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A modeling study of Aeolian erosion enhanced by surface wind confluences over Mexico City

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ABSTRACT

Using wind erosion and air quality models, a study on the effect of PM_{10} from aeolian erosion episodes in Mexico City is presented. The important contribution of aeolian erosion on urban air quality, its genesis, morphology, location and regional implications such as the role played by surface confluences, the dry Lake of Texcoco and agricultural lands to the east and south-east of Mexico City is established. All analyzed episodes showed that wind erosion is a major cause of high PM_{10} concentrations in Mexico City.

The wind erosion and air quality models used here provide useful computational tools to study the aeolian erosion phenomenon, its sources and impact on urban regions.

1. Introduction

Mexico City (MC) (19°20′N, 99°05′W) is located in the Valley of Mexico comprising an area of approximately 9560 km^2 at an elevation of 2240 m above sea level. The Lakes of Texcoco and Chalco that existed in the valley up to the 16th century have been desiccated and are currently dry. The only remain of this lacustrine system is the Lake of Xochimilco in the south of MC. Today the Lake of Texcoco is an area prone to wind erosion that affects MC air quality (Jáuregui, 1971, 1983, 1989) and as a consequence, population health. As will be shown here, in addition to the Lake of Texcoco, the agricultural lands of Tenango del Aire and Chalco (Fig. 1), are the main sources of PM_{10} from wind erosion. Also an important atmospheric process for the formation of dust storms in the valley is shown: the presence of surface wind confluences that enhance the strength and scope of the phenomenon.

Several environmental studies confirm the presence of soil material in the air of MC. For example, Chow et al. (2002) reports that the main inorganic component in the chemical composition of PM_{10} particles in northern MC is geological material, which accounts for 48% of the inorganic particulate mass. Vega et al. (2002) shows that the dry Lake of Texcoco is still a dust source that affects air quality of north-east of Mexico City. Querol et al. (2008) report that during the campaign Megacities Initiative: Local and Global Research Observations (MILAGRO) (MCE^2, 2009) that took place in March, 2006, PM_{10} particles included approximately 30% of crustal material in its chemical composition. Using receptor models Mugica et al. (2009), claim that during the MILAGRO campaign, soil was one of the most important particulate sources emitting up to 26% of the fine particles in some areas of MC. During the MILAGRO campaign, Fast et al. (2007) established that wind-blown dust during March, 2006, was generated by the presence of strong winds associated with cold fronts. Another modeling study using CALMET/CALPUFF paired with the Wind Erosion Equation (WEQ) by López et al. (2002) shows that the source of dust events was located in the area of dry Lake of Texcoco.

In this work, four representative aeolian erosion episodes over MC are studied by coupling the Multiscale Climate and Chemistry Model (MCCM) (Grell et al., 2000; García-Reynoso, 2002; Jazcilevich et al., 2002, 2003, 2005) whose meteorology is based on MM5 and the Wind Erosion Prediction System (WEPS) (Hagen, 1995, 2001, 2004; van Donk et al., 2003). We call this system MCCM–WEPS.

As will be shown, MCCM–WEPS not only allows studying the dispersion of particles from natural sources (unprotected soils) of the mostly dry Lake of Texcoco and agricultural lands located around MC, but also allows the analysis of the genesis, morphology, time and spatial localization of dust storms over MC. In particular the major role played by surface wind confluences in the formation and plume range of aeolian dust storms is established.

Computational models such as MCCM–WEPS are important to design control and mitigation policies for dust storms that affect

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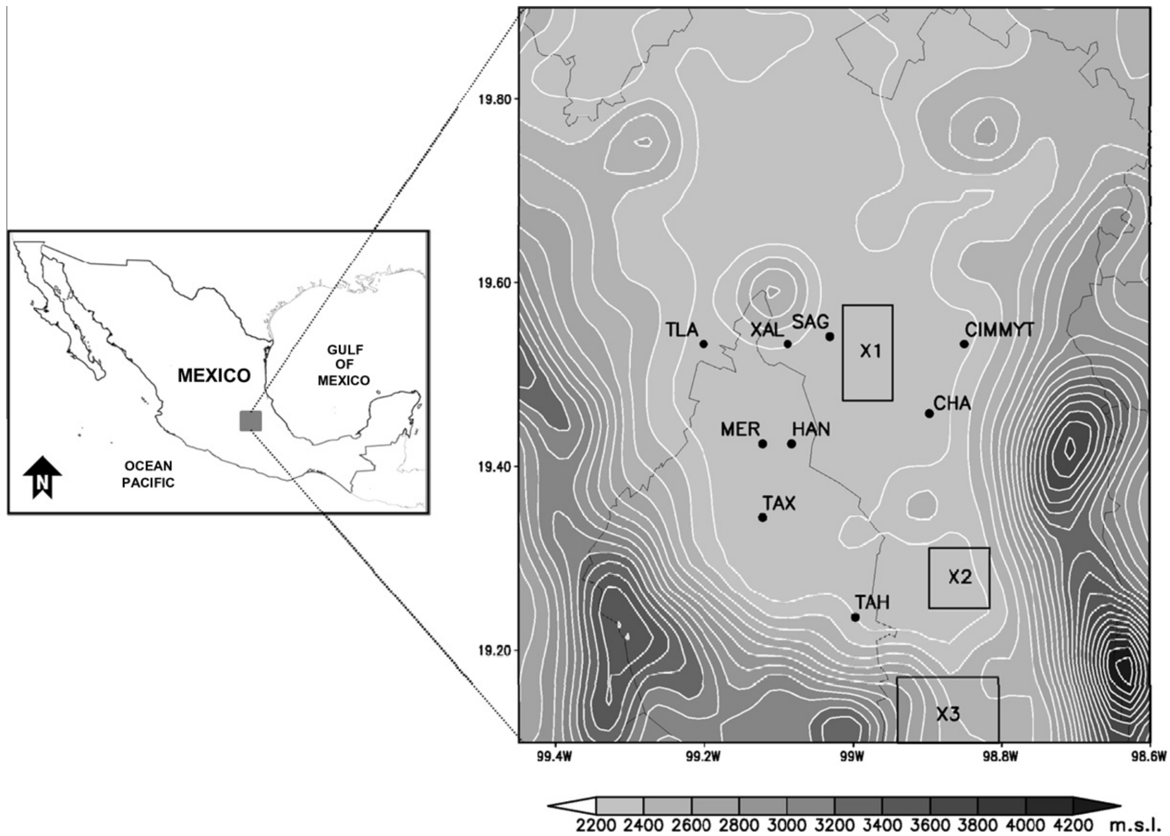

Fig. 1. Location of interest sites on Valley of Mexico. The stations of the local monitoring network (SIMAT) are Chapingo (CHA), Hangares (HAN), Merced (MER), San Agustin (SAG), Tlahuac (TAH), Taxqueña (TAX), Tlanepantla (TLA) and Xalostoc (XAL). Lake of Texcoco (X1) and agricultural lands of Chalco (X2) and Tenango del Aire (X3) areas are also shown. CIMMYT is the site where field campaign was conducted. Slight black lines represent political boundaries.

large populated areas of the Valley of Mexico, and other regions where dust emissions represent a major problem on air quality as was the case on 23rd, September, 2009 over eastern Australia (NASA, 2009).

2. Methods

2.1. MCCM–WEPS system

The air quality model used is the Multiscale Climate and Chemistry Model (MCCM) that was developed in the Institut für Meteorologie und Klimaforschung-Fraunhofer Institute (IMK-IFU) of Germany (Grell et al., 2000), and has been implemented for the central region of Mexico by García-Reynoso (2002) and Jazcilevich et al. (2002, 2003, 2005). The model includes modules for meteorology, photolysis, biogenic and anthropogenic emissions, radiation and deposition among others. MCCM version 3 has PM_{10} and $PM_{2.5}$ transport capabilities. The meteorological module of MCCM is based on the fifth-generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5). MM5 is a terrain following vertical coordinate, non hydrostatic model. It has a multi-scale option, contains explicit cloud schemes and multilevel soil/vegetation parameterizations (Grell et al., 1994).

The MCCM includes two separate detailed gas-phase chemistry mechanisms (RADM2 and RACM) with 39 and 47 chemical species, respectively, and particulate matter (PM_{10}) as a passive tracer is included in MCCM. In association with the gas phase chemistry processes, 22 photolysis frequencies are computed depending on cloud cover, ozone, temperature and pressure in the model atmosphere. Biogenic emissions are calculated based on land use data, surface temperature and radiation. This model couples the meteorological conditions, the transport and the chemical transformations of pollutants in each computational step. For a detailed description of this see Grell et al. (2000).

The emissions inventory used by MCCM includes point and area sources. These data are obtained from emission inventories performed by the city government in which the PM_{10} anthropogenic emissions are considered (GDF, 2002).

