September 2010 Regional Sea Ice Outlooks: July Report

Community Contributions
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2010 Regional Sea Ice Outlook for Greenland Sea and Barents Sea
July Contribution

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The monthly mean sea ice extent for June 2010 based on Norwegian ice charts produced primarily from passive microwave satellite data, supplemented with high resolution SAR imagery from 2007, is compared with the corresponding monthly mean for June for the previous years 2007-09 (Fig. 1), and with 30, 20, and 10 year averages for monthly means for the periods 79-08, 80-99 and 99-08 (Fig. 2).

For more details on the regions, see the corresponding report from the previous month (May data) and references given in there.

In the Greenland Sea, in general the sea ice extent in June 2010 differs only little from the previous years, and intercomparisons with the different means over 1-3 decades do not show substantial differences. The extent now in June 2010 is slightly larger in the south and slightly less in the north (Figs. 1 and 2).

In contrast, sea ice extent in the Barents Sea varies more both between years and with the decadal means. Most prominent, the area between Svalbard and Franz Josef Land had significantly less sea ice in 2010 compared with the past 3 years (June means, Fig. 1). A relatively large area south of Franz Josef Land was ice free in the June 2010 mean sea ice extent. This was ice covered in all years 2007-2009, and it also appears ice covered in the 1-3 decadal means shown in Fig. 2.

Compared with the previous month (May data), the situation relative to earlier years appears similar for the Greenland Sea. In the Barents Sea, differences with earlier years are largest in the north-western Barents Sea, whereas in May changes were largest in the north-eastern Barents Sea.
Fig. 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 2010, orange = June 2009, green = June 2008, blue = June 2007).

Fig. 2: 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 2010, orange = mean June 1999-2008, green = mean June 1979-2008, purple = mean June 1980-1999).
2010 Regional Sea Ice Outlook
July Report

Preben Gudmandsen
Danish National Space Institute
Technical University of Denmark

Lincoln Sea and Nares Strait

Figure 1 is an Envisat ASAR scene acquired on 30 June 2010 16:40 showing the ice conditions in the Lincoln Sea and the Nares Strait with few vectors representing floe movements during the 48.7-hour interval between two acquisitions. Movements range from 10 – 45 km in the Lincoln Sea to 120 km in the Kennedy Channel. [The figure illustrates the difficulty in safely recognising 'markers' in the two scenes applied due to melting surfaces]. The relative fast movements of 2.5 km/hour (65 cm/s) in Kennedy Channel is the result of strong northern winds during the preceding days increasing from 8 to 11 m/s to reach 15 m/s during the first 20 hours of the period. Temperatures were at 2°C to 3°C.

Studies of the winter 2009-10 showed moderate in-flux of multiyear ice from the Arctic Ocean from northwest and northeast as well as from north in periods. Furthermore, an ice barrier formed twice near the entrance to the Nares Strait, once in January and later in March with durations of 6 days and 55 days, respectively. With monthly average temperatures ranging from -20°C to -13°C in March and April thickening of the residing ice has taken place at an unknown amount.

The ice concentration in Lincoln Sea is close to 100% with a concentration of multiyear ice at 45%, see Figure 1. With temperatures at about +5°C increasing with time substantial surface melt and disintegration will take place during the drift through the Nares Strait. Observations of winds in 2008 and 2009 show generally low winds at 10 m/s and lower during the month of July but with southern winds in about 70% of the month at monthly average air temperatures of 3.4°C and 5.4°C, respectively. With similar conditions this year the flow rate will be low and if air temperatures increase as before the overall judgement tells that the amount of ice – multiyear and new ice – from the Lincoln Sea that enters North Water south of the Nares Strait in July will be small, somewhat compensated by the first-year ice that has been in the process of breaking off in the Kane Basin during the past June, see Figure 1.
Winds and temperatures are measured at 177 m a.s.l. by an Automatic Weather Station installed on Hans Island in the centre of Kennedy Channel on 4 May 2008. The data are half-hour averages. The average monthly temperature in July 2009 was 1.8°C higher than in July 2008.
SEARCH Regional Sea Ice Outlook 2010 July Report
Region of Interest: Western Parry Channel region of the Northwest Passage
By: Stephen Howell (Stephen.Howell@ec.gc.ca) and Tom Agnew (Tom.Agnew@ec.gc.ca)
Climate Research Division, Environment Canada

