June Report: Outlook Based on May Data
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NIC Provisional Outlook for September Minimum

Issued June 5, 2009

National/Naval Ice Center, Suitland, MD

Best Guess: 4.736 million km^2
Method: Statistical/Heuristic

Overview:

For this outlook we use a heuristic approach based on the National Ice Center (NIC) ice charts and statistics spanning 1972-2008. This outlook was prepared by considering a NIC chart of Ice Conditions for May 25, 2008, the most recent NIC hemispheric chart. Any ice containing multiyear ice (MYI) was identified and classified by the partial amount (1/10, 2/10, etc.). All other ice was considered first year ice (FYI). In 2008, much of the central Arctic was devoid of MYI, a situation not observed prior in the satellite era. Because NIC and CIS make no distinction between second year ice and MYI, the ice in the central basin is once again MYI. However, we note that it is likely to be thinner and weaker than "traditional" MYI.

Analysis of previous summers indicates that much of the FYI will melt. Even with the central pack, only 13% of FYI remained from its March maximum. For this summer, we remove any parcel containing only FYI will melt out regardless of location. Once again, we present 4 outlook levels of severity: Conservative, Moderate, Aggressive, and Extreme. Conservative represent the cautious end of the spectrum, while Extreme would be the case of a warm Arctic summer combined with the "Transpolar Express" of 2007.

The summer minimum will depend on how much ice is lost during the melt season (July-September). It should be noted that the primary ice type represents the final stage of development of the ice (based on a theoretical ice thickness model using cumulative freezing-degree days). For example, ice classified as thick FYI may not necessarily be thicker than 120 cm at present. Thus, the actual ice thickness may be much thinner than the primary ice type would indicate. This is especially true of the second-year MYI.

The primary question about summer 2009 continues to be the fate of the FYI in the central Arctic, but for this outlook we have tied it to the presence of MYI.

The current conditions (figure 1):

Ice extent 11.842 million km^2
Ice Area 10.527 million km^2,
Avg concentration 88.9%

Multiyear ice extent 5.224 million km^2
Multiyear ice area 2.600 million km^2
Avg concentration: 49.8%

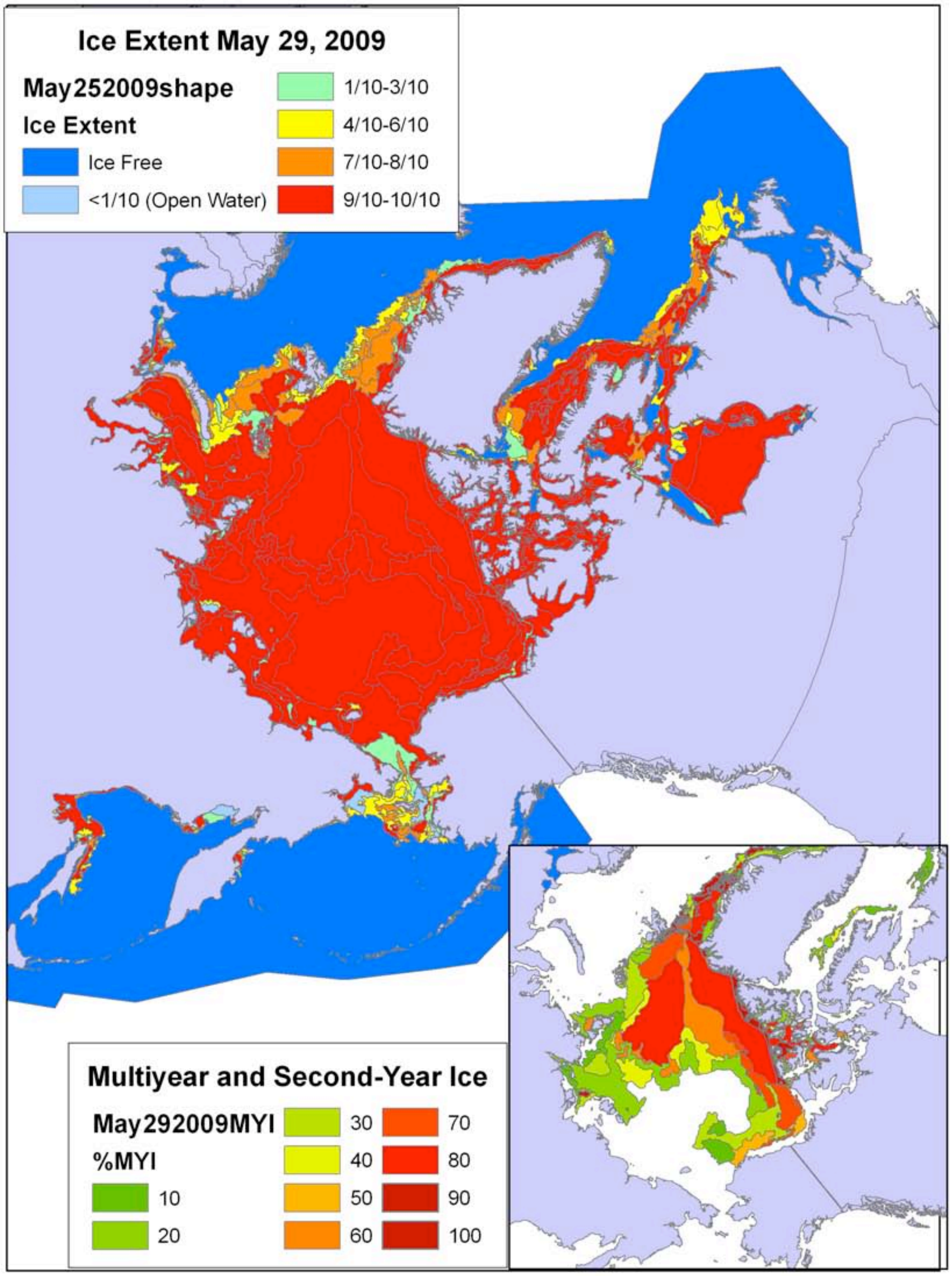

Figure 1: Sea ice conditions for May 29, 2009, and multiyear ice by percentage (inset).

