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Declassified Intelligence Satellite Photography (DISP) Coverage of Antarctica

Robert Bindschadler and Wendy Seider

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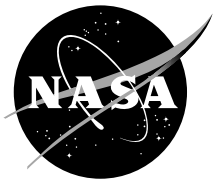

Declassified Intelligence Satellite Photography (DISP) Coverage of Antarctica

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ABSTRACT

This report summarizes the results of a nine-week summer project examining all Declassified Intelligence Satellite Photography (DISP) of Antarctica. It was discovered that the data were collected in three separate missions during 1962 and 1963. The first two missions covered only the coastal areas, while the third mission covered the entire continent. Many of the 1782 frames collected were cloudy. This is especially true of West Antarctica. An optimal set of photographs covering the entire Antarctic coastline is identified along with some examples that show changes in the coastline which have occurred since the early 1960s.

INTRODUCTION

On February 22, 1995, the President of the United States ordered declassification of satellite intelligence photography collected from 1960 through 1972. These photographs comprise a unique record of the condition of the planet in the years prior to civilian spaceborne imaging. Because the desire to detect environmental change is usually hampered by the relatively short time period of available observations and by natural variability, it is expected that this collection of early photographs will make a significant contribution to efforts to identify and quantify environmental change.

This report summarizes the results of a nine-week summer project, undertaken in 1998, at NASA Goddard Space Flight Center to study the collection of declassified intelligence satellite photography (DISP) of Antarctica. The goals of the project were:

- identify all DISP data collected of the Antarctic continent;
- determine the individual missions employed to collect the photography;
- assess the cloud cover present during those missions;
- acquire an optimal set of DISP data to prepare a "snapshot" of the ice sheet; and
- investigate possible changes in the ice sheet which have occurred during the 35 years since the DISP data were collected.

All goals were met either wholly, or in part.

BACKGROUND

In 1960, during the height of the Cold War and immediately following the failure to reliably collect intelligence photography from high-altitude U2 aircraft, President Eisenhower initiated a program to collect photography from space for intelligence purposes (McDonald, 1995) The sophistication and quality of the satellite-borne camera systems rapidly improved, driving an increased reliance of the intelligence community on the collection of satellite photography. As a result, numerous spacecraft were launched between 1960 and 1972 under the code names Corona, Argon, and Lanyard and a total of more 2,000,000 feet of film was collected. A brief history of these systems, their camera system parameters, dates of operation, and the number of photographs produced is available on the Word Wide Web (http://edcwww.cr.usgs.gov/Webglis/glisbin/guide.pl/glis/hyper/guide/disp).

The only Antarctic data collected were part of the Argon program (also designated as KH–5 satellites) which operated from February 1961 until August 1964. The Argon program consisted of 12 separate missions, only half of which were even partially successful. The mission objective was primarily cartographic, collecting over 38,000 frames on 5-inch wide black-and-white film at a nominal scale of 1:4,250,000. Each frame was nominally 500 km x 500 km at a ground resolution of 140 meters. These photographs were used extensively in the preparation of the Polar Regions Atlas (CIA, 1978).

As a result of the declassification order, each DISP negative was copied with the original and one copy delivered to the National Archives and the second copy delivered to the USGS Eros Data Center (EDC). EDC ingested metadata on the parameters of each frame into their web-based Global Land Information System (GLIS). This system allows users to search for DISP data by geographic location, acquisition date, mission number, or ID number. The search results specify an ID number for each frame, the mission, revolution and frame numbers, the acquisition date, the camera type and its resolution. Browse images can be viewed along with a mapped location of the frame and various metadata. Data products (prints, negatives, and transparencies) also can be ordered.

DATA SEARCH RESULTS

In our study, the search was conducted for all regions south of 60° S in a series of eight octants (each 45 degrees of longitude). The search results were then compiled into a single list (Table 1). Any individual photograph in Table 1 is specified by an ID number of the form:

DS0**mmmm**A**rrr**MC**fff**

where **mmmm** is the mission number, **rrr** is the revolution number, and **fff** is the frame number. The 'DS' denotes declassified satellite, 'A' denotes the Argon program, and 'MC' denotes the mapping and cartography purpose of the mission.

The search yielded a total of 1782 photographs of Antarctica collected during three Argon missions. Table 2 indicates the distribution of phootgraphs among the three missions. The large number of photographs is somewhat deceptive. Successive frames overlapped approximately 70% to facilitate the Argon program objective of mapping. DISP data of other missions overlapped approximately 10%. Also there are large areas of ocean contained within the search area, photos of which contribute little to the study of the ice sheet. Figures 1, 2, and 3a show the geographic coverage of each mission. Due to the larger number of revolutions in Mission 9050A, Figure 3 is further divided into three parts (b–d) to aid identification of individual revolutions. Below, each mission is discussed separately.

Mission 9034A

This mission was the first attempt to map the Antarctic continent in a systematic fashion, let alone from space. The collections were made during the late austral autumn and much of the interior of the ice sheet was dark. Thus, each revolution stopped coverage at approximately 71° S. Figure 1 shows the pattern of revolutions in this mission. The browse imagery confirms that the southern edge of each revolution's southernmost frame is extremely dark, negating any value for more southerly collections.

The photographs from this mission do cover the entire Antarctic coastline, with the exception of the Ross and Ronne/Filchner Ice Shelves. Visual review of these photographs, however, indicates that most of the coastline was extremely cloudy during this period. The only notable exception is the region between 64° E and 111° E longitude.

Mission 9058A

This second mission also was conducted during a period when the southern interior of the ice sheet was dark. Again, coverage only included the coastal perimeter of the continent. Fewer revolutions were included in this mission, but most of the coast was photographed (Figure 2). Fortunately, clouds were far less prevalent, increasing the usefulness of this photographic set in study of the ice sheet, however, the austral season was late winter and sea ice adjacent to the coast was more extensive. The presence of sea ice made it difficult to determine the boundary between it and either ice shelf or shore-fast ice. Figure 5 includes examples of photographs from this mission.

Mission 9059A

This mission took place in the austral spring, when the entire continent was sunlit. Revolutions extended across the entire continent producing a much larger data set (Figure 3). Some of these photographs have already been used for scientific research (CNER, 1998; Bindschadler and Vornberger, 1998, Jezek, 1998; Paulsen and Wilson, 1998).

Time limitations and cloud movements made the production of a mosaic of the ice sheet impractical. Nevertheless, two focused studies were undertaken to glean from these data some examples of how they might be used for Antarctic research.

West Antarctic Ice Sheet Study

Short-term changes have been documented in the West Antarctic ice sheet (Bindschadler and others, 1998). This ice sheet lies primarily in the Western Hemisphere and is separated from the East Antarctic ice sheet by the Transantarctic Mountains and Pensacola Mountains. All DISP data of the West Antarctic ice sheet were examined. It was found that persistent cloud cover obscured almost the entire ice sheet. The only exceptions were the central and eastern portions of the Ross Ice Shelf, extending into the interior along the Transantarctic Mountains.

Coastline Study

The coastline of the Antarctic ice sheet is usually defined as the seaward limit of ice flowing from the inland ice sheet. This includes floating ice, called ice shelves, fed by the ice sheet, but excludes sea ice which is formed by freezing sea water. Most of the sea ice is no thicker than a few meters and is seasonal, disappearing each summer.

However, there are areas where sea ice survives the summer melt season and this “fast ice” can grow to thicknesses of tens of meters, complicating the definition of the ice-sheet boundary.

Episodic iceberg calving constantly changes the position of the ice-sheet coastline. Most often the calving is modest and relatively steady ice flow eventually restores the coastline to a quasi-static position, beyond which the exposure of ice to oceanic currents leads to subsequent calving. Recently, however, a number of ice shelves have experienced more severe retreat with little likelihood of recovery (Doake and Vaughan, 1991; Rott and others, 1996; Vaughan and Doake, 1996).

Based on visual review of browse images, an optimal set of 44 DISP photographs was identified that covered the entire Antarctic coast (Table 3). Spatial continuity was verified by downloading browse images from GLIS in compressed “jpeg” format (450 pixels x 450 pixels), printing each photograph, and constructing a paper mosaic of the coastline. These photographs were then ordered in the form of 4" x 5" negatives from EDC.

Comparisons of the 1962-63 coastline with a more recent coastline was accomplished using the image mosaic produced from Advanced Very High Resolution Radiometer (AVHRR) data by the U.S. Geological Survey. This mosaic is available in digital form at 1-km resolution on the World Wide Web and in paper form (Ferrigno and others, 1996). It is composed of pieces from 38 separate images with acquisition dates ranging from January 18, 1980 to January 15, 1994.

The AVHRR mosaic is projected in a polar stereographic coordinate system while the DISP photographs are collected at satellite nadir, which leads to a natural space oblique Mercator projection. Coregistration of the two data sources was done digitally using image processing software (trade name PCI EASI/PACE) by selecting common points. Initially, browse images of the DISP data were used. These were at roughly the same 1-km resolution as the AVHRR data, but the degraded spatial detail of the browse images made it extremely difficult to identify the same points in the DISP and AVHRR data.

While awaiting delivery of data from EDC, Jane Ferrigno of the U.S. Geological Survey made many of the same data available to us. Four-inch by five-inch negatives were scanned at 600 dpi to create a digital version of each frame at approximately 200 m spatial resolution. Scanned negatives contained much more detail than scanned contact prints made from the negatives. When the EDC order arrived, all negatives were scanned at the above resolution.

The experience with the browse images also identified limitations of the AVHRR mosaic. The radiometric enhancement of the AVHRR mosaic, while improving the subtle topographic details of the ice-sheet interior, saturated many coastal features. This, combined with the fact that the illumination geometry of the AVHRR data and DISP photographs were frequently different, complicated the identification of suitable tie points.

Tie points were most often mountains or islands located near the transition between grounded and floating ice, or peculiar segments of the coastline. Some DISP/AVHRR pairs contain substantially more tie points than others depending on the amount of cloud cover and the number of visible features in a given image. A few photographs contained tie points only in a limited area or only along the coastline. Typically 15 to 20 tie points were selected and the DISP image was linearly warped to match the AVHRR image. Higher order warping should not have been required given the projections of the two source images. Table 4 lists the numbers of tie points and the mean residuals of the coregistration for the fourteen photographs used in this coastline study.

Coregistration was checked two ways: one quanitiative, and the other qualitative. First, the software calculated the residual between the location of each tie point in the AVHRR image and the warped position in the DISP image. If residual errors of any tie point exceeded 2.5 km in either coordinate direction, those tie points with the largest errors were omitted and other tie points were selected. The second check was applied by superimposing the two images and flickering between the two. This method was effective at confirming the superposition of both prominent features, often associated with tie points, and of the junction between the grounded ice (generally a rough surface) and the floating ice (a much smoother surface).

Once the coregistration passed these checks, the coastline in the two images was examined for changes. One means used for this analysis was to assign the AVHRR and DISP images different colors on the computer display. The presence of both colors, or the absence of one, highlighted regions where change had occurred.

At this stage, another limitation of the AVHRR mosaic for this study became apparent. In the production of this mosaic, the USGS had clipped the original imagery along the continental perimeter they considered

represented the coast. Seaward of this point the AVHRR imagery was deleted and the mosaic is black. Without obtaining the original imagery, it is impossible to independently assess this coastal determination. In some locations, discussed below, we suspect the coast included multiyear fast ice, while in other areas fast ice is omitted.

Positions of the fourteen DISP photographs used to examine coastal change are shown in Figure 4. Figure 5a–n show the individual warped DISP photos with the AVHRR coastline (as determined by the USGS) indicated by a solid line. These figures show a number of large changes which have occurred in the past three decades although any change must be qualified with the caveat that we have not confirmed the USGS coastline determination.

Beginning with Figure 5a of the northern Antarctic Peninsula, some differences can be seen in the position of the Larsen Ice Shelf. These changes are not nearly as large as those recently reported as the disintegration of the northernmost section of the Larsen Ice Shelf (see Rott and others, 1996). Within the southern embayment in the photograph, there is evidence of slight retreat while farther north, the 1963 edge has advanced. This adds to the record of shelf-front fluctuations reported by Skvarca (1994).

In Figure 5d, the distinctive "toothed" front of the Filchner Ice Shelf shows a uniform advance of approximately 28 km, corresponding to an advance rate of 1.7 km/a, in agreement with the measured ice flow rate (Crabtree and Doake, 1980). On the other (left) side of the stationary Berkner Island, the ice front has retreated almost an equal distance indicating a major calving event between the collection of DISP and AVHRR data.

