Data Visualisation and Dashboarding

Week 8 – Spatial data

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What do we mean by “spatial”?

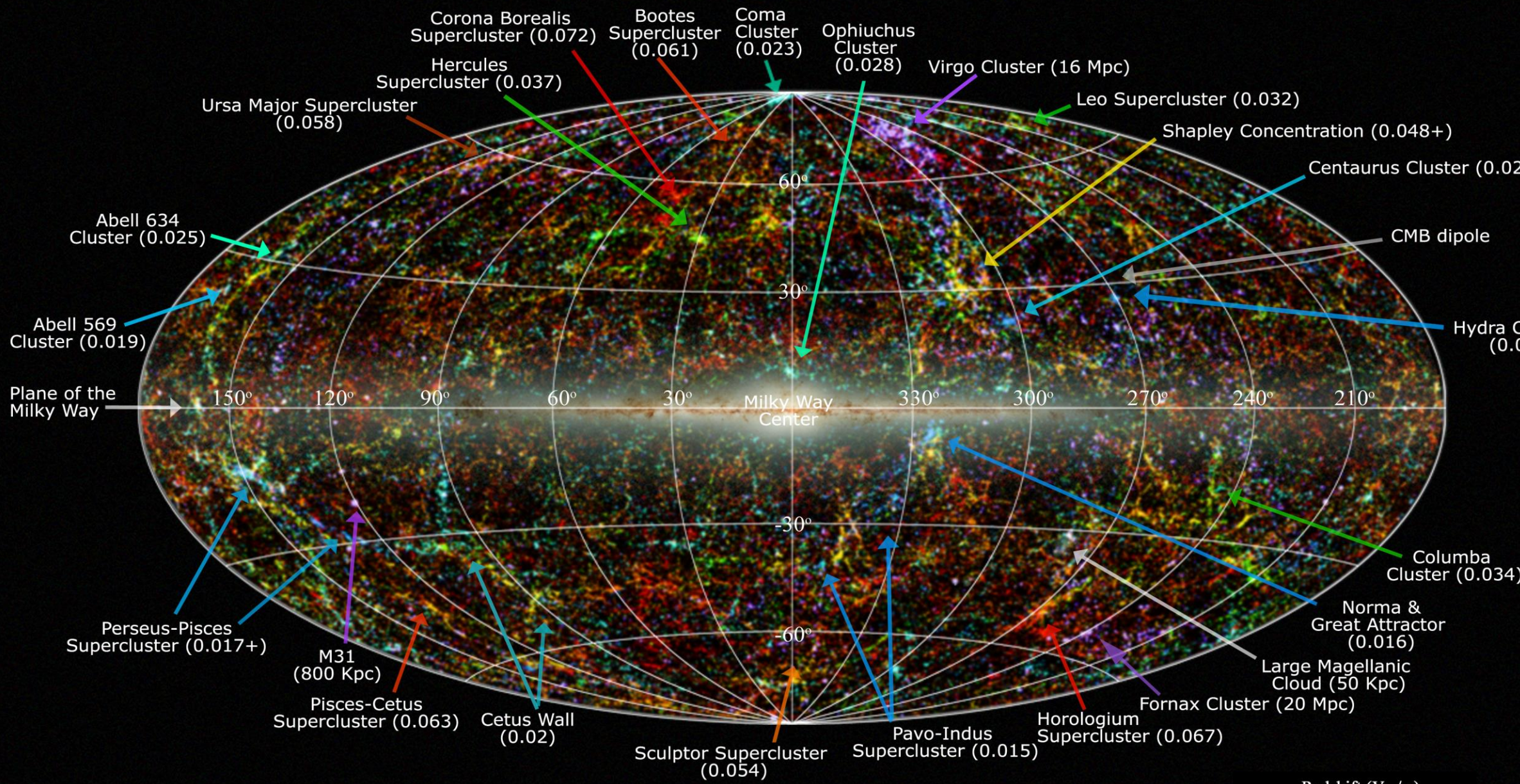
Spatial data is any data relation to space.

Multiple applications for visualisations: geographic, astronomical, medical, scientific observation, etc.

Focus on geospatial data

Astronomical

2MASS Redshift Survey

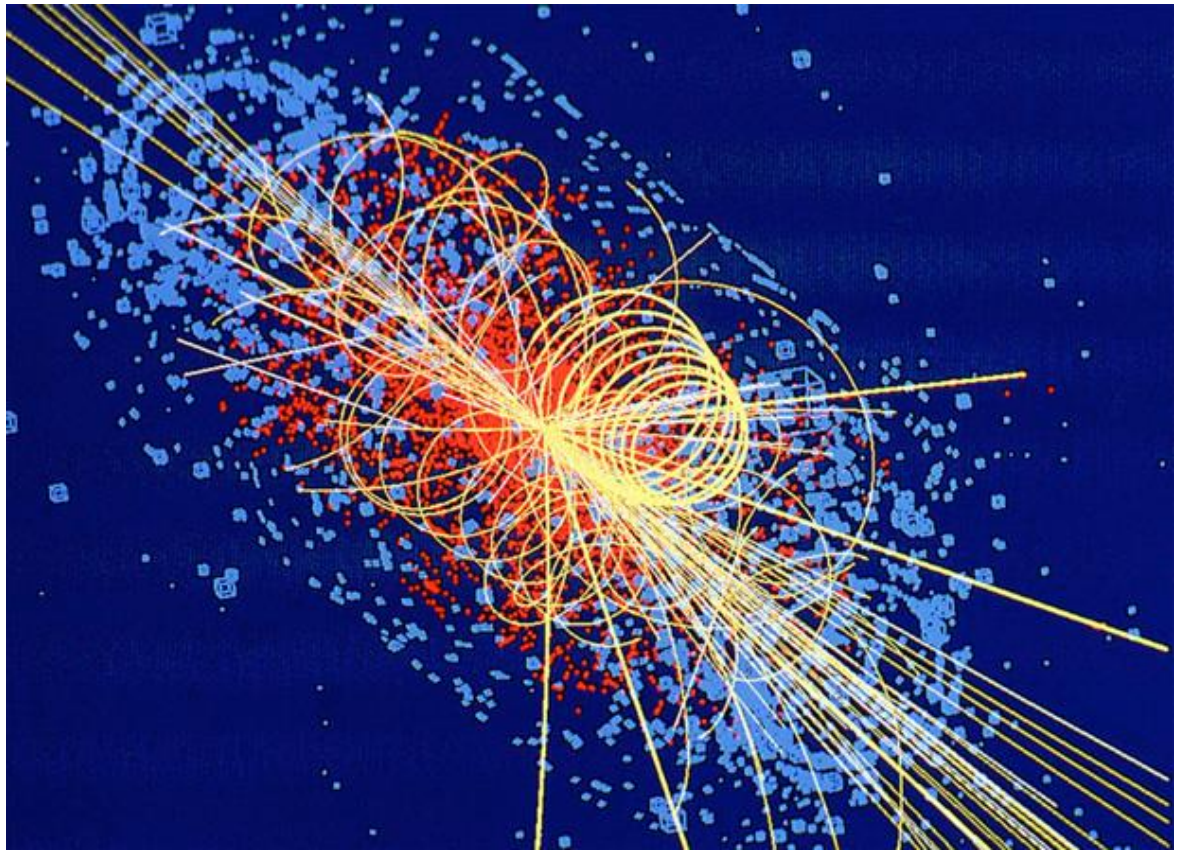


Legend: image shows 2MASS galaxies color coded by the 2MRS redshift (Huchra et al 2011); familiar galaxy clusters/superclusters are labeled (numbers in parenthesis represent redshift).

Graphic created by T. Jarrett (IPAC/Caltech)

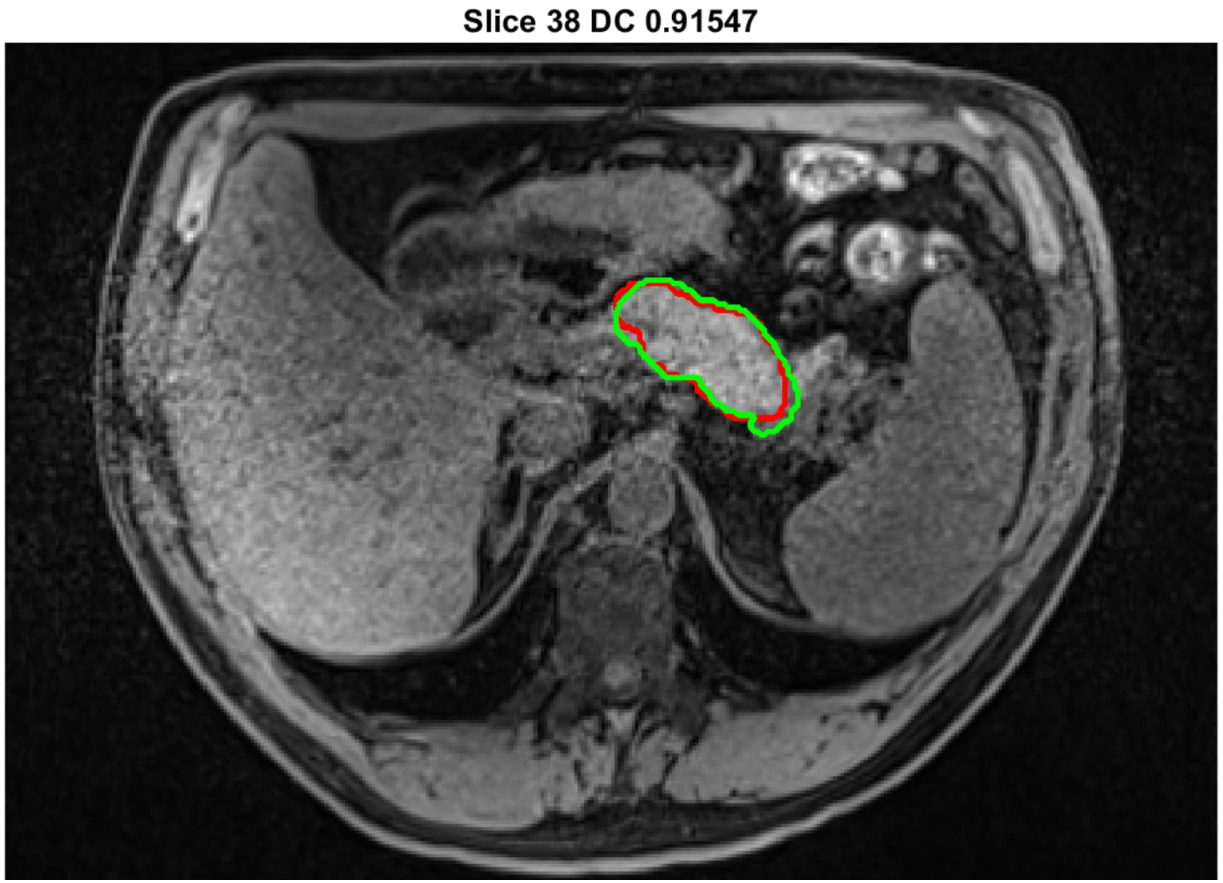
Scientific observation

Image representation of a particle collision which produces a Higgs Boson.



Medical

Location of Pancreas in MRI image (Asaturyan et al, 2019)



Geographic

London air pollution heat map showing annual mean Nitrogen Dioxide (NO_2) concentration

Environmental Research Group, Imperial College London, 2018

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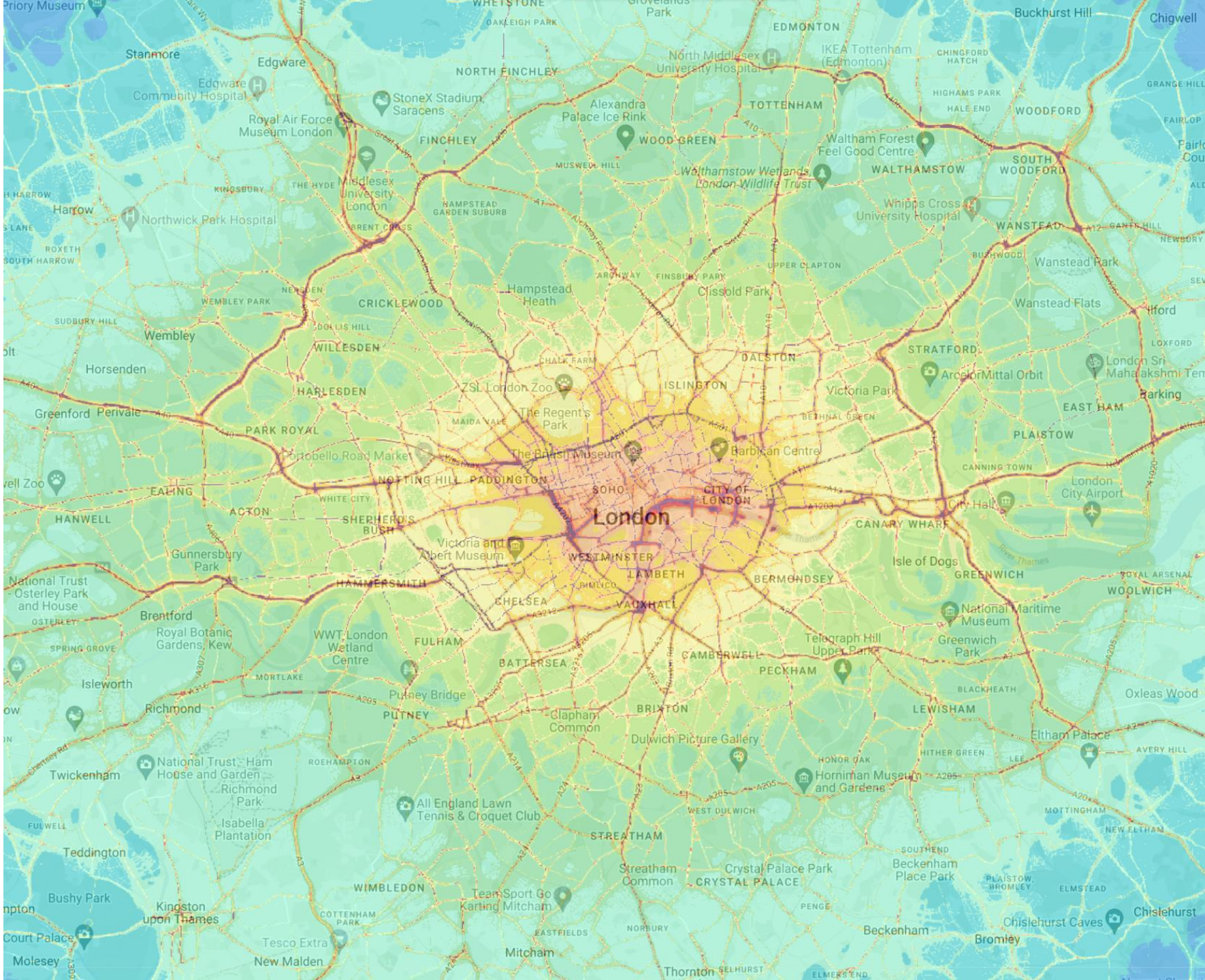


Challenges?

