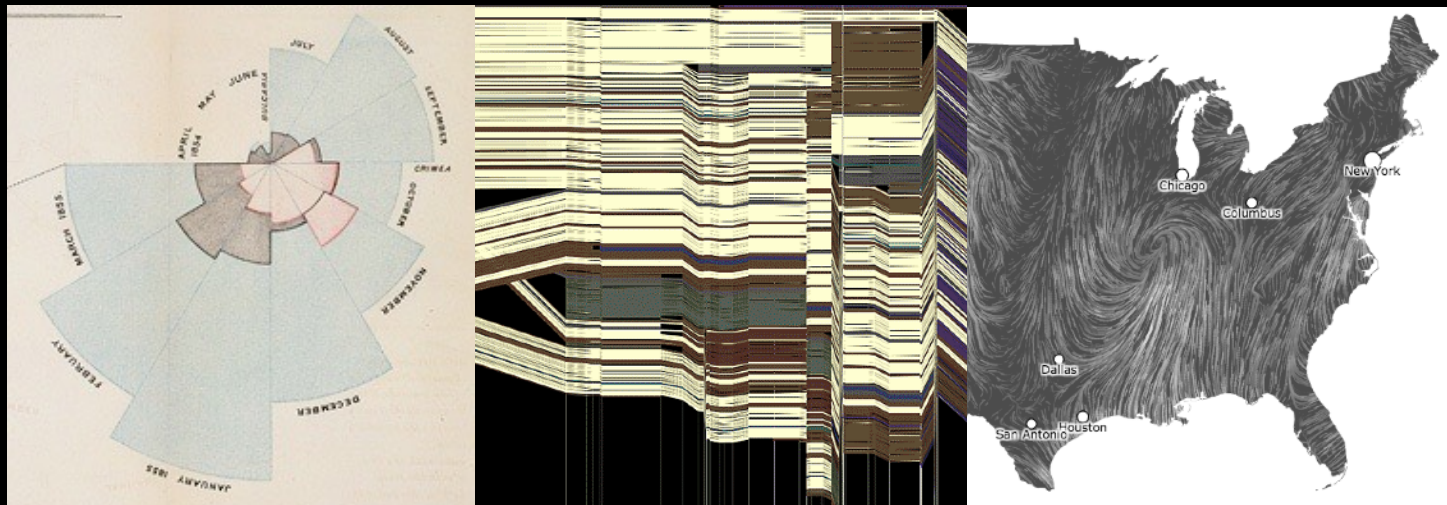


**CSE 442** - Data Visualization

# Mapping & Cartography



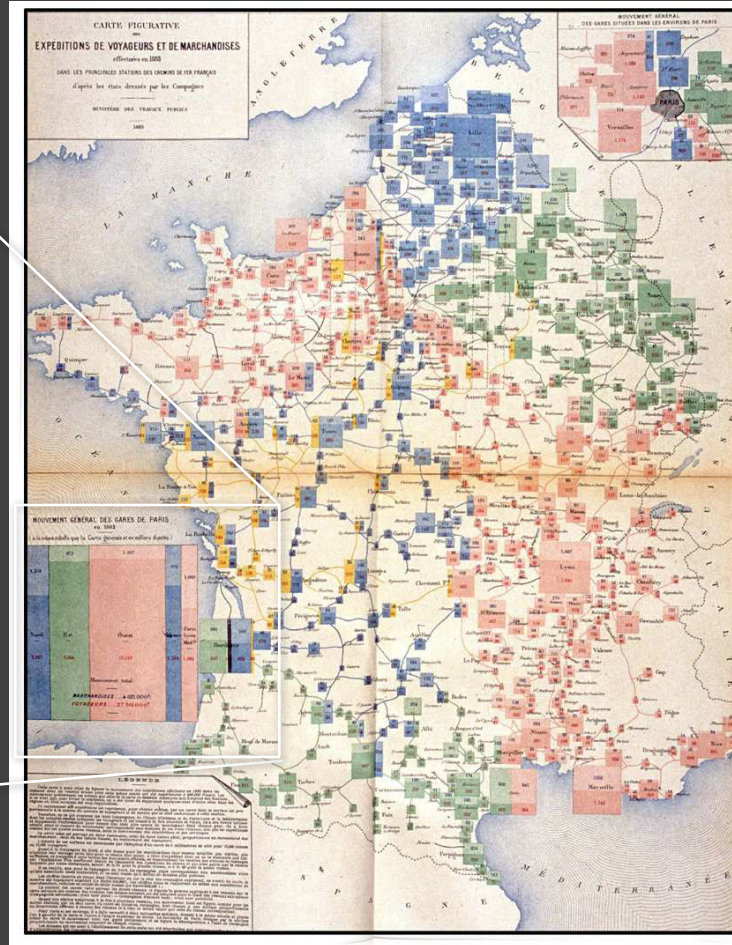
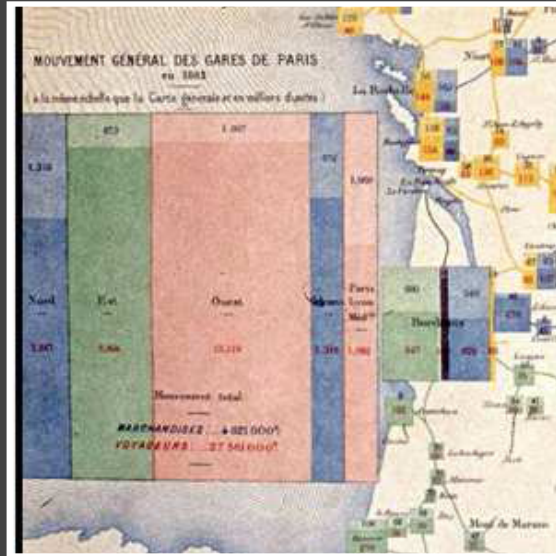
**Jeffrey Heer** University of Washington  
(with significant material from Michal Migurski)

# Mapping

Visualizing Geospatial Data

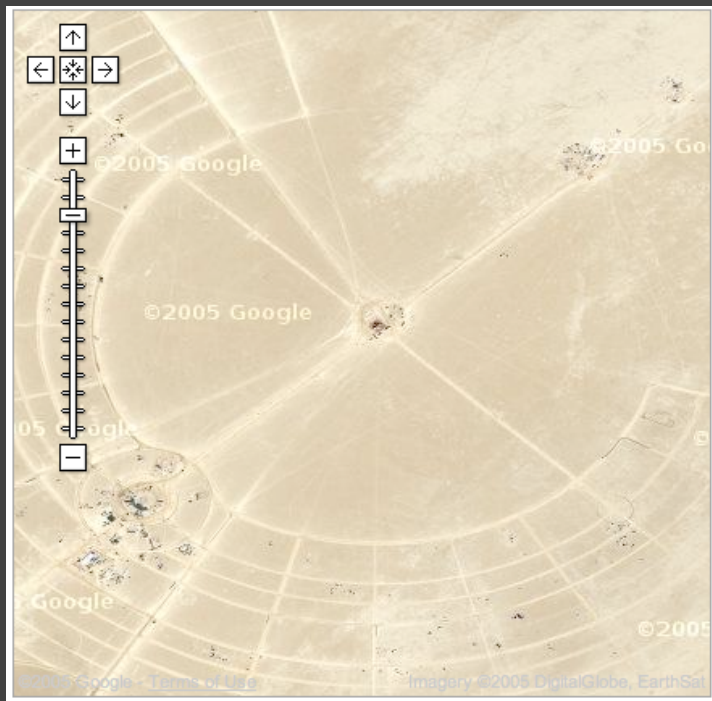


Ptolemy's Geographica  
Original ~150AD, This Map ~1300AD

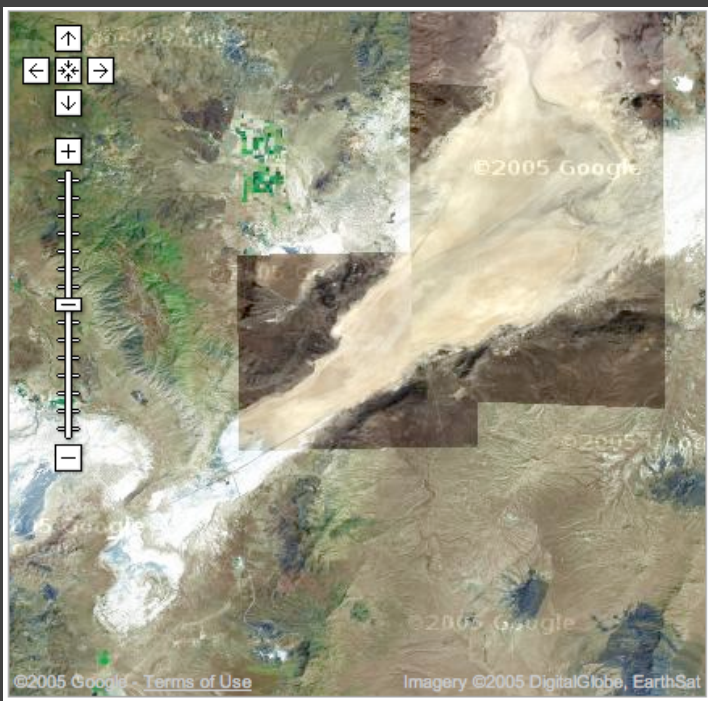


Rail Passengers and Freight from Paris 1884





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](#)

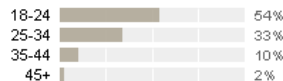
Use the slider below to investigate the demographics and military status of U.S. service members who died during the war in Iraq.

