High Resolution Digital Elevation Model (HRDEM)

– CanElevation Series –
Product Specifications

Edition 1.5

2023-10-13

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
2018-04-10	1.2	Addition of information for the HRDEM product in the North.
2019-08-29	1.3	Modification of the resolution from 5 m to 2 m for the product in the North part.
2022-11-15	1.4	Standardization of various sections with the other specifications from the CanElevation Series.
2023-10-13	1.5	Addition of a section on the mosaics by project in Cloud Optimized GeoTIFF (COG) format.

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 and National Science Foundation public-private initiative to automatically produce a high-resolution, high-quality 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)

The Canadian Geodetic Vertical Datum of 2013 (CGVD2013) is the reference standard for heights across Canada. This system has replaced the Canadian Geodetic Vertical Datum of 1928 (CGVD28). For more information on CGVD2013, visit the following resource: https://www.nrcan.gc.ca/maps-tools-and-publications/tools/geodetic-reference-systems/canadian-spatial-reference-system-csrs/9052

CanElevation

Series of elevation products created in support of the National Elevation Data 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 relative to the vertical datum.

Digital Terrain Model (DTM)

A representation of the bare ground surface without any objects such as vegetation and man-made structures. The Digital Terrain Model (DTM) provides the height of the ground relative to the vertical datum.

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.

National Hydro Network

The National Hydro Network (NHN) focuses on providing a quality geometric description and a set of basic attributes describing Canada's inland surface waters. It provides geospatial digital data compliant with the NHN Standard such as lakes, reservoirs, watercourses (rivers and streams), canals, islands, drainage linear network, toponyms or geographical names, constructions and obstacles related to surface waters, etc. The best available federal and provincial data are used for its production, which is done jointly by the federal and interested provincial and territorial partners. The NHN is created from existing data at the 1:50 000 scale or better.

North American Datum 1983 CSRS (NAD83(CSRS))

The North American Datum of 1983 CSRS (NAD83(CSRS)) is the official geometric reference system in Canada. NAD83(CSRS) is a dynamic 3D representation of NAD83(Original) adapted for Canada. NRCan maintains NAD83(CSRS) aligned to the North American plate using plate motion estimation. For more information on NAD83(CSRS), visit the following resource: https://www.nrcan.gc.ca/maps-tools-and-publications/tools/geodetic-reference-systems/canadian-spatial-reference-system-csrs/9052

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.

LiDAR Point Cloud

This is the primary data product of a LiDAR instrument. In its crudest form, a LiDAR point cloud is a collection of range measurements and sensor orientation parameters. After initial processing, the range and orientation associated with each laser pulse is converted to a position in a three-dimensional frame of reference. In its final form, the points in the LiDAR point cloud are classified according to various classes such as ground, noise, buildings and bridge structures. This spatially coherent cloud of classified points is the base for further processing and analysis. The raw point cloud typically includes first, last, and intermediate returns for each emitted laser pulse.

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.

TABLE OF CONTENTS

1. Overview

1.1 Title

High Resolution Digital Elevation Model: Product Specifications

1.2 Reference Date

2022-11-15

1.3 Product Responsible

Natural Resources Canada
Strategic Policy and Innovation Sector
Canada Centre for Mapping and Earth Observation

Customer Service:

Telephone: +01-819-564-4857 / charge free: 1-800-661-2638 (Canada and United-States)
Fax: +01-819-564-5698
Email: geoinfo@nrcan-rncan.gc.ca
URL: https://open.canada.ca/en/open-maps

1.4 Language

Languages in which the product specifications are available according to the ISO 639-2 standard:
fra – French
eng – English

1.5 Informal Description of the Product

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. The need for elevation data continues to grow and become more specialized, and the acquisition technologies for this type of data are becoming more accessible and efficient.

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 Data 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 but other remote sensing methods, such as radar interferometry, may be used to complete the coverage. Occasionally, airborne LiDAR data may be acquired in the North 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.

