



Comment on **essd-2021-46**

Ben Davison (Referee)

Referee comment on "Greenland ice velocity maps from the PROMICE project" by Anne Solgaard et al., Earth Syst. Sci. Data Discuss.,
<https://doi.org/10.5194/essd-2021-46-RC2>, 2021

General comments

The PROMICE ice velocity product represents a significant improvement on existing operational Greenland Ice Sheet velocity products, particularly in terms of temporal resolution and timeliness. Indeed, the community has no doubt already benefitted substantially from this product and will continue to do so in future. With that in mind, this paper is an important source of documentation for what is, and will continue to be, a widely used product; therefore, it is crucial that the paper is clear and thorough throughout.

This paper presents a detailed description of the PROMICE ice velocity product and the operational processing chain used to produce it. The paper is (in most places) clear, detailed and thorough: it includes clear and accurate descriptions of each processing stage, error sources and estimation, validation, as well as the product itself. Whilst there are no major issues with the paper, I felt that some sections would benefit from more detail (or alternative descriptions) and, particularly in the second half of the manuscript, the writing lost some of the precision and concision found in the first half of the manuscript. I also have some suggestions that I believe will improve the clarity of the figures and associated descriptions. With these changes and suggestions implemented, I would be happy to recommend the manuscript for publication in this journal.

Below, I provide more specific comments, going through the paper line by line:

Page 1, line 7: when describing the GPS validation in the abstract, I think it would be beneficial to also provide the biases, and perhaps also the uncertainty estimation from velocity estimates over bedrock, because both are useful measures and ones which many readers will be familiar with.

Page 1, line 9: would 'east-west and north-south' be clearer than ' v_x and v_y ' at this stage in the manuscript?

Page 1, line 11: By 'excellent data coverage', do you mean comprehensive/complete imaging of the ice sheet by Sentinel-1? I realise that's a bit more clunky, but could you be more specific here?

Page 1, line 14: 'and dynamics of glaciers' - can you add a timescale here? Such as '...over seasonal and longer timescales' (as discussed in the conclusion).

Page 1, line 18: I'd suggest that 'obtain **ice sheet-wide** observations of ice-flow velocities' makes an even stronger case for the product.

Page 1, line 22: Can you add 'tidewater glacier' before 'ice-flow velocities'? I assume this is the intended focus given the introduction on sea level rise and the reference (Ahlstrom et al., 2013). Alternatively, it would be worth also referencing one or two of the GPS studies carried out on land-terminating sectors.

Page 1, line 23: I suggest 'inaccessibility **and size** of the GrIS, **as well as** the harsh...'. Alternatively, a subsequent sentence stating that the size of the GrIS makes it impractical to obtain continuous measurements of the whole ice sheet through field observations.

Page 2, line 3: 'IV' doesn't seem to be used in preference to 'ice velocity' throughout the manuscript. I don't have a strong preference for either, but perhaps just stick to ice velocity for simplicity?

Page 2, line 28: The statement about weighted averaging is repeated a few lines later - perhaps it could be removed from one of the two sentences?

Page 4, line 2: I wonder if it would be worth providing the pixel spacing (2.3x14.1 m) as well as the resolution here? This would help maintain consistency with the description of the output grid dimensions in section 4.2, which seem to be based on pixel spacing.

Page 4, line 20: Isn't stripmap mode higher resolution?

Page 5, line 8: Is the DEM downsampled before calculating the vertical component of ice displacement? If so, I think it would be worth quantifying how this affects your vertical displacement estimate.

Page 6: The need to focus SAR images is mentioned briefly in the discussion, but I can't see any description of how the SAR images were focused, which should acknowledge the difficulties associated with TOPS mode data.

Page 7, lines 10-15: Was there any filtering of the intensity images prior to cross-correlation to e.g. minimise the visibility of long-wavelength features, or to enhance the contrast in the images? I've found it increases the signal to noise ratio in my own, much smaller scale, investigations.

Page 7, lines 10-15: I think it would be worth mentioning here that several techniques that are often used to co-register Sentinel 1 images fail over moving ice (such as cross-correlation or Enhanced Spectral Diversity) fail because they rely on stationary surfaces, and so you have to rely on the orbit information and DEM.

