Terrain Data

for Flight Simulators

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1. Resources

1.1. Blue Marble Next Generation

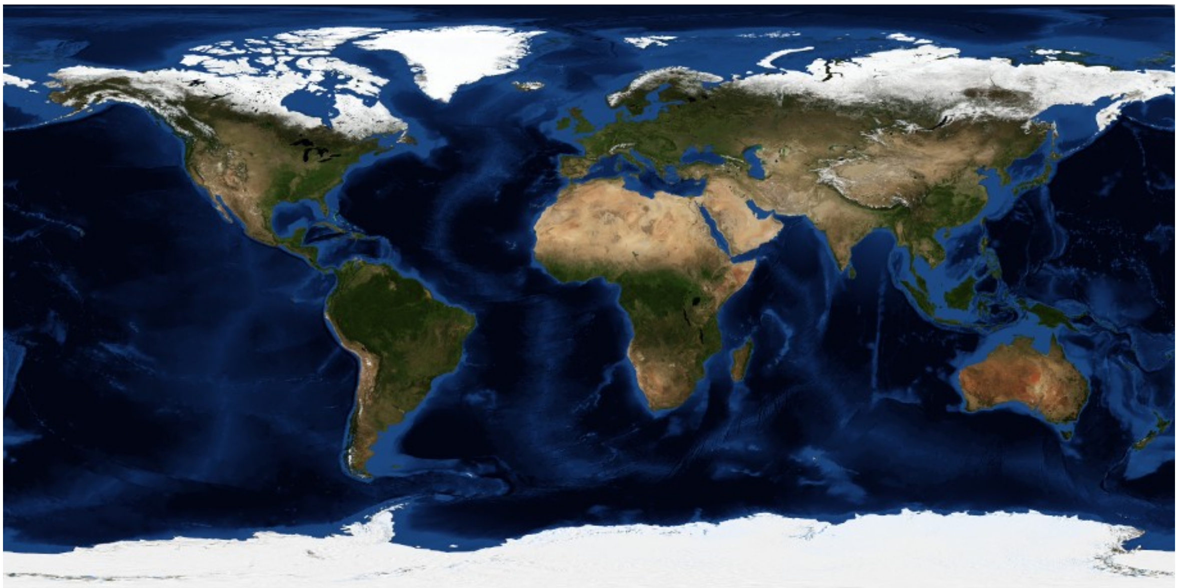

Figure 1-1: Blue Marble Next Generation with Topography and Bathymetry – May

The original Blue Marble is a photo taken by Apollo 17 astronauts on their way to the Moon on December 7th, 1972. In 2005 NASA released a series of satellite imagery of the entire Earth called Blue Marble Next Generation (BMNG). [1]

Blue Marble Next Generation data is available in georeferenced TIFF (GeoTIFF) file format.

Blue Marble Next Generation data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

Blue Marble Next Generation includes:

Collection	**Resolution**
Monthly images	ca. 500 m/pixel
Topography	ca. 1 km/pixel
Bathymetry	ca. 1 km/pixel
Clouds	ca. 1 km/pixel
Land Surface, Ocean Color and Sea Ice	ca. 5 km/pixel
Earth Lights	ca. 2.5 km/pixel

Tabela 1-1 Blue Marble Next Generation Collections

Larger data sets are divided into subdomains.

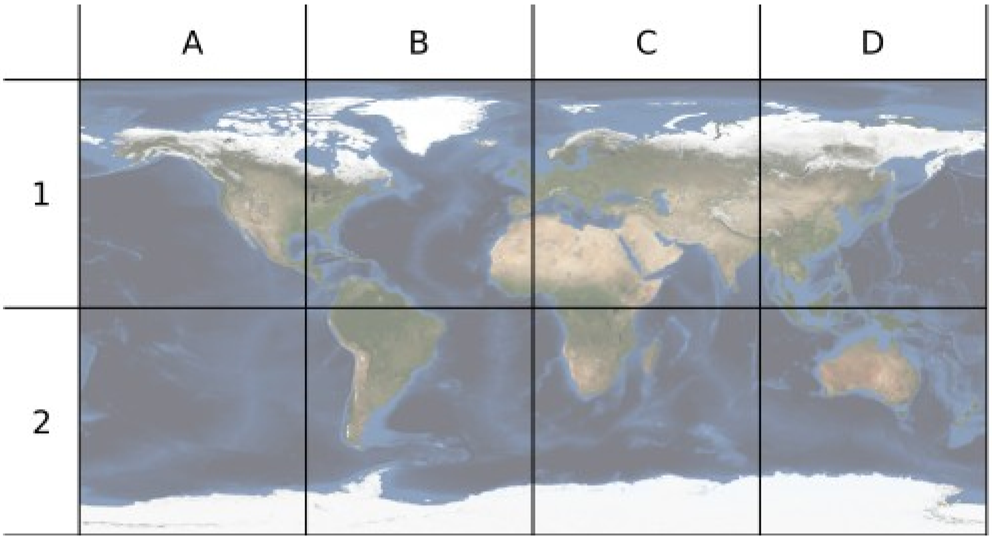

Figure 1-2: Blue Marble Next Generations Subdomains

Blue Marble Next Generation can be obtained from:

https://visibleearth.nasa.gov/view_cat.php?categoryID=1484 [2].

