Climate Data Record (CDR) Program

Climate Algorithm Theoretical Basis Document (C-ATBD)

Northern Hemisphere Snow Cover Extent

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RESPONSIBILITY

Prepared By:	Thomas W. Estilow	Research Analyst	Rutgers University
	Signature		Date
Reviewed By:	David A. Robinson	PI	Rutgers University
	Signature		Date
Reviewed By:	Alisa Holley Young	Subject Matter Expert	NCDC
	Signature		Date
Approved By:	<Name>	<Title>	<Organization>
	Signature		Date
Approved By:	<Name>	<Title>	<Organization>
	Signature		Date

REVISION HISTORY

Revision	Description	Revised Sections	Date
1	Initial submission to CDR Program	New Document	09/12/2012
2	Added section 6.1 to assumptions and limitations	6.1	09/21/2012
3	Updated document to reflect improvements in grid	Entire Document	07/01/2013

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Meaning
AFWA	Air Force Weather Agency
ASCII	American Standard Code for Information Interchange
AVHRR	Advanced Very High Resolution Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer–EOS
AMSU	Advanced Microwave Sounding Unit
ASCAT	Advanced Scatterometer
ASAR	Advanced Synthetic Aperture Radar
CATBD	Climate Algorithm Theoretical Basis Document
CDR	Climate Data Record
DMSP	Defense Meteorological Satellite Program
EOS	Earth Observing System
ESA	European Space Agency
ESSA	Environmental Science Services Administration
GOES	Geostationary Operational Environmental Satellite
GMS	Geostationary Meteorological Satellite
GSL	Global Snow Lab
IMS	Interactive Multisensor Snow and Ice Mapping System
METAR	Meteorological Aerodrome Report
MTSAT	Multi-functional Transport Satellite
MVIRI	Meteosat Visible and Infrared Imager
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite, Data, and Information Service
NH	Northern Hemisphere

NIC	National Ice Center
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NPOES	National Polar Orbiting Environmental Satellites
OSDPD	Office of Satellite and Product Operations
PSC	Polar Stereographic Coordinates
QuikSCAT	Quick Scatterometer
SAB	Satellite Analysis Branch
SCE	Snow Cover Extent
SMS	Synchronous Meteorological Satellite Program
SNODAS	Snow Data Assimilation System
SSMI/S	Special Sensor Microwave Imager/Sounder
TIROS	Television Infrared Observation Satellite Program
USAF	United States Air Force
VAS	VISSR Atmospheric Sounder
VISSR	Visible Infrared Spin Scan Radiometer

1. Introduction

1.1 Purpose

This document describes the algorithm used to create the Northern Hemisphere (NH) Snow Cover Extent (SCE) Climate Data Record (CDR) which has been submitted to the National Climatic Data Center (NCDC) by David A. Robinson, Rutgers University. The NH SCE CDR product merges the improved NOAA NH weekly SCE product developed at Rutgers University and the National Ice Center (NIC) Interactive Multisensor Snow and Ice Mapping System (IMS) snow product to form a continuous SCE record from October 1966 to present. The goal of the NH SCE CDR is to provide a consistent, reliable, and well-documented product that meets the guidelines for Climate Data Records from Environmental Satellites as defined by the National Academy of Sciences (2004). The processing scripts (code) used to develop the NH SCE CDR have been provided with this document. Thus the intent here is to provide a guide to understanding the processing scripts, algorithm, and other necessary files from a scientific perspective and to assist users and software engineers who evaluate the code.

1.2 Definitions

Due to the nature of the NH SCE CDR product and its theoretical basis, no symbols supporting the algorithm have been defined.

1.3 Document Maintenance

The current form of this C-ATBD supports version 1 revision 1 of the Northern Hemisphere Snow Cover Extent Climate Data Record. This document is under configuration management and will be updated when proposed changes have been coordinated with the CDR Program Office.

2. Observing Systems Overview

2.1 Products Generated

The generated product is the weekly NH SCE CDR. Weeks from October 1966 to May 1999 consist of digitized weekly SCE maps originally created by NOAA and previously reprocessed at Rutgers University. Updates to the SCE record from June 1999 onward are based on daily 24 km resolution IMS snow maps generated by NIC analysts. IMS daily 24 km resolution snow maps are reformatted to correspond to the spatial and temporal resolution of the early SCE maps and appended to the SCE record. The NH SCE CDR grid stems from the NMC Limited Area Fine Mesh grid, developed for early numerical weather forecasting. To digitize SCE, this grid was extended to cover the entire Northern Hemisphere. Each cell was then subdivided into four smaller cells (2 × 2) to create the NMC “half mesh” 128 × 128 grid used in the CDR (see Figure 3). Although earlier versions of the NH weekly SCE product utilize an 89 × 89 half mesh grid subset, only an 88 × 88 subset of the NMC half mesh grid falls entirely within the Northern Hemisphere (see Figure 4). For this reason, the netCDF file associated with the NH SCE CDR provides an 88 × 88 NMC-based half mesh grid corresponding to a Cartesian grid with a spatial resolution of 190.5 km at a standard parallel of 60 degrees. The grid has been draped over a polar stereographic projection and has cell areas that range from ~10,700 sq. km near the equator to ~41,800 sq. km near the pole.

2.2 Instrument Characteristics

The NIC IMS represents the latest generation of SCE mapping tools first implemented by the Satellite Analysis Branch (SAB) of NESDIS when they began generating NH weekly maps derived from visible satellite imagery in late 1966. Current daily IMS SCE maps are produced at approximately 23.8 km resolution (standard parallel 60 degrees) once per day by trained analysts using an interactive workstation application that incorporates a wide variety of satellite imagery (AVHRR, GOES, SSMI, etc.), derived mapped products (USAF Snow/Ice Analysis, AMSU, AMSR-E, etc.), and surface observations. Although satellite observations and other derived products are used to create the NH SCE product, these observations are not used according to a formal algorithm. Instead the product relies on the expertise of the trained analyst who either produced a hand drawn map of SCE or interactively used the IMS workstation to develop the SCE product.

