Large-scale atmospheric circulation and sounding derived parameters associated with windstorm events in Lisbon (Portugal)

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Abstract. Prior research has allowed the building of a windstorm database in the Lisbon City Council, (LCC) Portugal (Lopes et al., 2008), based on a systematic selection of strong wind events responsible for damage, and tree falls (1241 occurrences from 1990 to 2006). The study of the atmospheric environment related with windy weather conditions in the Lisbon region is an ongoing research. The results presented in this paper evolve two main achievements. First, the results of an automatic classification of large-scale atmospheric circulation patterns associated with windstorm events in Lisbon will be presented and discussed. Secondly, results from a systematic analysis of selected sounding derived parameters, using available radionsonde data from the Lisbon/Airport station, will be carried out. These two main tasks allowed the improvement of the understanding of the main synoptic weather context and dominant thermodynamic forcing associated with windstorm events in the Lisbon region.

Introduction

Trees' benefits for the urban environment are frequently accompanied by hazards caused to the human population and infrastructure, particularly during strong wind events, due to total or partial tree falls in public and private open spaces. Windstorms damages to trees greatly depend on the physical conditions imposed by the urban environment. A windstorm database based on fallen trees occurrences in Lisbon (since 1990 and with on time updating) was constructed compiling data collected and stored by the Lisbon Fire Brigade and Rescue Services (Lopes et al., 2008). This updated windstorm inventory allows to explore this information under different perspectives. An important and ongoing research line (see more information available at http://www.ceg.ul.pt/urbklim/index.html) is the study the atmospheric environment associated with windstorm events in the Lisbon region, from the large-scale to the local scale. Windstorm events may occur in Lisbon in all seasons, but the synoptic weather controls are quite different when in compare the summer events with the episodes occurring out of the warm season. During summer, the wind regime in the city of Lisbon is dominated by a relatively strong northerly wind that occurs near the western coast of the Iberian Peninsula, the *Nortada*. This regional circulation occurs when a strong pressure gradient is maintained by a persistent thermal depression in the warm continent and the Azores anticyclone is above the cooled ocean. The upwelling of the cooler ocean waters near the shore reinforces the pressure gradient, increasing wind speeds near the ground, and sometimes triggering stronger winds. Windy weather conditions out of summer months are always related with cyclonic circulations and occur more frequently during the winter, when the westerly flow is more intense, bringing more tracks of frontal disturbances to the Portuguese latitudes. Different studies focused on the large-scale atmospheric types associated with rainfall regimes and patterns in Portugal (Santos et al 2005; Fragoso and Gomes, 2008), but remains quite unknown the atmospheric circulation controls related with windy weather conditions over this territory. A first attempt was already carried out with a preliminary classification (Fragoso and Lopes, 2008). Expecting to contribute to fill this gap, this study aims to identify the main (large-scale) atmospheric circulation patterns that promote windstorm events over the Portuguese area. Local thermodynamic conditions in Lisbon area during windstorm events will also be analysed, using the available radiosonde information, from their sounding station located at the Airport (northern part of the city).

Data and Methods

The initial information from the LCC windstorm database permitted to obtain an inventory of 128 windstorm days in Lisbon (in the 1990-2006 period). This inventory is in fact a subset of the total number of windstorm events, because we want to put in relation their large-scale atmospheric context with the thermodynamic features observed at mid-day (12:00 UTC) soundings in Lisbon/Airport, the only daily time balloon release operated at this station. Therefore, the selected 128 windstorm days are the subset of windstorm days that were associated with fallen trees damages from 9:00 UTC to 15:00 UTC, the 6 hours period that permits a more suitable and useful analysis from radiosoundings information. These 128 case events were analysed according to their atmospheric context, evolving two different sets of data, whose description and applied methods should be considered separately: atmospheric data fields and radiosonde data. Atmospheric fields concerns Sea Level Pressure (daily means) grid data from the NCEP reanalysis-2 database (Kanamitsu et al., 2002). This information is suitable to analyse the surface pressure systems that controls the wind field near to the ground. The extracted fields were limited by the latitudes of 25º and 65º N and the longitudes of 35ºW and 10º E, defining a geographical window with 323 grid points. Appling a tested methodology from earlier researches (Fragoso and Gomes, 2008), these data were used in a computational method that combines the Principal Component Analysis (PCA) and the K-means clustering, and seeks to define the fundamental large-scale circulation types associated with windstorm events in Lisbon.

On the other hand, the use of radiosounding Lisbon (Lisbon/airport station) was conducted in order to identify the dominant forcings and processes to windstorm initiation. Our focus is on the analysis and calculation of several parameters deduced from radiosonde data, trying to test their ability as indicators of wind gusts triggering. These parameters evolve well known stability indices and thermal buoyancy estimators (e.g. Lifted index, CAPE, DCAPE, among many others) and their comparative analysis may contribute to discriminate strong wind events related with

non-convective and convective storms.

Results and discussion

The main output of the automatic classification procedures may be summarised in a typology of large-scale atmospheric circulations containing three fundamental clusters (Fig. 1).

