Community Submissions for June Sea Ice Outlook Report

14 July 2008

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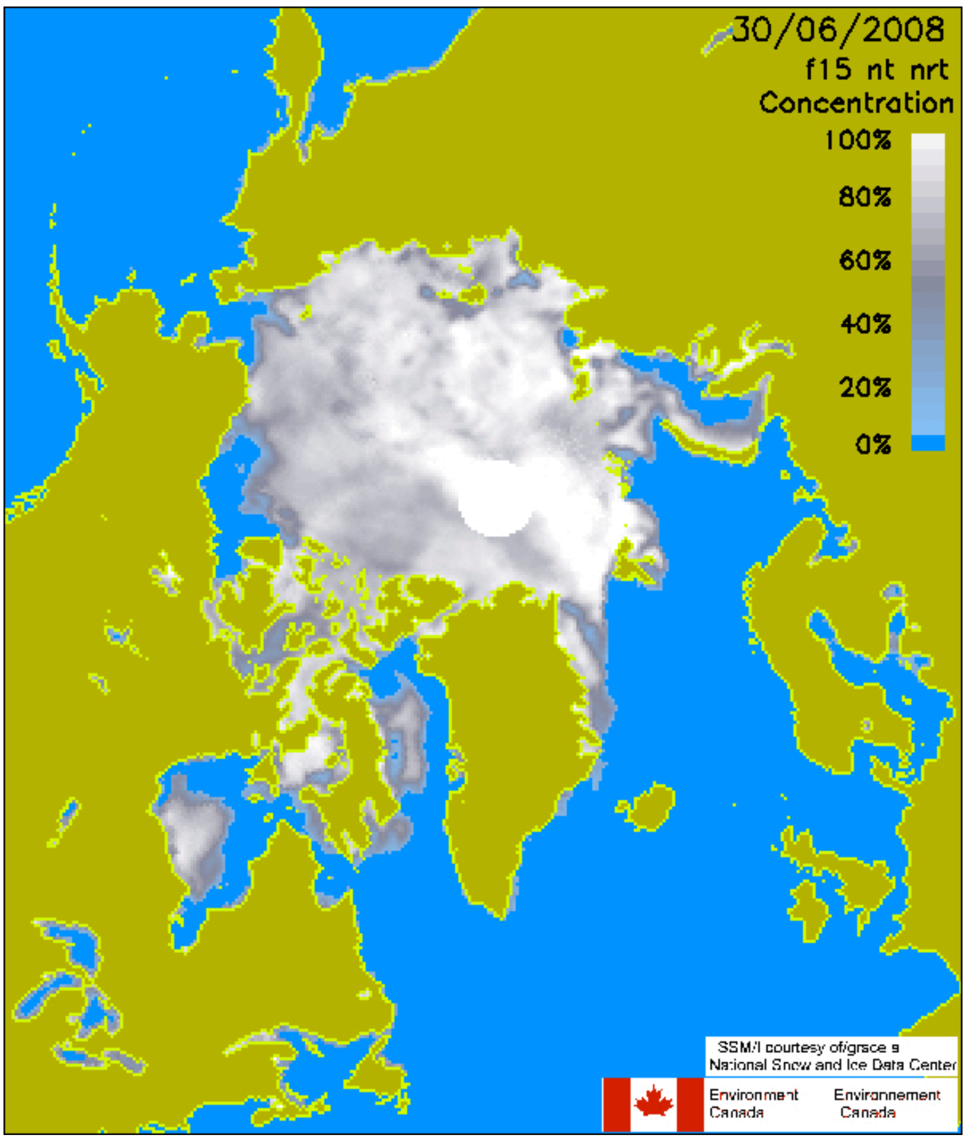
#1—Tom Agnew

1. Names of Scientist(s) making the Outlook.

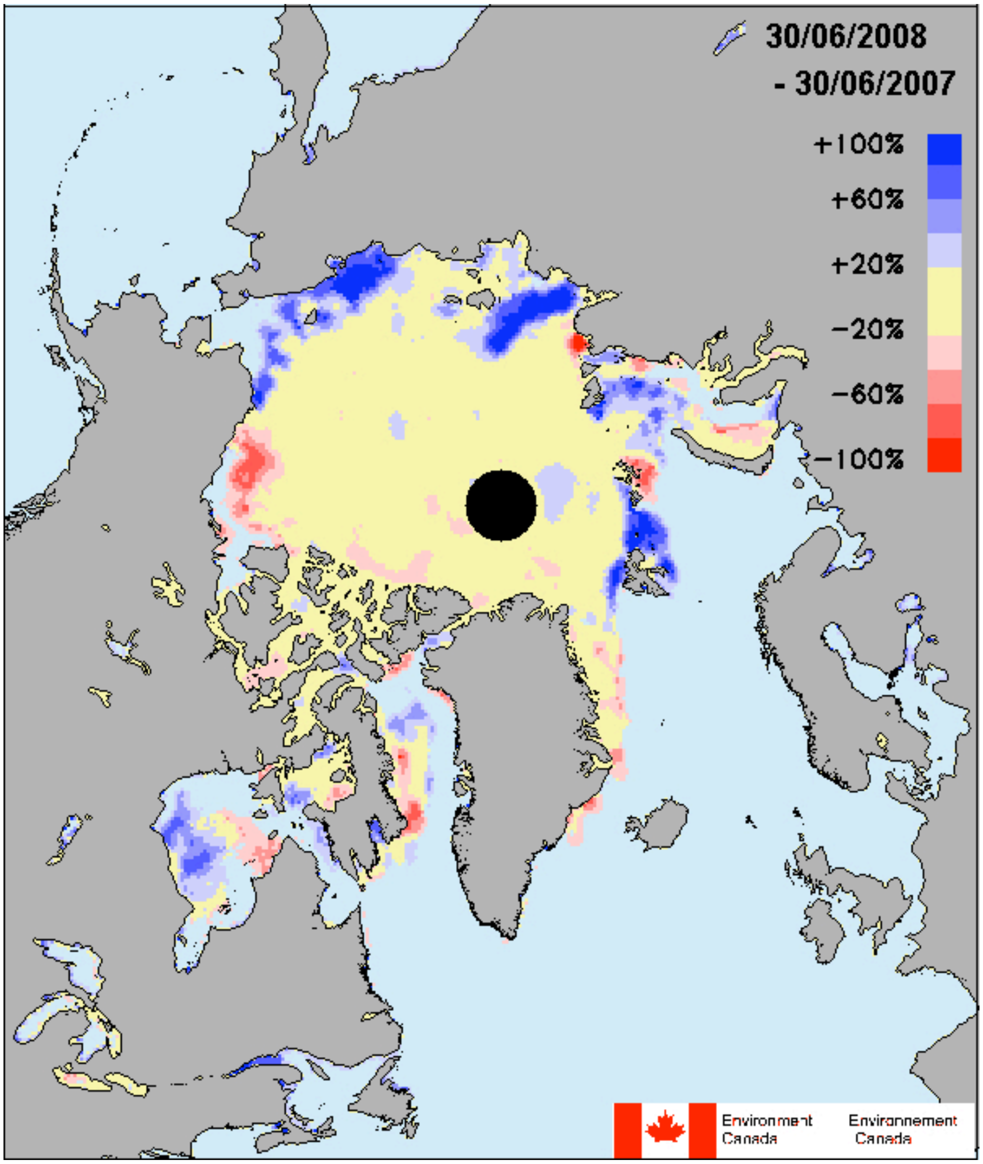
Tom Agnew

2. Estimate of sea ice extent for the month of September 2008 (the value for September 2007 was 4.3 million square kilometers).

I tend to agree with Cecilia Bitz and the other more conservative opinions. The high pressure which sat over the Beaufort and Chukchi Sea last summer was the major reason for the large region of open water in the Siberian, Chukchi and Beaufort Seas in the summer of 2007. The chance that this will happen again this summer is unlikely. The most recent ice cover shows these regions still ice covered (Fig 1) unlike last year. Fig 2 is the difference between this year and last year. Blue regions mean there is more ice this year than last year at this time. There is no indication that the Siberian or Chukchi seas have opened up as they did last summer.



(Figure 1)



(Figure 2)

3. Principal Method (numerical model, statistical model, comparison to 2007 weather and satellite data, etc.) Keep this short as it will go into a table.
Comparison to 2007

4. A short several sentence summary of your primary physical reasoning behind the estimate provided in #2.
Not provided.

5. Any expanded information with figures which backs up #4.
None provided.

6. Any information on regional sea ice conditions or outlooks.
None provided.

#2—Todd Arbetter, Pablo Clemente-Colón, C. Szorc, Tim Holden, & Ignatius Rigor (NIC)

Provisional Outlook for 2008 September Minimum

Prepared by the National Ice Center - 3 July 2008

T. Arbetter and P. Clemente-Colón
NIC Science and Applied Technology Department

C. Szorc and T. Holden
NIC Operations Department

I. Rigor
Polar Science Center, University of Washington

Overview: This outlook was prepared by assessing conditions captured in the National Ice Center (NIC) sea ice chart for June 22, 2008. Ice regions containing concentrations of multiyear ice (MYI), classified in the chart by the partial amount (1/10, 2/10, etc.), have been combined to represent the extent of MYI in this analysis. All other ice areas are then considered first-year ice (FYI).

The following assumptions were made to produce the outlook:

1) None of the existing ice in Baffin Bay or the Greenland Sea would survive.
2) No areas with of 1/10 or 2/10 MYI concentration would survive.
3) Advection and ice deformation are not considered at this time in the assessment.

The non-surviving ice areas described above were removed graphically from the June ice chart using ArcGIS and the extent of the leftover ice was estimated. When applying this approach analogously to the NIC sea ice chart for June 25, 2007, the remaining ice for September 2007 was estimated at 3.89 million km^2, which is very close to the calculated NIC September chart minimum of 3.98 million km^2.

For 2008, the question still remains on whether the FYI in the central Arctic would survive the summer, and how much. This will depend on the actual warming/melting trend that will be ultimately experienced. Presently, the ice extent retreat is following last year's trend according to the NIC observations. Still, a major contrast with last year is the fact that a much larger extent of FYI is dominating the central Arctic following the MYI boundary crossing of the North Pole very early in the season. This may put us into new territory as there are no previous observations of a potential wide regional melt out at the pole.

In order to assess a range of possible outcomes, a set of 2008 outlooks were produced with various FYI melt scenarios ranging from conservative to extreme. Four cases were considered.

