

## Introduction for ATL11XO

The ATL11XO, or ATL11-crossover product, is a new way of providing full-mission height-change data at the points where ICESat-2 pair tracks cross. The ATL11 product provides slope-corrected surface height time series at a series of points along each of the reference pair tracks, giving up to four height measurements per year at each point. Where two ICESat-2 pair tracks cross one another (crossover points), there is an opportunity to make up to eight measurements at each point, which can be helpful in observing the details of height change driven by snowfall and melt.

Crossovers are also useful in comparing measurements from cycles 1 and 2 of the ICESat-2 mission (spanning October 2018 to April 2019) to measurements from the rest of the mission. During these two cycles the instrument was not pointed at the reference tracks, so the measurements are not included in the normal along-track ATL11 time series.

We describe the two tracks included in the crossover as the *datum track* and the *crossing track*. The ATL11 along-track algorithm calculates a reference surface from the repeat measurements along the datum track, which defines the slope and curvature of the surface based on data from many (up to 28 as of May 2026) repeated measurements of the same track. The crossing tracks come from different reference ground tracks, and the reference surface from the datum track is used to correct the measurements from the crossing track so that they can be directly included in the datum track's time series (see Fig. 1 for a sketch of each set of tracks).

Each ATL11XO granule includes measurements from both the datum tracks and crossing tracks

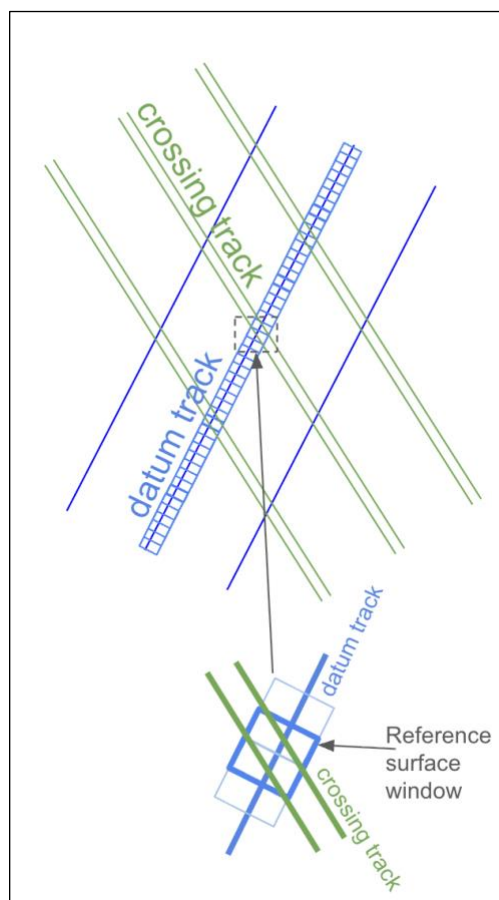


Figure 1. Reference and datum track geometry. The reference surface is defined on 120x120-m patches (blue squares) spaced every 60 m along the three pair tracks of the datum track. The ATL11XO product is provided for points where crossing tracks intersect these surfaces.

so that the full time series can be constructed without the need for the user to refer to the ATL11 along-track product. The locations of the data points are in the root group of each granule, and the height measurements from each set of tracks are in the *datum\_track* and *crossing\_track* groups.

## File information

### Format

Data are provided as HDF5-formatted files.

### Granule Regions

ATL11XO is divided into Arctic and Antarctic granules.

Arctic granules use the NSIDC Sea Ice Polar Stereographic projection (EPSG:3413), while

Antarctic granules use the Antarctic Polar Stereographic projection (EPSG:3031.)

### File contents

A complete list of all ATL11XO parameters is available in the [ATL11XO data dictionary](#).

