4.2 Saharan Dust over the Eastern Mediterranean: Model Sensitivity

Pavel Kishcha, Slobodan Nickovic, Eliezer Ganor, Levana Kordova and Pinhas Alpert

Abstract 3D-dust distributions, daily predicted by the Tel Aviv University Weather Research Center, are used by the Ministry of Environmental Protection to distinguish between natural and anthropogenic aerosols. Two different dust prediction systems were used to perform a sensitivity experiment and to compare the accuracy of the models. The first one was the original DREAM model with four dust particle size classes (0.7, 6.1, 18.0 and 38.0 μm); only the first two classes have a radius less than 10 μm and can be used in comparisons with PM10 measurements. The second model used was the modified DREAM model (DREAM-8) with a more detailed set of dust particle size classes with a radius of between 0.1 and ~7 μm (0.15, 0.25, 0.45, 0.78, 1.3, 2.2, 3.8, and 7.1 μm). The sensitivity experiment was carried out by using a quantitative comparison between PM10 measurements of surface dust concentrations and those predicted by models, for the high dust activity season in Israel, from February to June 2006. Quantitative comparisons showed that the use of eight particle size classes including four less than 1 μm in dust modelling, instead of only two classes, improves dust forecasts.

Keywords Forecast, PM_{10} measurements, Saharan dust

1. Introduction

3D-dust distributions of the Saharan dust transport over the Mediterranean region are daily predicted by the Tel Aviv University Weather Research Center and displayed on the web-site (http://wind.tau.ac.il/dust8/dust.html). The Israeli Ministry of Environmental Protection uses the forecasts to distinguish between natural and anthropogenic aerosols. As found by Kishcha et al. (2007), the use of four particle size bins in the dust modelling instead of only one size bins improves dust forecasts. This study was aimed at evaluating dust distributions predicted by modified DREAM model with a more detailed set of eight dust particle size classes, in order to better understand the model's capabilities for providing reliable dust forecasts. Provided by the Israeli Ministry of Environment Protection, the PM10 measurements for three different sites in Israel (Beer-Sheva (31.3° N, 34.8° E), Tel-Aviv University (32.1° N, 34.8° E) and Carmiel (32.9° N, 35.3° E) were used for

model evaluation. The period under investigation was that of maximum dust activity in the Eastern Mediterranean, from February to May 2006.

2. Dust Prediction Systems

Two different dust prediction systems were used to perform a sensitivity experiment and to compare accuracy of the models. The first one is the original DREAM model, and the second one is the modified DREAM model (DREAM-8) with a more detailed set of dust particle size classes, as described below. The four-particle-size original DREAM model incorporates the state-of-the-art parameterizations of all the major phases of atmospheric dust life such as production, diffusion, advection and removal (Nickovic et al., 2001). Dust productive areas in the model are specified using the US Geological Survey (USGS) data of 30 seconds resolution on land cover. For each soil texture class, the fractions of clay and silt are estimated with four particle size radii of 0.7, 6.1, 18.0 and 38 μm respectively. In DREAM, the dust cycle is described by a set of K-independent Euler-type concentration equations allowing no inter-particle interactions, where $K = 4$ indicates the number of particle size class. The area covered by the model is 20° W to 45° E and 15° N to 50° N. The model has a horizontal resolution of 0.3° and 24 vertical levels between the surface and ~15 km. One can see, however, that only the first two size classes in the original DREAM model have their radii less than 10 μm, which could be used in comparisons with PM10 measurements. These fine particles could be transported far away from their sources in Sahara by means of intensive cyclones, which are responsible for dust transport over the Mediterranean. The other two coarse particle classes are deposited near their sources because of their weight. In order to improve 3D-dust forecasting, the modified version of DREAM model, which is called hereafter DREAM-8, with a more detailed set of eight dust particle size classes between 0.1 and ~7 μm, has been recently developed (Nickovic, 2005; Pérez et al., 2006). All eight dust particle size classes (0.15, 0.25, 0.45, 0.78, 1.3, 2.2, 3.8, and 7.1 μm) contribute to dust concentrations on comparing with PM10 measurements.

