- Responses to reviewers' comments to manuscript tc-2014-142, *The organic carbon pool of permafrost regions on the Qinghai-Xizang (Tibetan) Plateau.*

- **Reviewer 1**

- *This study provides the first comprehensive estimate of shallow and deep soil organic carbon (SOC) stocks in the Qinghai–Xizang (Tibetan) Plateau (QXP). The authors synthesize existing field data for near surface soils (0-1 m depth) and provides new field data for deeper deposits (1-25 m depth). This constitutes a timely contribution of data from a region that has previously been under-sampled. There are however aspects of the SOC upscaling which need more work and the dataset for deep SOC stocks needs to be more carefully described. I would also recommend that the manuscript is carefully proof-read and edited with regards to the English language.*

  **Response:** Thanks for your kind words for our manuscript. We have carefully performed SOC pools estimation upscaling in the revised version and provided the description as follow:

  For the organic carbon storage in 0~1 m depth, the reported SOC densities data of 190 sampling sites were collected through their distribution in permafrost regions (Fig. 1). The area of alpine meadow, alpine steppe and alpine desert in permafrost regions was calculated through overlaying the vegetation map over the QXP permafrost regions (Fig. 2). For the organic carbon storage in 1~2 m depth, the organic carbon densities of 11 boreholes were extrapolated to the located vegetation type area. For the organic carbon storage in 2~3 m and 3~25 m depths, the area of permafrost regions in the Quaternary, Triassic and Permian stratigraphies on the QXP was calculated through overlaying the distribution of geological stratigraphies over the permafrost map (Fig. 3). The organic carbon pools of 2~3 m and 3~25 m depth was estimated through deep organic carbon densities multiplied by the area of geological stratigraphies. The three geological stratigraphies had thick sediments of about 25 m (Fang et al., 2002; 2003; Qiang et al., 2001).

  The detailed description of dataset of deep SOC stocks was provided in the supplement materials.

- *I would strongly recommend that the authors calculate basic confidence intervals or uncertainty ranges for their estimates. Hugelius (2012, Global Biogeochemical Cycles) exemplifies how simple confidence intervals can be calculated. Note that it is likely not realistic to report the stock estimates with two decimals for a Pg given the uncertainties associated with estimates like this.*

  **Response:** The uncertainty ranges for their estimates were added in the

revised version using average values and standard error. We took two decimals off using rounding method and gave new numbers. However, in some cases, we still have one decimal point.

- *The authors have chosen to upscale point observations from soil pits and boreholes using a generalized vegetation map. It would be beneficial with some discussion and justification of this choice. How do the authors expect that the identified vegetation classes and their properties interact with the pedogenic processes that cause accumulation of SOC in soils?*

  **Response:** It was explained in the revised version as follows:
  Lines 77~84: For the top layer, important factors controlling SOC pools are vegetation type and climate (Jobbagy and Jackson, 2000). The vegetation type and climate conditions related closely to each other on the QXP (Wang et al., 2002). Thus it is possible to calculate the SOC pools at 0~2 m depth according to the area of vegetation type (Chinese Academy of Sciences, 2001) in the permafrost regions (LIGG/CAS, 1988). For deep layers, the geomorphology and lithological conditions play an important role in the distribution of SOC pools (Hugelius et al., 2013). Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in permafrost regions on the QXP.

- *A major strength of the paper is the new data from 11 deep boreholes which are used to estimate SOC stocks down to 25 m. Are all these 11 boreholes exactly 25 m deep? Looking at the data in Figure 2 it seems like ca. 5-6 sites has data extending below 10 m depth? This type of deep borehole data is very valuable and it would be very valuable of the authors provided more detail on individual boreholes, possibly as an online supplement? Data on C%, bulk density, ice-content and texture from such boreholes would be very valuable to the wider scientific community.*

  **Response:** Soil depth at several sampling sites was not exactly 25 m due to the situation of factual drilling work in field. Geographic location for the 11 boreholes, together with the active layer depth, sampling depth, vegetation type, quaternary geological stratigraphies, SOC contents, bulk density, water contents and texture were shown in the supplement in the revised version.

- *The authors have upscaled deep SOC stocks from eleven boreholes, mainly located along the railway, to the entire QXP. How likely is it that the entire non-forested section of the QXP is actually covered by 25 m thick unconsolidated sediments? If the authors maintain this claim, it needs to be justified with references to studies of Quaternary deposits in the region. I would*

*expect that the deeper deposits only extend to some fraction of the QXP.*

**Response:** Thanks a lot for the suggestion. The area of geological stratigraphy in permafrost regions was determined through overlaying the quaternary geological stratigraphy map over the permafrost map of the QXP. Then we estimated the organic carbon pools in the three stratigraphies of Quaternary, Permian and Triassic in permafrost regions, based on the geological stratigraphy of 11 boreholes. There are 25 m thick unconsolidated sediments in the three stratigraphies of Quaternary, Triassic and Permian, which was proved by the field drilling. The description in the present version was as follows:

Lines 81~84: For deep layers, the geomorphology and lithological conditions play an important role in the distribution of SOC pools (Hugelius et al., 2013). Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in permafrost regions on the QXP.

Lines 146~150: The three geological stratigraphies had thick sediments of about 25 m (Fang et al., 2002; 2003; Qiang et al., 2001). As for other geological stratigraphies, the poor soil development was reported and soil thickness was usually less than 3 m (Wu et al., 2012; Yang et al., 2008; Hu et al., 2014). Thus other stratigraphies were not considered in the estimation of deep organic carbon pool in the permafrost regions.