Unlike the along-track ATL11 product, in which each granule provides all the data from a single reference track, the ATL11XO product combines data from all tracks in a given orbital cycle into 200x200-km square tiles, defined in standard coordinate systems for Arctic and Antarctic data. Figure 2 shows the tile extents for the Arctic and Antarctic. One set of tiles is generated for each cycle of the ICESat-2 mission each time new data become available. For example, the currently available data has tile sets for cycles 1 through 30, although the tiles for cycle 30 are incomplete because the latest available ATL06 data (the source for ATL11) did not complete this cycle. The next data release will cover the remainder of cycle 30 and part of cycle 31, at which time we will release a revised version of the cycle-30 tile set, and a partial version of the cycle-31 tile set.

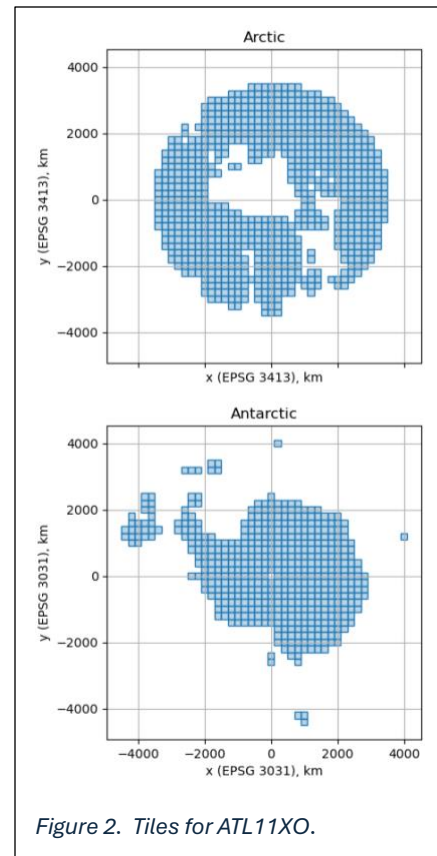


Figure 2. Tiles for ATL11XO.

Each granule (Fig. 3) contains a root group, two data groups (*datum\_track* and *crossing\_track*), and four groups containing product metadata and programmatic fields (*METADATA*, *ancillary\_data*, *orbit\_info*, and *quality\_assessment*).

