Reply to Referee Comments 1

We first would like to thank the reviewer (Adrian McCallum) for the positive and insightful as well as detailed comments. We take all the comments into account, reply in italic text and will update accordingly in the revised manuscript.

General comments

Thank you for the opportunity to review this very interesting work that examines how variations in stochastic signals resulting from micro cone penetration in snow can be used to discern snow type/microstructure.
Field data is compared with laboratory data to enable characteristic signals to be identified and variation in two noise types (diffusive and jump) is particularly examined to suggest snow microstructure behaviour and thus snow type/composition. This work relies on the assumption that the SMP penetration process is analogous to Brownian motion.
I found it a very interesting paper and I recommend it for publication. Below I make a few specific comments and numerous technical observations which the authors may wish to consider.

Specific comments

My primary comment is that you may wish to consider altering the title/context/frame of your paper. I say this because McCallum has written many papers on Cone Penetration Testing (CPT) in polar snow, some of which examine microstructure assessment using CPT. You may wish to briefly comment on these works in your introduction, or you may wish to refer to your work as 'micro' cone penetration testing, just to differentiate between the large body of McCallum's large-scale (36.7 mm penetrometer) work and the body of work that you discuss here, primarily pertaining to the SMP, Johnson and Schneebeli's work etc. I am happy with whatever you chose to do; but, if you keep it as cone penetration tests, you probably should mention McCallum's work...

The title is now changed to:
"Stochastic analysis of micro-cone penetration tests in snow"
and McCallum's works is also mentioned in the introduction.

The rest of my comments are essentially of a technical nature.

Technical observations

Please re-examine your tense throughout the document. You start off in past tense but this alters; please review and amend.

We check the used tense accordingly in the revised manuscript.

Now by line #, for your consideration please:
3 "more and more" etc. please re-phase/tighten this sentence.

We now change it to "By using small penetrometer tips at this high vertical resolution, further details of the penetration process get resolved, leading to much more stochastic signals."

5 delete "employing"

Corrected.

8 replace allows with enables

Corrected.

11 probably less-dense not lighter; keep terminology consistent.

We now use "less-dense"

13 single: how do you discern/confirm this? Perhaps reword.

We now outline that these are our interpretation and findings of our analysis.

14 Perhaps: with micro cone penetration tests.

We specifically mention now as "micro-cone penetration tests"

24 Perhaps: supposedly

Corrected.

26 can be resolved

Corrected.

40 Reference re. important applications?

The text is reworded as "These models are now commonly used to characterize the snowpack stratigraphy from SMP measurements."

41 to some of the most...

Corrected.

47 delete "the" in the fluid

Corrected.

49 what are micro-events? Please better explain.

We reformulate the sentence and explain it in the revised manuscript. "Due to the sum of several collisions with the molecules in the fluid as illustrated in Fig. 1, the large red particle undergoes a motion described by a stochastic process."

53 shot noise? correct?

Our interpretation of Poisson jump noise corresponds to the shot noise. We mention it now in the revised manuscript.

57 Please reword this last sentence; perhaps: Via this advanced analysis, we seek more detailed snow characterisation from micro cone penetration test resistance data.

Done. We used your suggestion

59 Delete "the" Sect. 3

Corrected.

63 explains the equations?

Corrected.

64/5 note that although the drive is constant the actual penetration rate may not be.

We agree. In the paper, we do not mention the penetration rate.

75 fix "as of the"

Corrected.

77 probably just Friedrich () and Rinn () (instead of semi-colon).

Corrected.

85 do you mean: small depth interval (z)? Also "similar"

Yes and corrected.

91 probably: Such a jump-diffusion dynamic...

Corrected.

107 Wick's theorem: reference?
Added.

114 where here we use...
Corrected..

117 do you mean: small depth interval (z)?
Yes and corrected.

122 perhaps state: "; this is the same as Eq. 2 but..."
Corrected..

128 perhaps "is considered instantaneous".
Corrected.

129 Please spell out OU and SDE in Fig. 2 caption.
Done.

129 Please use drift-jump and jump consistently so as not to cause confusion.
We now change jump to drift-jump.

134 Rephrase "as above"; this is unclear.
Corrected. "as above" is now deleted.

136 "which is a zero-one..."
Corrected.

137/138 etc. "process were generated"; please change tense to past throughout.
Corrected and we now change the tense throughout the paper accordingly.

139/140 "Left, a pure..., middle, ... and right, ..."
Corrected.

141 negligibly
Corrected.

142 “Dots” in Fig. 3 caption
Corrected.

143 process, another parameter that we considered was...
Corrected.

144 proof evidence? Perhaps: to validate our method, based on the KM coefficient...; then. comma after “Eq. 8”; “were chosen”
Corrected.