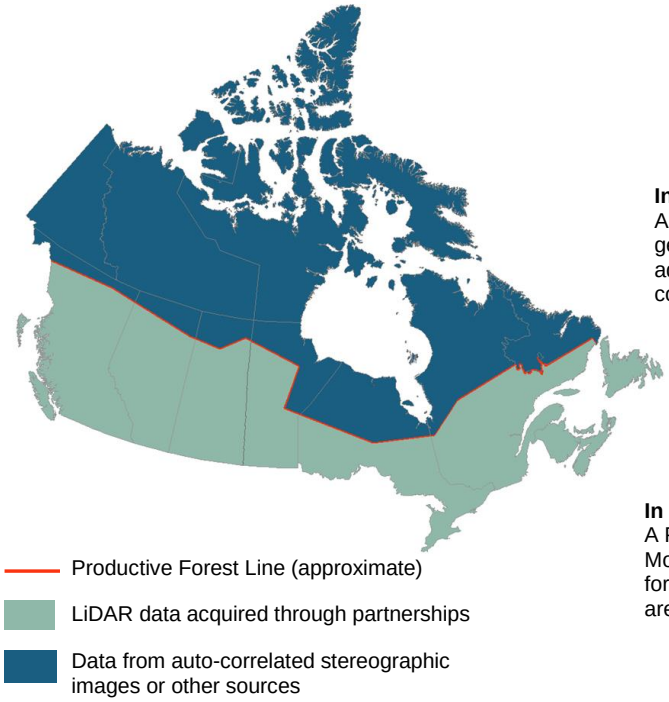

Figure 1: General acquisition plan for the elevation strategy

HRDEM product is created to provide high accuracy data with minimum distortion, for local needs. To ensure consistency, data is distributed by acquisition project.

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.

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

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

HRDEM in the south

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.

HRDEM in the north

Most of the DSM datasets located north of the productive forest line have optical imagery as their source data. They are generated at a 2 m resolution using the Polar Stereographic North coordinate system referenced to WGS84 horizontal datum.

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 2 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 map
- Color shaded relief map
- Digital elevation model
- Digital surface model
- Digital terrain model
- LiDAR
- Shaded relief map
- 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 man-made structures.

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

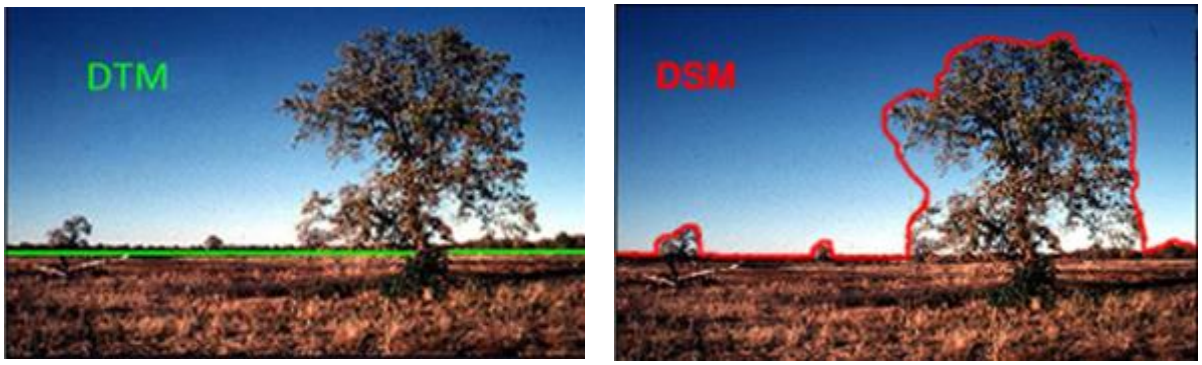

Figure 2: DTM and DSM representations (source: Wikipedia)

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 surface conditions at the acquisition time, several waterbodies contain artifacts, areas of high roughness or void areas on the raw ArcticDEM products.