- *P5016 line 8-9: Note that this direct comparison of fraction SOC below 3 m is not applicable since the Tarnocai et al. (2009, Global Biogeochemical Cycles) estimate only includes selected deep deposits and makes no attempt to include deep deposits outside the yedoma region and deltas.*

  **Response:** Thanks, the expression was replaced by that "The percentage of SOC storage in deep layers (3~25 m) on the QXP (80%) was higher than that (39%) in the yedoma and thermokarst deposits in arctic region." (lines 18~19).

- *P5016 line 18: This is an oversimplification. The previously frozen SOC becomes available for mineralization. Whether or not this leads to greenhouse gas release depends on multiple environmental factors.*

  **Response:** Thanks for the corrections. It was replaced by "Climate warming will thaw permafrost, which can cause the previously frozen SOC become available for mineralization" (lines 29~30).

- *P5017 line 21-22: I would not advise you to apply such a generalized statement for all deep permafrost deposits. The genesis and age of deep deposits is very different in different locations. Many deposits are epigenetic, which implies that they were permafrost-free for some time prior to permafrost aggradation.*

**Response:** Thanks, deleted.

- *P5018 line15: It is not essential that vegetation is used. It is one of several viable options for upscaling.*

**Response:** Deleted. We added the related contents in the introduction as follows:

Lines 77~84: For the top layer, important factors controlling SOC pools are vegetation type and climate (Jobbagy and Jackson, 2000). The vegetation type and climate conditions related closely to each other on the QXP (Wang et al., 2002). Thus it is possible to calculate the SOC pools at 0~2 m depth according to the area of vegetation type (Chinese Academy of Sciences, 2001) in the permafrost regions (LIGG/CAS, 1988). For deep layers, the geomorphology and lithological conditions play an important role in the distribution of SOC pools (Hugelius et al., 2013). Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in permafrost regions on the QXP.

- *P5020, equation 1: Note that if the BD was calculated based on initial frozen core volume, the ice content should not be subtracted again in the formula. It is already accounted for by the lower sample BD when ice melts and water evaporates in the drying of the sample.*

**Response:** Thanks very much for the corrections. We used the right formula in calculation, while this equation was wrongly created in a special tool. We have corrected the formula $SSOC = C \times BD \times T \times (1 - CF)$ (Dorfer et al., 2013), where C was the organic carbon content (wt%), BD was the bulk density (g $cm^{-3}$), T was the soil layer thickness and CF was the coarse fragments (wt%). (lines 129~133).

- *P5021 line 6: Please report the standard deviations of these mean values. This applies whenever means are reported in the paper.*

**Response:** Changed. It was changed as follows:

Lines 166~172: According to the distribution of sampling sites at the geological stratigraphies, for the Quaternary stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 0.8±0.6% and 0.8±0.7%. For the Triassic stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 1.1±0.3% and 1.2±0.6%. For the Permian stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 1.5±0.4% and 1.1±0.3%. As for the permafrost regions in HHRB, the SOC contents

(Heihe-1, Heihe-2) were higher than those of the predominately continuous permafrost zone on the QXP, with a range of 5.1±3.7% and 2.7±2.4% to depth of 19 m.

- *P5021 line13: "depth of 6 cm" This is likely a mistake and should be 6 m?*

  **Response:** Changed. It should be 6 m.

- *P5021 equation 2: The authors may consider is this function could be applicable to upscaling their deep SOC stocks (with uncertainty ranges) to those parts of the QXP where they expect deep deposits to occur. This may replace the simple thematic upscaling currently used. There is however the complicating factor that some individual cores show an increase with depth rather than a decrease. This may reflect different Quaternary deposits?*

  **Response:** Thanks a lot. The discussion was changed in the revised version as follows:

  Lines 226~235: SOC decreases with the depth on the QXP (Fig. 4), which is in good agreement with those reported in circum-Arctic regions (Strauss et al., 2013; Zimov et al., 2006). This could be explained by the dynamics of Quaternary deposit and organic carbon formation in permafrost regions (Strauss et al., 2013). However, the organic carbon contents of deep layers in some sites (XSH, KL150 and KL300) were higher than those in the top layers (Fig. 4), which may be caused by the cryoturbation and sediment burying process (Ping et al., 2010), and Quaternary deposits following the uplift of Tibetan Plateau (Li et al., 1994; 2014). Overall, SOC decreases exponentially with depth (equation 1) in permafrost regions on the QXP, this is in agreement with results from other regions (Don et al., 2007). Certainly, more efforts are still needed in studying the distribution of deep organic carbon density in permafrost regions.

- **Reviewer 2**

- *The paper represents a great attempt to summarize all the past research on soil carbon stores and distribution in different ecosystems (cover types) of the Qinghai-Xizang Plateau (QXP). The authors have reviewed many published works/research done by the Chinese colleagues over the past several decades. It is timely and would contribute to our understanding of the relationships between carbon stores and vegetation covers. This paper has the potential being a monumental work if the authors can tie the physiography, soils, vegetation, permafrost to define the ecosystems of the QXP and how these ecosystem attributes affect the OC store on the QXP. But, there are some*

*shortcomings must ne addressed before being considered for publication. I would recommend the manuscript be accepted after major revision.*

**Response:** Thank you very much for your valuable comments. We have revised the manuscript according to your detailed suggestion.

- *I am confused if the objective of this paper is to estimate the organic carbon (OC) pools only of the permafrost regions of the Qinghai-Xizang Plateau (QXP) or the whole QXP. The authors calculated the total area of the permafrost regions of the QXP is $1.35\times10^6$ $km^2$. But the total area of QXP is $2.5\times10^6$ $km^2$. Therefore, 46% of the QXP are seasonal frozen grounds which also exist beyond the boundary of the QXP.*

**Response:** Sorry for the previous confused expression. Our intention is only for permafrost regions of the QXP, not the entire QXP. The permafrost area of different vegetation type was calculated again through overlaying the vegetation type map over the permafrost map in the present version.

