Replies to Reviewer 1

We would like to thank Reviewer 1 for taking time to read and make recommendations for the paper. We find them useful for us to improve our paper. According to the comments, we have made corresponding changes in our manuscript. We are now checking the English definitely once again, and we hope the revised manuscript, which will be submitted at the end of the interactive discussion, will meet the requirements of the reviewer.

Replies to specific comments of the reviewer are as follows:

Comment 1:

The paper discusses the temporal trend and spatial variability of extreme snowfall indices in northern Xinjiang. A general increasing tendency for the 5 investigated indices is found. Only a small area in the east shows a downward trend. This paper presents good case study of snow changes in Xinjiang and which should help to provide good reference for regional responses. The objective and research question is ok, but the English definitely needs improvement. The meaning of the sentences is sometimes hard to understand due to bad English.

Authors' answer:
We would like to thank the reviewer firstly for evaluating the article as a good case study of snow changes in Xinjiang which should help to provide good reference for regional responses. And then, thank the reviewer for pointing out the issues about our English definitely. We will invite someone very good at English to help us.

Comment 2 (The main comments for the paper):

Comment 2.1:
The indices are badly defined. What is a "weather process"?
Authors' answer:
Thanks for the reviewer's question. Maybe it is easier to understand if we change "a weather process" as "a snowfall process". A snowfall process in this paper is discriminated by the criterion that the intervals of snowfall events are less than 24 hours. Accordingly, we will make some changes in Page 7085, Table 3. We will change the sentence "Maximum of the cumulative snowfall in a weather process in winter" as "Maximum of the cumulative snowfall in a snowfall process (the intervals of snowfall events are less than 24 hours) in winter".

Comment 2.2
The data description is very poor. For example, I have to assume only Dec, Jan, Feb

data were used.

Authors' answer:

Thanks for the reviewer's question. Indeed, the data description in this paper is relatively poor, and we have made many changes according to the reviewer's advice in the section of "2.1 Data", and the final result of modification will be placed in the end of this reply.

In this paper, we do only use the daily precipitation data of Dec, Jan, Feb. The reasons are listed below. Firstly, our aim is to study the extreme snowfall events in northern Xinjiang, China, and these events universally occurred in the winter. Additionally, due to the winters in Northern Hemisphere are universally from December to next February, so we choose the months from December to next February. Secondly, in order to make sure the precipitation type is snowfall, we must choose the months which temperatures are below 0℃. Because in northern Xinjiang, China, the average daily temperatures from December to next February are all below 0℃, so we selected the daily precipitation dataset from December to next February. Thirdly, great snowfall events in northern Xinjiang all happen in December to next February, so we chose the three months to study the extreme snowfall events in northern Xinjiang.

Comment 2.3:

The authors miss to write anything about the rain gauge type (diameter, height above ground, wind shield), which has serious consequences on the catch rate.

Authors' answer:

Thanks for the reviewer's advice. The diameter, height above ground, and wind shield, indeed has serious consequences on the catch rate, and we haven't clarified these clearly in our previous paper. We now describe these in the following paragraph.

The daily precipitation dataset for this study was provided by China National Meteorological Information Center. In China, the precipitation of various precipitation types (sleet, snow, fog, dew, frost, etc.) are all caught by gauges and then are recorded in water equivalent, which unit is millimeter (mm). When the precipitation type is snow, we use the gauge to catch the snowfall and then record the water equivalent when it melts at room temperature. The diameter of the gauge is 20 cm, and it is placed 70 cm high above ground (the distance from the tube mouth to the ground). When the precipitation type is snow, the windshield is used. In order to ensure the precipitation falling into the gauge without being disturbed, the gauge is set where is flat and has no obstructions near it. And usually, the distance between the obstruction and the gauge shouldn't be less than twice as the height difference between the top of the obstruction and the instrument (gauge) mouth.

Comment 2.4:

Moreover, any change in the setup or design of the gauges over time cause inhomogenities and may make the data unusable for trend analysis.

Authors' answer:

Thanks for the reviewer's question. Before trend analysis, we carefully checked on document and files, and did not find any information on change in the setup or design of the gauges over time. We will clarify this in our paper to be formally published.

Comment 3 (Other general comments):

Comment 3.1:

Table 1 uses indexes, which are only introduced in table 3.

Authors' answer:

Thanks for the reviewer's question. We will delete the details about the indices in Table 1 and list them in a new table, which will be numbered after Table 3, Page 7085.

Comment 3.2:

According to table 2 a daily snowfall amount between 5 and 10 mm is already a heavy snowfall. It's hard to believe that such amounts can be seen as natural hazard.

