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Sighting surveys from a ship and a helicopter in the Weddell Sea in 2006/07 and 2008/09

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Abstract

Helicopter and shipboard surveys were conducted for cetaceans in the Weddell Sea from the German research vessel 'Polarstern'. The first survey in 2006/07 started south of South Africa, went to Neumayer Station in Atka Bay (70°29.6' S/07°57.6' W), crossed the Weddell Sea from Neumayer to south of Elephant Island and worked around the South Shetland Islands and east of the Antarctic Peninsula in front of former Larsen A and B glaciers. The second survey covered two transects: the first more westerly one started at 57°09.3' S/00°39.1' E and went to Atka Bay (70°29.6' S/07°57.6' W) whereas the second (return leg) followed a more easterly course from Atka Bay over Maud Rise to 57°03.1' S/12° 27.5' W. No observations could be conducted from 63 to 57°S on the return cruise due to fog (visibility < 200 m) and swell. Standard line transect survey protocols were followed while the helicopter and the ship followed track lines that could not be designed (i.e. fully randomized) in advance due to unpredictability of the ice conditions and the need to meet several objectives simultaneously. Helicopter track lines covered a total of 13 124 and 13 417 km in 2006 and 2008 respectively while the ship survey covered 1 171 and 2 011 km respectively. We were particularly interested in the distribution and abundance of Antarctic minke whales in the pack-ice. Minke whales were primarily seen in the ice. Killer and southern bottlenose whales were also seen in the ice while all baleen whales other than minke whales, and sperm whales were only observed in open water. Humpback whales were the most frequently sighted species on the shipboard survey in 2006/07 and the helicopter survey in 2008/09. Environmental information, including proportion ice coverage, was collected continuously. One striking finding from this summary was a much higher encounter rate for all cetaceans from the ship than from the helicopter. This difference could be explained by observers on the helicopter missing more animals on the track line than those from the ship (i.e. g (0) < 1); it could equally be explained if whales were drawn to leads created while RV 'Polarstern' broke the ice. This discrepancy warrants closer attention.

Introduction

IDCR/SOWER (International Decade of Cetacean Research and Southern Ocean Whale Ecosystem Research) cruises to estimate whale abundance (primarily minke whales, *Balaenoptera bonaerensis*) have been conducted within the remit of the IWC since 1978/79 during three circumpolar cruises (CP I, II, and III). They extended from 60° S as far south as the northern limit of the pack-ice (e.g. Branch and Butterworth 2001; Ensor et al., 2007). Due to logistic constraints, IWC/SOWER cruises do not penetrate into the pack–ice. Therefore, existing survey data are unable to account for the proportion of whales that inhabit the pack-ice at the time of the survey. Furthermore, substantial changes made to survey and experimental design and equipment after CP I had finished in 1983/84, made CP I not as easily comparable as CP II and CP III to each other (Branch and Butterworth, 2001).

Considerable differences in abundance estimates of minke whales in the Southern Ocean exist between those estimated from CP II (786 000, CV = 0.094) and CP III (338 000, CV = 0.079). The abundance estimate from the third circum-Antarctic survey accounted for only 55% (closing mode) to 45% (IO mode) of the two first cruises (Branch and Butterworth, 2001; Branch, 2006). Both estimates rely on the assumption that all minke whales on the track line are detected with certainty (i.e. g (0) = 1). Other attempts to estimate abundance dependant on the model approach used resulted in substantial difference between authors. Estimates provided by Okamura and Kitakado (2009), for example, using the OK method, were twice as high as those accepted widely in the Scientific Committee (Branch, 2006).

A large part of these differences still awaits reconciliation. Several hypotheses have been brought forward to explain at least part of these differences (e.g. Branch, 2007; Okamura and Kitakato, 2007, 2008, 2009; Matsuoka et al., 2008). One hypothesis suggests that the differences are due to a large number of minke whales inhabiting sea ice-covered waters not accessible to the survey vessels (Shimada and Kato, 2002a, b, 2003, 2005, 2007); this implies that there was also a major distributional shift between CP II and CP III. The difficulty in testing or rejecting this hypothesis remains in the fact that the survey vessels previously and currently being used for IDCR/SOWER cruises are unable to penetrate further into the pack-ice than the marginal ice zone (up to 5% ice coverage) to test this hypothesis. Comparatively few studies have been undertaken in the pack-ice (Thiele et al., 2002, 2004; Shimada and Kato, 2005; Scheidat et al., 2007) to test the validity of this hypothesis. A second hypothesis is based on the finding that the extent of sea–ice varied considerably between years and from CP II to CP III and that, as a consequence, survey coverage differed markedly between the same survey areas during CP II and CP III (Matsuoka et al., 2009). Abundance was high at the year when the survey was able to cover most of the statistical area (CP II), and low when the survey was not able to do so due to the high ice concentration (CP III). This explanation was suggested to explain the considerable decline in whale abundance between CP II and CP III.

Three model approaches are currently followed by the Scientific Committee to obtain reliable estimates of minke whale abundance:

- the Integrated Model (Cooke, 2009),
- the OK method (Okamura et al., 2003, 2005; Okamura and Kitakado, 2008), and
- the SplintR Model ((Bravington, 2008, 2009; Bravington and Hedley, 2009).

Previous studies (Plötz et al., 1991; Franeker, 1992; Kelly et al. 2009) have demonstrated that helicopters and airplanes may provide a useful means to survey cetaceans in the pack-ice. We conducted two parallel aerial and shipboard surveys in November to January 2006/07 and in December/January 2008/09 from board the German research vessel 'Polarstern'. Given the various scientific programmes run in parallel to the whale observations and the re-supply of Neumayer Station as well as the difficulty of predicting ice conditions in order to plan the ship's cruise track, it was not possible to design a fully randomized survey design in advancing cruise tracks of the vessel to meet the specific requirement of a dedicated cetacean survey. In that respect, RV 'Polarstern' was used as a platform of opportunity for comparing density of whales across a wide range of ice conditions.

First results to the IWC were provided in Scheidat et al. (2007) and Kock et al. (2009). We report here some further results of cetacean observations in the course of this cruise with emphasis on abundance of minke whales in the pack-ice.

Material and Method

Information on the two cruises including itineraries, cruise tracks etc. is detailed in Gutt (2008) and Boebel (2009). A short description is provided in Table 1. Cruise tracks are provided in Figure 1. Speed of the ‘Polarstern’ through the ice was 6–10 knots depending on ice conditions.

The aerial surveys followed standard line transect (distance sampling) methodology. Flying altitude was 600 feet; the helicopter’s speed was 80 knots. The first observer/data recorder occupied the port front seat of the helicopter and observed the area to the front while focusing on the transect line. The second observer was positioned behind the first observer and observed the port side of the helicopter, perpendicular to the cruise track (Scheidat et al., 2007). In contrast to 2006/07, a third observer was placed behind the pilot and observed the starboard side of the helicopter in 2008/09.

The shipboard survey was conducted from the crow’s nest at 27 m above sea level. Each observer covered an angle of 90° perpendicular from the bow to the side of the vessel. When a whale was sighted the second observer left his/her position temporarily to record the sighting and ancillary information (2006/07). A third person to record this information was used in 2008/09. Sighting effort in both aerial and shipboard surveys is provided in Table 2.

During each flight and crow’s nest occupancy GPS position and information on ancillary environmental parameters were collected continuously using the software “VOR” (aerial survey) or "LOGGER" (shipboard survey). GPS positions were recorded continuously. Environmental data collected included the proportion of ice cover, sea state, cloud cover, glare, and glare intensity. A digital tape recorder provided an audio backup for later reference. The following information was recorded for each whale sighting: species, group (pod) size, group composition, inclination angle (helicopter), behaviour, cue, swimming direction, dive, and possible reaction to the platform.

Results

Sea-ice conditions

The development of the sea-ice in the course of the two cruises was provided in figures 2a–f and 3a-c (Spreen et al., 2008). Ice broke up earlier in the Eastern Weddell Sea in December 2006 compared to December 2008. A large part of the eastern Weddell Sea was ice-free on 12 December 2006 while a large pat of the area was still covered in dense pack-ice on 12 December 2008 (Figures 2b, 3a). The ice continued to break up in the course of December 2006 while most of the eastern Weddell Sea remained still ice-covered on 20 December 2008 (Figures 2c, 3b). Most of the eastern Weddell Sea was ice-free on 27 December 2006 whereas the central Weddell Sea only started to open up on 27 December 2008 with the eastern Weddell Sea still covered largely in pack-ice (Figures 2d, 3c). Most of the eastern and central Weddell Sea to 67° S was free of ice in January 2007 (Figures 2d, e).

Sightings

All sightings were conducted during the two cruises from the helicopter (in 2006/07 and 2008/09), the deck below the crow’s nest (in 2006/07), and crow's nest (in 2008/09). The location of sightings is shown in Figure 4.

2006/07

34 days of survey flights covering 13 124 km and 24 days of observation from the crow’s nest covering 1171 km were conducted in 2006/07. A total of 101 whale sightings were recorded by the helicopter and another 45 sightings occurred from the crow’s nest. A total of 295 individual whales were identified during the 101 aerial sightings with 14 remaining unidentified. 81 whales were recognized from the crow’s nest while 11 remaining unidentified (Tables 2, 3).