3. PM_{10} Measurements

The 24-hour dust forecasts were compared with PM10 measurements, taken at the following three different sites in Israel: Beer-Sheva (31.3° N, 34.8° E,), Tel-Aviv University (32.1° N, 34.8° E,) and Carmiel (32.9° N, 35.3° E,), which are located in the southern, central and northern parts of Israel respectively. PM10 surface aerosol concentrations for the high dust activity season in Israel, from February to June 2006, were used for comparisons with model data. The dust models, used in this study, produce forecast of Saharan dust, which is transported from the Sahara into the Mediterranean. No local air pollution is included in the models. On the other hand, PM10 measurements include all kids of atmospheric aerosols both natural and anthropogenic. To compare correctly PM10 vs model data, we have to distinguish between mineral dust, transported from the Sahara, and local PM10 aerosols. Without conducting some chemical analysis this is not a simple task. To get around this problem we used the following approach. When aerosol concentrations retrieved from PM10 measurements were highly correlated with each other at different sites, this was the evidence that we deal with aerosols from remote sources, i.e. from the Sahara desert. As estimated, for example, for days with PM10 > 100 μg/m^3, the correlation is higher than 0.5 between any two PM10-sites. On the contrary, low correlation between PM10 measurements taken at different sites is the evidence of local aerosols. In particular, for days when PM10 < 100 μg/m^3, the correlation is about 0.2. Therefore, for those days without significant dust, i.e. when PM10 < 100 μg/m^3, we could characterize an average level of local aerosols by estimating their mean and standard deviation. The threshold of local PM10 aerosols was determined as their mean plus standard deviation. As estimated, the threshold in Tel-Aviv (59.7 μg/m^3) is higher than that in Beer-Sheva (56.6 μg/m^3) or in Carmiel (48.7 μg/m^3). Only PM10 measurements, which exceeded the threshold of local aerosols, have been compared with model data.

4. Quantitative Comparisons Between Model and PM_{10} Data

As an illustration, Figure 1a shows a comparison between 24-hour model-predicted surface dust concentrations and PM10 measurements taken at Tel Aviv during March 2006. It is clearly seen that for dusty days, when Saharan dust is transported over Israel, dust aerosols dominate PM10 concentrations. With respect to model capabilities to produce dust forecasts, we see that the old DREAM model frequently underestimates PM10 data. DREAM-8 produces more accurate forecasts than the old DREAM. The correspondence between model data and PM10 measurements higher than the threshold of local aerosols over Tel-Aviv, Israel, was evaluated by means of scatter-plots (Figure 1b). The bisector curve, shown in the scatter-plot, indicates ideally accurate forecasts: the points on or close to the bisector represent the best correspondence between the model-simulated data and the PM_{10} measurements.

