

Create / distribute tiled map

Taro Matsuzawa

Georepublic Japan

Notes

- This presentation use some command line tools
 - Open following link in your browser.
 - Copy and paste the command line to your terminal.

https://smellman.github.io/jica_2023/

Self introduction

- GIS Engineer at Georepublic Japan
 - Programming: Python, JavaScript, TypeScript, Ruby etc.
 - UNIX and Linux guru
 - GIS skill: Data processing, Tiled based Map
- Community
 - Director of [OSGeo.JP](#)
 - Director of [OpenStreetMap Foundation Japan](#)
 - Sub president of [Japan Unix Society](#)
 - [UNOpenGIS/7](#) volunteer
- Contact: taro@georepublic.co.jp / @smellman on Twitter

Today's agenda

- System setup
- What is tiled map?
- Introduction of software and data in this presentation
- How to create your own tiled map
- How to design your own tiled map
- How to distribute your own tiled map

System setup

- This presentation requires Linux based OS.
 - Use Raspberry Pi 4.

System setup - Connect to jump host

- Connect to SSID "vectortiles"
- Launch Terminal
 - Windows: Use PowerShell
 - Mac: Use Terminal.app
- Connect to Raspberry Pi with SSH

```
ssh portal@j2213.local
```

System setup - Connect to Your Raspberry Pi

```
make <YOUR HOST NAME>
```

e.g.

```
make m321
```

System setup - Install software

```
sudo apt install -y git make
git clone https://github.com/smellman/jica_scripts.git
cd jica_scripts/system
sudo HOME=$HOME USER=$USER make install
```

What is tiled map?

Tile technology

- Provide map image or data over the internet.
 - Map images are separated as tiles.
 - Zoom Level 0 = World
 - Each zoom level doubles in the dimensions.
 - Too many tiles use "Web Mercator" projection.



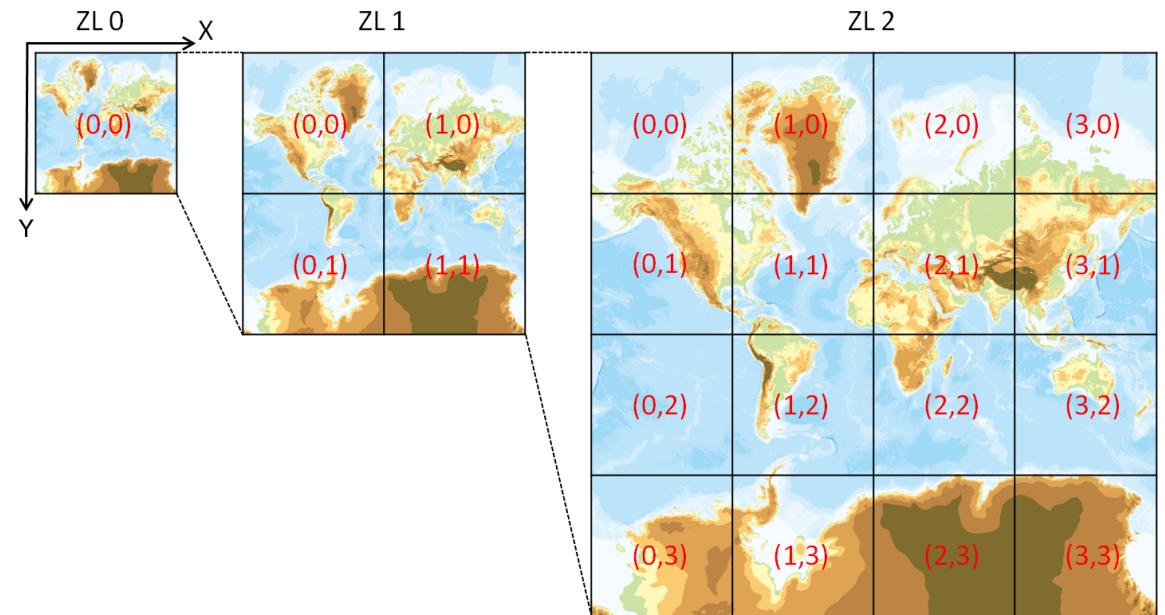
<https://a.tile.openstreetmap.org/0/0/0.png>

Useful to web

- Structure of tile is useful for web.
 - Enable to scroll map smoothly.
 - Enable to zoom up and zoom down map smoothly.
 - HTTP GET request.
- Tile become known for Google Maps.
 - Tile has existed from the late 1990s.

Zoom

- Zoom level 0 : 1 file
- Zoom level 1 : $2 \times 2 = 4$ files
- Zoom level 2 : $4 \times 4 = 16$ files
- ...
- Zoom level 18 : $2^{18} \times 2^{18} = 262,144 \times 262,144 = 68,719,476,736$ files



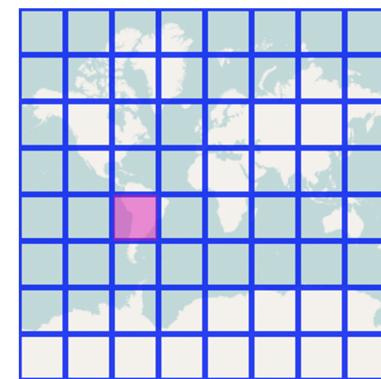
<https://maps.gsi.go.jp/help/image/tileNum.png>

GET Request

- Many services use REST API(GET Request).
 - <https://.../Z/X/Y.Format>
 - Z: Zoom Level
 - X: X coordinate
 - Y: Y coordinate
 - Format:
 - Raster image format(png, jpg, webp)
 - Vector data format(pbf, mvt)

