Community Submissions
for
May Sea Ice Outlook Report

11 June 2008

Prepared by the North American Ice Service

A collaboration of the Canadian Ice Service and the National/Naval Ice Center

04 June 2008

Seasonal Outlook

For North American Arctic Waters

Summer 2008

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Introduction

This outlook is produced by the North American Ice Service, which is a joint co-operation of the Canadian Ice Service and the U.S. National Ice Center.

It will give an indication of the expected pattern of breakup and clearing of ice in the North American Arctic waters. It will identify areas and timings when breakup and clearing will likely occur with emphasis on those areas where there is ship navigation and other marine activities.

The outlook has been developed through the analysis of the meteorological and ice growth regimes. Thorough analyses have been done of extensive Radarsat/Envisat imagery collected during the past winter and spring. NOAA and MODIS satellite imageries were also used for the evaluation of the ice cover. All of this ice information was used in the preparation of regional ice analyses for the Arctic and Hudson Bay.

The results of the meteorological and ice analyses are then compared with previous year's ice conditions and, in conjunction with the forecast for wind and temperatures for June, are applied to evaluate the breakup and the clearing of ice in the areas of interest. The Canadian Meteorological Centre provides the temperature regime for the period from the end of June to the end of August. Any variations from these forecast parameters have an impact on the forecast breakup pattern and timing.

Tables are included showing the forecast breakup or clearing dates along with median dates and last year's dates for each region. During the summer these events will be updated by a twice monthly issue of a 30-day forecast to enable planning of shipping or other activities according to changing trends. These forecasts will also include a prediction of the beginning of the freeze-up process throughout the regions.

Daily radio broadcasts of ice charts and forecasts will be made to support ongoing operations in the various areas where ice affects marine activities. Appendix A provides a link to the key to ice symbols showing the principle features of the International Ice symbols used on the ice charts. Appendix B contains links to these broadcast schedules as well as Aerial Reconnaissance Radio Facsimile Broadcast and NOAA Alaskan Marine Radio frequencies.

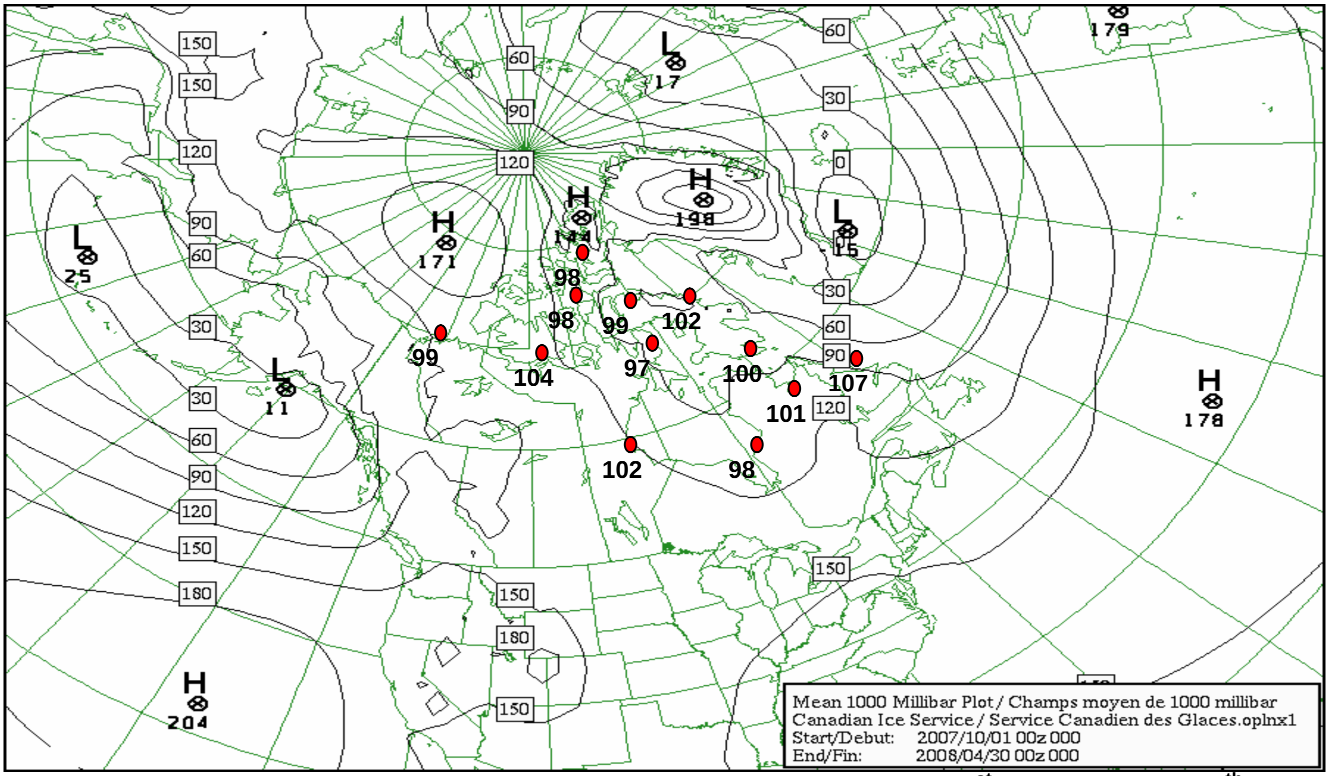


Figure 1: Percentage of Normal Freezing Degree Days from October 1st, 2007 to April 30th, 2008

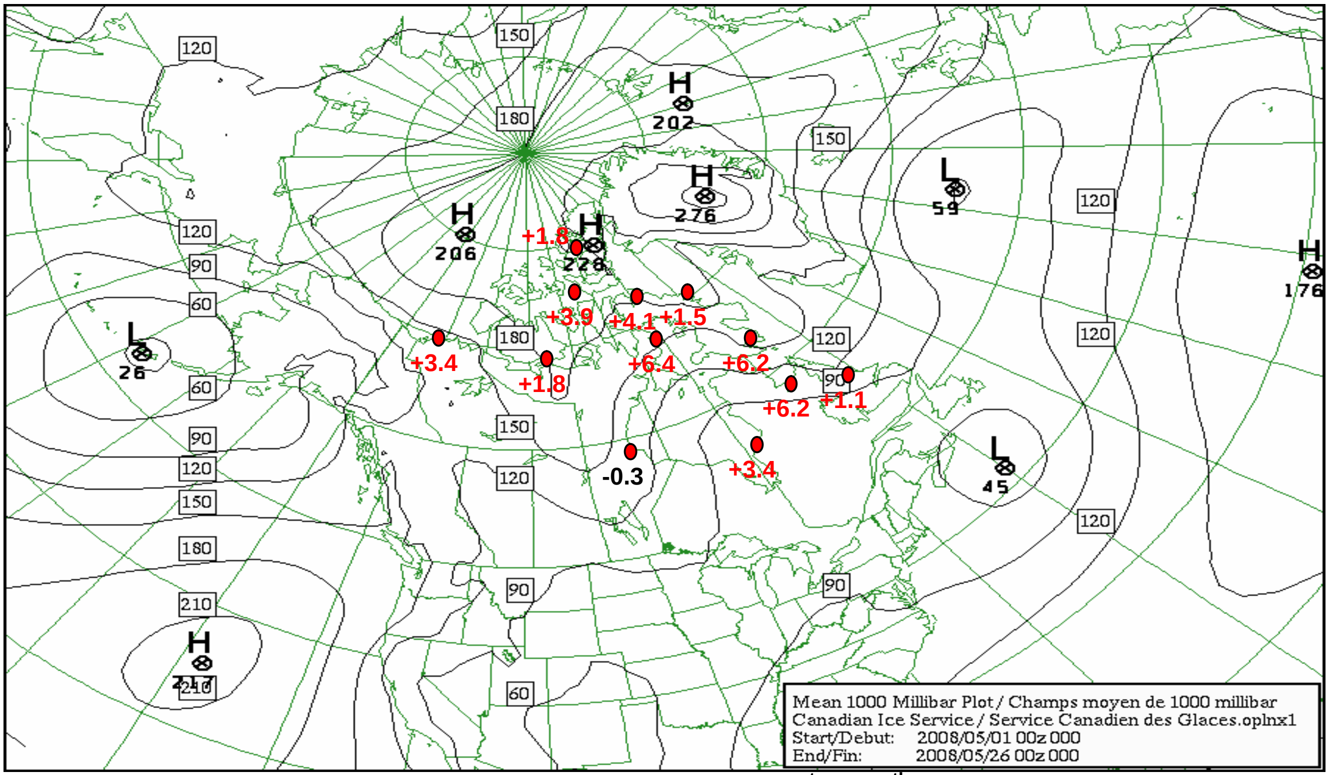


Figure 2: Departure from Normal Temperatures for May 1st to 26th, 2008

General Winter Conditions and Brief Outlook

The mean 1000 mb pressure pattern from October 01st, 2007 to April 30th, 2008 is represented in Figure 1. A low pressure system persisted east of southern Greenland with a trough lying along the western shore of Greenland. A weaker trough was also present over the eastern portion of Hudson Bay. A strong high pressure area prevailed over the Beaufort Sea. As a result, a light to moderate north to northwesterly flow prevailed along the Labrador Coast, in Davis Strait, over Hudson Bay and in Foxe Basin while a more westerly flow prevailed over the Hudson Strait area. Meanwhile, moderate northerly winds prevailed over the Canadian Arctic Archipelago while a moderate to strong easterly flow dominated the western Arctic regions west of Banks Island and along the Alaskan Coast.

During the winter season from October 2007 to April 2008, mean air temperatures were normal over most of the Arctic. However, temperatures were above normal in the western Arctic region west of Banks Island. Temperatures were 1 to 2 °C above normal along the coastal regions of the Yukon and Northwest Territories west of the Amundsen Gulf area. The temperatures reached 1°C below normal values in the Cambridge Bay region. Freezing degree day accumulations for the winter period reached normal values everywhere except exceeded normal values by 4 to 7 percent in the Central Arctic region and along the Labrador Coast. These values are indicated in Figure 1.

The mean 1000 mb pressure pattern up to May 26th is shown in Figure 2. A broad high pressure area dominated the High Arctic with a primary ridge extending southward along the east coast of Baffin Island and a secondary ridge extending southward through Cambridge Bay. Low pressure systems remained well south of the Arctic regions (60°N) with a first system on the East Coast south of Sable Island and a second one near the Aleutian Islands. Trough lines extended along the west coast of Greenland and across central Hudson Bay. Light to moderate east to northeast winds prevailed in the Eastern Arctic and Hudson Bay regions while the High Arctic remained under a light easterly flow during the period. Moderate easterly winds persisted over the Western Arctic during much of May. Throughout this period, above normal temperatures ranging between +1 to +6 °C prevailed over all Arctic regions except for the western shore of Hudson Bay which remained near normal values.

For the first half of June, above normal temperatures are generally forecast for the whole Arctic area except for near normal temperatures over south-western Hudson Bay. From June to August the temperatures are forecast to remain above normal for much of the Arctic regions south of 75°N while the High Arctic regions temperatures are forecast to remain near normal. Consequently, the Western Arctic region will experience an earlier than normal break up pattern, while the Central and High Arctic should expect near normal break up events. The presence of old ice east of the Baffin Island coast coupled with above normal temperature will cause the break up events to occur near normal dates. The Hudson Bay region will see normal break up events while the Hudson Strait and the Labrador Coast will see earlier than normal break up events.

Hudson Bay and Approaches

Freeze-up and Winter Ice Regime

Air temperatures were near normal for most of Hudson Bay during freeze-up. Below normal air temperatures over west coast sections during the last week of October led to a 1-week earlier-than-normal freeze-up there. Elsewhere, freeze-up was delayed by 1 week over most of the bay and by 2 weeks to the east of the Belcher Islands. In Hudson Strait, freeze-up was 1 week early along the western shores of Ungava Bay, 1 week late over the extreme western part of Hudson Strait and southeast of Baffin Island, but near normal elsewhere. Measured ice thicknesses at Coral Harbour were normal at the beginning of December and slightly greater than normal at the end of January.

Ice growth began early along the west and south coasts of Hudson Bay, and then slowed significantly by mid-November. New ice started to form along the shores of Southampton Island, in Roes Welcome Sound and along the western shore of Hudson Bay during the last week in October. By mid-November, new ice also extended along the southern shore of Hudson Bay and had formed along the western shores of Ungava Bay. By the end of November, grey-white ice dominated Roes Welcome Sound and extended south of Southampton Island. Grey-white ice in western Davis Strait reached south of Cumberland Sound, which was filled with grey ice. New and grey ice lay along all the shores of Hudson Bay and James Bay except southeast of the Belcher Islands. New and grey ice filled the southern halves of Hudson Strait and Ungava Bay.

Ice growth was slightly slower-than-normal in December. By the end of the month, Hudson Bay, Hudson Strait, Davis Strait, and the Labrador Coast were completely ice covered, and concentrations were everywhere near-normal. However, ice thicknesses in southeastern Hudson Bay and in Hudson Strait were less-than-normal, with grey-white as opposed to first-year ice predominating in these areas.

By the end of January, Hudson Bay and Davis Strait were covered with thin to medium first-year ice. Hudson Strait and the Labrador Coast were covered with thin first-year ice. The ice extent was near normal over all areas except much greater than normal along the northern Labrador Coast and in Davis Strait. The trace of old ice lay just east of Cape Chidley at this time. Higher-than-normal concentrations of old ice were present in Davis Strait and extending south of Cape Dyer.

From early February until the end of March temperatures were below normal over all of Hudson Bay and its Approaches. This resulted in significant ice growth throughout the regions and the unusual development of young ice which extended much further east than normal along the northern portion of the Labrador Sea. By the end of March, the entire region had caught up to normal with respect to freezing degree days and ice thicknesses. Very close pack medium and thick first-year ice covered most of the area except for open drift to close pack grey-white and first-year ice along the ice edge. The ice edge extended about 100 to 200 miles off the Labrador Coast. By the end of March, the old ice had continued its southward movement. A narrow band of 1 to 3 tenths multi-year ice lay roughly 40 to 60 miles off the Baffin Island Coast. The southern extent of this narrow band of old ice covered the entrance to Hudson Strait to just north of 60°N. A trace of multi-year ice was also present further offshore along the Baffin Coast and along the Labrador Coast.

During April and most of May, the temperature trend had reversed and above normal temperatures were reported over the entire area except for near normal temperature along the western shore of Hudson Bay. Some cracks and leads developed along portions of the coast in late April and some areas widened by late May to create larger areas of open water in the northwestern portion of Hudson Bay and bergy water regions at both ends of Hudson Strait. In Hudson Bay, coastal leads helped loosen the prevailing very close pack thick first-year ice condition. Small areas of open water seen along the eastern coast of Hudson Bay and in the vicinity of most islands in early May had widened by late May to a 30 to 60 mile open water corridor running along most of the entire eastern shore of Hudson and James Bays. Despite these large openings, many major ports are still affected by the coastal fast ice. During this two-month period, the eastern ice edge in southern Davis Strait retreated westward to a slightly less than normal extent. This westward ice drift forced some old ice which trickled along the east coast of Baffin Island to move into Hudson Strait north of Ungava Bay. However, by late May, much of the old ice had flushed out of the entrance to Hudson Strait leaving only a trace of old ice in that area. Further south along the Labrador Coast, the ice pack had loosened somewhat in April to create areas of close pack to open drift medium and thick first-year ice with a trace of old ice. By late May, the prevailing easterly winds had packed the ice closer to the coast into a lesser than normal extent. The Groswater Bay area was showing areas of bergy water near the shore in early April and the bergy water areas expanded during May as the first-year ice melted back. Lake Melville broke up during the third week of May and open water conditions were reported towards the end of May.

Over Newfoundland waters, despite near normal temperatures between April and late May, the retreat of the ice pack was, in general, delayed by nearly two weeks. By late May, much of Newfoundland and south Labrador Coast waters were bergy water with only an area of very close pack first-year ice remaining near the Baie Verte Peninsula. Isolated patches of open drift ice were also present along portions of the Northern Peninsula coast and off the south-Labrador coast regions.

Observed Ice Conditions

The regional ice chart in figure 3 was based on the analysis of Radarsat/Envisat and NOAA/MODIS imageries from around May 26th, 2008. This chart reveals some of the following features:

a) A 30 to 60 mile open water lead running along most of the eastern side of Hudson and James Bays.

b) The ice edge over Davis Strait and Labrador Waters is slightly further west than normal but the ice was more closely packed than normal.

c) Normal leads were present along the northwestern shore of Hudson Bay and west of Southampton Island.

d) The coastal fast ice grew thicker this winter than in past 3 to 5 years.

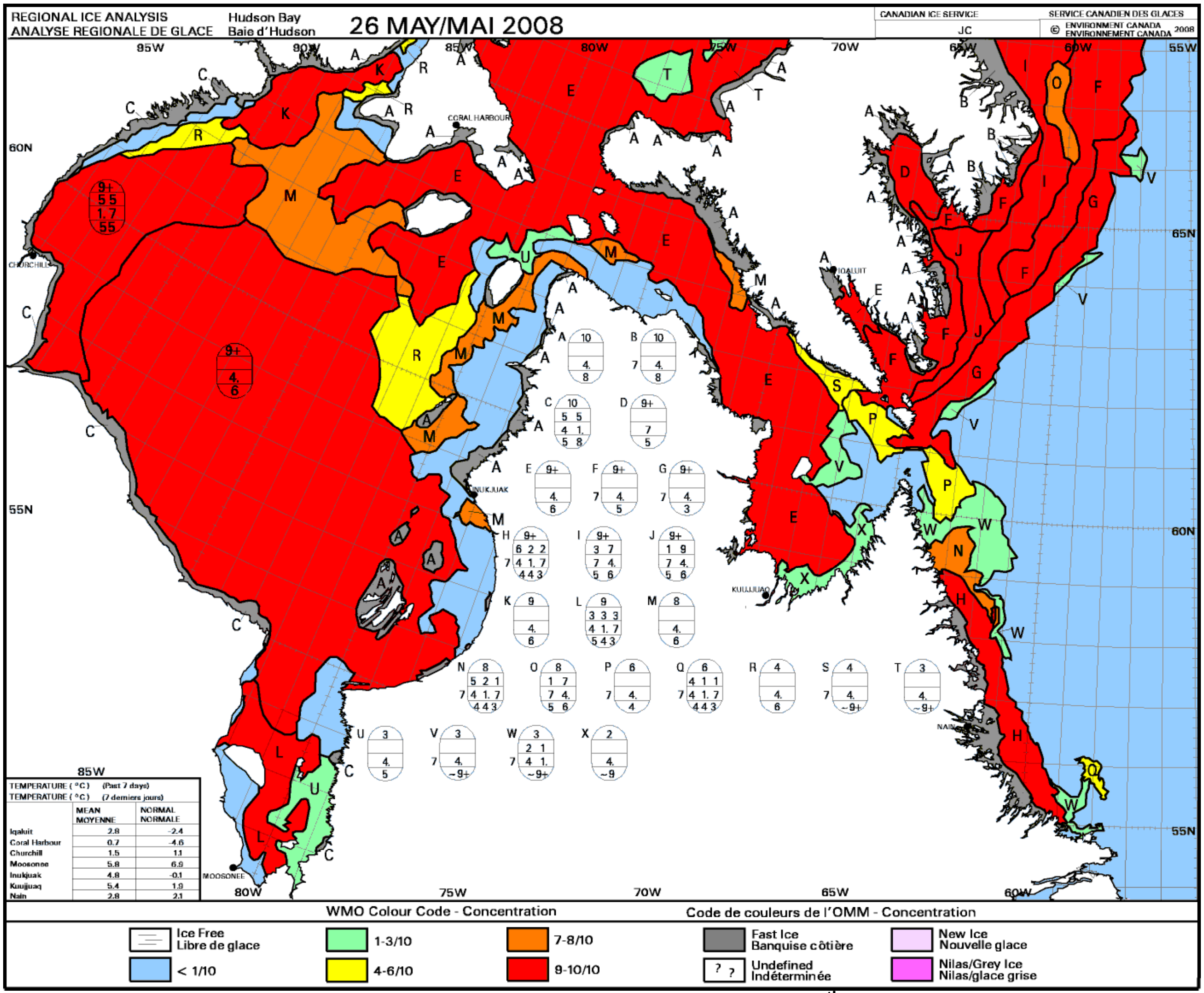


Figure 3: Hudson Bay and Approaches Regional chart for May 26th, 2008

Outlook for Hudson Bay and Approaches

For the end of May through mid-June, temperatures are forecast to be above normal values everywhere except for near normal values along the western shore of Hudson Bay. Summer temperatures from June to August are forecast to be above normal over all areas of Hudson Bay and the East Coast. These above normal temperatures are expected to counteract the additional freezing degree days accumulated during the second half of the winter. The significant melt of the ice along the southern region of the Labrador Coast will favour an early clearing of the ice along the Labrador Coast up to Cape Chidley; this is expected to occur near mid-July. The Hudson Strait region, which is already showing regions of bergy water at both ends, is expected to develop a bergy water route near mid-July while the complete clearing of the ice in the strait and Ungava Bay will not occur until the end of July. The ice in Hudson Bay will continue to loosen along the eastern shore while maintaining higher ice concentrations along the western shore. At the end of July, much of the ice along the shores will have melted allowing for an open water route into Churchill. The last ice will clear from the south central region of the bay by mid-August. For James Bay, even though the break up had already started in the southern region by mid-May, the overall melt pattern in the southern part of Hudson Bay will affect the clearing of the northern half of James Bay. As a result, the total clearing will only occur in early August. For the Frobisher Bay area, the temperature forecast points toward a rapid clearing of the bay, however, the presence of old ice flowing southward along the Baffin Island coast and near the entrance of the bay will result in a normal break up pattern. Consequently, the open drift or less route will develop near mid-July while the bergy water route to Frobisher Bay will only develop in the first week of August.

Table 1: Hudson Bay and Approaches - Break-up Outlook Dates

	2007	Median	Outlook for 2008
Labrador Coast to Cape Chidley - Clearing	15 Jul	29 Jul	12-14 Jul
Frobisher Bay - Open drift or less - Clearing	15 Jul 03 Aug	19 Jul 07 Aug	17-19 Jul 05-07 Aug
Ungava Bay - Clearing	17 Jul	03 Aug	27-29 Jul
Bergy water route through Hudson Strait (eastern entrance to south of Nottingham Island)	10 Jul	27 Jul	14-16 Jul
Hudson Strait - Clearing	22 Jul	08 Aug	28-30 Jul
Bergy/open water route to Churchill (eastern entrance of Hudson Strait to Churchill)	10 Jul	30 Jul	26-28 Jul
Open water route through northern Hudson Bay (south of Nottingham Island to Churchill)	08 Jul	20 Jul	26-28 Jul
Hudson Bay - Clearing	03 Aug	16 Aug	16-18 Aug
James Bay - Clearing	30 Jul	30 Jul	04-06 Aug

Eastern Arctic

Freeze-up and Winter Ice Regime

Temperatures were above normal over most of the area until the end of October. They were below normal over sections south and west of Jones Sound during the first 3 weeks of November, and below normal in southern Baffin Bay and Davis Strait in the last week of November. Temperatures were again above normal everywhere through most of December. Freeze-up was 1-2 weeks early in the very extreme northwest of Baffin Bay, but delayed by a week over Jones Sound and Baffin Bay / Davis Strait and delayed by 3-4 weeks in Lancaster Sound, Prince Regent Inlet, and the Gulf of Boothia. By the end of January, measured ice thicknesses in Resolute Bay and Eureka were greater than normal due to patchy colder-than-normal January temperatures, although calculated ice thicknesses predicted normal conditions in these areas. End-of-January measured ice thicknesses in Hall Beach were normal.

By the end of the summer of 2007, the old ice distribution was greater than normal along the east coasts of Ellesmere and Devon Islands, in Nansen and Eureka Sounds, and in Norwegian Bay. At the same time, old ice amounts in the Gulf of Boothia and Committee Bay were drastically reduced.

By mid-September, new ice started forming in Nansen and Eureka Sounds and in northwestern Norwegian Bay. By the end of September it was forming in Jones Sound and northwestern Baffin Bay.

By mid-October, ice had not yet formed in Lancaster Sound, Prince Regent Inlet or the Gulf of Boothia. Ice in these areas did finally form by the end of October, later than normal. By the end of October, ice in the Gulf of Boothia, Lancaster and Jones Sounds, and Northern Baffin Bay had thickened to grey and grey-white ice, while ice in Norwegian Bay and northwards had thickened to thin first-year ice. Nansen and Eureka Sounds consolidated near mid-October, both areas 1 week later than normal.