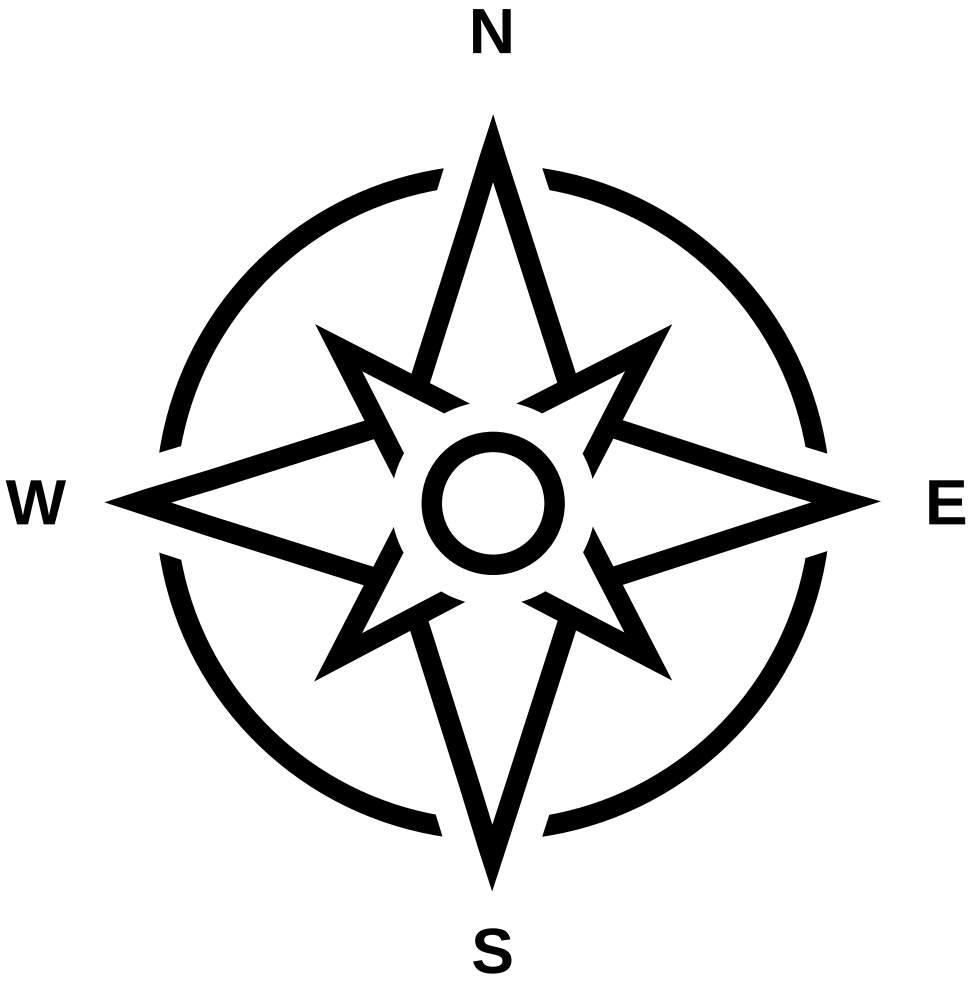
Viewer’s spatial understanding

Projections

Data accuracy

Question

Where is South America in relation to Africa?



Where is South America?

Many people place South America and Africa on similar latitudes

In reality, South America is far more South than Africa

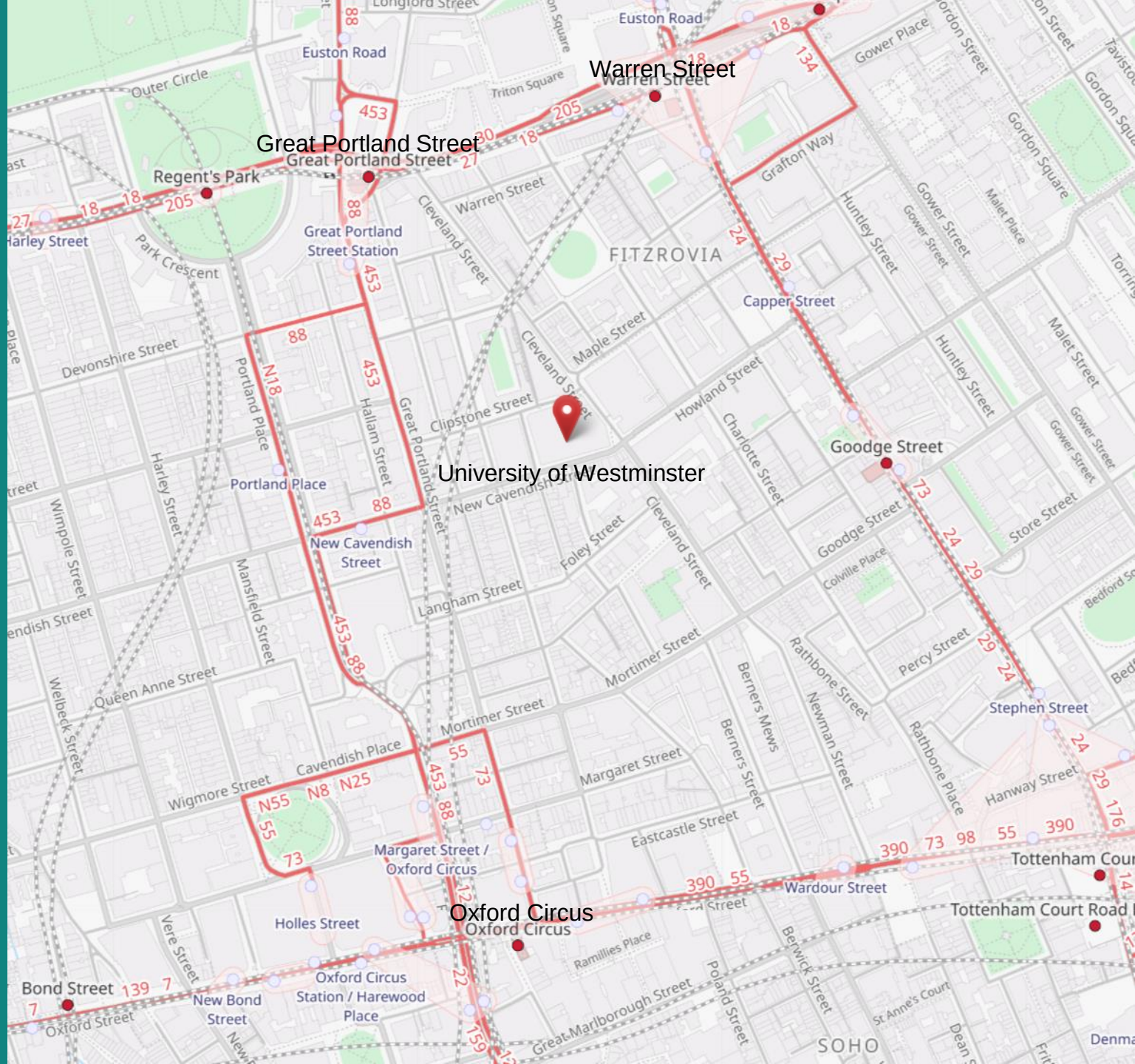
This is a useful simplification of a cognitive map

Cognitive Maps

Draw on the map how you're going to the next tube station

Cognitive maps are often simplified and not perfectly accurate

That doesn't make them useless or wrong!



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What are we looking at?

Earth seen from Apollo 17 - NASA

How about now?

Earth seen from Apollo 17 - NASA

Understanding maps – visual vocabulary

Maps form strong visual vocabulary

Brain associates shapes with specific geographic information

North being at top is pivotal to a viewers understanding of a spatial context

Why is North up?

The modern approach to maps orientates north at the top - but it wasn't always this way.

Historical Middle Eastern, Indian and Asian maps refer to east being at the top - potentially derived from solar patterns.

Ptolemy (a Greek scholar working in Egypt) was one of the first to define north at the top.

His work influenced later important European cartographers such as Mercator.

One of the benefits of North at the top was for easier navigation at sea (via the Polaris)

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Reconstitution of the map Tabula Rogeriana (1154) by arab geographer Al Idrisi, by German cartographer Konrad Miller

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Reconstitution of the map Tabula Rogeriana (1154) by arab geographer Al Idrisi, by German cartographer Konrad Miller

What shape is the Earth?

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The actual shape of the Earth

Difference in densities mean sea level is irregular

Oceans are not flat!

The mean sea level is called geoid

It is *roughly* an ellipsoid

Fun fact: The actual prime meridian is about 102 metres east of the Royal Observatory due to the earth's shape being irregular

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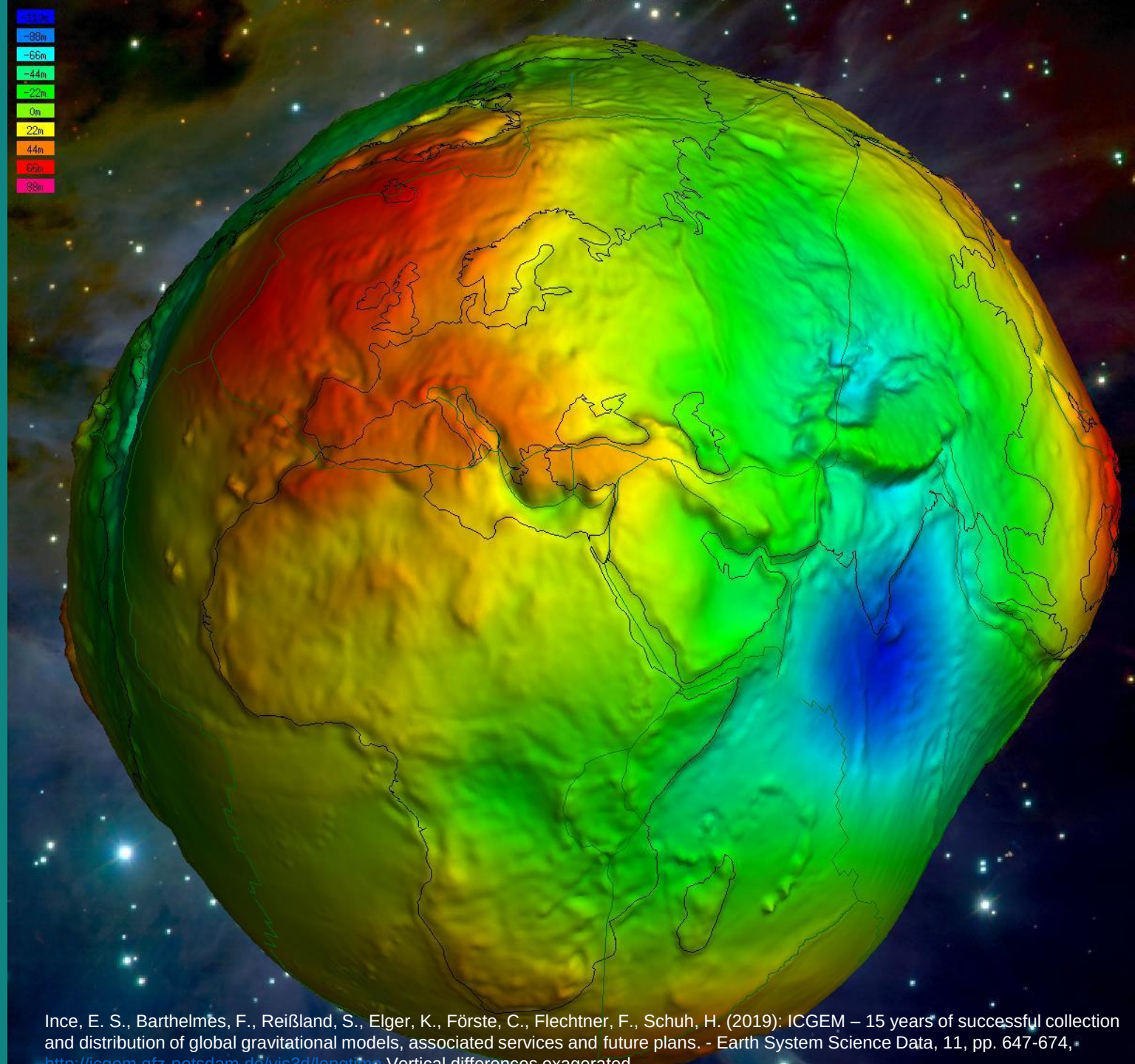
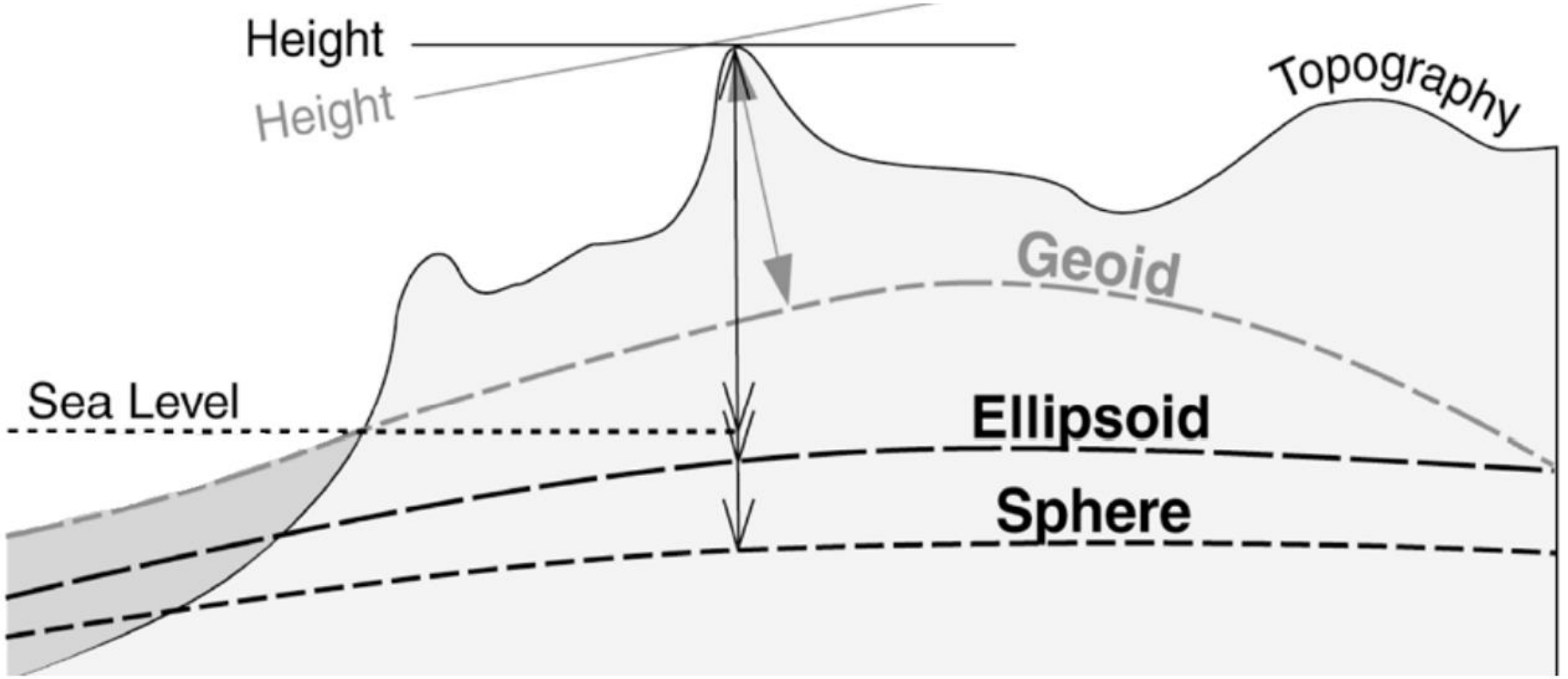


Ince, E. S., Barthelmes, F., Reißland, S., Elger, K., Förste, C., Flechtner, F., Schuh, H. (2019): ICGEM – 15 years of successful collection and distribution of global gravitational models, associated services and future plans. - Earth System Science Data, 11, pp. 647-674, http://icgem.gfz-potsdam.de/vis3d/longtime. Vertical differences exaggerated.

The shape of the earth



Fazal, S. (2008) GIS basics. New Delhi: New Age International P Ltd., Publishers.

