MEaSUREs Northern Hemisphere Terrestrial Snow Cover Extent Daily 25km EASE-Grid 2.0, Version 1

USER GUIDE

How to Cite These Data

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

Robinson, D. A., D. K. Hall, and T. L. Mote. 2014. *MEaSUREs Northern Hemisphere Terrestrial Snow Cover Extent Daily 25km EASE-Grid 2.0, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/MEASURES/CRYOSPHERE/nsidc-0530.001. [Date Accessed].

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National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This data set consists of daily 25 km snow cover extent for the Northern Hemisphere from 1 January 1999 through 31 December 2012. Snow cover extent is represented in four different variables derived from the following three source products:

- The Interactive Multisensor Snow and Ice Mapping System
- MODIS Cloud Gap Filled Snow Cover
- Passive microwave brightness temperatures

Three of the snow cover variables are derived from one of the individual products listed above. The fourth merges the other three into a single variable that uses codes to specify where one or more of the source products indicates snow.

1.1 Format

Data files are formatted in Network Common Data Form, Version 4 (NetCDF-4) (.nc) following version 1.6 of the Climate and Forecast (CF) metadata conventions. For more information about working with NetCDF formatted data, visit the UCAR Unidata Network Common Data Form Web site.

1.2 File Naming Convention

This section explains the file naming convention used for this data set with an example.

Example File Name: nhtsd25e2_19990101_v01r01.nc

nhtsdxxe2_yyyymmdd_v01r01.nc

Refer to Table 1 for the valid values for the file name variables listed above.

Table 1. File Naming Convention Description

Variable	Description
nhts	Northern Hemisphere Terrestrial Snow
d	Daily
xx	Resolution (km)
e2	EASE-Grid 2.0
yyyy	Year
mm	Month
dd	Day
v01r01	Version 1.1
.nc	netCDF-formatted file

1.3 File Size

Data files are approximately 2 MB. The entire data set is approximately 10 GB.

1.4 Spatial Coverage

Northern Hemisphere:

Southernmost Latitude: 0.0°
Northernmost Latitude: 90.0°
Westernmost Longitude: -180.0°
Easternmost Longitude: 180.0°

1.4.1 Spatial Resolution

25 km

1.4.2 Projection and Grid Description

Data are provided in the 25 km Northern Hemisphere Equal Area Scalable Earth Grid 2.0 (EASE-Grid 2.0). Grid dimensions are 720 x 720. For a complete description of EASE-Grid 2.0, visit NSIDC's EASE-Grid 2.0 Format Description page.

This data set also utilizes a corresponding EASE-Grid 2.0, 25 km Land-Ocean-Coast-Ice (LOCI) mask derived from the Boston University MOD12Q1 V004 Land Cover Product (BU-MODIS). For more information about the BU-MODIS LOCI 25 km mask, see EASE-Grid 2.0 Land-Ocean-Coastline-Ice Masks Derived from Boston University MODIS/Terra Land Cover Data.

1.5 Temporal Coverage

1 January 1999 - 31 December 2012

1.5.1 Temporal Resolution

Daily

1.6 Parameter or Variable

Snow cover extent in this data set is represented by four different NetCDF variables. Snow cover variable names utilize the following abbreviations:

- The Interactive Multisensor Snow and Ice Mapping System (IMS)
- MODIS Cloud Gap Filled Snow Cover (CGF)
- Passive microwave brightness temperatures (MW)

1.6.1 Variable Description

Data files contain the variables listed in Table 2.

Table 2. Variable Names and Descriptions

Variable Name	Description	Dimensions	Data Type
ims_snow_cover_extent	IMS-derived snow cover extent	720 x 720	byte (signed)
modis_cloud_gap_filled_snow_cover_extent	CGF-derived snow cover extent	720 x 720	byte (signed)
passive_microwave_gap_filled_snow_cover_extent	MW-derived snow cover extent	720 x 720	byte (signed)
merged_snow_cover_extent	Indicates which input products report snow	720 x 720	byte (signed)
latitude	Latitude, center of 25 km EASE-Grid 2.0 cell	720 x 720	float[1]
longitude	Longitude, center of 25 km EASE-Grid 2.0 cell	720 x 720	float[1]
cols	x coordinate, center of 25 km EASE-Grid 2.0 cell (m from origin)	1 x 720	int
rows	y coordinate, center of 25 km EASE-Grid 2.0 cell (m from origin)	720 x 1	int
coord_system	EASE-Grid 2.0 grid and projection parameters	—	char
time	Days since 12/31/1998	—	int
[1]32-bit single precision floating point			

1.6.2 Parameter Range

The three variables derived from individual source products indicate the location of snow and, where applicable, where the original data were changed to reconcile the source data land-cover mask with the BU-MODIS LOCI 25 km mask described in the 1.4.2 section. In the merged snow cover extent variable, land and water areas, as well as permanent ice values masking out most of Greenland and some other areas, correspond to BU-MODIS LOCI 25 km mask.

