About the SEARCH Sea Ice Outlook

The Study of Environmental Arctic Change (SEARCH) Sea Ice Outlook is an international effort to provide an integrated, community-wide summary of the state of arctic sea ice over the summer season.

This effort, which emerged from discussions at the "Arctic Observation Integration Workshops" (www.arcus.org/search/meetings/2008/aow/index.php) held March 2008 in Palisades, NY, is a response by the scientific community to the need for better understanding of the arctic sea ice system, given the drastic and unexpected sea ice decline witnessed in 2007.

The 2009 Sea Ice Outlook produced monthly reports based on an open and inclusive process that synthesized input from a broad range of scientific perspectives:

- Each month, a request to the international arctic science community solicited information on the current and expected state of the arctic sea ice.
- The community submissions were synthesized and reviewed by the Sea Ice Outlook Core Integration Group and Advisory Group.
- An integrated monthly report was produced that summarized the evolution and expected state of arctic sea ice for September 2008, based on the observations and analyses submitted by the science community. These reports were posted on the SEARCH Sea Ice Outlook website (www.arcus.org/search/seaiceoutlook/index.php) and widely distributed.

The process for producing the Sea Ice Outlook reports was repeated monthly from June through September 2009. The intent was not to issue predictions, but rather to summarize all available information from ongoing observing and modeling efforts to provide the scientific community, stakeholders, and the public the best available information on the evolution of the arctic sea ice cover.

The SEARCH Sea Ice Outlook is implemented through close cooperation with the DAMOCLES program and other relevant national and international efforts. Sea Ice Outlook activities are supported in part through the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA).

For more information, please visit the SEARCH Sea Ice Outlook website (www.arcus.org/search/seaiceoutlook/index.php), or contact James Overland at NOAA (james.e.overland@noaa.gov), Hajo Eicken at the University of Alaska Fairbanks (hajo.eicken@gi.alaska.edu), or Helen Wiggins at the Arctic Research Consortium of the U.S. (ARCUS) (helen@arcus.org).

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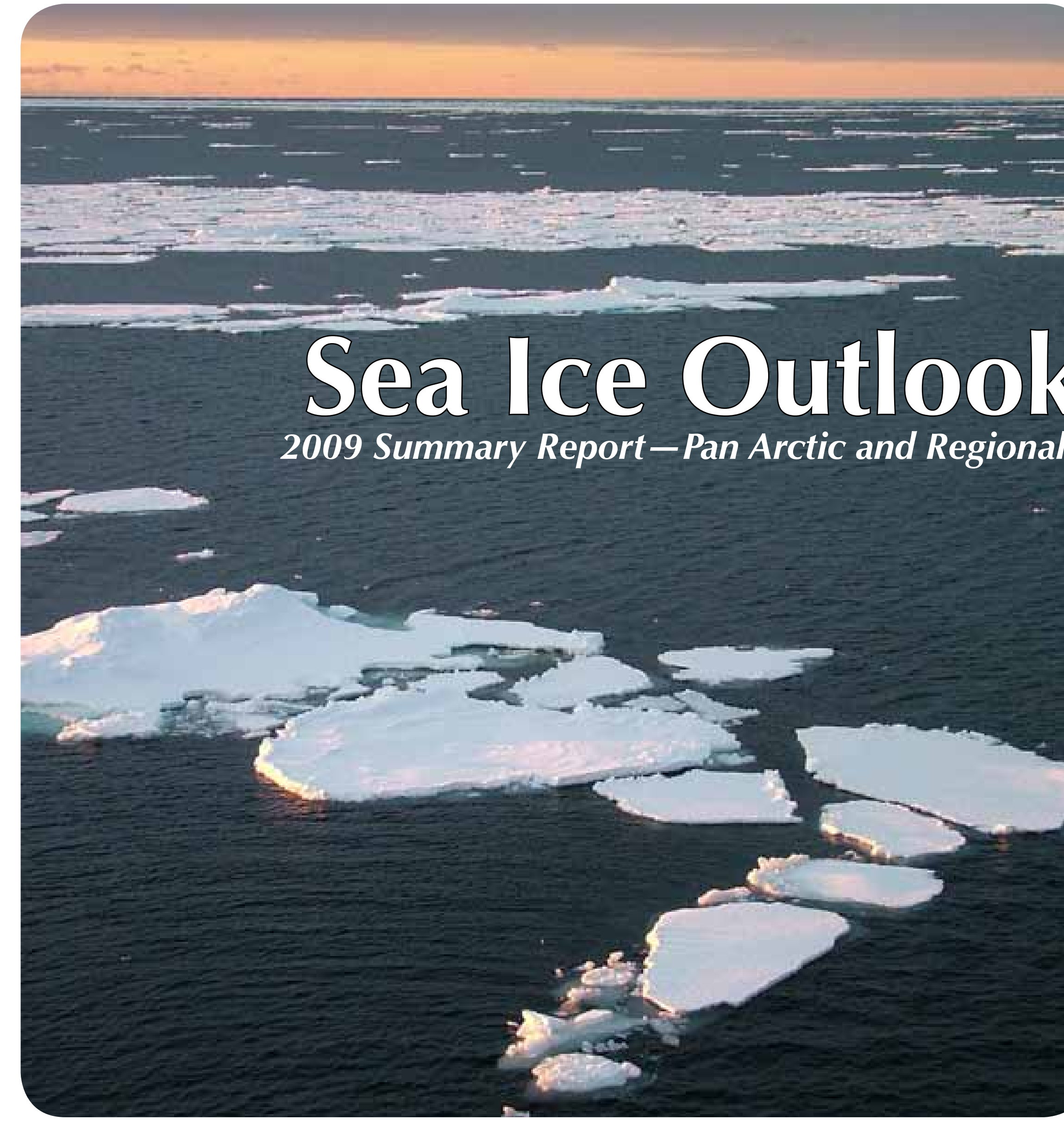


Sea Ice Outlook

2009 Summary Report—Pan Arctic and Regional

Status and Disclaimer

A request was sent to the contributors of the 2009 SEARCH Sea Ice Outlook to summarize the 2009 arctic sea ice season. A key question was: were there systematic or physical changes that contributed to a greater observed sea ice extent this year or was it within the range of natural variability? We appreciate all participants and reviewers who contributed their time to making the 2009 Outlook effort a success for the second year.