1.2. Landsat 7 ETM+

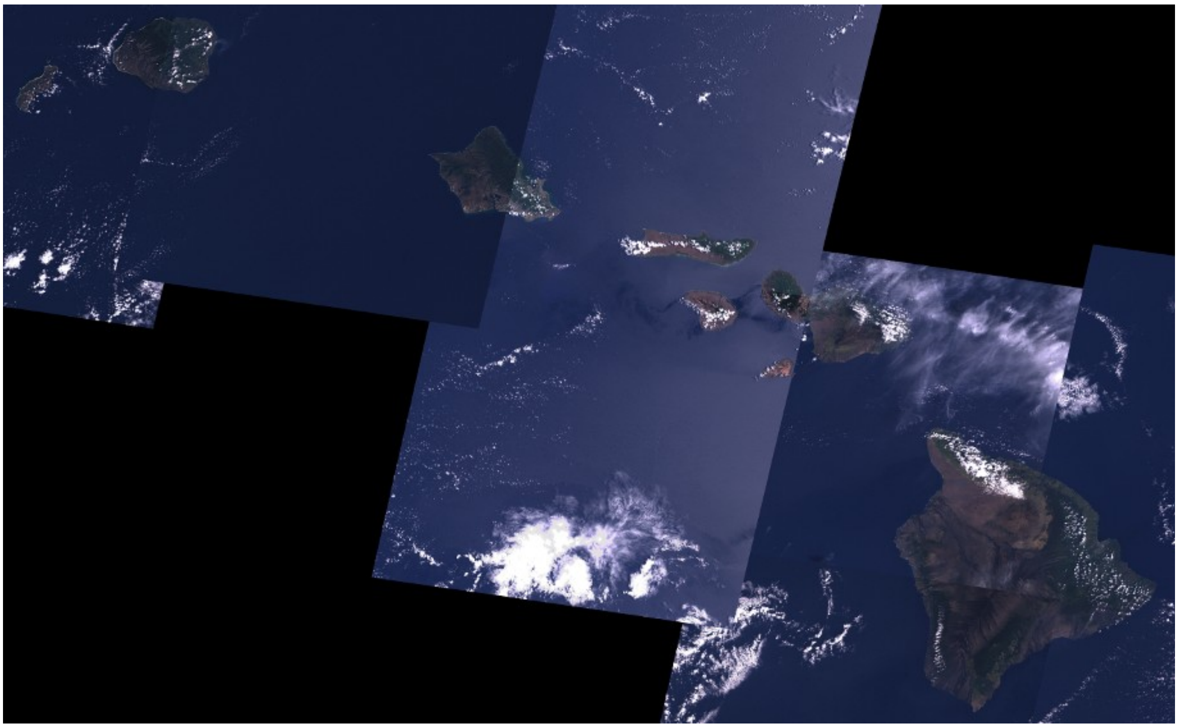

Figure 1-3: Landsat 7 Enhanced Thematic Mapper Plus True-Color Imagery Mosaic

Landsat is a joint USGS ans NASA program to obtain satellite imagery of Earth. Data from Landsat 7 satellite Enhanced Thematic Mapper Plus (ETM+) sensor can be used to obtain Earth true-color imagery. Data covers most of Earth land area.

Bands 1-4 can be used to generate true-color imagery while band 8 can be used to enhance resolution.

Band	**Wavelength**	**Resolution**
1 – Blue	0.45 – 0.52 µm	ca. 30 m/pixel
2 – Green	0.52 – 0.60 µm	ca. 30 m/pixel
3 – Red	0.63 – 0.69 µm	ca. 30 m/pixel
4 – Near Infrared	0.77 – 0.90 µm	ca. 30 m/pixel
5 – Short-Wave Infrared 1	1.55 – 1.75 µm	ca. 30 m/pixel
6 – Thermal	10.40 – 12.50 µm	ca. 60 m/pixel
7 – Short-Wave Infrared 2	2.09 – 2.35 µm	ca. 30 m/pixel
8 – Panchromatic	0.52 – 0.90 µm	ca. 15 m/pixel

Table 1-2: Landsat 7 Enhanced Thematic Mapper Plus Bands

Landsat 7 ETM+ data is organized according to the Worldwide Reference System-2.