Refer to the following tables for keys to the values stored in the snow cover extent variables.

Table 3. Key for ims_snow_cover_extent

Value	Description
10	Snow covered land
11	Ocean converted to snow covered land
20	Snow free land
21	Ocean converted to snow free land
40	Ocean
41	Snow covered land converted to ocean
42	Snow free land converted to ocean
90	Missing
-99	Fill value for grid corners

Table 4. Key for modis_cloud_gap_filled_snow_cover_extent

Value	Description
10	Snow covered land
11	Ocean converted to snow covered land
20	Snow free land
21	Ocean converted to snow free land
40	Ocean
41	Snow covered land converted to ocean
42	Snow free land converted to ocean
90	Missing
91	Night
92	Cloud (Cloud Persistence Count > 5. See CGF product description.
-99	Fill value for grid corners

Table 5. Key for passive_microwave_gap_filled_snow_cover_extent

Value	Description
10	Snow covered land
20	Snow free land
30	Permanent ice covered land
40	Ocean
90	Missing
-99	Fill value for grid corners

Table 6. Key for merged_snow_cover_extent

Value	Description
10	IMS, MW, and CGF report snow
11	CGF and MW report snow
12	CGF and IMS report snow
13	MW and IMS report snow
14	CGF reports snow
15	MW reports snow
16	IMS reports snow
20	Snow free land
30	Permanent ice covered land
40	Ocean
-99	Fill value for grid corners
IMS: Interactive Multisensor Snow and Ice Mapping System CGF: MODIS Cloud Gap Filled Snow Cover MW: DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures, Version 2	

2 SOFTWARE AND TOOLS

Unidata at the University Corporation for Atmospheric Research maintains an extensive list of freely available Software for Manipulating or Displaying NetCDF Data.

3 DATA ACQUISITION AND PROCESSING

Source products for this data set were either downloaded via public website or delivered by project investigators directly to Rutgers University for processing. The following sections describe how each source product was converted into its corresponding snow cover extent variable.

3.1 The Interactive Multisensor Snow and Ice Mapping System

3.1.1 Data Acquisition

The Interactive Multisensor Snow and Ice Mapping System (IMS) product is produced at the National Ice Center (NIC) from a variety of sources, including:

Visible and Infrared Spectral Data

- Advanced Very High Resolution Radiometer (AVHRR) Channels 1 & 3
- Geostationary Operational Environmental Satellite (GOES) East and West
- Meteosat 7
- Meteosat Second Generation (MSG)
- Moderate Resolution Imaging Spectroradiometer (MODIS) Channel 8
- Multi-functional Transport Satellite (MTSAT)
- Suomi National Polar-Orbiting Partnership

Ancillary Data

- Surface Observations (METAR)

Derived Data

- Air Force Weather Agency (AFWA) Snow Depth
- Advanced Microwave Scanning Radiometer for EOS (AMSR-E)
- Advanced Microwave Sounding Unit (derived snow, ice, and rain)
- Advanced Scatterometer (ASCAT)
- Envisat Advanced Synthetic Aperture Radar (ASAR) operating in Global Monitoring Mode
- SSMI/S (Derived snow, ice and rain)
- NASA Quick Scatterometer (QuikSCAT)
- NOAA Office of Satellite Data Processing and Distribution (OSDPD) Automated Multisensor Snow and Ice
- National Operational Hydrologic Remote Sensing Center (NOHRSC) Snow Data Assimilation System (SNODAS)
- United States Air Force Snow and Ice Analysis Product

Trained analysts at NIC produce IMS daily 24 km snow maps once per day, using an interactive workstation application to incorporate a wide variety of satellite imagery, derived mapped products, and surface observations. IMS daily ASCII files were acquired from NIC, converted to binary using the NCAR Command Language (NCL), and regridded to EASE-Grid 2.0 with Mapx.

3.1.2 Processing Steps

The data were compared with the BU-MODIS LOCI 25 km mask. In cases where an ocean pixel was converted to land, a 3x3 moving box filter was used to determine snow cover. With the converted cell in the center, surrounding land cells were examined and if more than 50 percent of the original surrounding land cells were snow covered, the cell was assigned a snow cover value. Otherwise the cell was determined to be snow-free land.

In cases where an island pixel was created by converting ocean to land, the same 3x3 box filter was utilized to determine the percentage of adjacent cells with IMS values for ice. If more than 50 percent of the surrounding water cells were ice, the new pixel was assigned a snow cover land value.