By mid-November, Pelly Bay, McDougall Sound, Admiralty Inlet (up to Nanisivik), Eclipse Sound and Navy Board Inlet had consolidated. Ice extents were near normal everywhere except along the leading edge of the ice in mid-Baffin Bay, in Cumberland Sound and along the west Greenland Coast. At this time the ice growth in Davis Strait / Baffin Bay extended eastward to 60°W and southward from 75°N along the western Greenland Coast to 65°N near the entrance to Cumberland Sound. Freeze-up in most of Baffin Bay was about 1 week later than normal. There was patchy two-tenths of old ice in western Baffin Bay. Most of Foxe Basin was covered with grey-white to thin first-year ice.

By the end of December, Barrow Strait west of Resolute Bay had become consolidated. Baffin Bay was covered with medium first-year ice with areas of 3-tenths of old ice in western sections. The bergy water lead along the west Greenland Coast had closed down to near 67°N.

By the end of January, the ice extent was normal everywhere except greater than normal along the Greenland Coast. Barrow Strait had entirely consolidated with Lancaster Sound and Prince Regent Inlet remaining mobile. Ice in Nares Strait remained mobile, allowing old ice to continue flowing from the Lincoln Sea into Baffin Bay. As a result, there was a long line of three to five tenths of old ice in the main ice pack in Baffin Bay. The bergy water along the west Greenland Coast was restricted to a much narrower-than-normal strip, barely reaching north of 67°N.

Between early February and the end of March temperatures were below normal inside the archipelago while temperatures along the east coast of Baffin Island remained near normal, with warmer periods interspersed with colder ones. The ice thickened up to mostly thick first-year ice inside the archipelago while medium first-year ice was the predominant ice type in Baffin Bay, Davis Strait and Foxe Basin. The ice continued to be mobile in Lancaster Sound and Prince Regent Inlet. The old ice continued to pour into the western portion of Baffin Bay because the bridge in Nares Strait only briefly formed in Smith Sound at the end of March. This initial bridge formation collapsed a few days later and a new bridge reformed by mid-April, roughly 60 miles further north in Kane Basin. A 120-mile wide corridor of old ice, with pockets reaching concentrations of 3 to 5 tenths, continued to move southward along the east coast of Baffin Island. This corridor narrowed significantly south of 68°N. The overall ice extent along the Greenland coast was still greater than normal with a brief period of no bergy water at all appearing on the regional charts near mid-March. The ice thickness near the Greenland Coast, however, was only a mix of grey-white and thin first-year ice.

From early April to late May, with the advent of the spring sunrise, temperatures were predominantly above normal over all regions, although the mean air temperature remained below zero. By late May, predominantly thick first-year ice existed throughout the region except for a large region of bergy water south of the Nares Strait ice bridge. The ice bridge re-consolidated in its usual location across Smith Sound near the end of April and has been holding ever since. From April through mid-May small areas of coastal fast ice containing old ice broke off south of the bridge. As a result, small pieces of old ice drifted into northwestern Baffin Bay and across the entrance to Lancaster Sound. During the latter part of May, ice concentrations decreased significantly along the west Greenland Coast, allowing for an open drift navigable route to develop there. The ice edge in Davis Strait was slightly further west than normal; however the ice was more closely packed than usual. Small openings in the ice in Cumberland Sound near mid-May gradually filled back up by the end of May. The ice in Lancaster Sound briefly consolidated north of the Brodeur Peninsula and in the northern portion of Prince Regent Inlet during the third week of April but managed to become mobile again as far west as Prince Leopold Island near mid-May. At that time, several small areas of lower ice concentrations were appearing in the Foxe Basin region. By late May, these small regions grew slightly bigger to form several pockets of open water.

Observed Ice Conditions

The regional ice chart in figure 4 was based on the analysis of Radarsat/Envisat and NOAA/MODIS imageries from around May 26th, 2008. This chart reveals some of the following features:

a) The bergy water lead along the west Greenland Coast extended northward to 73°N which is further north than normal; an open drift route was already present north of this point.

b) The fast ice edge in eastern Barrow Strait was located near Prince Leopold Island which is normal.

c) No old ice was present in Admiralty Inlet, the Gulf of Boothia and Committee Bay.

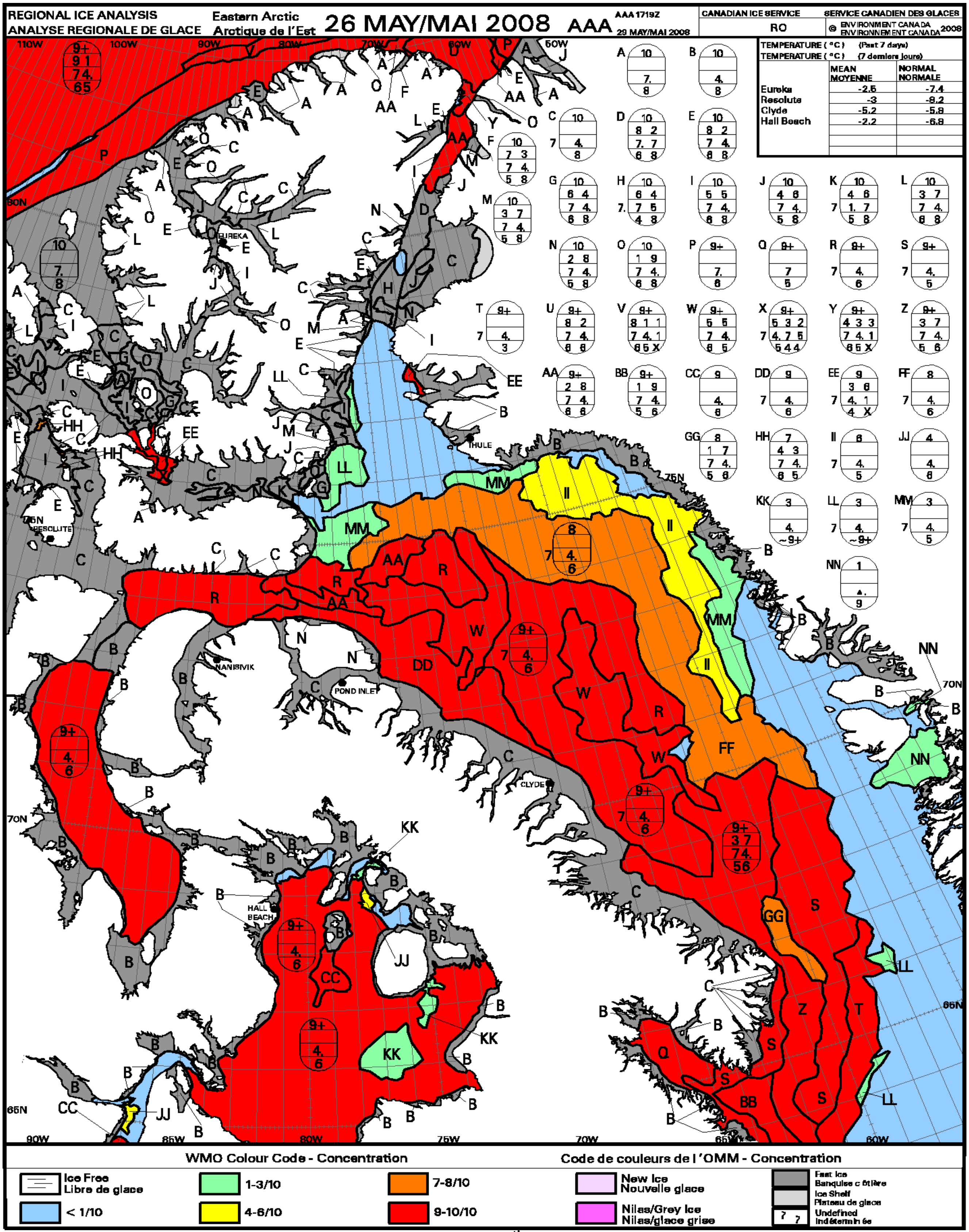
d) The eastern extent of the sea ice was slightly further west than normal in Davis Strait and southern Baffin Bay.

e) More old ice than normal was present in western Baffin Bay, in northern Davis Strait and in Eureka Sound.

f) The North Open Water polynia had extended into a large area of bergy water.

g) More openings than normal were present in the Foxe Basin region.

h) A tightly packed multi-year ice region prevailed beyond the northwestern coast of the Canadian Arctic Archipelago.



TEMPERATURE (°C) (Past 7 days) TEMPERATURE (°C) (7 derniers jours)	MEAN MOYENNE	NORMAL NORMALE
Eureka	-2.6	-7.4
Resolute	-3	-8.2
Clyde	-5.2	-5.8
Hall Beach	-2.2	-6.8

Figure 4: Eastern Arctic Regional chart for May 26th, 2008

Outlook for the Eastern Arctic

The temperature from mid-May through mid-June and throughout the months of July and August is forecast to be above normal for most of the Arctic regions. Normal temperatures are expected for only a few areas north of 75°N. This will help the open drift or less route in northern Baffin Bay to develop after mid-July. The ice bridge in Nares Strait is also expected to collapse during this time, allowing for more old ice to penetrate the entrance of Lancaster Sound and invade that area during the summer months. Because of the significant concentration of old ice, the complete clearing of Baffin Bay is not expected until the second week of September while the Davis Strait region is expected to clear in early September. The open drift or less routes into Home Bay and Cape Dyer will occur normally towards the end of July or the first week of August.

A warmer than normal temperature forecast coupled with a trace of old ice in the eastern half of the Northwest Passage will promote a navigable passage again this summer; this could represent the first time in history that the Northwest Passage will be predominantly open water two years in a row. Unfortunately, because the Archipelago region was subjected to below normal temperatures during the winter months, this event is only expected to occur in early August. Consequently, the usual fracturing events over the various regions will take place on normal dates (e.g. early July for the eastern portion of Barrow Strait and the third week of July for the western section). The fracturing of Jones, McDougall and Eureka Sounds including Norwegian Bay is expected to occur in the first week of August at the latest.

The Foxe Basin region will continue to develop more extensive areas of open water around the many islands throughout June and July, but the open water route into Hall Beach is only expected to develop at the end of August.

For Pelly Bay, no old ice was observed southeast of Somerset Island during the winter and only a small area containing trace amounts of old ice was noted east of the island. This situation will help in the melting of the first-year ice this summer. The clearing of the southern part of Prince Regent Inlet, however, will only occur at the end of August or in early September.

Although the open drift or less route to Thule is almost navigable now, the coastal fast ice in the vicinity of Thule will not break until the third week of June. The annual Pacer Goose mission will not be threatened by ice conditions this summer.

Table 2: Eastern Arctic - Break-up Outlook Dates

	2007	Median	Outlook for 2008
Route across Northern Baffin Bay			
- Open drift or less	21 Jun	18 Jul	19-21 Jul
- Bergy water route	27 Jul	28 Jul	29-31 Jul
Baffin Bay			
- Clearing	06 Sep	10 Sep	09-11 Sep
Davis Strait			
- Clearing	04 Sep	02 Sep	02-04 Sep
Home Bay			
- Open drift or less	06 Aug	08 Aug	05-07 Aug
Cape Dyer			
- Open drift or less	28 Jul	27 Jul	28-30 Jul
Open water route to Hall Beach	29 Aug	03 Sep	29-31 Aug
Foxe Basin			
- Clearing	03 Oct	21 Sep	20-22 Sep
Pond Inlet			
- Fracture[1]	22 Jul	24 Jul	19-21 Jul
- Clearing	07 Aug	12 Aug	06-08 Aug
Admiralty Inlet northern half			
- Fracture[1]	19 Jul	21 Jul	20-22 Jul
- Bergy water	11 Aug	10 Aug	10-12 Aug
Lancaster Sound			
- Fracture[1]	Not consolidated	08 Jul	Not consolidated
Barrow Strait to Resolute			
- Fracture/eastern[1]	23 Jun	09 Jul	04-06 Jul
- Fracture/western[1]	15 Jul	25 Jul	19-21 Jul
Wellington Channel			
- Fracture[1]	16 Jul	28 Jul	26-28 Jul
McDougall Sound			
- Fracture[1]	21 Jul	03 Aug	02-04 Aug
Kane Basin			
- Fracture[1]	Not consolidated	23 Jul	18-20 Jul
Jones Sound			
- Fracture[1]	28 Jul	31 Jul	01-03 Aug
Norwegian Bay			
- Fracture/southern[1]	21 Jul	01 Aug	02-04 Aug
- Fracture/northern[1]	26 Jul	08 Aug	09-11 Aug
Eureka Sound			
- Fracture[1]	26 Jul	02 Aug	01-03 Aug
- Bergy water	Never cleared	18 Aug	Never clear
Pacer Goose route to Thule			
-Open drift or less	25 Jun	19 Jul	19-21 Jun
-Bergy water route	09 Jul	29 Jul	28-30 Jun

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[1] Fracture indicates complete breakage of consolidated ice.

Western Arctic

Freeze-up and Winter Ice Regime

Temperatures were above normal everywhere until the end of October. As a result, freeze-up was delayed by one to two weeks over all areas. Two periods of below-normal temperatures occurred: 1) in early November, east of Amundsen Gulf and M'Clure Strait; and 2) beginning in late December along the Alaskan coast, then spreading across the entire Beaufort Sea in early January. As a result, by the end of January, measured ice thicknesses were close to normal at Cambridge Bay, although calculated ice thicknesses were less than normal. Measured and calculated ice thicknesses were less than normal at Inuvik and Tuktoyaktuk as a result of persistent warmer than normal sea surface temperatures in the southern Beaufort Sea.

At the end of summer 2007 (at the beginning of freeze-up), the old ice extent was considerably less than normal in the Beaufort Sea, M'Clure Strait, Viscount Melville Sound and M'Clintock Channel. Although pockets of greater than normal concentrations of old ice could be found in narrow straits and bays, the Northwest Passage was open from end to end. The Ayles Ice Island had entered Sverdrup Channel, where it had fractured into two pieces. There was open water from Larsen Sound through Dease Strait into the Amundsen Gulf and over the southern Beaufort Sea up to 75°N, except for a section of the pack between 130-150°W which reached down to 72°N. The main pack of old ice had disappeared north of the Alaskan Coast.

New ice growth started in mid-September in M'Clure Strait and Viscount Melville Sound, thickening to grey ice by the end of September in these areas. Elsewhere, new ice formation did not occur until the second and third weeks of October, 1-2 weeks later than normal.

By the end of October, new and grey ice covered most of the southern Beaufort Sea and the southern route of the Northwest Passage. The old ice pack remained well north, concentrated in the central Beaufort Sea, and grey-white ice surrounded the edges of the pack. Areas of open water still existed in Coronation Gulf, between the shore and pack ice north of the Alaskan coast, and west of Point Barrow. Thin first-year ice filled M'Clure Strait, M'Clintock Channel and Peel Sound, and Larsen Sound was covered with predominantly grey-white ice. Portions of the Tuktoyaktuk Peninsula and Mackenzie Bay had become consolidated. By the end of October, ice had consolidated in Prince Gustaf Adolf Sea and in Sverdrup and Peary Channels. The two fragments of the Ayles Ice Island had become trapped in the fast ice, one on either side of Amund Ringnes Island.

By mid-November, Larsen Sound was covered in thin first-year ice and the southern route of the Northwest Passage, from Rae Strait to Amundsen Gulf was covered in grey-white ice. By the end of November, Rae Strait to Amundsen Gulf was also covered in thin first-year ice, and thin first-year ice also surrounded the old ice pack in the central Beaufort Sea, which remained north of 73°N. Ice had consolidated in M'Clure Strait and Viscount

Melville Sound as well as from Peel Sound to Coronation Gulf, although not in M’Clintock Channel. Ice had also consolidated around Cape Parry and along the Alaskan coast east of Point Barrow. West of Amundsen Gulf, between the mainland coast and 71.5°N, ice continued to be composed mainly of new and grey ice, and significant areas of open water persisted. Normally, by the end of November, this area would be entirely covered with thin first-year ice and the old ice edge would extend southwards to 71.5°N.

By mid-December, ice in and to the east of M’Clure Strait and Dolphin and Union Strait had thickened to medium first-year ice. Ice had consolidated in Dolphin and Union Strait. The old ice pack in the central Beaufort Sea had skewed eastward and lay close to the Banks Island coast. Thin first-year ice mostly covered the southern Beaufort Sea except in the vicinity of Point Barrow and westward, which was covered in grey-white ice. By the end of December, the old ice pack in the Beaufort Sea showed significant fragmentation and was interspersed with areas of grey, grey-white, and medium first-year ice. The ice in M’Clintock Channel had finally consolidated, one month later than normal.

During the first week of January, the consolidated ice in M’Clure Strait fractured in an unusual event. A large lead also opened between the consolidated ice in Dolphin and Union Strait and the mobile first-year ice in Amundsen Gulf. Large leads of grey and grey-white ice could be seen in the old ice pack in the Beaufort Sea. By mid-January, the ice in the leads in the old ice pack had thickened to predominantly thin first-year ice, while the lead or polynia in Amundsen Gulf remained predominantly covered in grey-white ice. By the end of January, all consolidated ice within the archipelago and along the mainland Canadian and Alaskan coasts had thickened to thick first-year ice. Elsewhere, except for the old ice pack, the ice cover was primarily composed of medium first-year ice. The old ice pack had pushed southwards to 70.5°N, but remained extremely fragmented and narrow, not reaching further west than 150°W.

From the beginning of February to the end of March, the temperature oscillated between cold outbreaks and warm spells for the area west of Amundsen Gulf but remained predominantly below normal within the central Canadian Arctic region. The week-long warm spells during the winter months were responsible for creating large leads in the eastern part of Amundsen Gulf, west of Banks Island and off the fast ice edge along the Yukon and Northwest Territories’ coast. The leads quickly filled with young ice which thickened back up to thin and medium first-year ice by the end of March. Meanwhile, the old ice pack south of 75°N raced westward – traveling more than 120 miles – along the Alaskan coast but managed to stay beyond 60 miles north of the coast. Further north, prevailing northerly winds kept the old ice tightly packed along the west coasts of the northern islands of the archipelago. Although M’Clure Strait reconsolidated east of 120°W by mid-March, the Amundsen Gulf never consolidated during the period.

From April to mid-May, the sun had already started to warm the entire region. Near to above normal temperatures prevailed over all areas although the actual values remained below zero. For the last two weeks of May, temperature started to rise above zero at the coastal stations located on the mainland and at Sachs Harbour located on the southwestern tip of Banks Island.

By early April, M’Clure Strait had reconsolidated between Banks Island and Prince Patrick Island. Most of the winter seasonal ice had thickened to thick first-year ice throughout the Archipelago. By the end of April, the accumulated freezing degree days in the central Canadian Arctic had reached values not seen for the past four years, while Cambridge Bay had reached values unrivalled in the past 17 years. By late May, large openings existed in the pack ice east of a line between Herschel Island and the southwestern tip of Prince Patrick Island and in the Amundsen Gulf, although the thickening of the ice in the leads was by now considerably reduced due to the warmer air temperatures. Such openings in the pack ice are usually seen in late June. This suggests the current deterioration of the ice in that region is one full month ahead of normal. Medium and thick first-year ice still prevailed in these more loosely packed ice areas with the thinnest observed ice being grey-white ice; the grey and new ice have already melted. Meanwhile, the old ice has continued its westward movement along the Alaskan Coast and the heaviest concentration now lies northwest of Point Barrow. Only a trace to one tenth of old ice is found within 100 miles of the Alaskan Coast. Most of the Bering Strait is still covered with medium and thick first-year ice. A lead off the coastal fast ice has developed early along the western Alaskan coast between Point Barrow and Cape Lisburne. Only a narrow band of very close packed medium first-year ice near Point Hope prevents the open drift or less route to Wainwright from forming at this time.

Observed Ice Conditions

The regional ice charts in figures 5 and 6 were based on the analysis of Radarsat/Envisat and NOAA/MODIS imageries from around May 26th, 2008. These charts reveal some of the following features:

a) Only a trace of old ice can be found in the western portion of the Northwest Passage between Amundsen Gulf and Peel Sound.

b) The maximum southern extent of the old ice was normal in the Beaufort Sea; however, the main old ice pack was roughly 250 miles further north than normal with an abnormally broad region of 6 to 8 tenths old ice concentration found between 72 and 77°N.

c) The northern sections of M’Clure Strait and Viscount Melville Sound only contained a trace of old ice while the southern sections only showed 6 tenths of old ice; this represents significantly less old ice than normal for both regions.

d) A significant lead was present between Cape Lisburne and Point Barrow.

