GSD Geografiska™ Sverigedata
LANTMÄTERIET

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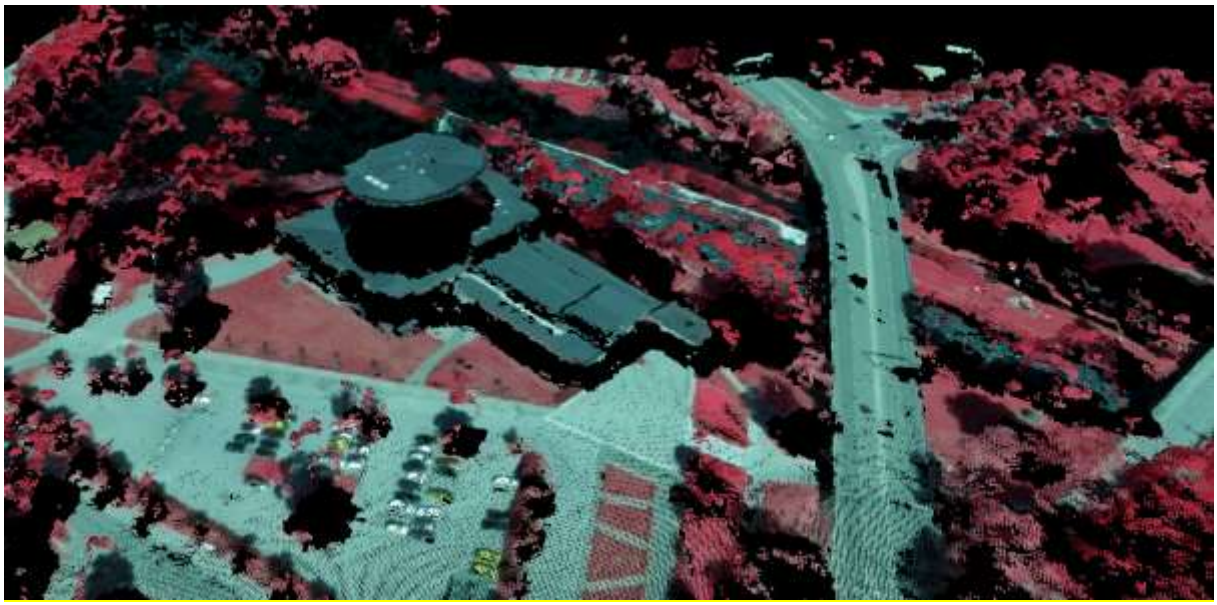
Product description:
Digital Surface Model from Aerial Photos and Digital Surface Model from Aerial Photos, CIR



List of contents

1 General description 3
1.1 Contents 3
1.2 Geographic coverage 3
1.3 Delivery tiles 3
1.4 Reference system 3
2 Quality description 4
2.1 Data collection method (version 1) 4
2.2 Currency 5
2.3 Resolution 6
2.4 Positional accuracy 6
2.4.1 Known artefacts 6
2.5 Completeness - omission 7
2.6 Metadata 9
2.7 Usability 9
3 Contents of the delivery 10
3.1 Delivery format 10
3.2 Folder structure at delivery 10
3.2.1 File names 11

1 General description

The digital surface model is a type of elevation model that describes what can be seen from the air. The top of vegetation, buildings and other artefacts above ground are included (unlike a terrain model, where these are omitted). For open spaces where there is no vegetation, buildings or other artefacts, the digital surface model shows the ground surface. The points that make up the digital surface model are not a 3D swarm of points, it is a layer of elevation-based points (2.5D model).

The digital surface model is created through aerial image matching. There will be holes in the model where matching has been unsuccessful.

The digital surface model has several applications, including calculating forest growth, establishing elevations for 3D data, finding changes or measuring how gas emissions are spread.

This document describes both products, the *Digital surface model from aerial images* and *Digital surface model from aerial images CIR*. The products are delivered as files.

