Canadian Ice Service Contribution

to the

September 2013 Sea Ice Outlook
(June Issue)

Environment Canada's Canadian Ice Service (CIS) is predicting the minimum Arctic sea ice extent to again be near or just below 4.0 million square kilometres in September, 2013. A value of ~**3.8 million square kilometres** is predicted, which will make the Arctic sea ice extent in September, 2013, the second lowest in the 1979-2012 record. This value lies well below the 1979-2013 average September extent of 6.4 million square kilometres based on the NSIDC sea ice index.

As with previous CIS contributions the 2013 forecast was derived by considering a combination of methods: 1) a qualitative heuristic method based on observed end-of-winter Arctic ice thicknesses and extents, as well as an examination of Surface Air Temperature (SAT), Sea Level Pressure (SLP) and vector wind anomaly patterns and trends; 2) an experimental Optimal Filtering Based (OFB) Model which uses an optimal linear data filter to extrapolate NSIDC's September Arctic Ice Extent time series into the future; and 3) an experimental Multiple Linear Regression (MLR) prediction system that tests ocean, atmosphere and sea ice predictors.

Based on winter sea ice extents and thicknesses, a September 2013 *minimum* ice extent value of **3.6 million square kilometres** is heuristically predicted. The CIS experimental OFB model predicts a September 2013 *average* ice extent of **4.05 million square kilometres**. The CIS experimental MLR forecast system predicts a September 2013 *average* sea ice extent of **5.0 million square kilometres** (3 model runs with a range of 4.4 to 5.7). The average forecast value of the three methods combined is **4.2 million square kilometres.** However, although it has proven skilful and outperforms the OFB model in many regions of the Canadian Arctic, the MLR forecast system has considerably overestimated the pan-Arctic minimum ice extent for the past several years. For this reason, the CIS is excluding its contribution from the final estimate this year. Therefore, based on a combination of the heuristic and OFB model predictions only, the CIS is forecasting a 2013 pan-Arctic September sea ice minimum of ~**3.8 million square kilometres.**

The CIS will be continuing its verification studies of the predictions produced by these methods/models in the coming years.

Heuristic Forecast

- Based on a visual examination of the NSIDC time series for average September sea ice extent, it is rare to see sea ice extents continue to decrease for more than two or three years in a row – simply due to the inter-annual variability about the prevailing trend.
- Some recirculation of the Arctic Ocean multi-year ice pack into the Beaufort Sea occurred this past winter (as a result of a predominantly negative AO pattern), partially limiting the dynamic loss of MYI through Fram Strait (Figure 1).
- The sea ice in Nares Strait consolidated very early this past winter, in November 2012 (2-3 months earlier than normal according to the Canadian Ice Service Digital Ice Chart Database). This event, which was aided by a large fragment of the 2012 Petermann Ice Island that had grounded in southern Kane Basin, therefore served to block MYI losses through this gateway for an additional 2-3 months this past winter.
- Air temperatures in the southeastern Beaufort Sea were well below both the 1971-2000 and 1981-2010 normals this past winter, especially in February. These cold temperatures, combined with the southward compaction of the sea ice due to the negative-AO-enhanced Beaufort Gyre, caused the sea ice in this area to become almost immobile for an extended period. When movement in the ice pack resumed, the sudden re-fracturing of the Beaufort ice at the end of February / early March was catastrophic and made news headline everywhere. Following this fracture event, limited movement and colder than normal air temperatures in the southern Beaufort Sea then resumed. The onset of melt in the southern Beaufort Sea is therefore expected to be "near-normal" this year, as opposed to "earlier than normal".

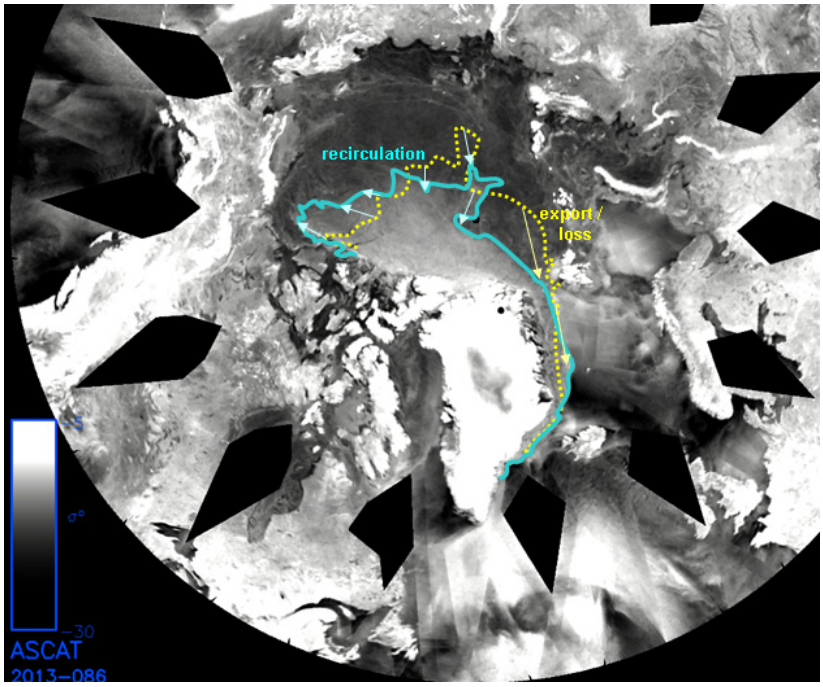

Figure 1. Change in Arctic Ocean Multi-year ice extent between 02 December 2012 (yellow) and 28 March 2013 (blue).