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

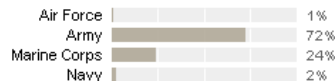
[Show all](#) | [Initial invasion](#) | [First invasion of Falluja](#) | [Second invasion of Falluja](#) | [Since troop buildup began](#)

4,097 deaths

## Age



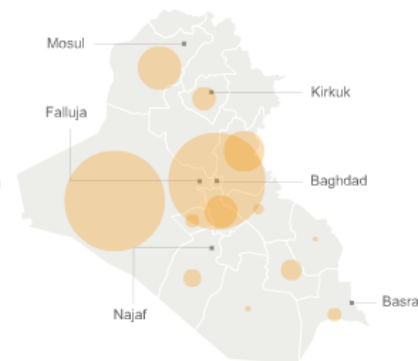
## Branch of Military



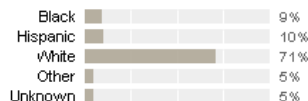
## Location of death

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

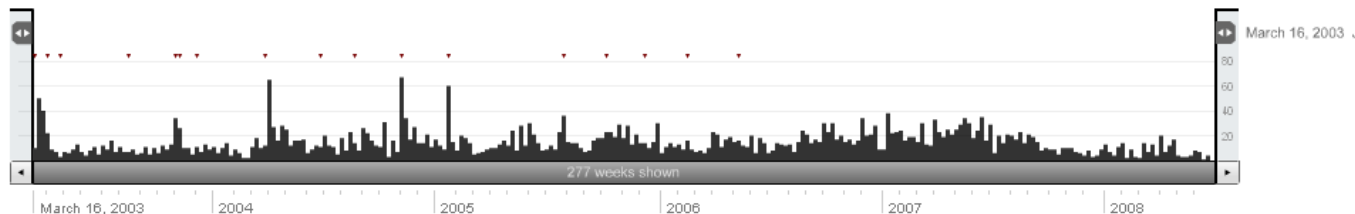
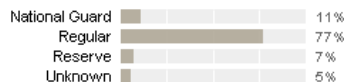
[Show home](#)



## 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

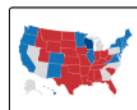
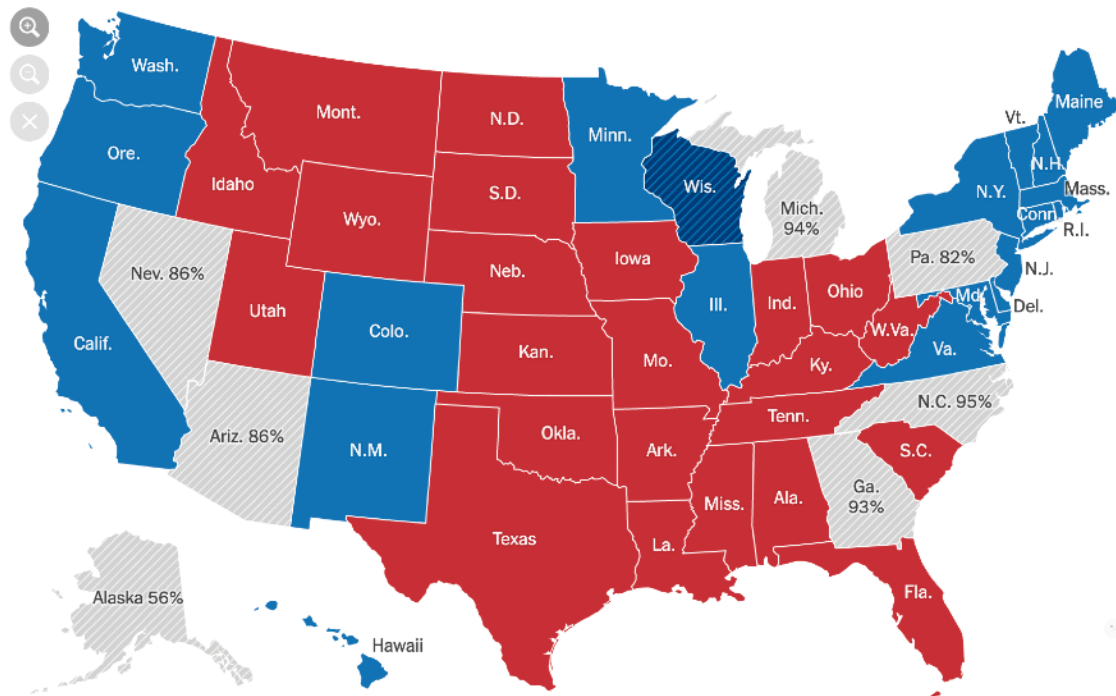
remaining

270  
TO WIN

214

Donald J. Trump

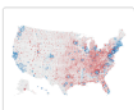
67,072,823 votes (48.1%)



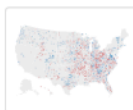
By winner



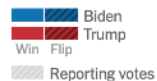
Electoral votes



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

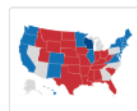
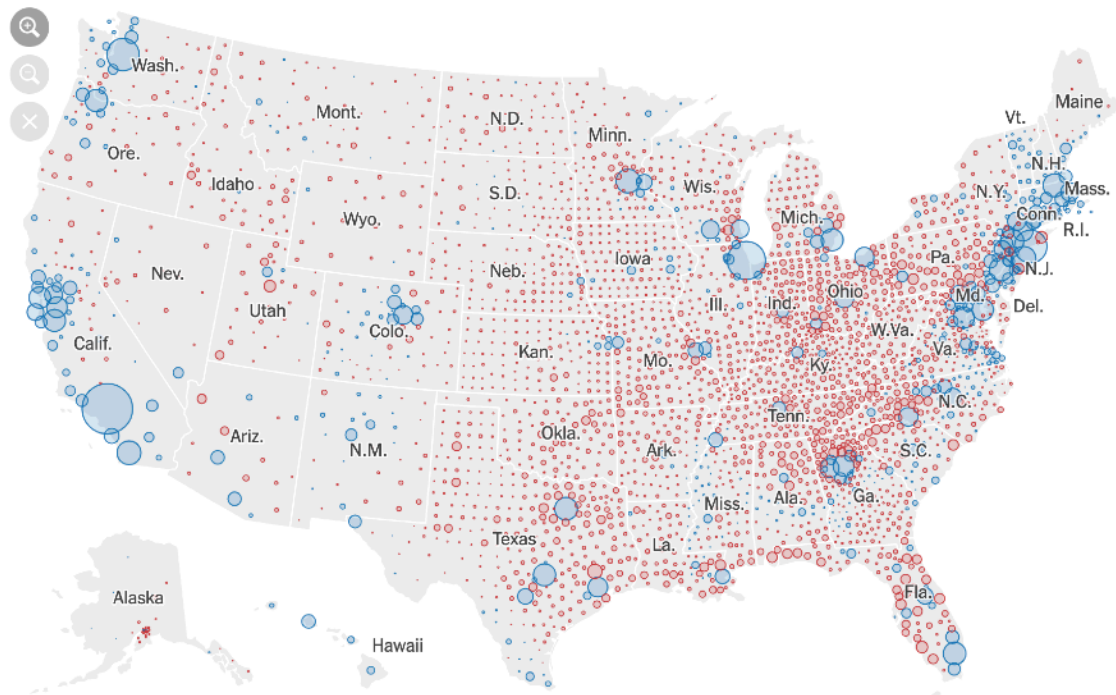
remaining

270  
TO WIN

# 214

Donald J. Trump

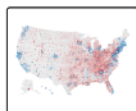
67,075,300 votes (48.0%)



