

## ***Interactive comment on “Leads and ridges in Arctic sea ice from RGPS data and a new tracking algorithm” by Nils Hutter et al.***

**Anonymous Referee #1**

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The authors have taken the sea-ice deformation data from the Radarsat Geophysical Processor System (RGPS) and used it to create a data set of Linear Kinematic Features (LKFs), i.e. leads and ridges that extend across the Arctic pack ice. Spatial coverage includes the western Arctic Ocean with 12.5 km grid size; temporal coverage is 1996-2008 during the winter season (Nov-Apr) with 3-day resolution. The LKFs are tracked over time using a new algorithm. Summary statistics of the LKF data set are presented.

The new data set could prove to be useful for calibration and validation of high-resolution sea-ice models, and as a climatology of LKFs for comparison with a future Arctic sea-ice cover. The paper is mostly a description of algorithms (pages 4-19), but its value lies in the end product – the LKF data set. In my opinion, the paper should be

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published after the following comments are addressed.

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### General Comments

Leads are not distinguished from pressure ridges in the data set – they are both labelled as LKFs. Wouldn't it be useful, once an LKF has been identified, to label it as "lead" or "pressure ridge"? Wouldn't it be possible to do this based on the values of divergence within the LKF, with positive divergence indicating a lead and negative divergence indicating a pressure ridge? Leads and pressure ridges are radically different types of features. Leads are the sites of new ice growth, contributing to the thin end of the ice thickness distribution. Pressure ridges affect air and water drag, and contribute to the thick end of the ice thickness distribution. Considering that 165,000 LKFs have been identified, wouldn't it be useful to know what percent of them are leads and what percent are pressure ridges? In my opinion, the authors should either go back and label each LKF as a lead or pressure ridge, or explain why it's impossible or too difficult to do so, or why it doesn't matter.

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### Specific Comments (in page order)

#### Page 3 Section 2.1

(i) The RGPS data set needs a reference. Where does it come from? A NASA web site? The Alaska Satellite Facility?

(ii) It would be courteous to give credit for the creation of the RGPS, such as:

Kwok R. (1998) The RADARSAT Geophysical Processor System. In: Analysis of SAR Data of the Polar Oceans. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-60282-5\\_11](https://doi.org/10.1007/978-3-642-60282-5_11)

#### Page 3 Section 2.2

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Again the source of the RGPS Lagrangian drift data should be cited.

Page 3 line 24

Please clarify that "px" = pixel and that 1 pixel = 1 grid cell = 12.5 x 12.5 km.

Page 4 line 14

After the equation, say that  $\text{eps}_I$  is divergence and  $\text{eps}_{II}$  is shear.

Page 4 lines 15-16

The LKFs are not "marked" by regions of high deformation, they are DEFINED by regions of high deformation. Consider writing: "LKFs are defined by regions of high deformation rates, which are located along the boundaries of ice floes..."

Page 4 lines 25-26

"radius  $r_1 = 1$ " and "radius  $r_2 = 5$ " – please include the UNITS – presumably "pixels" or "grid cells".

Page 5 line 2

"threshold of 15" – what units? Are the pixel values (grid cell values) scaled to the range [0,255] after the histogram equalization, with black=0 and white=255? "threshold of 15" is meaningless unless we know what the scale is.

Page 6 line 15

The sentence "All segments..." references Figure 3(a) but Figure 2 has not been referenced yet. Furthermore, this section (3.1.2) describes segment detection in general, whereas Figure 3(a) is one particular example of segment detection, which is not made clear in the sentence. I'd suggest either deleting this sentence or clarifying that it refers to a particular example.

Page 7 Figure 2

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The diagram needs more labeling or the caption needs more explanation. It should be stated explicitly that the red and blue segments are LKFs. What is  $v$ ? What is  $a_{\text{parallel}}$ ? What is  $a_{\text{perpendicular}}$ ? What are the black dotted lines? Etc.

Page 7 Equation (2)

What are alpha and beta? There is no explanation.

Page 8 line 12

What are the units of the deformation rate  $\text{eps}_0 = 0.75$ ? What are the units of the minimum length  $l_{\text{min}} = 2$ ?

Page 8 end of Section 3.1.3

It might be appropriate to reference Figure 3(a) here, instead of at the end of Section 3.1.2

Page 8 Section 3.1.4

The title of this section is "Parameter optimization", but page 9 lines 9-12 says "finding a global minimum of the cost function is impossible" and "we use a set of parameters estimated with a simple brute-force algorithm" and "We do not regard this set of parameters as the global optimum, but rather as a useful working basis". Therefore this section should not be titled "Parameter optimization" but rather "Parameter selection" or "Parameter determination". There is no optimization taking place, as far as I can tell.