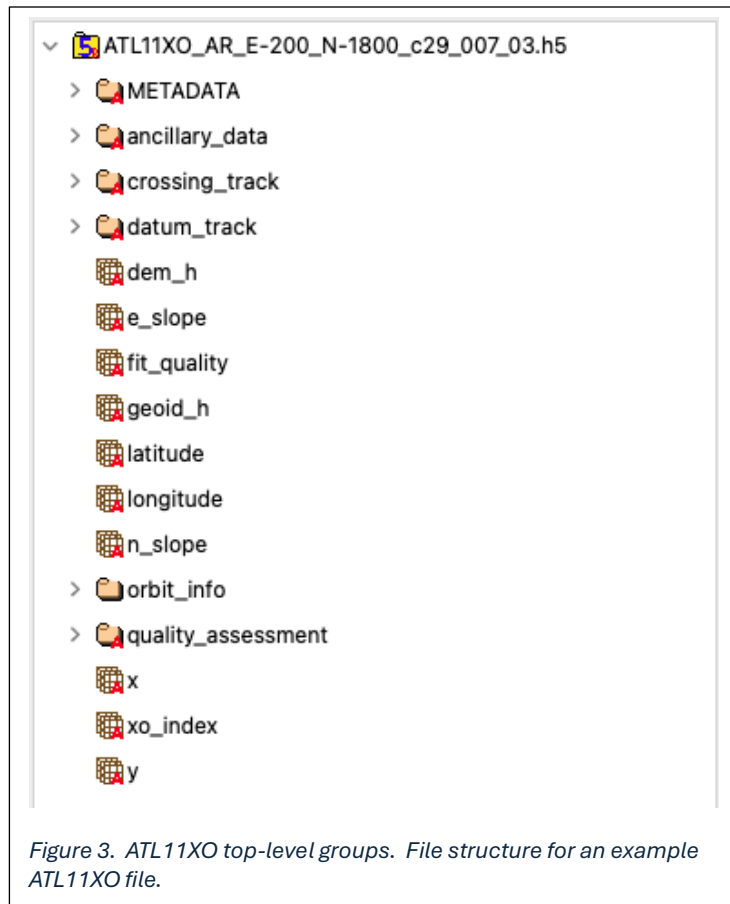
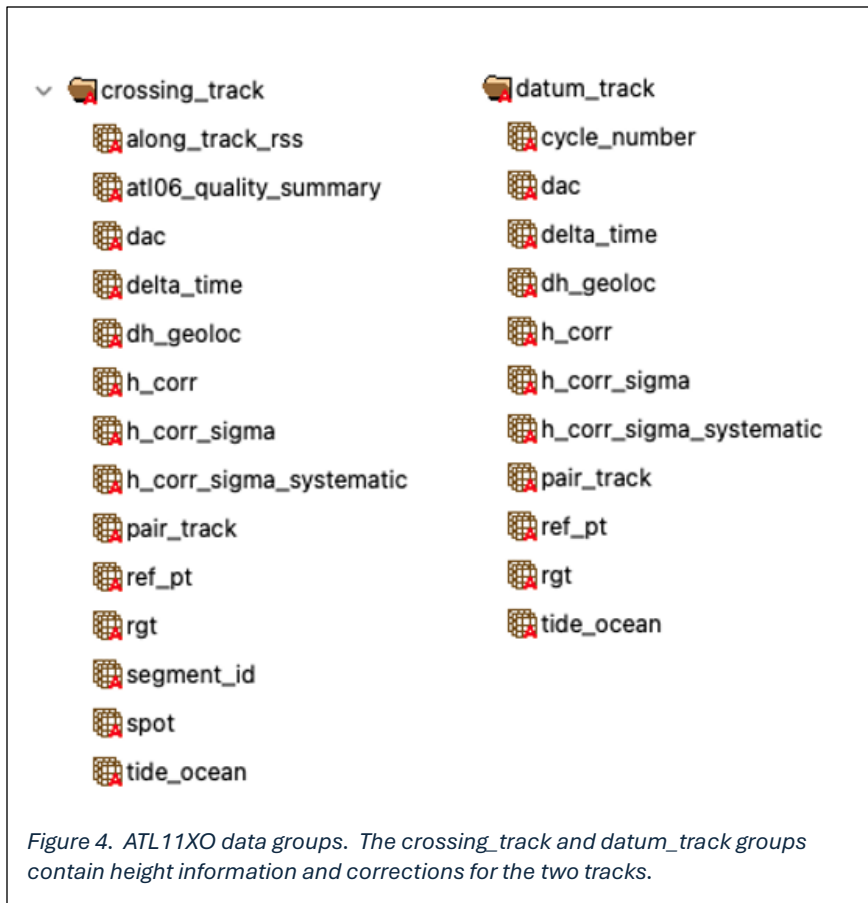


Figure 3. ATL11XO top-level groups. File structure for an example ATL11XO file.

The root group contains geolocation information for the ATL11 reference points that are intersected by each crossing track (blue squares in Fig. 1, *latitude*, *longitude*, *x*, and *y*), as well as metadata describing the reference surface (*e\_slope*, *n\_slope*, *dem\_h*, *geoid\_h*).

The two data groups (*datum\_track*, *crossing\_track*) describe the surface height derived from the datum track and the crossing track (Fig. 4). Each group contains parameters that define how the data was collected (*pair\_track*, *rgt*, *delta\_time*), define the height for the cycle contained in the granule (*h\_corr*, *h\_corr\_sigma*, *h\_corr\_sigma\_systematic*), and provide altimetry corrections (*dh\_geoloc*, *dac*, *tide\_ocean*). Some information is distinct between the crossing track and the datum track: The datum track is defined based on the ATL11 along-track product, so its along-track identity is defined by the reference point number (*ref\_pt*), while the crossing track is specific to a particular ATL06 segment, described by *segment\_id* and *spot*.



