AUTHORS COMMENTS

The authors thank the Reviewers and Editor for their constructive comments and corrections that have significantly increased the scientific quality of the manuscript and its clarity.
Here we present our answers to the reviewer's comments. In particular the manuscript has been significantly modified and presented more concisely (10% reduction in length), with additional analysis and expanding key points in the discussion section. In addition, we provide, according to the reviewers' suggestions, detailed comparisons of the data and their correlation along the examined transects, the classification of the glazed surface using topographic, NIR albedo and temperature brightness parameters and clarify the megadune migration processes and implications.
The revised version and a version with tracked changes are provided, but due the manuscript reshaping the tracked change is very difficult to follow.
We hope that the revised version of the manuscript has improved the quality of the text and of the scientific message.

Changes and answers in response to the Reviewer's comments/suggestions (in italic) are highlighted in bold A.

Reviewer Scambos (Remarks to the Author):
GENERAL COMMENT

Much as I like this paper, and learned from it, it is not ready for publication. In general, the description of the work is too wordy, to diffuse, and it seems to track the path of the investigation, rather than present the results as they were perceived at the end of the study. The paper could be much shorter, and could move some of the detailed comparisons (e.g. between Landsat and Sentinel2 results, other nuances in the SPWD and GPS work) to supplemental information.

I would suggest that the authors lay out a somewhat more direct goal of the research in the abstract and move the statements about confirming past work, setting up the study, to the Introduction. Along the lines of : 'We investigate two EAIS megadune fields with significant past in-situ measurement data, using in addition current imaging sensors (Landsat 8 and Sentinel2), elevation models (REMA), and accumulation models (RACMO) to explore spectral, thermal, and windward slope relationships with a view towards generating a mapping algorithm for time-series investigation. We also use detailed elevation and ice flow data to determine the net migration and the sedimentological migration of the windward face of megadunes. Our study finds strong correlations between ...NIR, ..thermal and ...slope... but with seasonal variations... and a range of accretionary migration rates that imply all or most of the regional accumulation (as determined by RACMO and other models) is gathered in the accretionary faces.' Results indicate. Xxx correlations, and yyy migration rates.... Our study sets a course for more regional evaluations of.....'

A: As suggested by both Reviewers and Editor the manuscript has been completely rewritten and presented more concisely (10% reduction in length).

I would suggest combining some of the graphics, since there were few material differences between EAIIST and It-ITASE study sites, and not a lot of justification for showing both the absolute and the normalized plots.

A: As suggested by the Reviewer, the graphs of figure 4, 5 and 6 have been merged and only an example (Fig. 2) is presented in the manuscript.

Also, show the correlation scatter plots for the parameters that correlate highly,, with the correlation line adn statistics.

A: A figure with the scatter plot of the parameters and their relationship is now included in figure 3 in the revised manuscript as suggested. We have also expanded the results section on this point, by comparing NIR albedo and SPWD on transect over time and evolution of NIR albedo over each transect. At lines 262-265 of the revised manuscript, we have written: "Along the transects, the correlation of NIR albedo from the different images is high (R2 up to 0.99) during the spring season (24 Nov 2013, 27 Dic 2013) and decreases by the end of the summer and in comparison with the following years, with an R2 of 0.7 only after 2 years (17 Dec 2015) and up to 0.6 after 6 years (Dec 2019). A Similar decrease in correlation occurs from the comparison of the SPWD and NIR albedo from 2013 (R2 0.66) to 2019 (R2 0.39)."

There also seems to be a lot of zig-zagging in the text between Methods, Results, and Discussion. Try to iron these out, saying things once and saying the most definite things that you wish to share in each section.

A: The manuscript has been largely rewritten and presented more concisely (10% reduction in length).

Detailed comments

L16 – change to: …taking advantage of the most recent….
A: The sentence was removed because the manuscript was shortened according to the referees' suggestions.

L19 suggest present tense: analyse, not analysed.
A: We have modified the sentence as suggested.

