Response to Reviewer 1

Thank you very much for reviewing our manuscript and raising the interesting idea of combining the two SAR-based approaches (i.e., from SAR-based ice motion and from the SAR image classification) into an improved SAR-based lead fraction product. In this manuscript, we focus on the different approaches to find out their advantages and disadvantages. A combined approach would potentially bring both the advantages and disadvantages together, so a merged approach requires careful evaluation of the present results and could be a subject of a future study. We suggest to add the following comment to the discussion in the manuscript:

"The comparison of lead fraction products presented here allows us to explore ways to mitigate their drawbacks by combining them. A promising approach could be to merge the two SAR-based methods, $LF_{accu.\ div}$ and LF_{SAR}, within a single algorithm, as they both are based on the same data source. Leveraging the higher resolution of LF_{SAR} (80 m compared to 700 m), we can use LF_{SAR} to precisely pinpoint the location of leads when $LF_{accu.\ div}$ indicates their presence. Simultaneously, $LF_{accu.\ div}$ and LF_{SAR} can be used as pre-filter for the respective other, replacing or relaxing the existing, potentially stricter filters. This combined approach has the potential to reduce the number of misclassifications and to suppress noise but may also bring the disadvantages of both methods together, so a merged approach requires careful evaluation of the present results and could be a subject of further studies."

Our answers to your minor comments (black) are given below in blue.

Minor comments:
Line 23. I suggest replacing "fast new ice formation" with "rapid new ice formation" to avoid any confusion with "fast ice" term.
Good point. We replaced it.

Line 161. Please explain why HV channel was not used for ice motion detection.
We use an existing sea ice drift algorithm that was, so far, mainly tested and applied to co-polarized SAR (e.g., Hollands 2012, Griebel and Dierking, 2017, including previous work of the author, e.g., von Albedyll et al. 2021). For consistency with previous estimates of uncertainty, we use the HH channel. HH has the advantage that the magnitude of co-polarization is larger than of cross-polarization which is notably affected with thermal, scalloping, and speckle noise. However, we are aware that there are indications that cross-polarized images record ice structures more clearly provided that the noise level is sufficiently low (Komarov and Barber, 2014). Nevertheless, due to the lower signal to noise ratio in the HV, pattern matching in HV can be prone to errors and would require additional extensive quality checks before being ready to use.

Hollands, T. and Dierking, W.: Performance of a multiscale correlation algorithm for the estimation of sea-ice drift from SAR images: initial results, Annals of Glaciology, 52, 311–317, https://doi.org/10.3189/172756411795931462, 2011.
Griebel, J. and Dierking, W.: Impact of Sea Ice Drift Retrieval Errors, Discretization and Grid Type on Calculations of Ice Deformation, Remote Sensing, 10, 393, https://doi.org/10.3390/rs10030393, 2018.
von Albedyll, L., Haas, C., and Dierking, W.: Linking sea ice deformation to ice thickness redistribution using high-resolution satellite and airborne observations, The Cryosphere, 15, 2167–2186, https://doi.org/10.5194/tc-15-2167-2021, 2021.
Komarov A. S., and Barber D. G. "Sea ice motion tracking from sequential dual-pol RADARSAT-2 images." IEEE Trans. Geosci. Remote Sens. 2014, vol. 52, no. 1, pp. 121–136. doi:10.1109/TGRS.2012.2236845

Line 194. Beginning of the sentence with “b1 each lead-fraction …” does not seem to be correct.
Yes, b1 should be replaced with “We advect”

Line 197. “Next, b1 the lead” does not sound correct
Here, as well, b1 should be replaced with “we advect”

Line 226. “LFLKF” -> “LF_{LKF}”.
Done

Line 393-394. Remove comma in “56-112,m”, “56,m”, “1500,m”.
Done

Equations 2-3. It seems that lead fraction uncertainty (sigma_LF) should be dimensionless. However, from equations 2-3 it seems to have a unit [s^{-1}]. Please explain.
Thanks for spotting this inconsistency. We suggest to clarify in the text:

To quantify the uncertainty of the lead fraction magnitude, we first simplify the calculation of the dimensionless lead fractions by omitting the time step information. The lead fractions can also be expressed as the ratio of the difference in displacement (Δ Disp) and the grid cell length scale(L=700 m), thus: LF = Δ Disp/L . Based on the simplified equation, we calculate the uncertainty of the lead fraction magnitude of a single time step from the tracking uncertainty using error propagation assuming no geolocation errors following Dierking et al. (2020). Adapting their equation 17, the uncertainty of the lead fractions σLF is given by the ratio of the tracking uncertainty σtr and spatial L scale: $\sigma LF = \sqrt{2}\sigma_{tr}/L$. With a tracking uncertainty of σ_{tr} = 40 − 80 m (Hollands and Dierking, 2011) and a spatial scale of L=700 m this results in an uncertainty of σ_{LF} = 0.08-0.16 for a single lead fraction pixel. Translated into lead width, this corresponds to 56–112 m per day when assuming that the lead has opened only along one dimension. For the accumulated lead fractions, we add up the absolute errors of each time step assuming that they are independent from each other. Averaging over larger spatial scales assuming independent errors, we quantify the uncertainty of the $LF_{accu.\ div}$ with the standard error of the mean lead fractions:
$\sigma_{LF\ k\ accu.\ div} = k \cdot \sigma_{LF}/(\sqrt{n})$
where k is the number of accumulations and n is the number of pixels that fit into circles with radius 10 km, 50 km, 100 km, and 150 km. For $LF_{5x\ accu.\ div}$, this calculation yields uncertainties for the spatially averaged lead fractions of $\sigma_{LF\ 5x\ accu.\ div}$ = 0.019−0.038 (10 km), $\sigma_{LF\ 5x\ accu.\ div}$ = 0.004−0.008 (50 km), $\sigma_{LF\ 5x\ accu.\ div}$ = 0.002−0.004 (100 km) and $\sigma_{LF\ 5x\ accu.\ div}$ = 0.001−0.003 (150 km).

Equation 3. It is not clear why parentheses in “(n)” are required.
We removed the parentheses.

Line 421. “spatial scale of ΔL=700 m” -> “spatial scale of L=700 m”
We removed Δ as it is not needed.

Fig. 5a. It is very difficult to distinguish vertical blue bars and the blue line as they are both blue.
We have revised this part of the manuscript and removed Figure 5a completely.

Line 512. “by two magnitudes” -> “by two orders of magnitude”.
Done

Lines 560-561. “LFPMW”->”LF_{PMW}”.
Done