## Naming convention

ATL11XO granules are named based on the location of the tile and the cycle of the data it contains:

ATL11XO\_[HH]\_E(xxx)\_N(yyy)\_c[cc]\_[rrr]\_[vv].h5

Here HH is a string indicating the hemisphere (AR for arctic, AA for Antarctic), xxx specifies the tile center x coordinate, in km, yyy specifies the tile center y coordinate (xxx and yyy may be up to four digits and may be positive or negative), cc indicates the cycle collected, rrr indicates the data release, and vv indicates the version of the granule (where the version matches that of the along-track ATL11 products).

This filename syntax allows users to directly locate the granule they need based on its location. For example, to find granules Upernavik Glacier, Greenland (-51.94356, 72.41818°N), a user would convert its coordinates to polar stereographic coordinates and round them to the nearest 200 km. This gives (200, -2000). The granule name for cycle 1 would then be:

ATL11XO\_AR\_E200\_N-2000\_c01\_007\_03.h5

In Python, this granule can be found using the `earthaccess` API as follows:

```
import earthaccess

results = earthaccess.search_data(short_name = 'ATL11XO', version = '007',
granule_name='ATL11XO_AR_E200_N-2000_c01_007_*.h5')
```

Here we have used a wildcard for the version number because we do not necessarily know that 01 is the most recent version. An alternative is to use the geographic search feature in `earthaccess` to find the granule based on location:

```
results = earthaccess.search_data(

    short_name = 'ATL11XO',

    version = '007',

    point=(-51.944, 72.418),

    granule_name="*c01*")
```

Here the wild card is used to specify cycle 01 only; omitting it would return one granule from each cycle between 01 and 31 (or more). The results of this search can be downloaded or accessed directly from the cloud, and because the granules are small (<5-6 MB/cycle at this latitude) either option is likely to be straightforward.

## Limitations and uncertainties.

1. The ATL11XO dataset provides a very limited sampling of elevations. Most users will find using the ATL11 along-track product simpler as it provides a more comprehensive spatial sample of measurements. The exception is likely to be users who need short-period surface sampling (more often than the 3-month ICESat-2 repeat interval) or users who need height-difference measurements from cycles 01 and 02, which were not measured on the repeat tracks.
2. In many cases the `datum_track` group will contain invalid height measurements. This is because each granule only contains data from a single cycle, so if the surface was obscured by clouds during the measurement of the datum track for that cycle, the datum track height will be marked invalid. This includes cycles 1 and 2, where there are no measurements on the datum track, so all `datum_track/h_corr` values are marked invalid.
3. Some users may find it confusing that there are multiple values in ATL11XO for each combination of RGT and beam pair. This is because, as depicted in Fig. 1, each beam of each crossing track may intersect the reference surface window for two or more reference points. The ATL11 algorithm will report a corrected height for each

such overlap, so there may be multiple height measurements for a given combination of tracks in each granule. Users may choose to average these measurements or may select the measurement with the smallest estimated error for each combination of RGTs and beam pairs.

## Using ATL11XO data

Two likely use cases for ATL11XO data are:

1. Calculating densified time series at crossover points by combining data from repeat and crossing tracks
2. Building longer-term time series by combining cycle 01 and 02 crossover data with along-track data from the remainder of the mission.

To build crossover time series for a location, the user would:

1. Use `earthaccess` to generate a list of granules matching their region of interest
2. For each granule, use the `x` and `y` fields to determine which data points match their location of interest
3. Read the `h_corr`, `h_corr_sigma`, and `delta_time` fields from the `datum_track` and `crossing_track` groups, and the `ref_pt` group from `datum_track`
4. (optionally) Filter the crossovers by `ref_pt` to obtain a time series for a particular along-track location.

To build an ATL11 time series that includes cycle 01 and cycle 02, the user would first read the along-track ATL11 product for their region of interest. They would then use a geographic query to `earthaccess` to read the ATL11XO tiles for the same area, for cycles 01 and 02. The points in the `crossing_track` group would then contain height data directly compatible with the collection of heights from cycles 03 and later in the along-track ATL11 data (this process is described in the ATL14/15 ATBD).