Estimating degree-day factors based on energy flux components
Referee #2: Lander Van Tricht (Comments and Responses)

General Comments

The manuscript describes the possibility to estimate degree-day factors based on energy flux components. It studies in detail the contribution of each component as well as the variation (spatial, temporal, climate change). Consequently, the study is a valuable contribution in the context of calibrating DDF in temperature-index models to better represent melting. This is relevant given the importance of correctly calibrated models to assess (future) snowmelt.

The paper is well written, and the methods/formulations are clearly described. Further, the main ideas are very well presented in the introduction which ensures that the reader is immediately introduced in the topic and knows what the study focuses on. The study also contains an enormous number of references and (explanations of) parametrisations that sometimes make it read like a literature review, especially in the method section. The study is not particularly "innovative", but it does contribute to a better understanding of DDF and the implementation and calibration of these factors in models that can be used to determine snowmelt.

In conclusion, I think the study is worth publishing with some smaller (technical) revisions. Further, the authors may consider making the structure/division of method - results - discussion a bit clearer. Now it is not entirely clear what certain datasets are used for in this study (Brunnenkopfhütte, Upper Indus Basin, etc.). Furthermore, it could be an option to do an analysis with the hourly temperature data instead of just looking at the average, as this data is available from the meteorological station.

Dear Reviewer,

Thank you very much for your helpful comments and suggestions to improve the manuscript. We are very grateful for the manuscript summary. As suggested, we shall restructure the results and discussion section in order to make it clearer. We have estimated degree-days based on hourly data which is then aggregated to daily and then 10-daily values as mentioned in the model comparison section. We have summarized our data on daily basis because degree-day factors are estimated on daily basis.

Based on your comments and suggestions, we shall now 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

Specific comments

Line 23: yields <-> yielded

We shall update it in the revised manuscript.

Line 24: mm w.e.? If water equivalent is used, use this abbreviation

Thank you for your comment. We shall updated the y-axis label in Figure 7, where it was missing. Here we have used the units as mentioned in the literature (e.g. Braithwaite and Hughes, 2021, Hock, 2003). In our opinion, the *DDF* are representing the melt so the units should be in mm instead of mm w.e.

Line 24: What is BIAS? RSME is clear for most readers. Use the full notation, especially the first time.

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 it in the revised manuscript.

Line 45: Odd use of however in this sentence

We shall replace it with modify it in the revised manuscript.

Line 61-66: Some repetition with previous paragraphs. Consider integrating this a little more in other paragraphs. That way, the text can also become a bit shorter.

We shall integrate the text in the previous paragraphs so that there shall be no repetition.

Line 88: Why does albedo decrease with increasing altitude?

Albedo is not decreasing with increasing altitude. In this sentence, it was mentioned that the degree-day factor increases with decreasing albedo. We shall clarify this sentence in the revised manuscript.

Line 96: .. and topographic settings?

As suggested, we shall update it in the revised manuscript.

Line 117: a part of "the" Isar River system "lying" in the …

As suggested, we shall update it in the revised manuscript. The revised sentence shall read "The study area covers the Dreisäulerbach catchment, which is a part of the Isar River system and lies in the sub-alpine region of Bavaria in the Ammergauer Alps, Germany".

Line 122: made up sounds a bit strange. Is mainly composed or characterised?

As suggested, we shall update it in the revised manuscript. We shall use word 'characterised'.

Line 123: A reference here is not essential.

We shall delete the reference here in the revised manuscript.

Line 128: Have <-> has

We shall update it in the revised manuscript.

Line 130: Sometimes British – American English is used (parametrise – parametrize etc.)

Thank you for your comment. We shall update it in the revised manuscript and use only 'British English'.

Line 130: Summarizes

We shall update it in the revised manuscript.

Table 1: Some variables need explanation. What is Kt? SRin?

We shall add an explanation of each parameter in footnote 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 1: Snow station or meteorological station?

We shall use '*Automatic snow and weather station*' in the revised manuscript.

Line 151: Units are in water equivalent?

The units are in '*mm*' because it refers to melt.

Line 155: What is the difference between part 1 and part 2 of this sentence? "T is set to 0°C" vs "The freezing point is chosen."

Thank you very much for your comment. We shall add the following sentence 'T_{DD} is set to 0°C'. We shall also add T_0 as symbol for reference temperature.

Line 193-194: Which value is used in this study?

We have used 1361 $W\ m^{-2}$ in this study and shall clarify this in the text.

Line 252: Odd use of however. Use a different word or rephrase the (part of the) sentence.

We shall update it in the revised manuscript

Line 294: Parametrise vs parametrize

We shall update it with British English in the revised manuscript.