1) Conservative melt: Most of the FYI survives
2) Moderate melt: Less FYI bordering open water areas above Fram Strait and above Lomonosov Ridge survives
3) Aggressive melt: Only FYI packed along the Canadian Arctic Archipelago survives
4) Extreme melt: No FYI survives

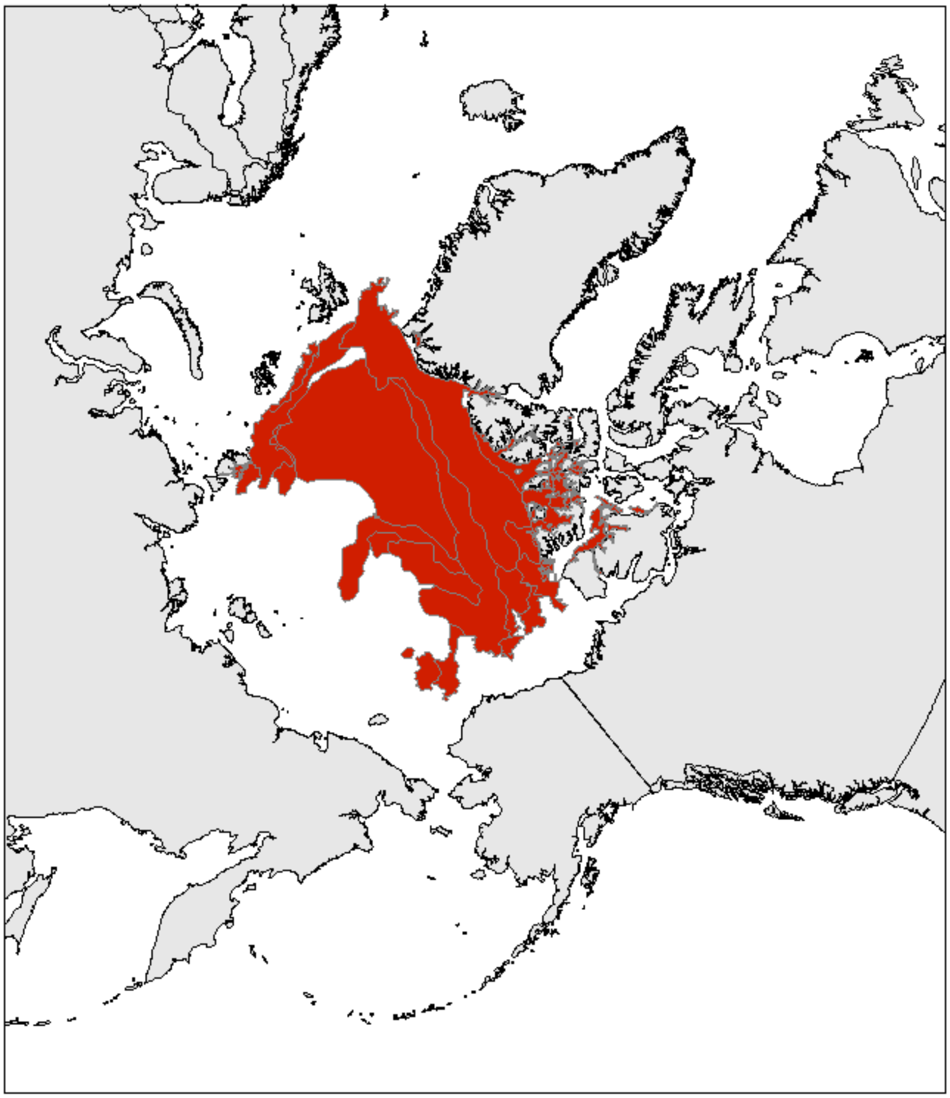
The charts below indicate in red what ice would remain in the Arctic under each scenario. It should be emphasized that this is not a forecast of the ice locations in September. The ice shown here will be advected around the Beaufort Gyre and toward and through Fram Strait. Some floes may filter through the Canadian Arctic Archipelago. Additionally, export through Fram Strait during summer could also reduce the amount of MY ice in the Arctic basin further influence the September estimate.

The 4 outlook scenarios presented next were produced by the NIC Science Team and presented to the Operations Senior Analysts/Forecasters. The opinion of the forecasters was that the most likely scenario was somewhere between Moderate and Aggressive scenarios. The average of these two scenarios gives a 2008 September minimum of 2.65 million km^2. This value is well below last year's record value of 3.98 million km^2.

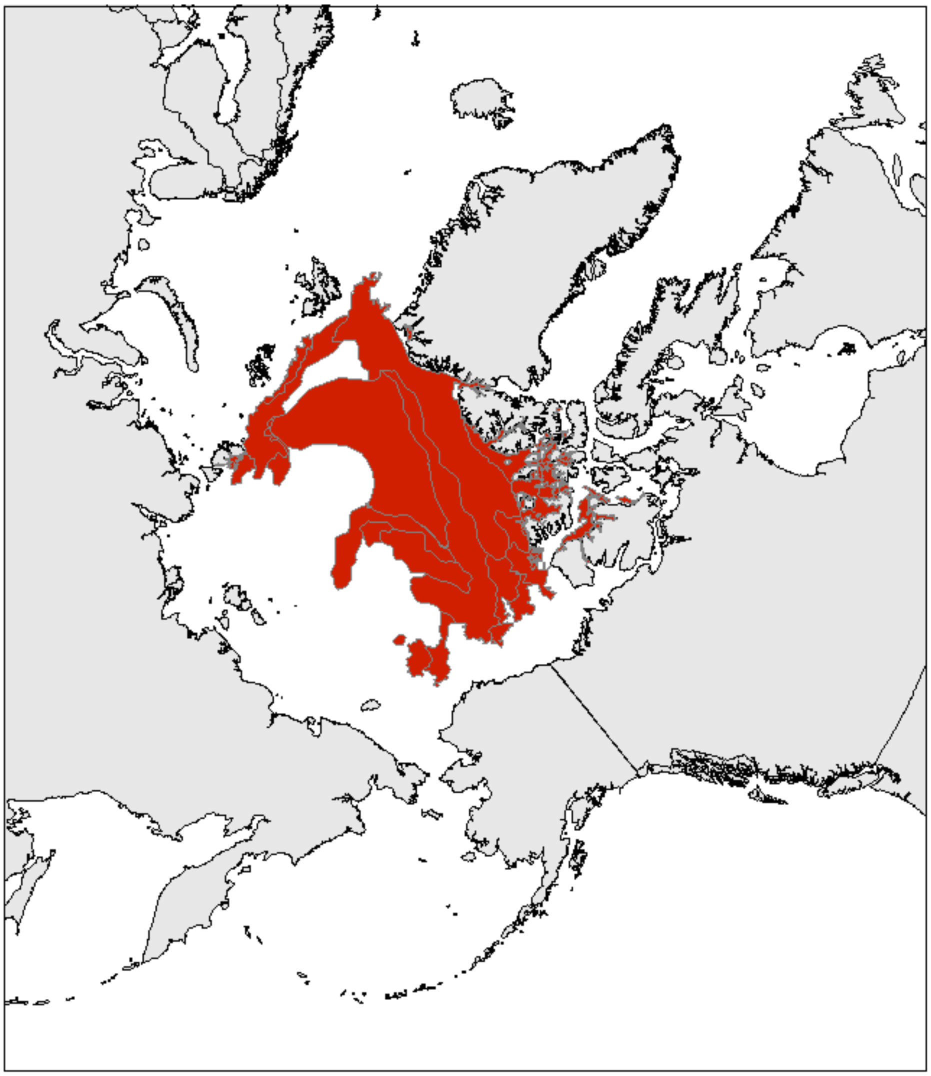
This outlook will be updated two more times throughout the remainder of the 2008 summer season after the third week in July and the third week in August. A long-range forecast of Polar weather patterns for summer 2008 (not considered here) as well as advection considerations will give a clearer indication of the fate of the FYI, and also whether to modify the assumption of surviving MYI.

While the charts should not be considered a spatial forecast, the lack of MYI in the lower Canadian Arctic Archipelago in these scenarios suggests the possibility the Northwest Passage may again become navigable in 2008, particularly the southern (shallow water) route.

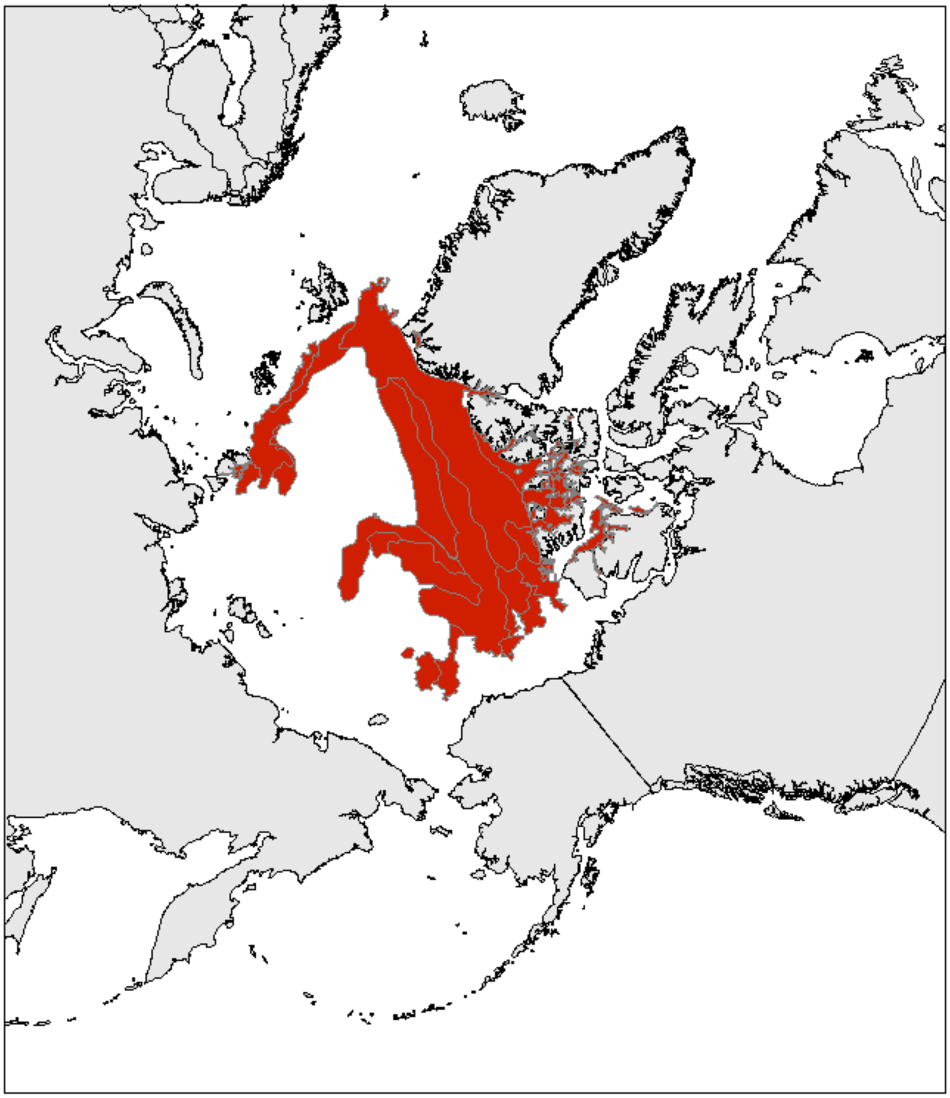
Sea ice conditions for 22 June 2008. First-year ice is shaded light blue, while all ice containing Multi-year ice is shaded green.
The total ice extent is 10.78 million km^2. The extent of multiyear ice (green) is 4.13 million km^2.



