

# Open sea area in the south of the ice edge in IDCR/SOWER CPII and CPIII

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## ABSTRACT

Open sea area in the south of the ice edge in IDCR/SOWER CPII and CPIII was calculated by using sighting effort data and sea ice data derived by satellite. First, start and end dates in each 5° longitudinal sector were identified using sighting effort data. Then, mean sea ice concentrations in the south of the ice edge in each 5° longitudinal sector were calculated based on the dates. Finally, Open sea area in the south of the ice edge in each 5° longitudinal sector was calculated. The data prepared by this exercise will be used as a basis for estimation of number of Antarctic minke whales in the south of ice edge. As previously reported, sea ice conditions in the south of the ice edge were varied in both regions and years. In addition, other environmental conditions and number of other baleen whales were different between CPII and CPIII in some regions. Region-specific integrated approach should be taken to estimate number of animals in the south of the ice edge because factors affecting abundance estimate are different from region to region. Development of appropriate model to estimate number of animals in the south of the ice edge is critically important.

## INTRODUCTION

The International Whaling Commission (IWC) conducted sighting surveys for assessing the abundance of the Antarctic minke whale (*Balaenoptera bonaerensis*) from 1978/79 to 2009/10 in the Antarctic in austral summer (Matsuoka *et al.*, 2003 for review). The names of the cruises were firstly the International Decade of Cetacean Research programme (IDCR, from 1978/79 to 1995/96) and then the Southern Ocean Whale and Ecosystem Research programme (SOWER, from 1996/97 to 2009/10). These cruises covered three circumpolar surveys for the purpose of comprehensive assessments: 1978/79-1983/84 (first circumpolar, CPI), 1984/85-1990/91 (second circumpolar, CPII) and 1991/92-2003/2004 (third circumpolar, CPIII). Abundance estimates based on the IWC standard method revealed that an appreciable difference between CPII and CPIII (Branch and Butterworth, 2001; Branch, 2006). The reasons of the difference have been investigated by the Scientific Committee of the IWC (IWC/SC) since 2001 (IWC, 2002a) but conclusion has not been reached. Number of animals in the south of the ice edge where IDCR/SOWER research vessels could not conduct surveys has been identified as one of the reasons of the difference (IWC, 2002b; IWC, 2003b). Several studies were attempted to estimate number of animals in the south of the ice edge by using IDCR/SOWER data and sea ice data derived from satellite (e.g. Shimada *et al.*, 2001). However, they used not open sea ice area in the south of the ice edge but sea ice extent. Because Antarctic minke whales are distributed in the open sea area in the south of ice edge, use of open sea area in the south of ice edge rather than sea ice extent is appropriate to estimate number of animals. In this paper, open sea ice area in the south of ice edge in each IWC management area by 5° longitudinal sector in CPII and CPIII are presented. This exercise was conducted based on the recommendation of the 62nd IWC/SC (IWC, 2011).

## MATERIALS AND METHODS

Sighting effort and stratum boundary data prepared as a standard data (Burt, 2004) were used in this analysis. Sighting effort data were separated in 1 km segments and aggregated in 5° longitudinal sectors to identified start and end dates of the survey in the sectors. More than one survey was conducted in same longitudinal sector in CPIII. Survey-once option described in Branch (2005) was used to determine 5° longitudinal sectors in this paper. Ice edges in this paper were the southern boundaries of the IDCR/SOWER survey areas determined by the cruise leaders and defined by a level of ice cover that prevented the survey from being conducted at nominal survey speed of 11.5 knots (IWC, 2003a). Areas between the ice edges and the coast line of Antarctica were identified as sea ice area. The coast line in Antarctic Digital Database version 3 provided by the Scientific Committee on Antarctic Research (SCAR) was used. Polygons of the sea ice areas were prepared using a geographic information system (GIS) software, ArcGIS (Version 9.3.1).

Satellite derived daily sea ice data, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999) from 1978 to 2004 was used in the analysis. The data was provided by the National Snow and Ice Data Center (NSIDC, US). Sea ice observation using the satellite passive microwave sensors was started

with the launch of Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7 in 1978. The sensor was changed to Special Sensor Microwave/Imager (SSM/I) in 1987 and the data collection is still on going. The data were collected every other day for the SMMR whereas those were collected every day for the SSM/I. Sea ice concentration is expressed as percentage of area covered by sea ice in every 25km×25 km grid cell. Sea ice concentrations more than 15% was considered as grid cells with sea ice as in the cases of other studies (Bjørøgo, et al., 1997; Hanna, 2001; Zwally, et al., 2002). Therefore, grid cells with less than 15% sea ice concentrations in original data were treated as 0% sea ice concentration. The original data was in the NSIDC polar stereographic projection.

Average sea ice data were calculated in each 5° longitudinal sector based on start and end dates of the surveys. Exceptions were the Weddell Sea region of Area II and the Ross Sea region of Area V. As pointed out by Murase and Kitakado (2010), the surveys in these areas were conducted following retreating ice to the south as well as to longitudinal directions. Therefore, average sea ice data during the survey periods were calculated in these areas. Average sea ice data in the area between the ice edges and the coast line were then extracted. All geographically referenced data were converted to the South Pole Lambert azimuthal equal area projection to obtain size of area accurately as much as possible. Central meridians and latitude of origins were different in each management area (Table 1). Geometric corrections were applied to the average sea ice data to convert the projection. Resolution of sea ice data was changed to 30×30 km grid cell by the inverse distance weighted interpolation with the aid of ArcGIS. Open sea ice area corresponding to sea ice concentrations was then calculated.

## RESULTS AND DISCUSSION

Start and end dates of the surveys used to calculate average sea ice data are listed in Table 2. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in each IWC management area in CPII and CPIII is shown in Tables 3-8. Maps of sea ice conditions at the time of surveys are shown in Figs. 1-6 by the IWC management areas. Survey strata and surveyed tracklines are also shown in these figures. The survey in each IWC management area was completed in one year in CPII while it took 2 to 3 years in CPIII. Longitudinal survey coverage in CPIII in each year is also shown in Tables 3-8 and Figs. 1-6.

The data prepared by this exercise will be used as a basis for estimation of Antarctic minke whales in the south of ice edge. Though a model to estimate abundance of Antarctic minke whales in the south of ice edge was briefly discussed in 59th IWC/SC (IWC, 2008), further investigation is required. As previously reported, sea ice conditions in the south of the ice edge were varied in both regions and years. Shapes of sea ice edges and sea ice concentrations in the south of the ice edges in Area II, western part of Area III and eastern part of Area V were totally different from CPII and CPIII. In addition, the surveys in Area II were conducted in extreme sea ice conditions (Murase and Kitakado, 2010). CPII in Area II (1986/87) were conducted from late December to early February. Because sea ice melted rapidly in Area II from late December to early January, CPII was conducted in unstable sea ice conditions. CPIII in Area II (1996/97 and 1997/98) was conducted from late January to mid February when sea ice conditions were stable. However, unusual large polynya existed in 1997/98. Such polynya was not observed by satellite in CPII. Such sea ice dynamics should also considered in addition to open sea ice area in the south of the ice edge.

Sea ice conditions in the south of the ice edges in Area I, IV and western part of Area V were similar between CPII and CPIII. However, extent of spatial distribution of large baleen whales was expanded in these areas from CPII to CPIII (Murase *et al.*, 2011). Environmental condition in Area I was also different between CPII and CPIII. Number of Antarctic minke whales in the south of ice edge should be related to the multiple factors. Region-specific integrated approach should be taken to estimate number of animals in the south of the ice edge because factors affecting abundance estimate are different from region to region.

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Table 1. Central meridians and latitude of origins used in the the South Pole Lambert azimuthal equal area projection.

Area	Central meridians	latitude of origins
I	90W	66S
II	30W	69S
III	35E	65S
IV	100E	65S
V	165E	69S
VI	145W	65S

Table 2. Start and end dates of survey used to calculate average sea ice concentrations.

