September 2009 Sea Ice Outlook:
July Report

Community Contributions

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By: Ron Lindsay

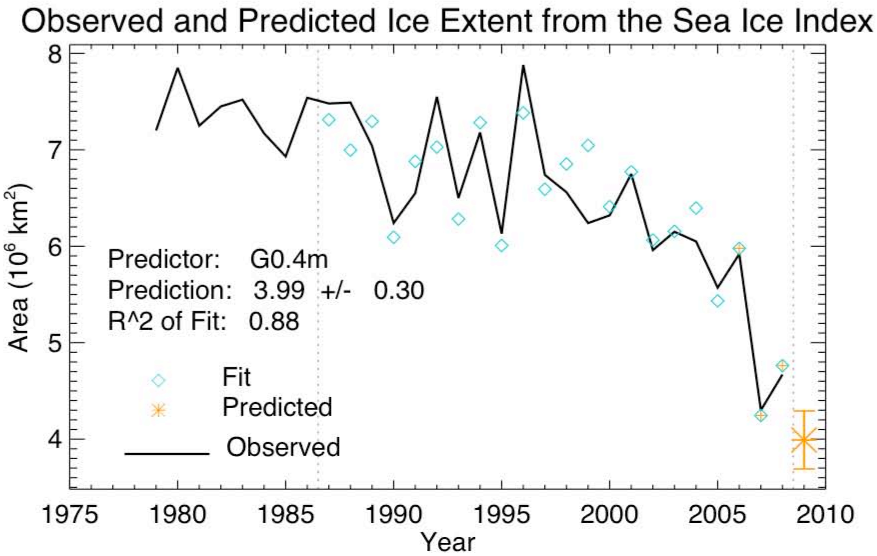
The predicted mean ice extent in September is 3.99 +/- 0.30 million km^2, a record low; it is based on the fractional area of ice and open water less than 0.4 m thick (G0.4) obtained from model retrospective simulations. This prediction is substantially lower than that from May data (4.98 ± 0.50, based on G1.9). The anomalous thin ice in the Beaufort Sea is most influential in making the prediction, but widespread anomalies in this measure contribute, including an area in the Barents Sea.

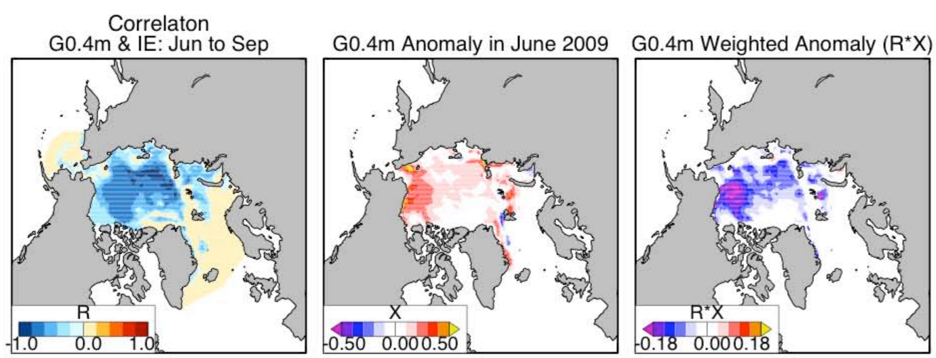
The three maps in the attached figure show a) the correlation of the September mean ice extent with the G0.4 measure of the ice thickness for 1987-2008, b) the anomaly of the G0.4 measure in June 2009, and c) the product of a) and b). The integral of c) is used as the predictor to obtain the estimate of the September ice extent.

The mean ice thickness and the G1.0 measure give larger predictions but they have larger error bars (4.87 ± 0.46 and 4.53 +/- 0.33 respectively). The spatial patterns of the region most influencing the prediction, thin ice in the Beaufort, are similar. The fact that the different predictors give quite different predictions lowers the reliability of the forecast. However, the fit to past observations (blue diamonds in the top panel) for the G0.4 measure is very good in the last three years.

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.

Predictions for September 2009 from June





Lindsay

September 2009 Sea Ice Outlook: July Report

By: Ignatius G. Rigor[1,2], Son V. Nghiem[3], Pablo Clemente-Colón[4], Kyle Obrock[4], and Todd Arbetter[4]

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1. Extent Projection
   We estimate that the September monthly mean sea ice extent will reach a new record minimum of 4.16 million square km (Figure 1, right).

2. Methods and Techniques
   This estimate is based primarily on statistics of 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., Figures 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 (Figure 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 near the North Pole (Figure 2), 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 Figure 1, right. Depending on inter-annual variability of sea ice conditions in the archipelago, this is another source of uncertainty.

Figures

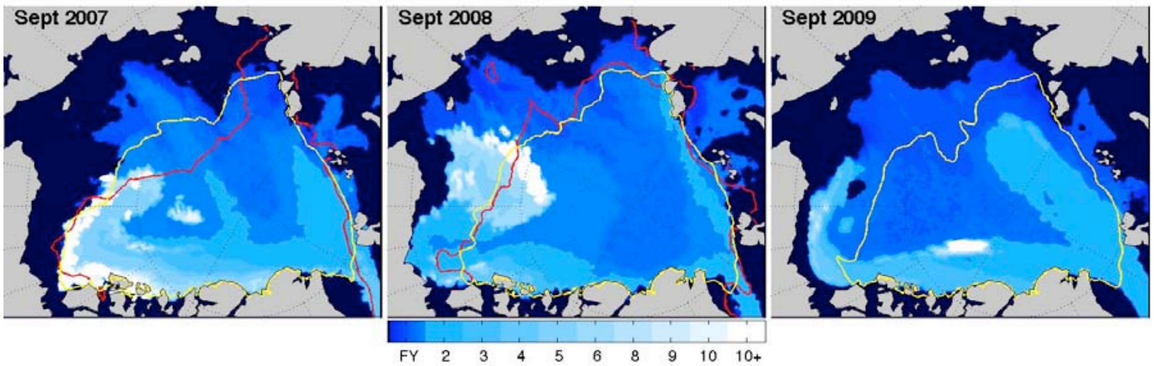

Figure 1. Maps of the age of sea ice for September 2007 and 2008, and the expected distribution of the age of sea ice in September 2009 based on June data. The red line shows the observed 15% sea ice concentration line that we use to define sea ice extent, while the yellow line shows the expected 15%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

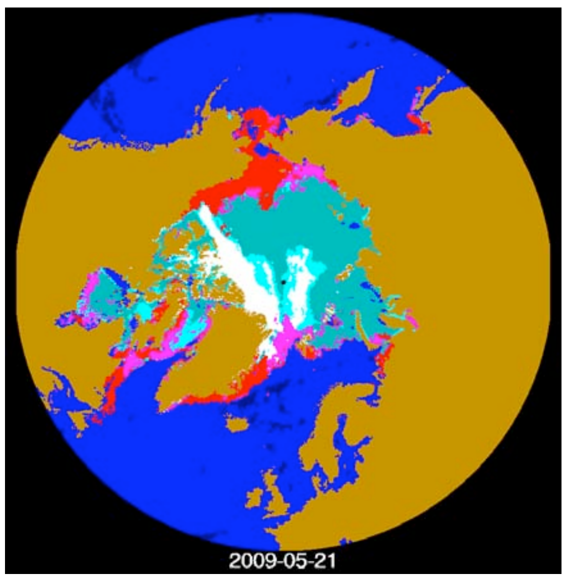

Figure 2. Maps of arctic sea ice distribution based on QuikSCAT for May 21, 2009. The colors show perennial ice (white), mixed ice (aqua), seasonal ice (teal), ice with current melting surface (red), and ice with melted surface within the previous ten days (magenta). The extent of perennial ice was about the same on 1 May 2009, and 1 May 2008, while there is more second year ice in 2009, due to more ice surviving 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.

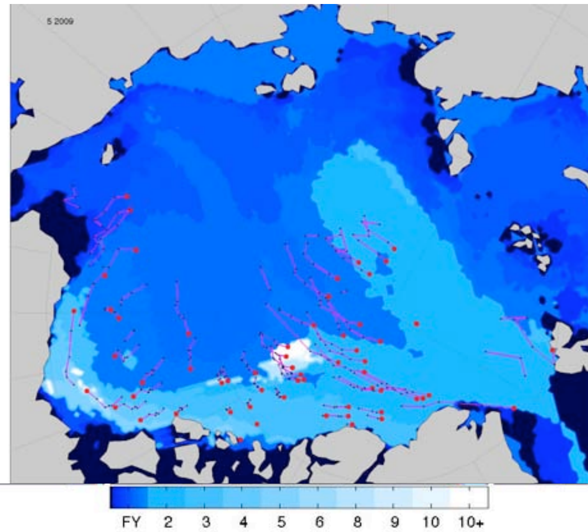

Figure 3. Map of the age of sea ice (in years) based on the buoy Drift-age Model for April 2009. Note the correspondence between the areas of FY and MY ice (ice older than 1 year) shown on this map and Figure 2.

September 2009 Sea Ice Outlook: July Report
By: AWI/FastOpt/OASys contribution
F. Kauker[a,b], R. Gerdes[a], M. Karcher[a,b], T. Kaminski[c], R. Giering[c], and M. Vossbeck[c]

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[c] FastOpt GmbH, Hamburg, Germany

Experimental setup

For the July outlook the coupled ice-ocean model NAOSIM has been forced with atmospheric surface data from January 1948 to July 2nd 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 with different prescriptions of the initial conditions on July 2nd 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 2nd 2009.

Ensemble II starts from an optimised 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 2nd 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 merged 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).

The variational assimilation system minimises the difference between observations and model analogues, by variations of the models 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.

EM-Bird data

The EM-Bird (*Haas et al.*, 2009) was operated for the first time from the AWI research aircraft (POLAR 5, DC3-Turbo) during the PAM-ARCMIP (Pan-Arctic Measurements and Arctic Regional climate model simulations) field campaign in the western Arctic from April, 4th to April, 26th 2009. Surveys were conducted based from the airports in Longyearbyen (Svalbard), Station Nord (Greenland), Canadian Forces Station Alert (Ellesmere Island, Canada), Sachs Harbor (Banks Island, Canada) and Barrow (Alaska).

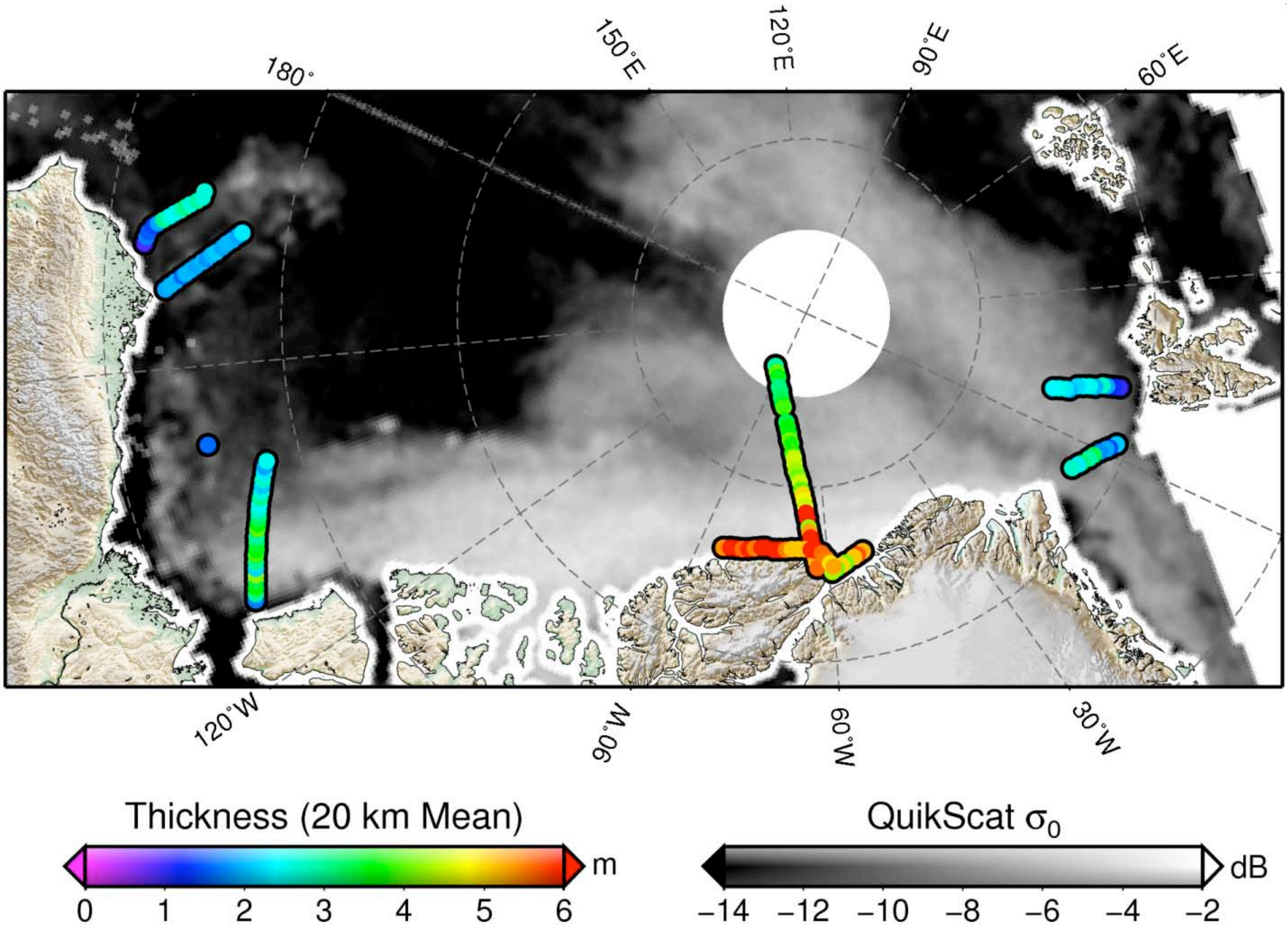


Figure 1. EM-Bird ice thicknesses from the PAM-ARCMIP aircraft campaign in April 2009 (shown here: 20 km mean) with QuikScat backscatter map (pers. comm. Stefan Hendricks, AWI).

