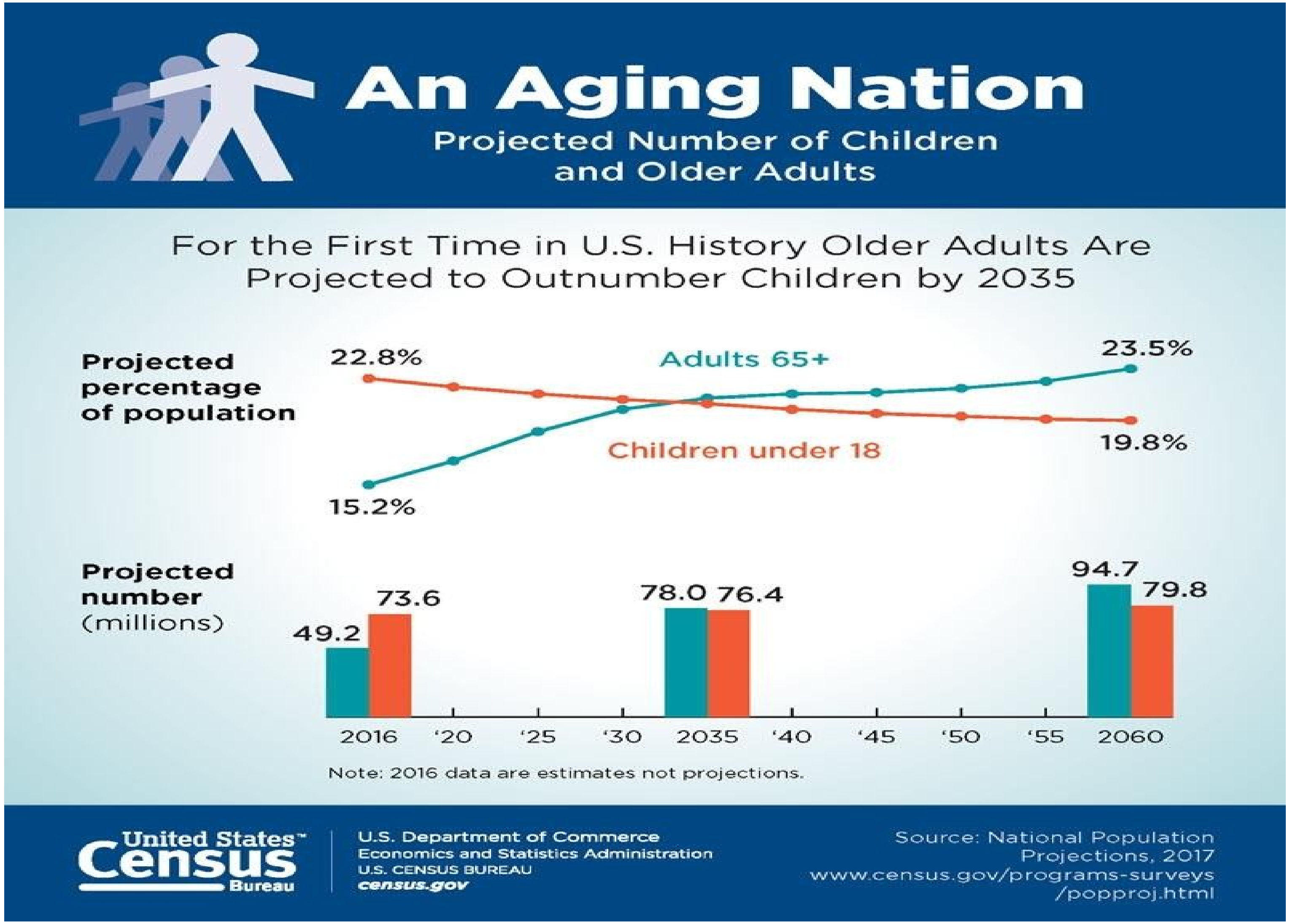
Data Visualisation Lecture Week 10 – Visualising Geospatial Data

Dr. Cathy Ennis

Learning Outcomes Week 10

- Analyse and evaluate how mental models aid in the interpretation of complex visual displays.
- Select, formulate and integrate metaphors to suit data-driven tasks
- Create and deploy successful data visualisations using leading software tools
- Demonstrate an understanding how visualisation is used in date journalism to communicate complex ideas and stories

Visualisation of the Week



Overview

In this lecture we will cover:

- Introduction to spatial relationships
- Map projections
- ggplot commands for basic visualisations

INTRODUCTION

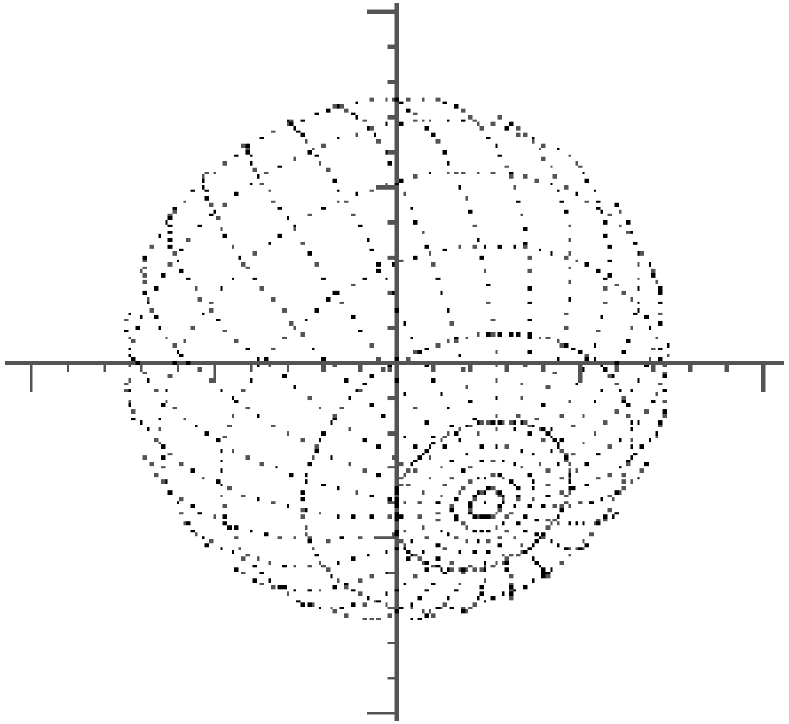
Introduction

- Maps are a sub-category of visualisation

- Maps are
  - usually very intuitive
  - a great way to understand your data
  - essentially scaled down, accurate versions of the physical world

What To Look For

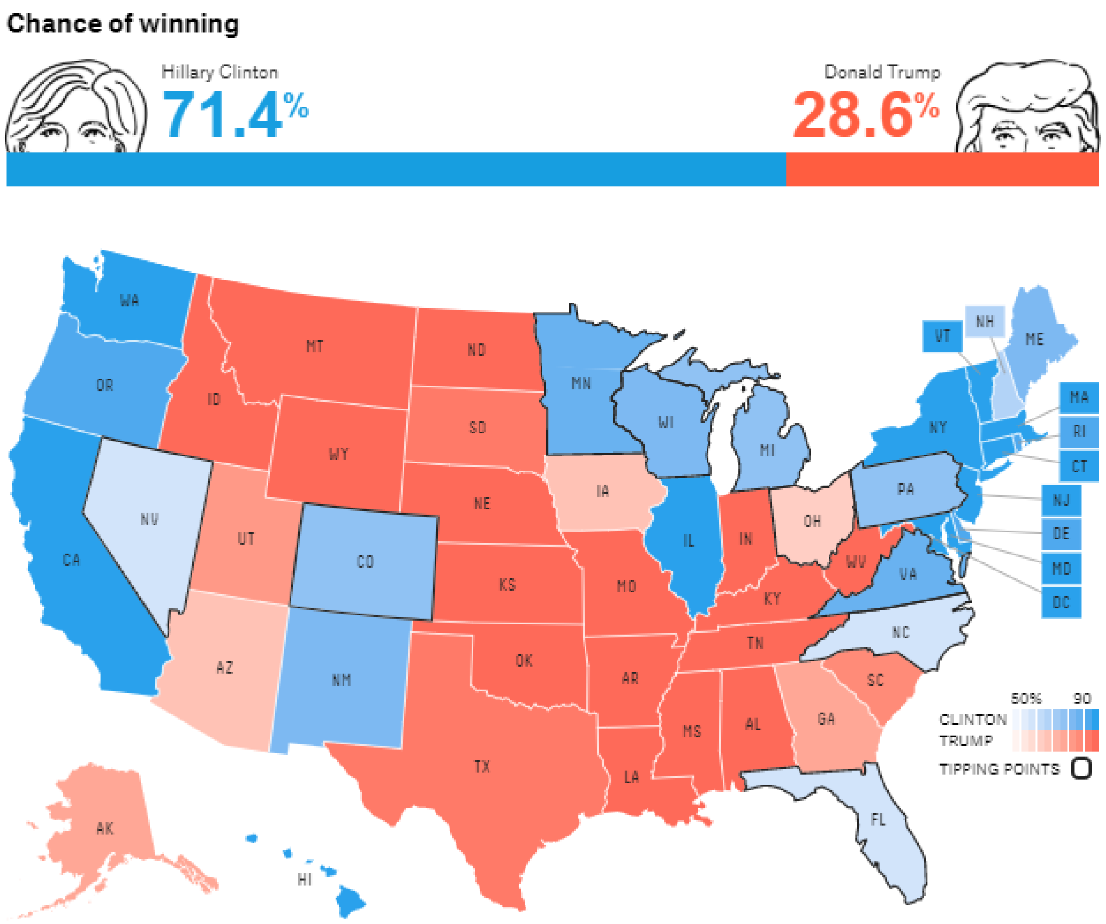
- You read maps much the same way that you read statistical graphics
  - You still look for clustering in or comparisons of specific regions



What To Look For

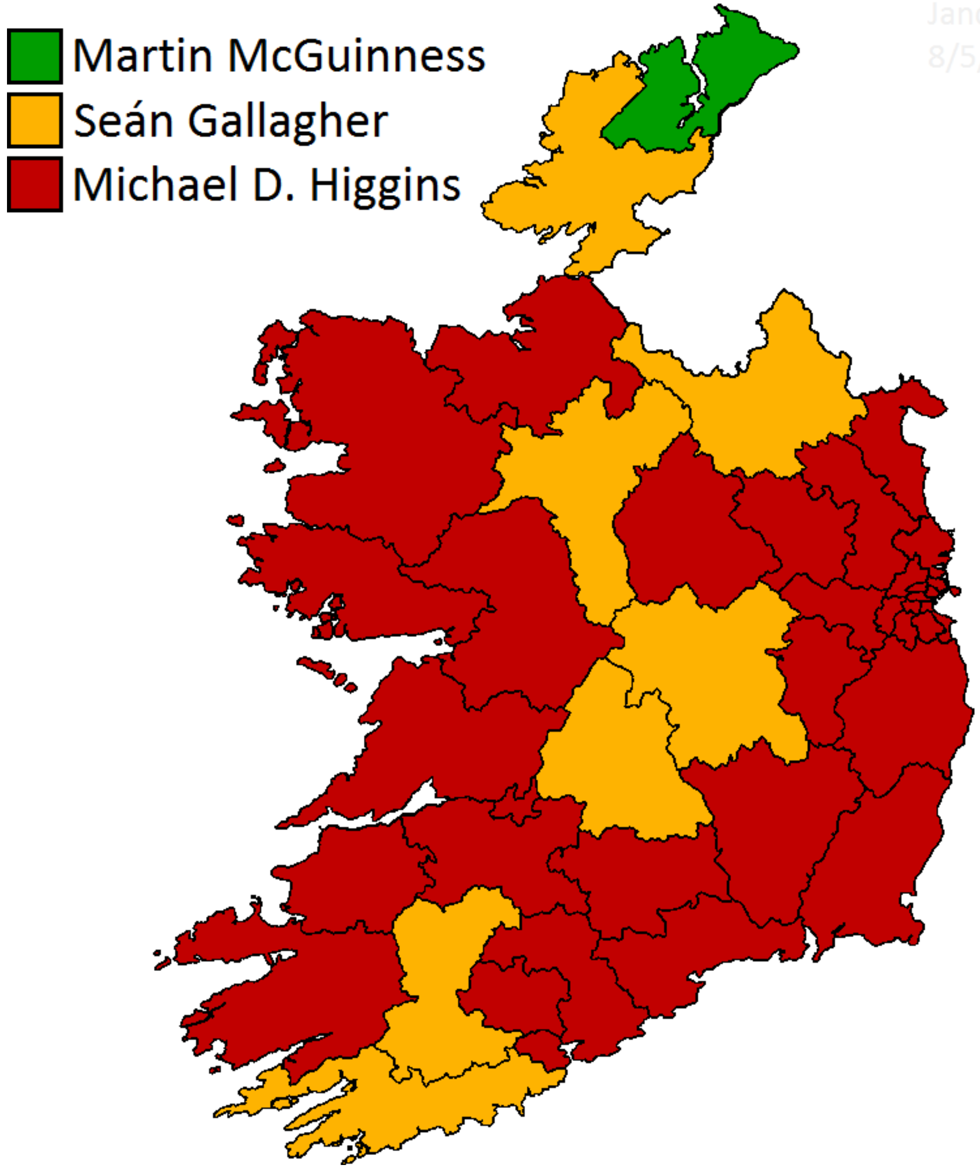
- Things can get especially interesting when you introduce time
- A single map represents a moment in time, but you can represent multiple timeframes with several maps
  - small multiples
- Can also animate changes If the map is interactive, readers can easily focus in on their area to see how things have changed

Clinton V Trump



https://projects.fivethirtyeight.com/2016-election-forecast/

Irish Elections



http://irishpoliticalmaps.blogspot.com/2011/10/irish-presidential-election-2011.html

MAP PROJECTIONS

Map Projections

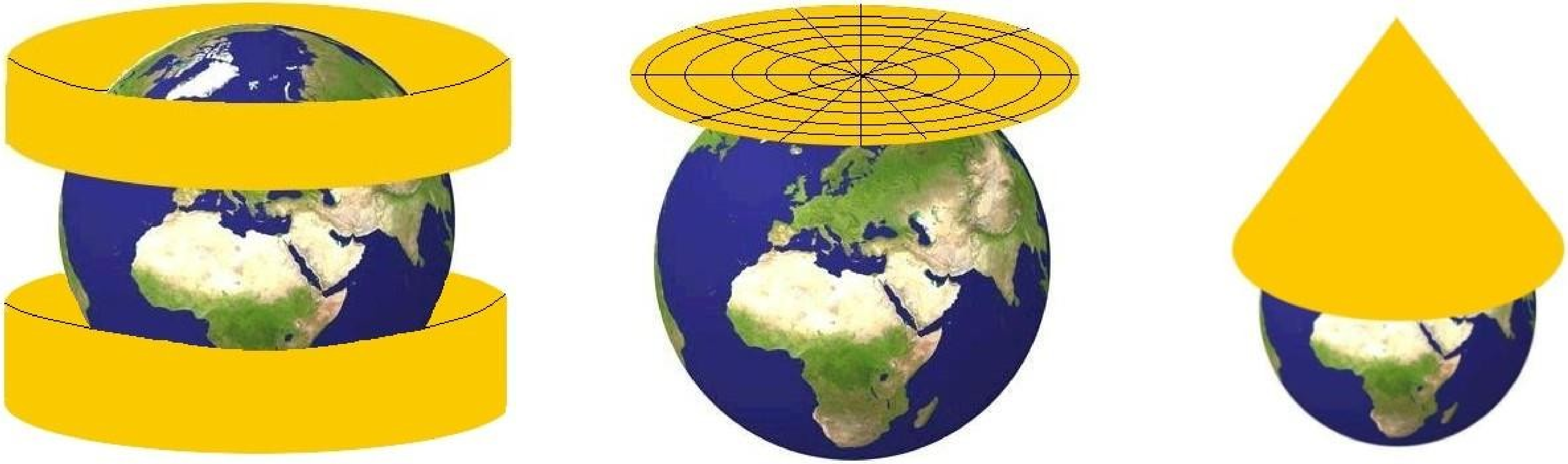
- A map projection is a method used to represent the 3- dimensional surface of the earth or other round body on a 2-dimensional plane in cartography
- This process is typically a mathematical procedure and the resulting 2D image is always a distorted version of reality
- The metric properties of a map are:
  - Area – Equal area projections maintain this
  - Shape – Conformal projections maintain this
  - Direction
  - Distance
  - Scale

https://www.gislounge.com/map-projection/

Types of Projections

- **Azimuthal or zenithal** - Preserves direction from one or two points to every other point
- **Conformal** - Preserves shape locally
- **Equal-area** - Preserves area
- **Equidistant** - Preserves distance between one or two points and every other point

