57th EASTERN SNOW CONFERENCE
Syracuse, New York, USA, 2000

Prospects for the Interactive Multisensor Snow and Ice Mapping System (IMS)

BRUCE H. RAMSAY[1]

ABSTRACT

The National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service (NOAA/NESDIS) operationally implemented the daily Interactive Multisensor Snow and Ice Mapping System (IMS) in 1997. This geographic information system replaced the manual Northern Hemispheric weekly snow mapping process in 1999, and its products are used as input to the National Weather Service's Eta model. Preliminary validation of the daily product was completed in 1998. A more rigorous validation of the daily product with respect to its use in the continuance of the climatologies produced from the weekly snow and ice maps is underway. Output from an experimental automated snow and ice mapping algorithm for North America, using visible and infrared imagery from NOAA's Geostationary Operational Environmental Satellite Imager and microwave data from the Defense Meteorological Satellite Program's Special Sensor Microwave/Imager, is under evaluation by operational meteorologists in NOAA/NESDIS for potential use as a first guess in IMS. In addition, 1.6 Φm imagery from the NOAA-15 satellite's Advanced Very High Resolution Radiometer/3, and snow and ice products from the National Aeronautics and Space Administration's Moderate Resolution Imaging Spectroradiometer, aboard the Earth Observing System Terra satellite, are under evaluation for potential inclusion in IMS. This paper presents a brief overview of the current IMS and its near future prospects.

Key Words: Mapping, Remote sensing, Snow cover

[1] Land Scientist, NOAA/NESDIS/Office of Research and Applications (E/RA11), Room 712-T, NOAA Science Center, 5200 Auth Road, Camp Springs, Maryland 20746-4304, USA
email: bramsay@nesdis.noaa.gov

INTRODUCTION

NOAA/NESDIS prepares a daily snow and ice chart of the Northern Hemisphere (NH). Chart preparation is performed by a meteorologist through the inspection of visible imagery from sensors on-board geostationary satellites including the Geostationary Operational Environmental Satellite (GOES), the Meteorological Satellite (METEOSAT), and the Geostationary Meteorological Satellite (GMS), polar orbiting satellites including the Polar-orbiting Operational Environmental Satellite (POES), and imagery from the Defense Meteorological Satellite Program=s (DMSP) Special Sensor Microwave/Imager (SSM/I), as well as sea ice charts from the National Ice Center and ground weather observations. The areal coverage of snow and ice is charted on a map with a polar stereographic projection centered on the North Pole (Ramsay 1998).

Weekly charts, made largely by hand, were produced from 1966 to 1999. Figure 1 shows a hand drawn snow and ice chart of the NH for the week of 09-15 November 1998 (Office of Research and Applications 1998). NOAA/NESDIS meteorologists have created daily charts through the use of the Interactive Multisensor Snow and Ice Mapping System (IMS) since 1997. The two year overlap period from 1997 to 1999 provided a data set of manual weekly and IMS daily charts for comparison and validation of the IMS daily maps. NOAA's National Weather Service (NWS) has used the IMS daily maps in a regional Numerical Weather Prediction (NWP) model since June 1998. The complete 34 year satellite-derived snow and ice chart data set is used in climate analysis (Robinson 2000; Robinson et al. 1993). The purpose of this paper is to outline likely near-term future enhancements to IMS.

DISCUSSION

The Interactive Multisensor Snow and Ice Mapping System

IMS, a geographic information system, was developed to permit meteorologists to interactively prepare daily NH snow and ice maps and to take advantage of additional remotely sensed imagery such as that based on DMSP passive microwave data from SSM/I. The previously used manual method in production of the weekly chart took eight to ten hours depending upon the season. Meteorologists using IMS routinely produce daily maps in under 90 minutes. IMS provides the opportunity for meteorologists to compare imagery and other snow and ice maps in the same scale and format to produce a more accurate product at higher spatial and temporal resolution than with the manual production of snow and ice maps. The spatial resolution of IMS charts are 23 kilometers (km) while the weekly charts were prepared at 190 km. Figure 2 is an IMS snow and ice chart of North America for 12 March 2000 (Satellite Services Division 2000). The enhanced spatial and temporal resolution provided through IMS was sought by the NWS to improve NWP model output over North America.