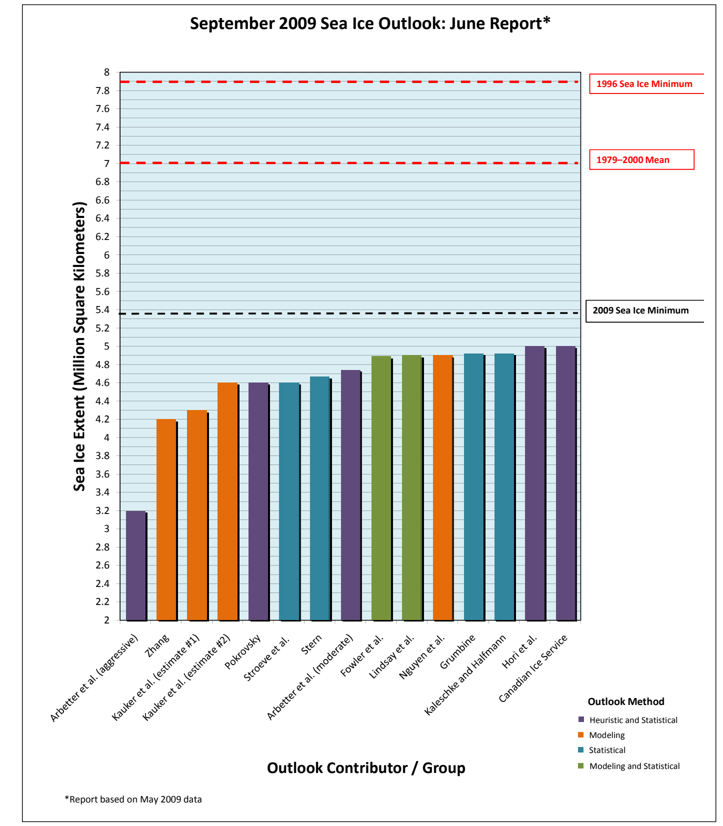
The Sea Ice Outlook provides a forum for researchers to evaluate their understanding of the state of arctic sea ice and for the community to jointly assess a range of factors that contribute to arctic summer sea ice minima. The Sea Ice Outlook is not a formal consensus forecast or prediction for arctic sea ice extent, nor is it intended as a replacement for existing efforts or centers with operational responsibility. Additional background material about the Outlook effort can be found online at: www.arcus.org/search/seaiceoutlook/index.php.

Summary

The arctic summer sea ice extent minimum in September 2009 (5.36 million square kilometers) was greater than that observed in 2007 or 2008, but still much less than the 1979–2000 mean value (7.1 million square kilometers), based on NSIDC September mean estimates. The 2009 observed extent is approaching the 30-year linear trend line of previous September minima (5.5 million square kilometers). All Outlook projection values for September 2009 were less than the observed value, with a median projection of 4.6 million square kilometers and a range of 4.2-5.2 million square kilometers based on June data. While sea ice extent at the beginning of July and weather conditions in June and July were largely conducive to a new sea ice extent minimum, weather in August and September was unfavorable. In fall of 2009, the area of second-year sea ice has increased relative to 2007 and 2008. However, the arctic ice pack remains substantially younger, thinner, and more mobile than prior to 2005. The long-term trend in summer sea ice extent is still downward. Furthermore, the rate of refreezing at the end of October is less than in 2007.

2009 Minimum Sea Ice Extent

The projections of the Sea Ice Outlook groups for the September 2009 mean minimum ice extent had a median value of 4.7 million square kilometers based on May data and 4.6 million square kilometers based on June data with a range of 4.2-5.2 million square kilometers (Figure 1). These estimates are below the observed value of 5.36 million square kilometers as provided by Walt Meier, NSIDC. Figure 2a and 2b show the spatial extent of mid-September sea ice for 2008 and 2009.



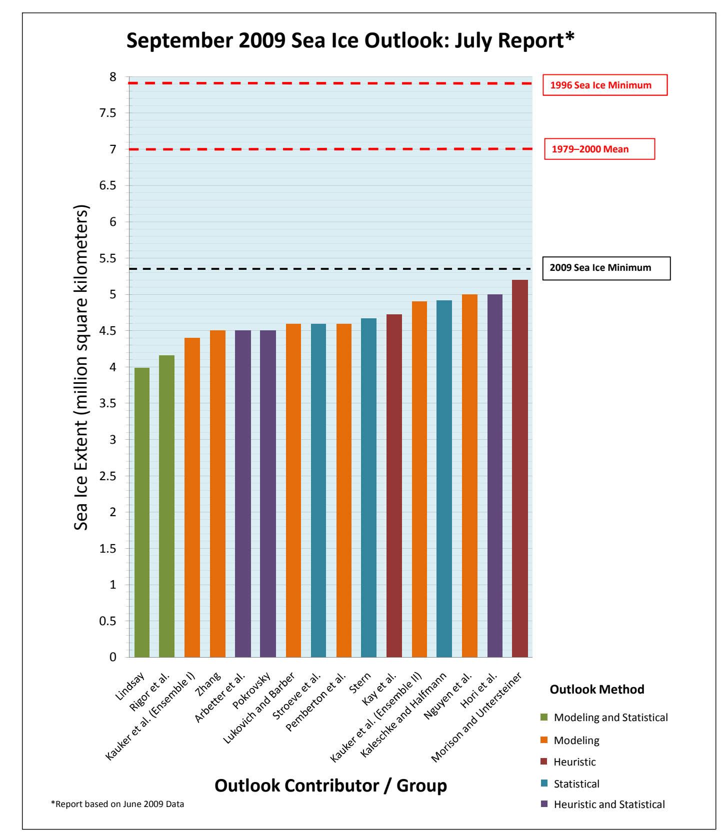


Figure 1. Distributions of outlook projections for September 2009 arctic sea ice extent based on May and June data.

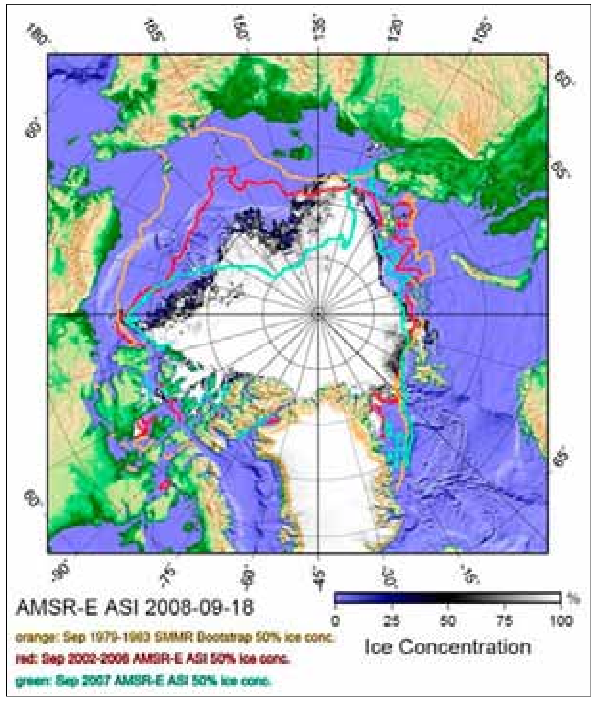


Figure 2a. Sea ice extents for mid-September 2007 and 2008. Note: Hamburg uses a 50% sea ice concentration for the extent and NSIDC uses 15%. Credit: Spreen and Kaleschke. http://www.ifm.uni-hamburg.de/.