3. Algorithm Description

3.1 Algorithm Overview

The data record for the NH SCE CDR spans from October 4, 1966 to present. Data prior to June 1999 are based on satellite-derived maps of weekly NH SCE produced by trained NOAA meteorologists. These maps are primarily based on a visual interpretation of photographic copies of shortwave imagery. This data initially consisted of observations from meteorological satellites with a subpoint resolution of ~4 km. Beginning in October 1972, the Very High Resolution Radiometer (VHRR) provided imagery with a spatial resolution of 1.0 km. As time progressed, analysts continued to incorporate various sources of imagery into the SCE mapping process as they became available (e.g., AVHRR, VAS, etc.).

Visual interpretation of satellite imagery led to manually produced weekly SCE charts that were hand-drawn by analysts then digitized to an 89 × 89 Cartesian grid laid over a NH polar stereographic projection. When digitizing the hand-drawn SCE maps, cells that contained 50% or more snow cover on land were counted as snow covered. The 89 × 89 half mesh grid is based on the NMC Limited-Area Fine Mesh grid, which was used for numerical weather prediction. Although the original data was obtained from NOAA, it has undergone re-processing at Rutgers University. This processing includes the use of a binary land/water mask to more consistently identify the presence of snow covered land. An example of the original hand drawn maps developed by SAB analysts is provided in Figure 1 for week 15 of 1993 with the corresponding digitized map provided in Figure 2.

