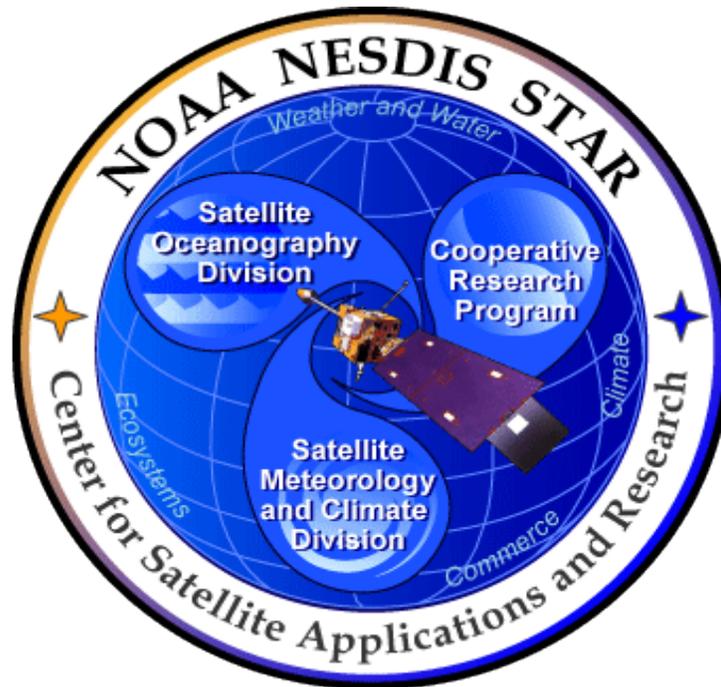


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**NOAA NESDIS
CENTER for SATELLITE APPLICATIONS
and RESEARCH**

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

ALGORITHM THEORETICAL BASIS DOCUMENT

Version 2.0 Draft 4.1

NOAA NESDIS STAR

ALGORITHM THEORETICAL BASIS DOCUMENT

IMS V3 ATBD Version: 2.0 Draft: 4.1

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IMS ALGORITHM THEORETICAL BASIS DOCUMENT VERSION 1.0

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IMS V3
PROJECT BASELINE REPORT
VERSION HISTORY SUMMARY

Version	Description	Revised Sections	Date
1.0	New Document for IMS V3 Critical Design Review (CDR)	New Document	01/30/2012

document impact on product quality if alternatives to GHCN daily data are used.

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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
DDS	NESDIS Distribution Server
ENVI	Environment for Visualizing Images
EOS	Earth Observation Satellite
GAC	Global Area Coverage
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
INDOEX	INDian Ocean EXperiment satellite
McIDAS	Man computer Interactive Data Access System
METEOSAT	Meteosat program satellite

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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
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

1. 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 of all, the preprocessing system takes all products and imagery from their native formats and resolutions to project them into IMS set format and resolutions. These processed products and imagery are sent to the Polar Server. Secondly, IMS GUI system picks up the processed data from the Polar Server 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 produce final products and distribute final products to proper destinations.

1.1. Product Overview

The IMS version 3 system produces several daily output files all generated from scripts that run from cron. Five general types or products are made, the IMS snow/ice map files (in ASCII and ENVI formats), GeoTIFF files, the GIF (Graphic Interchange Format) web images and GRIB-2 files. More than one IMS GUI system and Pre-processor are currently being used but only the operational GUI system will distribute products to the users. The other backup (test systems) and COOP systems pull data from a preceding step and store this data locally, but do not transmit any output data to a another system unless they are activated to do so.

1.1.1 Product Description

The ASCII and ENVI products exist in three separate resolutions (24km, 4km and 1km resolutions) and have basically the same data format (ASCII file has an embedded header and is packed differently from the ENVI product). The final product data values range from 0 to 4 and are currently produced once a day for the ENVI and the 24km ASCII files (before 00z) and 2xday for 4km and 1km ASCII files (before 18 and 00 UTC) via cron after the analysts have completed the interactive portion of the IMS analysis and due to ENVI/IDL licensing, requires the IMS GUI to be closed in order to process correctly.

Another type of output products being produced are GIF images for five area regions (World, USA, Alaska, Asia/Europe, and Afghanistan). These are simply a GIF image representation of the IMS 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.

GeoTIFF files are used for the IMS GIS webpages. A script running through cron at the end of the day uses the 4km and 1km ENVI format final product file and generates 4 GeoTIFF images for the IMS GIS server and for posting on the distribution server. There are four images produced (each rotated 90 degrees from the other) to provide four different views of the earth. Only the GeoTiff centered on 80 degrees west is posted on the distribution server along with a .aux file (generated on the IMS GIS server) to allow proper projection.

A fifth type of output product is GRIB-2 files. The GRIB-2 formatted files are created using the ASCII 4km and 1km product files. This is an add-on process that is run off cron to convert the format of the ASCII into the NCEP GRIB-2 format at the request of NCEP. This process uses a set of routines provided by NCEP to temporarily produce a GRIB-1 file then convert that output to GRIB-2. IDL 8.0 directly supports GRIB2 read, write conThis format includes snow cover, snow depth, ice cover, ice thickness, and days since last observed as unique product layers on a common file. The GRIB-2 output will be produced twice per day (before 18 and 00 UTC).

1.1.2 Product Requirements

The ASCII daily snow and ice products are currently produced once a day via cron after the analysts has completed the interactive portion of the IMS analysis, due to ENVI/IDL licensing. The primary user of these products 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 and 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 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 ENVI product 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 kept in an ENVI file format (simply a data array) that can easily be opened in ENVI/IDL or any GIS application. Since these files are in ENVI format, the data point (1,1) starts in the upper left corner which is different from the ASCII equivalent products. The data contained in the files are in the same format (values 0 – 4) as the ASCII product.

