Modeled Daily Thaw Depth and Frozen Ground Depth, Version 1

USER GUIDE

How to Cite These Data

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

Oelke, C., R. Armstrong, M. Serreze, and T. Zhang 2003. *Modeled Daily Thaw Depth and Frozen Ground Depth, Version 1* [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center: https://doi.org/10.7265/whf6-t406. [Date Accessed].

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set contains modeled daily thaw depth and freezing depth for the Arctic terrestrial drainage basin. Thaw and freezing depths were calculated over the study area with a resolution of 25 km x 25 km. Data extend from September 1998 through December 2000. A finite-difference model for one-dimensional heat conduction with phase change calculates daily thaw and freezing depths, based on data of snow water equivalent, soil temperature, soil dry-bulk density, and soil water content. Data are in space-delimited ASCII text format and are available via FTP.

1.1 Parameters

This data set provides daily thaw depth and freezing depth. The thaw layer is the layer of ground subject to annual thawing and freezing in areas underlain by permafrost. Freezing depth refers to soil or rock in which part or all of the pore water has turned into ice in areas not underlain by permafrost. See the Frozen Ground Glossary for more details.

1.2 File Information

1.2.1 Format

Data are in space-delimited ASCII text format, compressed with gzip.

Input data are interpolated to the NSIDC Northern Hemisphere EASE-Grid. Modeled thaw depth data and freezing depth data are gridded to a spatial subset of the Northern Hemisphere EASE-Grid projection that represents the Arctic drainage basin (39,926 total pixels). The file "ease721_drainage_lakglac.txt" provides the corresponding EASE-Grid latitude and longitude of each thaw depth or freezing depth value within the Arctic drainage basin subset. Data are output to ASCII text format.

File Size:

Data files compressed with gzip: 627 KB - 1.8 MB
Data files uncompressed: 10.9 MB
ease721_drainage_lakglac.txt: 1.3 MB

1.2.2 File Contents

Data are separated into 28 thaw depth files and 28 freezing depth files; each monthly file contains daily data for that month. The file "ease721_drainage_lakglac.txt" provides the latitude and longitude of each EASE-Grid pixel within the Arctic drainage basin (39,926 total pixels) and a permafrost code that indicates if the cell represents continuous, discontinuous, or isolated permafrost; seasonally-frozen ground; or glacier/lake.

Depth values are in cm.

1.2.2.1 Sample Data Record

Each data file consists of a one-line header followed by columns for EASE-Grid cell numbers, latitude, longitude, and depth (m) for each day of the month. Missing data, or when days 29, 30 and 31 do not exist, are indicated by values of "-9999.0." Following are the first four lines in a sample thaw-depth file called "ALD.1998.09.txt":

1998 09 Active Layer Depth (ALD) in [m/100], C. Oelke, NSIDC

"CellID" "Lat" "Long" "01" "02" "03" "04" "05" "06" "07" "08" "09" "10" "11" "12" "13" "14" "15" "16" "17" "18" "19" "20" "21" "22" "23" "24" "25" "26" "27" "28" "29" "30" "31"

1 56.5398 201.6560 -9999.0

2 56.6259 201.2912 -9999.0

3 56.7107 200.9245 79.8 80.4 81.4 82.3 83.2 84.2 85.1 85.9 86.8 87.7 88.5 89.3 90.2 91.0 91.8 92.6 93.4 94.2 95.0 95.8 96.5 97.3 98.0 98.7 99.4 100.1 100.8 101.5 102.1 102.8 -9999.0

The file "ease721_drainage_lakglac.txt" provides latitude and longitude of each EASE-Grid cell. Columns represent an index number, EASE-Grid i,j coordinates, latitude, longitude, and a permafrost code, where:

1 = continuous permafrost
2 = discontinuous permafrost
3 = isolated permafrost
4 = seasonally-frozen ground
5 = glacier or lake

Grid cells with a permafrost code of "5" are inside the Arctic drainage basin, but they should be masked because the model does not account for heat transfer through glaciers, ice caps, or lakes. Grid cells for seasonally-frozen ground ("4") are set to the minimum value in thaw depth files.