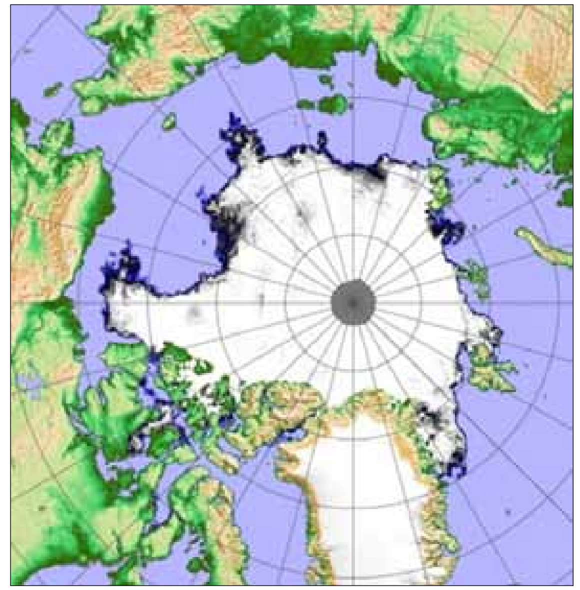


Figure 2b. Sea ice extent for 16 September 2009.

Comparison of 2009 with 2007, 2008, and earlier years will require further analysis. A major question is whether large one-year changes in extent such as the decline from 2006 to 2007 or the increase from 2008 to 2009 are simply a result of natural variability or whether they indicate systemic changes leading to an acceleration or deceleration in the decline. The vast areas of open water in 2007 and 2008 increased the amount of summer ocean heat storage. At the start of fall freeze-up, sea ice continues to be thinner and more mobile than prior to 2005, which might cause the decline in extent to persist or accelerate. Considerable first-year sea ice survived summer melt in 2009 to constitute second-year sea ice, in contrast with low survival in other recent years. Further, it only took one month of persistent wind conditions to slow the rate of sea ice loss, resulting in an increase in 2009 sea ice extent compared to 2007 and 2008.

Another way of stating the question is whether below normal multi-year ice fractions account for a persistence in ice extent anomalies on interannual time scales, or whether the ice pack is now back in a mode with no interannual correlation between extent anomalies (Bitz, personal communication). Lindsay comments, "with nonstationary statistics, the standard error of the fit over past years is not a good measure of the uncertainty in the prediction."

With regard to the 2009 outlook projections relative to the observed value, Kaleschke states that the projections are at the upper range of the uncertainty based on statistical methods and Kauker finds that the observed extent is within the error tolerance based on model hindcast estimates. For example, seven of the twenty ensemble members from the Alfred Wegener Institute modeling group gave Outlook estimates above 5.0 million square kilometers. He adds that their group believes that the likelihood of '2007 events' is higher now than a decade before and that this is connected to the gradually reduced sea ice thickness.

The range of Outlook projections in 2009 was narrower than in 2008. The estimates in 2008 covered a range of plausible scenarios driven by physical processes that could favor a return to previous conditions or a continued loss of all first-year sea ice. Neither extreme was observed. 2009 Outlook contributions suggest a focus on persistent conditions and extent values relative to 2008. The 2009 Outlook results point out the importance of a more thorough exploration of approaches that can help establish a probabilistic range of September sea ice conditions. Difficulties are mentioned by Lindsay.

One potential analog for the future evolution of the arctic ice pack comes from the work of Holland, Bitz and Tremblay (2006), based on the September extent from a seven-member ensemble of the Community Climate System Model Version 3 (CCSM3, Figure 3). If one examines the ensemble member shown in black in Figure 3, periods of stagnation in ice decline as long as ten years can be discerned between major ice loss events. Is 2009 simply part of such an extended pause, as it will take another near-perfect synchrony of summer weather conditions to provide another major drop in sea ice extent (Overland)? Or does the background trend in Figure 3 represent the global warming "forced" signal of an ever-increasing sea ice loss, plus natural variability (Bitz)? Or are these two interpretations of the same thing? The data from 2007-2009 suggest further lively discussions on the future of the Arctic at meetings during the coming year.

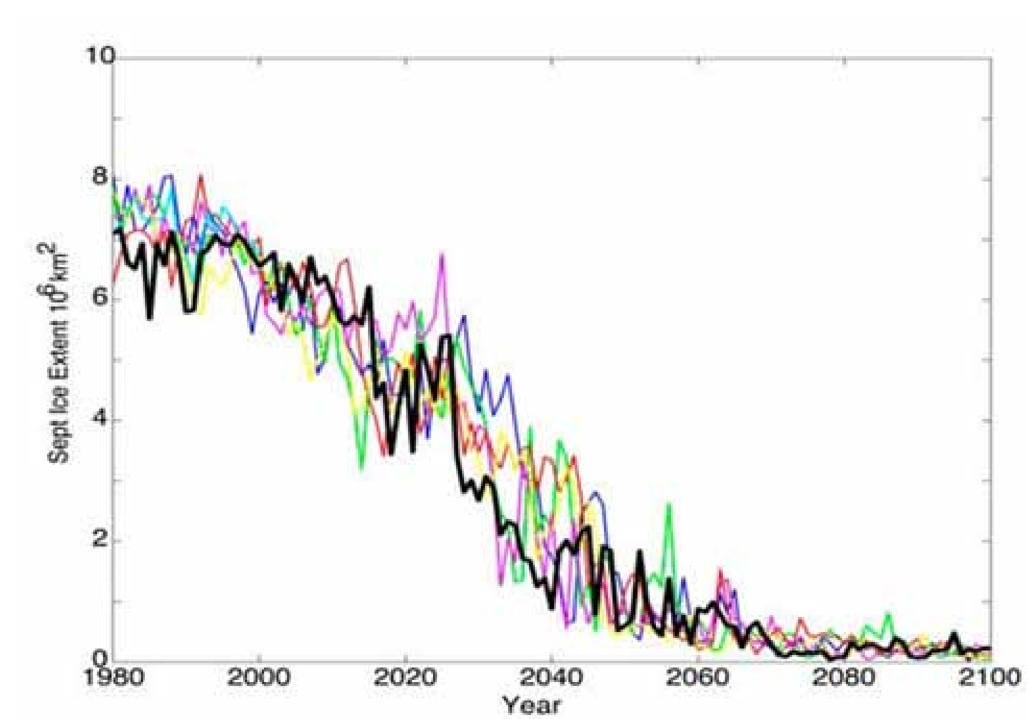


Figure 3. Projections of future summer minimum sea ice extents, each colored line (including the heavy black line) is from a single ensemble member. Redrawn from the work of Holland, Bitz, and Tremblay (2006).

Summer 2009 Sea Ice and Meteorological Conditions

Different seasonal progressions of summer sea ice loss are apparent in daily time series of sea ice extent from different years (Figure 4). In the summer of 2009, sea ice was more extensive at the beginning of July than in 2007 and less extensive than in 2008. The rate of loss was greater in July 2009 than in 2007. As with 2005, the sea ice extent minimum remains below the 2-standard deviation mark based on the years 1979–2000.