Based on the points above, Arctic Ocean September sea ice extents (while expected to be well below the 1979-2013 average of 6.4 million square kilometres, and while expected to continue to be near or below 4.0 million square kilometres) are therefore expected to experience a slight recovery, preventing a repeat of last year's record. The CIS heuristic forecast for the 2013 pan-Arctic end-of-melt-season minimum sea ice extent is **3.6 million square kilometres**.

Statistical Method #1: Optimal Filtering Based Model Forecast

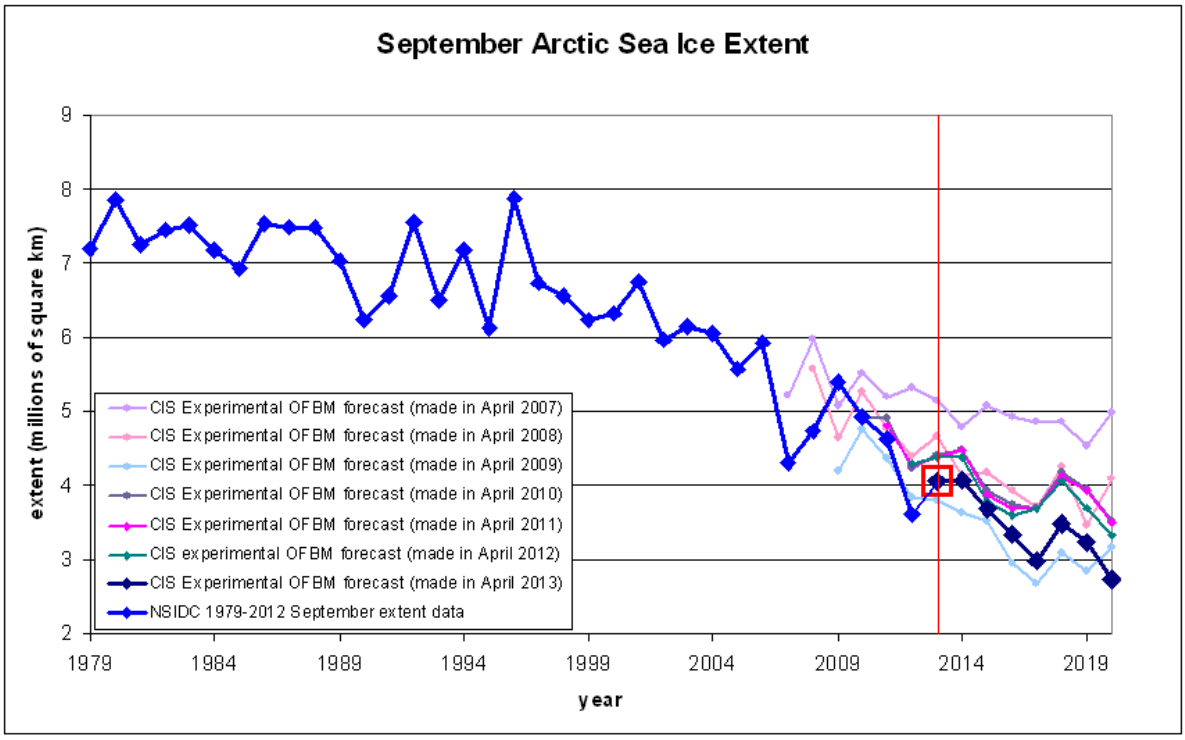

Figure 2. The Optimal Filtering Based model (OFBM) forecast for 2013-2020 (made in April 2013 – indigo line, based on NSIDC September extent data – blue line). The **2013 forecast** for the September average sea ice extent is **$4.05*10^6$ km^2**. The forecasts out to 2020 made in previous years are also shown for comparison.

Model Details

Details of the Optimal Filtering Based Model (OFBM) used here, as well as the model code, can be found in Press et al. (1992). Models based on optimal linear data filters have proven skilful at predicting other climate indices (e.g. Nino3 and Nino3.4 SSTs – Kim and North, 1998; 1999).

year	forecast	observed	difference
2007	5.21	4.3	0.91
2008	5.56	4.68	0.88
2009	4.2	5.36	-1.16
2010	4.91	4.9	0.01
2011	4.8	4.61	0.19
2012	4.3	3.61	0.69

Table 1. Verification: CIS OFBM forecasts for past September average sea ice extent (millions of square kilometres)

References:

Kim, K-Y., and G.R. North (1998): EOF-Based Linear Prediction Algorithm: Theory. *Journal of Climate*, **11**, 3046-3056.

