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Interactive comment on "Influence of urbanization on permafrost: a case study from Mohe County, northernmost China" *by* W. B. Yu et al.

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This manuscript deals with the impacts of several processes operating concurrently on the dynamics and stability of permafrost in Mohe County, northernmost China:

1) the well documented climate warming in excess of 1 °C over 50 years as observed from the end of 1950's to the beginning of 2010's (Figure 1), and 2) the urbanization influence divided in four processes: a) the disturbance of the surface conditions by human activities (destruction or removal of the vegetation cover, construction of road embankment and building foundation, . . .), b) the heat transfer from heated building to the ground, c) the effect of urban heat island (the air temperature is higher in cities than in undisturbed areas), and d) the thaw subsidence inducing a heat transfer by convection where the cold permafrost core is becoming closer to the warm surface.

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The urbanization is not something static over time. The authors have documented the increase in population of 16 000 residents over 20 years. As stated in the manuscript (last paragraph in page 4330), the city's footprint has also increased accordingly to meet the needs of the population growth. The four previous processes along with the climate warming impact concurrently the permafrost stability and induce permafrost degradation and thawing. They have also larger impacts acting concurrently altogether than if each process is acting alone. However, it can be very challenging to distinguish the impact of one process from another. The cumulative impact of the climate warming and urbanization can be extremely catastrophic for maintaining permafrost and for the sustainable development of a city such as Mohe County. Moreover, the permafrost degradation affects the maintenance cost and lifespan of human infrastructures and the quality of life of the population.

The authors have between their hands adequate data for the Mohe County such as climatological record, historical records of population growth and increase in city's footprint, observation of mechanical failures on human infrastructures, drilling logs, temperature profiles and geophysical surveys to document not only the permafrost conditions in Mohe County and its surroundings but also the impacts of urbanization on permafrost thermal regime and stability. However, the English level is poor and the structure of the manuscript is deficient to support their original findings. This is quite sad because, at my knowledge, there are not many papers in the scientific literature to show the cumulative impact of the climate warming and urbanization on permafrost stability and, ultimately, on performance of human infrastructures.

As a reviewer, it is not my task to improve the English level. I have to concentrate on the scientific content. Please find in the following few comments on this matter in the order that I found something arguable in the manuscript. Moreover, I will make also some comments on the structure of the manuscript which the authors may address for improving their manuscript. And, finally, I have read the comments of Professor Michel Allard modulating somewhat my own comments.

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1) In lines 9 and 10 in the abstract (page 4328), the depth where the mean annual ground temperature was measured and calculated should be given. Due to the geothermal gradient, there is a natural increase in temperature with depth. Without a measurement depth or a reference depth, the mean annual ground temperature has no meaning for comparison purpose between the thermal conditions of urban and undisturbed areas. See also elsewhere in the text.

2) From lines 8 to 12 in the abstract (page 4328), instead of giving in two sentences the depths of the permafrost table in the urban and undisturbed areas and letting to the reader the interpretation work to figure out the impacts of urbanization on permafrost table, theses depths should be compared in the same sentence. The same comment applies for the mean annual ground temperatures observed in the urban and undisturbed areas.

3) In the first paragraph of the introduction (page 4328): - Johansson et al., 2011 and not Margareta Johansson, 2011 - Callaghan et al., 2011 and not Callaghan, 2011 - Schuur, 2011 and not Schuur, 2013 - The impacts of climate warming and human activities on permafrost as observed in the references given in the text should be also described in the text. That will allow the authors to put in the context their own observations later in the text.

4) In the second paragraph of the introduction (page 4329): - Hinkel et al., 2003 and not Hinkel, 2003 - Klene et al., 2003 and not Klene, 2003 - the reference of Benson et al. (1983) is not given in the list of references at the end of the manuscript - this paragraph is related to the urban heat island (UHI). The last sentence of this paragraph about the work of Allard et al. (2002), Buteau et al. (2004) and Fortier et al. (2011) is not related to UHI but to the impacts of climate warming on permafrost thermal regime and the impacts of climate warming and road embankment working simultaneously on permafrost stability.

