CLASSIFICATION OF METEOROLOGICAL PATTERNS AND ITS RELATION WITH THE OZONE EPISODES IN THE BASQUE COUNTRY

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ABSTRACT

This work presents a classification of patterns by means of statistics tools, like the cluster analysis, applied to meteorological parameters measured in different stations of the Air Quality Network from the Basque Government during the last seven years (1997-2003).

The relations between the patterns and the ozone episodes have been analyzed. The separation of the local and regional component has been estimated, and in some singular episodes a backward trajectories model has been used to point out the origin of precursors.

As result, it is proposed a useful tool based on an objective procedure of data analysis to carry out a diagnosis of the situation and to anticipate its daily evolution.

Key words: ozone episodes, dispersive patterns, cluster analysis, regional transport, backward trajectories model.

1. INTRODUCTION

The ozone pollution episodes in the northern and central European countries are associated to anticyclonal situations of slow evolution, characterized by weak wind and cloudless sky. The phenomenon of ozone transport can reach distances of hundreds of kilometres; therefore it must be treated on a regional scale. When this phenomenon occurs, the ozone maximums depend on more or less complex interactions between dispersive processes that take place on different scales, and they reach values that can exceeded the established limits.

In urban and industrial zones, the maximum ozone concentrations are registered downwind, and it is possible the case of convergence and reinforcing of urban plume with other plumes coming from point sources (thermal power stations, refineries, etc.). If a regional transport is added, a severe episode of ozone is presented.

The ozone measurements in the Basque Country began in 1987. In 1995 began the extension of the monitoring network to all the territory and from 1998 some monitoring stations are situated in locations that can be considered of background, indicators of a regional transport, as natural parks inland (ex. Valderejo), in the coastal zone (ex. Mundaka) and in the mountain top. In the last years, about 37 ozone monitors are in operation.

The criterion for the protection of human health to fulfil in 2010 (Directive 2002/3/CE on February 12th of 2002, relative to the ozone in the ambient air), allows to exceed the value of 120 $\mu g/m^3$ 8-hour mean ozone concentration an average of 25 days per year in an average of 3 years, with a population information threshold of 180 $\mu g/m^3$ hourly mean ozone concentration. In the Basque Country these values are exceeded (Table 1).

Table 1. Summary of ozone target exceedances.

Year	Maximum daily 8-hour means > 120 $\mu g/m^3$		Hourly means > 180 $\mu g/m^3$		
	Number of days	3 years average	Nº of days	Nº of hours	Nº of stations
1999	37		2	7	2
2000	23		0	0	0
2001	32	30	5	14	6
2002	17	24	1	2	2
2003	64	37	12	48	20

The ozone episodes that have taken place, selected by their long-lasting and spatially extensive high concentrations, have been analyzed in the different studies carried out. The main result is that: most of the

episodes are associated to a meteorological synoptic pattern with a centre of high pressures in high latitudes, to the west and central Europe, originating a general wind circulation of east component that can vary from the northeast to the southeast, enabling local circulations in the most superficial layer.

In the last years the effort has gone to the characterization of the typical dispersive patterns at local level and its relation with the ozone episodes, establishing the relations cause-effect on the basis of the parameterization of selected indicators and the space-temporary distribution of the ozone concentration associated. The objective is to build an expert system of diagnostic to prevent episodes.

In the characterization of the dispersive patterns, statistical methods of multivariate analysis have been combined with the acquired knowledge of the ozone episodes studied, following the philosophy by which the statistical methods must be guided by an understanding of the underlying physical mechanisms in the processes (Thomson et al.).

The data of the Air Quality Network of the Basque Government Environment Department, in the last 7 years 1997-2003, between the months April and September (both included) have been used to the statistical analysis.

2. METHODOLOGY

The observed meteorological conditions have been classified in hourly patterns by means of the statistical technique of cluster, being this one an objective method that allows to identify the typical and more frequent patterns.

The used variables are: temperature, relative humidity, pressure, radiation and wind measured in 11 surface stations, as well as the upper wind data (1100 and 1500 m) provided by the radar profiler located in the coast (Punta Galea) belonging to the Basque Government Climatology and Meteorology Department. The variables have been previously transformed so that their distributions have 0 mean and 1 standard deviation (zscores).

The analysis becomes more complex when it´s needed to combine the different hourly meteorological patterns to obtain the evolution of the 24 hours from the day, to separate the typical daily dispersive patterns.

Several techniques have been used for that, among them a tool specifically designed to combine the similarity matrixes with hierarchic cluster. The similarity matrixes are symmetrical matrixes in which the rows and the columns fit with the days and the cells correspond with the number of hours in which both days (the one of the row and corresponding column) share the same meteorological pattern.

Different daily dispersive patterns having associated higher ozone values are identified. Kriging interpolation method has been used to calculate the spatial distribution of the hourly ozone concentration in each pattern. The observation of the levels registered in the different stations (coastal, inland, mountain top...) and its evolution in the different patterns, has allowed carrying out a series of hypothesis about the background levels, the formation and the local transport, as well as the regional transport.

