High Resolution Digital Elevation Model (HRDEM)
– CanElevation Series –
Product Specifications

Edition 1.1

2017-08-17

Government of Canada
Natural Resources Canada

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RELEASES HISTORY

Date	Version	Description
2017-08-17	1.1	Addition of datasets at a 1 m resolution

ACRONYMS

ANPD	Aggregate Nominal Pulse Density
CGVD28	Canadian Geodetic Vertical Datum of 1928
CGVD2013	Canadian Geodetic Vertical Datum of 2013
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
HRDEM	High Resolution Digital Elevation Model
ISO	International Organization for Standardization
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
NAD83 (CSRS)	North American Datum of 1983 (Canadian Spatial Reference System)
NRCan	Natural Resources Canada
TIN	Triangular Irregular Network
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

TERMS AND DEFINITIONS

Aggregate Nominal Pulse Density (ANPD)

A variant of nominal pulse density that expresses the total expected or actual density of pulses occurring in a specified unit area resulting from multiple passes of the light detection and ranging (LiDAR) instrument, or a single pass of a platform with multiple LiDAR instruments, over the same target area. In all other respects, ANPD is identical to nominal pulse density (NPD). In single coverage collection, ANPD and NPD will be equal.

ArcticDEM

ArcticDEM is a National Geospatial-Intelligence Agency (NGA) and National Science Foundation (NSF) public-private initiative to automatically produce a high-resolution, high-quality digital surface model (DSM) of the Arctic using optical stereographic imagery, high-performance computing, and open source photogrammetry software. The product is a collection of time-dependent DEM strips and a seamless terrain mosaic that can be distributed without restriction. DEM(s) were created from DigitalGlobe, Inc., imagery and funded under National Science Foundation awards 1043681, 1559691, and 1542736.

Canadian Geodetic Vertical Datum of 2013 (CGVD2013)

Natural Resources Canada (NRCan) has released the Canadian Geodetic Vertical Datum of 2013 (CGVD2013), which is now the reference standard for heights across Canada. This height reference system is replacing the Canadian Geodetic Vertical Datum of 1928 (CGVD28).

CanElevation

Series of elevation products created in support of the National Elevation Strategy implemented by NRCan.

Digital Elevation Model (DEM)

A digital representation of relief composed of an array of elevation values referenced to a common vertical datum and corresponding to a regular grid of points on the earth's surface. These elevations can be either ground or reflective surface elevations.

Digital Surface Model (DSM)

A representation of the earth’s surface including vegetation and man-made structures.

The Digital Surface Model (DSM) provides the height of the vegetation, canopies and structures above the vertical datum.

Digital Terrain Model (DTM)

A representation of the bare ground surface without any objects such as vegetation and buildings.

LiDAR

Stands for Light Detection and Ranging. It is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.

Metadata

Metadata summarizes basic information about data, which can make finding and working with particular instances of data easier.

North American Datum 1983 (NAD83)

The horizontal control datum for the U.S., Canada, Mexico and Central America, based on the Geodetic Reference System 1980 (GRS80) geocentric reference ellipsoid. The Canadian Spatial Reference System (CSRS) reflects the integration of the Canadian geodetic network to the NAD83.

Orthometric height (elevation)

It is the elevation of a point above the geoid. It is measured along the plumb line, which is perpendicular to the equipotential surfaces.

Point Cloud

A point cloud is a set of data points in some coordinate system. In a three-dimensional coordinate system, these points are usually defined by *X*, *Y*, and *Z* coordinates, and often are intended to represent the external surface of an object. In geographic information systems, point clouds are one of the sources used to make digital elevation model of the terrain.

World Geodetic System 1984 (WGS84)

WGS84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields.

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1. Overview

Elevation data is a core theme that has been provided by Natural Resources Canada (NRCan) to Canadians as essential geographic information. New technologies, including LiDAR data, provide opportunities for enhancing elevation information, products and services. In fact, the needs for elevation data continue to grow and become more specialized, and the acquisition technologies for this type of data are not only increasing, but are also becoming more accessible and better functioning.

