2009 Sea Ice Outlook:
Pan-Arctic Summary Report

Community Contributions

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Comments on the 2009 Minimum versus the NIC Seasonal Outlook

Todd E. Arbetter, UCAR Visiting Scientist, National Ice Center (NIC), Suitland, Maryland

NSIDC minimum value: 5.36 million km^2

NIC minimum value: 5.00 million km^2

NIC outlook values:

Outlook	Conservative	Moderate
June	5.224 million km^2	4.763 million km^2
July	5.261 million km^2	4.528 million km^2
August	4.773 million km^2	4.151 million km^2

The NIC Conservative Outlook values for June and July were close to the NSIDC reported minimum of 5.36 million km^2, while the August value fell away. Since the outlook was explicitly linked to the amount of MYI in the basin, the drop in the August value is not surprising; all ice types are decreased in that month. Nevertheless, the results this year are encouraging. Given a relatively simple method, we were able to come within 2.5% of the NSIDC value.

The accuracy of the outlook values is promising. However, it should be noted that the method by which NIC creates its operational sea ice charts (on which the outlooks are based) is different than that by which NSIDC creates their Sea Ice Index (the value used as "truth" for the ARCUS Sea Ice Outlook). NSIDC ice extent, based solely on SSM/I retrievals, is calculated as the area within the 15% sea ice concentration contour as measured on a 25 km^2 grid. But SSM/I has difficulty measuring low ice concentrations. NIC uses a variety of instruments including SAR, MODIS, SSM/I, and AMSR-E; an ice analyst synthesizes this information to create an ice chart. The extent is obtained by measuring the sections of the chart where the ice concentration is greater than 10%.

Other research facilities and operational centers may have different techniques for obtaining a minimum value. Within the Outlook project, there may be differences in how each group obtains their area (e.g., model grid cells of varying resolution, sea ice charts, satellite observations); each of these could produce a different value for ice extent than the two methods above. When considering the success and accuracy of a given method, it is important to take into account whether and how the area of ice extent value is obtained and if this value is significantly different than the "true" (NSIDC) value.

The perennial pack ice in the southern Beaufort Sea was not as it appeared in the summer of 2009.

David G. Barber[1], Ryan Galley[1], Matthew G. Asplin[1], Roger De Abreu[4], Kerri-Ann Warner[1], Monika Pućko[1,2], Mukesh Gupta[1], Simon Prinsenberg[3], Stéphane Julien[5]

[1]Centre for Earth Observation Science
Faculty of Environment, Earth and Resources
University of Manitoba
Winnipeg, MB

[2]Freshwater Institute
Fisheries and Oceans, Canada
Winnipeg, MB

[3]Bedford Institute of Oceanography
Fisheries and Oceans, Canada
Halifax, NS

[4]Canadian Ice Service
Environment Canada
Ottawa, ONT

[5]Canadian Coast Guard
Laurentian Region
Quebec City, PQ

In situ observations of the atmosphere-sea ice-ocean system in the southeastern Beaufort Sea were made from the Canadian Research Icebreaker (NGCC) *Amundsen* deployed for the ArcticNet/IPY–GeoTraces project between 27 August and 12 September 2009. The cruise track is shown in Figure 1. Canadian Ice Service (CIS) digital ice charts were employed for real-time planning of station locations and sailing routes during the cruise. In situ observations from CCGS *Amundsen* indicate that the MY sea ice pack in the southern Beaufort Sea was not as ubiquitous as it appeared within satellite remote sensing data products (Figure 1) in early September 2009. A large sector of what was remotely sensed to be MY sea ice at 7 to 9+tenths ice cover, consisting primarily of MY ice floes, was in fact a surface of heavily decayed ice composed of some small MY floes (1 tenth) interspersed in a cover dominated by heavily decayed FY floes (1 tenths) and overlain by new sea ice in areas of negative freeboard and in open water between floes. In some areas (e.g., stations L1 and MYI: Figure 1) the ocean surface was dominated in some areas by MY sea ice that was much thicker than the heavily decayed FY sea ice previously discussed.

In situ measurements of active microwave scattering (to a C-band polarimetric scatterometer) and to passive microwave radiometers (37 and 89 GHz) showed that the rotten ice and the late season multiyear sea ice had overlapping signatures. This case of mistaken identity is physically explained by the factors which contribute to the return to Radarsat-1 from the two surfaces; both ice regimes had similar temperature and salinity profiles in the near-surface volume, both ice types existed with a similar amount of open water between and within the floes, and finally both ice regimes were overlain by similar, recently formed new sea ice in areas of negative freeboard and in open water areas. The fact that these two very different ice regimes could not be differentiated using Radarsat-1 data, *in situ* C-band scatterometer or microwave radiometer measurements, has significant implications for climate studies and for marine vessel navigation in the Canada Basin. The results also suggest that operational agencies (such as the CIS) should consider making ice decay a variable in their ice charts. Our results are also consistent with ice age estimates (Fowler and Maslanik, http://nsidc.org/news/press/20091005_minimumpr.html) that show the amount of multiyear sea ice in the northern hemisphere was the lowest on record in 2009 suggesting that multiyear sea ice continues to diminish rapidly in the Southern Beaufort Sea. This work is presented in more detail in Barber et al. 2009.

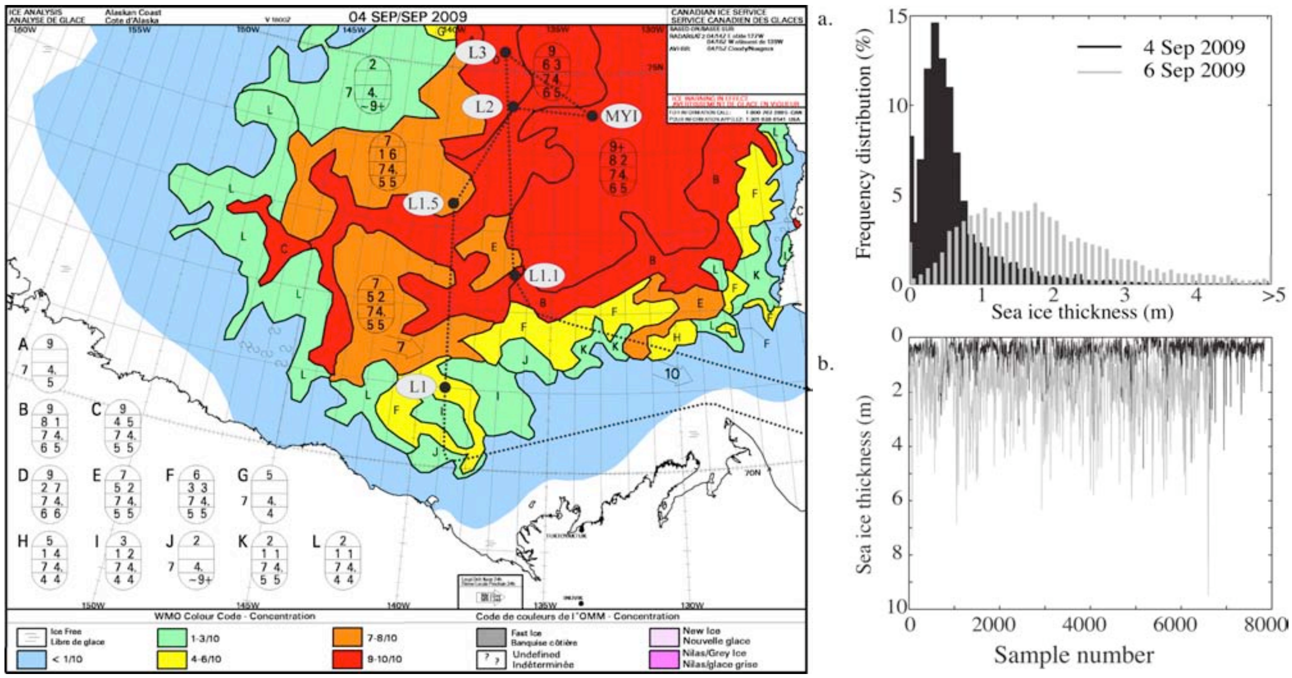
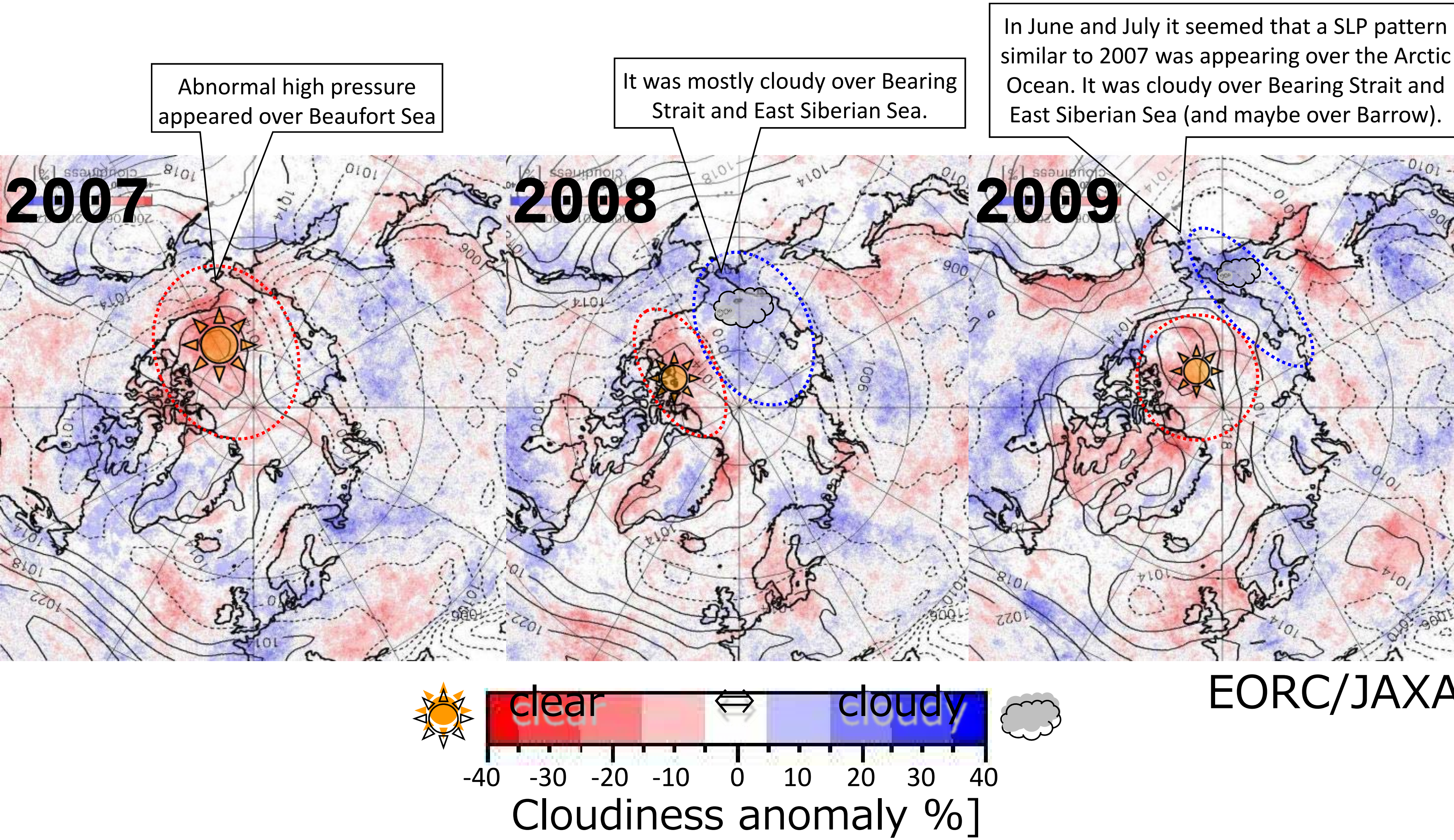


