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NSIDC Land, Ocean, Coast, Ice, and Sea Ice Region Masks

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Walter N. Meier
J. Scott Stewart
NSIDC

Contents

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Introduction

Analysis of geophysical data often requires surface type masks to delineate valid regions for parameter retrievals. For example, ocean properties should only be retrieved over ocean regions and land should be masked out. Delineation of regions can be useful to parse sub-global or sub-hemispheric characteristics and to estimate statistics in specific geographic locations. This report documents two products: a set of surface type masks (to be published soon) and polar region masks (NSIDC-0780; Meier and Stewart, 2023). Both masks have been developed primarily to support sea ice products, but they are potentially useful for other applications.

Surface Type Masks

Background

Surface masks are used in nearly all geophysical applications. “Surface masks” encompass a variety of fields, including land cover classification, coastal outlines, etc. They may be applied to simply delineate surface features in data visualizations, but often they are used to either prescribe where valid data can be retrieved or where the surface type is important in the processing or analysis of data fields. Surface masks can vary in complexity. Some are simple land vs. water discriminators. Others may have different classifications of land and water bodies. Land can be discretized into a few primary categories (bare land, glacier or ice sheet, lake or river) or involve multiple land classification categories (e.g., boreal forest, desert, agricultural, urban, etc.). Such masks may be in raster or vector format. Raster fields are gridded at some spatial resolution on a defined projection and grid. Vector fields are polygons defined by vertices at specified latitude and longitude coordinates. For vector fields, the vertices are not depended on a Coordinate Reference System (CRS); however, the polygons do need to be defined on a CRS.

Retrieval of sea ice properties requires at least a basic land vs. water discrimination because sea ice occurs only in ocean (saline) water. Instruments on satellite or airborne platforms typically collect continuous data, over land and ocean. Thus, a land mask is required to derive sea ice properties only over the ocean. Although visible and infrared sensors are used to obtain sea ice information, passive microwave have most commonly been used for long-term climate monitoring of the ice cover because they provide near-complete daily coverage of sea ice covered regions, even in darkness and in cloudy conditions. In addition to the basic land-ocean discrimination, land masks are important for passive microwave data because of their coarse spatial resolution. Many passive microwave radiometers have sensor footprints on the order of 70 km by 50 km for at least some frequencies. This leads to a mixture of land and ocean within grid cells. Such mixtures can be interpreted by sea ice concentration algorithms as sea ice, which results in false ice along the coastline. Filters have been developed to remove such ice (e.g., Cavalieri et al., 1999), but an accurate land mask is essential for such filters to work properly.

Passive microwave records of sea ice concentration began in 1972 with the launch of the NASA Electrically Scanning Microwave Radiometer (ESMR) on the NASA Nimbus-5 satellite.

Continuous and consistent monitoring began in October 1978 with the launch of the NASA Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 platform.

From the beginning, analysis of sea ice from these sensors has required a land-ocean mask. The first mask, for ESMR, was adapted from a U.S. Central Intelligence Agency (CIA) World Data Set II high-resolution coastline (Gloersen et al., 1992) and then modified for the different grid that SMMR used). The mask employed a 50% threshold of each grid cell to determine whether a grid cell was denoted as land or ocean (>=50% land in a grid cell was assigned to land; <50% land in a grid cell was assigned to ocean). A "coast" grid cell designation could also be made, defined as a land grid cell adjacent to water (i.e., "coast" cells are land).

The sea ice concentration record was continued with a series of Special Sensor Microwave Imager (SSMI) instruments on U.S. Defense Meteorological Satellite Program (DMSP) platforms. The first SSMI was launched in July 1987. SSMI sensors were later replaced with Special Sensor Microwave Imager and Sounder (SSMIS) instruments on DMSP satellites. These began in 2003 and are continuing to operate (as of December 2022). New land masks, described in Martino et al. (1995), were derived for SSMI sea ice concentration products, based on the U.S. Geological Survey Digital Chart of the World database. As with the ESMR and SMMR masks, land grids were defined as cells with ≥50% land.

Several algorithms have been developed to derive sea ice concentration from passive microwave radiometer data. Two early algorithms, both developed at NASA Goddard, are the NASA Team (Cavalieri et al., 1984) and Bootstrap (Comiso, 1986). Both are still in wide use and data products from the algorithms that span the SMMR, SSMI, and SSMIS eras (1978 to present, as of December 2022) are archived at the NASA Snow and Ice Distributed Active Archive Center (DAAC) at NSIDC (Digirolamo et al., 2022; Comiso, 2017). The SSMI land mask has continued to be used for the NASA Team product. The Bootstrap product updated its land mask for the Southern Hemisphere to account for changes in the Larsen ice shelves off the Antarctic Peninsula that occurred during the late 1990s and early 2000s (Comiso and Nishio, 2008); however, the details and sources for that change were not explicitly documented.

The passive microwave sea ice concentration products have been derived on the **NSIDC Polar Stereographic North and South grids** (https://nsidc.org/data/user-resources/help-center/guide-nsidcs-polar-stereographic-projection) and the land masks described above were derived for these grids (except for ESMR, which was a smaller region). More recently, equal area Lambertian projection grids were developed, called **Equal-Area Scalable Earth (EASE) Grid** (https://nsidc.org/data/user-resources/help-center/guide-ease-grids). An initial EASE Grid (Brodzik and Knowles, 2002) was developed, which has since been superseded by EASE-2.0 (Brodzik et al., 2012, 2014), which is more compatible with modern image analysis tools (such as GIS). For these grids, masks were derived that subdivided land into bare land, land ice (glaciers, ice sheets), and coast. These were designated as "Land, Ocean, Coast, Ice" or "LOCI" masks (Knowles, 2004). These LOCI masks were derived from Boston University MODIS/Terra land cover data. The masks have been found to have errors where there is bare land, land ice, and ocean in close proximity where land (either bare land or land ice) is incorrectly flagged as ocean; this primarily effects the Greenland coast, Svalbard, Novaya Zemlya, but any coastal areas with land ice may be erroneously flagged. Such coastal errors limit the utility of such masks for any data near the coast in the polar regions, such as sea ice parameters.

Methodology

The original motivation of the new masks described here was to address the errors in the EASE LOCI masks. However, because the polar stereographic grids are widely utilized for sea ice, new masks were derived for those grids as well. As described below, the categories in the new mask are broader than simply “land” or “LOCI”, so the new masks are described as “surface mask” fields.

The primary source for the new surface masks is the MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500 m SIN Grid (MCD12Q1) Version 6 (Friedl and Sulla-Menashe, 2019). It is used for all regions except Greenland and Antarctica. This product derives 16 land cover classifications from MODIS reflectance data based on the International Geosphere-Biosphere Programme (IGBP) scheme. The MCD12Q1 data are 500 m resolution tiles on a sinusoidal (SIN) grid.