Area	Longitude	CPII			CPIII			Area	Longitude	CPII			CPIII													
		Year	Start	End	Year	Start	End			Year	Start	End	Year	Start	End											
I	120W-115W	1989/90	1990/2/8	1990/2/10	2000/01	2001/1/31	2001/2/11	IV	70E-75E	1988/89	1989/1/12	1989/1/20	1994/95	1995/2/11	1995/2/20											
	115W-110W		1990/2/5	1990/2/9		2001/2/7	2001/2/15		75E-80E		1989/1/10	1989/1/21		1995/2/13	1995/2/24											
	110W-105W		1990/1/31	1990/2/6		1994/1/4	1994/1/7		80E-85E		1989/1/8	1989/1/11		1999/1/20	1999/1/26											
	105W-100W		1990/1/24	1990/1/31	1993/94	1994/1/6	1994/1/11		85E-90E		1989/1/2	1989/1/9	1999/1/23	1999/1/29												
	100W-95W		1990/1/22	1990/1/25		1994/1/9	1994/1/18		90E-95E		1988/12/31	1989/1/4	1999/1/26	1999/1/31												
	95W-90W		1990/1/16	1990/1/22		1994/1/15	1994/1/22		95E-100E		1988/12/29	1988/12/31	1999/1/28	1999/2/1												
	90W-85W		1990/1/14	1990/1/19	1999/00	1994/1/18	1994/1/31		100E-105E		1989/1/25	1989/1/28	1998/99	1999/2/1	1999/2/5											
	85W-80W		1990/1/12	1990/1/18		1994/1/25	1994/2/2		105E-110E		1989/1/27	1989/1/30		1999/2/3	1999/2/8											
	80W-75W		1990/1/7	1990/1/15		2000/1/15	2000/1/27		110E-115E		1989/1/29	1989/2/3		1999/2/5	1999/2/10											
	75W-70W		1990/1/4	1990/1/11	1999/00	2000/1/17	2000/2/3		115E-120E		1989/2/1	1989/2/5	1999/2/10	1999/2/15												
	70W-65W		1989/12/30	1990/1/7		2000/2/1	2000/2/10		120E-125E		1989/2/5	1989/2/7	1999/2/15	1999/2/21												
	65W-60W		1989/12/29	1990/1/4		2000/2/7	2000/2/13		125E-130E		1989/2/8	1989/2/10	1999/2/17	1999/2/22												
	II		60W-55W	1986/87	1986/12/29	1987/2/4	1997/98		1998/1/20		1998/2/15	V	130E-135E	1985/86	1985/12/26	1986/2/18	2001/02	2001/12/27	2002/1/2							
55W-50W		2002/1/1	2002/1/28																							
50W-45W		2002/1/6	2002/2/3																							
45W-40W		2002/1/23	2002/2/10																							
40W-35W		2003/1/29	2003/2/7																							
35W-30W		2003/2/5	2003/2/15																							
30W-25W		2002/03	2003/2/18					2003/2/25																		
25W-20W		2002/12/23	2003/1/25																							
20W-15W		1996/96	1997/1/16					1997/2/14		1996/96			1997/1/16					1997/2/14	165E-170E (N of 71S)	165E-170E	1985/86	1985/12/26	1986/2/18	2003/04	2003/12/27	2004/2/8
15W-10W																										
10W-5W																										
5W-0																										
III		0-5E	1987/88					1988/1/23		1988/1/24			1992/93					1992/12/26	1992/12/31	VI	175W-170W	1990/91	1991/1/3	1991/1/9	1996/1/13	1996/1/23
	5E-10E	1988/1/19		1988/1/24	1992/12/31	1993/1/3	170W-165W	1991/1/7	1991/1/13	1996/1/20	1996/1/30															
	10E-15E	1988/1/18		1988/1/22	1993/1/3	1993/1/7	165W-160W	1991/1/12	1991/1/16	1996/1/27	1996/2/4															
	15E-20E	1988/1/15		1988/1/20	1993/1/6	1993/1/11	160W-155W	1991/1/14	1991/1/20	1995/96	1996/2/4	1996/2/10														
	20E-25E	1988/1/11		1988/1/19	1993/1/11	1993/1/16	155W-150W	1991/1/19	1991/1/21	1996/2/10	1996/2/20															
	25E-30E	1988/1/9		1988/1/17	1993/1/17	1993/1/23	145W-140W	1991/1/23	1991/1/26	1996/2/20	1996/2/22															
	30E-35E	No sea ice data		1994/95	1993/1/20	1993/1/25	140W-135W	1991/1/26	1991/1/31	2001/01	2001/1/16	2001/1/23														
	35E-40E				1993/1/24	1993/1/31	135W-130W	1991/1/31	1991/2/6	2001/1/22	2001/1/26															
	40E-45E				1995/1/14	1995/1/17	130W-125W	1991/2/6	1991/2/8	2000/01	2001/1/24	2001/2/22														
	45E-50E	1995/1/16		1995/1/25	1995/1/25	1995/1/27	125W-120W	1991/2/9	1991/2/11	2001/1/28	2001/2/20															
	50E-55E	1995/1/25		1995/1/27	1995/1/27	1995/1/30																				
	55E-60E	1995/1/27		1995/1/30	1995/2/4	1995/2/9																				
	60E-65E	1995/2/4		1995/2/9	1995/2/7	1995/2/12																				
65E-70E	1995/2/7	1995/2/12																								

Table 3. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area I in CPII and CPIII.

Sea ice concentration	Area I												Total
	CPII (1989/1990)												
	120W-115W	115W-110W	110W-105W	105W-100W	100W-95W	95W-90W	90W-85W	85W-80W	80W-75W	75W-70W	70W-65W	65W-60W	
0-5%	5,109	393	3,023	4,938		455		4,178	341	4,547	25,831	9,823	58,639
10-15%		792		809	1,613	1,121	404		2,756	64	2,109	1,893	11,561
15-20%	565	2,209	297				30	1,854	1,928	497	847	969	10,419
20-25%	1,411	750	697	689	348	1,165	493	1,156		126	649	44	7,530
25-30%	56	835	469	1,277	772	3,124	1,196	656	671	638	1,398	896	11,987
30-35%	452			616	1,039	443	1,224	2,863	607	20	644	50	7,959
35-40%	714	2,594	455						567	2,130	660	276	7,580
40-45%	1,009	220	1,010	3,400	1,523	1,010	532	537	2,791	55	904		12,992
45-50%	285	483	1,857	2,380		457	482		1,381	1,571	485		9,382
50-55%	896	1,331	1,687	2,138		439		2,945	1,042	3,278	251		14,008
5-10%	1,640	3,314	290	1,613			224	928	404	190	2,290	2,202	13,095
55-60%	351	1,130	1,399	1,045	402	1,163	1,887	2,538	2,206	528	120		12,769
60-65%	668	1,395	1,288	1,638	699	315	317	2,000	193	941			9,453
65-70%	586	577	1,285	1,143	310	862	302	1,727	1,349	240	3		8,384
70-75%	643	240	1,419	631	515		509	1,277	1,145	292			6,671
75-80%	222	499	969	1,033	408	374	620	610	375	330	88		5,530
80-85%	588	1,176	1,275	1,412			915	1,184	493	143	181		7,367
85-90%	210	219	988	1,515	304	307	428	823	533	79	31		5,437
90-95%	395	381	1,044	217	37	464	681	257		287			3,765
95-100%	382	465	335	117	518	944	607						3,367
Total	16,183	19,005	20,595	27,416	7,997	11,955	12,271	28,930	16,223	14,772	36,230	16,313	227,892

Sea ice concentration	Area I												Total
	CPIII (2000/2001)			CPIII (1993/1994)						CPIII (1999/2000)			
	120W-115W	115W-110W	110W-105W	105W-100W	100W-95W	95W-90W	90W-85W	85W-80W	80W-75W	75W-70W	70W-65W	65W-60W	
0-5%	2,680	7,424	10,290	457	564	11,368	1,126	1,375		6,252	16,307	8,675	66,518
10-15%	305	1,573	794	111	608	769	799	1,039	4,300	3,895	660	1,908	16,760
15-20%	843	1,217	752	842		799	909	1,776	1,470	1,490	1,931	523	12,550
20-25%	3,694	1,372	699	1,272	1,321	1,413	1,353	2,058	3,333	1,412	2,074	564	20,566
25-30%	1,084	1,777	1,294	47	275		1,312	3,912	1,998	2,604	585	37	14,926
30-35%	1,890	1,405	573	365	1,188	1,598	496	1,787	1,218	423	983		11,927
35-40%	2,317	1,694	581	2,276	956		407	3,799	1,988	559	607	347	15,530
40-45%	1,644	1,046	519	1,519	978	535	1,584	1,518	3,364		310		13,017
45-50%	1,966	986	927	959	1,292	1,395	3,753	2,724	2,375	336	184		16,898
50-55%	826	421	857	1,708		880	433	3,420	835	766	1,227		11,373
5-10%	818	1,674	1,684	1,134	661	2,461		1,706	353	5,030	3,786	1,610	20,918
55-60%	412	783	390	774		395	595	2,286	582	765	49		7,030
60-65%	976	665	1,028	1,093	1,337		2,405	3,723	1,216	650	564		13,657
65-70%	1,142	601	575			291	804	2,302	788	1,014			7,517
70-75%	505	729	242	260		736	502	986	953	676	463		6,052
75-80%	581	926	144	835	200		1,581	1,353	641	1,534			7,795
80-85%	706	139	1,120	429	167	319	779	822	610	181			5,271
85-90%	637	335	573	424	209	254	763	248	426	400	210		4,479
90-95%	361	507	455	169	79	219	784		237	166	131		3,109
95-100%	454	440	611	139	290	298	412		204	125	184		3,160
Total	23,840	25,711	22,033	15,564	8,969	23,217	19,542	36,571	27,811	31,111	29,851	14,833	279,053

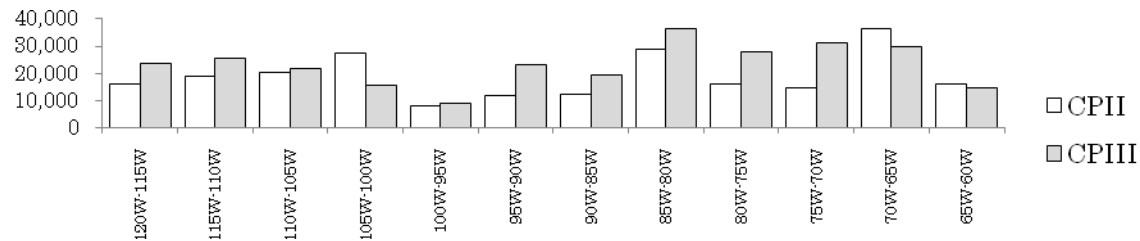


Table 4. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area II in CPII and CPIII.

