Estimating degree-day factors based on energy flux components

Referee #1: Roger Braithwaite (Comments and Responses)

Substantive Comments

Ismail and others (submitted) is an interesting article and is very timely as many of us are concerned about the increased melting of snow and ice and its effects on streamflow. The basic premises and ambitions of the study are well presented in the ABSTRACT and in the INTRODUCTION.

The basic idea is to explain the empirical degree-day approach in terms of energy fluxes. This was done by Braithwaite (1995a) and the present paper does something similar but with a broader array of methods and models. Modern workers have access to detailed measurements from sophisticated monitoring systems and should use them where they can. Workers modelling historic data may have to use obsolete variables such as maximum and minimum temperatures and sunshine duration if these were measured with simple instruments.

Ismail and others (submitted) address both communities. Ismail and others (submitted) discuss the basic formulation of degree-day sums on lines 150-159. They are correct that several methods have been used in the past, but the common method of equating daily degree-day sum to the daily mean temperature if positive (or greater than the reference temperature if not 0 °C) is open to the criticism that there may be melt in part of the day even with daily mean temperature below zero (Arnold and McKay, 1964). Workers should calculate their degree-day sums from a sum of positive temperatures throughout the whole day if they have a modern data logger.

Braithwaite and Hughes (2022) suggest a new way of calculating degree-days if you only have maximum and minimum temperatures. This takes account of the daily temperature range, which can be quite large at lower latitudes, e.g., the Himalaya, and may cause degree-day factors to vary with latitude, as mentioned in line 146.

Ismail and others (submitted) is exceptional well-referenced, but I would like them to cite a 'senior' degree-day publication by Zinng (1951) that has stood the test of time.

Dear Reviewer,

Thank you very much for your constructive comments and suggestions to improve the manuscript. We are very grateful for the comprehensive manuscript summary and acknowledging our contribution. We shall incorporate all the necessary new references including Zinng (1951). We shall calculate the degree-day sums (if positive) based on hourly temperature data mentioned in Braithwaite and Hughes (2022).

We shall polish the language in the revised version of this manuscript. Based on your comprehensive comments and suggestion, we shall make numerous changes in the revised version of our manuscript. Below, we repeat each of your comment and our reply to them one by one. All responses are in blue font for clarity of reading.

Muhammad Fraz Ismail

On behalf of all the authors

USE OF ENGLISH AND RERENCING

Ismail and others (submitted) is well written, but I wish they would use active verbs more often, and they do overuse 'however'. The text may be about 25% too long and they should remove padding and re-arrange text, so any issue is only addressed once. The reference list is accurate except for leaving out names of journals in some places, which may be an artefact of citing on-line journals.

We shall make use of more active verbs in the revised manuscript as well as minimize the use of specific words. We shall update the reference list including the journal names wherever it is missing in the list.

DETAILED POINTS

Line 24: define BIAS and RMSE the first time they occur.

We acknowledge that we made a typing mistake and wrote the bias in capital letters which was creating confusion. Bias is calculated by taking the average of observed – simulated. We shall clarify bias as well as define Root Mean Square Error (RMSE) in the revised manuscript.

Lines 25-26: Better to say 'cloud cover and snow albedo under clear sky'

We shall update it in the revised manuscript.

Lines 30-32: Good point!

Thank you.

Line 36: 'main' is better than 'unique'

We shall update it in the revised manuscript.

Line 41: 'more' is better than 'most'.

We shall update it in the revised manuscript.

Line 52: add citation to Braithwaite (1995a) here.

We shall add citation in the revised manuscript.

Line 88: According to Braithwaite (1995a) degree-day factors depend on mean temperatures

We shall update it in the revised manuscript.

Lines 105-115: Good!

Thank you.

Table 1. Some variables should be defined in caption or in a foot note

We shall add an explanation of each parameter in footnote for Table 1 in the revised manuscript. The footnote reads as follows.

T_a = Air temperature
P = Precipitation
u = Wind speed
RH = Relative Humidity
A= Albedo (*only considered when ground is snow covered*)

K_T = Clearness index
SR_{in} = Incoming shortwave radiation

Figure 2: Is 'Wolfgang Bogacki, 2016' reference to a publication?

It is not a reference to a publication. The picture was taken in November 2016. In the revised manuscript, we shall delete the year from image credit which causes the confusion.

Line 147: 'following' is better than 'along'

We shall update it in the revised manuscript.

Lines 151-159: I already mentioned this

Thank you very much for the comment. We shall provide the necessary reference.

Lines 168-169: They should not have done this! From my own thinking about the data used by Braithwaite (1995a) I am quite sure that degree-day factors are only valid for periods of many days, e.g., 10-20 days when you might expect a combination of different weather conditions and when day-to-day measurement errors may compensate.