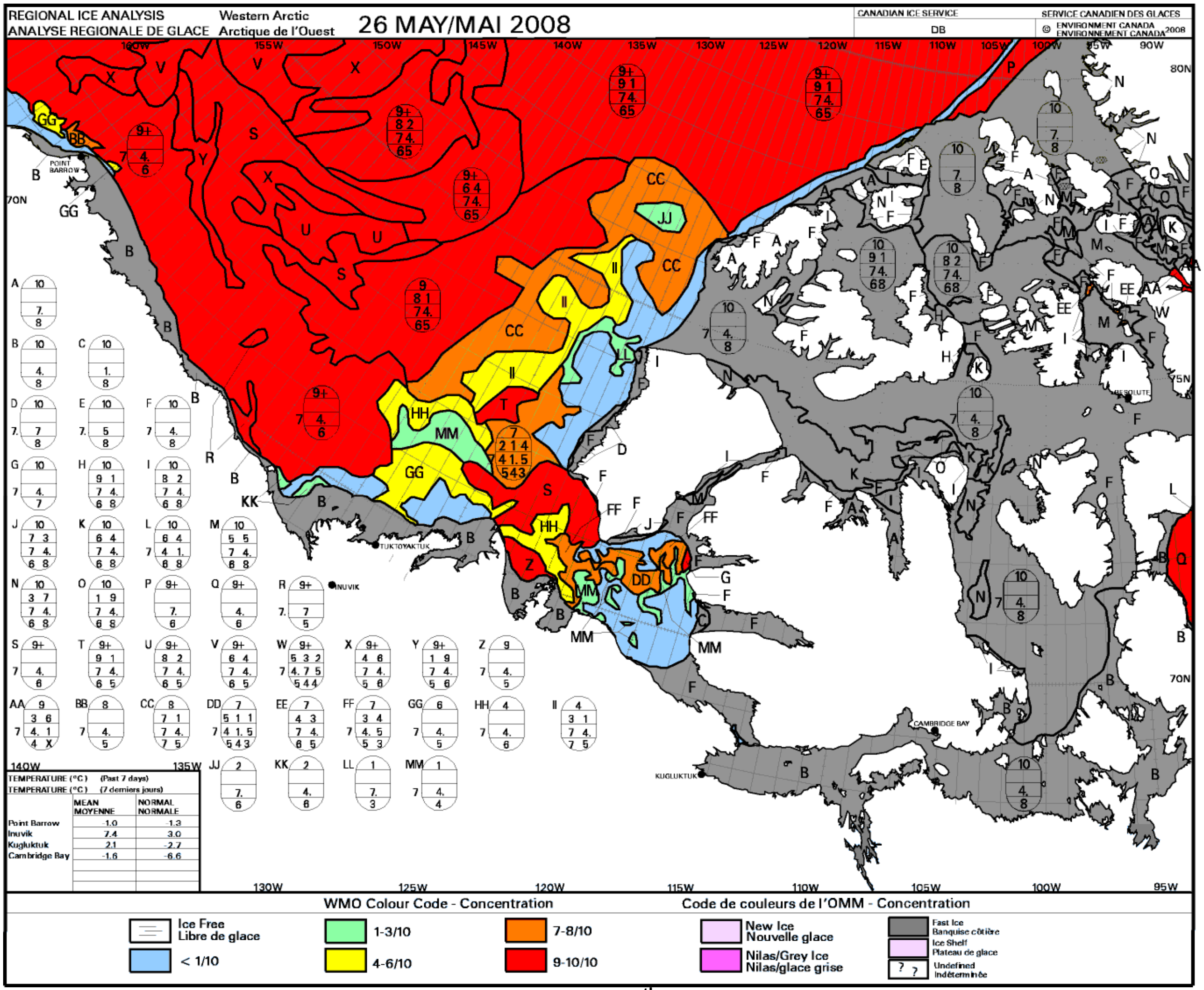
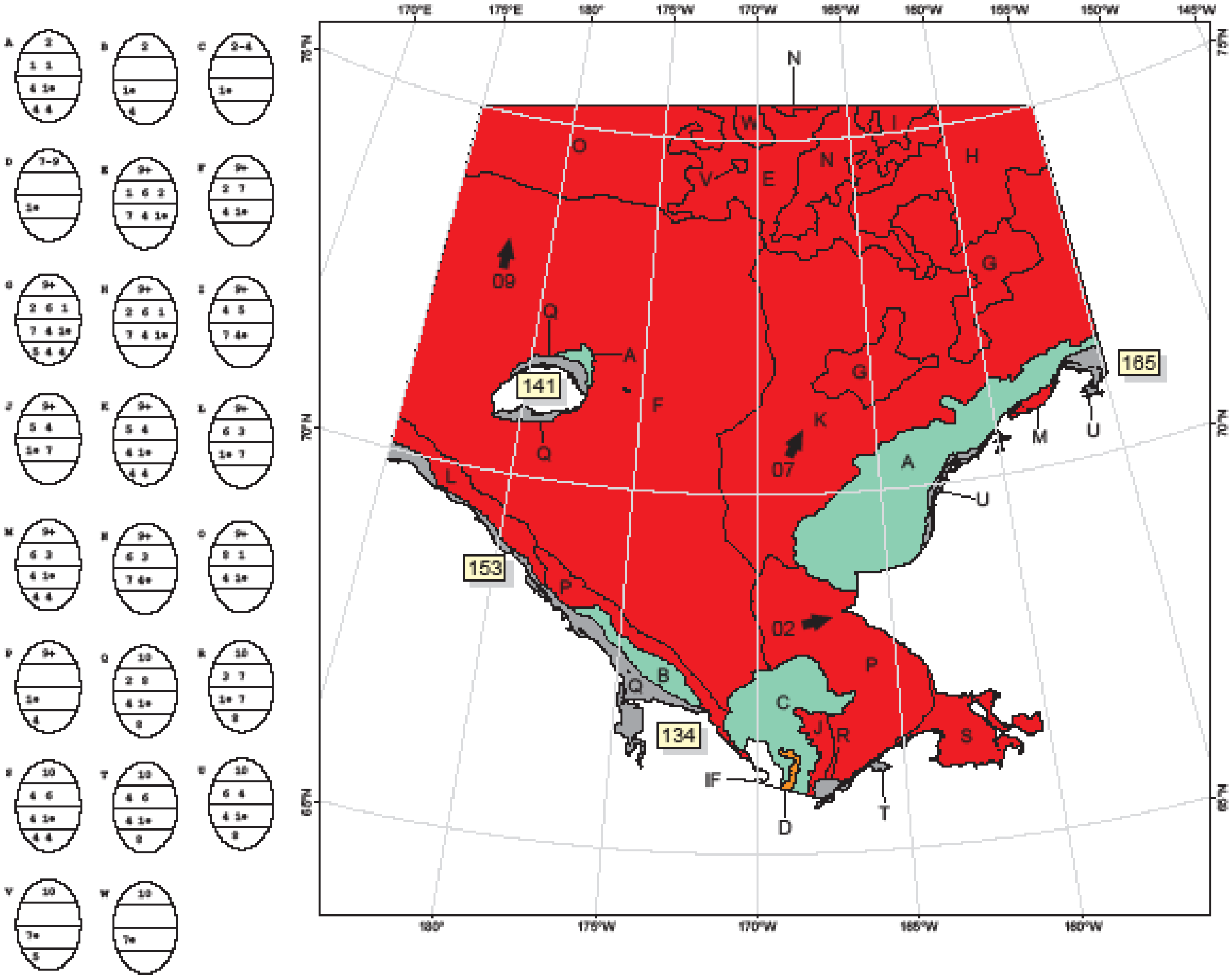


Figure 5: Western Arctic Regional chart for May 26th, 2008



CM - THEORETICAL ICE THICKNESS IN CENTIMETERS

NM - 168HR ANAL DRIFT VECTORS IN NAUTICAL MILES

IF - ICE FREE

COLOR CODES BASED ON TOTAL CONCENTRATION

⬜	ICE FREE	🟨	4-6 TENTHS	⬛	FAST ICE (TEN TENTHS)
🟦	LESS THEN 1 TENTH	🟧	7-8 TENTHS	⬜	ICE SHELF
🟩	1-3 TENTHS	🟥	9-10 TENTHS	⬜	UNDEFINED ICE

ICE ANALYSIS
Chukchi Sea
NATIONAL/NAVAL ICE CENTER
Analysis Week 26 - 30 May 2008

Data Sources	Date
RADARSAT	24 - 27 May
OLS	25 May
ENVISAT/GMM	25 - 27 May

Analysts: Heisler, Kevin AG2
UNCLASSIFIED

Figure 6: Chukchi Sea Regional chart for May 26th, 2008

Outlook for the Western Arctic

Temperatures for June are forecast to be above normal over all coastal regions of Alaska, Yukon and the Northwest Territories while the three-month period from June through August is forecast to be above normal. Only the northwestern portion of the Canadian Arctic Archipelago is forecast to experience normal temperatures throughout the entire summer. The June coastal temperatures support the early clearing of the Amundsen Gulf region. However, it should be remembered that once the first-year ice has melted, the multi-year ice in Prince of Wales Strait will be free to drift into the northern portion of the Amundsen Gulf region. This will prevent the region from clearing completely this summer. Although an open water route between Mackenzie Bay and Cape Bathurst is expected to develop roughly one full month earlier than normal, the coastal route will only be navigable near the mid-July period once the fast ice breaks free from the Tuktoyaktuk Peninsula. The old ice pack in the Beaufort Sea should remain 90 miles beyond the coast and should not pose a serious threat to offshore shipping or transit. The coastal fast ice along the Alaskan Coast will break and melt near normal dates. This will cause the open drift or less coastal route from Mackenzie Bay to Prudhoe Bay to be fully navigable by the tugs in the second week of August. The above normal temperature forecast for the central Arctic region will counteract the additional freezing degree day values accumulated during the winter months. Consequently, the fracturing of the ice in Coronation Gulf is expected to occur during mid-July while the Queen Maud Gulf, Larsen Sound and Peel Sound areas will only fracture in the last week of July or in early August. Once the ice starts fracturing, the melt of the ice will accelerate. This will promote a navigable corridor across the western portion of the Northwest Passage by mid-August. The open water route to Taloyoak is the only event which is forecast to occur later than normal; this should take place towards the end of August. At that time, the southern route of the Northwest Passage will also be open water.

This summer is the last field season of the International Polar Year. Science vessels are expected to venture far inside the Beaufort Sea region where the multi-year ice pack traditionally resides. Subsequent to the huge leads and cracks which opened in the multi-year ice pack throughout the winter south of 76.5°N, the overall concentration of old ice will range between 5 to 8 tenths in that region. The old ice concentration will increase rapidly as vessels travel north of 77°N.

Table 3: Western Arctic - Break-up Outlook Dates

	2007	Median	Outlook for 2008
Mackenzie Bay **- Clearing**	21 Jun	18 Jun	18-20 Jun
Kugmallit Bay **- Clearing**	21 Jun	26 Jun	22-24 Jun
Tuktoyaktuk Peninsula **- Fracture**[1]	01 Jul	02 Jul	03-05 Jul
Mackenzie Bay to Cape Bathurst **- Open water route**	12 Jul	27 Jul	18-20 Jul
Coastal waterway Mackenzie Bay to Prudhoe Bay **- Open drift or less**	22 Jul	14 Aug	08-10 Aug
Coastal waterway Prudhoe Bay to Point Barrow **- Open drift or less** **- Close pack (refreeze)**	25 Jul 08 Oct	01 Aug 08 Oct	08-10 Aug 10-12 Oct
Cape Lisburne to Point Barrow **- Open drift or less** **- Open water route**	10 Jun 02 Jul	03 Aug 17 Aug	18-20 Jun 06-08 Aug
Wainwright **- Open drift or less**	24 Jun	29 Jun	18-20 Jun
Coastal waterway Prudhoe Bay to Barter Island **- Open drift or less**	20 Jul	12 Aug	08-10 Aug
Open water route to Taloyoak	07 Aug	16 Aug	26-28 Aug
Amundsen Gulf **- Fracture**[1] **- Clearing**	Not consolidated Never	07 Jul 15 Aug	Not consolidated Never clear
Coronation Gulf **- Fracture**[1] **- Clearing**	15 Jul 26 Jul	15 Jul 31 Jul	17-19 Jul 04-06 Aug
Queen Maud Gulf **- Fracture**	21 Jul	22 Jul	26-28 Jul
Larsen Sound **- Fracture**[1]	23 Jul	31 Jul	01-03 Aug
Peel Sound **- Fracture**[1]	23 Jul	31 Jul	01-03 Aug

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[1] Fracture indicates complete breakage of consolidated ice.

Table 4: Selected Sea Ice Data and Severity Index for the north coast of Alaska (1953-2007)

		1	2	3	4	5	6	7	8	9		
Rank	**Year**	**10 Aug**	**15 Sep**	**10 Aug**	**15 Sep**	**date**	**date**	**# days**	**# days**	**# days**	**Obs Inx**	**Fcst Indx**
1	2007	150	397	183	515	16-Jul	08-Oct	63	84	77	1136	221
2	2004	13	238	70	260	16-Jul	08-Oct	71	68	77	637	602
3	1958	50	150	50	210	19-Jul	25-Oct	92	99	74	624	446
4	1968	25	165	30	200	19-Jul	18-Oct	86	91	74	615	495
5	1998	15	105	20	240	15-Jul	21-Oct	72	100	78	584	486
6	2005	70	130	85	250	23-Jul	03-Oct	63	70	70	580	381
7	2003	18	167	27	185	21-Jul	20-Oct	52	92	72	568	481
8	1993	0	130	5	185	18-Jul	07-Nov	64	112	75	565	388
9	2002	0	135	18	225	13-Aug	14-Oct	32	64	49	504	293
10	1962	25	150	30	150	19-Jul	30-Sep	49	68	74	490	406
11	1973	5	80	5	190	31-Jul	20-Oct	73	82	62	486	344
12	1954	20	115	20	210	01-Aug	30-Sep	38	61	61	484	552
13	1997	28	150	40	150	08-Aug	10-Oct	47	63	54	463	297
14	1963	5	130	5	130	13-Aug	18-Oct	67	67	49	442	351
15	1990	0	90	40	90	23-Jul	12-Oct	75	105	70	429	173
16	1961	15	105	15	135	25-Jul	24-Sep	49	62	68	418	414
17	1996	10	65	70	155	16-Jul	25-Sep	37	71	77	405	446
18	1979	0	125	0	125	04-Aug	08-Oct	31	56	58	394	178
19	1989	10	70	55	110	19-Jul	22-Oct	34	95	74	383	284
20	1974	10	100	10	100	06-Aug	05-Oct	35	61	56	351	372
21	1978	5	70	30	95	25-Jul	09-Oct	35	76	68	343	492
22	1986	10	80	10	110	29-Jul	21-Oct	30	58	64	342	517
23	1999	15	45	45	105	30-Jul	08-Oct	56	70	63	338	98
24	1977	5	55	25	85	02-Aug	15-Oct	63	74	60	336	381
25	1959	20	65	20	65	19-Jul	06-Oct	42	86	74	331	271
26	1995	30	30	50	50	15-Jul	17-Oct	70	94	78	329	477
27	1972	0	60	30	90	31-Jul	01-Oct	45	63	62	320	251
28	1982	0	85	0	95	03-Aug	10-Oct	21	69	59	318	271
29	2006	17	18	17	69	04-Aug	13-Oct	60	70	58	275	-462
30	1994	10	35	10	60	05-Aug	24-Sep	44	55	57	251	334
31	1957	5	45	70	60	01-Aug	06-Oct	18	67	61	250	300
32	1987	0	10	0	85	05-Aug	30-Oct	35	59	57	250	299
33	1981	0	0	35	100	26-Jul	01-Oct	0	66	67	232	521
34	2000	10	70	10	75	31-Jul	02-Oct	19	33	62	228	274
35	1985	0	35	0	55	01-Aug	15-Oct	22	52	61	224	245
36	1967	15	0	30	50	25-Jul	12-Oct	25	68	68	213	212
37	1984	0	25	0	50	11-Aug	15-Oct	21	42	51	209	219
38	1966	5	0	5	45	01-Aug	22-Oct	24	65	61	194	296
39	1992	15	0	15	75	09-Aug	19-Sep	24	37	53	188	560
40	1965	0	10	0	70	25-Aug	25-Sep	25	32	37	173	182
41	2001	0	25	15	25	17-Aug	08-Oct	26	52	45	172	262
42	1980	15	25	15	25	05-Aug	30-Sep	11	42	57	159	426

		1	2	3	4	5	6	7	8	9		
Rank	**Year**	**10 Aug**	**15 Sep**	**10 Aug**	**15 Sep**	**date**	**date**	**# days**	**# days**	**# days**	**Obs Inx**	**Fcst Indx**
43	1953	0	0	5	35	27-Jul	16-Sep	5	52	66	157	213
44	1976	0	15	0	15	15-Aug	07-Oct	21	53	47	150	106
45	1971	0	0	0	30	23-Aug	01-Nov	8	71	39	147	166
46	1991	0	0	0	20	16-Aug	02-Oct	0	46	46	111	199
47	1960	0	0	20	20	05-Aug	07-Sep	0	34	57	110	231
48	1988	0	0	0	25	09-Aug	20-Sep	0	32	53	110	354
49	1964	0	0	0	5	13-Aug	20-Sep	0	39	49	95	536
50	1983	0	10	0	10	08-Aug	16-Sep	0	21	54	92	41
51	1970	0	0	5	0	06-Aug	14-Sep	0	32	56	87	251
52	1956	0	0	0	40	07-Sep	30-Sep	0	24	24	87	93
53	1969	0	0	0	30	07-Sep	18-Sep	5	12	24	70	157
54	1955	0	0	5	15	13-Sep	24-Sep	0	12	18	44	44
55	1975	5	0	5	0	NEVER	NEVER	0	0	0	0	8

1 - Distance from Point Barrow northward to ice edge (10 Aug)

2 - Distance from Point Barrow northward to ice edge (15 Sept)

3 - Distance from Point Barrow northward to boundary of five tenths ice concentration (10 Aug)

4 - Distance from Point Barrow northward to boundary of five tenths ice concentration (15 Sep)

5 - Initial date the entire sea route to Prudhoe Bay is less than or equal to five tenths ice concentration.

6 - Date that combined ice concentration and thickness dictate end of prudent navigation.

7 - Number of days the entire sea route to Prudhoe Bay is ice free.

8 - Number of days entire sea route to Prudhoe Bay less than/equal to five tenths ice concentration.

9 - Number of days between initial opening date and 01 Oct.

Appendix A : Key To Canadian Ice Service Sea Ice Symbols

For more information on this section, please refer to the following web link on the Canadian Ice Service web site:

http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?Lang=eng&lnid=76&ScndLvl=no&ID=11030

or on the National Ice Center web site:

http://www.natice.noaa.gov/egg_code/index.html

Appendix B : Broadcast Schedules For Arctic Ice and Marine Conditions

For more information on this section, please refer to the following web links:

Canadian Coast Guard (Radio Aids to Marine Navigation):

http://www.ccg-gcc.gc.ca/eng/CCG/MCTS_Radio_Aids

Alaska Marine VHF Voice:

http://www.nws.noaa.gov/om/marine/akvhfv.htm

NOAA MF/HF Voice – 4125 kHz:

http://www.nws.noaa.gov/om/marine/noaahfv.htm

NOAA Weather Radio at U.S. Coast Guard Sites in Alaska:

http://www.nws.noaa.gov/om/marine/aknwr.htm

For further information, please contact Canadian Ice Service by:

Phone:	1-877-789-7733
Fax:	1-613-947-9160
E-Mail:	ECWeather-Meteo@ec.gc.ca

Or National Ice Center by:

Phone:	1-301-394-3099
E-Mail:	liaison@natice.noaa.gov

The Canadian Government funded the Circumpolar Flaw Lead (CFL) System Study as a major contribution to the International Polar Year (IPY). The Canadian Research Icebreaker (NGCC Amundsen) has been operating in the Canadian Arctic since July of 2007 in support of CFL. She over-wintered in the Amundsen Gulf (AG) and the Southern Beaufort Sea (SBS) conducting a large scale multidisciplinary investigation of the Banks Island Flaw Lead polynya complex. There have been over 300 investigators from 15 countries participating through 10 integrated science teams rotating on 6 week legs between Sept'07 and August'08 (www.ipy-cfl.ca).

The sea ice conditions during the fall of 2007 and winter of 2008 were significantly different than the past 30 year climatology. The fall began with a very slow freeze-up due to the fact that the multiyear pack ice retreated to a position much further north than usual (Figure 1). This caused a northward migration of the high pressure system to coincide with the northward migration of the multiyear (MY) pack ice edge. As the fall progressed the Beaufort Sea Ice gyre was very active resulting in high velocity circulation of MY ice in an anticyclonic direction away from the Banks Island Coast (compare across dates in Figure 1). This opened up very large flaw leads along the West coast of Banks Island which we were able to use to navigate the Amundsen northwards along the western coast of Banks Island in Late November, 2007. We entered into the pack ice near the northern limit of Banks Island (Figure 2) at the entrance to McClure Strait. We found the MY pack to be highly decayed: thaw holes were common; lots of snow on the surface of the ice and the average thickness of he MY ice was only about 2.8 m. The MY ice spun off banks island opening large cracks and leads in the pack ice and forming large flaw leads again the west coast of Banks Island. This consolidated with first-year ice forming in the interstices of the MY ice (Figure 2). The late fall and early winter saw lots of open water in Amundsen gulf. This was due to cyclones tracking along the open water area from the Chuckchi Shelf through the Southern Beaufort Sea to Amundsen Gulf. The cyclones kept the ocean surface very rough (figure 2) and contributed to a large ocean to atmosphere heat flux. Our in situ measurements showed that the surface mixed layer contained a lot of heat due to the long period of open water in the summer and fall of 2007. This period of open water and very thin ice continued through until about mid to late December when things began to consolidate. Once the ocean was capped the ice grew relatively rapidly. Throughout the winter period the flaw lead polynya of Cape Bathurst and Banks Island consisted of a lot of open water due to first year divergence. These leads were sufficiently large that we were able to keep the Amundsen mobile in this region throughout the winter. Our science plan was predicated on a fast ice bridge forming between Cape Perry and Cape Lambton (the south tip of Banks Island). This never happened due to the late formation and lack of thickness in the first-year ice in Amundsen Gulf. At the time of writing this brief our icebreaker is operating largely in open water (late May'08) and the melt onset has begun. We are about 1 month ahead of climatology for this region for both melt onset and the clearing of ice from Amundsen Gulf. Several Key features regarding projections of sea ice can be gleaned from our experiences overwintering in the Southern Beaufort Sea:

1) At the hemispheric scale we expect the multiyear sea ice pack to retreat to a level approximately the same or less than the record reduction of 2007. This is due to a number of factors:
    a. The remnant MY sea ice had a lot of new snow on it in the late fall of 2008 (so much that we could not land our helicopter on it). This new snow will have restricted growth of the MY ice through the winter of 2008.
    b. The MY pack was dispersed in the late fall due to an anticyclonic rotation in the Beaufort Sea Ice gyre (see figure 1). This caused thin first-year sea ice to grow

    between MY floes thereby decreasing the overall albedo of this surface in the spring of 2008 (see Figure 2).
    c. The MY pack ice was much more mobile that in other years due to the lack of sufficiently thick ice to slow down dynamic processes. We released 24 ice beacons as part of our CFL projects. These beacons are currently sending telemetry data and have recorded ranges in velocity f from 0.02 km/hr to over 2.0 km/hr depending on beacon, date and location. The largest values are associated with the anticyclonic rotation of the MY ice pack in the Beaufort Gyre.

2) In the Southern Beaufort Sea (SBS) sub-region we expect the spring to progress ahead of climatology and for the ice to be approximately the same or less than the record reduction in 2007. This is due to a number of factors:
    a. The ice was thinner than in previous years due to the late formation of sea ice in the SBS and Amundsen Gulf (AG). This late season freeze-up was due to the large heat storage in the surface mixed layer and the feedback drawing cylones over the open waters of the AG in the fall of 2007. These cyclones kept the ocean surface roughness higher than usual and resulted in delayed onset of freeze-up.
    b. The fast ice bridge never formed this year between Cape Perry to Cape Lambton (south tip of Banks Island). Strong winds in April and May flushed the ice out of AG and the flaw lead system is now largely open water. This condition is about 1 month ahead of climatology.
    c. The open water is beginning to retain a lot of heat from surface insolation and a stable and warming surface mixed layer is beginning to form (late May). This is also about 1 month early. This heat will continue to build over the summer and will likely result in delayed freeze-up in the fall of 2008.

3) In the western limit of the NW passage we expect the spring to progress ahead of climatology and for the ice to be approximately the same or less than the record reduction in 2007. This projection is due to a number of factors:
    a. There is only a remnant amount of multiyear sea ice north of Banks Island in McClure Strait. This ice entered the passage last fall and circulated down through Prince of Whales Strait back into Amundsen Gulf.
    b. No MY ice plug formed in the fall of 2007 in McClure Srait due to the fact that the Beaufort Sea Ice Gyre rotated ice away from the entrance to McClure in the fall when this plug typically formed. Because the surface flow was from the east to the west the MY ice never entered McClure stait when it was open in the fall. This means that the majority of ice in the NW limit of the NW passage is FY ice. We also note that if the MY edge retreats to north of the western entrance to McClure then we would expect no ingress of MY ice into this passage in August or September of 2008 either.
    c. The first-year ice in McClure is relatively thick (170cm) but is predominantly first-year sea ice thus we expect it to weaken as the spring progresses and it will become mobile earlier than if the usual plug of MY ice was present.
    d. Given these conditions we expect the western limits of the NW passage to be similar to those which occurred in 2007. We note that the NW passage was open to ship traffic from August to December of 2007.

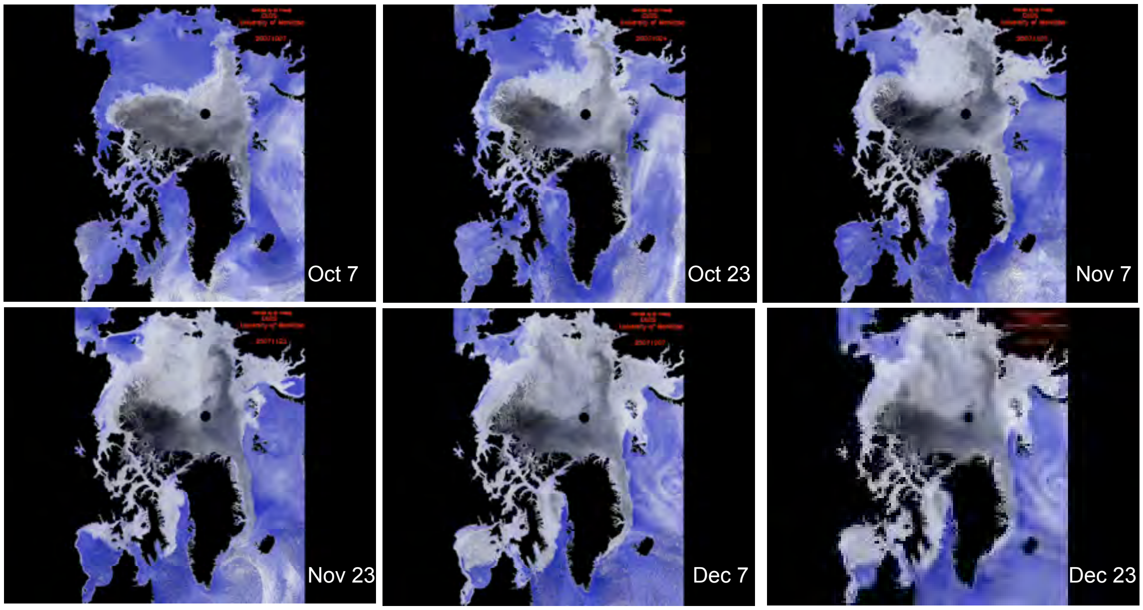

Figure 1. A selection of AMSR-E passive microwave images from October to December of 2007 for the northern hemisphere showing the distribution of multiyear sea ice. The pack ice was very mobile in the fall of 2007 (see text) that had implications for how the northern hemisphere, southern Beaufort Sea and NW passage ice is expected to evolve this summer.

