

***Interactive comment on* “Brief Communication: Mesoscale and submesoscale dynamics of marginal ice zone from sequential SAR observations” by Igor E. Kozlov et al.**

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We would like to thank the Reviewer for his positive evaluation of the paper, constructive comments and careful paper reading. Technical issues were addressed directly in the revised version of the manuscript. Below are our answers to the main points raised by the Reviewer:

“How much effort is it to obtain the velocity vectors for an individual image pair? If it is a lot of work: Can you share the software code such that researchers can run it for their own individual time/location of interest? If it is not much work: Can you make this method operational and provide to others the velocity vectors at all times/locations

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where appropriate image pairs from Sentinel 1A/B exist?”

In general, our data processing scheme includes two separate tasks – data pre-processing and velocity calculation. The first step includes cutting out the overlapping SAR image fragments, their calibration and normalization, and is planned to be automated soon. The second step (velocity calculation) also needs some additional work with image fragments prior to velocity calculations (e.g. data filtering) and during post-processing (e.g. elimination of false correlations), and currently is done in supervised manner. These two steps are made separately and not yet combined into a single code/procedure. We are working now toward the automatization of the entire procedure to provide velocity vectors to all interested users at least over a single pre-selected site (e.g. Fram Strait), as suggested by the reviewer. Yet, there are still many small issues of the processing chain that are subject of constant improvement, but we hope to finish it asap, at least in the simplified way using the MCC method at the core.

“When can this method be used? What is the range of sea ice concentrations where it applies? Are there differences between seasons in the detail/precision/ease with which the method can be used? E.g. maybe in July (melt season) there is less texture on the sea ice that the satellite could pick up than in September (start of refreezing). Are there influences of weather on the method (e.g. clouds, fog)?”

We haven't yet tested the method over a very large number of paired SAR images spanning different seasons, background ice concentrations and other environmental factors (like near-surface winds), but our experience from various dates in summer season of 2017 suggests that the MCC works rather effectively for typical sea ice concentrations encountered in the marginal ice zone (20-80%), provided the movement of ice floes is apparent in the sequential SAR images. Though our current experience is lacking to address the question regarding the season, we already plan a more detailed study spanning a longer period of SAR observations over the Fram Strait MIZ. The major issue arising during the processing is the change in the SAR viewing geometry between two sequential scenes. Usually, the desired region of interest would be seen

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in the near-range in one image, and in the far-range in another. As a result, the level of radar backscatter (signal strength) over the particular surface area would be different, and so would affect the clarity of eddy manifestation in each of the SAR images in the pair. In such case, individual ice floes shaping the eddy structure might be well seen in one image and poorly seen or have inverted radar contrast in the another one. This issue is addressed during the normalization step, but might be difficult to overcome for very thin ice (either in the beginning of melt season or during freeze onset) whose radar backscatter might become inverted due to the differences in the viewing geometry or varying winds. In regard to weather conditions, SAR is not sensitive to fog and clouds as microwaves effectively penetrate through the atmosphere. Yet, the locally varying near-surface winds may cause some difficulties in the data analysis as described above. If the near-surface winds change over the region of interest during existing time gap between sequential observations, this again might change the radar contrast (signal level) of the sea ice features traced in MCC, resulting e.g. in low correlations and/or inability to retrieve horizontal currents over such ice-covered pixels. Condensed answer to the above two questions is now introduced in the paper.

"The example presented here is from September 2017 in the marginal ice zone in Fram Strait. My high resolution shipboard in-situ study of a submesoscale filament (von Appen et al GRL 2018) was from July 2017, i.e. 3 months earlier. Is there a reason you chose the later time? A direct comparison between the in-situ and the remote sensed data could benefit both methods and reveal more information on the ocean than to consider them separately. I'm not suggesting to change the example presented here, but it might be nice to follow up by also using the method on the July 2017 example, hence also the motivation for the questions under point 1 above."

The only reason here was to show the applicability of the method to retrieve both meso- and submesoscale dynamics in the MIZ. That is why we have chosen specifically the data from 17 September, when the development of the large anticyclone was observed in the MIZ, out of many other paired images in September 2017 (or other months).

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We completely agree with the reviewer and would be happy to make a follow-on study considering the entire summer season including the dates when the high-resolution cruise measurements were made in July 2017.

"The grammar in the manuscript needs careful editing. Especially articles (a/the) are often missing. I point out a few (but by no means all) of these instances below. I'm not sure whether this should be done now or will take place anyways after acceptance by the journal's copy editors."

Thank you for pointing the grammar issues of the text, we did our best to improve it.

I23 Can that melt rate also be expressed as m/day in the vertical?

Here we simply cite the facts that are given in the original paper by Johannessen et al. (1987) in the form that emphasizes the horizontal melt rates. As we do not address vertical melt rates further in the paper, the present form seems to be acceptable. However, if the Reviewer insists we can make that change.