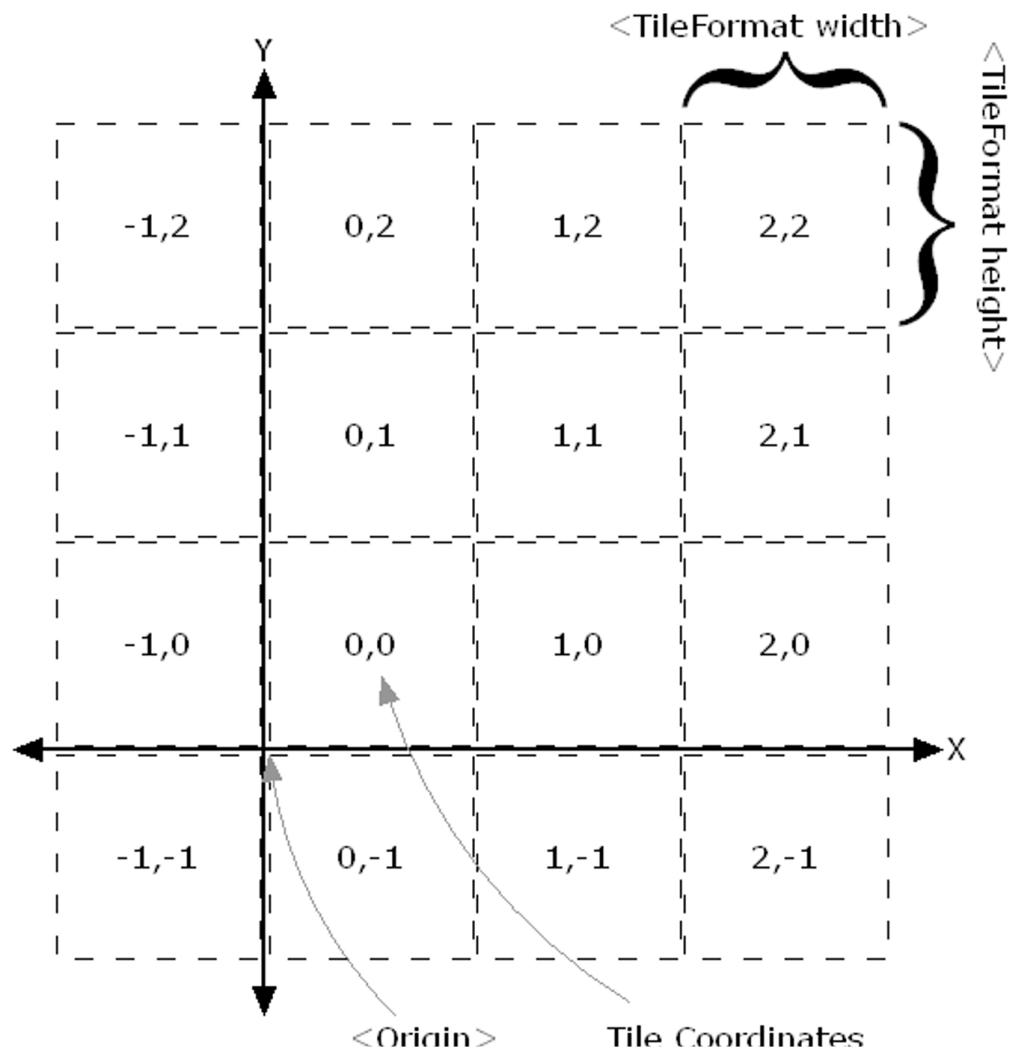
GET Request example

- <https://a.tile.openstreetmap.org/3/2/4.png>
 - Zoom = 3, X = 2, Y = 4,
format = png
 - X and Y coordinates start
with 0.

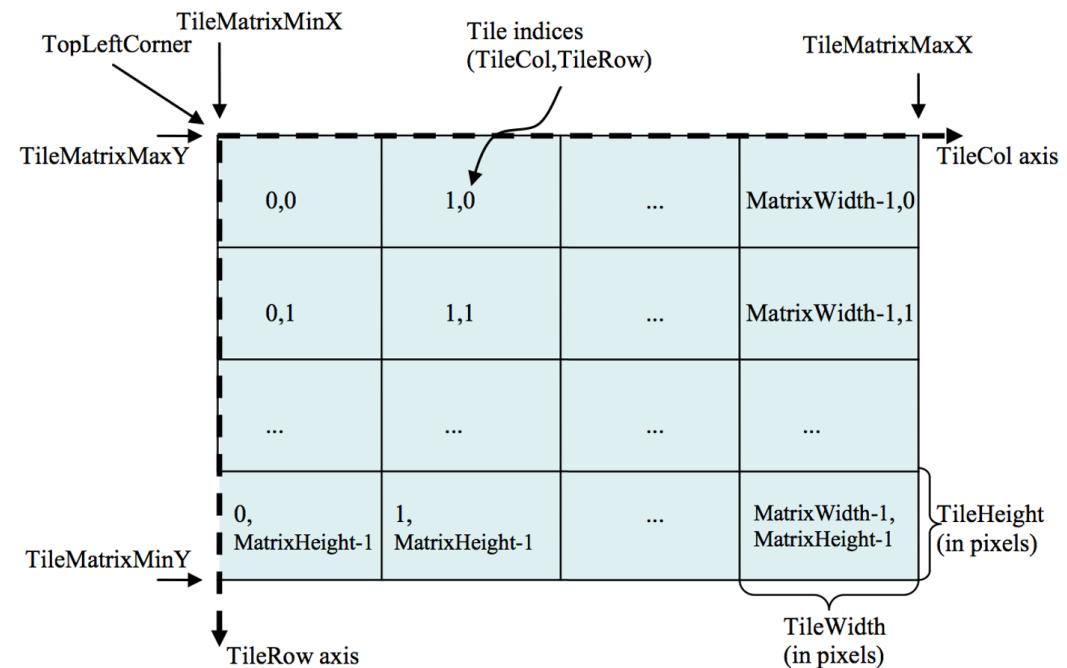


Specification

- Two tile service specifications are popular.
 - Tile Map Service(TMS)
 - Web Map Tile Service(WMTS)
- TMS is simpler than WMTS.
- TMS's X Y coordinate is started from bottom left.
 - Same as Cartesian coordinate system.
- WMTS's X Y coordinate is started from top left.
 - Same as Coordinate system of 2D computer graphics.



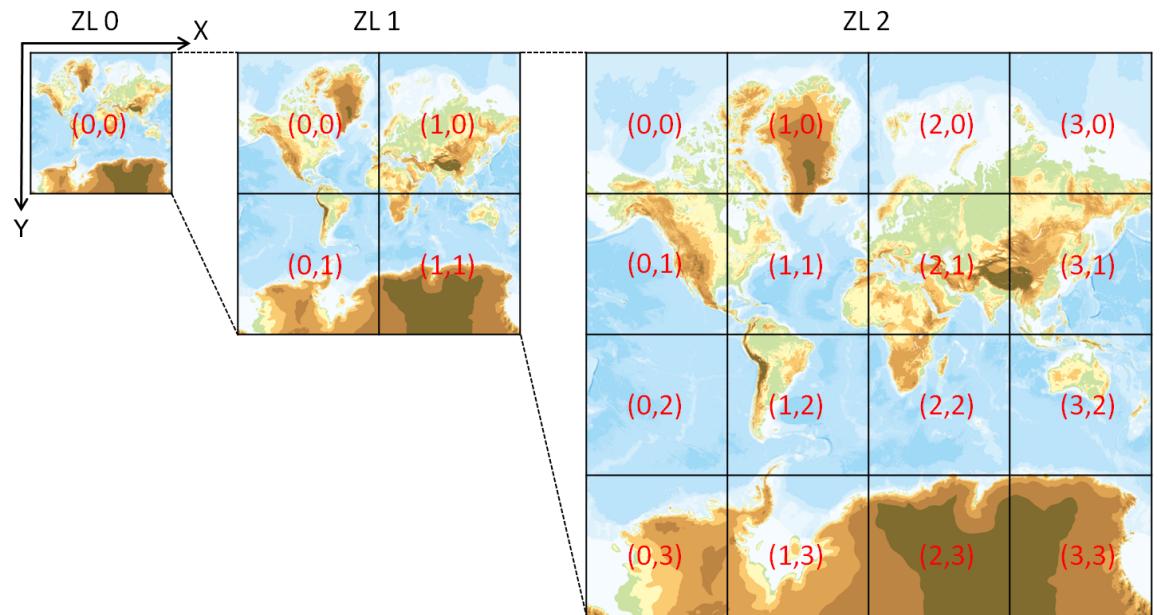
TMS



WMTS

The Y coordinate flipped

- OpenStreetMap use TMS like protocol but Y coordinate is numbered from top.
 - OpenStreetMap call "Slippy Map".
 - We call xyz tile.
 - $\{z\}/\{x\}/\{y\}.png$
 - Also we call zxy tile.



