The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-122-RC2, 2020

The Cryosphere Discussions

Interactive comment on "Detecting seasonal ice dynamics in satellite images" *by* Chad A. Greene et al.

Anonymous Referee #2

Received and published: 29 June 2020

The authors present a workflow to fit a sinusoidal function to a data set of clustered velocity estimates on ice sheets and outlet glaciers. The work is well written, and the authors clearly identify the need to extract more concise information of this vast collection of Eath observation data. The steps taken by the authors are explained, but in general there is a tendency to highlight the strong points of the methodology in their argumentation. Being a methodology paper, there might be a reason to keep this presentation brief, but it might be more than worthwhile to emphasis points of improvement and why certain decisions are taken.

My main concern with this work stems from the property that the authors define seasonal variation as a cycle. In this way the reader is pushed into a certain narrative, which limits how to approach this issue. The authors are correct about the sinusoidal

variation of the forcing (the sun and the seasons), but this does not mean the ice velocity has the same reaction. Personally, I see the seasonal variation more as a perturbation, to which there is a reaction time/response, a peak and fade out/reorganization. Thus a perturbation (including a sinus function, but also a lot of other responses) occurs every year, due to surface melt run-off, but the time span does not need to extend towards a whole year, as is assumed here. If we look at other studies short spikes are clearly visible (Kjeldsen et al. 2017, 10.1002/2017GL074081; Derkacheva et al. 2020; 10.3390/rs12121935), or in the dynamics of a surging icecap (Dunse et al. 2015, 10.5194/tc-9-197-2015) where a step function is seen, that is initiated by meltwater perturbation. So I miss a discussion on how good a sinus-function is as a model. There is only testing of how good the observations meets the model description, and not how good the model fits the observation. Putting everything on "background interannual variability" is a bit easy.

Another question arising is the wording of climatological velocity, I am not able to figure out what the authors mean with this term. This directly also brings me to a second point on the sinus fitting, as it is treated as a cyclic function similar to (Menchew et al., 2017, 10.1002/2016JF003971). They look at a tidal time span, where the forces are highly repetitive in magnitude and phase. However, if this is the case for seasonal glacier velocities is not so clear, as the amplitude of glacier velocity seem to correlate with surface mass balance. This has been observed with GPS in Greenland (van de Wal et al. 2015, 10.5194/tc-9-603-2015) or on Nordenskiöldbreen, Svalbard (van Pelt et al. 2018 10.1029/2018GL077252). But the sinus function of the authors does not take the change in amplitude, from year to year into account. However, this (to me) would be a climatological velocity (if I had to guess what the authors mean).

Other influencing phenomena, like the ocean/front position have similar seasonal amplitude change (Kehrl et al. 2016, 10.1002/2016JF004133). By putting all these into a cyclic function, the signals of phase and amplitude might smooth out. In connection to this, at high latitudes, the coverage is concentrated towards the summer season.

Hence, how do short term perturbation propagate into the velocity estimation? From the synthetic test the methodology can be "considered agnostic", but this is true for reconstruction purposes of a sinusoidal function. It is also not clear where the authors are after, the onset of speed-up, or "identify the seasonal maximum velocity"? Other studies/data/methods are able to find the timing of such speed-up events (Altena et al. 2017 10.3389/feart.2017.00053, Vijay et al. 2019, 10.1029/2018GL081503), though not as precise or automatic as presented here, but are less constrained. So, there are some issues on the amplitude, but also on the phase. The argument of the authors for using a sinus, as it is "elegant" is a bit weak in my opinion. It would very much strengthen the manuscript, if these influencing effects/considerations are highlighted, as it gives handholds on the way forward.

The authors have formulated their estimation procedure by decoupling the x- and y-velocities. Is there a certain reason for this? I can imagine it can be beneficial, to include co-variance functions, so outliers in one dimension are also excluded in the other. In addition, given these phase angles are estimated independently, do the authors see a difference between both axis. If so, this would imply a change in flow direction, if not what would that mean? Also, why did the authors do filtering (using the MAD), and not do robust least squares, or at least use such procedure in the estimation? Neither is it clear to me why several iterations are applied, see (https://ccrma.stanford.edu/∼jos/filters/Sum_Sinusoids_Same_Frequency.html), or is the estimation not restricted to a yearly cycle? Or is the iteration not done on the residuals?

