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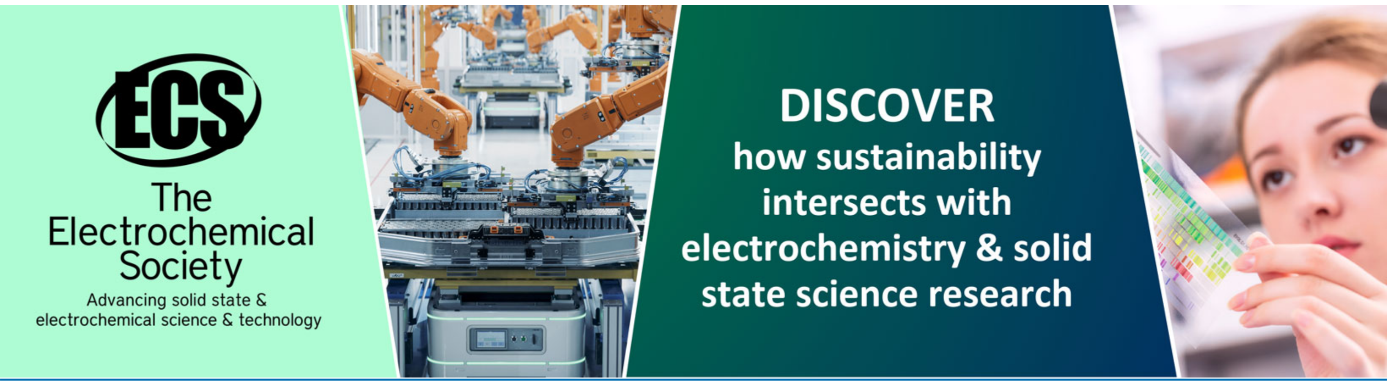

Effect of water vapor in the SW and LW downward irradiance at the surface during a day with low aerosol load

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Abstract. The aim of this study is to analyze the effect of the water vapor content on the downward irradiance measured at the Earth's surface. For that purpose, downward irradiance values have been estimated with the radiative transfer model libRadtran in different spectral ranges: shortwave (SW: 285-2800 nm) and longwave (LW: 3500-50000 nm), and with different water vapor content in the column. These simulations have been made for Évora, Portugal, the August 4, 2012, a cloud-free day and with low aerosol optical depth.
The comparison between the simulated irradiance with different water vapor contents shows differences in both spectral ranges. For SW, the irradiance reaching the surface increases when the water vapor content decreases, obtaining an increase of up to 4 %, 2 % and 1%, corresponding the largest increases to the smallest values of water vapor. For LW, the behaviour is the opposite, the irradiance decreases when the water vapor content decreases, obtaining a decrease of up to 10 %, 4 % and 2 %, corresponding the largest decreases to the smallest values of water vapor. The effect of water vapor in the aerosol radiative forcing (ARF) has also been analyzed, obtaining relative difference values of up to 2.5 % for SW and 35 % for LW.

1. Introduction

Water vapor is an important atmospheric component, influencing the Earth's climate in many ways. It plays a key role in the global radiation budget, in energy transport mechanisms in the atmosphere as well as in photochemical processes. As for the radiative budget, the water vapor is a key element, contributing directly by means of infrared radiation absorption emitted by the Earth's surface and the atmosphere, or indirectly by means of microphysical processes favoring the formation of clouds, and affecting the size, shape and chemical composition of aerosols and thus modifying the aerosol role in the radiative forcing.

Estimations of downward irradiance provided by a reliable radiative transfer code, as libRadtran model [1], using different water vapor contents in the column are of great interest in order to analyze the water vapor effects in the irradiance and in the radiative balance of the Climate System. Therefore, the aim of this study is to analyze the effect of different water vapor contents in the simulated downward irradiance values at the surface in different spectral ranges: shortwave and longwave. This work is organized as follows: a brief description of the study region and instrumentation is presented in section 2; data set and methodology are provided in section 3; results are discussed in section 4. Finally, conclusions are given in section 5.

