Sea Ice Outlook Contribution, 31 May 2014

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Average Prediction: 4.97 $\pm$ 0.73, range 3.97 to 5.82 10^6 km²

Summary

We use the survival of ice of different ages to statistically predict the 2014 minimum. Ice age fields are based on the ice age algorithm of *Fowler et al*. [2003]. The ice age product is based on a 15% sea ice concentration threshold to be consistent with the threshold used for mapping overall sea ice extent. In addition, the use of a 15% threshold captures greater detail within the marginal ice zone. Using this approach and taking into consideration that the survivability of ice during the summer melt season has changed in recent years, gives an estimate of 4.97 $\pm$ 0.73 10^6 km² using an average of ice survival rates from the last 5 summers (2009-2013). This is slightly above the linear trend value of 4.79 10^6 km². The predicted extent increases to 5.35 $\pm$ 0.92 10^6 km² using an average from the last 10 years. Because the summer atmospheric circulation pattern plays an important role in how much ice survives each summer, the predictive skill remains low during anomalous years. To estimate a range, we used estimates from the summer with the lowest (2012) and highest (2009) survival rates within the last 5 years, giving an expected range of 3.97 10^6 km² to 5.82 10^6 km². We do not predict a new record low will occur in 2014.

Method

At any time of the year, the total sea ice area can be defined as the sum of the areas of the individual ice age classes, such that the total ice area (SI) is defined as:

$$SI = F_1 + F_2 + F_3 + \ldots + F_n$$

Where F_1 is the area fraction of first-year ice, F_2 is the area fraction of second year ice, etc. The amount of ice left over at the end of summer (SI_{sep}) then depends on the survivability of the winter ice cover (SI_{mar}) which can be defined as the survivability of the ice of different ice age classes, i.e. s_1 equals the survivability of the winter first-year ice fraction (F_{mar_1}). Thus, SI_{sep} equals:

$$SI_{sep} = s_1{}^*F_{mar\_1} + s_2{}^*F_{mar\_2} + \ldots + s_n{}^*F_{mar\_n}$$

where the survivability for a specific ice age class (e.g. s_1) is equal to the ratio of the September to April fraction of that age class (e.g. F_{sep_1}/F_{mar_1}). In this context, survivability includes melt and transport components.

As we did last year, we account for survival rates as a function of latitude to compensate for the fact that over the past few years', first-year ice has been found at much higher latitudes than has been typical during previous years. Breaking up the analysis into 2-degree latitude bands, the total September ice area is then the sum of all survival rates for each ice age category and for each latitude band:

$$SI_{sep} = \sum_{lat} s_{1lat} * F_{mar\_1_{lat}} + s_{2lat} * F_{mar\_2_{lat}} + \ldots + s_{nlat} * F_{mar\_n_{lat}}$$

One problem with this approach however, is that the ice age data are restricted to open ocean areas only, where ice motion can be resolved with the satellite passive microwave data. Thus, this data set does not cover the passages in the Canadian Archipelago. In order to take into consideration the sea ice area of the Canadian Archipelago, we add the survival rate of the region for each year

so that the final equation can be written as:

$$SI_{sep} = (\sum_{lat} s_{1_{lat}} * F_{mar\_1_{lat}} + s_{2_{lat}} * F_{mar\_2_{lat}} + ... + s_{n_{lat}} * F_{mar\_n_{lat}}) + CAA\_survival * March\_CAA$$

