## 1. TITLE

### 1.1 Data Set Identification

ISLSCP II Northern Hemisphere Monthly Snow Cover Extent

### 1.2 Database Table Name(s)

Not applicable to this data set.

### 1.3 File Name(s)

The following files are included in this data set:

**snow_cover_data_XX_YYYY.csv**: Original files submitted by the Principal Investigator in tabular format. These original data contain gridded Northern Hemisphere monthly snow cover extent, in percent, arranged within 10 yearly files. XX is qd, hd, or 1d indicating a spatial resolution of one quarter, one half, or 1 degree, respectively, in both latitude and longitude. YYYY is the year from 1986 to 1995. These files are in the "snow_cover_data" directories. See Section 8.2 for complete file descriptions.

**snow_cover_map_1d_YYYYMM00.asc:** 120 files with the 1 degree gridded snow cover extent data arranged on a global grid. YYYY is the year from 1986 to 1995 and MM is the month from 01 to 12. The 00 means this is a monthly average. These files are in the "snow_cover_map_1deg" directory. **NOTE***:** At this revision, these files are only available at a 1 degree spatial resolution.

**snow_cover_mask_diffs_1d.asc**: gridded ASCII map showing the differences between the ISLSCP II land/water mask and the original data set: All points with negative values ("-1") are those where the ISLSCP II mask showed water but where the original data set showed land and this point was removed. All points with a value of zero are those points where the two land/water masks agreed.

### 1.4 Revision Date of this Document

April 26, 2010

## 2. INVESTIGATOR(S)

### 2.1 Investigator(s) Name and Title

Richard L. Armstrong, Senior Research Scientist, Cooperative Institute for Research in Environmental Sciences (CIRES) and National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder.

### 2.2 Title of Investigation

ISLSCP II Northern Hemisphere Snow Cover Extent.

### 2.3 Contacts (For Data Production Information)

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### 2.4 Data Set Citation

Armstrong, R.L., and M.J. Brodzik. 2010. ISLSCP II Northern Hemisphere Monthly Snow Cover Extent. In Hall, Forrest G., G. Collatz, B. Meeson, S. Los, E. Brown de Colstoun, and D. Landis (eds.). ISLSCP Initiative II Collection. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/982

### 2.5 Requested Form of Acknowledgment

Users of the International Satellite Land Surface Climatology (ISLSCP) Initiative II data collection are requested to cite the collection as a whole (Hall et al. 2006) as well as the individual data sets. Please cite the following publications when these data are used:

Hall, F.G., E. Brown de Colstoun, G. J. Collatz, D. Landis, P. Dirmeyer, A. Betts, G. Huffman, L. Bounoua, and B. Meeson, The ISLSCP Initiative II Global Data sets: Surface Boundary Conditions and Atmospheric Forcings for Land-Atmosphere Studies, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007366, 2006.

Please acknowledge the National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder, when these data are used.

## 3. INTRODUCTION

### 3.1 Objective/Purpose

Because snow and ice surfaces represent exceptionally high albedo, with associated effects on surface energy exchange, compared to other surface types, it was considered important to create a data set that provided the longest possible time series of combined snow cover and sea ice extent. This time series is also important because fluctuations in snow and ice extent are considered important indicators of climate change. The sea ice extent data are part of another data set also included in the ISLSCP II collection.

### 3.2 Summary of Parameters

Northern Hemisphere monthly snow cover extent from 1986 to 1995 is provided in their original tabular format by year (three spatial resolutions), and as individual monthly files on a global 1.0 degree Earth grid. The individual monthly files have been made consistent with the 1.0 degree land/water mask used in this collection. An ancillary file that shows the differences between this mask and the land/water boundaries in the original 1.0 degree data sets is also provided.

