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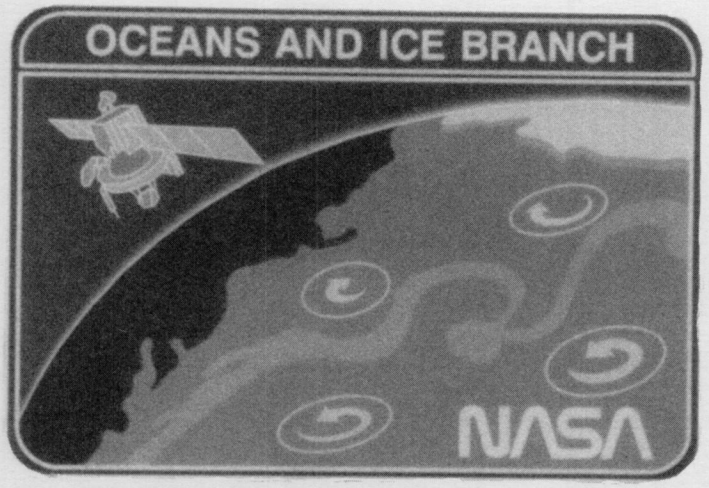

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An Improved Land Mask for the SSM/I Grid

Michael G. Martino
Hughes STX
Lanham, Maryland

Donald J. Cavalieri, Per Gloersen, and H. Jay Zwally
NASA Goddard Space Flight Center
Greenbelt, Maryland

James G. Acker, Technical Editor
Hughes STX
Lanham, Maryland

National Aeronautics and
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Goddard Space Flight Center
Greenbelt, Maryland 20771

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ABSTRACT

This paper discusses the development of a new land/ocean/coastline mask for use with Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) data, and other types of data which are mapped to the polar stereographic SSM/I grid. Pre-existing land masks were found to disagree, to lack certain land features, and to disagree with land boundaries that are visible in high resolution sensor imagery, such as imagery from the Synthetic Aperture Radar (SAR) on the Earth Resources Satellite (ERS-1) . The Digital Chart of the World (DCW) database was initially selected as a source of shoreline data for this effort. Techniques for developing a land mask from these shoreline data are discussed. The resulting land mask, although not perfect, is seen to exhibit significant improvement over previous land mask products.

1. INTRODUCTION

Data from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I), used for polar research purposes, are distributed on a polar stereographic map with grid resolutions of 12.5 km, 25 km, and 50 km at a latitude of 70°. For the Northern Hemisphere, the 25 km grid has 304 columns and 448 rows, and for the Southern Hemisphere, the grid has 316 columns and 332 rows (National Snow and Ice Data Center 1992). The North Pole is located at the $[x, y]$ coordinates [154, 234] (referenced to $x, y = [0, 0]$ at the upper left corner), and the South Pole is located at $[x, y]$ coordinates [158, 174]. Data are provided to 31° N in the Northern Hemisphere and to 38° S in the Southern Hemisphere, at the corners of the grid (Gloersen et al. 1992). Although data from many different sensors are currently mapped in this particular manner, the grid was originally developed for the DMSP F-8 SSM/I, and is commonly referred to as the *SSM/I grid.*

Previous land mask bitmaps for the SSM/I grid have been produced at Goddard Space Flight Center (GSFC) and the National Aeronautics and Space Administration (NASA)/California Institute of Technology Jet Propulsion Laboratory (JPL). The land mask bitmaps are distributed on Compact Disk-Read Only Memory (CD-ROM) by the National Snow and Ice Data Center (NSIDC), along with data from either the NIMBUS-7 Scanning Multichannel Microwave Radiometer (SMMR) and the DMSP SSM/I.

The GSFC land mask was based on the Central Intelligence Agency (CIA) World Shoreline Data Bank II, and is distributed with the SMMR data. The JPL land mask was based on the CIA World Shoreline Data Bank I, and is distributed with the SSM/I data. These two land masks will hereinafter be referred to as the *GSFC land mask I* and the *JPL land mask*, respectively. These land masks show disagreement with each other, and in some areas, notably St. Lawrence Island and northern Greenland, the land masks also did not match well with land boundaries visible in geo-coded Earth Resources Satellite (ERS-1) Synthetic Aperture Radar (SAR) data. One form of disagreement occurred where the GSFC land mask I classified some grid cells as *ocean* which were unambiguously identified as land in the SAR images. The JPL land mask, in contrast, classified some grid cells which appeared to have less than 50% land coverage (in SAR imagery) as *land* . While these discrepancies might have only negligible effect in studies of large ocean areas, an inaccurate coastline or land mask may seriously affect coastal studies.