In the revised version, it was shown as "Based on the vegetation data in permafrost regions on the QXP (Figs. 1, 2), the area of permafrost regions in the alpine meadow, alpine steppe and alpine desert are $0.302\times10^6$ $km^2$, $0.772\times10^6$ $km^2$ and $0.175\times10^6$ $km^2$ respectively, with a total area of approximately $1.249\times10^6$ $km^2$." (lines 154~156).

- *The authors estimated the total carbon stock of the QXP based on vegetation cover types; alpine desert, alpine steppe, and alpine meadow. The forest area in SE QXP was shown in the map but no carbon data was presented. To my understanding, except the forest area, each of the land cover types includes both permafrost and seasonal frozen ground. In general, the carbon contents in permafrost-affected sites are higher than those without permafrost (because of soil moisture contents). The authors claimed that the database relied on 706 profile sites distributed among these three cover types. I question if all these sites have permafrost within measurable depths? Except some broad basins, there are large areas with steppe and desert vegetation communities have very shallow soils due to the shallow depths of weathering. These sites cannot be called permafrost sites or permafrost soils. The carbon contents in wet meadows are generally much higher than those well-drained Kobrecia meadow soils.*

**Response:** The sampling sites (190 sites) in permafrost regions on the QXP were collected though the permafrost map in the revised version. We have made a detailed description as follows:

Lines 77~84: For the top layer, important factors controlling SOC pools are vegetation type and climate (Jobbagy and Jackson, 2000). The

vegetation type and climate conditions related closely to each other on the QXP (Wang et al., 2002). Thus it is possible to calculate the SOC pools at 0~2 m depth according to the area of vegetation type (Chinese Academy of Sciences, 2001) in the permafrost regions (LIGG/CAS, 1988). For deep layers, the geomorphology and lithological conditions play an important role in the distribution of SOC pools (Hugelius et al., 2013). Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in permafrost regions on the QXP.

The 11 deep sampling sites were mainly located in the three vegetation types of alpine meadow, alpine stepper and alpine desert (Fig. 2), and three stratigraphies of Quaternary, Triassic and Permian (Fig. 3).

"permafrost sites or permafrost soils" were changed into "in deep soils of permafrost regions" in the revised version".

- *There has never before a comprehensive study or review of the carbon pools of the QXP. Because of this, it is crucial for the authors to scrutinize the dataset. In order to support the information in Table 1. The authors need to submit a supplement file that contains all the cited source of carbon data, site (pedon) by site as %C, bulk density, land cover type (meadow, steppe, desert, etc.), active layer depth, soil texture, sampling depth, elevation (asl) if these information is provided in the original source.*

  **Response:** We provided geographic location for the 11 boreholes, together with the active layer depth, sampling depth, vegetation type, Quaternary geological stratigraphies, SOC contents, bulk density, water contents and texture in the supplement in the revised version. The data in the previous studies were available in the Yang et al., (2010), Liu et al., (2012), Wu et al,, (2012), and Mu et al., (2013), which are concluded in Table 1.

- *One of the coauthors, Dr. GD Cheng has studied the distribution of permafrost of the QXP for many years. Why not overlay the land cover type map over his permafrost map to separate the carbon pools in the permafrost and non-permafrost of the same cover type? This approach would improve the accuracy of the estimate. If this paper is to represent the whole QXP. Then the forest regions in SE QXP should be included. Professor Zhang Wan Ju of the Chinese Forest Sciences Academy studied forest soils including the LinZhi District in the 1970 to 1980 period and published the book Forest soils of China by Ministry of Forestry. Another reference is the Qinghai Province Soils by Bao Xingqui of the Xining Alpine Botany Institute.*

  **Response:** Thank you for your suggestion. We have overlaid the vegetation type map over the permafrost map to separate the carbon pools in the permafrost and non-permafrost of the same cover type. Thus, we can

select the sampling sites and calculate the permafrost area in the three vegetation types again. The forest regions were not included in the present study because this paper focuses on the estimation of the organic carbon pool in permafrost regions on the QXP, not the whole QXP. Although the references (Zhang Wanju and Bao Xingqui) provided important data for the soils under the forest cover, we found it was very difficult to merge these data into our work partly because the permafrost cover was largely unknown in these forest regions.

- *Next, an important question is about the uncertainty or variations caused by different lab procedures. The OC of the 11 deep sampling sites were determined by high temperature combustion with pre-treatment to remove inorganic carbon. But most of the carbon contents data in published Chinese literatures were determined by wet oxidation (for example, dichromate oxidation) and or loss on ignition. There could be 10-18% difference among the 3 procedures. I have not seen any study in China dealing with the calibration among these three analytical procedures. But at least the methods used in each cited source of data point should be noted in the supplement.*

**Response:** The different analytical procedures indeed can cause uncertainly. The analytical methods used in each cited data has been noted in Table 1. Thanks for the suggestion, which can make us pay more attention to the analytical methods of soil carbon in the future.

Lines 213~217: "In addition, the different analytical methods may also contribute to the differences of carbon contents (Table 1). It has been demonstrated that if taking the dry combustion method as standard, the recovery of organic carbon was 99% for wet combustion and 77% for Walkley-Black (Kalembasa and Jenkinson, 1973; Nelson and Sommers, 1996)" was added in the discussion of revised version.