Methodology:

Using the most current hemispheric ice chart and ArcGIS, the map is edited to select all parcels with MYI as the primary ice type. All other parcels are discarded. The remaining ice is edited following the assumptions below. A senior ice analyst (Mr. Szorc) examines and approves the outlooks.

The Seasonal Outlooks:

Conservative: Any area with MYI survives
Ice extent: 5.224 million km^2
Ice area: 4.832 million km^2
Avg concentration: 92.5%
MYI extent: 5.224 million km^2 (includes all parcels containing MYI)
MYI area: 2.600 million km^2
Avg concentration: 49.8%

Moderate: Any area with 20% or more MYI survives
Ice extent: 4.763 million km^2
Ice area: 4.400 million km^2
Avg concentration: 92.4%
MYI extent: 4.763 million km^2
MYI area: 2.553 million km^2
Avg concentration: 53.6%

Aggressive: Any area with 40% or more MYI survives
Ice extent: 3.440 million km^2
Ice area: 3.253 million km^2
Avg concentration: 94.6%
MYI extent: 3.440 million km^2
MYI area: 2.150 million km^2
Avg concentration: 62.5%

Extreme: Any area with 70% or more MYI survives
Ice extent: 1.920 million km^2
Ice area: 1.825 million km^2
Avg concentration: 95.1%
MYI Extent: 1.920 million km^2
MYI Area: 1.493 million km^2
Avg concentration: 77.8%

As was the case last year, the charts represent the *parcels* of ice that we believe will survive the summer. However it *does not* represent their final location. Drift due to wind and water will transport along the Beaufort Gyre out of the Beaufort and Chukchi Seas. Some ice in the Amundsen Basin will be transported out into the Barents Sea. The picture of the ice in September 2009 will be somewhat different than the current (May 29) conditions.

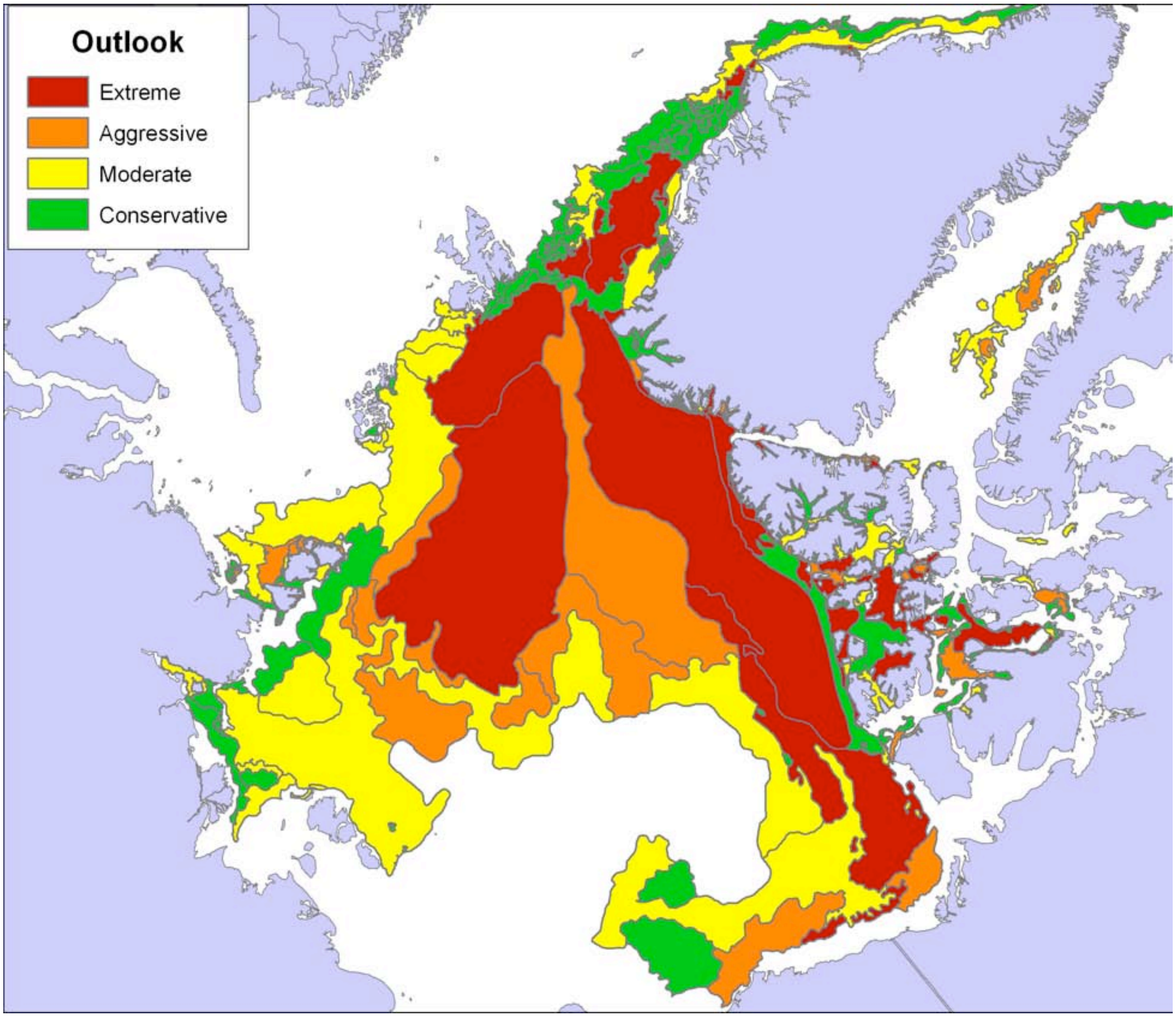

Figure 2: Surviving ice parcels. Extreme = red, Aggressive= red + orange, Moderate= red + orange + yellow, Conservative=red + orange + yellow + green.

