Air quality in São Paulo – Brazil: temporal evolution and spatial distribution of carbon monoxide, coarse particulate matter and ozone

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INTRODUCTION

The Metropolitan Region of Sao Paulo (MRSP) is formed by 39 cities (Fig. 1), has more than 20 million inhabitants and 7 million vehicles in approximately 8,000 km^2 of area.Stationary and mobile sources of air pollution emit yearly 165,000 tons of carbon monoxide (CO), 46,000 tons of hydrocarbon (HC), 71,000 tons of nitrogen oxides (NOx), 10,000 tons of sulfur oxides (SOx), and 5,000 tons of particulate matter (PM). Vehicular emission are responsible for 97% of CO, 82% of HC, 78% of NOx, 43% of SOx, and 40% of PM (CETESB, 2015). In the MRSP 9,700 deaths a year may be attributed to air pollution (Miranda et al., 2012). This work aims to analyze the spatial distribution and temporal evolution of the pollutants in the MRSP, and their relation to the meteorological variables.

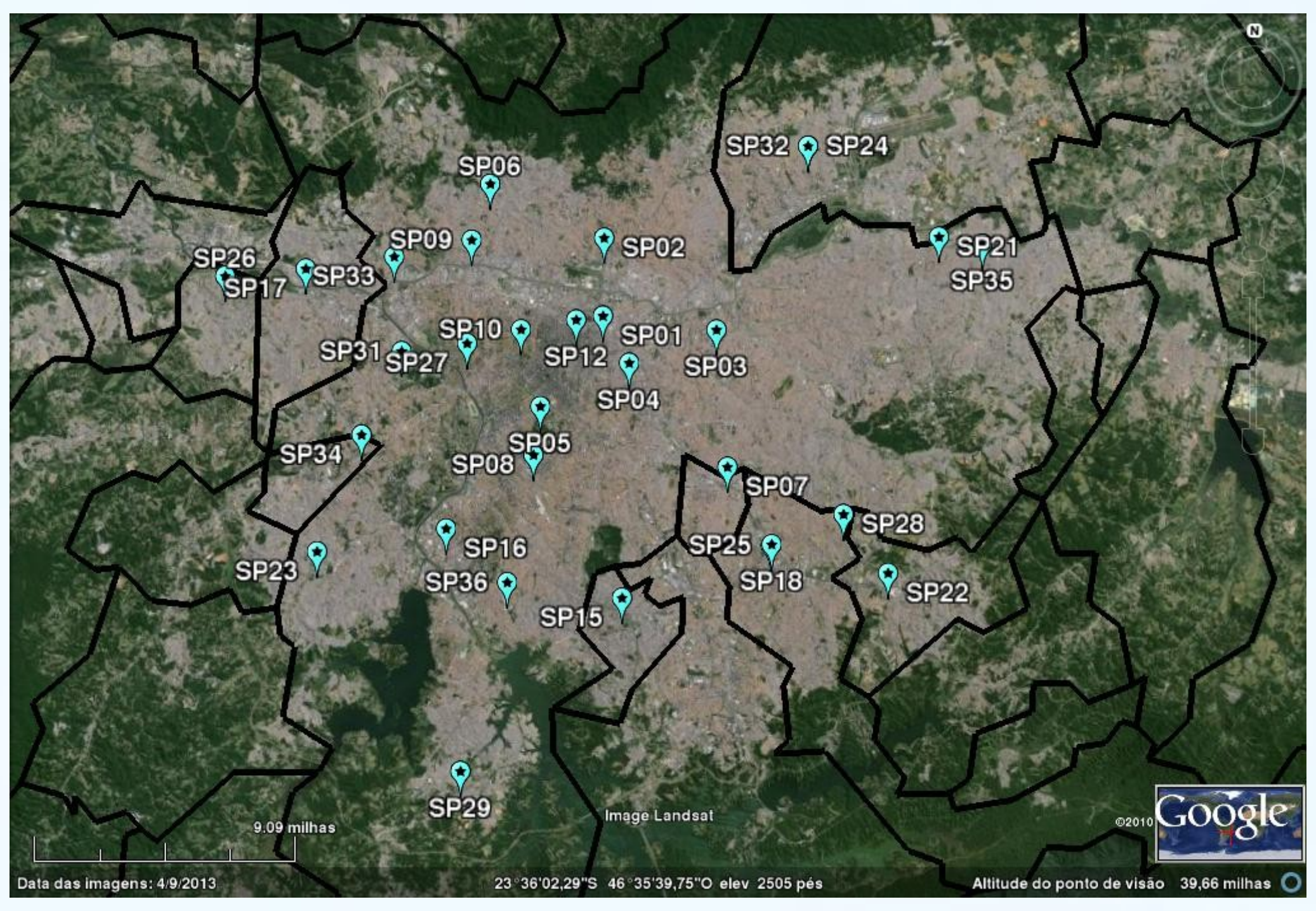

Figure 1: Metropolitan Region of Sao Paulo and the location of the monitoring stations. Black lines are the boundaries of the municipalities and the larger area is Sao Paulo city (23° 32' 51''S and 46° 38' 10''W).

METHODOLOGY

The hourly-averaged records of 30 stations of the Environmental Agency of the state of Sao Paulo (CETESB) for CO, PM, O3, temperature, relative humidity, and wind speed are used, from 1996 to 2013. For each station and each air pollutant, it was performed:

- a spectral analysis to assess the most significant periods of variation of the pollutants;
- diurnal and annual cycles;
- a scatter plot with monthly averages in time and a trend line analysis that fits a function to the scatter plot (the best fit was chosen using the coefficient of determination (R^2);
- annual averages and a diagram of the spatial distribution;
- correlation between the pollutant and each meteorological variable (statistical confidence of 95%).

CONCLUSIONS

Public policies are able and should continue to control emissions to provide improved air quality, particularly in high populated areas, although each pollutant requires a different treatment.

CO concentrations have decreased, however is now stabilizing; greater concentrations near heavy traffic during rush hours; weakly correlated to meteorological variable.

PM concentrations have decreased; more difficult to control than CO; greater concentrations near heavy traffic at night and early morning; moderately correlated to meteorological variables.

O3 is highly difficult to control; greater concentrations over parks and vegetaded area in the afternoon; highly correlated to meteorological variables; no clear tendency.

REFERENCES

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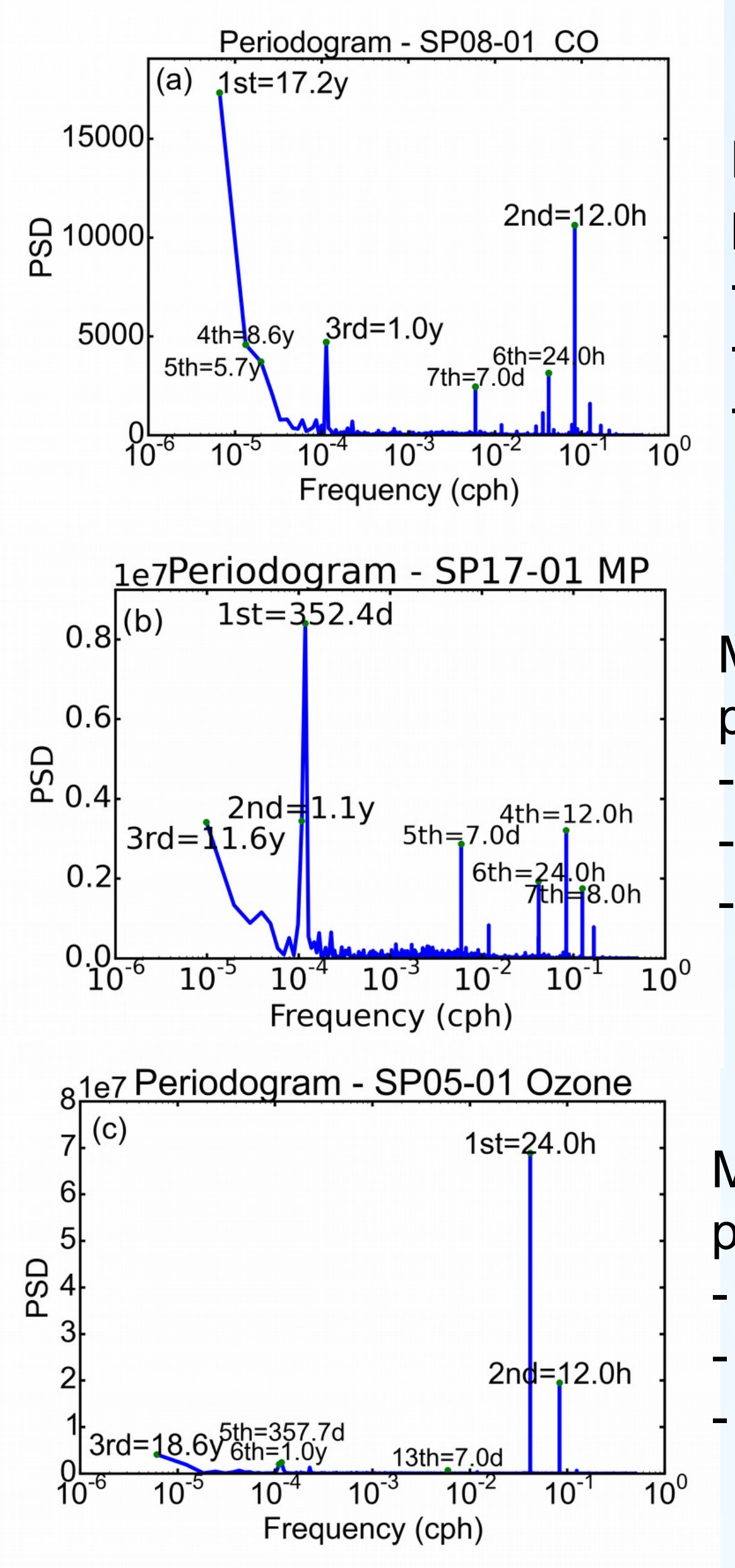
RESULTS