2. NEW LAND MASK

The Digital Chart of the World (DCW) database, obtained from the U.S. Geological Survey (USGS), provided a new coastline dataset to serve as a basis for a new land mask. This new land mask will be referred to as the *GSFC land mask II.* The DCW was selected because of its accuracy, and because it was the most recently published source of worldwide shoreline data. The DCW is derived primarily from the Defense Mapping Agency (DMA) Operational Navigation Chart (ONC) and Jet Navigation Chart (JNC) series. It was developed from 1989 though 1991, and was published on CD-ROM in 1992 (Environmental Systems Research Institute 1992 and DMA 1992). Records of political and ocean boundaries constitute a portion of the database. For the purpose of the research described here, edge records classified as *Coastline*, *Coastal Closure*, and *Seawall* were extracted from the complete database and *Ice/Water line* records were also extracted for the Southern Hemisphere (DMA 1992). The *Ice/Water line* records will require periodic adjustments based on the availability of newer data.

As a preliminary step to producing the GSFC land mask II, a 6.25 km resolution land mask was produced by pixel replication from the JPL 12.5 km land mask. This file was used as a first approximation to a land mask which matches the DCW coastline. The DCW data extracted from the CD-ROMs were closely spaced longitude-latitude

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pairs. These coordinates were mapped to the 6.25 km SSM/I grid, and overlaid onto the expanded JPL land mask. Any 6.25 km grid cell that contained at least one DCW coastline point was reclassified as a coastline cell. The 6.25 km map was then manually edited to correct the following three types of problems:

1) In some areas, the coastline was not continuous, and gaps were manually filled.
2) In some areas, the DCW coastline extended beyond the expanded JPL land mask—these areas were reclassified as land.
3) In other areas, the expanded JPL land mask extended beyond the DCW coastline—these areas were reclassified as ocean.

In addition, several land features that are not present in either the JPL land mask or GSFC land mask I were present in the DCW coastline data. These missing land features include several islands near Denmark, Siberia, and also in Hudson Bay. The correct locations for these islands were verified using maps found in published atlases (National Geographic Society 1981). The grid cells inside these features were then reclassified, where appropriate, as land or coast.

The edited 6.25 km land/coast mask was used to produce both the 12.5 km and 25 km land masks. The two lower resolution land masks were derived independently of each other, from the 6.25 km mask, by similar techniques. The technique for deriving the 12.5 km land mask is as follows:

a) The 6.25 km grid cells are grouped into 2×2 arrays, with each of these arrays corresponding to a single 12.5 km grid cell.
b) The 2×2 array composing the 12.5 km grid cell is analyzed in a two-step process. In the first step, ocean and land grid cells are counted, and coast grid cells are counted as land. In the second step, ocean and land grid cells are again counted, but this time coast grid cells are counted as ocean. The classification of the 12.5 km grid cell is determined by summing the ocean counts and the land counts from the two steps, then classifying the grid cell as land or ocean depending on which class had the greater sum of counts. If the ocean counts and land counts are equal, then the entire 12.5 km grid cell is classified as coast.
c) A continuous coastal boundary is then produced by reclassifying as coast any land grid cell which shares at least one side with an ocean grid cell.

The 25 km resolution land mask is produced similarly, but by grouping the 6.25 km grid cells into 4×4 arrays. The GSFC land mask I was derived with a similar technique (Gloersen et al. 1992). The 25 km land masks were made directly from the 6.25 km land mask, because the use of a 12.5 km land mask as an intermediate product results in an unacceptable loss of detail in the coastlines. This loss of detail from repeated application appears to be a feature of the classification technique. The technique described in this paper will classify as land or coast grid cells containing 25% ocean, and will similarly classify as ocean grid cells containing 50% land. The bias in favor of ocean results from the the classification method used.

Land features that are smaller than half of the grid cell size will not appear in the land mask. This bias is warranted on the basis of both the DCW data and available SAR images, which indicate that the 6.25 km coastline grid cells can, in fact, be almost entirely occupied by water.

Differences between the GSFC land mask II and the JPL land mask for the Northern Hemisphere are presented in Fig. 1. The GSFC land mask II shows more land area in Europe, and more ocean area around the various islands between Greenland and Canada.