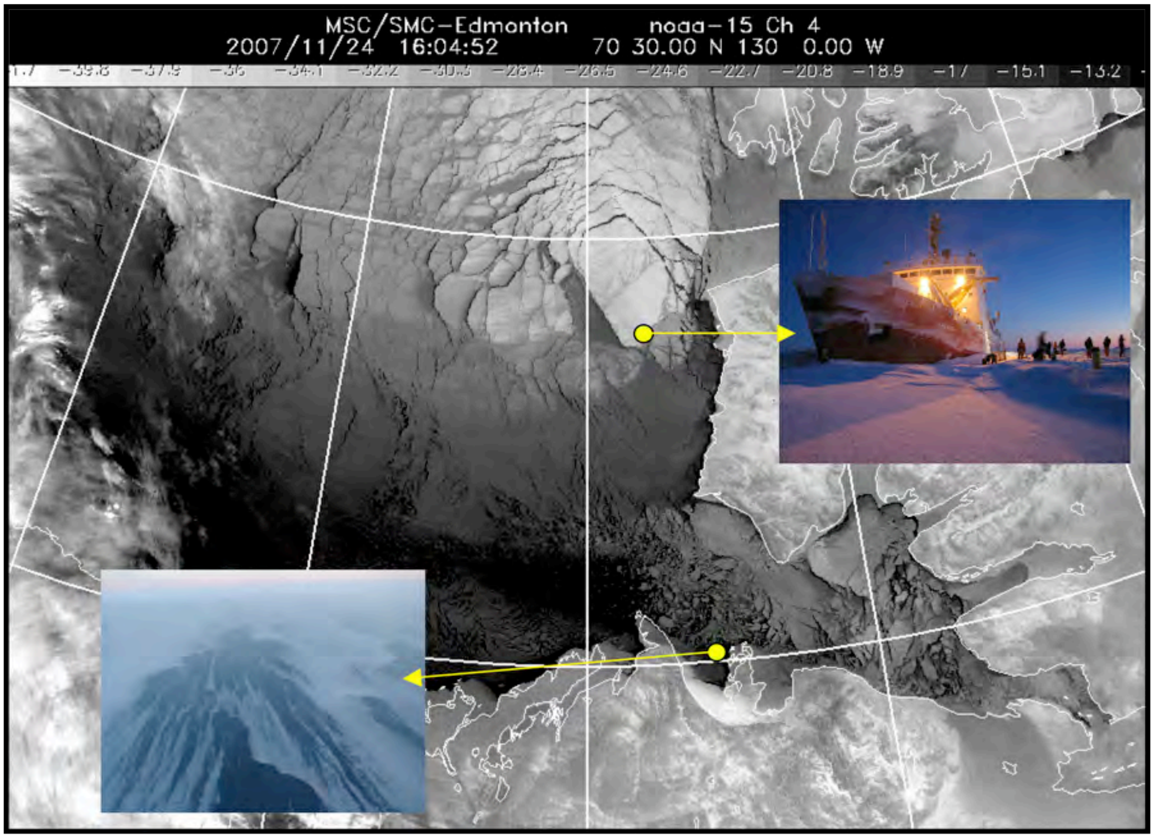

Figure 2. AVHRR near infrared image of the southern Beaufort Sea and Amundsen Gulf showing the NGCC Amundsen sampling mulitiyear sea ice and open water conditions in late November, 2007.

Sea Ice Outlook based on Statistics of Observed Ice Extent

May 2008 by Cecilia Bitz

1. What will the sea ice extent for the Arctic as a whole be at the 2008 minimum?

   5.30 million square kilometers

2. Short basis for prediction

   The 29 year observational record of September sea ice extent has zero autocorrelation, zero skew, and zero correlation with the May extent. These statics are in general agreement with much longer records that are available from the Community Climate System Model version 3, CCSM3. Therefore, I have extrapolated the trend line for September sea ice extent to 2008.

3. Longer basis for prediction

   With no statistically significant correlations or skew in the observations (Fig. 1a) the conservative estimate for the future is on the trend line. An extrapolation of the trend line (Fig. 1b) to year 2008 gives 5.30 million square kilometers. Furthermore this May, the sea ice extent is very near the trend line for May. There is a significant correlation between June and September sea ice extent, so next month a skillful prediction will be possible based on statistics alone.

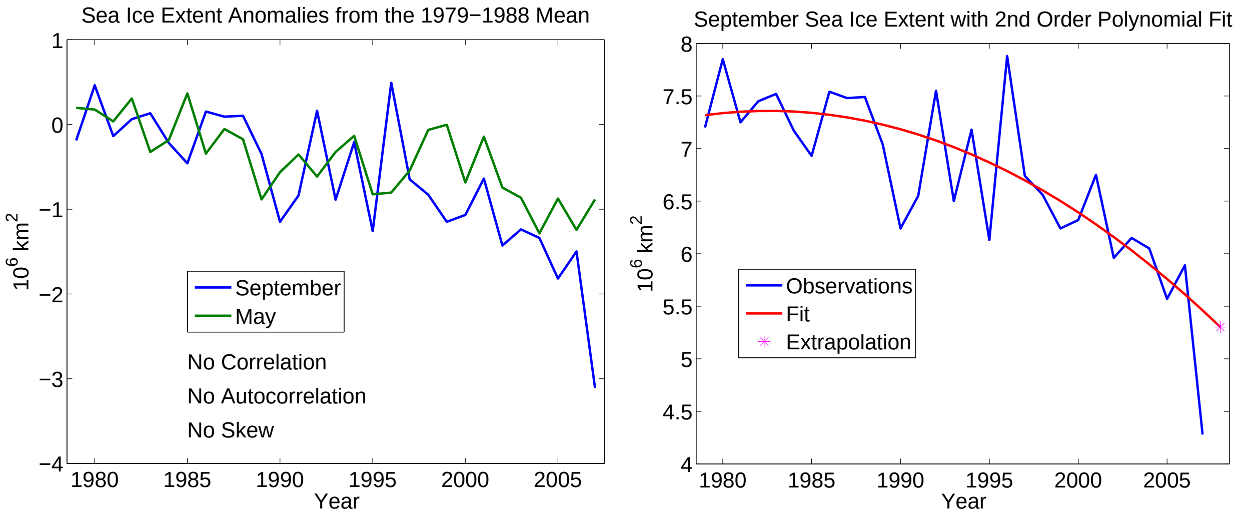

Figure 1. *Left panel:* The twenty-nine year observational record of September sea ice extent has zero autocorrelation, zero skew, and zero correlation with the May extent. All timeseries are detrended BEFORE correlation and skew are estimated. *Right panel:* Observed September sea ice extent and trend line with extrapolation to 2008. The trend line is given by a 2nd-order polynomial fit to the record in years 1979-2007.

The observational results were compared with a statistical analysis of an ensemble of 20th and 21st century simulations and long control runs from CCSM3. With ensembles and multi-century control runs giving far more degrees of freedom, it is clear that CCSM3 does have a weak but significant autocorrelation in September ice extent. However, the autocorrelation is so weak that it did not compell me to modify my prediction based solely on the observations. In contrast, there is more considerable lagged correlation between thickness and extent, as expected owing to the much much greater memory in thickness.

Figure 2 shows that years with September sea ice loss comparable to the 2007 observed loss are very rare.

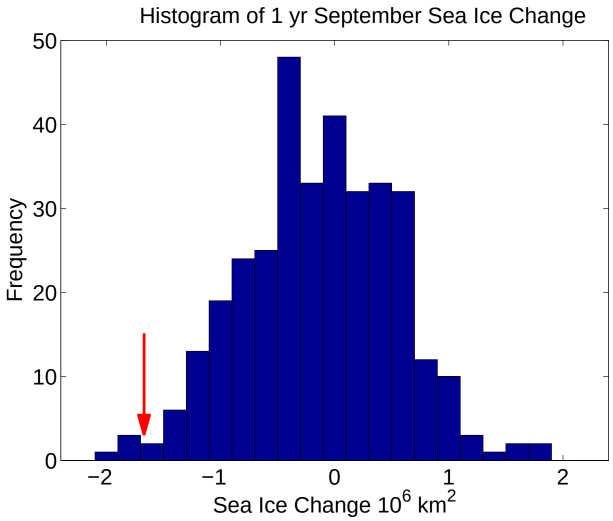

Figure 2. Histogram of September-to-September sea ice extent change in the first half of the 21st century in seven ensemble members from CCSM3 SRES A1B scenario (350 yrs total). This model has a very rapid loss of September sea ice extent, essentially loosing 30–40% of the sea ice extent in one decade (2030-2040). Yet a 1 yr drop as large as observed in 2007 (red arrow) only occurs about 1% of the time.

4. Additional information needed

Sea ice thickness can be used to predict sea ice extent with some skill according to CCSM, so real-time basin-wide measurements of sea ice thickness are quite likely to be of value for prediction.

Klaus Dethloff, Wolfgang Dorn, Annette Rinke

Alfred Wegener Institute for Polar and Marine Research, research Unit Potsdam

Since the sea-ice retreat in summer 2007 reached far into the Arctic basin and was exceptional in terms of the usual sea-ice variability, one might argue that the Arctic sea ice is no longer in a metastable state and has already passed a "tipping point" toward thinner and less extensive sea-ice cover as discussed by Lindsay and Zhang (2005) . The thinning of the sea-ice cover is a major reason for its increased response to variations in the atmospheric and oceanic circulations. On the one hand, the ice-thinning was initiated by a strong decrease of thick multi-year ice during 1989-1990 when the Arctic Oscillation was in an extreme high-index phase and internal thermodynamic changes related to the positive ice-albedo feedback, not external forcing, have dominated the ice-thinning process afterwards. This means that greenhouse gas induced warming of the Arctic have not caused the ice-thinning but might only have contributed to maintain the trend.

On the other hand, the ice-thinning on its own does not represent a sufficient condition for the occurrence of extremely low sea-ice extent at the end of the summer, or even for its total disappearance. Model results by Dorn et al. (2007) show that an Arctic climate state without summer sea ice is not stable under forcing conditions for the 1990s. A model simulation without sea ice at the end of the summer 1989 generates an ice thickness distribution and ice extent at the end of the 1990s which is quite similar to a corresponding simulation with very thick ice cover in 1989 (see Dorn et al., 2007, their Figures 3 and 8). Furthermore, recent model predictions of Arctic sea ice for the spring and summer of 2008 by Zhang et al. (2008) show that another record low of summer sea ice can only be expected under similar atmospheric forcing conditions as in 2007. Forcing conditions as in the years from 2001 to 2006 will not result in further decline of the summer ice extent (see Zhang et al., 2008, their Figure 3). In summary, forcing conditions as in the recent past, except for 2007, are not sufficient for another record low of summer sea ice, in spite of the dramatic thinning of the ice cover in recent years.

Observational data show that the atmospheric circulation in summer 2007 was characterized by the typical, but exceptionally strong high pressure area over the Beaufort Sea (see Kay et al., 2008, their Figure 4). In addition, exceptionally low pressure occurred over Siberia, which led to advection of warm air from the North Pacific region into the inner Arctic and favored a wind-forced ice drift toward Greenland and out of the Arctic through Fram Strait.

Furthermore, the anticyclonic atmospheric circulation in summer 2007 was accompanied by anomalously low cloudiness (approximately 20% below average) which led to a considerable increase in downwelling shortwave radiation (Kay et al., 2008). This should have led to enhanced surface ice melt and is consistent with warmer sea surface temperatures, which in turn enhanced lateral and basal ice melt as discussed by Kay et al. (2008).

In principle, the recurrence of such anomalous conditions as in 2007 is possible and would reinforce the ice loss, maybe even induce abrupt reductions as seen in climate model simulations by Holland et al. (2006). However, the persistence of all these anomalies that appeared in 2007 is rather unlikely, since they are at least partly not a result of a continuous climate change of anthropogenic origin. It is more likely that the coincidence of several favorable factors for low sea-ice extent is responsible for this extreme event.

Some of them are likely to persist or still strengthen in the near future and will preserve the vulnerability of the Arctic sea-ice cover to further decline, but the important role of internal climate variability in the recent decline makes a prediction for the sea-ice minimum in summer 2008 rather difficult if not impossible. A temporal return to previous conditions or stabilization at the current level can not be excluded just as further decline, depending on the atmospheric conditions in summer 2008, which unfortunately we are not able to predict.

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Zhang J, Steele M, Lindsay R, Schweiger A, Morison J. Ensemble 1-Year predictions of Arctic sea ice for the spring and summer of 2008. Geophys Res Lett. 2008; 35: L08502.

Kay JE, L'Ecuyer T, Gettelman A, Stephens G, O'Dell C. The contribution of cloud and radiation anomalies to the 2007 Arctic sea ice extent minimum. Geophys Res Lett. 35; 2008: L08503.

Holland MM, Bitz CM, Tremblay B. Future abrupt reductions in the summer Arctic sea ice. Geophys Res Lett. 2006; 33: L23503.

Sea Ice Outlook 2008: A regional perspective on ice evolution in the Pacific Arctic sector [Eicken]

Data

Ice extent:

- Passive microwave data (SSM/I) distributed by the National Snow and Ice Data Center (NSIDC) indicate well above-normal ice extent in the Bering Sea for spring 2008 into mid-May (see Fig. 1). In late May, rapid ice retreat, aided by comparatively thin ice (see below) brought ice extent into the normal range, with significant amounts of open water in the southern Chukchi and Beaufort Sea due to retreat of thin ice.

Ice thickness and ice characteristics:

- *Eastern Chukchi/Western Beaufort Sea:* Ice thickness surveys with an airborne electromagnetic induction instrument indicate modal total ice thicknesses (snow & ice) of 0.4 m (primary mode), 1.6 m (secondary mode) and 3.3 m (tertiary mode) along 272 km of transects north of Barrow, Alaska (Fig. 1). Radar satellite imagery indicates that multiyear ice was advected from the Canada Basin and high Arctic southwards and now reaches to within 120 and 250 km of the coast of the Beaufort and eastern Chukchi Seas (with the shortest distance at Barrow). Ground-based measurements and ice coring indicate that multiyear ice north of Barrow is between 5 and 7 years of age and of mean thickness of between 3 and 3.5 m for level, undeformed ice. In the western Beaufort and eastern Chukchi Sea, thin (<0.5 m) first-year ice dominated as a result of ice formation in coastal polynyas. First-year ice north of Barrow was highly deformed through ridging and rafting. Data from 2007 available at penguin.sfos.uaf.edu with 2008 data posted within the next month after quality control.

Coastal sea ice:

- At *Wales*, in Bering Strait, level shorefast ice thicknesses were 1.14 m in the first week of May. These values are comparable to the previous ice season's thicknesses, despite late ice formation in the fall/winter. A local ice observer reported above-normal open water in the months of April and May with little access to offshore drift ice for marine mammals hunts. The shorefast ice was considered somewhat unsafe near town with a trail for boat access established further to the North of town.
- At *Barrow*, level shorefast ice thicknesses in early April were at the low end of the normal range (1.3 to 1.4 m), despite very late landfast ice formation in the fall (last week of December). Ice growth and snow depth monitoring indicate that recovery from late ice formation was aided by well-below normal snow depth (<0.1 m) into early April, with substantial snowfall in mid-/late April. Local ice observers and thickness surveys indicate a near-complete lack of grounded ridges and absence of multiyear ice, suggesting an inherently unstable landfast ice cover. Data available at www.gi.alaska.edu/BRWICE.

Outlook and potential impacts

- Break-up and onset of seasonal ice retreat: Thin ice in the Bering and southern Chukchi Sea (and by inference from satellite data in the southeastern Beaufort Sea) are likely to result in above-average rates of initial ice retreat. Lack of multiyear ice and grounded ridges render landfast ice in Bering Strait region and eastern Chukchi Sea potentially unstable and promote rapid deterioration and break-up. At Pt. Hope, shorefast ice break-out event in May required boat rescue of marine mammal hunters. At Barrow, unstable ice conditions have resulted in early dismantling of hunting camps on shorefast sea ice.
- Summer conditions: Predominantly thin ice along southeastern Chukchi and western Beaufort Sea is likely to retreat rapidly, impacting marine mammals which may be deprived of feeding and resting platforms on inner shelf, in turn affecting subsistence hunters from coastal communities. Thin ice will also promote solar heating of inshelf waters, potentially accelerating ice retreat. Thick, old multiyear ice is within 120 to 250 km of the Chukchi and Beaufort coast and likely to survive well into the melt season. This presents a potential hazard for coastal shipping and offshore exploration with potential advection of ice during periods of winds from northern sector. At the same time, if advected further south, multiyear ice may serve as important substrate for ice-associated fauna.

Information needed to improve outlook

- At the regional level, atmospheric circulation and surface winds are key drivers of seasonal evolution of the ice pack, mid-range forecasts of prevailing wind patterns will improve assessments of potential for multiyear ice incursions and solar heating of surface waters.

Submission information

Submitted by Hajo Eicken (hajo.eicken@gi.alaska.edu) on behalf of Seasonal Ice Zone Observing Network (SIZONet) project with support from the National Science Foundation’s Arctic Observing Network Program and additional support from the Alaska Ocean Observing System.

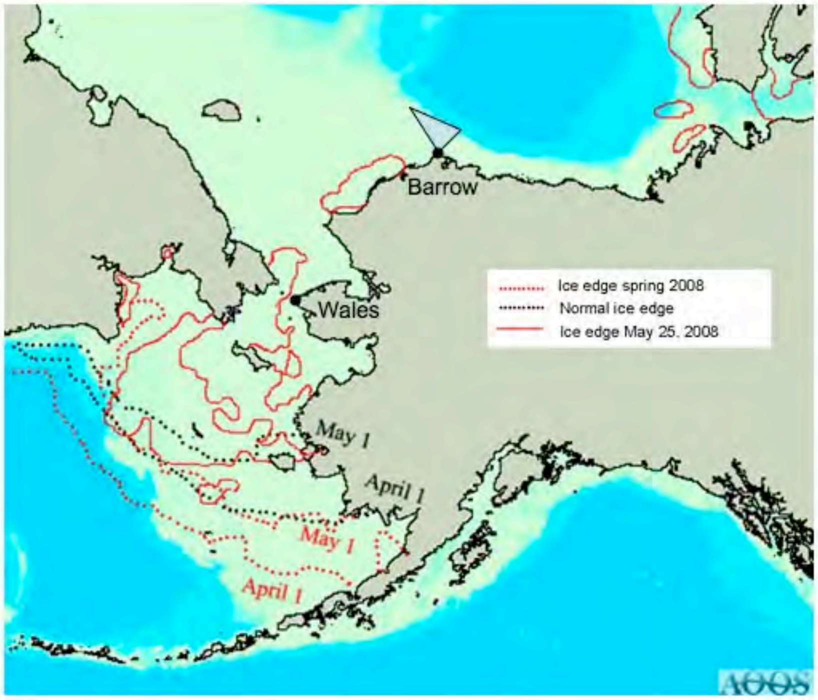

Fig. 1: Ice extent derived from passive microwave satellite data (SSM/I, data provided by NSIDC, nsidc.org) for Pacific Arctic sector. Shown are observed ice edges for April and May along with "normal" ice edges (median positions) from 1979 to 2007. The triangle and dots denote locations of airborne and coastal station measurements.

Initial ice thickness and ice type in the region between Ellesmere Island and the North Pole at the outset of the 2008 summer

Christian Haas, University of Alberta, Edmonton, Canada

Data

Ice type

The developmental history of the ice can be obtained from satellite radar data as well as from buoy drift measurements. Backscatter maps obtained by QuickScat show a continued decrease of the fraction of old ice in the Arctic Ocean, and in the region of the North Pole a replacement of second-year ice by first-year ice, a major regime shift which had occurred during the summer of 2007 (Figure 1).

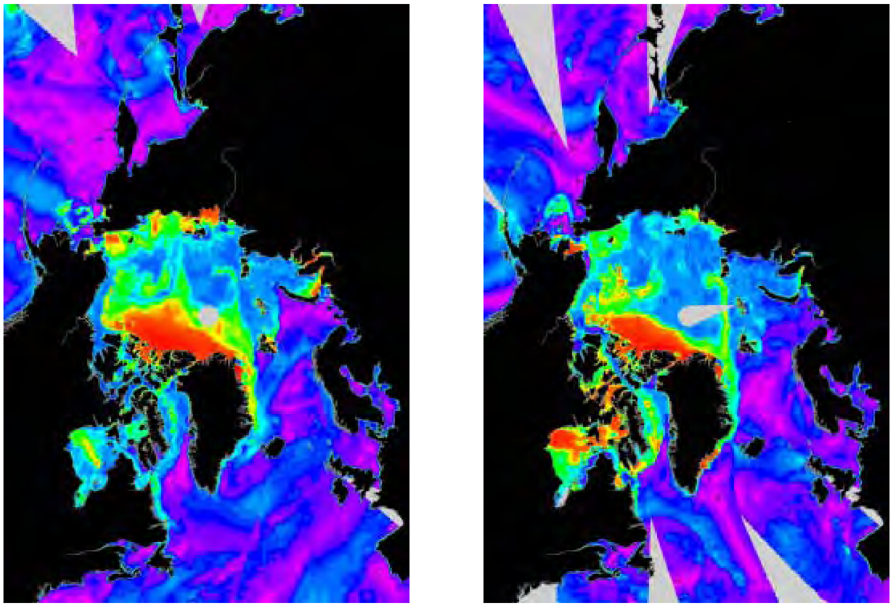

Figure 1: Quickscat HH backscatter maps of the Arctic provided by Leif Toudal (at www.seaice.dk), May 23 2007 (left) and 2008 (right). Red to green indicates high backscatter and multiyear ice in the Arctic Ocean proper, blue and purple indicates low backscatter and first-year ice in the Arctic Ocean proper (Haas & Eicken, 2001).

Ice thickness

A 3.5 km long ground-based EM thickness profile was obtained on April 12 2008 close to the North Pole at 88º20’N, 15ºE (Figure 2). Its modal and mean snow-plus-ice thickness was 2.08±0.58 and 1.95 m. Mean snow thickness was 0.14±0.10 m, with a mode of 0.1 m. This can be compared with a similar, 1.7 km long profile obtained at 89º30’N, 19ºW on April 22, 2007, which resulted in a mean and modal thickness of 3.31 ± 1.51 m and 2.35 m. Note that there was a secondary mode at 1.65 m representing first-year ice. Overall, the ice was considerably thicker in April 2007 than in April 2008. The thinner ice in 2008 can be mainly explained by the absence of second-year ice. However, note that the first-year ice snow-plus-ice thickness in April 2008 was 0.30 m thicker than in 2007, despite a thinner snow cover. This is remarkable, as the delayed ice formation after the record minimum ice summer in 2007 would have left much heat in the mixed layer, which could have retarded first-year ice growth.

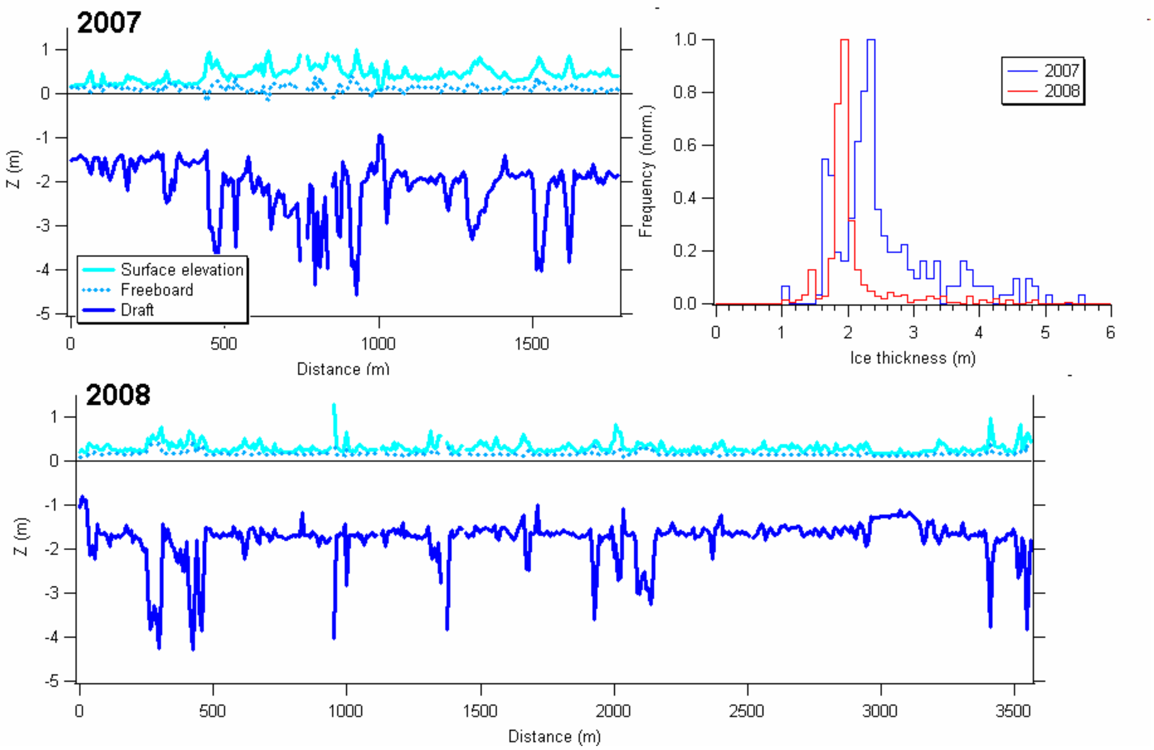

Figure 2: Ice thickness profiles and distributions close to the North Pole, April 2007 and April 2008.

