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The Cryosphere
Discussions

Interactive comment on "A model study of the energy and mass balance of Chhota Shigri glacier in the Western Himalaya, India" *by* F. Pithan

Anonymous Referee #1

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I have read the manuscript and recommend asking the author to make major revisions. The paper is valuable because i) it deals with a glacier in the Himalaya, where only few glacier energy and mass balance studies have been performed so far, ii) it presents calculations with an energy balance model, including a sub-surface module, and therefore attempts to describe much of the relevant physics, iii) various sensitivity experiments have been performed and iv) it is well written. I do, however, have major objections against the presentation of the results, which can be summarized as follows:

1) There are too few figures and most of the included figures are incomplete, both in terms of what is plotted and in terms of the captions. I do have several suggestions for adding other figures, which the author should consider (specific comments 10, 18, 20, 22, 29 and 45).

2) In many instances only qualitative statements are made where numbers should be added.

3) There is plenty of room for tuning the model, e.g. with the roughness lengths, the temperature model, the ice albedo, the fresh snow albedo and the precipitation gradient (which is zero in the model, but a non-zero gradient would have been perfectly plausible). I am sure that the model was tuned but this is not mentioned at all in the manuscript. Please, add a sub-section describing this process, perhaps making a distinction between tuning to obtain the correct absolute values, the correct interannual variation and the correct mass-balance gradient. Tuning is related to sensitivity in the sense that those parameters or assumptions that, when varied within their uncertainty range, have the largest effect on the mass balance are the prime candidates for tuning the model. Perhaps the topics of tuning and sensitivity can be linked in the paper.

4) As far as I could understand the diurnal cycle of the input is poorly represented. Even short-wave fluxes have no diurnal cycle (IMD input) or hardly a diurnal cycle (NCEP input; 6 hourly values). I consider this as a major weakness of the approach, which does not seem necessary in view of the model time step of 5 minutes.

5) It is unclear which input data are used. Specify which type of input data (IMD or NCEP) is used for which variable.

I cannot judge whether the author takes due consideration of previous work as I am not familiar with most of the existing literature.

Specific comments

1) page 100, line 9: Add an overview of the model and therefore an introduction to section 2.

2) page 100, line 11: should be: "The equation containing all the energy fluxes between the atmosphere and the glacier surface (G and G, 2003) reads:". The surface energy balance includes the sub-surface flux and melting.

3) page 100, line 22: Mention the model value of the ice albedo.

4) page 101, Equation 2: What are air, u and Lob? How is Lob computed?

5) page 101, line 16: Which values did you take for z0, zT and zq?

6) page 101, line 15: In the equations I see αm and αh instead of α.

7) page 102, line 3: should be: "When in a snow layer the water content exceeds the irreducible water amount or entirely melts". The current formulation suggests that water percolates downwards when the pore volume is completely filled with water ("saturated with water").

8) page 102, line 7: Remove the bold heading and replace it by an introduction to the list of steps below.

9) page 103, line 4: What are NCEP and IMD?

10) page 103, lines 5-12: Add a figure showing the temperature as a function of elevation i) at the 2 meter level over the glacier, ii) outside the glacier and iii) according to NCEP. Perhaps ii) and iii) are identical. From which NCEP model layer did you take the temperature (humidity and wind) forcing? As the temperature profile varies with the input NCEP temperature, which supposedly comes from a fixed model level, it would be interesting to see temperature profiles for different input NCEP temperatures.

12) page 103, lines 20-25: How is precipitation tuned to obtain agreement between modeled and measured mass balance in the highest part of the glacier? By taking a fixed multiplication factor which is applied to the whole time series (daily values, I suppose) of precipitation? Are neighbouring grid points the four nearest grid points? What is the grid size of the NCEP model? Write clearly that there is no precipitation gradient in the model, if I understood this correctly. Which temperature is the threshold for rain and snow?

13) page 104, line 5: you write "surface fluxes". What is meant? "Turbulent fluxes" or

really all surface fluxes including the radiative fluxes?

14) page 104, lines 8-9. Write that the diurnal cycle is not (IMD) or hardly (NCEP) resolved.

15) page 105, line 2: Wind speed near the surface of valley glaciers tends to be hardly related to large-scale winds simulated by models, certainly in the ablation season when wind speed really matters. If no local measurements are available, I suggest taking a constant (in time and space) wind speed of ~5 m/s and considering this parameter as a possible tuning parameter.

16) page 105, lines 12-14: I imagine that the following is done: calculation of monthly (or yearly) means of e.g. temperature for the two climate runs, computation of the difference, and adding the resulting monthly (or yearly) anomalies to the input time series of the reference run to obtain the forcing of the model for the future? Is this correct? Please, describe the process clearly.

17) page 106, line 3: Which part of the glacier is covered by debris? What is the elevation interval, for which you perform the calculations and present results?

18) page 106, section 4.1: Add a figure with six mass balance profiles, 3 years, calculated and measured. Discuss how well you capture the mass balance gradient and the interannual variation. In Figure 3 these two important aspects cannot be distinguished. You may consider omitting Figure 3 and only mentioning the correlation coefficient. In case Figure 3 is not removed, the scaling of the two axes should be the same and the 1:1 line should be drawn.

19) page 106, Section 4.2: Add a table with all the mentioned sensitivities: by how much is the mass balance underestimated if the zero-degree assumption is applied, if the roughness lengths are varied, etc.?