### 3.3 Discussion

This International Satellite Land Surface Climatology Project (ISLSCP) Initiative 2 data set is derived from the NSIDC Northern Hemisphere Equal-Area Scalable Earth Grid (EASE-Grid) Weekly Snow Cover and Sea Ice Extent Version2 product which combines snow cover and sea ice extent at weekly intervals for October 1978 through June 2001, and snow cover alone from 1966 through June 2001 (Sea ice data were not available prior to October 23, 1978). Snow cover extent is based on the digital National Oceanic and Atmospheric Administration (NOAA)-National Environmental Satellite Data and Information Service (NESDIS) Weekly Northern Hemisphere Snow Charts, revised by D. Robinson (Rutgers University) and regridded to the EASE-Grid. The original NOAA-NESDIS weekly snow charts are derived from the manual interpretation of Advanced Very High Resolution Radiometer (AVHRR), Geostationary Operational Environmental Satellite (GOES), and other visible-band satellite data.

The original data set was the first representation of combined snow and sea ice measurements derived from satellite observations for the period of record. Designed to facilitate the study of Northern Hemisphere seasonal fluctuations of snow cover and sea ice extent, the original NSIDC data set also includes monthly climatologies describing average extent, probability of occurrence, and variance. These original data are provided in a 25 km equal area grid (NSIDC EASE- Grid). (see http://nsidc.org/data/nsidc-0046.html ). The original data were re-gridded by NSIDC from their original 25km spatial resolution and EASE-Grid into equal angle Earth grids with quarter, half, and one degree spatial resolutions in latitude/longitude. The ISLSCP II staff have also adjusted the re-gridded one degree original data to match the ISLSCP II land/water mask.

## 4. THEORY OF ALGORITHM/MEASUREMENTS

Since 1966 NOAA has produced weekly snow extent charts for the Northern Hemisphere land surface using visible-band satellite imagery (Robinson et al., 1993; Frei and Robinson, 1999). These snow extent maps are the result of the manual interpretation of 7 consecutive days of visible satellite imagery (including data from all visible sensors available to the operator with AVHRR and GOES being the most common and consistent source). Each final weekly product shows snow boundaries on the last day of the chart week that the surface in a given region is seen by the operator. These charts were then digitized using an 89 by 89 cell Northern Hemisphere grid in a polar stereographic projection (Dewey and Heim, 1982). Cell resolution ranges from 16,000 to 42,000 square kilometers. Only cells interpreted to be at least 50% snow covered were considered snow covered. The original NOAA data, subsequent to thorough quality control by Robinson et al. (1993), have been re-gridded to the NSIDC Equal-Area Scalable Earth Grid (EASE-Grid) via nearest neighbor interpolation. When the EASE-Grid pixel being set mapped to a NOAA pixel classified as snow, it was simply set to snow to retain as much of the original information as possible.

## 5. EQUIPMENT

Snow extent maps are derived from the manual analysis of all visible satellite data available to the operator, typically AVHRR, GOES, METSAT, and other visible band satellite sensors providing data during the period 1966 to 1999. For more information on the original source data see http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html .

Although snow may be one of the single easiest features on the surface of the Earth to identify from space, verifying its presence is not always a straightforward matter. Not only do clouds look like snow in the visible wavelengths, but during the polar winter, darkness limits the viewing opportunities over snow covered regions. Polar orbiting satellites have suitable resolution for mapping snow on a global basis, but a given location may only be viewed once per day, except at the highest latitudes. Nevertheless, because in most cases even the most persistent clouds will depart a particular area after several days, on a weekly basis, global snow maps generally give a good indication of where snow exists.

## 5.1 Instrument Description

### 5.1.1 Platform (Satellite, Aircraft, Ground, Person)

Satellites (see above).

### 5.1.2 Mission Objectives

Various.

### 5.1.3 Key Variables

Northern Hemisphere monthly snow extent, probability of occurrence.

### 5.1.4 Principles of Operation

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html for more information on the original source data.

### 5.1.5 Instrument Measurement Geometry

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html for more information on the original source data.