Figures 5e–h captures much of Queen Maud Land. The photographs show that there have been a number of smaller changes to the front of the narrow Fimbul Ice Shelf that lines this coast. Retreats outweigh advances. The largest event recorded in these four photographs is in Figure 5f where an extended tongue of the ice shelf has disappeared where it is fed by Jutulstraumen ice stream. This tongue, given the name Trolltunga (literally "troll's tongue"), calved off in 1967 and was observed frequently in its 11-year drift through the Weddell Sea and eventually into warmer waters of the Southern Atlanctic Ocean (McClain, 1978). The Jutulstraumenn ice stream can be seen in Figure 5e.

In Figure 5i, the comparison indicates the complete loss of a major ice shelf along the western half of the DISP photograph. If true, this would have been a major event, but it would be prudent to verify the AVHRR coastline determination first.

Similar precautions are warranted for some of the larger changes indicated in Figures 5 j–l. Figures 5i and 5j are from Mission 9058A at the end of the austral winter when sea ice is more prevalent. It is difficult to confirm that the more extensive ice cover relative to the AVHRR coastline is sea ice that has not yet broken up. The larger extensions of ice in Figures 5j and 5k are bordered by recently separated ice floes suggesting the decay process would continue to remove the entire feature by the end of summer.

Figures 5j (and 5n) are considerably distorted. This is a result of tie points being concentrated along the coastline. Without tie points in the interior, improper distortion of the interior was unavoidable. For these two figures, the positions of points far from the coast suffer large distortion.

Ross Island appears in Figure 5m. To the east (left) of Ross Island, the edge of the Ross Ice Shelf has retreated immediately adjacent to the island, while farther along the front, at the edge of the photograph, the ice shelf has advanced. To the west (right) of Ross Island, the DISP-era ice cover is farther advanced than the AVHRR coastline. In this region it is known that the McMurdo Ice Shelf follows the AVHRR coastline and that there is a thick sea ice cover in the region between the AVHRR coastline and the DISP ice edge. This thick sea ice has persisted throughout some, but not all winters.

Finally, Figure 5n shows considerable discrepancy between the DISP ice edge and the AVHRR coastline. Again, it is premature to claim significant changes in extent of ice shelves because the DISP photograph shows that sea ice is still extensive in the region and complete summer retreat has not occurred.

SUMMARY

The DISP data set affords a unique view of the Antarctic continent. Over most of the continent, these photographs are the very first view of this portion of the planet. It is expected that scientists will continue to exploit these data in studies of changes that have taken place in the latter half of the 20th century.

The data were collected in three separate missions. The first two missions covered only the coastal areas, while the third mission covered the entire continent. Most of the West Antarctic ice sheet was cloudy during the third mission and the coast was generally cloudy during the first mission. Nevertheless, there are many excellent frames that show changes in the margin of the ice sheet. Our study was limited in time and did not examine changes that may have taken place elsewhere along the coast or in the interior of the ice sheet.

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TABLES AND FIGURES

Table 1. DISP Data of Antarctica Organized by Mission Number and Revolution

ID # of Starting Frame	Date of Acquisition	Rev.	Starting Frame	Ending Frame
Mission 9034A				
DS09034A002MC059	1962/05/15	2	59	60
DS09034A003MC108	1962/05/16	3	108	113
DS09034A004MC108	1962/05/16	4	108	113
DS09034A005MC107	1962/05/16	5	107	113
DS09034A006MC108	1962/05/16	6	108	113
DS09034A007MC107	1962/05/16	7	107	113
DS09034A008MC109	1962/05/16	8	109	113
DS09034A009MC108	1962/05/16	9	108	113
DS09034A010MC108	1962/05/16	10	108	113
DS09034A011MC108	1962/05/15	11	108	113
DS09034A012MC107	1962/05/16	12	107	113
DS09034A013MC104	1962/05/16	13	104	113
DS09034A014MC104	1962/05/16	14	104	113
DS09034A015MC109	1962/05/16	15	109	113
DS09034A016MC111	1962/05/16	16	111	113
DS09034A017MC111	1962/05/16	17	111	113
DS09034A018MC111	1962/05/16	18	111	113
DS09034A019MC107	1962/05/17	19	107	113
DS09034A020MC107	1962/05/17	20	107	113
DS09034A021MC108	1962/05/17	21	108	113
DS09034A022MC108	1962/05/17	22	108	113
DS09034A023MC108	1962/05/17	23	108	113
DS09034A024MC108	1962/05/17	24	108	113
DS09034A025MC108	1962/05/17	25	108	113
DS09034A026MC108	1962/05/17	26	108	113
DS09034A027MC108	1962/05/15	27	108	113
DS09034A028MC104	1962/05/17	28	104	113
DS09034A029MC104	1962/05/17	29	104	113
DS09034A030MC105	1962/05/17	30	105	113
DS09034A031MC111	1962/05/17	31	111	113
DS09034A032MC111	1962/05/17	32	111	113
DS09034A033MC111	1962/05/17	33	111	113
DS09034A034MC108	1962/05/18	34	108	113
DS09034A035MC107	1962/05/18	35	107	113
DS09034A036MC108	1962/05/18	36	108	113
DS09034A037MC108	1962/05/18	37	108	113
DS09034A038MC108	1962/05/18	38	108	113
DS09034A039MC108	1962/05/18	39	108	113
DS09034A040MC108	1962/05/18	40	108	113
DS09034A041MC108	1962/05/18	41	108	113
DS09034A042MC108	1962/05/15	42	108	113
DS09034A043MC104	1962/05/18	43	104	112
DS09034A044MC105	1962/05/18	44	105	113
DS09034A045MC105	1962/05/18	45	105	113
DS09034A046MC111	1962/05/18	46	111	113
DS09034A047MC111	1962/05/18	47	111	112
DS09034A048MC111	1962/05/18	48	111	113
DS09034A049MC108	1962/05/19	49	108	113
DS09034A050MC108	1962/05/19	50	108	113

Table 1 (continued)

ID # of Starting Frame	Date of Acquisition	Rev.	Starting Frame	Ending Frame
DS09034A051MC108	1962/05/19	51	108	113
DS09034A052MC108	1962/05/19	52	108	113
DS09034A053MC108	1962/05/19	53	108	113
DS09034A054MC108	1962/05/19	54	108	113
DS09034A055MC108	1962/05/19	55	108	113
DS09034A056MC108	1962/05/19	56	108	113
DS09034A057MC108	1962/05/19	57	108	113
DS09034A058MC105	1962/05/19	58	105	113
DS09034A059MC105	1962/05/19	59	105	113
DS09034A060MC103	1962/05/19	60	103	113
DS09034A061MC110	1962/05/15	61	110	113
Mission 9058A				
DS09058A002MC116	1963/08/29	2	116	119
DS09058A003MC116	1963/08/29	3	116	119
DS09058A004MC112	1963/08/29	4	112	119
DS09058A005MC112	1963/08/29	5	112	119
DS09058A006MC112	1963/08/29	6	112	119
DS09058A007MC112	1963/08/29	7	112	119
DS09058A008MC112	1963/08/29	8	112	119
DS09058A009MC112	1963/08/29	9	112	119
DS09058A010MC112	1963/08/29	10	112	119
DS09058A011MC113	1963/08/29	11	113	119
DS09058A012MC112	1963/08/29	12	112	119
DS09058A013MC109	1963/08/29	13	109	119
DS09058A014MC109	1963/08/29	14	109	119
DS09058A015MC109	1963/08/29	15	109	119
DS09058A016MC116	1963/08/29	16	116	119
DS09058A029MC109	1963/08/29	29	109	111
DS09058A030MC109	1963/08/29	30	109	111
DS09058A031MC110	1963/08/29	31	110	111
DS09058A034MC116	1963/08/29	34	116	119
DS09058A035MC112	1963/08/29	35	112	119
DS09058A036MC112	1963/08/29	36	112	119
DS09058A037MC112	1963/08/29	37	112	119
DS09058A038MC112	1963/09/01	38	112	119
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DS09058A042MC112	1963/08/29	42	112	119
DS09058A043MC112	1963/08/29	43	112	119
DS09058A044MC112	1963/08/29	44	112	119
DS09058A045MC109	1963/08/29	45	109	119
DS09058A046MC109	1963/08/29	46	109	119
DS09058A047MC114	1963/08/29	47	114	119
DS09058A048MC116	1963/09/01	48	116	119
DS09058A055MC111	1963/08/29	55	111	111
DS09058A057MC075	1963/09/02	57	75	77
DS09058A061MC109	1963/08/29	61	109	111
DS09058A062MC109	1963/08/29	62	109	111

Table 1 (continued)

ID # of Starting Frame	Date of Acquisition	Rev.	Starting Frame	Ending Frame
Mission 9059A				
DS09059A001MC078	1963/10/29	1	78	94
DS09059A003MC075	1963/10/29	3	75	94
DS09059A004MC075	1963/10/29	4	75	94
DS09059A005MC075	1963/10/29	5	75	94
DS09059A006MC075	1963/10/29	6	75	94
DS09059A007MC075	1963/10/29	7	75	94
DS09059A008MC075	1963/10/29	8	75	94
DS09059A009MC075	1963/10/29	9	75	94
DS09059A010MC075	1963/10/29	10	75	94
DS09059A011MC075	1963/10/29	11	75	94
DS09059A012MC074	1963/10/29	12	74	94
DS09059A013MC072	1963/10/29	13	72	94
DS09059A014MC072	1963/10/29	14	72	94
DS09059A015MC078	1963/10/29	15	78	94
DS09059A016MC078	1963/10/29	16	78	82
DS09059A017MC078	1963/10/29	17	78	82
DS09059A018MC075	1963/10/29	18	75	82
DS09059A019MC075	1963/10/29	19	75	82
DS09059A020MC075	1963/10/29	20	75	82
DS09059A021MC075	1963/10/29	21	75	82
DS09059A022MC075	1963/10/29	22	75	82
DS09059A023MC075	1963/10/29	23	75	82
DS09059A024MC075	1963/10/29	24	75	82
DS09059A025MC075	1963/10/29	25	75	82
DS09059A026MC075	1963/10/29	26	75	82
DS09059A027MC075	1963/10/29	27	75	82
DS09059A028MC072	1963/10/29	28	72	82
DS09059A029MC072	1963/10/29	29	72	82
DS09059A030MC072	1963/10/29	30	72	82
DS09059A031MC078	1963/10/29	31	78	82
DS09059A032MC078	1963/10/29	32	78	94
DS09059A033MC078	1963/10/29	33	78	94
DS09059A034MC075	1963/10/29	34	75	94
DS09059A035MC075	1963/10/29	35	75	94
DS09059A036MC075	1963/10/29	36	75	94
DS09059A037MC075	1963/10/29	37	75	94
DS09059A038MC075	1963/10/29	38	75	94
DS09059A039MC075	1963/10/29	39	75	94
DS09059A040MC075	1963/10/29	40	75	94
DS09059A041MC075	1963/10/29	41	75	94
DS09059A042MC075	1963/10/29	42	75	94
DS09059A043MC075	1963/10/29	43	75	94
DS09059A044MC072	1963/10/29	44	72	94
DS09059A045MC072	1963/10/29	45	72	94
DS09059A046MC072	1963/10/29	46	72	94
DS09059A047MC078	1963/10/29	47	78	94
DS09059A048MC078	1963/10/29	48	78	82
DS09059A049MC078	1963/10/29	49	78	82
DS09059A050MC075	1963/10/29	50	75	82

Table 1 (contined)

ID # of Starting Frame	Date of Acquisition	Rev.	Starting Frame	Ending Frame
DS09059A051MC075	1963/10/29	51	75	82
DS09059A052MC075	1963/10/29	52	75	82
DS09059A053MC075	1963/10/29	53	75	82
DS09059A054MC075	1963/10/29	54	75	82
DS09059A055MC075	1963/10/29	55	75	82
DS09059A056MC075	1963/10/29	56	75	82
DS09059A057MC075	1963/10/29	57	75	82
DS09059A058MC075	1963/10/29	58	75	82
DS09059A059MC075	1963/10/29	59	75	82
DS09059A060MC072	1963/10/29	60	72	82
DS09059A061MC072	1963/10/29	61	72	82
DS09059A062MC078	1963/10/29	62	78	82
DS09059A063MC078	1963/10/29	63	78	82
DS09059A064MC078	1963/10/29	64	78	94
DS09059A065MC078	1963/10/29	65	78	94
DS09059A066MC075	1963/10/29	66	75	94
DS09059A067MC075	1963/10/29	67	75	94
DS09059A068MC075	1963/10/29	68	75	94
DS09059A069MC075	1963/10/29	69	75	94
DS09059A070MC075	1963/10/29	70	75	94
DS09059A071MC075	1963/10/29	71	75	94
DS09059A072MC075	1963/10/30	72	75	94
DS09059A073MC075	1963/10/31	73	75	94
DS09059A074MC075	1963/11/03	74	75	94
DS09059A075MC075	1963/11/03	75	75	94
DS09059A076MC072	1963/10/29	76	72	94
DS09059A077MC073	1963/10/29	77	73	94
DS09059A078MC078	1963/10/29	78	78	94
DS09059A079MC078	1963/10/29	79	78	93

Table 2. Dates, Number of Revolutions and Number of Photographs for each DISP Antarctic Mission.