Mean September Ice Extent 2009

Ensemble I

The result for all 20 realizations ordered by the September ice extent is shown in Figure 2. 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 systematic bias to the results of Ensemble I. The Ensemble I mean value is 4.92 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 years 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 state 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 5%,
probability to fall below 2008 (second lowest) is about 26%,
probability to fall below 2005 (third lowest) is about 95%.

With a probability of 80% the mean September ice extent in 2009 will be in the range between 4.42 and 5.42 million km^2.

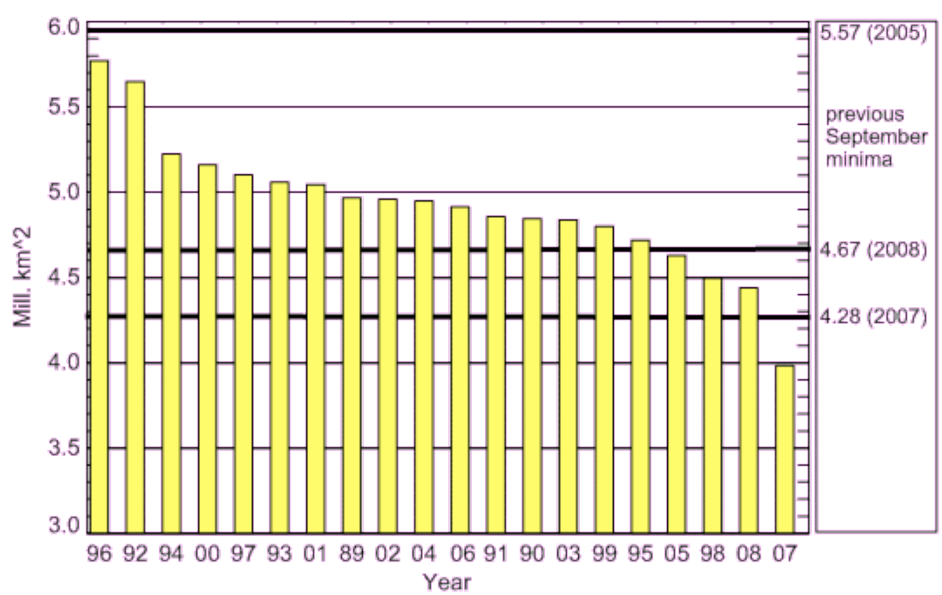


Figure 2. **Ensemble I** - Simulated mean September ice extent in 2009 [million km^2] when forced with atmospheric data from 1989 to 2008 (non-optimised initial state on July 2nd 2009). Model derived ice extents have been adjusted assuming a systematic bias (see text). The thick black horizontal lines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

Ensemble II (optimised initial conditions)
The mean September sea ice extent for all 20 realizations starting from optimised initial conditions is shown in Figure 3. 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 0.39 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%.

With a probability of 80% the mean September ice extent in 2009 will be in the range between 3.92 and 4.92 million km^2.

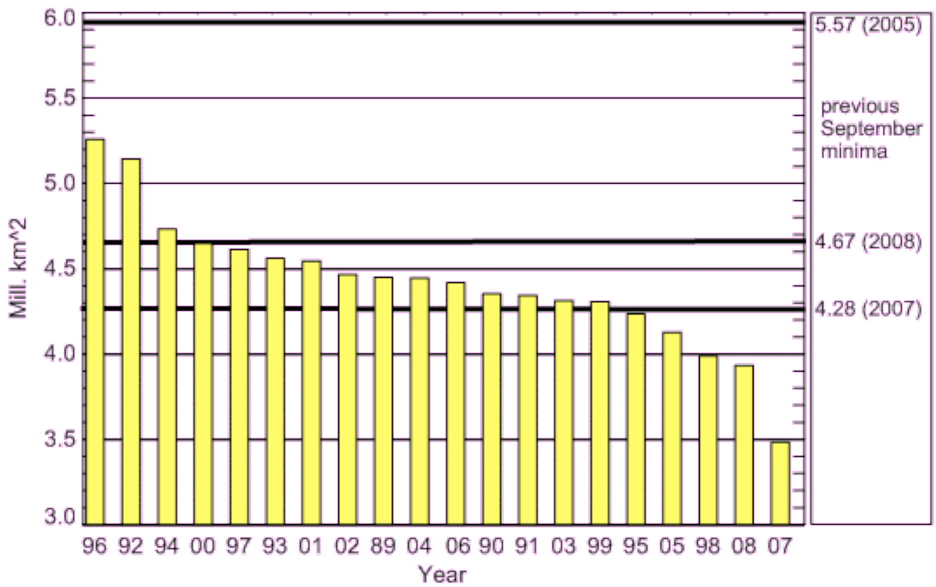


Figure 3. **Ensemble II** - Simulated mean September ice extent in 2009 [million km^2] when forced with atmospheric data from 1989 to 2008 from the optimised initial state on July 2nd 2009. The thick black horizontal lines display the minimum ice extents observed in 2005, 2007 and 2008.

References:

Haas, C., J. Lobach, S. Hendricks, L. Rabenstein, and A. Pfaffling (2009), Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM bird, Journal of Applied Geophysics, 67, 234-241.

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.

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.

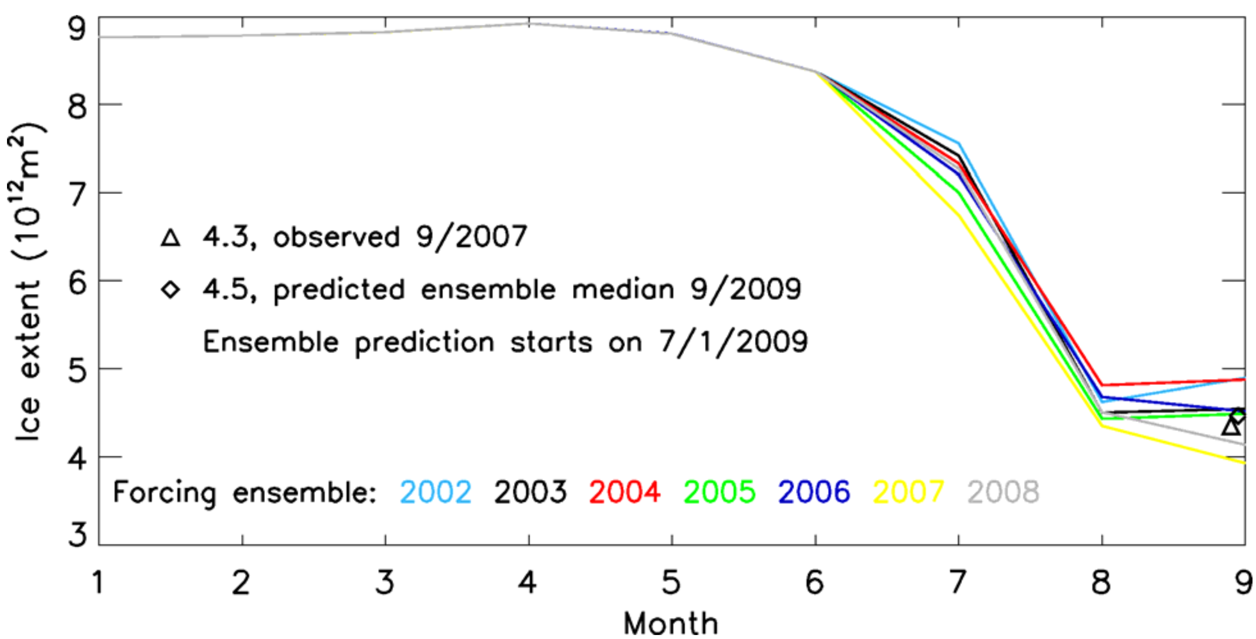


Figure 1. Monthly ice extent over January–September 2009 from seven ensemble members and their ensemble median for September 2009. Results for January–June are from the retrospective simulation and results for July–September are from the ensemble predictions (prediction range is 7/1 – 9/30/2009). The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

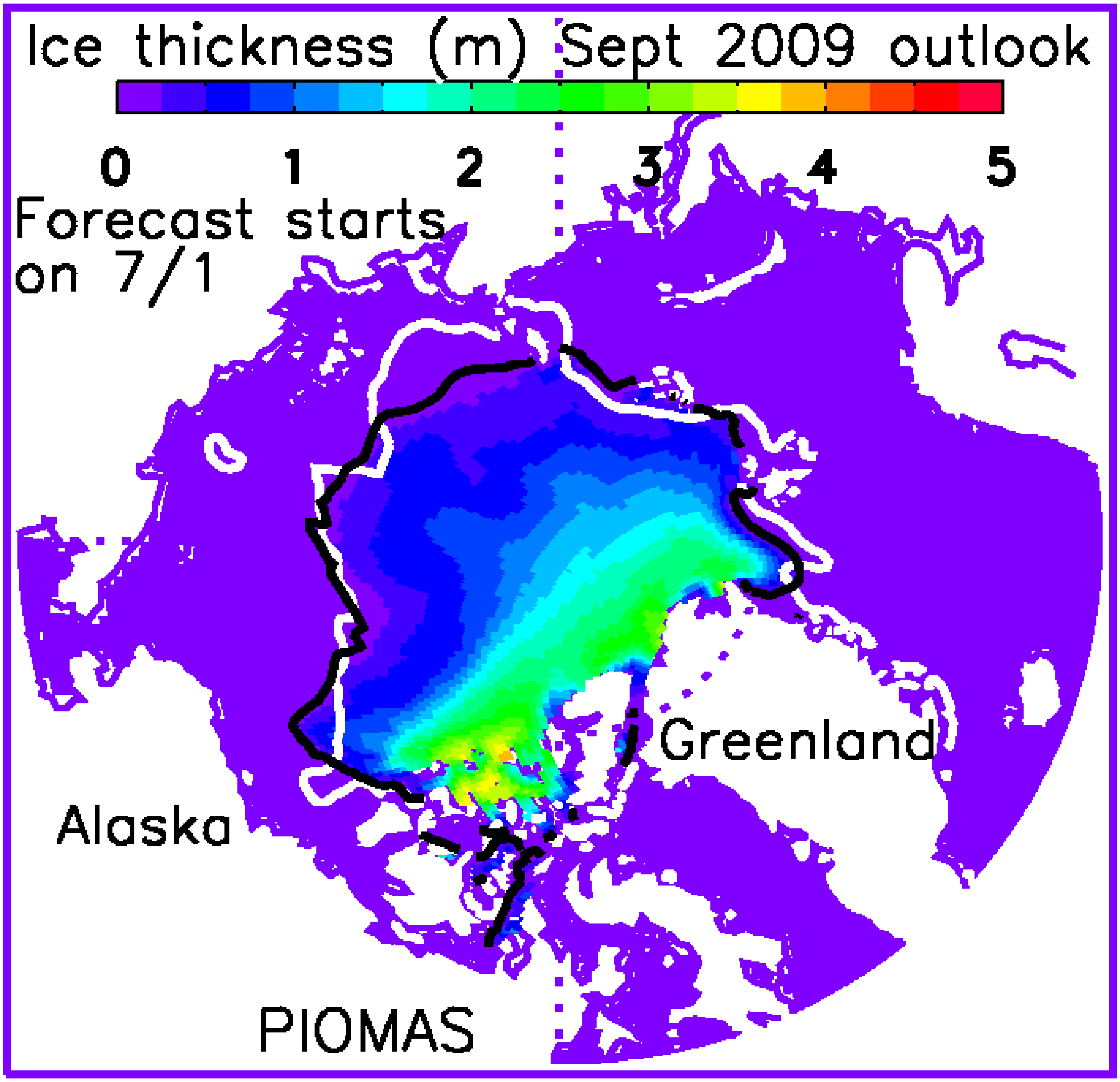


Figure 2. Ensemble prediction of September 2009 sea ice thickness. The white line represents satellite observed September 2008 ice edge defined as of 0.15 ice concentration, while the black line model predicted September 2009 ice edge.