GeoTIFF images are made for the IMS GIS webpage. These are generated along with the final processing (once daily) that makes the ASCII and ENVI files and require use of the IDL/ENVI license (GUI has to be closed). Four output GeoTIFF images are produced. These 4 different images display the entire North Hemisphere but are rotated differently to allow for a different reference point when looking at the imagery. GeoTIFF file names imply the amount of rotation from having a central meridian at 90 degrees west longitude.

Another main product set of the IMS are the GIF images made for the NIC web page. These are generated along with the final processing (once daily) that makes the ASCII and ENVI files and require use of the IDL/ENVI license (GUI has to be closed). 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. All GIF images use the 4km IMS snow/ice analysis (higher resolution) 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.

The GRIB-2 formatted files are created using the ASCII 4km and 1km product files. This process uses a set of routines provided by NCEP to temporarily produce a GRIB-1 file then convert that output to GRIB-2 using the following naming convention:
imsYYYYMMDD.grb.grib2. IDL 8.0 supports GRIB 2 conversion.

1.2. Revisions

This is the original version (Version 1) of this document, dated January 2012. Updates will be incorporated into this document as the project progresses.

1.3. Document Overview

This document contains the following sections:

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Section 1.0 -	Introduction
Section 2.0 -	Snow Cover / Ice Algorithms
Section 3.0 -	Snow Depth Algorithm
Section 4.0 -	Assumptions and Limitations

2. SNOW COVER / ICE ALGORITHMS

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 several sources of imagery and products which 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 six 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 composite (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 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 doesn't really produce any output files. All of the IMS output products are created separately from the interactive analysis by scripts running from cron. Five basic types of output files are produced by the jobs running from cron on the GUI workstation (ASCII product, ENVI product, GeoTIFF files, GIF image products and GRIB2

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 system, through the Polar Server, automatically through CRONTAB jobs calling script files that FTP the datasets. These datasets are in a binary image format (ENVI format minus header files) and “sectorized” to the needed areas of the 36 possible IMS area regions. These datasets are most all put into a single TAR file for ease and speed for transferring 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, exists in a specialized format only usable by that system. The NIC MIZ product, NAIS Sea Ice Model, NAVO Sea Ice Model, SAR Imagery, sea ice chart shapefiles only need to be received which is done directly by the GUI system without going through the 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 at nsidc.org/data/g02156.html.

2.2.1 AMSR-E 12km Ice Concentration Product

Note: The plan is to replace AMSR-E with AMSR-2 in Fall 2014.

The Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) 12-km resolution ice concentration product is a Level-3 product showing ice concentrations over the Northern Hemisphere received from the EOS data gateway. Due to timeliness, the previous day’s product is used for processing and the filename format is as follows:

AMSR_E_L3_Sealce12km_B06_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 "SI_12km_NH_ICECON_DAY". Since the area of coverage remains constant, a static geo-location file has been set up so the ice concentration data is the only field needing to be extracted from the file. The ice concentration field has an array size of 608x896 and ranges in values from 0 – 120. Sea ice concentrations range from 0 – 100 (% concentration), areas of missing data have a value of 110, and land areas have a value of 120.

AMSR-E data is no longer available in real time. AMSR-2 will provide real time data in the future. Until this is available, IMS V3 will use SSMI/S Ice concentration.

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

2.2.2 AMSR-E 6km Brightness Temperature Products

The Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) 6-km ice concentration products are Level-3 products containing two polarized sets of imagery which, when differenced, help determine areas of sea ice. The input HDF file is also received via the EOS data gateway and is also yesterday's product with the filename format shown below:

AMSR_E_L3_Sealce6km_B06_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. Two products are extracted from the HDF file, a vertically polarized product with HDF argument "SI_06km_NH_89V_DAY" and a horizontally polarized product with HDF argument "SI_06km_NH_89H_DAY". Each composite image product extracted covers the same location as the 12km product but has twice the resolution with an array size of 1216x1792 and is in integer format with a wide range of values (0 – 1000+).

AMSR-E data is no longer available in real time. AMSR-2 will provide real time data in the future. Until this is available, IMS V3 will use ASCAT data.

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

2.2.3 AMSR-E Snow Water Equivalent Product

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 days 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

AMSR-E data is no longer available in real time. AMSR-2 will provide real time data in the future. Until this is available, IMS V3 will use MiRS high resolution SWE.

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

2.2.4 AMSU Products

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

NPR.ABMP.NL.DYYJJJ (NOAA-16 [L])

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 using sFTP 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. All three products (for all four satellites) 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**

2.2.5 GOES-EAST Imagery

The Geostationary Operational Environmental Satellite - EAST (GOES-EAST) imagery consists of six visible (Channel-1) images over Eastern North America produced twice 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 the GOES-EAST North Hemisphere remapped sectors available twice hourly. A McIDAS BATCH job then remaps these North Hemisphere 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 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**

2.2.6 GOES-WEST Imagery

The Geostationary Operational Environmental Satellite - WEST (GOES-WEST) imagery consists of six visible (Channel-1) images over Western North America produced twice 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 the GOES-WEST North Hemisphere remapped sectors available twice hourly. A McIDAS BATCH job then remaps these North Hemisphere 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 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 INDOEX (METEOSAT-7) Imagery

The METEOSAT-7 (INDOEX program) imagery consists of six visible (Channel-1) images over the western/central Asia region produced twice 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 the INDOEXVIS sectors available twice hourly. 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 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**

2.2.8 METEOSAT (METEOSAT-8) Imagery

The METEOSAT-8 (METEOSAT program) imagery consists of six false color images (Red=band1, Green=band2, Blue=band3) over Europe and western Asia produced twice 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). Since imagery has multiple channels, channels 1, 2, and 3 are stacked to make band combinations. The input data are the INDOEXVIS sectors available twice hourly. 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.