Mission Number	Dates	Number of Revolutions	Number of Photographs
9034A	May 15-19, 1962	60	369
9058A	August 29-September 1, 1963	37	250
9059A	October 29-November 3, 1963	78	1163

Table 3. Preferred Photographs Providing Continuous Coverage of Antarctic Coastline.

Photograph ID Number	Mission Number	Acquisition Date	Revolution	Frame	Center Latitude	Center Longitude
DS09059A037MC077	9059A	1963/10/29	037	077	-66.31	109.95
DS09058A006MC115	9058A	1963/08/29	006	115	-66.20	120.57
DS09058A037MC115	9058A	1963/08/29	037	115	-65.86	132.17
DS09059A004MC077	9059A	1963/10/29	004	077	-66.18	142.03
DS09059A067MC078	9059A	1963/10/29	067	078	-67.97	146.21
DS09059A035MC079	9059A	1963/10/29	035	079	-69.92	155.34
DS09059A066MC080	9059A	1963/10/29	066	080	-71.59	168.81
DS09059A066MC083	9059A	1963/10/29	066	083	-77.00	168.58
DS09059A065MC084	9059A	1963/10/29	065	084	-78.87	168.69
DS09059A001MC083	9059A	1963/10/29	001	083	-76.60	-150.10
DS09059A016MC082	9059A	1963/10/29	016	082	-75.34	-131.91
DS09059A047MC082	9059A	1963/10/29	047	082	-75.33	-118.39
DS09059A015MC081	9059A	1963/10/29	015	081	-73.58	-109.04
DS09058A016MC119	9058A	1963/08/29	016	119	-70.99	-102.29
DS09059A030MC081	9059A	1963/10/29	030	081	-73.44	-84.80
DS09058A047MC119	9058A	1963/08/29	047	119	-70.99	-90.35
DS09059A014MC081	9059A	1963/10/29	014	081	-73.61	-86.25
DS09059A045MC081	9059A	1963/10/29	045	081	-73.56	-74.70
DS09059A045MC079	9059A	1963/10/29	045	079	-69.95	-72.56
DS09059A013MC077	9059A	1963/10/29	013	077	-66.19	-63.09
DS09058A014MC115	9058A	1963/08/29	014	115	-65.71	-62.58
DS09059A076MC076	9059A	1963/10/29	076	076	-64.42	-58.70
DS09059A029MC080	9059A	1963/10/29	029	080	-71.59	-68.01
DS09058A014MC117	9058A	1963/08/29	014	117	-68.38	-60.05
DS09058A014MC119	9058A	1963/08/29	014	119	-70.99	-56.81
DS09059A060MC082	9059A	1963/10/29	060	082	-75.37	-54.63
DS09059A075MC083	9059A	1963/11/03	075	083	-77.08	-36.51
DS09059A059MC082	9059A	1963/10/29	059	082	-75.38	-31.85
DS09059A011MC082	9059A	1963/10/29	011	082	-75.27	-17.95
DS09058A012MC119	9058A	1963/08/29	012	119	-71.21	-10.88
DS09059A042MC080	9059A	1963/10/29	042	080	-71.71	-4.29
DS09059A010MC080	9059A	1963/10/29	010	080	-71.63	5.00
DS09059A057MC079	9059A	1963/10/29	057	079	-70.02	13.98
DS09059A009MC079	9059A	1963/08/29	009	079	-69.87	27.87
DS09059A072MC079	9059A	1963/10/30	072	079	-69.86	32.17
DS09058A041MC117	9058A	1963/08/29	041	117	-68.55	43.42
DS09058A009MC116	9058A	1963/08/29	009	116	-67.26	53.06
DS09059A055MC077	9059A	1963/10/29	055	077	-66.38	59.75
DS09059A023MC078	9059A	1963/10/29	023	078	-68.16	68.90
DS09059A007MC078	9059A	1963/10/29	007	078	-68.09	73.55
DS09059A070MC078	9059A	1963/10/29	070	078	-68.11	77.84
DS09059A038MC077	9059A	1963/10/29	038	077	-66.25	87.16
DS09059A006MC077	9059A	1963/10/29	006	077	-66.23	96.45
DS09059A053MC077	9059A	1963/10/29	053	077	-66.19	105.33

Table 4. ID Number and Coregistration Parameters for Photographs in Figure 5.

Figure	ID#	# tie points	Residuals (km)
5a	DS09059A076MC076	10	2.31
5b	DS09059A029MC080	33	2.77
5c	DS09059A045MC081	29	2.81
5d	DS09059A012MC084	6	1.41
5e	DS09059A042MC080	23	2.49
5f	DS09059A010MC079	29	2.97
5g	DS09059A041MC079	23	3.03
5h	DS09058A042MC118	26	2.52
5i	DS09058A009MC116	19	2.67
5j	DS09058A006MC115	9	2.64
5k	DS09059A067MC078	9	2.44
5l	DS09059A066MC080	15	2.10
5m	DS09059A003MC084	19	2.61
5n	DS09059A001MC083	14	2.79

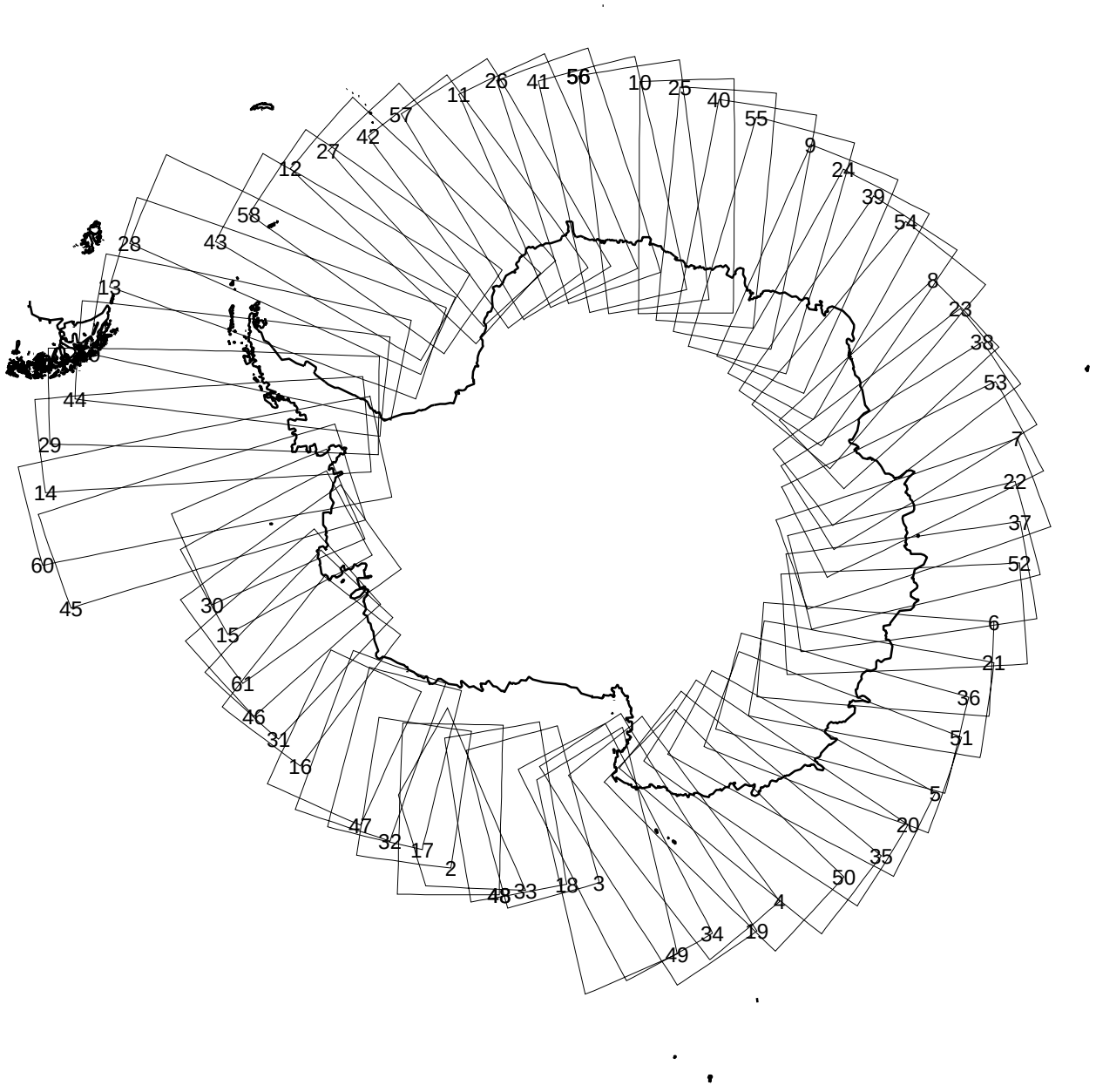


Figure 1. Mission 9034A. Outline of Antarctic continent with location of each revolution indicated. Revolution number is positioned at the northwest corner of the corresponding outline.

