ICESat-2 Calibration/Validation LVIS L1B Georeferenced Imagery, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Blair, B. J., M. Hofton, N. T. Kurtz, and J. P. Harbeck. 2023. *ICESat-2 Calibration/Validation LVIS L1B Georeferenced Imagery, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/K1EYYP0SL2PF. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IS2OLVIS1BCV

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Parameters

Georeferenced imagery from the NASA Land, Vegetation, and Ice Sensor (LVIS) PhaseOne medium-format camera, which was operated on high-altitude segments of flights during the ICESat-2 2022 Arctic Summer calibration campaign.

1.2 File Information

1.2.1 Format

The imagery is provided as GeoTIFF files.

1.2.2 File Contents

The georeferenced imagery is provided at two resolutions: (1) full resolution of 150 megapixels (MP) and (2) a user-friendly reduced resolution of ~38 MP. All georeferenced images are provided at both resolutions, which are included in the file names. An example of a GeoTIFF image is shown in Figure 1.

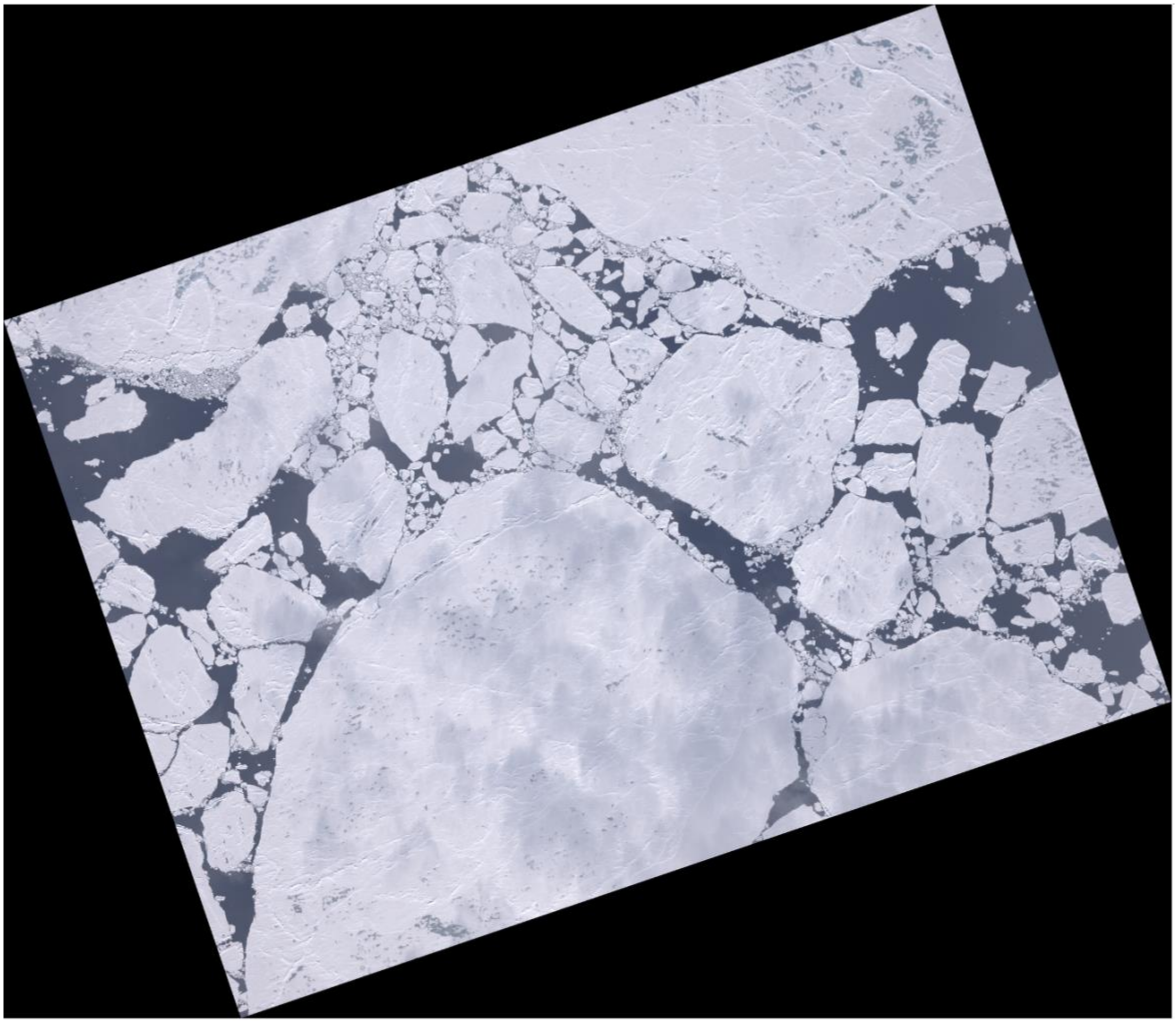

Figure 1. Example GeoTIFF image (38 MP).

1.2.3 Naming Convention

The files are named according to the following convention, which is described in more detail in Table 1:

```
IS2OLVIS1BCV_CAMrrrMP_GL2022_MMDD_RYYMM_hh-mm-ss.sss.tif
```

Example:

```
IS2OLVIS1BCV_CAM038MP_GL2022_0711_R2212_12-26-15.138.tif
```

Table 1. File Naming Convention

Variable	Description
IS2OLVIS1BCV	ICESat-2 Calibration/Validation LVIS L1B Georeferenced Imagery data set
CAM	Indicates camera system was used
rrrMP	Image resolution: 038MP or 150MP
GL2022	Campaign identifier = Greenland 2022 ICESat-2 Cal/Val
MMDD	Two-digit month and two-digit day of start of data collection
RYYMM	Date (two-digit year, two-digit month) of data production
hh-mm-ss.sss	Number of seconds since GPS midnight of the day on which data collection started; time in hours (hh), minutes (mm), and seconds (ss.sss) of flight day (UTC)