Figure 1. Canadian Ice service (CIS) icechart for Sept 4, 2009. Amundsen transect went from L1 to L1.5 then to L2. This entire transect was in rotten ice (very thin first-year and heavily decayed MY ice forms; see text). We then headed eastwards to MYI (to seek out Multiyear sea ice). At the MYI station we found what was the more expected; thick MY forms of sea ice. EM induction estimates of ice thickness for station MYI (grey) and the rotten ice at L2 (black) are depicted in a histogram (a) and a linear profile of thickness (b).

Citation:

Barber, D. G., M.Asplin, R.Galley, K. Warner, M.Pucko, M.Gupta, S. Prinsenberg, R. De Abreu[3] , Captain S.Julien. The summer perennial pack ice in the southern Beaufort Sea is not as it appears. Geophysical Research Letters. In review (Oct'09).

Cloudiness anomaly in June-July (2-month average)



EORC/JAXA

Anomaly from 10-year average (2000-2009)

MODIS

Contour with solid and broken lines are Sea Level Pressure from NCEP/NCAR reanalysis data

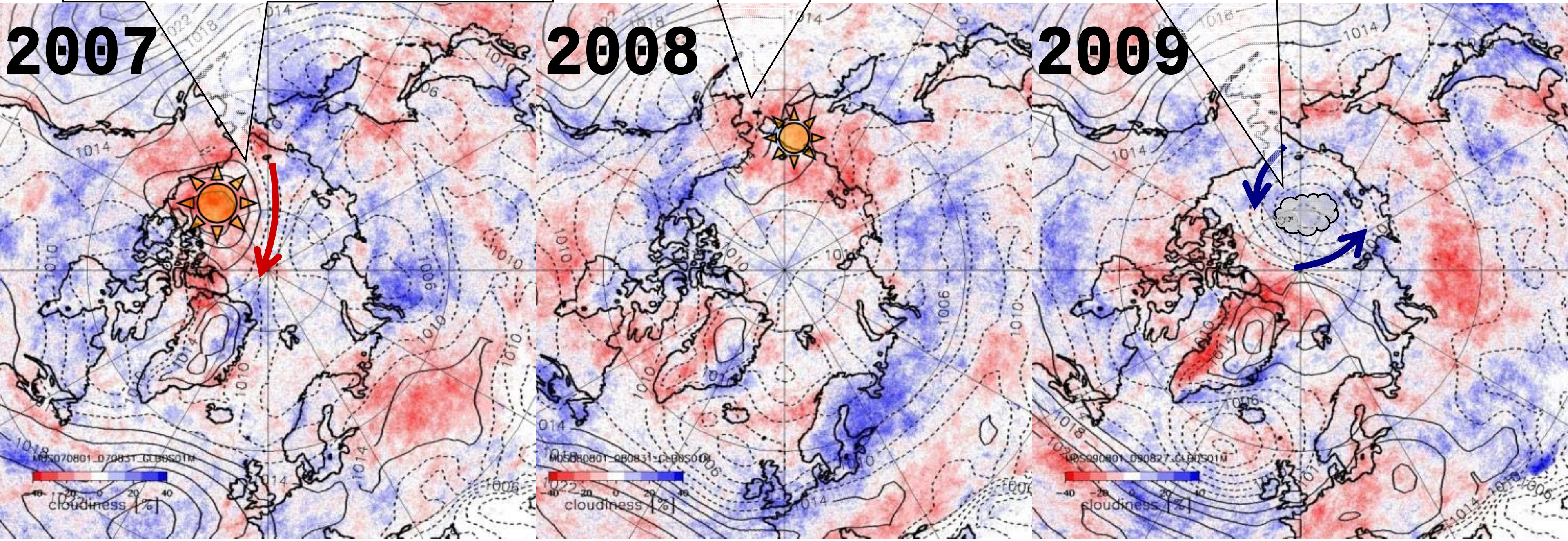
Hori et al.

Cloudiness anomaly in August (1-month average)

The abnormal high pressure pattern persisted in August. After sea ice concentration began to reduce in the Arctic Ocean, sea ice could be forced to move by strong southerly wind.

Sunny weather appeared over Bearing Strait and East Siberian Sea. Wind speed seem to be calm over the Arctic Ocean in this season.

Atmospheric pressure pattern had drastically changed in August. Low pressure persisted over the Arctic Ocean and it was mostly cloudy there. Wind pattern seems unfavorable for ice reduction.



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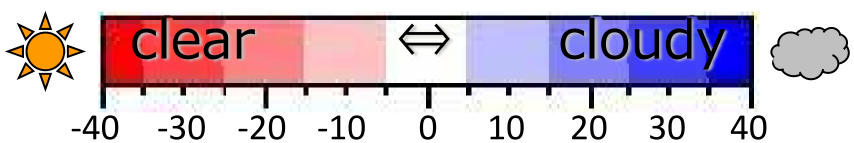


Cloudiness anomaly %]

Anomaly from 10-year average (2000-2009)

MODIS

Hori et al.

Contour with solid and broken lines are Sea Level Pressure from NCEP/NCAR reanalysis data

2009 Sea Ice Outlook Retrospective

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

October 15, 2009

Our first guess was 4.92 ± 0.43 Mio. km^2 and was not updated through the season. The actual September extent lies just at the upper range of the uncertainty. It should be mentioned that 2009 lies below the linear extrapolation of the decreasing long term trend. It is difficult to judge if a linear or a quadratic model better fits the observed trend (Fig. 1).