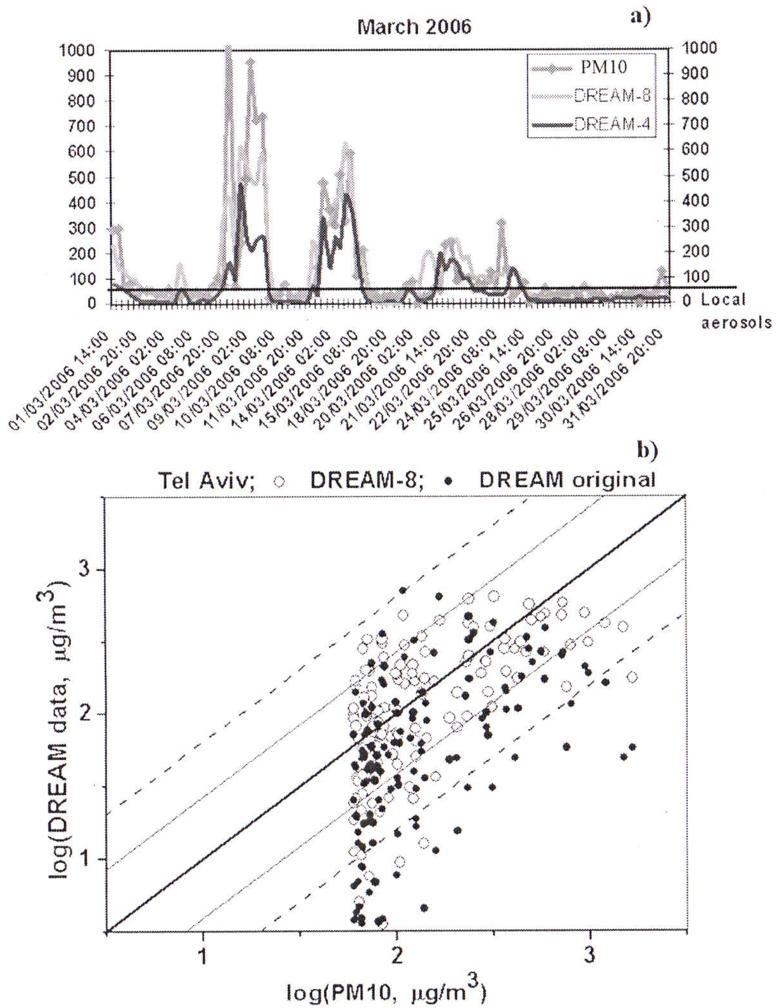

Fig. 1 a – the comparison between PM10 and model data at Tel Aviv during March 2006. The horizontal line corresponds to the level of local aerosols. b – The scatter-plot between the common logarithm of PM10 and model data at Tel Aviv obtained during the period from February to June 2006. The dashed lines show the root-mean-square interval of the original DREAM deviations from the bisector, while the thin lines show the root-mean-square interval of DREAM-8

The root-mean-square interval of deviations of points from the bisector can be used in order to characterize the range of forecast accuracy. One can see that the root-mean-square interval for DREAM-8 is half as wide as that for the original DREAM (Figure 1b). This conclusion is supported by the results of the correlation analysis. A high correlation 0.54 between PM10 and DREAM-8 data was obtained, in contrast to that of 0.27 for the old DREAM model. This suggests the advantage of DREAM-8 compared to the original DREAM.

5. A Typical Route for Dust Transport to Israel

As described by Alpert and Ziv (1989), a typical route for dust transport into Israel in spring is from the Sahara desert, through Egypt, into the Eastern Mediterranean. Sometimes, typical dust transport into the Eastern Mediterranean ends with an anti-clockwise movement of dust around the Eastern Mediterranean, based on DREAM-8 predictions of dust transport and wind distributions between 13 and 14 March 2006. The dust transport over Gulf of Suez, Sinai, Israel to Cyprus and Turkey was associated with a low-pressure system centred over Greece. The SeaWIFS satellite picture corroborates model simulations by displaying dust around the Eastern Mediterranean cost on March 13 (not shown). Note that Ganor (1991) described a similar event of counter-clockwise dust transport around the Eastern Mediterranean, observed on April 29, 1987. For the dust event on 13–14 March 2006, the comparison between PM10 measurements of surface dust concentration, taken in Tel Aviv with 24-hour model-predicted data, shows that both models produced dust forecasts of quite good accuracy.

6. Unusual Clockwise Dust Transport

We noticed that, sometimes, Saharan dust could be transported to the Eastern Mediterranean in an unusual long-distance clockwise movement, from the western part of the Sahara desert through Southern Europe towards Alps and then to the Eastern Mediterranean, based on DREAM-8 predictions. This dust transport started on April 5, 2006 (Figure 2a). The synoptic situation was characterized by the specific structure consisting of an extensive high, dominating the whole of North Africa and the western Mediterranean, and an intensive low over the eastern Atlantic, near the Iberian Peninsula. The low significantly affected the western part of the Sahara desert, as revealed by the wind distribution at 3,000 m altitude. A strong airflow with speeds higher than 20 m/s moved from the Western Sahara to the Western Mediterranean. Such a synoptic situation produced favourable conditions for the development of a heavy dust storm accompanied by an intensive dust intrusion into southern Europe. On the following day, April 6, as the low shifted eastward from the Atlantic across Europe, dust was transported through the central Mediterranean, Italy, Greece, into the Black Sea (Figure 2b). On April 7, dust movement shifted eastward in such a way that dust reached Cyprus and, eventually, the Eastern Mediterranean (Figure 2c).