L42 – change to: ….that can be observed from satellites…
A: The sentence has been removed in the restructuring of the introduction

Figure 1 – suggested caption text: Satellite image map of the Antarctic continent (Jezek, 1999) with elevation contour lines at 1000m a.s.l. intervals. Megadune regions are shown as cross-hatched blue areas (Fahnestock et al., 2000), with net surface mass balance in color for areas with SMB < 50 kg m-2 yr-1, based on RACMO (van Wessem et al., 2014). The main study areas, shown as dark boxes in panel a, are the EAIIST region (panel b) and It-ITASE sites, both represented by Landsat 8 images (give path, row, and dates of Landsat acquisitions). (no need to mention the projection)
A: The caption text was partially modified as suggested, except for some additional modifications due to manuscript restructuring. Also, Figure 1 and 2 were merged together. The caption now reads: "Figure 1: Location map of megadune area: (a) Satellite image map of the Antarctic continent (Jezek, 1999) with elevation contour lines at 1000 m a.s.l. intervals, megadune regions are shown as cross-hatched blue areas (Fahnestock et al., 2000), with snow precipitation by RAMCO in colour for areas with precipitation < 50 kg m2 a-1 (Van Wessem et al., 2014), black rectangle (b box). (b) The megadune field with two study sites, EAIIST red rectangle (c box) and It-ITASE blue rectangle (d box). (c) Landsat 8 OLI image in false colour (069119 scene, 17/Dec/2015) of the EAIIST area; the red polygon is the area for the analysis of variations of glazed surfaces (Fig. 4). (d) Landsat 8 OLI image in false colour (081114 on 18/Dec/2014) of the It-ITASE area and D6 core site; the green rectangle shows the location of Fig. 5. In (c) and (d) boxes, red arrows represent ERA5 wind direction and green arrows sastrugi-based wind direction, while the yellow lines show the location of the transects studied."

L63 – change to ….provide a detailed survey of Antarctica's megadunes using remote sensing….
A: We have modified the sentence as "The aim of the study is to provide a detailed survey of two megadune areas using remote sensing data"

L65 – suggested notation, ….two Landsat 8 scenes, P069 R119 (EAIIST site) and P081 R114 (It-ITASE site), in order…. I suggest not giving a lat-long point here, the scenes cover a large area. Perhaps you could show the corner positions of the scenes in Figure 1, outside the images at their corners.
A: We have rephrased the sentence to focus on the areas and have added "centered at" for lat-long. We have also added the coordinates of scenes in figure 1.

L67 – in what band will you provide brightness temperature – thermal? passive microwave? (thermal, ok).
A: Yes, it is thermal TRS1. This is now specified throughout the manuscript.

L90-91 – This sentence is a bit odd – the katabatic wind direction is known from models and wind observations; this wind direction is fundamental to megadune orientation, not the reverse. I think this sentence could be removed or converted to a different sentence about the katabatic winds and megadunes.
A: Thank you for pointing this out. The sentence has been removed in the shortening of the manuscript

L91-92-93; the SPWD slopes of the leeward and windward sides of megadunes are of opposite sign -- please note that.
A: The sentence has been removed owing to the restructuring of the manuscript; we now point out the differences in sign of the SPWD in the results section 3.1, at lines 309-311, where we have written: " For the SPWD on megadunes, we found a mean value of 5.6±1.0 m km-1 for the leeward side and negative SPWD values, with a mean of -4.2±1.6 m km-1 on the windward flanks."

L126 – no need to capitalize 'metadata'.
A: We have removed the capitalization throughout the manuscript

L165 – these sentences, beginning with 'The transect plots…' are hard to understand, I suggest rewording them and referring to Figure 2 and perhaps other figures.
A: This information has been moved to section 2.2.1, at lines 205-208 of the revised manuscript, where we have written: "Moreover, we determined the strength of the relationship between SPWD vs NIR albedo, and SPWD vs thermal brightness temperature (applied on the moving averages of 11 pixels weighted based on the distance from the central point) using linear regression. The comparison analysis was conducted at seasonal scale for the 2013-2014 (4 images) and at pluriannual scale on 17 images distributed over 8 years."
Additionally, the information is reported in the caption of Figure 2 in the revised manuscript which now reads: "Figure 2: (a) moving average (based on 11 transect pixels) of NIR albedo (α) between November 2013 and February 2014 for transect C at the EAIIST site (see Fig. 1c for location) and elevation from REMA DEM. Corresponding normalised moving average of NIR albedo (b) and thermal brightness temperature TIRS1 (c) during the austral summer season 2013-2014 for transect C and elevation from REMA DEM (detrended topography)."

Figure 2 caption – add 'lines' : …of transects (yellow lines) on the …. No need for the latlong positions, the images cover extensive areas. …green rectangle (b) is the area shown in Figure 3a…. NOTE: if you did not reproject the L8 images, they are in polar stereographic projection, not UTM – that is how they are distributed (all images south of 60°S latitude are in polar stereographic).
A: Figure 2 has now been merged with Figure 1 and the caption has been modified accordingly. See comment on Figure 1 for details on the new caption.