Datum

- A datum defines reference system that describes
  - Shape of earth
  - Origin, orientation of coordinate system
- Hundreds of different datums
- Same coordinate point to different locations in different datums

Coordinate Reference System

Global coordinates usually described as degrees (°), minutes (‘) and seconds (“) latitude and longitude

$1° = 60' = 60^{2''}$

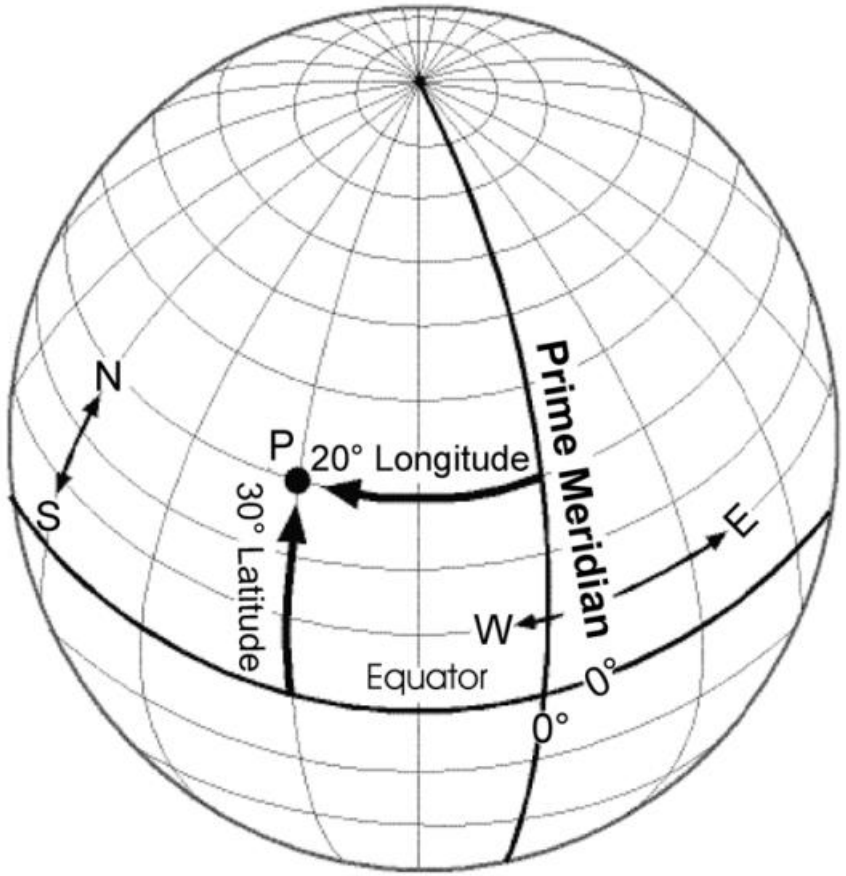
1 nautical mile (1852 metres) corresponds roughly to 1’ latitude

Latitude describes North-South axis (from 90° N to 90° S)

Longitude describes East-West axis (from 180° E to 180° W)

Circles parallel to the equator are known as parallels

Circles from North Pole to the South Pole are meridians



OS Grid system

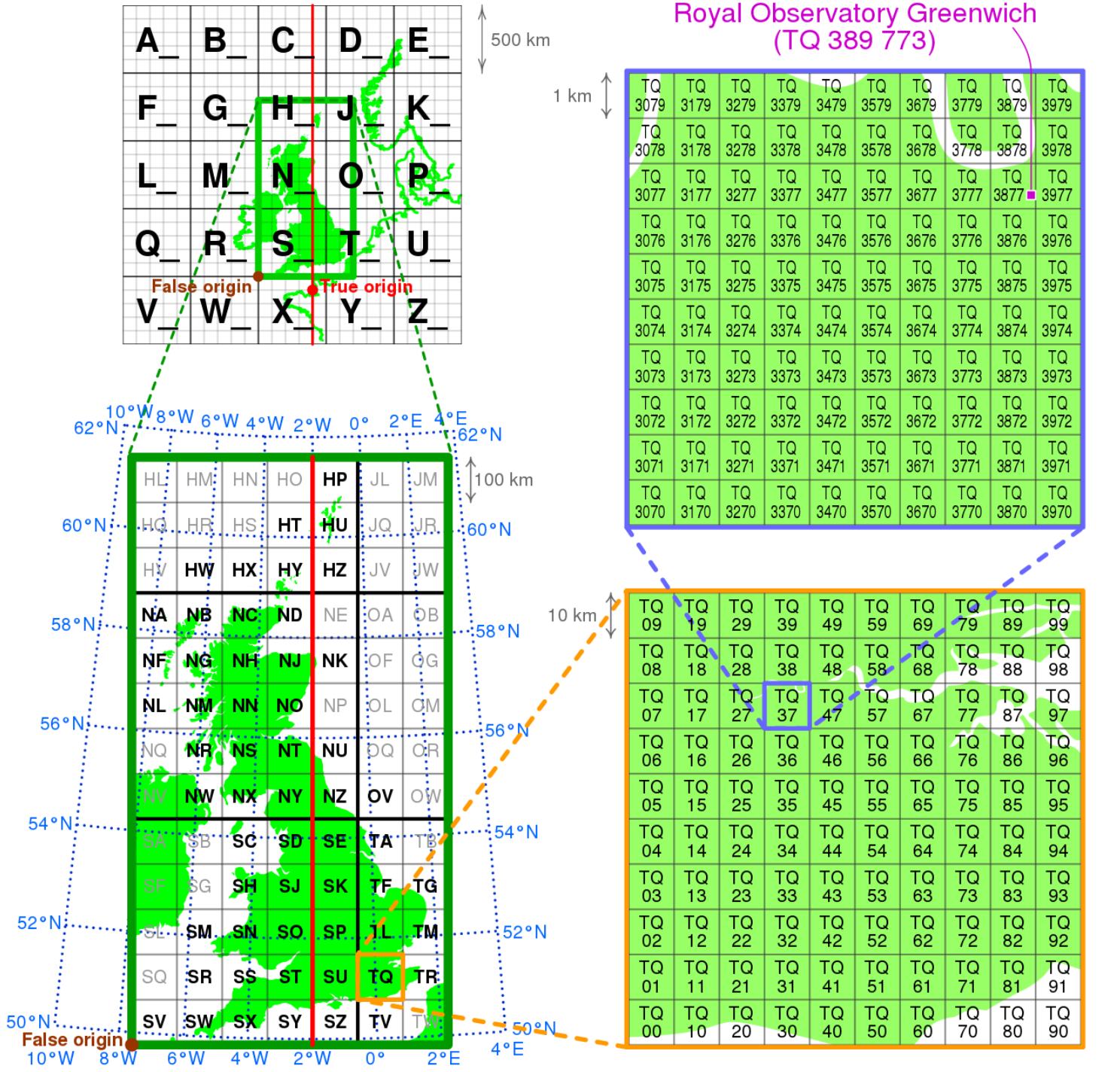
Used by Ordnance Survey

Distinct from longitude and latitude

Royal observatory cords are:

TQ 389 773, or

Easting 538900, Northing 177300



File:Ordnance Survey National Grid.svg - Wikimedia Commons

Projections

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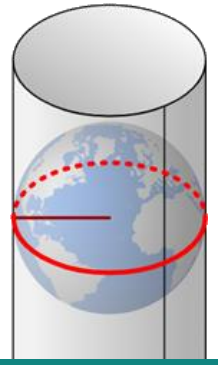
Photo by Tima Miroshnichenko: https://www.pexels.com/photo/woman-flipping-the-pages-of-a-book-5428000/

Projections

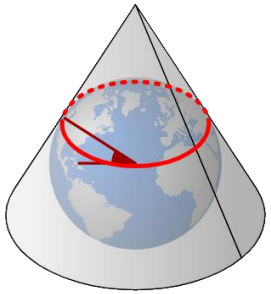


Cylindrical

Transform spherical surface to tangent (or secant) cylinder

Meridian are equally spaced vertical lines

Parallels are horizontal lines

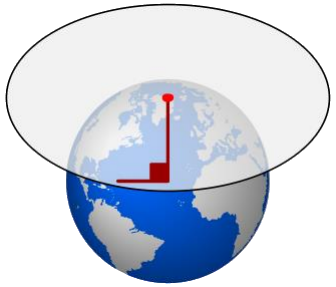


Conic

Surface of cone tangent at a small circle or intersect at two small circles

Meridians are straight lines

Parallels are arcs of circles



Azimuthal

Flat sheet is placed in contact with one point or intersecting small circle

Meridians are straight lines

Parallels are complete circles

$$x = R\frac{2\sqrt{2}}{\pi}(\lambda - \lambda_0)\cos\theta\,,$$

$$y = R\sqrt{2}\sin\theta$$

Non-Geometric

Some projections cannot be expressed geometrically and have only mathematical descriptions

Preservation of metric property

Conformal

Preserves shape and local angles

Usually distorts area/size

Equal-area

Preserves area/size

Usually distorts shapes

Equidistant

Preserves distance from one or two points

Compromise

A balance between distortions

Preserves neither shape nor area/size perfectly

Images from List of map projections - Wikipedia

Mercator projection

The Mercator projection is a cylindrical map projection presented by Flemish geographer and cartographer Gerardus Mercator in 1569.

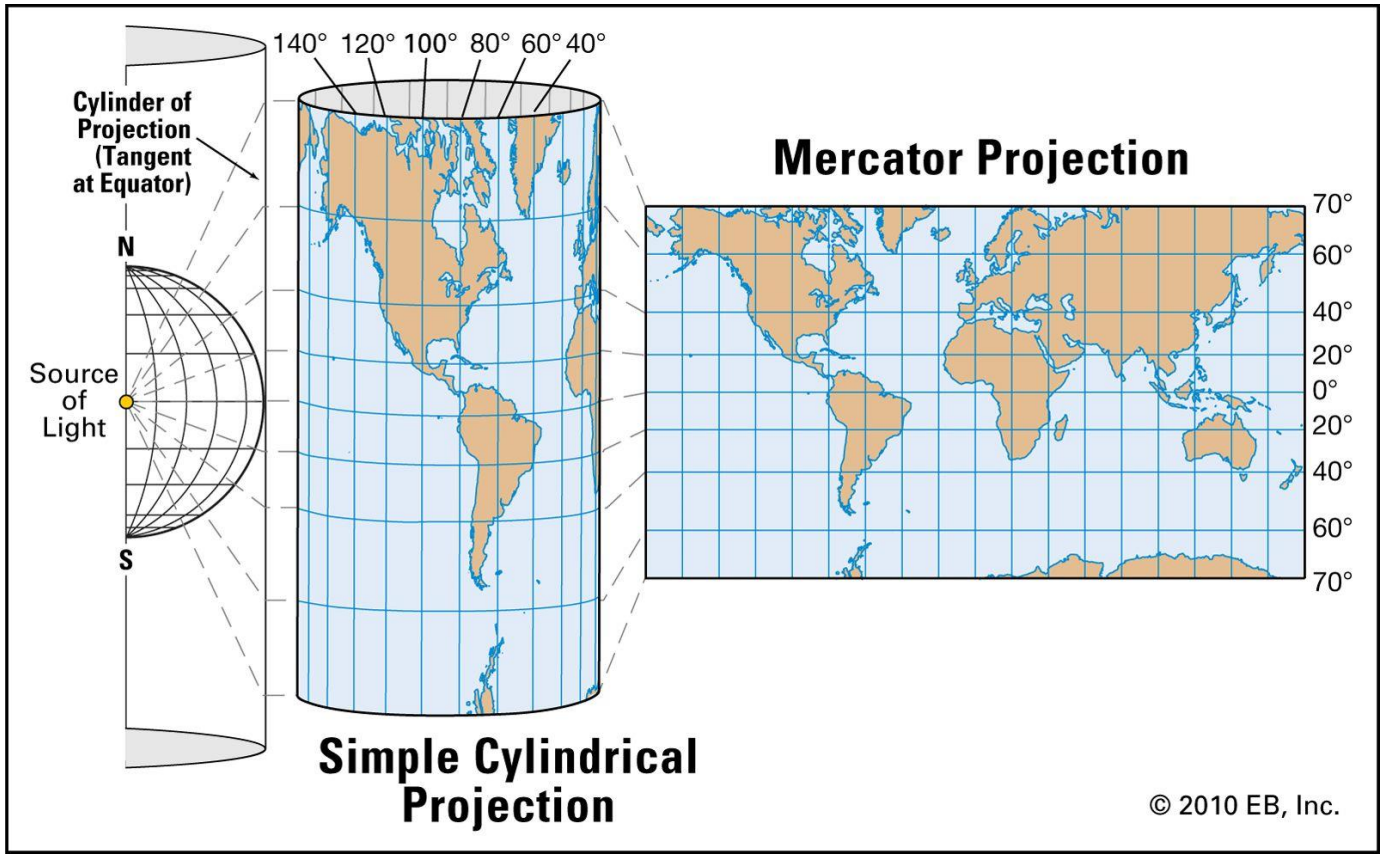
It became the standard map projection for navigation because it is unique in representing north as up and south as down everywhere while preserving local directions and shapes.

It is a conformal map projection in which every angle between two curves that cross each other on Earth (a sphere or an ellipsoid) is preserved in the image of the projection

the Mercator projection inflates the size of objects away from the equator.

This inflation is very small near the equator but accelerates with

increasing latitude to become infinite at the poles.



Encyclopædia Britannica, Inc

Mercator projection

Mercator projection of the world between

85°S and 85°N.

Note the size comparison of Greenland and Africa

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Problems with Mercator projections

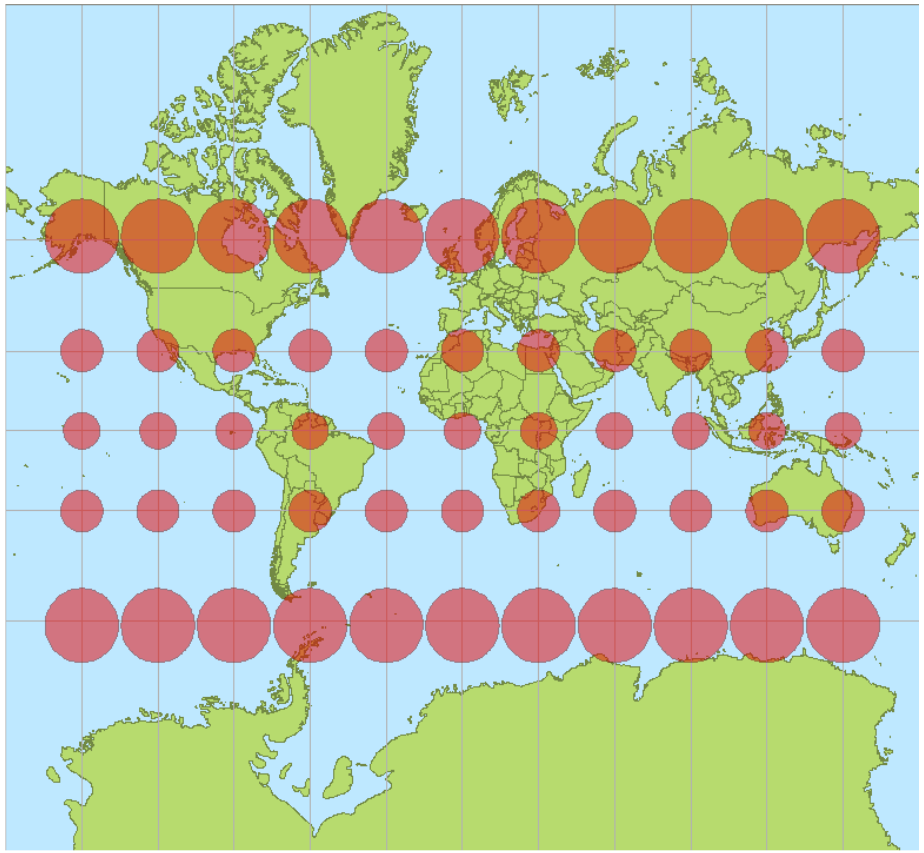
Tissot's indicatrices (coloured red) are mathematical contrivance presented by French mathematician Nicolas Auguste Tissot in 1859 and 1871 in order to characterize local distortions due to map projection.

A single indicatrix describes the distortion at a single point.

Because distortion varies across a map, generally Tissot's indicatrices are placed across a map to illustrate the spatial change in distortion.

A common scheme places them at each intersection of displayed meridians and parallels.

These schematics are important in the study of map projections, both to illustrate distortion and to provide the basis for the calculations that represent the magnitude of distortion precisely at each point.



Integrity

Consider the faces and imagine this as a graph – how much graphical integrity does the Mercator have?

Elements in Map Projection, 1921

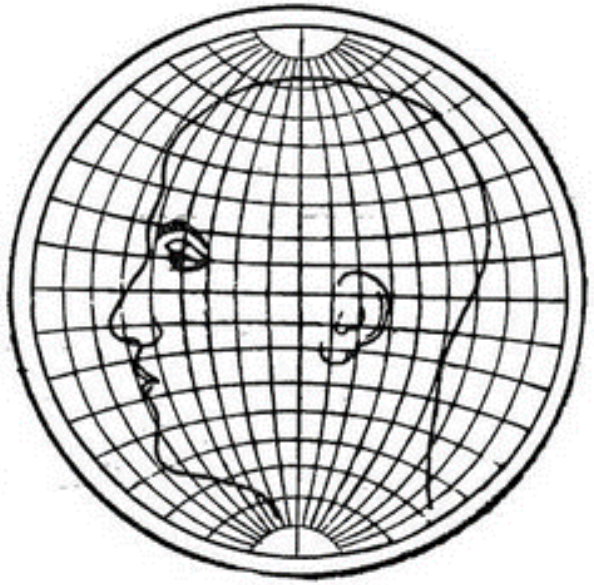


FIG. 42.—Man's head drawn on globular projection.

