September 2015 Sea Ice Outlook

(June Issue)

Canadian Ice Service

Environment Canada's Canadian Ice Service (CIS) is predicting the 2015 minimum Arctic sea extent at $4.7 * 10^6$ km^2.

As with previous CIS contributions, the 2015 forecast was derived by considering a combination of methods: 1) a qualitative heuristic method based on observed end-of-winter Arctic ice thickness extents, as well as winter Surface Air Temperature, Sea Level Pressure and vector wind anomaly patterns and trends; 2) a simple statistical method, Optimal Filtering Based Model (OFBM), that uses an optimal linear data filter to extrapolate the September sea ice extent time-series into the future and 3) a Multiple Linear Regression (MLR) prediction system that tests ocean, atmosphere and sea ice predictors.

Based on winter air temperatures and sea ice extents and thickness, a September 2015 minimum ice extent value of $4.5*10^6$ km^2 is heuristically predicted. The CIS OFB model predicts $4.42*10^6$ km^2 and the CIS MLR model predicts $5.3 *10^6$ km^2. The average forecast value of the three methods combined is $4.7 *10^6$ km^2.

Heuristic Forecast

The CIS heuristic for the 2015 September minimum is 4.5 $*10^6$ km^2. The uncertainty in the heuristic forecast is estimated at ±0.2 10^6 km^2

Rational:

- Early spring melt is starting to slow and we expect an over melt season that is close to normal
- Winter temperature anomalies (Nov-April) were warmer than normal over most of the Arctic Ocean particularly the Chukchi, Kara and Laptev seas. Temperatures were colder than normal over the Labrador Sea and in some parts of the Canadian Arctic Archipelago (CAA)
- Maximum level FYI thickness was probably thinner than normal throughout the Arctic Ocean and likely closer to normal throughout the CAA.
- Little MYI growth in the Beaufort Sea last year (see early Oct ice chart)

