September 2009 Regional Sea Ice Outlooks: July Report

Community Contributions

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September 2009 Regional Sea Ice Outlook: July Report
A regional perspective on ice evolution in the Pacific Arctic sector (SIZONet project)
Submitted By: Hajo Eicken, Chris Petrich, and Mette Kaufman on behalf of the Seasonal Ice Zone Observing Network (SIZONet)

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(1) Region of interest: Bering-Chukchi-Beaufort Seas

(2) Ice development and status in early July 2009

Ice extent:
• Passive microwave data (SSM/I) distributed by the National Snow and Ice Data Center (NSIDC) indicate above-normal ice extent in the Bering Sea for April 2009 (Figure 1). Starting in early May, vigorous and early melt resulted in rapid northward retreat of the ice edge to below normal extent in June and early July (Figure 2).

Ice thickness and ice characteristics:
• *Eastern Chukchi/Western Beaufort Sea:* End-of-winter ice thickness distribution as presented in our June Report, i.e., much less multiyear ice of thickness comparable to previous years (3.6 m total level ice thickness mode) and first-year ice thicknesses comparable to or thicker than past years (1.7 m total level ice thickness mode with thicker deformed ice).

Coastal sea ice:
• At *Wales*, in Bering Strait, local ice experts reported somewhat more sluggish ice decay. While overall ice retreat was very rapid, large ice floes lingered late into June, aiding coastal communities in gaining access to seals and walrus on the ice. As described by W. Weyapuk Jr. in his daily observations for June 19: "It is unusual to see large floes this late in the season (for recent years) as most have broken into smaller floes by now." On June 26, roughly two weeks later than in previous years, the last remnants of nearshore ice near Wales were pushed north by the winds. Evidence of persistent northward drift is also provided by a surface drifter placed on an ice floe in May at Wales that is now, in early July more than 600 km further north, northeast of Wrangell Island.

• At *Barrow*, the ice cover experienced early melt onset in late April, resulting in much superimposed ice formation similar to Wales (see June Report) and early onset of decay. However, in June, a balance appears to have been struck between the effects of such

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early-melt preconditioning and overall cool, and unusually overcast weather conditions. As a result, early onset of ice decay did not result in early break-up of landfast ice. Early ice melt-out near the beach provided hunters with boat access to a coastal channel starting June 18. However, the grounded ridges continue to linger in particular north of town well into July, likely because of reduced solar heating of surface waters and little variability in wind direction. This development is also evident in Figure 3, which puts 2009 as one of the years with lowest surface input of solar radiation over the past decade. An ice mass balance buoy placed on first-year ice in April provides valuable data both on the northward drift of ice in this region but also on the later onset of melt on the pack ice compared to coastal landfast ice and sluggish onset of bottom melt (roughly 10-15 cm in early July; see summary of buoy data by Perovich). At Barrow, with ice lingering near town, hunters are successful at catching bearded seals and walrus.

(3) Outlook for the summer ice season and potential impacts

• Break-up and onset of seasonal ice retreat: Due to unusually cloudy and cool weather, we have revised our earlier outlook (based on early melt onset and sunny weather in the first week of June) to suggest **normal to late break-up**. This estimate is based on an experimental break-up forecast combining observed solar heat input and 2-week atmospheric forecasts (see Figure 2; details at http://www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast).

• Summer conditions: As detailed in the June Report, offshore ice retreat is estimated to proceed less rapidly during the initial phase due to cooler weather and thicker first-year ice. However, the lack of multiyear ice will lead to more substantial retreat later in the season, suggesting **lighter ice conditions than in 2008.** Last year, multiyear ice lingered and presented a platform for feeding walrus throughout summer and a hazard for vessels bound for the eastern Beaufort Sea. This year, there is less likelihood of such lingering ice. Sealevel atmospheric pressure patterns so far are developing similar to 2005 and 2007 with persistent high pressure over the Beaufort Sea and easterly sector winds at Barrow. However, in contrast with 2005 and 2007 this year is much cloudier (Figure 3). Nevertheless, typically the Beaufort High breaks down sometime in early to mid-July so it will only become apparent later in the month whether atmospheric circulation is favoring ice retreat.

This outlook is based on heuristics and a statistical model for break-up timing (see website at http://www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast/). Jing Zhang and Jeremy Krieger kindly provided two-week WRF weather forecast model runs (knik.iarc.uaf.edu).
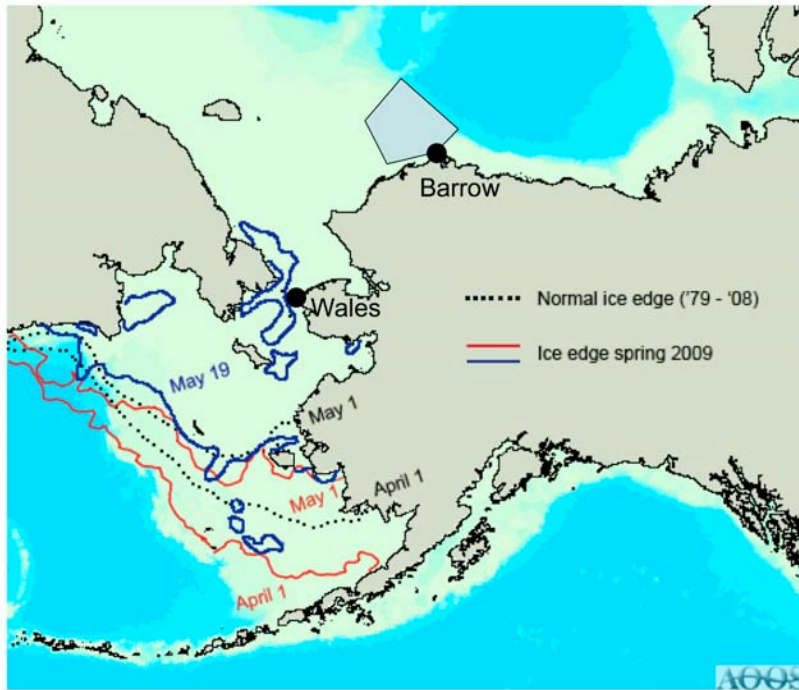
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Figure 1. Ice extent derived from passive microwave satellite data (SSM/I, data provided by NSIDC, nsidc.org) for Pacific Arctic sector. Shown are observed ice edges for April and May along with "normal" ice edges (median positions) from 1979 to 2008. Locations of the airborne surveys and coastal stations are also shown.
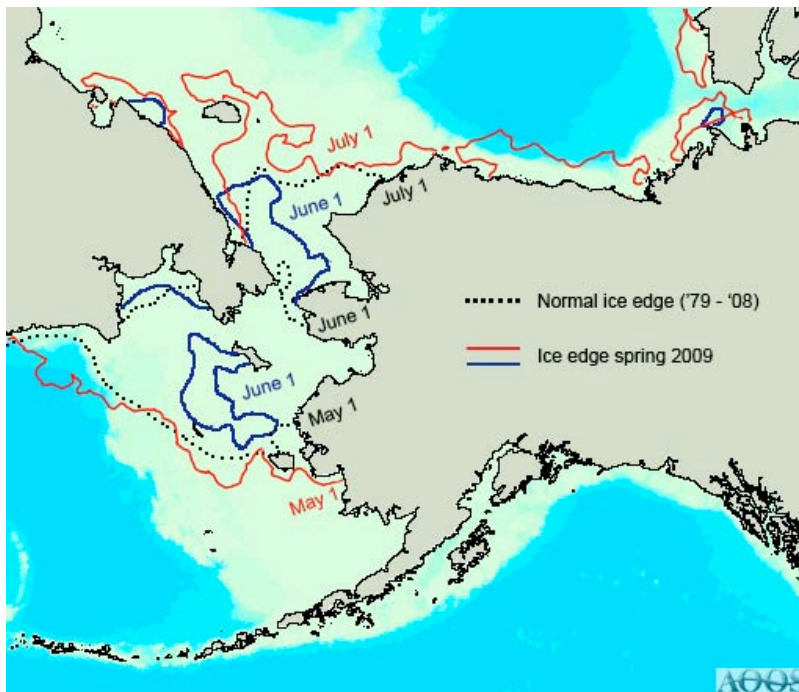

