Biogeosciences Discuss.,
doi:10.5194/bg-2015-575-AC3, 2016


Biogeosciences Discussions
Open Access
EGU



# *Interactive comment on* "Spaceborne potential for examining taiga-tundra ecotone form and vulnerability" *by* P. M. Montesano

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Received and published: 11 April 2016

Responses to RC4

Comment 1. The paper is lacking some basic definitions and descriptions of terms the authors are using. How do they define terms such as "patches", "form", "vulnerability", "plot" vs. "stand". Issues related to TTE form determination are examined throughout the paper, but vulnerability is not directly addressed. The authors should make it clear from the beginning of the paper that vulnerability of forest patches can be directly linked to forest structure. This idea is suggested throughout the paper but is not stated clearly at the beginning.

Response: We agree the next version should more clearly define some of these terms. We point out that 'form' is defined in Section 1.2. In Section 3.2 we will clarify the a



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plot is a 15m in radius while stands are derived from Bondarev et al. 1997. We will introduce 'patch' in Section 1.2 (see Reviewer #2 Comment #6/Response). We'd like to introduce 'vulnerability' in at the end of Section 1.2 in the following manner: "Epstein et al. 2004 provide a synthesis of how TTE dynamics and patterns are linked, and that a better understanding of vegetation transitions can improve predictions of vegetation sensitivity. Their observations provide a basis for the inference that TTE structure is most vulnerable to temperature-induced changes in structure where its structure is temperature-limited. Vulnerable portions of the TTE are areas most likely to experience changes in forest structure that alter TTE structural patterns."

Comment 2. One of the main conclusions of the study is that because the uncertainty is around 40%, remote sensing data, as presented in this paper, is not able to distinguish forest patches in terms of height or structure. Although this point is clear in the discussion and conclusion, it is not really covered in the abstract.

Response: We will update the abstract to better align with the point as it is made in other sections.

Comment 3. P.2, Line 3 : why "asynchronous"? Explain or remove from abstract.

Response: We will remove this from the abstract to avoid confusion.

Comment 4. The introduction is clear and interesting, but it would be nice to put the role of TTE into a more global perspective (how much do they represent, in terms of forest cover and/or biomass, why is it important to study them. . .) and to mention climate change and its impacts on TTE.

Response: We will add a point to the Introduction mentioning the global importance of the TTE.

Comment 5. P.4, L.18-21 : Sentence is not clear.

Response: We will reword this sentence to clarify.





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Comment 6. The authors are using thresholds to mask or classify their remote sensing data, but do not explain how or why they picked these thresholds. What NDVI threshold did they use? Was that choice based on other studies? Why did they use a roughness threshold of 5.5? Same question for p.9, l.11.

Response: The thresholds for both NDVI and roughness used to classify forest were based on preliminary interpretation and sampling of these image layers for forest and non-forest areas across all forest patch mapping sites. The goal of this preliminary explorative work was to understand the range of roughness and NDVI values that indicated forest. This explorative work identified thresholds that were image independent and could be used in an automated patch classification protocol. While used in an image independent manner across study sites, these thresholds are sensitive to the seasonality of vegetation and, likely, the sun-sensor-target geometry at which the imagery was acquired. A more in-depth examination of how the distribution of NDVI and roughness varied for forest patches across different images was not part of this work. We can note this in the next version of the manuscript. See also Comment #2/Response to Reviewer #1.

Comment 7. p.7, l.11-14 : Ground reference data should be described in more details here. What kind of measurements have been made? Why are they outside of the selected sites?

Response: We provided reference to a paper (Montesano et al .2014) where ground data collection was described in more detail in a previous. However, we agree that it may be helpful to provide a bit more detail. In summer 2008, we measured tree diameters at breast height (DBH, 1.3 m) and tree heights (clinometers for 97% of trees and tape measurement for 3%) at plots coincident with GLAS LiDAR footprints. The data used for this study included DBH for all tree stems with DBH >3 cm ($\pm$0.1 cm) and corresponding tree heights for each tree in each plot. These plot data represented a range of sparse Larix forest conditions found across northern Siberia Larix forests, excluding prostrate Larix forms. The forest mapping sites do not spatially coincide with





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our ground plots because this study aims to examine the TTE on the Kheta-Khatanga Plain which exhibits a range of TTE forms, where the TTE covers a broader area, and where we had access to both stereo and multispectral HRSI data. While not spatially coincident, our ground plots characterize very similar forest conditions - the main difference being the ecotone is compressed (covers a smaller area) in the region of our ground data due to topography. The forest type (Larix gmelini) and structure is consistent across the broader region (see stand data from regionally distributed sites in Bondarev 1997).