These product specifications apply to the High Resolution Digital Elevation Model (HRDEM) which includes Digital Terrain Model (DTM), Digital Surface Model (DSM) and other derived data. It is part of the CanElevation Series created in support to the National Elevation Strategy implemented by NRCan. This strategy aims to increase high-resolution elevation data coverage for Canada and improve accessibility to the products. The acquisition strategy has two main components: north, and south of the productive forest line (see Figure 1). The productive forest line is used to separate the northern and the southern parts of the country. This line is approximate and may change based on requirements.

Because of the high similarity between DSM and DTM datasets in the north, due to the low density of vegetation and infrastructure, only DSM datasets are generated north of the productive forest line. This should satisfy many needs regarding geology, climate change adaptation, geo-hazards and polar continental shelf logistics support. Most of these datasets are derived from autocorrelation of high resolution optical satellite images and other remote sensing methods such as interferometry and stereographic radargrammetry from radar satellite images. Occasionally, airborne LiDAR data may be acquired based on project planning needs. The data from the ArcticDEM project are used by NRCan to increase the coverage of high resolution elevation data in the northern part of Canada.

In the southern part of the country (south of the productive forest line), more accurate elevation data such as airborne LiDAR data is needed for forest inventory, coastal monitoring, flood plain mapping, precision agriculture, infrastructure, etc. The federal government is currently working with the provinces and territories to free-up existing airborne LiDAR data and to participate in new acquisitions. Both DSM and DTM datasets in this region are generated from airborne LiDAR data.

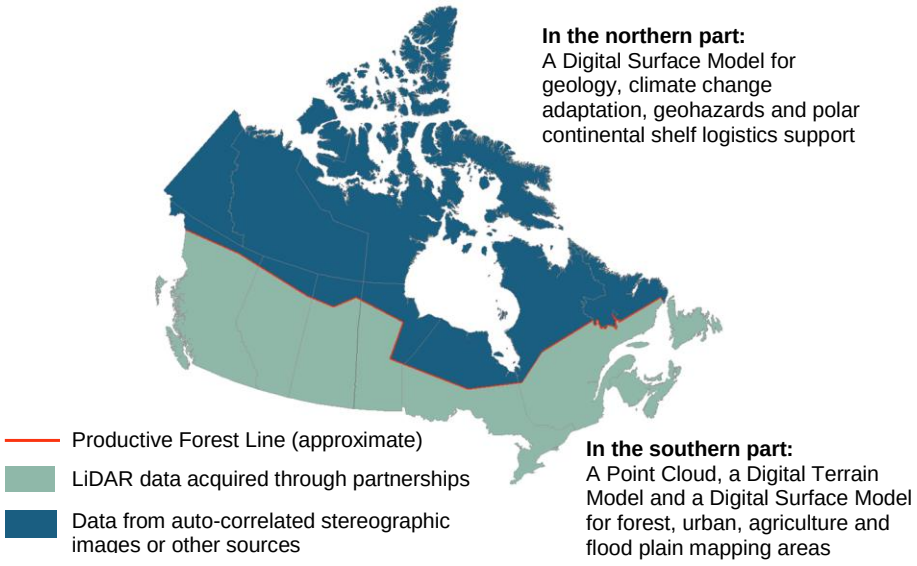

Figure 1: Elevation Strategy Acquisition Plan

HRDEM product is created to provide high accuracy data with minimum distortion, for local needs. To ensure coherence, the data is distributed according to its acquisition requirements.

DTM and DSM datasets generated from airborne LiDAR data are mostly located south of the productive forest line. They are offered at a 1 m or 2 m resolution, depending on the aggregate nominal pulse density (ANPD) of the source data, and projected to the UTM NAD83 (CSRS) coordinate system and the corresponding zones.

Most of the DSM datasets located north of the productive forest line have optical imagery as their source data. They are generated at a 5 m resolution using the Polar Stereographic North coordinate system referenced to WGS84 horizontal datum or UTM NAD83 (CSRS) coordinate system.

The HRDEM product is referenced to the Canadian Geodetic Vertical Datum of 2013 (CGVD2013), which is now the reference standard for orthometric heights across Canada.

DTM datasets, derived data (layers), such as slope, aspect, shaded relief, color relief and color shaded relief maps are available.

DSM datasets, derived data (layers), such as shaded relief, color relief and color shaded relief maps are available.

