Data Set Documentation

Nimbus-7 SMMR Global Monthly Snow Cover and Snow Depth

Summary

The data set consists of monthly global snow cover and snow depths derived from Nimbus-7 SMMR data for 1978 through 1987. The SMMR data are interpolated for spatial and temporal gaps, and averaged for display in polar sterographic projection. Maps are based on six-day average brightness temperature data from the middle week of each month. Data are placed into 1/2 degree latitude by 1/2 degree longitude grid cells uniformly subdividing a polar stereographic map according to the geographic coordinates of the center of the radiometers' fields of view. Overlapping data from separate orbits in the same six-day period are averaged to give a single brightness temperature assumed to be at the cell's center. Oceans and bays are masked so that only microwave data for land areas are displayed.

Data are available via ftp. Contact NSIDC User Services for details.

Table of Contents

1.Data Set Overview

Data Set Identification

Nimbus-7 SMMR Derived Global Snow Cover and Snow Depth 1978-1987 (Chang)

Data Set Introduction

In the Northern Hemisphere, the mean monthly snow cover ranges from about seven percent to over 40 percent of the land area, making snow the most rapidly varying natural surface feature. This variability means that snow is a sensitive indicator of climate change, depending on temperature, precipitation and solar radiation for existance. Yet, once on the ground, snow influences each of these climatic factors, with important economic consequences: moisture stored in winter snowpack supplies as much as one third of the world's irrigation waters (Gray and Male 1981).

Snow cover and depth change rapidly over large areas during fall buildup and spring melt. To adequately forecast and model these changes, accurate snow and ice observations are needed, and long-term data bases of snow parameters must be collected. To understand heat transfer between the atmosphere, snowpack and ground, snow depth *and* snow extent must be known.

Prior to the use of microwave technologies, snow extent was monitored via satellite using visible and near infrared frequencies, but data acquisition was often impaired by cloud cover or darkness. Most snow depth observations were limited to point measurements, with the result that sparsely inhabited areas were poorly represented.

Beginning in November 1978, the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 satellite, with its capacity for penetrating clouds and snow packs, made it feasible to measure snow extent, calculate snow depth on an areal basis, and retrieve snow water equivalent regardless of weather or lighting conditions.

Passive microwave data from SMMR and SSM/I have the ability to provide wider and more realistic synoptic representations of snow than have previously been available. With time and evaluation, such data may prove invaluable to the study and understanding of the climatic and economic impacts of snow.

Objective/Purpose

This snow cover data set supports climate modeling, snow melt run-off, and other geophysical studies.

Summary of Parameters

This data set provides snow depth and snow cover extent. Global monthly files extend from November 1978 through August 1987.

from SMMR is usually about ten percent less than that measured by the earlier products, because passive microwave sensors often can't detect shallow dry snow less than about 5 cm deep. Snow depths are comparable, showing SMMR results to be especially good for uniform snow covered areas such as the Canadian high plains and Russian steppes. Heavily forested and mountainous areas tend to mask the microwave snow signatures, and SMMR snow depth derivations are poorer in those areas.

Satellite snow cover records are presently too short to determine definite trends. Continued monitoring will be needed to define snow accumulation and depletion patterns, and to detect correlations between snow cover and large-scale circulation patterns.

Related Data Sets

- Nimbus-7 SMMR Polar Radiances and Arctic and Antarctic Sea Ice Concentrations on CD-ROM
- Historical Soviet Daily Snow Depth (HSDSD)
- Rand Corporation Global Monthly Snow Depth

2.Investigator

Investigator's Name and Title

Alfred T. C. Chang

Title of Investigation

Nimbus-7 SMMR Derived Global Snow Cover and Snow Depth 1978 - 1987 (Chang)

Contact Information

NSIDC User Services
National Snow and Ice Data Center
CIRES, 449 UCB
University of Colorado
Boulder, CO 80309-0449 USA
phone: +1 303.492.6199
fax: +1 303.492.2468
form: Contact NSIDC User Services
e-mail: nsidc@nsidc.org

3.Theory of Measurements

Microwave radiometery is useful as a remote sensing tool because the emissivity of an object depends on its composition and physical structure. Thus, determination of emissivity provides information on the physical properties of the emitting medium. The equivalent temperature of the microwave radiation thermally emitted by an object is called its brightness temperature (Tb). It is expressed in units of temperature (Kelvin) because for microwave wavelengths, radiation emitted from a perfect emitter is proportional to its physical temperature. An object's emissivity is determined by measuring the brightness temperature radiometrically and by measuring the physical temperature in some manner (Foster et al. 1984).