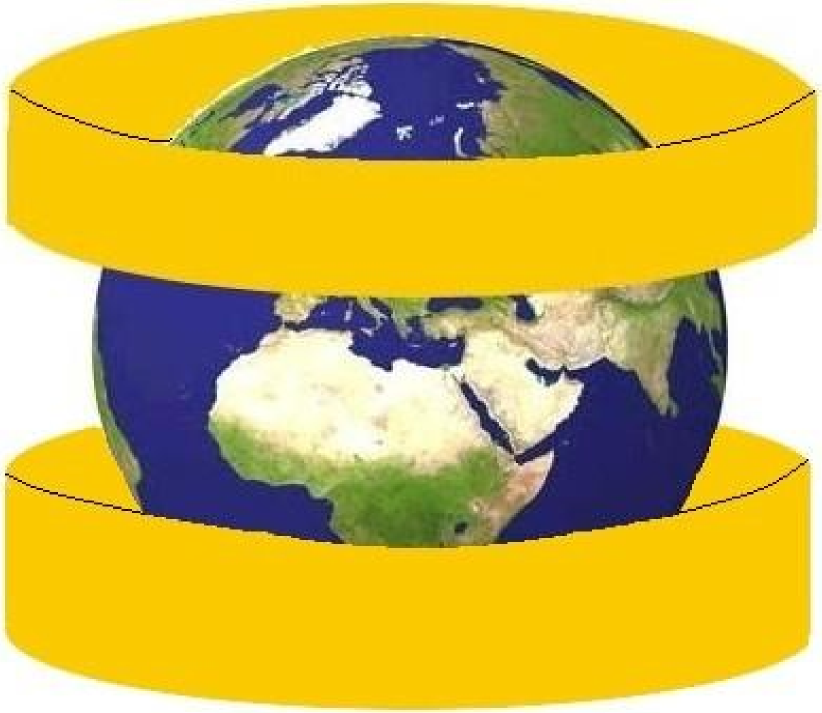
Map Projections



Cylinder, plane, and cone projections

“Interactive Data Visualisation”, M. Ward, G Grinstein & D Keim, AK Peters, 2010

Map Projections – Cylinder Projection



- Straight coordinate lines with horizontal parallels crossing meridians at right angles
- All meridians are equally spaced
- Scale is consistent along each parallel

“Interactive Data Visualisation”, M. Ward, G Grinstein & D Keim, AK Peters, 2010

Map Projections – Cone Projection

- Cone projections are defined by the cone constant
  - dictates the angular distance between meridians
- Meridians are equidistant and straight lines which converge in locations along the projection regardless of if there's a pole or not

“Interactive Data Visualisation”, M. Ward, G Grinstein & D Keim, AK Peters, 2010

Map Projections – Plane Projection

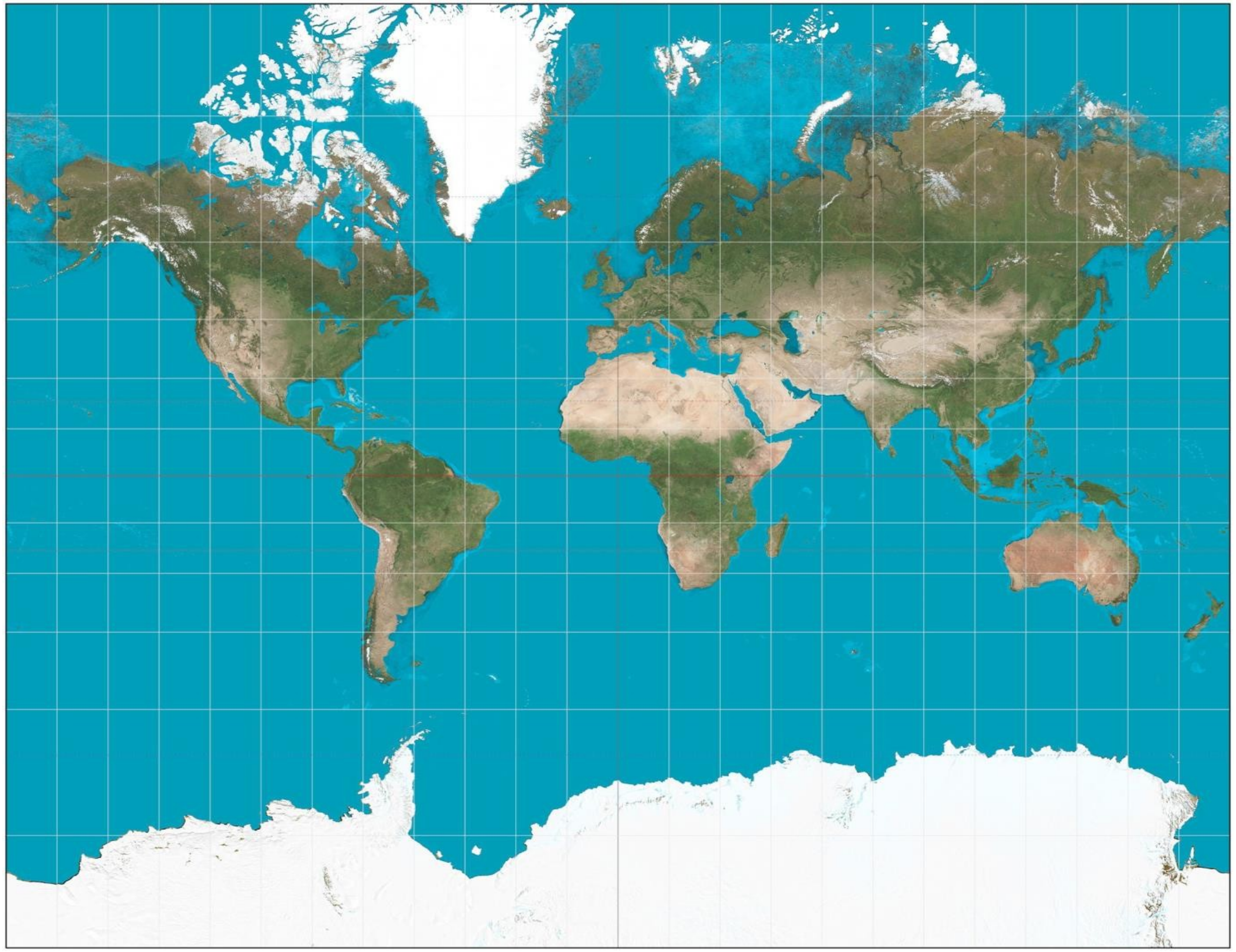
- Azimuthal projection is a projection of the globe onto a plane
- Straight meridian lines, radiating out from a central point, parallels that are circular around the central point, and equidistant parallel spacing

“Interactive Data Visualisation”, M. Ward, G Grinstein & D Keim, AK Peters, 2010

Map Projections

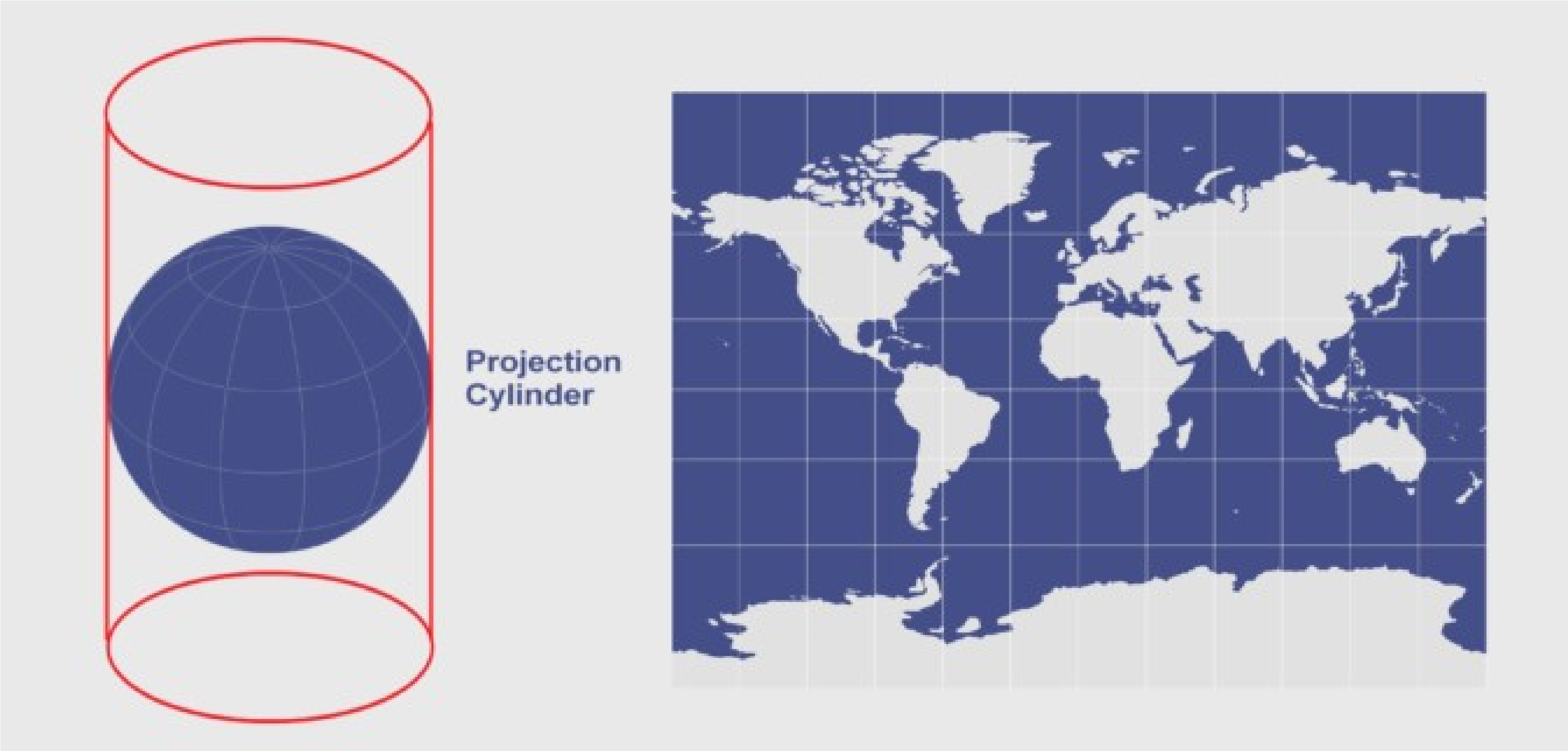
- Cylinder projections
  - Mercator
  - Lambert cylindrical
  - Galls-Peters
- Plane projections
  - Gnomonic
  - General perspective
- Cone projections
  - Albers conic
  - Lambert conic
- Compromise projection
  - Winkel Tripel

Mercator Projection



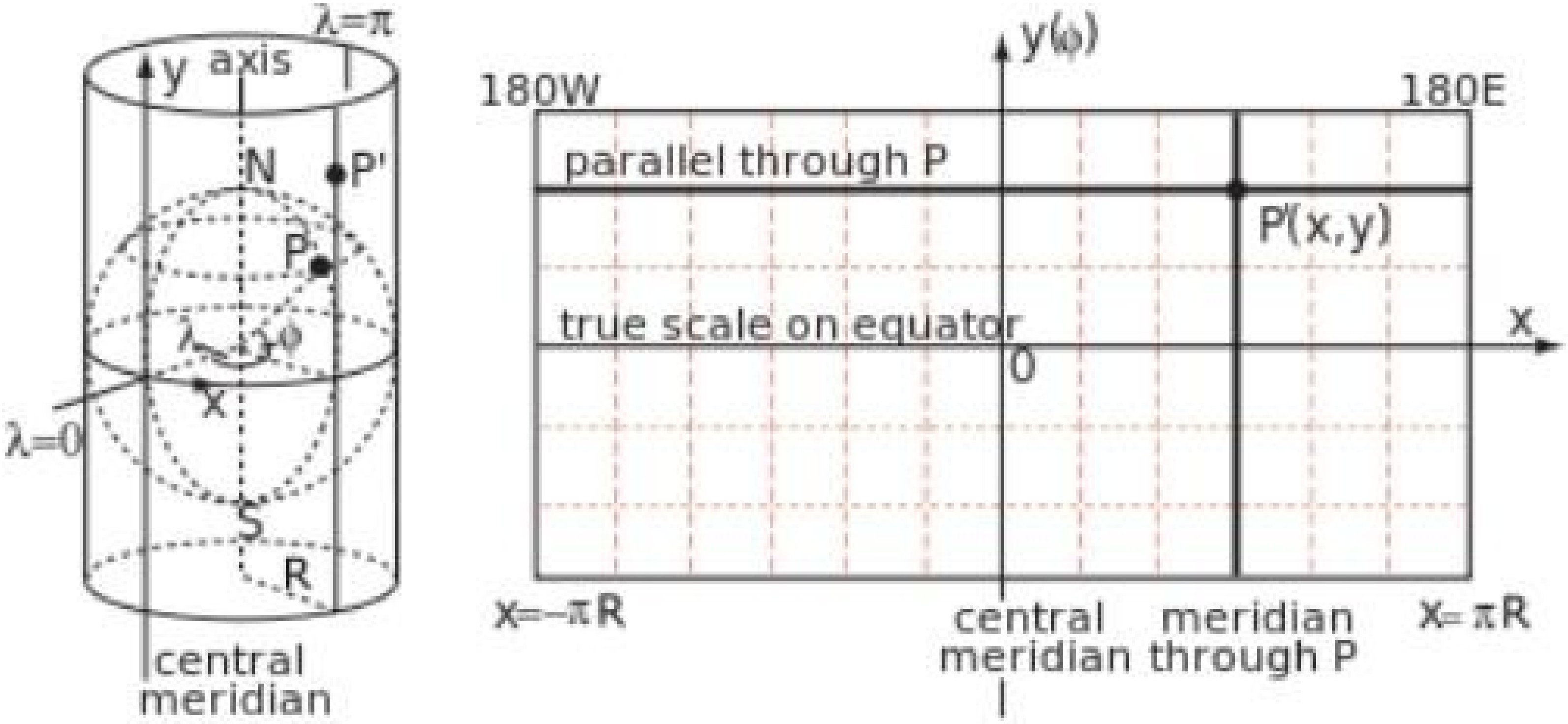
http://en.wikipedia.org/wiki/File:Mercator_projection_SW.jpg

Mercator Projection



https://gisgeography.com/cylindrical-projection/

Mercator Projection



Mercator Projection

- Mercator map projection (1569) shows true direction between places the best, but are not equal area or equidistant
- This is the projection of choice from Google maps for this reason, despite how the south and north poles distort land size
- Directions along a rhumb line (line of constant direction) are true between any two points on a map
- Distances are true only along the Equator
- Although it has a conformal property, areas are greatly distorted increasing size at poles