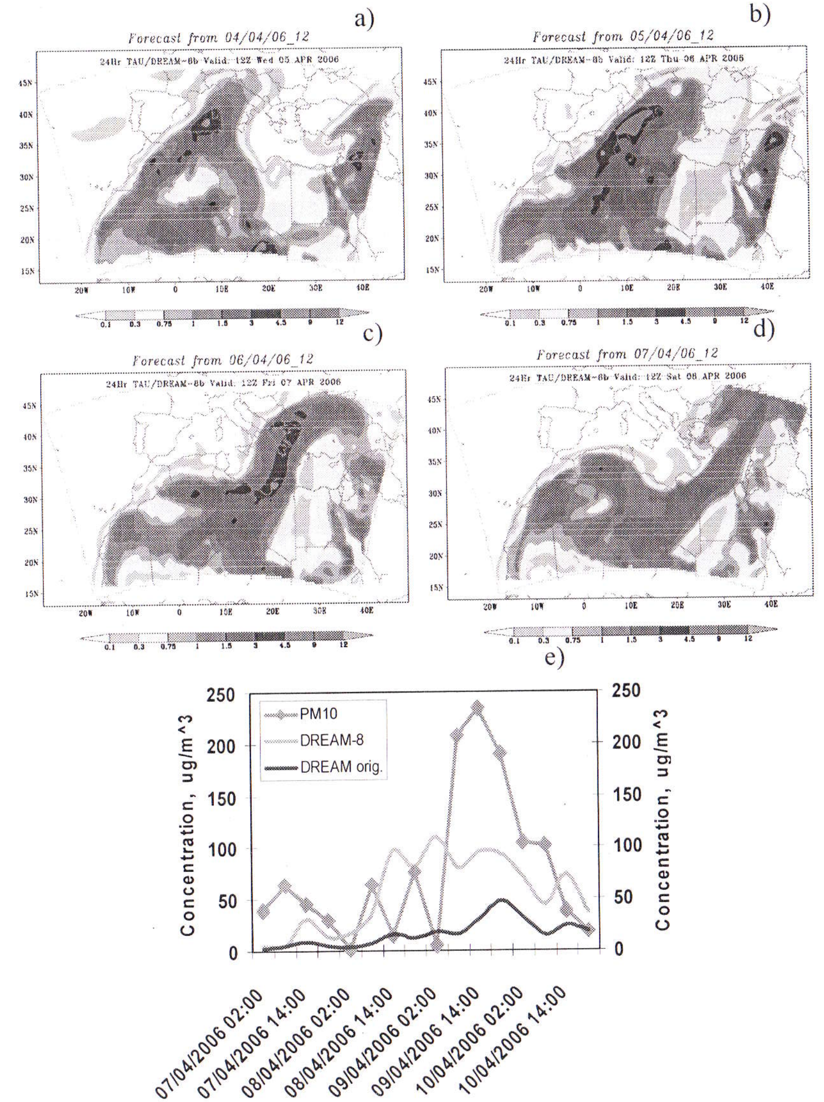

Fig. 2 a–d are dust loading predicted by DREAM-8 on 5–8 April 2006 respectively, e – is the comparison between PM10 and 24-hour model-predicted data at Tel-Aviv

On April 8, however, another intensive low developed over the Eastern Mediterranean near Turkey, which caused strong wind over Lybia. As the low shifted eastward between 8 and 10 April, the typical counter-clockwise dust transport was observed over the Eastern Mediterranean and Israel (Figure 2d). The aforementioned dust event was unusual for the season in question – the spring. In fact, it was a combination of clockwise long-distance transport through southern Europe supplemented in the end, on April 7, 2006, with counter-clockwise transport through Egypt. This situation suggests that both fine dust particles from the Western Sahara and coarse dust particles from the Eastern Sahara could have been presented in the atmosphere. The comparison between PM10 measurements with model-simulated data clearly shows the advantage of DREAM-8 compared to the original DREAM (Figure 2e). In particular, the maximum PM10 concentration is about 240 $\mu g/m^3$, while the one of DREAM-8 is about 100 $\mu g/m^3$. We also see that the original DREAM model hardly displays dust. This suggests that the use of eight dust-particle-size classes including four less than 1 µm (DREAM-8) instead of two classes (the original DREAM model) could be significant for long-distance dust transport predictions.

7. Conclusions

The quantitative comparison between the PM10 measurements and those, predicted by the DREAM models, showed that the models are capable of giving mainly acceptable forecasts. For DREAM-8, the correlation between model data and PM10 data was found to be higher than that for the original DREAM, indicating that the use of eight-particle size bins in the dust forecasting instead of only two size bins improves dust forecasts. The advantage of DREAM-8 compared to the original DREAM is particularly significant for long-distance dust transport predictions. During spring 2006, Saharan dust was transported into the Eastern Mediterranean not only in the typical route (from the Sahara desert through Egypt into Israel), but also in an unusual clockwise movement from the western part of the Sahara desert through Southern Europe into Israel.

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Discussion

D. Syrakov:

What is the threshold in your first figure? What does it mean? Is there concentrations less then it and how have you determined it?

