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

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"Precipitation measurements intercomparison in the Qilian Mountains, Northeastern Tibetan Plateau" by R. Chen et al. presents a 4-year data series from four different precipitation sensor configurations. The standard Chinese manual precipitation gauge CSPG in its original configuration was compared with the same gauge in a pit gauge configuration, inside a DFIR-shield (similar constructed as the WMO-recommended Double Fence Intercomparison Reference) and with a single Alter shield. Accumulation scatter plots, catch ratios for the whole time series as well as catch ratios per event are shown. Special attention is drawn to the comparability of the pit gauge configuration with the double fence configuration and the authors argue that the pit gauge could act as a reference of equal or better quality than the usual double fence reference.

The presented data set is indeed valuable as precipitation measurements with the possibility to compare to reference set ups are generally sparse. The wide use of the Chinese standard gauge CSPG in China justifies further tests of its performance and the evaluating of possible adjustment functions and their ability to improve standard precipitation measurements performed by this gauges is of interest. Furthermore, the evaluation of the pit gauge as a reference for sites with low annual snow cover and very limited blowing snow is valuable.

Within the WMO Solid Precipitation Intercomparison Experiment (SPICE) a number of precipitation gauges are currently tested, but additional studies on evaluations of those or other gauge configurations are very welcome as they will add to our knowledge about precipitation measurements. Thus, significant results of the presented study fit into the special issue "The World Meteorological Organization Solid Precipitation InterComparison Experiment (WMO-SPICE) and its applications" (AMTD/ESSDD/HESSD/TCD Inter-Journal SI)".

However, the described analysis methods, the presented results and discussions in this manuscript are in a rather premature state and the drawn conclusions are partly speculative. I encourage the authors to perform further analyses on their data and to revise their manuscript substantially.

Answer: Thank you very much. After three Reviewer's advices, now the manuscript has been majorly revised and been improved. Major revisions include: 1) The data are updated till April 30 2015, so the precipitation events especially the snowfall and mixed events are added which improves the certainties of the correlations between

catch ratio and wind speed; 2) The CSPG with a DFIR shield is used as the only reference; 3) Best relationship are found between catch ratio and wind speed, and their probabilities are tested by F-test; 4) Two kinds of adjusting equations are established. One is for easy application by using 10m-height wind speed during the period of precipitation in China. Another type is similar to Eqs.(2)-(4), which use daily mean wind speed at gauge height (0.7m); 5) The Abstract, Introduction, Data and Methods, Results and Discussion, and Conclusions are all rewritten. Tables and Figures are redrawn. Some references are added. Two figures are deleted, whereas a new important Table 4 is added.

**Please See the attached revised manuscripts (revision after your advices )**

**General comments:**

Abstract: The abstract contains a lot of details and very little general information about the background and goals of the study. It is not written very clear and needs substantial improvement The word calibration is not used correctly. As no absolute truth is known you are hardly able to calibrate your precipitation measurements, but rather correct or adjust them. I suggest replacing "calibration equation" with "adjustment equation" and "calibration" with "adjustment".

Answer: 1) The first sentence is rewritten as: 'Systematic errors in gauge-measured precipitation are well-known, but the wind-induced error of Chinese standard precipitation gauge (CSPG) has not been well tested.' ; 2) All the 'calibration ' and 'corrected' are replaced as 'adjustment ' or 'adjusted' according to your and Reviewer 3's advices.

You refer to two sets of adjustment equations for the CSPG by Goodison et al. (1998) and Yang et al. (1991, 1995) and state an uncertainty connected to these equations without applying the equations to your data or comparing them to your adjustment functions. Your results and the results from Yang et al (1991) are very similar (as presented in subsection 4.1), which can be also supported by the similar climatology of these sites and their relative proximity. It remains unclear why you see the need for developing new equations Comparison with other studies.

Answer: This question has been described clearly in the revised versions. Yang et al. have conducted systematic precipitation intercomparison experiments and observed huge and valuable data at the Tianshan site. Because of the contemporary economy conditions during 1987-1992, there are no observed wind speed data at the Tianshan site. The used wind speed data are observed at Daxigou station (Yang et al., 1991). The distance is about 1.7km between the Tianshan site and Daxigou site, which would induce some uncertainties.