Authors' answer:

Thanks for the reviewer's question. Table 2 introduced the China National Standard on Snowfall Grade Classification. This Standard bases on the snowfall amount, not the depth of snow cover. The snowfall amount we used here means snow water equivalent, which is liquid. Sun Jianqi et al (2010) have already used the snowfall equal to or larger than 5 mm to study the extreme snowfall events in China, and they said that if this kind of snowfall events produces snow cover over the land, they can result in some risks to society, such as the death of the domestic animals in pasturing areas and traffic congestion. Furthermore, snowfall amount can be converted into snow depth. Because the density of water is $1g/cm^3$, and the snow density is only about $0.1g/cm^3$, according to the formula: Mass = density * volume (volume=area* height/depth), and the law that the mass of snow doesn't change after it melts into liquid water, thus, we can easily know that the volume of snow reduces by 10 times after it melts into water. Thence, the snowfall amount between 5 and 10 mm (millimeter) can produce the snow cover whose depth is between 5 and 10 cm (centimeter). Snow cover at a depth between 5 and 10 cm can cause a natural hazard.

Comment 3.3:

An analysis of the temperature trends would be large asset for this study and could be used help explaining the causes behind the snow changes.

Authors' answer:

Thanks for the reviewer's advice. Generally, the temperature rising due to global warming are causing more and more extreme precipitation events in the world, and the trends in the intensities and frequencies of extreme precipitation events are increasing. However, many researches (Jiang et al, 2007; Zhai et al, 2005), have showed that the trends in extreme precipitation events are not consistent in space, and they have obvious regional and local nature. Therefore, for a local region, the rising temperature can result in either increasing or decreasing trends in extreme precipitation events. In other words, the rising temperature indeed causes more and more extreme precipitation events worldwide, but in the local regions, the trends of temperature cannot be used to explain the trends of extreme precipitation events due to the local and uneven characteristics of precipitation events. Additionally, this paper aims mainly to study the extreme snowfall events, if we analyze the temperature trend at the same time, the relationship between the title and main body of this paper will be not close enough, and the paper will not be concise. Therefore, we did not analyze local temperature variation, and also did not use the potential temperature variation to help explaining the causes behind the snow changes in our previous text. Despite of this, in our revision, conclusions from other researchers will be cited and employed to explain the phenomenon. For example, we will make some changes in the section of discussions.

References used in this reply:

Jiang, Z. H., Ding, Y. G., and Chen, W. L.: Projection of Precipitation Extremes for the 21st Century over China , Advances in Climate Change Research, 3, 202-207, 2007 (in Chinese)

Zhai, P. M., Zhang, X. B., Wan, H., Pan, X. H.: Trends in Total Precipitation and Frequency of Daily Precipitation Extremes over China, *J. Climate*, **18**, 1096–1108, 2005

Comment 4 (More detailed comments and technical corrections)

(http://www.nat-hazards-earth-syst-sci-discuss.net/1/C2199/2014/nhessd-1-C2199-2014-supplement.pdf):

Comment 4.1:
Page 7060, Line 2, insert "China" behind "Xinjiang".
Authors' answer:
We will correct it accordingly.

Comment 4.2:
Page 7061, Line 4, insert "An" before "extreme".
Authors' answer:
We will correct this error.

Comment 4.3:
*Page 7062, Line 4-5:"*Maximum snow depth and maximum snow water equivalent are decreasing in Japan (Tachibana, 1995; Ishizaka, 2004; Yamaguchi, 2011; Kawase, 2012).*"*
"This has nothing to do with ESEs."
Authors' answer:
Thanks for the reviewer's suggestion. We will delete the sentence.

Comment 4.4:
*Page 7062, Line 8-11: "*For the Swiss Alps, the frequency of ESEs was constant or increased slightly for the period 1933–1999, despite a marked decrease in snow depth and duration at mid-to-low elevations, as a consequence of warmer temperatures (Laternser and Schneebeli, 2003).*"*

"This reference used is outdated. Only use the more recent Marty abd Blanchet (2012) for Switzerland."

Authors' answer:

Thanks for the reviewer's advice. We will delete the reference of Laternser and Schneebeli (2003) and only use the more recent Marty abd Blanchet (2012) for Switzerland. Additionally, we want to make a small change based on the suggestion of the reviewer. As in the introduction of this paper, we introduced the characteristics of extreme snowfall events in various regions worldwide. These regions involved are Japan, UK, Alps, Austria, Switzerland, and Antarctic. Due to the Alps and Switzerland regions are somewhat overlap, and the references we used for the two regions are also somewhat duplicate, for example, Schmidli and Frei, (2005) is not only used for Alps but also for Switzerland. Thus, we are planning to delete the introduction on the extreme snowfall events of Alp and only keep that of Switzerland. Finally, based on the reviewer's advice and our corresponding change, which is intended to make the paper logical, we decide to delete the following sentences (Page 7062, Line 8-15): "For the Swiss Alps, the frequency of ESEs was constant or increased slightly for the period 1933–1999, despite a marked decrease in snow depth and duration at mid-to-low elevations, as a consequence of warmer temperatures (Laternser and Schneebeli, 2003). Such an increase has also been observed for extreme winter precipitation in north of the Alps (Schmidli and Frei, 2005). Strasser (2008) suggested that the predicted variability in climatic extremes may lead to more frequent heavy snowfall in the Bavarian region (Germany)."

Comment 4.5:

Page 7063, Line 13-14: "The winter precipitation in northern Xinjiang could be considered as snow because its winter temperature are below 0℃."