Figure 2. Same as Figure 1, but for ice extent on the first of May, June and July 2009.
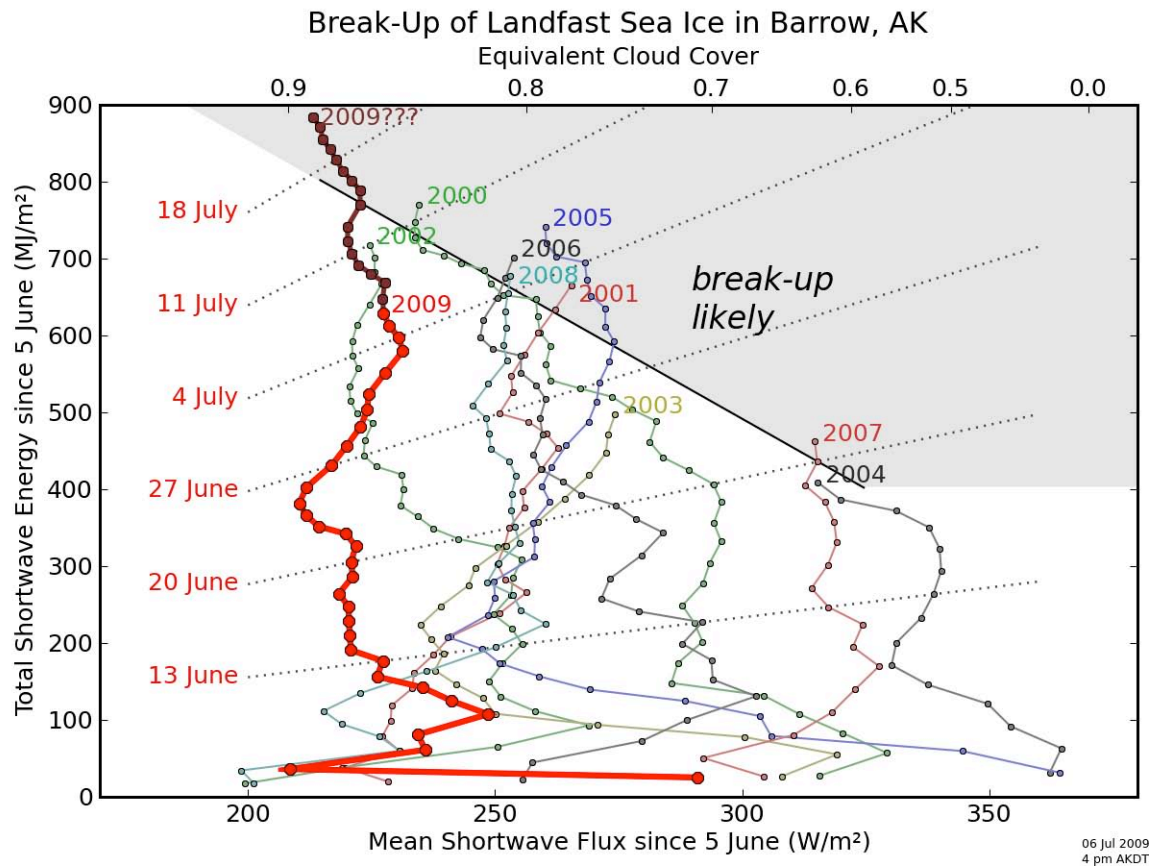
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Figure 3. Break-up timing and solar shortwave energy incident at the surface (mean and cumulative shown on bottom and left axis, respectively) for 2009 (thick red line—observed as of July 6; thinner dark red line—forecast) and other recent years. For prior years curves terminate at observed break-up. The shortwave flux is used as an indicator for the combined effect of both radiative and wind forcings. The grey area at the top corresponds to the seasonal stage at which ice break-up is imminent and determined by local sealevel and winds. Details at http://www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast/.

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September 2009 Regional Sea Ice Outlook: July Report
By: Oleg Pokrovsky

1. *A sea ice projection for the September monthly mean arctic sea ice extent (million square kilometers),* **4.5-4.6**

2-*The type of estimate:* heuristic, and statistical

3-*The physical rationale for the estimate.*

1. Major impact factor to the ice extent variability in the Atlantic sector of the Arctic Ocean is the SST anomalies in the Northern Atlantic in previous month. The SST anomaly in May 2009 (fig.1), which is now available but was not for previous report, demonstrated a "warm tongue" of the inflow stream directed to Eastern part of Arctic. That explained a more ice degradation in this part of Arctic Ocean (fig.2) with account to reference 1979-2000. Invasion of more warm Atlantic waters appeared recently in North Atlantic could lead to further reduction of the ice extent here. Thus there is some uncertainty in the September ice extent **estimate: 4.5-4.6.**

2. Major impact factor to the ice extent variability in the Pacific sector of the Arctic Ocean is the vector wind anomalies occurred in the Northern Pacific. May picture (fig. 3) is very similar to those for previous month. That explains the ice edge in Chukcha Sea is close to reference border (red curve at fig.2). Thus there is no trend in our previous estimate in this part of Arctic.
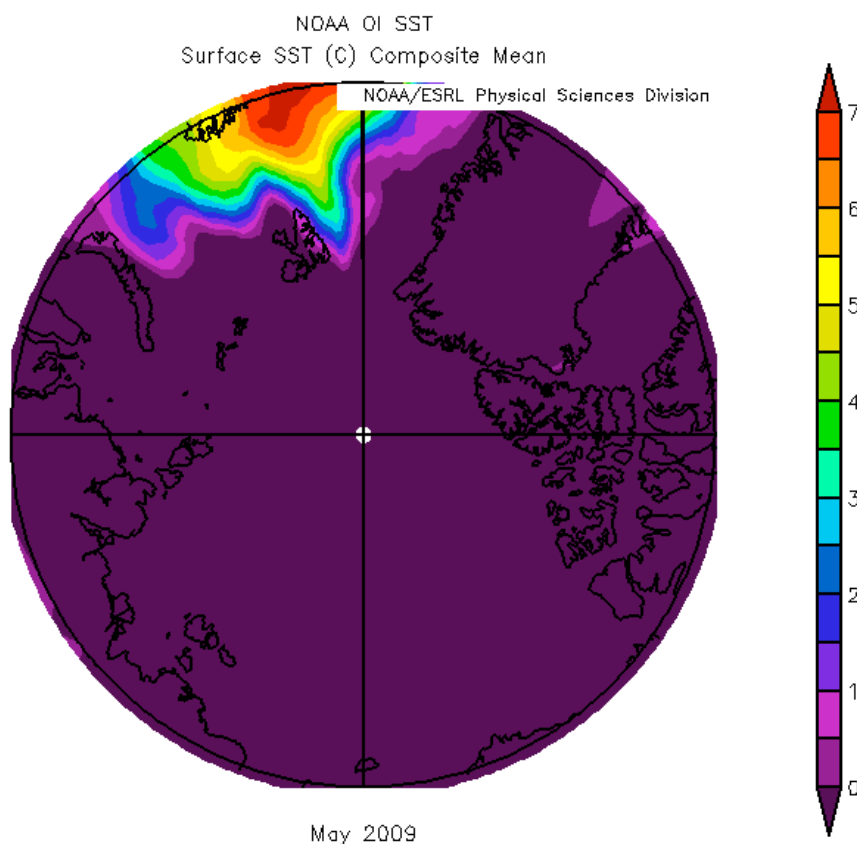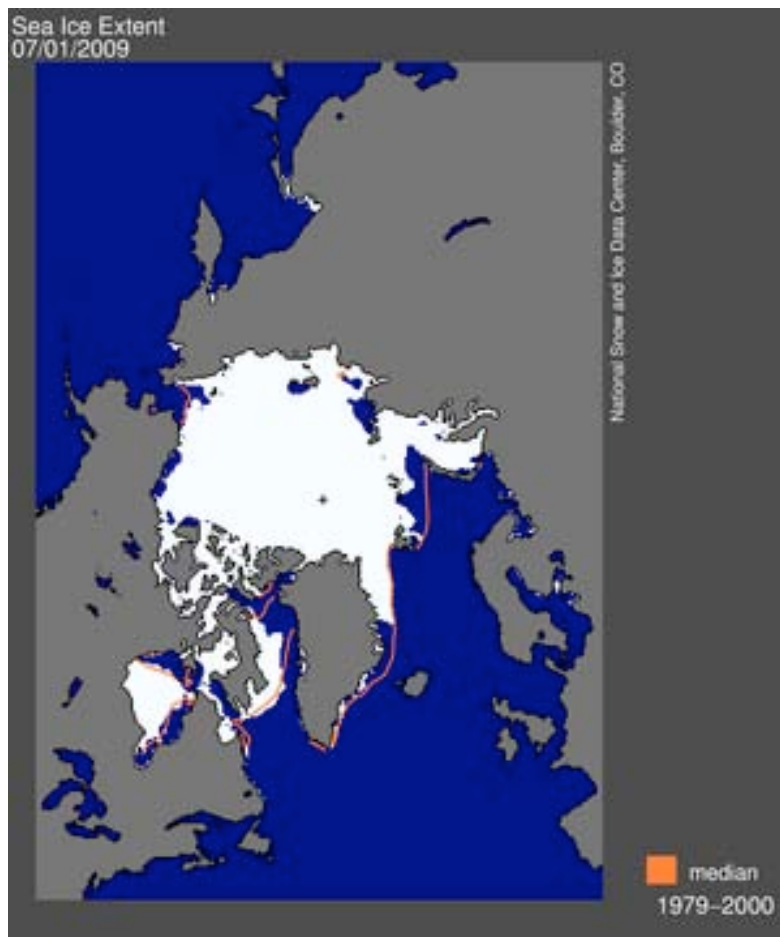