The third paragraph of the Introduction is revised as :

The DFIR has been operated as part of reference configurations at 25 stations in 13 countries around the world (Golubev, 1985), but deviations from the DFIR measurements vary by gauge type and precipitation type (Goodison et al., 1998; Sevruk et al., 2009). In China, the Chinese standard precipitation gauge (CSPG) and the Hellmann gauge were firstly compared by using DFIR shield as reference configurations in the valley site of Tianshan (43°7′ N, 86°49′ E, 3720 m), during the third WMO precipitation measurement intercomparison experiment from 1987 to 1992. The wetting, evaporation losses and trace precipitation of CSPG were well quantified based on the huge observation data (Yang, 1988; Yang et al., 1991). Because there are not wind data at the intercomparison site (Yang et al., 1991; Goodison et al., 1998), for the wind-induced undercatch, the derived CSPG catch ratio equations were based on the 10m height wind speed at the open Daxigou Meteorological Station (43.06°, 86.5°E, 3540 m; Yang, 1988; Yang et al., 1991). The distance is about 1.7 km between the Daxigou site and the Tianshan valley site thus their wind speeds are different, inducing uncertainty in the catch ratio equations established by Yang et al. (1991) for the CSPG. Before the year 1993, Ren and Li (2007) had conducted an intercomparison experiment at 30 sites (altitude varies from about 4.8 m to 3837 m) over China, and they used the pit as reference shield. A total of 29,000 precipitation events had been observed. However, the DFIR was not used as reference configurations, and there were only 3 stations located in the West Cold Regions of China (Chen et al., 2006) where the solid precipitation often occurred. Blowing snow and thick snow cover have traditionally limited the pit's use as a reference shield for snowfall and mixed precipitation (snow with rain, rain with snow). Ye et al. (2004, 2007) developed a bias-error adjusting method based on the observed data from 1987 to 1992 at the Tianshan valley site, and they found a new precipitation trend according to the adjusted precipitation data over the past 50 years in China (Ding et al., 2007). The new adjusted precipitation would change the knowledge on water balance in many basins in China (Tian et al., 2007; Ye et al., 2012). Although adjustment procedures and reference measurements were developed in several WMO international precipitation measurement intercomparisons (Goodison et al., 1998; Yang, 2014), and several bias-error adjusting methods had been put forward for the CSPG (Ye et al., 2004, 2007), the wind-induced error of CSPG had not been well tested especially in the cold and high regions such as the Tibetan Plateau, China. In these cold regions, solid precipitation often occurs and additional attention must be paid to wind-induced errors of gauge measured precipitation. Because of the limited intercomparison observation data in China, Ma et al. (2014) used the adjusted equations from surrounding countries except for the results from Tianshan China (Yang et al., 1991) to correct the wind-induced errors on Tibetan Plateau. However, their precipitation gauges are Tretyakov, MK2, Nepal2003, Indian and U.S. 8″ in the surrounding countries. As the third pole in the world, the Tibetan Plateau is an ecologically fragile region and the source of several large rivers in China and neighboring countries, accurate precipitation data are urgently

needed. Therefore, we present a nearly five-year intercomparison experiment in the Qilian mountains at the northeastern Tibet Plateau, China, to establish adjustment equations for the widely used unshielded and single Alter shield (Struzer, 1971) around CSPGs ($CSPG_{UN}$ and $CSPG_{SA}$).

It is neither documented why your equations should be superior to the cited equations. Instead of developing a new set of equations, it would be very valuable to thoroughly test and evaluate the existing equations with your dataset. And only in cases of obvious discrepancies you should start the effort of trying to improve the earlier suggested adjustments.

Answer: The reason is similar to the above.

Your chapter "Data and methods" is combining information about the geography and climatology of the site, instrumentation and layout, measurement techniques, data corrections and the existing adjustment functions from other authors. I suggest dividing into several subsections with appropriate names.

Answer: Thank you very much. In the revised version, we divided this chapter into two parts: 2.1 data and 2.2 methods. After reading your good advices, we rewire this chapter again: 2.1 Intercomparison experiments and relevant data; 2.2 Adjustment methods. Some descriptions are changed.

The writing needs improvement. A complete language review of the manuscript needs to be performed by the author.

