September 2009 Sea Ice Outlook: August Report

Community Contributions

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September 2009 Sea Ice Outlook: August Report
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Issued July 31, 2009

Best Guess: 4.151 million km^2
Method: Heuristic/Statistical

Update:

The current conditions (Figure 1):
Ice extent 8.375 million km^2
Ice Area 6.842 million km^2,
Average concentration 81.7%

Multiyear ice extent 4.900 million km^2
Multiyear ice area 2.544 million km^2
Average concentration: 51.9%

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. Mr. Holden and Ms. Panowicz also provide input.

The Seasonal Outlooks:

Conservative: Any area with MYI survives
Ice extent: 4.773 million km^2
Ice area: 4.279 million km^2
Average concentration: 89.7%
MYI extent: 4.773 million km^2 (includes all parcels containing MYI)
MYI area: 2.439 million km^2
Average concentration: 51.1%

Moderate: Any area with 20% or more MYI survives
Ice extent: 4.151 million km^2
Ice area: 3.890 million km^2
Average concentration: 93.7%
MYI extent: 4.151 million km^2
MYI area: 2.253 million km^2
Average concentration: 54.3%

Aggressive: Any area with 40% or more MYI survives
Ice extent: 2.935 million km^2
Ice area: 2.785 million km^2
Average concentration: 94.9%
MYI extent: 2.935 million km^2

MYI area: 1.974 million km^2
Average concentration: 67.3%

Extreme: Any area with 70% or more MYI survives
Ice extent: 1.849 million km^2
Ice area: 1.760 million km^2
Average concentration: 95.2%
MYI Extent: 1.849 million km^2
MYI Area: 1.432 million km^2
Average concentration: 77.4%

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 distribution of the ice in September 2009 will be very different than the current August 1 conditions.

From the spread of prognostications, we believe the Moderate case (4.151 million km^2) is the most likely. This would be a record or near-record, depending on the method used to measure the ice extent and concentration. The National Ice Center (NIC) uses ice charts where the data used to make the chart can come from a variety of sources (e.g., RadarSAT, MODIS, AMSR-E, SSM/I). The National Snow and Ice Data Center (NSIDC)—the center most often cited for sea ice extrema—uses the Sea Ice Index, based primarily on SSM/I measurements. Differences in how the data are processed can also lead to different values of sea ice extent and area.

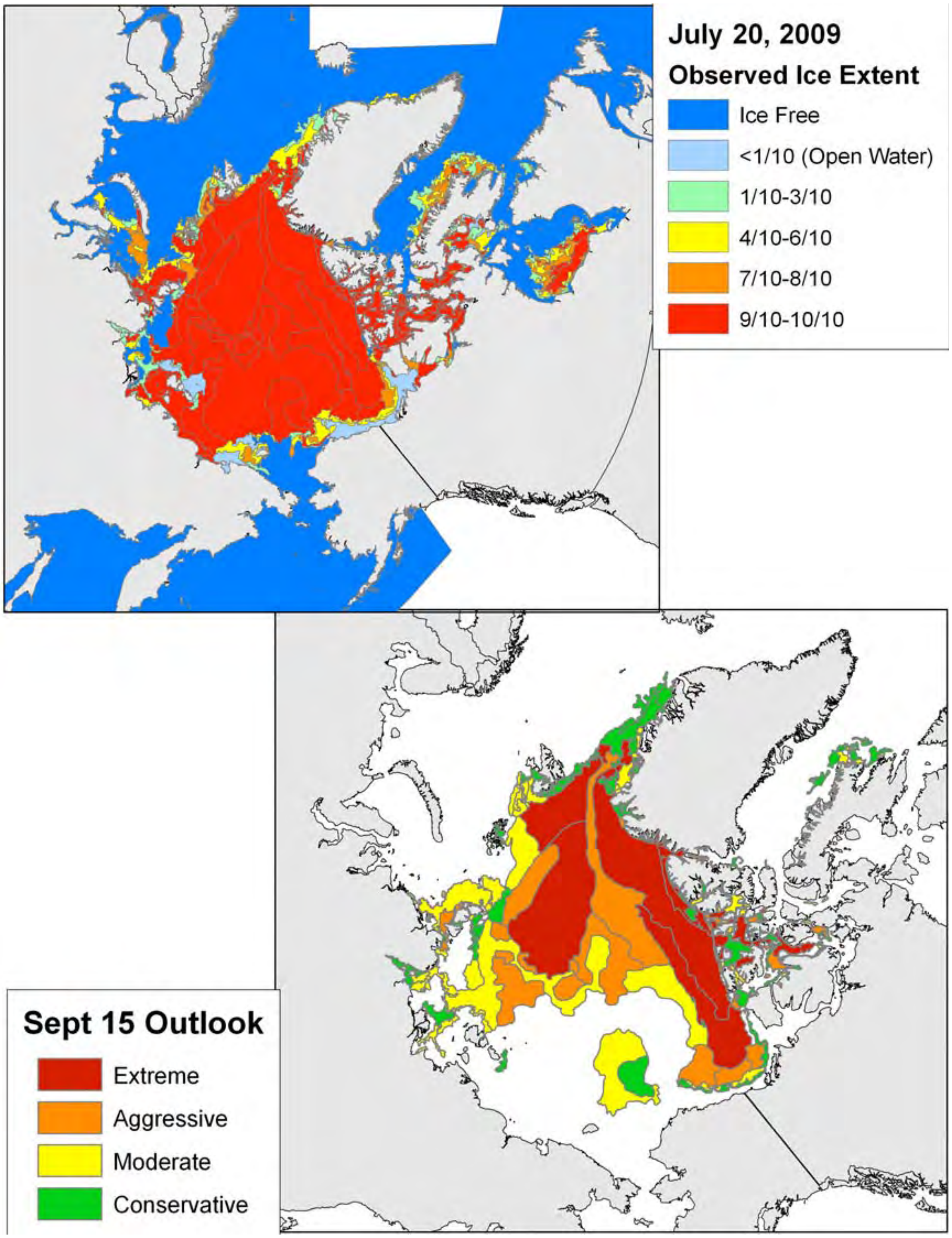

Figure 1: Sea ice conditions for June 22, 2009, and projections for September 15, 2009. For the projections, Extreme = red, Aggressive = red + orange, Moderate = red + orange + yellow, Conservative = red + orange + yellow + green.

Sea Ice Outlook for September 2009 (Based on July Data)

Ignatius G. Rigor[1,2], Son V. Nghiem[3], Pablo Clemente-Colón[4], Kyle Obrock[4], and Todd Arbetter[4]
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[2]NOAA/UW Joint Institute for the Study of the Atmosphere and Ocean
[3]Jet Propulsion Laboratory, California Institute of Technology
[4]Naval/National Ice Center

1. Extent Projection

   We estimate that the September monthly mean sea ice extent will reach a new record minimum of 4.3 million square km (Fig. 1, right), about a 0.1 million sq. km. increase in comparison to

2. Methods and Techniques

   This estimate is based on 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), and the expected sea ice concentration at each grid cell based on the age of sea ice in September from 1979-2008. The DM model has been validated using independent estimates of ice type from QuikSCAT (e.g. Figs. 2 and 3; 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).

   This year we have emphasized the spatial distribution of sea ice types in our outlook, rather than just the fractions of sea ice types over the whole Arctic Ocean as we did last year.

3. Rationale

   The evolution of the concentration of sea ice and the retreat of sea ice extent during summer is strongly dependent on the initial (end of winter) thickness of sea ice across the Arctic Ocean. We use the age of sea ice as a proxy for sea ice thickness. In comparison to 2007 and 2008, there is much more FY ice (darker blues) in the Beaufort and Chukchi seas in 2009 (Fig. 1), which we expect to precondition this area for more extensive retreat than in 2007 and 2008. The age of sea ice in the Transpolar Drift Stream is also younger in the areas north of the East Siberian Sea (~80N 150E), which also preconditions this area for more retreat compared to previous years.

Although there is some FY ice in the area of the North Pole, this area also gets much less sunlight, thus is less likely to melt out.

Some uncertainty exists in this (and other) outlooks related to variations in wind which redistributes sea ice across the Arctic Ocean, and the advection heat into the area during summer. Since we do not estimate the age of sea ice in the Canadian Archipelago, we add 0.5 million sq. km. to the area bounded in yellow in Fig. 1, right. Depending on inter-annual variability of sea ice conditions in the archipelago, this is another source of uncertainty.

The estimates of the age of sea ice based on the observed buoy drift during July (Fig. 4) rather than just the mean field ice motion for July, shows more advection of sea ice from the Chukchi Sea into the East Siberian Sea, which increased the average age of sea ice in this area, and thus the likelihood that more of the ice in this area would survive when compared to our June estimates.

Figures

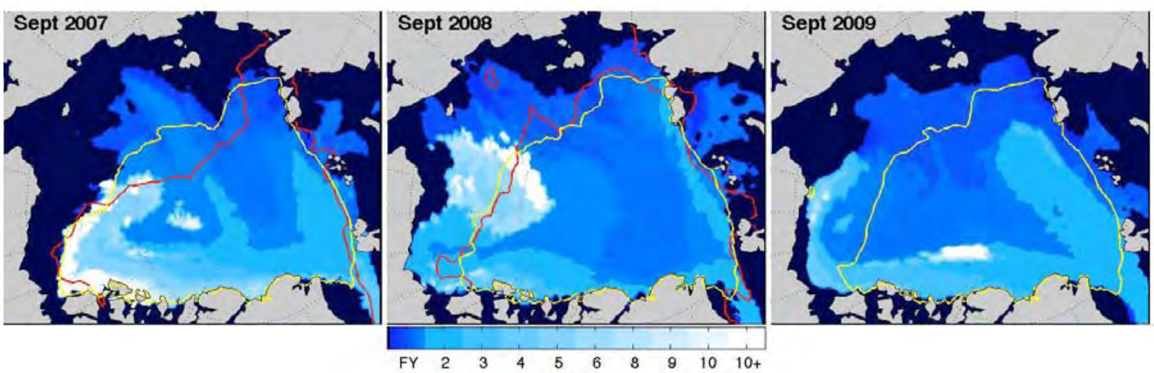

Figure 1. Maps of the age of sea ice for September 2007 and 2008, and the projected age of sea ice in September 2009 based on July data. The red line shows the observed 15% sea ice concentration line that we use to define sea ice extent, while the yellow line shows the expected 15% sea ice concentration line based on the age of sea ice.

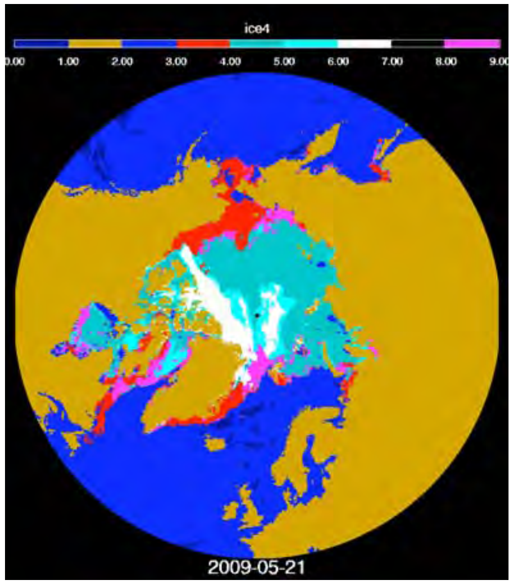

Figure 2. Maps of Arctic sea ice distribution based on QuikSCAT for April 21, 2009. The colors show perennial ice (white), mixed ice (aqua), seasonal ice (teal), ice with current melting surface (red), and ice with melted surface within the previous ten days (magenta). The extent of perennial ice was about the same on 1 May 2009 and 1 May 2008, while there is more second year ice in 2009 due to more ice survived summer 2008. Springtime perennial ice extent was the lowest in 2008 as observed by QuikSCAT data in the decade of 2000s and by the buoy-based estimates in the last half century.

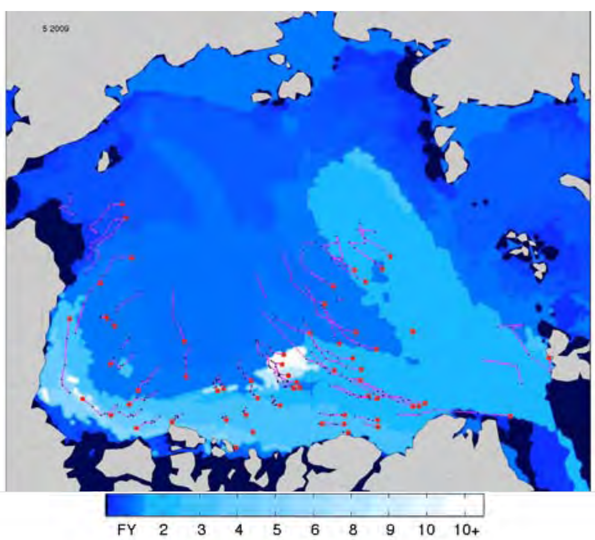

Figure 3. Map of the age of sea ice (in years) based on a buoy Drift Model for April 2009. Note the correspondence between the areas of FY and MY ice (ice older than 1 year) shown on this map and Fig. 2.

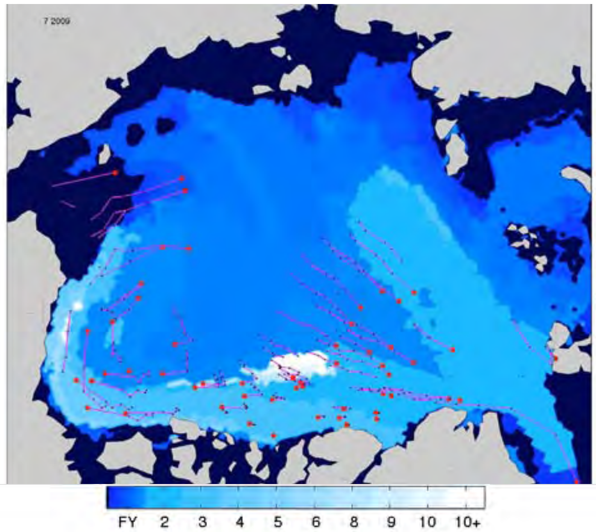

Figure 4. Maps of the age of sea ice for July 2009. The red dots show the current positions of buoys, while the black dots behind these show the positions of the buoys during the previous 6 months.

