

**NOAA NESDIS  
CENTER for SATELLITE APPLICATIONS and RESEARCH**

# **Interactive Multisensor Snow and Ice Mapping System Version 3 (IMS V3)**

**ALGORITHM THEORETICAL BASIS DOCUMENT  
Version 2.5**

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 2 of 74

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IMS ALGORITHM THEORETICAL BASIS DOCUMENT VERSION 2.4

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### DOCUMENT HISTORY DOCUMENT REVISION LOG

The Document Revision Log identifies the series of revisions to this document since the baseline release. Please refer to the above page for version number information.

Algorithm Theoretical Basis Document		
DOCUMENT CHANGE HISTORY		
Revision No.	Description	Date
1.0	Original version, written for IMS V3 Critical Design Review (CDR).	January 2012
2.4	Revised by STAR and OSPO for IMS V3 Phase 2 Delta Operational Readiness Review (ORR).	November 2018
2.5	Revised for IMS V3 Phase 2 promotion to production.	July 2019

## LIST OF CHANGES

Significant alterations made to this document are annotated in the List of Changes table.

<b>Algorithm Theoretical Basis Document</b>		
<b>LIST OF SIGNIFICANT CHANGES</b>		
<b>Version Number</b>	<b>Date</b>	<b>Description of Change(s)</b>
1.0	01/01/12	Original version.
1.0 – 2.3	Unknown	Unknown revisions. No description of changes survived.
2.4	11/02/18	Rewrote portions of Product Description, Product Requirements and Algorithm Output to clarify various product details. Updated and expanded various Algorithm Inputs for both Snow/Ice Cover and Snow Depth to be current. Updated Snow/Ice Cover and Snow Depth validation sections with details of what was done. Updated nearly every section with additional information or clarity.
2.5	7/15/2019	Updated Snow Depth data units for both hemispheres. Added new AMSR-2 products, updated SAR and GOES-16/17 products.

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## TABLE OF CONTENTS

	<u>Page</u>
DOCUMENT HISTORY.....	3
LIST OF CHANGES .....	4
TABLE OF CONTENTS .....	5
LIST OF FIGURES.....	9
LIST OF ACRONYMS .....	10
1.0 INTRODUCTION .....	13
1.1 Product Overview .....	13
1.1.1 Product Description.....	13
1.1.2 Product Requirements.....	15
1.2 Document Overview.....	16
2. SNOW / ICE COVER ALGORITHM.....	17
2.1 Processing Overview .....	17
2.2 Algorithm Input.....	18
2.2.1 GOES-EAST C02 Imagery .....	18
2.2.2 GOES-EAST RGB Imagery .....	19
2.2.3 GOES-WEST C02 Imagery .....	19
2.2.4 GOES-WEST RGB Imagery.....	20
2.2.5 METEOSAT-11 Imagery .....	20
2.2.6 METEOSAT-8 Imagery .....	21
2.2.7 Himawari 8 Imagery .....	21
2.2.8 Radar Observations.....	21
2.2.9 Metop A AVHRR (GAC) RGB Imagery.....	22
2.2.10 Metop A AVHRR (GAC) Grayscale Imagery .....	22
2.2.11 Metop A AVHRR (FRAC) RGB Imagery .....	22
2.2.12 NOAA-18 AVHRR (GAC) Imagery .....	23

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 6 of 74

---

---

2.2.13 NOAA-18 AVHRR (HRPT) Imagery .....	23
2.2.14 NOAA-19 AVHRR (GAC) Imagery .....	23
2.2.15 NOAA-19 AVHRR (HRPT) Imagery .....	23
2.2.19 MODIS AQUA Imagery .....	25
2.2.20 MODIS TERRA Imagery .....	25
2.2.21 Polar MODIS Imagery (image loops 1 and 2) .....	25
2.2.22 VIIRS I5 Imagery .....	26
2.2.23 VIIRS RGB (False Color) Imagery .....	26
2.2.24 VIIRS NCC Imagery .....	27
2.2.25 VIIRS Sea Ice Age .....	28
2.2.26 VIIRS Snow Cover .....	29
2.2.27 AMSR-2 Brightness Temperature Products .....	29
2.2.28 AMSR-2 Ice Concentration Product .....	30
2.2.29 AMSR-2 Snow Depth Product .....	30
2.2.30 SAR Imagery .....	31
2.2.31 SAR Ice Mask .....	32
2.2.32 ASCAT Sea Ice Product .....	32
2.2.33 AMSU Products .....	32
2.2.34 SSM/I Products .....	33
2.2.35 USAF Products .....	35
2.2.36 North Hemisphere 4km AutoSnow Product .....	36
2.2.37 North Hemisphere 4km AutoSnow DSLO Product .....	36
2.2.38 NIC MIZ .....	37
2.2.39 NOHRSC Product .....	37
2.2.40 MMAB (OMB) SSM/I Sea Ice Product .....	38
2.2.41 NCEP GFS Snow Depth Change .....	38
2.2.42 CMC Snow Depth .....	39
2.2.43 IMS Snow Depth .....	39
2.2.44 NAVO Sea Ice Model .....	39
2.2.45 (Disabled) NAIS Sea Ice Model Output .....	40
2.2.46 (Disabled) NIC Sea Ice Thickness and Concentration .....	41
2.2.47 Hourly Surface Data Product .....	41
2.2.48 Daily Surface Data Snow Depth .....	42

---

---

2.2.49 Ancillary data in the format of Shapefile or GeoTIFF .....	42
2.2.50 Political boundaries.....	42
2.2.51 Land water mask.....	42
2.2.52 Digital elevation .....	43
2.3 Theoretical Description.....	43
2.4 Algorithm Output.....	46
2.4.1 ASCII Files .....	46
2.4.1.1 ASCII File (24km).....	46
2.4.1.2 ASCII File (4 km).....	48
2.4.1.3 ASCII File (1 km).....	49
2.4.2 ENVI Files.....	51
2.4.3 GeoTIFF image files .....	51
2.4.4 GRIB-2 files.....	52
2.4.5 GIF web image files .....	53
2.5 Performance Estimates .....	58
2.6 Practical Considerations .....	59
2.6.1 Programming and Procedural Considerations .....	59
2.6.2 Quality Assessment and Diagnostics.....	60
2.6.3 Exception Handling .....	60
2.7 Validation .....	60
3.0 SNOW DEPTH ALGORITHM.....	61
3.1 Processing overview .....	61
3.2 Data inputs.....	62
3.2.1 IMS 4km Snow/Ice Cover Product ( <i>Northern Hemisphere Only</i> )....	62
3.2.3 Surface Data (hourly report) Product .....	63
3.2.4 MIRS High Resolution Products .....	64
3.2.5 (Disabled) AMSR-E Snow Water Equivalent Product .....	65
3.2.6 Land water mask .....	65
3.2.7 Digital elevation .....	66
3.3 Theoretical Description.....	66
3.4 Algorithm Output.....	68

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 8 of 74

---

---

3.5 Performance Estimates .....	69
3.5.1 Test Data Description .....	70
3.5.2 Retrieval Errors.....	70
3.6 Practical Considerations.....	70
3.6.1 Programming and Procedural Considerations .....	70
3.6.2 Quality Assessment and Diagnostics.....	70
3.6.3 Exception Handling .....	70
3.7 Validation .....	71
4.0 ASSUMPTIONS AND LIMITATIONS.....	72
4.1 Performance Assumptions.....	72
4.2 Potential Improvements.....	73
5.0 LIST OF REFERENCES.....	73

---

---

## LIST OF FIGURES

	<u>Page</u>
Figure 2-1. 24km IMS product decision tree.....	45
Figure 2-2. 24km sample header record .....	48
Figure 2-3. 4km sample header record .....	49
Figure 2-4. 1km sample header record .....	50
Figure 2-5. GIF (world region) image .....	54
Figure 2-6. GIF (USA region) image.....	55
Figure 2-7. GIF (Alaska region) image .....	56
Figure 2-8. GIF (Asia/Europe region) image .....	57
Figure 2-9. GIF (Afghanistan region) image .....	58
Figure 3-1. Data Flow Diagram for Northern Hemisphere Snow Depth.....	67
Figure 3-2. Data Flow Diagram for Southern Hemisphere Snow Depth .....	68
Figure 3-3. IMS Snow Depth Errors for 1/3/10, 1/15/10, and 2/15/10 .....	72

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### LIST OF ACRONYMS

ADDE	Abstract Data Distribution Environment
AMSR-E	Advanced Microwave Scanning Radiometer – Earth Observing System
AMSU	Advanced Microwave Sounding Unit
ASCII	American Standard Code for Information Interchange
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
CDR	Critical Design Review
CFS	Climate Forecast System
CICS	Cooperative Institute for Climate Studies
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIOSS	Cooperative Institute for Oceanographic Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CREST	Cooperative Remote Sensing and Technology Center
ENVI	Environment for Visualizing Images
EOS	Earth Observation Satellite
FRAC	Full Resolution Area Coverage
GAC	Global Area Coverage
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Geographic Tagged Image File Format
GFS	Global Forecast System
GOES	Geostationary Operational Environmental Satellite
GRIB	GRIdded Binary
GUI	Graphical User Interface
HDF	Hierarchical Data Format
HRPT	High-Resolution Picture Transmission
IDL	Interactive Data Language
IMS	Interactive Multisensor Snow and Ice Mapping System
IMS V3	Interactive Multisensor Snow and Ice Mapping System Version 3
IMSG	I. M. Systems Group
McIDAS	Man computer Interactive Data Access System

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 11 of 74

---

---

METEOSAT	Meteosat program satellite
MIZ	Marginal Ice Zone
MMAB	Marine Modeling and Analysis Branch [formerly OMB]
MODIS	Moderate Resolution Imaging Spectroradiometer
MTSAT	Multi-function Transport Satellite
NAIL	North American Ice Link
NAIS	North American Ice Services
NAM	North American Mesoscale Model
NAVO	Naval Oceanographic Office
NCAR	National Center for Atmospheric Research
NCDC	National Climate Data Center
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NIC	National Ice Center
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NPP	NPOESS Preparatory Project
OMB	Ocean Modeling Branch [now MMAB]
OSPO	Office of Satellite and Product Operations
PDA	NESDIS Production Distribution and Access system
PDR	Preliminary Design Review
PreProc	Preprocessing
RAD	Requirements Allocation Document
RAS	Requirements Allocation Sheet
RUC	Rapid Update Cycle
SAR	Synthetic Aperture Radar
SPSRB	Satellite Products and Services Review Board
SSMI	Special Sensor Microwave Imager
STAR	Center for Satellite Applications and Research
SWA	Software Architecture Document
USAF	United States Air Force

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 12 of 74

---

## 1.0 INTRODUCTION

The Interactive Multisensor Snow and Ice Mapping System (IMS) is an operational software package for monitoring snow and ice coverage. This software enables qualified OSPO analysts to look at images and products in order to make an informed decision as to snow and ice cover over the Northern hemisphere. The National Centers for Environmental Prediction (NCEP) relies on IMS for snow cover and lake cover initialization for the Global Forecast System (GFS), Climate Forecast System (CFS), N. American mesoscale Model (NAM) and Rapid Update Cycle (RUC) models. The RUC model also applies ice cover fields from the IMS for ice initialization.

The IMS operation can basically be broken down into four steps. First, the preprocessing system takes all products and imagery from their native formats and resolutions to project them into IMS set format and Secondly, IMS GUI system picks up the processed data from the preprocessing system at intervals throughout the day and displays the data on IMS projection. Thirdly, the analysts tag locations as snow covered and ice covered over the entire Northern Hemisphere. Last, cron scripts on the IMS GUI system produce final products and distribute final products to proper destinations.

### 1.1 Product Overview

#### 1.1.1 Product Description

The IMS V3 system produces a number of output files, all generated twice a day: prior to 18 and 00 UTC. The products are nowcasted to be valid at exactly 18 and 00 UTC. The 00 UTC products are valid for the entire Northern Hemisphere coverage area; whereas the 18 UTC products are guaranteed to be valid only with-in North America and other regions may contain analysis from the previous 00 UTC product. Five formats of snow and ice products are made: ASCII files, ENVI files, GeoTIFF files, GRIB-2 files, and quick-look GIF (Graphic Interchange Format) web images. More than one IMS GUI system and Preprocessor are currently being used but only the operational GUI system will distribute products to the users. The other backup and COOP systems pull input data, but neither generate nor transmit any output data to another system unless they are activated to do so.

The ASCII and ENVI snow and ice cover products for the northern-hemisphere exist in three separate resolutions (24km, 4km and 1km). Each product data value can indicate snow, ice, non-snow-covered land and open water. These products are currently generated twice a day (before 18 and 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. Only the ASCII products are distributed; ENVI products are internal. The values that are used in these products are:

- 
- 
- 0 = outside coverage area (Northern Hemisphere) "space" pixel
  - 1 = open water
  - 2 = land without snow
  - 3 = sea ice
  - 4 = snow covered land

The GeoTIFF snow and ice cover output products for the northern-hemisphere exist in two resolutions (4km and 1km). In an identical manner to the ASCII products, each data value can indicate snow, ice, non-snow-covered land and open water. These products are currently generated once a day (before 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. The products include 4 GeoTIFF's per resolution, each rotated 90 degrees from the other, to provide four different views of the earth. Only the GeoTIFFs with a central meridian of 80 degrees west, one for 4km and one for 1km, are distributed; the other views are internal.

The GRIB-2 snow and ice cover (separate files) output products for the northern-hemisphere exist only in 1km resolution. The snow cover product data values can indicate either snow or non-snow-covered land; the ice cover product data values can indicate either ice or open water. These products are currently generated twice a day (before 18 and 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. Both products are distributed.

The GRIB-2 days-since-last-observed output product for the northern-hemisphere exists only in 1km resolution. Each product data value is the smaller of the number of days since that data value was updated in the IMS snow/ice cover by an analyst, and the number of days since last updated by AutoSnow&Ice. The region of coverage is limited to locations where the IMS and ASI spatially overlap. This product is currently generated twice a day (before 18 and 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. This product is distributed.

The GRIB-2 snow-products output for the northern-hemisphere exists only in 4km resolution. Each product file includes an IMS snow cover, snow depth, snow depth quality value, days-since-last-observed for each pixel. The snow depth values are primarily the output of an automated program. The product is currently generated twice a day (before 18 and 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. This product is distributed.

The GRIB-2 ice-products output for the northern-hemisphere exists only in 4km resolution. Each product file includes an IMS ice concentration, ice thickness, uncertainty for each, and a days-since-last-observed for each pixel. Currently ice concentration is degraded to

ice cover, with ice thickness and uncertainties being unavailable. The product is generated twice a day (before 18 and 00 UTC), after the analysts have completed the interactive portion of the IMS analysis. This product is distributed.

A 2km GRIB-2 snow depth output for the southern-hemisphere includes a snow depth, and a snow depth quality value. This product is the result of an automated algorithm, and does not contain any analyst input. The product is currently generated once a day (before 24 UTC). This product is distributed.

The GIF snow and ice cover output products for the northern-hemisphere are GIF images for five area regions (World, USA, Alaska, Asia/Europe, and Afghanistan). These are simply a GIF image representation of the IMS snow/ice cover product over specified regions of the world with snow, ice, land and ocean areas set to white, yellow, green, and blue respectively. Some overlays such as political boundaries and text describing the graphic (such as date and time) are also included with each graphic. These products are currently generated once a day (before 00 UTC). These are posted to the IMS webpage.