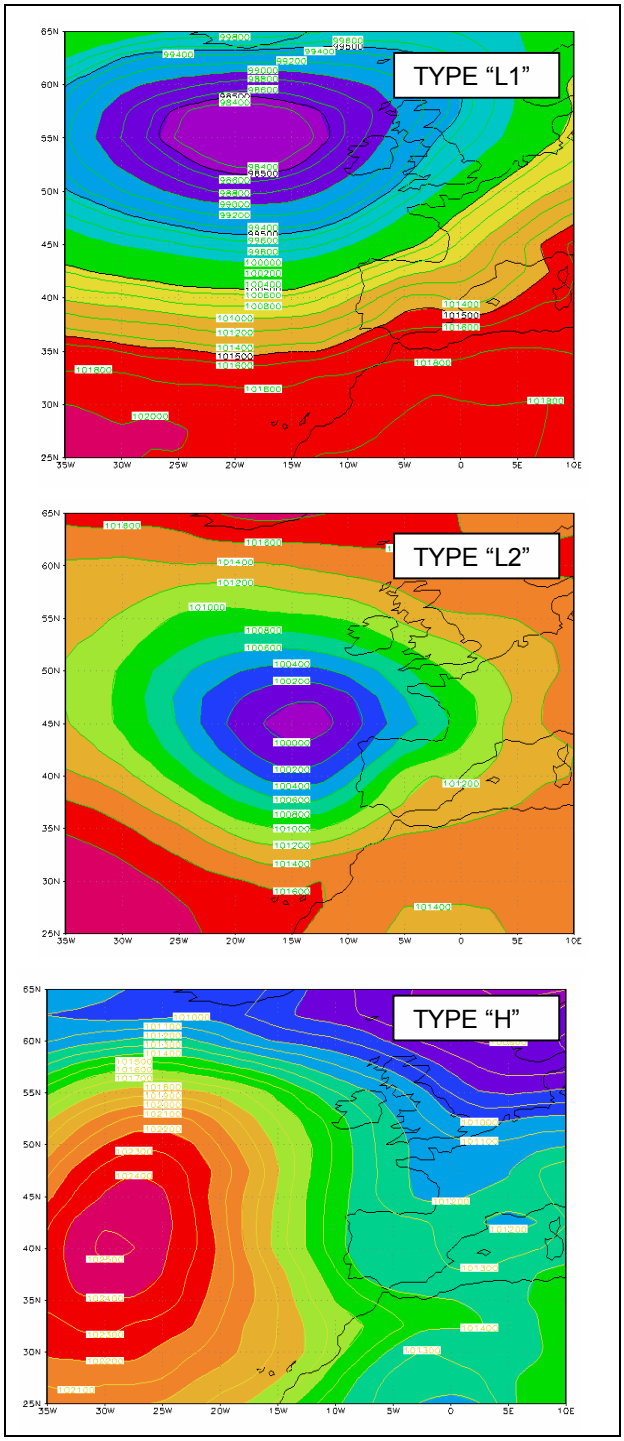

Figure 1. Large-scale atmospheric patterns (Sea Level Pressure average fields based on a coupled principal component analysis and cluster analysis classification). Source of the data: NCEP, NOAA.

The three illustrated atmospheric circulation types were obtained clustering the loadings of the 128 case events of the first 5 PC´s retained eigenvectors, explaining 80,2 % of the total variance. Type "H" corresponds to northerly windstorm events related with the combination of an anticyclone (margin) over the Eastern Atlantic and a low pressure system over the centre of the Iberian Peninsula (particularly during summer) or over the Western Mediterranean/Eastern Spain (during fall, winter and spring months). Type "L1" illustrates the windstorm events related with intense migratory cyclones tracking eastward at British Islands latitudes. These events occur more frequently during winter and promote strong W or SW winds over Portugal. A different context is represented by the "L2" type, which is associated with the influence of low pressure systems located NW or W of the Iberian Peninsula, and promoting strong SW or S winds over the Portuguese region.

Results from the statistical analysis of the sounding derived parameters are based in just 91 radiosondes/daily windstorm events, considering that there are no available soundings from 1994 until 1997. The results show a general increase of thermodynamic instability severity during the fall season, when the occurrence of convective storms is more dominant. On the opposite, winter windstorms are in general related with synoptic forcings associated with intense frontal cyclones, promoting strong gradient winds.

Conclusions

Windstorms in Lisbon are mainly related with three general main surface circulation patterns. One of them (type "H" of the classification) may correspond to a two different situations: one is typical in summer and is related with the "*Nortada*" wind regime; the other one is common out of this season, but triggers also strong northerly winds. Fall windstorms were the most frequent episodes in the analysed inventory of windstorms and are triggered, in general, under a more thermodynamic unstable environment, related with convective storms activity.

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Positives/Pozitíva association the synoptic situations with windstorm and atmospheric stability for Lisboa region
Advices/Odporúčania the Table introducing could be positive for results interpretation, for cluster types the statistical characteristic for stable and unstable therm. environment and season should be presented, to characterize the stability conditions for cluster type it can be interesting to try analyze other aerologic station close to Lisboa station (of course it should be carefully interpret with windstorm database), may be this is the reason, that only 2pages are allowed
Formal corrections/Formálne úpravy the figures are dark and not well readable, in the fig.: label contains the suspicious character, may be I prefer using autumn instead fall

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