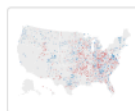
By winner



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

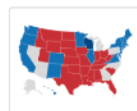
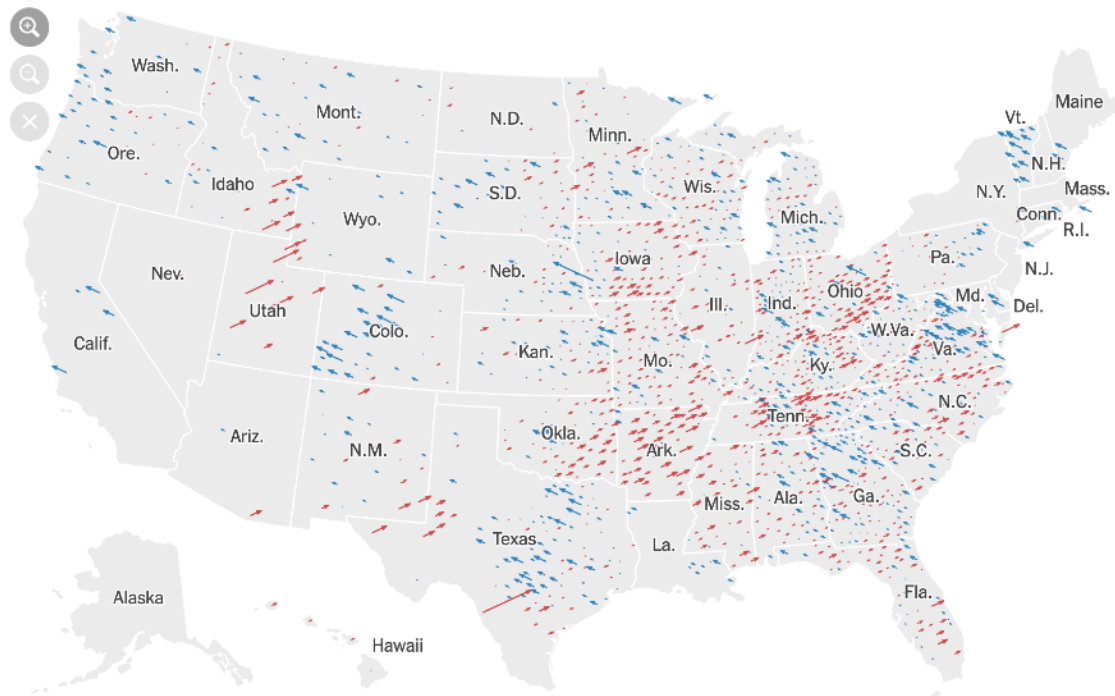
remaining

270  
TO WIN

# 214

Donald J. Trump

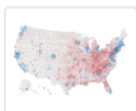
67,075,309 votes (48.0%)



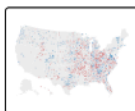
By winner



Electoral votes



Size of lead



Shift from 2016

**SHIFT IN MARGIN**  
In counties that have reported almost all of their votes

← More Democratic  
→ More Republican

Symbol Map  
[NY Times]

237

Joseph R. Biden Jr.

70,122,063 votes (50.2%)

87

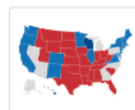
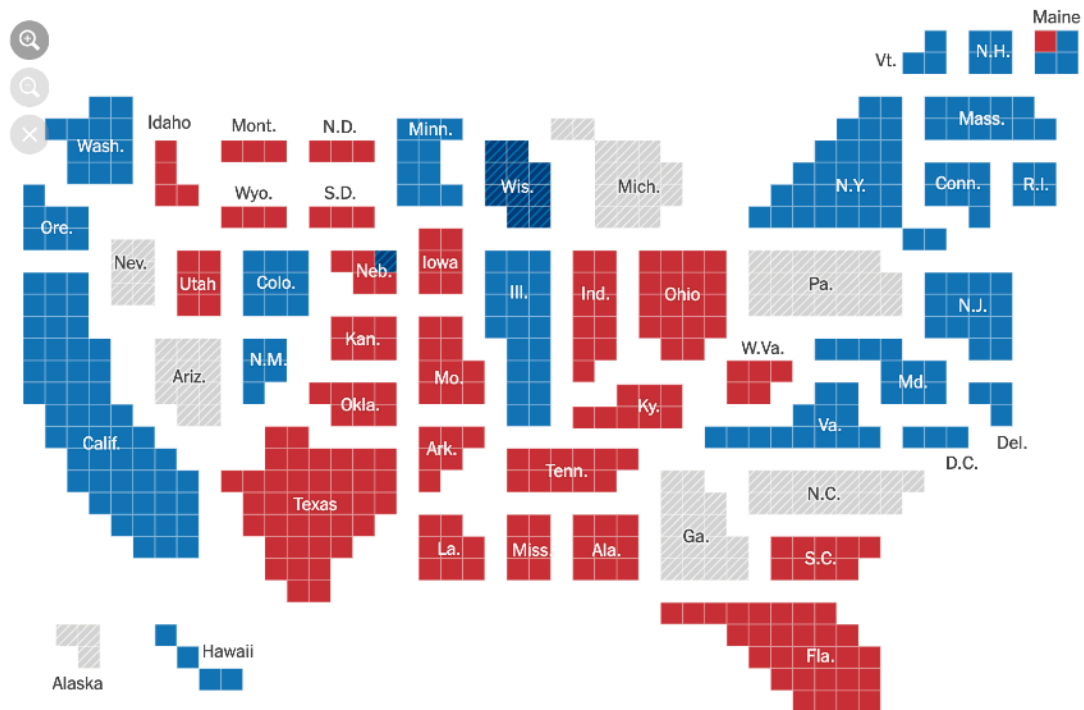
remaining

270  
TO WIN

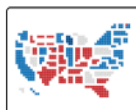
214

Donald J. Trump

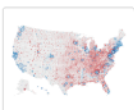
67,075,300 votes (48.0%)



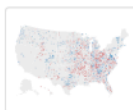
By winner



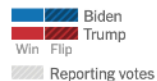
Electoral votes



Size of lead

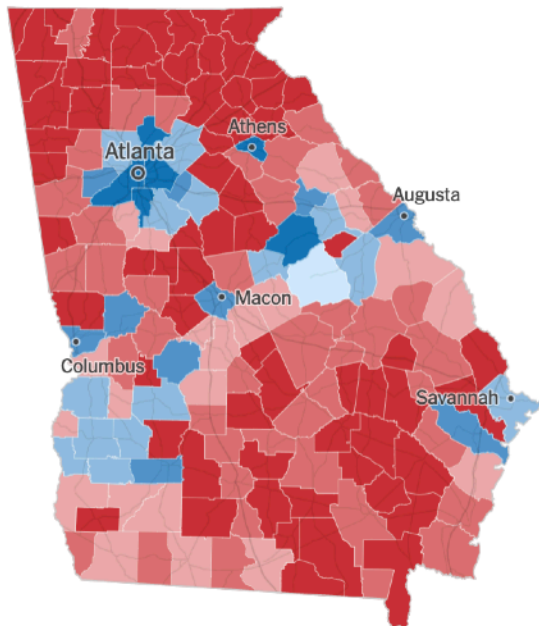


Shift from 2016

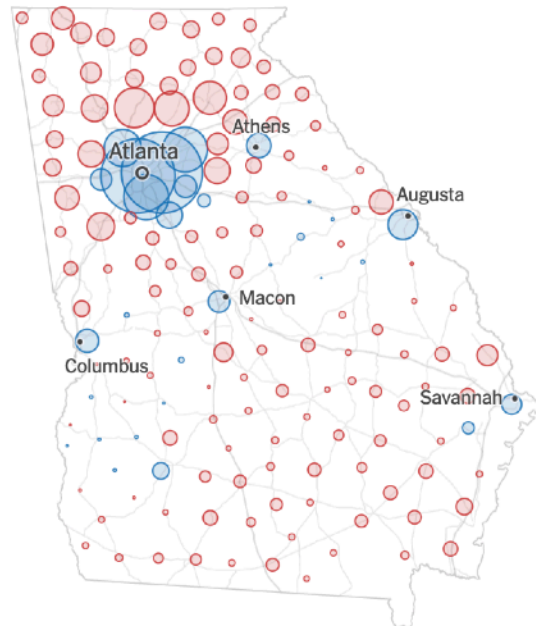
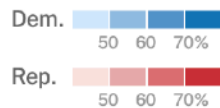


Cartogram  
[NY Times]





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

---

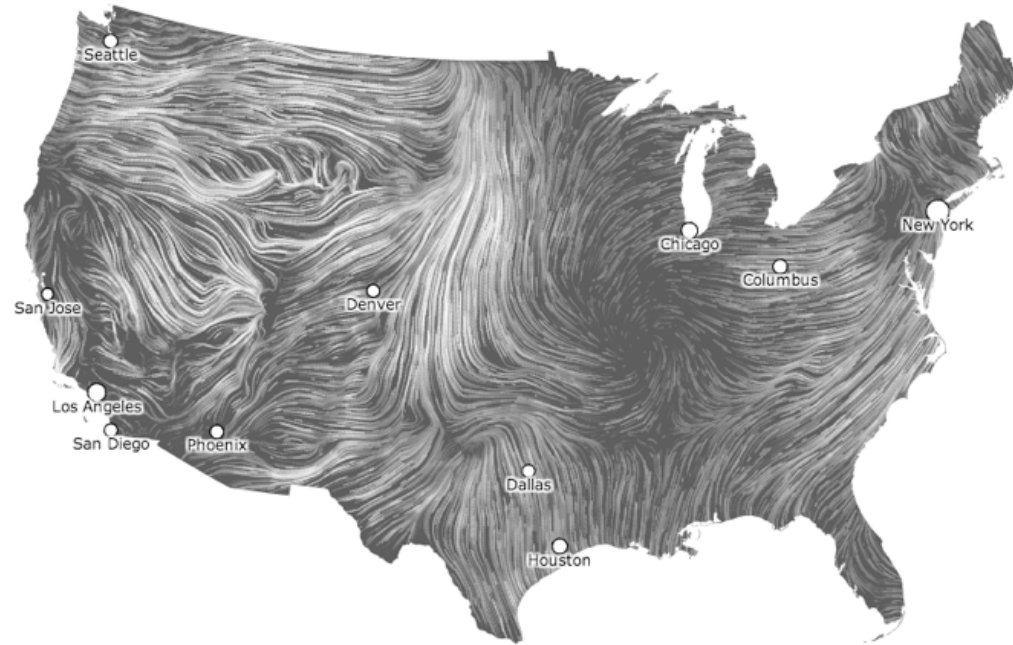
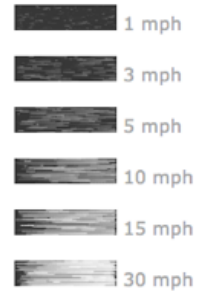
**February 19, 2014**

