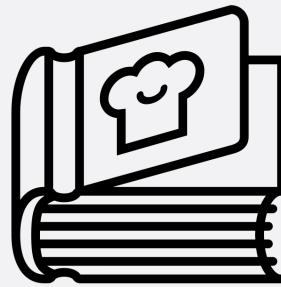


Geographical Information Systems concepts

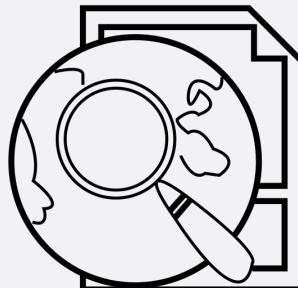
Maurizio Napolitano
[\(napolitano@fbk.eu\)](mailto:napolitano@fbk.eu)

the GIS cookbook



Projections

Data Model



Distribution protocols

Spatial Analysis

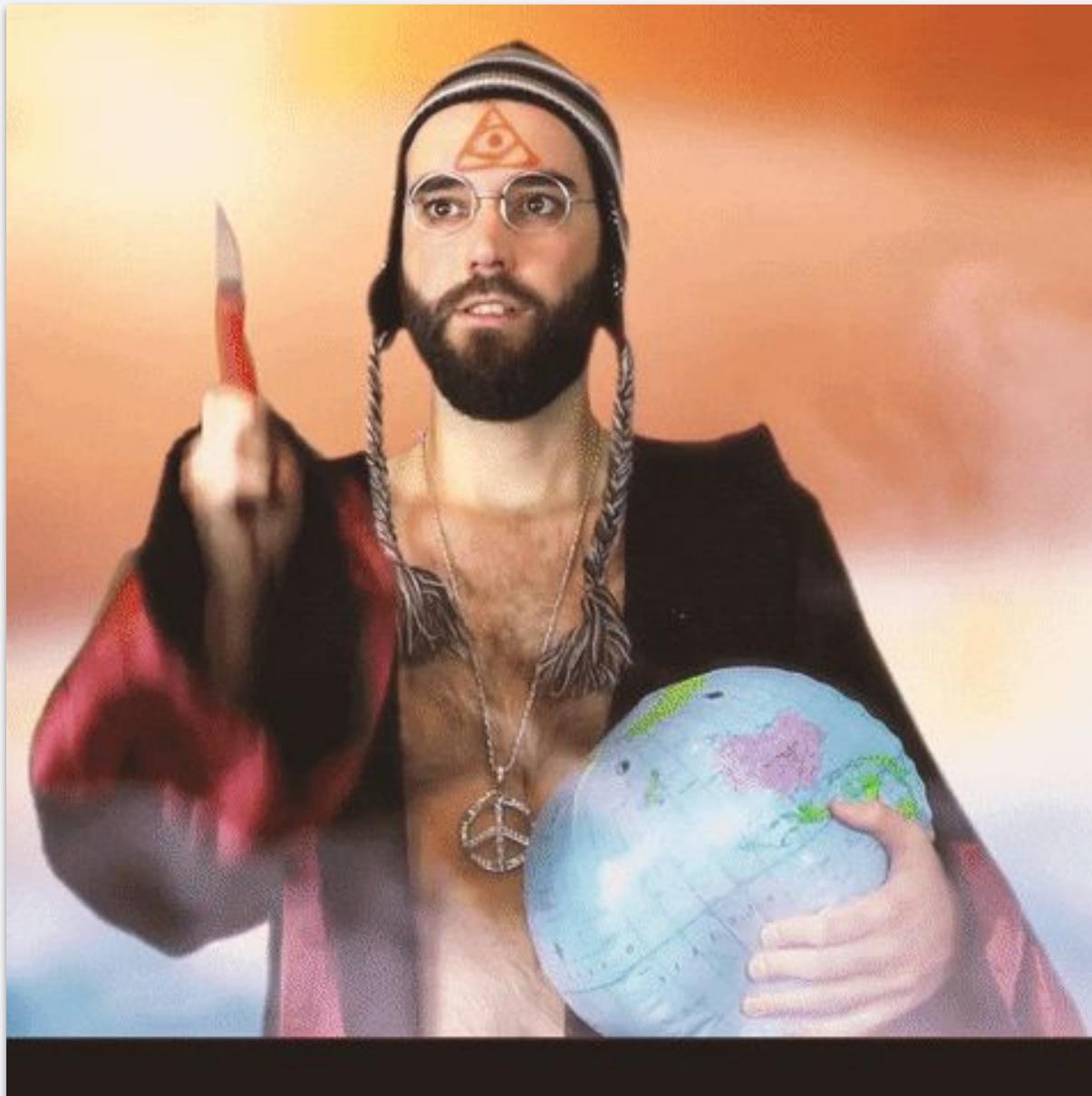


Rendering

Are you a flat earth-er ?



but in many cases we need to make it flat





MERCATOR



YOU'RE NOT REALLY INTO MAPS.

VAN DER GRIJNEN



YOU'RE NOT A COMPLICATED PERSON. YOU LOVE THE MERCATOR PROJECTION; YOU JUST WISH IT WEREN'T SQUARE. THE EARTH'S NOT A SQUARE, IT'S A CIRCLE. YOU LIKE CIRCLES. TODAY IS GONNA BE A GOOD DAY!

PEIRCE QUINCUNCIAL



YOU THINK THAT WHEN WE LOOK AT A MAP, WHAT WE REALLY SEE IS OURSELVES. AFTER YOU FIRST SAW INCEPTION, YOU SAT SILENT IN THE THEATER FOR SIX HOURS. IT BREAKS YOU OUT TO REALIZE THAT EVERYONE AROUND YOU HAS A SKELETON INSIDE THEM. YOU HAVE REALLY LOOKED AT YOUR HANDS.

WATERMAN BUTTERFLY



REALLY? YOU KNOW THE WATERMAN? HAVE YOU SEEN THE 1909 CAHILL MAP IT'S BASED ON... YOU HAVE A FRAMED REPRODUCTION AT HOME?! WHOA... LISTEN, FORGET THESE QUESTIONS. ARE YOU DOING ANYTHING TONIGHT?

A GLOBE!



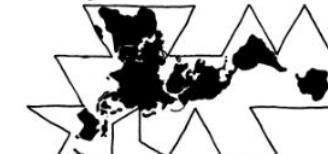
YES, YOU'RE VERY CLEVER.

ROBINSON



YOU HAVE A COMFORTABLE PAIR OF RUNNING SHOES THAT YOU WEAR EVERYWHERE. YOU LIKE COFFEE AND ENJOY THE BEATLES. YOU THINK THE ROBINSON IS THE BEST-LOOKING PROJECTION, HANDS DOWN.

Dymaxion



YOU LIKE ISAAC ASIMOV, XML, AND SHOES WITH TOES. YOU THINK THE SEGWAY GOT A BAD RAP. YOU OWN 3D GOGGLES, WHICH YOU USE TO VIEW ROTATING MODELS OF BETTER 3D GOGGLES. YOU TYPE IN DVORAK.

GOODE HOMOLOSINE



THEY SAY MAPPING THE EARTH ON A 2D SURFACE IS LIKE FLATTENING AN ORANGE PEEL, WHICH SEEMS EASY ENOUGH TO YOU. YOU LIKE EASY SOLUTIONS. YOU THINK WE WOULDN'T HAVE SO MANY PROBLEMS IF WE'D JUST ELECT NORMAL PEOPLE TO CONGRESS INSTEAD OF POLITICIANS. YOU THINK AIRLINES SHOULD JUST BUY FOOD FROM THE RESTAURANTS NEAR THE GATES AND SERVE THAT ON BOARD. YOU CHANGE YOUR CAR'S OIL, BUT SECRETLY WONDER IF YOU REALLY NEED TO.

GALL-PETERS



I HATE YOU.

PLATE CARRÉE (EQUIRECTANGULAR)



YOU THINK THIS ONE IS FINE. YOU LIKE HOW X AND Y MAP TO LATITUDE AND LONGITUDE. THE OTHER PROJECTIONS OVERCOMPLICATE THINGS. YOU WANT ME TO STOP ASKING ABOUT MAPS SO YOU CAN ENJOY DINNER.

WINKEL-TRIPÉL

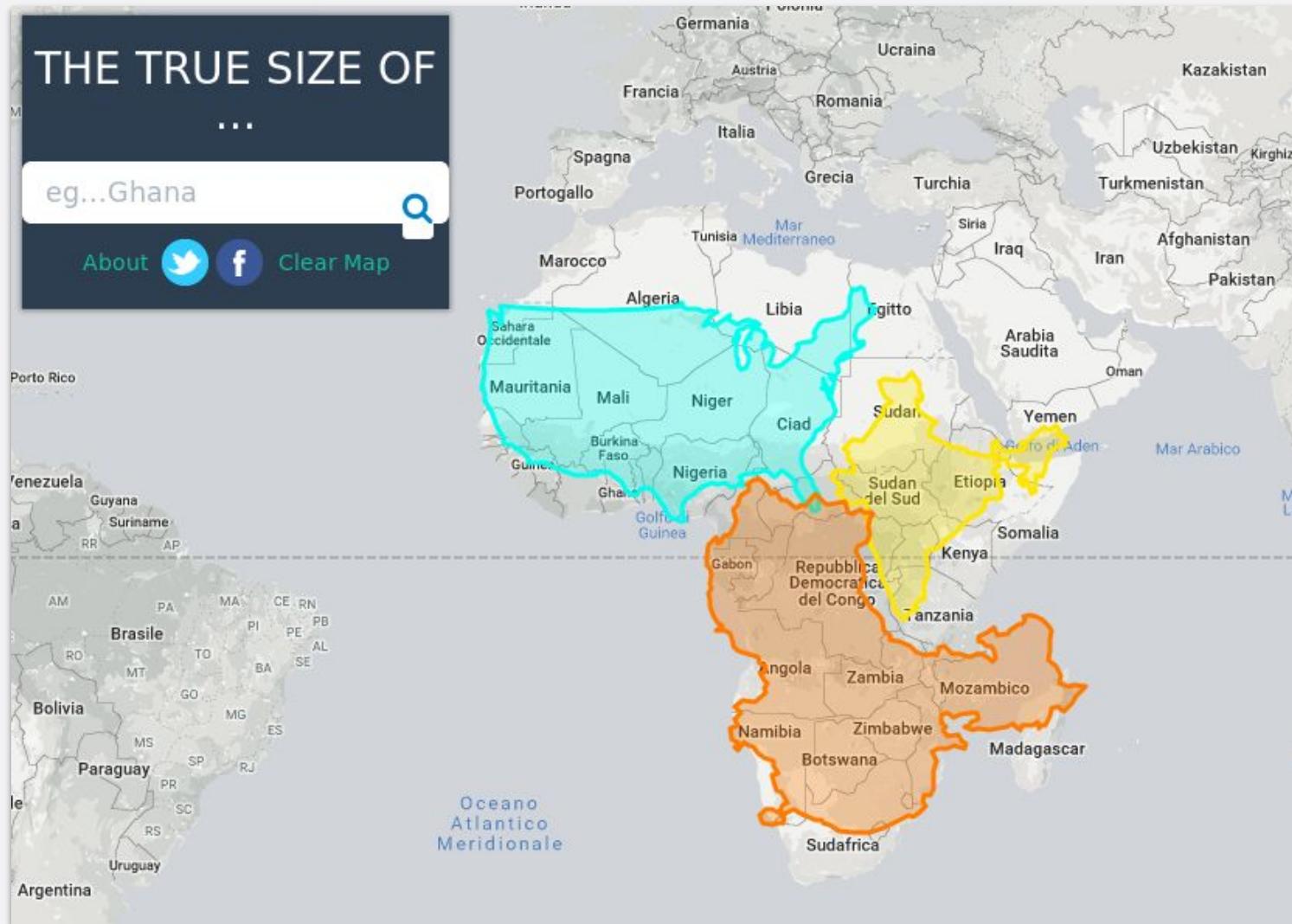


NATIONAL GEOGRAPHIC ADOPTED THE WINKEL-TRIPEL IN 1998, BUT YOU'VE BEEN A WT FAN SINCE LONG BEFORE NAT GEO SHOWED UP. YOU'RE WORRIED IT'S GETTING PLAYED OUT, AND ARE THINKING OF SWITCHING TO THE KAVRAYSIN. YOU ONCE LEFT A PARTY IN DISGUST WHEN A GUEST SHOWED UP WEARING SHOES WITH TOES. YOUR FAVORITE MUSICAL GENRE IS "POST-".