- *My next concern is the extrapolation of the deep OC stores (3-25 m). Please note even in the 2-3 m OC store estimation in the North Circumpolar Carbon Database, there is wide disparity and very high uncertainty. When Strauss, Schirrmeister and their collaborators studied the OC store in the yedoma deposit, they gave a definite geographic distribution base on geomorphology and lithological data (stratigraphy) in that the yedoma OC store does not extrapolated to the whole Arctic Coastal Plain. Thus, I'd urge the authors be discretionary as how far (in area extent) can this deep OC data can be extrapolated. Geomorphic and or geological information would help such extrapolation.*

*I'd strongly encourage the authors to go back to the cited dataset or data points and reorganize the data and consider the comments and synthesize all the previous work. Only after that the authors would be able to find the gaps in the previous work and pointing to the needs of future research.*

**Response:** Thanks, we provided the distribution of sampling sites on the quaternary stratigraphies (supplement material). The 11 deep sampling sites were mainly located in the three stratigraphies of Quaternary, Triassic and Permian (Fig. 3). Thus the estimated deep carbon pools in the present version were the carbon storages in Quaternary, Triassic and Permian stratigraphies in permafrost regions on the QXP. Thus the carbon storage in deep layer was recalculated and discussed in the present version.

· ***In addition, there are some revisions we made as follows:***

***Major revisions:***

The number of sampling sites was changed from 706 to 190, and the area of vegetation type was changed in the revised version. It was because that we overlaid the vegetation type map over the permafrost map to separate the sampling sites in the permafrost and non-permafrost of the same cover type. Thus, we selected the 190 sampling sites and used the organic carbon data to calculate the carbon storage at 0~1 m depth. In addition, the permafrost area in the three vegetation types was calculated again using the same method, then the carbon storage at 1~2 m depth was changed.

The calculation method for the deep carbon pools at depth of 2~3 m and 3~25 m in the permafrost regions was changed according to the geomorphology and lithological conditions because they play important roles in the distribution of SOC pools for the deep layer. Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in the permafrost regions on the QXP. We estimated the organic carbon pools in the three stratigraphies of Quaternary, Permian and Triassic in permafrost regions, based on the geological stratigraphy of 11 boreholes.

Therefore, the storage of soil organic carbon at depth of 0~2 m in permafrost regions on the QXP was recalculated and changed according to the area of vegetation type in permafrost regions. The deep organic carbon pools at different depth of 2~25 m was recalculated according to the area of located Quaternary geological stratigraphies. The previous total organic carbon pool in permafrost regions on the QXP was changed in the revised version.

***Other changes:***

Line 1: The title was changed into "*Organic carbon pools in permafrost regions on the Qinghai-Xizang (Tibetan) Plateau*"

Line 3: The order of author names was changed according to the

contribution of this revised version. Dr. Bo Cao contributed to the geological data analysis.

Line 13~14: It was changed into "*The current Northern Circumpolar Soil Carbon Database did not include organic carbon storage in permafrost regions on the Qinghai-Xizang (Tibetan) Plateau (QXP).*"

Line 15: "of the permafrost regions" was replaced by "*in the permafrost regions*".

Line 15: "at different layers form the top 1 m" was changed into "up to 25 m".

Line 16: "706 soil profiles" was changed into "*190 soil profiles*".

Lines 16~18: The SOC pools at different depth were changed in the present version. We re-analyzed the data and realized that we made some mistakes in the previous version. We have checked the data of the present version.

Lines 18~19: "The percentage of SOC storage in deep layer on the QXP was larger than that (38.8%) in the northern circumpolar permafrost region" was replaced by "*The percentage of SOC storage in deep layer (3~25 m) on the QXP (79.5%) was higher than that (38.8%) in the yedoma and thermokarst deposits in arctic regions*".

Lines 21~23: We added that "*Total organic carbon pool in permafrost regions on the QXP was approximately 8.7% of that in northern circumpolar permafrost region.*"

Lines 23~24: It was replaced by "*The present study demonstrates that the total organic carbon storage is about 1832 Pg in permafrost regions on northern hemisphere.*".

Line 28: "greenhouse content" was replaced by "*greenhouse gas contents*".

Line 30: "*releasing trapped carbon in permafrost affected soils into the atmosphere and further exacerbating global warming*" was replaced by that "*which can cause previously frozen SOC become available for mineralization*".

Line 30: "*Schafer et al., 2011*" was deleted.

Lines 30~32: "*Permafrost carbon has been potentially most significant carbon-climate feedbacks because of the size of carbon pools and intensity of climate forcing*" was changed into "*Permafrost has potentially the most significant carbon-climate feedbacks not only due to the intensity of climate forcing, but also the size of carbon pools in permafrost regions*".

Lines 34~36: "*Recently, carbon stored in permafrost regions has created many concerns because of the implication on global carbon cycling (Ping et al., 2008; Burke et al., 2012; Zimov et al., 2006; Michaelson et al., 2013; Hugelius et al., 2013).*" was added.

Lines 39~41: It was replaced by "*Based on newly available regional soil maps, the estimated storage of SOC in 0~3 m depth of soils is estimated to 1035±150 Pg (Hugelius et al., 2014), about 1% higher than the previous estimate by Tarnocai et al. (2009).*".

Lines 50~53: *"It has been suggested that SOC in permafrost regions on the QXP was very sensitive to global warming, due to the permafrost characteristics of high temperature (< −2.0 ℃), thin thickness (< 100 m) and unstable thermal states (Cheng and Wu, 2007; Li et al., 2008; Wu and Zhang, 2010)*" was added.

Lines 55~57: "*Mean annual permafrost temperatures at 6.0 m depth increased by a range of 0.12 ℃ to 0.67 ℃ from 1996 to 2006 (Wu and Zhang, 2008), and increased ~0.13 ℃ from 2002 to 2012 (Wu et al., 2015). Active layer thickness increased, on average, approximately ~4.26 cm* $y^{-1}$ *along the Qinghai-Tibetan Highway from 2002 to 2012 (Wu et al., 2015).*" was added.