Sea-ice Outlook for Summer 2009

An T. Nguyen, Ronald Kwok, Dimitris Menemenlis
JPL/Caltech

1 Extent Projection

Our guess of the September monthly mean Arctic sea-ice extent based on July atmospheric conditions is 4.4 ± 0.5 millions km^2. With JRA25 July 2009 forcings, the model produces less ice loss than those predicted using May and June data. However, there is a systematically higher sea-ice extent of approximately 0.9 million km^2 in our model results when compared with that from SSMI for both June and July of this year (Fig. 1). A closer look shows that the model over-estimates sea-ice extent in the Laptev, Kara, and Barents Sea, consistent with what Kauker et al. reported last month in their report. We correct this month estimate by 0.9 million km^2 to arrive at 4.4 ± 0.5 millions km^2.

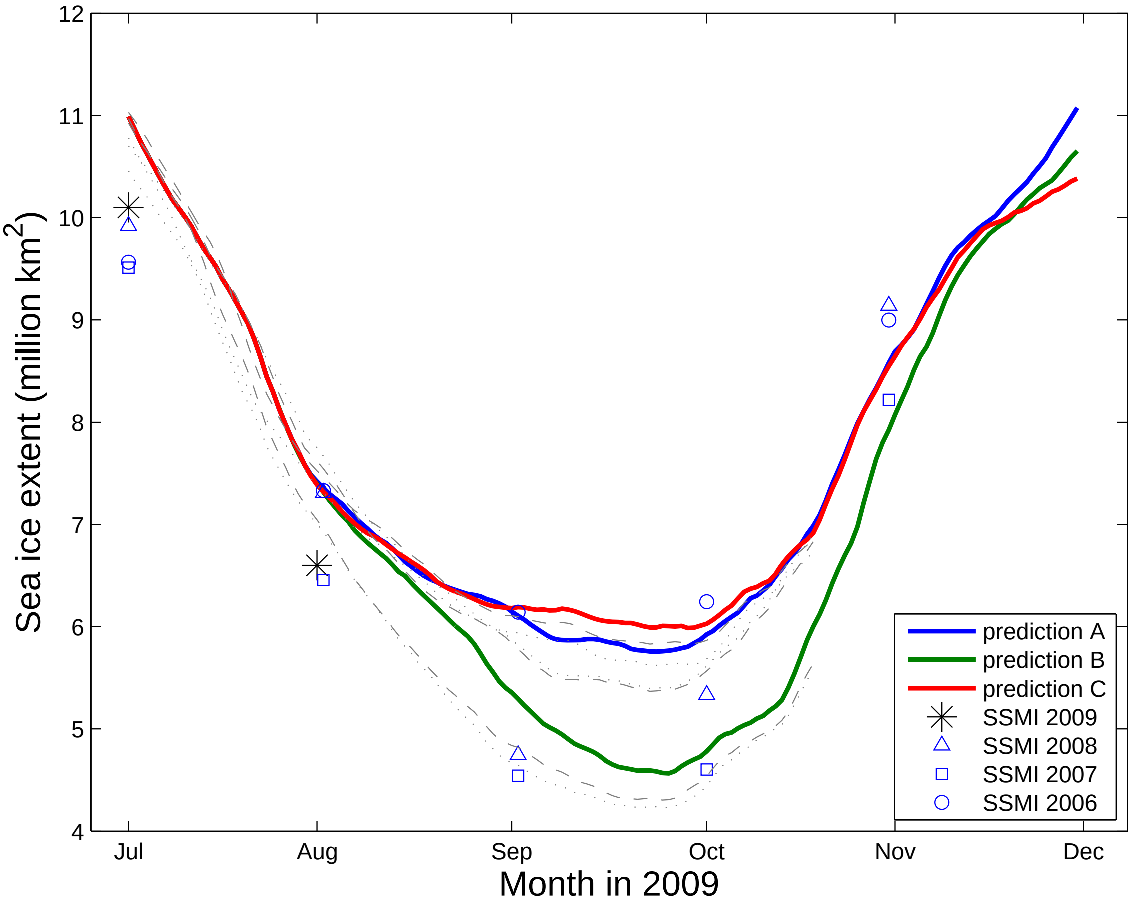

Figure 1: September 2009 sea-ice extent predictions based on 2008 (Prediction A), 2007 (Prediction B), and 2006 (Prediction C) atmospheric forcings beginning in July 26. Predictions based on June and May data are shown in dashed (June) and dotted (May) thin gray lines. The model over-estimates July sea-ice extent for 2009 by approximately 0.9 million km^2 when compared with daily SSMI data from the National Snow and Ice Data Center (NSIDC). Our estimate of 4.4 ± 0.5 millions km^2 is the mean and spread of predictions A and B adjusted for the 0.9 million km^2 model bias.

September 2009 Sea Ice Outlook: August Report

By: F. Kauker [a,b], R. Gerdes [a], M. Karcher [a,b], T. Kaminski [c], R. Giering [c], M. Voßbeck [c]

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[b] O.A.Sys - Ocean Atmosphere Systems GmbH, Hamburg, Germany
[c] FastOpt GmbH, Hamburg, Germany

4 August 2009

Experimental setup

For the August outlook, the coupled ice-ocean model NAOSIM has been forced with atmospheric surface data from January 1948 to July 11th 2009. This atmospheric forcing has been taken from the NCAR/NCEP- reanalysis. A detailed description of the method can be found accompanying the June outlook.

Two ensemble experiments starting from different initial conditions on July 11th 2009 were performed:

Ensemble I starts from the state of ocean and sea ice as it is calculated by a forward run of NAOSIM driven with NCEP atmospheric data from January 1948 to July 11th 2009.

Ensemble II starts from an optimized state derived by applying the variational assimilation system NAOSIMDAS (Kauker et al., 2009) for April and May 2009, followed by a one month forward integration (driven with NCEP June 2009 surface data) until July 11th 2009. NAOSIMDAS is being developed in the EU FP6 project DAMOCLES (http://www.damocles-eu.org). Observational data used are:

- Hydrographic data from Ice Tethered Platform profilers (http://www.whoi.edu/page.do?pid=20756) which have been deployed as part of several IPY initiatives, covering part of the central Arctic Ocean.
- Hydrographic data from ARGO profilers provided by the CORIOLIS data center (http://www.coriolis.eu.org/cdc/default.htm) mostly covering the Nordic Seas and the northern North Atlantic Ocean.
- Daily mean ice concentration data from EUMETSAT Ocean and Sea Ice SAF (www.osi-saf.org), based on multi-sensor SSM/I analysis, with a spacial resolution of 10 km.
- Two-day mean ice displacement data from passive microwave (SSM/I, AMSR-E) or scatterometer (e.g. ASCAT) signals provide by EUMETSAT Ocean and Sea Ice SAF (www.osi-saf.org), with a spatial resolution of 62.5 km. For May, only the ASCAT instrument is used. The uncertainty in the formulation of the costfunction associated to this data stream is set to 2cm/s for April and 4cm/s for May.
- Sea ice thickness (5 km mean) obtained by an airborne electromagnetic induction sounder (EM-Bird). Data were collected along transects from various air strips in the western part of the Arctic in April during the PAM-ARCMIP campaign (Herber et al., 2009). See the Sea Ice Outlook July-Report on details concerning the EM bird data set.

The variational assimilation system minimises the difference between observations and model analogues, by variations of the model's initial conditions on April 1st and the surface boundary conditions (wind stress, scalar wind, 2m temperature, dew-point temperature, cloud cover, precipitation) in April and May 2009.

Mean September Ice Extent 2009

Ensemble I

The result for all 20 realizations ordered by the September ice extent is shown in Figure 1. Since the forward simulation underestimates the September extent compared with observed extent minima in 2007 and 2008 by 0.40 million km^2, we added this bias to the results of Ensemble I.

The Ensemble I mean value is 5.02 million km² (bias added). This is the most likely value. The standard deviation of Ensemble I is 0.39 million km^2, which is twice the uncertainty of last year's AWI/OASys July-outlook that was initialized on June 30th (standard deviation of 0.20 million km^2.). Assuming a Gaussian distribution we are able to derive probabilities (percentiles) that the sea ice extent in September 2009 will fall below a certain value.

The probability deduced from **Ensemble I** that in 2009 the ice extent will fall below the three lowest September minima is:

- probability to fall below 2007 (record minimum) is about 3%,
- probability to fall below 2008 (second lowest) is about 18%,
- probability to fall below 2005 (third lowest) is about 92%.

With a probability of 80% the mean September ice extent in 2009 will be in the range between 4.52 and 5.52 million km^2.

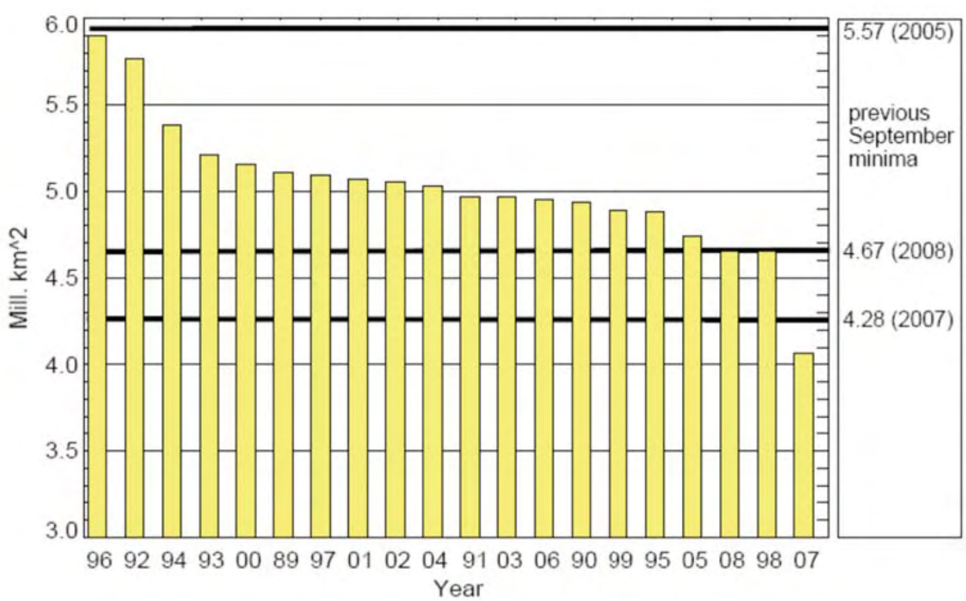


Figure 1. Ensemble I—Simulated mean September ice extent in 2009 [million km^2] when forced with atmospheric data from 1989 to 2008 (non-optimized initial state on 11 July 2009). Model derived ice extents have been adjusted by subtracting a bias (see text). The thick black horizontal lines display the minimum ice extents observed in 2005, 2007 and 2008.

Ensemble II (optimized initial conditions)
The mean September sea ice extent for all 20 realizations starting from optimized initial conditions is shown in Figure 2. Note that for Ensemble II we applied no (summer) bias correction. Hence, the Ensemble II mean of 4.42 million km^2 is somewhat lower than the mean of Ensemble I. As for Ensemble I the standard deviation of Ensemble II is 0.38 million km^2.

The probability deduced from Ensemble II that in 2009 the ice extent will fall below the three lowest September minima is:

- probability to fall below 2007 (record minimum) is about 36%,
- probability to fall below 2008 (second lowest) is about 74%,
- probability to fall below 2005 (third lowest) is about 99.9%.

With a probability of 80% the mean September ice extent in 2009 will be in the range between 3.93 and 4.93 million km^2.

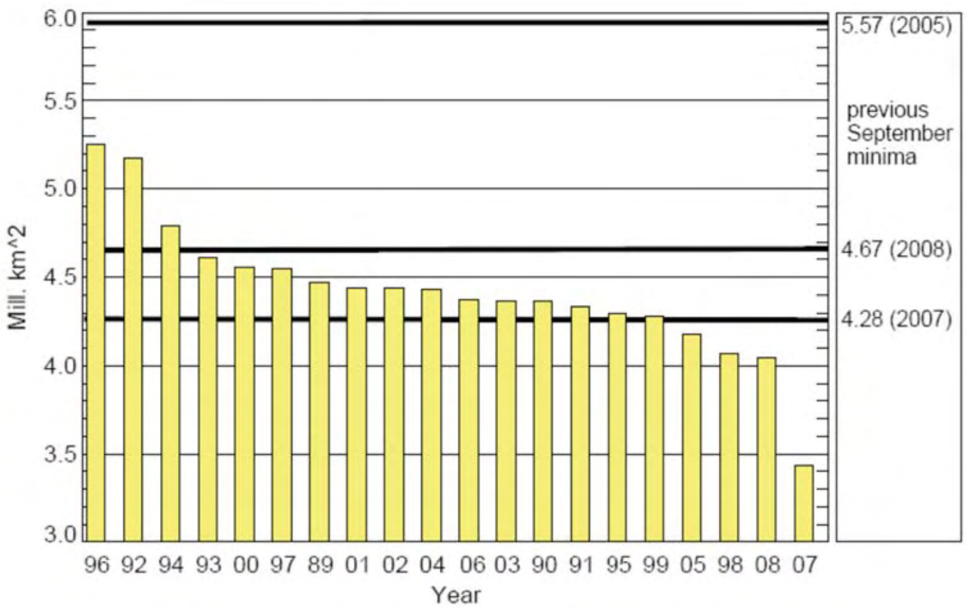


Figure 2. Ensemble II—Simulated mean September ice extent in 2009 [million km2] when forced with atmospheric data from 1989 to 2008 from the optimized initial state on 11 July 2009. The thick black horizontal lines display the minimum ice extents observed in 2005, 2007 and 2008.

