Replies to both referees RC1 and RC2 on "Brief communication: Surface energy balance differences over Greenland between ERA5 and ERA-Interim" by U. Krebs-Kanzow et al. (EGUSPHERE-2023-525)

We found both reviewers' comments very constructive and helpful. In our response we include some new figures from additional analyses inspired by the reviewers' questions. As we see it, most of these figures are beyond the scope of the paper, but we found them quite interesting, and we offer to include them in the supplement.

Thank you very much for helping to improve the manuscript! We have compiled our replies to all raised issues and points in this document. The Referees' texts are in black print, while our responses to each item are in blue. This pdf file contains both replies in consecutively order. New figures for the manuscript and supporting figures are included at the end of this response.

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RC1: 'Comment on egusphere-2023-525', Anonymous Referee #1, 07 Apr 2023
Review of

Brief communication: Surface energy balance differences over Greenland between ERA5 and ERA-Interim by Uta Krebs-Kanzow and others

General

This paper issues a warning that researchers that previously used ERA-Interim to estimate Greenland ice sheet (GrIS) surface energy/mass balance (SEB/SMB) must recalibrate their methods when switching to ERA5. The authors find significant differences in near-surface climate, notably near-surface air temperature, and SEB, notably the flux of incoming solar radiation. The paper is generally well written with clear figures but see my technical comments below. The paper is well-timed, as ERA-Interim will be phased out soon at the expense of ERA5. Unfortunately, no interpretation as to why the differences occur between the two products is provided, making the scientific impact of this study somewhat limited.

We are aware of the manuscript's descriptive nature. We wanted to disseminate the reported differences to those using ERA5 to hindcast (reproduce the historical) Greenland's surface mass balance (SMB) estimates since these differences are essential and will impact SMB estimates from surface mass and energy balance models. We have chosen the brief communication format to inform the community timely.

Major comments

In Figure 1 I assume some of the small-scale features in the marginal ice sheet are associated with the interpolation procedure, in combination with comparing two datasets of different resolutions.

This is most certainly right. Near the margins, changes over small spatial scales (e.g., albedo, local circulation, turbulent exchange, steep topographic gradients) will be better represented in ERA5 with roughly two times higher resolution in all spatial dimensions, and local biases are not surprising. In our manuscript, we focus on relevant differences on larger scales and which might induce systematic bias in surface mass and energy balance model results on larger scales. To clarify it, we will adjust the abstract by replacing:

"In summer, ERA5 differs significantly from ERAI, especially in the melt regions"
➔ " *small scale ERA5- ERAI differences, as particularly prominent near the ice sheet's margins, can be explained by the different resolution while large scale differences might indicate a different representation of physical processes in the two reanalyses.*"

Minor and textual comments

l. 9: persistent warming trend -> persistent positive trend

We have changed it to a "persistent positive temperature trend."

l. 10: "a mean warming of 5.3 K is projected for the 21st century". This is ambiguous. By "mean" do you mean model mean, or the mean over the (remainder of) the century, or end-of-century? Please be precise. Also, consider presenting a number from a more likely scenario.

We propose the following modification and addition: *"*...and an ensemble mean of SSP5-8.5 projections yields warming of 5.3 K from the first to the last two decades of the 21st century. Considering a wider range of scenarios, projections generally indicate warming over Greenland*,* which is weaker than *across* the *remaining Arctic*, slightly stronger than the global trends*,* and mostly comparable to trends over northern hemisphere land surfaces (IPCC, 2021, Fig. 4.19*)".*

Ref.: IPCC2021: Lee, J.-Y., J. Marotzke, G. Bala, L. Cao, S. Corti, J.P. Dunne, F. Engelbrecht, E. Fischer, J.C. Fyfe, C. Jones, A. Maycock, J. Mutemi, O. Ndiaye, S. Panickal, and T. Zhou, 2021: Future Global Climate: Scenario-Based Projections and Near- Term Information. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 553–672, doi:10.1017/9781009157896.006.

l. 11: "The associated reduction in Greenland Ice Sheet's surface mass balance (SMB) leads to more runoff " It is the other way around: the associated increase in runoff leads to a reduction of the GrIS SMB...Again, please be precise, there is already enough confusion about ice sheet mass balance.

Agreed. We plan to modify as follows: "The associated increase in surface melt and runoff leads to a reduction in the GrIS SMB."

l. 13: Consider replacing "Surface mass balance models" with "Surface energy balance models".

We will use "surface mass and energy balance models".

l. 16: near-surface temperature -> near-surface air temperature

We will change it accordingly.

l. 33: Reanalysis Era-Interim (ERAI) -> ECMWF Reanalysis - Interim (ERA-Interim, henceforth ERAI)

Changed as suggested.

l. 34: Reanalysis v5 (ERA5) -> ECMWF Reanalysis v5 (ERA5)

Changed as suggested.

l. 34: ERA5 runs from January 1940 to the present

It is correct that ERA5 now dates further back to January 1940. We have corrected the text and by state "… begins in January 1940, runs until the present, ...".

l. 37: For clarity and consistency with previous work, consider using T2m rather than T2M

Will do.

l. 70: Please use higher/lower temperatures rather than warmer/colder temperatures throughout.

OK.

l. 75: stronger -> larger

Replaced as suggested.

Citation: https://doi.org/10.5194/egusphere-2023-525-RC1

RC2: 'Comment on egusphere-2023-525', Anonymous Referee #2, 09 May 2023

A Review of «Brief communication: Surface energy balance differences over Greenland between ERA5 and ERA-Interim» by Krebs-Kanzow et al.

Overview and general comment

Authors present here a comparison of a part of surface energy balance components between both ERA-Interim and ERA5 reanalysis with the aim to adapt SMB calculation by EBMs to the highlighted differences. Originality of the comparison come from the focus on the area below 2000m of the ice sheet to better compare the datasets over the ablation area, and the use of a temperature lapse rate to correct the 2m-temperature of differences in surface elevation when interpolated on a common 1km-grid. The comparison is clear, straightforward and well-written.

