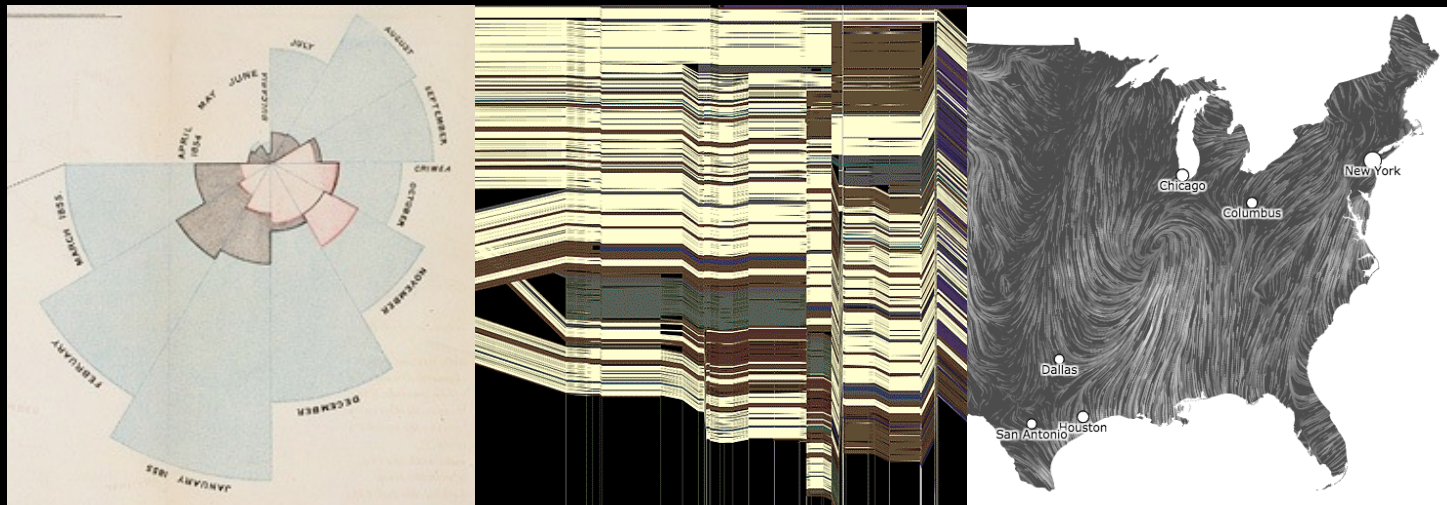


CSE 442 - Data Visualization

Mapping & Cartography



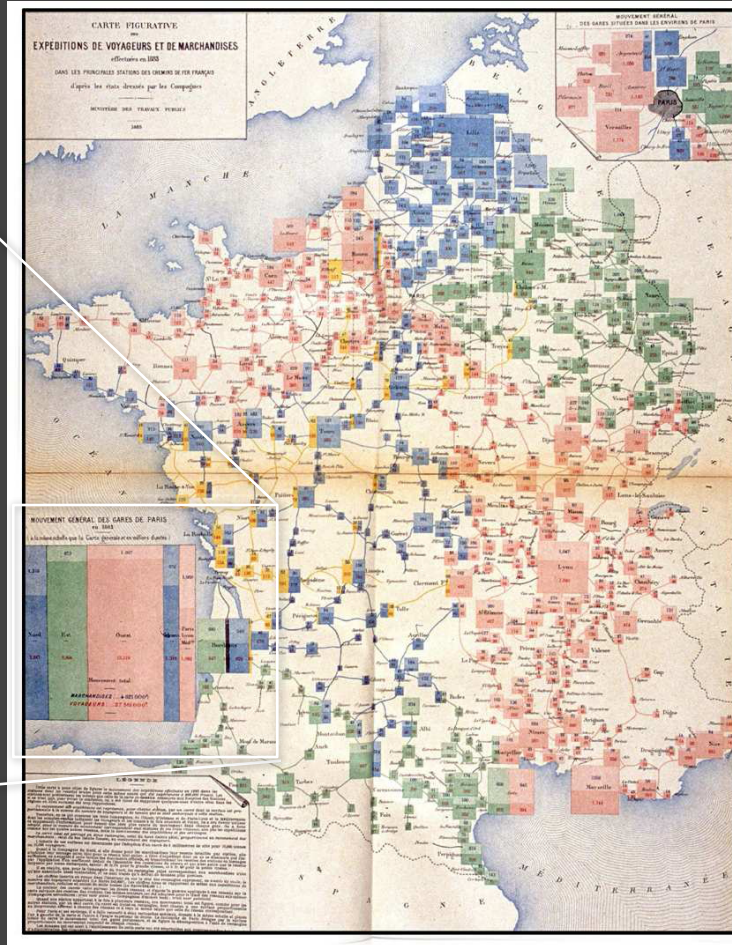
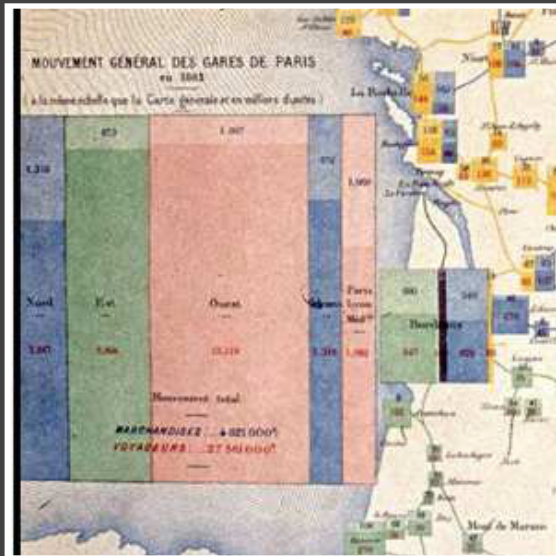
Jeffrey Heer University of Washington
(with significant material from Michal Migurski)

Mapping

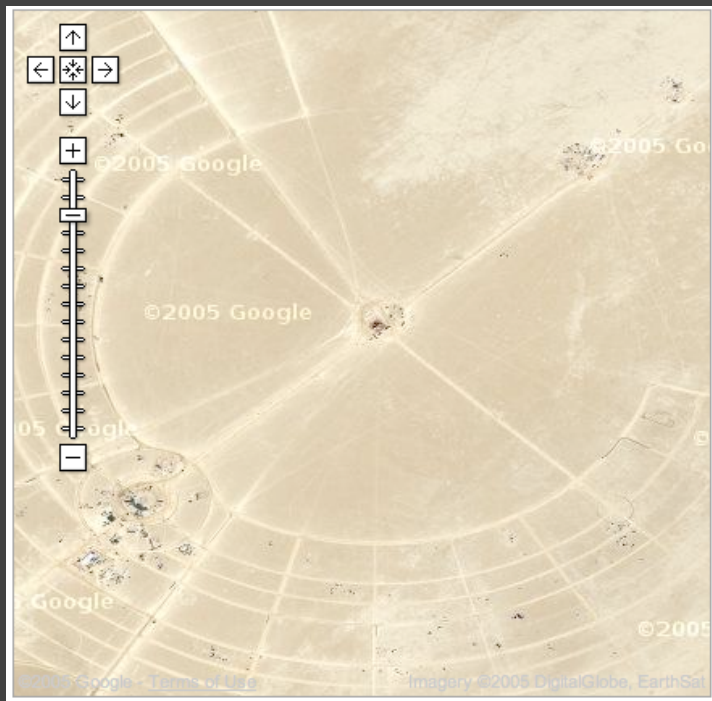
Visualizing Geospatial Data



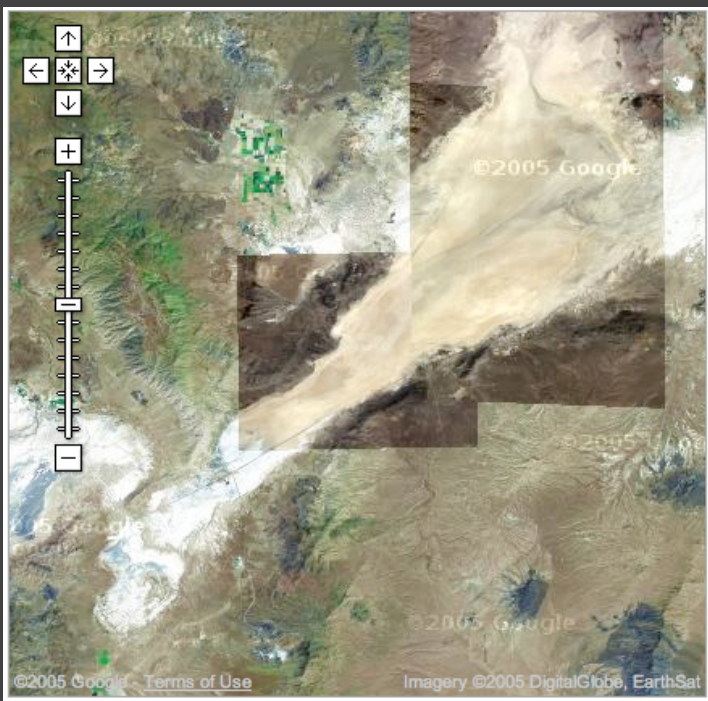
Ptolemy's Geographica
Original ~150AD, This Map ~1300AD



Rail Passengers and Freight from Paris 1884



Black Rock City, Nevada
(Burning Man)



Google Maps 2005

[WORLD](#) [U.S.](#) [N.Y. / REGION](#) [BUSINESS](#) [TECHNOLOGY](#) [SCIENCE](#) [HEALTH](#) [SPORTS](#) [OPINION](#) [ARTS](#) [STYLE](#) [TRAVEL](#) [JOBS](#) [REAL ESTATE](#) [AUTOS](#)
[POLITICS](#) [WASHINGTON](#) [EDUCATION](#)

Casualties of War

[FACES](#) [ANALYSIS](#) [THEIR STORIES](#)
[E-MAIL](#) [FEEDBACK](#)

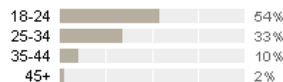
Use the slider below to investigate the demographics and military status of U.S. service members who died during the war in Iraq.