2. Data Identification

2.1 Spatial Resolution

Spatial resolution within the HRDEM product is dependent on data sources.

The datasets generated from airborne LiDAR data are offered at a 1 m or 2 m resolution depending on the density of the source data. When the ANPD of the source data is equal or greater than 2 pls/m^2, the resolution of the HRDEM products is 1 m. When the ANPD of the source data is less than 2 pls/m^2, the products are generated at a 2 m resolution.

When the source data is optical imagery, the datasets are offered at a 5 m resolution.

2.2 Language

NOT APPLICABLE

2.3 Character Set

NOT APPLICABLE

2.4 Topic Category

According to the Government of Canada Core Subject Thesaurus, the HRDEM product is classified according to the following keyword:

- Digital elevation data

Free text keywords:

- Aspect map
- Color relief
- Color shaded relief
- Digital elevation model
- Digital surface model
- Digital terrain model

- LiDAR
- Shaded relief
- Slope map

2.5 Geographic Box

The HRDEM production will occur over several years and will cover the following geographic box or minimum-bounding rectangle:

- West-bounding coordinate: 142° West (or -142°)
- East-bounding coordinate: 52° West (or -52°)
- North-bounding coordinate: 84° North (or 84°)
- South-bounding coordinate: 41° North (or 41°)

2.6 Geographic Description

The geographic area is comprised of land and water that fall within the Canadian jurisdiction. In some cases, the project coverage may extend to other jurisdictions.

2.7 Extent

The vertical domain of the dataset identifies the lowest and highest vertical extent contained within the data. The vertical extent is expressed in meters and the maximum elevation is 5,959 meters (Mount Logan) in Canada.

2.8 Supplemental Information

2.8.1 Elevation

The elevation values in the DTM datasets represent the bare ground surface without any objects such as vegetation and buildings.

The elevation values in the DSM datasets represent the surface above the vegetation (canopies) and structures.

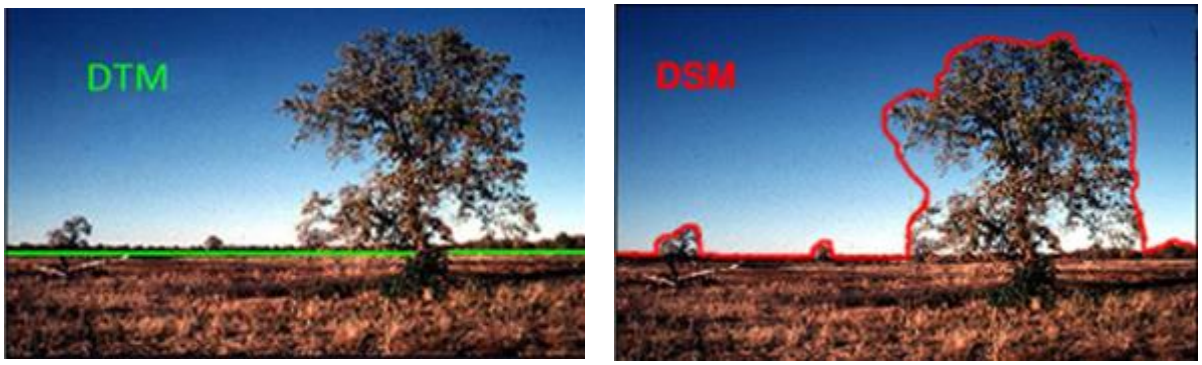

Figure 2: DTM and DSM representations (source: Wikipedia)

2.8.2 Waterbodies

Airborne LiDAR source data:

Due to the properties of the LiDAR used, the pulses are absorbed by water, reducing the point densities in water areas. The DEMs derived from LiDAR points, generated without breaklines, depict water surfaces with artifacts and void data resulting from the interpolation and void filling processing affecting accuracy.

Optical imagery source data:

Due to the seasonal variation in optical imagery acquisition time, some waterbodies can be frozen while others remain open. Considering that stereographic autocorrelation becomes problematic over open water due to the changing surface conditions, void data in areas of open water can be expected. The process can then generate incorrect elevation values in waterbodies. Frozen waterbodies appear in the DEMs as relatively flat surfaces with varying degrees of texture.