Major Comments

A complete analyse of the surface energy budget components (longwave radiation too) should be presented, at least in supplements if it doesn't add significant conclusions.

Thank you for this point. We agree that it is worthwhile also to consider differences in longwave radiation (ΔLWD, Fig R1 lower right).

We can also demonstrate that recalculating LWD(Td, ε) according to Eq.1 as a function of downscaled near-surface air temperature and effective atmospheric emissivity ε, reduces differences in longwave radiation (ΔLWDd , Fig R9, upper panel).

Finally, we can attribute differences in LWD to differences in effective temperature by considering

$\Delta LWD_T = LWD(T_{ERA5}, \varepsilon_{ERA5}) - LWD(T_{ERAI}, \varepsilon_{ERA5})$

(Fig. R9, lower left panel).

Likewise we can identify the emissivity-related differences as

$\Delta LWD_e = LWD(TERA5, \varepsilon ERA5) - LWD(TERA5, \varepsilon ERAI)$

(Fig. R9, lower right panel). There is no indication of strong synergy between both contributors as

$LWD - \Delta LWD_T - \Delta LWD_e << \Delta LWD$ (not shown).

To keep the paper concise, we propose to replace the cloud cover of the original Fig. 1 with Fig. R1. We can also add LWD in Fig. 2 and 3 (Fig R2 and Fig R3).

Emissivity is calculated on the respective grid of both reanalysis, which implies that when downscale to 1km-grid, there is no correction relative to the elevation differences whereas ε is depending on the temperature. It would help to have an idea of this influence as you are considering a lapse rate to correct the temperature.

The effective atmospheric emissivity depends on temperature primarily due to the temperature dependance of the atmospheric saturation water vapor content. However, cloud cover and atmospheric circulation are also important factors. The spatial pattern of the emissivity bias (Fig.1, lower left panel) does not indicate a strong correlation between bias and steep topographic gradients. However, inspired by your comment, we tested some first-order, linear downscaling parameters. We found that agreement between the two reanalyses and agreement with PROMICE data was reduced and not improved, while the lapse-rate correction for temperature resulted in a visible improvement. Since this paper does not aim to discuss potential downscaling strategies, we have decided not to include these results in the manuscript.

To estimate different lapse rates to correct temperature of surface elevation differences, authors calculate local lapse rates for each grid. Why don't use directly these lapse rates to correct temperature? Depending of the results, this could be add in the comparison (Figure S5) in the supplements.

As pointed out above optimizing downscaling procedures is not the focus of this paper. Nevertheless, we have included the lapse rate correction of temperature here to demonstrate that disagreement is to some extent related to resolution differences and a steep topography. Near the margins a locally diagnosed choice might indeed improve the downscaling procedure. Still, in that case, one should also consider the coefficient of determination (R^2) for the local linear regression between temperature and elevation, as other parameters (like distance from the coast, the surface temperature of adjacent land, etc.) might also control the temperature distribution. Fig. S 4 is intended to give an orientation, interpreting regions with homogenous slope lapse rates to indicate that a lapse rate correction is justified.

AWS data in ablation area are used to compare both reanalysis. These observations are sometimes biased (instrument or sensors malfunction,...). Are these data preprocessed before used for the comparison? If no, this could influence the realised evaluation.

For our comparison with AWS data, we utilize the clean (preprocessed) PROMICE data.

In Figure 3 and associated comments in the main text, please precise if averaged variable are obtained from the respective original grid of the reanalysis, or if it's calculated after interpolation? (Please precise in the main text and in the caption.) In both case, is the spatial resolution differences could explain part of differences in the 4 variables?

Thanks for indicating some ambiguous descriptions. We have clarified this in the text.

There are too few assumptions to understand and explain differences between both datasets. This could help to adapt EBMs models.

We will include a short discussion of which biases might be resolution dependent (and could be reduced by downscaling) and which might be related to differences in the physical parameterizations.

Minor Comments

P1, L11-12 : “[…] The associated reduction in Greenland Ice Sheet’s surface mass balance (SMB) leads to more runoff […] ”: SMB does not lead to more runoff, but runoff leads to more negative SMB.

We have rephrased this accordingly.

P1, L13: EBMs = Energy balance models and not surface mass balance models. Please clarify used acronyms.

Done; we will use "surface mass and energy balance models".

P2, L24: ERA5 start at least in 1950. This had to be corrected everywhere else.

We have corrected the starting date of ERA5 – see also reply to reviewer #1.

P2, L26: Precise SMB derived from EBMs.

OK.

P2, L54-55: Two times respective and respectively in the same sentence.

We have removed one.

P3, L70: 1°C is inconsistent with the use of kelvin everywhere else (same in figure 1, 3 and similar figures in the supplements).

Thanks for indicating this inconsistent use of the units. We use the Kelvin unit ("K") on page three, line 70 (P3, L70) and page four, line 94 (P4, L94).

P3, L84: Please precise that the bias of 0.74 is in summer.

OK

P4, Figure 1: Color scales are not symmetrical.

The upper and lower ends of the colorbar reflect the non-symmetric value range. Otherwise, the colorbar is symmetric.

P4, Figure 2: unit is missing in subplot 2.

Thanks for reporting the missing units. We have added the missing unit information to the related property label of the x-axis.

P6, Figure 3: I suggest to also add comparison for other surface elevation classes, at least in supplements.

We have done so for intervals [0,1000], [1000,2000],[2000,3000],[3000,4000] : (Fig. R4 - Fig.R7).