### 1.1.2 Product Requirements

The primary user of the ASCII snow/ice cover products, produced twice a day, is the National Centers for Environmental Prediction (NCEP), where the product is used as input to numerical weather prediction models. The scheduled delivery time for the 24km is before 00 UTC, 4km and 1km products are before 18 and 00 UTC. The products contain Northern Hemisphere snow and ice coverage represented by five possible values. The ENVI snow/ice cover products files that are generated come in the same three resolutions as the ASCII product (24km, 4km and 1km) but help to serve a different user community. While not specifically required, these products are effectively a plain-binary file format (simply a data array) that can easily be read into any programming language. The data contained in the files are in the same format (values 0 – 4) as the ASCII product. Currently these products are not distributed.

GeoTIFF snow/ice cover product is posted on the NIC IMS webpage in two resolutions (4km and 1km). This product can easily be opened in any GIS application, and is generated to enable easy access to the data for customers using commonly available software. The scheduled delivery time for the product is before 18 and 00 UTC.

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The GRIB-2 snow and ice cover, as well as days-since-last-observed products are created in 1km resolution. Additionally, a two more GRIB-2 product files are produced: one containing snow cover, Northern-Hemisphere snow depth and days-since-last observed, and the other containing ice cover, ice thickness and days-since-last-observed. Product output in this format was originally requested by NCEP. The scheduled delivery time for these products is before 18 and 00 UTC.

Another product set of the IMS are the quick look GIF snow/ice cover images made for the NIC IMS web page. All GIF images use the 4km IMS snow/ice analysis to start with but depending on the GIF regions coverage, some detail may be lost. There are 5 different coverage regions for the GIF images and 15 total images produced each day. Of these 15 files, 10 are simply copies of the 5 different area regions needed for the web page. The GIF image sizes and layout structure have been previously specified by the web page developers. The scheduled delivery time for these products is before 00 UTC.

## 1.2 Document Overview

This document contains the following sections:

- Section 1.0 - Introduction
- Section 2.0 - Snow and Ice Cover Algorithm
- Section 3.0 - Snow Depth Algorithm
- Section 4.0 - Assumptions and Limitations
- Section 5.0 - List of References

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## 2. SNOW / ICE COVER ALGORITHM

This section describes the algorithms for retrieval of snow cover, ice cover, and ice thickness.

### 2.1 Processing Overview

The IMS version 3 preprocessing uses a large variety of sources of imagery and products which, together, provide data for all regions of the Northern Hemisphere. All imagery is in the highest resolution offered or at the 1km maximum resolution required by the IMS V3. For Geostationary satellite imagery, a sequence loop of images (obtained during the peak daylight hours) is offered over the full region of coverage for that satellite. Polar satellite imagery is offered both in an image mosaic (lower resolution but full Northern Hemisphere coverage) as well as orbitally (higher resolution but only over select areas). The products used as inputs are of differing resolutions with some imagery being moderate resolutions (1km) while other microwave products being rather coarse (~20-km).

The IMS version 3 GUI uses mostly pre-processed input data that is in ENVI Image file format “sectorized” for different areas around the Northern Hemisphere. Rather than producing single image files that fully envelop the entire coverage area in the Northern Hemisphere, the products and imagery are split into one or more of the 36 predefined Northern Hemisphere IMS areas. For each product or set of imagery used in the GUI (except the NIC ice edge shape file, sea ice chart shapefiles, and surface data text reports) there are three sets of files that always exist (a “world” dataset, “sec\*1024\*” dataset(s), and “sec\*4096\*” dataset(s)). The “world” files are files which encompass all of the 36 Area regions composited into a 24km Northern Hemisphere view used in the IMS GUI zoom level 0 and 1. The “sec\*1024\*” files are a 4-km resolution file for one or more of the 36 IMS “areas”. The “sec\*4096\*” files are a 1km resolution file for one or more of the 36 IMS sectors. Depending on the input data type, many different subsets of the 36 area files may be used depending on the coverage of the product or satellite. Even if the resolution of the input data is coarser than 1km, the 1km “sec\*4096\*” files are made to provide seamless operation of the IMS GUI.

Based on the IMS GUI, the analysts tag locations as snow covered and ice covered over the entire Northern Hemisphere. The GUI system also generates snow depth, ice thickness, and time since last observation via code that analysts can also alter before the analysis is exported. These interactive analysis steps simply updates the dataset used to create the final products and do not really produce any output files. All of the IMS output products are created separately from the interactive analysis by final product generation scripts running from cron. Five basic types of output files are produced by the jobs running

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from cron on the GUI workstation (ASCII product, ENVI product, GeoTIFF files, GIF image products and GRIB-2 products).

The snow depth product processing system consists of two main processing components: the automated algorithm that blends in-situ and microwave derived snow depths over IMS snow-covered pixels to produce a 4-km intermediate snow depth product, and the analyst updating of the intermediate snow depth fields produced by the automated system. The automated algorithm processes IMS ascii snow covered fields which constrain the snow-covered area to be populated with snow depth estimates.

## 2.2 Algorithm Input

Most input data are acquired from the IMS pre-processing systems automatically through CRONTAB jobs calling script files that download the preprocessed datasets via SFTP. These datasets are in a plain-binary image format (ENVI format conventions minus header files) and “sectorized” to the needed areas of the 36 possible IMS area regions. Each dataset is put into a single TAR file for ease and speed of transfer, then un-tarred by the script transferring them. The products and imagery created for the IMS GUI’s are specifically made for use with that system and, for the most part, exist in a specialized format only usable by that system. The TIFF and Shapefile imports do not need to pass through a pre-preprocessing step.

All of the image and image data products to be used in the IMS must be mapped in a Polar Stereographic projection with latitude of true scale equal to 60 degrees north and the longitude below the pole of map (Standard Parallel) equal to 80 degrees west longitude. All image data used in the IMS is broken up into 36 sectors (most image data uses only some of these sectors) which cover the entire Northern Hemisphere. More information regarding the IMS Projections can be found in the IMS Maintenance Manual and at [nsidc.org/data/g02156.html](http://nsidc.org/data/g02156.html).

### 2.2.1 GOES-EAST C02 Imagery

The Geostationary Operational Environmental Satellite - EAST (GOES-EAST) grayscale imagery consists of twelve visible (Channel-2) images over eastern North America, produced twice daily. The input data is received via PDA, the data naming convention is as follows:

```
OR_ABI-L2-CMIPF-MXC02-G16_sYYYYMMDDHHMMSSS_eYYYYMMDDHHMMSSS_
cYYYYMMDDHHMMSSS.nc
```

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 19 of 74

---

---

(where X = instrument mode, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The eastern North America portion of each full disk image is cutout and remapped for use with-in the IMS via a Python/GDAL preprocessing routine. Each run of the processing includes data for 3 hours, with 4 images per hour.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.2 GOES-EAST RGB Imagery

The Geostationary Operational Environmental Satellite - EAST (GOES-EAST) RGB imagery consists of twelve visible (Channels 13, 02, 05) images over eastern North America, produced twice daily. The imagery is stretched to appear similar to the AWIPS Day Cloud Phase product. The input data is received via PDA, the data naming convention is as follows:

OR\_ABI-L2-CMIPF-MXCZZ-G16\_sYYYYMMDDHHMMSSSS\_eYYYYMMDDHHMMSSSS\_  
cYYYYMMDDHHMMSSSS.nc

(where X = instrument mode, ZZ=channel, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The eastern North America portion of each full disk image is cutout and remapped for use with-in the IMS via a Python/GDAL preprocessing routine. Each run of the processing includes data for 3 hours, with 4 images per hour.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.3 GOES-WEST C02 Imagery

The Geostationary Operational Environmental Satellite - WEST (GOES-WEST) grayscale imagery consists of twelve visible (Channel-2) images over western North America, produced twice daily. The input data is received via PDA, the data naming convention is as follows:

OR\_ABI-L2-CMIPF-MXC02-G17\_sYYYYMMDDHHMMSSSS\_eYYYYMMDDHHMMSSSS\_  
cYYYYMMDDHHMMSSSS.nc

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(where X = instrument mode, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The western North America portion of each full disk image is cutout and remapped for use with-in the IMS via a Python/GDAL preprocessing routine. Each run of the processing includes data for 3 hours, with 4 images per hour.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.4 GOES-WEST RGB Imagery

The Geostationary Operational Environmental Satellite - WEST (GOES-WEST) RGB imagery consists of twelve visible (Channels 13, 02, 05) images over western North America, produced twice daily. The imagery is stretched to appear similar to the AWIPS Day Cloud Phase product. The input data is received via PDA, the data naming convention is as follows:

OR\_ABI-L2-CMIPF-MXCZZ-G17\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_  
cYYYYMMDDHHMMSSS.nc

(where X = instrument mode, ZZ=channel, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The western North America portion of each full disk image is cutout and remapped for use with-in the IMS via a Python/GDAL preprocessing routine. Each run of the processing includes data for 3 hours, with 4 images per hour.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.5 METEOSAT-11 Imagery

The METEOSAT-11 imagery consists of six high-resolution visible (channel-12) images over Europe and western Asia produced once daily. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The six images that are chosen are decided by the time the job is run from the cron (the latest 6 images are chosen). The input data are full disk images at 1 KM nadir resolution, with only certain portions containing data, available four times an hour. A McIDAS BATCH job then remaps these sectors in a rectilinear projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

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Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.6 METEOSAT-8 Imagery

The METEOSAT-8 imagery consists of six visible (channel-1) images over the western/central Asia region produced once daily. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The six images that are chosen are decided by the time the job is run from the cron (the latest 6 images are chosen). The input data are full disk images at 3 KM nadir resolution available four times an hour. A McIDAS BATCH job then remaps these sectors in a rectilinear projection centered on a specific point and c

ut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.7 Himawari 8 Imagery

The Himawari 8 imagery consists of twelve visible (channel-1) images over the Eastern Asia. The input data is received via PDA and remapped for use in the IMS preprocessing routine. The twelve images that are chosen are decided by the time the job is run from the cron (the latest 12 images are chosen). The input data are the Himawari 8 GLOBAL sectors at 1 KM resolution available twice an hour. A McIDAS BATCH job then remaps these sectors in a rectilinear projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file, which is then remapped to the IMS projection via a Python/GDAL program.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.8 Radar Observations

The surface radar observations from around the US are generated on 5 minute intervals. They come from the McIDAS Product Server through ADDE. Updates for the past 15 minutes (3 frames) are available to be pulled to the IMS Preprocessor. A McENV session is run which uses the PTLIST command to select the latest 15 minutes of surface data reports and deposit them into an ASCII data file. The SELECT keyword is set to a day/time range and only certain parameters are used to limit the selection to the desirable information. A PERL script is then run for data reformatting and an ENVI script is run to convert coordinate systems to match that of the IMS. Radar Observations apply the following naming conventions:

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AREA50XX

XX designates time segment that can be run in a loop.

Importance to Production: **2 – needed for improved quality or coverage**

### **2.2.9 Metop A AVHRR (GAC) RGB Imagery**

The Metop A AVHRR GAC mosaic imagery consists of the latest 14 GAC orbits over the North Hemisphere. The input data is received via McIDAS ADDE at an effective nadir resolution of 4 KM and then remapped into a common projection and an IMGOPER McIDAS command is used to mosaic together all data into a single AREA file which is sent through the AXFORM command to output a simple binary image file for use with the ENVI programs. The imagery is false color composite with of bands 1, 2 and 3a. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### **2.2.10 Metop A AVHRR (GAC) Grayscale Imagery**

The Metop A AVHRR GAC channel 3A mosaic imagery consists of the latest 14 GAC orbits over the North Hemisphere. The input data is received via McIDAS ADDE at an effective nadir resolution of 4 KM and then remapped into a common projection and an IMGOPER McIDAS command is used to mosaic together all data into a single AREA file which is sent through the AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### **2.2.11 Metop A AVHRR (FRAC) RGB Imagery**

The Metop A AVHRR FRAC imagery consists of up to 14 false color images (Red=band1, Green=band2, Blue=band3a) over most areas of North America. The input data is received via McIDAS ADDE at an effective nadir resolution of 1.1 KM and remapped for use in the IMS preprocessing routine. The job runs once per day and will process through the latest 14 passes and produce products for those passes which are visible (the routine removes the dark passes). A Perl routine will remove the dark passes and build a McIDAS BATCH job which will remap each pass in a polar stereographic projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.12 NOAA-18 AVHRR (GAC) Imagery

The NOAA-18 AVHRR GAC mosaic imagery consists of the latest 14 GAC orbits over the North Hemisphere. The input data is received via McIDAS ADDE at an effective nadir resolution of 4 KM and then remapped into a common projection and an IMGOPER McIDAS command is used to composite together all data into a single AREA file which is sent through the AXFORM command to output a simple binary image file for use with the ENVI programs. The imagery is false color mosaic with the band 1, 2 and 3b. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.13 NOAA-18 AVHRR (HRPT) Imagery

The NOAA-18 AVHRR HRPT imagery consists of up to 14 false color images (Red=band1, Green=band2, Blue=band3b) over most areas of North America. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The job runs once per day and will process through the latest 14 passes and produce products for those passes which are visible (the routine removes the dark passes). A Perl routine will remove the dark passes and build a McIDAS BATCH job which will remap each pass in a polar stereographic projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.14 NOAA-19 AVHRR (GAC) Imagery

The NOAA-19 AVHRR GAC mosaic imagery consists of the latest 14 GAC orbits over the North Hemisphere. The input data is received via McIDAS ADDE and then remapped into a common projection and an IMGOPER McIDAS command is used to mosaic together all visible channel-1 data into a single AREA file which is sent through the AXFORM command to output a simple binary image file for use with the ENVI programs. The imagery is false color composite with the band 1, 2 and 3b. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.15 NOAA-19 AVHRR (HRPT) Imagery

The NOAA-19 AVHRR HRPT imagery consists of up to 14 false color images (Red=band1, Green=band2, Blue=band3b) over most areas of North America. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The job runs

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once per day and will process through the latest 14 passes and produce products for those passes which are visible (the routine removes the dark passes). A Perl routine will remove the dark passes and build a McIDAS BATCH job which will remap each pass in a polar stereographic projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.16 Arctic Composite Visible Imagery

Hourly NOAA GOES/POES mosaic visible-band (~0.65  $\mu\text{m}$ ) imagery products are generated in the NOAA OSPO GEO System by using satellite imagery in GOES West/East, Meteosat, Himawari 8, NOAA 18 & 19 AVHRR, Aqua/Terra, MetOp-A, MetOp-B, S-NPP, and NOAA 20. Each image covers from at least 50th parallel north, and is composed of a mosaic from multiple satellites. The 12 images that are chosen are decided by the time the job is run from the cron, with the most recently available 12 images being chosen. Area files are obtained via McIDAS ADDE, and an IDL program is then executed to extract images from the Area files and re-project the images onto the standard IMS map projection.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.17 Arctic Composite Infrared Imagery

Hourly NOAA GOES/POES mosaic infrared-band (~11.0  $\mu\text{m}$ ) imagery products are generated in the NOAA OSPO GEO System by using satellite imagery in GOES West/East, Meteosat, Himawari 8, NOAA 18 & 19 AVHRR, Aqua/Terra, MetOp-A, MetOp-B, S-NPP, and NOAA 20. Each image covers from at least 50th parallel north, and is composed of a mosaic from multiple satellites. The 12 images that are chosen are decided by the time the job is run from the cron, with the most recently available 12 images being chosen. Area files are obtained via McIDAS ADDE, and an IDL program is then executed to extract images from the Area files and re-project the images onto the standard IMS map projection.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.18 Arctic Composite Shortwave Imagery

Hourly NOAA GOES/POES mosaic shortwave-infrared-band (~3.8  $\mu\text{m}$ ) imagery products are generated in the NOAA OSPO GEO System by using satellite imagery in GOES West/East, Meteosat, Himawari 8, NOAA 18 & 19 AVHRR, Aqua/Terra, MetOp-A, MetOp-B, S-NPP, and NOAA 20. Each image covers from at least 50th parallel north, and is composed of a mosaic from multiple satellites. The 12 images that are chosen are decided by the time the job is run from the cron, with the most recently available 12 images being chosen. Area files are obtained via McIDAS ADDE, and an IDL program is then executed to

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extract images from the Area files and re-project the images onto the standard IMS map projection.