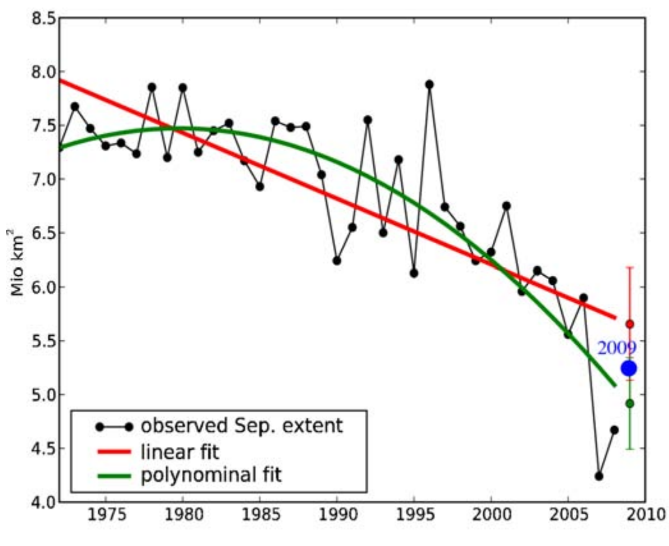


Figure 1: Outlook based on a quadratic and linear extrapolation of the measured September sea ice extent timeseries.

Retrospective Summary Comments SIO 2009 – AWI/FastOpt/OASys

F. Kauker[a,b], R. Gerdes[a], M. Karcher[a,b]

T. Kaminski[c], R. Giering[c], M. Vossbeck[c]

October 9th, 2009

[a] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[b] O.A.Sys - Ocean Atmosphere Systems GmbH, Hamburg, Germany
[c] FastOpt GmbH, Hamburg, Germany

Please provide comments on the results of this year's outlook - all estimates this year came in below the September monthly average of 5.36 million square kilometers. Our projected error from last year was ~0.5 million square kilometers. Is this within the error tolerance? Or, was there something systematic or physical that contributed to lower projections or a higher observed value this year?

We think that the observed extent is within the error tolerance. Although we think that there is something systematic (or physical) which we explain in the following:

Our projections for the June/July/August outlook were 4.60/4.92/5.02 million square kilometers (Ensemble I - without data assimilation). The projections increase from the June to the August outlook.

Our technique assumes that the state of the sea ice-ocean system in spring/early summer determines at least partly the extent in September ((almost) all others methods assume that as well). We use no predictions of the summer atmosphere but assume that the atmosphere will stay most likely close to the atmosphere in the years 1989 to 2008. This gives us a mean value and a range of possible values. Even for the August outlook the range was pretty large. The atmosphere of 1996 gives a value of about 5.9 million square kilometers and the 2007 atmosphere a value of about 4.1 million square kilometer.

We interpret our increasing projections as follows: During the setup of our June projection (22nd of May) the sea ice thickness was relatively low (almost no multi-year ice). This leads to a mean projection of 4.60 million square kilometers. The July outlook was set up on July 2nd. The mean projection was considerably larger than a month before (4.92 million square kilometers). In our setting that means that the June 2009 atmosphere was less prone to reduce the sea ice (thickness) than the mean of the last 20 years. We set up the August outlook on July 11th. The August projection is again (slightly) larger than the July projection although the August outlook was initialized only 9 days after the July outlook. This suggests that the first days in July were also less prone to reduce the sea ice.

We are also interested in your thoughts and ideas on the following:
1. Factors driving the 2009 minimum.

We did no dedicated analysis.

2. Additional data or data products that would be useful for improving outlooks in the future, including any critical gaps in field observations.

Definitely ice thickness and snow thickness data, but we have not applied any quantitative analysis (network design/Observation System Simulation Experiment). See item 4.

3. Implications, based on this year's results, for the future state of arctic sea ice.

Looking at the September mean extent of 2007, 2008, and 2009, one gets the impression that the Arctic sea ice recovers slowly from the 2007 extreme event (see Fig1, http://www.arcus.org/search/seaiceoutlook/2008_outlook/downloads/monthly-reports/aug-sept/1979-2008-minimum.png). 2009 is pretty close to 2005 and pretty close to the decadal trend as well. This might imply that 2007 was really a singular event and that the ice cover in 2008 and 2009 returned to 'normal' values. However, we believe that the likelihood of '2007-events' is much higher now than a decade before and this is connected to the gradually reduced sea ice thickness.

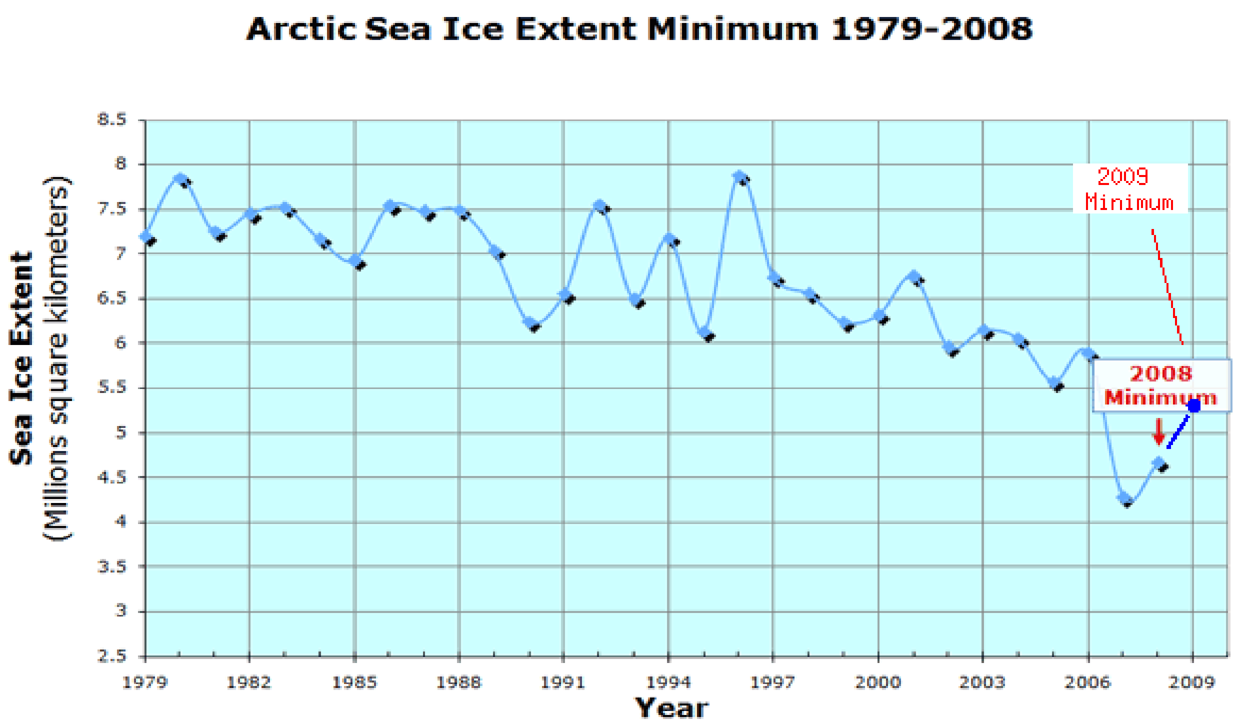


Fig 1: From http://www.arcus.org/search/seaiceoutlook/2008_outlook/downloads/monthly-reports/aug-sept/1979-2008-minimum.png. 2009 minimum added.

4. Any other "lessons learned" - including the usefulness of the Outlook as a community synthesis tool, suggestions for future outlook activities, or any other topic you want to comment on.

We used the outlook for a first test of our variational data assimilation system NAOSIMDAS under 'next -to-operational' conditions, even though the system is still under construction.

For the projections which we called Ensemble I we used the sea ice-ocean model NAOSIM without any data assimilation. We know that NAOSIM tends to underestimate the September ice extent especially north of the Laptev Sea. We corrected for this bias by subtracting a constant.

The second set of projections (Ensemble II) uses an initial state of the sea ice-ocean system which has been optimzed with NAOSIMDAS. We hoped that this would avoid the bias in Ensemble I. The projections of Ensemble II for the June/July/August outlook were 4.30/4.42/4.43 million square kilometers. Compared to Ensemble I these values are considerably lower. In other words we failed even for the August outlook.

It was not until the August outlook that we noticed a problem in our setup of NAOSIMDAS. The sea ice-ocean model code used in NAOSIMDAS is not identical to the original code of NAOSIM. The latter has many code fragments which are not differentiable. For instance, to ensure that the ice concentration `a` is within the interval [0,1], non differentiable statements like `a=max(a,0)` and `a=min(a,1)` are used. Another more physical example is the use of two albedos for melting and freezing conditions, respectively. Depending on the air temperature an if-statement is used:

```
if (tair < 0.) then
  alb=alb_freeze
else
  alb=alb_melt
endif
```

This statement is not differentiable at `tair=0`. The sea ice-ocean model code used in NAOSIMDAS has been carefully analyzed for such code fragments and the code have been modified. Analytical functions like `atan` are employed to smooth these code fragments. In the example, this yields a small range around zero degree Celsius were a mixture of the freezing and the melting albedo is used. This range reflects the temperature variability within a model grid box. The value reflecting this variability is determined by comparing model runs with the 'smoothed' and the 'not smoothed' code. If the differences get too large the value is reduced.

