We appreciate the Reviewer's comments below and we have responded to the points in **bold text**.

<u>Anonymous Referee #3:</u>

General comments:
In their paper, the authors evaluate the susceptibility of High-Arctic permafrost terrain to disturbances (ALD and ME) related to high pore water pressure. To do so, they used a GIS-based approach, statistics, and field validation, and made the demonstration that such an approach is exportable to other sites. The results indicate that terrain characteristics of ALDs and MEs differed in the modelled high susceptibility zones, whereas they were similar in low susceptibility zones. They have shown that slope was the main variable driving ALD initiation and distance to water was the most important variable explaining ME formation. Although this paper makes an interesting contribution to permafrost landscape hazards and permafrost landscape dynamics studies, I think it would be better suited for a GIS-dedicated journal or a hazards-dedicated journal. Indeed, my impression is that the cryospheric components in this article are not developed sufficiently to justify a publication in Cryosphere. If the editor decides differently, then the authors should develop a section on ground ice and particularly clarify the concept of 'transient layer' and how it applies at the landscape scale, how to model it and how to incorporate it in their GIS-based approach. A point should be made about the distribution of ground ice in a given watershed and along topo-sequences. Unfortunately, it is mentioned in the paper that ground ice was not specifically taken into account in the analysis due to a lack of data about this aspect. Some of the results of the modelling makes a lot of sense although other are very surprising. I think the authors should explain better the 'correlations' they obtained. In particular, I would like to see more explanations on the 1) PISR: the peak for ME and the fact that the probability decreases as PISR increase for ALD (is this a ground ice effect? Less PISR, ice closer to the surface?), 2) distance to water (probability decreases and then increases with distance to water for ME and ALD), 3) TWI for ME: probability increases and decreases with rise of TWI. Again, I would like to stress that I consider the quality of this paper to be good to very good but that the authors would benefit in terms of dissemination and citations to publish it in a different journal with a better-targeted readership.

Response: We thank the anonymous referee for their constructive comments. We have added as much information about ground ice as is available at our study site currently. This includes permafrost cores which have recently been taken at the site near an ALD, and the data shows ice enrichment from 60-80 cm bgs (Lamhonwah et al., in press). Secondly, observations in the headwalls of ALDs show ~0.5 m of massive ice starting at ~80 cm.

Section 5.1 has been elaborated to explain observed relationships between the high susceptibility zones for ALDs and MEs and the terrain variables.

Specific comments:
Abstract, L12 : The link between high pore water pressure and landscape degradation isn't clear. I understand it but it is implicit in the text. The authors should clarify this in the abstract and later

in the text. Perhaps by stressing which geomorphological processes can be triggered by high pore water pressure, how high PWP are generated and how these geomorphological processes can have an impact on landscape evolution, landforms, or, to a different scale, active-layer/surface dynamics.

Response: This has been reworded. We have also re-written the introduction to be more clear about how PWP are generated and the impacts of ALDs and MEs on the landscape.

Abstract, L17-18: 'distance to water' repeated in the same sentence. Correct please.

Response: This has been corrected.

Abstract, L20: delete 'accurately'. Let the reader judge if this was indeed 'accurately modelled'.

Response: This has been deleted.

Abstract, L22-23: the authors use the term 'relatively' (. . .low PISR, . . .far from water). I propose to eliminate relatively and suggest to change to something like 'lowest PISR' or simply 'low PISR' and 'far from water' or 'farthest away from water'.

Response: More specific details have been added to this section.

Abstract, L23: '. . . areas that may be sensitive to high PWPs'. This sentence weakens the abstract. I think it is reasonable to say: '. . .areas sensitive to high PWPs' without 'that may be .'.

Response: This has been changed.

Introduction, L30: delete 'seasonal'. The active layer is a seasonal phenomenon.

Response: This has been deleted.

Introduction, L31: 'water and ice enrichment at the base of the active layer'. I believe the authors should add 'and in the upper part of permafrost'.

Response: This has been added.

p. 2, L3: 'during the summer months'. This should be either deleted or 'beginning of winter' be added. Indeed, the bottom of the active layer often thaws as the top of the active layer is refreezing.

Response: It has been deleted.

p. 2, L4-5: 'During the fall freeze-back period this water undergoes refreezing, consequently developing an ice-rich transient layer at the base of the active layer (Hinkel et al., 2001; Kokelj and Burn, 2003, Shur et al., 2005).' The transient layer is not explained properly here. The authors have to explain that this water refreezes and remains in the 'permafrost portion' of the soil column during cold year (s) whereas during warm years the transient layer thaws partially, that is the active layer deepens (thawing of the active layer and upper portion of permafrost). The following two years (or more), depending if these years are colder or warmer than the previous ones, the active layer will continue to deepen or the lower portion of it will not thaw and then will be part of the upper permafrost. The authors should re-write the text around the concept of transient layer.