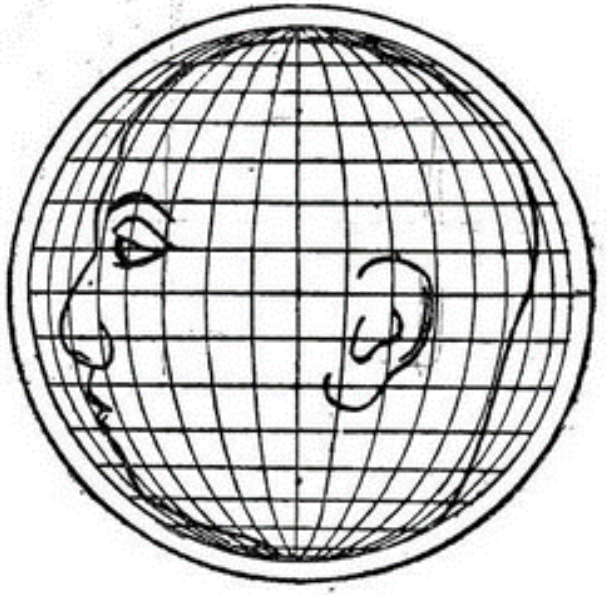


FIG. 43.—Man's head plotted on orthographic projection.

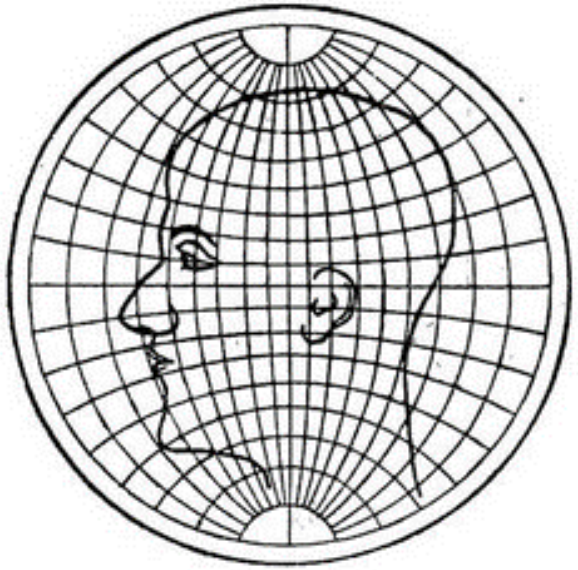


FIG. 44.—Man's head plotted on stereographic projection.

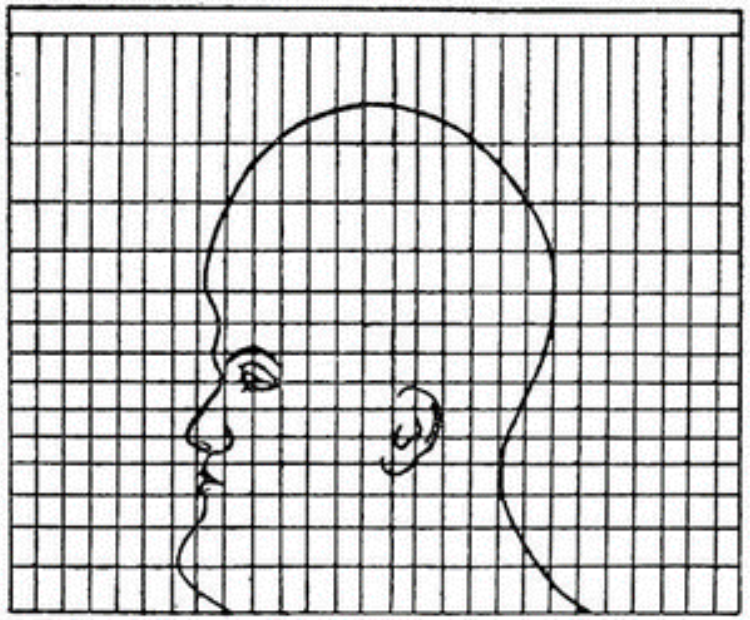


FIG. 45.—Man's head plotted on Mercator projection.

The true size of Africa

Kai Krause, “The true size of Africa”

