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A micrometeorological data base for the Mexico City Metropolitan Area

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Summary. — In order to overcome the lack of the surface micrometeorological data required for air quality studies in the Mexico City Metropolitan Area (MCMA), a long-term micrometeorological campaign was carried out in this area along the 2001-year. Three micrometeorological surface stations were installed at sites located at north, north-east, and south sectors of the MCMA. Each station was equipped with a 3D ultrasonic turbulence sensor and with conventional meteorological sensors for temperature, relative humidity, pressure, global radiation, net radiation, and rain. The sampling rates were 10 Hz for the ultrasonic sensor, and 1 Hz for the conventional sensors. One-hour averages were calculated for all the meteorological parameters and for the turbulence parameters such as friction velocity, scale temperature, Monin-Obukhov length, sensible heat flux and turbulent kinetic energy, among others. A simple micrometeorological database was prepared and mounted on a free access Internet page to furnish a specialized tool to the local Authorities to be utilized in health prevention and pollution regulation applications.

PACS `92.60.Sz` – Air quality and air pollution.
PACS `92.60.Ek` – Convection, turbulence, and diffusion.

1. – Introduction

One of the main problems affecting the metropolitan areas around the world is the high level of air pollution that is being measured there. In the Mexico City Metropolitan Area, as in many others in the world, air pollution has reached really worrying levels that, for some many years, have called the attention of the environmental authorities. A

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number of efforts have been made in promoting and planning relatively successful emission abatement actions although not always easy of quantification in terms of prevention. What is evident, however, is the need of understanding the reasons that give rise to such high air pollution levels in the metropolitan areas. The pollutant emissions, which for metropolitan areas result mainly from the vehicular traffic, are, in fact, the most important responsible of air pollution. However, it is also well known that the prevailing meteorological characteristics (or better, the micrometeorological characteristics) of the highly polluted areas constitute a very important element in the establishment of these high-risk situations.

In order to evaluate in advance the efficiency of the clean air initiatives it is frequently required to use computer models to simulate the transport, dispersion and physicochemical transformation processes experimented by the pollutants in the atmosphere. However, due to the high complexity (topographic, climatic, and microclimatic) of the urban and suburban areas, the air quality models that must be used in this kind of studies belong to a medium-to-high complexity models class, such as the Lagrangian particle models or the photochemical Eulerian models. These kinds of models, however, require not only an accurate time-space description of the emissions, but also an accurate description of the long-scale air movement and of the turbulence in the urban boundary layer.

The study of urban micrometeorology is very recent and, as it is reflected in the available literature, many of its main aspects are really far from to be completely understood. Urban areas possess surface roughness characteristics that play a very important role in the micrometeorological description of the measurement site, and a lot of efforts have been dedicated understand them (see, for example, [1]). Also important is the study of the wind velocity vertical profile inside the urban areas, so as its relations with its behavior in the adjacent rural areas [2]. The urban morphology of the megacities, such as the Mexico City Metropolitan Area, determines a very complex wind field inside, which, in general, only can be studied by numerical simulations [3] or wind tunnel experiments. The knowledge of the mean wind field, however, is not enough to satisfy the micrometeorological requirements of the simulation models. The most recent air quality models require a very accurate knowledge of the dispersion capability of the urban canopy layer implying, of course, a very detailed description of the micrometeorological conditions that prevail in the area. A very interesting review of these arguments can be found in Roth [4] and Rotach [5]. The turbulence intensity in urban areas depends not only on surface roughness, but also on the particular surface energy balance proper of the site. In Oke and McCaughey [6], for example, a comparison between suburban and rural surface energy budgets using synchronously observed data is provided for the Vancouver area. In Grimmond and Oke [7] some non-radiative heat flux submodels of the local urban meteorological parameterization scheme (LUMPS) are outlined and are evaluated using local-scale meteorological data collected in seven North American cities (included Mexico City).

In the last decade [7, 8], a relatively large number of urban turbulence experimental data has become available as a part of the so-called Multicity Urban Hydrometeorological Database (MUHD). Although this database constitutes a very useful instrument to support a wide class of urban micrometeorology theoretical studies and for the purposes of calibration of a wide class of micrometeorological models, it is characterized by an intrinsic time limitation (1-8 weeks), as it is underlined by Grimmond and Oke [7].

Although some preliminary efforts have been made also to carry out an experimental characterization of the Mexico City Metropolitan Area (MCMA) micrometeorol-

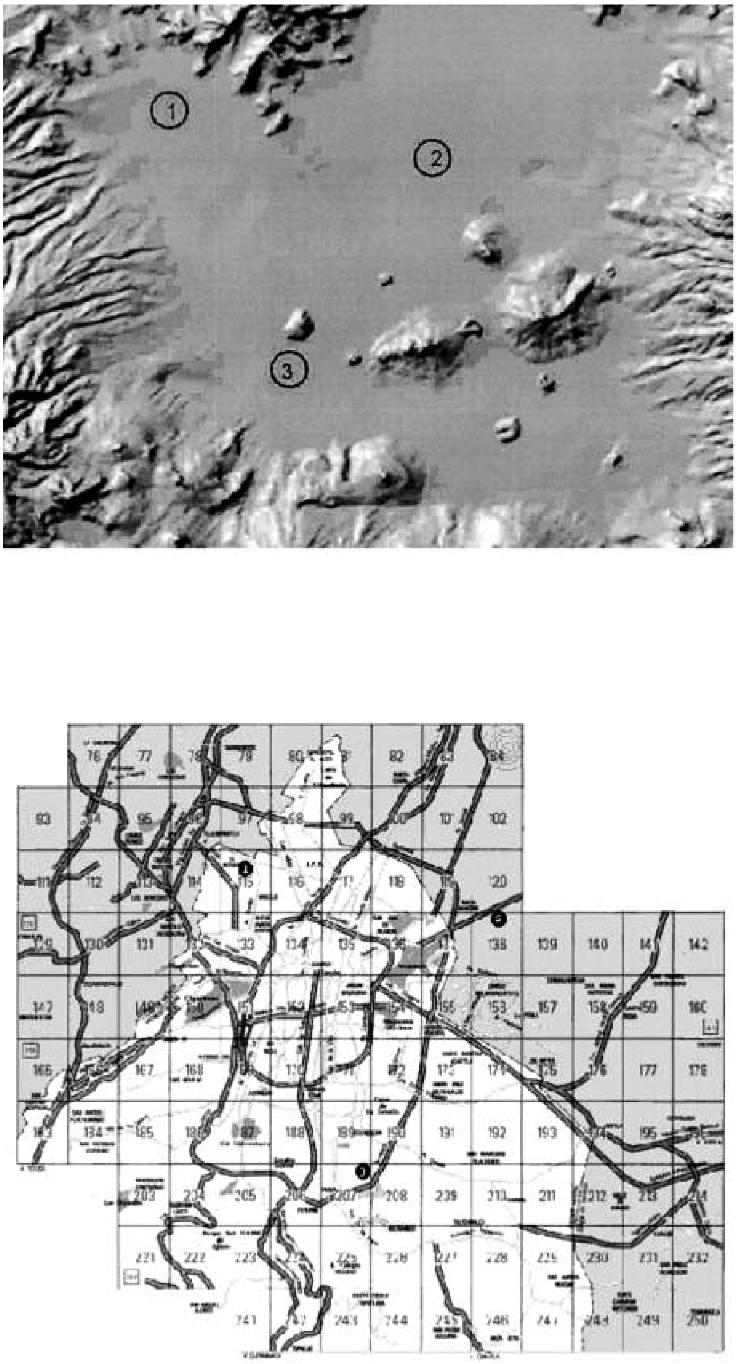

Fig. 1. – Geographical locations of the MCMA micrometeorological stations: (1) Azcapotzalco, (2) Texcoco, (3) Xochimilco.

TABLE I. – *Geographic position of the monitoring sites.*

Station	ID	Latitude	Longitude	Altitude (m.a.s.l.)
Texcoco	TEX	N 19°27′53.1″	W 98°59′54.4″	2250
Xochimilco	XOC	N 19°18′18.3″	W 99°6′6.2″	2250
Azcapotzalco	AZC	N 19°30′9.4″	W 99°11′12.2″	2190

ogy [9-11], one of the main drawbacks of air quality modeling in MCMA is still the lack of the proper micrometeorological data required by the advanced dispersion models. The MCMA meteorological stations, included those ones of the Mexico City Atmospheric Monitoring System (SIMAT), provide only conventional meteorological data which is not enough to feed the more recent air quality models. In particular, none of the atmospheric turbulence parameters is measured. However, with the economic support of the Mexican Consejo Nacional de Ciencia y Tecnología (CONACyT, grant No. 218470-5-R32457-T), the M^{4}CA group of the Mexican Electrical Research Institute (Instituto de Investigaciones Eléctricas, IIE) carried out a long-term surface micrometeorological campaign (January to December, 2001) in the MCMA, and the collected data were used to prepare a one-year micrometeorological database for the air quality modeling purposes. A three surface stations meteorological network was installed. One of them was located in a rural terrain site nearby the old Texcoco lake (NE sector of MCMA), and the other two in urban sites located at the Azcapotzalco and Xochimilco camps of the Metropolitan University (NNW and S sectors of MCMA). Each station was equipped with a 3D ultrasonic anemometer and also with conventional meteorological sensors for temperature, pressure, relative humidity, net and global solar radiation, and rain, mounted on a 10 m tower. The ultrasonic sensor data (temperature and wind velocity components) made it possible to use the eddy covariance method to estimate the atmospheric turbulence parameters such as friction velocity, scale temperature, sensible heat flux and Monin-Obukhov length, among others. The micrometeorological database was prepared with the one-hour averages of all the meteorological variables measured and estimated, and an Internet page was mounted to make available these data to the scientific community interested on studying MCMA air pollution.

In this paper a detailed description of the experimental campaign and of the micrometeorological database is presented as a tool, actually available on web, to be utilized for regulatory purposes by local authorities and by the scientific community to implement the knowledge of turbulence patterns on different “canopies”.

2. – The 2001 MCMA experimental campaign

Three surface meteorological stations (Texcoco (TEX), Azcapotzalco (AZC) and Xochimilco (XOC)) were installed at sites whose geographic positions are described in table I and shown in fig. 1.

The Texcoco station was located in the north-east (NE) sector of the MCMA, nearby the old Texcoco lake. It is a rural terrain (bare soil) site close to the Mexico City international airport. The other two stations were installed on urban sites located in the north-north-west (NNW) and south (S) sectors of MCMA, in facilities of the Azcapotzalco and Xochimilco campus of the Metropolitan University. The site of the Azcapotzalco station is practically immersed in the MCMA industrial zone, while a residential area surrounds

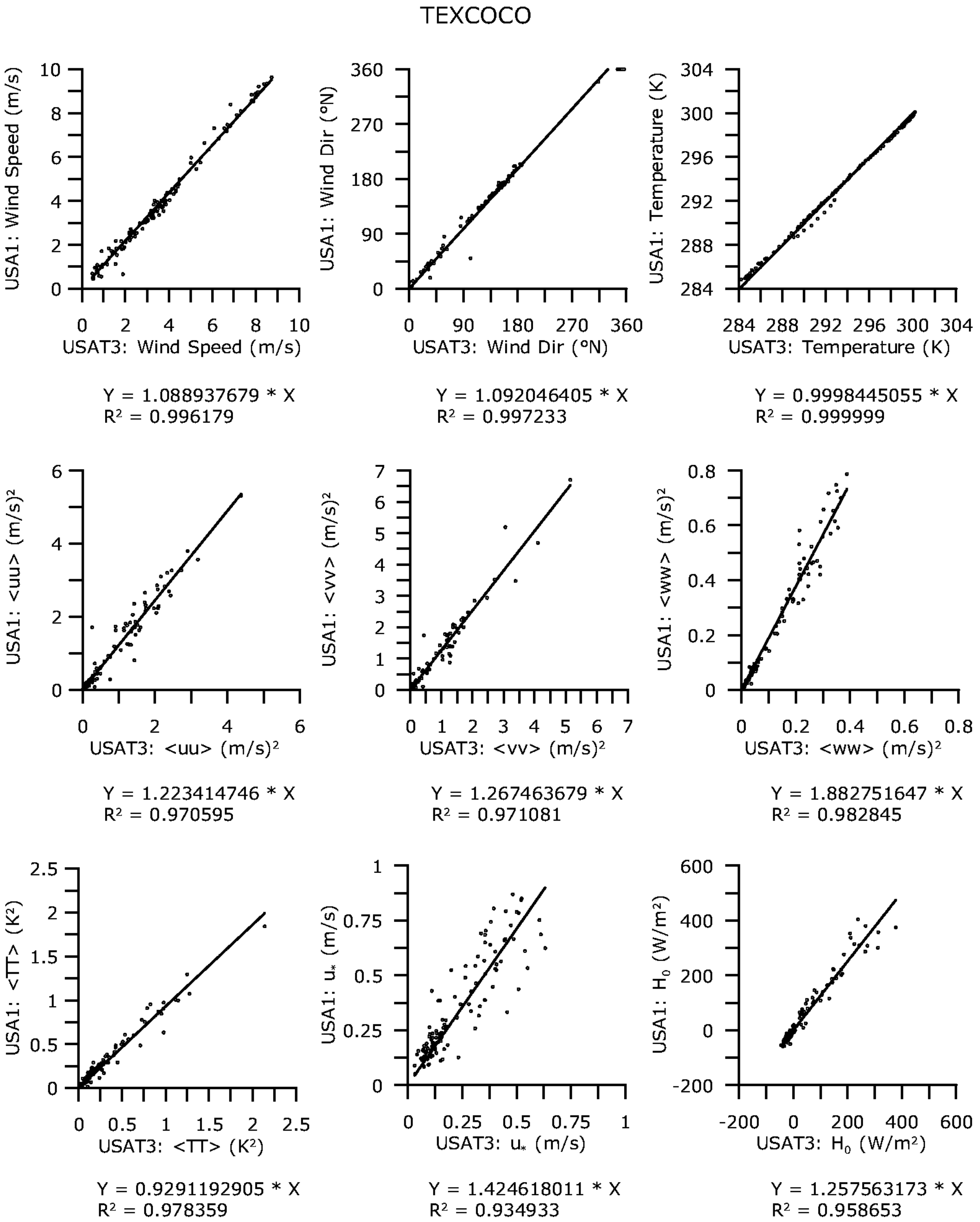

Fig. 2a. – Comparison of sonic anemometers performances (USAT3 *vs.* USA1) at the Texcoco site.

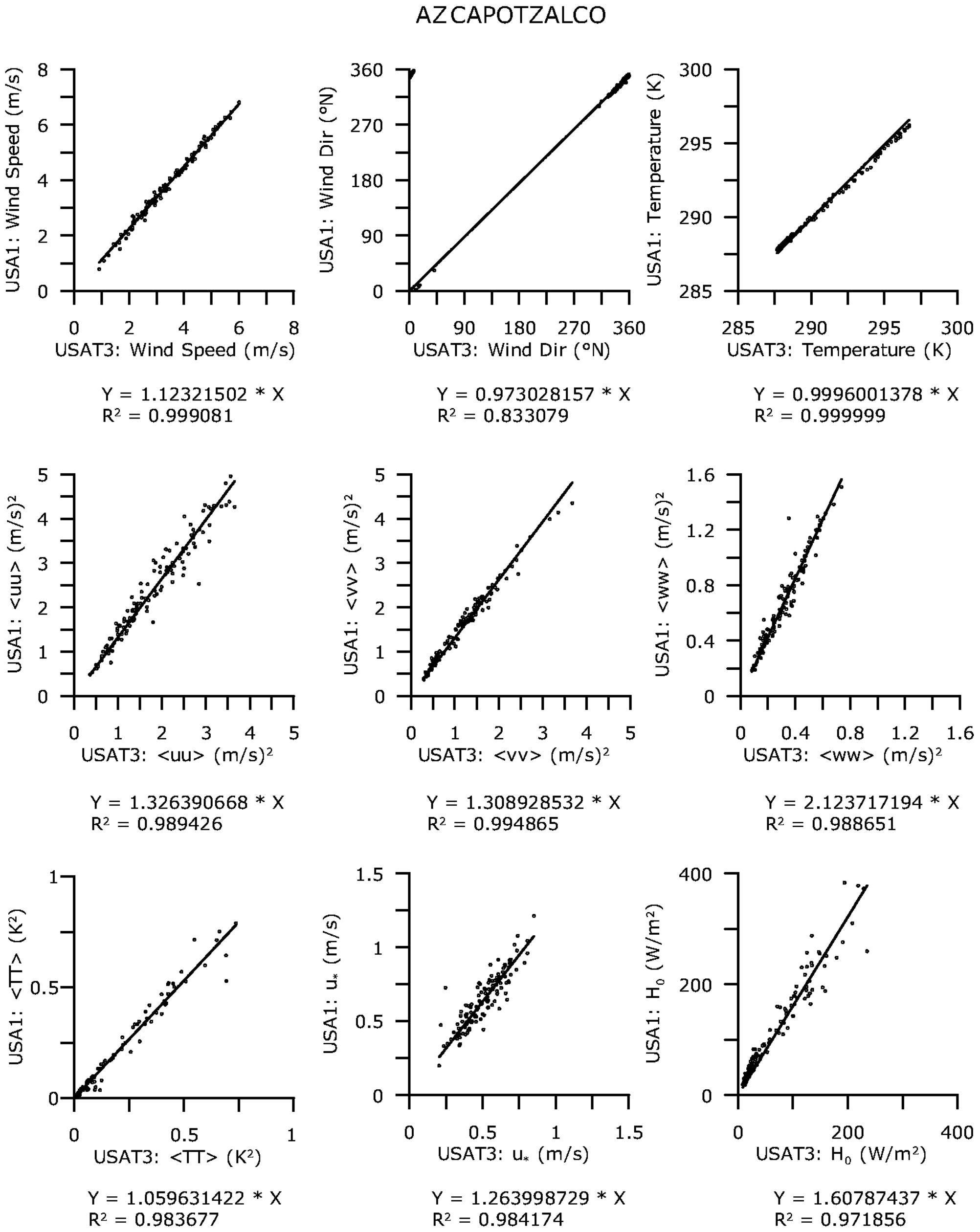

Fig. 2b. – Comparison of sonic anemometers performances (USAT3 *vs.* USA1) at the Azcapotzalco site.