2. Study region and instrumentation

The location of Évora radiometric station is shown in Figure 1. It is installed in the Évora pole of the Institute of Earth Sciences in Évora, whose geographical coordinates are: 38.6º N, 7.9º W, 293.0 m a.s.l. This station is located near the center of a small town with about 60,000 inhabitants, about 100 km eastward from the Atlantic west coast. Évora is influenced by different aerosol types, namely urban as well as mineral and forest fire aerosol particles [2-7].

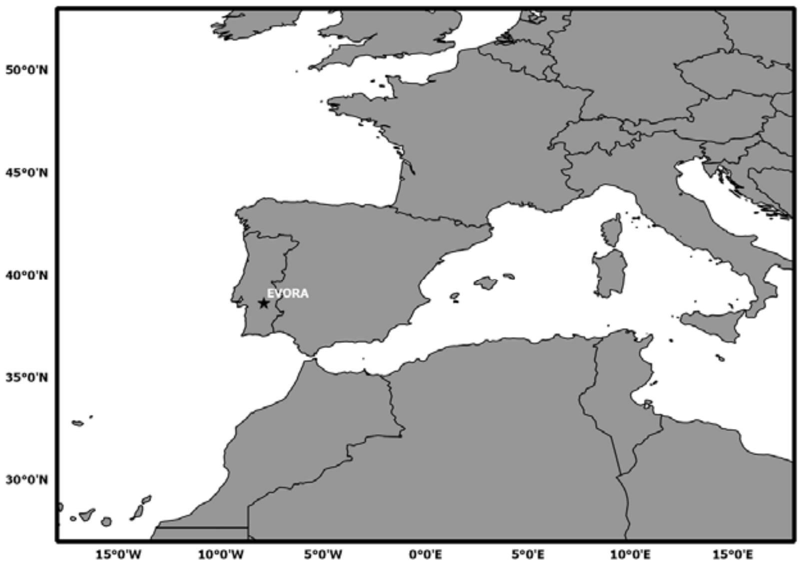

Figure 1. Iberian Peninsula showing the location of Évora station.

Évora station is managed by the Évora pole of the Institute of Earth Sciences, at the University of Évora (Portugal). This station is equipped with an Eppley Black & White pyranometer, an Eppley pyrgeometer and CIMEL CE-318 sunphotometers, among several other radiometric instruments. An Eppley Black & White pyranometer measures the global shortwave irradiance (285-2800nm), providing 10 minutes averages of 10 seconds sampling time. The uncertainty associated with this instrument is estimated to be about 5% encompassing calibration, temperature and cosine characteristics of the radiometer. The Eppley pyrgeometer is a broad-band infrared radiometer of wide spectral range (λ> 4000 nm), and measures the downward flux density of atmospheric radiation at the horizontal surface with a temporal sampling of 10 minutes. The CIMEL CE-318 sunphotometer is integrated in the NASA AERONET (Aerosol Robotic NETwork) network [8], make direct sun measurements with a 1.2º full field of view at 340, 380, 440, 500, 675, 870, 940 and 1020 nm. In addition, measurements of sky radiances in the almucantar and principal planes geometries, at 440, 675, 870 and 1020 nm, are also performed by this instrument. The channel of 940 nm channel is used to estimate the precipitable water vapor [9]. This instrument is operating continuously in Évora since 2003. More details about this instrument are given by Holben et al. (1998) [8]. The parameters obtained from Cimel sunphotomers and used in this study are aerosol optical depths (AOD), Ångström α exponent (440-870) (α), single scattering albedo (ω), asymmetry factor (g) and precipitable water vapor column (PWC). These parameters have been used as input to the radiative transfer model.

3. Dataset and methodology

In this study, the effect of different water vapor content on the downward irradiance values at the surface in different spectral ranges, shortwave (SW: 285-2800 nm) and longwave (LW: 3500-50000 nm), has been analyzed. This was done through the comparison of 10-min averaged estimations of downward irradiance using different water vapor contents, provided by libRadtran model [1]. These estimations have been made for Évora, Portugal, the August 4, 2012, a cloud-free day and with low aerosol optical depth.