Computing this for every year, using each year's survival rates together with the ice age distribution from the end of 2014 and the "extra" ice not mapped by the ice age data gives the results show in **Figure 1**, which shows the predicted minimum September extent for 2014 as a function of individual yearly survival rates, ordered by high to low predicted values. For reference, the blue line indicates the observed 2012 minimum and the red line the 1981-2010 climatology mean September extent. These predictions indicate that it is not forecasted that the extent will break a new record low, but that it is likely the extent will remain well below climatology.
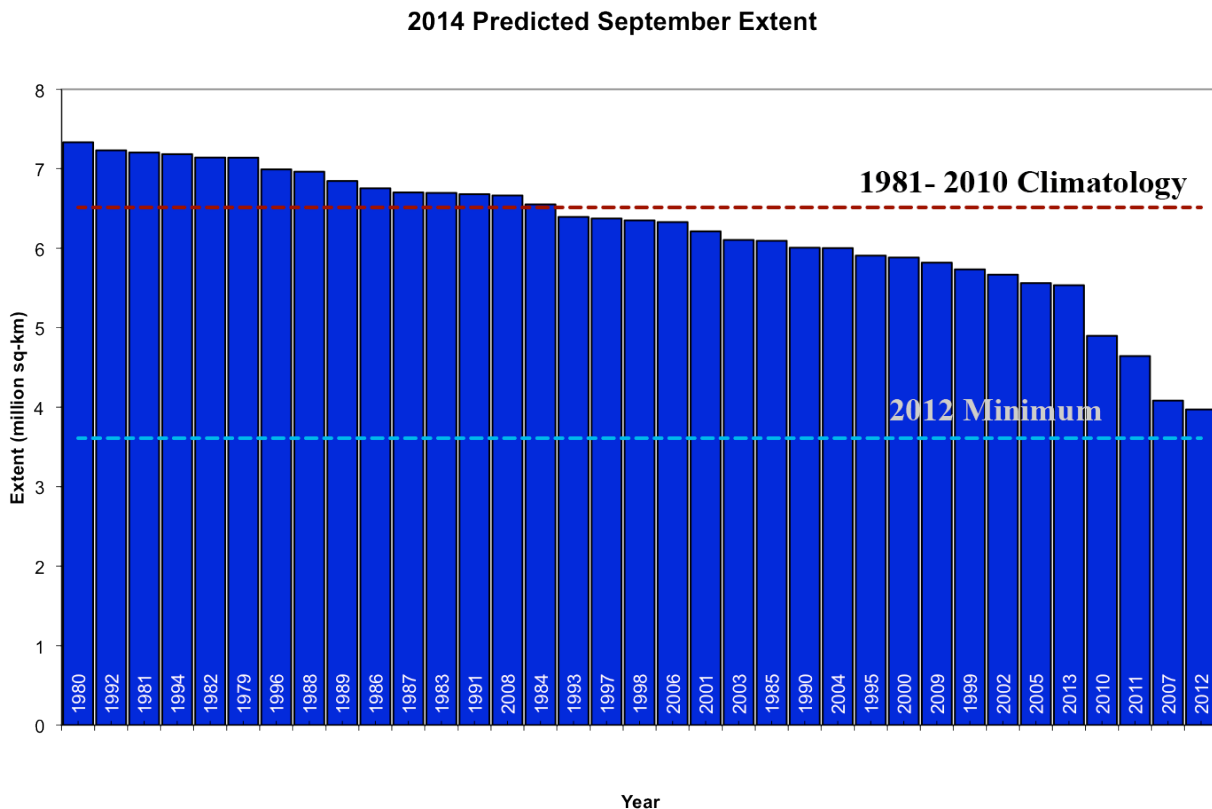

Figure 1. Estimated 2014 minimum extent based on ice age survival rates from previous years (1979-2013). Blue line shows the observed 2012 September extent, red line shows the observed 1981-2010 climatology for reference.

Discussion

The first result is that given the distribution of ice age this April (**Figure 2**), a new record minimum is not predicted. This winter has seen an increase of old ice within the Beaufort Sea that will likely help to slow ice loss in that region. Additionally, there is a tongue of 2nd year ice extending from the central Arctic Ocean towards the E. Siberian Sea. The fraction of the Arctic Ocean covered by first-year ice at the end of April is 68% compared to 77% in 2013. This is the smallest fraction of FYI since 2007 when 64% of the Arctic Ocean was covered by FYI. If a summer such as 2007 were to occur this year, we would expect slightly less ice at the end of September than we saw in 2007 (4.08 10^6 km^2 vs. 4.30 10^6 km^2).