References:
Herber, A., et al. (2009). PAM-ARCMIP. Pan-Arctic measurements and arctic regional climate model simulations (internal AWI report available from Andreas.Herber@awi.de).

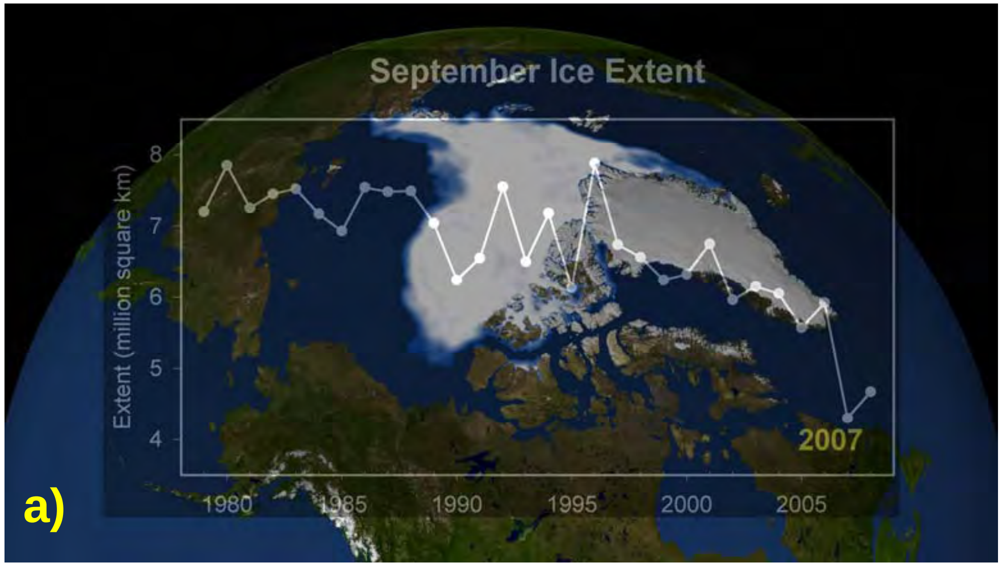
Kauker, F., T. Kaminski, M. Karcher, R. Giering, R. Gerdes, and M. Voßbeck. (2009). Adjoint analysis of the 2007 all time arctic sea-ice minimum. Geophys. Res. Lett, 36, L03707, doi:10.1029/2008GL036323.

Sea Ice Outlook: Use Dipole Anomaly (DA) index to predict Arctic summer ice minima

PI: Jia Wang; and Xuezhi Bai, NOAA GLERL

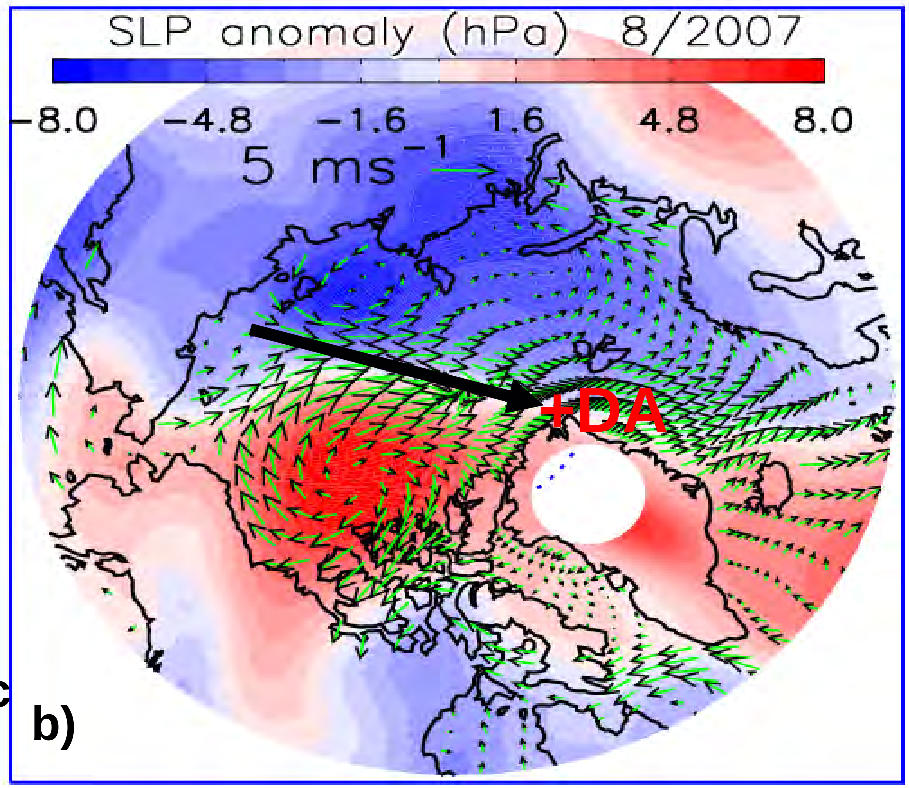
- DA is defined as the second SLP mode in the Arctic; the first mode is Arctic Oscillation (AO)
- Using winter-spring mean DA index and summer DA index, we have proven ice minima in 1995, 1999, 2002, 2005, 2007, and 2008
- Using 2009 winter-spring (+0.61) and summer (+1.06) DA indices, now we can project that 2009 summer ice will reach another minimum, or at least stay similar to 2008 level
- Reference: Wang et al. 2009, GRL, "Is the Dipole Anomaly a major driver to record lows in Arctic summer sea ice extent?"
- Collaborators: IARC/UAF, UW. Hokkaido Univ.

Record low Summer ice extent on Sep. 24, 2007 and time series of September ice area



Sea-level pressure anomaly (in color: Red/blue, high pressure) and wind anomaly, relative to long-term mean.

Black arrow: max wind anomaly due to positive DA, flushing sea ice out of Arctic into northern Atlantic



Record lows:

1995,

1999,

2002,

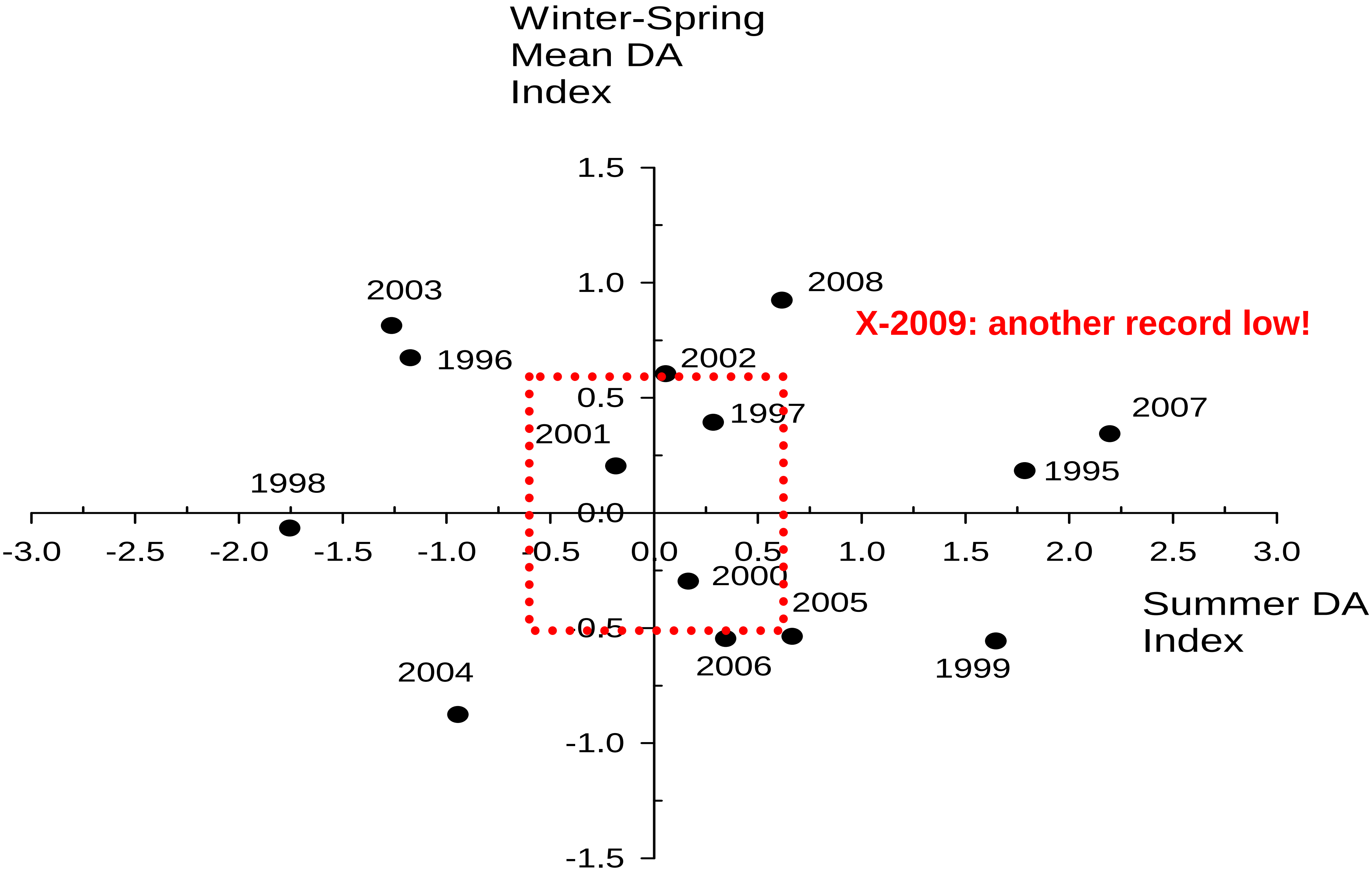
2005,

2007,

2008 (not record low,

but 2nd lowest ever!)

DA predicts record lows: 1995, 2002, 2007, and 2008 (+DA persists from Win-Spr-Sum); 1999 and 2005 (-DA in Win-Spr, but +DA in summer). So, summer DA is the key! The 2009 (red cross X) DA indices indicates an sea ice minimum will occur in September 2009 at a magnitude of at least the 2008 ice cover!



Outlook of 9/2009 Arctic sea ice from 7/1/2009

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

The predicted September 2009 ice extent is **4.5 million square kilometers**. This is based on ensemble predictions starting on 7/1/2009. 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 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 7/1/2009. The initial ice-ocean conditions are obtained by a retrospective simulation that assimilates satellite ice concentration data. Of course, no data assimilation is performed during the predictions. More details about the prediction procedure can be found in Zhang et al. (2008) http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf.

See three figures below.

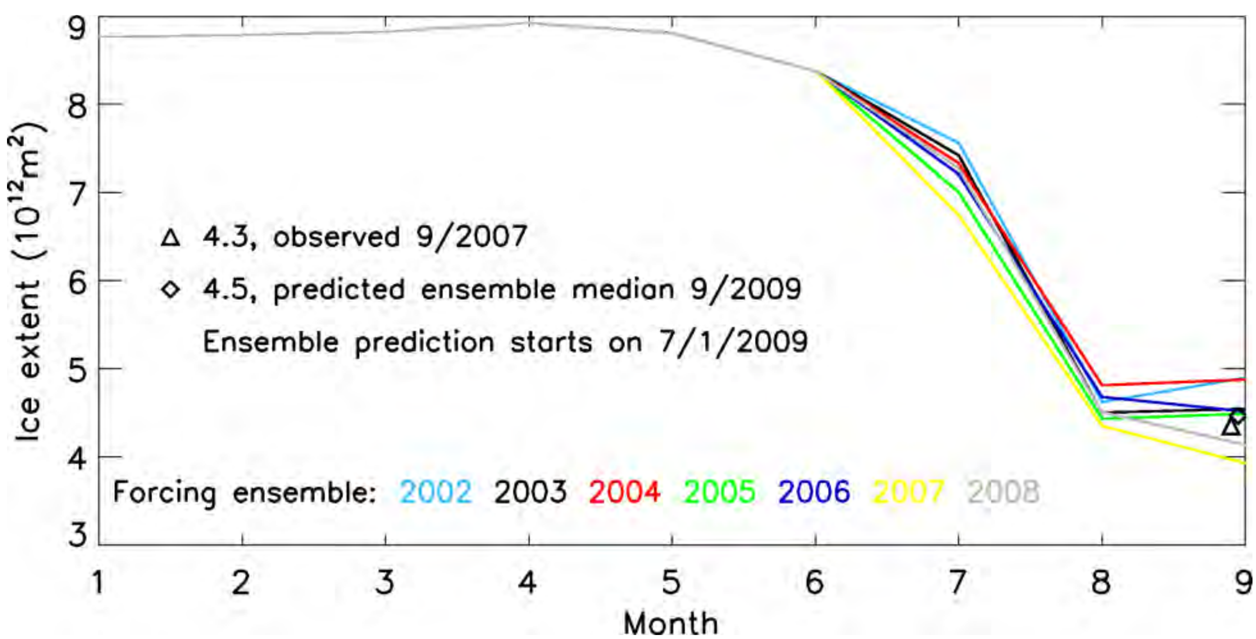


Figure 1. Monthly ice extent over January–September 2009 from seven ensemble members and their ensemble median for September 2009. Results for January–June are from the retrospective simulation and results for July–September are from the ensemble predictions (prediction range is 7/1 – 9/30/2009). The ensemble median is considered to have a 50% probability of occurrence

and the ensemble median ice extent for September 2009 is 4.5 million square kilometers, slightly higher than that in September 2007 at 4.3 million square kilometers.