5) In the third and fourth paragraphs of the introduction (page 4329), specific details

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on the population growth and climate warming are given while this information should appear in the section on the study area (Section 2.1 Physical settings). An introduction on the manuscript focus should be rather given.

6) In the fourth paragraph of the introduction (page 4329), instead of 0.357 °C 10 a−1, please use 0.357 °C decade−1. See also in the third paragraph of the section 2.1 Physical setting (page 4330), instead of 9.65 cm 10 a−1, please use 9.65 cm decade−1.

7) In Figure 1 (page 4340) called for the first time in the third paragraph of the introduction (page 4329), no spline curve should be drawn to link the data points. In addition to the linear regression line, a moving average of 5 years should be drawn to decrease the noise and put in evidence the trend to climate warming.

8) In the first paragraph of the section 2.1 Physical setting (page 4330), the reference of Zhou et al. (2000) is not given in the list of references at the end of the manuscript. See also in the eighteenth paragraph of the section 3 Results and analysis (page 4334)

9) In the second paragraph of the section 2.1 Physical setting (page 4330), details are missing on the vegetation cover in undisturbed area and in urban area. What is Carex heterolep? What kind of forest cover is in undisturbed area?

10) In the second paragraph of the section 2.1 Physical setting (page 4330), a graph of mean daily air temperature should be given to document the climate in Mohe County.

11) In the second and third paragraphs of the section 2.1 Physical setting (page 4330), details are missing on the snow cover. Is the value of 2.12 m the maximum thickness of snow cover observed in winter? Or is this value the cumulative thickness of snow fall? A graph of the snow cover thickness or cumulative snow fall thickness over the period from the end of 1950's to the beginning of 2010's similar to the figure 1 for the mean annual air temperature should be given. A linear regression line should be drawn on this graph. This major increase in snow fall may be another process for explaining

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the permafrost warming and degradation (see my first comments). What is the natural spatial distribution of the snow cover in undisturbed area? How the snow fall is plowed away in the Mohe County? Any snow accumulation by plowing operation can have a very large impact on the thermal regime of permafrost underneath.

12) In the third paragraph of the section 2.1 Physical setting (page 4330), the impacts of permafrost degradation on groundwater dynamics is very interesting. Details are also needed on the disposal of used water. Is there any sewage system in Mohe County? Any seepage of the sewage system or direct spill of used water may cause contamination of groundwater used as a source of drinking water.

13) In the section 2.1 Physical setting (page 4330), more details should be given on the evidences of permafrost degradation of Mohe County and on the mechanical problems observed on the human infrastructures related to permafrost degradation. Such details will strengthen the manuscript and support the following sections on the permafrost conditions, warming and degradation.

14) In Figure 2 (page 4341) called for the first time in the first paragraph of the section 2.2 Methodology (page 4331), the aerial photograph should be enlarged to see the details and study sites. The study site I away from Mohe County is not located in Figure 2.

15) In the second paragraph of the section 2.2 Methodology (page 4331), the authors did not only drilled permafrost for the installation of thermistor cables but also sampled permafrost (Figures 5 and 9).

16) In the third paragraph of the section 2.2 Methodology (page 4331), is the lecture of the thermistor cables manual or automated? These thermistor cables are fairly new and the authors have no long record of permafrost temperature in undisturbed and urban areas. This is a weakness in their manuscript because they cannot document the long-term variations in permafrost temperature over time. They can only document the spatial variations in permafrost temperature by comparing the temperature profiles

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from one location to another; from the undisturbed area to urban area. But there is a natural variation in permafrost temperature even without any human disturbance due to spatial variability in surface conditions. Without long-term record of permafrost temperature, it's hard to clearly document the impacts of urbanization on permafrost and distinguish between the processes (see my first comments).

17) In the fourth paragraph of the section 2.2 Methodology (page 4331), at my knowledge, a pulseEKKO 1000 has no 100 MHz antennas; only the pulseEKKO Pro has.