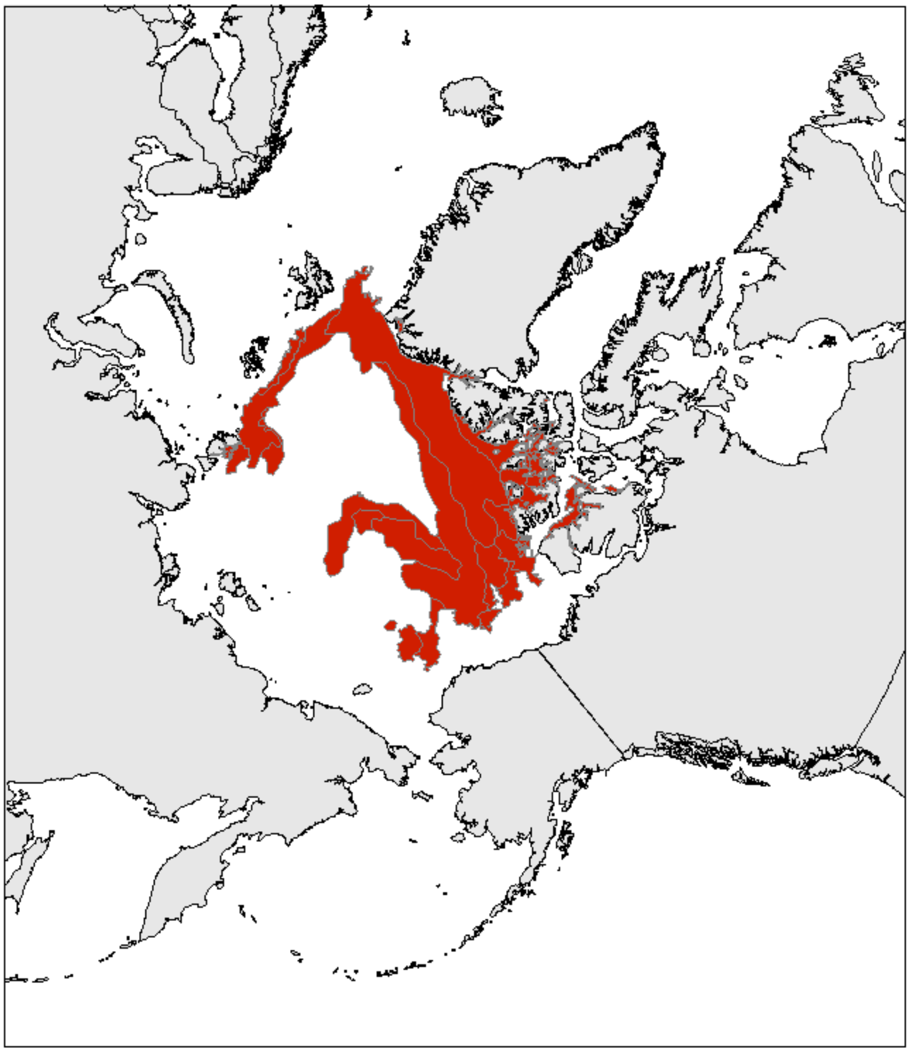
Conservative Scenario:
Minimum September 2008 Ice Extent
3.10 million km^2



Moderate Scenario
Minimum September 2008
Ice Extent
2.89 million km^2



Aggressive scenario
Minimum Sept 2008 Ice Extent
2.42 million km^2



Extreme Scenario
Minimum September 2008 Ice Extent
2.19 million km^2

#3—Cecilia Bitz

1. Name of contributor: Cecilia Bitz

2. Estimate of the sea ice extent for the Arctic as a whole for the month of September 2008
5.30 million square

3. Principal method
Statistical, based on observations and coupled climate model

4. Short basis for prediction

The 29-year observational record of September sea ice extent has zero autocorrelation, zero skew, and only a weak correlation with the extent in the prior June. The June extent in 2008 lies very close to the long-term trend. Therefore, my prediction for September 2008 is an extrapolation of the long-term trend for September. These statistical relationships are in general agreement with much longer records that are available from the Community Climate System Model version 3, CCSM3.

5. Longer basis for prediction

With little deviation from the long term trend in June 2008 and no significant autocorrelation or skew from one September to the next in the observations (Fig. 1a), the conservative estimate for the future is on the trend line in September. An extrapolation of the trend line (Fig. 1b) to year 2008 gives 5.30 million square kilometers.
It is worth noting that this method would have given a very poor estimate of September 2007 because the monthly mean extent in June 2007 was also very near the long term trend.

However, extent in the last week of June 2007 was much lower than earlier in the month. I suspect that the extent near the end of the month of June (rather than the average for the month) is more highly correlated with September extent and could be useful for estimating the extent in September. Yet in 2008, the extent at the end of June was not below the long-term trend, so refining the method would not alter my prediction for this year. The observational results were compared with a statistical analysis of an ensemble of 20^{th} and 21^{st} century simulations and long control runs from CCSM3. With ensembles and multi-century control runs giving far more degrees of freedom, it is clear that CCSM3 does have a weak but significant autocorrelation in September ice extent. However, the autocorrelation is so weak that it did not compel me to modify my prediction based solely on the observations.

In contrast, there is more considerable lagged correlation between thickness and extent, as expected owing to the much much greater memory in thickness. Figure 2 shows that years with September sea ice loss comparable to the 2007 observed loss are very rare.

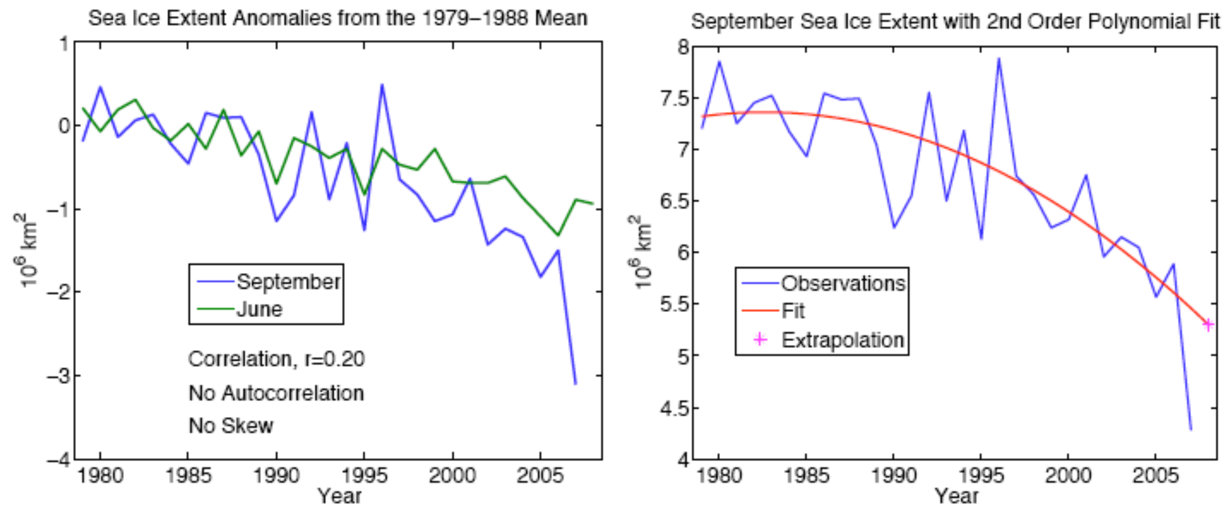


Figure 1: Left panel: The twenty-nine year observational record of September sea ice extent has zero autocorrelation, zero skew, and only a weak correlation with the June extent. All time series are detrended BEFORE correlations and skew are estimated. Right panel: Observed September sea ice extent and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

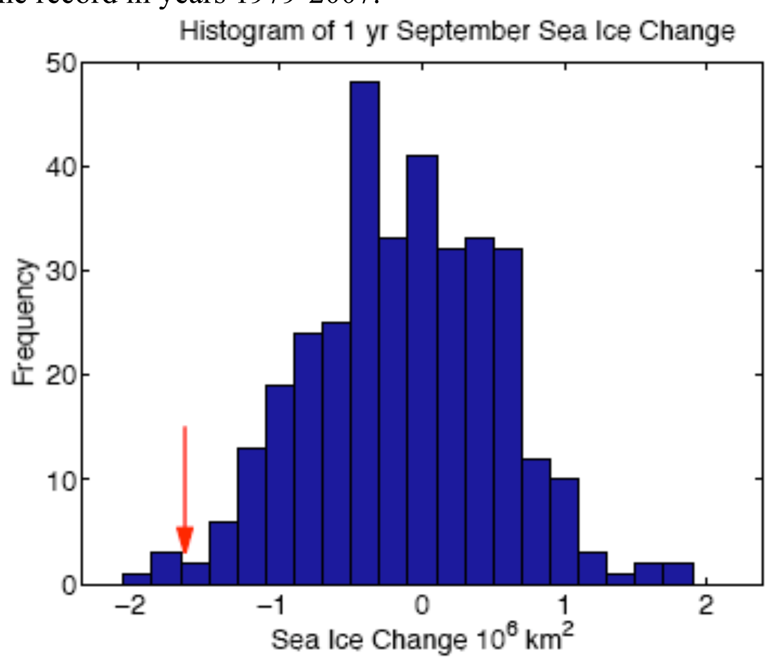


Figure 2: Histogram of September-to-September sea ice extent change in the first half of the 21st century in seven ensemble members from CCSM3 SRES A1B scenario (350 yrs total). This model has a very rapid loss of September sea ice extent, essentially loosing 30–40% of the sea ice extent in one decade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

#4—Sheldon Drobot, James Maslanik, and Chuck Fowler

1. Names of Scientist(s) making the Outlook.
Sheldon Drobot, James Maslanik, Chuck Fowler

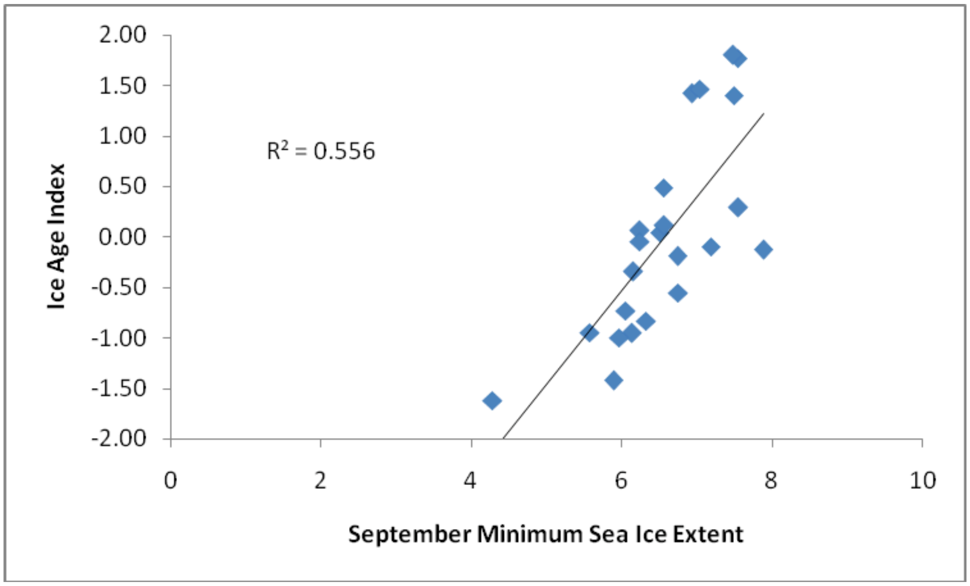
2. Estimate of sea ice extent for the month of September 2008 (the value for September 2007 was 4.3 million square kilometers).
Based on data available in early June, our *most likely* solution is 4.40 million square kilometers.