A preliminary analysis of the 1997 to 1998 NH snow season daily and weekly snow chart data sets indicated the daily IMS product was superior to the weekly product in accuracy as well as in its spatial and temporal resolution. Map accuracy was determined by resampling the higher resolution IMS daily maps produced on Mondays to the lower resolution of the weekly snow maps, also produced on Mondays, and then comparing both low resolution data sets to weather station reports. Additional validation of the data sets over the two year period is being continued. The integration of data from the daily snow maps into the Eta Data Assimilation System used by the NWS National Centers for Environmental Prediction over North America began on 03 June 1998 (Environmental Modeling Center 1998). Figure 3 shows three Eta model horizontal grid domains over North America and extended areas at 48, 29, and 32 km resolution (Rogers et al. 1999). Eta-32 is the most recent of the three grids implemented. The primary difference between the grids is their vertical resolution (not shown).

Experimental Automated Snow Mapping System

NOAA/NESDIS developed an automated snow mapping system based on a decision tree algorithm. This system began experimental production in 1999. The algorithm uses GOES visible

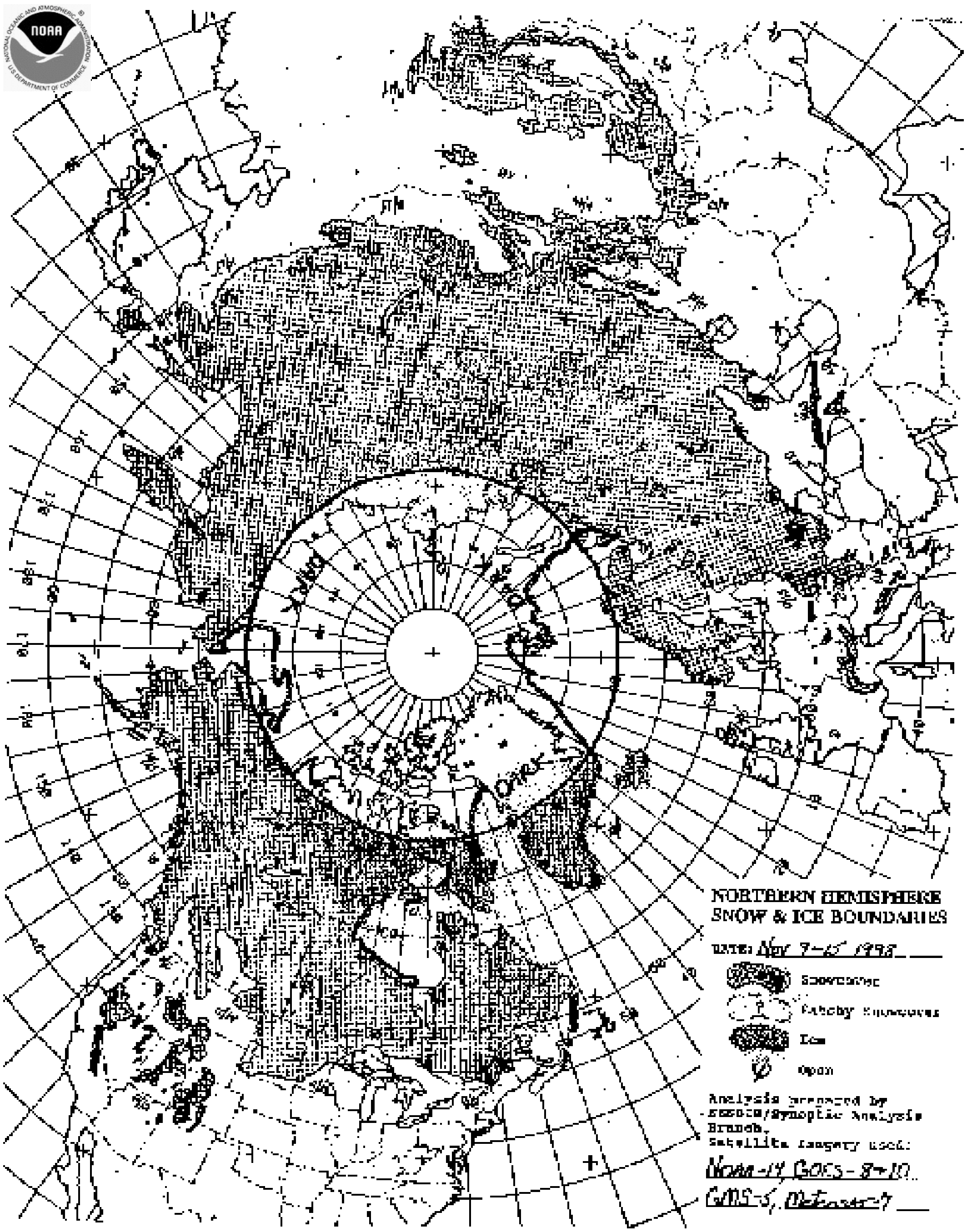

Figure 1. Northern Hemisphere Snow and Ice Boundary Chart for the week of 09–15 November 1998.