18) In the fourth paragraph of the section 2.2 Methodology (page 4331), the reference of Fortier et al. (2011) is not appropriate for GPR common mid-point (CMP) sounding. In Fortier et al. (2011), the authors only mentioned the use of CMP sounding to assess the radar signal velocity in the ground without explaining this type of sounding.

19) In Figure 3 (page 4342) called for the first time in the fourth paragraph of the section 3 Results and analysis (page 4332), without knowing the depth of the thawing front, I challenge the authors to pinpoint the reflector in this GPR reflection profile associated with the thawing front or the permafrost table. From my point of view, the GPR is a good geophysical method to image the sedimentary structures in the ground. For the GPR reflection profiles given in this manuscript (Figures 3 and 4), very little useful information can be obtained on the active layer and permafrost.

20) In the third paragraph of the section 3 Results and analysis (page 4332), a radar signal velocity of 0.075 m ns-1 is low and representative of unfrozen and saturated ground. See also in the sixth paragraph of the section 3 Results and analysis (page 4332), a radar signal velocity of 0.071 m ns-1 is also mentioned.

21) In the fourth paragraph of the section 3 Results and analysis (page 4332), what is the relationship between the study site A (GPR profile in Figure 3) and the study site H (temperature profiles in Figure 8). These two sites are away from each other and they cannot be compared. What is the meaning of the calculation of the thawing depth on October 15th 2012? The term "thawing rate" is more appropriate than "thawing

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velocity".

22) In Figure 4 (page 4343) called for the first time in the fifth paragraph of the section 3 Results and analysis (page 4332), reflectors at depths between 4 and 5 can be noticed. What is the cause of these reflectors?

23) In the seventh and eighth paragraphs of the section 3 Results and analysis (page 4332), the GPR reflection profile carried out in site E mentioned in the text is not given in the figures. See also in the twelfth paragraph of the section 3 Results and analysis (page 4333), the GPR reflection profile carried out in site C is not provided.

24) In the tenth paragraph of the section 3 Results and analysis (page 4333), what do the authors mean by "unrefrezonable"?

25) In the last sentence of the twelfth paragraph of the section 3 Results and analysis (page 4333), according to my own expertise on GPR, the absence of permafrost cannot be directly deduced from the interpretation of a GPR reflection profile within the depth of penetration of the radar signal. Again, the GPR is not the best geophysical method to infer the absence/presence of permafrost.

26) In the fourteenth paragraph of the section 3 Results and analysis (page 4334), -1.00 °C instead of 1.00 °C. The ground warming is observed over a one-year period from 2012 to 2013 and not over "a short span of two years" as stated in the last sentence of this paragraph. The thickening of the active layer from 1.65 to 2.00 m over that one-year period appears to me a more significant effect of permafrost degradation than the ground warming at depth.

27) In the sixteenth paragraph of the section 3 Results and analysis (page 4334), the GPR reflection profile carried out in site G is not provided. See the comment no. 25.

28) In the eighteenth paragraph of the section 3 Results and analysis (page 4334), according to my own interpretation of the temperature profile given in Figure 9, taking the last two temperature values at 65 and 70 m deep where the geothermal gradient

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is higher than at shallower depths, the extrapolation based on these two data points gives a depth of the permafrost base of about 110 m and a permafrost thickness of 108 m for an active layer of 2 m thick. This value is much closer to the ones from 50 to 100 m according to Zhou et al. (2000) than the ones from 140 to 281 given by the authors in the text. The isothermal conditions at a ground temperature close to -2.7 °C from 15 to 55 m deep may be due to the climate warming over the last 50 years (Figure 2). If one uses this very weak geothermal gradient over that depth range to extrapolate to the depth of the permafrost base, he will find very thick permafrost.

29) In the third paragraph of the section 4 Discussions and conclusions (page 4335), did the fire in 1987 also destroy the vegetation and affect the surface conditions? The impacts of this fire on permafrost should be explained. That may be another process to take into account among the others that I gave in my first comments.

30) For comparison purpose between the several temperature profiles provided in the manuscript (Figures 5 to 8), the scales of temperature and depth axis used in the graphs should be the same respectively.

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