Greenland Annual Accumulation along the EGIG Line, 1959–2004, from Airborne Radar and Neutron Probe Densities

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Detailed Data Description

This data set reports mean annual snow accumulation rates in meters water equivalent (m·w.e.) from 1959 to 2004 along a 250 km segment of the Expéditions Glaciologiques Internationales au Groenland (EGIG) line. Accumulation rates are derived from Airborne SAR/Interferometric Radar Altimeter System (ASIRAS) data and high resolution neutron-probe (NP) density profiles. Two snow accumulation rate reconstructions are provided: one using ASIRAS data and NP densities (ASIRAS NP); and a second, for comparison, derived from ASIRAS data and modeled densities using the Herron and Langway (HL) empirical model of polar snow densification.

Format

ASCII, space delimited (extentsion varies by file)
MATLAB workspace (.mat)

File and Directory Structure

Data files are available on the HTTPS site in:

https://daacdata.apps.nsidc.org/pub/DATASETS/nsidc0644/Greenland_EGIG_line_v1/

This top-level directory contains the following three subdirectories:

/asiras_accumulation_ascii/ .... (snow accumulation, geolocation files in ASCII format)
/asiras_accumulation_matlab/................ (snow accumulation, geolocation files in MATLAB format)
/ancillary/... (ancillary data from Overly, et al., 2016. See File Contents.)

File Naming Convention

Table 1: File Names, Sizes, and Descriptions

File Name	File Size	Description
accum_mwe_ASIRAS_HL_2004_1959.xz	37 MB	Mean annual snow accumulation (m·w.e.) derived from ASIRAS layers and Herron and Langway (HL) modeled densities. Available in ASCII (.xz) and MATLAB (.mat) formats.
accum_mwe_ASIRAS_HL_2004_1959.mat	17 MB	
accum_mwe_ASIRAS_NP_2004_1959.xz	37 MB	Mean annual snow accumulation (m·w.e.) derived from ASIRAS layers and neutron probe (NP) measured

accum_mwe_ASIRAS_NP_2004_1959.mat	17 MB	densities. Available in ASCII (.xz) and MATLAB (.mat) formats.
egig_lonlatelev.xyz	2.6 MB	Latitude, longitude (decimal degrees), and elevation (m) for each location along the EGIG line. Negative longitudes correspond to the W. Hemisphere. Available in ASCII (.xyz) and MATLAB (.mat) formats.
egig_lonlatelev.mat	1 MB	
dist_egig.x	800 KB	Cumulative distance (km) for each location from the first value in egig_lonlatelev. Available in ASCII (.x) and MATLAB (.mat) formats.
dist_egig.mat	440 KB	
asiras_table1.txt asiras_table2.txt asiras_tableA1.txt table-titles.txt	1–5 KB	Values and titles from Table 1, Table 2, and Table A1 in Overly et al., 2016. See File Contents | Ancillary for details. Available in ASCII (.txt) format.

File Contents

Mean Annual Snow Accumulation

Accumulation files contain a 74,038 row x 46 column matrix of mean annual snow accumulations in meters water-equivalent. Rows correspond to horizontal positions along the EGIG line. Columns represent years in the accumulation record, with the first value corresponding to 2004 and the last to 1959. The accumulation year is defined as 1 October–30 September of the following year. For example, the 1959 accumulation year runs from 1 October, 1958 to 30 September, 1959.

Geolocation

The file `egig_lonlatelev` contains the latitude and longitude in decimal degrees and elevation in meters for each of the 74,038 locations along the EGIG line.

The file `dist_egig` contains the cumulative distance (km) for each location from the first location in `egig_lonlatelev`.

Ancillary

The following ancillary files are also available:

- `asiras_table1.txt`
- `asiras_table2.txt`
- `asiras_tableA1.txt`
- `tables-titles.txt`

The first three files above contain the values reported in Table 1, Table 2, and Table A1, respectively, in Overly et al., 2016. They are provided here in digitized form as a convenience to users. All three table titles from the paper are provided in `tables-titles.txt`.