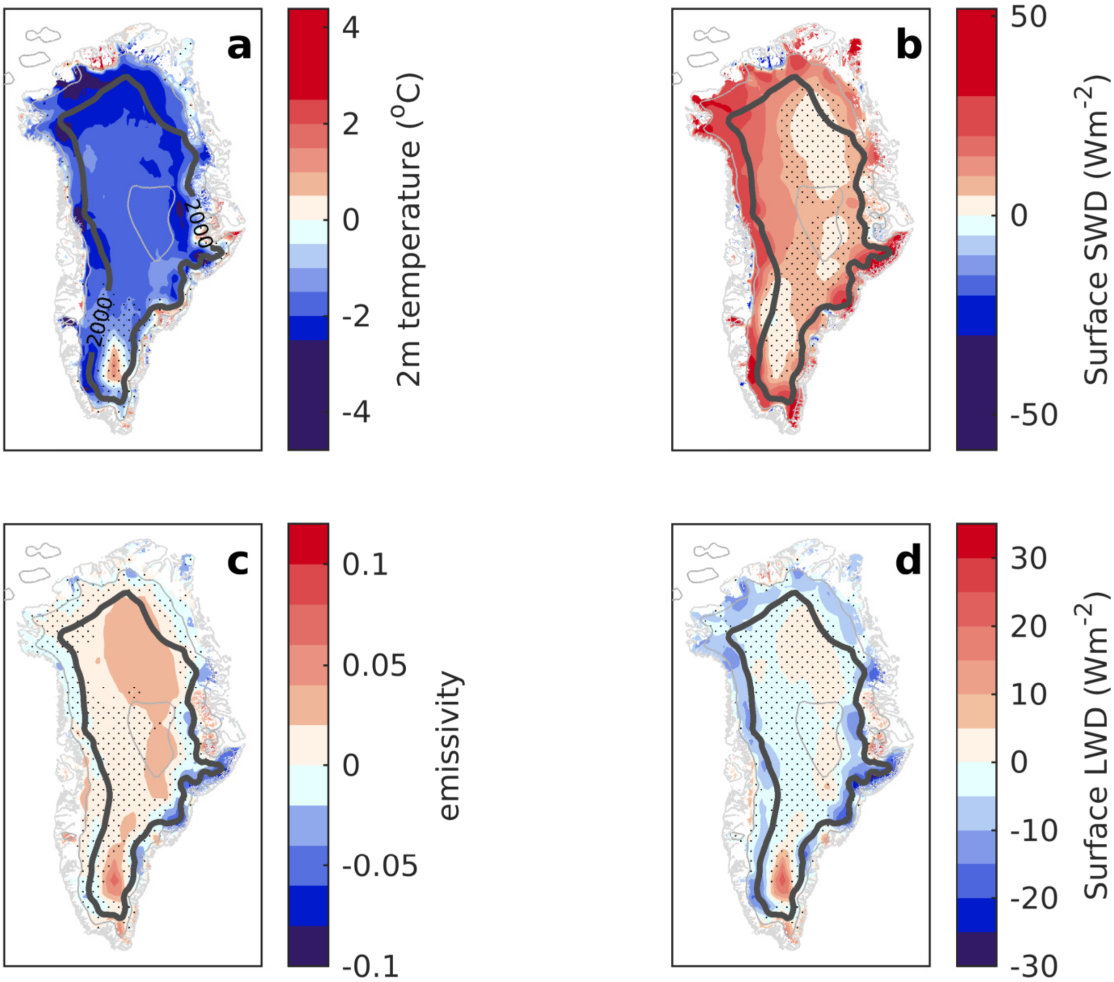

Figure R1. (This Figure could replace Fig. 1 in the article) Mean bias between ERA5 and ERAI for the summer mean (i.e., June, July, and August, JJA) 1979–2018 period of the 2m-air temperature (top left), downward shortwave radiation (top right), emissivity (bottom left) and downward longwave radiation (bottom right). Stippling indicates regions where the mean bias is smaller than two respective standard deviations.

Figures

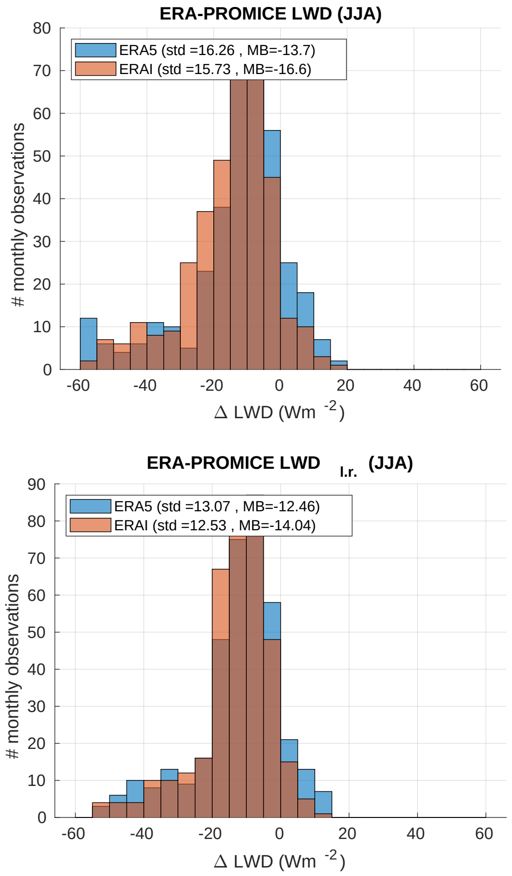

Figure R2. (The second panel could be added to Fig. 2 in the article) Distribution of ERA5 and ERAI biases with respect to monthly PROMICE observations for the summer months (June, July, August) in 2007–2016: downward longwave radiation (top), downward longwave radiation as recalculated via lapse rate corrected temperatures and emissivity The text box insets provide standard deviation (std) and mean biases (MB) for the respective distributions.

