Replies to the comments of Anonymous Referee #2

Authors' replies are in BLUE color.

Interactive comment on "Variability in snow cover phenology in China from 1952 to 2010" by C. Q. Ke et al.

Anonymous Referee #2

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This manuscript presents the spatio-temporal snow cover data of China on the timing (snow cover onset and end dates: SCOD and SCED) and duration (snow cover days: SCD) and analyses their relationships with air temperature and arctic oscillation. While substantial datasets were used, the data were not well interpreted and analysed, and no significant conclusions were drawn. The results and conclusions are even suspicious considering the way they treated the data. I suggest to reject and resubmit.

Replies: We do not agree with the referee.

We analyzed the climatology of several snow variables (snow cover days, onset and end date of snow cover), their spatiotemporal evolution, extreme years and trends from 1952-2010 in China for a large number of stations. Temperature variable and climate pattern (Arctic Oscillation, AO) are used to explain the results. Trends in some places differ with the overall shortening of the snow period in the Northern Hemisphere. This conclusion is different from previous research works reported in literature.

We believe that our works are significant and we have reasonably explained the results and have achieved solid conclusions.

Given this recommendation, I would only give some major comments.

1. The data. "According to the Specifications for Surface Meteorological Observations (China Meteorological Administration, 2003), an SCD is defined as a day when the snow cover in the area fulfils two requirements: at least half of the observation field is covered by snow, and the minimum snow depth is 1 cm. For any day with at least half of the observation field covered by snow but with snow depth of less than 1 cm, the snow depth is denoted as 0, i.e. a thin

SCD." (P4475: Lines 19-24). ": : :in western China, station density is low, and the observation history is relatively short... If all stations with short time series are eliminated, and thin SCDs are not taken into account, the spatial representativeness of the dataset would be a problem. Therefore, a time series of at least 30 years is included in this study, including those thin SCDs." (P4476: Lines 3-8).

In my opinion, however, including those thin SCDs is more problematic than excluding them. As far as I know, the snow cover observations are commonly conducted at 8:00 (Beijing time) in the morning, and most of the thin snow covers correspond to the snowing events in which snow exists only several hours. This is also the case for many SCDs with snow cover depths not less than 1 cm.

Replies: We do not agree with the referee's argument to remove the 'thin SCDs' for consideration. The thin SCD mainly exist in western China, especially in the Tibetan Plateau. We can agree that thin SCD is not needed when investigating snow climatology with snow depth data, however it has to be considered when studying snow climatology with the SCDs, especially in the Tibetan Plateau. Many previous studies did the same.

For example, An et al. (2009) compared the difference between using thin SCD and without using thin SCD , based on the weather station data from 1951 to 2005 for the Tibet, and suggested that thin SCDs in the Tibet should be considered, since thin SCD accounts for more than **40% (very high proportion)** in the most stations, especially in the beginning and end of snow season. SCD in Tibet features bimodal, frequent snowfall occurs in seasonal transition period, i.e. summer and autumn (September, October), winter and spring (April, May). During these periods, although there are many snowfall events, temperature is relatively high. Therefore snow cover does not exist longer, resulting in many thin SCDs.

Ma et al. (2012) and Xi et al. (2009) also considered thin SCDs in their studies. He and Li (2011) also considered thin SCDs when they compared snow cover days from remote sensing and weather stations. We are citing these references to explain why we considered thin SCDs in the version.

An, D., Li, D. L., Yuan, Y. and Hui, Y.: Contrast between snow cover data of different definitions, J. Glaciol. Geocrol., 31(6), 1019-1027, 2009.

He, L. and Li, D.: Classification of snow cover days and comparing with satellite remote sensing data in west China, J. Glaciol. Geocrol., 33(2), 237-245, 2011.

Ma, L. and Qin, D.: Temporal-spatial characteristics of observed key parameters of snow cover in China during 1957-2009, Sci. Cold Arid Reg., 4, 384-393, 2012.

Xi, Y., Li, D. and Wang, W.: Study of the temporal-spatial characteristics of snow covers days in Hetao and its vicinity, J. Glaciol. Geocrol., 31, 446-456, 2009.

Except for several small regions, there have been not much snow in China during recent three decades. In this sense, there have been very few snow covers, but several snowfalls per year in a considerably large area of China (south, central and north China, and even a large area of western China) in recent _30 years. Therefore, for these areas, it may make more sense to conduct statistics of precipitation phase rather than the SCDs.

Replies: The referee did not provide any data, figures or references to indicate that "Except for several small regions, there have been not much snow in China during recent three decades".

Even if the referee's point is correct, it does not mean that there is less snow in China in the recent three decades and there is no need to study snow any more.