Spatial Coverage

Accumulation estimates lie along a 250 km segment of the Expéditions Glaciologiques Internationales au Groenland (EGIG) line, within the following bounding box:

Northeast Corner:	71.207715° N, -36.232431° E
Southwest Corner:	70.585609° N, -42.838297° E

The segment spans the eight T-sites shown in Figure 1, starting at T21a (2700 m) and ending 250 km to the east beyond the ice divide at T43 (3200 m).

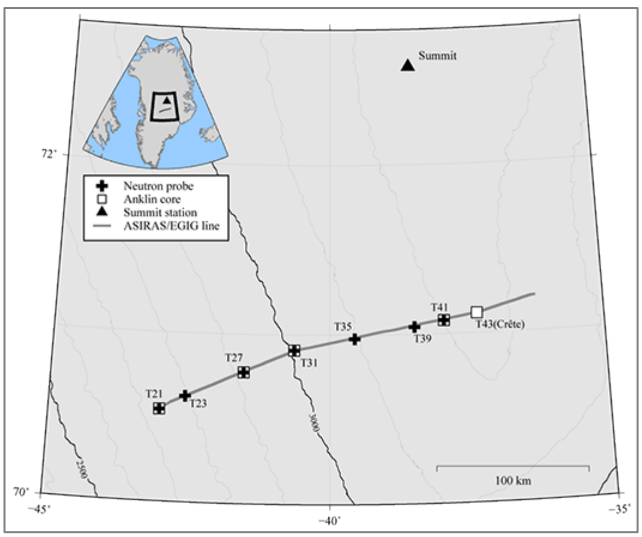

Figure 1. T sites along the 250 km segment of the EGIG. ASIRAS radar data span 2700 m to 3200 m elevation.

Spatial Resolution

Approximately 3 m

Projection and Grid Description

Latitudes, longitudes (decimal degrees), and elevations (m) are provided for each data point. Negative longitudes correspond to the Western Hemisphere.

Temporal Coverage

1 October, 1959–30 September, 2004

Temporal Resolution

Annual. The accumulation year is measured from 1 October to 30 September. E.g. the 1959 accumulation year runs from 1 October, 1958 to 30 September, 1959.

Data Acquisition and Processing

Background

Physical Setting

With major joint European expeditions in 1958–1959 and 1967–1968, the Expéditions Glaciologiques Internationales au Groenland (EGIG) established study sites across central Greenland along two axes: an 800 km traverse that crosses the continent from west to east and a 300 km north-south line near the island's western edge.

This data set focuses on a 250 km segment of the EGIG west-to-east transect spanning eight T sites (see Figure 1).

Radar Snow Depth Profiling

The European Space Agency's Airborne SAR/Interferometric Radar Altimeter System, or ASIRAS, is equipped with a Ku-band radar altimeter that measures ice sheet surface elevation and detects internal reflection horizons corresponding to changes in density. Hawley, et al., 2006 measured annual accumulation from 1995 to 2002 at EGIG site T21 (see Figure 1) using ASIRAS radar and a neutron probe (NP) density profile. More recent work (e.g. Helm et al., 2007; de la Peña et al.; 2010; Simonsen et al., 2013) has shown that annual accumulation rates can be derived from ASIRAS data combined with local snow density profiles.

Estimating Snow Density

A neutron probe (NP) consists of a radioactive americium-241/beryllium source of fast neutrons around a cylindrical detector that is sensitive to slow (thermal) neutrons only. The emitted fast neutrons lose energy by scattering as they move through the snow and thus the number of slow neutrons that arrive back at the detector per unit time relates to the density of the snow.

In the spring and autumn of 2004 and the spring and summer of 2006, Morris and Wingham (2011, 2014) collected near-surface *in situ* NP density profiles at 17 “T-sites” along a 365 km section of the EGIG line. These density profiles extend from the surface down to approximately 13 meters.