The processing steps for deriving the surface masks from the MOD12Q product are:

1. From the MOD12Q 500 m SIN grid, create three 500 m SIN grids, one for each of Land, Water, and Ice (L, W, I). Land encompasses all classifications of non-ice-covered land (values of 1-15 in MOD12Q1). Ice is assigned from the MOD12Q1 value (16) for “Permanent Snow and Ice”. Water is assigned from the “Water Bodies” (17) value. Each grid cell in the L, W, and I grids are assigned value of 0 (not present) or 200 (present).
2. The three 500 m SIN grids are then regridded using mapx software onto either the PS or EASE projection at 390.625 km grid resolution. This resolution divides evenly into the lower resolution output grids of 3.125 km, 6.25 km, 12.5 km, and 25 km. The regridding is done via a bilinear interpolation, so the 0 or 200 values in the SIN grid have interpolated values between 0 and 200 on the PS and EASE2 grids. Effectively, each grid value contains a percent coverage at 0.5% intervals on each of the L, W, and I grids.
3. Due to the high resolution, the grids are quite large. To make the processing more manageable, each grid is split (“tiled”) into sub-grids. For the EASE2 grids, each is split into 4 x 4 (16 total) tiles; for the PS grids, each is split into 2 x 2 (4 total) tiles. All computations below are done on these individual tiles before they are reconnected at the lower resolution final output grids.
4. The three individual L, W, I grids are combined into a single grid with each grid point assigned a value for land, water, or ice. First, a thresholding is done on non-water (land or ice). If the L+I percentage is $\geq$50%, the 390.625 m grid cell is assigned “non-water”. If the L+I percentage is <50%, the grid cell is assigned the “water” value. Then a threshold is applied to the “non-water” grid cell: if $L \geq I$, the grid cell is assigned the “land” value, otherwise it is assigned to the “ice” value”.
5. The “water” grid cells are then split into “ocean” and “freshwater (river or lake) based on a connectedness criterion. If water connects to the open ocean regions at the 390.625 m resolution, it is considered “ocean”. If water does not connect (i.e., land is between the water and the open ocean). This creates a “Land, Ocean, Ice, Lake” or “LOIL” mask, where “Lake” means any freshwater (including rivers). Note that this approach is based purely on grid-based contiguousness,

not salinity and results in ocean grid cells extending into estuaries and freshwater regions (e.g., river deltas).

6. The 390.625 km resolution fields are binned up to the lower resolution fields of the products at 3.125 km, 6.25 km, 12.5 km, and 25 km using the same threshold criteria to determine the classification of each lower resolution grid cell. Each lower resolution field is binned independently from the source 390.625 km field – e.g., the 6.25 km grids are derived directly from the 390.625 km fields and are not created by binning the 3.125 km grids. In other words, the lower resolution output grids are not binned up from higher resolution grids.
7. The tiles of lower resolution output fields are "stitched" together into full grids. The fields are then inspected for small inconsistencies and corrected.
8. At the lower resolutions, some areas designated as "ocean" become enclosed by land after the 390.625 m grid is binned up. Such regions may be freshwater or brackish (e.g., river deltas) and some may be ocean (saline) waters (e.g., narrow inlets such as fjords). In other words, some water cells are ocean, but when binned to lower resolution, they become enclosed by land. Such grid cells are designated as "Disconnected Ocean".

The MOD12Q land classification product does include ice shelves or marine-terminating (aka tidewater) glaciers. Ice shelves and tidewater glaciers are ice of land origin that have flowed into and are floating upon the ocean. However, such floating ice is not sea ice and ocean areas covered by ice shelves and tidewater glaciers preclude sea ice formation. Thus, for the purposes of sea ice, it is important to mask such ice where feasible, particularly in the Antarctic where the Ross and Ronne-Filchner Ice Shelves are each nearly 500,000 km^2. Since MOD12Q does not provide ice shelf information, two other sources of surface type were used where ice shelves are primarily found: Antarctica and Greenland.

For Antarctica, the **Antarctic Digital Database (ADD)** (https://www.bas.ac.uk/project/add/) was used as the source for the masks. The ADD "High resolution vector polylines of the Antarctic coastline" Version 7.3 product (Gerrish et al., 2020), at a resolution of 500 m, was downloaded as a shapefile and rasterized into the 390.625 km grid resolutions. The same steps as above were then followed, with the ice shelf classification added.

For Greenland, the mask parameter from the IceBridge BedMachine Greenland, Version 5 (Morlighem et al., 2022) was employed. The 150 m resolution grid was regridded into the 390.625 km grids. The same steps as above for MOD12Q were then followed, with the ice shelf classification added.

While MOD12Q could have been used for Greenland and Antarctic regions other than ice shelves and tidewater glaciers, for consistency the ADD and BedMachine fields fully replaced the MOD12Q product for the two regions. Tidewater glaciers exist outside of Greenland and Antarctica, primarily in the Canadian Archipelago and the southeast Alaska coast. Such glaciers are relatively small and have limited impact on the land mask grids described here. For simplicity, these glaciers were ignored.

Product Description

The land mask products are in NetCDF4 format with one geophysical parameter, "surface_mask". The mask values given below in Table 1.

The masks are provided in the NSIDC Polar Stereographic North and South Grids and EASE2 North and South Grids at 3.125 km, 6.25 km, 12.5 km, and 25 km grid resolutions (25 km EASE2 shown in Figure 1). Note that the polar stereographic grids are not equal-area. The grid resolutions are true at 70° latitude, with area varying at other latitudes, as described in Stewart et al. (2022). Grid specifications are provided in Table 2.

Table 1. *Surface mask file flag values and flag meanings from the NetCDF metadata and description. "Off Earth" is used only for EASE2 grids, indicating the corner regions of the grid beyond the circular earth region.*

Flag Value	Flag Meaning	Description
50	ocean	Ocean
80	ocean_disconnected	Disconnected Ocean
150	land	Bare land (ice-free)
175	fresh_free_water	Freshwater (rivers, lakes)
200	ice_on_land	Land Ice
220	floating_ice_shelf	Ice Shelf
250	off_earth	Off Earth

Table 2. *Grid specifications for the polar stereographic (PS) and EASE2 grids. The* ***EPSG codes*** *provide specifics on the projections at https://epsg.io. The rows for each grid resolution provide the grid dimensions in columns x rows.*

	PS North	PS South	EASE2 North	EASE2 South
EPSG	3411	3412	6931	6932
3.125 km	2432 x 3584	2528 x 2656	5760 x 5760	5760 x 5760
6.25 km	1216 x 1792	1264 x 1328	2880 x 2880	2880 x 2880
12.5 km	608 x 896	632 x 664	1440 x 1440	1440 x 1440
25 km	304 x 448	316 x 332	720 x 720	720 x 720

