MODELING OF INDUSTRIAL SO_2 EMISSIONS AND TUPRAS FIRE RELEASES DURING 1999 EARTHQUAKE IN GEBZE-KOCAELI, TURKEY

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ABSTRACT

Gebze-Kocaeli region is located in Izmit Gulf and is one of the largest industrial areas of Turkey, including the giant petrochemical industry, TUPRAS. The gulf is surrounded by high hills in north and south reaching up to the height of 900 m and majority of industry is located in coastal areas. This situation leads to trapping and accumulation of pollutants in the gulf region under anticyclonic pressure systems. The region has also special importance in terms of its close proximity to Istanbul and Kocaeli cities. In this study, we present the results of RIMPUFF-Riso Mesoscale Puff model application to the emissions of Gebze-Kocaeli industrial region and to the releases of 1999 Earthquake in the region. We analyzed the SO_2 distribution over the area by Kriging. The emission inventory was formed by gathering emission data from 202 plants in the region. Ambient SO_2 concentration data were obtained for 8 stations operated by Kocaeli Municipality. After analyzing the distribution of SO_2, 11 days were found to be highly critical with daily average SO_2 values larger than 200 $\mu g/m^3$. Simulations were carried out for these 11 cases. It is found that SO_2 is accumulating over and nearby of Kocaeli city, causing dangerous atmosphere for the inhabitants. The model simulations for the TUPRAS Fire, indicate the SO_2 dispersion towards Marmara Sea away from the Kocaeli city, thanks for the northeasterly wind that was dominant during the fire period. This situation was validated by the satellite observations.

INTRODUCTION

The management of the atmospheric environment is complicated by the fact that pollutants can be transported over long distances and the across political boundaries. Through the mechanisms of long range transport, chemical species emitted into the atmosphere from urban and industrial centers can be distributed over large regions and as a result such widespread pollution problems as regional elevated oxidant levels, acid depositions, and decrease in the visibility can occur.

Clean air is considered to be a basic requirement for human health and their wellbeing. Air pollution has become an alarming problem with industrialization, and protection of air quality turned into a topic of great interest since early 1960's. The United Nations Conference on Environment and Development (UNCED) held in 1992 at Rio de Janeiro, Brazil, adopted the Framework Climate Convention which underlined the need of air pollution control. Also, the declaration of Habitat II (United Nations Conference on Human Settlements held in June 1996, at Istanbul, Turkey) emphasized the "sustainable development" and "sustainable human settlements" for the protection of environment. In sustainable human settlements clean air was one of the most important considerations put forward among the other environmental issues.

In this article, our aim is to model the SO_2 emission from industries and residential areas located around Gebze-Kocaeli region by RIMPUFF. Receptors points used in the study provided ambient SO_2 concentrations and we analyzed the spatial variability of SO_2 over the area by Kriging. After analyzing the distribution of SO_2, 11 days were found to be highly critical with daily average SO_2 values larger than 200 μg/m^3. These critical days have been simulated by RIMPUFF. The outputs of the model and the real cases are compared.

STUDY AREA, DATA SET AND METHODOLGY

Kocaeli is divided into three regions that are west, middle and east; and these regions composed of 6 counties which are Merkez, Gebze, Golcuk, Kandira, Karamursel, and Korfez. Gebze-Kocaeli region is located in Izmit Gulf and is one of the largest industrial areas of Turkey, including the giant petrochemical industry, TUPRAS. The gulf is surrounded by high hills in north and south reaching up to the height of 400 m in the north and 900 m in the south. Topography of the area is illustrated in Fig. 1. Majority of industry is located in coastal areas where the terrain is almost flat and very close to the sea level. This situation leads to trapping and accumulation of pollutants in the gulf region under anticyclonic pressure systems. The region has also special importance in terms of its close proximity to Istanbul and Kocaeli cities.