L179 'firstly' is not wrong, but old-fashioned – suggest change to 'first'
A: We have replaced "firstly" with "first" as suggested

L180-185 FYI, the USGS is now providing 'analysis ready data' which in fact includes TOA reflectance. I am not certain that this extends globally yet, but a request to USGS to specially process a handful of images would be worth trying. This can be outside this paper, ***but*** *if the 'analysis ready data' is available, it should compared with your work.*
A: Thank you for the comment. Unfortunately, the data are not available for the Antarctic continent; it would be definitely worth checking them in future work if they become available

L198-204 This could be a significant issue: the Landsat 8 thermal channels 10 and 11 had some problems, and in fact it was recommended that channel 11 not be used for analysis. Depending upon when you retrieved L8 data, it may or may not have had a corrected channel 10 value, corrected for stray light impacts and pushbroom detector noise.
A: We now only consider band 10 TRS1 in the analysis and have checked that band 10 had stray light correction implemented

L214-216 section between the commas: … , where Band 5 NIR …. Frezzotti et al., 2002b), … Remove from the sentence, perhaps find another place for these words. It is distracting from your edge-detection of sastrugi method for determining wind direction from the imagery.
A: We have removed this sentence as part of the restructuring of the manuscript.

L218 – what was the variation in degrees between (a) extracted wind directions in a uniform section of the images, and (b) among the wind directions determined in the repeated imagery for the same areas? 'Only small differences'… I'm sure you are right, but a value in degrees would be useful to underscore that.
A: The differences are smaller than 5° in both cases. We have now added this information in the manuscript at lines 300-302, where we have written: "The analysis of sastrugi direction using 7 Landsat scenes from the spring and summer months during the period 2013-2020 show small differences in direction within each image and in repeated imagery (< 5°), confirming the stability in direction of sastrugi landforms and thus the persistence of katabatic wind. "

L222-230 – I suspect this adjacent-pixel method was a bit noisy – and you are saying that determining the SPWD over a 90m cell (3x3 pixels) would significantly reduce the slope? This does not seem right to me. Also – I'm not seeing how Equation 4 does not include either trigonometric functions, or, more than two pixels with some kind of ratio for the elevations of the windward pixels - ?
A: We have recalculated the SPWD using the method described by Scambos et al. (2012), with wind direction derived from ERA5 and sastrugi. The differences between the two methods are rather small, i.e. 1 m km-1. We nevertheless chose to use the methods by Scambos et al. (2012). We have therefore replaced the text at lines 197-201 of the revised manuscript with: "To further estimate the SPWD based on the wind direction from ERA5 and Landsat-derived sastrugi, we used the approach of Scambos et al. (2012), i.e., we calculated the dot product between the slope derived from the REMA DEM and the wind direction. The algorithm was applied to ERA5 and sastrugi-based wind directions resampled at 120 m spatial resolution, and the REMA DEM was resampled to match ERA5 and sastrugi-based wind directions using bilinear interpolation. The resulting SPWD has units of m km^{-1}."
All the SPWD values mentioned in the revised manuscript now reflect the changes in the method used to calculate it.

L233 'modules' is not the right word here – 'modes' might be what you mean, but while it sort of works, the meaning is unclear. Perhaps just end the sentence at 'directions'.
A: We have replaced "modules" with "intensity" here.

L234 remove 'thus', not needed.
A: We have removed "thus" as suggested

Figure 3. It would be a bit better to flip the x-axis of 3b around, since 3a shows the wind moving from left to right, and the topography goes downhill left to right as well.
A: We have remade figure 3 (figure 5 in the revised manuscript) by adding more GPS survey transects acquired at It-ITASE and flipped the x axis around as suggested and add the internal layering from GPR.