The new polar stereographic masks are a potential replacement for the old NASA masks. Figure 2 shows the differences between the new mask and the old NASA mask used in the NASA Team algorithm sea ice concentration (DiGirolamo et al., 2022; Meier et al., 2021) products archived at the NSIDC DAAC. The main differences are in the Antarctic Peninsula where the Larsen-B ice shelf collapsed since the old NASA Team mask was developed. As mentioned above, the Bootstrap algorithm product does use a newer mask that accounts for the Larsen-B changes. Most changes around Antarctica, and likely Greenland, reflect changes in ice shelve and glacier termini location. Otherwise, the changes are generally small and are focused along the coast and around lakes. The coastal changes likely reflect slight differences in mapping that can affect edge cases:

where the land percentage is very close to 50% and a small change can "flip" a grid cell from one category into another. Similarly, such edge cases would influence lake versus land classifications. It is also possible that coastal processes (erosion, subsidence, uplift) may have changed coastal boundaries,

It is important to note that these masks are derived from the source data at specific time period and are static. However, ice shelves and tidewater glaciers are constantly changing, calving icebergs, or surging into the ocean. So, these masks are meant as a general climatological surface mask, not for specific mapping of features.

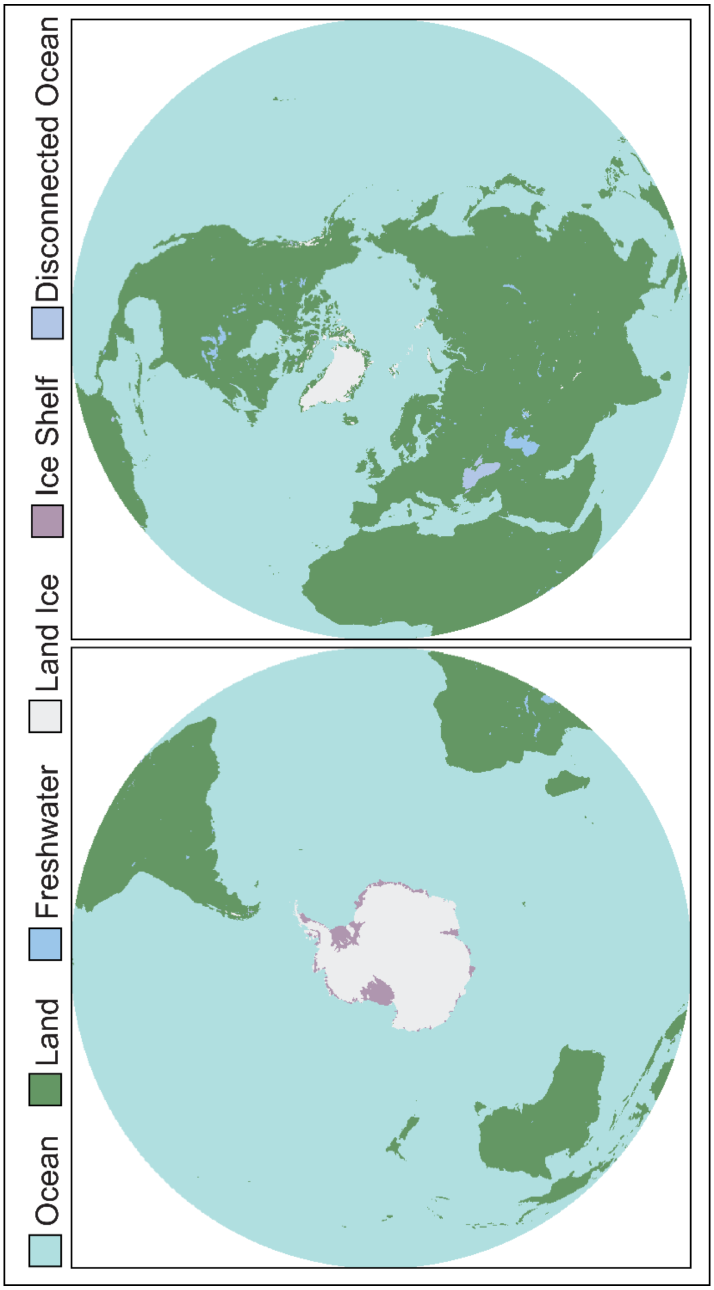

Figure 1. *Northern Hemisphere (top) and Southern Hemisphere (bottom) surface mask with color-coded surface types. As an example, the Black Sea is designated as "Disconnected Ocean" and the Caspian Sea is designated as "Freshwater" (Lake).*