146 “as the previous example”
Corrected.

152 Probably: Firstly, small snow samples whose microstructure was fully characterised... were used to test... Secondly,... we analysed one... and provided...
Corrected

156 Fig. 4 caption; final sentence: Sub-samples shown are ...
Corrected.

158 tested
Corrected.

159 Reference for snow types; the samples were prepared.
The reference Fierz et al. (2009) is added.

160 Temperature of sintering? Microstructure was captured.
Sintering temperature is -10 °C and added in the revised manuscript.

161 test was conducted
Corrected.

162 on sample preparation..
Corrected.

163 Main sample properties are summarised in Table 1 and the measured hardness profiles...
Corrected.

167 focussed on the fluctuations of the hardness profiles. Each profile was first detrended.

Corrected.

173 divided

Corrected.

174 were separated

Corrected.

175 We estimated the KM coefficients of each sample. . . ; how?

We use Eq. 2 to estimate them and mention it in the revised manuscript.

179 data were determined

Corrected.

180 was determined

Corrected.

181 ". . . 0, and the higher order KM. . . "

Corrected.

182 This indicates the presence. . .

Corrected.

186 normalizaton, the fixed. . .

Corrected.

187 length scale is given

Corrected.

189 Figure 5 caption: Setup of micro cone penetration test; The samples were placed in the cylindrical sample holder. . . ; Is "Kistler 9207" the type of force sensor?

Corrected in the figure caption. Yes, "Kistler 9207" is the force sensor used in SMP.

Figure 6 caption. The wording here is unclear: "have smallest trend and fluctuation force"; are you using all these terms consistently? In the next sentence you talk of size not force? Please re-examine. . .

We now use fluctuation "force" in the figure caption 6.

Figure 7 caption. . . . for better visualisation.
Corrected.

197 Perhaps: Results are summarized in Table 2; we discuss these in Sect. 4.
Corrected.

198 Perhaps: Hardness of Field Data or Application to Field Snow Data?
we change the title of 3.2 to "Application to Field Snow Data".

200 The measurements were also performed with a SMP, but the tip had a different sensitivity of. . . what was it?? Spatial sampling was again. . .
we reword the text as "the tip had a slightly different shape corresponding to the standard version of the SMP (Johnson & Schneebeli, 1999)."

Figure 8 caption. Please reword last sentence; it is difficult to understand.
we now change it to "Comparing the correlation length scales $L_{\mathrm{C}} = \frac{1}{\gamma}$ *where* $D^{(1)} = -\gamma R'$ *with those of the autocorrelation functions (ACF), we find that both length scales have the same ordering of their values for all snow types."*

203 methods was irrelevant, as we subsequently show. . . that in principle, the. . . really snow data, and that. . .
Corrected.

Figure 9 caption. "< 2; we focus our statistical. . . "
Corrected. The last line of the caption is also changed to "The blue horizontal lines show the mean values of the respective parameters in the range of $-2 < R' < 2$*."*

206 therefore, we used. . .
Corrected.

207 profile was separated. . . and detrending was performed on each window. . . 0.6 mm, formalised with. . . deviation as in our previous analysis of laboratory data.

Corrected.

Figure 10 caption. parameters were determined... are also plotted to enable better comparison (right column); they are shifted... reference to the local characteristic snow types from laboratory measurements,

Corrected.

212 for better comparison

Corrected.

213 Interpretation of these results will be discussed next.

Corrected.

217 "it is found that sufficient large particle"?? Please reword. "In our interpretation,..."

Corrected.

218 perhaps: "in the immediate surroundings of the SMP, in addition to the pushing aside..."

Corrected.

219 Delete However; Perhaps: The jump noise may represent (or be representative of) the bond-breaking events occurring directly at the tip of the SMP...

Corrected.

221 perhaps: it is clear that snow type morphology, shown in Fig. 4, is essential for effective stochastic analysis as outlined herein.

Corrected.

223 We started...

Corrected.

230 "R', and can be approximated..."

Corrected.

249 our earlier discussion,

Corrected.

252 “bigger ice structures”: consider rewording/clarifying this sentence: “thicker grain necks”?

We now use “larger grain size”.

255 “allows”? perhaps: enables differentiation between...

Corrected.

257 perhaps: “With reference to the local characteristic snow types from the laboratory measurements (), we see dynamics that suggest mixtures of different snow types within this depth segment.

Corrected.

261 “the developed methodology appears... in the field, but further quantitative evaluation is required.”

Corrected.

264 allows differentiation of

Corrected.

268 the denser structures typical of DH and...

Corrected.

270 Delete: “we have to remember that”

Corrected.

273 Perhaps: Finally, we would... of a complex material, snow, by a...

Corrected.

276 Perhaps: types, complementing existing methods.

Corrected.