September 2016 Sea Ice Outlook

(July Issue)

Canadian Ice Service

Environment Canada's Canadian Ice Service (CIS) is predicting the 2016 minimum Arctic sea extent at $4.3 * 10^6$ km^2.

As with previous CIS contributions, the 2016 forecast was derived by considering a combination of methods: 1) a qualitative heuristic method based on observed end-of-winter Arctic ice thickness/extent, as well as winter surface air temperature, spring ice conditions and the summer temperature forecast; 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 2016 minimum ice extent value of $4.3*10^6$ km^2 is heuristically predicted. The CIS OFB model predicts $4.1*10^6$ km^2 and the CIS MLR model predicts $4.6 *10^6$ km^2. The average forecast value of the three methods combined is $4.3 *10^6$ km^2

Heuristic Forecast

The CIS heuristic for the 2016 September minimum is **$4.3 * 10^6$ km^2**. The uncertainty in the heuristic forecast is estimated at **± 0.2 10^6 km^2**

Rational:

Winter conditions (Nov-Apr)

- Above normal air temperatures across most of the Arctic and much higher than normal temperatures over the norther Barents Sea near Svalbard and over much of the Arctic Basin. Baffin Bay, Hudson Bay and Labrador saw near normal temperatures
- At the beginning of the winter less MYI than normal in the Beaufort Sea and many regions of the Canadian Arctic Archipelago; anomalies similar to 2010, 2011 and 2012 (Figure 1)
- April ice thickness from Cryosat shows thicker ice north of the Canadian Archipelago compared to the record 2012
- Measured fast ice thicknesses at select stations throughout the Canadian Arctic were near normal to below normal at the end of April, the exception is southern Baffin Island where measured fast ice thicknesses were above normal

Spring ice conditions

- Very early spring melt in the southern Beaufort Sea and Baffin Bay
- Fast ice fracture and melt season is 1 to 2 weeks ahead of normal throughout the CAA

Summer temperature forecast

- Above normal temperatures forecast through to October over the entire Arctic basin except for over the Laptev Sea where forecast is for slightly below normal temperatures. Forecast summer air temperatures for 2016 are most comparable to 2010 and 2011.

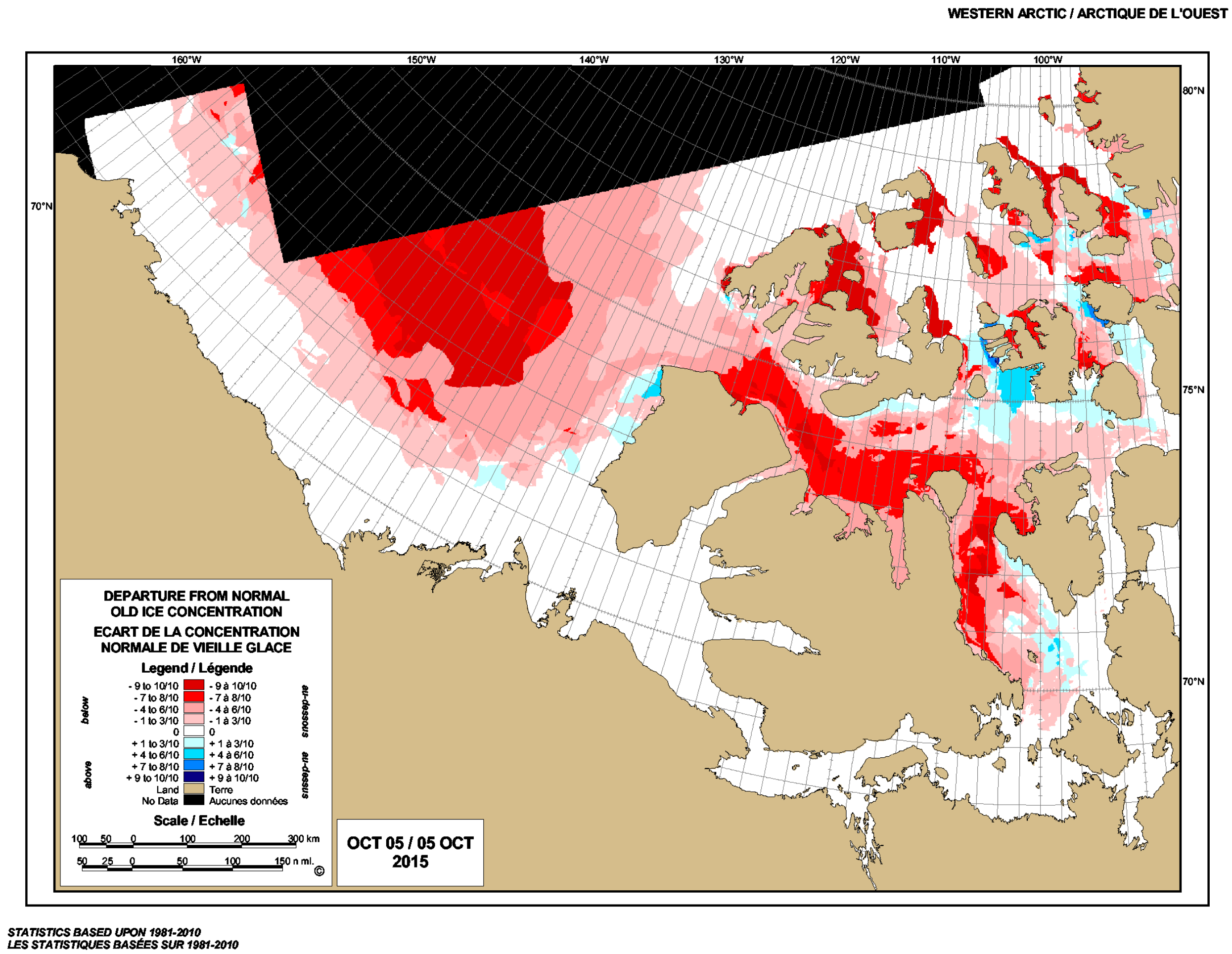

Figure 1. October 5, 2015 anomalies in multi-year ice concentrations (1981-2010 climatology)

Statistical Method #1: Optimal Filtering Based Model

Forecast: The 2016 forecast for the September sea ice extent is **4.1 $*10^6$ km^2**.

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

Forecast: The 2016 forecast for the September sea ice extent is **4.6 $*10^6$ 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 0.75, 0.74 and 0.69. The mean absolute error and cross validated mean absolute error are 0.46 and 0.48.

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, global SST; monthly atmosphere teleconnection indices from NOAA/CPC, monthly AO, monthly SOI, monthly PDO and monthly sea ice extent.

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	4.63	4.7	0.07	4.5	-0.13	4.42	-0.21	5.3	0.67
2016				4.3					
MAE			0.55		0.58		0.60		0.74

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	4.63	5.71	1.08	4.27	-0.36	5.28	0.65
2016		5.63		4.06		4.75	
MAE			1.24		0.54		1.0

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.