3. Principal Method (numerical model, statistical model, comparison to 2007 weather and satellite data, etc.) Keep this short as it will go into a table.
Probabilistic statistical model

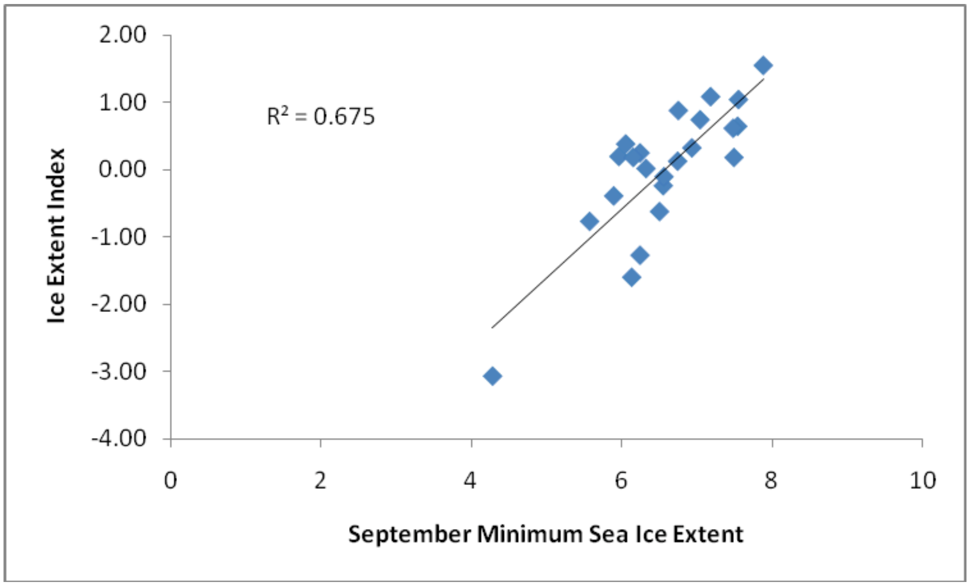
4. A short several sentence summary of your primary physical reasoning behind the estimate provided in #2. Last time I extracted most of this information from your essays, but it is better if you provide this up front.
Our model follows the methods outlined in [Drobot, S.D., 2007: Using remote sensing data to develop seasonal outlooks for Arctic regional sea-ice minimum extent. Remote Sensing of Environment, 111, 136-147, doi:10.1016/j.rse.2007.03.024]. For this forecast, we are relying mainly on the spatial pattern of early June sea-ice concentration and an ice-age index [which is based on Figure 2 in Maslanik, J. A., C. Fowler, J. Stroeve, S. Drobot, J. Zwally, D. Yi, and W. Emery, 2007: A younger, thinner Arctic ice cover: Increased potential for rapid, extensive sea-ice loss. *Geophysical Research Letters*, 34, L24501, doi:10.1029/2007GL032043.] Compared to last year, the sea-ice extent is similar, but the ice age data indicates that the ice pack is more vulnerable to loss this year. Air temperatures over the last couple of months have been cooler this year than last year, which helps to explain why our current forecast is slightly higher than the preceding one, which was 3.83 million square kilometers. More details will be online at http://ccar.colorado.edu/arifs [*note: That will be up next week!*]

5. Any expanded information with figures which backs up #4.
We can provide these in better formats if requested:

The first image is a scatterplot of the September sea ice extent and the ice age index.



Next, we have a scatterplot of the September sea ice extent and the June ice extent index.



Lastly, since our model is probabilistic, we can provide a probability of setting a new record. We are forecasting a 40% chance of setting a new record this year (down from 59% in the last forecast).

Any information on regional sea ice conditions or outlooks. We still have not done any probabilistic regional forecasts this year.

#5—Hajo Eicken (Regional Outlook)

Sea Ice Outlook 2008: A regional perspective on ice evolution in the Pacific Arctic sector (June update, released 2 July 2008)

Data

Ice extent:

• Passive microwave data (SSM/I) distributed by the National Snow and Ice Data Center (NSIDC) indicate that rapid ice retreat observed in May has slowed down somewhat in June. In the southern Chukchi and eastern East Siberian Sea, the ice edge is near its normal position in late June, while it is much further north than normal in the Beaufort Sea (slightly further north than its 2007 summer position at the same time of year; see Fig. 1).

Ice thickness and ice characteristics:

• *Eastern Chukchi/Western Beaufort Sea:* The multiyear ice studied off Barrow in April 2008 (5-7 years old, level ice 3.3 m thick; see May Sea Ice Outlook document) continues to linger. While thinner ice found north of Barrow in late spring has melted back substantially, rotten, deformed ice remains in the area. Coastal sea ice:

• At *Wales*, in Bering Strait, the shorefast ice broke up on June 9, over a week later than last year. Local ice observers reported the last ice offshore on June 22, almost two weeks later than in 2007.

• At *Barrow*, level ice thickness at the end of the ice growth season was somewhat below normal with thicknesses between 1.4 and 1.5 m. Surface melt commenced with a major rainfall event on May 24 and then proceeded in leaps and bounds with episodes of snowfall and freeze-back. By June 17, total melt amounted to 18 cm of snow and 32 cm of ice lost. Lack of grounded ridges resulted in sequential loss of landfast ice from at its outer edge, with a significant breakout on June 27. On July 2, level ice had melted all the way through in larger stretches alongshore. Subsistence hunting on the landfast ice ceased by the last week of May, at least in part as a result of lack of stable ice (reported by local ice experts and evident from ice thickness surveys) at the landfast ice edge.

Outlook and potential impacts:

Landfast ice disintegrated somewhat later (about one week) in the region than last year, but was already unstable and unsafe in many areas prior to that. Ice retreat is now lagging behind last year's pace due to surface circulation and lack of warm weather, but is still somewhat more advanced than climatology. First-year ice is expected to melt out further with significant retreat of the ice edge, as currently occurring over the eastern Beaufort shelf, where ice is starting to retreat from the coast of Banks Island. However, complete meltback of multiyear ice advected from the North in late spring (see May Sea Ice Outlook) is increasingly unlikely due to lack of surface warming. This may result in fields of rotten multiyear ice off the northern coast of Alaska for the duration of the summer, with potential impacts on marine mammals (providing a platform for foraging walrus well into the season) and ship traffic.

Information needed to improve outlook:

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

Submission information:

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

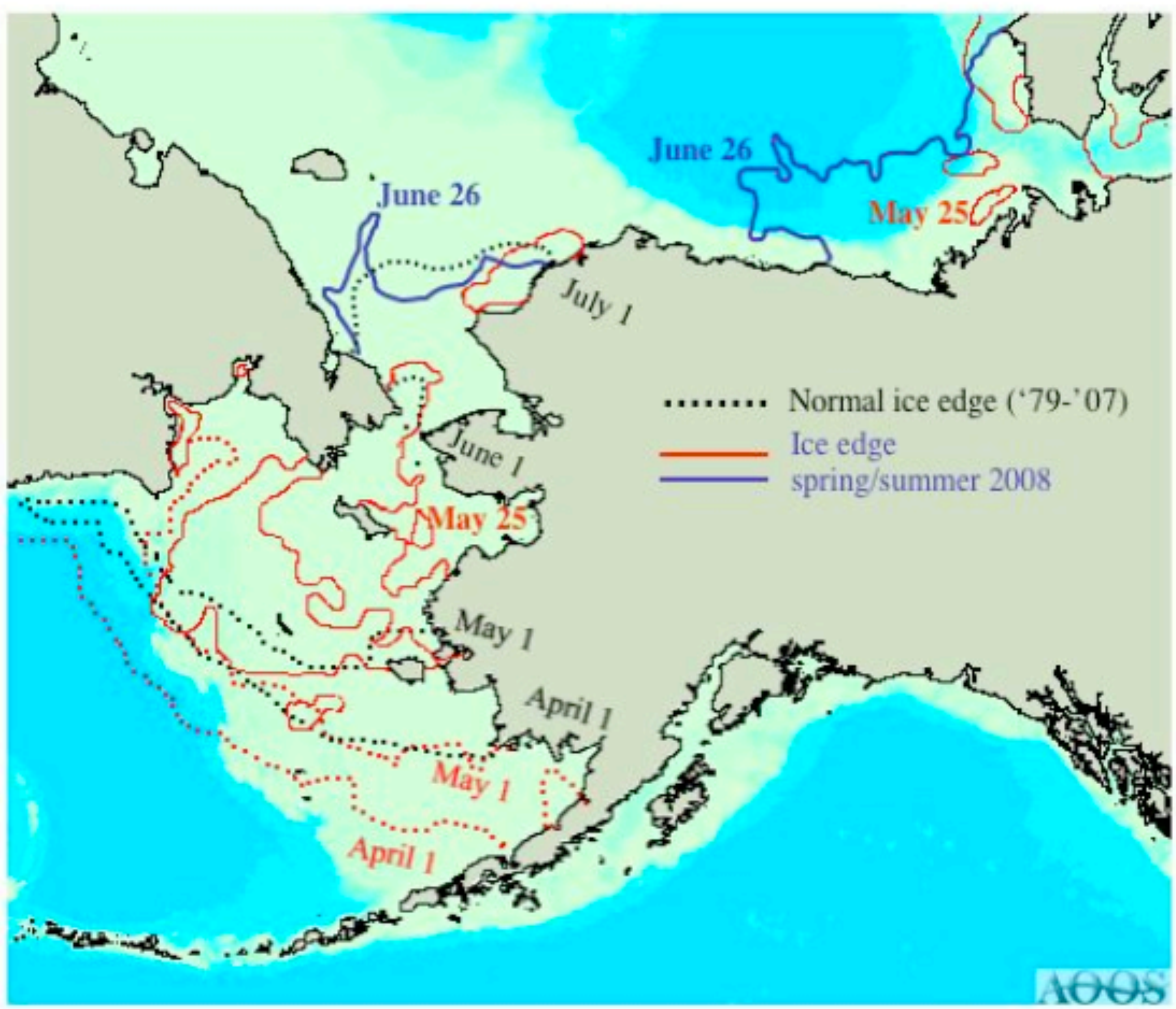


Figure 1: Ice extent derived from passive microwave satellite data (SSM/I, data provided by NSIDC, nsidc.org) for Pacific Arctic sector. Shown are observed ice edges for April, May and June (shown as red dots for April and May 1, or red or blue lines for May 25 and June 26), along with "normal" ice edges (median positions, shown as black dots) from 1979 to 2007.

