Answers to Anonymous Referee #2

This paper improved and extended the lead and ridge detection method described in Linow and Dierking 2017, adding a new tracking algorithm. The LKF dataset derived in this study, therefore provides both spatial and temporal statistics of LKFs, which is of great advantage in evaluating sea ice model outputs. The manuscript can be published after minor revision.

We thank the anonymous referee #2 for his review.

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General comments:
1. It should be explained in the text why leads and ridges are bounded together to LKFs. If it is impossible to distinguish leads and ridges based on the current ice drift and deformation data, what kind of additional data is needed to get separate information of leads and ridges?

This answer is the same as for referee #1 who had the same comment.

We fully agree that this topic needs to be discussed in further detail. The idea to use divergence rates to distinguish leads and pressure ridges is obvious, but bears some pitfalls. In general, it is right that leads show divergence and pressure ridges convergence of ice motion and the converse of this relation can be used to label newly formed LKFs. For LKFs with longer lifetime, the converse does not necessarily hold true. Imagine a lead that formed in the previous RGPS image due to diverging ice motion and now starts to close due to convergence. Depending on how strong the converging ice motion is the lead might develop into a pressure ridge or stay a lead: for weak convergence, the lead is just partly closed but still be an opening in the ice cover. For strong convergence, the lead is fully closed and a pressure ridge builds up. Therefore, it is only possible to separate leads and pressure ridges using the divergence data for LKFs for which the sign of the divergence does not change within the lifetime of the LKF. In addition, the spurious noise in divergence rates for RGPS for strongly deformed cells (“Boundary-definition errors” in Lindsay & Stern, 2003, Bouillon & Rampal, 2015) introduces uncertainties in this classification. Combing the LKF data-set with sea-ice thickness and concentration data (that is not provided by RGPS but for model output) allows to clearly distinguish between leads and pressure ridges by using the additional constraints: (1) along a lead the sea-ice concentration decreases within the time step, and (2) along pressure ridges the sea-ice thickness increases.
Given these limitations we refrain from classifying all LKFs in the data-set. Nevertheless, we already provide the deformation rates for each LKF in the data-set along with position data to leave the user the option to use this information for classification. An appropriate evaluation of this classification would need to be done by the users themselves. We estimate that the data-set contains 46% leads, 41% pressure ridges, and 13% not-classified LKFs. For this estimate all LKFs are assigned depending on the sign of the divergence rate. If the sign of the divergence changes for LKFs with lifetimes longer 3 days, we only use the divergence data before the sign change for labeling and mark LKF for the remaining lifetime as not-classified. We add a paragraph to Section 5.1 “Generation of LKF data-set” that provides these estimates and a summary of difficulties explained above:
“The deformation, more precisely the divergence rate, which is saved for each LKF, can be used to distinguish leads from pressure ridges in the generation of an LKF. In general, leads form in divergent and pressure ridges in convergent ice motion and the converse of this relation can be used to label newly formed LKFs. Persistent LKFs can also be labeled in this way, as long as the sign of divergence does not change during the lifetime of an LKF. Consider an LKF, initially labelled as a lead in divergence, that encounters convergent motion. Depending on the magnitude of convergence, the lead may either only partly close and continue to be an open lead, or it may close completely and even evolve into a pressure ridge, making differentiating between leads and ridges difficult. Thus, we refrain from labeling all LKFs in the data-set into leads and pressure ridges, but provide the deformation rates for each LKF and leave this classification and its evaluation to the informed user. As an approximate first-guess, we estimate that 46% of the LKFs in the data-set are leads, 41% are pressure ridges, and 13% are unclassified (because the associated

mean divergence rate along the LKF changes sign over the lifetime of the LKF). For the classified leads and pressure ridges the sign of divergence does not change over the lifetime. Please note, that these estimates especially for short LKFs are likely contaminated with grid-scale noise in the divergence data of RGPS (Lindsay & Stern, 2003; Bouillon & Rampal, 2015). Combining the LKF data-set with sea-ice thickness and concentration data would allow to clearly distinguish between leads and pressure ridges by using these additional constraints: (1) along a lead the sea-ice concentration decreases within the time step, and (2) along pressure ridges the sea-ice thickness increases."