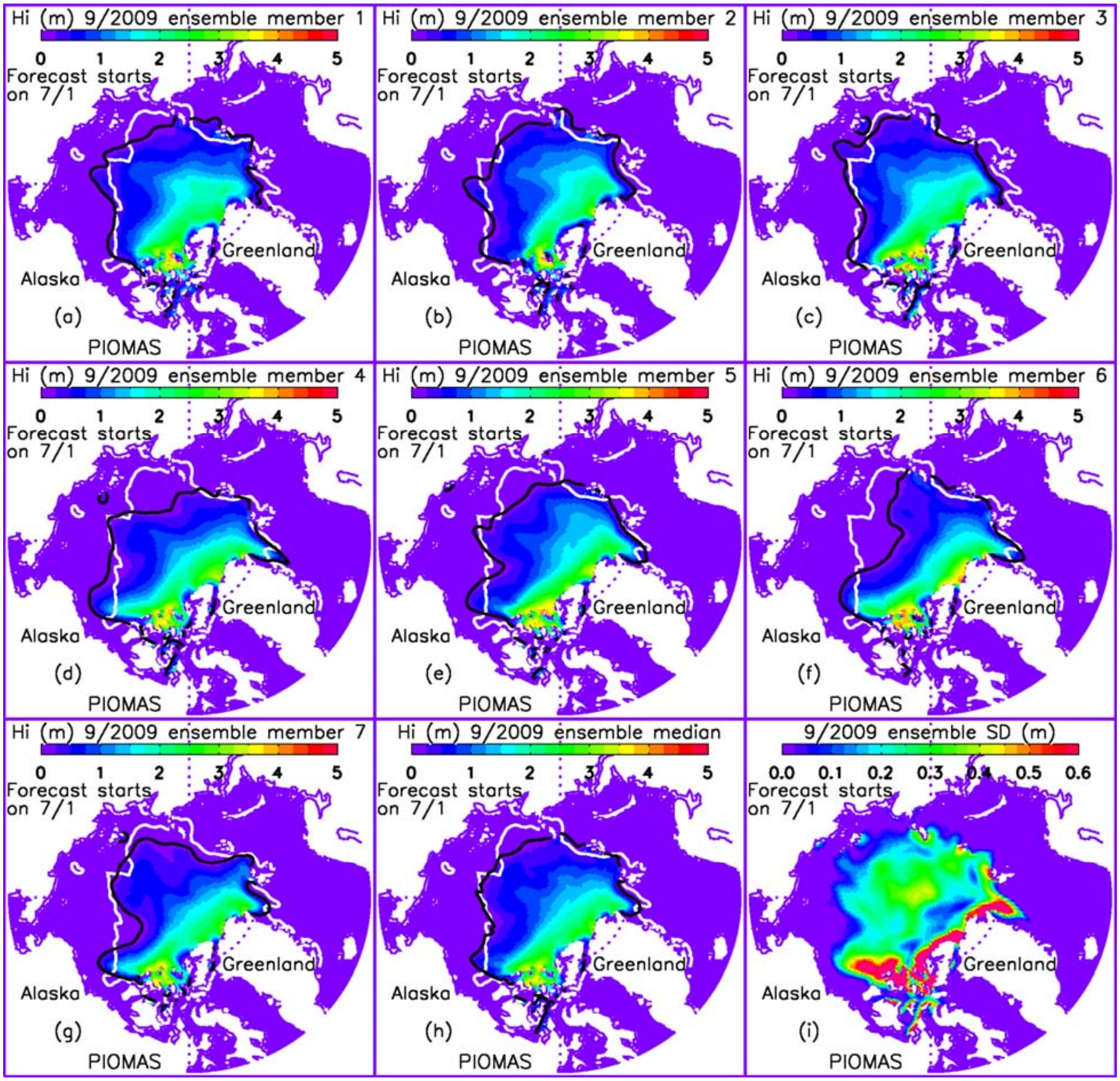


Figure 3. September 2009 sea ice thickness predicted by seven individual ensemble members, ensemble median ice thickness, and ensemble standard deviation (SD) of ice thickness. The spatial ensemble median ice thickness distribution (Figure 3h, the same as Figure 2) is most likely to occur in September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

September 2009 Sea Ice Outlook: July Report
By: Todd Arbetter, Sean Helfrich, Pablo Clemente-Colón (Science and Applied Technology)
Chris Szorc, Tom Holden (Operations Dept)
National/Naval Ice Center, Suitland, MD

Issued July 1, 2009

Best Guess: 4.528 million km^2
Method: Heuristic/Statistical

Update:
The current conditions (figure 1):

Ice extent 10.554 million km^2
Ice Area 9.135 million km^2,
Avg concentration 86.6%

Multiyear ice extent 5.348 million km^2
Multiyear ice area 2.612 million km^2
Avg concentration: 48.8%

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. Holden) examines and approves the outlooks.

The Seasonal Outlooks:
Conservative: Any area with MYI survives
Ice extent: 5.261 million km^2
Ice area: 4.802 million km^2
Avg concentration: 91.3%
MYI extent: 5.261 million km^2 (includes all parcels containing MYI)
MYI area: 2.600 million km^2
Avg concentration: 49.4%

Moderate: Any area with 20% or more MYI survives
Ice extent: 4.528 million km^2
Ice area: 4.240 million km^2
Avg concentration: 93.6%
MYI extent: 4.528 million km^2
MYI area: 2.382 million km^2
Avg concentration: 52.6%

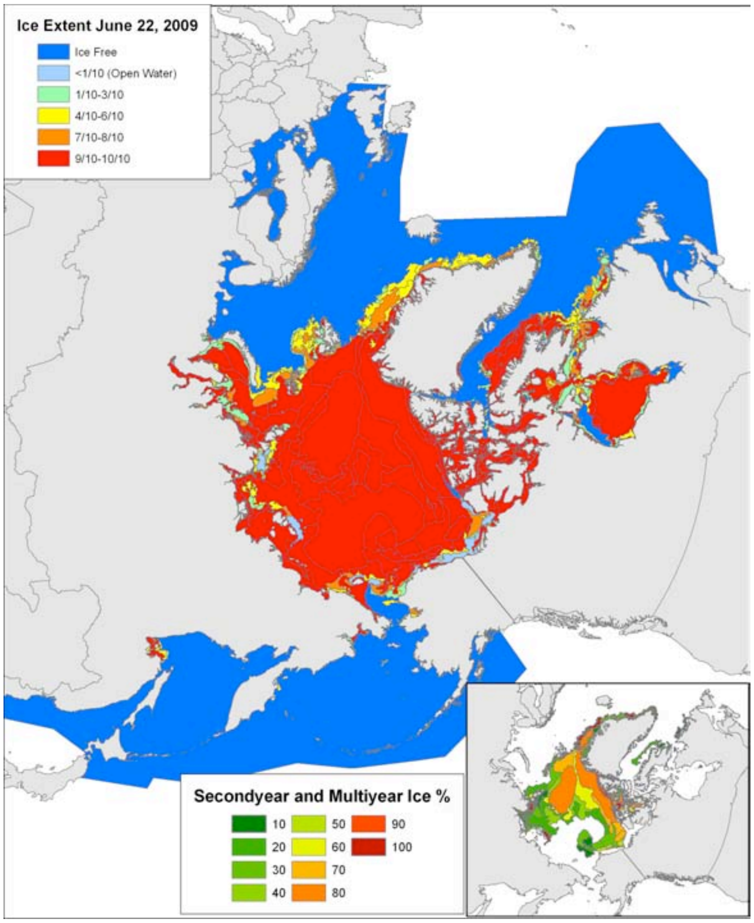


Figure 1: Sea ice conditions for June 22, 2009, and multiyear ice by percentage (inset).

Aggressive: Any area with 40% or more MYI survives
Ice extent: 2.881 million km^2
Ice area: 2.736 million km^2
Avg concentration: 95.0%
MYI extent: 2.881 million km^2
MYI area: 1.992 million km^2
Avg concentration: 69.1%

Extreme: Any area with 70% or more MYI survives
Ice extent: 1.956 million km^2
Ice area: 1.857 million km^2
Avg concentration: 94.9%
MYI Extent: 1.956 million km^2
MYI Area: 1.523 million km^2
Avg concentration: 77.9%

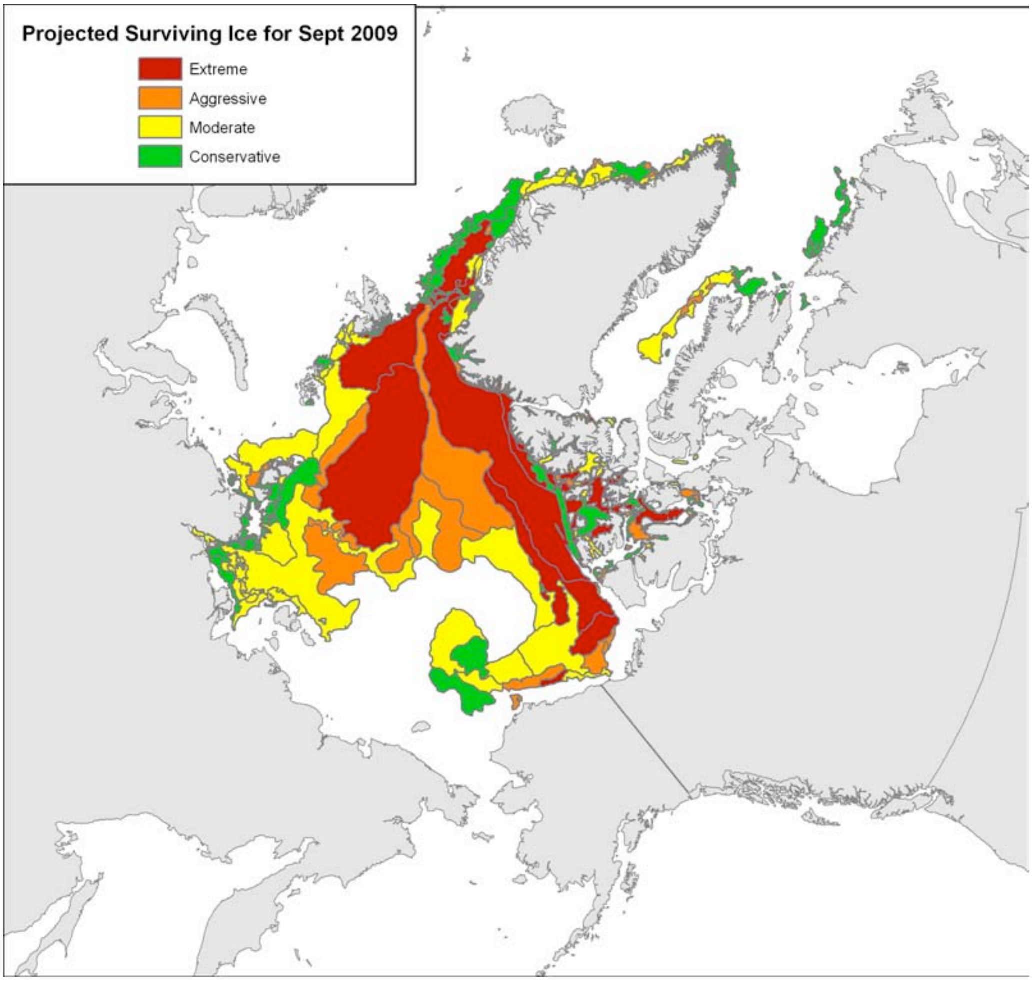


Figure 2: Surviving ice parcels. Extreme = red, Aggressive= red + orange, Moderate= red + orange + yellow, Conservative=red + orange + yellow + green.

As was the case last year, the charts represent the *parcels* of ice that we believe will survive the summer. However it *does not* represent their final location. Drift due to wind and water will transport along the Beaufort Gyre out of the Beaufort and Chukchi Seas. Some ice in the Amundsen Basin will be transported out into the Barents Sea. The picture of the ice in September 2009 will be somewhat different than the current (June 22) conditions.

From the spread of prognostications, we believe the Moderate case (4.528 million km^2) is the most likely, although at this point it is too early to tell how the atmosphere and ocean will set up.