MCCM was implemented using three nested domains. The area of interest is contained in the third domain and it has a 3 km spatial resolution (Fig. 2). The domains are showed over a normalized difference vegetation index (NDVI) image (Tucker et al., 2004, 2005; Pinzon et al., 2005). Location of Mexico City corresponds to NDVI = 0 in map of the Fig. 2. As can be seen, several low vegetation cover areas are present, representing important potential dust emission sources.

The soil erosion model used in this work is the Wind Erosion Prediction System (WEPS). It was developed by the Engineering and Wind Erosion Research Unit (USDA-ARS-WERU) (2001) of the United States Department of Agriculture (USDA) (Hagen, 1995, 2001, 2004; van Donk et al., 2003). WEPS is a process-based, daily time-step model that simulates weather, field conditions, and wind erosion. The WEPS model has a modular structure that includes additional submodels to simulate the wind erosion over a specific area. The erosion submodel can be operated as a stand-alone model to simulate erosion for a single event in a sub-daily time resolution and this is the part of the model that we are interested in. For this study we used an hourly time scale.

The erosion submodel determines when wind friction velocity exceeds the threshold for particle movement using parameters that describe the soil surface conditions of roughness, aggregate size

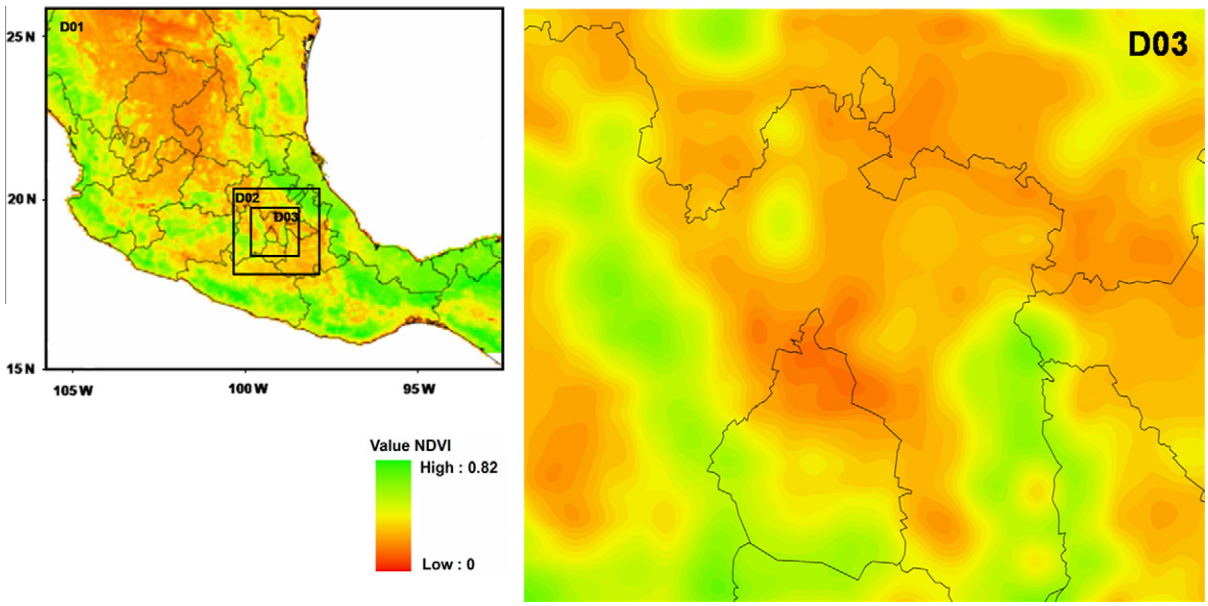

Fig. 2. Nested domains implemented for application of MCCM. Valley of Mexico is located on D03 which has 61 × 52 cells with 3 km spatial resolution. NDVI ≈ 1 (green) represent a high vegetation cover areas. NDVI ≈ 0 (red) represent areas with high urbanization index (Tucker et al., 2004, 2005; Pinzon et al., 2005). Slight black lines represent political boundaries. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

distribution, flat biomass cover and standing biomass leaf and stem areas. If winds are strong enough, these parameters determine if wind erosion can occur in a simulation. If erosion can occur, then the submodel simulates the process of soil movement (Hagen, 2001, 2004).

The WEPS erosion submodel calculates total soil loss (kg/m^2) as well as suspension (<0.1 mm) and, saltation plus creep (0.1–2.0 mm) fractions. PM_{10} emissions are calculated as a fraction of the suspension component.

To couple WEPS with MCCM, code modifications were made to provide WEPS with wind direction and speed from MCCM. As mentioned, at each time step, the emissions provided by WEPS are introduced in the emission subroutine of MCCM, thus obtaining an online dynamic coupling between meteorology, emissions and transport.

Two erosion areas were considered: the agricultural lands located around MC and the Lake of Texcoco area. For each case, soil parameters describing the corresponding soil conditions were used.

For the case of Lake of Texcoco, the area was divided in six soil sub-regions as shown in Fig. 3. The soil parameter data were interpolated to obtain values for the complete set of cells. The soil data were obtained from data bases generated during a project conducted on the dry Lake of Texcoco (Fernández-Buces, 2006).

2.2. Soil parameters estimation

To obtain the soil parameters of the agricultural lands surrounding Mexico City, a field campaign was conducted during February and April, 2007. The experimental lot (110 × 125 m) was located in the Centro Internacional de Mejoramiento del Maíz y Trigo (CIMMYT) (19°31′53″N, 98°50′48.5″W) located in the northeast part of the valley as is shown in Fig. 1.

The instruments used were: Two Sensit H11B (2006) to monitor saltation activity over the soil surface. A Minivol Portable Sampler Airmetrics SN: 3603 was used to sample PM_{10} with Polycarbonate Filters. A Davis Meteorological Station was installed to obtain wind

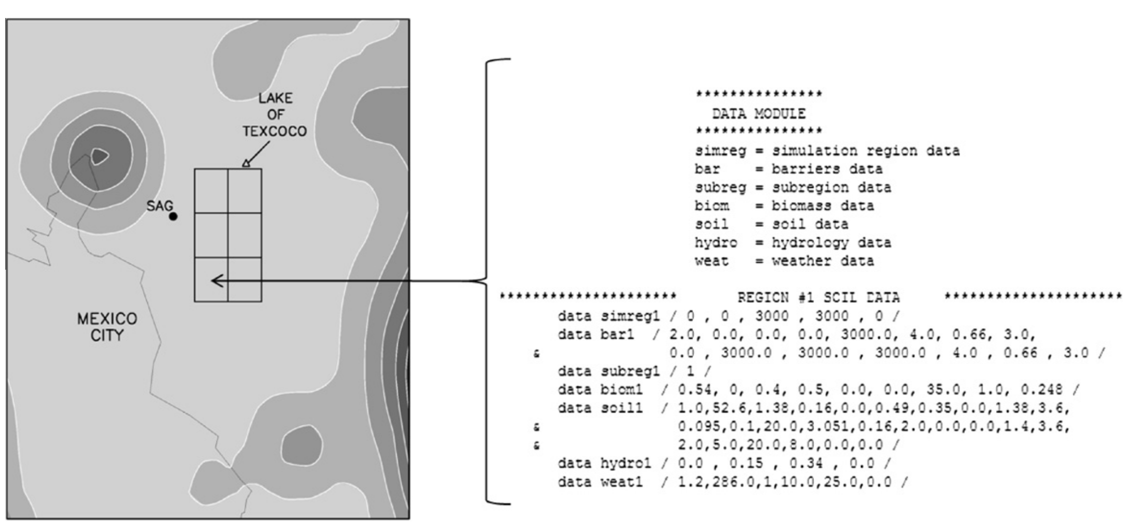

Fig. 3. Dry Lake of Texcoco sub-regions (left) and list of soil parameters interpolated to sub-region number 1 (right).