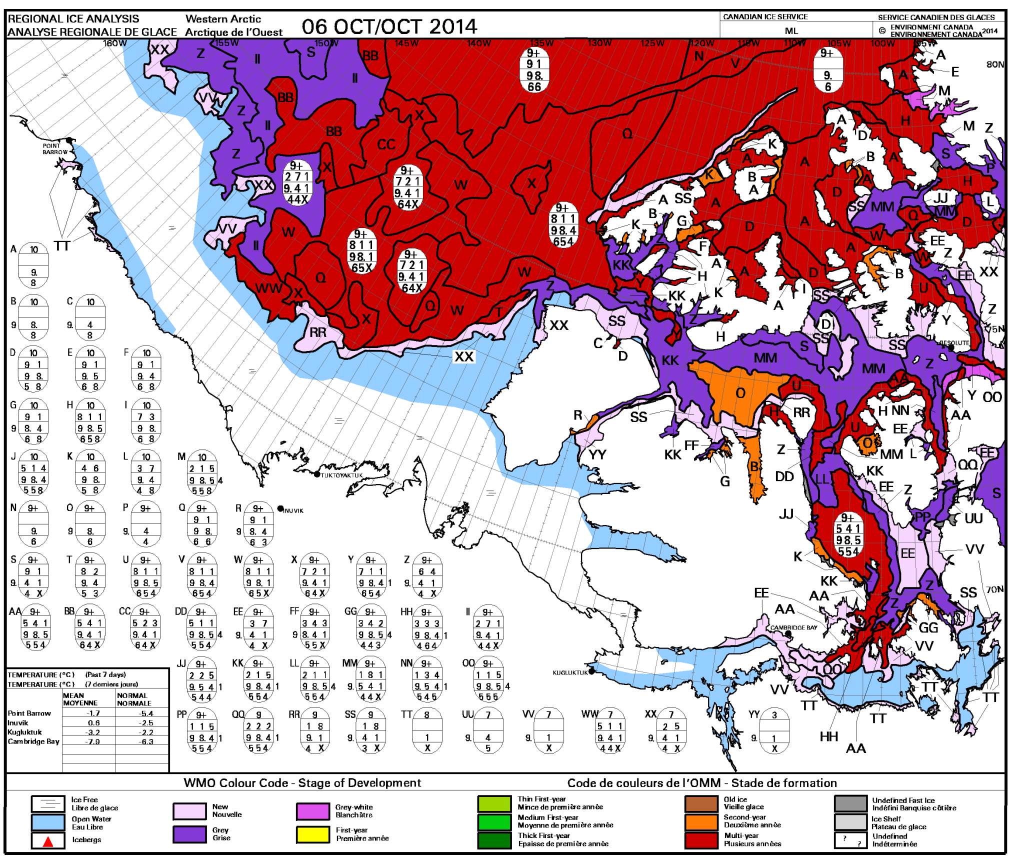

Figure 1. October 6, 2014 ice chart for the western Canadian Arctic Archipelago and Beaufort Sea. Areas in orange show second year ice, first-year ice that survived the 2014 summer melt season.

Statistical Method #1: Optimal Filtering Based Model

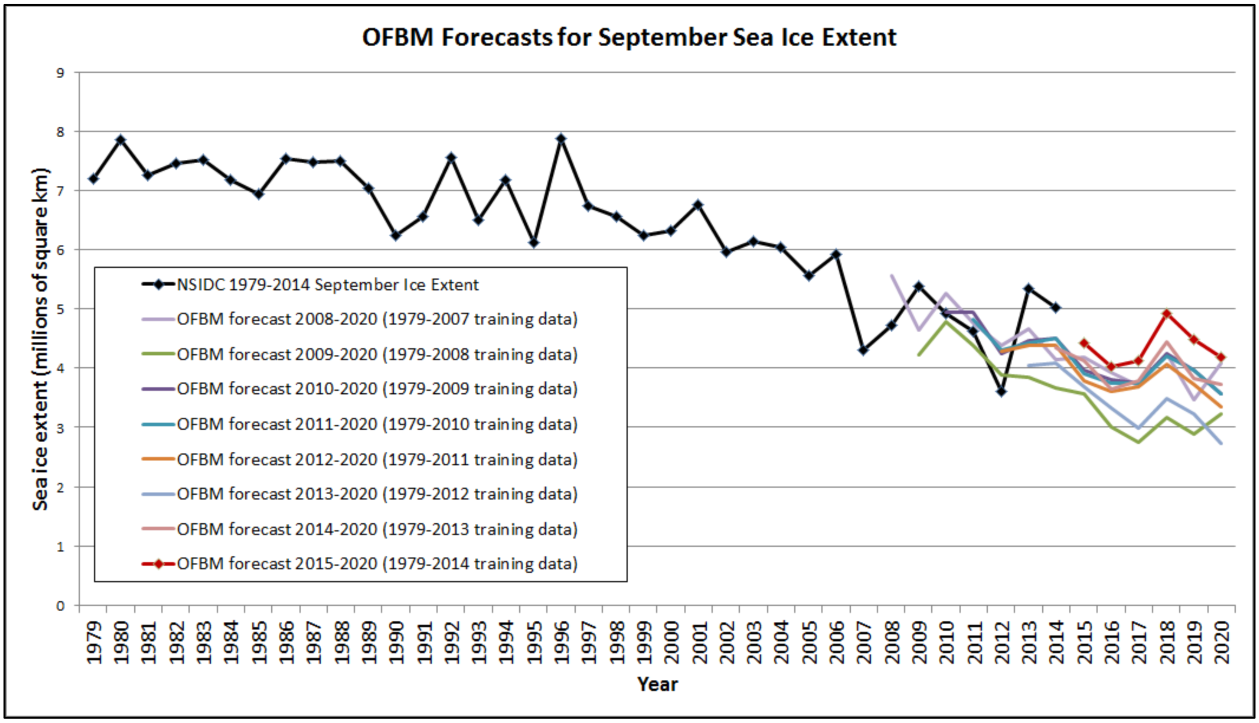

Figure 2. Optimal Filtering Based Model (OFBM) forecast for 2015-2020 based on 1979-2014 training data.

Forecast: The 2015 forecast for the September sea ice extent is **4.42 $*10^6$ km^2**.

Uncertainty: an estimate of uncertainty is given as the envelope of forecasts made in previous years out to 2020. The upper bound is this year's predictions and the lower bound is prediction made in 2009 using 1979-2008 as the training period.