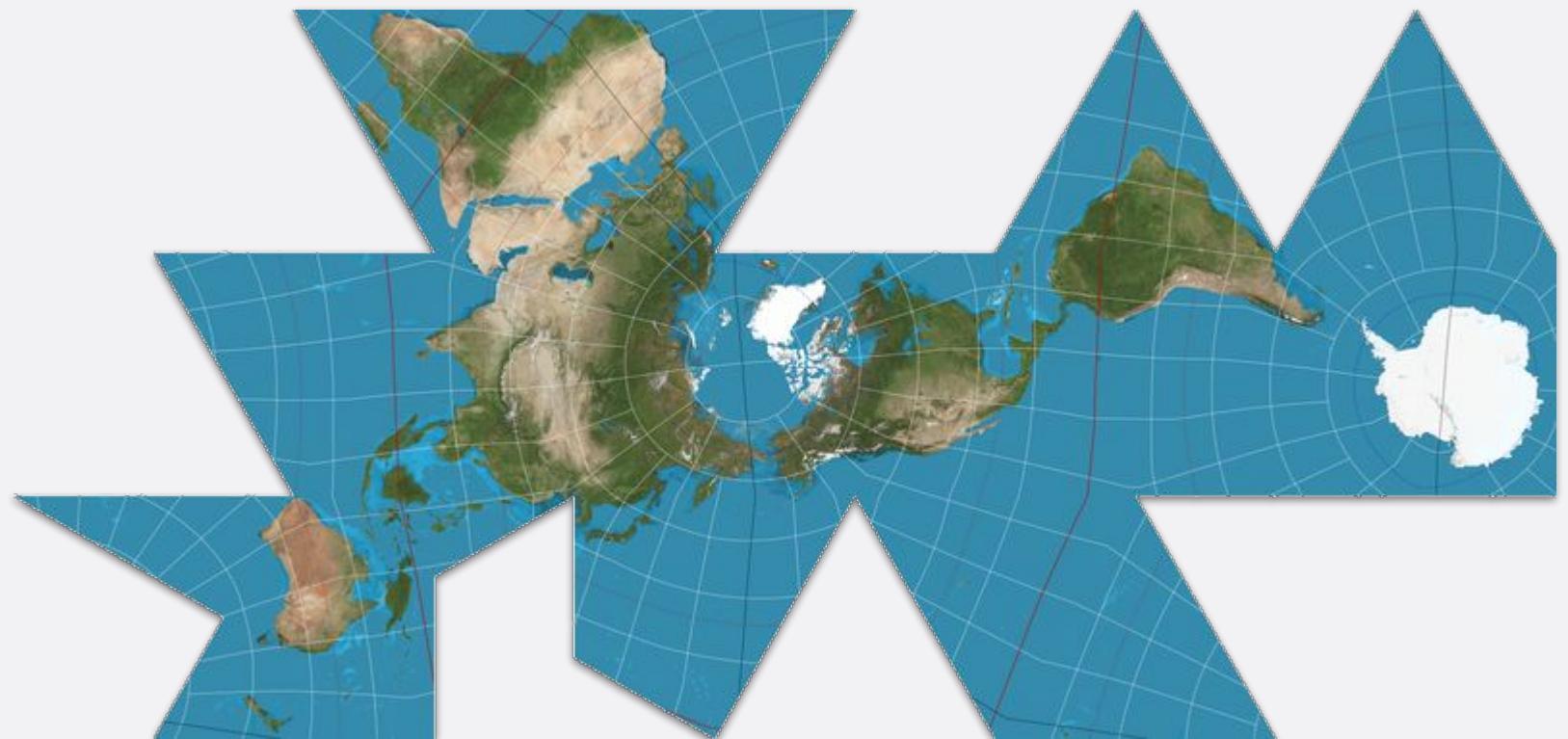
HOBO-DYER



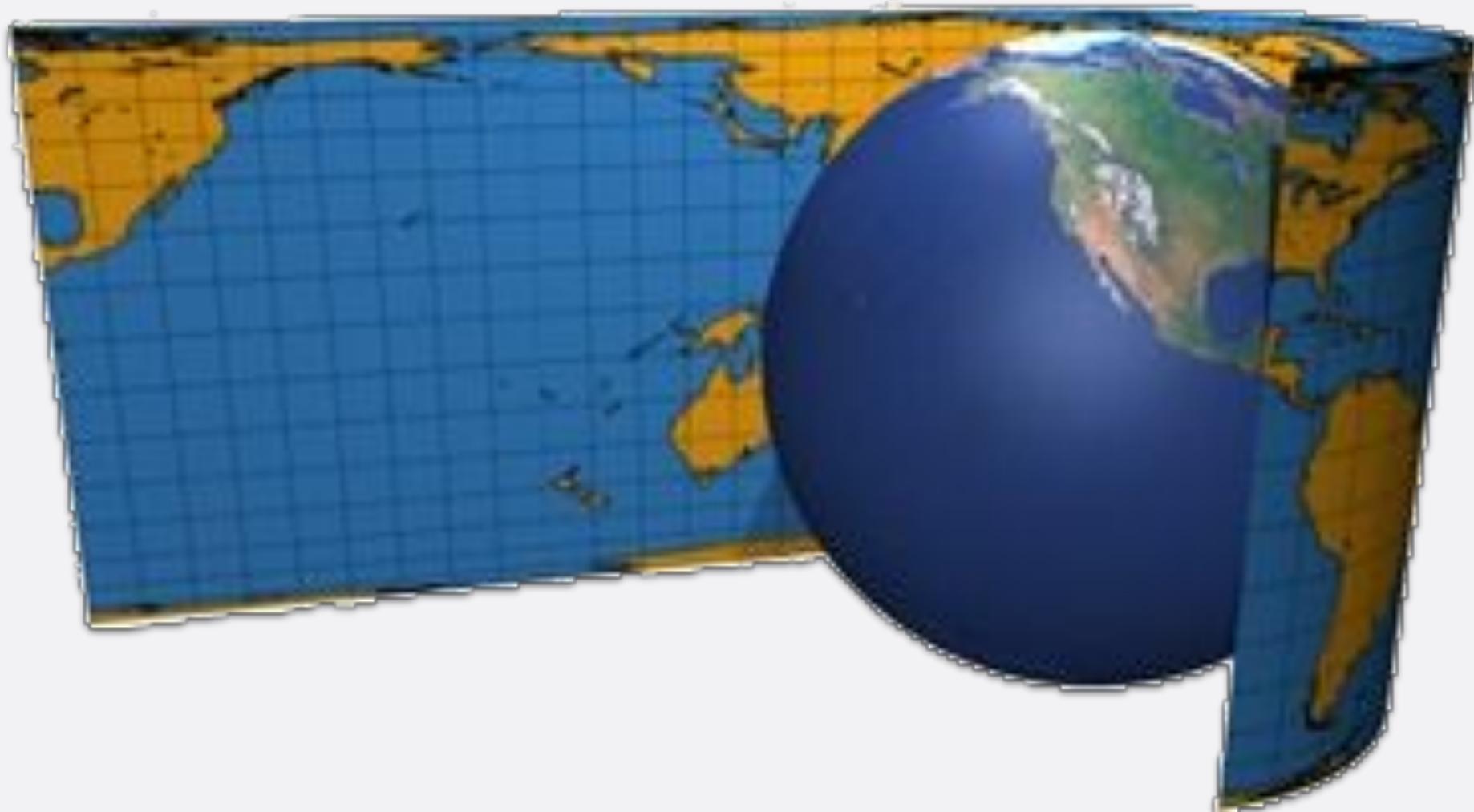
YOU WANT TO AVOID CULTURAL IMPERIALISM, BUT YOU'VE HEARD BAD THINGS ABOUT GALL-PETERS. YOU'RE CONFLICT-AVERSE AND BUY ORGANIC. YOU USE A RECENTLY-INVENTED SET OF GENDER-NEUTRAL PRONOUNS AND THINK THAT WHAT THE WORLD NEEDS IS A REVOLUTION IN CONSCIOUSNESS.



Dymaxion

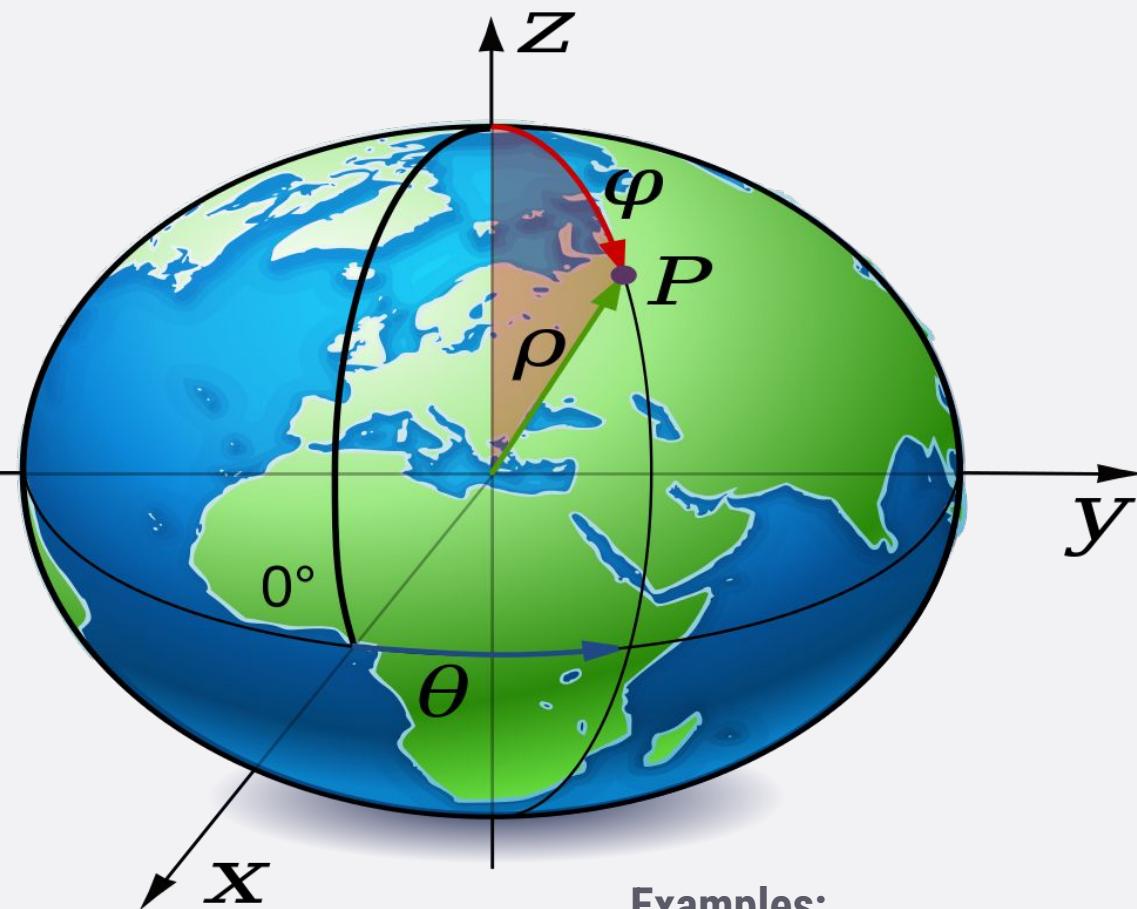


Cylindrical projection

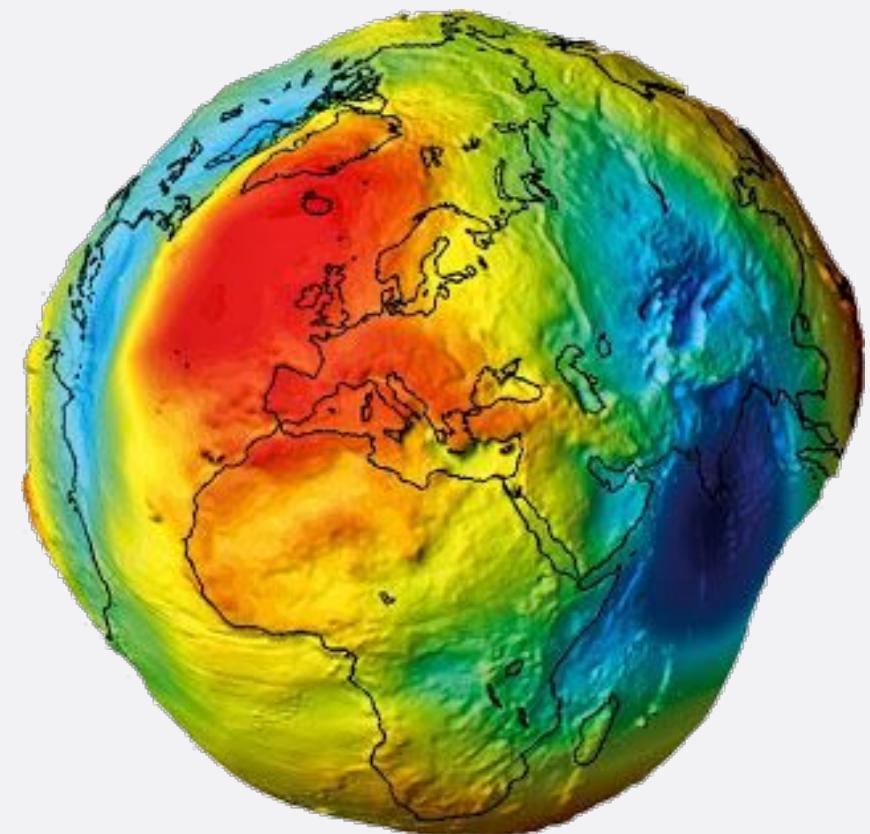


Datum

oblate spheroid



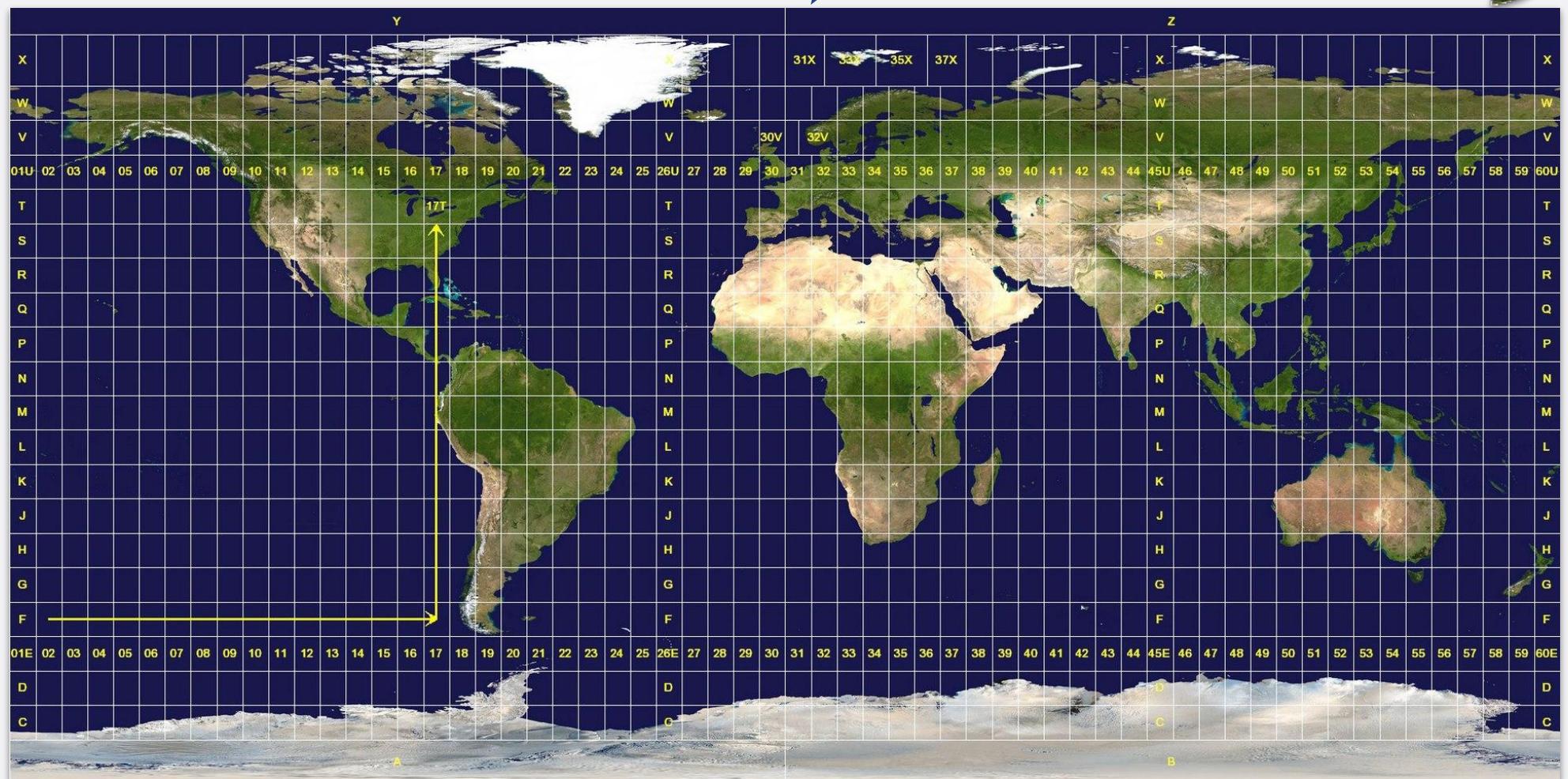
geoid



Examples:

- Rome 40
- European Datum 1950
- European Terrestrial Reference System 1989
- World Geodetic System 1984

Universal Transverse Mercator



The most used for the web

EPSG:4326 - WGS84

- Degree (lat/long)
- WGS84

EPSG: 3857 - Web Mercator

- Meters
- WGS84
- World without polos

former EPSG: 900913 Google
Mercator
(digit version of the word Google)



EPSG???