and infrared imagery and SSM/I data. The experimental product currently provides coverage of North America and will be evaluated by NOAA/NESDIS operational meteorologists during the forthcoming 2000-2001 NH snow and ice season. One of the objectives is to evaluate this product as a potential first guess in IMS over North America. Figure 4 is a snow map from this system for 12 March 2000 (Office of Research and Applications 2000). The most recent snow map from the automated snow mapping system may be viewed at (http://orbit-net.nesdis.noaa.gov/crad/sat/surf/snow/HTML/snow.htm). Snow maps from August 1999 to the present, plus a new experimental snow fraction product for use in the Eta model, from March 2000 to the present, may also be accessed at this site.

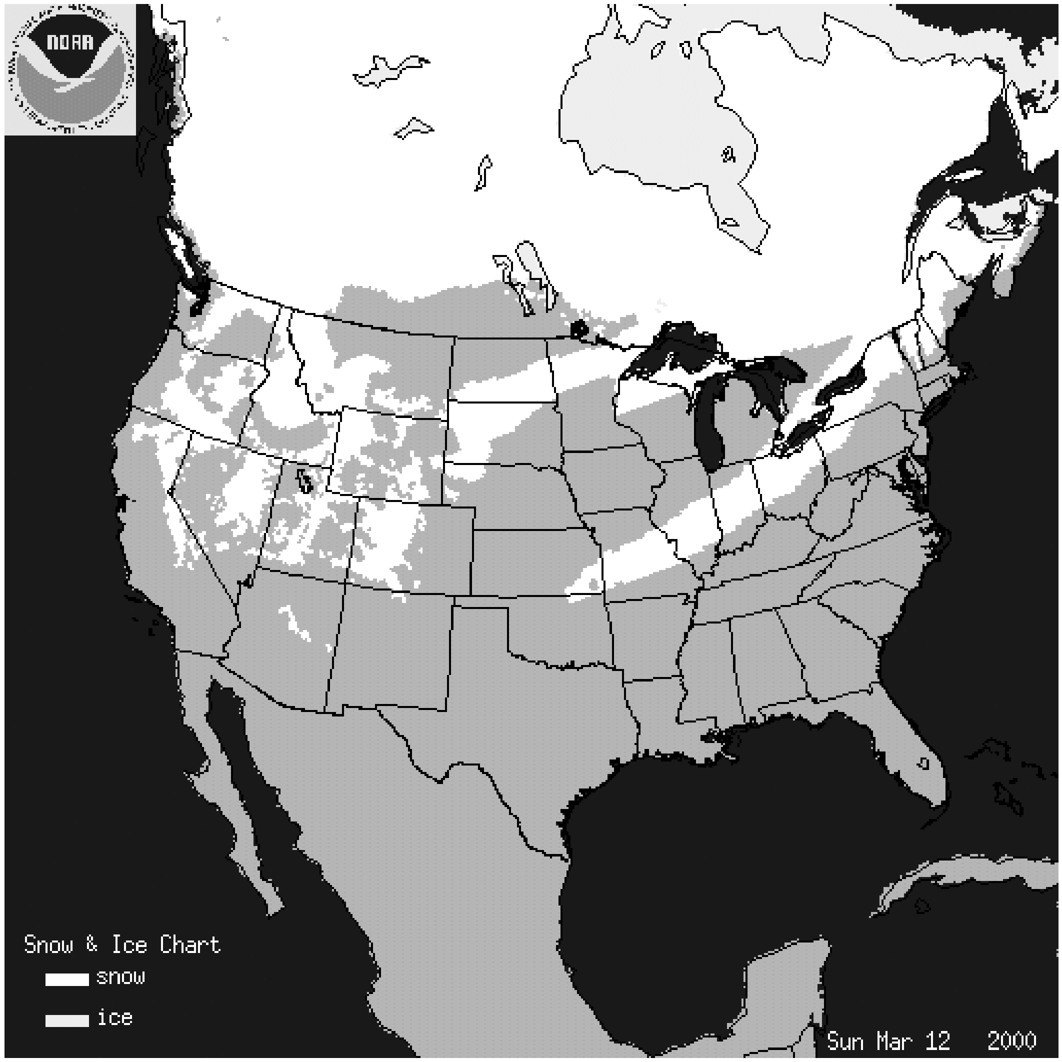

Figure 2. Snow and ice chart for North America from NOAA's Interactive Multisensor Snow and Ice Mapping System for 12 March 2000. Snow is white, ice is light grey, land is medium grey, and water is dark grey.

