"Monitoring ice break-up on the Mackenzie River using MODIS data" by P. Muhammad et al.

We thank the reviewer for her/his comments and suggestions. We have implemented the changes suggested. In particular, the methodology was made clearer and more concise and additional tables added as requested by this reviewer.

First Review

1. Using visual inspection of the data and manual sampling, or using intersection of the MODIS data with the river outlines and then automatic sampling? At selected points/reaches or the entire river?

Thank you very for the comments. With regards to the first major concern, MODIS data was manually sampled through visual inspection. MODIS data was collected along the river outline manually, wherever it was observable. Please refer to MODIS Processing section 2.2 (p. 8, lines 62-64) and new Figure 2 for an updated description of the methodology.

2. The SDS data could have errors, in particular over the mixed pixels over the river, consisting of water, land, and ice. The MODIS L3 algorithms might not have been designed for this type of highly variable ground cover. Some validation study is needed, for instance as part of the method section, to characterize the success and accuracy of the SDS. For instance, classifications from coincident Landsat data could be compared to MODIS SDS.

To avoid error in the SDS data collected, mixed pixels over the river consisting of water, ice and land were omitted. Furthermore, in sections of the river where pixel mixing was common as a result of smaller river widths, MODIS L1B was used. MODIS L1B with a spatial resolution of 250 m enabled to maximize data collection and minimize mixed pixel omission. It would be useful to classify Landsat images coincident to that of MODIS SDS. Although this was not explored in this paper, other have reported high correlation of ice detection when comparing high resolution Landsat to MODIS images (MOD09GQ – 250-m spatial resolution). Chaouch et al. (2012), manually and through visual interpretation, compared ice cover from Landsat images (30-m spatial resolution) to ice covered MODIS images and concluded good levels of agreement (91%). This information has been added to the revised manuscript Section 2.2.2 page 12 (lines 140-143).

During the sampling of the MODIS pixels, only ice or thereafter water pixels during the melt/break-up period were sampled. Please refer to MODIS Processing section 2.2 (p. 8, lines 62-64).

3. How do the authors use MODIS L1B under cloud cover conditions (page 2789, line 12)?

During cloud free conditions, MOD10 was used to sample data along sections of the river. Furthermore, to maximize the availability of data collected, MODIS L1B was used when cloud cover was present in MOD10 swaths. It was concluded that more data pixels were available to collect from MODIS L1B when cloud cover was present in MOD10. The MODIS snow product at 500-m spatial resolution presents a cloud mask at 1 km spatial resolution. Using MODIS L1B enabled a higher availability of recordable pixels at geographic locations, which were cloud covered in the MOD10 products. Cloud obscuration limited ice cover detection. To alleviate data omission, MODIS L1b from both Aqua and Terra satellites were used. Please refer to MODIS Processing section 2.2.2 (p. 11, lines 119-126) and figure 2.

4. Any idea to what extent the displacement of ice features as measured according to section 2.3 really reflects ice velocities? The apparent velocity of such features (measured manually or automatically?) is not necessary the velocity of ice debris. For instance a feature could be stable even if ice floes pass through it at higher speed by accumulating at the upstream side and release of ice debris at its downstream side.

Unfortunately, due to the coarse resolution and the limitation of twice daily acquisitions from two satellites (Aqua and Terra), this study would not be able to outline the ice feature measured as being the exact velocities. However, ice floe velocities from similar time periods (1-2 days) of the given year and location has been correlated to field measurements as reported in other published articles (Beltaos et al. 2012; Beltaos and Kaab, 2014), and are close to values reported in this study. Furthermore, the movement of ice floes was estimated manually.

5. Fig 7. To the referee, the correlation between air temperature and albedo seems not very obvious. How high is the correlation (e.g. R2)?

Albedo was not a variable measured in Figure 7. Ice break-up dates, air temperatures and precipitation were the only variables plotted in Figure 7.

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Second Review

With regards to the specific comments:

1. - Section 2.2 MODIS Data should be divided in two sections. 2.2.1 MODIS Data and 2.2.2 MODIS processing or a new section MODIS processing could be added.

Thank you for this suggestion. We have now divided into two separate sections.

2. - Page 2788, a Table should be prepared to describe the parameters of MODIS L3 and L1 product (resolution, wavelength of each band, DN, SDS. . .,). As Cryosphere is not a remote sensing journal, the spectral color of each band should be added too (red, green, infrared,..).

Figure 2 was added as a new figure illustrating the processing chain of L1B and L3 data. We also edited Table 2 to describe MODIS L1b and L3 in greater detail with the description of different bands used.