Figure 1. SST anomaly in May 2009

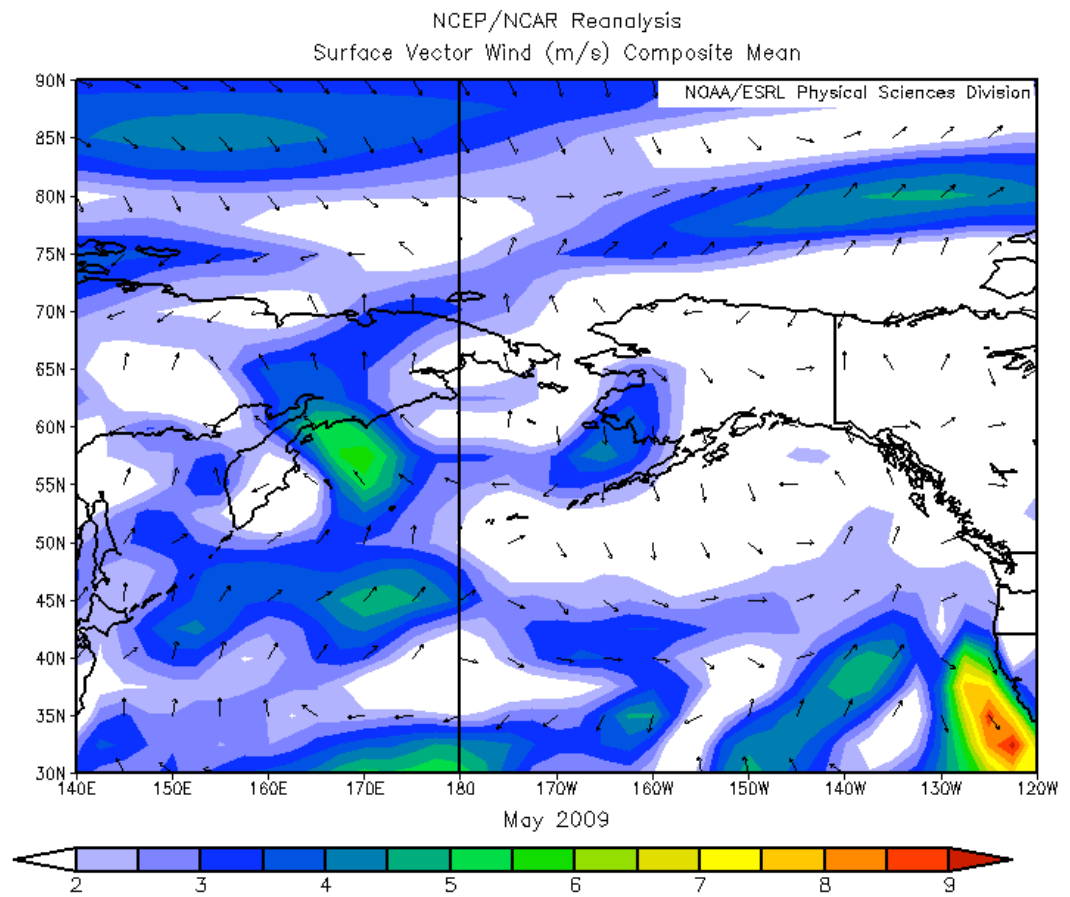Pokrovsky

Figure 2. Arctic ice extent at 01 July 2009.

Pokrovsky

Figure 3. Anomaly vector wind field in May 2009.

Pokrovsky

September 2009 Regional Sea Ice Outlook: July Report
By: Don Perovich
Region: High Arctic

As of 28 June there are 7 ice mass balance buoys deployed in the Arctic as indicated in the map below. At the start of June melting had not yet began at the sites. Early in June air temperatures rose above freezing at the two southernmost sites (2007J, 2009B) initiating surface melt. Air temperatures at the northernmost buoys gradually warmed during June and ranged between 0 and -2 C by the end of the month. Data from the NPEO buoy (2009A) show that during the month of June there was 0.1 m of snow melt at the surface, but there was still a 0.4 m deep snow cover at the end of the month. The two southernmost buoys each had 0.12 m of bottom ablation. This is a region where large amounts of bottom melt were observed in both 2007 and 2008. All the other buoys showed modest growth during June of a few centimeters.

Perovich
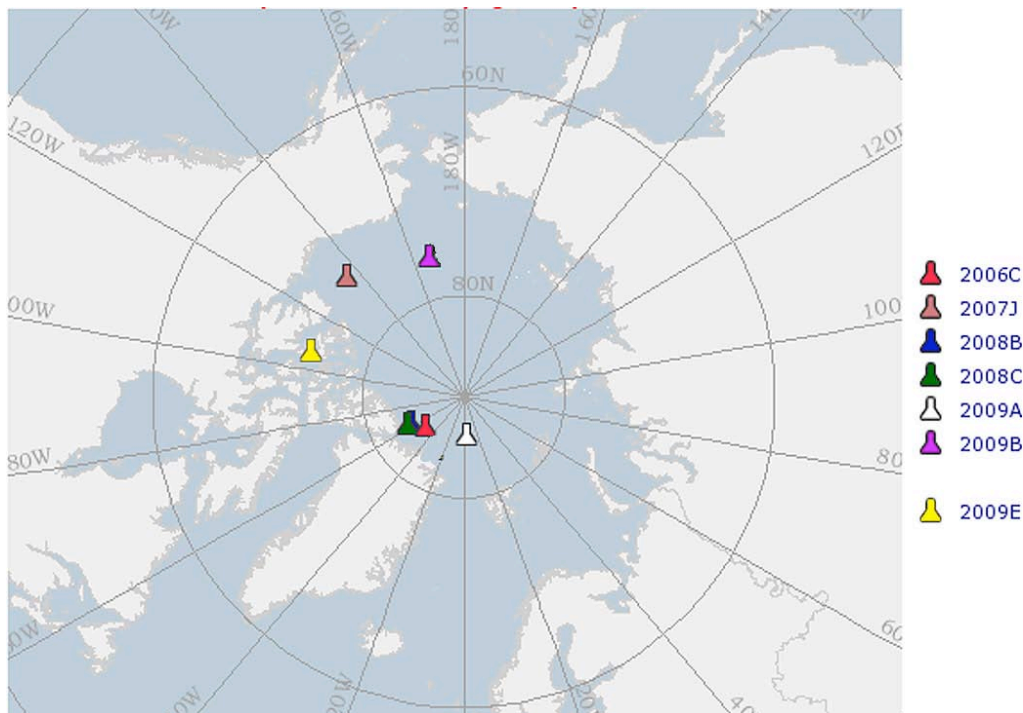
September 2009 Regional Sea Ice Outlook: July Report
Regional: Beaufort and Chuckchi Seas, High Arctic, and Northwest Passage
By: **Charles Fowler, Sheldon Drobot, James Maslanik**

No Changes from June

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1A. Extent Projection

Predicted minimum extent based on data to date is 4.89 million sq. km. Estimated confidence interval for this estimate is +/- 0.39 million sq. km.

