Simulation of a dust transportation event in Istanbul through a regional climate model

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Abstract

Dust transportation from arid zones can influence urban air quality and have an impact on climate variables. In this study, we simulated a dust incursion from Saharan Desert to Istanbul. The dust transportation occurred on March 22, 2018. At first, the transportation pattern was simulated using a regional climate model. The model is RegCM, which is developed by The Abdus Salam, International Centre for Theoretical Physics. The study domain was selected to include both dust source and receptor locations. Community land model version 4.5 was used to define surface-climate interactions. Although burden was highest at March 22 18:00, the highest ground-level concentration was at March 23 12:00. This was related to development of planetary boundary layer. Dust was settled after mixing height was elevated at a huge extent.

Key words: Dust, regional climate model, particulate matter concentration

1. Introduction

Atmospheric constituents have impact on warming or cooling of the global temperatures and this issue is depicted in IPCC's report [1]. Ambient particulate matter has strong influence on climatic parameters. It can alter the absorption, scattering, radiative forcing of the atmosphere [2]. Dust from some desert areas are transported through natural mechanisms from time to time. Being located to the North of African Continent, Istanbul is sometimes exposed to dust incursion [3, 4, 5]. It was stated in a model study that dust transportation from Saharan Desert is expected to be increased in the next years [6]. Such a case indicates that increasing effects due to dust transportation can be observed in the next decades. Those incidences not only influences radiative forcing but also have an impact on human health. Therefore, determining the future dust events can be helpful in understanding the climate variations. In the past years, dust module was included to regional climate models, which is used to downscale global circulation models [7]. A dust transportation event was studied in detailed in Istanbul before by Agacayak et al. [6]. It included transportation patterns, concentration, and radiative forcing effects of particles. However, there is not much study related to dust transportation in our study area. This is a crucial deficiency for Istanbul because dust transportation usually occurs in spring seasons. This study aims to simulate a dust transportation event using a regional climate model and determine diurnal changes of dust concentrations.

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2. Materials and Method

In this study, we employed RegCM simulations when a dust incursion was observed in Istanbul. The dust transportation event was captured by a satellite of NASA and shown in Figure 1.