Mercator Projection

- The formulae for calculating the x and y coordinates for a point in a Mercator projection are:

$$x = \frac{W}{2\pi}(\lambda - \lambda_0)$$

$$y = \frac{W}{2\pi} \ln \left[\tan \left(\frac{\pi}{4} + \frac{\phi}{2} \right) \right]$$

where λ is a longitude, Φ is a latitude and W is the width of the map

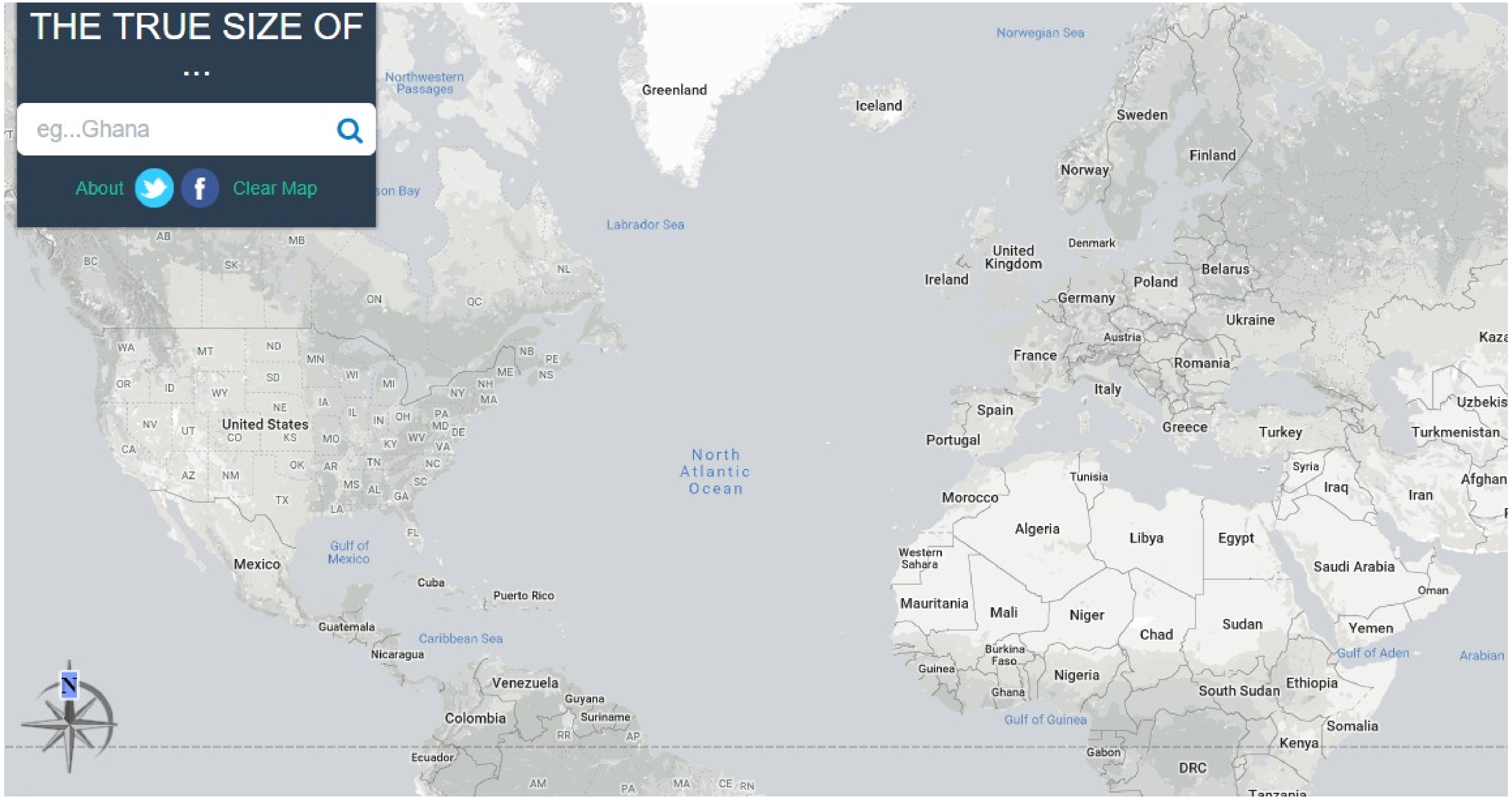
Mercator Projection

- The Mercator projection exaggerates areas far from the equator, for example:
  - Greenland takes as much space on the map as Africa, when in reality Africa's area is 14 times greater and Greenland's is comparable to Algeria's alone.
  - Alaska takes as much area on the map as Brazil, when Brazil's area is nearly five times that of Alaska
  - Finland appears with a greater north-south extent than India, although India's is greater
  - Antarctica appears as the biggest continent, although it is actually the fifth in terms of area

http://en.wikipedia.org/wiki/Mercator_projection

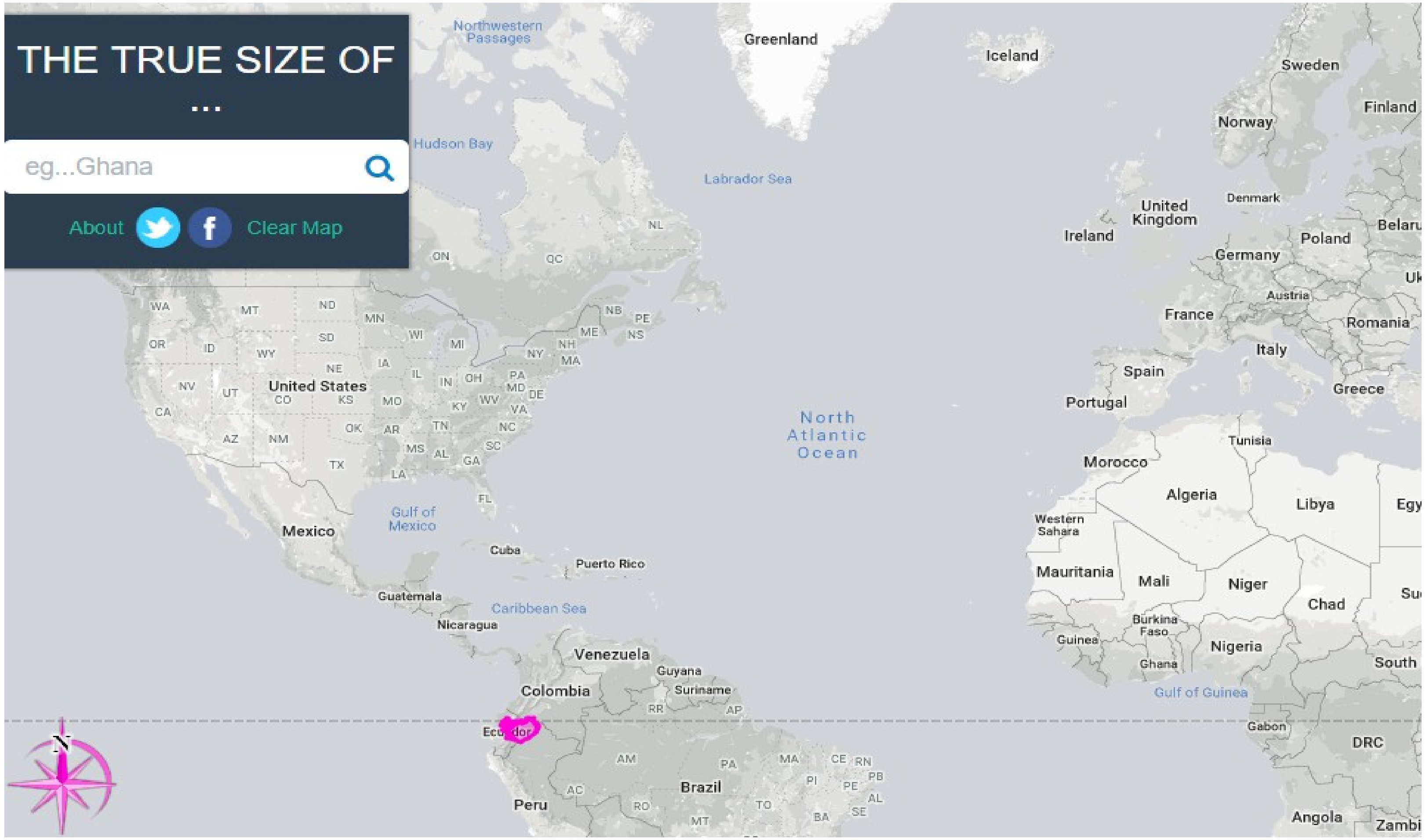
Mercator Projection

Compare size of Iceland and Ecuador



http://thetruesize.com

Mercator Projection



http://thetruesize.com

Data Visualisation
Lecture Week 10 – Visualising Geospatial Data

Dr. Cathy Ennis

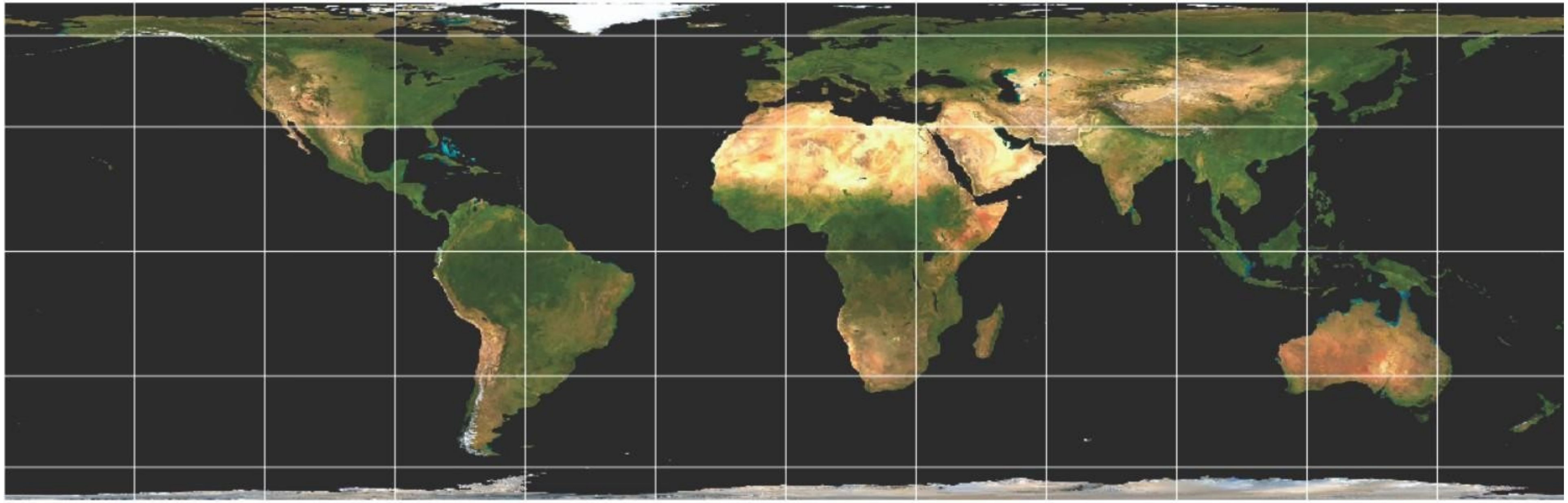
Lambert Cylindrical Projection

- Cylindrical equal area projection (1772)

- This projection is undistorted along the equator, which is its standard parallel, but distortion increases rapidly towards the poles

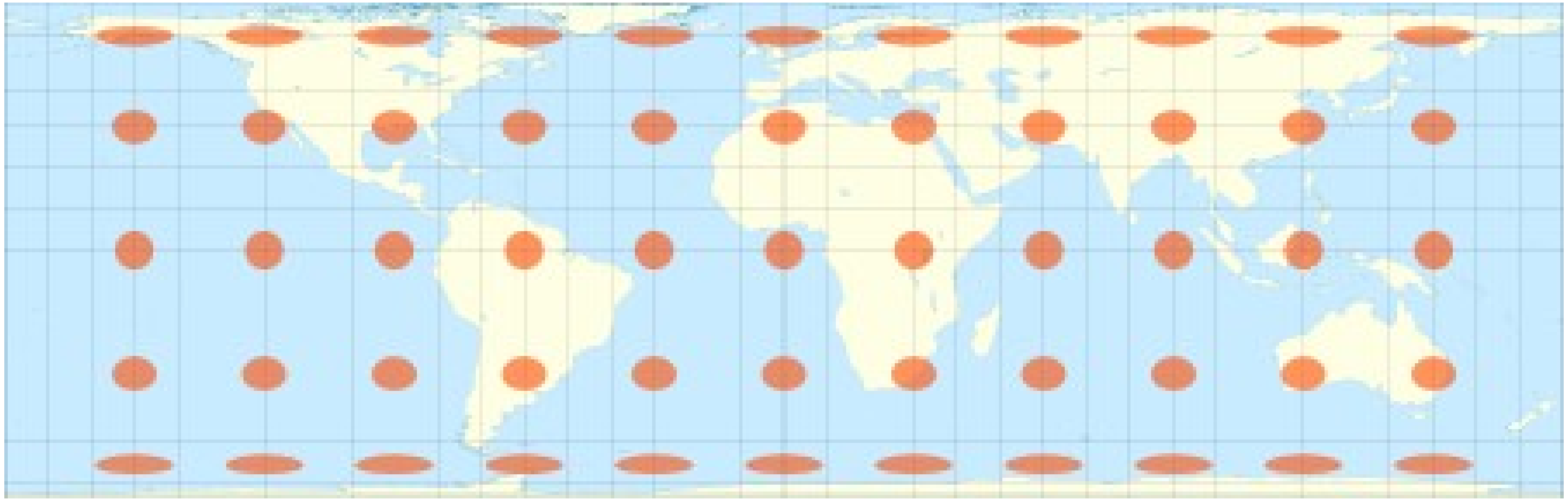
- Like any cylindrical projection, it stretches parallels increasingly away from the equator. The poles accrue infinite distortion, becoming lines instead of points

Lambert Cylindrical Projection



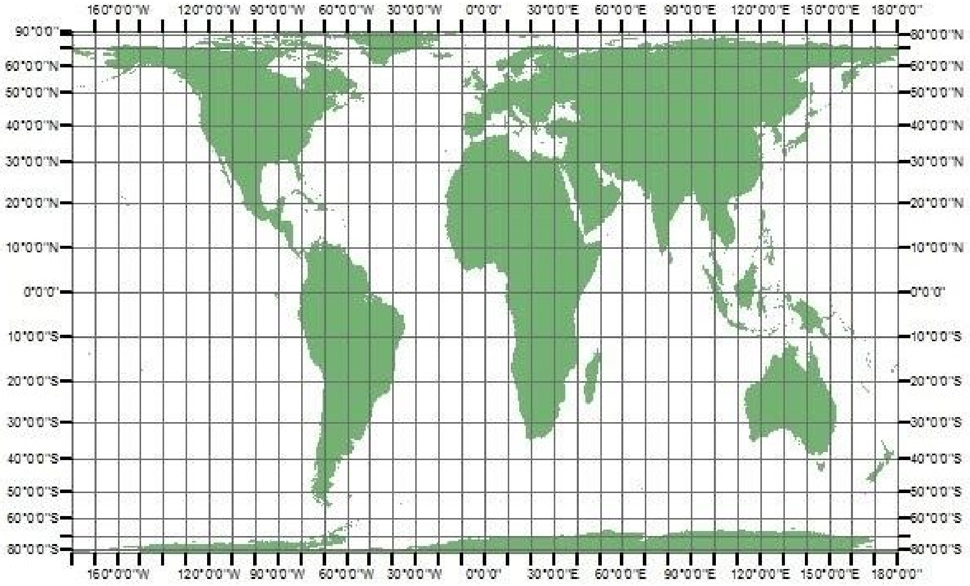
"Interactive Data Visualisation", M. Ward, G Grinstein, D Keirn, AK Peters, 2010

