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The Cryosphere
Discussions

Interactive comment on "Future Arctic marine access: analysis and evaluation of observations, models, and projections of sea ice" *by* T. S. Rogers et al.

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1. "During Winter, sea ice in the Russian and Canadian quadrants grows until it hits the coast. Very little change can be expected to occur in sea-ice extents in winter and spring until so much warming occurs that ice doesn't reach the coast anymore. I'm surprised to see statistically signiïňĄcant trends (Table 2) in these quadrants during months when ice has ïňĄlled the basin. How is this ice loss occurring? I looked at maps of ice extent using NSIDC's Sea Ice Index, and during March for each year of this study, the ice was solidly packed up against the coast in the Canadian quadrant. There might be some variability around Novaya Zemlya that accounts for changes in

the Russian quadrant, but I don't see how a negative trend emerged during winter in the Canadian quadrant."

The ice loss in the Canadian region occurred between Greenland and Canada, towards the southern tip of Greenland, as well as along the eastern coast of Canada. These results reached significance above the 95%, but below the 99% level. The winter ice loss in the Russian region occurs both in the very western region the Russian quadrant, and south of Russia. The significance of this loss was also between 95% and 99%. Note that the decreases can be statistically significant even if they are not large, because the land barriers reduce the variability in addition to the magnitudes of the overall changes. This regional time series plots from The Cryosphere Today (UIUC) show that there has indeed been a reduction of sea ice in these regions of seasonal (winter) sea ice cover:

http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/recent365.anom.region.4.html
http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/recent365.anom.region.6.html

2. "The correlation found between winter ice and SSTs in the North Atlantic quadrant was previously found by Francis and Hunter (2007), which should be cited. The lead-lag relationship, however, is opposite to their conclusion. It is difïňĄcult to imagine a mechanism by which ice would lead SSTs, thus I agree with Walt Meier's suggestion that perhaps this aspect should be downplayed in the paper until the relationship can be conïňĄrmed and understood."

We cite the paper by Francis and Hunter (2007). The SST lead/lag results we obtained are indeed counter-intuitive, and thus deserve further investigation. A mechanism by which this could happen is through the consumption of greater (lesser) amounts of oceanic heat for melting ice when the ice in the North Atlantic is more (less) than normal. For example, greater-than-normal winter ice in the North Atlantic would require more latent heat for melting, thereby delaying the springtime increase of ocean temperature and resulting in negative SST anomalies in the following months.

3. "3. P. 3970, line 2: I suggest changing “ice-free summer sea” to “ice-free summer Arctic Ocean”. Lines 23-24: The use of “catch” and “catching” in this paragraph seems too colloquial – perhaps “simulate” or “realistically represent” would be better."

We have made the suggested changes. Line 2 now says” ice-free summer Arctic Ocean”. “Catch” is now “simulate”, and “catching” is now “representing”.

4. "P. 3971, lines 15-25: I’ve read the explanation for how the composite rankings were calculated, but I just don’t get it. Can you please take another shot at describing the methodology. Perhaps include an example for how one of the values in Table 4 was determined."

We have improved this explanation in the revision. Lines 17-21 discuss the creation of the annual cycle. 21-23 explains the creation of the composite rank. I think clarifying the annual cycle will help; starting with line 17, "The third performance metric..." we have changed the text to: “The third performance metric, named the annual cycle, was based on the twelve calendar-month differences between the observed and modeled SIE from 1980-2008. The modeled mean value for each month (e.g. January) from 1980-2008, was subtracted from the observed mean value. Once each monthly value was computed, the absolute values of the 12 monthly differences were averaged to create this metric.” This is then followed by, "Each model earned a rank (from 1 to 13) for each metric, and the different metrics were summed for each model”, which explains the process for determining the composite rank. For example, HadGEM performed 1st in the September trend, 1st in the March trend, and 3rd in the annual cycle, to create a composite rank of 5.