20) page 106, line 10: The sensitivity to the lapse rate depends on the lapse rate itself and the way the temperature above the glacier is tied to the input temperature. There-

fore, specify the considered lapse rate and plot it in the suggested 2 m temperature profile figure. It that case it can be compared with the computed glacier-wind model temperature profile.

21) page 106, lines 24-25 or earlier: I suggest using three terms for different parts of the year, namely accumulation season, ablation season before the monsoon and ablation season with monsoon. Define these terms (from when to when?). Do not use “summer and winter”, unless this does not coincide with the accumulation and ablation season. If summer and winter differ from accumulation and ablation season, they must be defined again.

22) page 107, lines 4-10: Add a figure with 3 mass balance profiles: one for the standard run, a second in which you subtract all monsoon accumulation from the standard run, and finally a profile from a model run with no monsoon accumulation. That will show the discussed effects.

23) page 107, lines 11-14: Winter accumulation also has an effect on the surface albedo during the ablation season, but its effect is smaller than the effect of summer accumulation!

24) page 107, Ablation section: add at least one more elevation to Figure 5, namely where ablation starts in late April.

25) Table 1: split this table up in accumulation season, ablation season before the monsoon starts and ablation season after monsoon beginning. Also split it up for 2-4 different elevations. Replace "turbulent heat" by "sensible heat".

26) page 109, line 2: What is day 250?

27) page 109, lines 16-19: Remove that sentence about "credibily". The good agreement between modeled and measured mass balance was obtained after tuning. You have various tuning options, e.g. in the albedo parameterization, precipitation gradient, temperature modelling. Due to compensating effects, let us say temperature and

albedo both too high, you may get a good agreement although single components (albedo, temperature) are poorly simulated. Without on-site measurements of temperature, albedo etc. you have too few constraints.

28) page 109, lines 18-19: Quantify the correlation.

29) page 109, section about long wave radiation. Add a plot with the various energy fluxes as a function of elevation during the ablation season (which you have to define). Then, reformulate the discussion about the elevation variation in the long-wave radiation on page 110.

30) page 110: Sensible heat flux is missing.

31) page 111, lines 15-20: What is the annual precipitation (accumulation at top glacier) in the simulations?

32) Table 2: specify the elevation range, for which these numbers are valid. In general, more text should be added to the figure captions, so that the figures can more or less be understood without reading the text.

33) page 113, snowfall section: Give mean annual snow fall, so that it can be compared to annual precipitation and the mentioned sensitivity.

34) page 113, line 7: Give the value found by Jiang.

35) page 113, section 4.4.6.: Define monsoon season, give monsoon precipitation and accumulation (mean for glacier).

36) page 114, lines 1-8: the precipitation sensitivity of your temperature sensitivities are in conflict with the findings by Oerlemans and Fortuin: in your case temperature sensitivity increases with decreasing precipitation: O&F found the inverse. Can you explain this and does this discrepancy remain for larger perturbations? Take the same range of temperature change as used for the derivation of the temperature sensitivity mentioned in Table 2, so the results become comparable and only perturb precipitation

and temperature for these experiments.

37) page 114, line 17: quantify those changes in humidity and cloud cover.

38) page 114, lines 19-21: define monsoon season. Next page, line 9, you define monsoon season (June - August), but this seems in conflict with Figures 4 and 7, where the monsoons seems to start in July.

39) page 115, lines 10-11: reformulate: "It also reduces ablation by 1000 mm w.e. due to the effect of summer snowfall on the surface albedo".

40) page 115, line 17: refer to the table (comment 19) in which you mention the sensitivity to the zero-degree assumption.

41) page 116, line 1: Add a reference of a paper dealing with observed sensible heat fluxes on mid-latitude glaciers.

42) page 116: Sentence in line 13 is in direct conflict with the sentence in lines 14-16, see comment 36.

43) Figures 4, 5 and 7: Do the ticks refer to the middle of the months or to the first day of the months?

44) Figure 6: add zero-line.

45) Figure 7: add the reduction of long-wave radiation due to clouds and cloud cover (second axis). You should consider plotting running means. In caption: "Reduction of incoming short-wave radiation ...."

46) Figure 1. Show the location of the major mountain ranges. As background a precipitation map would be useful.

47) Figure 2: Add elevation labels.

Small issues:

1) page 96, line 8: "in 50 m altitude intervals"

2) page 96, lines 9-10: "Monsoon precipitation accounts for a quarter or a third of total accumulation, which is more than previously assumed".

3) page 96, last line: insert a comma between "glaciers" and "observations".

4) page 97, line 10: year is missing in citation

5) page 98, line 19: insert a comma between "fluxes" and "both"

6) page 100, line 5: year is missing in citation

7) page 100, line 15: last word should be "long-wave" instead of "short-wave".

8) page 101, line 14: should be "Von Karman's constant".

9) page 104, line 16: remove "model results"

10) page 106, line 16: should be "confidence"

11) page 110, lines 24-26: "..., the advection of moist air masses contributes to ablation by limiting the negative (towards the surface) latent heat flux or making the latent heat flux positive.

12) page 113, line 8: year is missing in citation

13) page 114, lines 13-14: "..., the glacier model should be run with output generated by a climate model".

14) page 116, line 19: replace "those" by "the observed".

15) page 117, line 3: replace "on" by "at".

Interactive comment on The Cryosphere Discuss., 5, 95, 2011.