Clearing of the Northwest Passage:
As the melt season begins in the Western Parry Channel region of the Northwest Passage, multi-year ice (MYI) conditions are well below the historical 1968-2000 average (Figure 1; Figure 2). What’s more is that they are only slightly above the record low conditions of 1999 and less than 2007 when the region cleared for the first time during the satellite era (Figure 2). However, light ice conditions at the start of the melt season within the Western Parry Channel are not a precursor to complete clearing – 1999, 2008 and 2009 are evidence of this. The spatial distribution of MYI in the surrounding regions and the flux of MYI from Queen Elizabeth Islands into the region are both vital to its clearing. Given these factors and particularly the spatial distribution of MYI in the M’Clintock Channel (Figure 1) it seems the region will not clear during 2010.

Method:
The method is based on the distribution of MYI at the start of the melt season. Since MYI is harder to melt than first year ice, much of MYI will likely survive the melt season and cause difficulties for marine transportation. This of course will also depend on the severity of the summer melt so the forecast is updated each month based on the previous month’s distribution of MYI. There are key locations in the Canadian Arctic Archipelago where the presence of MYI will make it more likely that Northwest Passage routes will be blocked with ice.

Rationale:
If MYI concentrations are high in the M’Clintock Channel this limits the flux of MYI from the Queen Elizabeth Islands but it also means less sea ice will be transported southward hence, concentrations remains high in the central Western Parry Channel during the melt season – this was the case in 2009. Conversely, if the M’Clintock Channel contains little MYI then sea ice can be transported southward but the flux of MYI from the Queen Elizabeth Islands directly across the Western Parry Channel increases – this was the case in 2008. Indeed, there is very little MYI present in the Western Parry Channel but within the M’Clintock Channel, MYI conditions mirror the 1968-2000 historical average (Figure 3). The latter will likely delay breakup in the central region of the Western Parry Channel in a similar process to 2009.
Figure 1. Spatial distribution of multi-year ice (in tenths) within the Western Parry Channel region of the Northwest Passage on May 1st for a heavy ice year (2004), a light year ice (1999), clearing year (2007), last year (2009), and 2010. Data is from the Canadian Ice Service.

Figure 2. Time series of the evolution of multi-year ice (MYI) for selected years within the Western Parry Channel. Data is from the Canadian Ice Service.
Figure 3. Time series of the evolution of multi-year ice (MYI) for selected years within the M’Clintock Channel. Data is from the Canadian Ice Service.
Predictions of Alaskan Summer Ice Conditions, July Report

R. Lindsay and J. Zhang
Polar Science Center
University of Washington, Seattle

Here is our outlook for the Barrow navigation season from the end of May and now the end of June:

<table>
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All of the measures show a more open season than what was predicted last month because of the rapid thinning of the ice simulated by the PIOMAS model. It remains to be seen if this rapid thinning is actually observed. The date of the start of navigation was predicted to be 3 July last month and 20 June this month, yet there is still ice seen in the MODIS image of 9 July around Point Barrow, so already our forecast is blown. Obviously much of the variability is due to changing summer winds which our method cannot predict, yet there is still a high correlation between many of the measures and the output of the model. For reference I'll put the correlation table in again, the same as I submitted last month:
Predictor fields: IC = ice concentration,
   G1.0m = area fraction of open water and ice less than 1 m thick
   G0.4m = area fraction of open water and ice less than 0.4 m thick
1. Extent Projection

Our overall projection for minimum ice extent remains unchanged from last month. That estimate is that the end-of-summer ice extent will be $4.5 \times 10^6 \text{ km}^2$, with the possibility of $3.8 \times 10^6 \text{ km}^2$ depending on atmospheric circulation.

2. Methods/Techniques

The following is based on subjective analyses based on various data sets and historical patterns. This includes assessment of U. of Colorado satellite-derived (Lagrangian drift) sea ice age and ice drift in the context of conditions in previous years, along with review of atmospheric fields and a variety of other data sets.