From the spread of prognostications, we believe the Moderate case (4.763 million km^2) is the most likely, although at this point it is too early to tell. NIC is also working on an Arctic minimum sea ice outlook index which should strengthen the confidence we have in a particular outlook. Preliminary results of the index favor the Conservative estimate, but further refinement is required before the index will be considered in our outlook.

Sea Ice Outlook 2009: A regional perspective on ice evolution in the Pacific Arctic sector (SIZONet project)

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

(2) Ice development and status in late May 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 (Fig. 1). Starting in early May, vigorous and early melt resulted in rapid northward retreat of the ice edge to below normal extent in late May.

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 1.7 m (primary mode, first-year ice formed in the fall), 0.9 m (secondary mode), 0.2 m (new ice) and 3.6 m (level multiyear ice) along several hundreds of km of transects north of Barrow, Alaska (Fig. 1), very much comparable to what was found in the past two years. However, radar satellite imagery (QuikScat) shows much less multiyear ice in the area in spring. In fall, a narrow band of multiyear ice was advected from the eastern Beaufort and resulted in multiyear ice floes entrained into the landfast ice at Barrow. Coring revealed that multiyear ice was typically at least several years in age, likely originating in the high Canadian Arctic.

Coastal sea ice:

• At *Wales*, in Bering Strait, level shorefast ice thicknesses were around 1.2 m in the first week of May. These values are slightly higher than in the last couple of years. Much of this is due to the accretion of superimposed and possibly snow ice, driven by above-normal snowfall throughout the winter. Local ice observers reported persistent anomalous southerly winds throughout winter dumping much snow onto the ice. For hunters, these snow dumps and overflow from early melt were affecting access to the landfast ice edge. Southerly winds prevented offshore leads from opening up and made for comparatively few hunting opportunities in spring.

• At *Barrow*, level shorefast ice thicknesses in May were at the low end of the normal range (1.4 m, similar to last year), with above-normal snow depths of 0.3 m and more. Melt onset was unusually early in late April and continued through May. Local ice observers and thickness surveys indicate a comparatively few grounded ridges, but some multiyear ice in the landfast ice cover, though not sufficient to stabilize the ice cover on a large scale.

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

• Break-up and onset of seasonal ice retreat: Melt onset was much earlier than in the past few years, thinning and weakening the ice along the coast. Openings north of the ice edge in mid-May (Fig. 1) are likely also a combination of melt and ice dynamics. At Barrow, prevailing onshore winds kept the coastal lead closed, resulting in poor whale harvests, preventing early landfast ice breakout and limiting the amount of solar heating of coastal waters. An experimental break-up forecast based on solar heat input and 2-week atmospheric forecasts suggests slightly **earlier or normal break-up** (see Figure 2) – details at www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast/. Note, that a buoy north of Barrow indicates that in the drifting ice pack, melt onset occurred much later with less vigorous melt.

• Summer conditions: The first-year ice offshore is thicker this year than in 2008. At the same time, there is a lack of multiyear ice compared to the past two years in the Chukchi and western Beaufort Seas. Ignoring any impacts of anomalous ice dynamics, this situation suggests that overall ice retreat in 2009 north of Barrow is likely to proceed less rapidly than in 2007 and 2008, at least offshore where the effects of early coastal melt onset are not felt. At the same time, the absence of multiyear ice throughout much of the region suggests that a complete removal of sea ice is possible during the summer, with **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.

This outlook is based on heuristics and a statistical model for break-up timing (see website at www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast/). For the statistical model predicting break-up at Barrow, improved representation of sea ice (as a boundary condition) and improved forecasts of surface solar radiation in two-week WRF runs (kindly provided by Jing Zhang and Jeremy Krieger, knik.iarc.uaf.edu) would be beneficial.

Submission information

Submitted by Hajo Eicken (hajo.eicken@gi.alaska.edu), Chris Petrich (chris.petrich@gi.alaska.edu) and Mette Kaufman (kaufman@sfos.uaf.edu) on behalf of the Seasonal Ice Zone Observing Network (SIZONet, www.sizonet.org) with support from the National Science Foundation's Arctic Observing Network Program and the Alaska Ocean Observing System.

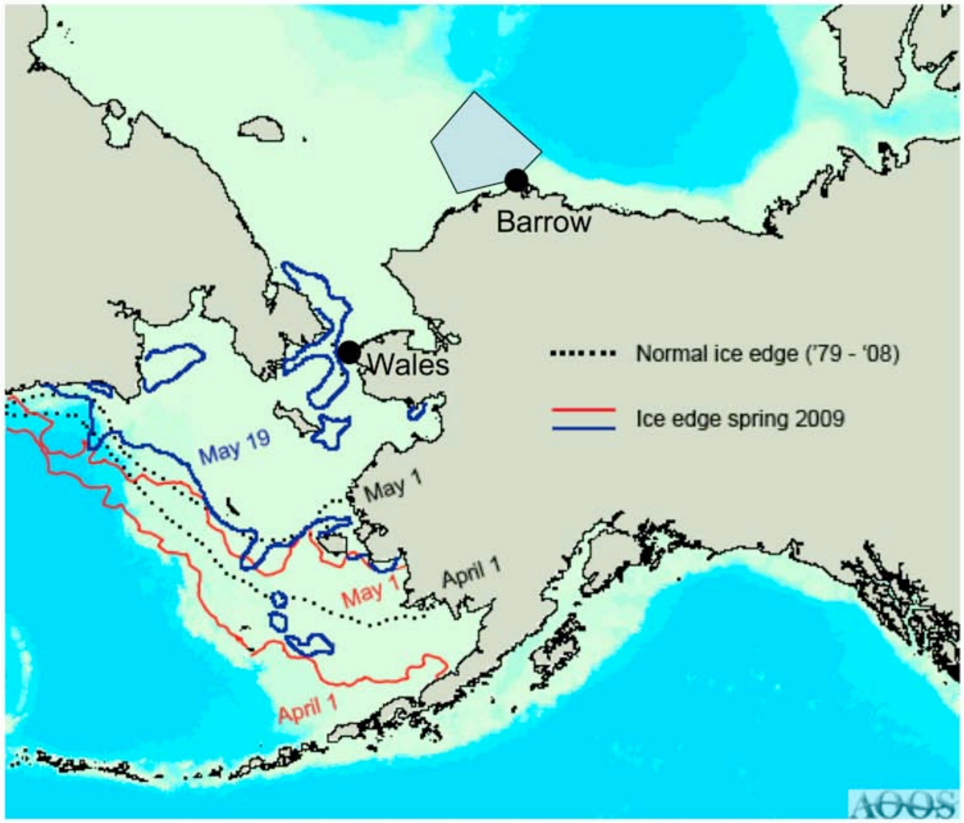

Fig. 1: Ice extent derived from passive microwave satellite data (SSM/I, data provided by NSIDC, nsidc.org) for Pacific Arctic sector. Shown are observed ice edges for April and May along with "normal" ice edges (median positions) from 1979 to 2008. Locations of the airborne surveys and coastal stations are also shown.

