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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 #2

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The subject of the paper, to compute mass balance of a Himalayan glacier using available reanalysis data, is a valuable one to test in this data-sparse region. Data from climate reanalysis and a weather station are used to derive inputs for a mass balance model based on standard surface energy balance equations, incorporating conduction of heat into the glacier body. The surface energy/mass balance model is tuned by adjusting the precipitation input to match the uppermost annual mass balance measurements (on the assumption of no ablation at the highest measured point of the glacier), and, after this tuning, model output provides a mass balance profile which compares very well with mass balance over the whole glacier altitude profile. Perturbing 4 years of reanalysis data by the anomalies resulting from scenario A2 in the PRECIS regional climate model indicates that the effect of projected warming in this area could be offset by increased monsoon precipitation, although the results of future emissions scenarios

in regional climate model output in this region do not consistently predict increased monsoon precipitation.

The paper lacks sufficient detail in terms of explaining the model parameterization and input data, consequently it is difficult to evaluate the modeling approach used. Many of the questions I raise are simply where the text needs to be more precise in order to clarify the methods applied. In general the results and discussion are presented in an insufficiently quantified manner, and include too many broad and unsubstantiated statements. Both the choice and presentation of figures could be improved.

In terms of structure, I think it would be useful to add a section with a succinct explanation of the motivation and goals of the paper before starting section 2, and although I can see why section 2 has been structured as it is, I think it would be more helpful to sub-section this as (i) the point SEB model, (ii) the structure with which it was applied at the glacier scale. To my mind the section detailing data used, and how input parameters were derived from the data would appear in a more logical order if it were between these 2 sub-sections.

I hope the points I have raised are useful in improving the work, which is pursuing a very useful line for glaciological studies.

SPECIFIC COMMENTS/QUESTIONS:

2.1 Explain and give values for standard values used within the model: âĂć emissivity of ice taken to be 1? âĂć explain αh and αm âĂć what roughness lengths were used? âĂć is surface specific humidity taken to be always saturated? Summarise remaining required inputs to the surface energy balance model (after the standard values you use) and then move discussion of how these inputs were derived into the current section 2.3 (forcing) which I think should be linked more explicitly (or moved) to the 'data used' section. For input parameterisation, need to clarify the following: âĂć how shortwave is computed – from meteorological variables in the reanalysis data and observed cloud amount? How did you account fo the different time series? Is inci-

dent shortwave adjusted to account for local surface slope on the glacier? âĂć what albedo values are assigned to fresh snow? is a 'thin' layer of snow <0.02m (same as Kayastha et. al, 1999)? âĂć what albedo values are assigned to ice? is ice albedo altitude-dependent? âĂć is longwave radiation from surrounding terrain adjusted for snowcovered and snowfree periods (i.e. run the energy balance model over the whole DEM not just the glacier?)

2.2 What values are used for the thermal conductivity and density of snow and ice? Combine references to capillary action (P102, L2 and L19-21). Does 'run off' mean complete removal of meltwater from ice surface?

2.3 Why are temperatures at the start of each year not taken as those from the end of the previous years modeling (after the first year of the run)? Need to state how each input parameter is derived: source data for computation and method used (see the content I think should be expanded and moved from section 2.1) What lapse rates are used? Based on what data? Precipitation input data does not come from the same grid point at each time step? I understand that Manali precipitation is tuned to match annual accumulation at the top of the glacier – on the assumption that there is no ablation occurring there. How valid is that assumption, can you justify it? What exactly was the tuning procedure?

2.4 State more explicitly that radiative components are computed at each DEM cell, but that the full surface energy balance equation is computed at a single point per 50m elevation band, so effectively modeling a mass balance profile for the glacier. I am confused about how the 6hrly and daily meteorological values are integrated with the 5 minute sub-surface computation timestep. Please clarify this. I am not sure that averaging the shortwave inputs over 6 hrs (06:00-12:00 and 12:00-18:00) gives a good representation of the daily cycle, which can be expected to be important in the ablation computation. I am not clear what time step your input data has.

3 On first reading, it is difficult to understand what data has been used. This needs to

be stated more clearly. What I understand has been used is NCEP/NCAR reanalysis as an input for 6hrly surface temperature, surface relative humidity, surface pressure and surface wind speed (some of which have a lapse rate applied to find values representative for the glacier elevation), and IMD data for cloud cover and precipitation (which is tuned to match the upper glacier). For the climate sensitivity runs these data were perturbed on the basis of daily anomalies from a PRECIS run of scenario A2 (which provides a value for all required input parameters). I am still not sure if this is a correct interpretation, and am unclear of how you reconcile daily inputs from IMD with 6hrly NNRP and a 5 minute sub-surface model structure. Was only NCEP/NCAR surface data used? Why not pressure level data at a height equivalent to the glacier?