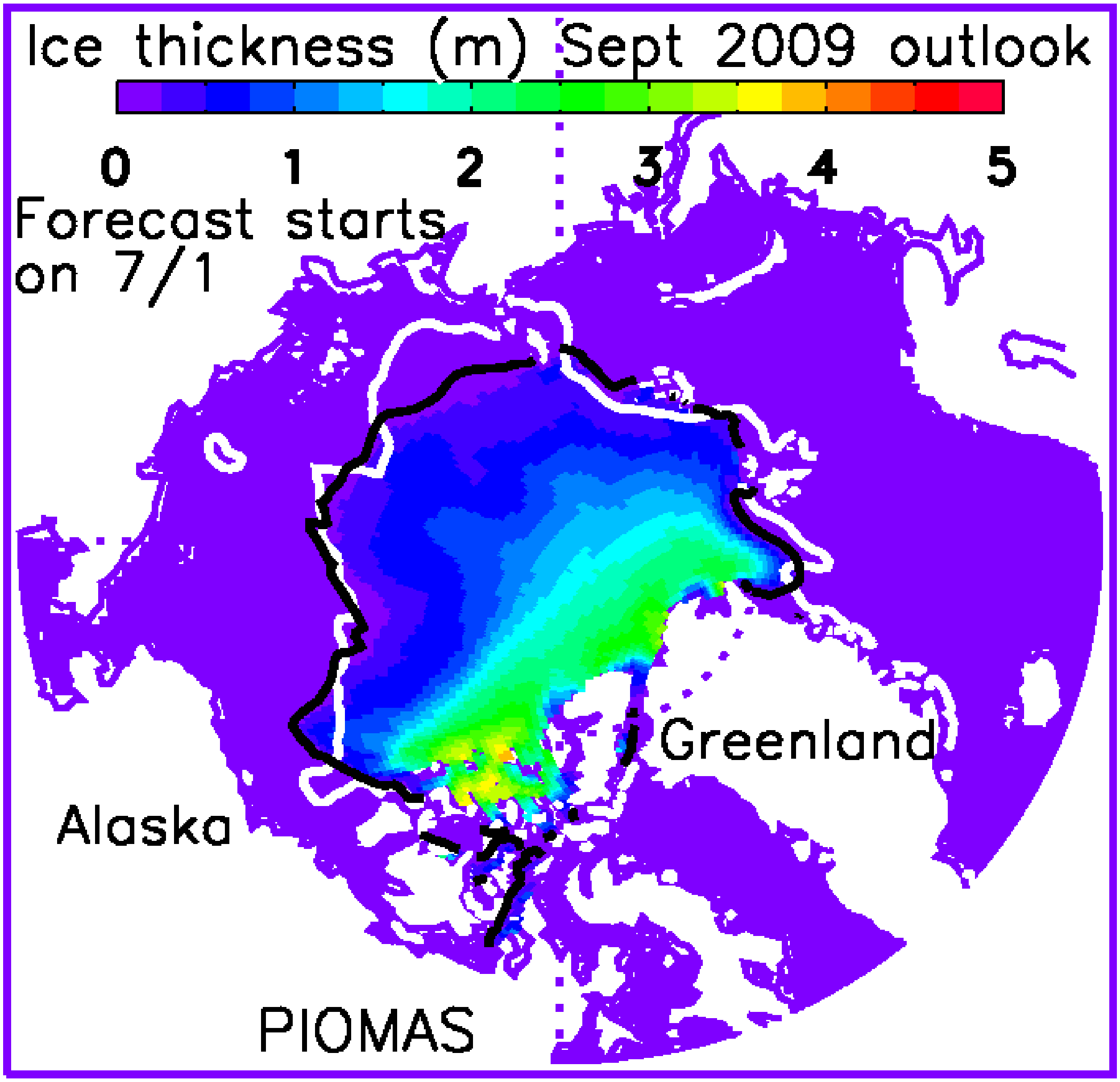


Figure 2. Ensemble prediction of September 2009 sea ice thickness. The white line represents satellite observed September 2008 ice edge defined as of 0.15 ice concentration, while the black line model predicted September 2009 ice edge.

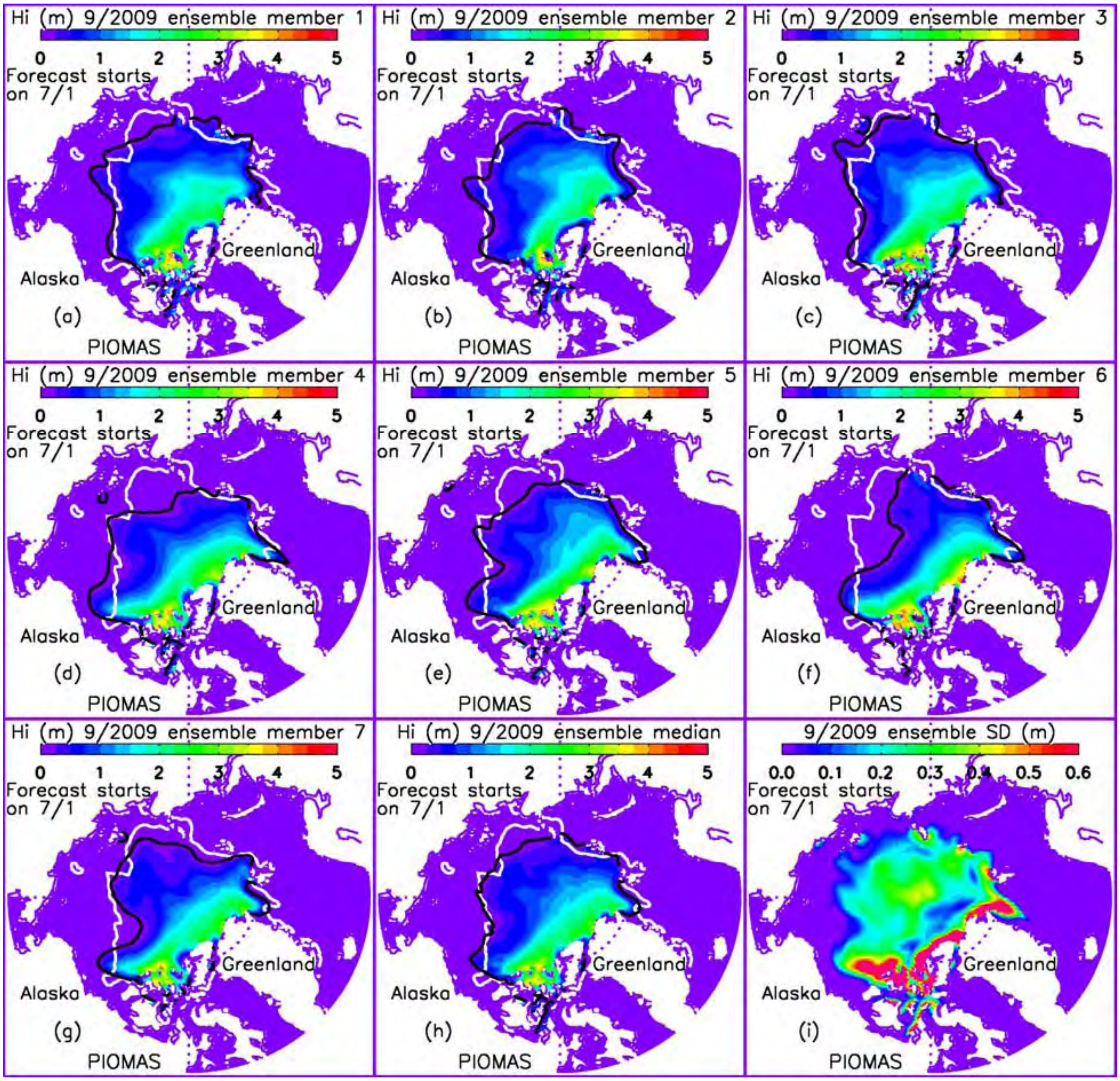


Figure 3. September 2009 sea ice thickness predicted by seven individual ensemble members, ensemble median ice thickness, and ensemble standard deviation (SD) of ice thickness. The spatial ensemble median ice thickness distribution (Figure 3h, the same as Figure 2) is most likely to occur in September 2009.

Sea Ice Outlook August 2009

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Extent projection

4.62 million km^2 based on the ensemble mean.

August set-up

The methodology of our approach is still the same as for our July Outlook which we describe in the July Outlook report[1]. For the August Outlook we have updated the initial conditions of the ensemble by integrating the ocean/sea-ice model RCO until the end of July (29th), forcing the model with atmospheric data from ECMWF.

Ensemble results

The 20 different realizations of the total sea-ice extent for September 2009, with a 1.1 million km^2 bias removed, are shown in sorted order in Figure 1. The ensemble mean value is 4.62 million km^2 which is basically the same as for the July Outlook. The standard deviation has decreased somewhat from 0.54 to 0.39 million km^2.

The individual ranking between the 20 different years has also changed, as expected, but the anomalous atmospheric conditions of 2007 still clearly produces the lowest sea-ice extent prediction and all predictions are below the third lowest observed sea-ice extent, from the summer of 2005.

Assuming that the realizations belong to a Gaussian distribution we can state probabilities that the sea-ice extent will fall below a certain value by calculating percentiles.

The probability that the 2009 September mean total sea-ice extent will fall below,

2007 satellite derived all-time minimum (4.28 million km^2) is 21 %

2008 second lowest satellite derived (4.67 million km^2) is 56 %

2005 third satellite derived (5.57 million km^2) is 99 %.

1 http://www.arcus.org/search/seaiceoutlook/2009_outlook/july_report/downloads/pdf/panarctic/9_Pemberton_etal_JulyOutlook_JuneData.pdf

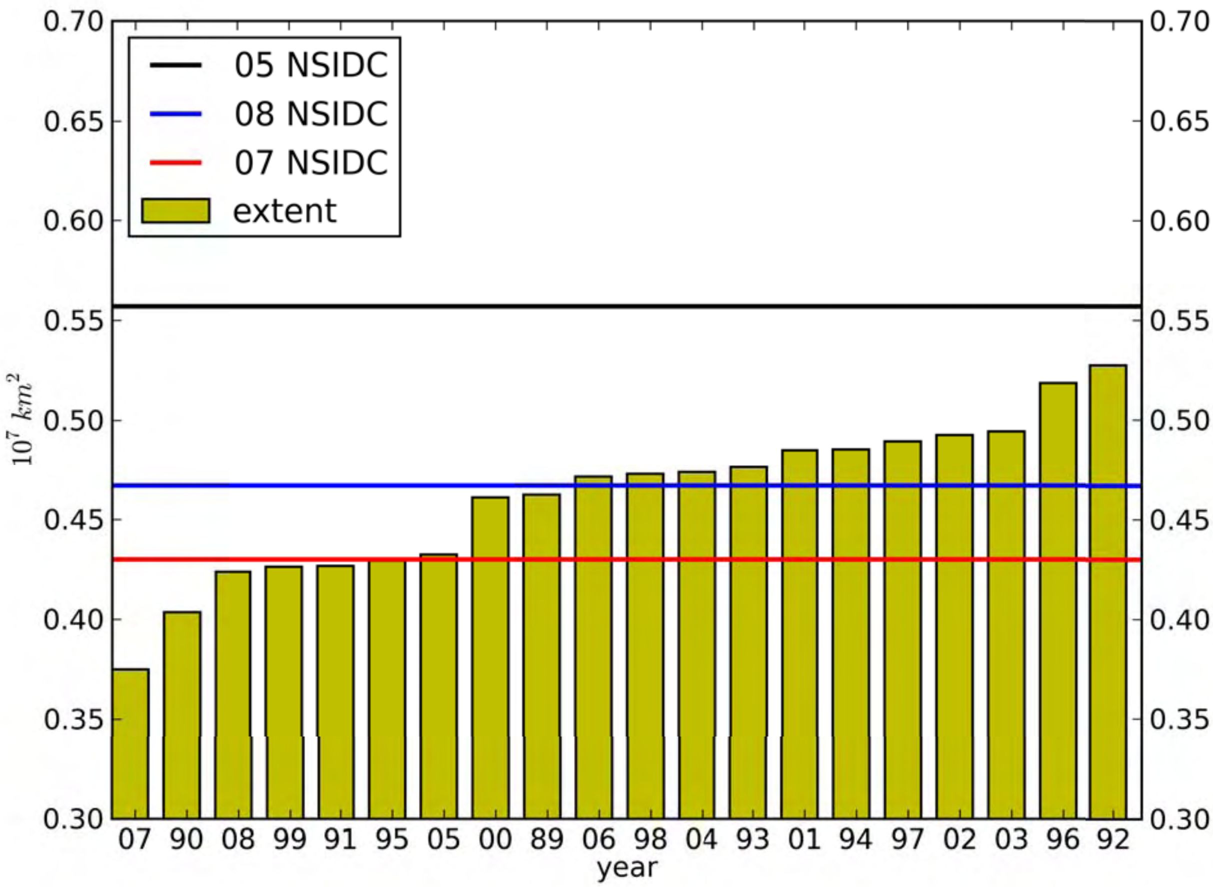

Figure 1. The 20 realizations of September 2009 mean sea-ice extent in sorted order. The horizontal lines show the minimum of 2005 (black), 2007 (red) and 2008 (blue) (data from www.nsidc.org).

September 2009 Sea Ice Outlook: August Report
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Sunny weather was seen over the Arctic Ocean in the former half of July. It seems to have promoted sea-ice melting to some extent. The sea level pressure pattern during the June–July period also seems to be similar to that in 2007 when the historic sea-ice reduction occurred. However, a lot of sea-ice still remains in the East Siberian Sea this year. Considering the smallest fraction of multi-year ice this spring, the annual minimum extent of sea-ice this year could be larger than that of 2007 (4.3 million square kilometers) and similar to or a little bit smaller than that of last year (4.7 million square kilometers).