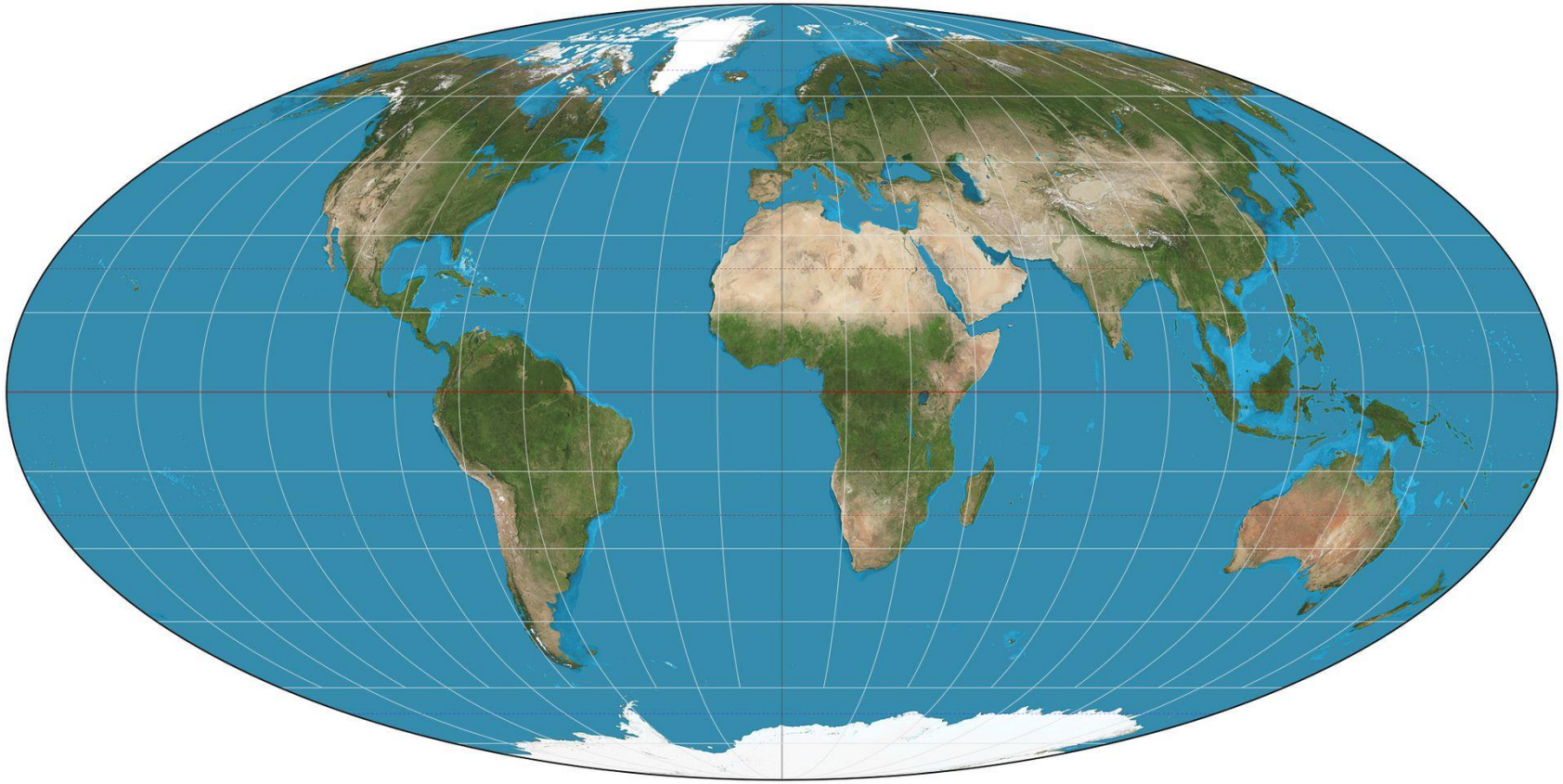
Alternative projections

Mollweide projection

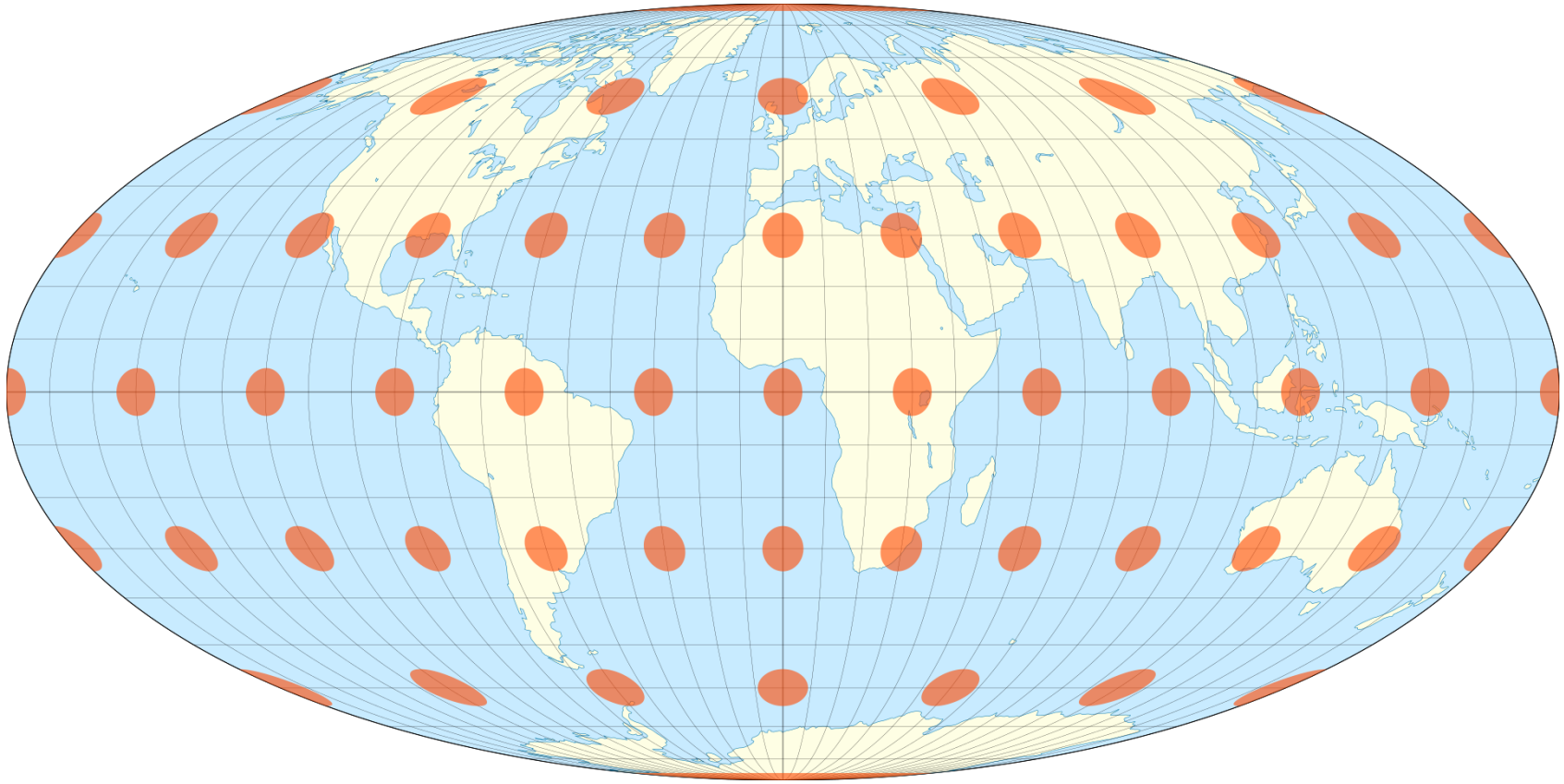
Equal area

Distorted shapes and angles

Good for maps depicting global distributions



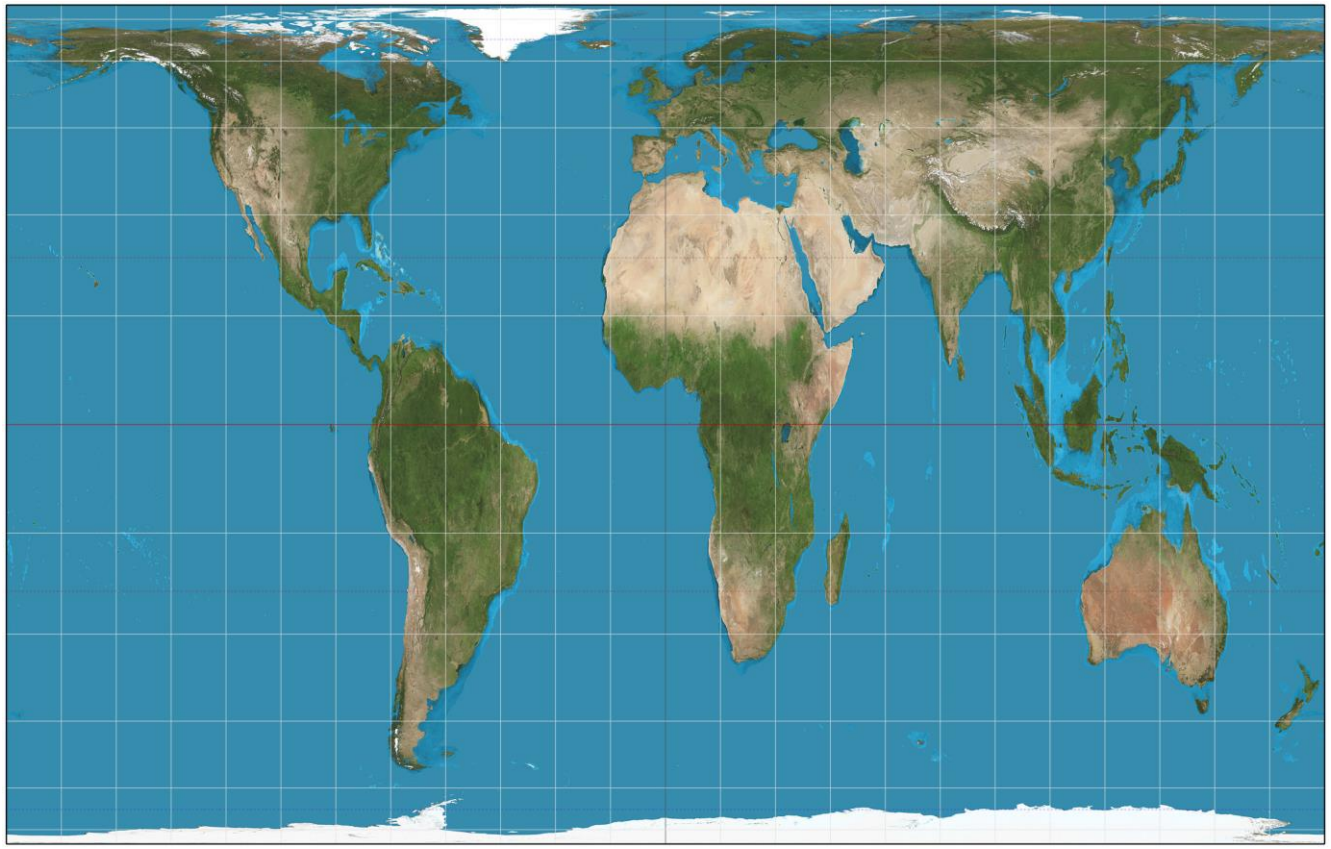
Mollweide projection



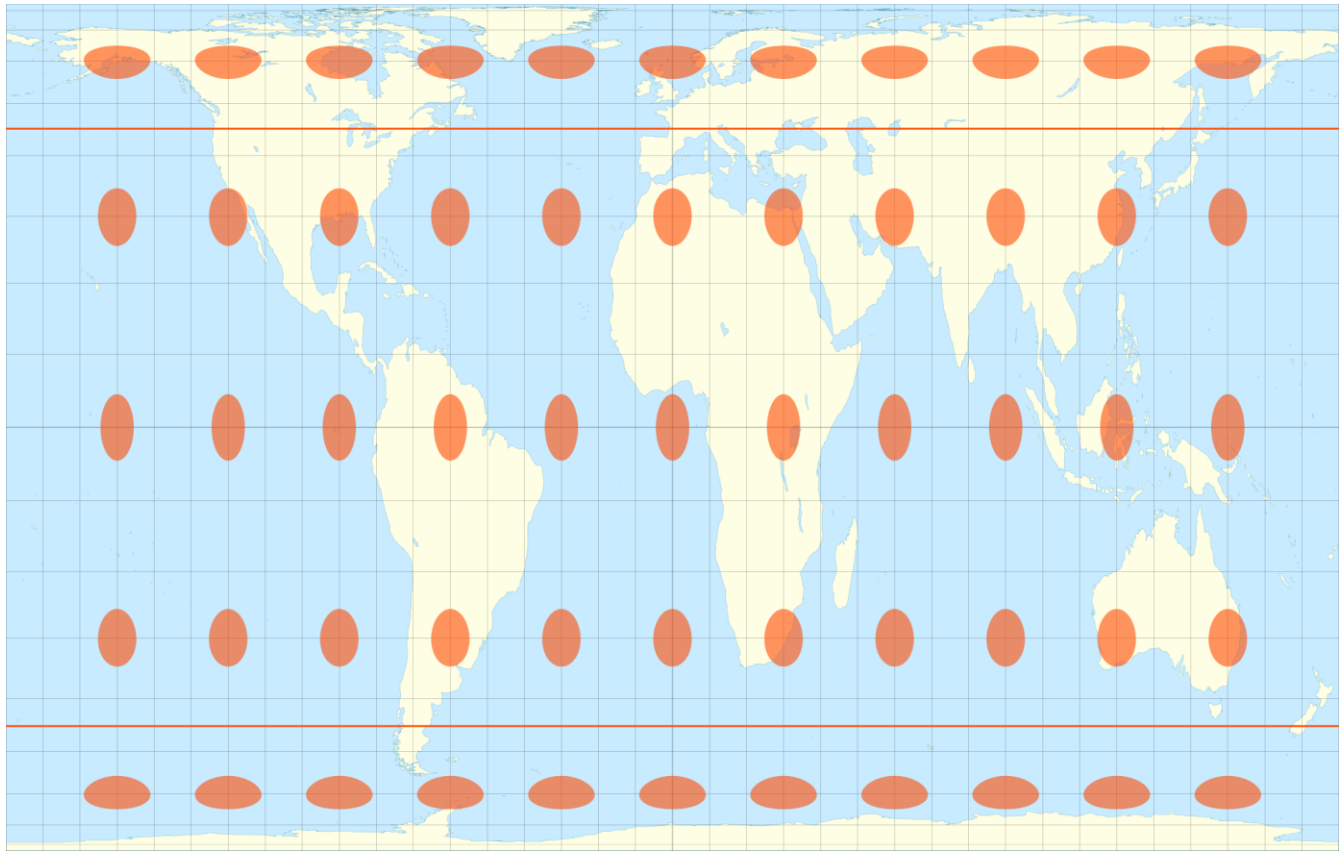
Gall-Peters Projection

Rectangular, equal-area

Distorts shapes



Gall-Peters projection

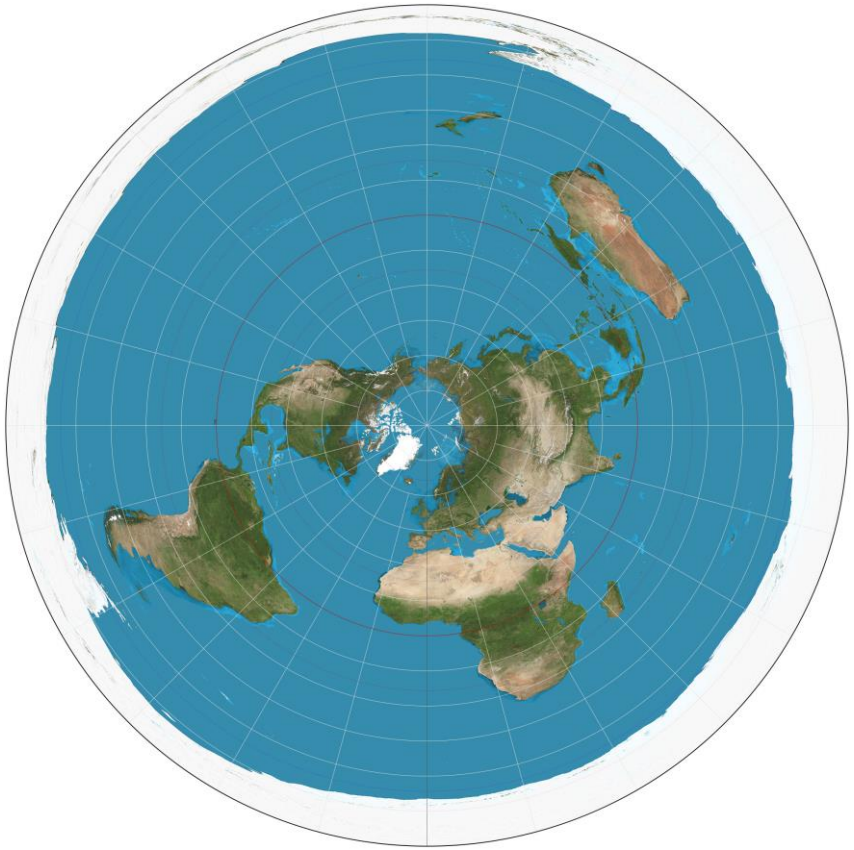


Azimuthal equidistant

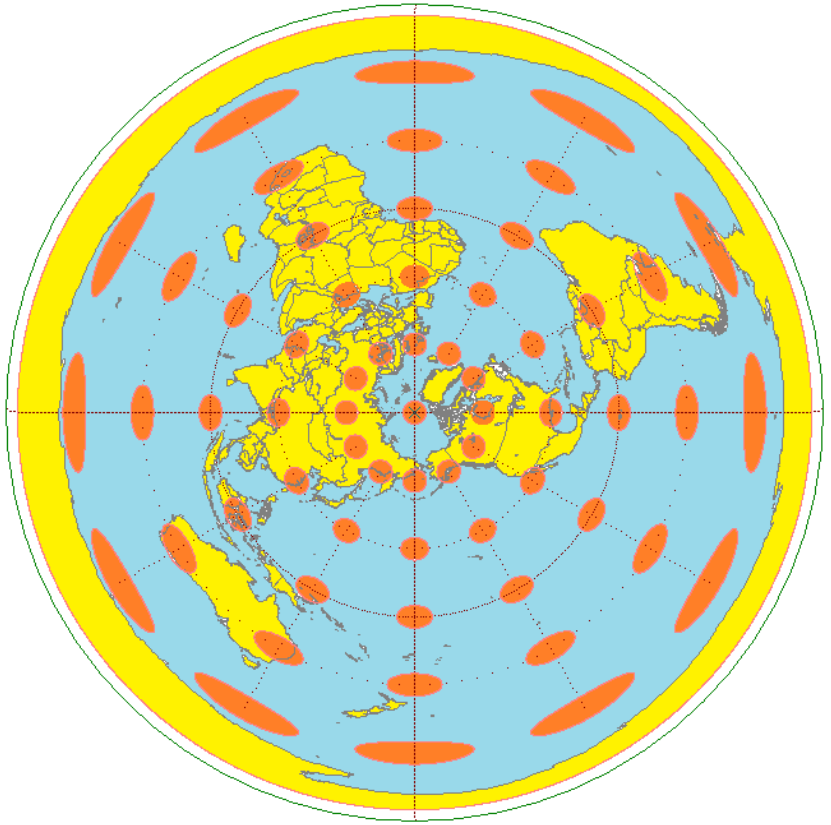
All points are at proportionally correct distances from the centre

Used in the flag of the United Nations

Highly distorted at the edge



Azimuthal equidistant



Alternative projections

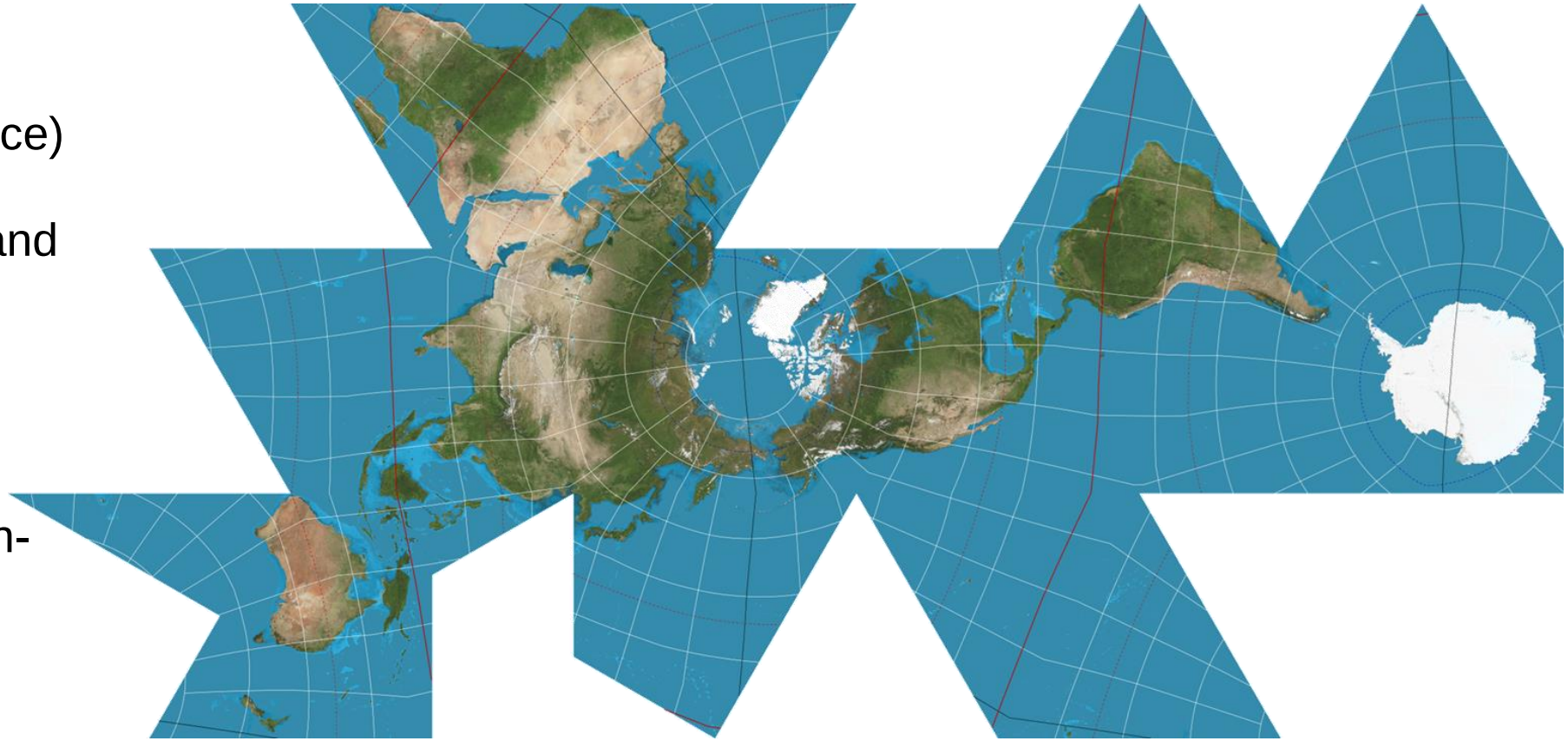
Dymaxion map

Projected globe onto icosahedron (20-faced dice)

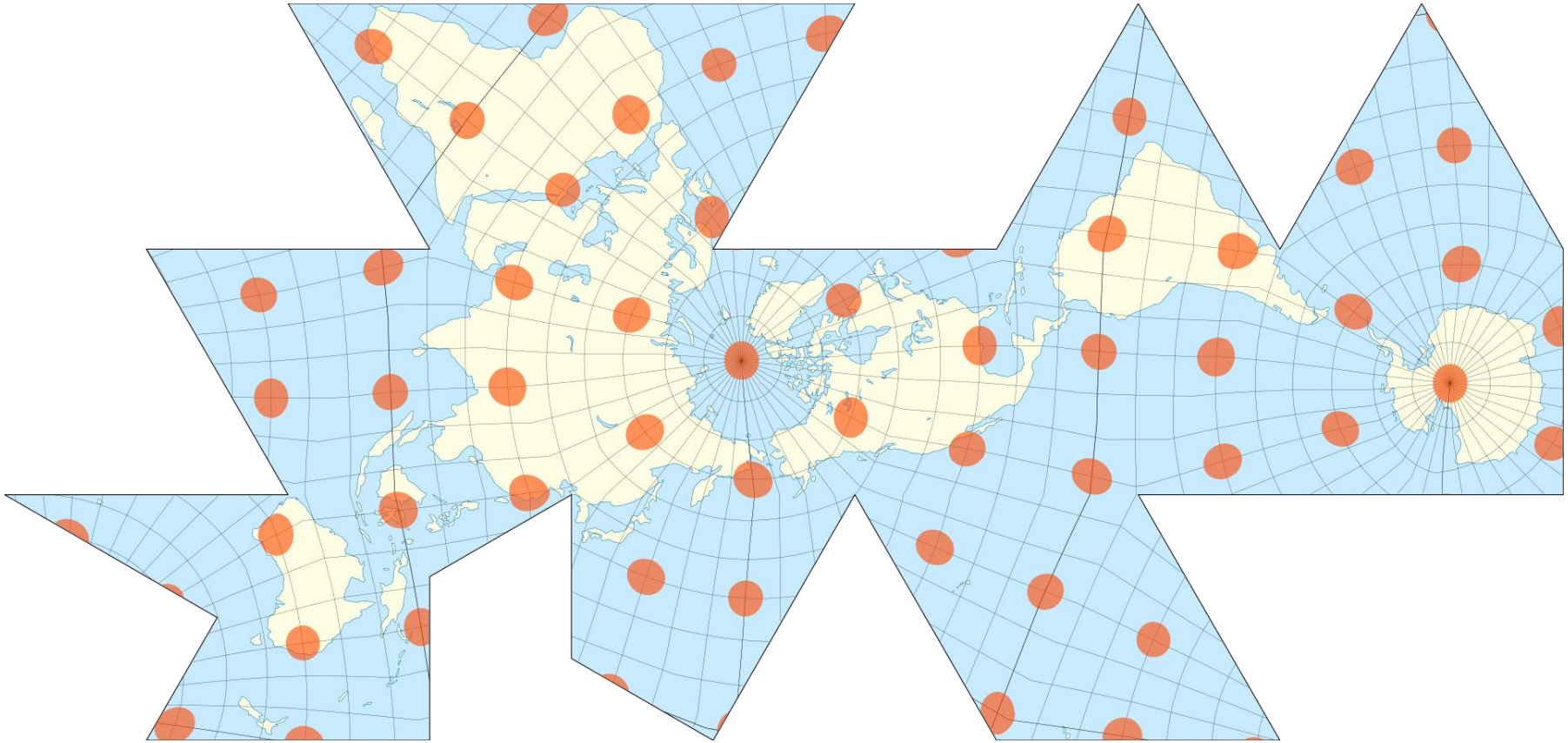
Less distortion of areas and shapes

Heavily interrupted

Not north-facing (or south-facing)



Dymaxion map



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Visualising spatial data

What data can we visualise?

Spatial data

Single locations (Points, e.g. train stations)

Shape (London boroughs)

Routes/Lines (Two or more points, e.g. King's Cross-Inverness)

Non-spatial data

Location-related data (e.g. train station passenger numbers)

Region-related data (population per borough)

Route-related data (number of trains per day)

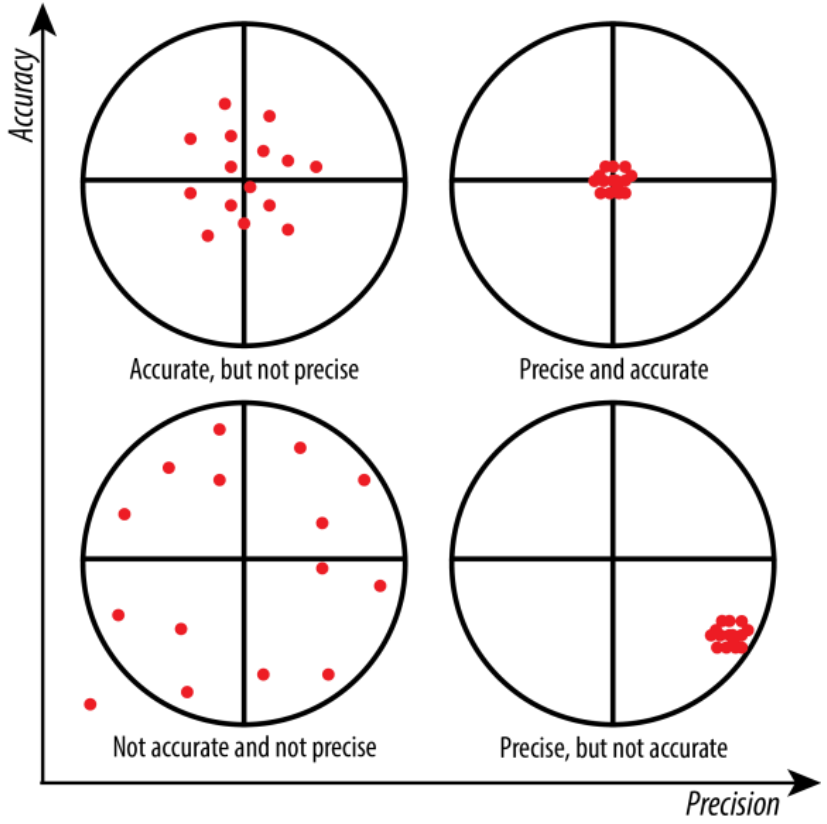
Data quality

Point data - which of these is both precise and accurate?

