LiDAR Point Clouds

– CanElevation Series –
Product Specifications

Edition 1.0

2023-01-19

Government of Canada
Natural Resources Canada

Telephone: +01-819-564-4857 / 1-800-661-2638 (Canada and USA)
Fax: +01-819-564-5698
E-mail: geoinfo@nrcan-rncan.gc.ca
URL: http://open.canada.ca/en/open-maps

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RELEASES HISTORY

Date	Version	Description
2023-01-19	1.0	Original version

ACRONYMS

ASPRS	American Society for Photogrammetry and Remote Sensing
ANPD	Aggregate Nominal Pulse Density
CGVD28	Canadian Geodetic Vertical Datum of 1928
CGVD2013	Canadian Geodetic Vertical Datum of 2013
COPC	Cloud Optimized Point Cloud
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
ISO	International Organization for Standardization
LAZ	Compressed LASer format
LiDAR	Light Detection and Ranging
NAD83 (CSRS)	North American Datum of 1983 (Canadian Spatial Reference System)
NRCan	Natural Resources Canada
PDAL	Point Data Abstraction Library
$RMSE_z$	Vertical Root Mean Square Error in the z direction (elevation)

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.

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.

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.

Metadata

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

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)

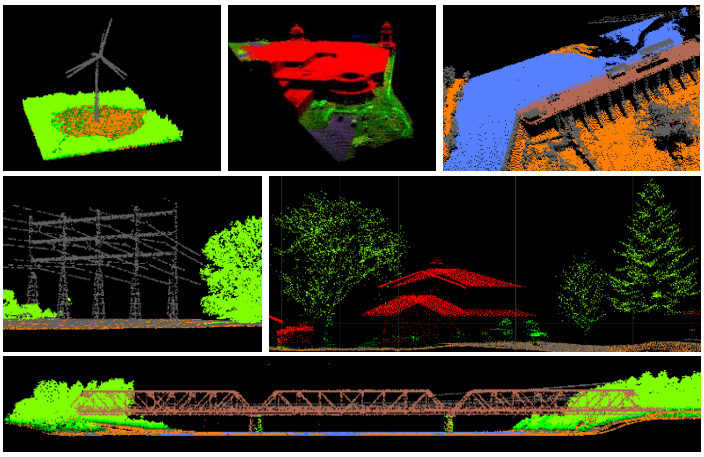
It is the elevation of a point above the geoid. It is measured along the plumb line, which is perpendicular to the equipotential surfaces.

TABLE OF CONTENTS

1. Overview

1.1 Title

LiDAR Point Clouds: Product Specifications



1.2 Reference Date

2023-01-19

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 Context

Elevation data is a core theme 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.

The National Elevation Data Strategy is led by NRCan and aims to increase the coverage of accurate, high-resolution elevation data across the country to support government priorities. Collaboration with various partners is essential to the success of the Strategy, to ensure the availability of existing data and to acquire new LiDAR data across the country. Key partners include the federal government, provincial and territorial governments, municipalities and indigenous communities.

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.

South of the productive forest line, accurate elevation data such as airborne LiDAR data are needed for flood mapping, forest inventory, coastal monitoring, precision agriculture, infrastructure, etc. The federal government is currently working in partnership with multiple partners across the country to free-up existing airborne LiDAR data and participate in new acquisitions.

North of the productive forest line, due to the low density of vegetation and infrastructure, elevation data are primarily generated from satellite image autocorrelation for most of this region. This meets the many needs for geology, climate change adaptation, geo-hazards and polar continental shelf logistics support. Occasionally, airborne LiDAR data may be acquired in the North to meet the needs of certain projects, for example in northern communities and cities.

Figure 1: General acquisition plan for the elevation strategy

1.6 Informal Description of the Product

These specifications relate to the **LiDAR Point Clouds** product. This product is part of the CanElevation Series created to support the National Elevation Data Strategy implemented by NRCan.

This product contains point clouds from various airborne LiDAR acquisition projects conducted in Canada. These airborne LiDAR acquisition projects may have been conducted by NRCan or by various federal, provincial, territorial and municipal partners.

The point clouds files are distributed using the compressed .LAZ / Cloud Optimized Point Cloud (COPC) format. The COPC open format is an octree reorganization of the data inside a .LAZ 1.4 file. It allows

efficient use and visualization rendering via HTTP calls (e.g. via the web), while offering the capabilities specific to the compressed .LAZ format which is already well established in the industry. Point cloud files are therefore both downloadable for local use and viewable via URL links from a cloud computing environment.