HL Snow Density

Because logistical challenges limit the acquisition of direct measurements on ice sheets, the simple Herron and Langway (HL) empirical model of polar snow densification provides a viable alternative to estimate density in the absence of *in situ* data. Briefly, the model can generate a density profile at any point along EGIG given three input parameters: mean annual accumulation, mean annual temperature, and initial surface snow density (see Herron and Langway 1980).

Data Acquisition Methods

The raw ASIRAS data were acquired via the European Space Agency’s EO Data Access site* (Data Volume: 115). The neutron probe data were obtained from Professor Elizabeth M. Morris at the Scott Polar Research Institute, University of Cambridge.

* Requires registration

Derivation Techniques and Algorithms

The following sections provide a brief outline of the approach used to generate annual accumulation rates from ASIRAS radargrams and NP- and HL-derived densities. For a detailed description, consult (Overly et al. 2016).

ASIRAS-traced layers

SAR processed level_1b ASIRAS data were processed using waveform alignment, stacking, and gain. Each column of the radargram represents the centered mean of the surrounding 100 columns; hence 100 columns stacked into one record represents approximately three horizontal meters. Because the ASIRAS signal weakens with increasing depth through the snowpack, a ramped gain was applied to the signal to enhance the visual contrast of the radargram. The investigators then traced annual layers by tracking the maximum reflected power across adjacent columns within the vertical range of a moving window. Automated layer tracing occurs one layer at a time, with visual inspection and approval of the final traced layer.

The shallowest (1st) layer corresponds to the 2005 accumulation surface and the deepest (48th) traced layer represents the 1959 accumulation year (see Figure 2).

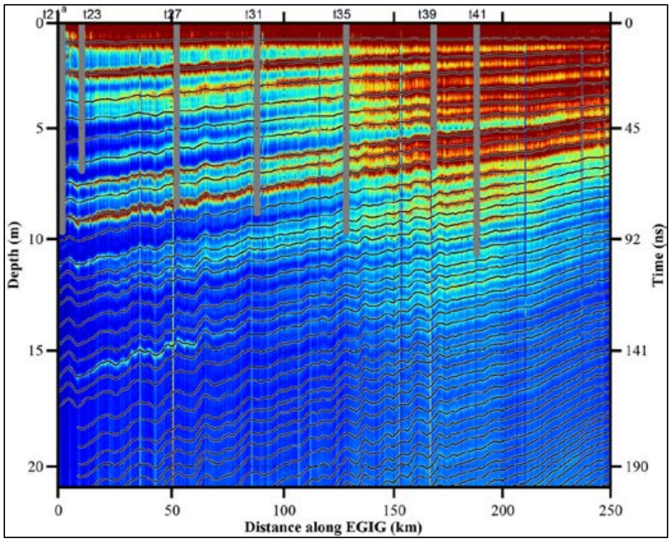

Figure 2. ASIRAS radargram of a portion of the 47 traced internal layers down to 20m depth. The uppermost layer represents the 2005 accumulation year. Distance along EGIG corresponds with the gray line in Fig. 1, with 0 km at 2700m on the western slope and 250 km ending below 3200m on the eastern slope. The left axis shows depth. The right axis shows the two-way travel time of an ASIRAS radar pulse. Figure

Density Profiles

NP

The 16 NP density profiles at eight T-sites (T21a, T23, T27, T31, T35, T39, T41) bound by the combined T21a and GISP2 b-core densities on the west and the T41 and GISP2 b-core densities on the east, provide anchor points for interpolating depth-density values at every point along the EGIG line. Annual accumulation rates were calculated from 1959 to 2004 at the T-sites, with the exception of 2005 due to its proximity to the April 2006 ice sheet surface at the time the radar and NP data were collected. The NP densities represent the most detailed density measurements along EGIG, correcting ASIRAS travel time through the snowpack to create the ASIRAS-NP accumulation rates.