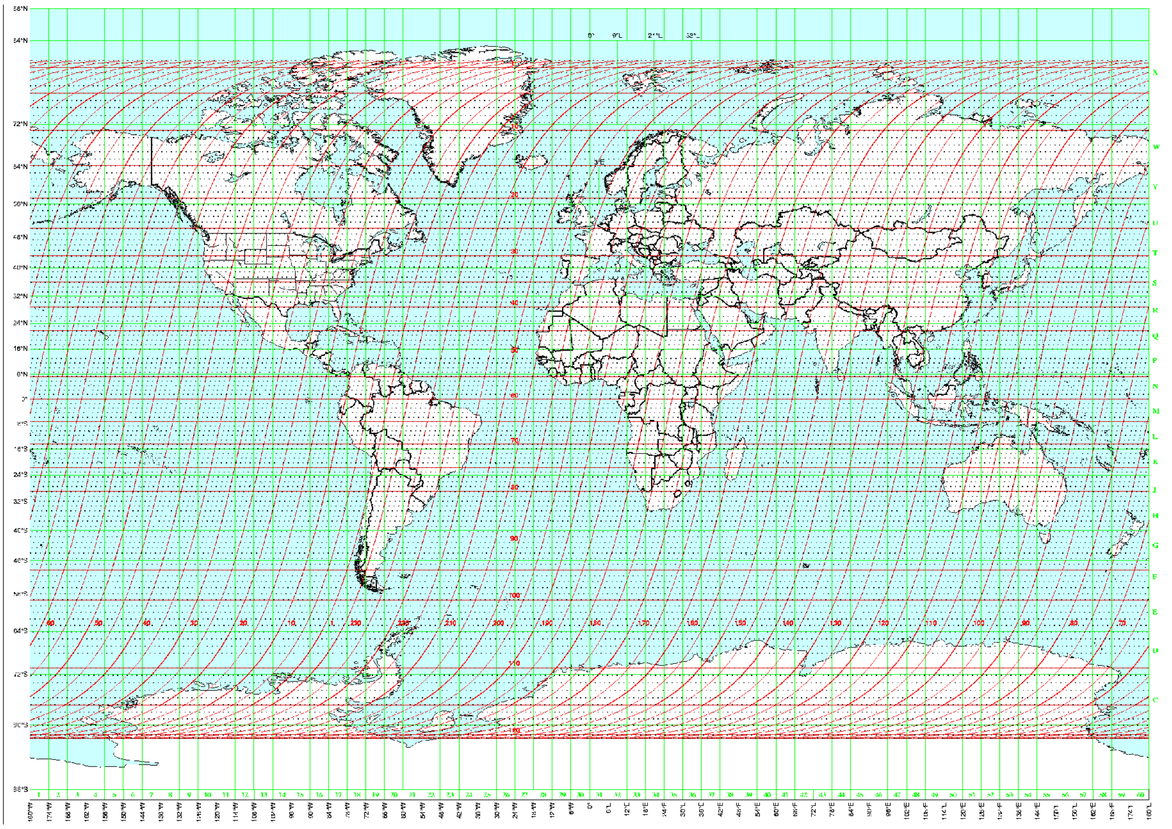

Figure 1-4: Map of the Worldwide Reference System-2

Landsat 7 Enhanced Thematic Mapper Plus data is available in georeferenced TIFF (GeoTIFF) file format.

Landsat 7 Enhanced Thematic Mapper Plus data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

Landsat 7 ETM+ data can be obtained from:

http://glcf.umd.edu/data/landsat/ [3]

http://schorsch.efi.fh-nuernberg.de/data/terrain/Landsat/EarthSat/ [4].

1.3. High Resolution Orthoimagery

Figure 1-5: High Resolution Orthoimagery – O'ahu Mosaic

USGS High Resolution Orthoimagery (HRO) is a collections of aerial photographs with resolution 1 m/pixel or finer, managed and distributed by the USGS EROS Center. Since data came from multiple vendors, resolution, area of coverage, projection, etc. varies.

High Resolution Orthoimagery digital products are distributed in georeferenced TIFF (GeoTIFF) file format.

