COMPARISON OF OBSERVED AND MODELED CLOUD-FREE LONGWAVE DOWNWARD RADIATION (2010-2016) AT THE HIGH MOUNTAIN BSRN IZAÑA STATION

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A 7-year (2010–2016) comparison study between measured and simulated longwave downward radiation (LDR) under cloud-free conditions was performed at the Izaña Atmospheric Observatory (IZA, Spain). This analysis encompasses a total of 2062 cases distributed approximately evenly between day and night. Results show an excellent agreement between Baseline Surface Radiation Network (BSRN) measurements and simulations with LibRadtran V2.0.1 and MODerate resolution atmospheric TRANsmission model (MODTRAN) V6 radiative transfer models (RTMs). Mean bias (simulated-measured) of <1.1% and root mean square of the bias (RMS) of <1% are within the instrumental error (2%). These results highlight the good agreement between the two RTMs, proving to be useful tools for the quality control of LDR observations and for detecting temporal drifts in field instruments. The standard deviations of the residuals, associated with the RTM input parameters uncertainties are rather small, 0.47 and 0.49% for LibRadtran and MODTRAN, respectively, at daytime, and 0.49 to 0.51% at night-time. For precipitable water vapor (PWV)>10 mm, the observed night-time difference between models and measurements is +5Wm^{-2} indicating a scale change of the World Infrared Standard Group of Pyrgeometers (WISG), which serves as reference for atmospheric longwave radiation measurements. Preliminary results suggest a possible impact of dust aerosol on infrared radiation during daytime that might not be correctly parametrized by the models, resulting in a slight underestimation of the modeled LDR, of about -3Wm^{-2}, for relatively high aerosol optical depth(AOD>0.20). These results have been recently published in GMD (García et al., 2018a).

SITE DESCRIPTION

The Izaña Atmospheric Observatory (IZA) is part of the Global Atmospheric Watch (GAW) programme and is managed by the Izaña Atmospheric Research Center (IARC) belonging to the Meteorological State Agency of Spain (AEMET). It is located in the Tenerife Island (The Canary Islands; 28º18' N, 16º29' W, 2.367 m a.s.l). Its location in the Atlantic Ocean and above a stable inversion layer, typical for subtropical regions, provides clean air and clear sky conditions most of the year, offering excellent conditions for calibration and validation activities. Since 2009, IZA is part of the BSRN (García et al., 2018b).

INSTRUMENTS AND MEASUREMENTS

The LDR measurements used in this study were taken by the Izaña BSRN (#61, IZA; http://bsrn.aemet.es (García et al., 2012) with a broadband Kipp & Zonen CG(R)4 pyrgeometer (hereafter CG(R)4) mounted on a sun tracker equipped with dome shading (Figure 1). These measurements have applied the recommended quality control by BSRN and we found that the LDR measurements are within the limits (Figure 2).

Figure 1.- Pyrgeometer Kipp & Zonen CG(R)4 installed on a sun tracker Owel INTRA 3 at Izaña BSRN