As noted below, the potential exists for more extensive ice loss if the large expanse of 2nd.-year ice in the central Arctic does not survive or if substantial amounts are transported northward toward the Canadian Archipelago or through Fram Strait. This is in part due to the fact that so little of the older, thicker multiyear ice exists at present in the Arctic Basin compared to previous years.

2A. Method

This estimate is based on a statistical regression model that uses passive microwave derived sea-ice concentrations, and estimates of ice age and thickness regressed against the minimum ice extents over the past 26 years. The ice age and thickness information used are derived from Lagrangian tracking of ice regions, with a different mean ice thickness assigned to each ice age category of multiyear ice, for 2nd.-year through 10th.-year ice. This is combined with a simple temperature-driven ice growth model and melt parameterization to estimate first-year ice thickness. In this implementation, "open water" is defined as less than 40% ice concentration.

3A. Rationale

The approach assumes relationships between ice disappearance and concentration, age, and thickness. In this approach, the model does not directly factor in the removal of ice due to transport. Instead, the parameters relate mostly to ice melt. To the degree that the parameters influence susceptibility to transport though, the statistical model probably captures some of these indirect affects. For example, assuming that thinner ice and/or first-year ice is more affected by ice kinematics and transport, then the model would include such effects indirectly.

A key driver for the prediction is extent of ice of different ages. Figure 1 shows our estimate of ice age at the end of April, 2009 (panel 4) along with the ice age coverage at the end of April for the three previous years. The main points to take from these maps are the relatively small coverage of the older, thicker age classes, and the extent of 2nd.-year

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ice within the central Arctic Basin. This ice is less susceptible to melt than first-year ice but still presumably more susceptible to loss than the older ice classes. In addition, our data suggest a considerable amount of first-year ice mixed in with the 2nd.-year ice in this area, perhaps predisposing the region toward greater melt and convergence. A switch to positive NAO wind patterns could also drive this 2nd.-ice northward, exposing more open water within the central Arctic Ocean, perhaps extending to the vicinity of the North Pole.
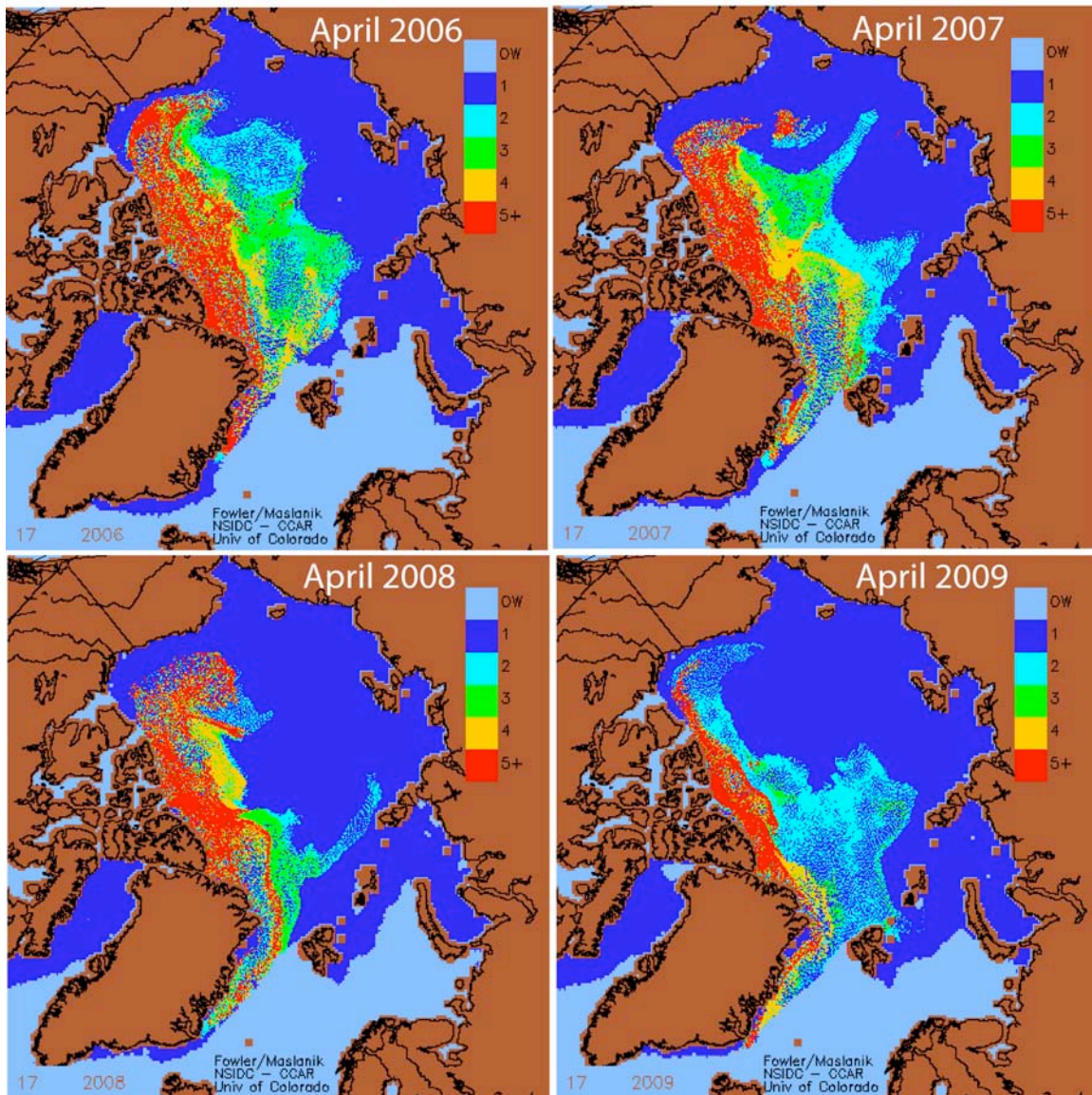

Figure 1. Estimated ice age for the end of April for 2006-2009.

1B. Estimates of Ice Conditions in Specific Regions

Two discussions are provided. The first draws from ice-pack opening dates that we have estimated for each 25km grid cell in the Arctic. Here, we limit the opening-date results to the Beaufort and Chukchi seas. The full grid of opening dates is available, but our confidence in performance for other areas is considerably less. The second discussion addresses distributions of multiyear ice of different ages and the possible effects on ice conditions through summer.

1B. 1. Opening Dates in the Beaufort and Chukchi Seas

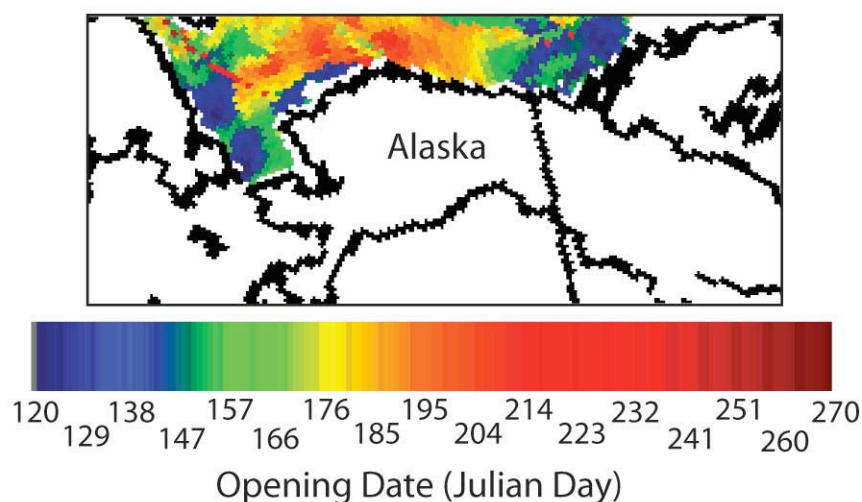Estimated opening dates are shown in Figure 2.

Figure 2. Estimated opening dates in the western Arctic.

At the time of this writing (end of May), open water has formed in the southern Chukchi Sea – reasonably consistent with the dates in Figure 2. The eastern Beaufort Sea is still mostly ice covered (albeit with reduced concentration), so our estimated opening dates for that area were too early.

