

General comments

This paper concerns the development of a new lumped-element glaciohydrological model adapted from Clarke (1996) and applied to study diurnal variations in the passage of water through the subglacial system. Results are compared with data collected from two field sites, Gornergletscher and Unteraargletscher, which have contrasting modes of moulin input-drainage. Gornergletscher represents the site of previous published studies by Werder and Funk; Unteraargletscher has seen previous work from Schuler and Funk – what marks this paper out as novel is the use of both sites to verify a model of en/subglacial hydraulics, and the concentration on diurnal variations in subglacial flow. Detailed studies of diurnal variations in water flow through subglacial systems remain surprisingly rare yet are demonstrably critical for the interpretation of tracer-based studies over all timescales of glacier study, as Schuler et al (2004) have already demonstrated. Moreover, the development of a model capable of simulating (even better, investigating, where contrasts exist) observed behaviour, and in helping to determine future optimal sampling strategies, is very welcome. The paper is very well written and I recommend its publication. I suggest only some minor alterations below.

Specific comments

When it comes to the results and comparing the model with observations, overall and especially in the results/discussion the paper gives equal weight to studies from Gornergletscher and Unteraargletscher. Yet in the Introduction and Setting, it is as though the paper is mostly going to deal with the Gornergletscher experiments. I suggest slight restructuring to amend this discrepancy. In the Introduction, I would reduce the size of paragraph 2 (the first sentence, for example, contains material best left to the Setting section) and instead introduce more accurately and at this early stage what the paper is really about – i.e. you develop a model, and use it to investigate two different situations, Gornergletscher (steadier moulin input via lake drainage) and Unteraargletscher (high diurnal variability). In Section 2 I would introduce 1) Gornergletscher (as is already done but perhaps with some material now moved into it from Introduction) and 2) a new section introducing Unteraargletscher in an equivalent manner, with map (perhaps a part b to Figure 1). The same is also true for part 3, field methods – a small section on Unteraargletscher would improve the paper's balance. Yes, the Unteraargletscher setting/methods may have been given in previous Schuler papers (as in fact Gornergletscher details are described in previous ETH papers), but any reader with only this paper to hand would be best equipped by equivalent details being given on both glaciers.

I also note that in all sections of the paper, it would also clarify the reading if, where possible, the glaciers can always be discussed in the same order, i.e. Gorner first and Unteraar second. For example, it is the opposite way round on p.673.

Giving the moulin element a cone-like geometry is a rather interesting and underplayed element of the paper. What is the basis for using a cone geometry here but not cylindrical as used before, e.g. the 1995 Kohler study previously mentioned? Your results suggest it seems to work, and anyway I suppose a cylinder could be described as an infinitely invariable cone, but is there any observational reasoning behind this development? It would be nice to see a little more exposition on this. Incidentally, you could redraw Fig. 2 to represent the moulin element as a cone.

P666,I22: Use of Uranine: does this not lose fluorescence with exposure to daylight... (see e.g. Gremaud et al., 2009, Hydrogeology Journal 17, 1833-48)? If so, the dye travelling 1.25 km from the proglacial outlet to the gauging station could be a concern – might the dye be decaying preferentially during daylight hours? Can you comment on this?

P666,I24: Can you clarify how close you were to the moulin, especially as the canyon was becoming more deeply incised... were you close enough that an open channel flow component (pre-moulin) to the model is not a concern?

P669,I11-12: Can you clarify what the lake level is measured with respect to? I also do not think 'hypsoetry' is the correct word for the parameter $A(lake)$ – it looks like it ought to mean surface area or some sort of average area? Anyway, hypsoetry usually describes changes to vertical elevation with units m, whereas the quantity $A(lake)$ has units m^2 . All this means I am also confused as to what you determined by photogrammetry (I16-17).

Section 5.2: This is an interesting discussion – can it be further clarified with some graphical representation, I wonder? It would be nice to see moulin residence times plotted versus channel residence times, perhaps in association with the input discharge record. Even if this cannot be achieved with data or model results per se, can it be drawn conceptually?

The discussion probably ought to include some additional consideration of factors not modelled as well – such as the possibility that at times of high discharge water is forced out the subglacial channel into (non-modelled) storage pockets – this sort of phenomenon is mentioned by Bingham et al (2006) ESPL, p.1477, Nienow et al. (1996) investigated such effects using the additional parameters of dispersion and dispersivity, and you have previously mentioned related phenomena in your Journal of Glaciology papers.