#6—Sebastian Gerland and Harvey Goodwin (Regional Outlook)

Notes for the Arctic Sea Ice Outlook for the areas Greenland Sea and Barents Sea (Status: 1st July 2008)

The Greenland Sea and the Barents Sea are Arctic regions with different basic sea ice regimes. The Fram Strait in the northern Greenland Sea represents the only deepwater connection between the Arctic Basin and the other world oceans. The dominant part of sea ice exiting the Arctic Basin drifts through the Fram Strait, at the end of the transpolar drift. Consequently, ice in the very dynamic Fram Strait and Greenland Sea consist to a large part of advected sea ice that was formed further north in the Arctic Basin, or in the Siberian shelf seas. Ice types in the Fram Strait include multi-year ice, and first-year ice (season depending). Contrary, the more shallow Barents Sea consists mainly of seasonal ice (first-year ice), that was formed in the Barents Sea and Kara Sea.

The difference in the ice regimes in these two regions make the Barents Sea more likely to respond faster and more directly to changes in atmospheric and oceanic conditions, and climate.

Regarding the development in 2008, we review the mean ice extent for June 2008 relative to means of time spans on decadal scale back to 1979 (Fig. 1). However, these ice edges are limited in what they can show, since i. the spatial resolution of passive microwave sensors is limited to about 10-20 km (depending of year of observation and post-processing), ii. because monthly means average over different conditions within one month. Ice conditions in early June can differ from those in late June substantially, and iii. means over 10-20 and 30 years remove interannual variability of ice extents. Saying this, we find this choice is still well illustrating changes over the last decades. In large parts of the Barents Sea one can see that the position of the marginal ice zone in June was on average further north since 1999 compared to the 20 years before that. 2008 fits in the same range. In the Fram Strait, no big changes in ice extent can be seen (on this scale), both the decadal means and the 2008 observations are in the same area. The data show also the appearance of polynyas east of northern Greenland and south of Franz Josef Land (NE Barents Sea). These areas are known for their polynyas. For the area south of Franz Josef Land, it is interesting that the polynya appears also in the 1999-2008 mean.

In September 2007 (Fig. 2), the sea ice extent means indicate changes during the last 10 years for the Barents Sea, where the MIZ was significantly further north. Also in the Greenland Sea the last decade shows less ice, but 2007 appears rather similar to extents from earlier than the last decade.

The passive microwave satellite observations do not give information on ice thickness, and here we have only considered ice concentration more than 30% and not taken account of variability of higher ice concentrations. Combining the limitations of this data with the (interannual) variability in atmospheric and oceanic conditions between now and September 2008 leaves a wide range of scenarios open for how sea ice conditions may develop throughout the summer.

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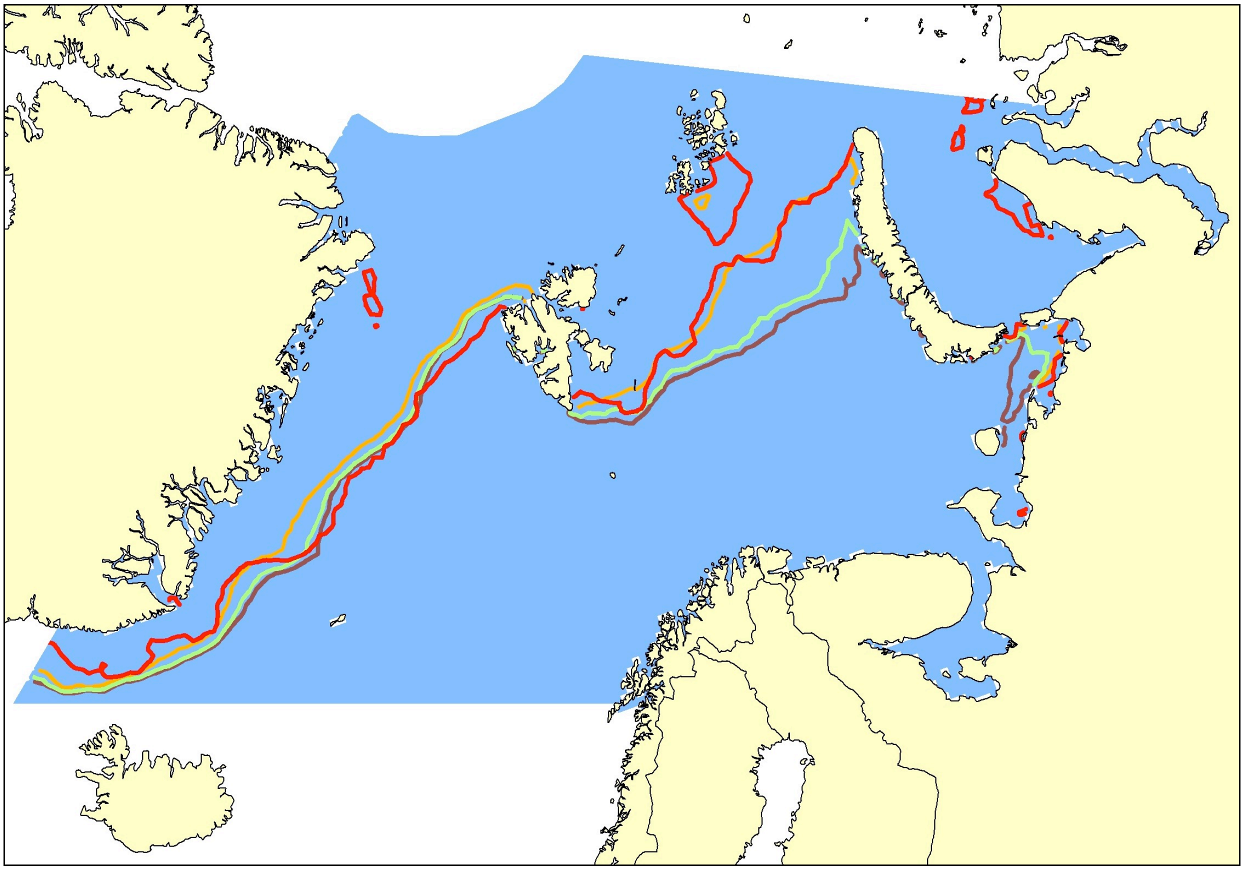

Figure 1: Ice extent (monthly means, June) southern border of 30% ice concentration) in the Greenland Sea/Fram Strait and Barents Sea, based on passive microwave satellite data (red = June 2008, orange = mean June 1999-2008, green = mean June 1979-2008, purple = mean June 1980-1999).

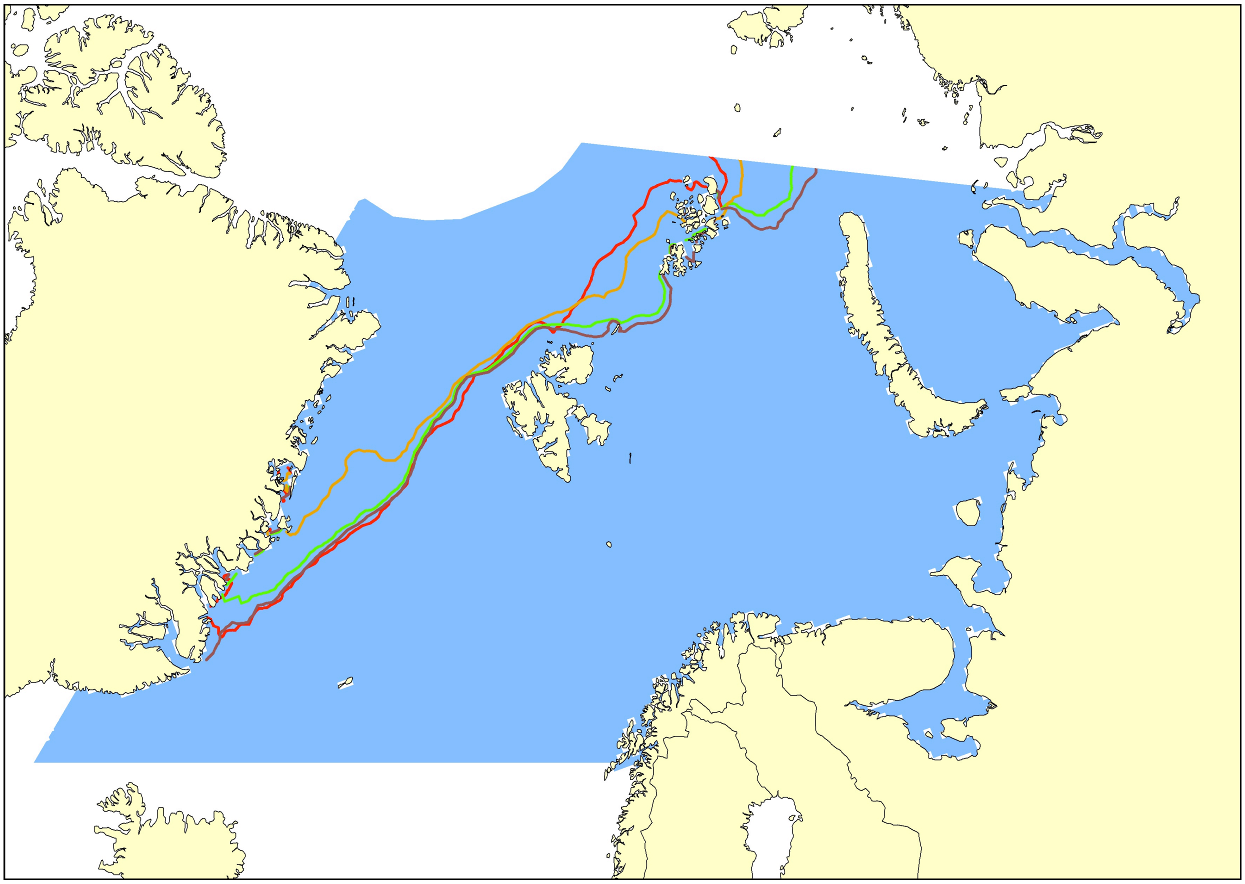

Figure 2: Ice extent (monthly means, September) southern border of 30% ice concentration) in the Greenland Sea/Fram Strait and Barents Sea, based on passive microwave satellite data (red = Sept. 2007, orange = mean Sept. 1999-2007, green = mean Sept. 1979-2007, purple = mean Sept. 1980-1999).