Lambert Cylindrical Projection

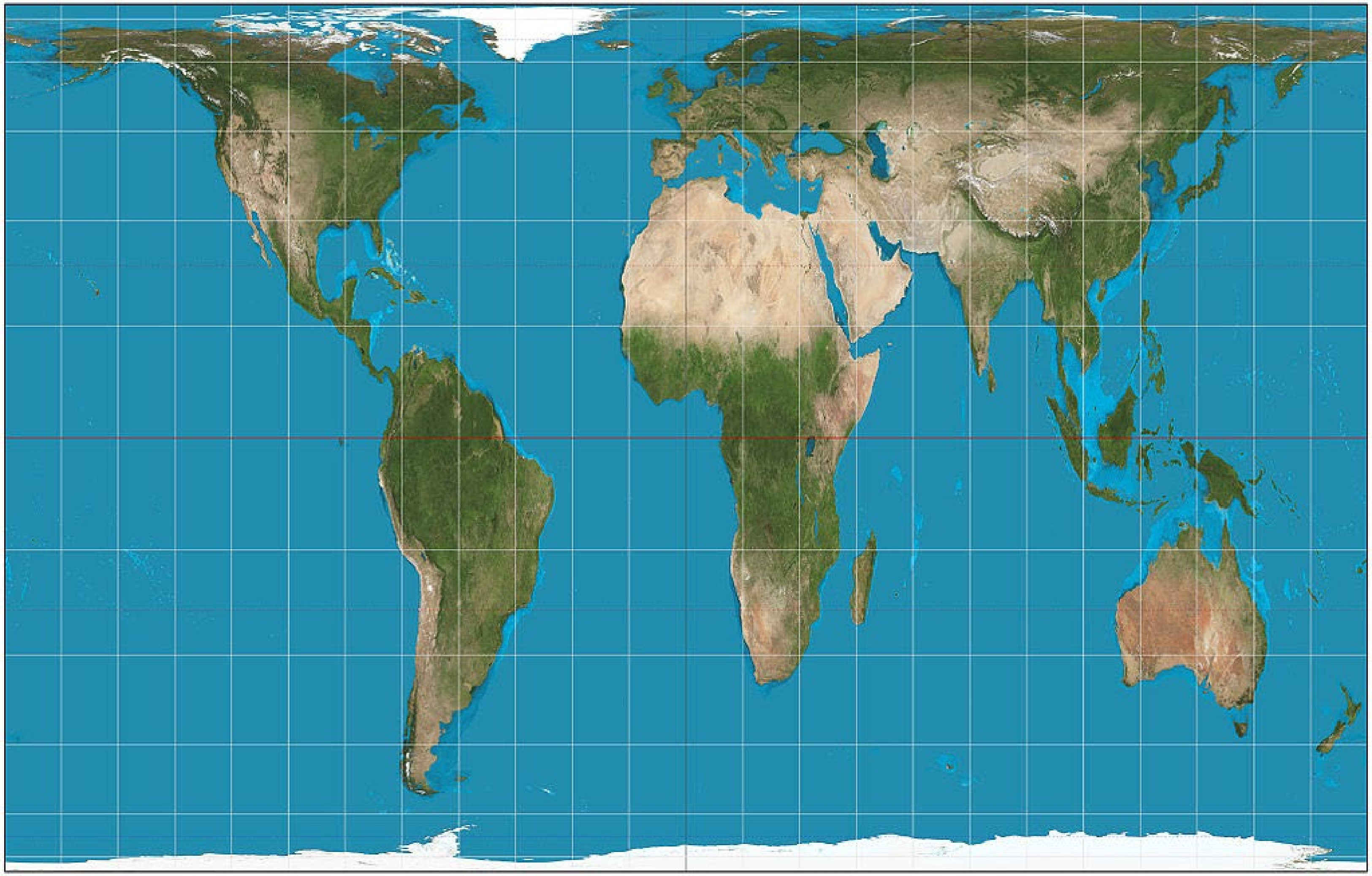


Gall-Peters Projection

- Equal area, cylindrical projection (1855-1973)
- Standard parallels 45° N/S
- All areas on the map are equal in size and all meridians and parallels are mapped as straight lines
- A downside with Gall-Peters projection is that it is geometrically inaccurate even around the equator

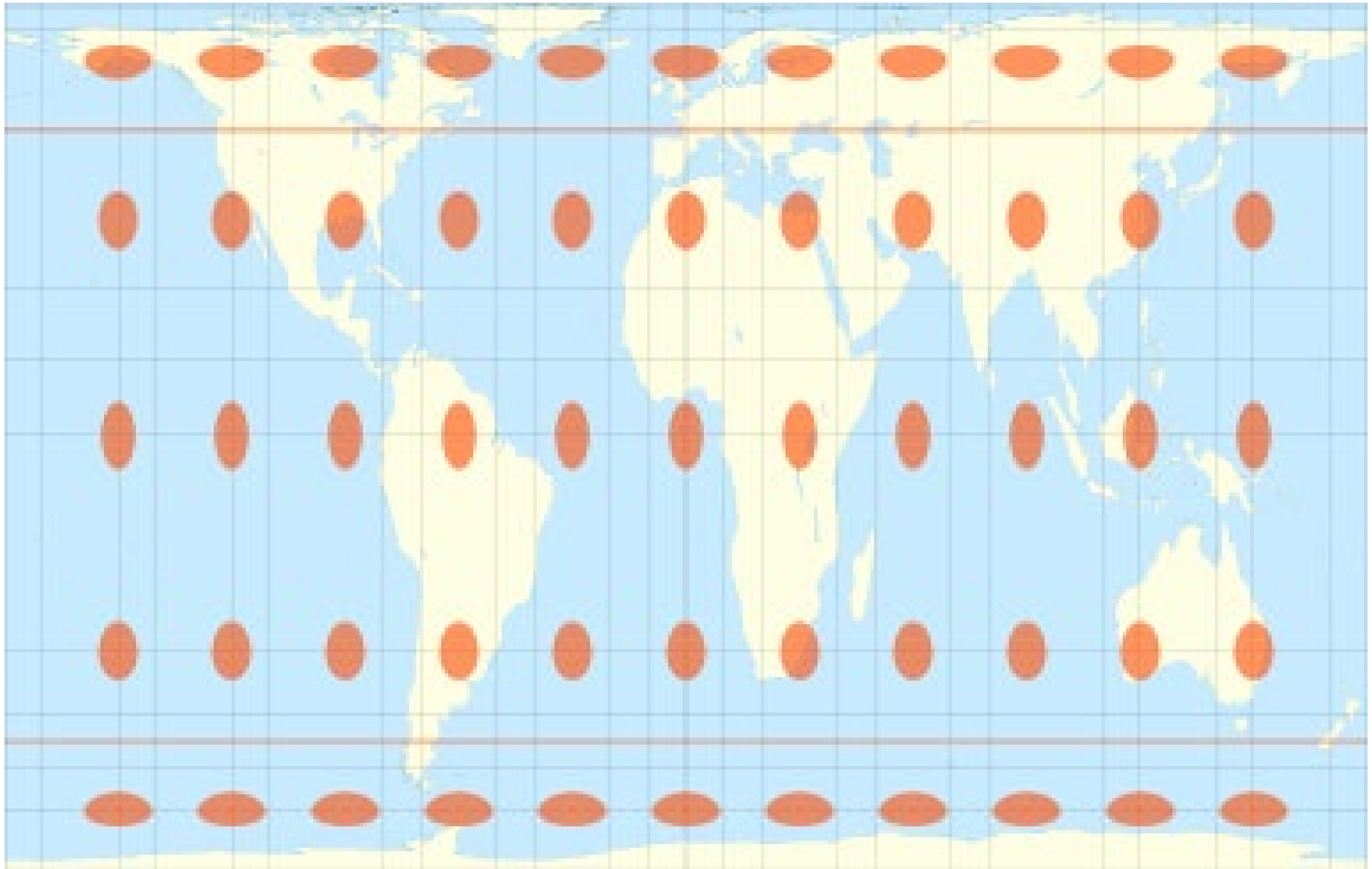


Gall-Peters Projection



https://en.wikipedia.org/wiki/Gall%E2%80%93Peters_projection#/media/File:Gall%E2%80%93Peters_projection_SW.jpg

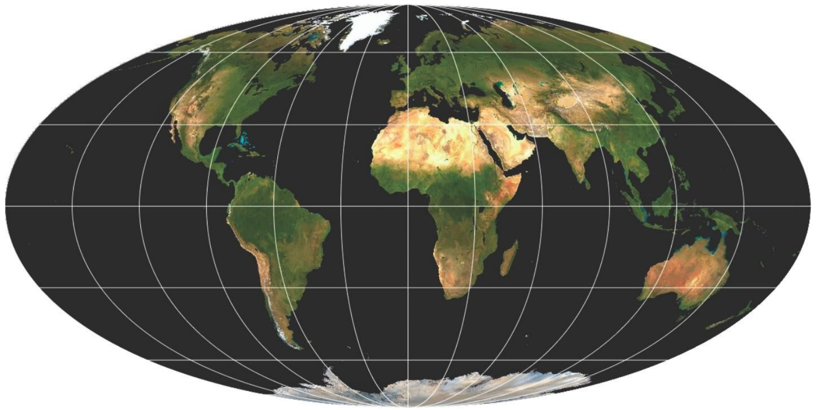
Gall-Peters Projection



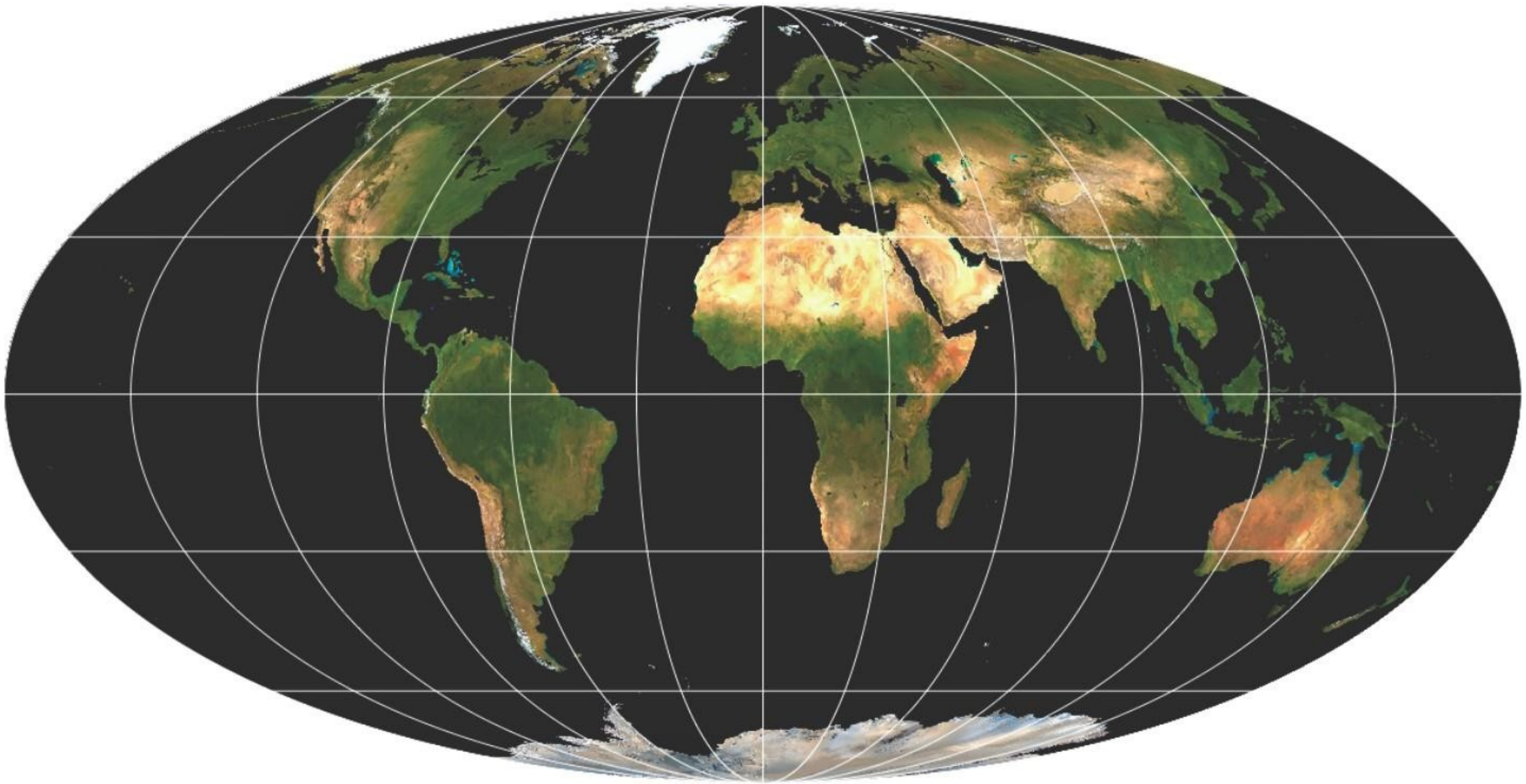
https://en.wikipedia.org/wiki/Gall%E2%80%93Peters_projection#/media/File:Tissot_indicatrix_world_map_Gall-Peters_equal-area_proj.svg

Mollweide Projection

- Equal area
- Pseudocylindrical
- Non conformal - trades accuracy of shape and angle for area accuracy
- Converging meridians and straight parallels
- Used for maps where area is needed e.g., global distribution
- Ocean areas and sky

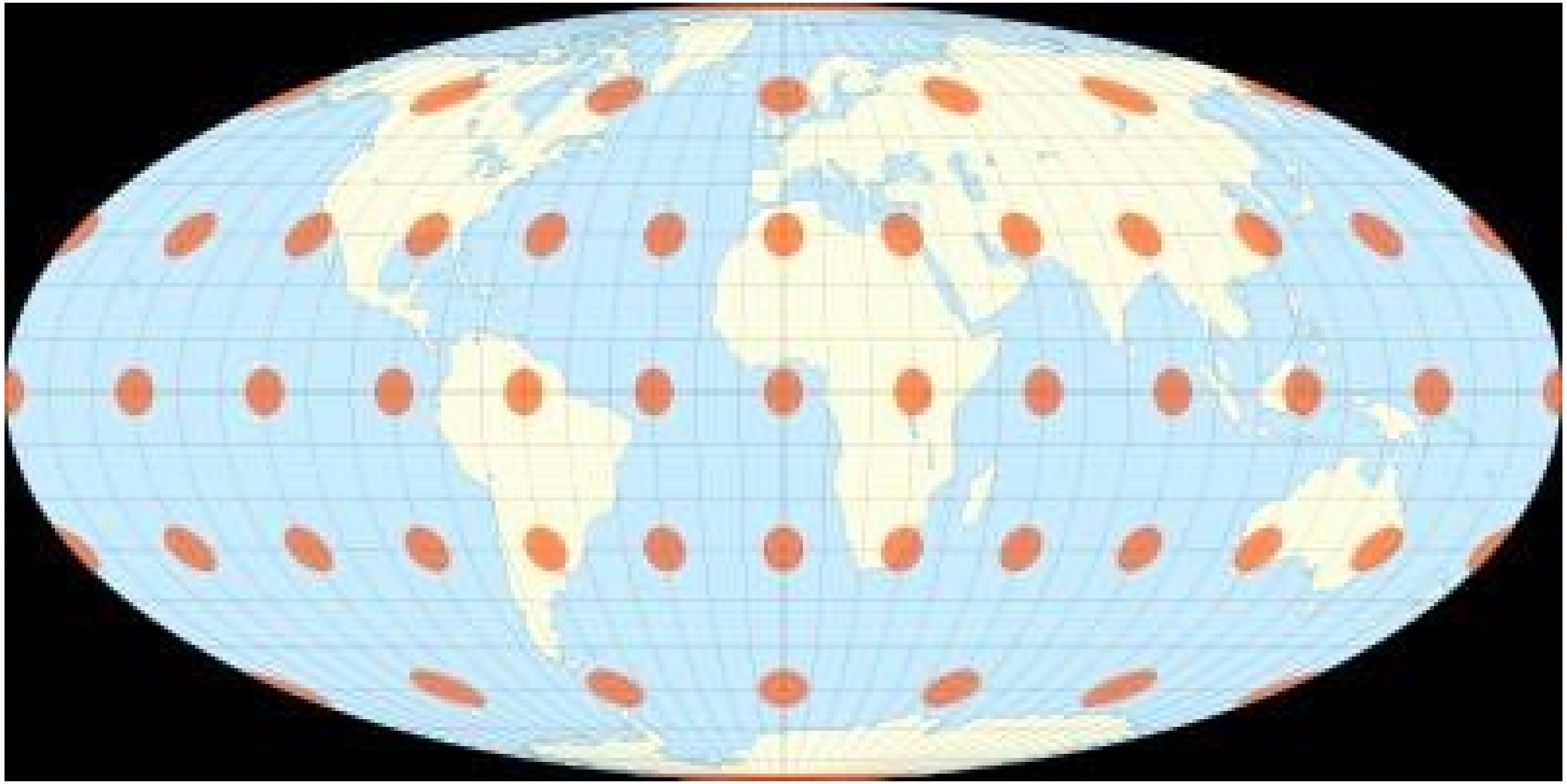


Mollweide Projection



"Interactive Data Visualisation", M. Ward, G Grinstein 8: D Keirn, AK Peters, 2010