Sea ice concentration	Area II												Total	
	CPII (1986/1987)													
	60W-55W	55W-50W	50W-45W	45W-40W	40W-35W	35W-30W	30W-25W	25W-20W	20W-15W	15W-10W	10W-5W	5W-0		
0-5%	2,509	89	38,262	53,609	83,137	5,571	9,443	10,860	9,636	2,392			215,509	
10-15%	374	3,875	7,035	12,619	5,522	36,961	20,442	25,941	2,443	1,607	1,837	216	118,871	
15-20%	178	3,864	6,692	10,422	5,205	23,053	11,801	27,732	2,290	2,054	2,139	1,072	96,502	
20-25%		7,833	7,661	9,771	2,774	5,570	7,157	17,070	695		861	851	60,244	
25-30%	653	5,646	4,584	7,867	3,918	3,282	17,247	18,272	1,754	387	629	3,289	67,527	
30-35%	347	4,787	4,859	7,957	1,831	4,288	15,270	6,783				592	46,684	
35-40%	3,104	4,272	5,637	7,905	3,374	2,821	16,675	493		549			1,636	46,467
40-45%	2,043	3,085	5,661	5,707	2,056	6,316	12,945			969			638	39,420
45-50%	756	2,815	6,107	4,317	2,823	9,205	9,887				803		1,309	38,020
50-55%	435	2,545	7,276	4,727	3,401	7,514	2,448						448	28,793
5-10%	1,077	3,701	9,159	12,501	19,955	7,649	22,628	5,751	2,102	419	836		85,779	
55-60%	1,334	4,154	9,559	3,064	4,971	4,322	3,304						293	31,000
60-65%	371	2,689	11,871	4,063	3,053	4,693	1,324			326			106	28,496
65-70%		2,602	8,209	2,287	2,361	2,902	890			479				19,730
70-75%	737	2,692	4,215	1,693	1,246	3,246					202			14,031
75-80%	277	4,025	2,054	1,578	1,421	3,637				144				13,136
80-85%	63	2,450	1,790	1,243	1,382	1,708								8,635
85-90%	1,036	2,670	1,110	1,697	1,614	1,776								9,903
90-95%	1,008	2,850	2,046	1,012	1,778	591								9,284
95-100%	4,499	3,665	2,071	1,851	1,570	170								13,826
Total	20,801	70,309	145,860	155,889	153,390	135,245	151,462	112,901	18,920	10,330	6,302	10,450	991,859	

Sea ice concentration	Area II												Total
	CPIII (1997/1998)						CPIII (1996/1997)						
	60W-55W	55W-50W	50W-45W	45W-40W	40W-35W	35W-30W	30W-25W	25W-20W	20W-15W	15W-10W	10W-5W	5W-0	
0-5%	70,462	70,724	79,248	31,040	53,098	37,533	66,167	5,884	2,712	5,238	5,011	1,776	428,891
10-15%	4,812	5,061	10,975	18,598	12,781	8,472	782	796	3,784	6,300	3,198		75,559
15-20%	761	5,884	8,136	25,384	12,573	4,826	57	2,177	2,995	1,243	5,218	1,388	70,642
20-25%	2,075	2,786	7,005	20,726	17,251	4,218		707	695	2,827	3,437	1,497	63,223
25-30%	1,302	3,892	9,120	26,064	7,164	3,879		662	3,233		2,405	3,148	60,871
30-35%	1,608	3,666	6,721	15,884	4,881	3,041		1,233	1,850		2,144		41,029
35-40%	565	2,299	5,115	11,874	8,491	1,704		1,128	2,823	1,086	2,871	543	38,500
40-45%	1,033	3,100	5,172	9,804	5,684	1,964		1,032	3,206	536	1,734	2,734	35,999
45-50%	925	3,834	2,859	8,911	5,223	1,848		1,425	1,391		743	1,106	28,266
50-55%	1,339	2,918	3,859	7,215	5,176	414		1,661	1,339	436	1,339	734	26,429
5-10%	5,074	8,160	15,675	19,454	15,969	13,548	4,421	2,465	413	6,585	2,407	1,669	95,840
55-60%	1,489	1,524	2,610	5,023	4,963			1,318			134		17,060
60-65%	2,218	4,665	1,683	4,988	2,711	41		2,367	340	788			19,801
65-70%	1,721	3,805	3,530	2,673	605			1,989		335			14,657
70-75%	1,435	2,626	3,935	3,747	737	649		639					13,767
75-80%	1,184	1,740	3,445	2,006	395			648		285			9,704
80-85%	294	1,749	3,439	1,722		26		581					7,811
85-90%	838	1,642	3,452	1,521				129					7,583
90-95%	818	1,681	2,256	1,495	458	119							6,827
95-100%	1,993	2,801	2,055	644	348	18							7,859
Total	101,946	134,557	180,290	218,773	158,507	82,300	71,428	26,839	24,781	25,658	28,497	16,740	1,070,316

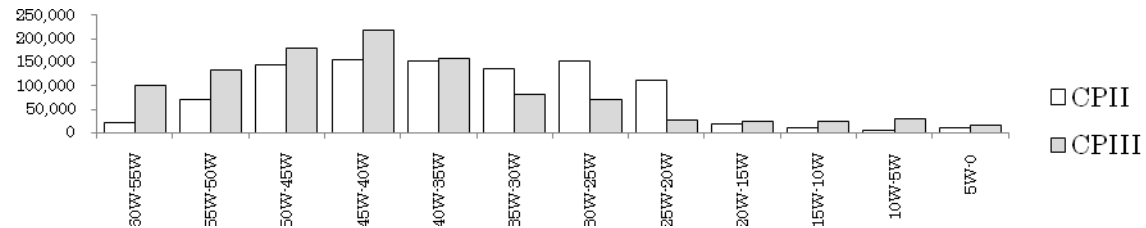


Table 5. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area III in CPII and CPIII. Note that satellite sea ice data were not available between 30°E and 70°E in CPII.

Sea ice concentration	Area III															Total
	CPII (1987/1988)															
	0-5E	5E-10E	10E-15E	15E-20E	20E-25E	25E-30E	30E-35E	35E-40E	40E-45E	45E-50E	50E-55E	55E-60E	60E-65E	65E-70E		
0-5%	2,326	3,583	1,954	4,357	15,631	747										28,597
10-15%		356	777	796	1,575	1,997										5,501
15-20%			230	738	614	1,491	1,533									4,606
20-25%			189	1,545	1,390	703	2,695									6,523
25-30%				1,238	7	2,182	153									3,580
30-35%				617	630	1,232	1,185									3,664
35-40%				1,133		1,127	583									2,844
40-45%				1,519	456	511	1,034									3,520
45-50%					90	682	940									1,712
50-55%				459	389	867	422									2,137
5-10%		888	1,821	2,171	3,152											8,032
55-60%					1	370	984			NA						1,355
60-65%				301	339	581	710									1,930
65-70%					75	121	904									1,101
70-75%					20		686									706
75-80%						280	165									445
80-85%							22									22
85-90%																0
90-95%																0
95-100%																0
Total	2,326	5,246	12,192	11,244	30,507	14,761										76,275