Microwave emission from a layer of snow over a ground medium consists of emission by the snow volume and emission by the underlying ground. Both contributions are governed by the transmission and reflection properties of the air-snow and snow-ground interfaces, and by the absorption or emission and scattering properties of the snow layer (Stiles et al. 1981).

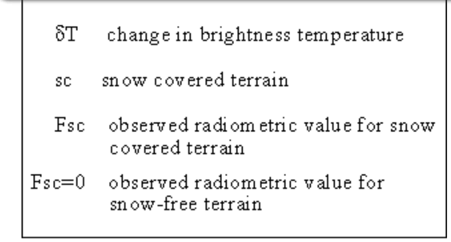
The intensity of microwave radiation emitted through and from a snowpack depends on physical temperature, grain size, density, and underlying surface conditions of the snowpack. In general, the microwave emissivity of snow increases when liquid water is present in the snow; snow often exists near its melting point and, as one of the most unstable natural substances, is subject to extreme structural changes ocurring with freeze-thaw cycles.

Recognizing the microwave signatures of the many forms of snow comes with understanding the way snow's permittivity changes through the various stages of metamorphism. A material's dielectric properties are characterized by the dielectric constant, a measure of the material's response to an applied electric field. This response combines the wave's propagation characteristic (velocity and wavelength) in the material with the energy losses in the media.

Snow parameters significantly affecting microwave sensor response are: liquid water content, crystal size, depth and water equivalent, stratification, snow surface roughness, density, temperature and soil state, moisture, roughness and vegetation. For example, the dielectric constants of water and ice are so different that even a little melting causes a strong microwave response. The low dielectric constant for snow also provides sufficient contrast with bare ground in the brightness temperature range for snowfield monitoring (Rango et al 1979).

Radiation emerging from a snowpack can be derived by solving radiative transfer equations (Chandrasekhar 1960, England 1975, Chang et al. 1978, Tsang and Kong 1977) and using them to calculate brightness temperatures with different physical parameters. When radiometric measurements of brightness temperature are made at more than one microwave wavelength or polarization, it's possible to deduce additional information about the medium. This potential provides the rationale for the development of inversion techniques that calculate desired physical parameters from brightness temperatures measured at multiple wavelengths and polarizations (Gloersen and Barath 1977).

Algorithms to evaluate and retrieve snow cover and snow depth have been derived from research using a combination of microwave sensors aboard satellites, aircraft, and trucks, as well as in situ field studies. A method relating microwave radiometric data to snow cover and snow depth is to examine the differences between the brightness temperature observed for snow-covered ground and that for snow-free ground. The general form of a snow cover algorithm is:



δT	change in brightness temperature
sc	snow covered terrain
Fsc	observed radiometric value for snow covered terrain
Fsc=0	observed radiometric value for snow-free terrain

4.Equipment

Please refer to the Scanning Multi-channel Microwave Radiometer (SMMR) instrument description document.

5.Data Acquisition Methods

Nimbus-7 SMMR flight data were received by the Meteorological Operations Control Center (MetOCC). The user-formatted output tape from MetOCC was then transferred to and processed by the Science and Applications Computer Center. Two calibrated brightness temperature tapes, CELL-ALL and TCT (Temperature Calibrated Tape) were produced. CELL-ALL data were gridded according to SMMR spatial resolution while TCT data retained footprint configuration. TCTs were used for the snow parameters.

6.Observations

Please review The Snow Microwave Data Set.