71 of the 101 sightings from the helicopter were minke whales. They consisted of 158 individual whales. Average group size was 2.2. The geographical distribution of group sightings of minke whales is shown in Figures 5-7. Minke whales were seen in all densities of pack-ice as far south as close to the continent and fast ice areas. Most groups consisted of 1 or 2 animals. Larger groups were rarely encountered.

Other baleen whale species were never seen in the pack-ice. In addition to minke whales 13 groups of humpback whales (*Megaptera novaeangliae*) were observed which consisted of 31 individuals. The average group size was 2.4 animals. 10 sightings were fin whale (*Balaenoptera physalus*) groups. They accounted for 26 individuals with an average group size of 2.6 animals. In addition 7 sightings of 5 other whale species were recorded: strap toothed beaked whale (*Mesoplodon layardii*), Gray's beaked whale (*M. grayi*), Arnoux's beaked whale (*Berardius arnuxii*), southern bottlenose whale (*Hyperoodon planifrons*) and killer whale (*Orcinus orca*). Average sighting rate during aerial surveys was 0.008 sightings/km. The average sighting rate for minke whales was 0.006 sightings/km (Tables 2, 3).

The most frequently sighted species seen from the crow's nest (24 sightings) were humpback whales with 50 individuals. Average group size was 2.1 animals. 21 sightings from the crow's nest were minke whales. They consisted of 31 individuals. Average group size was 1.5 animals. Average sighting rate was 0.038. Average sighting rate for minke whales was 0.018 sightings/km (Tables 2, 3).

2008/09

23 days of survey flights covering 13 417 km and 21 days of observation from the crow's nest covering 2011 km were conducted in 2008/09. A total of 112 whale sightings were observed from the helicopter whereas another 55 sightings occurred from the crow's nest. The aerial survey resulted in 340 individual whales from the 112 aerial sightings. 20 sightings could not be identified to species. 123 whales were recognized from the crow's nest not including 13 individuals which could not be identified to species level (Tables 2, 3).

34 of the 112 sightings from the helicopter were humpback whales. They consisted of 92 individual whales. The average group size was 2.7 whales. 24 groups of minke whales were observed. They were constituted of 28 individuals. The average group size was 1.2 whales. 35 sightings were fin whales. They accounted for 49 individuals. The average group size was 1.4 whales. 3 sightings were made up of 143 rough toothed dolphins. Their average group size was 47.7. In addition 15 sightings of 7 other whale species were recorded: sperm whale (*Physeter macrocephalus*), sei whale (*Balaenoptera borealis*), southern right whale (*Eubalaena australis*), strap toothed beaked whale, southern bottlenose whale and killer whale. Average sighting rate

(sightings/km) was 0.008. The average sighting rate of minke whales was 0.002 sightings/km (Tables 2, 3).

The most abundant species seen from the crow's nest were minke whales with 22 sightings including 28 individuals and humpback whales with 14 sightings of 36 individuals. The average group size for minke whales was 1.3 animals. The average group size in humpback whales was 2.6 animals. 5 fin whale sightings accounted for 10 individuals. Their average group size was 2.0 animals. In addition, four other species were observed: sperm whale, sei whale, killer whale and an unidentified beaked whale. Average sighting rate from the crow's nest was 0.027 (sighting/km). Average sighting rate of minke whales was 0.011 sightings/km (Tables 2, 3).

Discussion

Species diversity of the cetacean community changed remarkably with distance to the ice edge (Figure 4, see also Kasamatsu, 2000). Species diversity during IDCR cruises from 1978/79 to the late 1980s was lowest at the ice edge and increased until 200 nm from the ice edge after which diversity started to decline again (Kasamatsu, 2000). Kasamatsu suggested that the Marginal Ice Zone (MIZ), as an area of high productivity, attracts baleen whales.

It has been well established that (adult) minke whales inhabit the pack-ice year-round with a preference for areas of lighter ice cover (<50%) and leads and polynyas (Taylor, 1957; Naito, 1982; Ainley, 1985, 2007; Ensor, 1989; Ribic et al., 1991; Plötz et al., 1992; van Franeker, 1992; Aguayo – Lobo, 1994a, b; Kasamatsu et al., 1996, 1998a, b, 2000; Joiris, 1991, 2000; Thiele et al, 2000, 2002, 2004, 2005; Shimada and Kato, 2005).

The three most commonly seen cetacean species during our two surveys were minke whales, humpback whales and fin whales. Humpback whales and fin whales were only observed north of the pack–ice while minke whales were seen in pack–ice densities of more than 50%. The only species observed in the pack–ice were minke whales, southern bottlenose whales and killer whales. Minke whales are of small size, occur often singly or in small groups and surface in areas where killer whales are potentially around for very short intervals (Ainley et al., 2007).

Sighting rates obtained from the bridge of RV 'Polarstern' (2 observers) during ANT XXI/4 (27 March to 6 May 2004) in the eastern Weddell Sea inside and outside the pack-ice combined (0.0160 whales per km) (McKay and Asmus, 2005) were similar to 2006/07 (0.0179) and 2008/09 (0.0109). The average group (school) size of minke whales (1.4) was very similar to the average group size observed during our surveys (1.5/1.3). Minke whale groups consisted mostly of one individual whale and less often of two whales while larger schools were rarely encountered both in 2006/07 and 2008/09 (Figures 5-7).

The minke whale data are being analysed using density surface models. These density estimates will b subject to a companion paper (SC/62/IA?). In terms of counts/encounter rates, similar numbers of minke whales compared to our shipboard survey in 2008/09 were found in the Amundsen and Bellingshausen Seas by Kasamatsu et al. (2000) in austral summer 1982/83 and 1989/90 and west of the Antarctic Peninsula in winter (Thiele and Gill, 1999) and in East Antarctica from 80° to 150° E in December – February 1995/96 (Thiele et al., 2000). Fewer animals were observed in spring in the northern and central Weddell Sea in October-November 1988 (Joiris, 1991) and in the Ross Sea in May – June 1998 (van Dam and Kooyman, 2004). Mean school size was higher during two surveys in February-March 1994 in the Amundsen and Bellinghausen Sea where school sizes of up to 9 animals were encountered (Ainley et al., 2007), and in the Ross Sea in December–January 1976–80 where mean school size was 1.97 animals (Ainley, 1985). It is yet unknown to what extent these differences reflect natural fluctuations between surveys or seasonal changes with fewer minke whales present in the pack-ice in spring and early winter than in summer. Results from our surveys underline the fact that sea–ice forms an important habitat for minke whales.

One striking result was a much higher encounter rate for all cetaceans from the ship than from the helicopter (Table 2). This is consistent with a low value of g(0) from the helicopter. Unfortunately, the differences can equally be explained by a strong effect of responsive movement due to the presence of the ship (i.a. if whales were drawn into the leads opened up by the ice-breaking). We have not yet compared effective strip width from the two platforms. However, this several-fold difference in encounter rate is large relative to the decline in minke whale abundance from CP II to CP III, and warrants closer attention. If the difference in encounter rate between the two platforms is due to responsive movement, then this has important implications for the design of future surveys.

Our understanding of the distribution pattern of minke whales in and outside the pack-ice, however, is limited. There is evidence from several studies now for a close relationship between sea-ice, cold water, and minke whale distribution and abundance: extension of sea-ice cover in the Ross Sea in 1994/95 covered the typically krill-rich slope region during summer (which also provides other abundant euphausiids such as *E. crystallorophias* and *Thysanoessa macrura*, the hyperiid *Themisto gaudichaudii*, and the Antarctic silverfish *Pleuragramma antarcticum* as secondary food items locally which were often observed together with abundant krill in the stomach contents, Bushuev, 1986; Ichii and Kato, 1991; Tanura and Konishi, 2006), and prevented minke whales to exploit this habitat in the usual manner. As a consequence, body fat condition of minke whales was poorer than in ‘normal’ years (Ichii and al., 1998).

Based on sightings obtained from mid-February to end of March, Ainley et al. (2007) found a significant inverse relationship between minke whale density and sea ice concentration in the Amundsen and Bellingshausen Seas. Minke whales move offshore to the MIZ once waters within the pack-ice began to freeze permanently. Kasamatsu et al. (2000) obtained evidence that lower sea surface temperature and sea floor type associated with the extent of sea-ice and cold water intrusions influenced the distribution and abundance of minke whales in the Bellingshausen Sea. Ichii (1990) speculated that the formation of krill concentrations induced by oceanographic fronts over the shelf break and banks is another important factor influencing the distribution and abundance of minke whales. Indications for a close relationship of whale distribution and oceanic fronts was also described by Tynan (1997) and Kasamatsu et al. (1998b). Tynan (1997), Kasamatsu et al. (1998b), and Ainley et al. (2007) suggested that neither sea-ice nor sea surface temperature alone are sufficient to explain minke whale abundance but that the complex dynamics of several processes were responsible in shaping the distribution and abundance of minke whales. Nicol et al. (2008) condensed these findings into a complex spatial structure in which baleen whales live in relation to their prey and environment at meso- and micro-scales.

Sea-ice coverage, density and extent have undergone considerable changes in the Southern Ocean since the earliest available records from whaling in the early 1930s (de la Mare, 1997, 2002, 2009). Although it is still debatable whether sea-ice has retreated on a circum-Antarctic scale (Vaughan, 2000; Ackley et al., 2003), it is widely accepted that sea-ice has retreated regionally. This has particularly been the case regionally in the Weddell Sea and the neighbouring Antarctic Peninsula (Vaughan et al., 2003). These regions have seen considerable variability in sea-ice retreat and warming of the area in past decades (Cotté and Guinet, 2007).