Sea ice concentration	Area III															Total
	CPII (1992/1993)						CPIII (1994/1995)									
	0-5E	5E-10E	10E-15E	15E-20E	20E-25E	25E-30E	30E-35E	35E-40E	40E-45E	45E-50E	50E-55E	55E-60E	60E-65E	65E-70E		
0-5%	79,383	51,330	48,454	1,828	2,119		5,841	5,528			2,007		6,954	9,223	212,667	
10-15%	3,202	2,364	797	2,102	74		3,908	989	33		125		802	3,909	18,306	
15-20%	3,659	1,475	1,465		1,865	1,116	759	1,537					367	1,822	14,064	
20-25%	2,978	693	1,394	1,408	711		691	690			1,406	34	581	2,470	13,057	
25-30%	354	2,610		1,306	2,028		650	2,060			1,083	722	1,266	1,427	13,505	
30-35%		1,800	602		893	1,658	1,226	603					534	2,698	10,013	
35-40%	958	1,678	1,098			432	3,310						562	830	8,868	
40-45%		1,422	1,006	1,043		1,895	1,315	945			518	847		1	8,992	
45-50%		2,781	463		1,409	849	2,122	456	757			460	1,357	490	11,144	
50-55%		1,587	440	406	1,166	2,637	872	412	338			256	667	1,078	9,860	
5-10%	8,057	4,148	3,309	1,125	1,151	181	2,216	1,856	99		1,397			1,741	25,279	
55-60%		1,344	747	1,143	276	2,255	217	1,164	192	8	392		771		8,509	
60-65%		1,798	959		325	2,325	679	326		49		1,757	357		8,576	
65-70%		1,392	1,511	312	851	2,250	364			376		1,289			8,343	
70-75%		957	2,719	246	1,041	2,196	233	260	250	383		233	466		8,985	
75-80%			639	208	1,278	1,581	182	224	278	359		641	607		5,997	
80-85%			137	350	799	479	335	349	467	89	6	164	870		4,045	
85-90%			220	476	217	132	133	370	122	101		18	147		1,936	
90-95%			75	549	464		44	207	56	326	10	144	261		2,136	
95-100%				179				337	385	155	28	158	42		1,283	
Total	98,592	77,379	66,033	12,682	16,666	19,988	25,097	18,314	2,975	1,846	7,227	7,133	17,022	24,611	395,566	

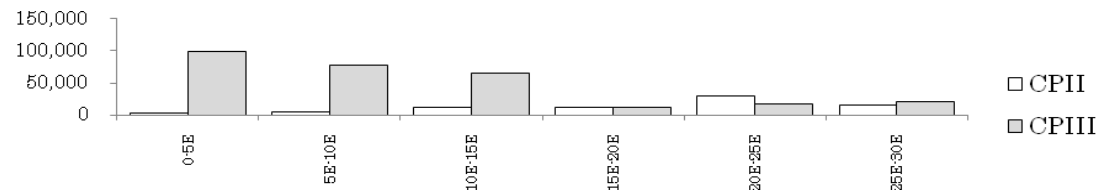


Table 6. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area IV in CPII and CPIII.

Sea ice concentration	Area IV												Total	
	CPII (1988/1989)													
	70E-75E	75E-80E	80E-85E	85E-90E	90E-95E	95E-100E	100E-105E	105E-110E	110E-115E	115E-120E	120E-125E	125E-130E		
0-5%	7,880	18,949			14,850	3,809		7,291	365		869		54,014	
10-15%	2,346	2,278			6,194	807		3,109	2,733		47		17,514	
15-20%	1,455	3,208		268	2,352				2,051				9,335	
20-25%	437	4,779			3,304			2,150	1,445	1,282	1,279		14,676	
25-30%	465	829	662		3,218			1,277	1,978	1,239	636		10,304	
30-35%	1,832	1,832	13		2,239			621	1,209				7,746	
35-40%	650	1,594	181		3,935	1,333	523	1,016	1,067	1,141	319		11,758	
40-45%	2,590	1,707	1,058	506	2,112	511	356	169	1,217	1,020	555		11,802	
45-50%	438	3,840	1,552	755	470			632	471	1,408	910	924	465	11,867
50-55%	924	2,098	1,327	277	844	870	1,709	442	847	1,180	998	1,214	12,730	
5-10%	1,010	3,319			11,588			1,925	5,163	1,775	1,033		25,812	
55-60%	1,381		1,367	564	396	2,780	580		782	1,501		1,172	10,524	
60-65%	915	504	1,549	358			356	678		95	1,000	978	344	6,778
65-70%	271	306	1,434	396	72	1,555	1,273	235		100	1,492	1,044	8,178	
70-75%	1,935		1,113	1,148			1,313	887	508		849	502	17	8,271
75-80%	207		812	630	186	189	619	147		858	849	40	4,539	
80-85%	356		915	82			736	307	136		578	1,001	945	5,056
85-90%	236	27	726	179	87	1,359	320	214		644	130	363	4,284	
90-95%	101		518	58	3	908	60	126		274			946	2,994
95-100%			348	204			220	44	125		237		216	1,394
Total	25,430	45,270	13,576	5,426	51,849	16,745	7,988	19,962	20,362	14,589	11,613	6,765	239,575	

Sea ice concentration	Area IV												Total	
	CPIII (1994/1995)		CPII (1998/1999)											
	70E-75E	75E-80E	80E-85E	85E-90E	90E-95E	95E-100E	100E-105E	105E-110E	110E-115E	115E-120E	120E-125E	125E-130E		
0-5%	50	57	186	0	78	4		5				2	381	
10-15%	161		263	121	491	74					326	133	1,569	
15-20%	59		499	94	147	150				14	24	449	1,435	
20-25%	1,171	187	405	173	373			179	137	128	42	616	430	3,840
25-30%	335		116	380	228			920			617	899	505	4,001
30-35%	5		903	313	582			898				307	199	3,207
35-40%				673	1,771	330		852	229	158		633	8	4,654
40-45%			1,063	320	763	364		355		1,231	754	816		5,667
45-50%			1,215		1,293			397	426	1,396		1,334	438	6,500
50-55%			1,613	1,925	1,934	461		3,089	1,401	1,616	911	460	934	14,343
5-10%	122	122	350		125	90		101			68	58	27	1,063
55-60%			1,572		1,543	675	510	2,070	2,509	535	2,951	804	13,170	
60-65%			1,116	1,593	558	373	723	2,354	1,752	1,654	560	1,693	12,376	
65-70%			1,838	597	1,413	594	2,434	628	4,359	341	1,218	640	14,061	
70-75%			1,285		1,348	1,536	1,958	1,941	1,636	1,334	1,981	2,810	15,829	
75-80%			2,767	676	1,388	5,701	1,358	1,686	949	2,509	2,004	712	19,749	
80-85%			1,520	753	1,444	4,256	4,524	2,066	742	6,397	1,382	1,507	24,591	
85-90%			3,604	788	202	3,952		1,505	2,415	3,196	2,571	4,924	23,158	
90-95%			4,947	1,671	3,623	3,332	1,314	2,918	1,630	6,182		3,314	28,931	
95-100%			8,862	9,506	4,634	27,251	7,048	16,012	3,187	24,652			101,151	
Total	1,904	365	34,124	19,583	23,937	49,142	26,665	33,372	23,722	49,194	18,142	19,527	299,676	

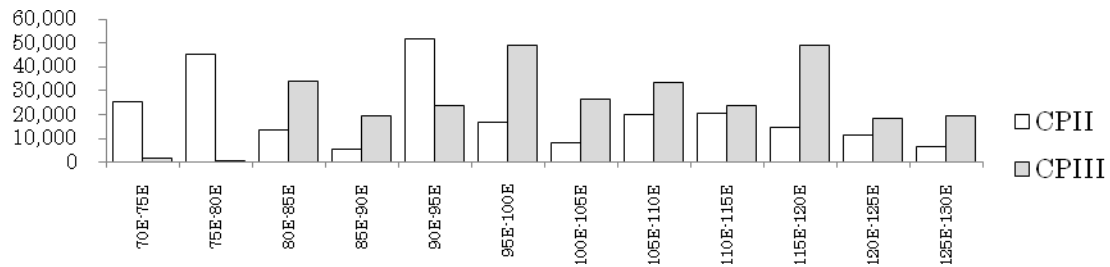




Table 7. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area V in CPII and CPIII.