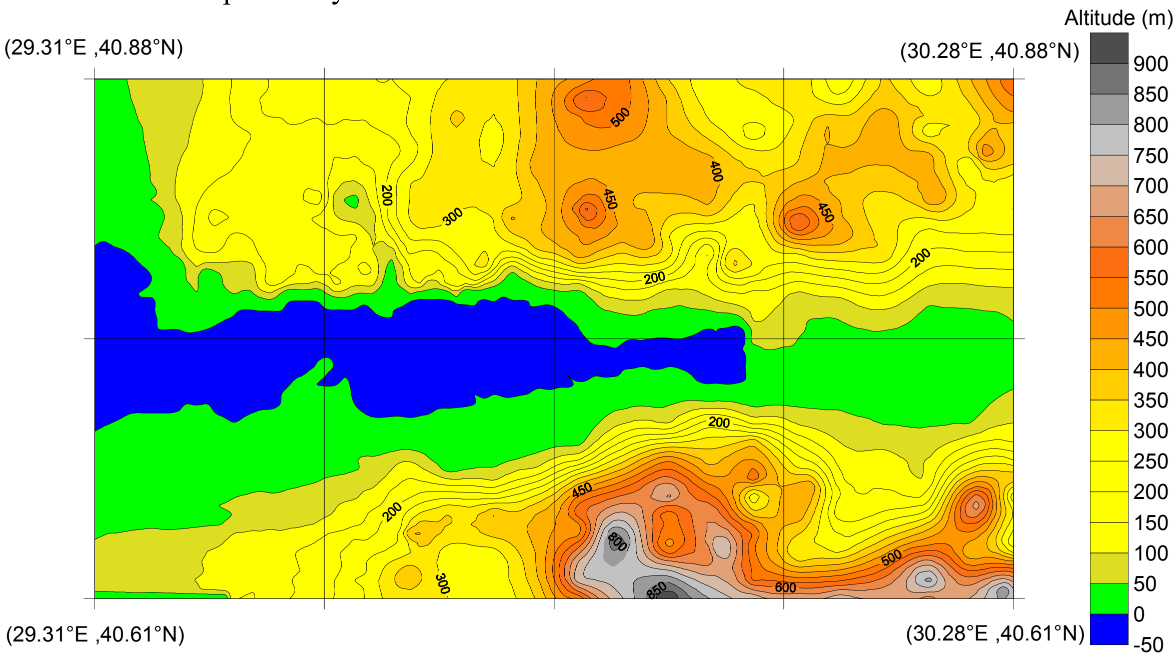

Fig. 1. Surface patterns and elevation of the study region.

The climate of the region is a transitional type between the Mediterranean and the Black Sea climates, exhibiting a mild weather with much precipitation in winter and a warm summer with an appreciable amount of rain. The climate is mostly affected by the close proximity of the region to the sea. The vegetation cover of the region is mainly composed of olive groves, maquis and forests in the north.

The emission inventory was formed by gathering emission data from 202 plants in the region. Unfortunately, most of them provided emissions of natural gas combustion with no SO_2 emission, hiding any emissions from coal combustion. Only 31 plants provided SO_2 emission data. Ambient SO_2 concentration data were obtained for 8 stations operated by Kocaeli Municipality; EML (Endustri Meslek Lisesi), Gebze, Belediye, Derince, Korfez, Golcuk, Santral, Dilovasi. Meteorological data was obtained from DMI (State Meteorological Organization) for 8 meteorological stations. Study area including the places of factories, receptor points and meteorological stations is presented in Fig. 2.