MARCH 16, 2003 JULY 5, 2008 (277 WEEKS)

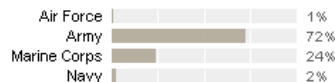
[Show all](#) | [Initial invasion](#) | [First invasion of Falluja](#) | [Second invasion of Falluja](#) | [Since troop buildup began](#)

4,097 deaths

Age



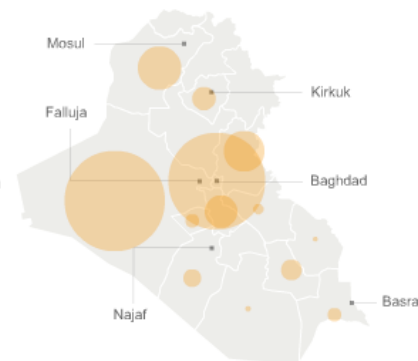
Branch of Military



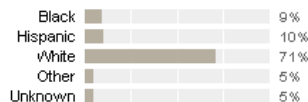
Location of death

Circles sized according to percentage of deaths in each Iraqi province.

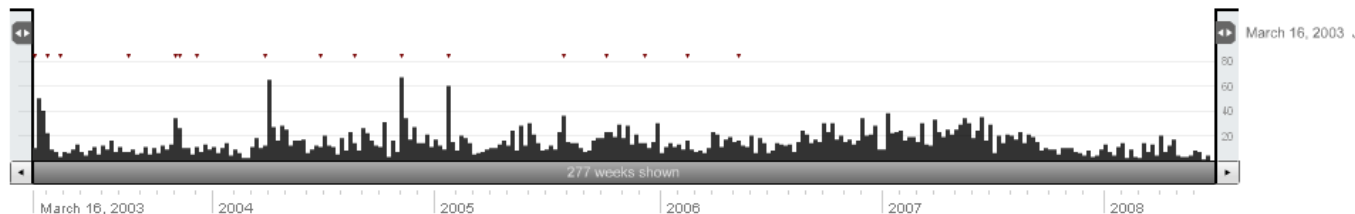
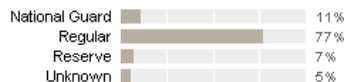
[Show home](#)



Race



Type of Duty



MIDDLE EAST

SHARE



A Rogue State Along Two Rivers

How ISIS Came to Control Large Portions of Syria and Iraq

By JEREMY ASHKENAS, ARCHIE TSE, DEREK WATKINS and KAREN YOURISH July 3, 2014

The militant group called the Islamic State in Iraq and Syria, or ISIS, seemed to surprise many American and Iraqi officials with the recent gains it made in its violent campaign to create a new religious state. But the rapid-fire victories achieved over a few weeks in June were built on months of maneuvering along the Tigris and Euphrates Rivers.

The Euphrates



Ramadi: The Government Provides an Opening for ISIS ISIS Control

Tensions between this city's residents, who are mostly Sunni, and the central government had been brewing here for at least a year. Then in December, Iraq's prime minister, Nuri Kamal al-Maliki, **ordered security forces to dismantle a protest camp** — an outlet for disenchanting Sunnis angered at their treatment by the Shiite-dominated government. The action ignited days of violence and created the opening ISIS needed to seize parts of the city, the provincial capital.

Falluja: A Symbolic Fall ISIS Control

Just days after the raid on the camp in Ramadi, **ISIS fighters destroyed the Police Headquarters and mayor's office here**, planted their flag on government buildings and decreed the city to be theirs. Ten years earlier, American forces had captured this city from Qaeda-style insurgents at a considerable cost of American lives.



17 MILES TO BAGHDAD

NY Times
2014

237

Joseph R. Biden Jr.

70,098,068 votes (50.2%)

87

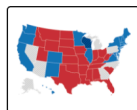
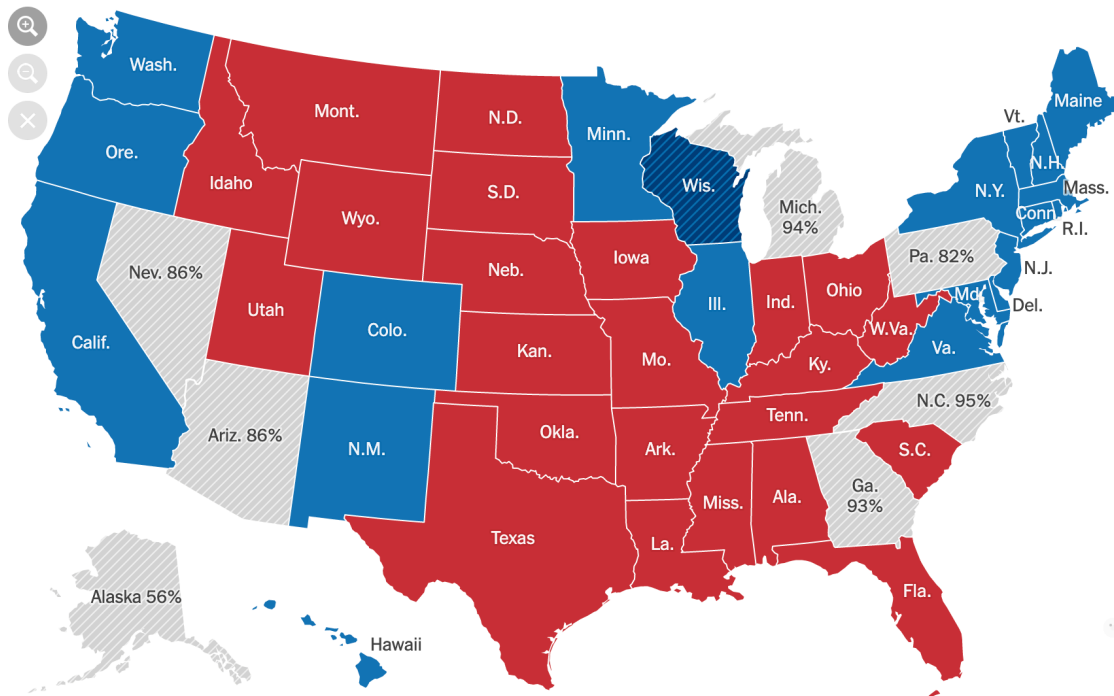
remaining

270
TO WIN

214

Donald J. Trump

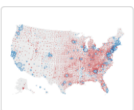
67,072,823 votes (48.1%)



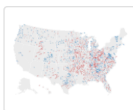
By winner



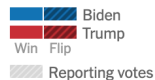
Electoral votes



Size of lead



Shift from 2016



Percentages are estimates of how much vote has been counted.

Choropleth Map
[NY Times]

237

Joseph R. Biden Jr.

70,122,063 votes (50.2%)

87

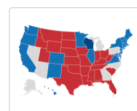
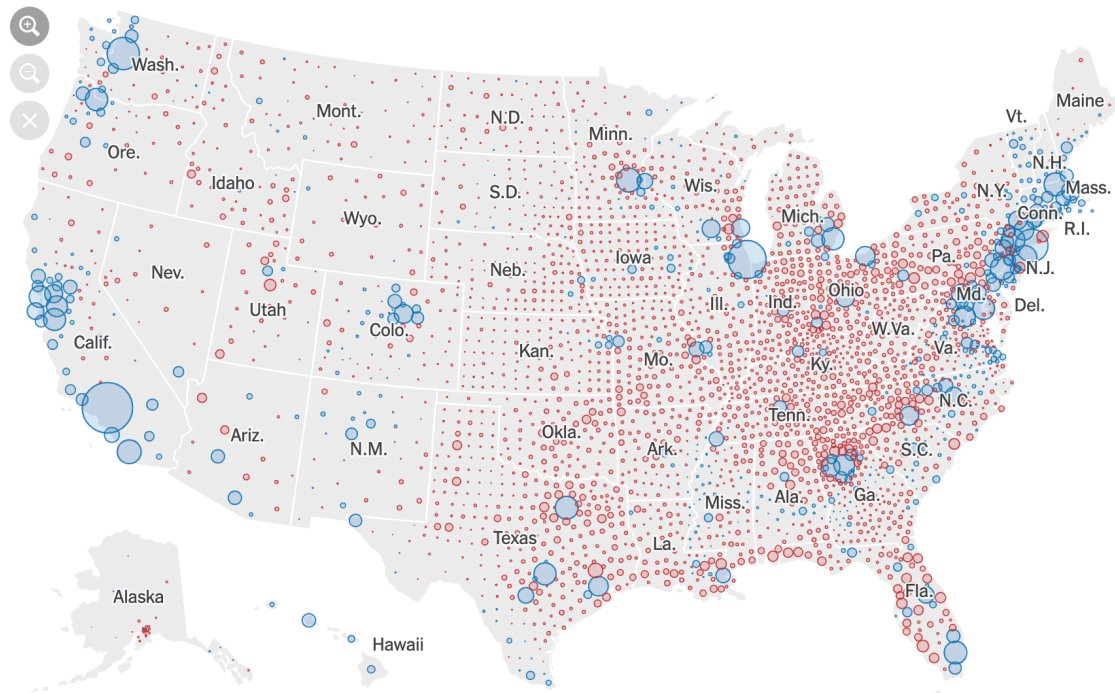
remaining

270
TO WIN

214

Donald J. Trump

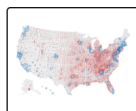
67,075,300 votes (48.0%)



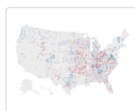
By winner



Electoral votes



Size of lead



Shift from 2016

LEADER: ● Biden ● Trump
Circle size is proportional to the amount each county's leading candidate is ahead.