Our analysis indicates that there are three major stable snow regions with more than 60 annual mean SCDs: Northeast China, North Xinjiang, and the Tibetan Plateau, and the longest annual mean SCDs are 169 days (Fig.3). Among the 352 stations with more than 10 annual mean SCDs, there are 54 stations (15%) with a significant negative trend, and 35 stations (10%) with a significant positive trend (both at the 90% level), while 75% of stations show no significant trends. We also cite some relevant researches to compare with or validate our results. Several extreme snowfall events occurred in the past decades (Fig.5).

We agree referee's view that precipitation phase is important, but cannot deny the significance of SCDs, our results mentioned above are enough to show the significance of climatology study on SCD. There are many studies focusing on SCD in China or other countries, some are cited in our manuscript and listed in the references, we do not list them here again.

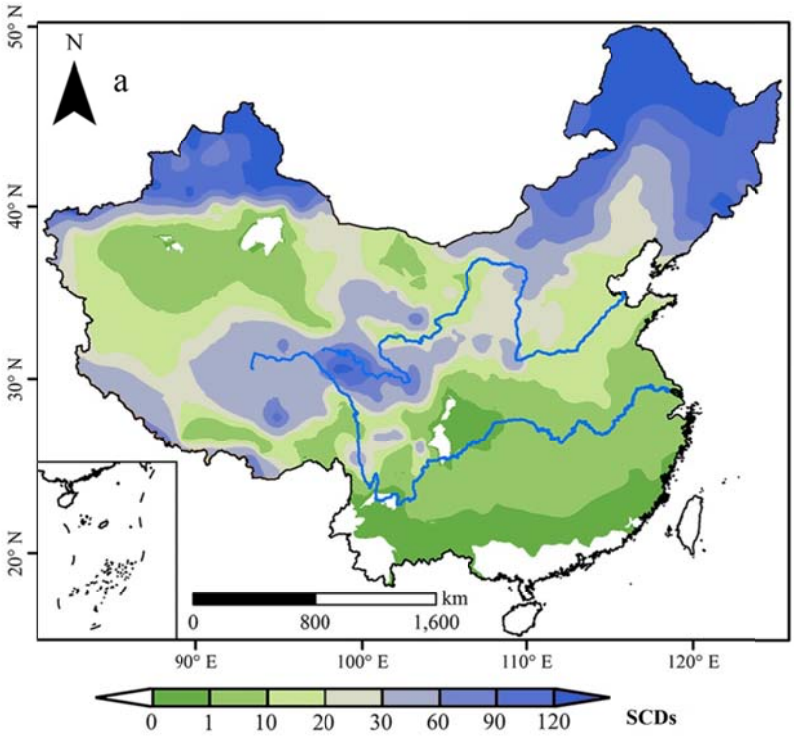

Fig.3 Annual mean snow cover days (SCDs)