The second result is that if we took an average of survival rates over the entire data record, the minimum is forecasted to be 6.22 10^6 km^2, slightly below the September climatological ice extent from 1981-2010 of 6.51 10^6 km^2. However, it is clear that climate conditions have changed during the last several years, which impacts on the survivability of the winter ice cover. The Arctic atmosphere has warmed in all months during the last decade [e.g. *Stroeve et al.*, 2011a], melt onset begins earlier in the year and the ice freezes later [e.g. Stroeve et al., 2014; Markus et al., 2009], resulting in an enhanced the ice-albedo feedback [*Perovich et al.*, 2011] and increased the sensible heat content of the ocean. In addition, there is evidence that the old ice has thinned.
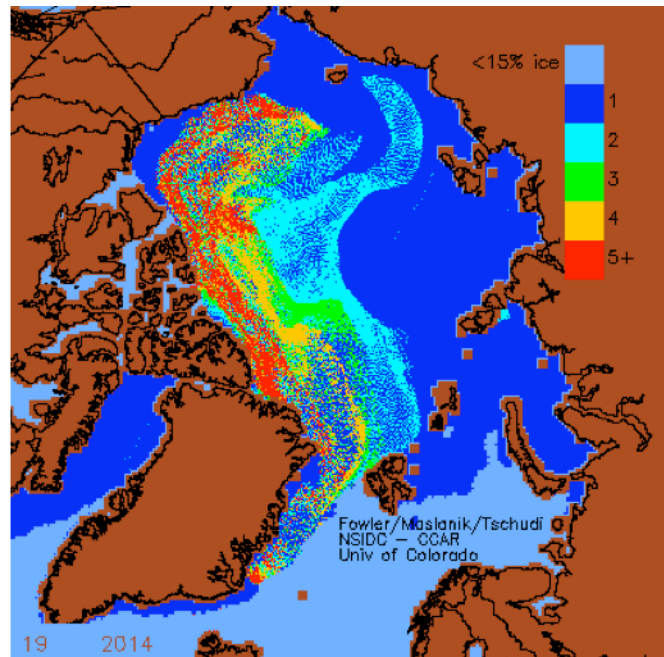
Figure 2. Map of ice age from week 19 (end of April 2014) based on the Fowler et al. 2003 algorithm.

Figure 3 illustrates how sensitive the forecast from 1990 to present is on the choice of ice survival rates. Shown are hindcast and 2014 September ice extent predictions for each year from 1990 to 2013 based on the choice of survival rates, including using 5 or 10 years prior to the year being predicted, or using all years. During the 1990s, using the prior 5 or 10 years of survival rates resulted in similar predictions for the September ice extent that were near those observed. These predictions in general performed reasonably well, with a mean difference of 57,720 km^2 when using the 5 prior years, and 9,620 km^2 when using the prior 10 years from that observed during 1990-1999. Anomalous years however remained hard to predict. The applicability of using prior years for an estimate of how much ice survives each summer breaks down after 2006, except in 2009 and 2013, which had observed extents near the long-term trend. This supports the conclusions of Stroeve et al. 2014 that summer weather patterns place a limit on how well the September minimum can be forecasted. Also shown is how predictions

would have fared for all years if using just the last 5 or 10 years (2009-2013 or 2004-2013) as an estimate. This indicates that survival rates have substantially changed in the last decade, such that if those rates had been valid in the 1990s, ice conditions for September would have been between 5 and 6 million km^2 rather than 6 to 8 million km^2.

Predicted September Sea Ice Extent
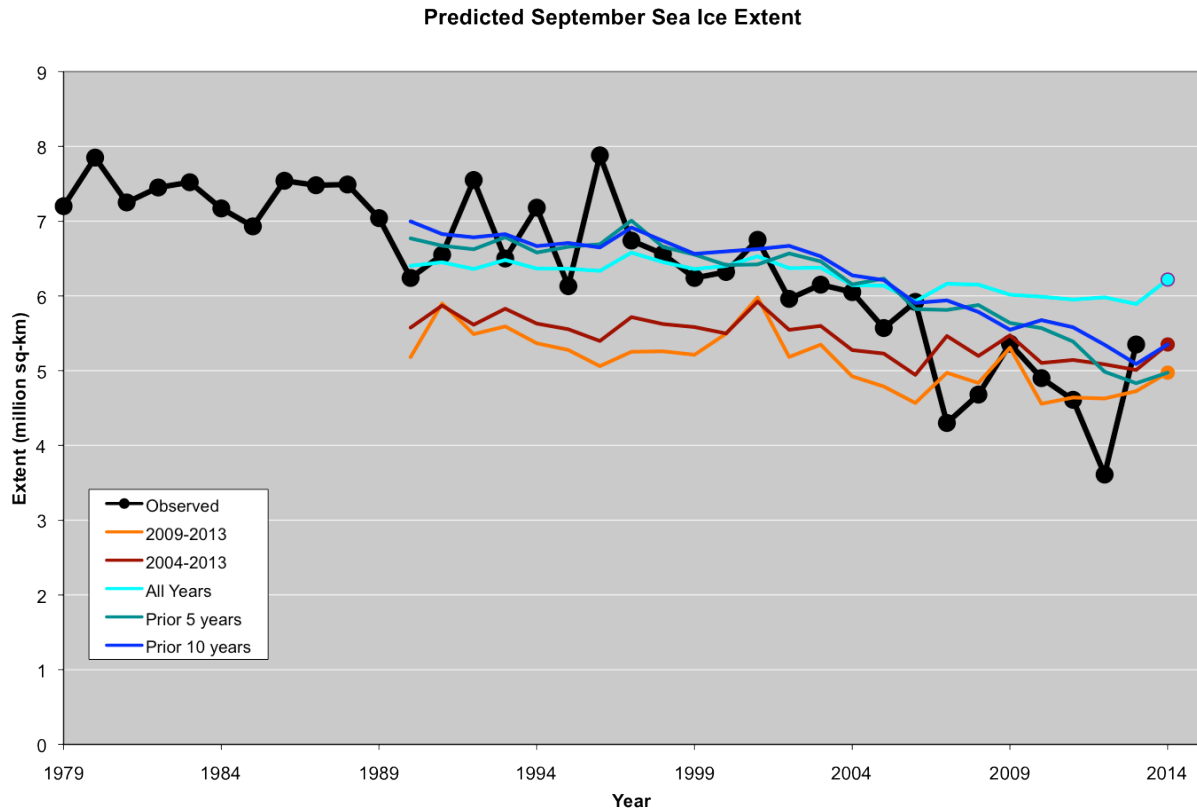
Figure 3. Comparison of predicted September extent from 1990 to 2013 with that observed (black lines). Each colored line represents a hindcast prediction and 2014 prediction based on different estimates for how much ice survives each summer. Results are shown for different ice survival rate time-periods (i.e. 5 and 10 years prior to the actual year to be predicted, predictions based on all years survival rates, and how predictions perform if using the 2009-2013 and 2004-2013 as in indicator) and illustrate the importance of variability in ice survival rates.

