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A Selection of Documentation Related To National Ice Center Sea Ice Charts in Digital Format

Special Report #13 14 August 2006

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Citation

Fetterer, F., compiler. 2006. *A Selection of Documentation Related To National Ice Center Sea Ice Charts in Digital Format*. NSIDC Special Report 13. Boulder, CO, USA: National Snow and Ice Data Center. http://nsidc.org/pubs/special/nsidc_special_report_13.pdf

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Introduction

This report compiles scattered written descriptions of National Ice Center (NIC) sea ice chart digitization efforts into a single citable document. NIC is a joint U.S. Navy, NOAA, and Coast Guard center that produces operational ice analyses. The NIC sea ice chart series begins in 1972, and offers a valuable record of ice conditions that supplements records from other sources, such as passive microwave satellite data. Analyses are available on-line from NIC in Geographic Information Systems (GIS) compatible form. Past and present collaborations between NIC and the polar research community have made the chart series available in other formats as well (e.g., Arctic Climatology Project, 2000; National Ice Center, 2006). Researchers using the NIC data sets distributed by NSIDC will benefit from understanding how charts are created, what data sources are used, how charts have been digitized in the past, and how chart information has changed over the years. This report complies some useful information pertaining to these issues. Other useful references are Dedrick et al. (2001) and Partington et al. (2003), with information on how the charts can be used to study sea ice; van Woert (2002) with general information on NIC products and processes; and Kokaly (1996), with information on gridding sea ice chart data.

This report includes *National Ice Center 7-Day Sea Ice Charts*, which is a compact description of the charts on the Environmental Working Group (EWG) Sea Ice Atlas (Arctic Climatology Project, 2000) and how they were produced. It also includes *Satellite Platform and Sensor Availability*, consisting of tables that summarize the annual availability of each satellite platform and sensor used to produce NIC's global sea ice analyses for 1972 through 1994. (These are the years covered by the EWG Sea Ice Atlas). . *National Ice Center Sea Ice Climatology* is a description of the climatology on the EWG Sea Ice Atlas that explains how source data for the climatology differ from the 7-Day Sea Ice Charts that are also on the EWG Sea Ice Atlas. Finally, the documentation from the data set on CD-ROM titled *Arctic and Antarctic Sea Ice Data, 1972-1994*, produced by NIC, the Fleet Numerical Meteorology and Oceanography Detachment, and the National Climatic Data Center, is included. This product is no longer distributed by NSIDC because it contained some erroneous data and the EWG Sea Ice Atlas replaced it. However, the documentation contains useful information for investigators working with NIC chart products.

The documents are complied in this Special Report in order to better preserve the information they contain, and to make the information more easily accessible. Unless otherwise noted, they are included in complete and unedited form.

Documentation from the National Ice Center

Overview of NIC documentation

The documentation from NIC includes information useful for understanding how NIC ice charts are made, and how methods and data sources have changed over the years, and how the products on the EWG Sea Ice Atlas were made. At the time of this writing, the documents are also posted on the NIC Web site and on an NSIDC Web page that has ancillary information on the Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas (User Notes, at http://nsidc.org/data/docs/noaa/g01962_ewg_sea_ice_atlas/faq.html).

On NIC Weekly Charts

The following summary was written by Lt. Kyle Dedrick in October 2003 (LTJG Brian Wagonseller, NIC Liaison, personal communication, 23 September 2004). Lt. Dedrick was active duty with NIC at the time he wrote the document.

(begin documentation by Lt. Dedrick)

National Ice Center 7-Day Sea Ice Charts

Introduction

The National Ice Center's (NIC) mission is to provide global sea ice analyses and forecasts to US military and civilian government customers. Manpower and fiscal resources for the NIC are provided through a cooperative agreement between the Department of the Navy (DoN), the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard (USCG). Customers of NIC, federal and otherwise, use analog and digital ice guidance products in mission planning, scientific research and in support of real-time vessel operations in polar regions. NIC was formerly known as the Navy/NOAA Joint Ice Center (JIC).

In 1996, NIC agreed to undertake a data re-analysis and conversion project which would make its historical or legacy data more useful for environmental research under the auspices of the Gore-Primakov Commission Environmental Working Group (EWG). In undertaking this legacy data digitization project, NIC intended to review and correct all its historical weekly ice analyses in order to provide the most accurate data possible for the production of an ice climatology in the Arctic.

Description of NIC Sea Ice Charts

Since 1972, NIC has produced routine weekly analyses of global sea ice conditions. Until 1996, NIC produced all of these charts using traditional hardcopy cartography techniques. NIC represents sea ice on its charts as unique polygonal areas ("polygons"), each containing somewhat homogeneous sea ice conditions. That NIC analysts determined that the sea ice entities falling within the boundaries of a polygon shared common attributes such as overall concentration or stage of development of individual ice entities. NIC has traditionally portrayed sea ice attributes associated with each unique polygon in the form of the WMO ice code label (egg code) which serves to encapsulate all of the pertinent sea ice information into a concise form for reference on a paper chart. These attributes would eventually form the basis for exporting this information into digital gridded fields or GIS data sets, in the form of tabular information relationally linked to the spatial polygon features in a vector data set or a group of grid cells in a raster data set.

The complexity of information contained in the unclassified sea ice charts varied from year to year depending on the availability of remotely sensed and in-situ oceanographic data. Ice analyses produced during the early years of this database often lacked detail and generalized actual ice extent and coverage. Early analysis shortfalls resulted from: 1) poor resolution of early hardcopy (analog) satellite imagery, 2) the absence of verifiable in-situ data and 3) the degradation of image quality due to the high frequency of obscuring meteorological (clouds) and oceanographic (suspended sediment) conditions. With the recent introduction of digital Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) fine (0.55 km resolution) imagery, NIC analysts acknowledged they often under-reported the extent of the sea ice in early years.

NIC originally produced its ice charts using all available satellite imagery, in-situ reports and meteorological/oceanographic guidance data. Appendix A summarizes the annual availability of these data. Note that these tables list data available for the analysis of ice in all Arctic regions. Analysts typically produced charts using any data up to 72 hours old. Data older than this were also analyzed but then adjusted with ancillary meteorological and oceanographic model guidance (specifically, air temperature, surface winds, ice drift and theoretical ice thickness). Therefore, the ice charts are composite charts rather than snapshots of the ice coverage on a certain day or time. Ice parameters of interest include: ice edge, ice concentration, stage of development (or thickness) and in some cases form of ice (e.g. landfast ice). Thus, depicted areas (polygons) or boundaries (lines) may be analyzed or estimated (from model output) based on changes in any of the above listed parameters.

It is important to realize that the relative accuracy and level of analysis detail varies considerably over the 23 year record of the SIGRID data set. Early Arctic ice charts (1972-1979) described ice conditions based on total concentration alone. The 1980-1991 Arctic analyses described total ice concentration as well as the predominant stages of development or ice type. Analysis done during these years was performed primarily on imagery in a hardcopy format. In 1992, improved sea ice prediction models and the increasing use of digital satellite data allowed analysts to break down the amount (or partial concentration) of each ice type within each defined area in the Arctic. The only forms of ice described throughout all analyses of the data set are landfast and belts/strips. It was standard analysis procedure (in all years) to use remotely sensed and/or in- situ data that was up to (but not exceeding) 72 hours old from the date of the analysis. Therefore, ice analyses were often derived from more than one data source and those sources may have been acquired at different times.

In most cases, areas of similar ice concentration are identified through the subjective interpretation of percent ice cover evident on visible and infrared imagery. An exception to this procedure would be the use of concentration products derived from microwave satellite sensors and direct observations by airborne or ship/shore based observers. Thus, concentration estimates are directly affected by the quality and resolution of the data. Stages of development are identified primarily by in-situ observations (including aerial reconnaissance and ship/shore reports) and theoretical ice thickness estimates based on freezing degree day accumulations. In some cases, new and young ice may be identified by the color or appearance on visible/infrared imagery. In general, the most recent ice analyses (in the data set) do the best job of characterizing the sea ice cover. Particular emphasis is given to defining the sea ice in the marginal ice zone. Areas of sea ice may be differentiated based on total concentration, ice type, form or a combination of these parameters.

The recent improvement in NIC analysis capabilities can be attributed to three factors: 1) a progressive increase in volume of incoming satellite data, 2) an improvement in the resolution of data used in each analysis and 3) the ability to process and enhance remotely sensed data in digital format. Prior to obtaining the capability to enhance digital satellite imagery on NIC workstations, hardcopy imagery was enhanced using look-up tables designed to meet the requirement for cloud detection as well as sea ice. The NIC began to process and display TIROS AVHRR and DMSP OLS Fine digital data in 1988 and 1993, respectively.