Spectral Analysis

A periodogram was performed for each series and the most frequent periods were ranked. CO and PM series also presented periods as long as the series, indicating a significant trend line.



CO
Most frequent periods:
- 24 hours;
- 12 hours;
- 1 year.

MP
Most frequent periods:
- 1 year;
- 24 hours;
- 7 days.

O3
Most frequent periods:
- 24 hours;
- 12 hours;
- 1 year.

Figure 2: Examples of periodograms: hourly-averaged records of (a) 10.6 years of CO concentration at SP08 station, (b) 11.6 years of PM concentration at SP17 station, and (c) 18.6 years of O3 concentration at SP05 station.

Correlation to Meteorology

Pollutant	Temperature	Relative Humidity	Wind Speed
CO	inverse/ weak	inverse/ weak	inverse/ weak to moderate
PM	inverse/ weak to moderate	inverse/ weak to moderate	Inverse/ weak to moderate
O3	direct/ moderate	inverse/ moderate	inverse/ weak-moderate

Table 1: Correlation between pollutants and meteorological variables.

Diurnal and Annual Cycles

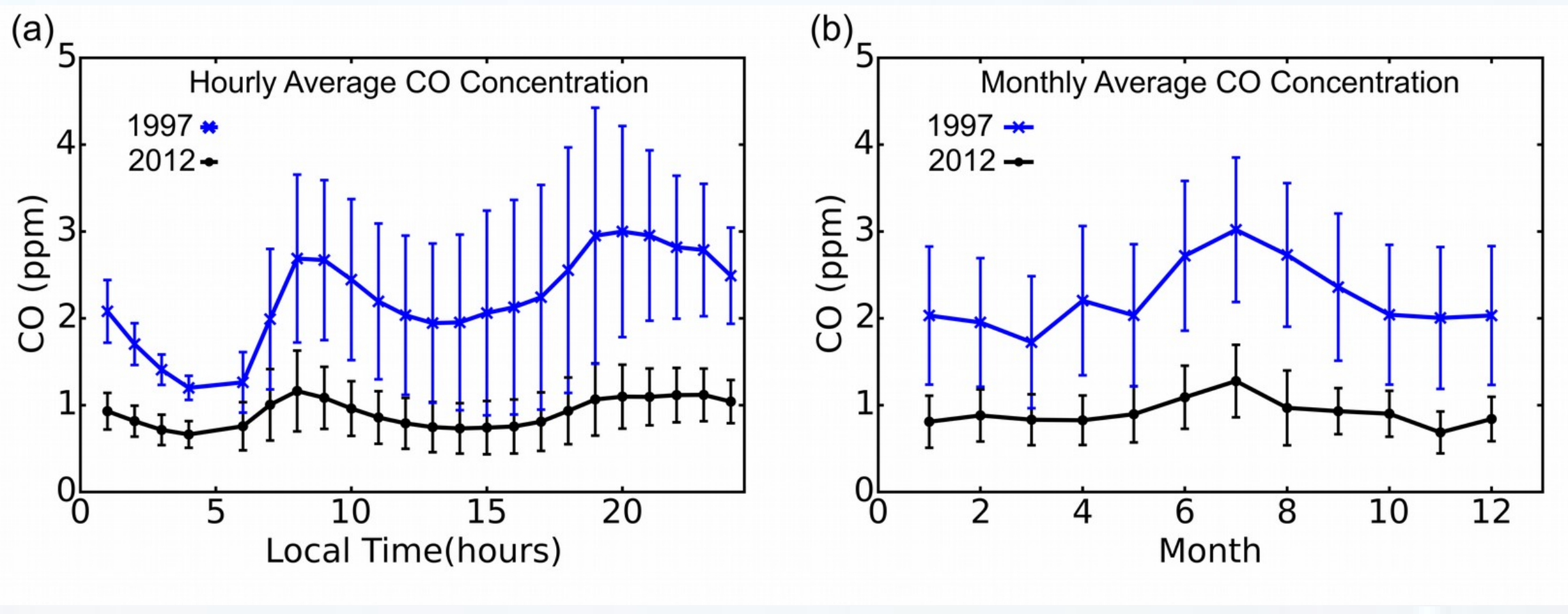


Figure 3: (a) Diurnal and (b) annual evolutions of CO in the MRSP.

