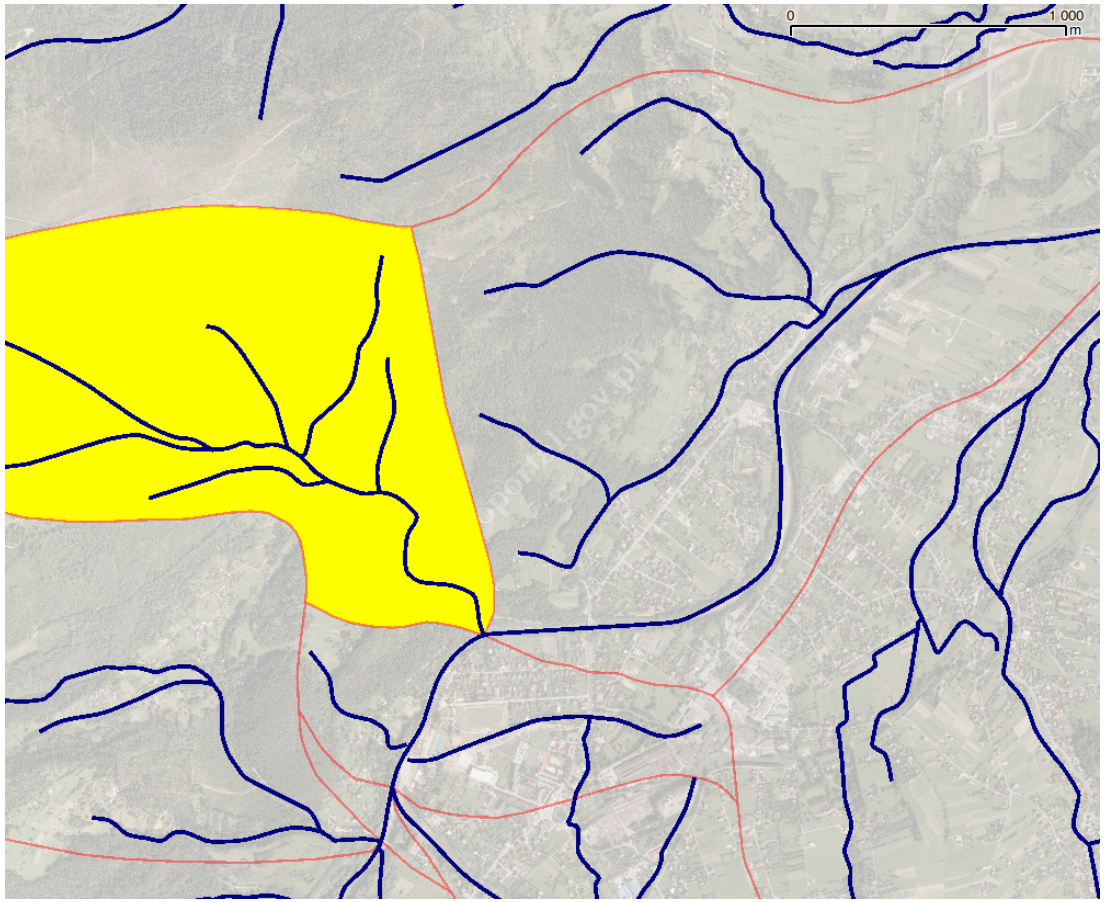
source: www.kenvisiontechniks.com

Vector representation

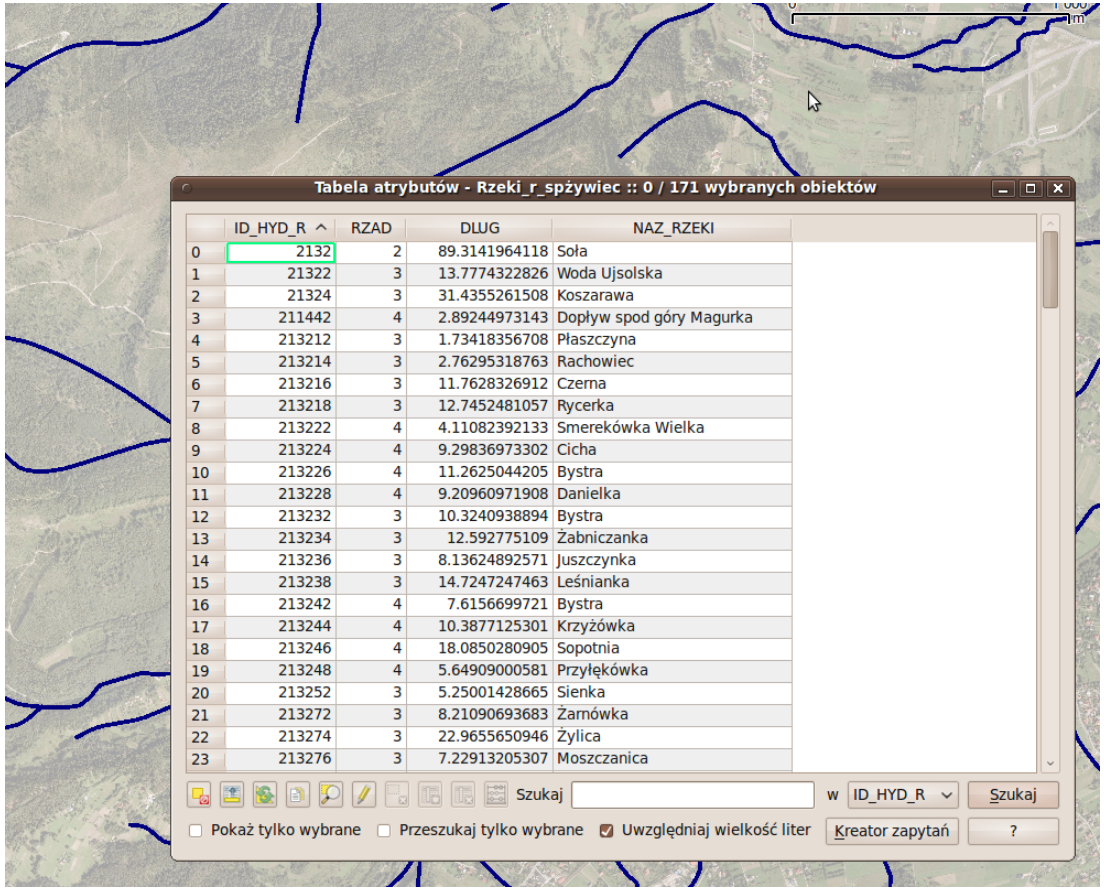
Basic vector types:

- point
- line
- polygon

Vector representation

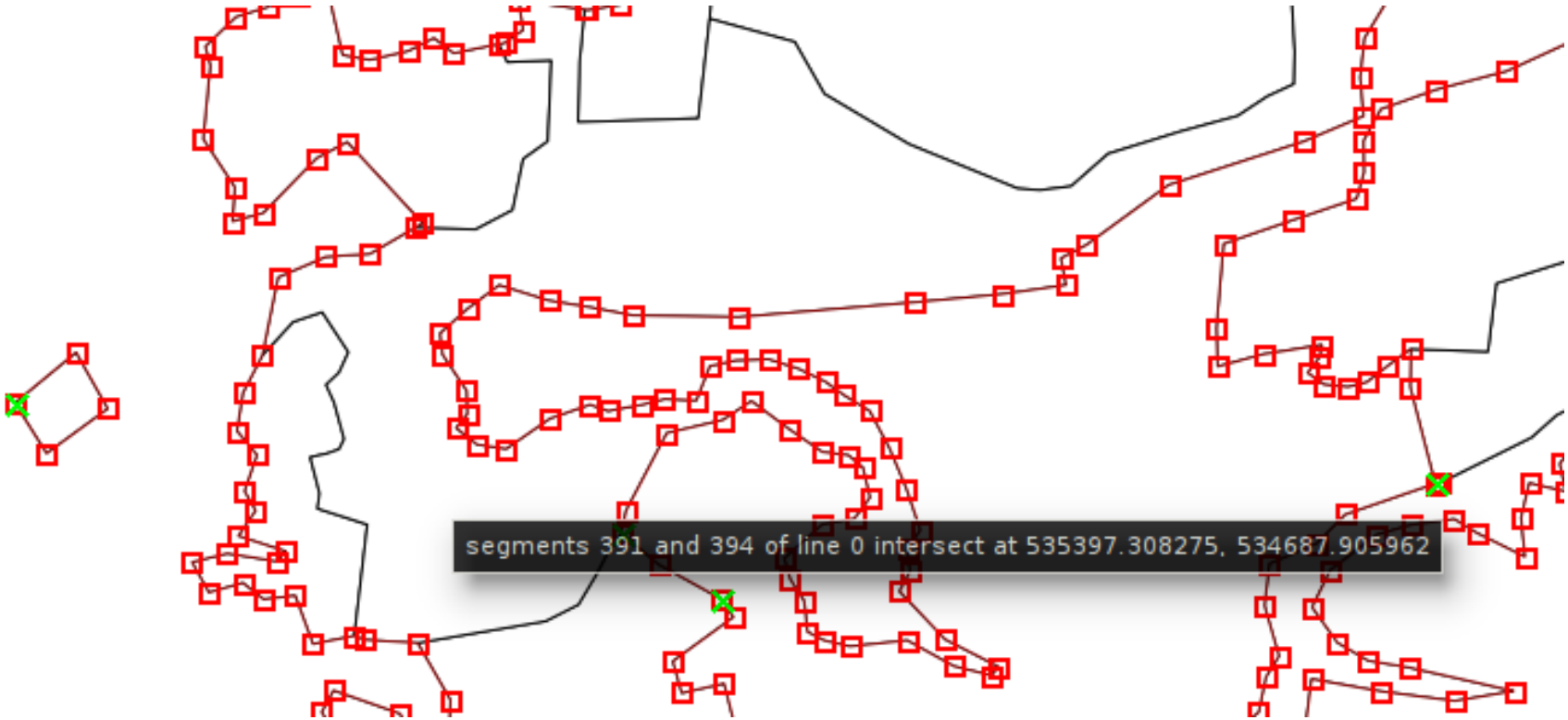


Vector data model



	ID_HYD_R	RZAD	DLUG	NAZ_RZEKI
0	2132	2	89.3141964118	Soła
1	21322	3	13.7774322826	Woda Ujsolska
2	21324	3	31.4355261508	Koszarawa
3	211442	4	2.89244973143	Dopływ spod góry Magurka
4	213212	3	1.73418356708	Płaszczyna
5	213214	3	2.76295318763	Rachowiec
6	213216	3	11.7628326912	Czerna
7	213218	3	12.7452481057	Rycerka
8	213222	4	4.11082392133	Smerekówka Wielka
9	213224	4	9.29836973302	Cicha
10	213226	4	11.2625044205	Bystra
11	213228	4	9.20960971908	Danielka
12	213232	3	10.3240938894	Bystra
13	213234	3	12.592775109	Żabniczanka
14	213236	3	8.13624892571	Juszczynka
15	213238	3	14.7247247463	Leśnianka
16	213242	4	7.6156699721	Bystra
17	213244	4	10.3877125301	Krzyżówka
18	213246	4	18.0850280905	Sopotnia
19	213248	4	5.64909000581	Przyłękówka
20	213252	3	5.25001428665	Sienka
21	213272	3	8.21090693683	Żarnówka
22	213274	3	22.9655650946	Żylica
23	213276	3	7.22913205307	Moszczanica