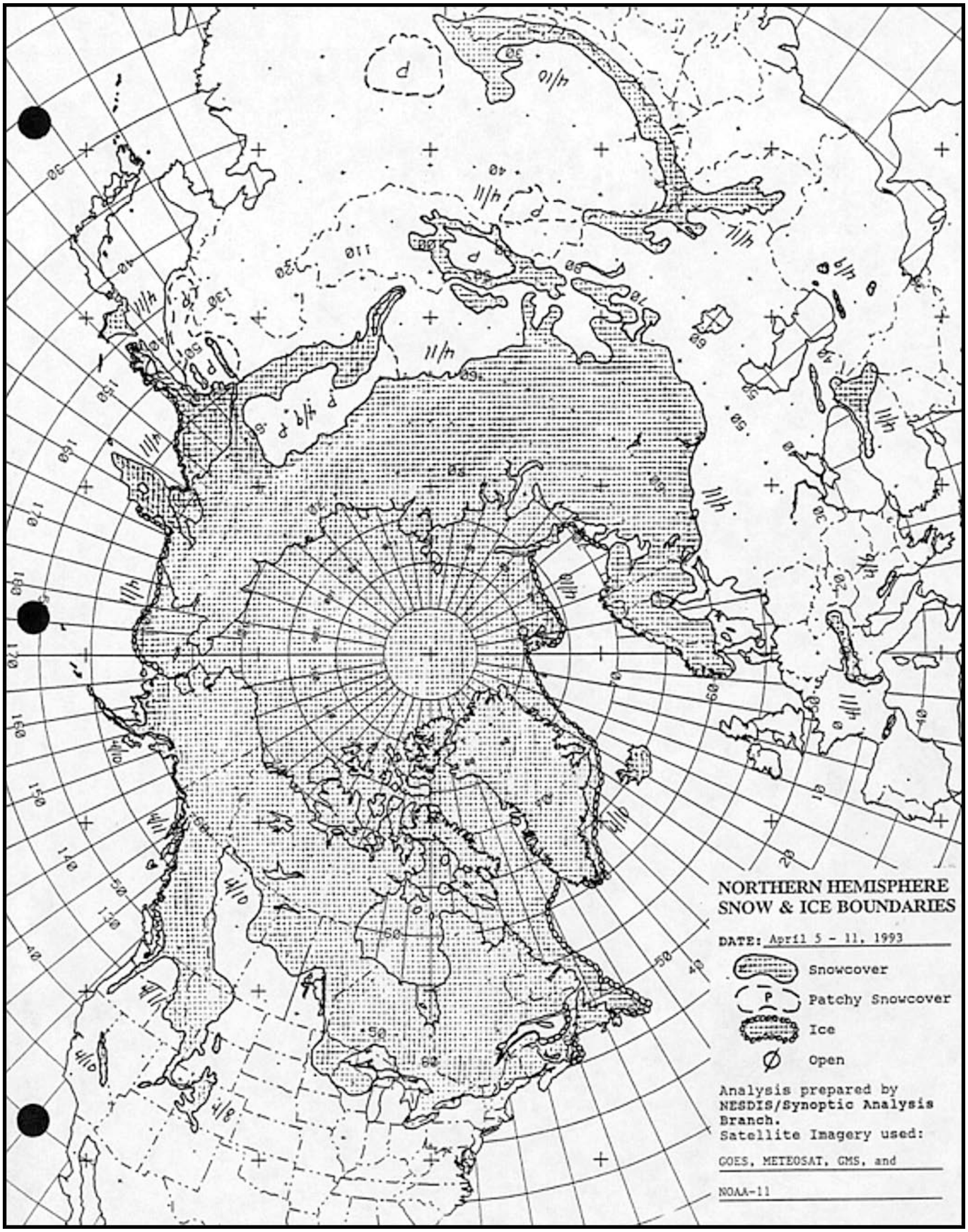

Figure 1. NOAA hand-drawn SCE corresponding to week 15 of 1993

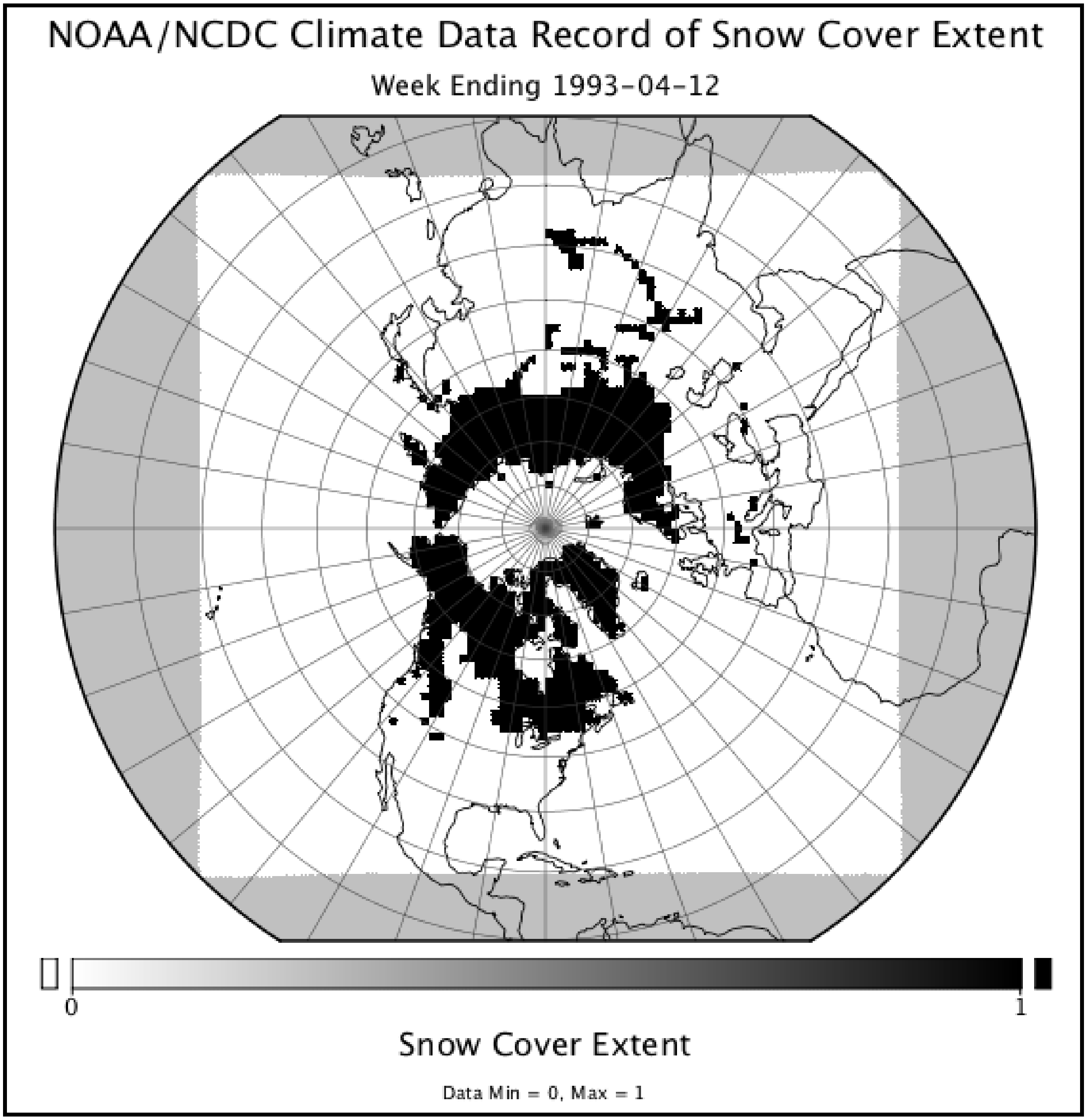

Figure 2. Digitized SCE for week 15 of 1993 on the NMC half mesh grid

Weekly maps like Figures 1 and 2 typically show SCE boundaries on the last day that the surface in a given region is seen. In June 1999, weekly hand drawn NOAA NH SCE maps ceased production and were replaced by daily SCE output from the IMS.

The 24 km NIC IMS snow maps are also based on the NMC Limited-Area Fine Mesh grid. This grid is known as the 1/16 mesh grid since each grid cell was subdivided into 256 smaller cells (16 × 16) corresponding to a 1024 × 1024 cell Cartesian grid draped over a polar stereographic projection. To match the half mesh grid used in the historical weekly digitized SCE maps, a subset of the IMS snow maps measuring 704 × 704 cells is utilized during CDR processing. Each 88 × 88 half mesh grid cell is subdivided into 64 smaller IMS grid cells (8 × 8). Both the IMS subset of 704 × 704 grid cells and the corresponding weekly 88 × 88 half mesh grid cells appear square with outer boundary corners nearly touching the equator when the NH is mapped using a polar stereographic projection.