Following are the first five lines of "ease_721_drainage_lakglac.txt":

1 225 307 56.5398 201.6560 4
2 225 308 56.6259 201.2912 4
3 225 309 56.7107 200.9245 3
4 226 306 56.6703 202.1664 4
5 226 307 56.7584 201.8014 4

1.2.3 Naming Convention

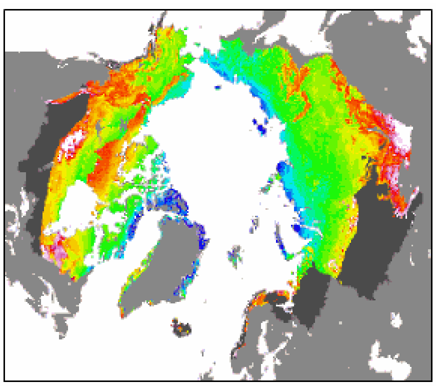
The file-naming convention is "ALD.yyyy.mm.txt.gz" and "FGD.yyyy.mm.txt.gz," where:

ALD = thaw depth
FGD = freezing depth
yyyy = four-digit year
mm = two-digit month
gz = compressed with gzip

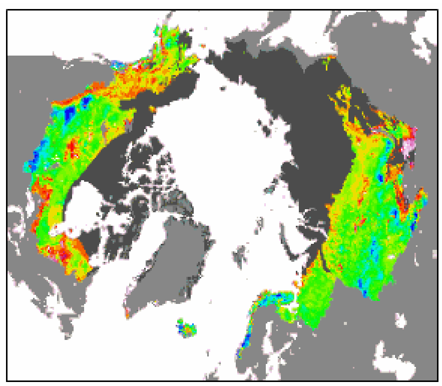
1.3 Spatial Information

1.3.1 Coverage

This data set covers the entire Arctic terrestrial drainage basin. This area includes land with ice or water that empty into the Arctic Ocean, Hudson Bay, James Bay, Hudson Strait, and the Bering Sea. The Arctic drainage basin spans overs regions of seasonally-frozen ground in the south, to permafrost regions in the north. Continuous permafrost underlies nearly half of the Arctic drainage basin (Brown et al. 1998, Zhang et al. 2000).



Extent of thaw depth. Black indicates areas of seasonally-frozen ground.



Extent of freezing depth. Black indicates areas of continuous permafrost.

1.3.2 Resolution

Thaw depth and freezing depth are calculated with a resolution of 25 km x 25 km.

1.4 Temporal Information

1.4.1 Resolution

Daily data are available from 01 September 1998 through 31 December 2000.

1.5 Acquisition

Oelke et al. (2003) obtained model input data from the following sources:

1.5.1 Temperature

National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data (Kalnay et al. 1996) generate air surface temperatures at the lowest signal level (0.995 σ) with modifications. The reanalysis data have a horizontal resolution of 2.5° x 2.5°. Oelke et al. adjusted the topography, based on NCEP/NCAR tropospheric lapse rates, the 0.995 σ level temperature, and topography from a digital elevation model (DEM). Elevation is a first-order determinant of the spatial variation in surface air temperature. The topography adjustments effectively improve the resolution of the NCEP/NCAR data set, making it more compatible with the snow cover data also used for model forcing.

1.5.2 Snow Cover

Oelke et al. (2003) calculated snow water equivalent from the DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures data set, available from NSIDC. The Chang (1987) algorithm, originally used for calculating snow water equivalent from Scanning Multichannel Microwave Imager (SMMR) passive-microwave data from 1978 to 1987, was modified for SSM/I data.

Oelke et al. derived snow height from snow water equivalent by dividing by a climatological snow density at various locations and seasons. A 45-year time series (1955-1999) of Canadian snow data from the Meteorological Service of Canada (MSC 2000) defined the climatological seasonal cycles of snow density for tundra, taiga, prairie, alpine and maritime regions. Sturm et al. (1995) defined these snow classes, based on climatological values of temperature, precipitation, and wind speed. Over 90% of snow in the Arctic drainage basin is from tundra and taiga regions. More information about the snow classes is available from the Global Seasonal Snow Classification System data set, available from the Arctic System Science Data Coordination Center (ARCSS-ADCC) at NSIDC.

Passive-microwave sensors cannot detect very thin snow cover because this type of snow does not provide a sufficiently strong scattering signal. Oelke et al. used the Northern Hemisphere

EASE-Grid Weekly Snow Cover and Sea Ice Extent data set, available from NSIDC, to identify snow. This data set represents a digital version of National Oceanic and Atmospheric Administration (NOAA) / National Environmental Satellite, Data and Information Service (NESDIS) snow-cover charts, which were based on information from several visible-band satellites. For grid cells where SSM/I does not detect snow cover but the NOAA charts do, Oelke et al. assume a snow thickness of 3 cm. The NOAA charts are most useful at the beginning of the winter season and for the southern margin of snow cover. Erroneous SSM/I detection of snow, for example, in the middle of summer, is eliminated through comparison with the NOAA snow charts.