11:55 am EST

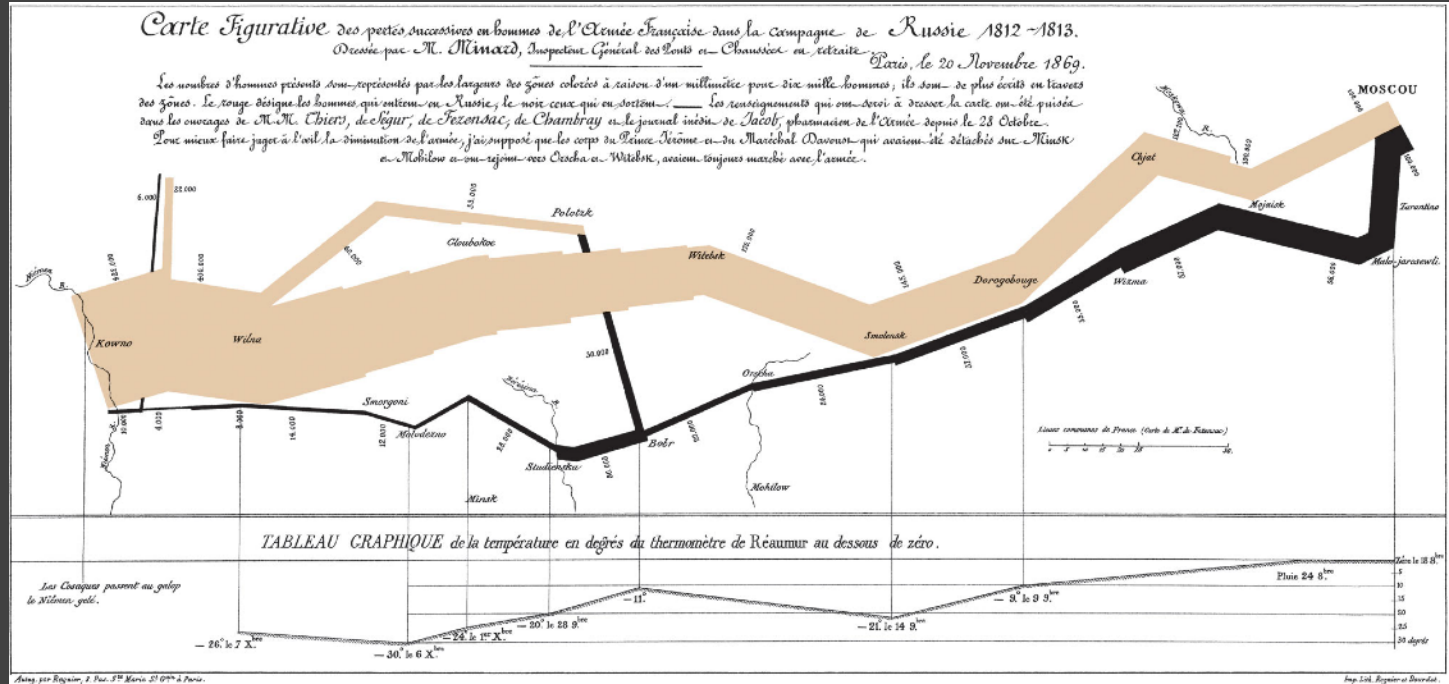
(time of forecast download)