Data Sources

The global sea ice analysis effort at the NIC requires the fusion of many data sources having widely varying scales, capabilities and resolutions. Theses operational data sources have evolved over the years and can be grouped into the following categories: satellite data, ship and shore station reports, aerial ice reconnaissance observations, drifting buoy reports, data and analyses from other national and international ice centers, and climatology. During the 1950s and 1960s, sea ice information was gathered almost exclusively from visual observations from US Navy aerial reconnaissance missions and from observations reported by ships at sea or shore stations. At that time, ice analyses were typically done only in direct support of ships operating in the ice. In 1972, newly acquired visual and infrared imagery from NOAA weather satellites were combined with aerial reconnaissance data to give the NIC the capability to produce weekly Arctic sea ice analyses year ‘round. Today, approximately 85 percent of the data used for sea ice analysis are satellite-derived products. The two largest sources of satellite data are AVHRR aboard the TIROS series of satellites and OLS aboard the US Air Force DMSP satellite series. Both provide imagery in the visible and infrared portions of the spectrum. AVHRR data has a 1.1 km resolution and is received in both the HRPT and LAC transmission modes on a daily basis. DMSP OLS Fine has a 0.55 km resolution and is received daily at the NIC. ERS-1 SAR data also provided a small and infrequent contribution to the overall composited global analyses from 1992 – 1994.

Although the NOAA AVHRR and DMSP imagery are of a resolution suitable for NIC global and regional scale products, the sensors are not all-weather since clouds limit their capability for ice detection. These data are augmented with SSM/I concentration products in cloud covered regions. Although the resolution of these data are too coarse to allow for tactical-scale ship support, SSM/I is an all-weather sensor, which is useful in identifying the ice edge and major concentration areas. When SSM/I data is used in conjunction with AVHRR and OLS, the overall ice conditions can be effectively characterized.

Aerial ice reconnaissance data was also available from the Navy component of the NIC, the Canadian Ice Service and the Danish Meteorological Institute’s ice reconnaissance programs. This data contains detailed information on ice edge, concentration of ice, stage of development and ice topography and serves to provide excellent ground truth data.

Appendix A contains tables that summarize the annual availability of each satellite platform and sensor used to produce the global sea ice analyses. It is important to note that the percent utilization of each data type varies both temporally and spatially in the weekly analysis files which make up the complete 1972 – 1994 unclassified sea ice data set.

Data Revision and Conversion

In 1995, NIC began digitizing its entire unclassified hardcopy sea ice chart archive (1972-1994) through services provided by the National Climatic Data Center (NCDC) in Asheville, NC. NCDC digitized these charts as vector (point, line and polygon) data, then converted the resulting data to

25km cell-size ASCII gridded fields in the World Meteorological Organization's Sea Ice in Gridded Format (WMO SIGRID). Attributes, derived from the egg code used to describe each area, were entered via a keyboard. Translation of the resulting digital (x-y coordinate) file into a grid cell format was accomplished through the use of a master grid table. Once the sea ice attributes were linked to each grid cell, the program generated the SIGRID data group records. These gridded data sets include SIGRID ice codes on total ice concentration, partial ice concentrations associated with various ice types or stages of development, and in some cases, the form of ice. These data were further converted into ARC/INFO polar stereographic grids and tables of ice code values with SIGRID ice codes. Contiguous groups of grid cells which had all ice attributes in common in the final ARC/INFO format grids were assigned unique values based on the total number of ice polygons in the original sea ice chart. This unique value was then linked to the actual sea ice attribute information within ARC/INFO, creating gridded fields which were relationally linked to tabular attribute information. These latter ARC/INFO grids were provided to ERIM International for conversion into EASE formatted and SIGRID formatted data as described in the section on EASE ice chart methods.

Data Coverage

One of the significant shortfalls in the data set is the arbitrary exclusion of ice south of 45 N in the Arctic. In some years, sea ice may extend south of 45N in the waters south of Newfoundland, Sea of Okhotsk and the Sea of Japan. Weekly maps of sea ice in the Yellow Sea are currently being digitized at the NIC and are not included in the SIGRID database. Without re-digitizing the original hardcopy charts, data south of 45N can no longer be reconstructed due to the inadvertent disposal of the x-y coordinate files. Another potential weakness in the SIGRID data is that there is no metadata describing the source of information for each weekly analysis. Analyses may be based on DMSP OLS fine data, SSMI passive microwave or in some cases an estimate of ice drift.

In January 1997, National Ice Center became aware that many SIGRID files contained errors in ice code attribute information and in some cases, depiction of ice region boundaries. Types of errors which quality controllers corrected included: (1) incorrectly labeled sea ice polygons (regions) and (2) inconsistencies in the egg code attributes assigned to the sea ice areas along the seams (90W and 90E meridians) of the weekly global Arctic ice analyses. The latter inconsistency was found because both the Arctic East and Arctic West data files often did not contain the identical information along common boundaries. In some cases, the joining of the data files revealed minor differences in the described ice attributes.

During the original 1995 effort to correct the SIGRID data set, quality controllers discovered five weekly SIGRID files could not be recovered due to excessive landmask inconsistencies and other data problems. These corrupted fields are not included in the final SIGRID data set. The omitted gridded fields include (g197705qcf; g198505qcf; g198603qcf; g199113qcf, and g199140qcf).

Acknowledgements

The following NIC staff are acknowledged for their contributions to sea ice database: LCDR Don Taube, USN; Lt. Sean Memmen, USN; Lt. Kyle Dedrick, USN; Lt. Keith Rohwer, USN; Mr. Eric Tran; Ms. Ellen Haas; ET2 (SW) Mark Segall, USN; AG3 Jennifer Werner, USN; AG2 Donald Werner, USN; MST2 Richard Hernandez, USCG; AG1 Robert Dorsett, USN; AG1 Joseph Chastain, USN; AG1 Paul McKenna, USN; Mr. Paul Seymour; Mr. David Benner; Ms. Selina Nauman; Mr. Frank Kniskern; Mr. Don Barnett; Mr. John Breckenridge; Mr. Martin Doody; Mr. Ralph Perniciaro. A very special thank you to all of the current and former sea ice analyst, production team members and Information Technology personnel of the National/Naval Ice Center, Washington DC, since 1972.

(end documentation by Lt. Dedrick)

On data sources for NIC analyses, 1972-1994

The following summary was written by Lt. Kyle Dedrick in October 2003 (LTJG Brian Wagonseller, NIC Liaison, personal communication, 23 September 2004). Lt. Dedrick was active duty with NIC at the time he wrote the document. It summarizes the satellite platforms and sensor data that were used for chart production over the time period covered by the chart series on the EWG Atlas.

(Begin documentation by Lt. Dedrick)

Appendix A: Tables of Satellite Data Sources: 1972-1994

Table 1. 1972 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-72 12-72	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
10-72 12-72	NOAA 2	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global

Note: Nimbus-5 launched 11 Dec 72; NOAA 2 launched 15 Oct 72

Table 2. 1973 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-73 12-73	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-73 12-73	NOAA 2	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
11-73 12-73	NOAA 3	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4km	Global

Note: NIMBUS-5 launched 11 Dec 72; NOAA 2 launched 15 Oct 72; NOAA 3 launched 6 Nov 73

Table 3. 1974 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-74 12-74	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-74 12-74	NOAA 2	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
1-74 12-74	NOAA 3	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
11-74 12-74	NOAA 4	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global

Note: NIMBUS-5 launched 11 Dec 72; NOAA 2 launched 15 Oct 72; NOAA 3 launched 6 Nov 73; NOAA 4 launched 15 Nov 74

Table 4. 1975 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-75 12-75	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-75 1-75	NOAA 2	VHRR VIS IR	0.60 – 0.70um 10.5 – 12.5um	1 km 4 km	Global
1-75 12-75	NOAA 3	VHRR VIS IR	0.60 – 0.70um 10.5 – 12.5um	1 km 4 km	Global
1-75 12-75	NOAA 4	VHRR VIS IR	0.60 – 0.70um 10.5 – 12.5um	1 km 4 km	Global

Note: NIMBUS-5 launched 11 Dec 72; NOAA 2 launched 15 Oct 72; NOAA 3 launched 6 Nov 73; NOAA 4 launched 15 Nov 74

Table 5. 1976 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-76 12-76	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-76 8-76	NOAA 3	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
1-76 12-76	NOAA 4	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
7-76 12-76	NOAA 5	VHRR VIS IR	0.6 – 0.7 um 10.5 – 11.5 um	1 km 4 km	Regional

Note: NIMBUS-5 launched 11 Dec 72; NOAA 3 launched 6 Nov 73; NOAA 4 launched 15 Nov 74; NOAA 5 launched 29 Jul 76

Table 6. 1977 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-77 12-77	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-77 12-77	NOAA 4	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
1-77 12-77	NOAA 5	VHRR VIS IR	0.60 – 0.70 um 10.5 – 11.5 um	1 km 4 km	Global

Note: NIMBUS-5 launched 11 Dec 72; NOAA 4 launched 15 Nov 74; NOAA 5 launched 29 Jul 76

Table 7. 1978 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-78 12-78	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-78 11-78	NOAA 4	VHRR VIS IR	0.60 – 0.70 um 10.5 – 12.5 um	1 km 4 km	Global
1-78 12-78	NOAA 5	VHRR VIS IR	0.60 – 0.70 um 10.5 – 11.5 um	1 km 4 km	Global
10-78 12-78	NOAA-7	AVHRR HRPT/LAC VIS IR	0.55 – 0.90 um 10.5 – 11.5 um	1 km	Regional
		GAC VIS IR	0.55 – 0.90 um 10.5 – 11.5 um	4 km	Global