2. The parameter optimization part (section 3.1.4) is not quite convincing. It might be beneficial to separate the hand-picked validation datasets into several randomly selected groups and repeat the parameter optimization procedure, to confirm that the same optimized values can be achieved from different evaluations.

We agree that we do not perform an optimization in a strict mathematical sense, because we choose the parameters that minimize the number of not-detected features from 5^6=15625 different sets of parameters. Therefore, we renamed the section title to "Parameter selection". Nevertheless, we tested the robustness of our "optimal" set of parameters by repeating the parameter selection process for five random subsamples of the evaluation data set as suggested. For each subsample we randomly pick half of the features in the evaluation data-set. For two of those random subsamples the "optimal" set of parameters that was determined using all evaluation data also minimise the number of not-detected features of the subsampled features. For the other random subsamples we find 1, 2, and 44 set of parameters showing a 0.24%, 0.48%, and 2.39% higher amount of detected features. The stronger deviations of one subsample can be explained by the too small amount of long LKFs by random subsampling given that the distribution of LKF length is heavy tailed. Because the deviations of different subsets are small, we conclude that the "optimal" set of parameters is the best estimate obtained for the limited amount of evaluation data. For a more robust optimization that aims to find a global minimum of the number of not-detected features would require a larger evaluation data set. We attempt to make this clear by our extensive discussion of this problem in the manuscript and by the renaming of the section.

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Specific comments:

P1L7: based → based on

We changed the manuscript accordingly.

P2L6: CryosSat-2 → CryoSat2

We changed the manuscript accordingly.

P3 section 2.1: provide a short description how deformation rate is calculated or give a reference. Also uncertainties in the deformation data should be mentioned.

We now cite Lindsay & Stern (2003) in the description of the deformation data to refer the interested reader to the equations of the line integral approximation.

P3 section 2.2: As I understand, sea-ice deformation is calculated from ice drift information, and this same ice drift data is used to track the LKFs?

In principle, yes. RGPS, however, provides drift information only as a Lagrangian data-set, whereas deformation is also available interpolated to an Eulerian grid. As the tracking algorithm works on regular meshes, we interpolate the Lagrangian drift data-set to the same Eulerian grid used for the deformation data-set.

P3L23: visual → visually

We changed the manuscript accordingly.

P4L14: does this deformation rate include shear? It is known that shear is one of main factors to form leads.
The total deformation rate that the algorithm uses is sqrt(divergence**2 + shear**2). Thus, it includes shear. We clarified this in the manuscript:
"The standard input data of the LKF detection algorithm is the total deformation rate of sea ice epsilon_tot=sqrt(epsilon_I^2+epsilon_II^2), where epsilon_I is the divergence and epsilon_II the shear both of which can be derived from both satellite data and model output."

P6 section 3.1.3 Reconnection: It would be nice to illustrate some examples of pairs of segments which could be connected to one LKF and which could not be connected to one LKF according to the three criteria.
We assume you had a figure similar to Fig. 5 in Linow & Dierking (2017) in mind that illustrates the simple(r) reconnection scheme of the original algorithm (minimising the difference in orientation for all segments that have elliptical distance below a certain threshold). In our case, the reconnection scheme is more complex by taking into account also the difference in deformation rate and by weighting the three contributions of the probability estimate (difference in elliptical distance, in orientation, and in deformation rate). The elliptical difference and difference of orientation are already illustrated in Figure 2 of the manuscript. We can not think of a more compact way of illustrating the additional weighting of the three terms than the mathematical description given in Eq. (1). As the manuscript already includes 11 figures, we refrain from adding a new figure because we are afraid that it would add more complexity and would not facilitate the understanding.

P8L11: I suppose the unit of D0 and Lmin are pixels?
Yes, both are given in pixels. Following the suggestions of reviewer #1 we extended Table 1 and 2 with a column including the units of all parameters used.

P9L12: Can this strong non-linearity problem be solved if more reference data are available?
A larger amount of reference data would dampen the non-linearity in the cost function. This is already explained in the conclusions of the manuscript (P22 L31-32). However, creating such a reference data set by hand-picking is time consuming and beyond the scope of this paper.