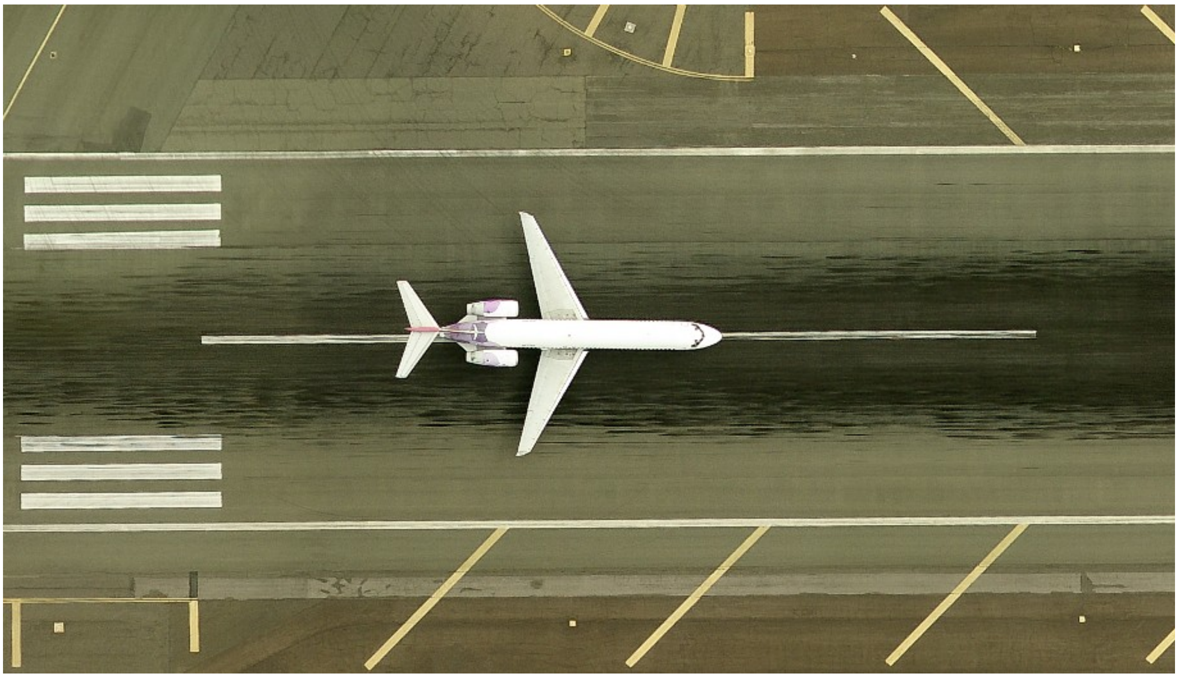

Figure 1-6: High Resolution Orthoimagery – Honolulu International Airport

High Resolution Orthoimagery data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

High Resolution Orthoimagery can be obtained from:

https://earthexplorer.usgs.gov/ [5]

1.4. Shuttle Radar Topography Mission

Shuttle Radar Topography Mission was conducted in February 2000 during STS-99 on board of the Space Shuttle Endeavour. Its purpose was to obtain high resolution digital elevation models of most of the Earth surface.

The Shuttle Radar Topography Mission data is available in two resolutions, 1 arc second resolution (approximately 30 m/pixel) and 3 arc seconds resolution (approximately 90 m/pixel).

The Shuttle Radar Topography Mission data is distributed as georeferenced TIFF (GeoTIFF) files arranged into tiles, each covering one degree of latitude and one degree of longitude, named according to their south western corners.

