Web Mapping Back End: Tiles

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Overview and Structure

- Web Mapping Architecture
- OGC Standards
  - Web Mapping Service (WMS)
  - Web Feature Service (WFS)
  - Web Map Tile Service (WMTS)
  - Web Coverage Service (WCS)
  - Web Feature Service Transactional (WFS-T)
- Web Map Servers
  - Geoserver
  - Mapnik
  - Mapserver
  - QGIS Server
- Vector Tiles
- Vector Tile Servers
  - TileStache
  - Tilelive
- CartoDB

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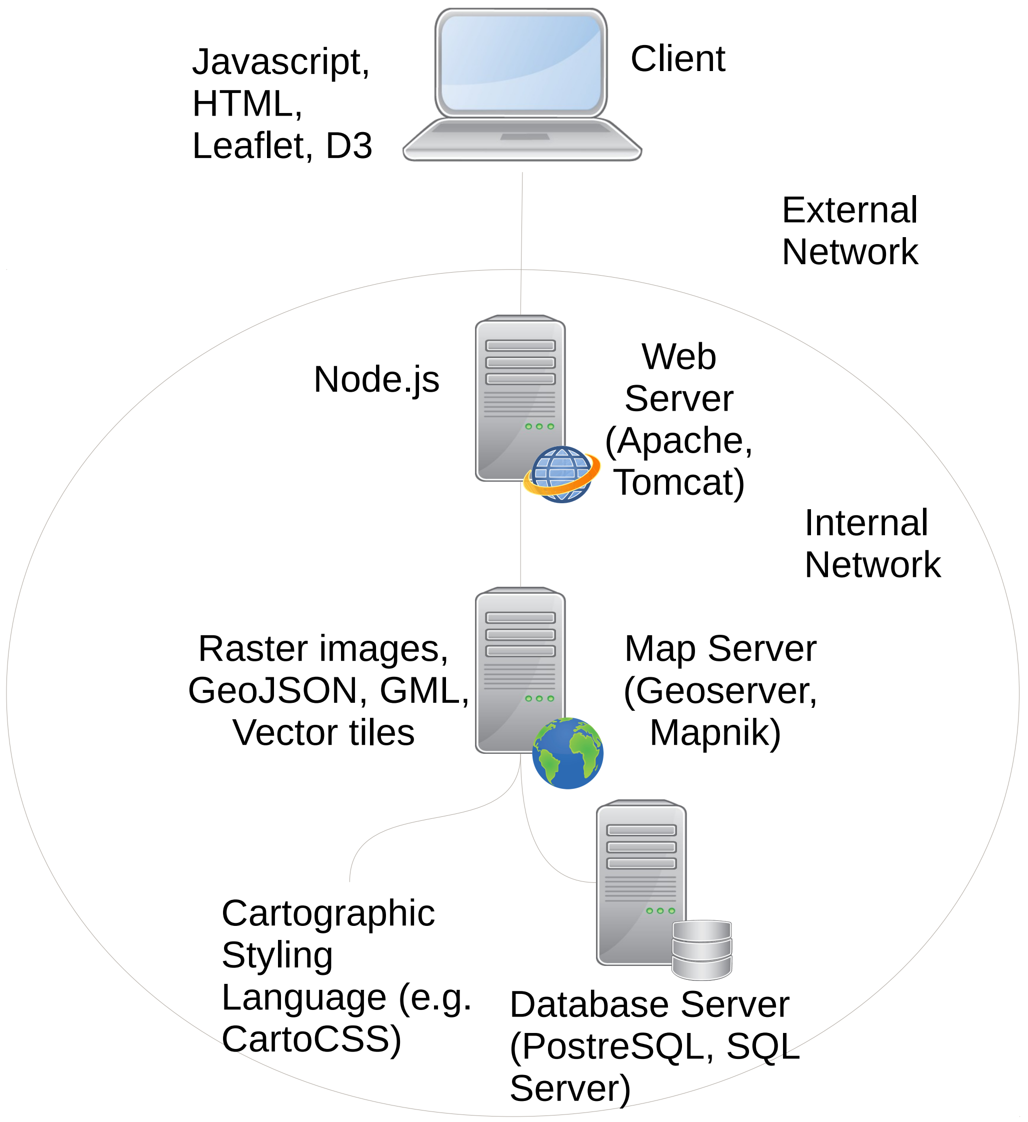
Elements of Web Maps

- Maps consist of layers usually drawn in order from back to forth[1].
- Basemap:
  - Provides geographic context, not the main focus.
  - Tiled image, may consist of many sublayers e.g. roads, buildings, parks.
  - OpenStreetMap, Google Maps, Stamen.
- Thematic layers:
  - The main focus of the web map.
  - Often raster tiles but also data queried from a database and rendered as raster or vector.
- Interactive elements:
  - Provide extra information or allow editing and querying the data.

[1]Painter's algorithm: https://en.wikipedia.org/wiki/Painter's_algorithm

Architecture

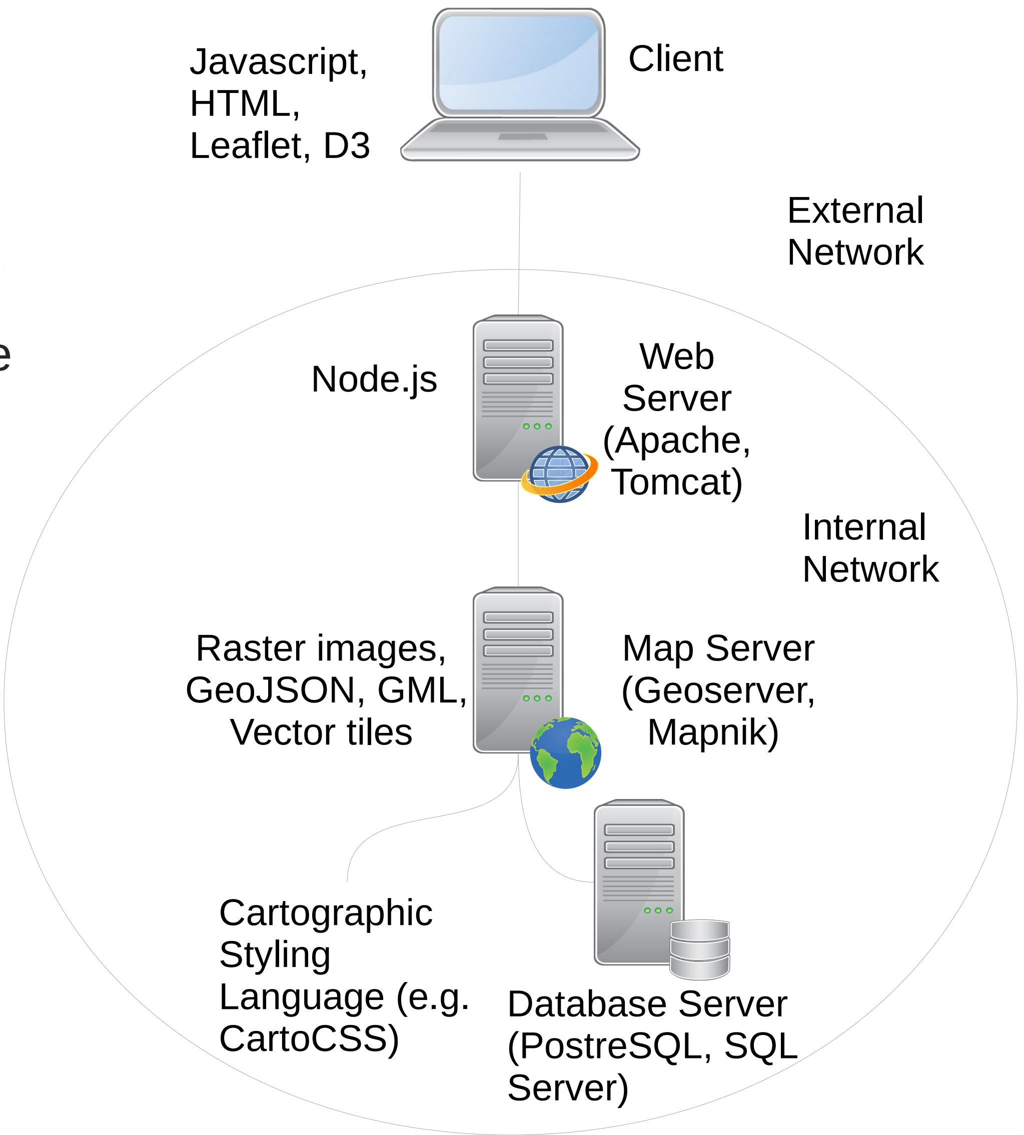
- A web server is a program that serves content (web pages, images, etc) using HTTP (Hypertext Transfer Protocol).
- A web mapping server is a specialized subset of web server for drawing maps and performing spatial queries and analysis.
- A database server holds GIS data but it can also be used for spatial analysis.