Kim, K-Y., and G.R. North (1999): EOF-Based Linear Prediction Algorithm: Examples. *Journal of Climate*, **12**, 2076-2092.

Press, W.H., S.A. Teukolsky, W.T. Vetterling and B.P. Flannery (1992): Numerical Recipes in Fortran 77, Second Edition: The art of scientific computing. Cambridge University Press, Cambridge, UK. [Chapter 13, section 13.6].

Statistical Method #2: MLR Prediction System Forecast

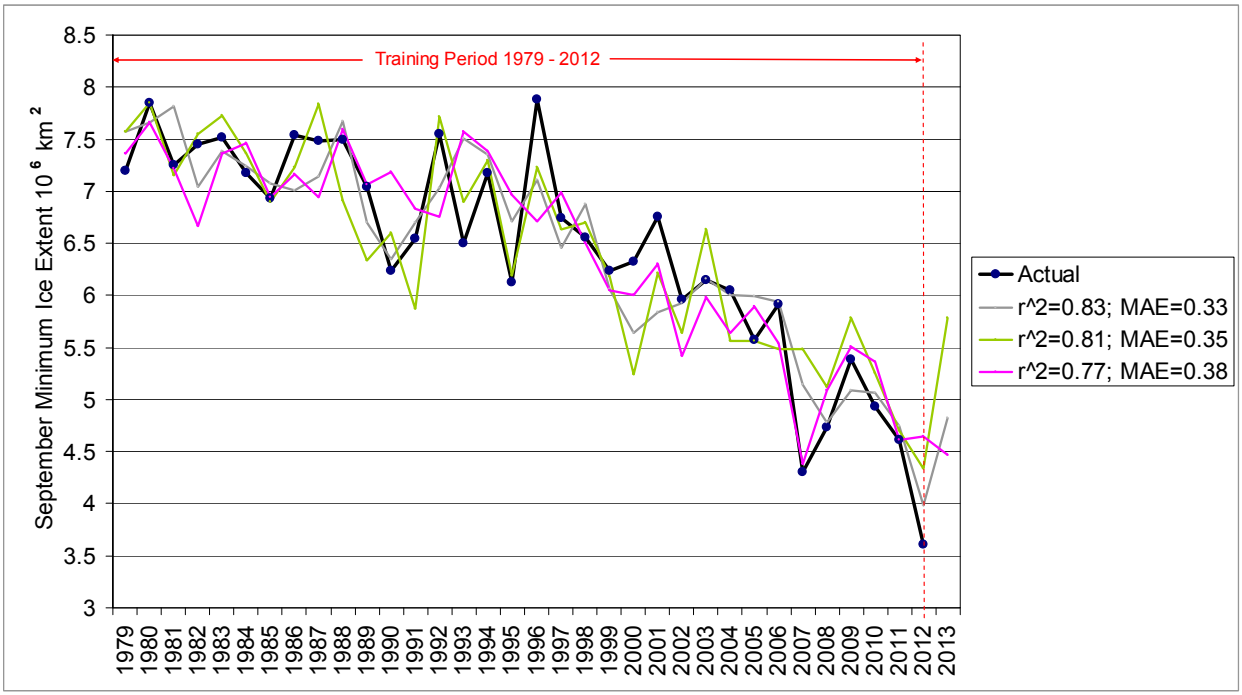

Figure 3. Regression based forecast for the 2013 Average September Ice Extent. The model is trained on the 34-year period from 1979-2012. The **2013 forecasts** from the 3 model runs range from 4.4 to 5.7 and average **5.0*10^6 km^2**.

Model Details

The regression models are generated using an automated selection scheme (Tivy et al., 2007) based in part on step-wise regression and where the maximum number of predictors is restricted to two. Predictors in the original predictor pool included: pan-Arctic sea ice concentration, SLP and z500, near-global SST, and indices for ENSO, the PDO, the AO, NAO and other atmospheric teleconnections. Each predictor was tested at lags ranging from 5 to 18 months. After each model run the first predictor was removed from the predictor pool, this process was repeated until no models were generated. Three regression equations were generated for the September minimum; it is important to note that they are not necessarily independent. The pairs of predictors for the 3 models are: MMJ SST & ICE CT, SON SLP & SNOW, JAS SAT & z500.

year	forecast	observed	difference
2009	5.65	5.36	0.29
2010	5.70	4.90	0.80
2011	5.60	4.61	0.99
2012	5.10	3.61	1.49

Table 2. Verification: CIS MLR forecasts for past September average sea ice extent (millions of square kilometres).

Reference:

Tivy, A., B. Alt, S.E.L. Howell, K. Wilson, and J.J Yackel. (2007). Long-range prediction of the shipping season in Hudson Bay: A statistical approach. Weather and Forecasting, 22, 1063–1075, doi:10.1175/WAF1038. WAF10