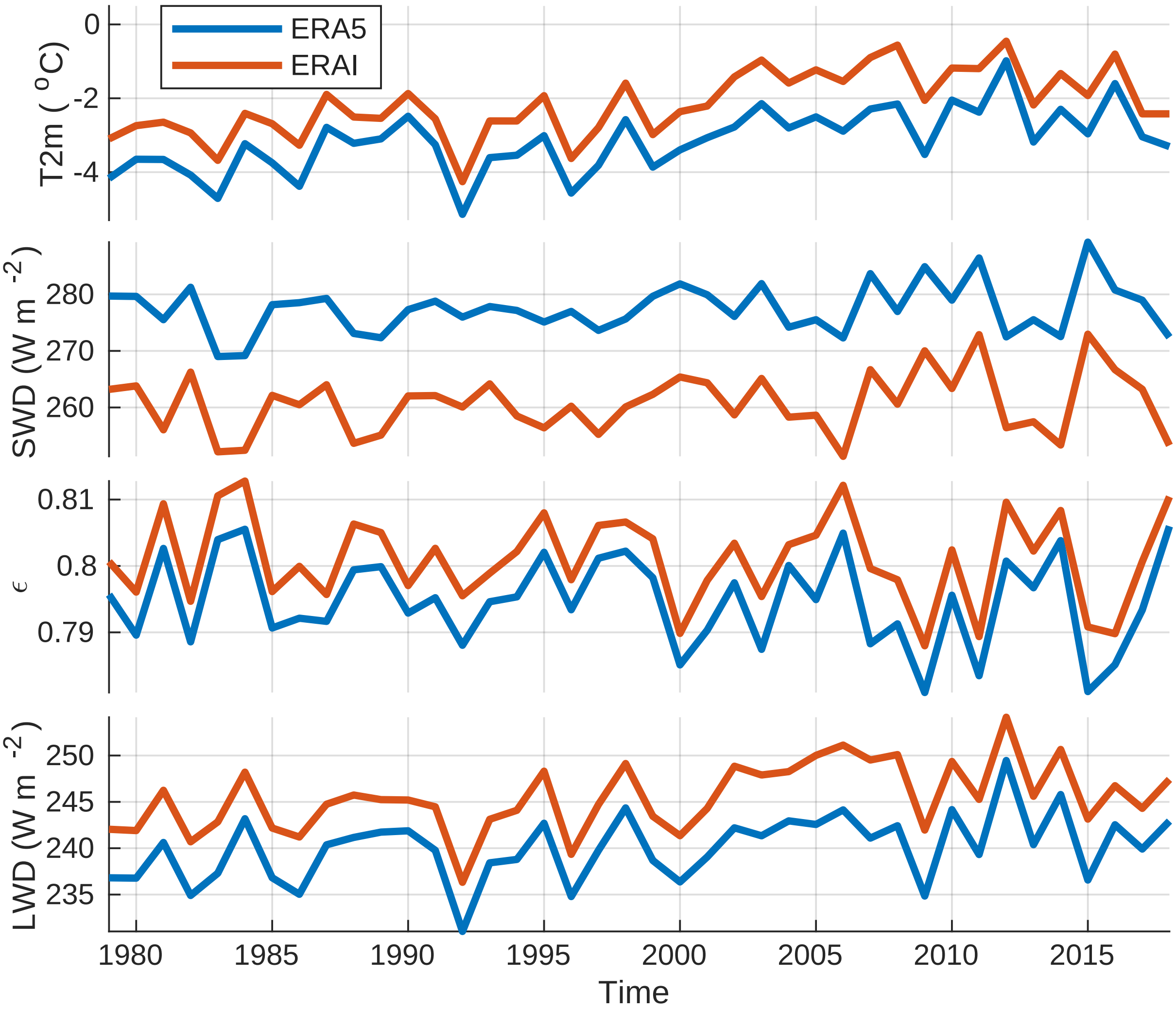

Figure R3. (This Figure could replace Fig. 3 in the article) 1979–2016 yearly summer means of (a) 2m-air temperature, (b) downward surface shortwave radiation, (c) emissivity, and (d) cloud cover for ERA5 (blue) and ERAI (red) averaged over the $0\,\mathrm{m}$ to $2000\,\mathrm{m}$ elevation range of the GrIS.