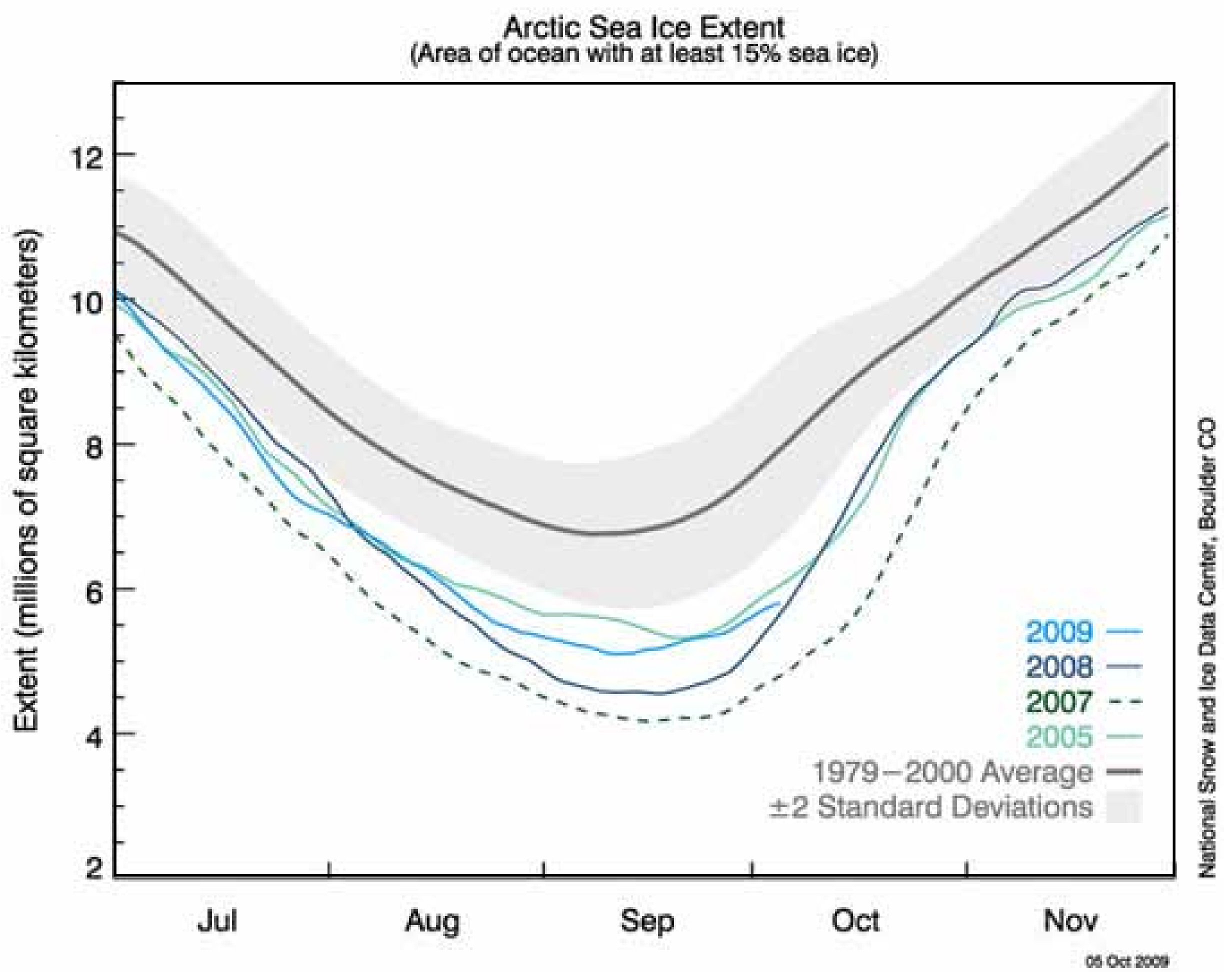


Figure 4. Daily arctic sea ice extent from passive microwave satellite data (SSM/I). The solid light blue line indicates 2009 relative to 2005, 2007 and 2008. The solid gray line indicates average extent from 1979 to 2000. Credit: National Snow and Ice Data Center.

With regard to summer meteorological forcing, June and July of 2009 were dominated by a strong Arctic Dipole climate pattern in sea level pressure (SLP) similar to 2007, with high pressure over the Beaufort Sea and winds blowing from the Bering Strait across the North Pole, promoting both advection of warm air and compaction of the ice pack (Figure. 5). Unlike 2007, however, August and September 2009 SLP patterns were not conducive to continued sea ice loss.

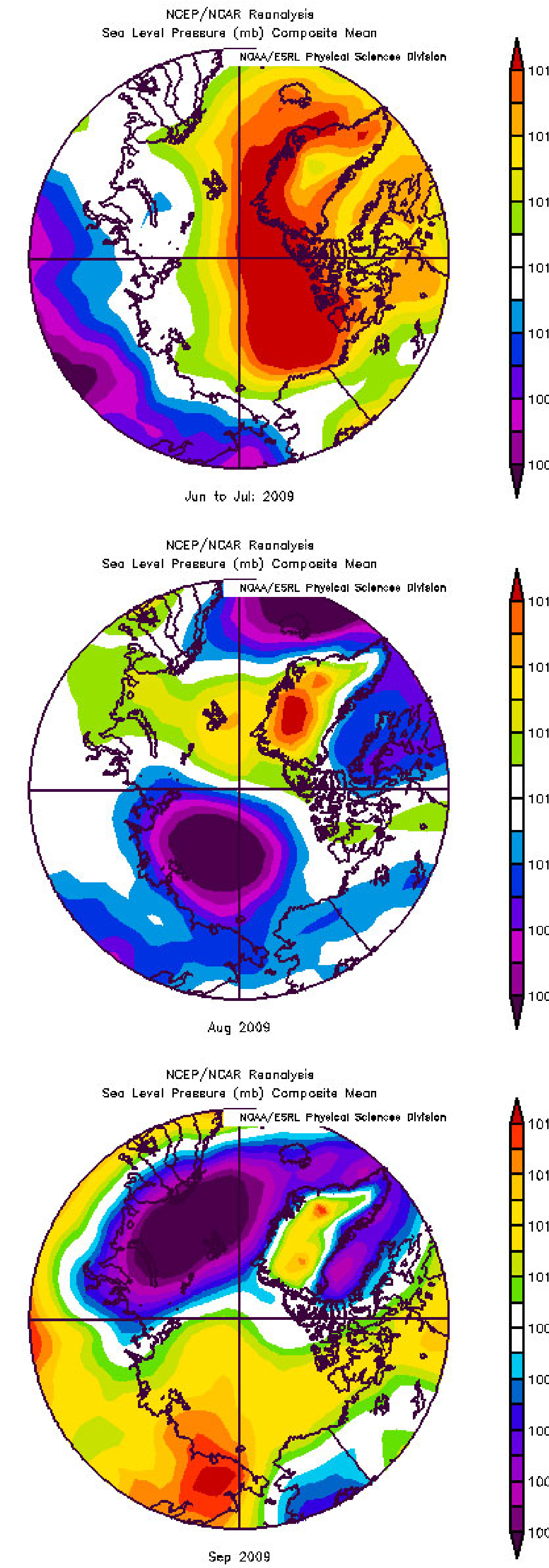


Figure 5. SLP patterns for June/July 2009, August 2009, and September 2009. Credit: NOAA/CDC.