7.Data Description

Spatial Characteristics

Spatial Coverage

Data are global, and although nearly all of the SMMR analysis and validation have been performed in the Northern Hemisphere, snow cover observations for the Southern Hemisphere are included in this data set.

However, there is very little variation in snow cover on an annual basis in the Southern Hemisphre. Over 99 percent of the snow is confined to the continent of Antarctica, which, except for coastal areas and the Antarctic Peninsula during the summer months, is always snow covered. Seldom are areas larger than the SMMR pixel completely snow covered in Australia and Africa. The South Island of New Zealand and western South America have numerous glaciers in the Southern Alps and Andes mountain, but the only extensive area of seasonal snow in the Southern Hemisphere is found in Chile and Argentina (Patagonia and Pampas regions). In 1980, the snow covered area reached a maximum of over one million square kilometers in South America, and in 1979 the maximum was less than 700,000 square kilometers as measured from the NOAA satellites (Dewey and Heim 1983). Thus, it's likely that the snow cover area and variability are large enough to affect the weather and climate in nonequatorial areas of South America.

Spatial Resolution

Data are placed into 1/2 degree latitude by 1/2 degree longitude grid cells uniformly subdividing a polar stereographic map according to the geographic coordinates of the center of the radiometers' fields of view.

Projection

Data are gridded in the polar stereographic projection.

Grid Description

The maps are constructed by projecting points on the Earth's surface onto a plane tangent to the surface at one of the poles, with the vertex of the projection being the other pole (Parkinson et al. 1987).

Data are displayed in half-degree grids. The maps have the following specifications:

- Top latitude: 85 degrees North
- Bottom latitude: 85 degrees South
- Left longitude: 180 degrees West
- Right longitude: 180 degrees East
- No. of columns (1/2 degree longitude/col.): 720
- No. of rows (1/2 degree latitude/row): 340 (not including the header, see Sample Data Record).
- Map grid data type: unsigned 8-bit integer

Temporal Characteristics

The SMMR sensor operated 25 October 1978 through 20 August 1987. The sensor was placed in an alternate-day operating pattern on 19 November 1978 due to spacecraft power limitations, providing complete global coverage every six days. Regions poleward of 72 degrees have complete coverage for each day the sensor was recording data.

SMMR data were interpolated for spatial and temporal gaps. Overlapping data in a cell from separate orbits within the same six-day period are averaged to give a single brightness temperature, assumed to be at the center of the cell. The snow cover maps are based on six day average brightness temperature data from the middle week of one month.

Sample Data Record

The data consist of 106 files of snow data from November 1978 to August 1987. Each file is one monthly map. Each file contains 341 logical records. The first record is an ASCII character header. It contains the period of the map. The days used to create the maps are given as ranges expressed in Julian days, and for some maps, also in calendar days. These are usually two ranges of days. The year is included as is themap number with the first map being "world map #1." This information is not given in the same sequence in each header file, so users need to read the entire header. For example:

```
NITE 005    DAY 305 - 307    YR  1978--WORLD MAPS #01    NITE 007   DAY 308 - 310 YR 1978--WORLD MAPS #01
NITE 001    DAY 004 - 008    YR  1979 -TCT0 16-   4JAN- 8JAN WLD#04   NITE 003   DAY 010 - 014  YR 1979--WORLD MAPS #04
```

8.Data Organization

Data Granularity

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format

See Grid Description and Sample Data Record. The map grid data are unsigned 8-bit integers. Grid elements may have the following values:

- 255 -- water
- 254 -- permanent ice
- 253 -- no data available, or data failed quality filters
- 252 -- unused
- 251 -- unused
- 3 - 250 -- snow depth in centimeters
- 0 -- no snow, or snow less than 2.5 cm

9.Data Manipulations

The monthly snow cover and snow depth maps produced for this data set were generated using the algorithm developed by Chang et al. (1987). The algorithm assumes a uniform or "ideal" snowpack for the entire snow-covered part of the Northern Hemisphere. Because snow is not uniform, results from the algorithm are more accurate in snow-covered areas in which the snow conforms to the ideal.

