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The Cryosphere
Discussions

Interactive comment on "Glacier Image Velocimetry: an open-source toolbox for easy and rapid calculation of high-resolution glacier-velocity fields" *by* Maximillian Van Wyk de Vries and Andrew D. Wickert

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The study describes a new ice-velocity mapping toolkit using visible – near-infrared image pairs or multiple images spanning a range of time. The authors have applied several well-used and a few clever filtering and information-extraction methods in the toolkit. It is good to have one software package that provides both the vectors and a thorough means of editing them in one workflow. The authors then demonstrate the value of the velocity mapping with a group of case studies spanning the range of glacier and small ice cap environments in the northern hemisphere and a tropical location.

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Discussion paper

This is a well-written paper, and the method seems sound and very useful, although there are several similar tools available at this time. This should be published with minor revisions. The only major change I suggest is removing the ice thickness estimation and place it in another paper with other similar targets so that the calculations will be more visible to the community. It is not necessary to place it in this method-and-validation paper. I make several significant suggestions for the abstract as well, and many further suggestions in the rest of the text.

In general, references should be listed in time order, from earliest publication date to most recent. Adopting this convention will mean several minor changes in the manuscript.

Suggested changes to Abstract: We present 'Glacier Image Velocimetry' (GIV), an open-source and easy-to-use software toolkit for rapidly calculating high spatial resolution glacier-velocity fields. Glacier ice velocity fields reveal their flow dynamics, ice flux stability, and (with additional data and modelling) ice thickness. Obtaining glacier-velocity measurements over wide areas with field techniques is labour intensive, and often a safety risk. Recent increased availability of high-resolution, short-repeat-time optical imagery allow us to obtain ice displacement fields using 'feature tracking' based on the presence of persistent irregularities on the ice surface, and hence, velocity over time. GIV is fully parallelized, and automatically detects, filters, and extracts velocities from large datasets of images. Through this coupled toolchain and an easy-to-use GUI, GIV can rapidly analyze hundreds to thousands of image pairs, requiring only a moderately high-end laptop or desktop computer. We present four examples of how the GIV toolkit may be used: to complement a glaciology field campaign (Glaciar Perito Moreno, Argentina), calculate the velocity fields of small (Glacier d'Argentière, France) and very large (Vavilov ice cap, Russia) glaciers, and determine the ice volume present within a tropical ice cap (Volcán Chimborazo, Ecuador). Fully commented code and a standalone app for GIV are available from GitHub and Zenodo.

Consider adding these very pertinent additional references in the introduction Line 20-

21 : Howat, I.M., Porter, C., Smith, B.E., Noh, M.J. and Morin, P., 2019. The Reference Elevation Model of Antarctica. Cryosphere, 13(2), https://doi.org/10.5194/tc-13-665-2019 Scambos, T.A., Haran, T.M., Fahnestock, M.A., Painter, T.H. and Bohlander, J., 2007. MODIS-based Mosaic of Antarctica (MOA) data sets: Continent-wide surface morphology and snow grain size. Remt. Sens. Env., 111(2-3), 242-257, https://doi.org/10.1016/j.rse.2006.12.020. Line 32: Stearns, L.A., Smith, B.E. and Hamilton, G.S., 2008. Increased flow speed on a large East Antarctic outlet glacier caused by subglacial floods. Nature Geoscience, 1(12), 827-831, https://doi.org/10.1038/ngeo356. Line 42: Bindschadler, R.A. and Scambos, T.A., 1991. Satellite-image-derived velocity field of an Antarctic ice stream. Science, 252(5003), 242-246, https://doi.org/10.1126/science.252.5003.242. Line 47: Fahnestock, M., Scambos, T., Moon, T., Gardner, A., Haran, T. and Klinger, M., 2016. Rapid large-area mapping of ice flow using Landsat 8. Remt. Sens. Env., 185, 84-94, https://doi.org/10.1016/j.rse.2015.11.023. Line 52: you may want to note these two data sites, presenting already-processed data – https://nsidc.org/data/golive https://nsidc.org/apps/itslive/ Table 1: PyCorr is the tool behind Fahnestock et al., 2016, which produced some of the mosaics in Gardner et al., 2018.