The regional progression of the early stages of the melt season can have a substantial impact on ice evolution later in the summer. Anomalies in ice albedo or downwelling shortwave radiation at the start of the melt season have more than a five-fold larger impact on solar heating of ice than those at the end of the melt season (Perovich et al., J. Geophys. Res., 2007, doi:10.1029/2006JC003558). As evident from contributions for the regional outlook, above normal cloudiness resulted in delayed ice break-up and sluggish melt in the Western and Central Arctic. The contribution by Hori illustrates how above normal cloudiness in particular in the later stages of summer was set up by the same atmospheric circulation pattern that impacted ice extent in other ways as well.

The long-term time series of sea ice extent and trend since 1979, as plotted by NSIDC, is shown in Figure 6. While the value for 2009 is near the trend line (see Stern), arctic sea ice internal conditions are considerably different from 2005. There has been a major reduction in multi-year sea ice (~35 %) since 2004 (Kwok et al., 2009).

The amount of perennial sea ice in May 2009 was similar to May 2008 (Figure 7). The tongue of perennial sea ice between the North Pole and Eurasia is the sea ice that survived the summer of 2008. Over the winter and spring 2009, this feature became smaller as some of the sea ice was entrained in the Transpolar Drift Stream and exported into the Greenland Sea (Kwok, personal communication). Since the forcing along the Transpolar Drift was not consistently strong in summer 2009, this region of the perennial ice pack mostly remained in place (Nghiem, personal communication), as confirmed by the adverse August/September weather patterns shown in Figure 5. Based on sea ice age calculations, much of this sea ice tongue remained in the Arctic Ocean basin to become second-year sea ice (as discussed on the NSIDC web site by Fowler and Maslanik; and by Ignatius Rigor as Figure 8 below). In situ observations from Barber suggest that satellite products may in fact be overestimating the amount of multi-year sea ice in the southeastern Beaufort Sea. An arctic ice pack that consists mostly of first- and second-year rather than multi-year sea ice, implies a thinner, more mobile ice cover relative to conditions five or more years ago.

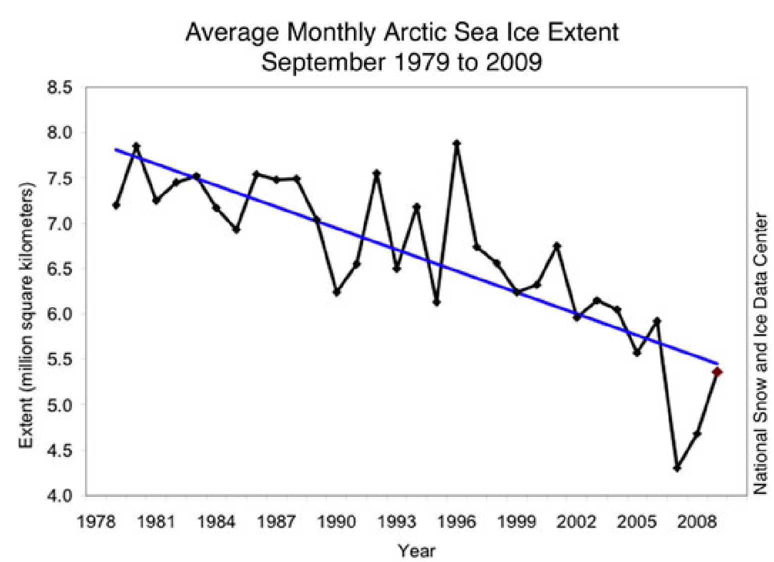


Figure 6. September ice extent from 1979 to 2009 shows a continued decline. The September rate of sea ice decline since 1979 has increased to 11.2 percent per decade. Credit: NSIDC.

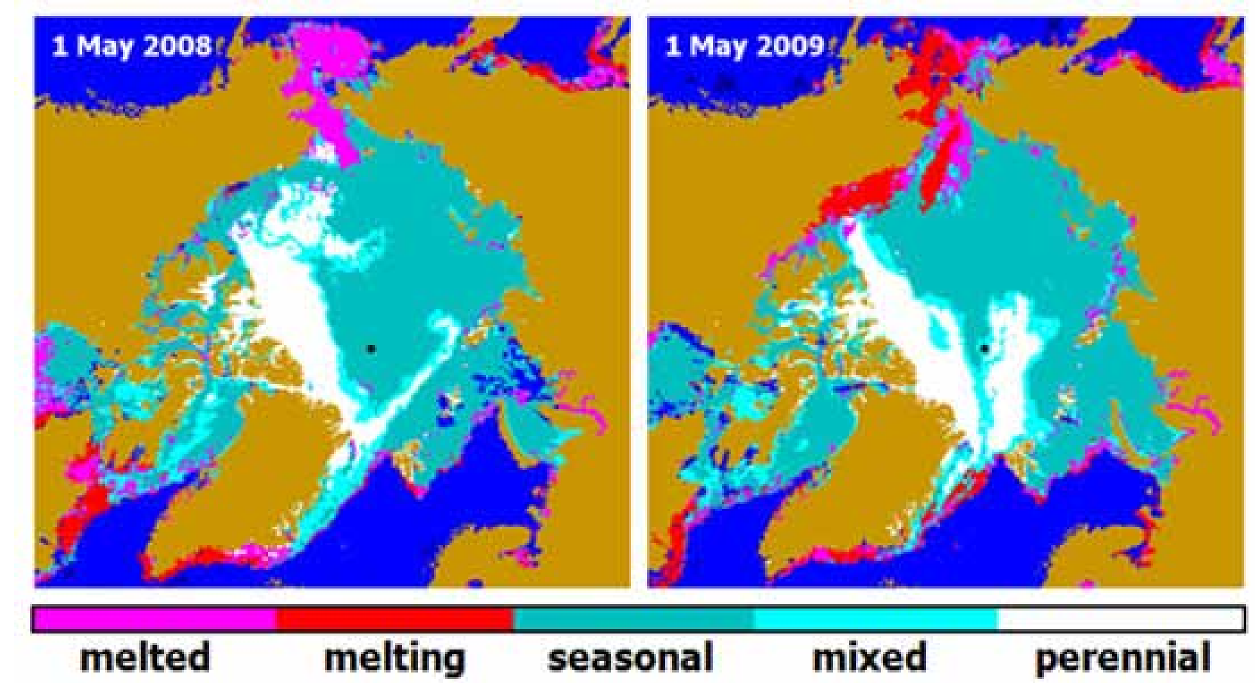


Figure 7. Sea Ice Distribution in May 2009 versus 2008 derived from QuikSCAT scatterometer: perennial ice (white), mixed ice (aqua), seasonal ice (teal). Credit: S. V. Nghiem Jet Propulsion Laboratory. Regions of white indicate sea ice that survived the summer 2008 melt season.

