OBJECTIVE TOOLS FOR THE STUDY OF THE RELATIONSHIP BETWEEN SYNOPTIC SCALE METEOROLOGY AND AIR POLLUTION

Cecilia Soriano¹, Javier Remón¹, Antonio Fernández², Javier Martín-Vide³ and Rosa Soler⁴
¹Universitat Politècnica de Catalunya. Dpt. of Applied Mathematics I. Barcelona, Spain
²Centro Meteorológico de Cienfuegos, Cienfuegos, Cuba
³Group of Climatology, Universitat de Barcelona, Barcelona, Spain
⁴Universitat de Barcelona, Dpt. of Astronomy and Meteorology, Barcelona. Spain

INTRODUCTION
This contribution shows an objective tool aimed to assist air pollution managers in the understanding and prediction of processes related to air quality at the regional level. This works shows (in an objective way) the relationship between the synoptic situation and the levels of air pollution registered in a given study region (Kim Oanh et al., 2005). The bottom line of the study is that each synoptic situation has particular atmospheric circulatory patterns associated with it, which play a decisive role in the dispersion of the emitted pollutants and therefore in the final concentration level. In particular, the procedure has been applied to study the relationship between the synoptic situation in the Iberian Peninsula and the resultant ozone concentration in Catalunya (Northeastern Spain).

OBTENTION OF THE AUTOMATED SYNOPTIC CLASSIFICATION
The first step has been the development of an automatic classification of the synoptic situations (Fernández et al., 2003; Soriano et al., 2005), what we have called the Objective Synoptic Processes (OSPs). One of the main characteristics of this new classification, as opposed to others already exiting, is that it is based in the analysis of the evolution, during three days, of surface pressure (Psfc) and geopotencial height at 500 hPa (Z500). Generally, synoptic classifications take into account maps for the day to be classified, while here we have included in the analysis the previous and the following day. An iterative procedure results in an objective grouping of the configurations describing the large-scale situations.

This routine has been applied over an appropriate domain covering the Iberian Peninsula (the working window covered 25°N - 65°N and 30°W - 30°E at a resolution of 2.5°) to obtain OSPs in the region for the bi-month July-August, using daily NCEP’s synoptic maps for years 1990 to 1999. It has resulted in 22 synoptic classes obtained for that period. Figure 1 shows the frequency distribution for each of them (empty bars), from which it can be observed that the top-6 OSPs comprise almost half of the days analyzed (48.8 %), and the first 12 for the 75%.

![Fig. 1: Relative frequency (white) and persistence (dashed) for the OSPs.](image-url)
In the same graph we have also represented the percentage of persistence for each OSP (dashed bars). This value accounts for the probability of a given synoptic processes to progress as itself the following day. In general, persistence is high almost for all the OSPs, which can be explained if we take into account that the bi-month analyzed (July-August) is generally characterized by rather stable synoptic situations (mainly due to the installation of the Azores anticyclone).

Each OSP is represented by 6 maps, 3 for Psrf and three for Z500, corresponding to days D-1, D, D+3. OSP’s maps are obtained by averaging all the maps for all the days that the procedure classified into each synoptic process. As an example, Figure 2 shows maps describing OSP1. It is characterized by a typical blocking pattern, with the North Atlantic Anticyclone over the British Islands, and a weak easterly-north-easterly flow over the Iberian Peninsula and the Mediterranean Basin, as the pressure gradient is very low.

**Fig. 2; Synoptic maps for OSP1 obtained with the new classification method. Psfc (top) and Z500 (bottom) have been represented for days D-1, D and D+1.**

**APPLICATION TO OZONE FOR THE SUMMERS 2001 AND 2003**

For the purposes of this investigation (to establish a possible link between days of relative high ozone concentration, or episodic days, in Catalonia and certain synoptic processes) we have investigated the months July-August of years 2001 and 2003. The reason for choosing these two summers was that a large number of ozone episodes (hourly concentration over 180 μg/m³) were registered by the network of surface immission stations of the Department of the Environment (DMA) of the Catalan Government.