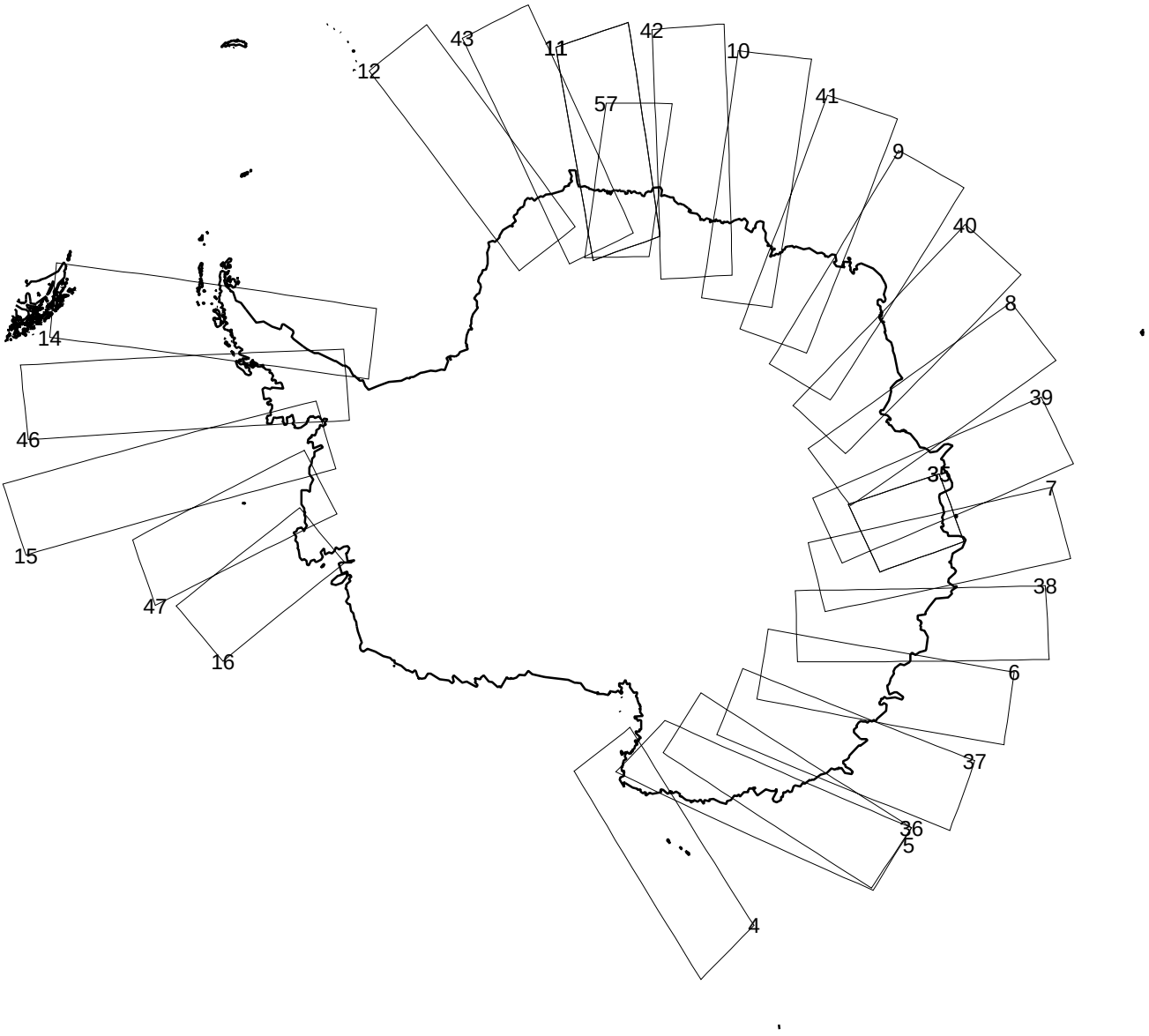
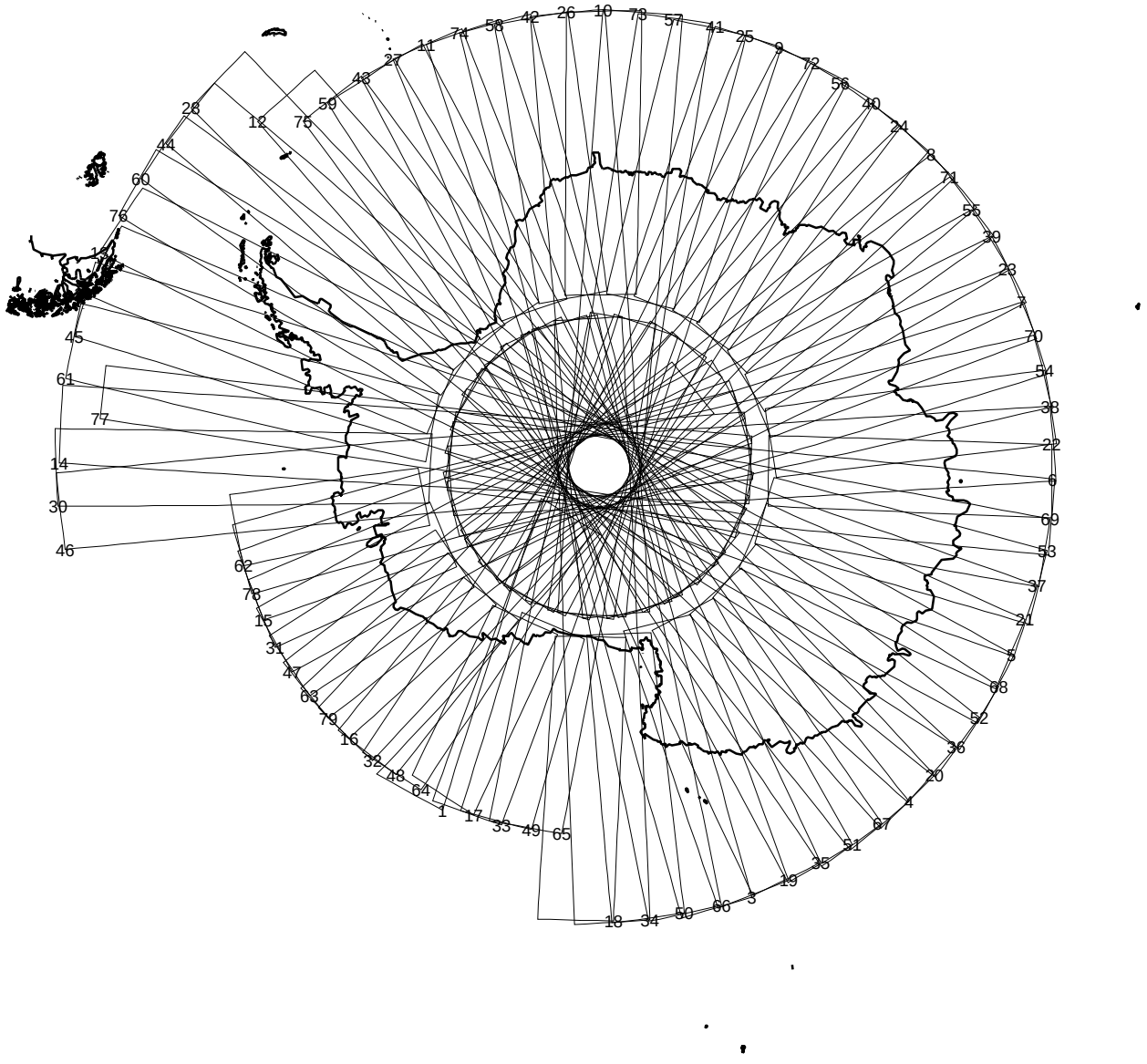
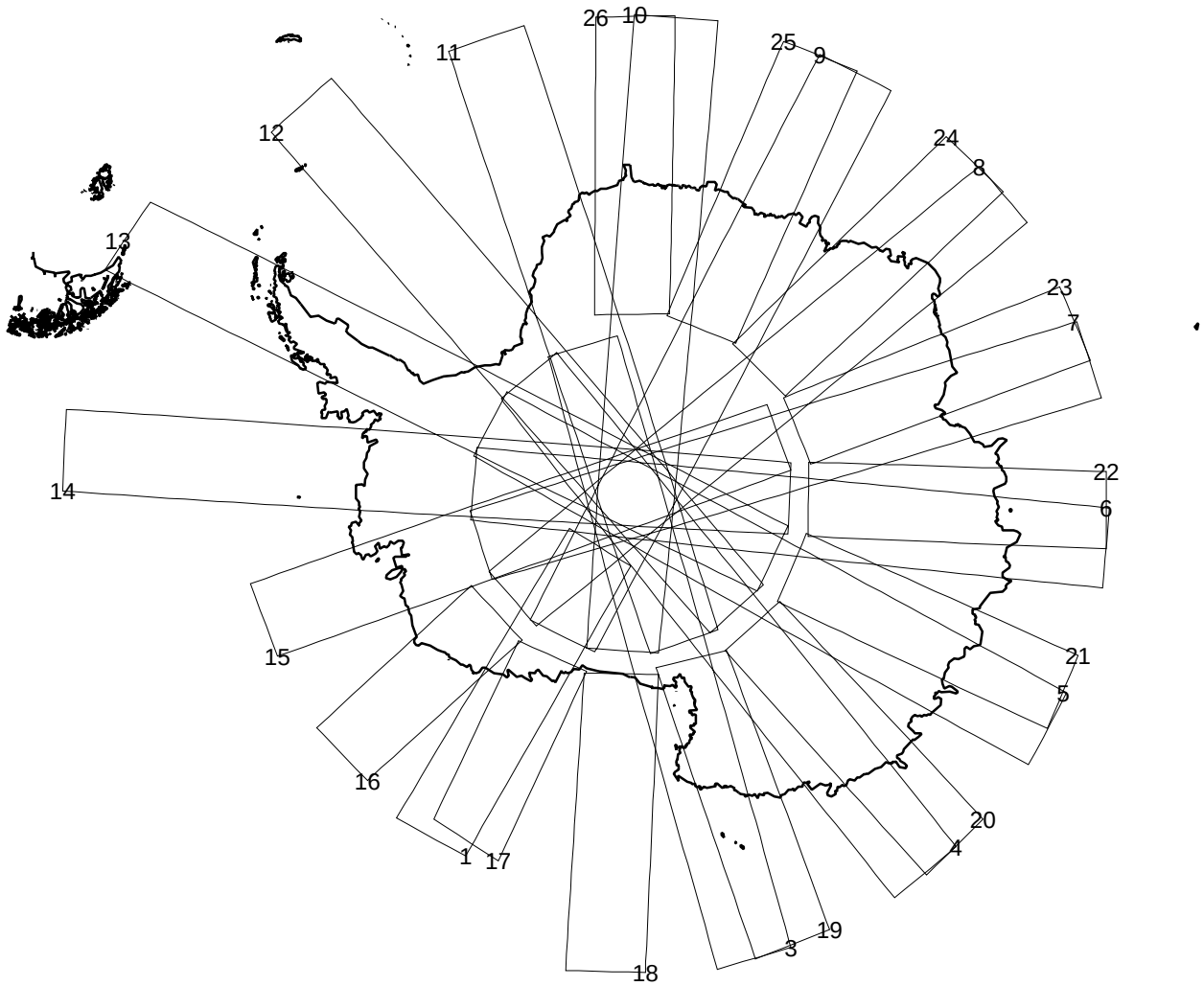


Figure 2. Mission 9058A. Outline of Antarctic continent with location of each revolution indicated. Revolution number is positioned at the northwest corner of the corresponding outline.

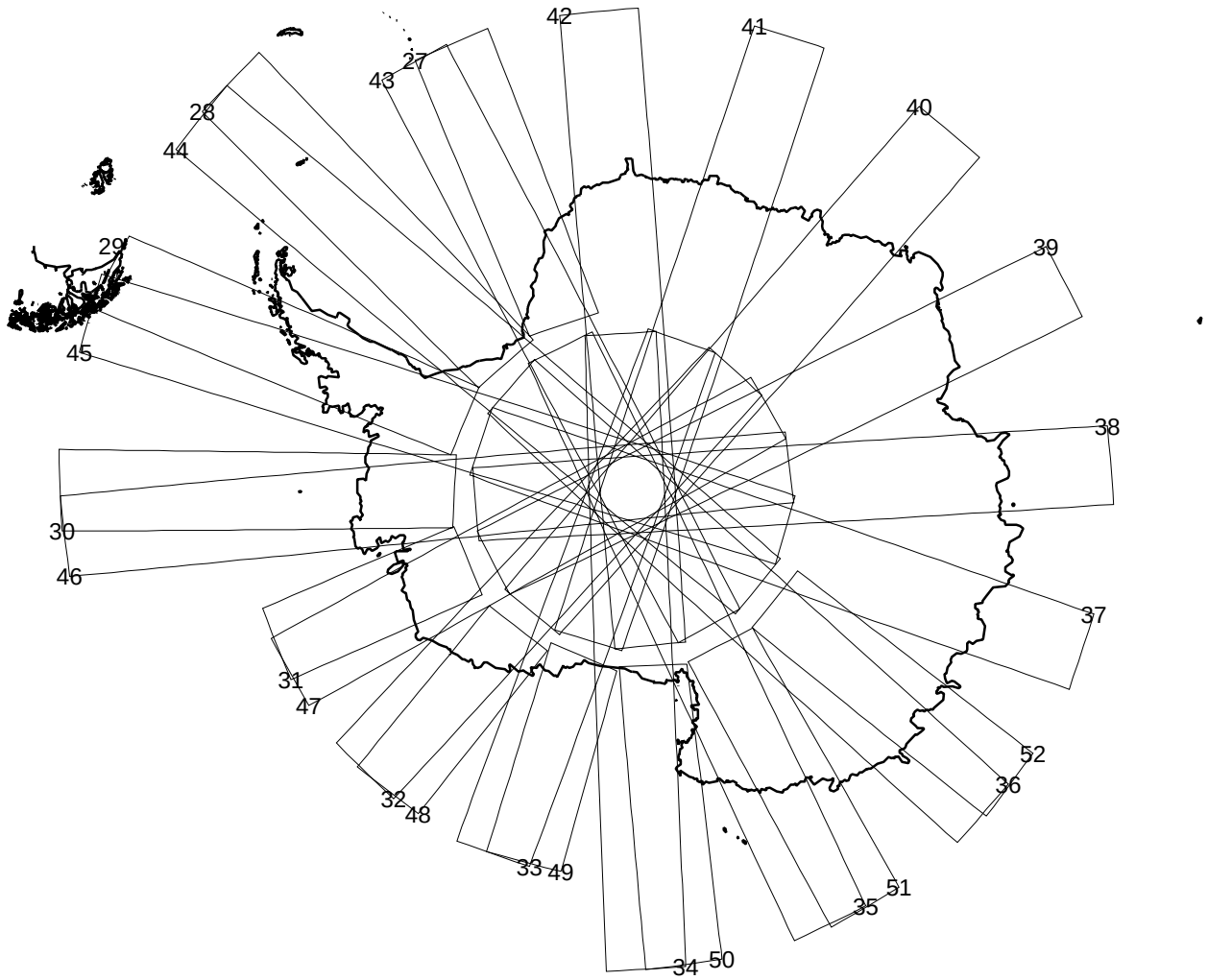


(3a)

Figure 3. Mission 9059A. Outline of Antarctic continent with location of each revolution indicated. Revolution number is positioned at the northwest corner of the corresponding outline. a) total mission; b) early mission (revolutions 1 to 26); c) mid-mission (revolutions 27 to 52); d) late mission (revolutions 53 to 79).