Javascript, HTML, Leaflet, D3
Client
External Network
Node.js
Web Server (Apache, Tomcat)
Internal Network
Raster images, GeoJSON, GML, Vector tiles
Map Server (Geoserver, Mapnik)
Cartographic Styling Language (e.g. CartoCSS)
Database Server (PostreSQL, SQL Server)

Architecture

- Requests are sent to the web server which are interpreted and responded. The request takes the form of a url: http://example.com/some/path/page.html
- However, in a web mapping server the requests and responses are designed specifically toward the transfer of geographic information.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OGC Web Standards

- Web Mapping Service (WMS) is a standard to publish raster and vector data in image format (e.g. jpeg, png, tiff).
- Web Feature Service (WFS) is a standard to render raw vector data (e.g. GML, GeoJSON).
- Web Coverage Service (WCS) provides raw raster data.
- Web Map Tile Service (WMTS) renders vector and raster data as maps (i.e. raster tiles) at fixed scales that can be easily cached. It's more scalable than WMS and less taxing on the server.
- Web Feature Service Transactional (WFS-T) allows web users to edit geometry data without giving them direct access to the database.

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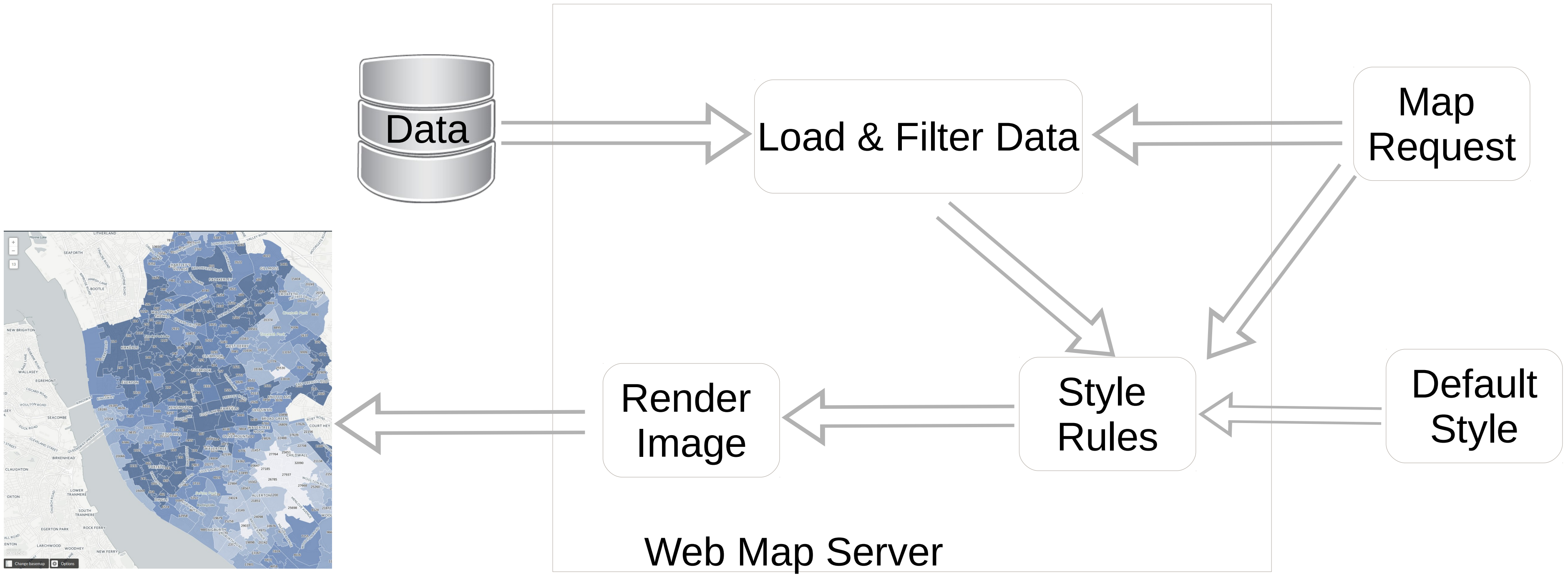
OGC Standards: WMS



- A WMS request defines parameters such as the extent of the map, the layers to include, the projection to use. It returns a geo-registered map image as JPG, GIF, PNG that can be displayed in a browser.

OGC Standards: WMS

- WMS request example:

http://a-map-co.com/mapserver.cgi?VERSION=1.3.0&REQUEST=GetMap&CRS=CRS:84&BBOX=-97.105,24.913,-78.794,36.358&WIDTH=560&HEIGHT=350&LAYERS=AVHRR-09-27&STYLES=&FORMAT=image/png&EXCEPTIONS=INIMAGE

  - ? Separator indicating start of query string.
  - & Separator between parameters in query string.
  - = Separator between name and value of parameter.
  - CRS Coordinate Reference System
  - BBOX Bounding Box

- The three operations defined for a WMS are GetCapabilities (metadata), GetMap (map), and GetFeatureInfo (other information).

