Assessment Of The Radiative Feedbacks In An On-Line Coupled Model Over The Iberian Peninsula

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Abstract. The effects of atmospheric aerosol over the Earth's climate are produced mainly by their optical, microphysical and chemical properties, which condition the radiative budget of the Earth. In this sense the objective of this work is to assess whether the inclusion of aerosol radiative feedbacks in the on-line coupled WRF-Chem model improves the modelling outputs over the Iberian Peninsula. For that purpose, the methodology bases on the evaluation of modelled aerosol optical properties by observational data under different simulation scenarios. The results indicate that although there is only a slight improvement in the simulation results when including the radiative feedbacks, the BIAS and the correlation coefficients are improved for some stations and regions. The largest improvements are found for the vertical distribution of aerosols, with improvements of more than 8% in the vertical representation of the backscatter coefficients.

Keywords: aerosols, radiative feedback, model, WRF-Chem, AERONET, MODIS, EARLINET, Iberian Peninsula.

INTRODUCTION

Atmospheric aerosols together with greenhouse gases and clouds are the main forcing agents of the climate system, modifying the radiative budget. The principal mechanisms by which aerosols influence the Earth radiation budget are scattering and absorbing solar radiation (the so-called "Aerosol-Radiation Interactions") and modifying clouds and precipitation, thereby affecting both radiation and hydrology (the so-called "Aerosol-Cloud Interactions"). The uncertainty of the aerosol effects over the Earth radiative budget is much higher than any other climate-forcing agent. This happens because the physical, chemical and optical aerosol properties are highly variable in space and time scales due to the aerosol particles short-lived and non-uniform emissions. Moreover, the radiative forcing by anthropogenic aerosols is thought to be of comparable magnitude to the positive forcing resulting from the increase of greenhouse gases concentrations [1]. With the aim of reducing this uncertainty and estimating the radiative forcing causes for this forcing agent, the study of atmospheric aerosols by chemistry-climate models is needed. Realistic simulations of the aerosol-radiation and aerosol-clouds interactions requires the use of models where the interactions of aerosols, meteorology, radiation, and chemistry are coupled in a fully interactive manner [2].

Hence, the object of this work **is to assess the representation of aerosol optical proprieties by an online-coupled model (WRF-Chem) and to determine whether the inclusion of aerosol radiative feedbacks improves the modelling outputs over the Iberian Peninsula.**

MODELS AND DATA

A. WRF-Chem: An On-Line Regional Chemistry-Climate Model

The evaluated data comes from regional air quality-climate simulations performed using the WRF-Chem online-coupled meteorology/chemistry model [3]. The modelling domain covers all Europe, but for the purpose of this work data from the Iberian Peninsula with a resolution around 0.2º has been extracted for two important aerosol episodes in the year 2010 (a Saharan desert dust outbreak and a forest fires episode). The simulations are run for two different scenarios differing in the inclusion (or not) of aerosol radiative feedbacks, denoted NRF and RF, respectively.

B. Satellite data: Moderate Resolution Image Spectrometer (MODIS)

The MODIS Aerosol Products monitor the ambient aerosol optical thickness over the oceans globally and over a portion of the continents. These data have a spatial resolution of a 10x10 1-km (at nadir)-pixel array. There are two MODIS Aerosol data product files: MOD04_L2, containing data collected from the Terra platform; and MYD04_L2, containing data collected from the Aqua platform. The MXD04_L2 provides full global coverage of aerosol properties from the Dark Target (DT) and Deep Blue (DB) algorithms [4]. The variables used from MODIS are estimated applying the DB algorithm and these variables are: aerosol optical depth at 0.55 µm for both ocean and land and Angstrom exponent for 0.55 and 0.86 µm over the ocean.

C. Ground-based data: Aerosol Robotic Network (AERONET)

The data used from AERONET are aerosol optical depth (AOD) at different wavelengths (AOD440, AOD675, AOD870 and AOD1020 nm) and Angström exponent (AE440/870 nm) from the Iberian Peninsula stations available in 2010: Autilla, Barcelona, Burjassot, Cabo da Roca, Cáceres, Évora, Granada, Huelva, Málaga and Sagres.

D. Ground-based data: European Aerosol Research Lidar Network (EARLINET)

The EARLINET data used are the backscatter profiles at 355, 532 and 1064 nm. The only station with available data for the studies cases in the Iberian Peninsula during the year 2010 is Granada.

METHODOLOGY

The evaluation of the simulations has been performed by using classical statistics. The individual model-prediction error or bias (e_i), the spatial and temporal mean bias error (MBE), mean absolute error (MAE) and the spatial and temporal correlation coefficient (r) have been calculated.

RESULTS AND DISCUSSION

For the comparison between model output and MODIS data (Figure 1), the results indicate a general slight improvement for AOD in the case of including the radiative feedbacks in the model and a slight worsening for the Angström exponent. For AOD, the model outputs present low values of temporal and spatial mean bias both for NRF and RF simulations, but for the latter the bias is reduced. For the fire episode, generally, the bias is lower than for the dust episode. However, the fire episode shows a peak of positive bias over the fire area, thus the model overestimates AOD for fire particles for both simulations, but this may be influenced because MODIS underestimates AOD levels. The bias improvement for RF simulation with respect to NRF is quantified in 0.3% for both episodes. Regarding the correlation coefficient, both episodes show similar values of this statistic, which are higher than for Angström exponent. Generally, for the Angström exponent, the model tends to overestimate the values and underestimate the variability of this variable. However, for some days, for the highest values of this variable, the model produces a slight underestimation of the mean value. This occurred for both episodes and may be related to the fact that the size distribution of the aerosol function within WRF-Chem considers a medium size of particles, smaller for dust and larger for fires particles. On the other hand, the correlation coefficient presents worse values than for AOD. For this variable, the bias improvement for RF simulations is not very noticeable.