The daily dispersive patterns do not separate the occurrence of a severe episode in which the population information threshold can be exceeded. The attempts to associate these episodes with a greater emission of precursors, including the indicator day of the week, have not been satisfactory but a typical evolution beyond the daily cycle has been observed in some severe episodes. It can be interpreted as a sequence in the synoptic meteorological conditions favouring a regional transport and causing the increase in the registered ozone levels.

The analysis of the severe episodes, that generally last a few days, is focused in calculating the trajectories followed by the atmospheric mass that arrives at the Basque Country, and in studying if this mass can transport ozone generated from precursors, emitted in zones like big cities and/or important point emissions sources, under favourable conditions for it.

3. RESULTS AND DISCUSSION

Fifteen hourly meteorological patterns have been classified fulfilling the objective to describe in detail the different observed conditions. Four daily dispersive patterns have been identified as having associated higher

values of ozone, about a 25% of the total days in the period April-September. Some days (a 3% of the total days) the population information threshold can be exceeded, but there is not possible yet to identify these days in a separate pattern.

It has been observed that the evolution of the patterns is similar in some severe episodes like the two presented in Table 2, with a change of a daily evolution from 7 (first hours of the day) and 4 (central hours) to a daily evolution of hourly patterns 2 (to first hours of the day), 9 and 13 (in the central hours). The hourly pattern 10 is an indicator of the change, in agreement with the movement of the centre of high pressures towards the interior of the European continent, that results in a south component upper wind that inhibits the superficial nocturnal undocking and the diurnal see breeze formation.

Table 2. Result of the classification in hourly meteorological patterns along two ozone severe episodes.

	Hours GMT																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
June of 2001																								
Day 17	6	6	6	6	6	6	6	6	12	12	12	12	12	12	12	12	12	12	12	12	12	15	7	7
Day 18	7	7	7	7	7	7	7	15	12	12	4	4	4	4	4	4	4	4	4	15	15	7	7	7
Day 19	7	7	7	7	7	7	7	4	4	4	4	4	9	4	4	4	4	4	10	10	10	10	10	2
Day 20	2	7	7	7	7	7	10	10	9	9	9	9	9	9	9	9	9	9	8	10	10	10	10	10
Day 21	2	2	2	2	2	2	10	10	9	9	9	9	9	13	13	13	13	13	8	8	8	2	2	2
Day 22	2	2	2	2	2	2	2	10	9	9	9	13	13	13	13	13	13	8	8	8	8	8	8	8
Day 23	8	8	8	8	15	15	15	8	6	8	12	12	12	12	12	12	8	8	8	15	15	15	15	15
June of 2003																								
Day 17	15	15	15	15	15	6	6	8	8	8	8	12	12	8	12	8	8	8	8	15	15	15	15	15
Day 18	15	15	15	15	15	15	15	15	15	12	12	12	4	4	4	4	12	12	12	12	15	15	15	15
Day 19	7	7	7	7	7	15	15	4	4	4	4	4	4	4	4	4	4	4	8	15	15	15	15	15
Day 20	15	15	7	7	7	7	2	10	4	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10
Day 21	10	10	10	10	2	10	10	9	9	9	9	9	9	9	9	9	9	9	9	8	8	2	2	2
Day 22	2	2	2	2	2	2	2	8	9	9	9	9	13	13	13	13	13	8	8	8	8	8	8	2
Day 23	2	2	2	2	2	2	2	2	8	8	8	13	13	8	8	8	8	8	8	2	2	2	2	2

In the episode of June of 2003, the population information threshold had been exceeded in a greater number of stations and lasts longer.

On June 21th the population information threshold had been exceeded in the northwest zone of the territory, where almost half of the population lives (Figure 1).

In this day the diurnal hourly meteorological pattern is number 9, which has a frequency of appearance of 3.6% exclusively between the 8 and 20 GMT (maximum at 12). This pattern corresponds to a weak see breeze, characterized itself by a variable weak surface wind, towards inland near the coast, and a south component upper wind. The greater temperatures are reached in this pattern, spatially located inside coastal valleys.