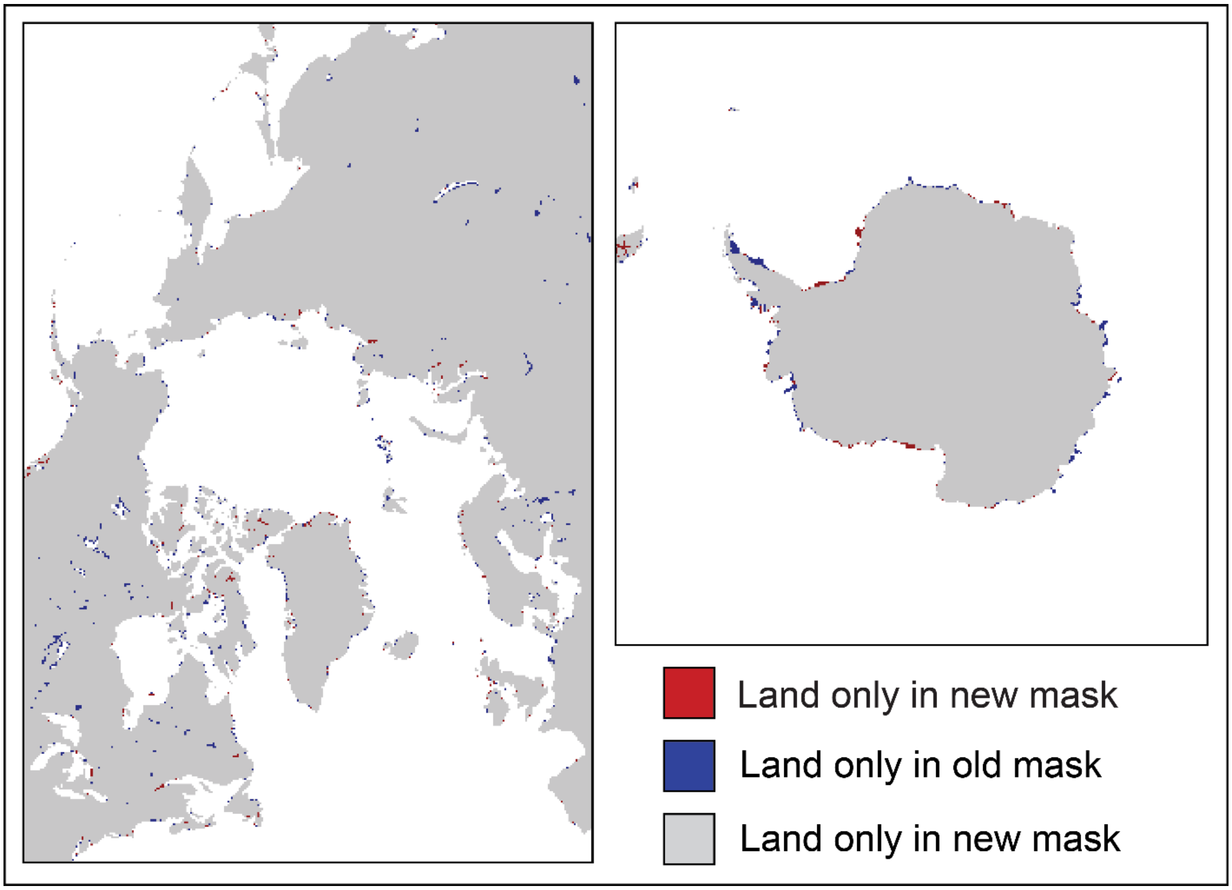

Figure 2. *Comparison of new and old polar stereographic 25 km land mask. For this comparison, ice shelves and ice sheets are considered "land".*

Sea Ice Region Masks

Background

This section presents a set of new region masks for sea ice applications (NSIDC-0780; Meier and Stewart, 2023). The motivation for new region masks is to provide greater provenance, adhere more to broadly accepted region definitions, and to provide masks on different grids and spatial resolutions. The defining philosophy is to keep some consistency with the previous region masks while following modern standards.

Sea ice region masks have been developed to assist in analyzing sea ice characteristics at more discrete scales than the entire Arctic or Antarctic. For example, for sea ice, there are distinct regional differences in variability and trends in different parts of the Arctic and Antarctic. By analyzing regions individually, one can better discern how the sea ice cover evolves, both seasonally and interannually. Such regional variability also has impact for ecosystem studies and human activities. Low ice in regions of polar bear habitat is critical for diagnosing the species health. Local communities need information in their specific region as opposed to hemispheric totals. Shipping vessels navigate along defined routes through selected regions.

Region masks were originally defined by scientists at NASA Goddard for use with ESMR data in the Arctic (Parkinson et al., 1987) and the Antarctic (Zwally et al., 1983). These regions were expanded for use with the NSIDC polar stereographic grids used for SMMR. The SMMR grid extended further south than ESMR, so the Sea of Japan was added to the Sea of Okhotsk region and a new Gulf of St. Lawrence region was added (Gloersen et al., 1992). These Goddard region masks have been used in several sea ice extent and area time series analyses of SMMR, SSMI, and SSMIS data (e.g., Parkinson, 2022; Zwally et al., 2002; Parkinson et al., 1999). The masks were defined only on the 25 km NSIDC polar stereographic grid.

The NASA masks are provided by the **NSIDC DAAC** (https://nsidc.org/data/user-resources/help-center/does-nsidc-have-tools-extract-and-geolocate-polar-stereographic-data#anchor-7) and are used to create regional timeseries of total area and extent for the NSIDC Sea Ice Trends and Climatologies from SMMR and SSM/I-SSMIS, Version 3 (NSIDC-0192) (Stroeve and Meier, 2018).

The NASA Arctic mask was extended by Meier et al. (2007), splitting the Arctic Ocean region into coastal seas (Beaufort, Chukchi, East Siberian, and Laptev Seas) and the Barents and Kara Seas were split into individual regions. The boundaries of these subdivided regions were manually derived within the 25 km polar stereographic grid by outlining "regions of interest" polygons in ENVI. The boundaries between regions were defined in an ad hoc manner using straight lines in the polar stereographic grids. The longitude boundaries were generally consistent with accepted definitions, but they were not precisely determined. The northern boundaries were straight lines in the polar stereographic grid that roughly corresponded to 80° N latitude.

The Meier mask was adapted for the NSIDC Multisensor Analyzed Sea Ice Extent – Northern Hemisphere (MASIE-NH) product (USNIC and NSIDC, 2010). The MASIE mask was created by manually drawing polygons in GIS that roughly corresponded to the Meier boundaries. However, the MASIE mask is not an exact mapping of the Meier mask.

While the Arctic masks have evolved over time, the Antarctic masks have been consistent, with five regions delineated by simple longitude boundaries (Zwally et al., 1983). More recently, Raphael and Hobbs (2014) suggested alternate longitude boundaries that better encompasses spatially correlated variability in the regions, which have been included in this product.

Methodology

The primary reference for the Arctic regions is the International Hydrographic Organization (IHO) Limits of Oceans and Seas (IHO, 1953), which provides latitude and longitude bounding vertices for global oceans and seas. These have been digitized into machine-readable form (IHO and Sieger, 2012). A digital map was created by Fourcy and Loverlec (2013).

While these proved useful references, the new region masks relied on these primarily for general guidance for two reasons. First, some regions do not fit well with sea ice applications. For example, the IHO definition for the northern boundary of the Beaufort Sea region is line from St. Patrick Island to Point Barrow, yielding a much smaller area than has been used in the previous masks. Such a small area is not particularly useful for sea ice because it would miss much of the sea ice dynamics that result from the Beaufort Gyre atmospheric circulation.

The second reason is that the latitude and longitude vertices at land boundaries are defined at the coastal boundary of the IHO map. However, different projections and grids may not be consistent with the IHO coast and would yield artifacts along the coast that would need to be corrected.

Thus, the approach for the new region masks is to follow the IHO boundaries where they make sense for sea ice, deviate where necessary to provide greater utility and to be more consistent with the previous masks. At the coast, the approach is to define vertices inland from the coast to provide flexibility with a variety of land masks.

Vertex coordinates were manually selected using the IHO coordinates as a guideline where appropriate, but with points offset inward onto land. This allows the regions to overlap land and should provide valid region points regardless of the land mask use. However, in some places, such as the Canadian Archipelago, small islands limited how far inland the vertex could be placed; thus, it is possible that some land masks may result in artifacts (e.g., ocean grid cells with and undefined region).

For simplicity, lines of constant latitude and longitude were used whenever reasonable. The northern boundary of the Beaufort, Chukchi, and East Siberian Seas was set at 76.09° N, corresponding to the IHO latitude of the northeast Beaufort Sea boundary on the coast of St. Patrick's Island. This is southward of the previous mask boundaries in Meier et al. (2007), so these coastal seas have a smaller area than the previous masks (see Appendix for region areas).

In the Antarctic, the Goddard regions were largely unchanged except slight diversions to avoid crossing into the Ronne-Filchner Ice Shelf. A region mask based on the Raphael-Hobbs regions was also created.

The vertices were saved as a text file and input into QGIS in latitude-longitude projection to create polygons. The polygons were then rasterized into a grid and then reprojected into the polar stereographic and EASE2 grids at the different grid resolutions.

