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The Cryosphere Discussions

Interactive comment on "The Northeast Asia mountain glaciers in the near future by AOGCM scenarios" *by* M. D. Ananicheva et al.

Anonymous Referee #2

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'The Northeast Asia mountain glaciers in the near future by AOGCM scenarios' by M.D. Ananicheva et al.

General comments

The paper presents results of modelling vertical glacier mass balance profiles and position of equilibrium line altitude (ELA) in the mountains of north-eastern Russia for the baseline and future climates using output from ECHAM 4 GCM. Regions with different types of climate and glacier ice formation are discussed: (i) regions with climates of extreme continentality (Chersky, Orulgan; Suntar-Khayata) and (ii) a maritime Kamchatka region. There is a lack of information about glaciers of north-eastern Russia (especially Siberia) in the western literature and further data on this little-researched region are welcome. In this sense, research presented in this paper is original and of

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interest. However, the paper is poorly written (including structure, information included and style of writing) and there are many omissions that make it difficult to evaluate quality of the research. The paper is based on modelled data rather than observations and a detailed examination of data quality and uncertainties is required. This is not provided. The climate model outputs have not been validated and it is not clear whether data with a spatial resolution of 2.8o can be used for the purpose of ablation / accumulation reconstruction. There are perhaps too many assumptions regarding the derived ELA values and these assumptions and associated uncertainties need to be addressed. Data and methodology require a lot more clarity and error evaluation in order to understand what is the quality of the results presented in the paper. In the discussion, results should be linked to wider research. In all, the paper requires substantial improvements, however, if these are completed successfully, the paper will make a valuable contribution to research on climate and glacier change in one of the most under-investigated regions. The paper should be proof-read by a copy editor or a native English speaker before publication.

The main problems to be addressed are as follows:

1. The title should be revised. 'Modelling positions of glacier termini and equilibrium line altitude of mountain glaciers in north-eastern Russia using ECHM4 GCM data' will be more informative and appropriate.

2. The abstract is not informative. Please outline the main results.

3. It would be useful if the paper could follow Introduction – Study Area –Data and Methods – Results – Discussion – Conclusions structure. Currently, it is difficult to read as discussion of regional climate (temperature and precipitation) appears in Methods rather than Study Area; information on characteristics of meteorological stations is hidden in Present Accumulation / Ablation Calculations section; etc. Currently, one has to skip between sections all the time to find the required information and it does not assist any reader.

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4. Given how little is published in western literature about glaciers of north-eastern Russia, a more informative summary of the up-to-date research on glacier-climate interaction in the area is required including a review of western (very few papers but Gurney et al., 2008 is relevant), Russian (Koreisha, 1991; various papers by Ananicheva and co-authors) and Japanese (see Bulletin of Glaciological Research) research. It is essential to provide a good, informative background because few readers outside Russia and Japan are familiar with research conducted in this region. Discussion on page 720 is related to glacier changes in different regions, however, these changes are not discussed previously in the paper and there are no references.

5. A more detailed description of study area is required as very little is published on these areas in English. Please discuss climatic conditions and type of glaciers / glacier formation regimes in each of the mountain systems. Include only those aspects that are relevant to the paper. For example, why Arctic advection in winter is highlighted in the description of climate (page 710)? Why is it relevant? The Arctic air masses do deliver warmer air into the landlocked regions of north-eastern Siberia in winter but why is it relevant for climate-glacier interaction and should be mentioned? Include graphs with air temperature and precipitation climatologies for high-altitude stations in each region (include coordinates; altitudes; and periods of observation; avoid pre-1950s precipitation measurements because of the introduction of new rain gauges and associated inconsistencies in measurements). Explain whether these are cold-based glaciers as their response may be different. It would be useful to include a table showing the extent of glaciations in each region (referenced to an approximately the same period(s)) and their characteristics (glacier sizes, classes, position of ELA, altitudes of glacier tongues, etc) or at least a reference to Table 1. Currently this information is spread between sections and is hard to compare. Provide coordinates of each study region and show locations of glaciated regions on Fig. 1 if not all mountain ranges are glaciated.

6. ECHAM4 data. How appropriate are the data with 2.8o horizontal resolution for reconstructing glacier mass balance and ELA? This is a fundamental question and

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should be discussed and limitations / resulting uncertainties should be explained. How are the studied mountain systems represented in ECHAM 4? References are made to grid points in Section 3.3: how many; how does their altitude match reality; etc? Were the data averaged over study regions or was it one grid box vs one given location ?

