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Interactive comment on "Precipitation measurement intercomparison in the Qilian Mountains, Northeastern Tibetan Plateau" *by* R. Chen et al.

R. Chen et al.

crs2008@lzb.ac.cn

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Please see the attached .pdf files

1. General comments The discussion paper 'Precipitation measurement intercomparison in the Qilian Mountains, Northeastern Tibetan Plateau,' by R. Chen et al., presents analysis of manual precipitation measurements using a Chinese standard precipitation gauge (CSPG) in various configurations. The analysis covers four years of measurements using the CSPG in unshielded, single-Alter shield, and pit configurations. Measurements during the last two years were also obtained using a CSPG in a Double-Fence Intercomparison Reference (DFIR) shield, which is the World Meteorological Or-

ganization (WMO) recommended reference configuration for snowfall measurements. Scatter plots comparing measurements from different configurations indicated that the pit and DFIR configurations performed comparably for mixed and solid precipitation, suggesting that the pit configuration could be a viable option for a reference configuration for these precipitation types in similar environments. The pit configuration is a lower-cost option than the DFIR, so this is an important result for operational networks in regions with limited annual snow cover and blowing snow. Additional plots investigated the influence of wind speed on the catch ratios of precipitation measured by a given configuration to that measured by a reference configuration for events in different precipitation regimes (liquid, mixed, solid). Linear fits to these plots were used to develop equations that could be used to 'adjust' measurements in non-reference configurations for the influence of wind. While these plots certainly provide insight into the catch ratio-wind speed relationships for different configurations and precipitation types, the small number of events and apparent poor fit quality do not impart a high degree of confidence in the use of the resulting equations for adjusting precipitation observations. Overall, the authors make good use of tables and figures to convey results and analysis that can be a bit cumbersome to follow in the text. The background information and discussion are presented well, but the paper would benefit from some additional description of methods (as discussed further in the Specific Comments, below). The applicability of the findings to operational networks, albeit to a limited number of stations with specific conditions, is the main strength of this paper, and warrants publication for broader distribution and implementation. The broader applicability of the adjustment equations, however, is questionable, and careful consideration should be given to how these are presented in the manuscript.

Answer: Thank you very much for your detailed advices. We have updated the data to April 30 2015, and now there are total 608 precipitation events from September 2010 to April 2015 and 283 events during September 2012 to April 2015. According to the advices of the former two Reviewers, the paper has been majorly revised. After revision, the adjustment equations have been carefully considered. Please see Table

4 and other equations in the text. The new version after your advices is uploaded this time. It is the least version (Version 2), but it is not the last version. Because I received two Reviewer's comments on the same day June 4 2015, but this discussion would be closed on June 5, thus this revised Version 2 was not perfect. We will upload Version 3 tonight.

2. Specific comments a. Abstract and Introduction As identified by Reviewer 1, this study focusses on the analysis of the same precipitation gauge in different configurations, rather than different 'precipitation gauges,' as indicated in the text. The wording and gauge configuration nomenclature proposed by Reviewer 1 should be implemented to help address this issue throughout the paper. When stating catch ratios in the abstract, it is important to note which configuration is being used as the reference (i.e. the denominator when computing catch ratios).

Answer: This kind of problem has been revised in the new version. Thank you very much. CSPGUN, CSPGSA, CSPGPIT and CSPGDFIR have been used. The nomenclature 'catch ratio' is wrongly used before in the abstract and in some text.

b. Data and methods

When taking the manual observations, are any additional measures taken if there is frost on the collector, or if there is solid precipitation accumulated on the rim of the collector?

Answer: The measurements are based on the criterion published by China Meteorological Administration (CMA). In the cold season, the rain collector and glass bottle are removed from the CSPG. Instead, it use the solid precipitation (P) collector. There are two choices according to the CMA's criterion. We use the second one. That is, when there is solid P, anther snow collector is used to replace the present using one, and the using one is weighted by an electronicbalance with high accuracy (0.1g or 0.003mm). If there is frost on the outer wall of the collector, it will be removed by using a dry hand towel. If there is solid P on the rim of the collector, half of them (semi circular) will be

removed and then the collector is weighted. However, this phenomenon little happens because the rime of the CSPG is well designed. We would add these words in the text as:' If there is frost on the collector, it will be wiped up by using a dry hand towel. In rare cases of snowfall accumulating on the rim of the collector, half of them (semi circular) will be removed before they are weighted. '.