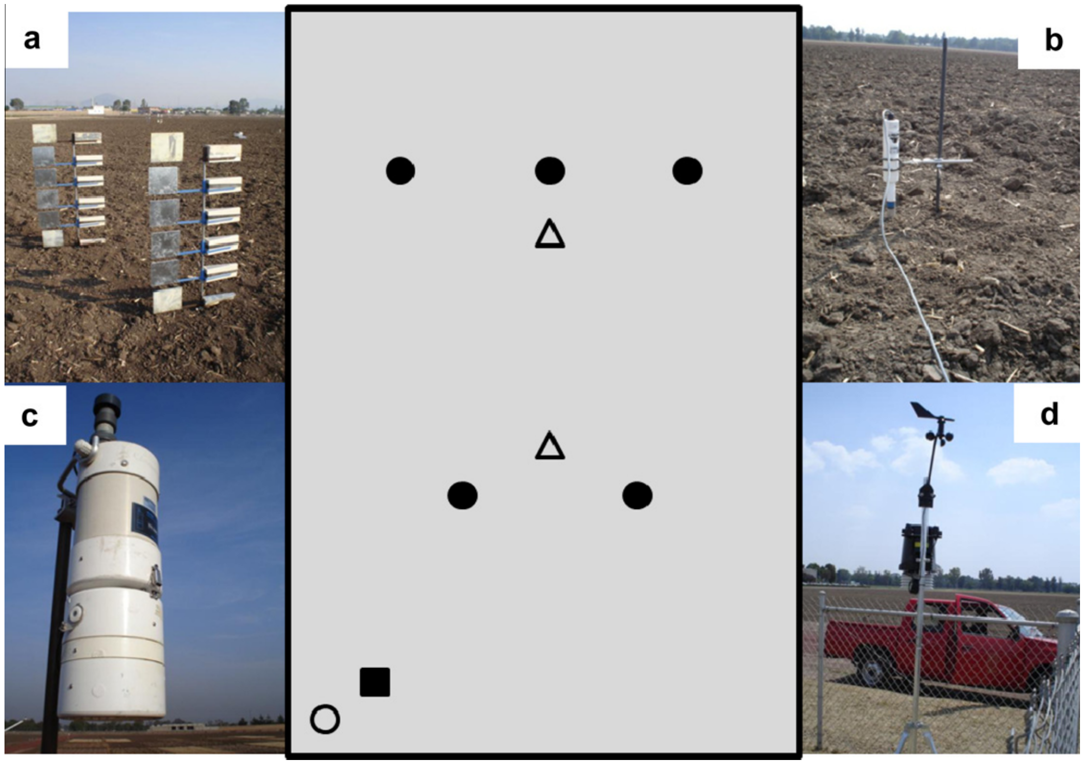

Fig. 4. Instruments layout on experimental field (center). (a) BSNE's towers (•). (b) Sensits (Δ). (c) Minivol (■). (d) Meteorological Station (○).

direction and wind speed. Six towers with six BSNE dust samplers (Fryrear et al., 1991) were mounted to catch the soil particles to estimate dust emissions. The BSNE trays were weighted to estimate soil loss during field campaign. The instruments and their respective layout are shown in Fig. 4.

Soil samples were analyzed in soil laboratories at the Instituto de Geologia (UNAM) and the Engineering and Wind Erosion Research Unit (EWERU-USDA) to obtain soil texture, roughness and aggregate stability data. These data, shown in Table 1, were used to select the values of the corresponding WEPS parameters (van Donk et al., 2003).

2.3. Selection of modeling episodes

The first episode, 18–20 March, 2006, corresponds to the MILAGRO campaign where measurements and observation documenting dust storms over the valley were reported. The other three episodes, 10–12 January, 4–6 April, 28–30 November 2008, correspond to highest PM_{10} concentrations reported by the Atmospheric Monitoring System (SIMAT) during 2008 (SMA, 2008). Hourly average PM_{10} concentrations are reported by SIMAT stations using TEOM 1400 monitors (Rupprecht & Patashnick, Inc.). The location of SIMAT stations used to compare PM_{10} measured and modeled concentrations are shown in Fig. 1. All episodes coincide with the dry season when agricultural activities begin with removal of the vegetative cover.

Table 1
Soil data used by MCCM–WEPS after field campaign.

Parameter	Updated value
Biomass cover	0.064
Ridge height (mm)	0.0
Ridge spacing (mm)	0.0
Ridge width (mm)	0.0
Sand content (%)	63.58
Very Fine Sand content (%)	45.30
Silt content (%)	14.07
Clay content (%)	22.35
Aggregates stability (ln(J/kg))	3.15
Allmaras random roughness (mm)	16.2 as average
Soil layer geometric mean diameter (mm)	7.22 as average
Soil layer geometric standard deviation (mm)	17.5 as average

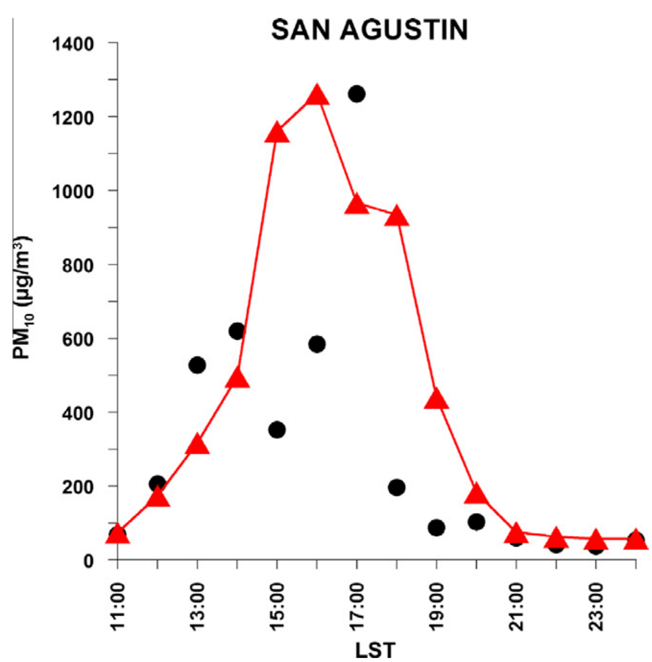

Fig. 5. Comparison of PM_{10} concentrations in µg/m^3 between SIMAT station (●) and MCCM–WEPS (▲) system data.

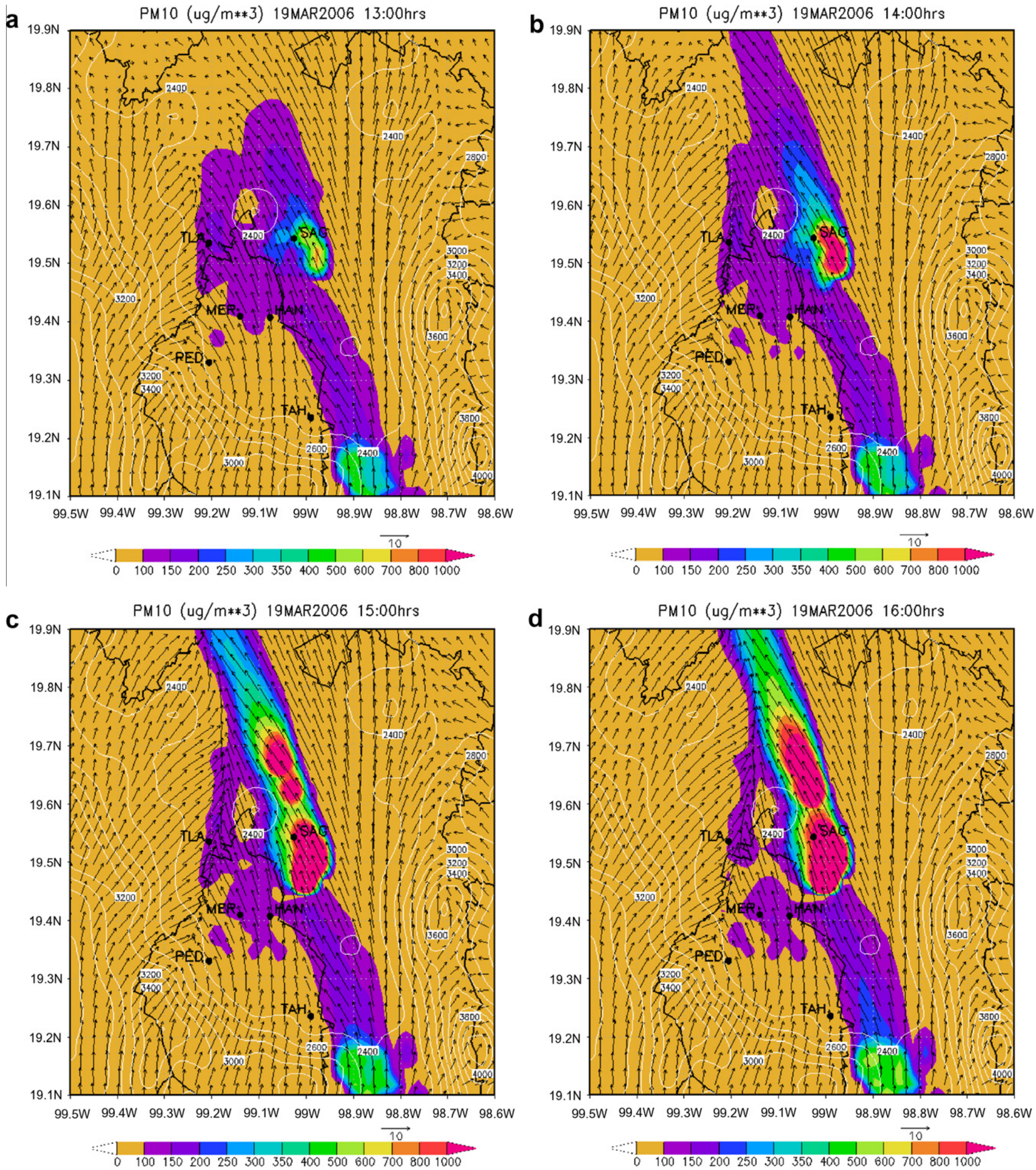

Fig. 6. Wind fields and concentrations generated over the dry Lake of Texcoco for March 19th event. White lines represent elevation in m.s.l.