International
Association
of Oil & Gas
Producers

former
European Petroleum Survey Group

<http://www.epsg.org/>

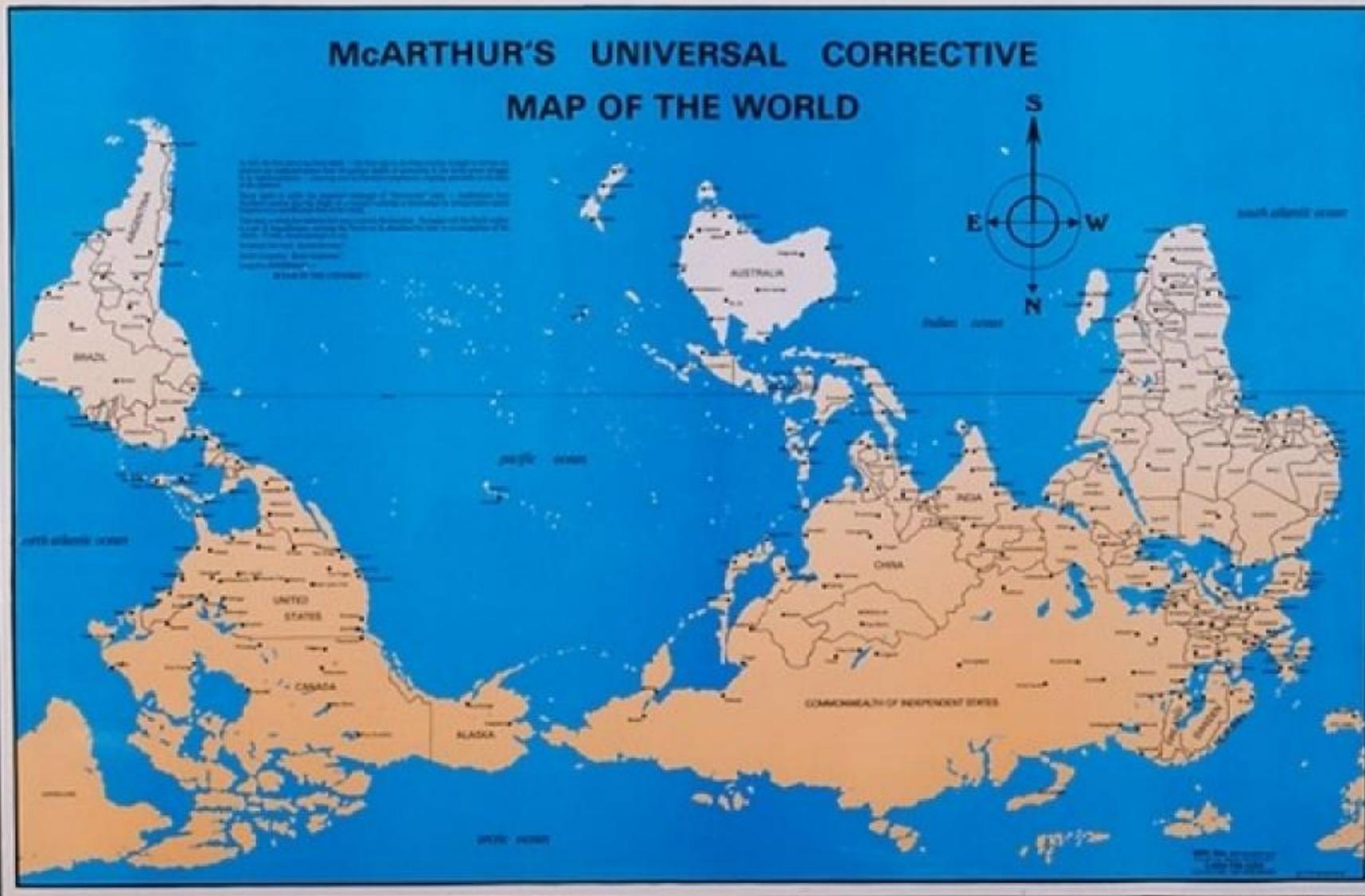


<http://spatialreference.org/>

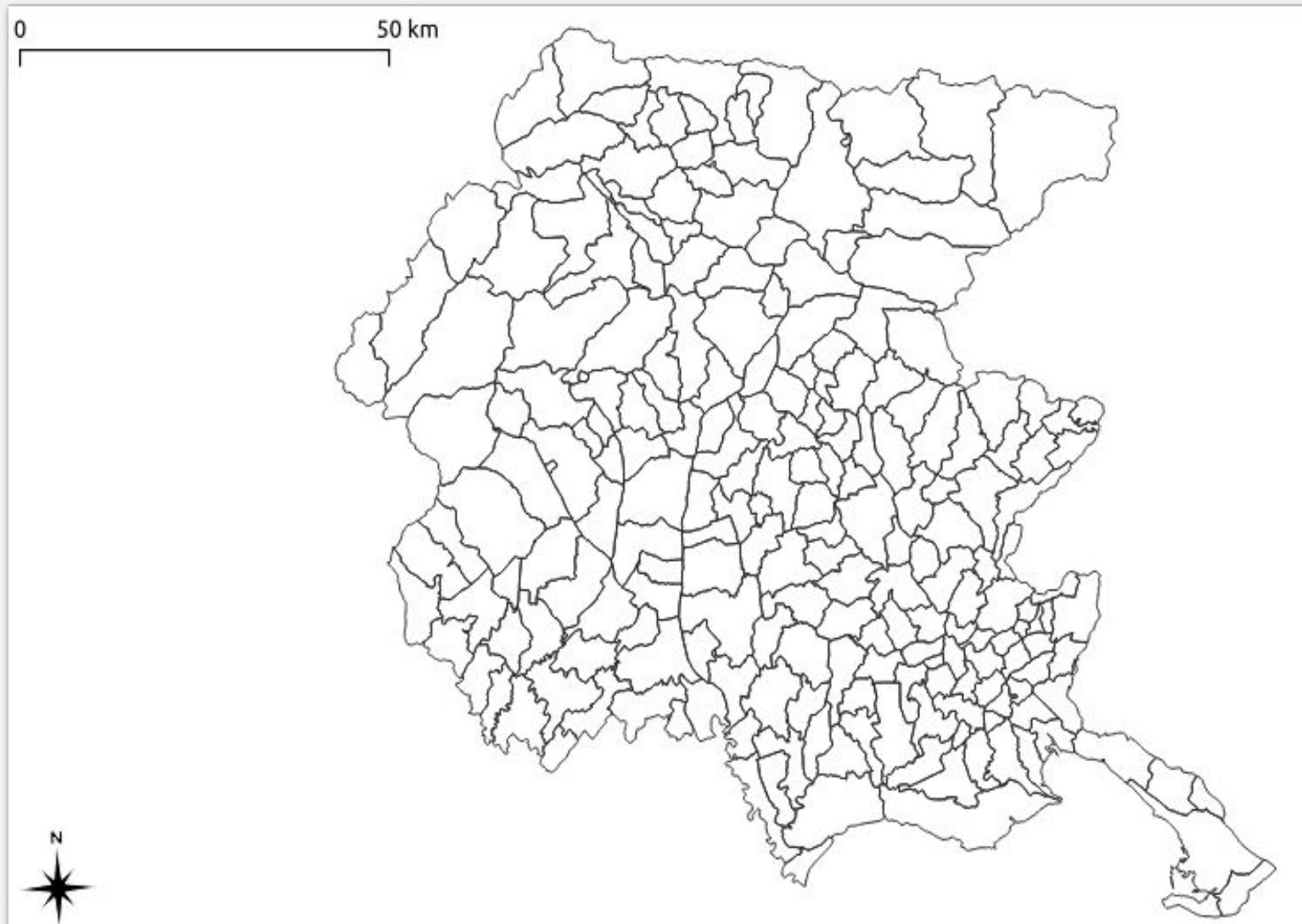


<http://epsg.io/>

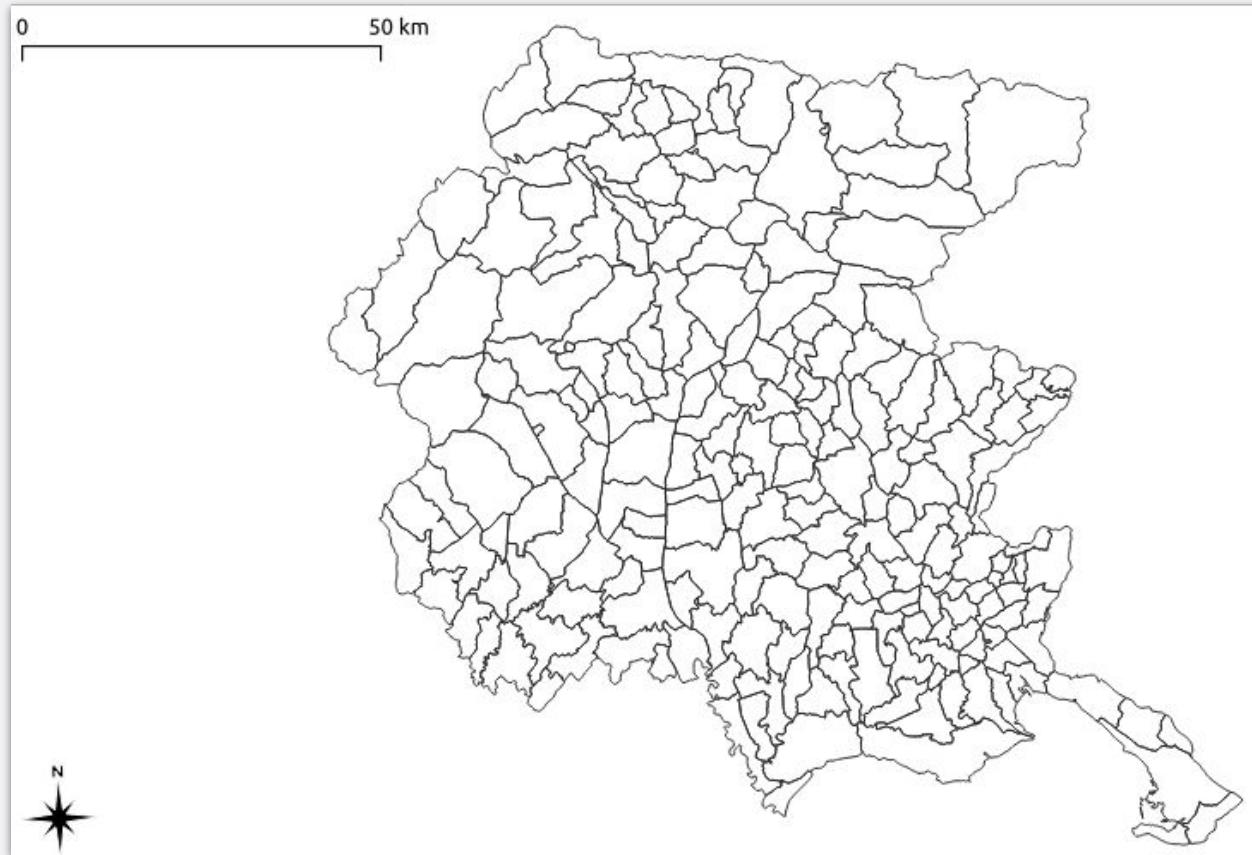




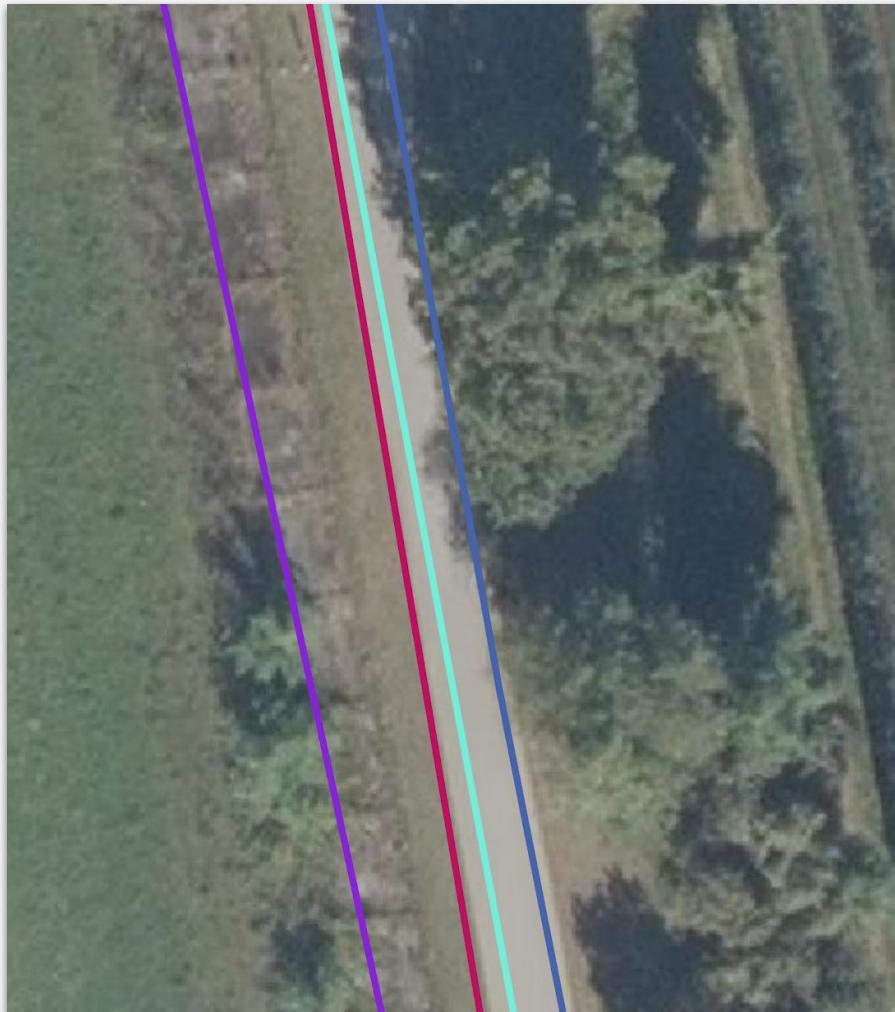
the details of the scale used



the details of the scale used

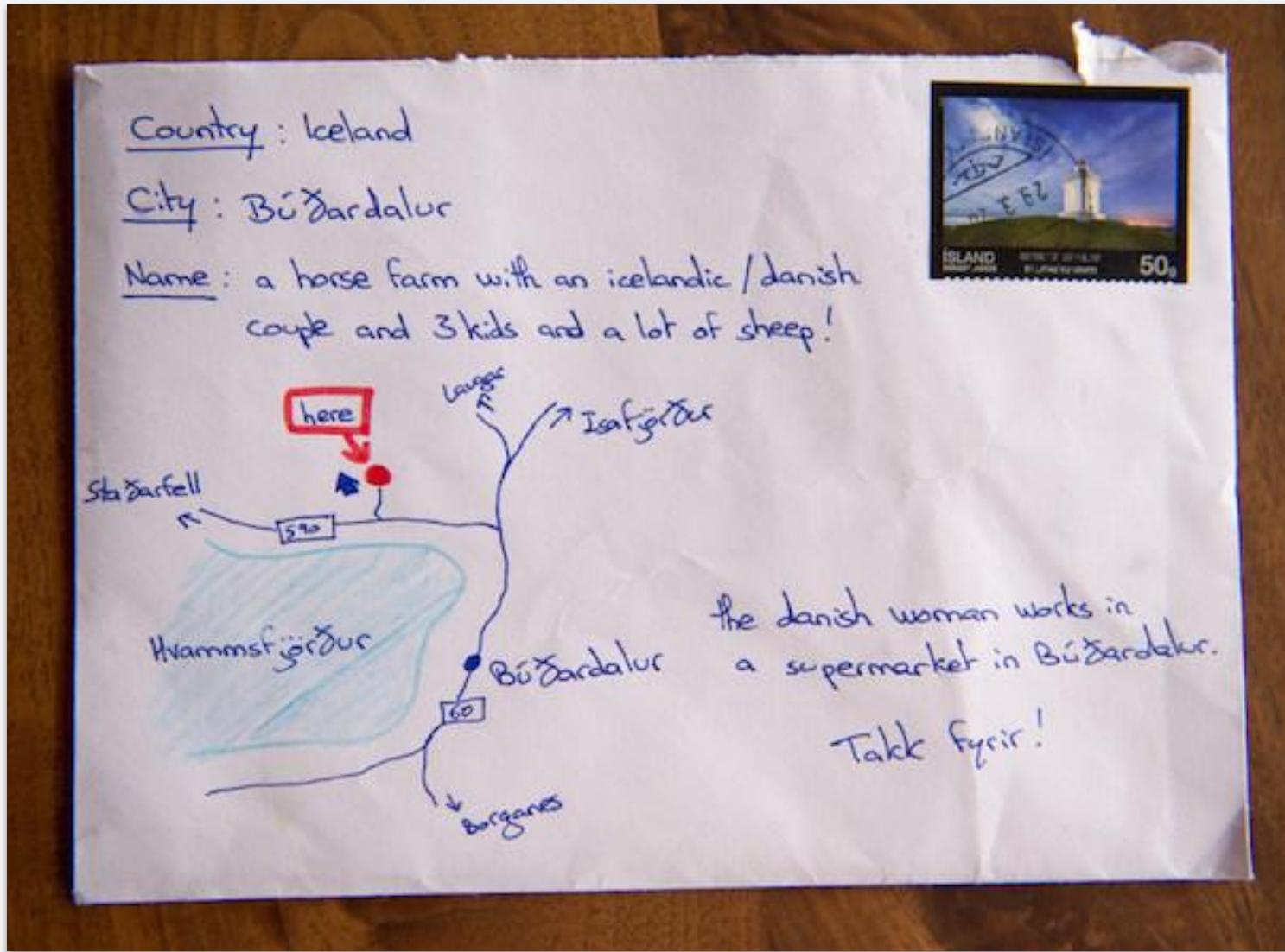


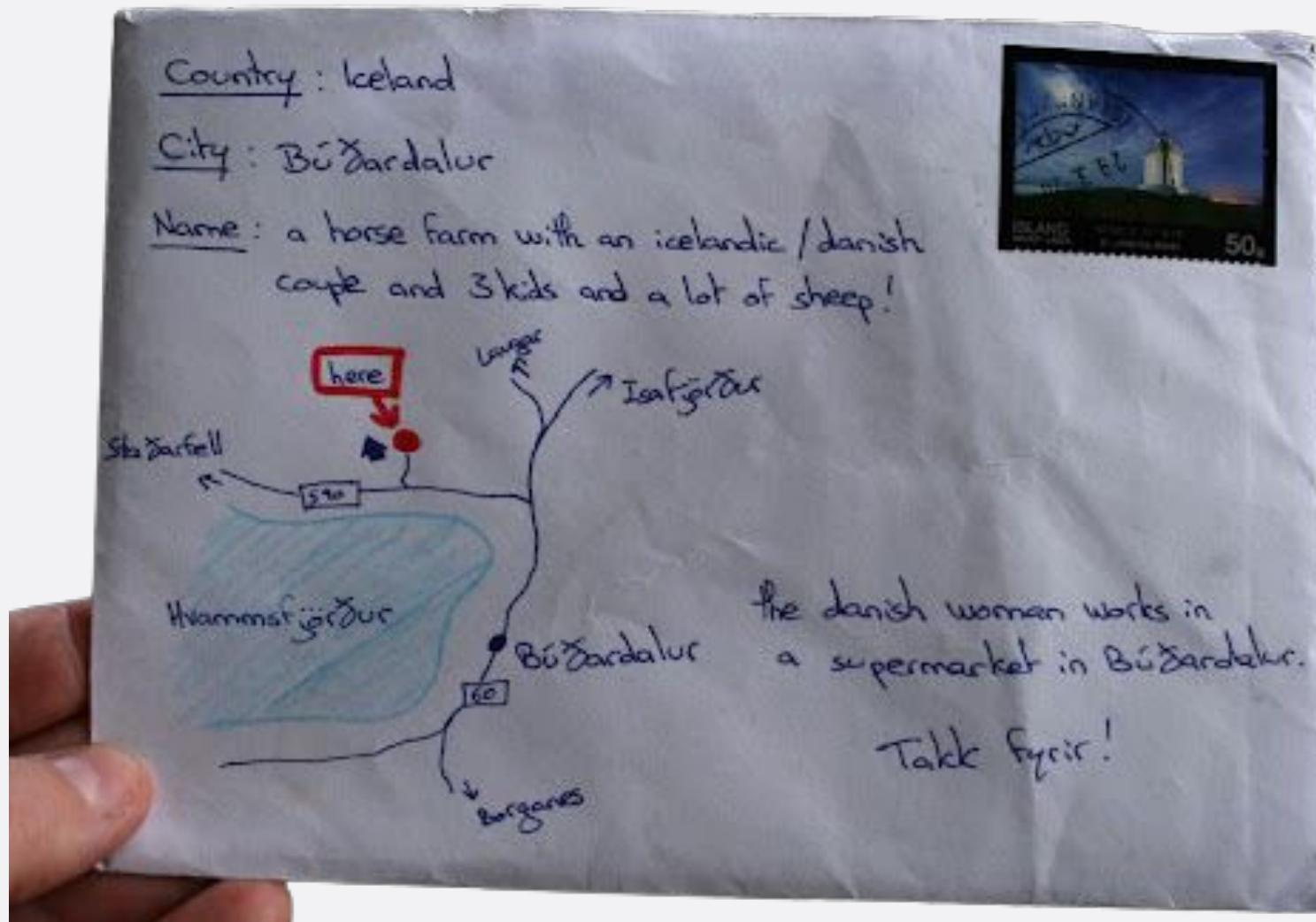
The cycle paths of Trentino

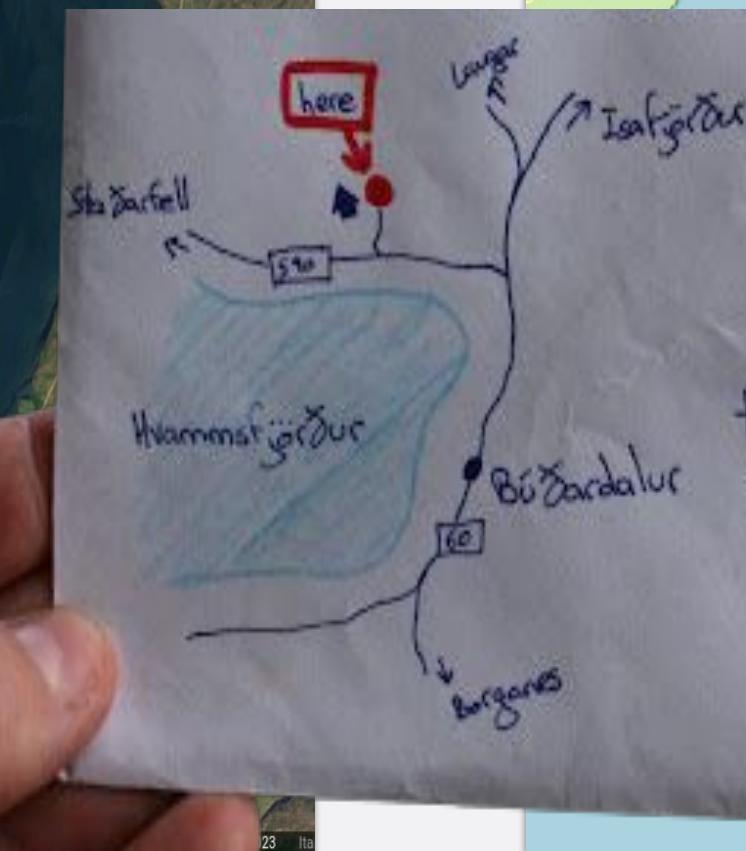


- OpenStreetMap
- Azienda Promozione Turistica
- Provincia Autonoma di Trento
- Comune di Trento

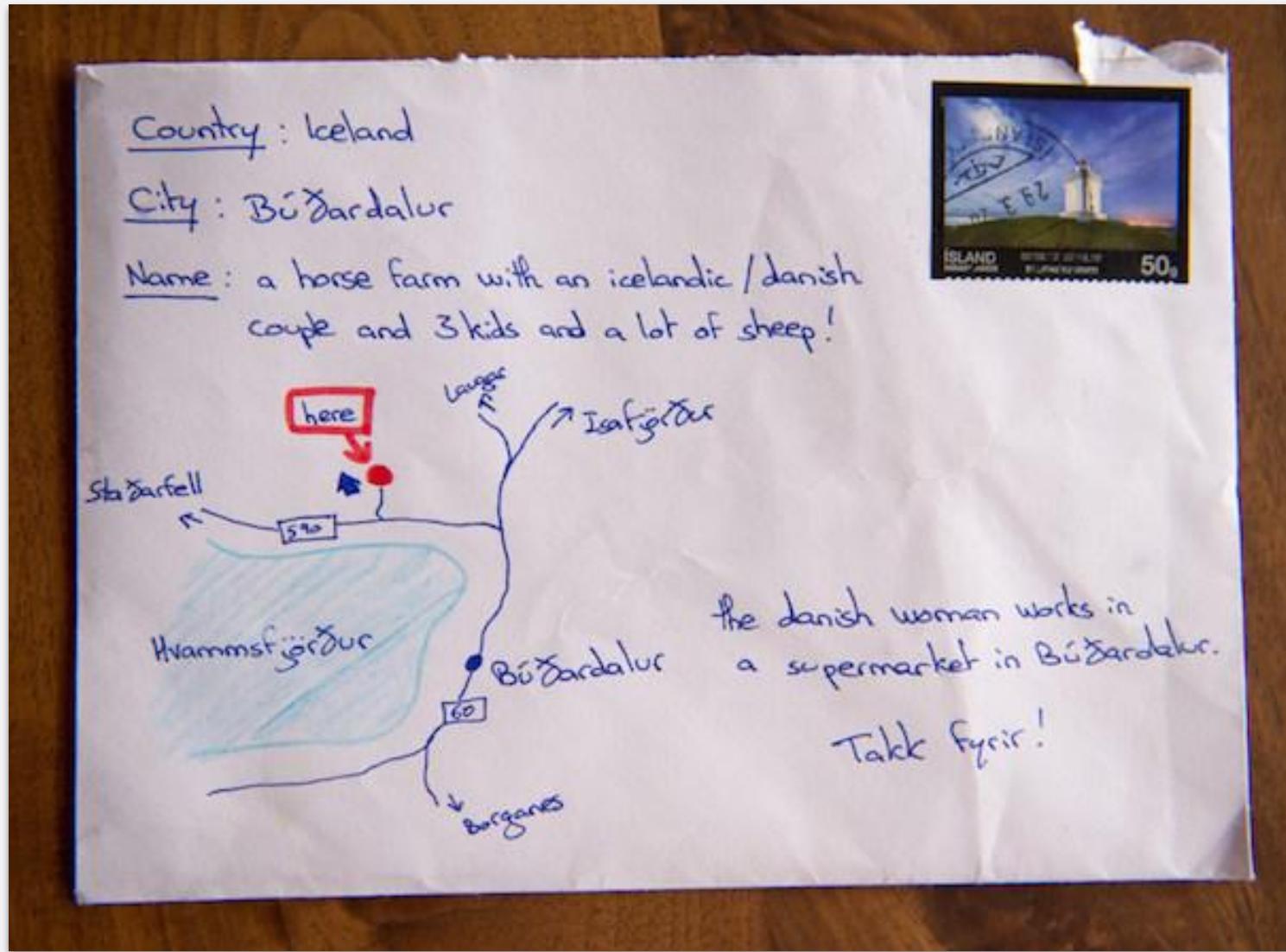
A map inform the people







A map inform the people



A map is not the territory - Alfred Korzybski

1931

≡ WIRED SECURITY POLITICS GEAR BACKCHANNEL MORE ▾ SIGN IN SUBSCRIBE

MARK BROWN SECURITY NOV 8, 2018 9:45 AM

Nicaraguan Invasion? Blame Google Maps