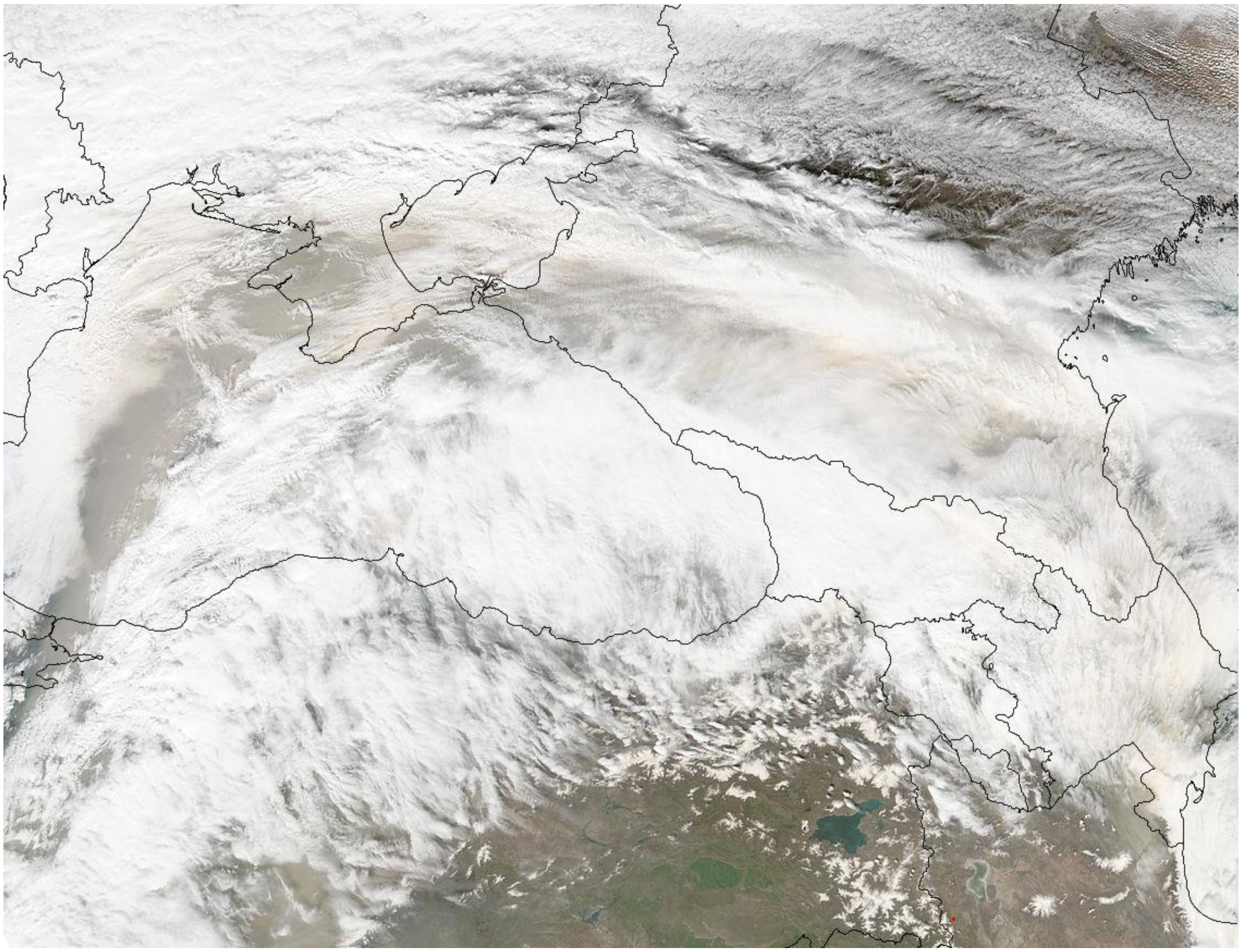


Figure 1. View of the dust transportation on March 22nd, 2018

It is clear that Istanbul is the on the pathway of the transportation. After determining the exact date, study domain was selected. It was selected according to saltation area and the receptor location in concern. Therefore our domain included Northern Africa, Middle and Eastern Europe, and Ukraine. The domain along with the terrain elevations are shown in Figure 2.

