The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-76-AC2, 2020

The Cryosphere Discussions
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Interactive comment on "The ERA5-Land Soil-Temperature Bias in Permafrost Regions" *by* Bin Cao et al.

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Received and published: 12 June 2020

Responses of Anonymous Referee #2

The authors would like to thank the reviewer for the constructive feedback, and the thorough assessment of the manuscript. Below we provide a point-to-point response to each comment, reviewer comments are given in black, responses are given in blue. Additionally, we have included details of how we intend to address these changes in a revised submission.

General comments:

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Discussion paper

This paper presented a good assessment of the soil temperature at a large scale using in-situ observations and previous products/maps. Understanding current soil temperature bias in reanalysis could improve further Earth-system model design by accounting more essential permafrost processes and hence benefit the permafrost community. This paper is generally well written. I have some comments for further revisions.

Major comments:

- As Reviewer#1 stated, some important points became clear a little bit late. To casual readers, this may be not easy to follow.
  Please see our responses to the general comments of RC#1.
- The authors MUST recheck this statement in L70–71. From the ERA5L website, they said: "Temperature of the soil in layer 1 (0–7 cm) of the ECMWF Integrated Forecasting System. The surface is at 0 cm. Soil temperature is set at the middle of each layer, and heat transfer is calculated at the interfaces between them." This is very important because these depths were used to interpolate soil temperature profiles and to determine ALT, if my guess is correct. If incorrect depths were used, the comparisons were already artificially altered.
  We've noticed the differences of soil depth from the ERA5L document website and model description document (see Table 8.7 in IFS Documentation CY45R1 (https://www.ecmwf.int/en/elibrary/18714-part-iv-physical-processes). We also contacted the scientist from ECMWF, and I simply copied the reply below.

  "The soil temperature of a given layer is an averaged value over of the thickness of that layer and assigned to the middle of the layer. From the modeling point of

view this temperature is a valid temperature for any point in the layer, whereas in reality it'll be different depending on the depth. This is one of the limitations when the soil is discretised in a finite number of layers."

For this reason, we followed the depth in model document as described in L70–71: *"The soil column of ERA5L is discretized into four layers with node depths (layer boundaries) of 0.07 (0–0.07), 0.21 (0.07–0.28), 0.72 (0.28–1.00), and 1.89 (1.00–2.89) m."*

- The authors should describe the estimate of ALT by using ERA5L.
  In paragraph of section 3.1, we'll add *"ERA5L ALT is derived through linear interpolation from ERA5L soil temperature-depth profiles."*

- Did the authors consider the uncertainties from vegetation?
  Our results indicated that the ERA5L soil temperature bias are mainly from the MAAT bias (Figure 1), and snow (see larger bias in winter from Figure 2, and Figure 7). That's why we considered the MAAT bias and snow as possible predictors rather than the vegetation, and the linear model of Eq. (1) indicated the success of variable selection. We hope you agree.

- In section 2.3, I miss a description of air temperature observation, while it is used for analyses of ERA5L soil temperature bias (i.e. in Table 1 and the linear model). Authors have to add a brief description here, and even show them in a proper way. This could be easily done, for example, by changing the shape of the station with both air and soil temperatures in Figure A1.
  In the revision, we'll add the air temperature observation info (see the attached figure).

Specific comments:

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Discussion paper

P2, L27: The RMSE of reanalyses soil temperature? Please clarify.
Will revised as *"For example, over the Qinghai–Tibetan Plateau (QTP), Hu et al.,(2019); Yang and Zhang (2018) reported that the root mean squared error (RMSE) of daily soil temperature from different reanalyses (i.e. ERA5-Interim/Land, MERRA-2, and CFSR) was up to 1.8–5.1∘C, and they are generally consistently cold bias."*

P2, L40: ... and example numerical or process-based simulation...
Will be revised.

P2, L57: Note that ERA5L is now available from 1981.
In the revision, we'll add *"Note that, during writing only ERA5L data after 2001 are released and hence this evaluation is conducted for data between 2001–2018."*.

P4, L86: The soil temperature from the TTOP and CP maps are used as comparisons, please as mention here.
In the revision, we'll add *"The mean annual ground temperatures (MAGT) from the TTOP and CP maps are also used for ERA5L evaluation."*

P4, L89: ...(denoted as PZI map)","..., should it be ";"? Similar in L91.
Will be revised.

P4, L97: The MAGT of TTOP and CP maps are additionally used as reference in your Table 1 and Figure 3. Please clarify here.
Will be revised.

P5, L104: ...in the same ERA5L grid cell...
Will be revised.

P5, L107: ...of ERA5L soil temperature....
Will be revised.

P5, L126: there is a repeat of the "the".
Will be revised.

P5, L134: ...and (2) an increase of 1 m wSD_{max}
Will be revised.