Sea ice concentration	Area V															Total	
	CPII (1985/1986)																
	130E-135E	135E-140E	140E-145E	145E-150E	150E-155E	155E-160E	160E-165E	165E-170E	170E-175E	175E-180	180-175W	175W-170W	170W-165W	165W-160W	160W-155W		155W-150W
0-5%	2,944	14,786	245	5,330	503	5,316	21,347	1,710	1,419	320	332		1	5,208	3,250		62,711
10-15%	3,158	1,497		1,542	77	2,479	2,361	984	417			335		1,226	4,146		18,223
15-20%	8,321		235	1,012	1,358	1,508	2,221	5,541	259			759			2,432		23,646
20-25%	779			1,275	2,846	667	931	5,452	304			831			2,083		15,168
25-30%	603			325	769	1,334	1,302	3,351	1,940			2,120	1,242		9,486	10,321	32,794
30-35%			30	235	1,161	1,246	1,636	5,659				402	3,025	898	4,580	14,186	33,058
35-40%	235		19	1,435		1,688	1,486	1,084	51			3,970	1,888	489	8,617	9,892	30,854
40-45%				745		521	954	3,196	46			3,204	3,741	1,164	2,396	3,073	19,041
45-50%			35		454	952	985	2,986				2,050	1,391	2,091	5,683	3,013	19,641
50-55%				425		1,725	601	2,815				1,324	2,146	1,942	6,364	3,416	20,757
5-10%	9,035	4,063	504	1,594		1,354	7,717	1,071						1,149	2,601		29,089
55-60%			87	558	149	2,447	1,554	2,998				2,748	772	2,774	6,143	3,938	24,167
60-65%			28	809		1,006	1,436	675				326	2,343	1,625	8,060	6,084	22,392
65-70%				211		1,605	1,480	2,129				1,569	578	2,910	2,355	11,674	24,511
70-75%						340	2,230	1,150				1,433	1,909	2,102	3,646	736	13,546
75-80%				22		406	1,286	1,974				224	3,908	2,554	1,387	1,232	12,991
80-85%							874	798					3,907	2,843	995	476	9,894
85-90%						122	3,574	475					2,165	3,441	498		10,276
90-95%						12	734							252			998
95-100%																	
Total	25,075	20,347	1,183	15,518	7,318	24,730	54,707	44,050	4,435	320	332	21,296	29,016	32,669	74,722	68,041	423,757

Sea ice concentration	Area V															Total	
	CPII (2001/2002)			CPII (2002/2003)					CPII (2003/2004)								
	130E-135E	135E-140E	140E-145E	145E-150E	150E-155E	155E-160E	160E-165E	165E-170E	170E-175E	175E-180	180-175W	175W-170W	170W-165W	165W-160W	160W-155W		155W-150W
0-5%	33,408	2,058	1,650	938			6,621	2,116	21,866	538		1,092	44,341	50,150	38,311	42,493	245,581
10-15%	3,288	56		1,159			2,382	2,625	1,193		245	783	2,349	3,874	765	1,828	20,547
15-20%	730			832			1,505	1,535	740	741	2,626	1,190		732	2,549	750	13,930
20-25%	362	646	5	652			81	713	887	3,372	3,912	3,259	1,386	1,403	682	715	18,076
25-30%	670	1,165		642			2,508	1,379		3,277	1,238	795	1,215	1,330	661	1,911	16,792
30-35%	1,584	302		213		196	251	3,139		2,045	1,844	765	1,792	33	69	1,193	13,426
35-40%	580	613	94	1,266			3,244	1,635		3,832	2,947	1,139	2,804	1,132	616	3,369	23,270
40-45%	383	1,017		804	182		1,123	3,882	2,089	6,634	2,089	1,037	514	2,050	3,839	25,642	
45-50%	61	4		435			1,448	3,006	35	479	4,223	1,432	934	2,353	3,922	1,863	20,193
50-55%	39	421		63			590	3,377	42	5,599	423	2,143	1,718	2,660	2,529	19,603	
5-10%	2,479	721	176	911			5,535	290	3,456			16	5,640	2,046	851		22,119
55-60%		326		764	371		1,539	1,125			2,714	2,102	1,911	2,983	4,735	765	19,334
60-65%	346	692		657			1,498	1,335			3,469	2,724	3,679	6,030	8,623	2,345	31,398
65-70%		220		307	272	20	1,086	2,258	42		2,652	3,169	7,641	6,695	6,725	2,053	33,140
70-75%	97	228		255	231		1,517	528			262	7,911	5,018	4,315	5,169	3,990	29,519
75-80%	5	216		435	334	115	808	1,066				1,652	2,895	2,198	1,918	4,036	15,678
80-85%		490		272		72	1,269	674					172	347	515	2,557	6,368
85-90%		260		373	30	714	325	897	171							1,062	3,833
90-95%		351		59	655	802	312	773								2	2,955
95-100%				182	734	566	369	710									2,561
Total	44,033	9,786	1,925	11,219	2,809	2,486	34,011	33,061	28,432	16,372	38,365	30,540	84,956	87,855	80,821	77,299	583,968

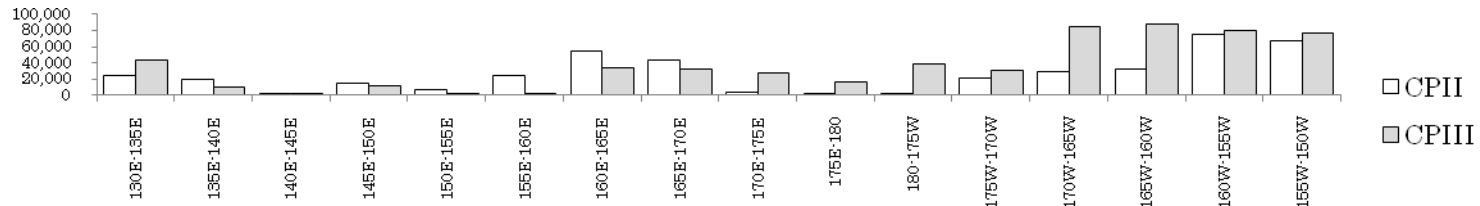
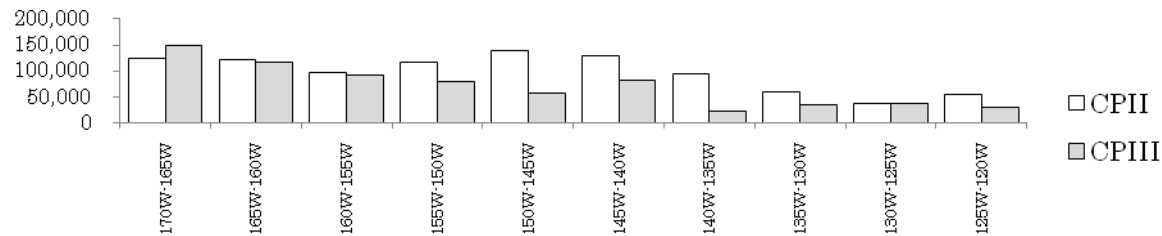


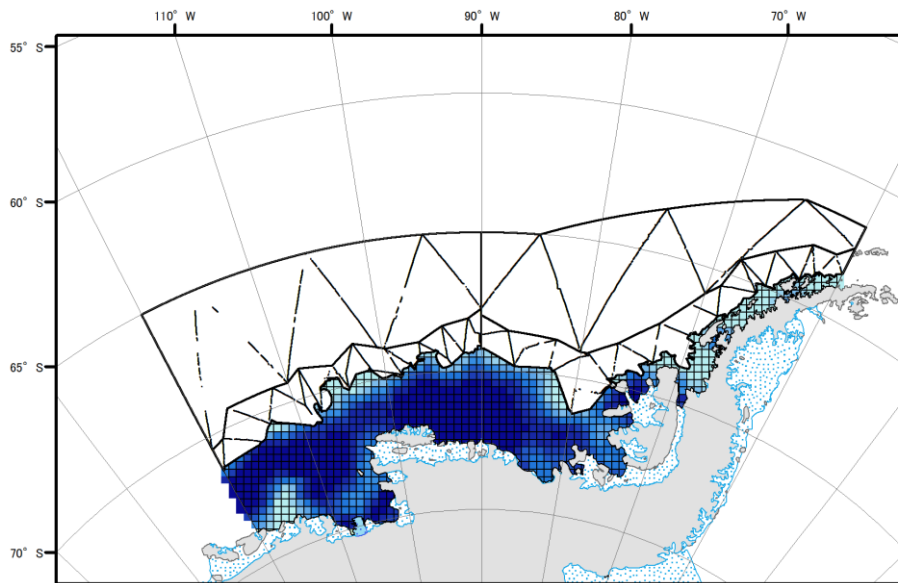
Table 8. Open sea ice area (km<sup>2</sup>) in the south of ice edge in each 5° longitudinal sector in Area VI in CPII and CPIII.