5. "Following comment #1, it seems that the months and quadrants in which ice is confined largely by coastlines should not be used in the model ranking. These trends are small and probably not reliable, so models should not be overly judged by these values."

This is a good point, and it is consistent with our decision to use the models that per-

formed best in the pan-Arctic region, as opposed to using models that performed best regionally. This decision was made because the pan-Arctic nature of the major shipping routes, and the reviewer’s comment makes such a strategy even more prudent. In future work, we will revise this method for future analyses of model performance, so metrics of winter performance in the Russian and Canadian quadrants receive less weight (although we note that the inclusions of year-round metrics can be justified for the Atlantic and Pacific quadrants).

6. "Table 3: Why is the annual cycle for observed sea ice not included? Should the March trend for the CNRM model have a negative sign?"

Following on the clarifications to comment #4, the mean annual cycle for observed sea ice does not differ from itself, hence the difference-based metric is 0. The CNRM model showed increasing sea ice during the month of March from 1980-2008, hence its trend is positive.

7. "Table 5: It’s very difficult to distinguish bold from non-bold Xs. I suggest using some other symbol, such as +, to denote the best 5 models."

We have modified this table using your suggestions. The caption now reads: “This table synthesizes model performance over several studies. An X indicates the model was identified by that individual study. A + indicates the model was one of the best five models identified in that earlier study and in our pan-Arctic evaluation. An underlined + or X indicates the model was also one of the best five models in our combined quadrants evaluation” (Fig. 1).

8. "Fig. 2: Please make plot lines thicker – they’re hard to see in printed copy."

We have made the lines thicker in the revised version of the figure (Fig. 2)

9. "Fig. 4: plots should have the same scale on the x-axis to enable comparison. The lag is not discernible."

We have modified the x and y axes so they are clearer. We’ve added another sentence to the end of the Fig. 4 caption: "The left graph has lead-lag correlations squared for the data; the right graph has lead-lag correlations squared for the detrended data." Both graphs are showing the same amount of lag between SIE and SSTs, but one graph uses the normal data, while the other uses detrended data (Fig. 3).

10. "Fig. 6: The different plot lines would be much easier to see if they were in color or included symbols. The HadGem line doesn't show up at all in my copy."

The intention of this graph is not to show the individual projections of each model; rather, it is to show the range of projections for top performing models for the rest of this century. In the revision, we now use a different style of line for HadGEM so that it is more discernible (Fig. 4).

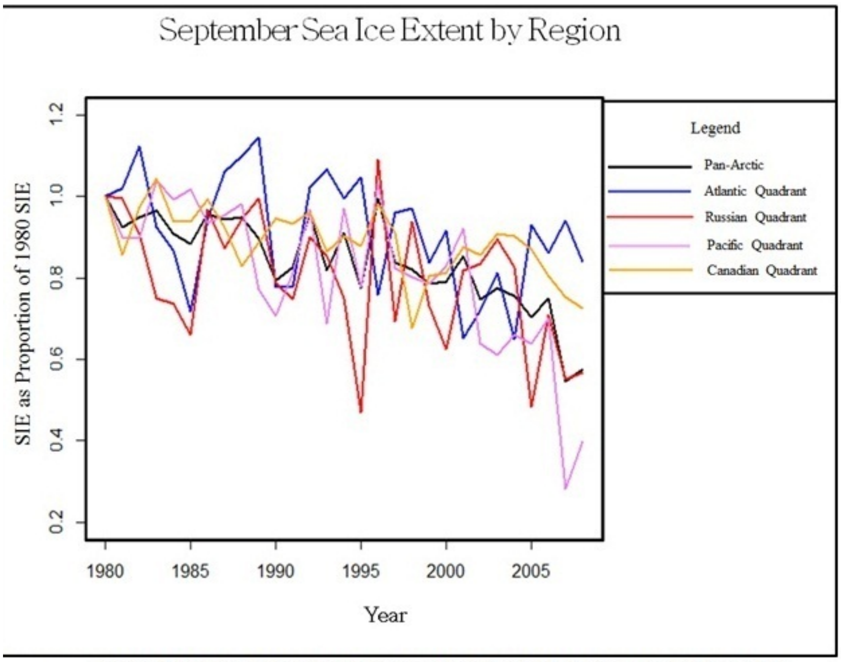
11. "Fig. 10: Again, it is very difficult to discern the different dashed lines. Please use color instead or add symbols."