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

2.2.9 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**

2.2.10 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**

2.2.11 MTSAT Imagery

The MTSAT imagery consists of six visible (Channel-1) images over the Eastern Asia. 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 the MTSAT GLOBAL sectors available once hourly. 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 programs [see information below]. 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**

2.2.12 Metop A AVHRR (HRPT) Imagery

The Metop A AVHRR HRPT 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 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**

2.2.13 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 (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 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**

2.2.15 North America 4km AutoSnow Product

The 4km North America AutoSnow product is an automated product using satellite data to map snow cover over much of the North America region. Due to timeliness, the previous day's product is used and is available on the Product Server as a binary file with the following file naming convention:

S.X4YYJJZSM

(where YY = two 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 (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 4000x1625 and has values of 0, 1, 2, 3, 4 or 10. The breakdown of values is shown below:

0 = water

1 = land without snow

2 = AVHRR and SSM/I detected snow cover

3 = GOES and SSM/I detected snow cover

4 = both (AVHRR and SSM/I) and (GOES and SSM/I) detected snow cover

10 = missing

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

2.2.16 North Hemisphere (NH) 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 Product Server 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**

2.2.17 NH 4km AutoSnow “days since last update” Product

This 4km North Hemisphere AutoSnow 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 Product Server 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**

2.2.18 Metop A AVHRR GAC Composite Imagery

The Metop A AVHRR GAC composite 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 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 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**

2.2.19 NOAA-18 AVHRR GAC Composite Imagery

The NOAA-18 AVHRR GAC composite 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 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 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**

2.2.20 NOAA-19 AVHRR GAC Composite Imagery

The NOAA-19 AVHRR GAC composite 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 composite 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**

2.2.21 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 DDS as a geotiff with the following naming convention:

Msfa_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 4.45km² resolution. Data values range from 0-255.

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

2.2.21 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 using sFTP 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**

2.2.23 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)

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**

2.2.24 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 daily EDR files are made available on the Polar Server and have the following naming conventions:

PRD.SPPROD.F15EDRNH

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

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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 using sFTP 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**

2.2.25 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 Model Server with the following naming convention:

seaice.t00z.northpsg_MM_DD_YYYY

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

The input is received using sFTP and an ENVI program is used to break apart the file to extract needed information. The sea ice file is a binary file containing 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**

2.2.26 Surface Data (hourly report) 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

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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**

2.2.27 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 Polar Server. These daily files are made available on the Polar Server and have the following naming conventions:

PRD.SPPROD.SNODEPH.NHMAMAP

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 using sFTP 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**

2.2.28 SAR Imagery

Northern Hemispheric 3-day composites of SAR imagery from ENVISAT are provided in 1km resolution. Processing of the ENVISAT SAR to generate at the NIC using ArcGIS. The current day's product is available on the NIC NAIL as a set of a geotiff, auxiliary, and pyramid layer files with the following naming convention:

```
envisat_gmm_n_YYYYMMDD.tif  
envisat_gmm_n_YYYYMMDD.aux  
envisat_gmm_n_YYYYMMDD.rrd
```

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

The input file is received using FTP and a shell program from the IMS GUI directly. 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 6803x6803 with 1.003km² resolution. Data values range from 0-255.

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

2.2.29 Daily 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)

These reports are an alternative to the GHCN daily data. Impact to the product quality should be minimal because the additional sites available from GHCN are in the U.S. where there is already a high density of surface snow depth observations. This will be confirmed during Transition.

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

2.2.30 CMC Snow Depth

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

YYYYMMDD_cd.gz

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

The input file is received using sFTP and a shell program unzips and untars the data file. Next, the untarred file is assigned georeferencing using Fortran code to assign latitude and longitudes to each value in another ASCII file. The georeferenced ASCII file is then imported to 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 geolocation file has been set up so to speed up the processing time. The data has an array size of 1440x360 with .25 degree resolution. Data values range represents centimeters. Importance to Production: **2 – needed for improved quality or coverage**

2.2.31 NAVO Sea Ice Model

NAVO has began output in 2010 of a coupled ocean/sea ice model named the Arctic Cap Nowcast/Forecast System (ACNFS). Sea ice thickness and concentrations from the ACNFS. The ACNFS data is pulled by the NIC from NAVO servers as a netCDF with over 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:

ACNFS_YYYYMMDD00_hi.zip (Nowcast sea ice thickness)

ACNFS_YYYYMMDD00_aice.zip (Nowcast ice area)

ACNFS_YYYYMMDD_hi24hr.zip (24h forecast Sea Ice Thickness)

ACNFS_YYYYMMDD_aice24hr.zip (24h forecast Sea Ice Area)

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

The input file is received using FTP and a shell program unzips the files 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 final output also needs to be scaled to 8 bit, with a color map to stretch the data visualization to display on the GUI. 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 4km² resolution.

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

2.2.32 NCEP GFS Snow Depth

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

snowd.YYYYMMDD.tif.tar.gz

(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/fews/gfs/37_km/00z/gis/SNOWD_INT/ and unzipped to Geotiff files. The 37.5km resolution file are available in geotiff formats and sliced to just incorporate the northern hemisphere and reprojected to the IMS projection. Snow depth values range from 0-255 and represent the depth in centimeters.

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

2.2.33 Radar Observations

The surface radar observations from around the US are generated on 5 minute intervals. They come from the Mcldas 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:

AREA50XX

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

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

2.2.35 NAIS Sea Ice Model Output

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 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 5km² resolution.

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

2.2.36 NIC Sea Ice Thickness and Concentration

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 4km².

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

2.2.37 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 webserver for the IMS to pull via ftp by 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 FTP and unzipped using a shell program from the IMS GUI directly. The data file needs only to be renamed and reprojected to the IMS base projection to be utilized in the IMS GUI.

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

2.2.38 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**

2.2.39 VIIRS False Color Imagery

The VIIRS False Color imagery consists of globally composited color images (Red=I1, Green=I2, Blue=I3) over most areas north of 50 degrees latitude and land areas in Asia, Europe, and North America. The input data is received via NDE and remapped for use in the IMS preprocessing routine. Format types are TBD but should be either Geotiffs or NetCDF. The job runs twice per day. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time. Data Array size is TBD.