Topology


segments 391 and 394 of line 0 intersect at 535397.308275, 534687.905962

Raster representation

source: geoportal.gov.pl

Raster representation

source: geoportal.gov.pl

Vector data model

Shapefile

Files for one layer:

- **.shp** – geometry saved in binary format,
- .dbf – attribute table in dBase format,
- .shx – index file,
- .prj – coordinate reference system information,
- ...

Shapefile limitations

- No topology.
- One layer – one type.
- File size limit to 2 GB (.shp and .dbf).
- dBase limitations:
  - attribute name limit to 10 characters,
  - max. 255 attributes.

GDAL/OGR

Library for spatial data handling (read, write, conversion).

GDAL/OGR

Raster data model

What is a raster/bitmap

Graphical resolution:
screen 72-100 ppi (*pixels per inch*)
printer 300-1200 dpi (*dots per ich*)

Spatial resolution (Landsat 8):
15m – channel 8 (panchromatic)
30m – channel 1-7, 9 (multispectral: visible, IR)
100m – channel 10-11 (thermal IR)

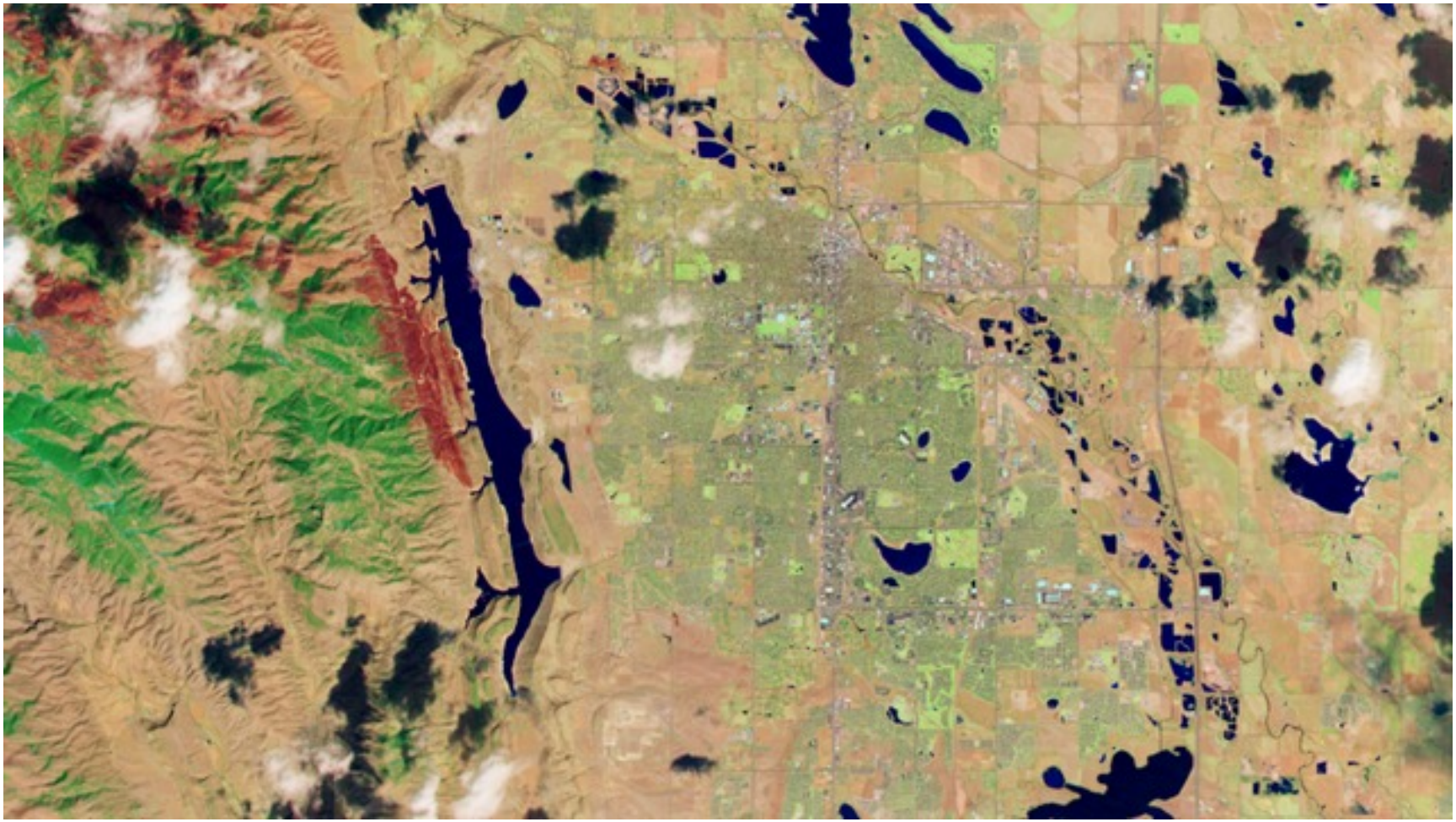
Colour is secondary

Landsat 8, Operational Land Imager (OLI), year 2013
Fort Collins, Colorado, USA

Image 1:
Natural colorus: channel 2 (blue), channel 3 (green), channel 4 (red).