I39 Can you give a number what "relatively low concentrations" means (see main point 1 above)? In this part of text we cite the paper by Manucharyan and Thompson (2017), where sea ice concentrations considered were from 50% down to zero.

I88 "the velocity detection threshold in this case would be 0.03 m s⁻¹" I think it is not just the threshold, but also the precision of your method. I.e. you can only determine the velocity to be 0.03m/s, 0.06m/s, 0.09m/s, and so on. Or am I misunderstanding this?

In fact, this '0.03 m s⁻¹' is the lower limit below which we can't resolve the object's movement working with S-1 GRD EW mode images. The precision of velocity calculations is then set up by the pixel spacing (equal to 40 m) which equals to 40 m/48 min = ± 0.01 m s⁻¹. This is now added to the text.

I93 Did you mean 1150km²? Otherwise the area would only be 2km long (multiplied by 60 km width).

Thank you for noting this typo, the correct value is $\sim 15\,000\text{ km}^2$ as the average length of the MIZ was about 220 km long (being 60 km wide).

“meaning” How does the second statement (reflects underlying circulation) follow from the first statement (3-5m/s)? Maybe you should state that the winds were very weak or something like that.

Thank you, we have slightly rephrased this sentence. Now it sounds: “According to WindSat and ASCAT scatterometers’ data for 17 September 2017 (not shown), the wind conditions were characterized by low south-easterly winds of 3-5 m s⁻¹ under which the ice drift near the ice edge should reflect the underlying ocean circulation (Shuchman et al., 1987; Manucharyan and Thompson, 2017).”

l165 “instability, of”

Here we meant “the barotropic and baroclinic instability of an ice edge jet...”. Shall it be separated by comma in this case?

Fig3 Consider to also show strain in a subplot. Also add the “A, C1, F1” letters and the F1 arrows to all subplots to make a comparison easier.

Thank you for the suggestion. We have incorporated all the suggested changes into the figures. Yet, we are already at the limit of the word count and paper length for the manuscript type “Brief Communication”. We, therefore, have no extra space to accommodate one more subplot and its description in the text. This can only be done at the expense of other material in the paper.

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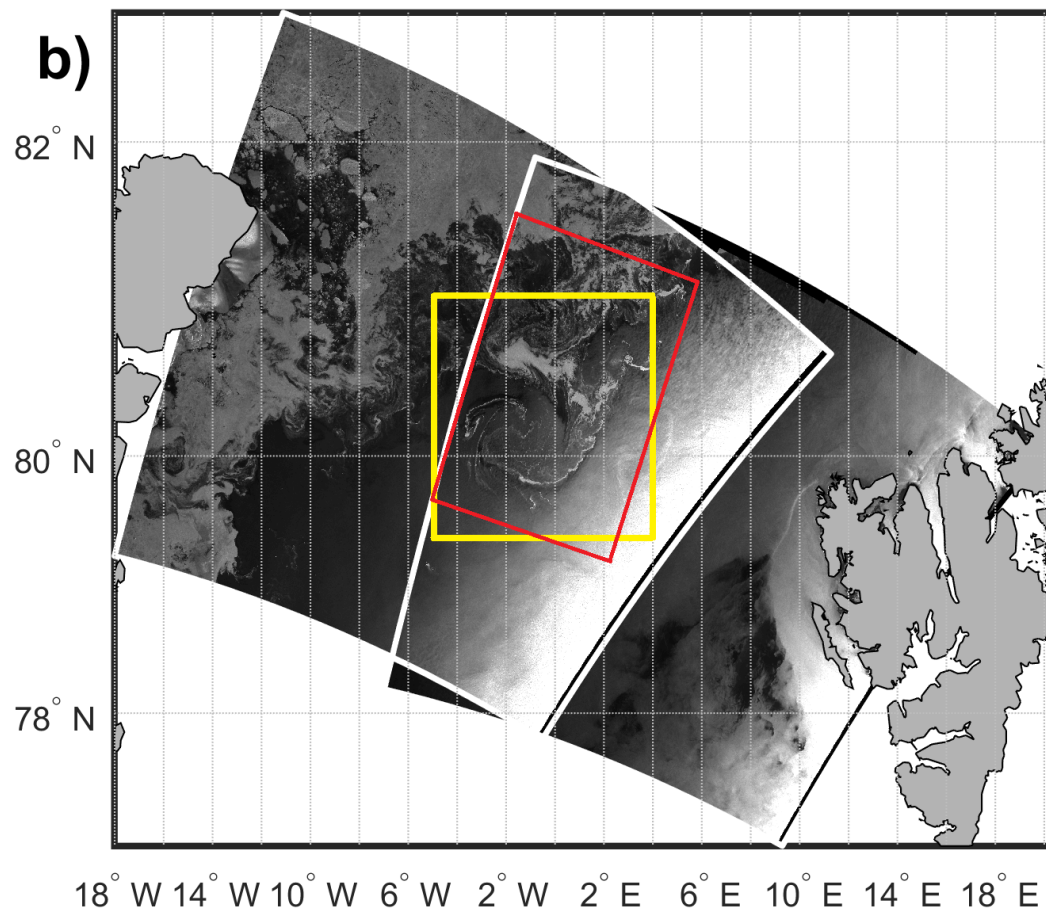