"*This sentence belongs to the data chapter.*"

Authors' answer:

It is right. So we will make no change.

Comment 4.6:

Page 7065, Line 10: "18 out of 23" *based on what?*

Authors' answer:

Thanks for the reviewer's advice. In our study, the station, whose continuously missing data of daily precipitation is more than a month, or whose daily precipitation record doesn't cover the period from December 1959 to February 2009, will not be contained in our study. Based on this standard, 18 out 23 national basic meteorological stations were finally selected for our study. We will clarify this in our forthcoming edition.

Comment 4.7:

Page 7075, Line 11-14: "we identified the hot-spots where all the five ESE indices increased or the intensity and frequency of ESEs were all increasing, and identified the cold-spots where all the five ESE indices decreased or the intensity and frequency of ESEs were all decreasing."

"The naming can be misleading. I assume the temperature changes in east are not smaller than in the west?"

Authors' answer:

Thanks for the reviewer's question. The hot-spots are the gathering areas of high value of what we research in the study area, and conversely, the cold-spots are the gathering areas of low value of what you research. In this paper, what we studied are the linear trends of five ESE indices, so the hot-spots are where all the five ESE indices increased, and the cold-spots are where all the five ESE indices decreased. Thus, in this paragraph, the hot-spots and cold-spots have nothing to do with temperature.

Comment 4.8:
Page 7075, Line 18: "east of northern"
Authors' answer:
We will change "east of northern" into "east of northern Xinjiang".

Comment 4.9:
Page 7085, Table 3: "times"
"Number?"
Authors' answer:
Thanks for the reviewer. Yes, the "times" mean numbers here. If "times" is hard to understand, we will replace it with "numbers".

Comment 4.10:
Page 7088, Table 6:
*"Italics is hard to see, rather uses * & **."*
Authors' answer:
Thanks for the reviewer's advice. We will replace italic type with *.

Comment 4.11:
Page 7089, Fig. 1:
"What is the rectangular box in the east of China?"
Authors' answer:
It is the South China Sea, which are enlarged in the rectangular box in Fig. 1.

Comment 4.12:
Page 7090, Fig. 2:
"What is the purpose of the correlation coefficient?"
Authors' answer:
In the linear equations, y=a*x+b, "a" represents the slope of the linear trend line in the Fig. 2. In this paper, we use it to express the linear tendency rate. And "R^2" represents the goodness of fit of the linear equations. We will make a clarification in our forthcoming paper.

The modification for the section, "2.1 Data" will be as follows.
The daily precipitation dataset for this study was provided by China National

Meteorological Information Center. In China, the precipitation of various precipitation types (sleet, snow, fog, dew, frost, etc.) are all caught by gauges, and then are recorded in water equivalent, which unit is millimeter (mm). When the precipitation type is snow, we use the gauge to catch the snowfall and then record the water equivalent when it melts at room temperature. The diameter of the gauge is 20 cm, and it is placed 70 cm high above ground (the distance from the tube mouth to the ground). When the precipitation type is snow, the windshield is used. In order to ensure the precipitation falling into the gauge without being disturbed, the gauge is set where is flat and has no obstructions near it. And usually, the distance between the obstructions and the gauge should be not less than twice as the height difference between the top of the obstructions and the instrument (gauge) mouth.

In this paper, our aim is to study the extreme snowfall events in northern Xinjiang, China. Therefore, in order to make sure the precipitation type is snowfall, we used the daily precipitation of December to next February. We select the data in these three months for the following reasons. Firstly, in northern Xinjiang, China, the average daily temperatures from December to next February are all below 0℃. Secondly, great snowfall events in northern Xinjiang all happened in months of December to next February.

Owing to natural and anthropogenic reasons, in northern Xinjiang, the meteorological stations are relatively sparse and the record lengths are different. Before using the daily precipitation data in trend analysis, it is necessary to do preliminary quality controls on the choice of the record length and on the missing data. Rigorous quality control has been conducted before the data mentioned above was released. The missing data were completed by Jiang et al. (2013) using conventional statistical methods including: (1) if only one day has missing data, the missing data was replaced by the average value of the same day in all selected years; (2) if consecutive two or more days have missing data, the missing data would be processed by simple linear correlation between its neighboring stations (distance< 100 km). And in order to avoid the false trends caused by relocation of meteorological station, any change in the setup or design of the gauges over time, and any other human factors, we also did homogenization for the daily precipitation dataset of meteorological stations in northern Xinjiang. The software used to detect and adjust shifts in the time series of daily precipitation are RHtestsV3 and RHtests_dlyPrcp (http://etccdi.pacificclimate.org/software.shtml). And the experiment showed that the stations we used don't have change point in their time series of daily precipitation. In our study, the station, whose continuously missing data of daily precipitation is more than a month, or whose daily precipitation record doesn’t cover the period from December 1959 to Febuary 2009, will not be contained in our study. Based on this standard, 18 out 23 national basic meteorological stations were finally selected for our study. Detailed information of the meteorological stations and dataset can be referred to Table 1. The location of the selected meteorological stations can be referred to Fig. 1.