Line 117 – you say 'multipass methods take advantage of the reduction in chip size to improve the signal to noise'. I think this needs to be rephrased – in general, if there is low shear or deformation across the scene, large chip sizes produce much better matches.

Line 150 – at what 'scale' or number of grid cells are these statistical values calculated? I would assume this scale is either set by the user or by some extracted geography of the ice within the image pair(s).

Figure 5 – label the color bars, with 'Flow Speed' and 'Bearing'.... Could also add degree symbols to the bearing indices,

Figure 7 – the perspective view is a bit difficult to follow without somewhat more area

Interactive comment

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covered to gain a feel for the 3-dimensional structure. . .. The figure is nice but takes a while to orient mentally. Expand view, or, a second inset that shows the map view?

Figure 8 – Expand the velocity scale (taller) in one of the top two insets, and no need to repeat it in both (a) and (b). The titles of (a) and (b) should be 'ice speed' unless you include a few vectors for direction. Include the month of the velocity mapping in the 'title' of the insets for (a) and (b).

Line 263 – suggest change to '. . ..or ice basal conditions are identified.'

Figure 9 – What is the difference, exactly? GIV minus Zheng or Zheng minus GIV?. The scale of the speed differences is large for the margins, and appears to be locally consistent. However it does not extend outside of the glacier boundaries, so it would seem that its not due to a rotational mis-registration. It would seem that somehow the two mappings captured a true physical shift in the margins or speed profile across Vavilov during May 2017 somehow.

Lines 268-269 – Was geolocation necessary? Landat 8 geolocation is generally within 5 meters, i.e. significantly less than a panchromatic band pixel; Sentinel-2 image geolocation is similar. What was the scale of the error in geolocation that you corrected?

Line 272 – remove 'total', makes it sound like you are summing the velocities. . .note also, it's speed, not velocity: velocity is a vector.

Line 290 – please provide the lat long for Chimborazo, and for the other sites (sorry if I missed it).

Line 295 – change to '. . .but for this single point (which we use for benchmarking our method), combined with. . ."

Lines 306 – 316: Hmm. Do you not have a thermal profile from the 54 meter core to the base? It is very likely that the base of the ice is warmer than the air-temperature-based isotherm because of insulation. Moreover, the presence of waterlogged ice (a firn aquifer) means that it is likely that water drains to the bed – and further, you note that the glacier supplies water to the local watershed so seasonal melting is significant (and in general, meltwater on a glacier finds its way through the ice and to the ice-bedrock interface, warming the bedrock.

Rather than take on this complex mountain glacier, why not apply your method to the Vavilov Ice Cap outside of the area of sudden rapid flow? Or you might try a glacier where it is more certain that <0°C conditions exist at the bed, and with more validation data – Commonwealth Glacier or Canada Glacier in the Dry Valleys would be good.

More generally — this paper does not need this section on thickness estimation – your point is to show off the quality and extent and usefulness of the GIV data, and the extensive processing and filtering steps you take – and while this is a demonstration of 'usefulness', it's better as a stand-alone study of Chamborazo or a small set of glaciers where the result will not be lost in the literature (no one will find your thickness estimate in this paper). A series of ice thickness estimates for cold-based Andean glaciers, or Dry Valley glaciers, or selected Himalayan glaciers, using GIV, would be cited extensively.

Line 322 – re-write, confusing. Maybe you mean: local -basal- stresses induced by the ice are much greater than lateral stresses between columns of ice. . .?

Line 340 – 3090 Sentinel -2 image pairs in 2 hours on a Dell laptop – did you subset the Sentinel-2 to just cover the Chimborazo summit area? I am also surprised there are that many pairs – you might include a statement as to how many distinct images were processed.

Lines 344-355 – There is no need for all this speculation on your ice thickness estimate in this paper – this belongs in a separate paper where the approach can be developed more and applied to a set of related areas (perhaps). I strongly suggest cutting this ice thickness section out and placing it in a separate paper. I think it might be interesting to apply GIV to an ice sheet region such as Nimrod Glacier or Peterman Glacier.

Line 390 – change to '. . .alternative. GIV is easily learned and is not computationally time-consuming, and the results. . ..' Not to be harsh, but GIV itself does not learn, and doesn't run either.

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