

#### 4.11 MODELING OF SO<sub>2</sub> EMISSIONS FROM YATAĞAN POWER PLANT – A CASE STUDY

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##### INTRODUCTION

Air quality problems in Turkey are mostly related to energy production and consumption patterns that reflect the country's economic development. Yatagan Power Plant is one of the largest lignite - fired power plants in Turkey with a total capacity of 630 MW. It has been operated in the Yatagan region at the western Anatolia since 1982, emitting 76,000 tons of sulfur emissions per year. This paper presents a dispersion and monitoring study of the SO<sub>2</sub> pollution emitted by the Yatagan Power Plant (YPP). YPP is located in a complex environment and experiences low wind and stable conditions during most of the year. The results of this study were compared with the observations conducted by the Local Environmental Authority of Mugla City. The study covers a period of 120 hours in December 2000, when the district of Yatagan suffered high levels of SO<sub>2</sub> pollution, exceeding the air quality limits prescribed by the Legislation of Air Pollution and Control (1986).

Yatagan is a small district of Muğla, which is located in the Aegean part of Turkey. The centrum of Yatagan is located in a valley – like part of the region and surrounded with hills, which behave as natural barriers that trap air pollutants, particularly of the Yatagan Power Plant located in the district. The maximum height in the north of the modeling area is 700 m, whereas in the south of the modeling domain is 600 m (Figure 1.). The simulation area is divided into 15 x 15 x 9 grids with a grid spacing of 1 km for x and y directions and varying resolution in vertical direction with a ceiling height of 1620m.

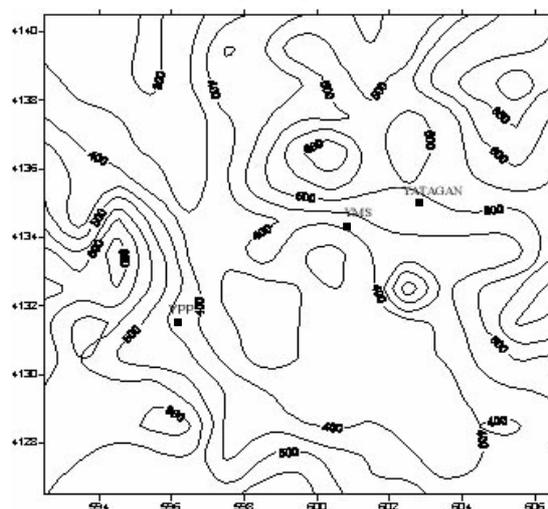


Figure 1. Contour map (elevation in meters) of the modeling area.

Numerical study was carried out employing the U.S. EPA CALPUFF Modeling System (EPA, 1995a and b). The system includes three main programs: the meteorological model CALMET, the dispersion model CALPUFF, and the post processing model CALPOST.

CALMET was used to predict the hourly meteorological fields for 96 hours, starting from December 1, 2000, to December 4, 2000, while CALPUFF was used to predict the hourly ground level SO<sub>2</sub> concentrations over a region of 15 km x 15 km grid with 1 km resolution.

## **NUMERICAL STUDY**

### **CALMET Meteorological Model**

CALMET is a meteorological model that develops hourly wind and temperature fields on a three – dimensional gridded modeling domain, including two – dimensional fields such as mixing height, surface characteristics and dispersion properties. The diagnostic wind field module uses a two – step approach to the computation of wind fields (Douglas and Kessler, 1988). In the first step, an initial – guess wind field is adjusted for kinematic effects of terrain, slope flows and terrain blocking effects, to produce a Step 1 wind field. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence – minimization procedure to the initial guess wind field.

CALMET consists of two boundary layer models for overland and over water applications. For overland surfaces, the energy balance method of Holtslag and van Ulden (1983) is used to compute hourly gridded fields of the heat flux, surface friction velocity, Monin – Obukhov length, and convective velocity scale. Mixing heights are determined from the computed hourly surface heat fluxes and observed temperature soundings. The model also determines the Pasquill – Gifford stability class and optional hourly precipitation rates.

CALMET reads hourly surface observations of wind speed, temperature, cloud cover, ceiling height, surface pressure, relative humidity, and precipitation type codes (only if wet removal is to be computed). The upper air data required by CALMET include vertical profile of wind speed, wind direction, temperature, pressure, and elevation. CALMET also requires geophysical data including gridded fields of terrain elevations and land use categories. Gridded fields of other geophysical parameters, such as surface roughness length, albedo, Bowen ratio, soil heat flux parameter, anthropogenic heat flux, and vegetation leaf area index.