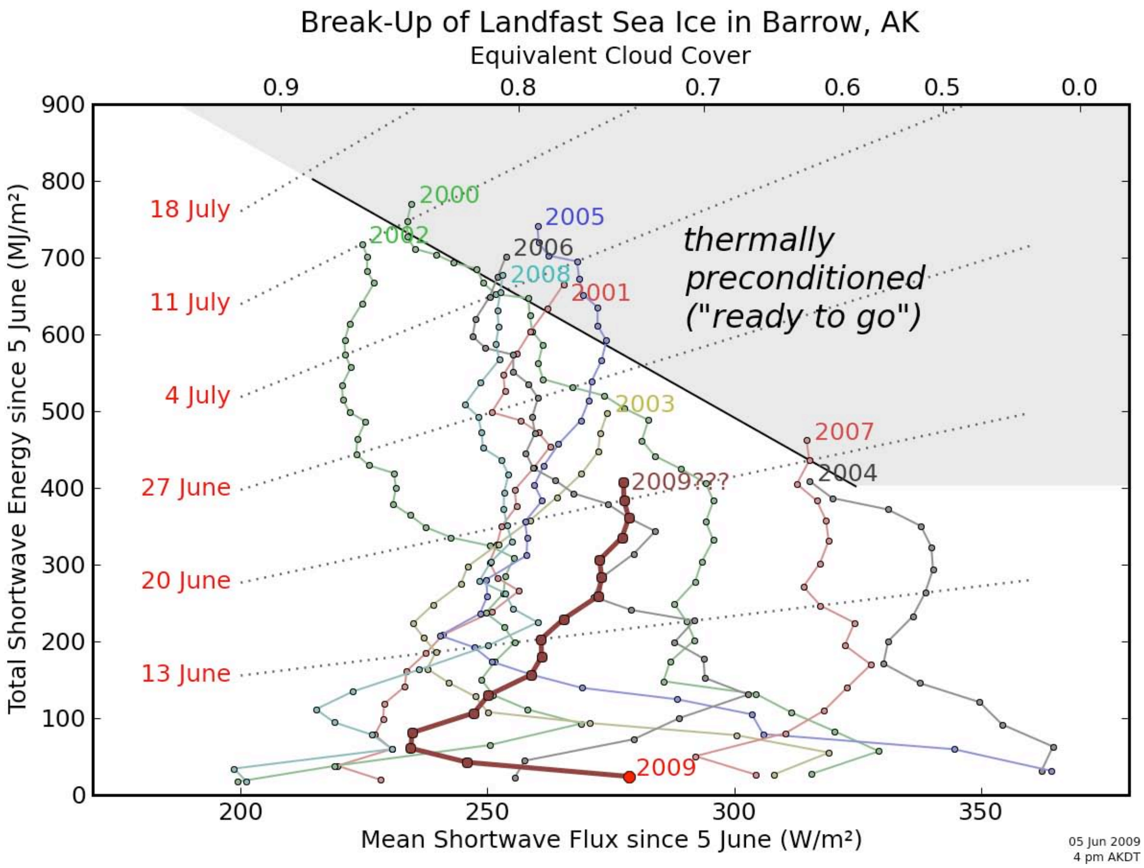

Figure 2: Observed (2000-2008, thin lines) and projected (thick red line) decay of landfast ice at Barrow, AK. Details of the method employed are provided at www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast.

June Report: Outlook Based on May Data
Regional Outlook: Beaufort and Chuckchi Seas, High Arctic, and Northwest Passage

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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 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.