Airborne EM surveys north of Ellesmere Island showed a significantly thinner ice in April 2008 than in previous years. Preliminary results indicate that there was a strong thickness gradient with modal thicknesses decreasing from > 4 m at 82.5°N, to 2.5 m and 84°N. This thinning is probably a result of the presence of much thinner ice in the region due to the narrowing of the older ice area between Ellesmere Island and the North Pole (cf. Figure 1).

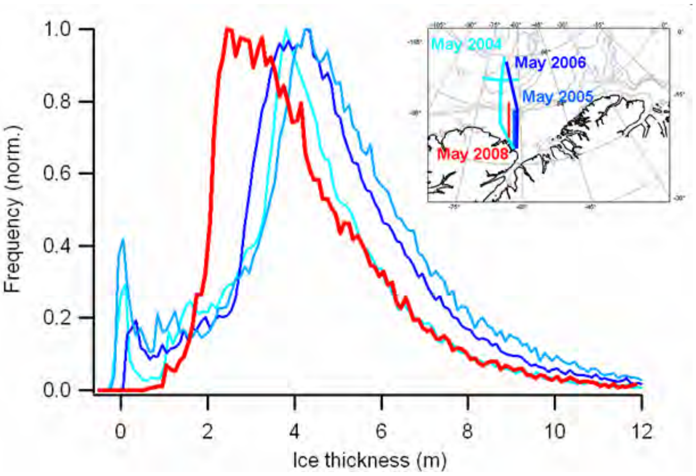

Figure 3: Ice thickness distributions between Ellesmere Island and 86°N in May 2004, 2005, 2006, and 2008, observed by airborne EM profiling. Note significantly reduced ice thickness in 2008.

Outlook

Typical summer melt rates in the high Arctic Ocean range between 0.3 and 0.8 m, depending on oceanic and atmospheric heat fluxes. Therefore, it is unlikely that any of the surveyed ice will completely melt during the 2008 summer. However, this requires that the sampled ice fields remain in the Central Arctic Ocean.

Therefore, it will depend on the actual ice drift in the coming months if the North Pole will become ice free of not. Summer ice conditions in the high Arctic Ocean depend strongly on the atmospheric circulation regime during the months June to August, which is on average characterized by low sea level pressure over the Arctic with a reversal of the mean annual drift. This was demonstrated by Haas & Eicken (2001) for the 1995/1996 summers, when a year with minimum ice extent and thickness (1995) was followed a year with maximum ice extent and absent melt ponds (1996). 1996 was characterized by low sea level pressure over the central Arctic Ocean, which led to ice divergence into the marginal seas, and prevented the advection of warm air from southern regions.

Overal reductions of MYI thickness and area point to a likelihood that the MYI area will further decrease during the summer of 2008.

Additional data requirements

A more sophisticated outlook would require improved estimates of the development of atmospheric circulation patterns during June, July, and August. More extensive ice thickness observations would allow judging the vulnerability of ice in larger and more widespread regions to disappearing completely by melting.

Acknowledgement

Stefan Hendricks, Jean-Louis Etienne, and Emmanuelle Périé contributed to the data gathering in 2008. Leif Toudal provided QuickScat backscatter maps.

Reference

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Sea Ice Assessment within the Northwest Passage for 2008

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Outlook for 2008:

Based on multi-year sea ice (MYI) observations from the Canadian Ice Service since 1970, the current sea ice conditions within Western Parry Channel region of the Northwest Passage (NWP) do not seem to favor its clearing for 2008.

Basis for Outlook:

Figure 1 shows the MYI conditions (pre-breakup) within the Western Parry Channel region of the NWP on May 19, 2008. The Western Parry Channel region of the NWP is part of a "drain-trap" mechanism operating in the western Canadian Arctic Archipelago that has historically been responsible for maintaining heavy MYI conditions within this region of the Northwest Passage. Specifically, the seasonal first-year ice regions melt earlier than the MYI regions and the currents and wind then slowly transport MYI southeastward from the Western Parry Channel. As a result, whenever MYI is removed it always recovers as witnessed by the stable time series of MYI within the region from 1970-2007 (Figure 2). If the low MYI conditions of 2006 and 2007 are a part of this process then we should expect MYI to begin recovery in 2008. Breakup in this region typically begins in late July, providing a short two-month window (August and September) when this region of the NWP will be susceptible to MYI import from the Queen Elizabeth Islands and/or the M'Clure Strait. The historically heavy MYI conditions within this region of the NWP have also been the result of considerable *in situ* MYI formation (Figure 3). This has not occurred since 2004 (Figure 3) and has been linked to longer melt seasons (2005-2007). Should 2008 be a significantly long melt season this will relax ice conditions within the NWP provided MYI dynamic import does not compensate for less MYI grown *in situ*.

Reference:

Howell, S. E. L., A. Tivy, J. J. Yackel, and S. McCourt (2008). Multi-Year Sea Ice Conditions in the Western Canadian Arctic Archipelago Region of the Northwest Passage: 1968-2006. *Atmosphere-Ocean*. Vol. 46, No. 2, 229-242. doi:10.3137/ao.460203

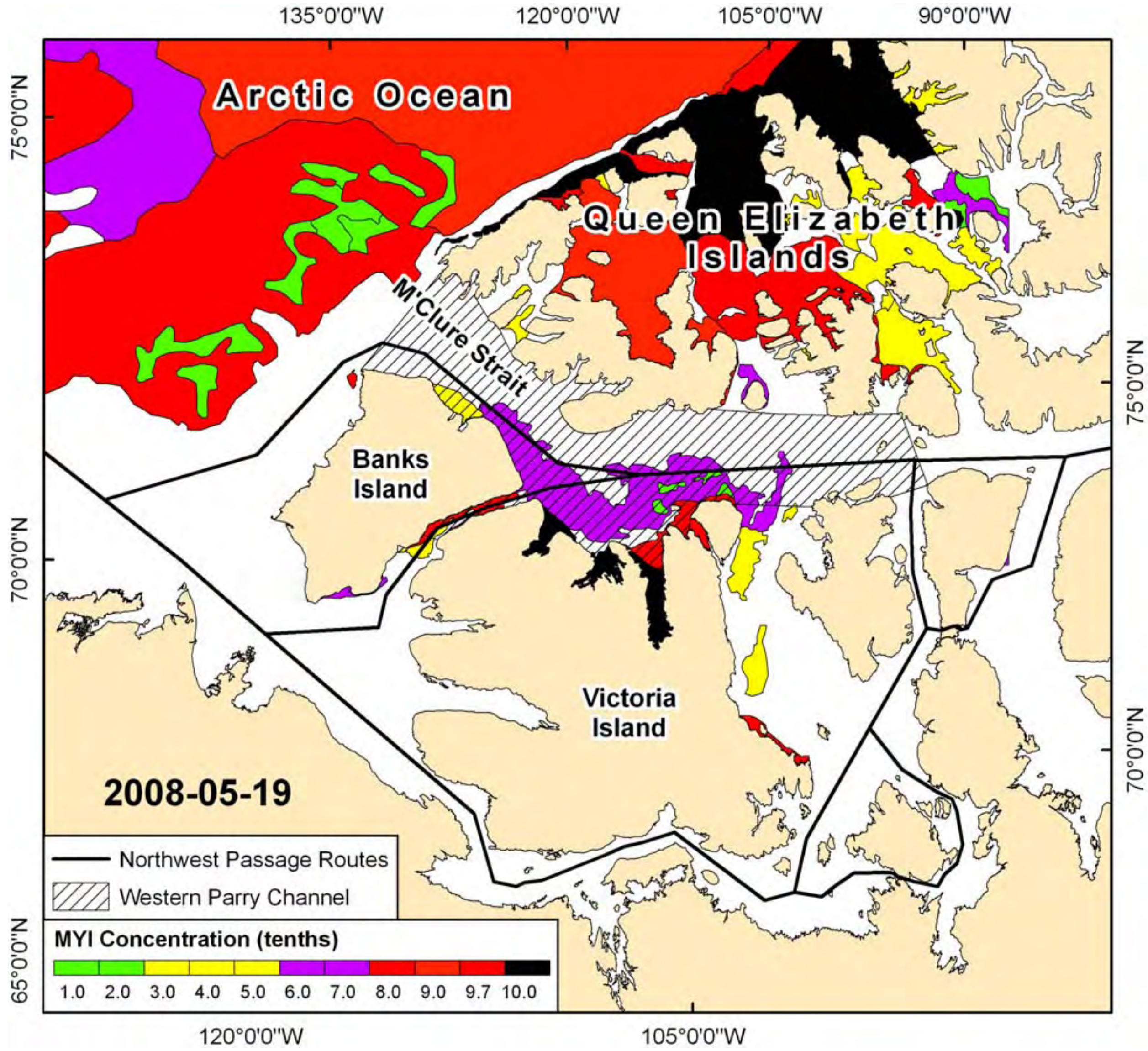

Figure 1. Multi-year ice conditions in the western Canadian Arctic Archipelago on May 19, 2008. The location of the Northwest Passage route through the Western Parry Channel is also shown.

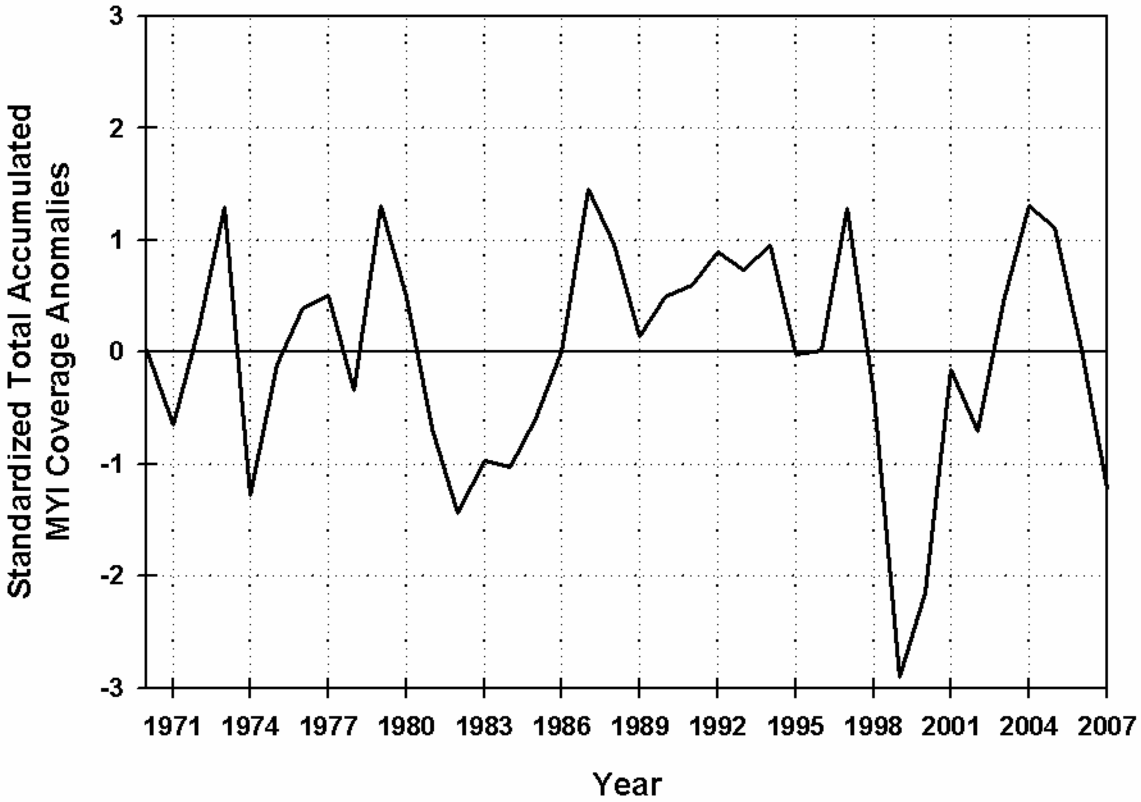

Figure 2. Standardized anomalies of the Total Accumulated Multi-Year Ice Coverage (km^2) from June 25th to October 15th in the Western Parry Channel region of the Northwest Passage, 1970 to 2007.

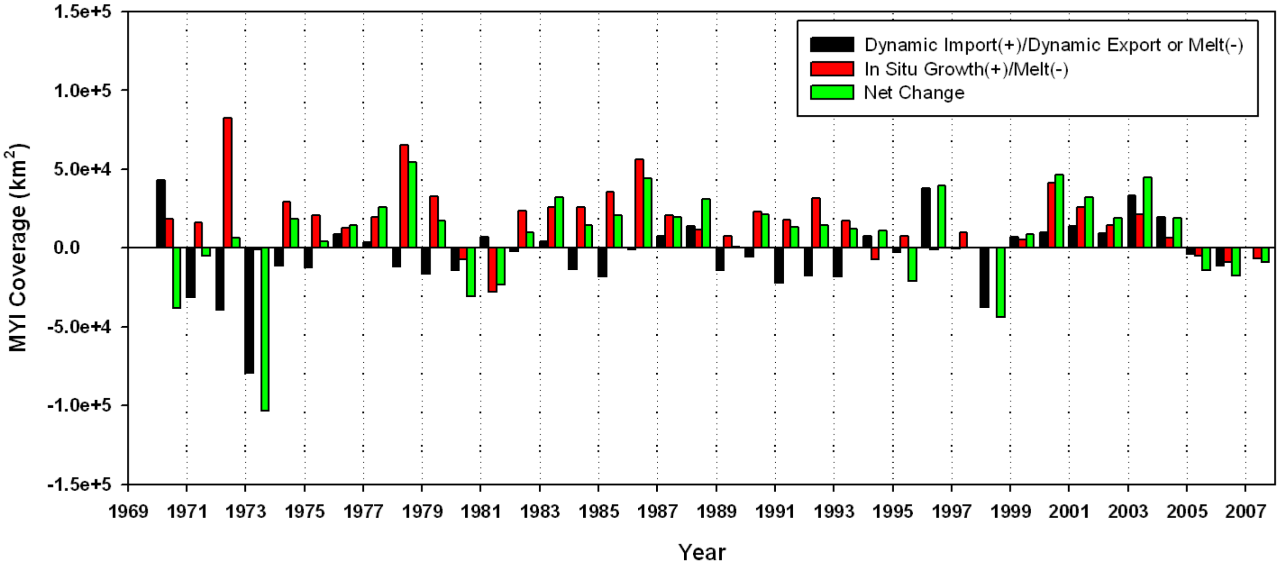

Figure 3. Time series of dynamic and thermodynamic multi-year ice contributions within the Western Parry Channel region of the Northwest Passage from 1970 to 2007.

A neural network based prediction of the September sea ice extent using winter air temperature and the extent of the previous year

Lars Kaleschke, Institute for Marine Research, University of Hamburg, 23.5.2008

A neural network approach was used to predict the September sea ice extent by the use of two state variables, the surface air temperature of the northern hemisphere from NCEP reanalysis and the September sea ice extent of the previous year. The time series of Cavalieri et al. (2003) and the Sea Ice Index (NSIDC) was merged to a 36 years monthly dataset starting in 1972.
A feed forward neural network with two input neurons, a hidden layer with two neurons and one output neuron was used with a random initialization of the weights (ffnet by Marek Wojciechowski). Two different runs with five realizations were performed. In the testing run the year to be predicted was left out in the training data. In the next run the years to be predicted were included in the training data except for (of course) 2008. The results are shown in Figure 1 and 2. The prediction for September 2008 is **3.6 Mio km²**.

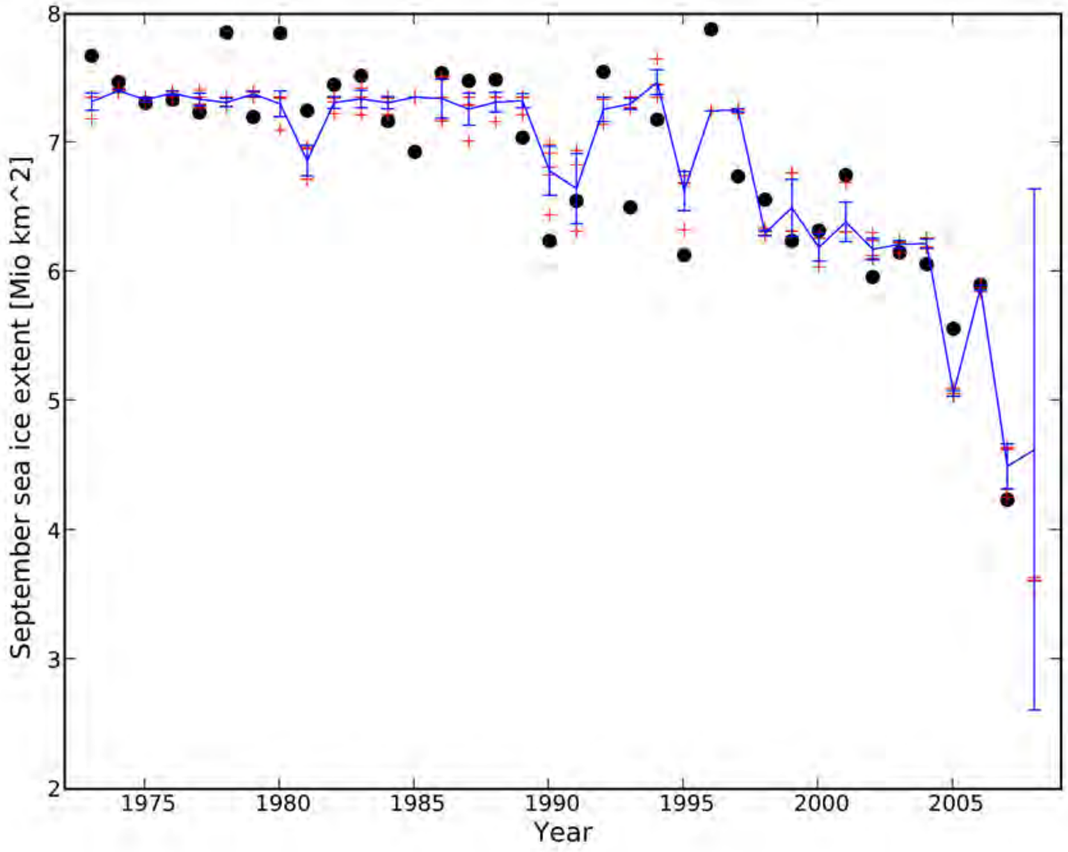

Figure 1: Neural network based prediction of the September sea ice extent. Black dots are from satellite observations. Red crosses mark five different realizations of the neural net predictor. The blue error bars indicate their mean and standard deviation. The average correlation of all individual realizations of the prediction with the true ice extent is 0.9

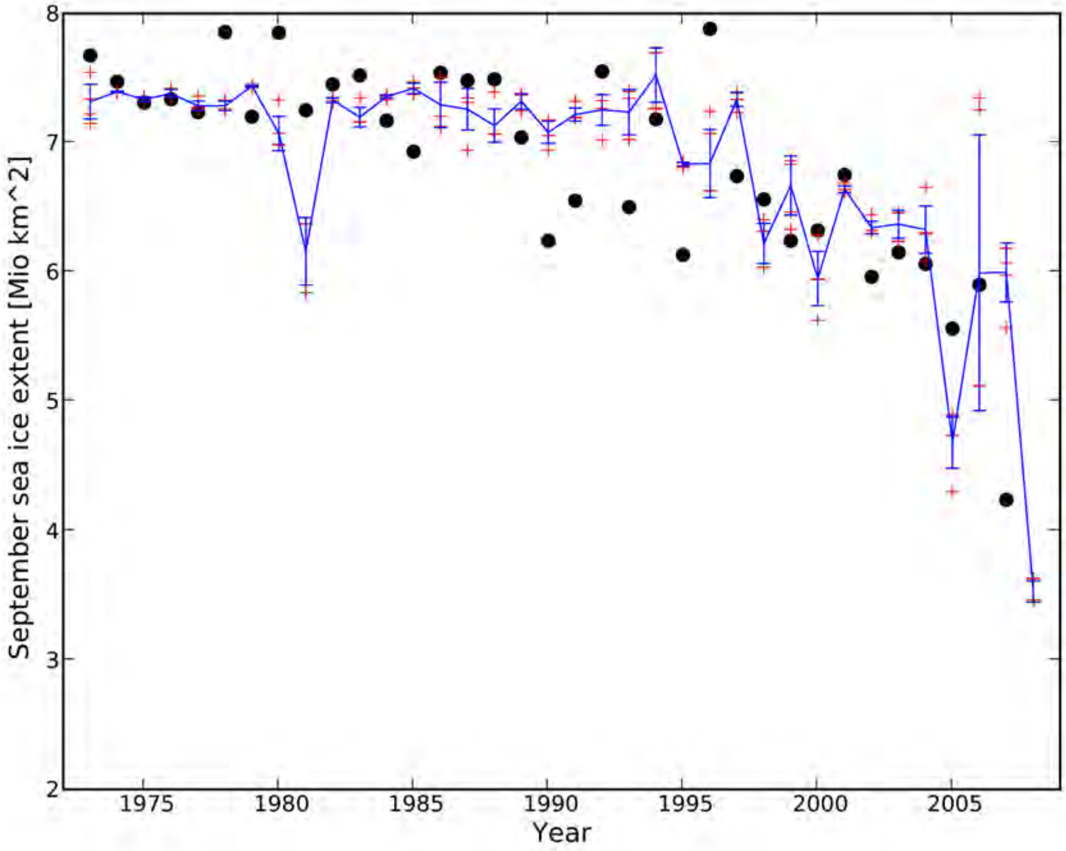

Figure 2: Same as Figure 1 but with the individual years to be predicted left out in the training dataset. The average correlation of all individual realizations of the prediction with the true ice extent is 0.7

2008 September sea ice outlook – R. Kwok

1. Sea ice extent of the Arctic at summer minimum: 5×10^6 km^2

2. Basis of assessment:

Condition of the seasonal ice cover: even though the seasonal ice cover was formed later in the fall of 2007, the mean thickness of the FY ice cover at the end of March seems comparable to that of the previous two seasons because of lower snow accumulation and thus faster growth i.e., higher ice production. The higher latitude seasonal ice cover is also thicker and regions with typically shorter melt seasons can be expected to have a better chance of surviving the summer. This is based on ICESat estimates.

Condition of the old ice cover: the MY ice coverage is at a record low (~2×10^6 km^2) near the end of May, but because of the location of the ice cover (north of Greenland and Ellesmere) it is expected that additional losses of MY will be due primarily to export rather than melt. The average thickness of the MY ice cover is only slightly lower than the thickness of the previous winter. Again, this is based on a preliminary analysis of ICESat sea ice freeboard and QuikSCAT MY coverage.

Freezing degree-days (FDD): The Oct-May FDD (from NCEP/NCAR fields) for the entire Arctic Ocean is actually comparable to the winter of 2007.

Assumptions about the summer: If the anomalous circulation pattern of the 2007 summer were not repeated (those patterns caused a combination of: a) advection of warm air from the south; b) advection of sea ice from the Pacific to the Atlantic sectors and increased outflow at the Fram Strait and other passages; and, c) perhaps a decrease in cloudiness and thus increased insolation at the surface) then we expect a net replenishment of the ice cover this summer.