3. Results and episode analysis

3.1. 18–20 March, 2006

This event took place during the MILAGRO campaign. SIMAT reported high PM_{10} concentrations over stations at San Agustin (SAG), Cerro de la Estrella (CES) and Tlahuac (TAH). MCCM-WEPS shows that emissions came from three different areas: from the south-east of the Valley of Mexico City (Tenango del Aire), from the dry Lake of Texcoco area and from the agricultural lands

Table 2
PM_{10} emissions from soil calculated using MCCM–WEPS during the episodes at the main identified sources.

Episode	Emission (kg km^{-2} s^{-1})		
	Lake of Texcoco	Tenango del Aire	Valle de Chalco
March 19th, 2006	12.597	6.697	***
January 11st, 2008	1.581	***	***
April 5th, 2008	4.110	***	4.180
November 29th, 2008	1.300	3.370	***

*** No emission during the episode.

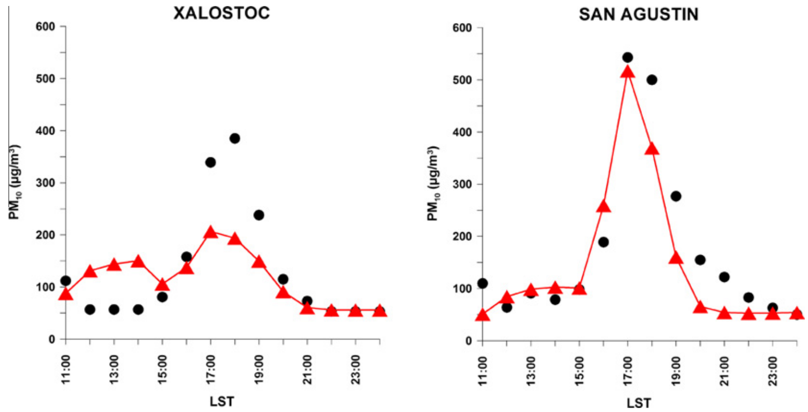

Fig. 7. Comparison of PM_{10} concentrations in $\mu g/m^3$ between SIMAT stations (●) and MCCM–WEPS system data (▲) during January 11st.

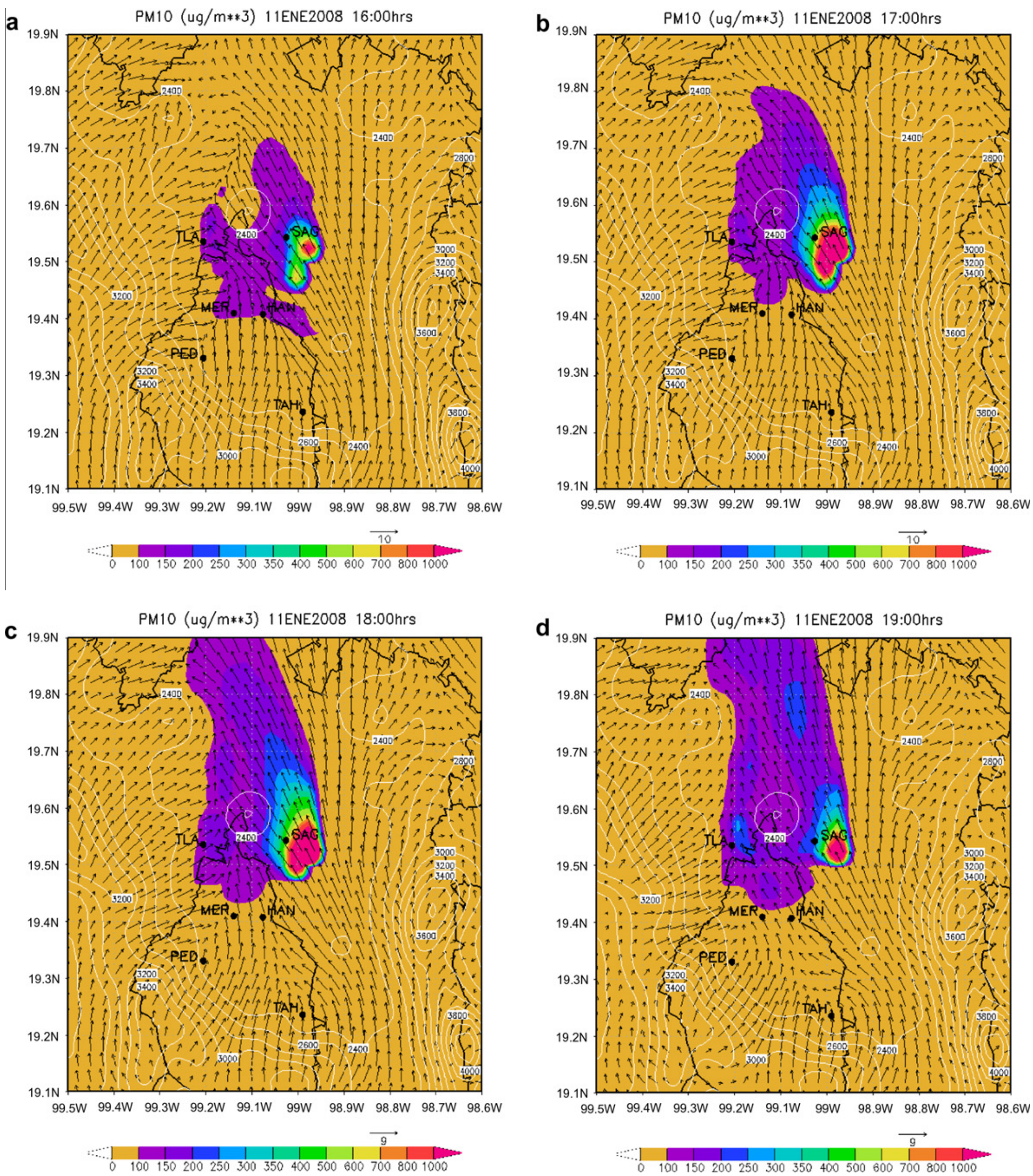

Fig. 8. Wind fields and concentrations generated over dry Lake of Texcoco during January 11st. White lines represent level isolines in m.s.l.