Figure 2 presents differences between the GSFC land mask II and the GSFC land mask I for the Northern Hemisphere. In this case, the GSFC land mask II generally shows more ocean area, yet includes more small islands in the Arctic. In order to distinguish important differences between the land masks, detail images of Greenland and Alaska are shown in the Fig. 3. The greater coastal detail, and the relocation of certain features in northern Greenland, are visible in this figure.

Tables 1 and 2 display total numbers of land grid cells for each of the three land masks, as well as the difference between the GSFC land mask II and each of the earlier land masks. The more recent DCW land boundaries show several Antarctic ice shelves to be larger than they appeared in the earlier CIA coastlines. Consequently, the GSFC land mask II is somewhat larger than the earlier land masks in the Southern Hemisphere.

The land mask described in this paper is stored as four binary image files, one file at 12.5 km resolution and one file at 25 km resolution, for both the Arctic and Antarctic regions. Grid cells classified as ocean have the value 0, land grid cells have the value 1, and coast grid cells have the value 2.

3. SAR COMPARISONS

An ERS-1 SAR image of St. Lawrence Island in the Bering Sea, at a resolution of 100 m, is shown in Fig. 4. The grid cell coordinates for the 25 km northern hemisphere SSM/I grid are indicated. Each land grid cell is labeled to indicate in which mask (GSFC land mask I or II, or the JPL land mask) it was classified as *Land*. The classification method used to produce the GSFC land mask II was designed to classify as *Land* any grid cell containing at least 50% land. Note that grid cell [60, 167], containing approximately 50% land, is classified as *Land* in both land masks. Grid cell [59, 166], which contains less than 50% land, is classified as *Ocean* in the GSFC land mask II, but