Symbol Map
[NY Times]

237

Joseph R. Biden Jr.

70,122,064 votes (50.2%)

87

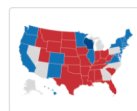
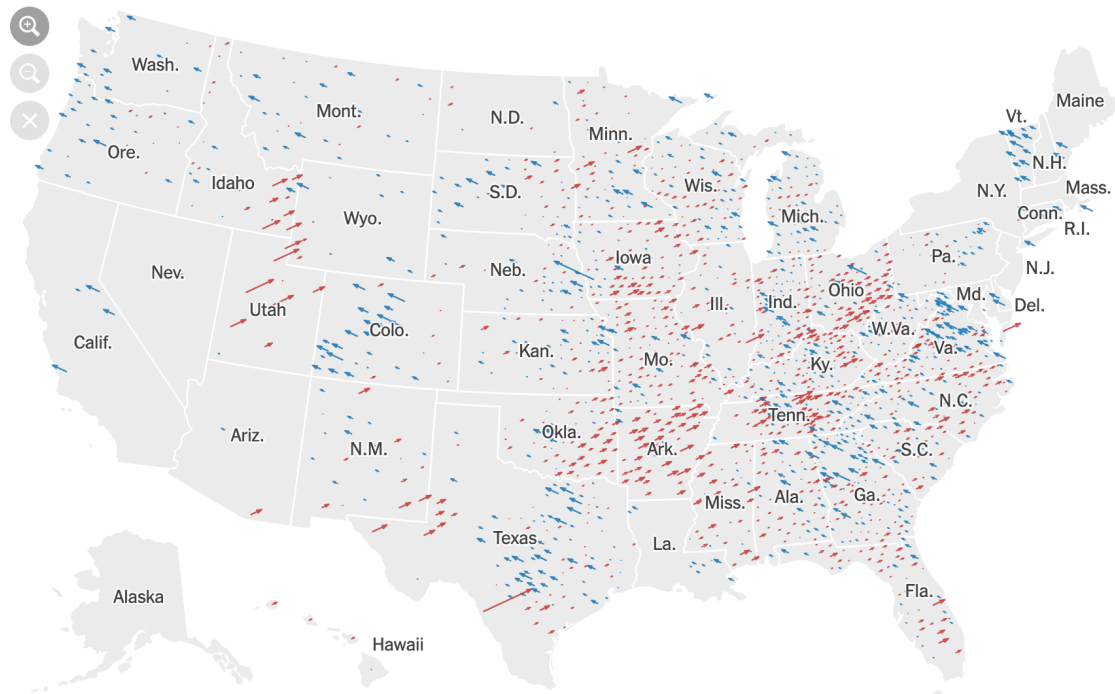
remaining

270
TO WIN

214

Donald J. Trump

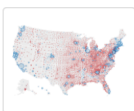
67,075,309 votes (48.0%)



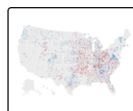
By winner



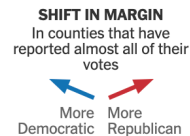
Electoral votes



Size of lead



Shift from 2016



Symbol Map
[NY Times]

237

Joseph R. Biden Jr.

70,122,063 votes (50.2%)

87

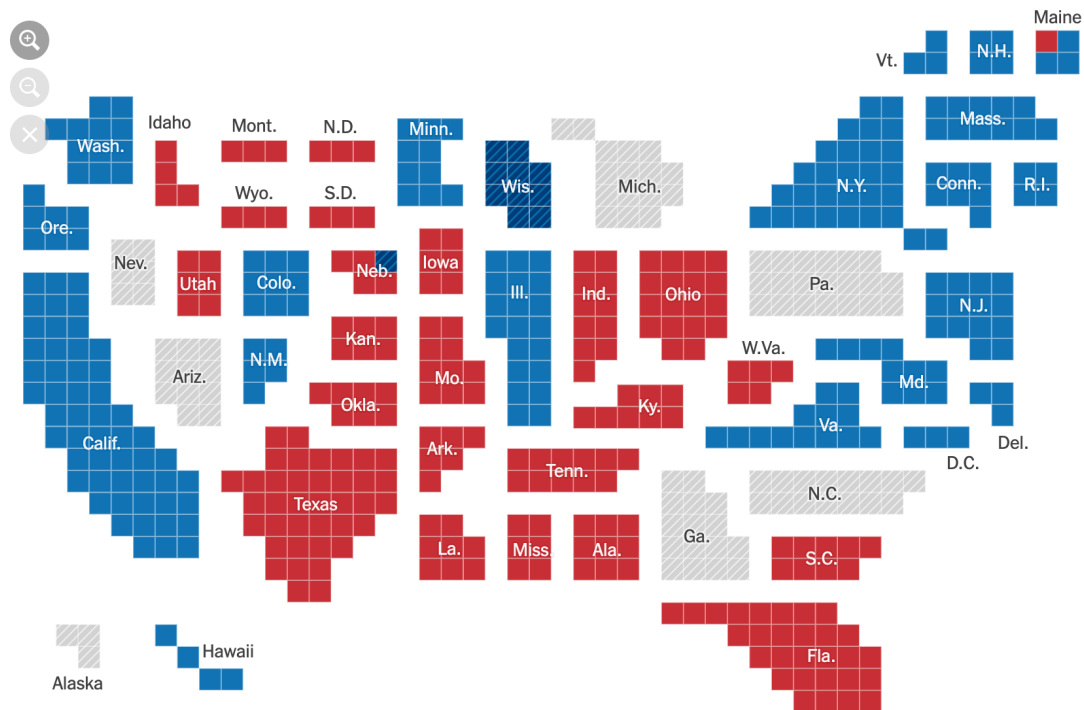
remaining

270
TO WIN

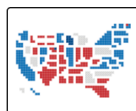
214

Donald J. Trump

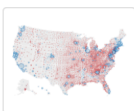
67,075,300 votes (48.0%)



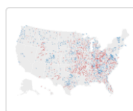
By winner



Electoral votes

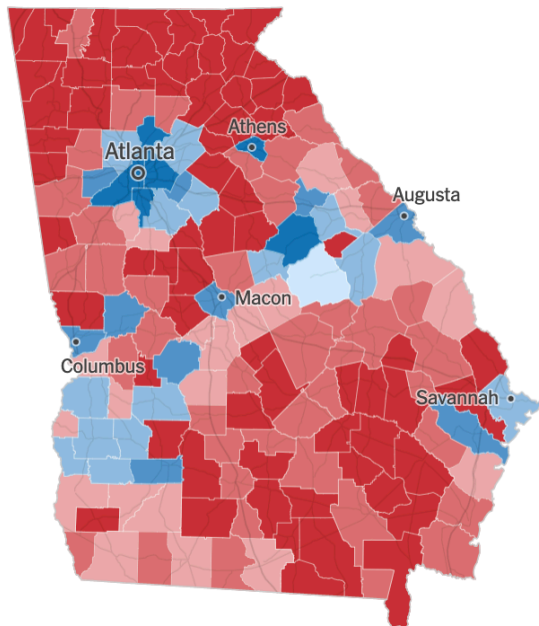


Size of lead

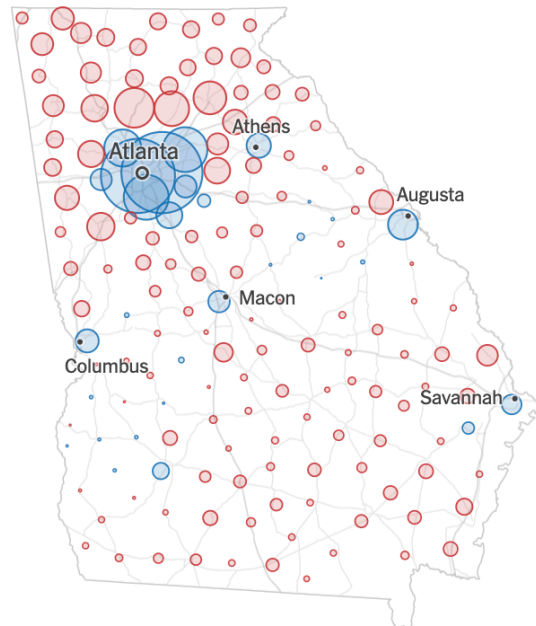
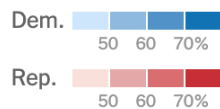


Shift from 2016

Cartogram
[NY Times]



Choropleth Map
[NY Times]



Symbol Map
[NY Times]

Circle size is proportional to the amount each county's leading candidate is ahead.