References

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Details

Our first Outlook contribution in 2008 employed ice age fields provided by Chuck Fowler and Jim Maslanik (Univ. Colorado, Boulder). Because most of the summer ice loss is due to first-year ice (FYI), the survival of FYI is an important component of the end-of-summer minimum extent. How much FYI survives the summer melt season depends on a number of factors, e.g., the amount of FYI at the start of the melt season, the location of the FYI within the Arctic, advection of FYI ice (within and out of the Arctic basin), and of course the evolution of summer atmospheric and oceanic conditions. Though less of a percentage than FYI, some older multiyear ice (MYI) also does not survive the melt season due to the same factors. Thus, we accounted for the survival rates of all ice age types.

Historically, different summers have had substantially different survival rates. If we assume that conditions during the forthcoming summer will fall somewhere between the extremes of the historical period between 1985 and 2013, we provide a reasonable range of potential minimum extent based on the range of survival rates through previous summers.

In 2008 our range was too high and largely overestimated the minimum extent. We assessed that this was due to the fact that after the extreme low of 2007, there was far more FYI much farther north than normal. This FYI, though likely of similar thickness as previous years, was subject to lower solar forcing because of the high latitude. Thus, for 2009, we adjusted our method by calculating survival rates in 2 degree latitude bins. This slightly overestimated the minimum extent, perhaps because the low amount of FYI at high latitudes in previous years did not provide robust statistics. However, the overestimation was 27,810 km^2 (5 prior years) to 18,690 km^2 (10 prior years). Since then the algorithm has not performed as well, though except for 2012, the predicted extent was within 800,000 km^2 of that observed for each year, with the best performance in 2013. In 2012, the predicted extent was well over a million km^2 higher than observed.

This year presents an interesting challenge. Unlike recent winters, there is more multiyear ice in the Arctic Basin, an amount similar to 2007. There has also been advection of MYI into the Beaufort Sea that may help to slow ice loss in that area this summer, and tongue of 2nd year ice extends into the E. Siberian Sea (Figure 2). The significant amount of FYI that was retained at the end last summer, has since aged (and thickened) into 2nd year ice resulting in an overall larger fraction of 2nd year ice than 2007 and every year since except 2010. The fate of this 2nd year ice is a bit of a wildcard in our estimates because if much of this ice does melt out completely, our prediction will be too high. The minimum extent for 2014 based on the average of the previous 5 years is 4.97 10^6 km^2, with a one-standard deviation range of 4.24-5.71 10^6 km^2 million square kilometers. Based on the extremes of survival rates from previous years give a range between 3.97 10^6 km^2 (based on 2012 survival rates) and 7.33 10^6 km^2 (based on 1980 survival rates). None of the yearly survival rates suggest a new record low this summer, though if ice survival rates are similar to 2007 and 2012, 2014 would be the second lowest on record.