Sea ice concentration	Area VI											Total
	CPII (1990/1991)											
	170W-165W	165W-160W	160W-155W	155W-150W	150W-145W	145W-140W	140W-135W	135W-130W	130W-125W	125W-120W		
0-5%	51,979	42,042	11,771	22,125	59,560	78,686	68,964	23,982	15,039	14,142	388,290	
10-15%	6,093	3,600	3,600	3,600	4,500	2,700	1,800	900	1,800	3,413	32,006	
15-20%	1,775	1,530	2,295	1,530	9,180	6,885	765	1,997	1,206	901	28,064	
20-25%	6,310	4,320		720	2,160	3,600	720	2,880	720	2,160	23,590	
25-30%	2,025	4,050	2,700	5,400	2,025	3,375	1,350	675	1,350	1,343	24,293	
30-35%	3,910	3,780	3,476	3,150	4,410	3,780	630	630		4,754	28,520	
35-40%	5,202	4,680	2,925	8,190	2,925	3,510	585	4,315	585	2,731	35,649	
40-45%	6,436	5,400	5,940	12,960	4,860	3,240	2,552	2,578	3,236	3,814	51,017	
45-50%	4,507	3,960	5,940	16,830	8,910	1,485	1,980	1,738	495	3,682	49,527	
50-55%	4,500	7,200	12,150	17,550	10,800	1,350	2,250	4,944	450	6,009	67,203	
5-10%	4,073	9,888	1,261	1,800	14,400	9,900	2,700	2,700	3,600	1,800	52,122	
55-60%	2,107	6,075	13,450	7,290	5,423	810	2,419	6,075	1,620	4,802	50,071	
60-65%	3,240	2,880	5,040	6,840	3,180	2,160	1,457	3,600	2,520	2,880	33,796	
65-70%	3,140	4,095	7,870	4,095	2,554	1,675	2,835	945	2,205	1,583	30,997	
70-75%	4,285	3,510	7,809	3,048	1,942	2,627	1,615	1,080	1,080	270	27,265	
75-80%	4,568	4,500	6,750	1,575	900	1,973	1,800	225	1,124	342	23,756	
80-85%	5,278	4,320	2,160	896	360	1,440	291			360	15,104	
85-90%	4,046	4,185	675		135	1,080				278	10,668	
90-95%		540	90							360	1,151	
95-100%										45	405	
Total	123,472	120,555	95,902	117,599	138,223	130,275	94,713	59,263	38,388	55,101	973,491	

Sea ice concentration	Area VI											Total
	CPII (1995/1996)						CPIII (2000/2001)					
	170W-165W	165W-160W	160W-155W	155W-150W	150W-145W	145W-140W	140W-135W	135W-130W	130W-125W	125W-120W		
0-5%	52,370	57,818	23,405	18,742	12,742	42,825	184	1,416	5,057	2,899	217,458	
10-15%	10,182	9,455	3,977	5,400	2,872	5,400	2,619	129	2,700	3,133	45,867	
15-20%	8,866	3,825	2,295	3,060	2,295	3,825	1,431	769	5,507	765	32,639	
20-25%	12,458	4,320	8,640	2,880	3,600	2,160		3,485	3,164	2,350	43,058	
25-30%	11,570	5,400	4,409	6,750	6,075	2,700	675	1,760	242	842	40,424	
30-35%	11,757	2,520	5,794	8,820	3,780	1,260	630	1,807	1,890	1,260	39,517	
35-40%	4,233	4,095	7,020	7,020	5,850	2,340	1,755	3,225	2,102	1,756	39,395	
40-45%	6,664	5,940	15,079	5,940	2,160	1,620	540	1,966	1,080	3,850	44,839	
45-50%	4,781	3,960	8,415	4,950	1,980	990	856	2,234	1,980	1,980	32,126	
50-55%	2,430	3,600	4,950	900	3,150	450	900	1,795	1,350	2,925	22,439	
5-10%	10,310	11,701	7,200	10,813	3,650	16,004	870		3,595	1,367	65,510	
55-60%	4,648	810	1,215	405	3,240	405	2,025	2,430	2,023	405	17,605	
60-65%	2,527	1,800	360	1,737	2,160	360	2,151	1,800	1,440	1,112	15,447	
65-70%	1,214	2,205		315	945	315	630	1,575	630	315	8,144	
70-75%	1,764	270		1,179	1,080	270	1,094	4,590	1,080	532	11,858	
75-80%	1,150			933	720	225	1,350	2,925	225	450	7,978	
80-85%	717			612	540	1,800	1,800	1,439	360	7,267		
85-90%	359			267	552	1,350	1,080		135	3,742		
90-95%	20				336	1,478	540	815	471	3,660		
95-100%						458	90	1,362	2,005	3,916		
Total	148,007	117,719	92,759	79,843	57,178	82,577	22,797	35,415	37,681	28,913	702,889	



Area I CPII (1989/90)



Area I CPIII (1993/94, 1999/00, 2000/01)

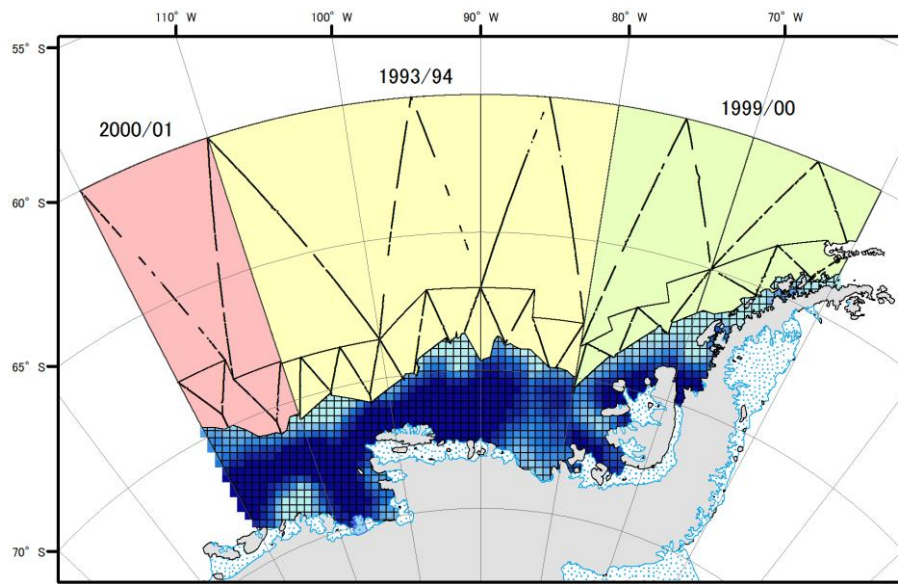
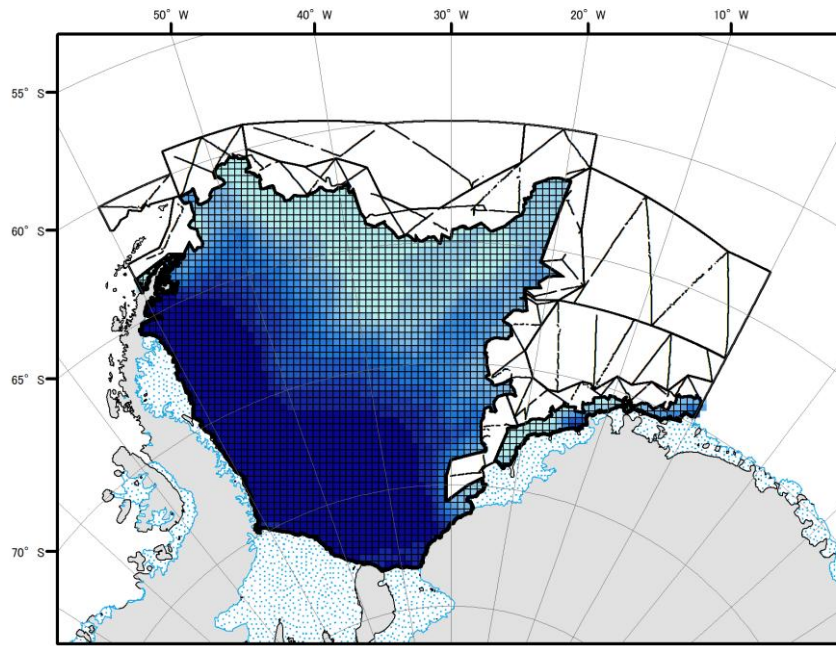


Fig. 1. Sea ice conditions in the south of ice edge in Area I in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII.

Area II CPII (1986/87)



Area II CPIII (1996/97, 1997/98)