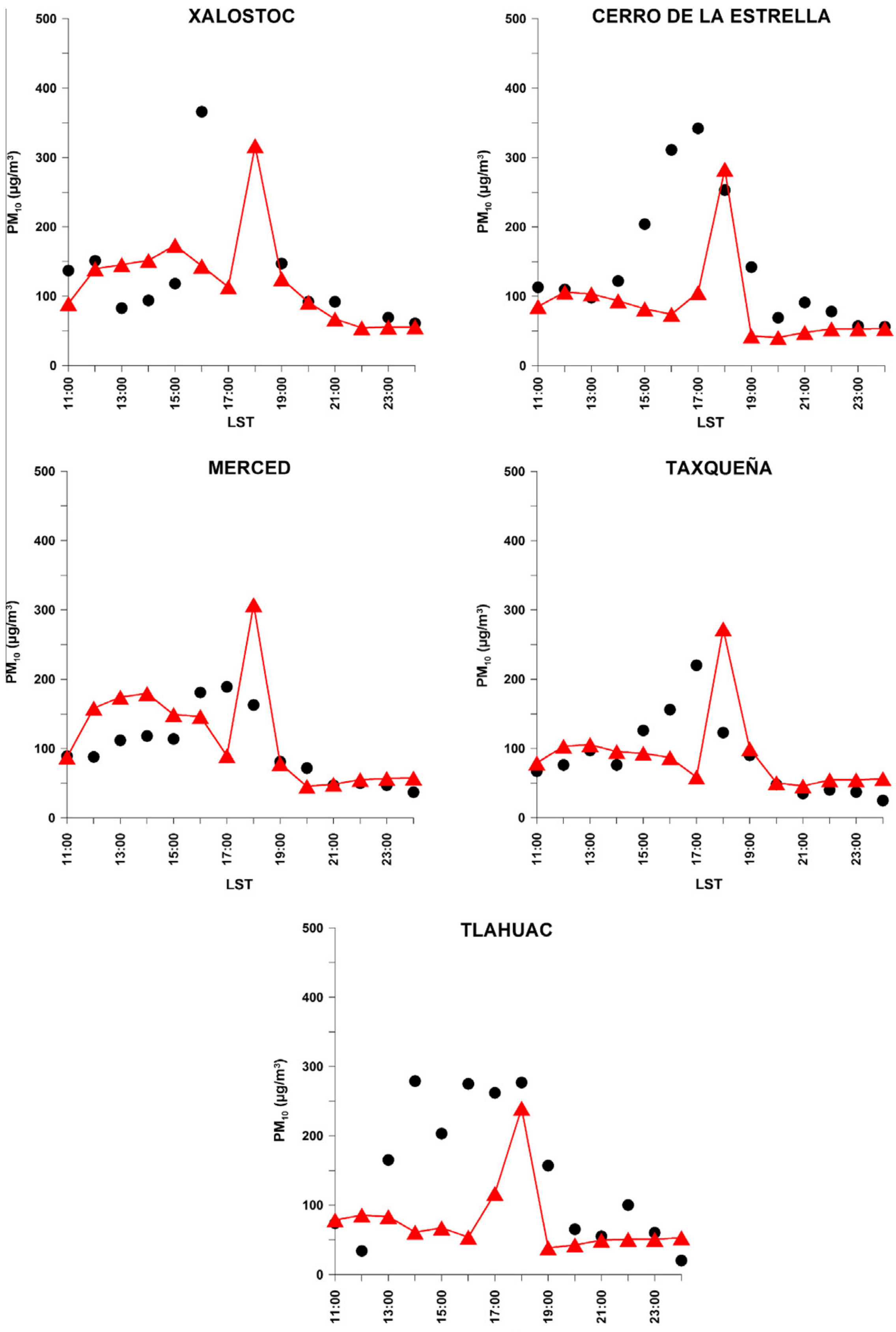

Fig. 9. Comparison of PM_{10} concentrations in µg/m^3 between SIMAT stations (●) and MCCM–WEPS system (▲) data during April 5th.

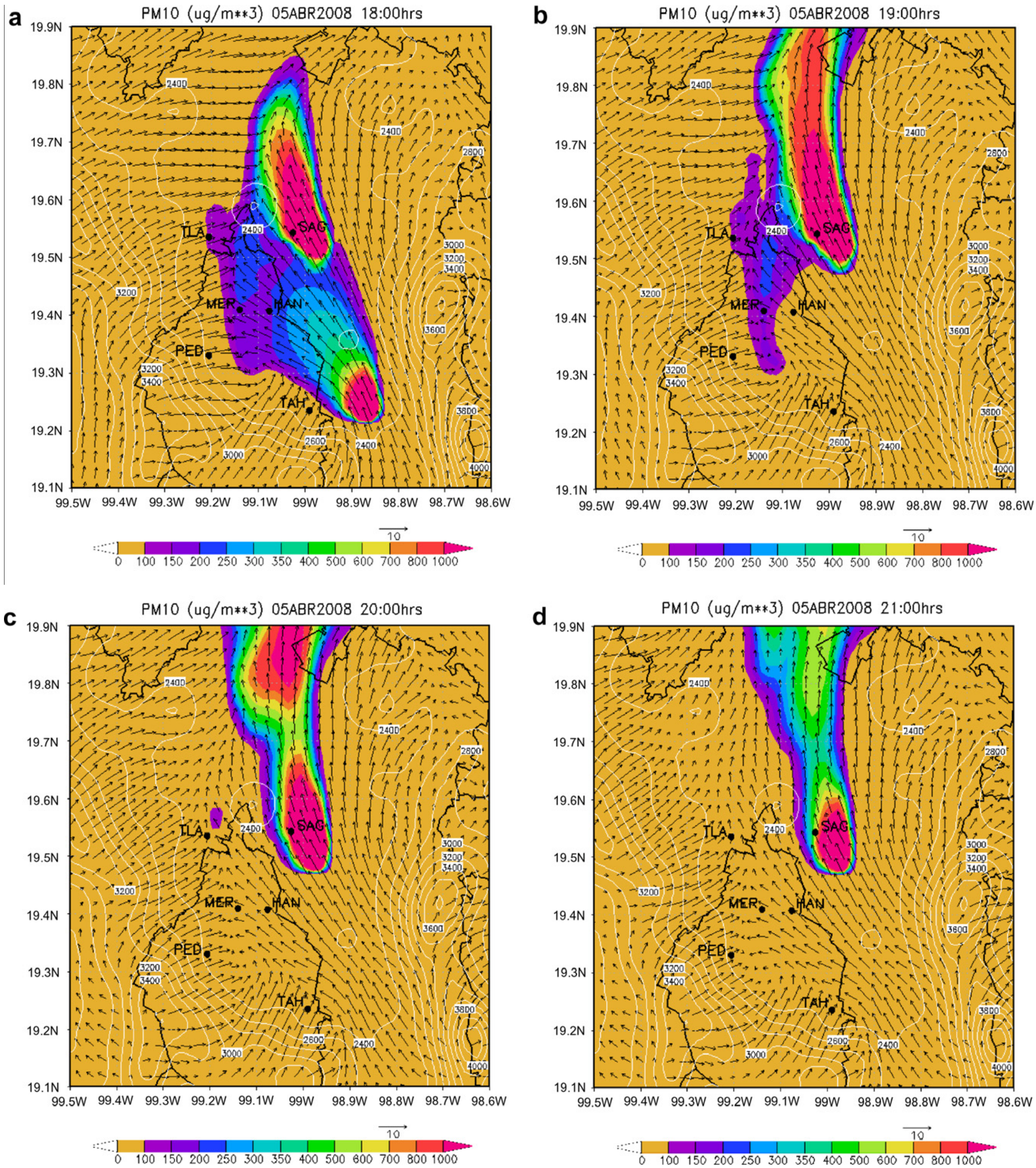

Fig. 10. Wind fields and concentrations generated over dry Lake of Texcoco during April 5th. White lines represent isolines in m.s.l.

located north of the dry lake (Fig. 6). As can be seen in Fig. 6, Mexico City was mainly affected by the emissions from Tenango del Aire and dry Lake of Texcoco.

In Table 2 the PM_{10} emissions during the event are quantified using MCCM–WEPS. The dust emission from Texcoco is almost twice than Tenango del Aire. The strongest source during this episode was the area of Texcoco.

Measurements of PM_{10} for SAG on March 19th from 13:00 to 20:00 h in local standard time (LST), report 1261 $\mu g/m^3$ maximum concentration, while the model generates 1262 $\mu g/m^3$ (Fig. 5). Measurements lag the modeled concentration maximum by one hour.

Fig. 6 shows hourly surface distribution of the PM_{10} dust plume. It can be seen that station SAG is affected by dust emissions. The plume travels from south to north starting in Tenango del Aire. The wind speed is around 9 m/s and it is strengthened over the dry Lake of Texcoco with local speeds of 10 m/s. The modeled plume narrowly misses TAH and CES stations, and therefore measured and modeled concentrations disagree there in time and mag-