Fig. 1. Updated Fig.1b

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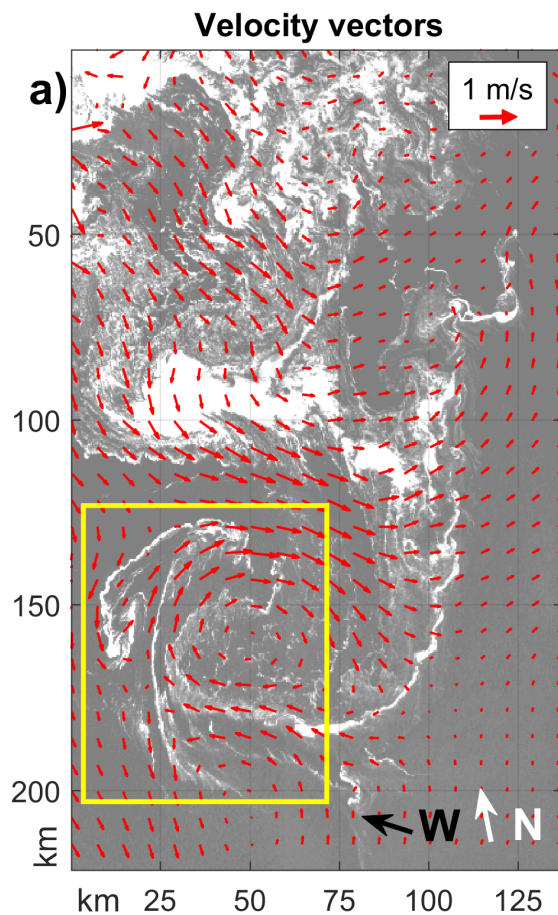


Fig. 2. Updated Fig.2a

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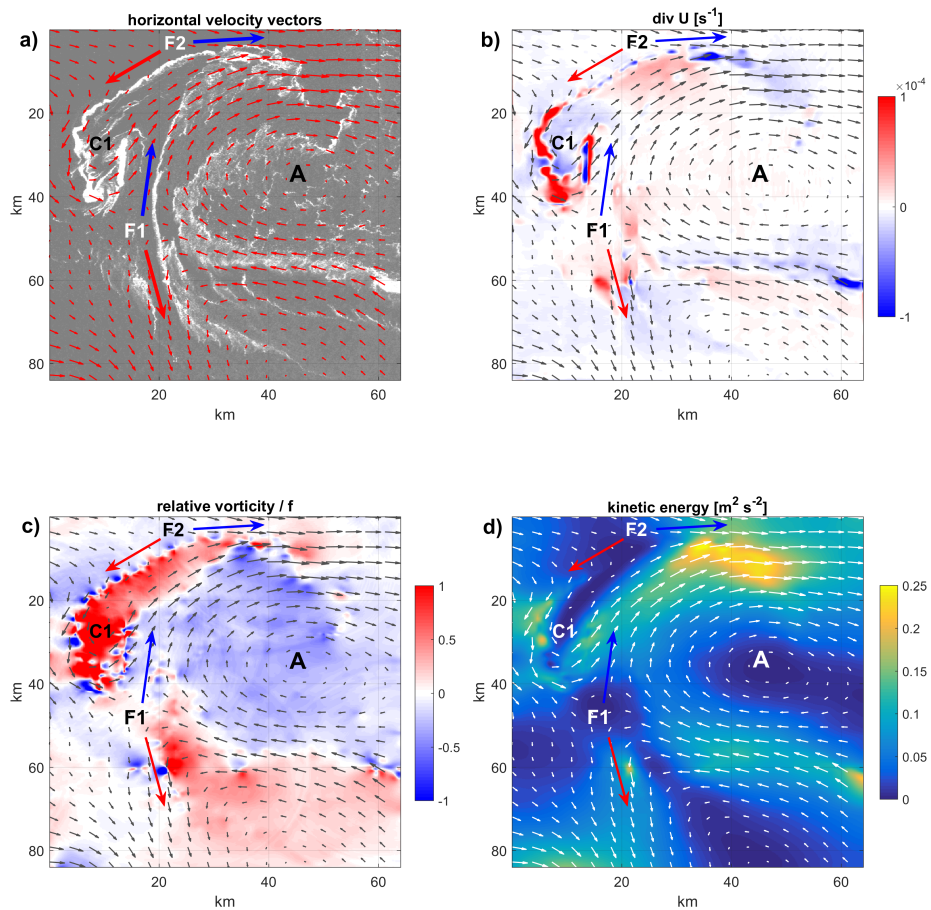


Fig. 3. Updated Fig.3