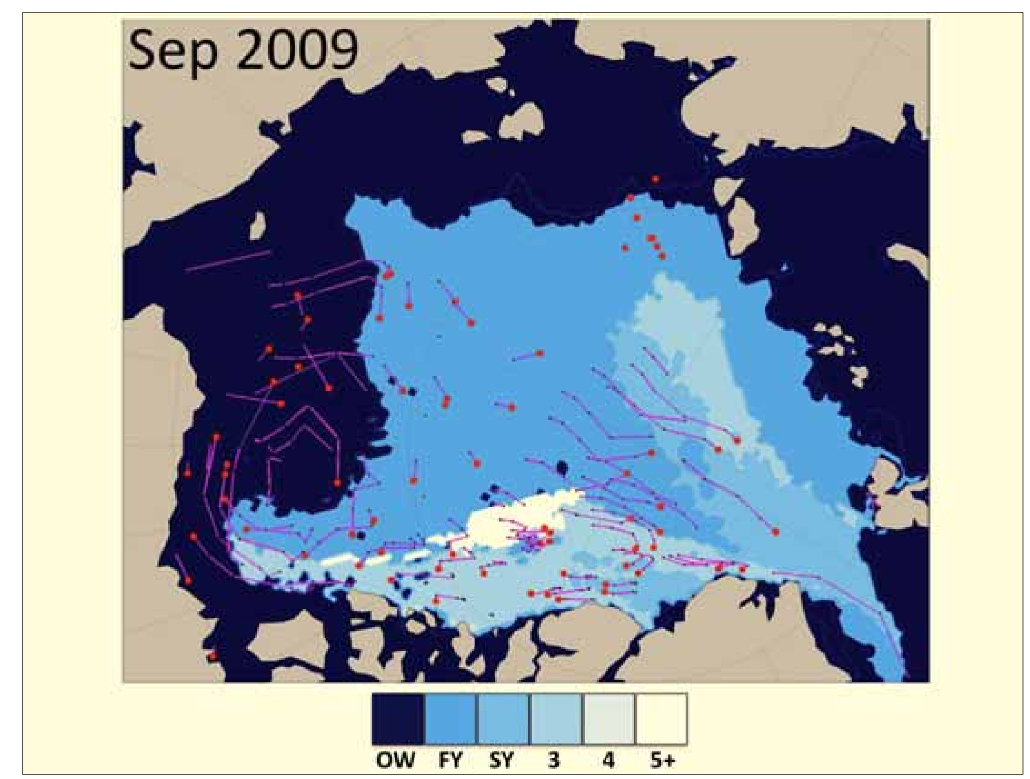


Figure 8. Sea ice age for September 2009 and buoy drift as contributed by I. Rigor. OW=open water, FY=first year, SY=second year, 3 etc= older sea ice. There is no 4th year sea ice remaining in this analysis.

Lessons Learned From the 2009 Outlook

September 2009 sea ice extent was driven by preexisting sea ice conditions at the end of spring, as well as variable wind patterns over the course of summer. 2007 remains as an anomalous year dominated by steady meteorological conditions during the entire summer. In 2009, August and September wind patterns were not conducive to major sea ice loss.

The fact that all 2009 Outlook projections were below the observed September 2009 value is of concern. However, when projection uncertainty is taken into account, as well as it can be, the observed value is within an expected range of values. Of concern is the convergence of the Outlook projections into a narrow range.

The last point emphasizes the need for further development and analysis of probabilistic forecast ranges and measures of uncertainty, critical to future efforts.

2009 signals that it could be several more years, in a probabilistic sense, before conditions favor another major sea ice loss event. However, the increase in sea ice extent for 2009 does not exceed past interannual variability in a near-continuous, 30-year downward trend in summer sea ice extent.

Melt-out of sea ice near the North Pole continues to be more exceptional than in the Beaufort and Siberian sectors because of the decreasing importance of solar forcing. This may be a limiting factor in the rate of future sea ice loss.

Consideration of multiple sources of data, including visual observations, is important for reducing uncertainty in the Outlooks. Buoys provide key observations for mapping and attributing summer ice loss: drift, bottom vs. top melt, amount of snow accumulation, nature of ponds (even if anecdotal from web cams), and thickness of level ice. Considerable effort should be made to estimate thickness distributions of ice and snow cover needed to initialize simulations. Aircraft and other reconnaissance are also helpful.

Because of the importance of initial conditions for the sea ice state, more work is needed on remote sensing retrieval and interpretation of spring and summer ice concentrations and ice conditions, even if the present operational algorithms are not changed.

Both full sea ice models and seasonal melt projections applied to detailed sea ice distributions and trajectories provided the main semi-quantitative information for the Outlook.

Overview

For the 2009 SEARCH Sea Ice Outlook, regional perspectives on ice evolution during the summer had been solicited, both to synthesize relevant field observations and modeling activities and to encourage communication between different sea ice experts and user groups. Nine different individuals or groups responded to this request, with input ranging from coupled ice-ocean model ensemble simulations and statistical/semi-empirical models to heuristic models and tracking of sea ice at the regional level using remote sensing.

Anticipating ice development at the regional scale is in some ways more challenging than at the pan-arctic level because the difficulties and uncertainties characterizing pan-arctic forecasts are amplified because of the even greater role local weather patterns and other small scale anomalies can play. At the same time, anomalies in local ice conditions, such as the presence of mult-year ice discussed for the North West Passage (NWP below), may persist well into the melt season and provide some measure predictability. Local knowledge of recurring ice retreat patterns constrained by, e.g., topography or ocean currents can further enhance outlooks at the regional scale, which is also discussed for the NWP below.

Contributors were asked to provide, where possible, a categorical forecast of ice conditions over the summer, i.e., light, medium (normal) or heavy ice conditions. A summary of these contributions by region indicates that responses ranged from quantitative assessments of specific variables (opening dates provided by Maslanik et al., ensemble simulations by Zhang, 2-week break-up forecast for Barrow by Petrich and Eicken) to broader assessments integrating a range of data sources (state of NWP and Northern Sea Route).

Northwest Passage:
Open – Zhang;
Closed – Howell and Duguay (Parry Strait Route);
Closed – Arbetter et al. (Parry Strait Route)

Nares Strait:
Open with inflow of ice from High Arctic – Gudmandsen

Northern Sea Route:
Most likely open but less drastic ice retreat than in 2007 – Pokrovsky;
Open – Maslanik et al.

Chukchi and Beaufort Seas:
Early onset of melt and opening (Maslanik et al.);
In Barrow region lighter than normal ice conditions with sluggish initial ice retreat – Eicken et al.;
Potential masking of old ice as a result of complicated ice decay processes – Barber et al.

