Response to Reviewer 2 Comments

Scientific aspect:

1. The search for empirical expressions for longwave downwelling irradiance for China is a welcome contribution. The measurement of longwave down welling irradiance has been rare worldwide, and especially in China. In this sense, this reviewer does not demand the expansion of the scope to large regions. To build an empirical relationship between the longwave down welling irradiance with widely available climatic elements requires accurate irradiance measurements. The required accuracy is made not only of an instrumental accuracy, but also of the traceability to the international standard. This latter point is very important for any long-term observations, and is the basis for the Baseline Surface Radiation Network. This development comes from a bitter experience to realize serious differences among the longwave calibration methods practiced by many contries. It has become necessary to establish the global standard in longwave calibration, which is materialized as the World Standard Group of pyrgeometers at the World Radiation Centre in Davos. Within the BSRN, there was only one Chinese station, Xianghe, which jointed the BSRN, more than 10 years later than other sites, and ceased to operate already in 2015. The continued functioning of this site was an international wish. It is not a constructive direction for each country to establish own baseline radiation network. If this is done, however, like Chinese Baseline Radiation Network (CBSRN), its traceability to the World Standard must be established. This point is missing in the presented paper, reducing the trustworthiness of the accuracy of the proposed equations. The current status of the BSRN is summarized in Driemel et al. 2018, Earth Syst. Sci. Data, 10, 1491-1501. Li et al., 2013 may present the information on the CBSRN, but this literature is not accessible for most readers. Its main content can be introduced in the paper.

Thank you very much for your valuable comments. It is really true that the DLR measured at the CBSRN should traceable to the World Standard in order to improve its reliability and comparability compared to measurements from other radiation networks (e.g., BSRN). Fortunately, the pyrgeometers used in the CBSRN are irregularly calibrated via comparison with the reference CGR4 of China Meteorological Administration (CMA).

Therefore, in section 2.2 of the revision, two sentences and related references were added: "To assure the DLR measured at CBSRN is traceable to the World Radiometric Reference like that observed at Baseline Surface Radiation Network (Driemel et al., 2018), the IR02 pyrgeometers used in this study were calibrated against the reference CGR4 pyrgeometer (Kipp & zonen, the Netherlands) of China Meteorological Administration (CMA). The CGR4 can be traced to the World Infrared Standard by participating in the International Pyrgeometer Comparison organised by Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (e.g., Gröbner et al., 2014; PMOD/WRC, 2022)."

2. The empirical relationships under the cloudless sky are quite straightforward, as the depth of the atmospheric emission effectively reaching the surface the surface is quite thin as the authors pointed out. The mathematical shapes adopted in this sort of calculation are usually grey body emission. There are, however, at least two original proposals, which are independent of the graybody preoccupation. These original proposals are made by

Swinbank's 1963 QJRMS and Ruckstuhl's 2007 JGR papers, Swinbank is quoted in the manuscript but his originality is not appreciated.

Thank you very much for your valuable comments. The content between Line 39-44 in the manuscript is modified in the revision as: "Following the pioneering work of Ångström, numerous investigators have presented empirical relationships between effective atmospheric emissivity (hereafter referred to as emissivity) under clear-sky conditions and vapor pressure (e) (e.g., Brunt, 1932; Weng et al., 1993; Niemelä et al., 2001). Nevertheless, for a limited isothermal atmosphere emissivity would be less than unity and independent of temperature only if the atmosphere were of a constant greyness. In the real atmosphere, emissivity must, in principle, be temperature (Ta) dependent (e.g., Swinbank, 1963; Idso and Jackson, 1969). Moreover, some investigators even pointed out that the empirical emissivity depends on the dewpoint temperature (Td) (e.g., Berdahl and Fromberg, 1982), e and Ta (e.g., Brutsaert, 1975; Satterlund, 1979; Idso, 1981; Iziomon et al., 2003), relative humidity (∅) and Ta (e.g., Carmona et al., 2014) or even the total amount of water vapor (e.g., Ruckstuhl et al., 2007)."

