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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Modeling of Saharan dust outbreaks over the Mediterranean by RegCM3: case studies" *by* M. Santese et al.

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Dear Referee#2,

many thanks for your comments and suggestions some of which are the subject of a work on progress. We have done our best to fulfill your suggestions in order to improve the paper. Answers to your comments are reported below and can also be found in the marked copy of the revised manuscript attached as supplement file. The revised paper has also been changed in accordance with the comments of Referee#1

Major comments:

1. Model description: It does not look like that there has been any significant model development, since the authors refer extensively to previous publications. While this is fine for the most part, I would like to know more about the assumptions made regarding the treatment of dust. For example the authors state in the introduction that "sign and magnitude of the direct dust radiative forcing are controlled by the dust optical properties, which depend on the dust size distribution and refractive index. The latter in turn depends on the mineral composition and particle mixing state". This leads to my questions: What are the assumptions made regarding optical properties?

Details about the assumptions on the dust treatment have been added in the revised paper in addition to few comments on the main goal/differences of this paper with respect to previous papers on the use of RegCM3. In particular, the following sentences have been added in the revised paper:

"….In this paper, RegCM3 is coupled with a radiatively active aerosol model with online feedback on the radiation scheme (Zakey et al., 2006, Konare et al., 2008; Todd et al., 2008; Zhang et al., 2009), and for the first time, it is used to investigate the aerosol radiative forcing (at solar and thermal wavelengths) and related climate effects during African dust intrusions over the central Mediterranean. Note that the inclusion of the aerosol feedback both at solar and thermal wavelengths can lead to a decrease of the bias between modeled and observation-based atmospheric parameters….."

"….Note that compared to the work of Zhang et al. (2009) that is related to the simulation of dust aerosol over East Asia, our simulations also include anthropogenic aerosols…."

"…The dust module has a size spectrum from 0.01 to 20.0μm, which is divided into 4 size-bins, each covering part of the whole spectrum of particle diameter: i.e. the fine (0.01-1.0 μm), accumulation (1.0-2.5 μm), coarse (2.5-5.0 μm), and giant (5.0-20.0 μm) particle mode. The evolution of each bin is described by a prognostic equation for the dry size of the dust particle (Zakey et al., 2006; Solmon et al., 2006)…"

"….The dust SW radiative effect is calculated using asymmetry factor, single scattering albedo, and mass extinction coefficient obtained from Mie calculations. The refractive indices of mineral dust aerosols for the relevant SW spectral windows are taken from the OPAC database (Hess et al., 1998). In the LW domain, dust effects are accounted for by introducing the dust emissivity (and hence absorptivity) according to the parameterization of Kiehle et al. (1996). The dust LW emissivity is calculated according to: (1) where D=1.66 is a diffusivity factor, b(z) is the dust burden (gm) of a given layer and is the mass absorption coefficient calculated using Mie theory for the relevant LW spectral windows, for each size bin and using LW refractive indices consistent with Wang et al. (2006). The OPAC dataset allows the calculation of dust optical properties at 61 wavelengths between 0.25 and 40μm, providing the real and imaginary parts of the refractive indices for each wavelength range. In our study we use the wavelength range from 0.2 to 4.5 μm. Figure 1 shows (a) single scattering albedo and (b) asymmetry factor versus wavelength retrieved from Mie calculations for the four size bins. The plots of Figs. 1a-b are in satisfactory accordance with the corresponding ones by OPAC dataset and with AERONET data (e.g. Bergamo et al., 2008). …."

1-bis. And what is the sensitivity of the results regarding the optical properties? Since the results show that SW and LW radiative forcing partially compensate each other, one important question that a model like this could investigate is: How robust are the findings on overall radiative forcing when the optical properties are varied within the range of their uncertainties? The size distributions should be looked at since this may help to explain the underestimation of dust load after transport. If the particles sizes are simulated too large, the removal due to gravitational settling might be overestimated.

As previously mentioned, in this paper we have, for the first time, tested the RegCM3 performance with the interactive aerosol model by also including the anthropogenic aerosol component and the aerosol effect in the LW spectral range. In addition, one of the paper's main goals is to test the model parameterization of the dust and the anthropogenic aerosol component during a dust event over the Mediterranean. Work

is on progress to test the model sensitivity to grid spacing and to size distribution and optical properties of dust particles. These studies will be the subject of a forthcoming paper in order to not lengthen too much the present study.

2. Regional climate model versus global model: It would be useful to highligt which processes can be represented more accurately with RegCM3 compared to a global model. The authors mention on page 19408 that aerosol effects vary within few tens of kilometers and conclude that high resolution regional climate models are necessary to resolve this. While I agree with this statement in general, I am wondering if the 50 km resolution is actually high enough to do so. Also please add information on the model time step.

See answers to 1-bis comments. In addition the following sentences have been added in section 2.3 of the revised paper:

"…. It is worth noting that the grid spacing of 50 km used in this test study is not much higher than the ones used by some GCMs with an aerosol module. Nevertheless, we believe that the selected grid spacing does not represent a limiting factor of the paper's main scope. However, our modelling system can operate at smaller grid spacing. ….."

"…The model time step is of six hours …"

3. Section 3.3: The comparison of lidar measurements and model calculation shows that the model underpredicts the extinction coefficient in Lecce. The authors attribute this to "weak long range transport". What does this exactly mean? Are the wind fields wrong? However, on page 19394 the authors conclude that the wind patterns are captured well. Are the emissions too low? Are there biases in the prediction of the size distribution? The paper would be greatly improved if this discussion were deepened. Given that the underprediction occurs in the lowest 3 km it looks more like this is due to the missing anthropogenic aerosol contribution.