Image 2:
Channel 3 [G] (blue), channel 5 [Near IR a) b)] (green), channel 7 [Shortwave IR a)] (red).

source: USGS/NASA Earth Observatory

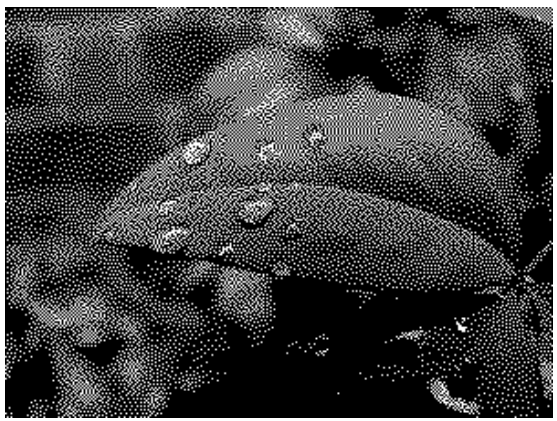


source: USGS/NASA Earth Observatory

Colour depth

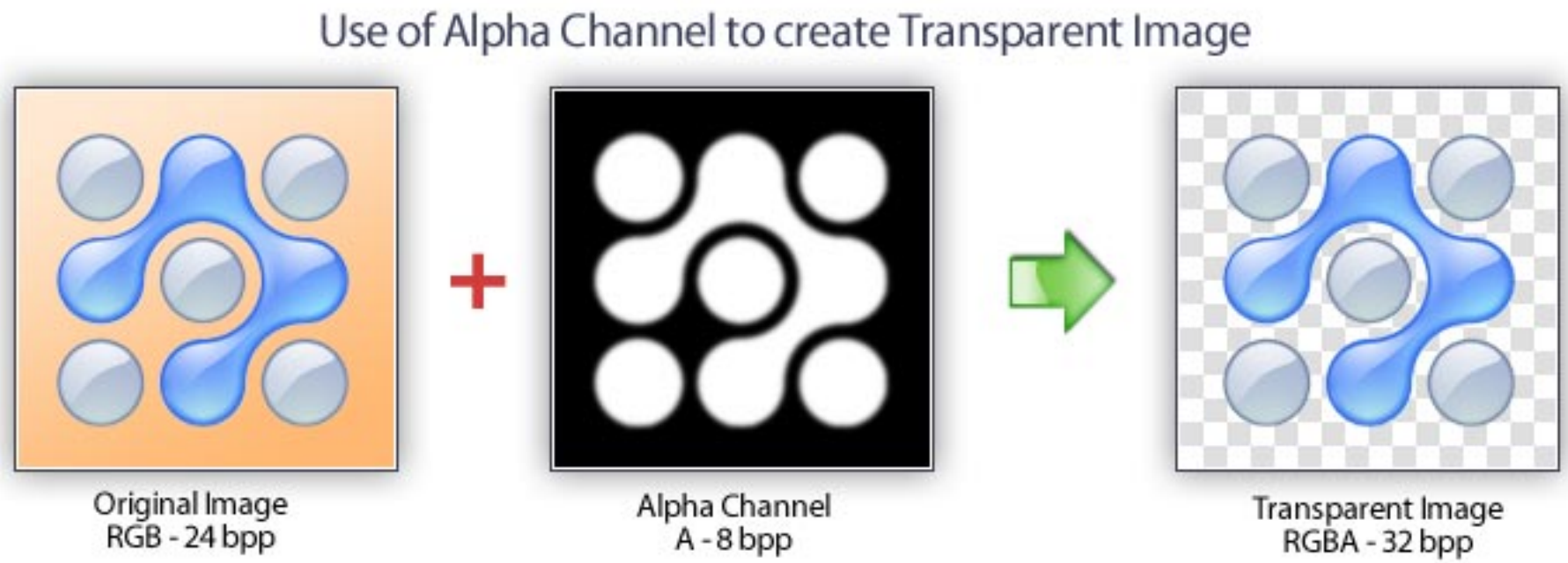
Number of bits „n”.
2^n

1-bit – 2 colors (monochromatic)
8-bit – 256 colors
24-bit – 16 777 216 colors (truecolor)