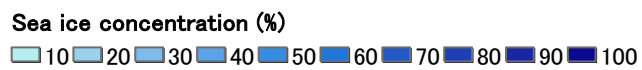
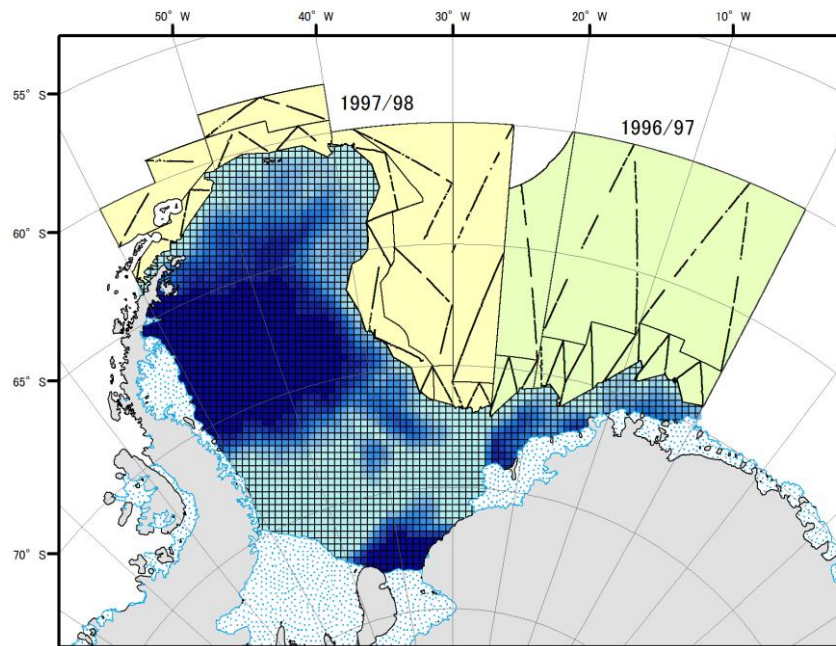
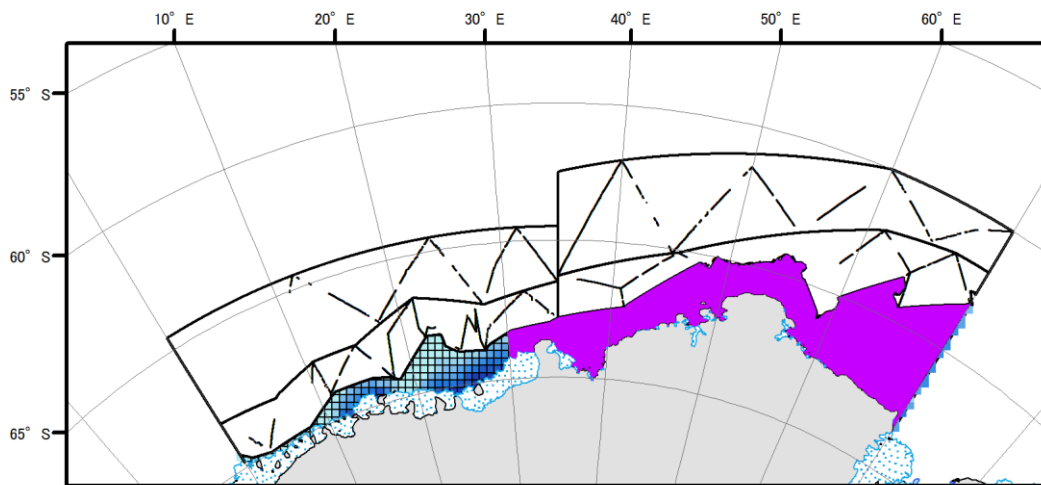
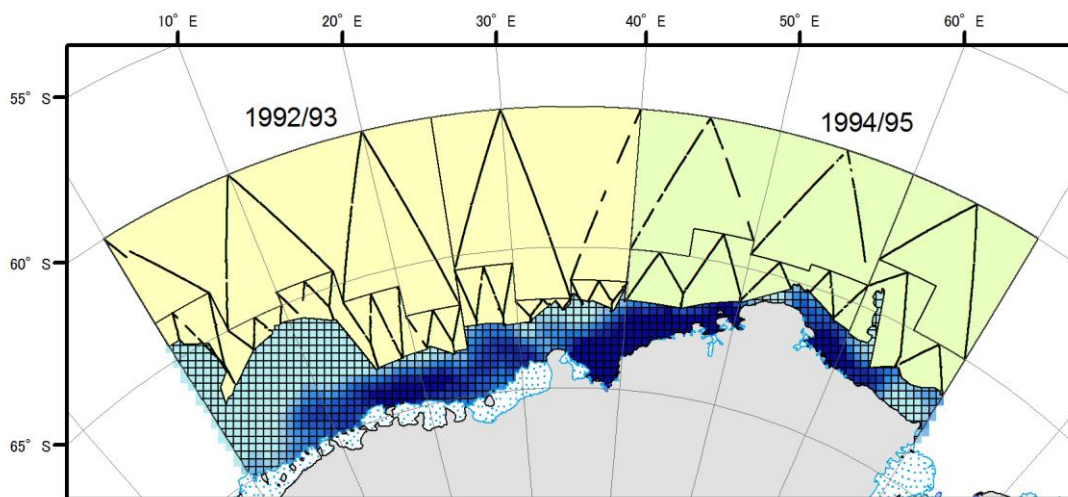


Fig. 2. Sea ice conditions in the south of ice edge in Area II in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII.

Area III CPII (1987/88)



Area III CPIII (1992/93, 1994/95)



Sea ice concentration (%)

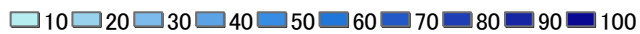
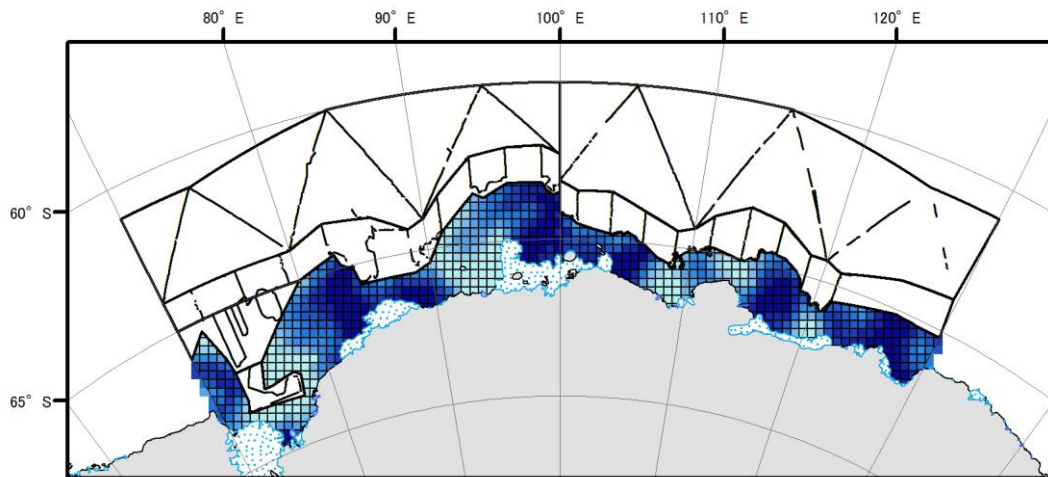


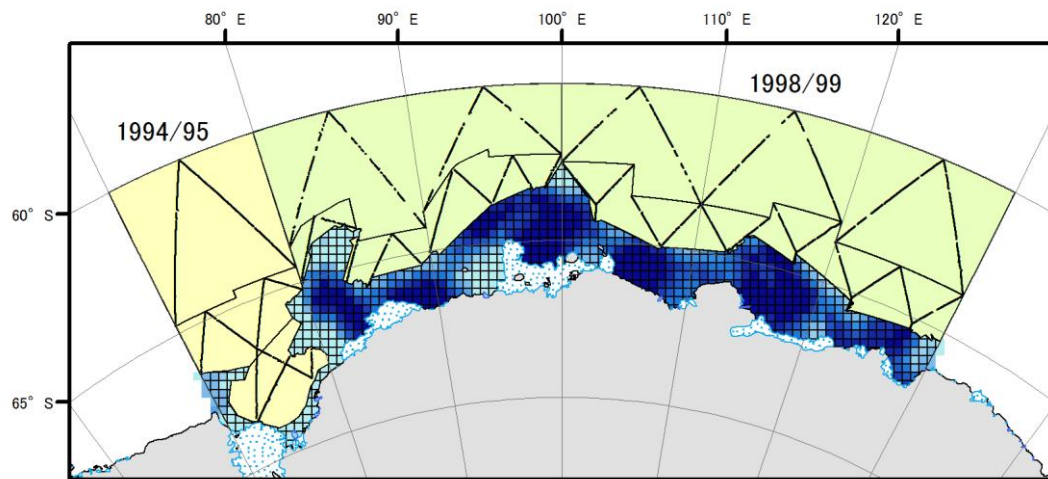
Fig. 3. Sea ice conditions in the south of ice edge in Area III in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII. Note that satellite sea ice data were not available between 30°E and 70°E in CPII (purple area in the top).