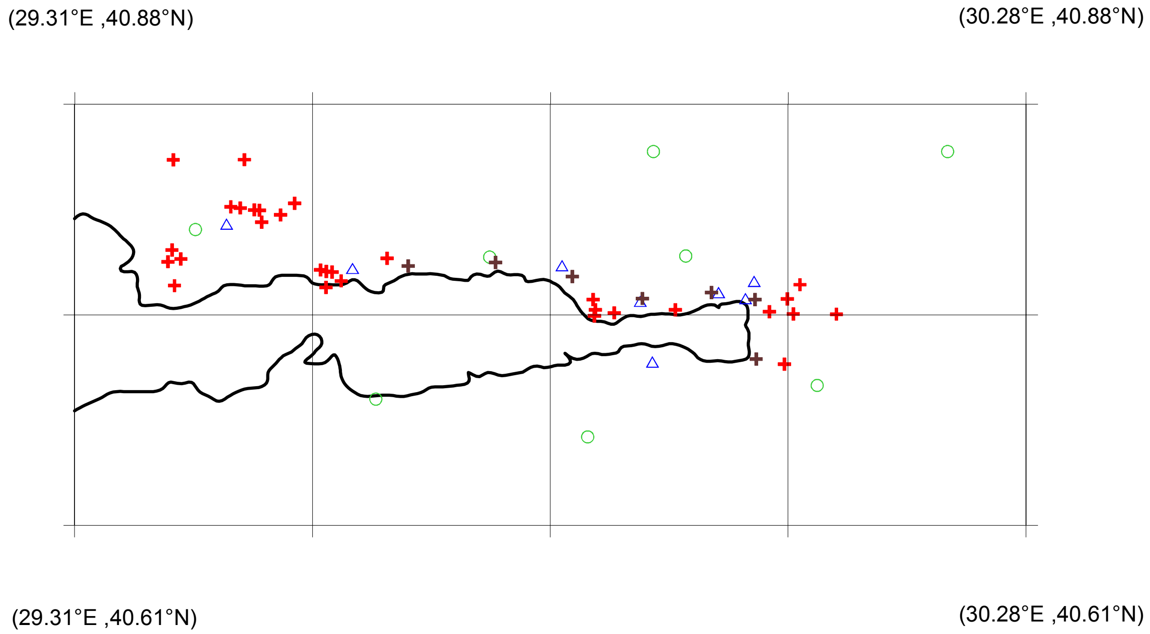

Fig. 2: Positions of factories, receptor points and meteorological stations on the gulf. Plus symbols indicate factories, triangles represent detector points and circles show meteorological stations.

An optimum interpolation technique, kriging, is used to obtain spatial distribution of SO_2 over the gulf from the measurements of 8 receptor points. More detailed information on the kriging can be obtained from [1]

RIMPUFF-Riso Mesoscale Puff model calculates the concentration at each grid point by summing the contributions from surrounding puffs at each advection step. The grid concentrations can either accumulate or simply be updated with the latest instantaneous value calculated for time t_{av}. The model output consists of time integrated air concentrations and depositions in grid points at times specified in the input data. The well known Pasquill diffusion scheme and its associated dispersion parameters have been among the most frequently applied dispersion schemes all over the world. Parameterization schemes of the model are based on Pasquill diffusion scheme. More detailed information on the RISØ puff diffusion model and its use of parameterized puff diffusion is available in [2, 3].

RESULTS

Ambient SO_2 concentration data obtained for 8 stations operated by Kocaeli Municipality are analyzed and 11 days were found to be highly critical with daily average SO_2 values larger than 200 μg/m^3. Spatial distribution of SO_2 for these 11 cases is generated by using the kriging technique and the daily average ambient concentrations of

SO_2 of the 8 stations. In order to verify the results of the model, the model runs are also carried out for these 11 days and the visualized results of the model are compared with the spatial distribution results of the kriging.

Model simulations are carried out by using the emission inventory of the plants and by assuming 10 hour/day emission from the plants. Wind profiles have been created by considering the topography and meteorological data. The simulated wind speeds range from 0.5 m/s to 2.0 m/s and increase by increasing altitude. To simulate the worst case conditions stability class has been taken as F for all cases. Dominant meteorological factor is observed as the wind where the SO_2 smoke spread according to the wind direction and speed.

Study Case 1: January 28, 1997

Daily spatial distribution of SO_2 over the gulf generated by kriging from the data of 8 stations is provided in Fig. 3.