An embarrassing error on Google Maps has been blamed for Nicaragua's accidental invasion of Costa Rica. Last week, Nicaraguan troops crossed the border, took down a Costa Rican flag and defiantly raised their own flag on Costa Rican turf. But the troops' commander, Eden Pastora, told a Costa Rican newspaper, *La Nacion*, that his invasion [...]

An embarrassing error on Google Maps has been blamed for Nicaragua's accidental invasion of Costa Rica. Last week, Nicaraguan troops crossed the border, took down a Costa Rican flag and defiantly raised their own flag on Costa Rican turf.

But the troops' commander, Eden Pastora, told a Costa Rican newspaper, *La Nacion*, that his invasion was not his

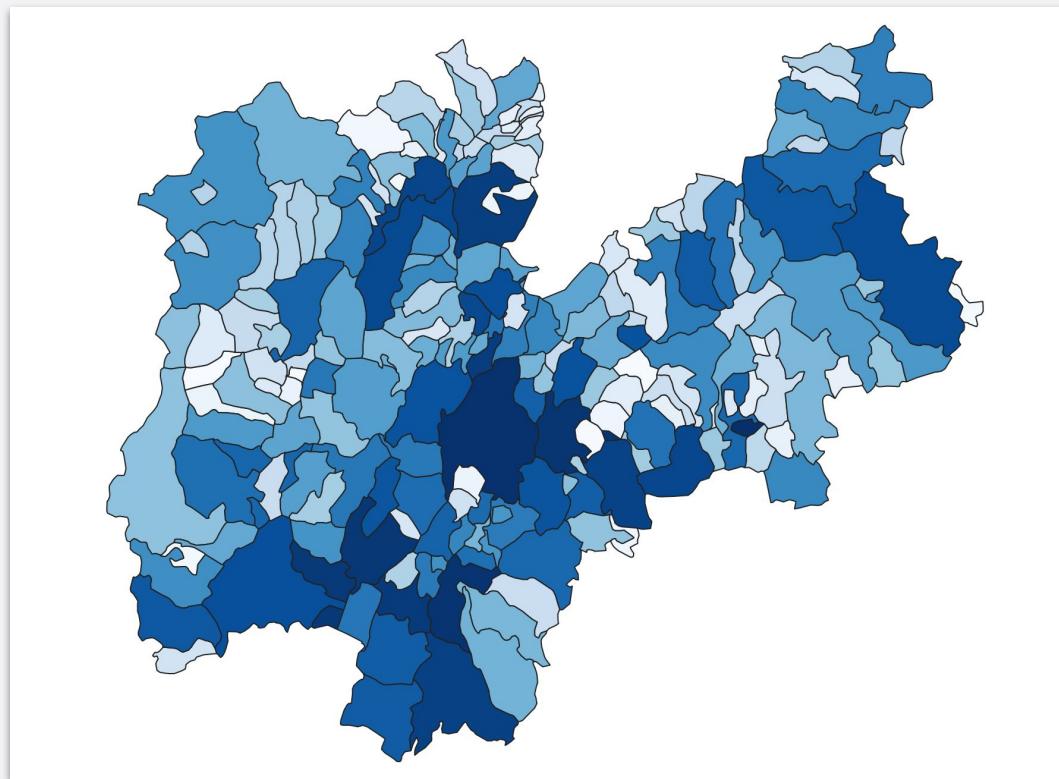
A misrepresentation of borders on Google Maps has reignited an old territorial dispute between San José and Managua (2018)

borders of India according to various media



(disputed borders)