Technical corrections

Title, p664 & p690 (Collins ref): 'alpine' can be written with lowercase 'a'.

Abstract, line 2: *...an alpine glacier (Gornergletscher) over a diurnal...* and line 7: *...another site (Unteraargletscher) using a moulin...* i.e. I suggest naming these sites explicitly in the abstract.

P664,I13, sp. assess

P664, I19: clarify this as 'basal sliding rates'.

P665,I1: *Dye tracer experiments have proven to comprise a powerful tool for studying...*

P665,I3-4: *...1979) and to investigate the drainage system on a seasonal (e.g. Nienow et al., 1998) and diurnal time scales (e.g. Nienow et al., 1996).*

P665,I5-6: I think it is worth just referring to the fact that there are alternative parameters one could use as well, e.g. dispersivity, as given by e.g. Nienow et al. (1996).

P665, I8-12: The sentence beginning "Modulation..." is not clearly written. Do you mean that the main subglacial stream's flow (more steady) is modulated by the flow entering into it from the injection moulin (high diurnal variability)?

P666,I8; p673,I12; Data *were* collected, not *data was* collected.

P666,I13: Should probably use (c.f. Raymond...), i.e. not using c.f. implies Raymond describes this specific phenomenon (Gorner) rather than a similar event.

P668,I5: *...as if the fluorometer were positioned...*

P673,I19: Add 'respectively' to the end of this sentence.

P674,I3-5: Errors *in*, not errors *on*.

P675,12 – need to clarify in this section-introductory sentence these results are from Gornergletscher.

P675,19: Could use *diurnally* rather than *regularly*.

P675: Throughout this section, you state ranges that are not exactly the same as on the figures. For example, borehole water pressure head varies between “315 and 345 m” – yet when I look at Figure 4c the maximum (Day 2) seems to exceed 345 m and the minimum (start of Day 3) seems to fall below 315 m... To ameliorate this issue, either use the nearest integer values or use \sim such that e.g. h varies between ~ 315 and ~ 345 m.

P675,122-27: Confusingly phrased sentences.

Figure 4: As most of the graphs in this figure appear again in Figure 5, I question whether this figure is necessary. Anyway, I think it is inappropriate in part b to join the points (you do not do this in Figure 5). Essentially I think you could incorporate part c of Figure 4 into part d of Figure 5, and just add part a of Figure 4 as an extra part to Figure 5.

P676,paragraph1: Insert actual injection times.

P676,116-17: “The model reproduces...” not clear enough for me. I would prefer: *Modelled transit speed v scales with observed Q_m on all three modelled days.*

P676,122: apart *from*, not apart *for*.

P676,124 to p677,14: These two sentences could be more clearly written. For the first, I suggest: *Except during the iceberg-blockage event, when the moulin residence time Δt_{atm} reaches ~ 200 min, Δt_{atm} varies between ~ 5 -105 min, its minimum occurring at 06:00 and its maximum at around 16:00...* I suggest a similar clarity could be applied to the next sentence.

Figure 5: Suggest this incorporates all of Fig 4 as described above, and also in the caption change *model output* to *modelled transit speed*.

Figure 6 caption: It's fine to keep this relatively short by stating it largely follows the format of Figure 5, in which case why is there even a need to describe part (b) again here? The added description to part a is OK, because there is the cross symbology not appearing in Figure 5 that needs to be introduced here.

P681,111: sp. led (not lead)

P683,17: *...is largely dominated by effects that can be attributed to tracer passage through the moulin...*

P684,18: Can you add, perhaps in brackets, approximately how large the moulin diameter was observed to be?

Section 5.4, final paragraph on the Nienow data: Is this section really worth including here? I am not sure it really adds to the paper simply to armwave in such a superficial fashion that the model works on another dataset – it leads me to want to see lots more detail, either in an appendix or another paper...

P685,110: *...allow the formulation of a measurement strategy...*

P685,123-24: Cut the word *previously* and lose the Schuler reference at this stage.

P687,11-2: *...experiments and we emphasise the critical importance of a measurement strategy that constrains the evolution of the drainage...*

P687,13: Results *demonstrate* (present tense), not *demonstrated*