One of the important processes shaping the use of habitat is food. Murase et al. (2002) found that minke whale concentrations were mostly observed along the ice edge over the continental slope in summer between 35° E and 145° W. They were rarely seen offshore even when krill was abundant. It remains questionable if the MIZ in summer (when the IDCR cruises took place) is the zone of highest krill biomass and thus the most favourable feeding ground for minke and other baleen whales. Considerable inter-annual variability in the distribution of krill biomass over large oceanic areas (and not concentrated along the MIZ) casts further doubts on the validity of this hypothesis (Atkinson et al., 2008). Regional krill abundance in summer appears to be positively correlated to the extent of sea-ice in the previous winter (Brierley et al., 1999; Hewitt et al., 2003). It is debatable, however, if such a simple cause-and-effect relationship exists between the extent of sea-ice and krill and whether climate change is already having already an adverse effect on krill abundance (Atkinson et al., 2004; Nicol et al., 2008).

It seems that prey distribution may not be the only driver of habitat selection: The avoidance of inter-specific competition appears to be another reason for minke whales to prefer ice-laden habitats. Minke whales and humpback whales, for example, utilize different feeding areas possibly to avoid competition for food (Murase et al., 2002). Finer-scale analyses note that minke and humpback whales avoid competition by targeting different water depths and size classes of krill (Friedlaender et al., 2009). It remains debatable whether minke whales utilize the pack-ice to avoid predation by killer whales (Murase et al., 2002). Killer whales have been observed as deep into the pack-ice as minke whales (Gill and Thiele, 1997; Thiele and Gill, 1999; Scheidat et al., 2007). Attacks of killer whales on minke whales have also been observed in the pack-ice (Murase et al., 2002).

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Table 1: Cruise itinerary Polarstern ANT XXIII/8 (25 November 2006- 1 February 2007) and ANT XXV/3 (5 December 2008-5 January 2009)

Cruise	ANT XXIII/8	ANT XXV/2
Leaving Cape Town	23 November 2006	5 December 2008
Enter pack-ice (Date/Position)	27/28 November 2006/ 58° S	12 December 2008/ 58° 20’ S
Pack-ice passage	Dense pack-ice (muß ich in meinem Tagebuch nachsehen)	Dense pack-ice (60-90%) from 62-64° S, new ice formation south 65-66° S
Reach fast ice	6 December 2008 close to Neumayer	17 December 2008
Reach Neumayer	6 December 2006	17 December 2008
Leave Neumayer	10 December 2006	20 December 2008
Cross Weddell Sea/direction	West-northwest towards Antarctic Peninsula	North, 20 – 27 December 2008
Leave pack-ice	18 December 2006, Start Bottom trawl survey	27 December 2008, passage to Cape Town
Re-enter pack-ice	6 January 2007	-
Leave pack-ice/ Date/position	24 January 2007	-
Enter port	Punta Arenas/ 30 January 2007	Cape Town/ 5 January 2009

Table 2: Sighting effort and no. of whale sightings during 'Polarstern' ANT XXIII/8 and ANT XXV/2 in the Weddell Sea in November 2006 to January 2007 and December 2008 to January 2009

Survey	Platform of observation	Effort Days	km	No. of whale sightings	Av. sighting rate *)	Av. sighting rate minke whale *)
XXIII/8	ship	24	1171	45	0.038	0.018
	helicopter	34	13124	101	0.008	0.006
XXV/2	ship	21	2011	55	0.048	0.010
	helicopter	23	13417	112	0.008	0.002

*) Sighting/km

Table 3: Whale species sighted, no. of individuals sighted and group size of abundant whale species during cruises ANT-XXIII/8 and XXV/2

Survey	Platform of observation	Whale species sighted	No. of schools	/ind. sighted	Average group size
XXIII/8	ship	minke whale	21	31	1.48
		humpback whale	24	50	2.08
	helicopter	minke whale	71	158	2.20
		humpback whale	13	31	2.39
		fin whale	10	26	2.60
XXV/2	ship	minke whale	22	28	1.27
		humpback whale	14	36	2.57
		fin whale	5	10	2.00
	helicopter	minke whale	22	28	1.20
		humpback whale	30	105	3.50
		rough t. dolphin	3	143	**?**
		fin whale	16	49	3.10

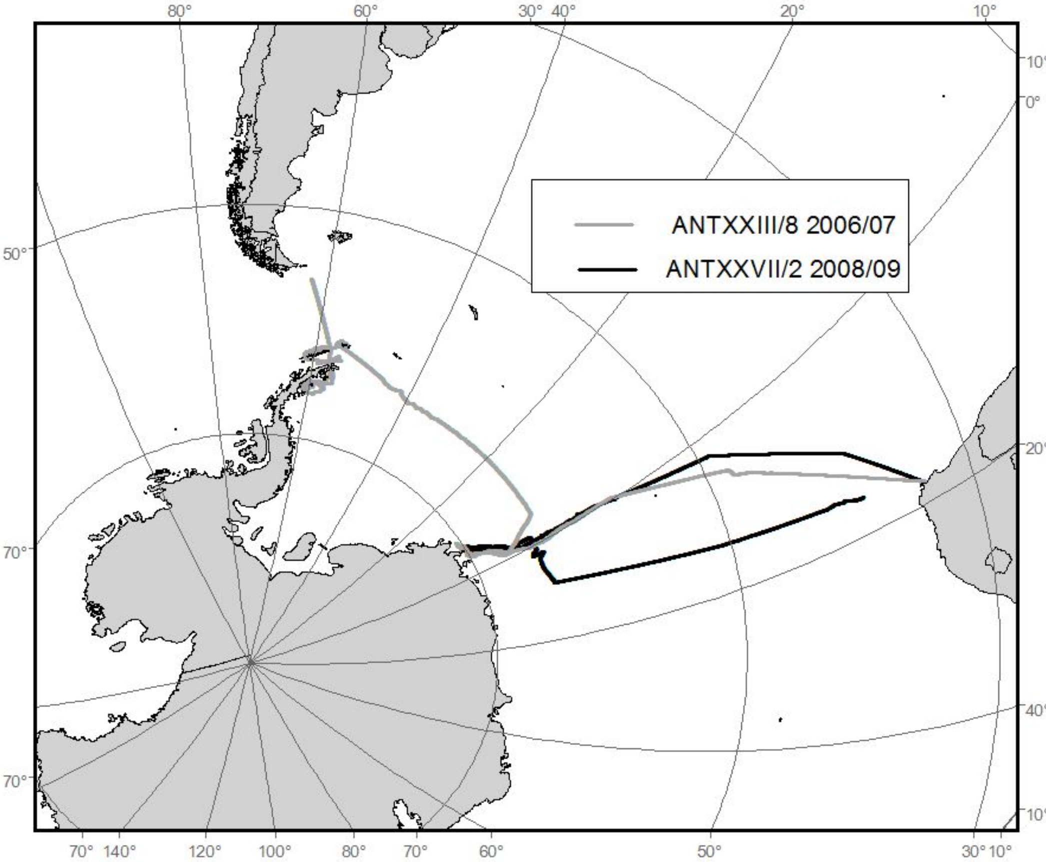

Figure 1: Tracks of both RV ‘Polarstern’ cruises in 2006/07 (ANT-XXIII/8) and 2008/09 (ANT-XXV/2). The grey line indicates the cruise in 2006/07, the black line the cruise in 2008/09