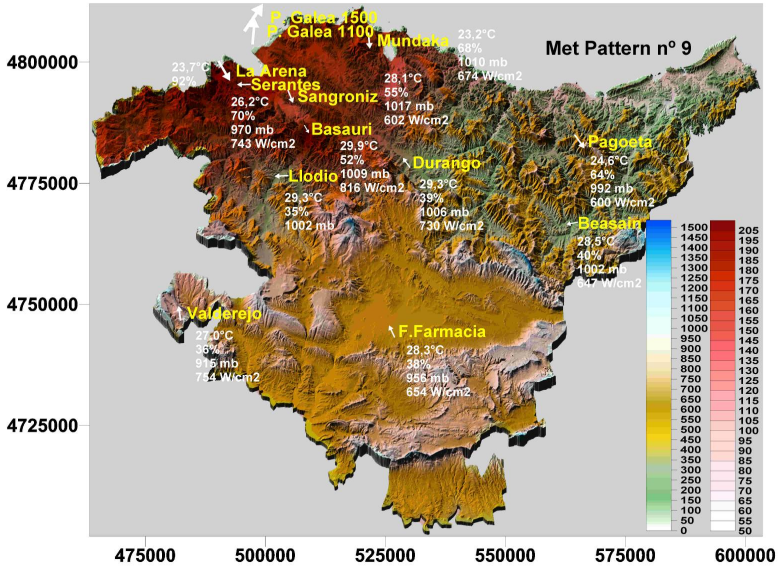

Figure 1. Topographic map of the Basque Country (UTM coordinates), where the hourly ozone concentrations ($\mu g/m^3$) interpolated from the measurements in the surface network and the hourly meteorological pattern on June 21th of 2003 at 16 GMT are superposed.

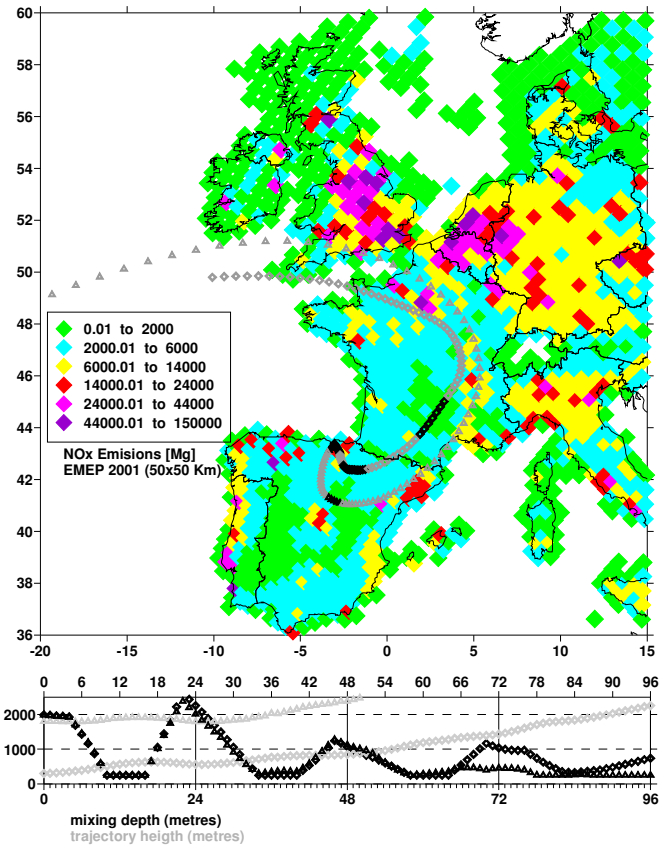

Figure 2. Backward trajectories (model HYSPLIT NOOA-AIR RESOURCES LABORATORY) with destiny Punta Galea (Getxo), height 300 and 1800 m on June 21th of 2003 at 16 UTC, and origin 96 hours before. The coloured map reveals the resulting NO_x emissions inventory EMEP (50x50 km) for year 2001. In the bottom are represented the cruising altitudes and the mixing layer height throughout their route.

The most reasonable hypothesis is that the ozone is coming from the zones where the atmospheric mass crosses to arrive at the high part of the mixing layer (Figure 2):

- The higher backward trajectory is located about 2000 m on the vertical of a great NO_x emission point at early morning of day 20.

- Soon at evening, ozone can be generated with a strong radiation conditions (the convective mixing layer reaches a height of 2386 m).

- Next day the high concentration ozone mass can arrive to the northwest area in the Basque Country at the upper part of the mixing layer.

That would explain why the principal affected zone in the Basque Country is its northwest area, where ozone transported from remote areas can be added to local generated one.

After studying the severe episodes and compared the reached levels in the different patterns at selected stations, the different considered components would be: 47% background level, 30% local formation and 23% regional transport.

4. CONCLUSION

The statistical methodology process-driven is a useful tool to predict many ozone pollution episodes. The classification of dispersive patterns using cluster analysis applied to the Basque Country monitoring network variables has been tested and the result can be considered good.

The contribution of ozone coming from the outside is quite clear, although in each severe episode it would be necessary to analyze in detail the flows of transport and the atmospheric conditions to determine its possible origin.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Thomson M.L. et al. (2000) A review of statistical methods for the meteorological adjustment of tropospheric ozone. Technical Report Series NRSCE (National Research Centre for Statistics and the Environment) No. 026

HYSPLIT Trajectory Model - NOAA Air Resources Laboratory http://www.arl.noaa.gov/ready/hysplit4.html

Co-operative programme for monitoring and evaluation of long-range transmission of air pollutants in Europe http://www.emep.int/