The NWS has a requirement for snow and ice products over the Southern Hemisphere (SH). Additional data sets and applicable methods of analysis are being considered to expand the algorithm to provide global coverage. Experimental regional products for areas over South America are planned for production this year. These products will also be evaluated for potential inclusion into IMS.

Advanced Very High Resolution Radiometer/3 Channel 3A

NOAA's newest addition to POES is NOAA-15. The NOAA-KLM satellite series has an upgraded Advanced Very High Resolution Radiometer (AVHRR) sensor, AVHRR/3. NOAA-K became NOAA-15 on its successful launch on 13 May 1998, and is in a morning orbit. Among other improvements to AVHRR/3, Channel 3 was split so that data may be collected at a new spectral range centered on 1.6 micrometers Φm), noted as Channel 3A , or in the previously configured 3.7 Φm spectral band, now designated as Channel 3B. Channel 3A was explicitly designed for use in the discrimination between snow cover and clouds. The albedo of clouds is higher than that of snow at 1.6 μm (Hall et al. 1998; Dozier 1989). The switch for Channel 3A and 3B may only turn on one or the other channel, but not both simultaneously. The decision was

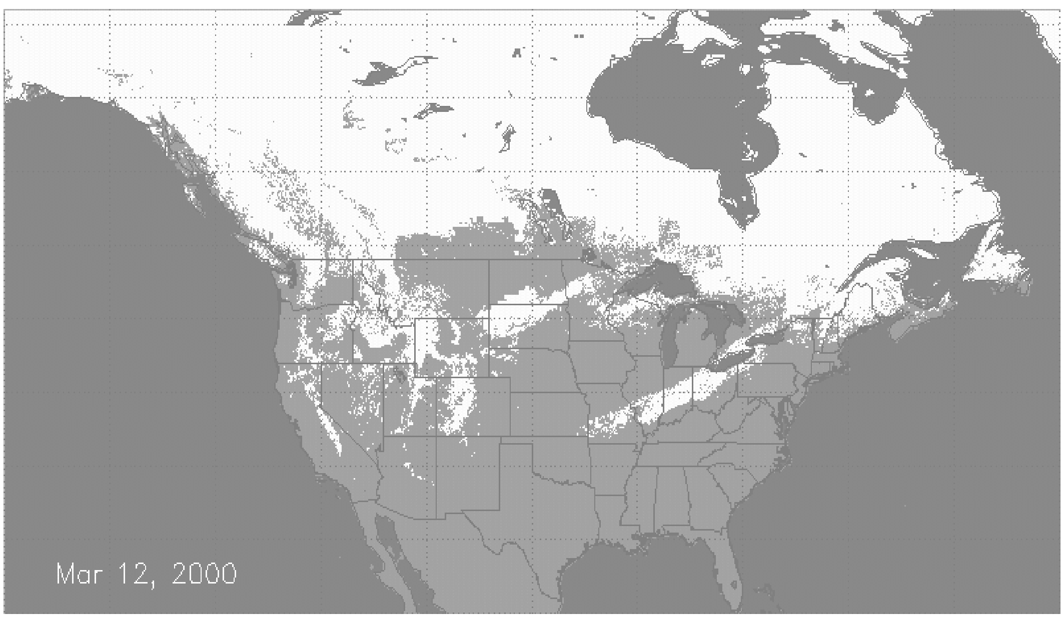

Figure 4. Snow map of North America from NOAA's Experimental Automated Snow Mapping System for 12 March 2000. Snow is white, land is medium grey, water is dark grey.

made to collect Channel 3A imagery for evaluation during part of the 1998-1999 NH snow and ice season but to leave Channel 3B turned on and in operational mode the rest of the time. NOAA-L is scheduled for launch in August 2000 in an afternoon orbit (Kidwell 1999).

Two NOAA-15 AVHRR images taken at the same time of snow and ice cover over the U.S., from Ohio to New York, are displayed in Figure 5. They provide the opportunity for a visual comparison of imagery from Channel 1 and Channel 3A. The shortwave infrared image on the left