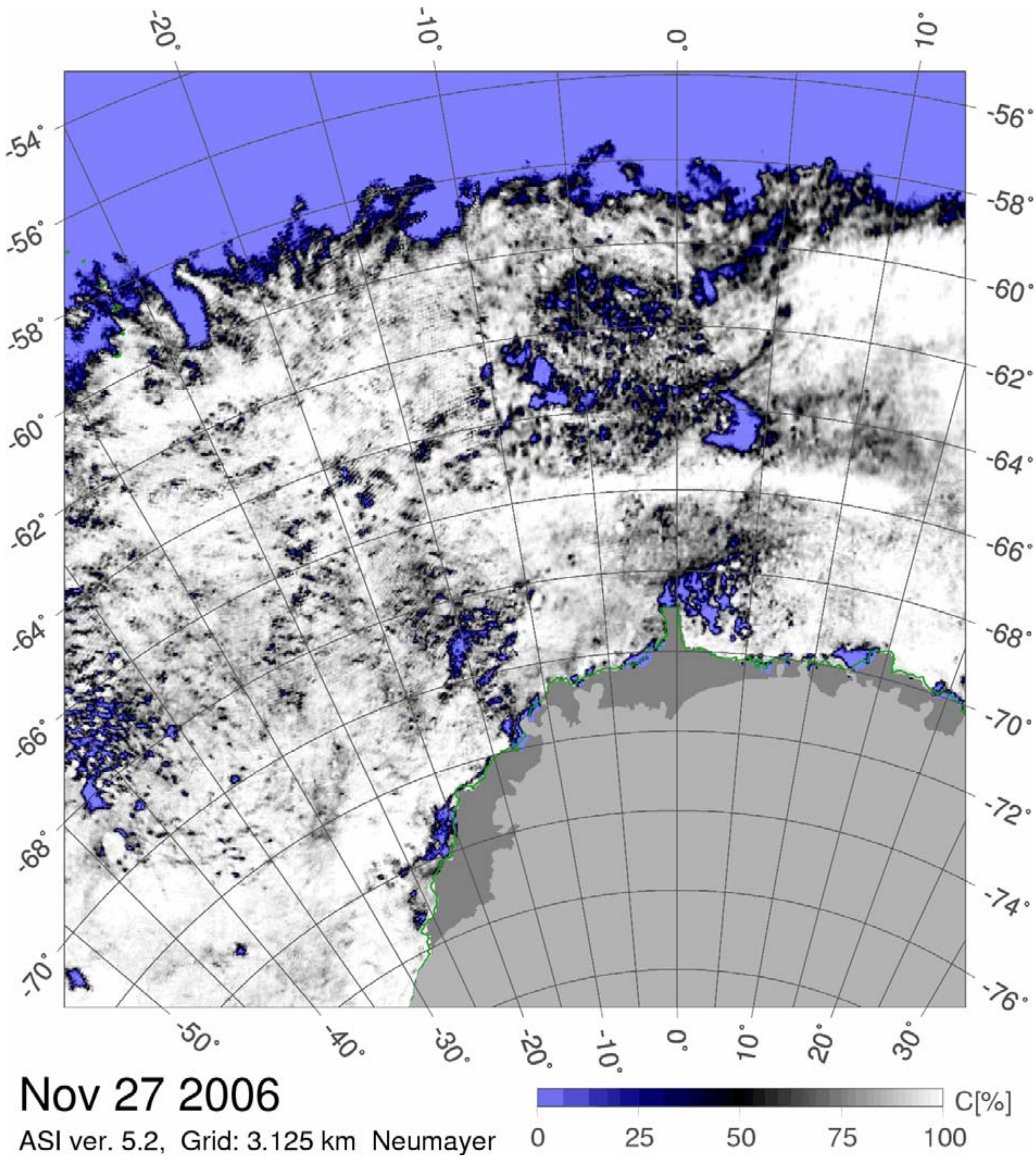

Figure 2a: Pack-ice coverage of the Weddell Sea on 27 November 2006 when RV 'Polarstern' was about to enter the pack-ice south of South Africa (Spreen et al., 2008)

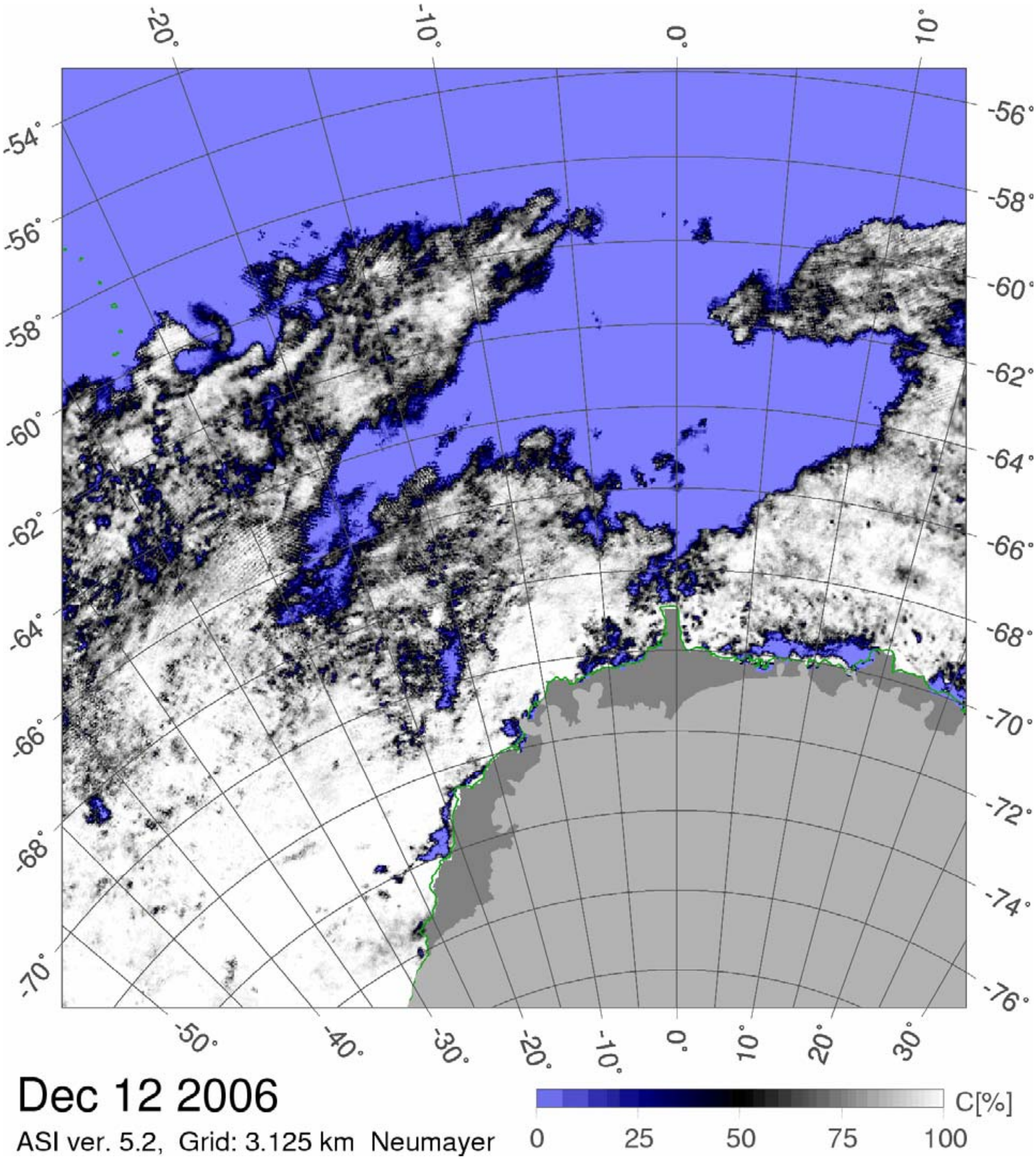

Figure 2b: Pack-ice coverage of the Weddell Sea on 12 December 2006 two days after RV ‘Polarstern’ had left Neumayer Station on her way to Elephant Island (Spreen et al., 2008)

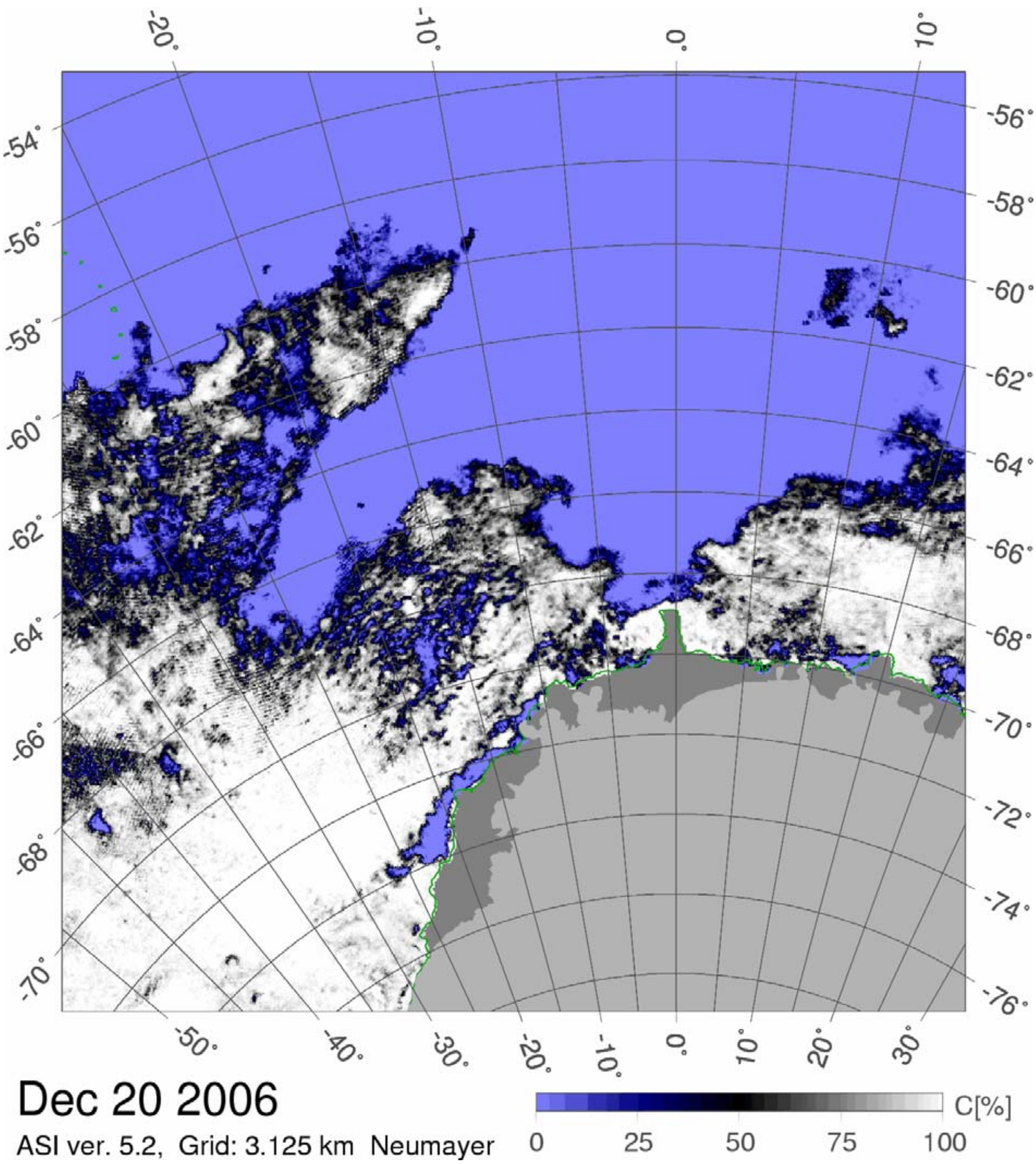

Figure 2c: Pack-ice coverage of the Weddell Sea on 20 December 2006 while RV ‘Polarstern’ was fishing off Elephant Island (Spreen et al., 2008)