Response: We have reworded the text and better explained the idea of the transient layer.

p. 2, L7-8: 'This addition of moisture, as well as infiltration from late season precipitation, results in high pore-water pressures (PWP) at the base of the active layer'. This is the case for saturated (porosity filled with ice and, upon melt, with water) fine-grained soils essentially. Unsaturated sediment will not develop high pore water pressure upon thaw and coarse sediment will usually drain and won't develop high pore water pressure. Please specify. The reference cited could be improved, perhaps cite specific studies concerning pore water pressure in permafrost environment or classic geotechnical literature about PWP and mass movements.

Response: This is a general statement about how high PWP is generated in areas with ice-rich transient layers. Previous work in the study site indicates fine-grained soils throughout the area. Similarly an ice-rich layer at the top of the permafrost has been observed at the site from cores (Lamhonwah et al., in press). This information has been added to the study site section and expanded on throughout the text. The references have been updated to include more classic geotechnical literature about slope instability, and this section of the introduction has been rewritten for clarity.

p. 3, L20-22: 'The site is underlain by Devonian sandstone and siltstone bedrock comprising the Weatherall, 20 Hecla Bay, Beverley Inlet and Parry Islands (Burnett Point Member) formations (Harrison, 1995), but outcrops are uncommon'. I suggest to change for: 'The site is underlain by sandstone and siltstone bedrock but outcrops are uncommon (Harrison, 1995).'

Response: Thank you for the constructive suggestion and this has been changed.

p. 4, L24-25: the reason why distance to water (10 m) and distance to ALD (20 m) needs to be explained. 10 m from water appears close to me for the topic and scale of the study.

Response: On average the width of channels at Cape Bounty are less than 10 m, to ensure that randomized points were not placed in a stream a rule of >10 m was selected. Again, to ensure that randomized points were not placed within the boundary of existing ALDs a minimum distance of 20 m was selected. Points were generated using the "Random Point" tool in ArcGIS with the additional criteria (>10 m from a water source and >20 m from an initiation point). The text has been clarified.

p. 5, L4-5: the reason why large spatial clusters of ME were removed from the analysis needs to be explained. It could indeed be interesting to see these large clusters.

Response: Analysis was done with and without declustering, and was more representative of the study area with the declustering as it reduced statistical bias to the landscapes where the clusters were found. Declustering was achieved by creating a 10 m buffer zone around each mapped ME feature in ArcGIS 10.1, and areas where buffer zones intersected were treated as one large polygon to represent the region of the cluster. A single point representing a ME was randomly generated as a representative point for every 10 clustered points within the polygon (i.e., a cluster of 25 MEs would result in 3 points). This has been reworded in the text for clarification.

p. 6, L5-6: what is the scale of the surficial deposit map used? Could this map along with the marine limit elevation be used to infer, although very generally, the potential distribution of ground ice, given the general relation between grain-size distribution, frost-susceptibility and ground ice? The lack of data on ground ice is, in my view, one of the main weakness of that paper.

Response: We did not use a surficial deposit map for this analysis, and such a map does not exist for this site. We did use marine limit (elevation) as a proxy for ground ice, as generally there will be finer-grained sediment below marine limit and thus more ground ice. This is stated in section 3.3 of the methods. We've added more data on the ground ice conditions at the site.

p. 6, L10-11: 'While ground ice content is linked to high PWPs, it is not used as an input variable as ground ice maps were unavailable and impractical to attain'. The authors mentioned that ground ice is more abundant below the marine limit (p. 5, L17-19). Was there a factor/weight added to the cells below the marine limit as PWP is more likely to be generated in areas with high ground ice content? Please describe surficial sediment/(cryo) stratigraphy above and below the marine limit. Models indicated 50 and 80 m as key elevations. What's going on around these elevations that could help understand the output of the model better?

Response: The estimation of marine limit at the site is approximately 60-80 m, but it is a diffuse gradient that is not clearly defined, so we didn't put any weight on the cells below marine limit. We do not have data for ground ice conditions above and below marine limit, and the surficial sediments do not show a clear difference above and below marine limit.

Note that table 2 has been updated and 60m is a key elevation for MEs, attributed to drier, barren, plateau environments which have deeper annual thaw. Results indicate that 50 m is a key elevation for ALDs, which is below the marine limit of 60-80 m for the site indicating that ground ice likely plays a role here. More information has been added to section 5.1 on this matter.

p. 11, L20: 'Landscapes composed of fine-grained surficial sediments are susceptible to a wide range of permafrost degradation processes, including the development of high PWP in the active layer'. The development of high PWP is not a permafrost degradation process. High PWP and excess PWP lead to the development of mass movement and this could be included as a 'permafrost degradation process'. Please change.