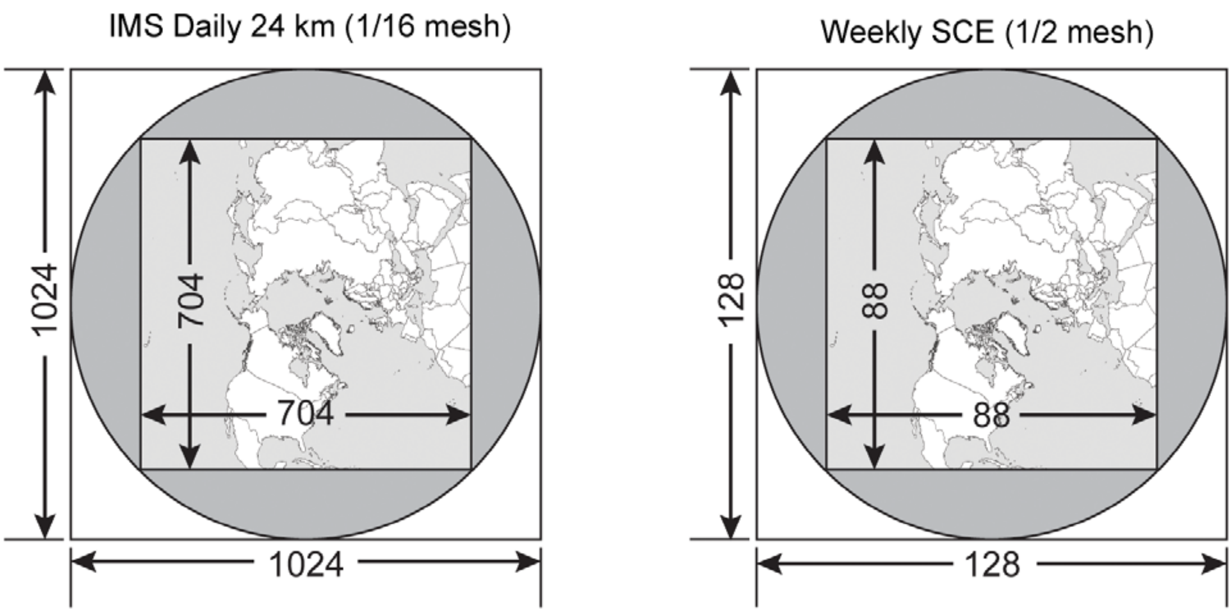

Figure 3. IMS daily 24km grid and corresponding weekly SCE grid cells.
The gray circle represents the Northern Hemisphere.

Before discontinuing the weekly hand drawn maps, both the daily IMS 24 km and the original weekly 89 × 89 SCE maps were independently produced during an overlap period spanning from June 1997 to May 1999. To merge and compare the two datasets, the 24 km daily IMS data was produced at a reduced resolution to conform to the historical weekly 89 × 89 NH SCE product and the land mask was also applied. Comparison between the two datasets showed that under conditions when 42% or more of the IMS land cells falling within the larger weekly grid cell indicated snow the predecessor product also indicated snow. This 42% threshold was determined to be a best match at Rutgers University after comparing SCE areas calculated during the overlap period.

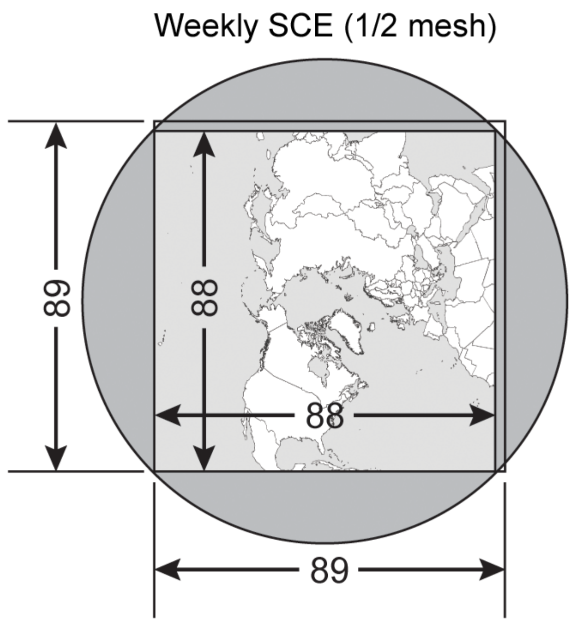

Figure 4. Historical 89 x 89 weekly SCE matrix compared to the 88 × 88 subset used for netCDF output. The row and column falling partially outside the Northern Hemisphere are not included in the CDR.

To develop the NH SCE CDR, the 24 km daily SCE output from the IMS is acquired from NIC (NHSCE_acquireIMS.pl) and processed at Rutgers University to generate weekly 89 × 89 granules that are consistent with the historical product (NHSCE_updateweekly.pl) using the 42% threshold. Each weekly NH SCE granule represents SCE for seven days spanning from Tuesday—Monday, starting from the beginning of the record on Tuesday October 4, 1966. Thus IMS SCE output captured on Monday is used to generate each weekly granule. For example, IMS SCE output for Monday, July 23, 2012 is used to create the weekly NH SCE product granule representing SCE from Tuesday July 17 through Monday July 23, 2012. ASCII text of 1024 × 1024 IMS data for Monday are downloaded and reduced in resolution to match the NMC half mesh grid, then a subset is extracted to match the historical weekly 89 × 89 matrices. After new weekly IMS observations are reformatted they are written to an ASCII text matrix, which contains the entire SCE record spanning from 1966–present.

Values from an 88 × 88 subset of the weekly SCE matrices are used to populate the final netCDF-4 binary file (NHSCE_convert2netcdf.pl). Cell areas for the 88 × 88 grid range from ~10,700 sq. km to ~41,800 sq. km with larger cells falling closer to the North Pole.

3.2 Processing Outline

The flow diagram provided in Figure 3 illustrates the processing for the NH SCE CDR as provided by Rutgers University. This outline is consistent with the necessary data inputs, processing scripts, and lookup tables that are used to produce the NH SCE CDR. Details of the processing, inputs, and lookup tables are further described in subsequent sections.