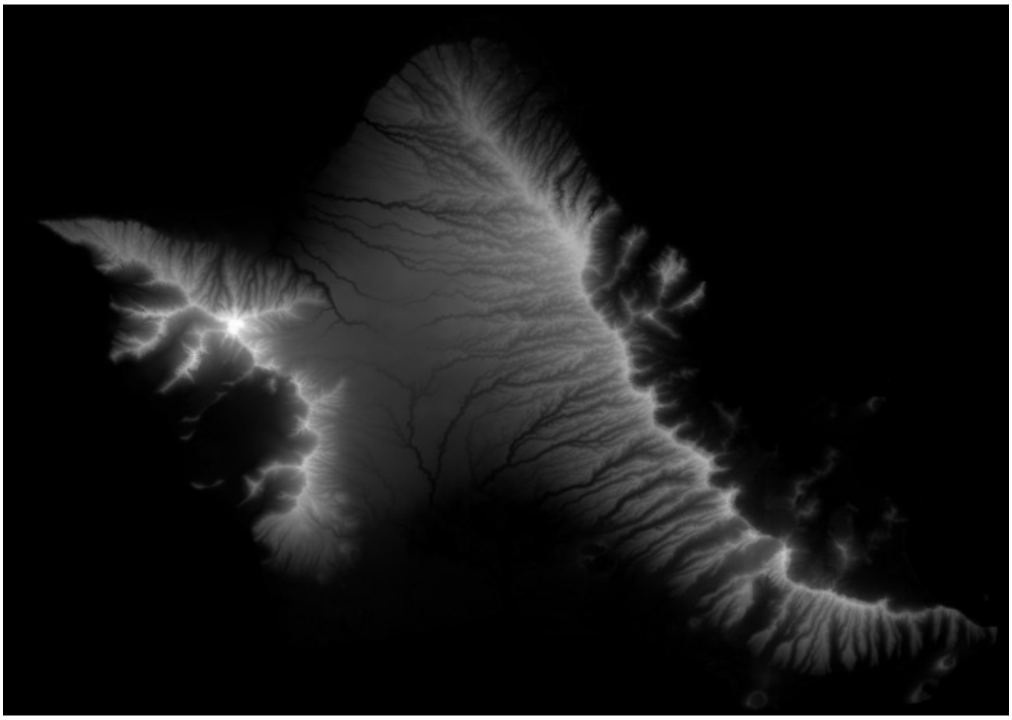

Figure 1-7: SRTM Digital Elevation Model – Greyscale – O'ahu

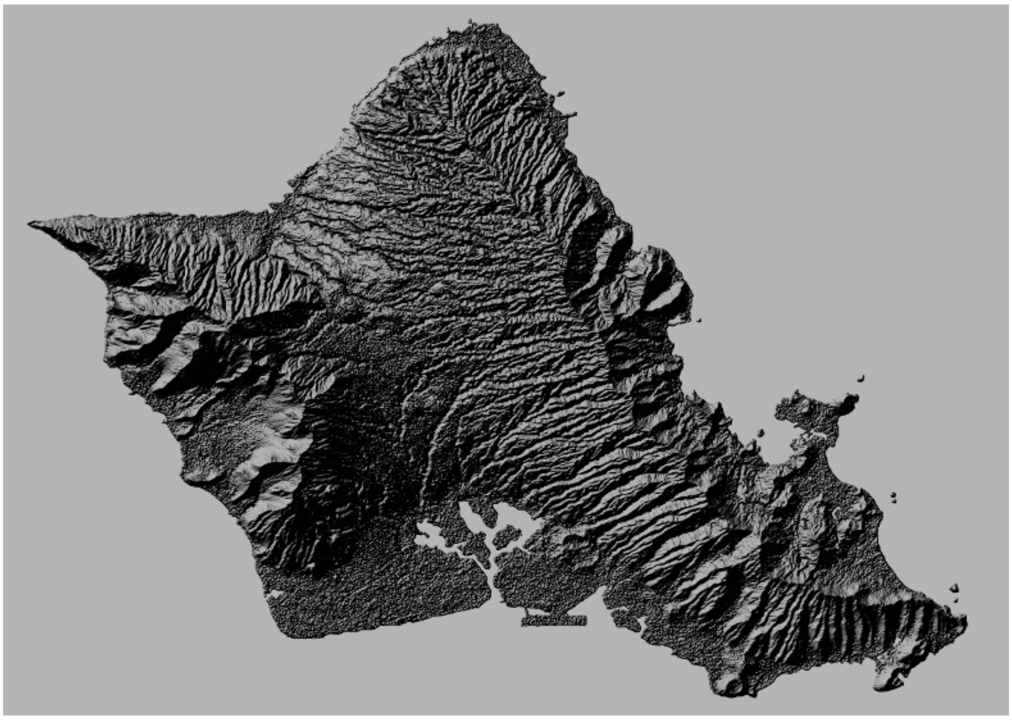

Figure 1-8: SRTM Digital Elevation Model – Hillshade – O'ahu

Shuttle Radar Topography Mission data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

Shuttle Radar Topography Mission data can be obtained from:

https://earthexplorer.usgs.gov/ [5]