(3b)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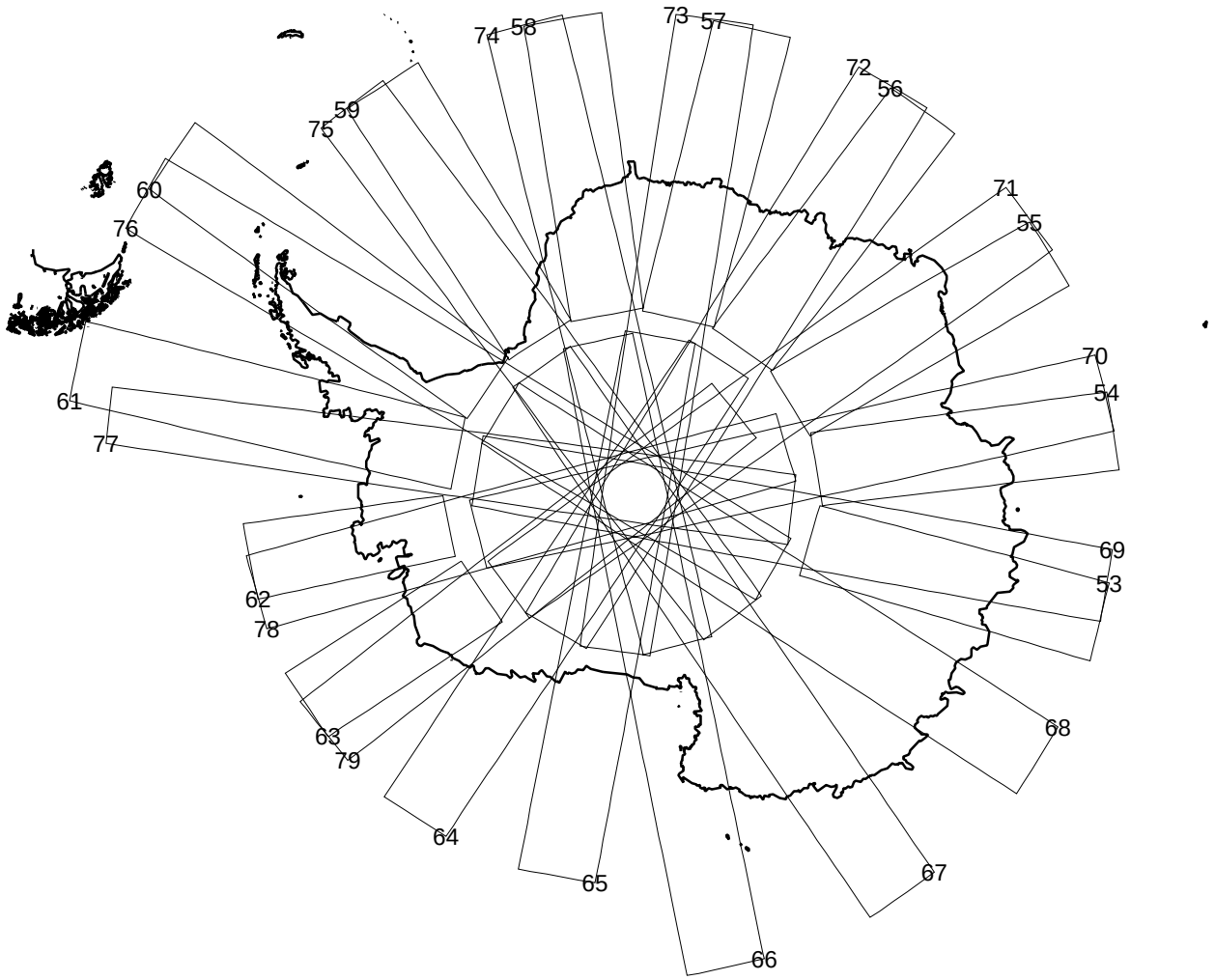
(3c)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(3d)

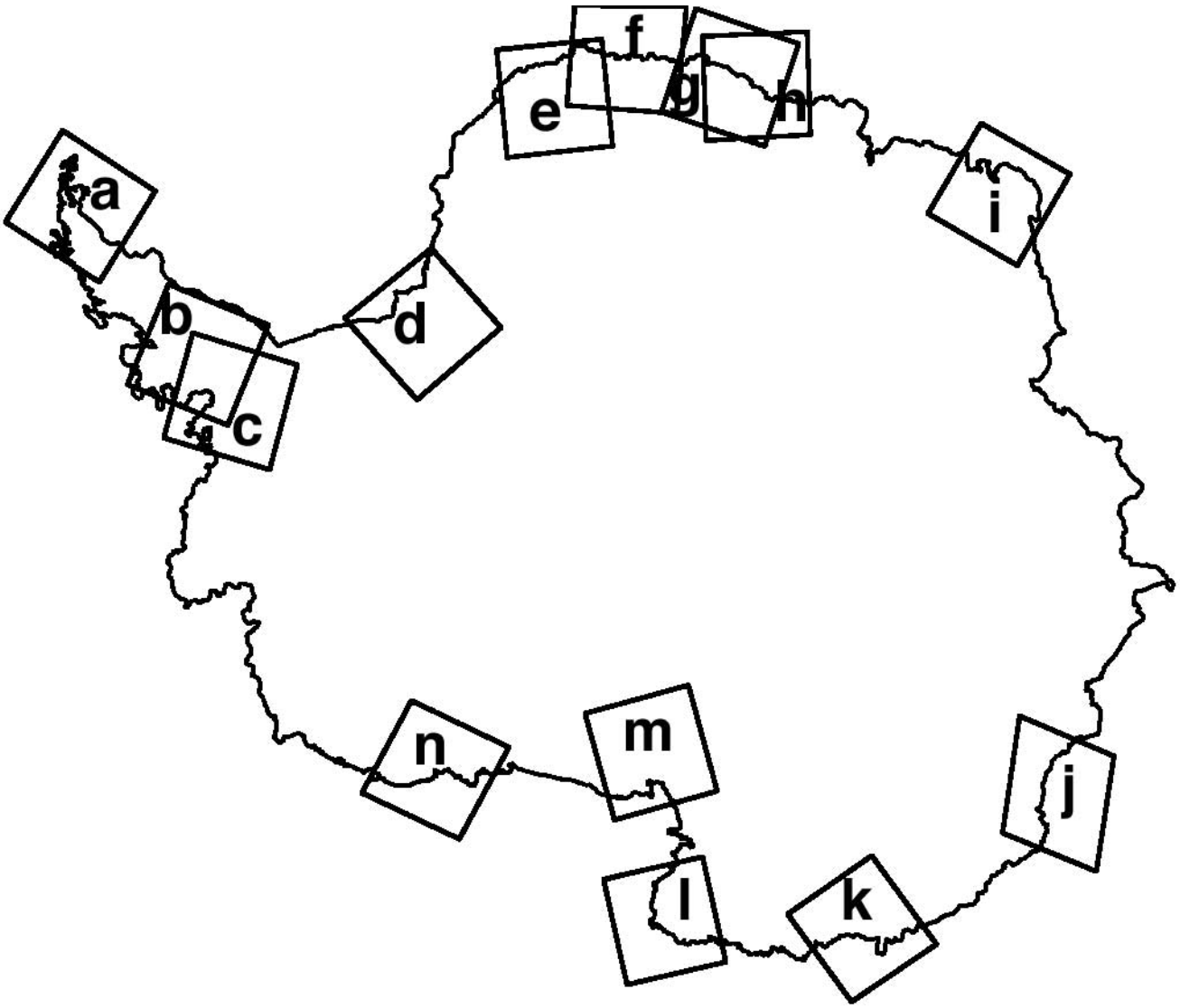
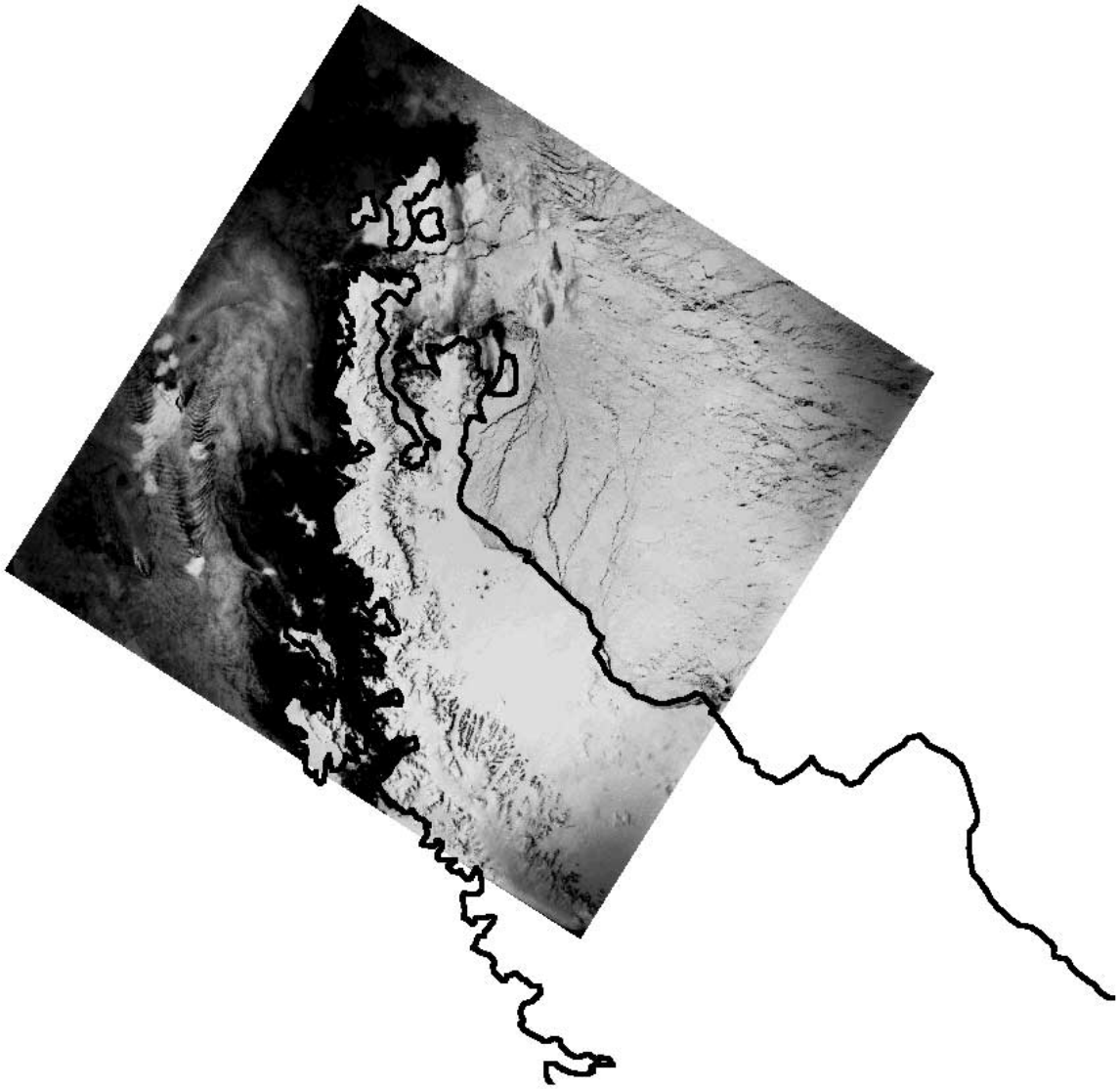
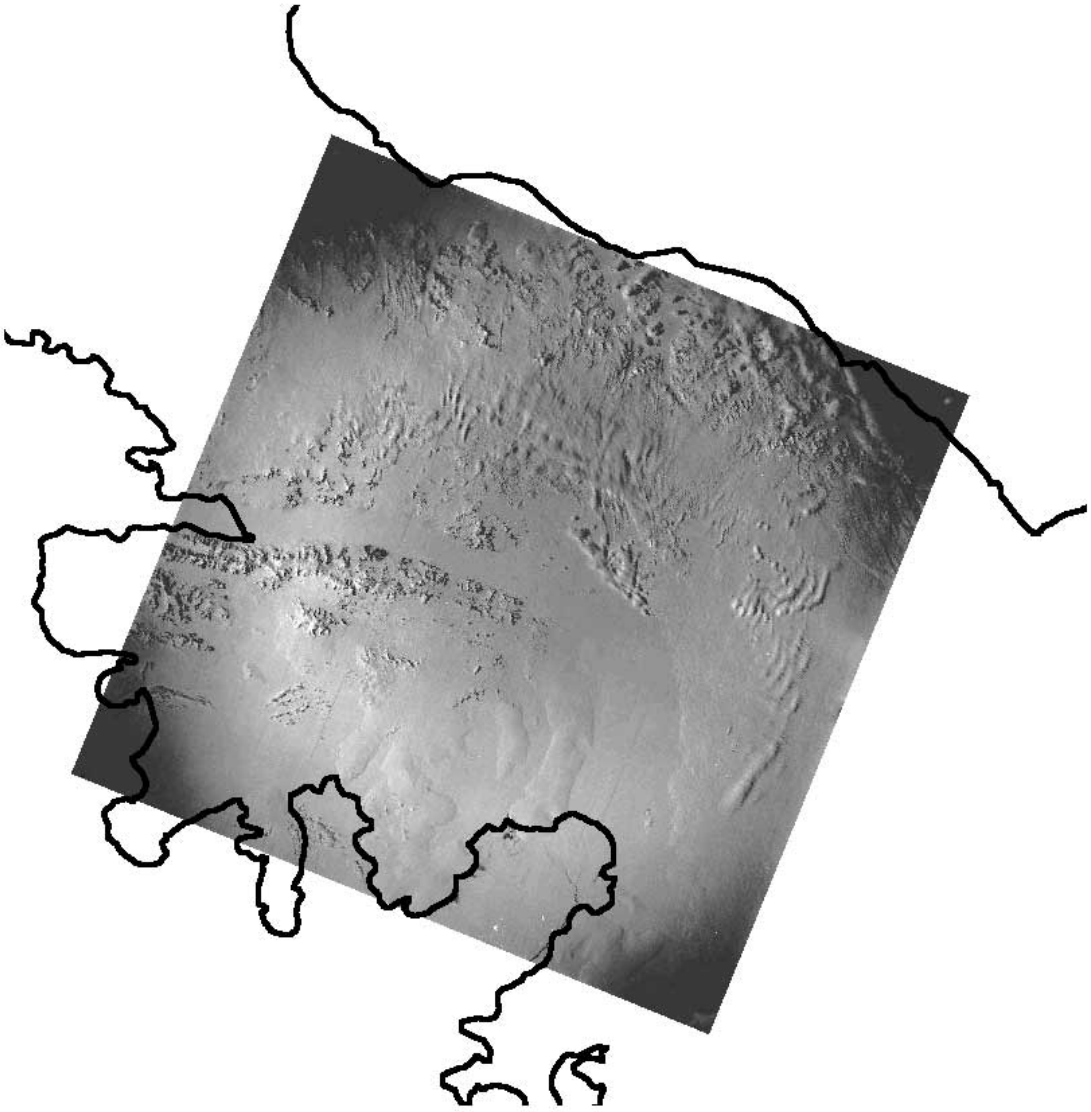