When integrating these products into the HRDEM product, where possible, lake flattening was performed using vector layers from the National Hydrographic Network. To do this, the minimum elevation found at the edge of a lake was attributed to all the pixels located within the lake boundaries. The small remaining void areas along lakes were then filled by interpolating from valid pixels around these areas. For rivers, areas of high roughness identified within them have been converted to void areas.

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, strong reliefs and dust can prevent high quality elevation data from being obtained. Open water, vegetation, and homogeneous terrain can also cause voids or artifacts.

2.8.4 Quality Control

Quality control of the source data is to be conducted by the partner responsible for its acquisition which can render non-homogeneous data among the projects.

Quality control of the HRDEM datasets is visually performed by NRCan.

2.8.5 Vector layer showing potential artifacts areas

Due to surface conditions during image acquisition and ArcticDEM processing methods, HRDEM datasets for the north may contain uncorrected artifacts over land and ocean. These artifacts are particularly present along void areas.

For each of the HRDEM datasets in the north on which artifacts are still present, a shapefile containing polygons encompassing areas of strong artifact potential is provided. This vector layer is created manually during visual inspection and is intended to guide users to avoid misinterpretation of the data. Note that some artifacts that were difficult to distinguish may not be represented in this vector layer. Each shapefile is zipped in the same directory as the products and according to the following nomenclature: <*Location*>*_Potential_Artifacts_Areas.zip.*

Example: 32_23_1_1_Potential_Artifacts_Areas.zip

3. Geospatial Characteristics

3.1 Spatial Representation Type

A grid format is used to represent the elevation data.

3.2 Spatial Representation

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.

When the source data is optical imagery, the datasets cover an area of 50 km X 50 km at a 2 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 edge-matching 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. When the source data is optical imagery, the HRDEM product adheres to a 2 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) in the South or WGS84 (EPSG:6326) in the North.

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 north of parallel 60. Elsewhere in the country, the UTM projection is used. In the cases where a product overlaps 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 to 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:

DSMs at a 2 m resolution were created by the Polar Geospatial Center (University of Minnesota) from the best quality strip DSMs (2 m) which have been co-registered and merged to reduce void areas and artifacts due to horizontal integration. ICESat altimetry data have been used to improve absolute accuracy of the DSMs. The strip DSMs were previously generated by using autocorrelation techniques of high-resolution optical satellite images (see the article by Noh and Howat (2017)* for more information on the algorithm). When integrating the 2 m DSMs in the HRDEM product, these underwent transformations within lakes and rivers, as explained in the section 2.8.2, and the elevations were converted to the CGVD2013 datum.

* Noh, M. J., & Howat, I. M. (2017). The Surface Extraction from TIN based Search-space Minimization (SETSM) algorithm. *ISPRS Journal of Photogrammetry and Remote Sensing*, *129*, 55-76.

7.3 Completeness

NOT APPLICABLE

7.4 Logical Consistency

NOT APPLICABLE

7.5 Positional Accuracy

For the HRDEM products derived from LiDAR, the accuracy value in the File Geodatabase of the project metadata is the accuracy from the LiDAR of this project. Generally, HRDEM products generated from airborne LiDAR data have an accuracy better than 1 m.

For the HRDEM products that comes from the ArcticDEM project, the accuracy value in the File Geodatabase of metadata is the vertical accuracy of the DSM at 90% confidence level (LE90 = Standard deviation X 1.6449), that is 1.6 m. In this formula, the standard deviation is taken from Candela et al. (ArcticDEM Validation and Accuracy Assessment, AGU meeting, December 2017) and corresponds to the standard deviation of the difference between some ArcticDEM DSMs and LiDAR data (ICESat satellite and NASA G-LiHT LiDAR data). The accuracy is inferior along waterbodies given the flattening performed using the National Hydro Network.