● Trump ● Biden

wind map

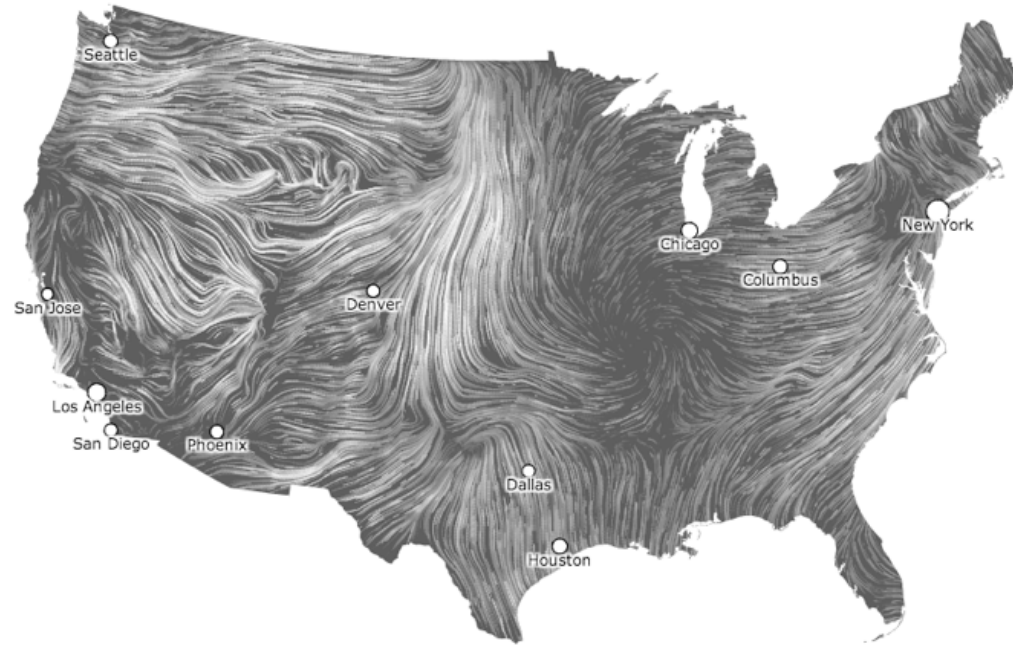
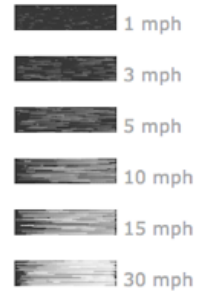
February 19, 2014

11:55 am EST

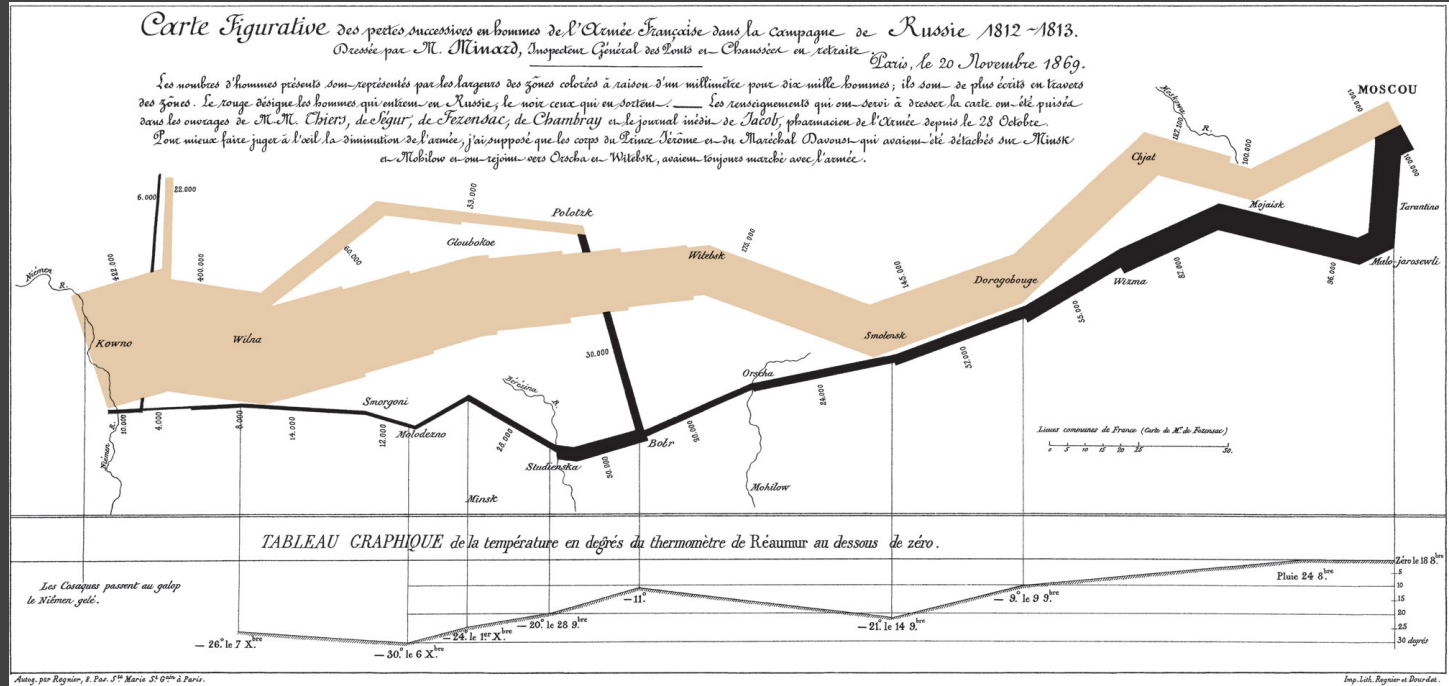
(time of forecast download)

top speed: **35.3 mph**

average: **11.6 mph**

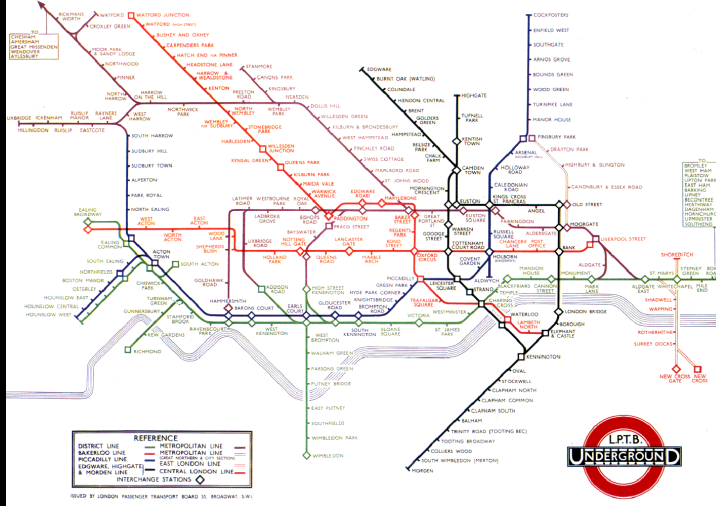


Minard 1869: Napoleon's march

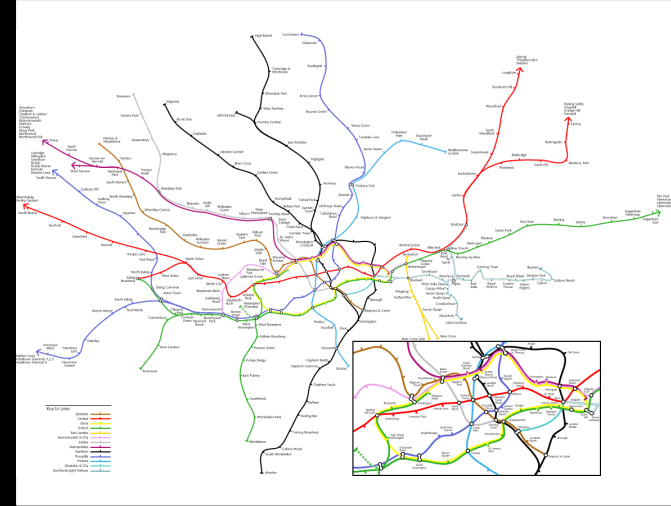




Beck's London tube diagram



London Underground [Beck 33]