1.3 Spatial Information

1.3.1 Coverage

The geographic regions covered by the data product are the Arctic Ocean, Northern Canadian Archipelago, and Northern Greenland, as indicated by the following coordinates:

Northernmost Latitude: 90° N
Southernmost Latitude: 60° N
Easternmost Longitude: 180° E
Westernmost Longitude: 180° W

1.3.2 Resolution

The nominal resolution is 3 km x 2 km (20 cm/px) at 32,000 ft but varies depending on the aircraft height.

1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45° E
Latitude of true origin	70° N
Scale factor at longitude of true origin	1
Datum	WGS 84

Ellipsoid/spheroid	WGS 84
Units	meters
False easting	0
False northing	0
EPSG code	3413
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3413

1.4 Temporal Information

1.4.1 Coverage

This data set covers the ICESat-2 2022 Arctic Summer calibration campaign from 11 July 2022 to 26 July 2022.

1.4.2 Resolution

Varies

NOTE: Imagery is captured every four seconds, although georeferencing is only performed on images that contain LVIS lidar returns (i.e., no completely cloudy imagery). As such, the input OLVIS1A data set will likely have more files than the IS2OLVIS1BCV data set.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

In July 2022, NASA's LVIS Facility was used to collect data over the Arctic Ocean, including along ICESat-2 Reference Ground Tracks. The georeferenced imagery was captured contemporaneously to LVIS-F lidar data, which provide surface elevation and structure information.

2.2 Acquisition

Input data are imagery from the LVIS L1A Geotagged Images (OLVIS1A) dataset, as well as aircraft attitude and position data, also measured by the LVIS team. Imagery is taken along-track, and georeferencing is only performed on imagery that contains valid LVIS lidar returns, which is typically indicative of a reasonably cloud-free nadir view of the Earth's surface.