High Arctic:
Lighter ice conditions than normal – Maslanik et al.;
Sluggish melt (observation from buoys, not forecast) – Perovich

Greenland and Barents Seas:
Below normal ice conditions (observations from remote sensing, not forecast) – Gerland and Hall

The diversity of categories and the selective focus on aspects of ice conditions that are inherently more predictable (e.g., impact of multi-year ice on summer ice conditions) preclude any rigorous evaluation of the predictive success of the regional outlook. However, a majority of the contributions were reasonably accurate with respect to the anticipated ice conditions. In general, it appears that statistical, semi-empirical as well as heuristic approaches fare reasonably well because they are able to build on sparse or qualitative information concerning the initial conditions in a specific sub-region. Ice-ocean model simulations, on the other hand, have requirements with respect to data density and quality, e.g., for observed ice thickness fields used in initialization of model runs, that are currently not being met by existing data sources (with the exception of, e.g., satellite-observed ice concentration fields). Exploring ways of melding different forecasting approaches may hold some promise in the future.

The evolution of regional ice conditions is discussed further below and in more detail by the individual contributors. In summary, all sub-regions of the Arctic appear to have been characterized by sluggish ice melt and retreat, due in part to above average cloudiness and atmospheric circulation favoring cooler conditions (see pan-arctic outlook summary discussion). In the Siberian Arctic and the Chukchi Sea, the absence of multi-year ice still resulted in lighter than normal ice conditions, as anticipated by outlook contributors. In the Beaufort Sea and the high Canadian Arctic, multi-year ice persisted throughout summer, resulting in medium to slightly lighter than normal ice conditions. In the NWP region, multi-year ice distribution patterns suggest that the coming year will only see limited openings in the northern parts of the route.

Feedback from local observers and vessels operating in the North American Arctic also highlights the need for further work on reconciliation between different ice nomenclatures and ice information derived from different sources (satellite remote-sensing, ship-based observations, buoys etc.). Thus, as commented on by one of the mariners taking a sailboat through the NWP, at the regional scale ice located outside the proper ice edge (which may be defined by the 10 or 15% ice concentration contour) may still present a formidable obstacle to progress with a small vessel. Similarly, data transmitted from an ice mass balance buoy located well outside of the ice edge in the western Chukchi Sea, suggest that while not of climatological importance, pans and cakes of ice may still be relevant as potential ice habitat or navigational hazard.

Regional perspectives (full details provided online)

Tracking of ice conditions through the Northwest Passage (NWP) highlighted the importance of having a clear definition of what constitutes an "open" passage. Ensemble model simulations by Zhang suggested an opening of the passage along several routes. As detailed in his contribution, initial underprediction of ice conditions improved as the season evolved and the window of higher predictive skill extended out to include the September minimum ice extent period. A key challenge with coupled ice-ocean model runs appears to be the limited spatial resolution in regions with complicated topography. At the same time, local observers reported significant remnants of ice that presented potential hazards to non-ice strengthened vessels.

As highlighted by Arbetter et al. in their contribution, in particular from the perspective of navigation in ice-covered waters, it is important to recognize differences between different forecasting and remote-sensing approaches as to the definition of ice extent, location of the ice edge and related variables describing ice conditions. Here, considerable value can be derived from ship-based observations, aerial overflights, and drifting (mass-balance) buoys that provide a more accurate picture of the distribution of different ice types.

Howell and Duguay's approach of deducing likely summer evolution of the Parry Channel route of the NWP based on past conditions of multi-year ice distributions was quite successful in predicting ice evolution at high spatial resolution. Figure 1 illustrates an example of extreme years in this region in relation to the past three years.

Gudmandsen and Kwok point out that the Lincoln Sea appears now to be recovering from the great ice outflow events of 2007 and 2008, with thicker ice building up after reestablishment of an ice barrier to the South.

The distribution of multi-year ice also impacted ice retreat in the Beaufort Sea, where sluggish melt damped by high cloudiness helped preserve large swaths of ice in the eastern Beaufort Sea. This ice will likely affect both winter and spring ice conditions in the coming year. In contrast, lack of multi-year ice in the Chukchi Sea at the start of the melt season had allowed significant retreat of sea ice. Impacts of this retreat include walrus congegrating in large numbers along the eastern Chukchi coast, similar to but not quite as extensive as in 2007. Predictions of melt onset by Maslanik et al. were on target for the Chukchi Sea, but did not anticipate the evolution of cloudiness in June and July that greatly slowed melt. The impact of low shortwave fluxes came out well in two-week forecasts of a semi-empirical break-up model forced with output from a long-range weather forecast (contribution by Petrich and Eicken). Break-up in 2009 at Barrow occurred later than during any of the previous nine years (Figure 2).

Barber and colleagues report about the masking of different signatures of old ice (first-year ice and multiyear ice that survived summer melt) in the Beaufort Sea with potential implications for assessing the extent and state of the ice cover. They found that invasion of seawater into rotten ice and decay of first-year ice resulted in a complex mixture of ice types not distinguished properly in remote sensing data.

In the Siberian Arctic, heuristic forecasts by Pokrovsky and statistical forecasts by Maslanik et al. predicted opening of the Northern Sea Route, which were on target (Figure 3). However, as with the NWP, opening based on the position of the 15% or 10% ice concentration contour apparent from passive microwave satellite imagery may not necessarily capture ice conditions in some of the straits that can substantially hamper maritime traffic.