Geographic version of map

Principle: Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information

Approaches to Mapping Data

Symbol Maps → plot data over a map

Choropleth Maps → colored regions

Heatmaps & Contours → show densities

Cartograms → distort to show quantities

Flow Maps → flux across regions

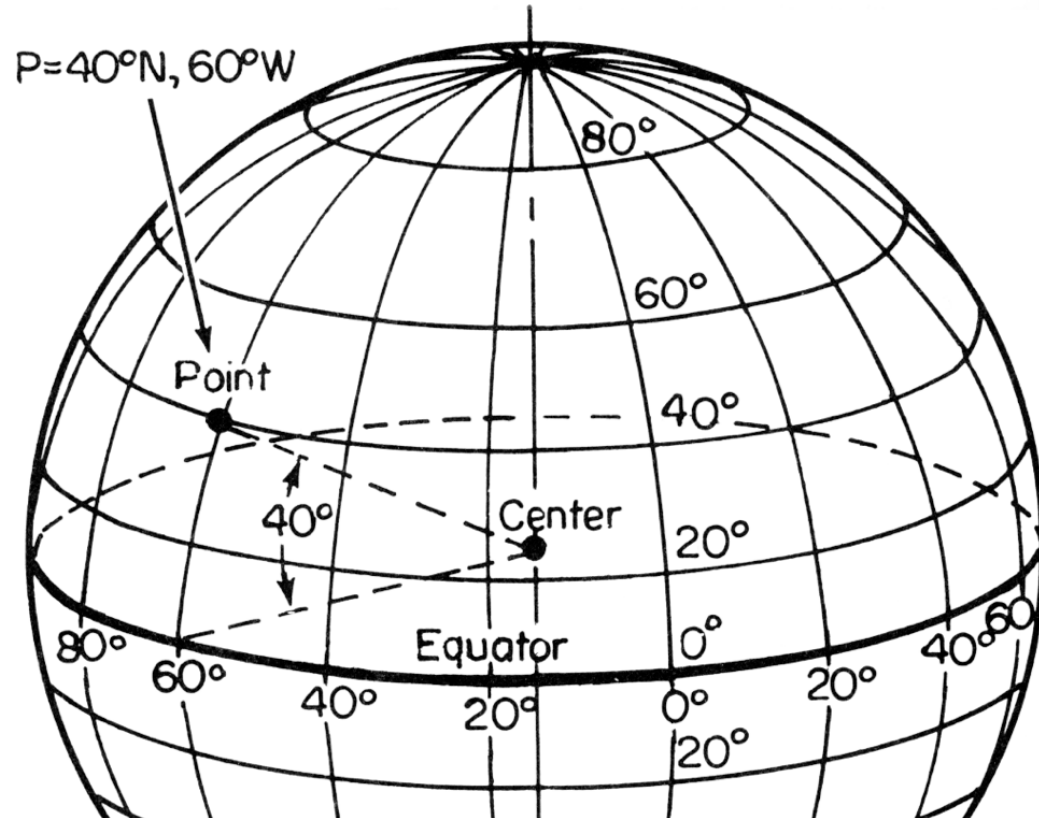
Generalization → distort/abstract to aid tasks

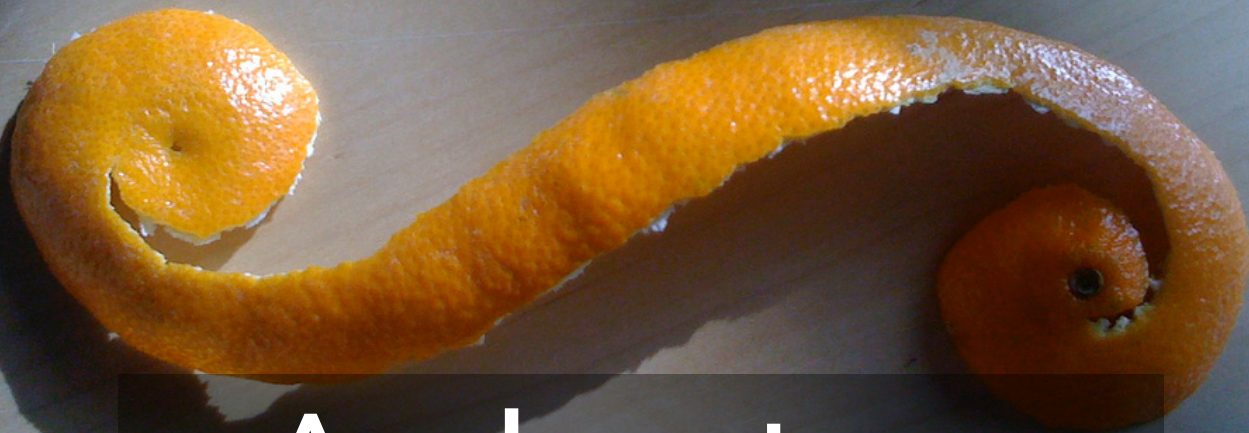
Cartography

The Making of Maps

Projections

Latitude, Longitude





**A sphere tears
when you flatten it**

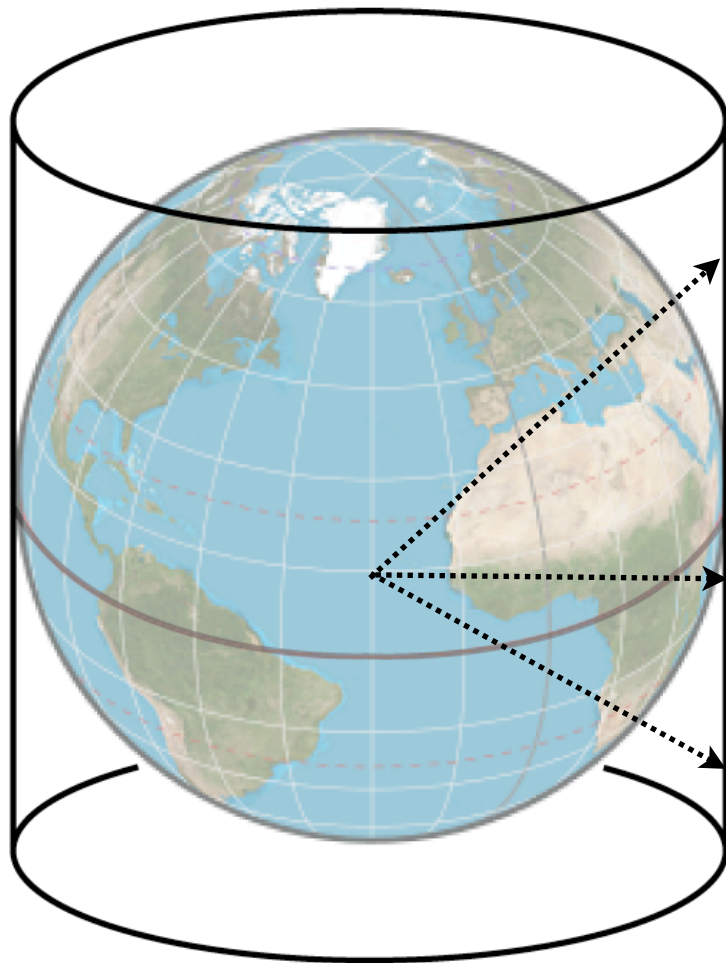
Projections

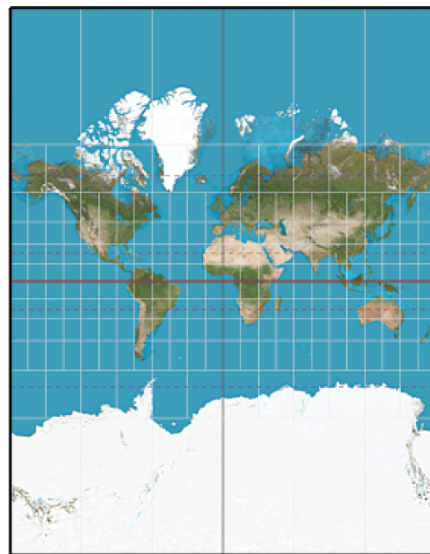
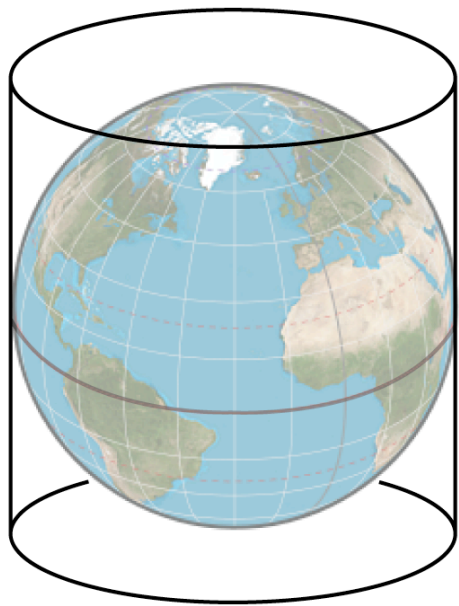
$$f(\phi, \lambda) \rightarrow (x, y)$$

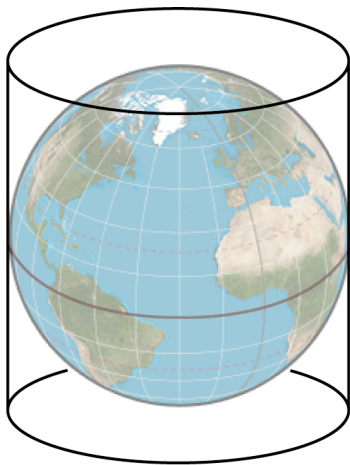
Projections

$$f(\phi, \lambda) \leftrightarrow (x, y)$$

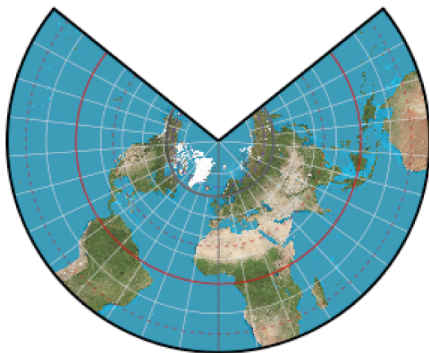
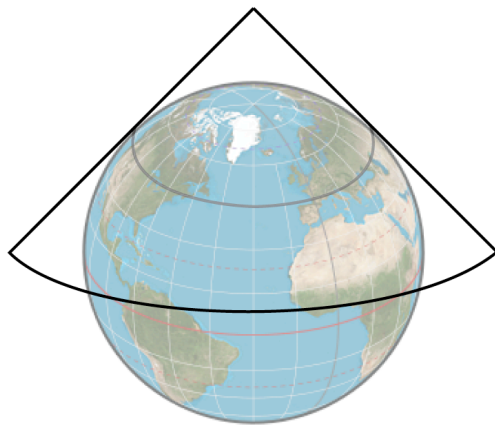
??



