SIO 2011: Final Report for September Minimum Ice Extent Outlook

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Summary

For 2011, NSIDC declared that the date of minimum sea ice extent was reached on September 9, 2011, with the ice extent dropping to 4.33 million km^2, just slightly above the all-time minimum (of observed conditions since 1979) observed in 2007. This value is the accepted "correct" value for the purposes of the ARCUS/SEARCH Sea Ice Outlook. NIC's Multiple Linear Regression statistical model, being developed for operational mid-range and seasonal projections at the National Ice Center, over-predicted the actual value of the sea ice minimum (when adjustments for model domain are taken into account) for the first three outlooks; the projection produced August 1 was much closer, but still over 100,000 km^2 higher than the actual minimum, and predicting it would occur 1-2 weeks later than observed.

Performance of NIC Multi-Linear Regression Model

The statistical sea ice outlook model being developed for medium range and seasonal forecasting at the US National Ice Center uses a slightly different dataset to determine its minimum. Like NSIDC, it is based on satellite observations from remote sensing (SSM/I); however, because NIC is interested in the weekly average (similar to its ice charts) rather than the day-to-day variability, the weekly average of SSM/I conditions is used here.

The model uses multiple linear regressions on SSM/I sea ice extent, NCEP 2-meter air temperature analyses, and NCEP sea level pressure analyses to predict a sea ice extent. Regressions are done for each point in the model domain. For each of four outlooks, week-by-week projections were done to project a time series of ice extent over summer 2011. As seen in Figure 1, the date of minimum sea ice extent shifts between the first and third week of September, but the values for the first three minimums are all much higher than the actual value. The sea ice extent is over-predicted because climatologically, the past 10 summers had more ice even given similar atmospheric conditions. Thus the projected values were stuck in a statistical rut. It was understood before August that the MLR model was likely over-predicting the September minimum; the question was whether the MLR model could project "outside the box" and adjust to unusual conditions. For the August 1 Outlook, it finally did.

[1] Funded by the UCAR Visiting Scientist Program
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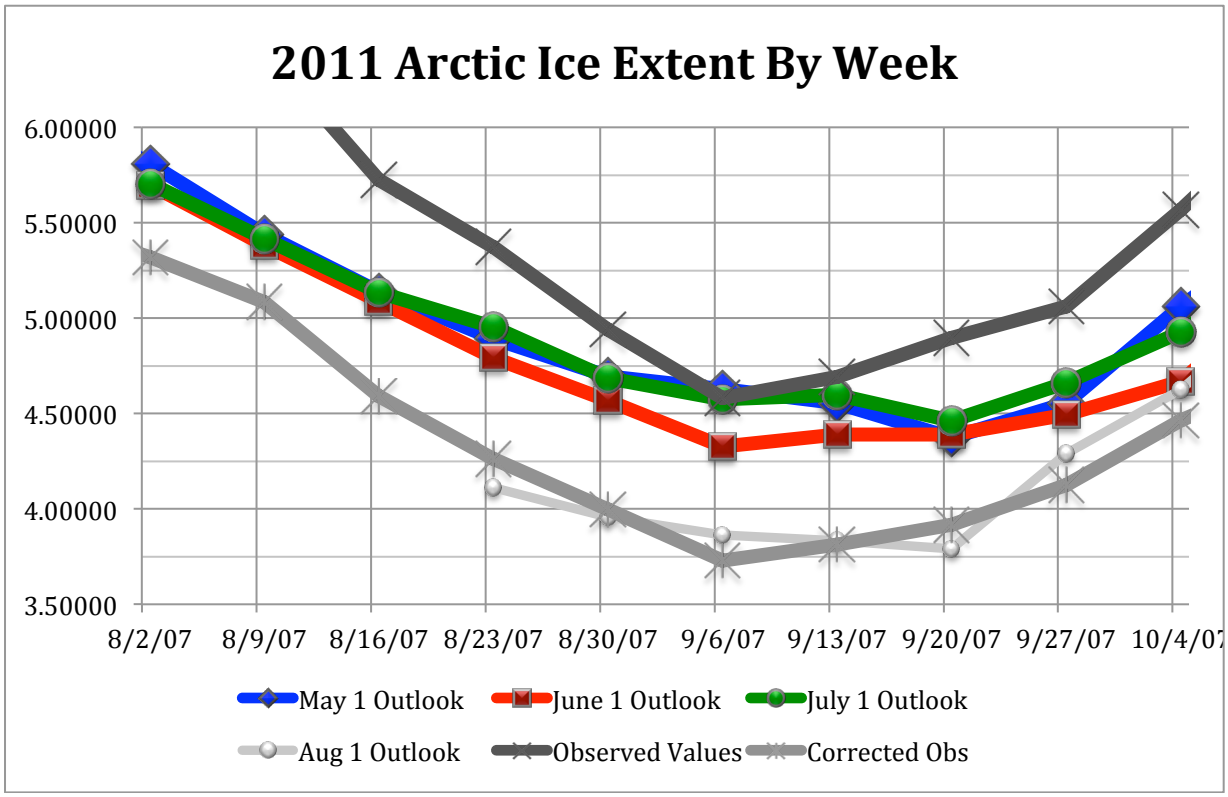

Figure 1: Projected sea ice extents for summer 2011 by the NIC multiple linear regression (MLR) model, with observed ice extent and corrected observations (see text for explanation).