1B.2. Distribution of Multiyear Ice Types

Beaufort and Chukchi seas
As indicated in Figure 1, the most recent ice age map suggests that some multiyear ice is present further south in the Beaufort Sea than during the past 2 years. However, this ice appears to be predominantly 2nd.-year ice, in contrast to previous years (including years earlier than those shown in Figure 1) when the multiyear ice in the Beaufort Sea was some of the oldest and presumably thickest ice in the Arctic Basin (as a result of ice transport from the Canada Basin and central Arctic). The mixture of 2nd.-year and first-year ice is also more diffuse than previously, so as melt progresses through summer, it seems likely that scattered, isolated multiyear floes will persist, but within otherwise open-water areas. It is also likely that the remaining 2nd.-year floes will disappear faster

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due to melt than was the case in summer 2008, when multiyear ice persisted in small bands, particularly north of Barrow. Last year's multiyear ice was likely to have been older, thicker ice though, as noted above, so this summer's multiyear ice in the area may not last as long. As in recent years, we expect that the remaining multiyear ice in the Beaufort Sea will melt out as in moves westward into the Chukchi Sea, with virtually none of this ice recirculating into the Canada Basin to replenish the loss of multiyear ice due to melt.

High Arctic (Central Arctic/Canada Basin)
Our data show the western sector of the High Arctic (along with most of the Canada Basin) region to be covered nearly entirely by first-year ice, unlike any previous spring over the 1979-present satellite record. We anticipate that most of this area will become ice free by the end of summer. The High Arctic areas adjacent to the Canadian Archipelago continue to experience reductions in coverage of the oldest ice types, with the remaining oldest ice compacted against the Archipelago coast.

The remainder of the High Arctic north of 85 deg. is covered by predominantly multiyear ice, but this ice is mostly 2nd-year ice. Based on climatological conditions though, it is unlikely that under "normal" conditions, this ice would melt out, so heavy ice may remain in this area throughout summer. The most likely scenario for a retreat of this multiyear ice edge would be if atmospheric circulation produces persistent and strong southerly winds that reduce ice extent through ice transport.

Northeast Passage
Also depending on ice transport patterns (for example, if the ice is pushed northward), the potential exists for the remaining first-year ice to melt out along the Northeast Passage. (Caution: As noted above, our definition of "open water" is an ice coverage of 40% or less. So, there may be ice present even in areas that we describe as open – a significant distinction for operations in areas that satellite products such as ours define as "open water.")

Other
More multiyear ice is present along the northeastern Svalbard coast than is typical. Ice free dates may therefore be delayed in this area, although wind patterns will probably be the main factor affecting the date due to the relatively short distances the ice edge needs to retreat to free the Svalbard coast.

2B. Methods

The opening dates are estimated by regressing the opening dates for the past 10 years against the above-described ice thickness/age conditions and 2-m air temperatures for the end of April 2009.

The discussion of the location and significance of multiyear ice types is based on the ice age data noted above.

3B. Rationale

The basis for the opening date results is the same as for the extent prediction above. For the discussion of multiyear ice, we rely on subjective interpretations of conditions in previous years and on general knowledge of ice behavior in different locations.

Outlook of 9/2009 sea ice in the Northwest Passage region from 7/1/2009

Jinlun Zhang
Polar Science Center, Applied Physics Lab, University of Washington

This outlook from July 1, 2009 shows that more of the Northwest Passage (NWP) is ice free in September 2009 (Figure 1) than the outlook from June 1 (Figure 2). The ensemble predictions are made by the Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS), which is forced by NCEP/NCAR reanalysis data and assimilates 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 2002 NCEP/NCAR forcing, member 2 uses 2003 forcing, …, and member 7 uses 2008 forcing. Each ensemble prediction starts with the same initial ice–ocean conditions on 6/1/2009. The initial ice-ocean conditions are obtained by a retrospective simulation that assimilates satellite ice concentration. Ensemble median is considered to have a 50% probability of occurrence and taken as the outlook product. More details about the prediction procedure can be found in Zhang et al. (2008) http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf.
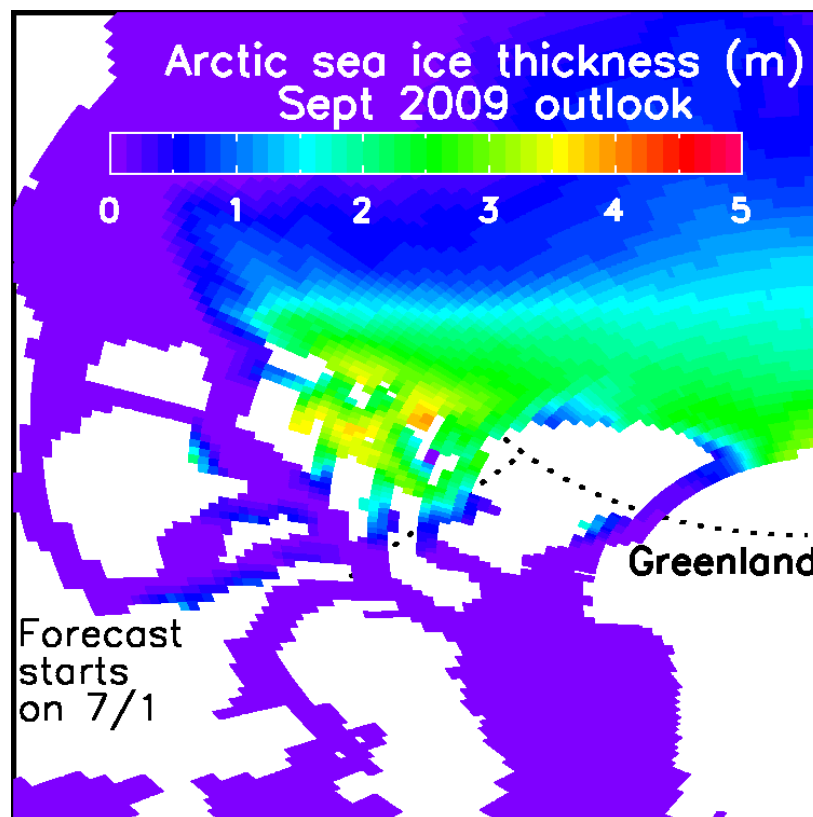
Figures 1 and 2 are compared below:

Figure 1. Ensemble prediction of September 2009 sea ice thickness in the NWP region. Prediction starts on 7/1/2009.
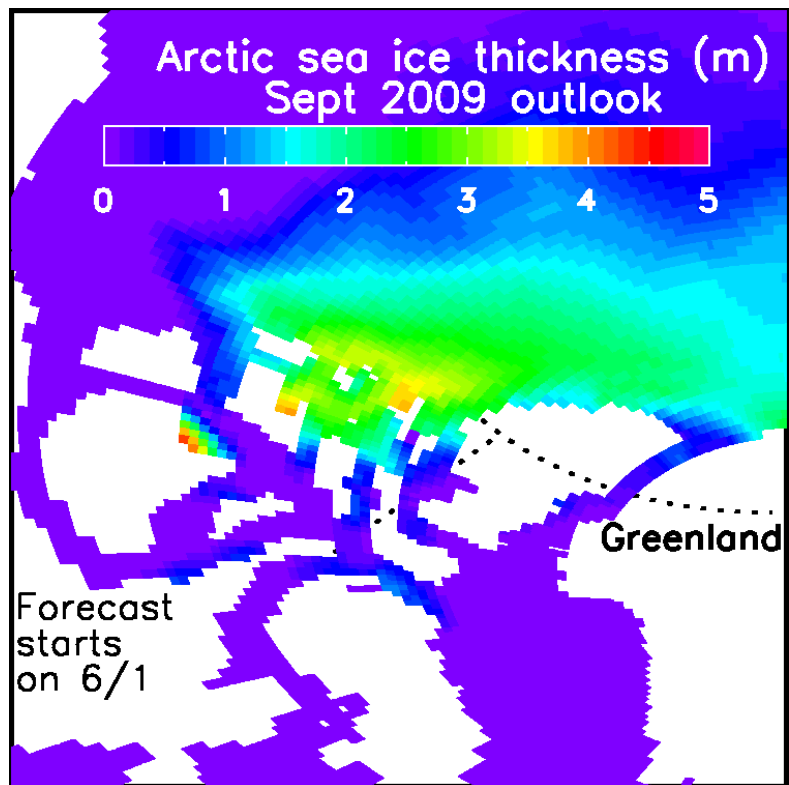
Figure 2. Ensemble prediction of September 2009 sea ice thickness in the NWP region. Prediction starts on 6/1/2009.