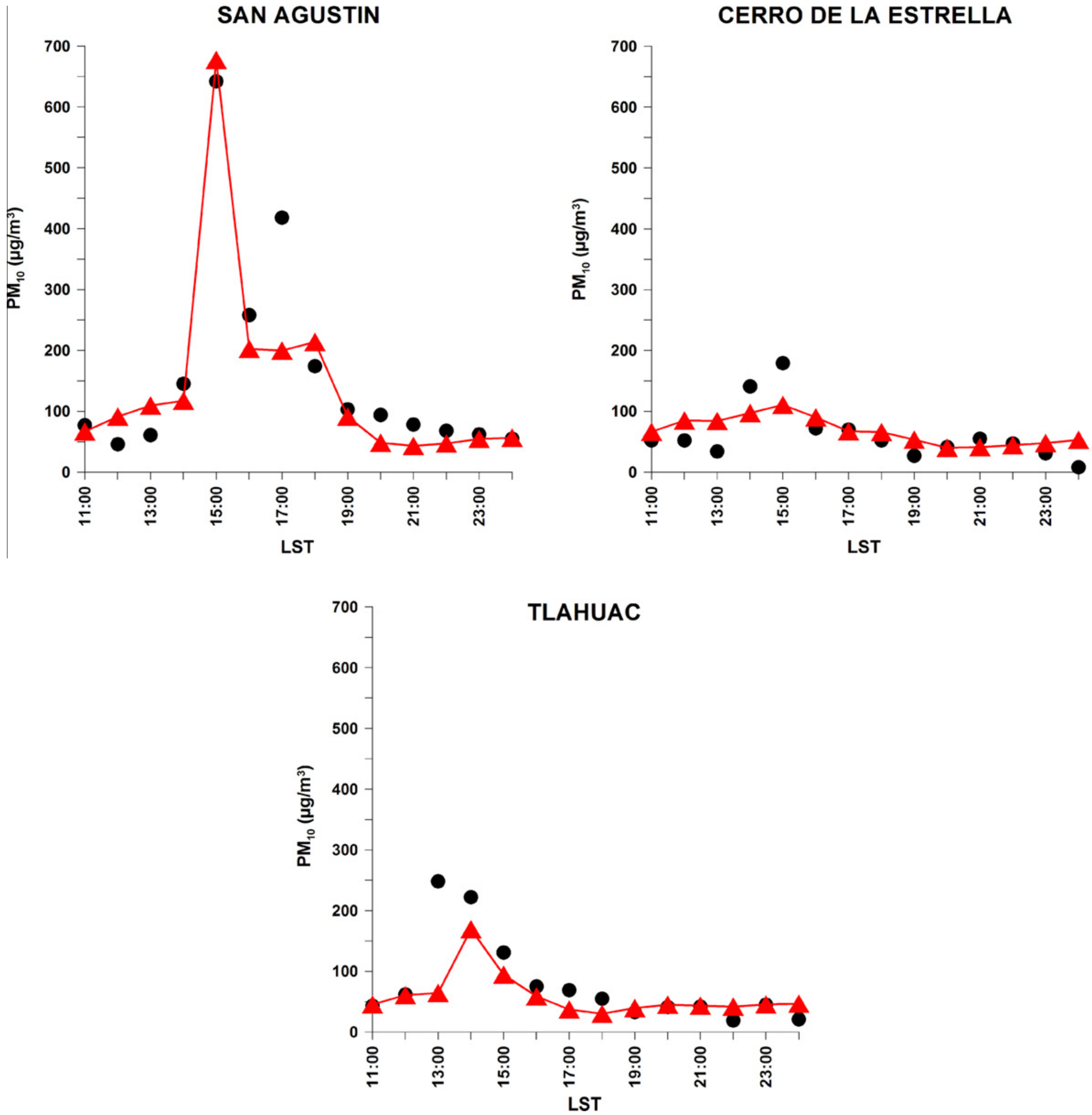

Fig. 11. Comparison of PM_{10} concentrations in µg/m^3 between SIMAT stations (●) and MCCM–WEPS system (▲) data during November 29th.

nitude. Nevertheless, in general terms MCCM–WEPS correctly captures the episode path and strength.

The affected areas were mainly in the eastern part of MC. At 15:00 LST the presence of a confluence line over Tlalnepantla (TLA) shown in Fig. 6c drives up the plume outside the valley towards Hidalgo State as will be shown in Section 4.

The modeling results presented here explain the presence of soil material during the MILAGRO campaign, as discussed in Querol et al. (2008), Mugica et al. (2009) and agrees with Fast et al. (2007).

3.2. 10–12 January, 2008

At noon January 11th, SIMAT reported high PM_{10} concentrations over stations San Agustin (SAG) and Xalostoc (XAL), whose locations are shown in Fig. 1. As shown in Fig. 8, MCCM–WEPS reports that the emissions came from dry Lake of Texoco affecting the northern part of the valley. The PM_{10} emission is quantified in Table 2.

Modeled and observed PM_{10} results for stations SAG and XAL on January 11th are shown in Fig. 7. From 15:00 to 21:00 LST SAG reports 543 µg/m^3 maximum concentration while the model generates 517 µg/m^3 at the same time. Modeled concentrations for XAL, shown in Fig. 7, were under predicted during the same time period.

Fig. 8 shows hourly evolution of the dust plume over north part of the valley. It can be seen that station SAG is influenced by the plume coming from dry Lake of Texcoco where local speeds reached 10 m/s. The modeled plume narrowly misses XAL and that is why observed and modeled concentrations disagree in magnitude.

As shown in Fig. 8 the affected areas are north and north-east of MC as was the case for the March 19th episode. The main dust source was the dry Lake of Texcoco.

In this occasion the confluence lines were not as intense as those during the March 19th episode. Since the dust plume was not able to reach the confluence, no strong vertical intrusion of particles took place.

3.3. 04–06 April, 2008

On April 5th, SIMAT reported high PM_{10} concentrations over stations Xalostoc (XAL), Cerro de la Estrella (CES), Merced (MER), Taxqueña (TAX) and Tlahuac (TAH). MCCM-WEPS determined that

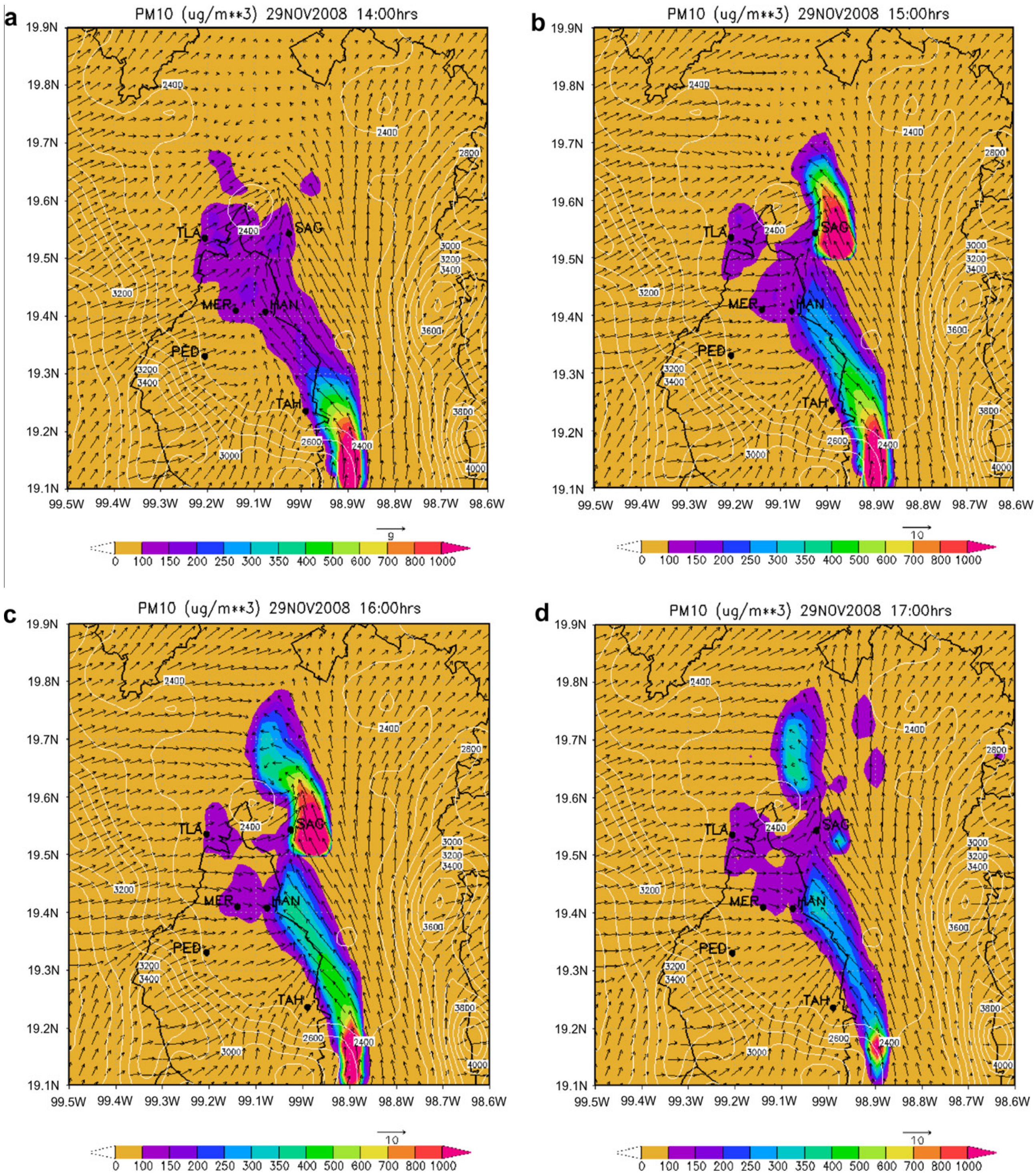

Fig. 12. Wind fields and concentrations generated over east part of Valley of Mexico during November 29th. White lines represent level isolines in m.s.l.

dust emissions came from two different areas: agricultural lands located east of the valley (Valle de Chalco) and from the dry Lake of Texcoco (Fig. 10a). The PM_{10} emissions from these areas are quantified in Table 2. The two areas emitted almost the same quantity during this air pollution episode.

Modeling and observed measurements of PM_{10} for the mentioned SIMAT stations are shown in Fig. 9. From 15:00 to 19:00 LST all stations except TAH reported high PM_{10} concentrations. In TAH maximums occurred from 13:00 to 19:00 LST. The MCCM–WEPS concentrations lag measurements in some stations.

Hourly location of plumes concentrations are shown in Fig. 10. While SAG and XAL areas are influenced by emissions from dry Lake of Texcoco with local wind speeds of 10 m/s, CES, MER, TAX and TAH are influenced by a plume coming from Valle de Chalco that also affects stations SAG and XAL. Winds speeds of 10 m/s are present over the eastern part of MC.

As shown in Fig. 10, the affected areas were mainly in the east, center and north of MC. At 18:00 LST the presence of wind confluences leads the plume outside the valley towards the north, as was the case for the March 18th episode.

