Review of - *TICOI: an operational Python package to generate regularized glacier velocity time series*

By *Laurane Charrier, Amaury Dehecq, Lei Guo, Fanny Brun, Romain Millan, Nathan Lioret, Luke Copland, Nathan Maier, Christine Dow, and Paul Halas*

The authors describe a new open source python package, TICOI, for the creation of regularly temporally spaced velocity measurements from large velocity pair stacks. The package builds on some of the authors recent work with 'overdetermined system' inversions, and adds an interpolation step to create regularly spaced outputs in time. The manuscript is well written overall, and the package described will be useful to the community. I have included a number of comments below, but these are all relatively minor and should not require any major reorganisation of the manuscript. Overall, I recommend publication in TC following minor revisions.

On the whole, this will be a substantial improvement to our treatment of ice velocity timeseries, and to their usability by wider audiences (the uneven temporal spacing is always a source of confusion). There are still a number of open questions about the best way to treat uncertainties in this data but I cannot fault the authors for not resolving these here. This package also makes for an excellent baseline for future development to build off, particularly as the authors have made sure it is open source and adequately documented.

I attach more detailed comments here:

L1 I understand the meaning but this is slightly awkward wording, maybe something more precise than "glacier mass redistribution and future geometry"?

L2 in open-source -> open source

L5 This point on numerical models could be elaborated on, for instance there are implications for SLR predictions through the ways ice velocity is used in ice sheet models – not always accounted for in final uncertainties.

L9 perhaps 'evaluated against' rather than 'validated using'?

L12-13 'also proves to be able to' -> 'can also'/'In addition, TICOI can'

L13 'under certain conditions' perhaps? I imagine it cannot do this reliably in all cases.

L14 'regularization' -> 'harmonization' / 'improving the intercompatibility'?

L14 It might be interesting to state what period you think might be optimal in most cases – daily, 5 days, weekly, monthly?

L16 + In the intro discussing the importance of ice velocity a quick mention of the hazard implications would also be good – it can be key to understanding dangerous surges (particularly where lake dams are formed; e.g. Singh et al., 2023 https://doi.org/10.1016/j.scitotenv.2023.161717; Beaud et al., 2022 https://doi.org/10.1016/j.geomorph.2019.106957), forecasting glacier detachments (e.g. Kaab et al. 2021 https://doi.org/10.5194/tc-15-1751-2021; Gilbert et al., 2018 https://doi.org/10.5194/tc-12-2883-2018), and understanding volcanic influences (e.g. Martin et al., 2025 https://doi.org/10.1017/jog.2024.107) among others. It is in this domain that challenges with data quality and uncertainty quantification can be particularly problematic so this can help you make the case for the value of TICOI. It is a step towards integrating satellite data in early warning systems for some of these processes – though this is perhaps still some way off.

L57 'associated quality indicator' is a little vague here – is this because it is a 'relative quality score' rather than 'absolute uncertainty'? A few more words to clarify would help.

L120 Specifying what 'a priori knowledge of the data quality' means here might be useful?

L140 Not sure 'relevant' is what you mean (?)

L143-144 The first point here is not clear, could you rephrase? It is not clear why this would prevent comparison as written. We don't typically have instantaneous velocities.

L144-145 for 2), this could be an argument against interpolation unless uncertainties are properly captured, as a regular interval interpolated from long/short baseline images would have different expected error profiles

L145 For 3) presumably this could be solved via interpolation also?

L148-149 This assumption will in fact be wrong over any time window, not just long ones (glacier velocity is never truly constant over any meaningful timescale, though the approximation may be closer in some cases). And seasonal variations/surges are not the only processes involved.

L155 I understand this might be covered in other paper, but does this account for low/no decorrelation over stable ground compared to the ice?

L159-160 Can you be more specific here rather than referring to 'the above'?

L162-169 As far as I understand this is assuming that decorrelation means bad data? Can you state this here?

L177 'affordable' -> 'valid'

L179 Do we not have some a priori information in all cases from our understanding of ice physics? (granted, with a wide range) Could the details of a constraint be calibrated further from easily available glacier data (e.g. geometry)?

L189-196 I gather this requires looping through all pixel timeseries individually. Is there no way to vectorise the least squares inversion step so that this can be run on the 3D cube in one operation? Would this then be gated by memory usage? This vectorisation should be fairly straightforward to do for the interpolation step if not already implemented.

L198-207 The VVC will penalise areas with real temporal variation in flow direction, right? E.g. parts of ice front or glacier convergence areas.