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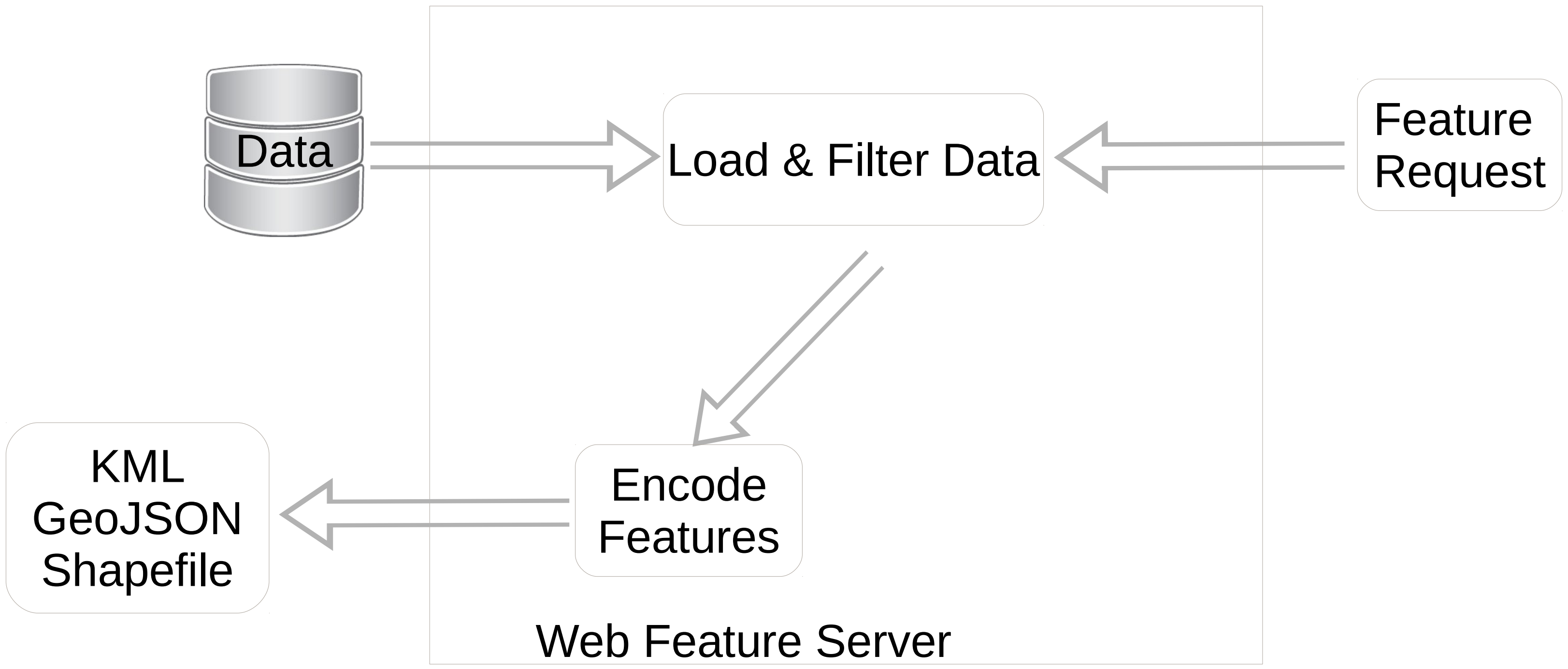
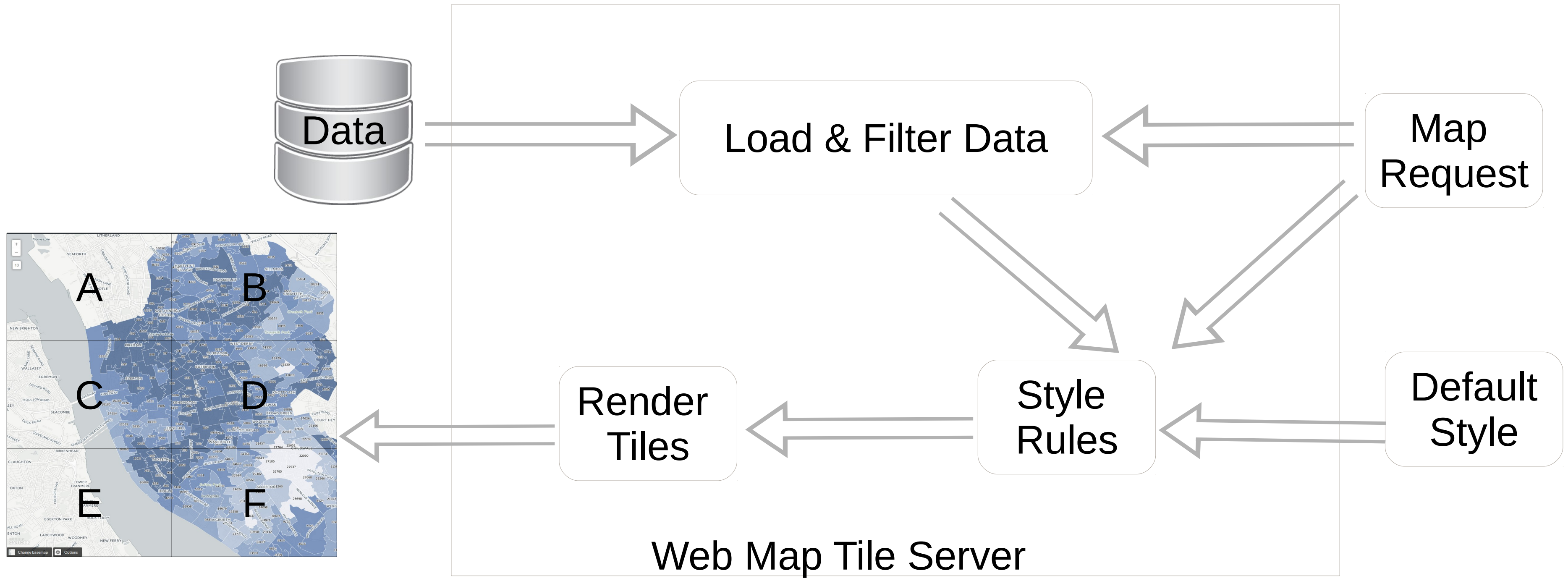
OGC Standards: WFS



- Remote access to vector source data (points, lines and polygons) can be obtained via the GetFeature request.
- Additional information can be obtained with the DescribeFeatureType request.
- Example: http://nsidc.org/cgi-bin/atlas_north?service=WFS&version=1.1.0&request=GetFeature&typename=greenland_elevation_contours

OGC Standards: WMTS



- Usually standard projection (Mercator), 256 * 256 pixels, png image format.
- The raster tiles include auxiliary information such as the extent of the map, the layers to include.

WMTS Example: OpenStreetMap

- OSM uses Apache and Mapnik.
- The tiles are rendered ahead of time and stored on disk.
- Each zoom level is a directory, each column of tiles a sub-directory, and each tile within that column a separate file.
- Typical slippy-maps URL for a tile has the form /z/x/y.
- z represents zoom level (typically 0-18).
- x and y coordinates determine the position of a tile within a square grid for the zoom level z, e.g. the first tile is 0/0/0.

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WMTS Continued

zoom level	tile coverage	number of tiles	tile size in degrees
0	1 tile covers whole world	1	360° x 170.1022°
1	2 × 2	4	180° x 85.0511°
2	4 × 4	16	90° x 42.5256°
n	2n × 2n	2^{2n}	360/2n° x 170.1022/2n°

- Advantages of raster tiles.
  - Tiles cache efficiently.
  - Tiles load progressively.
  - Tiles are easy to use.

