**Guide:** Introduction to ArcticDEM
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*The ArcticDEM is a collaborative project to produce a 2-meter resolution pan-Arctic Digital Elevation Model.*

## Background

ArcticDEM is a National Geospatial-Intelligence Agency (NGA) and National Science Foundation (NSF) public-private initiative to automatically produce a high-resolution, high-quality digital surface model (DSM) of the Arctic using optical stereo 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.

The Polar Geospatial Center and collaborating institutions are using a three-pronged strategy to produce over 20 trillion 2-by-2 meter elevation cells over an area of 20 million square kilometers.

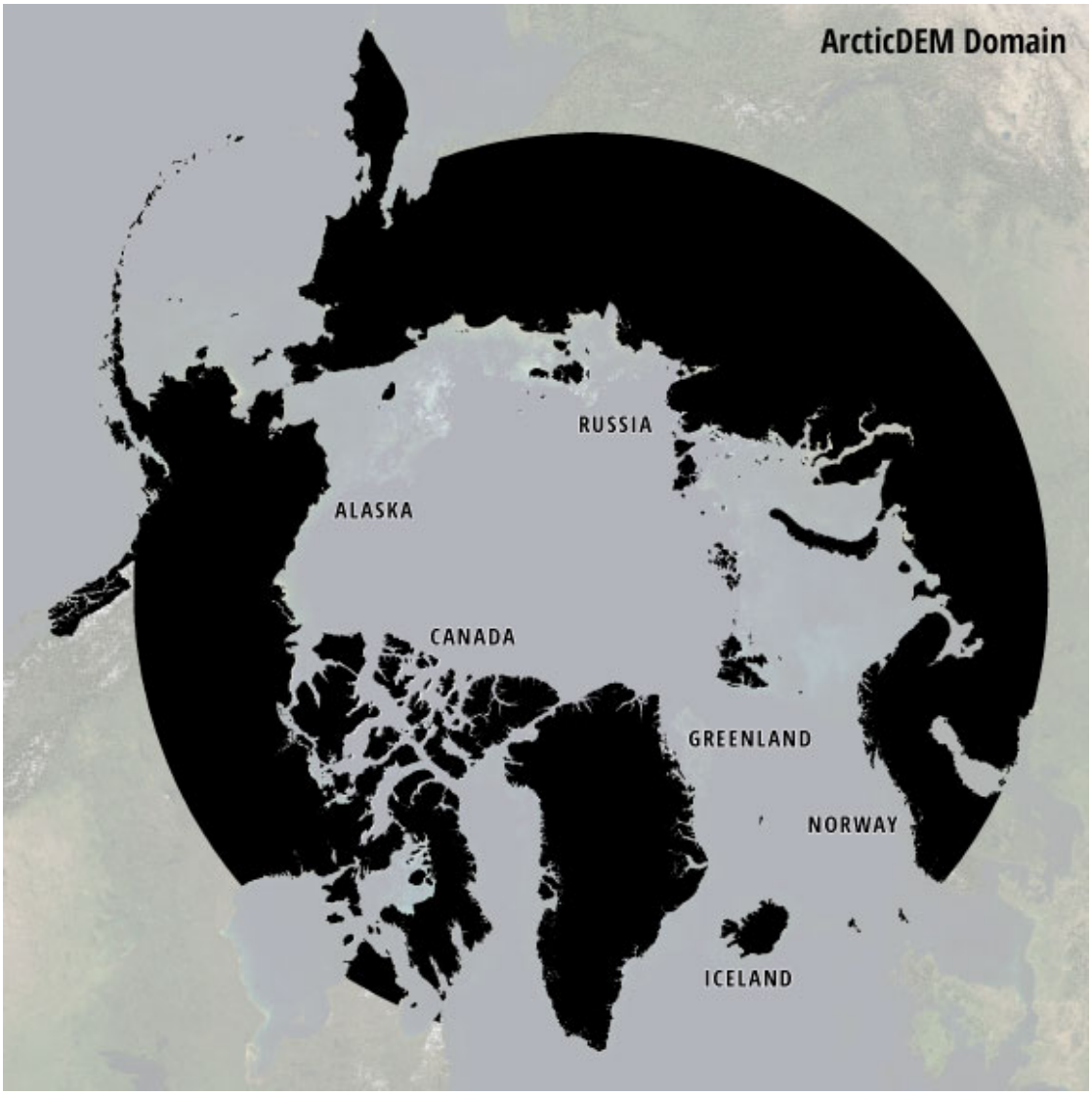
1. DigitalGlobe's WorldView-1, WorldView-2, and WorldView-3 satellites collect stereoscopic imagery of the Arctic.
2. The imagery is processed into 2 meter posting elevation models using the Ohio State University's software package Surface Extraction with TIN-based Search-space Minimization (SETSM).
3. The computation is performed on the NSF-supported Blue Waters petascale supercomputer at the National Center for Supercomputing Applications.

ArcticDEM offers a different way of producing and providing terrain data. It is a response to the need for high-quality data in remote locations, the availability of technology to cope with big data, and the need to measure topographic change. The producers did not intend the final product to be a single "eyes on" or edited product, but rather a collection of time-dependent elevation models and the infrastructure to process the flow of imagery from an ever-expanding constellation of satellites producing an ever-increasing volume of high-quality data.