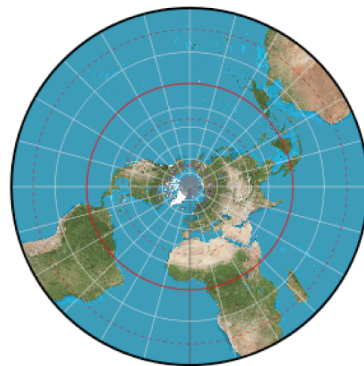
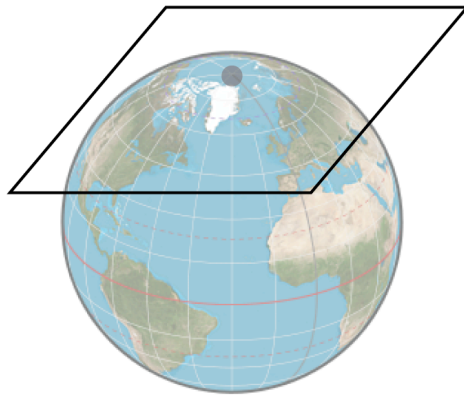




Cylindrical



Conical



Azimuthal

Exploring Projections...





Type

mercator

Scale



Yaw



Pitch



Roll





Type

mercator

Scale



Yaw

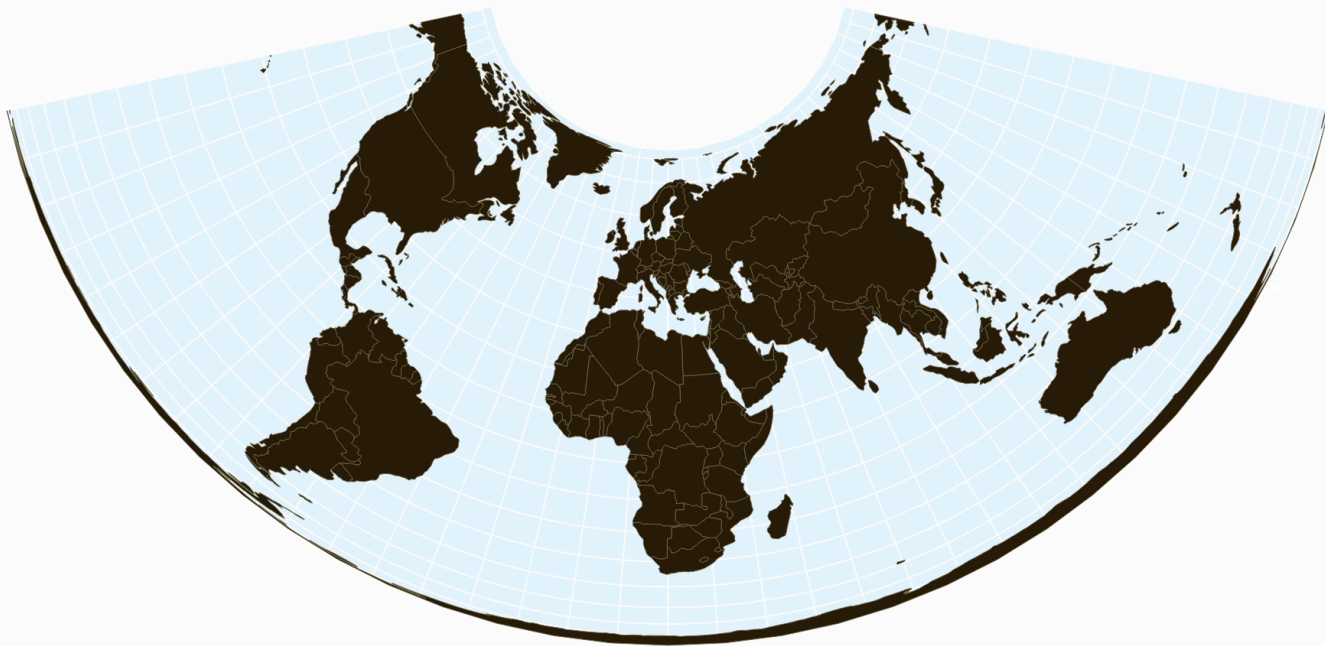


Pitch



Roll





Type

conicEqualArea

Scale

140

Yaw

-20

Pitch

0

Roll

0



Type

orthographic 

Scale

 140

Yaw

 0

Pitch

 0

Roll

 0

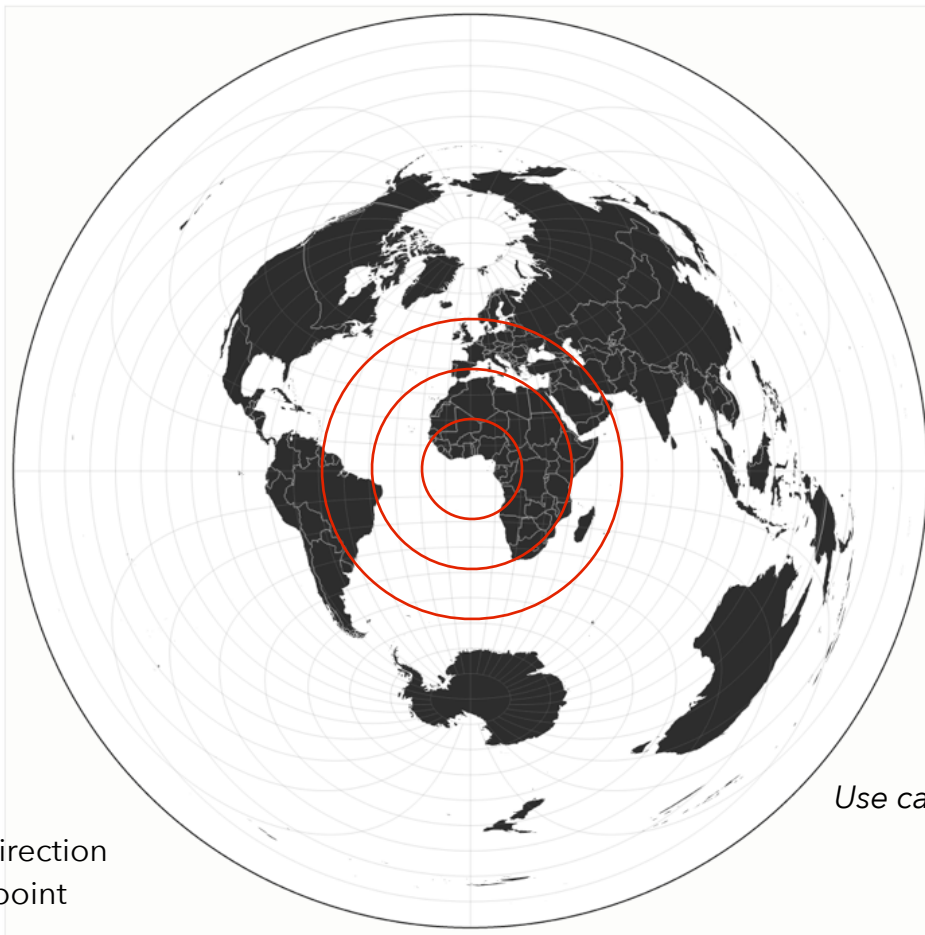
**We can categorize
projections by what
they preserve...**



Distance

Preserve distance / direction from center

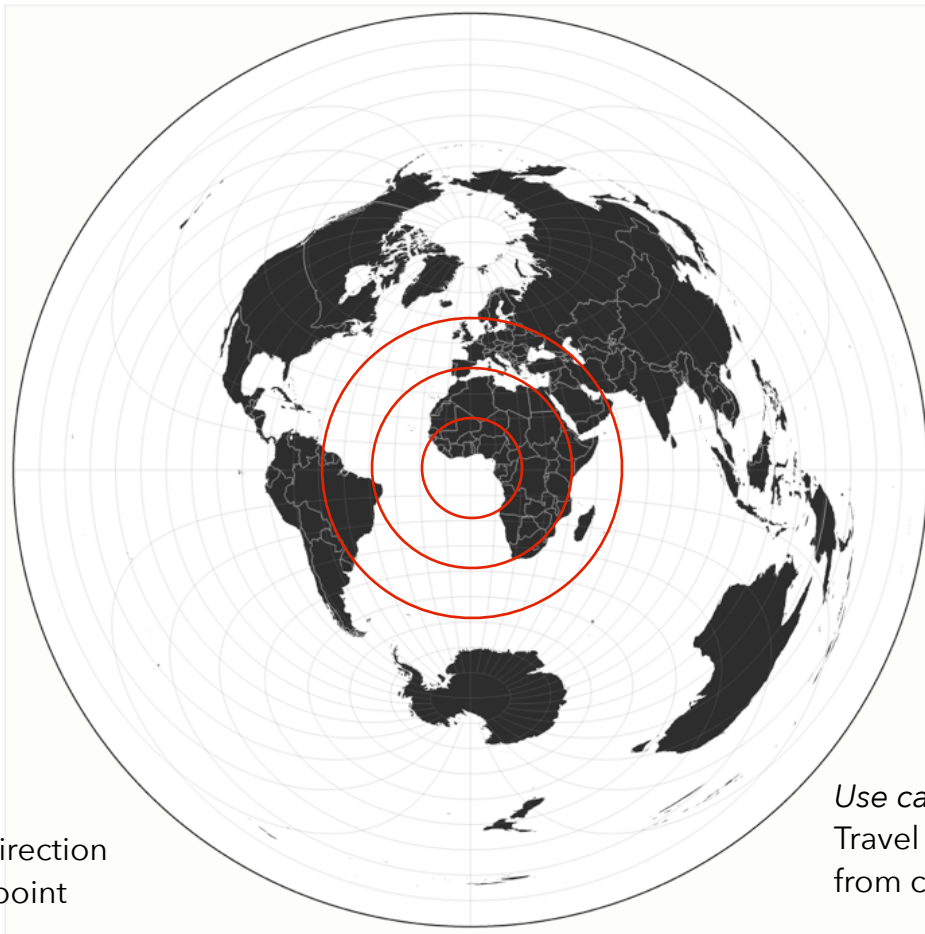
Azimuthal Equidistant



Preserves:
Distance & direction
from center point

Use cases?