Lines 57~58: "*In addition, the carbon stored in permafrost area was labile and a great part of the carbon was mineralizable (Mu et al., 2014; Wu, et al., 2014).*" was added.

Lines 59: "The studies have been conducted on …" was changed into "*Some studies has been conducted on …*".

Lines 60: "*Ohtsuka et al., 2008; Dorfer et al., 2013*" were deleted and "*Wu et al., 2012" was added.*

Lines 60~66: *"It was estimated that total SOC for the top 0.7 m was about 30~40 Pg in the grassland of the plateau. The disagreement among the studies on the SOC pools was attributed to the limited sampling points and the quality of the SOC data gathered to date. Despite the importance of SOC in permafrost areas, there are still few reports to the SOC storage in the permafrost regions of the QXP. So far, the current Northern Circumpolar Soil Carbon Database (Tarnocai et al., 2009) does not include the SOC in permafrost regions on the QXP (Tarnocai et al., 2009).*" was added.

Line 67: "*There are about 706 soil sites profiles were excavated in the permafrost regions on the QXP, which make it possible to calculate the SOC pools in this region*" was deleted.

Line 68: "*SOC in deep layer is usually earlier deposits and has been kept frozen, which has higher microbial decomposition (Waldrop et al., 2010)*" was deleted.

Lines 71~72: "*The total yedoma region contains 211+160/-153 Gt C in deep soil deposits [Strauss et al., 2013]*" was changed into "*It was reported that the total yedoma region contains 211+160/–153 Pg C in deep soil deposits (Strauss et al., 2013).*".

Lines 72~73: "*deep permafrost organic carbon*" was changed into "*deep organic carbon in permafrost regions*".

Lines 75~76: "*However, the distribution of permafrost organic carbon in the 0~25 m depth on the QXP has been largely unknown.*" was changed into "*Therefore, it is essential to study the distribution of organic carbon contents in deep layers of permafrost regions*".

Lines 77~84: "*For the top layer, important factors controlling SOC pools are vegetation type and climate (Jobbagy and Jackson, 2000). The vegetation type and climate conditions related closely to each other on the QXP (Wang et al., 2002). Thus it is possible to calculate the SOC pools at 0~2 m depth according to the area of vegetation type (Chinese Academy of Sciences, 2001) in the permafrost regions (LIGG/CAS, 1988). For deep layers, the geomorphology and lithological conditions play an important role in the distribution of SOC pools (Hugelius et al., 2013). Thus it is reasonable to estimate the SOC pools at 2~25 m depth according to the area of Quaternary geological stratigraphy in permafrost regions on the QXP*" was added.

Line 85: "*SOC pool*" was changed into "*SOC pools in permafrost regions*".

Line 86: "*Unlike those from previous assessment of SOC on the QXP*" was deleted.

Lines 87~90: "*SOC storages of the plateau were calculated using the published data of 190 soil profiles and 11 deep sampling sites in this study in combination with the vegetation map, permafrost map and geological stratigraphy map of the QXP (Figs. 1, 2, 3).*" was added.

Lines 90~92: "*The result might update new estimation of surface organic carbon mass and deep permafrost carbon storage, which can provide new insights in permafrost carbon on the QXP.*" was changed into "*The result would update current estimation of surface organic carbon pool and deep organic carbon storage in permafrost regions of the QXP, which can provide new insights in permafrost carbon on the global scale.*".

Line 95: "*Soil carbon database on the QXP*" was changed into "*Soil carbon database in previous reports*".

Line 96: "*Permafrost regions in China are mainly on the QXP (LIGG/CAS, 1988), which occupied approximately $1.35\times10^6$ $km^2$ of the QXP area [Ran et al., 2012]. Permafrost organic carbon was mainly distributed in the alpine meadow and alpine steppe, with the areas of $0.53\times10^6$ $km^2$ and $0.72\times10^6$ $km^2$, respectively [Yang et al., 2010]. In this paper, the remaining area of $0.092\times10^6$ $km^2$ was considered as the alpine desert. For the whole QTP with area of approximately $2.62\times10^6$ $km^2$, it was estimated that the area of alpine meadow, alpine steppe, alpine desert and forest*

*was 1.20×10$^6$ km$^2$, 0.85×10$^6$ km$^2$, 0.40×10$^6$ km$^2$ and 0.17×10$^6$ km$^2$, respectively, based on the China vegetation data [Chinese Academy of Sciences, 2001] (Fig. 1). The permafrost regions in the alpine meadow, alpine steppe and alpine desert are 0.53×10$^6$ km$^2$, 0.72×10$^6$ km$^2$ and 0.092×10$^6$ km$^2$, respectively, total 1.35×10$^6$ km$^2$.*" was deleted.

Line 96: "*were based on*" was changed into "*were retrieved from*".

Line 97: "*Wang et al., 2002*" was deleted.

Line 97: "*Moreover, we complemented …*" was deleted.

Line 100: "*the*" in "*in the 0~1 m depth*" was deleted.

Line 101: "*were calculated separately*" was added.

Lines 101~103: "*…, since their study regions of western QXP, Shulehe river basin (SLRB) and Heihe river basin (HHRB) belonged to the isolated permafrost zone and the climate conditions differed greatly with the continuous permafrost zones of the QXP*" was added.

Lines 103~105: "*The total permafrost carbon pool in the QTP was built up using 706 pedons, including 11 pedons in deep permafrost soils.*" was changed into "*The total organic carbon pools in 0~1 m depth in permafrost regions on the QXP were calculated using 190 profile sites from published sources.*".