Page 7, line 23: 'local medians' – can you specify what data this relates to? (i.e. velocity, flow direction etc)

Page 7, line 24: I wonder if these outliers due to surface melt could be removed using a 'dusting' approach as in Selley et al (2021), or using a region growing approach as in Luttig et al. (2017)

Luttig, C., Neckel, N., and Humbert, A. 2017. A combined approach for filtering ice surface velocity fields derived from remote sensing methods. *Remote Sensing*, 9(10). DOI: <https://doi.org/10.3390/rs9101062>

Selley, H. L., et al. 2021. Widespread increase in dynamic imbalance in the Getz region of Antarctica from 1994 to 2018. *Nature Communications*, 1133. DOI: <https://doi.org/10.1038/s41467-021-21321-1>.

Page 7, last line: Is this technically a resampling? I thought it was actually a scattered interpolation, because the ground-surface pixel size varies throughout the image.

Page 8, section 4.4: When fusing velocity estimates from both 6- and 12-day pairs to generate the 24-day mosaics, are the different time periods considered? And how? I imagine you could interpolate them both to daily values and weight them accordingly.

Page 10, line 2: 'knowledge' seems an odd word to use here. Perhaps 'accuracy' would be better?

Page 10, lines 4-6: It looks like these error estimates assume that the orbital errors apply to only one of the images. I think if you assume a 5 cm error in both images, these velocity errors would double? Since the product used the restituted orbits, I think it would also be more appropriate to frame these sentences in terms of the 10 cm accuracy of those data, even though your investigation shows that the measured errors are very similar for both of them.

Page 13, line 9: I'm a bit confused by the use of 'delays' because the timing aspect hasn't been introduced yet as far as I can tell. Would 'shifts' be appropriate, since it's used in the previous sentence?

Page 13, line 18: 'affecting the ability to measure ice velocity': can you be more specific here and relate this to the cross-correlation procedure?

Page 13, line 21: 'sub-resolution structure' of the snow/ice?

Page 13, line 23: I think that 'If the scene is moving... From the same track' is perhaps unnecessary and it would be sufficient just to say speckle can be used to track ice flow when the ice-flow is spatially uniform over the dimensions of the interrogation areas.

Page 13, line 24: perhaps 'steep spatial gradients in ice flow', or similar, rather than just 'rapid ice flow'.

Page 13, line 25: 'the noise level exceeds the signal' is a bit confusing (and impossible by definition?). Perhaps 'the signal to noise ratio is low' would be sufficient?

Page 13, lines 25-26: 'by averaging multiple measurements to reduce the noise' – can you specify what you mean by measurements in this context? Multiple shift maps in the mosaic? Or spatially over multiple pixels?

Page 13, line 28: It's not clear what the difference between 'noisy' and 'patchy' is in this context. Would one or the other suffice?

Page 15, line 4: We have used a variational stationary noise filter to good effect to remove ionospheric striping in the velocity estimates. The method we applied to the Sentinel 1 velocity estimates is described very briefly in Tuckett et al. (2019), and the underlying algorithm is described in Fehrenbach et al. (2012). I think the code is documented here: https://www.math.univ-toulouse.fr/~weiss/Codes/VSNR/VNSR_VariationalStationaryNoiseRemover.html

Fehrenbach, J., Weiss, P., and Lorenzo, C. 2012. Variational algorithms to remove stationary noise: applications to microscopy imaging. *IEEE Transactions on Image Processing*. DOI: 10.1109/TIP.2012.2206037.

Tuckett, P. A., Ely, J. C., Sole, A. J., Livingstone, S. J., Davison, B. J., van Wessem, M., Howard, J. 2019. Rapid accelerations of Antarctic Peninsula glaciers driven by surface melt. *Nature Communications*, 10, 4311. DOI: <https://doi.org/10.1038/s41467-019-12039-2>.

Page 17, line 2: See my comment re Figure 10. Perhaps referring to regions of low/high coverage, rather than regions of blue/yellow in Figure 10 would be clearer?

Page 17, line 8: Can you clarify what you mean by 'amount of data'?

Page 19, line 2: 'properties observed by the radar' is a bit vague. Can you be more specific here, for example by referring to coherence or speckle?

Page 19, line 6: It's not clear to me what this means – does it mean high standard deviation in the velocity maps? Or some other measurement of uncertainty?

Page 21, lines 21-22: 'outer most parts of the outlet glaciers still have reasonable coverage' is a little vague. Can you clarify what you mean by 'outer'? And by 'reasonable' do you mean that it is better than the 2-cycle PROMICE product?