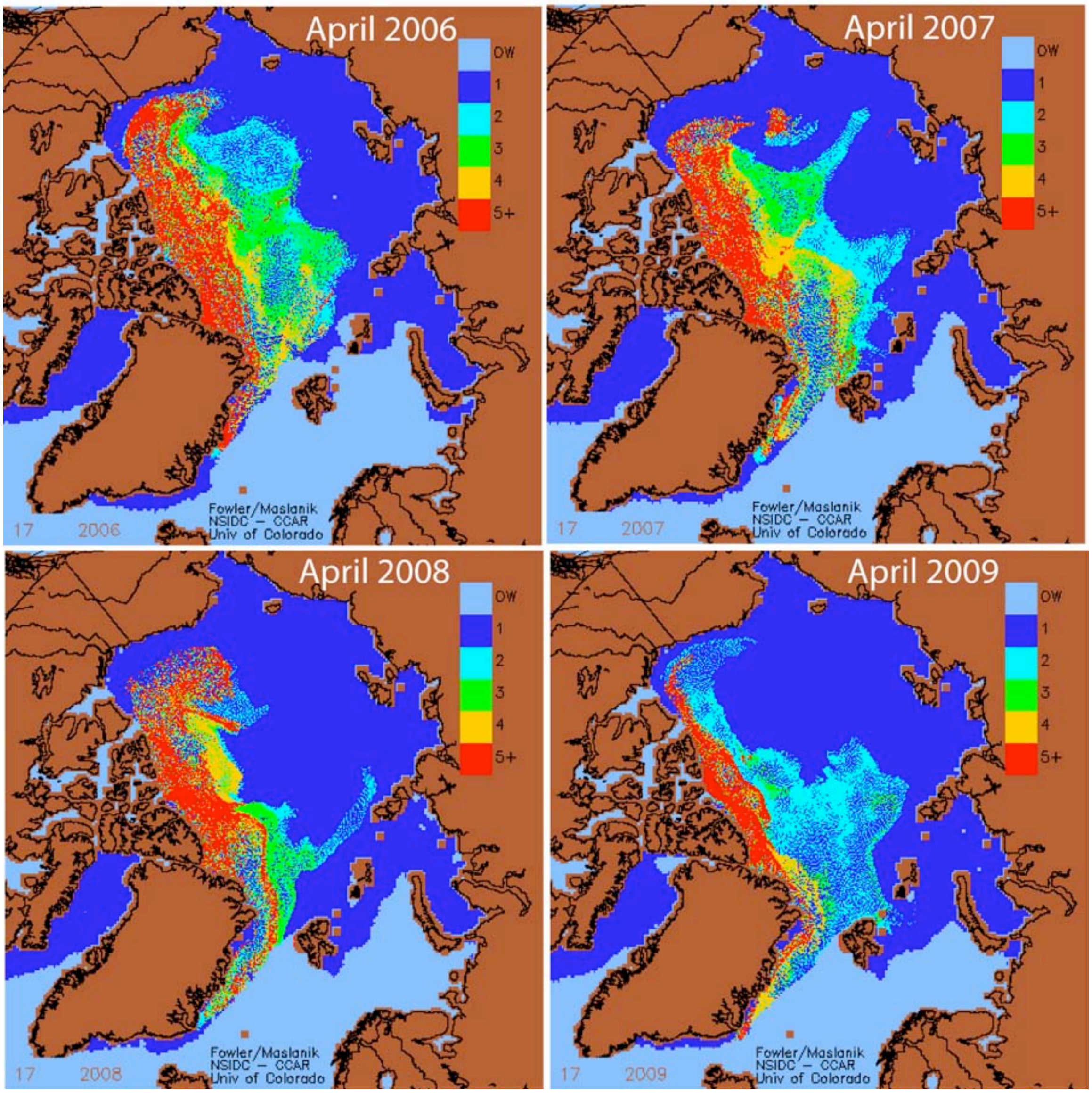

Figure 1. Estimated ice age for the end of April for 2006-2009.

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.

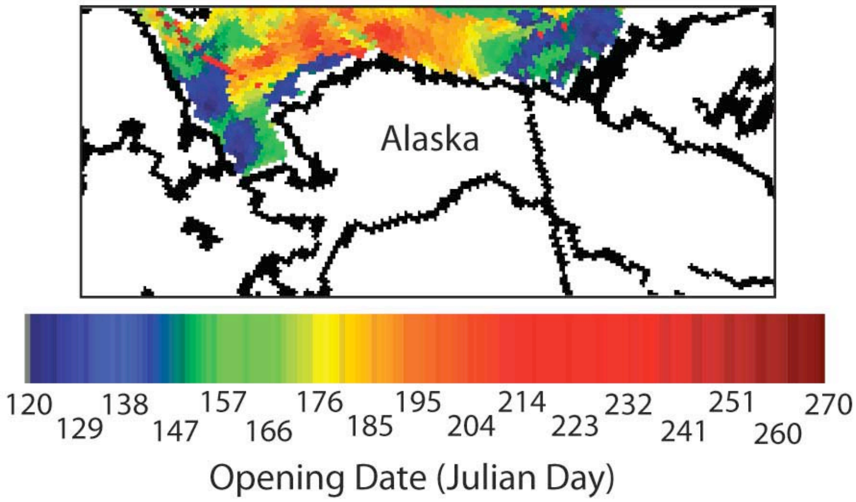

Figure 2. Estimated opening dates in the western Arctic.

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 the our estimated opening dates for that area were too early.

1B.2. Distribution of Multiyear Ice Types

<u>Beaufort and Chukchi seas</u>

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 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 continues 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.

June Report: Outlook Based on May Data
Regional 2009 Outlook: Western Parry Channel Route of the Northwest Passage
By: Stephen Howell (showell@uwaterloo.ca) and Claude Duguay
Interdisciplinary Centre on Climate Change (IC^3), University of Waterloo

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.

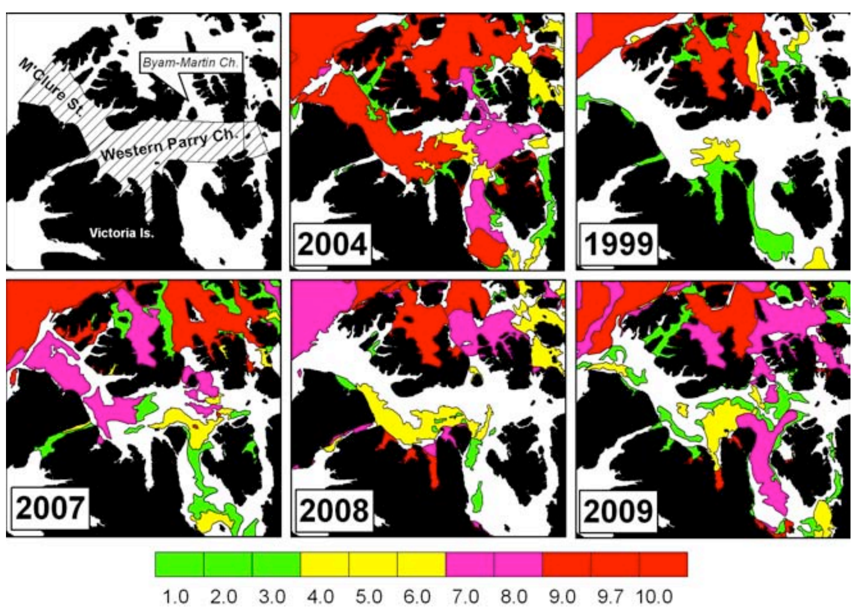

Figure 1. Spatial distribution of multi-year ice concentration (in tenths) within the Western Parry Channel region of the Northwest Passage on May 15th for a heavy ice year (2004), a light year ice (1999) and the last three years.