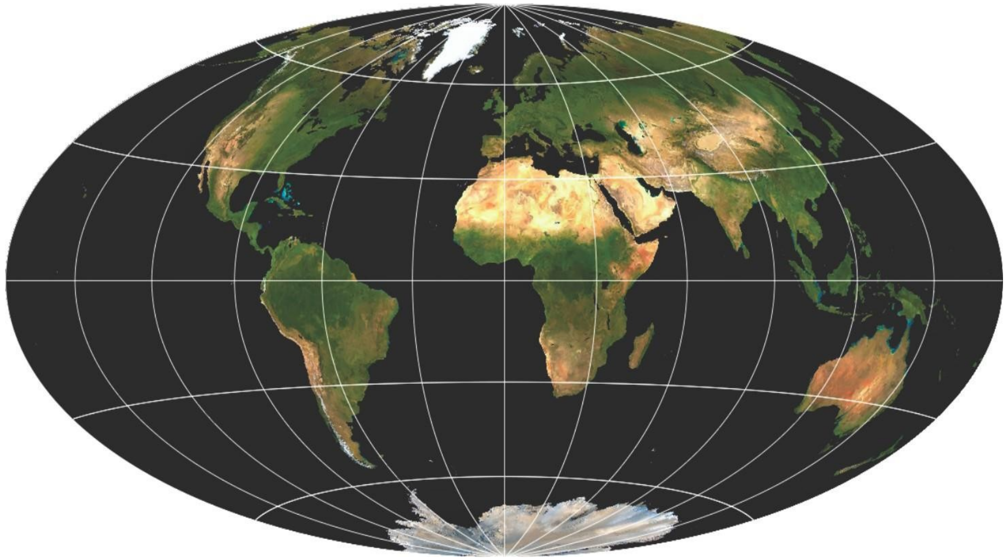
Mollweide Projection



"Interactive Data Visualisation", M. Ward, G Grinstein 8: D Keirn, AK Peters, 2010

Hammer-Aitoff Projection

- Equal area
- Pseudocylindrical
- Non conformal
- Converging meridians
- Reduced distortion in outer meridians
- Curved parallels



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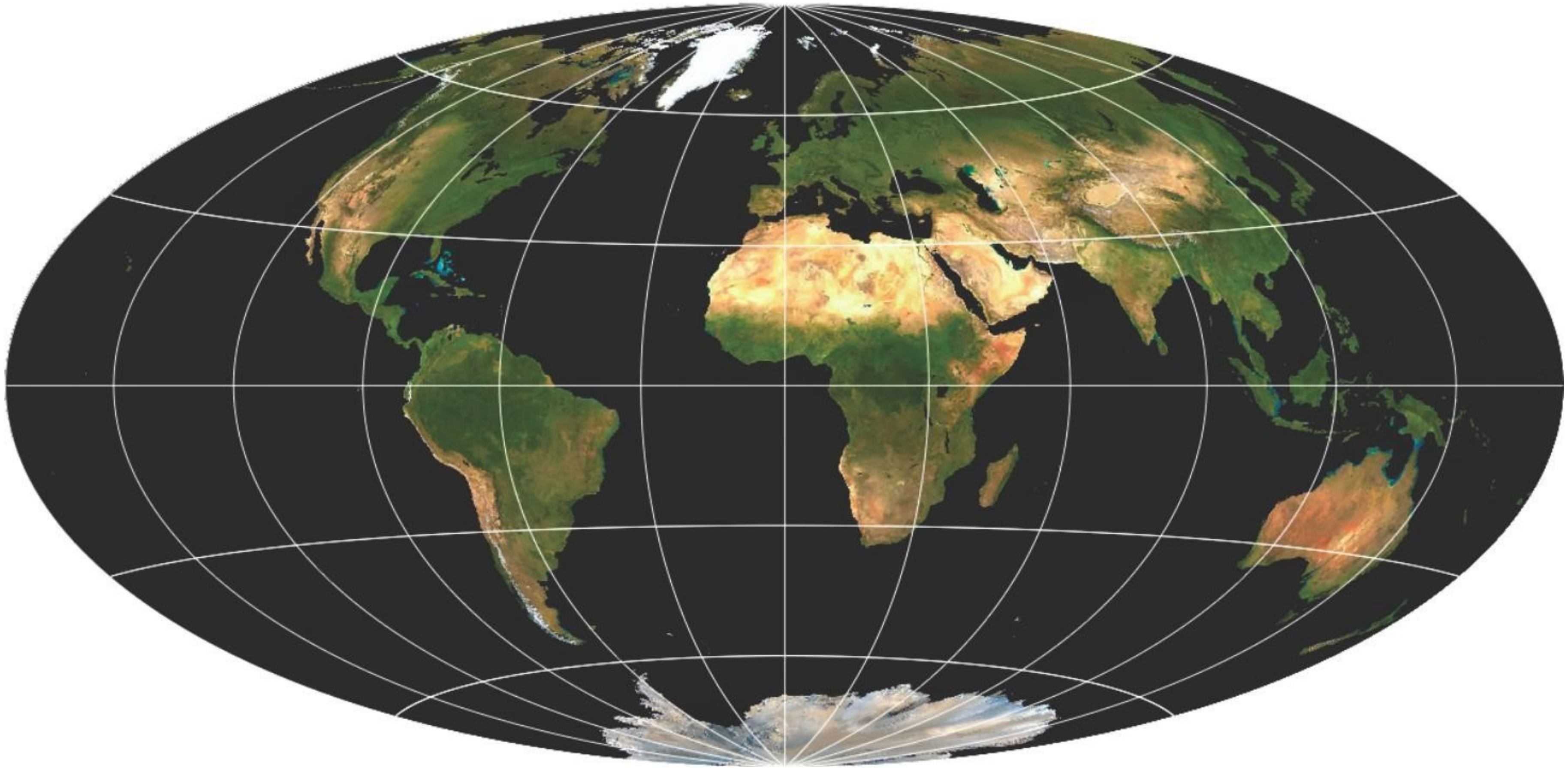
Hammer-Aitoff Projection



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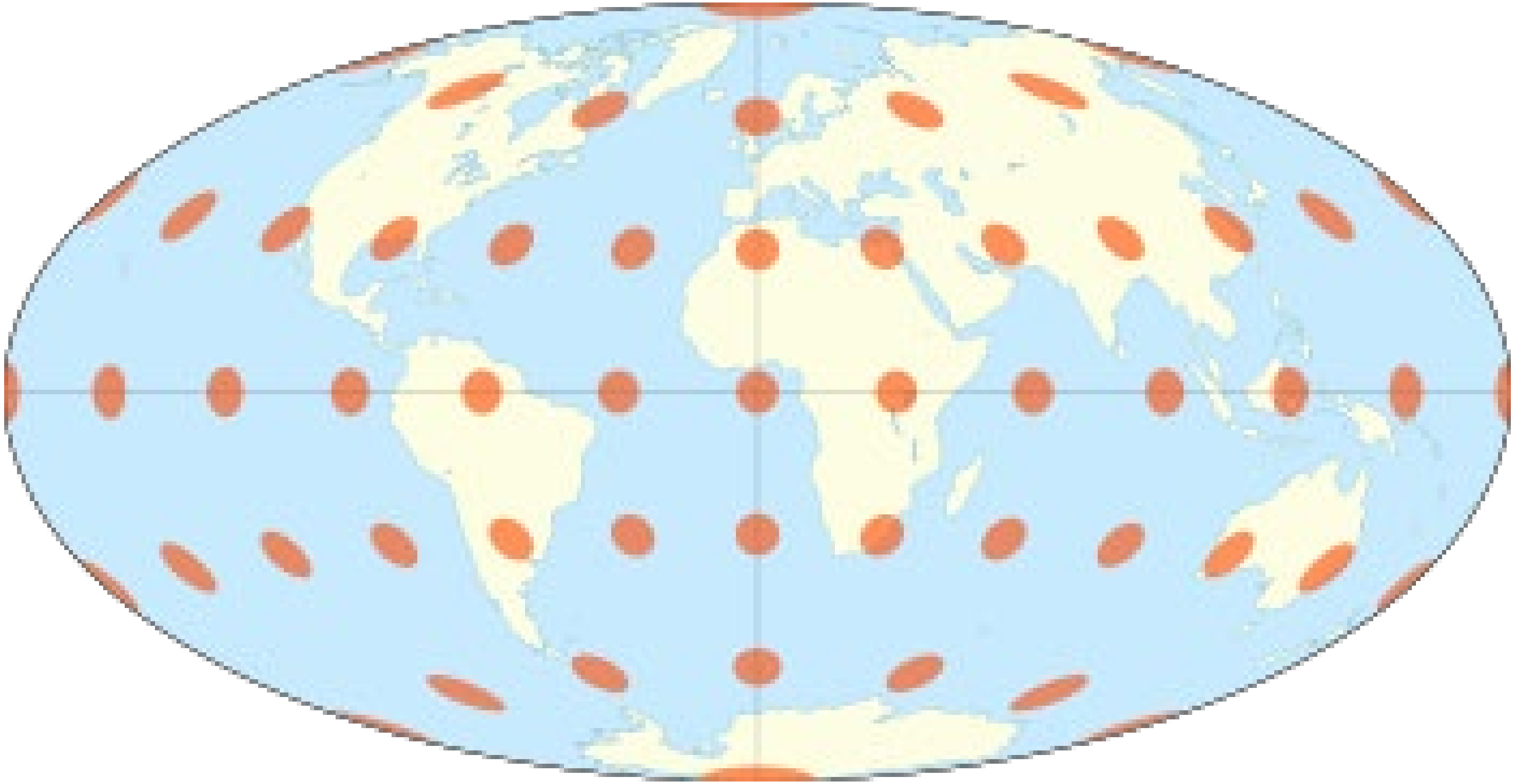
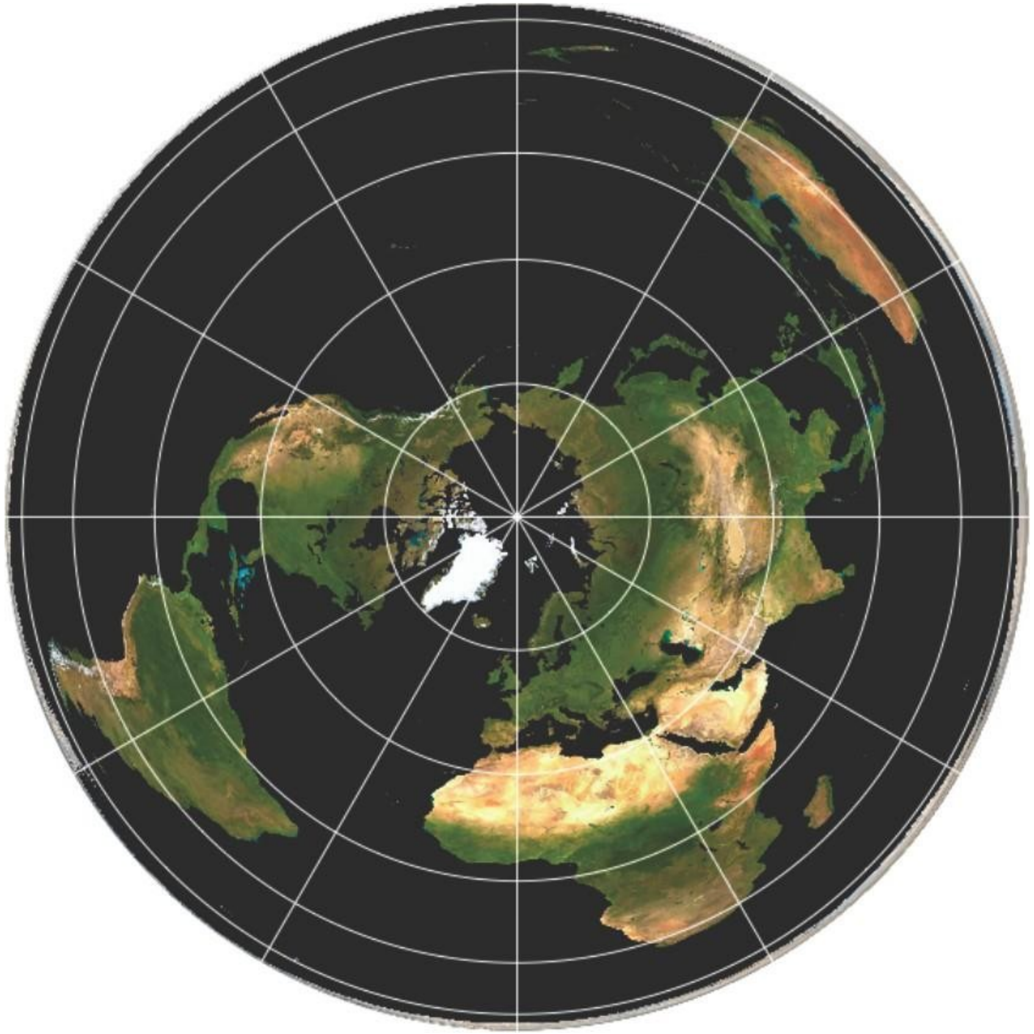
Hammer-Aitoff Projection



"Interactive Data Visualisation", M. Ward, G Grinstein 8: D Keirn, AK Peters, 2010

Albers Equal-area Conic Projection

- Equal area
- Uses 2 standard parallels to reduce distortion
- Non conformal
- Country or subcontinent view
    - Expanding East to West rather than North to South
- USA geological survey
- USA census



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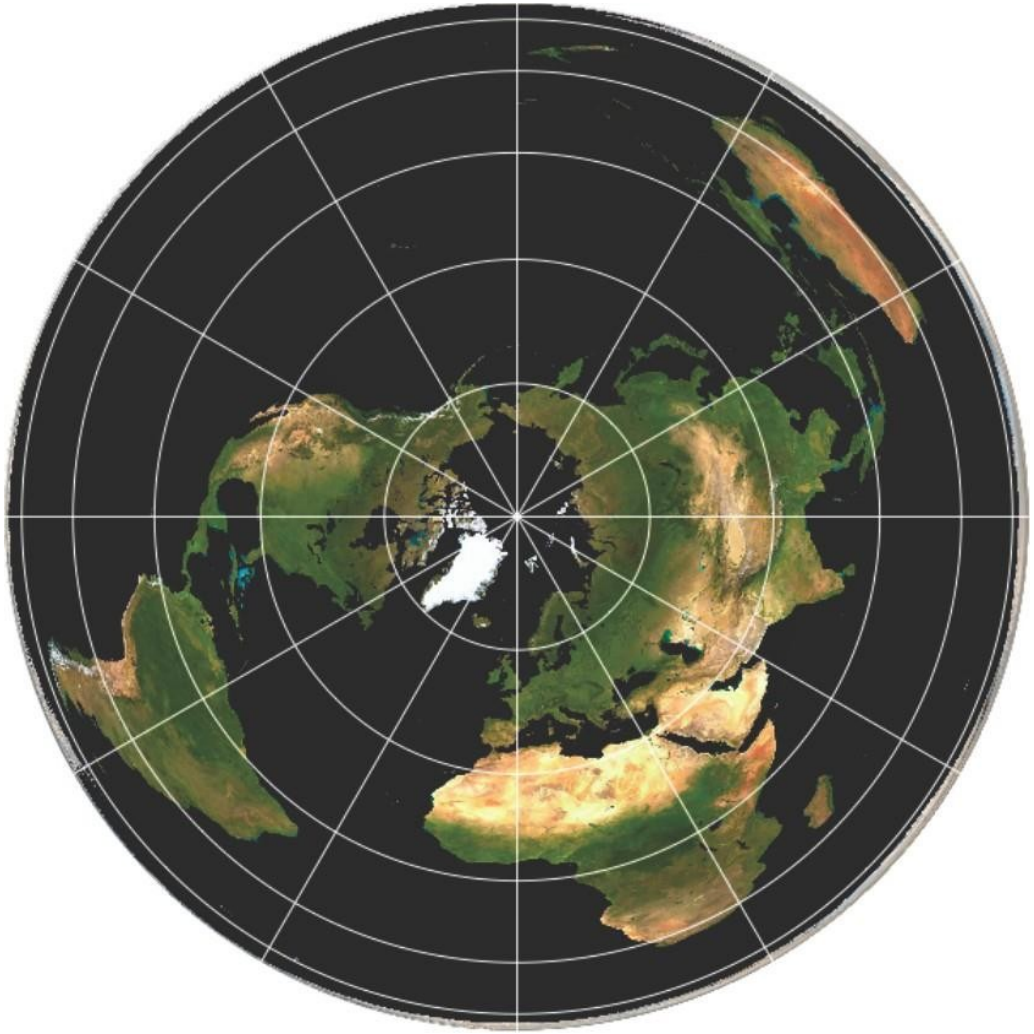