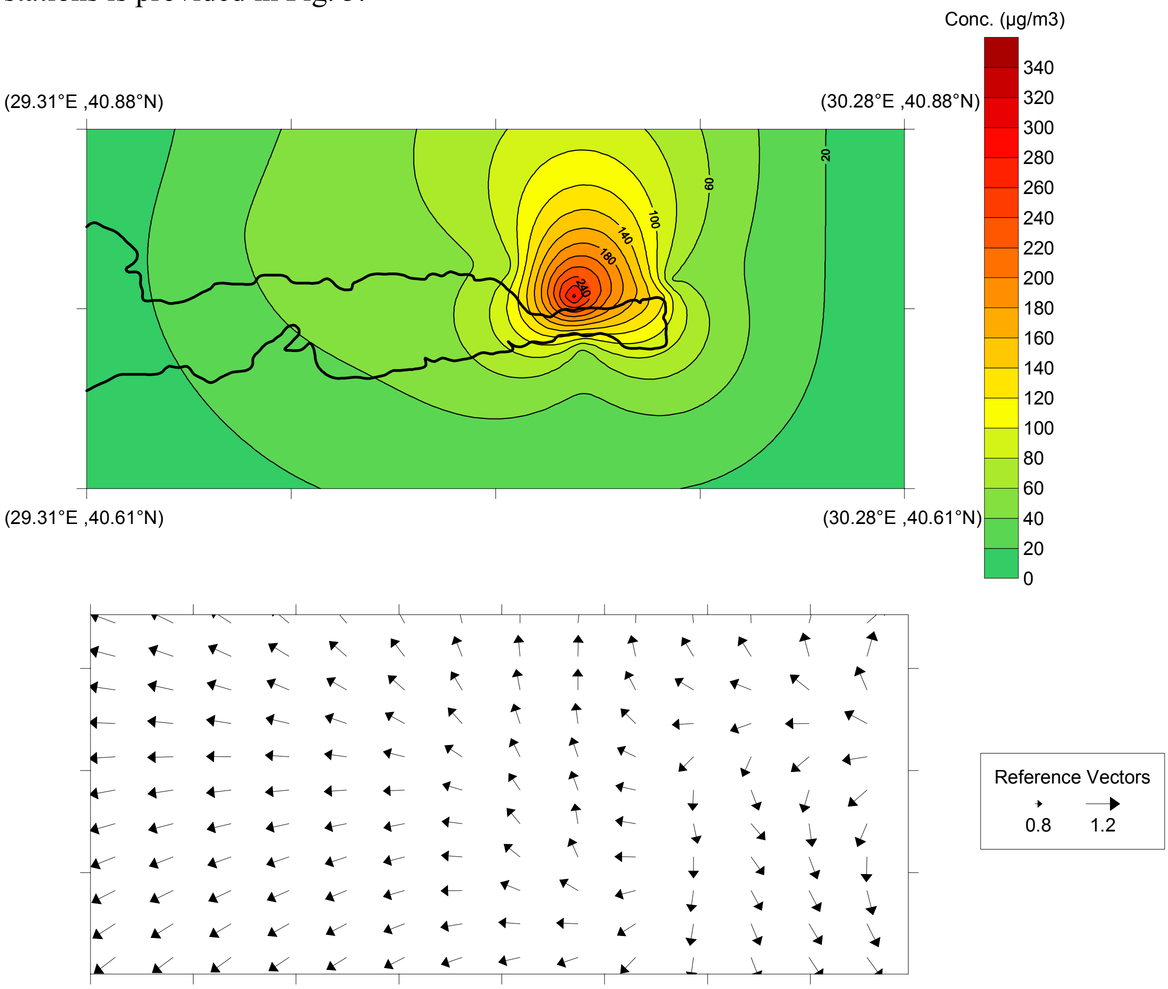

Fig. 3. Spatial daily averaged SO_2 distribution of January 28, 1997.