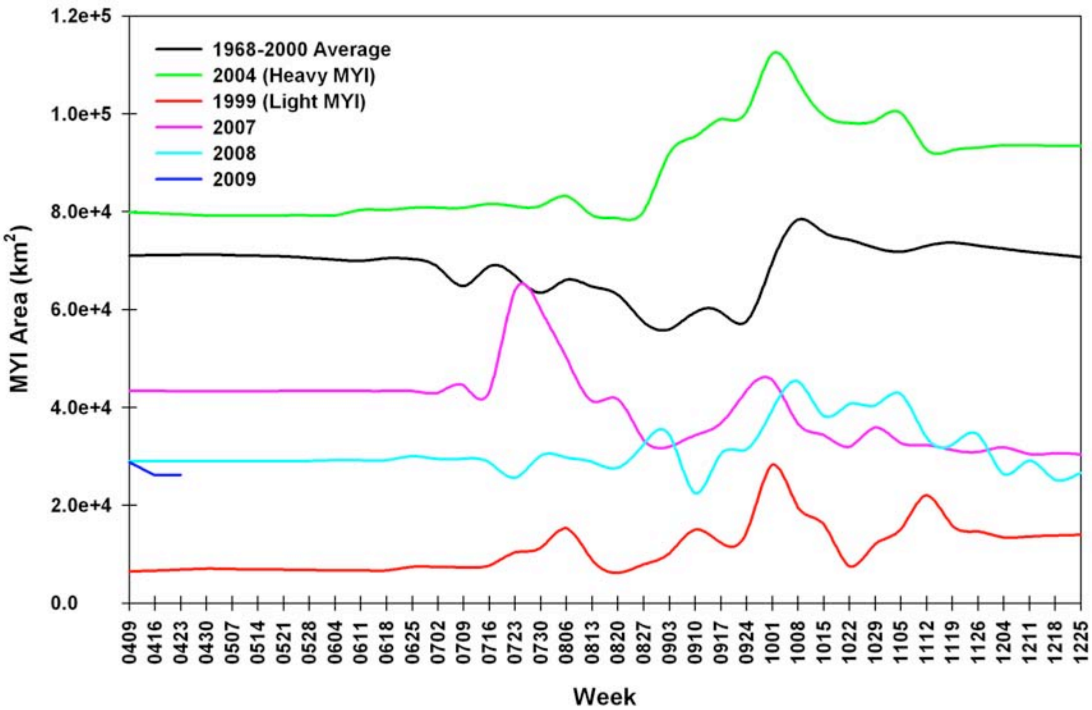

Figure 2. Time series of the evolution of multi-year ice area within the Western Parry Channel region of the Northwest Passage.

<u>Reference</u>

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.

June Report: Outlook Based on May Data
By: Oleg Pokrovsky
Region: North Pacific
May 2009

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

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

3-*The physical rationale for the estimate.*

There is opinion among Russian scientists that anomaly low sea ice extent (SIE) in September 2007 was occurred primarily due to rare circulation atmospheric regime held on in summer