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

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

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

3-*The physical rationale for the estimate.*

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

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

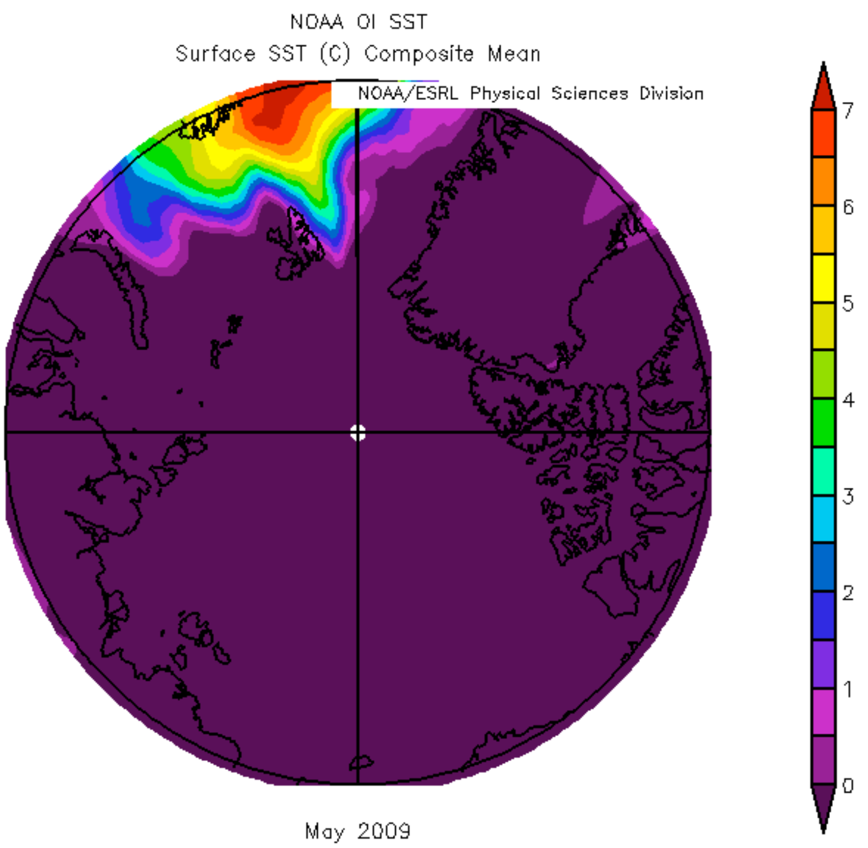


Figure 1. SST anomaly in May 2009

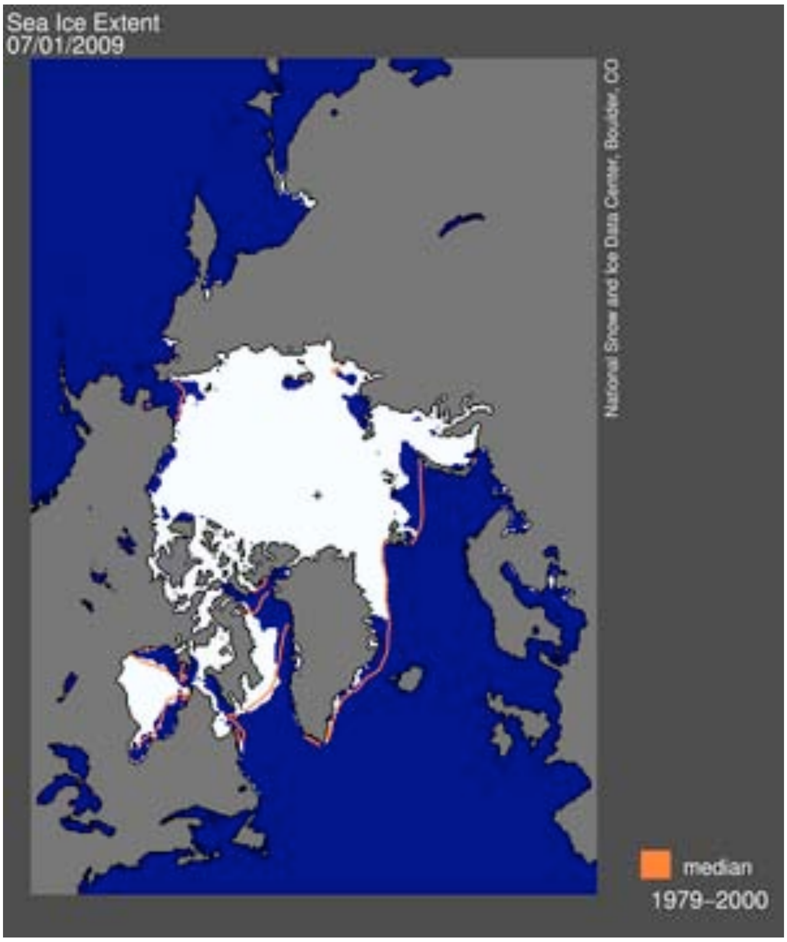


Figure 2. Arctic ice extent at 01 July 2009.

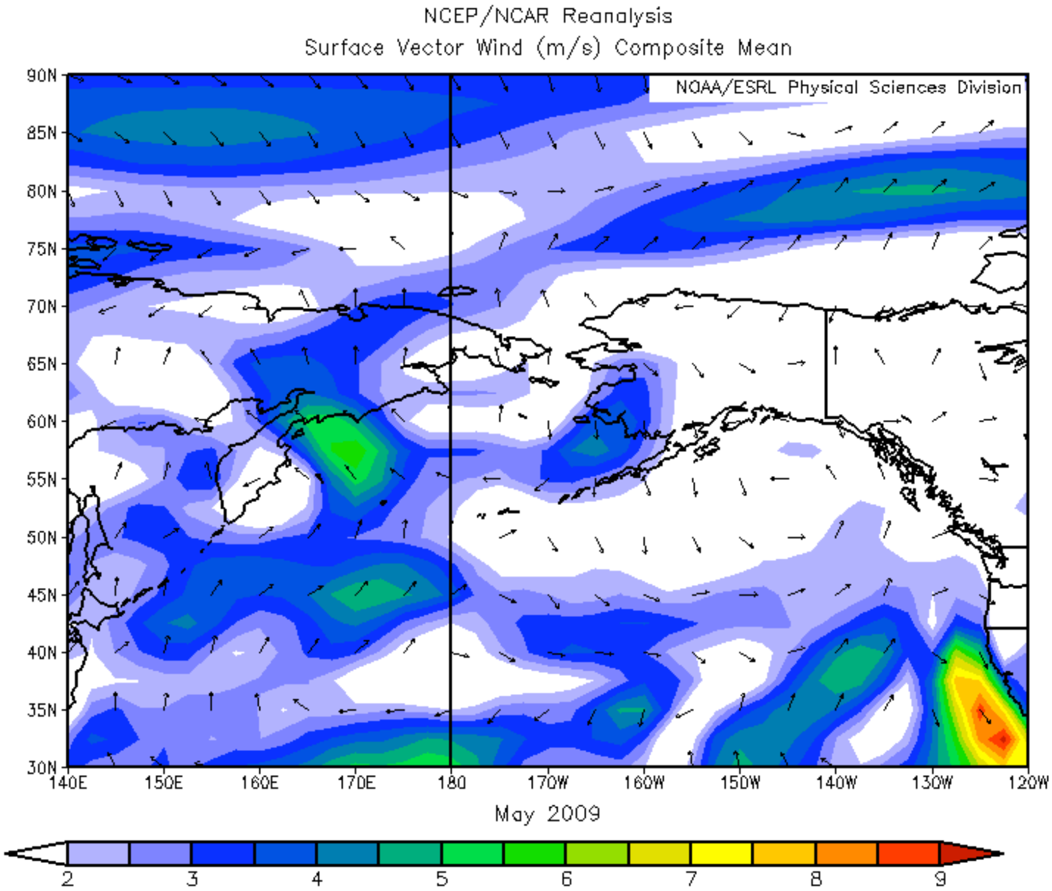


Figure 3. Anomaly vector wind field in May 2009.

September 2009 Sea Ice Outlook: July Report

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

Estimate for sea ice extent for September, 2009 is comparable to the 2008 minimum in sea ice extent, or ~4.6–4.7 · 10^6 km^2.

Rationale

The absence of a distinctive transition in spring of 2009 between cyclonic and anti-cyclonic circulation in the stratosphere characteristic of years with record lows in sea ice extent suggests that dynamical contributions will contribute to but not accelerate the decline in sea ice extent in September, 2009. Differences between surface winds and SLP, and vortex splitting and sea ice extent composites exhibit conditions that are unfavourable to export through Fram Strait in May, 2009; southwesterly versus southeasterly winds in the Beaufort Sea region may also limit free ice drift conditions and inhibit the acceleration evident in years exhibiting record lows in sea ice extent.

Methods

Connections between stratospheric dynamics and summertime sea ice extent in the Arctic are examined in the context of vortex splitting and displacement events. Examined in particular are the stratospheric (10 mb) relative vorticity fields prior to the onset of a rapid decline in sea ice extent to the present, from 2001 – 2009 for March and April during the breakup of the wintertime polar vortex. Monthly means of ECMWF ERA-Interim relative vorticity used in this study were obtained from the ECMWF data server.

Stratospheric wind composites for March are also presented for years characterized by vortex splitting, vortex displacement and minima in sea ice extent. Stratospheric winds were obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division. Years associated with vortex splitting and displacement events are defined as in Charlton et al. (2007); vortex splitting events include the years 1979, 1985, 1988, 1989, 1999, 2001, while vortex displacement events include the years 1980, 1981, 1984, 1987, 1998, 2000, 2002. 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).

Recent studies show that the wintertime stratosphere in 2009 is characterized by a major stratospheric sudden warming and vortex splitting event (Manney et al., 2009). Differences between May, 2009 surface winds and SLP, and composites for years associated with vortex splitting events and record lows in September ice extent provide a comparison and indication of this year's dynamical contributions to ice extent. Surface winds and SLP were also obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division. Moreover, wind vectors highlight contributions due to advection; SLP highlights convergence/divergence associated with anticyclonic/cyclonic activity.

Composites for vector surface winds and SLP for years associated with vortex splitting events, vortex displacement events, and record lows in ice extent for June – September also offer an indication of anticipated dynamical properties at the surface during years characterized by polar vortex splitting events and record minima. Departures from anticipated patterns in vortex splitting and record minimum composites for SLP and surface winds for months leading up to the September minimum provide a reference for regional differences in advection and convergence/divergence properties that will accelerate or inhibit summertime sea ice decline.

Figures

1. Stratospheric relative vorticity in March and April from 2001 – 2009
2. Stratospheric winds in March for years characterized by vortex splitting, vortex displacement and minima in sea ice extent.
3. Difference in May, 2009 vector winds and sea ice extent and vortex splitting composites.
4. Difference in May, 2009 SLP and sea ice extent and vortex splitting composites.
5. Vector surface wind composites for vortex splitting, vortex displacement, and minima in sea ice extent. Minima in sea ice extent and dipole anomaly pattern.
6. SLP composites for vortex splitting, displacement and minima in sea ice extent.

Results

Stratospheric relative vorticity fields

Investigation of stratospheric relative vorticity fields in March and April illustrates features during years exhibiting record lows in ice extent, namely 2002, 2005, and 2007 (Figures 1a and 1b). Low ice years are distinguished by a pattern comparable to the dipole anomaly presented in studies by Wang et al. (2009). In particular, low ice years are characterized by predominantly anticyclonic activity over the Arctic Ocean, and a distinctive transition from positive to negative vorticity, or between cyclonic and anticyclonic circulation in spring (middle panels in top and middle row and first panel in lowermost row corresponding to 2002, 2005, and 2007 respectively). The absence of such a transition in 2009 suggests that dynamical contributions will not accelerate ice loss or the decline in sea ice extent in September, 2009.

Stratospheric wind composites

Stratospheric (10 mb) wind composites are computed for March to identify patterns characteristic of vortex splitting events, vortex displacement events (Figure 2). Presented in particular are composites associated with vortex splitting events, vortex displacement events, record lows in minimum ice extent, and 2009. During vortex splitting events, maximum wind speeds are confined to the western Arctic, in contrast to vortex displacement events where maximum wind speeds exist throughout the Arctic. Noteworthy is the similarity in composites for years associated with vortex displacements and minimum sea ice extent.

Previous studies have shown trends and a persistence in patterns in atmospheric gradients from the middle stratosphere to the surface (Lukovich and Barber, 2009). The authors speculate that the spatial extent of wind speed maxima in the stratosphere and correspondence with sea ice extent composites may be an artifact of filamentation and deformation during vortex displacements, in contrast to vortex splitting events where cyclonic remnants may be less effective in sustaining stratosphere-surface connections.

Difference in May, 2009 surface winds and vortex splitting and sea ice extent composites
Differences between the most recently available surface winds in May, 2009 and vortex splitting and sea ice extent composites highlight distinctive spatial patterns near Fram Strait, in the Beaufort Sea, and to the north of the Chukchi Sea (Figure 3). Southerly winds predominate near Fram Strait, establishing conditions in May that are unfavorable to ice export through Fram Strait. Surface winds are characterized by southwesterly winds in the Beaufort Sea, in contrast to southeasterly winds associated with the minimum sea ice extent composite; southwesterly winds may inhibit acceleration in ice loss in this region evident in 2002, 2005, and 2007, and limit free ice drift conditions.

Difference in May, 2009 SLP and vortex splitting and sea ice extent composites
Differences between May, 2009 SLP and vortex splitting and sea ice extent composites further highlight surface wind patterns (Figure 4). Convergent activity associated with a SLP high (and anticyclonic activity) is observed in the southern Beaufort Sea in May, 2009. Negative values in the difference plots however suggest a weaker SLP high in May than is found for vortex splitting and mean sea ice extent composites; both a weaker SLP high and southwesterly winds will hinder free ice drift conditions that enable convergence of the central Arctic pack and poleward retreat of ice in the Beaufort Sea region. Predominantly negative values extending from Fram Strait to the Beaufort Sea across the pole further suggest increased cyclonic circulation in May that will hinder ice export through Fram Strait. Positive difference values over the Bering Strait are consistent with negative trends indicating increasing anticyclonic activity in spring (Lukovich and Barber, 2009).

Surface wind composites for June – September
Composites in surface winds for years characterized by vortex splitting events, vortex displacement events, and minima in sea ice extent from June – September illustrate distinctive spatial patterns in surface dynamical properties leading up to the minimum September sea ice extent (Figure 5). Vortex splitting composites indicate northerly winds over Fram Strait in September, in contrast to vortex displacement composites where northerly winds predominate in June. Record low sea ice extent composites highlight northerly flow over Fram Strait from June to September. In the southern Beaufort Sea region, vortex splitting events are characterized by southwesterly flow in June and July, and westerly flow in September. By contrast, vortex displacement events and record low ice extent composites are characterized by southeasterly flow in June and July, and easterly flow in September. As in the stratosphere, similarity in record low ice extent and vortex displacement composites at the surface suggests that record minima in ice extent in September are governed by vortex displacement rather than splitting events.