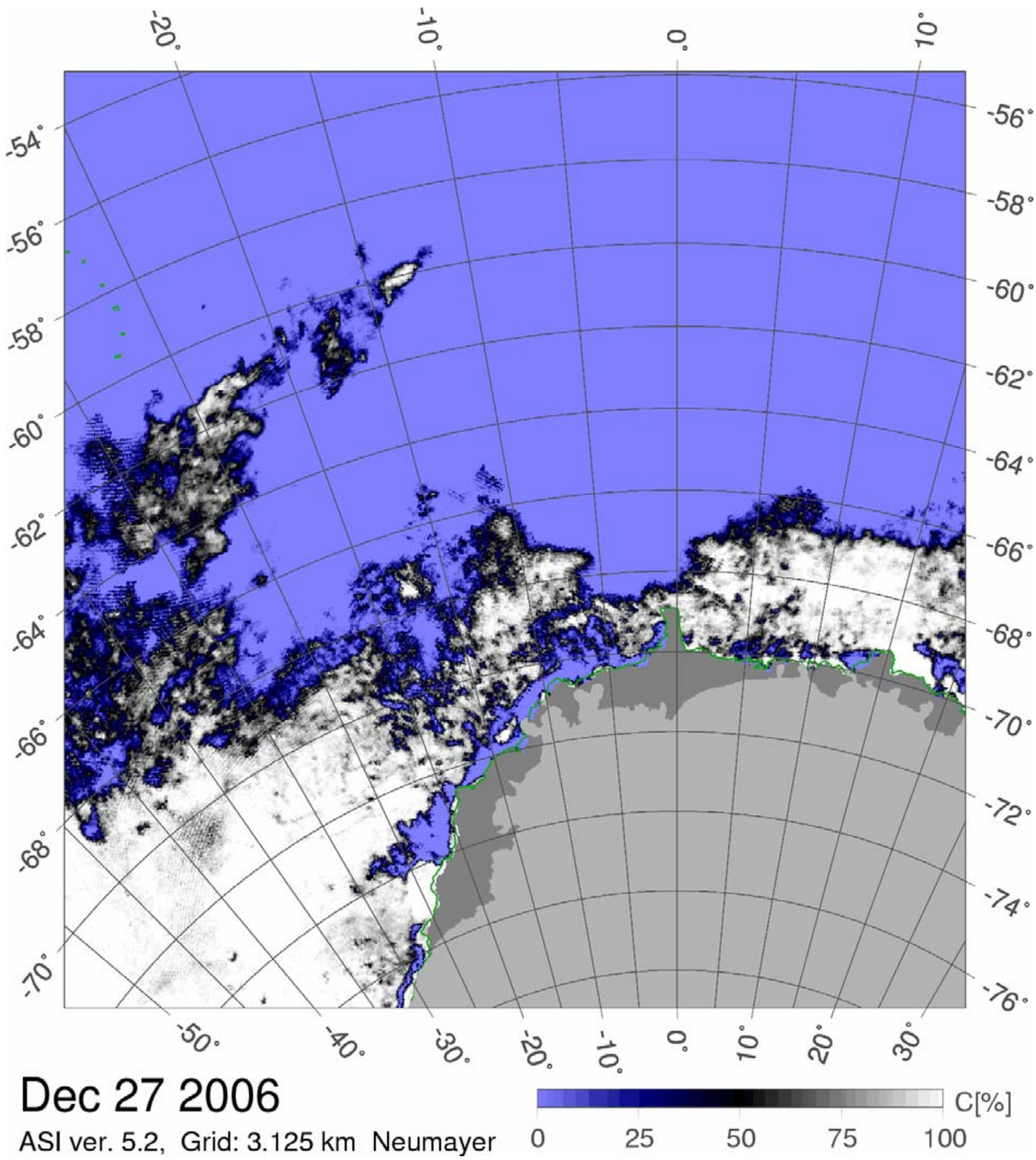

Figure 2d: Pack-ice coverage of the Weddell Sea on 27 December 2006 when RV 'Polarstern' operated off the South Shetland Islands (from Spreen et al., 2008)

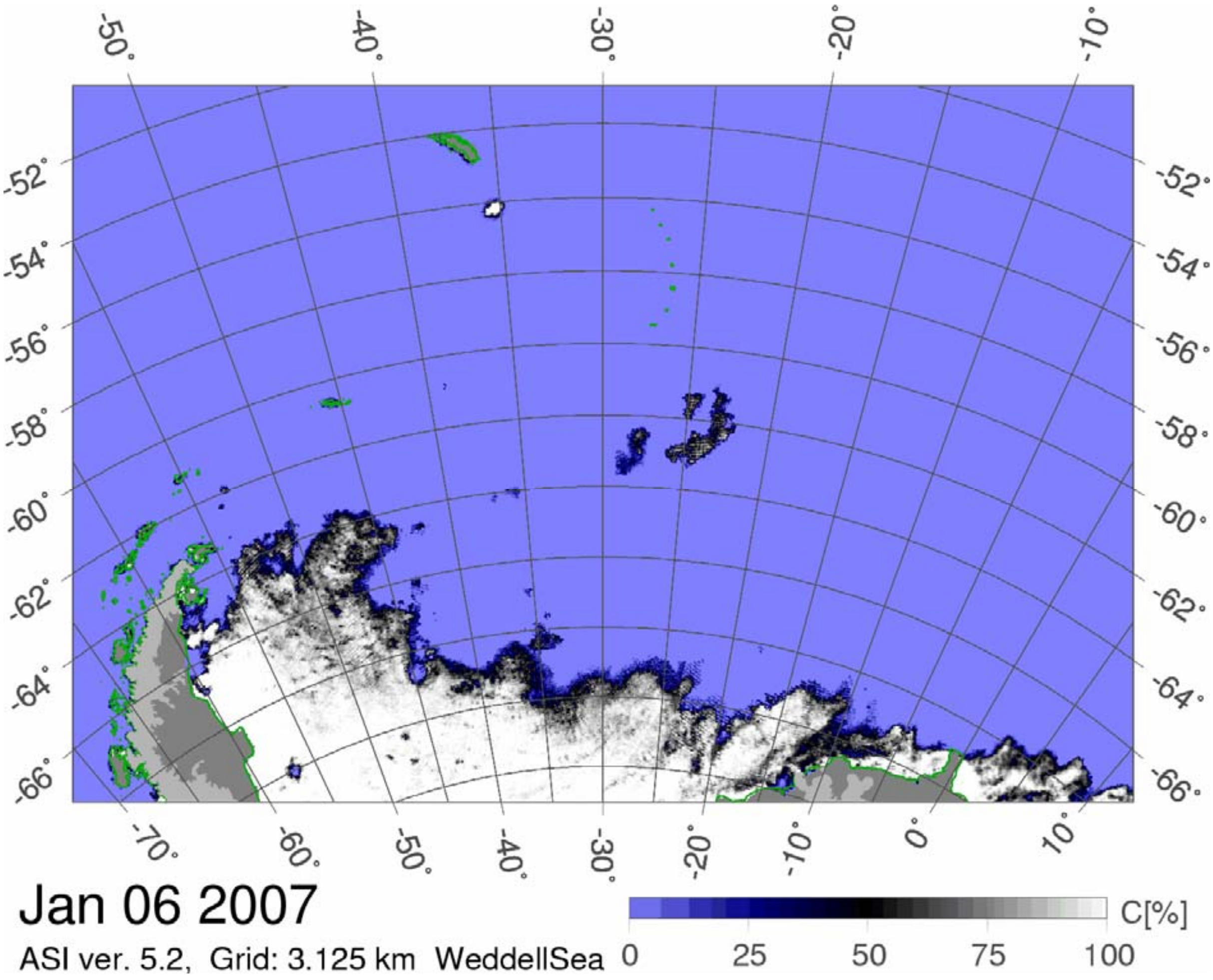

Figure 2e: Pack-ice coverage of the Weddell Sea on 6 January 2007 when RV 'Polarstern' re-entered the pack-ice south of Antarctic Sound (north western Weddell Sea) (Spreen et al., 2008)