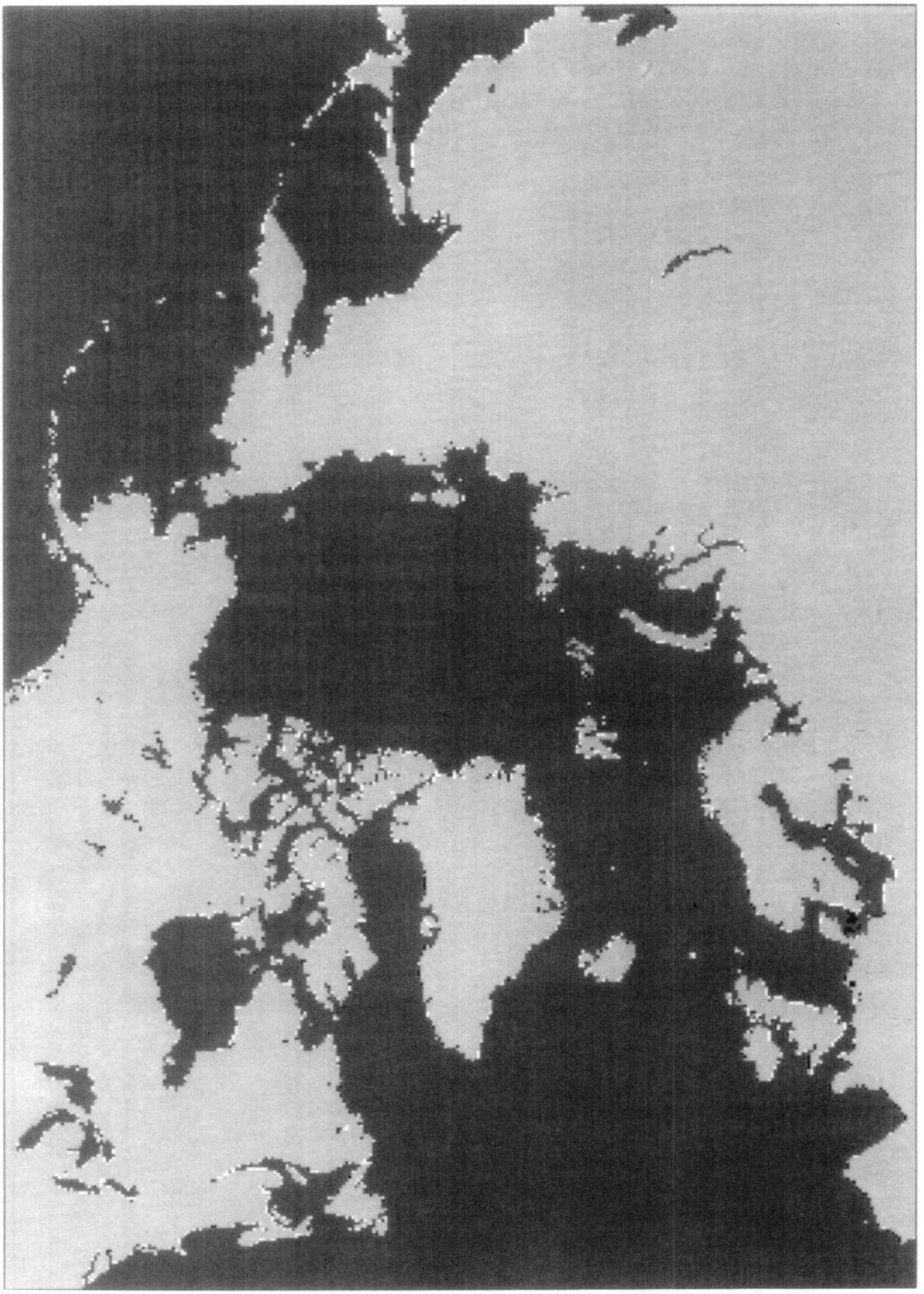

Fig. 1. Comparison of the GSFC land mask II to the JPL land mask for the Arctic Ocean and adjacent land areas. Black grid cells are identified as land only in the GSFC land mask II; white grid cells are identified as land only in the JPL land mask. Light gray and dark gray grid cells are identified as land or ocean, respectively, in both land masks.