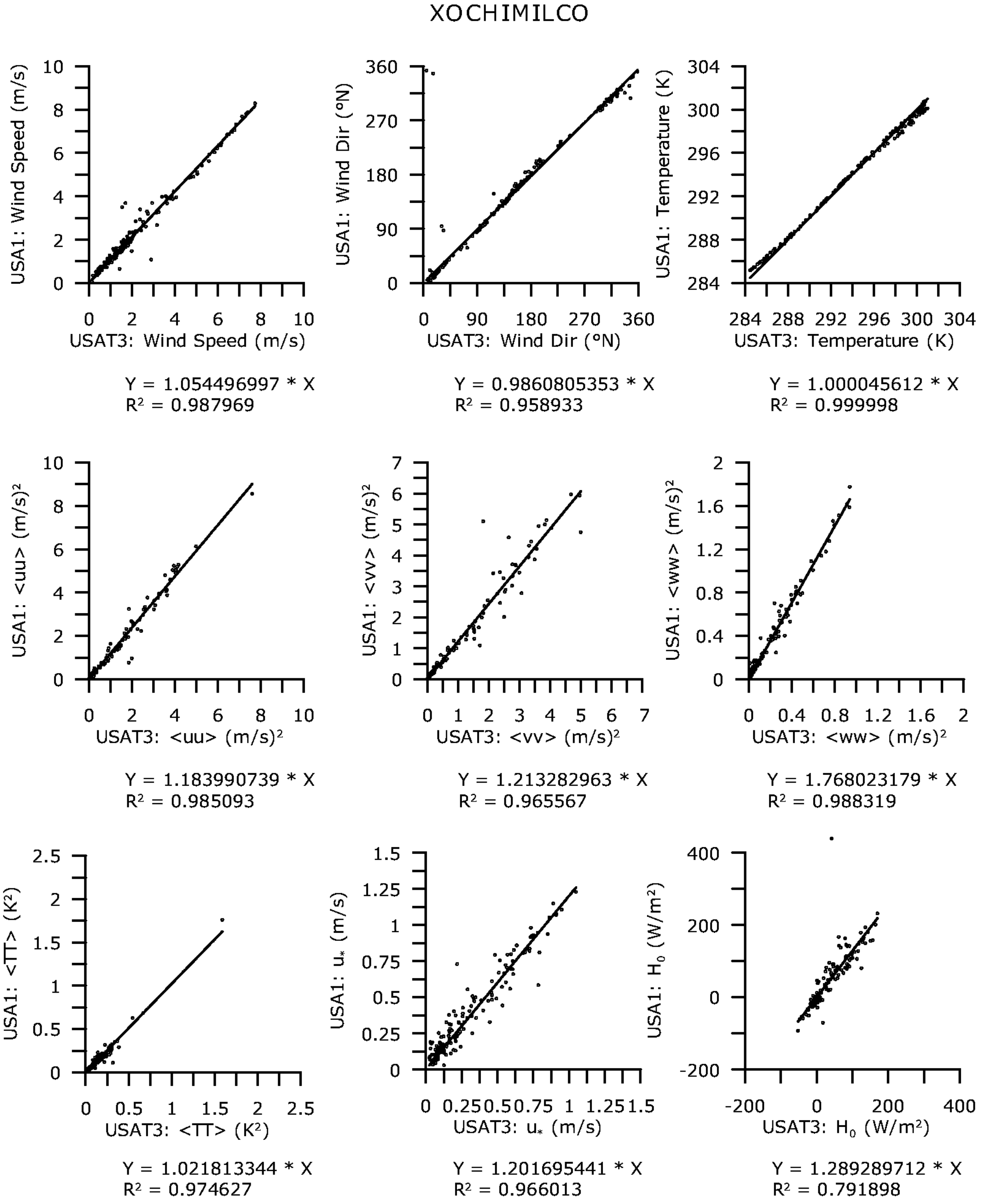

Fig. 2c. – Comparison of sonic anemometers performances (USAT3 *vs.* USA1) at the Xochimilco site.

Table II. – *Meteorological sensors installed in each station.*

Qty	Sensor	Trademark	Model
1	Ultrasonic Anemometer	METEK	USAT-3
1	Pressure Gauge	Campbell Scientific	PTA427
1	Temperature and Relative Humidity Probe	Campbell Scientific	HMP35C
1	Net Radiometer	REBS	Q-7
1	Pyranometer	LI-COR	LI200X
1	Rain Gauge	Texas Electronics	TE525MM

the site of the Xochimilco station.

The meteorological sensors were mounted on a 10 m tower, which, in the case of the Texcoco station, was installed directly on ground, but in the cases of the other two stations, the tower was installed on the roof of a 20 m-height building. In all cases, no relevant obstacles were found above the measuring height. Each station was equipped with a 3D ultrasonic turbulence sensor (measuring wind velocity components and temperature) and with conventional sensors for temperature, relative humidity, pressure, rain and net and global solar radiation. All the meteorological sensors that were installed in each one of the stations are described in table II.

Two data acquisition systems were used in each station, one for the ultrasonic sensor and the other one for the rest of the meteorological sensors. In the first one the sampling rate was 10 Hz and in the second one was 1 Hz.

In order to guarantee the quality of data it was followed the next control procedure:

– all the meteorological sensors were sent to the respective manufacturers for maintenance and calibration, and for all of them were prepared intercalibration plots against reference sensors, as is described in [12];

– during the last two weeks of April 2001 (four months later the campaign start date), for each one of the ultrasonic anemometers (METEK, USAT-3) one 24 hours comparison against a new ultrasonic anemometer (METEK, USA1) was carried out (*in situ*). In figs. 2, are shown the calibration plots obtained for these sensors. It is worth of mention that in this period it was found that the rain sensor installed at the Xochimilco station failed with no possibility of repairing;

– a preventive maintenance of all sensors and data loggers was carried out in the middle of the experimental campaign, approximately;

– along the experimental campaign, the data acquisition systems performed a first level quality control verifying all raw data and rejecting those ones out of a predefined range.

It is underlined that, in the case of the stations located in urban sites (AZC and XOC), the measurement height was 1.5 times the height of the building on which the meteorological tower was installed. Furthermore, as these buildings are higher than the surrounding obstacles in a neighborhood of at least 500 m, it can be considered that the measurements were carried out above the urban canopy layer [5, 13].

Once concluded the experimental campaign, a simple evaluation of the station data recovery performance was done, and a monthly qualification was assigned to each one of them. In doing this, the complete measuring equipment of a station was divided in two

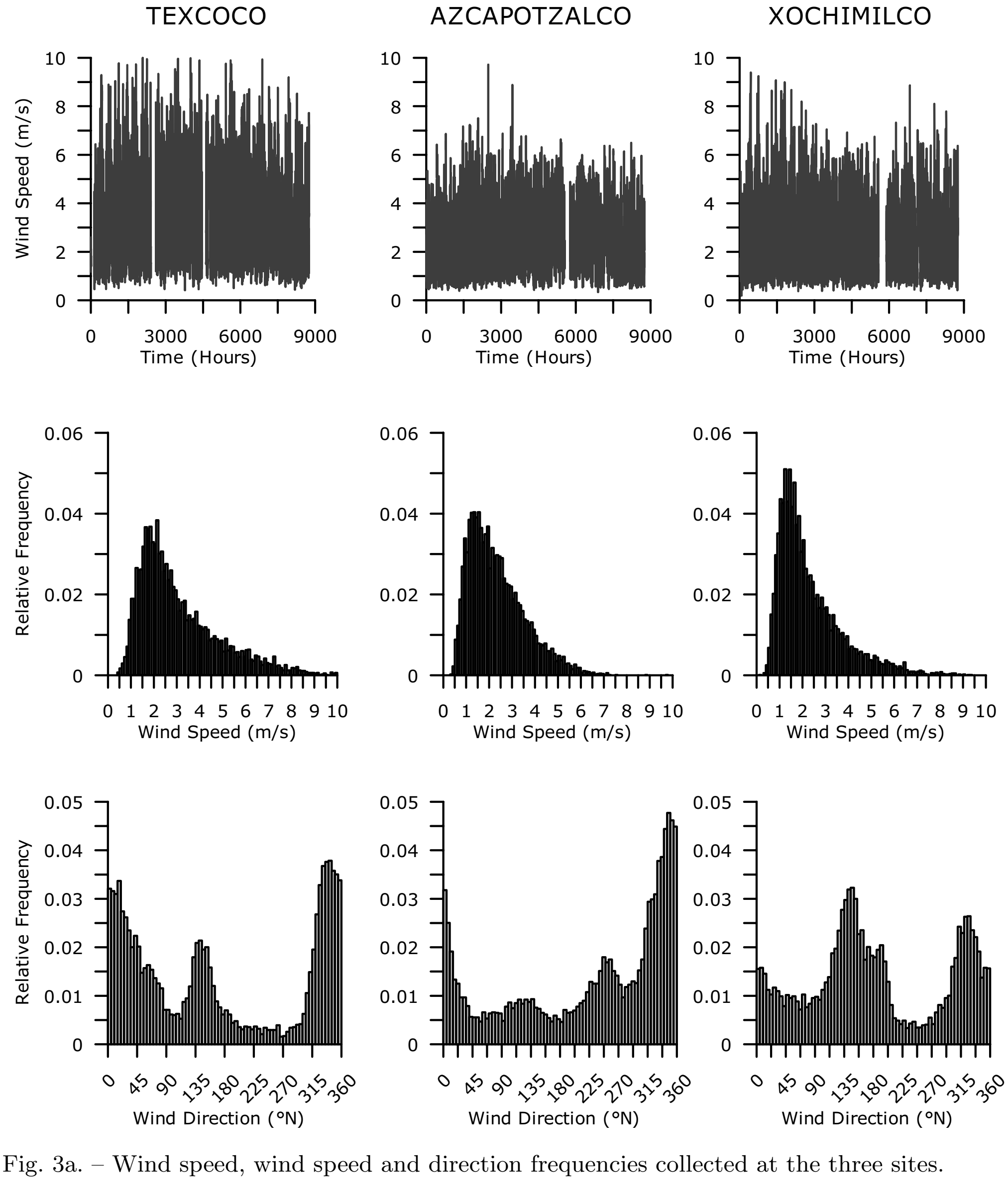

Fig. 3a. – Wind speed, wind speed and direction frequencies collected at the three sites.

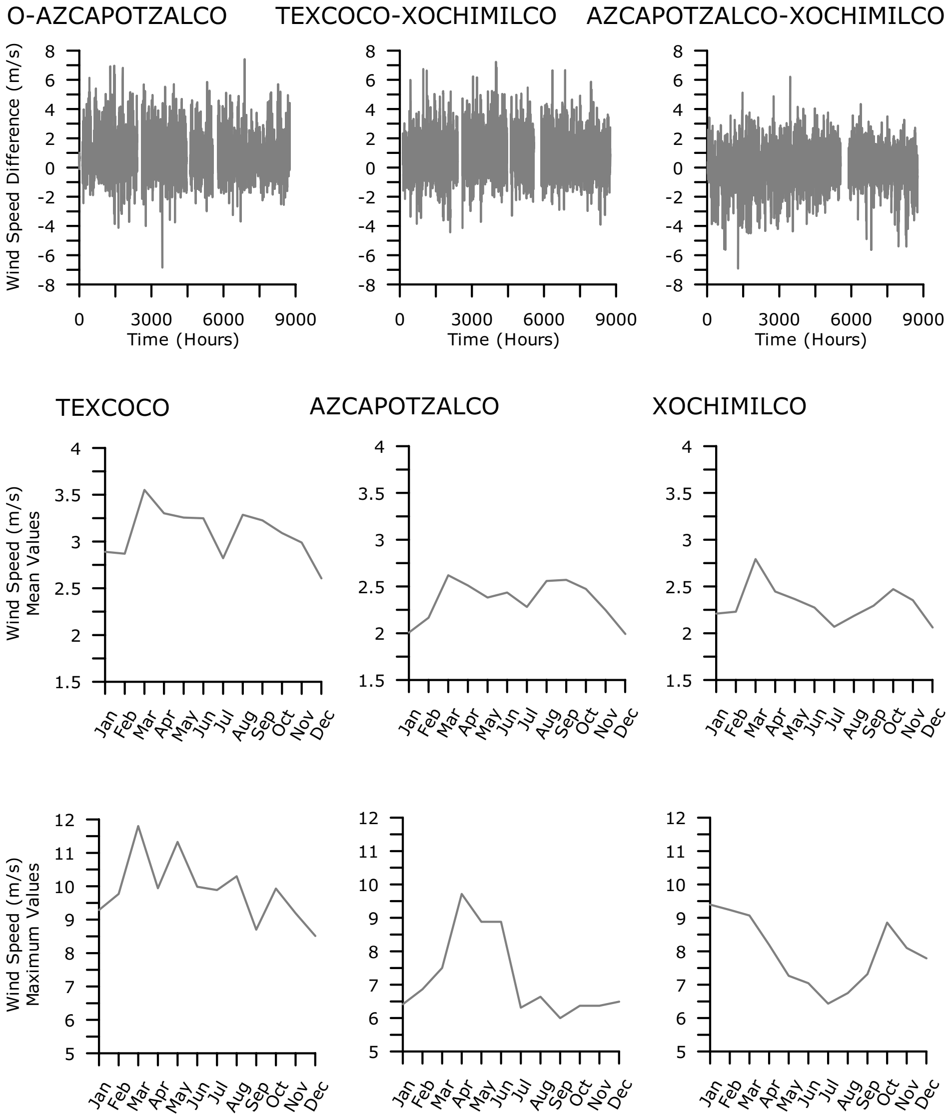

Fig. 3b. – Wind speed differences site by site and mean and maximum values at the three sites.

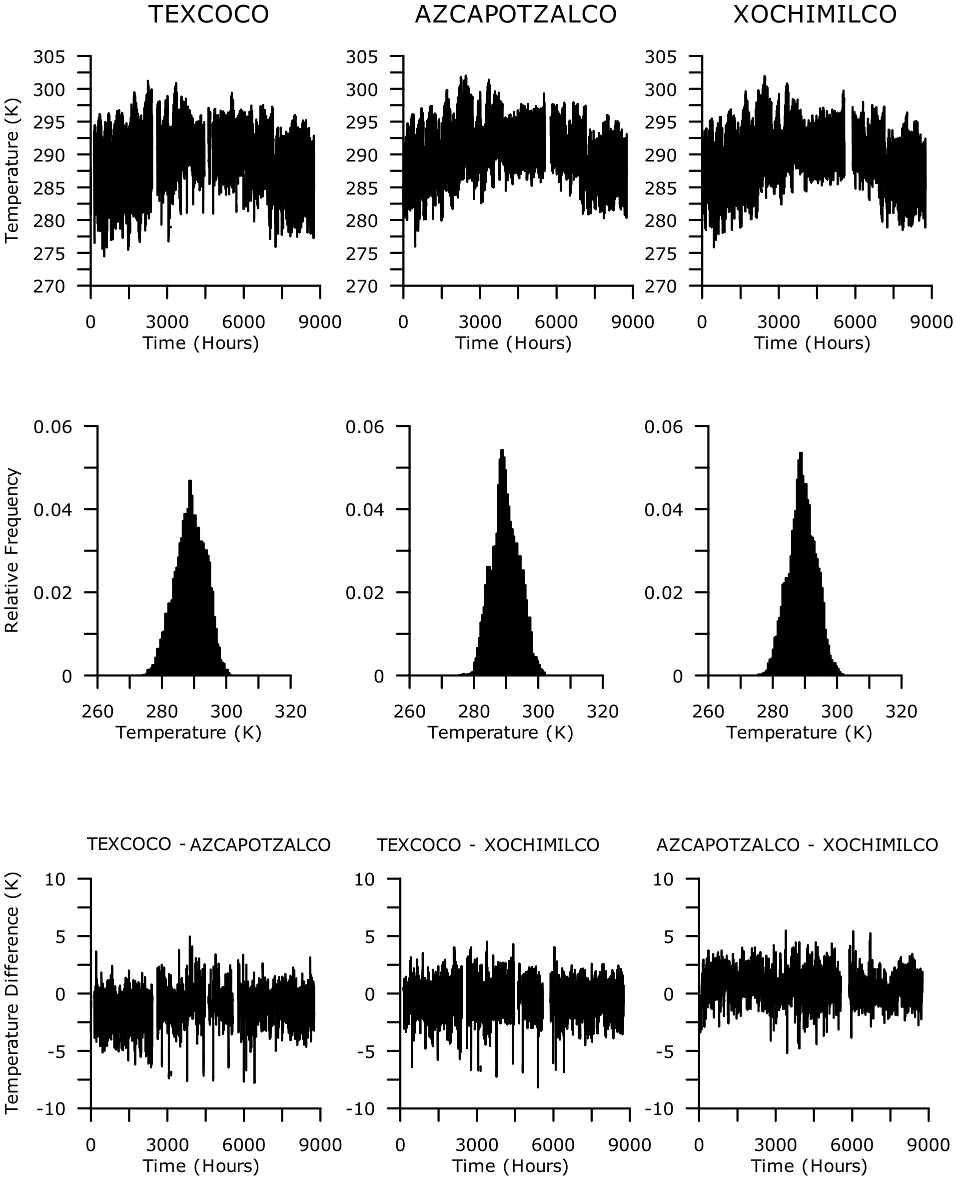

Fig. 4a. – Temperature values, frequencies and differences site by site.