The inputs of libRadtran model are: AERONET level 2.0 aerosol optical properties, AERONET precipitable water vapor column (PWC) and surface albedo, as well as total ozone column provided by the Ozone Monitoring Instrument (OMI). The values of the total column water vapor used in the simulations are: true value (corresponding to AERONET PWC), true value – 2, true value – 5 and true value – 10. The total column water vapor for that day ranges between 18.1 and 20.2 mm, being the average value equal to 19.4 mm. The level 2.0 aerosol properties used as input were: α and β Ångström coefficients (α is obtained here for the 440 and 870 nm wavelength range and the turbidity β from α and value and aerosol optical depth, AOD, at 1020 nm). Also, the asymmetry parameter (the average value of this parameter for the four wavelengths available (440, 675, 870 and 1020 nm) was used). The level 2.0 AERONET single scattering albedo, ω(λ), dataset is quite scarce since only cases with AOD at 440 nm greater than 0.4 are considered, which is very unusual in Évora. Therefore, a value of aerosol single scattering albedo equal to 0.95 for all wavelengths was used in model calculations of irradiance. The value of 0.95 is the average value in the level 2.0 in Évora and it is consistent with previous observations reported for this station [7]. The surface albedo values considered are those described in Obregón et al. (2015) [10], for the same station. The other variables taken into account in setting up the model simulations are the following: the extraterrestrial irradiance values (obtained from Gueymard (2004) [11]), profiles of temperature, air density, ozone and other atmospheric gases (taken from the midlatitude summer/winter standard atmospheres) and the radiative transfer equation solver (the discrete ordinate method of Stamnes et al. (2000) [12], DISORT2 with 16 streams, was used). To obtain the 10 minutes input values, interpolations from the existing AERONET properties values were made.

The water vapor can modify the aerosol role in the radiative forcing, and therefore the effect of water vapor in the aerosol radiative forcing (ARF) has also been analyzed. ARF is the effect of atmospheric aerosol particles on the radiation balance at a given level and indicates the magnitude of change in the radiative balance due to changes in aerosol physical/optical properties. The ARF is defined here as the difference between the downward global solar irradiance at the surface in the presence of aerosols, I_d, and the same quantity in background/baseline conditions, I^0_d, (Eq. 1), assuming that, in background/baseline conditions, the aerosol optical depth is null, as:

$$ARF = I_d - I_d^0 \; . \qquad \text{Eq. 1}$$

In addition, SW and LW radiations were measured by an Eppley pyranometer and an Eppley pyrgeometer, installed at the Évora Geophysics Center Observatory in Évora. Only cloud-free measurements corresponding to solar zenith angle lower than 80º have been considered in this study.

4. Results and discussion

The aim of this section is to analyze and to compare the effect of different water vapor contents on downward irradiance at the surface in both spectral ranges, SW and LW. Figures 2 and 3 show the temporal evolution of 10-min averaged downward irradiance values simulated with different water vapor contents, for SW and LW, respectively. It is shown that there are notable differences in both spectral ranges. For SW, the irradiance reaching the surface increases when the water vapor content decreases. For LW, the behaviour is opposite, the irradiance decreases when the water vapor content also decreases. This behaviour is also seen in Figure 4, where relative differences between the simulated irradiances with lower water vapor content respect to the simulated irradiances with the true water vapor content are shown. These relative differences indicate that SW irradiance increase up to 4 %, 2 % and 1%, respectively, corresponding the largest increases to the smallest values of water vapor, and the LW irradiance decrease up to 10 %, 4 % and 2 %, respectively, corresponding the largest decreases to the smallest contents of water vapor.