Note: Nimbus-5 launched 11 Dec 72; NOAA 4 launched 15 Nov 74; NOAA 5 launched 29 Jul 76; TIROS-N launched 13 Oct 78

Table 8. 1979 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-79 7-79	NOAA-5	VHRR VIS IR	0.6 – 0.7 um 10.5 – 12.5 um	1 km	Global
6-79 12-79	NOAA-6	AVHRR HRPT/LAC VIS NIR IR	0.55 – 0.58 um 3.55 – 3.93 um 10.5 – 11.5 um	1 km	Regional
1-79 12-79	NOAA-7	AVHRR, HRPT/LAC VIS IR GAC VIS IR	0.55 – 0.90 um 10.5 – 11.5 um 0.55 – 0.90 um 10.5 – 11.5 um	1 km 4 km	Regional Global
1-79 12-79	DMSP F-4	HR, MI	0.4 – 1.1 um 8.0 – 13.0 um	3.7 km 4.4 km	Global
1-79 12-79	NIMBUS-5	EMSR	19.35 GHz	25 km	Global
1-79 12-79	GEOS-3	ALT	13.9 GHz	7 km	Regional

Note: NIMBUS-5 launched 11 Dec 72; NOAA 5 launched 29 Jul 76; NOAA 6 launched 27 Jun 79; DMSP F4 launched 6 Jun 79; GEOS-3 launched 10 Apr 74

Table 9. 1980 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-80 12-80 2-80 12-80	NOAA-6	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	 0.55 – 0.68um 3.55 – 3.93µ 10.5 – 11.5µ 0.55 – 0.68µ 10.5 – 11.5um	 1 km 4 km	 Regional Global
1-80 11-80	TIROS N	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	 0.55 – 0.90um 3.55 – 3.93µ 10.5 – 11.5µ 0.55 – 0.90µ 10.5 – 11.5µ	 1 km 4 km	 Regional Global
1-80 8-80	DMSP F-4	HR MI	0.4 – 1.1 um 8.0 – 13.0 um	3.7 km 4.4 km	Global
1-80 12-80	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
4-80 12-80	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global

Note: NOAA 6 launched 27 Jun 79; TIROS-N launched 13 Oct 78; DMSP F-4 launched 5 Jul 80; NIMBUS-5 launched 11 Dec 72; NIMBUS-7 launched 24 Apr 80

Table 10. 1981 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-81 12-81	NOAA-6	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 um 0.73 – 1.10 um 3.55 – 3.93 um 10.5 – 11.5 um 0.55 – 0.68 um 10.5 – 11.5 um	1 km 4 km	Regional Global
7-81 12-81	NOAA-7	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.58 – 0.68 um 0.73 – 1.10 um 3.55 – 3.93 um 10.3 – 11.3 um 0.58 – 0.68 um 10.3 – 11.3 um	1 km 4 km	Regional Global
1-81 12-81	NIMBUS-5	ESMR	19.35 GHz	25 km	Global
1-81 12-81	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global

Note: NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NIMBUS-5 launched 11 Dec 72; NIMBUS-7 launched 24 Apr 80

Table 11. 1982 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-82 12-82	NOAA-6	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 um 0.73 – 1.10 um 3.55 – 3.93 um 10.5 – 11.5 um 0.55 – 0.68 um 10.5 – 11.5 um	1 km 4 km	Regional Global
1-82 12-82	NOAA-7	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 um 0.73 – 1.10 um 3.55 – 3.93 μ 10.3 – 11.3 μ 0.55 – 0.68 μ 10.3 – 11.3 μ	1 km 4 km	Regional Global
1-82 12-82	NIMBUS-5 *	ESMR	1.55 cm	25 km	Global Regional
1-82 12-82	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global

* NIMBUS-5 recorders failed on 23 November 1982, limiting data to the Alaska region
Note: NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NIMBUS-5 launched 11 Dec 72; NIMBUS-7 launched 24 Apr 80

Table 12. 1983 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
1-83 3-83	NOAA-6	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 μ 0.73 – 1.10 μ 3.55 – 3.93 μ 10.5 – 11.5 μ 0.55 – 0.68 μ 10.5 – 11.5 μ	1 km 4 km	Regional Global
1-83 12-83	NOAA-7	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 um 0.73 – 1.10 μ 3.55 – 3.93 μ 10.5 – 11.3 μ 0.58 – 0.68 μ 10.5 – 11.3 μ	1 km 4 km	Regional Global
3-83 12-83	NOAA-8	AVHRR HRPT/LAC VIS NIR IR IR GAC VIS IR	0.55 – 0.68 um 0.725–1.10 μ 3.55 – 3.93 μ 10.5 – 11.5 μ 0.58– 0.68 μ 10.3– 11.3 μ	1 km	Regional
1-83 12-83	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global

Note: NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NOAA 8 launched 28 Mar 83; NIMBUS-7 launched 24 Apr 80

Table 13. 1984 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-84 12-84	DMSP F-6, F-7	OLS FINE VIS IR	0.4 to 1.1 mm 10.2 to 12.8 mm	3.7 km 4.4 km	Regional Regional
01-84 12-84	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global
01-84 12-84	NOAA 6,7,8,9	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 11.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global

Note: DMSP F-6 launched 20 Dec 82; DMSP F-7 launched 18 Nov 83; NIMBUS-7 launched 24 Apr 80; NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NOAA 8 launched 28 Mar 83; NOAA 9 launched 12 Dec 84

Table 14. 1985 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-85 12-85	DMSP F-6, F-7	OLS FINE VIS IR	0.4 to 1.1 mm 10.2 to 12.8 mm	3.7 km 4.4 km	Global Global
01-85 12-85	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global
01-85 12-85	NOAA 6,7,8,9	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 11.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1 km 4 km	Regional Global

Note: DMSP F-6 launched 20 Dec 82; DMSP F-7 launched 18 Nov 83; NIMBUS-7 launched 24 Apr 80; NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NOAA 8 launched 28 Mar 83; NOAA 9 launched 12 Dec 84

Table 15. 1986 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-86 12-86	DMSP F-6, F-7	OLS FINE VIS IR	0.4 to 1.1 mm 10.2 to 12.8 mm	3.7 km 4.4 km	Regional Regional
01-86 12-86	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global
01-86 2-86 01-86 06-86 01-86 01-86	NOAA 6,9,10 NOAA 7 NOAA 8	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.73 to 1.10 mm 10.5 to 11.5mm 0.58 to 0.68 mm 10.5 to 11.5 mm	1.1km at nadir; 2.5km at edge 4km	Regional Global

Note: DMSP F-6 launched 20 Dec 82; DMSP F-7 launched 18 Nov 83; NIMBUS-7 launched 24 Apr 80; NOAA 6 launched 27 Jun 79; NOAA 7 launched 23 Jun 81; NOAA 8 launched 28 Mar 83; NOAA 9 launched 12 Dec 84; NOAA 10 launched 17 Sep 86; GEOSAT launched 13 Mar 85

Table 16. 1987 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-87 12-87	DMSP F-6, F-7, F-8	OLS FINE VIS IR	0.4 to 1.1 mm 10.2 to 12.8 mm	3.7 km 4.4 km	Regional Regional
01-87 12-87	NIMBUS-7	SMMR	0.81 cm 1.66 cm	50 km	Global
01-87 12-87	NOAA 9,10	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 11.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global
01-87 12-87	GEOSAT	Radar Altimeter	N/A	7 km	Regional

Note: DMSP F-6 launched 20 Dec 82; DMSP F-7 launched 18 Nov 83; DMSP F-8 launched 19 Jun 87; NIMBUS-7 launched 24 Apr 80; NOAA 9 launched 12 Dec 84; NOAA 10 launched 17 Dec 86; GEOSAT launched 13 Mar 85

Table 17. 1988 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-88 12-88	DMSP F-8, F-9	OLS FINE VIS IR	0.4 to 1.1 mm 10.2 to 12.8 mm	3.7 km 4.4 km	Regional Regional
01-88 12-88	NOAA 9,10,11	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 11.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global
01-88 12-88	GEOSAT	Radar Altimeter	N/A	7 km	Regional

Note: DMSP F-8 launched 19 Jun 87; DMSP F-9 launched 3 Feb 88; NOAA 9 launched 12 Dec 84; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88

Table 18. 1989 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-89 12-89	DMSP F-8, F-9	OLS FINE VIS IR SSM/I MW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35GHz and 37GHz	3.7 km 4.4 km 25 km	Regional Regional Global
01-89 12-89	NOAA 10,11	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global
01-89 12-89	GEOSAT	Radar Altimeter	N/A	7 km	Regional

Note: DMSP F-8 launched 19 Jun 87; DMSP F-9 launched 3 Feb 88; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88; GEOSAT launched 13 Mar 85

Table 19. 1990 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-90 12-90	DMSP F-8	OLS FINE VIS IR SSM/I MW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35GHz and 37GHz	0.62 km 0.62 km 25 km	Regional Regional Global
01-90 12-90	NOAA 10,11	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global

Note: DMSP F-8 launched 19 Jun 87; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88