Response: This has been reworded.

p. 11, L25-26: ‘While soil PWP measurements are not available to confirm pressurization in these instances, the inferred mechanism is diapirisation of sediment slurries from the base of the active layer caused by pore-water pressurization due to ice thaw’ Diapirism of sediment slurries can be from the base of the active layer or from lateral mass movement originating from upslope (there will be mass transfer, at least water, even with low angle slope). I also agree that is it probably more related to the base of the active layer, however the authors haven’t shown data to support it. Furthermore, the liquid limit threshold can be attained due to water release upon ice thaw but it can also be attained by the infiltration of rain in the active layer or from subsurface flow. This should be mentioned.

Response: Holloway et al. (2016) show evidence for MEs originating at the base of the active layer, and we have referenced this work. MEs mainly occur on flat terrain, so upslope contributions would be limited. There is very limited literature on MEs. We have removed discussion of liquid limits and have clarified the text.

p. 12, L11-13: ‘Hence, while surficial materials are broadly similar across CBAWO, the landscape zonation of these two features appears to follow a slope continuum.’ I agree and I think the authors should expand their explanation here. Please put this sentence in the context of High-Arctic polar desert watershed/toposequence so that readers could verify if these observations apply in other similar landscape settings. Clarify the link between toposequence, hydrology, moisture and the thermal regime of the active layer.

Response: Text has been added to describe the toposequence at our site. We’ve added information about the hydrology and active layer in the zones of high susceptibility in Section 5.1.

p. 12, L15-17: ‘In 2007, the warmest year since regional records began in 1949, deep active layer development and late July rainfall triggered widespread ALD formation.’ I would like to have more information about the effect of rainfall on ALD. There’s not enough information about it in the paper, even though it could be an important factor. If rainfall data are available, they should be included in the results and discussed later in the paper.

Response: Response: More specific details have been added about the frequency and magnitude of rainfall events, but rainfall wasn’t a variable we looked at in this study. Factors impacting PWP are either intrinsic (ex. slope, drainage, solar radiation) or extrinsic (temperature, rainfall) and although extrinsic factors are important, this model only identifies intrinsic factors. Similarly, all areas across the landscape experience relatively homogeneous rainfall, and it is only certain locations which have high PWP, ALDs and MEs due to specific qualities of the landscape at these locations. Therefore, we are using this model to identify these landscape variables. This section of the discussion has been removed, and the text has been reworded to clarify this.

p. 12, L20-22: ‘Similar conditions were observed with MEs associated with terminated active layer fractures in 2012 further suggesting the presence of fluid slurries in situations approaching those that generate ALDs.' . . .' These observations suggest that MEs, while clearly reflecting evidence for subsurface soil water pressurization also likely play a stabilization role through pressure release to the surface.' 'By contrast, ALDs are associated with sufficient pressurization to induce slope fracturing and downslope movement.' Are the authors suggesting that ME reduced the PWP and reduced therefore the occurrence of ALD? Please make it clear. Is it possible that ME occurred at the location of ALD prior to the slide? I would like the authors to provide their interpretation/opinion about this point. This can form interesting working hypotheses for future studies.

Response: We go into further detail in the subsequent section 5.2 about MEs possibly releasing pressures and stabilizing slopes. The text here has been reworded for clarity.

p. 14, L23-25: 'The susceptibility models demonstrate that ALDs are most probable on hillslopes with gradual to steep slopes and relatively low PISR, whereas MEs are associated with higher elevation areas, low slope angles and in areas relatively far from water (drier)'. I suggest to add concave slope for ALD and convex slope for ME.

Response: This has been added.

Format:
For all the text: add space between number and unit. Ex: 100 m.

Response: This has been corrected.

In the pdf version, at several places, space is missing between words, punctuation, units, etc.

Response: This has been corrected.

Figure 1: add scale (1a, d), add complete date (a, b, c, d).

Response: Scale has been added to Figure 1 a and d, and complete dates have been added to the figure caption.