We have revised the figure so that the different lines can be distinguished more easily (Fig. 5).

Interactive comment on The Cryosphere Discuss., 6, 3963, 2012.

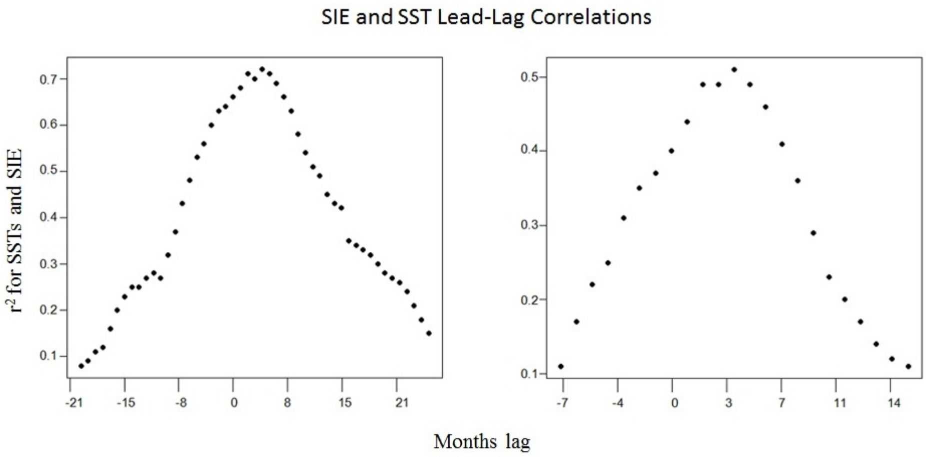
	Pan-Arctic	Combined Quadrants	Zhang & Walsh 2006	Arzel et al. 2006	Walsh et al. 2008	Overland & Wang 2007	Wang & Overland 2009	Zhang 2010
BCCR								
CCCMA			X	X		X		
CCSM	+					+	+	+
CNRM				X	X		X	X
CSIRO			X					
ECH					X	X		X
GISS		X	X	X		X		
HAD			X		X			
HADGEM	±	±				±	±	±
INM	±	±						
IPSL	+			+			+	+
MRCM	±	±	±	±	±	±	±	±
MRI		X						

Fig. 1. Table 5: Model evaluation synthesis



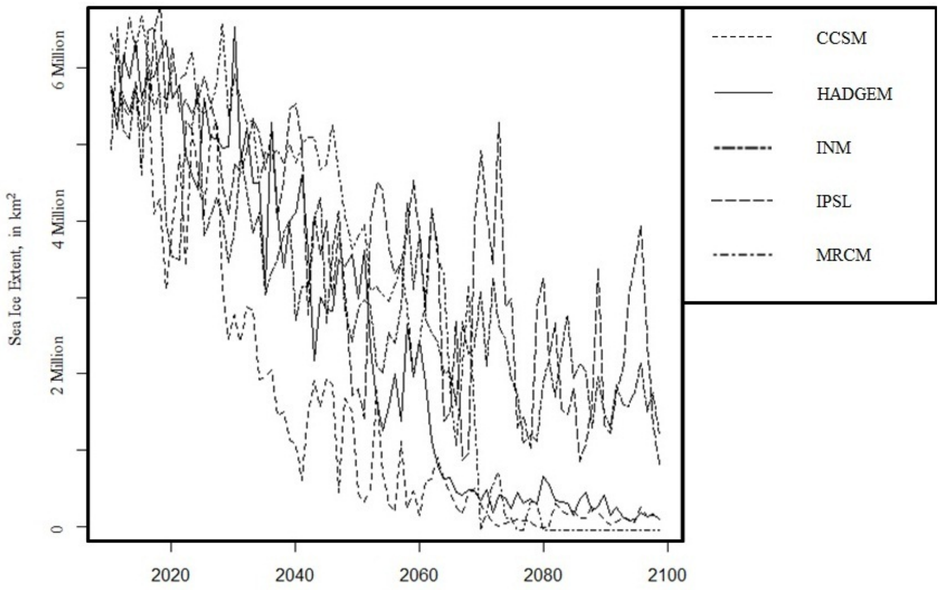
September sea ice extent (SIE) by region, 1980–2008. The legend indicates line colors of the different domains in the graph. The graph identifies that Atlantic and Canadian quadrant SIE are decreasing much slower than the pan-Arctic, while Pacific SIE is decreasing much faster than the pan-Arctic. The Russian quadrant has been decreasing similar to pan-Arctic trend.