#7—Stephen Howell and Claude Duguay (Regional Outlook)

No Changes in the Northwest Passage. The ice is still landfast.
(See May 2008 Outlook)

#8—Jennifer Hutchings
June 2008 outlook for Arctic end of summer ice extent in 2008

Jennifer K. Hutchings
July 2, 2008

1. Introduction

I have not been working on a method for seasonal prediction of Arctic ice conditions. However, as I work in the Arctic and am researching which mechanisms control the end of summer sea ice minimum extent in the Beaufort Sea, I would like to provide some qualitative insight and a best-guess outlook. My research into the interplay between ice dynamics and sea ice mass balance is funded by the National Science Foundation.

2 Outlook

I expect 2008 minimum ice extent will be lower than the 2007 minimum ice extent. 3.6 + / − 0.5Mkm2

3 Rational

As pointed out by several investigators in the batch of May Outlooks, the area of multi-year ice entering summer 2008 is reduced compared to 2007. The extension of this old ice into the coastal seas and marginal ice zone is as low this year as it was at the same time last year. Hence the presence of MY ice at southerly latitudes will not act to increase minimum sea ice extent from last years all time low.

The position of the ice edge, in regions other than the Beaufort Sea, will depend on summer ice drift and the rate of thermodynamic melt. Hence a longer, warmer summer than 2007 could push the 2008 minimum ice extent lower than last year. Also the presence of a younger ice pack in much of the central Arctic will act to increase melt out rate in this region. In the western Beaufort Sea, based on previous experience, and the fact that ice type distributions in this region are similar to a year ago (as shown by quickscat), I would not expect the ice edge to fall north of 77N. The distribution of ice types are similar to last year, and as it is unlikely the old ice tongue on the eastern edge of the Beaufort Sea will drift across the southern Beaufort, I expect Beaufort ice conditions at the end of summer 2008 will be similar to the 2007 minimum.

The vast area of first year ice that falls over the central Arctic will be very interesting to watch this summer. This area has expanded substantially over the winter, and hence will contain much thin ice that can melt out early in the summer. This will act to enhance solar heating of the upper ocean and further accelerate ice melt. In the region extending from the Laptev and East Siberian Seas across the Arctic we can expect a more northern ice edge compared to last year. I expect the final resting position of the ice edge at the end of summer will be determined by latitudinal variation in thermodynamic energy balance at the oceanic and atmospheric interfaces. If the central Arctic experiences an intrusion of warm air and low cloudiness similar to last summer, albedo feedback could lead to the loss of all the first year ice in the central Arctic. I do not know the likelihood of this happening. In the past the end of summer ice edge in this sector of the Arctic has typically followed the continental shelf break, with variability due to wind driven intrusions of old ice to lower latitudes and atmospheric circulation patterns. The end of summer ice edge tends to follow the perennial ice pack edge, except in a few years when less extensive ice loss than average was experienced. The conditions at the start of summer 2007 and 2008 are unusual, due to the poleward transport of ice pack in the previous winters. Hence there is no observational basis for estimating the variability of a thermodynamically driven ice edge in the region with the new pack conditions.

A conservative viewpoint would take the 2007 event as an extreme melt back, given the anomalous weather patterns. However, the end of summer ice edge followed the edge of the perennial pack in 2007. Which means that the full potential maximum latitude of first year ice melt back was not realized.

Hence I estimate that the lower limit on 2008 minimum ice extent would be 3.1Mkm2. We can expect the 2008 minimum ice extent to be lower than the 2007 minimum 4.1Mkm2. So my best guess at the 2008 minimum ice extent is 3.6+/−0.5Mkm2. Personally, I believe the 2008 minimum will fall at the lower range of this estimate - but that is just a hunch based on the understanding that the ice pack is set up for enhancement of this summer's albedo feedback.

4 Additional Information Required

Given the lack of observational information regarding the summer-time evolution of a seasonal ice pack that extends across the Arctic Basin, results from ensemble model runs could be of great importance in projecting this summer's ice conditions. Long-range and seasonal predictions of Arctic weather would help in assessing how we expect summer time ice drift and ice melt to vary from the norm.

5 Regional Prospective: The Beaufort Sea

At the time of writing the Beaufort melt season in underway in earnest. Ice loss in the eastern Beaufort is greater than the same day last year, or any previous year in the satellite record. As the spatial distribution of ice types matches last years in the Beaufort, I expect this year will once again have an open ice pack in the vicinity of Banks Island. The increased solar input to the ocean mixed layer could also act to extend the melt season in the southeastern Beaufort later in to 2008, as was experienced in 2007.

There is a thin zone of older ice along the Alaskan coast visible in quickscat imagery. This may persist far into the summer.

#9—Lars Kaleschke

Daily updated Sea Ice Outlook based on statistics of the sea ice area from 85 GHz SSM/I data 1992-2008

June 2008 by Lars Kaleschke

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Estimate of sea ice extent for the month of September 2008:
ftp://ftp-projects.zmaw.de/seaice/prediction/regression.png
ftp://ftp-projects.zmaw.de/seaice/prediction/prediction_timeseries.png

Principal method
Daily updated statistical regression based on sea ice concentration derived from 85 GHz SSM/I data.

Primary physical reasoning
The auto-correlation of the sea ice area anomaly time series is in the order of three months. Therefore, a skillful prediction of the September ice extent is possible based on the satellite derived sea ice area at the end of June.

Expanded information
For this outlook in June a different method is used as in May. In May a prediction based on the actual observed sea ice area was not possible because of the lack of statistical correlation for the May ice area with the Summer minimum. The situation is different in June. As we temporally approach the summer sea ice minimum, a skillful prediction is feasible based on the presently observed sea ice area. Because of the expected increase in predictive skill during July, a computer program was developed to update the September estimate on a daily basis.

Several algorithms exist to calculate the sea ice concentration from passive microwave data. Here the ARTIST Sea Ice (ASI) algorithm is used to derive the sea ice concentration from SSM/I data (Kaleschke et al. 2001). A validation with ship based observations in the summer season showed the good performance of the ASI algorithm in terms of standard deviation and correlation to the ground truth (Andersen et al. 2007).

Average values of the September sea ice area were calculated for the years 1992-2007. A linear scaling is used to convert the sea ice area to the extent which is justified by the high correlation of the September sea ice area with the extent. The sea ice area of the present day is used together with the same days of the 16 previous years and the September averages to estimate this year's September extent (Figure 1). A hindcast test of the method revealed that the skill of prediction that is given by the correlation sharply increases after mid of June. The time evolution of the prediction is shown in Figure 2.

NOTE: I'll expect my prediction to further decrease. Today's (0705) estimate is 5.6 +-1.

It is really interesting to see how the errorbar of the estimate is decreasing over the time. I suppose that we can provide a very reasonable estimate in about 2-3 weeks. You can check my website http://www.seaice.de for daily updates.

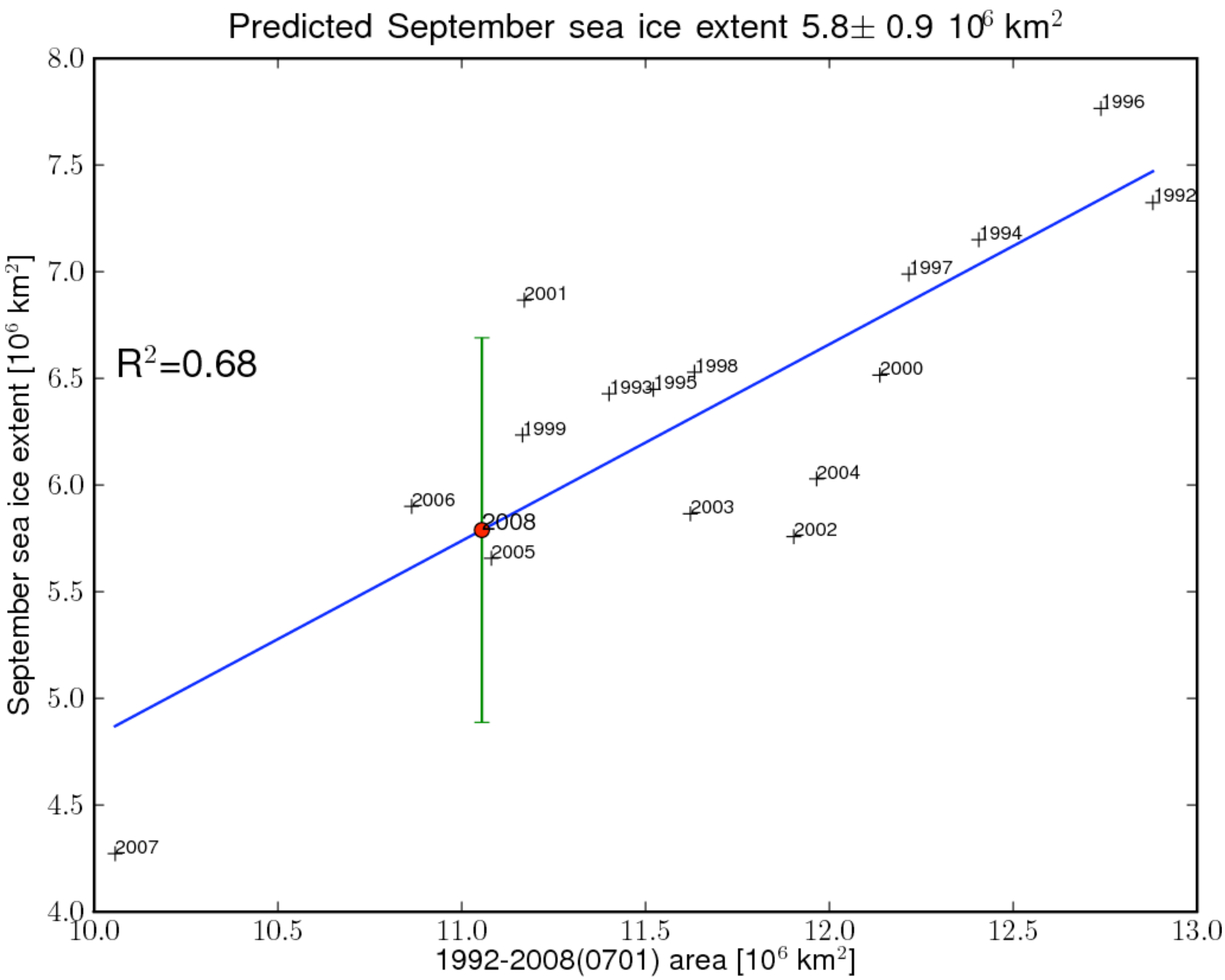

Figure 1: Predicted September sea ice extent. The linear regression line was calculated from the sea ice areas of the 30th June and the September average for the years 1992-2007. The September sea ice extent is estimated from the observation of the 30th June 2008. Daily updates of this figure are available at ftp://ftp-projects.zmaw.de/seaice/prediction/regression.png