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

2.2.40 VIIRS NCC Imagery

The VIIRS NCC imagery consists of composited color images (Red=I1, Green=I2, Blue=I3) over most areas north of 50 degrees latitude. The input data is received via NDE and remapped for use in the IMS preprocessing routine. Format types are TBD but should be either Geotiffs or NetCDF. The job runs twice per day. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time. Data Array size is TBD.

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

2.2.41 VIIRS Sea Ice Age

The VIIRS Sea Ice Age Product consists of composited files over most areas north of 50N degrees latitude. The input data is received via NDE and remapped for use in the IMS preprocessing routine. Format types are TBD but should NetCDF4 with the job run once per day. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time. Data Array size is TBD.

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

2.2.43 VIIRS Snow Cover

The VIIRS Snow Cover Product consists of hemispherically composited estimates of snow concentration over most areas north of 50 N degrees latitude and land areas in Asia, Europe, and North America. The input data is received via NDE and remapped for use in the IMS preprocessing routine. Format types are TBD but should NetCDF4 with the job run twice per day. Since the image is always remapped over the same area, a static geolocation file was made to help reduce processing time. Data Array size is TBD. File output will not only be available as a static layer, but can have selected areas chosen to import directly as snow cover field in IMS base snow layer.

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

2.2.44 MIRS High Resolution Products

Snow Water Equivalent (SWE) and Ice Concentrations products are also available to from AMSU applying an advanced alternative algorithm. The Microwave Integrated Retrieval System (MIRS) is available for Advanced Microwave Sounding Unit (AMSU) data is available for the NOAA 18 satellite series. MIRS High Resolution AMSU files will be made available on the DDS for the previous day data. The data set naming conventions are TBD.

The input files are received using sFTP and an ENVI program is used to break apart each HDF structured file and extract the data fields corresponding to snow water equivalent and ice concentration. Since the area of coverage remains constant for

the MIRS 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. 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: **1 – needed for processing**

2.3 Theoretical Description

Since the IMS is an analyst driven product there are very few algorithms ever used in the system. The few that are needed are for final product generation. 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 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 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.

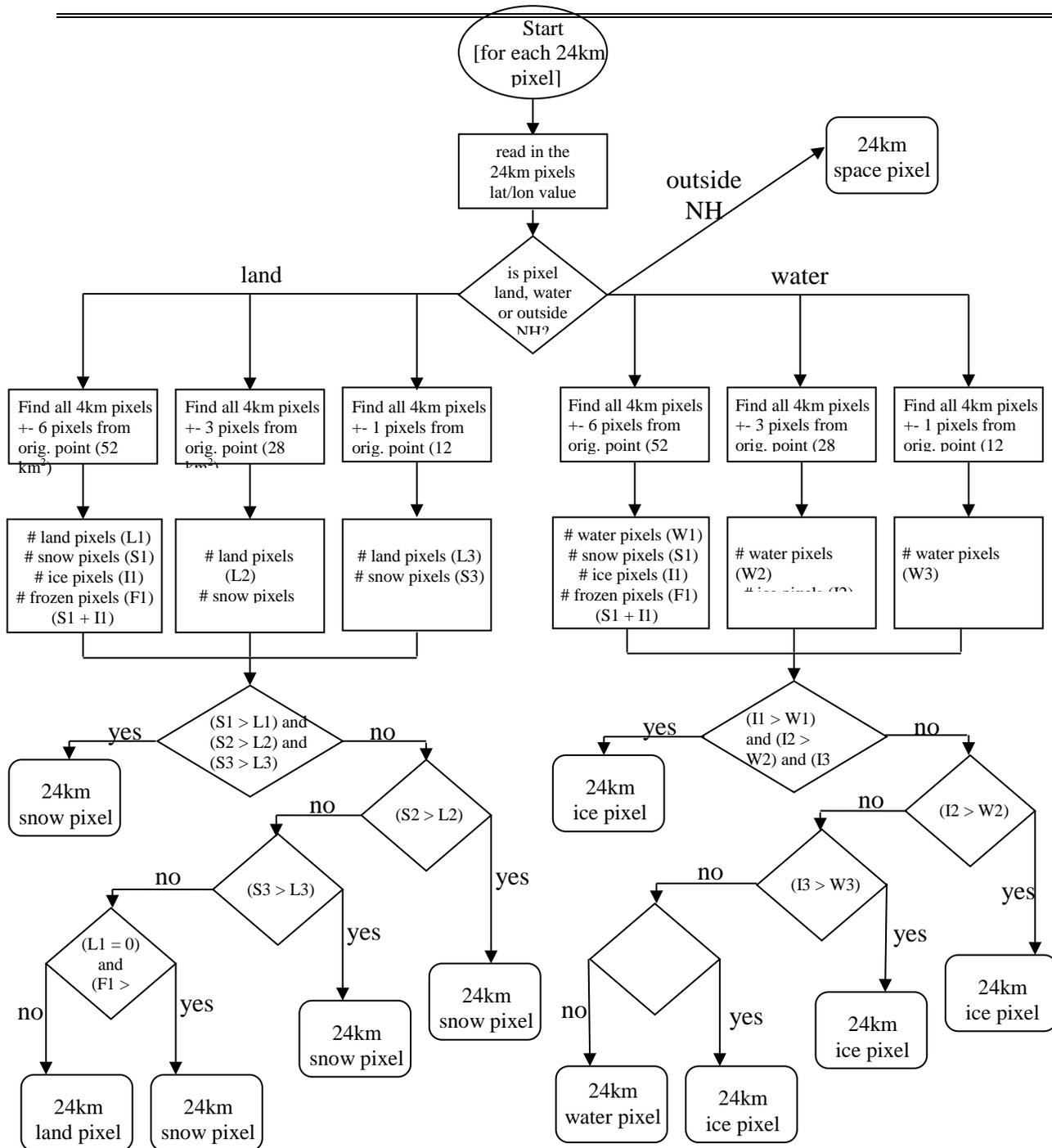


Figure 2-1. 24km IMS product decision tree

2.4 Algorithm Output

The IMS GUI system produces several daily output files all generated from scripts that run from cron. Five general types or products are made, the IMS snow/ice map files (in ASCII and ENVI formats), GeoTIFF files, and the GIF (Graphic Interchange Format) web images, and GRIB-2 files. More than one IMS GUI system is currently being used but only the operational GUI system will distribute products to the users with the other systems storing data locally or sending products to a test location.