The data was collected at different times of the year; therefore frozen and unfrozen waterbodies may not be represented.

2.8.3 Void Areas

Void areas (areas where there is no data) are represented by elevation values of -32,767.

For products generated from airborne LiDAR data, data may contain void pixels where there is a lack of LiDAR points. The lack of points in the point cloud is caused by surface absorbance of the LiDAR pulse, an obstruction of the LiDAR pulse, an instrument failure, or a flight planning issue.

Where the source data is optical imagery, atmospheric obstructions and environmental conditions such as clouds, fog, shadows, and dust can prevent high quality elevation data from being obtained. Open water, swaying trees, and homogeneous terrain can also cause voids or artifact.

2.8.4 Quality Control

The quality control for the source data is to be conducted by the partner responsible for its acquisition. And for this reason, renders non-homogeneous data among the projects.

3. Geospatial Characteristics

3.1 Spatial Representation Type

A grid format is used to represent the elevation data.

3.2 Spatial Representation

The HRDEM datasets are composed of tiles of 100 000 000 pixels.

The datasets, generated from airborne LiDAR data, at a 1 m resolution cover an area of 10 km X 10 km while datasets at a 2 m resolution cover an area of 20 km X 20 km.

Where the source data is optical imagery, the datasets cover an area of 50 km by 50 km at a 5 m resolution.

3.3 Coverage and Continuity

Complete coverage of the Canadian landmass is gradually implemented. HRDEM datasets are processed and made available as the data is acquired.

Source data for HRDEM datasets is acquired through multiple projects with different partners. Since data is being acquired by project, there is no integration or edgematching done between projects. However, there is an alignment of the tiles between them.

3.4 Resolution

Products generated from airborne LiDAR data adhere to a 1 m or 2 m resolution, depending on the ANPD of the source data. Where the source data is optical imagery, the HRDEM product adheres to a 5 m resolution.

3.5 Data Segmentation

NOT APPLICABLE

4. Data Model

NOT APPLICABLE

5. Data Dictionary/Feature Catalogue

The HRDEM Metadata Model provides information about the metadata polygon attributes describing the resource.

6. Reference System

6.1 Horizontal Reference System

Canadian Spatial Reference System (NAD83 (CSRS)) (EPSG:6140) or WGS84 (EPSG:6326) in the Arctic.

6.1.1 Horizontal Coordinate System

The HRDEM datasets are generated under a metric reference system of origin. The Polar Stereographic North (EPSG:3413) projection is used for the datasets located in the Arctic. Elsewhere in the country, the UTM projection is used. In the cases where a product straddles 2 UTM zones, it is distributed in both UTM zones which sides are extended 1 degree in order to cover as much territory as possible and minimize distortion within the same zone.

6.1.2 Horizontal Unit of Measure (coordinate system axis units)

Metric is used and represented in meters.

6.2 Vertical Reference System

Elevations are orthometric and expressed in reference to the Canadian Geodetic Vertical Datum of 2013 (CGVD2013) (EPSG:6647).

Source: https://www.NRCan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/9054.

6.2.1 Vertical Unit of Measure (coordinate system axis units)

The unit of measure for storing vertical data is meters. Elevations are expressed as floating points.

7. Data Quality

7.1 Scope

NOT APPLICABLE

7.2 Lineage

Airborne LiDAR source data:

The DTM datasets are generated from the LiDAR data using only the classified points Ground and Water. The used algorithm triangulates the LiDAR point cloud in a temporary TIN, then rasterizes the TIN to create a DEM. The small areas without data (usually no data areas) are filled by interpolating pixels from valid pixels around the edges of the areas.

The DSM datasets are generated from the LiDAR data with only the highest points. The algorithm used triangulates the LiDAR point cloud in a temporary TIN, then converts the TIN to create a DEM. The small areas without data (usually no data areas) are filled by the pixel values of the DTM.

Optical imagery source data:

The DSM datasets are created from the best quality strip DSM files which have been co-registered and blended to reduce void areas and edge-matching artifacts. Filtered ICESAT altimetry data has been applied to the raster files to improve absolute accuracy. Strip DSM files are generated by applying stereographic auto-correlation techniques to overlapping pairs of high-resolution optical satellite images.