Once reconciled with BU-MODIS LOCI 25 km mask, the data were written to the ims_snow_cover_extent variable.

For more information about the Interactive Multisensor Snow and Ice Mapping System, visit the U.S. National Ice Center IMS Products Web page.

3.2 MODIS Cloud Gap Filled Snow Cover

3.2.1 Data Acquisition

MODIS Cloud Gap Filled Snow Cover (CGF) data are derived from MOD10C1, the MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG fractional snow cover product. MODIS, the Moderate Resolution Spectroradiometer, is a key instrument onboard Terra, the flagship satellite in NASA's Earth Observing System platform.

MODIS snow-cover products are inherently limited by cloud cover, which obscures the sensor's view of the ground and introduces gaps into the daily snow cover maps. The cloud-gap-filled daily snow cover maps are produced using a simple algorithm that fills cloud-obscured grid cells with a previous day's observation of the ground.

3.2.2 Processing Steps

If the cloud cover in a cell is greater than or equal to 80 percent, according to the MODIS cloud mask, the last view of the ground is retained as the observation for the current day. To ensure that users are aware of the age of each observation on a per-grid cell basis, the number of days of cloud cover preceding the image date is tracked and updated daily for every grid cell. These data are written to a separate variable known as the Cloud Persistent Count (CPC). When a view of the surface is re-acquired after one or more days of cloud cover, the CPC is reset to zero for that grid cell. This approach typically results in a nearly cloud-free map of snow cover extent within 5 to 10 consecutive days of initiation (Hall et al., 2010).

The MODIS CGF source product input to this data set was generated at NASA Goddard Space Flight Center (GSFC)[1]. Observations were limited to five or fewer days (CPC ≤ 5) and the resulting cloud-gap-filled snow cover maps were regridded to EASE-Grid 2.0 using nearest neighbor interpolation. These data were then delivered to Rutgers University.

At Rutgers, fractional snow cover greater than or equal to 40 percent was set as the threshold for snow-covered land. The data were compared with the BU-MODIS LOCI 25 km mask and ocean pixels that were converted to land were evaluated in the same manner as the IMS product. With the converted cell in the center, a 3x3 moving box filter was used to examine the surrounding land cells. If more than 50 percent of the source data land cells were snow covered, the cell was assigned as snow covered land. Otherwise the cell was determined to be snow-free land. Once reconciled with the BU-MODIS LOCI 25 km mask, the data were written to the modis_cloud_gap_filled_snow_cover_extent variable.

For a complete description of the MODIS cloud-gap-filling algorithm, refer to Hall, et al 2010.

[1]This product is not available to the public.

3.3 Passive Microwave Brightness Temperature Gap-Filled Snow Cover

3.3.1 Data Acquisition

Snow cover extent was derived from passive microwave brightness temperatures using the DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures data set. In a series of ongoing missions, the Defense Meteorological Satellite Program (DMSP) has been acquiring brightness temperature data since 09 July 1987 with the Special Sensor Microwave/Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSMIS) instruments onboard DSMP satellites F8, F11, F13, F17.

Table 7 lists the satellites, instruments, and date ranges that were used for this data set.

Table 7. Satellite and Instrument Date Ranges

Satellite	Instrument	Dates
F13	SSM/I	1 January 1996 – 31 December 2007
F17	SSMIS	1 January 2008 – 31 December 2012

3.3.2 Processing Steps

The following steps were used to convert brightness temperatures into snow cover:

1. SSMIS F17 brightness temperatures were converted to SSM/I F13 based on the methodology in Meier et al., 2011. Ascending and descending passes were averaged into daily average brightness temperatures.
2. The presence of snow was identified where the 19/37 GHz and 22/85 GHz (91 GHz for SSMIS) vertical polarization frequency gradients exceed minimum thresholds. Additionally, the brightness temperature for the 37 GHz channels (horizontal and vertical polarization) and 85GHz (vertical polarization) must not exceed a maximum threshold. The approach is conceptually similar and uses the same frequency gradients and channels as the AMSR-E Snow Water Equivalent Algorithm. Refer to the text by Chang and Rango, 2000 for more information. Thresholds were set to achieve a 60 percent probability of detecting snow, determined by: hemispheric comparison with IMS snow; snow depth observations from available stations including the Global Historical Climatology Network, cooperative stations, and the Meteorological Service of Canada; and daily average brightness temperatures during the 2005-2006 snow season. The thresholds are listed in Table 8.

