Response to Reviewer 1 Comments

General comments:

1. This study investigates different empirical parameterizations of the surface downward longwave radiation regarding the adequacy for their use in China. In addition, the authors develop a new empirical parameterization and perform a comprehensive evaluation using data from 7 stations from the Chinese Baseline Surface Radiation Network. The authors conclude that the parameterizations and associated coefficients they derive are suitable for the determination of downward longwave radiation over China. The paper is well written, fairly straightforward and clearly structured. The applied methods are sound.

Thank you for this comment. We are grateful for reviewer's constructive comments.

2. My main reservation with this study is the relatively limited applicability of its results, being only of use for the determination of downward longwave radiation in China. To make the paper more attractive for readers outside China and to increase its impact in the community, information on the applicability of these parameterizations outside China would be valuable. For example, the Baseline Surface Radiation Network (BSRN, www.bsrn.awi.de) with numerous worldwide distributed high quality radiation stations would provide a framework to test and calibrate these parameterizations under more diverse geographical and climatological conditions. This would then allow to investigate the more general applicability of the parameterizations and make it more interesting for the worldwide readership of ACP. While such a broader analysis might be challenging to achieve within the limited time of a revision phase, I would find it at least useful if the authors could add a discussion of the potential and limitations of these parameterizations for their use outside of China, in order to provide guidance to readers interested to apply them for the determination of downward longwave radiation in other parts of the world..

Thank you for this valuable comment. Exactly, if more data observed from radiation stations (e.g., the BSRN, SURFRAD, etc.) is involved in building the parameterizations, the formulae in this study would be more attractive and suitable to retrieve the downward longwave radiation over more diverse geographical and climatological conditions around the world.

Due to the limited time of a revision phase, this suggestion is planned to be carried out in our future work. Whereas, we added a paragraph in section "**Discussion and conclusions**" of revision: "Due to limited data obtained from CBSRN used in building the parameterizations, the formulae presented in this study are mainly suitable to retrieve the downward longwave radiation in China rather than outside area. In the future, more data obtained from worldwide radiation stations (e.g., the BSRN, SURFRAD, etc.) is expected to be involved to establish the parameterizations, which could improve their capability to retrieve downward longwave radiation over more diverse geographical and climatological regions around the world."

3. While I think the English is overall adequate, there are still numerous minor issues as indicated in the technical comments. As I certainly not have caught all of them, I encourage the authors to doublecheck the manuscript in this respect, ideally with the help of a native English speaker..

We have checked the manuscript again and corrected some grammar errors. In addition, a native English speaker expert from the **LucidPapers** was invited to revise our manuscript, which made an obvious improvement on grammar and words in the manuscript.

4. I recommend the acceptance of the manuscript after revisions as outlined above and below.

Thank you for your consideration. We expect the manuscript can be improved after this revision.

Specific comments:

1. L69ff In addition to the climate zones, it would also be interesting to know if the stations are located in an urban, industrial or rural setting. This can give some indications to what extent the measurements could be influenced by local anthropogenic pollution sources.

Thank you for this suggestion. We have supplemented some descriptions and the related reference in Section 2.1 in the revision: "Moreover, the CBSRN stations represent various land covers in China. For instance, MH is the northernmost meteorological station in China surrounded by forest, which is located in the northwestern suburbs of Mohe County, Heilongjiang province (Liu et al., 2018). XL lies on the central of Inner Mongolia, where the main land cover is steppe. YQ, located on the northern margin of the Tarim Basin, is one of the representative stations in the desert and Gobi in northwest of China. SDZ is located in the northern North China Plain and only a few small villages with a sparse population around it (Zhou et al., 2021). XC is located in the central Henan province, which is surrounded by a wheat field and become one of typical representative stations for farmland in China. WJ is located in Sichuan Basin, which represents a paddy field. As a part of the Dali National Climate Observatory near the Erhai Lake in Yunnan province, DL is a represent station for wetlands."

2. Table 1: it would be worthwhile to include in this table also the measurement period for each site.

Thank you for this important suggestion, which can exhibit the history of establishment of CBSRN. As a pilot station, the XL was founded by China Meteorological Administration (CMA) in 2007. After approximately six-year operation of XL, other sites (i.e., MH, YQ, SDZ, XC, WJ, and DL) were established by CMA in 2013. We have added a column named "Measure period" in Table 1 in the revision.

3. L103: are there also collocated upper air soundings (radiosondes) available at some of the stations? BSRN recommends the high quality radiation stations to include upper air soundings for the interpretation of the measured fluxes and testing of models.