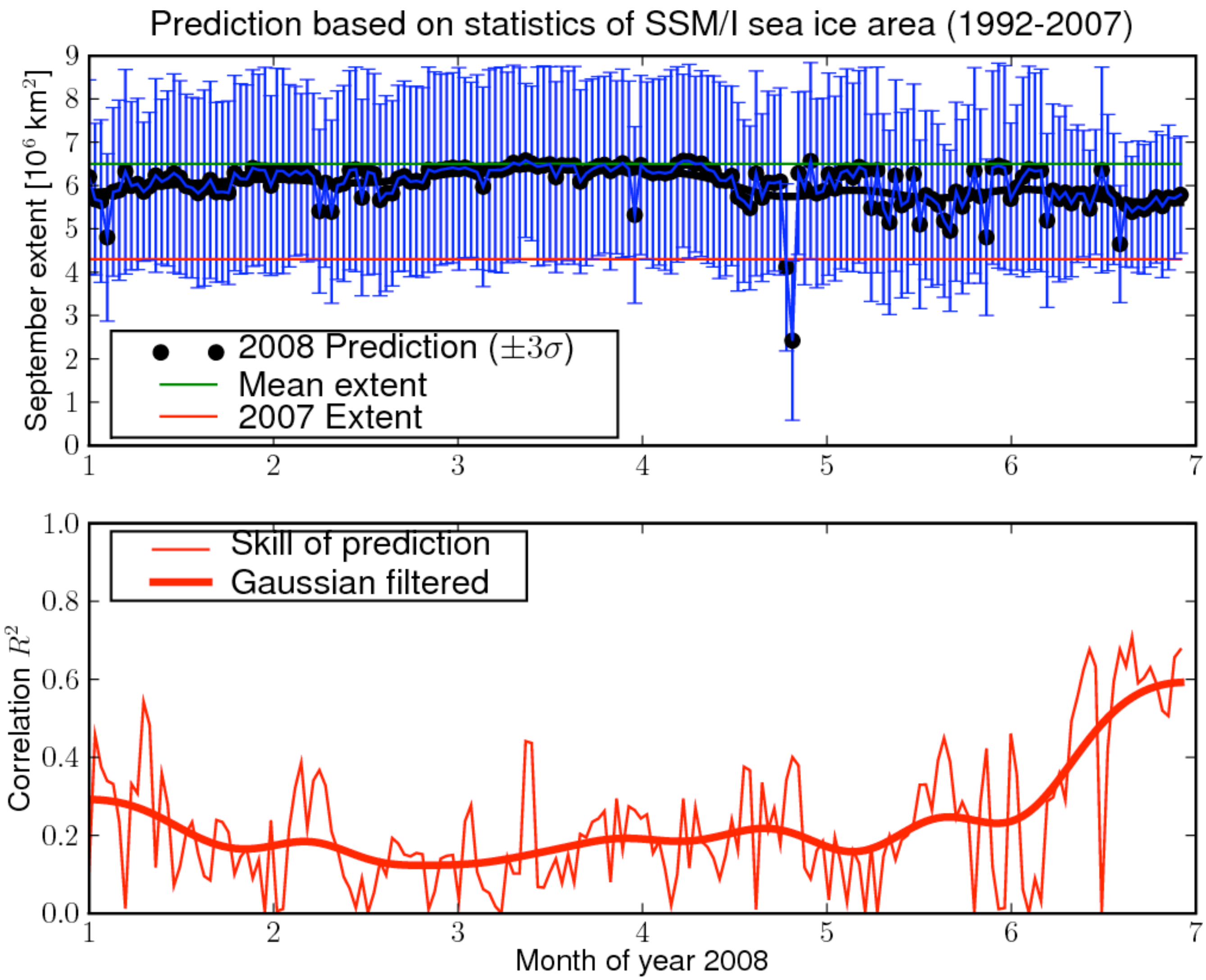

Figure 2: Estimated September sea ice extent and skill of the estimate (correlation). This graph is the result of the method shown in Figure 1 applied for every day of the year 2008. Daily updates of this figure are available at: ftp://ftp-projects.zmaw.de/seaice/prediction/prediction_timeseries.png

References:

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Kaleschke, L., C. Lüpkes, T. Vihma, J. Haarpaintner, A. Bochert,, J. Hartmann, and G. Heygster (2001), SSM/I sea ice remote sensing for mesoscale ocean-atmosphere interaction analysis, Can. J. Remote Sens., 27(5), 526– 537.

Daily gridded sea ice concentrations from http://cersat.ifremer.fr/data/discovery/by_parameter/sea_ice

#10—Frank Kauker, Rüdiger Gerdes, and Michael Karcher (AWI)

Arctic Sea Ice in summer 2008 - an outlook

Frank Kauker, Rüdiger Gerdes, and Michael Karcher

July3rd, 2008

Motivation: The Situation of Arctic Sea Ice

The area of the ocean covered by ice is an important climate parameter. A smaller ice cover means less reflection of sunlight and more storage of heat in the ocean. Both effects contribute to local warming which may further reduce the ice-covered area. The annual Arctic sea ice extent minimum occurs in September, at the end of the melting season. The Arctic sea ice extent minimum has a downward trend from about 7 million km^2 in the early 1980s to about 5.5 million km^2 in 2006.

The ice extent is defined by the outer edge of the ocean surface covered with sea ice. In practice, sea ice concentration (the fraction of area covered by sea ice) is measured from satellites and the 15% concentration contour is taken as the sea ice edge.

In September 2007 the sea-ice extent in the Arctic Ocean reached a new record minimum of 4.3 million km^2, 1.3 million km^2 below the old record minimum of September 2005.

Following this event there has been an intense scientific discussion on the cause of this sudden drop, basically whether this was a consequence of climate change or due to natural variability, or a mixture of both.

At present there is evidence that indeed there was interplay of both factors. There are indications for a sea ice thickness decrease in the last decade, accompanying the decrease of sea ice extent. The area covered by older, thicker ice has decreased to make space for younger, thinner ice. This has led to a larger vulnerability of the ice cover, since thinner ice can melt faster and offers less resistance to wind forcing. In addition to this long-term trend, for several months in 2007 unusual wind patterns occurred, which pushed ice from the Chukchi area north of the Bering Strait to the North and West. A larger area of open water evolved, and the extent of sea ice was drastically reduced.

Favourable winds acting on a rather thin, low concentration ice cover, made the transpolar drift from the ice production areas north of Siberia to the exit of sea ice through Fram Strait much faster than during earlier decades. The schooner TARA, an expedition vessel that was frozen into the drifting sea ice as part of DAMOCLES research project, experienced a drift velocity about twice as large as expected.

Triggered by the rising concern about the future development of the Arctic sea ice and as a contribution to the DAMOCLES project, scientists from AWI and OASYS have employed a technique called 'ensemble simulations' to predict the likeliness of certain sizes of the sea ice extent for September 2008. The method uses simulations with the coupled ice-ocean model NAOSIM, developed at AWI

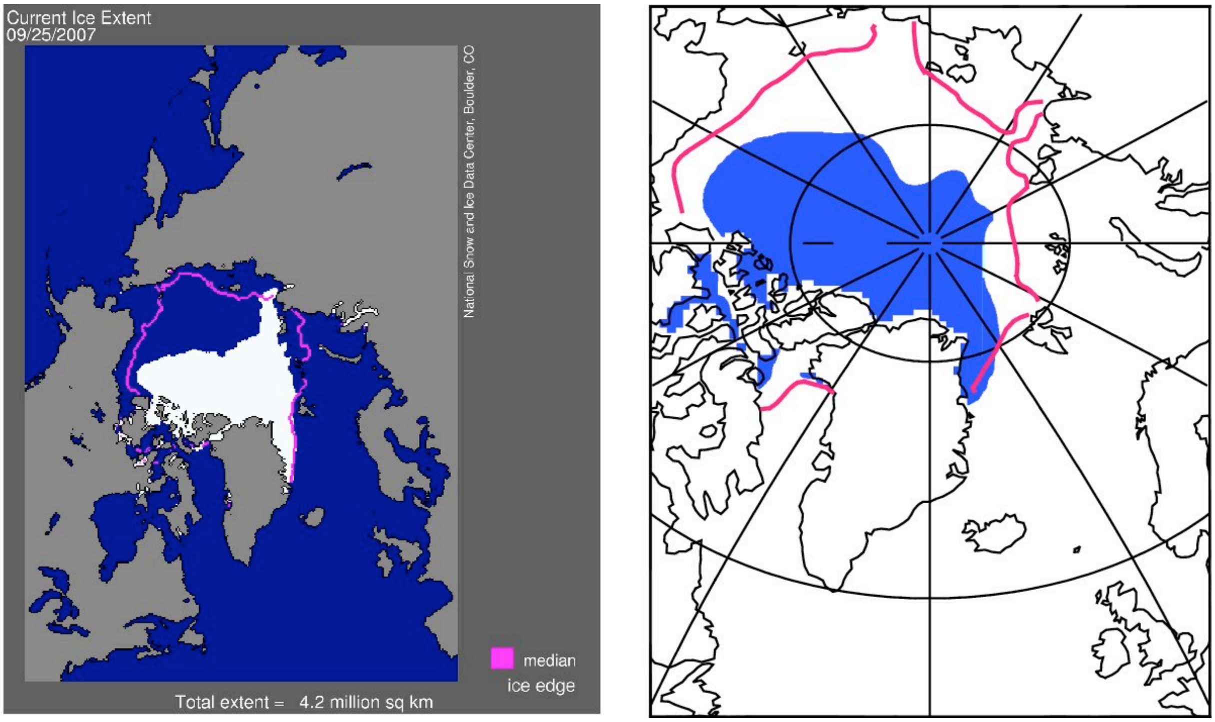

Figure 1: Area within the 15% sea-ice margin on 09/25/2007 as deduced from satellite data (left, white) (www.nsidc.org/arcticseaicenews) and computed by NAOSIM (right, blue). The magenta lines display the long-term September mean for 1988 to 2007.

The Concept of 'Ensemble Simulations'

While the sea ice state at the beginning of the melt season is important, the development until September depends strongly on the actual atmospheric conditions, especially the wind, cloudiness, and surface temperatures. The strong variability of the high latitude atmosphere is responsible for large fluctuations of sea ice extent from year to year. To actually predict sea ice extent in September, we thus would need to know the development of the atmospheric state over several months in advance. Such long-term weather forecasts are not available or have little skill. Thus, we can only make a probabilistic forecast: Given a certain range of atmospheric variability and the known conditions at the beginning of the melt season, how large is the probability that sea ice extent will fall below a certain value? To this end, we employ a technique named ‘ensemble simulation’ where we prescribe atmospheric conditions from the years 1988 through 2007 to force an ocean-sea model.