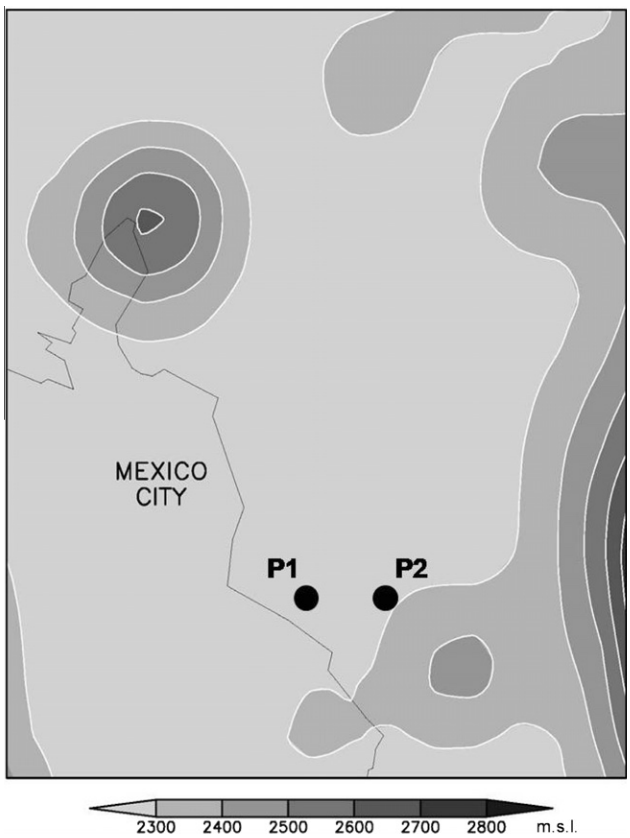

Fig. 13. Location of sites selected to dust plume vertical analysis.

Vertical analysis of the plume, performed in Section 4, shows that the presence of confluence lines enhances vertical dust transport.

3.4. 28–30 November, 2008

On November 29th, SIMAT reported high PM_{10} concentrations in stations San Agustin (SAG) and Tlahuac (TAH). MCCM–WEPS shows that the emissions came from south-east of the Valley of Mexico City (Tenango del Aire) and dry Lake of Texcoco. This situation is shown in Fig. 12b. The emissions are quantified in Table 2. For this case, Tenango del Aire presented the strongest emissions.

Modeling and measurements results of PM_{10} for both stations on 29 November are shown in Fig. 11. From 14:00 to 18:00 LST, measurements report 642 μg/m^3 maximum concentration, while the model generates 677 μg/m^3 at the same time for SAG. In Cerro de la Estrella (CES), the measurements maximum was 179 μg/m^3 while the model generates 110 μg/m^3 for the same period of time. In the case of TAH, measurement maximum was 248 μg/m^3 while the model generated 169 μg/m^3. In this case, measured maximum lags the modeled by one hour. The HAN station was not working the day of the event.

Hourly location of the plume dust concentrations is shown in Fig. 12. It can be seen that TAH is affected by emissions coming from the south-east that starts in Tenango del Aire (Fig. 12a) with local wind speeds around 6 m/s. Also SAG is under the plume that starts in Tenango del Aire. This plume is strengthened over the dry Lake of Texcoco with local wind speeds of 10 m/s. The modeled plume narrowly misses CES, and therefore measured and modeled concentrations disagree there in magnitude. This can be observed in Fig. 11, where PM_{10} concentration reported by CES is almost two times the value calculated by the model at 15:00 LST.

Eastern, central and northern parts of MC were the main affected areas during this event. At 15:00 LST the presence of a confluence line shown in Fig. 12b directs the plume from the central part of MC to the north of the city.

Vertical analysis of the plume shows that the presence of confluence lines enhances vertical transport. This was the case for the March, 2006 and April, 2008 episodes. Dust particles were transported vertically to the mixing layer height and then transported out of the Valley of Mexico affecting other regions.

4. Vertical analysis

The November 29th event was selected to perform the vertical analysis of PM_{10} concentration and wind direction. For this purpose two points were selected (P1 and P2), the locations of which are shown in Fig. 13.

The PM_{10} concentrations, potential temperature (θ) and wind speed and direction profiles at P1 and P2 are shown in Fig. 14, from 14:00 to 19:00 LST. As is shown in Fig. 14a, PM_{10} dust arrives at P1 at 14:00 h LST (see Fig. 12a for the corresponding surface distribution). Between the surface layer and 800 m, south-east winds speeds of about 5 m/s are present with near surface unstable conditions, while neutral and stable conditions exist in the upper layers. At P2, meteorological conditions were similar even though the dust screen has not reached this area (Fig. 14a′). Maximum PM_{10} concentrations were obtained near the surface at P1 (120 μg/m^3).

An increase in concentrations and change in the vertical conditions can be seen for P1 and P2 in Fig. 14b and b′, respectively. As shown before, in Fig. 12b, at 15:00 LST confluences are formed near to P1. This phenomenon increases PM_{10} concentrations in the upper layers where wind direction also changes (Fig. 14a). At this time a concentration peak of 200 μg/m^3 at ≈1 km height (mixing layer height) in P2 can be observed in Fig. 14a′. This is as a result of dust transport from P1 to P2.

At 16:00 LST the dust plume ascends higher as confluence gathers strength near to P1 as is shown in Fig. 14c and its corresponding Fig. 12c. The dust particles rise up to 2.1 km where they find the inversion capping the mixing layer. High surface concentrations are present due to continuous dust transport from the source in P1. Meanwhile in P2, dust transport occurs mainly in the upper layers while near the surface concentrations remain relatively low because the site is not a strong emission areas as shown in Fig. 12c and 14c′.

As shown in Fig. 12d, when emissions diminish due to lower wind speeds concentrations also diminish at P1 and P2. This is reflected in Fig. 14d and d′. The plume reaches ≈1 km height in P1 while in P2 it is at ≈1.3 km. Once the emissions disappear as a consequence of low wind speeds over dust sources, residual PM_{10} concentrations remain at ≈1 km over surface, as shown in Fig. 14e and e′. In Fig. 14f and f′, the surface concentrations are mainly due to anthropogenic sources and sedimentation of dust particles.

Figs. 12 and 14 show that vertical distribution of PM_{10} dust particles is enhanced by confluences lines, which also influence horizontal transport. The confluences cause the dust particles to be transported out of the Valley of Mexico.

5. Conclusions

Three aeolian erosion sources of PM_{10} were identified by the application of MCCM–WEPS for the episodes of March, 2006, April and November of 2008: the dry Lake of Texcoco and agricultural lands located to the south-east and east of the Valley of Mexico. For the January, 2008 episode the main source was the dry Lake of Texcoco. As shown in Table 2, the largest emissions were during March, 2006, where the dry Lake of Texcoco was the main source