It is true that the vertical detection or radiosonde can offer necessary data to help interpretation of the measured fluxes and testing of models at high quality radiation stations. Overall, the CBSRN stations involved in this study can be classified into three groups:

- Station with radiosonde (XL, WJ), in which two sounding observations at 0000 UTC and 1200 UTC are performed every day. Sometimes, two additional observations are carried out at 0600 UTC and 2000 UTC to meet special requirement.
- Station without radiosonde but with vertical detections (SDZ, DL). SDZ is not only a radiation station but also a Global Atmosphere Watch (GAW) station, in which several instruments (e.g. Microwave radiometer, Wind profile radar, Lidar, and Gradient observation tower) are adopted to detect the vertical structure of the atmosphere. DL is a National Climate Observatory, which has both tower observations and surface observation (meteorological elements, radiation, etc.).
- Station without radiosonde (MH, YQ, and XC). These stations are conventional weather stations in China, in which fundamental meteorological elements as well as radiation components are observed.

4. L130: I think the structure and formulation of the Brunt model and the Weng model should be explicitly described here or in the method section.

Thank you for this suggestion. We have added two sentences to explicitly describe the Brunt model and the Weng model in Section 4.1 in the revision: "The Brunt model is one of the earliest pronounced models, in which a simple formula connecting the downward radiation from the atmosphere, the total black-body radiation at temperature, and the vapour pressure (Brunt, 1932). The Weng model is one of the earliest parameterization presented to retrieve the DLR over China area from the atmospheric temperature and vapour pressure based on the experimental observation data on the Tibetan Plateau (Weng et al., 1993)."

5. L131:It would be good to describe precisely how the clear sky hourly data were identified as being clear sky.

Thank you for the comment. In the revision, We modified the description in L131: "In this study, the coefficients of the Brunt model and the Weng model were calibrated using the nonlinear curve fitting method with 12,368 hourly data pairs (DLR and e) under clear-sky condition (defined as the corresponding cloud fraction equal to zero) observed at seven CBSRN stations between January 2011 and December 2017."

6. L142ff: ok here come the formulations of the different parameterizations which I expected earlier on (comment L130). Maybe this part could be described in the method section in a paragraph describing the different parameterizations used in this study together with their formulas.

Thank you for the comment. This is revised same as comment L130.

7. L150: by eye it is hard to recognize much difference between the 2 models (red and black curve) for the dry conditions ($e \leq 17.5$ hPa), thus hard to fully appreciate the improved performance of the Weng model for dry conditons.

Thank you for your comment. Though small differences exist between the Brunt model and the Weng model in the case of the vapor pressure is less than 17.5 hPa, the red curve exhibits faintly higher than the black curve when the vapor pressure between 2.5 and 12.5 hPa.

8. L185ff: It is not clear to me how the structure of the parameterizations has been established. Why do they have precisely this form and not e.g. another one?

Thank you very much for your valuable comment. It is really a hard task to convert parameterization of the clear-sky DLR to that of all-sky DLR due to the determination the effect of cloudiness on the parameterizations. To illustrate clearly the background of the shapes of Eq. (5)–(7), a paragraph including the related references and formula is added in the Section 4.2 of the revision as follows:

Under all-sky conditions, the emission from clouds can supplement the radiation emitted by water vapor and other gases in the lower atmosphere. Therefore, the effective emissivity of the atmosphere is higher under all-sky condition compared to that under clear-sky condition (e.g., Li et al., 2017). Numerous formulae were presented to estimate the emissivity under all-sky condition based on the emissivity parameterization under clear-sky condition and cloud fraction (e.g., Maykut and Church, 1973; Crawford and Duchon, 1999; Duarte et al., 2006; Choi et al., 2008). The formula of Duarte et al. (2006) with an adjustment of atmospheric humidity was adopted in this study. For a site like Barrow, Alaska, where both the temperature and the partial pressure of water vapor are low during much of year, the effect of atmospheric humidity on emissivity under all-sky condition can be neglected (e.g., Maykut and Church, 1973). However, the temperature and atmospheric humidity over the CBSRN stations vary over a wide range during a year, the addition of moisture correction to the formula, thus, seems more reasonable. The structure of formula to estimate the emissivity under all-sky condition in this study as:

$$\varepsilon_{all} = \varepsilon_{clr}\left(1 - \alpha \mathrm{CF}^{\beta}\right) + \gamma \mathrm{CF}^{\delta} \emptyset^{\zeta}, \quad (5)$$

where ε_{all} represent all-sky emissivity; ε_{clr} is the clear-sky emissivity calculated using Eqs. (2)–(4); CF is the cloud fraction (0–1); $\emptyset$ is relative humidity (%); $\alpha, \beta, \gamma, \delta, \text{and } \zeta$ are regression coefficients, which were derived using the dataset of observations recorded at seven CBSRN stations between January 2011 and December 2020.

9. L194ff: I understand the independent clear-sky dataset is independent in the temporal sense, i.e. the data stem from another period (from 2018 onward rather than before 2018), however still from the same stations. Two questions here: 1.) why not all 7 stations have been used, but only 4? 2.) Is there a chance to do a validation also at independent stations (not only independent times)? Basically one could use the entire worldwide BSRN dataset for this (see general comments). This would have the advantage that one could also get an idea on the performance of these parameterizations in other parts of the world under different regimes.