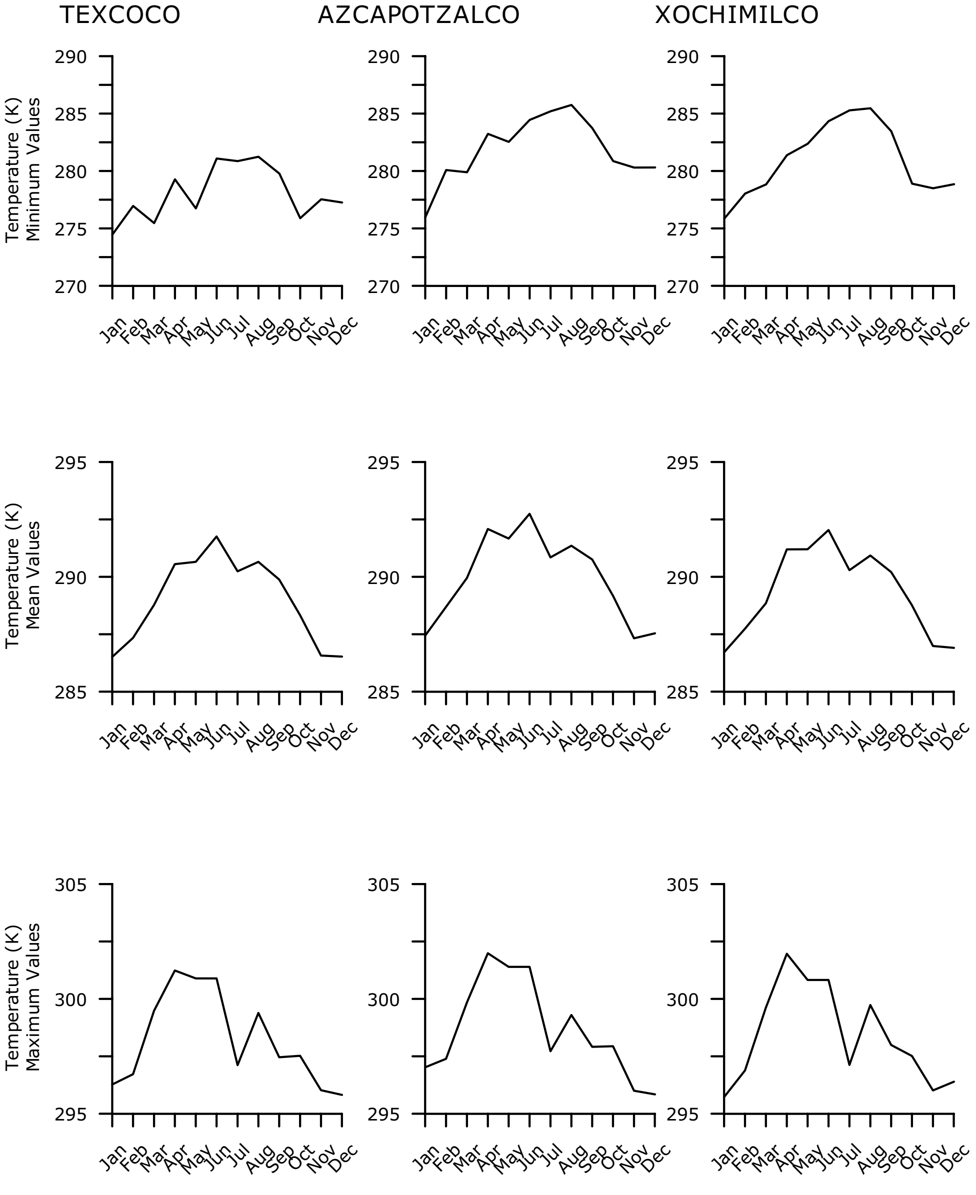

Fig. 4b. – Temperature minimum, mean and maximum values.

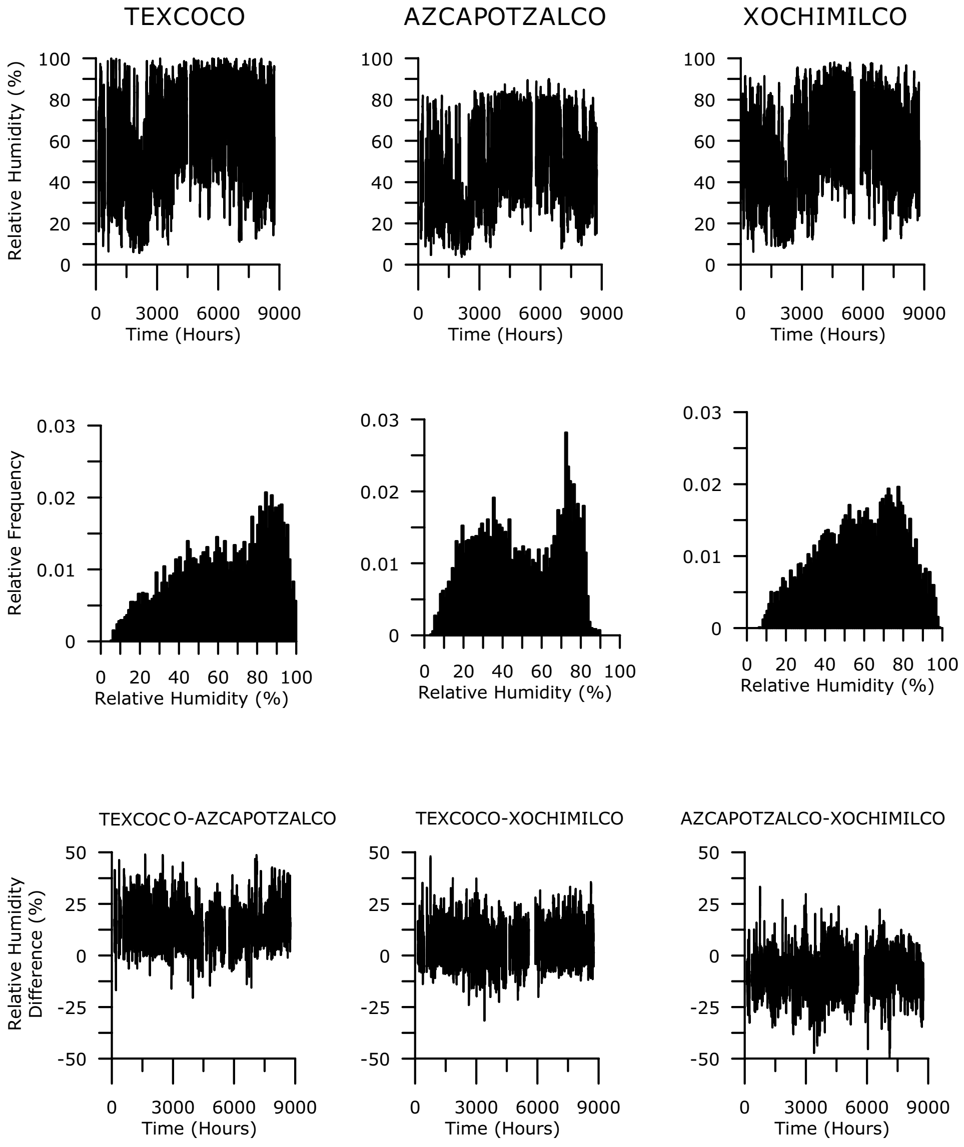

Fig. 5a. – As in fig. 4a for relative humidity.

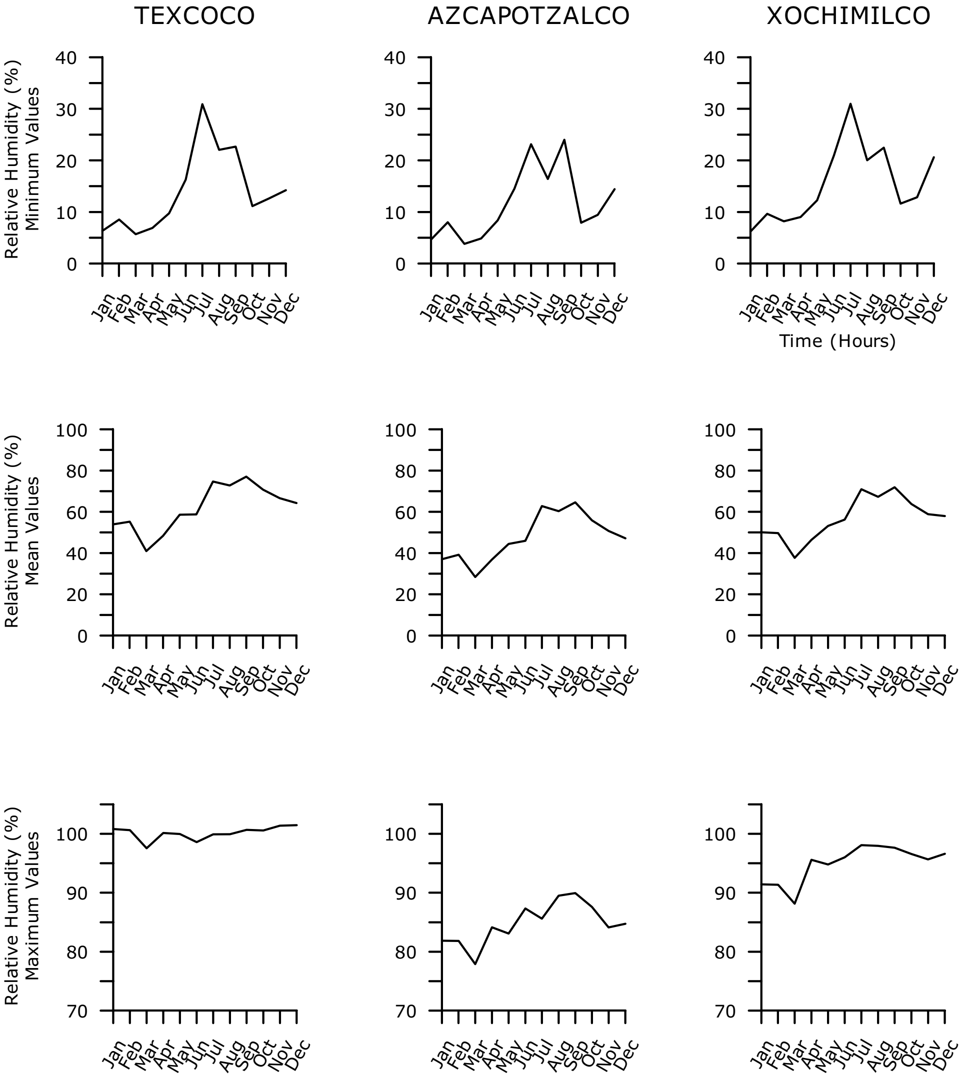

Fig. 5b. – As in fig. 4b for relative humidity.

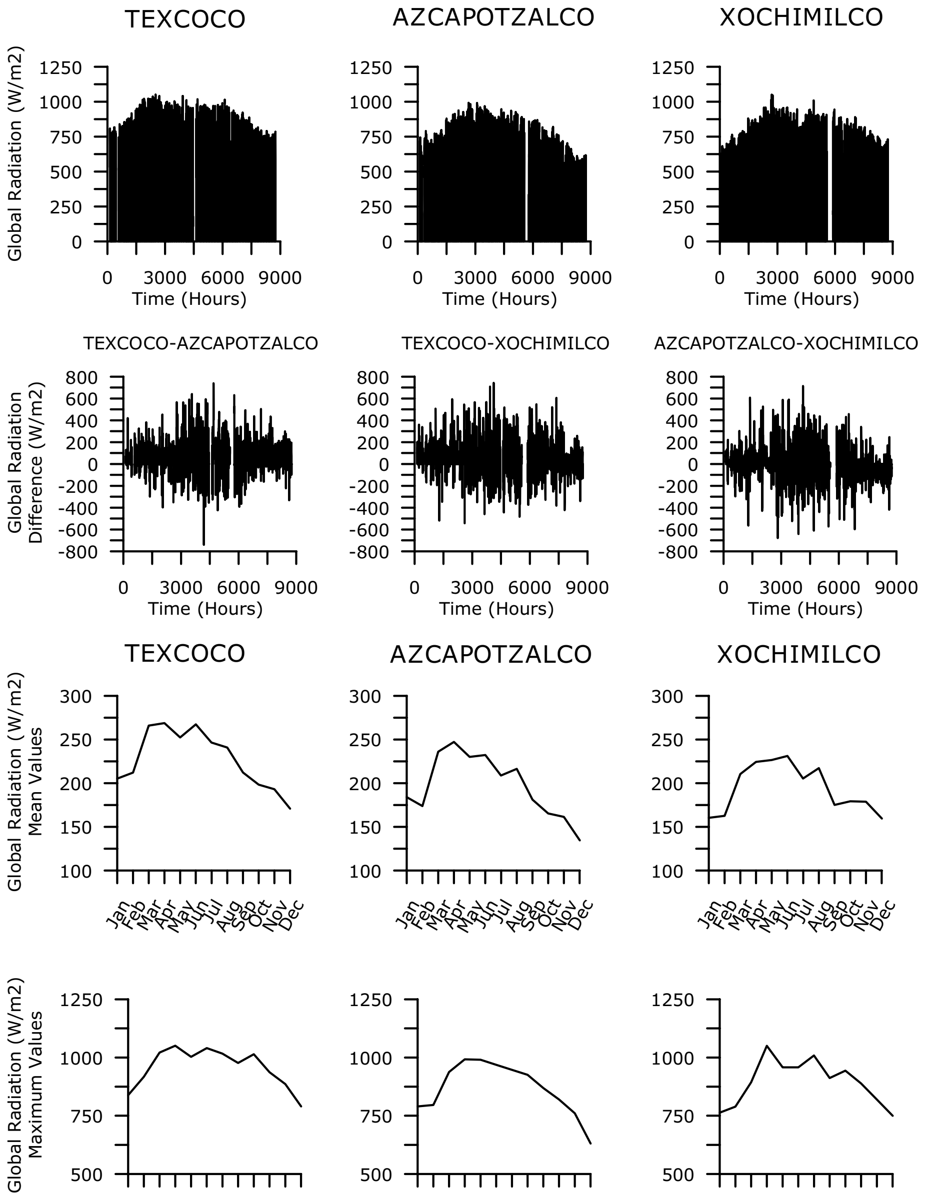

Fig. 6. – Global radiation parameters collected at the sites.

sets, one of them including only the ultrasonic sensor, and the other one including all the conventional sensors. The results of this performance evaluation are described in table III. The qualifications (in %) reflect the combined performance of the set of sensors and its respective acquisition system and were obtained by comparing the number of valid data against the number of all possible data that could be recovered each month. Xochimilco

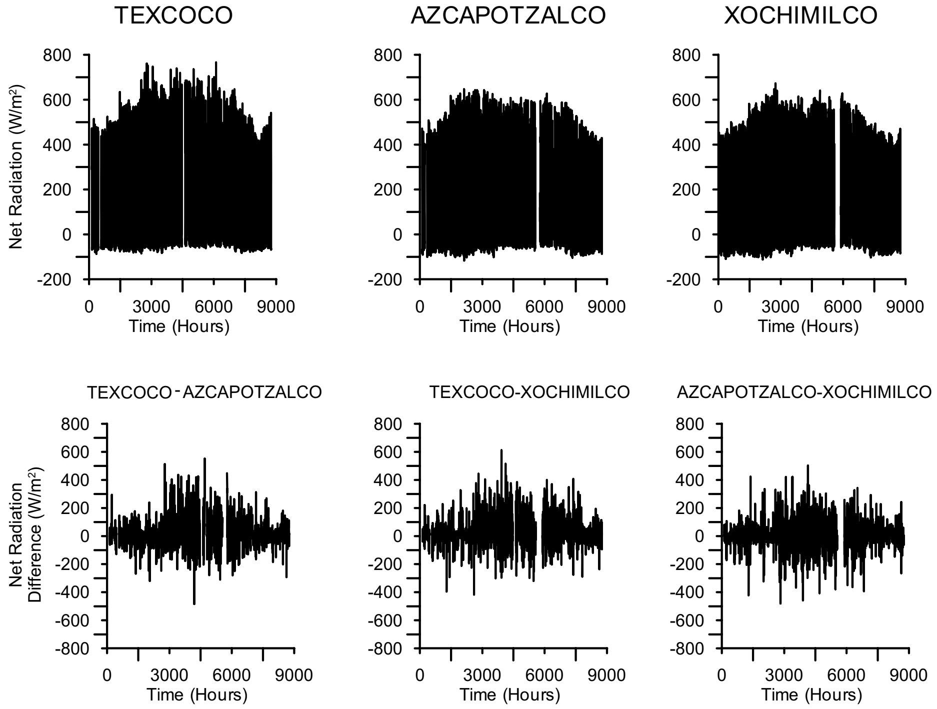

Fig. 7a. – Net radiation and net radiation differences values at the sites.

station obtained the better performance, with an average qualification of 92.9% for the ultrasonic sensor and 95.4% for the conventional sensors measuring set (excluding the rain sensor). Azcapotzalco station, with 72.2% of valid data for the ultrasonic sensor and 78.9% for the conventional sensors, got the worst performance qualification. In this sense, the average qualification of the experimental campaign was 85.0%.