2.4.1 ASCII Snow and Ice product files

The Daily Snow and Ice Product 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. It is currently produced once a day via cron after the analysts has completed the interactive portion of the IMS analysis, due to ENVI licensing. 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 identical naming conventions; they just reside under separate directories. The naming format is `imsYYYYJJJ.asc` where YYYY is four digit year and JJJ is three digit Julian day (ex. `ims2006255.asc`).

2.4.1.1 ASCII File (24km)

The 24km 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 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 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 since 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.

```
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)

This dataset has 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
```

2.4.2 ENVI product files

The ENVI product 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 kept in an ENVI file format (simply a data array) that can easily be opened in ENVI/IDL or any GIS application. Since these files are in ENVI format, 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).

2.4.3 GeoTIFF image files

Another main product set of the IMS are the GeoTIFF images made for the IMS GIS webpage. These are generated along with the final processing (once daily) that makes the ASCII and ENVI files and require use of the IDL/ENVI license (GUI has to be closed). Four output GeoTIFF images in two resolutions (4km and 1km) are produced. These 4 different images display the entire North Hemisphere but are rotated differently to allow for a different reference point when looking at the imagery (was too difficult to set up rotation on the GIS page at the time so this sufficed). Both resolutions of GeoTIFF files have identical naming conventions. They just reside under separate directories. For all files below, YYYY = four digit year, MM = two digit month, and DD = two digit day. TIFF file names imply the amount of rotation from having a central meridian at 90 degrees west longitude.

imsYYYYMMDD_10.tif

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

imsYYYYMMDD_100.tif

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

imsYYYYMMDD_190.tif

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

imsYYYYMMDD_280.tif

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

imsYYYYMMDD_280.tif

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

2.4.4 GIF web image files

The GIF images are made for the NIC web page. These are generated along with the final processing (once daily) that makes the ASCII and ENVI files and require use of the IDL/ENVI license (GUI has to be closed). 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.

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 (higher resolution) 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).

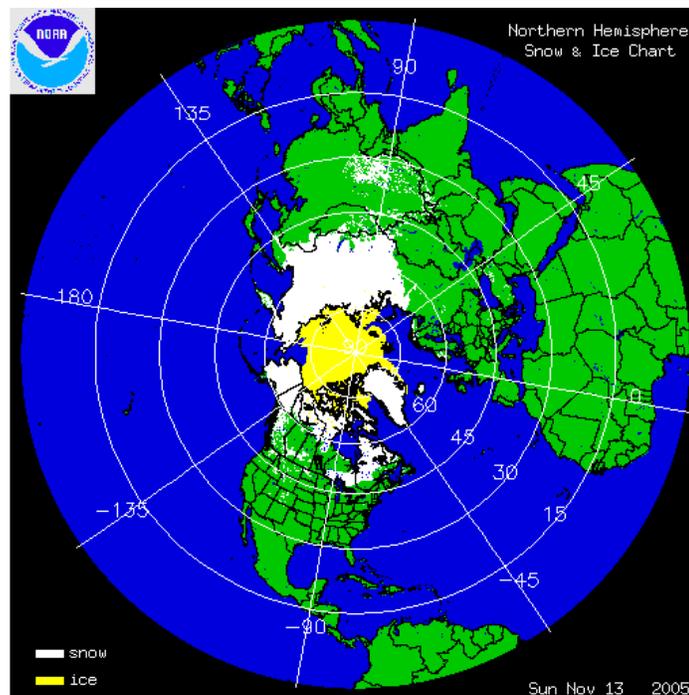


Figure 2-5. GIF (world region) image

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).

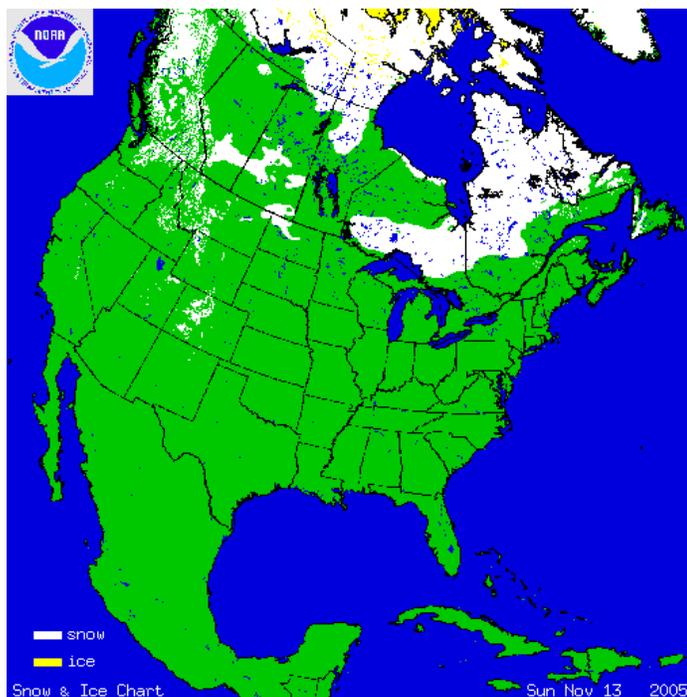


Figure 2-6. GIF (USA region) image

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).