<https://maps.gsi.go.jp/help/image/tile>

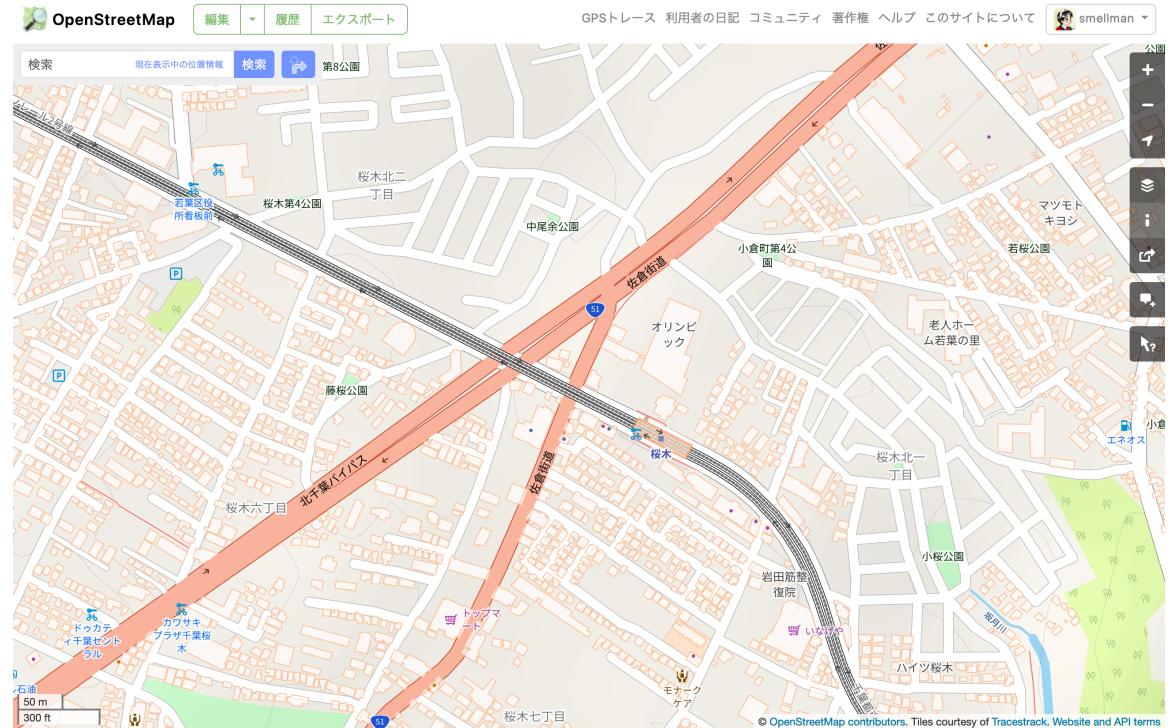
Num.png

XYZ tile

- De facto standard of tiled map.
 - Web Mercator projection
 - Y coordinate flipped TMS
 - Provide REST API
 - `{z}/{x}/{y}.{format}`
 - Anyone provide "Specification"
- Too many libraries support XYZ tile.
 - Leaflet, OpenLayers, Maplibre GL JS, Google Maps API etc.

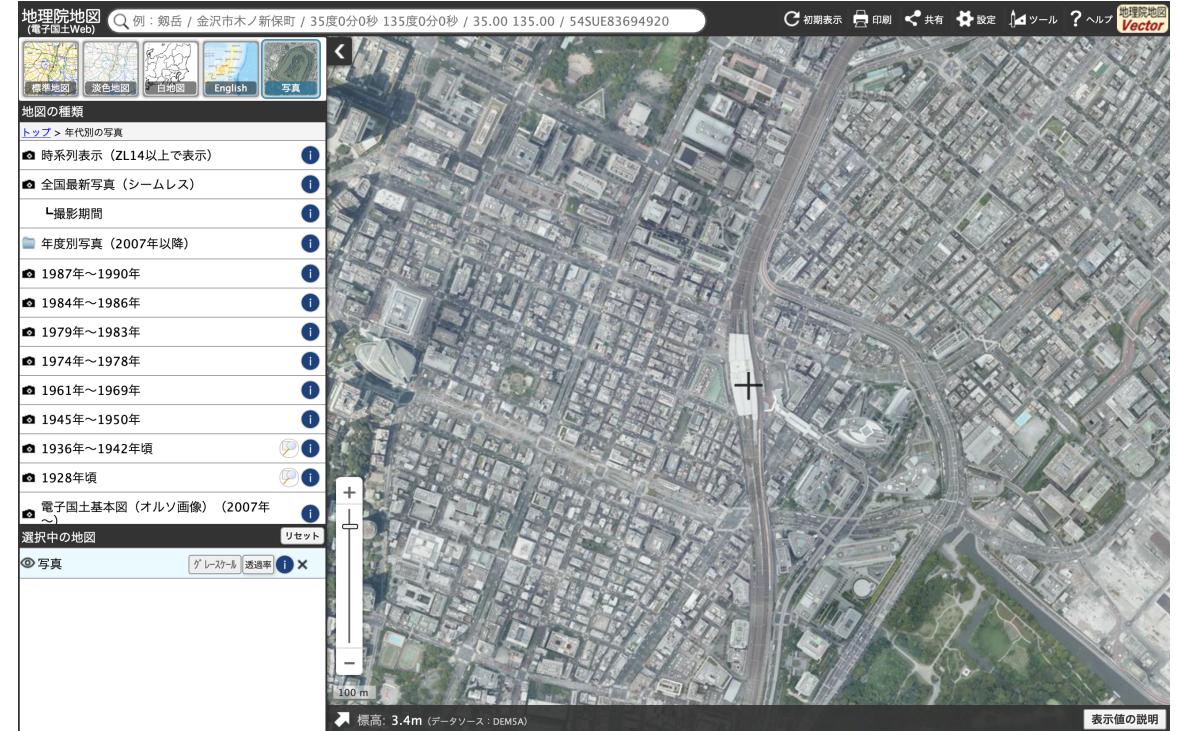
Raster tile (1/3)

- Provides "rendered image"
 - The image doesn't have any "data".
 - Focus to visualization.



