General comment

We would like to thank the anonymous referees very much for the thorough review of our manuscript. We appreciate the efforts and very detailed review of our work, which have provided constructive comments that significantly improved the manuscript. As a result of the extensive revision, several aspects of the methodology have been improved with implications for both the results and conclusions, and we summarize them below. We reply to the comments of the reviewer separately on the next pages.

The changes in methodology were done as a result of the valuable suggestions for improvement of the methodology we received from both referees:

- We redid calculations using the Randolph Glacier Inventory version 2.0.
- We now take into account projected changes in temperature and precipitation at a monthly scale, using monthly delta change values, instead of annual average changes in temperature and precipitation.
- We now use a thirty-year time span for the climatic reference period, instead of ten years.
- We now derive updated glacier areas by applying volume-area scaling at an annual time step, instead of a monthly time step.
- We improved the parameter uncertainty analysis

These major changes in the methodology lead to differences in results and adjustment of the conclusions in the revised manuscript. The main conclusions from the revised manuscript are:

- The range in projections for the CMIP5 ensemble is larger than for the CMIP3 ensemble.
- The CMIP5 ensemble shows higher projections for winter temperatures compared to CMIP3 while summer temperature projections are similar for both ensembles.
- The CMIP5 ensemble shows higher precipitation projections for the summer months compared to CMIP3 ensemble, while precipitation projections for the winter months are similar for both ensembles.
- The CMIP5 ensemble leads to a slightly wider range in projected glacier extent compared to the CMIP3 ensemble.
- It is imperative to use a representative selection of climate models and emission scenarios that span the entire range of possible future climates in climate change impact studies.
- Climate change signals should be analysed at a seasonal scale, when used to assess the response of glaciers to the changes in climate.

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Anonymous Referee #2

General comments
In principle, this is a well-written paper and could be of important scientific content if some revisions are considered. Reviewer #1 has invested significant effort for suggestions to improve the manuscript and to make it valuable contribution to the state of the art in our understanding of the future of the Central Asian glaciers, and to the methods we develop to investigate it.
I agree with his comments, and add the following from my percpecitve here.
My major concern is related to the general meaning of what is envisaged as scientific advance in the paper. Glaciers are very complex, non-linear systems and strongly influenced by threshold reactions, and feedback effects. Their understanding, and their modelling, is a challenge. In Your paper You put many simplifications together and You make an estimate of future glacier extent in a very large area, where data is scarce and no operational monitoring exists. You should add a robust argumentation for the combined method You present, and why You do not apply another one (or - do so!): E.g., You not even mention the subgrid modelling of future glacier extent and streamflow contribution in the Brahmaputra river basin, that has been developed in the framework of the Glowa-Danube (http://www.glowa-danube.de/eng/home/home.php) and BrahmaTwinn projects (http://www.brahmatwinn.uni-jena.de/index.php?id=5314&L=2). With Your argumentation as background, exactly describe what the meaning of the results really is: It would probably be benefitial to re-think whether You want to write a paper about the difference of the CMIP3 / CMIP5 ensembles (probably the easier way, since You already have most of the required material), or about the future of the Central Asian glaciers (then consider calibration, validation, and the water balance components in more detail; but for that purpose, Your linearizing of the climate change signal is questionable). Sharpen the focus!

We would like to thank the reviewer for the time and effort spent reviewing our manuscript. We appreciate the fact that the reviewer judges our manuscript as *well written* and for acknowledging the *important scientific content* it contains. We thank the reviewer for the suggested revisions improving the methodology and manuscript. We formulated a reply to his/her comments below.

Regarding the reviewers major concern related to the scientific advance in the paper we would like to note that this is the first climate change assessment comparing the CMIP3 and CMIP5 multi-model ensembles for Central Asia, which we consider as an important step to gain insight in the climatic future of this region. It is also the first study that considers for each of the two ensembles a very wide range of GCMs outputs, which we do because the spread in outputs of the models has been indicated as the main source of uncertainty in future climates (Hawkins and Sutton, 2009, 2010). We also now consider future changes in temperature and precipitation at a monthly basis, providing essential knowledge regarding seasonal patterns in climate change, necessary to estimate implications for the glacier cover.

We are aware that glaciers are very complex, non-linear systems strongly influenced by threshold reactions and feedback effects. We are also aware that their understanding and their modeling is challenging. Indeed we make simplifications in our approach and apply basin scale averaging to make an estimate of future glacier extent in this large area where data are scarce and no operational monitoring exists. The scarcity of data combined with our focus on the large river basin scale is forcing us to make simplifications (not model individual glaciers) and to apply basin-scale averaging. Our study area contains thousands of glaciers and recent mass balance measurements are only available for a few locations. However, these mass balance data all show the same order of magnitude over the last decades. Since we cannot model individual glaciers at this scale we use a regional mass balance budget to constrain the model parameters for a regional scale model. We declare all the simplifications of our approach. Our goal is to make an estimate of future glacier extent in these two large river basins to be able to use this glacier extent to force hydrological models running at 1 km grid scale or coarser. We emphasize that our approach is a first order approximation of future glacier evolution at the larger river basin scale and we fully acknowledge this. There is a tradeoff between spatial scale and physical detail that can be included in a model. Many large scale hydrological studies deploy bold assumptions on how glaciers will develop in the future. We are therefore confident that our approach is an important step forward as glacial retreat is now a function of both precipitation and temperature projections with melt model parameters constrained by regionally averaged observed historical mass balance trends.