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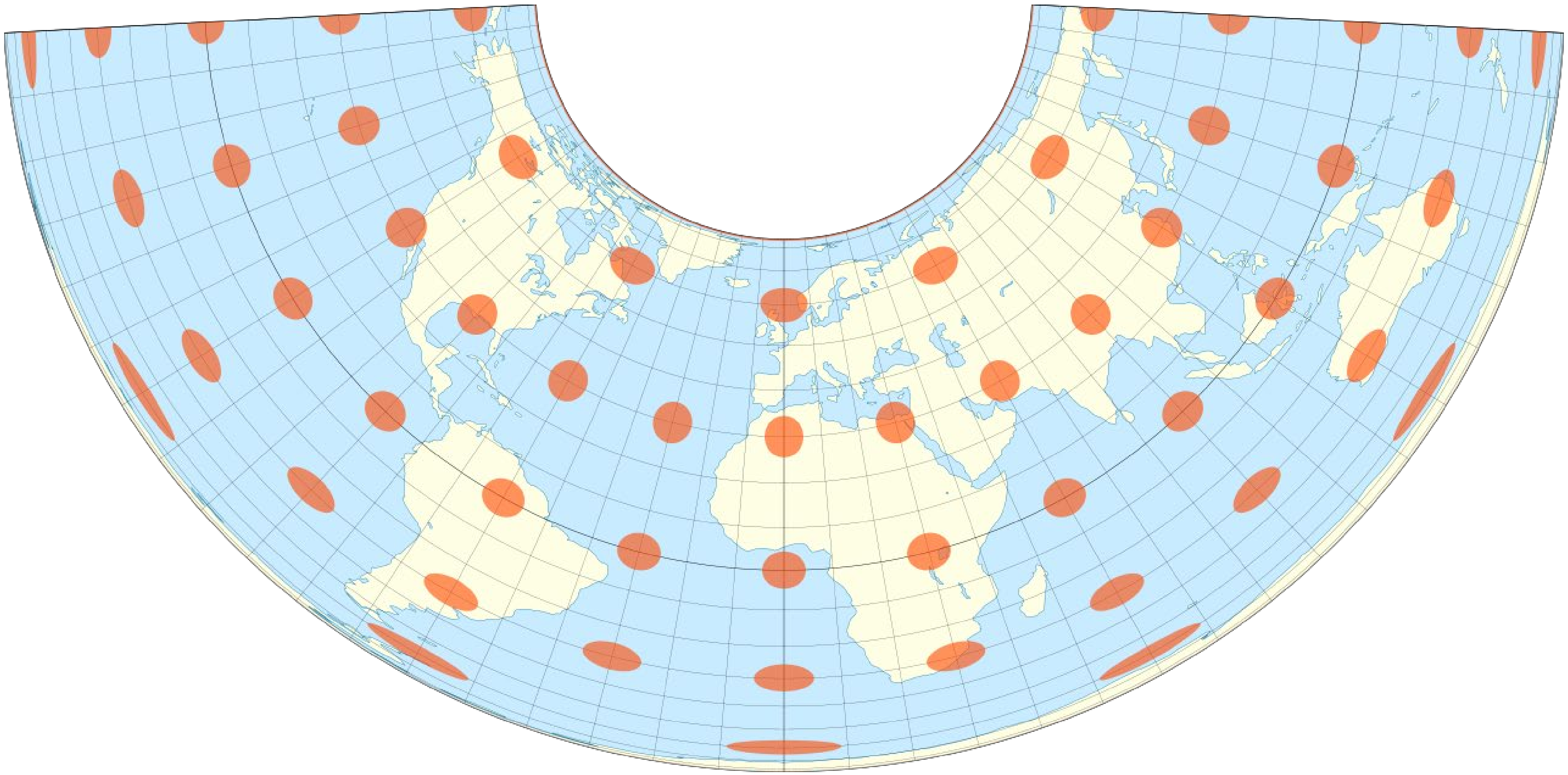

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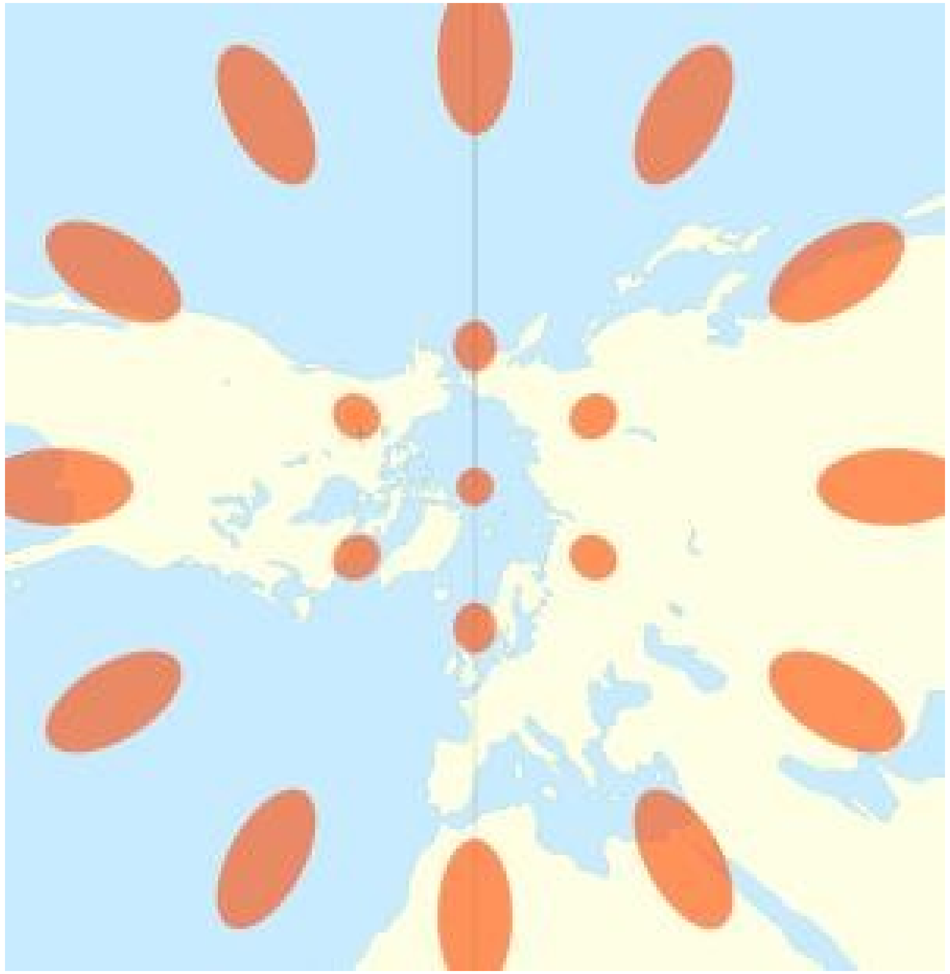
Gnomonic Azimuthal Projection

- Hemisphere or continent level
- Perspective, azimuthal projection
  - point of perspective at the centre of the globe
- Great distortion of shape, area and scale
  - Except at the centre
- Seismic work or navies plotting directions using radio waves