Answer: We have improved the language in the revised manuscript. Some reviewers have also helped to improve the English. If it is still not perfect, we will ask the language company for help.

Be consequent with denominator and nominator when using catch ratios. It is common to apply the reference as denominator.

Answer: Thank you. We have found this error now. The Reviewer 1 has also pointed it out. They are corrected in the revised version.

**Specific comments:**

Page 2203, line 9: Please check the height of the gauge, 30.5 m does not sound realistic

Answer: It is 30.5 cm. The Reviewer 1 has also pointed it out. Thank you.

Page 2203, line 11, line 13, line 14: Use the right and original references and cite appropriately for the three WMO-reports.

Answer: Ok. We have changed them.

Page 2203, line 16: No need to use three references for the fact that the DFIR was used as reference during the WMO solid precipitation intercomparison by Goodison et al., 1998. The citation of the report is enough

Answer: Ok.

Page 2203, line 22 and line 28: Please add a reference for WMO-SPICE itself. Yang (2014) is related to the SPICE effort, but it cannot be used as "the" SPICE reference as Goodison et al. 1998 for the WMO solid precipitation intercomparison . A SPICE website (http://www.wmo.int/pages/prog/www/IMOP/intercomparisons/SPICE/SPICE.html) exists, which can be used as a citation for SPICE. On the site you also find published meeting reports with relevant information and other publications related to SPICE. CIMO has also announced WMO-SPICE as an official program in their report.

Answer: Thank you very much. **Because now it is 23:02 June 5 2015 (Beijing time), and the discussion of this paper should be closed on June 5 2015, the detailed answers and revisions would not possible (We have also received the Reviewer 3's comments on June 4). We will revise these specific comments in the revised versions. If it is not closed, we will upload it tomorrow.**

Page 2203, line 25: Please find a more suitable publication for the reference in SPICE on the website, for example a TECO presentation related to SPICE references.

Answer: Ok.

Page 2204, line 2: You are writing that additional attention must be paid to systematic errors of gauge measuring precipitation. I could not find any further description of systematic errors in your manuscript which are not already mentioned in Goodison et al (1998).

Answer: We will revise the descriptions.

Page 2205, line 3: state already here, that the 10 m wind speeds you are using are adjusted values from wind measurements at a different height.

Answer: Yes, it's true. This is the bug of the experiment. Although the wind speeds are at 1.5 m and 2.5 m heights, they are observed at the same site as the precipitation intercomparison experiments. We will observe wind speeds both at gauge height an at 10 m heights in the future. A new tower has been installed in August 2014. We would change the wind speed observing heights.

Page 2206, lines 2-18: That section remains very unclear. Which of the corrections described are you applying? You cite concrete numbers for Pw (0.23 mm) and Pe (0.1-0.2mm, larger in summer). You describe Pe as very small although in the same order of magnitude as Pw, why? Are you adding Pt = 0.1 mm per day to compensate for trace events?

Answer: We will rewrite this part again. We want to say, the Pw, Pe and Pt etc. have been acquired by Yang et al. and Ye et al.. In this paper, we will not discuss them. Because only CSPG is used, the difference among the different installments ($CSPG_{UN}$, $CSPG_{SA}$, $CSPG_{PIT}$ and $CSPG_{DFIR}$) are only caused by wind.

Page 2206, line9: do you mean that instead of calculating Pc, you can follow from equation 1, that PDFIR=K*Pg ? Please clarify.

Answer: ok.

Page 2206, equations 2,3,4: Are these equations developed for CSPG? If so, apply to your data and discuss the results

Answer: They are not for CSPG. They are for shielded Tretyakov gauge. Here we want to use the forms of these equations for CSPG. In the revised version, the equations are given for the CSPG.

Page 2207, line 4: I assume that the equations 5,6,7 are from Yang et al., (1991). It remains unclear why are you citing Ye et al (2007). It seems, the latter was applying these equations, rather than developing them. You should note that.

Answer: ok.

Page 2207, lines 17-21: How do you define a precipitation observation? From later in the manuscript I understood that you were applying 3 mm in case of rain and 1 mm in case of snow and mixed precipitation as some threshold.

Are these criteria applied for the 578 and 253 observations?