### 5.1.6 Manufacturer of Instrument

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html for more information on the original source data.

## 5.2 Calibration

Snow extent maps are derived from the manual interpretation and analysis of all visible satellite data available to the operator, typically AVHRR, GOES, METSAT etc. See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html for specific calibration information of the original source data.

### 5.2.1 Specifications

#### 5.2.1.1 Tolerance

See above.

### 5.2.2 Frequency of Calibration

See above.

### 5.2.3 Other Calibration Information

See above.

# 6. PROCEDURE

## 6.1 Data Acquisition Methods

The original digitized NOAA/NESDIS Northern Hemisphere Snow Extent data were revised by D. Robinson, Rutgers University, and provided to NSIDC. NSIDC has made these data available to the ISLSCP II staff.

## 6.2 Spatial Characteristics

### 6.2.1 Spatial Coverage

Land surface of the Northern Hemisphere.

### 6.2.2 Spatial Resolution

This ISLSCP II data set is provided on an equal-angle Earth grid with spatial resolutions of 1/4, 1/2 and 1 degree in both latitude and longitude.

The original snow extent maps are the result of the manual interpretation of 7 consecutive days of visible satellite imagery and each final weekly product shows snow boundaries on the last day of the chart week that the surface in a given region is seen by the operator. These charts were then digitized using an 89 by 89 cell Northern Hemisphere grid in a polar stereographic projection (Dewey and Heim, 1982). Cell resolution ranges from 16,000 to 42,000 square kilometers. Only cells interpreted to be at least 50 percent snow covered were considered snow covered. The original NOAA data have been re-gridded to the 25 by 25 km version of the NSIDC Equal-Area Scalable Earth Grid (EASE-Grid) for ease of use and no increase in spatial resolution is achieved.

## 6.3 Temporal Characteristics

### 6.3.1 Temporal Coverage

January 1986 through December 1995.

### 6.3.2 Temporal Resolution

The snow extent probability maps are monthly.

# 7. OBSERVATIONS

## 7.1 Field Notes

Not applicable to this data set.

# 8. DATA DESCRIPTION

## 8.1 Table Definition with Comments

Not applicable to this data set.

## 8.2 Type of Data

| 8.2.1 Parameter/ Variable Name | 8.2.2 Parameter/ Variable Description | 8.2.3 Data Range | 8.2.4 Units of Measurement | 8.2.5 Data Source |
|---|---|---|---|---|
| **1) Original Files (snow_cover_data_XX_YYYY.csv)** | | | | |
| LONG | Longitude for the center of a cell. West longitudes are negative. | -179.50 degrees to 179.50 degrees | Decimal Degrees | NSIDC |
| LAT | Latitude for the center of a cell. South latitudes are negative. | 83.50 degrees to 24.50 | Decimal Degrees | NSIDC |

| | | | | |
|---|---|---|---|---|
| | | degrees$^{o}$ | | |
| JAN | Percentage of time in the month of January of the year YYYY that a particular cell was snow covered | 0-100 | Percent of period that grid cell was >50% snow covered | Multiple satellites |
| FEB | Percentage of time in the month of February of the year YYYY that a particular cell was snow covered. | 0-100 | Percent | Multiple satellites |
| **...** | **...** | **...** | **...** | **...** |
| DEC | Percentage of time in the month of December of the year YYYY that a particular cell was snow covered | 0-100 | Percent | Multiple satellites |
| LAND_MASK | Value of the ISLSCP II land/water mask:<br>0= Water<br>1= Land | 0-1 | See 8.2.2 | ISLSCP II land/water mask |
| **2) "Mapped" Files (snow_cover_map_1d_YYYYMM00.asc)** | | | | |
| Snow Cover Extent | Percentage of time in a given month that each cell was snow covered | 0-100<br>No Land Data=-88<br>Water=-99 | Percent | Multiple satellites |
| **3) File snow_cover_mask_diffs_1d.asc** | | | | |
| Points Changed | Differences between the ISLSCP II land/water mask and the original data:<br>-1 = ISLSCP II mask is water and original data is land (data removed)<br>0 = Data sets agree over land or water (data unchanged)<br>1 = ISLSCP II mask is land or water and original data is missing (fill value used). | -1 to 1 | See 8.2.2 | Original data and ISLSCP II land/water mask |