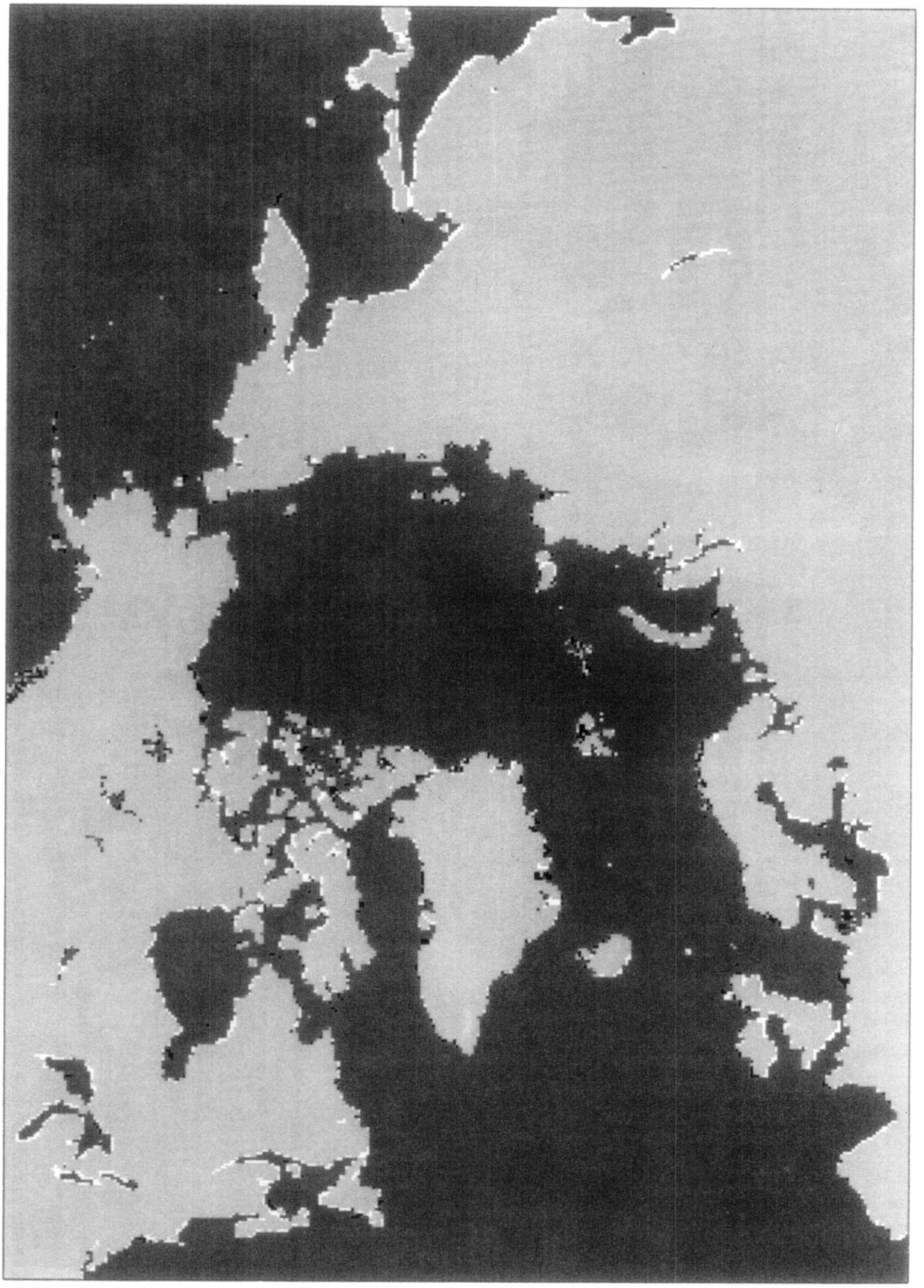

Fig. 2. Comparison of the GSFC land mask II to the GSFC land mask I for the Arctic Ocean and adjacent land areas. Black grid cells are identified as land only in the GSFC land mask II; white grid cells are identified as land only in the GSFC land mask I. Light gray and dark gray grid cells are identified as land or ocean, respectively, in both land masks.