Figure 4. Outline of Antarctic continent and locations of DISP photographs shown in Figure 5.

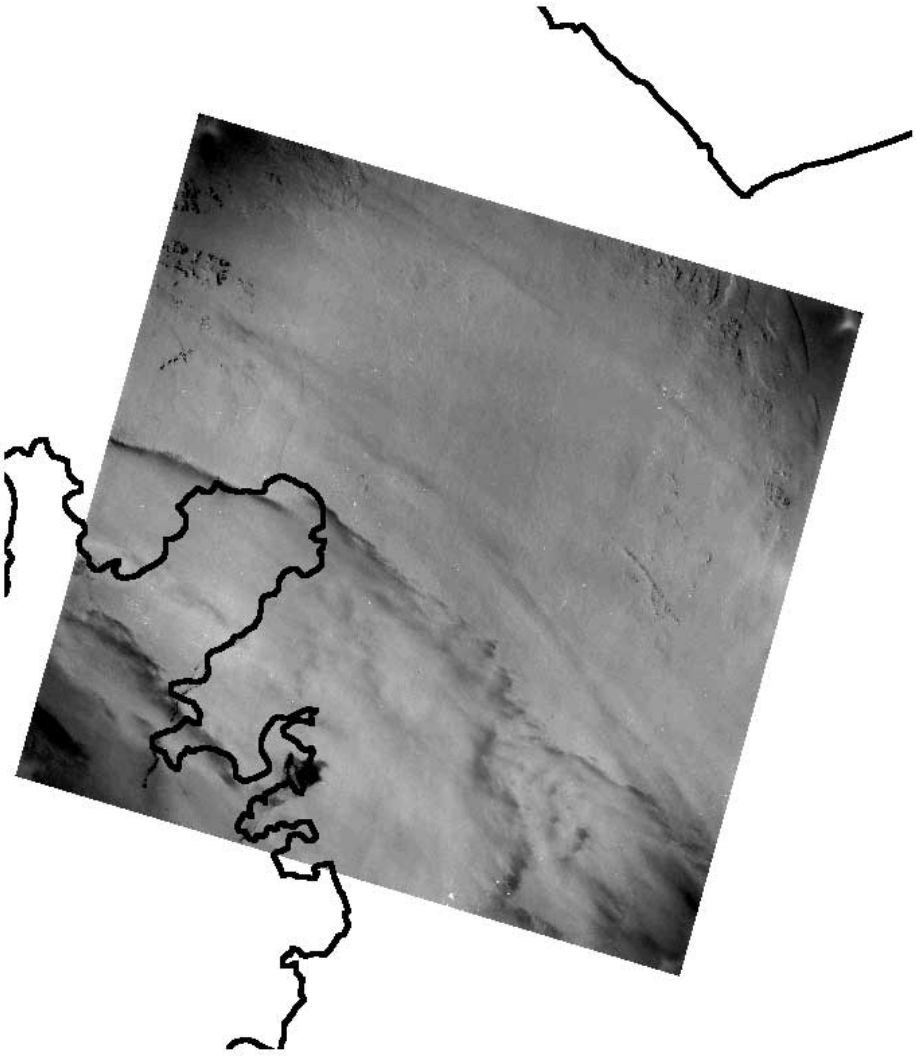


(5a)

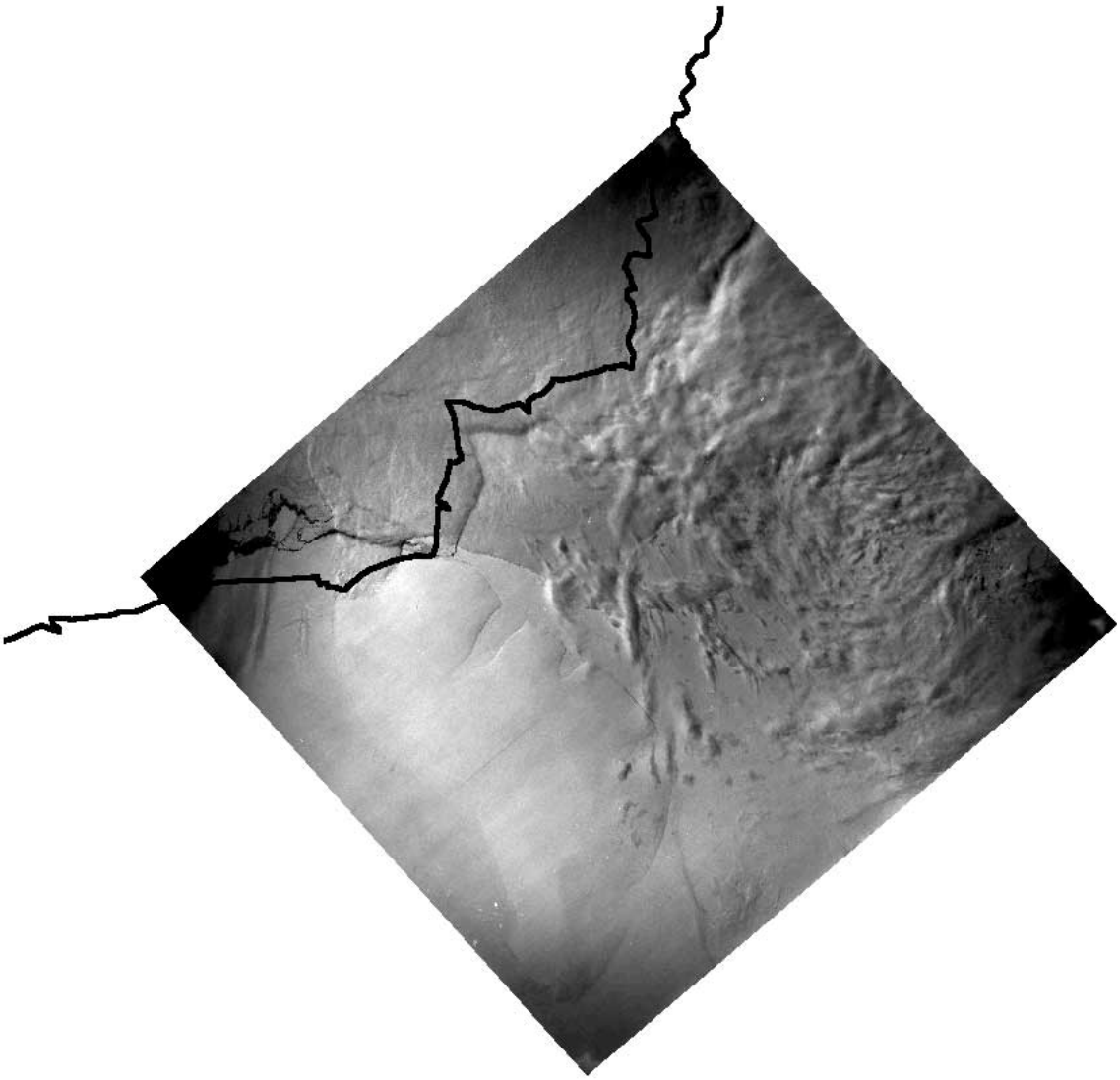
Figure 5. Warped DISP photographs coregistered with USGS AVHRR mosaic through the use of hand-selected tie points. Number and distribution of tie points varies with each photograph as discussed in text. Solid line is the continental edge determined by USGS. Location of each DISP photograph can be identified by the corresponding letter in Figure 4.



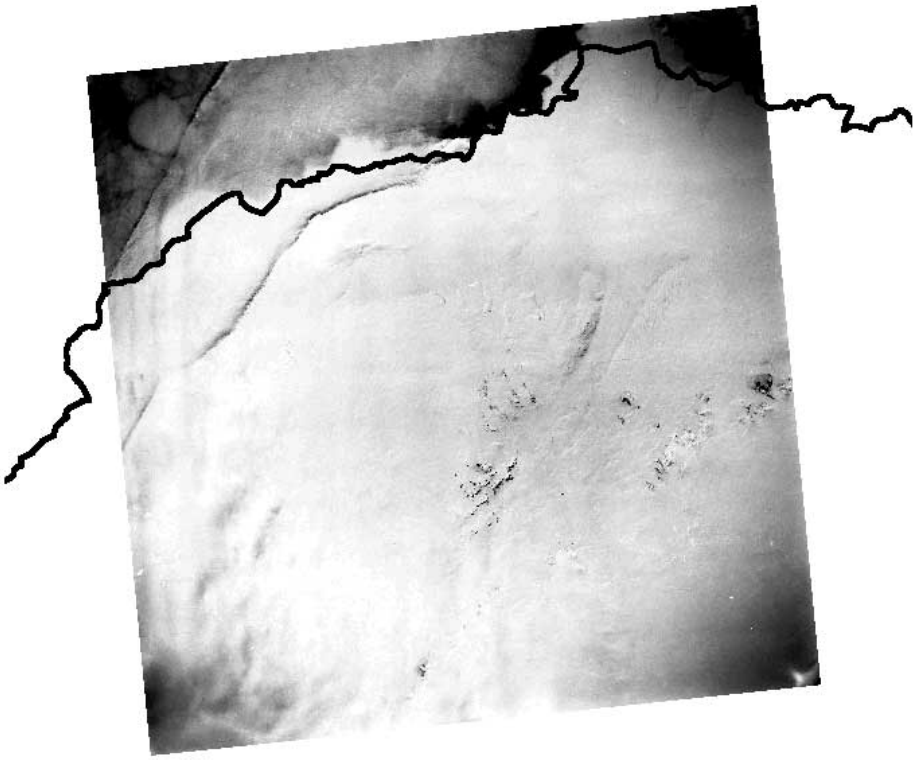
(5b)