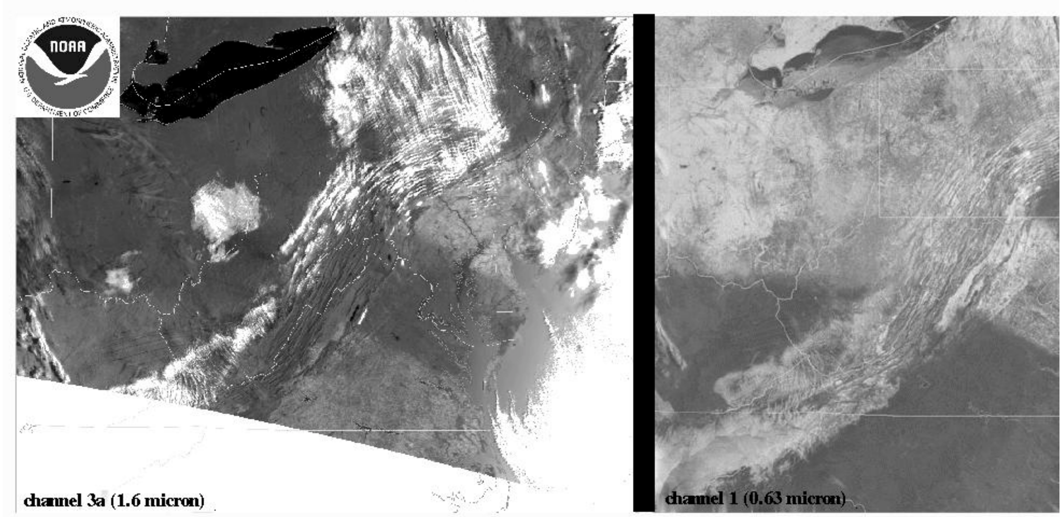

Figure 5. Images of snow and ice cover from the NOAA-15 Advanced Very High Resolution Radiometer for 12 March 1999. The shortwave infrared image on the left is from Channel 3A (1.6:m) and the visible image on the right is from Channel 1 (0.63:m). Snow and clouds cover the area over south-central New York, central Pennsylvania, and soutern Ohio. It is difficult to differentiate snow cover from clouds in the Channel 1 image (right); however, the clouds are much easier to identify as the bright white areas in the Channel 3A image (left).

is from Channel 3A, and the visible image on the right is from Channel 1 (0.63 Φm). Clouds are not easily distinguished from the snow cover on the ground in the visible image on the right. However, the clouds can be seen as the bright white areas over southern Ohio, central Pennsylvania, and south-central New York, and can are readily differentiated from the snow cover in the image on the left (Operational Significant Event Imagery Team 1999).

Initial evaluation of imagery from Channel 3A indicates a high potential value for use in creating new satellite-derived products, including snow maps, through channel differencing techniques (National Operational Hydrologic Remote Sensing Center, 2000; Hillger 1999). Plans have been implemented to develop an automated system to produce an AVHRR/3 experimental global snow and ice product based in part on the 1.6 m channel and to take advantage of the launch of NOAA-L during the 2000-2001 NH snow and ice season. NOAA-L will have Channel 3A turned on in operational mode for the collection of imagery over areas north of 30 degrees latitude. Channel 3B will be turned on in operational mode the remainder of the time over areas not impacted by seasonal snow cover. The images used in Figure 5 may be viewed in an enlarged format at (http://www.osei.noaa.gov/Events/Snow/). This site also provides other images of snow and ice over the Southern Hemisphere, as well as the NH, from 1996 to the present.

Moderate Resolution Imaging Spectroradiometer

The National Aeronautics and Space Administration (NASA) successfully launched the polar orbiting Earth Observation System (EOS) Terra satellite (formerly EOS AM-1) on 18 December 1999. On-board is the Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS has 36 channels providing spectral coverage from the visible to thermal infrared which includes a 1.6 m band, Band 6. The MODIS global product suite includes daily maps of snow cover, sea ice, and lake ice at either 500 meter (m) or 1 km resolution as well as 8-day and monthly composites at smaller scale for use in climate modeling and analysis (Riggs et al. 2000; Hall et al. 1998).

NOAA and NASA implemented a joint program in which a portion of the entire MODIS data stream transmitted, stored and processed by NASA, has been directed to a NOAA/NESDIS computer at NASA's Goddard Space Flight Center in Greenbelt, Maryland. Near real-time imagery and data are being processed and will be sent to NOAA/NESDIS for evaluation and use by NOAA atmospheric, oceanic, and terrestrial operational and research communities in the near