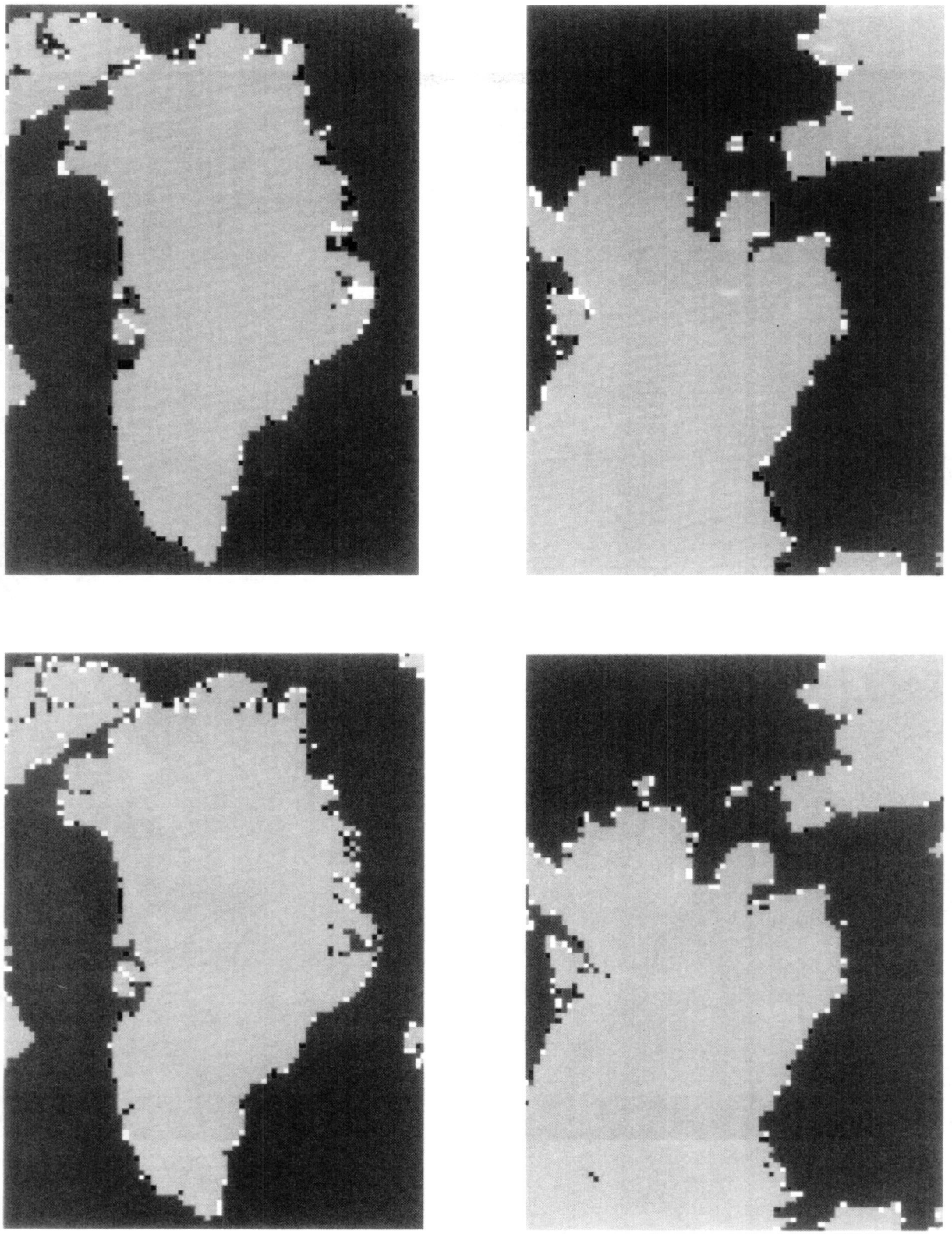

Fig. 3. Images of Greenland and Alaska, showing the differences between GSFC land mask II and GSFC land mask I (upper images), and between GSFC land mask II and the JPL land mask (lower images). Light gray and dark gray grid cells are identified as land or ocean, respectively, in all three land masks. The black grid cells (in all four images) are identified as *land only* in GSFC land mask II. The white grid cells in the upper images are identified as *land only* in GSFC land mask I, and the white grid cells in the lower images are identified as *land only* in the JPL land mask.

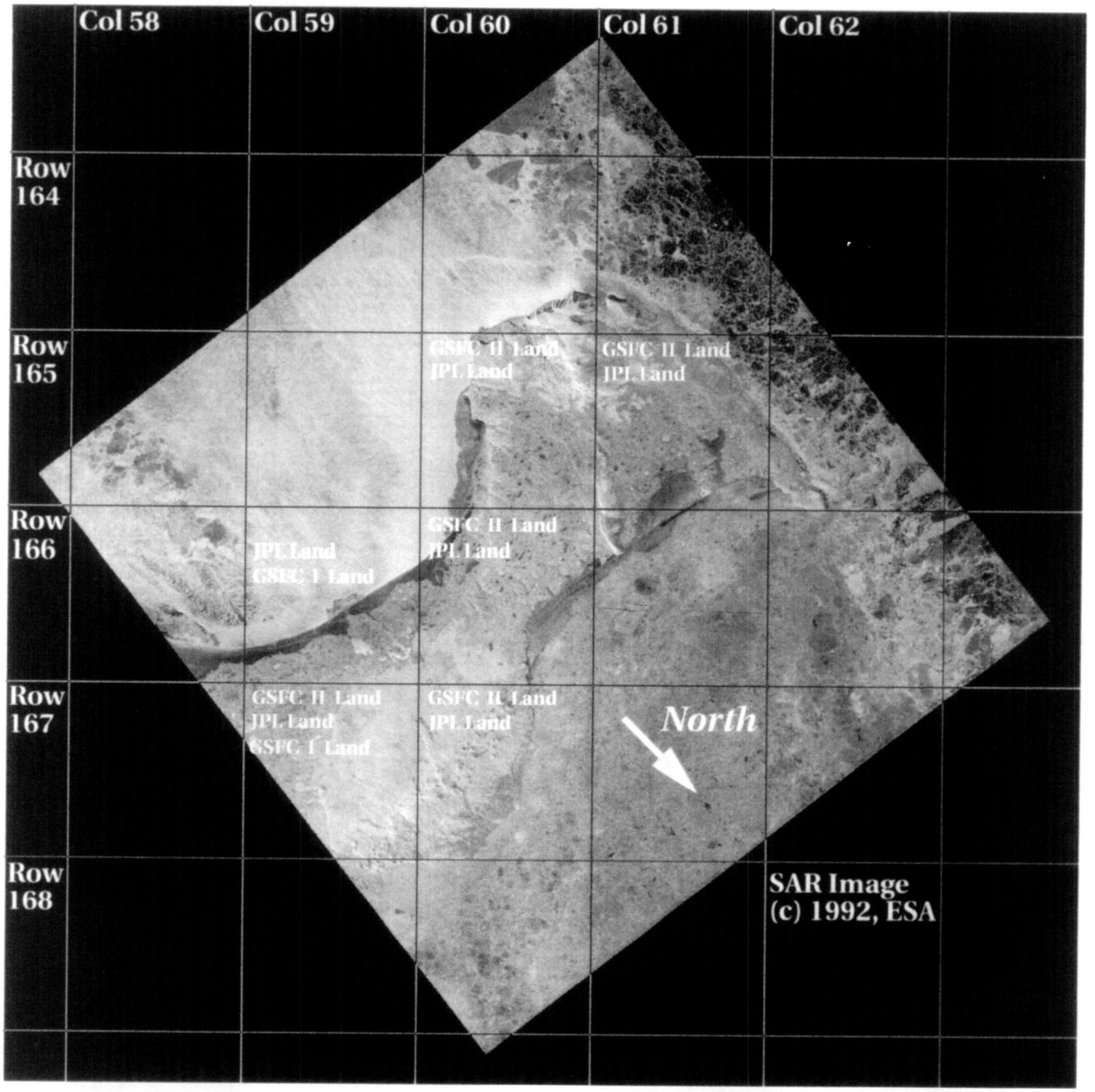

Fig. 4. An ERS-1 SAR image of St. Lawrence Island. Grid cell [59, 166] is misidentified as land in the JPL and GSFC I land masks, and four grid cells are misidentified as ocean in the GSFC landmask I. The GSFC land mask II correctly identifies these grid cells. (Image processed by the Alaskan SAR Facility.)