3. – The 2001 MCMA micrometeorological data-base

An off-line data processing procedure was applied to all valid raw data to obtain hourly values. In particular, the conventional meteorological data were elaborated in complaint with to the US-EPA guidelines [14], while the ultrasonic anemometer data were elaborated according to the eddy covariance method [15, 16]. In each case, the elaboration was performed only if the number of available data was larger than the 25% of the expected data number (3600 for the conventional sensors and 36000 for the ultrasonic anemometer). A despiking procedure was applied to the ultrasonic anemometer raw data according to Vickers and Mahart [17]. No other quality control has been done in order to avoid an over-filtering of data that could hide some possible interesting micrometeorological urban phenomena.

The data recovered from January to December 2001 at each station were averaged on an hourly base and used to prepare a one-year micrometeorological database for the MCMA. This database includes the average values of the following parameters: wind speed (WSP, m/s), wind direction (WDR, °N), temperature (TEM, K), standard deviation of wind direction (SWD, °), Pasquill-Gifford stability categories (STB, 1=A, ...,

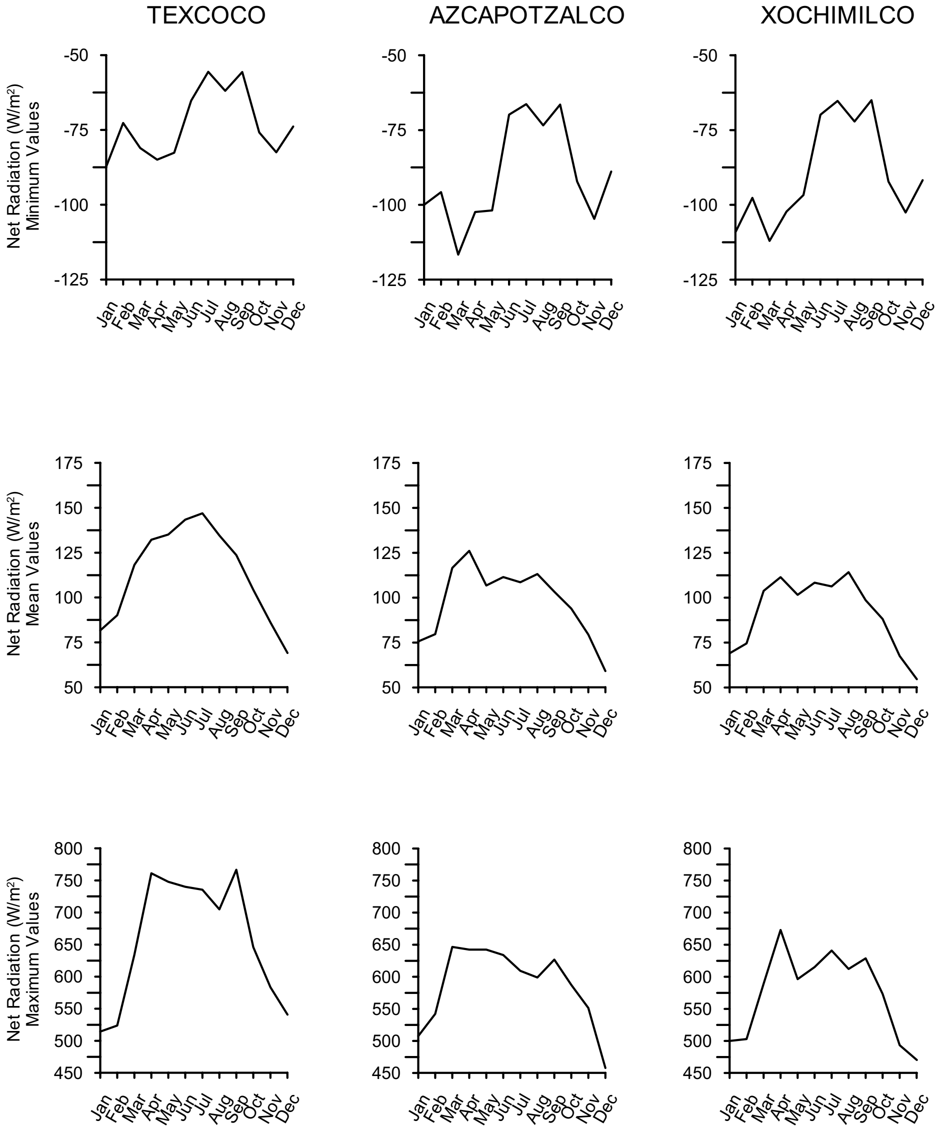

Fig. 7b. – Net radiation minimum, mean and maximum values.

6=F), relative humidity (HRL, %), global radiation (RGL, W/m^2), net radiation (RNT, W/m^2), atmospheric pressure (PAT, mmHg), accumulated rain (PPL, mm), variances and covariances of the turbulent fluctuations of the u, v and w wind velocity components and temperature ($\langle uu \rangle$, $\langle uv \rangle$, $\langle uw \rangle$, $\langle uT \rangle$, $\langle vv \rangle$, $\langle vw \rangle$, $\langle vT \rangle$, $\langle ww \rangle$, $\langle wT \rangle$ and $\langle TT \rangle$), friction velocity (UST, m/s), scale temperature (TST, K), sensible heat flux (FCS, W/m^2), Monin-Obukhov length (LMO, m) and turbulent kinetic energy (TKE, m^2/s^2).

The values reported for relative humidity, net and global radiation and pressure are the 1-hour averages obtained directly from the instantaneous data measured by the respective sensors. The rain value is the rain accumulated in one hour. The values of temperature

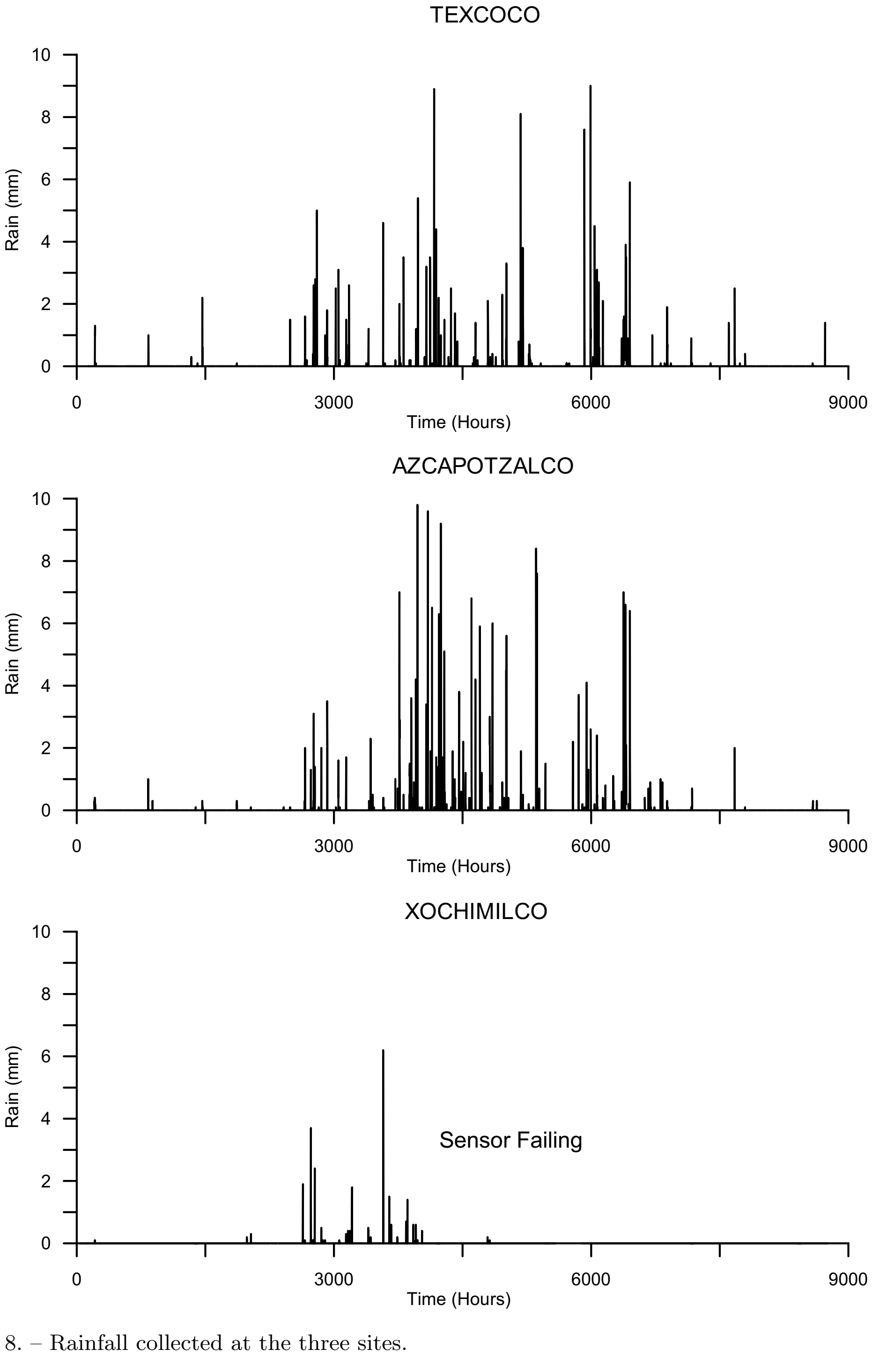

Fig. 8. – Rainfall collected at the three sites.

Table III. – *Monthly combined performance of sensors and acquisition systems.*

2001	Ultrasonic sensor measuring set			Conventional sensors measuring set		
Month	Texcoco	Azcapotzalco	Xochimilco	Texcoco	Azcapotzalco	Xochimilco
January	79.4	63.9	83.2	62.3	65.2	95.0
February	91.4	67.9	98.3	87.2	85.7	99.9
March	95.6	68.6	98.3	85.8	85.9	100.0
April	71.2	75.6	90.6	79.8	80.8	92.4
May	92.2	72.7	98.2	85.1	79.8	100.0
June	95.0	72.3	98.2	85.2	87.2	100.0
July	66.1	70.1	98.3	61.2	83.5	100.0
August	98.3	48.2	64.8	82.7	60.8	65.9
September	98.2	68.4	90.1	86.4	77.2	91.6
October	98.2	63.4	97.8	87.0	80.8	99.9
November	95.3	96.7	98.3	83.8	82.1	100.0
December	93.2	98.3	98.3	84.1	78.0	100.0
Sum	1074.1	866.1	1114.4	970.7	947.1	1144.8
Average	89.5	72.175	92.9	80.9	78.9	95.4

were obtained as the 1-hour averages of the data registered by the ultrasonic sensor. Once the wind velocity components (as registered by the ultrasonic sensor) were expressed in streamline coordinates (u, v, w), the 1-hour averages of the wind speed, wind direction, variances and covariances of turbulent fluctuations, friction velocity, scale temperature, sensible heat flux, Monin-Obukhov length and turbulent kinetic energy, were calculated following the procedures described by Sozzi and Favaron [16].

The 2001 MCMA micrometeorological database and related information has been made available to the scientific community through a free access Internet site at the address: `http://www.geocities.com/mexicomdb/`.

In table IV, the minimum, maximum, mean, standard deviation, and most frequent values found at each station along the 2001-year are reported for the main micrometeorological (1-hour) average variables. The third column in these tables includes the number of valid hourly values found along the full year. The last column gives the occurrence percent of the most frequent value.

4. – Preliminary data analysis

Although the main objective of this work is not the detailed statistical analysis and interpretation of the data obtained during the experimental campaign, in this section, an organized and synthetic presentation of the main meteorological and micrometeorological (1-hour average) variables behavior is performed.

4˙1. *Conventional meteorological variables.* – In this subsection, a preliminary analysis of the conventional meteorological variables, such as wind speed, wind direction, temperature, relative humidity, global and net radiation, and rainfall, measured at the MCMA along the experimental campaign is presented.

4˙1.1. Wind. In fig. 3 (a and b), some plots related to wind speed and wind direction are presented for all the stations. In particular, the wind speed trend, wind speed and

Table IV. – *Preliminary statistics of the experimental campaign data.*

TEXCOCO

Variable	Hours	Valid data	Minimum	Maximum	Mean	Standard deviation	Most frequent value	%
WSP	8760	8133	0.41	11.80	3.08	1.74	1.89	7.63
WDR	8760	8133			20.56	77.04	334.77	4.97
TEM	8760	8133	274.50	301.29	288.90	4.67	289.24	4.61
SWD	8760	8133	1.29	56.83	9.72	4.91	7.40	16.84
HRL	8760	7128	5.69	100.00	62.83	24.02	87.11	3.04
RGL	8760	7128	0.00	1050.92	224.13	311.81	10.51	42.32
RNT	8760	7128	−87.28	766.65	112.52	214.00	−44.59	16.08
PPL	8760	7128	0	12.70	0.04	0.41	0.13	79.40
UST	8760	8133	0.03	1.65	0.27	0.14	0.17	8.29
TST	8760	8133	−1.17	1.04	−0.09	0.18	0.04	22.91
FCS	8760	8133	−336.80	376.97	25.77	52.91	−1.32	34.55

AZCAPOTZALCO

Variable	Hours	Valid data	Minimum	Maximum	Mean	Standard deviation	Most frequent value	%
WSP	8760	8465	0.34	9.72	2.34	1.21	1.37	7.26
WDR	8760	8465			327.89	78.43	349.20	6.62
TEM	8760	8465	276.00	302.00	290.00	4.22	288.80	5.51
SWD	8760	8465	4.52	47.97	18.38	5.51	16.25	9.50
HRL	8760	6954	3.80	89.90	48.77	21.90	73.58	3.50
RGL	8760	6954	0.00	992.30	195.50	275.60	9.92	41.30
RNT	8760	6954	−116.60	646.52	97.45	205.88	−63.18	11.97
PPL	8760	6954	0	15.30	0.06	0.61	0.15	77.40
UST	8760	8465	0.05	1.19	0.35	0.18	0.15	5.70
TST	8760	8465	−0.46	0.11	−0.09	0.10	−0.03	8.90
FCS	8760	8465	−252.82	301.33	41.79	52.10	7.64	23.70

XOCHIMILCO

Variable	Hours	Valid data	Minimum	Maximum	Mean	Standard deviation	Most frequent value	%
WSP	8760	8365	0.19	9.40	2.31	1.39	1.39	8.40
WDR	8760	8365			111.75	120.94	147.60	4.40
TEM	8760	8365	275.83	301.95	289.13	4.22	288.11	5.39
SWD	8760	8365	2.54	43.99	14.24	6.22	12.07	7.17
HRL	8760	8357	6.19	98.08	57.70	21.19	73.27	3.30
RGL	8760	8357	0.00	1050.00	190.90	276.19	10.50	51.99
RNT	8760	8357	−112.05	672.95	90.08	196.94	−25.70	12.66
PPL$^{(*)}$	8760	8357	0.00	6.20	0.01	0.09	0.06	95.10
UST	8760	8365	0.01	1.07	0.26	0.16	0.10	5.87
TST	8760	8365	−0.39	0.25	−0.05	0.09	0.01	11.14
FCS	8760	8365	−287.74	255.45	17.03	32.90	0.14	36.53

(*) The rain data of the Xochimilco station are not good. The rain sensor was failing from April on, and it could not be repaired.