1.1 Contents

The product contains elevation points from aerial image matching, which create a 2.5D digital surface model. The product is available in two forms: *Digital surface model from aerial images CIR* which is supplied with colours from IR aerial images (CIR, i.e., infrared (IR), red and green), see image on first page of document; *Digital surface model from aerial images*, supplied without colors.

Metadata is also supplied with the product.

1.2 Geographic coverage

The product's geographic coverage area will include all of Sweden. However upon its launch; it will cover a smaller area of southern Sweden. Production speed follows Lantmäteriet's image provision programme. At www.lantmateriet.se/geolex, under Höjddata\Ytmodell, you can see the current production stage.

Read more under 2.2 Currency.

1.3 Delivery tiles

The tiles are 2.5 km x 2.5 km for both the digital surface model and metadata.

1.4 Reference system

In plane: SWEREF 99 TM

In height: RH 2000

2 Quality description

In Table 1 the quality is presented using the quality parameters described in the Standard SS-EN ISO 19157:2013 Geographic information – Data quality. A more detailed description of availability and quality is included in the text.

Table 1 Data quality elements and sub-elements for the Digital surface model from aerial images.

Data quality element	Data quality sub-element	Quality achieved
Completeness	Omission	Due to the matching technology there are holes in the digital surface model.
Positional accuracy	Absolute accuracy	Average errors in the digital surface model are expected to be approx. 0.4 m and approx. 0.8 m in elevation respectively; for the two different aerial photograph resolutions, 0.24 m and 0.48 m respectively.
Currency		Production follows the Lantmäteriet image provision programme, meaning that new data will be added annually, corresponding to approximately one-third of Sweden every year.
Usability		To visualise and establish elevations in 3D.

2.1 Data collection method (version 1)

The production process includes the following key stages:

The digital surface model is created through aerial image matching. This is when overlapping aerial images are matched against each other to find mutual image points. A point cloud is calculated, with an elevation value for each point. However matching does not always find comparable image points. This means that the point cloud includes empty areas and does not provide full coverage (see Figure 2 below).

The point cloud is then thinned out and re-sampled so there is a 0.5 m distance between the points where there are aerial images with a 0.24 m resolution on the ground and 1 m where there are aerial images with a 0.48 m resolution. Re-sampling takes the median elevation of the points close to the new point. Where there are several points, only the 30 highest points are used.

The resulting LAZ file (see section 3.1 Delivery format) saves the colour values (IR, red, green) for the matching image points. The points obtain their colours from the aerial images' pixel values. The colours represent the average values from the points in the re-sampling. Should the product be ordered without IR colour (i.e., *Digital surface model from aerial images*), colour details will be removed before delivery.

Very large errors will be filtered out during the production process. Very large errors are classed as everything lower than -100 m or higher than 200 m relative to the national elevation model. Very large errors also include points that are lower than -5 m or higher than 50 m relative to the national elevation model and cover an area smaller than 28 m².

The points are not classified, i.e., they do not state what type of area they describe.

The images used in matching are from aerial photographs from Lantmäteriet's image provision programme. The type of camera used to create the aerial images will be clear in the metadata.

In Table 2 the programme software for each stage of the production process will be presented.

Table 2: Programme software in the production process (the process' version number can be found in the attribute *Prod_ver* in the metadata file).

Production method, version	Matching programme	Thinning out programme	Filtering programme	Comments
1	Sure, version 1.3	Sure, version 1.3	Developed by Lantmäteriet	Sure uses the Semi Global Matching (SGM) algorithm for the matching. For thinning out, a method based on the selection per cell with help from the percentage value is used.

To read more about image matching techniques, please see the training compendium *Geodetisk och fotogrammetrisk mätnings- och beräkningsteknik*. Follow the link (or find via the Lantmäteriet website): https://www.lantmateriet.se/globalassets/om-lantmateriet/var-samverkan-med-andra/handbok-mat--och-kartfragor/utbildning/kompendium_131028_kap13-15.pdf

2.2 Currency

The product will be created for all of Sweden. Initially, aerial images from 2016 will be used, however as these only cover parts of Sweden, aerial images from 2013-2015 will be used to cover as much area of the country as possible. Initially, the digital surface model will not offer complete coverage of Sweden, as there are areas where we do not have sufficient aerial images available to create the digital surface model.