## Scope

ArcticDEM data encompasses all land area north of 60° north latitude. In addition, coverage includes territory of Greenland, the entire state of Alaska, and the Kamchatka Peninsula of the Russian Federation.

The project began with a release of data over Alaska in September 2016 and continued to other regions on a continual basis over the next two years. The objective of the ArcticDEM initiative was to create a comprehensive elevation model of the Arctic within the two-year term of the U.S. Chairmanship of the Arctic Council, which began in April 2015.




Map of the ArcticDEM Domain.

## Methodology

ArcticDEM data is generated by applying stereo auto-correlation techniques to overlapping pairs of high-resolution optical satellite images. Using the SETSM software developed by M.J. Noh and Ian Howat at the Ohio State University, stereopair images are processed to digital elevation models (DEMs) using the Blue Waters supercomputer located at the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign.

For additional information on SETSM software, see:

> Noh, M.J., I.M. Howat, Automated stereo-photogrammetric DEM generation at high latitudes: Surface Extraction from TIN-Based Search Minimization (SETSM) validation and demonstration over glaciated regions, GIScience and Remote Sensing, doi:10.1080/15481603.2015.1008621

Output DEM raster files are available as 1) “strip” files output directly from SETSM that preserve the original source material temporal resolution and 2) mosaic files compiled from multiple strips that have been co-registered, blended, and feathered to reduce edge-matching artifacts.

Strip DEM files correspond to the overlap area of the input stereopair image swaths as they are collected by DigitalGlobe's polar-orbiting satellites. Strip DEM dimensions will vary according to the satellite sensor that acquired the images and the off-nadir angle of collection. Most strips are between 16 km and 18 km in width, and 110 km and 120 km in length. Mosaic DEM files adhere to a regular 100 km x 100 km tiling grid covering the ArcticDEM production domain. Each mosaic tile has been further sub-tiled into four, 50 km x 50 km sub-tiles for file size and distribution considerations.

Filtered IceSAT altimetry data has been employed to improve the accuracy of both the strip and mosaic DEM files. ArcticDEM strip files are distributed with metadata describing the xyz offsets as determined by the altimetry data, but have not had this translation applied to the rasters. Mosaicked ArcticDEM files have been registered to IceSAT altimetry information.

The methodology and scale of this data production initiative has a number of inherent strengths and weaknesses:

## Strengths

- **The use of three polar orbiting satellites allows ArcticDEM to cover a large area in polar regions.** Satellites frequently revisit high-latitude areas and data generally can be collected quickly.
- **Areas can be recollected.** This allows for holes/gaps in ArcticDEM to be filled and also enables the potential for change detection.
- **Automation and high performance computing can generate a large amount of terrain in a short period of time.** Blue Waters has produced a 2 meter resolution DSM equivalent to the area of Argentina in 48 hours using onethird of the computer.
- **Elevation data can be regenerated as the photogrammetry software improves.**
- **Aircraft are not required.** High-latitude and remote areas are actually easier to collect than lower latitude areas near population centers.
- **Many different mosaics can be assembled as a time-dependent mix of elevation models to meet various requirements.** Users can construct mosaics from a specific year or season.

## Weaknesses

- **There is no "bare earth" product.** The source imagery cannot penetrate vegetation or man-made surface features. Such features will exist in the elevation values of the product.
- **This is not an "eyes on" or manually edited product.** The volume of data is such that manually editing to remove artifacts or improve data would be time and cost prohibitive. Pits, spikes, false landforms, and other DEM anomalies may exist in this dataset. Polygonal hydrographic features have not been flattened and the data has not been hydrologically enforced.
- **It is optically derived.** Clouds, fog, shadows, and other atmospheric obstructions can obscure the ground and make it impossible to extract terrain.
- **ArcticDEM strip files have not been edge-matched.** Visible seams and deviations between adjacent DEMs may be observed.
- **Data management can be a problem.** A single 17 km by 120 km strip of 2 meter resolution terrain data can be over six gigabytes.
- **Versioning of products presents a challenge.** As more DEMs become available, holes can be filled in mosaics and specialty products can be made.
- **Without ground control points absolute accuracy is approximately 4 meters in horizontal and vertical planes.** Uniform ground control must be applied to achieve higher accuracy. Laser altimetry data from the NASA IceSAT spacecraft has been applied to the ArcticDEM mosaic files. Users may wish to

use other sources for smaller areas, particularly on ArcticDEM strip files. Strip DEM files contain IceSAT altimetry offsets within the metadata, but have not had these values applied to the DEM files.
- **The imagery spans multiple years and seasons.** A single season/year mosaic is not possible for large areas.

## Source Material

ArcticDEM data is constructed from in-track and cross-track high-resolution (~0.5 meter) imagery acquired by the DigitalGlobe constellation of optical imaging satellites, licensed through the NGA NextView contract.

Most ArcticDEM data was generated from the panchromatic bands of the WorldView-1, WorldView-2, and WorldView-3 satellites. A small percentage of data was generated from the GeoEye-1 satellite sensor.

## Releases

ArcticDEM has been released on incremental bases through 2018. September 28, 2018 marks the final release, Release 7.

For more information on individual releases and geographic areas, visit the main ArcticDEM page.