Unfortunately it turns out, that these tests have been performed in summer and winter, respectively, but not in the seasons with largest melting and freezing rates. It was after delivering the August outlook, that we recognized large differences between the smoothed and not smoothed codes during these periods. The problem was easily resolved by decreasing one uncertainty parameter.

We re-ran the August outlook with the corrected NAOSIMDAS. We performed the optimization from May 1st to July 31th. Then we ran the model until July 11th and started the outlook. The corrected Ensemble II August value is 4.73 which is much closer to the corresponding Ensemble I values of 5.02 million square kilometers. NAOSIMDAS accomplishes this by perturbing the initial conditions at April 1st (start of assimilation window) (Fig. 2) and the surface boundary conditions in April to June (not shown). The largest perturbations are applied north of the Laptev Sea. Here the initial ice thickness is increased by up to 20 cm and the initial snow thickness is increased by about the same amount.

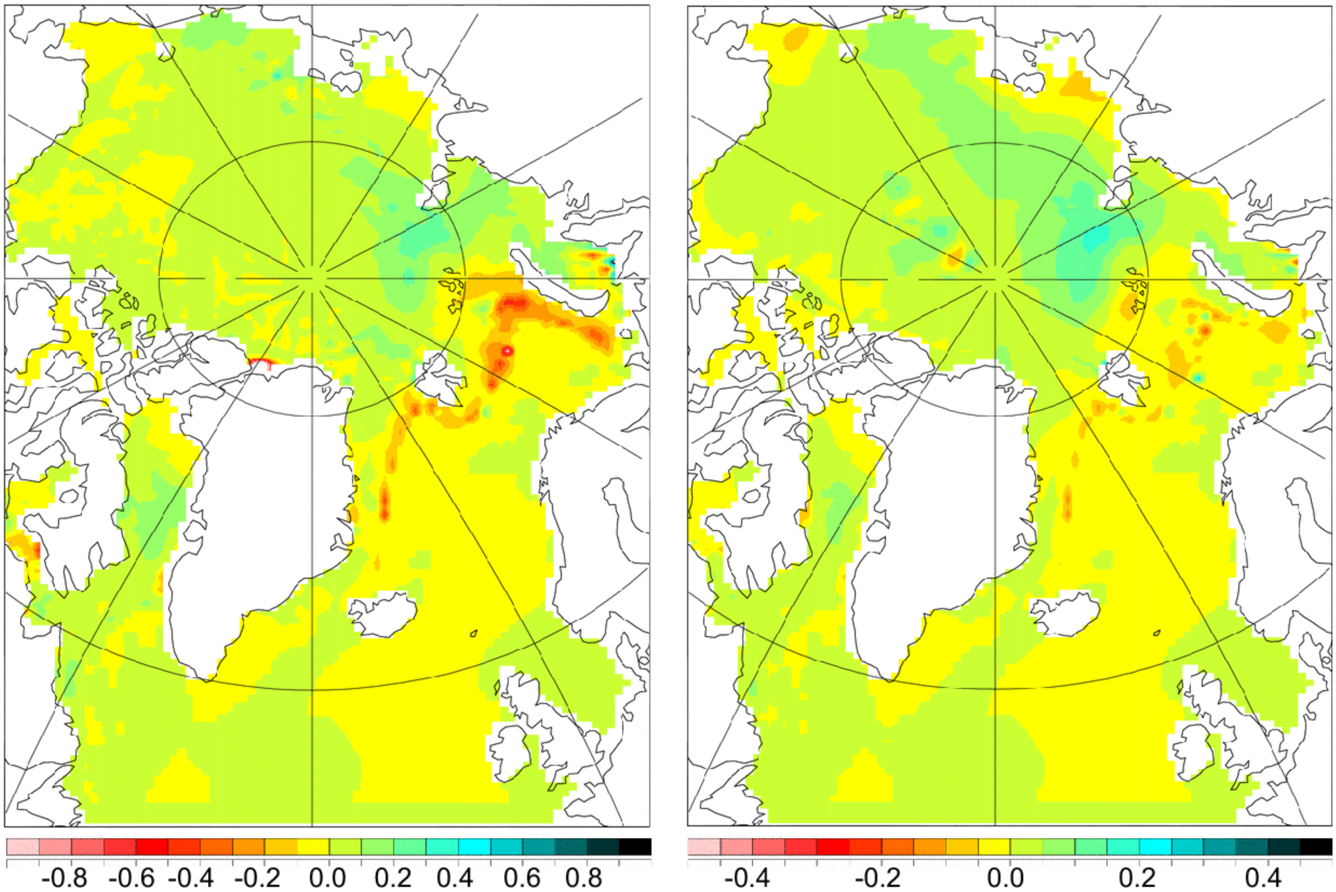


Fig 2: The perturbation applied on the initial ice thickness [m] (left) and the initial snow thickness [m] (right) at the beginning of the assimilation window (April 1 2009).

Fig. 3 shows the July 2009 mean ice thickness with and without data assimilation. North of the Laptev and Siberian Seas considerably more ice volume is visible in case of data assimilation. In the Beaufort Sea the data assimilation reduces ice volume. In September the extra ice volume north of the Laptev and Siberian Seas is responsible for the increased projected ice extent in September.

Note that we do not assimilate ice thickness observation north of the Laptev and Siberian Seas. The assimilation procedure increases the ice thickness there because the 'free' sea ice-ocean model underestimates the ice concentration with the start of the melting season in these areas. NAOSIMDAS corrects this by increasing the initial ice thickness and snow thickness (see Fig. 2) and by perturbation the surface boundary conditions (mainly the wind stress, not shown). The resulting ice thickness in July (Fig. 3) is now more consistent with the observed sea ice concentration and the hydrographic observations. This clearly demonstrates the strength of a variational data assimilation system.

Although NAOSIMDAS in the presented setup is able to produce more consistent sea ice thickness fields it would still be desirable to have ice thickness and snow thickness observations north of the Laptev and East Siberian Seas, or even better, Arctic wide. We hope that we have these data (or at least freeboard data) available for next year's outlook.

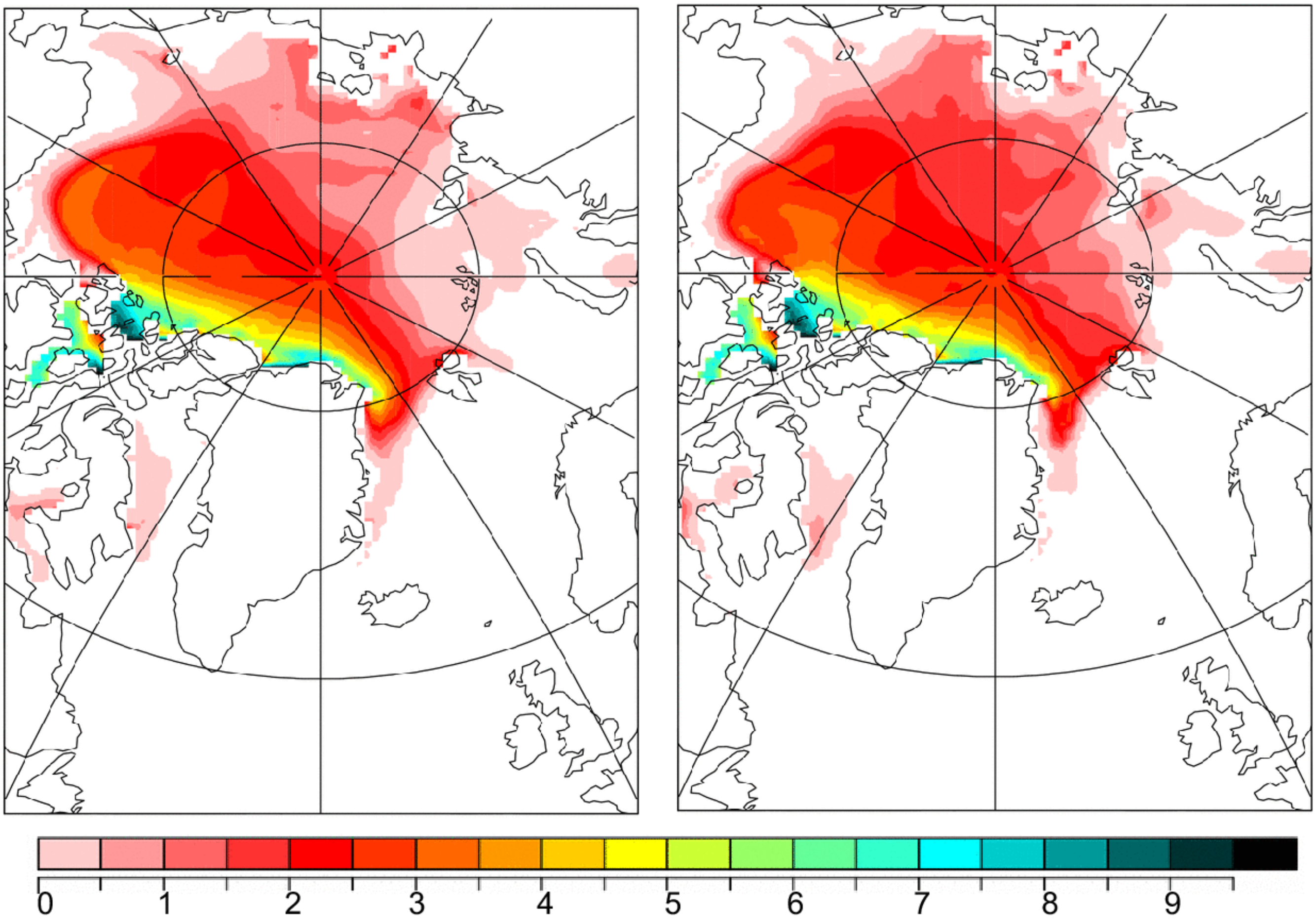


Fig 3: The July mean ice thickness [m] without (left) and with (right) data assimilation.