Model Details/References

- Details of the Optimal Filtering Based Model (OBFM) used here, as well as model code, can be found in: Press, W.H., S.A. Teukolsky,W.T. Vertterling 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]
- Models based on optimal linear data filters have proven skill at predicting other climate indices (e.g. Nino3 and Nino3.4 SSTs): 1) Kim, K-Y., and G.R. North (1998): EOF-Based Linear Prediction Algorithm: Theory. J Clim, 11, 3045-3056. 2) Kim, K-Y, and G.R. North (1999): EOF-Based Linear Prediction Algorithm: Examples. J.Clim, 12, 2076-2092.

Statistical Method #2: Multiple Linear Regression Model

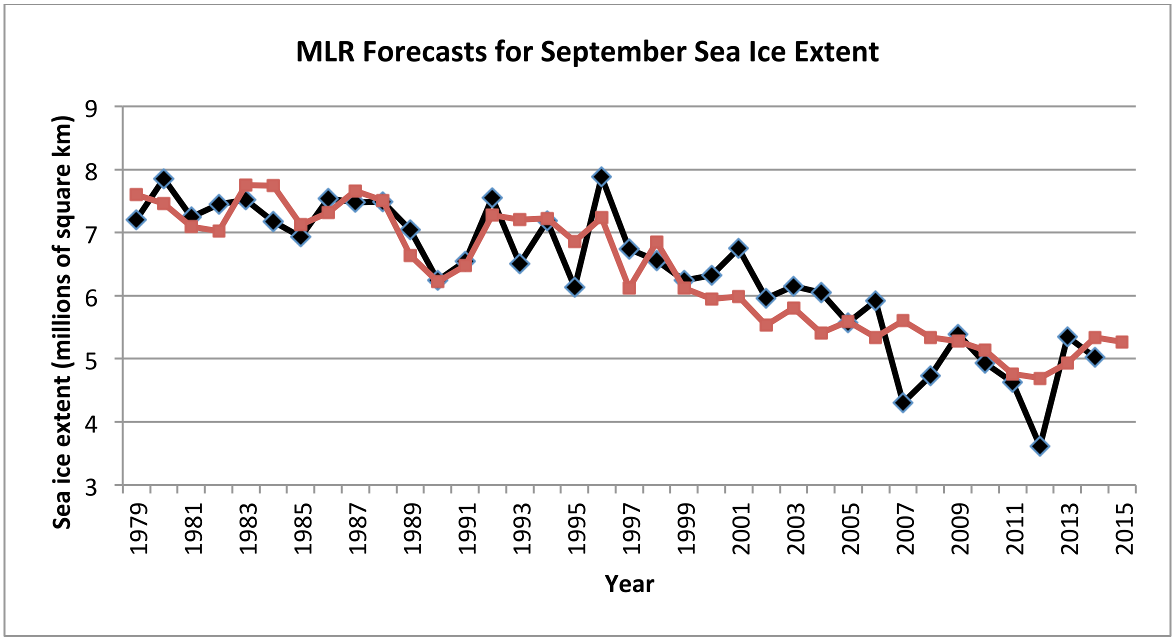

Figure 3. Regression based forecast for the 2015 September sea ice extent. The model is trained on the 36-year period, 1979-2014.

Forecast: The 2015 forecast for the September sea ice extent is **$5.3 * 10^6 km^2$**.

Uncertainty: The 90% confidence interval for the predicted value is ±0.8 $10^6 km^2$. The r-square, adjusted r-square and cross validated r-square for the regression equation are 0.79, 0.78 and 0.74. The mean absolute error and cross validated mean absolute error are 0.39 and 0.44.

Model Details/References

The regression model was generated using an automated selection scheme (Tivy et al. 2007) that uses step-wise regression and limits the number of predictors to only 2. Predictors included in the original predictor pool: pan-arctic (60N-90N) SLP and SAT; northern hemisphere z500 and z850; global, north pacific and north atlantic SST; monthly atmosphere teleconnection indices from NOAA/CPC, monthly AO, monthly SOI and monthly PDO. All predictors were tested at lags ranging between May (4-month lag with September) and the previous June (15-month lag with September).

The correlation patterns for the 2 predictors in the regression equation (Figure 3) are shown in Figure 4. The dominant predictor is summer (Jun-Jul-Aug) global sea surface temperature (left). The second predictor is March 500mb geopotential height (right).