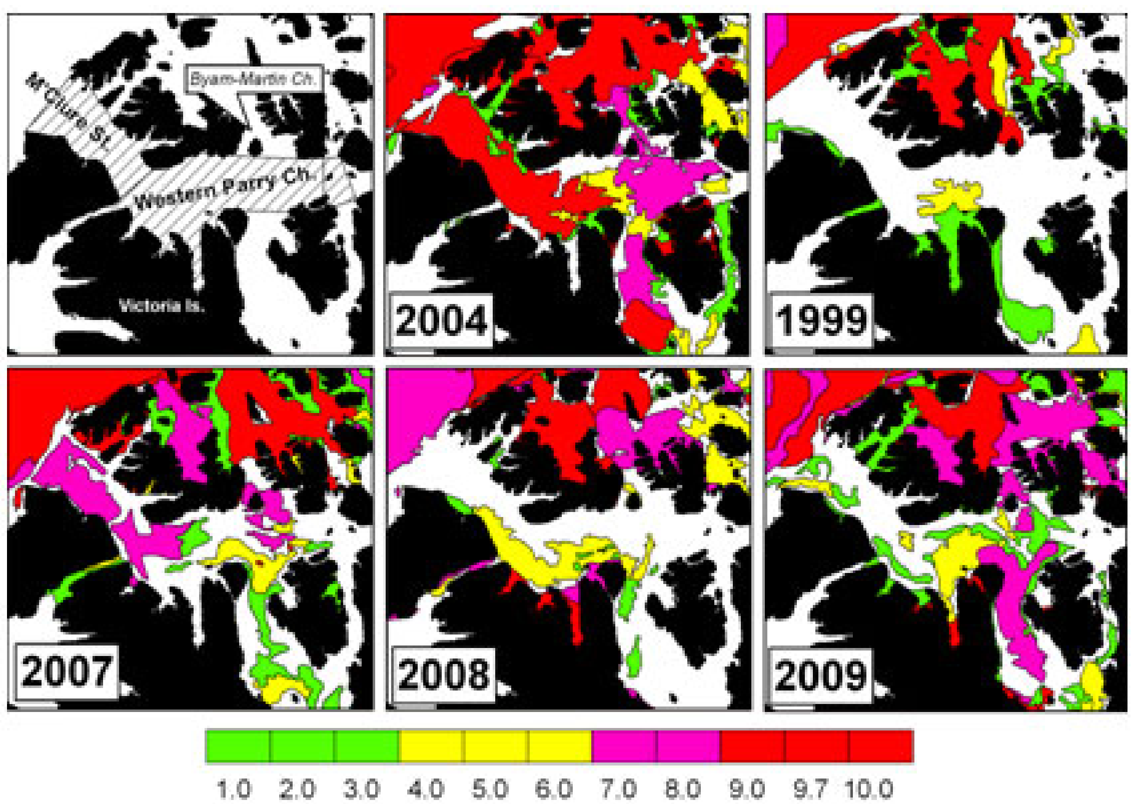


Figure 1: Spatial distribution of multi-year ice (in tenths) within the Western Parry Channel region of the Northwest Passage on May 1st for a heavy ice year (2004), a light year ice (1999) and the last three years. Data is from the Canadian Ice Service. (for details, see contribution by Howell and Duguay).

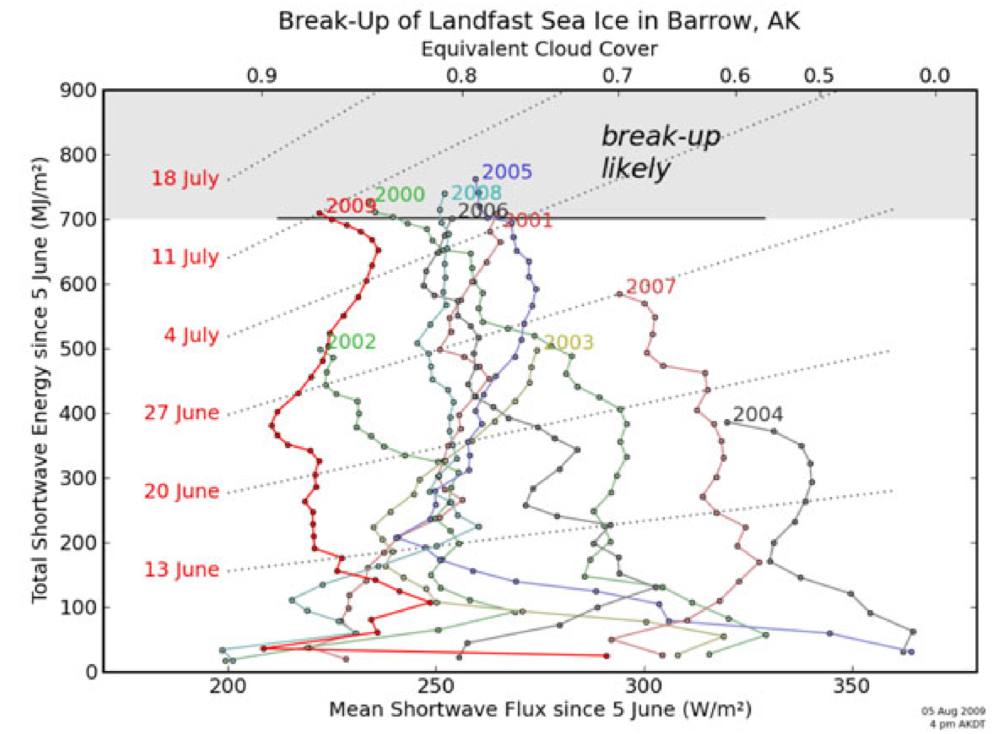


Figure 2: Break-up timing and solar shortwave energy incident at the surface (mean and cumulative shown on bottom and left axis, respectively) for 2009 (thick red line) and other recent years. Curves terminate at observed break-up. The shortwave flux is used as an indicator for radiative forcings. The grey area at the top corresponds to the seasonal stage at which ice break-up is imminent and determined by local sealevel and winds. Details at www.gi.alaska.edu/snowice/sea-lake-ice/Brw09/forecast/. (for details see contribution by Eicken et al.)

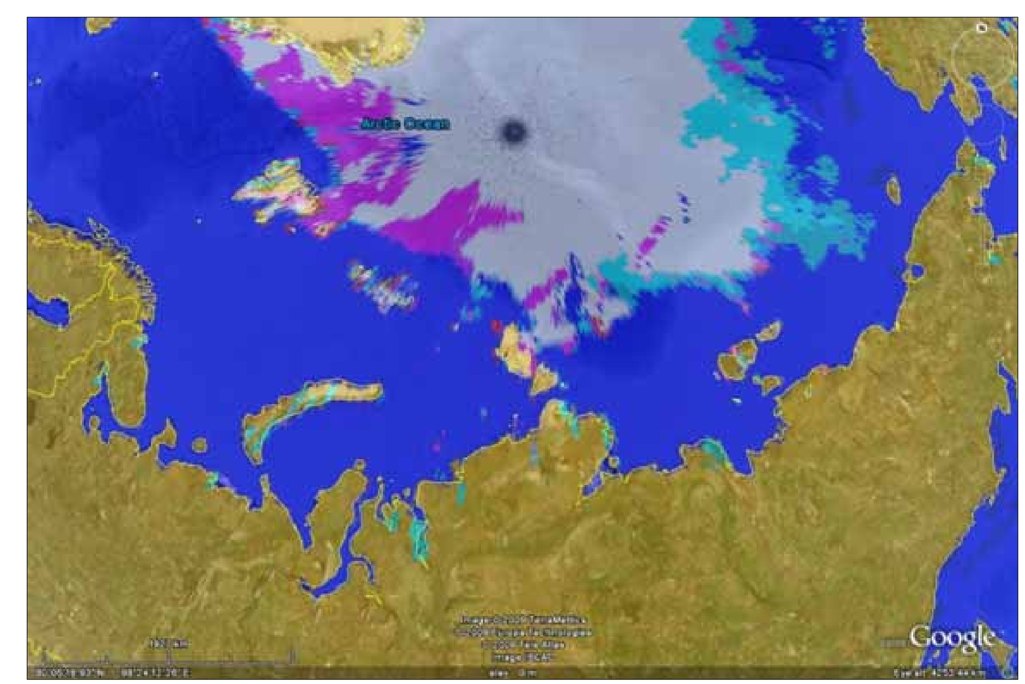


Figure 3: Ice distribution along the Northern Sea Route based on QuikScat radar data provided by Son Nghiem (JPL) for September 29, 2009. Note that while the passage appears to be open, the National Ice Center (NIC) indicates conditions were only marginally "open" from a maritime traffic perspective (see NIC contribution).