7. Time slices and comparisons between the baseline and future climates. It follows from the Abstract that the authors compare observations (1950-1990s) with modelled data for 2040-2069. Is it indeed so? If yes, than the whole analysis is hardly valid as this comparison incorporates not only changes in climate but also model uncertainties. The rule of thumb is to compare modelled baseline climate against modelled future climate assuming that model uncertainties are consistent. On page 715, it appears that modelled 1950-90 data are used. So what is used?! Also, the time frame of the analysis is not clear from page 714: when talking about temperature increase in 2040-69, what exactly do the authors discuss, temperature change from the mid-20th century to the mid-21st century or temperature change during the 2040-69 period? I suggest that the authors should put in a table or outline bullet-point style which exactly time slices were used, what types of data (observed or modelled) were used, and what was compared.

8. How well does ECHAM4 perform in north-eastern Russia? Model outputs should be validated against observations or reanalyses (NCEP/NCAR and ERA40) and uncertainties discussed. This is especially important with regard to precipitation intensity. Note that uncertainties in [especially cold season] precipitation measurements should also be addressed (see Groisman and Rankova, 2001) as they are a likely source of bias. Currently, the modelled climate data are used without any validation. When validating model outputs against observations, pay attention to differences between model domain elevation and station elevations as this is a source of discrepancy.

9. As stated in Section 3.2, accumulation is calculated from solid precipitation. What exactly does it mean? Solid precipitation throughout the year and if yes, how this information was obtained? In section 3.1, solid fraction of precipitation is calculated using

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Bogdanova method (Bogdanova, 1976; Bogdanova et al., 2002 quoted in the text). Briefly outline the method. Surely solid and liquid fractions of precipitation are provided by ECHAM. Why not use it? Or is it precipitation for months with sub-zero temperatures? If yes, how important is this source of accumulation for glaciers accumulating mass through the formation of superimposed ice (e.g. Chersky) ? This issue is briefly mentioned in Section 3.2 but needs more attention.

10. The cold-based and temperate glaciers are discussed together in the paper. Is there a difference in their reaction to climatic warming?

11. Separate Data from Methods. Methodology should be clearly explained step by step. Currently it is mixed with other issues and is hard to follow.

12. Error evaluation of ELA using aerial photography requires a more detailed discussion. Which images were used? How was ELA derived from aerial photos (reference to an authoritative methodological paper might be enough here); how many glaciers were assessed for error evaluation, etc.

13. What is the quality of accumulation data "calculated from Glacier Inventory data or obtained from their maps"? And how was it calculated? This needs an explanation.

Specific and technical comments:

p. 708; Abstract: replace 'Pole of Cold' with 'a region of the lowest temperatures in the Northern Hemisphere'

p.708; Abstract: "Also for selected key glacier systems other models were applied for comparison" What does it mean? Unclear; please specify.

p.710: "Observations are available from one or two glaciers". Please name the glaciers (Koryto for Kamchatka and N31 for Suntar-Khayata?), list observed variables (winter and summer mass balances, ELA), periods of observations and provide references were these data are published. It would be useful to show time series of the observed values. How were aerial photographs were used to derive accumulation, ablation and

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ELA? The USSR Glacier Inventory is now a part of the World Glacier Inventory (WGI) from the National Snow and Ice Data Center in Boulder, Colorado (NSIDC, 1999; http://nsidc.org/). Please quote this reference too as it is more accessible to readers than the published Russian-language sources.

p. 710: Quote IPCC 2007 instead of IPCC 1995. It surely confirms the warming trends for Siberia.

p. 710 Section 2: explain 'regime types'.

p. 710; Section 2.2: Why "a number of ridges" mentioned ? What is unusual or important about it? What is NE66? What is ELA 68? The glaciated part of Chesky Range does not appear to be located much closer to the Aleutian low than the Suntar-Khayata; if anything Chersky is further away from the coast and the Sea of Okhotsk is more important than the northern Pacific in terms of moisture supply. Explain, why the Aleutian low is important. When and to what extent does it control precipitation in the region (April-October?); how does this influence differ between the Chersky and Suntar-Khayata and is it actually important for glaciers? It is useful to briefly explain and compare precipitation regimes and controlling factors (possibly other than the Aleutian low). Note that capital L is not used in 'low'; this is 'low' not 'Low'.

p. 711; Section 2.4: reference is required after the statement on the extent of Kamchatka glaciers. Why is it important for glaciers that volcanism is Quaternary? Omit if irrelevant.

p. 711: rather than stating that Kamchatka receives the highest precipitation across Russia (which may just as well be on the eastern Black Sea coast), state the amount of precipitation and maybe long-term accumulation values from Koryto Glacier (a WGMS reference glacier). As mentioned above, time series of the observed winter and summer mass balances and ELA might be useful.

p. 712; Section 3: "The method is consistent with both GCM and palaeo-analogue

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scenarios". What does it mean? Explain and provide references.

p. 712; Section 3: Provide details of GGa11 scenario: what are the CO2 levels under this scenario ?

p. 712: It would be useful to show on a map where the 17 studied regions are located.