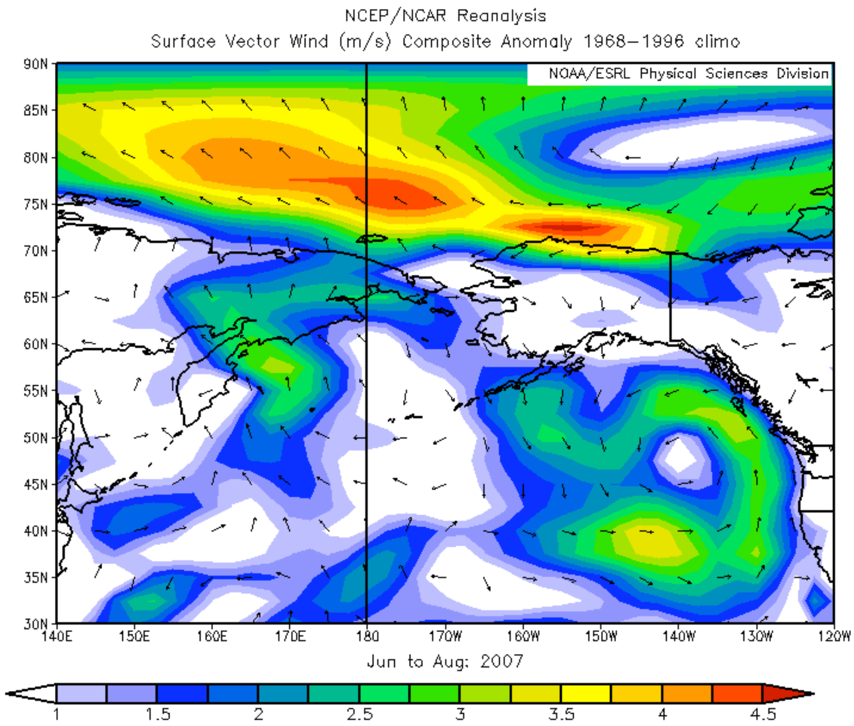

Figure 1. Surface vector wind field for summer 2007

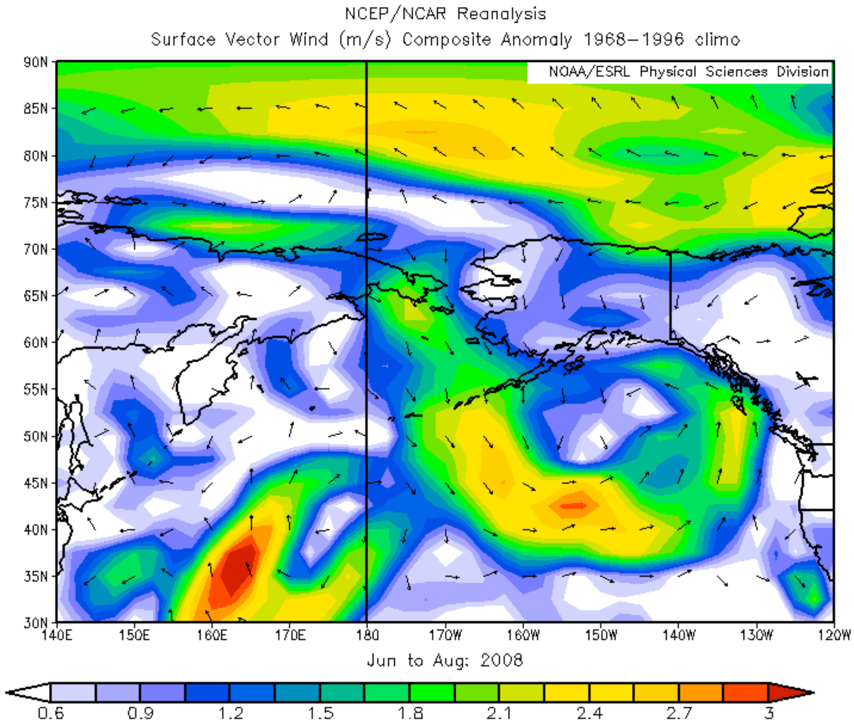

Figure 2. Surface vector wind field for summer 2008

(see fig.1). There is an opinion that extremely low Arctic sea ice extent (ASIE) magnitude was observed in 2007 due to strong eastward wind, which destroyed thin ice cover in Pacific (especially in Alaska and Canadian) sector of Arctic melted by warm air masses inflow from low latitudes. The wind field last (2008) year (fig.2) has been distinguished by strong north wind occurred in Siberia. As a result September ASIE in 2008 was partly recovered with account to 2007.

Wind field anomalies are generated partly by SST occurred in previous months. Our main attention should be drawn to North Pacific (NP) area. Spring field of SST (fig.3) reveals negative anomaly in eastern part of NP and significant temperature contrast between the east and west parts. That led to generation of atmospheric high in eastern part of NP and rapid transport of warm air from south. The SST field in 2009 (fig.4) demonstrates quite opposite SST anomaly. That suggests a different regime of air circulation in summer months 2009. Thus the ASIE in Pacific sector is expected to be close to last year value.

The ASIE in Atlantic sector is regulated mainly by temperature of Atlantic inflow waters. Most important indicator is a temperature of Atlantic waters at 300 m core depth. Unfortunately, the SST is only available indicator to be used. Thus there is some uncertainty, based only on the SST fields. Nonetheless, the SST field is a valuable source of data to predict ASIE in western Arctic (I mean Nordic, Barents, and Kara seas). The difference between January-April SST fields 2009 and 2007 (fig.5) shows that this year Atlantic water inflow is much cooler than those in 2007. So, we expect that the ASIE value in this area will be higher 2007 magnitude.

April ASIE value is more close to those of 2008 and higher than those of 2007. Thus, we can expect that September ASIE value of 2009 will be close to those of 2008: **4.6**.