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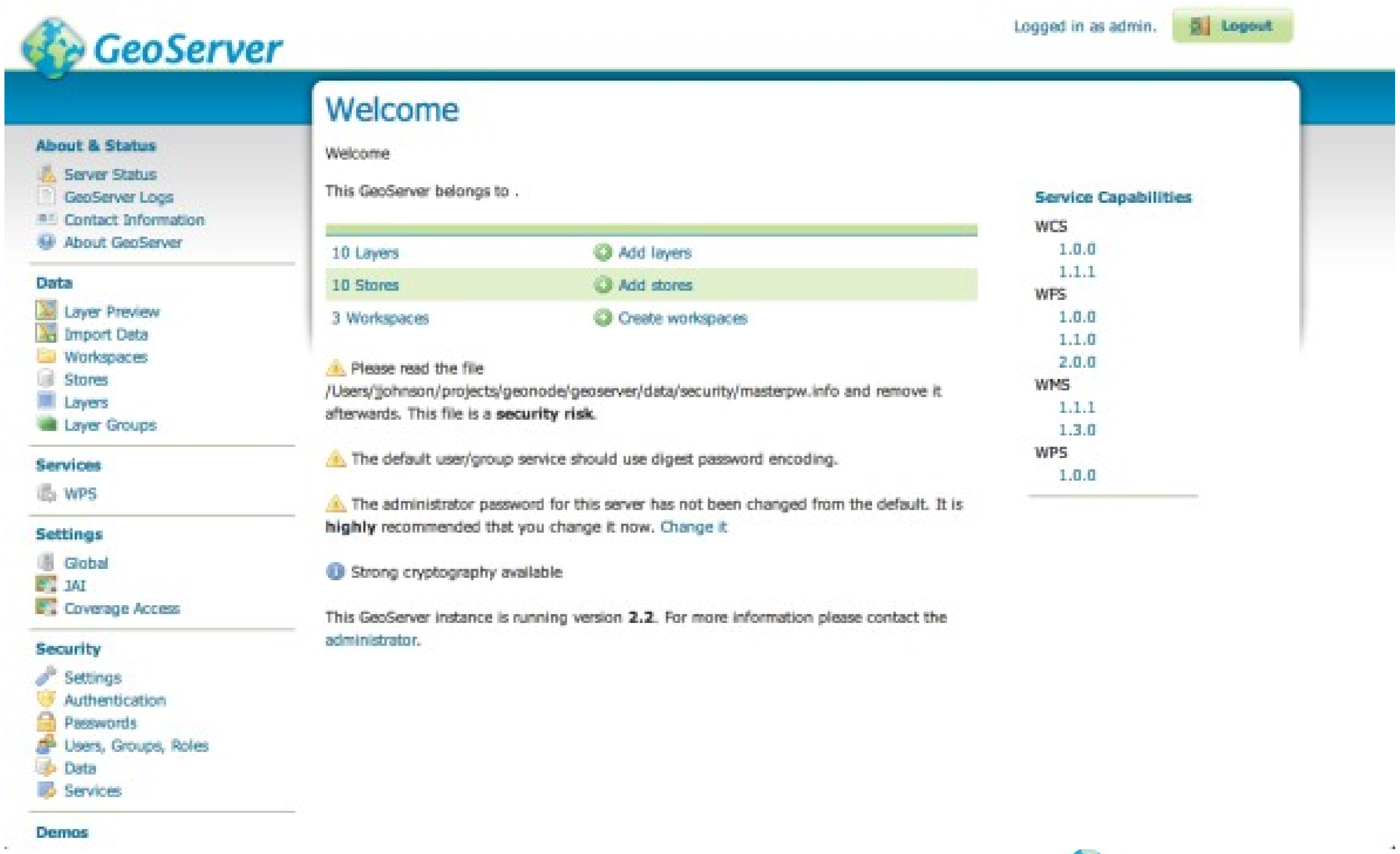
https://www.mapbox.com/help/how-web-maps-work/

Map Servers

Mapping Servers	Geoserver	MapServer	Mapnik	QGIS Server
Language	Java	C/C++	C++, Node.js	C++
OGC Formats	WMS/WMTS/ WFS/WFS-T	WMS/WMTS/ WFS/WFS-T	WMS/WMTS/ WFS/WFS-T	WMS/WFS/WFS-T
Web Admin Interface	Yes	No	No	No
FastCGI	No	Yes	Yes	Yes
Web Server	Tomcat	Apache	Apache	Apache
Comments	Good performance	Good performance, Integration with QGIS	Good performance, good visualization	Average performance, WYSIWYG from QGIS

http://www.geotests.net/cours/sigma/webmapping/2014/schema6_2014p.pdf

GeoServer



Welcome

Welcome

This GeoServer belongs to .

10 Layers	Add layers
10 Stores	Add stores
3 Workspaces	Create workspaces

⚠ Please read the file /Users/jjohnson/projects/geonode/geoserver/data/security/masterpw.info and remove it afterwards. This file is a **security risk**.

⚠ The default user/group service should use digest password encoding.

⚠ The administrator password for this server has not been changed from the default. It is **highly** recommended that you change it now. Change it

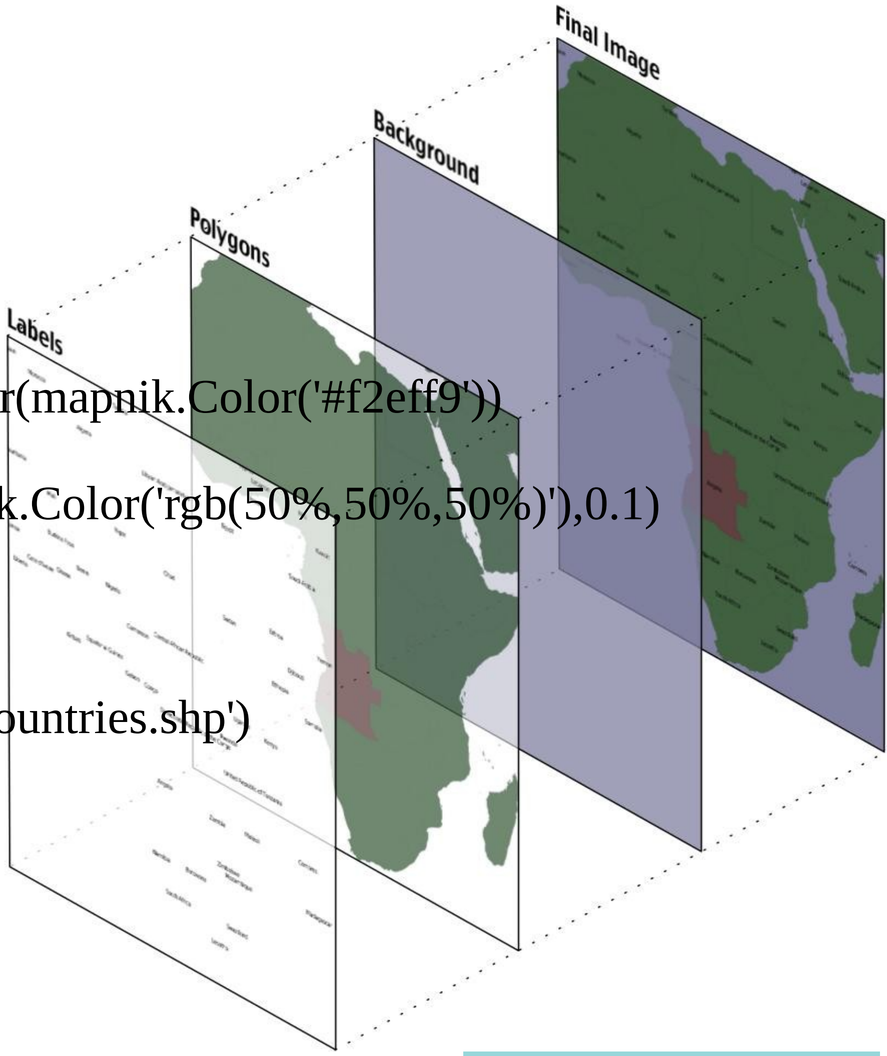
Strong cryptography available

This GeoServer instance is running version **2.2**. For more information please contact the administrator.