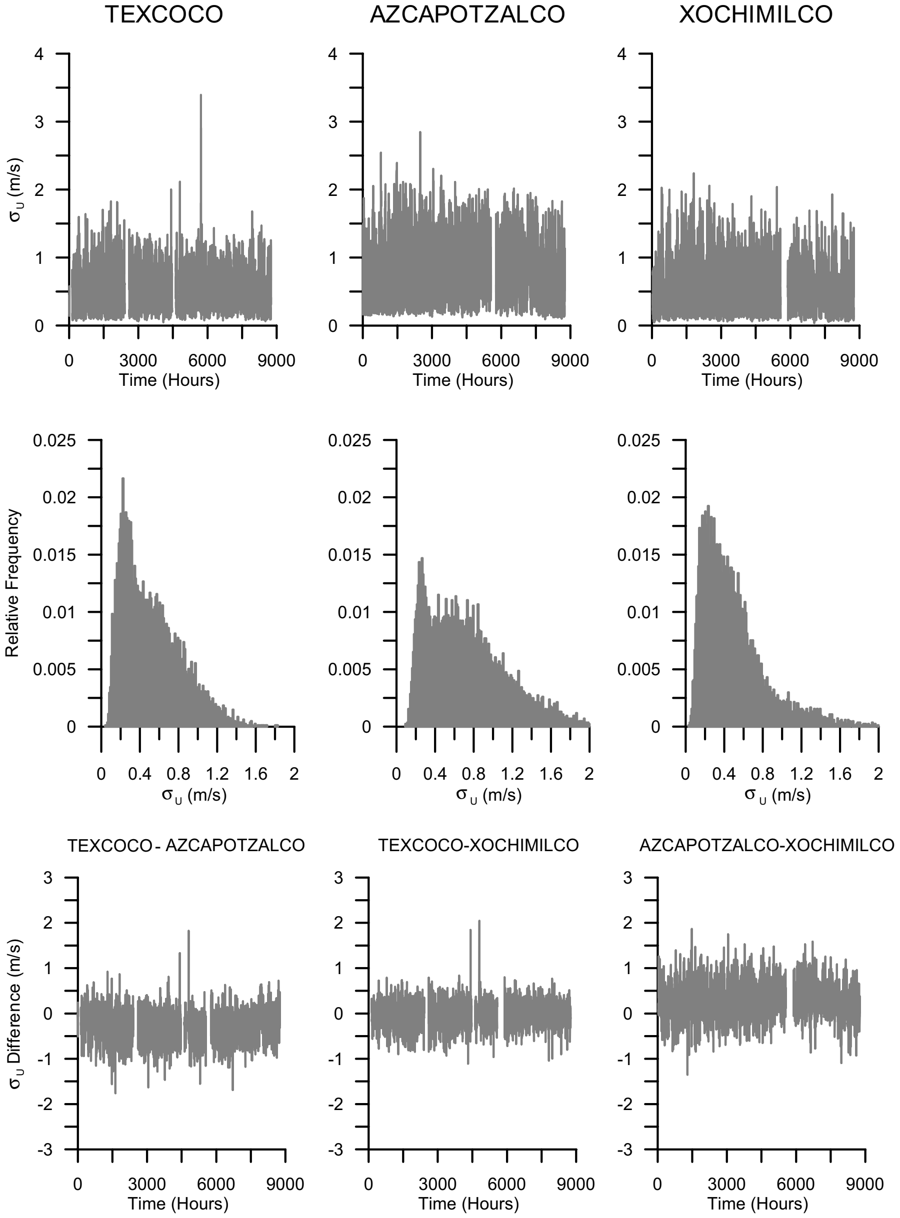

Fig. 9a. – Standard deviation of the u component, frequency distributions and differences site by site.

direction relative frequencies, wind speed difference trend for each pair of stations (TEX-AZC, TEX-XOC, AZC-XOC), and the mean and maximum wind speed monthly trends are shown.

In general terms, it is qualitatively observed in these figures that the largest wind speeds were registered at the Texcoco station (rural site) and the smallest at the Az-

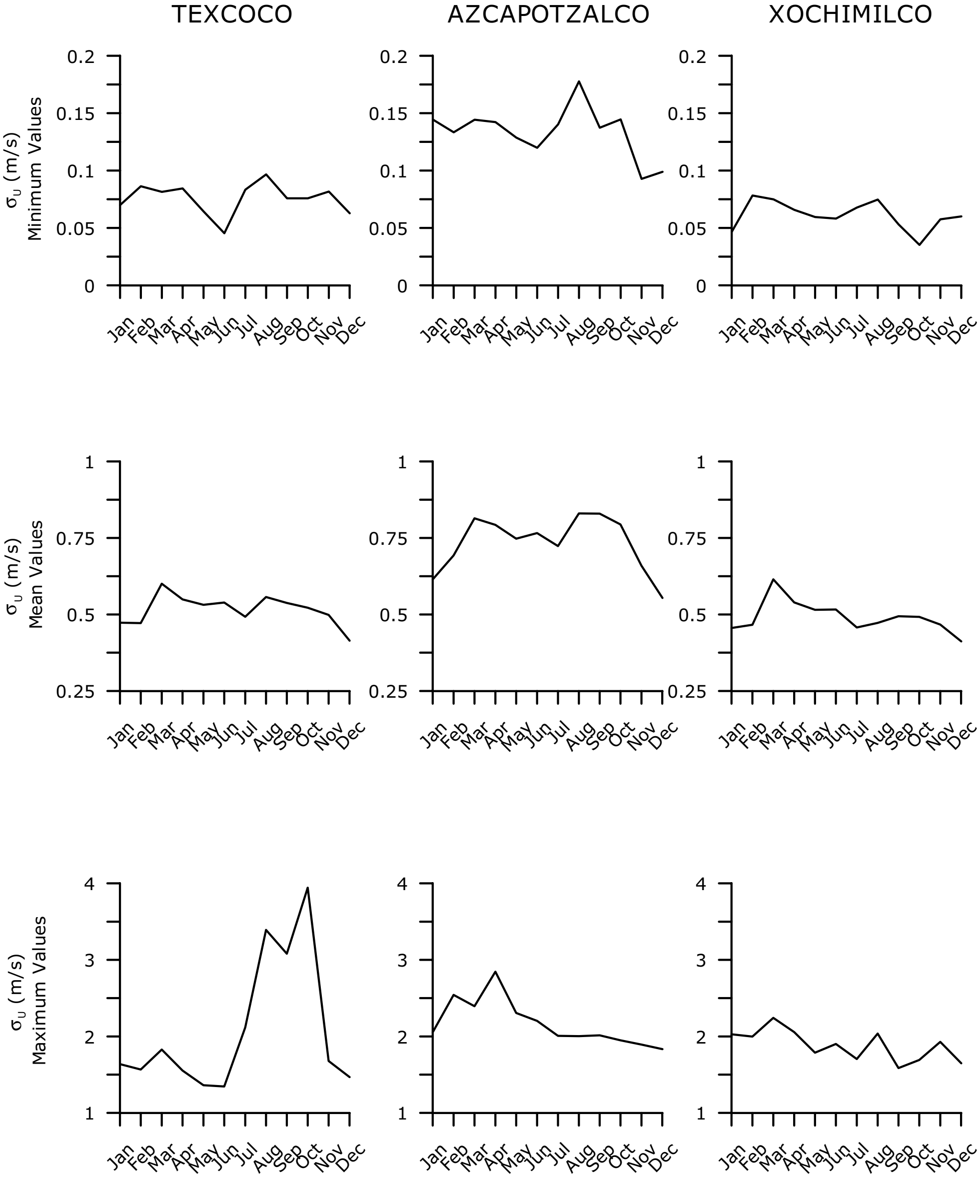

Fig. 9b. – Standard deviation of the *u* component minimum, mean and maximum values.

capotzalco station (industrial zone). However, the relative frequency plots (and table IV) show that the mean and most frequent wind speeds were, respectively, 3.08 and 1.89 m/s in Texcoco, 2.34 and 1.37 m/s in Azcapotzalco, and 2.31 and 1.39 m/s in Xochimilco.

With respect to the wind direction, we observe in general the presence of the upslope and downslope wind flows in the Azcapotzalco and Xochimilco stations, but also it can be observed that the wind flow follows the topography surrounding the MCMA.

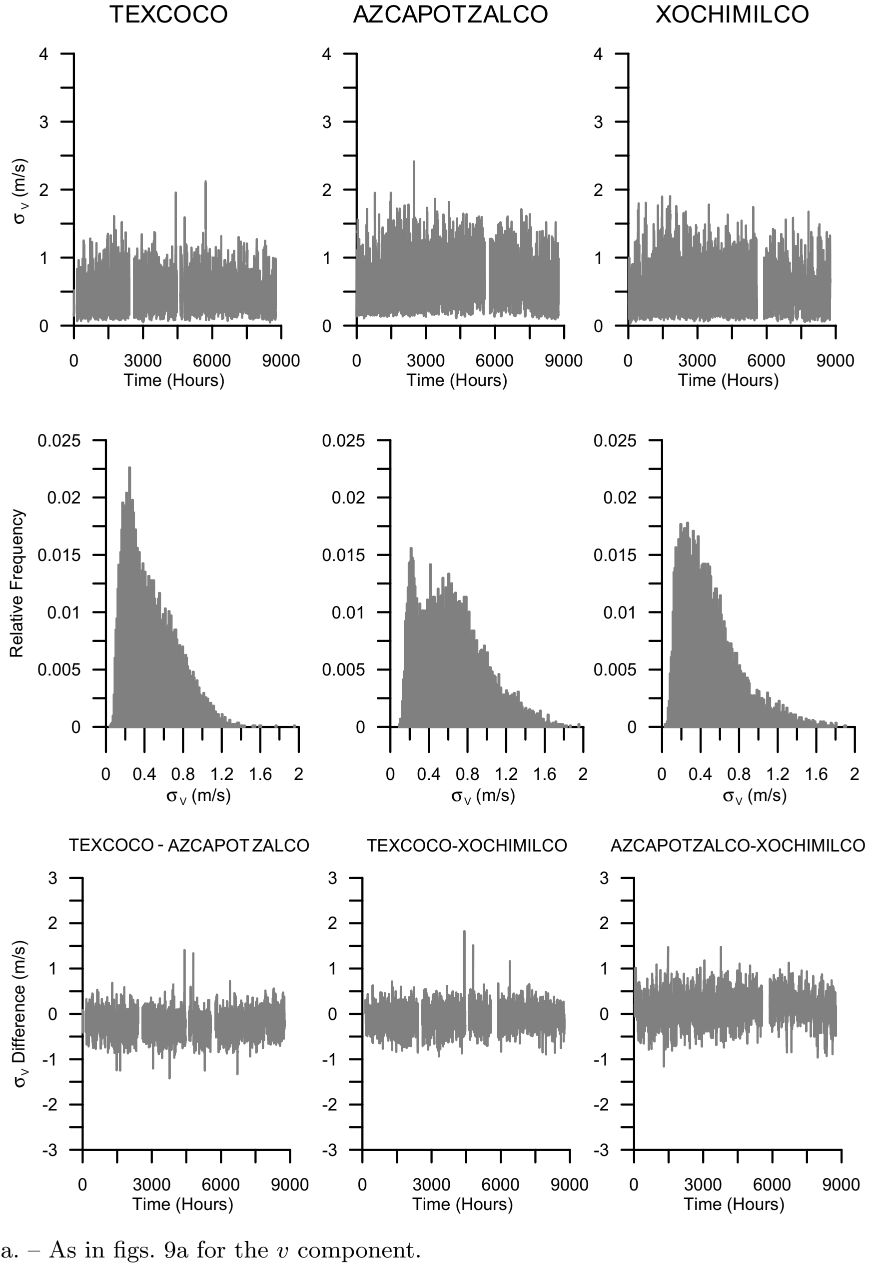

Fig. 10a. – As in figs. 9a for the v component.

4·1.2. Temperature and relative humidity. In figs. 4 and 5, respectively, the temperature and relative humidity trends at the measuring sites are presented. It can be observed that the temperature hourly trends are very similar. However, the hourly trends of the temperature differences between station pairs (TEX-AZC, TEX-XOC, AZC-XOC) and the figures presented in table IV show that, on average, the temperatures measured at Texcoco were smaller than those of Azcapotzalco and Xochimilco, and that

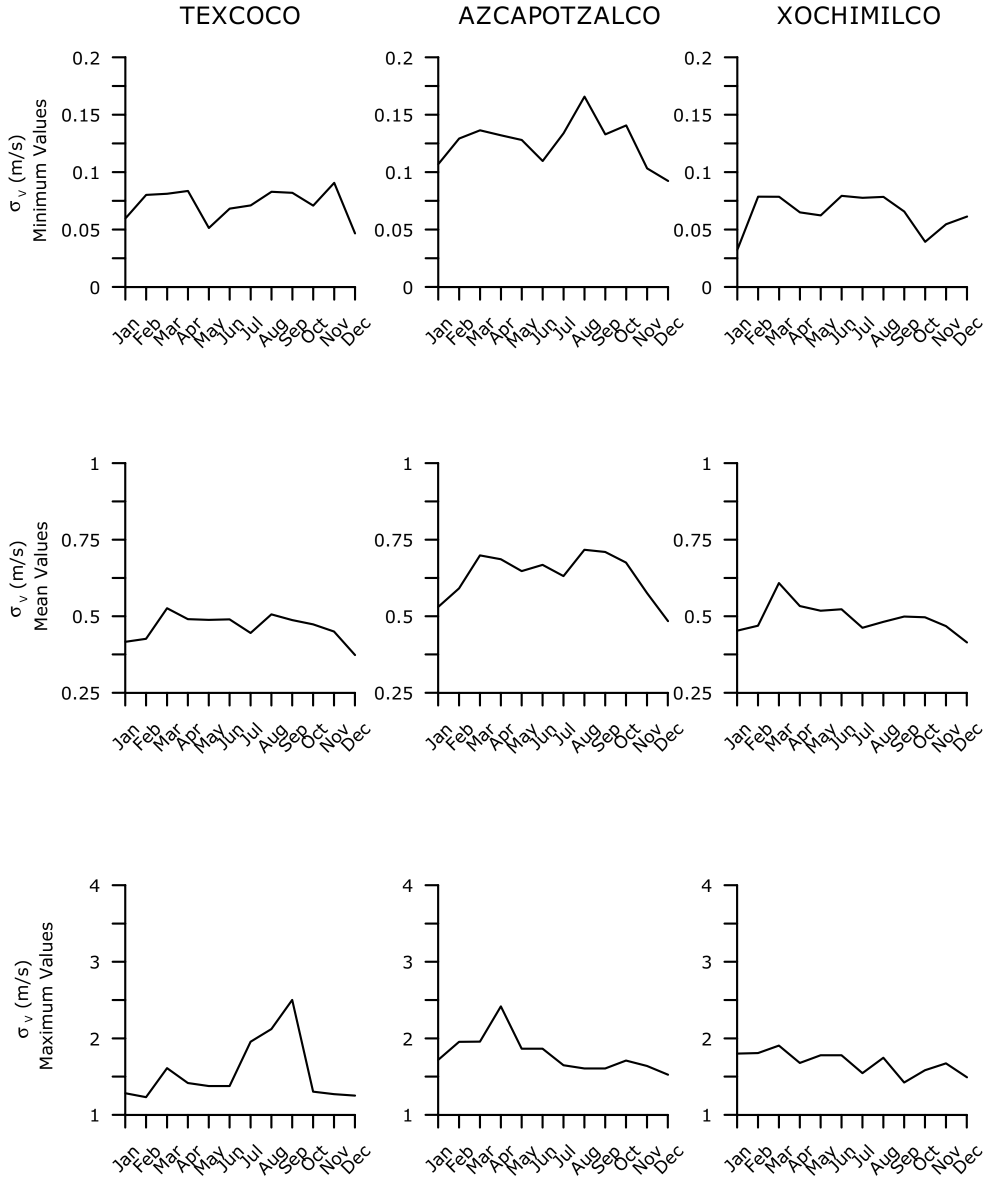

Fig. 10b. – As in figs. 9b for the v component.

the Azcapotzalco temperature was higher than in Xochimilco.

As in the case of temperature, the hourly trends of relative humidity are very similar for the three stations. It can be observed, however, that on average the moisture concentration is larger in Xochimilco than Azcapotzalco and Texcoco, and that the smallest moisture concentration is found in Texcoco.

4·1.3. Global and net radiation. As is well known [18-20], global radiation depends mainly on the geographic location, Julian day, local time, and cloud cover. Thus,

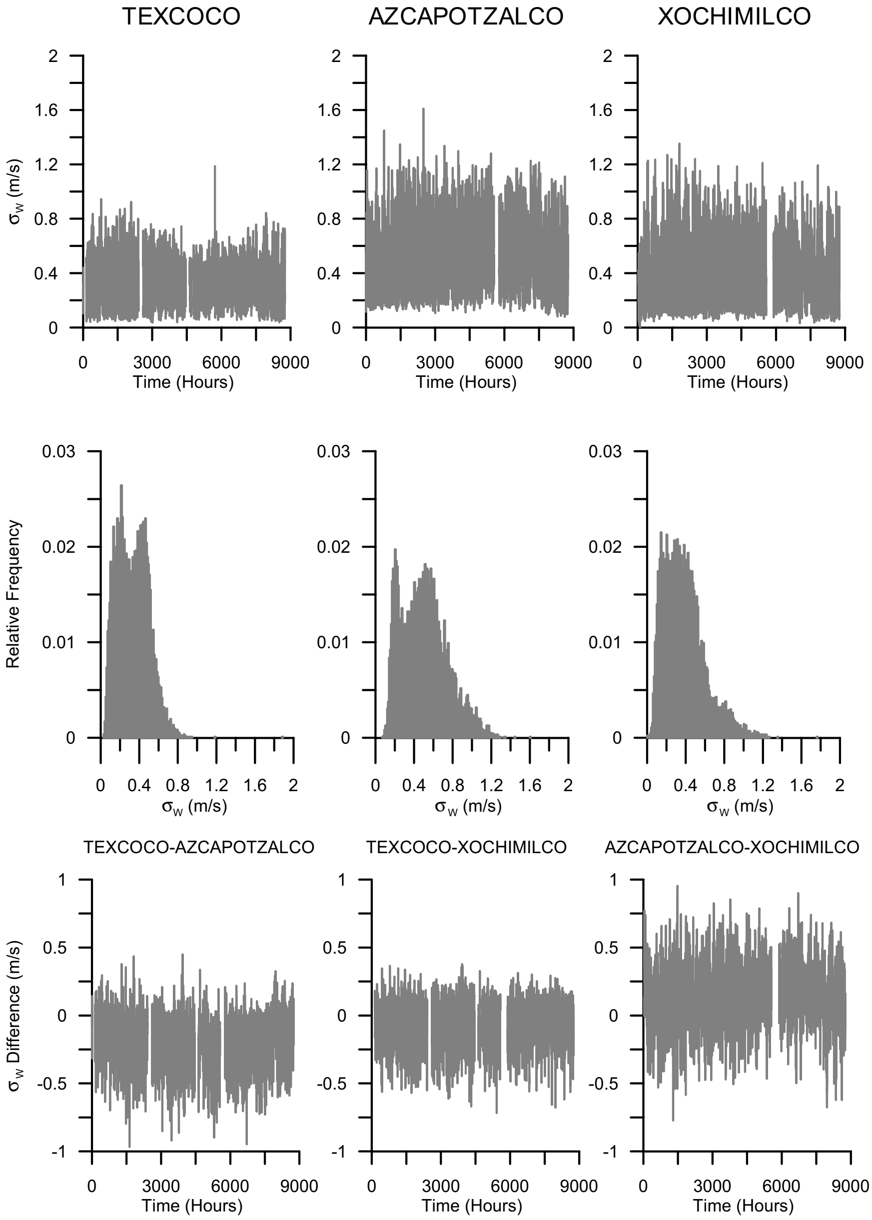

Fig. 11a. – As in fig. 9a for the *w* component.

under clean air conditions, it could be expected that in the MCMA no relevant differences might be found between the global radiation averages at the different measuring sites, especially over long time periods or on a monthly base. However, in fig. 6, it is observed that the monthly mean values of global radiation are considerably larger in Texcoco than in Azcapotzalco and Xochimilco, but also larger in Azcapotzalco than in Xochimilco.