top speed: **35.3 mph**

average: **11.6 mph**



# Minard 1869: Napoleon's march

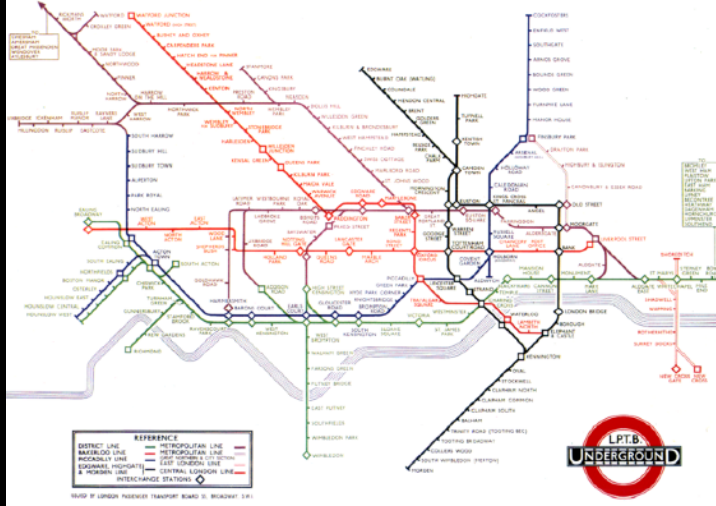




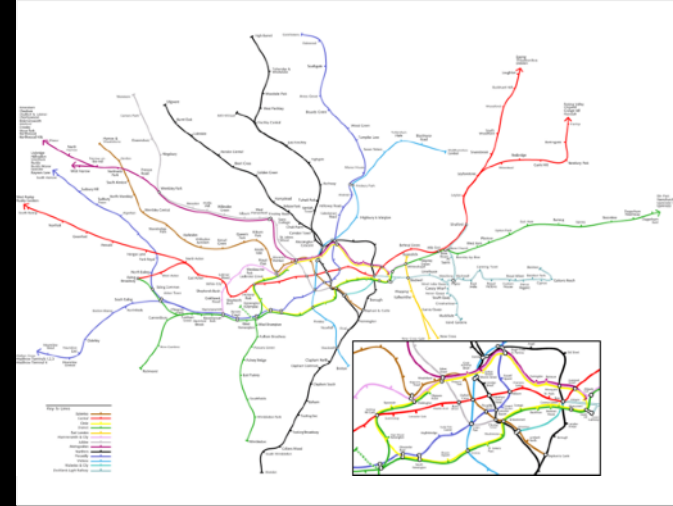




Beck's London tube diagram



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

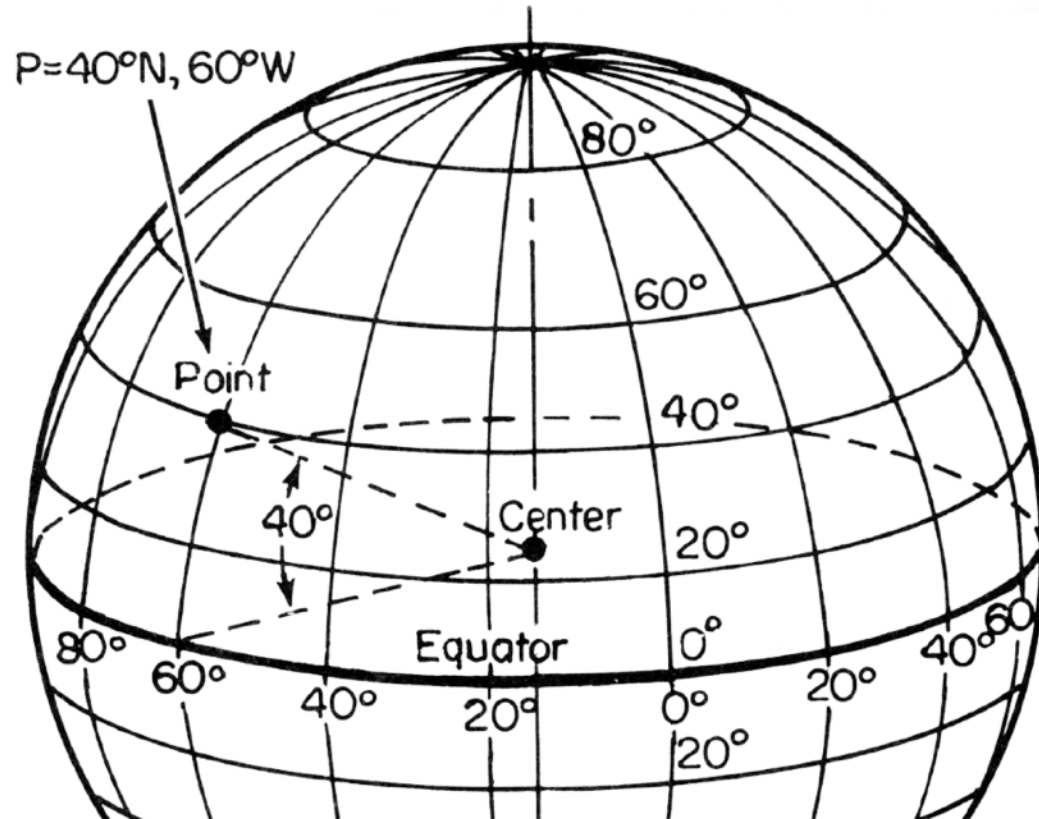
# Cartography

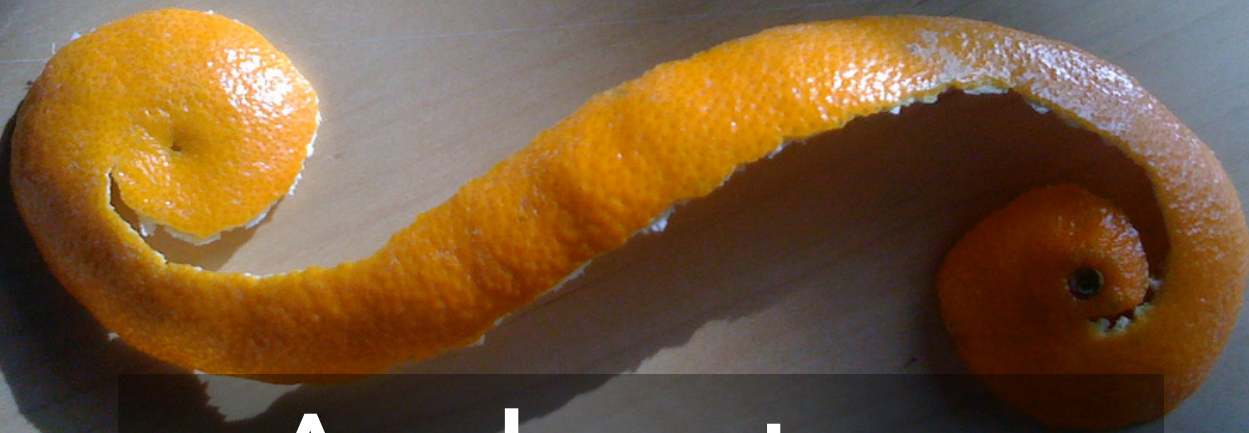
The Making of Maps



# Projections

# Latitude, Longitude





**A sphere tears  
when you flatten it**

# Projections

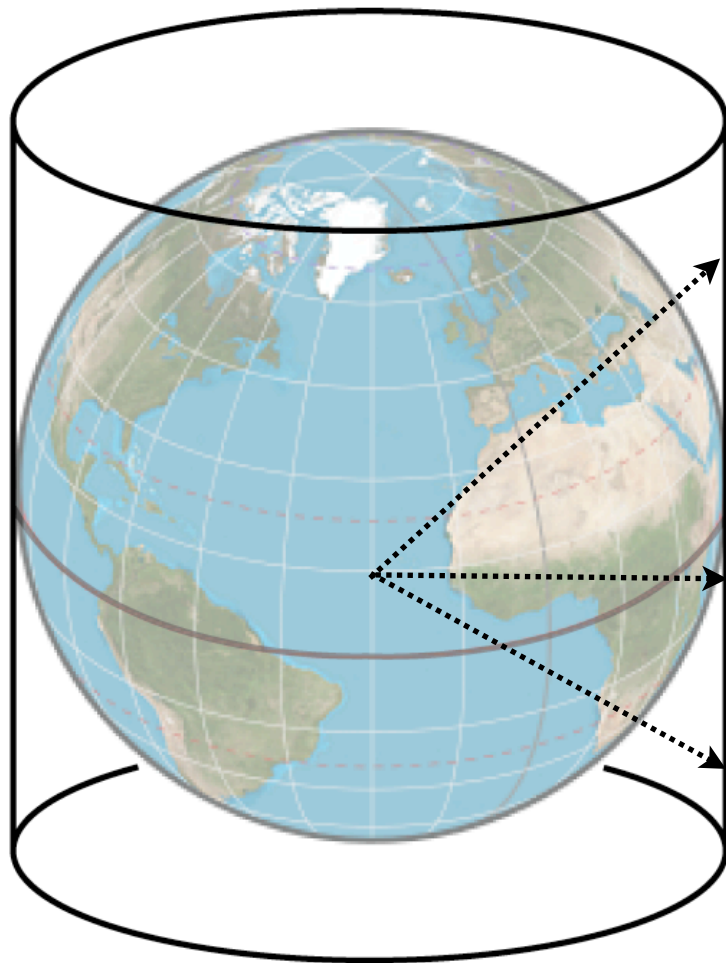
$$f(\phi, \lambda) \rightarrow (x, y)$$

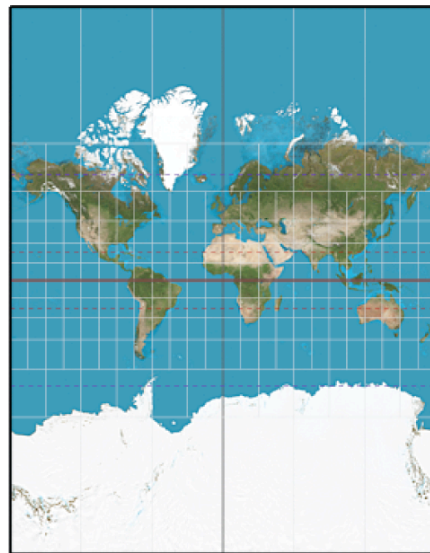
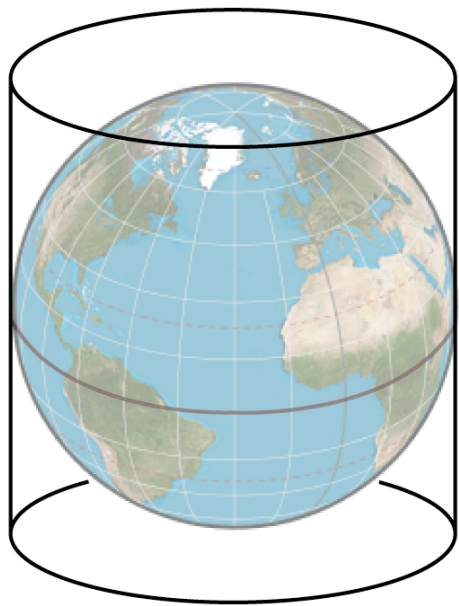


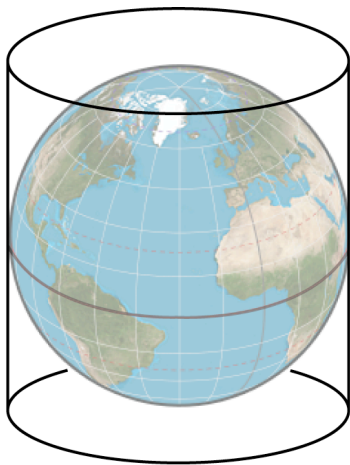
# Projections

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

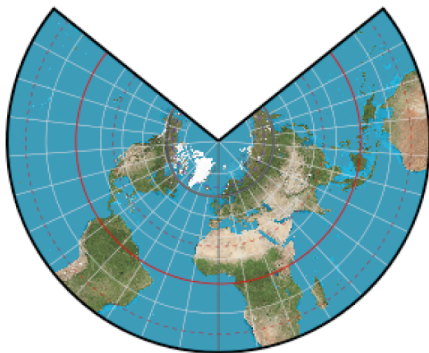
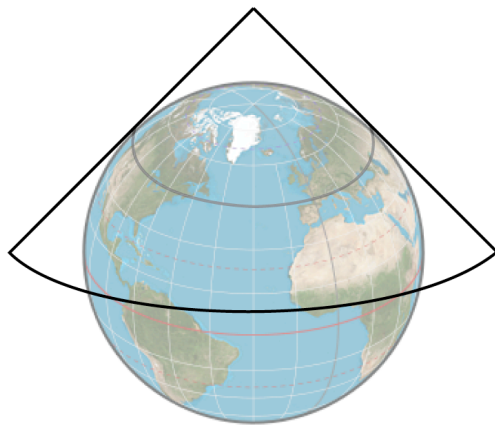
??