Table 20. 1991 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-91 12-91	DMSP F-10, 11	OLS FINE VIS IR SSM/I MW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35GHz and 37GHz	0.62 km 0.62 km 25 km	Regional Regional Global
01-91 12-91	NOAA 10,11,12	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm 0.58 to 0.68 mm 10.5 to 11.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global

Note: DMSP F-10 launched 1 Dec 90; DMSP F-11 launched 20 Nov 91; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88; NOAA 12 launched 14 May 91

Table 21. 1992 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-92 12-92	DMSP F-10, 11	OLS FINE VIS IR SSM/I PMW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35GHz and 37GHz	0.55 km 50 km 25 km	Regional Global Global
01-92 12-92	NOAA 10,11,12	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm 0.58 to 0.68 mm 10.5 to 12.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global
01-92 12-92	ERS-1	SAR AMW	C- Band (5.3 Ghz)	240m (FR)	Local

Note: DMSP F-10 launched 1 Dec 90; DMSP F-11 launched 20 Nov 91; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88; NOAA 12 launched 14 May 91; ERS-1 launched 30 May 91

Table 22. 1993 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-93 12-93	DMSP F-10, 11	OLS FINE VIS IR SSM/I PMW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35GHz and 37GHz	0.55 km 50 km 25 km	Regional Global Global
01-93 12-93	NOAA 10,11,12	AVHRR HRPT/LAC VIS NIR IR GAC VIS IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm 0.58 to 0.68 mm 10.5 to 12.5mm	1.1km at nadir; 2.5km at edge 4km	Regional Global
01-93 12-93	ERS-1	SAR AMW	C- Band (5.3 Ghz)	100-240m	Local

Note: DMSP F-10 launched 1 Dec 90; DMSP F-11 launched 20 Nov 91; NOAA 10 launched 17 Sep 86; NOAA 11 launched 24 Sep 88; NOAA 12 launched 14 May 91; ERS-1 launched 30 May 91

Table 23. 1994 Arctic Satellite Data Sources

From To	Sensor Platform	Sensor Type	Spectral Region	Resolution	Coverage
01-94 12-94	DMSP F-10, 11, 12	OLS FINE VIS IR SSM/I PMW	0.4 to 1.1 mm 10.2 to 12.8 mm 19.35 and 37GHz	0.55 km 25 km	Regional Global
01-94 12-94	NOAA 11,12	AVHRR HRPT/LAC VIS NIR IR	0.58 to 0.68 mm 0.725 to 1.10 mm 10.5 to 12.5mm	1.1km at nadir; 2.5km at swath edge	Regional
01-94 12-94	ERS-1	AMI SAR RA	C- Band (5.3 Ghz) (13.8 Ghz)	100-240m 7.0km	Local Regional

Note: DMSP F-10 launched 1 Dec 90; DMSP F-11 launched 20 Nov 91; DMSP F-12 launched 29 Aug 94; NOAA 11 launched 24 Sep 88; NOAA 12 launched 14 May 91; ERS-1 launched 30 May 91

Abbreviations and Acronyms Used on Satellite Tables

AMI – Active Microwave Sensor
AMW – Active Microwave
AVHRR – Advanced Very High Resolution Radiometer
cm - centimeter
ERS– Earth Remote Sensing Satellite
ESMR – Electrically Scanning Multifrequency
FR – Full Resolution
GAC – Global Area Coverage
GHz – Giga-hertz
HRPT – High Resolution Picture Transmission
IR - Infrared
km - kilometer
LAC – Land Area Coverage
LR – Low Resolution
MW - Microwave
NIR – Near Infrared
OLS – Operational Linescan System
PMW – Passive Microwave
RA – Radar Altimeter
SAR – Synthetic Aperture Radar
SMMR – Scanning Multifrequency Microwave Radiometer
SSM/I – Special Sensor Microwave Imager
um - micrometer
VHRR – Very High Resolution Radiometer
VIS – Visual

(end documentation by Lt. Dedrick)

On the EWG Sea Ice Atlas climatology

This is a description of the climatology on the Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas (Arctic Climatology Project, 2000), explaining how source data for the climatology differs from source data for the 7-Day Sea Ice Charts, by Lt. Kyle Dedrick, 14 October 2003. The 7-Day Sea Ice Charts and climatology are products contained in the same EWG Atlas.

(begin documentation by Lt. Dedrick)

National Ice Center Sea Ice Climatology

Introduction

The Environmental Working Group (EWG)-Arctic Climatology Project, tasked with producing an Arctic sea ice atlas, identified nineteen years (1972-1990) of these highly detailed classified ice analyses as a scientifically significant database. NIC originally produced these data as hard copy charts. It was proposed in 1996 that these sea ice charts be re-analyzed, quality controlled and then converted into digital data by manual digitizing in a Geographic Information System (GIS). The analyses did not necessarily cover the entire Arctic for any given week, but it was obvious that the added detail resulting from larger scale mapping procedures in the classified charts would prove beneficial to the final climatological database.

Original NIC classified sea ice charts were rarely completed by analysts as coherent, smoothed sea ice analyses like those traditionally produced in the unclassified realm. More typically, sea ice analysts simply compiled "pieces" of sea ice information from a wide variety of national security sources and plotted these data as point observations, tabular information or annotational information. Because of this, NIC was required to undertake an enormous effort of "re-analyzing" these charts to produce the most realistic and complete "picture" of sea ice conditions for a given "work chart".

Data Analysis

The objective of the analysis effort was to review, analyze, quality control and record metadata for 608 classified ice charts. The effort encompassed nineteen years of ice analysis charts that covered the Arctic marginal seas, the North Pacific, Sea of Okhotsk and Sea of Japan. Ice analysts worked primarily with two types of basic ice analysis charts: weekly work charts and publication charts from previously printed annual ice atlases based upon the NIC 7-day ice chart series. The most representative charts for mid-month ice conditions were selected. The following items were reviewed as part of the process.

- The validity of data sources
- The location of ice concentration boundaries
- The completeness and closure of all analysis lines forming unique "polygons" of sea ice information
- The accuracy of polygon labels describing ice parameters (including ice concentration, stage of development, and form of ice).
- The accuracy of ice conditions in overlap area of any two weekly Arctic charts
- Continuity of ice conditions between sequential ice analysis charts

NIC required that final corrected charts be in a condition which was suitable for manual digitizing, with the overall goal of developing an Arctic sea ice database derived from classified data.

NRL established several standard basemaps to accommodate the large variety of classified charts (various projections and scales) early in the project. NRL produced these basemaps using NIMA's World Vector Shoreline (WVS). The digitizing team registered the re-analyzed charts in ARC/INFO's Arcedit module. Once digitized, the digitizing team built topology for and cleaned the polygon coverages. NRL then re-projected the ice charts to polar stereographic tangent at 60N, 180W, which allowed the technician to "mapjoin" all charts representing a given week, creating a "composite" view of the Arctic for a representative week for each month for the years 1972 – 1990. The team then used a custom-built "ice tagging" tool to add polygon attributes to the polygons. These attributes described the ice conditions for that polygon based on the analyst's original annotations on the working chart.

NIC then used a GIS data extraction routine, written in Arc Macro Language (.aml). This routine specifically extracted the "total concentration" (CT) value from the polygons. With this done, NIC then converted the GIS coverages to binary gridded fields (ARC/INFO format), using the GRID module in ARC/INFO. They created grids based on the CT value alone. The output grid cell size was 12.5 km (the units of the coverages were meters in a polar stereographic projection). An identical "CT extraction" routine allowed NIC to create total concentration grids from the unclassified SIGRID data as well, then facilitating the merging of data sets derived from both classified and unclassified sources, and ensuring complete Arctic coverage for a given representative monthly gridded sea ice chart. This technique facilitated the computation of grids depicting climatological attributes based on the values from each grid from a month, from all the available years.

Climatological Grids Derived From Merged Charts

In April, 1999, the National Ice Center (NIC) completed production of the climatological data sets extracted from previously classified sea ice data in support of the Gore-Primakov Commission's Environmental Working Group. NIC determined that the most useful climatological product derived from the EWG data set would be monthly Arctic grids. NIC created a complete monthly data set by merging the monthly grids based upon the weekly ice charts with derived grids from classified sources. Legacy classified and unclassified Arctic sea ice analyses were re-analyzed, revised and quality controlled, where necessary, in an effort to provide the most accurate depiction of the annual cycle of sea ice formation and decay. These are monthly climatological gridded fields depicting (1) median total ice concentration and (2) the occurrence of sea ice.

NIC employed GRID again to compute the climatology from all available gridded fields. The first statistic computed was "probability of occurrence of any ice", which is an enumeration of the number of years for a given week that ice of any concentration occurred in a given pixel (total number of years being 19). The possible grid values for this output grid are the integers from 0 through 19. The next statistic, median total ice concentration, was obtained by computing the median CT value for a given pixel for all available grids for a given month (i.e. half the data in the 19-value sample fall on or above this median value, half fall on or below this value). (See Appendix B for file naming convention). NIC is working with the National Security Agency to seek the release of monthly gridded fields of total ice concentration created from the merged data set.