author: Thegreenj

Alpha channel (transparency) – RGBA

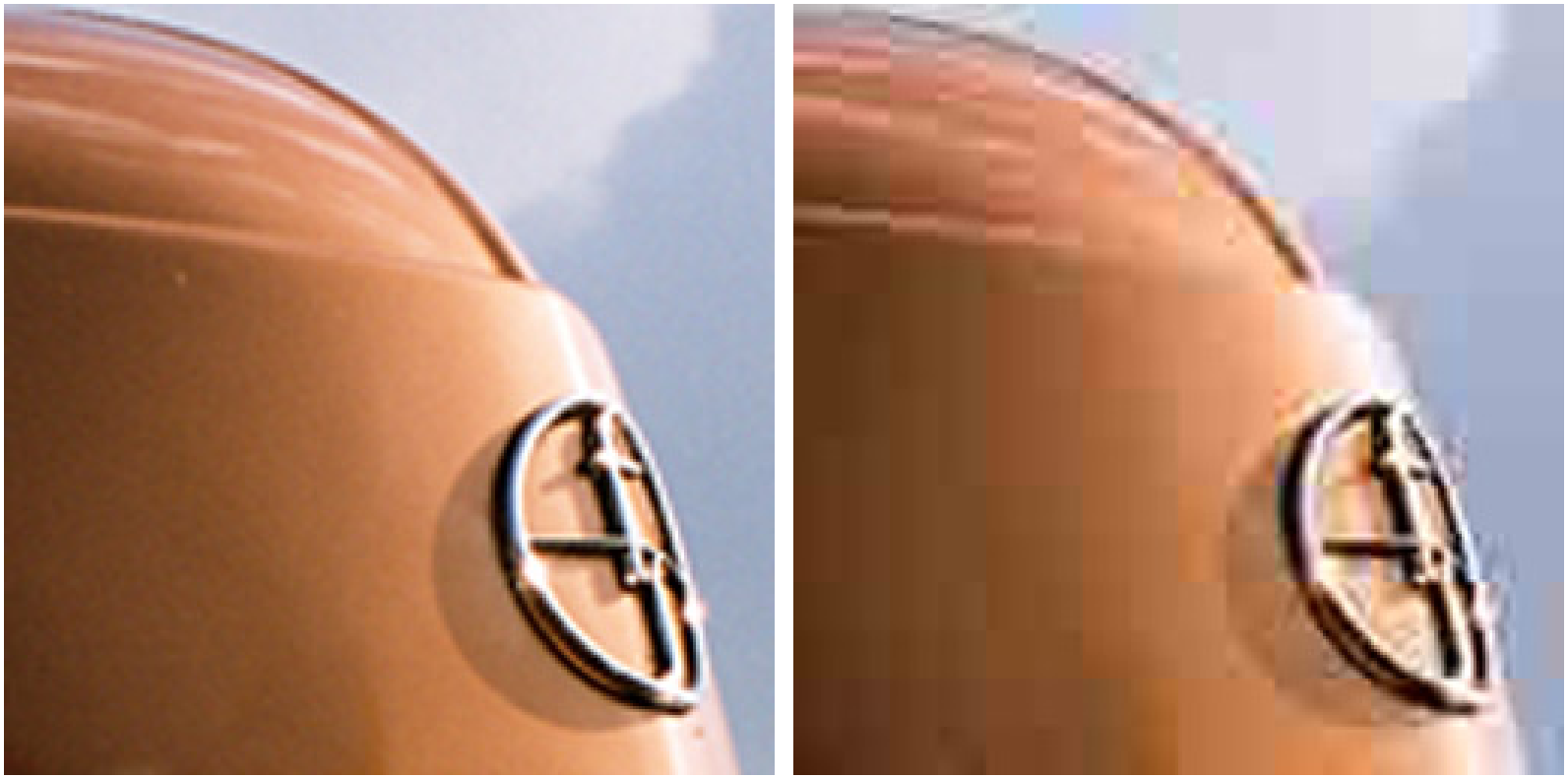


source: Axialis software

File size

1 000 x 1 000 px
1 bit: 1 000 000 bits = 125 kiB
32 bits: 32 000 000 bits = 4 MiB

Artefacts; compression



author: Blueshade

GIF

Graphics Interchange Format
animations
limited number of colours
alpha channel

JPEG

Joint Photographic Experts Group

no alpha channel

advanced compression [23:1; 144:1]

author: Toytoy

TIFF

Tagged Image File Format
compression
great colour depth possible
version with georeference **GeoTIFF**