### 2.2.19 MODIS AQUA Imagery

The MODIS AQUA HRPT imagery consists of up to 25 visible (Channel-1) images over most areas of North America. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The job runs once per day and will process through the latest 25 images and produce products for those passes which are visible (the routine removes the dark passes). The input data covers both NASA 5 minute granules and the Wisconsin “stitched” granules. A Perl routine will remove the dark passes and build a McIDAS BATCH job which will remap each pass in a polar stereographic projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.20 MODIS TERRA Imagery

The MODIS TERRA HRPT imagery consists of up to 25 visible (Channel-1) images over most areas of North America. The input data is received via McIDAS ADDE and remapped for use in the IMS preprocessing routine. The job runs once per day and will process through the latest 25 images and produce products for those passes which are visible (the routine removes the dark passes). The input data covers both NASA 5 minute granules and the Wisconsin “stitched” granules. A Perl routine will remove the dark passes and build a McIDAS BATCH job which will remap each pass in a polar stereographic projection centered on a specific point and cut to a set size. The resulting AREA files are then sent through an AXFORM command to output a simple binary image file for use with the ENVI programs. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.21 Polar MODIS Imagery (image loops 1 and 2)

The Polar MODIS imagery consists of Polar region TERRA and AQUA HDF granules received mainly for Coastwatch applications. The HDF files are available on the EOS data gateway and the IMS preprocessing script will run once per day to transfer over all passes from the previous day; passes are restricted to North Hemisphere polar region and averages about 80/day. The filenames have the following naming convention:

MOD021KM.AYYYYJJJ.HHMM.hdf (Terra satellite granules)

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MOD021KM.PYYYYJJJ.HHMM.hdf (Aqua satellite granules)

(where YYYY = four digit year, JJJ = three digit Julian day, HH = two digit hour, and MM = two digit minute)

The input file is received using sFTP and an ENVI program is used to break apart the HDF file and extract the data with HDF arguments (“EV\_250\_Aggr1km\_RefSB”, “longitude”, and “latitude”). Since the imagery is not a fixed size, headers are read in the HDF to determine the input array size and the imagery is stored in integer format (normal ranges are from 0 – 10,000+). This imagery is then passed through a filter in the program to remove any outlier values as well as byte scale the imagery into the necessary 0 – 255 range.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.22 VIIRS I5 Imagery

The SNPP VIIRS I5 mosaic imagery consists of grayscale I5 images over most areas north of 50N degrees latitude. The input data, in the form of NetCDF files tailored for the IMS by NDE, and received through the PDA. The data naming convention is as follows:

Imagery:

VIIRS\_I5\_IMG\_EDR\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

Geolocation:

VIIRS\_IMG\_GTM\_EDR\_GEO\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The individual granules are mosaiced together into a global image and remapped for use in the IMS via the preprocessing routine. The processing is run three times per day, with each run increasing the spatial coverage. The mosaic is reset each night. The output data has a nominal resolution of 1 KM.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.23 VIIRS RGB (False Color) Imagery

The SNPP VIIRS False Color mosaic imagery consists of global-mosaic RGB images (Red=I1, Green=I2, Blue=I3) over most areas north of 50N degrees latitude and land areas in Asia, Europe, and North America. The input data, in the form of NetCDF file tailored for the IMS by NDE, and received through the PDA. The data naming convention is as follows:

Imagery:

VIIRS\_IC\_IMG\_EDR\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

Geolocation:

VIIRS\_IMG\_GTM\_EDR\_GEO\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

(where C = channel, XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The EDR imagery NetCDF files contain a single grayscale imagery granule for one channel. The geolocation files contain the latitude and longitudes corresponding to each pixel in the imagery files.

The individual granules are mosaiced together into a global image and remapped for use in the IMS via the preprocessing routine. The processing is run three times per day, with each run increasing the spatial coverage. The mosaic is reset each night. The output data has a nominal resolution of 1 KM.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.24 VIIRS NCC Imagery

The SNPP VIIRS Near Constant Contrast (NCC) mosaic imagery consists of grayscale NCC imagery over most areas north of 50N degrees latitude. The input data, in the form of NetCDF files tailored for the IMS by NDE, and received through the PDA. The data naming convention is as follows:

Imagery:

VIIRS\_NCC\_IMG\_EDR\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

Geolocation:

VIIRS\_IMG\_GTM\_EDR\_GEO\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The EDR imagery NetCDF files contain a single grayscale imagery granule for the NCC “channel”. The geolocation files contain the latitude and longitudes corresponding to each pixel in the imagery files.

The individual granules are mosaiced together into a global image and remapped for use in the IMS via the preprocessing routine. The processing is run three times per day, with each run increasing the spatial coverage. The mosaic is reset each night. The output data has a nominal resolution of 1 KM.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.25 VIIRS Sea Ice Age

The SNPP VIIRS Sea Ice Age Product consists of an estimate of sea ice age over most areas north of 50N degrees latitude. The input data, in the form of NetCDF files tailored for the IMS by NDE, and received through the PDA. The data naming convention is as follows:

Imagery:

VIIRS\_SIC\_EDR\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

Geolocation:

VIIRS\_IMG\_MOD\_GEO\_TC\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The product’s NetCDF files contain sea ice age for single granule. The geolocation files contain the latitude and longitudes corresponding to each pixel in the ice age files.

The individual granules are mosaiced together into a global image and remapped for use in the IMS via the preprocessing routine. The processing is run three times per day, with each run increasing the spatial coverage. The mosaic is reset each night. The output data has a nominal resolution of 4 KM.

Importance to Production: **2 – needed for improved quality or coverage**

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## 2.2.26 VIIRS Snow Cover

The SNPP VIIRS Snow Cover Product consists of an estimate of snow concentration over most areas north of 50N degrees latitude and land areas in Asia, Europe, and North America. The input data, in the form of NetCDF files tailored for the IMS by NDE, and received through the PDA. The data naming convention is as follows:

Imagery:

VIIRS\_SCD\_BINARY\_SNOW\_FRAC\_EDR\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eY  
YYYYMMDDHHMMSSS\_cYYYYMMDDHHMMSSS.nc

Geolocation:

VIIRS\_MOD\_GEO\_TC\_IMSXXXX\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSS  
SS\_cYYYYMMDDHHMMSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The product's NetCDF files contain snow cover fraction for single granule. The geolocation files contain the latitude and longitudes corresponding to each pixel in the ice age files.

The individual granules are mosaiced together into a global image and remapped for use in the IMS via the preprocessing routine. The processing is run three times per day, with each run increasing the spatial coverage. The mosaic is reset each night. The output data has a nominal resolution of 4 KM.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.27 AMSR-2 Brightness Temperature Products

The Advanced Microwave Scanning Radiometer, onboard the GCOM-W1 satellite, has 89 GHz brightness temperature products containing two polarized sets of imagery which, when differenced, help determine areas of sea ice. The input orbital NetCDF files for the last 24 hours are received via the PDA with the filename format shown below:

AMSR2-MBT\_v2r0\_GW1\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_  
cYYYYMMDDHHMMSSS.nc

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(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

Two main products are extracted are extracted from the NetCDF files: “Brightness\_Temperature\_89\_GHz\_AV” and “Brightness\_Temperature\_89\_GHz\_AH”, which represent the vertically and horizontally polarized components; the longitude/latitude arrays provided are also taken. Values in the input product range from 0 to 1000. A Python/GDAL program is used to remap the individual orbital files into the IMS projection and assemble them into mosaic scenes. The product is made once a day, and covers the full Northern Hemisphere with a nominal resolution of 6x4 KM.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.28 AMSR-2 Ice Concentration Product

The Advanced Microwave Scanning Radiometer, onboard the GCOM-W1 satellite, has a sea ice concentration product over the Northern Hemisphere. The input NetCDF file, obtained via the PDA, contains ice concentration derived from the last 24 hours of data, and its filename format is as follows:

AMSR2-SEAICE-NH\_v2r0\_GW1\_sYYYYMMDDHHMMSSSS\_eYYYYMMDDHHMMSSSS\_cYYYYMMDDHHMMSSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The “NASA\_Team\_2\_Ice\_Concentration” product and the corresponding latitude/longitude array are extracted from the NetCDF file. The input sea ice concentrations range from 0 – 100 (% concentration), with an array size of 1050x1050, and typically cover the Northern Hemisphere above 20N degrees latitude. A Python/GDAL program is then used to remap into the IMS projection. The product is made once a day.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.29 AMSR-2 Snow Depth Product

The Advanced Microwave Scanning Radiometer, onboard the GCOM-W1 satellite, has a snow depth product. The input orbital NetCDF files for the last 24 hours, where each file contains derived snow depth based on that orbit, are received via the PDA with the filename format shown below:

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AMSR2-SNOW\_v2r0\_GW1\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_  
cYYYYMMDDHHMMSSS.nc

(where XXXX = name of spatial area covered, YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

Two main products are extracted are extracted from the NetCDF files: “Snow\_Depth” and “Snow\_Cover”. The snow depth field contains values in units of cm. Breakdown of values in the snow cover field is shown below:

0 = missing

1 = land without snow

2 = land with wet snow

3 = land with dry snow

The snow depth product does not include areas where snow depth could not be calculated, thus the snow cover product is used to augment the IMS input, by showing an unknown depth in those snow covered regions.

A Python/GDAL program is used to remap the individual orbital files into the IMS projection and assemble them into mosaic scenes. The product is made once a day, with a nominal resolution of 6x4 KM.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.30 SAR Imagery

Northern Hemispheric 24-hour rolling mosaics of SAR imagery from Sentinel 1 A&B and RadarSAT 2 are provided in 1km resolution, with four updates a day. The input data is available on the STAR HTTPS and FTP servers, as well as NIC NAIL, as a GeoTIFF file with the following naming convention:

NRCS\_Composite\_1km\_YYYYMMDDThhmm\_YYYYMMDDThhmm\_N###.tif

(where YYYY = four digit year, MM = two digit month, DD = two digit day, hh = two digit hour, mm=two digit minute, though the the two hhmm fields are rarely identical)

The input file is reprojected to the IMS base projection to be utilized in the IMS GUI. The data has an array size of 6803x6803 with 1.003km<sup>2</sup> resolution. Data values range from 0-255.

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Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.31 SAR Ice Mask

A Northern Hemispheric 24-hour rolling SAR Ice Masks from Sentinel 1 A&B and RadarSAT 2 are provided, with four updates a day. The input data is available on the STAR HTTPS and FTP servers, as well as NIC NAIL, as a GeoTIFF file with the following naming convention:

SARIceMask\_Composite\_1km\_YYYYMMDDThhmm\_YYYYMMDDThhmm\_N###.tif

(where YYYY = four digit year, MM = two digit month, DD = two digit day, hh = two digit hour, mm=two digit minute, though the the two hhmm fields are rarely identical)

The input file reprojected to the IMS base projection to be utilized in the IMS GUI. The data has an array size of 6803x6803 with 1.003km<sup>2</sup> resolution. Data values range from 0-255.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.32 ASCAT Sea Ice Product

The Advanced Scatterometer (ASCAT) is an active microwave on board the ENVISAT polar orbiting instrument. Processing of the sigma 0 values is done in NOAA to produce a spectrally-enhanced ASCAT backscatter return that highlights the location of ice cover and ice age. The current day's product is available on the PDA as a GeoTIFF with the following naming convention:

Msf\_a\_NHe-a-YYYYJJJJ.sir.geotiff

(where YYYY = four digit year, JJJ= three digit Julian day)

The input file is received using sFTP and a shell program from the IMS GUI directly. The the data file needs only to be renamed and reprojected to the IMS base projection to be utilized in the IMS GUI. The data has an array size of 2340x2340 with 4.45 km resolution. Data values range from 0-255.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.33 AMSU Products

The Advanced Microwave Sounding Unit (AMSU) data is available for the NOAA-NP satellite series and is used in the IMS. AMSU files are made available on the PDA for the previous day data for NOAA- N, and P satellites. The data set naming conventions are as follows:

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NRP.MHMP.NN.DYYJJJ (NOAA-18 [N])

NPR.MHMP.NP.DYYJJJ (NOAA-19 [P])

(where YY = two digit year, JJJ = three digit Julian day)

The input files are received from the PDA and an ENVI program is used to break apart each HDF structured file and extract the data fields 10, 11, and 12 (corresponds to rain rate, snow coverage, and ice coverage). Since the area of coverage remains constant for the AMSU products, a static geo-location file has been set up so the three data fields are the only data needing to be extracted from the file. Both products (one for each satellite) have a common array size of 1024x1024 corresponding to about 24km resolution. The data values are 0 – 30 for rain rate (in mm/hr), 0 – 150 for snow coverage (in % coverage but allows for outlier values), and 0 – 100 for ice coverage (in % coverage).

Importance to Production: **3 – nice to have, but not needed**

### 2.2.34 SSM/I Products

The SSM/I (Special Sensor Microwave Imager) is a microwave instrument aboard the DMSP (Defense Meteorological Satellite Program) satellites and is currently available for the IMS from DMSP-15 only. The EDR (Environmental Data Record) file contains several different products from which the IMS uses 7 (ice age, ice concentration, ice edge, rain rate, snow/ice cover, snow depth, and maximum surface temperature). The EDR files are made available on the PDA, with each having a varying amount of data that generally averages to about a day, and have the following naming conventions:

noaa\_snow\_f15.north.YYYYMMDDHH.YYYYMMDDHH

(where YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour)

The EDR file consists of many datasets arranged in the format:

header 1 (1024 integer array)  
dataset 1 (512 x 512 integer array)  
header 2 (1024 integer array)  
dataset 2 (512 x 512 integer array)  
header 3 (1024 integer array)  
..

The IMS preprocessing program will read through each header and data set, picking out

only the records needed for the IMS.

Rain Rate product:	EDR dataset 8
Ice Concentration product:	EDR dataset 11
Ice Age product:	EDR dataset 12
Snow/Ice Edge product:	EDR dataset 13
Surface Temperature product:	EDR dataset 15
Snow Depth product:	EDR dataset 16
Surface Type product:	EDR dataset 18

The input file is received from the PDA one a day and an ENVI program is used to restructure the data to make it usable in the IMS GUI. Since the area of coverage remains constant (in Geographic projection), a static geo-location file has been set up so to speed up the processing time. The data has an array size of 512x512 and has several data values shown below:

Rain Rate product:

0 - 25 = Rain rate in mm/hr

Ice Concentration product

0 = Open Water

1 – 20 = Ice Concentration Values (scaled with 20 = 100% Ice)

254 = Land

Ice Age product (product may not be displayed correctly):

0 = Outside North hemisphere (poss. Single year ice)

1 = Single Year Ice (poss. Multi-year ice)

254 = No Ice

Snow/Ice Edge product:

0 = Not Ice Edge

1 = Ice Edge

254 = Not Analyzed

Surface Temperature product:

Product is currently not available, changed formats, or is severely degraded.

Snow Depth Product:

Product is currently not available, changed formats, or is severely degraded.