### 8.3 Sample Data Record

Sample data records for the original file **snow_cover_data_1d_1986.csv** are given below:

```
LONG,LAT,JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC,LAND_MASK
-38.50,83.50,100,100,100,100,100,100,100,100,100,100,100,100,1
-37.50,83.50,100,100,100,100,100,100,100,100,100,100,100,100,0
-36.50,83.50,100,100,100,100,100,100,100,100,100,100,100,100,1
-35.50,83.50,100,100,100,100,100,100,100,100,100,100,100,100,1
-34.50,83.50,100,100,100,100,100,100,100,100,100,100,100,100,0
```

### 8.4 Data Format

All of the files in the ISLSCP Initiative II data collection are in the ArcGIS ASCII Grid format. The original data files **snow_cover_data_XX_YYYY.csv** all have a total of 15 columns separated by a single comma and a number of rows that ranges from 8585 (file **snow_cover_data_1d_1994.csv**) to 140621 (file **snow_cover_data_qd_1987.csv**). No data are written to the tables for cells which had 0% snow cover for the entire year. Only numerical fields are included as described in Section 8.2.

The file format for the "mapped" monthly snow cover extent files **snow_cover_map_1d_YYYYMM00.asc** and the **snow_cover_mask_diffs_1d.asc** files consists of numerical fields of varying length, which are delimited by a single space and arranged in columns and rows. The files each contain 360 columns by 180 rows. All values in these files are written as real numbers. Water cells in the **snow_cover_map_1d_YYYYMM00.asc** files are given the value –99. There are 3 cells over land that have no data (value=-88).

All files are gridded to a common equal-angle lat/long grid, where the coordinates of the upper left corner of the files are located at 180 degrees W, 90 degrees N and the lower right corner coordinates are located at 180 degrees E, 90 degrees S. Data in the map files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North.

### 8.5 Related Data Sets

See References and http://www.nsidc.org/. A Sea Ice Extent data set from NSIDC covering the same period as this one is also available in this collection. ISLSCP II data sets may also be obtained from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC): http://daac.ornl.gov/ISLSCP_II/islscpii.html .

## 9. DATA MANIPULATIONS

### 9.1 Formulas

#### 9.1.1 Derivation Techniques/Algorithms

The original NOAA Northern Hemisphere weekly snow extent maps were produced using visible-band satellite imagery (Robinson et al., 1993; Frei and Robinson, 1999). These snow extent maps are the result of the manual interpretation of 7 consecutive days of visible satellite imagery (including data from all visible sensors available to the operator with AVHRR and GOES being the most common and consistent source). Each final weekly product shows snow boundaries on the last day of the chart week that the surface in a given region is seen by the operator. These charts were then digitized using an 89 by 89 cell Northern Hemisphere grid in a polar stereographic projection (Dewey and Heim, 1982). Cell resolution ranges from 16,000 to 42,000 square kilometers. Only cells interpreted to be at least 50 percent snow covered were considered snow covered. Because this is a manual procedure, no "algorithm" in a numerical sense is involved. The original NOAA data, subsequent to thorough quality control by Robinson et al. (1993), have been re-gridded to the NSIDC EASE-Grid via nearest neighbor interpolation. When the EASE-Grid pixel being set mapped to a NOAA pixel classified as snow, it was simply set to snow to retain as much of the original information as possible.