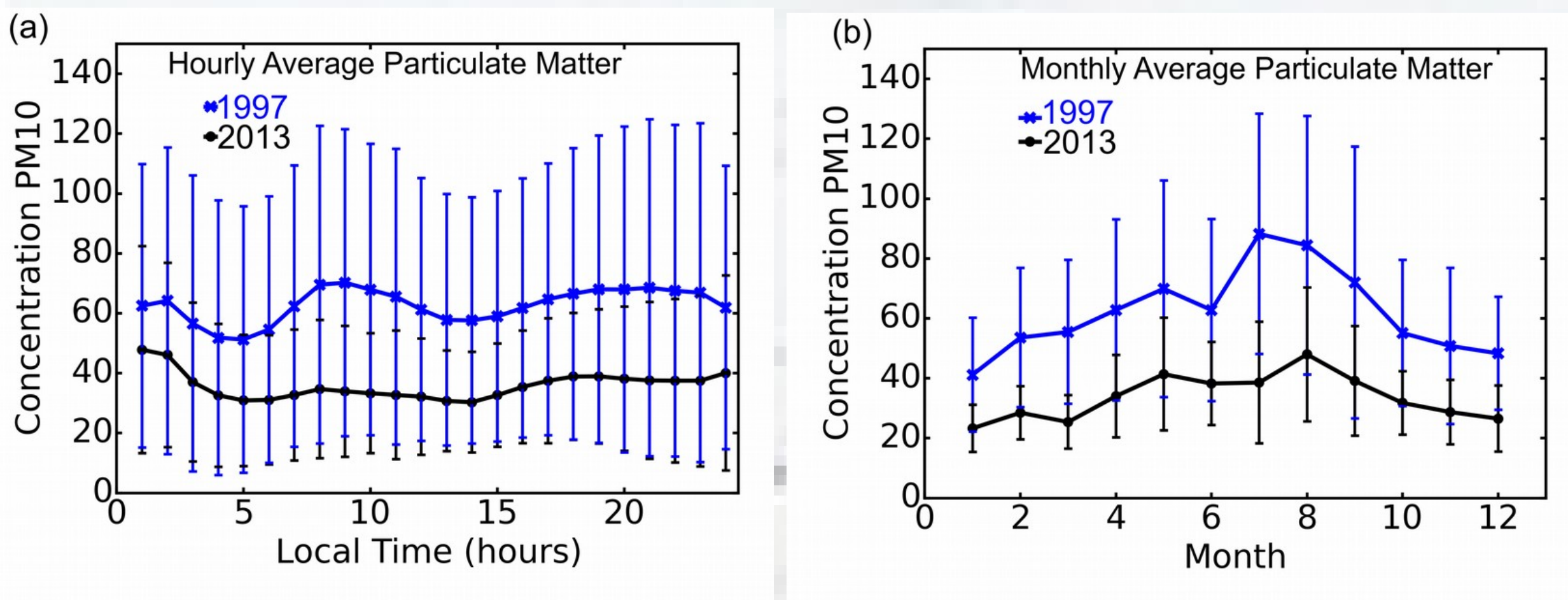


Figure 4: (a) Diurnal and (b) annual evolutions of PM in the MRSP.

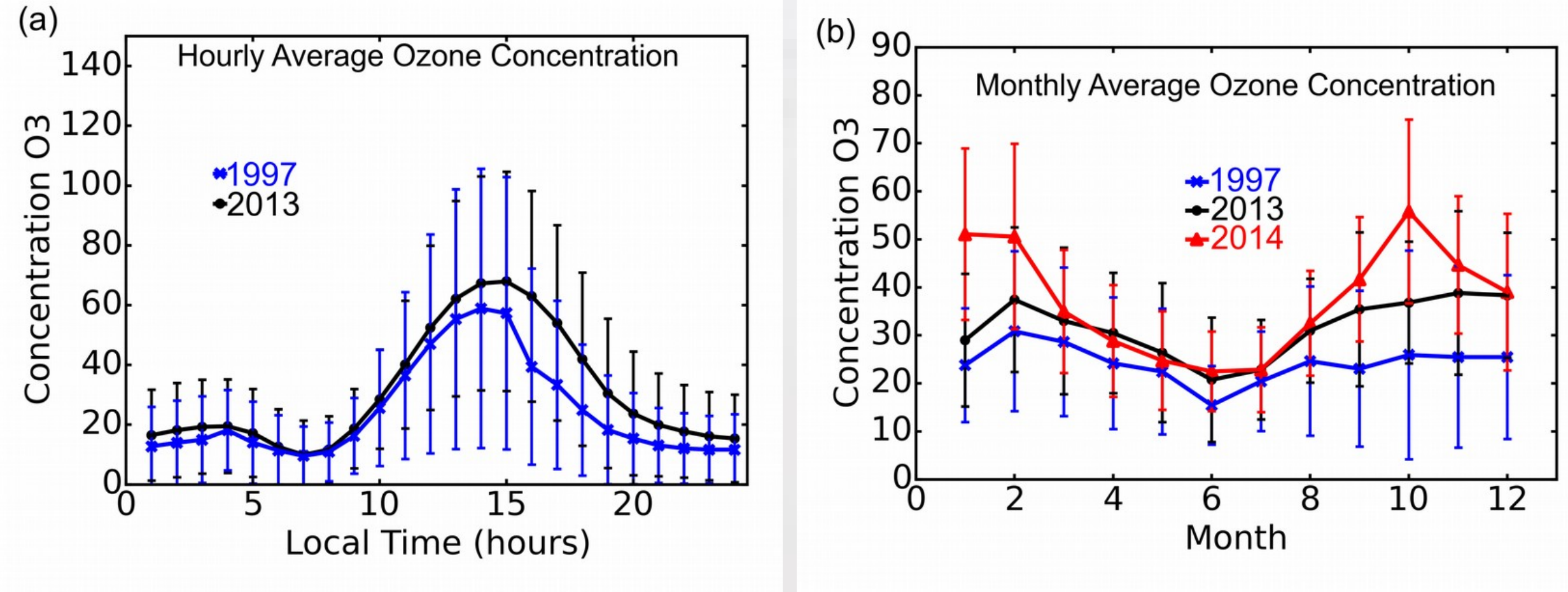


Figure 5: (a) Diurnal and (b) annual evolutions of O3 in the MRSP.

Trend Line

CO and PM have decreasing tendencies, that are lately stabilizing. O3 has no clear tendency. CO longest series have determination coefficients of 62%, as for PM the average coefficient of determination is 30 % for the longest series.