The ocean-sea ice model NAOSIM calculates oceanic circulation, temperature, and salinity as well as sea ice drift, thickness, and concentration among other variables. The model incorporates the basic dynamical and thermodynamic equations that govern ocean and sea ice. Thus, it is able to reconstruct, starting from given initial conditions, the history of ocean and sea development through time. Input to the model are several atmospheric quantities that are necessary to calculate the heat, water and momentum exchanges between the different media. We say that the model is “forced” by these atmospheric data.

The coupled ice-ocean model NAOSIM is forced with atmospheric surface data from January 1988 to the end of June 2008. This atmospheric forcing has been taken from the “NCEP reanalysis”. These data are no observations but the output of a global atmospheric model constrained by observations. This is similar to the first step in numerical weather prediction, where all available atmospheric data are gathered and interpolated to a regular grid using an atmospheric model to incorporate the atmosphere dynamics. Reanalysis data are not without errors, especially in the sparsely observed Arctic.

Figure 1 displays the ice extent on 09/25/2007 as deduced from satellite-data and as simulated by NAOSIM. The model is able to reproduce the large ice-free areas in the central Arctic Ocean. Some discrepancies compared to the observations are visible, partly reflecting unavoidable shortcomings of resolution and representation of physical processes in the model. However, it is not possible to determine if these discrepancies are due to inadequate atmospheric forcing data or due to flaws in the ice ocean model. As in the observations the model simulates an all-time minimum ice extent in September 2007 (Fig. 2). These results (and many more that were used to validate the model in the past) convince us that the model simulations are suitable for the task.

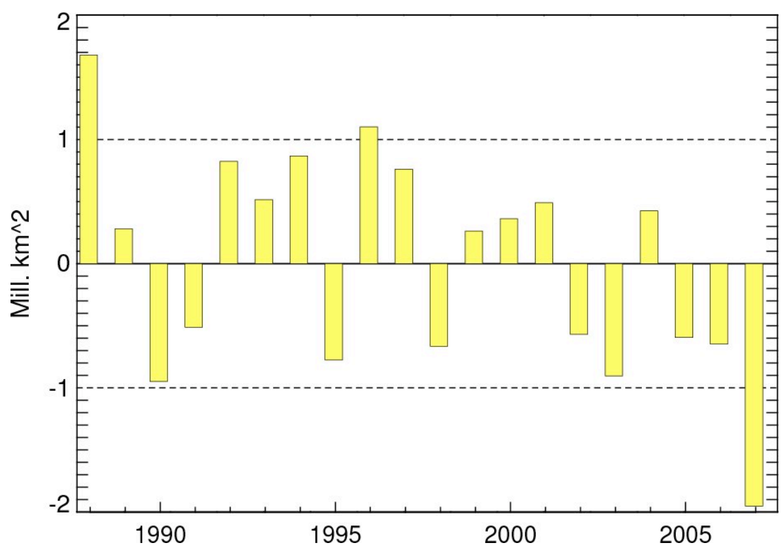

Figure 2*: The simulated September sea-ice extent anomaly [Mill. km^2] for the years 1988 to 2007.*

For the coming summer 2008 the atmospheric situation is unknown. However, we can use end of June to September atmospheric data from the past years 1988 to 2007 to get an estimate of the possible range of minimum sea ice extent. The model experiments all start from the same initial conditions on the 27^{th} June 2008. We thus obtain 20 different realizations of the possible sea ice development from July through September 2008. We use this ensemble of realizations to derive probabilities of specific sea-ice extent values to be expected as minimum in the summer 2008. The method also provides the probability for reaching a new record minimum below the 2007 value.

Results

Minimum Ice Extent 2008

The summer minimum sea ice extent for all 20 realizations is shown in Figure 3, ordered by the magnitude of ice extent. With the atmospheric forcing from the extraordinary year 2007, the minimum sea ice extent occurring in September 2008 comes out even lower than it was in 2007 by 0.22 million km^2. The ensemble mean value for the 20 summers is 4.43 million km^2. This is the most likely value under the assumption that the atmospheric conditions in the remaining months of summer 2008 do not fall out of the range of the previous 20 years. The standard deviation of the ensemble is 0.21 million km^2. Assuming a Gaussian distribution we are now able to state the probabilities that sea ice extent will fall below a certain value.

The probability that in 2008 the ice extent will fall below the minimum from September 2007 is about 8%, the probability to fall below the minimum of 2005 (second lowest value in the last 20 years) is practically 100%. With a probability of 80% the minimum ice extent in 2008 will be in the range between 4,16 and 4.70 million km^2.

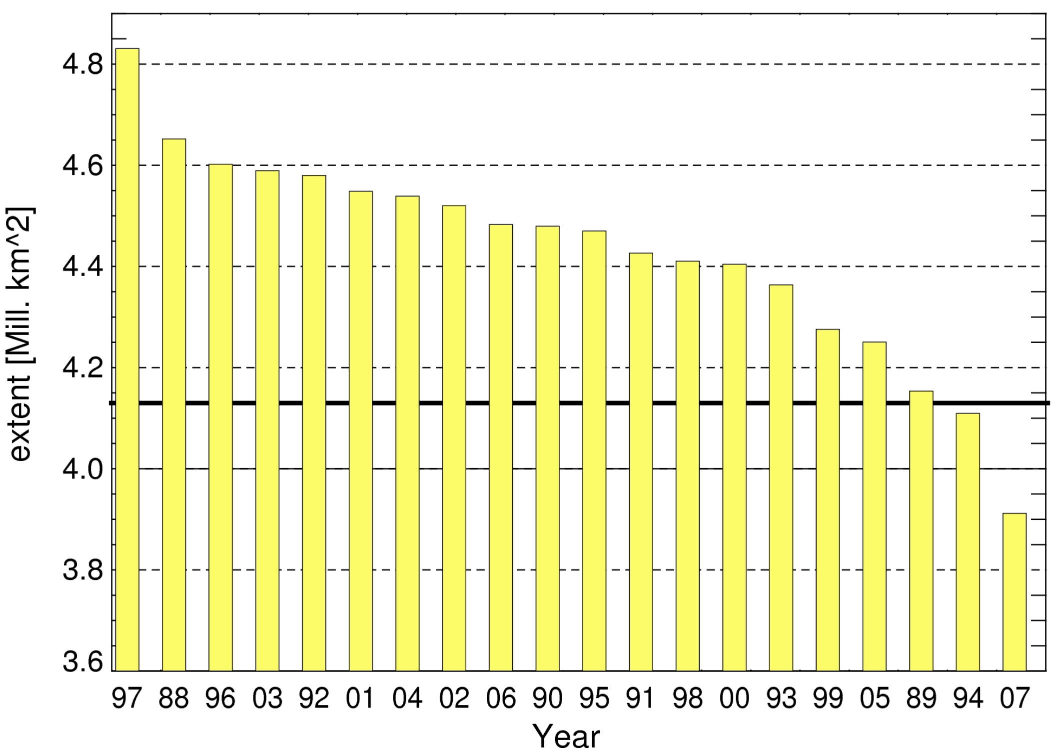

***Figure 3**: Simulated minimum sea-ice extent in 2008 [Mill. km^2] when forced with atmospheric data from each year between 1988 and 2007 from the initial state of June 27, 2008. Model derived ice extents have been adjusted with a constant offset to account for discrepancies with satellite-derived ice extents. The thick black horizontal line displays the minimum ice extent observed in 2007.*

Influence of previous winter conditions

For an improvement of seasonal sea ice outlooks in the future it is important to know which of the data that we can observe at the end of the winter season have the largest influence on the sea ice extent in September.

Our model experiments reveal that especially the ice thickness at the end of winter has a big influence on the following September ice extent. In March 1988 for example, the ice thickness was much larger than in 2007 or 2008. When performing the ensemble simulation for the atmospheric forcing of all years from 1988 to 2007, atarting from the initial ice conditions in March 1988, the smallest of the September sea ice extents from the ensemble members is almost 2 Mio km^2 larger than with initial ice conditions from March 2007. The largest of the September mean sea ice extents occurring for the ensemble simulation is 1 Mio km^2 above the one starting in March 2007. The ensemble mean ice extent of September for starting in March 1988 is 0.73 Mio km^2 higher than the corresponding value for starting in March 2007.

We can therefore conclude that the initial ice conditions in March are responsible for a difference of 1-2 Mio km^2 in the monthly mean September sea ice extent.

The strong reduction of ice extent in 2007 left large areas to form new ice in winter 2007/2008. Comparatively large areas of rather thin, young ice therefore characterize the situation at the beginning of the melt season in spring 2008. This can be seen in satellite derived first-year ice fractions, e.g. from NIC (see www.nsidc.org/arcticseaicenews/), as well as in the model results. Therefore, a model run driven with atmospheric data from 2007 which is started from spring ice conditions in 2008 instead of 2007 leads to even smaller ice extent.

#11—Ron Kwok

No changes.
(See May 2008 Outlook)

#12—Ron Lindsay

Our best estimate is 4.44 +/- 0.21 million sq km using the G1 predictor (the area fraction of ice and water less than 1 m thick).
(See May 2008 Outlook)

#13—Oleg Pokrovsky

Arctic Ice Extent Outlook for September 2008(June)

Oleg M. Pokrovsky

Current observing data confirm previous ice extent forecast. I expect higher ice extent magnitudes (at least 0.1 million km^2) in September 2008 than those occurred in 2007. But, ice coverage will be quite different with account to those of 2007. More significant ice extent retreat is expected in Canadian/Alaska sector of Arctic due to enhance of warmer air inflow. In contrast, Russian sector will demonstrate more complicated picture. Less ice coverage is expected in Barents and Kara seas. In contrast, more strong ice sheet will be in Eastern Seas (Laptev and East-Siberian Seas). Latter might be explained by two factors:

(i) Remained basin of warm waters in Barents Sea,
(ii) Cold water basin in Bering Sea (fig.4) and colder air inflow in Eastern Siberia.

This assumption might be explained by following data:

- Higher ice extent values during January-May of 2008 with respect to corresponding data for 2007 (table).
- Lower SAT values in May 2008 with respect to corresponding data for 2007 ((with an exception of Arctic coast of Alaska and Canada)) (fig.1)
- Absence of persistent northward wind in North Pacific (fig.2a) directed to and entered in Arctic Ocean, which was a major cause of unprecedented ice melting and destruction in Eastern sector of Arctic last summer (fig.2b)
- The SST attains lower values in most Arctic margin seas (with an exception of Eastern Chukchi Sea) (fig.3)
- There is a negative tendency in the SST in the Arctic Mediterranean and in the North Pacific during last 3 years (fig.4). Thus, more cold waters will arrive in Arctic in next years.

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

Year/month	Arctic Ice extent (million sq. km)
2007/Feb	14.5
2008/Feb	15.0
2007/March	14.7
2008/March	15.2
2007/April	13.9
2008/April	14.5
2007/May	13.0
2008/May	13.2
2007/June	11.5
2008/June	11.4