3. Supporting data

Our outlook is based ot the mean summer behavior of the ice extent of the past five years 2002-2007 (see figures) weighted by the conditions of 2007.

Fig. 1 Outlook of the summer ice coverage within the Arctic Ocean (boundaries at the Fram Str, Svalbard -Franz Jozef Land, Franz Jozef Land-Severnaya Zemlya)- it does not include the sea ice coverage outside of the Arctic Basin. Dashed line shows the Jun-Sep ice extent; error bars show the variability of the ice extent between 2002-2007. The large red dot is our projection of the 2008 minimum ice extent after adding in the ice coverage outside the Arctic Ocean.

Fig. 2 Behavior of 2007 summer ice extent within the Arctic bounds described in Fig. 1.

4. Additional data

There is considerable deformation of the surviving ice cover at the end of the summer and early fall when the ice is thin and when ice compactness is low. There needs to be a better quantification of ice dynamics on the ice thickness distribution during this time as it affects the consistency of multiyear ice coverage estimates at summer minimum and during winter.

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Kwok, R. (2007), Near zero replenishment of the Arctic multiyear sea ice cover at the end of 2005 summer, Geophys. Res. Lett., 34, L05501, doi:10.1029/ 2006GL028737.

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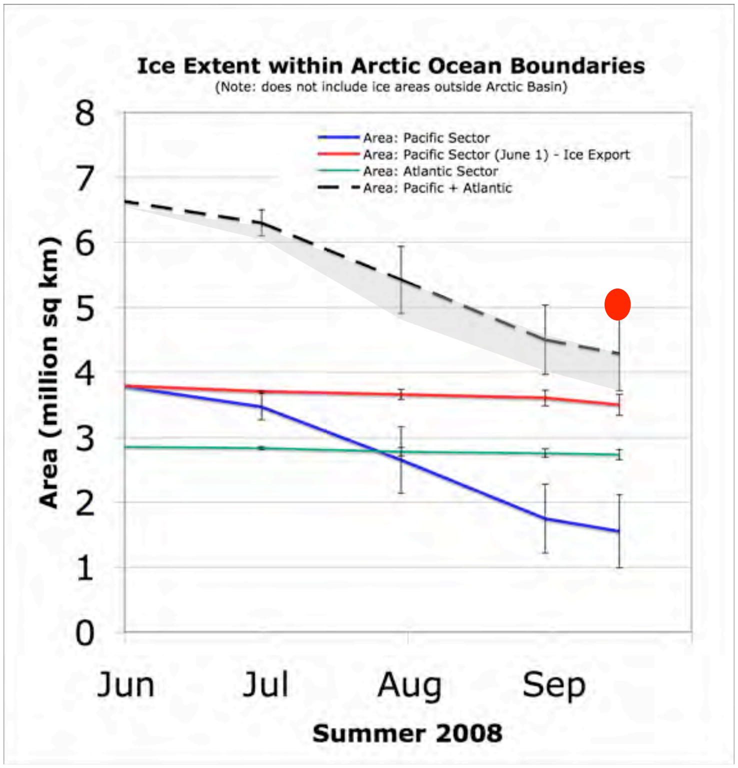
Ice Extent within Arctic Ocean Boundaries
(Note: does not include ice areas outside Arctic Basin)
Area: Pacific Sector
Area: Pacific Sector (June 1) - Ice Export
Area: Atlantic Sector
Area: Pacific + Atlantic
Area (million sq km)
8
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Jun
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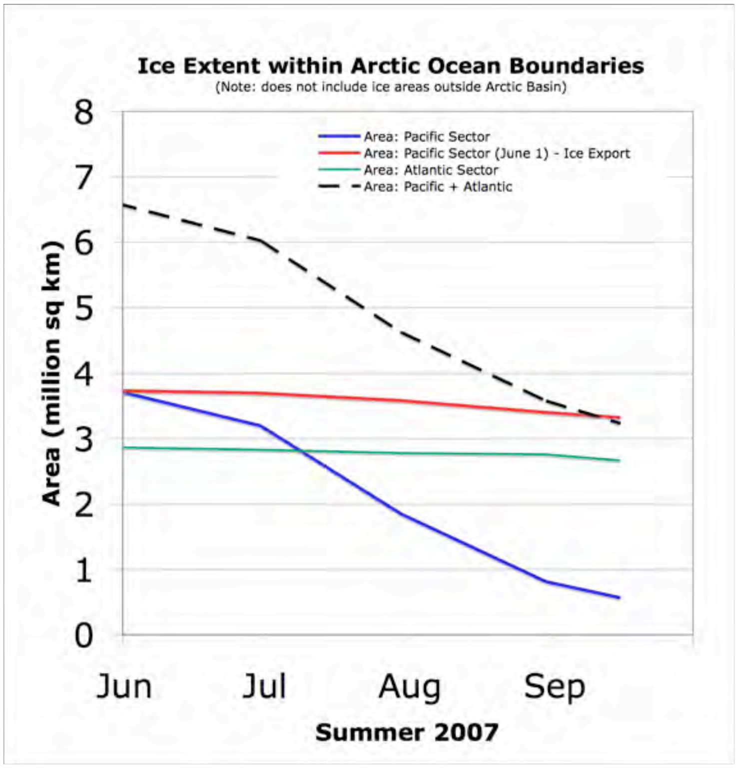
Summer 2008

Fig. 1


Ice Extent within Arctic Ocean Boundaries
(Note: does not include ice areas outside Arctic Basin)
Area: Pacific Sector
Area: Pacific Sector (June 1) - Ice Export
Area: Atlantic Sector
Area: Pacific + Atlantic
Area (million sq km)
8
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Summer 2007

Fig. 2

Ron Lindsay

Ice Forecast for September 2008

Our forecast for the September mean ice extent is 4.5 ± 0.2 million sq km. This is just a little more than the record minimum last year, but still below the trend line. The prediction is made from an ice/ocean model estimate of the state of the system at the end of April 2008. The model field in April that is best correlated with the pan-Arctic ice extent in September over the last 20 years is the area of ice and water less than 2 m thick (what we call the G2 field). The predicted ice extent is 4.5 ± 0.3 million sq km. This field is correlated at a level of R2=0.86. The field of G2 for 2008 would predict a very low ice extent in September but the prediction is not as low as the prediction for 2007 and is much above the observed extent for 2007. The simulated G2 field shows very little ice 2 m thick in the Chukchi Sea, but near normal conditions elsewhere.

The method is based on a retrospective analysis of the state of the ice and ocean system created by a high resolution coupled ice/ocean model. The model uses the observed air temperature, wind, clouds, and precipitation to estimate maps of the ice motion, ice thickness distribution, and ocean temperatures and currents for past years, up to and including the most recent month. Statistical relationships between the model parameters in March (or any other month) and the ice extent in September are found from past years using a method developed by Dr. Drobot. This relationship is then used with the current March model output to predict the September ice extent. The method may be used to predict either the pan-Arctic ice extent or the ice extent in particular regions. It depends fundamentally on a stable relationship between the various components of the system, such as ice thickness in April compared to the ice extent in September.

Reference:
Lindsay, R. W., J. Zhang, A. J. Schweiger, and M. A. Steele, 2008: Seasonal predictions of ice extent in the Arctic Ocean, J. Geophys. Res., 113, C02023, doi:10.1029/2007JC004259.

Link:
http://psc.apl.washington.edu/lindsay/pdf_files/Lindsay_etal_JGR2008_seasonal_predictions.pdf

Also, see the web page at
http://psc.apl.washington.edu/lindsay/Prediction/seasonal%20ice%20prediction.html

The method seemed to work fairly well using historical data. However the summer of 2007 showed a tremendous loss of sea ice and the predictions were way too conservative. This has led me to think that the statistical relationships between the ice extent and the state of the ice and ocean are changing rapidly and the past relationships cannot be a reliable guide to the future.

Concerns about publicizing forecasts of ice conditions

Can we make accurate forecasts of the ice conditions months in advance? This is a challenging and interesting scientific problem, and I, among others, have certainly had a go at it.

But if we as a community want to publicize predictions it is perhaps wise to consider if it is in either the publics or our own best interest. We could do ourselves a disservice if the basis for the forecasts and the expected errors (and how they are calculated) are not clearly stated and if it appears like we, as a community, have not understood the nature of the predictability problem as it applies to sea ice.

What is to be forecast and why? Minimum total ice extent, September total ice extent, regional ice extents? In fact regional extents are probably the only forecasts that could make a difference in somebodies plans. Basin-wide projections make little difference to anybody, so maybe they are harmless. Error estimates for the forecasts are essential. Do the error estimates for the forecast depend on an assumption of stationary statistics? Is this a valid assumption? Is the error bar a 1-sigma (one standard deviation) of the expected error or something else? What constitutes a skillful forecast? Is it compared to persistence (the previous year) or to the trend? Or maybe a blend? A good or bad forecast for this particular year may not indicate that a method is good or bad…it takes a number of years of making forecasts (not withheld-data validations) with the same method to properly validate or invalidate a method.

A better service to the public, and probably for the science, may be to clearly outline the issues of predictability in the Arctic: initial conditions vs memory vs weather. How far in advance can skillful forecasts be made? How are the skills seasonally dependent?

Prepared by Sheldon Drobot, James Maslanik and Charles Fowler
27 May 2008
University of Colorado
Contact: James.Maslanik@colorado.edu
303-492-8974

1. What will the sea ice extent for the Arctic as a whole be at the September 2008 minimum? Quantitative estimates in square kilometers are preferred (the value for 2007 was 4.3 million square kilometers), but qualitative estimates are also accepted.

We tend to provide probabilistic forecasts only, and we're really not keen on giving a single number. This is because a single number can be misleading to the public, as it implies a sense of accuracy that we do not have (may never have?) for a seasonal forecast. Also, the AMS and NOAA are spearheading a new effort to push probabilistic forecasts. So, on our web page (http://ccar.colorado.edu/~arifs) we just talk about probabilities, and based on April sea ice, temperature, and AO data, we're forecasting a 59% chance of a new record. However, to fully answer the question, our "most likely" model solution is 3.83 million square miles. We can provide probabilities for any number though.

2. A short summary of a few lines that gives the basis of your assessment, and that can be abstracted into a larger synthesis.

The forecast is based on ice age, sea ice concentration, 925hPa temperatures, and the Arctic Oscillation Index. We use a multiple regression framework, as discussed in Drobot (2007), which is available at http://ccar.colorado.edu/~drobot/publications.html.

In addition to the specific forecast noted above, our approach also includes an ongoing examination of atmospheric circulation patterns, ice motion, and patterns of formation of leads and changes in ice concentration. This qualitative assessment is then factored into our overall view of likely summer ice conditions. For example, multiyear ice is confined to a smaller portion of the Arctic Basin than any previous year. Unless conditions are such that first-year ice survives summer melt, this suggests substantial reduction in ice extent. Also, persistent easterly winds this spring has probably contributed to earlier-than-normal opening of the ice pack in the eastern Beaufort Sea - a situation similar to that seen in spring 1998, preceding record (for that time) ice area loss in the western Arctic later than summer.

3. A supporting paragraph and possible figures that expand and help explain the basis for your outlook.

Briefly, we expect a good chance for a new record because (a) the ice cover is younger and thinner than at any time in our recorded past; (b) air temperatures were above normal over much of the Arctic this winter; and (c) wind patterns favour light ice conditions. For example, 63% of the Arctic Ocean is covered by younger-than-average ice and only 2% is covered by older than-average-ice, and above normal sea surface and air temperatures from last summer through the winter also contributed to a delay in sea ice growth in the Chukchi Sea until December, likely leading to a thinner winter ice pack in the western Arctic. The ARIFS site has a nice image of ice age: http://ccar.colorado.edu/arifs/forecasts.html. We can provide it at higher resolution if you want it.

4. A brief statement of what type of additional information would help to improve your outlook, if any.

The biggest thing we are lacking is ice thickness information. Of course, there is not enough observed ice thickness information out there, but if we could acquire some modeled ice thickness values, that would surely help. Another valuable parameter would be heat content of the ocean mixed layer. A third factor particularly relevant for survival of the first-year ice is snow cover, so snow depth information is another parameter of particular interest. Snow depth also affects the accuracy of estimates of sea ice thickness obtained from ICESat data, so snow depth is useful in that regard as well.

5. The organizers of this activity also invite brief assessments of the anticipated ice evolution over the course of the summer (June-September) in the following subregions: Bering/Chukchi/Beaufort Seas, Barents Sea, Northern Sea Route, and the Northwest Passage.

We can provide some of this information for the next forecast cycle, but in brief, ice in the Bering Sea has decreased earlier than normal, and wind patterns to date along with preconditioning suggest another large retreat in ice extent in the Chukchi and Beaufort seas. The Northern Sea Route in the past has remained blocked through summer by perennial ice north of Severnya Zemlya. However, only a relatively narrow strip of this ice remained at the end of last summer, and recent satellite imagery suggest that this strip is narrower this spring. Opening of the NSR will likely depend on whether this narrow strip of multiyear ice survives summer melt.

While first-year ice may mostly melt out of the Northwest Passage, scattered multiyear ice floes are likely to continue to be present.

Walt Meier Mark Serreze Julienne Stroeve
NSIDC's outlook for the 2008 September sea ice minimum:

September minimum sea ice extent: 3.48 ± 0.62 million sq km (i.e., a low estimate of 2.86 and a high estimate of 4.10 million sq km). This compares to the record minimum of 4.13 million square km set in mid September of 2007 as determined from NSIDC's analysis.

This estimate is based on survival rates for ice of different age classes through the summer, as determined by the Maslanik et al. (2007) approach published in GRL. Specifically, the estimate is calculated by multiplying the average (for the period 1985-2007) amount of ice that does not survive the summer (between the March maximum and the September minimum) by this year's March extent, with the range in the estimates from the ± 1 standard deviation of the survival rates.
This is a purely statistical estimate and does not take into consideration initial conditions of the ice (other than the March extent). The survival rate is simply assessed from the March-September difference in ice extent for different age categories; thus it aggregates the effects of melt and dynamic contribution to the loss of ice. A cooler than normal summer and/or a circulation pattern that tends to keep ice in the Arctic and/or produce a less compact ice cover will allow a greater amount of ice to survive and the minimum to be on the high end of the range. A warm summer and/or circulation that cause ice loss and/or a more compact ice cover will yield a minimum extent on the low end of the range.

The range of estimates is based simply on the standard deviation and is assumed to be uniform above and below the average, but there are reasons to believe that may not be appropriate this year. First, the low end of the range may include the melt of thicker, older multiyear ice that may be less likely to disappear. Second, this year there is a significant amount of first-year ice at higher latitudes. Because this ice is so far north, it will tend to be less prone to melt than first-year ice in more typical southerly locations. Thus, a greater than normal amount of first-year ice may survive this summer, which also would tend to make the higher part of the range more likely than the lower part of the range.

Walt Meier
Mark Serreze
Julienne Stroeve

-

Walt Meier   Research Scientist
National Snow and Ice Data Center   Univ. of Colorado
UCB 449, Boulder, CO 80309   walt@nsidc.org
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Arctic Ice Extent Outlook

Oleg M. Pokrovsky

1. Value of the Arctic Ice extent in September 2008 will be lower than those in corresponding period of 2007. It is evident from data presented in below *table*. For example, an ice extent retreat between March and April in 2007 was equal to 0.8, but it was only– 0.7 in 2008. Moreover, Atlantic-Pacific passage (Northern Sea Route) through Russian margin seas will be open in narrower mode than in past 2007 year as it can be seen from SSMI ice concentration pictures (*fig.1*).
   Most probable scenarios is that the ice extent in Atlantic sector of Arctic will not be reduced, but in Pacific sector it will be slightly increased or remained at the level of 2007 year. However, there are some other impact factors, which are not yet taken into account (e.g. ice thickness or SSMI ice concentration data, ice melting by warm underwater streams).

Table. Comparison of the Arctic ice extent values between winter and spring months of 2007 and 2008.

Year/month	Arctic Ice extent (million sq. km)
2007/Feb	14.5
2008/Feb	15.0
2007/March	14.7
2008/March	15.2
2007/April	13.9
2008/April	14.5

3. Major factors used for ice extent outlook mentioned above:

- More ice extent in Bering Sea in 2008 with respect to 2007
- Atmospheric pressure fields (*fig.2a, b*) and circulations (*fig.3a, c*) in March-April in Pacific sector of Arctic were substantially different between 2007 and 2008. In 2007 there was a persistent cyclone over Bering Sea determined a sustainable northward flow of warm air from low latitudes (*fig.3a, b*). In contrast, there was an anticyclone stabilized in April 2008. Therefore, an atmospheric flow from South-East Asia to Arctic appeared in April of 2008 (e.g. later than in 2007).
- Surface water salinity in Pacific sector of Arctic was lower in last autumn than in previous year because of more intensive ice melting in August and September. Seasonal ice in winter should be thicker last winter.
- SSMI ice concentration picture (*fig.1*) leads to opposite conclusion. Actually, arctic ice in Pacific sector is rather thin now. Therefore, its destruction is more or less probable under condition of last year atmospheric circulation regime will be repeated.
- The SAT field of 2008 April has lower positive anomaly in domain of Chukchi and Bering seas (*fig.4a*). Meanwhile, much more strong SAT positive anomaly was occurred in past year corresponding field over Kara Sea and Eastern Siberia (*fig.4b*).

4. Thus an above outlook is rather uncertain. There is a shortage of data on:

- Ice thickness
- Water temperature in Atlantic core layer within Arctic Ocean.

Highly developed self-learning prediction model is needed. I would suggest to employ a fuzzy-neural type of model in this study due to its highly flexibility.

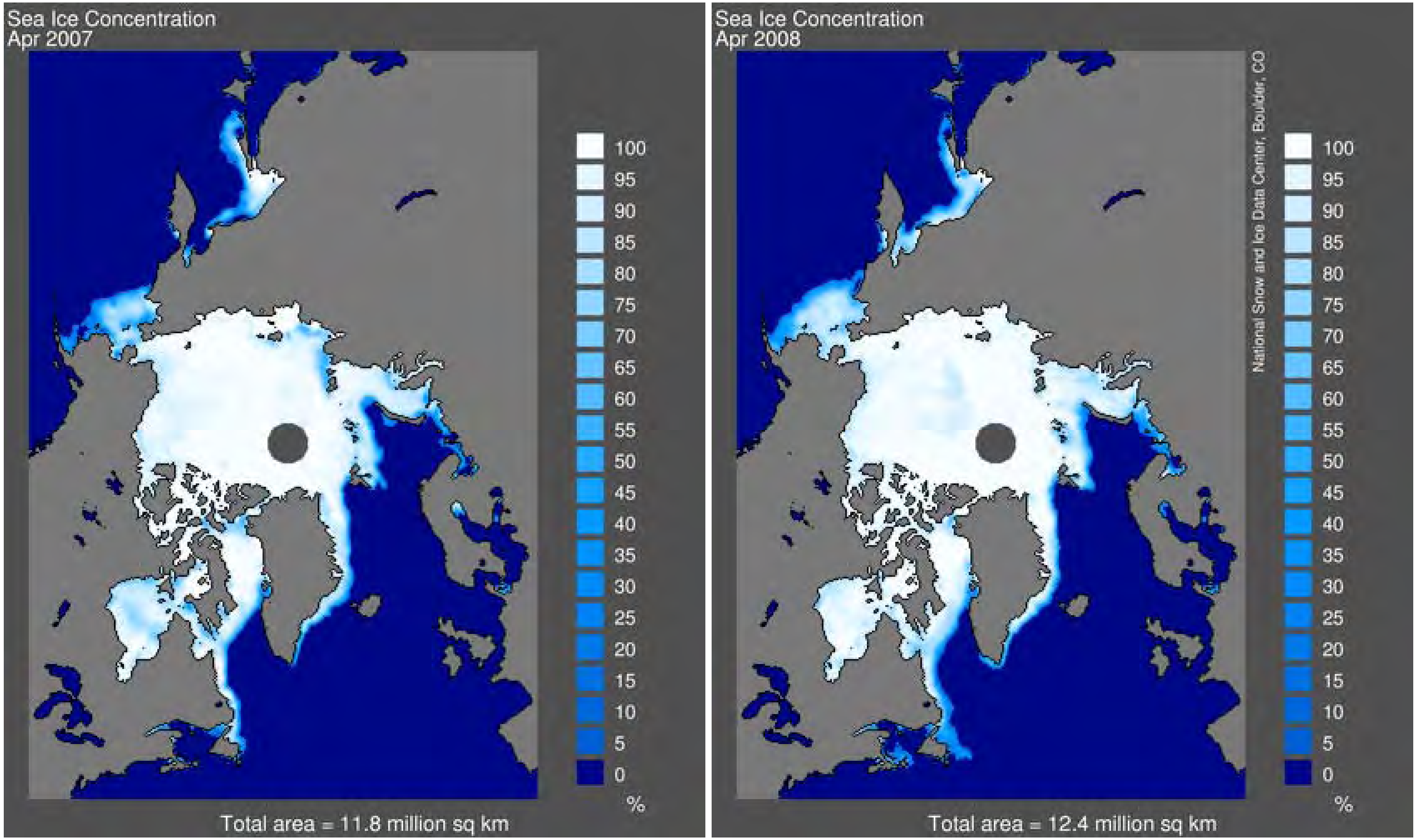

Figure 1. Comparison of ice concentrations between April 2007 and April 2008

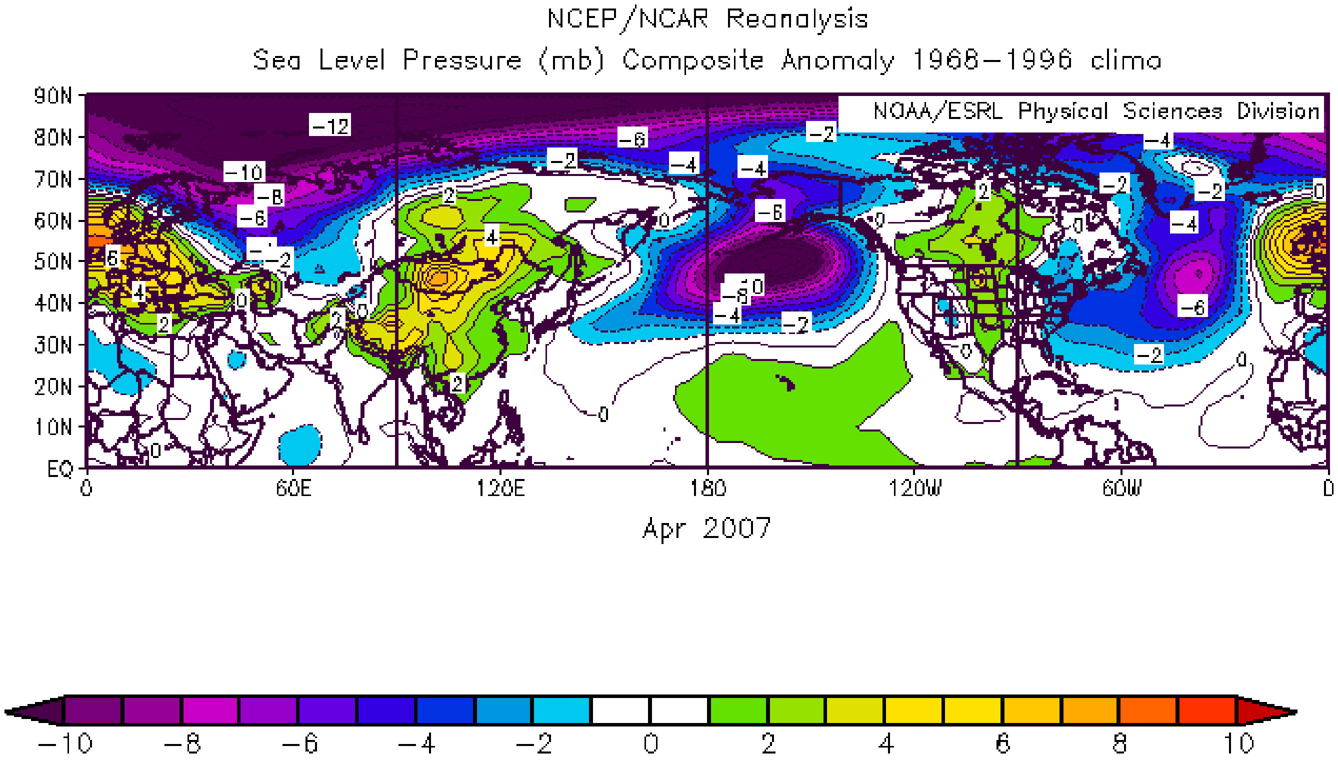
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Fig.2a