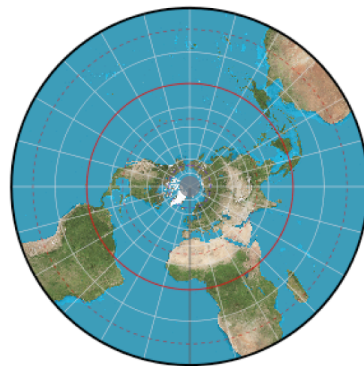
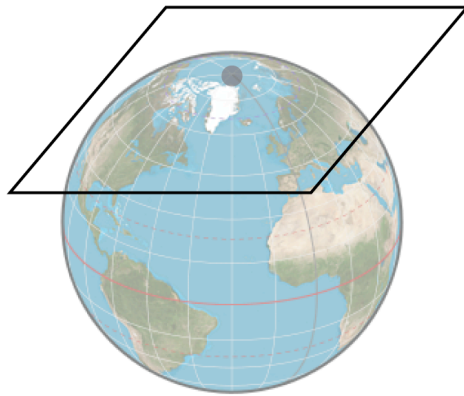




Cylindrical



Conical



Azimuthal

# Exploring Projections...







Type

mercator

Scale



Yaw



Pitch



Roll





Type

mercator

Scale

140

Yaw

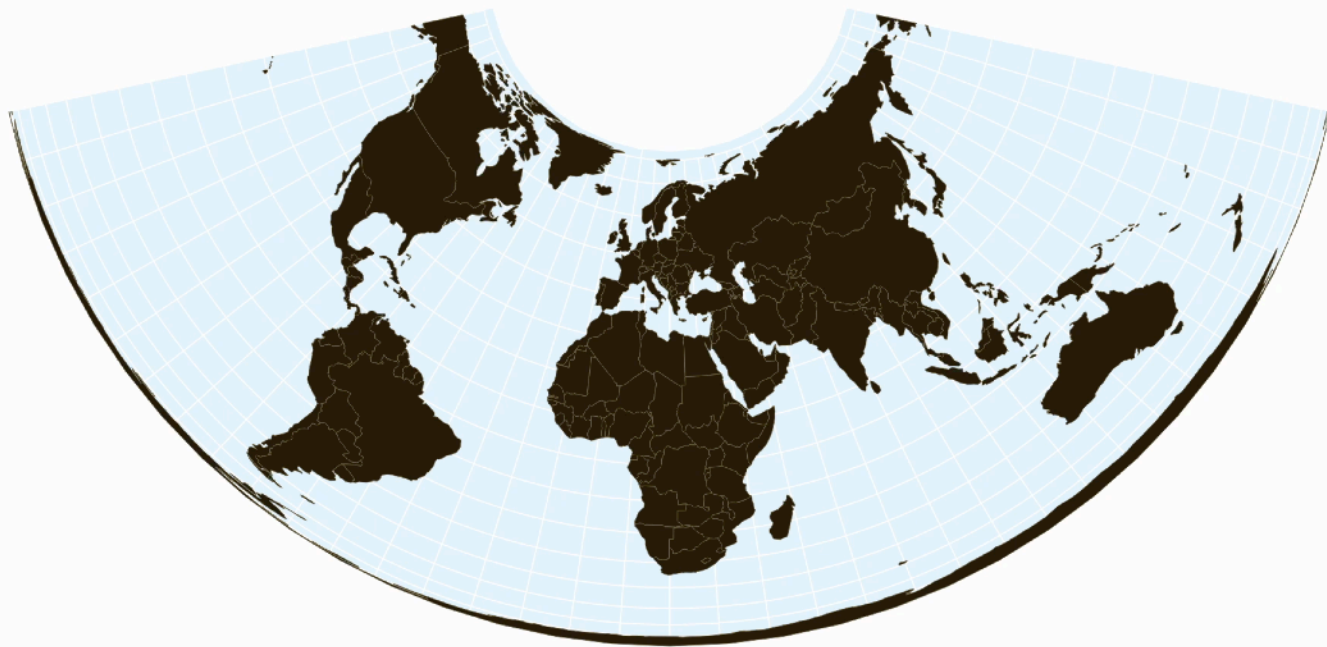
0

Pitch

0

Roll

0



Type

conicEqualArea

Scale

140

Yaw

-20

Pitch

0

Roll

0



Type

orthographic v

Scale

140

Yaw

0

Pitch

0

Roll

0

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

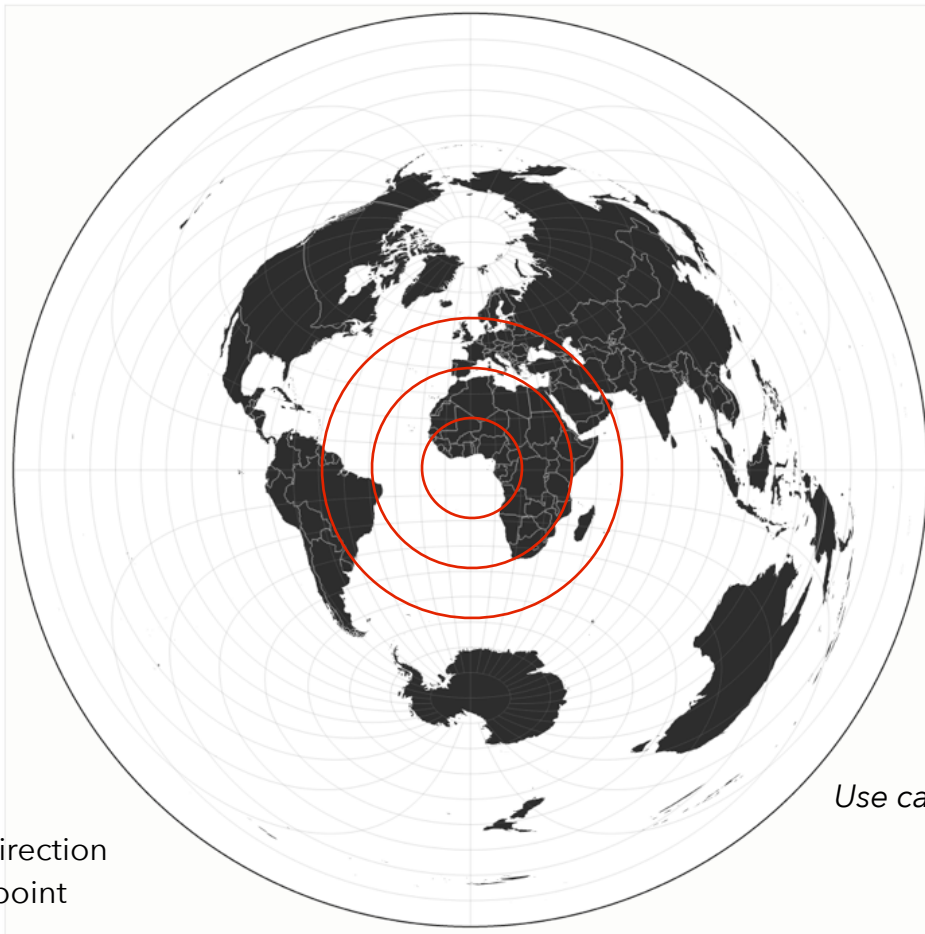




# Distance

Preserve distance / direction from center

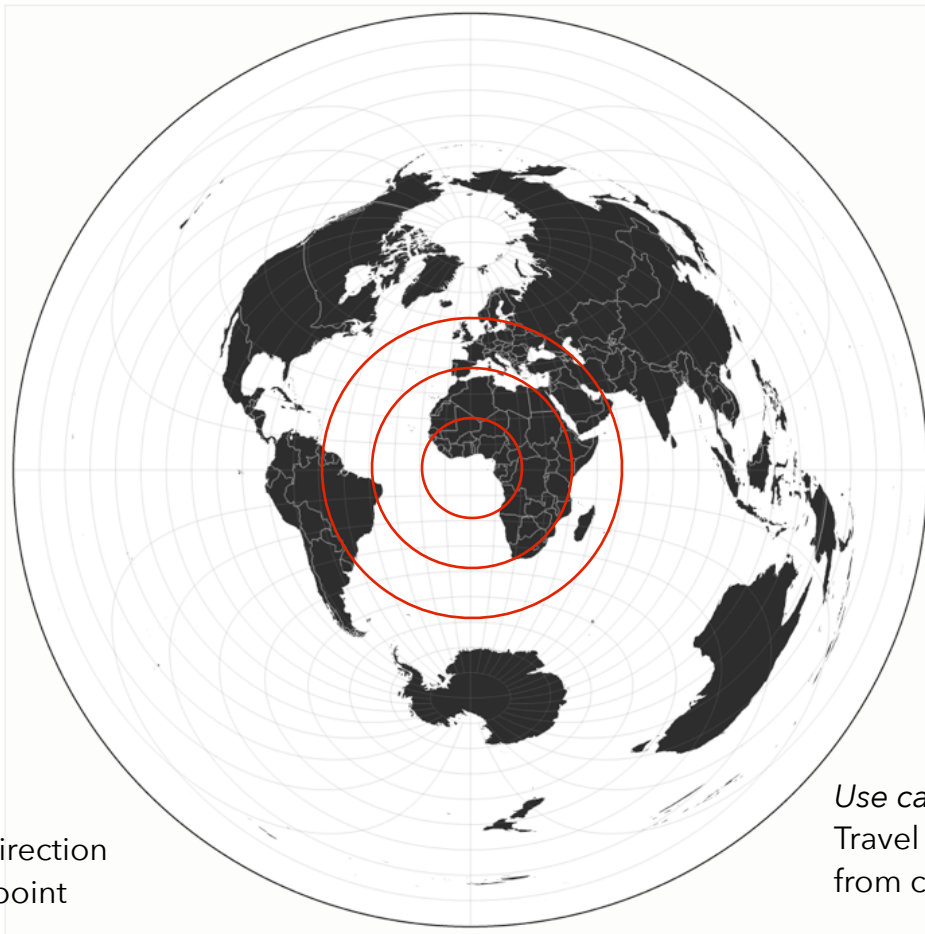
# Azimuthal Equidistant



*Preserves:*  
Distance & direction  
from center point

*Use cases?*

# Azimuthal Equidistant



*Preserves:*  
Distance & direction  
from center point

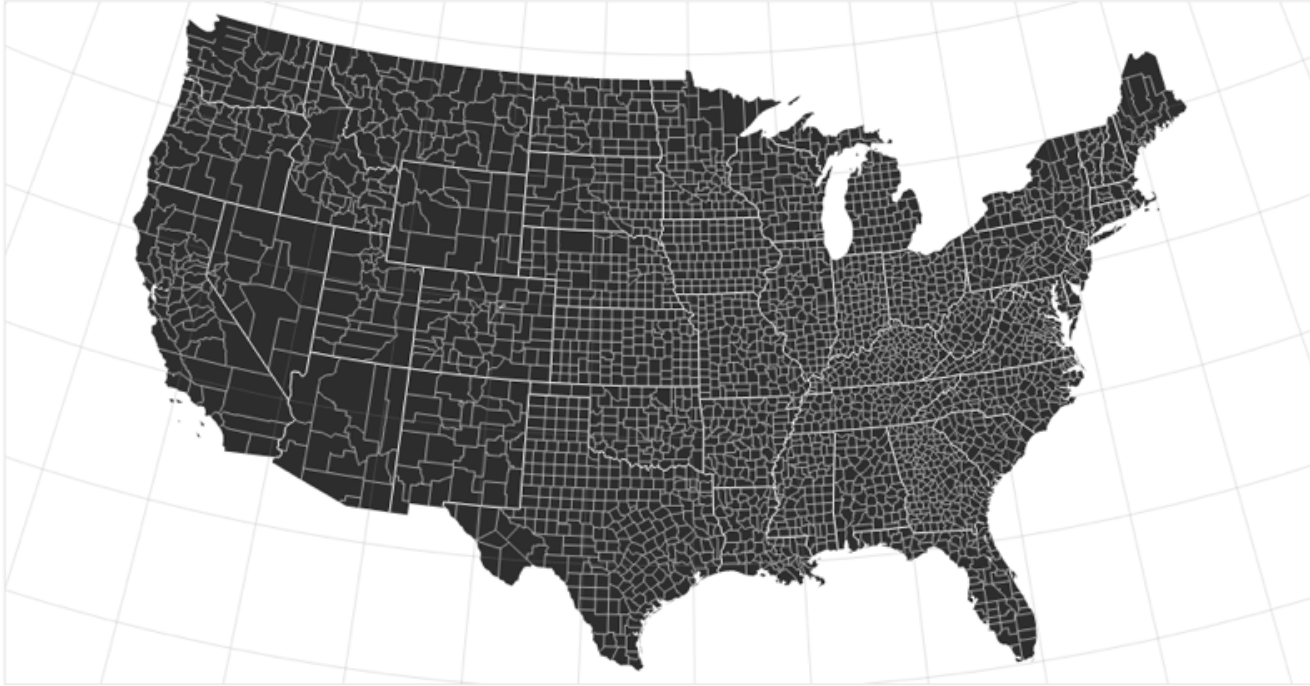
*Use cases:*  
Travel / propagation  
from center point