The difference between the SMMR 37 GHz and 18 GHz channels is used to derive a snow depth-brightness temperature relationship for a uniform snow field:

$$SD = 1.59 \bullet (T_{B18H} - T_{B37H})$$

where SD is snow depth in cm, H is horizontal polarization, and 1.59 is a constant derived by using the linear portion of the 37 and 18 GHz responses to obtain a linear fit of the difference between the 18 GHz and 37 GHz frequencies. If the 18 GHz Tb is less than the 37 GHz Tb, the snow depth is zero and no snow cover is assumed.

Evaluation of similar algorithms shows that only those that include the 37 GHz channel provide adequate agreement with manually measured snow depth and snow water equivalent values. It may be noted that the Tb18H - Tb37H often gives better results than the 37 GHz channel alone. Using the 18 GHz channel reduces the snow temperature, ground temperature, and atmospheric water vapor effects on brightness temperatures.

10.Errors

Seasonal and annual variability in snow extent have been measured from SMMR data as well as Advanced Very High Resolution Radiometer (AVHRR) data collected on the NOAA satellites, but the error bands are lacking for both products. The SMMR and NOAA products agree fairly well, but SMMR data produce consistently lower snow covered area estimates than do the NOAA data. For example, snow covered area in the Northern Hemisphere for January 1984 as measured from the SMMR and NOAA data differ by about 16 percent. The error in the SMMR-derived snow depths is difficult to determine because there is no reliable data set with a spatially dense enough network with which to compare them, on a hemispheric basis. The only other data set available with which to derive global snow volume is the data set produced by the Rand Corporation. The monthly averaged Rand data set was constructed using climatological averages from meteorological station data. Preliminary comparisons between the SMMR and the Rand Northern Hemisphere snow volume data indicate that the sets are comparable. The error bands are unknown and may be large; however, this SMMR temporal data set is the only source of monthly snow volume currently available (Chang et al 1990).

11.Notes

The establishment of the microwave snow data set has permitted a quantitative assessment of changes in global snow depth and volume and has demonstrated that considerable interannual variability in snow volume exists. Thus far, the Southern Hemisphere snow data have not been analyzed as thoroughly as those of the Northern Hemisphere. The data record is too short to detect any trends that may exist, but preliminary analysis indicates that variations between South American and North American seasonal snow cover are poorly correlated.

12.Application of the Data Set

Please review Trends.

13.Future Modifications and Plans

Advanced snow cover data sets are being developed; please watch these pages.

15.Data Access

NSIDC User Services
National Snow and Ice Data Center
CIRES, 449 UCB
University of Colorado
Boulder, CO 80309-0449 USA
phone: +1 303.492.6199
fax: +1 303.492.2468
form: Contact NSIDC User Services
e-mail: nsidc@nsidc.org

16.Output Products and Availability

This data set is available ftp. Please contact NSIDC User Services to request data on alternate media.

17.References

The information in this document has been primarily summarized from:

Chang, A. T. C., J. L. Foster, D. K. Hall, H. W. Powell, and Y.L. Chien. 1992. *Nimbus-7 SMMR Derived Global Snow Cover and Snow Depth Data Set.* The Pilot Land Data System. NASA/Goddard Space Flight Center. Greenbelt, MD.

Please consult the reference list for the comprehensive bibliography.

18.Acronyms and Abbreviations

The following acronyms and abbreviations are used in this document.

URL	Uniform Resource Locator

19.Document Information

Document Revision Date

August 1995

Document Review Date

August 1995

Document ID

NSIDC-0024

Citation

As a condition of using these data, you must cite the use of this data set using the following citation. For more information, see our Use and Copyright Web page.

Chang, A. T.C. 2003. *Nimbus-7 SMMR Derived Monthly Global Snow Cover and Snow Depth*. [indicate subset used]. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center.

Document Curator

NSIDC Writers

Document URL

http://nsidc.org/data/docs/daac/nsidc0024_smmr_global_snow.gd.html