L250 This approach may have a problem. In Landsat 8, there is a strong correlation, even spanning years, to the linear sastrugi pattern and 'surface roughness' at the decameter scale; the megadunes themselves are much 'softer' features and are probably not the features that would be tracked by IMCORR (or PyCORR – see GoLIVE data at NSIDC; or ITS_LIVE data at NSIDC as well). You could address this by filtering --- use a high-pass filter of ~150m length scale on the image pairs to isolate the sastrugi pattern and erase the megadunes; and a low-pass filter of the same scale to smooth out the sastrugi and leave the megadune features for IMCORR or PyCORR. You may want to use a large highpass filter as well for the megadunes (~6km), to supress bedrock-driven features (the 'undulation field') from the megadunes-only image pair. Note you would need to use a large reference area size to track the megadune pattern after filtering (or downsample the images, or both). This should allow a direct comparison of the two motion maps you are after. The high-pass filtered mapping should isolate the true ice sheet flow, directly downhill; and the low-pass filtered map should emphasize the megadune migration, a combination of sedimentological advance and ice flow. I see in L270 you attempted this with edge-detection of glaze-accumulation zones.
A: We have applied a Fast Fourier Transform with the suggested wavelengths before performing megadune feature tracking and sastrugi identification. We have added a description of this process at lines 234-235 of the revised manuscript, where we have written: "Prior to feature tracking, each image pair was pre-processed by using a low pass filter with a length scale of 150 m implemented through a Fast Fourier Transform to smooth out the sastrugi and leave megadune features for tracking", and at lines 193-194 of the manuscript, where we have written: " Prior to edge detection, each image was pre-processed by using a high pass filter with a length scale of 150 m implemented through a Fast Fourier Transform to highlight the sastrugi." In the revised manuscript, we report the new values of megadune movement and sastrugi-based wind speed after this operation. Differences between the two methods are in the order of 1%.

L257-259 – please include these attempts in the table.
A: The results from the comparison of Landsat 8 and 7 ETM+ are unreliable; therefore, we decided to remove them from the manuscript altogether.

L290-309 – I think this section could be stated more briefly and simply. Also – did you explore surface grain size or a normalized red-infrared band difference? NDSI?

A: Thank you for the comment. We have considerably shortened the section. We did not use other approaches but plan to do so in future work. We have therefore added a sentence in the conclusion section pointing at future developments, at lines 477-478 of the revised manuscript, which reads: "Further research might consider other parameters to automatically detect snow glazed surfaces, including snow grain size or the normalised difference snow index."

L295 and Figure A1 – do you have any explanation for the decreased albedo with increased SZA? (sastrugi shadowing…).
A: Please note that we have now removed images with a SZA higher than 75°, as suggested by the other referee. Sastrugi shadowing is probably the driver of higher NIR albedo variability of windward flank. We have therefore added a sentence in the discussion section, at lines 399-401 of the revised manuscript, which reads: "The observed change on NIR albedo and brightness temperature on the windward flank is correlated to the sastrugi formation and deterioration during the season, and their relative change in shadow (Warren, 1982)."

L322-328 – again please check – it may be that for this analysis, brightness temperature only, and perhaps with some spatial averaging of values? This application will be ok – but prior to 2020 there were significant issues with Band 11 in Landsat 8 (which were partiall addressed by processing for the entire archive in 2020). It would be better to base your brightness temperature solely on Band10
A: We now consider only Landsat 8 Band 10 for calculation of brightness temperatures as suggested in your other comment and have modified the manuscript accordingly throughout.

Figure 5 Please re-plot with the y-axis warmer=up!
A: We have merged figures 4 and 5 in one, showing normalized temperature and NIR albedo, now shown in Figure 2 in the revised manuscript. We chose to maintain the y axis with the warmer temperatures down to ease comparison with the megadune topography, as temperatures and topography show an inverse relationship.

L347 change to '….is generally east (….
A: We have modified the sentence accordingly.

L348-349 change to '…The regional topographic slope (10 km scale) is on average 1.5 m km-1….'
A: We have modified the sentence accordingly.

Table2 – please put the regions in the upper left of each sub-table, EAIIST (left) and It-ITASE(right).
A: We have modified the table as suggested

L355-362 this could be written more concisely.
A: We have restructured the paragraph to shorten it as suggested. At lines 303-305 in the revised manuscript we have written: "The comparison of the results of wind direction obtained using sastrugi direction by satellite (resampled using bilinear interpolation) and ERA5 present similar values for both areas, with lower difference in the EAIIST area (differences of 1° in average values) compared to It-ITASE (9-14°)."

Section 3.4 – the goal of this section could be presented more concisely with crossplots of

the parameters showing the strong correlations.
Overall - -most of this up to this point is nice to see, but not a surprise – NIR albedo lower, temperature higher, SPWD trends, sastrugi versus model wind, all these are tightly correlated and are a function of the published characteristics and formation ideas for megadunes. So, while I understand that it was work to put it all together, and you'd like to show it, it is much more interesting that you combined them to create a classification method for megadunes that you can use to look for seasonal and interannual changes.
Section 3.5 – I think this is the best part of the manuscript – a slghtly quicker pace to get to this part of the paper might be better.
A: We have considerably shortened the manuscript to get more quickly to the megadune mapping section. Section 3.1 now reports all the information on the evolution of NIR albedo and thermal brightness temperature on the transects and the megadune mapping and their relationship. We now show in section 3.1 a new figure (figure 3 in the revised manuscript) with crossplots of NIR albedo and brightness temperature against the SPWD as suggested.