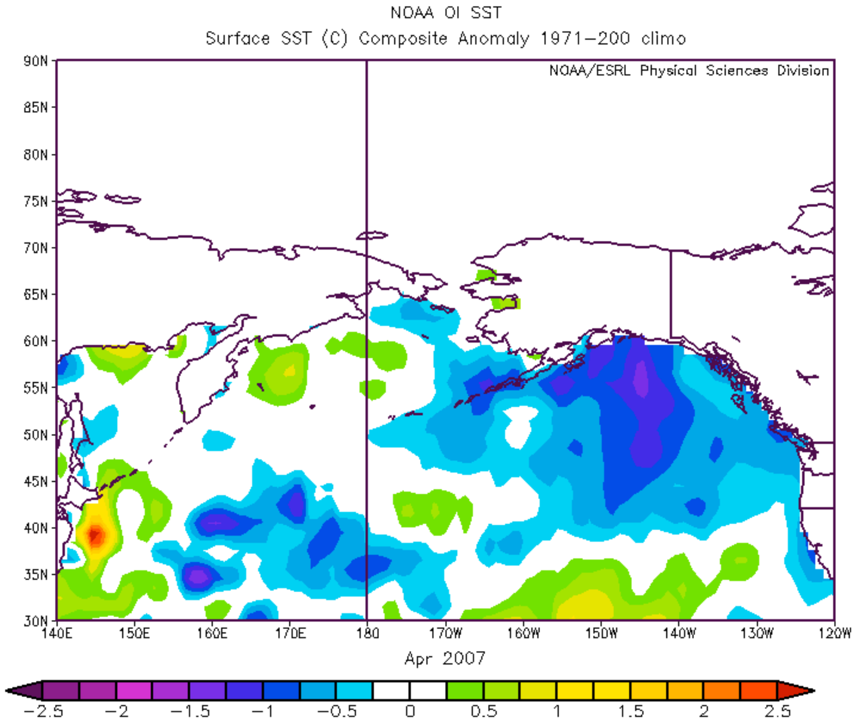

Figure 3. SST field anomaly in NP for April 2007

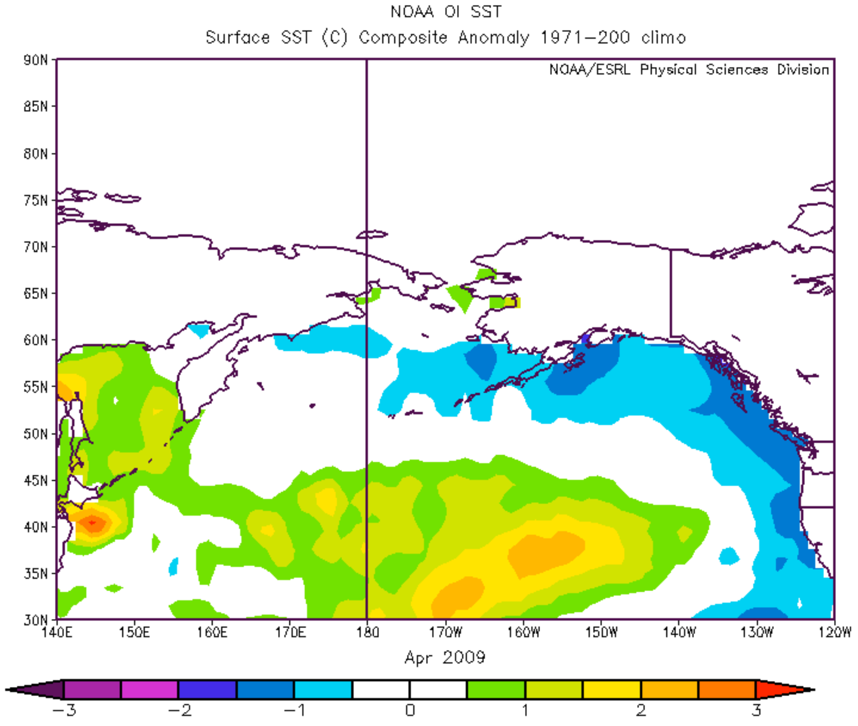

Figure 4. SST field anomaly in NP for April 2009

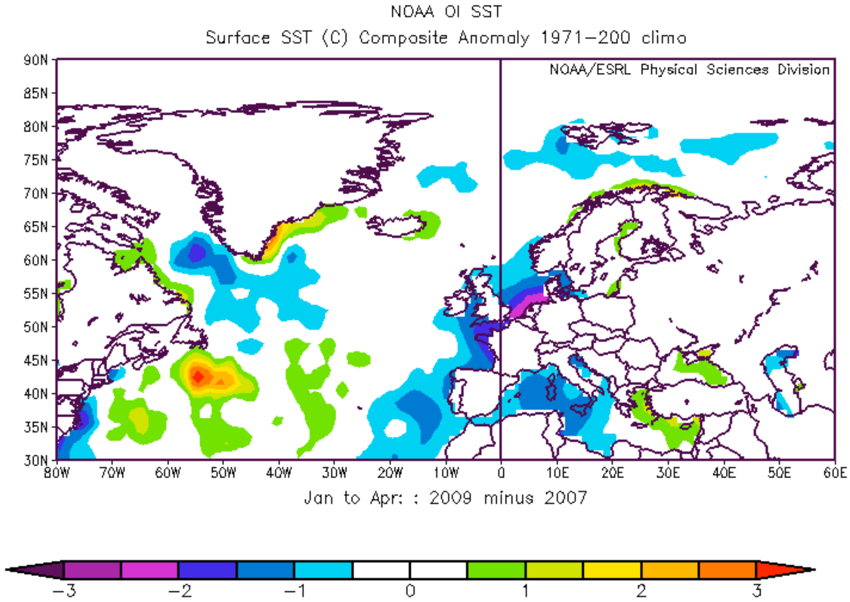

Figure 5. The difference between January-April SST fields 2009 and 2007.

Outlook of 9/2009 sea ice in the Northwest Passage region from 6/1/2009

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

The outlook shows that most of the Northwest Passage (NWP) is ice free in September 2009 (Figure 1). This is based on ensemble predictions starting on 6/1/2009. 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.

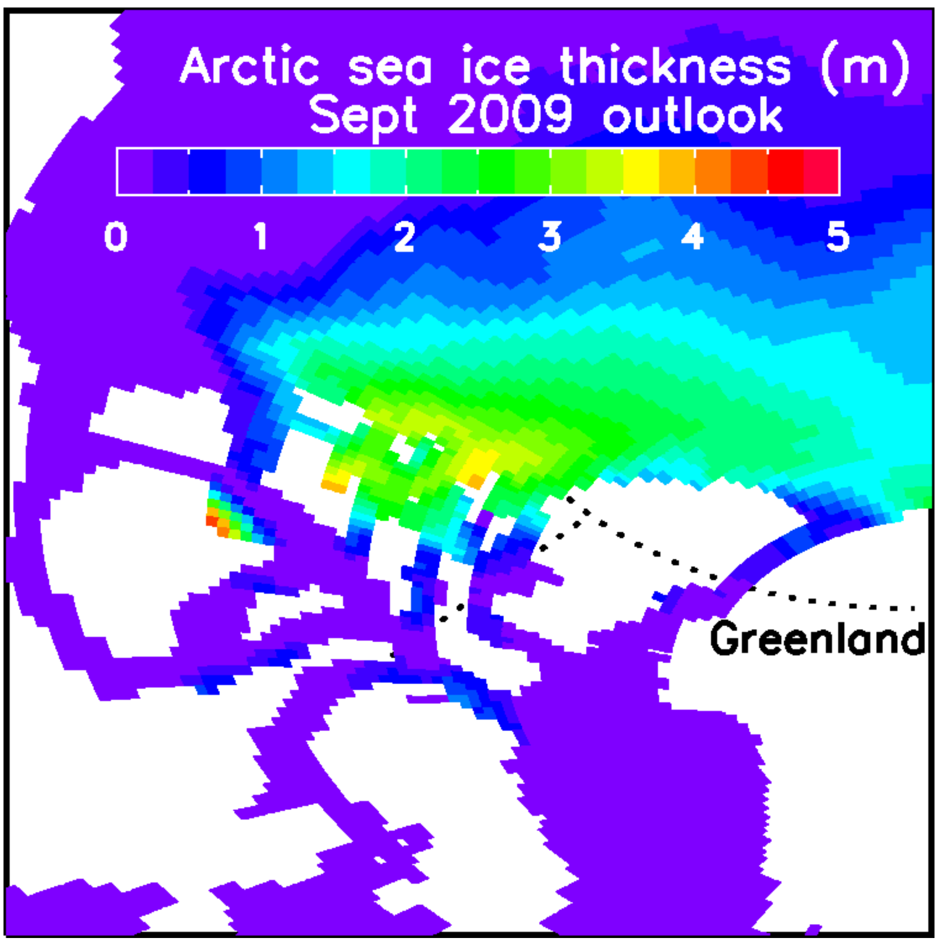

Figure 1. Ensemble prediction of September 2009 sea ice thickness in the NWP region.