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

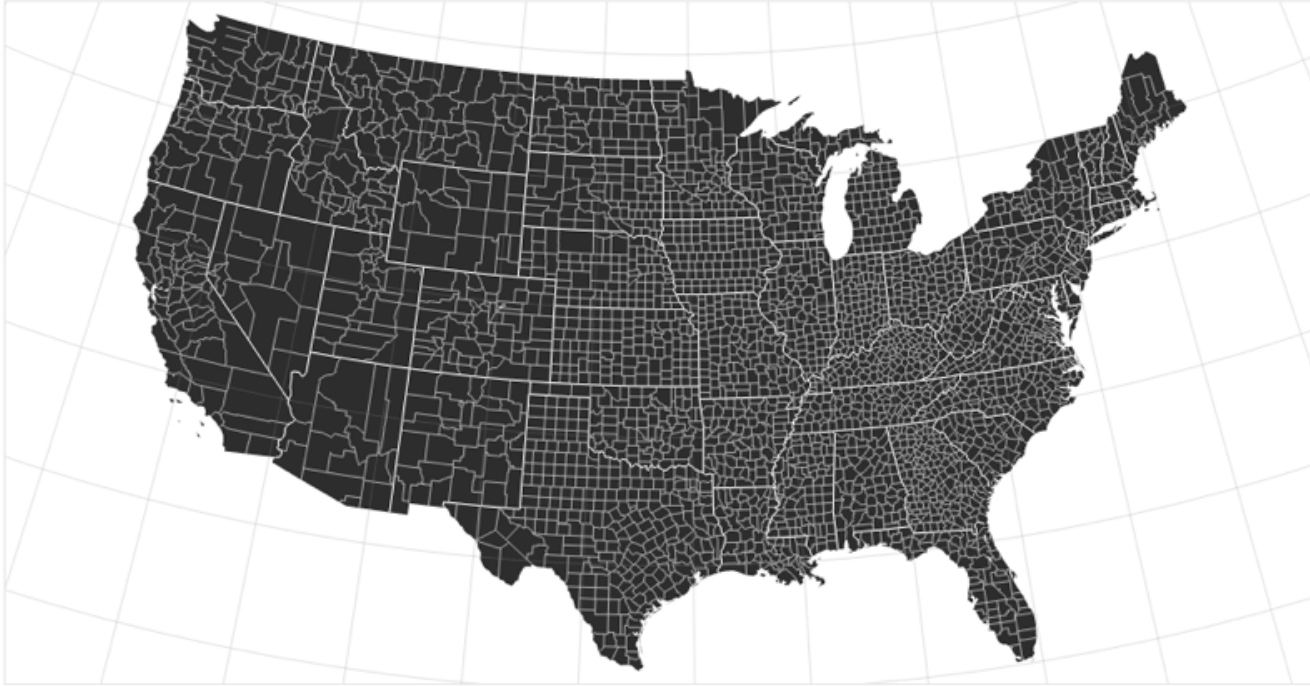


*Preserves: Proportional area of geographic regions*

*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

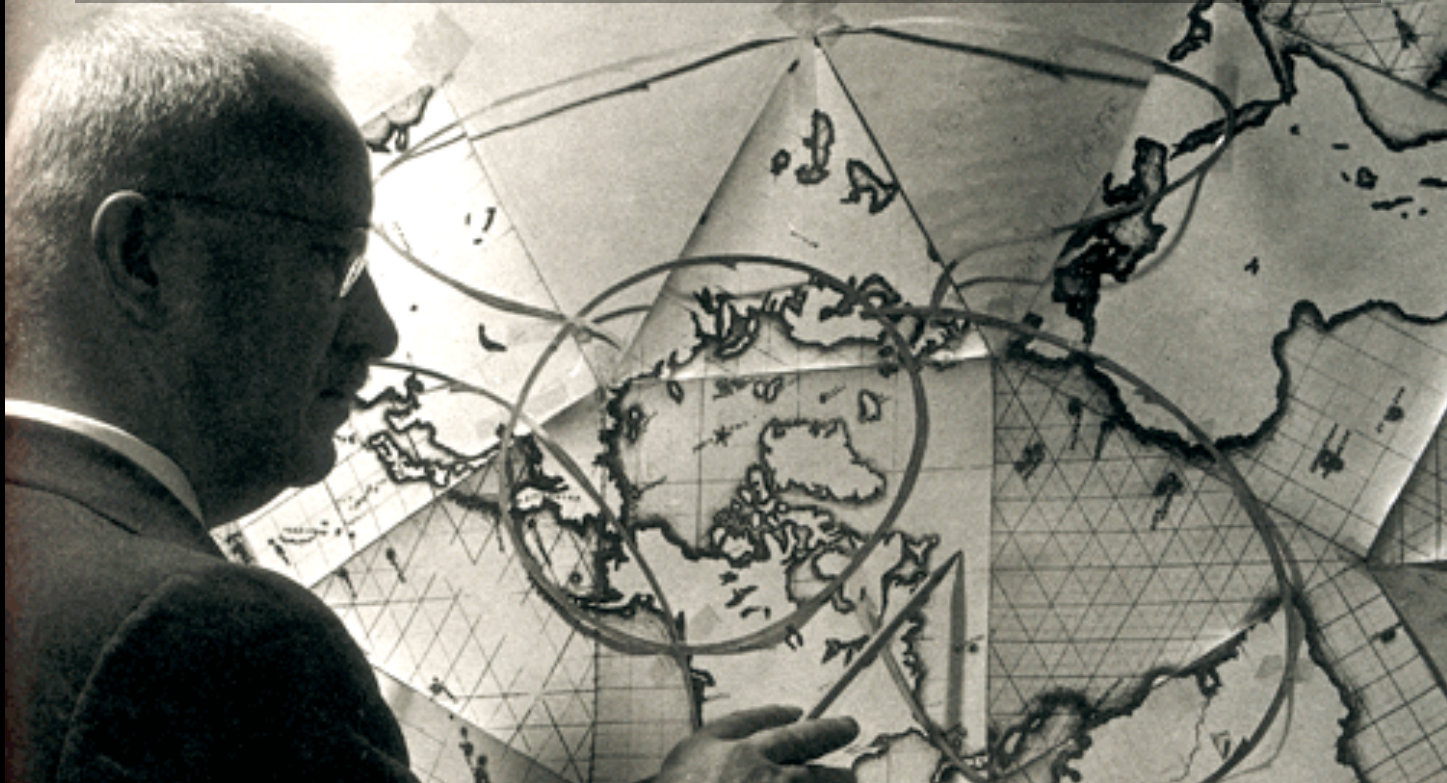
*Use cases:*  
Navigation

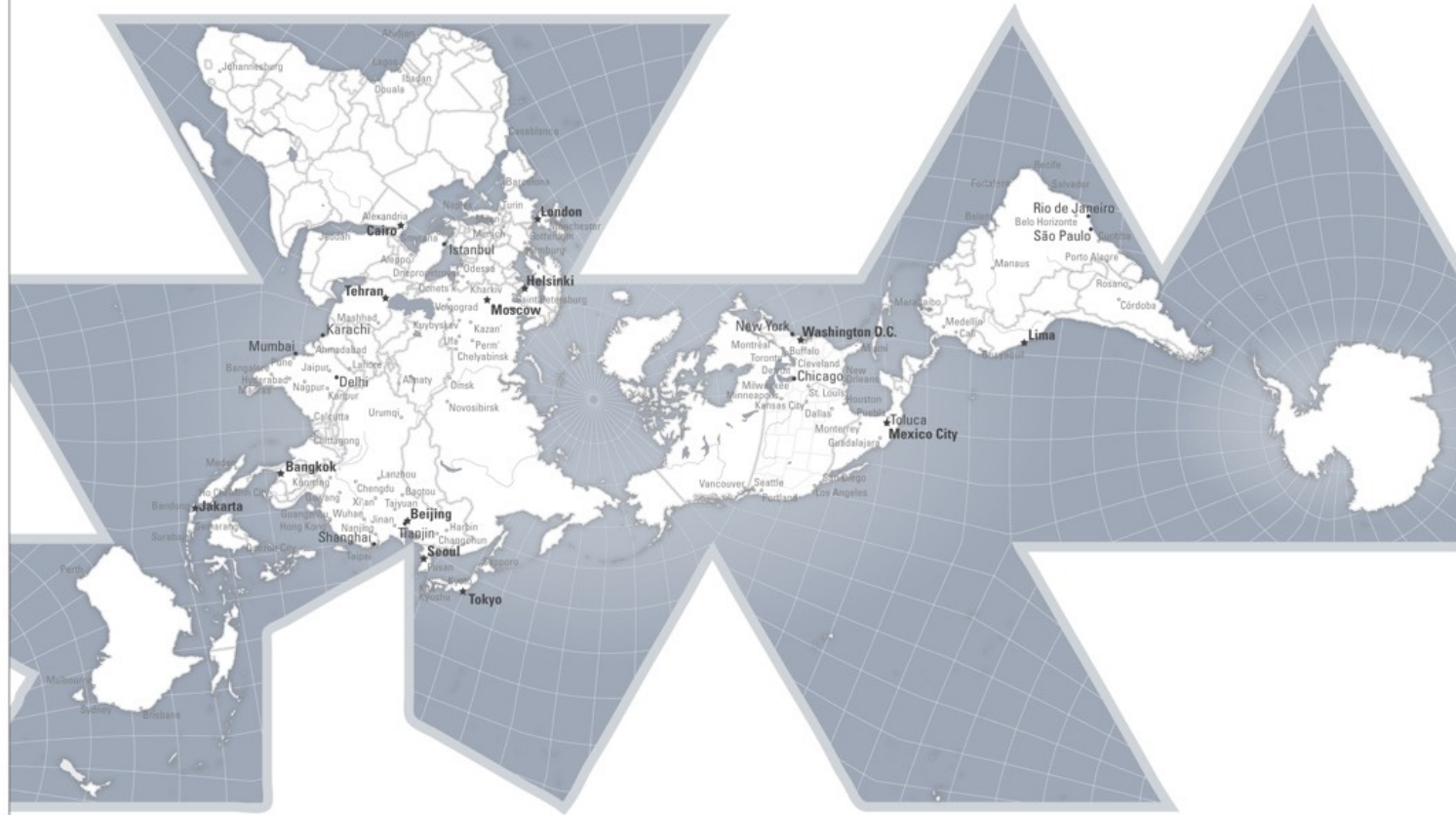


**There are interesting  
ways to tear spheres**



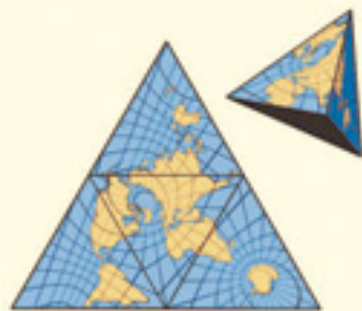
One notable interesting  
way to tear a sphere



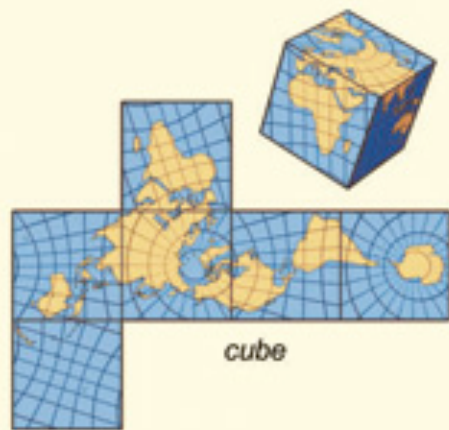


Balances preservation of area and shape.

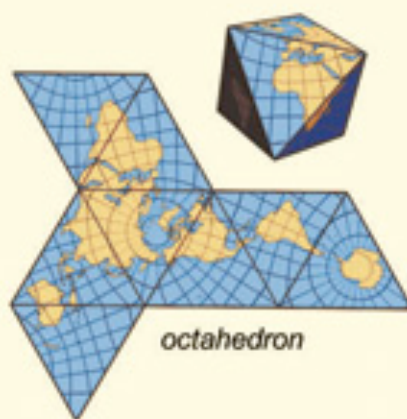
*Provides different ways of thinking about the world!*



*tetrahedron*



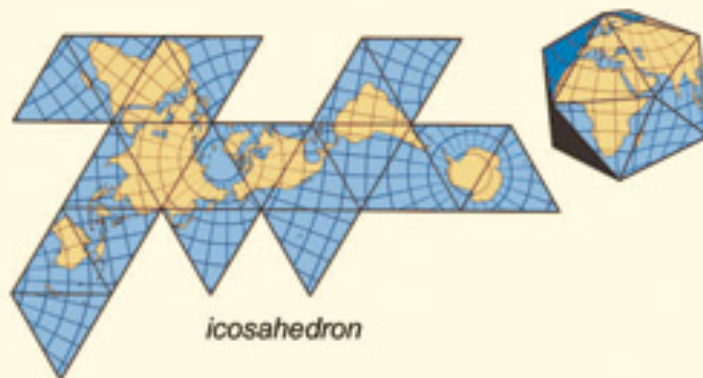
*cube*



*octahedron*



*dodecahedron*



*icosahedron*

