2012 Pan-Arctic Sea Ice Outlook
July Report based on June Data

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1. **Extent Projection 4.0 +/- 95% confidence interval of 0.9 M Km^2 based on past forecast performance of this technique.**

2. **Methods/Techniques - Statistical**

3. **Rationale**

   As previously, I use regression methods to predict the expected deviation from gompertz fit of September Extent. The alternative method I used last year of predicting falls from current area still does not show any skill at this length of time before the minimum.

   As last month, I use a linear regression to predict the deviation from Gompertz fit. The regression uses the residual from a gompertz fit of Cryosphere Today area at the end of June.

4. **Executive Summary**

   I attempt to predict the residual from a Gompertz fit of NSIDC average September Extent by a linear regression that uses Cryosphere Today area at 30 June residual from a Gompertz fit.

5. **Estimate of Forecast Skill**

   The standard error arising in the linear regression is .38 M Km^2. However, standard error of a method tends to underestimate the errors likely in practice. So I have used only information up to 30 June of the year being predicted to predict each of the last 10 years. As shown in the table this gives RMSE of .46 M Km^2. 0.46 has been doubled to give a 95% confidence interval of 0.92 M Km^2.

Estimates at 31 May of year concerned

Year	Gompertz Fit	Residual Est	Estimate	Error
2002	6.44	-0.32	6.12	0.16
2003	6.17	0.00	6.17	0.02
2004	6.06	0.18	6.24	0.19
2005	5.95	-0.21	5.74	0.17
2006	5.65	-0.25	5.40	-0.52
2007	5.62	-0.31	5.31	1.01
2008	4.74	0.19	4.92	0.19
2009	4.40	0.59	4.99	-0.40
2010	4.58	-0.37	4.21	-0.72
2011	4.48	-0.02	4.45	-0.16
2012	4.29	-0.26	4.03	
			RMSE	0.461

6. **Discussion of thickness and limits to method used**

I have attempted to predict PIOMAS volume minimum and Cryosphere Today area minimum using similar techniques. For PIOMAS volume, I try to predicting the fall from 30 June volume using a multiple linear regression with 3 predictors: 30 June PIOMAS volume, the residual from a gompertz fit of 30 June volume and the decline in volume in June. This gives a prediction of 2.2 K Km^3 +/- standard error of 0.55. This is a substantial 45% decline in the volume from the record low 2011 minimum of 4.02K Km^3.

I predict Cryosphere Today area minimum by using a gompertz fit of the minimum daily area and predicting the residual by a linear regression with residuals from a Gompertz fit of CT areas at 30 June. This gives a prediction of 2.6 M Km^2 +/- standard error of 0.27.

There is little difference in timing of minimum area and minimum volume so dividing one by the other to get an average thickness gives 0.85m to compare against previous years:

2009 2.01m
2010 1.44m
2011 1.38m

These years were all record low average thicknesses and they show a rapid decline. The projection suggest a potential 58% decline in average thickness at minimum in 2012 compared with 2009. These are the best statistical schemes I have found but time was limited and there may well be better schemes.

A 58% decline in thickness over 3 years or a 45% decline in volume this year should not be translated into a projection of the ice all disappearing by 2015 without a discussion of whether the rate of loss will accelerate or decline. The two major feedback are a positive

one: albedo feedback increasing the volume decline in summer and a negative one: faster growth of ice in winter as more heat can be lost through thinner ice. With PIOMAS showing a decline in volume at 30 June 2012 compared with 30 June 2011 of 1.1K Km^3, there is little sign of this negative feedback showing up to any great extent let alone dominating the albedo feedback. However the feedback should be expected to get stronger as the ice gets thinner so just because we have not seen the effect getting stronger does not mean it will not dominate the albedo feedback. The negative feedback is likely to be limited to restoring winter ice volumes not exceeding them because once the faster growth of ice catches up with previous years thicknesses the reason for the faster growth disappears. If this negative feedback works to full effect, would this stop further increases in the volume decline in summer? If the ice volume declines to 2.2K Km^3 this year, I would suggest there would still be further declines in MYI and this may allow faster melt and albedo feedback as a result of that faster melt. While it may be possible to find assumptions that lead to the rate of decline of ice almost disappearing once the ice reaches a minimum volume of around 2K Km^3, I would suggest these assumptions would have to be rather bizarre best case assumptions.

These large potential figures of 45% decline in volume in 2012 and 58% decline in thickness from 2009 to 2012 do emphasize how little time there is for negative feedbacks like this to kick in and slow the rate at which ice is being lost.

Implications for my statistical method of estimating extent

My method of predicting extent mainly relies on a naive Gompertz extrapolation fitting the extent minimums. Clearly thickness is declining as well as extent. If the rates of extent decline and thickness decline were not interrelated then you could expect a discontinuity in the extent trend when the thickness runs out. In the real world, it may show up as a further acceleration as volume gets very low. The extent prediction method I have used is therefore likely to be conservative as a seasonally ice free state is approached.

Worst Case scenarios: 2013 onwards

In the PIOMAS record, 5 of the 32 year show a decline in volume from minimum to minimum exceeding 2.2K Km^3. So even if a negative feedback should kick in to slow the rate of decline, 2013 onwards could already be down to a volume that could disappear if the weather conditions happen to be favourable towards enhancing volume decline.

Note, PIOMAS volumes may not be correct. Schweiger et al 2011 Uncertainty in modeled Arctic sea ice volume reports a conservative estimate for October Arctic ice volume uncertainty of 1.35 × 10^3 km^3. So we could be nearer or further from a melt out than indicated by just taking the PIOMAS volumes as true.

2012 worst case

A melt out this year seems a remote possibility. If PIOMAS is reporting volumes that are 1K Km^3 too high and a 2 sigma weather towards increased volume decline occurred then the prediction would reduce from 2.2K Km^3 by 1+.55*2 K Km^3 before considering albedo feedback. A melt out this year is therefore only a remote possibility but it is difficult to rule it out at around the 1% or 2% level.

Discussion Conclusions

It is very difficult to be 95% confident of whether the arctic ice will substantially melt out this decade and many scientists seem clear this should not be claimed. However, volumes do appear to be approaching levels where there could be a substantial chance of a melt out and perhaps such probabilities could be estimated rather than waiting to obtain 95% confidence. The method I have used to estimate September Extent could be conservative but for the moment I will leave it as it is with a caution that there could be a thick tail all the way down to zero extent. If my estimates of PIOMAS minimum volume and average thickness decline seems credible, then the probability of melt out in the next fews years seems a sufficient risk that it may be sensible to change climate modelling priorities towards ascertaining regional climate effects of a seasonally ice free arctic.