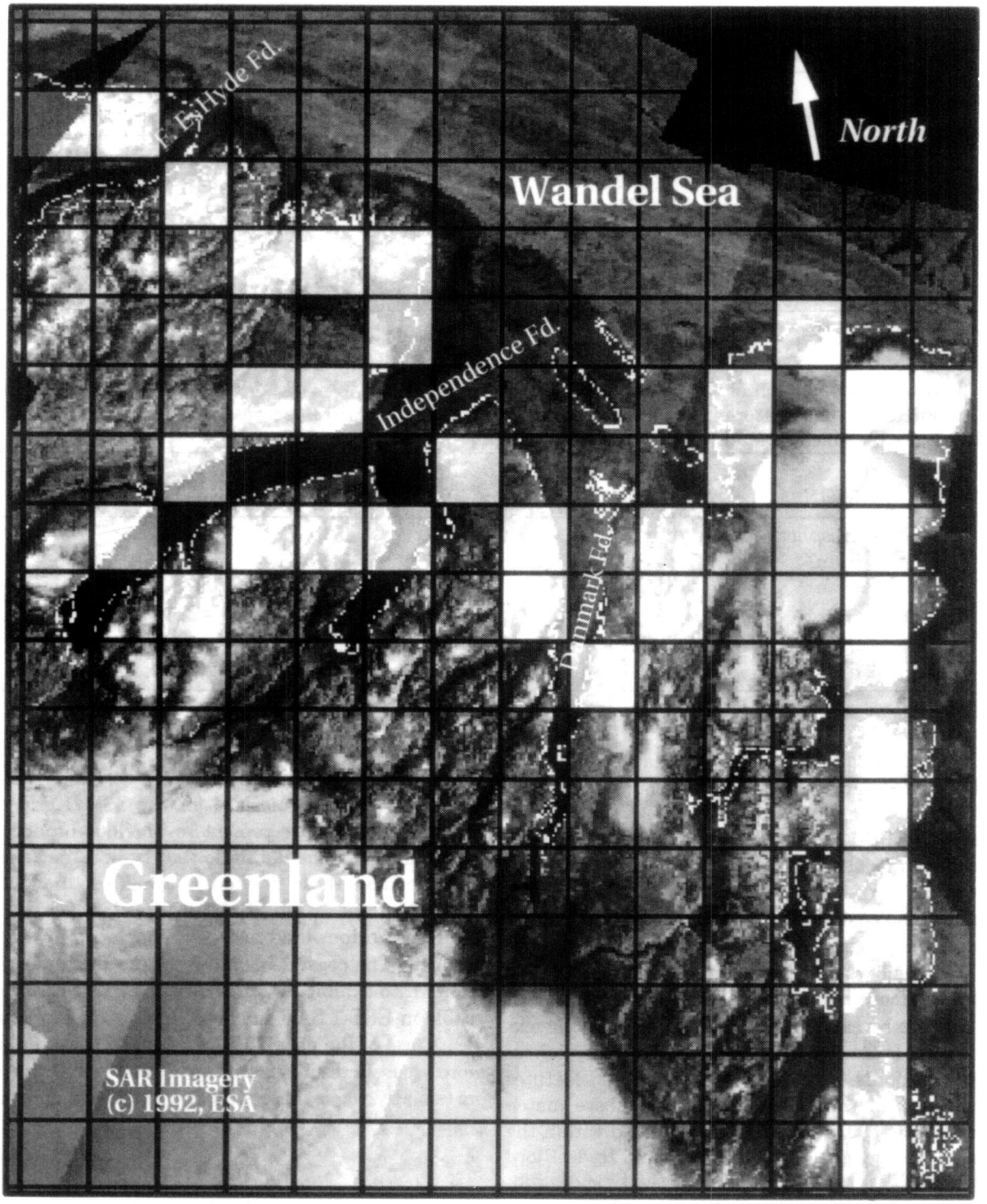

Fig. 5. An ERS-1 SAR mosaic of northeastern Greenland. The broken white line is the DMA coastline, which closely matches the land features visible in the SAR imagery. Grid cells with less than 50% land are classified as ocean. Three islands in the Wandell Sea are too small to appear in the 25 km land mask. (SAR mosaic courtesy of Mark Fahnestock, Joint Consortium for Environmental Science Studies, University of Maryland at College Park.)