We believe that the missing of the anthropogenic aerosol contribution can be significant. So, the discussion has been improved in the revised paper:

"…….Thus, the larger extinction coefficients retrieved at Lecce by lidar measurements may also be an indication of weak long range transport of dust. Note that dust particles affect all the aerosol column few hours after the onset of the dust event, in accordance with lidar measurements, (e.g. Pavese et al., 2008). The underestimate of the anthropogenic aerosol amount also may represent a contributing factor: morphological and elemental analyses on particulate matter samples collected at Lecce show that the anthropogenic fine mode aerosol, mainly composed of nitrate, sulfate, and carbon particles, can represent more than 50% of the aerosol load even during dust outbreaks (Bellantone et al., 2008). …."

4. Page 19402, line 7: Which aerosol optical and microphysical properties are meant here?

The sentence has been changed as follows:

"…The different contribution of dust and anthropogenic particles, which varies with the distance from the particle sources, is responsible for the different variability range of FEs over Sahara and Europe, as clearly revealed by Table 1, where mean FEs over Europe and Sahara are reported..….."

5. Case study for 17 and 24 July: The results for 17 and 24 July look qualitatively quite similar, what is the point in showing both of these? If nothing new is added, one of the cases should be omitted, which would reduce the number of figures.

As mentioned, one of the paper's main goal is to test the model performance during dust events over the Mediterranean. Therefore, we believe that it is convenient to show results referring at least to two days. In addition, the comparison of Table 1 and 2 shows that the interactive aerosol effect can significantly vary from day to day. So, we believe that it is convenient to have in the paper 17 and 24 July data.

6. Section 5, Discussion on aerosol radiative feedbacks, page 19403, line 14: What is

meant by "internal model variability"? Throughout this paragraph there it is mentioned that the results are dependent on "simulation assumptions". What does this mean? Figures 13 and 14 show that simulations REF and Exp1 are slightly different.

The discussion has been improved by adding results on ground wind speed and aerosol extinction coefficient changes. The sentence regarding the "internal model variability" has been deleted. Then, the following sentences have been added in the revised paper: "…. Aerosol effects on the atmospheric dynamics and hence on dust production and advection toward Europe are responsible for the marked dependence over the whole simulation domain of aerosol CB values on the simulated experiment. Figure 11e-f shows the daily-averaged differences between REF and Exp1 ground wind speeds (WS) for 17 and 24 July, respectively and it is worth noting that color-coded plots are very patchy: daily-averaged WS differences take positive and negative values that vary from -6 m/s up to 6 m/s either over Sahara or Europe. Hence, surface wind speeds markedly changed between the interactive- and non-interactive cases. In particular, the comparison of Fig. 11a and Fig. 11e, and of Fig. 11b and Fig. 11f, shows that WS differences are markedly large over the domain areas significantly affected by dust transport. Daily values of ground WSs averaged both over the whole simulation domain and for the regions below and above 35ïĆř N are given in Table 1 and 2 for the REF-and the Exp 1-simulation, respectively. The domain-averaged WS difference is 0.015 and -0.014 m/s on 17 and 24 July, respectively, despite the large values of local WS differences. In addition, the mean WS difference is -0.002 and -0.052 m/s on 17 and 24 July over the western Africa domain located from 10ïĆř W to 15ïĆř E, where main dust sources are located. Therefore, the decreased CB of the REF simulation is probably associated with less efficient dust production induced either by the lower ground wind speeds and by the increased stability due to dust-forced surface cooling (Zhang et al., 2009), as outlined below.…."

6-bis Supposedly simulation REF is closer to reality as it includes radiative feedback. Does this improve the quality of the simulation?

As we have mentioned in the introduction of the revised paper:

"... the inclusion of the aerosol feedback both at solar and thermal wavelengths can lead to a decrease of the bias between modelled and observation-based atmospheric parameters. ...."

However, the comparison of experimental data with REF-simulation data could result worse than that with Exp1-simulation data, as a consequence of the uncertainties on aerosol properties. We believe that Figs. 13 and 14 show that interactive aerosol effects are quite dependent on site location and AODs. In addition, Fig.13d shows that large local changes of the aerosol vertical distribution may not significantly affect the local vertical distribution of temperature.

7. Simulation Exp2: With this simulation the impact of radiative forcing of mineral dust alone should be isolated. The authors conclude that mineral dust has a significant role. However this conclusion is not surprising as they state earlier that anthropogenic aerosol contribution might be underestimated. Please comment on this.

We believe that the comparison of REF and Exp2 simulation allows isolating the mineral dust effects. In addition, the Exp2-simulation indicates that the model probably underestimates the anthropogenic aerosol contribution over the Mediterranean and this result must be accounted for in future studies. As we have mentioned, for the first time in this paper, RegCM with the interactive aerosol module that accounts for anthropogenic aerosols in addition to dust particles, is used to investigate a dust event over the Mediterranean.

Minor comments: 1. page 19399, line 9: Notation "–(10-5) W/m2". Looks confusing to me. I suggest replacing it with "-10 to -5 W/m2".

Done

2. The multi-panel figures are very small and too low resolution. They need to be improved to make them publication quality.

Done

Please also note the Supplement to this comment.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 19387, 2009.