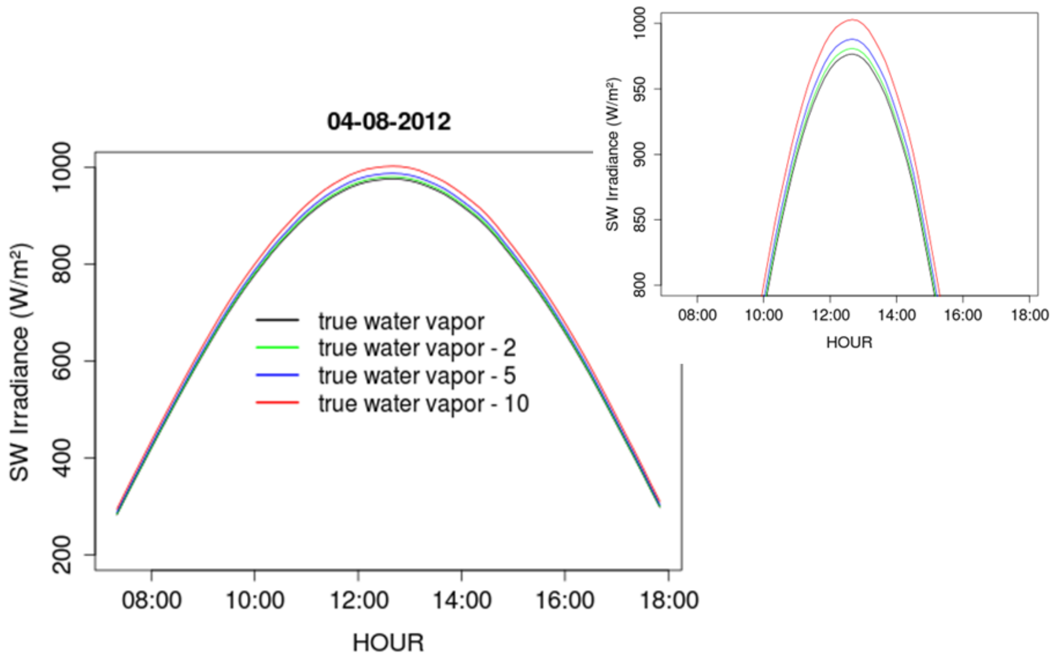

Figure 2. Temporal evolution of simulated SW irradiance with different water vapor contents.

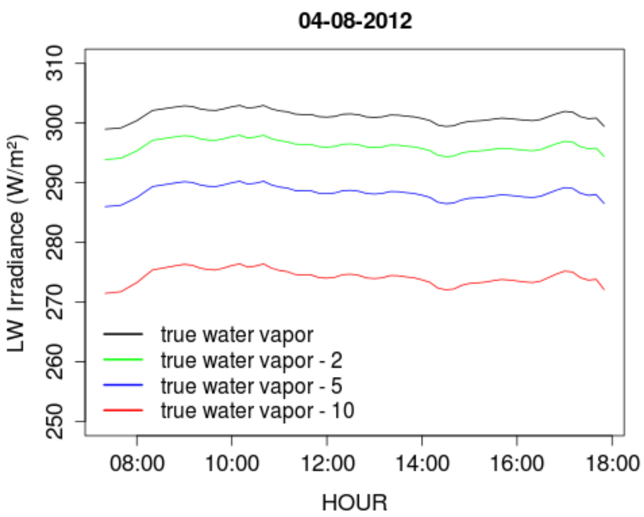

Figure 3. Temporal evolution of simulated LW irradiance with different water vapor contents.