3. Rationale

Our projection is based on the following rationale:

Comparing our latest ice age data (for 21 June 2010; left) to current (14 July) ice extent data shows that the pack edge has retreated back to the multiyear ice edge in the eastern Arctic and in the Beaufort and Chukchi seas. (It is important to emphasize that since we use a 40% concentration cutoff, this means that ice still could be present in areas where we show “open water” in these maps.) Further retreat may therefore be delayed in those areas, which might account for the decrease in the previously rapid rate of ice loss seen in the total ice extent plot on NSIDC’s Sea Ice Index page. Ice remains extensive in the East Siberian and Laptev seas, consistent with wind patterns that have favored westward and southward drift into those areas during June. Over the first part of July however, low pressure has become more dominant in the central Arctic, which could set up northward drift along with warm air transport in those areas. This pattern would be consistent with mean pressure fields for July-September. The result could be a rapid retreat of the first-year ice cover in the Siberian seas and Canada Basin and
accelerated decrease in total extent. We still anticipate some retreat of the second-year (light blue) ice in the central Arctic and persistence of the older ice into late summer.

Beaufort and Chukchi seas:

As noted in the pan-Arctic outlook discussion, the 40% concentration ice edge has retreated to the edge of the band of the several-year-old multiyear ice in the Beaufort and Chukchi seas. Since our data show this multiyear ice as being close to shore near Barrow, it is likely that ice will persist in that area relatively late into the melt season. Some offshore, northward drift of this strip of ice is likely, particularly in the Chukchi Sea if typical summer circulation patterns occur.

We anticipate that the ice further north, beyond the oldest ice (yellow and red) will melt out first, perhaps leaving a narrow strip of multiyear ice but with a semi-enclosed "polynya" opening up in the western Canada Basin.

East Siberian and Laptev seas:

As noted above, we think it likely that the first-year ice persisting in these areas will melt or retreat rapidly through the rest of July and August.

4. Executive Summary

We anticipate that the end-of-summer ice extent will be $4.5 \times 10^6$ km$^2$. A larger decrease to $3.8 \times 10^6$ km$^2$ is possible depending on atmospheric circulation patterns. Ice extent is likely to retreat rapidly in the East Siberian and Laptev seas, with thick multiyear ice persisting in the southern Beaufort Sea and eastern Chukchi Sea. Overall, we expect the loss of ice extent to accelerate, following the slow-down seen over the last few weeks.
2010 REGIONAL SEA ICE OUTLOOK
July Report

Petrich, Druckenmiller, Eicken
Geophysical Institute, University of Alaska Fairbanks

1. Region of Interest:
Chukchi Sea at Barrow, Alaska.

2. Sea Ice Parameter

Break-up date of landfast ice at Barrow, Alaska

URL: http://seaice.alaska.edu/gi/observatories/barrow_breakup

An operational break-up forecast was performed based on insolation measured and forecasted over a two-week period. It was assumed that break-up would take place in a way similar to previous decades, i.e. grounded pressure ridges hold rubble and level landfast ice in place until the latter starts to disintegrate from melt due to solar radiation. The research station at NARL, North of Barrow, served as reference location for the forecast. Measured and forecasted insolation indicated early on that break-up should happen about 5 days earlier this year than in 2009, i.e. around July 5. Break-up in 2009 – on July 11 – was among the latest observed in the last 10 years. However, landfast ice was insufficiently grounded in 2010 and broke out in discrete floe fragments before it could melt in place. South to North from Barrow to Point Barrow, ice broke out on June 25, July 4, and July 8 at downtown Barrow, NARL, and Point Barrow, respectively. Tentative investigations indicate that the break out events appear to be associated with low sealevel pressure (June 25 and July 4) and wind direction and speed (July 8). Break-up as a series of discrete break-out events was also observed in 2003, 2004, and 2007. Of the years with break-out, break-out in 2010 took place one to three weeks later than in previous years.