P. Kishcha:

The dust models, used in this study, produce forecast of Saharan dust, which is transported from the Sahara into the Mediterranean. No local air pollution is included in the models. On the other hand, PM_{10} measurements include all kids of atmospheric aerosols both natural and anthropogenic. To compare correctly PM_{10} vs model data, we have to distinguish between mineral dust, transported from the Sahara, and local PM_{10} aerosols. Without conducting some chemical analysis this is not a simple task. To get around this problem we used the following approach:

When aerosol concentrations retrieved from PM_{10} measurements were highly correlated with each other at different sites, this was the evidence that we deal with aerosols from remote sources, i.e. from the Sahara desert. As estimated, for example, for days with PM10 > 100 $\mu g/m^3$, the correlation is higher than 0.5 between any two PM10-sites. On the contrary, low correlation between PM_{10} measurements at different sites is the evidence of local aerosols. In particular, for days when $PM_{10} < 100\ \mu g/m^3$, the correlation is about 0.2.

Therefore, for those days without significant dust, i.e. when $PM_{10} < 100\ \mu g/m^3$, we could characterize the average level of local aerosols by estimating their mean and standard deviation. The threshold of local PM_{10} aerosols was determined as the mean plus standard deviation. Only PM_{10} measurements, which exceeded the threshold of local aerosols, have been compared with model data.

S. Hanna: In your statistical evaluations (e.g. correlation coefficients) of the observed and modeled concentrations, you applied a threshold to the observed concentrations but not to the modeled concentrations. Shouldn't you also apply the same threshold to the modeled concentrations? This is, the statistical calculations should use only those data pairs where both observed and modeled concentrations exceed the threshold.

P. Kishcha: Two models were evaluated by using PM_{10} measurements: DREAM-8 and the old DREAM. It was obtained that the old DREAM model underestimated dust concentrations, while DREAM-8 produced more accurate forecast. We could not apply the same threshold to model-simulated data as we did to PM_{10} measurements: otherwise we could remove low model values produced by the old DREAM model, and thereby artificially improve its forecasts.

G. Kallos: In order to use eight size classes in dust particles you need to have an accurate source area classification. Do you have such data available or you use just what was in the model version developed at the University of Athens several years ago (SKIRON project)?

P. Kishcha: In DREAM-8 with eight particle size bins we use the same dust sources as in the original DREAM model with four particle size bins (and also in SKIRON). Ref.: Nickovic et al., JGR, 18, 113–118,129, 2001.

Y.P. Kim: What was the dry deposition algorithm in the model?

P. Kishcha: The dry deposition of dust particles was parameterized according to the scheme of Georgi JGR, 9794-–9806, 1986.

4.3 Air Quality Ensemble Forecast Coupling ARPEGE and CHIMERE over Western Europe

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Abstract The quality enhancement of the results encountered on numerical weather prediction ensemble runs has encouraged the air quality modellers' community to test the same methodology to foresee air pollutants concentrations in the atmosphere. In air quality forecast it is important to know in advance if the event exceedences of a certain threshold value will happen in order to implement mitigation measures concerning air pollutant emission. The ensemble approach allows giving this information within a probability range.

Within this work both perturbation on the circulation model and the chemical transport model will be implemented. The ensemble system is composed by the numerical weather prediction model ARPEGE, the meteorological model MM5 and the chemical transport model CHIMERE. Meteorological perturbations will be addressed firstly by a set of ten ensemble members derived by the ARPEGE model, plus a control run, which will force MM5 simulations. Since the concept of air pollution ensemble forecast is not the same than the one for meteorology, we propose here an original approach for the chemistry-transport model perturbations based on previously done CHIMERE sensitivities studies: focus will be made on plausible emissions scenarios and different daily emissions profiles, boundary layer evolution, vertical mixing and photolysis rates. The ensemble based simulations will cover July and August 2006, each includes the heat wave period that influenced the weather and air quality conditions of central Europe.

Keywords Chemical, ensemble, forecast, ozone

1. Introduction

The chaotic nature of the atmosphere arises in the numerical resolution of the equations that present different solutions for slightly different values of the initial conditions.

Based on the definition of the chaotic dynamical system given by Lorenz (1963), the ensemble forecast concept was initially used to estimate the dependence of weather forecasts uncertainty to the initial boundary conditions errors (Hamill et al., 2000) by the ECMWF on Europe, and by the NCEP on the United States of America. Nowadays numerical weather prediction based on operational ensembles