Quality Assurance of Climatology Grids

NIC revised the resulting climatology by deleting or joining any small sea ice anomalies to the ice edge or within the ice field itself and merged them with surrounding attributes. NIC smoothed continuous regions of sea ice concentration and probabilities to more accurately depict ice edge, marginal ice zone, and the concentrated ice pack. Obvious errors were compared to original charts and subjectively edited as deemed fit. In particular, NIC revised fast ice extent using knowledge of local ice regions that were not known in early ice analysis years.

(end documentation by Lt. Dedrick)

Documentation from *Arctic and Antarctic Sea Ice Data, 1972-1994*

In 1996, NIC, the Navy Fleet Numerical Meteorology and Oceanography Detachment, and the NOAA National Climatic Data Center (NCDC) jointly released a CD-ROM titled *1972-1994 Arctic and Antarctic Sea Ice Data*. This product was distributed by NCDC and by NSIDC. In 1997, NSIDC became aware of errors in the SIGRID coding for partial concentrations on this product, and sent a message to registered users of the product. NSIDC also removed the entry for this product from our on-line catalog. The documentation contains information on how NIC chart data was encoded in SIGRID. It also contains the text of an article describing the first work done to create a digital record of NIC charts. This began in 1981.

The documentation includes references to an earlier data set of SIGRID format ice charts that the files on the CD-ROM replace. The provenance of this earlier data set is not known. It was not distributed by NSIDC. The author of the documentation on the CD-ROM is not known, although (see “Acknowledgements”) it appears that it was prepared at NSIDC.

There are three documents on the CD-ROM. The contents of the “README.ADT” file and the “KNIGHT.ADT” file are included here. The third file, “SIGRID2.ADT”, is not included here. The first few lines of the SIGRID2.ADT follow:

```
TITLE:   FORMAT FOR THE ARCHIVAL AND EXCHANGE OF SEA-ICE DATA IN
         DIGITAL FORM (SIGRID).

SOURCE:  ANNEX TO RECOMMENDATION 11 - THE ABRIDGED FINAL REPORT
         OF THE TENTH SESSION OF THE WMO COMMISSION FOR MARINE
         METEOROLOGY (FEBRUARY, 1989).
```

The contents of SIGRID2.ADT can be obtained from the World Meteorological Organization, or see NSIDC’s Global Digital Sea Ice Data Bank (GDSIDB) pages [nsidc.org/noaa/gdsidb/].

(Begin 1972-1994 Arctic and Antarctic Sea Ice Data *documentation)*

`[README.ADT]`

Title: 1972-1994 Arctic And Antarctic Sea Ice Data National Ice Center

Table of Contents

1. Introduction

The mission of the National Ice Center (NIC) is to provide global sea ice analyses and forecasts to U.S. military and civilian government customers. Manpower and fiscal resources for the NIC are provided through a cooperative agreement between the Department of the Navy, the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard (USCG). NIC analog and digital ice guidance products are used in mission planning, scientific research and in support of real-time vessel operations in the polar regions. The NIC was formerly known as the Navy/NOAA Joint Ice Center (JIC). This CD-ROM contains digital sea ice data from 1972-94 NIC Arctic and Antarctic analysis charts. NIC 1995 sea ice data are currently unavailable (in digital format) at the time of this publication. CD-ROM directories contain weekly sea ice data files separated by area of interest: Arctic East, Arctic West and Antarctica. Charts were manually digitized and translated into the international format for archival and exchange of sea ice data (SIGRID) by the National Climatic Data Center (NCDC) in Asheville, NC. These digitized data, in a compacted raster format, contain information on total ice concentration, partial concentrations of ice type or stage of development and in some cases the form of ice. Location of the ice edge, ice extent, ice coverage and distribution of level ice thickness categories can be derived from these data. The level of analysis detail varies from year to year based on availability of remotely sensed and "in-situ" oceanographic data. During 1995, SIGRID files on this CD-ROM underwent an extensive quality control and correction process. Section 4 of this document describes this process and details the types of errors leading to the reprocessing of the data set. Files on this CD-ROM should be used to replace all previous versions of JIC/NIC SIGRID data.

2. Description Of NIC Sea Ice Charts

Since 1972, the National Ice Center (beginning with the U.S. Navy and the Navy/NOAA Joint Ice Center) has produced routine weekly analyses of global sea ice conditions. Sea ice information, like other spatial geographic data, have historically been made available to users in the familiar two dimensional form of paper maps. These maps consist of sea ice information presented as a group of points, lines and areas (polygons) which are positioned with reference to the latitude/longitude coordinate system. Non-spatial attributes, such as ice concentration and thickness, are linked to the location of these map elements via a map legend and an internationally recognized system of sea ice symbols known colloquially as the "egg code". This symbology forms the basis for the coding system used when translating digitized sea ice information into the SIGRID format. Sea ice variables used on NIC charts include: total ice concentration, partial concentrations of the various stages of development and the form of ice.

2.1 Analysis Areas

Routine weekly NIC sea ice analyses are separated into three areas of interest within which can be found permanent or seasonal occurrences of sea ice.

a) Arctic East (90W eastward to 90E; 45N to 90N)—
   Seas within this area include the waters in and around the eastern portion of the Canadian archipelago (Northwest Territories); Hudson Bay; Baffin Bay; Davis Strait; Labrador Sea; Gulf of St. Lawrence; East Greenland Sea; Baltic Sea; Barents Sea; White Sea, Kara Sea and Arctic Ocean.
b) Arctic West (90E eastward to 90W; 45N to 90N)—
   Seas within this area include the Arctic Ocean, Laptev Sea, East Siberian Sea, Chukchi Sea, Beaufort Sea, the western portion of the Canadian archipelago, Bering Sea, Sea of Okhotsk and Sea of Japan.

c) Antarctic (all seas surrounding the continent south of 50S).

2.2 Data Sources

Historically, all NIC sea ice analyses have been produced through the integration of remotely sensed and in-situ oceanographic and meteorological data. During the 1950's and 60's, sea ice information was gathered almost exclusively from visual observations from U.S. Navy aerial reconnaissance missions and from observations reported by ships at sea or shore stations. At that time, ice analyses were typically done only in direct support of ships operating in the ice. In 1972, newly acquired visual and infrared imagery from NOAA weather satellites provided the NIC with the capability to routinely produce Arctic sea ice analyses even during the extended periods of polar darkness. In January 1973, routine Antarctic ice analyses began as NIMBUS-5 ESMR microwave imagery provided the NIC with an all-weather global capability to detect and map sea ice. From 1972 onward, the NIC augmented aerial reconnaissance data with satellite-derived sea ice information. Today, sea ice analysis is done almost exclusively with remotely sensed data. The satellites and sensors used to produce global sea ice analyses included:

- TIROS visible/infrared GAC/LAC/HRPT (VHRR and AVHRR) data;
- NIMBUS passive microwave (ESMR and SMMR) data;
- DMSP visible/infrared (OLS) smooth and fine data;
- GEOSAT altimetry data;
- DMSP passive microwave (SSMI) data;
- ERS-1 Synthetic Aperture Radar (SAR) data.

It is important to note that the percent utilization of each data type varies both temporally and spatially in the weekly analysis files which make up the SIGRID data set. For example, Knight (1984) documented that summer ice analyses (during the period 1972-1983) were based on 60% visible/infrared data, 30% microwave data and 10% conventional (aerial recon or in-situ) observations. Winter ice analyses during this same time period, were based on 33%, 65% and 2%, respectively. These data utilization estimates may not adequately represent the ice analyses done in later years or the difference in data availability between the Arctic and Antarctic seas. In 1994, for example, Arctic winter analyses are estimated to be derived from 75% visual/infrared, 24% microwave and 1% conventional observations. During the period of increased summer cloudiness, the 1994 Arctic breakdown is estimated as 60%, 35% and 5%, respectively. In comparison, 1994 Antarctic analyses done during the austral summer shipping season are estimated to be based on a ratio of 55%, 44% and 1%, respectively. 1994 Antarctic winter ice analyses demonstrated the heaviest dependence on an all-weather data source with a estimated break-down of 35%, 64% and 1%. Although available from 1992-94, ERS-1 SAR data provided infrequent and small contributions (100km x 100km) to the overall "blended" global analyses.

2.3 Analysis Detail and Sea Ice Parameters

As users, it is important to realize that the relative accuracy and level of analysis detail varies considerably over the 23 year record of the SIGRID data set. Early Arctic ice charts (1972-1979) described ice conditions based on total concentration alone. Analyses done during those years relied heavily on TIROS visible/infrared GAC (4 km) and single channel (19 GHz) passive microwave ESMR (25 km) data. From 1980-1991, Arctic analyses described total ice concentration as well as the predominant stages of development or ice type. Analyses done during these years used large amounts of TIROS visible/infrared LAC(1.1 km), DMSP OLS visible/infrared smooth (4 km), DMSP OLS fine (0.6 km) and multichannel passive microwave (SMMR 50 km/SSMI 25 km) data. Many of these data remained in the difficult to use hardcopy format. In 1992, improved sea ice prediction models and the increasing use of digital satellite data allowed analysts to break down the amount (or partial concentration) of each ice type within each defined area in the Arctic. In 1994, Antarctic analyses also began to describe partial ice concentrations of various ice types.