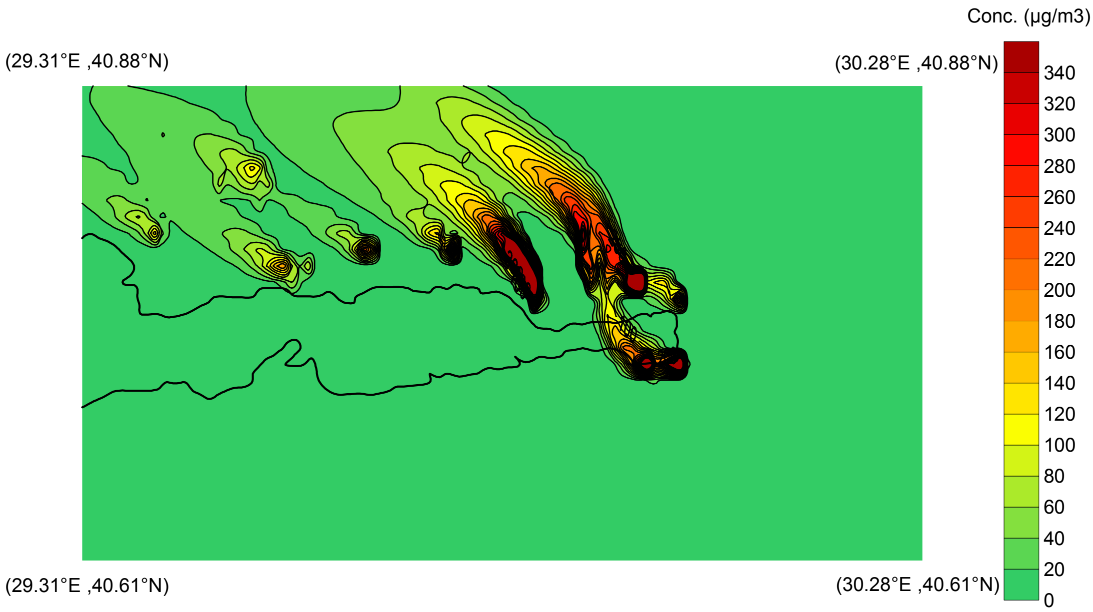

Fig. 4. Daily averaged RIMPUFF simulation for January 28, 1997.

Model results including emission data only from factories didn't work well. In reality, people living in the area consume coal for heating purposes and this produces a lion's share in the SO_2 emissions. Thus, to represent the residential SO_2 emissions, 8 hypothetical area sources were added to the emission inventory. Fig. 4 presents the outcome of the model after the addition of hypothetical residential sources. It is obvious from the figures that the majority of the pollution has accumulated over and nearby of the Kocaeli city and the model is a good simulator of the daily average concentration of SO_2.

Study Case 2: March 8, 1998

Daily spatial distribution of SO_2 over the gulf generated by kriging for March 8, 1998 is provided in Fig. 5.