Line 304: Parametrise vs parametrize

We shall update it with British English in the revised manuscript.

Line 324: It would be interesting to also mention a typical value for these conditions (W m^{-2}).

As suggested, we shall add typical values in the revised manuscript.

Line 391: Analysed vs analyzed

We shall update it with British English in the revised manuscript.

Line 419-420: This is based on data of the Hutt? How is the mean calculated?

Present section 4.6 of the manuscript is based on the data from Brunnenkopfhütte station. The data is available on 10-minutes interval which is then aggregated on mean hourly and daily basis. We shall clarify different data sources and their respective use in the revised manuscript.

Line 470: I think it is clearer to put the panel letter before the sentence.

As suggested, we shall update it in the revised manuscript.

Line 474: Snow station or meteorological station?

We shall use '*Automatic snow and weather station*' throughout the manuscript.

Line 488-489: An average temperature of 20°C, it is not very common in early spring, right?

We agree that in early spring an average temperature of 20 °C is not common. But here we have used a broad range of degree-days for our illustrative examples and summary tables.

Line 492 and Figure 5: for selected cloudiness and average air temperatures?

Thank you for your suggestion. We shall change it in Figure 5 as 'for selected cloudiness [%] and degree-days [°C d].

Line 510-512: Would it be an option to derive an average using the average hourly wind speeds?

The automatic snow and weather station data has temporal resolution of 10-minutes. This data is then aggregated on hourly and then daily basis for analysis purpose.

Line 539: I prefer "refreezes" <-> is refrozen

As suggested, we shall update it with 'refreezes' in the revised manuscript.

Line 554: meteorological station <-> snow station

We shall use 'Automatic snow and weather station' throughout the manuscript.

Line 563: What is BIAS? Use full notation the first time

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 make it clear in the revised manuscript.

Line 563-565: The snowmelt periods which are neglected, are these particular days? Or 10-day periods?

Those 10-daily snowmelt periods in which a new snow event occurred (marked by hollow circles in Figure 8) were excluded from the calculation of the error metrics.

Line 582: "is" or "to be"

We shall update it with 'to be' in the revised manuscript.

Line 704-706: Where does this data come from? The area of Indus Basin is not elsewhere introduced or mentioned.)

We shall update the dataset as well as Upper Indus Basin (UIB) catchment information in the revised version of this manuscript. For climate change impact assessment (i.e. temperature) the bias-corrected climate scenarios from four GCMs (GFDL-ESM2M, HadGEM2-ES, IPSL-

CM5A-LR, MIROC5) driven by two representative concentration pathways (RCPs), which were provided by the ISIMIP project (Hempel et al. 2013; Frieler et al. 2017) were used (Ismail et al. 2020).

- Frieler, K., Lange, S., Piontek, F., Reyer, C. P. O., Schewe, J., Warszawski, L., Zhao, F., Chini, L., Denvil, S., Emanuel, K., Geiger, T., Halladay, K., Hurtt, G., Mengel, M., Murakami, D., Ostberg, S., Popp, A., Riva, R., Stevanovic, M., Suzuki, T., Volkholz, J., Burke, E., Ciais, P., Ebi, K., Eddy, T. D., Elliott, J., Galbraith, E., Gosling, S. N., Hattermann, F., Hickler, T., Hinkel, J., Hof, C., Huber, V., Jägermeyr, J., Krysanova, V., Marcé, R., Müller Schmied, H., Mouratiadou, I., Pierson, D., Tittensor, D. P., Vautard, R., van Vliet, M., Biber, M. F., Betts, R. A., Bodirsky, B. L., Deryng, D., Frolking, S., Jones, C. D., Lotze, H. K., Lotze-Campen, H., Sahajpal, R., Thonicke, K., Tian, H., and Yamagata, Y.: Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b), Geosci. Model Dev., 10, 4321–4345, https://doi.org/10.5194/gmd-10-4321-2017, 2017.
- Hempel, S., Frieler, K., Warszawski, L., Schewe, J., and Piontek, F.: A trend-preserving bias correction – the ISI-MIP approach, Earth Syst. Dynam., 4, 219–236, https://doi.org/10.5194/esd-4-219-2013, 2013.
- Ismail, M.F., Naz, B.S., Wortmann, M. et al. Comparison of two model calibration approaches and their influence on future projections under climate change in the Upper Indus Basin. Climatic Change 163, 1227–1246 (2020). https://doi.org/10.1007/s10584-020-02902-3

Line 734: Parametrizes <-> parametrises (probably I have missed other ones)

We shall update it with British English in the revised manuscript.