The only "form" of ice described throughout all analyses of the data set are landfast and belts/strips. It was standard analysis procedure (in all years) to use remotely sensed and/or "in-situ" data that was up to (but not exceeding) 72 hours old from the date of the analysis. Therefore, ice analyses were often derived from more than one data source and those sources may have been acquired at different times. In most cases, areas of similar ice concentration are identified through the subjective (human) interpretation of percent ice cover evident on visible and infrared imagery. An exception to this procedure would be the use of concentration products derived from microwave Environmental Data Records and direct observations by aerial recon or ship/shore observations. Thus, concentration estimates are directly affected by the quality and resolution of the data. Stages of development are identified primarily by "in-situ" observations (including aerial reconnaissance and ship/shore reports) and theoretical ice thickness estimates based on freezing degree day accumulations. In some cases, new and young ice may be identified by the "color" or appearance on visible/infrared imagery.

In general, the most recent ice analyses (in the data set) do the best job of characterizing the sea ice cover. Particular emphasis is given to defining the sea ice in the marginal ice zone. Areas of sea ice may be differentiated based on total concentration, ice type, form or a combination of these parameters. The recent improvement in NIC analysis capabilities can be attributed to three factors: 1) a progressive increase in volume of incoming satellite data, 2) an improvement in the resolution of data used in each analysis and 3) the ability to process and enhance remotely sensed data in digital format. Prior to obtaining the capability to enhance digital satellite imagery on NIC workstations, hardcopy imagery was enhanced using one look-up table designed to meet the enhancement requirements for clouds as well as sea ice. The NIC began to process and display TIROS AVHRR and DMSP OLS fine digital data in 1988 and 1993, respectively.

3. Description Of Data File Format

For many applications, analog formats (like NIC paper ice charts) restrict the user's ability to extract, transfer or integrate ice information with other spatial data. To address these concerns, the World Meteorological Organization Commission for Marine Meteorology (WMO-CMM), in 1982, established an international archival and transfer standard for digital sea ice data known as SIGRID.

3.1 Overview of SIGRID

Sea Ice in the Digital Form (SIGRID) was originally designed to meet the sea ice requirements of large-scale climate and statistical studies. SIGRID is a very flexible format which allows for the inclusion of up to 53 sea ice parameters. NIC sea ice charts typically describe only 14 variables. Very simply, SIGRID is a compacted raster format that allows the user to assign numerical values to the sea ice attributes and then read these values at given points in an overall grid cell array. Starting from a defined origin (i.e. 45N/90W), the data are ordered in strips of latitude (rows) running equatorward to poleward. Within each strip, the data are ordered by longitude from east to west. The resolution of each grid cell is no worse than 15 nautical miles. The format provides for compaction by the use of a repeater constant which allows one data group to describe from 1 to 99 adjacent grid points. The WMO-CMM documentation describing SIGRID is contained as a reference paper on this CD-ROM. Listed below in sections 3.4 and 3.5 are the two required header records which contain all the information needed to identify the analysis (or paper ice chart) from which the data were taken. Examples of the data record format are listed in section 3.6.

3.2 Coordinate Grid System

The National Ice Center produces three ice charts on a weekly basis which cover the North and South Polar regions. The charts are called Arctic East (E), Arctic West (W), and Antarctica (A). The E chart extends from 90 degrees W to 90 degrees E longitude, the W from 90 degrees E to 90 degrees W, and the A is a full circle of the southern hemisphere. Two constraints were imposed upon the chosen coordinate grid system:

a. The grid point resolution must always be Û [divisible by] 15 nm.
b. The quotient produced by dividing 180 degrees by the longitudinal grid point spacing must be an integer. These constraints have led to the choice of the following longitudinal grid point spacing:

Latitudinal Range	Grid Point Spacing in Degrees
45.00 - 59.75	.25
60.00 - 75.75	.50
76.00 - 82.75	1.00
83.00 - 85.75	2.00
86.00 - 86.75	3.00
87.00 - 87.75	4.00
88.00 - 88.75	5.00
89.00 - 89.75	10.00
89.50 - 89.50	20.00
89.75 - 90.00	30.00

The latitude grid point spacing is .25 degrees everywhere. Note that the E and W charts extend from 45 degrees N to the pole whereas the A chart extends from 50 degrees S to 85 degrees S. The National Ice Center data files list the gridded ice data along a parallel from west to east and from lower latitudes to higher latitudes. West-to-east means direction and thus is not a reference to a hemisphere. Using the convention of a minus sign to refer to locations in the Western Hemisphere, the grid points will be listed in the following longitudinal sequences:

```
               GRID LINE at 50 degrees N or S
Map Type   Beginning        Center           Ending
           Longitude        Longitude        Longitude

E (0)         -90               0               90
W (2)          90            -180              -90
A (6)        -180               0           179.50
```

3.3 File Naming Convention

Weekly SIGRID files are arranged in yearly subdirectories under three directories on the CD-ROM:

- `ant - Antarctic` (total of 1148 files)
- `are - Arctic East` (total of 1199 files)
- `arw - Arctic West` (total of 1196 files)

Files names are based on the year and week in which the analysis was done. The exact day in which the analysis was done is described in the second line of the file header record. Please note that there may be a greater or lesser number than the expected 52 weekly files per year.

3.4 File Header Record

Weekly sea ice analyses done between 1972-91 have header records in the following format:

```
SIGRIDINF:USJC:099:A2450009000:B1810721:C0015:D05CTCACBCCCF
SIGRIDNN:E99101290000:F000
```

Individual components of the header can be interpreted as follows:

`SIGRIDINF`	Identifier of SIGRID header file.
`:`	start of new information group.
`USJC`	U.S. Joint Ice Center (former name of the Joint Ice Center).
`099`	Geographic grid with definitions of grid coding (099) vs. contour coding (098).
`A2`	Area of interest (i.e. East=0, West =2, Antarctic=6).
`4500 09000`	Coordinates of origin; scanned toward increasing latitude (south to north and west to east in northern hemisphere).
`B181 0721`	Max number of grid cells along meridian (181) and max number of grid cells along parallel (0721).
`C0015`	Grid cell mesh size (i.e. 15 nm).
`D05CTCACBCCCF`	Total number (D05) of sea ice variables and list of variables. 1992-94 Arctic ice analyses and 1994 Antarctic analyses include seven variables (`D07`) by including CN and CD groups (i.e. :`D07CTCACBCCCFCNCD`).
`SIGRIDNN`	Chart data file.
`E99101290000`	Year, month, day, UTC time of chart in whole hours, and time period of observations upon which chart is based (i.e. 1991, Jan 29, 00Z time and `00` is default or no entry). Although last category is not used, user should assume data is never more than 72 hours old).
`F000`	Serial no. of chart (not used).

3.5 Grid Line Record

Weekly sea ice analyses done between 1972-94 have grid line records in the following format:

`=K001:L008001:M0721:X02`

=K001	Ratio of longitude/latitude mesh width (ranges from 001 to 120). Note: N/S resolution never changes while E/W resolution changes with longitude (the worst case for E/W resolution is 15 nm). For example...K001 means that E/W resolution is .25 degrees; K002 mean that E/W resolution is .50 degrees while K120 (30 degrees of longitude/.25 degrees of latitude = 120) near the pole.
L008 001	coordinates of first grid cell on grid lines expressed as the number of grid cells along meridian and along parallel counted from the origin (i.e. 008 lines up from origin (ranges 001 to 181); 001 never changes.
M0721	number of grid cells along line or row
X02	Every header line is followed by (X02) number of data lines.

3.6 Data Group Record

Weekly sea ice analyses done between 1972-91 often contain values only for total ice concentration and ice type or stage of development. An example of a grid line record in this format is as follows:

`:R15LL:R14CT00:R09CT92CA998608:R04CT13CA998399CB998199`

R15LL	R is repeater constant with 15 grid cells) on a line coded as land. NOTE: Originally, cells that are off the chart were coded as bogus (i.e. :R15LU). This is no longer done in the files on this CD-ROM. All cells located off the chart (but part of the overall grid cell array) are coded as land even if the cells are not really land!
R15LL	15 grid cells on line are land.
R14CT00	14 grid cells on line are ice-free.
R09CT92CA998608	9 grid cells on line are 10 tenths (total concentration) consisting of first year (86) landfast (08) ice.
R04CT13C998399CB998199	4 cells on line are 1-3 tenths (total concentration) consisting of young (83) and new (81) ice.

Weekly Arctic sea ice analyses done between 1992-94 and 1994 Antarctic analyses typically contain additional sea ice information. An example of a grid line record with additional information is as follows:

`:R21LL:R18CT57CA109399CB209199CC208799CF1999CN95CD83`

`R21LL` = 21 grid pts on line are coded as land
`R18CT57CA109399CB209199CC208799CF1999CN95CD83` = 18 cells on line are 5-7 tenths (total concentration) consisting of 1/10th of first year thick (93) ice, 2/10th's of first year medium (91) ice, 2/10th's of white (87) ice, ice arranged into belts and strips of 9/10th's, a trace or less than 1/10th of old (95) ice and a fifth ice type (no defined amount) of young (83) ice.