Production of the digital surface model will follow the Lantmäteriet image provision programme and new data will be added annually, due to new aerial images becoming available, with approximately one-third of Sweden each year. In the long term, it will be possible to order digital surface models from different years for the same area.

A specification of the tiles available from each year, in addition to a rough production plan, are provided in pdf and shape files which can be obtained from Geolex, under Höjddata\Ytmodell (www.lantmateriet.se/geolex).

2.3 Resolution

The distance between the points is 0.5 m in areas where aerial photographs with a 0.24 m resolution have been used (the light green area on the map here, as well as some areas within the blue area) and 1 m where the images have a resolution of 0.48 m (the blue area).

2.4 Positional accuracy

The absolute positional accuracy is influenced by two main factors, image orientation and matching. As a rule, image orientation generates an error margin (RMSE) of approx. 1.5 pixels vertically and 1 pixel horizontally. Matching often provides a very good result, but also includes large errors, some of which remain even after filtering. This means that the points in the digital surface model can be expected to have an error of approx. 0.4 m and 0.8 m for the two different aerial image resolutions. The image orientation sometimes includes local elevation displacements, but viewed across the entire block, the given figures apply.

2.4.1 Known artefacts

Some artefacts in the digital surface model can be seen with help from images that show an elevation difference between the digital surface model and the national elevation model. Occasionally, an irregular striped pattern appears and sometimes seams are seen, “elevation jumps” between stereo models and between flight paths. The striped pattern shows a known effect that originates from image matching (SGM algorithm). The elevation jumps are a result of image orientation and underlying models and calibrations. See Figure 1.