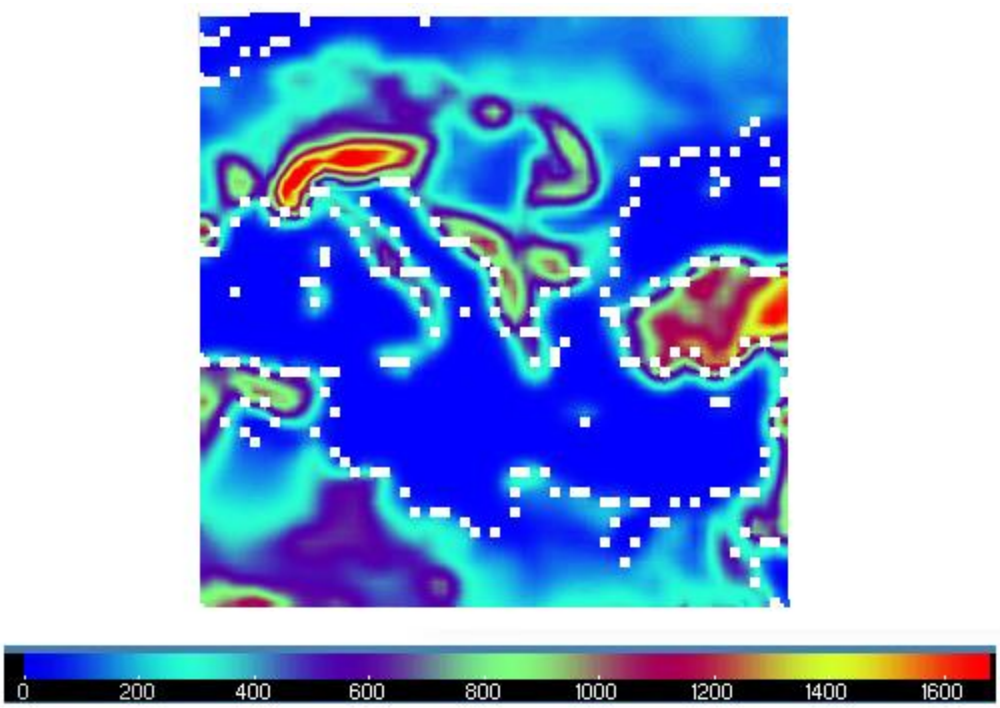
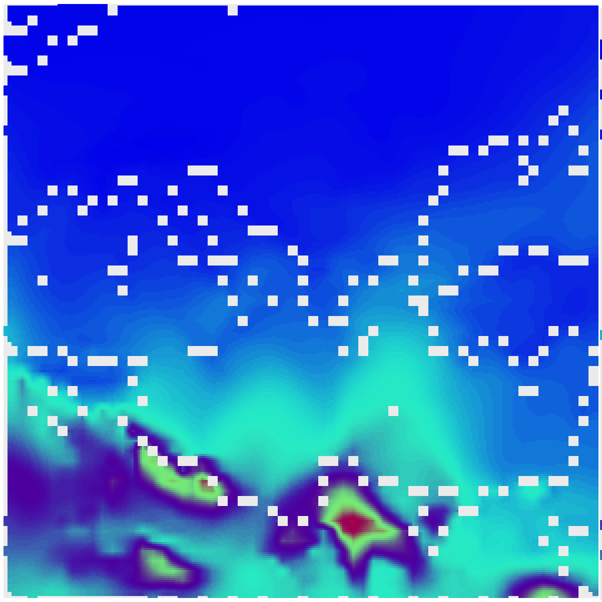


Figure 2. Study domain with terrain elevations in meters

CLM4.5, which was developed by National Center of Atmospheric Research (NCAR) as part of the Community Climate System Model (CCSM) [8], was enabled as land surface model. It includes five probable snow layers, ten heterogeneously distributed soil layers [9]. The RegCM has option to run at both hydrodynamic and hydrostatic schemes. In this study, hydrostatic option was selected. The extents of each grid was 50 km. The model was executed for 18 sigma levels. The top pressure was 5 hPa. Globdatparam namelist is used by sea surface temperature (SST) and initial condition boundary condition (ICBC) programs. The selected parameters were as follows: boundary condition interval 6 hours, SST was IO_WK, global analysis datasets was GFDL RCP4.5, run time was between 22 March 2018 and 23 March 2018, lateral boundary condition scheme was relaxation, boundary layer scheme was Holtslag PBL [10], moisture scheme was explicit moisture [11], ocean flux scheme was according to Zeng et al [12], the scenario was RCP4.5. The activated chemistry namelist parameter was DUST which included 4 size bins. Those bins are 0.01-1, 1-2.5, 2.5-5, 5-20 μm [13].

3. Results

The simulation of the dust transportation was executed for 48 hours. Dust burden was shown in Figure 3.



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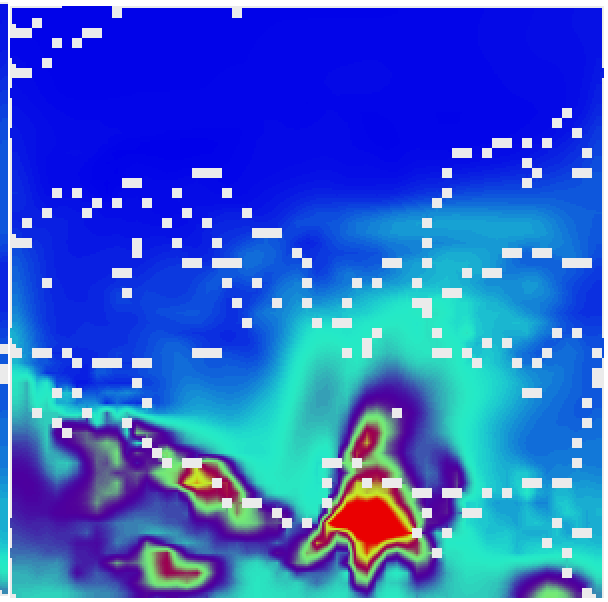