Page 9 Table 1.

The UNITS of the parameters in the table need to be given. I'd suggest adding a column to the table for the units.

Page 11 lines 18-19

While it's true that 18.54% is slightly smaller than 18.74%, it seems to me that the difference is negligible and that these errors are essentially the same.

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Page 12 lines 13-14

"The deformation rates in RGPS are known to be prone to grid scale noise" – and more fundamentally, the deformation rates are subject to uncertainty due to tracking and geolocation errors in the underlying SAR images, which have pixel size 100 meters. See:

Lindsay, R.W., and H.L. Stern, 2003, The RADARSAT Geophysical Processor System: Quality of Sea Ice Trajectory and Deformation Estimates, *J. Atmos. Ocean. Tech.*, 20, 1333-1347.

In light of this, is it possible that some of the deforming cells identified in the present paper are actually "in the noise" compared to the background deformation level?

Page 12 line 16

Please give the units of  $d_{LKF} = 15$

Page 13 line 7

Please give the units of  $\Delta_{\epsilon_0} = 1.25$

Page 13 line 8

"common logarithm" and " $10^{1.25}$ " implies log base 10, but page 4 line 21 says that the "natural logarithm" is used, i.e. log base e. Don't these both refer to  $\log(\text{deformation rate})$ ? If so, then which base is correct, 10 or e? If not, then what is the difference in usage of the log on page 4 vs. the log here on page 13?

Page 14 Figure 7

I can't tell the difference between the points labelled "rounded indices" and the points labelled "1-pixel uncertainty". Perhaps different symbols could be used in the figure.

Page 16 Table 2

The UNITS of the parameters in the table need to be given. I'd suggest adding a  
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column to the table for the units.

Page 17 Figure 9

It's hard to distinguish the colors of the darker lines. I can see the yellow and green lines, but the other lines all look brown or black to me. Perhaps a different color scheme could be used.

Page 20 lines 21-22

Regarding the distribution of LKF lengths, "The PDF is described accurately by a power-law for LKF length between 60 and 600 km." I strongly dispute that statement. Figure 11(c) shows the PDF. The authors are apparently basing their claim on a least-squares fit in log-log space using evenly spaced bins in LKF length. Such a method leads to a very biased estimate of the power-law exponent; see:

White, EP, Enquist, BJ and Green, JL. 2008. On estimating the exponent of power-law frequency distributions. *Ecology* 89(4): 905–912. DOI: <https://doi.org/10.1890/07-1288.1>

and

Clauset, A, Shalizi, CR and Newman, MEJ. 2009. Power-law distributions in empirical data. *SIAM Rev* 51(4): 661–703. DOI: <https://doi.org/10.1137/070710111>

The proper way to fit a power law to data is to calculate the Maximum Likelihood Estimate (MLE) of the power-law exponent. After the exponent has been calculated, a goodness-of-fit test should be applied to determine whether or not a power law is in fact an accurate model of the data. It looks to me (Figure 11(c)) as if the PDF has concave-down curvature in log-log space throughout its range. If the authors hypothesize that LKF lengths follow a power-law distribution, they should use the MLE to calculate the exponent, and then apply a goodness-of-fit test to check whether a power-law model does in fact accurately describe the PDF.

(i) Figure 11(b) is not described in the text.

(ii) In Figure 11(b) (upper panel), is the y-axis label on the left side of the figure supposed to be "Storm strength" or "Number of cyclones"? The label itself says "Storm strength" [misspelled] but the caption says "number of cyclones".

(iii) In Figure 11(b) (lower panel), the y-axis label on the left side of the figure says "No. of LKFs (normalized)". How is the normalization done? Per unit area? Fraction of the total number of LKFs? The sum of the bars does not seem to be 1.

(iv) In Figure 11(b) (lower panel), what's the story with the gap in early April?

(v) In Figure 11(b) (lower panel) the color (red-yellow) gives the total deformation rate (1/day) from January to May. That time series of deformation rate could be compared with Figure 6 of:

Stern, H. L., and R. W. Lindsay (2009), Spatial scaling of Arctic sea ice deformation, *J. Geophys. Res.*, 114, C10017, doi:10.1029/2009JC005380

in which the total deformation rate (1/day) from January to July is plotted, based on RGPS data.

Page 22 lines 3-4

"exponential distribution with an exponent of 0.34" An exponential distribution can be written in one of two ways:  $(1/b) \cdot \exp(-t/b)$  where  $b$  is a time scale (units: time), or  $c \cdot \exp(-c \cdot t)$  where  $c$  is a rate (units: 1/time).

(i) The authors have not said which form they are using, and therefore the reader does not know whether 0.34 is a time scale or a rate. No units are given.