Recap of Predictions of September 2009 Arctic Sea Ice Extent

R. Lindsay
Polar Science Center, Applied Physics Lab
University of Washington

Our method uses estimates of ice thickness from a coupled ice-ocean model as predictors for a statistical forecast of the Sea Ice Index mean ice extent in September. Fields of ice thickness (H), ice concentration (IC), area with less than 0.40 m thick ice (G0.4m), and area with less than 1.00 m thick ice (G1.0m) are the predictors considered in this forecast. The method is described in Lindsay et al (2008a). The model fields are collapsed to scalar time series by weighting each field with its correlation to the September ice extent (Drobot, 2006). A statistical model is then fit for the years 1987–2008. The performance of each predictor at each lead time from February through August is shown in Figure 1.

In retrospect the mean thickness H was the best predictor from almost all months, particularly early in the season, but the error standard deviation of the prediction equation using H in past years was larger than that for the G1.0m predictor. Unlike last year, the G1.0m predictor was the best every month in terms of the minimum prediction error. This variable measures the fractional area of both open water and thin ice less than 1.0 m thick. The region with the greatest influence in determining the value of this variable, that is where the correlation with the September ice extent is high and where there is a significant anomaly in the G1.0m parameter is in the Beaufort Sea. This region had both high values of the G1.0m parameter and high correlations for it with the September ice extent. As shown in Figure 1, the observed September mean ice extent, 5.36 million sq km, was within the error bars of the predictions except for the short lead times, July and August.

To improve predictions using a statistical approach such as the one we used would require a longer and more accurate record of the seasonal changes in the ice thickness distribution. Unfortunately that is only obtainable through models. New observations can't help much except for driving improvements in the models because they can't give a consistent record of the past behavior of the system. Perhaps a more problematic issue is that the statistical relationships between elements of the system are changing rapidly. Until a new stable regime is established and we can get an adequate number of sample years of this new regime, statistical methods of prediction will be limited in their accuracy. With nonstationary statistics the standard error of the fit over past years is not a good measure of the uncertainty in the prediction.

References

Drobot, S. D., J. A. Maslanik, and C. F. Fowler (2006), A long-range forecast of Arctic summer sea-ice minimum extent, *Geophys. Res. Lett.*, 33, L10501, doi:10.1029/2006GL026216

Lindsay, R. W., J. Zhang, A. J. Schweiger, and M. A. Steele, 2008a: Seasonal predictions of ice extent in the Arctic Ocean, *J. Geophys. Res*., 113, C02023, doi:10.1029/2007JC004259.

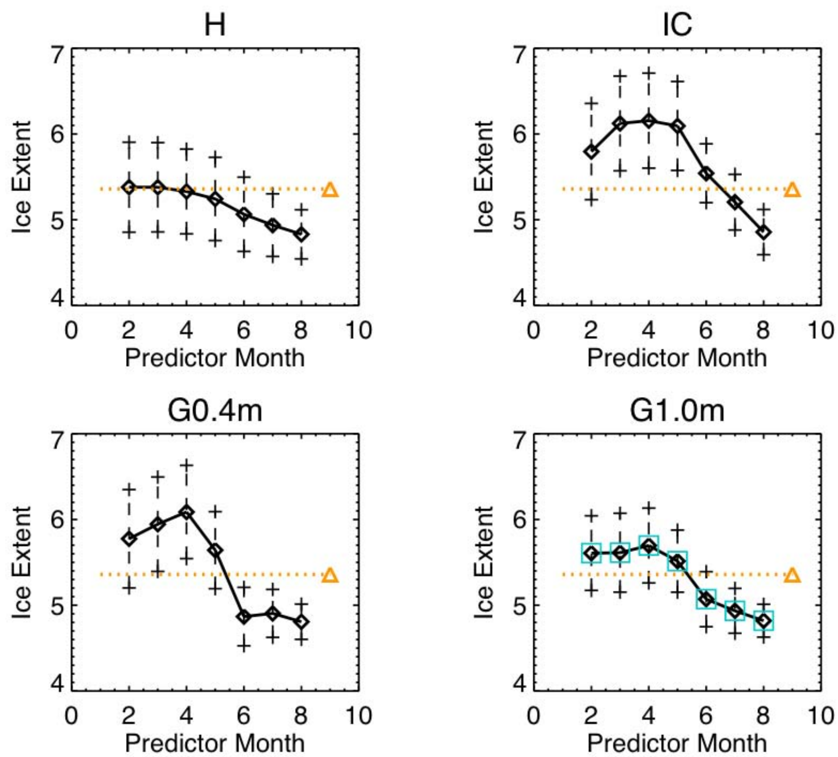


Figure 1. The performance of each predictor in 2009 in predicting the September minimum ice extent (in million sq km) using data through the end of each predictor month. The orange triangle and dotted line is the observed mean September ice extent (5.35 million sq km) from the NSIDC Sea Ice Index web site.

The black lines show the prediction based on each of the four variables for each predictor month back to February. The dashed lines are the prediction uncertainties…the error standard deviations of the linear regression fit. The blue squares in the G1.0m plot show that this variable of the four had the minimum prediction uncertainty in each month and hence was he basis of the value chosen for the prediction at the end of each month.

Sea ice outlook 2009 overview: Stratospheric dynamics and sea ice extent

J.V. Lukovich and D.G. Barber
Centre for Earth Observation Science (CEOS)
University of Manitoba

The results from an investigation of stratospheric circulation in winter and spring, and comparison of summertime surface winds and SLP with vortex splitting and minima in sea ice extent composites suggested that the September, 2009 ice extent would be comparable to or less than the September ice extent minimum in 2008, based on dynamic considerations. It was shown that springtime stratospheric circulation patterns were not conducive to a record minimum in ice extent in 2009. In particular, the absence of a distinctive transition between cyclonic and anticyclonic stratospheric circulation over the Arctic Ocean associated with sea ice minimum composites in spring of 2009 indicated that dynamical contributions would not accelerate ice loss or the decline in sea ice extent in September, 2009.

Differences between summer surface winds and SLP and vortex splitting and sea ice extent composites provided further evidence of dynamic contributions to the third record minimum ice extent observed in September, 2009. Despite the existence of a strengthened SLP to the north of the Canadian Archipelago and Greenland and increased convergence in these regions, comparison of SLP in June, 2009 and minimum sea ice extent composites highlighted 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). Similar results were found for July. Further examination of stratospheric and surface dynamical phenomena throughout the annual cycle provides one instrument with which to understand preconditioning events and feedback mechanisms responsible for changes in summertime ice extent in the Arctic.

Explanation of the Morison and Untersteiner Estimate of 2009 Summer Ice Extent

Our forecast of the September arctic sea ice extent was mainly qualitative argument guided by several principles, observations, intuition, and guesswork:

1.Complex systems are capable of flipping off the deep end, but they prefer not to.

2. After the extreme 2007 minimum, the ice cover has shown to be capable of a slight recovery, despite the anomalous heat storage in the ocean at the end of summer.

3. The ice export through Fram Strait has shown no significant trend during the past 30 years (Kwok, Spreen et al., and others).

Thus, the loss of ice during the past decade should be dominated by melting within the Arctic Basin. [This guided Norbert's thinking. Jamie feels that the short-term surges in ice export (e.g., summer 2005 and 2007) can inordinately affect minimum ice concentration, and worked on the estimate under the assumption of no pathological ice drift during the summer of 2009.]

4. Given item 3, above, the energy for causing a negative ice balance must come from radiation, ocean heat flux, or some anomalous distribution of the seasonal snow fall, for instance, more autumn snow to slow down accretion and provide more meltwater and melt ponds in spring. Sporadic snow measurements by NPEO did not indicate increased snow thickness.