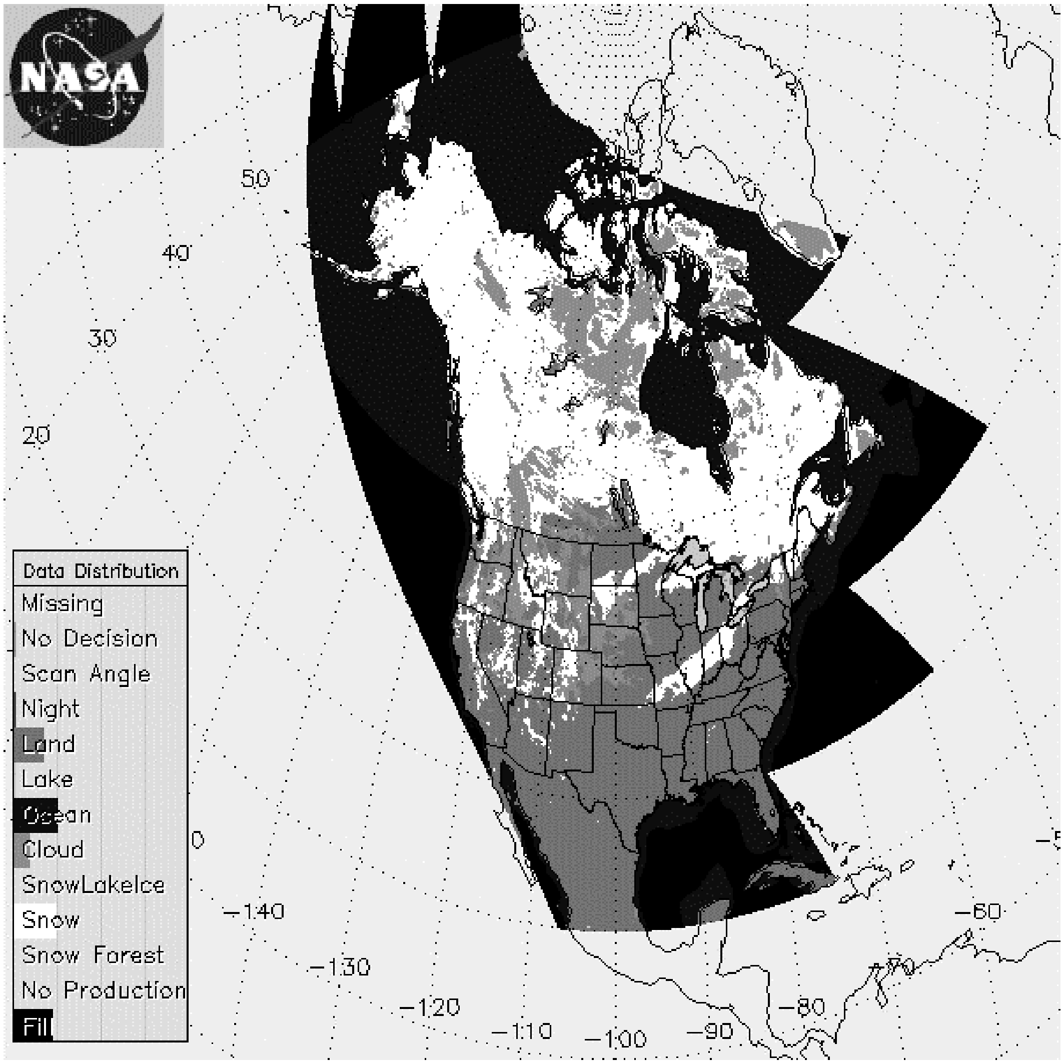

Figure 6. Snow and ice map of North America from NASA's Moderate Resolution Imaging Spectro-radiometer showing the maximum snow cover over an eight-day period from 05 March to 12 March 2000. Snow is white, clouds are light grey, land is medium grey, and water is dark grey.

future. NOAA/NESDIS operational meteorologists will evaluate MODIS snow and ice imagery and products for potential use in IMS.

The NASA-provided map derived from MODIS imagery in Figure 6 shows snow and ice cover over North America composited overan eight-day period from 05 to 12 March 2000 (Hall 2000). Although a composite map, a comparison by visual observation with the daily operational IMS snow and ice chart in Figure 2, and the daily experimental automated snow map in Figure 4 shows generally good agreement among the three products. This and other snow and ice products from MODIS may be viewed at (http://snowmelt.gsfc.nasa.gov/MODIS_Snow/modis.html).