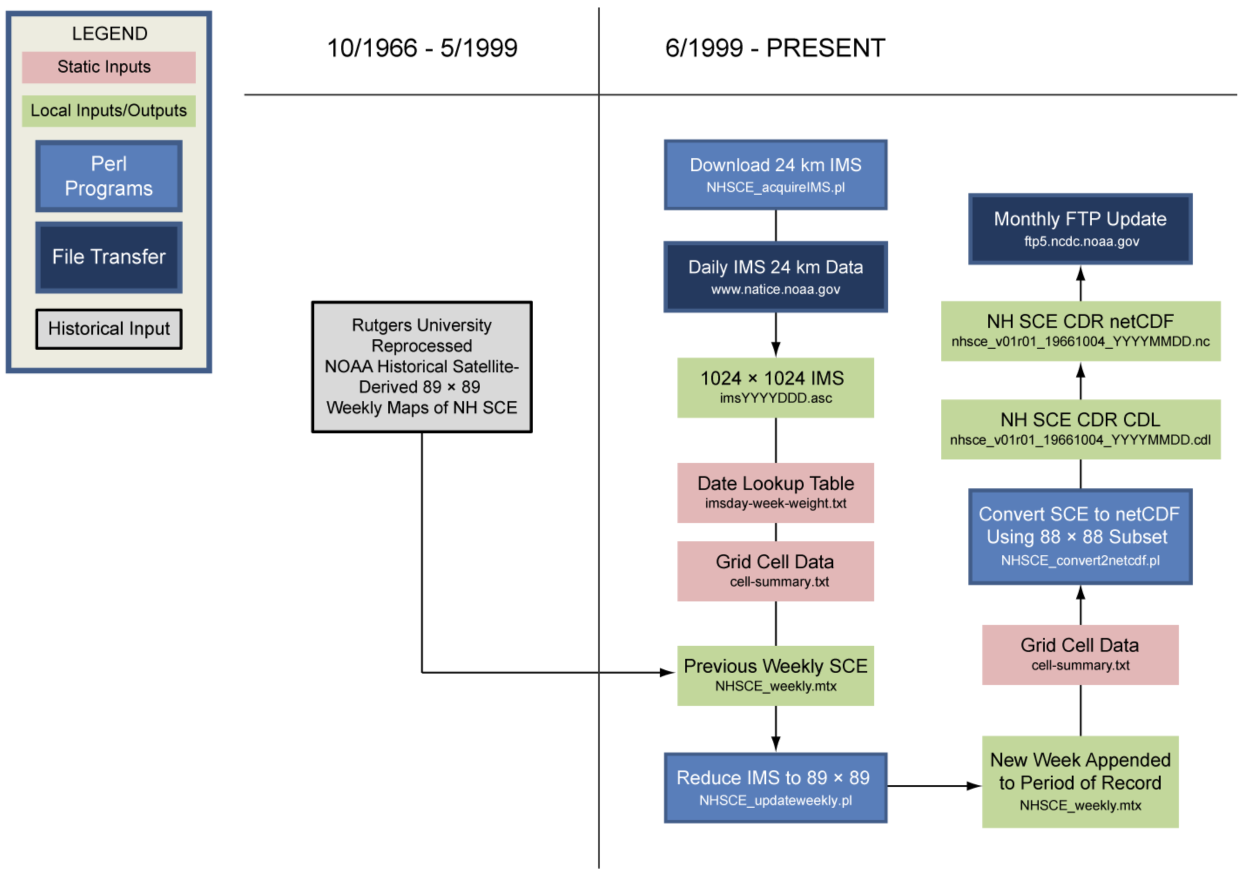

Figure 5. NH Snow Cover Extent CDR processing overview.

3.3 Algorithm Input

The input data for the NH SCE CDR product primarily relies on the Rutgers University reprocessed weekly 89 × 89 SCE data and NIC IMS data that has been produced at temporal and spatial resolutions consistent with the historical SCE product. The inputs described below outline the inputs used by SAB analysts to create the NH SCE product during the pre-IMS era and during the IMS era.

3.3.1 Primary Sensor Data

NOAA analysts used visible satellite data from the following platforms to determine weekly SCE boundaries during the pre-IMS era.

Year	Satellites
1973-74	ESSA-8 NOAA-2/3
1975-76	NOAA-4/5 SMS
1977-78	DMSP GOES-1/2/3 NOAA-5 SMS
1979-80	DMSP GOES NOAA-5/6 TIROS-N
1981-82	GOES METEOSAT NOAA-6/7
1983-84	GOES NOAA-7
1985-86	GOES NOAA-7/9
1987-88	GMS GOES METEOSAT NOAA-9/11
1989-92	GMS GOES METEOSAT NOAA-11
1993-95	GMS-4 GOES-7/8 METEOSAT-3/5 NOAA-9/14
1996-97	GMS-4/5 GOES-7/8/9 METEOSAT-5/6 NOAA-14
1998-99	GMS-5 GOES-8/9 METEOSAT-5/6/7 NOAA-14/15

Table 1. Sources of imagery used in weekly SCE mapping during the pre-IMS era

Visible and infrared spectral data used to produce the 24 km, derived IMS product include:
AVHRR (Channels 1 & 3)
GOES (East & West)
Meteosat 7
Meteosat Second Generation (MSG)
MODIS (Channel 8)
MTSAT
NPOES

3.3.2 Ancillary Data

Ancillary data used to produce the 24 km, derived IMS product include:
Surface Observations (METAR)

3.3.3 Derived Data

Derived data used to produce the 24 km, derived IMS product include the following derived snow and ice products:
AFWA Snow Depth
AMSR-E
AMSU (Derived snow, ice, and rain)
ASCAT
Envisat ASAR operating in Global Monitoring Mode
SSMI/S (Derived snow, ice and rain)
NASA QuikSCAT
NOAA OSDPD Automated Multisensor Snow and Ice
NOHRSC SNODAS
USAF Snow/Ice Analysis

3.3.4 Forward Models

Not Applicable.

3.4 Theoretical Description

To continue producing the weekly NH SCE product in a manner consistent with the historical record, the daily IMS 24 km ASCII product was formatted to the same resolution as the historical data. Like the hand drawn maps that were digitized and converted to the 89 × 89 grid using a minimum criterion that at least 50% of the land within each grid cell must contain snow, a threshold had to be used to systematically convert the higher resolution IMS grid to the lower resolution weekly grid cells. Figure 4 shows a comparison of the high resolution IMS product (blue dots) within the weekly 89 × 89 grid cells in the Western US.