Data source? Spatial datum used in data capture makes a difference!

Data quality matters for spatial data

- Need to understand the data collection method used.
- How detailed is the co-ordinate provided? What was the collection method?
- For example, GPS co ordinate accuracy varies by device and location (cheaper devices in cities are often less accurate due to using fewer satellites to 'fix' location and can be affected by signal scatter due to built up areas.)



A note on generalisation

Maps can often contain very intricate features

E.g. a border may have several small bends

Sometimes, these features are imported (e.g. in a land dispute)

Other times, we don’t need these fine details (e.g. while displaying a high-level view of a border)

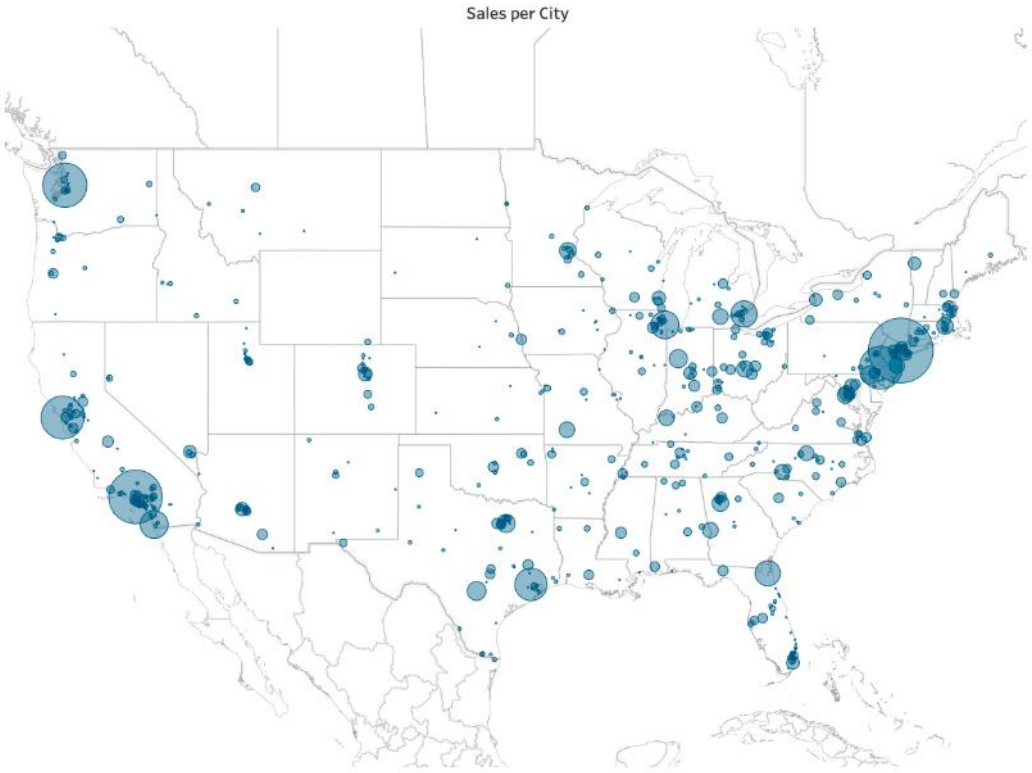
Generalisation is the concept of removing fine details that are not necessary on smaller-scale maps

Symbol Maps

Symbol Maps display quantitative values for specific locations on a map

Values are usually represented via proportionally sized circles

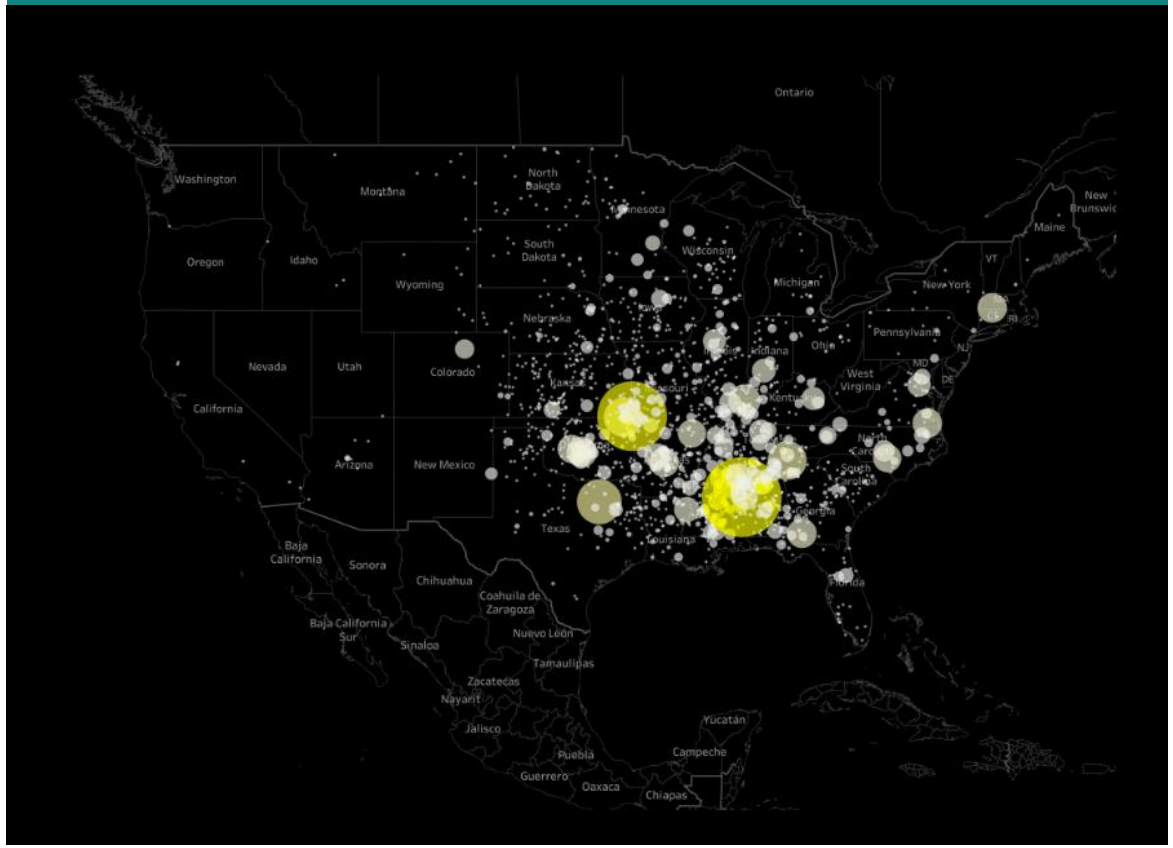
Colour can indicate a further category



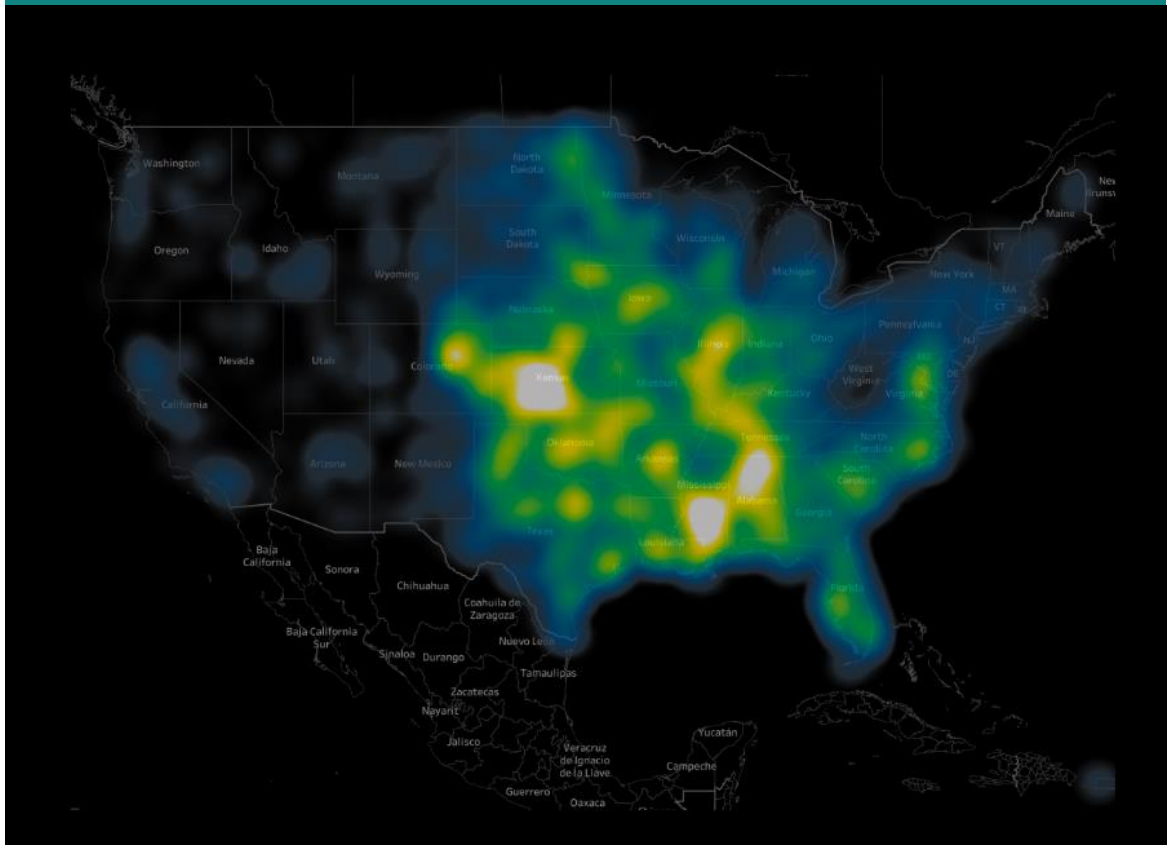
Understanding and Using Symbol Maps | Tableau

Symbol Map vs Heat map

Poor example



Better alternative



Animated symbol map

Symbol maps can be neatly combined with animations to illustrate more complex data

This animations shows the touch-ins and outs of Oyster cards at London's tube and train stations

The proportion between touch-ins and touch-outs is shown using a red-green diverging colour scale

Example: London's Oyster Card Tidal Flow – Suprageography (oobrien.com)

Density Plot

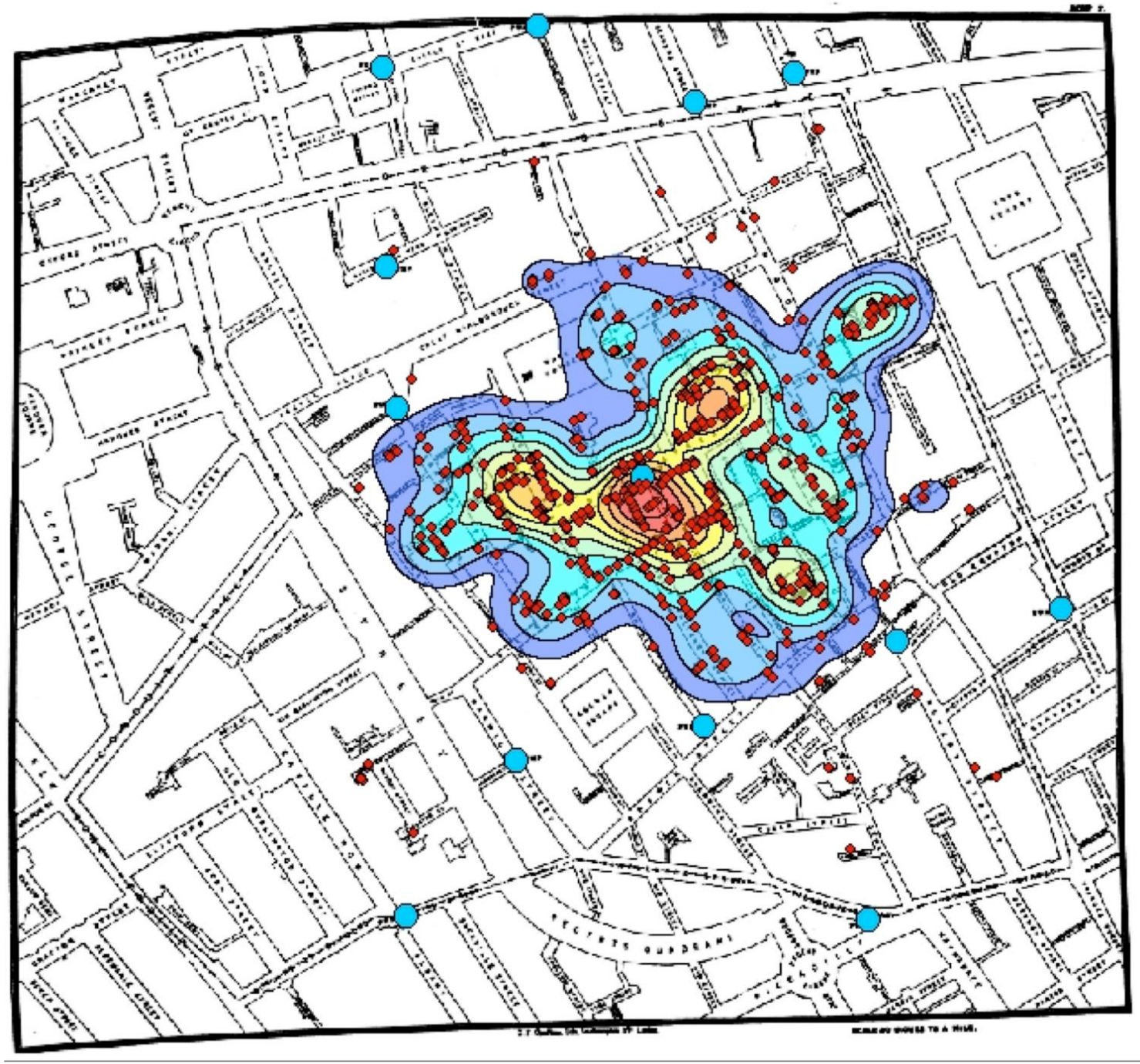
This is an isoline density plot generated from Dr Snow's observations of the Soho Cholera deaths

Mapping the 1854 London Cholera outbreak J. Mackenzie, 2010

Spatial density converts distributed points into a continuous raster surface.

This has the benefit of understanding hot spots in context with all of the map.

However, it is easy to misinterpret a hotspot as an actual physical location - it may just be the central point between actual hot spots.