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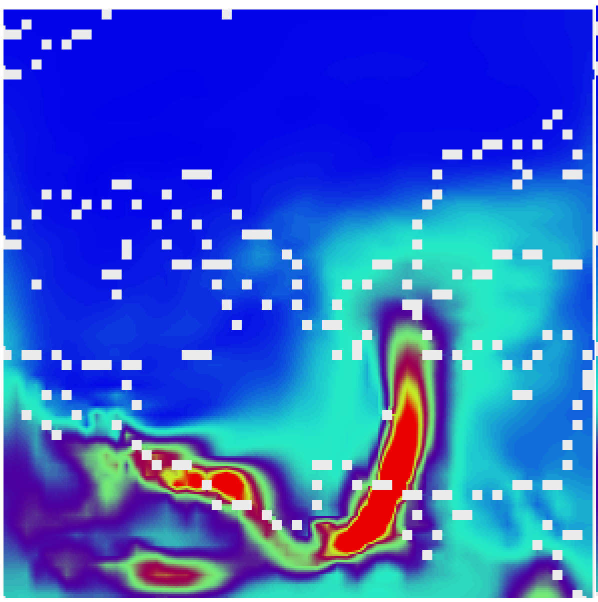

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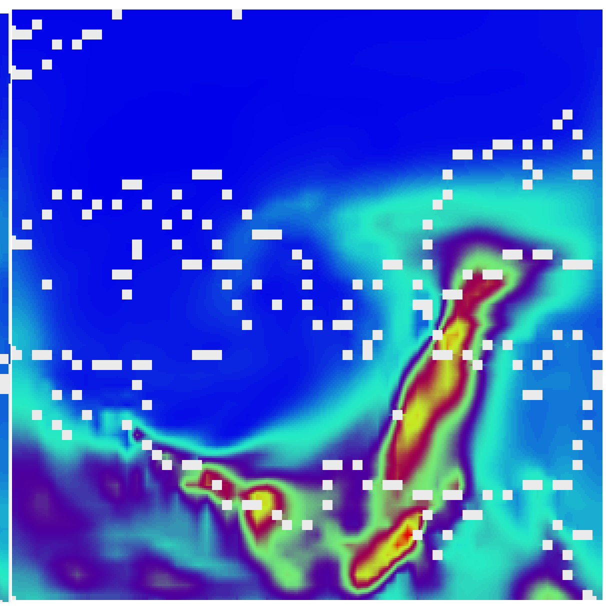