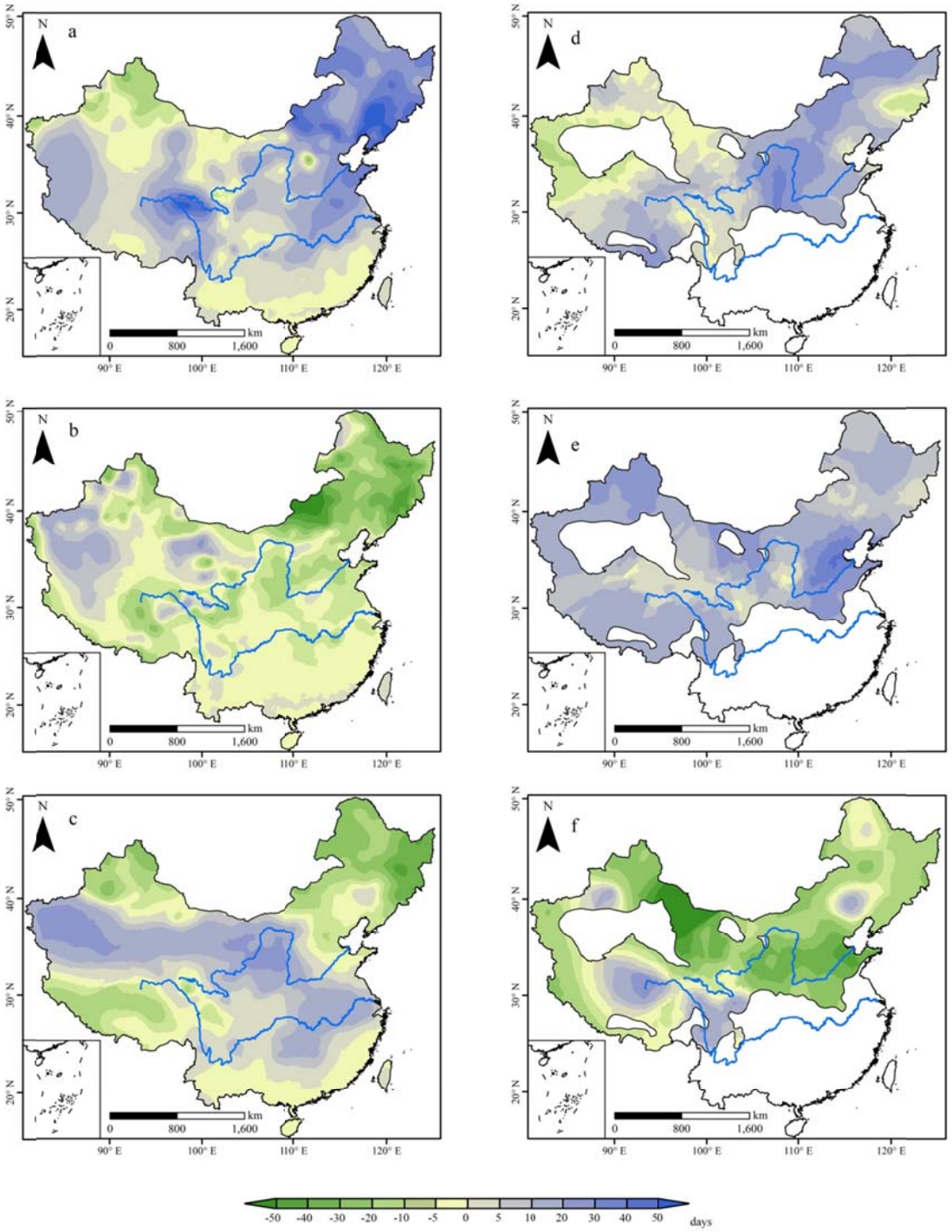

Fig.5 SCD anomalies in 1957 (a), 2002 (b), 2008 (c), snow cover onset date (SCOD) in 2006 (d), and snow cover end date (SCED) in 1957 (e), and 1997 (f).

2. Some basic information on the spatio-temporal distributions of snow cover water equivalent or snow cover depth should be provided. Readers need these information for judgements.

Replies: In this paper, we only investigate several snow variables (snow cover days, onset and end date of snow cover), their spatiotemporal evolution, extreme years and trends, and also their relations to temperature variables and climate patterns (Arctic Oscillation, AO). It already has 36 pages, including 4 tables and 8 figures, long and comprehensive enough, therefore we do not provide snow water equivalent or snow depth result. We do not see any problem to focus only on SCDs.

Choi, G., Robinson, D. A. and Kang, S.: Changing Northern Hemisphere snow seasons, J. Climate, 23, 5305-5310, 2010.

Dong, A., Guo, H., Wang, L. and Liang, T.: A CEOF analysis on variation about yearly snow days in Northern Xinjiang in recent 40 years, Plateau Meteorol., 23, 936-940, 2004.

Marty, C.: Regime shift of snow days in Switzerland, Geophys. Res. Lett., 35, L12501, 2008.

Scherrer, S. C., Appenzeller, C. and Laternser, M.: Trends in Swiss Alpine snow days: The role of local- and large-scale climate variability, Geophys. Res. Lett., 31, L13215, 2004.

Xu, L., Li, D. and Hu, Z.: Relationship between the snow cover day and monsoon index in Tibetan Plateau, Plateau Meterol., 29, 1093-1101, 2010.

Ye, H. and Ellison, M.: Changes in transitional snowfall season length in northern Eurasia, Geophys. Res. Lett., 30, 1252, 2003.

3. Analysis. Analysis is lacking on the climatic and physical interpretations/processes of the statistical results throughout the manuscript.

Replies: We analyzed the climatology of several snow variables (snow cover days, onset and end date of snow cover), their spatiotemporal evolution, extreme years and trends from 1952-2010 in China for a large number of stations. The relationships among SCDs and temperature and Arctic Oscillation are the climatic and physical interpretation in our view. All statistic results are conducted significant test, we only think about the results passed 90% or 95% significant test, and explanation is given in the manuscript.

4. Definition and analysis of heavy-snow and light-snow years (Sections 3.1.2 and 3.2.1). A heavy-snow year or a light-snow year was determined in terms of the relative time duration of

SCDs of a region. This is logically problematic. Authors should know that, for a given station, a longer period of SCDs does not necessarily mean a year of more snowfall.