Fig. 2. Figure 2: September SIE by region



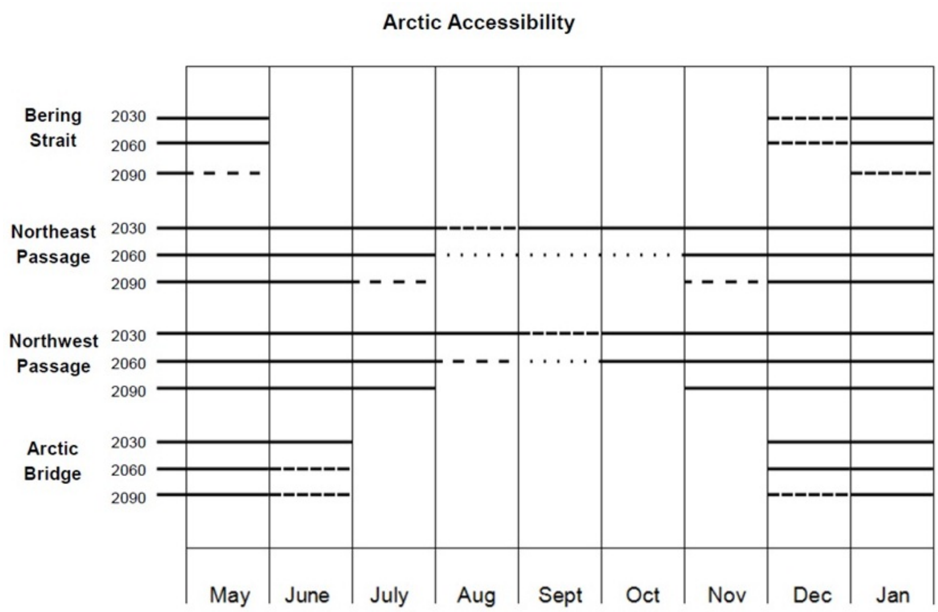
The left graph has lead-lag correlations squared for the data; the right graph has lead-lag correlations squared for the detrended data." Both graphs are showing the same amount of lag between SIE and SSTs, but one graph uses the normal data, while the other uses detrended data.

Fig. 3. Figure 4: SIE and SST lead-lag correlations



Pan-Arctic sea ice extent projections, September 2010–2100. Models include CCSM, HADGEM, INM, IPSL, and MRCM.

Fig. 4. Figure 6: Pan-Arctic SIE projections



Summary of projected future Arctic marine accessibility. A solid line indicates that no models showed accessibility. A long line with a very small dash indicates that one model showed accessibility. A dashed line with equal space indicates two models showed accessibility. A sparsely dotted line indicates three models showed accessibility. No line indicates that all models showed accessibility.

Fig. 5. Figure 10: Arctic accessibility