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Displaying spatial data

Choropleth (Filled Map)

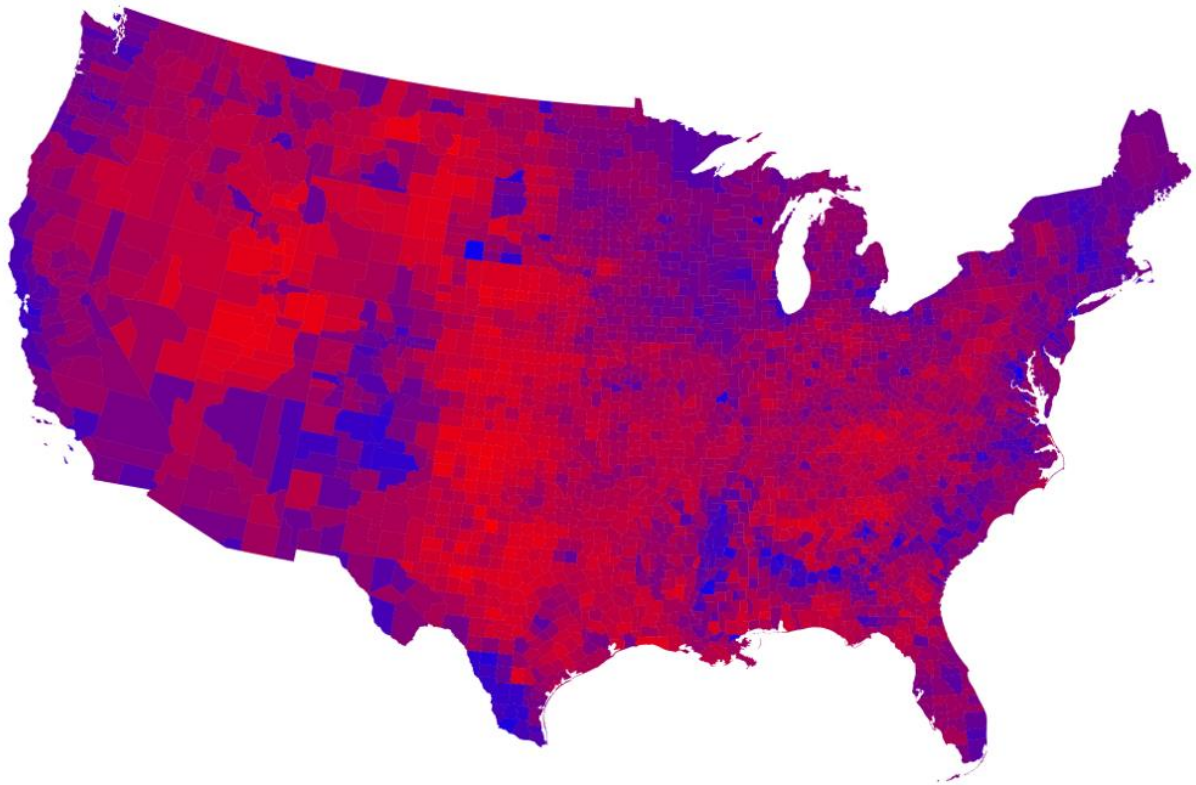
A map which uses differences in shading, colouring, or the placing of symbols within predefined areas to indicate the average values of a particular quantity in those areas.

Maps of the 2012 US presidential election results

Choropleths are a common approach to showing data values by re colouring area polygons.

However, they are prone to mis-stating data values due to their area-based encoding u which tricks the viewer.

Consider the US election map - which side won? (Democrat Blue won but Republican Red looks more or equally dominant)



http://www-personal.umich.edu/~mejn/election/2012/countymappurple1024.png

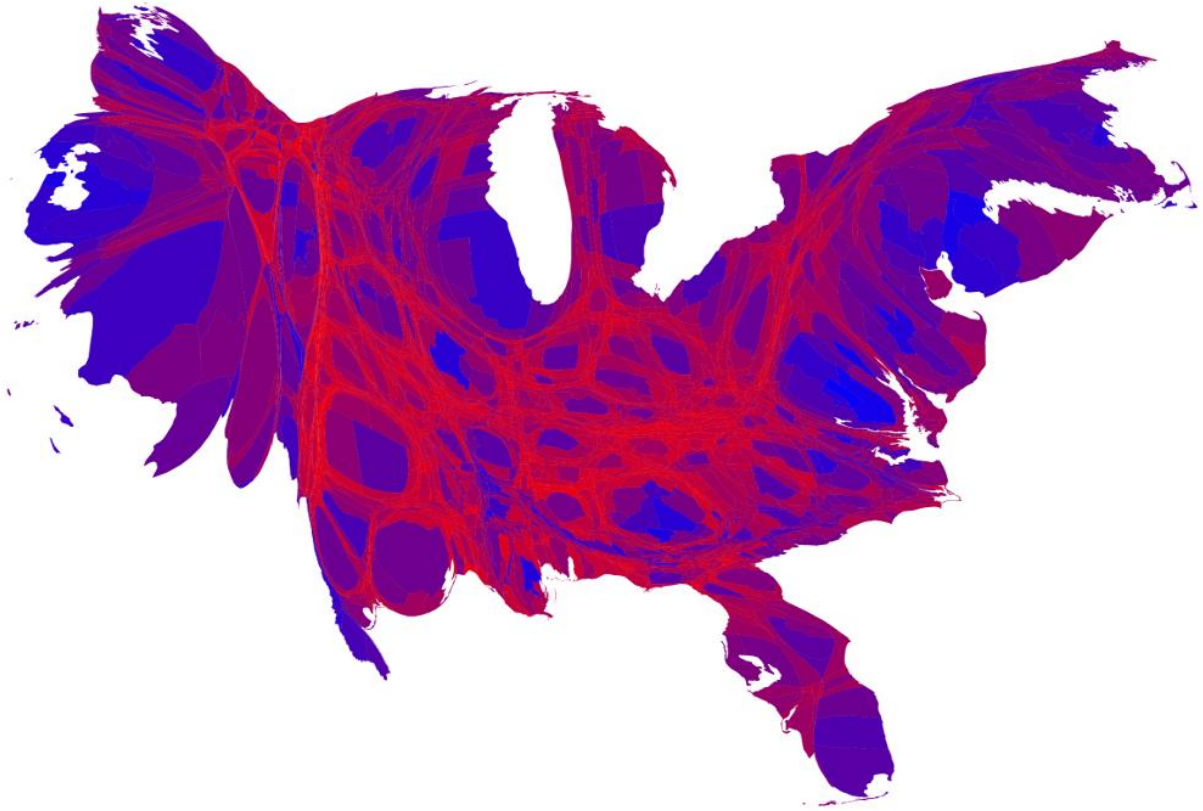
Displaying spatial data

Cartogram

A cartogram (also called a value-area map) is a thematic map of a set of features in which their geographic size is altered to be directly proportional to a selected ratio-level variable, Geographic space itself is thus warped.

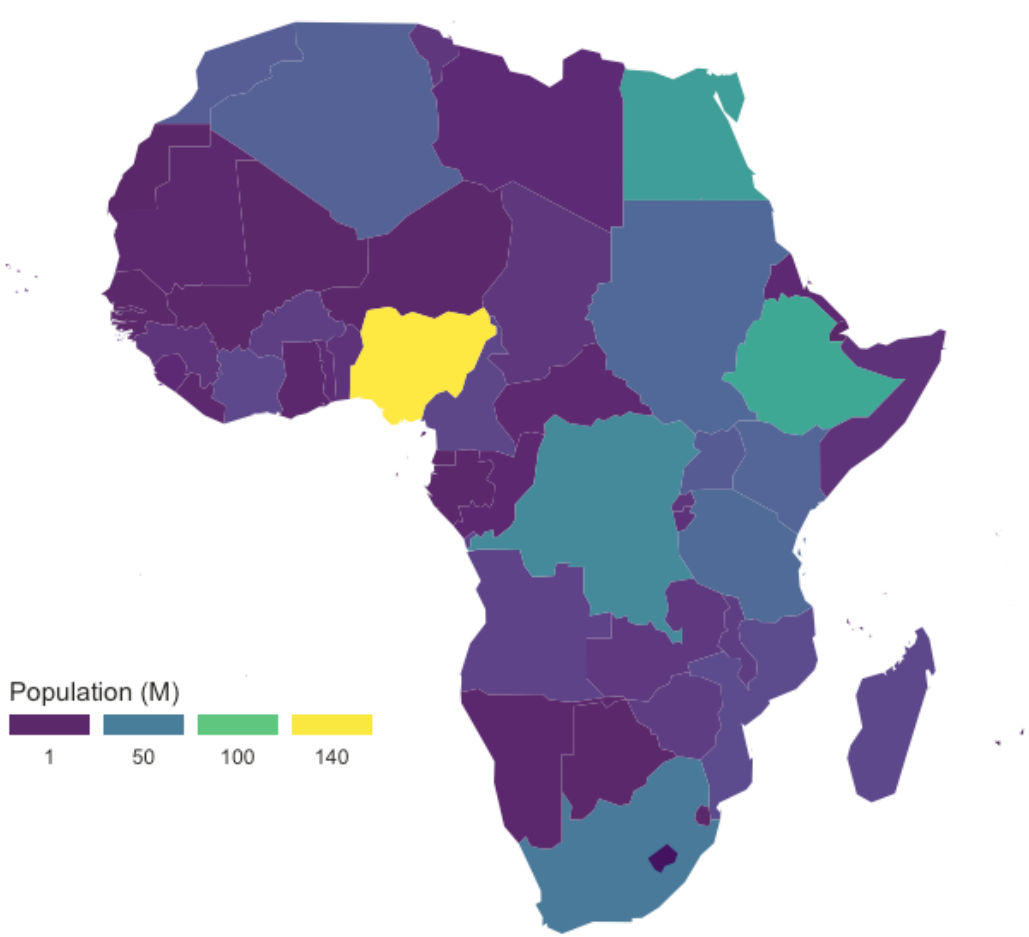
These attempt to rectify Limitations of Choropleth by re-shaping the map to a base area statistic such as population.

This does create a better area colour encoding but does break the visual encoding of a map shape for viewers to understand spatial context.

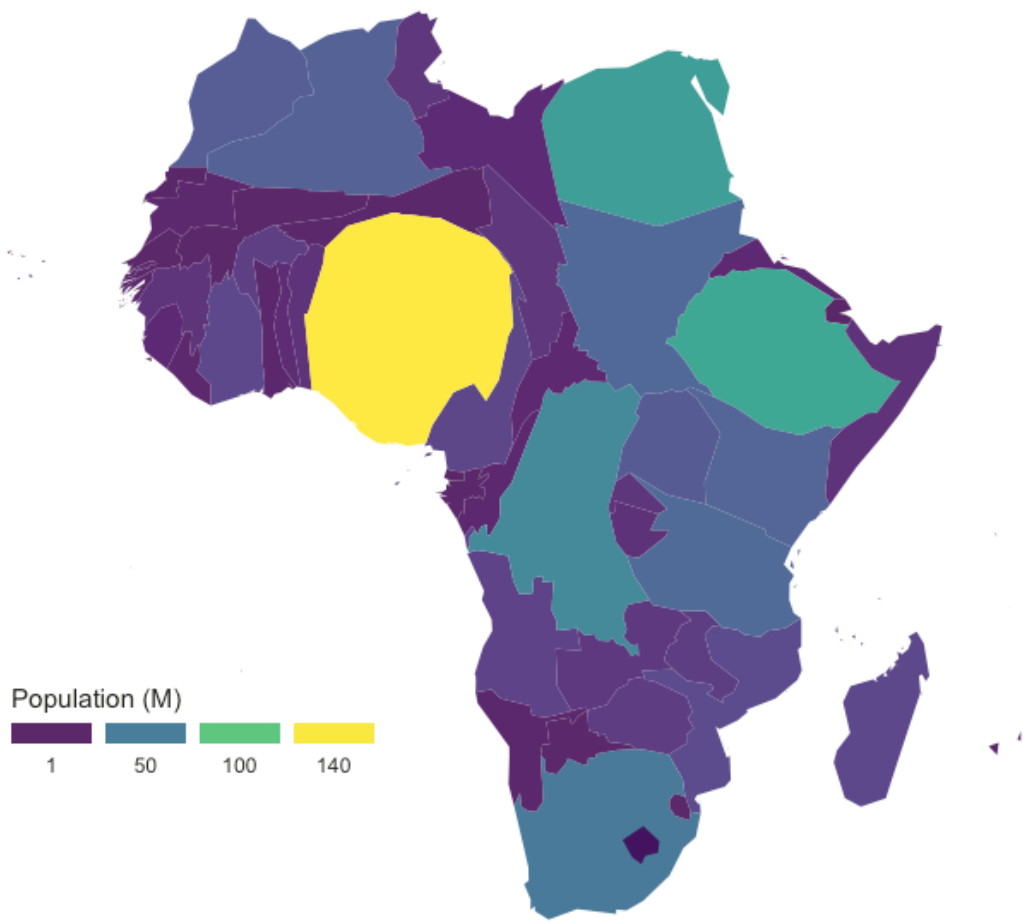


http://www-personal.umich.edu/~mejn/election/2016/countycartpurple1024.png

Real boundaries



Cartogram

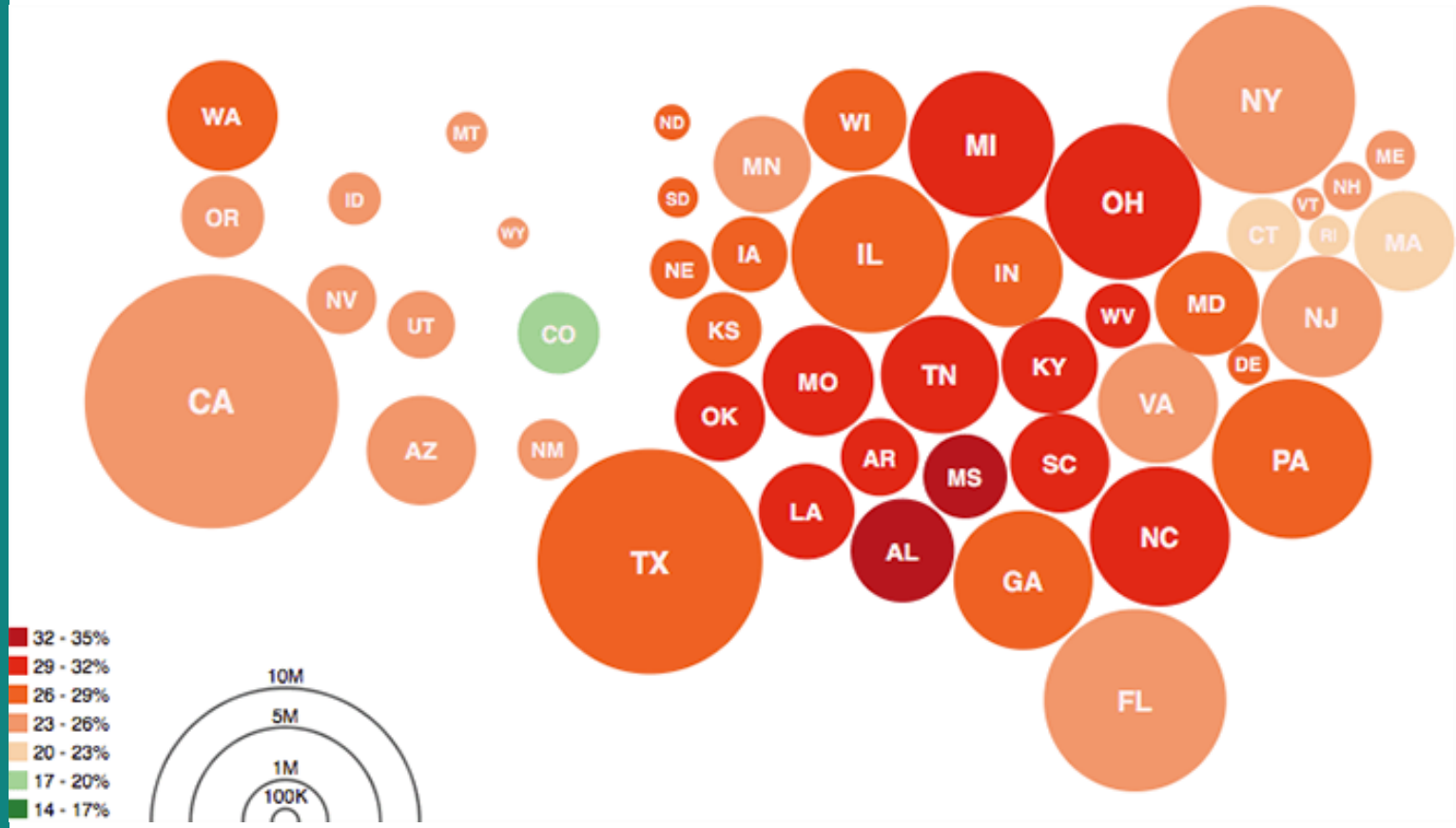


Dorling Cartogram

Encodes quantitative value associated with a region

Each region is represented by a circle proportionally sized to represent a value

Colour can encode another value (quantitative or categorical)