Product Description

The primary format for the region masks NetCDF4. Within each NetCDF4 file, regions are provided as plain masks – i.e., just the regions ("sea_ice_region") – and with the new land mask overlaid on the regions ("sea_ice_region_surface_mask"). The plain masks allow users to overlay whatever mask they wish, while the land-region layer provides a convenient built-in mask (Figure 3). In the southern hemisphere, both the NASA Goddard ("_NASA") and the Raphael and Hobbs ("_RH") masks are provided (Figure 4). The same grids (PS and EASE2) and resolutions are provided as for the land masks (Table 2). The values for the regions are given in Table 3.

The mask information is provided in a couple other formats as well. First, the source shapefiles are provided. This provides convenience for GIS users as well as provenance for the gridded NetCDF4 files. It is important to note that the GIS shapefiles are projected in latitude-longitude. If users wish to remap the files into a different projection, they must first "densify" the polygons, adding more vertices to assure that the polygon lines follow the intended coordinates. For example, the vertices mark only points needed to define the polygons in latitude-longitude, with straight lines between the vertices. If reprojection is done without densification, the straight lines will be maintained in the new projection and they will not match the coordinates of the original lines.

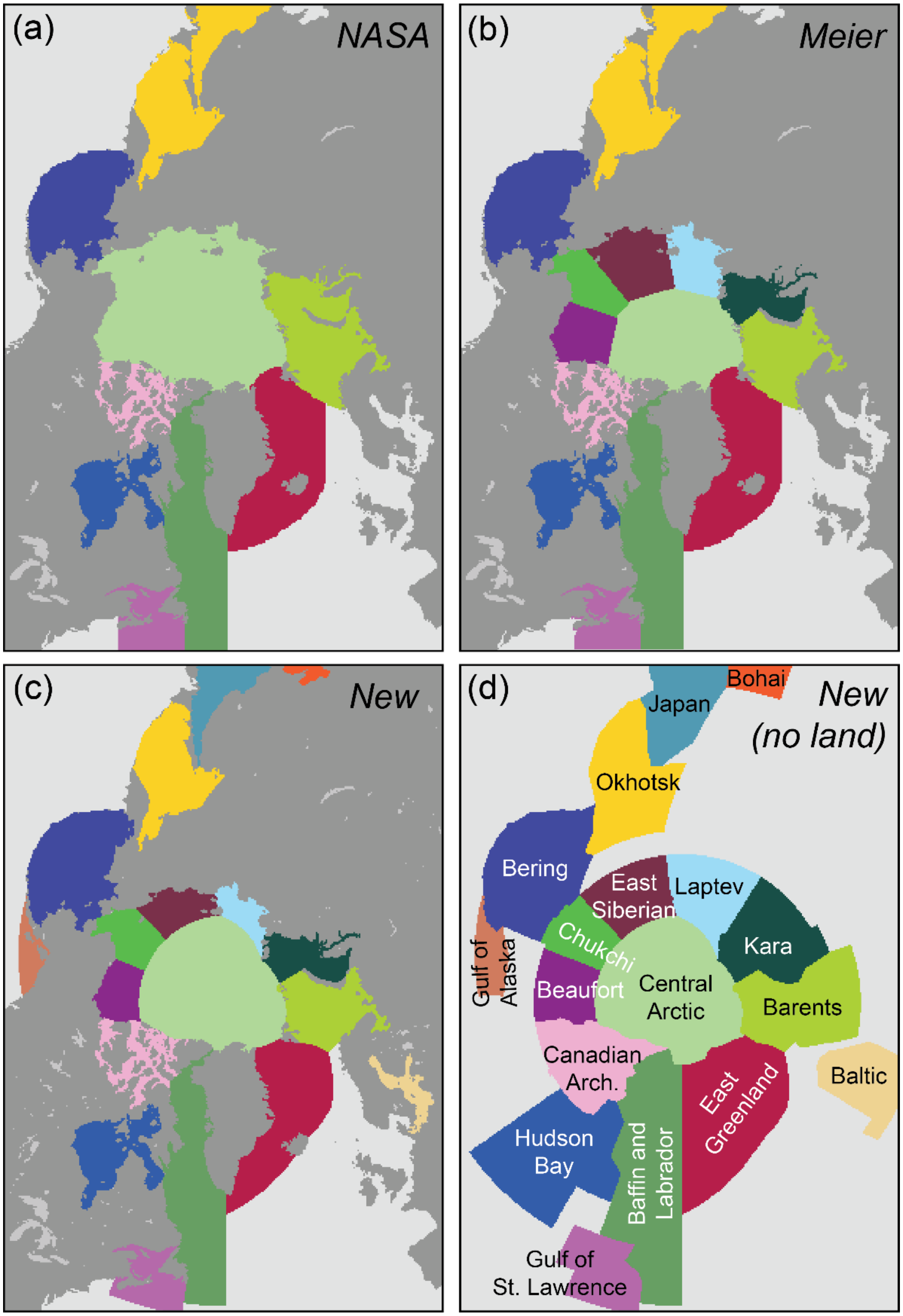

Figure 3. *Northern Hemisphere region masks for (a) old NASA (SMMR and SSMI/SSMIS), (b) old Meier, (c) new with land mask, and (d) new without land mask and with regions labeled.*

