

Dear Dr. Alfredsen,

Thank you for your revised manuscript. It will be suitable for publication in TC with some minor revisions that I have suggested below.

Best regards,

Peter

Editorial comments:

P1,L10: “supply, riparian” becomes “supply, and riparian”

P1,L13: “and satellite imagery, data from satellite-based radars as increasingly aerial and terrestrial imagery are currently applied” becomes “and data from satellite-based sensors and, increasingly, aerial and terrestrial imagery are currently applied”

P1, L17: “the ice and with considerable less measurement efforts compared to traditional surveying methods” becomes “the ice, and with considerably less measurement effort compared to traditional surveying methods.

P1, L17: “The methodology applied to ice mapping is outlined here, and examples are shown on how to successfully apply the method to derive data on ice processes” becomes “A methodology applied to ice mapping is outlined here, and examples are shown on how to successfully derive quantitative data on ice processes.”

P1, L22: “Physical monitoring” becomes “Physically monitoring”

P1, L25: “integrated satellite images (MODIS) with radar data (RADARSAT-2)” becomes “integrated optical (MODIS) and radar (RADARSAT-2) satellite data”

P1, L26: “also evaluated the dataset with aerial- and terrestrial imagery to evaluate the satellite” becomes “also used aerial- and terrestrial imagery to validate the satellite”. Please check this edit to see if it is true.

P1, L28: “successive satellite imagery” becomes “successive radar? optical? satellite images”. Did they use optical or radar, or both? Please clarify.

P2, L1-5: “time series of these ice data for the lower Nelson River, Canada. Most satellite-based approaches described in the existing literature are applied to large rivers and may not be applicable to smaller rivers and streams due to the resolution of the satellite imagery. Methods are therefore needed to monitor ice formation in smaller rivers. Further work is also needed to

move from a qualitative evaluation of ice (focussing on ice types and presence or non-presence of ice) towards a quantification of ice volumes and the spatial distribution of ice” becomes “time series of these ice data for the lower Nelson River, Canada. Most satellite-based approaches described in the literature are applied to large rivers and may not apply to smaller rivers and streams due to the coarse resolution of the satellite imagery. Remote sensing methods are therefore needed to monitor ice formation in smaller rivers. Further work is also needed to move from a qualitative evaluation of ice (focussing on ice types and presence or non-presence of ice) towards a quantification of ice volumes and the spatial distribution.”

P2, L6: “aerial drones. Such drones increasingly have camera systems of sufficient quality, and the resultant aerial” becomes “aerial drones with camera systems of sufficient quality that the resultant aerial”

P2, L9: “Combined with ground control points, surface models can be georeferenced and combined with other spatial data for analysis. Based on the georeferenced point cloud and aerial images, digital elevation models of high accuracy and resolution can be developed” becomes “Ground control points can be used to georeference the point cloud and aerial images generated by the drone, in order to develop digital elevation models of high accuracy and resolution.

P2, L11: “Additionally, derived surface texture can be overlaid onto surface models and imagery can be undistorted and reprojected as georeferenced orthophoto mosaics to provide an accurate aerial image of the study object” becomes “Additionally, surface texture may be derived and overlaid on the surface models, and derived georeferenced orthophoto mosaics to provide an accurate aerial image of the study object”

P2, L14: “needed (Westoby et al., 2012;Smith et al., 2016), where the method” becomes “needed (Westoby et al., 2012; Smith et al., 2016), and the method”

P2, L16: “(Vasquez-Tarrio et al., 2017;Arif et al., 2016)” Becomes “(Vasquez-Tarrio et al., 2017; Arif et al., 2016).

P2, L17: “glaciers e.g (Ryan et al., 2015) and in the study of snow accumulation (Nolan et al., 2015)” becomes “glaciers (e.g. Ryan et al., 2015) and snow accumulation (e.g. Nolan et al., 2015).”

P2, L20: “jams forming” becomes “jams formed”

P2, L21: “dams forming” becomes “dams formed”

P2, L23-26: “flooding and thereby severe damage to infrastructure and the riverine flora and fauna (Beltaos, 1995;Prowse and Culp, 2003). Anchor ice dams control the freeze-up process in small rivers and streams, and are thereby important for understanding winter conditions in such streams (Stickler et al., 2010;Turcotte and Morse, 2011). A possible drawback with the small drones as employed here is limits to flight distances (typically 1000-1300 meters) and

battery life time in cold conditions” becomes “flooding, and thereby severe damage to infrastructure and the riverine flora and fauna (Beltaos, 1995; Prowse and Culp, 2003). Anchor ice dams control the freeze-up process in small rivers and streams, and are thus important for understanding winter 25 conditions in such streams (Stickler et al., 2010; Turcotte and Morse, 2011). A possible drawback with the use of small drones as employed here is limited flight distances (typically 1000-1300 m) and battery life time in cold conditions”