1.5.3 Soil Properties

The three major model layers use soil bulk density data derived from the pedon database in the International Geosphere-Biosphere Program's (IGBP) SoilData System (Global Soil Data Task 2000). This database generates maps of soil parameters at any depth and spatial resolution. Since the SoilData System accounts only for mineral soil types, Oelke et al. parameterized a percentage of organic soil (peat) for the top two major soil layers. They also extracted relative compositions of clay, silt, sand and gravel from the SoilData System for each grid cell. These concentrations are used to weight the thermal conductivities of fine-grained and coarse-grained soils in both frozen and thawed states (Kersten 1949). Finally, the University of New Hampshire Permafrost/Water Balance Model (Holden et al. 2001) provided daily soil water content, derived from a 20-year model climatology (1981-2000).

1.6 Processing

Oelke et al. calculated daily thaw depth and freezing depth using a finite-difference model for one-dimensional heat conduction with phase change. Details of this model are described in (Goodrich 1982). This model has shown excellent previous results for active-layer depth and soil temperatures when driven by well-known boundary conditions and forcing parameters at specific locations (Zhang, Osterkamp, and Stamnes 1996).

The researchers applied the frozen-ground model to the entire Arctic drainage area on a daily, 25-km, EASE-grid scale. They divided soil into three major layers: 0-30 cm, 30-80 cm, and 80-1500 cm, and calculated 54 model nodes ranging from a thickness of 10 cm near the surface to 1 m at 15-m depth. They determined thermal properties of mineral soils from soil dry-bulk density and water content according to Kersten (1949) and Lunardini (1988) for peat.

Oelke et al. chose initial temperatures for the model, based on a grid cell's permafrost classification from the International Permafrost Association (IPA) Circum-Arctic Map of Permafrost and Ground-Ice Conditions (Brown et al. 1998). They ran the model for a simulated 365 days to obtain realistic start conditions for temperatures at all model layers. All soil down to the lower model boundary was set to sub-freezing initial temperatures for the thaw depth. The upper model boundary represents the snow surface when snow cover is present. Daily mean air temperature defines the upper boundary condition. When snow is absent, the model's upper boundary is the ground surface, represented by surface temperature (°C). In this model, heat transfer within the snow layer is by conduction only, and snow densities and thermal conductivities are climatological. Oelke et al. assigned an initial geothermal heat flux for every grid cell using a temperature gradient of 3 K per 100 m. They ran the model for 20 years with this condition, and they used the resulting temperature gradient between the lowest two model layers together with the bottom-layer thermal conductivity to calculate the new geothermal heat flux.

Freezing depth was calculated by setting initial soil temperatures to above-freezing values at all depths. Freezing depth increases during winter and decreases with spring thawing.

Oelke et al. calculated thaw depth for areas identified from the IPA map as continuous permafrost, and the frozen parts of discontinuous and sporadic permafrost. Thaw depth was not determined for seasonally frozen-ground areas. In this case, the corresponding model grid cells were coded as "missing" with values of -9999.0. Freezing depth was calculated for areas of seasonally-frozen ground and for the non-frozen parts of sporadic and discontinuous permafrost. Freezing depth was not calculated for areas of continuous permafrost, based on the IPA map. Corresponding grid cell values were coded as missing (-9999.0) in this case. The researchers simulated thaw depth and freezing depth for the regions of discontinuous permafrost and for sporadic permafrost. In areas of continuous permafrost, Oelke et al. showed only simulated thaw depths; only one freezing depth was simulated for seasonally-frozen ground.

1.7 Quality, Errors, and Limitations

Oelke et al. (2003) compared modeled thaw depth measurements for the years 1999 and 2000 with actual measurements from 60 Circumpolar Active Layer Measurement (CALM) sampling locations. The modeled values agree reasonably well with the measured values within their standard deviation. A Root Mean Square (RMS) error of 33.5 cm between measured depth from the 2000 CALM samples and modeled thaw depth results primarily from the difference in grid resolution between 10-m CALM grid values (100 m2 x 100 m2areas) and the 25-km grid interval used in the model.

Modeled thaw depths for sporadic permafrost areas, primarily in the southern parts of the Arctic drainage basin, can be spuriously high. In these regions, permafrost is very isolated and occurs at sub-grid scales. The model input data (surface air temperature, snow cover, and soil bulk density) are likely not representative of the true forcing conditions for these small areas, and can produce an unrealistic increase of thaw depth with time. Frozen-ground depths of small non-permafrost areas within discontinuous permafrost are likely too high, as forcing parameters are more representative of colder permafrost climate at these grid cells (Oelke et al. 2003).

2 CONTACTS AND ACKNOWLEDGMENTS

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4 DOCUMENT INFORMATION

4.1 Publication Date

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4.2 Date Last Updated

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