3. Outline of Methods / Techniques

The degree of grounding of landfast ice was assessed from observations of pressure ridge thickness derived from ice thickness measurements and estimates based on sail heights. Observation of ice near-shore ice movement (i.e. break-up) was based on webcam, coastal RADAR, local observers, and satellites. Insolation was measured with a Kipp-Zonen radiometer (courtesy ARM), estimated based on NOAA cloud cover observations, and forecast for 16 days based on a GFS/WRF weather forecast (Zhang and Krieger).
4. Estimate of Forecast Skill

The operational break-up forecast was consistent to +/- 2 days for up to two weeks in advance and consistent to the day up to one week prior to the final break-up prediction. However, while it was assumed that near-shore ice would break up by moving along the coast in response to partial melting of level ice and winds, it actually broke out in floe fragments probably in response to bottom melt of pressure ridges, sealevel fluctuations, winds and currents. The proximity of forecast break-up date at NARL (July 5) and observed break-out at NARL (July 4) is likely coincidence.

![Graph showing forecast and observed break-up dates](image)

Forecast break-up date (red dots) based on insolation measurements (wide, green bars), estimates based on cloud observations (narrow, purple bars), and weather forecast (black lines). Black triangles indicate that break-up was expected beyond the reach of the forecast. Only break-up forecasts based on 00:00Z weather forecast runs are shown.

5. Improving Outlook Detail and Accuracy

A more suitable quantification is needed of the degree to which landfast ice is grounded. Since the ice broke out rather than melt in place, the quality of the thermodynamic component cannot be assessed this year.
2010 PAN-ARCTIC OUTLOOK  
JULY REPORT

Prepared by Oleg Pokrovsky  
Main Geophysical Observatory, Russia

1. Extent Projection  
Sea ice projection for the September monthly mean arctic sea ice extent – 4.9 (in million square kilometers)

2. Methods / Techniques  
Statistical analysis of the AMO, PDO and AO time series based on specific regression model

3. Rationale  
Substantial bias in previous sea ice projection for the September was obtained because of principal change in atmospheric circulation over Asia and Eastern part of European Russia, which was found in recent monthly SLP fields (fig.1). It is in contrast to Jan-Apr average wind field (fig.2). Southward flow direction was turned in Northward. The reason of this change is related to increasing of SST in North-East Atlantic domain (fig.3) and development of considerable SLP low anomaly. As a result hot air masses from South Asia and Africa have arrived in Siberia and Russian Arctic (fig.4). Relatively thin ice cover will be subjected to rapid melting due to the SAT substantial increasing in Russian Arctic and in North East of Canada.

4. Executive Summary  
Future SIE estimates in Arctic might be obtained by joint analysis of time series of three climate indicators: AMO, PDO, AO for last thirty years. I used a modified regression analysis approach.
Figure 1. May-June SLP field
Figure 2. Jan-April vector wind field
Figure 3. May-June SST field
Figure 4. May-June SAT field
Sea Ice Outlook for September 2010 (July Report Based on June Data)

Ignatius G. Rigor¹, Son V. Nghiem², Pablo Clemente-Colón³
¹Polar Science Center, Applied Physics Laboratory, University of Washington (UW)
²Jet Propulsion Laboratory, California Institute of Technology
³Naval/National Ice Center

1. Extent Projection

5.4 million sq. km. We estimate that the September 2010 mean sea ice extent will remain below the mean September sea ice extent (1979 – 2009).

2. Methods and Techniques

This estimate is based on the prior winter AO conditions, and the spatial distribution of the sea ice of different ages as estimated from a Drift-age Model (DM), which combines buoy drift and retrievals of sea ice drift from satellites (Rigor and Wallace, 2004, updated). The DM model has been validated using independent estimates of ice type from QuikSCAT (e.g. Fig. 1 left; and Nghiem et al. 2007), and in situ observations of ice thickness from submarines, electromagnetic sensors, etc. (e.g. Haas et al. 2008; Rigor, 2005). For this analysis, we used the NCEP operational SIC analysis to determine which areas of sea ice survived in Sept. 2009, but the Bootstrap SIC analysis for previous years.