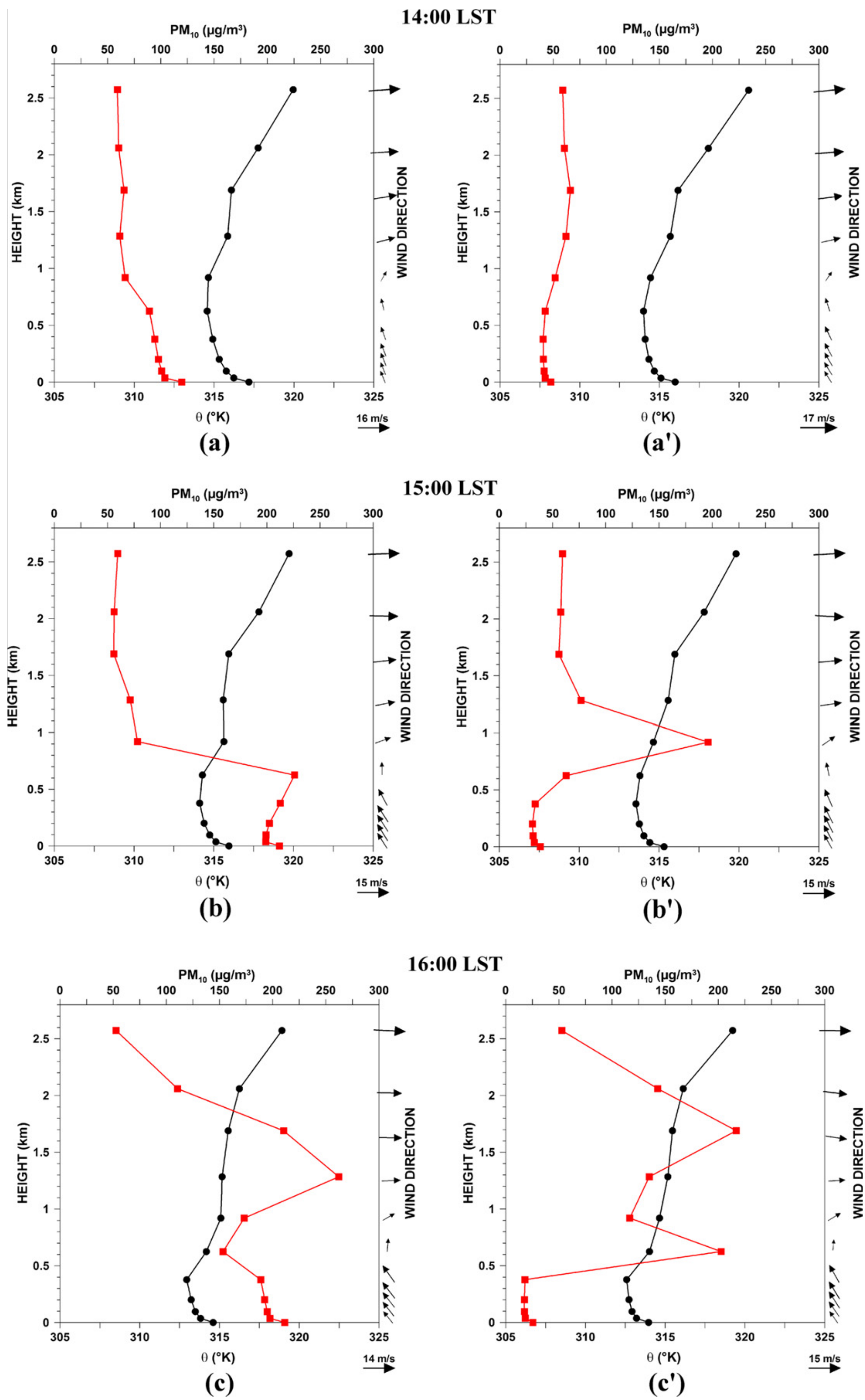

Fig. 14. PM_{10} (■) and Potential Temperature (●) vertical profiles obtained for P1 (left) and P2 (right) from 14:00 (a–a′) progressively to 19:00 LST (f–f′) of November 29th. Horizontal wind speed and wind direction in different heights are shown at right side of each graph. Arrow size represents the wind scale intensity.

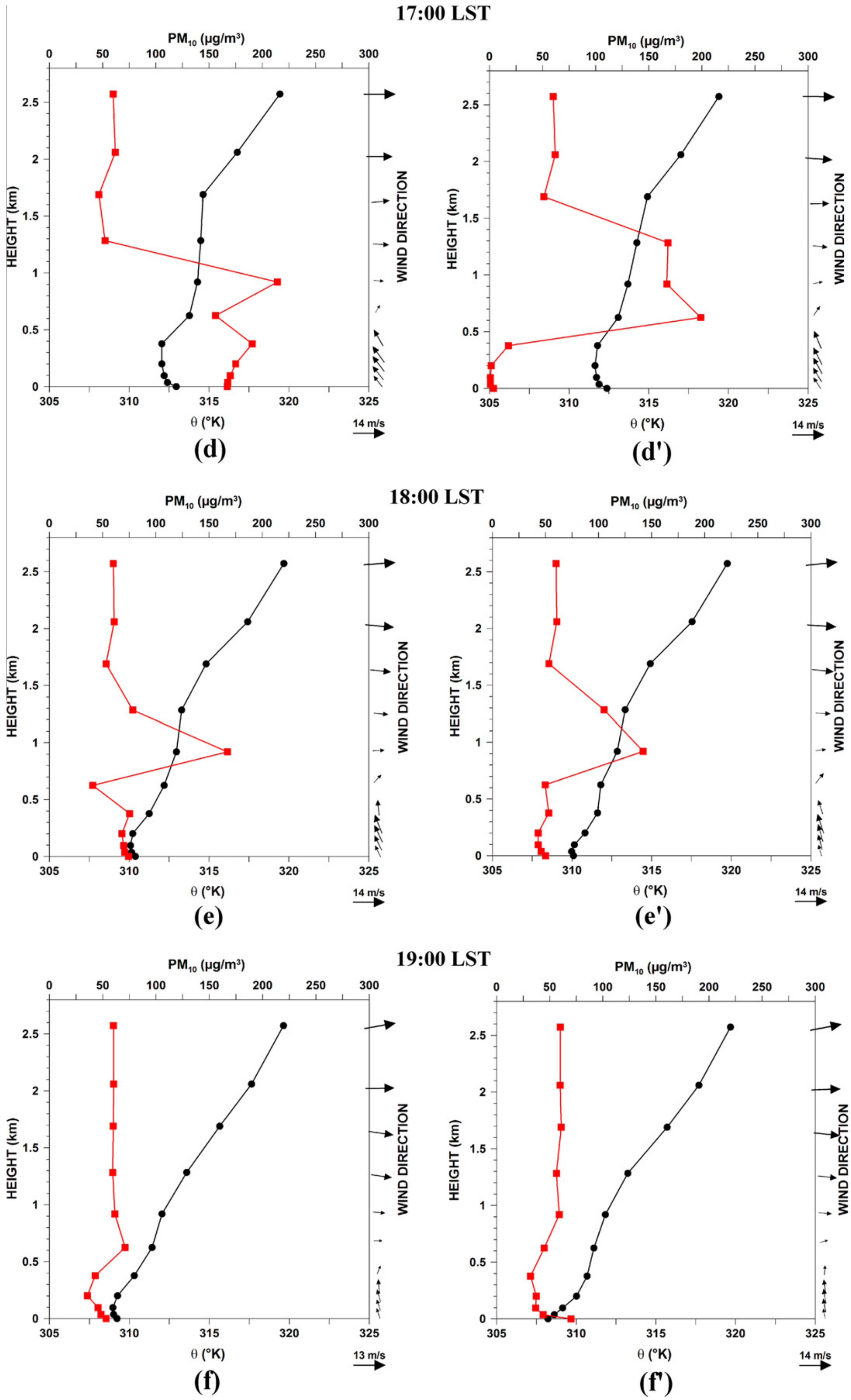

Fig. 14 (*continued*)

explaining the highest PM_{10} concentrations over San Agustin (Fig. 5). For April, 2008, emissions from Texcoco and agricultural lands in Valle de Chalco were very similar. These emissions together with meteorological conditions caused high surface PM_{10} concentrations over monitoring sites east of Mexico City (Fig. 9). San Agustin did not work that day. Considering the modeling results it is probable that this site would have reported PM_{10} concentrations as high as the March, 2008 epsidoe. The lowest emissions were during January and November, 2008, over dry Lake of Texcoco and Tenango del Aire. Meteorological conditions at San Agustin reported high PM_{10} concentration during these episodes (Figs. 7 and 11).

The strength of the sources resulting in high PM_{10} surface concentrations during the four analyzed episodes was well approximated by MCCM–WEPS. In the majority of cases, the events reported by the measuring stations are reproduced by the model. The cases where modeling and measurements differed are explained by the fact that an error of less than 30 degrees in modeling wind direction may cause the relatively slender aeolian erosion plume to miss a station.

During the extraordinary event of March 2006, PM_{10} concentrations (observed and simulated) were above 1000 $\mu g/m^3$ (Figs. 5 and 6). This event coincided with the MILAGRO campaign. The modeling experiments confirm the results reported by Fast et al. (2007), Querol et al. (2008) and Mugica et al. (2009) regarding the presence of wind-blown dust and high crustal content on particles in MC during the campaign period.

Effective measures to reduce the incidence of dust from the dry Lake of Texcoco were implemented in the 1960's (Moreno Sánchez, 2007; Lomelí et al., 2009). They included the partial recovery of the dry lake by building the lake Nabor Carrillo and planting resilient vegetation to the local soil and climate conditions. These interventions greatly reduced the dust storm problems but as shown here, airborne soil material coming from this area is still present in Mexico City, potentially affecting the health of its inhabitants. Additional source areas such as agricultural lands in the south-east (Tenango del Aire) and East (Chalco) were also identified as an important component of PM_{10} aeolian erosion that affects MC.

According to the results, soil emissions from the four extraordinary events studied in this work represented a serious problem to the air quality of Mexico City. The dry Lake of Texcoco is the most important area source that affects the north-east part of the city. This source alone generated around 80% of the total coarse particles measured at SAG in the north-east of Mexico City during all events. On the other hand, the agricultural lands (Tenango del Aire and Chalco) affected the central, south and south-east parts of the city, contributing with about 75% of the total coarse particles over TAH during the April and November events.

3D analysis of the modeling results shows that transport of PM_{10} is accelerated horizontally when nearby confluences are formed generating low pressure systems and vertical transport of the particles is enhanced. Confluence lines are a main factor for vertical mechanical convection of dust particles. In the case of the November, 2008 episode, the particles were transported up to the mixing layer height and then transported out of the Valley of Mexico.

This paper demonstrate that MCCM–WEPS can be used as a useful tool in evaluating dust emissions contribution to air quality and also as a method to evaluate and develop control policies regarding soil regeneration or other control measures to decrease dust emission impacts on air quality of MC.

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