Area IV CPII (1988/89)



Area IV CPIII (1994/95, 1998/99)



Sea ice concentration (%)

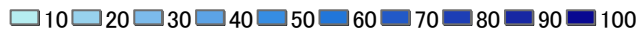
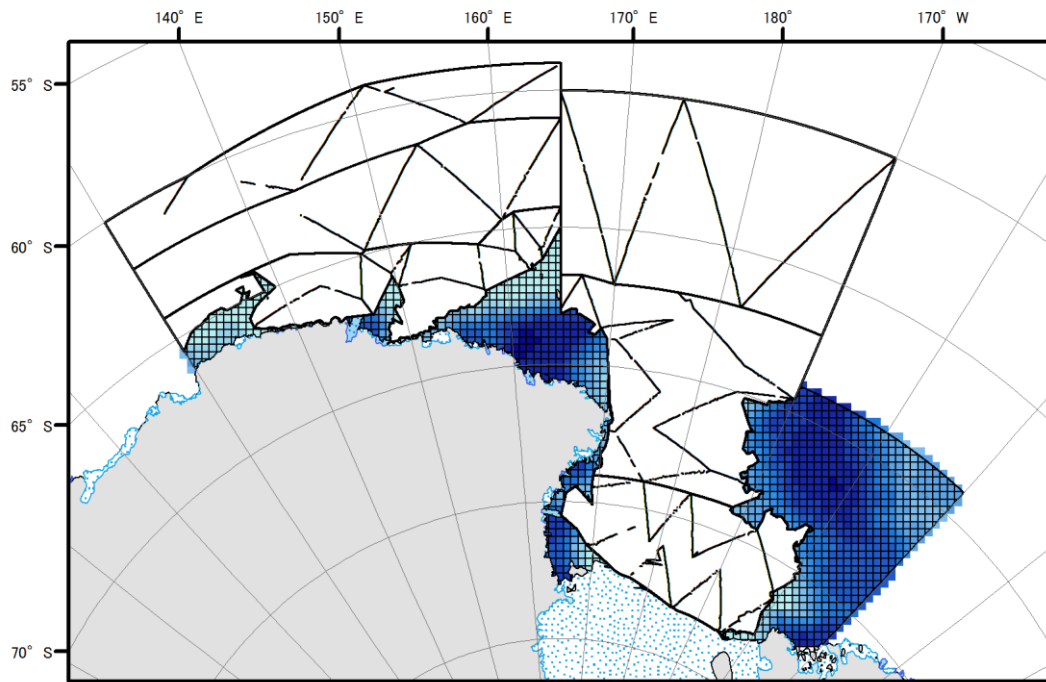


Fig. 4. Sea ice conditions in the south of ice edge in Area IV in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII.

Area V CPII (1985/86)



Area V CPIII (2001/02, 2002/03, 2003/04)

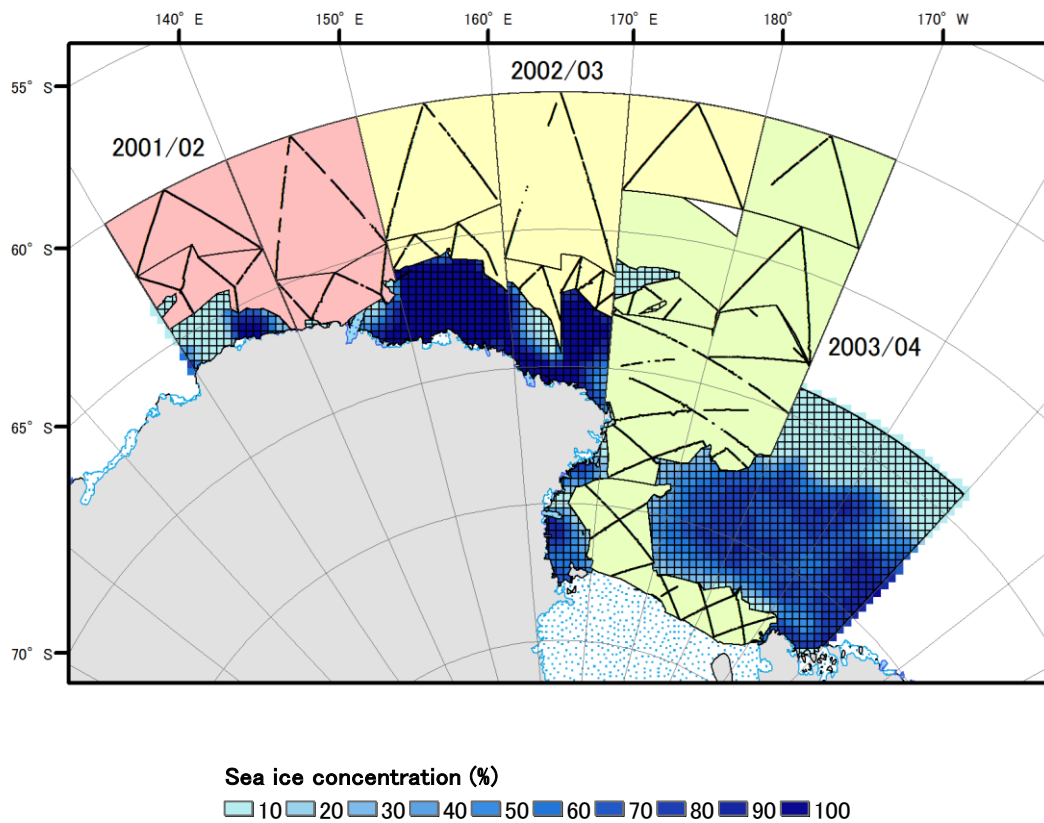
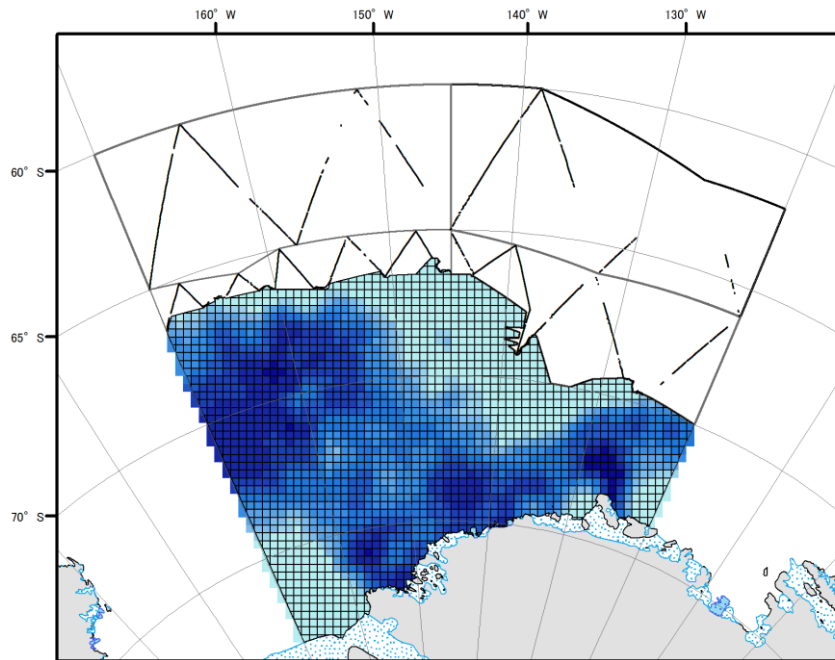


Fig. 5. Sea ice conditions in the south of ice edge in Area V in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII.

Area VI CPII (1990/91)



Aera VI CPIII (1995/96, 2000/01)

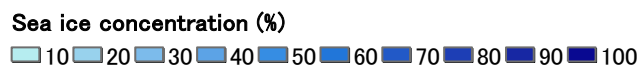
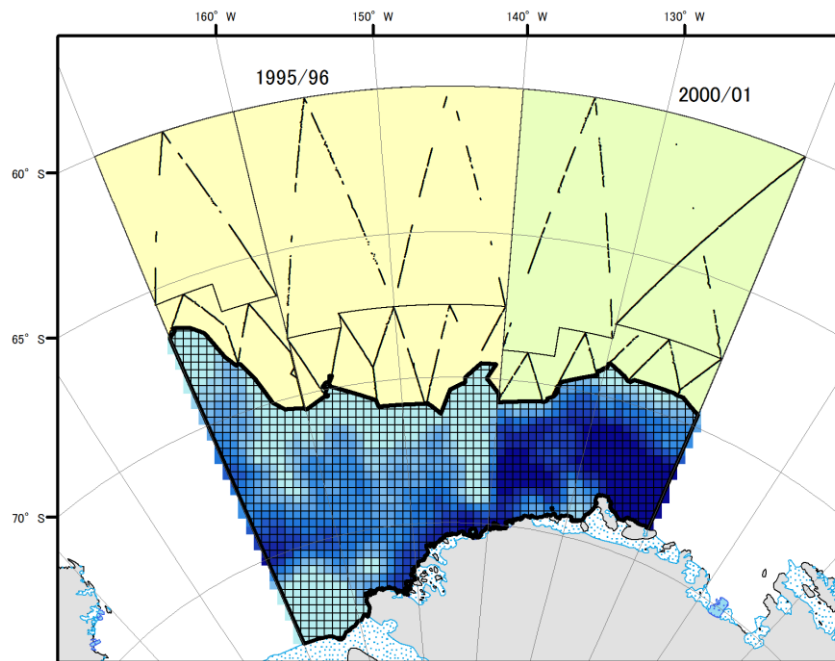


Fig. 6. Sea ice conditions in the south of ice edge in Area VI in CPII (top) and CPIII (bottom). Survey strata and surveyed tracklines are also shown. Surveyed years are shown in different colors in CPIII.