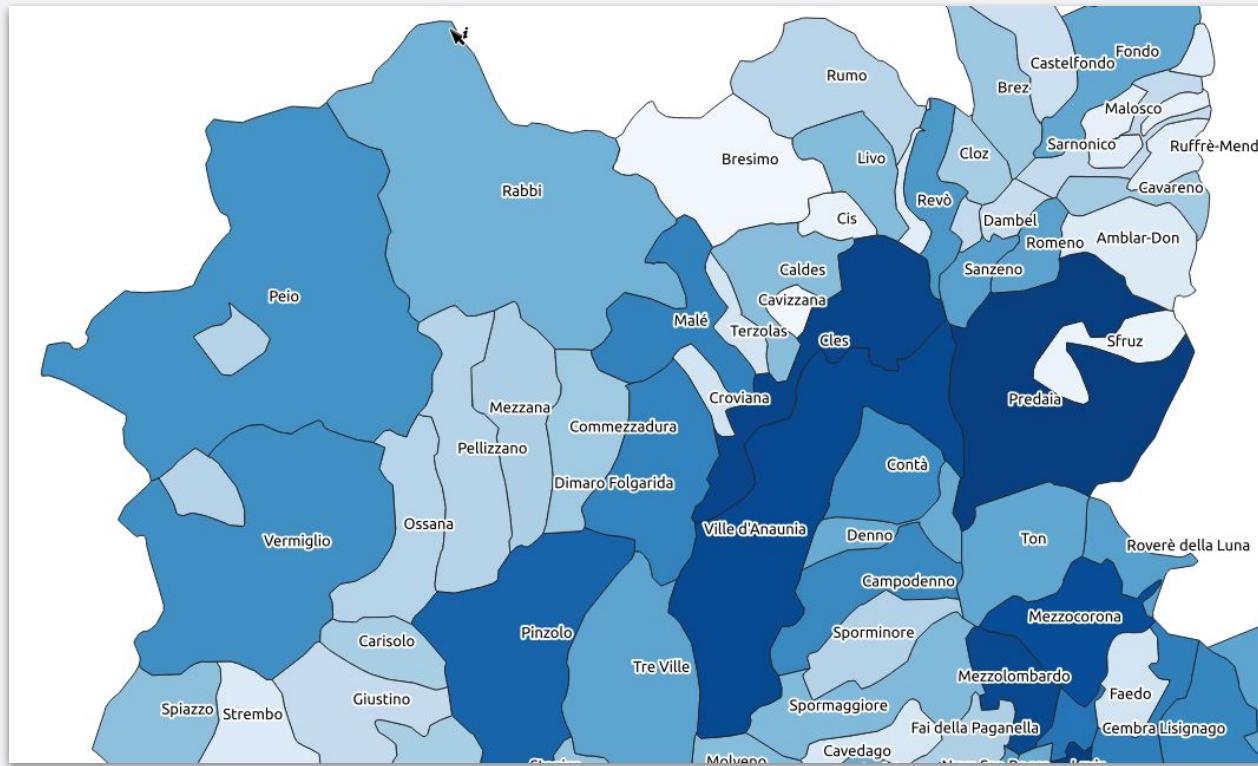
A Map of Trentino



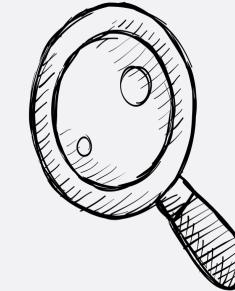
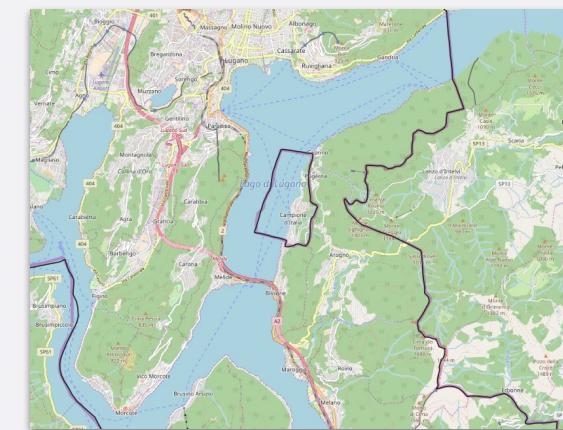
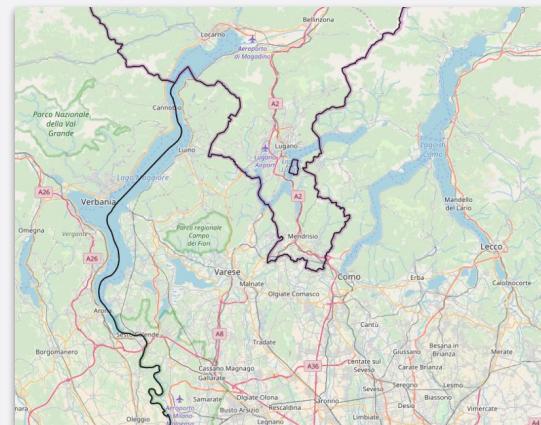
number of taxpayers as at 2016 according to tax return



... the enclaves ...



BOUNDARIES: ENCLAVE and EXCLAVE



tantotanto 288 Followers About Following ... Upgrade

Il decreto “di Natale”, in chilometri

Sono previsti spostamenti di 30 chilometri: ecco dove, quando e quanto

Andrea Borruso Dec 22, 2020 · 8 min read

Il [decreto legge numero 172 del 18 dicembre 2020](#) — detto in maniera un po’ fastidiosa “di Natale” — definisce delle misure urgenti per le festività natalizie e di inizio anno nuovo.

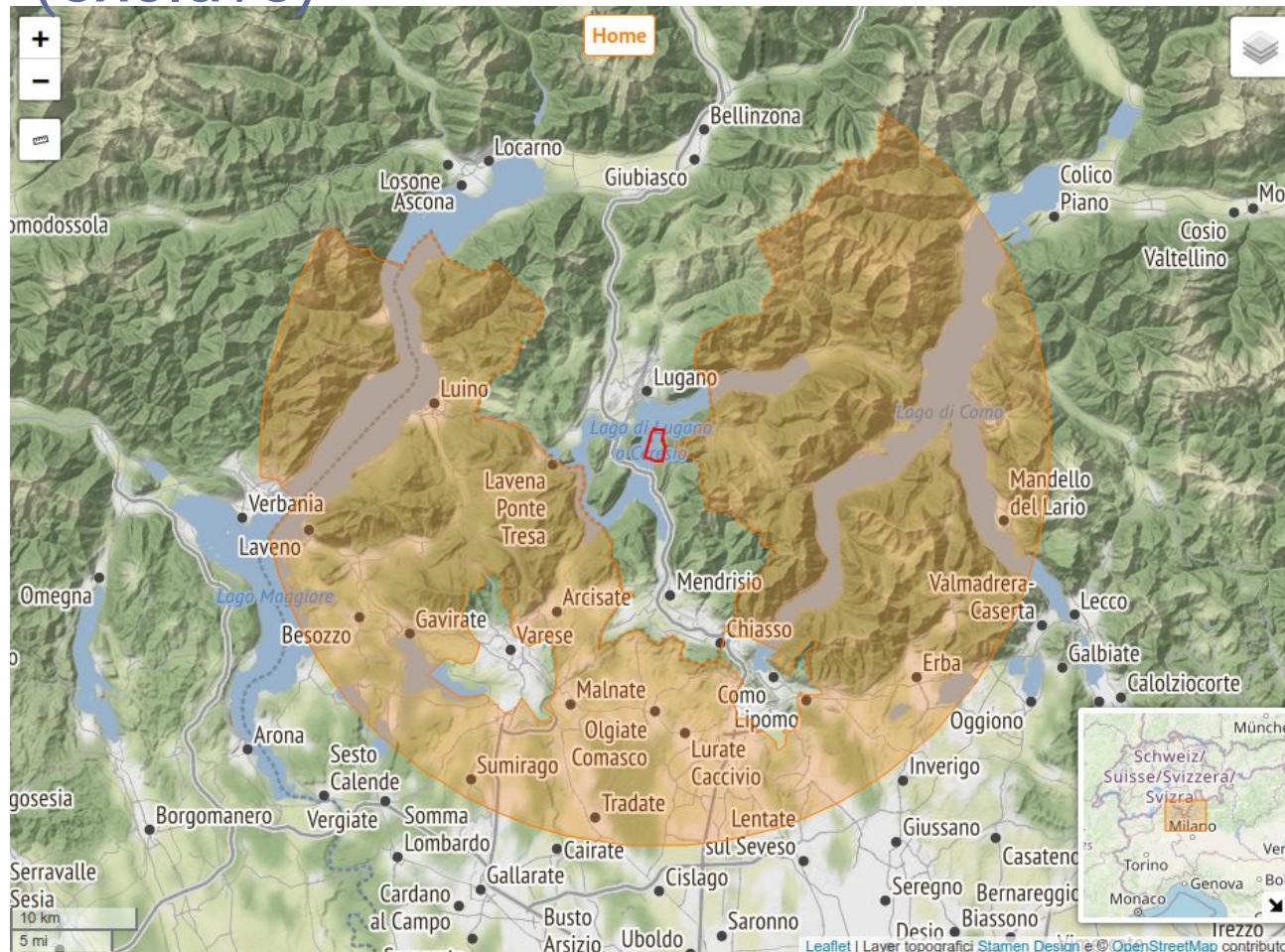
In questo si legge:

nei giorni 28, 29, 30 dicembre 2020 e 4 gennaio 2021 si applicano le

The screenshot shows a dark-themed web application interface. On the left, a sidebar contains links: 'Intro' (with a house icon), 'comuni' (with a grid icon), 'Telegram' (with a speech bubble icon), 'FAQ' (with a question mark icon), and 'Embed' (with a code icon). The main content area has a large title 'Il decreto “di Natale” in chilometri'. Below it, a text block reads: 'Il decreto legge numero 172 del 18 dicembre 2020 - detto in maniera un po' fastidiosa "di Natale" - definisce delle misure urgenti per le festività natalizie e di inizio anno nuovo.' To the right of this, another text block says 'In questo si legge:' followed by a long italicized quote: 'nei giorni 28, 29, 30 dicembre 2020 e 4 gennaio 2021 si applicano le misure di cui all’articolo 2 del medesimo decreto del Presidente del Consiglio dei ministri 3 dicembre 2020, ma sono altresì consentiti gli spostamenti dai comuni con popolazione non superiore a 5.000 abitanti e per una distanza non superiore a 30 chilometri dai relativi confini, con esclusione in ogni caso degli spostamenti verso i capoluoghi di provincia.'

<https://ondata.github.io/30cappa/>

Campione d'Italia (CO)- 1940 citizens (exclave)



GERRY MANDING

Elbridge Gerry



5th Vice President of the United States

In office

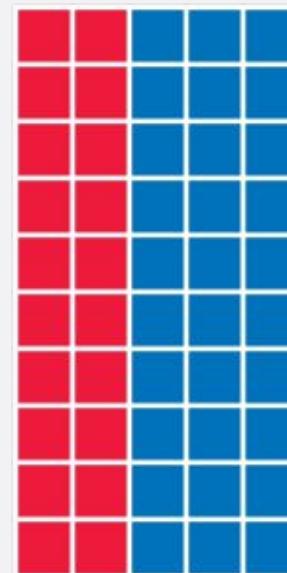
March 4, 1813 – November 23, 1814

President James Madison

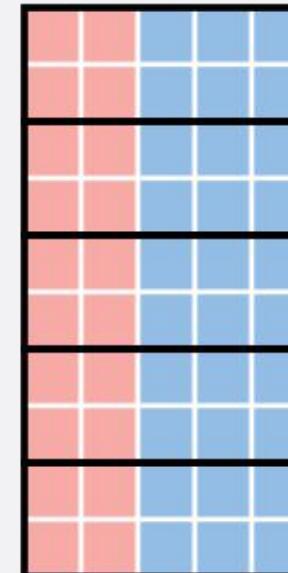
Preceded by George Clinton

Succeeded by Daniel D. Tompkins

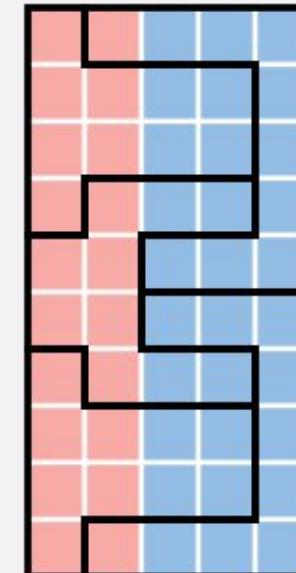
HOW TO STEAL AN ELECTION



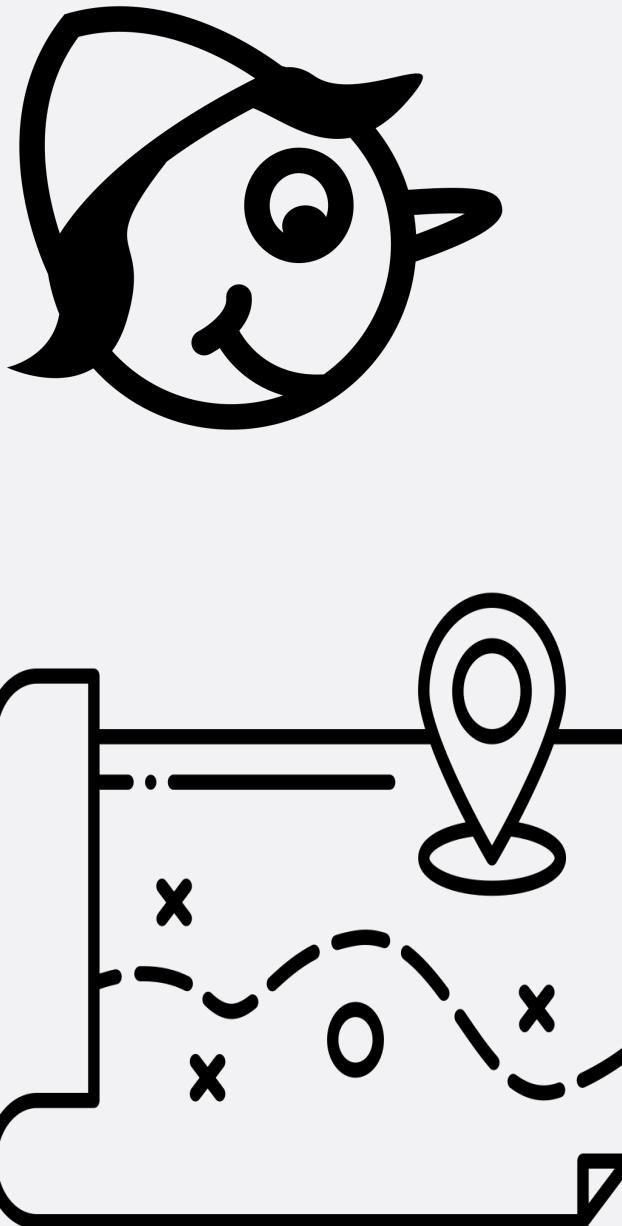
50 PRECINCTS
60% BLUE
40% RED



5 DISTRICTS
5 BLUE
0 RED
BLUE WINS



5 DISTRICTS
3 RED
2 BLUE
RED WINS



how maps are deceiving

Projections
Scale
Point of View
Political issues
Classification

DATA MODELS

Vector

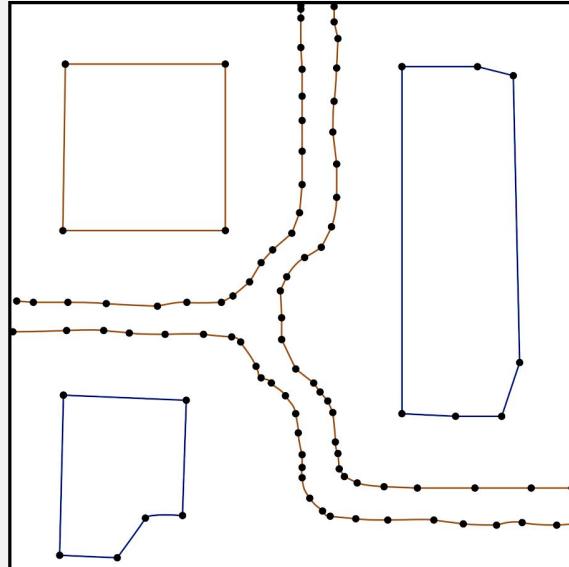
Vectors with attributes

Eg.