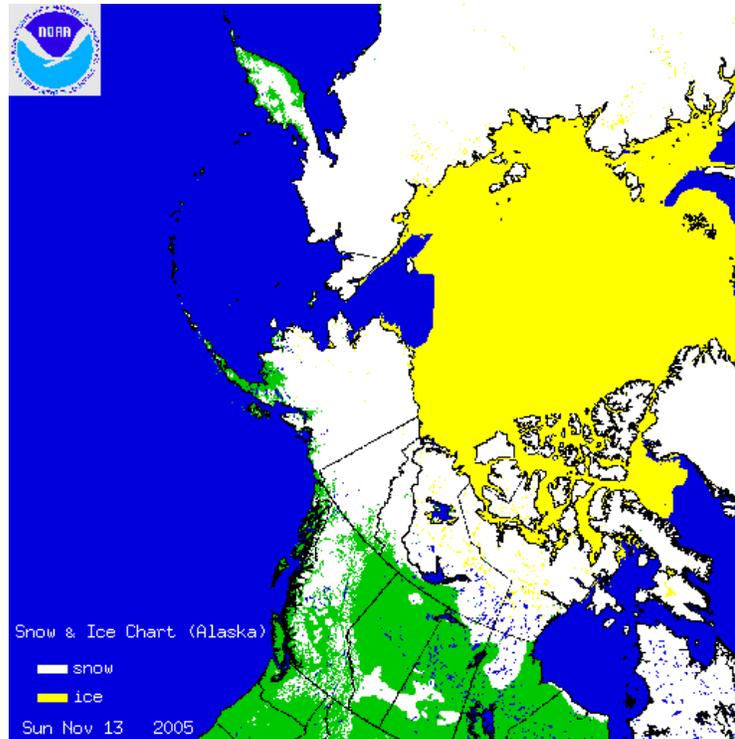


Figure 2-7. GIF (Alaska region) image

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_alaksa.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).

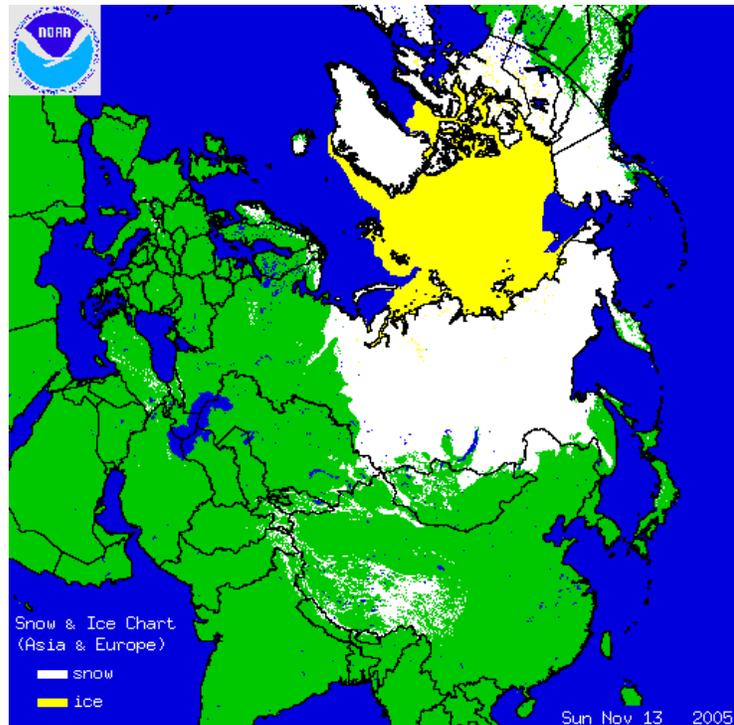


Figure 2-8. GIF (Asia/Europe region) image

For this area, three files are produced daily:

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

cursnow_asiaeurope.gif (copy of imsYYYYJJJ_asiaeurope.gif)

prvsnow_asiaeurope.gif (copy of previous days cursnow_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.

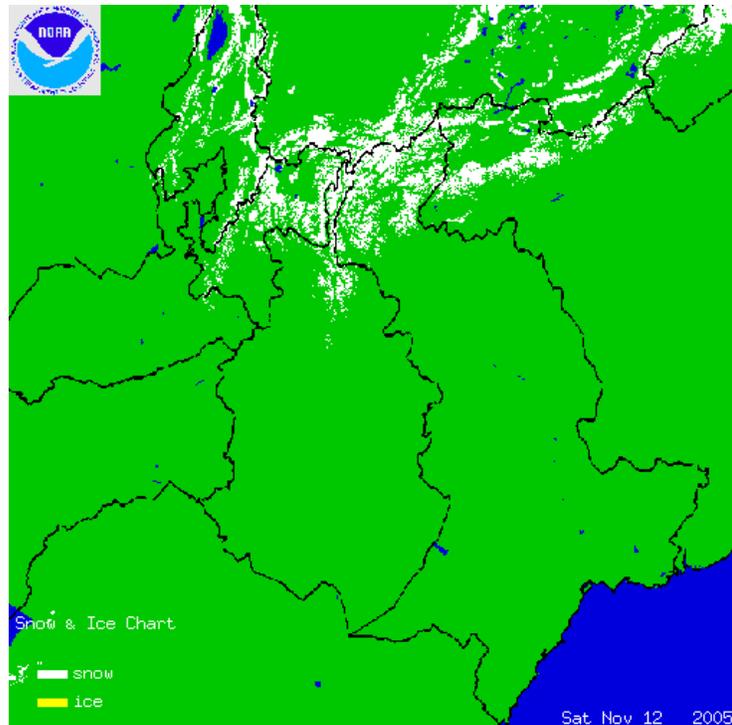


Figure 2-9. GIF (Afghanistan region) image

For this area, three files are produced daily:

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

currsnow_afghanistan.gif (copy of imsYYYYJJJ_afghanistan.gif)

prvsnow_afghanistan.gif (copy of previous days currsnow_afghanistan.gif)

2.4.5 GRIB-2 files

The GRIB-2 formatted files are created using the ASCII 4km and 1km product files. This is an add on process that is run off cron (on Satepsdistb1) to convert the format of the ASCII into the NCEP GRIB-2 format at the request of NCEP. This process uses a set of routines provided by NCEP to temporarily produce a GRIB-1 file then convert that output to GRIB-2. The output is then sent to the Product Server using the following naming convention:

imsYYYYMMDD.grb.grib2

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:

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. Hydrometeorol.*, 6, 1002–1017. doi: 10.1175/JHM447.1

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 surface data.