----

1. Extent Projection

    4.6 million square kilometers

2. Methods/Techniques

    A diagnosis based on the analysis of remote sensing (AMSR-E and MODIS) data.

3. Rationale

    Cloudiness over the whole arctic region was estimated from MODIS data. Also, AMSR-E sea-ice concentration was used for estimating sea-ice extent which is available at http://www.ijis.iarc.uaf.edu/cgi-bin/seaice-monitor.cgi?lang=e.

    High pressure pattern and thus low cloudiness condition persisted over the Alaskan and Canadian sectors of the Arctic Ocean. Thus, downward shortwave radiation in this June to July seems to be large. The AMSR-E derived sea-ice extent now became smaller than the average of the recent 6 years (2003-2008).
    http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm

4. Supplemental images

    Attached are the images on which the diagnosis is based.

    Figures 1A, 1B, and 1C. Two-month (June–July) averaged cloudiness anomalies in the Arctic of the past three years (a) 2007, (b) 2008, and (c) 2009 derived from MODIS data. The anomalies are deviations from the 10-year average (2000-2009). Contour lines indicate the spatial pattern of sea level pressure taken from the NCEP/NCAR Reanalysis data set.

    Figure 2. Seasonal variations of the arctic sea ice extent during the last 7 years.

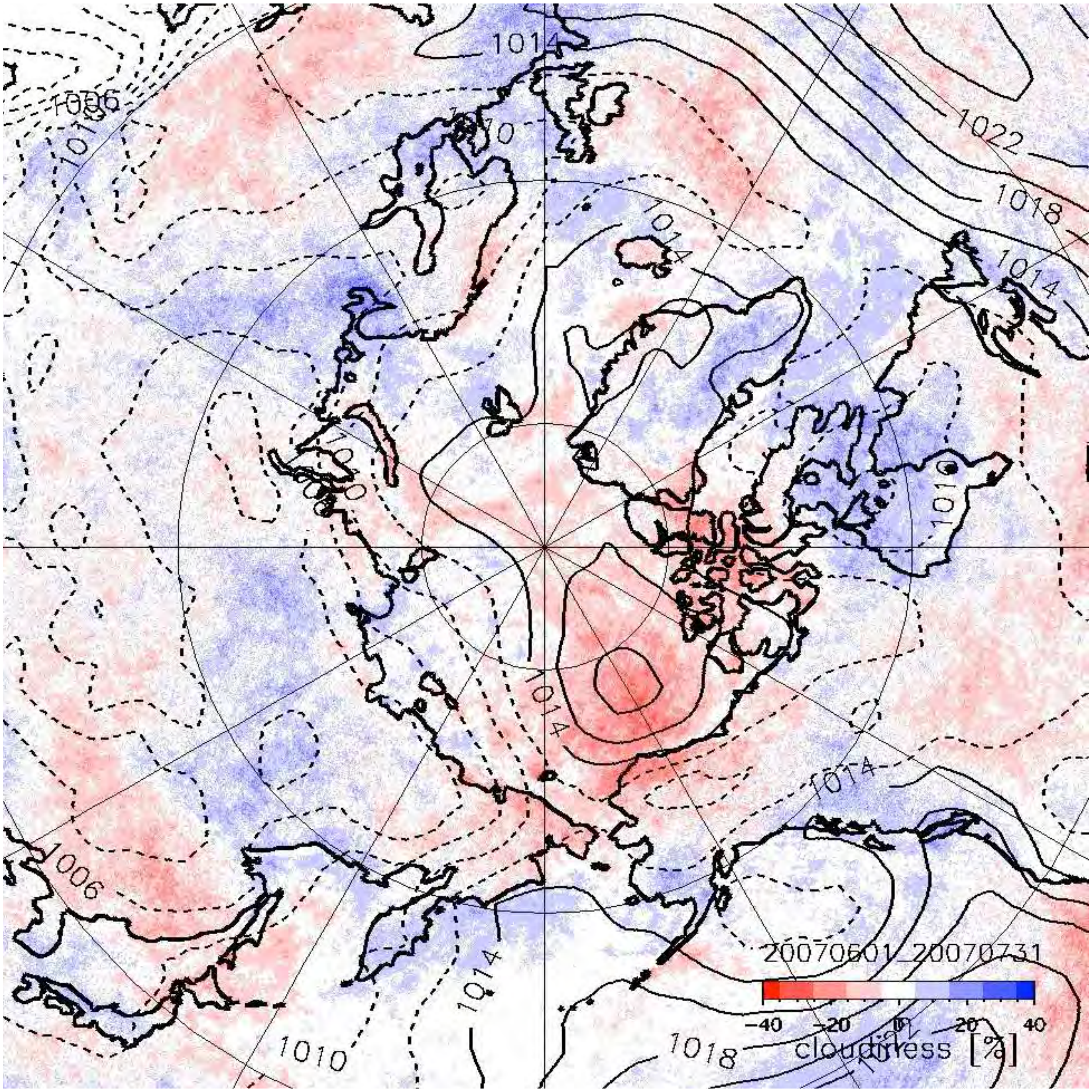

Figure 1A. Two-month (June–July) averaged cloudiness anomalies in the Arctic of 2007 derived from MODIS data. The anomalies are deviations from the 10-year average (2000–2009). Contour lines indicate the spatial pattern of sea level pressure taken from the NCEP/NCAR Reanalysis data set.

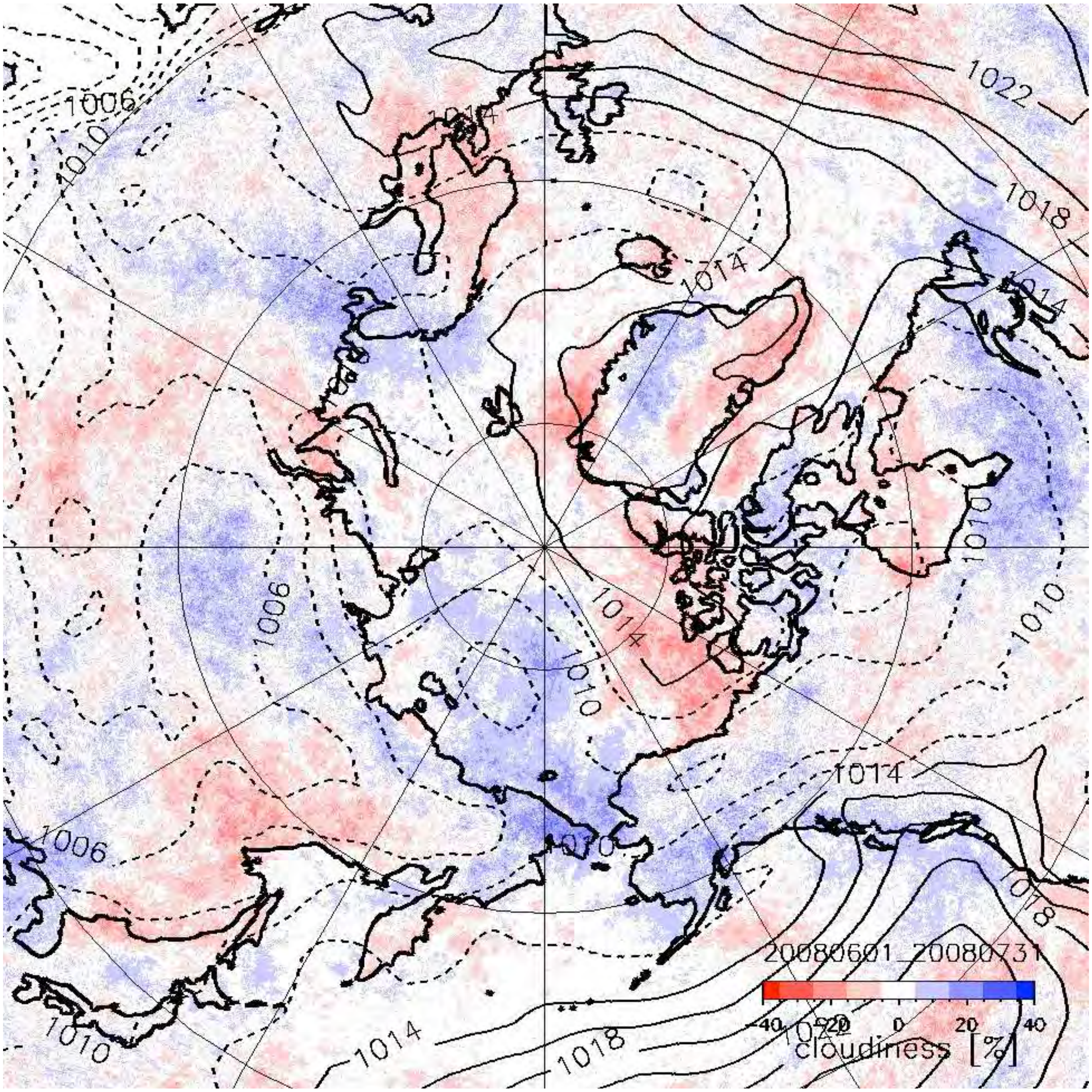

Figure 1B. Two-month (June–July) averaged cloudiness anomalies in the Arctic of 2008 derived from MODIS data. The anomalies are deviations from the 10-year average (2000–2009). Contour lines indicate the spatial pattern of sea level pressure taken from the NCEP/NCAR Reanalysis data set.

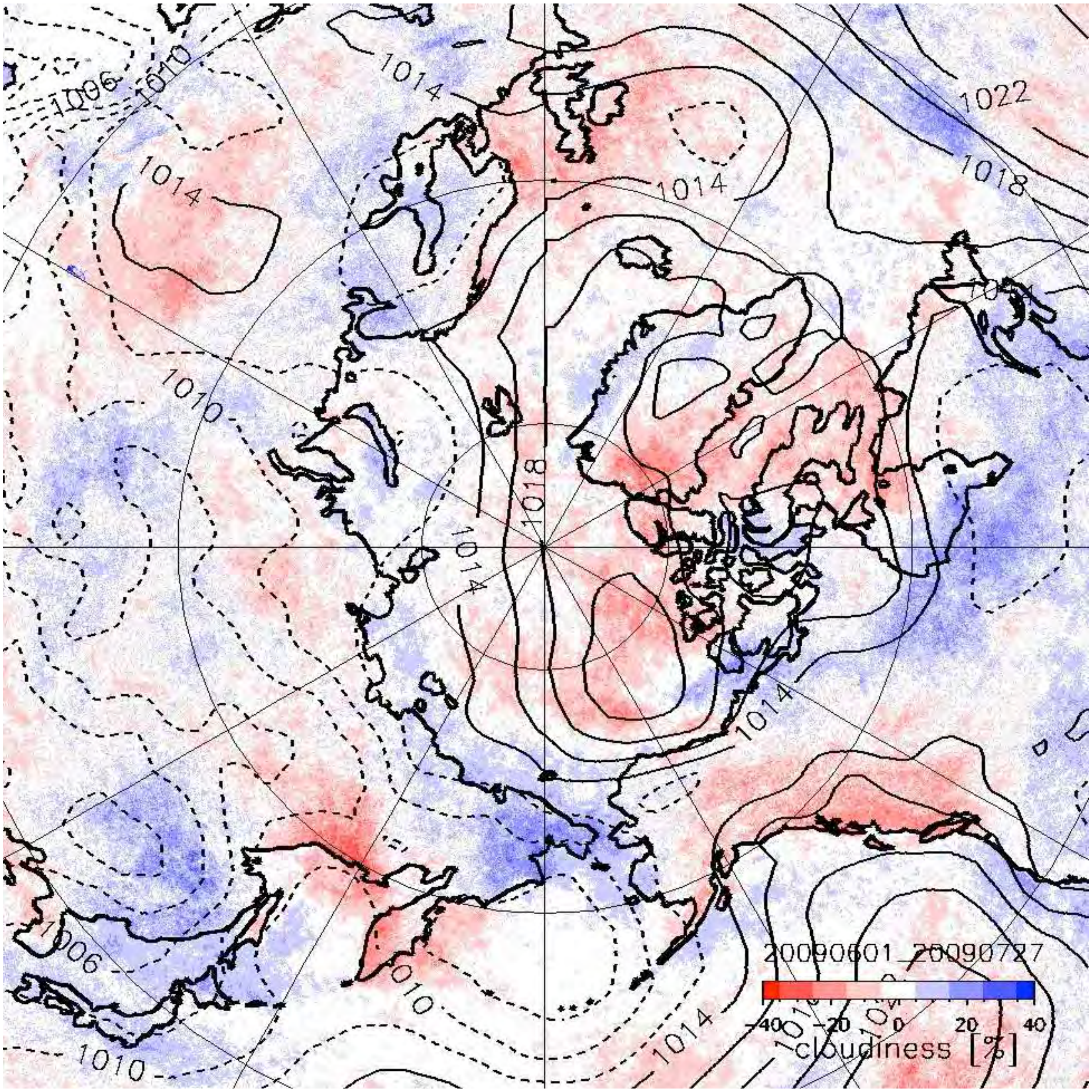

Figure 1C. Two-month (June–July) averaged cloudiness anomalies in the Arctic of 2009 derived from MODIS data. The anomalies are deviations from the 10-year average (2000–2009). Contour lines indicate the spatial pattern of sea level pressure taken from the NCEP/NCAR Reanalysis data set.