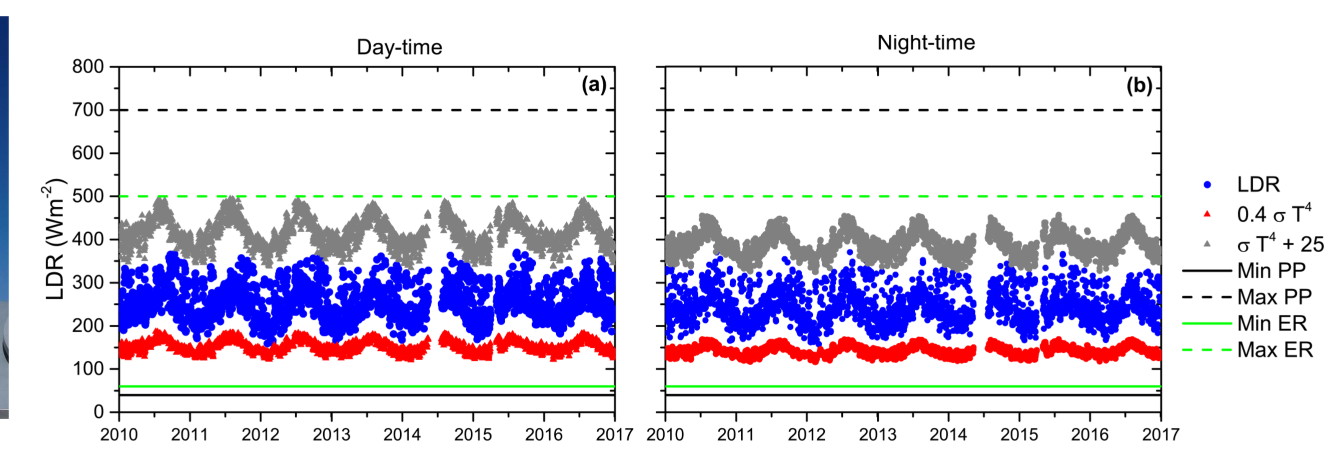

Figure 2.- The LDR time series obtained at (a) daytime and (b) night-time with a CG(R)4 pyrgeometer between 2010 and 2016 at IZA BSRN (blue dots). The black and green lines represent the physically possible (Min PP, Max PP) and extremely rare limits (Min ER, Max ER), respectively; the grey and red dots represent the upper (σT^4+25) and lower (0.4σT^4) limits, respectively, where σ is Stefan–Boltzmann constant (5.67 × 10−8 Wm^{-2} K^{-4}) and T is the air temperature in K.

RADIATIVE TRANSFER MODELS AND INPUT PARAMETERS

The simulations of surface LDR were determined with two RTMs: LibRadtran and MODTRAN. The two models were run using the same inputs, atmosphere and geometry in order to minimize. The rest of the inputs measured at IZA are:

- Radiosondes: temperature and relative humidity profiles (WMO GRUAM station #60018)
- PWV : the PWV has been take every 1 h obtained from GPS installed at IZA
- CO_2 and N_2O profiles: the volume mixing ratio (VMR) profiles of atmospheric CO_2 and N_2O trace gases were used. These were obtained from the monthly average profiles performed with the ground-based Fourier transform infrared spectrometer (FTIR) at IZA between 1999 and 2015
- CO_2 and N_2O in situ: since 2007 the CO_2 in situ measurements have been taken with the LICOR-7000 NDIR analyzer and the N_2O in situ measurements with a VARIAN GC-ECD 3800
- AOD: atmospheric aerosols have been included in the simulation process by means of the column integrated aerosol optical depth (AOD), extracted from *AERONET*
- Total ozone column (TOC): TOC measurements with Brewer spectrometer at IZA

We have estimated the theoretical uncertainty for the LibRadtran and MODTRAN LDR simulations due to the uncertainties in the input parameters. The uncertainties of the PWV and AOD dominate the total uncertainty with respect to the other components (see Table 1).

Table 1.- Estimation of type A uncertainties in Wm^{-2} and in % (in brackets), sensitivity (%), and bias (Wm^{-2}) of the difference between non-perturbed and perturbed LDR simulations (simulation − (simulation + δ)) with LibRadtran and MODTRAN models. The combined uncertainty is calculated as the root square sum of all the uncertainty components.

Uncertainty component	LDR (daytime) SD of residuals W m^{-2} (%) (sim + δ)	LDR (daytime) regression (sens/bias) (%)/W m^{-2}	LDR (night-time) SD of residuals W m^{-2} (%) (sim + δ)	LDR (night-time) regression (sens/bias) (%)/W m^{-2}
libRadtran model				
AOD	0.30 (0.09)	−0.73/1.65	0.23 (0.08)	−0.46/1.01
TOC (DU)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
PWV (mm)	0.84 (0.46)	−1.20/6.26	0.86 (0.48)	−1.42/6.89
CO_2 in situ (ppm)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
N_2O in situ (ppb)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
Temperature profile	< 0.01 (< 0.01)	< 0.01/< 0.01	0.03 (< 0.01)	< 0.01/< 0.01
RH profile	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
Combined uncertainty (u)	*0.89 (0.47)*		*0.88 (0.49)*	
MODTRAN model				
AOD	0.39 (0.16)	0.59/−1.37	0.27 (0.10)	0.42/−0.91
TOC (DU)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/0.03
PWV (mm)	0.85 (0.46)	−1.18/6.19	0.91 (0.50)	−1.48/7.03
CO_2 in situ (ppm)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
N_2O in situ (ppb)	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
Temperature profile	< 0.01 (< 0.01)	< 0.01/< 0.01	0.02 (< 0.01)	< 0.01/< 0.01
RH profile	< 0.01 (< 0.01)	< 0.01/< 0.01	< 0.01 (< 0.01)	< 0.01/< 0.01
Combined uncertainty (u)	*0.93 (0.49)*		*0.95 (0.51)*	