Points

Lines

Polygons



Raster

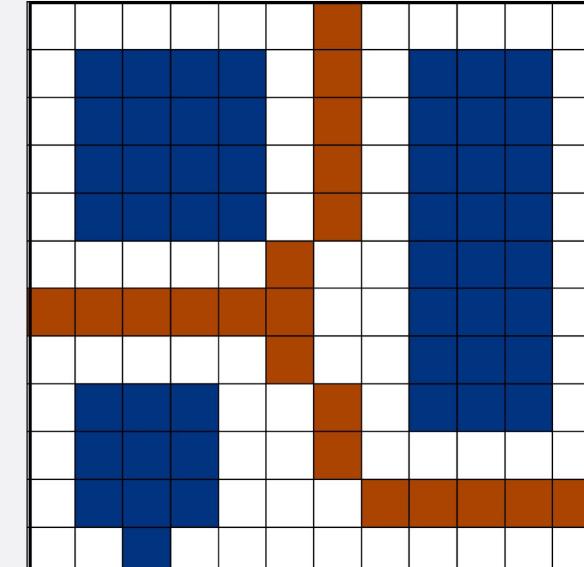
Matrix

Eg.

Digital Elevation Models

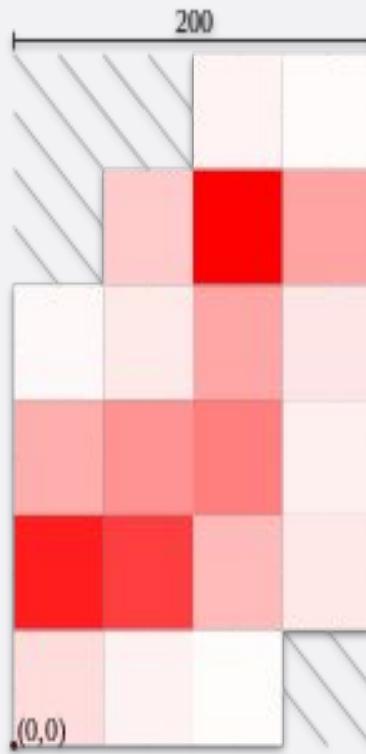
Solar Power Cells

Orthophotos



Example RASTER

GRID IMAGE



VALUES

	25	75	125	175
275	NA	NA	5	2
225	NA	20	100	36
175	3	8	35	10
125	32	42	50	6
75	88	75	27	9
25	13	5	1	NA

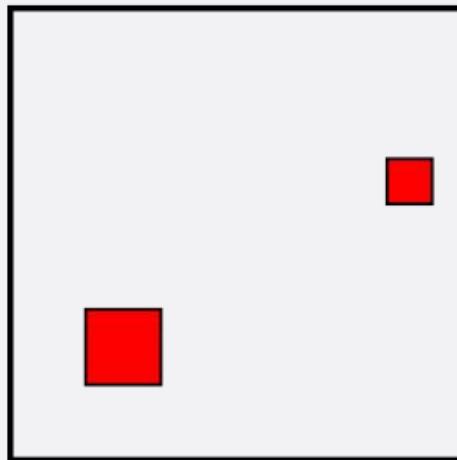
ASCII Grid Format

```
ncols          4
nrows          6
xllcorner     0.0
yllcorner     0.0
cellsize       50.0
NODATA_value -9999
-9999 -9999 5 2
-9999 20 100 36
3 8 35 10
32 42 50 6
88 75 27 9
13 5 1 -9999
```

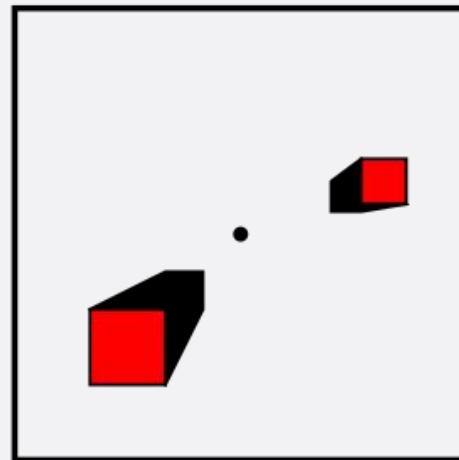
Orthophoto

an aerial photograph that has been geometrically corrected and georeferenced

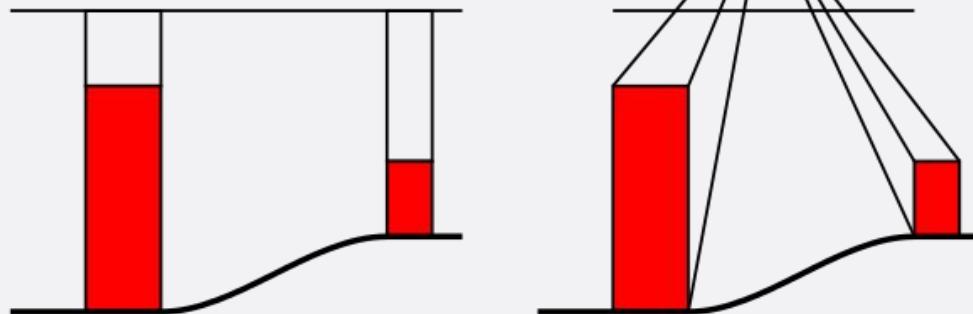
Orthographic view



Perspective view



Datum plane



(geo)TIFF



TIFF

0.1000000000

0.0000000000

0.0000000000

-0.1000000000

655950.0500000000

5114049.9500000002

Pixel Resolution

Rational Components
rotation options
set to zero in the
case of an
unrotated mapsheet

Easting and
Northing of the
upper left pixel
(0,0 in image
coordinates).

TFW = Tiff World File

a TIFF needs a TFW file with the same name

Eg.

orthophoto.tif

orthophoto.tfw

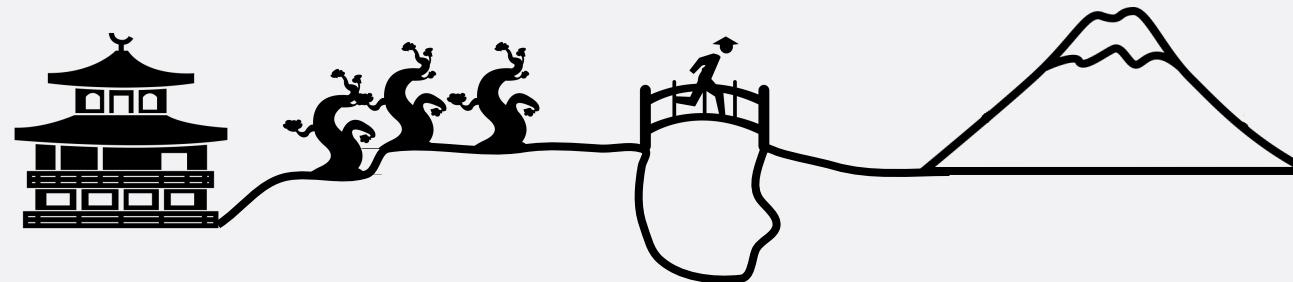
a GeoTIFF contains all the information in an only
one file .tiff

The spatial reference system is a external
information

DSM vs DTM

DEM is often used as a generic term for DSMs and DTMs

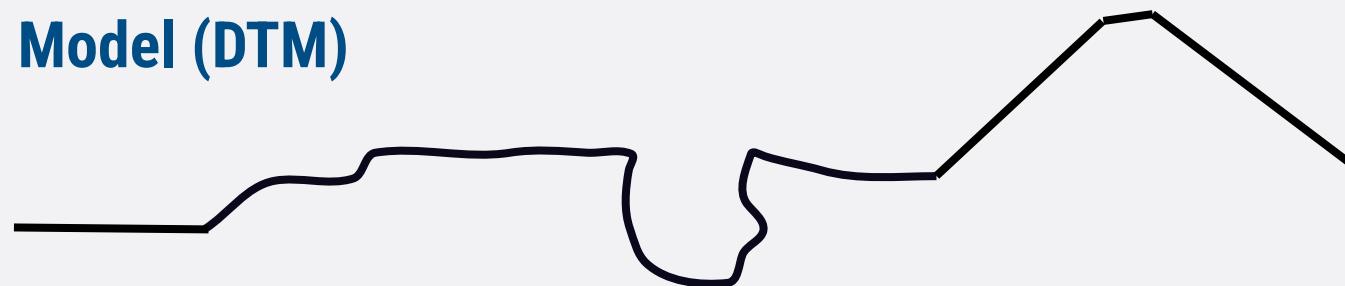
Real World



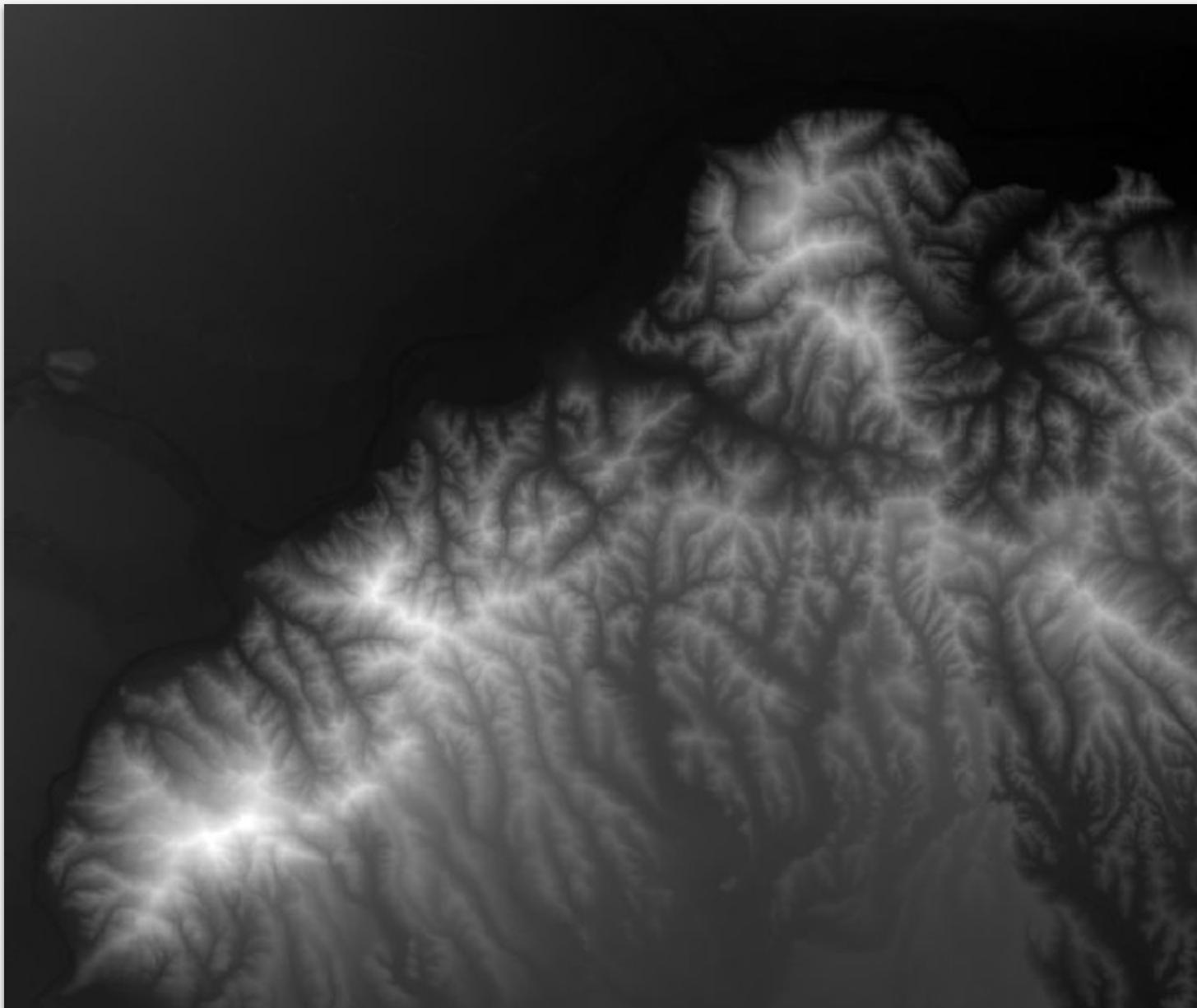
Digital Surface Model (DSM)



Digital Terrain Model (DTM)