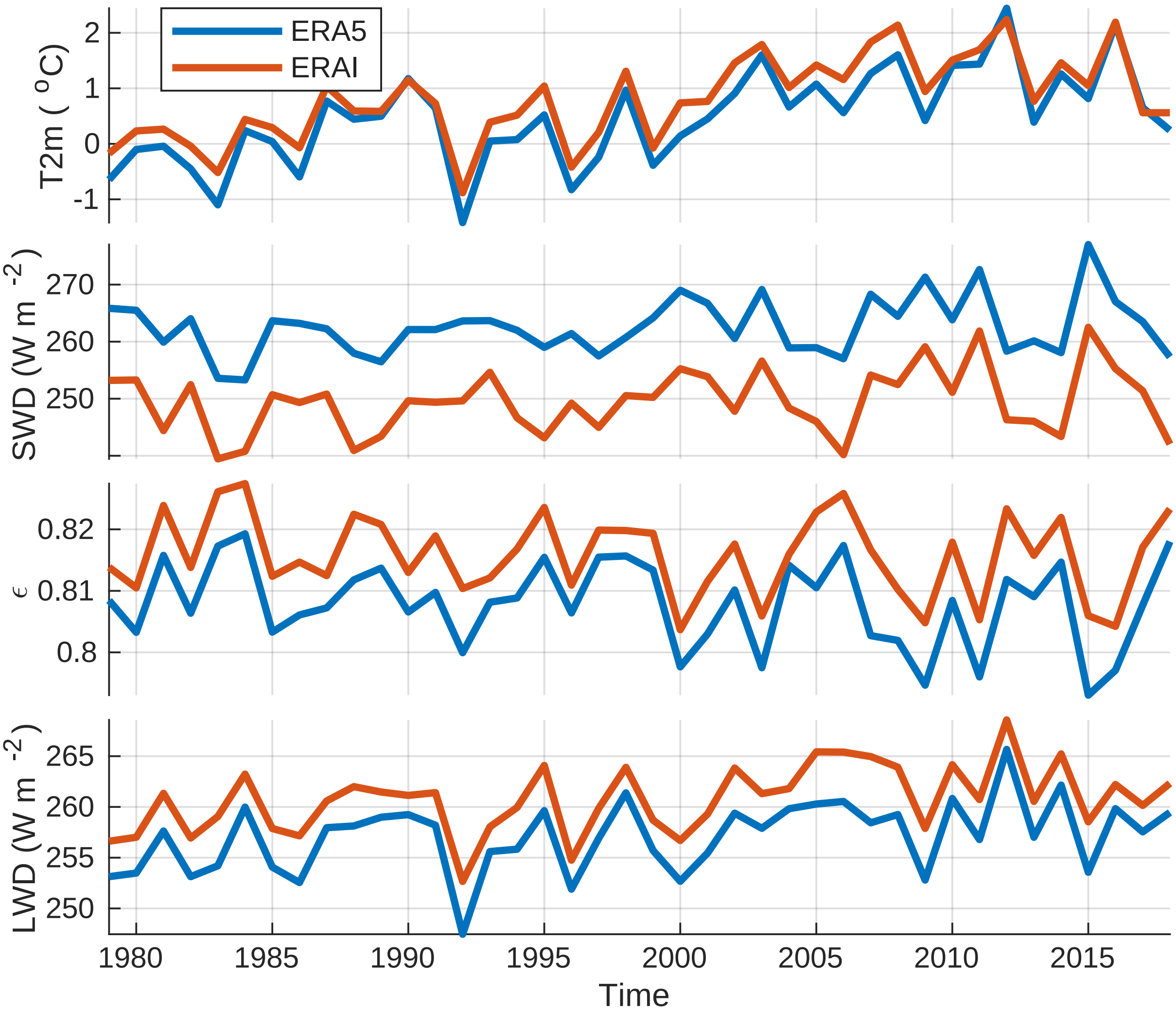

Figure R4. (This Figure could be added to the supplement) 1979–2016 yearly summer means of (a) 2m-air temperature, (b) downward surface shortwave radiation, (c) emissivity, and (d) cloud cover for ERA5 (blue) and ERAI (red) averaged over the 0 m to 1000 m elevation range of the GrIS.