1.5. MODIS MOD44W

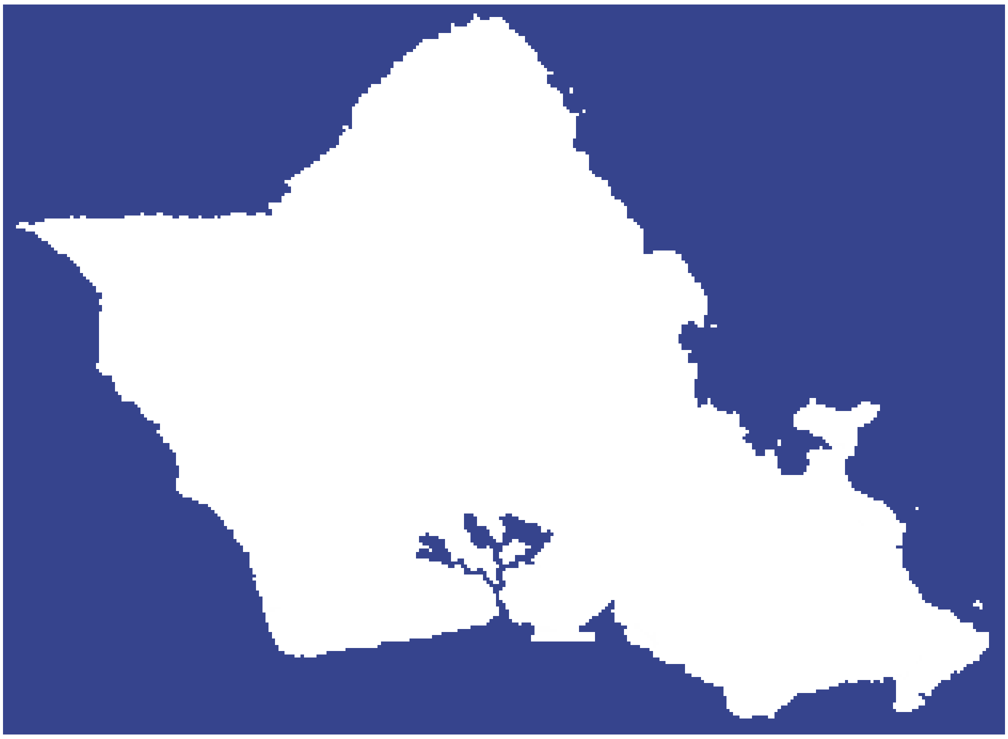

Figure 1-9: MODIS MOD44W Watermask – O'ahu

Moderate Resolution Imaging Spectroradiometer (MODIS) is an imaging sensor on board of the Terra satellite. It was launched by NASA in 1999. MODIS Land Water Mask (MOD44W) is a global raster water mask at 250 m/pixel resolution.

MODIS MOD44W data is available in georeferenced TIFF (GeoTIFF) file format.

MODIS MOD44W data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

MODIS MOD44W watermask data can be obtained from:

http://glcf.umd.edu/data/watermask/ [6]

1.6. Vector Map Level 0

Figure 1-10: Vector Map Level 0 – O'ahu

Vector Map Level 0 (VMAP0) provides worldwide coverage of vector-based geospatial data that is equivalent to the 1:1,000,000 scale. [7]

No.	Name	Coverage
1	NOAMER	North America
2	EURNASIA	Europe and North Asia
3	SOAMAFR	South America, Africa and Antarctica
4	SASAUS	South Asia and Australia

Table 1-3: Vector Map Level 0 Data Sets

Vector Map Level 0 data is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the Code of Laws of the United States of America.

NGA Vector Map Level 0 can be obtained from:

http://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/4911752 [8].

1.7. Hawaii Statewide GIS Program

Figure 1-11: Landsat True-Color Imagery Mosaic

State of Hawaii provides geospatial data of Hawaii, including watermask, land cover, satellite true color imagery, elevation data, and more.

Hawaii Statewide GIS Program data can be obtained from:

http://planning.hawaii.gov/gis/download-gis-data/ [9].

2. Tools

2.1. GDAL

GDAL (Geospatial Data Abstraction Library) is an open-source software for manipulating raster and vector geospatial data. GDAL contains command line tools for data translation and processing. [10]

2.2. LibGrid

LibGrid is an open-source software including command line tools for merging, resampling and manipulation of geospatial imagery. [11]

2.3. OpenSceneGraph

OpenSceneGraph is an open-source 3D graphics library which comes with command line tools for 3D data visualization and processing.

2.4. Virtual Planet Builder

Virtual Planet Builder is an open-source command line tool for creating terrain databases from geospatial imagery and digital elevation models. [12]

3. Workflow

3.1. Blue Marble Next Generation

3.1.1. Elevation Data

`gdal_translate` utility can be used to rescale Blue Marble Next Generation elevation data from 8-bit normalized onto real elevation value. Output files must have 16-bit color depth.

```
gdal_translate -ot UInt16 -scale 0 255 0 8848 -of Gtiff \
  gebco_08_rev_elev_A1_grey_geo.tif \
  gebco_08_rev_elev_A1_grey_geo_scaled.tif
```

3.1.2. Land Surface, Ocean Color and Sea Ice

`gdal_translate` utility can be used to create Blue Marble Next Generation Land Surface, Ocean Color and Sea Ice georeferenced TIIF (GeoTIFF) files.

```
gdal_translate -a_ullr -180.0 90.0 180.0 -90.0 -a_srs \
  "+proj=latlong +datum=WGS84" -of Gtiff \
  land_ocean_ice_8192.png land_ocean_ice_8192.tif
```

3.2. Landsat 7 ETM+

LibGrid can be used to convert Landsat 7 ETM+ separate bands to true-color image. [13]

GDAL can be used for further processing resulting images to match Virtual Planet Builder data format requirements.

3.2.1. Extracting

Following script can be used to extract Landsat data.

```
#!/bin/bash
gunzip -c ${1}_nn80.tif.gz >${1}_nn80.tif
gunzip -c ${1}_nn40.tif.gz >${1}_nn40.tif
gunzip -c ${1}_nn30.tif.gz >${1}_nn30.tif
gunzip -c ${1}_nn20.tif.gz >${1}_nn20.tif
gunzip -c ${1}_nn10.tif.gz >${1}_nn10.tif
```

3.2.2. Merging Bands

`gridcopy` tool can be used to set the no-data value to 0.

```
#!/bin/bash
/usr/local/bin/gridcopy ${1}_nn80.tif ${1}_nn80.tif 0
/usr/local/bin/gridcopy ${1}_nn40.tif ${1}_nn40.tif 0
/usr/local/bin/gridcopy ${1}_nn30.tif ${1}_nn30.tif 0
/usr/local/bin/gridcopy ${1}_nn20.tif ${1}_nn20.tif 0
/usr/local/bin/gridcopy ${1}_nn10.tif ${1}_nn10.tif 0
```

