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Interactive comment on "Modeling the annual cycle of daily Antarctic sea ice extent" *by* Mark S. Handcock and Marilyn N. Raphael

Walter Meier (Referee)

walt@nsidc.org

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Summary:

This paper analyzes the seasonal cycle and interannual variability of Antarctic sea ice extent (SIE) using various statistically approaches. Different annual cycles are defined based on amplitude and phase. Variation in phase is found to explain more of the SIE variability, but combining both amplitude and phase explains substantially more variation than traditional methods. The approach shows that the low SIE extremes in 2016 were due mainly to a shift in phase.

General Comment:

This paper makes an interesting contribution to Antarctic SIE analyses. Two lingering

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questions with Antarctic SIE is the small positive trend that has been seen over the long-term satellite timeseries and the whiplash in recent years going from record highs to record lows within just a couple years. The analysis presented in this paper is unique for SIE and the paper brings to light many relevant characteristics of the SIE timeseries that provide insights into both short-term and long-term variability. For example, the idea that phase plays a more important role in the seasonal cycle than amplitude is revealing and seemingly important in better understanding the character and variability of Antarctic SIE. I have a few minor comments on various aspects. I recommend acceptance after minor revision to address these.

Specific Comments (by line number):

1: "troughing", while technically correct, reads awkwardly to me. Why not just say "reaches its minimum"? This occurs in a few other places in the text.

23: "peaking in September. . .and troughing in late February. . .on average." Though you say on average, which is accurate, that masks a lot of variability. The minimum does sometimes occur in October and ranges from early Sept (even late Aug one year) through early Oct. The maximum can occur in March and ranges over $\sim$3 weeks. It might be worth providing a range along with the average to give a better sense of the variability, which as is shown later in the paper is important

29: Some of the day-to-day variation is also due to land-spillover (coastal effect of mixed land/water grid cells). It's not as variable as weather or changes in the ice cover, but I think it is important enough to warrant mention. (This is less of an issue in Antarctica because of the land ice along the coast, but still worth noting I think.)

61-63: The data reference is a little confusing. You say use the SMMR-SSMI-SSMIS Bootstrap Version 3 product, but reference Comiso (2017), which is the correct reference. But you also reference Peng et al. (2013), and Meier et al. (2017), which refers to the NSIDC/NOAA Climate Data Record product. I understand the confusion here because the NSIDC/NOAA CDR does include the Bootstrap V3 concentrations

within the product. My assumption is that you used the Bootstrap V3 field within the NOAA/NSIDC CDR. So I think all three references are warranted, but this could be more clearly explained, e.g., "We used the Bootstrap Version 3 concentration fields (Comiso, 2017) from the "NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3" (Peng et al., 2013; Meier et al., 2017)." Or something like that.

66: You note that there are a number of days with no observations (in addition to the every-other-day SMMR). But one of those gaps is quite significant, with no data between early December 1987 and mid-January 1988. This is worth noting because it is unique in the record in terms of the length of the gap. Did you fill this in at all or leave the gap? Since the method doesn't require complete data, I assume not, but that should be made clear.

69: Day 0 is the minimum day of the year and then you just plot the next 364 days after that for each year. But of course, the date of the minimum differs from year to year. So, it seems like some years could have a gap – if the minimum of one year occurs before the minimum of the next year (i.e., >365 days between minimums) – where some data is not plotted, or conversely, you could have some data duplicated – if the minimum of one year occurs later than the minimum of the next year (i.e., <365 days between minimums). Is this correct? Are these "missed" or "duplicated" accounted for in any way? Or does that potentially skew results at all?

Figure 3: A few suggestions. First, the Day-to-day change is in Figure 4 (as noted in the Figure 3 caption). It seems like it is discussed in the context of Figure 4. So, is it necessary to include that line in Figure 3? Simpler is always better in my view, so one less line is helpful. And that would allow the y-axis to cover a smaller interval, which would more clearly show the variability lines. One thing that would be useful would be to label the max and min days (e.g., text with an arrow pointing to each). The day-to-day change does provide this, but it may not be immediately clear that the max occurs when the change turns from positive to negative. So, I think labeling would be helpful

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even if the day-to-day line is kept (but if labeling is included, then that line isn't really needed). The fonts on these figures are quite small – in the final version, they should be much better. Also, while the units are noted in the caption, it my view it is always better to include them with the axis labels. Similarly, for Figure 4.

Figure 4: There is an interesting feature in the traditional (orange) plot right around day 200, where the curve is less dense. All the other places have thin lines, highly varying day to day. But around day 200, there seems to be a period where the line just peaks and then declines over several days. Is that related to anything? Or is that just a quirk in the data, or just an optical illusion?

206-214: Why is the volatility higher for SMMR than for DMSP? Is it simply the every-other-day sampling? But there could also be an effect due to the sensor resolution (sensor footprint), which is actually smaller (higher resolution) in SMMR. I'm curious if the volatility of DMSP would match SMMR if every-other-day values were used from DMSP? Another, smaller aspect, is whether volatility changes from SSMI to SSMIS? If it's simply the temporal sampling, then I would expect there wouldn't be a change. But if there is a resolution component, then there might be a small effect since the sensor footprints are slightly different. While I think looking at that could be interesting, I guess it's not the main focus of the paper, so I can see not doing that. However, I think it is worth at least noting that the differences in volatility are due to temporal sampling (and maybe some resolution effect?), just to make that clear.

244: There is also more volatility at/near the maximum because there is more ice edge to vary. At the maximum, the perimeter of the ice cover is also at or near its maximum, which allows more areas to be affected by winds, currents, storms, etc.

Figure 5: What are the anomalies relative to – i.e., what is the base period? Likewise, for earlier figures, the y-axis should be labels with units.

281-291: I understand the rationale for using the daily values over monthly values, but the advantage of monthly values is that you capture roughly the same period in the

cycle – so you can look at trends near the maximum or near the minimum, which can be quite different than over a full year. But I also wonder is something is lost? – you're taking something with a big annual cycle and then just fitting trend lines through the entire ∼40 years. Would it make sense to do a Figure 6 for the max and min? Perhaps using the amplitude and phase adjusted? Also, how does the curvilinear trend handle the endpoints – i.e., how does it calculate a trend from the beginning? In other words, how does the function (Eq. 15) calculate a smooth trend at the beginning of the time series? I assume that there is an endpoint fitting/smoothing, which may be in the equation. But some plain English explanation would be helpful as well.

Figure 6: What are the thin pink dashed lines? Are these just the beginning and end dates of the two periods? And the dashed line around the curvilinear trend?

288: The trend standard deviation (+/-) values should be included with the linear trend and maybe the trend significance.

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