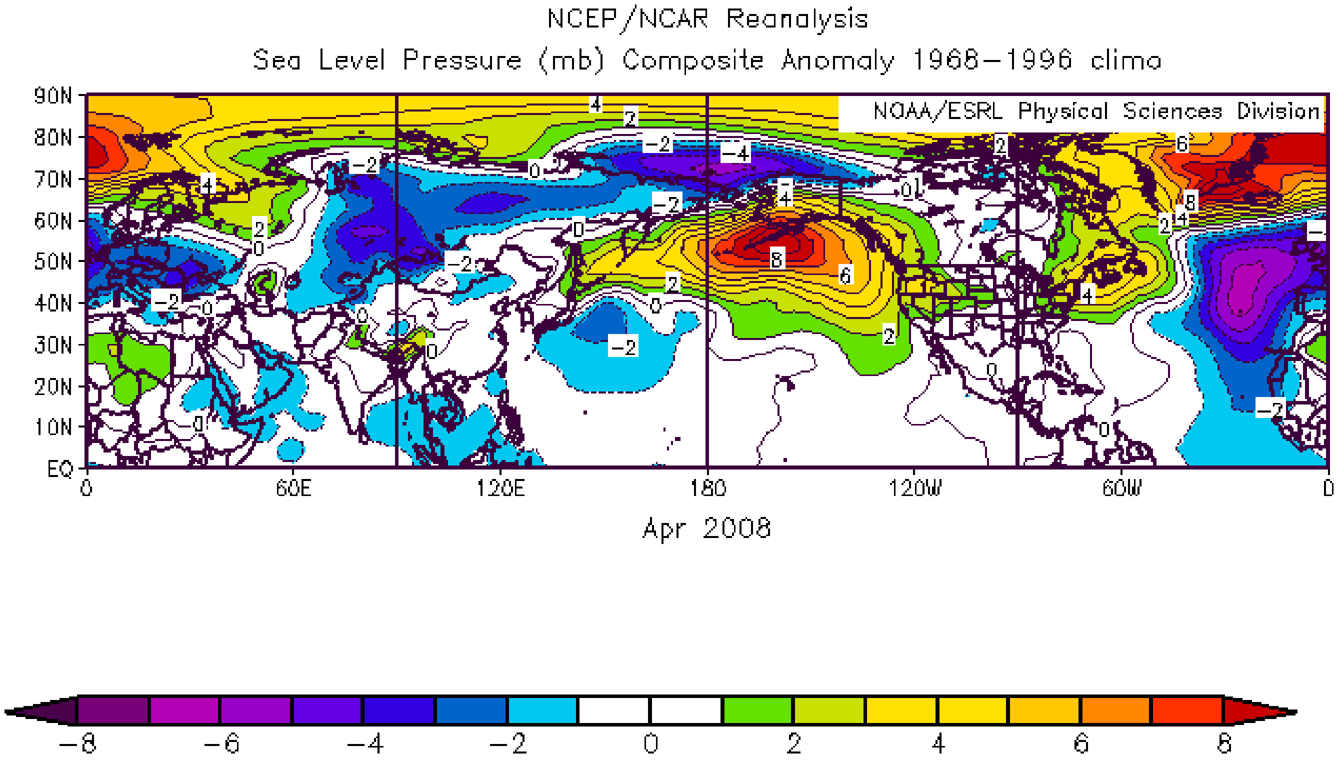
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Fig.2b

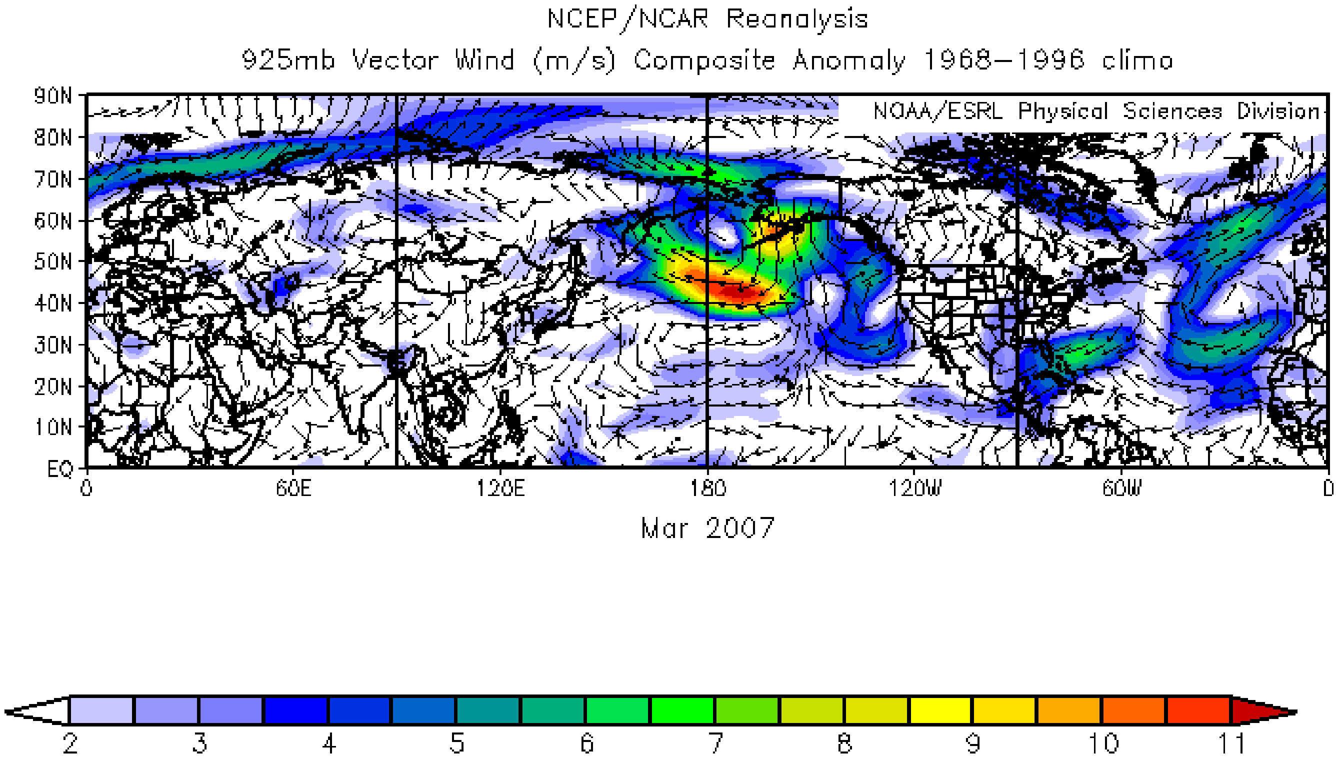
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Fig.3a

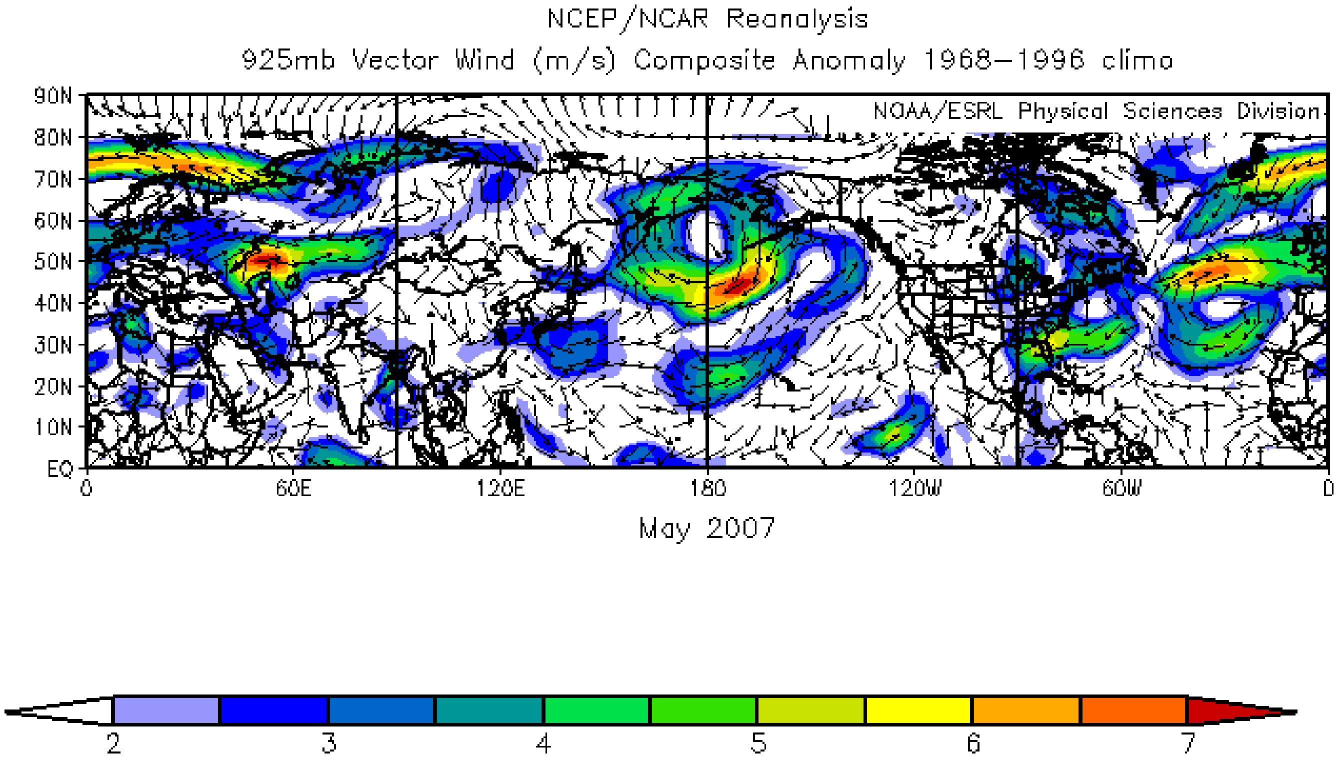
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Fig.3b

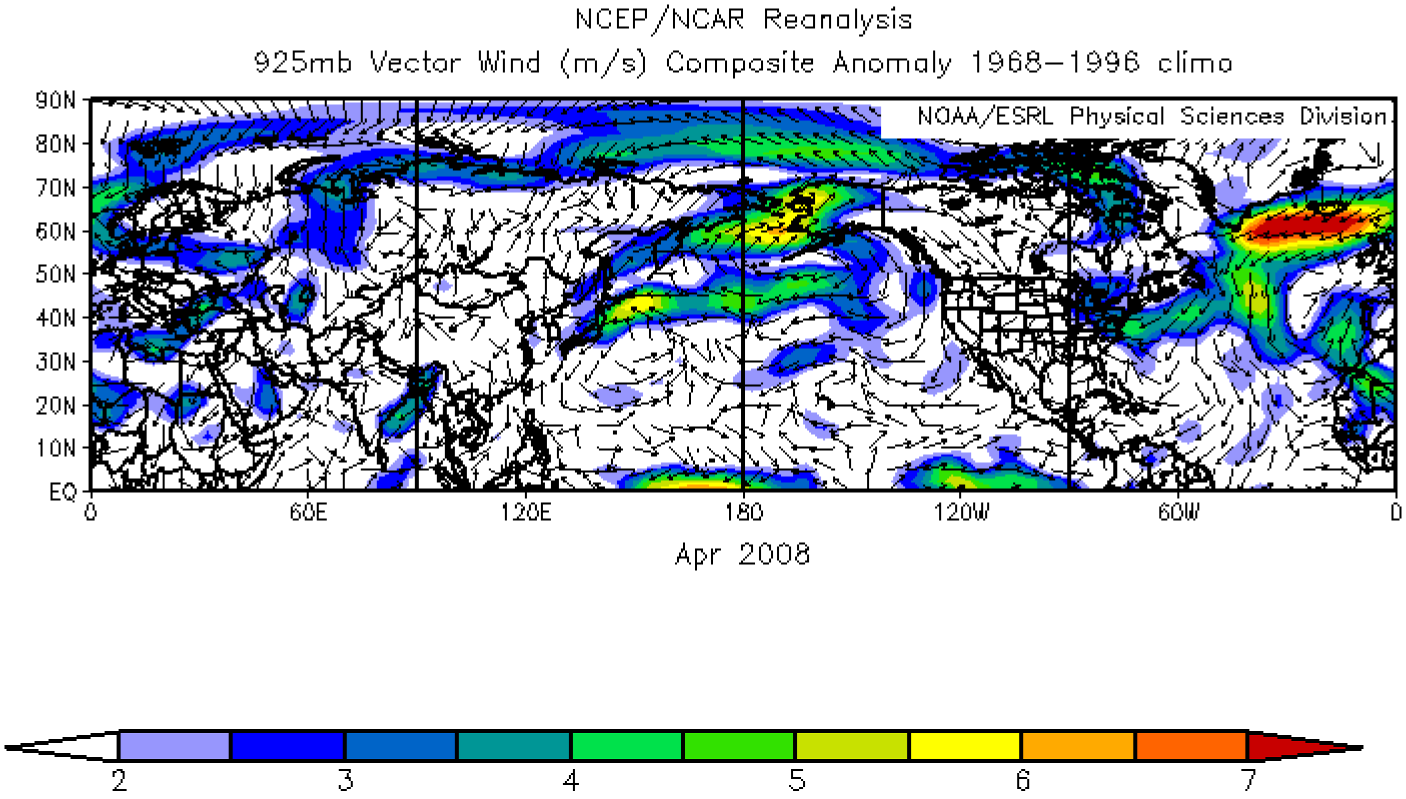
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Fig.3c

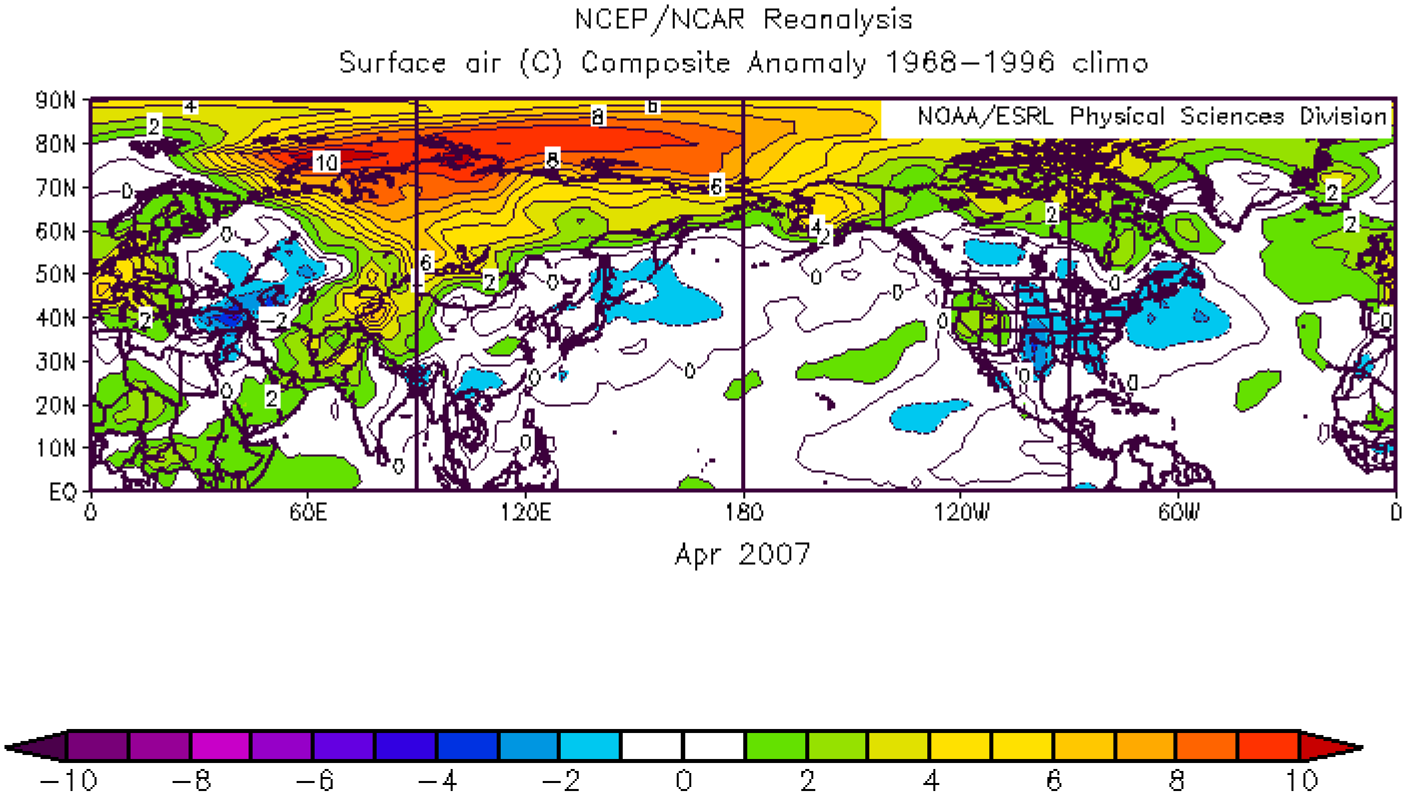
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Fig.4a

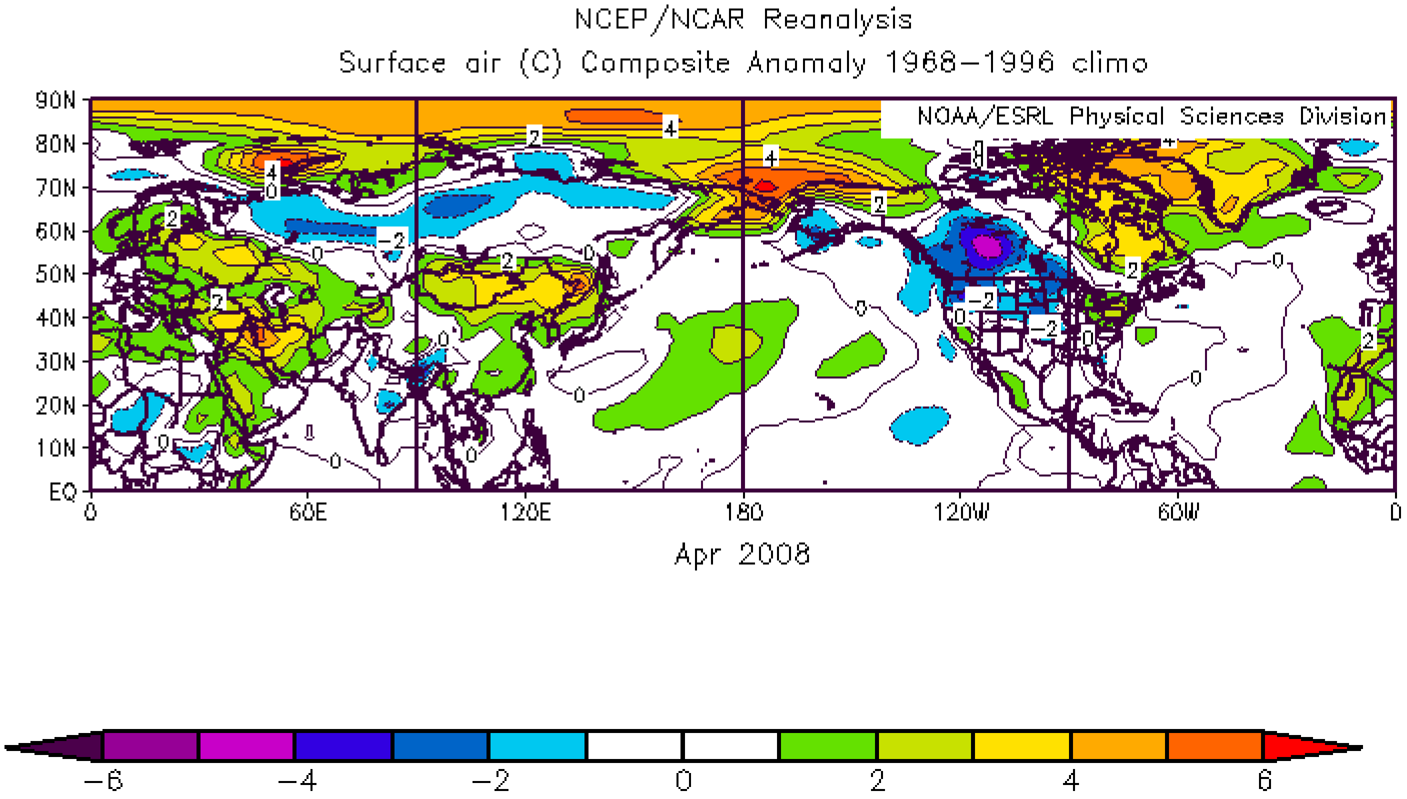
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Fig.4b

Prinsenberg, Simon

From what I saw in the Amundsen Gulf and imagery I feel we will have the same extent as last year "as a rebound" but then lose a lot more the following year. And the NW Passage to me will be passable Low ice concentration from now on in as no heavy Arctic pack ice is available at the entrance to M'Clure Strait to fill it after the summer.

Request for 2008 September Sea Ice Outlooks Study of Environmental Arctic Change (SEARCH) and Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies

(DAMOCLES) Programs

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2008 Outlook for Arctic Sea Ice this Summer

A Collaborative Project between the
Polar Science Center, National Ice Center and the NASA Jet Propulsion Lab.

Ignatius G. Rigor[1,2], Pablo Clemente-Colón[3], Son V. Nghiem[4], John Wood[3], James Brinkley[3], and Todd Arbetter[3]
[1]Polar Science Center, Applied Physics Laboratory, University of Washington
[2]NOAA/UW Joint Institute for the Study of the Atmosphere and Ocean (JISAO)
[3]Naval/National Ice Center
[4]Jet Propulsion Laboratory, California Institute of Technology

Introduction

The extent of arctic sea ice during summer has declined to record or near-record minima during the last few summers (Stroeve et al. 2008, e.g. Fig. 1). Can we predict future minima?

We have been working to improve our operational capability to predict the conditions of Arctic sea ice on weekly to seasonal time scales through a grant from the National Oceanic and Atmospheric Administration (NOAA) Transitions of Research Applications to Climate Services (TRACS). The forecasts provided by the National/Naval Ice Center help resources managers, navigators and hunters make better decisions regarding Arctic sea ice. Accurate sea ice information is important to naval operations, and increasing safety of life at sea.

Outlook

We expect that the minimum in summer sea ice extent in 2008 will break the record set during the summer of 2007 by about 1 million sq. km, and decrease from 4.1 million sq. km in September 2007 to 3.1 million sq. km in September 2008 (Fig. 1).

Rationale

As noted by Rigor et al. 2002, high Arctic Oscillation (AO) conditions during winter precondition summer sea ice for extensive retreats especially on the Eurasian sector of the Arctic Ocean. High AO conditions were observed during the winter of 2006/2007 preceding the current record minimum, and again this past winter of 2007/2008. The winds associated with these conditions pushed the remaining multi-year (MY, or perennial) sea ice against the Canadian Archipelago and out through Fram Strait (Fig. 2).

The area of MY sea ice over the Arctic Ocean has dropped another 1 million sq. km. from March 2007 to March 2008 (Nghiem et al. 2008). As argued by Rigor & Wallace (2004), the age of sea ice explains over 50% of the variance in summer sea ice extent along the Alaskan and Eurasian coasts. This leaves a vast area of first-year (FY) sea ice that simply does not have enough mass to survive even a cold summer melt season. The expected minimum of 3.1 million sq. km. also agrees with typical survival rates of FY and MY ice from 1956 – 2007.

The variability in winds during the prior winter and summer are also important (Rigor 2005). During some years, the winds may pile FY ice up against a coast increasing its areal average thickness, and thus making these areas more resistant to sea ice retreat, or it may blow the ice away as it did during the summer of 2007. From late December 2007 to early January 2008, low AO conditions prevailed favoring strong easterly winds from the Canadian Archipelago. These winds fractured and blew the remnants of MY ice in the Eastern Beaufort across the Beaufort and Chukchi seas (Fig. 3, more discussion and animations of this event may be viewed at http://www.ice.ec.gc.ca/app/WsvPageDsp.cfm?id=11892&Lang=eng). The extensive areas of FY ice that grew between the areas of MY ice are likely to melt earlier, quickly decreasing the concentration of sea ice, and as noted by Perovich et al. (2008), the extra sun light absorbed by the darker ocean may favor the rapid thinning of sea ice, and enhance the retreat of sea ice in the Beaufort and Chukchi seas.