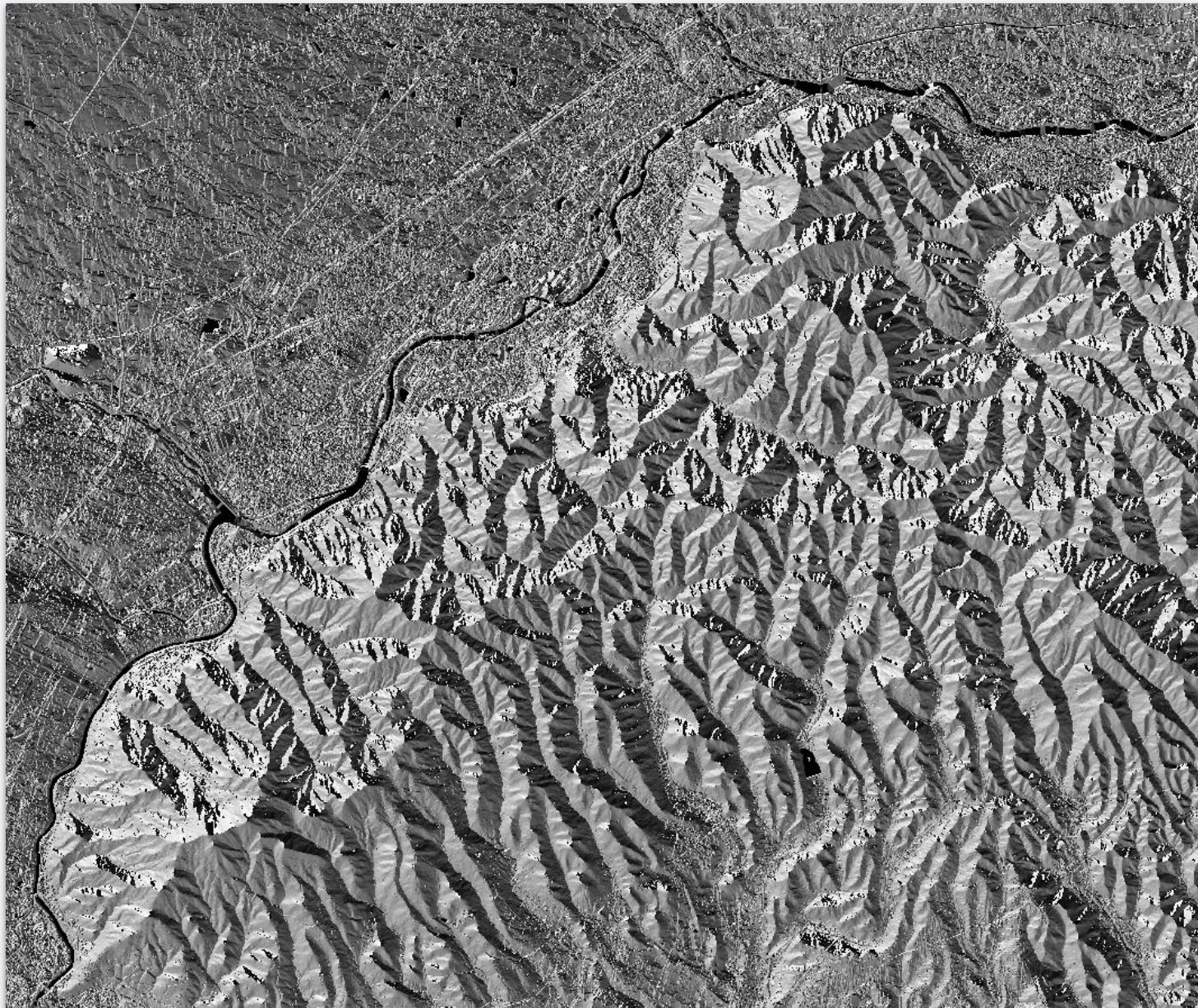
DTM - shades of gray



DTM - slope



DTM aspect



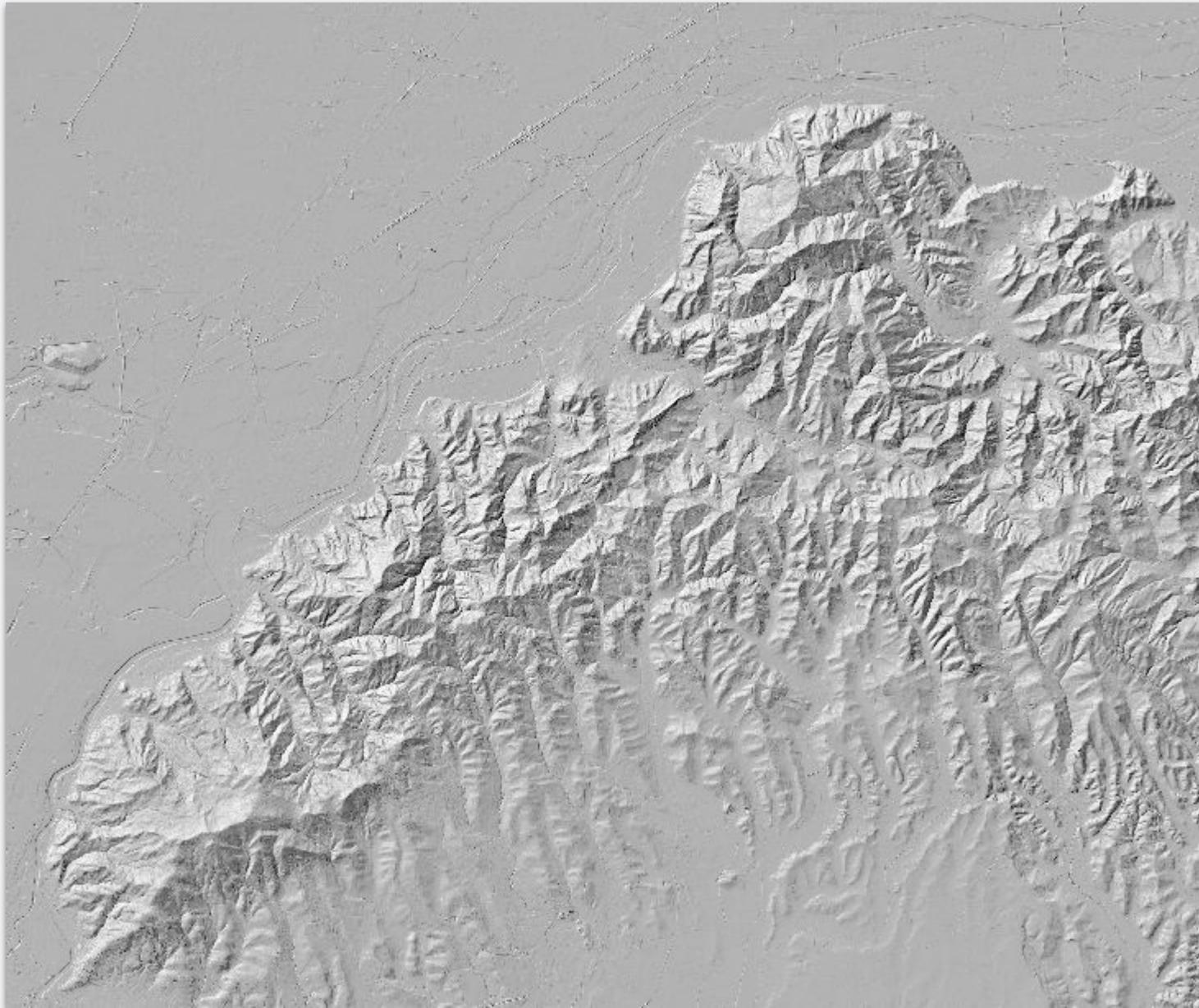
aspect is the compass direction that a slope faces



@napo



DTM Hillshade



simulation of lighting intensity with a shading effect from an azimuth and altitude of light
it can be used to produce the impression of the terrain relief.

Example Vector

```
{  
  "type": "FeatureCollection",  
  "features": [  
    {  
      "type": "Feature",  
      "geometry": {  
        "type": "Point",  
        "coordinates": [  
          11.1215698,  
          46.0677293  
        ]  
      },  
      "properties": {  
        "name": "Fontana dell'Aquila",  
        "amenity": "drinking-water"  
      }  
    }  
  ]  
}
```



