Review GMD-2017-303

Comparison of observed and modelled longwave downward radiation (2010-2016) at the high mountain BSRN Izaña station

1. General comments:

The manuscript presents a comparison of calculated and observed longwave downward radiation (LDR) for cloud-free conditions at the BSRN Izaña station using the radiative transfer models libRadtran and MODTRAN. Differences (bias ± RMSE) between calculated and observed LDR for 1014 night-time cases in the 2010-2016 period were less than 5 Wm^{-2} and hence within the measurement uncertainty with the model calculations being higher compared to the observations. Discrepancies between models and observations for 1048 cloud-free day cases were slightly higher with the models yielding lower irradiances. These differences in the statistics between day and night are currently not yet understood. Finally, the models confirm the water vapor dependency of observations traceable to the World Infrared Standard Group (WISG) which has been postulated in earlier studies using windowless radiometers (e.g., Gröbner et al., 2014).

The LDR is the second largest component in the radiation budget, directly related to the greenhouse effect and hence of great importance. The accurate calculation of the cloud-free LDR is relevant in many applications. Therefore, the manuscript is significant for the community and hence appropriate for this journal. The manuscript is in general well-structured and clearly written. Graphics and tables are clear and the captions self-explanatory. Therefore, I would recommend publishing the article in GMD after minor – mainly technical - revisions.

2.) Specific comments

i) Cloud-free detection:

p.5: I wonder if no observational method for night time is available at this site which detects high level clouds more reliably than the Clear-Sky Index (CSI) or APCADA does. Can you comment on that? Moreover, did you really use APCADA (i.e., did you determine the diurnal and annual variability of *k* and did you calculate fractional cloud cover) or did you just use the original CSI from Marty and Philipona (2000) which only distinguishes between cloud-free and cloudy skies? Please specify. It seems to me that you used the CSI from Marty and Philipona (2000) → if this is true delete APCADA and the corresponding reference in the text.

ii) Solar effect on the LDR and differences in the bias between the day and night comparisons of observed and calculated LDR:

I assume that the LDR observations used in this study were shaded (according to the guidelines of BSRN), i.e. both pyrgeometers were installed on a solar tracker? It is a bit confusing because the authors state (on p.4, line 4, based on McArthur (2005)) that the CG4 filters all solar radiation and hence no shading is necessary (I see this statement anyways a bit more critical: the longwave irradiance in the direct beam of the sun is measured by any pyrgeometer and its magnitude depends on the cut-on of the filter and the solar insolation and hence on atmospheric conditions (e.g., water vapor content, cloudiness). In fact, a CG(R)4 has a higher cut-on (approximately at 4.5 µm) compared to a Eppley PIR (approximately at 4 µm) and hence the CG(R)4 measures less longwave irradiance from the sun which has been already reported in previous studies (e.g., Meloni et al., 2012). Nevertheless, a few Wm^{-2} originating from the long-wave irradiance in the direct beam of the sun will be observed by a CG(R) 4 and thus it should be also operated in shaded mode). In any case, state clearly if your pyrgeometers were shaded (e.g., on p.3, line 30: '…with a shaded and ventilated broadband Kipp&Zonen…', or on page 4, line 4 after the reference of McArthur (2005)).

If the pyrgeometers were not shaded (unlikely), the long-wave irradiance in the direct beam of the sun could be a possible explanation for the small differences in the bias between the results of the day and night comparisons of measured and calculated LDR (p.11, lines 20-21/p.12, lines 1-2 and Fig. 4 or Table 4) which are in fact consistent with the results in Dürr et al, 2005. If the observations are shaded, it is reasonable that the differences between day and night are caused by additional measurement inaccuracies during daytime as stated by the authors. However, an underestimation of the models due to inaccuracies in the model input parameters during

day time (e.g., inaccuracies in the observed temperature/humidity profiles due to different heating of the radiosonde sensors by solar radiation) could be also possible (instead of instrumental inaccuracies). Could you comment on that? I would add this option at the end of the paragraph (p.12, line 2).

Summary:

p.3, line 30 or p.4, line 4: Specify if the LDR observations were shaded or not.

p.4, line 2: Replace 'all solar radiation' by 'most of the solar radiation'

p.11, line 13-21: I would re-arrange this paragraph and start with the night-time results first, i.e. with line 16 (in the night the uncertainties are in general smaller because of the absence of solar radiation). Then describe the results for day time.

p.11, lines 20-21/p.12, lines 1-2: If the LDR observations were not shaded the previously mentioned impact of the longwave irradiance in the solar spectrum on the LDR observations should be stated and the publication of Meloni et al. (2012) cited. If the observations are shaded, I agree with the content (but I would use '…with additional instrumental inaccuracies during day time' on p.11 line 21/p.12, line 1). In addition, I would add a sentence about possible inaccuracies in the model input parameters during day time which may result in an underestimation of the models.