Caveats and other Outlooks

Outlooks for summer sea ice are being produced by many researchers, and depending on methods, the outlooks range from a return to the trend line of 6 million sq. km, to as low as 2 million sq. km. (Fig. 1). This range of outlooks highlights the uncertainty in our ability to predict summer sea ice conditions this far in advance. Although we expect to break the record by 1 million sq. km., it may be worth noting that we have never broken the record 2 years in a row. And the effect of the summer winds is difficult to predict. If conditions similar to the summer of 2007 occur, then our outlook of 3.1 million sq. km. may be high.

Other outlooks for summer sea ice may be found at these links:

- Sheldon Drobot et al., http://ccar.colorado.edu/arifs/
- Ron Lindsay et al., http://psc.apl.washington.edu/lindsay/Prediction/seasonal%20ice%20prediction.html
- Jinlun Zhang et al., http://psc.apl.washington.edu/zhang/IDAO/seasonal_outlook.html

And more information on the latest condition of Arctic sea ice may be found at these links:

- National Snow and Ice Data Center (NSIDC), http://nsidc.org
- Cryosphere Today, http://arctic.atmos.uiuc.edu/cryosphere/

Figures

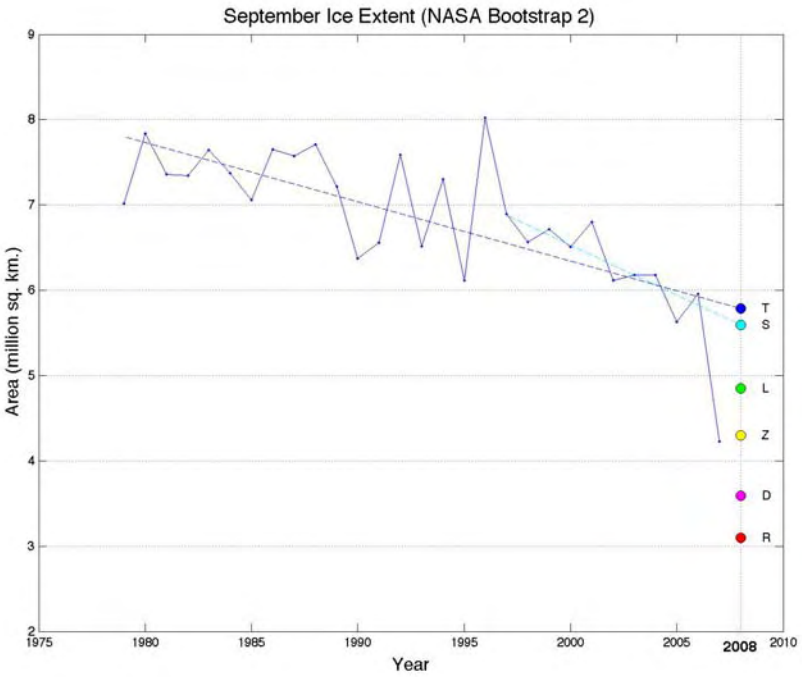


Figure 1. September average sea ice extent from 1979 – 2007 estimated from Bootstrap 2 (courtesy of Joey Comiso, NASA). We also show the expected minimum from various outlooks for this summer: T = 1979 – 2007 Trend Line; S = Stern et al., 1997 – 2006 Trend Line; L= Lindsay et al; Z = Zhang et al.; D = Drobot et al.; & R = Rigor et al.

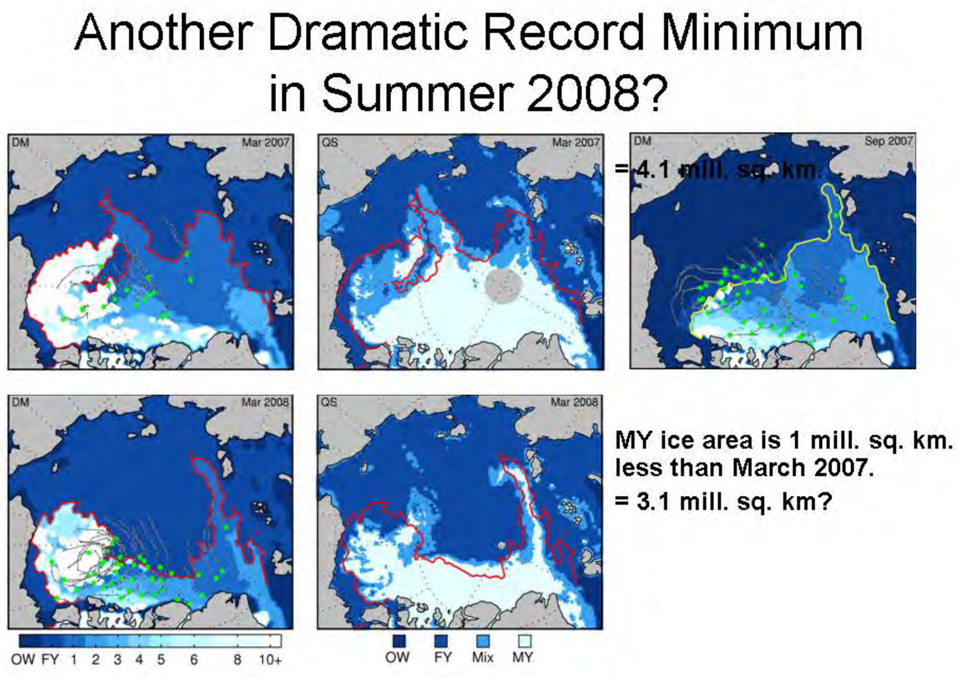
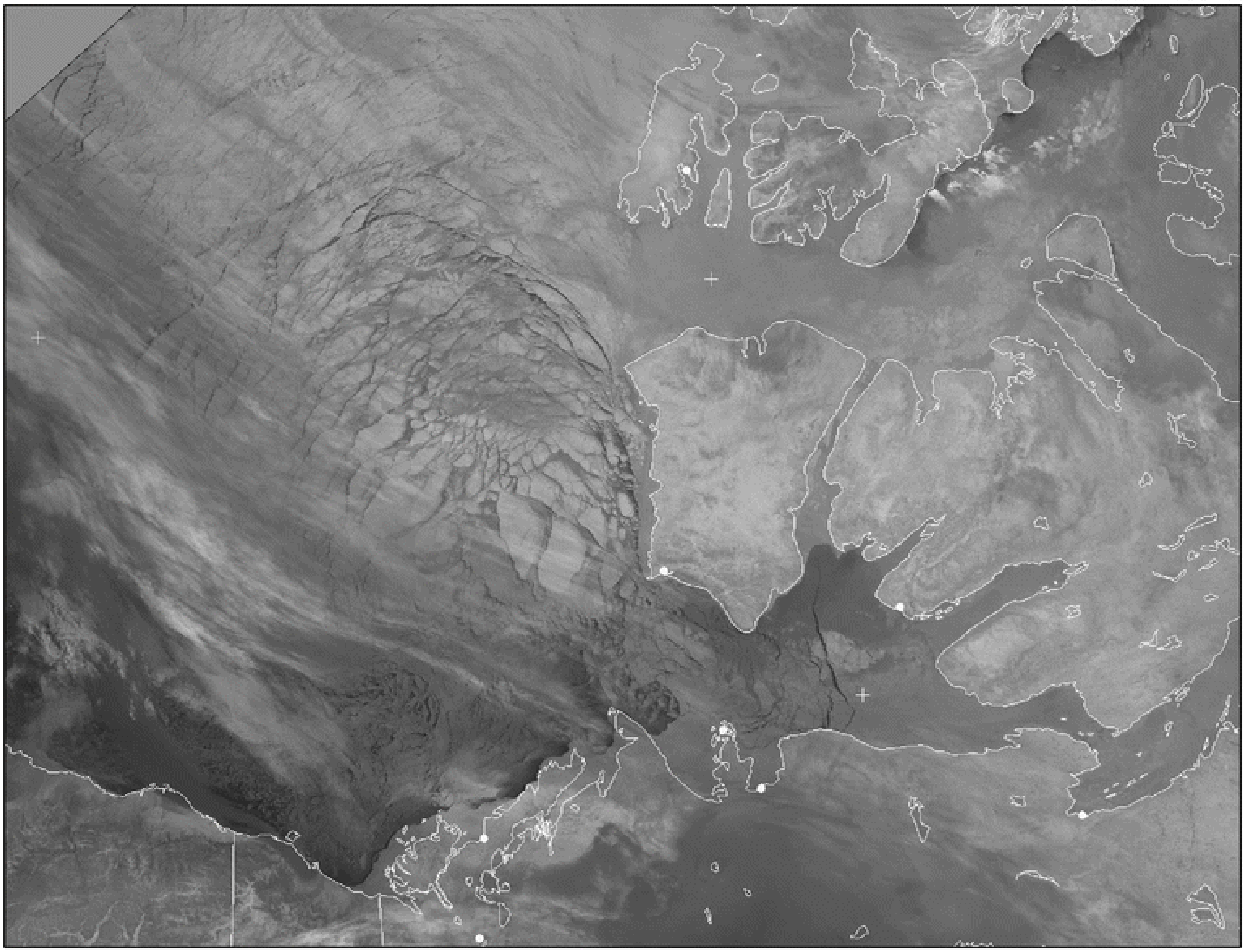


Figure 2. Age of sea ice from buoy drift model and QuikSCAT on March 2007 (top) & March 2008 (bottom), and the observed record minimum in September 2007. Adapted from Nghiem et al. 2008 and Nghiem et al. 2007. Animations of the age of sea ice may be obtained from http://seaice.apl.washington.edu/IceAge&Extent/.



Imagery courtesy of NOAA and prepared by Environment Canada / Les images sont une courtoisie de NOAA et ont été preparées par Environnment Canada

Figure 3. Fractured MY sea ice in the Beaufort and Chukchi seas. Animation was obtained from Environment Canada (http://www.ice.ec.gc.ca/app/WsvPageDsp.cfm?id=11892&Lang=eng), and uses imagery from NOAA.

Acknowledgements

This project is primarily funded by of the NOAA TRACS program through the NOAA/UW Joint Institute for the Study of the Atmosphere and Ocean (JISAO), by the National Ice Center and Applied Physics Laboratory of the University of Washington. We are also supported by the National Aeronautics and Space Administration, the NOAA Arctic Research Office through the JISAO, the National Science Foundation, and the Office of Naval Research.

This research is based on observations of ice motion provided by the International Arctic Buoy Programme (IABP), and ice concentration estimates from NSIDC and Joey Comiso at NASA.

2008 Outlook

Phyllis Stabeno <Phyllis.Stabeno@noaa.gov>

1. Ice extent: 4.1 million km2

2. First-year ice tends to melt faster than multi-year ice and the first-year ice is far extensive this year than it was last year. So initial conditions support a lower ice year than 2007.(A major factor.)

The Pacific is cold and ice in the Bering Sea is persisting (approximately half the shelf still ice covered). There will be little or no assistance with ice melt by warmer water from the Bering Sea as apparently occurred when the Bering Sea was very warm (2001-2005). (Probably a significant but not major factor.)

In addition to melting ice, in 2007 much of the multi-year ice exited to the Atlantic because of atmospheric patterns. The probability of the atmosphere setting up as perfectly as it did last year is unlikely. (A major factor.)

3. While initial conditions support the idea that there will be a lower minimum ice extent than occurred in 2007, the other two factors should balance that tendency. This would result in a minimum ice extent very similar to what occurred in 2007.

4. Improved observations of ice thickness, temperature structure of upper water column, and improved modeling capability.

2008 Outlook

Harry Stern <harry@apl.washington.edu>

1. What will the sea ice extent for the Arctic as a whole be at the September 2008 minimum? Quantitative estimates in square kilometers are preferred (the value for 2007 was 4.3 million square kilometers), but qualitative estimates are also accepted.

This estimate is for the AVERAGE September 2008 Arctic sea ice extent, NOT the extent on the particular day when the absolute minimum occurs.

Estimate: 5.56 million square kilometers
Standard deviation: 0.22 million square kilometers

2. A short summary of a few lines that gives the basis of your assessment, and that can be abstracted into a larger synthesis.

I believe it's important to include an estimate based on linear persistence. The degree to which this estimate is wrong is a measure of the degree to which the sea ice extent is not following a linear trend.

This estimate is based on linear extrapolation of the average sea ice extent for the 10 Septembers 1997-2006. For those years, the slope of the trend line is about -0.1 million sq km per year. Extrapolating the trend line to 2008 gives an estimated extent of 5.56 million sq km.

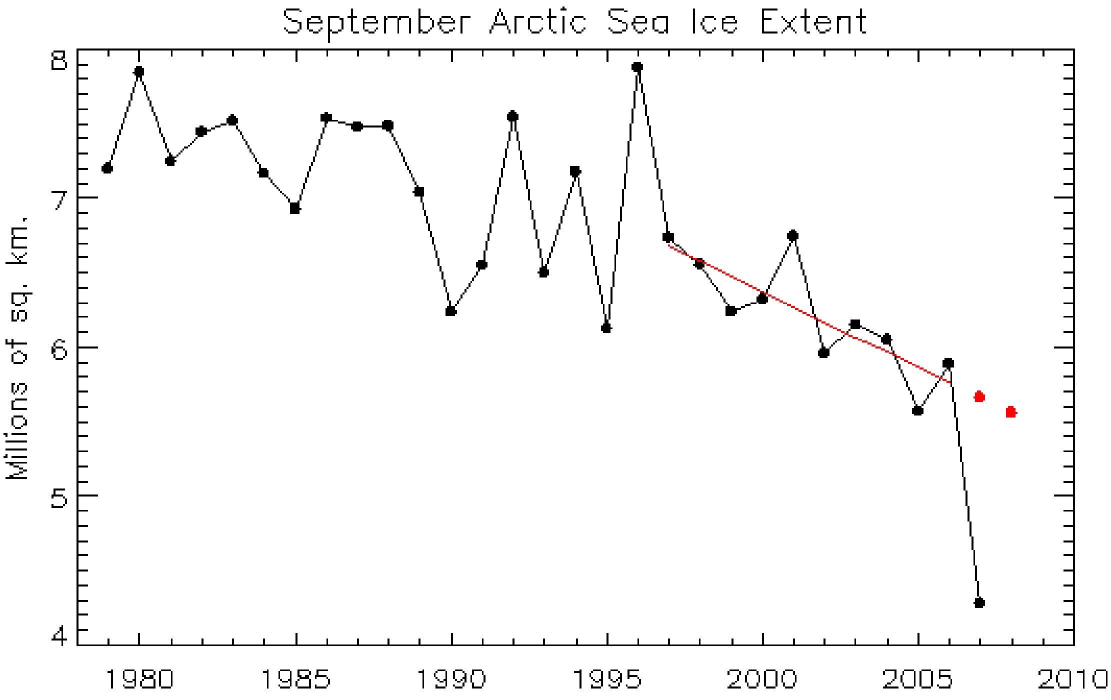
The standard deviation of the residuals from the trend line is about 0.22 million sq km. I purposely did not include 2007 in the calculation of the slope, because (statistically) 2007 was an extreme outlier: in terms of the standard deviation of the residuals, it was more than 6 standard deviations below the trend line. If 2008 proves to be 5.56 million sq km plus-or-minus one or two standard deviations, then we will say that 2007 was indeed an outlier. But if 2008 falls close to 2007, we will be in a good position to reject linear persistence.

3. A supporting paragraph and possible figures that expand and help explain the basis for your outlook.

I started with 1997 because before that, the variability of the September sea ice extent was much larger (see attached figure). 1995 was a record low up to that point, and it was followed by a record high in 1996. In contrast, the variability during 1997-2006 about the trend line was relatively small. In the figure, the trend line for 1997-2006 is shown in red, and the extrapolation of the trend line to 2007 and 2008 is shown as red dots.

4. A brief statement of what type of additional information would help to improve your outlook, if any.

This is obviously a very crude statistical estimate, and is not based on physical factors. This estimate is not a starting point for improved estimates of sea ice extent. Rather, it is a benchmark against which to gauge linear persistence of the ice extent, and against which to judge the skill of other estimates. No additional information is necessary to "improve" this outlook.

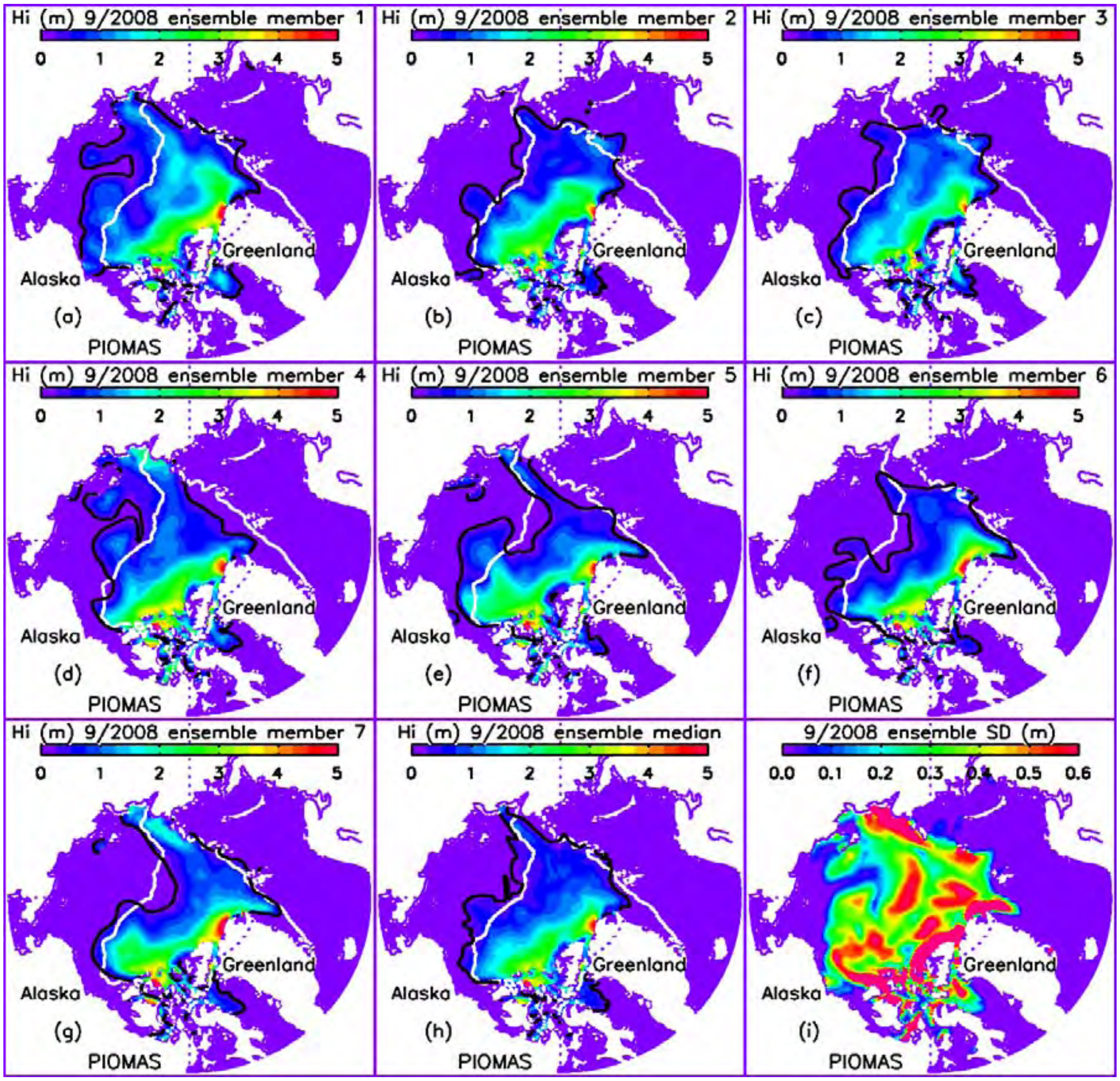


2008 September Arctic sea ice Outlook

Jinlun Zhang <zhang@apl.washington.edu>

We would like to participate in the 2008 September arctic sea ice outlooks by conducting ensemble predictions. The ensemble predictions are based on a synthesis of a model, NCEP/NCAR reanalysis data, and satellite ice concentration data. The model is the Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS), which is forced by NCEP/NCAR reanalysis data. It is able to assimilate satellite ice concentration data. The ensemble consists of seven members each of which uses a unique set of NCEP/NCAR atmospheric forcing fields from recent years, representing recent climate, such that ensemble member 1 uses 2001 NCEP/NCAR forcing, member 2 uses 2002 forcing, …, and member 7 uses 2007 forcing. Each ensemble prediction starts with the same initial ice–ocean conditions at a given starting date of prediction before September 2008. The initial ice-ocean conditions are obtained by a retrospective simulation that assimilates satellite ice concentration data. Of course, no data assimilation is performed during the predictions. More details about the prediction procedure can be found in a newly published paper:
http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf

The attached figure shows the predicted September 2008 ice thickness from these seven ensemble members and their ensemble median and standard deviation (SD). The prediction starts on May 1, 2008. The white line represents the satellite observed September 2007 ice extent and the black line the predicted September 2008 ice extent. As shown by the figure, most of the ensemble members (members 2, 3, 5, and 6) predict a September ice extent that is close to September 2007. Member 1 predicts a largest ice extent; while member 7 predicts an ice extent that is lower than September 2007. The ensemble median is considered to have a 50% probability of occurrence and the ensemble median ice extent is close to that in September 2007. This means that ice extent in summer 2008 is likely to be close to last summer, if not lower. Needless to say, there are many uncertainties with seasonal predictions of arctic sea ice. We will try to update the ensemble predictions every month, all the way to summer. As the starting date of prediction approaches September 2008, we hope the prediction uncertainties will be reduced. We would be happy to provide predicted ice thickness fields to you or the related organization every time we update the ensemble predictions. Additional prediction results and analysis may be found at our web page:
http://psc.apl.washington.edu/zhang/IDAO/seasonal_outlook.html.



Hi (m) 9/2008 ensemble member 1
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Hi (m) 9/2008 ensemble member 4
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Hi (m) 9/2008 ensemble member 7
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PIOMAS

ESARC
Martin Miles
Method: Semi-empirical / semi-theoretical (i.e.,"seat-of-the-pants")

Minimum sea-ice extent for the Arctic as a whole, 3.8 million square kilometers

In summary, While the winter/spring 2008 sea-ice extent has rebounded from the 2007 negative mega-anomaly, the age-class distribution at present is negatively skewed compared to satellite climatology and even the values for 2007, as is ice concentration within the ice –ocean margin that defines extent. Therefore, preconditioning would favor a less-extensive summer minimum ice cover than in 2007, unless offset by a return to atmospheric conditions that are opposite the anomalous ones in 2007 – conditions that lead to both dynamic (increased sea-ice export through Fram Strait) and thermodynamic (melt) losses. The 2007 mode cannot be expected to recur; however there is likewise no reason to expect opposite conditions. The net expectation here is 3.8 million square kilometers, exceeding the 2007 minimum by about a half million square kilometers.

The most compelling indication of a new record low is the observed strong (90–95%) relationship between seasonal ice and tendency to melt in summer, leaving predominantly only the multi-year ice that manages to survive the melt season. The potential importance of a long-term tendency toward more seasonal ice and less perennial, multi-year (MY) ice was expressed in, for example, Johannessen, Shalina and Miles in *Science* (1999). Since then, this trend towards less MY ice has continued and the trend in overall sea-ice extent has not only been increasingly negative, but increasingly non-linear. Therefore, whereas some may expect a rebound from the 2007 anomaly toward the (linear) trend, a curvilinear trend-line may be a more accurate reference. Furthermore, our logic of essentially disregarding the higher-than-2007 winter/spring ice extent is that a predominantly seasonal ice cover such as is evident in the Arctic at present will behave more and more like, e.g., the Baltic Sea, which is ice-free in summer regardless of the extent and severity of the previous winter ice cover.

The single most important additional information that would improve the prediction is the expected predominant mode(s) of atmospheric-circulation variability in the Arctic in June–September 2008.