SLP composites for June – September

Similar features and correspondence is observed in the SLP composites for June to September (Figure 6). A SLP low is positioned over the North Pole in June and later in September during vortex splitting events, with a weak SLP high in the Beaufort Sea region in June. The SLP low is displaced off the pole in June during vortex displacement events creating an east-west asymmetry in high and low SLP in the eastern and western Arctic regions that is also evident in the record low ice extent composites.

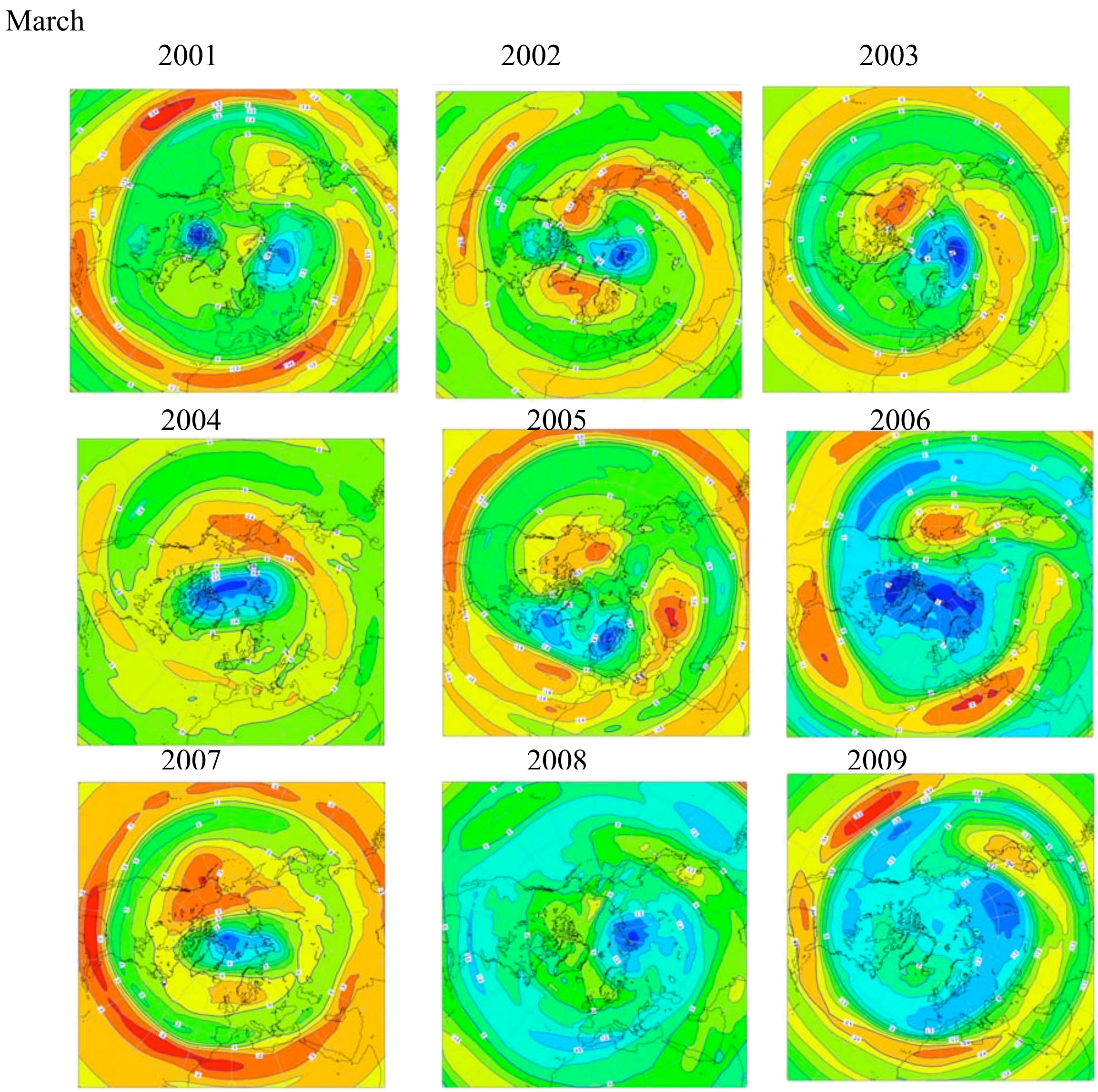


Figure 1a. Stratospheric (10 mb) relative vorticity fields from March, 2001 to March, 2009. Anticyclonic activity (negative relative vorticity) is depicted by red shading. Image provided by the ECMWF ERA-Interim data portal at http://data-portal.ecmwf.int/data/d/interim_moda/levtype=pl/.

April

2001 2002 2003

2004 2005 2006

2007 2008 2009

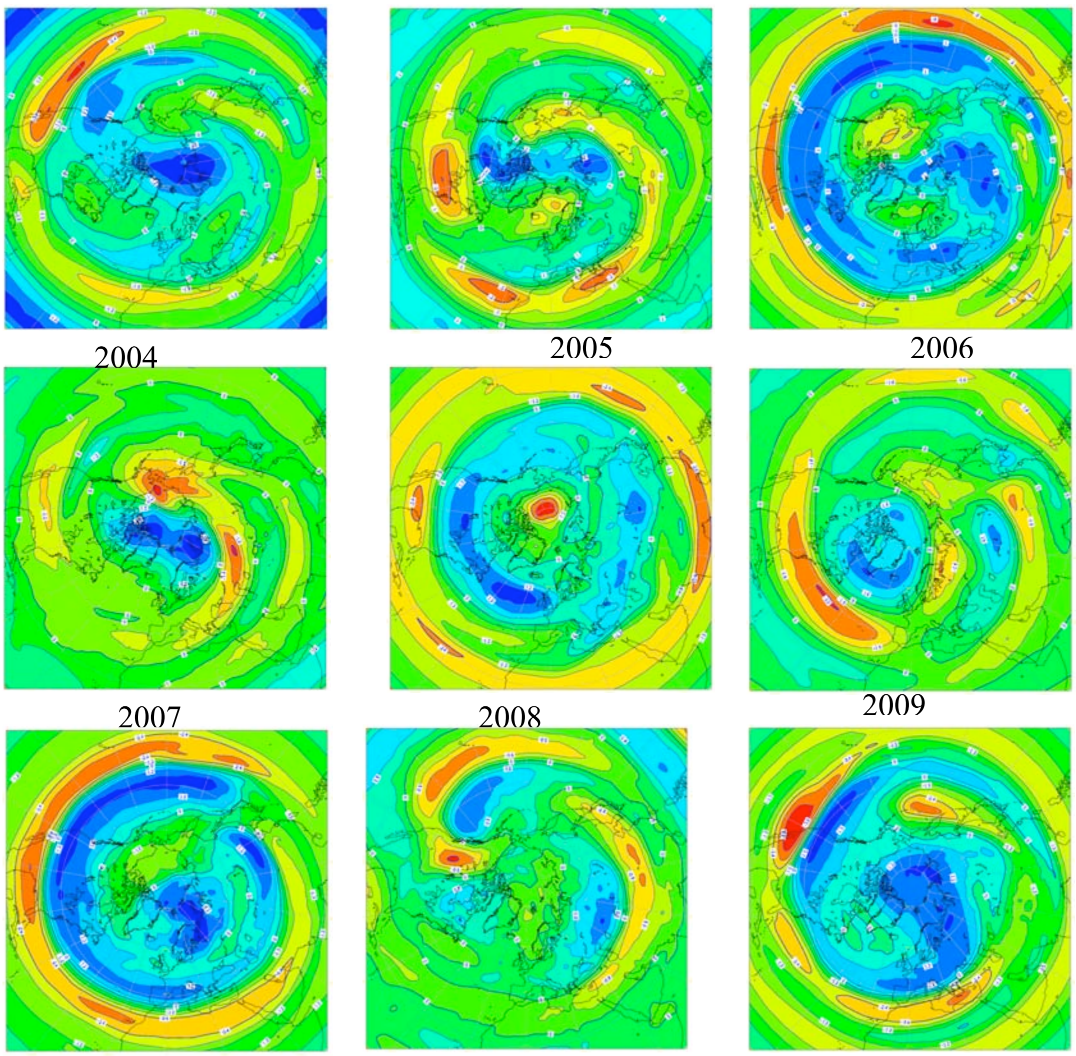
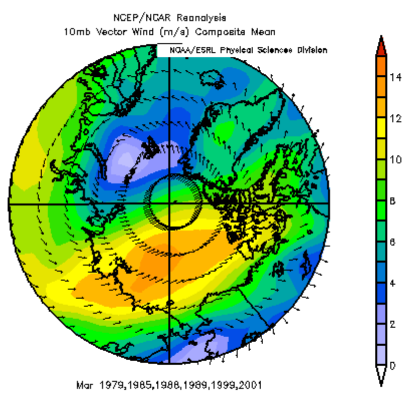
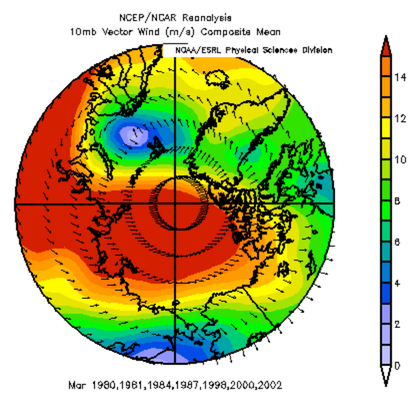


Figure 1b. Stratospheric (10 mb) relative vorticity fields from April, 2001 to March, 2009. Anticyclonic activity (negative relative vorticity) is depicted by red shading. Image provided by the ECMWF ERA-Interim data portal at http://data-portal.ecmwf.int/data/d/interim_moda/levtype=pl/.

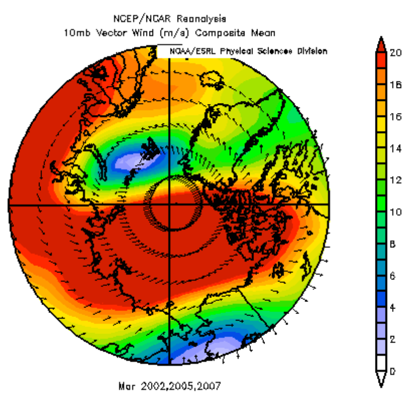
a)



b)



c)



d)

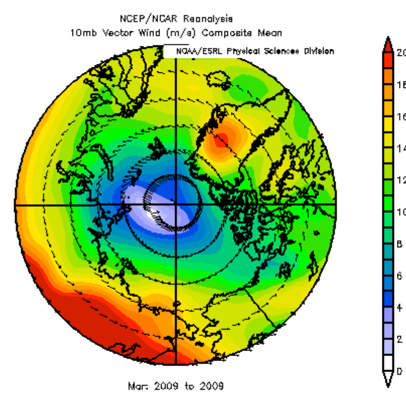


Figure 2. Composites of stratospheric winds in March for a) vortex splitting events, b) vortex displacement events, c) minima in sea ice extent, and for d) 2009. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

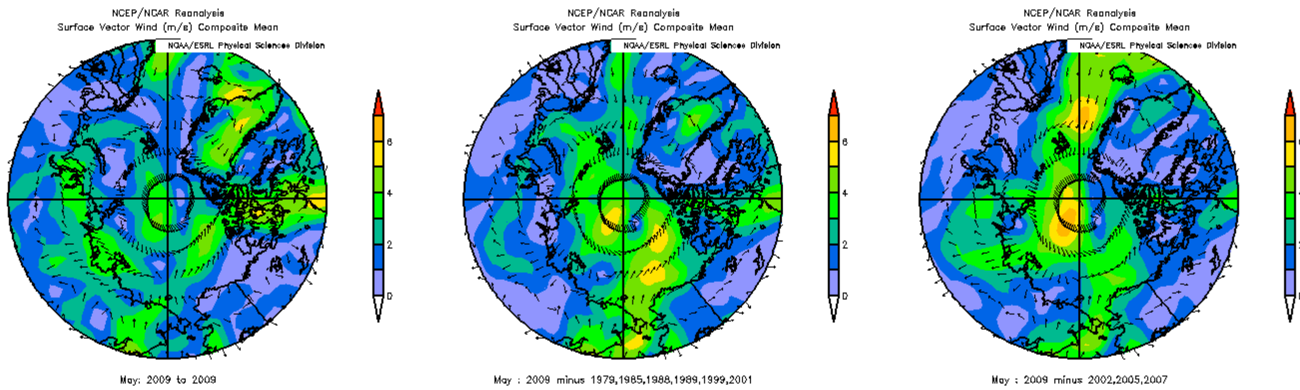


Figure 3. (Left) May, 2009 surface winds, and difference between May, 2009 and composite vector winds for (middle) vortex splitting events, and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