2.3 Processing

A series of coordinate transformations are applied because the sensor is mounted on an aircraft that is constantly in motion. The instantaneous camera sensor position and attitude are converted to a vector between each image pixel and the surface to obtain the geolocation for each recorded image pixel. If the airplane is traveling due north, the image pixel (0, 0) is assumed to be in the upper left (northwest) corner of the image.

2.3.1 Geolocation Procedure for Camera Sensor

For each image, differential GPS and aircraft attitude measurements are synced with the camera time stamp. To determine the position of the camera sensor from this information, the spatial distance between the camera and GPS antenna is measured prior to each flight campaign using a North, East, Down (NED) coordinate system. Coordinate transformations are then applied to correct for the camera offset from the GPS antenna location and determine the camera sensor location.

2.3.2 Geolocation Procedure for Image Pixels

To determine the geolocation of each camera pixel, the vector from each image pixel to the surface is calculated using a simple projection camera model. This approach is similar to the methodology described in Barber et al. (2006) but with modifications to account for the measurement system used on the campaign-specific aircraft. Two transformation matrices accounting for aircraft motion and mounting biases are constructed using homogeneous coordinates. To account for mounting biases of the camera, another transformation matrix is calculated in an equivalent manner to that of the transformation from the aircraft frame to the camera frame but using input parameters that correspond to the bias in the camera pitch, roll, and heading. A timing bias between the image acquisition time stamp and actual image acquisition is also estimated and applied. The procedure for determining the mounting and timing biases is described in the Quality, Errors, and Limitations section.

2.4 Quality, Errors, and Limitations

The quality of the image georeferencing procedure is mostly driven by the uncertainties in the airplane attitude as well as the uncertainties in the mounting and timing bias estimates applied to the data. To a lesser extent, the quality is also impacted by the uncertainty of the image acquisition time, the uncertainty of the GPS antenna position location, and uncertainties in the vertical distance to the surface — this is expected to be low because the onboard laser altimeter is used to obtain an accurate distance to the surface. Mounting and timing biases were determined by obtaining control points from previously surveyed portions of the Thule airport ramp and identifying the pitch, roll, heading, and timing biases that minimized the mean difference between the solution and control points. The standard deviation of the image pixel geolocation with the control points from this procedure was 1.062 m, which is one estimate of the expected uncertainty in the geolocation of the data.

The image pixel geolocation quality was also independently estimated by comparing unique sea ice features as control points in overlapping images during the science measurement portion of the campaign. Using 50 control points, the mean and standard deviation of the location from this procedure were 0.654 m and ±0.240 m, respectively. Overall, the estimated total geolocation error is likely not constant across an entire image but is expected to range from 0.7 m to 1.1 m.

Lens distortion correction was not applied to the data, so it is possible that the image geolocation accuracy degrades slightly with distance from the image center. Additional uncertainty may be present for sea ice imagery if an image pixel has a surface feature that is significantly different than the mean elevation determined by the laser altimeter for the image area. Lastly, the georeferencing procedure is only valid for points that contain the surface of the Earth, i.e., it is not valid for cloudy pixels.

2.5 Instrumentation

2.5.1 Description

The LVIS PhaseOne camera has an image resolution of 150 MP, a nominal resolution of 3 km x 2 km, and a nominal overlap of 67%. A description of the instrument is available on the NASA LVIS website.

2.5.2 Trajectory and Attitude

Flight trajectories and coverage maps are available on the NASA LVIS website.

3 RELATED DATA SETS

LVIS L1A Geotagged Images (OLVIS1A)

4 RELATED WEBSITES

NASA LVIS website

5 REFERENCES

Barber, D. B., Redding, J. D., McLain, T. W., Beard, R. W., & Taylor, C. N. (2006). Vision-based Target Geo-location using a Fixed-wing Miniature Air Vehicle. *Journal of Intelligent and Robotic Systems*, *47*(4), 361–382. https://doi.org/10.1007/s10846-006-9088-7

6 DOCUMENT INFORMATION

6.1 Publication Date

June 2023

6.2 Date Last Updated

June 2023