Hence the model's predicted sea ice extent number cannot be compared directly with the observations from NSIDC. But from Table 1, the week of minimum projected sea ice extent contained the minimum date observed by NSIDC. Table 2 shows the projected minimum for each of the four outlooks (May 1, June 1, July 1, and August 1, representing conditions from the end of April, end of May, end of June, and end of July). The dates of minimum sea ice extent are all the third week of September, with the exception of the June 1 Outlook, which predicted (correctly, it turns out) that the minimum would occur the week of September 7.

Table 1 shows the observed weekly minimums for September 2011 calculated from the SSM/I data. NSIDC's minimum value occurred during the week beginning September 7, and that is also the week of minimum sea ice extent seen here, 4.58 million km^2. However, due to the coarse resolution of the model (25 kilometer EASE grid), areas such as the Canadian Arctic Archipelago, Hudson Bay, and some narrow straits in the Arctic are masked out. Thus the model will only predict in more open areas of the Arctic. The corrected minimum represents those areas where the model can produce an outlook, and as shown in Table 1, the difference between all observed ice and that observed in the prediction zone can be up to 1 million km^2.

Table 1: Weekly observed sea ice extent values from SSM/I for September 2011. Corrections for the MLR model mask are also given.

Week	Observed Minimum (million km^2)	Corrected Minimum (million km^2)	Mask Difference (million km^2)
9/7/11	4.58000	3.72750	0.85250
9/14/11	4.69187	3.81250	0.87937
9/21/11	4.89563	3.91812	0.97751
9/28/11	5.06063	4.12500	0.93563

A crude approximation of the full ice extent, and hence a rough comparison with NSIDC values, can be obtained by adding the masked ice back to the projections. Of course the biggest assumption is that the masked ice would be there, and in this summer, a lot of it probably would have melted away. Nevertheless, the end value of 4.71 million km2 (now occurring the week of September 14) for the August Outlook is very close to the actual observed value of 4.69 million km2 for that week, and reasonably close to the absolute minimum of 4.58 million km2 seen the week before. These adjustments could be used next year to bring the NIC projections in line with a full Arctic domain; however, it is more likely that the MLR model will use higher resolution and a finer dataset, such as the IMS snow and ice product produced at NIC.

Table 2: Projections of September minimum Arctic sea ice extent by the NIC MLR model, and adjusted projections accounting for the model sea ice mask.

Outlook Date (2011)	Projected Minimum (million km^2)	Week of Projected Minimum	Adjusted Projection (million km^2)	Week of Adjusted Minimum	Difference from Observed (million km^2)
May 1	4.37187	9/21/11	5.34938	9/21/11	0.45375
June 1	4.32688	9/7/11	5.17938	9/7/11	0.59938
July 1	4.46187	9/21/11	5.42625	9/7/11	0.84625
August 1	3.79063	9/21/11	4.71187	9/14/11	0.02000

Comments on SIO Outlook Results

Compared to the ARCUS August report, two-thirds of the outlooks (including mine), in roughly equal numbers of statistical, physical, and heuristical modeling, overpredicted the actual sea ice minimum (not accounting for error bars). However, the majority of these overpredictions were fairly narrow in their error, from 100,000 km2 to 200,000 km2 above the actual value. To my knowledge, there was nothing exceptional about the atmospheric conditions over the Arctic in summer 2011 (although I have not looked at this closely); what was more important in 2011 was the preconditioning of the system. Specifically, the Arctic sea ice at the beginning of Summer 2011 was younger (less multi-year ice, more first-year ice) and thinner than in any previous year on record. First-year ice is more subject to melt because of its lower albedo, and with thinner ice (hence, less ice mass and volume), there was simply less to melt than in previous years. Although 2011 was not remarkable atmospherically speaking, the Arctic sea ice has apparently reached a point where even an average year will result in what was previously considered an exceptional amount of ice loss. Whether this is "the new normal", or the Arctic is still in a downward spiral remains to be seen. In order for the Arctic to return to historical conditions, it would require a sequence of colder than average winters in order to build up a multiyear ice pack. The most desirable new data to add to the mix would be sea ice thickness; however, this is also the most difficult to obtain.

Comments on the Sea Ice Outlook Project

To date, the SIO project has focused on the September Arctic sea ice minimum sea ice extent. This is a number that captures the imagination of the public, as it is easy to look at at a plot of a two decades of September and see that something is happening. From a research standpoint, it is a number that models of different flavors and stripes can predict, as has been seen over the past few years. In addition, regional outlooks are also included for September, and a separate outlook project for the Bering Strait region (the Sea Ice for Walrus Outlook) has been added.

The SIO focuses on September in the Arctic, but predicting conditions along the Alaskan North Slope for other summer months, as well as conditions in the Bering Sea year round, would aid the operational community. It was suggested at a recent workshop in Anchorage that the SIO use its organizational ability to encourage development of methods to be tested in the Bering and Chukchi Seas. North Slope outlooks were the impetus for the original Barnett Sea Index projections of navigation conditions between Barrow and Prudhoe Bay developed at NIC in the 1970s. With the likelihood of trans-Arctic international shipping routes coming through Bering Strait within a generation (or possibly sooner), it is of importance for commerce, search-and-rescue, and national security that accurate medium-range sea ice forecasting be developed for the Arctic, and particularly for the Alaska region.

Finally, the use of the NSIDC Sea Ice Index as "truth" for the SIO comes with an asterisk. It was chosen because it is the longest readily available indicator of Arctic sea ice extent and concentration (and hence a consistent dataset to use for hindcasting and other forms of model validation). But it is also understood that it is not the most accurate. As the need for improved methods increases, the SIO should consider using a higher-resolution product. The MASIE product, produced jointly by NIC and NSIDC, provides sea ice extent at up to 4 km resolution.