September 2009 Regional Sea Ice Outlook: July Report
By: Preben Gudmandsen, Ron Kwok, Andreas Muenchow, Roger Samelson, and
Jeremy Wilkinson—Friends of the Nares Strait
Region: Nares Strait, an outlet of the Arctic Ocean

Nares Strait is a narrow seaway between Ellesmere Island and northwest Greenland, which at places is only 30–50 km wide, see Figure 1. It carries substantial volumes of water and sea ice from the Artic Ocean to Baffin Bay. Estimates of volumes of flux are 0.8 ± 0.3 Sv of water and 136 km^3 of sea ice have been presented, the latter number based on an estimated average ice thickness of 4 m (Münchow et al. 2006, Kwok, personal communication, 2009).

The southwards transport of sea ice is largely controlled by the ocean current and especially the wind, that is orographically confined to the narrow strait between mountains of 1500 m and 500 m on the Ellesmere and the Greenland sides, respectively (Samelson et. al. 2006). However, the transport is also controlled by formation of ice barriers that appear at places from the Lincoln Sea to southern Kane Basin and may last for periods of weeks and months. The ice bridge that with few exceptions forms every year in southern Kane Basin is a well-known feature. The importance of the barriers is demonstrated by the observation that the flux of ice was 2.5 times larger in the year 2006–2007 when no barrier formed at all than the average flux stated above (Kwok, 2009). Admittedly, different wind conditions might also have influenced the situation.

The present year is a special case in that on 16 January 2009, an ice barrier established in Lincoln Sea north of the entrance to Nares Strait (Robeson Channel) prevented transport of the multi-year ice in Lincoln Sea southwards. Figure 1, a recent MERIS observation shows this, as well as the almost ice-free Strait south of the barrier. In the course of time, large quantities of sea ice formed just south of the barrier and drifted southwards controlled by current and wind. The automatic weather station on Hans Island (Wilkinson, J, et al. 2009) measured an average air temperature of -24.3ºC in the three-month period from 15 January to 15 April, when temperatures rose gradually to reach melting temperatures by the end of May.

During the same period the stagnant sea ice canopy in Lincoln Sea has increased in thickness. This is likely to have a bearing on the strength of the ice barrier that has practically not changed in position in the period. From changes of the signature of the sea ice surface it is concluded that surface melt began in Lincoln Sea by 17 June. An estimate of the time of break down is not possible, presently lacking important environmental parameters but also lacking a model describing the history of such barriers.

A previous case was encountered in the winter 2004–2005 when an ice barrier formed at almost the same place in Lincoln Sea at 14 November and broke down by 20 May 2005. With no information about the temperature, wind conditions, and ice properties in the period of breakdown, we may only conclude that the break-down is a result of increased warming that weakens the strength of the bridge.

However, the breakdown may have a bearing on the activities in the Strait in August this year. With a breakdown by late July, large quantities of sea ice will pass southwards in that month

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and hamper the activities that include recovery of moorings in southern Kennedy Channel, maintenance of weather stations in the region, and establishment of two new stations in addition to a number of oceanographic measurements.

References

Münchow, A., H. Melling and K. F. Falkner, 2006.
An observational estimate of volume and freshwater flux leaving the Arctic Ocean through Nares Strait.
 J. Phys. Oceanography, *36*, 2025-2041.

Samelson. R.M., T. Agnew, H. Melling and A. Münchow, 2006.
Evidence for atmospheric control of sea ice motion through Nares Strait
Geophys. Res. Lett, *33*, L02506,doi:10. 1029/2005GL025016

Wilkinson, J. M., P. Gudmandsen, S. Hanson and R Samelson, 2009.
Hans Island: meteorological data from an international borderline
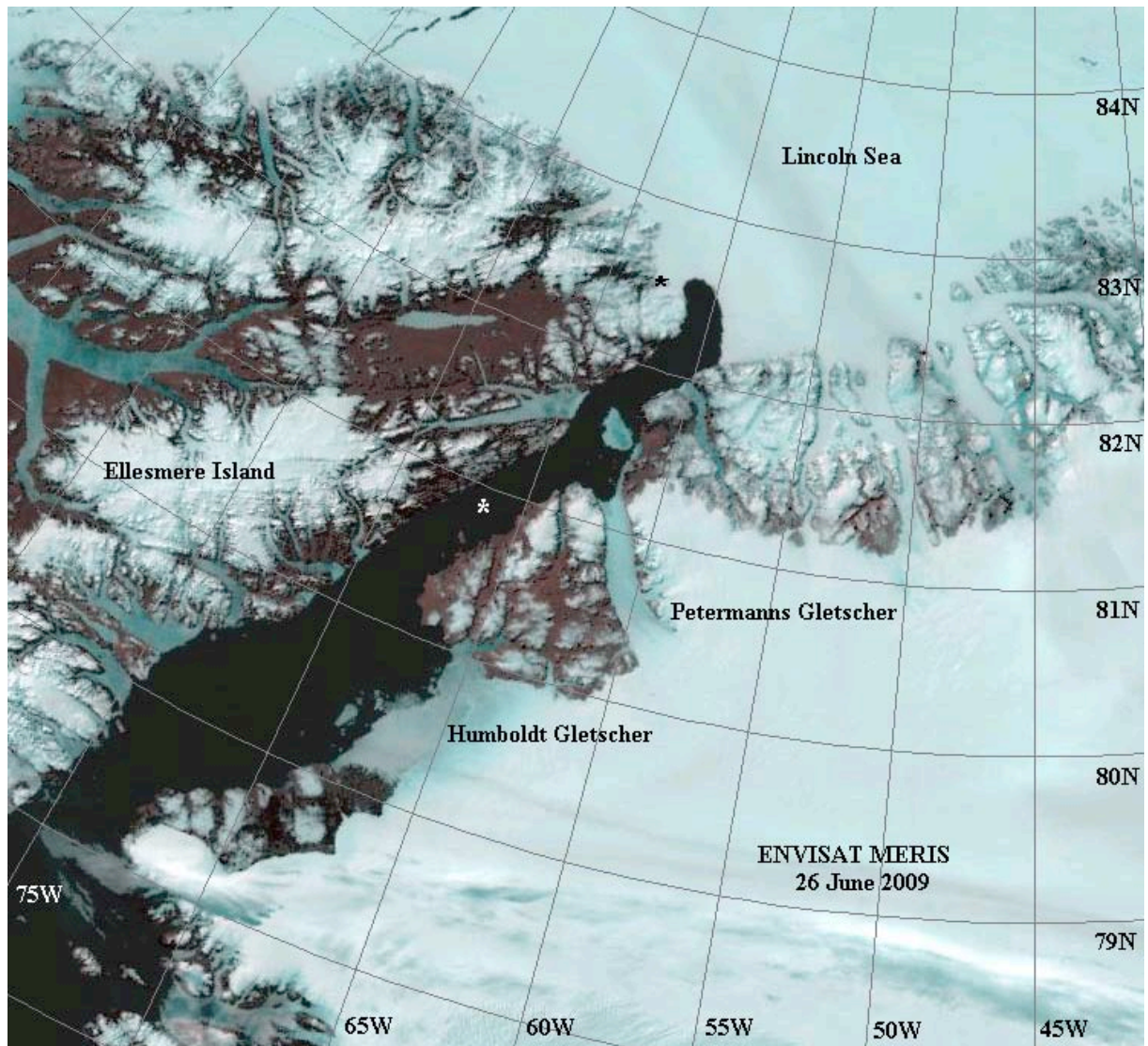EOS (in press).

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Figure 1. Region of Interest

Nares Strait between Ellesmere Island and northwest Greenland connecting the Arctic Ocean with Baffin Bay via Lincoln Sea.

The strait is divided in sections named after early explorers: from north to south, Robeson Channel, Hall Basin (with the large flow that broke off from the bay in front of Petermanns Gletscher two days before), Kennedy Channel with Franklin Island and Hans Island (asterisk), Kane Basin in front of Humboldt Gletscher and Smith Sound leading to North Water.