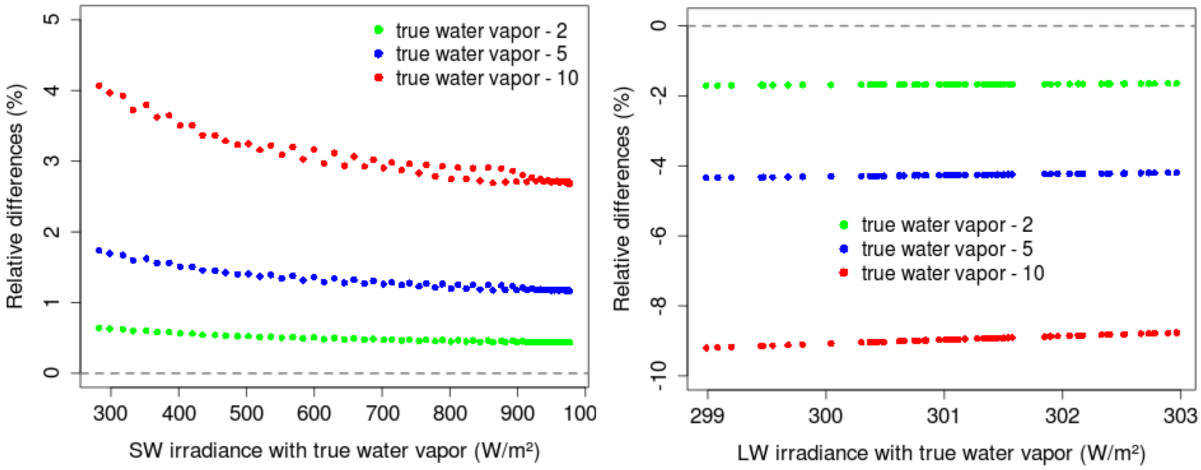

Figure 4. Relative differences between the simulated irradiances with true water vapour -2, true water vapour -5 and water vapor -10, with respect to the simulated irradiances with the true water vapor content. The figure on the left corresponds to SW and the figure on the right corresponds to LW.

The effect of water vapor in the ARF has also been analyzed, obtaining relative differences values, between the ARF calculated with lower water vapor content respect to the ARF calculated with the true water vapor content, of up to 2.5 % for SW and 35 % for LW (figure 5). These values also indicate that the water vapor affects to SW and LW irradiances, but this effect is greater in LW. ARF values in LW may vary about 35% when the true value of total water vapor -10 is used.

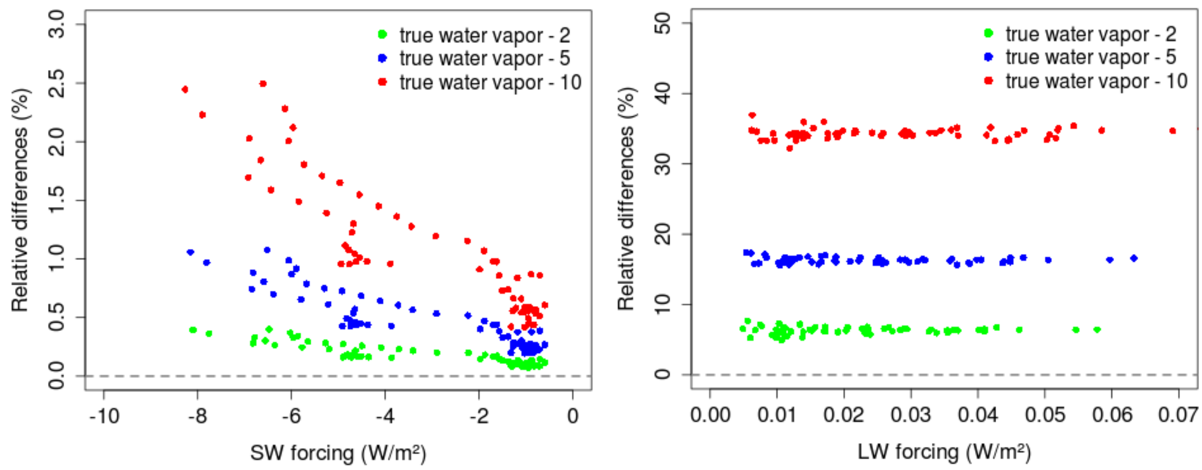

Figure 5. Relative differences between the ARF calculated with true water vapour -2, true water vapour -5 and water vapor -10, with respect to the ARF calculated with the true water vapor content. The figure on the left corresponds to SW and the figure on the right corresponds to LW.

5. Conclusions

This study contributes to the study of the effect of different water vapor contents on downward irradiance at the surface in different spectral ranges, shortwave and longwave The effect of the water vapor was analyzed through the comparison between 10-min averaged values of downward irradiance at the surface simulated with the libRadtran radiative transfer code and from different values of the total water vapor content in the column. From this comparison it can be concluded that the SW irradiance reaching the surface increases when the water vapor content decreases, whereas for LW the behaviour is opposite, i.e., the irradiance decreases when the water vapor content decreases.

This study shows the significant influence of water vapor content on the SW and LW irradiance measured at the Earth's surface, being more important in the LW. Therefore, it is concluded that, in order to obtain accurate estimations of the irradiance, the model must be fed with highly reliable values of the water vapor content.

Acknowledgments
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