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Interactive comment on "Inconsistency in precipitation measurements across Alaska and Yukon border" *by* L. Scaff et al.

L. Scaff et al.

yanping.li@usask.ca

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From S. Stuefer (Referee) sveta.stuefer@alaska.edu Received and published: 22 September 2015

Originality: The scope of the manuscript is well suited for The Cryosphere. This paper compares precipitation data from 3 gauges located in the Yukon Territory, Canada, with precipitation data from 2 gauges located in northern Alaska, USA. Both solid and liquid precipitation are considered in this comparison. The main finding of the paper is that monthly and yearly precipitation amounts are inconsistent between U.S. and Canadian stations along the Beaufort Sea coast. This inconsistency is attributed to the differences in instrumentation (precipitation gauges) between two countries.

Scientific quality: The purpose of this paper - to identify and quantify inconsistency in precipitation measurements - is well articulated. The methodology involved correction of systematic biases and a comparison of measured and corrected monthly and annual precipitation data between different stations using regression analysis and double mass curves.

Response: We greatly appreciate your review and suggestions. We have improved the paper during the revision.

Inconsistency in monthly and yearly precipitation can be attributed to several major factors: (1) differences in gauge performance, (2) the amount of missing data, and (3) natural variability in precipitation. Though the authors have most certainly considered all these factors, only one factor (gauge performance) is discussed in the current version of the manuscript. To omit discussion of the two other factors is a shortcoming that needs to be addressed.

Re: we agree with this important comment. The main approach of this paper is to quantify the difference of the gauge performance in the northern regions between US and Canada.

As suggested, the amount of missing data will affect data analysis, including the calculations of monthly and annual total precipitation. We considered this issue and set up 30% threshold for the maximum missing data in each month. For the months with greater missing percentages, monthly was not calculated. In this revision, we have included the missing data values in the results and figures, although this factor should be minor for our analysis with long-term data at multiple stations.

The natural variability in precipitation is the key question for this study. We are aware that the selected stations are not close enough to assume to receive similar amounts of precipitation, since they are subject to different environments perhaps with some local terrain effects. That is why the calculation of precipitation difference, i.e. the gradient across the border, is the focal point of the analysis. Furthermore, we also quantify the changes in precipitation gradient between the measured and corrected data. We think the results from the corrected data are more reliable and useful for regional climate analyses.

Factor 2 is important because of the low quality of precipitation data in the Arctic. Many days of missing precipitation data would lower the monthly and annual sums of daily precipitation and, therefore, introduce inconsistency between the different stations. It might be helpful to add a table or a plot showing the percentage of missing precipitation data each year, for each station. The information in such a table or plot would either address my comment or raise a discussion on another aspect of inconsistency.

Re: Following this suggestion, we have calculated the missing data at the monthly and yearly scales for each station. The mean missing values in % are shown in Figures 2, 5, 6 and 8 (and the maximum values for the monthly plots; Figs. 2 and 5).

We understand that missing data may affect regional precipitation analyses. In this study, we calculated the missing data percentages for all stations during the corresponding study periods, and set up a threshold of 30% to exclude those months with higher missing values from monthly precipitation calculations. We compared the precipitation amounts with and without the application of the threshold. The results do not show any significant changes in the differences of gauge measured annual mean precipitation across the border, although this filter affected annual precipitation in certain years. For instance, the northern station pair (Barter and Komakuk stations) has missing value of 32% on July 1987. Calculations of yearly precipitation for 1987 with and without this month show 16% and 10% difference at Komakuk and Barter Island stations, respectively. Over the study period of 11 years, the annual mean bias correction percentages remain the same (65% in Barter and 13% in Komakuk, c.f. Figure 7 in the manuscript) with or without the missing months. The mean annual decrease in bias correction amounts after the consideration of missing data is about 1-3% in the northern region. This analysis suggests that the effect of missing data for our study is not significant, particularly with the application of 30% missing threshold.

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For the central station pair, there are 3 months with 39%, 61% and 42% (Feb. 2006, Aug. 2008 and Jan. 2012) of missing data that were excluded from our analysis. These months represent 0.5%, 40% and 5% of the annual precipitation in the corresponding years at Eagle station, and 13%, 1% and 26% for Dawson. Because of the missing data at Dawson in August 2008, while Eagle recorded significant storms for this year, August contributed 40% to the annual Pm at Eagle. Over the study periods, the exclusion of these three months with higher missing records resulted in the mean Pm decrease by 3% at Eagle and 15% at Dawson. This impact is higher than the northern regions. Another important issue of missing data is related with remoteness of the sites and lower density for stations in the northern regions. Big storms can be missed during the non-recording days. It is hoped that remote sensing information may help to identify the missing storms over the surface weather network, although not much could be done for the historical missing records.

This information was summarized and included in the revised manuscript.