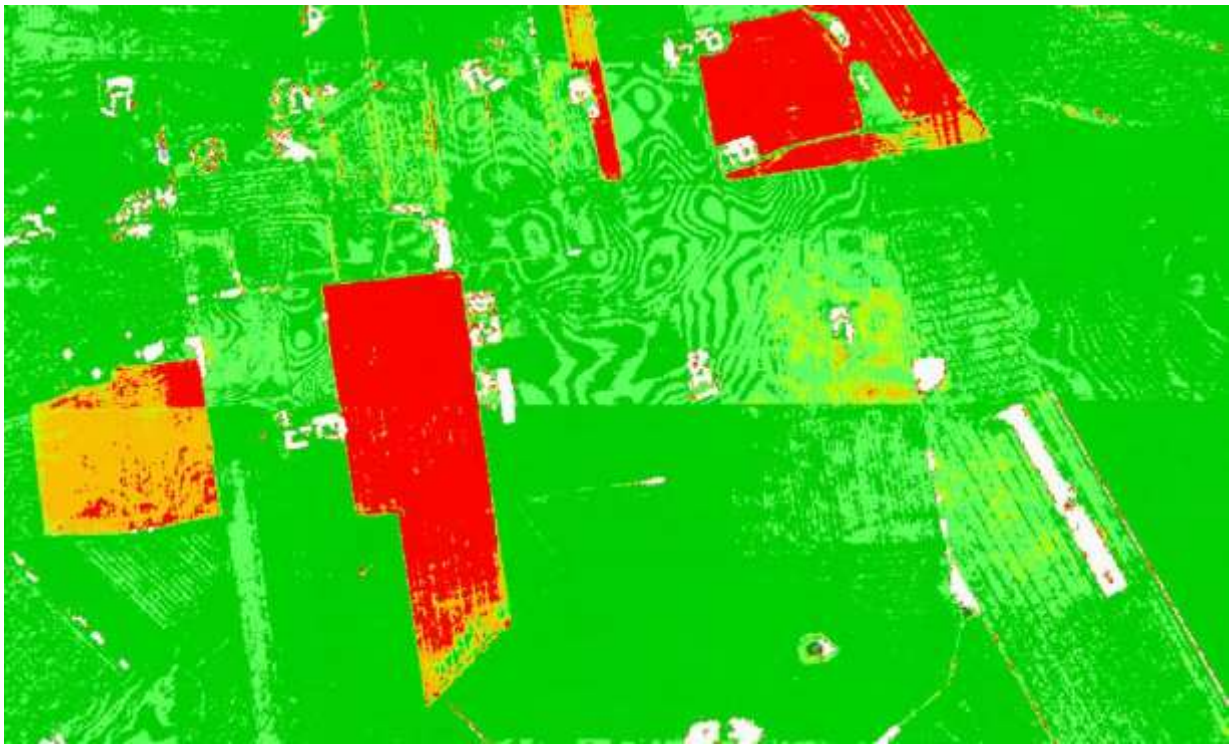


Figure 1: Artefacts present in the elevation differences between the digital surface model and national elevation model (a terrain model). Where the ground area can be seen in the image, a dark green tone is used where elevation differences are low. Increasing elevation differences are shown using the following sequence of colours: light green, orange, red and white. The seams between two stereo models can be seen from right to left in the centre of the image and the irregular striped pattern is clear in the upper section. The image also shows natural elevation differences, such as crops being grown (big red and orange fields). White areas can be forests.

2.5 Completeness – omission

The point cloud only contains points where matching has been successful. There will be holes in the digital surface model where matching has been unsuccessful. Holes in the digital surface model are the result of it not always being possible to find comparable image points in the two current aerial images. This can be found here and there in the digital surface model, see Figure 2 below.

Figure 2: There will be holes in the digital surface model where matching has been unsuccessful. The holes can be clearly seen against a white background and can also be seen in the image on the front page of this document.

Matching does not work well on low-textured surfaces (surface patterns) as it is also difficult to find comparable points. Consequently, the digital surface model may be uneven for asphalted areas, certain fields etc. The digital surface model is to be used with caution for water areas. These may be uneven or include gaps as wave movements often cause the matching results to be blurry (see Figure 3 below).

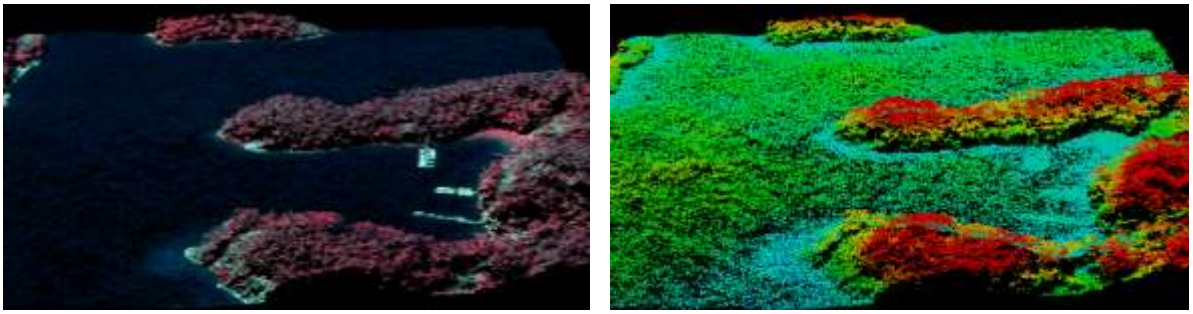


Figure 3: In the left image with IR colour, it is difficult to see that the matching has resulted in blurring over the water. It becomes clearer when the surface model is coloured based on elevation, like in the right image.

We currently have problems matching images of areas that are predominantly covered by water, e.g., certain lakes and the archipelago environment. The software initially interprets the large water-covered areas as areas where nothing can be found to match between the images. It then stops searching further. When the software ignores matching a current stereo model, it means that islands, rocky islets and irregularities within the area are not included as the entire area is left blank. Lantmäteriet is working together with the software suppliers to resolve this issue. Whilst we await this, we have nevertheless chosen to supply the areas where islands and rocky islets are missing.