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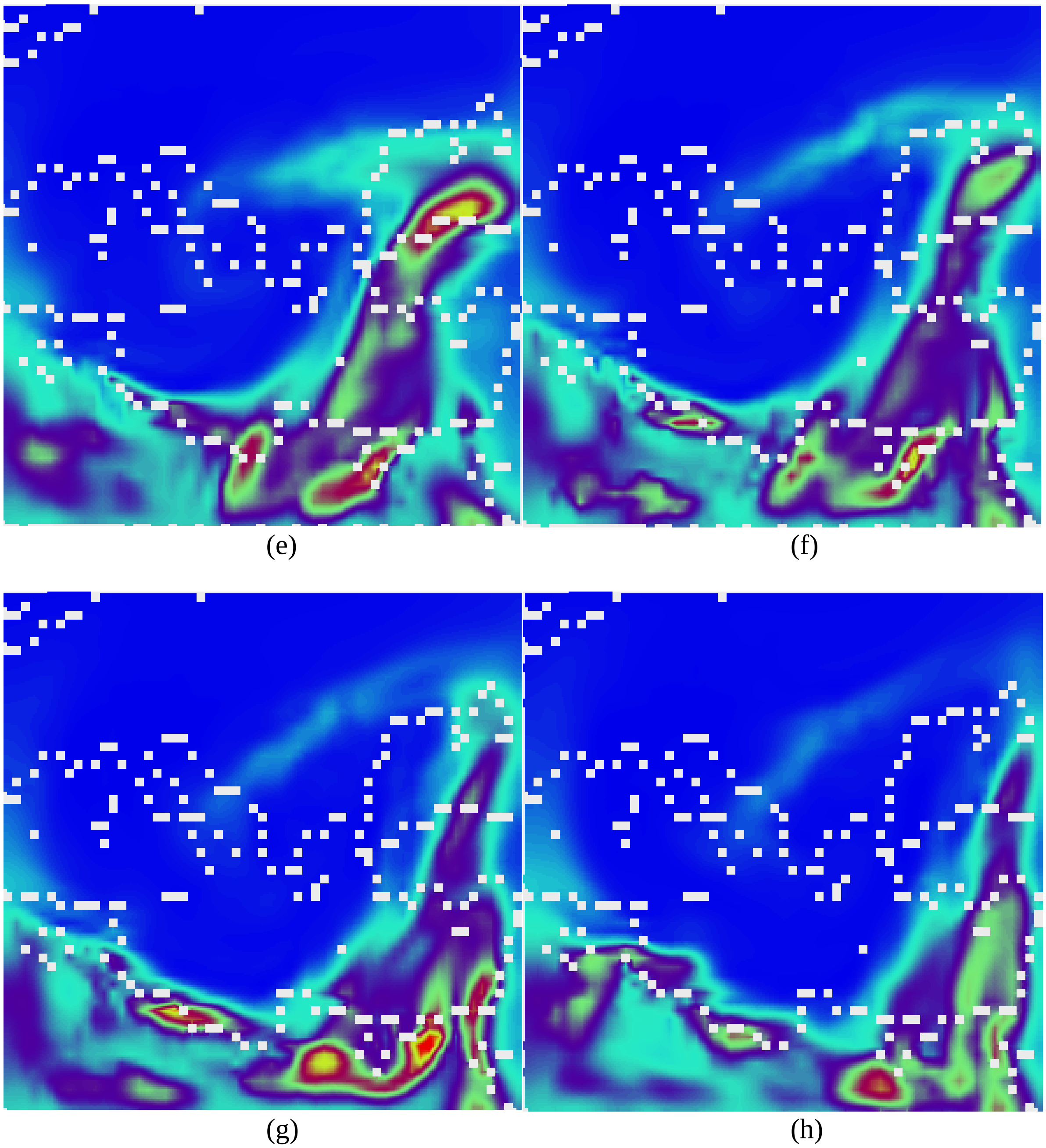
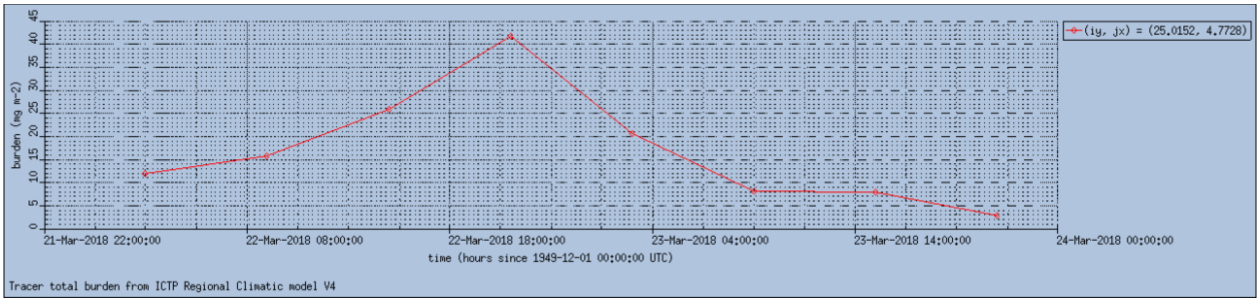
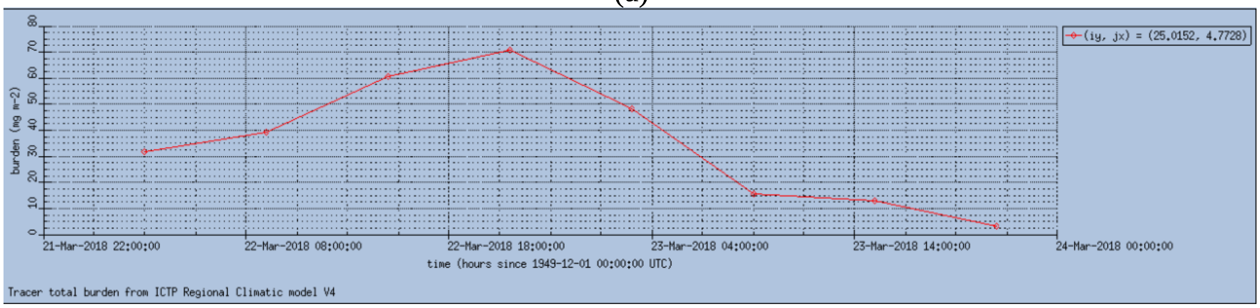