Points



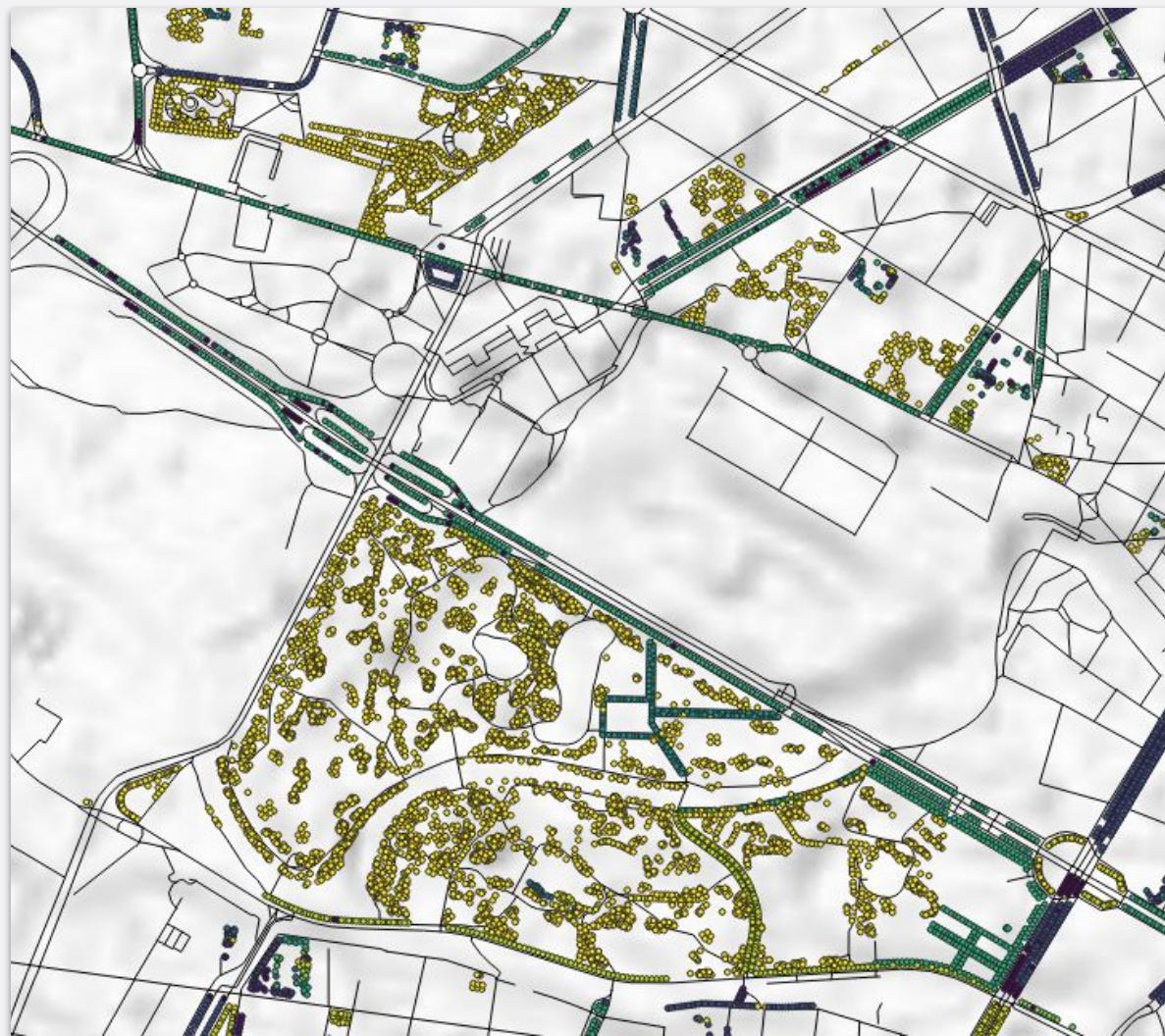
Lines



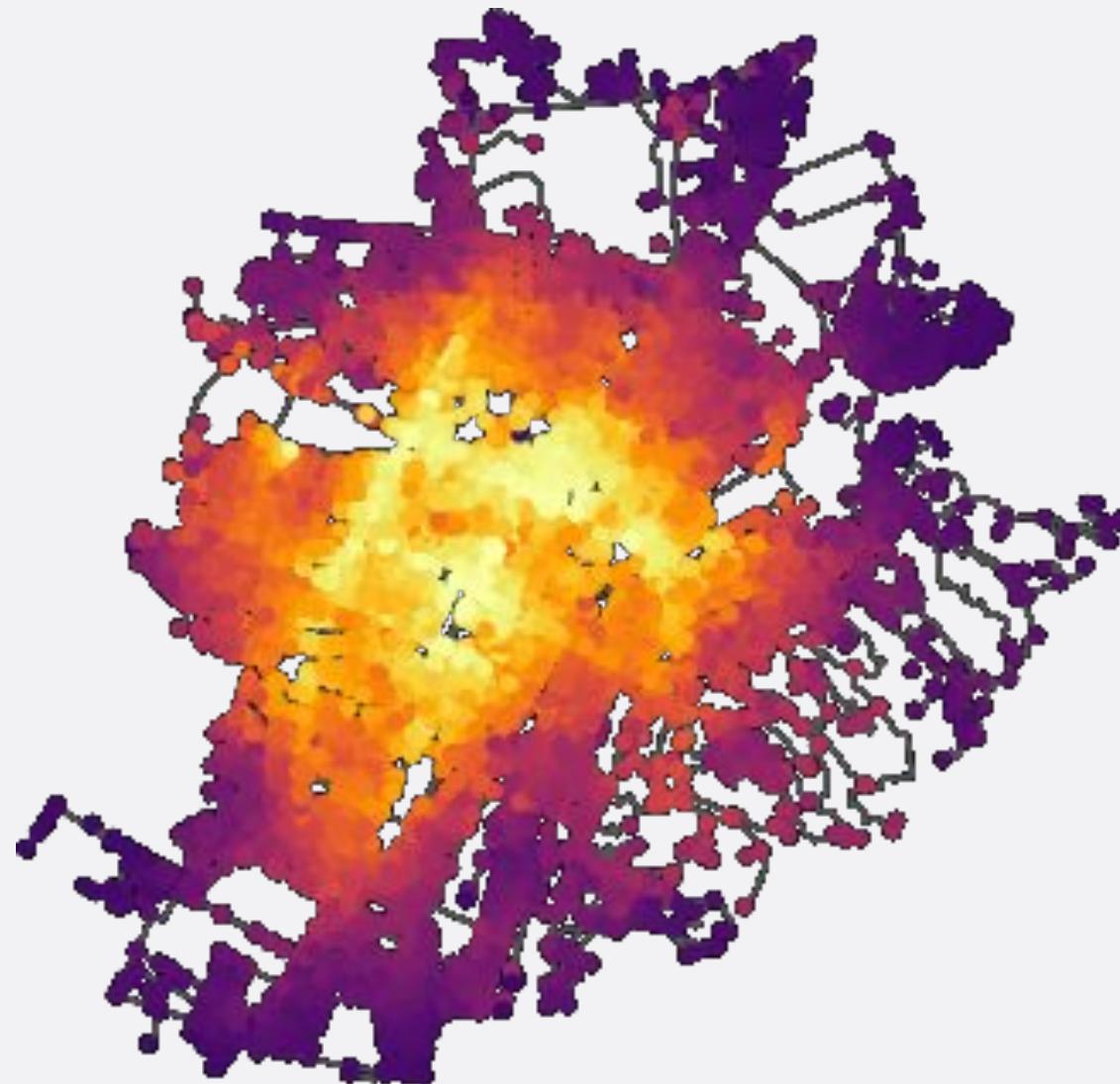
Overlay



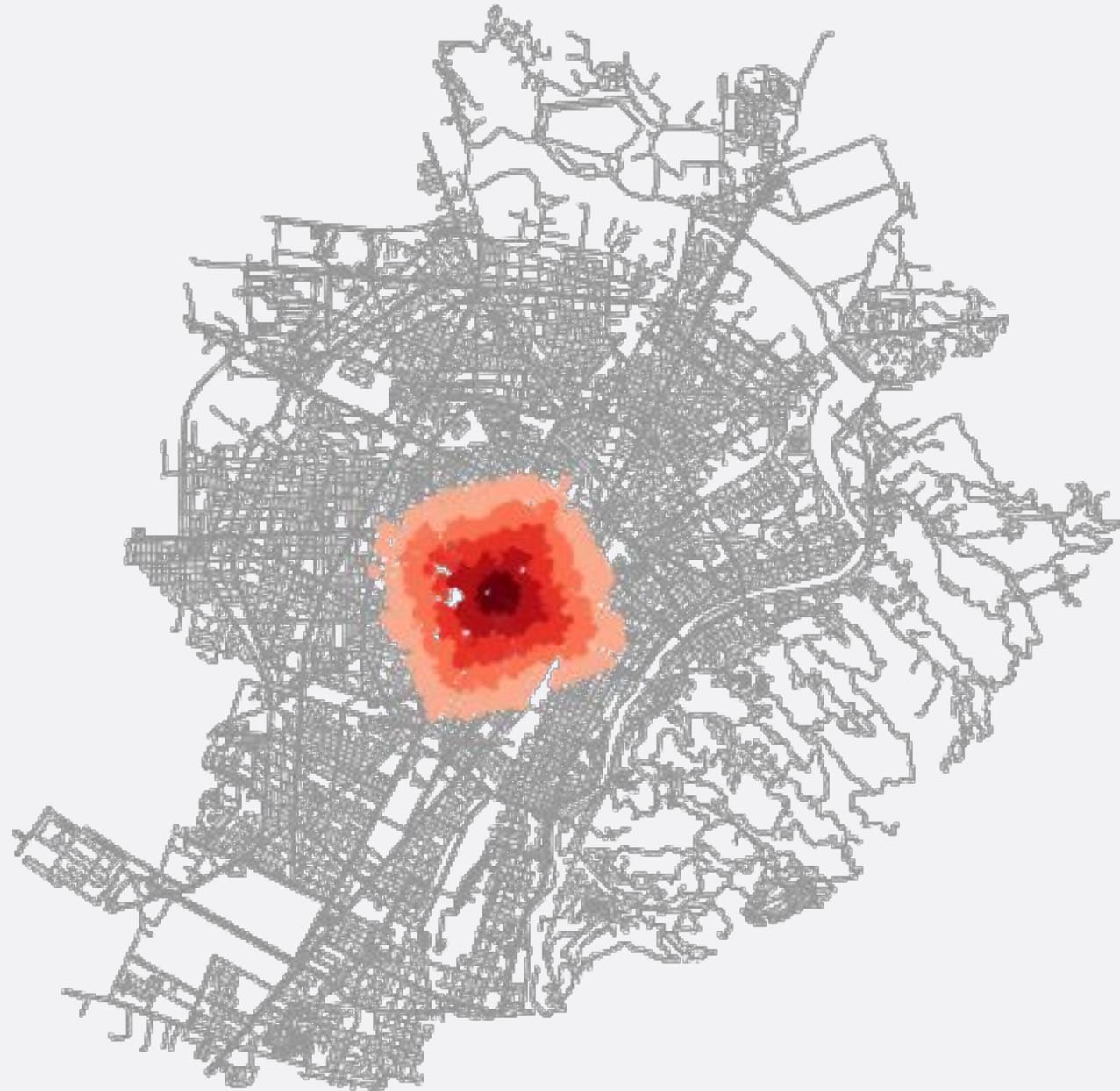
Queries



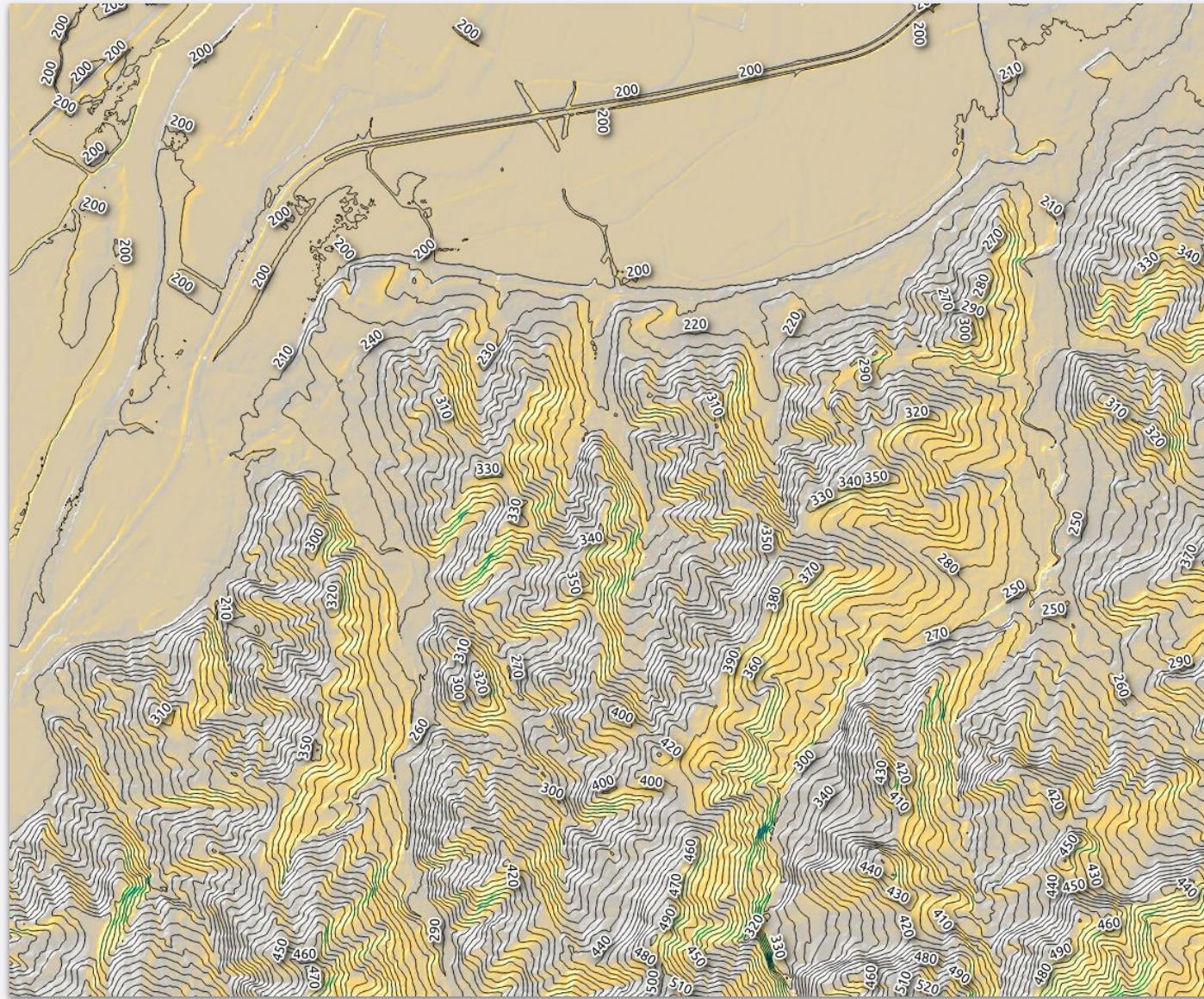
Network Analysis



Isochrones



Raster to Vector



the dark lines are created from the DTM values where the altitude is the same (**isopleths**)



@napo



Formats

Vectors

- ESRI Shapefile
- WKT
- GeoJSON
- KML
- ...

Raster

- Ascii Grid
- GeoTiff
- MBtiles

...



<http://www.gdal.org/>

ESRI Shapefile

Standard de facto

from 3 to 7 files with the same name and different extension

filename.shp →
filename.shx →
filename.dbf →
filename.prj →

geometry
index
table
projection

GeoPackage



GeoPackage



An Open Format for Geospatial Information

GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information.

The GeoPackage Encoding Standard describes a set of conventions for storing the following within an SQLite database:

- vector features
- tile matrix sets of imagery and raster maps at various scales
- attributes (non-spatial data)
- extensions

To be clear, a GeoPackage is the SQLite container and the GeoPackage Encoding Standard governs the rules and requirements of content stored in a GeoPackage container. The GeoPackage standard defines the schema for a GeoPackage, including table definitions, integrity assertions, format limitations, and content constraints. The required and supported content of a GeoPackage is entirely defined in the standard. These capabilities are built on a common base and the extension mechanism provides implementors a way to include additional functionality in their GeoPackages.

Since a GeoPackage is a database container, it supports direct use. This means that the data in a GeoPackage can be accessed and updated in a "native" storage format without intermediate format translations. GeoPackages that comply with the requirements in the standard and do not implement vendor-specific extensions are interoperable across all enterprise and personal computing environments. GeoPackages are particularly useful on mobile devices such as cell phones and tablets in communications environments where there is limited connectivity and bandwidth.

the next is GeoParquet

[Home](#) / [News](#) / OGC to form new GeoParquet Standards Working Group; Public Comment sought on Draft Charter

January 25, 2023

OGC to form new GeoParquet Standards Working Group; Public Comment sought on Draft Charter

GeoParquet adds geospatial types to Apache Parquet to serve as an efficient cloud-native vector data format.



The screenshot shows the homepage of the Open Geospatial Consortium (OGC) website. The header features the OGC logo and navigation links for About, Membership, Standards & Resources, Innovation, and News & Events. A prominent banner on the right side of the page displays the text "Making Location Information Findable, Accessible, Interoperable, and Reusable" and the OGC logo. The background of the banner features a close-up image of a satellite dish reflecting a view of Earth from space.

About OGC

The Open Geospatial Consortium (OGC) is an international consortium of more than **500** businesses, government agencies, research organizations, and universities driven to make geospatial (location) information and services FAIR - Findable, Accessible, Interoperable, and Reusable.

OGC's member-driven consensus process creates [royalty free, publicly available, open geospatial standards](#). Existing at the cutting edge, OGC actively analyzes and anticipates emerging [tech trends](#), and runs an agile, collaborative Research and Development (R&D) lab - the [OGC Innovation Program](#) - that builds and tests innovative prototype solutions to members' use cases.

The OGC Vision:
Using location, we connect people, communities, technology, and decision-making for the greater good.

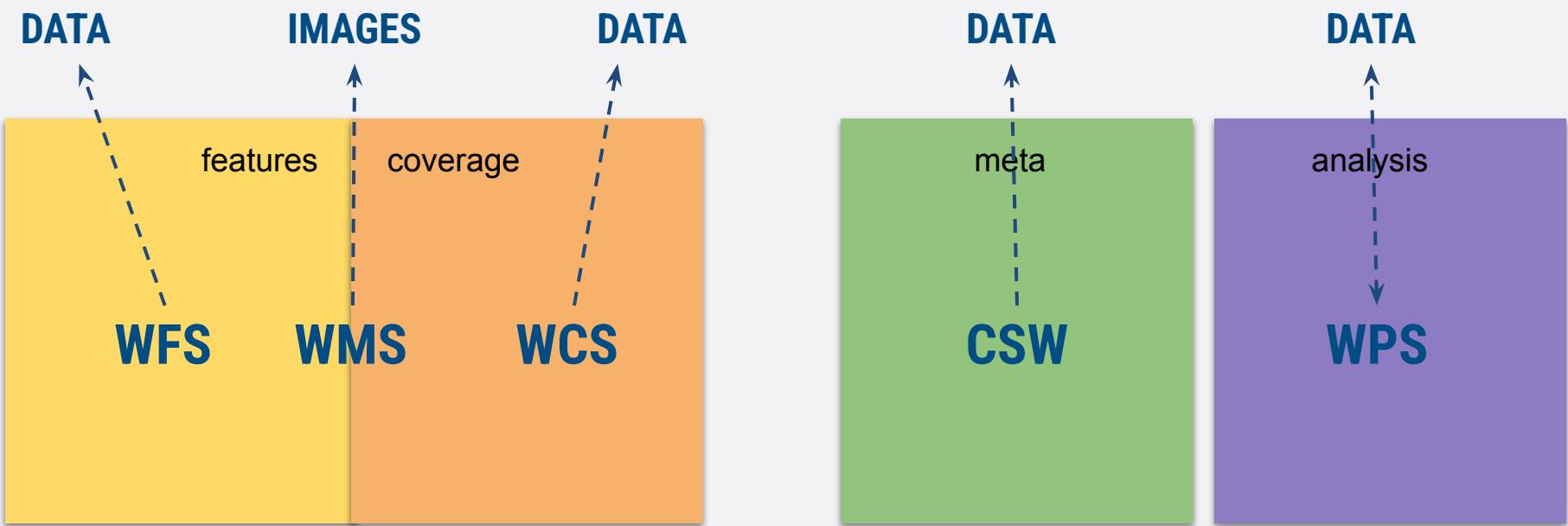
The OGC Mission:
Make location information more Findable, Accessible, Interoperable, and Reusable (FAIR).

The OGC Approach:
A proven collaborative and agile process combining consensus-based standards, innovation projects and partnership building.

The OGC Values:

- We are open, diverse, inclusive, and accessible*
- We value our technical excellence and innovation*
- We are passionate about the greater good*
- We are community-driven and we are fair, respectful, and responsible to our members*
- We always honor our commitments and aim to exceed expectations*

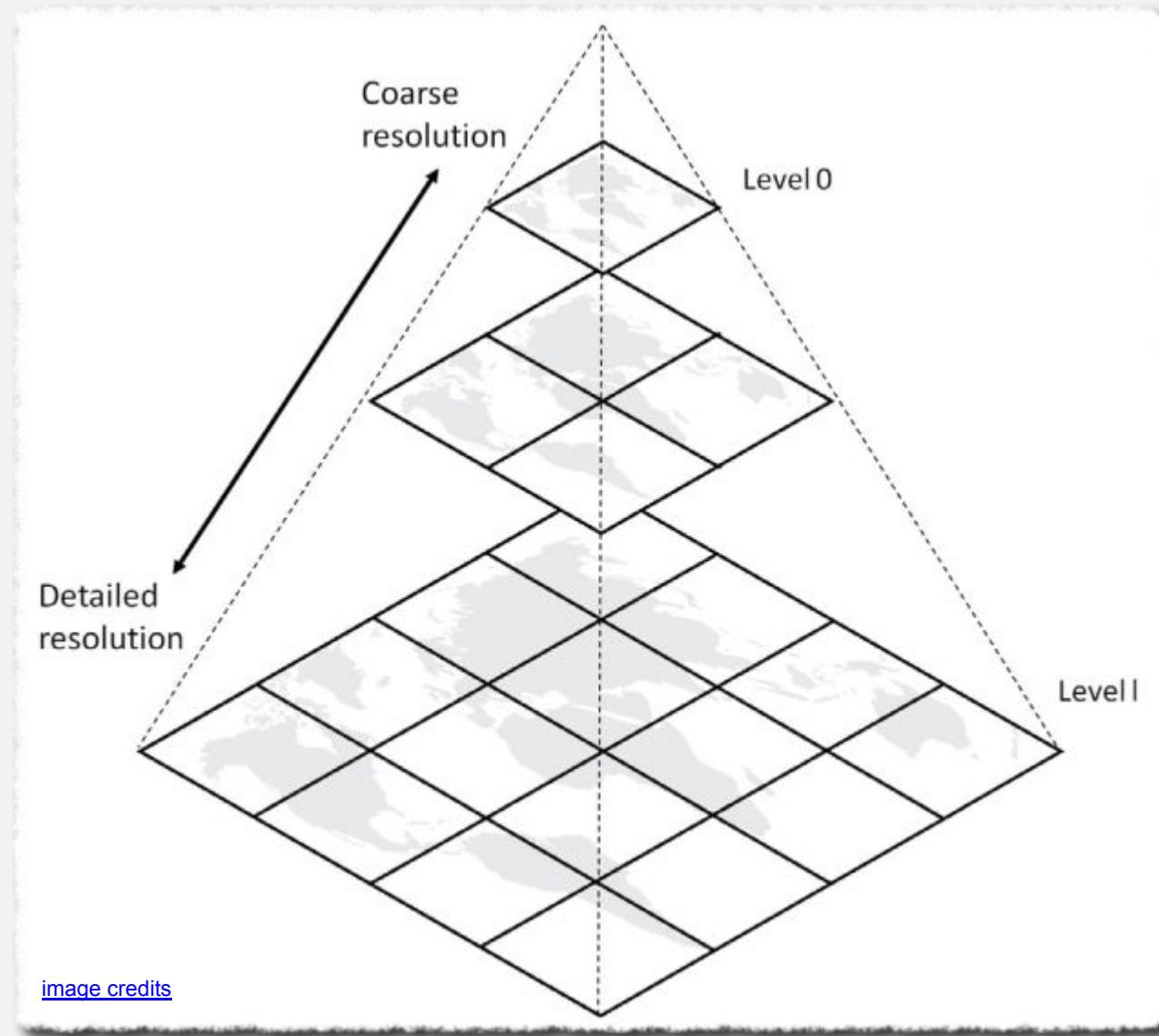
OGC Protocols



- | | | |
|------------|---|-----------------------------|
| WMS | - | Web Map Service |
| WFS | - | Web Feature Service |
| WCS | - | Web Coverage Service |
| WPS | - | Web Processing Service |
| CSW | - | Catalog Service for the Web |



TMS



Tile Map Service



VTS



Vector Tile Service



The image shows a promotional banner for OGC APIs. On the left, the OGC APIs logo (a blue cube with a white play button icon) is displayed next to the text "Building Blocks for Location". The background features a dark blue circular graphic with various white icons: a handshake, a calendar with a circular arrow, a dollar sign with a circular arrow, a person icon inside a gear, and a calendar with a clock. The top navigation bar includes links for CONTEXT, APIS, SPRINTS, VIDEOS, BLOGS, DOCUMENTS, and GET IN TOUCH.