---

---

Surface Type product:

- 0 = Outside North America
- 3 = Sea Ice
- 5 = Open Ocean
- 18 = Dry Snow
- 19 = Wet Snow
- 20 = Re-frozen Snow
- 21 = Glacial Snow

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.35 USAF Products

The USAF (United States Air Force) dataset currently have three products contained within (snow age, snow depth, and snow climatology) and are available on the PDA. These daily files are made available on the Polar Server and have the following naming conventions:

PRD.SPPROD.SNODEPH.NHMAMAP.DYYYYJJJ

(where YYYY = four digit year, JJJ = three digit Julian day)

The main binary data file consists of three main datasets arranged in the format:

- header 1 (1024 integer array)
- dataset 1 (512 x 512 integer array)
- header 2 (1024 integer array)
- dataset 2 (512 x 512 integer array)
- header 3 (1024 integer array)
- dataset 3 (512 x 512 integer array)

The input files are received via the PDA and an ENVI program is used to break apart each binary file and extract the three products. Since the area of coverage remains constant for the USAF products, a static geo-location file has been set up so the three data fields are the only data needing to be extracted from the file. The breakdown of data values for these 3 products is shown below:

Snow Age:

0 – 365 = Age of snow/ice cover in days

Snow Depth: 0 – 700+ = Snow depth in mm

---

---

4090 = Ice

Snow Climatology:

Product is no longer available (blank).

Importance to Production: **3 – nice to have, but not needed**

### 2.2.36 North Hemisphere 4km AutoSnow Product

The 4km North Hemisphere AutoSnow product is an automated product using satellite data to map snow cover over the entire North. Due to timeliness, the previous day's product is used and is available on the IMS preprocessing system as a binary file with the following naming convention:

NH.C17\_YYYYJJJ\_BLND\_SID

(where YYYY = four digit year, JJJ= three digit Julian day)

The input file is received using sFTP and then an ENVI program is used to restructure the data to make it usable in the IMS GUI. Since the area of coverage remains constant (in Geographic projection), a static geo-location file has been set up so to speed up the processing time. The data has an array size of 9000x2250 and has several data values shown below:

0 = Open water

1 = Land without snow

2 = Snow

3 = Ice

20 = Water, but no satellite data

21 = Land, but no satellite data

200 = Undetermined over land

210 = Undetermined over water

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.37 North Hemisphere 4km AutoSnow DSLO Product

This 4km North Hemisphere AutoSnow DSLO auxiliary product is an automated product that depicts the number of days since the AutoSnow product was last updated for each pixel of the analysis which can be useful for judging product confidence over specific areas. Due to timeliness, the previous day's products are used and are available on the IMS preprocessing system as binary files with the following naming conventions:

NH.C17\_YYYYJJJ\_BLND\_DAY

---

---

(where YYYY = four digit year, JJJ= three digit Julian day)

The input file is received using sFTP and then an ENVI program is used to restructure the data to make it usable in the IMS GUI. Since the area of coverage remains constant (in Geographic projection), a static geo-location file has been set up so to speed up the processing time. The data has an array size of 9000x2250 and has several data values shown below:

1 – 199 = Number of days since N. H. AutoSnow pixel was last updated

200 = No data / missing

Importance to Production: **3 – nice to have, but not needed**

### 2.2.38 NIC MIZ

Each day the NIC posts a shapefile outlining the pack ice and marginal ice zone (MIZ) areas over the Northern Hemisphere. This product is posted at the NIC NAIL, typically by around 1PM local time. The file naming convention is as follows:

nic\_mizYYYYJJJnc\_pl\_a.zip

(where YYYY = four digit year, JJJ = three digit Julian day)

The input file is received using SFTP and unzipped using a shell program from the IMS GUI directly. The IMS GUI itself reprojects the unzipped data to the IMS base projection.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.39 NOHRSC Product

The National Operational Hydrologic Remote Sensing Center (NOHRSC) snow cover product displays snow cover over the 48 contiguous United States. The current day's product is available on the polar server as a zipped and tarred binary file with the following naming convention:

us\_ssmv11034tS\_\_T0001TTNATSYYYYMMDD05HP001\_s.arz

(where YYYY = four digit year, MM = two digit month, DD = two digit day)

The input file is received from the PDA and a shell program unzips then untars the data file which is then input into an ENVI program which is used to restructure the data to make it usable in the IMS GUI. Since the area of coverage remains constant (in Geographic projection), a static geo-location file has been set up so to speed up the processing time. The data has an array size of 6935x3351 and has two data values shown below:

50 = No Snow

250 = Snow

---

---

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.40 MMAB (OMB) SSM/I Sea Ice Product

The Marine Modeling and Analysis Branch (MMAB) [previously OMB] sea ice product uses SSM/I to generate a sea ice concentration product in roughly a 12.7 km resolution in binary format. The product is available (for the current day) on the PDA with the following naming convention:

seaice.t00z.northpsg.grib2.MM\_DD\_YYYY

(where MM = two digit month, DD = two digit day, and YYYY = four digit year)

The input is received from the PDA, converted to GRIB1 and an ENVI program is used to break apart the file to extract needed information. The sea ice file in GRIB1 format contains a header of 80 bytes and a data array of 385 x 465 bytes. The data array location remains static so a static geo-location file has been set up to make re-navigating product for IMS much quicker. The breakdown of data values for this product is shown below:

0 = ocean

16 –128 = sea ice concentrations in percent (values greater than 100 are for >99%)

157 = land

177 = weather

195 = coast

224 = no data

Importance to Production: **3 – nice to have, but not needed**

## 2.2.41 NCEP GFS Snow Depth Change

Global output from NCEP GFS model for the current day's analysis is available for IMS Preprocessor. Filename convention is as follows:

gfs\_snowd\_change\_shp\_tif\_.YYYYMMDD.zip

(where YYYY = four digit year, MM = two digit month, DD = two digit day)

Data is picked up daily from [ftp://ftp.cpc.ncep.noaa.gov/GIS/gfs\\_0.25/](ftp://ftp.cpc.ncep.noaa.gov/GIS/gfs_0.25/) and unzipped to GeoTIFF files. The 0.25° resolution files are available in GeoTIFF formats and sliced to just incorporate the northern hemisphere and reprojected to the IMS projection. Snow depth change values range from -200 to 200 and represent the change in depth for the last 24 hours in centimeters.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.42 CMC Snow Depth

Each day, the Canadian Meteorological Center generates statistically modeled snow depth based on surface reports around the world. This data is not an operational source since it is not generated by NOAA, but is made available regularly through the PDA. The file is format for the name is the following.

YYYYMMDD18\_snow\_latlon0.2x0.2.nc

(where YYYY = four digit year, MM = two digit month, DD = two digit day)

The input netCDF file contains three datasets: the snow depth array, and the corresponding longitude and latitude for each point. The file is received via the PDA, and an IDL program is used to extract the datasets and restructure the data to make it usable in the IMS GUI. The data has an array size of 1800x900 with .2 degree resolution. Data value range represents meters.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.43 IMS Snow Depth

Each day, the internal NIC generates statistically modeled snow depth based on surface reports around the world. This data is generated as part of the output from the snow depth file and made available as a layer file to the IMS analyst for adjustment of snow depth that appears to be erroneous. While the IMS Snow Depth layer is not able to be edited directly by the analysts, they may generate snow depth edits via that “Draw Snow Depth” layer that is used in the next IMS Snow Depth production during as a part of the IMS final production run in the IMS GUI. The file is format for the name is the following.

imsSDYYYYJJJ.asc

(where YYYY = four digit year and JJJ=three digit Julian day)

The input ascii file contains just the estimated depth after last production run, and an IDL program is used to extract the datasets and restructure the data to make it usable in the IMS GUI display. The data has an array size of 6144 x 6144 with 4km resolution. Data value range represents cm.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.44 NAVO Sea Ice Model

NAVO begun output in 2010 of a coupled ocean/sea ice model named the Global Ocean Forecast System (GOFS). Sea ice thickness and concentrations originate from the ACNFS. The GOFS data is pulled by the NIC from NAVO servers as a netCDF with over

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20 fields and 4 forecast periods. This is processed at the NIC to generate 4 GeoTIFF set of files (Nowcast 00z Sea Ice Thickness, Nowcast 00z Sea Ice Area, 24h forecast Sea Ice Thickness, 24h forecast Sea Ice Area) using ArcGIS. The current day's products are available on the NIC NAIL as a set of a GeoTIFFs with the following naming convention:

gofs\_sea\_ice\_thickness\_YYYYMMDD\_t000\_n.tif (nowcast sea ice thickness)  
gofs\_sea\_ice\_area\_fraction\_YYYYMMDD\_t000\_n.tif (nowcast sea ice area)  
gofs\_sea\_ice\_thickness\_YYYYMMDD\_t024\_n.tif (24h forecast sea ice thickness)  
gofs\_sea\_ice\_area\_fraction\_YYYYMMDD\_t024\_n.tif (24h forecast sea ice area)  
(where YYYY = four digit year, MM = two digit month, DD = two digit day)

The input file is received using SFTP, and an ENVI program is used to restructure the data to make it usable in the IMS GUI. The data is reprojected to the IMS base projection and rescaled. Ice thickness values should be stretched to display data values from 0-12 with 8 bit 0-255 color values. Ice area values display data values from 0-1 with 8 bit color values from 0-100 (percentage of ice area). The data has an array size of 2770x6803 with 4km<sup>2</sup> resolution.

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.45 (Disabled) NAIS Sea Ice Model Output

*Note: This product is not currently available.*

The CMC also produces sea ice modeled ice concentrations based on passive microwave data, NAIS ice charts, and physical model estimates in their RIPS (Regional Ice Prediction System) model. This model produces a two dimensional sea ice concentration field covering all waters surrounding North America at a 5km horizontal resolution. Analyses are produced 4 times a day – valid at 0Z, 6Z, 12Z, and 18Z. This data is set to the NIC via the CIS in NetCDF4 and GeoTIFF formats. The GeoTIFF of ice concentrations (gl) and the days since last observed (dslo) is passed along to the IMS. This data naming convention is as follows:

YYYYMMDDHH\_054\_I3\_north@america\_I\_CIS@SFC@ANALYSIS\_gl\_000.tiff

YYYYMMDDHH\_054\_I3\_north@america\_I\_CIS@SFC@ANALYSIS\_dslo\_000.tiff

(where MM = two digit month, DD = two digit day, HH = Hour, and YYYY = four digit year)

The input file is received using FTP and from the IMS GUI directly. The data file needs to be renamed and reprojected to the IMS base projection to be utilized in the IMS GUI. The

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tifs have a pre-assigned color map, with a legend that is within the tif. Files are 8 bit with 0-255 color values. The data has an array size of 573x411 with 5km<sup>2</sup> resolution.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.46 (Disabled) NIC Sea Ice Thickness and Concentration

*Note: This product is not currently available.*

The NIC provides daily updated mean sea ice thickness estimates in gridded GeoTIFF format. The mean thickness is based on estimated total ice concentrations and ice stage of develop estimates from NIC ice charts and other ice charting information. Code to estimate the ice thickness is run on the NIC SciQuad2 and placed on the NIC webserver for IMS to ftp to the GUI. Two GeoTIFFs of ice concentrations (IZE) and the days since last observed (DSLO) are included. This data naming convention is as follows:

MosaicAvgThkMmYYYYMMDDJJJ.tif

MosaicAvgThkRMmYYYYMMDDJJJ.tif

MosaicTotConPptYYYYMMDDJJJ.tif

MosaicTotConRPptYYYYMMDDJJJ.tif

MosaicDateConYYYYMMDDJJJ.tif

(where YYYY = four digit year, MM = two digit month, DD = two digit day and JJJ=three digit Julian day)

The input file is received using FTP and from the IMS GUI directly. The files applies the same IMS base projection as the 4km IMS. No reprojection is required. Files are 8 bit with 0-255 color values. Values represent the estimated ice thickness in decimeters. (1=10 cm, 10 = 100 cm = 1 meter). The data array size has not yet been determined but the resolution will be 4km<sup>2</sup>.

Importance to Production: **2 – needed for improved quality or coverage**

## 2.2.47 Hourly Surface Data Product

The surface data reports, available for surface stations around the world on an hourly basis, come from the McIDAS Family of Services (FOS) through ADDE. A McENV session is run which uses the PTLIST command to select the latest 24 hours of surface data reports and deposit them into an ASCII data file. The SELECT keyword is set to a day/time range and only certain parameters are used to limit the selection to the desirable information. A PERL script is then run for data reformatting and an ENVI script is run to convert coordinate systems to match that of the IMS. More specific information about the McIDAS product is listed below:

Dataset used: RTPTSRC/SFCHOURLY

---

“SELECT settings”: DAY and TIME (ranges) are selection parameters

Parameters chosen: TIME, LAT, LON, T, WX1, PCP, SNO, VIS, ID, NUM=ALL

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.48 Daily Surface Data Snow Depth

Daily Snow Depth data includes SYNOP daily surface report and COOP daily surface report. The Family of Services (FOS) SYNOP surface data (daily report) is updated daily and contains surface data readings (time, temperature, precipitation and snow depth) from around the globe. The surface data preprocessing is run once daily from cron to capture previous day readouts from McIDAS ADDE. The group name is FOS and file name is SYN. The NCEP coop surface data (daily report) is updated daily and contains surface data readings (station ID, state, City, snow depth, snow fall, and elevation.) from around the United States. The COOP daily surface report is available on NCEP ftp:

ftp.cpc.ncep.noaa.gov as a set of ASCII file format with the following naming convention:  
snow-\*\*\*.txt

fall-\*\*\*.txt

(\*\*\*=Mon, Tue, Wed, Thu, Fri, Sat, Sun)

Importance to Production: **2 – needed for improved quality or coverage**

### 2.2.49 Ancillary data in the format of Shapefile or GeoTIFF

On occasion, data that is external to the IMS system is required to accurately identify the snow and ice conditions. If this data is properly georeferenced as a GeoTIFF or Shapefile, this data can be imported directly into the IMS GUI. The analysts will need to place the data that requires display into the following folder on the GUI. The analysts will import the data by using a button on the IMS GUI display to reproject the data into the required IMS base projection and display the data on the analysis map on the GUI.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.50 Political boundaries

Political boundaries can be overlaid on top of the imagery and map with-in the IMS, to serve as an additional geographical guide. The exact source of the data is unknown at present time, and appears to have been current for year 2000.

Importance to Production: **3 – nice to have, but not needed**

### 2.2.51 Land water mask

The land water mask is based on the surface type classification produced by the University of Maryland Department of Geography in 1998 (Hansen et al. 1998, 2000). Imagery from

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the AVHRR satellites acquired between 1981 and 1994 were analyzed to distinguish fourteen land cover classes. This product is available at three spatial scales: 1 degree, 8 kilometer and 1 kilometer pixel resolutions. For the IMS snow/ice cover algorithm, the 1 km data were aggregated into 4 km size grid cells.