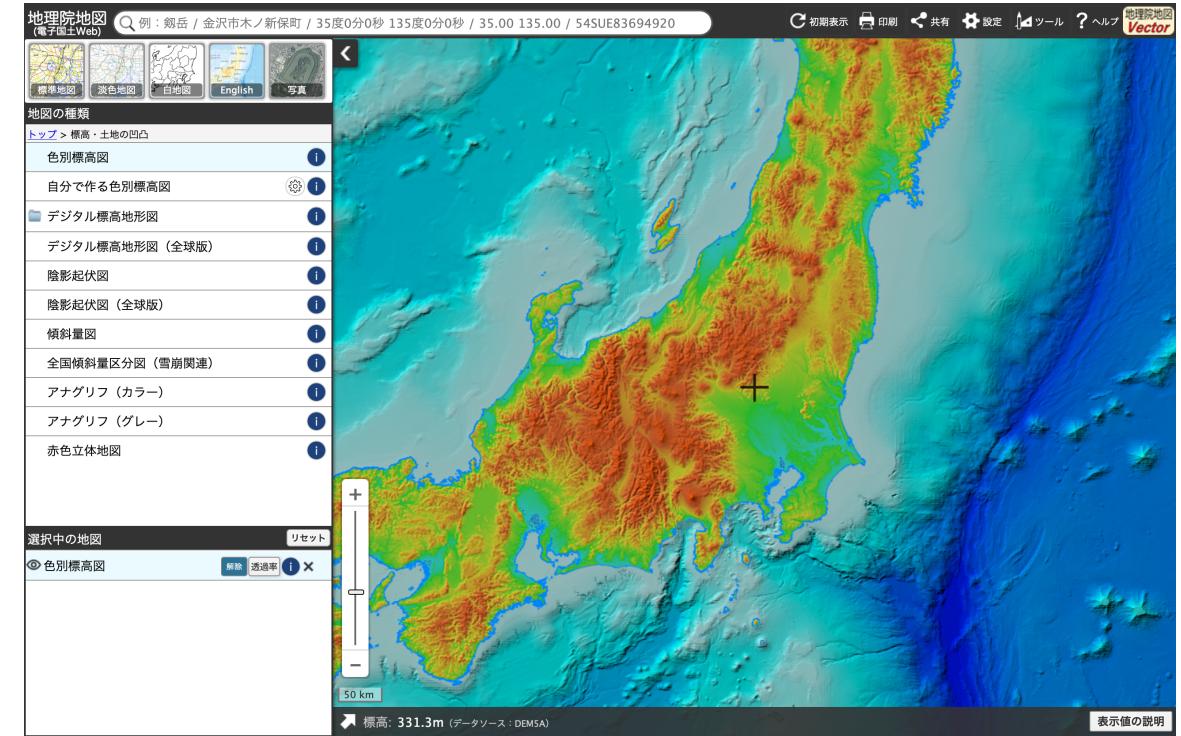
Raster tile (2/3)

- Provides "Satellite images" or "Aerial photograph"
 - Focus to photography.
 - The image doesn't have any "data" too.



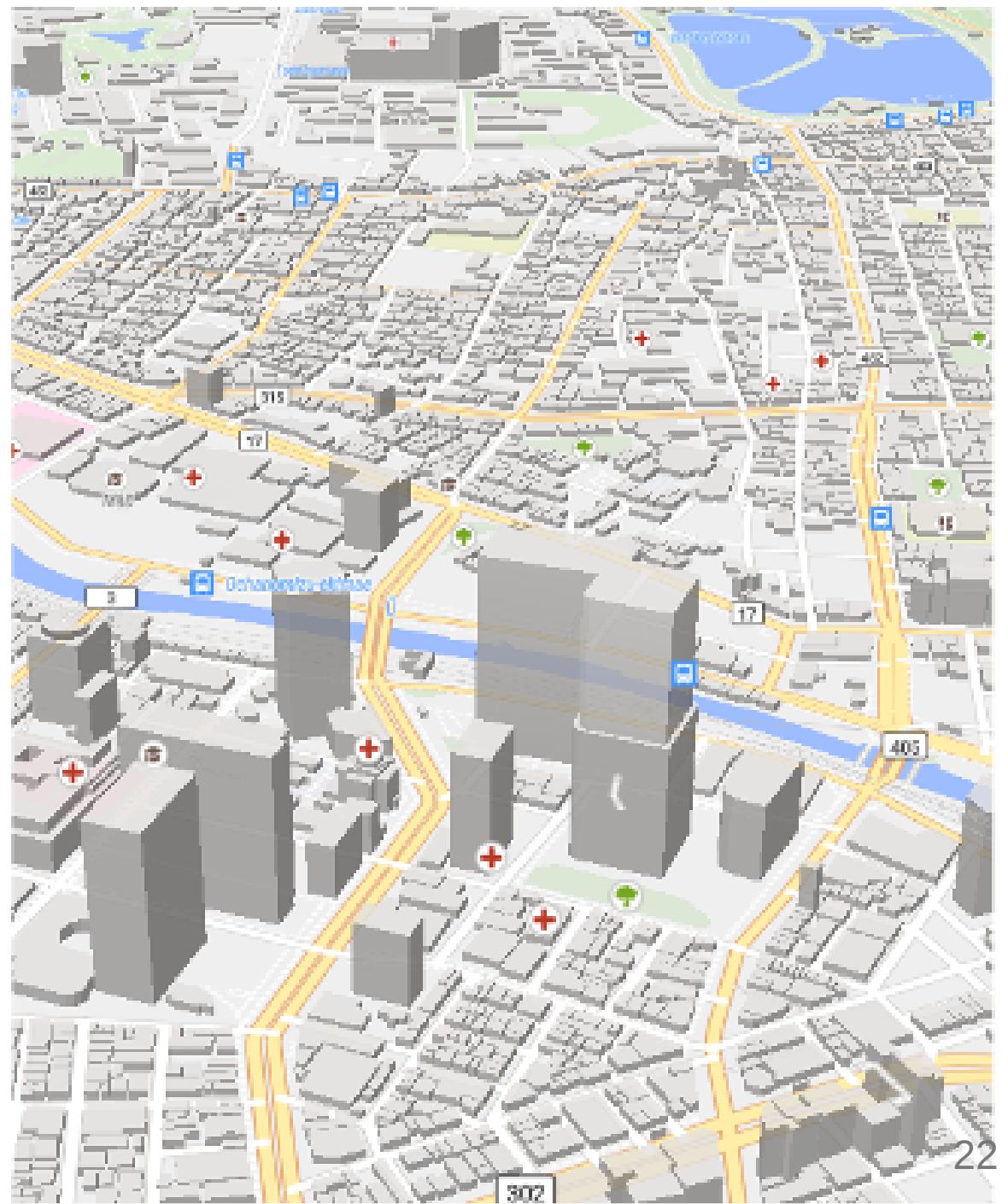
Raster tile (3/3)

- Provides "data" as image.
 - Focus to data.
 - Population,
Temperature, Rainfall,
Elevation, etc.
 - The image has "data" as color.
 - Sample raster tiles contain the elevation value obtainable by calculating with RGB values.



Vector tile (1/2)

- Provides "Vector data"
 - Each tile contains "Vector data".
 - The tile like a data container.

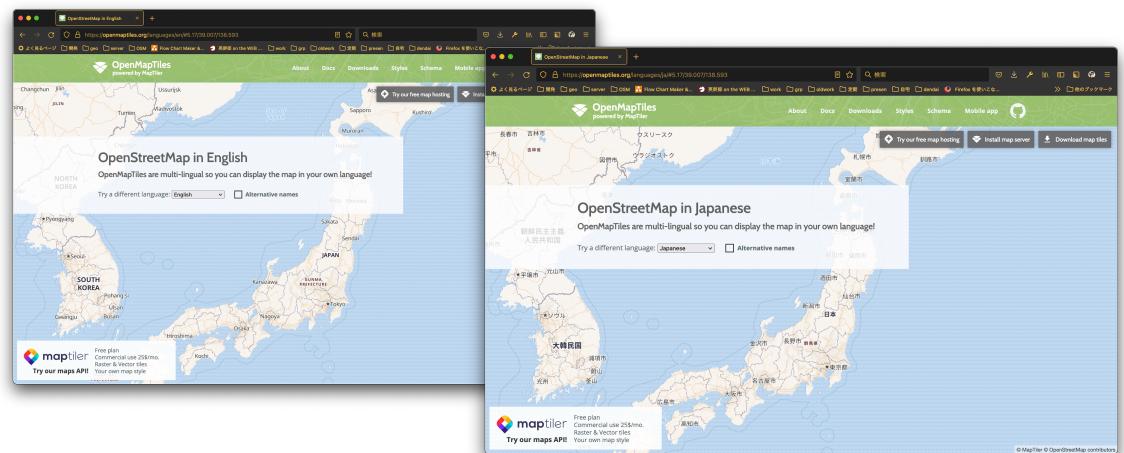


Vector tile (2/2)

- Vector tile doesn't have a style.
 - The client renders images with style settings.
 - Easy to rotation and bearing.
 - Supports 3D rendering.
- Programmable.
 - The client can change the style dynamically.