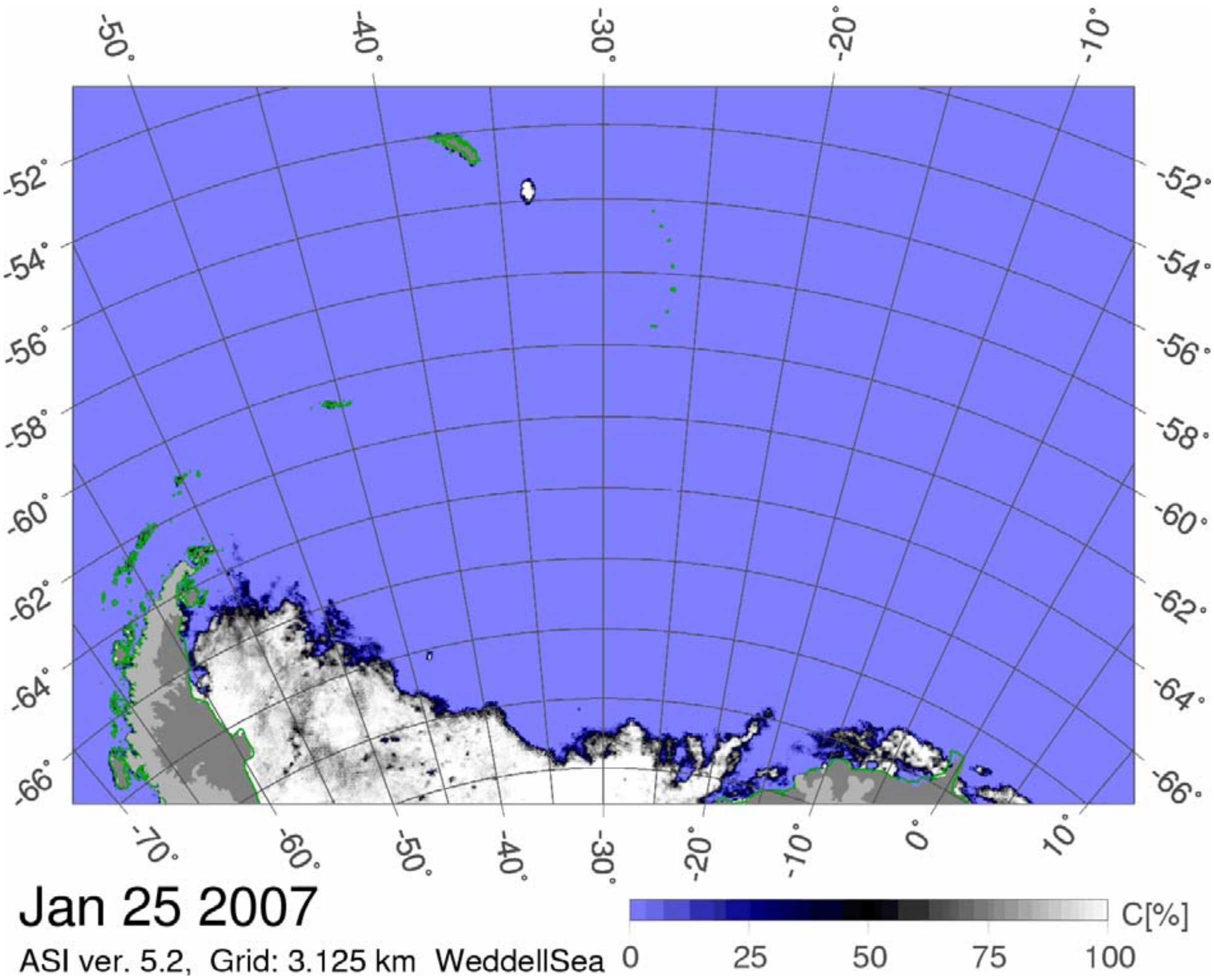

Figure 2f. Pack-ice coverage of the Weddell Sea on 25 January 2007 when RV 'Polarstern' left the pack-ice south of Antarctic Sound on her return voyage to Punta Arenas (Spreen et al., 2008)

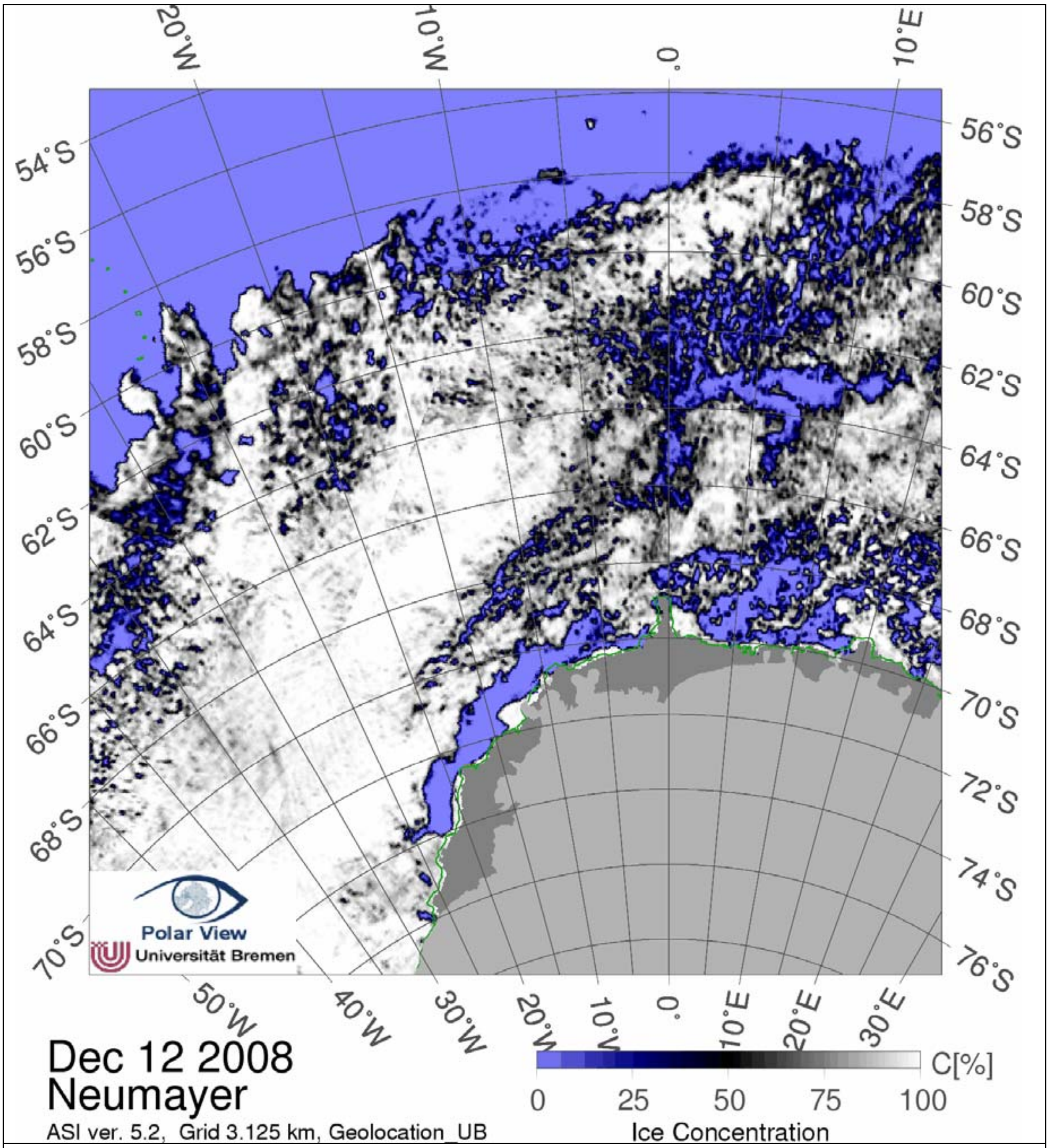

Figure 3a: Pack-ice coverage of the Weddell Sea on 12 December 2008 when RV 'Polarstern' entered the pack – ice (Spreen et al., 2008)