Is the precipitation measured by the DFIR configuration used to calculate the adjusted accumulation in Equation (1) when the Pit gauge is used as the reference?

Answer: In the revised version, the only reference is the DFIR shield around a CSPG (CSPGDFIR) when the catch ratio is calculated (except in part of Table 1).

What is the frequency of each type of observation (precipitation, wind speed, temperature)? Answer: each type of observation in the meteorological tower is observed every 30 seconds, and they are saved every half an hour (mean or sum). The following sentences are added: 'They are observed every 30 seconds and are saved as half-hourly values (sum or mean).' This is important in terms of how representative the conditions are for each measurement. Answer: Thank you. This kind of description will be added.

c. Results As indicated by Reviewer 2, the details of phase discrimination are critical, and must be included in the manuscript. With the method of phase discrimination used, how representative is the phase for each measurement? How can you be sure, for example, that a certain event was only snow, and not some combination of snow with mixed precipitation, ice pellets, etc.?

Answer: As we know, the best method to classify the P type is measured directly by using instrument such as raindrop spectrograph, double-polarization radar Doppler, etc. But we have not such instruments at our site. The traditional method is distinguished manually. This method is described in detail in the CMA's criterion. Though this method is some rough, it is used at the CMA's stations all over China in the past 50-60 years. Therefore, it is also used at out site. Surely this kind of observation is not satisfactory. The present methods of phase discrimination have been reported in the literatures, and

we will cite and describe them in the paper. But this kind of method is not better than the manual observation method for CSPG in China: 1) its accuracy is not higher than manual observation; 2) their reference data are still P phase data measured manually at the CMA's stations (distinguished by observer's eyes); 3) the used air temperature, dew point or wet bulb temperature of the present phase classification method is the average just before precipitation, during precipitation, or daily? The parameter of this kind of method also varied spatially. The following paragraph is added in the text: ' The precipitation phase (snow, rain and mixed) is discriminated by observer according to the CMA's criterion (CMA, 2007b). This method has been used since the 1950s at the more than 700 stations in China. For the CSPG, there are several methods of phase discrimination, such as the air temperature index method (e.g. Zhang et al., 2004; Ye et al., 2004; Chen et al., 2014b), dew point index method (e.g. Chen et al., 2014b), and the new wet bulb temperature index method (Ding et al., 2014). However, the parameters of these method vary largely in spatial, and their reference precipitation phase data are still from the CMA's stations. '

In Section 3.1, why is the reference changed for the 2012-2014 rainfall observations? Would it not make more sense to use the same reference (pit) for all rainfall events?

Answer: According to the Reviewer 1's advice, the only reference for all P phase is CSPGDFIR. In the revised version, we just compare the CSPG with different shields. Now who is reference is not so important, because they are all intercompared. On P. 2208, lines 5-6, you note that 'comparative studies indicate that the Pit gauge CR is superior to that of the DFIR or the other gauges (Fig. 2)'. How is this clear from Fig. 2? I see a near 1:1 relationship between the Pit and DFIR configurations, and no comparison plots are shown for the CSPG and Alter relative to the DFIR.

Answer: this note is based on the rainfall amounts, because the CSPGPIT measures more P than the CSPGDFIR. It may be not reasonable. Thus in the revised version, we have deleted all these kinds of conclusions.

Given the potential for spatial variability in falling precipitation, are the differences among the different configurations significant in rain? Is the Pit configuration really 'superior' if the maximum difference is less than 5%? What is the estimated uncertainty for the manual observations?

Answer: All these kinds of statements are deleted in the revised version. In Section 3.2, the Pit configuration catches about 2.5% more mixed precipitation than DFIR – is this significant?