(ii) In the present case, 0.34 must be a rate with units 1/day. So the time scale is  $1/0.34 = 3$  days, which makes sense.

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(iii) The parameter in an exponential distribution is not called an exponent. It could be called a time scale (first form,  $b$ ) or a rate (second form,  $c$ ). In the first form,  $b$  is also the mean value. In Figure 11(e), the legend says "exponent 0.34" which is not correct terminology. It could be written "rate 0.34 / day" or "mean value 3 days".

Page 22 lines 13-14 In reference to Figure 11(b), "This overall seasonal cycle is interrupted by a set of four strong cyclones...in March" – I don't see how Figure 11(b) shows four strong cyclones in March. Please tell the reader what to look for in the figure.

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#### Technical Corrections

Page 1 line 14. "is derived" should be "are derived"

Page 2 line 5 and following. Use capital "O" in "Arctic Ocean"

Page 5 line 1 of figure caption. "final output OF the..."

Page 5 line 10. "LKFs" should be "LKF" (singular)

Page 6 line 6. "segments" should be "segment" (singular)

Page 6 line 8. Better to end the sentence after the word "curvature" and start a new sentence: "As in the 2 pixel case, a 90-degree shift..."

Page 7 line 1 of figure caption. "illustration" should be "illustrating"

Page 7 line 3 of figure caption. "lay" should be "lie", and "half-ellipse" should be "half-ellipses" (plural)

Page 7 line 15 and following. Do not abbreviate Table as "Tab." Use "Table"

Page 8 line 15. "The choice of THE set of parameters..."

Page 9 line 19. "to which degree" should be "to what degree"

Page 10 line 3. "The principle idea" should be "The principal idea"

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Page 10 line 15. "overlap larger THAN 60%" and "overlap smaller THAN 60%"  
Page 10 line 19. "significant" should be "significantly"  
Page 12 line 2 of figure caption. "to to" (delete one of them)  
Page 12 line 9. Delete the word "also"  
Page 12 line 15. "sightly" should be "slightly"  
Page 13 line 2. "reconnect" should be "reconnected"  
Page 13 line 28. "an" should be "a"  
Page 14 line 17. "considered as \*a\* tracked feature..."  
Page 15 line 12. "advection" should be "advection"  
Page 15 line 23. "false positive" should be "false positives" (plural)  
Page 15 line 31. "algorithms" should be "algorithm" (singular)  
Page 16 line 2 of figure caption. "color" should be "colored", and "shows" should be "show", and "that is" should be "that are"  
Page 16 line 5. "where" should be "were"  
Page 16 line 6. Delete the comma (,)  
Page 18 line 1 of figure caption. "tracks" should be "tracked features"  
Page 18 line 2 of figure caption. "tracks" should be "tracked features" and "in growth" should be "into growth"  
Page 18 line 4. Delete "for"  
Page 18 line 11. Should "in shape" be "as shape"? I'm not sure.  
Page 18 line 13. "their" should be "its"

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Page 19 line 2. "an lifetime" should be "a lifetime"  
Page 19 line 7. "where" should be "were"  
Page 20 line 2. "winter 2001/01" – should it be "2001/02"?  
Page 20 line 24. "47.5 km" should be "37.5 km"  
Page 20 line 34. "given in A" should be "given in Appendix A"  
Page 21 Figure 11 panel (b). In the title on the vertical axis, "stength" should be "strength". However, the entire title "Storm strength" might be incorrect – should it be "Number of cyclones"?  
Page 21 Figure 11 panel (d). The x-axis label should include the units, i.e. "Intersection angle (degrees)"  
Page 21 Figure 11 panel (e). The x-axis label should include the units, i.e. "LKF lifetime (days)"  
Page 21 line 4 of figure caption. "new" should be "newly"  
Page 21 line 6. "less" should be "fewer"  
Page 22 line 9. Capitalize "Hemisphere"  
Page 22 line 10. "Fig 11" should be "Fig 11(b)"  
Page 22 line 11. "general" should be "generally"  
Page 22 line 14. "pass the Arctic oceans" should be "pass through the Arctic Ocean"  
Page 23 line 17. "11 winters" – I think it's 12 winters: 1996/97 through 2007/08.  
Page 23 line 22. "in Arctic ocean" should be "in the Arctic Ocean"  
Page 24 line 2. "grid spacing OF 2 km"  
Page 24 line 2. Delete "set of"

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Page 24 line 5. "for THE entire model domain"

Page 24 line 7. "KOBAYASHI" should be "Kobayashi"

Page 25 lines 23-24. Do not use all capital letters for the names.

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Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2018-207>, 2018.