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CLASSIFICATION OF ATMOSPHERIC CONDITIONS FACILITATING HIGH CONCENTRATIONS OF POLLUTANTS IN RIO GRANDE, BRAZIL

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1. INTRODUCTION

Particles and gases released to the atmosphere by industries, vehicles, power plants, and other sources generates air pollution. Its intensity (or concentration) is higher in periods when the dispersion is inhibited, during the cold season, when temperature inversions are present, or when the wind is calm.

Industrial processes, exhaustion of vehicles, suspend street dust, and biomass burning are the main anthropogenic sources if Total Particulate in Suspension (TPS). People may be affected by those particles, specially if they suffer from respiratory diseases such as asthma and bronchitis. Moreover, TPS also damage the vegetation, reduce visibility, and contaminate the soil.

Several events of high concentration of TPS were detected in Rio Grande by monitoring of the state agency of environmental protection. The town of Rio Grande has an industrial center composed by several fertilizers plants and an oil refinery, among others.

The relation of pollutants levels to meteorological conditions, for events since 1990, has been studied by Nóbrega (1997) and Saraiva e Krusche (2001 and 2002). Saraiva e Krusche (2001) evaluated the variation of meteorological surface variables, such as pressure, temperature, relative humidity, precipitation, wind speed intensity and direction, from three days before up to the day when an event of high concentration of TPS occurred. The period of study was the years 1990, 1994, and from 1997 to 1999. The data was measured at the principal meteorological station located at the university campus. Although the prevailing atmospheric conditions during the events of the high concentration of TPS were those of a raising pressure, decreasing temperature and relative humidity, little or no precipitation, and winds from northeast with intensity lower than 4.1 $m.s^{-1}$, their main result was that there was a significant seasonal variation which should be further studied.

Mok and Hoi (2005) analyzed the consequences of the meteorological conditions on the concentration of particulate matter smaller than 10 μm (PM10). They observed that dry and cold monsoons favor high concentrations of this pollutant, while wet summer monsoons do not. They also noted that low pressure and relative humidity, along with weakening of the winds and change of their direction, due to tropical cyclones, facilitate high concentrations of PM10. At a western Pacific coastal city, meteorological conditions that control abnormal PM10 indicators were determined by Wai and Tanner (2005). Those conditions are a) the passage of frontal systems and b) calm winds which happen under the influence of a high pressure center.

There is a need to further investigate the meteorological conditions present when high concentrations of TPS happen in the region of Rio Grande. Therefore, meteorological fields of surface pressure, temperatures, humidity, and winds, obtained by the Reanalysis project, were selected for those periods. A classification based on the distribution of the pressure and on the wind fields was elaborated.

The next section presents both the data and the methodology of selection. Then, the results are shown and discussed. We close with the conclusions.

2. METHODOLOGY

TPS concentration data was made available by Fundação Estadual de Proteção Ambiental Henrique Roessler (FEPAM), which is

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the state environmental protection agency. They were collected by a great volume collector in three different locations near the most populated region of the town, north-northwest of the industrial area, during the years of 1990, 1994, and 1997. The collector samples material during 24 hours, and the frequency of sampling is every seven days. The time series are not always complete, they lack data mostly from the summer months. For all possible days in 1990, the measurements were performed only in 57% of them, and, in 1994, in 75% of them. 1997 is the only year with 100% of measurements.

The primary concentration standard level is of 240 μm/m^3 and the secondary is 150 μm/m^3 (Conama, 1990). We decided to analyze all the events were the concentrations is high than 30 μm/m^3, both to compare our results with those of Saraiva e Krusche (2001) and to consider that a lower level will provide a larger sample, which is more statistically reliable.

Surface fields of pressure, temperature, specific humidity, and winds, along with sea surface temperature fields, were obtained from Reanalysis datasets, available at the National Centers for Environmental Prediction (NCEP) and at the National Center for Atmospheric Research (NCAR) websites.

The days when TPS concentrations were higher than 30 µm.m^{-3}, in all of the three measuring stations, were identified and the atmospheric data was selected for the period of measurement, corresponding to 12:00 of the day and 00:00 and 12:00 of next day.