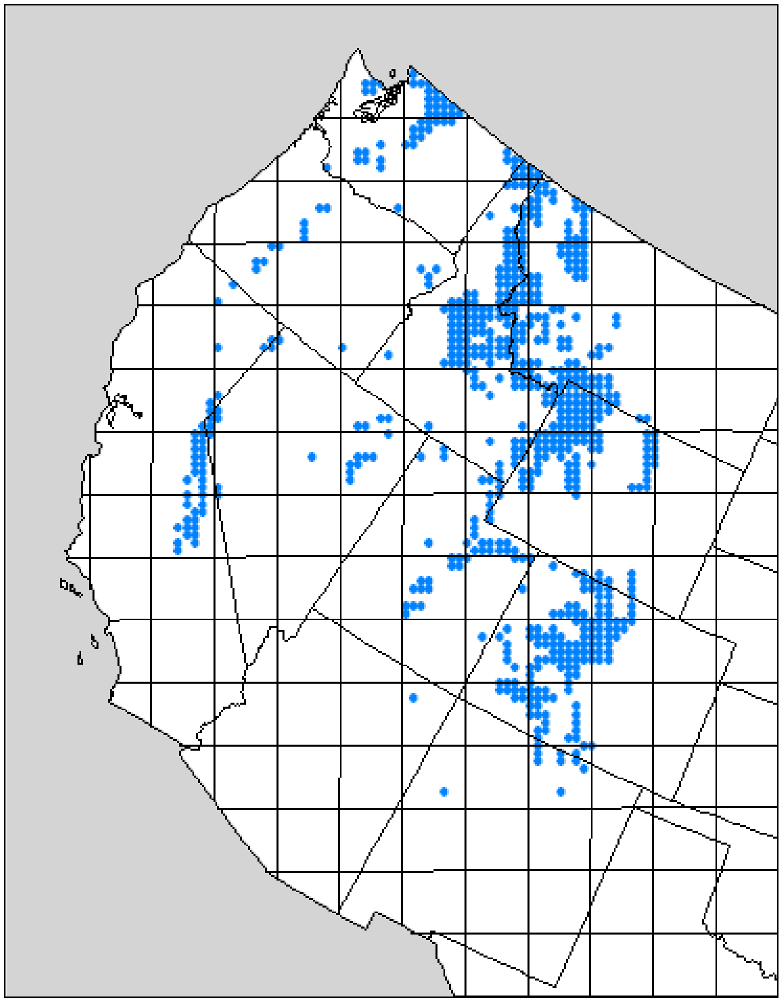

Figure 6. A comparison of IMS daily resolution (blue) to weekly grid cells.

Weekly SCE cells are best described as a binary snow cover mask, indicating snow (1) and no snow (0). Figure 5 further illustrates the evaluation of IMS data in each 89 × 89 cell. Snow is only indicated in weekly cells when 42% or more of the IMS land cells within the larger cell are snow covered. This threshold provides the closest match to historical digitization results. Since the 89 × 89 NMC half mesh grid is draped over a polar stereographic projection, cell areas increase from ~10,700 sq. km nearer the equator to ~41,800 sq. km closer to the pole. Similarly, the daily IMS 24 km product is a 1024 × 1024 grid overlaid on a polar stereographic projection. This results in IMS cells that increase in area from the equator to the North Pole in the NIC daily SCE product.

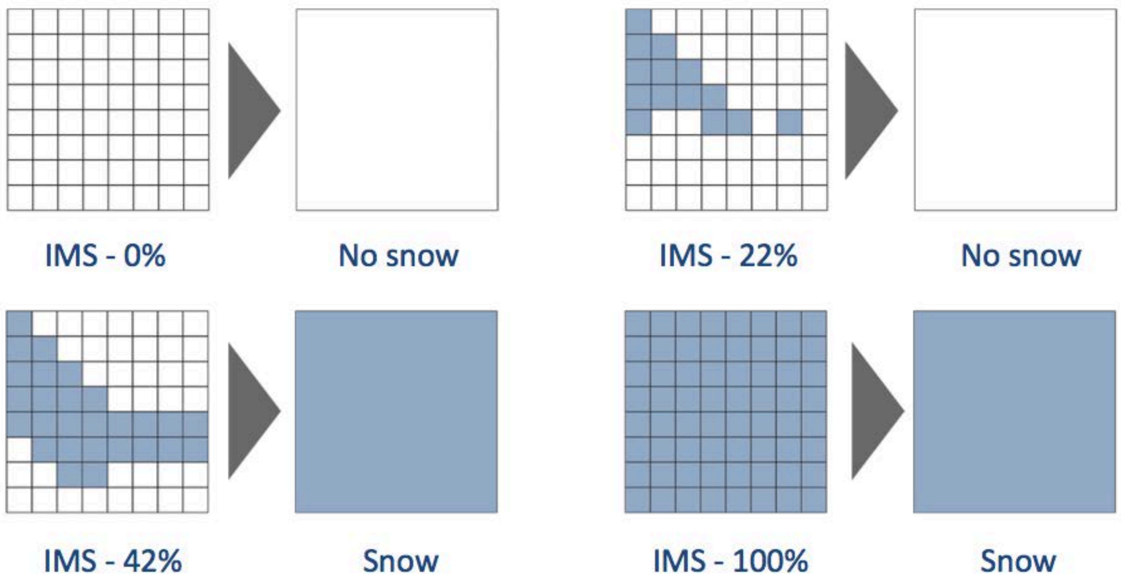

Figure 7. Examples of snow decision from IMS to weekly grid cells over land

Another item that ensures consistency in the weekly NH SCE CDR includes the application of a standard 89 × 89 land mask from October 4, 1966 to present. This land mask was developed at Rutgers University to resolve inconsistencies found in the coastal land/sea mapping in digitized SCE maps produced by NOAA analysts. The reduced IMS product is produced to conform to the weekly NH SCE CDR land mask; this results in a consistent coastline for the entire period of record. The 89 × 89 half mesh grid land mask is a binary land/water mask developed to indicate which weekly cells are at least 50% land covered.

3.4.1 Physical and Mathematical Description

No formal algorithm exists for the generation of this product, instead its physical description is based on NIC IMS operators who like SAB analysts mapped daily SCE beginning with the previous output (daily or weekly), then added or removed snow according to input from visible and microwave satellite imagery, derived snow products, and surface observations. NIC analysts use customized software to digitally record SCE. In cases where the surface cannot be seen, the last previously observed SCE remains. By integrating multiple sources of data (mainly visible satellite imagery), as well as providing animated image loops, the present production of SCE maps using IMS has improved on the previous approach to charting SCE by increasing the amount of information available to analyst. This has also allowed the IMS product to be produced at higher temporal (daily) and spatial (24 km) resolutions. More details about IMS processing are also given by Ramsey (1998) and Helfrich et al. (2007).