More information is available online at

<https://web.archive.org/web/20130115204530/http://glcf.umiacs.umd.edu/data/landcover/>

Importance to Production: **1 – needed for processing**

### 2.2.52 Digital elevation

Elevation information for every pixel is used as static input to allow snow cover in mountainous regions to follow the elevation change. The elevation dataset in the current version of the algorithm is based on USGS GTOPO30 model data averaged within 1 km grid cells. (<https://lta.cr.usgs.gov/GTOPO30>)

Importance to Production: **1 – needed for processing**

## 2.3 Theoretical Description

Since the IMS is an analyst driven product there are very few algorithms used for direct generation of the final product ever used in the system. Preprocessing algorithms are designed to reformat input data into IMS area files with a common projection, datum, and possibility as stacked looped images (when appropriate). Analysts provide manual interpretation of ice and snow cover at 1km based on observational data from one of more satellite, in-situ surface observations, and modeled estimates. The analysts apply expert knowledge to determine if more than 40% of the 1x1km grid is covered with ice or snow. The analysts nowcast the product out several hours, by tracking active storms, snow melt and ice motion, to be valid at 18 and 00 UTC. Areas are identified as containing snow/ice if the analysts determined that more than 40% of the cell is covered by this feature. Otherwise the cell is considered land/water. A land/sea mask is used to ensure that only water can be determined as ice covered and only land can be determined to be snow covered. The 1km resolutions are amalgamated to 4km cells, with an assumption that if 8 or more of the 1km cells has a particular class, the 4km cell will be identified as that cell.

The 24km ASCII file NCEP has been using around for many years and does not fully agree with the IMS basemap being used (IMS is much more accurate and up-to-date, even at 24km). To preserve the format (and NCEP's land/sea mask), the IMS values had to be transferred to the same "grid" that has always been used. To determine how to regrid the 4km IMS analysis onto the 24km NCEP grid, a nested grid style of calculation is performed and a decision tree is used (see Figure 2-1). The routine will process through each pixel of

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a base NCEP product file and use the outlined process to determine one of the 5 possible land cover values. After extensive testing with different decision paths, this decision tree provided over a 99% match to the old product (compared by performing old and new analysis on different systems in parallel and comparing output). After all values for each grid point has been determined, the ASCII file is generated. Embedded within the file is a 30 line text header record, followed by the 1024 line data record (1024 entries per line having values 0 – 4). It is important to note that the ASCII products start reading data from the lower left corner whereas ENVI inherently starts everything from the upper left corner. The data has to be flipped for the ASCII products before being written into the file.

The Snow Depth Algorithms will be reviewed in section 3.

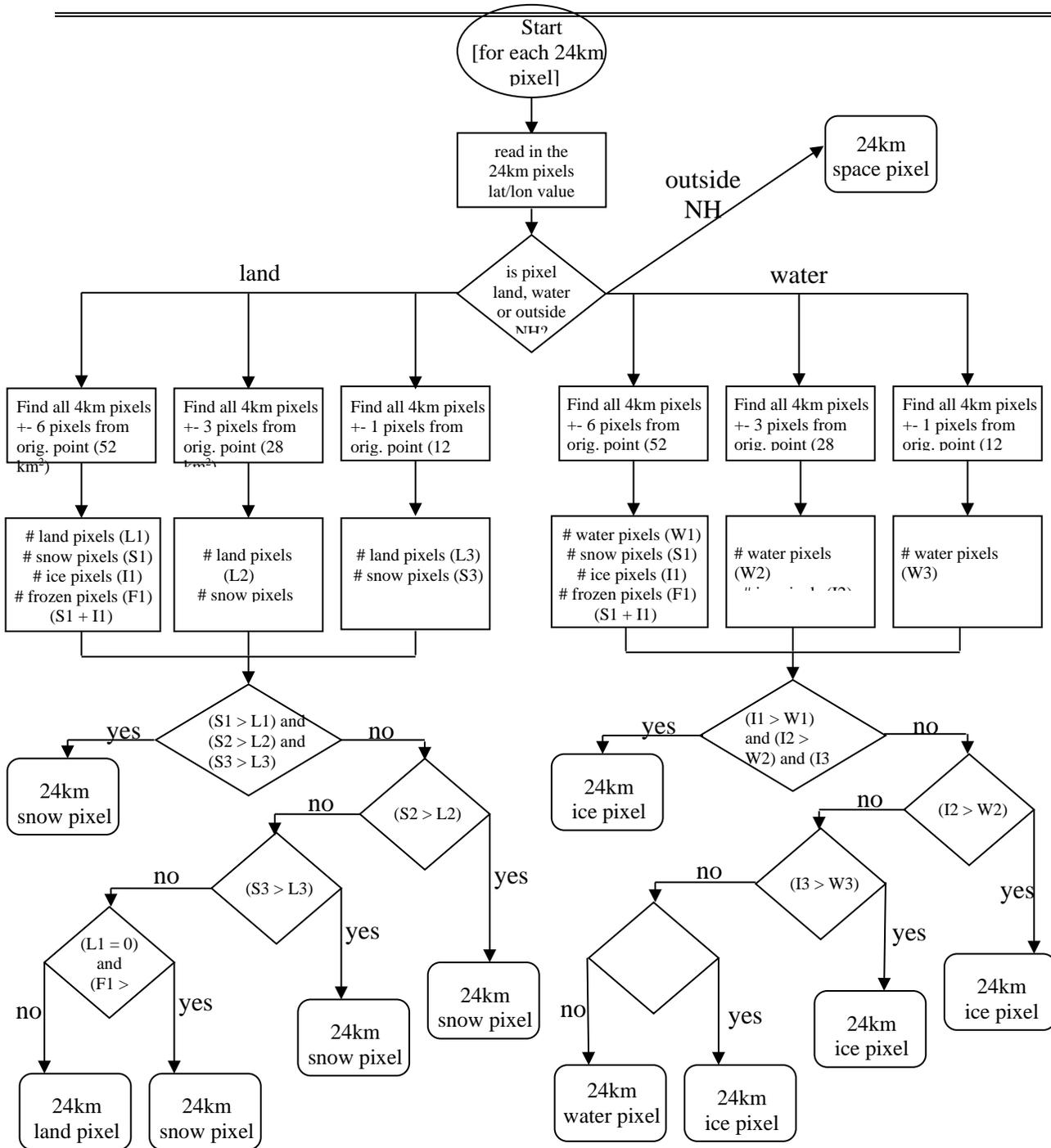


Figure 2-1. 24km IMS product decision tree

## 2.4 Algorithm Output

The IMS GUI system produces a number of output files all generated from scripts that run via cronjob. Five general types or products are made, the IMS snow/ice map files (in ASCII and ENVI formats), GeoTIFF snow/ice map files, and the GIF (Graphic Interchange Format) snow/ice map web images, and GRIB-2 files separately containing snow, ice and days-since-last-observed. The ASCII, ENVI and GRIB-2 formats are produced twice a day, forming the 18Z and 00Z products respectively. The GeoTIFF and GIF formats are produced once a day for the 00Z products. More than one IMS GUI system is currently being used but only the operational GUI system will generate and distribute products to the users.

### 2.4.1 ASCII Files

The ASCII snow and ice cover products are three separate map files (in 24km, 4km and 1km resolutions) in ASCII format (printable single byte characters) containing Northern Hemisphere snow and ice coverage represented by five possible values. These products are currently produced twice a day (before 18 and 00 UTC) via cron after the analysts have completed the interactive portion of the IMS analysis. The values that are used in these products are:

- 0 = outside coverage area (Northern Hemisphere) "space" pixel
- 1 = open water
- 2 = land without snow
- 3 = sea ice
- 4 = snow covered land

All resolutions of ASCII files have similar naming conventions upon distribution. The naming format is NIC.IMS\_v3\_YYYYJJJHH\_Rkm.asc.gz, where YYYY is four digit year, JJJ is three digit Julian day, HH is two digit product hour and R is resolution in KM (ex. NIC.IMS\_v3\_201800100\_1km.asc.gz). The datetime in the filename indicates the product valid time.

#### 2.4.1.1 ASCII File (24km)

The 24km snow and ice cover ASCII file NCEP has been using has been around for many years and does not fully agree with the IMS basemap being used (IMS is much more accurate and up-to-date, even at 24km). To preserve the format (and NCEP's land/sea mask), the IMS values had to be transferred to the same "grid" that has always been used.

To determine how to regrid the IMS analysis onto the 24km NCEP grid, a nested grid style of calculation is performed and a decision tree is used (see Figure 2-1). The routine will

# NOAA NESDIS STAR

## ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 47 of 74

process through each pixel of a base NCEP product file and use the outlined process to determine one of the 5 possible land cover values. After extensive testing with different decision paths, this decision tree provided over a 99% match to the old product (compared by performing old and new analysis on different systems in parallel and comparing output).

After all values for each grid point have been determined, the ASCII file is generated. Embedded within the file is a 30 line text header record, followed by the 1024 line data record (1024 entries per line having values 0 – 4).

An example of the 24km ASCII product file header is given in Figure 2-2.

```
1>Julian day of IMS data log: 2006256
2>Processing day          : Wed Sep 13 22:13:13 2006
3>Total # scientific data sets: 1
4>File description:
5>This file contains Northern Hemisphere snow and ice coverage produced by the
   NOAA/NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS) developed under
   the direction of the National Ice Center (NIC). For more information, please contact Mr. Sean Helfrich at
   Sean.Helfrich@noaa.gov
6>Map Label: Northern Hemisphere 1024x1024 snow and ice coverage
7>Coordinate System: Polar Stereographic
8>Data Values: 1 (sea), 2 (land), 3 (sea ice), 4 (snow),Data Values: 0 (outside Northern
   Hemisphere)
9>Format: I1
10>Dimensions: 1024 X 1024
11>(1,1) starts at: lower left corner
12>----- Data set starts here: -----
13>
14> Data Set #          1
15>  Data Label:
16>Northern Hemisphere 1024x1024 Snow & Ice Chart
17>  Coordinate System:          Polar Stereographic
18>  Data Type:                  BYTE
19>  Format:                      I1
20>  Dimensions:                 1024      1024
21>  Min/Max Values:             0 4
22>  Units:                      8-bit Flag
23>  Dimension #                 0
24>    Dim Label:                 Longitude
25>    Dim Format:                 Device Coordinates
26>    Dim Units:                 Pixels
27>  Dimension #                 1
28>    Dim Label:                 Latitude
29>    Dim Format:                 Device Coordinates
30>    Dim Units:                 Pixels
```

## Figure 2-2. 24km sample header record

### 2.4.1.2 ASCII File (4 km)

The 4km snow and ice cover ASCII file was not previously being used at NCEP and thus there were no requirements given for this product. Since there were no land/sea mask stipulations given, the IMS land/sea mask was used because it is higher resolution and a simple one to one conversion of the 4km analysis to ASCII is performed. The data is again flipped to match the 24km format and the header slightly differs as seen in Figure 2-3. Instead of 1024 lines in the data record, this dataset will have 6144 lines in the data record that are 6144 entries each.

An example of the 4km ASCII product file header is given in Figure 2-3.

```
1>Julian day of IMS data log: 2006256
2>Processing day      : Wed Sep 13 22:13:13 2006
3>Total # scientific data sets: 1
4>File description:
5>This file contains Northern Hemisphere snow and ice coverage produced by the
   NOAA/NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS) developed under
   the direction of the National Ice Center (NIC). For more information, please contact Mr. Sean Helfrich at
   Sean.Helfrich@noaa.gov
6>Map Label: Northern Hemisphere 6144x6144 snow and ice coverage
7>Coordinate System: Polar Stereographic
8>Data Values: 1 (sea), 2 (land), 3 (sea ice), 4 (snow),Data Values: 0 (outside Northern
   Hemisphere)
9>Format: I1
10>Dimensions: 6144 X 6144
11>(1,1) starts at: lower left corner
12>----- Data set starts here: -----
13>
14> Data Set #      1
15> Data Label:
16>Northern Hemisphere 6144x6144 Snow & Ice Chart
17>  Coordinate System:      Polar Stereographic
18>  Data Type:              BYTE
19>  Format:                  I1
20>  Dimensions:             6144      6144
21>  Min/Max Values:        0 4
22>  Units:                  8-bit Flag
23>  Dimension #           0
24>  Dim Label:              Longitude
25>  Dim Format:              Device Coordinates
26>  Dim Units:              Pixels
27>  Dimension #           1
28>  Dim Label:              Latitude
29>  Dim Format:              Device Coordinates
30>  Dim Units:              Pixels
```

**Figure 2-3. 4km sample header record**

### 2.4.1.3 ASCII File (1 km)

The 1km snow and ice cover ASCII file was not previously being used at NCEP and thus there were no requirements given for this product. Since there were no land/sea mask stipulations given, the IMS land/sea mask was used because it is higher resolution and a simple one to one conversion of the 1km analysis to ASCII is performed. The data is again flipped to match the 24km format and the header slightly differs as seen in Figure 2-3.

# NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

Version: 2.5

Date: July 15, 2018

IMS V3 ATBD

Page 50 of 74

Instead of 1024 lines in the data record, this dataset will have 24576 lines in the data record that are 24576 entries each.

An example of the 1km ASCII product file header is given in Figure 2-4.

```
1>Julian day of IMS data log: 2006256
2>Processing day           : Wed Sep 13 22:13:13 2006
3>Total # scientific data sets: 1
4>File description:
5>This file contains Northern Hemisphere snow and ice coverage produced by the
   NOAA/NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS) developed under
   the direction of the National Ice Center (NIC). For more information, please contact Mr. Sean Helfrich at
   Sean.Helfrich@noaa.gov
6>Map Label: Northern Hemisphere 24576x24576 snow and ice coverage
7>Coordinate System: Polar Stereographic
8>Data Values: 1 (sea), 2 (land), 3 (sea ice), 4 (snow),Data Values: 0 (outside Northern
   Hemisphere)
9>Format: I1
10>Dimensions: 24576x24576
11>(1,1) starts at: lower left corner
12>----- Data set starts here: -----
13>
14> Data Set #           1
15>  Data Label:
16>Northern Hemisphere 24576x24576 Snow & Ice Chart
17>  Coordinate System:           Polar Stereographic
18>  Data Type:                   BYTE
19>  Format:                       I1
20>  Dimensions:                   24576           24576
21>  Min/Max Values:               0 4
22>  Units:                         8-bit Flag
23>  Dimension #                   0
24>    Dim Label:                   Longitude
25>    Dim Format:                   Device Coordinates
26>    Dim Units:                   Pixels
27>  Dimension #                   1
28>    Dim Label:                   Latitude
29>    Dim Format:                   Device Coordinates
30>    Dim Units:                   Pixels
```

**Figure 2-4. 1km sample header record**

### 2.4.2 ENVI Files

The ENVI snow and ice cover product files are made in the same three resolutions as the ASCII product (24km, 4km and 1km) but help to serve a different user community. These products are currently generated twice a day (before 18 and 00 UTC) via cron, after the analysts have completed the interactive portion of the IMS analysis. While not specifically required and not currently distributed, these products can easily be read into any programming language. The products are effectively plain-binary format, with the assumption that the data point (1,1) starts in the upper left corner, which is different than the ASCII equivalent products. The data contained in the files are in the same format (values 0 – 4) as the ASCII product. All resolutions of ENVI files have identical naming conventions; they just reside under separate directories. The naming format is `imsYYYYJJJ.dat` where YYYY is four digit year and JJJ is three digit Julian day (ex. `ims2006255.dat`). The datetime in the filename indicates the product creation date; the valid datetime is the same as the ASCII products. These products are not distributed.

### 2.4.3 GeoTIFF image files

The GeoTIFF snow and ice cover product images are made in two resolutions (4km and 1km). These are generated once daily (before 00 UTC) via cron, after the analysts have completed the interactive portion of the IMS analysis. The data contained in the files are in the same format (values 0 – 4) as the ASCII product.

Four output GeoTIFF images for each resolution are produced, although only one of each is distributed. The GeoTIFF's use the polar stereographic projection, with a standard parallel at 60 degrees North. These four different images display the entire North Hemisphere but are rotated differently to allow for a different reference point when looking at the imagery.

`NIC.IMS_v3_YYYYMMDD_Rkm_10.tif`

TIFF image with the central meridian set at 80 degrees west.