BSRN AND MODELED LDR COMPARISON

We present the comparison between LDR measured with BSRN and simulated, considering the available and coincident cloud-free BSRN at daytime and night-time. A total of 1048 measurements at daytime and 1014 measurements at night-time. The observations were averaged over 30 min, in order match the flight time of the radiosonde over IZA. In particular, we averaged over 11:00–11:30 and 23:00–23:30 UTC for daytime and night-time measurements, respectively. The results obtained show that both models have a very similar behavior and yield similar performances. Both models underestimate the LDR at daytime by −1.73 Wm^{-2} (−1.1%) for BSRN/LibRadtran and by −1.79 Wm^{-2} (−0.7%) for BSRN/MODTRAN (Table 2). We found that the absolute differences between BSRN measurements and simulations depend mainly on water vapor and dust aerosols (Figure 3). Both models tend to underestimate LDR (up to 5 Wm^{-2}) in the case of daytime measurements with PWV<9 mm. An LDR bias around zero is observed for higher PWV, although it is necessary to emphasize that the number of data in this PWV range (between 4% and 5%) is much lower. At night-time, the dependence of LDR bias with PWV shows a negligible bias under dry conditions (PWV<6 mm), and a slight overestimation of both models (up to +5 Wm^{-2}) for higher PWV values.

	Daytime MB	Daytime RMS	Daytime R^2	Night-time MB	Night-time RMS	Night-time R^2
BSRN/libRadtran	−1.73 (−1.1 %)	6.52 (2.6 %)	0.970	0.15 (0.1 %)	4.41 (1.8 %)	0.969
BSRN/MODTRAN	−1.79 (−0.7 %)	6.30 (2.5 %)	0.969	1.14 (0.5 %)	4.53 (1.9 %)	0.968
libRadtran/MODTRAN	0.94 (0.4 %)	1.26 (0.5 %)	0.999	1.00 (0.4 %)	1.23 (0.5 %)	0.999

Table 2.- Statistics for the LDR bias between LibRadtran and MODTRAN simulations and BSRN LDR at IZA (in Wm^{-2}) performed with daytime (1048 cases) and night-time (1014 cases) data in the period 2010–2016 (MB, mean bias; RMS, root mean square of the bias; R^2). The statistics for the relative bias are in brackets (in %).