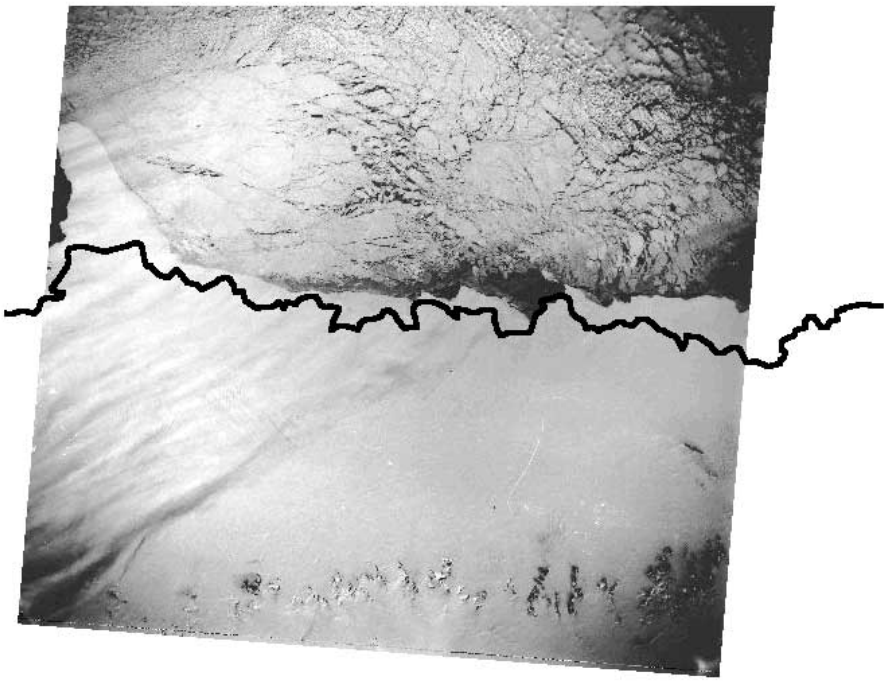
(5c)



(5d)



(5e)



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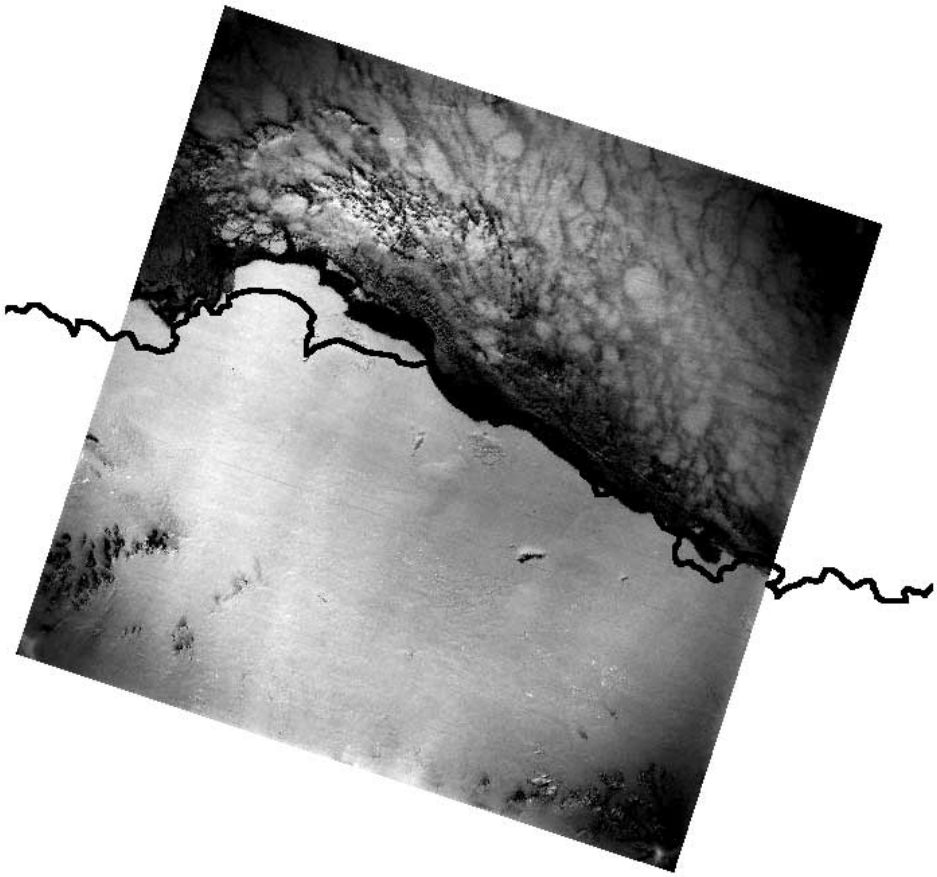
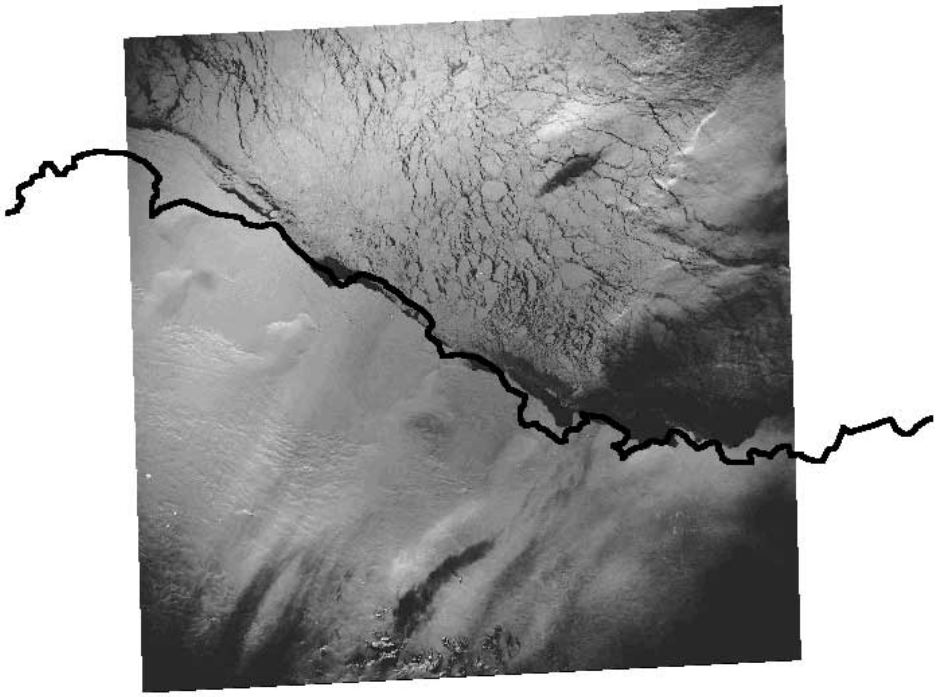
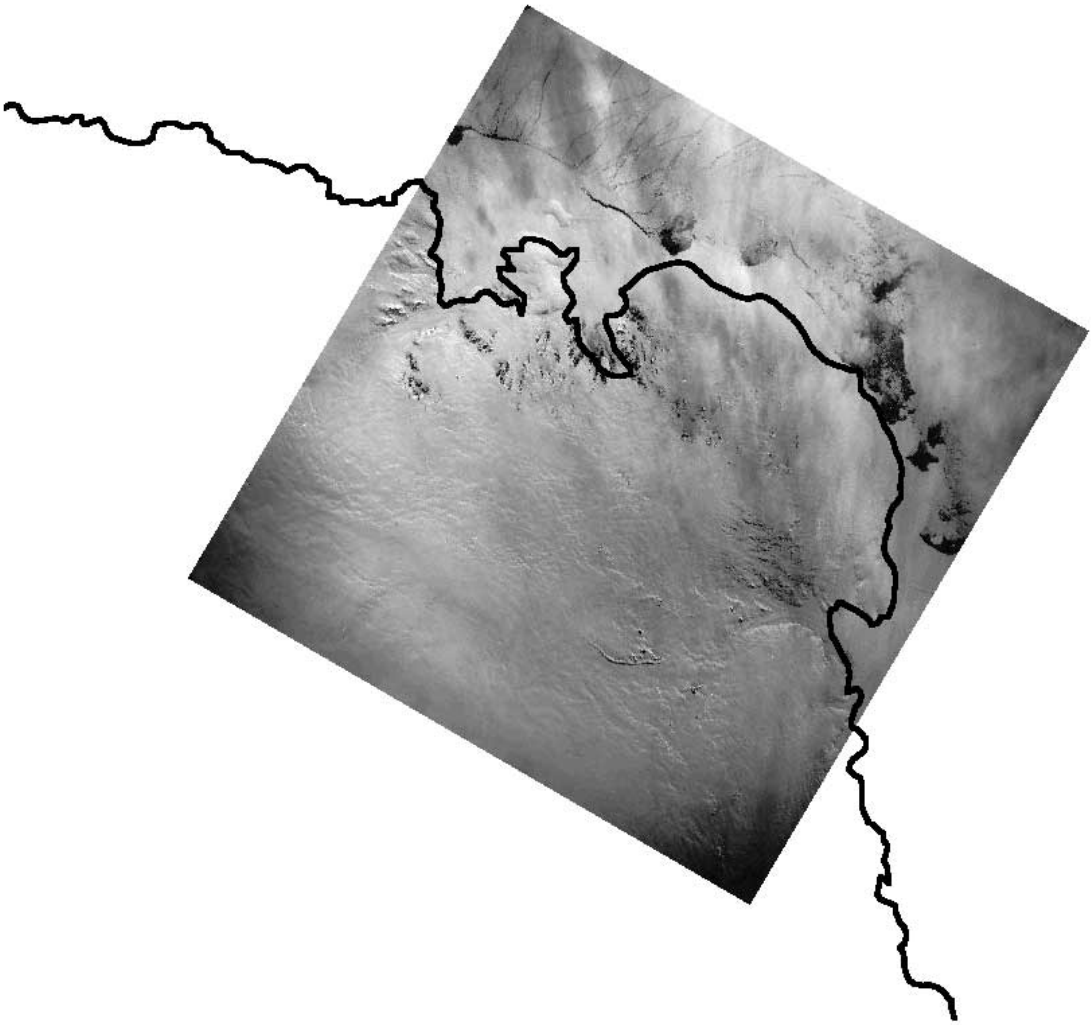


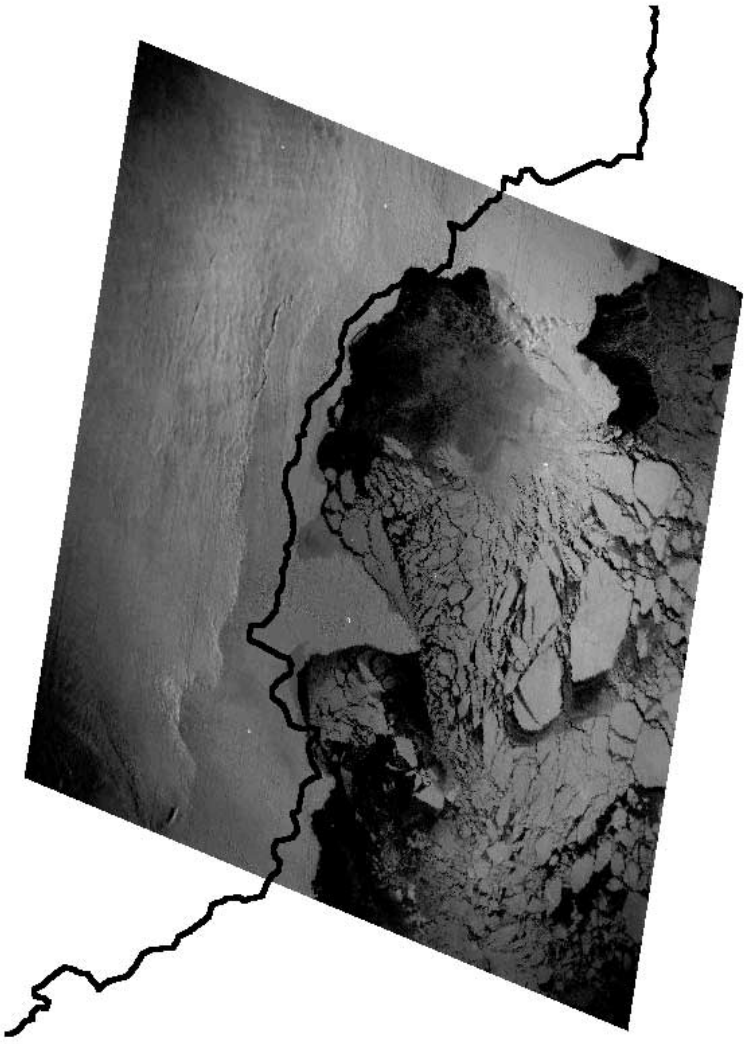
(5g)