Initial Joint Polar System and the Meteorological Operational Satellite Program

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the U.S. entered an agreement on 19 November 1998 to provide a mutually supported polar orbiting operational satellite system called the Initial Joint Polar System (IJPS) starting in 2003. EUMETSAT will launch and maintain the Meteorological Satellite (METOP) in a morning orbit (European Organisation for the Exploitation of Meteorological Satellites, 1999). The U.S. will continue the NOAA polar orbiting satellite series in the afternoon orbit. Both satellites will carry a core set of sensors, including AVHRR/3 among others, to maintain the continuity of operational data and meteorological observations, such as those of snow and ice (Office of Systems Development 2000; European Space Agency 1999). Additional information on the background and implementation of the IJPS and METOP may be obtained at (http://discovery.osd.noaa.gov/IJPS/),(http://www.eumetsat.de/en/index.html?area=left2.html&body=/en/area2/cgms/ap9-12.htm&a=284&b=2&c'280&d=200&e=0, or (http://www.esrin.esa.it/htdocs/esa/progs/METOP.html).

National Polar-Orbiting Operational Environmental Satellite System

The future of the DMSP, operated by the Department of Defense (DOD) through the U.S. Air Force, and the POES program, run by the Department of Commerce (DOC) through NOAA, is in the merger of these two programs into the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The Integrated Program Office (IPO) was established to oversee the successful convergence of these U.S. military and civilian polar orbiting satellite programs. The IPO is composed of representatives of the DOD, DOC, and NASA. The first NPOESS launch is schedule for 2008, after the current suite of POES and DMSP satellites have been placed in orbit. NASA is providing support for the development of new satellite and remote sensing technologies (NOAA Office of Public and Constituent Affairs 2000; Clinton 1994). Information on the IPO may be accessed at (http://www.ipo.noaa.gov/). The NPOESS Electronic Library may be viewed at (http://npoesslib.ipo.noaa.gov/).

Visible/Infrared Imager/Radiometer Suite

One of the sensors to be flown on NPOESS is the Visible/Infrared Imager/Radiometer Suite (VIIRS). VIIRS will provide imagery on the areal extent of snow and ice cover at 500 m resolution (the requirement is subject to review at this time), as well as a binary map indicating snow or no snow, and a fractional measure of snow cover in each grid cell. The number and spectral range of channels have yet to be determined (Associate Directorate for Acquisition 2000). Details on the VIIRS instrument and requirement specifications may be accessed at (http://npoesslib.ipo.noaa.gov/S_viirs.htm).

CONCLUSION

The development and operational implementation of IMS was predicated on specific requirements of the NWS and other customers for an accurate NH snow and ice cover product at higher spatial and temporal resolution then previously available. IMS has successfully met those needs over its brief three-year period of operation. However, it is necessary to enhance IMS based on new requirements, new satellite sensors, and new methods for mapping snow and ice cover. The NOAA/NESDIS experimental automated snow mapping system, the AVHRR/3 experimental global snow and ice mapping system, and imagery and automated maps from NASA's MODIS instrument will all provide opportunities to enhance IMS products and expand IMS coverage beyond the NH this year. These new requirements, sensors, and methods represent a link to the future of global snow and ice mapping for IMS in IJPS/METOP and NPOESS/VIIRS, among others. The plan is to take advantage of these new products to enhance IMS now and also use them to prepare for the future.

ACKNOWLEDGMENTS

Acknowledgment is given to Peter Romanov (Peter.Romanov@nesdis.noaa.gov), NOAA/NESDIS, for information on the NOAA/NESDIS experimental automated snow mapping system, George Stephens (George.Stephens@noaa.gov) from the NOAA/NESDIS Operational Significant Event Imagery Team for processing of the AVHRR/3 Channel 3A imagery, and to

Dorothy Hall (dhall@glacier.gsfc.nasa.gov), NASA/GSFC, for information on MODIS snow and ice map products.

REFERENCES

Associate Directorate for Acquisition, 2000. Visible/Infrared Imager/Radiometer Suite (VIIRS) Sensor Requirements Document (SRD) for National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Spacecraft and Sensors (Version 2d, 03 May 2000); available from http://npoesslib.ipo.noaa.gov/S_viirs.htm; accessed 16 May 2000.

Clinton, William J., 1994. Convergence of U.S.-Polar-Orbiting Operation Environmental Satellite Systems. Presidential Decision Directive/NSTC-2 (5 May 1994); available from http://www.ipo.noaa.gov/NPOESS.HTM); accessed 16 May 2000.

Dozier, Jeff, 1989. Remote Sensing of Snow in Visible and Near-Infrared Wavelengths. In *Theory and Applications of Optical Remote Sensing*, Ghassem Asrar (ed.). New York: John Wiley & Sons, 527–547.

Environmental Modeling Center, 1998. Mesoscale Modeling Branch FAQ: Eta model: what is the latest on the early meso upgrade? 09 Feb 98 Eta/EDAS Implementation (revised 06 November 1998); available from http://www.emc.ncep.noaa.gov/mmb/research/FAQ-eta.html#ETA; accessed 16 May 2000.