Line 107: "*In addition to the soil carbon in the 0~1 m depth*" was deleted.

Line 107: "*To calculate the deep carbon pools (2~25 m) in permafrost regions, 11 boreholes on the QXP were drilled from 2009 to 2013 (Fig. 1)*" was added.

Lines 107~108: "*we also reported deep permafrost carbon pools (0~25 m) by nine sites in the QTP and two sites in the upper reach of the Heihe River basin by field machine-drill from 2009 to 2013 (Fig. 1)*" was changed into "*To calculate the deep carbon pools (2~25 m) in permafrost regions, 11 boreholes on the QXP were drilled from 2009 to 2013 (Fig. 1)*".

Lines 108~110: "*Geographic location for the 11 boreholes, together with the active layer depth, sampling depth, vegetation type, geological stratigraphies, SOC contents, bulk density, water contents and soil texture were provided in the supplement materials.*" was added.

Line 111: "*Five sites near the Qinghai Tibetan Highway were located in the Kaixinling basin (KXL), Honglianghe valley (HLH-1, HLH-2), Xiushuihe valley (XSH) and Wudaoliang basin (WDL), respectively.*" was deleted.

Line 113: "*The elevation ranged from 4525 m to 4779 m. Soil types were mainly Quaternary alluvial sand, silt and silty clay, under where were Tertiary mudstone and sandstone (Luo et al., 2012). Ice-rich permafrost was found at some areas in this region (Lin*

*et al., 2010).*" was deleted.

Lines 111~121: The introduction of *deep soil carbon in permafrost in 2.2 Field sampling* was rewritten according to the located vegetation type and geological stratigraphies as follow:

The deep sampling sites were mainly located in three vegetation types of alpine meadow, alpine stepper and alpine desert (Fig. 2). Three sampling sites (KXL, HLH-1, HLH-2) were located in the vegetation type of alpine steppe. Another site (ZEH) was near to the Zhouerhu Lake in Kekexili, with soil formed from lacstrine deposits. It was typical alpine desert and perennially frozen, containing less amounts of organic carbon. Five sampling sites (KL150, KL300, KL450, WDL, XSH) were located in the vegetation type of alpine meadow. In addition, two sites in permafrost regions of the Heihe river basin (HHRB: Heihe-1, Heihe-2) with vegetation type of alpine meadow were rich in organic carbon with high soil water contents (Mu et al., 2013).

The deep sampling sites were mainly distributed in three geological stratigraphies: ZEH, WDL, XSH, Heihe-1 and Heihe-2 were in Quaternary stratigraphy, KL150, KL300, KL450, HLH-1 and HLH-2 were in Triassic stratigraphy, and KXL was in Permian stratigraphy (Fig. 3).

Line 133: "*and/or ice content*" was deleted.

Line 134: "*0~1 m*" was added in the "*the SSOC was calculated for the 0~1m, 1~2 m, 2~3 m and 3~25 m depth*".

Line 135: "*by the area with different vegetation type*" was replaced by "*by the distribution area*".

Lines 136~150: We added "For the organic carbon storage in 0~1 m depth, the reported SOC densities data of 190 sampling sites were collected through their distribution in permafrost regions (Fig. 1). The area of alpine meadow, alpine steppe and alpine desert in permafrost regions was calculated through overlaying the vegetation map over the QXP permafrost regions (Fig. 2). For the organic carbon storage in 1~2 m depth, the organic carbon densities of 11 boreholes were extrapolated to the located vegetation type area.

For the organic carbon storage in 2~3 m and 3~25 m depths, the area of permafrost regions in the Quaternary, Triassic and Permian stratigraphies on the QXP was calculated through overlaying the distribution of geological stratigraphies over the permafrost map (Fig. 3). The organic carbon pools of 2~3 m and 3~25 m depth was estimated through deep organic carbon densities multiplied by the area of geological stratigraphies. The three geological stratigraphies had thick sediments of about 25 m

(Fang et al., 2002; 2003; Qiang et al., 2001). As for other geological stratigraphies, the poor soil development was reported and soil thickness was usually less than 3 m (Wu et al., 2012; Yang et al., 2008; Hu et al., 2014). Thus other stratigraphies were not considered in the estimation of deep organic carbon pool in the permafrost regions.".

Lines 154~156: We added "*Based on the vegetation data in permafrost regions on the QXP (Fig. 1, 2), the area of permafrost regions in the alpine meadow, alpine steppe and alpine desert are* $0.302\times10^6$ *km*$^2$, $0.772\times10^6$ *km*$^2$ *and* $0.175\times10^6$ *km*$^2$ *respectively, total approximately* $1.249\times10^6$ *km*$^2$."

Line 157: "*On the QXP, organic carbon storage of the permafrost regions in the 0~1 m depth was…*" was replaced by that "*Organic carbon storage of the permafrost regions in the 0~1 m depth on the QXP was…*"

Lines 157~159: The organic carbon stocks and storages with three vegetation types in the 0~1 m depth were changed in the present version.

Line 160: "*was much variation…*" was changed into "*were great variations among the sites under alpine meadow area*".

Lines 161~164: It was replaced by "*SOC store in the HHRB (39.0±17.5 kg* $m^{-2}$*) was much higher than that of most sites in the predominately continuous permafrost zone on the QXP. In contrast, the SOC stores showed little variation over the sites in the alpine steppe and alpine desert area, with the ranges of* $6.9\pm3.6$ *kg* $m^{-2}$ *and* $3.9\pm1.5$ *kg* $m^{-2}$*, respectively*".

Line 165: "*deep permafrost organic carbon*" was replaced by "*Distribution of deep organic carbon*".