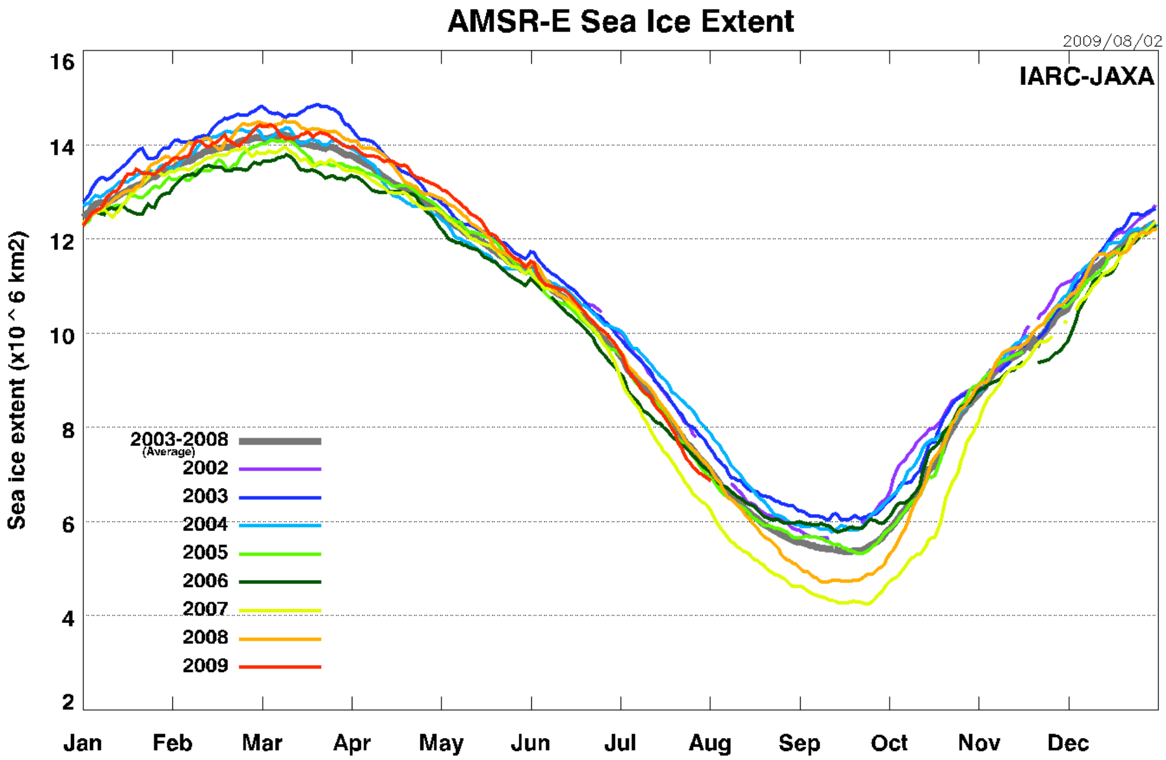

Figure 2. Seasonal variations of the arctic sea ice extent during the last 7 years.

September 2009 Sea Ice Outlook: August Report

By: Jennifer V. Lukovich and David G. Barber (Centre for Earth Observation Science (CEOS), University of Manitoba

Stratospheric dynamics and sea ice extent

September 2009 Sea Ice Extent Estimate

Comparable to the 2008 minimum in sea ice extent, or ~4.6–4.7 · 10^6 km^2.

Rationale

An update to differences between surface winds and SLP, and vortex splitting and minimum sea ice extent composites for June 2009, illustrates distinct patterns in the Beaufort, East Siberian, Kara and Barents Seas, and exhibits conditions in June 2009, that are favorable to ice export through Fram Strait, in contrast to those for May 2009. The presence of a SLP high also establishes conditions conducive to ice convergence to the north of the Canadian Archipelago.

Methods

In this study an update is provided for the difference between surface winds and SLP, and composites for years associated with vortex splitting events and record lows in September ice extent for June 2009, (Figures 4 and 5 in the July sea ice outlook submission). As in the July submission, surface winds and SLP were obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division.

Composites for vortex splitting events include the years 1979, 1985, 1988, 1989, 1999, 2001, as defined in Charlton et al. (2007), while composites based on record minima in sea ice extent in September include the years 2002, 2005, and 2007,in accordance with time series for monthly records of sea ice extent (http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php). The year 2009 is characterized by a vortex splitting event (Manney et al., 2009).

Figures

1. Difference in June 2009 vector winds and sea ice extent and vortex splitting composites.
2. Difference in June 2009 SLP and sea ice extent and vortex splitting composites.

Results

Difference in June 2009 surface winds and vortex splitting and sea ice extent composites.

In June 2009, northerly winds predominate near Fram Strait, while easterly winds exist in the Beaufort Sea region (Figure 1). Differences between surface vector winds and those for years characterized by vortex splitting composites (middle panel, Figure 1) exhibit distinct spatial patterns in the western Arctic. Similarity in surface wind patterns in June 2009, and those observed in vortex displacement composites (Figure 5, previous submission) indicate mechanisms that generate surface wind patterns comparable to those anticipated from vortex displacement events. It should be noted however, that maximum stratospheric predictability of surface events occurs during winter over two months (Baldwin et al., 2003) so that similarity between anticipated surface wind composites for years associated with vortex splitting events such as 2009 should not be expected following spring. Distinct spatial patterns in differences between surface winds and minima in sea ice extent composites (right panel, Figure 1) exist in the Beaufort, East Siberian, Kara, and Barents Seas and suggest that significant ice retreat may not occur in these regions. However, and in contrast to the May, 2009 conditions, comparatively small differences between surface winds and sea ice minimum composites underline the presence of northerly winds in Fram Strait and increased ice export due to advection by winds in summer. Northerly winds to the north of the Canadian Archipelago associated with the SLP high in this region may also contribute to ice convergence along the coast if persistent throughout the summer.

Difference in June 2009, SLP and vortex splitting and sea ice extent composites.

A SLP high predominates to the north of the Canadian Archipelago in June 2009, (Figure 2). Comparison with the vortex splitting SLP composite (middle panel, Figure 2) shows positive values extending from the Beaufort Sea across the pole to Fram Strait, in contrast to SLP conditions during May 2009. It is interesting to note that the June 2009 SLP pattern resembles the SLP pattern evident in years characterized by vortex displacement events (compare with Figure 6, previous submission) although as previously noted, maximum stratospheric predictability of surface events occurs during winter over two months. Positive values in the difference plots for SLP and sea ice extent composites indicate a strengthened SLP to the north of the Canadian Archipelago and Greenland and increased convergence in these regions. Moreover, comparison of SLP in June 2009, and minimum sea ice extent composites highlights an absence of the meridional pattern established by the SLP high (low) over the Beaufort Sea (Siberia) associated with a record reduction in ice extent in 2007, as outlined in Overland (2009). In particular, positive difference values over Siberia in June suggest a weaker SLP low than for years exhibiting a record low in ice extent.

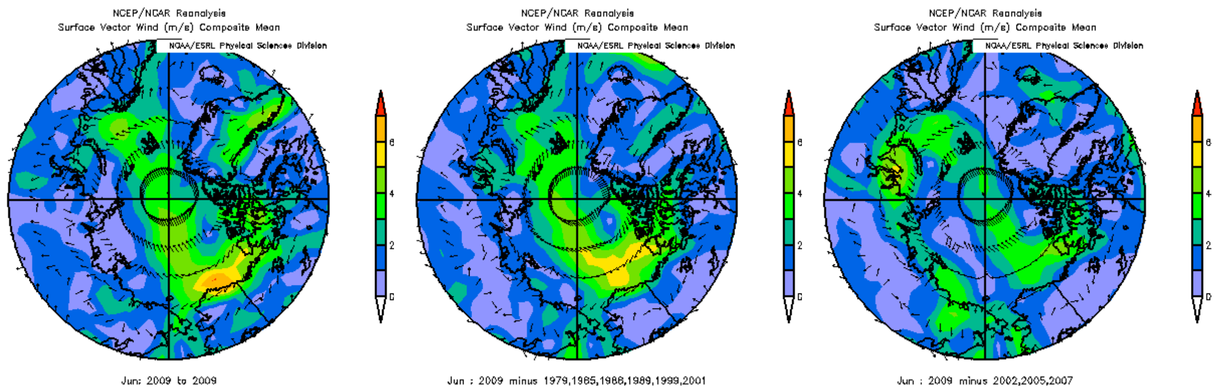

Figure 1. (Left) June, 2009 surface winds, and difference between June, 2009 and composite vector winds for (middle) vortex splitting events, and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/

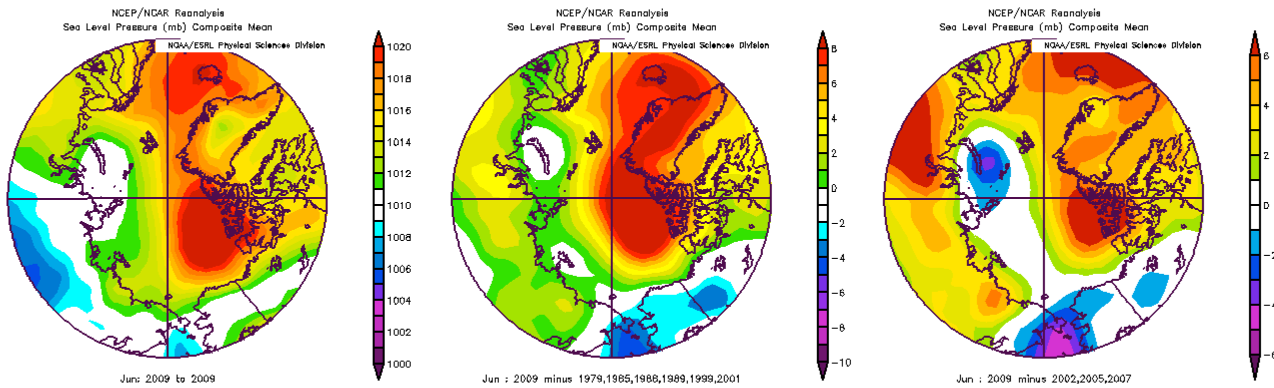

Figure 2. (Left) June, 2009 SLP and difference between June 2009, and composite for (middle) vortex splitting events and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

September 2009 Sea Ice Outlook: August Report
By: Julienne Stroeve, Walt Meier, Mark Serreze, Ted Scambos
National Snow and Ice Data Center (NSIDC)

Summary
NSIDC's original assessment of 4.6 million square kilometers, based on the initial amount and distribution of ice age types, remains unchanged. An alternative statistically-based method, using projected rate of sea ice extent decline from previous years' data, was implemented for an updated, complementary estimate. Simply applying statistical averages of rates of decline was deemed to likely yield too high of an estimate because the averages do not take into account the changed nature of the younger, thinner summer ice cover. Thus, a weighted average, subjectively weighting more recent years higher, was calculated. This approach yields a ***best estimate of 4.69 million square kilometers, with a range of 4.38 – 4.91 million square*** **kilometers**.

Rationale
NSIDC based its first two extent outlooks on the survival rate through the summer of the amount of ice age categories at the end of winter; the location of the ice age types relative to the pole was also taken into consideration to account for the varying amount of solar energy received through the summer.

Since that method is based only on the initial condition of the ice cover heading into summer, that estimate of 4.6 million square kilometers is unchanged. However, as discussed in our previous submissions, there are two main factors that determine the September sea ice extent: pre-conditioning of the ice cover before the summer begins and the magnitude of the dynamic and thermodynamic forcing (e.g., winds, air/ocean temperatures, clouds, etc.) through the summer.

Our earlier assessments were based solely on pre-conditions. However, now the summer has progressed enough so that we can begin to take into account the effect of atmospheric forcing. NCEP reanalysis fields indicate that the summer so far has been similar to 2007 in featuring a prominent Beaufort Sea anticyclone. This has promoted warm southerly to southeasterly winds west of the high along with fairly clear skies under the high, both of which favor melt over the western Arctic.

The impact of the forcing to date is realized through the effect so far on the sea ice extent, as shown in the figure below. We did not see an acceleration in the decline this year as occurred during early July 2007. However, the rate of decline during the second half of July 2009 was faster compared to the same period in 2007, though the rate slowed considerably the last couple days of the month due to a change in wind patterns.

Some of the effect of future forcing through the rest of the melt season cannot be forecast because it is due to synoptic activity over the next several weeks. However, as we have now passed the summer solstice, the effect of forcing starts to become constrained by the amount of solar insolation. As the sun sets in the Arctic, the amount of solar energy becomes less and starts to constrain the amount of further melt possible.

Methodology
Thus, current conditions start to become better correlated with the final September conditions and extrapolating forward is more appropriate. Here, we implement such a method by projecting the daily sea ice extent forward from 31 July through the end of September based on the daily rate of decline from previous years. The projected daily September extents are then averaged to calculate a monthly projection (Figure 1).

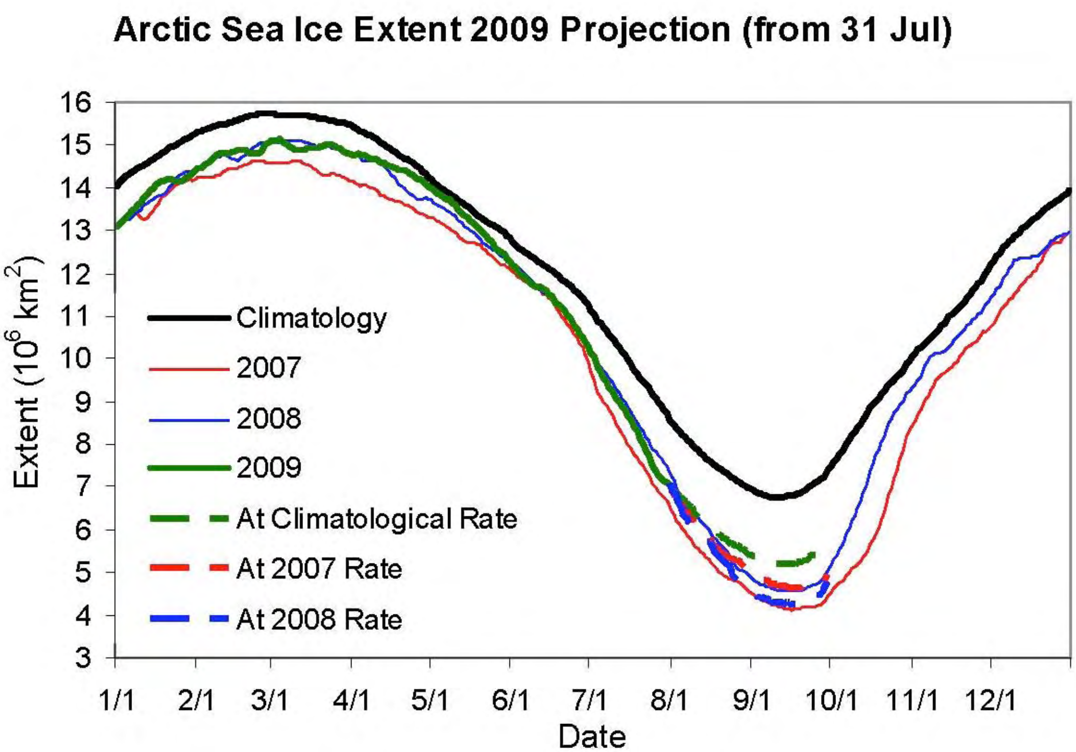

Figure 1. Daily sea ice extent (solid lines) and projections (dashed lines) based on daily rates of decline from (1) climatology (1979–2000) [green], (2) 2007 [red], and (3) 2008 [blue].