The black asterisk in northeast Ellesmere Island is the Canadian Station Alert.

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September 2009 Regional Sea Ice Outlook: July Report
Region: Western Parry Channel Route of the Northwest Passage
By: Stephen Howell and Claude Duguay

No Changes from June

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Estimate of Ice Evolution

Multi-year ice (MYI) conditions are much lighter than normal as the melt season begins in Western Parry Channel region of the Northwest Passage (Figure 1). The amount of MYI is just less than 2008 and even less than 2007 (Figure 2), when the region cleared for the first time during the satellite era. However, light ice conditions at the start of the melt season are not a precursor to complete clearing – 1999 and 2008 are evidence of this (Figure 1). It is also important to note that 2008 was the longest melt season on record within the Canadian Arctic Archipelago but a long melt season by itself is not sufficient to completely clear the Northwest Passage (Howell et al., 2009). This is because seasonal first-year ice (FYI) in the region can survive the melt season and ii) more seasonal FYI in the Western Parry Channel facilitates a steady flux of MYI through Byam-Martin Channel from the Queen Elizabeth Islands.

Although 2009 contains less MYI than 2008 at the start of the season, the spatial distribution is different (Figure 1; Figure 2). For 2008, the FYI broke-up south of Byam-Martin Channel early in the season, but by doing so allowed for MYI from the Queen Elizabeth Islands to continually flow into the Western Parry Channel. As the melt season gets underway for 2009, high MYI concentrations immediately south of Byam-Martin Channel will likely delay breakup in the region compared to 2008. When the ice within the Western Parry Channel eventually does become mobile, large flows of MYI present in Byam-Martin Channel and the Queen Elizabeth Islands are poised to be flushed into the region. As a result, it seems likely that 2009 MYI conditions within the Western Parry Channel during the season maybe 'less' than normal but this will not result in the clearing of the Northwest Passage for 2009.
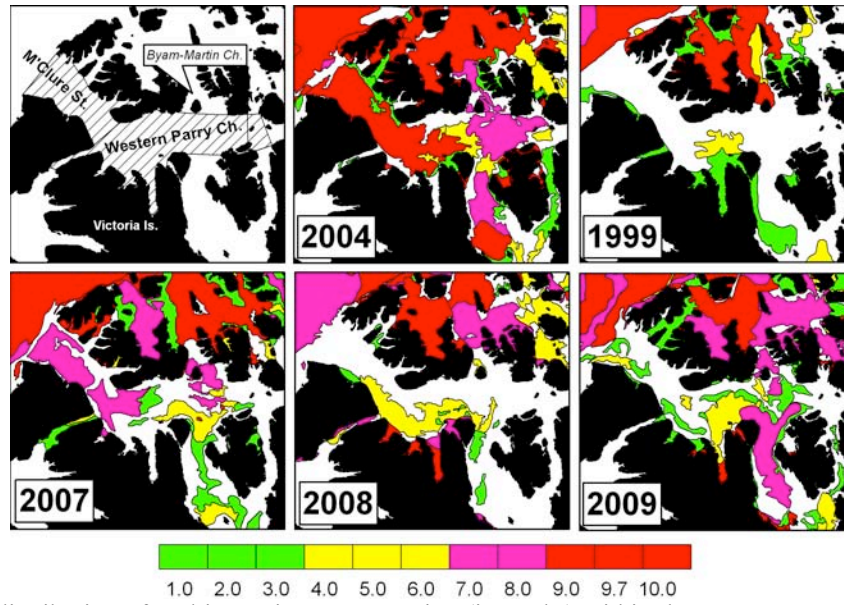
Figure 1. Spatial distribution of multi-year ice concentration (in tenths) within the Western Parry Channel region of the Northwest Passage on May 15th for a heavy ice year (2004), a light year ice (1999) and the last three years.
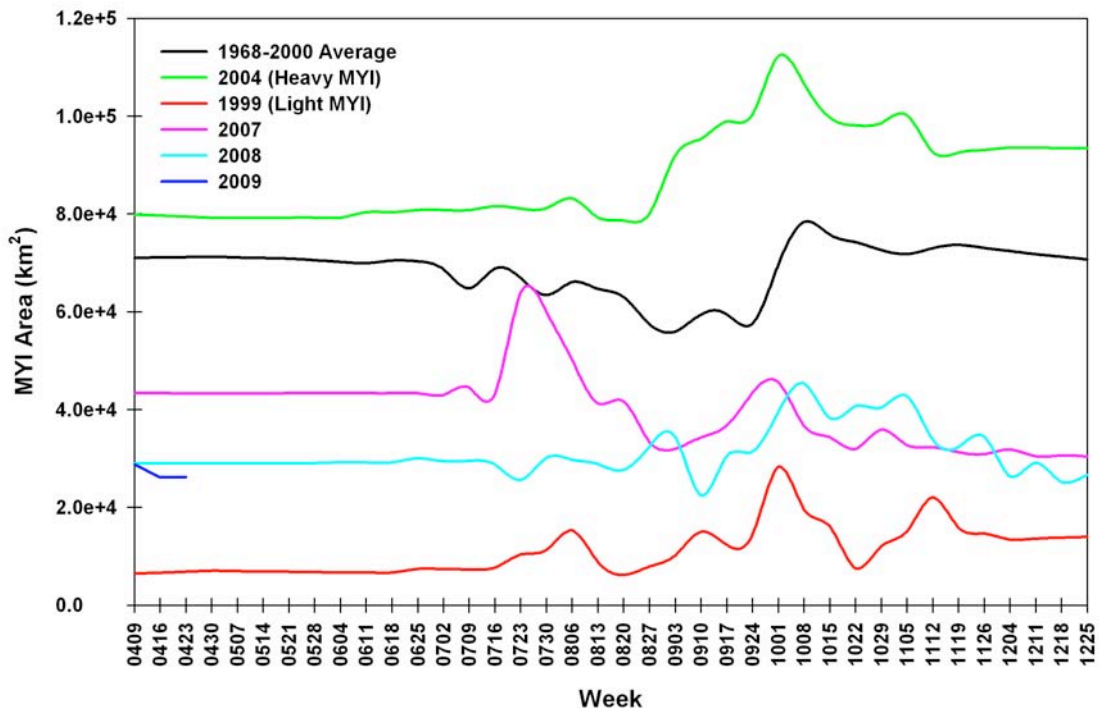

Figure 2. Time series of the evolution of multi-year ice area within the Western Parry Channel region of the Northwest Passage.

Reference
Howell, S. E. L., C. R. Duguay, and T. Markus (2009), Sea ice conditions and melt season duration variability within the Canadian Arctic Archipelago: 1979–2008, *Geophys. Res. Lett.*, 36, L10502, doi:10.1029/2009GL037681.

Howell and Duguay

September 2009 Regional Sea Ice Outlook: July Report*
By: Sebastian Gerland and Harvey Goodwin
Region: Greenland Sea and Barents Sea
*Based on data until the end of June 2009

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a. Sea ice extent, based on satellite data (passive microwave)

Monthly mean sea ice extent (30% concentration threshold) is compared with the corresponding monthly mean for June (Fig. 1) and May (Fig. 2) for the record minimum year 2007, and with 30, 20, and 10 year averages for monthly means for the periods 79-08, 80-99 and 99-08. The sea ice systems in the Greenland Sea and Barents Sea are substantially different. Sea ice in the Greenland Sea is (see e.g. Vinje et al. 1998) dominated by ice drifting with the transpolar drift and the East Greenland current out of the Arctic Basin southwards, whereas sea ice in the Barents Sea (see e.g. Vinje and Kvambekk 1991) consists to a high degree of seasonal ice formed in the same area during the past winter.