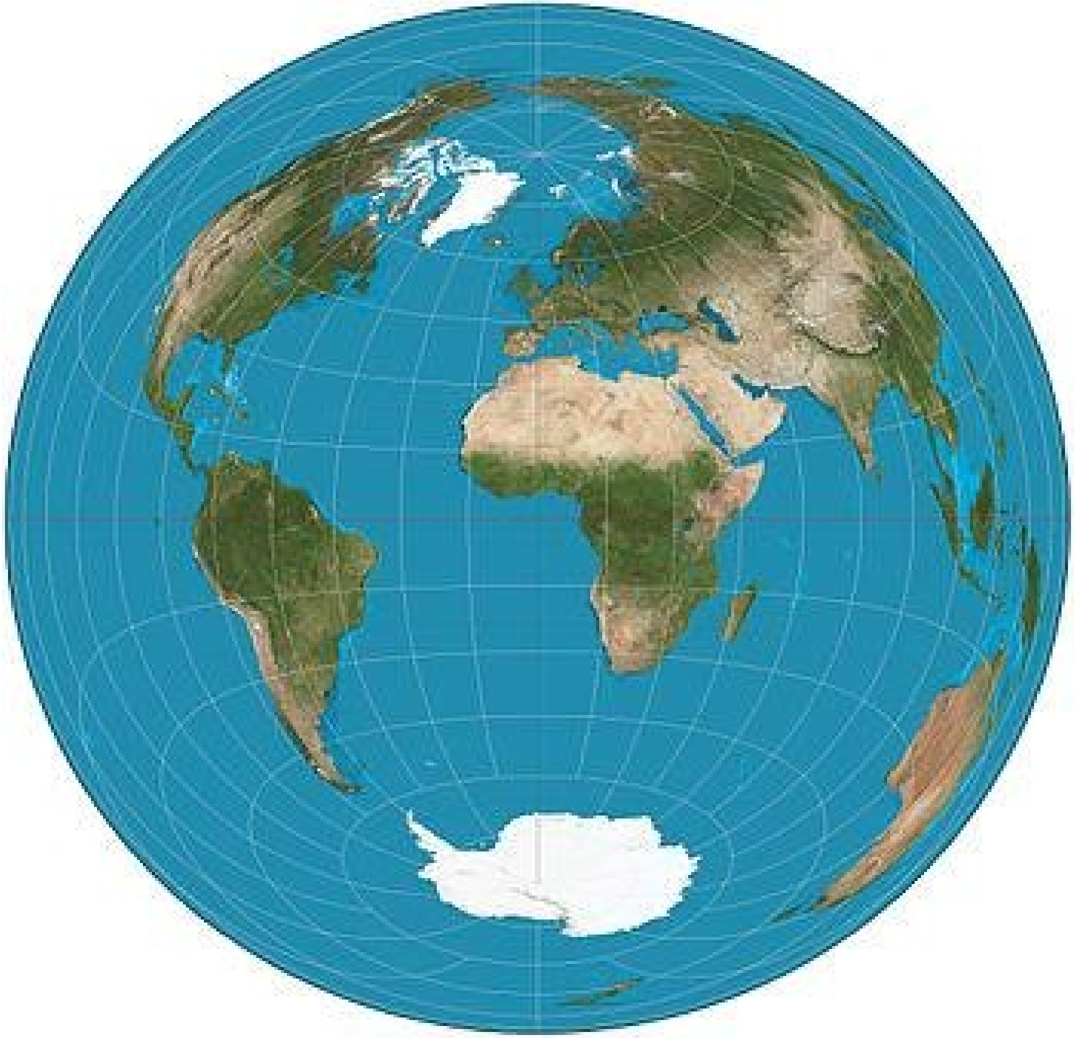
Gnomonic Azimuthal Projection

Gnomonic Azimuthal Projection

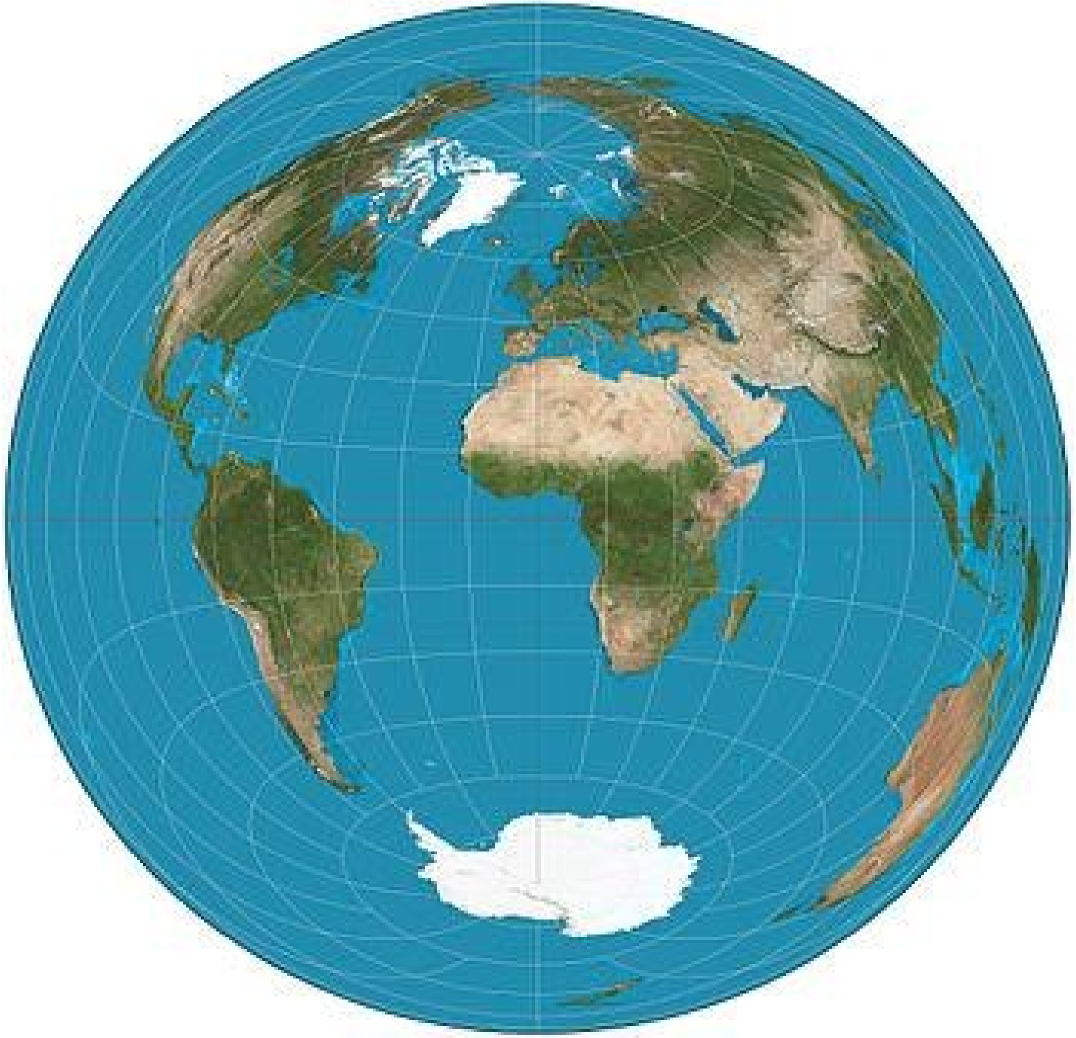


Lambert Azimuthal Equal Area Projection

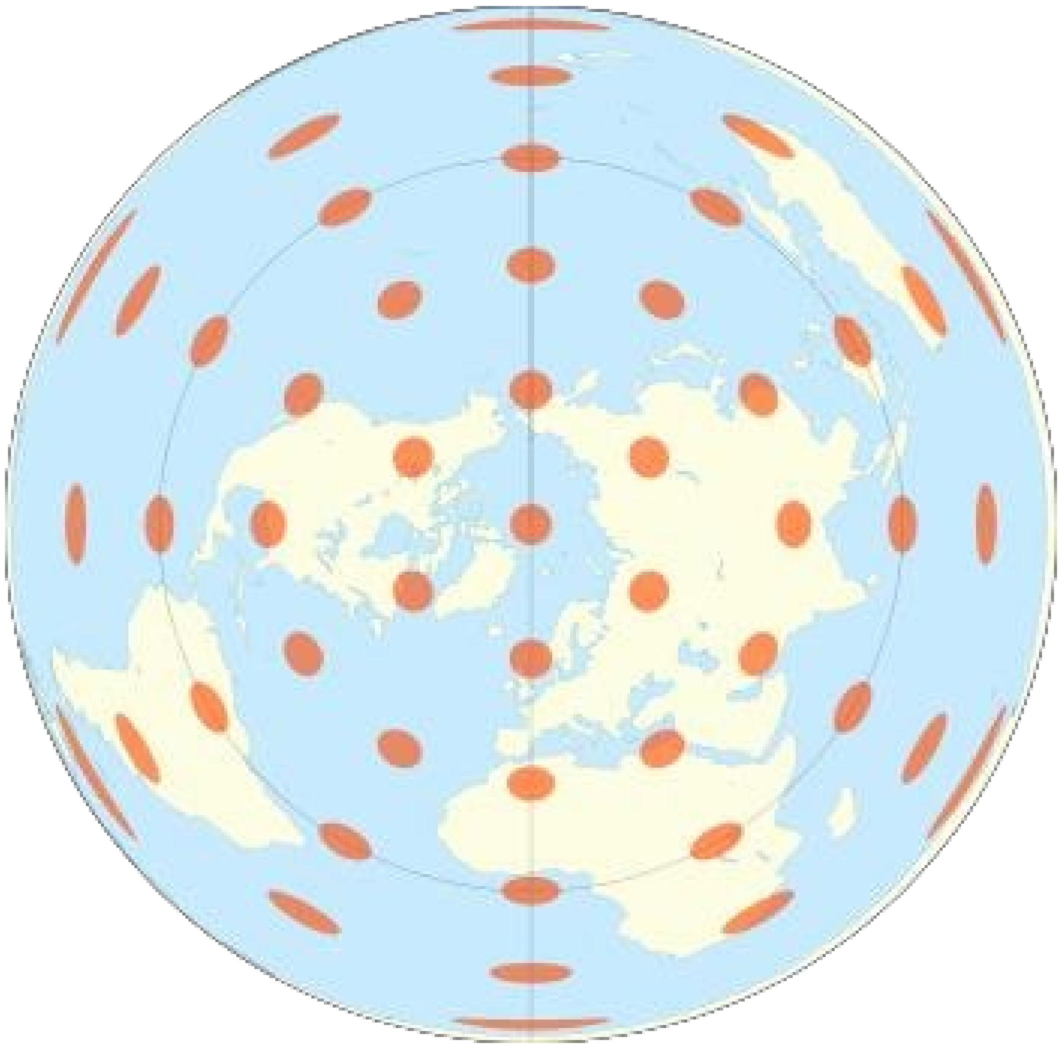
- Mapping sphere to a disk
- Equal area
- Non conformal
  - Does not accurately represent angles
- Hemisphere or continent level
- Geology – 3D mapping
- European Environment Agency



Lambert Azimuthal Equal Area Projection

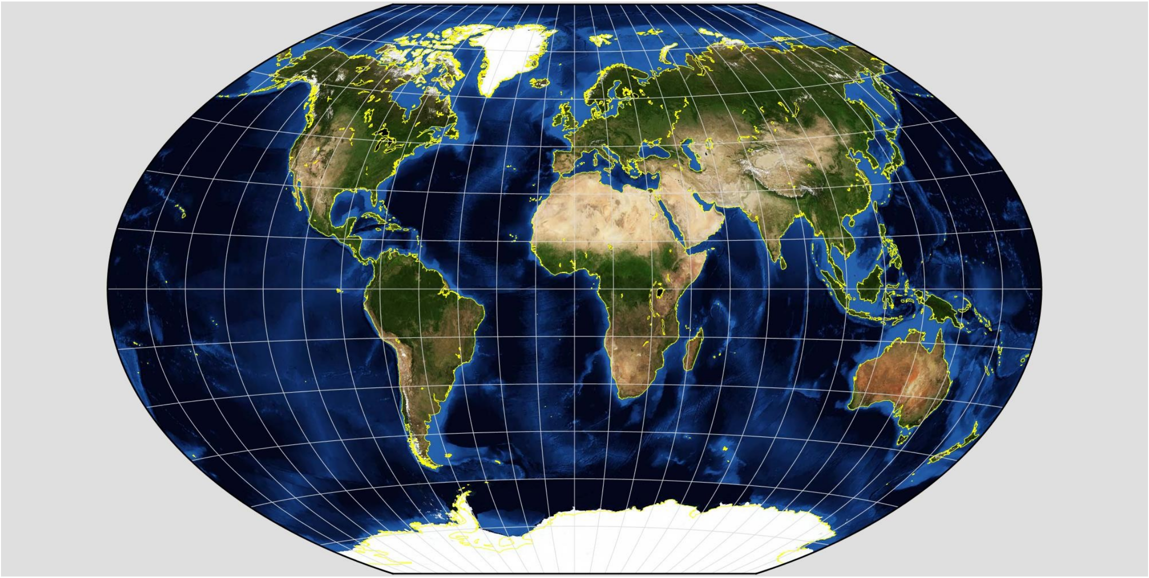


Lambert Azimuthal Equal Area Projection



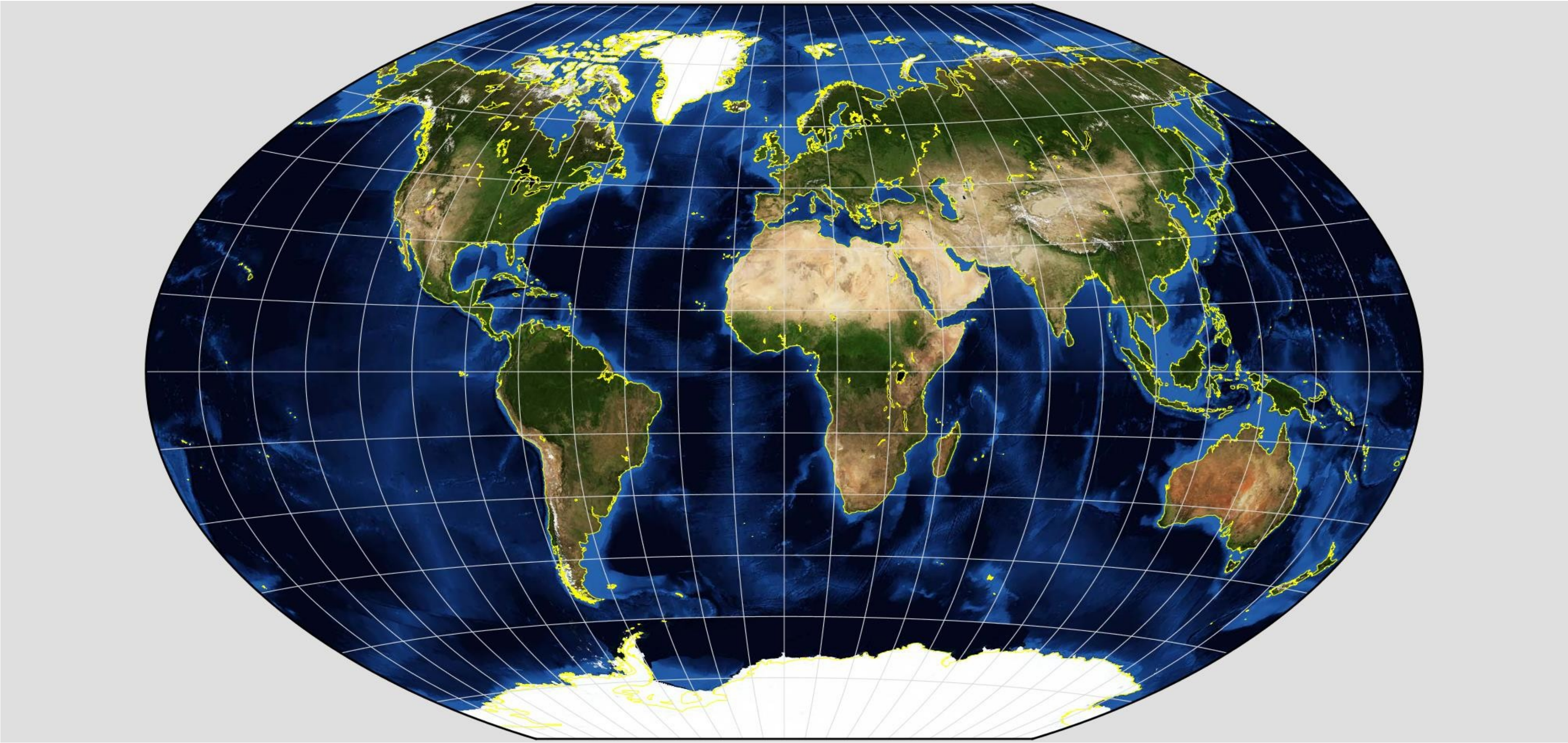
Winkel Tripel Projection

- Compromise projection
  - Give up the idea of perfectly preserving metric properties
  - Instead, strike a balance between distortions
- Neither conformal nor equal area
  - Minimizing distortions in area, direction, distance
- Whole world maps
- National Geographic



https://www.giss.nasa.gov/tools/gprojector/help/projections/

Winkel Tripel Projection



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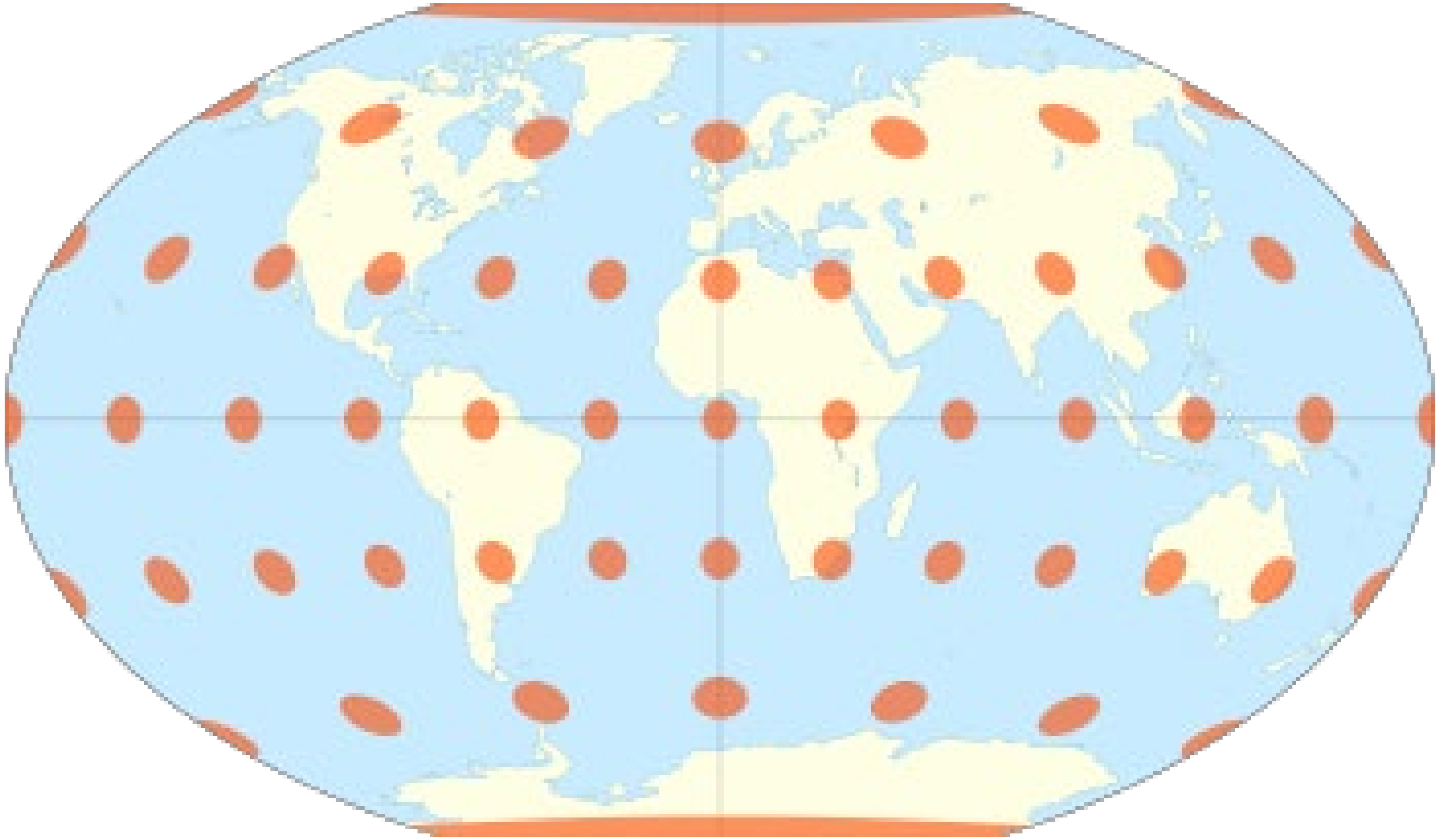
Winkel Tripel Projection



https://www.giss.nasa.gov/tools/gprojector/help/projections/

Gilbert Two world Perspective Projection

- Illusion
  - All countries are shown, even though only half the globe is visible
- Transformed conformally onto each hemisphere of a globe
- Resembles the world as people increasingly see it

https://www.giss.nasa.gov/tools/gprojector/help/projections/

Gilbert Two world Perspective Projection

https://www.giss.nasa.gov/tools/gprojector/help/projections/

Projections in R

- Different projections are included in the maps package

Projections in R

- Equatorial projections centered on the Prime Meridian (longitude 0). Parallels are straight horizontal lines

- **mercator()** equally spaced straight meridians, conformal, straight compass courses
- **gall(lat0)** parallels spaced stereographically on prime meridian, equally spaced straight meridians, true scale on lat0
- **mollweide()** equal-area, hemisphere is a circle
- **gilbert()** sphere conformally mapped on hemisphere and viewed orthographically
- Others
- **sinusoidal() cylindrical() rectangular(lat0) cylequalarea(lat0)**

https://cran.r-project.org/web/packages/maps/maps.pdf

Projections in R

- Azimuthal projections centered on the North Pole. Parallels are concentric circles. Meridians are equally spaced radial lines.
- **azequidistant()** equally spaced parallels, true distances from pole
- **azequalarea()** equal-area
- **gnomonic()** central projection on tangent plane, straight great circles
- **perspective(dist)** viewed along earth's axis dist earth radii from center of earth
- Others
- **orthographic() stereographic() laue() fisheye(n) newyorker(r)**

https://cran.r-project.org/web/packages/maps/maps.pdf

Projections in R

- Polar conic projections symmetric about the Prime Meridian. Parallels are segments of concentric circles
- **conic(lat0)** central projection on cone tangent at lat0
- **simpleconic(lat0,lat1)** equally spaced parallels, true scale on lat0 and lat1
- **lambert(lat0,lat1)** conformal, true scale on lat0 and lat1
- **albers(lat0,lat1)** equal-area, true scale on lat0 and lat1
- **bonne(lat0)** equally spaced parallels, equal-area, parallel lat0 developed from tangent cone

https://cran.r-project.org/web/packages/maps/maps.pdf

Data Visualisation
Lab Recap Week 10

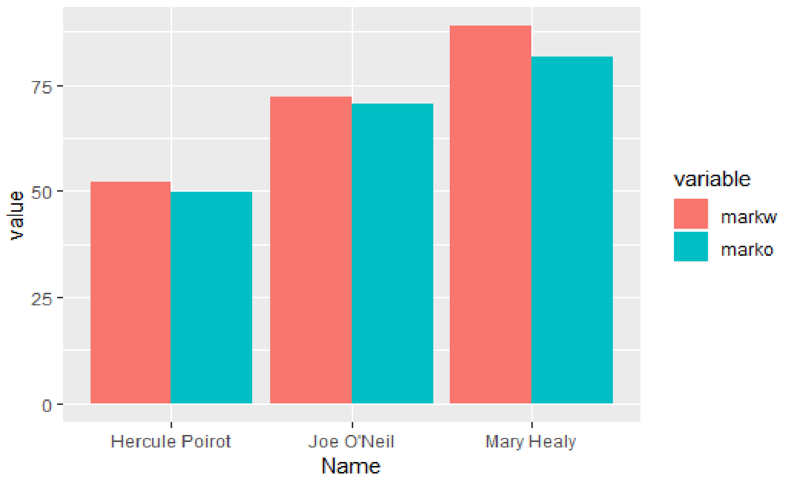
Dr. Cathy Ennis

Using ggplot in R

- Long Tables
- Bar charts
- Histograms
- Scatter plot and Bubble charts
- Line charts
- Smoothing