`merger` can be used to merge separate bands to true-color image.

```
#!/bin/bash
/usr/local/bin/merger ${1}_nn80.tif ${1}_nn40.tif \
  ${1}_nn30.tif ${1}_nn20.tif ${1}_nn10.tif ${1}.tif \
  --quiet -tilesize=0
```

3.2.3. Reprojection

`gdalwarp` can be used to reproject resulting true-color image to lat/long quasi-projection.

```
#!/bin/bash
gdalwarp -srcnodata 0 -dstalpha -t_srs "+proj=latlong \
  +datum=WGS84" -of GTiff ${1}.tif ${1}_latlong.tif
```

3.2.4. Merging Tiles

`gdalbuildvrt` can be used to merge resulting images.

```
gdalbuildvrt -srcnodata 0 merged.vrt *_latlong.tif
```

`gdal_translate` can be used to convert merged image to GeoTIFF.

```
gdal_translate -a_nodata 0 -of GTiff merged.vrt merged.tif
```

3.3. High Resolution Orthoimagery

3.3.1. Extracting

Following script can be used to extract data.

```
#!/bin/bash
mkdir extracted_temp
FILES=./downloaded/*
for f in $FILES
do
  filename=$(basename "$f")
  unzip -jn $f -d extracted_temp
done
mv extracted_temp/*.tif extracted/
rm -R extracted_temp/
```

3.3.2. Scaling

`gdal_translate` can be used to scale down images.

```
#!/bin/bash
FILES=./extracted/*
for f in $FILES
do
  filename=$(basename "$f")
  gdal_translate -outsize 300 300 -of Gtiff \
    extracted/$filename scaled/$filename
done
```

3.3.3. Merging Tiles

`gdalbuildvrt` can be used to merge tiles.

```
gdalbuildvrt -srcnodata 0 merged/merged.vrt scaled/*.tif
```

`gdal_translate` can be used to convert merged image to GeoTIFF.

```
gdal_translate -a_nodata 0 -of GTiff merged/merged.vrt \
  merged/merged.tif
```

3.3.4. Reprojection

`gdalwarp` can be used to reproject merged image to lat/long quasi-projection.

```
#!/bin/bash
FILES=./merged/*
for f in $FILES
do
  filename=$(basename "$f")
  gdalwarp -srcnodata 0 -dstalpha -t_srs "+proj=latlong \
    +datum=WGS84" -of GTiff merged/$filename latlong/$filename
done
```

3.4. Vector Map Level 0

3.4.1. Creating Shapefiles

Following script can be used to create shapefiles of different VMAP0 layers.

```
#!/bin/bash
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/usr/lib/ogdi

function createShapefiles()
{
  ogr2ogr -t_srs "+proj=merc +datum=WGS84" \
    ${1}_pop_builtupa.shp \
    gltp:/vrf${PWD}/${1}/vmaplv0/${2} 'builtupa@pop(*)_area'
  ogr2ogr -t_srs "+proj=merc +datum=WGS84" \
    ${1}_hydro_watrcrsl.shp \
    gltp:/vrf${PWD}/${1}/vmaplv0/${2} 'watrcrsl@hydro(*)_line'
  ogr2ogr -t_srs "+proj=merc +datum=WGS84" \
    ${1}_hydro_inwatera.shp \
    gltp:/vrf${PWD}/${1}/vmaplv0/${2} 'inwatera@hydro(*)_area'
  ogr2ogr -t_srs "+proj=merc +datum=WGS84" \
    ${1}_trans_roadl.shp \
    gltp:/vrf${PWD}/${1}/vmaplv0/${2} 'roadl@trans(*)_line'
  ogr2ogr -t_srs "+proj=merc +datum=WGS84" \
    ${1}_trans_railrdl.shp \
    gltp:/vrf${PWD}/${1}/vmaplv0/${2} 'railrdl@trans(*)_line'
}
```

```
createShapefiles v0eur_5 eurnasia
createShapefiles v0noa_5 noamer
createShapefiles v0sas_5 sasaus
createShapefiles v0soa_5 soamafr
```

3.4.2. Rasterizing

`gdal_rasterize` can be used to rasterize shapefiles.

```
gdal_rasterize -b 1 -b 2 -b 3 -burn 255 -burn 255 -burn 255 \
  v0eur_5_pop_builtupa.shp v0eur_5_pop_builtupa.tif
```

3.4.3. Converting

`osgconv` can be used to convert shapefiles to other file formats.

```
osgconv --use-world-frame -o -90-1,0,0 \
  v0eur_5_pop_builtupa.shp v0eur_5_pop_builtupa.obj
```

3.5. Building Terrain Database

Virtual Planet Builder can be used to build terrain database.