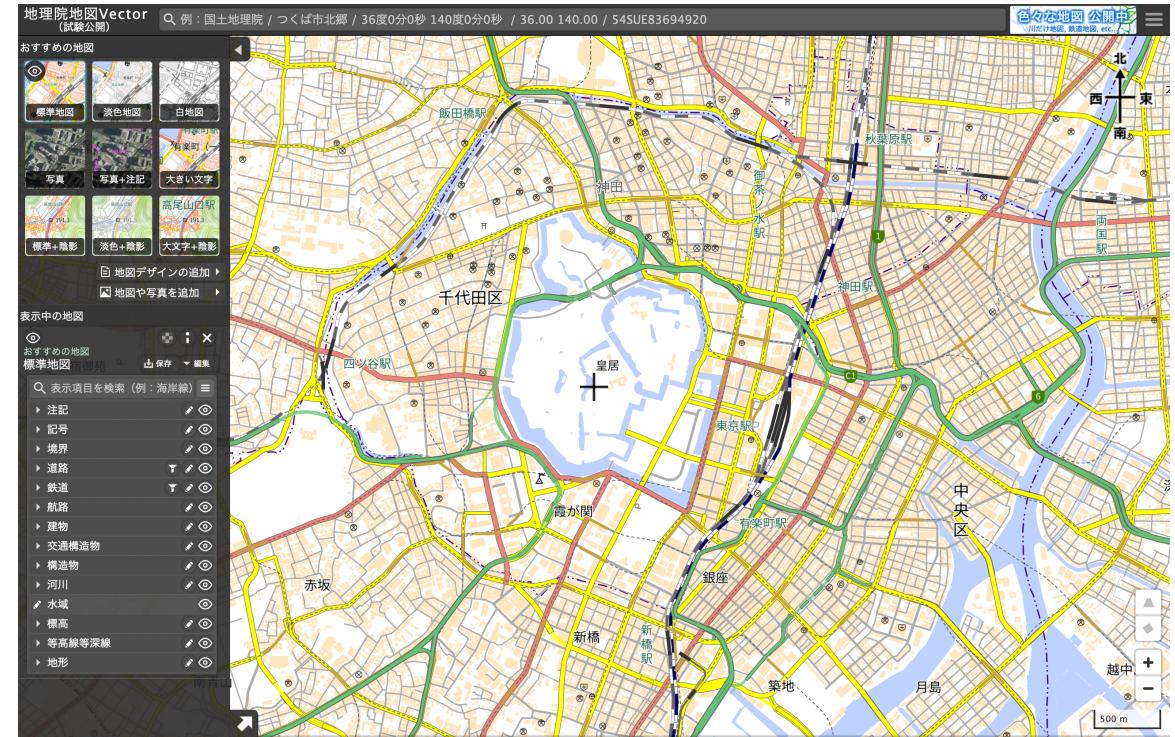
Vector tile example - Multilingual

- <https://openmaptiles.org/languages/>
 - Enable to change main language dynamically.



Vector tile example - Geospatial Information Authority of Japan

- <https://maps.gsi.go.jp/vector/>
 - GSI provides vector tile.
 - Enable to change style dynamically.



Mapbox Vector Tile

- De facto standard of vector tile.
 - Vector tile specification by Mapbox Inc.
- Specification
 - A tile encoded by Protocol Buffer format.
 - Desinged for Web Mercator projection.
 - Supports Layers and Features.

<https://docs.mapbox.com/data/tilesets/guides/vector-tiles-standards/>

Mapbox GL ecosystem and Style Specification

- Mapbox provides Mapbox GL JS(Web), Mapbox GL Native(Smartphone and Desktop application).
 - Mapbox provides specification of styling.
<https://docs.mapbox.com/mapbox-gl-js/style-spec/>



Note: Mapbox GL is proprietary software

- Mapbox GL became proprietary software from end of 2020.
 - Mapbox GL JS is OpenSource software until v1.5.
 - Mapbox GL JS over v2 must require mapbox service's token.
- MapLibre GL ecosystems are fork of mapbox OpenSource versions.
 - <https://maplibre.org/>
 - Highly recommend to use MapLibre GL JS now.

Tile support libraries - Javascript

- Leaflet
 - <https://leafletjs.com/>
 - Lightweight and easy to use.
 - Supports Mapbox Vector Tile with plugin.
- OpenLayers
 - <https://openlayers.org/>
 - Difficult to use but powerful.
 - Supports Mapbox Vector Tile.
- MapLibre GL JS
 - <https://maplibre.org/>
 - Easy to use for Mapbox Vector Tile.
 - Supports raster xyz tile too.

Tile support libraries - Android

- MapLibre GL Native
 - <https://maplibre.org/>
 - Easy to use for Mapbox Vector Tile.
 - Supports raster xyz tile too.
- Google Maps SDK
 - <https://developers.google.com/maps/documentation/android-sdk/overview>
 - Easy to use for raster xyz tile.

Tile support libraries - iOS

- MapLibre GL Native
 - <https://maplibre.org/>
 - Easy to use for Mapbox Vector Tile.
 - Supports raster xyz tile too.
- Mapkit
 - <https://developer.apple.com/documentation/mapkit>
 - Easy to use for raster xyz tile.

Desktop application

- QGIS
 - <https://qgis.org/>
 - Supports raster xyz tile.
 - Supports Mapbox Vector Tile.

Introduction of software and data in this presentation

Requirements

- This presentation requires Linux based OS.
- Also, you can use Raspberry Pi 4.
 - Raspberry Pi 4 is cheap and powerful.
 - Raspberry Pi 4 is ARM64/aarch64 architecture.
 - Raspberry Pi 4 is easy to use for GIS.
- My repository for this presentation supports only ARM64/aarch64 architecture.

Software - GDAL/OGR

- <https://gdal.org/>
- GDAL/OGR is the most popular GIS library and provides command line tools.
 - QGIS based on GDAL/OGR.
- GDAL/OGR supports many GIS data formats.
- GDAL/OGR supports raster xyz tile.

Software - Tippecanoe

- <https://github.com/felt/tippecanoe/>
- Build vector tilesets from large (or small) collections of GeoJSON, FlatGeoBuf or CSV features.
- Tippecanoe is the most popular vector tile builder.

Software - Charites

- Command line tool for writing Mapbox/MapLibre Vector Style Specification in YAML.
 - Organized by The United Nation Vector Tile Toolkit(UNVT).
- Charites convert Style Specification(JSON) to YAML.
 - YAML is easy to read and write for human.
 - YAML is easy to edit for beginners.
- Charites enable to dynamic serving style.