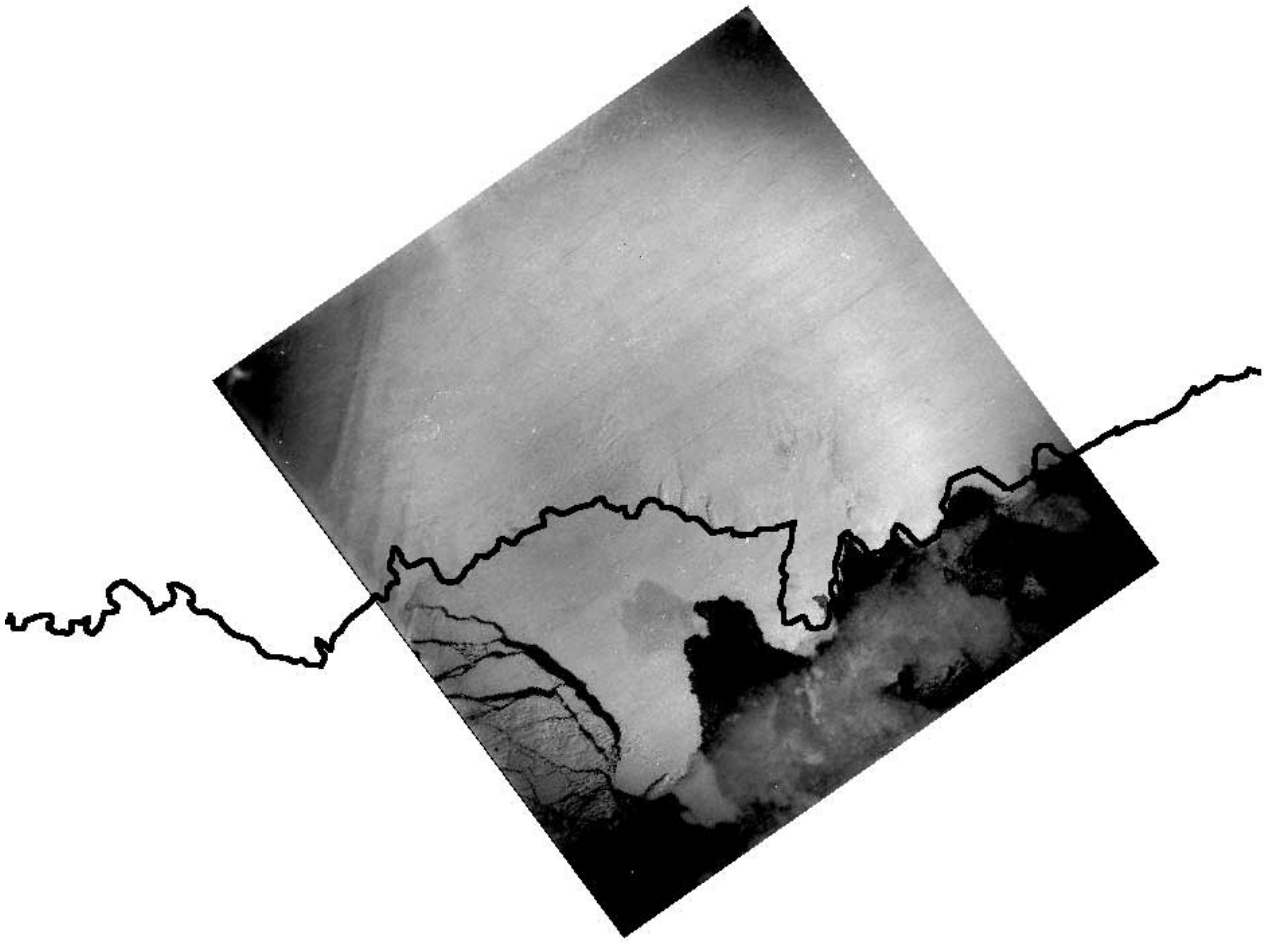
(5h)



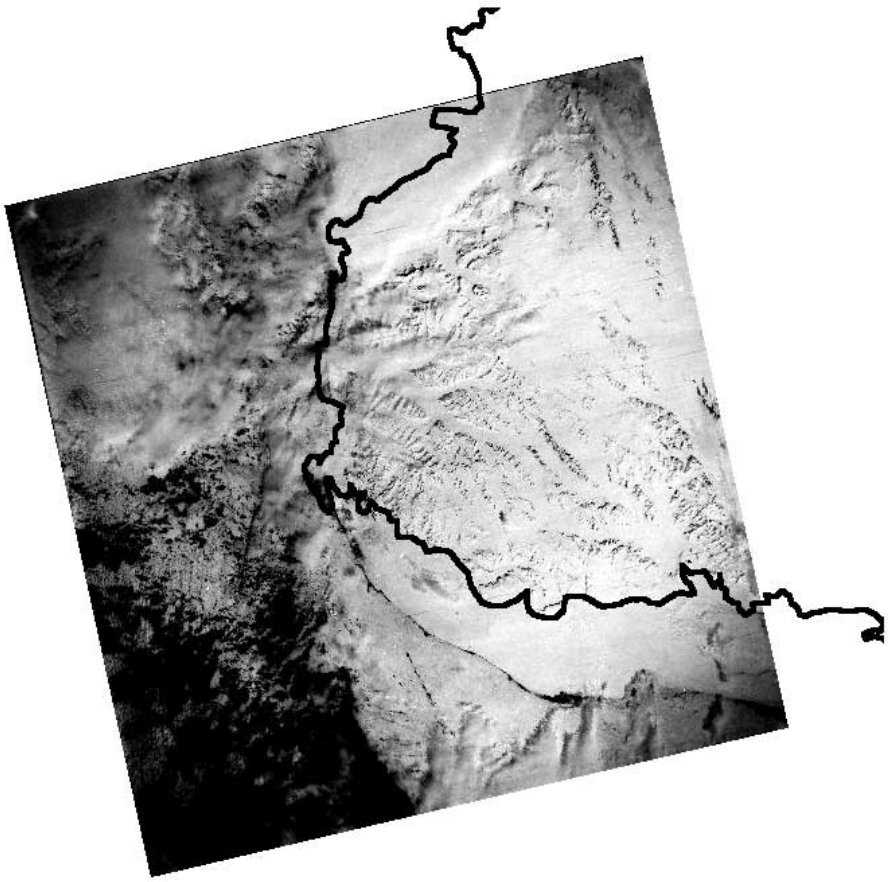
(5i)



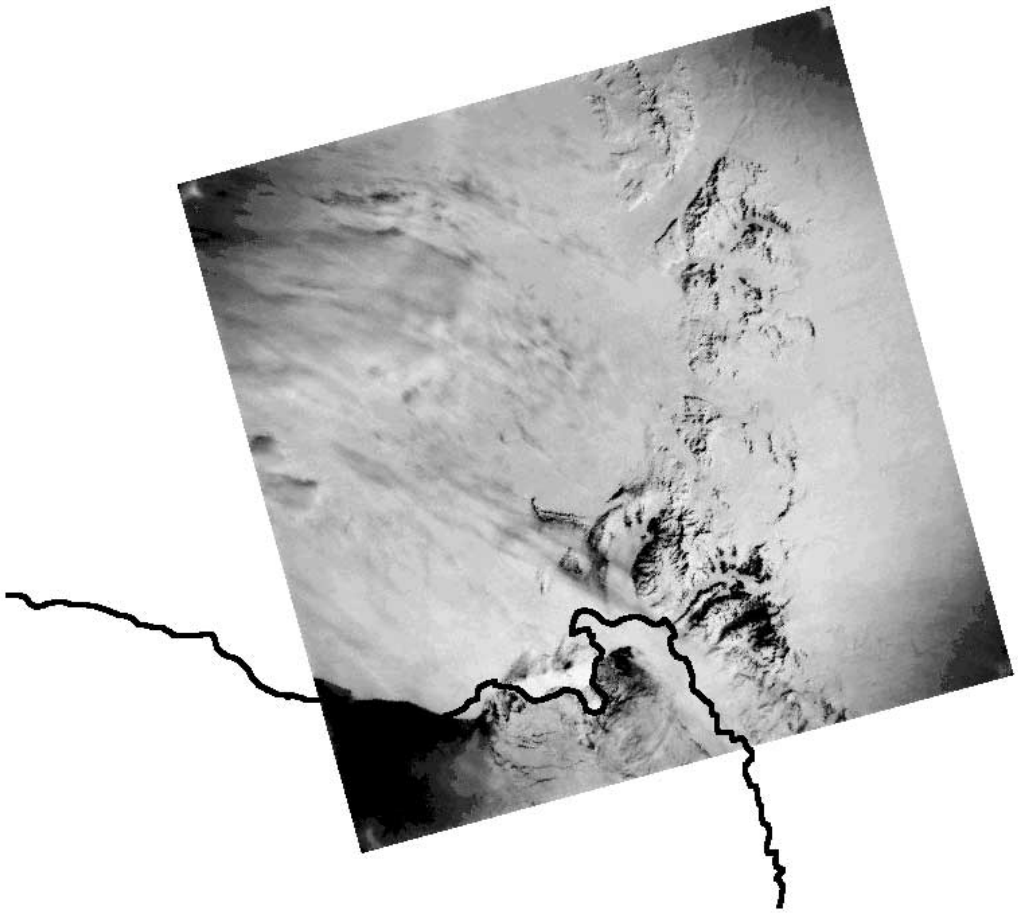
(5j)



(5k)



(5l)



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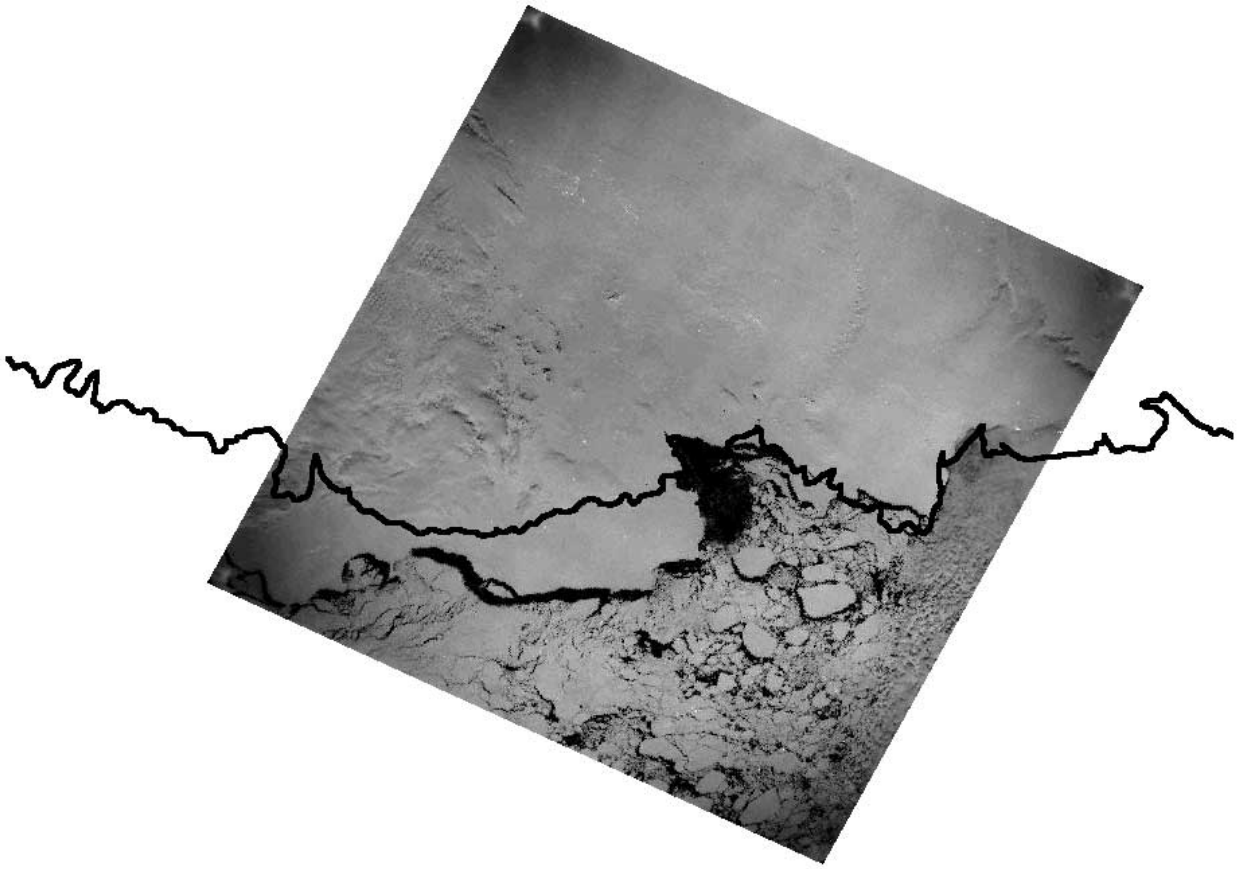

(5n)

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13. ABSTRACT *(Maximum 200 words)*

This report summarizes the results of a nine-week summer project examining all Declassified Intelligence Satellite Photography (DISP) of Antarctica. It was discovered that the data were collected in three separate missions during 1962 and 1963. The first two missions covered only the coastal areas, while the third mission covered the entire continent. Many of the 1782 frames collected were cloudy. This is especially true of West Antarctica. An optimal set of photographs covering the entire Antarctic coastline is identified along with some examples that show changes in the coastline which have occurred since the early 1960s.

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