3. - Page 2789, a second Table is needed which gives the number of L3 images available (downloaded) from Aqua and Terra each year (from DOY 100-160) as well as the number of images really used (absence or limited cloud cover) each year from Aqua and Terra. It will be also pertinent to add two columns for the L1B products used from Aqua and Terra

New Table 3 has been added with the total tally of images used divided into MODIS L3, L1b from Aqua and Terra satellites. The images are also illustrated by years, range of ice break-up period observed and sensor platform.

4. - The processing of the MODIS data needs to be explained in more details so the reader could do the same approach with other MODIS data sets if needed. I recommend that a schema be added showing all the analysis steps for the L3 and for the L1B products that the authors have done after extracting the data from the NASA data base and up to interpretation of the classified image. The processing chain seems different for the two products and they are not use for the same purpose either. It is not clear what is done automatically?

A schematic diagram (new Figure 2) has been added in the revised manuscript. We also clarified the processing chain for the MODIS L3 and MODIS L1B data. We apologize for the confusion, however, the analysis of images was all completed manually. The methodology (MODIS Processing) has also been updated on p. 11 (lines 119-126).

5. - The scientific data set values (SDS) should be explained. . .what processed have been done to this data set? How they are different then the DN values?

Explaining the differences SDS and DN values would be beneficial to the overall understanding of the paper.

See our answer to this point just below.

6. - What do you means by matching SDS values to derive the threshold values for L1B product? This should be explained and the schema of the processing chain could help to clarify the approach. Could you explain how the thresholds on Table 2 were established?

A better explanation of SDS threshold values of L1B is provided in MODIS Processing on p. 9, lines 72-79. The processing chain (flowchart) is provided in new Figure 2.

"Through visual interpretation varying land attributes DN values (snow, river ice, cloud, open water) in the MODIS L1b were defined from MODIS L3 SDS values of the same land attributes. This process was completed by observing and comparing the same areas of interest and dates from MODIS L3 and L1b images as seen in Table 2. A list of all of the MODIS L3 and L1B images used are shown in Table 3."

7. - Section 2.3 The approach to estimate the ice velocity is not clear either. The paragraph on the WSC data availability in section 3.1 should be move in this methodology section (Ice velocity)

The paragraph of WSC data availability was moved to 3.2. Page 12, section 2.3, lines 155-157 was edited to give a better explanation of estimated river ice velocity.

8. - Section 3.1 The first paragraph of this section should be moved to the section 2.1.1 MODIS Data.

The first paragraph of section 3.1 was moved as suggested to the methodology section 2.2.1 page 10 (MODIS data, lines 92-101).

9. - Section 4.1 This section should be in the RESULTS Section as section 3.3 (Ice break-up and snowmelt relation) because new results are presented (Fig. 10, 11 and 12). However, the last paragraph of this section (line 13-22, page 2796) could stay in the Discussion; the authors could see where this paragraph fit better.

As suggested, Section 3.2 and 3.3 was modified to include the results of Figures 10, 11 and 12 in the results section. Furthermore, the last paragraph was moved to the discussion section 4.1 page 22-23, lines 41-50.

10. Section 4.0 could start with the discussion about the Spatial and temporal ice breakup patterns (section 4.1). However a Table is needed to summarize all the information presented in the 1st paragraph on page 2796 and 2787. This Table could give the localization (name and kilometer) , the range of dates for each study (reference), and the tool used (MODIS, others) including this study. This Table would then replace the paragraph.

> The suggestion is very helpful. New Table 4 was included to illustrate a summary of past research conducted on the Mackenzie River. This includes relevant data: locations and distances, range of break-up period observed, years studied and tools used.

11. The last paragraph of section 4.3 mentioned that certain preconditions are required to use MODIS? Are-you referring to the ice velocities measurements? Probably, but this paragraph needs to be rewritten. You could directly specify the minimum width of a river to be able to estimate the ice velocities and the others conditions

> The last paragraph of section 4.3 is explained in lines 119-122, page 26, section 4.2. In order to measure river ice velocities, preconditions have to be met with respect to the river. This includes a minimum river width.

12. - Page 2800 - One of the conclusion is that channels bars, river meandering and channel constriction are important factors controlling ice runs and ice break-up. The sentence should be rewritten differently because those morphological controls are known for a while. The MODIS image may help to identify those.

> The conclusion was reworded and changed for better clarity. Page 27, lines 140-142 of revised manuscript.

13. - The reference to the Canaan River event is not pertinent.

> Unfortunately, the reference has been updated for the Canaan River event multiple times and the website location continues to changes. This reference has been removed.

14. Technical corrections: - P. 2791 Fig. 6 should be Fig. 5 (order of discussion). - P. 2792 Fig.6 should be Fig. 5 and inversely Fig.5 should be Fig.6 - Figure 2. For visibility, it would be better to select 3 years only, like 2002, 2007 and 2011.

> The figures numbering with references to the discussion have been changed to improve the continuity of the paper. The references have also been updated and checked to include the correct journals.