In figs. 7, the plots of the hourly trends of net radiation and its differences between

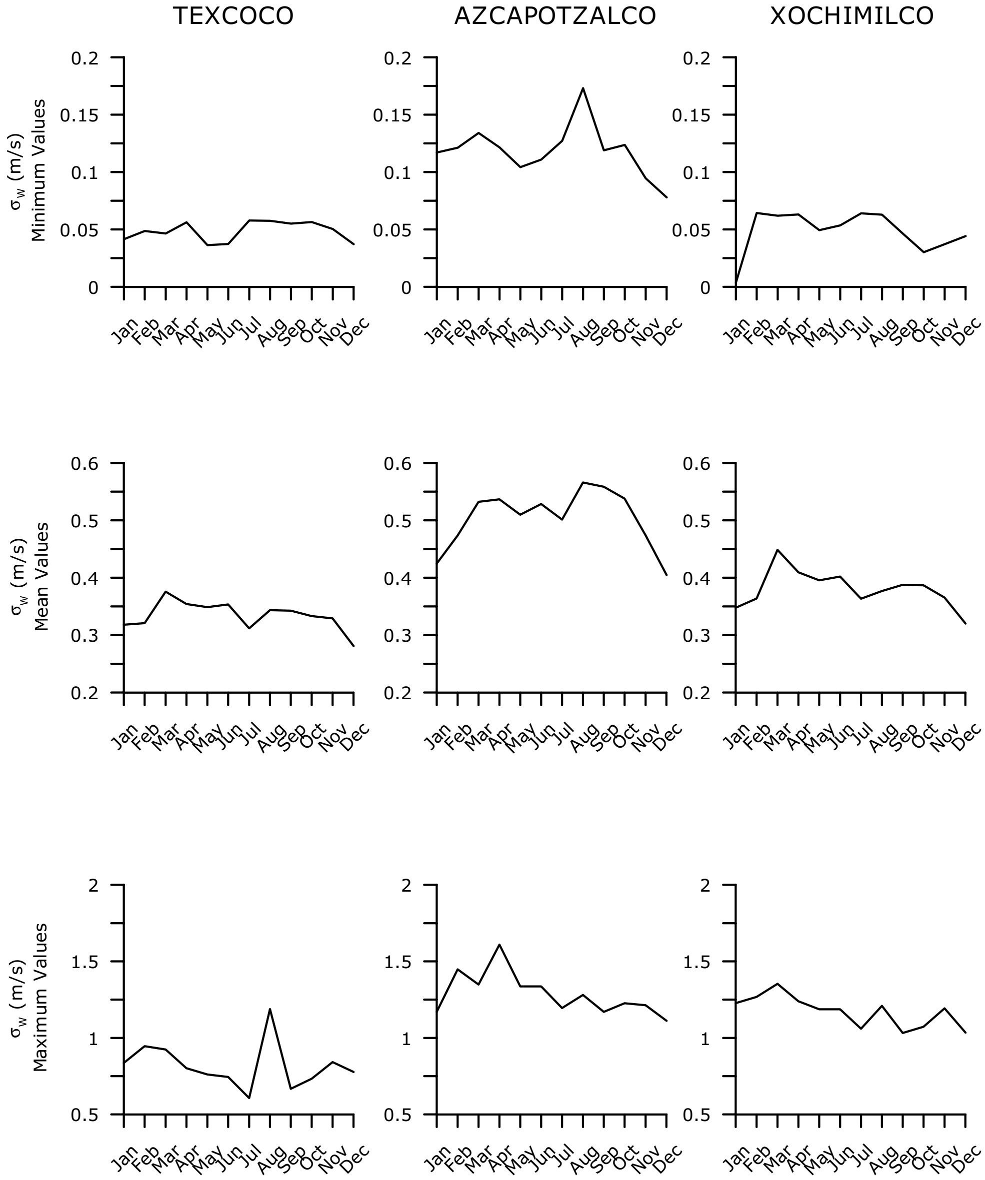

Fig. 11b. – As in fig. 9b for the w component.

station pairs (TEX-AZC, TEX-XOC, AZC-XOC), and of the monthly trends of the minimum, mean and maximum net radiation values are presented. From these plots and table IV, it is observed that on average net radiation is larger in Texcoco than in Azcapotzalco and Xochimilco, with its smallest values in Xochimilco. The net radiation monthly trends are very similar in the cases of Azcapotzalco and Xochimilco (urban sites), but it is not the case for Texcoco (rural site).

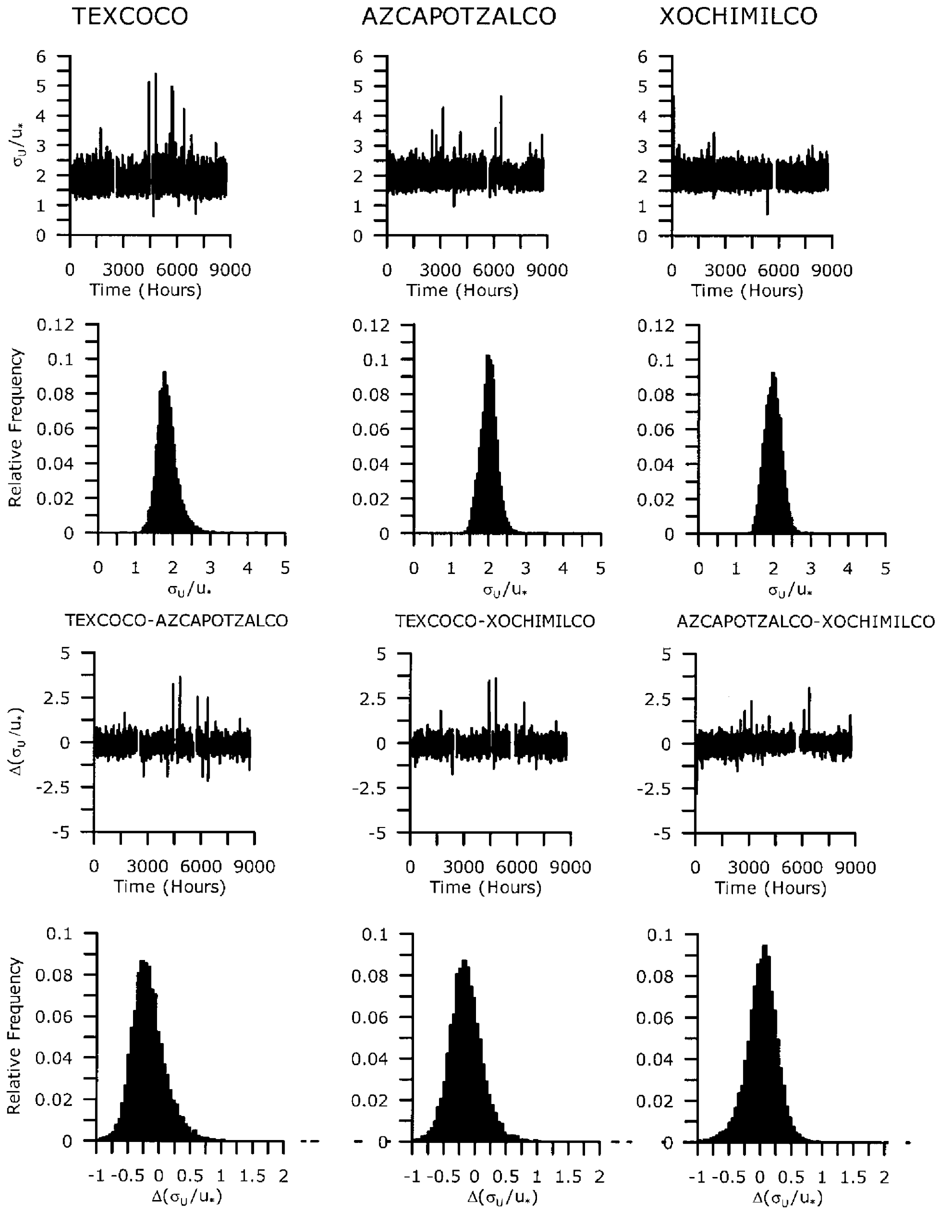

Fig. 12a. – Standard deviation of the u component normalized for friction velocity, frequencies and site by site differences.

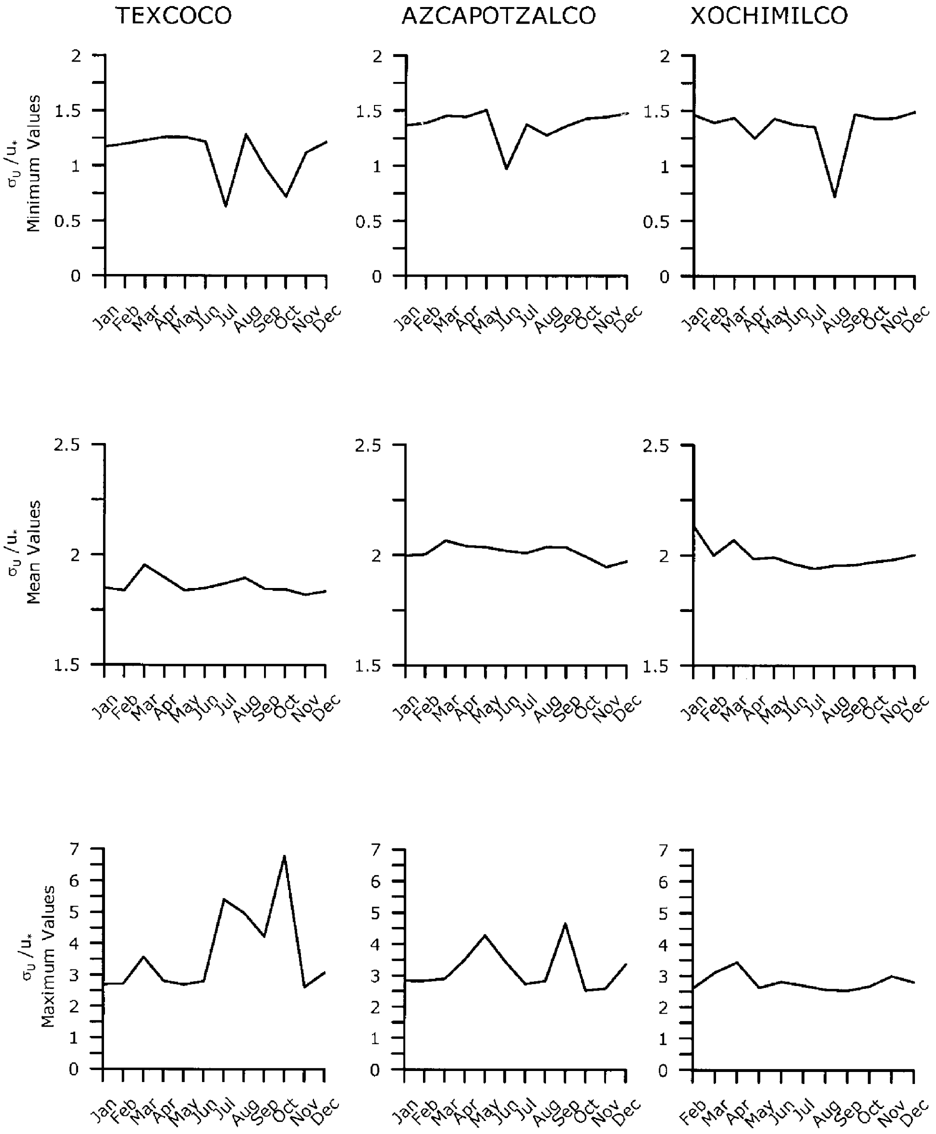

Fig. 12b. – Standard deviation of the *u* component normalized for friction velocity minimum, mean and maximum values.

4.1.4. Rainfall. In fig. 8, the hourly trends of rainfall are presented for all the measuring sites. Unfortunately, the pluviometer installed at the Xochimilco station failed from April on and it was not possible to repair or substitute it.

4.2. *Micrometeorological variables.* – The micrometeorological variables, such as the standard deviations of the wind velocity components and temperature, friction velocity and turbulent sensible heat flux, and turbulence intensity, define the state of atmospheric

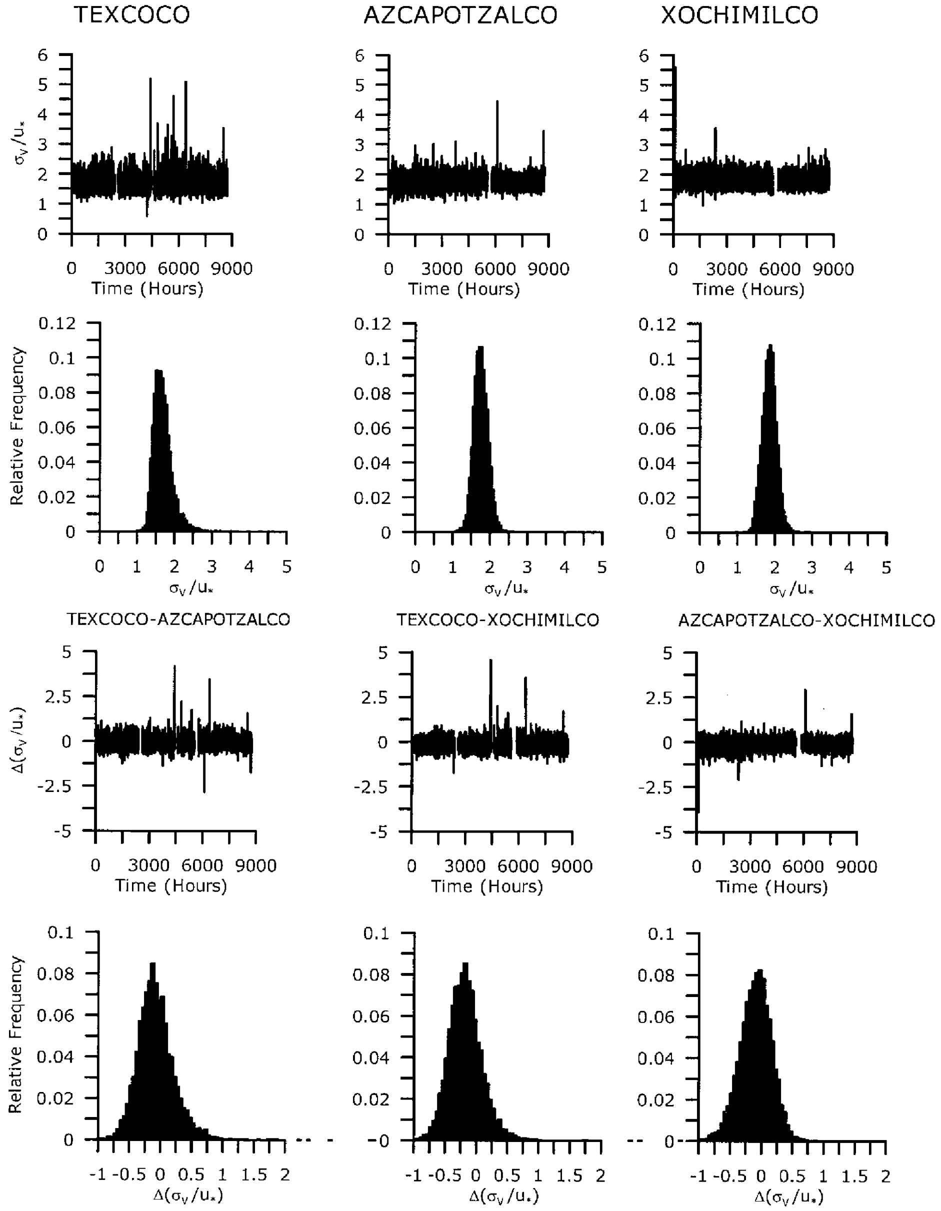

Fig. 13a. – As in fig. 12a for the v component.