Answer: All these kinds of statements are deleted in the revised version.

d. Catch ratio vs. wind speed (Section 3.4) When fitting the data, were any other curve types tried (besides linear)? The R2 values throughout suggest poor fit quality. These poor fits could result, at least in part, from the lower threshold accumulation for precipitation events (1 mm) relative to previous studies (3 mm). Answer: The best fitting curve types have been used after the new data are added in the revised version (Table 4 and some equations). Most of them are not linear. Their reliability is tested by using F-test method. For rainfall, precipitation events or daily P greater than 3.0mm are chosen, but for snowfall and mixed, the critical value of 1.0mm is used because there is few event greater than 3.0mm. I recommend referring to the application of the equations as 'adjustments' rather than 'calibrations.' Answer: Ok. Total 12 'calibrations' are replaced. Given the limited number of points and poor fit quality, would you recommend using these equations for adjusting precipitation measurements from a CSPG in unshielded or single-Alter configurations? I think that these results can be presented with the objective of illustrating general trends, but I question the applicability of the resulting adjustment equations, and whether they should be presented with this purpose in mind. Answer: The new equations are tested by using F-test method. The data are updated to April 30 2015, the results would be improved now. There is so much scatter in Fig. 8a that I don't think you can say that the 'Pit/DFIR CR is approximately 1' (P. 2210, lines 16-18). This statement is based on a linear fit with a very low R2 value. Answer: All these kinds of statements are deleted in the revised

version. The figures are redrawn after data updated. Also for Fig. 8a – given the scatter observed, one cannot really state with confidence that 'wind speed has little effect' (P. 2210, line 17). Answer: The confidence is added by using F-test in Table 4 in the new revised version (data are updated to April 30 2015.). For Fig. 8c, the magnitude of the slope is larger than for Alter/DFIR CR in Fig. 8b, yet it is stated that 'wind speed has no significant effect on Pit/DFIR CR' (P. 2211, line 10). Answer: They are revised. The scatter in values from about 0.8 to 1.2 should also be noted. Answer: ok. 3. Proposed technical corrections P. 2203, line 3: add comma after 'sytematic errors' Answer: ok. P. 2203, line 5: change 'It would affect' to 'These errors affect' Answer: ok. P. 2203, line 8: change 'an UK' to a 'UK' Answer: ok. P.2203, line 15: change 'Reference (DFIR) with a shielded Tretyakov gauge' to 'Reference (DFIR) shield with a manual Tretyakov gauge' Answer: ok. P.2203, line 16: change 'standard snow gauges' to 'standard snow gauge configuration' Answer: ok. P.2203, lines 19-20: 'Considering the automation of precipitation measurements' – this statement is unclear; please elaborate. Answer: ok. It is revised as: ' Because automation of precipitation measurements are widespread '. P.2203, lines 24-25: The WMO-SPICE project employs several different reference configurations, not just automatic gauges in the DFIR shield (see, for example, the report from the second session of the SPICE-IOC: http://www.wmo.int/pages/prog/www/IMOP/reports/2012/IOC-SPICE-2.pdf). Answer: It is revised as: 'the WMO-SPICE project still selected DFIR shield as part of the reference configurations.' P. 2204, line 5: change 'precipitation is concentrated in warm season' to 'precipitation occurs most frequently during the warm season' Answer: ok. P. 2204, line 3: change to 'The DFIR shield has been operated as part of reference configurations at 25 stations: : :' and please apply this type of terminology throughout Answer: ok. P. 2204, line 6: change to 'in the valley site' Answer: ok. P. 2204, line 9: change to 'at the open Daxigou Meteorological Station' Answer: ok. P. 2204, line 12: change to 'for the CSPG' Answer: ok. P. 2204, lines 13-14: change 'neighborhood' to 'neighboring' Answer: ok. P. 2204, line 14: change to 'accurate precipitation data are urgently needed' Answer: ok. P. 2204, line 15: change to 'conducted in or reported