PNG

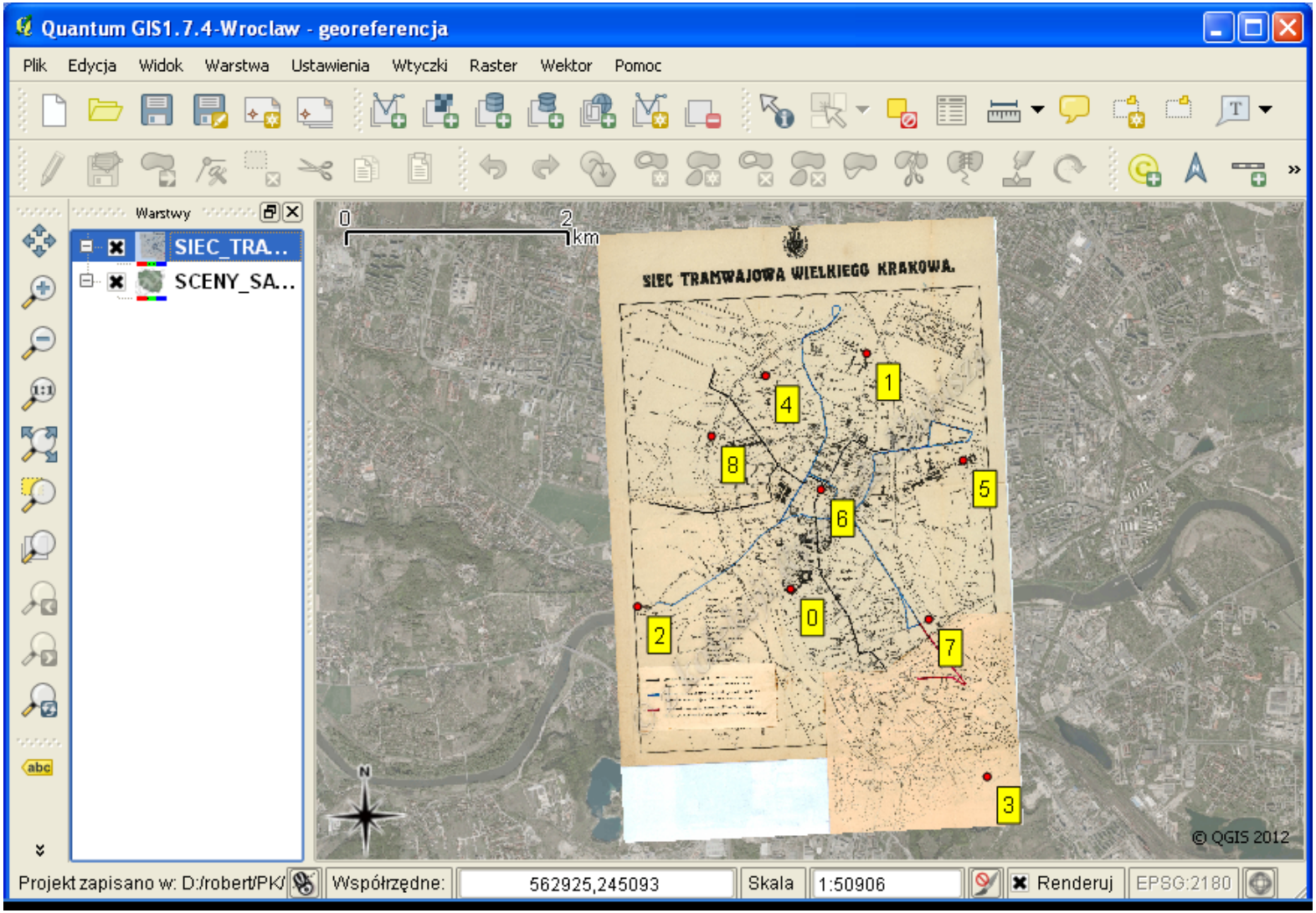
Portable Network Graphics

compression

great colour depth possible

alpha channel

Georeference; world files



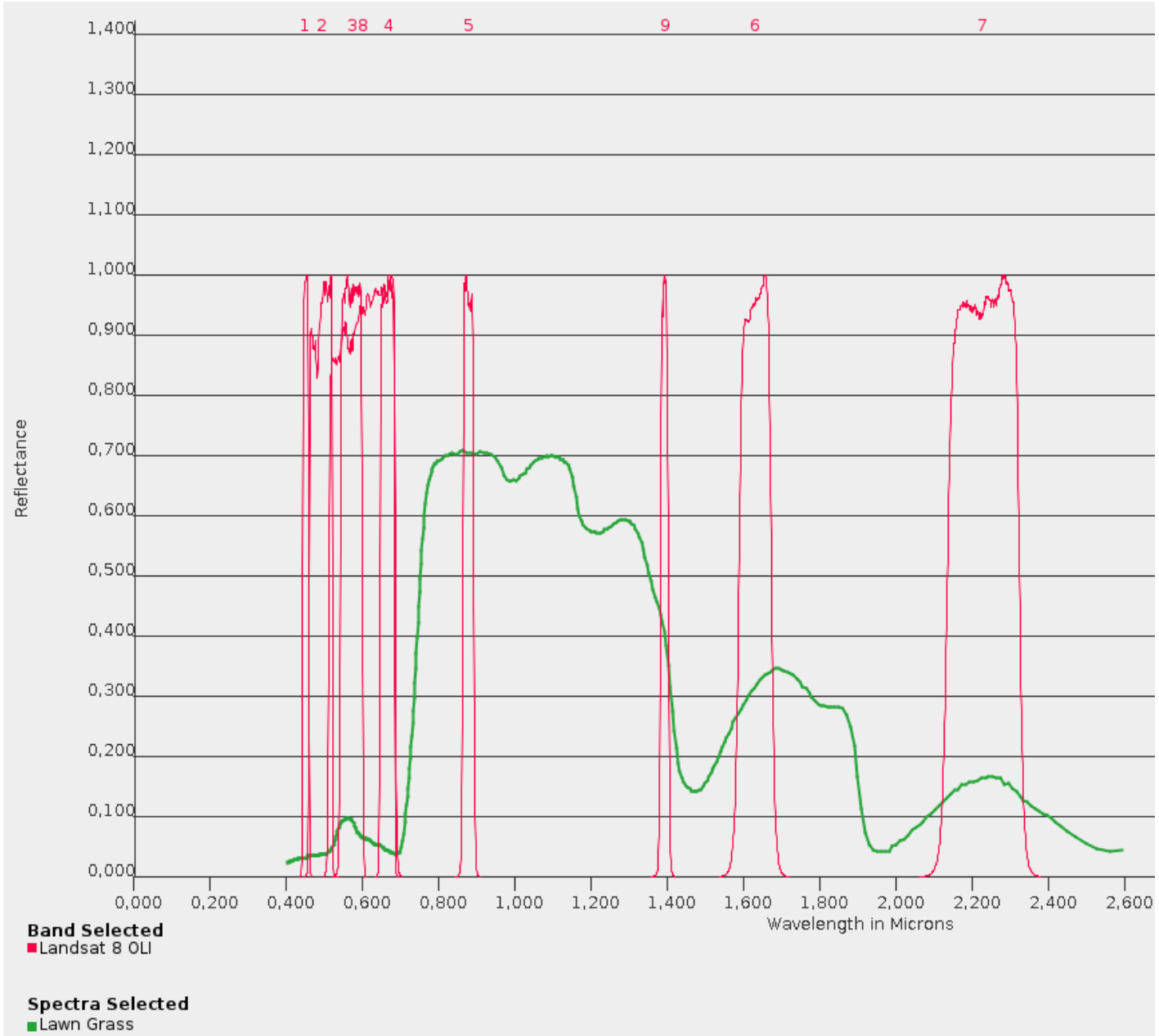
mapa.png $\longmapsto$ mapa.png + mapa.pngw