# Geographic Data Formats

# From Tables to Geometry: Basic Shapes

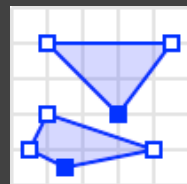
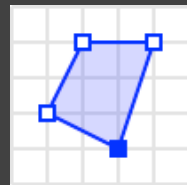
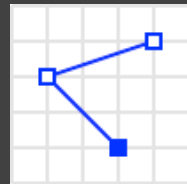
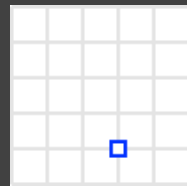
**Point:** An array containing 2D or 3D coords (e.g., [lon, lat])  
[125.6, 10.1]

**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 `[x, y]` are also supported.

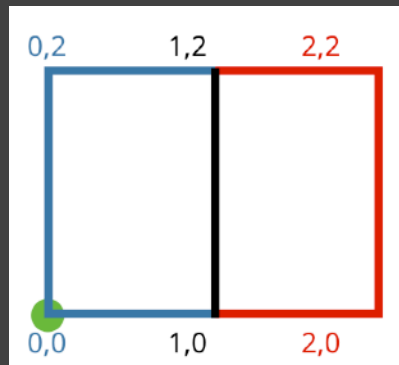
# TopoJSON Format

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](https://naturalearthdata.com)

## OpenStreetMap

[openstreetmap.org](https://openstreetmap.org)

## U.S. Government

[nationalatlas.gov](https://nationalatlas.gov), [census.gov](https://census.gov), [usgs.gov](https://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?**