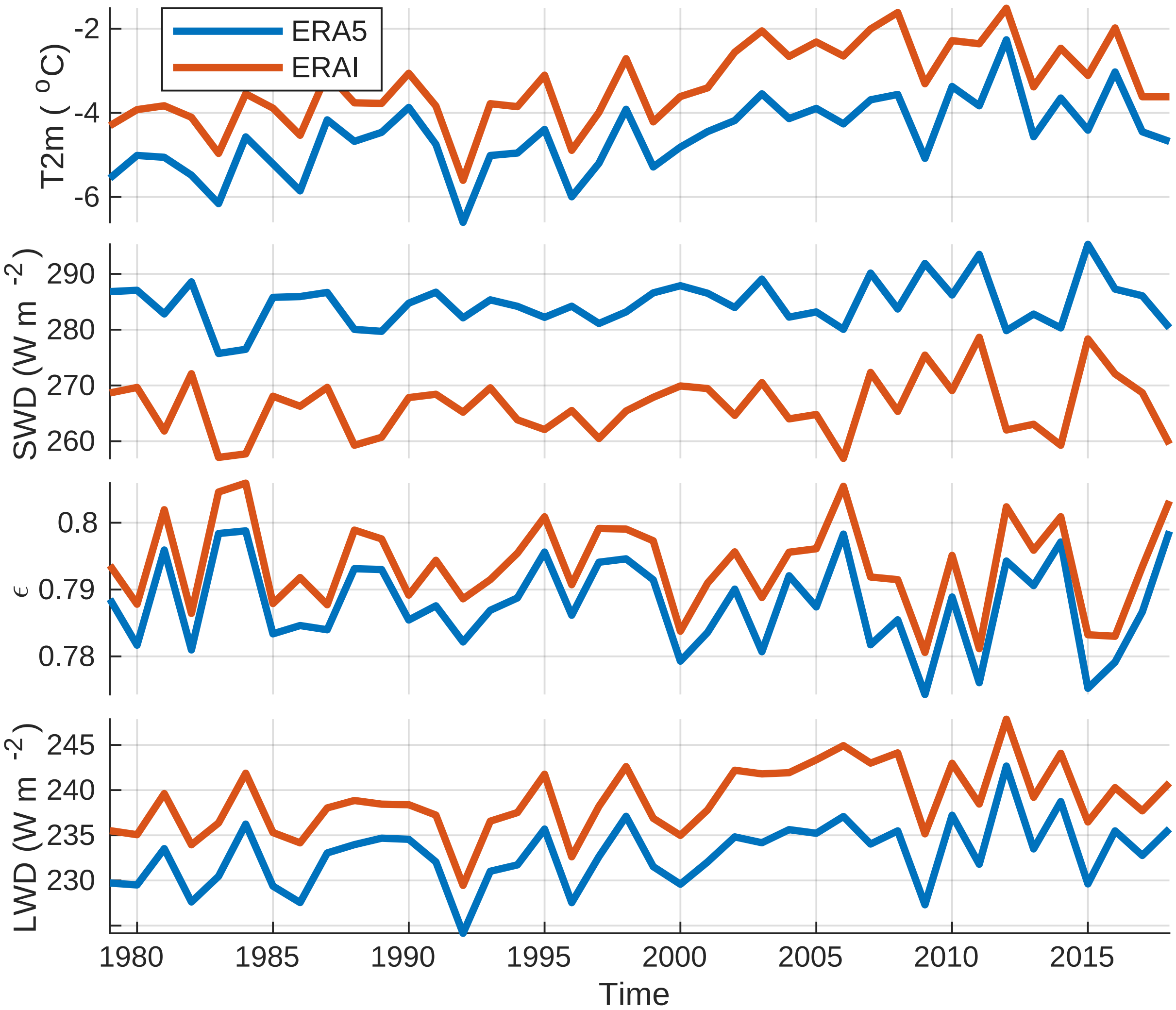

Figure R5. (This Figure could be added to the supplement) 1979–2016 yearly summer means of (a) 2m-air temperature, (b) downward surface shortwave radiation, (c) emissivity, and (d) cloud cover for ERA5 (blue) and ERAI (red) averaged over the 1000 m to 2000 m elevation range of the GrIS.

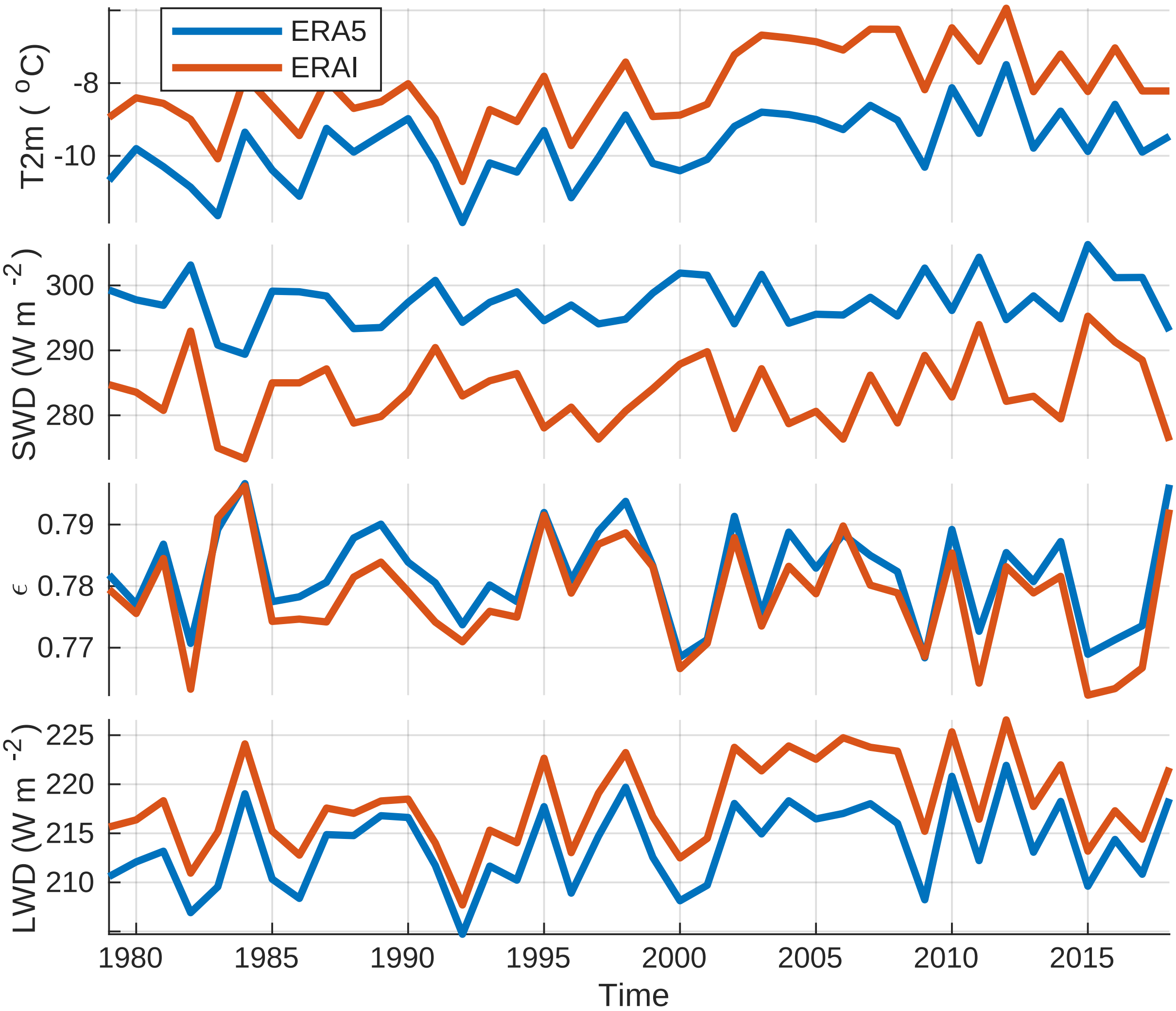

Figure R6. (This Figure could be added to the supplement) 1979–2016 yearly summer means of (a) 2m-air temperature, (b) downward surface shortwave radiation, (c) emissivity, and (d) cloud cover for ERA5 (blue) and ERAI (red) averaged over the 2000 m to 3000 m elevation range of the GrIS.