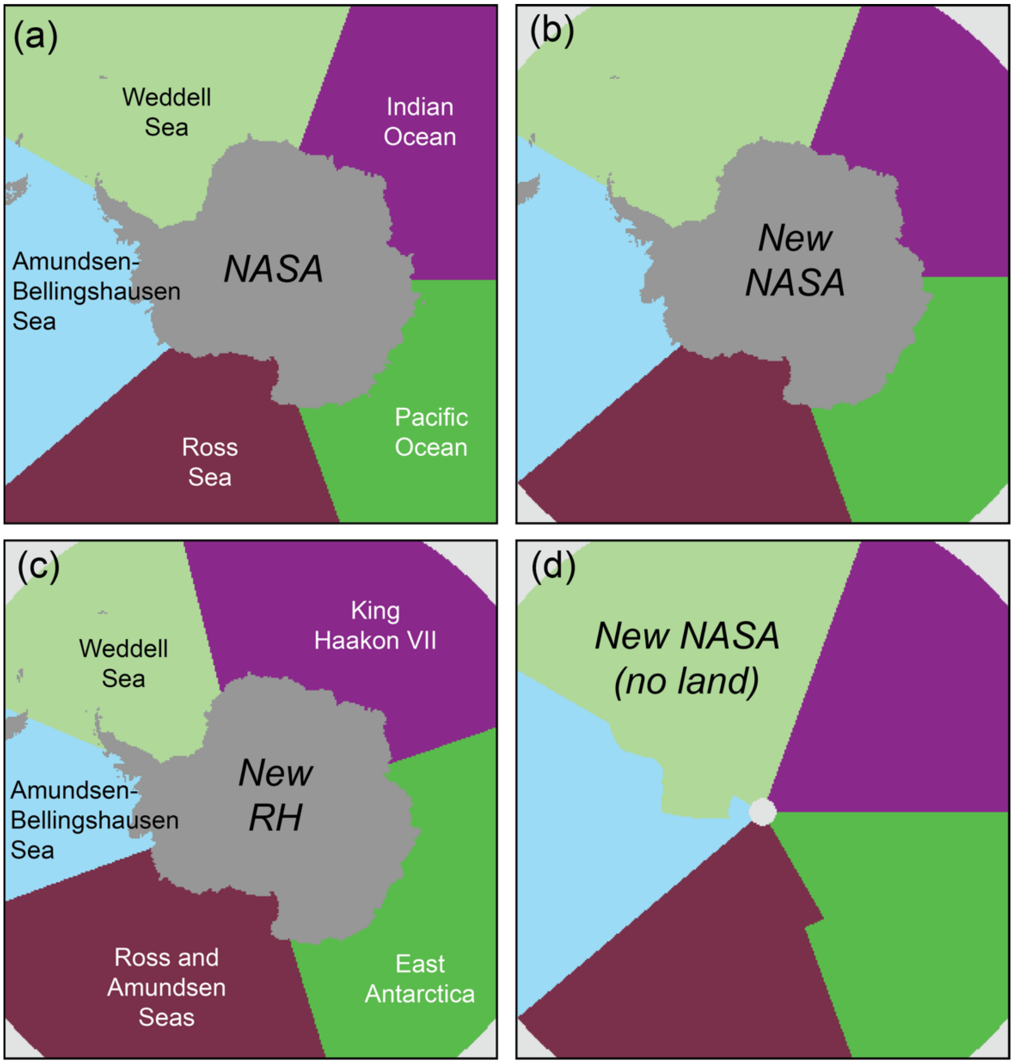

Figure 4. *Southern Hemisphere regions for (a) old NASA, (b) new NASA, (c) new Raphael and Hobbs (RH), and (d) new NASA without the land mask.*

In addition to the shapefile, the coordinates of all vertices are provided as comma-delimited (CSV) text files. These contain the values of the vertices for the polygons. A column is included that includes explanations of the points, including where IHO conventions were followed and where there are common points between different regions.

Usage Guidelines and Summary

The surface masks and region masks described here were developed primarily for sea ice applications. They may also be useful for many other research applications such as oceanographic studies, atmospheric circulation, and terrestrial and marine ecosystems. However, users may find other masks or maps more applicable to their individual studies.

Table 3. *Flag values in the new region mask files. Values of 30-35 are included in only in the "seaice_region_surface_mask". "Off Earth" only used for EASE2 grids.*

Value	**Northern Hemisphere**	**Southern Hemisphere NASA**	**Southern Hem. Raphael & Hobbs**
0	Non-Region Ocean	Non-Region Ocean	Non-Region Ocean
1	Central Arctic	Weddell Sea	Weddell Sea
2	Beaufort Sea	Indian Ocean	King Haakon VII Sea
3	Chukchi Sea	Pacific Ocean	East Antarctica
4	East Siberian Sea	Ross Sea	Ross & Amund. Seas
5	Laptev Sea	Amund.-Bell. Seas	Amund.-Bell. Seas
6	Kara Sea		
7	Barents Sea		
8	East Greenland Sea		
9	Baffin and Labrador Seas		
10	Gulf of St. Lawrence		
11	Hudson Bay		
12	Canadian Archipelago		
13	Bering Sea		
14	Sea of Okhotsk		
15	Sea of Japan		
16	Bohai and Yellow Seas		
17	Baltic Sea		
18	Gulf of Alaska		
30	Land	Land	Land
32	Freshwater	Freshwater	Freshwater
33	Land Ice	Land Ice	Land Ice
34	Ice Shelf	Ice Shelf	Ice Shelf
35	Disconnected Ocean	Disconnected Ocean	Disconnected Ocean
40	Off Earth	Off Earth	Off Earth

There are a few caveats that users should keep in mind when using these products. The land mask uses a 50% threshold to define land, which may not be optimal for some studies. Because the focus is on sea ice, less attention was paid to non-ocean surface waters. In general, the mapping of such waters should be reasonable, but is likely not optimal for specific research in such areas. Ice shelves have been mapped based on the sources at hand; ice shelves are mapped only for Greenland and Antarctica; even in those regions, not all maritime glacial ice is mapped. And the ice shelf designation was derived from a static data set for particular time. Ice shelves are always changing – calving off icebergs or surging forward. So, the ice shelf locations in these products may be different than is seen today.

As noted above, the region definitions are somewhat arbitrary. The IHO boundaries have been employed where reasonable, but the focus is on utility for sea ice applications and keeping reasonable consistency with earlier masks. The boundaries are purely geographical, corresponding to the coastline and/or latitude and longitude boundaries. They are not intended to correspond to any geophysical characteristics (e.g., bathymetry, ocean currents, atmospheric circulation, habitat, etc.).

The region labels also do not meet NetCDF compliance with CF-conventions. This is because the CF standard_name field for regions do not encompass all of the regions in the product, and because CF conventions to do not consistently define how combined regions (e.g., Amundsen-Bellingshausen Seas) in the product should be described.

The region masks have been designed primarily for use in the provided NSIDC Polar Stereographic and EASE2 grids. A vector shapefile was used as the initial source and is provided as part of the product. However, users should be careful in use of the shapefile if reprojection is required. As noted above, the shapefile needs to be densified (vertices added) to the desired resolution so that the polygon shapes are consistent in the new projection.

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Appendix

This appendix provides supplementary information, including a comparison of the region areas (in km^2) between the older NASA and Meier masks and the new masks. It also contains tables that compare the region areas for the masks at different resolutions.

The EASE2 Northern and Southern Hemisphere regions are also provided to complement the polar stereographic figures in the main content.