7.3 Completeness

NOT APPLICABLE

7.4 Logical Consistency

NOT APPLICABLE

7.5 Positional Accuracy

Generally HRDEM products generated from airborne LiDAR data have an accuracy better than 1 m, while products where the source data is optical imagery have an accuracy of 4 m or better according to the three axes (x, y, z).

7.6 Temporal Accuracy

NOT APPLICABLE

7.7 Thematic (attributes) Accuracy

NOT APPLICABLE

8. Metadata

The HRDEM product has a metadata record that complies with the *North American Profile of ISO 19115:2003 – Geographic information – Metadata*.

Metadata for HRDEM product consist of polygons and attributes. It is distributed in ESRI File Geodatabase format (.gdb). The attributes provided with the polygon are divided in three categories. Among others, each category covers:

- Metadata
  - Temporal extent
  - Description
  - Abstract
  - Title
  - Planimetric and altimetric accuracy
- Legal Constraints
  - Use limitation
  - Legal constraints type
  - Restriction type
- Source
  - Description
  - Title
  - Series
  - Organisation name

9. DATA Portrayal/Data Transfer Format/Physical Model

NOT APPLICABLE

10. Data Capture and Maintenance

NOT APPLICABLE

11. HRDEM Product Data Delivery

11.1 Format Information

The digital data exchange format for the datasets is GeoTIFF. The GeoTIFF format specification can be obtained from: http://www.pubdoc.org/fileformat/rasterimage/tiff/geotiff.pdf.

11.2 Medium Information

NOT APPLICABLE

11.3 Data Use and Restrictions

Information regarding the use of the data is defined in the Open Government Licence - Canada (http://open.canada.ca/en/open-government-licence-canada).

11.4 Data Extraction

HRDEM product data can be extracted in the form of tiles which are available on the Open Maps ftp site.

In order to ensure that the products are the same size and orientation, the tiles are aligned with each other.

11.4.1 Directory tree

All available products can be found on the Open Maps ftp site and the directory tree follows the pattern: http://ftp.maps.canada.ca/pub/elevation/dem_mne/highresolution_hauteresolution/<*ProductType_TypeProduit*>/<*Resolution*>/<*Provider*>/<*Project*>/<*CoordinateSystem*>/<*FileName*>*.tif.*

- *ProductType_TypeProduit:* Either dsm_mns (Digital SurfaceModel) or dtm_mnt (Digital Terrain Model).
- *Resolution:* Either 1m, 2m or 5m.
- *Provider:* The organization which produced the source data.
- *Project:* Name of the acquisition project.
- *CoordinateSystem:* Either UTM and zone number or polarstereo.
- *FileName:* Name of the tile. Refer to the next section for tile naming.

Examples:
http://ftp.maps.canada.ca/pub/elevation/dem_mne/highresolution_hauteresolution/dtm_mnt/2m/QC/2011_PLAISANCE-PAPINEAU_MTM09/utm18/dtm_2m_utm18_e_0_52.tif

http://ftp.maps.canada.ca/pub/elevation/dem_mne/highresolution_hauteresolution/dsm_mns/5m/arcticdem/31_23/polarstereo/dsm_5m_polarstereo _31_23_1_1.tif

11.4.2 Tile identifier

Each project is tiled to manageable file sizes. Tile identifiers are based on the following pattern: <*Product*>_<*Resolution*>_<*CoordinateSystem*>_<*Location*>.tif.

- *Product:* Either product type (DSM or DTM) or *DerivedData_ProductType* where derived data is aspect, slope, hillshade, colorhillshade or color.
- *Resolution:* Either 1m, 2m or 5m.
- *CoordinateSystem:* Either UTM and zone number or polarstereo.
- *Location:* The location of the tile is expressed differently whether the coordinate system is UTM or Polar Stereographic North.

Tile location when the coordinate system is UTM:

Tile location is defined according to the middle of the UTM zone and the most southerly latitude in Canada, which corresponds to UTM coordinates 500 000 and 4 000 000.