Service Capabilities

- WCS
  - 1.0.0
  - 1.1.1
- WFS
  - 1.0.0
  - 1.1.0
  - 2.0.0
- WMS
  - 1.1.1
  - 1.3.0
- WPS
  - 1.0.0

Mapnik



```
import mapnik
m = mapnik.Map(600,300)
m.background = mapnik.Color('steelblue')
s = mapnik.Style()
r = mapnik.Rule()
polygon_symbolizer = mapnik.PolygonSymbolizer(mapnik.Color('#f2eff9'))
r.symbols.append(polygon_symbolizer)
line_symbolizer = mapnik.LineSymbolizer(mapnik.Color('rgb(50%,50%,50%)'),0.1)
r.symbols.append(line_symbolizer)
s.rules.append(r)
m.append_style('My Style',s)
ds = mapnik.Shapefile(file='ne_110m_admin_0_countries.shp')
layer = mapnik.Layer('world')
layer.datasource = ds
layer.styles.append('My Style')
m.layers.append(layer)
m.zoom_all()
mapnik.render_to_file(m,'world.png', 'png')
print "rendered image to 'world.png'"
```

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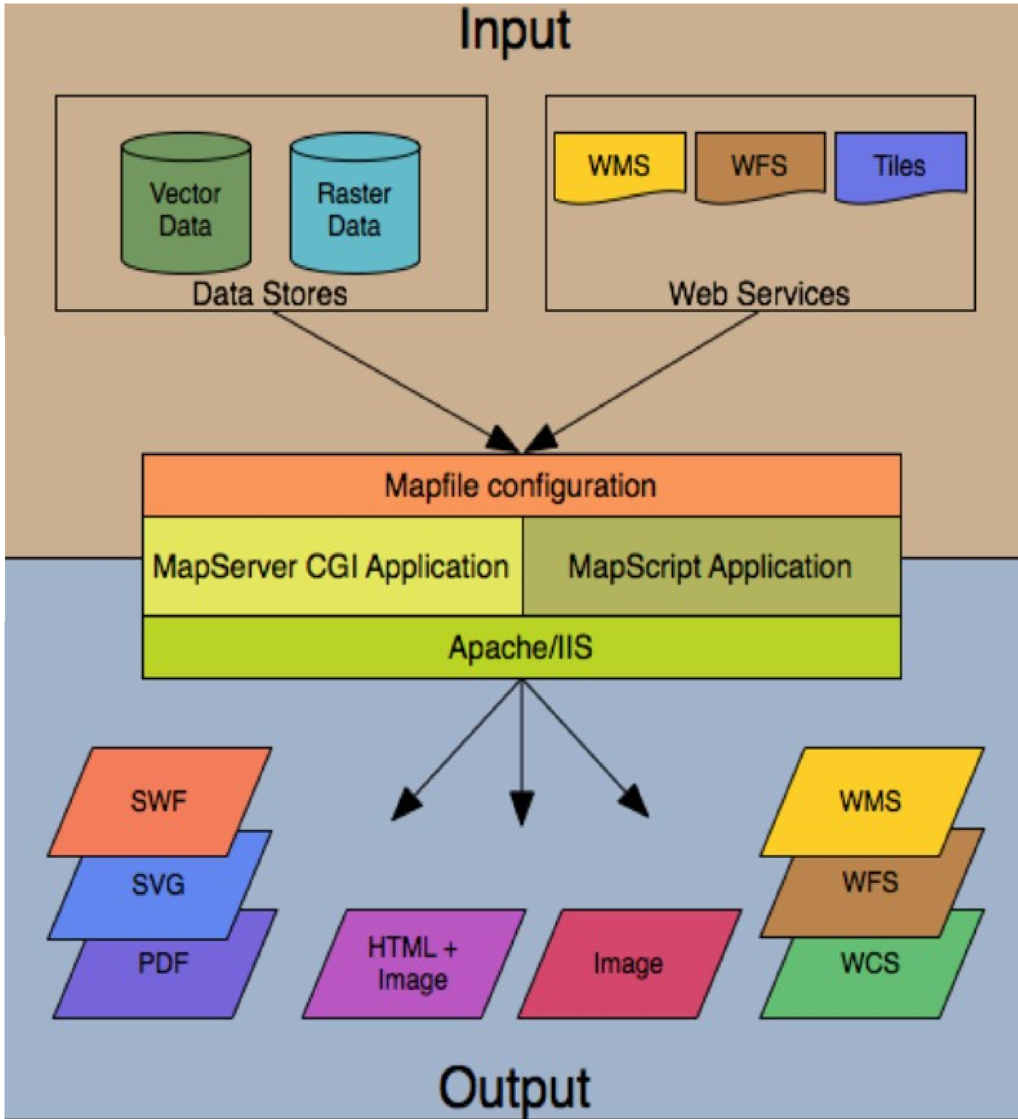
mapnik

MapServer

- The .map file is the basic configuration file for data access and styling for MapServer.

```
MAP
  NAME "sample"
  EXTENT -180 -90 180 90 # Geographic
  SIZE 800 400
  IMAGECOLOR 128 128 255
END # MAP
```

```
LAYER
     NAME "bathymetry"
     TYPE RASTER
     STATUS DEFAULT
     DATA "bath_mapserver.tif"
END # LAYER
```



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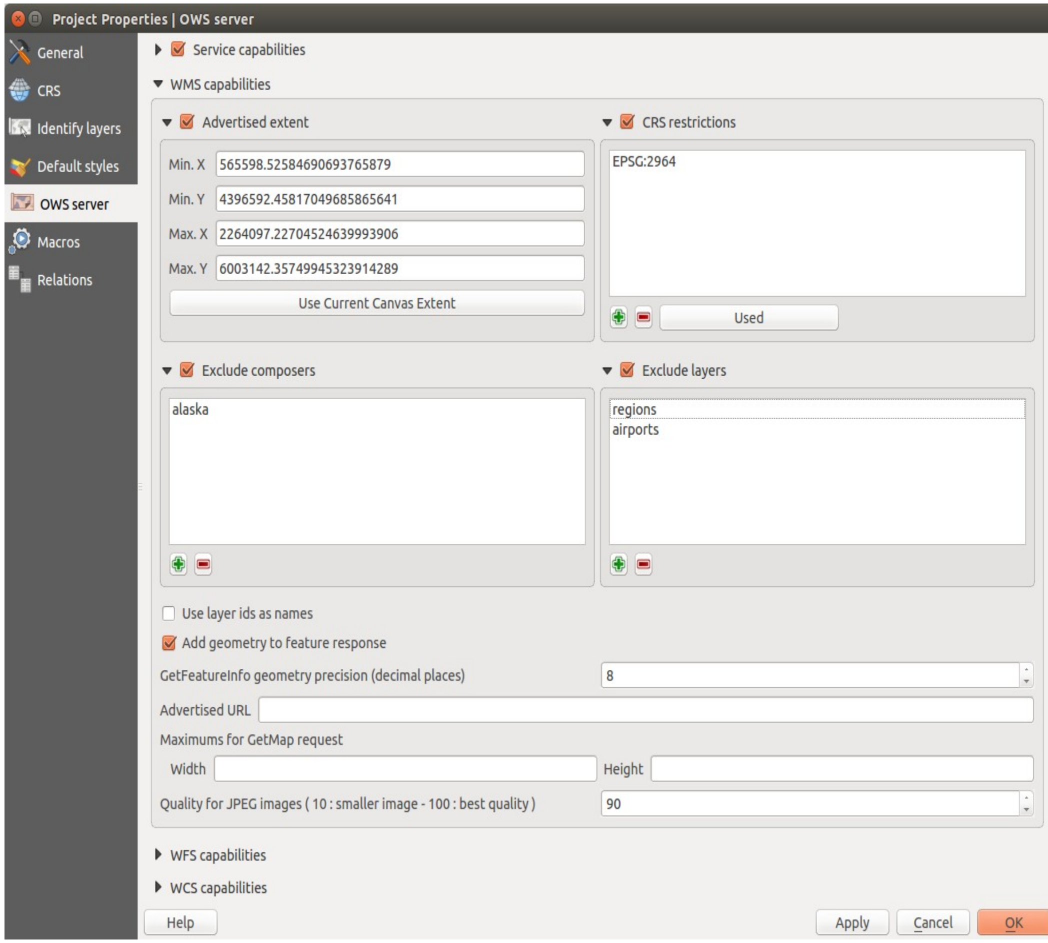
MapServer open source web mapping

QGIS Server

- Part of QGIS, it is based on the MapServer.
- Uses the same libraries as QGIS so what you see on the desktop is published on the web.
- You can also use the MAP parameter as in MapServer.