Region	New EASE2	New PS	NASA PS	Meier PS
Non-Region Ocean	130.911	14.502	14.815	14.853
Central Arctic	4.566	4.574		3.225
Beaufort Sea	0.692	0.688		0.940
Chukchi Sea	0.760	0.758		0.830
East Siberian Sea	0.715	0.719		1.304
Laptev Sea	0.495	0.493		0.872
Arctic Ocean	*7.228*	*7.412*	*7.158*	*7.171*
Kara Sea	0.897	0.893		0.919
Barents Sea	1.542	1.538		1.675
Kara and Barents	*2.439*	*2.431*	*2.602*	*2.594*
East Greenland Sea	2.562	2.570	2.937	2.933
Baffin and Labrador Seas	2.687	2.697	2.780	2.765
Gulf of St. Lawrence	0.681	0.675	0.715	0.691
Hudson Bay	1.246	1.246	1.234	1.234
Canadian Archipelago	0.823	0.815	0.751	0.761
Bering Sea	2.305	2.293	2.242	2.231
Sea of Okhotsk	1.587	1.589		
Sea of Japan	1.002	0.621		
Okhotsk and Japan	*2.589*	*2.210*	*2.208*	*2.208*
Bohai and Yellow Seas	0.473	0.112		
Baltic Sea	0.386	0.388		
Gulf of Alaska	0.360	0.356		
Freshwater (Lakes)	1.056	0.520	0.336	0.336
Disconnected Ocean	0.608	0.102		
Land, Ice-Free	97.273	35.317		
Land Ice	2.209	2.193		
Floating Ice Shelf	0.004	0.002		
Total Land	*99.486*	*37.512*	*37.883*	*37.883*
Off Earth	68.163			

Table A1. Northern Hemisphere grid areas, in 10^6 km^2, for legacy 25 km NASA and Meier polar stereographic (PS) grids and the new 25 km polar stereographic and EASE2 grids. Shaded rows are sum of two or more areas to match regions in the NASA and Meier PS fields. “Disconnected Ocean” are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are “cut off” from the ocean. “Total Land” includes ice-free land, land ice, and floating ice shelves. “Off Earth” refers to the area outside the circular hemispheric earth projection within the square EASE2 grid.

Region	New EASE2	New PS	NASA PS
Non-Region Ocean	146.658	1.204	
Weddell Sea	14.278	11.991	12.498
Indian Ocean	10.984	8.607	9.044
Pacific Ocean	10.562	7.695	7.774
Ross Sea	13.099	9.551	9.614
Amundsen-Bellingshausen Sea	11.590	7.946	7.996
Freshwater (Lakes)	0.187	0.000	
Disconnected Ocean	0.041	0.014	
Land, Ice-Free	34.476	0.098	
Land Ice	12.389	12.368	
Floating Ice Shelf	1.575	1.581	
Total Land	*48.440*	*14.047*	*14.130*
Off Earth	68.163		

Table A2. Southern Hemisphere grid areas, in 10^6 km^2, for legacy 25 km NASA and Meier polar stereographic (PS) grids and the new 25 km polar stereographic and EASE2 grids. Shaded rows are sum of two or more areas to match regions in the NASA PS fields. "Disconnected Ocean" are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are "cut off" from the ocean. "Total Land" includes ice-free land, land ice, and floating ice shelves. "Off Earth" refers to the area outside the circular hemispheric earth projection within the square EASE2 grid.

Region	25 km	12.5 km	6.25 km	3.125 km
Non-Region Ocean	130.911	130.564	130.361	130.284
Central Arctic	4.566	4.573	4.573	4.576
Beaufort Sea	0.692	0.689	0.688	0.688
Chukchi Sea	0.760	0.756	0.756	0.756
East Siberian Sea	0.715	0.716	0.716	0.718
Laptev Sea	0.495	0.503	0.502	0.500
Kara Sea	0.897	0.892	0.898	0.899
Barents Sea	1.542	1.540	1.539	1.538
East Greenland Sea	2.562	2.567	2.568	2.577
Baffin and Labrador Seas	2.687	2.689	2.694	2.704
Gulf of St. Lawrence	0.681	0.681	0.682	0.681
Hudson Bay	1.246	1.241	1.242	1.241
Canadian Archipelago	0.823	0.841	0.846	0.850
Bering Sea	2.305	2.291	2.288	2.289
Sea of Okhotsk	1.587	1.586	1.585	1.584
Sea of Japan	1.002	0.998	0.998	0.998
Bohai and Yellow Seas	0.473	0.474	0.474	0.474
Baltic Sea	0.386	0.385	0.383	0.382
Gulf of Alaska	0.360	0.358	0.356	0.356
Freshwater (Lakes)	1.056	1.213	1.365	1.527
Disconnected Ocean	0.608	0.578	0.588	0.568
Land, Ice-Free	97.273	97.040	96.815	96.585
Land Ice	2.209	2.250	2.292	2.327
Floating Ice Shelf	0.004	0.004	0.004	0.004
Total Land	*99.486*	*99.295*	*99.111*	*98.916*
Off Earth	68.163	68.571	68.788	68.895

Table A3. Northern Hemisphere EASE2 grid areas, in 10^6 km^2, at different resolutions. "Disconnected Ocean" are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are "cut off" from the ocean. "Total Land" includes ice-free land, land ice, and floating ice shelves. "Off Earth" refers to the area outside the circular hemispheric earth projection within the square EASE2 grid.

Region	**25 km**	**12.5 km**	**6.25 km**	**3.125 km**
Non-Region Ocean	146.658	146.311	146.132	146.031
Weddell Sea (NASA)	14.278	14.275	14.273	14.273
Indian Ocean (NASA)	10.984	10.983	10.983	10.983
Pacific Ocean (NASA)	10.562	10.562	10.562	10.562
Ross Sea (NASA)	13.099	13.096	13.097	13.098
Amund.-Bell. Sea (NASA)	11.590	11.593	11.595	11.612
Weddell Sea (RH)	9.590	9.593	9.589	9.588
King Haakon VII (RH)	13.689	13.681	13.682	13.682
East Antarctica (RH)	14.020	14.019	14.020	14.020
Ross and Amundsen Seas (RH)	16.214	16.212	16.213	16.214
Amund.-Bell. Sea (RH)	7.000	7.004	7.008	7.025
Freshwater (Lakes)	0.187	0.214	0.241	0.268
Disconnected Ocean	0.041	0.045	0.056	0.056
Land, Ice-Free	34.476	34.379	34.299	34.244
Land Ice	12.389	12.390	12.392	12.393
Floating Ice Shelf	1.575	1.581	1.581	1.584
Total Land	*48.449*	*48.350*	*48.272*	*48.220*
Off Earth	68.163	68.571	68.788	68.895

Table A4. Southern Hemisphere EASE2 grid areas, in 10^6 km^2, at different resolutions. "Disconnected Ocean" are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are "cut off" from the ocean. "Total Land" includes ice-free land, land ice, and floating ice shelves. "Off Earth" refers to the area outside the circular hemispheric earth projection within the square EASE2 grid.