As well as for MODIS, for the comparison between model output and AERONET data, the results indicate that the best-represented variable is AOD. For the dust and the fire cases, the model underestimates the high levels of AOD. All stations have a similar behaviour with similar bias values except for Huelva station, where the biases are higher. It is important to notice that for all stations the bias is higher for low wavelengths. In both cases, the Angström exponent is overestimated for low levels and underestimated for high levels due to the model Angström exponent values is more or less constant. For the fire case, special attention is paid to Autilla station (AERONET station closest to the Portuguese fires), where the radiative feedback inclusion produces a great improvement of the bias values.

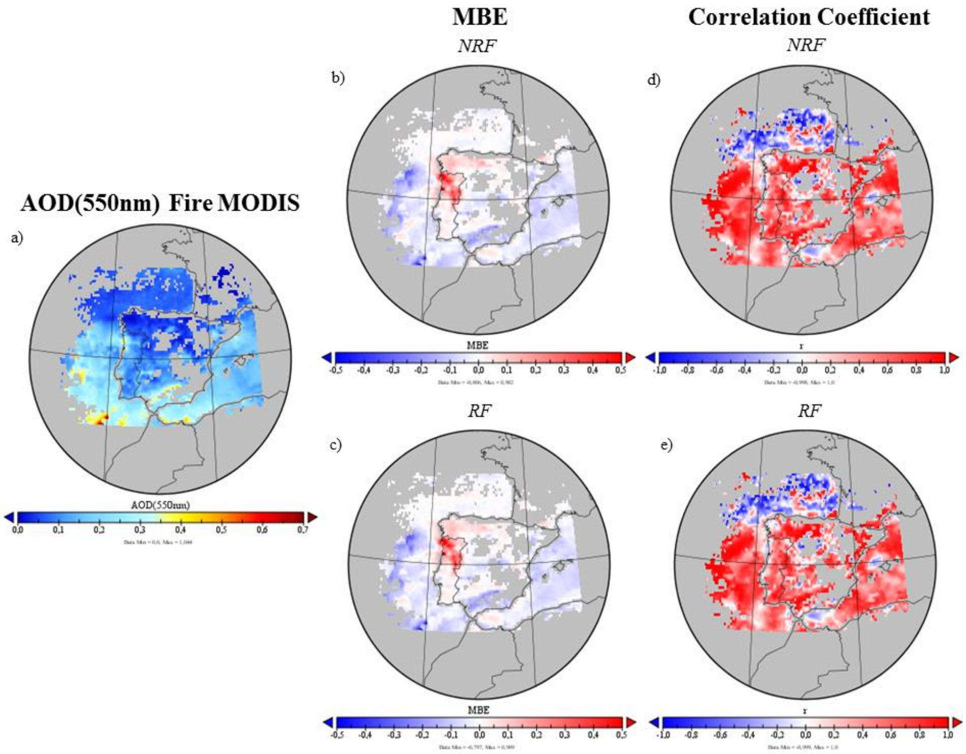

FIGURE 1. AOD at 550nm model output vs. AOD at same wavelength MODIS data from Aqua Platform for fire case. a) AOD MODIS values. b) Temporal MBE for NRF simulations. c) Temporal MBE for RF simulations. d) Correlation Coefficient for NRF simulations. e) Correlation Coefficient for RF simulations.

For the comparison between model output and EARLINET data (Figure 2), the results show a general improvement around 8% in the representation of vertical aerosol profiles when the radiative feedbacks are taken into account. For low wavelengths the backscatter profile is better represented.

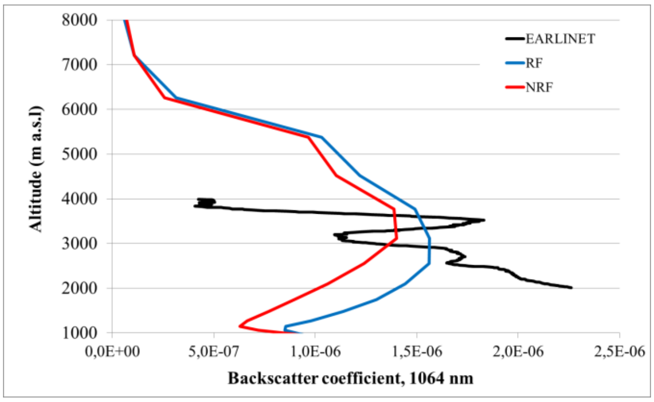

FIGURE 2. Model output vs. EARLINET data of backscatter coefficient at t 1064 nm for 05/07/2010 at 21:00 p.m.

CONCLUSIONS

For the spatial distribution the best-represented variable is AOD. For this variable the bias and correlation coefficient values are better than for AE. Concerning the improvement of RF simulation, although there is not a general significant improvement, the BIAS, the MBE and the correlation coefficient are improved for some stations and regions, usually the nearest to the emission sources of aerosol particles, where the main aerosol radiative effects can be found. The representation of aerosol vertical distribution improves when the radiative feedback simulation is included.

It is important take into account these consideration to improve the time-efficiency when running the simulations, because the inclusion of radiative feedbacks in the simulations has a notable increase of the computational time. The improvements observed, in particular related to the vertical distribution of aerosols, fully justifies the inclusion of radiative feedbacks in WRF-Chem on-line coupled model and the much higher time devoted to running the simulations.

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