3. The attempt to expand the empirical relationships to all sky conditions causes a problem, mainly owing to the diversity of the clouds and the limit in our observational documentation. Nevertheless, one of the earliest proposals was attempted by H. M. Bolz (1949) in Zeitschr. Meteorol. This is a systematic introduction of the effect of clouds. Relating to this matter, the description from Line 182 to Line 192 must be reformulated. It is necessary to present how the authors consider the shapes of Equations (5), (6) and (7) are justified, and how each independent variables offer the targeted results. There seem to be a slight confusion in expressing Greek variables also.

Thank you very much for your valuable comment. It is really a hard task to convert parameterization of the clear-sky DLR to 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) in the manuscript, 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 (%); $\alpha, \beta, \gamma, \delta,$ and ζ are regression coefficients, which were derived using the dataset of observations recorded at seven CBSRN stations between January 2011 and December 2020.

Formalities:

1. Generally, quoting earlier works for substantiating the point in the paper must be done carefully. Just quoting many papers does not support the point authors wish to make. As an example, let's take the first two sentences in the introduction, Line 28 to 32. The importance of the longwave downwelling radiation was not realized only in 1994 or 2020. These papers are rather recent papers in this subject. This reviewer suggests the authors to quote the first and most original paper on the subject and then several recent and best papers. Not all papers quoted in these lines do not necessarily represent the best knowledge of the present time.

Thank you for your comments, which urge us to pay more attention to the reference quoting in our future work. In this revision, We have added some important literature such as Idso and Jackson (1969), Wild and Cechet (2002) in the first paragraph of the Introduction. We also delete some literature that related less the object. Furthermore, we modified the unclear sentence in the Introduction, which responses in the comment 2 of "Scientific aspect", to improve the accuracy of expression in the Introduction.

2. Introduction can be shorter. Numerical detail can be summarily presented in Conclusions.

Thank you very much for your suggestion. As the main meaning of the last sentence in the **Introduction** is expressed in the **Discussion and conclusions**, it is deleted in the revision. ("This study represents an advance in comparison with previous work in terms of the following aspects: First, it not only recalculated the regression coefficients of the Brunt and Weng models, but also developed a new parametric formula suited for the estimation of DLR over China; 2) the hourly cloud fraction (CF) measured by a HY-WP1A Intelligent Weather Observation System was incorporated to considerably improve the handling of cloud effects in DLR retrieval under all-sky conditions; and 3) the spatial representativeness of the parameterization models over China was improved through use of measurements from the seven CBSRN stations in China"). After the modification, the **Introduction** in the revision seems more precise.

3. Line 44 to 49: in this discussion, Bolz's and Ruckstuhl's works can make a constructive contribution.

Thank you for your recommendation. Indeed, the work of Ruckstuhl (2007) gives us a lot of help and inspiration, which would not only improve our understanding in this study but also invoke our interesting of the greenhouse effects on the relationship between the DLR and (T_a, RH) in the future work.

4. Line 180, Table 2: Under Column Network/Site, Line Swinbank (1963), H. M. A. S. Diamantina in the Indian Ocean should be added to Aspendale and Kerang. The observation on board Diamantina over the Indian Ocean provided the measurement in very high humidity, and played an important role in generalizing Swinbank equation.

Thank you for your suggestion. This is fixed in the revision.

5. Line 185-191: There are confusions in Greek letters.

Thank you for your suggestion. This is fixed in the revision.

6. The analyses in Line 193 Section 4.3, and Line 236 Section 4.4 are well done and very useful.

Thank you for your approval.

7. Line 273-275: The seven CBSRN sites are all confined in the continental interior regions and do not represent the climate of the maritime regions. This bias should be considered.

Thank you for your comment.

Just as mentioned by the reviewer, within the BSRN, there was only one Chinese station, Xianghe, which ceased to operate in 2015. Fortunately, CMA has established the CBSRN in 2013, which consists of seven sites and plan to add other sites in the future. The CBSRN could fill up the deficiency of BSRN over China or even Eurasia to some extent. However, 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.

Due to the limited time of a revision phase, this suggestion is planned to be carried out in 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."

8. L373-379: The order of references, Liu, M. Q. et al. and Li, M. Y., et al. should be reversed. Likewise, Line 381-384: Niemelä et al., and Monteith can be reversed

Thank you for this suggestion. The order of references mentioned above and others are rearranged according to the alphabet of the first author's name.