Delivery of such an area comes with a GeoTiff image showing where data is missing. Shape files showing which areas are affected by this problem can be found on Geolex under Höjddata\Ytmodell (www.lantmateriet.se/geolex).

2.6 Metadata

Metadata is included as separate files with polygons for each 2.5 km tile, using the GeoJSON format.

The polygon attributes are:

Attribute	Type	Comment
Flygfotoar	string	Year of aerial image for entire block.
Upplosning_flygbild	float	Aerial image resolution in relative metres on the ground.
Block	string	Name of the block the digital surface model has been created from.
Prod_ver	integer	Version of the production process.
Ruta	string	Name of 2.5 km tile as per the index tile system, e.g., 632_47_2550.
Datum_fran	string	Earliest date of aerial image the digital surface model has been created from.
Datum_till	string	Most recent date of aerial image the digital surface model has been created from.
BildID	list (string)	List of image ID. State which images the digital surface model has been created from.
Upplosning_ytmodell	float	The digital surface model resolution in metres on the ground, where there are points.
Farg	string	Colour information for the digital surface model, state as ”CIR”* or ”Ingen_farg” (meaning “no colour”).
Bildoverlapp	integer	Image overlap within the area as a percentage.
Kameratyp	string	Type of aerial camera.

*CIR = colour infrared (IR, red and green).

2.7 Usability

The main areas of use with regard to the digital surface model are to visualise, analyse and establish elevation data in 3D. The data can be used to, for example, calculate forest growth, find changes or measure how gas emissions travel.

The digital surface model is unsuitable for visualising or analysing water.

3 Contents of the delivery

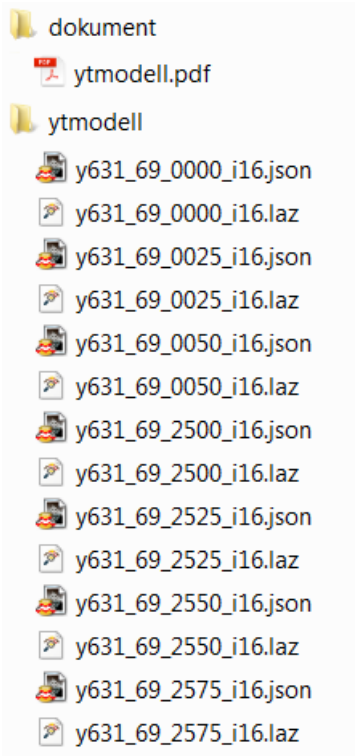
3.1 Delivery format

The product is supplied in the LAZ 1.2 file format (point data format 2), which is a compressed version of LAS. LAZ can be read directly by a range of programme software without needing to extract the file.

The GeoJSON format is used for metadata.

3.2 Folder structure at delivery

The digital surface model and metadata are supplied as shown in the image below.



When an area with production errors is supplied (read more in section 2.5 Completeness - omission), an additional file will be issued containing a GeoTIFF image showing where data is missing, marked with cerise and yellow stripes.

The *Digital surface model from aerial images CIR* product is supplied with IR colour, whereas the *Digital surface model from aerial images* is delivered without colour information. In the latter removes the point attributes of color_red (uses IR), color_green (uses red) and color_blue (uses green), and the polygon attribute ”Färg” is set to ”Ingen_färg”.

The value for the attribute classification is always set to 0 (Created, never classified).

3.2.1 File names

- **Digital surface model**

  The files are named using an initial letter from the product name. This is followed by a tile number using the index system for 2.5 km tiles. For files using IR colours, the letter “i” is used, followed finally by the year the aerial image was produced. Example file name: y632_47_2550_i16.laz.

- **Metadata**

  The files are named in the same way as the digital surface model, but use the file extension “.json”.