Replies: Yes, a heavy-snow year or a light-snow year is not only determined in terms of the relative time duration of SCDs of a region, and also including snow depth, temperature, and so on. However, in this paper, we only investigate SCD. We give the definition from a spatial scale (entire China or a stable snow cover region), there have many stations, not one station. Moreover, it is needed to meet two requirements at the same time: for a given year, if 70% of the stations have a positive (negative) anomaly and 30% of the stations have an SCD larger (smaller) than the mean +/- one standard deviation (1SD), we regard the year as a heavy-snow (light-snow) year.

Observation data of 672 stations are used in our study, 70% of them, that is, 470 stations have a positive (negative) anomaly, and 201 stations have an SCD larger (smaller) than the mean +/- one standard deviation (1SD), if these two conditions are met, it is enough to indicate that a given year is a heavy-snow year or a light-snow year. Original table 1, table 2 and Fig.5 also show correct results, and other studies also gave the similar conclusions (Fang et al., 2014; Gao, 2009; Hao et al., 2002). For each stable snow area, there are the same cases.

Fang, S., Qi, Y., Han, G., Zhou, G. and Cammarano, D.: Meteorological drought trend in winter and spring from 1961 to 2010 and its possible impacts on wheat in wheat planting area of China, Sci. Agricul. Sin., 47, 1754-1763, 2014

Gao, H.: China's snow disaster in 2008, who is the principal player? Int. J. Climatol., 29, 2191-2196, 2009.

Hao, L., Wang, J., Man, S. and Yang, C.: Spatio-temporal change of snow disaster and analysis of vulnerability of animal husbandry in China, J. Nat. Disaster, 11, 42-48, 2002.

5. Consistensy of data. As far as I know, for the Specifications for Surface Meteorological Observations of China, there have been several versions (1951?, 1980, 2003 and 2007?). There are some differences in the criteria between the versions (e.g. minimum snow depth of 0.5 cm in the 2007 version?). This should be addressed.

Replies: We find all "Specifications for Surface Meteorological Observations" in National

Library of China and other special Libraries, some information is different from those provided by the referee, and details are as follow.

1 Central Meteorological Administration, Specifications for Surface Meteorological Observations (it was not published by a press, informal publishing), 1955.

2 Central Meteorological Administration, Specifications for Surface Meteorological Observations (it was not published by a press, informal publishing), 1961.

3 Central Meteorological Administration, Specifications for Surface Meteorological Observations, China Meteorological Press, Beijing, 1979.

4 China Meteorological Administration: Specifications for Surface Meteorological Observations, China Meteorological Press, Beijing, 2003.

5 China Meteorological Administration: Specifications for Surface Meteorological Observations, China Meteorological Press, Beijing, 2007.

It is possible that change and update of measuring instrument have an important effect on data. Snow measurement is very simple, unlike other climate variables needing high accurate instrument, with only an ordinary ruler and a snow volumenometer or a balance. After checking all Specifications mentioned above, we find out that there are no changes in the requirements. Actual measuring minimum snow depth is 0.5 cm in all Specifications including the 2007 version. Snow depth is recorded as an integral in the meteorological information database and the unit is centimeter, and it is rounded as the nearest whole centimeter, for example, 0.5---1.4 cm snow depth measurement is rounded up to 1 cm, 1.5---2.4 cm is rounded up to 2 cm, and so on. Therefore, the final recorded minimum snow depth in the meteorological information database is 1 cm.

Thank you very much for your comments. Here, we made an error in the requirements description. We change the sentences as "…fulfils requirement: at least half of the observation field is covered by snow. For any day with at least half of the observation field covered by snow, snow depth is recorded as a rounded up integral if it is more than or equal to 0.5 cm, and the snow depth is denoted as 0 if it is less than **0.5** cm, i.e. a thin SCD".

Moreover, in this paper we do not use snow depth data, one possible difference is thin

SCD and normal SCD, but we considered thin SCDs when we analyze all data. In addition, we conducted data homogeneity test, and data provider, National Meteorological Information Center (Meteorological Data Services), has also implemented data quality control. The relevant description can be found in Lines 9-14 in page 4476.

6. The tilte. Authors used the word “phenology”. However, except the SCDs, SCODs and SCEDs, they did not analyze any of the important snow properties such as density. I would suggest not to use the word.

Replies: Yes, we did not analyze any of the important snow properties such as density, as well as snow depth, snow water equivalent. Although other experts used this word when they conducted the similar research, we can change the title to “snow cover variability of China from 1952 to 2010 under climate change”, if the referee would like.

Peng, S., Piao, S., Ciais, P., Friedlingstein, P., Zhou, L. and Wang, T.: Change in snow phenology and its potential feedback to temperature in the Northern Hemisphere over the last three decades, Environ. Res. Lett., 8, 014008, 2013.