Page 21, line 22: 'the increased temporal resolution may outweigh the downsides' – have you looked at a product using all 6 and 12 day pairs, but only over 1 cycle/12 days? I guess it will have reduced coverage and perhaps be less smooth, but may be useful for investigating the outlet glaciers.

Page 24, line 5: This is the first mention of the extra log following the winter campaigns. I wonder if it would be better mentioned earlier?

Page 24, line 18: 'vary' should be 'varies'

Page 24, line 20: I suggest adding ', which hinder velocity retrieval' or similar after 'high precipitation rates'

Page 24, line 25: add 'here' after 'presented'?

Next, I list some minor spelling and/or grammatical errors and suggestions:

Page 1, line 2: comma before 'which'

Page 1, line 4: 'span' should be 'spans'

Page 1, line 6: I think '6 and 12 day' should be '6- and 12-day' (here and throughout)

Page 1, line 18: 'Greenland Ice Sheet' should be GrIS

Page 2, line 10: 'SAR' should be defined on first use.

Page 2, line 25: 'Greenland wide' should be 'Greenland-wide'

Page 2, line 25: 'IPP' should be defined on first use.

Page 2, line 30: There should be a space after 'i.e.'

Page 3, line 3: 'timeseries' is sometimes given as 'time series'. I'm not actually sure which is correct, but I think you should be consistent.

Page 3, last line: should 'Wideswath' be 'Wide (IW) swath'?

Page 4, line 10: '5' should be 'Section 5' (here and elsewhere)

Page 9, line 21: should that be four groups instead of 'three'?

Page 10, line 8: I think 'Southwest' should be lowercase (there are similar errors throughout the manuscript).

Page 13, line 8: m/yr instead of m/s

Page 13, line 31: needs a comma after 'Section 4.2'

Page 14, line 4: Does 'Total Electron Content' need to be uppercase?

Page 15, line 16: '(Boncori et al., 2018)' should be 'Boncori et al. (2018)'

Page 15, line 28: 'can actually' – should this be 'could actually'? Or did you test this specifically?

Page 16, line 10: 'in the top panel', should instead just refer to the Figure/panel number/label. (same comment for line 15)

Page 17, line 14: 'surface-properties' doesn't need to be hyphenated.

Page 17, line 20: need a comma after 'baseline'

Page 20, first para: I found this a bit repetitive. I wondered if the penultimate sentence could be merged with the first sentence to streamline it a bit.

Page 20, line 25: suggest adding 'roughly' before 'east/west'

Page 21, line 12: is 'Supp' referring to the supplementary information in Hvidberg et al. (2019)? It's not really clear whether it's a typo.

Page 21, line 21: 'noticing' should be 'noting'?

Page 21, line 32: 'spatially better' sounds a bit odd to me. Perhaps 'A validation dataset that is not biased...' would suffice? And/or mention that a spatial distribution representative of a greater range of observed ice velocities/flow regimes would help?

Below, I provide some feedback on the figures and figure captions

Figure 2: Are you sure the blue polygons represent radar image footprints? Some of them seem too large. Looking online, it looks like they might be acquisition segments instead? (Though I couldn't find a clear explanation of the difference). Can you also provide the dates for the 12-day periods shown?

Figure 3: Should the culling prior to mosaicking be included in the flow chart?

Figure 4, caption: I don't think 'North' should be capitalised.

Figure 5, caption: Needs a space after 'a)

Figure 6: axis labels should have V_a and V_r as V_a and V_r

Figure 7, caption: 'Pair' should be lower case.

Figure 8, caption: '7' should be 'Figure 7'. 'Pair' should be lower case in both instances.

Figure 9: Panels should be labelled a/b. I'm not sure the panel titles add much here either. The legend in the bottom panel blocks some of the data – can the scale of the y-axis be changed so that it doesn't block the lines, or can it be placed outside the graph?

Figure 10: I wondered if you could calculate the number of days in an average/given year for which there is velocity data in each pixel? That seems more intuitive to me than the current unit on the colour bar. Using something like that might also make it easier to refer to the values in the text. I think it would also be helpful to label the areas mentioned in the text.

Figure 12: Inconsistent use of 'IV' and 'ice velocity' in the caption. Axis label font is a bit small. Rather than title the panels, I think labelling them a-c and describing them in the figure caption would be clearer. Axis labels should also be consistent with previous plots and text (i.e. use v_x and v_y).

Table 4, caption: 'info' should be 'information'.

Benjamin Davison