In the northern **Greenland Sea** ice extent appears roughly similar for all calculated means (Fig. 1). However, in the south (south of Scoresby Sund (Greenland) in the Denmark Strait, between Iceland and Greenland) the ice edge for June 2009 is located further north than ice extent for 2007 and for all 10- and 20-year averages calculated. In the central Greenland Sea, the 2009 June extent shows more ice than the last decade (99-08) average. In the Fram Strait all ice edges are very similar. One may note that polynyas are appearing in June 2009 and 2007 at different locations.
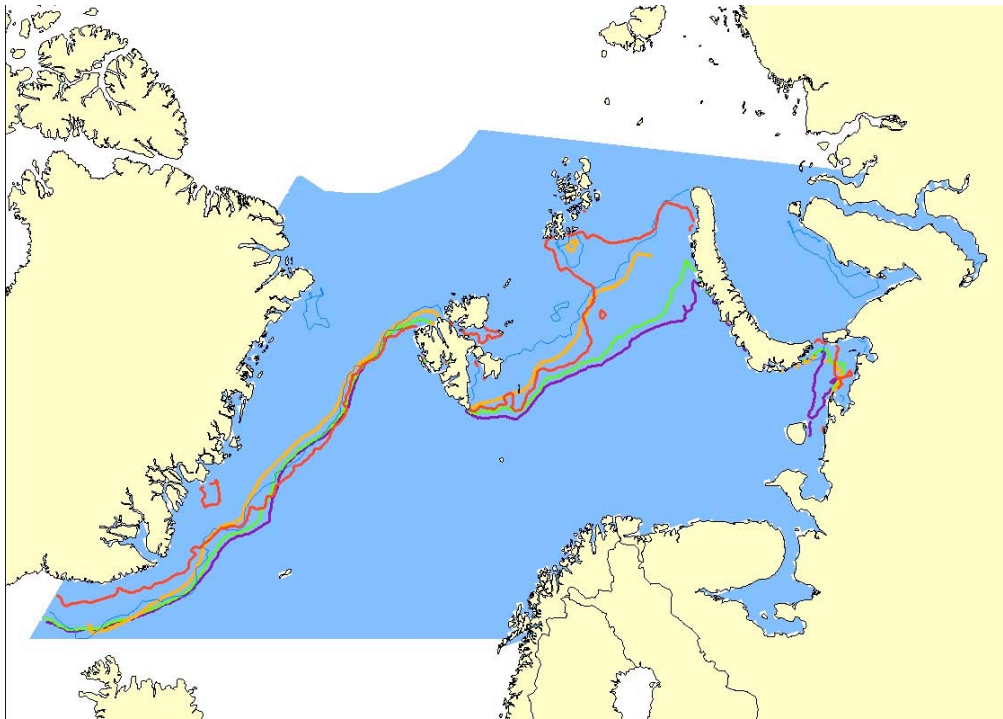
Gerland and Goodwin

Figure 1. Ice extent (monthly means, June) southern border of 30% ice concentration, in the Greenland Sea / Fram Strait and Barents Sea, based on passive microwave satellite data (red = June 2009, orange = mean June 1999-2008, green = mean June 1979-2008, purple = mean June 1980-1999). The thin blue line indicates the ice extent for June 2007.

Compared with the Greenland Sea, the sea ice extent in the **Barents Sea** shows more variability between individual years and also between 10, 20 and 30 year averages for June, especially for the eastern part. As known from Barents Sea monitoring studies (Gerland et al. 2009), the inter-annual variability of the position of the ice edge in spring and autumn is high, but shows a clear negative trend since 1979. In June 2009, ice extent was substantially less than the 10, 20 and 30 year averages in the north eastern Barents Sea (area between Franz Josef Land and Novaya Zemlya), whereas it was relatively similar to the mean extents in the north western Barents Sea, east of Svalbard. Interestingly, the 2007 June sea ice extent shows an opposing pattern west and east in the Barents Sea compared with June 2009. In the west, ice extent was less in 2007, and in the east the ice extended further south than in 2009. The fact that open water extended in June 2009 all the way to Franz Josef Land is interesting, and this could ease the warming of surface water masses, which as a part of a feedback process can increase the speed of ice melt.
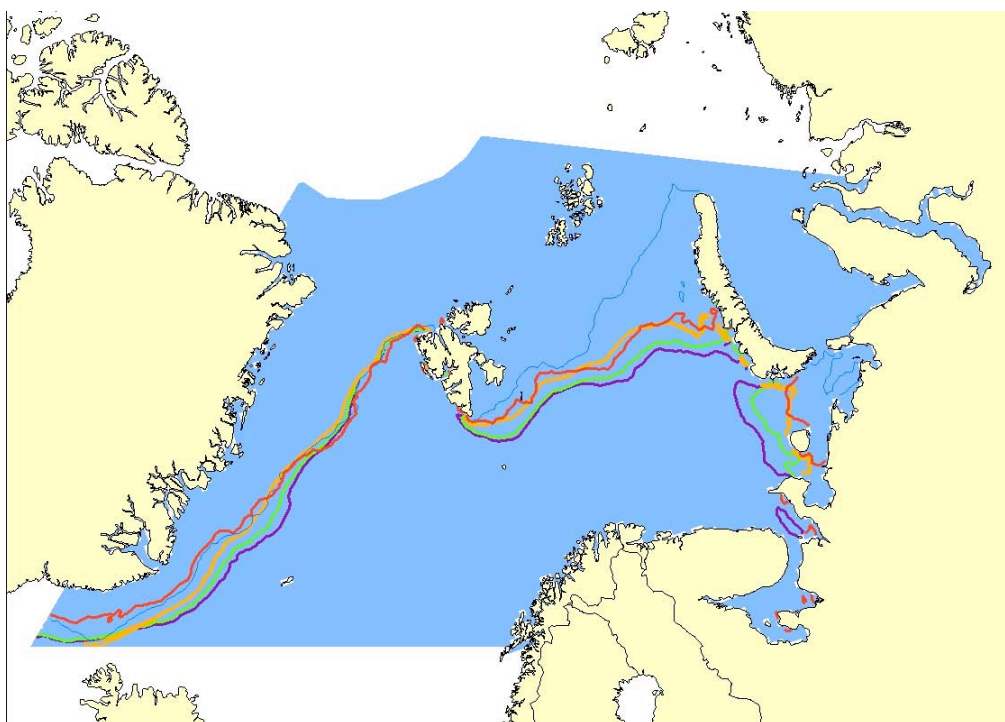
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Figure 2. Ice extent (monthly means, May) southern border of 30% ice concentration, in the Greenland Sea / Fram Strait and Barents Sea, based on passive microwave satellite data (red = May 2009, orange = mean May 1999-2008, green = mean May 1979-2008, purple = mean May 1980-1999). The thin blue line indicates the ice extent for May 2007.

The situation was different one month earlier, in May 2009 (Fig. 2): Then, the ice edge position was fairly similar to the means from the past decade (99-08). In the Barents Sea, especially in the eastern part, May 2007 and 2009 differ strongly. The difference in the picture for May and June (ice edges relative to each other) could relate to specific weather patterns, but it could also be related to different ice thicknesses in May ice relative to earlier years, corresponding to faster melting of Barents Sea ice in the eastern part compared to other years.

b. Sea ice extent and thickness at selected sites (Svalbard)

As a part of fast ice monitoring activities of the Norwegian Polar Institute, the ice near three Svalbard sites was observed in situ during the 2008/09 winter.

Since punctual ice thickness information can be strongly biased by local conditions, we do not discuss how these thickness observations might indicate the sea ice development in summer 2009 on a larger spatial scale. However, since ice thickness information is generally sparse, we give a brief summary of our 2009 *in situ* data. Kongsfjorden is located on the north western coast of Spitsbergen, Storfjorden on the eastern coast of Spitsbergen, and Hopen is an island in the north western Barents Sea. The monitoring setups and earlier data are described in Gerland and Renner (2007) and Gerland et al. (2008).

Early in 2009, **Kongsfjorden** had a larger fast-ice extent than the previous three winters (2006-08), when fast ice extent reached exceptional minimums in this fjord. The ice extent was more similar to years between 1997 and 2005, but its seasonal maximum thickness was with 0.52 m less than observed before 2006 (Gerland and Hall 2006).

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Storfjorden fast ice is usually thicker than Kongsfjorden ice, since it is not directly influenced by Atlantic water from the West Spitsbergen Current. The seasonal maximum fast ice thickness at a monitoring site in Inglefieldbukta the past winter was 1.37 m.

Hopen fast ice varies greatly inter-annually, overlaying a clear negative trend since observations started in 1966 (Gerland et al. 2008). In the past winter 2008/09, an ice thickness maximum of more than 1 m was measured twice. However, the coast at Hopen is less protected and the fast ice was removed twice during the winter by wind and currents. Hopen sea ice can also be dynamically influenced (ice advection and rafting/ridging).

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