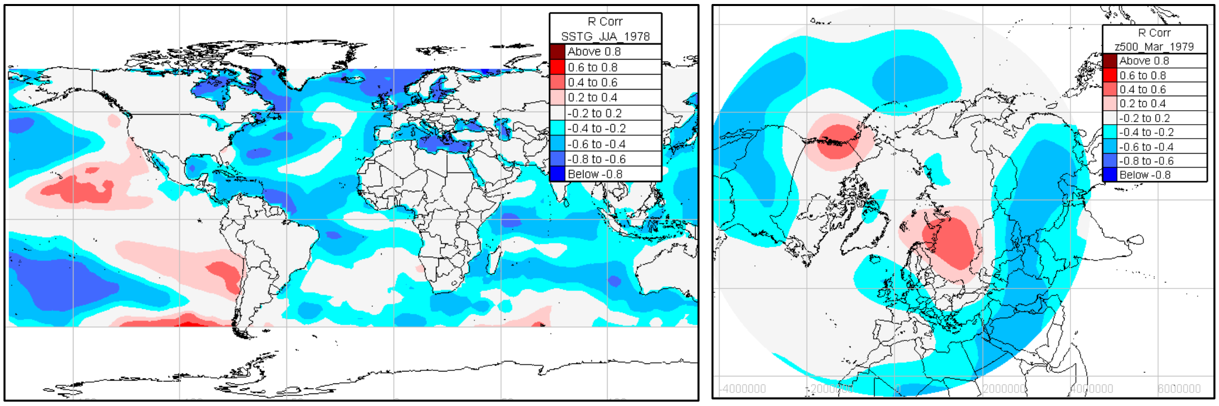

Figure 4. Correlation maps for the 2 predictors in the regression equation shown in Figure 3. Observations are regressed on the correlation map and summed over the domain to create a time-series. The dominant predictor is summer (Jun-Jul-Aug) global sea surface temperature (left) and the second predictor is March 500mb geopotential height (right).

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

Forecast Verification: Past June Outlooks vs 3 Benchmark Models

		CIS Forecast		Heuristic Forecast		OFB Forecast		MLR Forecast	
Year	Observed	Forecast	Diff.	Forecast	Diff.	Forecast	Diff.	Forecast	Diff.
2009	5.66	5	-0.66	5	-0.66	4.2	-1.16	5.65	0.29
2010	4.9	4.85	-0.05	4.85	-0.05	4.91	0.01	5.7	0.8
2011	4.61	4.9	0.29	4.7	0.09	4.8	0.19	5.6	0.99
2012	3.61	4.7	1.09	4.75	1.14	4.3	0.69	5.1	1.49
2013	5.35	3.8	-1.55	3.6	-1.75	4.05	-1.3	5	-0.35
2014	5.02	4.9	-0.12	4.8	-0.22	4.37	-0.65	5.6	0.58
2015						4.42		5.3	
MAE			0.63		0.65		0.67		0.75

Table 1. Verification of the CIS June outlook submissions starting in 2009. The final CIS forecast is a combination of a heuristic forecast and two statistical methods, optimal filtering based model and a multiple linear regression model.

		Climatology Forecast		Trend Forecast		Persistence Forecast	
Year	Observed	Forecast	Diff.	Forecast	Diff.	Forecast	Diff.
2009	5.66	6.32	0.93	5.25	-0.14	6.44	1.05
2010	4.9	6.24	1.31	5.15	0.22	6.12	1.19
2011	4.61	6.17	1.54	4.89	0.26	5.8	1.17
2012	3.61	6.07	2.46	4.63	1.02	5.98	2.37
2013	5.35	5.88	0.53	4.31	-1.04	5.76	0.41
2014	5.02	5.82	0.8	4.27	-0.75	5.4	0.38
2015		5.71		4.27		5.28	
MAE			1.26		0.57		1.1

Table 2. Verification of 3 benchmark models for the June outlook submission starting in 2009. The most common benchmark models are climatology, extrapolation of the long-term trend and anomaly persistence. The benchmark model forecasts are based on the previous 20 years as the training period. For example, the 2009 forecast is based on the 1989 – 2008 training period and 2014 is based on the 1993-2014 training period.