3.4.2 Data Merging Strategy

The data record for the NH SCE CDR spans from October 4, 1966 to present. As illustrated in Figure 3, the data records for this product are documented according to two time periods, pre-IMS from 10/1966–05/1999 and the IMS era from 06/1999–present. Data prior to June 1999 are based on manually produced satellite-derived maps of NH SCE produced weekly by trained NOAA meteorologists. Starting in June 1999, 24 km daily SCE output from the IMS is acquired from NIC and processed at Rutgers University to generate weekly granules.

During a two-year overlap period from June 1997 to May 1999, NOAA independently produced two NH SCE products for comparison, the IMS daily 24 km and the historic weekly 89 × 89 NH SCE.

Previous studies have shown that prior to June 1999, snow cover representation in NOAA weekly maps is weighted towards the end of the week. SCE boundaries were drawn on the last day that the surface in a given region was seen. NH SCE CDR week dates span from Tuesday–Monday. SCE area comparisons between the two independently produced NH SCE products during the overlap period determined that Monday's IMS data was the best match to the existing weekly product.

Additional SCE area calculations using data from the overlap period determined that a minimum of 42% of IMS land cells within a weekly grid cell must indicate snow for that weekly cell to be counted as snow covered. This threshold of ≥ 42% provided the best match between the weekly NH SCE product and the Monday IMS data during the overlap period. The IMS snow product is reduced using this threshold and subset to match the 89 × 89 half mesh grid used for weekly SCE mapping since October 4, 1966.

3.4.3 Numerical Strategy

The numerical threshold used to convert the manually drawn SCE charts to digitized records on the 89 × 89 grid is based on a threshold of 50%. The conversion of the higher resolution IMS data to the coarser weekly 89 × 89 grid is based on a numerical threshold of 42%. Other than these numerical thresholds no other numerical strategies are documented for the creation of this product.

3.4.4 Calculations

All calculations used to produce the NH SCD CDR product are designed to reduce the IMS 24 km SCE product to the NMC half mesh weekly grid. This process is executed in the script, NHSCE_updateweekly.pl. First arrays are built to determine which IMS cells fall within a larger NMC weekly grid cell. The percentage of IMS land cells indicating snow is then determined for each weekly grid cell. The next calculation is only performed on weekly grid cells defined as land by the Rutgers University 89 × 89 half mesh grid land mask.

If the percentage of IMS land cells indicating snow is 42% or greater, the weekly grid cell is determined to be snow covered (value = 1). If the half mesh weekly grid cell is not defined as land by the Rutgers University land mask, or the percentage of IMS land cells indicating snow within the weekly grid cell is less than 42%, the cell is determined to be absent of snow cover (value = 0).

3.4.5 Look-Up Table Description

A date look-up table (imsday-week-weight.txt) provides information specific to each weekly header in the ASCII text output file (NHSCE_weekly.mtx). The table provides the year and day of year representing the individual IMS Monday used to generate each week, the year and week number, the month, and the number of days each week falls within a given month. Columns are tab-delimited and consist of the following: Week ID, IMS year/day, Corresponding year/week, Month, Number of days week falls in month.

```
ROOT/scripts/lookup-files/imsday-week-weight.txt
```

The cell summary file (cell-summary.txt) lists information for each 89 × 89 cell that is used in the weekly SCE product, including values used in the land mask, cell area, latitude, and longitude variables. The last column is the weekly land mask, applied to all cells for consistency. Weekly cells are produced as land if they have been previously considered land in the historical SCE product. Land cells are considered snow covered if at least 42% of the IMS land cells falling within the larger 89 × 89 NMC half mesh grid cell indicate snow. Columns are tab-delimited and consist of the following: half mesh grid cell ID, latitude of cell center, longitude of cell center, column, row, cell area in square kilometers, and historical land mask as described by the values given in Table 2.

```
ROOT/scripts/lookup-files/cell-summary.txt
```

Value	**Description**
0	Water
1	Land

Table 2. NH SCE CDR Land mask values

3.4.6 Parameterization

Other than the thresholds described in Section 3.4.3 no other parameterizations are utilized in the generation of the NH SCE CDR product.

3.4.7 Algorithm Output

Each output week (imsYYYYDDD.asc) is appended to the entire period of record provided in the file NHSCE_weekly.mtx before being converted to a binary netCDF-4 output file which contains weekly SCE for all weeks spanning from October 4, 1966 to present. This netCDF-4 file is currently 19 MB, with each new week adding approximately 50 kB to the file size.

```
ROOT/scripts/nhsce_v01r01_19661004_20130701.nc (Example)
```

The output file consists of weekly 88 × 88 snow matrices stored in the variable snow_cover_extent, which indicates the presence of snow on land as given in Table 3.

Value	**Description**
0	No snow
1	Snow

Table 3. NH SCE CDR output values

4. Test Datasets and Outputs

4.1 Test Input Datasets

Various input datasets have been used in the generation of SCE for both the historical record and the current IMS processing. Frei et al. (2011) compared IMS observations with MODIS and AMSR-E derived snow products. Brown and Robinson (2011) evaluated the NH SCE CDR with several other datasets. Methods and results given for these evaluations are provided therein. No algorithm for comparing NH SCE CDR is provided in this documentation package.

4.2 Test Output Analysis

4.2.1 Reproducibility

As described in section 4.1, the steps needed to verify the reproducibility of this product as compared with other datasets is not outlined in this data package. When this product is produced as outlined in this document it can be reproduced when starting with the reprocessed Rutgers 89 × 89 derived historical NH SCE maps.