Since Snow cover performance is not based on system performance, but is based on analyst performance, the estimates of enhancements for Version 3 over Version 2 will not be performed by STAR.

2.6 Practical Considerations

2.6.1 Programming Considerations

All the program files for the IMS Products reside on the DELL - Linux workstation under different directories. Programs, mostly written in IDL/ENVI, are called upon by C shell or Perl script files scheduled in CRONTAB and run interactively. All IMS data transfer scripts use the Secure File Transfer Protocol (sFTP) as a means of receiving and distributing data. sFTP is a more secure form of FTP that is a TCP/IP protocol for reliable transmission of files over the Internet. The IMS input and output data on the pre-processing and IMS-GUI system reside in directories under restricted user accounts. Only certain individuals in operations have access to these accounts. Use of this software package, in conjunction with frequent system tape backups, will ensure the integrity of the operational IMS products and input data.

2.6.2 Procedural Considerations

A list of major steps involved in implementing the IMS into operating code is presented as follows:

(1) Have IDL (version 8.0) and ENVI (version 4.8) installed on the system and correctly licensed. Using an older version of the ENVI software will require alteration to the code for an updated structure used in mapping and newer versions of the software have not been tested. An important step is to make sure the ENVI license is correctly installed on the system (or nothing works correctly). To do this, simply open a Linux window and type "envi". If an ENVI window pops up and a command line returns in the Linux window, the full ENVI functionality has correctly been installed. If when running the command a "5-minutes Timed Demo Mode" text display appears on the screen, the ENVI/IDL combined license file has not correctly been installed on the system.

(2) Set up the user account in which IMS will be run. The account in which the IMS is to be run should exist and have adequate permissions to set up the needed directories as well and execute all programs. Setting up the main /data and /data1 directories may require the assistance of a systems person to extend the needed file permissions.

(3) Create the IMS directory structure and populate the directories. There is a multitude of data sources used for the IMS which translates to having many subdirectories for data input/output as well as code and scripts. The IMS needs all these directories and subdirectories to be set up correctly on the system to function properly.

(4) [optional] If different directory names are desired for setup then all code will need to be checked and updated where needed. All scripts and code under the \$HOME directory will need to be checked thoroughly and modified for any change in naming convention. It is highly recommended that the exact directory structure and naming is preserved for any new system, but it is possible to modify it if need be.

(5) Check the compilation of the IDL/ENVI code under the \$HOME directory.

(6) Check system accesses to remote systems. These systems need to be accessed directly by the scripts and need to be setup with automatic sFTP connections. These automatic connections are set up using ssh keys that can be set up by systems personnel or support programmers that have access to the systems. After setting these up, test each connection by typing sftp user@machine in a Linux window with user and machine being those listed above. If working properly, the sFTP should work resulting in a "sftp>" prompt. To quit sFTP mode, type "quit". Each connection has to be set up properly for the scripts to function.

(7) The McIDAS DATALOC must be set up so that data can be accessed through ADDE. The DATALOC listing must contain the following entries:
GER, GWR, IND, MSG, EOS, MTS, PLR, RTPSRC

(8) The cron entry must be setup. This can be done 1 of two ways depending if there is already a cron setup on the system being used for the IMS.

- a. If a cron is not currently being used, the \$HOME/crontab.txt file can simply be installed as the cron. To do this, navigate to the \$HOME directory and view the file (NOTE: some of the system paths may have to be edited depending on system settings). To install under cron simply type the command "crontab crontab.txt" to install on the system. A "crontab -l" command can be run to check that the cron entries were correctly set. All times of the cron have been set to coincide with data availability times and should only be modified when changes to the IMS preprocessor jobs have been made.
- b. If a cron already exists for the system, then appending the IMS jobs to the current cron entry would be desired. To do this, make a copy of the current cron under the \$HOME directory by typing "crontab -l > \$file" (where \$file is any filename except crontab.txt). Once done append the IMS jobs to the current jobs by typing "cat crontab.txt >> \$file" (the double arrows are very important!). Once done check that the IMS cron entries have been added to the current entries in \$file and set back to cron by typing "crontab \$file". This method will ensure the current cron entries remain while the IMS jobs are also added.

The IMS cron entries are set to pull input data as well as generate and send output data to needed servers. The times of the jobs have been carefully picked to coincide with data availability and should only be altered if data generation times change.

2.6.3 Quality Assessment and Diagnostics

Quality metrics will be included in the product files. Details will be provided in the Detailed Design Document (DDD).

2.6.4 Exception Handling

There are no hands-on monitoring procedures for the IMS products but an automated system of emails has been set up to automatically check that the product was made and transferred to the product server. Three possible email messages are sent if the final processing has errors or is not able to process.

Fatal error message (1):

This error message is sent out when daily processing has failed due to the final processing routine not being able to run correctly (most likely due to not having an ENVI/IDL license since the IMS GUI was left open). This is the worst error since it signifies that the final product has been missed for the day and that a programmer will need to manually run jobs to remake the missed product. This message signifies that a trouble ticket should be opened since a programmer will need to remake the missed product.