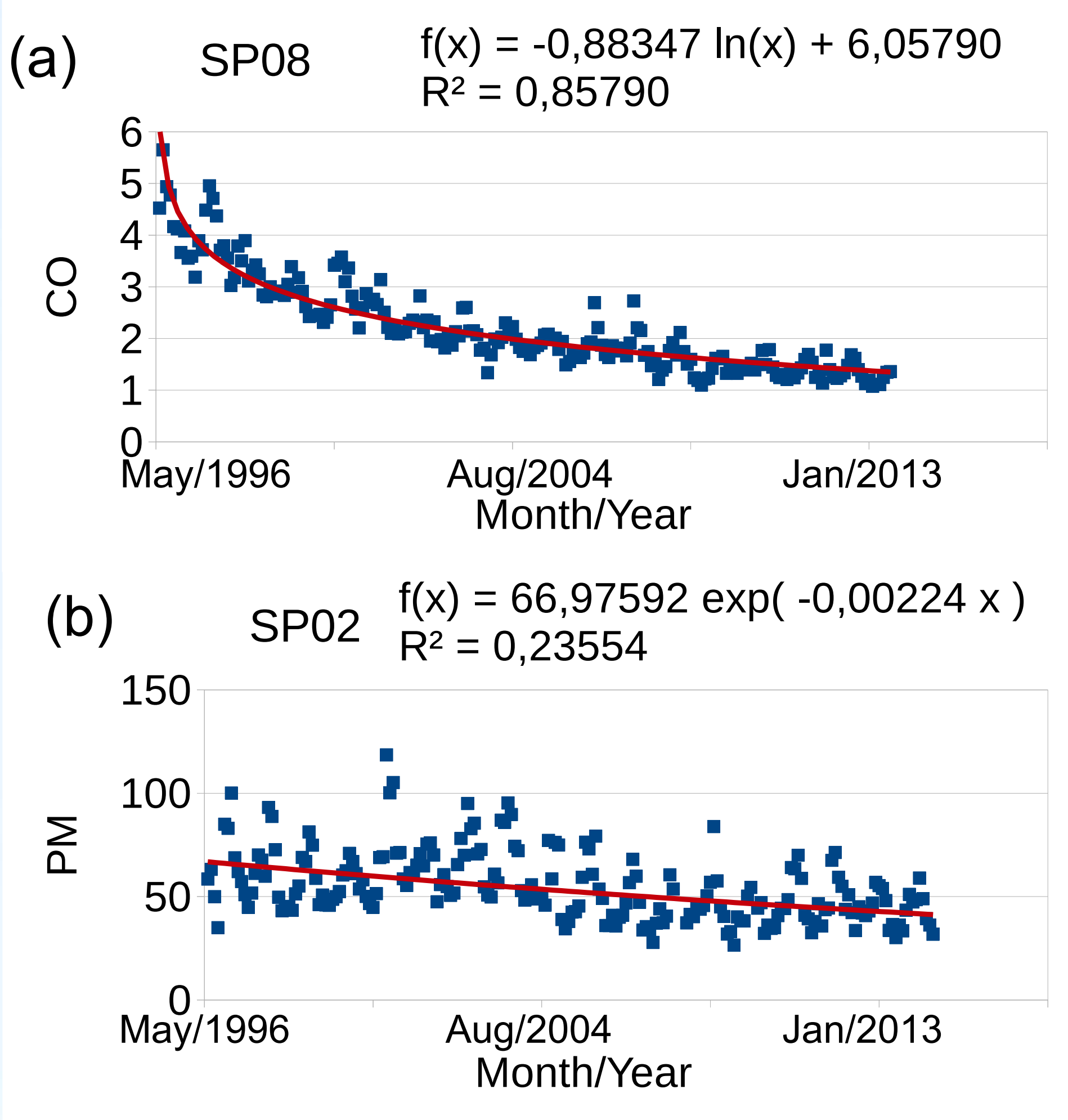


Figure 6: Monthly averages scatter plot and trend line of (a) CO concentration in station SP08 and (b) PM concentration in station SP02.

Spatial Distribution

Stations with higher CO and PM present lower O3, and stations with lower CO and PM present higher O3. Stations with higher concentrations of O3 are located inside parks, farther from the vehicular sources. CO and PM present higher concentration near heavy traffic roads. Spatial distribution show a more homogeneous field lately than in 1997.