Figure 7 – can you present this as an image with the change (glaze in November not January; and glaze in January not November) shown as colored strips on the black-andwhite NIR image?
A: Unfortunately, as the REMA DEM is only available from one date and so is the SPWD which is based on it, and owing to the megadune migration, applying an interannual classification based on albedo, brightness temperature and SPWD would be unreliable. Therefore, we have removed this analysis and now perform a comparison of the detection with/without SPWD and by applying thresholds for these variables on an entire Landsat tile and a narrow area. At lines 312-317 of the revised manuscript, we have written: "Applying the automatic detection on the entire Landsat scene from 17-Dec-2015, when excluding the SPWD, approximately 34% of the entire tile was detected as glazed snow, compared to 24% using also SPWD. On the smaller area instead, a slight variation was detected with and without SPWD (22% and 23% respectively). Clipping the glazed snow surface estimated on the entire Landsat 8 tile by using the tile-based thresholds to the extent of the narrower area, an overestimation of 70% was found in comparison with the results obtained directly on the smaller area with the area-specific thresholds and when using the SPWD, rising to +88% without SPWD (Fig. 4)."
We also now report in section 3.1 correlations between NIR albedo and SPWD on transects on different dates to show that NIR albedo and SPWD decorrelate over time and point out that the SPWD from a different date would be needed for the classification. At lines 262-265 of the revised manuscript, we have written: "Along the transects, the correlation of NIR albedo from the different images is high (R2 up to 0.99) during the spring season (24 Nov 2013, 27 Dic 2013) and decreases by the end of the summer and in comparison with the following years, with an R2 of 0.7 only after 2 years (17 Dec 2015) and up to 0.6 after 6 years (Dec 2019). A Similar decrease in correlation occurs from the comparison of the SPWD and NIR albedo from 2013 (R2 0.66) to 2019 (R2 0.39)."
The suggestions for the coloring scheme have been followed in the new image (Figure 5 in the revised manuscript).

L405 – Can you assemble Landsat images of the entire dune area for, e.g. 2013 and 2020, and look for regional expansion of glaze areas in January? This would be a very important result.

A: We have expanded the detection to the entire Landsat tile; however, unfortunately we cannot provide a reliable estimate of the interannual variability, as explained in detail in the comment above.

Section 3.6 – 'Superficial' in English means 'unimportant' or 'trivial'– I think just 'Ice sheet velocity and upwind megadune migration' would make a better heading here.
A: We have replaced the title with "megadune migration".

L422 – do you have a figure of the nine megadunes traversed by GPS? I see Figure 3b, but perhaps a graphic highlighting the GPS plus REMA assessment of migration? Also – what local accumulation rates are indicated by the frontal accretion? Assuming the glaze areas on the lee side of the dunes have near-zero accumulation, what does this mean for the regional accumulation rate, e.g. from RACMO, compared to what you observe?
A: Figure 5 in the revised manuscript now shows more GPS transects with REMA and GPS elevation, and also GPR layering to clarify the megadune migration. We have added a discussion on accumulation rates at lines 415-422 of the revised manuscript, where we have written: "The elevation change during 15 years observed using GPS and REMA shows a relative increase of accumulation on the windward flank with the maximum value at the trough compared to the glazed surface area from 29 to 46 mm w.e. a-1 with an average value of 34 mm w.e. a-1, using a density of 360 kg m3 in the first two metres. This value is very close to the estimated change of accumulation in the megadune area from 7 to 35 mm w.e. a-1 provided by Frezzotti et al., (2002b) using the variability of GPR internal layering at the megadune site (Fig. 5). The minimum value represents a decrease in accumulation up to 75% or more on glazed surfaces. The relative stability of glazed surfaces with respect to elevation change and NIR albedo confirms the extremely stable SMB low value of the glazed surfaces with respect to accumulation area, due to the long-term hiatus in SMB forced by wind scouring processes. "

L444 – change to 'near-identical' or 'identical within the limits of determination'
A: The sentence has been removed in the restructuring of the manuscript.

L451-467 – could you not evaluate the inter-annual changes using only, e.g. mid-January images?
A: We have removed the inter-annual analysis, as it is not possible to perform this with the SPWD from a single date, as explained in detail in the comment to Figure 7.

L484 – 'scalarly summed?' would it not be a vector sum to get the net migration?
A: We have removed "scalarly" here.