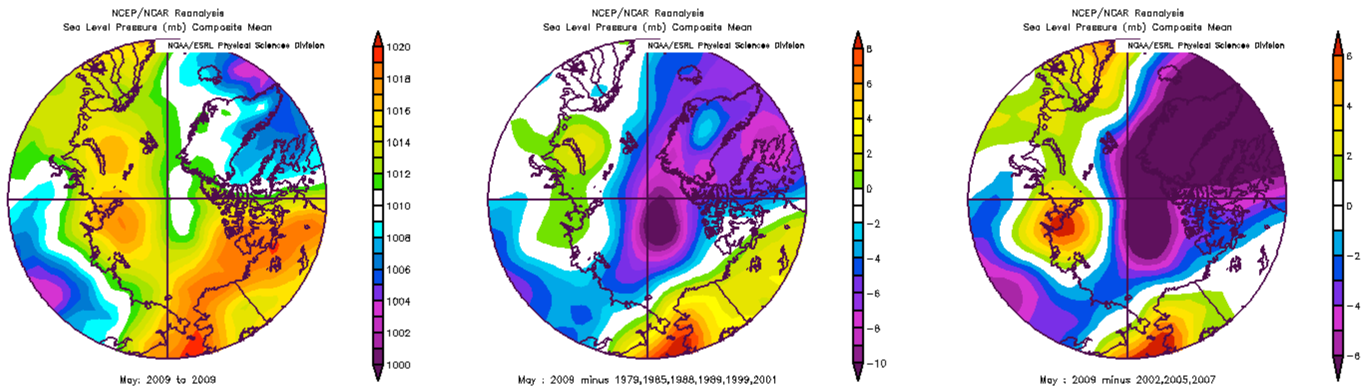


Figure 4. (Left) May, 2009 SLP and difference between May, 2009 and composite for (middle) vortex splitting events and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

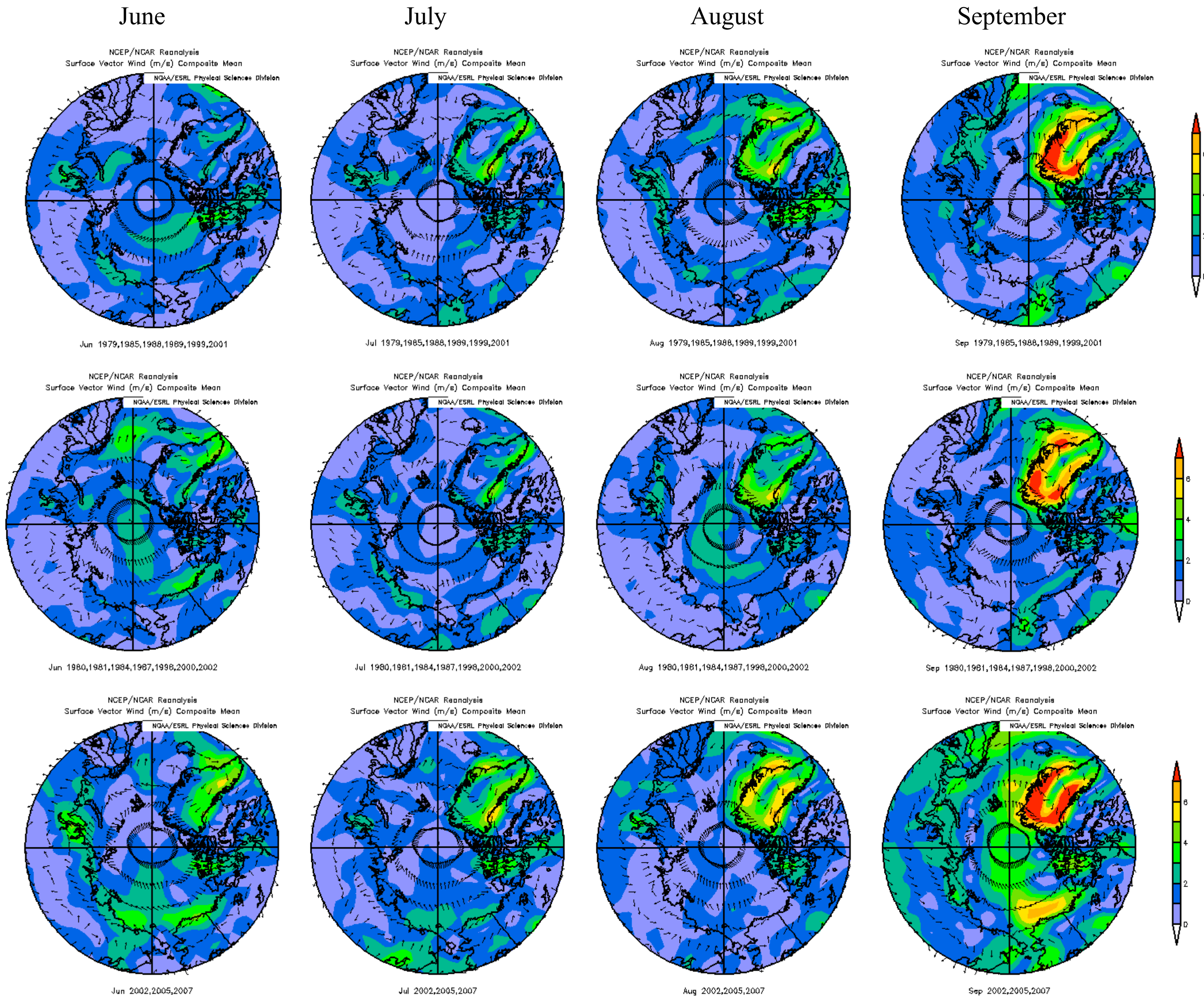


Figure 5. Composite wind vectors for (top row) vortex splitting events, (middle row) vortex displacement events, and (lowermost row) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

June July August September

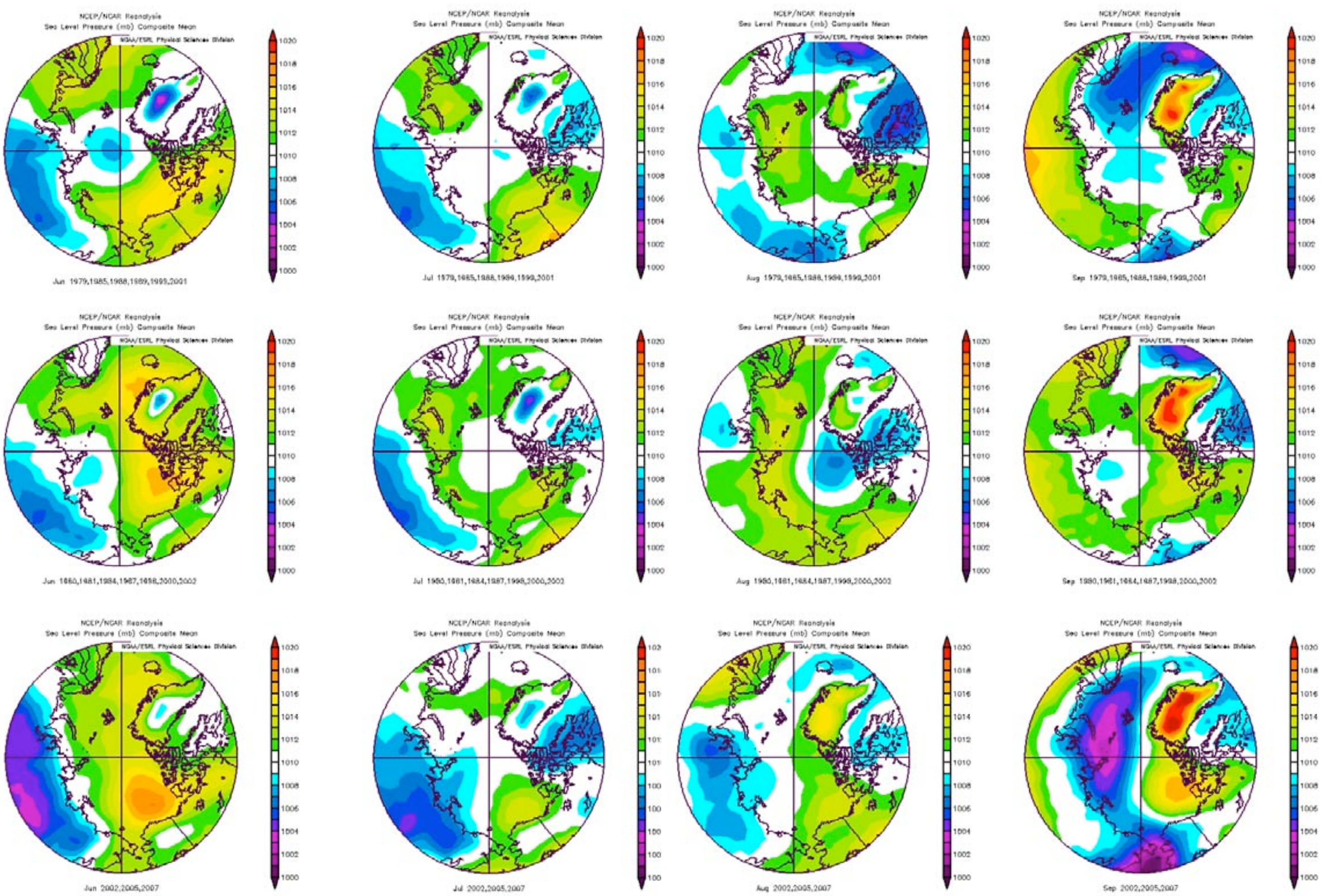


Figure 6. Composite SLP for (top row) vortex splitting events, (middle row) vortex displacement events, and (lowermost row) minimum sea ice extents for June, July, August, and September. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

September 2009 Sea Ice Outlook: July Report
By: Julienne Stroeve, Walt Meier, Mark Serreze, Ted Scambos

****No Changes from June****

Extent Projection: 4.6 million sq-km
Method: Statistical, based on ice age survivability

Rationale
The ongoing transition from a spring ice pack characterized by a high percentage of old thick ice to one with younger and thinner ice is a key driver of the strong downward trend in September ice extent. This is because a thinner spring ice pack tends to be more fractured (more leads) and requires less energy to completely melt. Dark open water areas develop earlier in the melt season than they used to. These dark areas readily absorb solar energy, warming the upper ocean and promoting even more melt.

However, as pointed out by many scientists, September ice extent in a given year is also strongly determined by summertime patterns of atmospheric circulation. As is now well known, the circulation during the summer 2007, featuring high pressure over the central Arctic Ocean and low pressure over Siberia, promoted especially strong summer melt, working in tandem with thin spring ice to yield a record low monthly September ice extent of 4.28 million sq-km. While the 2009 melt season started out more thin ice than observed in the last several decades, making it highly likely that ice extent in September will be well below average, whether or not a new record low is set depends critically on the circulation patterns that set up over the next few months.

One way to estimate the end-of-summer ice extent is to examine survival rates of ice of different ages in the Arctic. In the May 2008 blog entry at NSIDC's Arctic Sea Ice News and Analysis website (http://nsidc.org/arcticseaicenews/2008/050508.html), survival rates of different ice age classes based on ice age data from (Maslanik et al., 2007) were used to estimate the 2008 September ice extent. This method predicted a new record low would be set in September 2008 since 73% of the Arctic basin was covered by first-year ice in spring 2008, of which typically 60% melts out each summer. However, this method did not account for the fact that at more northern latitudes it is likely that the survival rates will be higher.

Using the same method but breaking up the survivability analysis into 2 degree latitude bins would have given an estimate for September 2008 of 4.77 million sq-km, which was close to the observed value of 4.67 million sq-km.

For 2009 the same method predicts an average monthly mean September ice extent of 4.57 million sq-km (see Figure). Note however, that if survival rates from the last few years are used, the 2007 record minimum would be broken in 2009. The last several years have seen persistent summer high pressure patterns, a pressure pattern that is favorable for ice loss. If this pressure pattern were to continue again in 2009, it is possible a new record low would occur given the fact that the ice is even thinner, and, on average, younger this year than in the previous two years.