Figure 3. Dust burden in mg/m2 a) 22 March 00:00 b) 22 March 06:00 c) 22 March 12:00 d) 22 March 18:00 e) 23 March 00:00 f) 23 March 06:00 g) 23 March 12:00 h) 23 March 18:00

The red colour shows the highest burden whereas it decreases towards blue colour. The dust eroded from Libya and reached Istanbul at 22 March 18:00. The burden values calculated for Istanbul is given in Figure 4.



(a)



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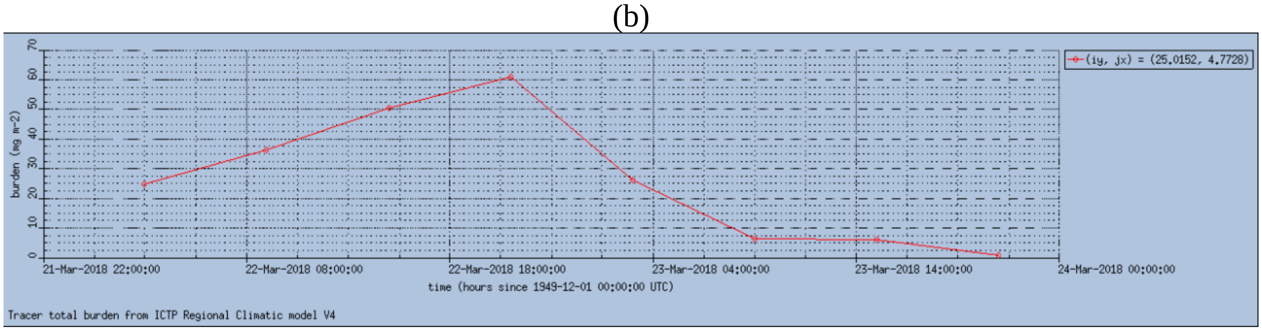