Answer: They are precipitation events. We have revised it. After filtration by 3mm and 1.0mm, the events amounts decrease.

Page 2208, line 6. I don't agree with your conclusion from Figure 2, that the Pit gauge is superior to the DFIR. Both, the visual check and the regression data suggest that they are about equal, as you have to consider instrument uncertainties and scatter due to the nature of the precipitation events. I also think it is exaggerated to talk about comparative studies (plural), when you are showing only one scatter plot as an indicator. Further, a more thorough analysis should also consider wind and other dependencies. Are they still comparable within their uncertainty for different wind/temperature/other conditions?

Answer: This part has been revised. Reviewer 3 has also pointed it out.

Page 2208 line 12: I don't understand the sentence starting with "close line relationships: : :"

Answer: It will be revised.

Page 2208, line 14: ": : : , which means: : :" is a rather strong statement. Try the words "suggest" or "indicate" or show more sound evidence

Answer: It has been revised. Reviewer 3 has also pointed it out.

Page 2208, line 18: The numbers are difficult to extract from Figures 4a and b. Please choose a different method to show these differences in a better way.

Answer: Ok. It has been revised in the new Table 3. Reviewer 1 has also pointed it out.

Page 2208, line 18: There is definitely scatter in figure 4a and b.

Answer: this figure has been redrawn after data updated to April 30 2015, and the results have been revised.

Page 2208, line 21/22: It is not possible to follow your arguments. Please check your explanations on Page 2209, lines 7-10. That is a much better way to express why you use the pit gauge as a reference instead of the DFIR.

Answer: Ok. All the RESULTS part has been rewritten.

Page 2209, lines 23-24: Did you use these thresholds for the analysis in the previous section as well? If yes, that information needs to be stated earlier, see comment above.

Answer: No.

Page 2210, equation 8: What results did you get for z0 – do they seem reasonable? Was there a lot of scatter? How much did the wind speeds change with this correction? I also suggest to apply or develop any adjustment function with the gauge height wind speed. You can compare the results and evaluate if the wind speed adjustment is introducing additional uncertainty.

Answer: Ok. We will check it.

Page 2210, equations 10 and 11: Did you check for temperature dependency? That is a variable in the existing adjustment functions. You need to comment, why you don't use it. And as commented under general comments: it is good practice to compare the new and old adjustment functions in a quantitative way. Use calculated RMSE or other statistics to quantify the differences when applying the different set of equations.

Answer: As answered above, two kinds of equations are given in the new versions. The F-test are used to test its statistics.

Page 2210, line 16 and lines 19/20: In all three figures, only ONE value is shown with a wind speed higher than 4 m/s. In panels b and c, this value is determining the slope of the regression line. That is too little evidence to conclude any existing or non-existing wind dependency.

Answer: New figures and equations have been given in the revised versions.

Page 2211, line 11. The catch ratio plots for Alter wind shield and Pit gauge and the calculated regression lines are rather similar, most likely due to the rather low wind speed interval shown. It remains unclear why the pit gauge can act as a reference, but the single Alter cannot.

Answer: This part has been revised after data updated.

Page 2212, lines 10-16: The cited results from Ren and Li (2007) are covering a large range, while your results are single numbers, which happen to be somewhere in the presented intervals from the other study. It would be more reasonable to pick sites which have a similar climate to what you experienced during your measurements and compare only those results to your findings.

Answer: Ok.

Page 2212, line 20: There is no evidence in your paper, that the pit gauge was superior to the DFIR in your study. There may be indications that it performed similar, but even that would need a more thorough analysis.

Answer: Ok. It has been revised.

Table 1: Insufficient caption; explanations of elements are needed.

Answer: Ok.

Figure 1: The layout in the upper right panel can hardly be realistic. The pictures indicate a rather short distance between the unshielded and single alter shield, far lower than the diameter of the DFIR. Please add distances in the layout and use a scaled illustration.

Answer: Ok. In fact, they are far.

Figures 2-9: Insufficient captions. At least, it needs to be stated that you are showing accumulation and catch ratios (don't use abbreviation here), respectively.

Answer: Ok.

**Now it is 23:37 June 5, I must upload the answers firstly. We will revise the paper detailed according to your good advices. Thank you again.**