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A NOVEL APPROACH FOR TRACING THE ORIGIN OF ODOUR NUISANCE WITH SMART METEO-DISPERSIVE MODELLING SYSTEM

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Abstract: A new methodology to trace backward the origin of odour nuisance has been developed. It is based on the modelling system SMART, where the RetroSPRAY model is interfaced with the regional atmospheric model MOLOCH. The novelty is represented by the pre- and post-processing of the input and output, respectively. For the input, the citizens' notifications of nuisance received through the NOSE Web-App are elaborated, for the output a combination of puffs released backward in time from the locations and at the time of the notifications is implemented. The approach used is briefly presented and discussed.

Key words: *odour nuisance; backward simulations; SMART modelling system; NOSE Web-App*

INTRODUCTION

Tracing the provenience and emission sources of odours is a challenging task, due to its transient characteristics, its distinctive features and the difficulty to have dedicated monitoring systems. Lagrangian particle dispersion models can be adapted and fruitfully used for this purpose. The meteo-dispersive modelling suite SMART (Spray-Moloch Atmospheric Regional Tool), recently developed (Bisignano et al. 2020, Trini Castelli et al. 2020), has been applied and further renovated in the frame of the NOSE Project (Network for Odours Sensitivity, *https://nose-cnr.arpa.sicilia.it/*) and its related web-application. NOSE has been realized by CNR-ISAC and ARPA Sicilia and it is aimed at tracking episodes of odour nuisance through a citizen-science approach.

A new and original approach has been developed for using the SMART system in the field of odour nuisance assessment, implementig in it a version of the SPRAY Lagrangian stochastic particle model that includes the backward-mode option, RetroSPRAY (Armand et al. 2013). When treating pollutant dispersion, with RetroSPRAY it is possible to trace the plausible location of an unknown source from concentration observations by identifying areas with maximum spatial and temporal consistency among backward puffs from each sensor (Tinarelli et al. 2018).

The new challenge regards using signals from citizens, i. e. qualitative and subjective information, in place of observed concentrations as input receptors for RetroSPRAY. The notifications received through the NOSE Web-App are sparse in space and time. In a first approach they have been aggregated in a regular grid and, based on thresholds and selective criteria, the grid cells representative of sensible "pseudo-receptors" for the backward releases are identified (Trini Castelli et al. 2022). Then, a second method based on a cluster analysis of the notifications and on the same selective criteria has been adopted, identifying the cluster centroids as pseudo-receptors, with the aim of making the elaboration of the input more automatic and reliable.

The simulations with RetroSPRAY are then performed by releasing, from the identified pseudo-receptor locations (either gridboxes or cluster centres), a series of retro-puffs at each time interval in which a significant number of signals are collected. As final output, the retro-concentration fields generated by the retro-puffs are combined at all possible emission times, through a process that produces maps describing the region where possible sources can be potentially located.

The two methods for elaborating the input for the backward release in SMART modelling system for the NOSE Web-App are briefly presented and compared. The applicability of this approach is supported by the results obtained in two case studies, related respectively to an unknown release and to a source that was identified after the area was monitored as a consequence of the citizens' warnings.

THE NEW DEVELOPMENTS

A clever elaboration of the received notifications (Figure 1) is the first step to generate proper 'receptors' for the back-trajectories and determine the input to the RetroSPRAY dispersion model. Citizen notifications include a subjective evaluation of odour intensity, on a scale from 1 to 5. In our approach, only alerts with intensity 3, 4 or 5 have been used. The period of time defining the event (enabling the definition of a notification peak, usually a few hours) is divided in 30-minute intervals. Then all notifications within the same time interval are associated at the same discrete time and spatially aggregated.

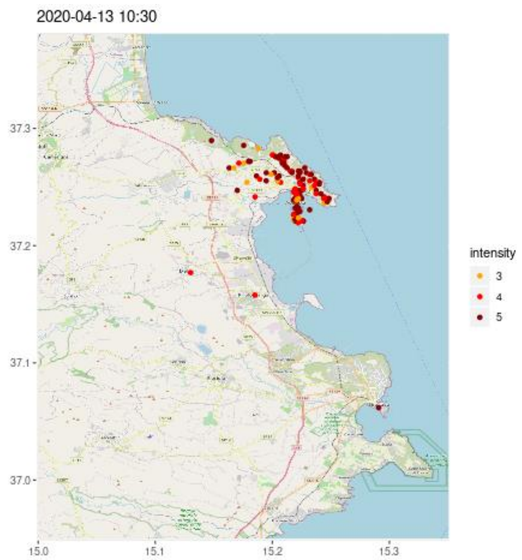

Figure 1. Example of the location of the citizens' notifications with their related 'intensity of nuisance' received in the interval 10:00-10:30 for the case study here considered.