Factor 3 is based on the observation that if two stations with different precipitation gauges are located very close to each other, the inconsistency in records is clearly attributed to gauge performance. This requirement of geographic proximity might hold for the Eagle and Dawson stations, but the northern stations are located on different sides of the Brooks Range, long distances apart (143 km and 138 km apart, shown in Figure 7). Please discuss the inconsistency in monthly and annual precipitation received by the northern stations in terms of the stations' proximity to the Brooks Range and to each other.

Re: The three northern stations selected for this study are located north of the Brooks Range. The approximate distances to the mountain edge are 100 km for the Barter Island station, 90 km for Shingle Point station, and 150 km for the Komakuk station. The two Yukon stations are along the shore line and the station in Alaska is an island site, right next to the coast line. The altitudes of the stations are 11, 7, and 49 m a.s.l., respectively.

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According to Manson and Solomon (2007), the summer storms coming from the open water in the Beaufort Sea are the greatest contribution to annual precipitation. The storm tracks are mainly from the Northwest, affecting the long coastal regions represented by the 3 stations. The storms are obstructed by the Brooks Range once moving inland. The weather patterns in the surrounding of the stations might be affected by the mountains, but the stations are not separated by the Brooks Range. Given this setting, it is not expected to see a great impact of mountain range on precipitation process and distribution along the relatively flat coast line.

The three stations are far part (approx. 140 km). We used them to find/quantify the spatial variation in precipitation for different seasons. We calculate precipitation gradient between 2 stations and compare the results between the measured and corrected precipitation data. We do see changes in precipitation gradient after the bias corrections, thus, achieving our goal to bring the issue of precipitation inconsistency between national standard gauges to the broader climate and hydrology community.

This information was summarized and included in the revised manuscript.

Significance: This manuscript represents a significant interest in the regional analysis of precipitation and climate in northern regions. I recommend acceptance of the manuscript once the above-mentioned points are carefully addressed.

Presentation quality: The paper is well structured and clearly organized. The text reads well, and the authors' logic is easy to follow. The quality of the tables and figures is generally good, but can be improved with the following suggestions:

Table 1: Add a column with the height of the precipitation gauge and the wind sensor above the ground, similar to Table 1 in Yang et al., 1998b. This information is not publically available, but is critical input for wind-induced corrections.

Re: Yes, this information is very useful for our analysis. We added information about the precipitation sensors in Table 1 and the standard rim of the Nipher and NWS-8inch.

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gauge height t in the text. However, the records are very sparse and poor of this kind of details.

Table 1, column heading “Measurement device snow”: Consider re-labeling this column “Snow gauge.” Also, include a column that describes the instrument used for the rainfall measurements.

Re: The column heading was modified.

Table 1 shows that analysis of precipitation data was performed for the two different data periods, 1978–1988 versus 2006–2013. Include a justification for the choice of this period in the text.

Re: The data availability is limited in the area, so after a revision of the common periods between pairs in the dataset, none of the north and central regions ranges were overlapped. With this, we chose the more extended periods in both regions even there was in different years.

Also there was major change of the observing program. For instance in the Canadian side Komakuk station was closed as of June 30, 1993 and Shingle Point became automated, READAC system (prototype of AWOS) was installed in November, 1993.

Figure 11 shows double mass curves without an explanation for the precipitation metric used. The addition of something like “monthly precipitation (mm) summed over the period specified in Table 1” would improve this figure.

Re: The units were included in the axis label.

Minor comments:

Page 4, line 7: At the end of the sentence, replace the comma with a period.

Re: The comma was replaced by a period.

Page 9, line 11: Correct the wording “is lowers.”

Re: The word was corrected.

Page 12, line 6–7: The verb is missing.

Re: A verb was added and the sentence was improved.

Page 15, lines 24–25: Consider moving this sentence to the Methods section.

Re: The sentence was removed from the conclusions, and included in the Method section.

Page 16, line 1–2: Consider referencing the recent paper on this topic by Kane, D.L., and S.L. Stuefer, 2015. Reflecting on the status of precipitation data collection in Alaska. Hydrology Research, Vol. 46, No. 4, pp. 478–493.

Re: The reference suggested is certainly relevant in this work. It was cited in the Discussion section.

Table 1: For latitude and longitude, replace "N" and "W" with the units of "decimal degrees."

Re: The table headers were improved.

Figure 10 and Figure 11: Consider labeling each axis with the plotted variable and corresponding units. For example, the axis label would appear as "Monthly Pc (mm)" or "Cumulative monthly Pc (mm)."

Re: Thank you, for noting this. The units were included in the figure caption of figure 10 and in the axis label for figure 11.

Re: Please, find the revised manuscript attached as a supplement document.

References: Manson, G. K. and Solomon, S. M.: Past and future forcing of Beaufort Sea coastal change, Atmosphere-Ocean, 45(2), 107–122, doi:10.3137/ao.450204, 2007.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/9/C2230/2015/tcd-9-C2230-2015-supplement.pdf

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Interactive comment on The Cryosphere Discuss., 9, 3709, 2015.