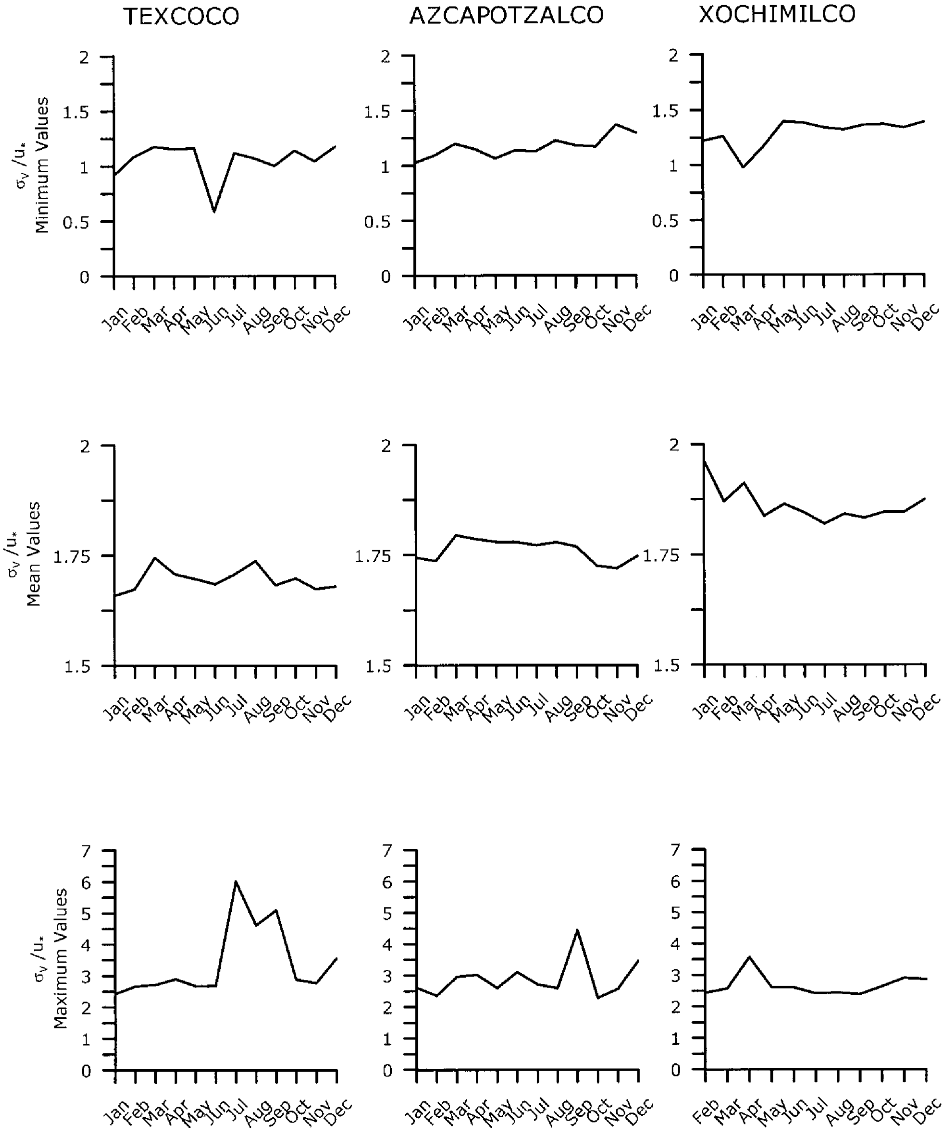

Fig. 13b. – As in fig. 12b for the v component.

turbulence in the urban boundary layer. All these variables may be determined from the ultrasonic anemometer data using the eddy covarience method [15, 16].

4·2.1. Standard deviations of the wind velocity components. In figs. 9, 10, and 11, the hourly trends of the standard deviations of the wind velocity components (σ_u, σ_v, σ_w), their frequency distributions, and the monthly trends of their minimum, mean and maximum values are presented.

From the plots of the hourly trends of σ_u, σ_v, and σ_w, their differences between

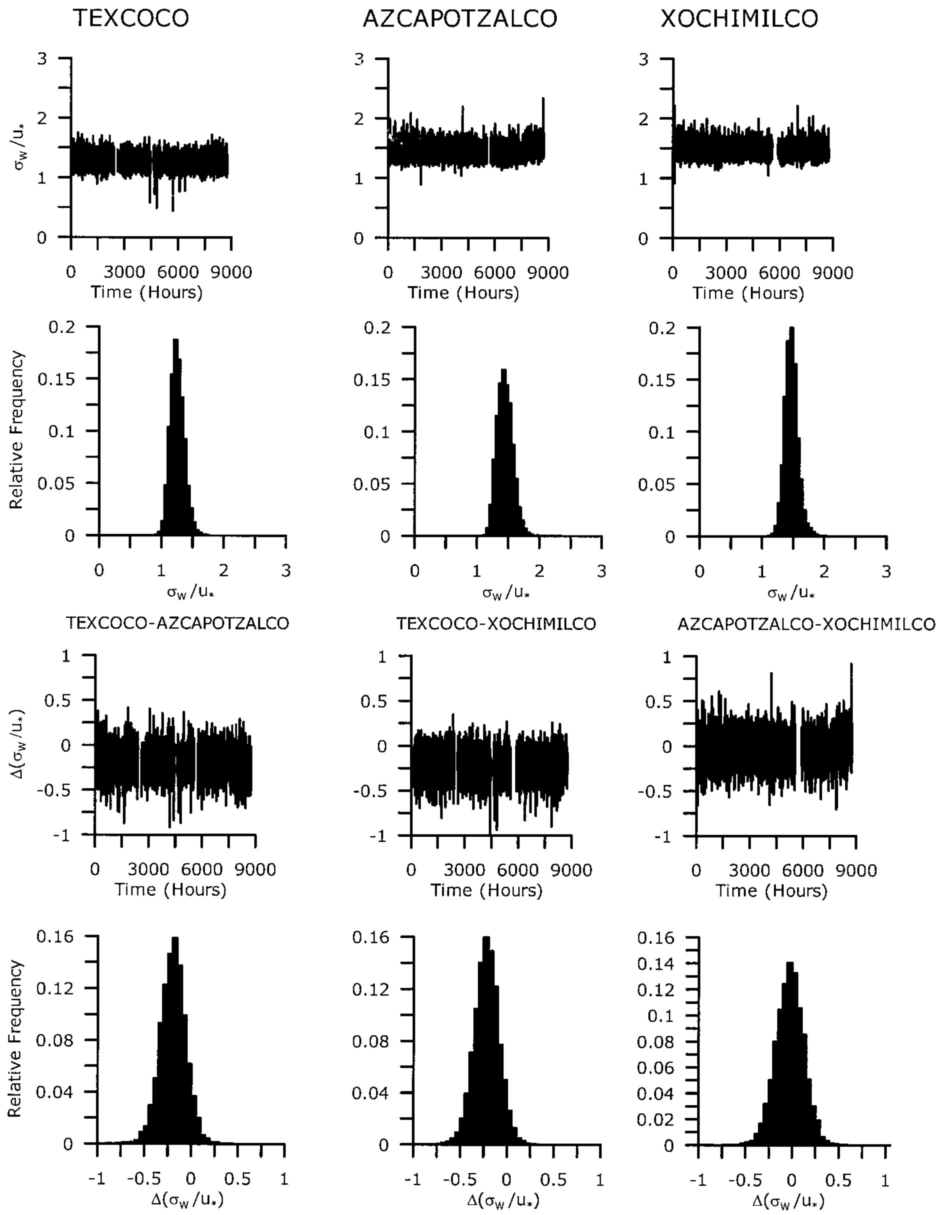

Fig. 14a. – As in fig. 12a for the w component.

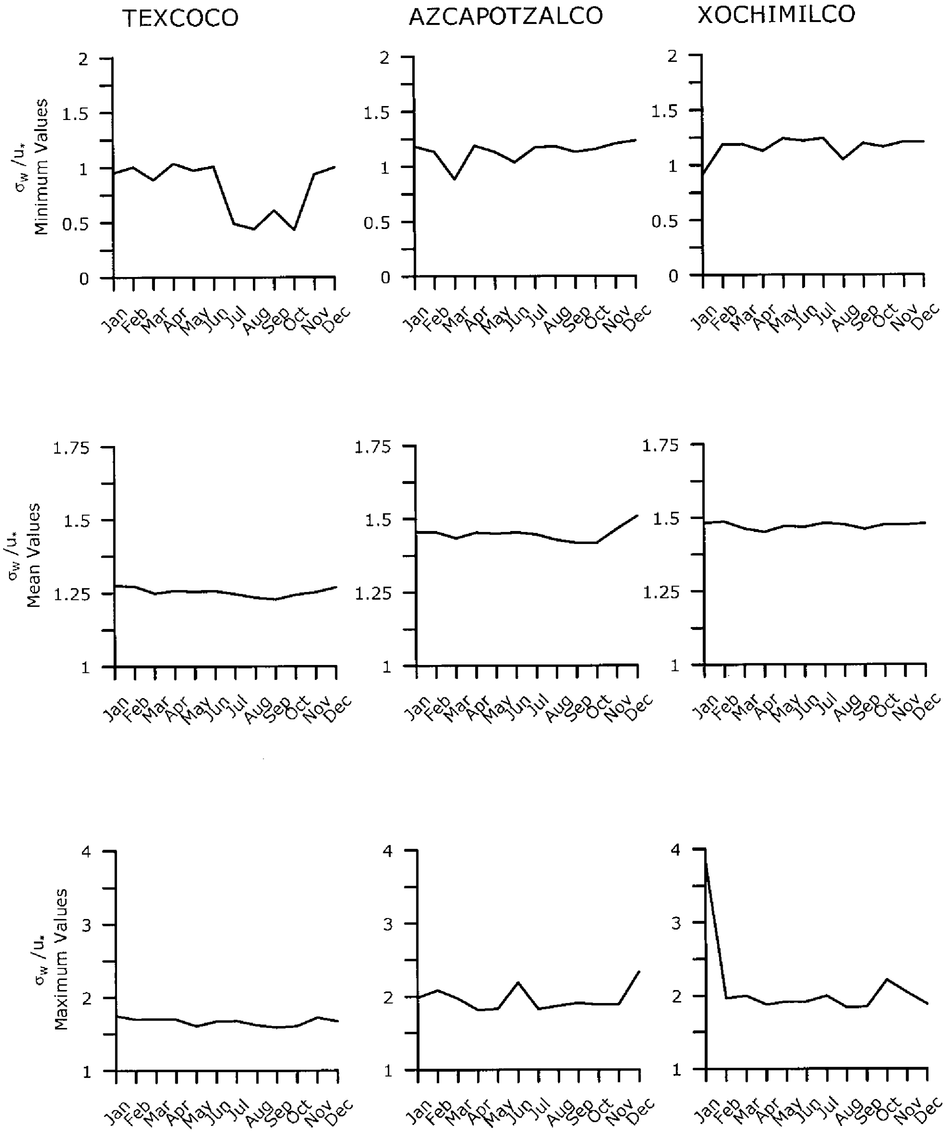

Fig. 14b. – As in fig. 12b for the w component.

station pairs, and the monthly trends of the minimum and mean values of these standard deviations, it is observed that the largest values of these variables were registered at the Azcapotzalco station (industrial zone). The values observed at Texcoco site, however, were very similar to those ones of Xochimilco. Normalized standard deviations of wind components, as defined by σ_u/U^*, σ_v/U^* and σ_w/U^*, U^* being the friction velocity, are shown in figs. 12a,b, 13a,b, and 14a,b.

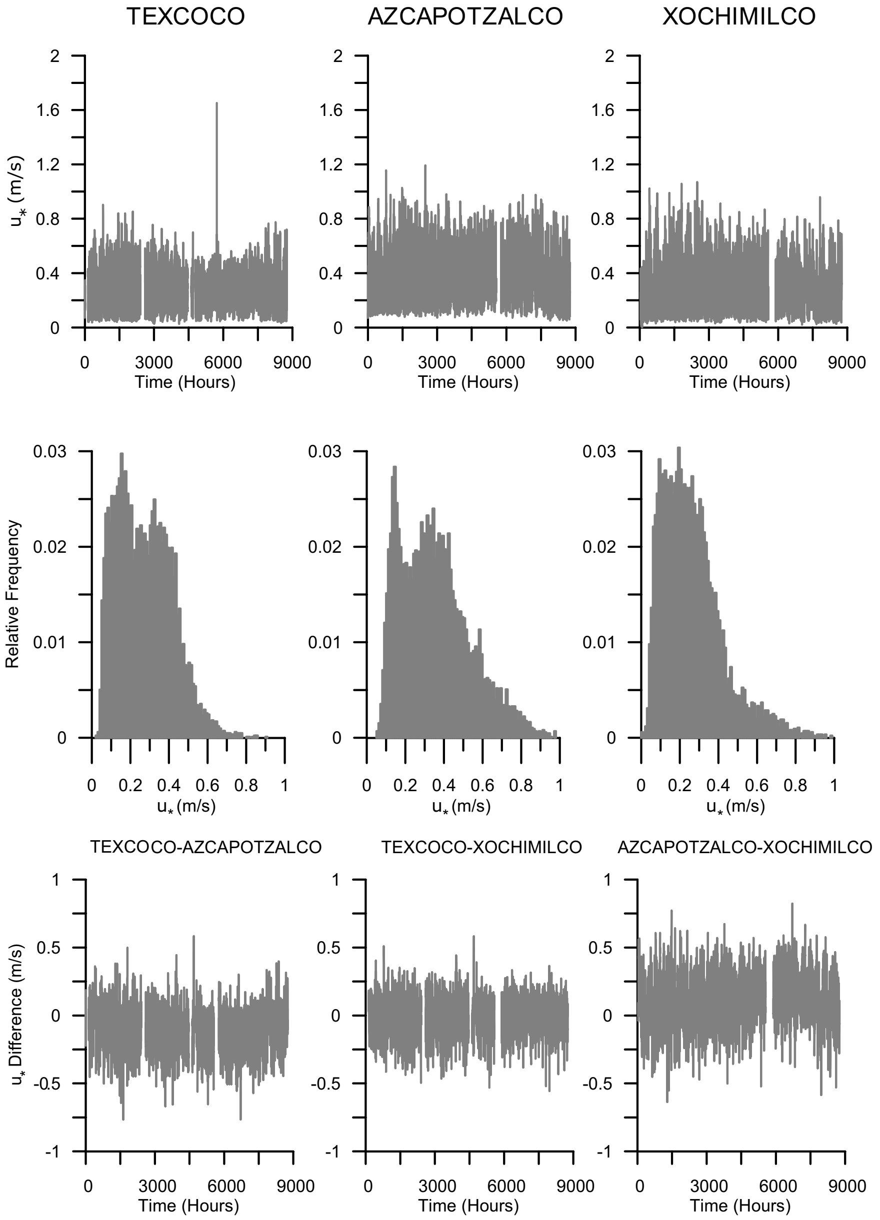

Fig. 15a. – Friction velocity, frequency and site by site difference values.

4·2.2. *Friction velocity*. Figure 15 shows the friction velocity behavior during the experimental campaign at all the measuring sites. On the average, the largest friction velocity values were found at Azcapotzalco site. Although Texcoco and Xochimilco are quite different one each other with respect to the surface roughness, the friction velocity values measured in these sites were very similar.

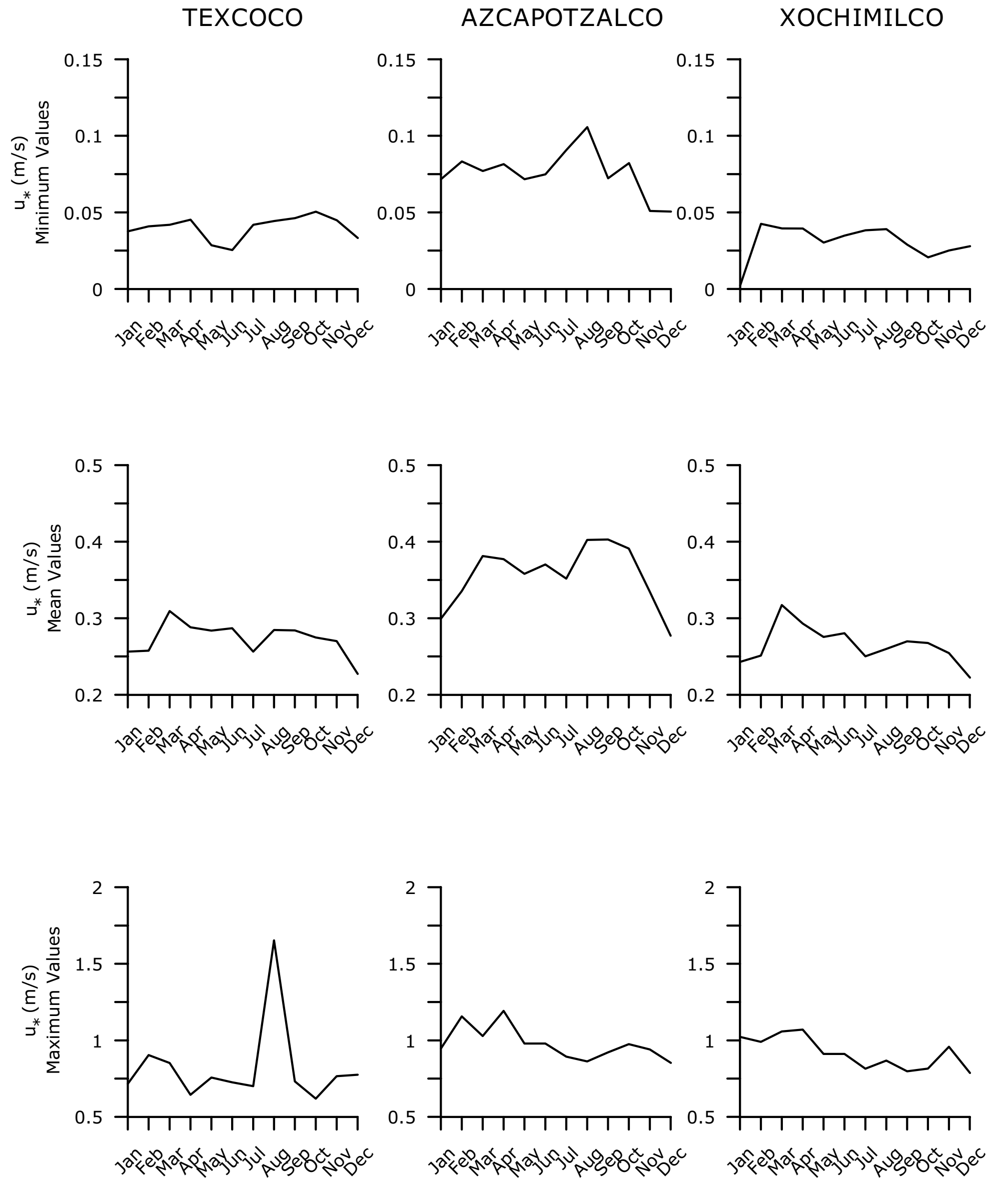

Fig. 15b. – Friction velocity minimum, mean and maximum values.