2. Data Identification

2.1 Spatial Resolution

The spatial resolution of point clouds is often associated with the density or spacing of laser pulses. In this specification, we use the Aggregate Nominal Pulse Density (ANPD) to describe the number of pulses measured per m² for a LiDAR point cloud. The ANPD value for each point cloud datasets varies according to the specifications of the corresponding LiDAR acquisition project and is specified by project in the metadata (see section 5).

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 LiDAR point clouds product is classified according to the following keyword:

- Digital elevation data

Free text keywords:

- LiDAR
- Point cloud

2.5 Geographic Box

The LiDAR point clouds acquisitions will occur over several years and will cover the following geographic rectangle or boundary 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

In a point cloud file, various information is contained for each point, including the X, Y, and Z elevation of the point. The elevation of a point represents the elevation at the exact point where the laser pulse reflected off a feature on the surface, before continuing on its way or returning to the LiDAR sensor on board the aircraft. Thus, the point cloud contains, among other things, points and elevation relative to the ground surface, walls and roofs of buildings and other infrastructure, branches and leaves of trees, as well as noise relative to the atmosphere.

2.8.2 Water bodies

Due to the properties of the LiDAR used, the pulses are absorbed by water, reducing the point densities in water areas. However, at nadir (below the aircraft), it is common to observe a greater density of points on water bodies due to the phenomenon of specular reflection.

The classification of points on water bodies may differ depending on the acquisition project. Generally, these points will be classified 9 (water) if the specifications of the acquisition project included water classification, or classified 2 (ground) if the specifications did not.

2.8.3 Void Areas

It is common to observe an absence of points at various locations in a point cloud. Absence of points is caused by absorption of the LiDAR signal by surfaces (e.g. roofs of buildings or water bodies) or by obstruction of the LiDAR signal (e.g. certain building facades). In rarer cases, the absence of points can be linked to an instrument failure or to a flight planning problem.

2.8.4 Classification

The LiDAR point clouds incorporated into the product are generally classified according to the classes recommended in the Federal Airborne LiDAR Data Acquisition Guideline, itself based on the ASPRS LAS 1.4 R15 specification. The classification performed on the point clouds varies according to the specifications of the corresponding LiDAR acquisition project, and the classes used are listed by project in the metadata (see section 5).

2.8.5 Other Information in Point Clouds

In addition to positioning and classification information, LiDAR point cloud files contain various other information about the points, such as sensor scan angle, GPS time, horizontal and vertical datums, intensity and number of returns. This information is available within the LiDAR point cloud files and can be accessed using specialized LiDAR point cloud software.

2.8.6 Quality Control

The majority of the point clouds included in this product have been validated by NRCan or a partner in accordance with the *Data Validation* section of the Federal Airborne LiDAR Data Acquisition Guidelines. Validations performed included data density and regularity, absolute and interswath accuracies, data gaps, classification and files structure.

Given the volume of data that represents LiDAR point clouds, some validations may have been performed on a sample basis rather than on all points and files. Thus, although NRCan or a partner has deemed these projects to be in compliance with the Federal Acquisition Guideline, anomalies may remain in the point clouds.

3. Geospatial Characteristics

3.1 Spatial Representation Type

Point cloud

3.2 Spatial Representation

The datasets in this product are represented as three-dimensional point clouds. Typically, the point cloud will contain points relative to the ground surface, walls and roofs of buildings, infrastructure, tree branches and leaves, and noise relative to the atmosphere. Because LiDAR technology is able to penetrate the canopy, a number of points will also come from the ground surface below the canopy.

Depending on the LiDAR acquisition specifications, atmospheric conditions, surface conditions (e.g. with or without leaves on the trees) and the area covered, the content and characteristics of the information contained in the point clouds may differ between projects.

3.3 Coverage and Continuity

The coverage of the Canadian territory is implemented gradually and according to the approach presented in section 1.5. The point clouds are distributed by acquisition project without integration between projects.

3.4 Resolution

See section 2.1

3.5 Data Segmentation

NOT APPLICABLE

4. Data Model

NOT APPLICABLE

5. Data Dictionary/Feature Catalogue

The Metadata Model used for the LiDAR Point Clouds product is available here. It provides information on the attributes of the metadata polygons that describe the resource.