Table 1. Comparison of the GSFC II land mask to the GSFC I land mask, demonstrating the reclassification of land and water pixels in the GSFC II land mask. *Land Pixels* represents the number of pixels that are classified as land in both land masks. *N/A* means that there is no data available for comparison at this pixel size.

REGION	*Land Mask* GSFC I	GSFC II	*Land Pixels*	*Difference* [pixels]	[%]
N. Hemisphere					
25.0 km	69,365	68,264	67,385	1,101	1.61
12.5 km	N/A	N/A	—	—	—
S. Hemisphere					
25.0 km	21,700	22,005	21,573	−305	−1.39
12.5 km	N/A	N/A	—	—	—

Table 2. Comparison of the GSFC II land mask to the JPL land mask, demonstrating the reclassification of land and water pixels in the GSFC II land mask. *Land Pixels* represents the number of pixels that are classified as land in both land masks.

REGION	*Land Mask* JPL	GSFC II	*Land Pixels*	*Difference* [pixels]	[%]
N. Hemisphere					
25.0 km	68,978	68,264	67,673	714	1.05
12.5 km	275,965	274,868	271,760	1,097	0.40
S. Hemisphere					
25.0 km	21,996	22,005	21,773	−9	−0.04
12.5 km	87,985	88,284	87,229	−299	−0.34

was misclassified as *Land* in the older JPL land mask. Also note that the irregular dark band on the south side of the island is shore fast ice, not land.

A mosaic of ERS-1 SAR images of northeastern Greenland from March 1992 is shown in Fig. 5. The mosaic is at 1 km resolution, with the SSM/I grid indicated. The grid cells classified as coast in the 25 km land mask are highlighted, and the original DMA coastline data points are indicated by small white dots. This figure illustrates the close correspondence between the DMA data and coastal features that are revealed in the SAR data. With the exception of F.E. Hyde Fjord, located in the upper left of the figure, the fjords, islands, and other coastal features that are present in the DMA coastline database match the corresponding features in the SAR data to within the resolution of the image. The mislocation of Hyde Fjord (approximately 6 km to the southeast) is the type of problem which was much more prevalent in the older coastline databases. The dark areas near the shore (but outside the DMA coastline) are sea ice areas, not land. The DMA coastline defines three small islands which also appear in the SAR data, but they are not readily noticable in this figure. None of these islands, however, occupies more than half of any 25 km SSM/I grid cell, and they do not appear in the land mask.

5. CONCLUSION

The GSFC land mask II for the SSM/I grid corrects several flaws that are present in previous products. It is based on a coastline database that is, in some areas, more accurate than those previously available. Land features larger than one 25 km SSM/I grid cell, which were missing from previous land masks, are included in the present product. The coastal boundary of the present land mask is shown to exhibit better correspondence with land edges visible in ERS-1 SAR imagery. In light of these improvements, use of the new GSFC land mask II should produce more accurate results in studies of polar sea ice and oceans, particularly when those studies concentrate on coastal regions.

Glossary

CD-ROM Compact Disk-Read Only Memory
CIA Central Intelligence Agency

DCW Digital Chart of the World
DMA Defense Mapping Agency
DMSP Defense Meteorological Satellite Program

ERS-1 Earth Resources Satellite

GSFC Goddard Space Flight Center

JNC Jet Navigation Chart
JPL Jet Propulsion Laboratory

NASA National Aeronautics and Space Administration
NIMBUS Not an acronym; the name of a series of satellites which carried a variety of Earth-sensing instruments
NSIDC National Snow and Ice Data Center

ONC Operational Navigation Chart

SAR Synthetic Aperture Radar
SMMR Scanning Multichannel Microwave Radiometer
SSM/I Special Sensor Microwave/Imager

USGS U.S. Geological Survey

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[1] 700 Robbins Ave., Bldg 4D, Philadelphia, PA 19111-5094.

[2] Available from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161, U.S.A.

[3] Available from the Cooperative Institute for Research in Environmental Sciences - University of Colorado, Boulder, CO, 80309-0449, U. S. A.

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13. ABSTRACT *(Maximum 200 words)*

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