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 consists 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

See section 5 for the HRDEM metadata model.

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.

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 Surface Model) or dtm_mnt (Digital Terrain Model).
- *Resolution:* Either 1m or 2m.
- *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/2m/arcticdem/31_23/polarstereo/dsm_2m_polarstereo_32_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*>_<*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 or 2m.
- *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:

<*Location*> = CoordinateSystem_E/W_X_Y

- The *utm* value and the zone number are inserted for the coordinate system.
- 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

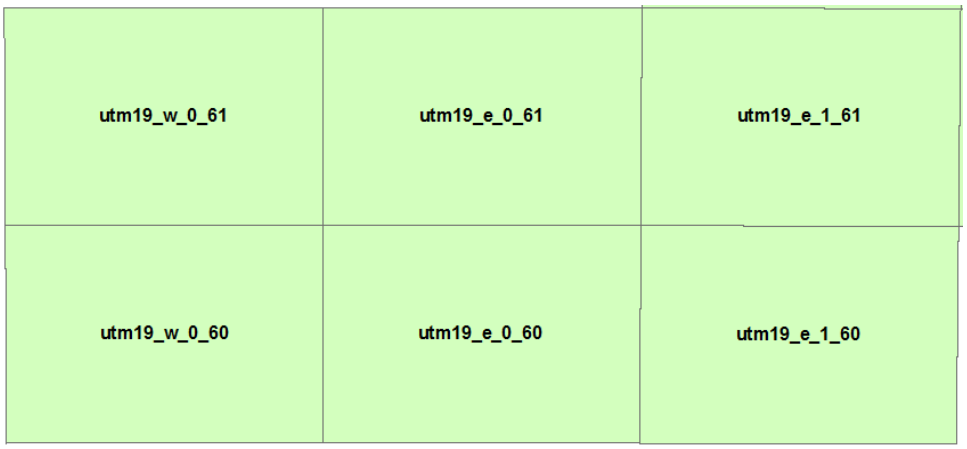

Figure 3: Cell Tiles and how they work when the coordinate system is UTM

Tile location when the coordinate system is Polar Stereographic North:

Tile location (50 km X 50 km) is defined as per ArcticDEM mosaic file naming and is expressed in the following manner:

<*Location*> = CoordinateSystem_Column_Row_Subtile

- The *polarstereo* value is inserted for the coordinate system.
- The Column_Row combination (ex: 32_23) represents an area of 100 km X 100 km. For the Canadian Territory, the tiles are located within columns 10 (east limit) to 43 (west limit), and rows 08 (south limit) to 38 (north limit), inclusively.
- A Row_Column combination is divided into four 50 km x 50 km sub tiles, which are 1_1, 1_2, 2_1, and 2_2 (see Figure 4).