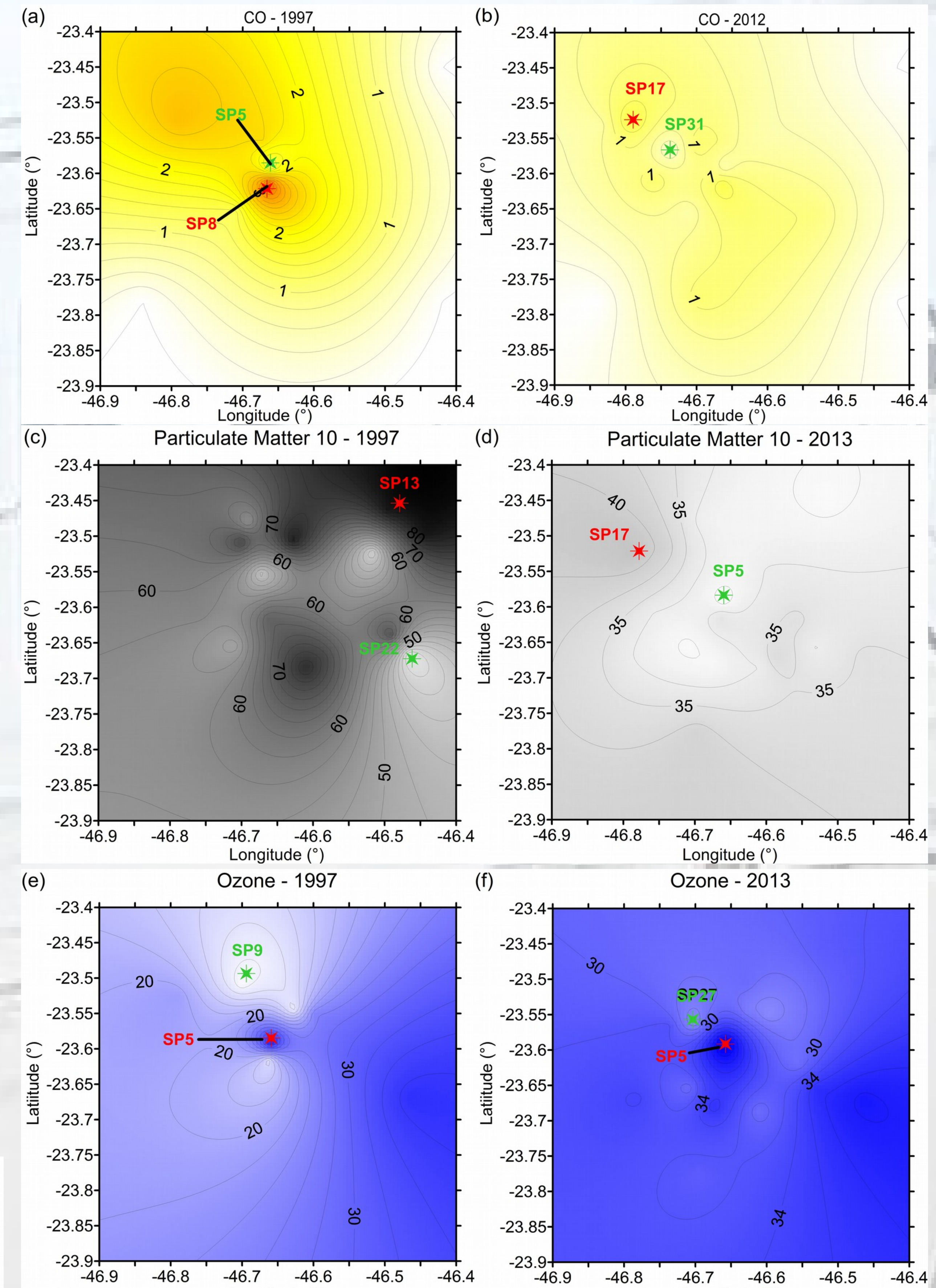


Figure 7: Annual average pollutants concentration over the MRSP for CO (a) in 1997 and (b) 2012 LT, PM (c) in 1997 and (d) in 2013, and O3 (e) in 1997 and (f) in 2013. Stations names in red represent maximum concentration and in green represent minimum concentration. Contour interval for CO is 0.2 ppm, and for PM and O3 is 2 μg m^{-3}.

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