Lines 166~172: The paragraph was replaced by that "*According to the distribution of sampling sites at the geological stratigraphies, for the Quaternary stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 0.8±0.6% and 0.8±0.7%. For the Triassic stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 1.1±0.3% and 1.2±0.6%. For the Permian stratigraphy, average SOC contents at 2~3 m and 3~25 m depths were 1.5±0.4% and 1.1±0.3%. As for the permafrost regions in HHRB, the SOC contents (Heihe-1, Heihe-2) were higher than those of the predominately continuous permafrost zone on the QXP, with a range of 5.1±3.7% and 2.7±2.4% to depth of 19 m.*".

Lines 172~174: "*SOC contents decreased with depth at the KXL, HLH-1 and HLH-2. While SOC contents in deeper depth were higher than those in the top layer at the XSH, WDL and KL300.*" was changed into "*SOC contents decreased with depth in most deep*

*boreholes, while SOC contents in deeper layers were higher than those in the top layer at the XSH, KL150 and KL300 (Fig. 4)*".

Line 175: "*deep permafrost soil data*" was replaced by "*With the deep soil data*".

Line 176: "*in deep permafrost soils*" was replaced by "*in deep soils of permafrost regions*".

Line 176: "*Fig. 2*" was changed into "*Fig. 4*" because two figures were added in the present version.

Line 177: The equation was changed into $SOC\% = 14.11h^{-1.20}$ ($R^2 = 0.68$, $p < 0.01$, $n = 362$) according to the data collected in the permafrost regions on the QXP.

Line 178: "*Deep permafrost organic carbon pools*" was changed into "*Deep organic carbon pools*".

Lines 179~182: We added "*Based on the Quarternary stratigraphies data in permafrost regions of the QXP (Fig. 3), the area of permafrost regions in the Quaternary, Permian and Triassic stratigraphies are $0.194\times10^6$ $km^2$, $0.135\times10^6$ $km^2$ and $0.238\times10^6$ $km^2$ respectively, with a total area of approximately $0.567\times10^6$ $km^2$, about 45% of the permafrost regions on the QXP*."

Line 183: "*organic carbon storage*" was changed into "*Organic carbon storages in permafrost regions*".

Lines 183~186: The organic carbon pools in 1~2 m, 2~3 m, and 3~25 m were changed in the revised version as follows:

*Organic carbon storages in permafrost regions on the QXP were approximately 10.6±2.7 Pg in the 1~2 m, 5.1±1.4 Pg in the 2~3 m and 127.2±37.3 Pg in deep depth of 3~25 m (Table 2). In total, it contains approximately 160±87 Pg of organic carbon at depth of 25 m in permafrost regions on the QXP.*

Line 186: "*The organic carbon storage in the 0~1 m depth was approximately twice that in the 1~3 m depth.*" was deleted.

Lines 189~191: It was replaced by that "*According to this depth, the organic carbon storage in permafrost layer (132±77 Pg) was approximately five times of that in the active layer (28±6 Pg)*".

Lines 192~194: "*SOC storages in the alpine meadow, alpine steppe and alpine desert were 32.4 Pg, 38.8 Pg and 0.8 Pg, of which 17.7 Pg (54.7%), 29.6 Pg (76.4%) and 0.3 Pg (39.0%) stored in permafrost-affected soils, respectively. Among the three vegetation types, more organic carbon is stored in deep permafrost soils in the alpine steppe.*" was changed into "*SOC storages in Quaternary, Triassic and Permian stratigraphies were 31±17 Pg, 69±53 Pg and 32±20 Pg at depth of 2~25 m, respectively. More than a half of organic carbon is stored in permafrost layers which belonged to the triassic stratigraphy".*

Lines 197~259: The six paragraphs in the *Discussion* were rewritten according the revised results and revisers' detailed suggestion in the present version.

Lines 262~270: The conclusions were rewritten using bullet points in the revised version.

Lines 262~263: "*deep permafrost*" was replaced by "*deep boreholes in permafrost regions*".

Line 263: "*permafrost organic carbon storage*" was changed into "*the organic carbon storages in permafrost regions*".

Line 264: *"…were approximately …*" was changed into "*… were estimated to approximately…*".

Line 265: "*…larger than that in previous analyses*" was deleted.

Line 267: "*It contained approximately 24.0 Pg SOC in the surface 0~3 m depth, with an additional 43.2 Pg carbon locked in deep layers (3~25 m) of alpine steppe (27.8 Pg), alpine meadow (15.4 Pg) and alpine desert (0.2 Pg).*" was deleted.

Line 269~270: It was replaced by "*The total carbon pools in permafrost regions in northern hemisphere are now updated to 1832 Pg.*".

Lines 273~276: The order of supported project was changed into "*National Key Scientific Research Project (Grant 2013CBA01802), National Natural Science Foundation of China (Grants 91325202, 41330634) and the Open Foundations of State Key Laboratory of Cryospheric Sciences (Grant SKLCS-OP-2014-08) and State Key Laboratory of Frozen Soil Engineering (Grant SKLFSE201408).*"

Line 276~278: "The authors gratefully acknowledge the reviewers, professor Gustaf Hugelius and professor Chien-Lu Ping, as well as the editor, Dr. M. Noe Steffen, for their constructive comments and suggestions." was added.

Line 284: The reference "*Burke, E. J., Hartley, I. P., and Jones, C. D.: Uncertainties in the global temperature change caused by carbon release from permafrost thawing. The Cryosphere, 2012, 6(5), 1063–1076.*" was added.

Line 298: The reference "*Don, A., Schumacher J., Scherer-Lorenzen, M., Scholten, T., and Schulze, E.D.: Spatial and vertical variation of soil carbon at two grassland sites — Implications for measuring soil carbon stocks, Geoderma, 141, 272–282, 2007.*" was added.