### 9.2 Data Processing Sequence

### 9.2.1 Processing Steps and Data Sets

The data range from 0 to 100 percent, indicating the fraction of time per month that the grid cell was at least 50% snow covered. Each original 25km weekly value was regridded to one degree, half degree, and quarter degree latitude longitude equal-area Earth grids using bilinear interpolation. The regridding software determined what fraction of the destination grid cell was covered by source cells with snow. Then, any destination grid cell that was snow covered at least 50% was marked "snow covered" for that week. If a given week extends between two months, that particular week was placed in the month that contained the 4th day of that week. The final value is the ratio of snow covered weeks to total weeks that month. For example, five weekly values fall into a month: 12%, 10%, 9%, 54%, 96%. Two weeks are at least 50% so the cell gets 40% for the whole month. No data are written to the table for cells which had 0% snow cover for the entire year**.**

### 9.2.2 Processing Changes

None.

### 9.2.3 Additional Processing by the ISLSCP II Staff

The ISLSCP II staff have taken the 1 degree resolution original data provided by the Principal Investigators and created global maps of monthly snow cover extent. Every cell in the **snow_cover_data_1d_YYYY.csv** files was assigned to its corresponding location on a global $1^{o}$ grid using the latitude and longitude coordinates that were provided. Individual monthly files were created and written to the ASCII format. These files are named **snow_cover_map_1d_YYYYMM00.asc**.

The **snow_cover_map_1d_YYYYMM00.asc** files have all been made consistent with the ISLSCP II one degree land/water mask. Because no land/water mask was provided with the original data, mismatches between these data and the ISLSCP II mask were identified by overlaying the ISLSCP II 1 degree mask onto an average of all the 1 degree, monthly snow cover extent data from 1986 to 1995. The 1986-1995 average was used because cells with zero snow cover located at the edges of the actual snow cover were not easily separable from zero values resulting from an actual mismatch between the land/water mask used in the original processing of the data and the ISLSCP II mask. Cases where the ISLSCP II mask showed water and the original data had any snow cover retrieval from 1986 to 1995 (n=439) were assigned the value of –99 (i.e Water), along with all other water cells in the ISLSCP II mask. Cases where the ISLSCP II mask showed land yet had no snow cover from 1986 to 1995 had to be separated into actual missing cells and land cells with no snow. Land cells with no snow were edited and removed by hand after examination of the 1986-1995 average. These were located at the southern edges of the actual snow cover data. Missing land cells (n=76) were identified because they were completely surrounded by non-zero snow cover cells in the 1986-1995 average. All of these 76 cells, except three, were filled from an average of the monthly snow cover in a 3 by 3 window of cells surrounding the particular cell. The three cells that could not be filled from surrounding cells were small islands located off the Northern coast of Russia and were assigned the value of –88, or missing data over land. A file that shows all of the cells which were changed was produced (file **snow_cover_mask_diffs_1d.asc**),

showing the results of applying the land/water mask, as a viewable ASCII map: all points added ("1"), all points unchanged ("0"), and all points removed ("-1").

### 9.3 Calculations

#### 9.3.1 Special Corrections/Adjustments

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

### 9.4 Graphs and Plots

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

## 10. ERRORS

### 10.1 Sources of Error

In the original NOAA data set a grid cell is considered to be snow covered only if 50 percent or more of the given cell is observed to be snow covered. Therefore, it is possible that a number of cells in a given area having snow but less than 50 percent will not be mapped as snow covered. Because data are "weekly" (representing the last day of the given week on which the observer could see the land surface) short duration snow cover events would not be mapped.

Although snow may be one of the single easiest features on the surface of the Earth to identify from space, verifying its presence is not always a straightforward matter. Not only do clouds look like snow in the visible wavelengths, but during the polar winter, darkness limits the viewing opportunities over snow covered regions. Polar orbiting satellites have suitable resolution for mapping snow on a global basis, but a given location may only be viewed once per day, except at the highest latitudes. Nevertheless, because in most cases even the most persistent clouds will depart a particular area after several days, on a weekly basis, global snow maps generally give a good indication of where snow exists.