The authors run tests on synthetic data, by imposing corruption to individual velocity estimates. This noise is done on an individual basis, which is partly due to measurement noise. But there is also dependent noise, as displacement estimates are derived for pairs of images. Hence, when one image is corrupted for some reason, there is a high probability it propagates to all displacements it is part of. However, this issue is not included into the analysis, though of importance (and due to the synthetic nature,

is possible to generate). This would give more insights then the 32 velocity estimates, stated now.

minor comments:

In general the manuscript is well written, the authors write in their mother tongue, so concerning this issue I am not able to do any better. But for a global audience the wording is sometimes a bit hard; I have learned quite a lot of new words. For sake of easy reading, and not having to go back and forth to a dictionary, please consider changing words a bit. Think of, "unwieldy" or "egregious"

I have tried to understand from the text what is done, and also looked in the code to be able to zoom into the plots/data. But the provided code and plotting does not work, as some functions ("itslive_tsplot" or "itslive_seasonal_deets") are absent.

title: be a bit more specific, maybe change to "Reconstructing seasonal oscillations" also include "glacier ice"

6: "dark polar winters" > "at high latitudes"

8: "climatological average winter velocities" what is meant here?

15: "sufficient quantity of data" is this due to quantity of data, the consistency of campaigns/ monitoring programs or simple availability of large computing power. Or is it opening up of the archives, making historical flow estimation possible (Cheng et al. 2019 10.5194/isprs-archives-XLII-2-W13-1735-2019).

18: "all of the world's ice" large bodies of glacial ice

20: "upended glaciology" Remote sensing is able to get geometric information about the (sub)surface, and is of great aid. To some extent this is a game changer, but it might be fair to also give credit to automatic weather stations, or put it into persective. This have been other great advancement in glaciology, think for example of (Ohmura et al., 1992; Oerlemans et al., 1998).

31: There is also an large collection of studies at the intermediate timescale, which is left out here, dealing with surges. For sake of completeness, this might be included.

37: "the logistical challenge of" what is meant here?

39: "robust extraction" using a robust pre-processing technique, is different from a robust methodology. Given its stiffness (non adaptive) towards one model (a sinusoidal) this might not be a correct formulation. It might be "precise"...?

40: "primarily focused on Antarctica" maybe better: on the ice sheets and their outlets ....?

53: "by feature tracking" add: over longer time spans

55: "the true magnitude" change to "a" instead of "true" or "a well fit"

56: I miss another possibility here, which is common practice in inSAR displacement estimation, being inversion (e.g.: Bontemps et al. 2018, 10.1016/j.rse.2018.02.023, Li et al. 2020, 10.1016/j.rse.2020.111695). This does not make it necessary to work with average time stamps or a model, and can resolves to very small time steps.

64: " first or second image" first and second? maybe be more clear or use "master-slave" "chip-search space" etc. 100: "most robust means" why is this robust, where do you get the reliability from? fig4: maybe it is good to note, why there are two groups of points, as one is +- a year and the other at short time intervals in summer.

btw: the purple line nicely follows the annual velocity clusters!

105: "exceeds 2.5 robust standard deviations" change to median absolute difference (MAD). this is a typical measure.

151: I don't think this is sensitivity, but more an analysis to get an idea how good the recovery is. As the model is corrupted with noise and then an attempt is made to reconstruct the model. If I understand correctly.

181: "recover", change to we "are able to describe the variation by seasonal cycles" or alike.

258: " is remarkable" subjective wording, please change

258: "robust", precise/accurate might fit better

267: "minuscule variations" subjective wording

283: " in the climatological sense, nature does not consistently time such events as calving or increases in basal water pressure with any greater precision than the method we have presented to detect them". What is meant here?

285: "In most cases, a sinusoidal will likely capture the majority of velocity variance throughout the year, and represent the fundamental mode of subannual variability in ice velocity." Please justify this claim, as this is the corner stone which the whole study is build upon.

291+: It seems the authors put all the misfits of the sinus model on the inaccuracies of the GPS measurements, while this sensor measures all kinds of physics decadal, annual, daily, ...

305: "our method can extract" please add "..by describing ice flow as an oscillation ..." in some way

309: "independent of the amplitude and phase of the seasonal velocity variability", this is not convincingly given

313: "fully three dimensional understanding" what is meant here?

322: "egregious outliers" egregious=outliers

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-122, 2020.