Long Tables in R

- Looking at last week's studentresults file, we may want to plot the results for the written and oral exams in two bars per student



- In order to plot those results in a bar chart with written and oral in separate bars, we need to convert the table into what is called long table format

Long Tables in R

Original Table

	Name	markw	marko
1	Hercule Poirot	52.06667	49.73333
2	Joe O'Neil	72.20000	70.40000
3	Mary Healy	88.86667	81.40000

Long Table

	Name	variable	value
1	Hercule Poirot	markw	52.06667
2	Joe O'Neil	markw	72.20000
3	Mary Healy	markw	88.86667
4	Hercule Poirot	marko	49.73333
5	Joe O'Neil	marko	70.40000
6	Mary Healy	marko	81.40000

Long Tables in R

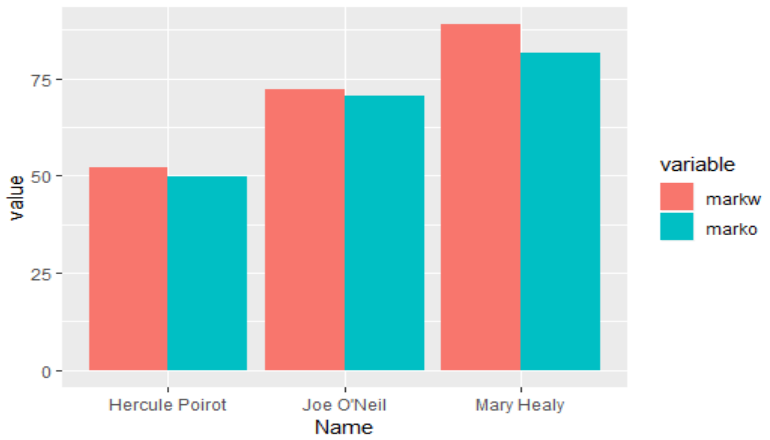
- We can create the long table using the function melt from the reshape2 package:

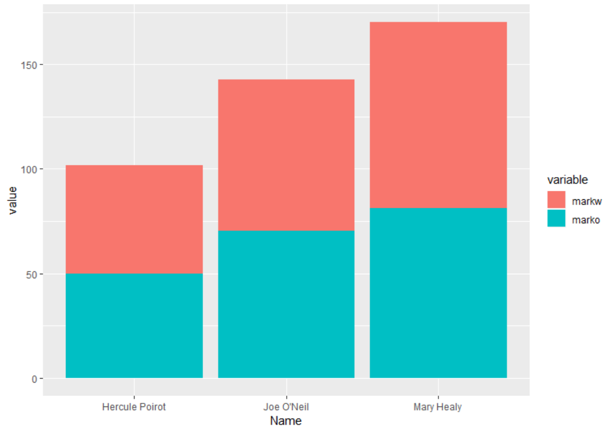
```
library(reshape2)

resultsW_O2 <- sqldf ( "select Name, avg(Mark_Written) as markw,
avg(Mark_Oral) as marko from studentresult group by Name")

head(resultsW_O2)
resultsW_Om<-melt(resultsW_O2,id.vars = c('Name'))
head(resultsW_Om)
```

Long Tables in R

- Now, we can use ggplot to plot the different values, using value for y axis and variable for fill colour, as well as position dodge to place written and oral bars beside each other instead of stacked.

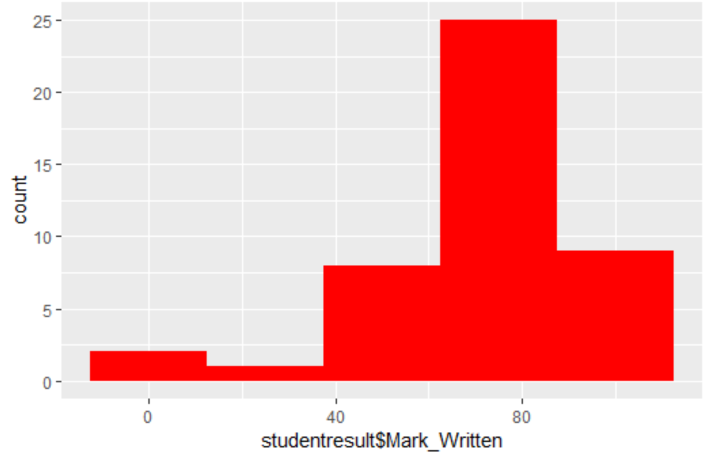
```
ggplot(resultsW_Om, aes(x = Name, y = value, fill = variable) ) +
geom_bar(stat="identity", position = 'dodge')
```





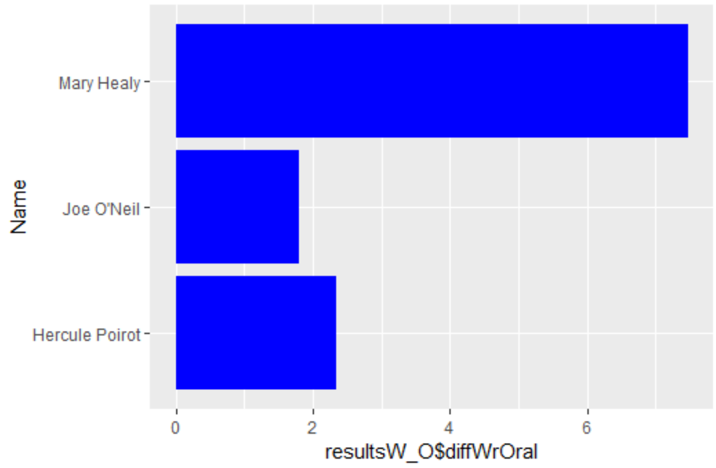
Visualisations using ggplot Histograms

- Plots one variable counting the instances that fall in each bin. Bin size can be adjusted with the command binwidth.



ggplot(data=studentresult, aes(studentresult$Mark_Written)) + geom_histogram(fill='red',binwidth = 25)

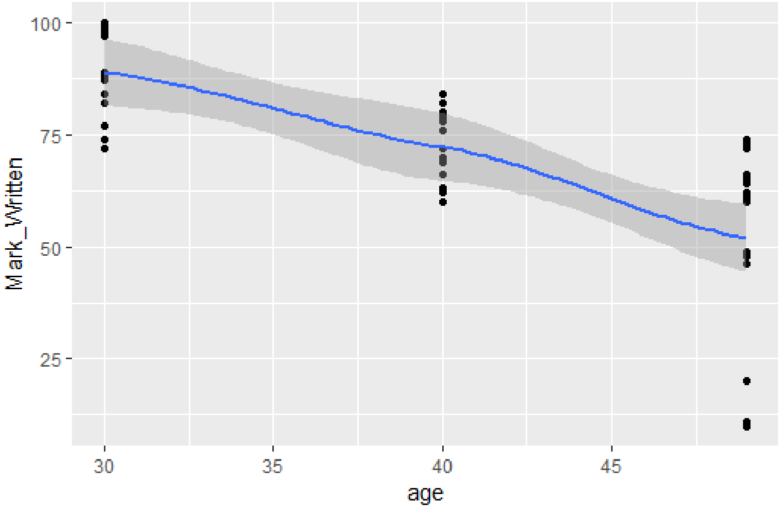
Visualisations using ggplot Horizontal Bar chart



ggplot(resultsW_O , aes(x = Name, y = resultsW_O$diffWrOral)) + geom_bar(stat="identity",fill='blue')+coord_flip()

Visualisations using ggplot
Fitting lines and smoothing methods

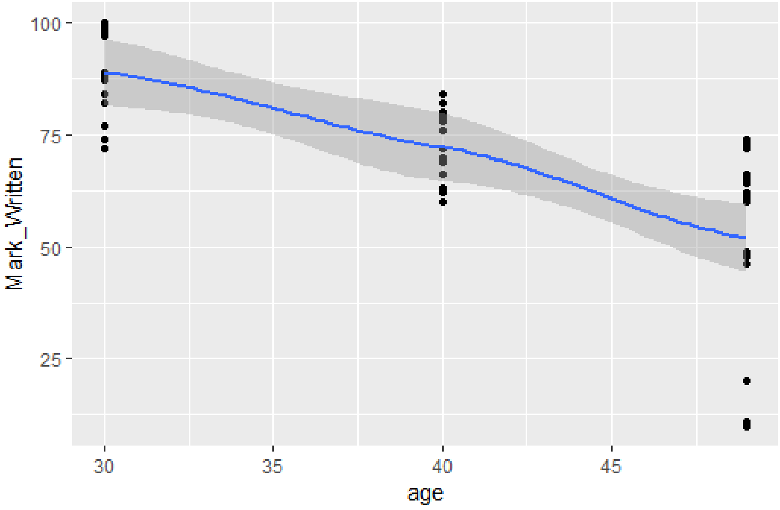
- Lines and curves can be fitted into scatter plots to help in the identification of patterns.
- Options
- method: LOESS, LM
- se: confidence interval display(TRUE,FALSE)



Visualisations using ggplot
Fitting lines and smoothing methods

- Lines and curves can be fitted into scatter plots to help in the identification of patterns.

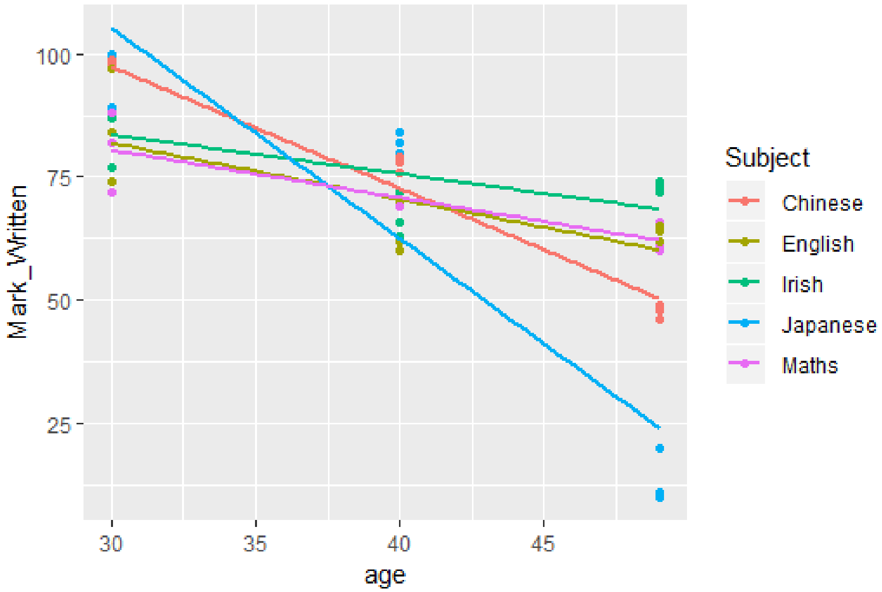
```
v<-ggplot(studentresult, aes(x = age, y =Mark_Written ) )
+geom_point()
v+geom_smooth(method='loess')
```



Visualisations using ggplot
Fitting lines and smoothing methods

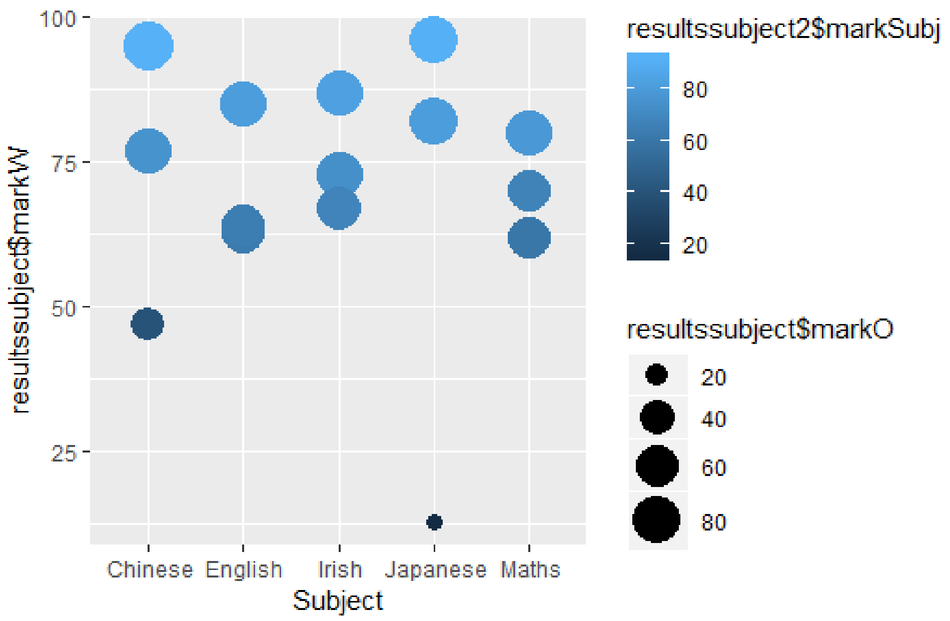
- Fitting separate lines for different data series (per subject)

```
v<-ggplot(studentresult, aes(x = age, y =Mark_Written ,color=Subject) )
+geom_point()
v+geom_smooth(method='lm',se=FALSE)
```



Visualisations using ggplot Bubble Charts

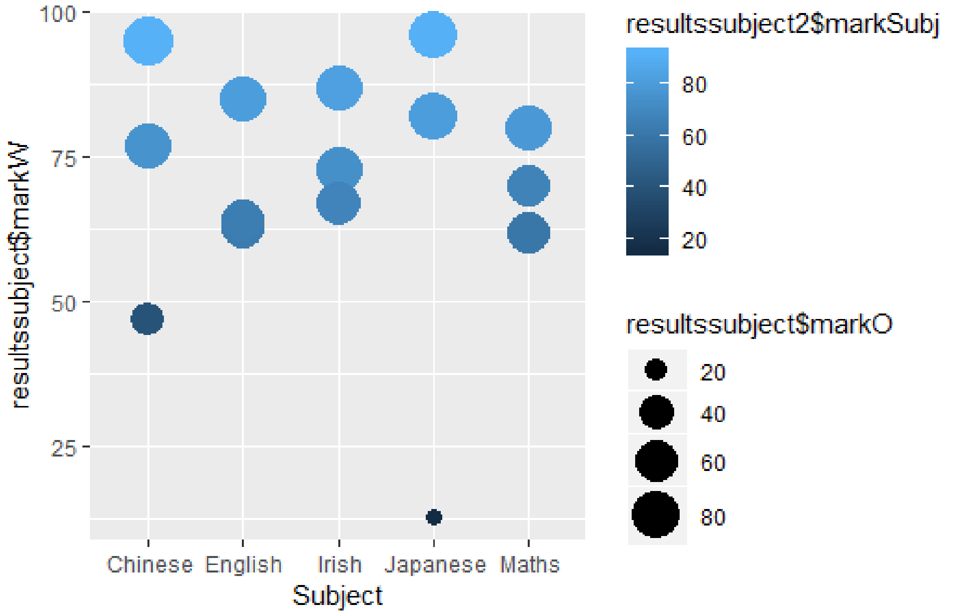
- Bubble charts are created using ggplot by creating a scatter plot and adding the third dimension in the aesthetic option size.
- A fourth dimension can be added using the colour fill.



Visualisations using ggplot Bubble Charts

ggplot(resultssubject, aes(x = Subject, y = resultssubject$markW)) +

geom_point(aes(size = resultssubject$markO, color=resultssubject2$markSubj)) + scale_size(range = c(3, 9))



Question for Lab

- Find one message in our studentresult data
- Create the best visualization to show the message

Assignment 2 – 30%

- You are a Data Scientist. You are tasked with conducting some exploratory analysis. Your goal is to find “insights” in the data and present those findings to your colleagues.

1. Select, Clean and Wrangle a Dataset – 4%
2. Decide on a story (user story) – 2%
3. Using R, create three visualisations 21%
4. Show previous iterations or alternatives 3%

Thanks To

- Marisa Llorens-Salvador, John McAuley, Colman McMahon and Brian Mac Namee for an earlier version of these lecture notes