☑ Service capabilities

WMS capabilities

☑ Advertised extent

Min. X 565598.52584690693765879
Min. Y 4396592.45817049685865641
Max. X 2264097.22704524639993906
Max. Y 6003142.35749945323914289

Use Current Canvas Extent

☑ CRS restrictions

EPSG:2964

Used

☑ Exclude composers

alaska

☑ Exclude layers

regions
airports

☐ Use layer ids as names

☑ Add geometry to feature response

GetFeatureInfo geometry precision (decimal places) 8

Advertised URL

Maximums for GetMap request

Width Height

Quality for JPEG images (10 : smaller image - 100 : best quality) 90

WFS capabilities

WCS capabilities

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Map Servers – Performance Tips

- On the fly reprojection is costly, store the data in the projection that they are most often requested.
- If the server supports FastCGI use it.
- 256 colour PNG is faster than PNG24.
- Response times are shorter for shapefiles than PostGIS but use PostGIS if you require functions for spatial analysis.
- “Eating the elephant in small bites” i.e. spatial operations of smaller features are faster than spatial operations of larger features. This is the essence of raster and vector tiling.

http://www.slideshare.net/ssuser185516/mapserver-vs-geoserver-16107836

Vector Tiles

- Using the idea of mosaic “slippy maps” with vector data.
- Supported by Mapbox, Google Maps, OSM, Mapnik.
- Advantages:
  - Local styling on the client.
  - Include attribute data in each tile.
  - Support multiple resolutions with a single zoom.
  - More compact compared to raster tiles.
  - Can be cached.
  - Scale efficiently.
  - Support for different formats.

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Vector Tile Formats

- GeoJSON
  - Human-readable, easy to use and debug not recommended for production (.json extension).
- TopoJSON
  - Small file after compression, reduced replication of shared geometry, good for JS web development (.topojson extension).
- Mapbox binary tiles
  - Based on Google protocol buffers, compact, supports partial reads and incremental parsing, good for mobile applications (.mvt extension).
- OpenScienceMap binary tiles
  - Based on Google protocol buffers, vector rendering for Android (.vtm extension).

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Using Vector Tiles Services

- Slippy maps url from Mapzen:
  - http://vector.mapzen.com/osm/{layers}/{z}/{x}/{y}.{format}?api_key={api_key}
- Example of getting OSM buildings as GeoJSON:
  - https://vector.mapzen.com/osm/buildings/16/19293/24641.json?api_key=vector-tiles-xxxxxxx

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Displaying Vector Tiles in a Map

- Browser-based rendering software:
  - Leaflet
  - D3
  - MapboxGL
  - Polymaps
- Example using D3:
  - d3.json("https://vector.mapzen.com/osm/{layers}/{zoom}/{x}/{y}.{format}")[1]

[1]Full example: https://github.com/mapzen/d3-vector-tiles/blob/gh-pages/geojson.html

Vector Tile Servers

- TileStache
  - Python-based vector tile server
  - One of the most mature and widely used vector tile servers.
  - Supports MVT, GeoJSON and TopoJSON formats.
- Tilelive
  - Part of the Node.js web framework environment, as such it is based on Javascript.
  - Can be combined with Mapnik using the node-mapnik bindings.
  - Supports MVT, GeoJSON and TopoJSON formats.

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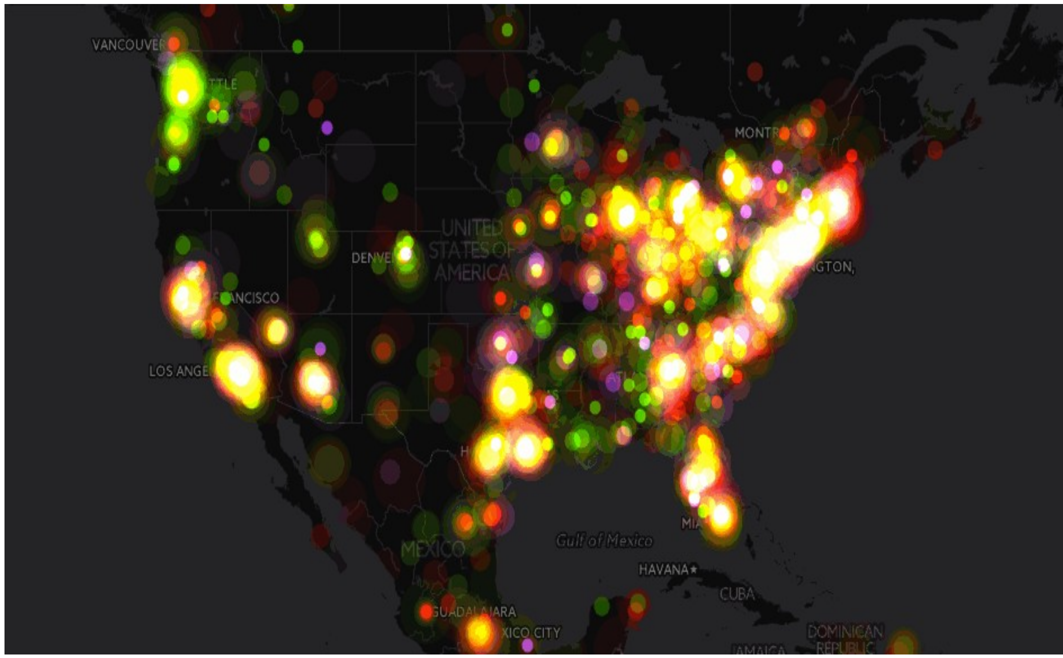
CartoDB

- Open source tool for the storage and visualization of geospatial data.
- At its core it uses PostGIS to store spatial data.
- Using the SQL API you can query the database with an SQL statement as part of the url.
- Can serve geospatial data using different formats (GeoJSON, TopoJSON).



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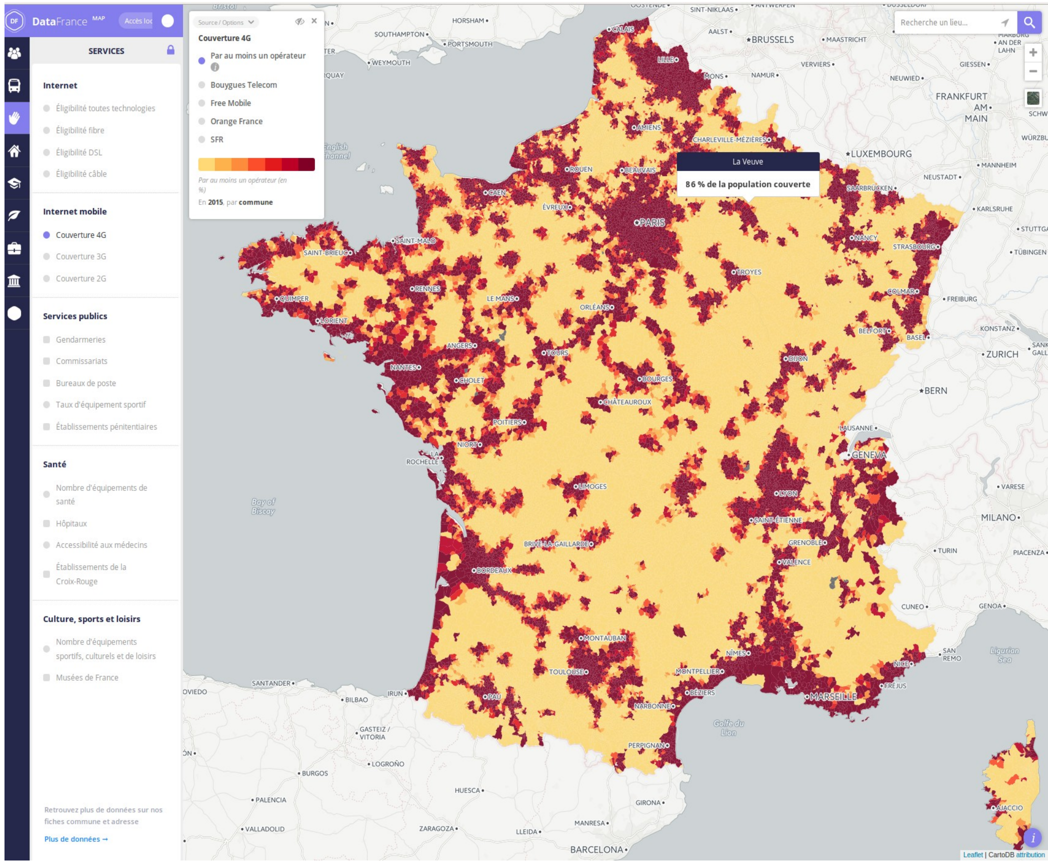
Applications – Portal for Open Source National-Scale Datasets