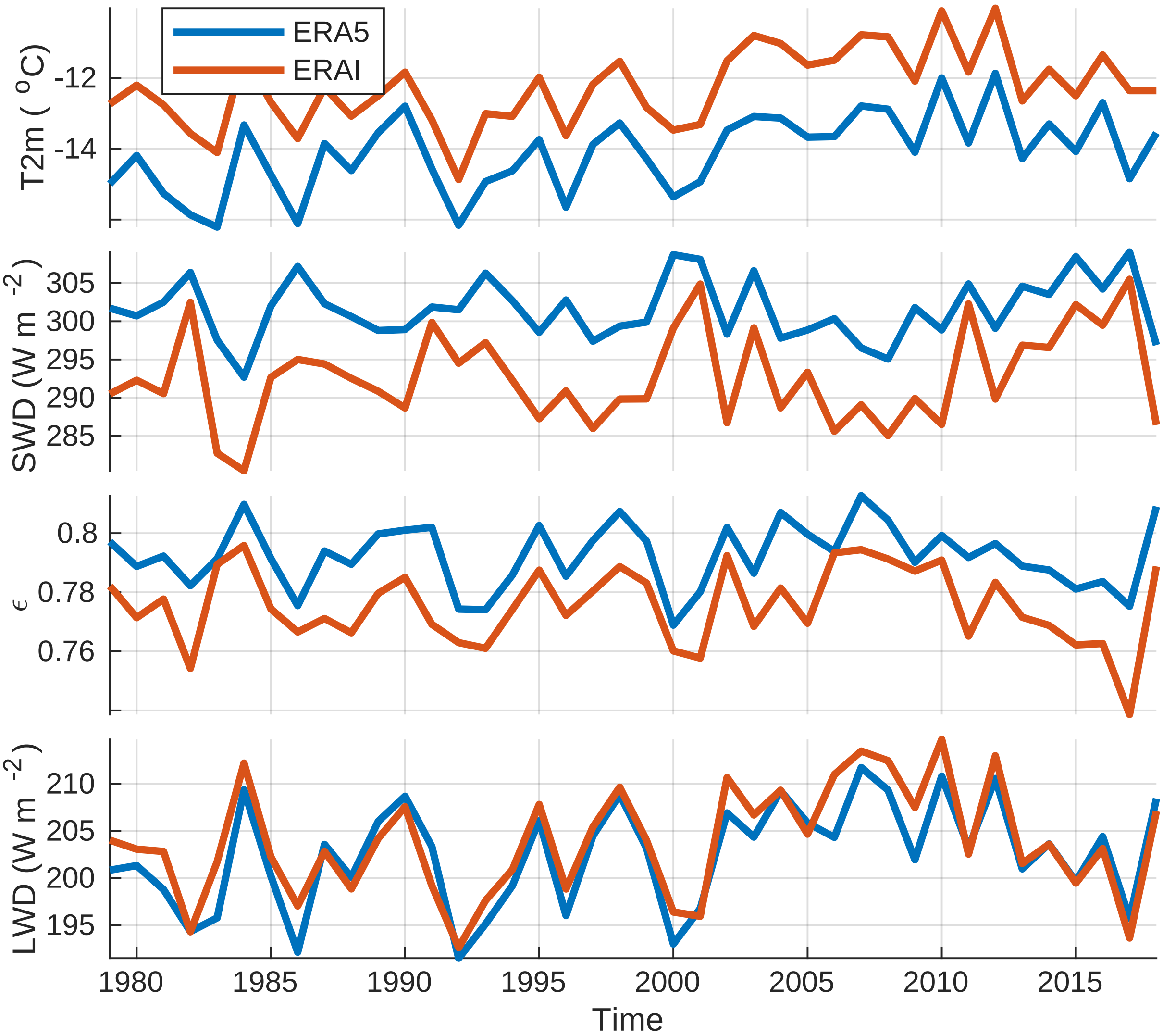

Figure R7. (This Figure could be added to the supplement) 1979–2016 yearly summer means of (a) 2m-air temperature, (b) downward surface shortwave radiation, (c) emissivity, and (d) cloud cover for ERA5 (blue) and ERAI (red) averaged over the 3000 m to 4000 m elevation range of the GrIS.