P2, 29-30: “Furthermore, we use the method to map the remnant of a stranded ice jam and a river section 30 with anchor ice dams.” becomes “Furthermore, we use the method to map the remnant of a stranded ice jam in one river section another river section with anchor ice dams”

P2, L33: “quality of data available and further improve our” becomes “quality of data available. This may further improve our”

P3, L6:” Haga bru and” becomes “Haga bru, and”

P3, L7: “The length” becomes “The lengths”

P3, L8-13: “are 350 m and 200 m for Gaula and Sokna respectively. During the measurements, the discharge in Gaula (at gauge Gaulfoss) was approximately $20 \text{ m}^3\text{s}^{-1}$ and in Sokna (at gauge Hugdal bru) approximately $3.5 \text{ m}^3\text{s}^{-1}$. This correspond to 28% of the mean 10 annual flow. The site in Gaula is about 75 meters wide and flows mainly over a bed of coarse gravel and smaller cobbles. At the site where the ice jam formed, the river narrows and the flow changes from a section with fast riffles to a deeper pool area. The Sokna site is steep (1/100) and consist of large cobbles and boulders and the river is characterised by short pools interspersed with drops and fast riffles/rapids. The width of the reach is around 18 meters” becomes “are 350 m and 200 m for Gaula and Sokna, respectively. During the measurements, the discharge in Gaula (at the Gaulfoss gauge) was approximately $20 \text{ m}^3 \text{ s}^{-1}$ and in Sokna (at the Hugdal bru gauge) approximately $3.5 \text{ m}^3 \text{ s}^{-1}$. These rates correspond to 28% of the mean annual flow. The Gaula site is about 75 m wide, and water flows mainly over a bed of coarse gravel and smaller cobbles. At the location where the ice jam formed, the river narrows and the flow changes from a section with fast riffles to a deeper pool area. The Sokna site is steep (1/100), the bed consist of large cobbles and boulders, and the river is characterised by short pools interspersed with drops and fast riffles/rapids. The width of the reach is around 18 m”

P3, L21-22: “Apple iPad with the DJI Go application for flight control. Though capable of autonomous operation according to a pre-planned flight plan with the DJI GS Pro application” becomes “Apple iPad with the DJI Go application. Though capable of autonomous operation according to a pre-planned flight plan generated with the DJI GS Pro application”

P3, L24: “information and the GPS” becomes “information and GPS”

P3, L25: “82 pictures was” becomes “82 pictures were”

P3, L27: “and 10 minutes was used for the flight” becomes “and the flight lasted 10 minutes”

P3, L29: “and they were identified using” becomes “and they consisted of”

P3, L30: After the sentence on the markers, and before the note on Gaula site GCPs, insert the following (or similar): “GCPs were spread out over the measurement domains as much as conditions allowed, but only one bank was accessible to us at the Sokna site.”

P4, 2-4: What did you learn from your previous experience? Perhaps you can expand your experience? I ask because you cannot use Goldstein et al (2015) as a reference. Their document is not peer-reviewed, and remains un-reviewed this many years later. Please delete from your reference list.

P4, L8: “computed by Agisoft Photoscan, and even if the documentation is not very clear on this issue, experience”. Please contact the software company and clarify the issue here for all readers. Then you can say “computed by Agisoft Photoscan based on..., and experience shows”

P4, L14: “Each marker were identified” becomes “Each marker was identified”

P4, L19: “the DEM and an orthophoto” becomes “the surface model, and an orthophoto”. Throughout the text I suggest calling your product the surface model rather than the “DEM” to distinguish it from the Norwegian DEM that you also use.

P4, Lines 20-22: Replace “was” with “were” in both instances. Change “in Gaula were taken from the 1 meter” to “in Gaula was taken from the 1 m”

P4, L26: “computed in Photoscan, and the results are shown in Table 1. The accuracy of the digital elevation model is considered good considering the errors in table 1, and ice features can be derived with high precision” becomes “computed in Photoscan. Given the low errors shown in Table 1, the accuracy of the digital elevation model is considered good and ice features may be derived with high precision”

P4, L31: “Gaula site, and the extent of the ice jam and the directional” becomes “Gaula site, the extent of the ice jam, and the directional”

P5, L5: “of the 5 SfM- derived DEM and” becomes “of the 5 SfM-derived DEM and”

P5, L6: “ice event and from observations in the field the jam” becomes “ice event, and from observations in the field, the jam

P5, L8-9: Transects A, B, and C should be A-A', B-B', and C-C'.. Please change in the text, and modify Figure 2 accordingly. This will make it obvious where the start and end of each transect is. With the orientation known, some text later on in this paragraph will make more sense.