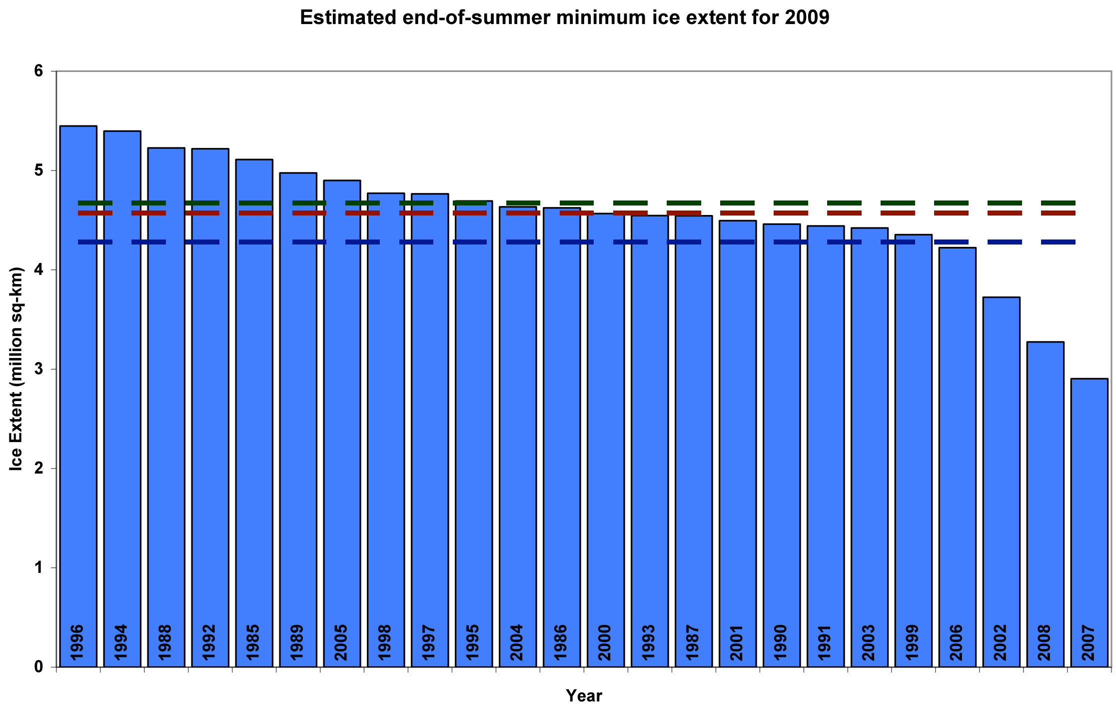


Figure 1. This bar plot shows estimates of monthly mean sea ice extent for September 2009 based on known ice survival rates derived at discrete 2 degree latitude bins. The blue dotted line indicates the record-breaking minimum extent of 2007; the green dotted line shows the minimum extent of 2008; and the red dotted line shows the mean estimate based on all years between 1983 and 2008.

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, dio:10.1029/2007/GL032043.

Sea Ice Outlook July 2009

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***) Department of Meteorology, Stockholm University, Stockholm, Sweden*

Extent projection

4.60 million km^2 based on the ensemble mean.

Objective

We have estimated the September mean sea-ice extent using an ensemble approach with a regional coupled ocean/sea-ice model and atmospheric forcing from ECMWF. The approach is similar to the method of Kauker et al. (2008) in that we based our prediction on atmospheric conditions from 20 different years and draw conclusion of the sea-ice evolution based on these realizations. Our prediction however uses a different reanalysis product, ECMWFs ERA-Interim and another advanced coupled ocean - multi-category sea-ice model. As the sea-ice and ocean conditions during winter are important factors for the predictability of the sea-ice extent during the subsequent summer, the usage of an advanced multi-category sea-ice model coupled to an high-resolution ocean model might increase the forecast skill because it has been shown earlier that with this type of sea-ice models biases in long-term hindcast simulations are significantly reduced (Vancoppenolle et al., 2009; Mårtensson et al., 2009).

Method

The Rossby Centre Ocean (RCO) model (Meier et al., 2003; Döscher et al., 2009) is a regional coupled ocean/sea-ice model, set-up over the Arctic Ocean and Northern Seas with a 0.25° resolution. The ocean model is coupled to a sea-ice component based on the multicategory sea-ice model HELMI (Happala, 2005) and forced at the surface by the fluxes of momentum, sensible and latent heat, and short- and long-wave radiation provided by an atmospheric model.

To obtain an initial state for our ensemble the RCO model was integrated forward in time starting in 1958, by first using a combination of the ERA-40 and ERA-Interim data set (only available to the end of March 2009), and then ECMWFs operational forecasts up to the end of June 2009. One of the lessons from the last years Sea Ice Outlook was that preconditioning is important. To get a good skill in the forecast, starting from the end of spring conditions, the initial state of the sea-ice model needs to be as realistic as possible. The mean sea-ice concentration during May (Figure 1) displays discrepancies between the simulated and satellite derived sea-ice extent, and also most likely there exists discrepancies between the modelled and real sea-ice thickness distributions. The latter is of course poorly known. These model errors will limit the skill of our prediction.

To account for the systematic model biases we have compared the 2007 and 2008 September total sea-ice extent results from the spin-up with satellite derived sea-ice extent and found an overestimation of about 0.7 million km^2, mainly due to sea-ice model shortcomings and uncertainties of the sea-ice thickness distribution. By doing a “test” ensemble of the summer of 2008 we have found that the model produces a bias of about 1.1 million km^2 for the ensemble mean. To account for the systematic model errors the ensemble mean bias have been subtracted from the September 2009 results.

The ensemble experiment was set-up by forcing the ocean/sea-ice model with July through September data from 20 different years (1989-2008) from the ECMWF reanalysis product ERA-Interim yielding 20 realizations of the sea-ice evolution over the period. All ensemble members started with the same initial conditions from the spin-up at the end of June 2009.

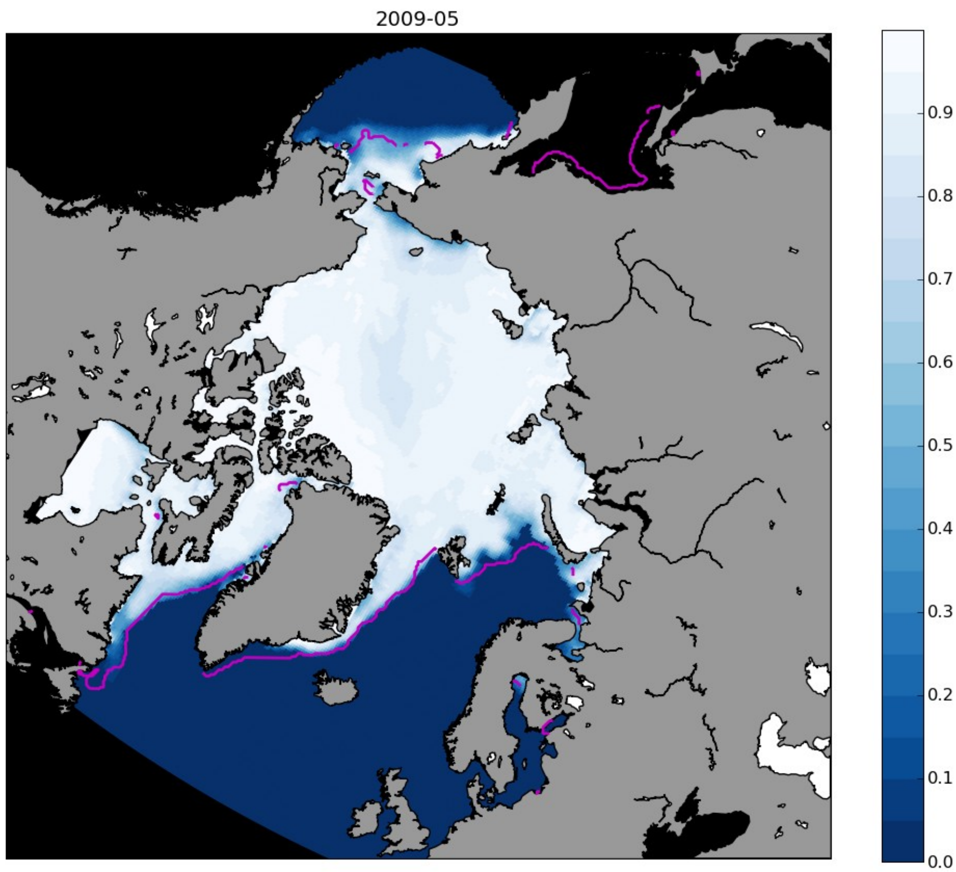

Figure 1. May 2009 mean sea-ice concentration in RCO and satellite derived sea-ice extent from www.nsidc.org (magenta line).

Ensemble results

The 20 different realizations of the total sea-ice extent for September 2009, with the bias removed, are shown in sorted order in Figure 2. The ensemble mean value is 4.60 million km^2 and the standard deviation 0.54 million km^2. The anomalous atmospheric conditions of 2007 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 28 %

2008 second lowest satellite derived (4.67 million km^2) is 55 %

2005 third satellite derived (5.57 million km^2) is 96 %.

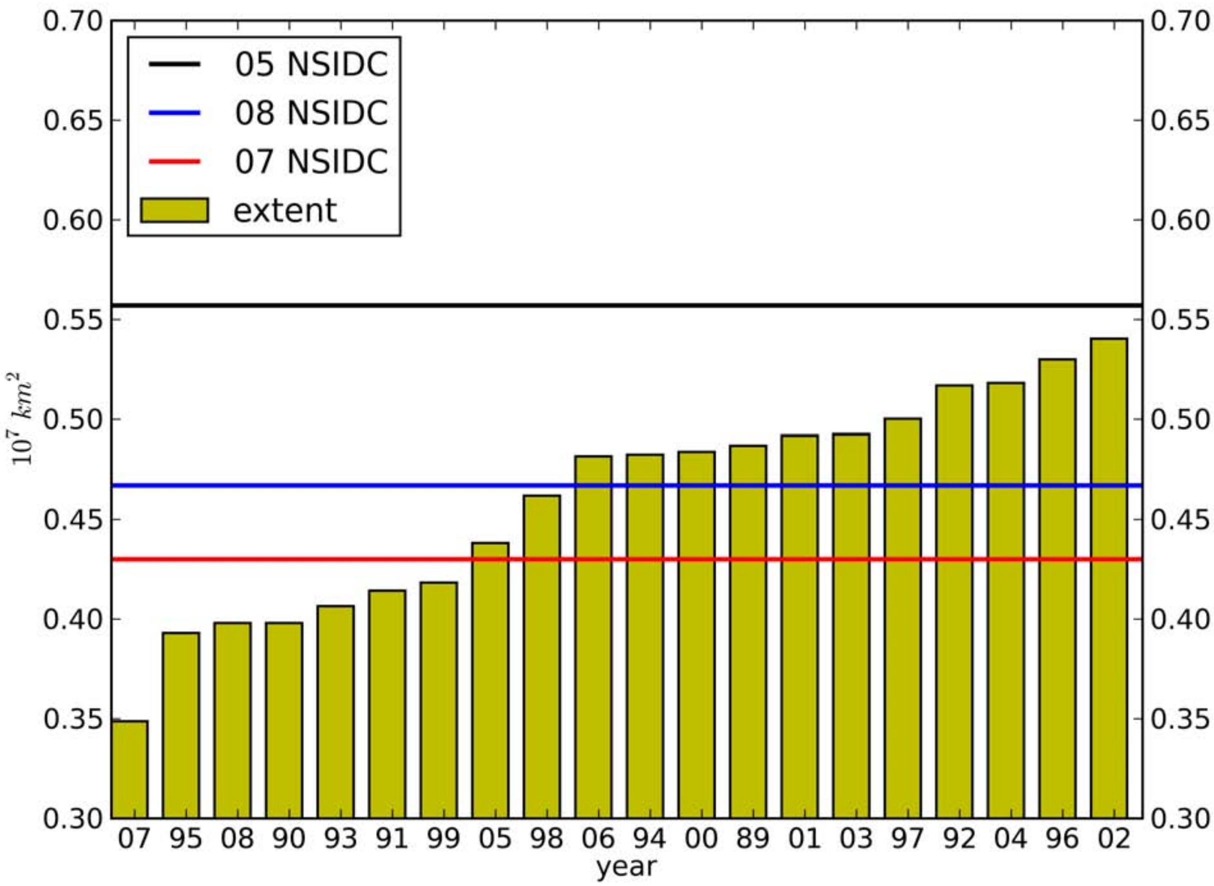

Figure 2. The 20 realizations of September 2009 mean sea-ice extent in sorted order. The horizontal lines show the minimum of 2005 (black), 2007 (red) and 2008 (blue) (data from www.nsidc.org).