HL

HL density profiles for each radar trace (one approximately every 3m horizontally) were modeled using spatially continuous input parameters for accumulation(Burgess et al. 2010), temperature (Steffen and Box 2001), and surface density (Morris and Wingham 2011).

Error Sources and Limitations

Figure 3 shows mean annual accumulation rates at T21, T27, T31, and T41 from ASIRAS NP compared with combined EGIG ground measurements from Anklin, et al. (1994) and Morris and Wingham (2011), plus three regional climate models: the Penn State/NCAR Mesoscale Model (MM5); Modele Atmospherique Regional (MAR); and the Regional Atmospheric Climate Model, Version 2.3 (RACMO2.3).

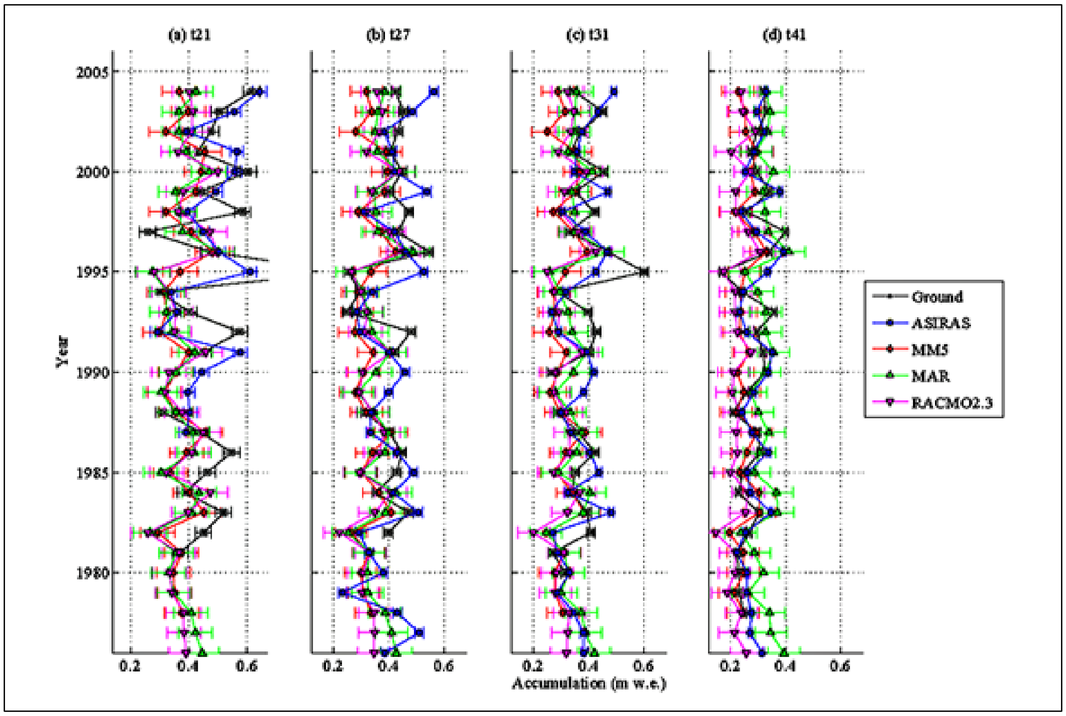

Figure 3. Mean annual accumulation rates for ASIRAS NP, MM5, MAR, RACMO2.3, and ground oberservations. Figure adapted from Overly, et al., 2016.

Sensor or Instrument Description

For a detailed description of the ASIRAS instrument, visit ESA's eoPortal ASIRAS web page.

Version History

Version 1

References and Related Publications

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Herron, Michael M, and Chester C Langway. 1980. “Firn Densification: An Empirical Model.” *Journal of Glaciology* 25 (93):373–85. https://doi.org/10.3189/S0022143000015239.

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Steffen, Konrad, and Jason Box. 2001. “Surface Climatology of the Greenland Ice Sheet: Greenland Climate Network 1995–1999.” *Journal of Geophysical Research: Atmospheres* 106 (D24):33951–64. https://doi.org/10.1029/2001JD900161.

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