4˙2.3. Standard deviation of virtual temperature. The evolution of the standard deviation of virtual temperature (σ_T) is shown in fig. 16 for all the measuring sites. From the monthly trends of the mean values and from the hourly trends of the differences between station pairs, it results that the largest σ_T values were registered at the Texcoco site. Furthermore, in spite of the spikes in the Xochimilco hourly σ_T trend, the monthly trends of the mean σ_T values are very similar in the urban stations (Azcapotzalco and Xochimilco).

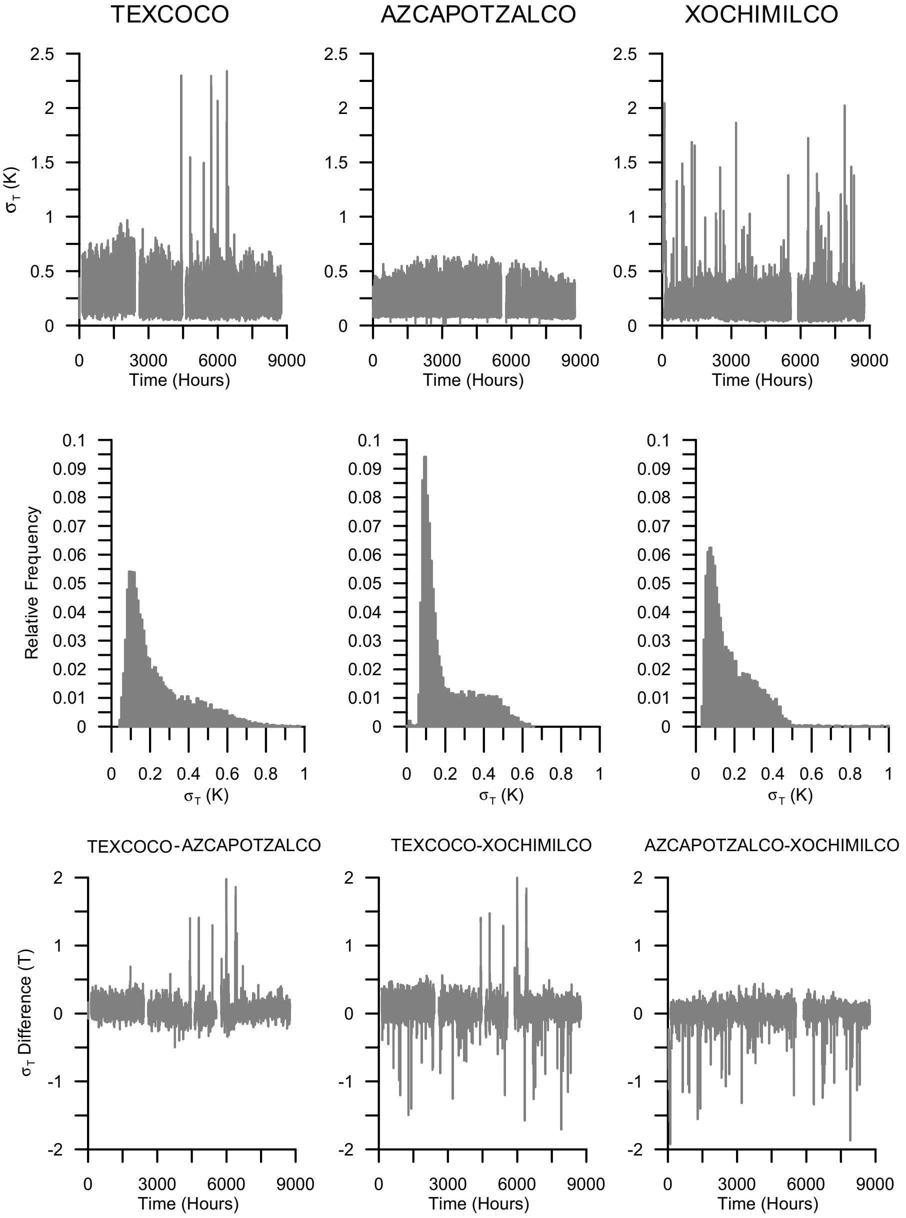

Fig. 16a. – Temperature standard deviation, frequency and site by site difference values.

4.2.4. Sensible heat flux. The hourly trends of sensible heat flux (H_0) and their differences between stations are presented in fig. 17. As can be seen in table IV and these plots, on average the largest H_0 values were observed at Azcapotzalco, while the smallest at Xochimilco. The same is observed in the monthly trends of the mean H_0 values. It is interesting to underline that the smallest minimum value of H_0 was registered at Texcoco (rural site), while in both urban stations the minimum H_0 values were similar to each

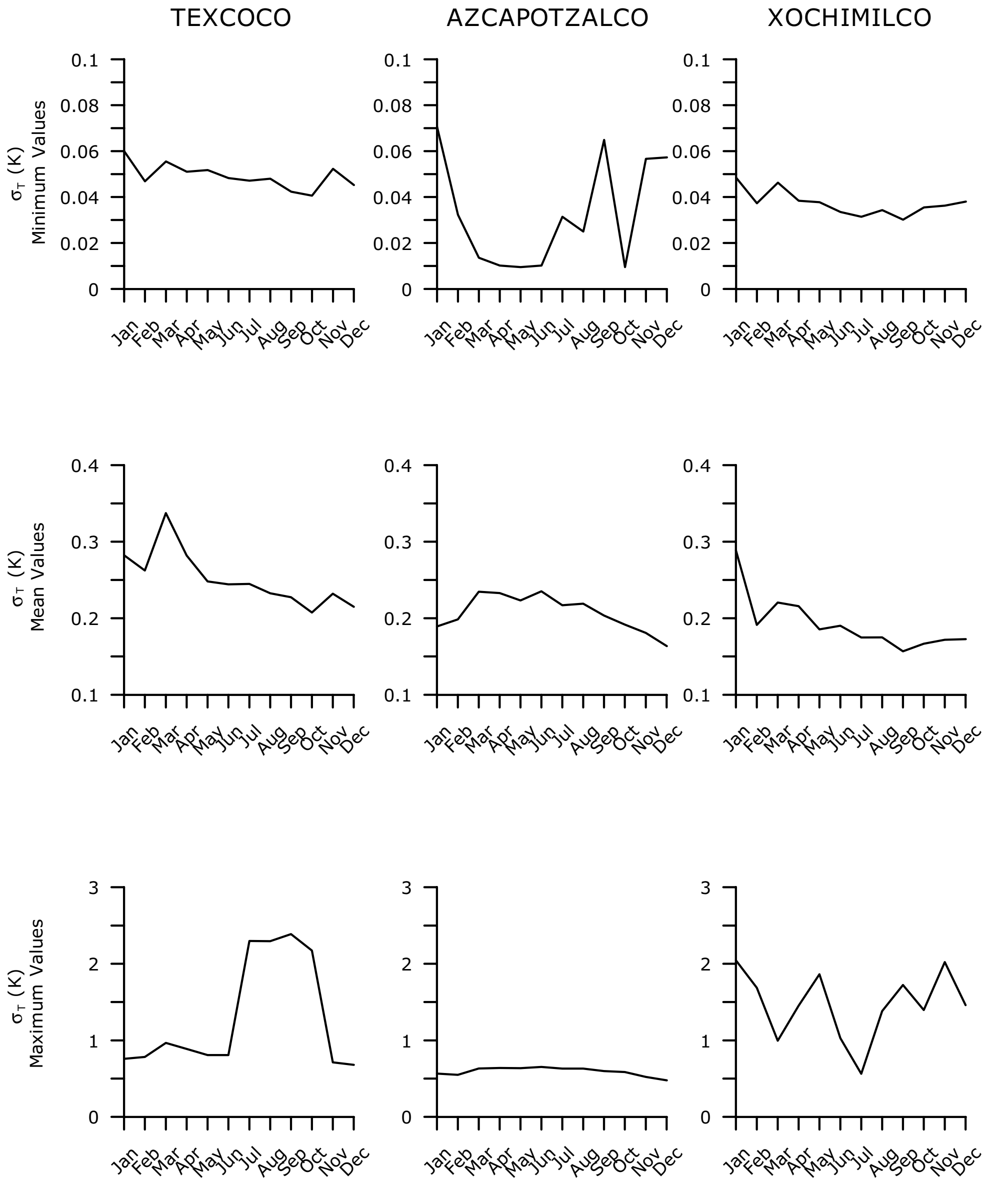

Fig. 16b. – Temperature standard deviation minimum, mean and maximum values.

other. The frequency distributions of H_0 present the characteristic peak around zero, which indicates the presence of the quasi-adiabatic situations, typical of the first hours of the day and of all those cloudy and strong windy conditions.

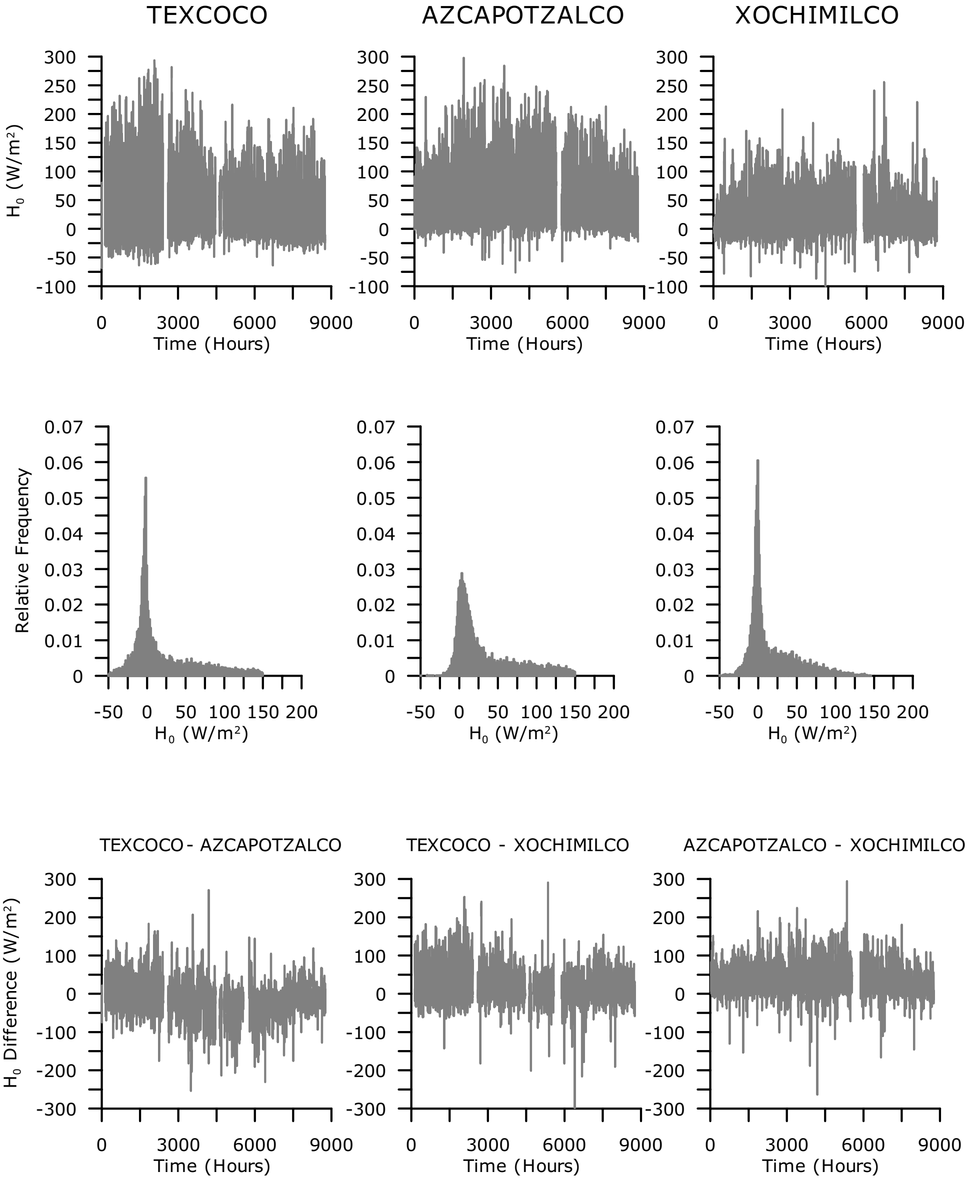

Fig. 17a. – Sensible heat flux, frequency and site by site difference values.

5. – Concluding remarks

A recent review of Arnfield [21] devoted to two decades of urban climate research, clearly states the high complexity of the urban environment and the difficulties encompassed in the applications and interpretation of urban modeling. In particular, a closer collaboration between modelers and field climatologists is encouraged.

This paper propose to the scientific "urban" community to utilize the data-set collected during one-year experiment at Mexico City as a tool by which testing parameterizations and models.

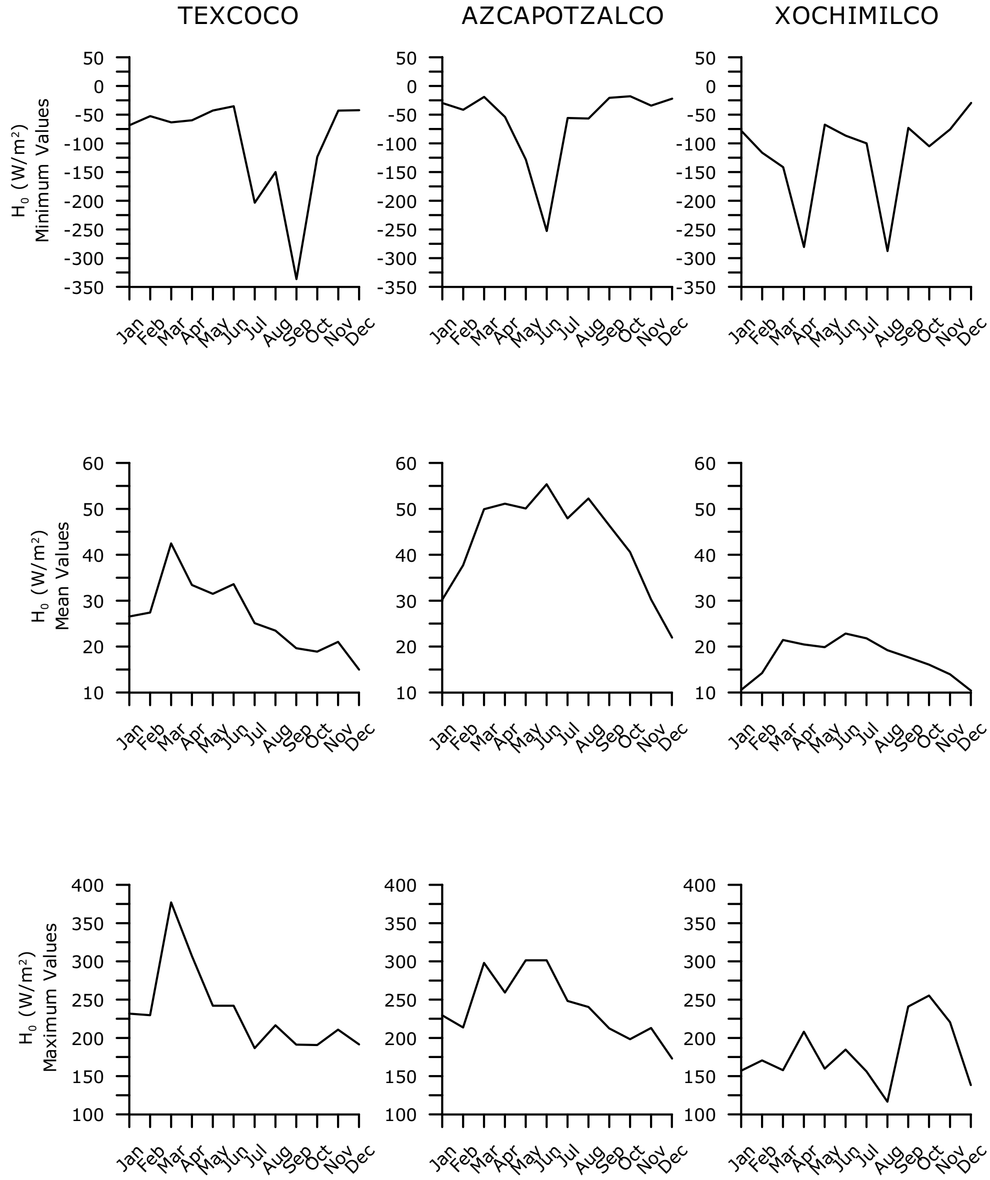

Fig. 17b. – Sensible heat flux minimum, mean and maximum values.

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