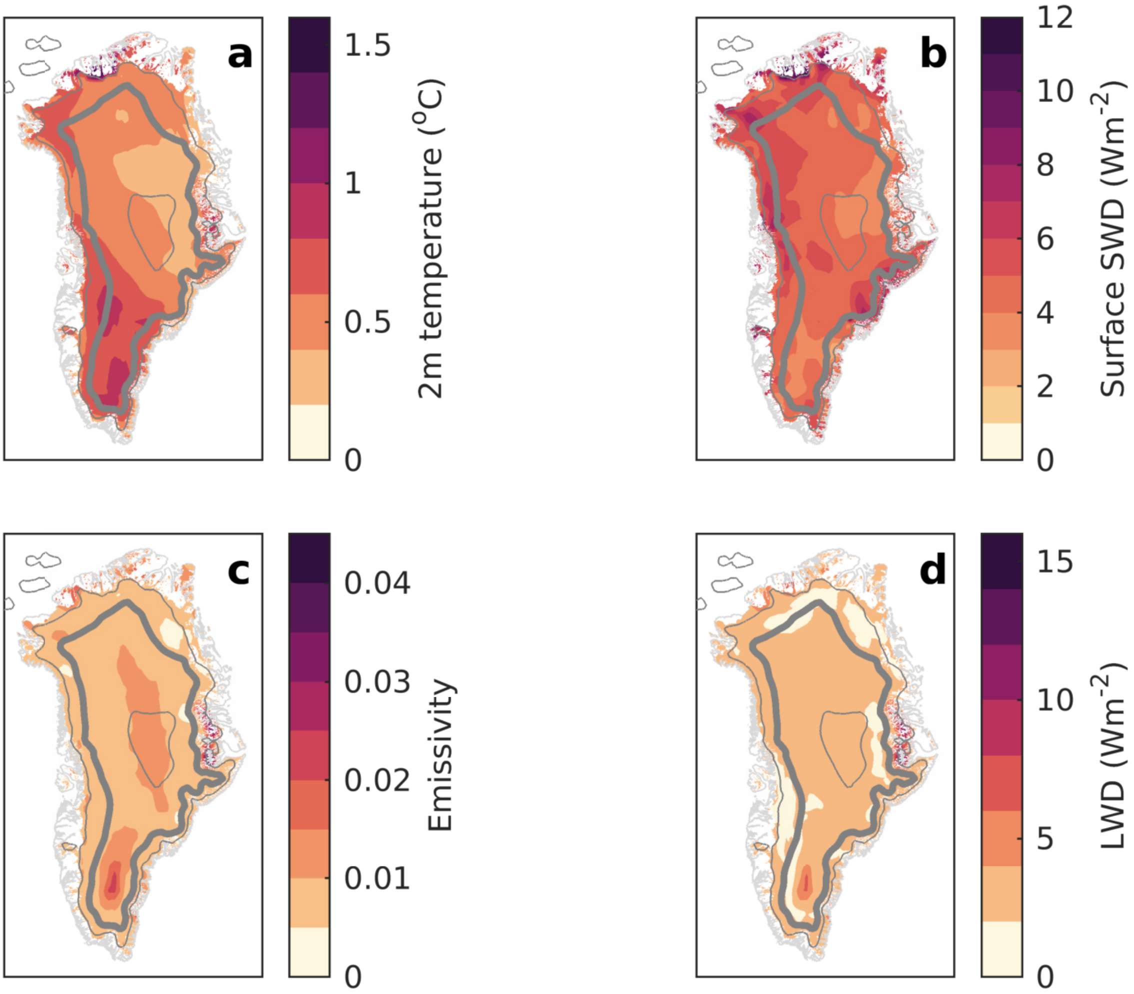

Figure R8. (This Figure could replace Fig.S3 in the Supplement) Same as Fig. 1 but for annual means.

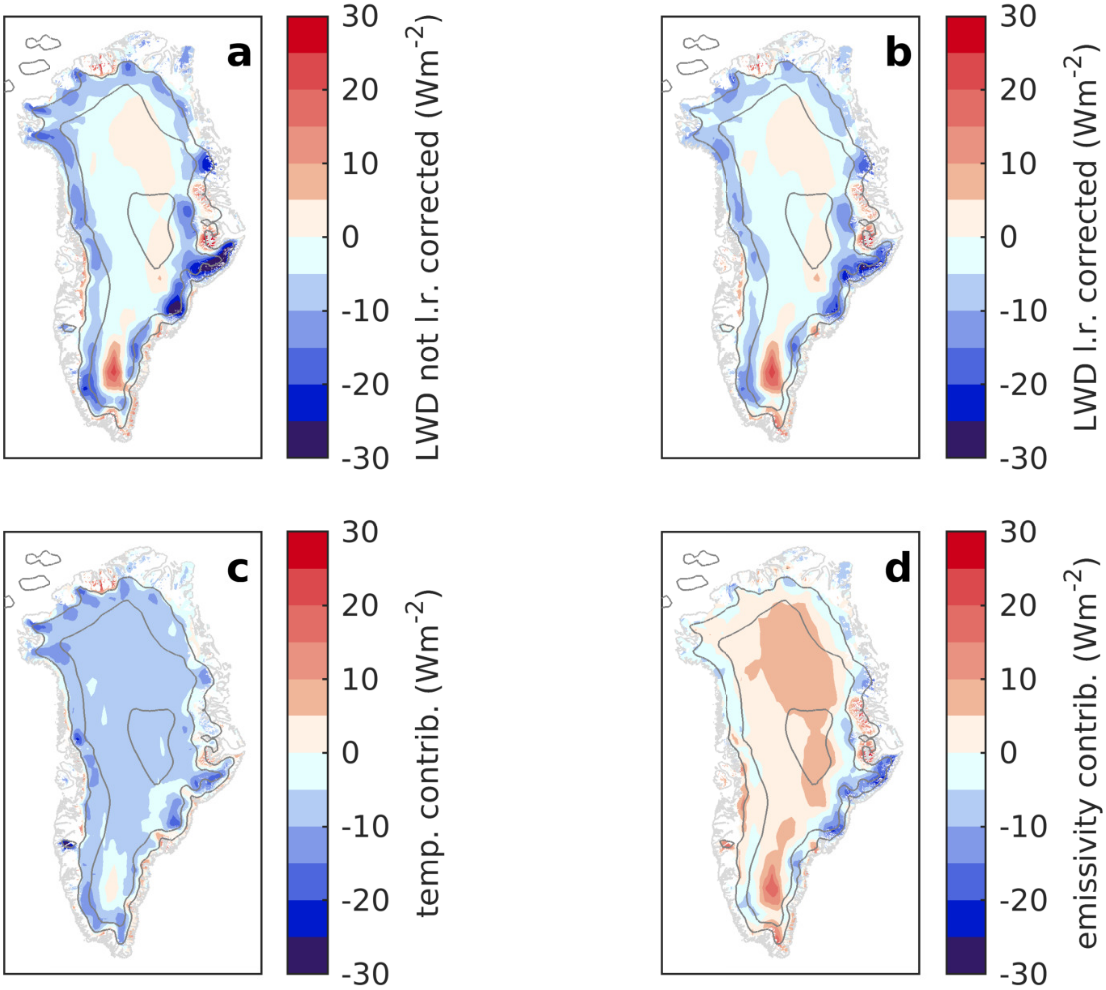

Figure R9. Mean bias between ERA5 and ERAI for the summer mean (i.e., June, July, and August, JJA) 1979–2018 period of the downward longwave radiation, origional LWD (top left), as recalculated via lapse rate corrected temperatures and emissivity (top right), temperature related bias contribution (bottom left, recalculated based on same emissivity but ERA5 and ERAI temperature), emissivity related bias contribution (bottom right, recalculated based on same temperature but ERA5 and ERAI emissivity)