The analysis of those fields was accomplished and the main weather systems were identified using surface pressure and wind fields, besides some evidence from the temperature and humidity fields, which characterize the air masses acting in the region. They were arranged according to their similarities in seven categories. For each one the average of the fields was evaluated, along with the standard deviation.

3. RESULTS

Fifty two events of concentration of TPS higher than 30 µm.m^{-3} were identified, 14% of them in 1990, 29% in 1994, and 57% in 1997. There were 12 events in the summer, 18 during autumn months, 14 in the winter, and 8 in the spring. The wind velocity intensity in the spring months is higher than during the rest of the year (Krusche et. al, 2003), which favors the dispersion of pollutants and may account for the smaller number of events in this period.

The seven categories are summarized in table 1. Class 1 is composed by 12 events, 42% of them happen in the autumn. It is characterized by a high pressure center east of Rio Grande, which generates moderate winds from Northeast. The temperature and specific humidity are low.

Table 1. Categories of atmospheric conditions which favor TPS high concentration in Rio Grande. Class is denoted by C, and the seasons by S for summer, A for autumn, W for winter, and P for spring. Total number of occurrences is represented by T. HP and LP denote high and low pressure, while NE, SW, SE, and E denote the directions northeast, southwest, southeast, and east. The town of Rio Grande is noted as RG.

C	Description	Occurrences				
		S	A	W	P	T
1	HP to the E and NE winds	2	5	3	2	12
2	HP over RG	0	4	5	1	10
3	Cold frontal system passage	2	1	1	3	7
4	Setting up of HP	0	4	3	0	7
5	HP at SE of RG, E winds	3	2	0	2	7
6	HP over RG, SW winds	2	2	2	0	6
7	Setting up of LP over RG	3	0	0	0	3
	Total	12	18	14	8	52

Class 2 presents a high pressure center over the town of Rio Grande, which generates calm winds and an anticyclonic gyre centered over the urban area. The specific humidity is low and associated to a flow from southwest to northeast of low temperatures, as shown ins Figure 2. 50% of the 10 events in this class occur in the winter.

Class 3 is composed by seven cases, 43% of them happen in the spring. It is characterized by the displacement of the high pressure center by a cold frontal system, and wind convergence which increases temperature and specific humidity.

The average field of the fourth class show the displacement of a low pressure center by another of high pressure. There is a low temperature flow from southwest to northeast, along with low specific humidity. 57% of the seven events in this class happened during autumn.

Class 5 indicates that the high pressure center is to the southeast of Rio Grande, which generates winds from east, associated with low temperature, and specific humidity. 3 of the seven events in this class, which represents 43%, happened during the summer.

Class 6 is characterized by the setting up of a high pressure system over the town, which generates winds from southwest, high temperature and low specific humidity. the six events of this class are evenly distributed in summer, autumn, and winter.

Three cases compose class 7, which shows the setting up of a low pressure center. They all happened in the summer, with high temperature and specific humidity.

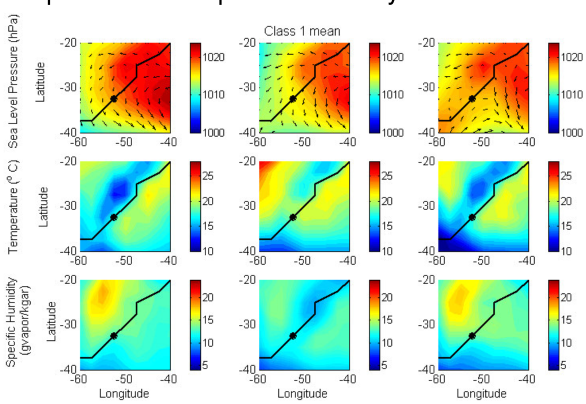

Figure 1. Mean fields for class 1, latitudes in the abscissa and longitudes in the ordinate. The first column corresponds to fields for 12:00 UTC of the day the TPS concentration measurements started, and the middle and the last columns represents fields of 00:00 and 12:00 of the day the measurements were complete. First row are pressure (hPa) and wind fields, middle row are temperature (^oC) fields, and lower row specific humidity fields. ($g_{vapor}.kg_{air}^{-1}$). Dark line represents the coast line, and dark dot the town of Rio Grande.