Software - editor

- `nano` is a simple text editor.
 - `nano` is easy to use for both beginners.
- `vim` is a powerful text editor.
 - `vim` is difficult to use for beginners.
 - `vim` is easy to use for experts.

Software - make

- make is a build automation tool.
- make is easy to use for both beginners and experts.
- make is a standard tool of UNIX and Linux.
 - This presentation use make for build and deploy.

Software - nginx

- nginx is a web server.
- nginx is easy to use for both beginners and experts.
- nginx is a standard tool of UNIX and Linux.
 - This presentation use nginx for serving tiles.

Software - tileserver-gl-light

- tileserver-gl-light is a vector tile server.
- useful for inspecting vector tile.

Software - docker

- docker is a container platform.
- docker is easy to use for both beginners and experts.
- This presentation use docker for serving tiles or running tileserver-gl-light.

Data - Global Map

- Digital geographic information
 - Provided by International Steering Committee for Global Mapping(ISCGM).
 - Composed of 8 Data Sets
 - Vector Data (Transportation, Boundaries, Darainage, Population Centre)
 - Raster Data (Elevation, Vegetation, Land Cover, Land Use)
- Free for non-commercial use.

Global Map - archive

- Archives and website were moved into github by GSI.
 - <https://github.com/globalmaps>
 - <https://globalmaps.github.io/>
- Old website was closed
- Some countries provides global map archives at the national site.
 - All links:
<https://github.com/globalmaps/projectmanagement/blob/master/REPOS.md>
- Some links are dead now.

Global map – format

- Vector data provide as Shapefile.
 - It provided as Geography Markup Language (GML) format.
- Raster data provide as GeoTiff file.
 - It provided as Band interleaved by line (BIL) format.

Data – Aerial photograph

- <https://www.mlit.go.jp/plateau/>
- In Japan, Plateau Project release too many Aerial photograph data.
 - Plateau released PointCloud, 3D data, and Aerial photograph.
 - Aerial photograph is released as GeoTiff data.
 - It is good sample to create raster tile.

Data - OpenStreetMap

- <https://www.openstreetmap.org/>
- OpenStreetMap is the most popular OpenData.
 - OpenStreetMap provides planet data as PBF format.
- Today's presentation use OpenStreetMap data as sample data.
 - Use small area data for easy to understand.

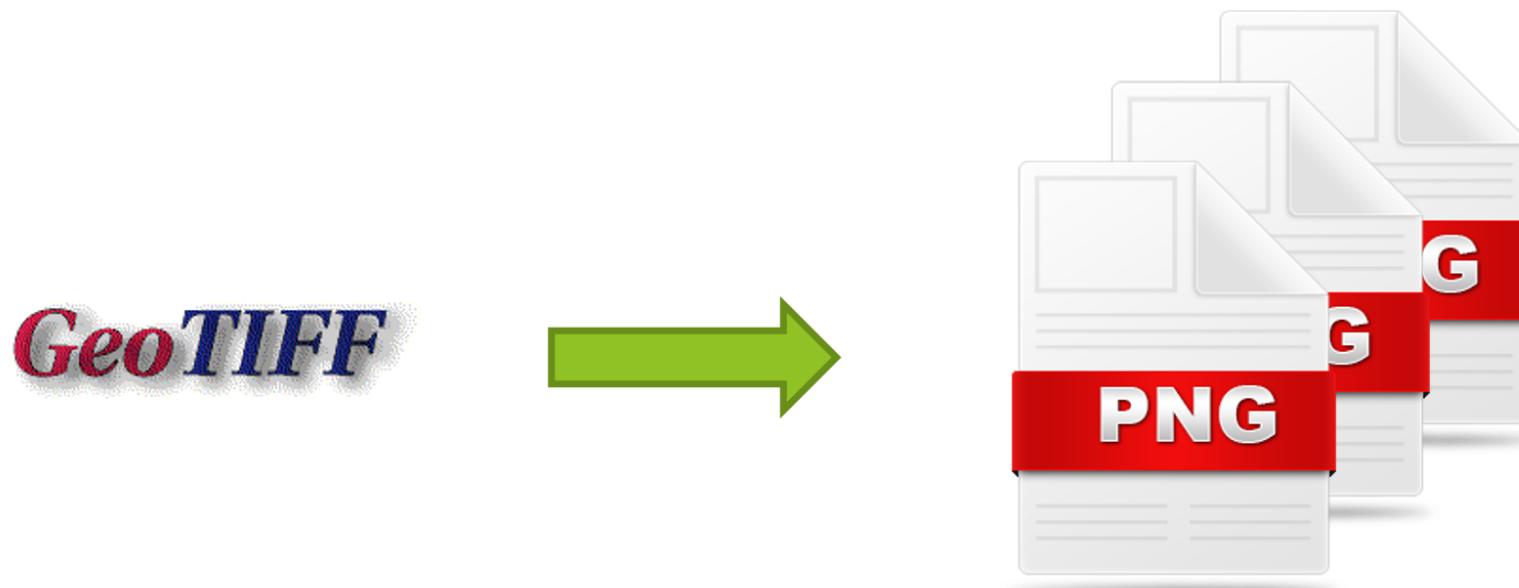
Data for this presentation

- Global Map Sri Lanka 1.0
 - <https://github.com/globalmaps/gmlk10>
- Global Map Sri Lanka 2.0
 - <https://github.com/globalmaps/gmlk20>
- Plateau Higashimurayama City in Tokyo GeoTIFF
 - <https://www.geospatial.jp/ckan/dataset/plateau-13213-higashimurayama-shi-2020>
- OpenStreetMap data
 - <https://tile.openstreetmap.jp/static/planet.pmtiles>

How to create your own tiled map

Raster tile processing pattern 1: Global map (One GeoTIFF file)

- Download GeoTIFF file from Global Map archive.
- Enable transparency.
- Convert GeoTIFF to XYZ tile using gdal2tiles.



How to process

```
cd ~/jica_scripts/raster_tile_gm  
make fetch # Download GeoTIFF file from Global Map archive.  
make transparent # Enable transparency.  
make generate_tile # Convert GeoTIFF to XYZ tile using gdal2tiles.  
make serve # run nginx
```

How to read Makefile

fetch:

```
git clone https://github.com/globalmaps/gmlk10.git
```

transparent:

```
gdalbuildvrt -srcnodata "0 0 99" el.vrt gmlk10/el.tif
```

generate_tile:

```
gdal_translate -of vrt -expand rgba el.vrt temp.vrt  
gdal2tiles.py --xyz -s EPSG:4326 -z 0-11 temp.vrt
```

serve:

```
docker run -p 8080:80 -v $(PWD)/temp:/usr/share/nginx/html:ro nginx
```