Line 301: The reference "*Fang, X. M., Lu, L. Q., Mason, J. A., Yang, S. L., An, Z. S., Li, J. J., and Guo, Z. L.: Pedogenic response to millennial summer monsoon enhancements on the Tibetan Plateau, Quaternary International, 106–107, 79–88, 2003.*" was added.

Line 304: The reference "*Fang, X. M., Lu, L. Q., Yang, S. L., Li, J. J., An, Z. S., Jiang, P.A., and Chen, X.L.: Loess in Kunlun Mountains*

*and its implications on desert development and Tibetan Plateau uplift in west China, Science in China, 45, 291–298, 2002.*" was added.

Line 311: The reference "*Hu, G. L., Fang, H. B., Liu, G. M., Zhao, L., Wu, T. H., Li, R., and Wu, X. D.: Soil carbon and nitrogen in the active layers of the permafrost regions in the Three Rivers' Headstream, Environ. Earth. Sci., 72, 5113–5122, 2014.*" was added.

Line 317: The reference "*Hugelius, G., Strauss, J., Zubrzycki, S., Harden, J. W., Schuur, E. A. G., Ping, C. L., Schirrmeister, L., Grosse, G., Michaelson, G. J., Koven, C. D., O'Donnell, J. A., Elberling, B., Mishra, U., Camill, P., Yu, Z., Palmtag, J., Kuhry, P.: Estimated stocks of circumpolar permafrost carbon with quantified uncertainty ranges and identified data gaps, Biogeosciences, 11, 6573–6593, 2014.*" was added.

Line 324: The reference "*Kalembasa, S. J., and Jenkinson, D. D.: A comparative study of titrimetric and gravimetric methods for the determination of organic carbon in soil, Journal of the Science of Food and Agriculture, 24, 1085–1090, 1973.*" was added.

Line 336: The reference "*Li, J. J., Zhang, Q. S., and Li, B. Y.: Main processes of geomorphology in China in the past fifteen years, Acta Geographical Sinica, 1997, 49, 642–648.*" was added.

Line 338: The reference "*Li, J. J., Fang, X. M., Song, C. H., Pan, B. T., Ma, Y. Z., Yan, M. D.: Late Miocene–Quaternary rapid stepwise uplift of the NE Tibetan Plateau and its effects on climatic and environmental changes, Quaternary Research, 81, 400–423, 2014.*" was added.

Line 339: The reference "*Lin, Z. J., F. J. Niu, Z. Y. Xu, J. Xu, and Wang, P.: Thermal Regime of a Thermokarst Lake and its Influence on Permafrost, Beiluhe Basin, Qinghai-Tibet Plateau, Permafrost and Periglac. Process., 2010, 21, 315–324.*" was deleted.

Line 344: The reference "*Luo, J., F. J. Niu, Z. J. Lin, and Lu, J. H.: Permafrost Features around a Representative Thermokarst Lake in Beiluhe on the Tibetan Plateau, Journal of Glaciology and Geocryology, 2012, 34(5), 1112–1117.*" was deleted.

Line 361: The reference "*Nelson, D. E., and Sommers, L. E.: Total carbon, organic carbon, and organic matter, Methods of soil analysis, Part 3 - chemical methods, 961–1010, 1996.*" was added.

Line 374: The reference "*Qiang, X. K., Li, Z. X., Powell, C. McA., and Zheng, H.B.: Magnetostratigraphic record of the Late Miocene onset of the East Asian monsoon, and Pliocene uplift of northern Tibet, Earth and Planetary Science Letters, 187, 83–93, 2001.*" was added.

Line 375: The reference "*Schaefer, K., T. Zhang, L. Bruhwiler, and Barrett, A. P.: Amount and timing of permafrost carbon release in response to climate warming, Tellus B, 2011, 63, 165–180.*" was deleted.

Line 406: The reference "*Wu, X. D., Fang, H. B., Zhao, L., Wu, T. H., Li, R., Ren, Z. W., Pang, Q. Q., and Ding, Y. J.: Mineralization and Fractions Changes in Soil Organic Matter in Soils of Permafrost Region in Qinghai-Tibet Plateau, Permafrost and Periglacial Processes, DOI:10.1002/ppp.1796, 2014.*" was added.

Lines 436~438: "*Supplement: Dataset of the geographic location for 11 boreholes on the Qinghai-Xizang (Tibetan) Plateau, together with the active layer depth, sampling depth, vegetation type, geological stratigraphies, soil organic carbon (SOC) contents, bulk density, water contents and soil texture.*" was added.

Line 441: The caption of table 1 was changed into "*Organic carbon pools in the 0~1 m depth with different vegetation type on the QXP*".

Lines 445~448: *Figure 1* was changed into "*Location of sampling sites on the QXP, shown on the background of QXP permafrost distribution (blue points were sampling sites in Yang et al., (2010); orange points were in Wu et al., (2012); red box was Shule river basin (SLRB) in Liu et al., (2012); black box was Heihe river basin (HHRB) in Mu et al., (2013))*".

Lines 452~454: Figure 3 (*Location of sampling sites on the QXP, shown on the background of QXP quaternary geological map*) was added in the present version.

Lines 455~456: The figure 4 caption was changed into "*Distributions of soil organic carbon contents in deep soils in permafrost regions on the QXP.*"

Line 457: "*Ecosystem*" was changed into "*Vegetation types*", and "*Soil content*" was changed into "*Soil stock*" in table 1. In addition, "*Analytical methods*" was added in table 1.

Line 458: The SOC pools in vegetation types were expressed as those in the geological stratigraphy in table 2.