### **CALPUFF Dispersion Model**

CALPUFF is a transport and dispersion model that advects puffs” of material emitted from modeled sources, simulating dispersion and transformation processes along the way, using the fields generated by CALMET. CALPUFF contains algorithms for near – source effects such as building downwash, transitional plume rise, partial plume penetration, subgrid scale terrain interactions as well as longer-range effects such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, over water transport and coastal interaction effects. A full resistance model is provided in CALPUFF for the computation of dry deposition rates of gases and particulate matter as a function of geophysical parameters, meteorological conditions, and pollutant species.

### **Meteorological Data**

Meteorological parameters were obtained from two meteorological stations; hourly surface data is provided from Yatağan Meteorological Station (Figure 1), and upper air data is provided from Isparta Meteorological Station. According to the meteorological data, the most frequent wind direction is south – westerly. Atmospheric stabilities used in CALPUFF model were the Pasquill categories (Zannetti, 1990). Inversion heights are calculated by the temperature - height profiles provided from the radiosonde data taken from Isparta Meteorological Station. The Yatagan climate is Mediterranean, characterized by warm and dry summers and relatively wet and mild winters.

### **Emission Data**

YPP consists of three units, each with a capacity of 210 MW and 120 m stack height.. The primary fuel is lignite and the secondary fuel is fuel – oil. Daily lignite consumption, under

full – capacity, is 16500 kg / day. The total emission rate of SO<sub>2</sub> emitted from the Power Plant is 3804 gs<sup>-1</sup>. The emission characteristics of the power plant is presented in Table 1.

Table 1. Emission characteristics of units

SO <sub>2</sub> Emission Rate	(gs <sup>-1</sup> )	1200 x 3
Exit Velocity	(ms <sup>-1</sup> )	4.1
Exit Temperature	(° C)	163
Stack Height	(m)	120
Max. Stack Diameter	(m)	11.3
Min. Stack Diameter	(m)	6.4

## RESULTS

Winds in the modeling period were light winds; varying from 1 to 8 ms<sup>-1</sup>. On December 2 and 3, 2000, starting from the early hours of the day to the afternoon hours, wind speeds turned out to be very low, varying from 0.1 to 0.5 ms<sup>-1</sup>, blowing south – westerly, carrying the pollutants towards the Centrum and leading to the accumulation as shown in Figure 2.

The main numerical results indicate that the maximum ground level concentrations are found northeast from the source, which agrees with the measurements. On the other hand, the results obtained with CALPUFF show differences compared to the observations. These discrepancies are due to the presence of complex wind patterns and their influence on the pollutant dispersion (Garcia *et al.*, 1999). The maximum concentration during the simulation period in the domain is calculated as 3140 µgm<sup>-3</sup> on the 38<sup>th</sup> hour of the period, on December 2, 2000, at 13:00, whereas according to the on site measurements recorded by Local Environmental Authority of Muğla, the highest ground level concentration measured is recorded as 4100 µgm<sup>-3</sup>.

This difference between the modeled concentration levels and measured concentration levels may originate from the inadequacies with meteorological data incorporated into the model. The fact that the meteorological station where radiosonde data are obtained from is outside the modeling domain causes the model not to resolve the meteorological conditions during the simulation efficiently. The predicted concentrations are calculated as the maximum average values within 1 hour intervals inside a 1 km x 1 km resolution whereas the on site observations represent the conditions at the particular moment at a particular point. The concentration distribution over the modeling domain is presented in Figures 3.