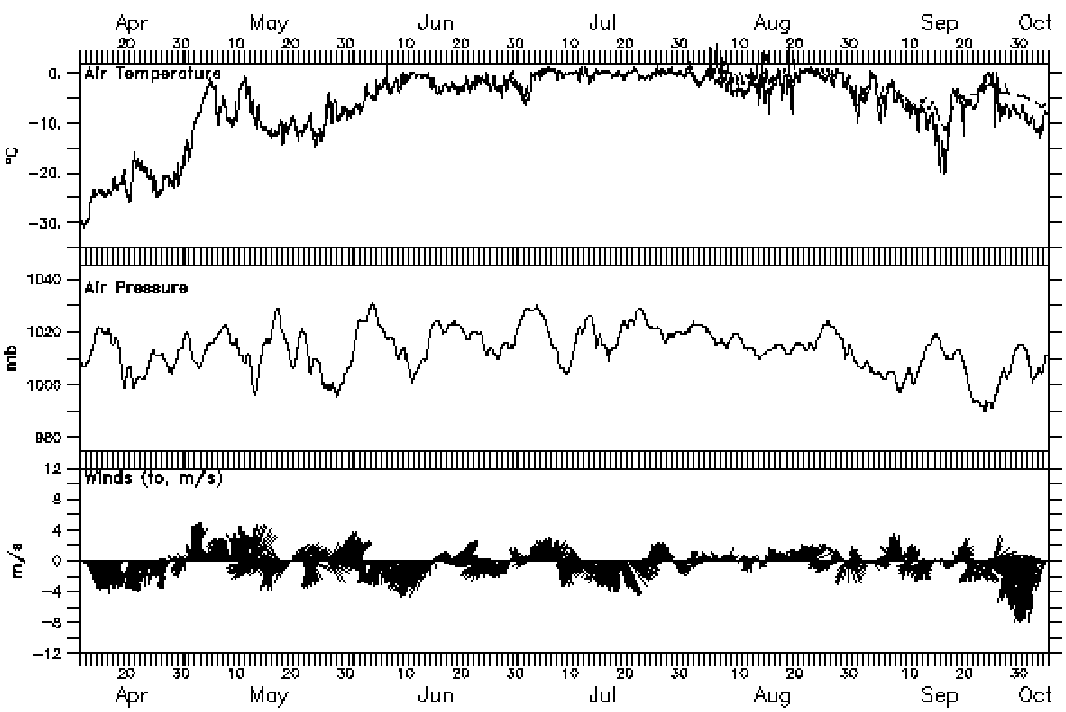
5. Snow cover appeared light and temperatures were very cold during the spring 2009 North Pole Environmental Observatory (NPEO) buoy deployment.

6. The NPEO met buoy and web camera buoy (Fig. X) indicated that snow & ice melt was delayed until about July 10, 2 weeks later than usual.

7. Polyakov et al. reported recent cooling of the Atlantic layer in the Eurasian Basin.

For these reasons we expected the ice extent to recover from 2008 to 2009 a similar amount to the recovery from 2007 to 2008 (see 2) plus a little for the added factors of little snow (see 5), late melt (see 6 and Fig. X), and some cooler water (see 7). Our estimate for 2009 was 5.2 $x10^6$ km^2.

a



b

Figure X (a) Air temperature, pressure, and wind from the North Pole Environmental Observatory (NPEO) Automated Drifting Station in the central Arctic Ocean. Except for a short period, air temperature was below freezing until July 1. (b) Web camera image from the NPEO Automated Drifting Station on July 10, 2009, when the first significant melt water appeared.

Sea-ice Outlook for Summer 2009

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

1 Retrospective Summary

The motivation for participating in the Sea-ice Outlook (our first time this year) is to start experimenting with the utilization of ICESat-derived sea-ice thickness as initial conditions for prediction of the summer sea-ice minimum in the Arctic Ocean. With the exception of initial sea-ice thickness, our approach is conventional: it is based on a coupled ocean and sea-ice model in combination with past years' surface atmospheric boundary conditions (BCs). Our predicted 2009 sea-ice minimum based on August data was $4.4 \pm 0.5 \times 10^6$ km^2, which was below this year's value of 5.36×10^6 km^2. Initial sensitivity experiments showed that near-surface air temperature and specific humidity fields already contain significant amount of information about the sea-ice coverage (Fig. 1). As a consequence, any sea-ice coverage ensemble forecast that uses the 2007 temperature and specific humidity fields as part of the input surface BCs will approximately have the 2007 sea-ice minimum as the lower-end estimate of the ensemble. In addition, a combination of thinner sea-ice initial conditions [Kwok and Rothrock,2009] and high surface temperature would significantly reduce Arctic sea-ice coverage. This is the main reason for our lower than observed sea-ice extent prediction. We used the 2007 and 2008 atmospheric BCs from the Japanese 25-year Re-Analysis (JRA25) and ICESat-derived sea-ice thickness for March 2009 to arrive at the low predicted 2009 sea-ice extent value of $4.4 \pm 0.5 \times 10^6 km^2$. In order to have more reliable predictions of sea-ice coverage, we need to improve the quality of our predicted atmospheric BCs.

Compared to the last two years, both 2009 surface air temperature and specific humidity are lower in August and September (Fig. 1, only temperature fields are shown here). In addition, summer 2009 did not have the 2007 pattern of high pressure over the Beaufort Gyre and low pressure over the Siberian coast, which drove the thick multi-year ice out of the Arctic Ocean (Fig. 2, only Sept. shown here). These factors could contribute to the higher sea-ice extent in the Arctic Ocean in late August to September this year compared to the two previous years. As mentioned above, however, as well as in last year's Outlook Summary Report, the Central Arctic sea ice is mostly thin, first-year ice. Therefore, anomalous summer atmospheric conditions such as those that occurred during the summer of 2007 can potentially reduce summer sea-ice coverage to another record low in the near future.

2 Reference

Kwok, R., and D. A. Rothrock. 2009. Decline in Arctic sea ice thickness from submarine and ICESat records: 19582008, Geophys. Res. Lett., 36, L15501, doi:10.1029/2009GL039035.

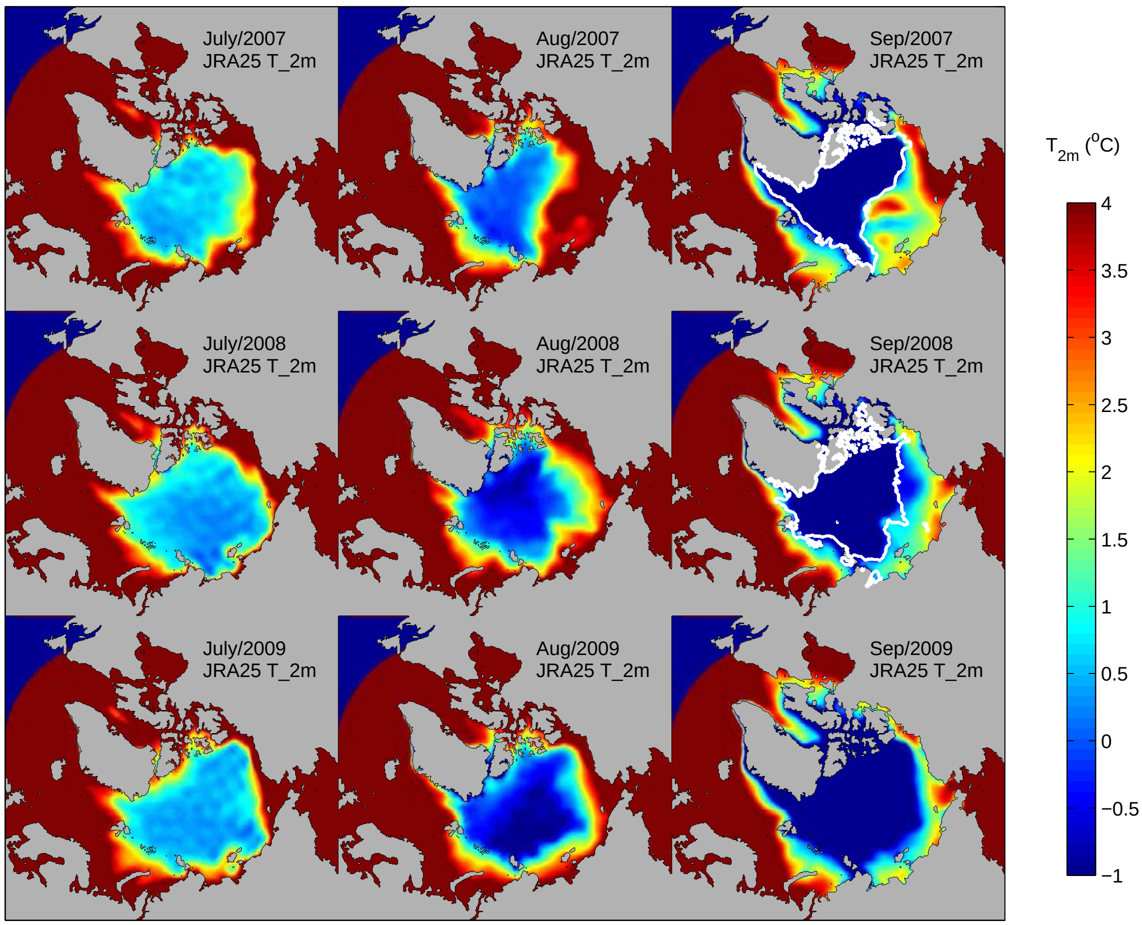


Figure 1: JRA25 monthly mean surface air temperature in degree Celsius (color scale) for summer 2007 to summer 2009. White contours are SSMI 15% sea-ice concentration for Sept 15 of the corresponding years. The surface temperature field contains information about the sea-ice coverage as seen by the SSMI contours outlining the low surface temperature in September 2007 and 2008. As a result, if initial conditions are similar, using atmospheric boundary conditions from any particular year to drive a coupled ocean and sea-ice model will yield approximately the sea-ice coverage for that year.