L210 Could you discuss a little more the choices of uncertainty metric here? In particular some of the potential weaknesses of the choice and reasons for excluding other common values (such as stable ground displacement and x-correlation signal to noise ratio).
In reality we have two types of uncertainty in feature tracking:

1) What is the likelihood that this displacement value is actually representing the real motion process (which you raise above with the discussion about decorrelation). If it is not, then there is no information in the resulting value and an ideal processing workflow would exclude it. This is similar to 'accuracy' but more of a binary real/not real.
2) For a displacement value representing the real motion process (i.e. 'real' in the above), how precise is this? This will be affected by warping of features, partial decorrelation, the subpixel algorithm choice, image georeferencing error, etc.

It seems that the approach here perhaps blends these two together – this can be fine as they are hard to separate out in many cases. It would be interesting to have a little more discussion about this and the choices made.

L294-294 Can you say a little more about this 'increased iteratively according to the normalized displacement coherence' – i.e. the window size increases if the noise (calculate from NDC) is above a given threshold. It is an important factor of AutoRIFT to understand, as the uneven window sizes leads to uneven smoothing (and thus error/noise) through space for a single image pair.

L306-308 Why was this necessary rather than reprojecting the NS and EW components?

L349 Can you show that this doesn't sometimes reject real long baseline data in areas where the shorter baseline data is particularly noisy?

L362 I like the KGE, but it is rarely used in this field so far. It might be useful to say in a little more detail here why you think it is a useful indicator and cite a relevant paper for more info (e.g. Gupta et al. 2009 https://doi.org/10.1016/j.jhydrol.2009.08.003). Give some idea of what a 'good' KGE might be (it is not a 0-1 quality metric as some might assume from a quick read of this as is).

Personally I might also look at the three KGE components separately also as the response can be dominated by one of them.

L369-375 The numbers are confusing in here. You use percentages in places I am not clear why – RMSE and KGE are not usually given in percent. Does "a reduction in RMSE from 9 to 69%" mean a reduction 'from 9 to 0.69', or this a typo and you mean 'from 69 to 9'? Please clear this up.

Tab 1: Interestingly, this seems to show that moving median can be decent for some glacier types. I wonder if the median split by temporal baseline might do even better in some cases (though of course not picking up abrupt changes as TOCOI can, but will always be much computationally faster).

L405 – This paragraph should capture the fact that flow direction will not be constant across all of a glacier, and some areas may have real processes leading to low VVC even without noise. The confluence of two glaciers is one such place (i.e. varying ice flux from one or the other will shift exact position of confluence and the local flow direction). This looks particularly of concern here for the terminus (of special interest, but also with naturally low VVC in many cases).

Figure 7 – I am a little confused by the visualisation here – is this showing that a large majority of estimate values are within 9cm of the true value? Seems too high, so I am perhaps misunderstanding.

Figure 8 – How do you know that the grey bars are 'correct'?

L465-466 Did you try this on the Lowell and Kaskawulsh case studies also? How well did you pick up the marked sub-annual variation in that case? I think section 4.6 likely oversells the generalisability of this to all cases.

L484-485 this should be 1m and 3m respectively for 0.1pix

L527 As currently set up this is fully parallelised right? So for ~300 CPU could be run in ~2hr? Seems feasible to run at least all non-ice sheet data with a large machine.

L530 Are there ways to exploit the spatial autocorrelation to reduce computational cost also?

L543 'entirely data-driven' – you mean it requires no a priori info/ model here right?

L544 KGE improvement can't really be capture in a percentage. From table 1 Kask L had a negative 260% change due to sign flip! Give absolute value increases for it.

L545 I agree this is a useful advance in the way this is done but I probably wouldn't describe it as a paradigm shift. The iterative procedure implemented in GIV can also do this (VWDV and Wickert 2022, https://doi.org/10.5194/tc-15-2115-2021), though almost certainly not as well – the iteration can be rather sensitive to outliers.

On a different note it would be nice to apply slightly more caution in the wording of this. Many areas have limited short baseline data due to high cloud cover (e.g. many HMA glaciers) but also large temporal variability within this period – it probably won't be very effective at reconstructing these. Including an assessment of the Lowell/Kask glaciers in the example above on this might help illustrate.

L555 instead of 'reasonable computational time' using an exact number here would be better.

Thanks again to the authors for this contribution and I look forward to testing TICOI myself.

-Max VWDV