Thank you for your comments. To be frank, as a new generation of radiation observation networks in China, the CBSRN is not yet mature despite a lot of efforts have been put in instrument maintenance, regular calibration, and data quality control of the raw data. Particularly, some defects like instrument failure, program error, and light stoke exist in the process of observation, which damage the integrity of the data. Despite not all data from 7 stations have been used in this study, the long-term observation of radiation can provide sufficient independent samples to establish and validate the parameterizations.

Just as pointed out by the reviewer, the integrality and data quality of the database derived from the CBSRN is a key issue in the application. Recently, we have completed another study on quality-assured database of baseline surface radiation at SDZ, in which detailed description on the instruments, data quality control, dataset assessment, and database construction are described.

10. L202ff: Similar comment as above, why only 3 stations are used here for a validation and not all seven? Again also an evaluation with (spatially) independent stations would be interesting, ideally even outside China.

Thank you for your comments. Besides the reasons explained above, another consideration of data used in this study is the balance of samples, i.e., the number of data pairs used in establishing parameterization is about 2–3 times of the one used to validate the parameters, through which to guarantee the representative of the samples on the one hand and assure enough samples to validate the parameterizations on the other hand. It is a good idea to use radiation data outside China even all over the world to establish a robust parameterization to estimate DLR.

11. L207: Why should more samples necessarily help to reduce the MBEs.

Thank you for your question. As we all know random error always exist in measurements of both radiation components and meteorological elements. In general, the distribution of MBE of emissivity (or DLR) between measured and estimated obeys the normal distribution, i.e., most of the MBEs close to zero but a few extraordinary samples far from the zero. Moreover, the effects of extraordinary samples on the MBEs would be weakened with the increase of total samples due to its average compensation effects. Furthermore, the calculated MBE would be more robust if more samples are used during calculation due to the smoothing effect of the samples.

12. L239ff/Figure 5: I assume this validation uses hourly values? And uses measurements from all 7 stations? This should be mentioned in the text or the figure caption.

Thank you for your reminder. Yes, this validation uses hourly measurements of DLR at four stations (YQ, XL, SDZ, and XC) during 2018−2021 and at three stations (XL, SDZ, and XC) from January 2021 to April 2022 to validate the clear-sky and all-sky DLR estimations derived from three models, respectively. In the section 4.4 of the revision, we have modified the corresponding sentences in the revision.

Technical comments:

1. L29: add “e.g.,” in front of the references, as there are many other and also earlier papers dealing with DLR.

Thank you. This is fixed in the revision.

2. L31: same comment, add “e.g.,” in front of the references, as there are many other application paper of DLR. There are several other places in the manuscript where an “e.g.,”

in front of the reference would be appropriate, as other papers could equally well be cited. The authors may check on this throughout the manuscript.

Thank you. This and others are fixed in the revision.

3. L40: hereinafter refer to > hereafter referred to as.

Thank you. This and others are fixed in the revision.

4. L44: the presence of cloudS

Thank you. This is fixed in the revision.

5. L59: in terms of > based on

Thank you. This is fixed in the revision.

6. L63: to estimation of > for the estimation of

Thank you. This is fixed in the revision.

7. L90: influencing > influences

Thank you. This is fixed in the revision.

8. L106: strictly quality controlled > strict quality controls

Thank you. This is fixed in the revision.

9. L140: hereinafter refer to > hereafter referred to as

Thank you. This is fixed in the revision.

10. L155: to have basis in physics > to be based on physics

Thank you. This is fixed in the revision.

11. L166: Circles represent data pairs > Circles represent hourly data pairs

Thank you. This is fixed in the revision.

12. L170: are in consistent > are consistent (inconsistent has the opposite meaning!)

Thank you. This is fixed in the revision.

13. L217: can overestimate > overestimates

Thank you. This is fixed in the revision.

14. L241 & L250: and that > and the one

Thank you. This is fixed in the revision.

15. L252 & L253 & L254 & L255: could underestimate > tend to underestimate

Thank you. This is fixed in the revision.

16. L269: three parameterization models > all three parameterization models

Thank you. This is fixed in the revision.

17. L278: improve accuracy > improve the accuracy

Thank you. This is fixed in the revision.

18. L279: this sentence sounds awkward and needs reformulation

Thank you. This sentence is deleted but a replacement is added in the revision: "Owing to limited data observed at seven CBSRN in China are used in establishing the parameterizations, the formulae presented in this study are mainly suitable to retrieve the downward longwave radiation in China."

19. L280: to establish > to be established

Thank you. Due to the sentence mentioned in L279 is deleted, this problem is also solved.

20. L286: whereas > however

Thank you. This is fixed in the revision.

21. L289: station > stations

Thank you. This is fixed in the revision.