First we made an estimate based on the 1979–2000 climatological daily rate of decline, with a one-standard deviation range (Figure 2). However, in light of the known large area of thinner first-year ice (pre-conditioning) more likely to melt completely by the end of summer (Figure 3), the climatological rate seems too slow and unrepresentative of recent conditions.

Because of the changing ice conditions, we made projections based on rates for each year from 2002 to 2008. These recent years are more indicative of this year's conditions, and thus are likely to provide a more realistic range than the standard deviation around the 1979–2000 climatology. We also calculate an average for 2002–2006 as potential estimate.

Period	Weight	Average	Range
1979–2000	0.05	5.31	4.39–6.22 (s.d.)
2002–2006	0.15	5.22	4.75–5.56 (min–max)
2007	0.4	4.73	
2008	0.4	4.38	
Weighted Estimate		**4.69**	4.38–4.91 (2008–avg. all 4 periods)

Table 1. Estimate of 2009 September extent based on daily decline rates for 1 August–30 September from previous years or averages of years. The range gives high and low estimates, based on standard deviation or minimum to maximum values.

Of the seven years, only the 2008 rate would near a new record low (4.38 million square kilometers), though 3 of the 7 years result in an extent that is at or near second lowest of the 1979–2008 data period. The faster rate during late summer of 2008 appeared to be due in large part to the substantial amount of first-year ice. This first-year ice thinned through the summer and even though the summer insolation decreases by August, there was enough energy that much of the vast amount of thinner first-year ice in 2008 reached the threshold at which it disappeared completely and the extent decline rate was faster than previous years. With yet again a substantial amount of first-year ice apparently remaining (Figure 3), it is possible that a similar situation will occur again. Thus, a new record may not be as unlikely as an average decline rate projection would seem to indicate.

As such, we feel that a simple statistical average using this approach is not valid. Thus, we produce a weighted average based on different years, or averages of years, with the most recent years weighted most heavily (Table 1). This is an ad hoc and subjective weight, based on our judgment of the character of the ice, but we feel this will be more accurate than any average over several years.

The weighted average uses equal weights for 2007 and 2008 of 40%, with the remaining 20% comprised from average rates for 1979–2000 and 2002–2006. This yields a ***best estimate of 4.69 million square kilometers*** for the 2009 September minimum. To provide a range for the estimate, we use the 2008 rate since that was the fastest observed rate of decline and current ice age conditions are similar to those at this time last year. For the upper bound of the range, we simply used an equal weighting between all four time periods. The approach yields a ***range of 4.38–4.91 million square kilometers***.

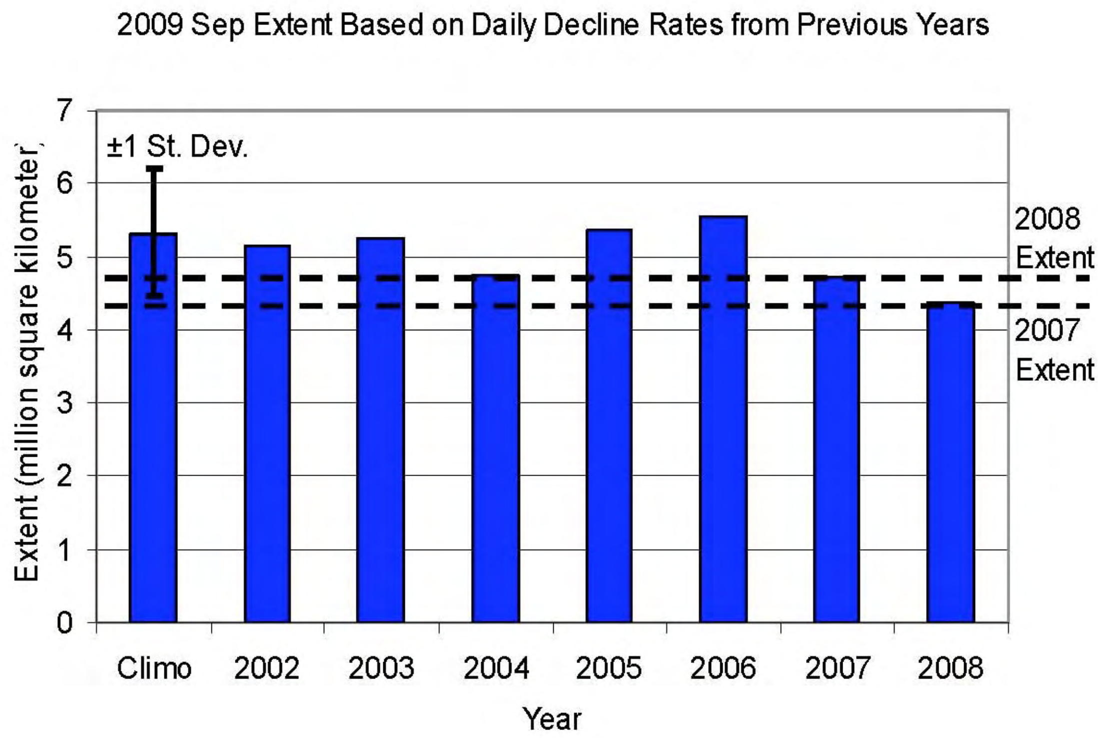

Figure 2. 2009 September sea ice extent based on the rate of decline from climatology (1979-2000) daily rates and rates from the past seven years.

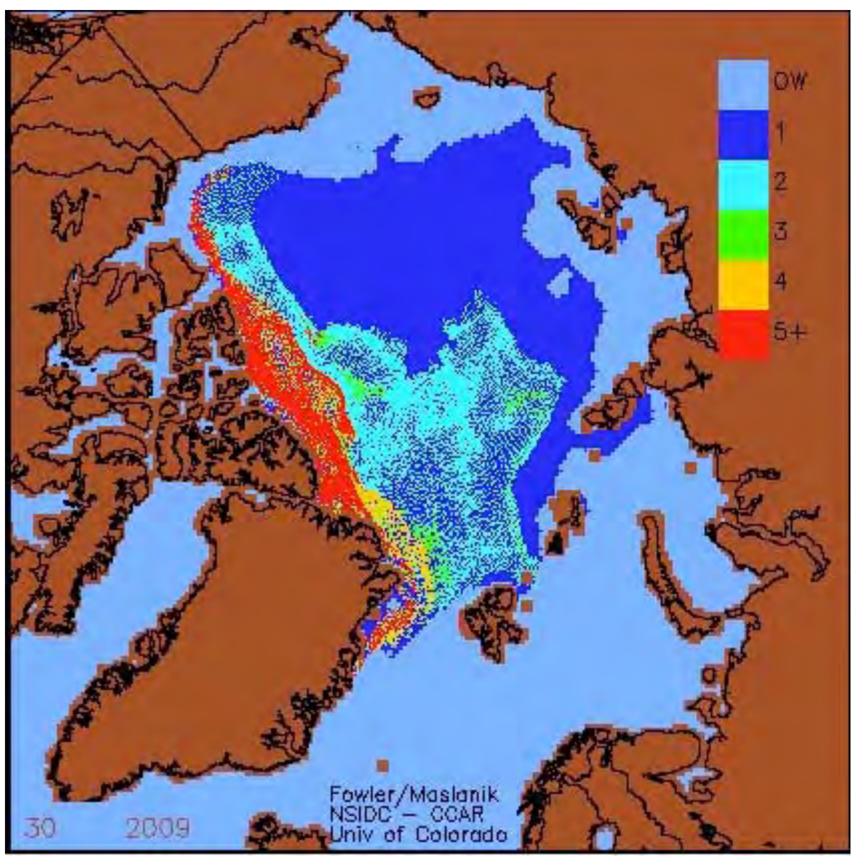

Figure 3. Ice age map for late July 2009 indicating the large area of first-year ice through the Alaskan-Siberian sector of the Arctic. Such ice is vulnerable to melting completely, even though the summer solar input is decreasing. Thanks to C. Fowler and J. Maslanik, Univ. of Colorado for image.

September 2009 Sea Ice Outlook: July Report
By: Harry Stern

****No Change from June and July****

Sea ice extent: 4.67 million sq km.
Standard deviation: 0.42 million sq km.

Type of estimate:

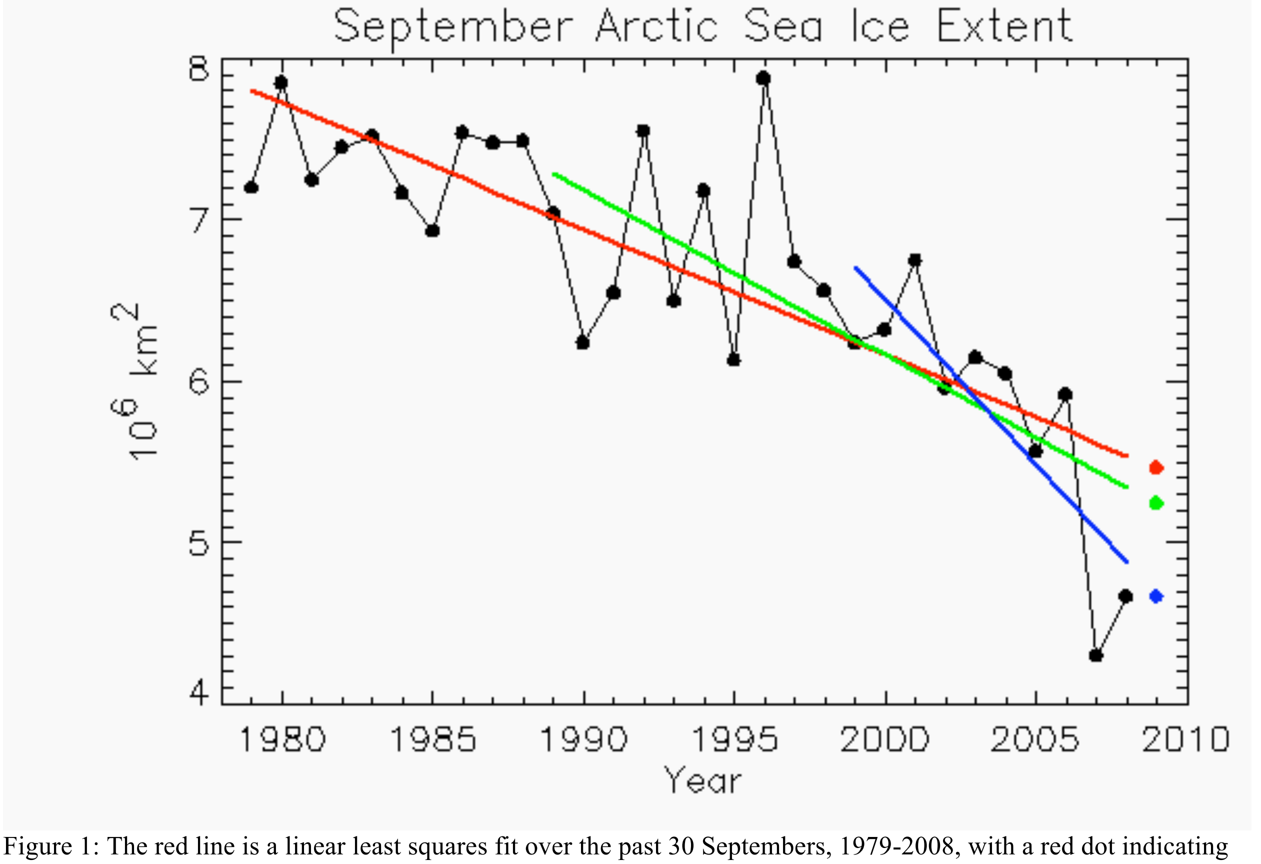

Figure 1: The red line is a linear least squares fit over the past 30 Septembers, 1979-2008, with a red dot indicating the projection for 2009. The green line is a fit over the past 20 Septembers, 1989-2008, with a green dot indicating the projection for 2009. The blue line is a fit over the past 10 Septembers, 1999-2008, with a blue dot indicating the projection for 2009.

My estimate for September 2009 is the blue dot, i.e. it is based on a linear least squares fit of the past 10 Septembers. The standard deviation of the residuals of the fit is 0.42 million sq km. The squared correlation (R^2) is 0.67.

Physical rationale for the estimate:
This is a purely statistical estimate with no physical factors contributing to it. I believe it's important to include in the Outlook a crude linear extrapolation that can serve as a benchmark against which to compare other, more sophisticated estimates.

Last year I also submitted an estimate based on a 10-year linear trend (1997-2006), purposely excluding 2007 because it appeared to be an extreme outlier. However, the sea ice extent in September 2008 turned out to be relatively close to that of 2007. Therefore I don't believe 2007 is an outlier, and I have included it in this year's linear fits.