The location is expressed in the following manner:

- UTM and zone number
- E or W to indicate whether the tile is located East or West of the UTM zone’s central meridian
- X - a numerical value to indicate the number of tiles from UTM zone’s central meridian
- Y - a numerical value to indicate the number of tiles from the Y origin

Example: utm19_w_0_61

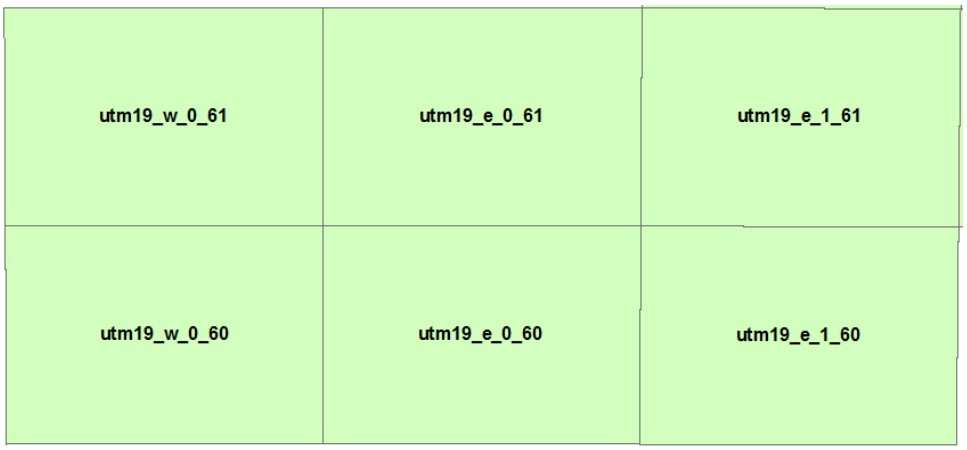

Figure 3: Cell Tiles and how they work

Tile location when the coordinate system is Polar Stereographic North:

Tile location is defined as per ArcticDEM mosaic file naming.

- Column 100 km X 100 km tile
- Line 100 km X 100 km tile
- Quadrant 50 km X 50 km sub-tile

Example: 31_23_1_1

11.5 Derived data

Besides DTMs and DSMs per se, the data is available as one of the following derived data (layer):

11.5.1 Shaded Relief (or Hillshade)

A relief representation which enhances the illumination and shadow variations, according to elevation and slope, is created by a light source located at a specified height and in a specified direction. The resulting 8-bit greyscale raster image provides realistic terrain visualization. This layer is provided for both DTM and DSM datasets.

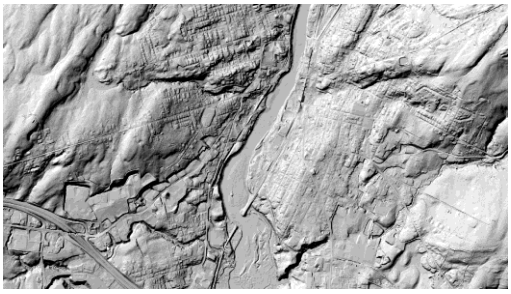

Figure 4: Relief Representation of a DTM

Figure 5: Relief Representation of a DSM

Parameters

Azimuth: Direction of light source, between 0 and 360, measured in degrees, clockwise from the north.

Default: 315.

Altitude: Vertical direction of light source, from 0 (horizon) to 90 degrees (zenith).

Default: 45.

zFactor: Vertical exaggeration factor.

Default: 5.

11.5.2 Color Relief

A relief representation in which the elevations are assigned different colours according to their value. The resulting product is a 3-band (RGB) raster image where the colours are blended gradually to depict elevations, according to a pre-defined correspondence table. This layer is provided for both DTM and DSM datasets.