Azimuthal Equidistant



Preserves:
Distance & direction
from center point

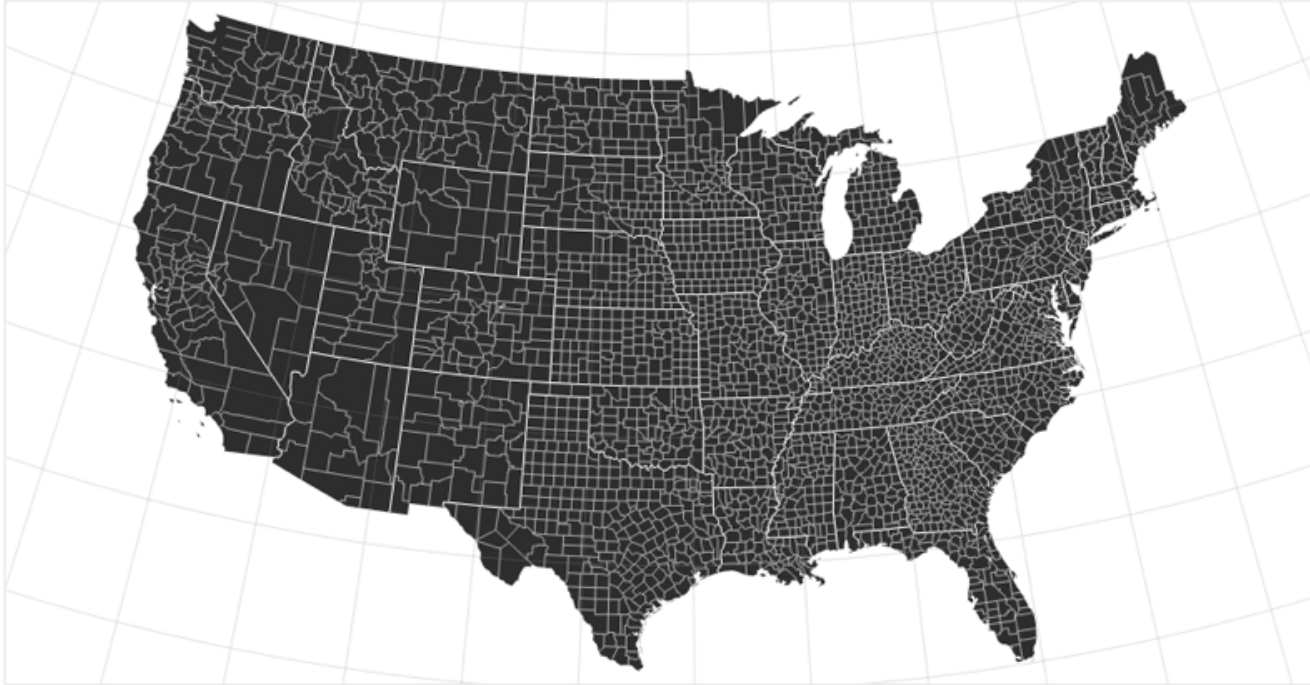
Use cases:
Travel / propagation
from center point

A world map with a dark gray background. The landmasses are outlined in black. A semi-transparent dark gray rectangle is centered over North America. Inside this rectangle, the text "Equal-Area" is written in a large, white, sans-serif font. Below it, the text "Preserve proportional areas" is written in a smaller, white, sans-serif font.

Equal-Area

Preserve proportional areas

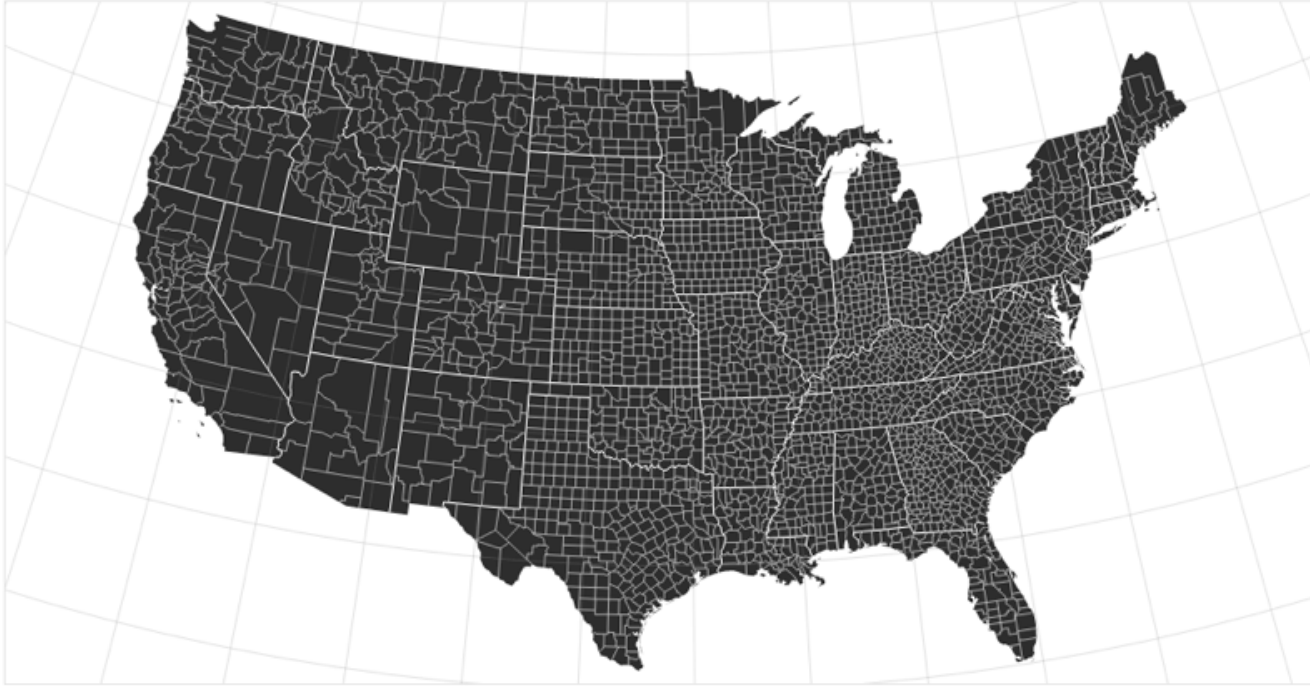
Albers Equal-Area Conic



Preserves: Proportional area of geographic regions

Use cases?

Albers Equal-Area Conic



Preserves: Proportional area of geographic regions

Use cases: Land surveys, choropleth (shaded) maps

A world map with yellow landmasses and dark grey oceans. A semi-transparent grey rectangular box is centered over the Atlantic Ocean, containing the text 'Conformal' and 'Preserve local angles ("shape")'.

Conformal

Preserve local angles ("shape")

Spherical Mercator



Preserves:
Compass bearing
as a straight line

Use cases?