European Organisation for the Exploitation of Meteorological Satellites, 1999. The Initial Joint Polar System (revised 02 July 1999); available from http://www.eumetsat.de/en/index.html?area=left2.html&body=/en/area2/cgms/ap9-12.htm&a=284&b=2&c=280&d=200&e=; accessed 16 May 2000.

European Space Agency, 1999. Metop (revised 10 September 1999); available from http://www.esrin.esa.it/htdocs/esa/progs/METOP.html; accessed 16 May 2000.

Hall, D.K., 2000. Eight-day composite map showing maximum snow cover in North America during the period from March 5-12, 2000 (revised May 2000); available from http://snowmelt.gsfc.nasa.gov/MODIS_Snow/imagegal.html; accessed 16 May 2000.

Hall, D.K., A.B. Tait, G.A. Riggs, V.V. Salomonson, J.Y.L. Chien, A.G. Klein, 1998. Algorithm Theoretical Basis Document (ATBD) for the MODIS Snow-, Lake Ice- and Sea Ice-Mapping Algorithms. Version 4.0 (revised 09 October 1998); available from http://snowmelt.gsfc.nasa.gov/MODIS_Snow/atbd1.html; accessed 16 May 2000.

Hillger, D.W., 1999. Using the new 1.6 Φm channel on NOAA-15 in satellite product development. *Preprints: 10th Conference on Atmospheric Radiation*, 28 June-2 July 1999, Madison, WI, AMS, 193-196.

Kidwell, K.B. (ed.), 1999. NOAA KLM User’s Guide (revised May 1999); available from http://www2.ncdc.noaa.gov/docs/klm/index.htm; accessed 12 July 2000.

National Operational Hydrologic Remote Sensing Center, 2000. 1.6 μm Wavelength Important for Operational Remote Sensing at NOAA; available from http://www.nohrsc.nws.gov/html/avhrr3a/avhrr3a.htm; accessed 12 July 2000.

NOAA Office of Public and Constituent Affairs, 2000. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) (revised April 2000); available from http://www.publicaffairs.noaa.gov/grounders/npoess2000.html; accessed 16 May 2000.

Office of Research and Applications, 2000. North American snow maps automated snow mapping system for 12 March 2000 (revised 1 May 2000); available from http://orbit-net.nesdis.noaa.gov/crad/sat/surf/snow/GIF/COMB/comb_snow_map_00072.gif; accessed 16 May 2000.

Office of Systems Development, 2000. The Initial Joint Polar-Orbiting Operational Satellite System (revised 06 January 2000); available from http://discovery.osd.noaa.gov/IJPS/; accessed 16 May 2000.

Operational Significant Event Imagery Team, 1999. Comparison between NOAA-15 Channels 3A and Channel 1 (revised 13 July 2000); available from http://hazard1.wwb.noaa.gov/Events/Snow/US_East/1999/SNWusE070_N5.jpg; accessed 14 July 2000.

Ramsay, Bruce H., 1998. The interactive multisensor snow and ice mapping system. *Hydrological Processes*, **12**, 1537–1546.

Riggs, George A., Jonathan S. Barton, Dorothy K. Hall, and Vincent V. Salomonson, 2000. MODIS Snow Products Users' Guide (revised February 2000); available from http://snowmelt.gsfc.nasa.gov/MODIS_Snow/SnowUsrGuide/usrguide.html; accessed 16 May 2000.

Robinson, David. A., 2000. Weekly Northern Hemisphere Snow Maps: 1966-1999. *Preprints: 12th Conference on Applied Climatology*, 8-12 May 2000, Asheville, NC, AMS, 12-15.

Robinson, David A., Kenneth F. Dewey, and Richard R. Heim, Jr., 1993. Global snow cover monitoring: an update. *Bull. Am. Meteorol. Soc.*, **74**, 1689-1696.

Rogers, Eric, Michael Baldwin, Thomas Black, Keith Brill, Fei Chen, Geoffrey DiMego, Joseph Gerrity, Geoffrey Manikin, Fedor Mesinger, Kenneth Mitchell, David Parrish, and Qingyun Zhao, 1999. Changes to the NCEP Operational "Early" Eta Analysis / Forecast System (revised 05 May 1999); available from http://www.nws.noaa.gov/om/447body.htm; accessed 16 May 2000.

Satellite Services Division, 2000. Snow and Ice (revised 06 April 2000); available from http://www.ssd.noaa.gov/SSD/ML/realtime.html#SNOW; accessed 16 May 2000.