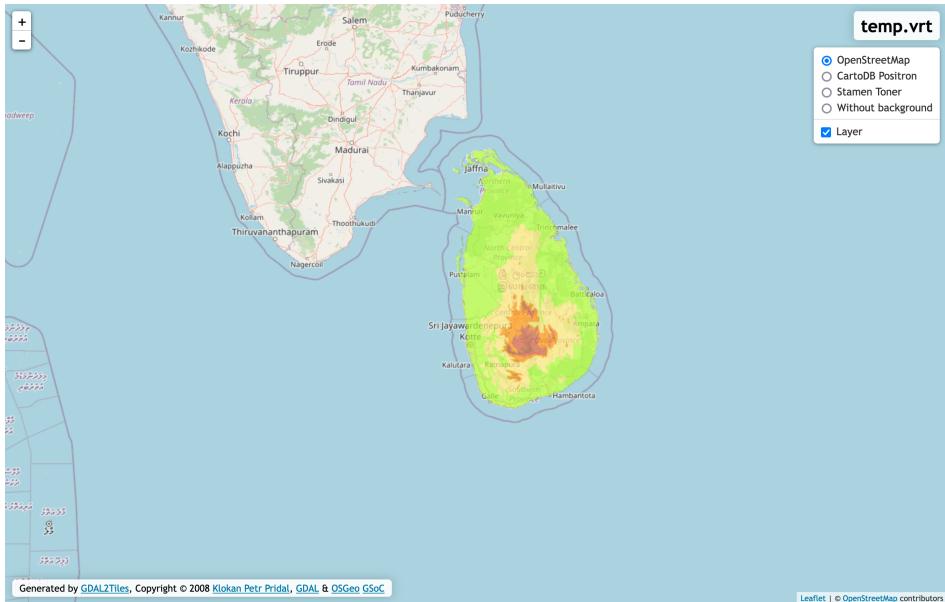
Makefile is simple to run tasks.

task_name:

command

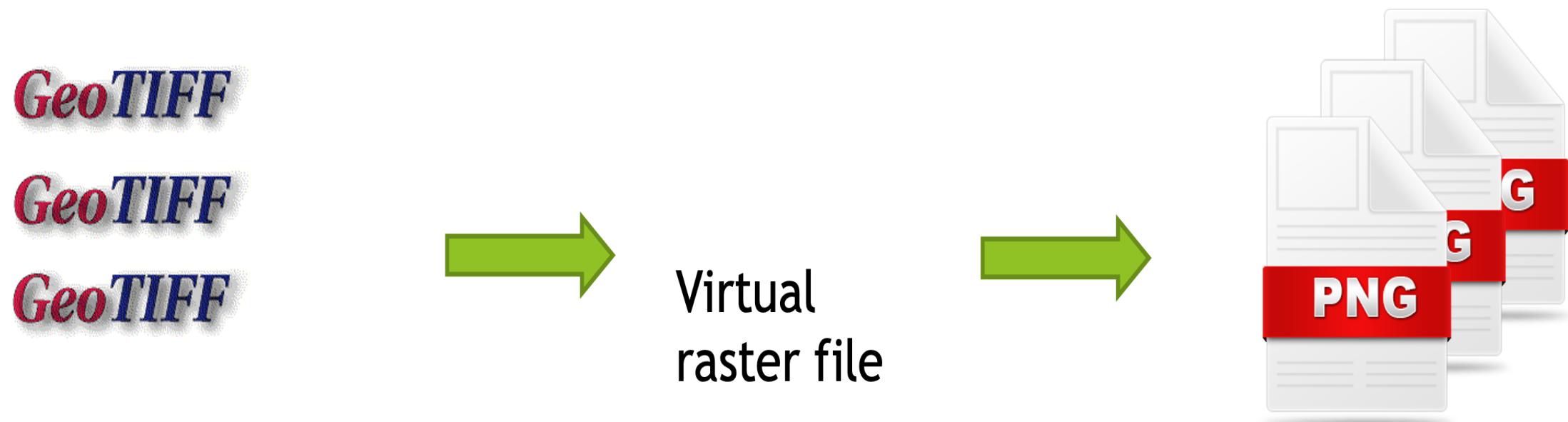
Result

Access to <http://<your host>.local:8080/leaflet.html>



Raster tile processing pattern 2: Plateau (Many GeoTIFF files)

- Generate VRT file from GeoTIFF files.
- Convert VRT file to XYZ tile using gdal2tiles.

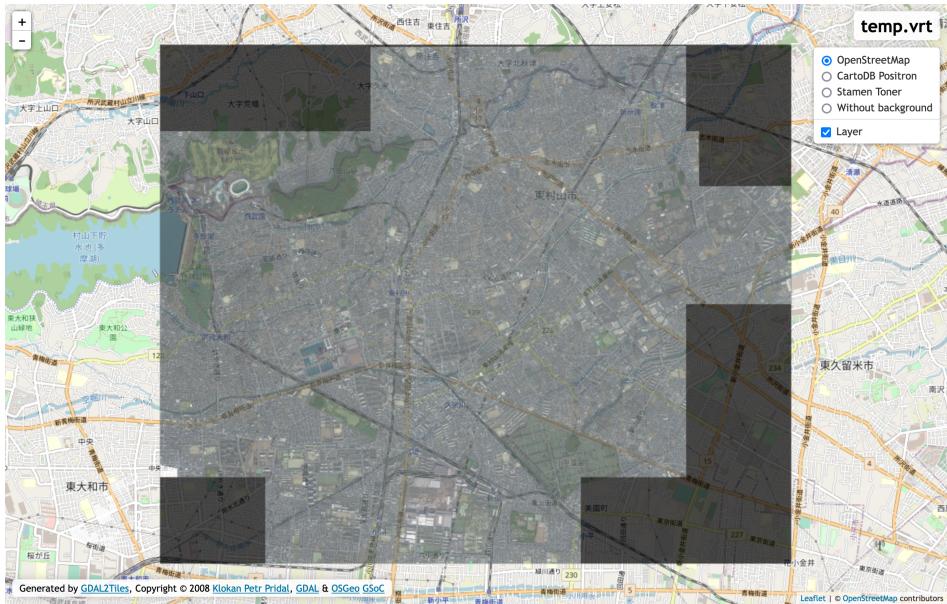


How to process

```
cd ~/jica_scripts/raster_tile_plateau  
make fetch # Download GeoTIFF file from Plateau archive and unarchive  
make buildvrt # Generate VRT file from GeoTIFF files.  
make generate_tile # Convert VRT file to XYZ tile using gdal2tiles.  
make serve # run nginx
```

Result

Access to <http://<your host>.local:8080/leaflet.html>



Vector tile processing pattern: Global map

- Download Shapefile file from Global Map archive.
- Convert Shapefile to GeoJSON using ogr2ogr.
- Convert GeoJSON to Mapbox Vector Tile using tippecanoe.