3.) Technical corrections

p.1, title: add 'cloud-free' between 'modelled' and 'longwave'.

p.1, line 4 and throughout the manuscript: 'libRadtran' instead of 'LibRadtran'.

p.1, line 4: Revise sentence: 'Results show an excellent….and simulations using the radiative transfer models (RTM) libRadtran and MODTRAN V6.' (delete 'similar for both models').

p.1, line 7: '…useful tools for the quality control of LDR observations…'

p.1, line 16: cloud cover is only one aspect; I would add 'cloud type'. Furthermore, water vapor is missing.

p.2, line 2: The CG4 is nowadays termed CGR4 → use 'CG(R)4 series'

p.2, line 2: put the reference of McArthur (2005) at the end of the sentence.

p.2, lines 3-4. I would delete this sentence. The specifications for the CG(R) 4 from Kipp&Zonen may not be representative for the other types of pyrgeometers listed previously.

p.2, line 6: delete here the reference of Ohmura et al. (1998).

p.2, line 9: Reference should be Ångström, also in the reference list.

p.2, line 11, use 'e.g.,' instead of 'i.e.'

p.2, line 17, 'Stefan-Boltzmann constant'

p.2, line 27: I would put 'as model inputs' at the end of the sentence.

p.3, line 28: I would term Section 3 as 'Observational Data and Methods', then Section 3.1 'Instrument and Measurements' and Section 3.2 'Cloud-free detection'

p.3, line 4: '…with values of +1.5 and –3.2 Wm^{-2} for night-time….'

p.3, line 12: rather use '…uncertainty assessment…' than '…quality assessment…'

p.3, line 13: '…temporal stability of the LDR observations…'

p.3, line 17: use 'location' instead of 'situation'.

p.3, line 21: I would use '…it has been actively contributing…'

p.3, line 21 and throughout the manuscript: an abbreviation should be define at its first occurrence in the manuscript, e.g., '…such as the Network for the Detection of Atmospheric Composition Change (NDACC; http://www.ndsc.ncep.noaa.gov/) since 1999, the Aerosol Robotic Network (AERONET, http://aeronet.gsfc.nasa.gov/) since 2004, the Total Carbon Column Observing Network (TCCON, http://www.tccon.caltech.edu/) since 2007,…'. Later, just use the abbreviation.

p.3, line 26: Revise reference (also in the reference list). Should be read 'WMO' or 'CIMO', I guess.

p.4, line 6: '… at the Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC).'

p.4, line 9: The reference is from 2002, I guess. Revise also in the reference list.

p.5, line 1: Here, I would use only the reference of Dürr and Philipona (2004) but only if you have really used APCACA (see my previous comments). Insert the reference of Marty and Philipona in line 4 (after 'at the station'). If you have used the CSI from Marty and Philipona (2000) replace APCADA and the corresponding reference with 'Clear- Sky Index (CSI) (Marty and Philipona (2000)' in line 1, p.5.

p.5, line 10: 'Stefan-Boltzmann'

p.5, line 10: ε_{AD} is an altitude-dependent emittance of a completely dry atmosphere (ε_{AC} is the apparent emittance of a cloud-free sky)

p.5, lines 11/12: Revise this sentence, e.g.: 'A CSI Index ≤ 1 and > 1 indicates cloud-free and cloud-sky, respectively.'

p.5, line 16: '… consists of…'

p.5, line 28: delete 'models'.

p.6, line 7: Hasn't the band model used in MODTRAN 6 a resolution of $0.1 cm^{-1}$?

p.7, line 10: The site of the radiosonde launch is located at sea level, more than 2000 m lower the IZO. I assume that you cut the profiles at the altitude of IZO to assimilate the profiles into the RTM?

p. 7, line 18: NDACC has been already defined on p. 3.

p.7, line 31: delete 'one'.

p.8, line 15: delete 'the'.

p.10, line 5: Did you average the observations over a certain time period (e.g., 30 minutes) in order to validate the RTM calculations? Or did you use the 1 min observations? Specify.

p.10, line 7: you may better use '… and R of 0.999, and are more consistent during nighttime'.

p.11, Table 4 (Caption): The number of day-time calculations given here (1075 cases) is not consistent with those given in the abstract, Section 5 (1048, p.10) and Section 6.

p.12, line 11: Could you specify what was changed in the location of the instrumentation in 2012?

p.14, line 3: 'supports'.

p.14, line 4: I would add 'However, the differences between day and night are currently not yet understood.'

p.17, line 37: Specify journal/meeting event of publication/presentation of Redondas and Cede.

References:

Dürr, B. and Philipona, R.: Automatic cloud amount detection by surface longwave downward radiation measurements, Journal of Geophysical Research: Atmospheres, 109, https://doi.org/10.1029/2003JD004182, 2004.

Dürr, B., Philipona, R., Schubiger, F., and 5 Ohmura, A.: Comparison of modeled and observed cloud-free longwave downward radiation over the Alps, Meteorologische Zeitschrift, 14, 47–55, https://doi.org/https://doi.org/10.1127/0941-2948/2005/0014-0047, 2005.

Gröbner, J., Reda, I., Wacker, S., Nyeki, S., Behrens, K., and Gorman, J.: A new absolute reference for atmospheric longwave irradiance measurements with traceability to SI units, Journal of Geophysical Research: Atmospheres, **119**, 7083–7090, 2014.

Marty, C. and Philipona, R.: Clear-sky index to separate clear-sky from cloudy-sky situations in climate research, Geophysical Research Letters, 27, 2649–2652, 2000.

McArthur, L.: Baseline Surface Radiation Network (BSRN) Operations Manual V2.1,World Climate Research Programme,wmo/td-no. 1274 25 ed., WCRP-121, 2005.

Meloni, D., di Biaggio, C., di Sarra, A., Monteleone, F., Pace, G., Sferlazzo, D.M., Accounting for the Solar Radiation Influence on Downward Longwave Irradiance Measurements by Pyrgeometers, J. Atmos. Oceanic Technol. **29**, 2012, doi: http://dx.doi. org/10.1175/JTECH-d-11-00216.1.