`NIC.IMS_v3_YYYYMMDD_Rkm_100.tif`

TIFF image (original image rotated 90 degrees clockwise) to have a central meridian at 10 degrees east.

`NIC.IMS_v3_YYYYMMDD_Rkm_190.tif`

TIFF image (original image rotated 180 degrees) to have a central meridian at 100 degrees east.

`NIC.IMS_v3_YYYYMMDD_Rkm_280.tif`

TIFF image (original image rotated 270 degrees clockwise) to have a central meridian at 170 degrees west.

Only the GeoTIFF's with central meridian set at 80 degrees west are distributed, with the following naming format: `NIC.IMS_v3_YYYYMMDD_Rkm.tif.gz`. For all files above, R = 1 or 4 KM resolution, YYYY = four digit year, MM = two digit month, and DD = two digit day. The

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datetime in the filename indicates the product creation date; the valid datetime is the same as the ASCII products.

### 2.4.4 GRIB-2 files

Several types of GRIB-2 product files are made by the snow and ice cover algorithm. All of them are generated twice daily (before 18 and 00 UTC) via cron, after the analysts have completed the interactive portion of the IMS analysis.

The GRIB-2 snow cover product is generated in 2 resolutions (1 km & 4km). The snow cover product contains the following values,

0 = land without snow  
100 = snow covered land

The GRIB-2 ice cover product is generated in 2 resolutions (1 km & 4km). The ice cover product contains the following values,

0 = open water  
1 = sea ice

The GRIB-2 days-since-last-observed product is generated in 2 resolutions (1 km & 4km). This product contains values, in days, from 0 to 200. Note that the product is computed as the minimum value between days-since-last-updated by an IMS analyst and the days-since-last-updated by AutoSnow&Ice. Data is only available where IMS and ASI overlap.

A combination GRIB-2 snow-products output, which contains snow cover and days-since-last-observed, along with northern-hemisphere snow depth and snow depth data quality (which are described in section 3 of the ATBD) is generated. Each sub-product is in 4km resolution. The snow cover and days-since-last-observed use the same data values as their 1km versions above. The snow depth values are in meters, data quality is 0 to 1 with increasing values indicating more confidence.

A combination GRIB-2 ice-products output, which contains ice concentration, ice thickness, uncertainties for each and days-since-last-observed is generated. Each sub-product is in 4km resolution. The ice concentration is currently degraded to ice cover, with ice thickness and uncertainties being unavailable. The ice cover and days-since-last-observed use the same data values as their 1km versions above.

A southern-hemisphere GRIB-2 product containing snow depth is also generated. This product is described in section 3.

The above described products use the following naming format,

NIC.IMS\_snow\_v3\_YYYYJJJHH\_1km.GRIB2.gz

GRIB-2 snow cover product at 1 KM resolution.

NIC.IMS\_ice\_v3\_YYYYJJJHH\_1km.GRIB2.gz

GRIB-2 ice cover product at 1 KM resolution.

NIC.IMS\_time\_v3\_YYYYJJJHH\_1km.GRIB2.gz

GRIB-2 days-since-last-observed (for snow/ice cover) product at 1 KM resolution.

NIC.IMS\_snow\_v3\_YYYYJJJHH\_4km.GRIB2.gz

GRIB-2 combined snow cover, days-since-last-observed, snow depth and snow depth quality product at 4 KM resolution.

NIC.IMS\_ice\_v3\_YYYYJJJHH\_4km.GRIB2.gz

GRIB-2 combined ice cover, days-since-last-observed, ice thickness and ice thickness quality product at 4 KM resolution.

NIC.IMS\_sh\_snow\_v3\_YYYYJJJHH\_2km.GRIB2.gz

GRIB-2 Southern Hemisphere snow depth and snow depth quality product at 2 KM resolution.

For all files above, YYYY is four digit year, JJJ is three digit Julian day and HH is two digit product hour. The datetime in the filename indicates the product valid time.

### 2.4.5 GIF web image files

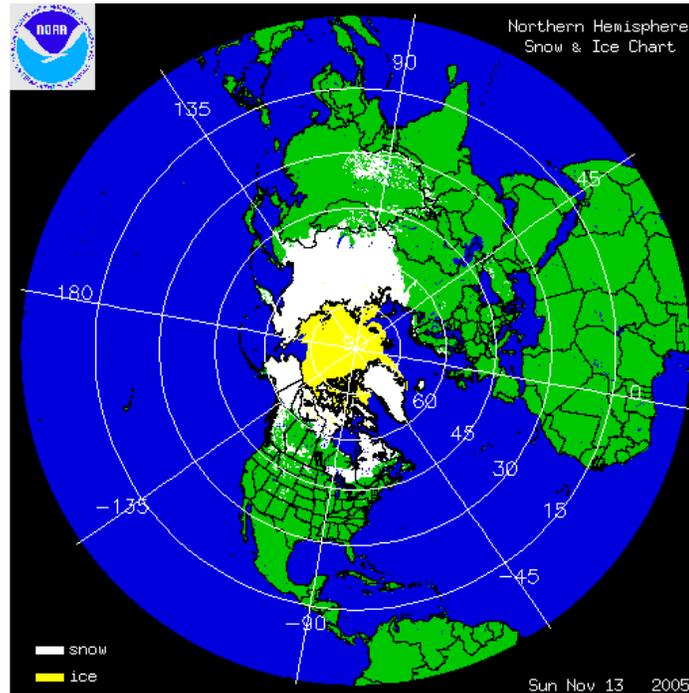
Five unique GIF snow and ice cover images are made for the NIC IMS web page. These are generated once daily (before 00 UTC). There are 5 unique coverage regions for the GIF images and 15 total images produced each day. Of these 15 files, 10 are simply copies of the 5 different area regions needed for the web page.

For all graphics with "cursnow" in the filename, these are simply a copy of the GIF image produced for that day. For the graphics with "prvsnow" in the filename, there are all copies of the previous days GIF image before it is overwritten (copies the previous days "cursnow" files). All GIF images use the 4km IMS snow/ice analysis to start with but depending on the GIF regions coverage, some detail may be lost.

All images have very precise regional coordinates and sizes since any changes will create a shift in the "30 day" image loops available on the NIC web page. The GIF image sizes and layout structure have been previously specified by the web page developers.

World graphic (region 1):

This image is a 512x512 pixel GIF centered at the North Pole which covers the entire Northern Hemisphere (see Figure 2-5).



**Figure 2-5. GIF (world region) image**

For this region, three files are produced daily:

imsYYYYJJJ.gif

(where YYYY is four digit year and JJJ is three digit Julian day)

cursnow.gif

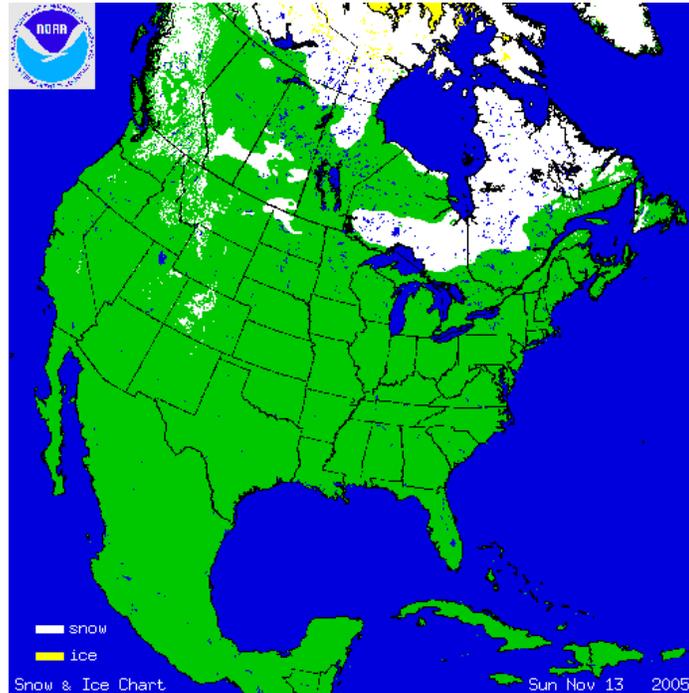
(copy of imsYYYYJJJ.gif)

prvsnow.gif

(copy of previous days cursnow.gif)

USA graphic (region 2):

The "USA" image is a 512x512 pixel GIF centered on the lower 48 states (see Figure 2-6). Since the coverage area is less (than the world graphic), the image is higher resolution (closer to the 4km input resolution).



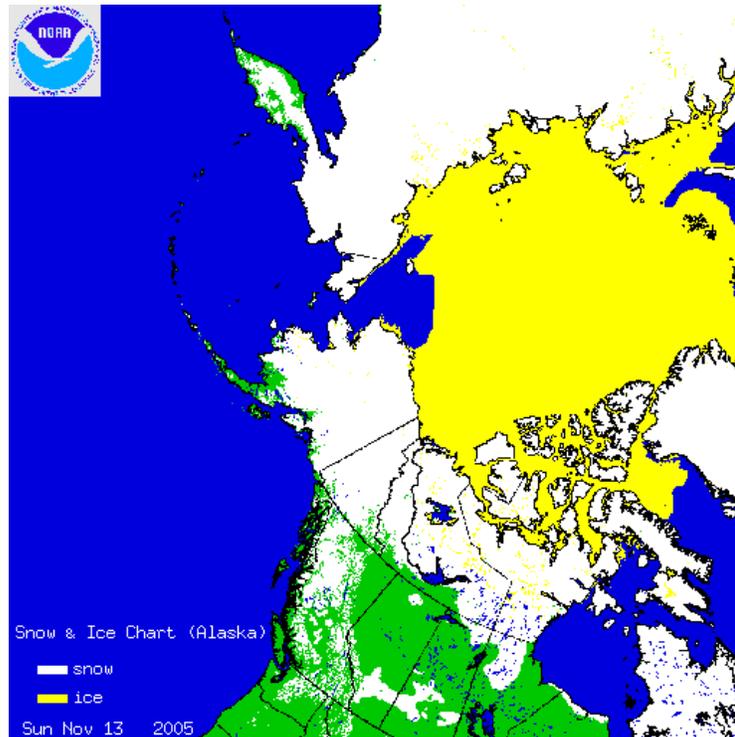
**Figure 2-6. GIF (USA region) image**

For this area, three files are produced daily:

imsYYYYJJJ_usa.gif	(where YYYY is four digit year and JJJ is three digit Julian day)
cursnow_usa.gif	(copy of imsYYYYJJJ_usa.gif)
prvsnow_usa.gif	(copy of previous days cursnow_usa.gif)

Alaska graphic (region 3):

The "Alaska" image is a 512x512 pixel GIF centered near Alaska (see Figure 2-7). Since the coverage area is less (than the world graphic), the image is higher resolution (closer to the 4km input resolution).



**Figure 2-7. GIF (Alaska region) image**

For this area, three files are produced daily:

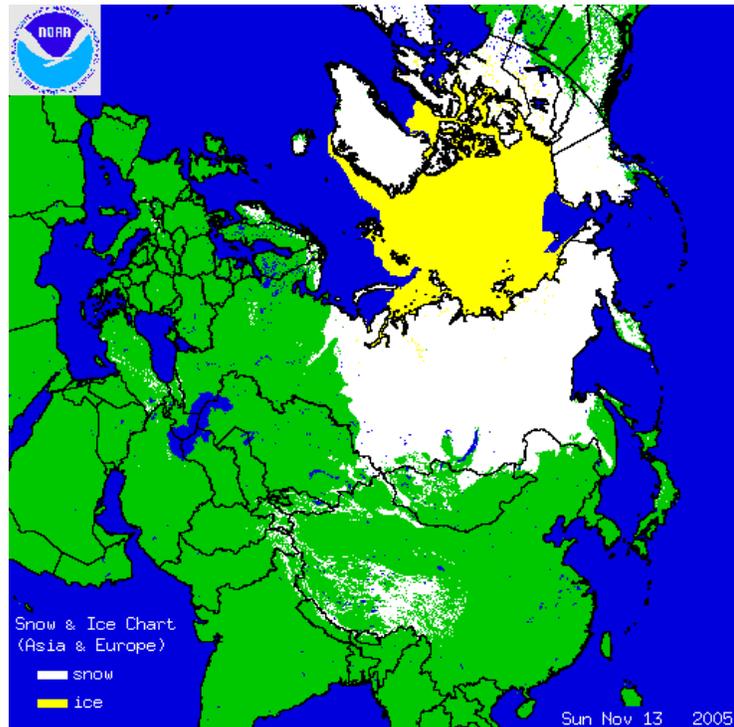
imsYYYYJJJ\_alaksa.gif (where YYYY is four digit year and JJJ is three digit Julian day)

cursnow\_alaska.gif (copy of imsYYYYJJJ\_alaska.gif)

prvsnow\_alaska.gif (copy of previous days cursnow\_alaska.gif)

Asia/Europe graphic (region 4):

The “Asia/Europe” image is a 512x512 pixel GIF centered over Asia (see Figure 2-8). Since the coverage area is less (than the world graphic), the image is higher resolution (closer to the 4km input resolution).



**Figure 2-8. GIF (Asia/Europe region) image**

For this area, three files are produced daily:

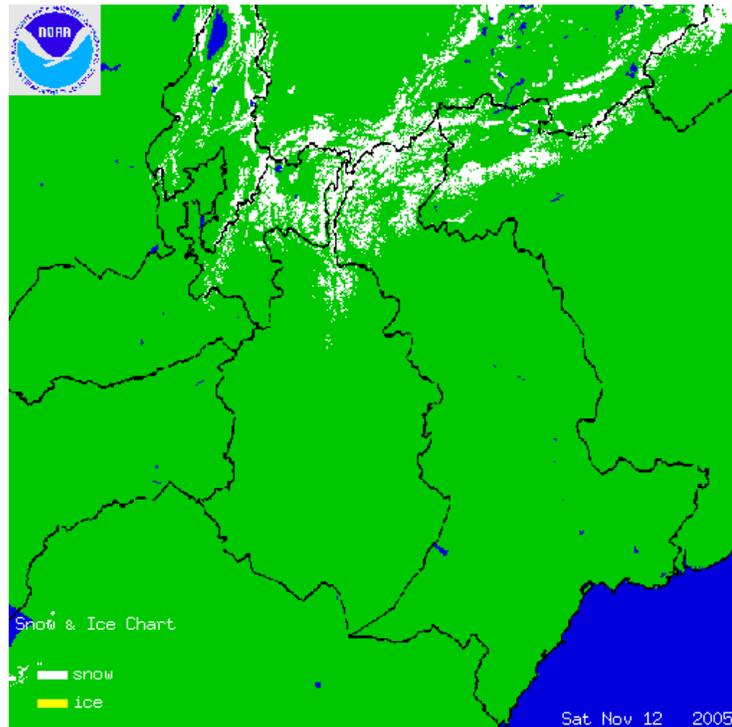
imsYYYYJJJ\_asiaeurope.gif (where YYYY is four digit year and JJJ is three digit Julian day)

currsnow\_asiaeurope.gif (copy of imsYYYYJJJ\_asiaeurope.gif)

prvsnow\_asiaeurope.gif (copy of previous days currsnow\_asiaeurope.gif)

Afghanistan graphic (region 5):

The “Afghanistan” image is a 512x512 pixel GIF centered over Afghanistan (see Figure 2-9). This is the smallest coverage area and displays with even greater detail in the snow/ice map.