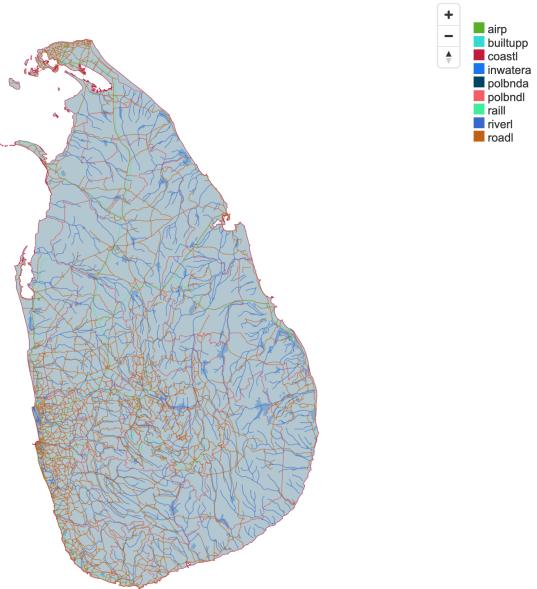


How to process

```
make fetch # Download Shapefile file from Global Map archive.  
make convert # Convert Shapefile to GeoJSON using ogr2ogr.  
make generate # Convert GeoJSON to Mapbox Vector Tile using tippecanoe.  
make tileserver-gl # run tileserver-gl-light
```

Result

Access to <http://<your host>.local:8081/>



Makefile (1/3)

fetch:

```
git clone https://github.com/globalmaps/gmlk20.git
```

convert:

```
cd gmlk20; \
ogr2ogr airp_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 airp_lka.shp; \
ogr2ogr builtupp_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 builtupp_lka.shp; \
ogr2ogr coastl_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 coastl_lka.shp; \
ogr2ogr inwatera_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 inwatera_lka.shp; \
ogr2ogr polbnda_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 polbnda_lka.shp; \
ogr2ogr polbndl_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 polbndl_lka.shp; \
ogr2ogr raill_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 raill_lka.shp; \
ogr2ogr riverl_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 riverl_lka.shp; \
ogr2ogr roadl_lka.geojson -s_srs EPSG:4326 -t_srs EPSG:4326 roadl_lka.shp
```

ogr2ogr convert Shapefile to GeoJSON. Notes: Those Shapefiles are not included .prj file.

Makefile (2/3)

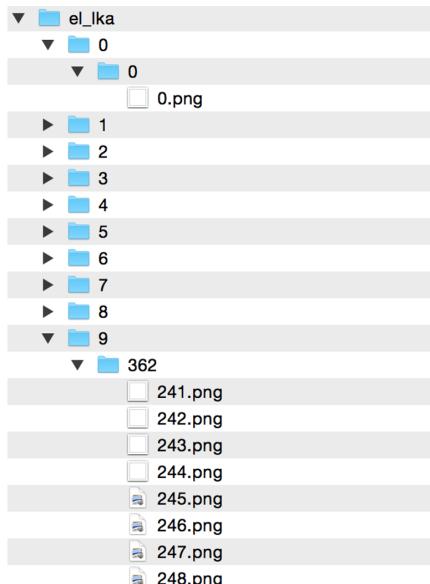
```
generate:
    tippecanoe -o lka.pmtiles \
        -L airp:gmlk20/airp_lka.geojson \
        -L builtupp:gmlk20/builtupp_lka.geojson \
        -L coastl:gmlk20/coastl_lka.geojson \
        -L inwaterna:gmlk20/inwaterna_lka.geojson \
        -L polbnda:gmlk20/polbnda_lka.geojson \
        -L polbndl:gmlk20/polbndl_lka.geojson \
        -L raill:gmlk20/raill_lka.geojson \
        -L riverl:gmlk20/riverl_lka.geojson \
        -L roadl:gmlk20/roadl_lka.geojson
    tippecanoe -o lka.mbtiles \
        -L airp:gmlk20/airp_lka.geojson \
        -L builtupp:gmlk20/builtupp_lka.geojson \
        -L coastl:gmlk20/coastl_lka.geojson \
        -L inwaterna:gmlk20/inwaterna_lka.geojson \
        -L polbnda:gmlk20/polbnda_lka.geojson \
        -L polbndl:gmlk20/polbndl_lka.geojson \
        -L raill:gmlk20/raill_lka.geojson \
        -L riverl:gmlk20/riverl_lka.geojson \
        -L roadl:gmlk20/roadl_lka.geojson
```

2 outputs

- tippecanoe runs 2 times and generate 2 outputs.
 - .mbtiles file
 - SQLite database file.
 - Contains vector tile.
 - .pmtiles file
 - "Cloud Native" format.
 - You can host .pmtiles as static file.

MBTiles - SQLite database

- MBTiles is container of tile.
 - MBTiles is single file database(SQLite).
 - TMS schema.



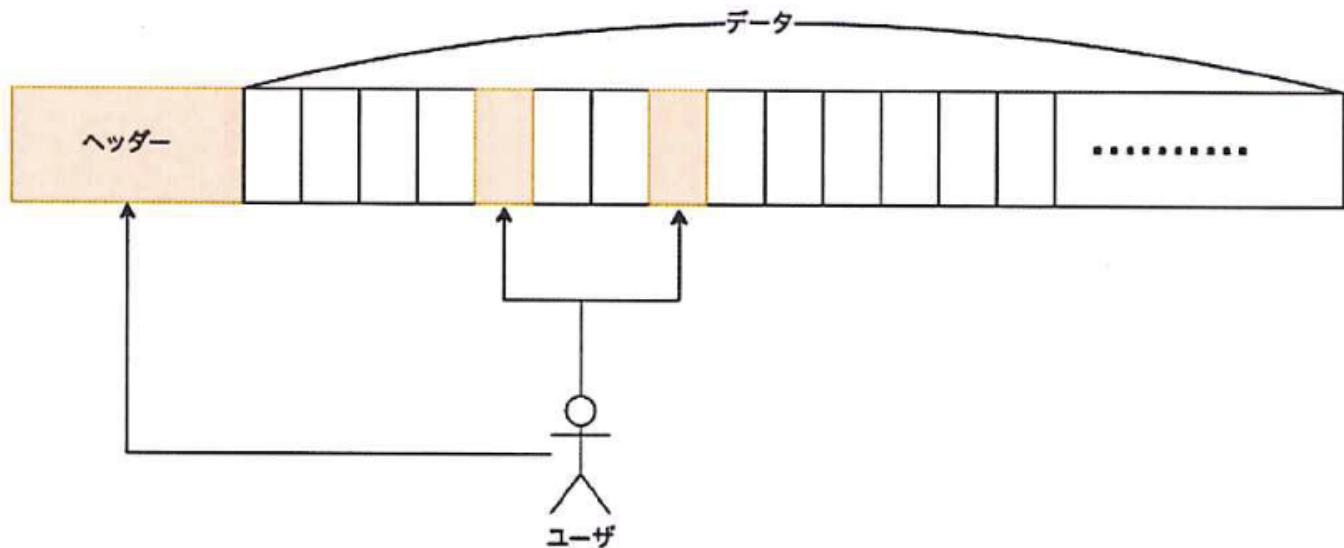
X	Y	Z	blob
0	0	0	(binary)
...
241	362	9	(binary)

Makefile (3/3)

```
tileserver-gl:  
    docker run --rm -it -v $(PWD):/data -p 8080:80 \  
        mptiler/tileserver-gl-light \  
        -p 80 --file /data/lka.mbtiles
```

PMTiles - Cloud Native format

- PMTiles is similar to MBTiles.
 - "Cloud Native" format.
 - You can easily convert mbtiles to pmtiles using `pmtiles` command.



<https://smellman.github.io/pmtiles-example/>

How to design your own tiled map

Design tiled map

- Vector tile doesn't have a style.
 - The client renders images with style settings.
- In this presentation, we use `charites` to design tiled map.
 - Charites convert Style Specification(JSON) to YAML.
 - YAML is easy to read and write for human.
 - YAML is easy to edit for beginners.

How to distribute your own tiled map

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