Thank you very much for your comment and necessary clarification.

Line 180: much better to say 'largest' and not 'most important' as this has caused lots of problems in the literature since about 1952.

We shall update it in the revised manuscript.

Line 192: 'although' is better than 'however'. This occurs in a few places.

We shall update it throughout the manuscript in the revised version.

Line 196: 'rigorous' is better than 'rigid' and 'but' is better than 'however'

We shall update it in the revised manuscript.

Line 200: 'Day of the year' is a modern muddle as 1 January is day 1 in the usual counting. This means that 12:00 on 1 January is day=1.5, which is obviously wrong! Sorry!

We agree there are different definitions of 'Day of the year' by different authors which causes confusion, in particular it has not to be confused with the modern definition of Julian day. We shall clarify, that in eq. 9 (as defined by Masters, 2004), J=1 on 1st January.

Line 209: Should 'attenuation' be 'reflection'?

Yes, we shall update it in the revised manuscript.

Line 215-218. The Prescott equation is useful for historic data but not needed for modern instruments

Thank you very much for your comment and necessary clarification. We have used this, as the effect of cloud-cover can nicely be demonstrated, but we have mentioned other equations (depending on diurnal temperature variation) as well. If one has the data to apply a more sophisticated sky-model, these results can also go into the *DDF* estimates.

Line 226: 'when' is better than 'that'

We shall update it in the revised manuscript.

Lines 233-239: Very comprehensive!

Thank you.

Line 319: Better is ‘the sensible heat component depends mainly on high wind speed and temperature’ because it uses an active verb.

We shall update it in the revised manuscript.

Line 321: better ‘is smaller on average than…’. The point is that sensible heat flux is generally smaller than the radiation components in most snowmelt situations, but sensible heat fluxes changes by a greater amount if you change temperature by 1 °C.

Thank you very much for your detailed comment and important clarification. We shall mention it in the revised manuscript as well.

Lines 352-353. Latent heat flux is generally a heat source to the ice/snow surface in South Greenland and a heat sink in North Greenland. This is explained by variations in vapour pressure and temperature.

Thank you very much for your detailed comment and important clarification.

Line 374: do you mean ‘… such events are rare…’?

Yes, the revised sentence shall be ‘such events are rare and occur only for a brief time period’.

Lines 392-394: Is this a small limitation?

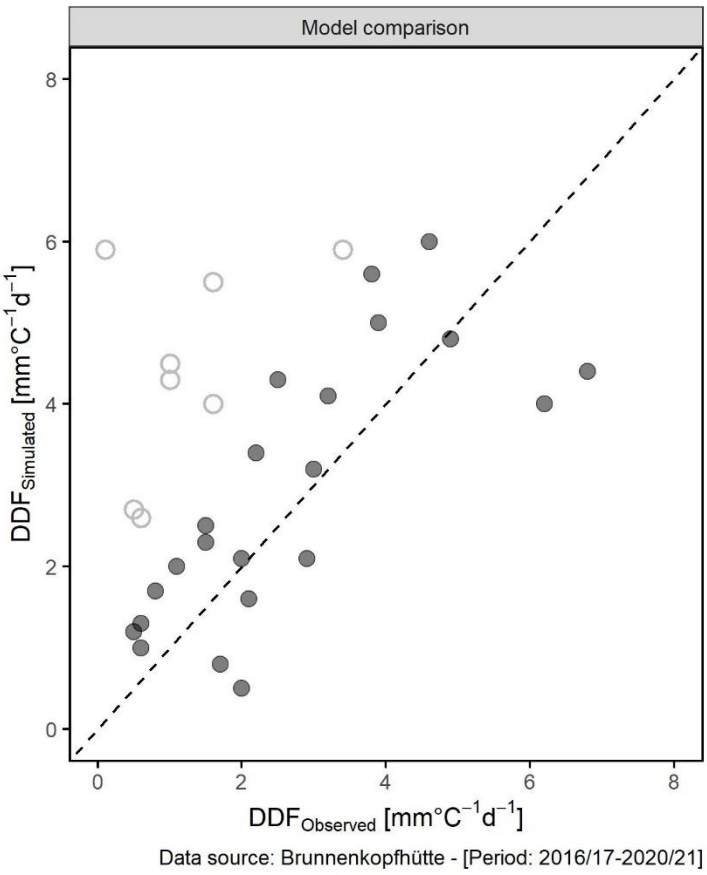
Yes, this is a limitation and should be subjected to further research as mentioned in the conclusions.

Line 415: I was confused by the start of a new chapter here. You probably mean ‘Results from Brunnenkopfhütte’. This brings me to a small concern. I accept this paper is much more than a data report from a single location, and I applaud this, but it is difficult to keep track of what material relates to which. Location. Please consider restructuring, e.g., you could discuss ALL results from Brunnenkopfhütte either before or after discussion of the more general modelling.