4.2.2 Precision and Accuracy

The NH SCE CDR is reliable at many times and in many regions. These include regions where: 1) skies are frequently clear, commonly in spring near the snowline, 2) solar zenith angles are relatively low and illumination is high, 3) the snow cover is reasonably stable or changes slowly, and 4) pronounced local and regional signatures are present owing to the distribution of vegetation, lakes and rivers. Under these conditions, the satellite-derived product will be superior to maps of SCE gleaned from station data, particularly in sparsely inhabited regions. Another advantage of the NH SCE CDR is the portrayal of regionally-representative snow extent, whereas maps based on ground station reports may be biased, due to the preferred position of weather stations in valleys and in places affected by urban heat islands, such as airports.

The NH SCE CDR has been used in international assessments of climate variability and change, and in investigations regarding the role of snow cover in the climate system. Mapping accuracy is such that this product is considered suitable for continental-scale climate studies. Researchers from around the globe have used this product for various applications including:

Snow cover and hydroclimate studies
Snow-atmosphere studies
Snow-sea ice studies
Seasonal cycle analysis
Forced model simulations
Model intercomparison/validation

References for these studies are provided in Section 8.

4.2.3 Error Budget

Error estimates and prospects for overcoming error budget limitations have not been outlined in Version 1 Revision 1 of this product.

5. Practical Considerations

5.1 Numerical Computation Considerations

No parallelization or difficulties in matrix inversions are expected. Round-off errors exist, but these are expected and well within the tolerance of the current algorithm.

5.2 Programming and Procedural Considerations

Weekly processing must take place Monday after 22:00 UTC, after NIC produces the daily IMS product and makes the file available. A Perl script, `ROOT/scripts/NHSCE_acquireIMS.pl`, acquires the latest daily 1024 × 1024 IMS file for processing from the NIC website using the Perl module LWP.

After IMS acquisition is complete the main processing script, `ROOT/scripts/NHSCE_updateweekly.pl` is executed. This code utilizes the local system time to determine current date information. New 89 × 89 SCE weeks are appended to an ASCII text file (`NHSCE_weekly.mtx`).

The resulting snow matrices are then converted to netCDF-4 by the script `ROOT/scripts/NHSCE_convert2netcdf.pl`, which first reads the SCE data along with ancillary information. The script writes a text CDL file using an 88 × 88 subset of the SCE data, which is finally converted to a netCDF-4 binary file using the NCO tool ncgen.

5.3 Quality Assessment and Diagnostics

Quality Assessment and Diagnostics have not been outlined in Version 1 revision 1 of this product.

5.4 Exception Handling

Any missing input or look-up table files will raise an error and exit the program. Running the main processing script before 22:00 UTC or on a day of the week other than Monday will raise an error and exit the program.

5.5 Algorithm Validation

At present no approach is provided in this package for validation of the product.

5.6 Processing Environment and Resources

The CDR code is run on a 3.20GHz 64-bit Xeon server, running CentOS Linux 6.2 and Perl v5.10.1 with approximately 4TB of storage. Given the simplicity of the code these specifications exceed minimum requirements to process weekly snow.

6. Assumptions and Limitations

6.1 Geographic Coordinates

The geographic coordinates and cell areas that were included in v01r00 of the NH SCE CDR were evaluated against a regular grid in Polar Stereographic Coordinates (PSC) with a cell size of 190.5 ×190.5 km. The total calculated area of the two grids agreed within −0.73785774% and indicated that the "NMC-based half mesh grid" in v01r00 of the NH SCE CDR slightly underestimated total area. With three exceptions, noted in Table 4, the longitudes and latitudes were found to be accurate to within +/-26 km and the areas were accurate to within +/-459 km^2. The three grid cells from v01r00 of the CDR product with significant discrepancies in longitude were adjacent to the North Pole grid vertex (latitude 90°). The cells are listed in Table 4 with expected (Regular Grid in PSC) and actual NH SCE CDR v01r00 values. In v01r01 of the product the three grid cells have been corrected and now correspond to the Regular Grid in PSC (see Table 4).

The grid was recalculated for v01r01of the CDR product to correct these errors. More importantly we also note that these errors in the geographic coordinates provided in v01r00 of the NH SCE CDR product do not impact the presence or absence of snow in these grid locations. The determination of snow is made in row and column space rather than by latitude and longitude coordinates.

Regular Grid in PSC			NH SCE CDR v01r00 Grid		
Row (i)	Column (j)	Lon	Row (i)	Column (j)	Lon
44	43	145.0	44	43	−35.0
44	44	55.0	44	44	77.5
45	43	−125.0	45	43	−12.5

Table 4. Expected longitude values of a regular grid in PSC and the NH SCE CDR grid.

6.2 Algorithm Performance

There are known inconsistencies over the period of record in the mountainous areas within and surrounding the Tibetan plateau. This is largely due to difficulties in mapping SCE in this area using visible satellite imagery due to snow cover often being patchy in nature and somewhat resembling the appearance of the frequent cloud cover in the region. Issues with mapping snow in this region using microwave satellite products are well known and station coverage is exceedingly sparse. Later in the satellite record, higher resolution imagery collected at a higher frequency from multiple sources (particularly animated imagery) has improved mapping in the region.

6.3 Sensor Performance

Human analysts have produced the NH SCE CDR from visible satellite imagery for over four decades, thus changes in mapping methodologies have occurred over time and there are differences in production of the historical data compared with IMS. No specific details regarding the performance of sensors used to develop the NH SCE CDR are outlined for this product.

6.4 Missing Data

There are missing weeks in the historical NH SCE record. These include the following weeks, which are written to netCDF output with no data:

1968 27-30
1969 23-43
1971 28-39

These correspond to the following dates:

19680702 – 19680729
19690603 – 19691027
19710706 – 19710927

7. Future Enhancements

Examples of future enhancements for the NH SCE CDR product may include, but are not limited to, Quality Assessments and Diagnostics, Algorithm Validation, and/or more rigorous uncertainty assessment.

8. References

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