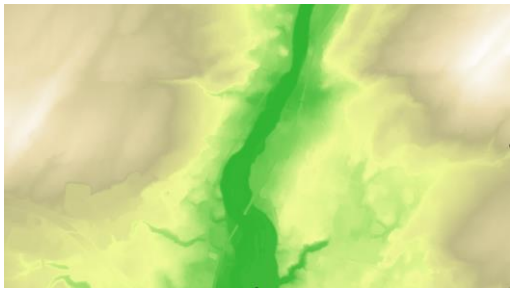

Figure 6: Color Relief Representation of a DTM

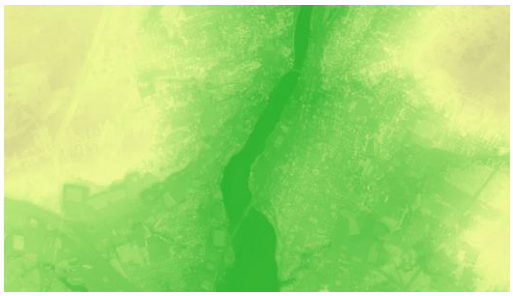

Figure 7: Color Relief Representation of a DSM

11.5.3 Color Shaded Relief (or Color Hillshade)

A relief representation combining a Color Relief image, in which the elevations are assigned different colours according to their value, and a Shaded Relief image, in which lighting enhances elevation and slope. The resulting product is a 3-band (RGB) raster image where colour intensity varies to provide realistic terrain visualization. This layer is provided for both DTM and DSM datasets.

Parameters

Azimuth: Direction of light source, between 0 and 360, measured in degrees, clockwise from the north.

Default: 315.

Altitude: Vertical direction of light source, from 0 (horizon) to 90 degrees (zenith).

Default: 45.

zFactor: Vertical exaggeration factor.

Default: 5.

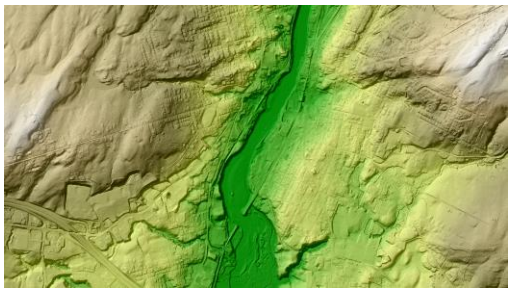

Figure 8: Color Shaded Relief Representation of a DTM

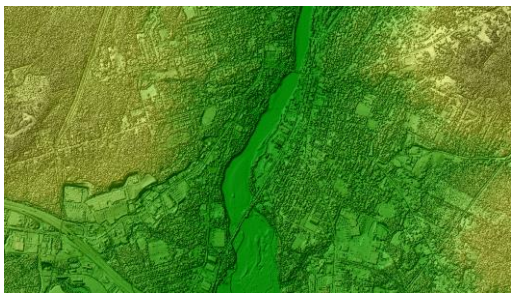

Figure 9: Color Shaded Relief Representation of a DSM

11.5.4 Slope Map

A relief-derived representation in which every pixel is attributed the value of the greatest slope (the measure of change in elevation over distance, in degrees from the horizontal or as a percentage) at the corresponding point of the represented surface. The resulting product is a 32-bit raster image of slope values. This layer is provided for the DTM dataset.

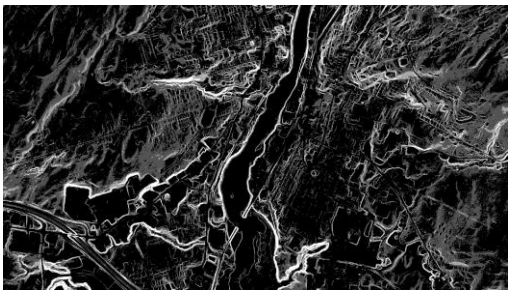

Figure 10: Slope Map Representation

Parameter

Slope type: Choice of degrees or percent slope.

Default: degrees.

11.5.5 Aspect Map

A relief-derived representation in which every pixel is attributed the value of the azimuth which the slope is facing. Such azimuth value is comprised between 0 and 360, measured in degrees, clockwise, from the north. The value -9999 can also be used in flat areas where the slope value is zero. The resulting product is a 32-bit raster image of azimuth values. This layer is provided for the DTM dataset.

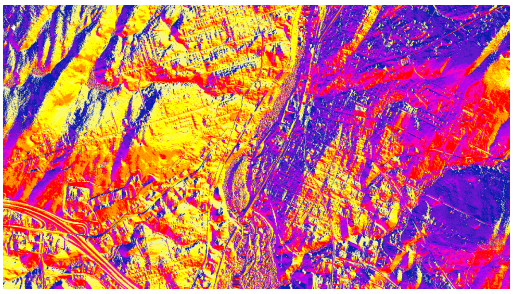

Figure 11: Aspect map Representation