3. Rationale

Figure 1 shows the estimated age of sea ice this spring. The average age of sea ice has been increasing since the record minimum ice extent in September 2007. There is more second year ice this spring, compared to last spring. This increase in the basin wide average age of sea ice was a result of extremely low Arctic Oscillation (AO) conditions during the winter of 2009/2010 (L’Heureux et al. 2010, and www.cpc.noaa.gov), which sequestered sea ice the larger Beaufort Gyre (e.g. Fig. 2; and Rigor et al. 2002), and compacted sea ice into the East Siberian Sea. However, these conditions are still far younger and thinner than the condition of sea ice prior to the 1990’s, and it would take a few years of similar conditions to allow sea ice to recover (Rigor 2005).

Regionally, we expect alternating areas of faster and slower retreats of sea ice due to the extreme low AO conditions during the past winter. Figure 2 shows the regression map of summer sea ice concentration and winter ice motion on the winter AO index. Note that the areas where sea ice extent is currently retreating (e.g. Banks Island, west of Barrow, and east coast of the Laptev Sea), are areas of much younger, thinner first-year ice where the low AO conditions blew sea ice away during the past winter. We realize that the current sea ice extent is 0.5 million sq. km. below the pace of 2007, but we also note that much of these decreases are primarily in the lees of the coast and fast ice, where the younger, thinner sea ice simply does not
have enough mass to survive the onset of summer. In the East Siberian Sea and east of Barrow, where sea ice has been packing into the coast we expect sea ice to hold out longer and thus slow the overall retreat of Arctic sea ice extent.

4. Executive Summary

Our outlook based on June data has not changed from May. As hypothesized in our outlook based on May data, the retreat of sea ice extent has slowed and is now behind the pace of the record minimum in 2007. The winds during the past two weeks have reversed the flow of the buoys and sea ice in the Beaufort Gyre and Transpolar Drift Stream, slowing export, and sequestering sea ice in the Arctic (Fig. 3). We continue to expect the September sea ice extent just above the minimum in 2009.

Figures

**Figure 1.** Maps of Arctic sea ice distribution based on QuikSCAT (QS) for March 2009 (left), and the age of sea ice based on the Drift-Age Model (DM) for each March 2009 and March 2010 (middle and right). The colors on the QS map shows perennial ice (white), mixed ice (aqua), seasonal ice (teal). The red dots on the DM maps show the current positions of buoys, while the black dots behind these show the positions of the buoys during the previous 6 months.
Figure 2. Regression map of summer sea ice concentration and prior winter sea ice motion on the prior winter Arctic Oscillation index. After low AO winters, the reds imply that sea ice concentrations should be higher in these areas, while blues imply lower than normal sea ice concentrations during the following summer. Based on Rigor et al. 2002.

Figure 3. Map of buoys drifting on the Arctic Ocean. The red dots show the current position of the buoys, while the grey tails behind these dots show how the buoys have drifted during the last 60 days. Note how the buoys in the Beaufort Gyre are drifting counter-clockwise, and near the pole they have turned away from Fram Strait driven by a deep low in Sea Level Pressure over the central Arctic. This wind and ice drift pattern slows the export of sea ice from the Arctic Ocean. Source http://iabp.apl.washington.edu.
2010 Regional Sea Ice Outlook
Data for July Report

Adrienne Tivy
International Arctic Research Center (IARC)

This outlook is a statistical forecast, which relies on empirical relationships between pre-season climate variables and the variable being predicted—in this case, September sea ice area. The 2010 forecast results are summarized in Table 1.

Pan-arctic ice area is expected to be greater than in 2009 but still remain below normal. Regionally, increases in ice area compared to 2009 are expected in the Beaufort/Chukchi Seas, the East Siberian/Laptev Seas, the Barents/Kara Seas, and the Central Arctic Ocean. Decreases in ice area compared to 2009 are expected in the Greenland Sea and the Canadian Arctic Archipelago.

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Table 1. Categorical and deterministic forecasts of September ice area for 2010; the actual ice area for 2009 is shown for comparison.