Raster layer types

Raster layer types

Continuous date (satellite data, e.g. temperature – Landsat 8)
Discrete data [categories, classes] (products – Corine Land Cover)

Satellite images – Landsat 8

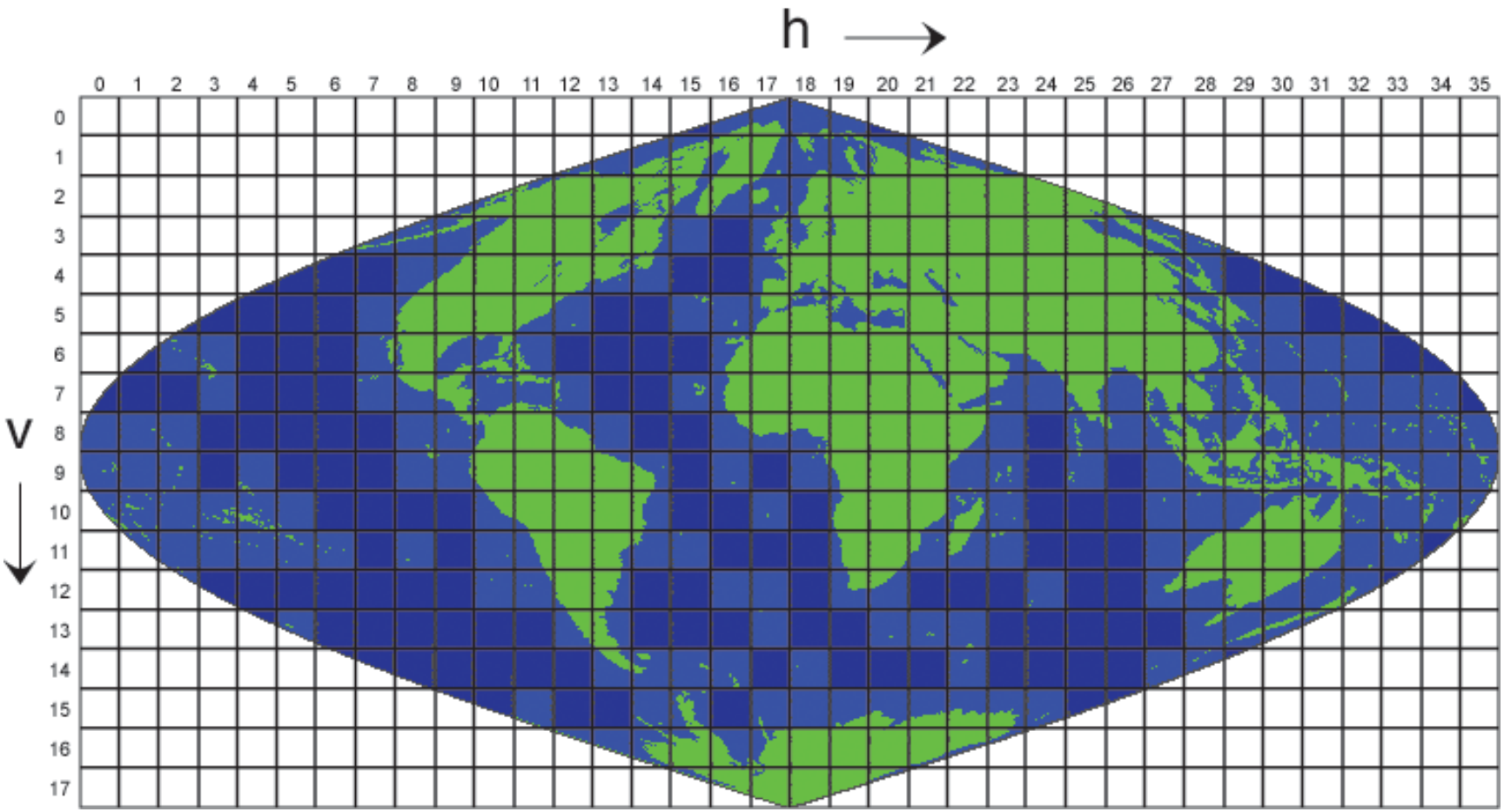


Satellite images – MODIS

Moderate Resolution Imaging Spectroradiometer

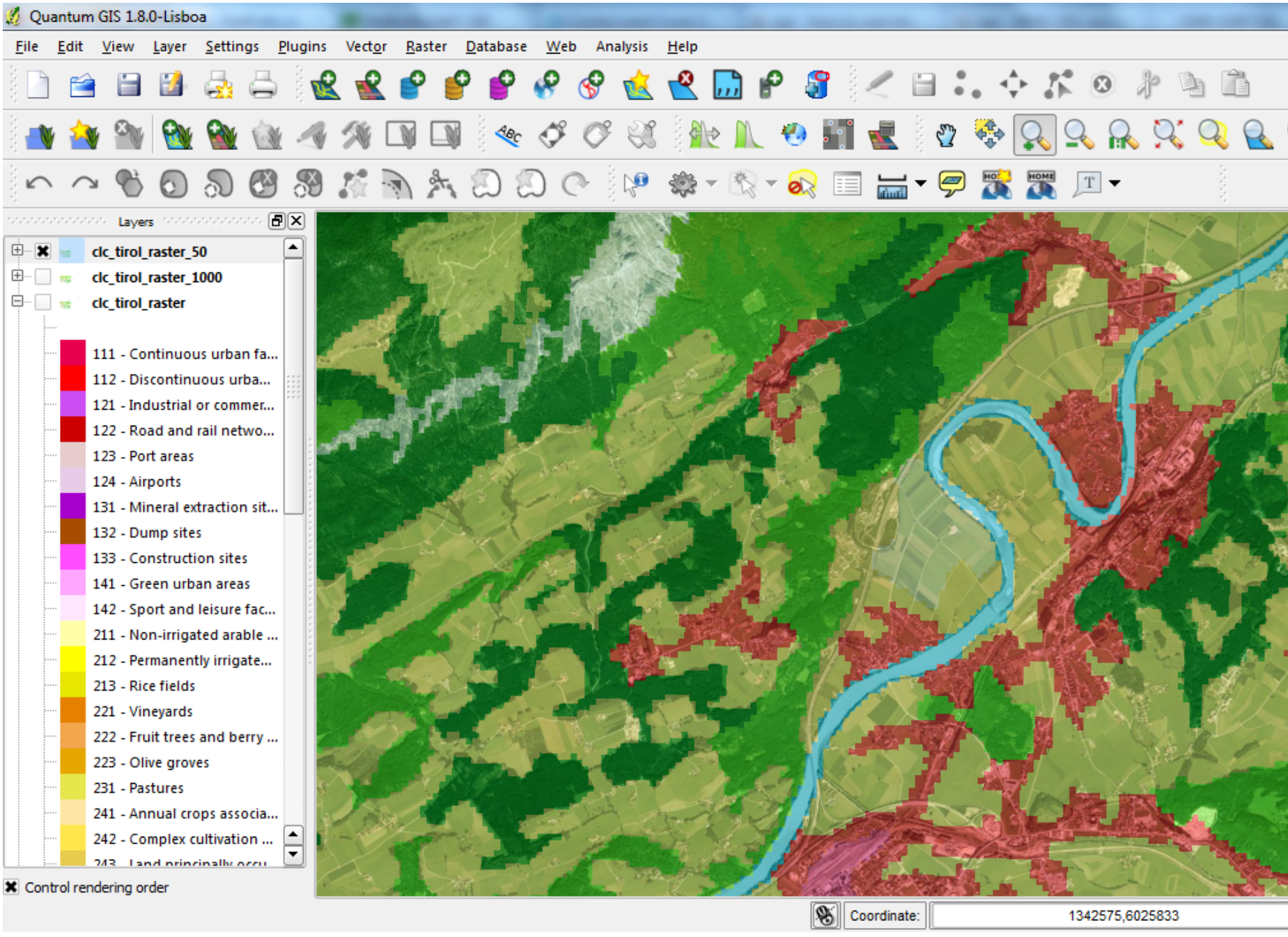
Satellites Terra and Aqua.
36 channels.
Spatial resolution: 250-1000m
Temporal resolution: 12 hours.
Several products.

Satellite images – MODIS tiles



CORINE Land Cover (CLC)

44 hierarchical land cover classes.
European Space Agency.
CLC1990, CLC2000, CLC2006, CLC2012, CLC2018
http://land.copernicus.eu/pan-european/corine-land-cover
raster 100m, 250m
wektor


Quantum GIS 1.8.0-Lisboa
File Edit View Layer Settings Plugins Vector Raster Database Web Analysis Help
Layers
clc_tirol_raster_50
clc_tirol_raster_1000
clc_tirol_raster
111 - Continuous urban fa...
112 - Discontinuous urba...
121 - Industrial or commer...
122 - Road and rail netwo...
123 - Port areas
124 - Airports
131 - Mineral extraction sit...
132 - Dump sites
133 - Construction sites
141 - Green urban areas
142 - Sport and leisure fac...
211 - Non-irrigated arable ...
212 - Permanently irrigate...
213 - Rice fields
221 - Vineyards
222 - Fruit trees and berry ...
223 - Olive groves
231 - Pastures
241 - Annual crops associa...
242 - Complex cultivation ...
Control rendering order
Coordinate:
1342575,6025833

Vector vs. raster

Vector vs. raster: feature location

VECTOR	RASTER
saved in geometry	saved in metadata

Vector vs. raster: spatial extent

VECTOR	RASTER
partial	complete

Vector vs. raster: location accuracy

VECTOR	RASTER
high	depends on resolution

Vector vs. raster: features representation

VECTOR	RASTER
easy	hard

Vector vs. raster: storage structure (human perspective)

VECTOR	RASTER
easy, hard (with topology)	easy

Applies only to text (non-binary) formats.

Vector vs. raster: data processing

VECTOR	RASTER
difficult, time consuming	easy and fast

Vector vs. raster: data sources

VECTOR	RASTER
CAD, vectorization	remote sensing

Vector vs. raster

Raster is faster,
but vector is corrector.

Cracow University
of Technology

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