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

****No Change from June****

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

Type of estimate:

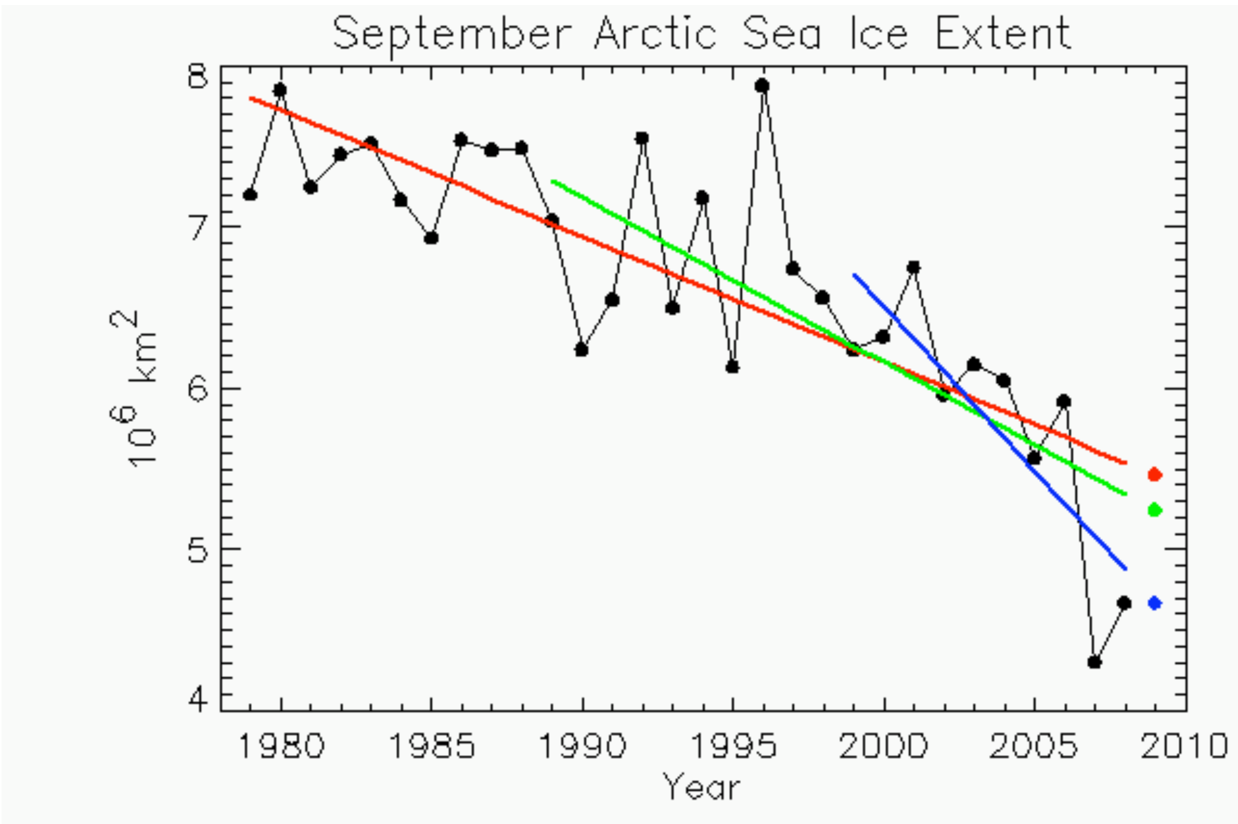

Figure 1: The red line is a linear least squares fit over the past 30 Septembers, 1979-2008, with a red dot indicating the projection for 2009. The green line is a fit over the past 20 Septembers, 1989-2008, with a green dot indicating the projection for 2009. The blue line is a fit over the past 10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

September 2009 Sea Ice Outlook: July Report
By: Jennifer Kay, Marika Holland, and David Bailey

Extent Projection
4.73 million sq. km. (stdev. 0.48, min. 3.99, max. 5.75)

Methods / Techniques
Informal inquiry of 19 climate scientists on June 1, 2009

Rationale
Our estimate should be considered an "expert opinion." Although some of the climate scientists contributing to our estimate did use statistics to inform their guess, many just went with their "gut."

This is the second year that I have assembled guesses for the September ice extent. Interest came from discussion of sea ice conditions at our lunch table. The discussion has involved both researchers intimately involved in sea ice research, and researchers who have no specific knowledge of sea ice processes, but have experience in climate research.

Discussion this year has focused on the vulnerability of the ice pack due to long-term thinning and the record-low 2007/2008 ice extent minima, the fast pace of the ice loss in May 2009, and on the importance of the unpredictable summer weather conditions.

For reference, our 2008 mean guess (N=15) was 4.67 million sq km. Thus, our 2008 estimate was within the observational uncertainty of the observed 2008 September ice extent.

Although our methods are very different than those used for other groups participating in the sea ice outlook, we think that they provide an interesting contrast.

Sea Ice Outlook - June 2009

Gregor Halfmann, Lars Kaleschke
KlimaCampus Hamburg
University of Hamburg
Contact: lars.kaleschke@zmaw.de, Tel. ++49 40 42838 6518

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

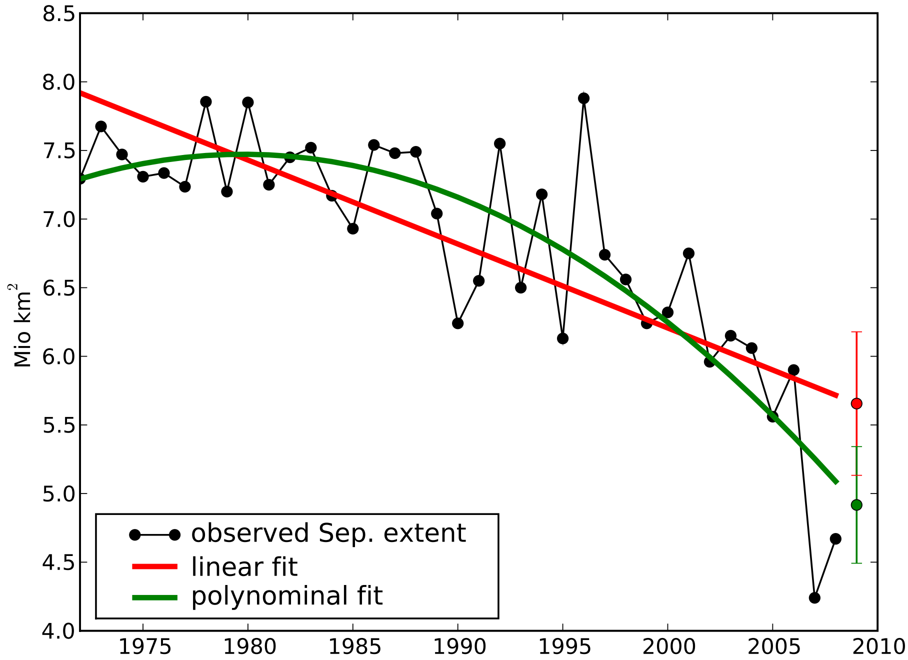

Figure 1: extrapolation of september timeseries, correlation coefficients $r_{lin} = 0.78$ and $r_{poly} = 0.86$

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.

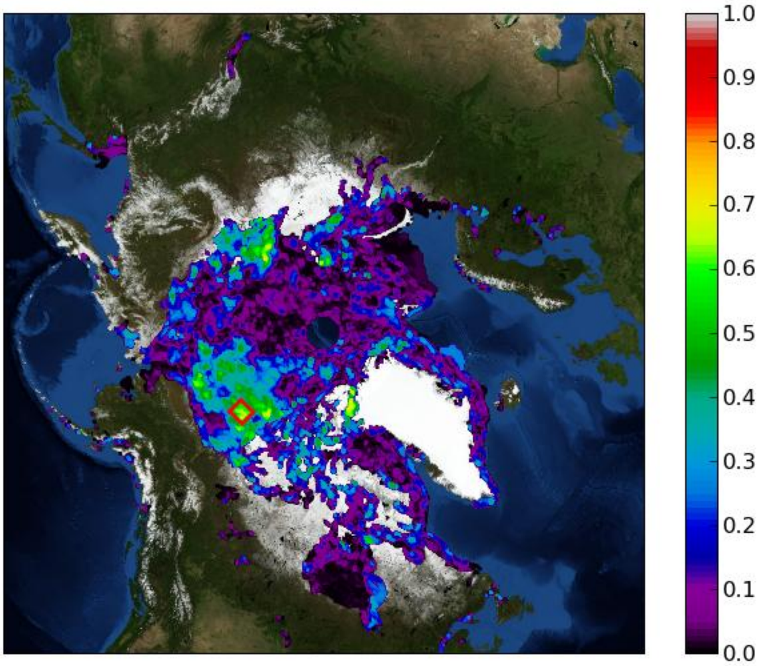

Figure 2: Correlation (r^2) of June sea ice concentration and September extent; significance levels are $p_{95} = 0.24, p_{99} = 0.54$

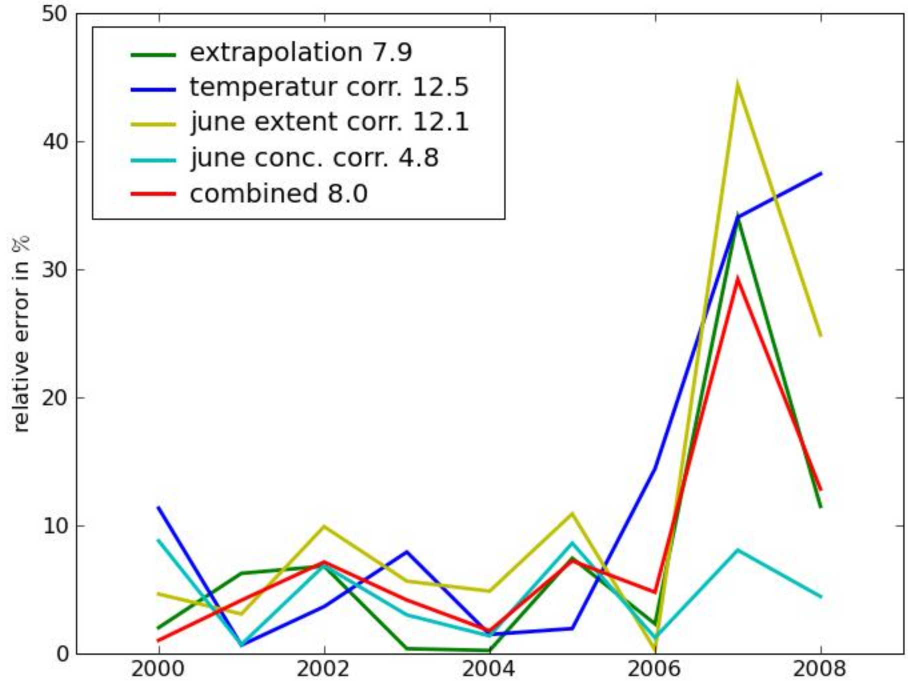

Figure 3: Prediction error hindcast experiment. The methods described in the text are used to predict the September minimum for the years 2000 to 2008. The relative deviation of the prediction to the actual sea ice extent are shown. The averaged errors in % are given within the legend.

September 2009 Sea Ice Outlook: July Report
By: An T. Nguyen, Ronald Kwok, Dimitris Menemenlis
JPL/Caltech

Extent Projection
Our guess of the September monthly mean Arctic sea-ice extent based on June atmospheric conditions is 5.0 ± 0.5 millions km2.

****No Change in Methodology from June****

Methods / Techniques
The 2009 sea-ice extent is estimated using a Pan-Arctic configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) and atmospheric surface boundary conditions from the Japanese 25-year Reanalysis Project (JRA-25) [Onogi et al., 2007]. The model has 18km horizontal grid spacing and 50 vertical levels. The K-Profile Parameterization (KPP) scheme is used for vertical mixing [Large et al., 1994]. Lateral boundary conditions are monthly and are taken from the Estimating the Circulation and Climate of the Ocean, Phase 2 (ECCO2) global optimized solution (http://ecco2.jpl.nasa.gov, [Menemenlis et al., 2008]). Initial hydrographic conditions are from the World Ocean Atlas 2005 [Antonov et al., 2006; Locarnini et al., 2006] starting in January 1992. Initial sea-ice condition is from Zhang and Rothrock [2003]. No climate restoring is used. The forward integration period is Jan 1992 to Feb 2009. On March 1, 2009, we re-initialize sea-ice thickness with preliminary thickness from ICESat [Kwok et al., in press] and then integrate the model forward until the end of the available JRA25 reanalysis (May 2009). For summer 2009, predictions are performed using JRA25 surface atmospheric conditions from 2006 to 2008.

Rationale
The 2006-2008 forcing period covers the extreme 2007 summer condition with anomalously clear sky and wind patterns, which resulted in a large retreat of the Arctic sea-ice cover [Drobot et al., 2008]. Thus, we use atmospheric conditions from the last three years (2006-2008) to estimate upper/lower bounds of the Arctic sea-ice extent. Using preliminary mid-February-to-mid-March ICESat-derived thickness as initial sea-ice thickness conditions, our solutions for September monthly mean sea ice extent are either 4.4 millions km2 for 2007 atmospheric conditions or 5.5 millions km2 for 2006 and 2008 atmospheric conditions. Our first guess of the monthly mean sea-ice extent for September of 2009 is 4.9 ± 0.5 °— 106km2, that is, the median of these experiments and their spread.

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September 2009 Sea Ice Outlook: July Report
By: Masahiro Hori, Kazuhiro Naoki, Keiji Imaoka
Japan Aerospace Exploration Agency (JAXA)

Extent Projection
5 million square kilometers

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

Rationale
Sea-Ice albedo was estimated from MODIS images. 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.

Overall albedo of the arctic sea-ice in June is still high (similar level to that in 2005) compared with that in 2007. Thus, shortwave forcing in June seems not to be strong enough to melt sea-ice as seen in 2007 at this moment. The AMSR-E derived sea-ice extent is still at an average level of recent 6 years (2003-2008).
More at: http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm.

September 2009 Sea Ice Outlook: July Report
By: James Morison and Norbert Untersteiner, International Institute of Advanced Cryospheric Sciences

Outlook: 5.2 million square kilometers

Considering the past years' extents, the extent observed so far this year, and current in situ data (primarily from the NPEO web cam and weather station) we submit an outlook of 5.2 million square kilometers. Being optimistic and slightly contrarian, we see several positive signs for extent compared to the last couple of years:
1) The melt at the NPEO seems very late; there is still plenty of snow and zero melt ponds;
2) Temperatures were cold during the spring deployment and there wasn't too much snow, implying good growth persisted longer than usual;
3) The extent in the spring was pretty good;
4) There was more second year ice this last year than in the previous year; and
5) Polyakov has reported cooler ocean conditions.

Our estimate is based on the same improvement from 2008 to 2009 as occurred going from 2007 to 2008 plus 200,000 sq km based on gut feeling. Note: We purposely didn't look at last month's estimates to avoid biasing our estimate.