**Figure 2-9. GIF (Afghanistan region) image**

For this area, three files are produced daily:

imsYYYYJJJ\_afghanistan.gif (where YYYY is four digit year and JJJ is three digit Julian day)

cursnow\_afghanistan.gif (copy of imsYYYYJJJ\_afghanistan.gif)

prvsnow\_afghanistan.gif (copy of previous days cursnow\_afghanistan.gif)

## 2.5 Performance Estimates

No complete performance estimates have ever been conducted on the IMS, though several studies have quantified the accuracy under certain conditions and compared to selected surface stations:

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Brubaker, K. L., R. T. Pinker, E. Deviatova, 2005: Evaluation and Comparison of MODIS and IMS Snow-Cover Estimates for the Continental United States Using Station Data. *J. Hydrometeor.*, 6, 1002–1017. doi: 10.1175/JHM447.1

Chen C, T. Lakhankar, P Romanov, It S Helfrich, A. Powell, and R Khanbilvardi. 2012, Validation of NOAA-Interactive Multisensor Snow and Ice Mapping System (IMS) by Comparison with Ground-Based Measurements over Continental United States, *Remote Sensing*, 4(5),1134-1145;doi:10.3390/rs4051134

Hall, D. K., and Coauthors, 2000: Intercomparison of satellite derived snow cover maps. *Ann. Glaciol.*, 31, 369–376.

Romanov P., D. Tarpley, G. Gutman, and T. Carroll, 2003: Mapping and monitoring of the snow cover fraction over North America. *J. Geophys. Res.*, 108, 8619, doi:10.1029/2002JD0031428619

Most studies suggest IMS snow cover has 85-90% agreement with all surface data and 95% agreement with stations reporting more than 1 inch or 2.5 cm.

Since snow and ice cover performance is not based on system performance, but is based on analyst performance, the estimates of enhancements for Version 3 over Version 2 in 2014 were verified to not be significantly changed for snow cover.

[https://www.star.nesdis.noaa.gov/smcd/emb/snow/validation/nhsnow\\_valid.html](https://www.star.nesdis.noaa.gov/smcd/emb/snow/validation/nhsnow_valid.html)

## 2.6 Practical Considerations

### 2.6.1 Programming and Procedural Considerations

The IMS snow and ice cover algorithm and product generation is dependent upon the correct hardware and setup of the IMS GUI and preprocessing machines. For reliability purposes, there should be at least a primary GUI machine, a backup GUI machine, an integration testing GUI machine, a primary preprocessor and a backup preprocessor. It is recommended to also have a COOP GUI machine and a COOP preprocessor; currently no COOP preprocessor is available. Each IMS machine should be a recent version of 64-bit Linux. To reduce lag during interactive analysis and enable quick final products generation, the IMS GUI machines should have fast hard drives (10K RPM or SSD recommended), a dedicated and powerful graphics card, and at least 8 cores with high single-thread performance. The IMS preprocessing machines should have at least 32 GB of RAM, and at least 32 cores in order to enable simultaneous preprocessing of multiple datasets.

The IMS system is critically dependent upon the availability of sufficient quantity of IDL and ENVI licenses (one per IMS GUI and Preprocessor system), as well as access to McIDAS for preprocessing of many datasets.

The setup procedures for the machines are described in the IMS Maintenance Manual and the IMS Preprocessor Manual.

## 2.6.2 Quality Assessment and Diagnostics

The IMS contains no QA tools, though analysts review each other's analysis on weekdays to ensure consensus assessment if the current surface conditions contain ice or snow.

## 2.6.3 Exception Handling

The IMS Preprocessing machines send out a status report email to the IMS maintainers every 2 hours during the daily analysis period. Success or failure of preprocessing for each product is noted in the status email.

On failure of an individual data input to preprocess, or of an entire preprocessing machine, the GUI will automatically try to obtain input data from the backup preprocessor.

The IMS GUI machines do not have hands-on monitoring during the analysis period. However, during final products generation and distribution, emails are sent to the IMS maintainers if an issue is detected. Following the conclusion of product generation and distribution (twice daily), emails will notify IMS maintainers and analysts on the status of product generation. On failure, the ESPC help desk will also be notified via an email.

On failure of the primary GUI machine, analysis and final products generation can continue on the backup GUI machine. Scripts are available to automatically transfer existing analysis to the backup GUI machine, and designate it as a temporary primary. On failure of final products generation unrelated to the machine, IMS maintainers will need to investigate and correct the issue.

All IMS machines are monitored by internal scripts for disk space usage, with IMS developers being alerted on high thresholds. Additionally, all IMS machines should be monitored by NAGIOS, via ESPC, for uptime and high load.

## 2.7 Validation

Validation of the IMS V3 snow and ice cover was only evaluated in the ability of the software performance to produce output. Any estimates of accuracy compared to earth observations are based solely on the quality of the analyst interpretation of the input data.

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This makes validation impossible to replicate on the impacts Version 3 would have over Version 2. However the estimates of enhancements for Version 3 over Version 2 in 2014 were verified to not be significantly changed for snow cover.

[https://www.star.nesdis.noaa.gov/smcd/emb/snow/validation/nhsnow\\_valid.html](https://www.star.nesdis.noaa.gov/smcd/emb/snow/validation/nhsnow_valid.html)

Impact assessments on model performance by applying a 1km versus a 4km grid should be sought from NCEP EMC and EMCWF.

### 3.0 SNOW DEPTH ALGORITHM

#### 3.1 Processing overview

The core of the snow depth processing system is the automated algorithm which blends in-situ and gridded microwave snow depth estimates to produce snow depth at IMS snow covered pixels of the 4-km ASCII product for the northern hemisphere and of the 2-km AUTOSNOW binary product for the Southern Hemisphere. The blending method is called 2-Dimensional Optimal Interpolation (2D-OI) whereby the blended estimate is computed as the weighted average of the data taking into account their spatial correlations (as functions of horizontal distance and elevation) as well as errors in the data. The final snow depth blends the snow depth of the automated product with the updates of the analyst. For the Northern Hemisphere, an innovative element of this automated-interactive system is the fact that analyst updates of snow depth are considered as “quasi automated input” by the 2D-OI, i.e., analyst snow depth values and confidence levels are blended in the 2D-OI algorithm in a similar fashion as in-situ and satellite data (only the Northern Hemisphere uses analyst snowdepth as input). The end result of this process is blended snow depth at 4 km resolution for the northern hemisphere and 2-km resolution at the southern hemisphere same 2D-OI approach but in a separate fashion. Processing sequence and steps are as follows:

Initial step in the automated processing for the Northern Hemisphere is reading of the most recent IMS V3 4-km ASCII snow cover and snow depth files. The Southern Hemisphere uses the same algorithm, with the exception of replacing the IMS 4km ASCII grid for snow cover with the AutoSnow&Ice (ASI) ASCII 2km Grid. The IMS and ASI snow covered pixels constrain snow cover fields that will be associated with snow depth estimates. Snow depth for snow-free pixels is set at zero. The snow depth generated in the previous run is the background or the initial guess. This initial guess will be updated with current in-situ and microwave derived snow depth data over the surrounding pixels using an optimal interpolation scheme. Over data-rich areas, only the in-situ snow depth data will be used, whereas over data sparse areas, gridded microwave-derived snow depth will also be blended. For the Northern Hemisphere, there is a final step in the processing algorithm to

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blend the snow depth of the automated algorithm with any snow depth observations made by an analyst.

The 4-km resolution Northern Hemispheric Snow Depth product files will be generated twice per day; snow depth production is integrated into the snow/ice cover output runs around 18 and 00 UTC. The 2-km resolution Southern Hemisphere Snow Depth product files will be generated once daily for the 00 UTC run.

## 3.2 Data inputs

### 3.2.1 IMS 4km Snow/Ice Cover Product (*Northern Hemisphere Only*)

The snow depth applies the IMS 4km snow and ice cover as a way to constrain the output to only generate data within the areas that analysts selected as having snow. This is only possible with the Northern Hemisphere since the IMS coverage is only available in this area. The IMS 4km snow/ice cover uses the 4km ASCII with the naming format of `imsYYYYJJJ_4km.asc`; where YYYY is four digit year and JJJ is three digit Julian day (ex. `ims2006255_4km.asc`).

The values that are used in the products are:

- 0 = outside coverage area (Northern Hemisphere) "space" pixel
- 1 = open water
- 2 = land without snow
- 3 = sea ice
- 4 = snow covered land

Importance to Production: **1 – needed for processing**

### 3.2.2 ASI 2km Snow/Ice Cover Product (*Southern Hemisphere Only*)

In the Southern Hemisphere, the snow depth applies the Autosnow and Ice (ASI) 2km snow and ice cover as a way to constrain the output to only generate data within the areas that have snow. The higher resolution of the SH ASI input allows for greater definition of the snow depth, though no validation has been possible due to the due to the lack of ground-based observations of snow depth in the Southern Hemisphere. The ASI 2km resolution snow/ice cover uses the 2km ASCII with the following naming format,

`sh_2km_multisensor_snow_ice_map_YYYYJJJ`

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(where YYYY is four digit year and JJJ is three digit Julian day.)

The Southern-Hemisphere ASI Snow Extent map is generated on the same systems as the IMS preprocessing. The SH ASI is a gridded map of 4500 lines by 18000 elements covering Southern Hemisphere where every land pixel is attributed to one of four categories: snow cover, snow-free land, cloud, undetermined/no retrievals/no data. The accumulated extent is calculated by adding areas of all pixels in the blended snow map identified as snow covered. The map projection is latitude-longitude. The grid cell size is 0.02 deg by 0.02 deg, or approximately 2 km at the Equator.

The values that are used in the SH ASI are:

0 = open water within the observational area

1 = land without snow within the observational area

2 = sea ice

3 = snow covered land

4 = outside coverage area

100 = open water outside of observational area

101 = land without snow outside of the observational

Importance to Production: **1 – needed for processing**

### 3.2.3 Surface Data (hourly report) Product

The surface data reports, available for surface stations around the world on an hourly basis, are obtained from the McIDAS Family of Services (FOS) through ADDE. A McENV session is run which uses the PTLIST command to select the latest 24 hours of surface data reports and deposit them into an ASCII data file. The SELECT keyword is set to a day/time range and only certain parameters are used to limit the selection to the desirable information. A PERL script is then run for data reformatting and an ENVI script is run to convert coordinate systems to match that of the IMS. More specific information about the McIDAS product is listed below:

Dataset used: RTPTSRC/SFCHOURLY

“SELECT settings”: DAY and TIME (ranges) are selection parameters

Parameters chosen: TIME, LAT, LON, T, WX1, PCP, SNO, VIS, ID, NUM=ALL

The surface data on GUI machines, retrieved from the IMS preprocessors, and read by the

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snowdepth program appears as a file named “SRF.YYYYJJJ” (contains NH and SH data) and “SRF.SH.YYYYJJJ” for SH. The SRF.SH file contains only Southern Hemisphere data which is extracted from the original SRF file.

Importance to Production: **2 – needed for improved quality or coverage**

### 3.2.4 MIRS High Resolution Products

Snow Water Equivalent (SWE) and Ice Concentrations products are also available from both AMSR and ATMS, generated within a retrieval and data assimilation system called the Microwave Integrated Retrieval System (MIRS). MIRS High Resolution ATMS files are obtained from the PDA. The Northern Hemisphere uses 33 second data, whereas the uses 33 minute amalgamations of the same data. The data set naming conventions are:

33-second granules:

NPR-MIRS-

IMG\_v11r1\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYYYMMD  
DHHMMSSS.nc

33-minute granules:

NPR-MIRS-

IMG\_33min\_v11r1\_npp\_sYYYYMMDDHHMMSSS\_eYYYYMMDDHHMMSSS\_cYYY  
YMMDDHHMMSSS.nc

(where YYYY = four digit year, MM = two digit month, DD = two digit day, HH = two digit hour, MM = two digit minute, SSS = deciseconds. The dates given are start date, end date and creation date respectively.)

The input files are received using sFTP and an IDL program is used to break apart each HDF structured file and extract the data fields corresponding to snow water equivalent and ice concentration. The extracted data is saved in an ASCII file with the name convention “MIRS\_SWEYYYYJJJ.asc”. Since the area of coverage remains constant for the MIRS ATMS products, a static geo-location file has been set up so the three data fields are the only data needing to be extracted from the file. All three products (for all four satellites) have about a 15km resolution. The data values are 0 – 150 for SWE (in cm coverage but allows for outlier values), and 0 – 100 for ice concentration (in % coverage).

Importance to Production: **2 – needed for improved quality or coverage**

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### 3.2.5 (Disabled) AMSR-E Snow Water Equivalent Product

*Note: AMSR-E data is no longer available. AMSR-2 will provide real time data in the future. This optional input is skipped.*

The Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) Snow Water Equivalent (SWE) product is a Level-3 product received from the EOS data gateway. Like the other AMSR-E products, the previous day's product is used in processing and has the following naming convention:

AMSR\_E\_L3\_DailySnow\_B07\_YYYYMMDD.hdf

(where YYYY = four digit year, MM = two digit month, DD = two digit day)

The input file is received using sFTP and an ENVI program is used to break apart the HDF file and extract the data with HDF argument "SWE\_NorthernDaily". Since the area of coverage remains constant, a static geo-location file has been set up so the snow water equivalent data is the only field needing to be extracted from the file. The SWE field has an array size of 721x721 and ranges in values from 0 – 255. The breakdown of values is shown below:

0 – 240 = snow water equivalent values (in mm)

248 = off earth

252 = land area or snow indeterminable

253 = ice sheet

254 = water

255 = missing

Importance to Production: **2 – needed for improved quality or coverage**

### 3.2.6 Land water mask

The land water mask is based on the surface type classification produced by the University of Maryland Department of Geography in 1998 (Hansen et al. 1998, 2000). Imagery from the AVHRR satellites acquired between 1981 and 1994 were analyzed to distinguish fourteen land cover classes. This product is available at three spatial scales: 1 degree, 8 kilometer and 1 kilometer pixel resolutions. For the algorithm development and testing 1 km data were aggregated in 4 km size grid cells.

More information is available online at

<https://web.archive.org/web/20130115204530/http://glcf.umiacs.umd.edu/data/landcover/>

Importance to Production: **1 – needed for processing**

### 3.2.7 Digital elevation

Elevation information for every pixel is used as static input to produce blended snow depth and also to screen high-elevation areas where snow depth retrievals may be inaccurate. Note that spatial correlation of snow depth distribution is computed from elevation and horizontal distance, the latter computed from the site coordinates of snow depth data. The elevation dataset in the current version of the algorithm is based on USGS GTOPO30 model data averaged within 4 km grid cells for the Northern Hemisphere, and 2km grid cells for the Southern Hemisphere. The data are available online at [http://eros.usgs.gov/#/Find\\_Data/Products\\_and\\_Data\\_Available/GTOPO30](http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/GTOPO30).

Importance to Production: **1 – needed for processing**

### 3.3 Theoretical Description

Optimal Interpolation (OI) technique has been used in updating surface parameters including snow depth. The Canadian Meteorological Service runs a daily 16-km snow depth product (Brasnett, 1999) over the Northern Hemisphere that employs the OI technique. The technique uses surface snow depth reports for updating SD fields and a simple snow evolution model for producing initial guess or background SD fields. NCEP also runs the SST product over ocean based on the OI technique developed by Reynolds and Smith (1994). Here, first guess fields are derived from previous analysis. HIRLAM also uses OI technique for updating SD fields (Cansado. 2003, Drusch et al., 2004). A general summary of the OI technique is provided below based on terminology of Reynolds and Smith (1994).