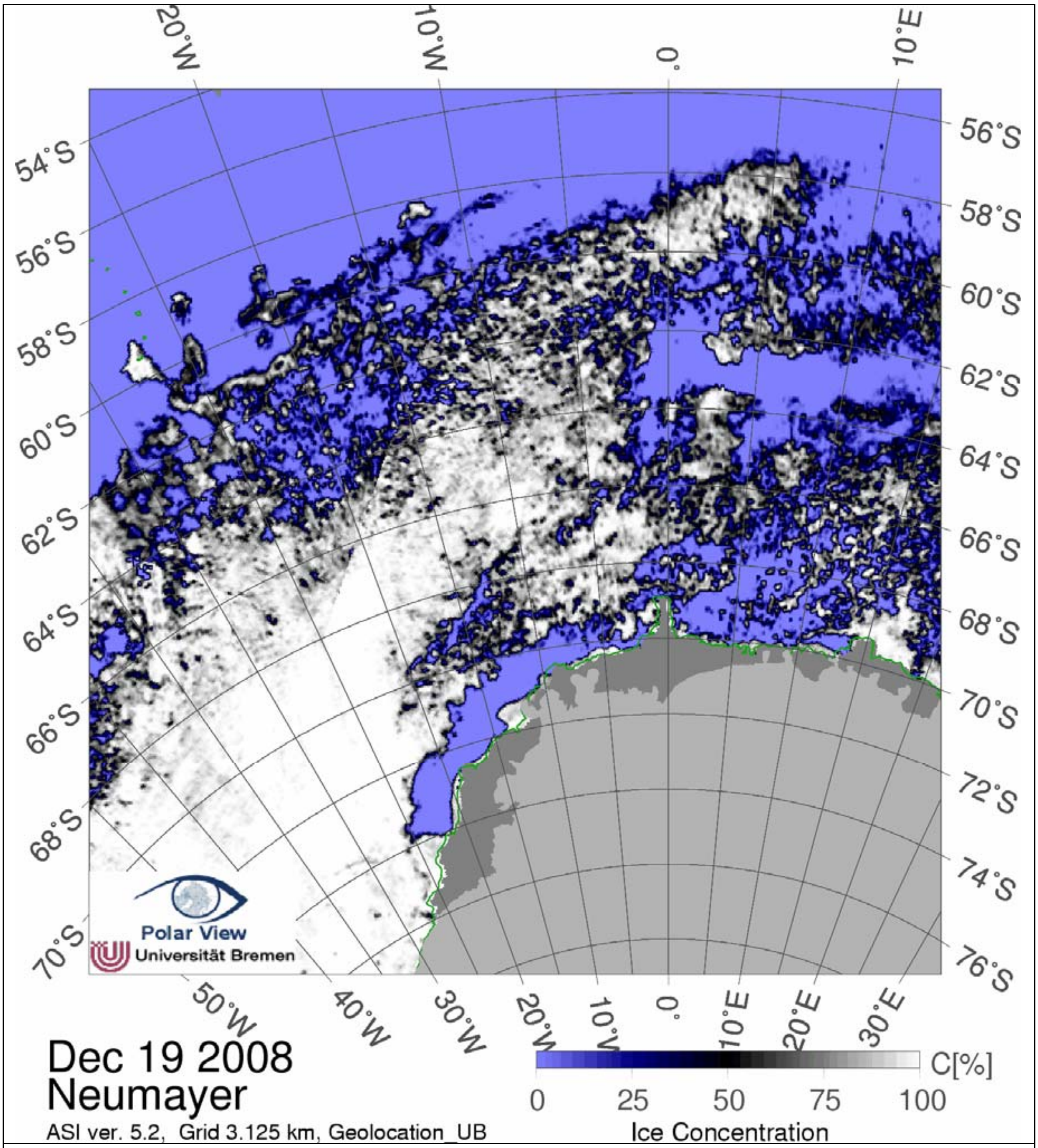

Figure 3b: Pack-ice coverage of the Weddell Sea n on 19 December 2008 when RV 'Polarstern' called in at Neumayer in Atka Bay (Spreen et al., 2008)

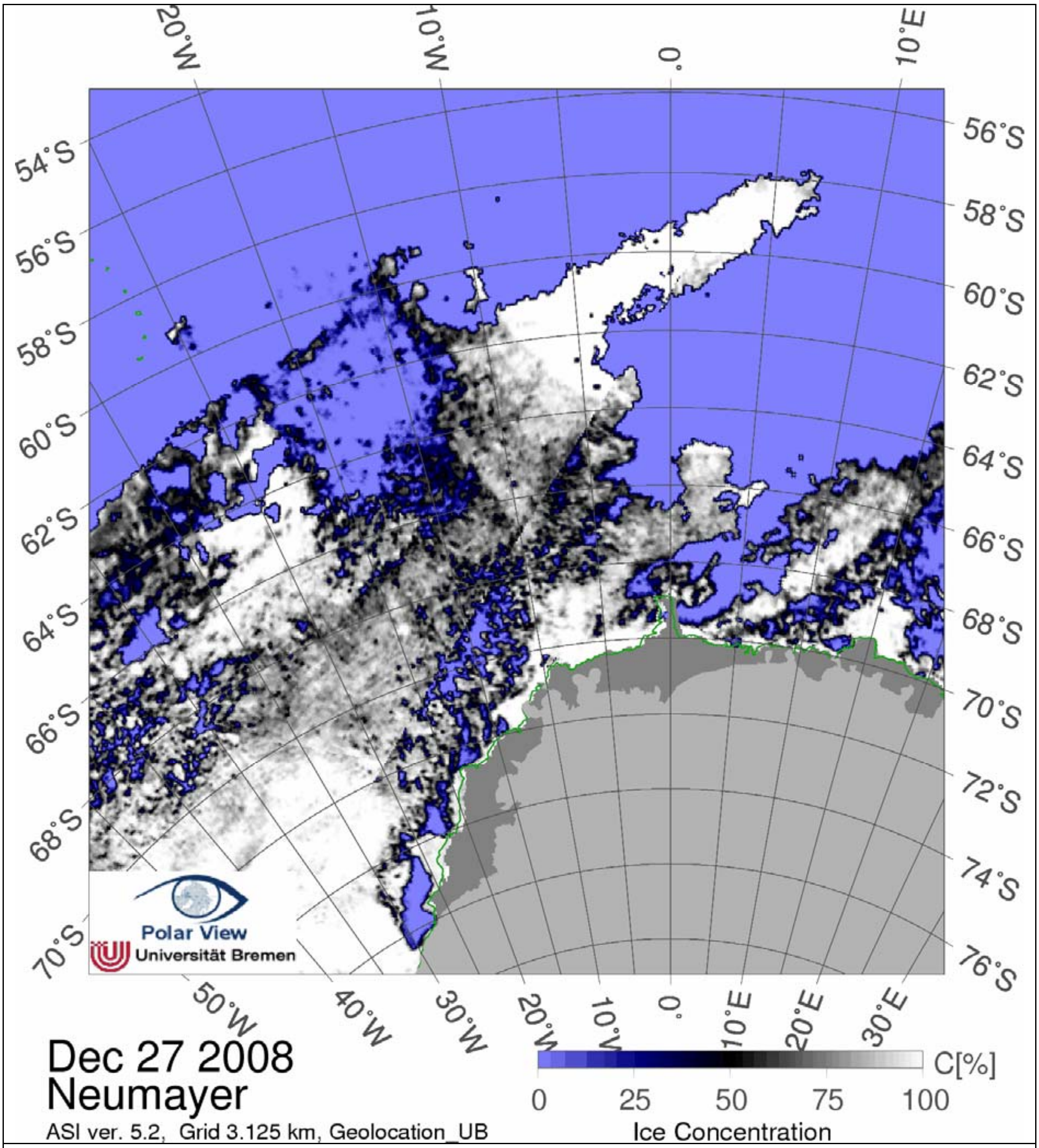

Figure 3c: Pack-ice coverage of the Weddell Sea on 27 December 2008 when RV 'Polarstern' left the pack – ice (Spreen et al., 2008)

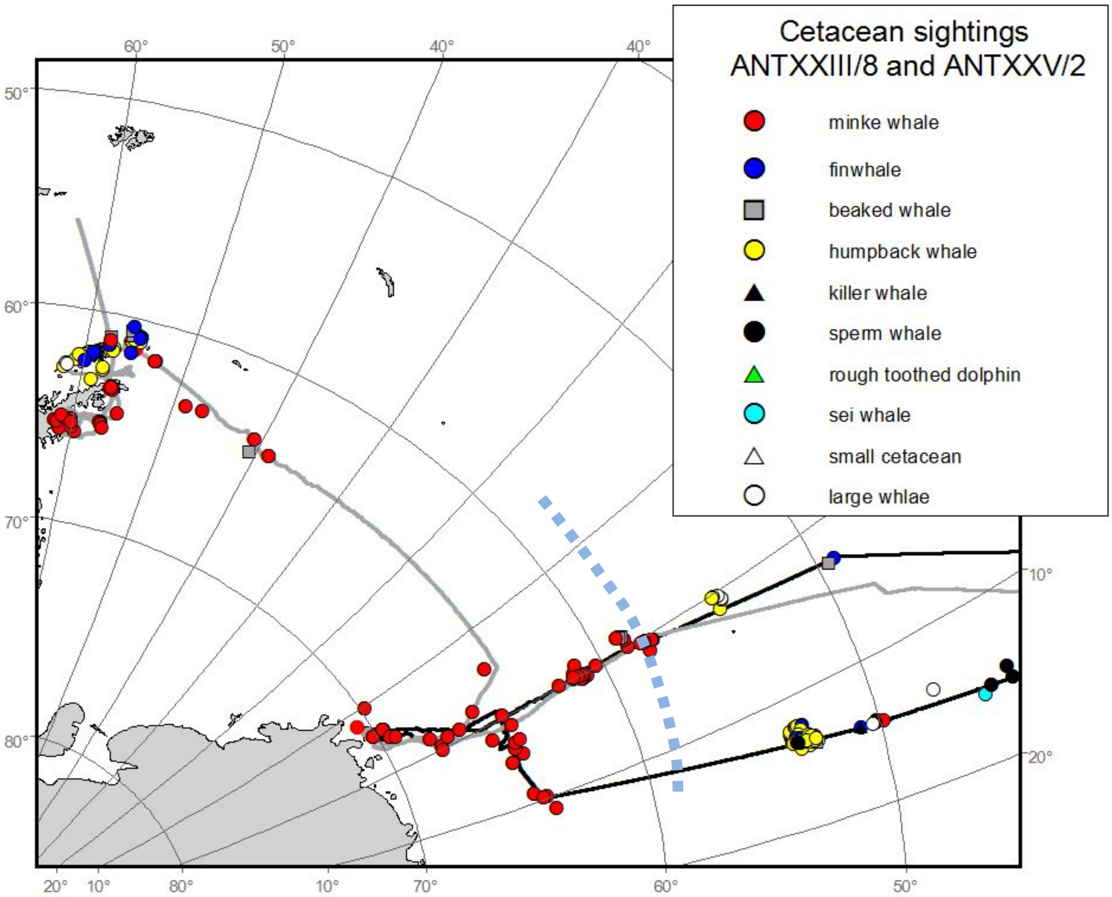

Figure 4: All cetacean sightings conducted during both surveys from Polarstern from helicopter and crow's nest. The blue dotted line denotes the approximate entrance into the Marginal Ice Zone, which during both cruises was located around 58° S.