P5, L10-14: “This is most likely a minimum volume since it is difficult to determine if the outermost meters of the DEM describing the ground is the actual ground level or the water surface of the river. The DEM used does not cover terrain under water, and it is not clear if we see the bottom or the water surface in the outer part of the ground level plot on Figure 2” becomes “This is most likely a minimum volume since it is probable that the Norwegian national DEM describes the river water surface rather than actual ground level, in particular for the last 10 m of each transect (Figure 2).”

P5, L26: “measured ground points the point cloud was georeferenced, and a digital elevation model and a georeferenced orthophoto mosaic developed” becomes “measured ground points, the point cloud was georeferenced and a digital elevation model and a georeferenced orthophoto mosaic were developed”

P5, L27-28: “data on ice thickness, volume and spatial distribution was extracted” becomes “data on ice thickness, volume, and spatial distribution were extracted”

P5, L29: “(e.g. Timalsina (2014)),” becomes “(e.g. Timalsina, 2014),

P5, L31: “was possible our new” becomes “was possible, our new”

P6, L2-10: “As is in the case with the Gaula ice jam, it is relatively simple to compute ice volumes and derive ice cross sections for ice grounded on a surface with known ice-free geometry. In cases where river ice has open water sections, the problem is more complicated, as is illustrated by considering the conditions shown in the Sokna case (Figure 3). Anchor ice dam positions and their widths and heights can be derived from the picture and the DEM, but unlike the Gaula case, no ice-free geometry of the river is available to assess the volume of ice. A possible approach as we show is to derive the elevation of the level of the open water from the SfM generated DEM and then use this to assess the thickness of the anchor ice dams seen in the picture. At the study site in Sokna, we could see that the open water would give a reasonable assessment of the thickness of the dams, but this do require field observations to confirm the method” becomes “At the Gaula ice jam, it was relatively simple to compute ice volumes and derive ice cross sections for ice grounded on a surface with known ice-free geometry, but in cases where river ice has open water sections the problem is more complicated. This is illustrated by considering the conditions shown in the Sokna case (Figure 3). Anchor ice dam positions and their widths and heights can be derived from the orthophoto mosaic and the surface model, but unlike the Gaula case, no ice-free geometry of the river was available to assess the volume of ice. A possible approach as we show is to derive the elevation of the level of the open water from the SfM generated surface model and then use this to assess the thickness of the anchor ice dams seen in the mosaic. At the Sokna site, we could see that the open water would give a reasonable assessment of the thickness of the dams, but this approach requires field observations to confirm the method”

P6, L25: Join to end of pervious paragraph. “6.17/55 mm” becomes “6.17 × 55 mm”

P6, L26: Period after (www.dji.com)

P7, L2: “improve picture quality and thereby the feature matching between cameras and the ability to generate better quality depth maps” becomes “improve picture quality, feature matching between cameras, and depth maps”

L7, L13-21: Much of this is repetitive, and similar to text on P5, L21-26. Please integrate the text here (or there).

P7, L23: “ the small drones in focus here” becomes “the DJI Phantom 3 Professional used here”

P7, L24: “1000 – 1300 meters” becomes “1000 – 1300 m”

P7, L26: “Another issue is related to” becomes “Another issues relates to”

P7, L29-31: “A last issue to consider is operational constraints set by federal aviation regulations. In Europe, systems with a take-off weight of less than 2 kilos have less restrictions than larger systems but this must be checked with local regulations in each case.” Becomes “A last issue to consider are operational constraints set by applicable aviation regulations that must be consulted before each flight, which may limit system size, mass, range, elevation, timing, etc.”

P8, L1: “ data of the” becomes “data on the”

P8, L2: “variables the DEM and” becomes “variables, the surface model and”

P8, L3: “Data can also” becomes “Data generated from SfM can also”

P8, L31: Delete Goldstein et al., 2015.

Figure 1: Red crosses are very hard to see. Please make bigger. You could also enlarge the blue triangles. The crosses on the railroad are also difficult to see. Please increase the thickness of the railroad line.

Figure 2: Labels for transects A, B, and C are cut off. Please change transect names to A-A', B-B', and C-C'.