4. Data Processing And Quality Control

Production and real-time quality control of the SIGRID data set was done by the NOAA National Climatic Data Center (NCDC) located in Asheville, N.C. A paper titled "Introduction to a New Sea Ice Database" by Knight (1984) summarizes the SIGRID production process and is included on this CD-ROM for reference.

4.1 Production Steps

All NIC ice charts were digitized using a digitizing tablet and customized software on a personal computer. Once each chart was initialized, header information was entered via a keyboard and x-y coordinates were generated by using a cross-hair cursor to trace sea ice boundaries. Attributes, derived from the "egg code" used to describe each area, were entered via a keyboard. Translation of the resulting digital (x-y coordinate) file into a grid cell format was accomplished through the use of a master grid table. Once the sea ice attributes are linked to each grid cell, the program generates the SIGRID data group records.

4.2 Identified Shortfalls

One of the significant shortfalls in the data set is the arbitrar exclusion of ice south of 45 N in the Arctic. In some years, sea ice may extend south of 45N in the waters south of Newfoundland, Sea of Okhotsk and the Sea of Japan. Weekly maps of sea ice in the Yellow Sea are currently being digitized at the NIC and are not included in the SIGRID data base. Without redigitizing the original hardcharts, data south of 45N can no longer be reconstructed due to the disposal of the x-y coordinate files. Another potential weakness in the SIGRID data is that there is no indication of the source of information for each weekly analysis. Analyses may be based on DMSP OLS fine data, SSMI passive microwave or in some cases an estimate of ice drift.

4.3 Identified Errors and Corrections

In January 1993, National Ice Center became aware that many SIGRID files contained errors in the text of the data group records. The NIC halted the distribution of these data in April 1993 and implemented a plan to identify and correct the errors. The issue of this CD-ROM is the result of those efforts. Three classes of errors were found in the SIGRID data records during the quality control review of the SIGRID files.

- Translation errors in the conversion of "egg code" sea ice attributes to the numerical SIGRID values assigned by tables in the WMO-CMM (1989) document. These translation errors were all corrected by a direct text replacement in the data group record of all SIGRID files.

- Inconsistencies in the areal extent of the Arctic land mask as documented by Breitenberger (1996). Two errors were identified: 1) an increase in total land area beginning in January, 1983 and 2) a smaller but equally identifiable change in total land area with season. The former problem was attributed to an unaccounted for change in map projection. The latter discrepancy appeared to be the result of land grid cells (particularly those adjacent to the ice-covered ocean) being erroneously coded as ice. This condition occurred when digitized edges of adjacent contours did not meet or overlap. Due to the negative effect on areal ice statistics, both landmask irregularities were corrected in the final SIGRID data base.

- Inconsistencies in the "egg code" attributes assigned to the sea ice areas along the "seams" (90W and 90E meridians) of the weekly Arctic ice analysis. This inconsistency was found because both the Arctic East and Arctic West data files should contain the identical information along the intersecting meridians. In some cases, the "joining" of the data files resulted in minor differences in the described ice attributes. These errors were not corrected in the final SIGRID data base because it was deemed relatively easy for the user to resolve these seam differences.

Some prominent examples of translation errors which were corrected in the data base are listed below:

a. Incorrect Total Ice Concentration -

   Open water (less than 1/10th ice) in most cases was coded as ice-free (00) vice open water (01) as shown in WMO code table 1.
   Coding Error: R--CT00
   Correct Code: R--CT01

b. Incorrect Stages of Development -

   Stages of development which utilize a code figure with a dot in the "egg code" were incorrectly interpreted in the translation to SIGRID. This occurred most often when several code figures (all with dots) are used within an egg at the same time. This problem was easily recognizable in the SIGRID data record because the code figures for the stages of development always decrease in magnitude when read from left to right.
   Coding Error: R--CT92CA608799CB309399CC108399
   Correct Code: R--CT92CA609599CB309399CC108399

c. Egg code with So and Sd Stages of Development -

   In many of the analyses in latter years, the "egg code" uses the variables CN (thickest ice present that is less than 1/10th concentration) and CD (the fifth or remaining ice type). Quite often these variables were deleted when translated to the SIGRID code. The absence of these variables significantly reduced the level of analysis detail as described by the SIGRID text.
   Coding Error: R--CT91CA509305CB209104CC108503
   Correct Code: R--CT91CA509305CB209104CC108503CN95CD84

d. Egg Code with Zero as a Partial Concentration Value

   This egg code to SIGRID translation problem is centered around the use of zero as a partial concentration value within the egg. The WMO recognizes the use of zero as an acceptable method to report less than 1/10th of a certain ice type (stage of development). The use of zero in most cases caused a "void" to occur in the text of the data record.
   Coding Error: R--CT79CA409505 void CC408399
   Correct Code: R--CT79CA409505CB018603CC408399

e. Landfast Ice

   Compact (10/10th's) landfast is sea ice attached to the coast. Landfast is a form of ice which was often erroneously coded into the stage of development position in the SIGRID data record.
   Coding Error: R--CT92CA920899
   Correct Code: R--CT92CA929908 or R--CT92CA929999CF0899

4.4 Bad SIGRID Files

It was discovered during the error correction process that five weekly SIGRID files contained either data errors or landmask inconsistencies that could not be corrected by the above described text replacement process. These corrupted files are not included on the CD-ROM because all are considered unusable for any climatological or statistical study. The corrupted files include: 197705.arw; 198505.arw; 198603.arw; 199113.arw and 199140.are.

5. Dataset Citation

All scientific papers describing investigations which use these SIGRID data should cite the National Ice Center as the originating agency. A suggested format for a citation is as follows:

National Ice Center (1996). 1972-1994 Arctic and Antarctic Sea Ice Data. CD-ROM#

Additional questions and inquiries regarding SIGRID data files should be addressed to :

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6. Acknowledgments

Funding and management for the production of the 1972-1994 SIGRID data base was provided by the U.S. Navy through the Fleet Numerical Meteorology and Oceanography Detachment (FNMOC) in Asheville, N.C. Ice chart digitization, translation to SIGRID format and data base quality control were done by the NOAA National Climatic Data Center (NCDC) also located in Asheville, N.C. Special thanks are given to the National Snow and Ice Data Center (NSIDC) for their assistance and advice in data base quality control and in the production of this "read-me" narrative. Special recognition is given to Dick Knight for his invaluable assistance in the error detection and correction effort. Additional recognition is also due to Scott Miller and Sean Memmen for their graphics work.

7. References

References (marked with an asterisk) are included on the CD-ROM to assist the user in the interpretation and use of NIC SIGRID data files. Please note that both ASCII documents are abbreviated reproductions of the original papers.

7.1 Technical Papers and On-Line Guides

Breitenberger, E. (1996). The Navy/NOAA Joint Ice Center Arctic Sea Ice Data Set: An Assessment of its Quality and Usefulness for Climate Research. *Journal of Climate*, In Press.

*Knight, R.W. (1984). Introduction to a New Sea Ice Database. *Annals of Glaciology*, vol. 5, p.81-84.

*World Meteorological Organization - Commission on Marine Meteorology (1989). Final Report of the 10th Session, February 1989, Recommendation 11, "Format for the Archival and Exchange of Sea Ice Data in Digital Form (SIGRID)."

7.2 Abbreviations and Acronyms

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AVHRR=  Advanced Very High Resolution Radiometer
DMSP =  Defense Meteorological Satellite Program
EDR  =  Environmental Data Record
ESMR =  Electrically Scanning Microwave Radiometer
GAC  =  Global Area Coverage
Ghz  =  Gigahertz
HRPT =  High Resolution Picture Transmission
LAC  =  Local Area Coverage
OLS  =  Operational Linescan System
SMMR =  Scanning Multifrequency Microwave Radiometer
SSMI =  Special Sensor Microwave Imager
VHRR =  Very High Resolution Radiometer
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KNIGHT2.ADT

Note: This is a 1984 article describing the development of the sea ice digitizing program at the National Climatic Data Center.

Annals of Glaciology 5, 1984
International Glaciological Society

Introduction To A New Sea-Ice Database

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Abstract

An important new sea-ice database is presently being created at the National Climatic Data Center in Asheville, North Carolina, USA. The data are digitized from weekly charts prepared at the U.S. Navy/National Oceanic and Atmospheric Administration (NOAA) Joint Ice Center and converted into a digital format prescribed by the World Meteorological Organization. The data cover both the Arctic and Antarctic for a ten-year period of record. The grid points are identified by earth coordinates and have a resolution of 15 nm or better. This paper is intended to inform potential users of sea-ice data about the availability of the new data set. Topics covered are (1) data source, (2) brief description of the processing procedures (3) the SIGRID output format, and (4) future plans.

