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The Cryosphere Discussions

Interactive comment on "Variability of sea ice deformation rates in the Arctic and their relationship with basin-scale wind forcing" *by* A. Herman and O. Glowacki

Anonymous Referee #1

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The authors use satellite-derived Arctic sea ice deformation data from RGPS, and wind data from the NCEP reanalysis, to show that: (1) spatially-averaged sea ice deformation has an annual cycle with a minimum in March, and (2) spatially-averaged short-term sea ice deformation is correlated with spatially-averaged wind stress. The authors write down a simple linear model that is supposed to show the plausibility of (2). They also suggest that the correlation may be increasing with time, as the sea ice thins.

This is a well written, concise paper that demonstrates a strong connection between spatially-averaged sea ice deformation and wind stress over short time scales. The authors are very familiar with the relevant literature on sea ice deformation and spatial

scaling. Their simple linear model, however, does not provide any insight.

I recommend publication after minor revisions.

Main Comments

The model presented at the bottom of page 3357 and on page 3358 is a weakness of the paper, for the following reasons: (1) The linear model contains only two terms (ice stress gradient and wind stress) and the rheology is linear, so it's really no surprise that the result is a linear relationship between deformation and wind stress. In that sense, the model really doesn't provide any insight. (2) The notation is unnecessarily complicated, with multiple subscripts where a single subscript would do. (3) The assumption of the linear rheology (which is questionable anyway) does not even need to be introduced until the last equation: the model could be formulated in terms of sigma instead of J*epsilon, and this would make the equations much simpler. (4) The correlations (C) between deformation and wind stress (as in Figures 2 through 5) already tell us how linear the relationship actually is. The model isn't necessary. A better approach is to start with the full momentum equation for sea ice, and estimate the sizes of all the terms. One finds that at short (daily) time scales, the dominant balance is indeed between the internal ice stress gradient and the wind stress. This result has been published in: Steele et al. (1997), The force balance of sea ice in a numerical model of the Arctic Ocean, J. Geophys. Res., 102, C9, 21061-21079. The authors need only cite this paper to establish that the dominant balance is between internal ice stress gradient and wind stress at daily time scales. The relationship between deformation and wind stress then depends on the rheology. If we make the authors' assumption of a linear rheology then of course there is a linear relationship between deformation and wind stress. Thus in my opinion the model in this paper is completely unnecessary and can be removed. The values of the correlation (C) between deformation and wind stress already tell us how linear the relationship actually is. For example, in Figure 2b, C = 0.71 so Cˆ2 = 0.5. Thus in a linear model the wind stress accounts for 50% of the variance of the deformation. Similarly in Figure 4, a linear model accounts for between

16% (0.4ˆ2) and 50% (0.71ˆ2) of the variance, depending on the moment q and the length scale L. The unexplained variance (1-Cˆ2) is some combination of non-linearity in the rheology, neglected terms in the momentum equation, and measurement error. A paragraph summarizing the above points could replace the whole "model" discussion.

Page 3354, lines 15-16. Cubic splines were used to estimate non-linear trends in the sea ice deformation, as in Figure 3(a). A little more detail is needed here. How many segments (cubics) are used over the entire time interval from day -50 to day +120? How did the authors arrive at this choice, as opposed to using fewer or more cubic segments?

Page 3356, last sentence. Sea ice deformation for large q (higher moments) and small L (short length scales) is not highly correlated with wind stress, and the authors state that such strong, localized deformation events may be decoupled from the overall large-scale deformation pattern resulting from the spatially-averaged wind stress. If wind stress is not responsible for strong, localized deformation events, then what is? Could it be thin ice along particular coastlines that deforms strongly during on-shore winds? Could it be loose ice along the free ice edge that appears to deform during off-ice winds? Is anomalous deformation concentrated in particular locations? The authors need not conduct another research project to answer these questions, but they should suggest some possible explanations, and test them if feasible.

Minor Comments (suggestions)

Abstract, line 1. Delete "In this paper," and just write, "The temporal variability of the..."

Introduction, line 3. "it influences THE ice thickness distribution..."

Section 2.1, line 1. Delete "In this work," and just write, "We use the..."

Page 3353, line 4. "x and y AXES" (plural)

Page 3354, line 1. "containing FEWER than"

Page 3355, lines 1-2. Change "Similarly to the exponent beta, the mean intensity of..." to "Similar to the exponent beta, the mean magnitude of..."

Page 3355, line 4. Delete "Obviously," and just write, "From the scaling..."

Page 3355, line 13. "equal TO 2 days"

Page 3356, line 16. "due to THE linear relationshipS IN Eqs. (5) and (6)."

Page 3356, line 20. Instead of "Lower, but still statistically significant values of C occur..." it would be clearer to write, "The lowest values of C, still statistically significant, occur..."

Page 3358, line 3. "equal TO 3 days"

Page 3358, line 11. "By integrating iteratively" – actually it is "summing cumulatively". It is simply the cumulative sum from cell 1 to cell i.

Page 3359, line 2. Change "was a consistency" to "is for consistency" and delete the comma before it.

Figure 3 and Supplementary Figure 1. These are nice figures. I have one suggestion (optional). In the upper right corner of each panel, print the correlation of tau_a and log(m).

Supplementary Figure 1. The labeling of the X axis (Time) is different in panels i-k than in panels a-h.

Interactive comment on The Cryosphere Discuss., 6, 3349, 2012.