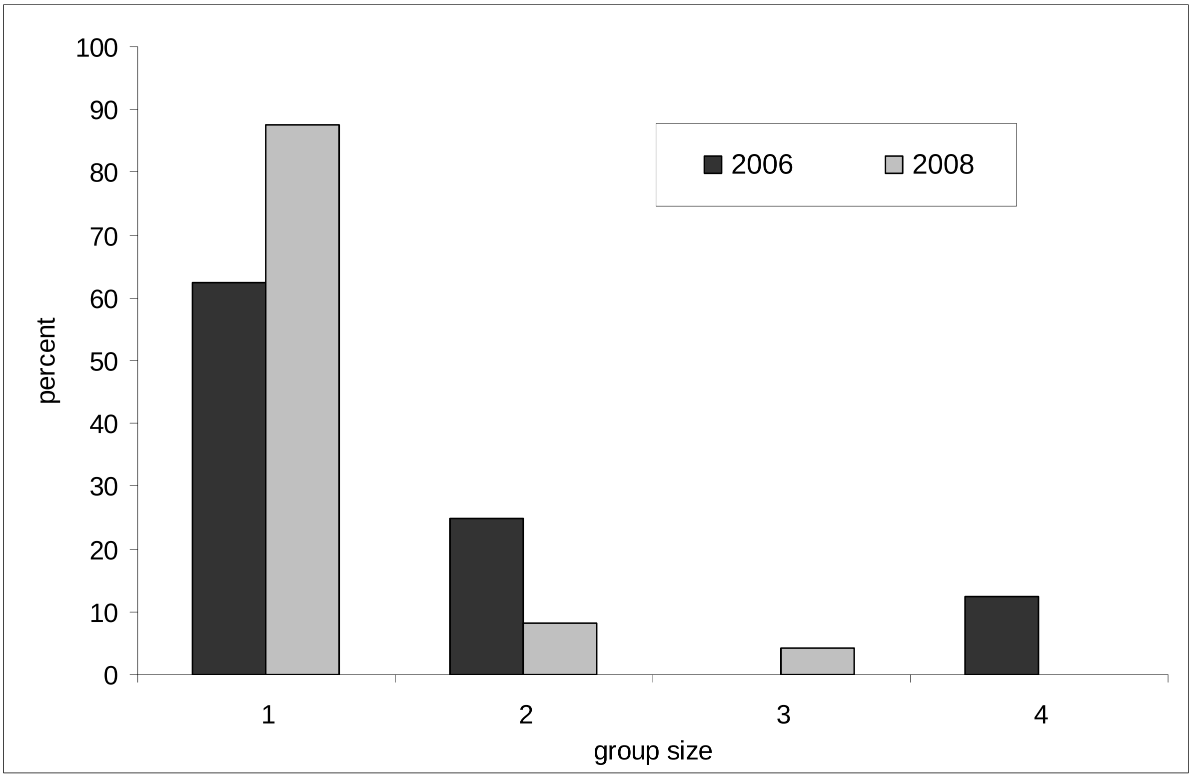

Figure 5: Distribution of group sizes in minke whales in 2006/07 (n=18) and 2008/09 (n=24) in the eastern Weddell Sea

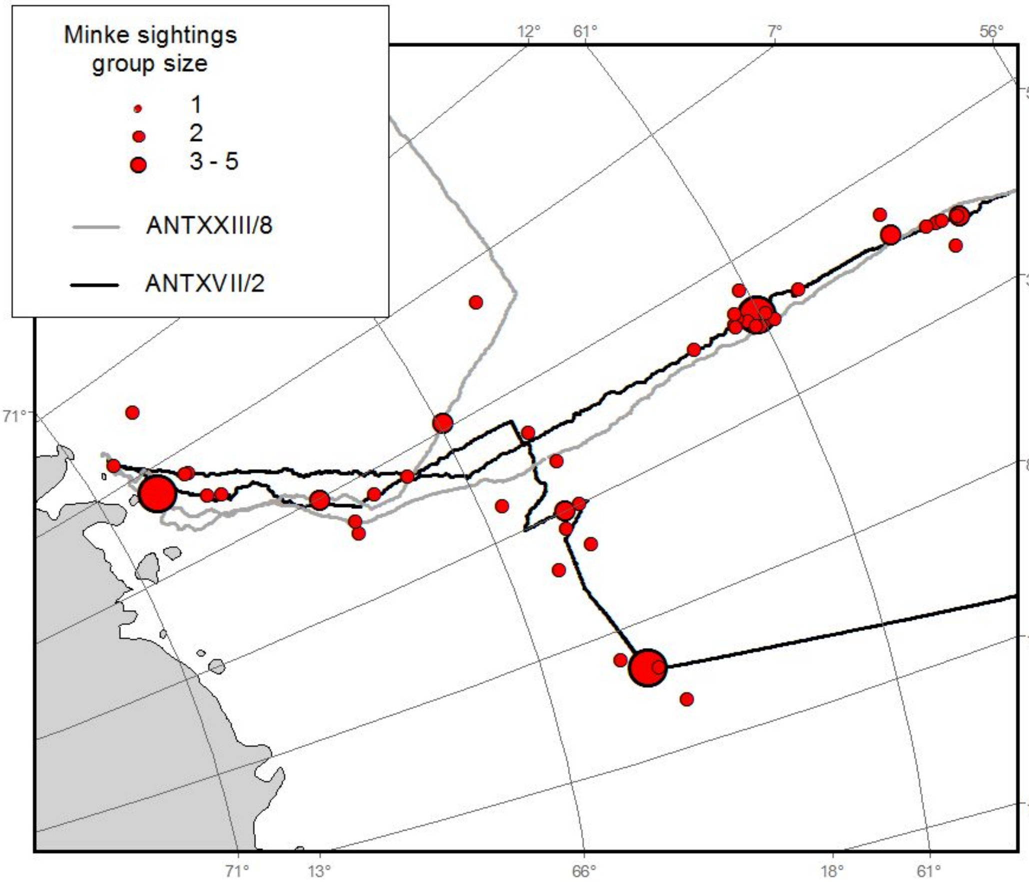

Figure 6: Minke sightings south of 57°S in the east of the Weddell Sea presented in group sizes during 'Polarstern' cruise ANT-XXV/2 in 2008/09

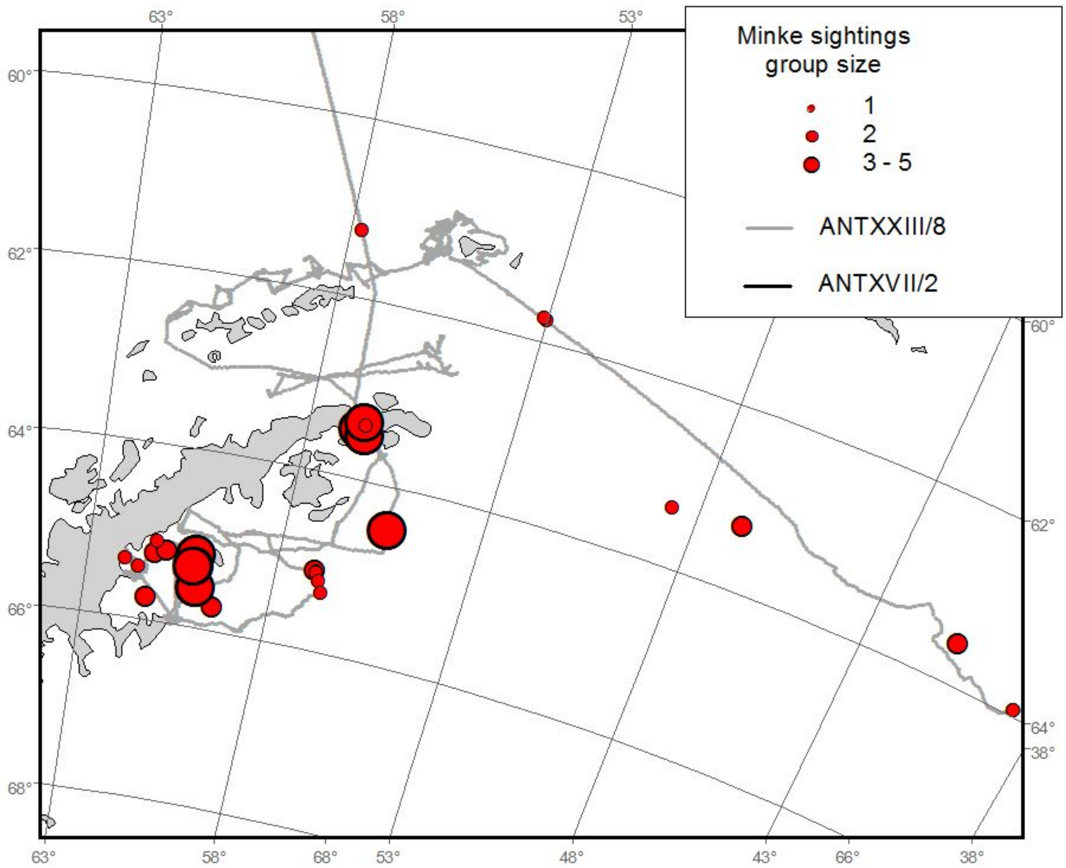

Figure 7: Minke sightings around the Antarctic Peninsula presented in group sizes for ANTXX-III/8