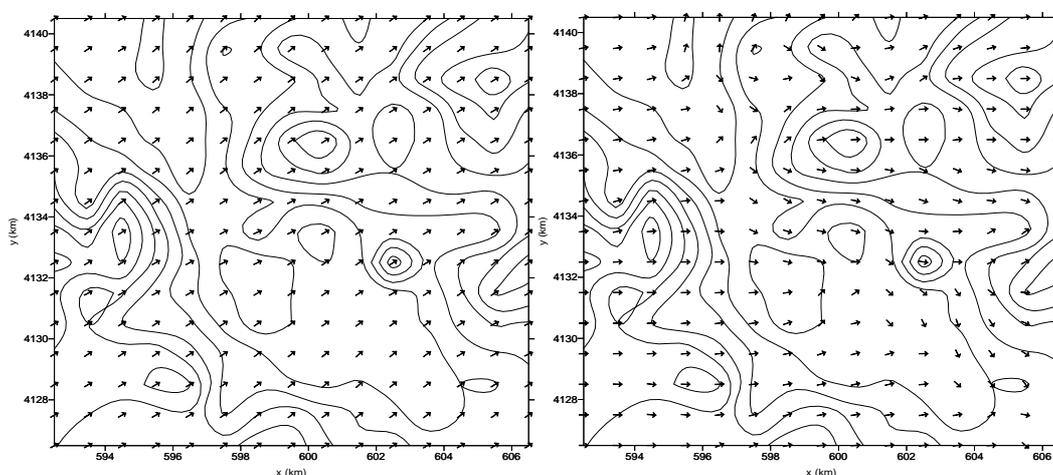


Figure 2. Wind field for the modeling area on December 2 and 3, 2000

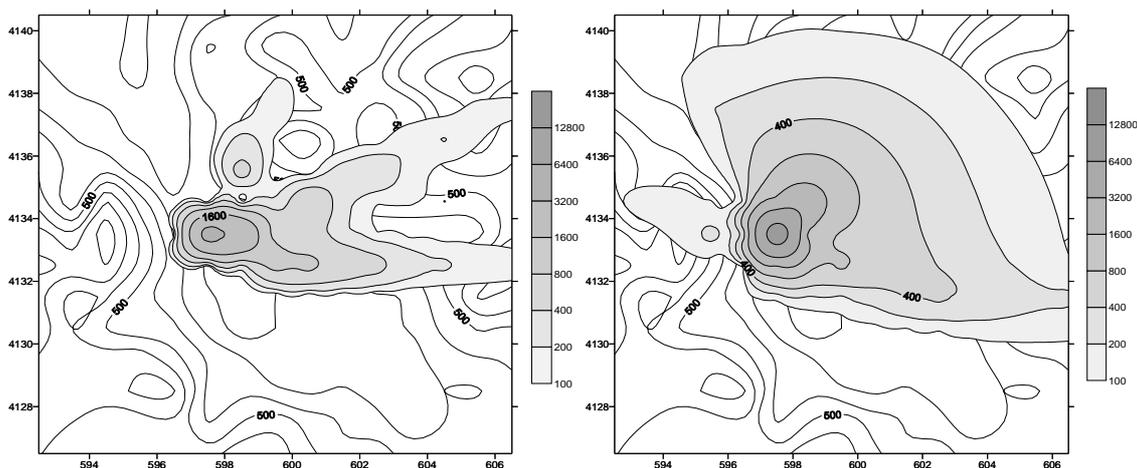


Figure 3. Concentration distribution ( $\mu\text{g}/\text{m}^3$ ) over the domain on December 2 and 3, 2000

The results of the model and the observations are compared in Figure 4.

## CONCLUSIONS

The CALMET and CALPUFF model have been applied to the city of Yatagan area for episodic conditions due to the power plant emissions in the city. We have shown how the model is able to reproduce the circulation patterns in the Yatagan district, considering that we have sufficient data. The maximum ground level concentrations are found northeast from the source, which agrees with experimental recordings and meteorological data. On the other hand, these concentrations differed from measurements in terms of magnitude. It is concluded that data obtained from only one meteorological station inside the modeling area may not permit to adequately resolve the episode. The fact that the meteorological station, where radiosonde data are obtained from, is outside the modeling domain causes the model not to resolve the meteorological conditions during the simulation efficiently.

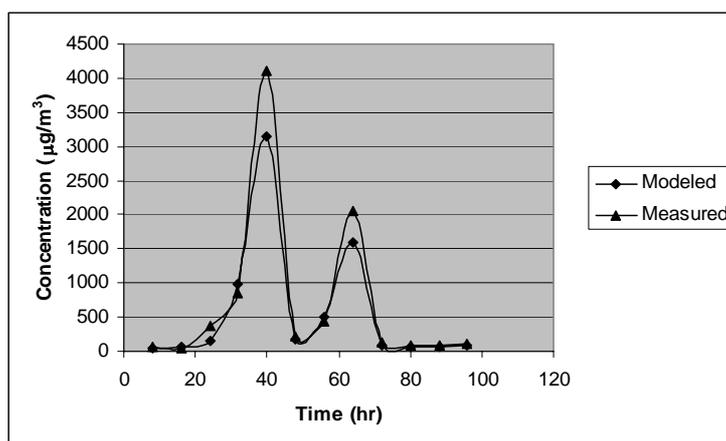


Figure 4. Comparison of model results to measurements

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