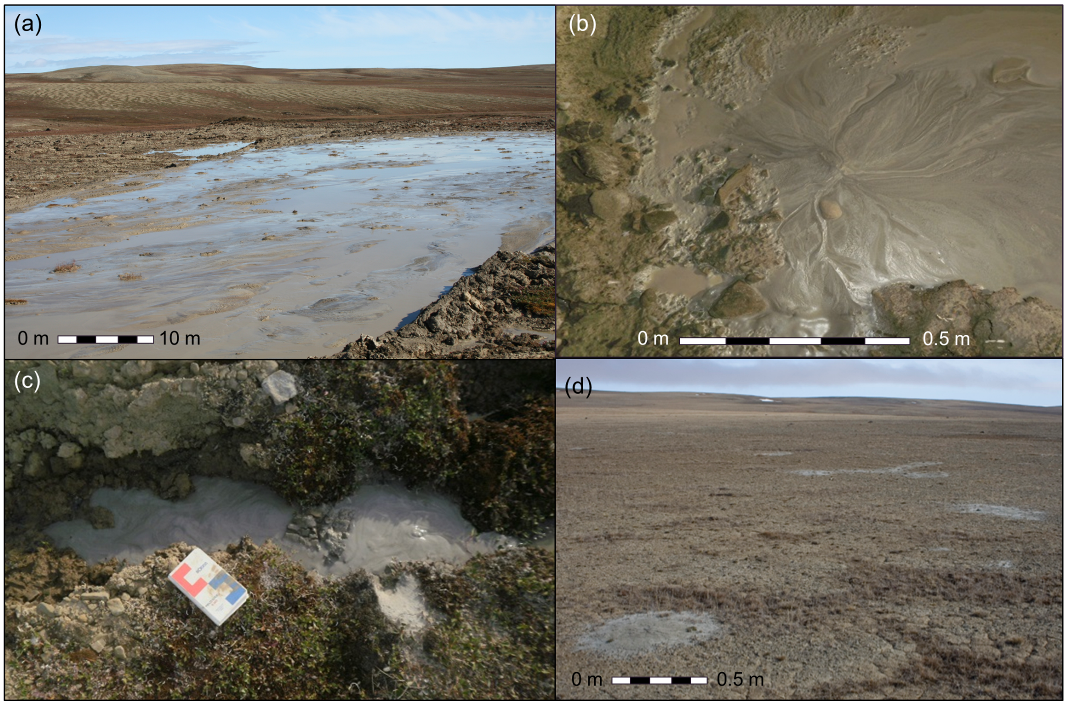

Figure 1: (a) Active layer detachment at Cape Bounty Arctic Watershed Observatory (CBAWO), Melville Island, NU, 28 July 2007. Clay slurry is evident along scar track immediately post disturbance. (b) Active mud ejection occurring on a plateau, 13 July 2012. (c) Clay slurry pooling in a crack at the headwall of a recently initiated active layer detachment, 16 July 2012. (d) Field of inactive MEs on a plateau, 18 June 2012.

Figure 6: add scale and complete date. Is the ALD visible in the background or are they more MEs? Please clarify in the figure caption or directly in the figure.

Response: Scale and complete date have been added. The picture is taken at the edge of the ALD looking out towards the adjacent terrain (the ALD is not visible). This has been clarified.

Figure 6: MEs adjacent to an ALD at CBAWO on 28 July 2007. The photo was taken at the edge of the ALD looking out towards the MEs and the adjacent terrain.

Table 2. It would be interesting to add some basic statistics to this table. The table provides mean values of terrain variables. Please add the range, the median and the standard deviation for these variables. It would be very useful if one's want to compare this study with other studies conducted in similar/different environmental set-ups.

Response: Table 2 has been updated with standard deviation. We did not add all these statistics as these values are for our specific modelled susceptibility zones and therefore not directly comparable to other sites.

Table 2: Mean and standard deviation (in brackets) values for terrain variables in each susceptibility zone for ALDs and MEs and performance metrics for ALD and ME single variable models.

	Very Low ALD/ME	Low ALD/ME	Moderate ALD/ME	High ALD/ME	Very High ALD/ME	AUROC ALD/ME
Slope (°)	4(3)/6(6)	6(4)/5(4)	8(4)/6(5)	1(5)1/6(6)	17(9)/8(9)	80/67
Elevation (m)	67(31)/63(31)	56(25)/67(20)	53(25)/67(16)	50(26)/66(15)	48(26)/63(14)	71/79
PISR (MJm^{-2})	1241(22)/1232(37)	1231(27)/1237(20)	1223(34)/1238(19)	1214(41)/1239(18)	1172(77)/1240(17)	70/74
TPI	0.4(1.4)/0.01(1.7)	-0.3(1)/0.3(1.3)	-0.6(1.4)/0.3(1.6)	-0.9(1.8)/0.1(1.8)	-1.73(3.2)/-0.5(2.6)	68/74
TWI	6.5(20.6)/6.2(15.7)	5.8(2.2)/6.2(27.6)	5.6(2.2)/6.1(2.6)	5.5(2.2)/6.2(2.8)	5.3(2.2)/6.5(3.4)	57/61
Distance to water (m)	308(192)/294(202)	287(239)/413(276)	310(258)/627(202)	339(277)/652(209)	346(283)/650(279)	66/83
NDVI	--/0.18(0.17)	--/0.04(0.12)	--/-0.02(0.15)	--/-0.05(0.17)	--/-0.09(0.21)	--/80