The analysis starts with a background or first guess at the analysis grid point,  $k$ . This background or first guess value at grid point  $k$  can be derived from climatology or from analysis at a previous time, e.g., previous day analysis. Given the first guess value at grid point  $k$ , the analysis increment,  $r_k$  is defined as the difference between the analysis and the first guess, and is given by the following equation:

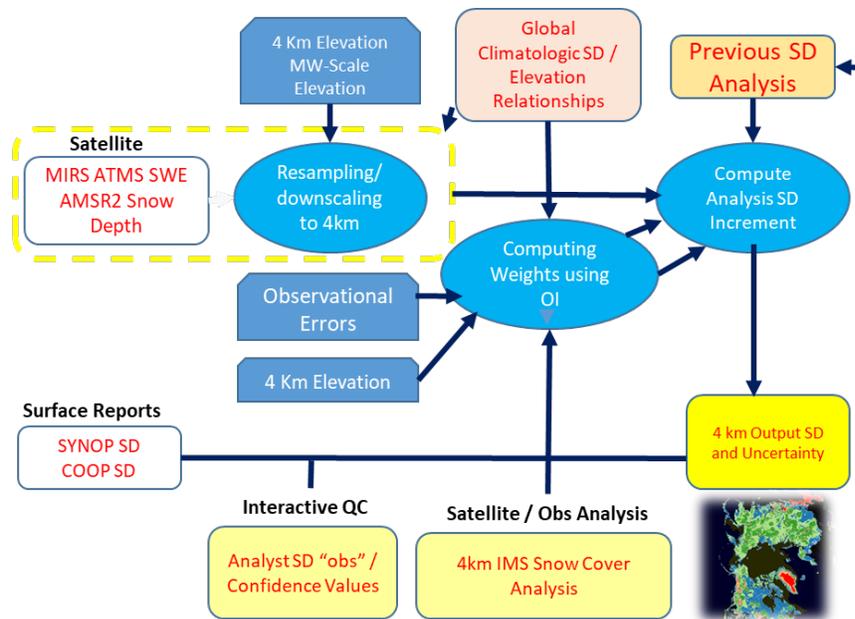
$$r_k = \sum_{i=1}^N w_{ik} q_i,$$

Where  $q_i$  are data increments computed as the difference between the first guess value and the data point value at location  $i$ , and  $w_{ik}$  are the optimal least squares weights. The

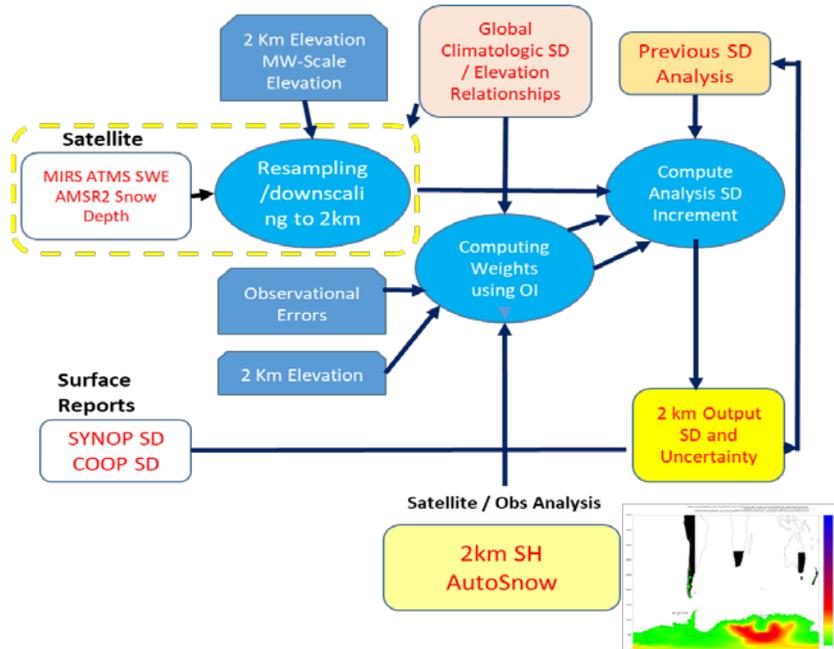
subscript  $k$  ranges over all grid points where solution is required. The subscript  $i$  ranges over the data points.

The weights are determined by least squares minimization. This procedure results in a set of linear equations with the weights as unknowns and with the coefficients the spatial correlation factors. Spatial correlation factors are computed using known prescribed equations of geomorphic attributes (e.g., distance and height between analysis grid point  $k$  and data point  $i$ ). Additionally, coefficients of the diagonal are computed from measurement and background errors.

A data flow diagram of the Northern Hemisphere algorithm is provided in Figure 3-1 while a data flow diagram for the Southern Hemisphere is provided in Figure 3-2.



**Figure 3-1. Data Flow Diagram for Northern Hemisphere Snow Depth**



**Figure 3-2. Data Flow Diagram for Southern Hemisphere Snow Depth**

### 3.4 Algorithm Output

The snow depth output file for the Northern Hemisphere will be in Polar Stereographic ASCII format at 4-km resolution, same grid as the 4-km IMS snow/ice cover ASCII file. Two files are generated, a Snow Depth file and a Quality Control Value file.

For the Northern-Hemisphere, generated twice daily at 18 and 00 UTC, the intermediate output files are,

NH Snow Depth

imsSDYYYYJJJ.asc

(where YYYY = four digit year and JJJ=three digit Julian day)

NH Snow Depth Quality Flag

(where YYYY = four digit year and JJJ=three digit Julian day)

Only a GRIB-2 version of the above product files is distributed. This combination GRIB-2 snow-products output, which contains snow cover and days-since-last-observed (described in section 2), along with northern-hemisphere snow depth and snow depth data quality as records 2 and 3 respectively. Each sub-product is in 4km resolution. The snow depth

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values are in meters, data quality is 0 to 1 with increasing values indicating more confidence. This output file has the following name pattern, indicating the product valid time,

NIC.IMS\_snow\_v3\_YYYYJJJHH\_4km.GRIB2.gz

(where YYYY = four digit year, JJJ=three digit Julian day, HH = two digit product hour)

For the Southern Hemisphere, the output will be in plain-binary format at 2 km resolution using a lat/long projection with a gridded map of 4500 lines by 18000 elements, identical to the Autosnow&Ice grid. The grid cell size is 0.02° by 0.02°, or approximately 2 km at the Equator. The intermediate output files are,

SH Snow Depth

sh\_2km\_SDYYYYJJJ.dat

(where YYYY = four digit year and JJJ=three digit Julian day)

SH Snow Depth Quality Flag

sh\_2km\_QCSnwDepthYYYYJJJ.dat

(where YYYY = four digit year and JJJ=three digit Julian day)

Only a GRIB-2 version of the above product files is distributed. This combination GRIB-2 snow depth output, which contains southern-hemisphere snow depth and snow depth data quality as records 1 and 2 respectively. Each sub-product is in 2km resolution. The snow depth values are in meters, data quality is 0 to 1 with increasing values indicating more confidence. This output file has the following name pattern, indicating the product valid time,

NIC.IMS\_sh\_snow\_v3\_YYYYJJJHH\_2km.GRIB2.gz

(where YYYY = four digit year, JJJ=three digit Julian day, HH = two digit product hour)

### 3.5 Performance Estimates

Performance metrics for Snow Depth fields were based on calculations of bias and root mean square error with respect to ground observations in a cross validation setting. Additionally, products were inter-compared with AFWA, ATMS, and NOHRSC snow depth estimates in the same locations but only under selected conditions.

### 3.5.1 Test Data Description

Snow Depth fields will be tested with AFWA snow depth, NOHRSC Snow Depth, and surface reports. IMS snow depth and AFWA Snow Depth will both be compared to NOHRSC snow depth from the SNODAS model estimates and compared to Surface reports. Random surface snow depth reports that are applied in the calculation of the IMS snow depth will be removed to test the stability of IMS snow depth reports and to evaluate the IMS snow depth in areas it has not received direct observations. A complete specification of snow depth test data will be provided in a future ATBD version.

### 3.5.2 Retrieval Errors

Accuracy statistics were tabulated for the IMS snow depth and the AFWA snow depth to determine the difference between each and the “ground truth” surface reports. This was determined to have 80% of snow depth estimates to be within 20cm of actual mean values. This will vary based on elevation, with high biases expected at higher elevations and lower bias at lower elevations.

## 3.6 Practical Considerations

### 3.6.1 Programming and Procedural Considerations

The snow depth retrieval code is integrated into the larger IMS V3 system. The relevant programming considerations are discussed in section 2.

On procedural considerations, the IMS analysts can provide input into the snow depth values for the Northern-Hemisphere, however in practice the majority of snow depth analyses are generated without any analyst input.

### 3.6.2 Quality Assessment and Diagnostics

Quality metrics are provided as a QC flags that accompany the snow depth. In the GRIB2 output files, data quality values are scaled from 0-1, with higher values indicating more confidence. Data quality tends to decrease with less collocation with in-situ observations and with increased elevation.

### 3.6.3 Exception Handling

The required inputs for the algorithm to run are specified in the Data Inputs section.

The MIRS data is not guaranteed to be available during a NESDIS COOP failover. It has previously been observed that the 33 second data used in the Northern Hemisphere was

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available, but the 33 minute data used in the Southern Hemisphere was not. Insufficient study has been performed to definitively verify code operation in this condition; however it is believed that a degraded analysis should still be generated.

Most other considerations, including failover, error reporting and similar are into the larger IMS V3 system, described in section 2.

### 3.7 Validation

Snow depth validation was conducted to assess the accuracy of data in areas with in situ observations to evaluate the effectiveness of the IMS Snow Depth in the Northern Hemisphere 4km grids to compare to CoCoRAHS station data in the Jan-Feb of 2010 and 2011. CoCoRAHS (<https://www.cocorahs.org/>) was used since they are independent of any surface observations applied directly in the IMS snow depth modeling application. Observational Snow Depth requirements were used from the NOAA Program Operational Requirement Documents (PORD) for NCEP EMC, which requires that 80% of satellite observations need to be within 20 cm of the actual snow depth. Given natural snow depth variability of any gridded observation compared to a single point measurements, it is questionable if a single point will ever be representative of a larger 4km grid, particularly in areas with high elevational variability. None the less, the 86.9% of CoCoRaHs sites in January were within 20cm of the IMS Snow Depth and 85.1% were within 20cm of the IMS Snow Depth for February. Results do suggest that there is a bimodal distribution of errors. This is due to the low bias/RMSE in low-elevation areas (4/7cm) and larger bias/RMSE in high elevation areas (35 cm/45 cm). Examples are provided in Figure 3-3. The Error in the current AFWA snow depth values compared to gauge performance is currently unknown and no validation test report has been shown. **It is recommended that the IMS snow depth is intercompared to AFWA by NCEP to determine improvements in model performance over the current NCEP snow depth input fields. In addition to using snow depth from field measurements, the snow depth from IMS and AFWA will be visually compared to NOHRSC snow depth fields that are estimated using snow model for selected days.**

No additional snow depth evaluation was performed over the Southern Hemisphere. There are only a very limited sample of in situ data is available for Southern Hemisphere snow depth validation. Furthermore, most sites do not report zero snow depth, so there is no way to verify if snow is missing and many sites only reported a few days of shallow snow cover. Thus, there is too limited a sample size to make a justified conclusion on the overall accuracy of the snow depth algorithm in the Southern Hemisphere, though the algorithms between the Northern and Southern Hemispheres are nearly identical with the exception of the snow cover input. **The IMS SH Snow Depth performance is expected to be nearly the same as the Northern Hemisphere** given the same limits to surface snow depth reporting stations in high elevations.

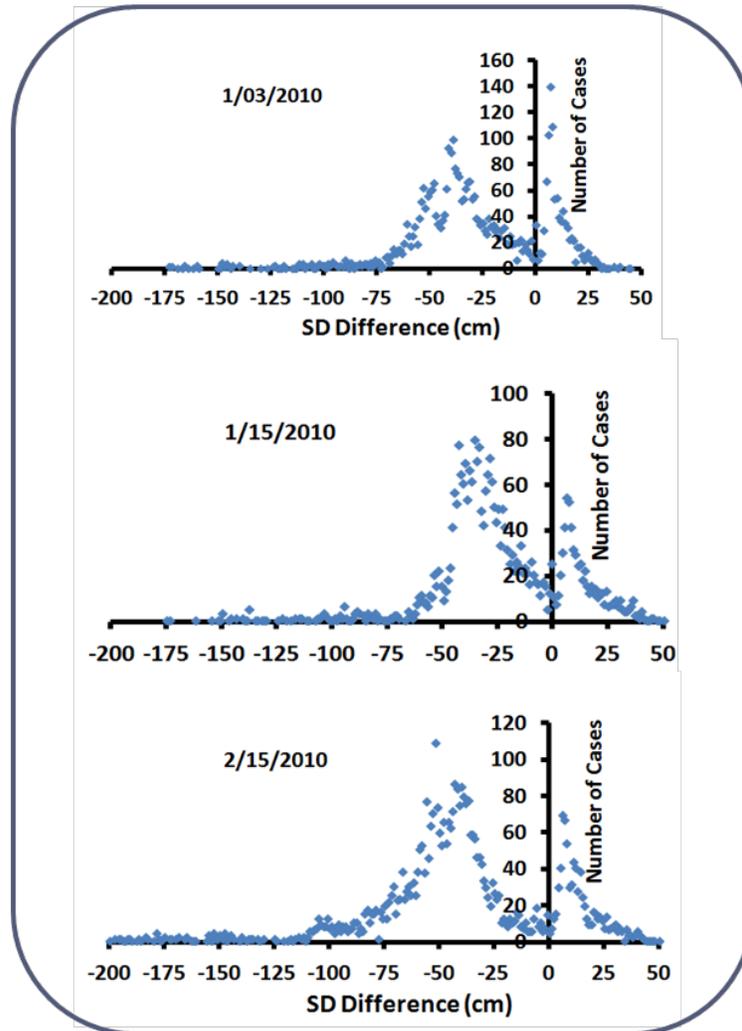


Figure 3-3. IMS Snow Depth Errors for 1/3/10, 1/15/10, and 2/15/10

#### 4.0 ASSUMPTIONS AND LIMITATIONS

##### 4.1 Performance Assumptions

All IMS outputs depend on having the necessary hardware, software and manpower to meet the product requirements. Hardware and software requirements are described in relevant portions of this document, as well as the IMS Maintenance Manual and the IMS Preprocessor Manual.

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Other performance aspects that may impact on the system's ability to meet requirements include:

- 1) The availability and expert training of analysts creating the product
- 2) The availability of input data could affect product quality and consistency

The IMS system is also entirely dependent upon the availability of IDL/ENVI licenses.

## 4.2 Potential Improvements

Potential improvements to the IMS have two broad categories: additional or improved data inputs, and additional output data products.

For interactive snow and ice cover analysis, frequent addition or replacement of aging data sources provides the analysts with better tools to determine the presence of snow and ice. In potentially near future, this could include integration of GOES16 and GOES17 RGB composites into the IMS GUI, usage of newer-generation of VIIRS derived products, resumption of NIC Sea Ice Thickness and Concentration product, as well as additional channels of MET-8 and MET-11. An additional output product in which NCEP and NAVO have expressed interest, is a confidence data array – such an array would likely contain a binary flag, in which most of the analysis is high confidence but regions where the analysts were especially uncertain could be marked as low confidence. There has also been interest expressed in using a more up-to-date land/water mask.

For snow depth algorithms, in either hemisphere, the addition or replacement of the current sources of Surface Data with Global Historical Climatology Network (GHCN) daily data would likely lead to an improved output product.

## 5.0 LIST OF REFERENCES

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