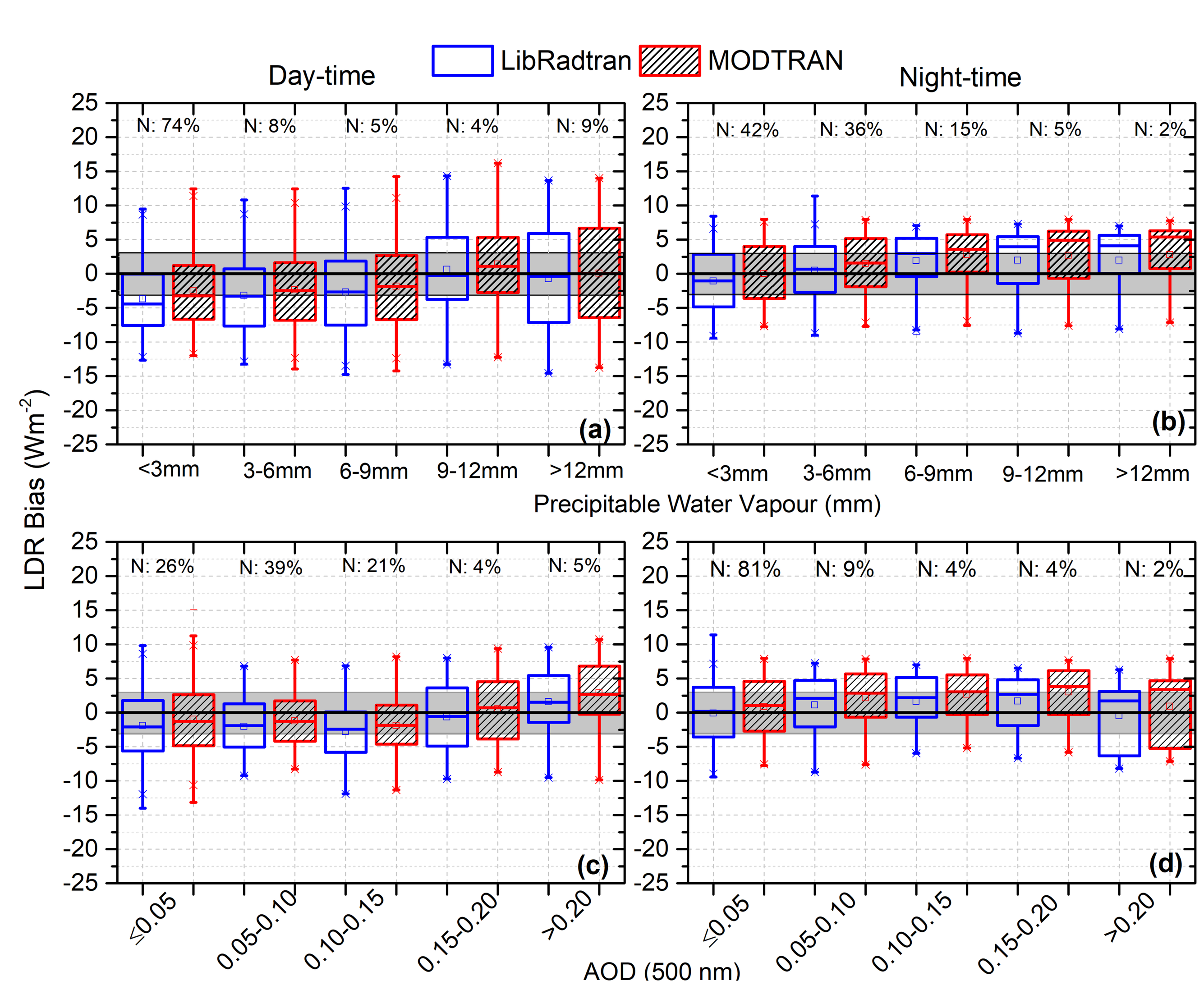

Figure 3.- Box plot of mean LDR bias (model–BSRN in Wm^{-2}) vs. PWV (mm) (a) at daytime (b) at night-time, and vs. AOD (500 nm) (c) at daytime and (d) at night-time between 2010 and 2016. Lower and upper boundaries for each box are the 25th and 75th percentiles; the solid line is the median value; the crosses indicate values out of the 1.5-fold box area (outliers); and hyphens are the maximum and minimum values. The blue boxes represent LibRadtran/BSRN and the red ones represent MODTRAN/BSRN. N indicates the number the measurements in each interval. Shadings show the range of instrumental error (±3 Wm^{-2}).

CONCLUSIONS

- The agreement between measurements and simulations is excellent and very similar for both models. The mean bias (simulations − BSRN measurements) is −1.73 Wm^{-2} (−1.1 %) and 0.15 Wm^{-2} (0.1%) for LibRadtran/BSRN at daytime and night-time UTC, respectively, and −1.79 Wm^{-2} (−0.7 %) and 1.14 Wm^{-2} (0.5%) for MODTRAN/BSRN at daytime and night-time, respectively. Both comparisons showed a RMS < 3% at daytime and < 2% at night-time. The mean bias and RMS are lower than the instrumental uncertainty (± 3 Wm^{-2}; 2%).Both models have demonstrated to be very useful tools for LDR quality control and for assessing the impact of atmospheric constituents on the Earth–atmosphere energy balance.
- The observed night-time difference between models and measurements of +5 Wm^{-2} for PWV > 10 mm supports previous measurements studies that report the existence of an offset between the World Infrared Standard Group of Pyrgeometers (WISG). Concerning the possible influence of aerosols, and specifically atmospheric dust, on LDR differences between models and measurements, our preliminary results show a greater underestimation (about −3 Wm^{-2}) of modeled LDR as AOD increases (AOD > 0.2) during daytime and dry atmosphere (PWV < 5 mm).

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