Fatal error message (2):

This error message is sent out when the files don't appear on the product server even after the script which transfers them has run. This may signify that the sFTP failed, the network is down, or that the remote system could be down. Whatever the cause, this is a major problem since this prevents our users from getting the data and a trouble ticket should be generated ASAP to look into the problems.

Warning message (3):

This message has been made to let the analysts know that final processing is trying to run and that the IMS GUI may have inadvertently been left open. The W-vaac machine was added to the notification list since it has an auditory message alarm that the analysts know to respond to immediately. This message gives the analyst a little extra time to check the system (or finish a long analysis) without a help ticket being made.

2.7 Validation

Validation of the IMS V3 snow cover, ice cover, and ice thickness fields will only be 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. This makes validation impossible to replicate on the impacts V3 would have over version 3. Impact assessments on model performance by applying a 1km versus a 4km grid will 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. The final snow depth blends the snow depth of the automated product with the updates of the analyst. Processing sequence and steps are as follows:

Initial step in the automated processing is reading of the most recent IMS V3 4-km ASCII snow cover and snow depth files. The IMS 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 IMS 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. The final step in the processing algorithm is the blending of the Snow depth of the automated algorithm with that produced by the analyst.

The 4 km resolution Snow Depth product files will be produced twice per day. Snow Depth production will be integrated into the Snow/Ice Cover Output runs between 1712-1742 UTC for the morning run over North America and 2212-2342 UTC for the NH afternoon run. The morning run produces "18Z" output files. The afternoon run produces "0Z" output files. Snow depth fields will only be generated for grid cells generated during the IMS snow cover analysis

3.2 Data inputs

We characterize the importance of the various input data sets with 3 categories: 1 – needed for processing, 2 – needed for improved quality or coverage, 3 – nice to have, but not needed).

3.2.1 AMSR-E Snow Water Equivalent Product

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 days 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

AMSR-E data is no longer available in real time. AMSR-2 will provide real time data in the future. Until this is available, IMS V3 will use MiRS high resolution SWE.

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

3.2.2 Surface Data (hourly report) 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**

3.2.3 MIRS High Resolution Products

Snow Water Equivalent (SWE) and Ice Concentrations products are also available to from AMSU applying an advanced alternative algorithm. The Microwave Integrated Retrieval System (MIRS) is available for Advanced Microwave Sounding Unit (AMSU) data is available for the NOAA 18 satellite series. MIRS High Resolution AMSU files will be made available on the DDS for the previous day data. The data set naming conventions are TBD.

The input files are received using sFTP and an ENVI program is used to break apart each HDF structured file and extract the data fields corresponding to snow water equivalent and ice concentration. Since the area of coverage remains constant for the MIRS 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. 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: **1 – needed for processing**

3.2.4 NCEP GFS Snow Depth

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

snowd.YYYYMMDD.tif.tar.gz

(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/fews/gfs/37_km/00z/gis/SNOWD_INT/ and unzipped to Geotiff files. The 37.5km resolution file are available in geotiff formats and sliced to just incorporate the northern hemisphere and reprojected to the IMS projection. Snow depth values range from 0-255 and represent the depth in centimeters.

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

3.2.3 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 (<http://glcf.umiacs.umd.edu/data/landcover/>). 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. The 1 km resolution product will be used for GOES-R ABI products.

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

3.2.4 Digital elevation

Elevation information for every pixel is used to screen high-elevation areas where snow depth retrievals may be inaccurate. The elevation dataset in the current version of the algorithm is based on USGS GTOPO30 model data averaged within 4 km grid cells.

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.

3.4 Algorithm Output

The snow depth output file will be in PS ASCII format at 4-km resolution, same format as the 4-km IMS ASCII file.

3.5 Performance Estimates

Performance metrics for Snow Depth fields will be based on calculations of bias and root mean square error with respect to ground observations in a cross validation setting. Additionally, product will also be inter-compared with AFWA snow depth estimates in the same locations.

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 are tabulated for the IMS snow depth and the AFWA snow depth to determine the difference between each and the “ground truth” surface reports and the NOHRSC snow depth estimates.

3.6 Practical Considerations

3.6.1 Programming Considerations

The snow depth retrieval code will be integrated into the larger IMS V3 system. There are no extra programming considerations.

3.6.2 Procedural Considerations

The snow depth retrieval code will be integrated into the larger IMS V3 system. There are no extra programming considerations.

3.6.3 Quality Assessment and Diagnostics

Quality metrics will be included in the product files. Details will be provided in the Detailed Design Document (DDD).

3.6.4 Exception Handling

TBS

3.7 Validation

Snow depth validation will be conducted to assess the accuracy of data in areas with in situ observations that are not applied directly in the IMS snow depth modeling application. It will also be compared to AFWA snow depth values to gauge 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 compared to NOHRSC snow depth fields that are estimated using snow model. The validation is underway and will be completed during the transition to pre-op status and will be provided to ATBD before operational status is implemented.

4.0 ASSUMPTIONS AND LIMITATIONS

4.1 Assumptions

The assumptions that were made in determining that the software system architecture as designed will meet the requirements include:

1. Have IDL (version 8.0) and ENVI (version 4.8) installed on the system and correctly licensed

2. Set up the account in which the preprocessing jobs and GUI will be run. The account in which the IMS preprocessing is to be run should exist and have adequate permissions to set up the needed directories as person to extend the needed file permissions.
3. Create the IMS directory structure and populate the directories
4. Set up the connections to remote systems including EOS server, Polar server, Product Server, Model Server, NIC server
5. The McIDAS DATALOC must be set up so that data can be accessed through ADDE
6. The cron entry must be set up

4.2 Limitations

Limitations that may impact on the system's ability to meet requirements include:

- 1) The availability of input data will limit the consistency of the snow and ice analysis

All final processing needs to use ENVI/IDL to successfully run which requires the IMS GUI to be shut down due to software licensing requirements.

5.0 LIST OF REFERENCES

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