The data filling procedure described in Section 9.2.3 introduces some 'synthetic' data into the data layers, albeit from actual snow cover surrounding the cells. This procedure introduces some errors.

### 10.2 Quality Assessment

#### 10.2.1 Data Validation by Source

No validation of original NOAA data as received by NSIDC beyond a few corrections of obvious errors involving snow in regions where no snow is possible.

#### 10.2.2 Confidence Level/Accuracy Judgment

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

#### 10.2.3 Measurement Error for Parameters and Variables

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

#### 10.2.4 Additional Quality Assessment Applied

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

## 11. NOTES

### 11.1 Known Problems with the Data

Data are limited to the Northern Hemisphere so that actual snow cover in the Southern Hemisphere is not provided. Local scale accuracy is low due to the very coarse spatial resolution of the data set. Regions covered by cloud for weeks at a time continue to be mapped as snow covered or snow free based on the last time that surface could be observed by the analyst.

### 11.2 Usage Guidance

Users should clearly understand the relationship between the original data (**snow_cover_data_XX_YYYY.csv**) and the data that have been re-processed by the ISLSCP II staff (**snow_cover_map_1d_YYYYMM00.asc**). Should any questions arise, the user can always refer to the original files because these are unchanged from what was submitted by the Principal Investigators. Users should also consult the **snow_cover_mask_diffs_1d.asc** file to see the spatial distribution of those 1 degree points that were filled and/or masked with the ISLSCP II land/water mask.

### 11.3 Other Relevant Information

See http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

## 12. REFERENCES

### 12.1 Satellite/Instrument/Data Processing Documentation

http://climate.rutgers.edu/snowcover/

http://nsidc.org/data/docs/daac/nsidc0046_nh_ease_snow_seaice.gd.html

### 12.2 Journal Articles and Study Reports

Armstrong, R.L. and M.J. Brodzik, 2001, Recent Northern Hemisphere snow extent: a comparison of data derived from visible and microwave sensors, *Geophysical Research Letters*, Vol. 28, No.19.

Dewey, K.F. and Heim, R. Jr. 1982. A digital archive of Northern Hemisphere snow cover, 1966 through December 1980, *Bull. Amer. Meteor. Soc.* 63:1132-1141.

Frei, A. and Robinson, D.A. 1999. Northern Hemisphere Snow Extent: Regional Variability 1972-1994. *International Journal of Climatology*, 19:1535-1560

Robinson, D. A., K. F. Dewey, and R. R. Heim, Jr. 1993. Global snow cover monitoring: an update. *Bull. Amer. Meteor. Soc.* 74:1689-1696.

## 13. DATA ACCESS

### 13.1 Contacts for Archive/Data Access Information

The ISLSCP Initiative II data are available are archived and distributed through the Oak Ridge National Laboratory (ORNL) DAAC for Biogeochemical Dynamics at http://daac.ornl.gov.

### 13.2 Contacts for Archive

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

### 13.3 Archive/Status/Plans

The ISLSCP Initiative II data are archived at the ORNL DAAC. There are no plans to update these data.

## 15. GLOSSARY OF ACRONYMS

| | |
|---|---|
| AVHRR | Advanced Very High Resolution Radiometer |
| CIRES | Cooperative Institute for Research in Environmental Sciences |
| DAAC | Distributed Active Archive Center |
| EASE | Equal Area Scalable Earth (Grid) |
| GOES | Geostationary Operational Environmental Satellite |
| GSFC | Goddard Space Flight Center (NASA) |
| ISLSCP | International Satellite Land Surface Climatology Project |
| NESDIS | National Environmental Satellite Data and Information Service (NOAA) |
| NOAA | National Oceanic and Atmospheric Administration |
| NSIDC | National Snow and Ice Data Center |
| ORNL | Oak Ridge National Laboratory |