- Combine CartoDB with javascript frameworks (e.g. AngularJS, Leaflet) to create multilayer, interactive map applications.

  http://map.datafrance.info/population



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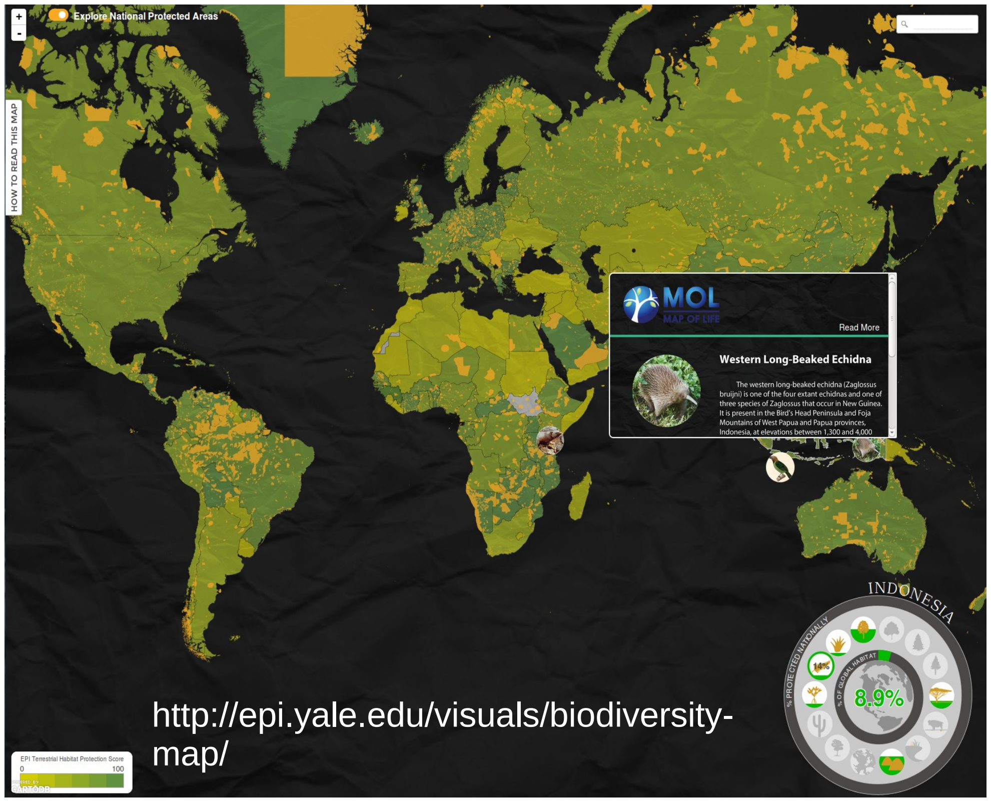
Applications – Map all species across the planet

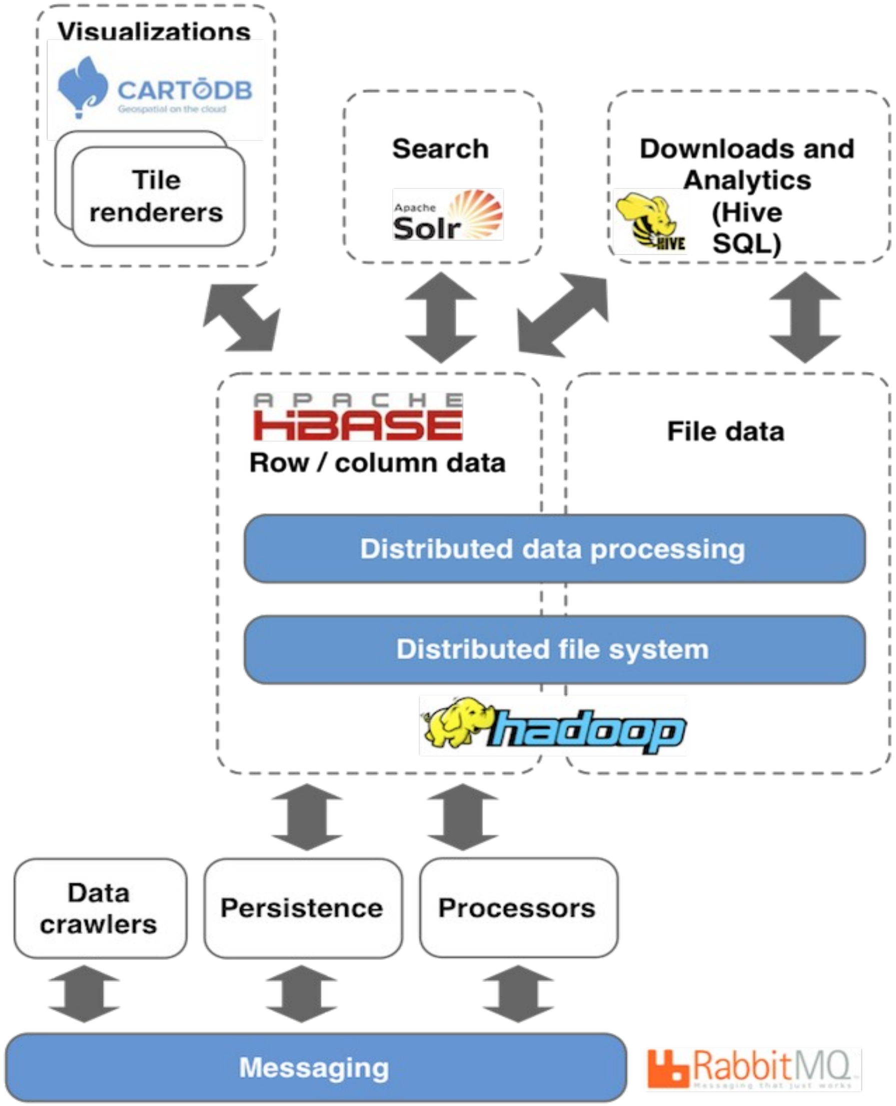
- Combine CartoDB with other frameworks to process large datasets.