Example: polarstereo_32_23_1_1

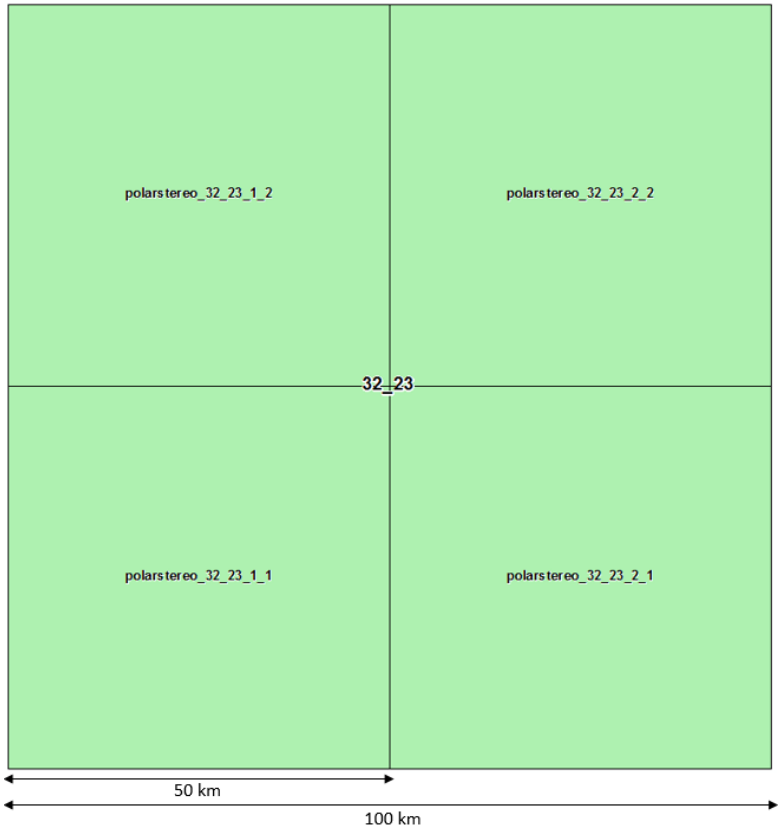

Figure 4: Cell Tiles and how they work when the coordinate system is Polar Stereographic North

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 Map (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.

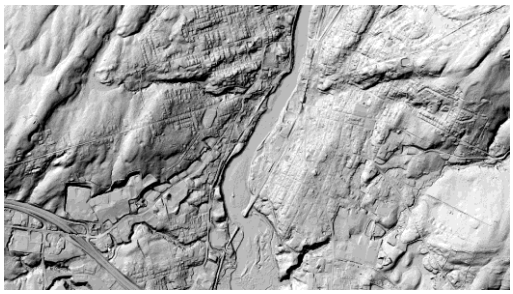
Figure 5: Relief Representation of a DTM


Figure 6: 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.

11.5.1 Color Relief Map

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.

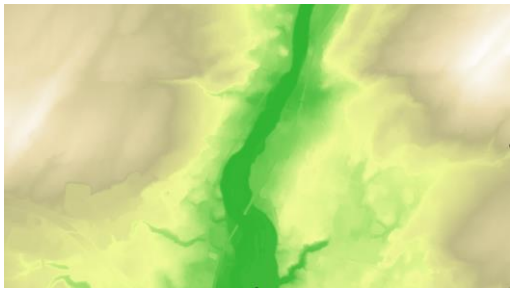

Figure 7: Color Relief Map representation of a DTM

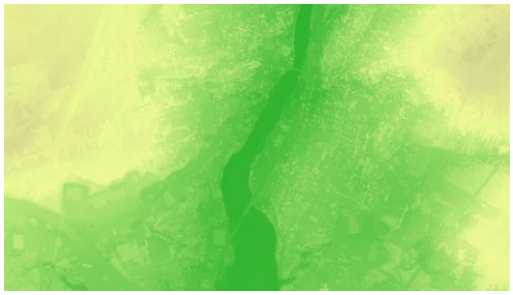

Figure 8: Color Relief Map representation of a DSM

11.5.2 Color Shaded Relief Map (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.

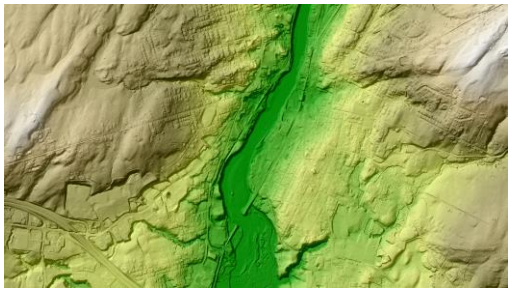

Figure 9: Color Shaded Relief Map representation of a DTM

Figure 10: Color Shaded Relief Map representation of a DSM

11.5.3 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.