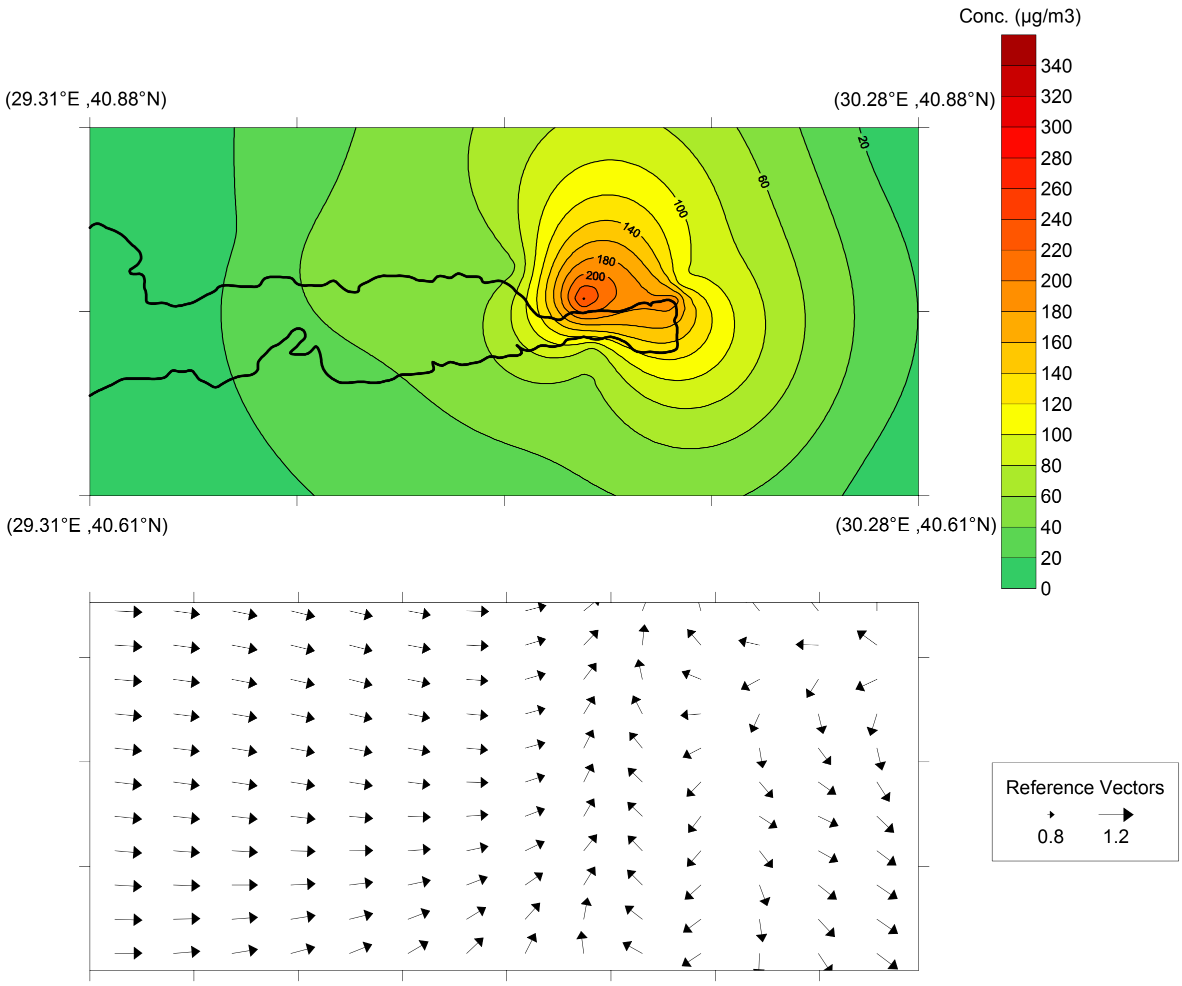

Fig. 5. Spatial daily averaged SO_2 distribution of March 8, 1998.