Region	**25 km**	**12.5 km**	**6.25 km**	**3.125 km**
Non-Region Ocean	14.502	14.502	14.509	14.513
Central Arctic	4.574	4.570	4.573	4.576
Beaufort Sea	0.688	0.689	0.689	0.688
Chukchi Sea	0.758	0.756	0.756	0.757
East Siberian Sea	0.719	0.717	0.716	0.719
Laptev Sea	0.493	0.501	0.501	0.501
Kara Sea	0.893	0.899	0.898	0.900
Barents Sea	1.538	1.539	1.539	1.538
East Greenland Sea	2.570	2.564	2.570	2.576
Baffin and Labrador Seas	2.697	2.696	2.698	2.705
Gulf of St. Lawrence	0.675	0.675	0.676	0.676
Hudson Bay	1.246	1.244	1.239	1.240
Canadian Archipelago	0.815	0.836	0.846	0.850
Bering Sea	2.293	2.290	2.288	2.291
Sea of Okhotsk	1.589	1.588	1.586	1.585
Sea of Japan	0.621	0.621	0.619	0.619
Bohai and Yellow Seas	0.112	0.113	0.113	0.113
Baltic Sea	0.388	0.385	0.383	0.382
Gulf of Alaska	0.356	0.356	0.356	0.356
Freshwater (Lakes)	0.520	0.607	0.705	0.818
Disconnected Ocean	0.102	0.091	0.091	0.070
Land, Ice-Free	35.317	35.217	35.087	34.956
Land Ice	2.193	2.202	2.217	2.229
Floating Ice Shelf	0.002	0.004	0.004	0.004
Total Land	*37.612*	*37.510*	*37.396*	*37.256*

Table A5. Northern Hemisphere Polar Stereographic grid areas, in 10^6 km^2, at different resolutions. "Disconnected Ocean" are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are "cut off" from the ocean. "Total Land" includes ice-free land, land ice, and floating ice shelves.

Region	**25 km**	**12.5 km**	**6.25 km**	**3.125 km**
Non-Region Ocean	1.204	1.210	1.211	1.211
Weddell Sea (NASA)	11.991	11.987	11.986	11.988
Indian Ocean (NASA)	8.607	8.606	8.605	8.605
Pacific Ocean (NASA)	7.695	7.690	7.690	7.688
Ross Sea (NASA)	9.551	9.547	9.548	9.548
Amund.-Bell. Sea (NASA)	7.946	7.947	7.947	7.959
Weddell Sea (RH)	8.604	8.603	8.600	8.602
King Haakon VII (RH)	11.070	11.064	11.064	11.064
East Antarctica (RH)	9.581	9.576	9.576	9.574
Ross and Amundsen Seas (RH)	12.146	12.139	12.141	12.141
Amund.-Bell. Sea (RH)	4.390	4.395	4.395	4.407
Freshwater (Lakes)	0.000	0.000	0.001	0.001
Disconnected Ocean	0.014	0.016	0.017	0.005
Land, Ice-Free	0.098	0.096	0.097	0.095
Land Ice	12.368	12.373	12.371	12.372
Floating Ice Shelf	1.581	1.583	1.583	1.583
Total Land				

Table A6. Southern Hemisphere Polar Stereographic grid areas, in 10^6 km^2, at different resolutions. “Disconnected Ocean” are grid cells that have a connection to the ocean (and thus are technically ocean), but whose connection is too small to be resolved by the grid and thus are “cut off” from the ocean. “Total Land” includes ice-free land, land ice, and floating ice shelves.

Figure A1. *New Northern Hemisphere regions on the EASE2 Grid. Regions are color-coded as in Figure 3.*

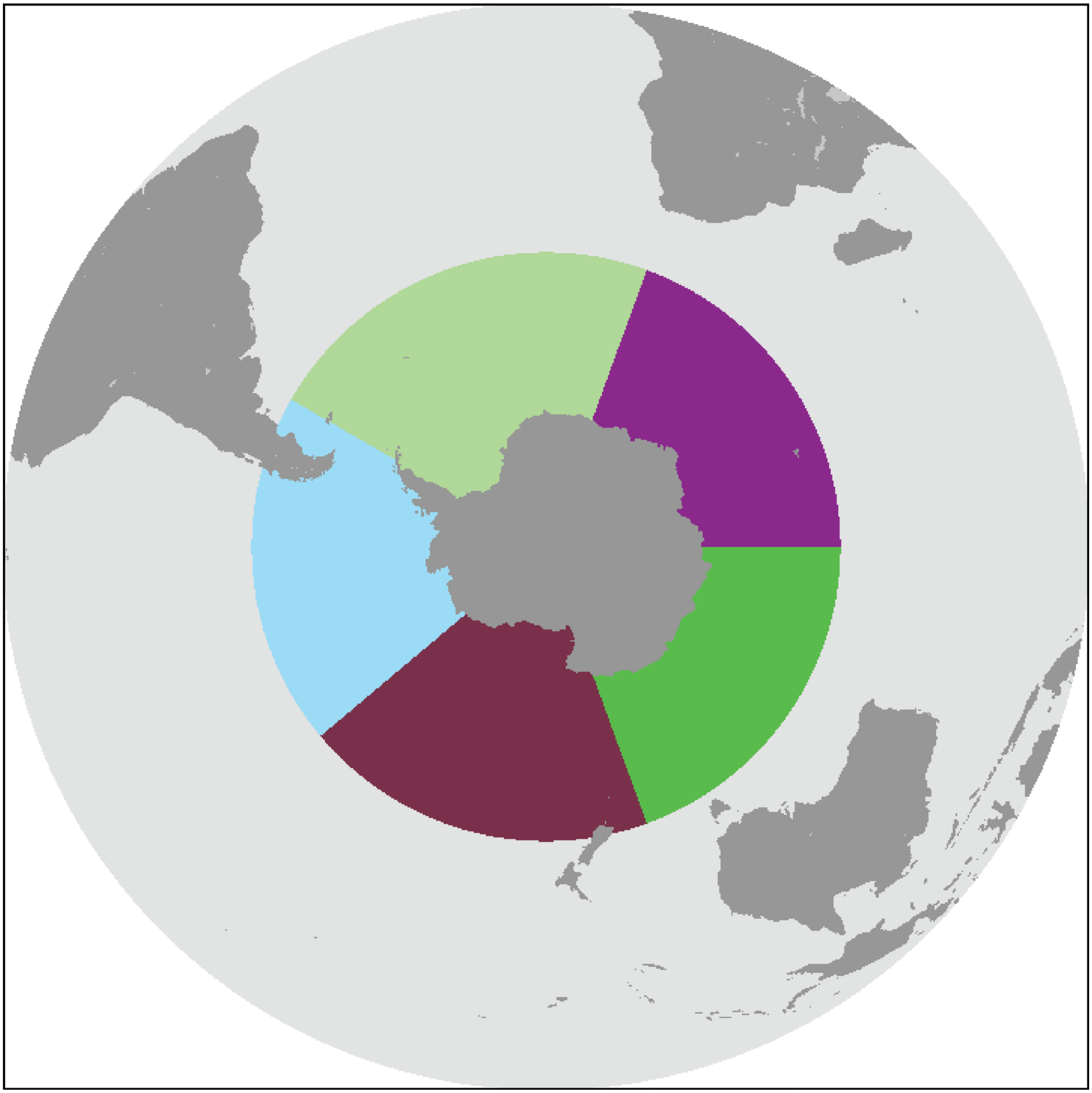

Figure A2. *New Southern Hemisphere regions on the EASE2 Grid. Regions are color-coded as in Figure 4.*