p.712: A paper by Cogley and McIntyre (2003) 'Hess Altitudes and Other Morphological Estimators of Glacier Equilibrium' might be useful in the context of the method of ELA estimation.

p. 713; Section 3.1: Description of climate should be given in the Study Area section not in Methods.

p. 713; Section 3.1: "The Chersky and Suntar-Khayata Ranges occupy an intermediate position in terms of glacier accumulation-ablation rate". Support this statement with data and references. Again, this should be in Study Area section not in Methods.

p. 713; Section 3.1: Glacier retreat from the 1950s: this again should be in Study Area section. The statement on 'appreciable changes' is too general (discussion on p. 720 refers to these changes too without any statistics). Specify how much of glacier surface area was lost and where. For example, Gurney et al. (2008) conclude that a half of glaciers in the Buordakh Massif of the Chersky Mountains have not retreated since the end of the Little Ice Age. Papers by Ananicheva et al. and Japanese scientists, many in English or with English abstracts, are useful.

p. 713; Section 3.1: 200-500 m glacier thickness is a rather high value. How were they obtained? Specify and give a reference.

p. 714 and Fig. 3. Temperature changes in the mountains: There is an inconsistency between the text and Fig. 3. Fig. 3 reveals greater warming in winter (also confirmed in many other studies) while the text states that summer warming prevails. Also, there is nothing in Fig. 3 about autumn and spring. Please clarify. Given the low temperatures observed in the region, is it worth referring to standard seasons? If you do refer

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to standard seasons, use abbreviations DJF (Dec-Jan-Feb) etc rather than standard seasons for clarity. 'Sources of intensification': spatial distribution of winter trends is consistent with the weakening of the Siberian high; see Panagiotopoulos et al., 2005. Do you really need to discuss changes in winter temperatures? Are they relevant to glacier change? Changes in June-July-August (JJA) and, possibly September (as a marginal ablation month) are important and deserve an in-depth discussion; winter is less important in the context of this study.

p. 714: Why are precipitation changes not illustrated? Provide time series or spatial distribution of annual, October-May and JJA precipitation. It would be useful to see a discussion of changes in solid and liquid fractions of precipitation and their influence on ablation. Can trends in solid and liquid precipitation be derived using Bogdanova's method quoted in the paper and discussed here?

pp. 714-715: Provide figures to illustrate projected changes in climate: show monthly baseline values and projected values of temperature; precipitation intensity; solid and liquid precipitation fractions for different regions.

p. 715: Sparse high-altitude met data: would be good to have a table listing stations with coordinates, altitudes, and periods of observations.

p. 717: Define 'coefficient of concentration'.

p. 717: Assessment of snow drift, avalanche snow transfer and drift from volcanic slopes required very detailed input data which are likely to be characterised by a strong spatial heterogeneity. How was this problem addressed?

p. 718: Increase in solid precipitation in north-eastern Siberia: quantify the change (related to the above comment on graphical presentation of data). What will it be in mm per months and will it be large enough to have an impact on glacier behaviour given the low values of winter precipitation? In which months will it occur and how will the timing affect glacier behaviour? Will the impacts be the same for the cold-based

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and temperate glaciers?

p. 719: Why is the assumption that solid / liquid precipitation fractions will not change with altitude under the warmer climate valid?

p. 720: Discussion on glacier change needs at least references.

PP 722-723: This section needs re-writing; not clear what the authors are trying to say.

Section 5.1 should be omitted in my view or it will require a very substantial improvement and expansion including validation of the modelled climate data. Why use HadCM2 when later versions of the Hadley Centre models are available? This is too much for one paper.

I have not addressed the linguistic issues here; these are numerous and should be dealt with be a copy editor.

References

Cogley, J.G. and M.S. McIntyre (2003) Hess Altitudes and Other Morphological Estimators of Glacier Equilibrium. Arctic, Antarctic, and Alpine Research., 35 (4): 482-488. Groisman, P.Y. and E.Y. Rankova (2001) Precipitation trends over the Russian permafrost-free zone: Removing the artefacts of pre-processing. International Journal of Climatology, 21: 657–678. Gurney, S.D. et al. (2008) A Glacier Inventory for the Buordakh Massif, Cherskiy Range, North East Siberia, and Evidence for Recent Glacier Recession. Arctic, Antarctic, and Alpine Research, 40 (1): 81-88. Koreisha, M.M. (1991) Oledenenie Verhoyansko-Kolymskoi oblasti (Glaciation in the Verkhoyansk-Kolyma Region). Nauka Publishers, Moscow. 114 pp. In Russian. Panagiotopoulos, F. et al. (2005) Observed Trends and Teleconnections of the Siberian High, a Recently Declining Centre of Action. Journal of Climate, 18: 1411-22.

Interactive comment on The Cryosphere Discuss., 4, 707, 2010.