Comment 8. p.8, l. 11 : define DSM (definition given p.9). Comment 9. P.9, l.15 : mention GLAS footprint size and explain why you used a radius of 10m (l.23).

Responses to 8,9: These changes will be made. GLAS footprints were approximated with ∼60m diameter footprints. The 10m radius was used as part of a filtering procedure to include GLAS footprints that were coincident with DSM elevation measurements that would be able to capture forest heights where trees are often < 12m. This radius helped remove footprints for which there was a broad range of DSM values near the footprint centroid that was indicative of terrain slope interfering with height estimates.

Comment 10. P.12, l8-10 : I find this sentence and Fig 3b misleading. The fact that the sampling density is higher in smaller patches is simply due to the fact that the authors only selected the patches that had GLAS shots in them, hence giving a higher number of samplings per ha in small patches. The reader should be reminded of this fact here. Adding the average and maximum number of samples per patch in each class would give a better idea of the distribution of samples, in addition to figure 3b.

Response: We report the density of LIDAR samples for the set of patches whose height was sampled with LiDAR (directly). So, within this group (defined explicitly as being sampled with LiDAR), the smaller patches will have higher sampling density (but not necessarily more samples). The violin plots demonstrate the distribution of sampling

densities for each general forest patch size group for which direct height measurements (using LiDAR) were made.

Comment 11. P.12, l.15 and figure 4 : what do you mean by plot/stand?

Response: This will be clarified. Trees measurements described in Montesano et al. 2014 are associated with the term 'plots' while 'stands' is the term used by Bondarev 1997.

Comment 12. P.12, paragraph 3.2 : a) Why are the ground data plots outside of the selected sites? Does it make a difference? b) Why are the calibration and validation sites separated spatially? Are the two areas similar in terms of topography, forest structure. . .? Wouldn't it be better and less biased to select them randomly for calibration or validation?

Response: (a) See response to Comment #7 (b) Figure 4b,c summarize the forest structure across all calibration and validation sites showing the range of tree heights measured in the field.

Comment 13. p.17, Discussion : The authors could mention future spaceborne missions, such as GEDI, and the possibilities they would bring for this kind of studies.

Response: We will note in section 4.3 that future spaceborne missions will provide more ground surface elevation samples needed for improving patch height estimates. ICESat-2 will be useful for the TTE, as GEDI will only sample below ∼50N.

Comment 14. P.17, l.14-17 : Sentence is not clear. Reformulate. Comment 15. Did the authors take the shape of GLAS footprints into account? GLAS footprint is not always exactly a circle of 60m diameter and these differences might have an impact on the results, if not taken into account.

Responses to 14,15: After Montesano et al. 2014, we used a 10m radius circle centered on GLAS footprint centroids to capture DSM surface elevations. Because we focus on DSM elevation data near the centroid, the precise shape of the footprint (which

is actually an ellipse) will not influence results.

16. P.19, l.19-13. Not clear, reformulate.

Response: We will clarify the link between horizontal structure and image texture.

Comments about figures : Figure 1 : Why are the study sites so far away from the ground reference sites? Their height and structure characteristics might be different than the ones of the study sites.

Response: See response to Comment #7

Figure 3 : a) I recommend to normalize the histograms, to make the two datasets more comparable. Instead of # of forest patches, show frequency (# / total # of each dataset). b) see comment 10).

Response: (a) We argue that it is more helpful to show the y-axis with absolute counts of forest patches (b) See response to Comment #10

Figure 4 : a) and b) do not match caption. a) : see comment 12b. b) Normalize histograms. c) In caption, add "50th, and 75th percentile of mean height" for clarity. Figure 7 b) Normalize histograms It would be much easier to compare the direct and indirect histograms if they were all normalized.

Response: We will switch the captions to match the figures and add "..percentile of mean height..' as suggested. We appreciate the suggestions to normalize histograms but we argue that showing actual numbers of forest patches per bin is easier to understand because it highlights the overall quantity of patches receiving indirect height estimates as compared to those receiving direct estimates.

Specific comments : 1) p.2, l.2 : "changes" instead of "change", or "occurs" instead of "occur". 2) P.4, l.24 : comma is not necessary : "group of trees, may help". 3) P.5, l.2 : remove "and" in "biodiversity, and biogeochemical". 4) P.5, l.26 : replace "," by "." In "structure, however". 5) P.11, l.11 : remove "the" in "specifying the both number". 6)

P.19, l.9 : “explains” instead of “explain”. 7) P.22, l. 9 : “suggest” instead of “suggests”

Response: These changes will be included in the next version of the manuscript.

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