MODEL DETAILS

The pan-arctic (Figure 1, below) and regional forecasts (Figures 3 to 8, below) for September ice area were generated from simple linear regression models. This statistical approach follows work done by Drobot et al. (2006, 2003) for forecasting the Beaufort Severity Index and the September minimum ice extent.

The predictors were chosen using an automated selected scheme (Tivy et al., 2007) based in part on step-wise regression and where the maximum number of predictors is restricted to two. Predictors included in the original predictor pool are: Sea Ice (Northern Hemisphere ice concentration, Northern Hemisphere multi-year ice concentration); Ocean (Near-global sea surface temperature, ENSO, PDO); and Atmosphere (Northern Hemisphere z500, Pan-Arctic [north of 60N] SAT and SLP, teleconnection indices). Each
predictor was tested at lags ranging from 5 to 18 months. The models are trained on the 27-year period from 1981–2006. Independent forecasts were generated for 2007–2010. The 2010 forecast is expressed both categorically and deterministically (Table 1, above).

Pan-Arctic (Figure 1)
The predictor for pan-arctic (northern hemisphere) September ice area is the preceding summer (May-June-July) sea surface temperature in the North Atlantic and North Pacific close to the marginal ice zone (14-month lag), where warm sea surface temperature (SST) anomalies are associated with reduced ice area. The regression r² and cross-validated r² are 0.83 and 0.78 respectively; the categorical forecast skill over the training period is 81%. While the model overestimated ice area for the three independent forecast years (2007–2009), the categorical forecasts of below normal ice area were correct for each year.

![Figure 1. Regression-based forecast for the 2010 September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The 2010 forecast is expressed both categorically, Below Normal, and deterministically, 5.7*10⁶ km².](image)
Regional Outlooks

Six regional forecasts were completed for the following regions: Beaufort/Chukchi Seas, East Siberian/Laptev Seas, Barents/Kara Seas, Greenland Sea, Canadian Arctic Archipelago, and Central Arctic Ocean (> 85N).

Figure 2. Sea ice regions: A – Beaufort/Chukchi Seas; B – East Siberian/Laptev Seas; C-Barents/Kara Seas; D- Greenland Sea; E- Canadian Arctic Archipelago; F- Central Arctic Ocean (>85N).
**Beaufort/Chukchi Sea (Figure 3)**
The main predictor is winter (Dec-Jan-Feb) air temperature over the Beaufort Sea, Alaska and the Canadian High Arctic (7-month lag), where warm surface air temperature (SAT) anomalies are associated with reduced ice area. The regression $r^2$ and cross-validated $r^2$ are 0.79 and 0.69 respectively; the categorical forecast skill over the training period is 77%. The model over-estimated ice area for the three independent forecast years (2007–2009), the model incorrectly predicted near normal years for 2007 and 2008 but correctly predicted 2009 as below normal.

![Beaufort / Chukchi Seas: Ice Area](image)

**Figure 3.** Regression based forecast for the 2010 Beaufort / Chukchi Seas September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The **2010 forecast** is expressed both categorically, **Below Normal**, and deterministically, **$5.7 \times 10^6 \text{ km}^2$**.
**East Siberian/Laptev Seas (Figure 4)**

The main predictor is summer (Aug-Sept-Oct) sea surface temperature in the North Atlantic (10-month lag), where warm SST anomalies are associated with reduced ice area. The regression r² and cross-validated r² are 0.62 and 0.56 respectively; the categorical forecast skill over the training period is 69%. While the model over-estimated ice area for the three independent forecast years (2007–2009), the categorical forecasts of below normal ice area were correct for two of the three years.

![Figure 4](image-url)  
*Figure 4. Regression based forecast for the 2010 East Siberian / Laptev Seas September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The 2010 forecast is expressed both categorically, Below Normal, and deterministically, $5.7 \times 10^6$ km$^2$.***
**Barents/Kara Seas (Figure 5)**
The main predictor is winter (Jan-Feb-Mar) sea level pressure over the Kara and Laptev Seas (6-month lag), where high sea level pressure (SLP) anomalies are associated with increased ice area. The regression $r^2$ and cross-validated $r^2$ are 0.72 and 0.65 respectively; the categorical forecast skill over the training period is 69%. The model over-estimated ice area for the three independent forecast years (2007-2009), the model incorrectly predicted near normal ice area for 2007 and 2009 but correctly predicted 2008 as below normal.