Spherical Mercator



Preserves:
Compass bearing
as a straight line

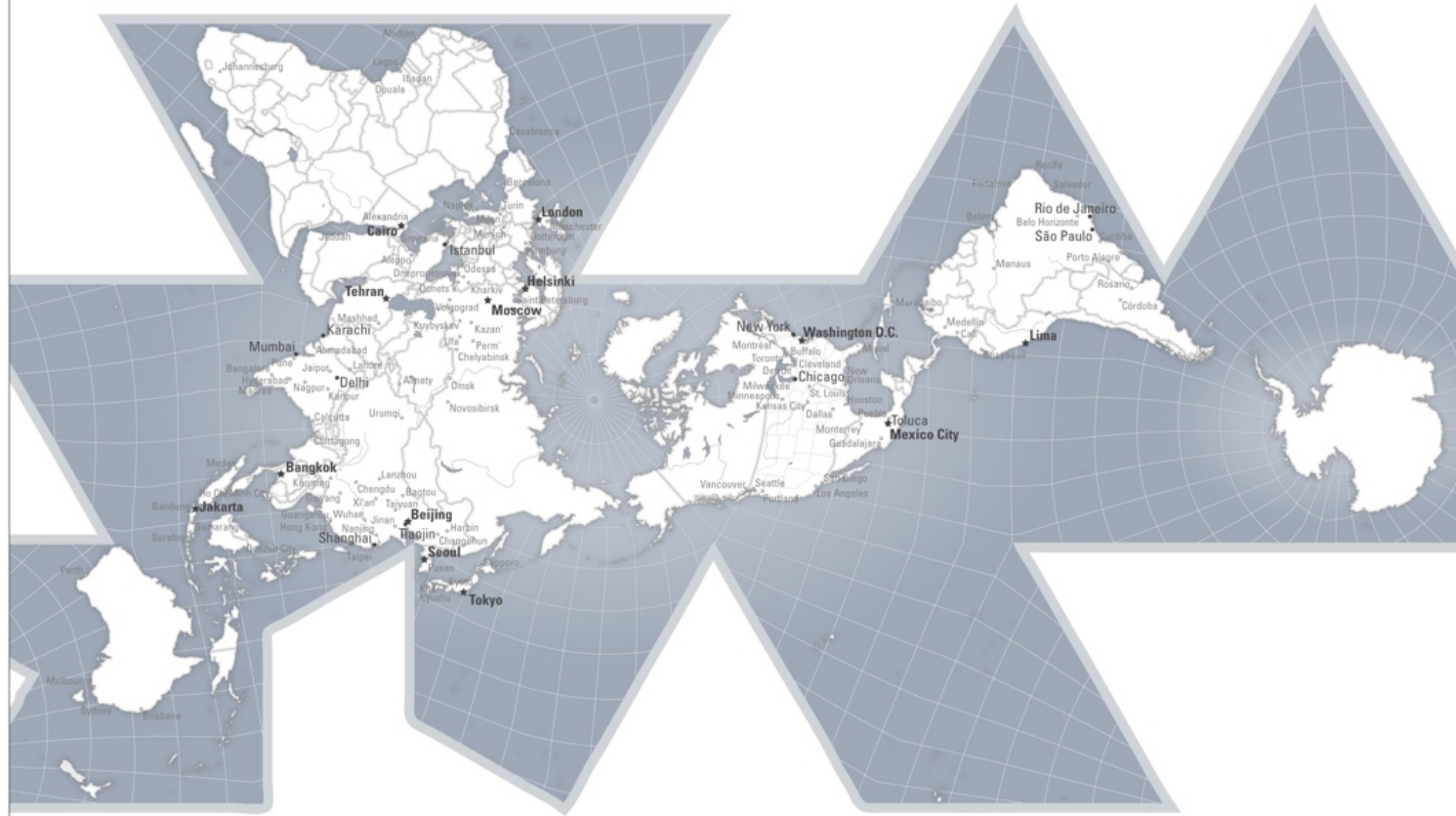
Use cases:
Navigation



**There are interesting
ways to tear spheres**

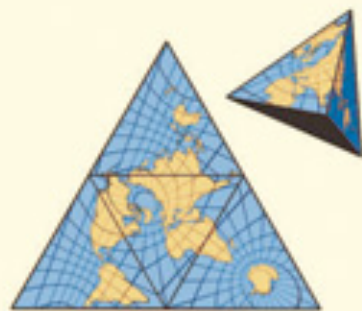
One notable interesting
way to tear a sphere



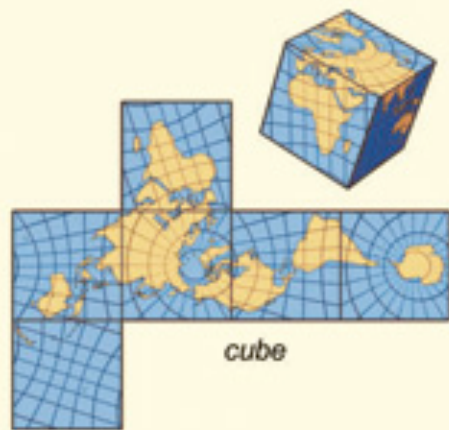


Balances preservation of area and shape.

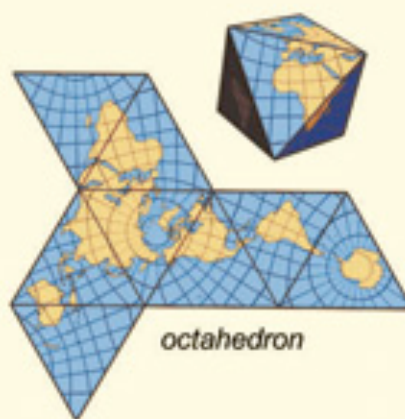
Provides different ways of thinking about the world!



tetrahedron



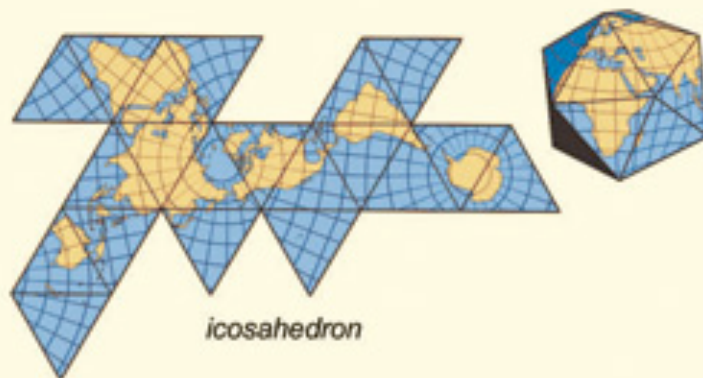
cube



octahedron



dodecahedron



icosahedron

Geographic Data Formats

From Tables to Geometry: Basic Shapes

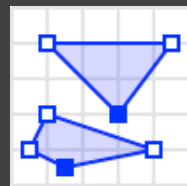
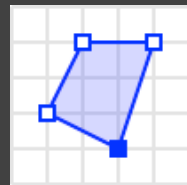
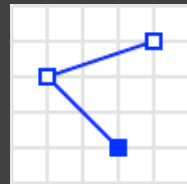
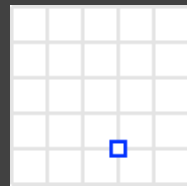
Point: An array containing 2D or 3D coords (e.g., [lon, lat])
[125.6, 10.1]

LineString: An array of points
[[30, 10], [10, 30], [40, 40]]

Polygon: One or more arrays of points
[[[30, 10], [40, 40], [20, 40], [10, 20], [30, 10]]]

MultiPolygon: An array of polygons

```
[  
  [ [[30, 20], [45, 40], [10, 40], [30, 20]] ],  
  [ [[15, 5], [40, 10], [10, 20], [5, 10], [15, 5]] ]  
]
```



GeoJSON Format

GeoJSON is a standardized JSON format for geometric data.

Geometry: An object with a type and a coordinates array

```
{“type”: “Point”, “coordinates”: [125.6, 10.1]}
```

```
{“type”: “Polygon”, “coordinates”: [[[30.0, 20.0], [45.0, 40.0],  
[10.0, 40.0], [30.0, 20.0]]]}
```

Feature: An object with a geometry and optional named attributes

```
{  
  “type”: “Feature”,  
  “id”: “optional_id_string”,  
  “geometry”: { “type”: “MultiPolygon”, ...},  
  “properties”: { “attr1”: “foo”, “attr2”: 12863 }  
}
```

GeoJSON Format, Continued

FeatureCollection: Top-level GeoJSON file object

```
{  
  "type": "FeatureCollection",  
  "features": [  
    { "type": "Feature", "geometry": ... },  
    { "type": "Feature", "geometry": ... }  
  ]  
}
```

Tools like D3, Vega-Lite, and Observable Plot all use GeoJSON as the primary means of representing geographic data. Points values often use `[longitude, latitude]`, but are not required to. For example, pre-projected planar geometries are also supported.

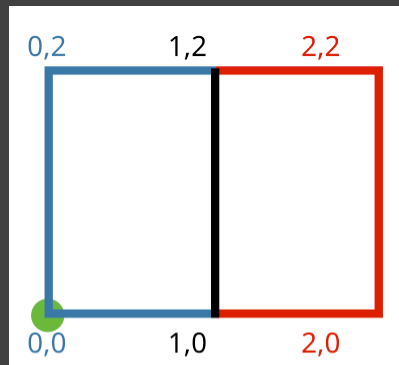
TopoJSON Format

TopoJSON is a compressed form of GeoJSON that stores *topologies* rather than raw geometries. For example, the border between Colorado and Arizona can be stored only once, then be extracted into separate borders for each state.

Prior to use in visualization, TopoJSON data must be parsed and extracted to geometry data - typically GeoJSON. Vega-Lite includes support to perform this extraction internally.

Otherwise, one can use the [topojson-client](#) library:

```
topojson.feature(data, "states") // get feature collection  
topojson.mesh(data) // get boundary mesh
```



Resources

Software Tools

Web Tools

d3-geo: projections, paths and more

GeoJSON: JSON format for geo data

TopoJSON: topology -> compressed GeoJSON

MapShaper: online editor for map data

Leaflet: open-source, customizable map tile system

Other

PostGIS: Postgres DB extensions for geo data

Mapnik: Render your own map tiles!

Data Resources

Natural Earth Data

naturalearthdata.com

OpenStreetMap

openstreetmap.org

U.S. Government

nationalatlas.gov, census.gov, usgs.gov

Tutorials

Cartographic Visualization in Vega-Lite

<https://observablehq.com/@uwdata/cartographic-visualization>

Command-Line Cartography

<https://medium.com/@mbostock/command-line-cartography-part-1-897aa8f8ca2c>

How to Infer Topology

<http://bost.ocks.org/mike/topology/>

Questions?