6. Reference System

6.1 Horizontal Reference System

6.1.1 Horizontal Coordinate System

The reference system used for all point clouds in the product is NAD83(CSRS), epoch 2010. The projection used is the UTM projection with the corresponding 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

LiDAR acquisition projects are carried out by firms specialized in airborne LiDAR acquisition. These firms use an aircraft-mounted LiDAR system to acquire a very high accuracy 3D point cloud of the ground and surface features.

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.

Firms are responsible for all processing associated with the creation of the point clouds according to contract specifications. The firms are also responsible for collecting check points, independent of the point clouds, in order to calculate the accuracy of the point cloud.

NRCan or a partner is responsible for defining the acquisition area and specifications, monitoring the acquisition and performing quality control of the LiDAR point cloud data. The quality control process is summarized in Section 2.8.6 of this specification.

When integrating the LiDAR point clouds into this product, the files are converted to LAZ / COPC format using the PDAL software.

7.3 Completeness

NOT APPLICABLE

7.4 Logical Consistency

Point clouds are distributed by LiDAR acquisition project without integration between projects. Thus, various projects covering the same region may overlap.

7.5 Positional Accuracy

The vertical and horizontal (optional) positioning accuracies of the point clouds are specified by acquisition project in the metadata (see section 5). Generally, the vertical accuracy of point clouds is

between 5 and 10 cm ($RMSE_z$). More details on the required accuracies for airborne LiDAR projects in Canada are given in the Federal Airborne LiDAR Data Acquisition Guideline.

7.6 Temporal Accuracy

NOT APPLICABLE

7.7 Thematic (attributes) Accuracy

NOT APPLICABLE

8. Metadata

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

Metadata for the LiDAR Point Clouds 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
  - Vertical and horizontal (optional) accuracy
  - LiDAR acquisition specifications
- Legal Constraints
  - Use limitation
  - Legal constraints type
  - Restriction type
- Source
  - Description
  - Title
  - Series
  - Organisation name

See section 5 for the complete metadata model.

9. Data Portrayal/Data Transfer Format/Physical Model

NOT APPLICABLE

10. Data Capture and Maintenance

NOT APPLICABLE

11. LiDAR Point Clouds Product Data Delivery

11.1 Format Information

The COPC open format is an octree reorganization of the data inside a .LAZ 1.4 file. It allows efficient use and rendering of visualization via HTTP calls (e.g. via the web), while offering the capabilities specific to the compressed .LAZ format.

For more details on the COPC format, see the following resource: https://copc.io/

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

Point cloud files can be downloaded for local use using URL links provided in the product web service in WMS or ESRI Rest.

Instructions for massive download are provided here.

The URL links can also be read and used directly for visualization in software allowing the reading of COPC files (Ex: QGIS version 3.26 and more recent).

11.4.1 Directory tree

All LiDAR point cloud files (or tiles) can be discovered on the Open Maps FTP site and the directory structure follows the following pattern:

https://download-telecharger.services.geo.ca/pub/elevation/pointclouds_nuagespoints/<*Supplier*>/<*Project*>/<*FileName*>.copc.laz

- *Supplier:* Organization that produces the source data. In the case of this product, the supplier is NRCAN.
- *Project:* Name of the acquisition project
- *FileName:* Name of the point cloud file

The pointclouds_nuagespoints directory also contains the following items:

- The full vector index of LiDAR point cloud files in shapefile format: Index_LiDARtiles_tuileslidar.zip
- The full vector index of LiDAR acquisition projects in shapefile format: Index_LiDARprojects_projetslidar.zip
- The full vector index of LiDAR point cloud files in geopackage format: Index_LiDARtiles_tuileslidar.gpkg

- The full vector index of LiDAR acquisition projects in geopackage format: Index_LiDARprojects_projetslidar.gpkg
- Bilingual metadata for LiDAR acquisition projects: Metadata_PointClouds_RNCAN.gdb.zip
- Metadata model in French: NuagesPoints_Modele_Metadonnees.html
- Metadata model in English: PointClouds_Metadata_Model.html
- Product specifications in French: CanElevation-NuagesPointsLidar_specs_produit_FR.pdf
- Product specifications in English: CanElevation-LiDARPointClouds_product_specs_EN.pdf
- Product download instructions in French: CanElevation-NuagesPointsLidar_instructions_telechargement.pdf
- Product download instructions in English: CanElevation-LiDARPointClouds_download_instructions.pdf

11.4.2 Tile identifier

LiDAR point cloud files for this product generally follow the nomenclature recommended in Section 6.3 of the Federal Airborne LiDAR Data Acquisition Guideline. In a few cases, other nomenclatures are used.

11.5 Derived Data

NOT APPLICABLE