Interestingly, the estimate of 4.67 million sq km, based on the 10-year linear trend, is exactly the same sea ice extent as observed in September 2008. In other words, the trend estimate is the same as simple persistence.

Finally, it is interesting to look at the 10-year trends of September sea ice extent for the three 10-year periods of sea ice observations during the satellite era:

Period	Mean	Trend	R^2
1979-1988	7.39	-0.0027	0.0010
1989-1998	6.84	+0.014	0.0053
1999-2008	5.79	-0.20	0.67

Table 1: The mean is in units of millions of sq km, the trend is millions of sq km per year, and R^2 is the squared correlation of the fit.

Within each of the first two decades there was virtually no trend, although the mean did decrease from the first decade to the second. In the third decade, the trend has been dramatic and significant.

Sea Ice Outlook - June 2009

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July 4, 2009

2009 September Extent

Our forecast remains at 4.92 ± 0.43 Mio. km^2.

Methods and Techniques

The estimate is based on a quadratic extrapolation of the measured September sea ice extent time series (Fig. 1)

Physical Rationale

We have a total of four different statistical forecast methods (see May outlook). Besides extrapolation of the September minimum timeseries, correlation of previous Winter surface air temperature and correlation of the June extent we additionally investigated June sea ice concentration data from CERSAT/IFREMER.
The correlation of June ice concentration with September minimum extent shows a region of significant correlation in Beaufort Sea (red box in Fig. 2). Mean ice concentration of this region and correlation was used for hindcast analysis and it shows to have great potential for prediction of the sea ice minimum, since it has the lowest mean relative error (Fig. 3). Of all parameters the June concentration shows clearly the best statistical relation for the last two years of extreme minima.
Unfortunately, June 2009 concentration data are not yet available from IFREMER due to problems with the SSM/I on the platform DMSP-F13 and the switch to DMSP-F17.
We used a different method for combining forecasts as compared to the May

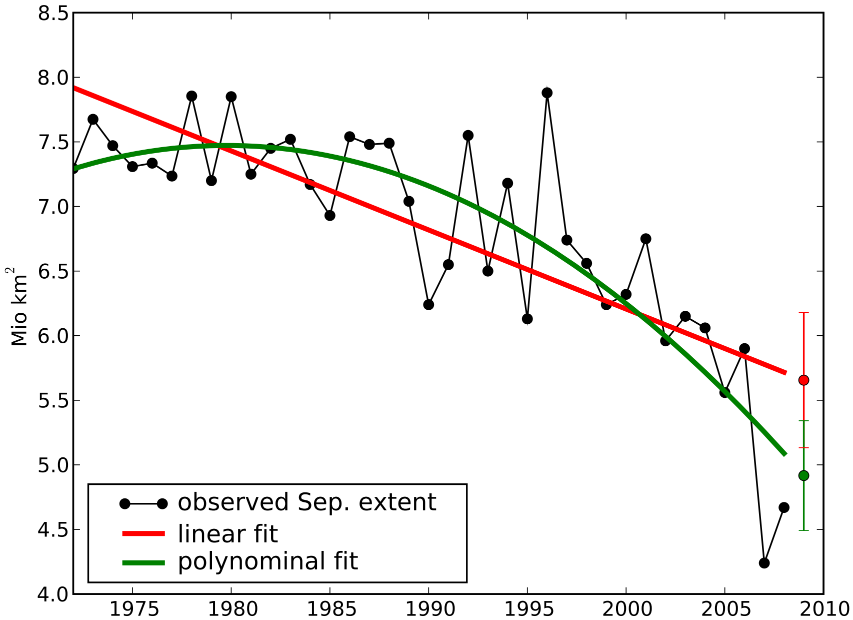

Figure 1: extrapolation of september timeseries, correlation coefficients $r_{lin} = 0.78$ and $r_{poly} = 0.86$

outlook. Weights were calculated from the mean relative error from each forecast taken from Figure 3. It shows that for 2008 the combination comes close to being as accurate as extrapolation. Since the prediction with best accuracy is missing this year, using the combination method without the concentration data would probably result in a rather unlikely combined forecast. Therefore our prediction remains at 4.92 ± 0.43 Mio. km^2 only using quadratic extrapolation.

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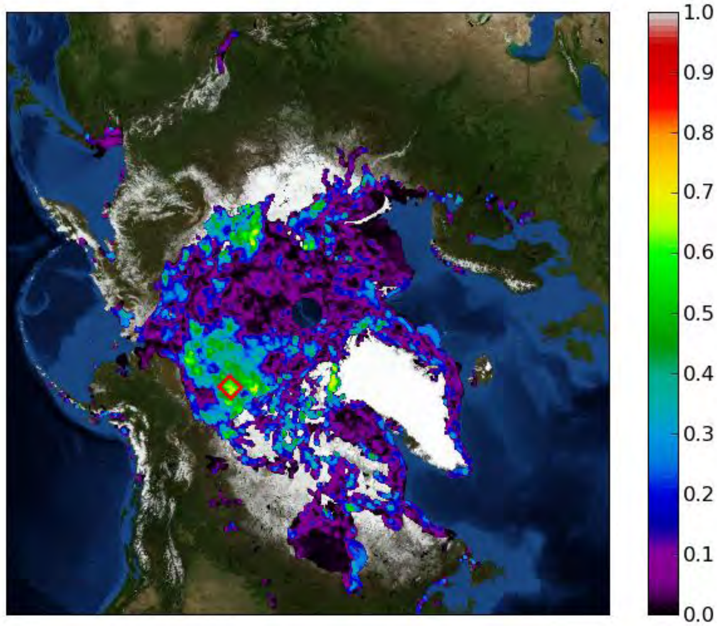


Figure 2: Correlation (r^2) of June sea ice concentration and September extent; significance levels are $p_{95} = 0.24, p_{99} = 0.54$

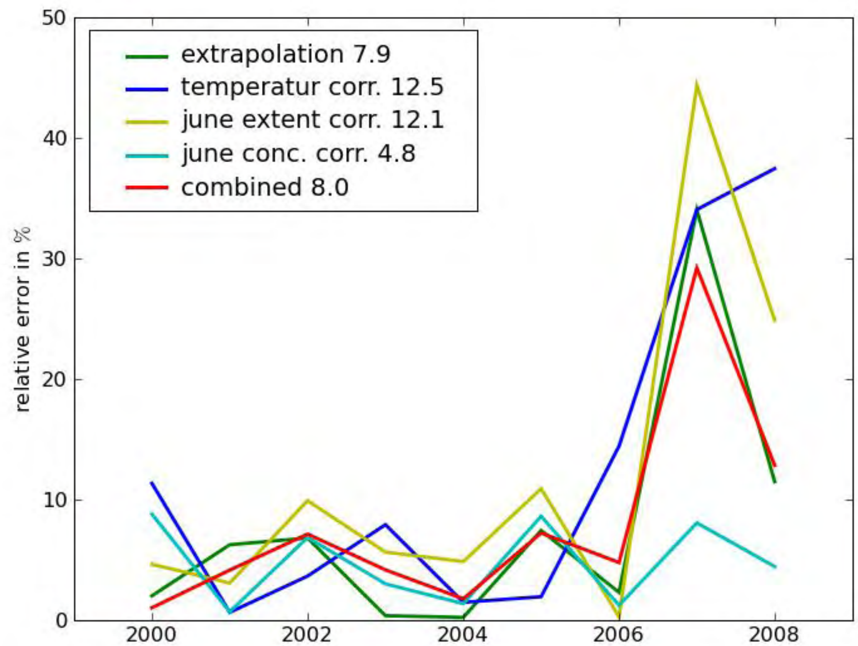


Figure 3: Prediction error hindcast experiment. The methods described in the text are used to predict the September minimum for the years 2000 to 2008. The relative deviation of the prediction to the actual sea ice extent are shown. The averaged errors in % are given within the legend.

September 2009 Sea Ice Outlook: August Report
By: Ron Lindsay

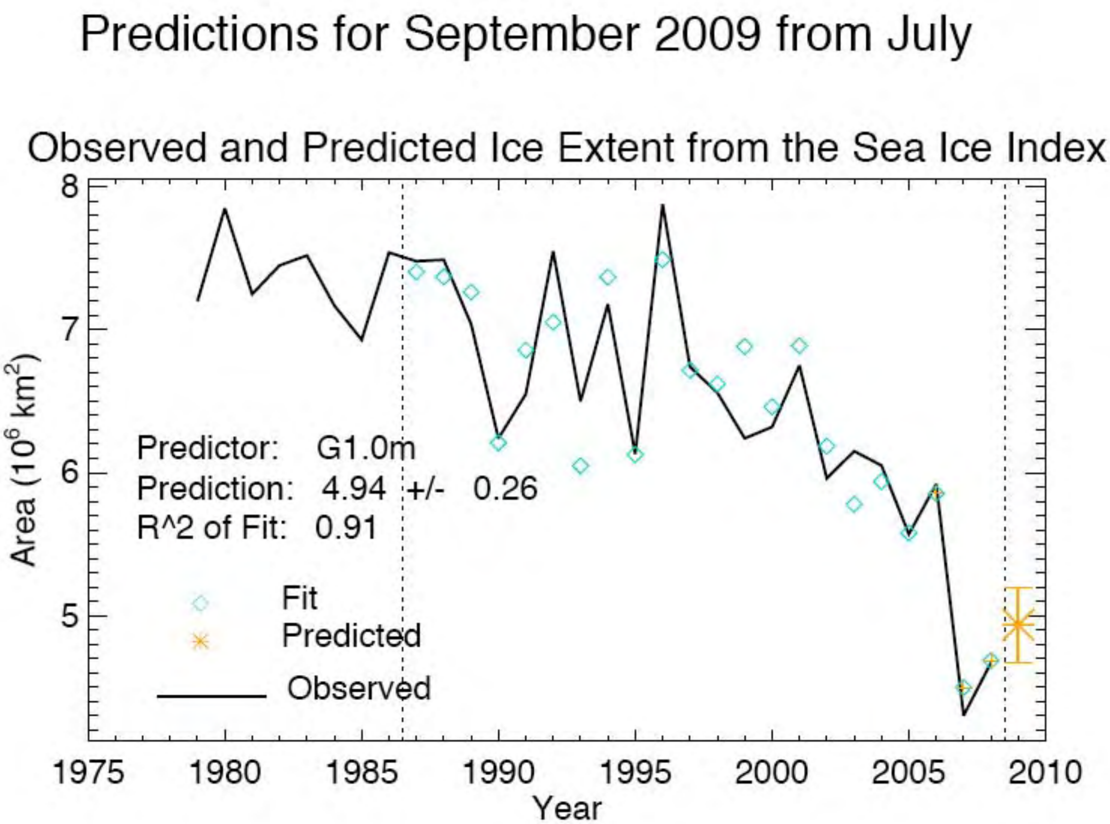
The predicted mean ice extent in September is 4.94 +/- 0.26 million km^2. It is a statistical prediction based on the fractional area of ice and open water less than 1.0 m thick (G1.0) obtained from model retrospective simulations created by Jinlun Zhang. This prediction is substantially greater than that from June data (3.99 ± 0.30, based on G0.4).

The anomalous thin ice in the Beaufort Sea and north of the Canadian Archipelago is most influential in making the prediction, but widespread anomalies in this measure contribute to the prediction.

The three maps in the attached figure show a) the correlation of the September mean ice extent with the G1.0 measure of the ice thickness for 1987–2008, b) the anomaly of the G1.0 measure in July 2009, and c) the product of a) and b). The area integral of c) is used as the predictor to obtain the estimate of the September ice extent.

The mean ice thickness fields give the same prediction but it has a larger error bar (4.94 ± 0.37).

The 1-sigma error bars are determined from the RMS error of the linear regression fit to past data. The errors are likely underestimated because of the changing statistical properties of the system.



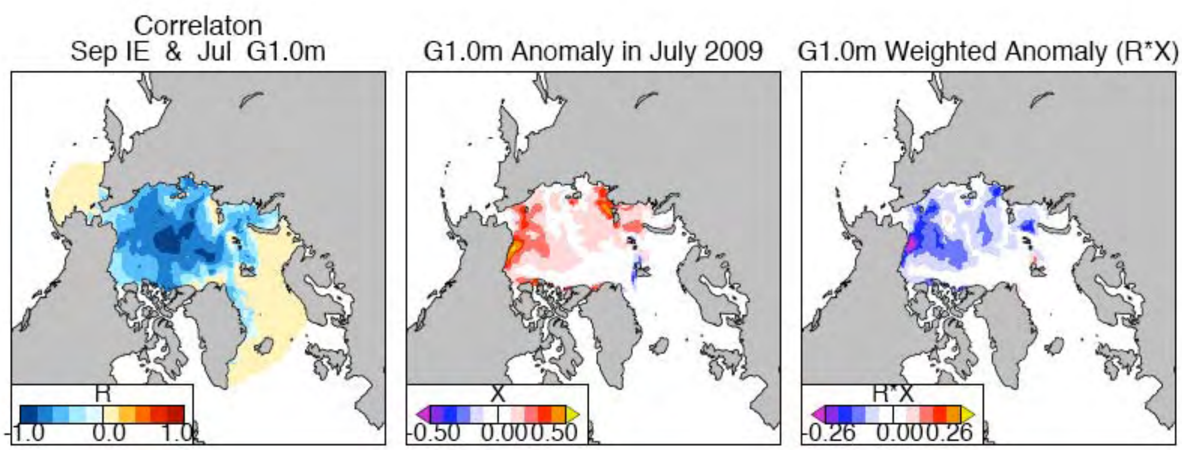


Figure 1. A) the correlation of the September mean ice extent with the G1.0 measure of the ice thickness for 1987–2008, B) the anomaly of the G1.0 measure in July 2009, and C) the product of A) and B). The area integral of C) is used as the predictor to obtain the estimate of the September ice extent.