P7, L149: Is the ALT also overestimated in high latitudes and underestimated in high altitudes?
It is difficult to say as most of the sites in mid-low are excluded before evaluation since their ALT $>$ 1.89 m. In this case, the evaluation shown here are generally for high latitudes (see Figure 5 for the site distribution of ALT $<$ 1.89 m). We'll change the caption of Figure 4 to *"The observed sites are mainly located in high latitudes, and the distribution is present in Figure 5."* to clarify.

P10, L164: Also mention the high spatial (and maybe temporal) resolution here, this is one of the most significant features of ERA5 compared to the others.
Will be revised as *"ERA5L has a number of advantages, such as long-term (back to 1950, eventually), high spatial resolution, and global coverage."*

P13, L215: ...for c_ξ in Eq. B5...
Will be revised.

P13, L216: It should be 150 kg m^{-3} based on Eq. B5, please double check.
Will be revised to 150 kg m^{-3}.

P14, L236: Underestimate permafrost...(what)? Permafrost area? Please clarify.
It is permafrost area, and will be clarified in the revision.

P14, L252–253: The bracket is incomplete
Will be revised.

P14, L255: Brackets are needed here for the url.
Will be revised.

P15, L270: Add space between m and s^{-2}
Will be added.

P16, L278: ρ_ξ is not included in Eq. (B5).
The sentence will be changed to *"where the a_ξ, b_ξ, and c_ξ are constant values of 2.8$\times 10^{-6}$ (s^{-1}), 0.042 (–) and 460 (m^3 kg^{-1}) derived or modified from Anderson(1976) and Jordan et al. (1999)."*

P16, L280: Considering move $\Delta\beta_s = 0$ to the upper so that Eq B6 would be aliened with the state of Eq. B8 and B10
Will be revised.

P16, L297: ...ice density of 920...
Will be revised.

Specific comments:

- Table 1: This is only for the observations in permafrost regions. Please clarify in the caption otherwise including the observations in non-permafrost regions.
  Yes, this is only permafrost regions. The caption is changed to *"Summary of soil temperature observations in permafrost regions..."*
- Figure 3: In the caption, it should be "...(observation-ERA5L)..."
  Will be revised.
- Figure 6: Considering add unit to the permafrost area changing rate.
  Unit will be added in the caption–*"...Linear lines represent the trend of permafrost area (10^6 km^2 $year^{-1}$) based on linear model..."*

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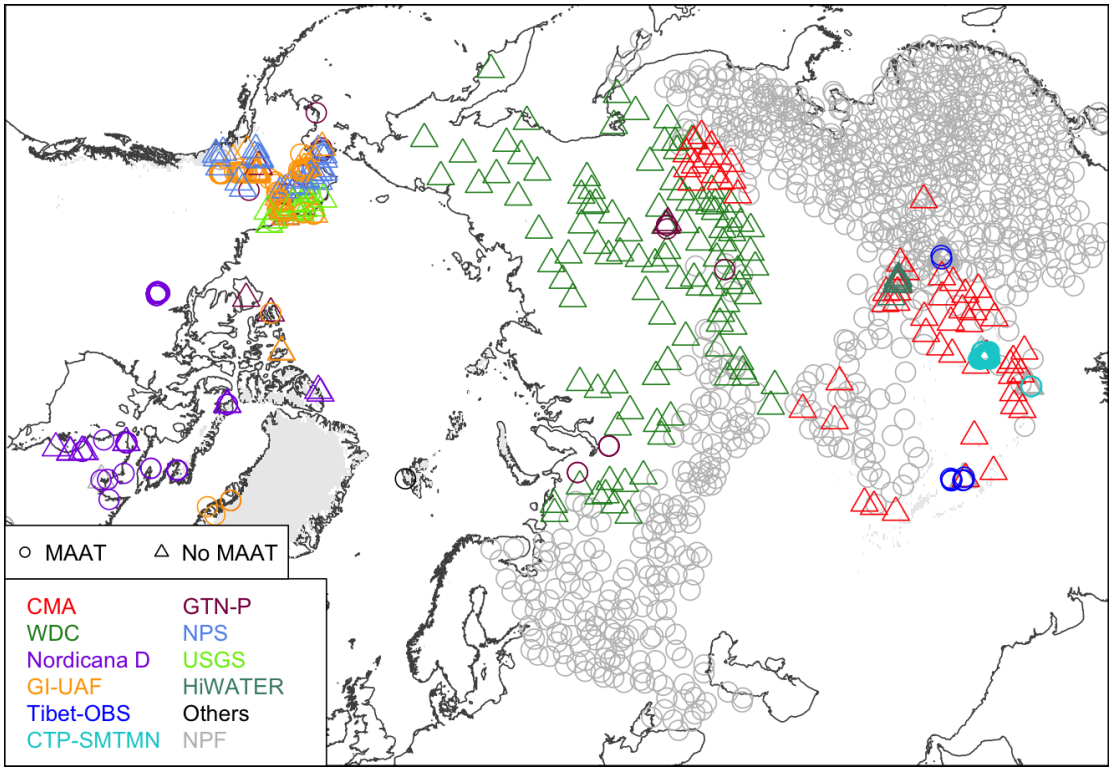

Fig. 1.

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