Table 8. Criteria for Identifying Snow

Channel	Threshold
19V–37V	> 7 K
22V–85V (22V–91V)	> 8 K
37V	< 256 K
37H	< 243 K
85V	< 253 K

3. At locations where the elevation exceeds 1500 meters above mean sea level, the 19/37 GHz and 22/85 GHz frequency gradients were reduced by 0.001 K and 0.002 K per meter elevation, respectively. This correction was applied because passive microwave snow retrievals overestimate snow-covered area in high elevation locations, and in particular the Tibetan Plateau, because the decrease in atmospheric thickness increases the spectral gradient.

Refere to the text by Savoie et al., 2009 for more information. The coefficients were determined by a comparison with high elevation (>1500 m) locations in the same manner discussed in Step 2.

4. In regions with a maximum snow-covered albedo ≤58 percent, the 19/37 GHz and 22/85 GHz frequency gradients were increased by 3 K and 4K, respectively. Because snow that falls through the canopy may not be apparent when on the ground (Foster et al. 1991), passive microwave snow retrievals underestimate snow covered area in densely forested locations such as the boreal forests. To account for this effect, a maximum snow covered albedo data set (Robinson et al., 1985) was regridded to EASE Grid 2.0 and used to identify regions in which snow cover is spectrally masked by vegetation. Coefficients were determined by comparing areas with maximum snow covered albedo ≤58% in the same manner discussed in step 2.
5. The criteria described in Step 2, as modified in steps 3 and 4, were applied to the daily average brightness temperatures to determine the presence or absence of snow. Internally, separate codes were used to track cells with snow cover identified by only the 19 GHz and 37 GHz channels or the 85 (91) GHz channels.
6. Areas of missing data were reduced by employing a six-day gap fill. If data were missing for a given date, the most recent previous date with valid data (up to five days prior) was retained as the observation for the current day.
7. The resulting gap-filled snow cover map was regridded to EASE-Grid 2.0 using Mapx.
8. Areas of permanent ice and ocean were masked using the BU-MODIS LOCI 25 km mask. A maximum snow cover extent mask was also applied based on all cells with IMS data that indicated snow on any date during a given month.
9. Intermediate, daily two-byte flat binary files in EASE-Grid 2.0 were created for the microwave snow layer. The data were then written to the passive_microwave_gap_filled_snow_cover_extent variable.

3.4 Merged Snow Cover Extent

3.4.1 Processing Steps

Once all snow cover variables were reconciled with the BU-MODIS LOCI 25 km mask, the merged snow cover extent variable was generated as follows:

1. BU-MODIS LOCI 25 km mask ocean and land pixels were written to an array.
2. Values for snow covered land and ocean converted to snow covered land were written to the array using the coding scheme in 1.6.2.
3. BU-MODIS LOCI 25 km mask permanent ice values were written to the array.
4. The data were written to the merged_snow_cover_extent variable.

3.4.2 Version History

Version 1.1 was released in July, 2015. Refer to Table 9 for this data set's version history:

Table 9. Version History

Version	Description
V1.1 (Jul, 2015)	Added 1D arrays named cols and rows that contain x and y coordinates (meters from origin) of the projection. v01r01 appended to data file names.
V1 (Sep, 2014)	Initial version.

3.4.3 Error Sources

Missing data represents the biggest impact to data quality, as all the input products lack some daily files during the period of record. The IMS snow cover maps are not constructed according to a formal algorithm, but instead rely on the expertise of trained analysts using the IMS workstation. Because the IMS workstation software is continually being evaulated and improved, changes in mapping methodologies have occurred over time. Error sources in the MODIS Cloud Gap Filled Snow Cover product are discussed in detail in Development and Evaluation of a Cloud-Gap-Filled Modis Daily Snow-Cover Product (Hall, 2010). For the passive microwave derived snow cover, errors in the input data may carry through to the output. For details about potential errors in passive microwave brightness temperatures, see the 3.4.3 section of the DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures, Version 2 documentation.

4 REFERENCES AND RELATED PUBLICATIONS

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4.1 Related Data Collections

- MEaSUREs Northern Hemisphere Terrestrial Snow Cover Extent Weekly 100km EASE-Grid 2.0
- MEaSUREs Arctic Sea Ice Characterization Daily 25km EASE-Grid 2.0
- MEaSUREs Greenland Surface Melt Daily 25km EASE-Grid 2.0
- MEaSUREs Northern Hemisphere State of Cryosphere Daily 25km EASE-Grid 2.0
- MEaSUREs Northern Hemisphere State of Cryosphere Weekly 100km EASE-Grid 2.0
- IMS Daily Northern Hemisphere Snow and Ice Analysis at 4 km and 24 km Resolution
- DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures
- MODIS Data: Overview

4.2 Related Websites

- MEaSUREs Data: Overview
- Northern Hemisphere Snow and Ice Climate Data Records at Rutgers University

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6 DOCUMENT INFORMATION

6.1 Publication Date

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6.2 Date Last Updated

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