Ozone data used in the analysis was acquired at 34 surface stations belonging the DMA which registered hourly immission concentrations (indicated as dots in Figure 3, left). However, for this study only maximum daily concentration was used. The DMA also divides the territory into what they call the Air Quality Zones (AQZ), which are also indicated in Figure 3 (left). Each AQZ covers a region with similar dispersion conditions (orography, climate, which results in similar immission values) and similar emissions sources. These AQZ will be used later in the analysis to study the geographical distribution of the O₃ concentrations.
The first step has been sorting the maps corresponding to the analyzed days into the 1990-1999 classification described above, using also automated methods. To do that, the 6 maps which describe every day were compared to the averaged maps of each of the OSPs of the original classification. A given day was classified as belonging to a certain OSP if it is the one which gives the minimum of all the RMSE between the maps of the day and the averaged maps of the 22 OSPs (that is, maps had the minimum distance among them).

**Grouping of the Synoptic Processes**

The analysis of the $O_3$ data and the OSPs as a whole showed the existence of several synoptic situations with similar morphologic characteristics (as far as their averaged maps is concerned) which also showed similar behavior in the resulting concentration levels of Ozone. These coincidences can be seen in Figure 3 (right), and also in the graph included in Figure 4 (where OSPs in the x-axis have already been arranged to show these coincidences).

This evidence suggested further grouping of the OSPs, which were simplified into 4 main groups (OSP-A to OSP-D). The main characteristics of which are described below:

- **OSP-A**: Blocking pattern over Great Britain and the Baltic. It is composed of rather persistent OSPs (all of them have persistence percentage over 55%).
- **OSP-B**: Its main characteristic is its strong zonal circulation index.
- **OSP-C**: North Atlantic Anticyclone and surface Northern advection.
- **OSP-D**: Anticyclonic wedge of the Azores Anticyclone, with a trough at 500 hPa West of the Iberian Peninsula.

Figure 4 shows that some synoptic processes (A & D) are especially prone to lead to episodes, or at least to high values of $O_3$. On the contrary, processes B and C are related to low immission values.
Fig. 4: For every OSP, percentage of days with at least one of the surface stations registering and $O_3$ exceedence (empty bar), and average number of AQZ affected (dashed bar).

Spatial Distribution
It is important for predictors to know if there is a relationship between the synoptic situation and the region of the territory susceptible to be affected by a pollution episode. That is why we have carried out a spatial analysis of the data to try to account for this possible spatial variability of the episodes.

In order to support the grouping we have performed and described in the previous section, the average number of AQZ affected under every OSP has been computed. This variable has been included as a dashed bar in Figure 4, and has revealed that those situations grouped under OSP-A lead to a high number of AQZ affected, while those under OSP-D generally affect less zones. However, Figure 5 shows that nonattainment situations are not uniformly distributed in the territory, since some AQZ are very likely to be affected by an episode (AQZ 6 & 8) while some others (AQZ 5 & 12) rarely experience exceedences.

Fig. 5: Ozone episodes as a function of OSP and AQZ.
To confirm this fact, for each of the 4 OSPs grouped before, the maximum daily concentration of ozone has been averaged for all the days belonging to every OSP. The spatial interpolation of the values has resulted in the maps represented in Figure 6, which shows how OSP-A can be classified as a situation leading to high levels of O₃ in all the territory (in that sense it could be classified as “statewide”). OSP-D is also related to high levels of ozone, but mainly in the regions situated in the NE (mainly affecting AQZ 6 & 8). OSP-B and OSP-C correspond to situations with low immission values. It is important to note that all graphs show lower levels of ozone in the area of Barcelona and its metropolitan region. This has to do with the well known fact that usually ozone episodes take place far away from the main emission sources.

![Maps of maximum daily O₃ concentration](image)

**Fig. 6; Average maps of maximum daily O₃ concentration registered in the measurement network (stations represented as dots) under the different synoptic processes.**

**REFERENCES**