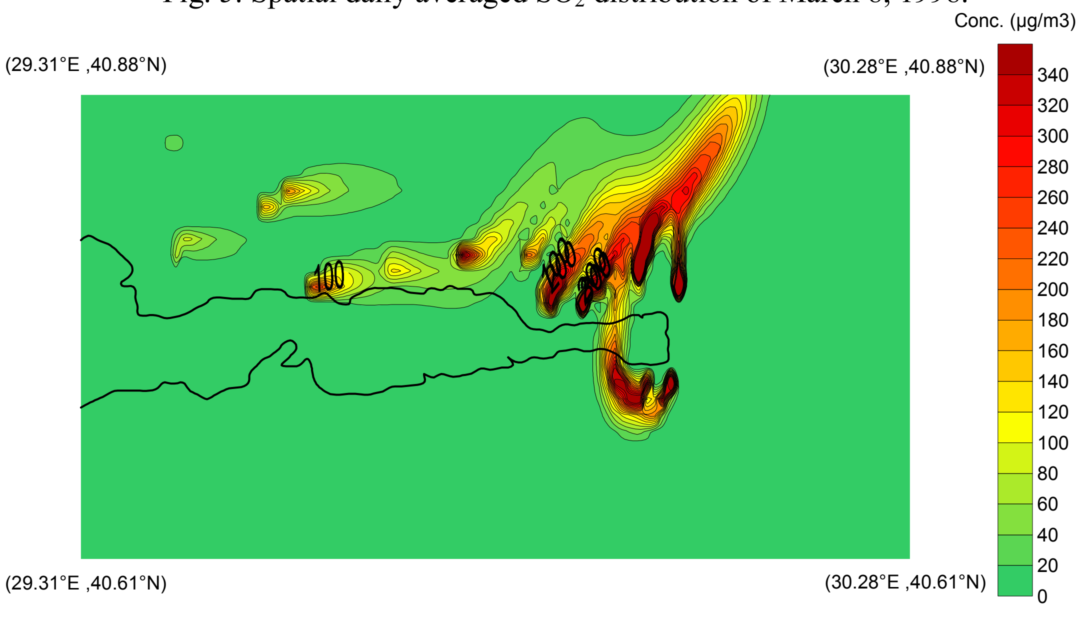

Fig. 6. Daily averaged RIMPUFF simulation for March 8, 1998.

Fig. 5 illustrates the simulation of the model for March 8, 1998 again with the hypothetical residential sources. A similar behaviour of emissions can be observed from Figs. 4 and 5, majority of the SO_2 pollution dispersing around the Kocaeli city and the model can predict the daily average distribution of SO_2 well, provided that the emission data is reliable.

Simulation of TUPRAS Fire

Fuel tanks of TUPRAS started to burn on 17^{th} August 1999 because of the devastating earthquake in the center of Golcuk and lasted in almost 10 days. Huge amount of smoke spread away and transported by winds to long distances. Eastern winds on certain days caused the transportation of the pollution towards Istanbul. It is estimated that the emission rate of the SO_2 from all of the burning tanks including different petroleum products is 860 g/s. Fig. 7 shows the model simulation and the satellite picture of the fire as of August 20, 1999. The resemblance of the dispersion in both of the pictures is very clear.

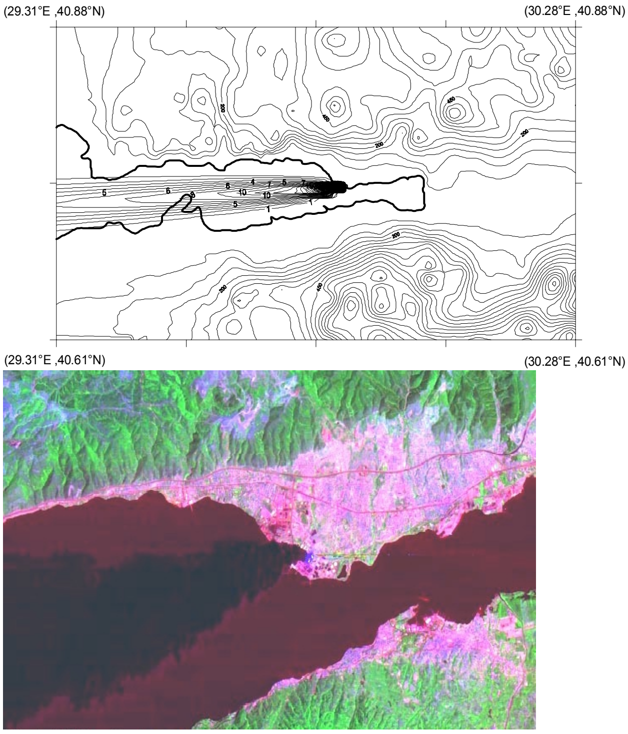

Fig. 7. RIMPUFF simulation and satellite picture of the TUPRAS fire as of August 20, 1999

SUMMARY AND CONCLUSIONS

It is found that SO_2 emitted from industries in the gulf is accumulating over and nearby the Kocaeli city, causing dangerous atmosphere for the inhabitants. Model results are in good correlation with the interpolated spatial distribution of SO_2. To improve the simulation quality, better emission inventory is necessary, including transportation, background and biogenic emissions around the area. The model simulations for the

TUPRAS fire, indicate the SO_2 dispersion towards Marmara Sea away from the Kocaeli city, thanks for the northeasterly wind that was dominant during the fire period. This situation was validated by the satellite observations.

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