![Barents / Kara Seas: Ice Area](image)

**Figure 5.** Regression based forecast for the 2010 Barents / Kara Seas September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The **2010 forecast** is expressed both categorically, **Below Normal**, and deterministically, $5.7\times10^6$ km$^2$. 


**Greenland Sea (Figure 6)**

The main predictor is fall (Sept-Oct-Nov) sea surface temperature in the North Atlantic (9-month lag), where warm SST anomalies are associated with reduced ice area. The regression r² and cross-validated r² are 0.62 and 0.44 respectively; the categorical forecast skill over the training period is 58%. The model under-estimated ice area for the three independent forecast years (2007-2009), the model incorrectly predicted below normal ice area for 2007 and 2009 but correctly predicted 2008 as below normal.

![Greenland Sea: Ice Area](image)

**Figure 6.** Regression based forecast for the 2010 Greenland Sea September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The **2010 forecast** is expressed both categorically, **Below Normal**, and deterministically, **5.7*10⁶ km²**.
**Canadian Arctic Archipelago (Figure 7)**

The main predictor is summer (May-June-July) multi-year ice (MYI) concentration in the Beaufort Sea (14-month lag), where increased MYI concentrations are associated with increased ice area. The regression $r^2$ and cross-validated $r^2$ are 0.6 and 0.56 respectively; the categorical forecast skill over the training period is 58%. The model incorrectly predicted near normal ice area for 2007 and below normal ice area for 2009 but correctly predicted 2008 as below normal.

**Figure 7.** Regression based forecast for the 2010 Canadian Arctic Archipelago September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The 2010 forecast is expressed both categorically, Below Normal, and deterministically, $5.7*10^6 \text{ km}^2$. 
Central Arctic Ocean (Figure 8)

The main predictor is preceding spring (March-April-May) multi-year ice (MYI) concentration in the Greenland Sea (17-month lag), where increased MYI concentrations are associated with increased ice area. The regression r2 and crossvalidated r2 are 0.79 and 0.73 respectively; the categorical forecast skill over the training period is 65%. While the model over-estimated ice area for the 3 independent forecast years (2007–2009), the categorical forecasts of below normal ice area were correct for each year.

Figure 8. Regression based forecast for the 2010 Central Arctic Ocean September Ice Area. The model is trained on the 27-year period from 1981-2006 (dark red) and independent forecasts were generated for 2007–2010 (red); actual values are shown in black. The 2010 forecast is expressed both categorically, Below Normal, and deterministically, $5.7 \times 10^6 \text{ km}^2$. 
References


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Outlook of 9/2010 Arctic sea ice from 7/1/2010

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The predicted September 2010 ice extent is **4.8 million square kilometers**. This is based on ensemble predictions starting on 7/1/2010. 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 2003 NCEP/NCAR forcing, member 2 uses 2004 forcing, ..., and member 7 uses 2009 forcing. Each ensemble prediction starts with the same initial ice–ocean conditions on 7/1/2010. The initial ice-ocean conditions are obtained by a retrospective simulation that assimilates satellite ice concentration data. No data assimilation is performed during the predictions. More details about the prediction procedure can be found in Zhang et al. (2008) [http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf](http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf). Additional information can be found in [http://psc.apl.washington.edu/zhang/IDAO/seasonal_outlook.html](http://psc.apl.washington.edu/zhang/IDAO/seasonal_outlook.html).

**Figure 1.** (a) Ensemble prediction of September 2010 sea ice thickness and (b) ensemble standard deviation (SD) of ice thickness which shows the uncertainty of the prediction. The white line represents satellite observed September 2009 ice edge defined as of 0.15 ice concentration, while the black line model predicted September 2010 ice edge.
Figure 2. Ensemble prediction of September 2010 sea ice thickness in the Northwest Passage (NWP) region. Most of the NWP is ice free except some thin ice in the Lancaster Sound.