The low pressure which characterizes class 7 indicates a similarity to some atmospheric conditions found by Mok and Hoi (2005). The other classes are similar to conditions observed by Wai and Tanner (2005).

To investigate a possible influence of the neighboring ocean in the intensity of the high pressure systems, fields of weekly averaged sea surface temperature (SST) were evaluate according the already described methodology. In classes 1, 2 (figure 3), and 4, characterized by high pressure and low temperatures , there was

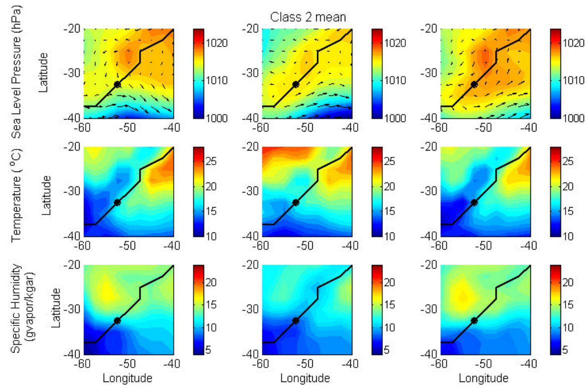

Figure 2. Mean fields for class 2, columns and rows and other symbols as in Figure 1.

a flow of cold water from the south. However, class 5, which is also associate to high pressure and low temperature, has moderate SST. In class 3, which presents low pressure associated to the cold front, and high temperature, has a SST also high, similar to what happens classes 6 and 7, where the high air temperatures are associated to high SST.

Analysis of the standard deviation of SST indicates that the cold water is associated to discharges of La Plata river for class 1, and with the discharges of Patos Lagoon in class 2, as can be noticed in figure 3.

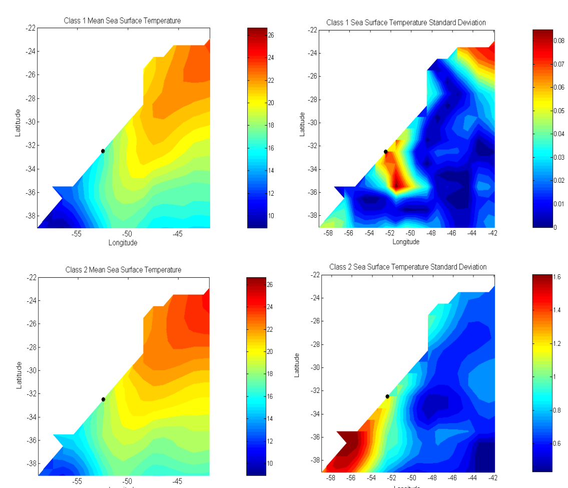

Figure 3. Mean weekly Sea Surface Temperature fields, latitudes in the abscissa and longitudes in the ordinate. The first column corresponds to mean fields for the week of the events of high TPS concentration, and the second column to the standard deviation of those fields. First row corresponds to class 1 and second row to class 2. Dark dot represents the town of Rio Grande.

4. CONCLUSION

The present analysis demonstrated that the atmospheric conditions which facilitate most of the high TPS concentration events are characterized by the passage of anticyclones over the region or to the south or to the north, bringing cold and dry weather. High pressure and calm winds keep the pollutants near the surface, inhibiting their dispersion to high levels.

The sea surface temperature usually presents a evolution similar to the temperature during the events of high pollutant concentration.

The Reanalysis dataset allowed us to build a classification of atmospheric conditions that favor high concentration of pollutants in the region of Rio Grande, along with a possible air-sea interaction with the local variations of SST.

This study will be continued to include a larger dataset of pollutants concentration, since probably the most significant oversight in our analysis is the small number of cases in each class. Furthermore, a objective classification scheme should be applied, the results of which might be apply to forecast situations with high risk of pollutant concentration.

5. ACKNOWLEDGMENTS

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