Western Long-Beaked Echidna

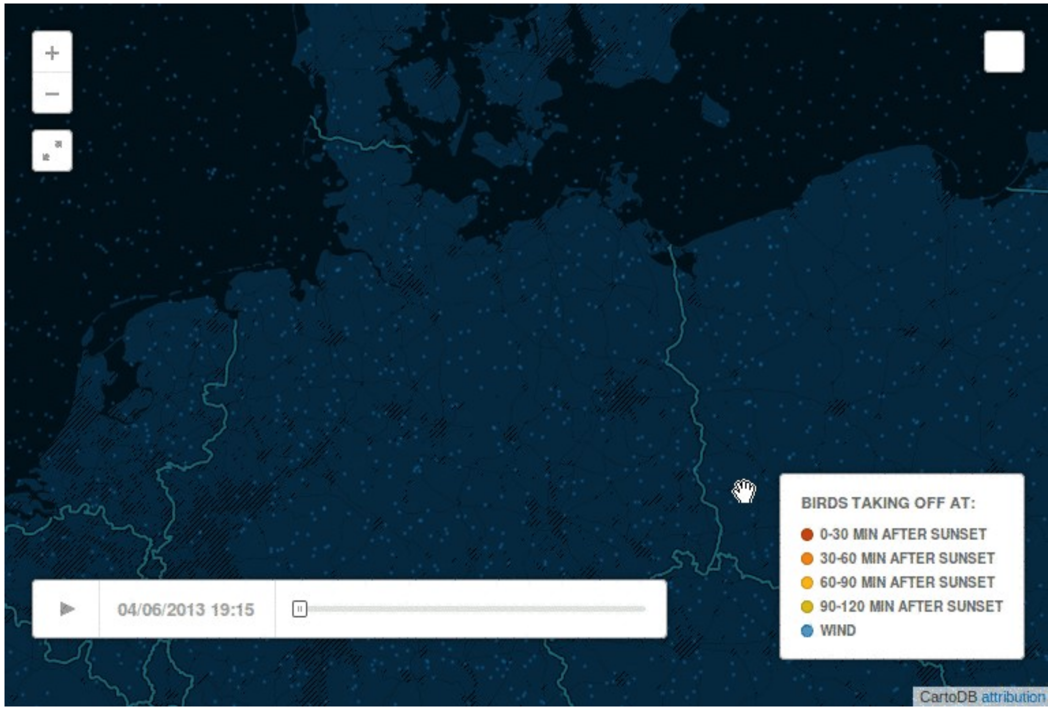
The western long-beaked echidna (Zaglossus bruijni) is one of the four extant echidnas and one of three species of Zaglossus that occur in New Guinea. It is present in the Bird's Head Peninsula and Foja Mountains of West Papua and Papua provinces, Indonesia, at elevations between 1,300 and 4,000

http://epi.yale.edu/visuals/biodiversity-map/



Applications – Animation of spatio-temporal point data

- Multidimension data as datacubes with Torque.js
- TorqueTiles:
  - Tiles + metadata
- Tiles:
  - GeoJSON
- Metadata:
  - Start/end time
  - Resolution
  - Number of steps
  - Bounding box



http://lifewatch.inbo.be/blog/posts/forward-trajectory-visualizations.html

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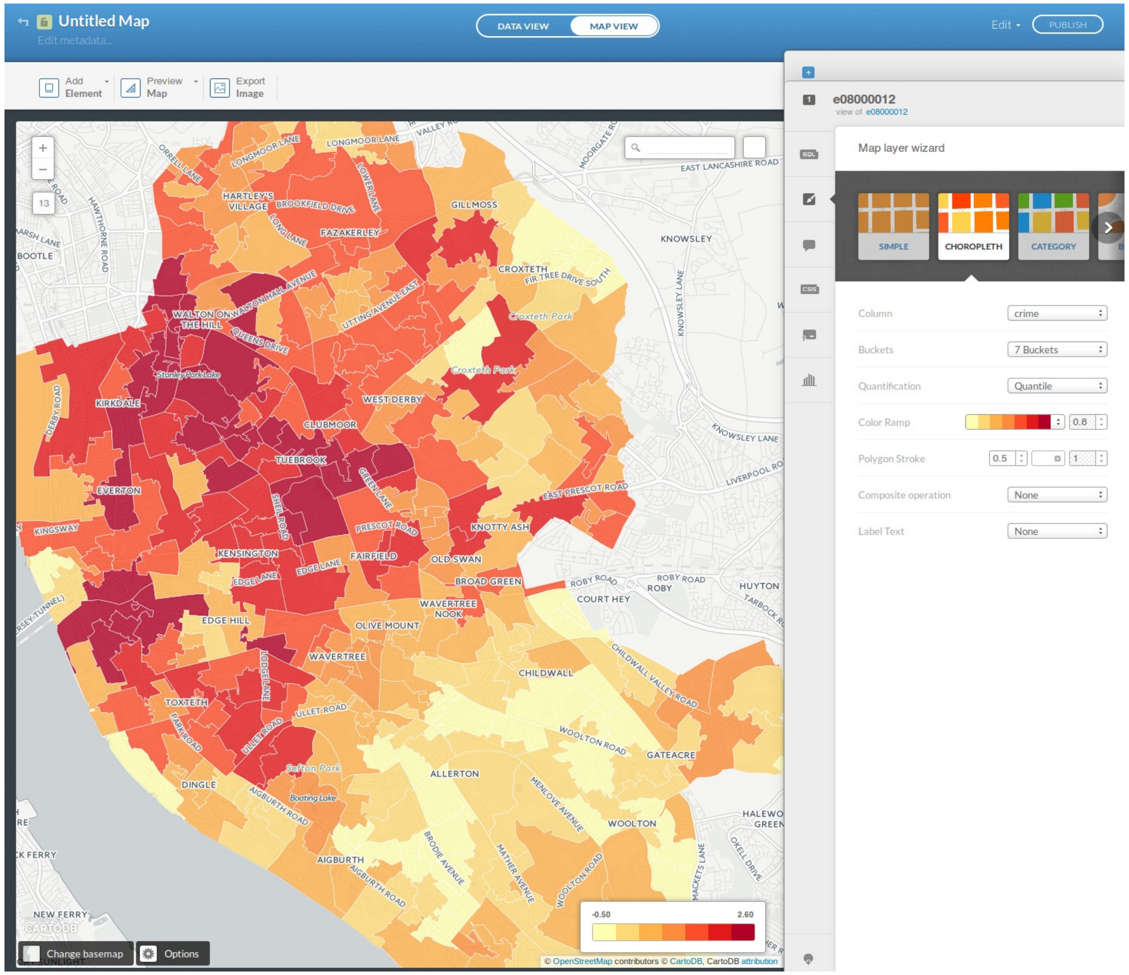
Components

- PostgreSQL
- PostGIS
- Redis
- PostgreSQL extension
- Editor
- Maps API
- SQL API



Column: crime
Buckets: 7 Buckets
Quantification: Quantile
Color Ramp: 0.8
Polygon Stroke: 0.5 1
Composite operation: None
Label Text: None

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Components

- PostgreSQL
  - Metadata storage
  - User data storage
- PostGIS
  - Geospatial functions
  - Geospatial types
- Redis
  - Key - value store engine
  - Metadata shared among Editor, SQL and Maps APIs
- PostgreSQL Extension
  - Extra functions used by Editor, Maps and SQL APIs
- Editor
  - Developed with Ruby on Rails
  - The core of CartoDB
- Maps API
  - Node.js API
  - Generate maps
- SQL API
  - Node.js API
  - SQL queries against CartoDB

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Reading Resources

- Mapmakers cheatsheet: https://github.com/tmcw/mapmakers-cheatsheet
- OGC Standards: http://www.opengeospatial.org/standards
- Slippy maps: http://wiki.openstreetmap.org/wiki/Slippy_map_tilenames
- Comparison of map servers: http://www.geotests.net/cours/sigma/webmapping/2014/schema6_2014p.pdf

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Many thanks…

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