3.5.1. Generating Basic Terrain

```
vpbmaster --geocentric --TERRAIN \
  -t BMNG/land_ocean_ice_8192.tif \
  -d BMNG/gebco_08_rev_elev_21600x10800.tif \
  -o terrain/terrain.osgb
```

3.5.2. Patching Textures

```
vpbmaster --patch build_master.source -t hi_res_texture.tif
```

3.5.3. Patching Elevation

```
vpbmaster --patch build_master.source -d hi_res_elevation.tif
```

4. Terrain Database

Figure 4-1: Terrain Database

Figure 4-2: Terrain Database

Figure 4-3: Terrain Database

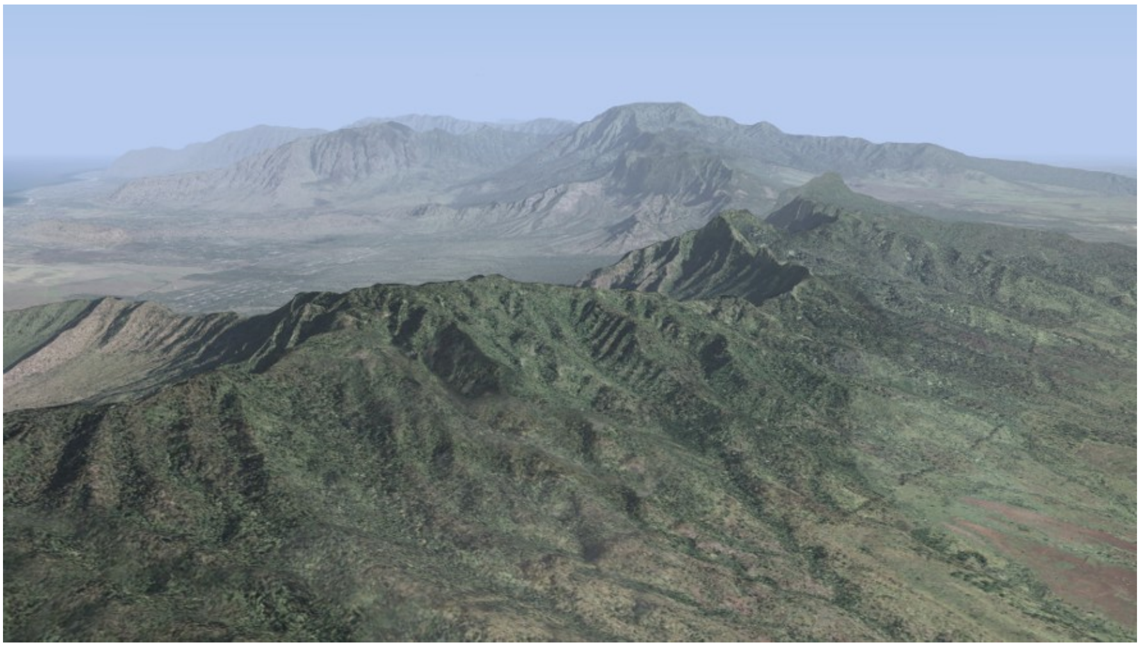

Figure 4-4: Terrain Database

Bibliography

[1] Reto Stockli: Blue Marble Next Generation. [online]. 2005 [Accessed 2018-11-11]. Available from: https://earthobservatory.nasa.gov/features/BlueMarble

[2] NASA Visible Earth. [online]. 2018 [Accessed 2018-11-11]. Available from: https://visibleearth.nasa.gov/view_cat.php?categoryID=1484

[3] GLCF: Landsat Imagery. [online]. 2018 [Accessed 2018-11-11]. Available from: http://glcf.umd.edu/data/landsat/

[4] EarthSat. [online]. 2019 [Accessed 2019-07-28]. Available from: http://schorsch.efi.fh-nuernberg.de/data/terrain/Landsat/EarthSat/

[5] EarthExplorer. [online]. 2018 [Accessed 2018-11-11]. Available from: https://earthexplorer.usgs.gov/

[6] GLCF: MODIS Water Mask. [online]. 2018 [Accessed 2018-11-11]. Available from: http://glcf.umd.edu/data/watermask/

[7] Vector Map Level 0 (VMAP0). [online]. 1998 [Accessed 2018-11-11]. Available from: https://earth-info.nga.mil/publications/vmap0.html

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[9] State of Hawaii - Office of Planning - Download GIS Data. [online]. 2019 [Accessed 2019-09-29]. Available from: http://planning.hawaii.gov/gis/download-gis-data/

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[13] OpenTerrain Projects/Open Satellite Data. [online]. 2011 [Accessed 2018-11-11]. Available from: http://www.open-terrain.org/index.php/Projects/OpenSatelliteData