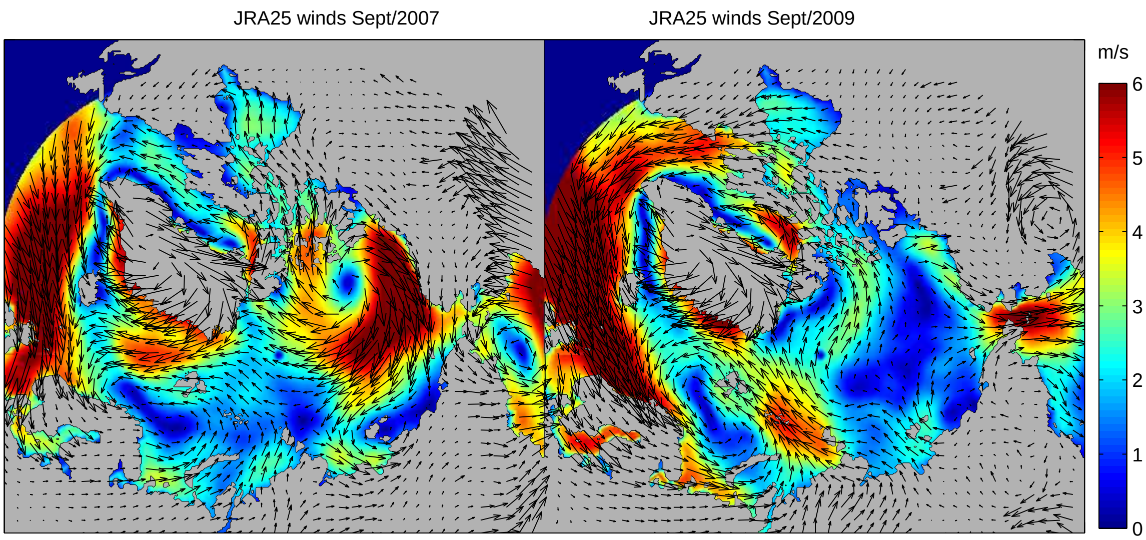


Figure 2: JRA25 September monthly mean surface winds for 2007 and 2009, with wind speed in m/s shown in color. In 2007, a high pressure system over the Beaufort Gyre and low pressure over the Siberian coast drove the thick multi-year ice along the Canadian Archipelago to the central Arctic for accelerated melting and export at Fram Strait. In summer 2009, surface temperature is lower than 2007 and 2008 (Fig. 1), and the 2007 anomalous high/low pressure system is absent. These factors could contribute to the higher sea-ice extent for this year in the Arctic Ocean compared to the two previous years.

My estimate for September average sea ice extent (4.67 million sq km) was simply based on extrapolation of the 10-year trend (1989-2008).

It turns out that extrapolation of the 30-year trend (1979-2008, 5.46 million sq km) would have been very close to the observed extent of 5.36 million sq km.

Sea ice extents in September 2007 and 2008 were well below the long-term trend. At the time, there was some speculation that the decline of sea ice extent was accelerating. Now the decline is right back on the long-term trend line. The apparent acceleration turns out to have been just a couple of anomalously low years.

Those low years were due in part to the loss of older sea ice, which was replaced by younger (hence thinner) ice that was more susceptible to summer melt. This year, at the end of the 2009 melt season, there is more second-year ice than in the past few years. This raises the possibility of a recovery of old ice. This will depend on the amount of sea ice exported through Fram Strait over the coming winter and spring. It appears that much of the second-year and older ice is close enough to Fram Strait to be exported within a year. A large export would set up the Arctic for another low ice extent next summer. On the other hand, low export this winter would promote a recovery of older ice and relatively greater ice extent.

It's important to note (for public consumption) that the trend in summer sea ice extent is still downward, even if 2009 had more ice than 2007 and 2008. Thirty-year trends are not reversed in one year, or even two.

Harry Stern

Ensemble Predictions of September 2009 Arctic Sea Ice Conditions (Summary)

Jinlun Zhang
Polar Science Center, Applied Physics Lab, University of Washington
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Ensemble predictions were conducted as a part of community-wide Arctic Sea Ice Outlook for September 2009. The September 2009 mean sea ice extent is predicted to be 4.5 or 5.3 million square km when the ensemble prediction starts on the first day of July or September. The NSIDC reported that the September 2009 mean ice extent is 5.4 million square km, based on satellite observations. To illustrate the results, the September 2008 sea ice conditions predicted on 7/1 and 9/1 are presented, followed by a summary.

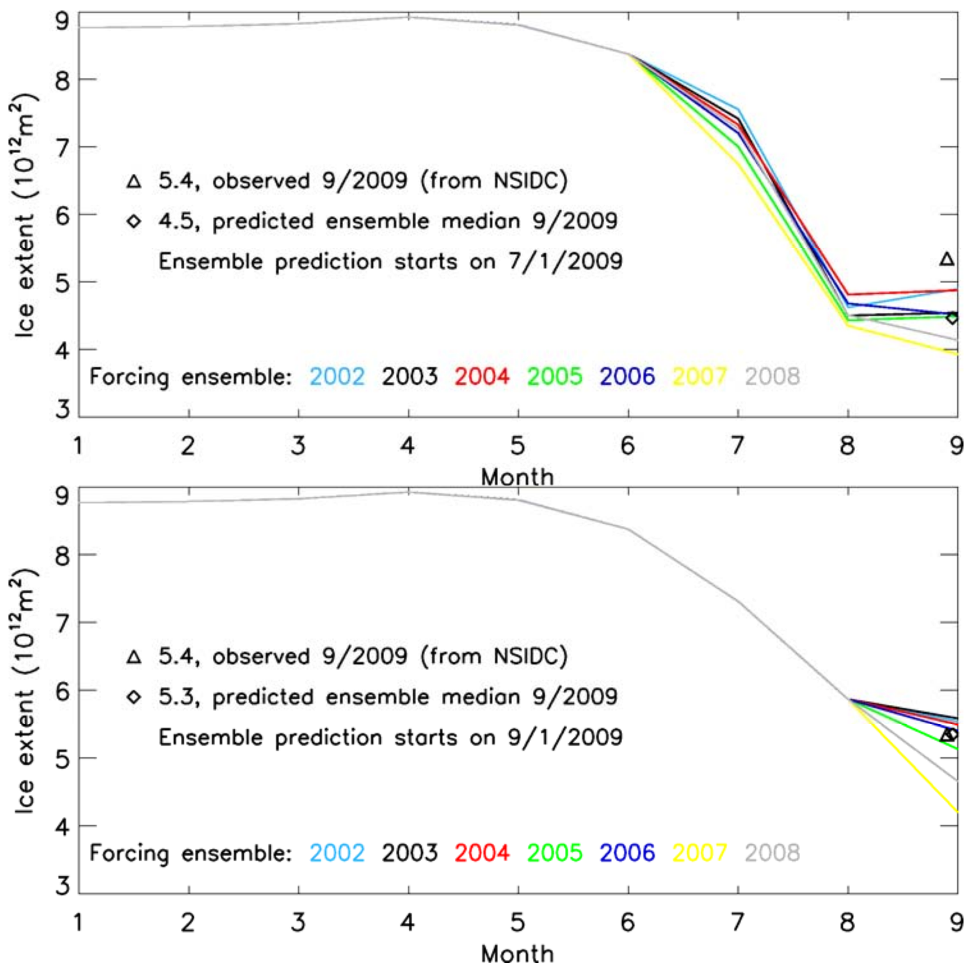

Figure 1. Monthly ice extent over January–September 2009 from seven ensemble members and their ensemble median for September 2009, with the starting date of prediction being 7/1 (upper) and 9/1 (lower). The ensemble median is considered to have a 50% probability of occurrence and the ensemble median ice extent for September 2009 is 4.5 million square kilometers when the prediction starts on 7/1 and 5.3 million square kilometers when the prediction starts on 9/1.