from' Answer: ok. This sentence has been deleted in the new version, and now it don't need revise. P. 2204, line 16: change 'around regions' to 'surrounding regions' Answer: ok. This sentence has been deleted in the new version and now it don't need revise. P. 2204, line 16: change 'here it presents four-years gauge intercomparison experiment'to 'we present a four-year Intercomparison experiment'. Answer: ok. P. 2204, line 23: change to 'Alter shield (Alter) was selected as another Intercomparison configuration for the present study' Answer: ok. P. 2204, line 28: change to 'rarely exceed 10 cm in most parts of China' Answer: ok. This sentence has been deleted in the new version and now it don't need revise. P. 2205, line 1: Pit and DFIR catch ratios relative to which reference? Answer: This part has been revised according to the Reviewer 1's advices. P. 2205, line 3: add comma after 'wind speeds' Answer: ok. This sentence has been deleted in the new version and now it don't need revise. P. 2205, lines 7-8: change to 'mountains, on the northeastern edge of the Tibet plateau' Answer: ok. P. 2205, line 10: change to 'and is concentrated during the warm season' Answer: ok. P. 2205, line 20: change 'Alter shelter' to 'Alter shield;' apply this change throughout the manuscript Answer: ok. It has been revised throughout the manuscript according to the Reviewer 1's advices. P. 2205, line 22: change to 'a Double Fence Intercomparison Reference shield with a Tretyakov-shielded CSPG' Answer: ok. P. 2205, line 24: add comma after 'precipitation events', and add 'the' between 'in' and 'warm season' Answer: ok. P. 2206, line 2: add comma after 'warm season' Answer: ok.

P. 2206, line 7: change to 'is the wetting loss' and 'is the evaporation loss' Answer: ok. P. 2206, line 10: remove 'and' preceding '0.30 mm' Answer: ok. P. 2206, line 12: change to 'value smaller than the other losses' Answer: ok. P. 2206, line 17: change to 'number of trace observations per day' Answer: ok. P. 2206, line 18: change to 'The most important factor' Answer: ok. P. 2207, line 10: change to 'This field experiment focusses on two key aspects.' Answer: ok. P. 2207, lines 10-11: change 'observations comparisons' to 'observation comparisons' Answer: ok. P. 2207, line 17: change to 'a total of 578 precipitation observations were recorded' Answer: ok. P. 2207, lines 18-19: change 'happened' to 'occurred' each time Answer: ok. A total of 8

'happened' are replaced. P. 2207, line 25: change to 'was selected as the reference configuration for rainfall events, and 479 events' Answer: This sentence is deleted in the new version. Fig. 2: text indicates these data are from Sept. 2012 to Sept. 2014, while caption indicates Sept. 2010 to Sept. 2014. Which data are plotted here? Answer: In the original Fig.2a and Fig.2b, the data are from Sept. 2010 to Sept. 2014, whereas in the Fig.2c, it is from Sept. 2010 to Sept. 2014. In the text, it compares the CSPGPIT and CSPGDFIR. Thus, data only can be compared from Sept. 2010 to Sept. 2014. In the new revised version, this question has been revised in the whole manuscript. P. 2208, line 12: change 'liner' to 'linear' Answer: ok. Reviewer 1 also give this advice. P. 2208, line 14: change 'means' to 'suggests that'; the latter is more appropriate, given the limited dataset Answer: This sentence has been deleted according to your above and Reviewer 1's advices. P. 2208, line 15: change to 'Figures 4a and 4b compare 32 mixed' Answer: ok. P. 2208, lines 16-17: consider changing to 'from which it is evident that the mixed: : :' Answer: ok. This part has been revised according to your above and Reviewer 1's advices. P. 2208, line 18: change to ': : :to 2 mm, with minimal scatter and no apparent outliers.' Answer: ok. This part has been revised according to your above and Reviewer 1's advices. P. 2208, line 22: change to 'gauge for mixed precipitation' Answer: ok. This part has been revised according to your above and Reviewer 1's advices. P. 2208, line 24: change to 'a total of 26 field observations' Answer: ok. P. 2209, line 4: change to 'close linear relationships are observed between' Answer: ok. P. 2209, line 5: change to 'From Fig. 5c, there is a linear correlation between' Answer: ok. P. 2209, line 16: change 'This means that' to 'This suggests that' Answer: ok. P. 2212, lines 2-3: change to ': : :and the ratios of Pit/CSPG for snowfall and mixed precipitation were 1.199 and 1.078, respectively' Answer: ok.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/9/C975/2015/tcd-9-C975-2015-supplement.pdf

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