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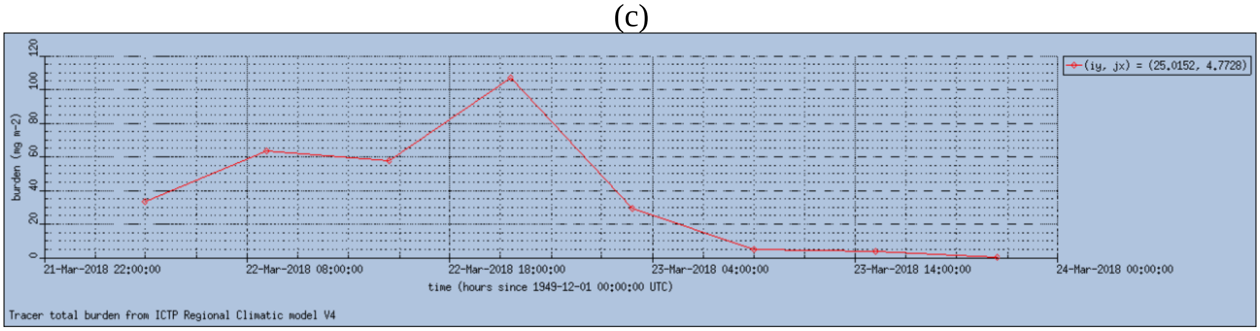

(d)

Figure 4. Dust burden variation in Istanbul (a) 0.01-1 µm (b) 1-2.5 µm (c) 2.5-5 µm (d) 5-20 µm

The highest burden valuesfor each bin was42, 70,61, and 105 mg/m^2. The highest burden was calculated for 5-20 µm dust size bin. Since it is not alone enough to calculate concentration, we extracted planetary boundary layer height from calculated outputs. The layer height variation is shown in Figure 5.

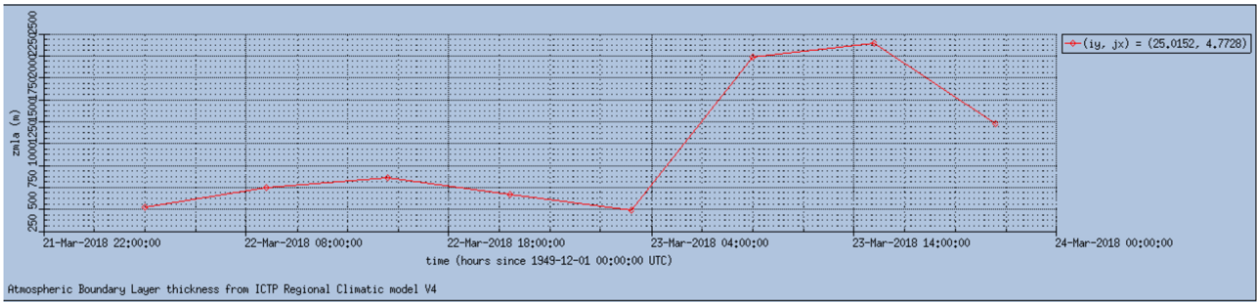

Figure 5. Atmospheric boundary layer variation

The boundary layer height was between 500 and 2400 m. It was 700 m at 22 March 18:00, when the highest concentration was calculated. In this case, it makes a concentration of 397μg/m^3 if the dust is evenly distributed within the boundary layer. In order to compare our data, we took air quality measurement records from Istanbul Metropolitan Municipality. The average PM_{10} concentration within the Marmara region was 17±12μg/m^3 for 22 March 18:00. But this was not the highest value for the concentrations. The highest value was 77±32μg/m^{3}at 23 March 12:00. This difference can be attributed to i) differences in size particles between measurement and simulation, ii) variation in the planetary boundary layer, and iii) retardence until dry deposition.

4. Discussion

The transportation pattern of dust incursion usually occurs at heights above 1,000 m [3]. Figure 5 clearly shows us that there was a critical increase in the boundary layer height after 23 March 00:00. It indicates that the transportation before that time is above boundary layer height, which is so called free troposphere. These dusts probably carried with advection instead of being settled. After the rise of the mixing layer, dusts started to settle and higher ground-level concentrations were observed.

Conclusions

This study focuses on a dust transportation event from North Africa to Istanbul. The effect of increased dust concentration is documented well in the literature. Therefore, understanding of the dust transportation process is crucial in estimating the possible effects of particulate matter. This also will make it possible to distinguish anthropogenic and natural sources of ambient particulate matter. In this preliminary study, the simulation of the dust was well matched with the satellite retrieval.

Acknowledgements

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