We shall restructure the results and discussion section in the revised manuscript. We shall mention general results as well as site specific results in different sections in order to make it clearer.

Line 419: You should base your degree-day sum on hourly data (if positive) from your nice AWS in Fig. 2. See Braithwaite and Hughes (2022).

Based on your suggestion to use only positive degree-day sum (i.e. hourly data) from the AWS. We have now updated figure 8 for the revised manuscript.



Line 430: That confusing 'most important' again.

We shall update it in the revised manuscript.

Chapters 4 and 5:

I am confused by all the examples given. Could you not define a few 'typical' cases and give energy flux values for each case? In general, I think both chapters would benefit from some smoothing. This is something you can do more easily 1-2 months after you have written the original text.

We shall restructure the results and discussion section in the revised manuscript.

Lines 557-361: I think this is correct, but you could phrase it better!

We shall update it in the revised manuscript.

Line 563: I know what RMSE means but what is BIAS? You should define all acronyms first time you use them.

We acknowledge that we made a typing mistake and wrote the bias in capital letters which was creating confusion. Bias is calculated by taking the average of observed – simulated. We shall clarify bias in the revised manuscript.

Figure 8: I like it. Braithwaite (1995a) should have done this for all the months in his study rather than just comparing grand-means of measured and simulate degree-day factors. I am thinking about a new paper on my old data and I will certainly make a figure like this.

We are grateful for your comment on Figure 8.

Chapter 5.

I like this. Braithwaite (1995b) looked in detail at the effect of stability on sensible heat flux model used by Braithwaite (1995a). The sensible (and latent heat) fluxes depend the density of air at the altitude in question so the degree-day factor should depend on altitude, and on latitude as lower latitude glaciers occur at greater altitude. There should be a greater latitude effect on degree-day factors than we have discovered so far. If not, why not?

We agree with the reviewer that sensible and latent heat fluxes depend on the density of air at the altitude in question. We shall consider this comment and will evaluate the effect in the respective examples/calculations.

The question concerning the influence of latitude, we considered the same melting conditions (i.e. same temperature) and same altitude which shows that at the same conditions there is only a limited influence of latitude. We shall make this clearer in the revised manuscript here and consider the effect of altitude on air density / latitude on glaciers in the discussion section.

Lines 612-617: Interesting!

Thank you!

Line 630-633. Walter Ambach is the master of albedo under overcast conditions. In Braithwaite (1995a) this is one factor that reduces the time-variability of the net radiation flux.

Thank you very much for your comment. We have already cited the work done by Walter Ambach. We shall also discuss his results in the revised manuscript.

Line 654: this should be 'breaking in'.

We shall update it in the revised manuscript.

Line 665-19. I think you well explain here the importance of rain on snow.

Thank you very much for your comment.

Section 5.6. Ingenious!

Thank you for your encouragement.

Section 5.7: Although Braithwaite (1995a) clearly showed the change of degree-day factor with changing energy balances, he assumed constant degree-day factors for climate change projections in his later papers. (I am not going to give references here as you already have too many!)

Thank you very much for the information. We shall provide the necessary references in the revised manuscript.

Acknowledgements

Was there no funding? No good advice from somebody?

We shall updated the funding source as 'Hochschule Koblenz University of Applied Sciences' and 'Technical University of Munich' in the revised manuscript.

REFERENCES CITED IN THIS REVIEW

- Arnold, KC and DK MacKay. 1964. Different methods of calculating mean daily temperatures, their effects on degree-day totals in the high Arctic and their significance to glaciology. Geographical Bulletin 21, 123-129.

- Braithwaite RJ 1995a. Positive degree-day factors for ablation on the Greenland ice sheet studied by energy-balance modelling. Journal of Glaciology 41, 137, 153-160.
- Braithwaite RJ 1995b. Aerodynamic stability and turbulent sensible-heat flux over a melting ice surface, the Greenland ice sheet. Journal of Glaciology 41, 139, 562-570.
- Braithwaite RJ and PD Hughes 2022. Positive degree-day sums in the Alps: a direct link between glacier melt and international climate policy. Journal of Glaciology1-11. http://doi.org/10.1017/jog.2021.140
- Zinng T 1951. Beziehung zwischen Temperatur und Schmelzwasser und Bedeutung für Niederschlags- und Abflüssfragen. International Association of Scientific Hydrology Publications 32, 1, 266-269.

Thank you very much for providing the list of important references we shall include/update these in the revised version of the manuscript.

References:

Masters, G. M.: Renewable and efficient electric power systems, John Wiley & Sons, Hoboken, NJ, 654 pp., 2004.