4.1 Exactly what do you compare? Your point mass balance per elevation interval with Wagnon et. al. mass balance per elevation interval as published in WGMS? Please be explicit. Discuss the cluster of high modeled mass balances in 04/05

4.2 Seems to be some contradiction about how sensitive the model is to surface roughness This section should be presented more fully, but clearly limited to assessing sensitivities in the model structure, as sensitivities to climate parameters are dealt with in section 4.

4.3.1 Back up the last sentence - it is not proven by your experiment as described.

4.3.2 Does the ablation season always end with a precipitation event in your model runs? – this finding could be unrealistic as your model does not account for any precipitation gradients over the glacier. Again, without understanding the timestep of the input data I am not clear how you model the diurnal cycle, but please specify under what conditions nocturnal ablation occurs. Clarify that the final paragraph may only hold true for the studied years.

4.3.4 Avoid using 'slightly smaller' and 'from about' – instead provide numbers.

4.3.5 Shortwave radiation flux appears enhanced during monsoon in fig 6, which con-

tradicts the first sentence.

4.3.6 Results will depend upon the snow covered condition of surrounding slopes, no? How was rock face distinguished from snowcovered slopes? What about the mass flux that goes along with the latent energy flux?

4.4 This section, as it stands, could be both shortened and made more precise. There are a number of statements made that are not well backed up by the sensitivity testing carried out. Alternatively it could be usefully extended into a more detailed consideration of how seasonal variations in meteorological parameters affect the annual mass balance. Graphical representation of changes in the profiles in response to input variables might help.

5.2 Was the precipitation tuning applied separately for the case study with no subsurface heat flux?

TECHNICAL CORRECTIONS:

P96 L1: Himalayan mountain glaciers rather than Himalaya (and thereafter)? . . .increasingly a subject. . . L5: change glacier regime to glacier mass balance L7: Results of mass balance computed using an energy-balance model. . . L8: . . .at 50m altitude intervals, not on L10: This has an additional importance, not It L11: . . .increases the surface albedo L24: reference the 'medium range'

P97 L16: at which resolution? L20: state the model (RegCM3) and resolution

P98 L2: Perhaps 'Since the Himalaya are subject to a marked seasonal temperature cycle, ablation occurs predominantly in the boreal summer.' reads better? L16: less instead of fewer

P99 L2: Author usually referenced as 'R.B. Kayastha' in other publications L6: change shading effect to rain shadow effect L7: . . .as an energy sink. . . L10: sensitivity of Western Himalayan glaciers to climate change

P100 L5: date for reference L8: . . .make Chhota Shigri suitable for the. . .

P101 L3: perhaps state here that the remaining flux components are dependent on surface temperature, which is dealt with in the following section as the melting point assumption is unlikely to be met, and only then go one to emitted longwave radiation and sensible heat flux.

P103 L2: . . .conditions are taken , or computed, from the . . . rather than adapted L4: NCEP (and PRECIS?) datasets, as described in section X.X. L5: . . .constant in space. L12: adopted not adapted L28: masking instead of to mask

P104 L24: add horizontal distance between Manali and CS glacier

P106 L13: major not mayor

P107 L2: . . .also shows the role of . . . L9: . . .glacier that experience almost no melt. . . L11: larger instead of bigger L12: does contribute 25-30%

P108 L9: replace overall with annual L18: . . .ranges from 20-25%... L24: Shortwave radiation is reduced . . .

P109 L2: no day numbers on figure – mark it or state it by date

P110 L2: sublimation rather than evaporation (and thereafter in this section)

P111 L9: is influenced by instead of depends

P113 L13: date for reference L26: . . .also to the reduction in surface albedo. . .

P114 L2: . . .directly, but also influences the . . .

P117 L3: . . .melt at high altitudes. . . L8: reference Hewitt

Table1: not very illuminating as it stands – possibly remove it is mean shortwave computed for night and day?

Fig1: include elevations of Manali and CS glacier, and NCEP/NCAR and PRECIS grid

point locations used (although it may become crowded then, so perhaps you will have to show a zoomed version as an inset to a wider regional map)

Fig2: show contour elevations remove fill pattern for the ice area show stake locations show 50m contour intervals over glacier surface show the ablation zone and accumulation zone show the debris covered area

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