1. Introduction

Since the arrival of high-resolution satellite imagery, it has been possible to map accurately sea ice in both polar regions. Weekly analyses have been prepared and published since 1972 by the U.S. Navy and National Oceanic and Atmosphere Administration (NOAA) Joint Ice Center located in Suitland, Maryland. A number of other ice data set exist (Walsh 1981), but the Joint Ice Center (JIC) charts appear to have the most beneficial combination of length of record along with spatial and temporal resolution, at least from the standpoint of creation of a digital database to be used for climatological summaries. During the summer of 1981, the JIC initiated plans to digitize all of the charts dating from 1972 (1973 for Antarctic) to the present. At about the same time, Dr. T. Thompson, in the capacity of World Meteorological Organization (WMO) consultant on sea ice, coordinated the writing of a proposed format for gridded sea-ice data. The timing of these two events was fortunate since having an output format greatly simplified the design of the digitizing system. This format is known as SIGRID (Thompson unpublished) and has generally been accepted as the new WMO standard, although the final version has not yet been approved at this writing. The sea-ice digitization system is now operational; a technician feeds analog data into a minicomputer and, a few hours later, a magnetic tape emerges containing gridded data in the SIGRID format. The primary purpose of this paper is to let the user community know that this database exists, so that climate modelers and ice researchers can begin to plan applications using the new data set.

2. Data Sources

The weekly analyses produced at the JIC result from the syntheses off our general classes of data. The sources of these data are (1) shore station reports. (2) ship reports, (3) aerial reconnaissance, and (4) satellite imagery (Godin 1981). The last group, however, dominates. Satellites provide between 90 and 98% of the data, depending on the season. There are two categories of satellites used. One is the visible/infrared type. The other is the scanning microwave type (Scanning Multi-frequency Microwave Radiometer (SMMR)/Electrically Scanning Microwave Radiometer (ESMR). D G Barnett and R H Godin (1983 personal communication) have made some estimates as to the percent of utilization of each. During the summer, visible/infrared provides about 60% of the data, microwave 30% and direct observations the remaining 10%. During the winter, the figures are approximately 33%, 65% and 2% respectively. Satellite microwave data were used in the Arctic and Antarctic analyses for the first time in January 1973. This allowed complete dark-season surveillance of the Antarctic. Infrared data were available for the Arctic in 1972 which allowed wintertime analysis there a year earlier (Barnett 1983 personal communication). The accuracy of the depiction of ice extent and ice concentration for the post-1972 Navy charts is considered quite good (Kukla and Robinson 1979). Since 1973, there has been little change in the reliability of the data sources over time. Occasionally the most current data may arrive to late for inclusion in the week's analysis. When this happens, ice coverages are estimated using data up to several days old in conjunction with the previous analysis and continuity considerations. Therefore, the database resulting from digitization of the Navy charts will be complete with no gaps caused by missing data.

3. Processing Programs And Procedures

The task of digitizing ice charts is straight forward. After a chart is mounted on the digitizing tablet and header information is entered into the keyboard terminal, digitizing begins. The digitizer operator follows the ice "contours" with a cross-hair cursor, and x-y coordinate pairs are generated and recorded at a rate of five points per second. The digitizer program invokes a dialog which prompts the operator for all of the required input. This approach to digitizing allows all of the salient information on a chart to be saved. If grid point resolution requirements were to change, one could modify the gridding programs and rerun the raw contour data from the digitizer program with no loss of information. Therefore, the contour digitization approach has a clear advantage over the more commonly used and more labor- intensive method of reading values at each grid point. Before discussing the gridding programs, it is necessary to digress for a moment to examine the grid point resolution requirements. Two constraints were imposed upon the chosen coordinate grid system: (i) the grid point resolution must always be 15nm, (ii) the quotient obtained by dividing 180 by the longitudinal grid point spacing must be an integer. These constraints have led to the choice of the longitudinal grid point spacing shown in Table II. The latitudinal grid point spacing is 0.25 over the entire map. Now, knowing the locations of the required grid points allows the raw contour data to be transformed into an ice type and concentration at a grid point. Heuristically speaking, the gridding program goes through the Master Grid point Table (MGT) and asks the question "Is this point inside or outside of the contour?" If the point is inside, it receives an appropriate value for ice type and concentration. If outside, no action is taken. Since there are approximately 146,000 grid points covering the Arctic region, this would be an inordinately lengthy procedure if it were not for the fact that only small parts of the MGT need be accessed for each contour. This is true because the MGT is arranged as a direct access file whose record numbers are based on geographic location. Therefore, the program only queries those grid points whose encompassed by the raw contour. This substantially reduces the number of computations and allows the gridding to proceed quickly. When this program has completed, the MGT contains a latitude, longitude. And an 18-digit grid point value which may identify ice, open water, or land. Each of these grid point records is then written to another file which is sorted first by latitude (equator to pole) and then by longitude (west to east). The sorted file then becomes input to the final programs which produce the SIGRID format.

TABLE II. GRID POINT SPACING ALONG PARALLELS CHOSEN TO SATISFY RESOLUTION REQUIREMENTS

Latitude range (*)	Grid point spacing (*)
45.00 - 59.75	.25
60.00 - 75.75	.50
76.00 - 82.75	1.00
83.00 - 85.75	2.00
86.00 - 86.75	3.00
87.00 - 87.75	4.00
88.00 - 88.75	5.00
89.00 - 89.25	10.00
89.50 - 89.50	20.00
89.75 - 90.00	30.00

4. The Sigrid Format

The vast majority of sea-ice data in the world today is stored in the form of ice charts prepared by the various ice services of different countries. It has long been recognized that data in this form have limited use for statistical and climatological summaries. Efforts are now being made to construct digital representations of these ice charts. SIGRID was designed to provide a versatile, yet comprehensive archival format for digital data. Having one uniform standard for all of the cooperating ice services should greatly facilitate information interchange. The SIGRID format is tremendously flexible allowing for the inclusion of many combinations of parameters from a total list of 53. All of the data received from the JIC can be coded using 12 parameters. When all 12 parameters are used the corresponding data group will be 38 characters long. However, data groups of the order of 2 parameters and 16 characters are far more typical. A fully expanded grid point record from a Navy chart would contain the following 12 parameters, although in practice, some would be designated as unknown. First, the total ice concentration (coverage) in tenths is listed. This is followed by three groups of three parameters each which describe the partial concentration, stage of development and form of ice respectively for the thickest, second thickest, and third thickest ice. The last two parameters describe the predominant and secondary form of ice and are only coded from Navy charts when ice occurs in strips and patches. SIGRID requires two header records which contain all of the information needed to identify the analysis from which the data were taken. In addition, there is information which will allow the data records which follow to be completely reconstructed as individual grid points with a latitude, longitude, and an ice concentration/type identifier. The data are ordered in strips of latitude running equatorward to poleward, and, within the strips, from west to east. The format allows for compaction by use of a repeater constant, which enables one data group to describe from 1 to 99 adjacent grid points. Shown below, is an example of part of a grid line record having three data groups:

```
R05LL:R12CT92CA929908:R3CT00
```

Data groups always begin with : R followed b the repeat constant. The LL in the first data group signifies land, so the first data group represents five land grid points. The second data group describes the next 12 grid points as having an ice concentration CT of ten-tenths (92). The partial concentration of the thickest ice CA is also ten-tenths and its stage of development is unknown (99).

The form of this ice (08) is fast ice. The final data group depicts three grid points of zero concentration which translates to open water.

5. Future Plans

We, at the National Climatic Data Center (NCDC), have begun work on some sea-ice climatological summaries. In general these summaries will be graphical products depicting some feature composited on a semi-monthly basis for a 10-year period of record. Some examples are (i) mean, maximum, and minimum ice edge, (ii) mean ice concentration in tenths, (iii) mean ice age, (iv) mean extent of 5/10ths or more concentration, and (v) mean extent of old ice. The summary charts will ultimately be published under the aegis of the Joint Ice Center. The complete should be available on two or three magnetic tapes in the SIGRID format by late summer of 1984. In addition, the data will be available in a more compacted format used for the production of the climatological summaries mentioned above.

(End 1972-1994 Arctic and Antarctic Sea Ice Data *documentation)*

References

Arctic Climatology Project. 2000. *Environmental Working Group joint U.S.-Russian sea ice atlas.* Edited by F. Tanis and V. Smolyanitsky. Ann Arbor, MI: Environmental Research Institute of Michigan in association with the National Snow and Ice Data Center. CD-ROM.

Dedrick, K., K. Partington, M. Van Woert, C. Bertoia, and D. Benner. 2001. U. S. National/Naval Ice Center digital sea ice data and climatology, *Can. J. Remote Sens*. 27(5), 457– 475.

Kokaly, R. F. 1996. *Methods for Regridding AARI Data in SIGRID Format to the EASE-Grid Projection.* NSIDC Special Report 9. http://nsidc.org/pubs/special/9/index.html

National Ice Center. 2006. *National Ice Center Sea Ice Charts and Climatologies in Gridded Format.* Edited by F. Fetterer and C. Fowler. Boulder, CO: National Snow and Ice Data Center. Digital media.

Partington, K., T. Flynn, D. Lamb, C. Bertoia, and K. Dedrick. 2003. Late twentieth century Northern Hemisphere sea-ice record from U.S. National Ice Center ice charts. *J. Geophys. Res.,* 108, C11, 3343. doi:10.1029/2002JC001623.

van Woert, M. 2002. U. S. Navy Operational Sea Ice Remote Sensing. IGARSS Proceedings, Toronto, Canada, June 24-28, 2002.