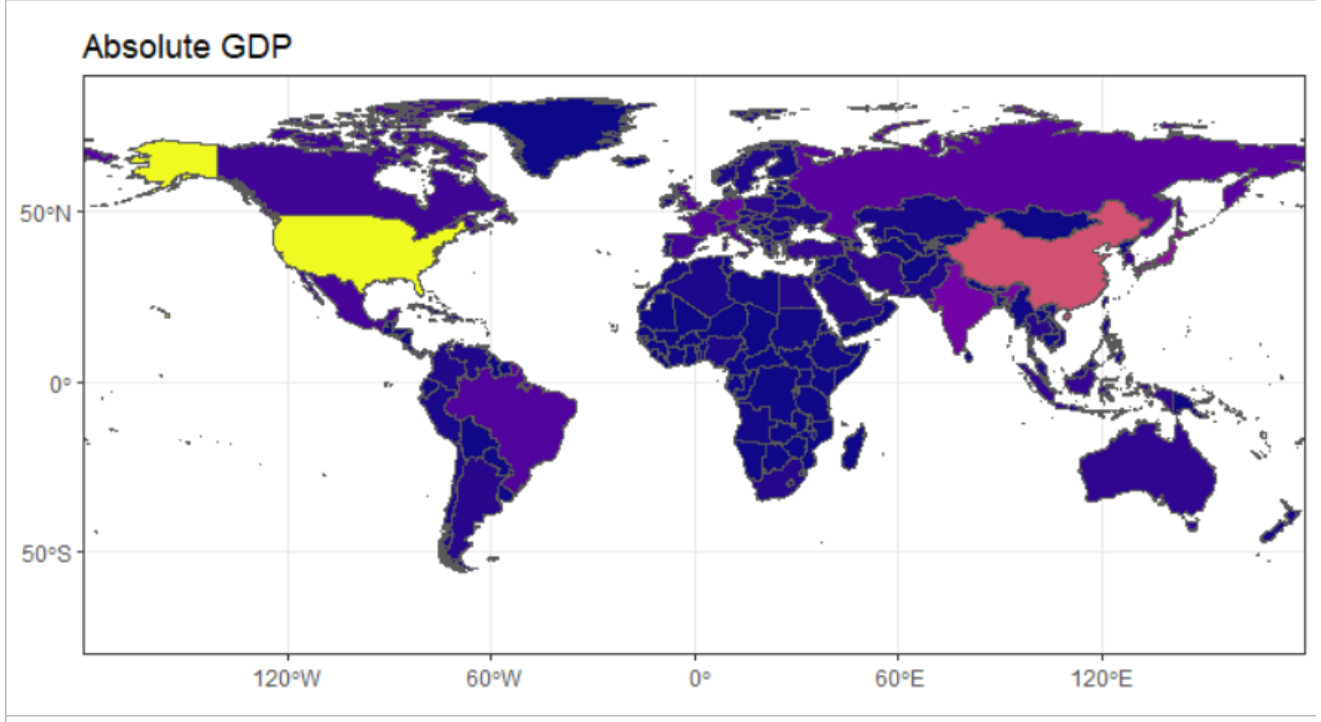


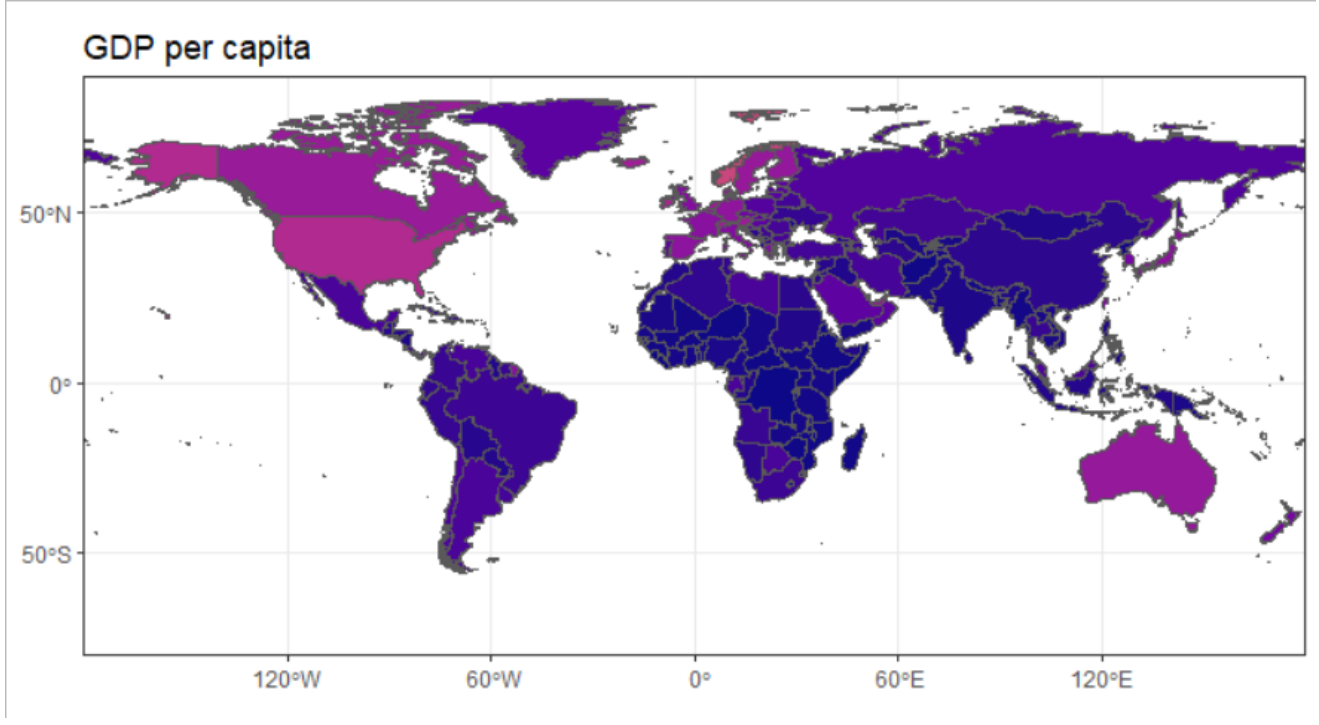
Per Capita

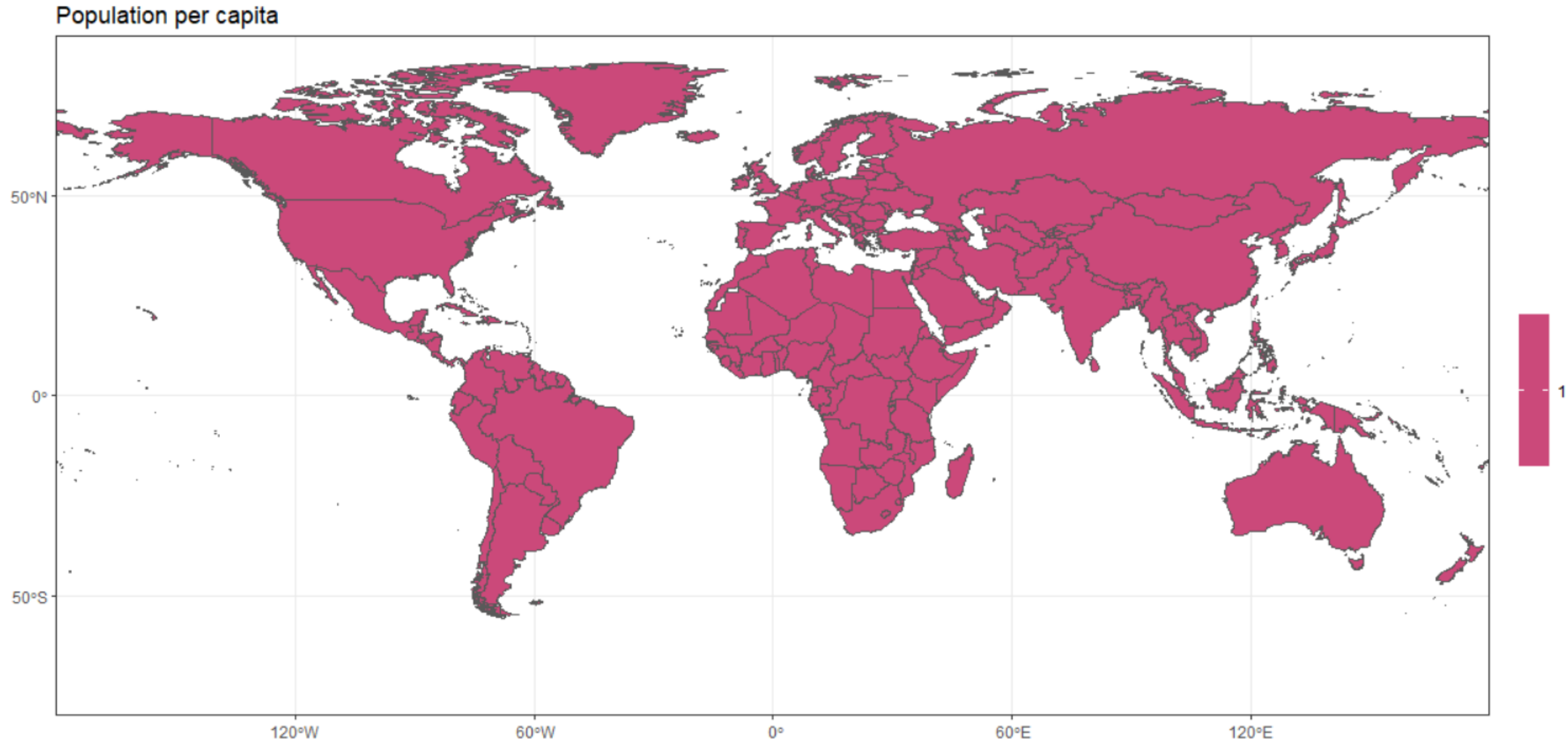
Comparing absolute values in a choropleth doesn't always make sense

Sometimes, a value is bigger because the country is bigger

Dividing values by population (per capita) is often better





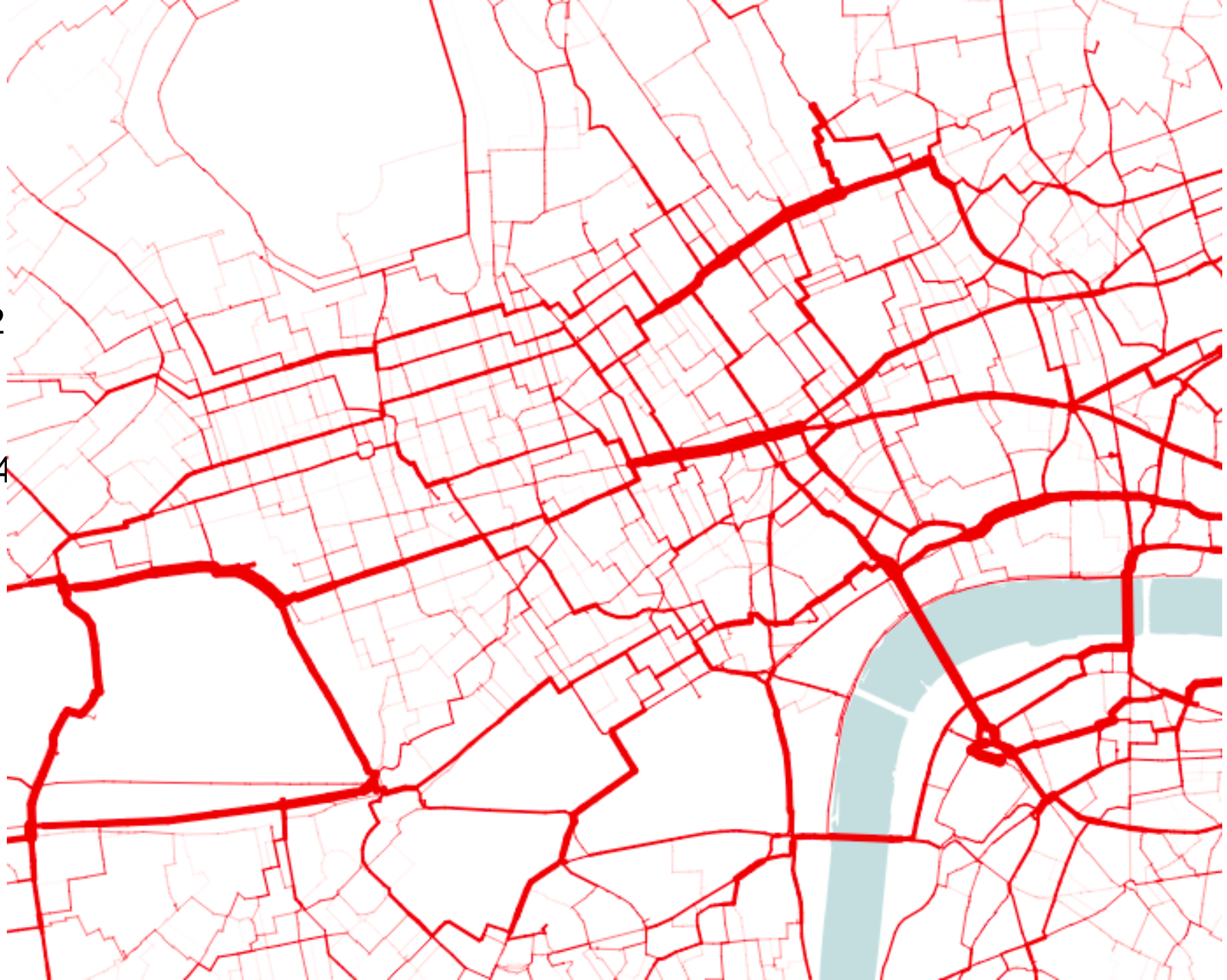

Population per capita
50°N
0°
50°S
120°W
60°W
0°
60°E
120°E
1

Line

London Cycle Hire Feb 2012

routes and volumes

O. O’Brien, CASA UCL, 2014



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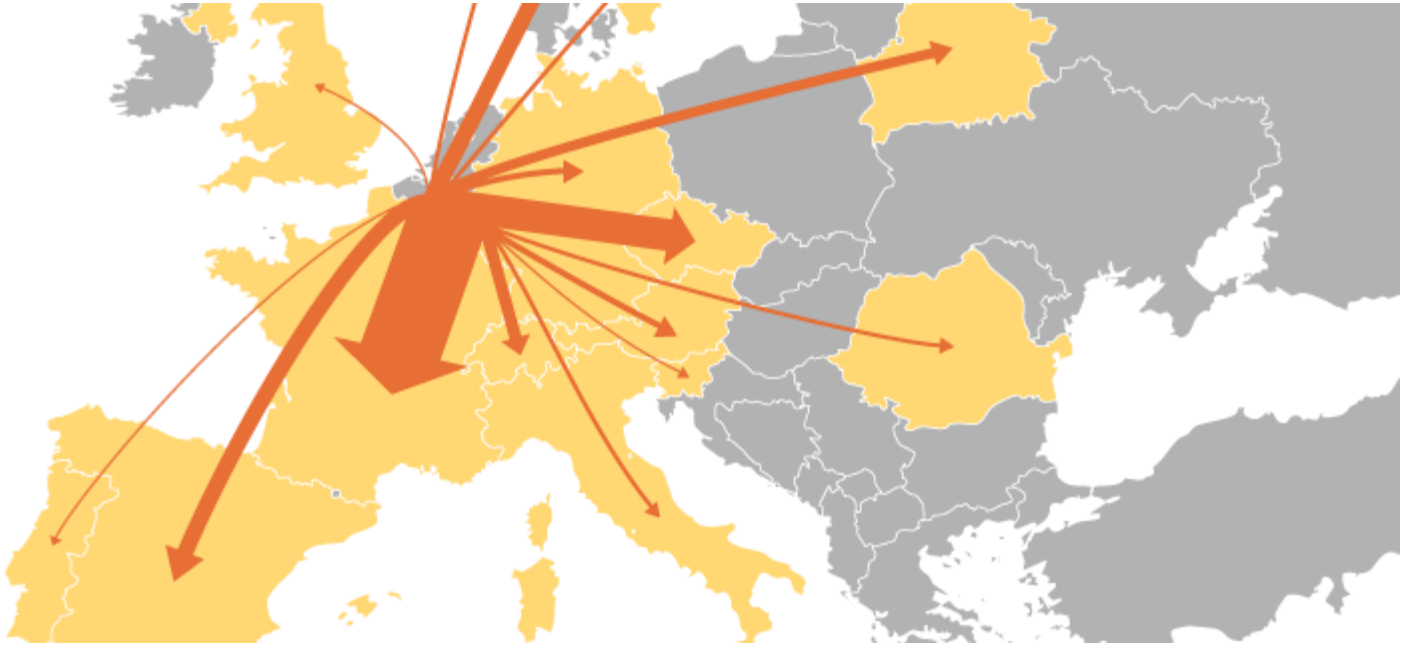
Flow Map

Visualised routes (origin to destination) and a qualitative value



Flow Map - Learn about this chart and tools to create it (datavizcatalogue.com)

Tools

Tools for geospatial data

GIS bespoke spatial tools

- QGIS (free open source),
- ESRI ArcGIS (industry mainstream proprietary), MapInfo (ESRI competitor)
- GDAL - Spatial data manipulation

Spatial data visualisation

- R & ggplot, Tableau, Javascript -D3, Leaflet, ModestMaps, Google Charts

Thank you

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