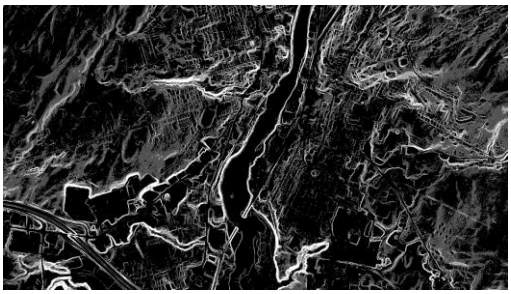

Figure 11: Slope Map Representation

Parameter

Slope type: Choice of degrees or percent slope.

Default: degrees.

11.5.4 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.

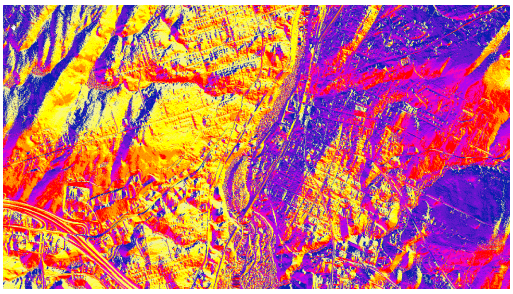

Figure 12: Aspect map Representation

11.6 Mosaic by project in Cloud Optimized GeoTIFF (COG) format

MNEHR data is also available as a Cloud Optimized GeoTIFF (COG) project mosaic. The COG format enables efficient data distribution, as compatible tools and software can now remotely access only the portions of the data they need, simplifying data management and improving access times. As the COG format is directly based on the GeoTIFF format, it enables all types of existing software to read these files without any further modification.

To efficiently use this data and to facilitate its integration with other national datasets, the Lambert conformal conic projection (EPSG:3979) is the reference system used for these files.

11.6.1 Data discovery

Mosaics can be discovered and consulted using a catalog service compatible with the SpatioTemporal Asset Catalog (STAC) specification. This type of catalog allows geospatial information to be described in a common language, and spatiotemporal searches to be carried out using a standardized application programming interface (API).

Two collections are currently available:

- hrdem-lidar

  Link to STAC collection: https://datacube.services.geo.ca/api/collections/hrdem-lidar

  Contains one item per HRDEM project derived from airborne LiDAR data. Each item contains links to access the data files.

- hrdem-arcticdem

  Link to STAC collection: https://datacube.services.geo.ca/api/collections/hrdem-arcticdem

  Contains HRDEM data derived from the ArcticDEM project. The files have been grouped into large 500km by 500km tiles. Each item contains links to access the data files.

11.6.2 Available resources

The items in the STAC collections provide resources for accessing the data. The main resources are links to the COG files and to Virtual Raster Layer (VRT) files. The latter format is offered to enable COG to be used on platforms that do not directly support the COG format. Here are resources details by collection.

11.6.2.1 hrdem-lidar collection

Name	Title	Description
dsm	Digital Surface Model (COG)	Digital Surface Model derived from Airborne LiDAR acquisition
dtm	Digital Terrain Model (COG)	Digital Terrain Model derived from Airborne LiDAR acquisition
dsm-vrt	Digital Surface Model (VRT)	Digital Surface Model derived from Airborne LiDAR acquisition
dtm_vrt	Digital Terrain Model (VRT)	Digital Terrain Model derived from Airborne LiDAR acquisition
thumbnail	Thumbnail	Thumbnail of the DEM
coverage	Data Coverage	Detailed vector extent of the DEM coverage
extent	Boundary of the LiDAR project extent	Boundary of the available data

11.6.2.2 hrdem-arcticdem collection

Name	Title	Description
dsm	Digital Surface Model (COG)	Digital Surface Model derived from optical imagery
dsm-vrt	Digital Surface Model (VRT)	Digital Surface Model derived from optical imagery
thumbnail	Thumbnail	Thumbnail of the DEM coverage
coverage	Data Coverage	Detailed vector extent of the DEM coverage
extent	Boundary of the available data	Boundary of the available data