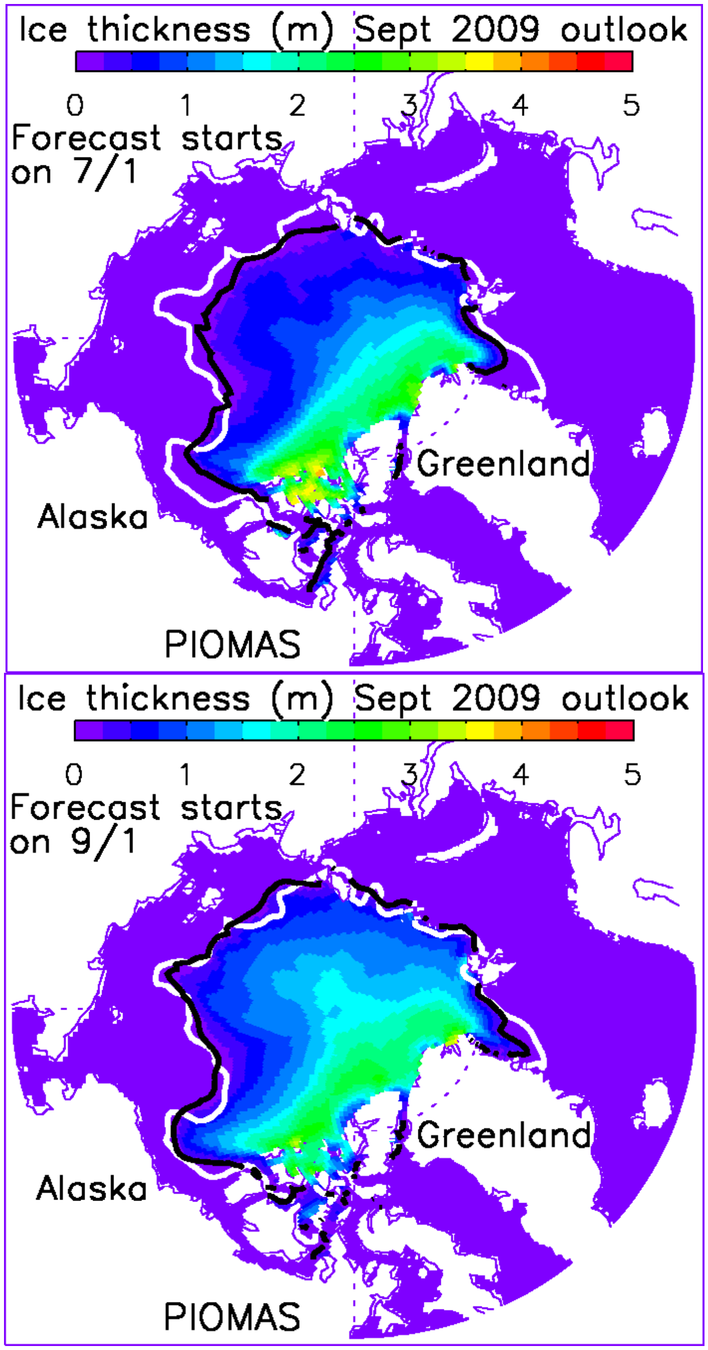

Figure 2. Ensemble predicted September 2009 sea ice thickness fields with two different starting dates of prediction. The white line represents satellite observed ice edge defined as of 0.15 ice concentration, while the black line model predicted ice edge.

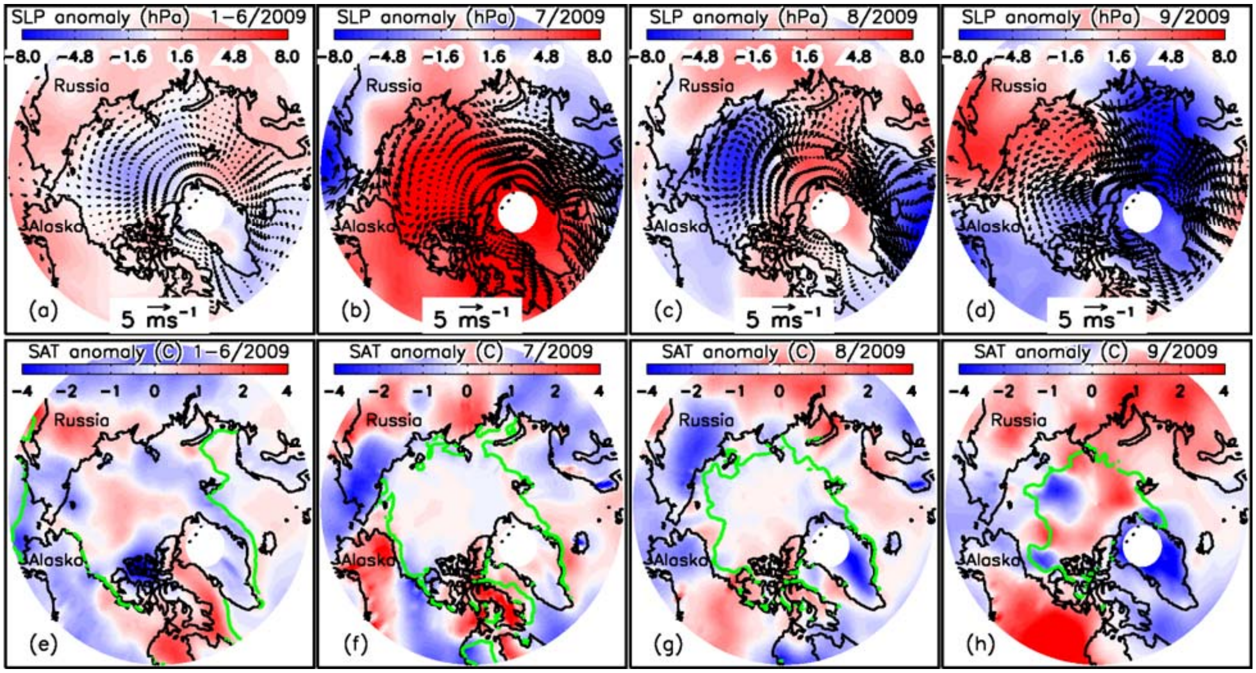

Figure 3. Anomalies of the NCEP/NCAR reanalysis sea level pressure (SLP) and surface wind (a–d) and surface air temperature (SAT) (e–h). An anomaly is defined as the difference between the 2009 value and the 2002–2008 average. The green line in (e–h) represents corresponding satellite observed ice edge.

Summary

(1) With the starting date of prediction being 7/1, the area of the predicted ice extent is smaller than that of the observed (Figures 1 upper), but the shape of the predicted ice extent is close to that of the observed and in various areas the predicted ice edge is close to observed ice edge (Figure 2 upper). Thus the prediction is perhaps within the error tolerance in many areas, but not in other areas. The model has the tendency to under-predict September ice extent because the SAT over a large area in the Arctic Ocean is higher than the recent (2002–2008) climate during January through June (Figure 3e). This may explain why many of the participating groups also under-estimate the September ice extent when the ice conditions during January through June were taken into account heavily.

(2) With the starting date of prediction being 9/1, the area of the predicted ice extent is very close to that of the observed (Figure 1 lower), and the predicted ice edge is mostly aligned closely with the observed ice edge (Figure 2 lower). This indicates that as the prediction range becomes shorter, realistic initial prediction conditions become important in capturing the size of the observed ice extent and the location of observed ice edge.

(3) The scattering of the predicted ice extent values among the 7 ensemble members is not reduced as the starting date of prediction moves from 7/1 to 9/1 (Figure 1). This indicates that atmospheric and oceanic forcing affects the prediction outcome regardless of prediction range. Thus when the ice conditions in spring are used as an indicator of what

may happen several months later in September, there is a need to significantly raise the error bar considering the significant variability of weather/climate.

(4) The under-prediction of September ice extent by the model with starting prediction date of 7/1 may be also attributed to the changes in the atmospheric circulation in August. In August, SLP is relatively low in the Pacific sector of the Arctic Ocean and relatively high in the European sector in comparison with the recent (2002–2008) climate, leading to a pattern of wind anomaly that tends to drive ice toward the East Siberian Sea (or to resist ice retreating from the East Siberian Sea) (Figure 3c). Because of the wind circulation pattern that tends to retain ice in part of the East Siberian Sea in August, the SAT there is slightly lower than the 2002–2008 mean (Figure 3g), which also tends to decelerate ice retreat in that area. In addition, the September wind and SAT pattern may also help resist ice retreat.

Information about ensemble predictions:

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 the first day of a particular month in 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).

Reference

Zhang, J., M. Steele, R.W. Lindsay, A. Schweiger, and J. Morison, Ensemble one-year predictions of arctic sea ice for the spring and summer of 2008. *Geophys. Res. Lett.*, *35*, L08502, doi:10.1029/2008GL033244, 2008. (http://psc.apl.washington.edu/zhang/Pubs/Zhang_etal2008GL033244.pdf)