The subgrid modelling of future glacier extent and streamflow contribution as developed for the Glowa-Danube and BrahmaTwinn projects is interesting. The approach's application in the Danube basin is described in Prasch et al. (2011) and Weber et al. (2010), in which is referred to the model manual (Weber and Prasch, 2010), and the approach is also described in Prasch (2010). From these publications we learn that this approach solves the surface energy balance and therefore requires additional atmospheric input, at the 1 hour time step (e.g. wind speed, precipitation intensity, direct short wave radiation, diffuse shortwave radiation, cloud cover). Most of these data are not readily available, forming a major drawback to use it in data-scarce areas. However, this method has been applied in the Lhasa basin in Tibet (Prasch et al., 2012 (under review at the time of writing)), where analogues from the better studied glacier properties in the Danube basin are applied to the data scarce Lhasa basin, since similar glaciers are present in both basins (Prasch, 2010). We added references to these studies in the 'Introduction'-section of the revised manuscript.

In the revised manuscript we sharpen the focus to (1) the comparison of the CMIP3 and CMIP5 ensembles of climate change projections in the Central Asian region and (2) the implications of differences between these two ensembles regarding the uncertainty in glacier extent projections in the region. We extended the comparison of the CMIP3 and CMIP5 multi-model ensembles from analysis of differences on an annual scale to analysis of differences on a monthly scale. This additional analysis is discussed in the 'Results and Discussion section' and accompanied by a new figure (Figure 9). Including monthly differences is a significant step forward compared to calculating the delta change values on an annual scale, as seasonal differences in the climate change projections are now taken into account. Although we still linearize the climate change signal, we firmly believe that in this way we make a scientifically substantiated assessment of the climate change projections using the well established delta change method.

We removed two figures from the 'Methods' section (Figure 9 and Figure 10) and removed the section on model sensitivity, to shift the focus from the glacier model to the assessment of the climate change signals and the implications for the Central Asian glaciers. We added a figure (Figure 10) to the results showing the implications of climate change for the glacier mass balance at the basin-scale, and added figures (Figure 13 and Figure 14) showing the projected changes in glacier extent at the 1 km grid cell scale for two selected areas in the Central Pamir and Tien Shan.
A calibration and validation of the model would be beneficial, but unfortunately it is not possible to validate the model. Since we do not model individual glaciers, we cannot validate our modelling results regarding changes in glacier area in this way. Neither are glacier extent datasets available which cover multiple and fixed moments in time to do a validation in this way. Considering this limitation we emphasize that our approach is a first order approximation of future glacier evolution at the larger river basin scale.

Specific comments
- 12694 (2 Study area): the size of the two catchments under investigation would be helpful here, not only the one of the glacierized area

We included the catchment areas for the Amu Darya and Syr Darya basins in this sentence.

- 12706 to 12708: the entire discussion chapter not really fits the argumentation flow of the paper at this position of the text. The first three paragraphs (until line 20 on page 12707) have the character of an introduction, and the rest the one of an outlook. You should consider to put the two text blocks to the respective positions in the text. Instead, in this section, more detailed figures about the future glacier extent like the two top panels in fig. 12., but much larger, would be benefitial. E.g., You could produce figures for the 4 extremes in the range of future temperature and precipitation (dry/warm, dry/cold, wet/warm and wet/cold, including exact explanation what this is) and discuss them in this section. And: add at least a consideration what this means for the water balance components.

We condensed the 'Discussion'- section to issues in modeling accuracy and included it in the 'Results & Discussion'-section. We moved parts to the 'Introduction' as well as the 'Conclusion'. We added more figures to the 'Results and Discussion' section. We included a figure showing the changes in glacier extent where we zoom in to specific regions in the Central Pamir and Tien Shan showing the projected changes for the mean projection and the two most extreme projections (wet/cold and dry/warm) (Figure 13 and Figure 14). The figure is discussed in the text of the revised manuscript.

Technical corrections
- 12696, line 12: better " … refer to the changes during 60 years."

This has been corrected.

- 12702, line 19 and 23: "Table 2" should be "Fig. 8", I assume?

The references to Figure 8 (Figure 7 in the revised manuscript) where indeed mistakenly replaced by references to Table 2. We corrected these references.

- 12707, line 4: You should include, consider and discuss here the other existing approaches to estimate future glacier extent, and streamflow contribution, with sparse data conditions, and move this part of the text to where it belongs to (the introduction).

We included the above mentioned approach developed in the Glowe-Danube and Brahmatwinn projects in the 'Introduction section', where we discuss several other methods to simulate future glacier extent. We are not aware of other approaches to estimate future glacier extent at the large river basin scale. As we do not cover the topic of stream flow contribution in this manuscript, we do not focus on this topic in the 'Introduction' either. The discussion of stream flow contribution and how it is affected by climate change is envisioned to be covered in another publication.

- 12725, figure subscription: "Panel C shows the effect of glacier size for a 1 km2, 5 km2, 20 km2 and 100 km2 ????? on change in glacier extent in 2050": subject missing.

We removed this figure from the manuscript, to sharpen the focus more on the spread in climate change projections and implications for glacier extent, and less on the glacier model.

12703, lines 8-11: how can this be learned from Panel A and B of of fig. 10? I do see a 30 % increase in average annual precipitation there.

Thirty percent should have been stated here and not twenty percent. We don't include the section on model sensitivity including this figure in the revised manuscript.

- 12727, fig. 12: add inscription to the vertical axes of the two diagrams.

We added labels to the axes in this figure.

References

Hawkins, E. and Sutton, R.: The Potential to Narrow Uncertainty in Regional Climate Predictions, Bulletin of the American Meteorological Society, 90(8), 1095–1107, doi:10.1175/2009BAMS2607.1, 2009.

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