In the first case, a 500-m-spacing grid is defined on the domain. Then alerts exceeding the (subjective) odour intensity threshold are counted within each grid cell at each time, in order to identify the cells that can be considered as sensible pseudo-receptors for the release of backward stochastic trajectories. In the second case a simple cluster analysis application based on spatial coordinates is applied at each time interval. A spatial scale of 500 m and a variable minimum number of alerts per cluster are used to choose the clustering level. The minimum alert number per cluster may vary from 3 to 10 depending on the maximum number of citizen notifications received at each time interval. The cluster centroids are identified as location of "pseudo-observations" and are used as "retro-emission" sources in a time-backward RetroSPRAY simulation.

In Figure 2 the two aggregation methods are compared, starting from the alerts shown in Figure 1. In the maps, only spatial locations of pseudo-receptors are shown. In both cases pseudo-observations are defined at some, not all, times within the event period here considered, from 08:00 to 11:00 on 2020-04-13. In the GRID case, only 5 gridboxes act as pseudo-receptors, defining a total of 14 pseudo-observations: their locations are the same at all times, so when a sufficient number of alerts falls within a gridbox an observation is defined and this may happen in the same gridbox at several times. On the contrary, the cluster centroids are recalculated at each time, then their locations differ at different times, even if they may happen to be close to each other. As a result, 12 pseudo-observations are defined within the time period, each at a different location.

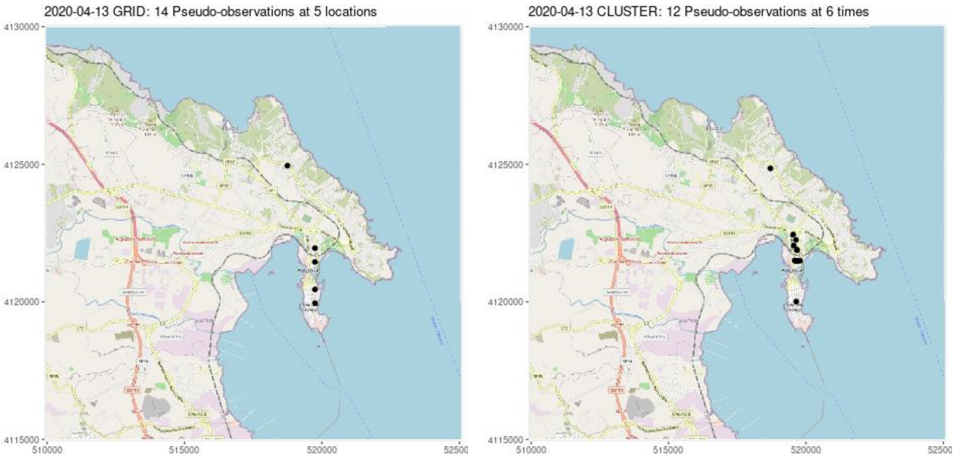

Figure 2. Aggregation of citizen alerts in pseudo-receptors, to be used as retro-sources in a RetroSPRAY backward simulation. Left: GRID aggregation; right: CLUSTER ANALYSIS aggregation. Only spatial locations are shown here: pseudo-observations (i. e. retro-emissions) are defined at some, not all, times in these locations, but, in both cases, they span the interval between 08:00 and 11:00 of 2020-04-13.

THE SIMULATIONS WITH SMART MODELLING SYSTEM

For the numerical simulations in the backward mode, to trace the potential origin of the odour nuisance, the SMART modelling system is applied. The 3D meteorological fields from MOLOCH atmospheric model, provided at 500 m horizontal grid space, are processed by the ARAMIS turbulence and boundary-layer parameterization code, preparing the proper input for the RetroSPRAY Lagrangian particle model.

The retro-emissions for RetroSPRAY are defined at the locations and at the time-intervals of the gridded or clustered notifications, which can be considered as 'pseudo-observations'. They are independent from each other and each of them generates a 'retro-concentration' field, as 'retro-puffs', moving backward, following the atmospheric flow upstream and dispersing according to the turbulence conditions. The RetroSPRAY simulations are performed by releasing, from the identified receptors, a series of retro-puffs at each time interval in which a significant number of signals are collected, here determined as a 30' time frequency. The retro-puff moving back from the location of a pseudo-observation indicates all possible positions of a source that, in a forward SPRAY integration, could determine that observation.

In the following an example of the simulated retro-puffs, originated by three of the emitting grid cells identified for the case study on 2020-04-13, is presented. Different pseudo-observations have been determined in the interval 0800-11:00 local time (LT). A total of 9 retro-puffs moving backward in time are thus traced. The numerical integration lasts for a reasonable time before the first pseudo-observations, here taken back to 06:00 LT. Thinking 'forward', this approach allows searching for a source area that could start emitting in the interval 06:00-06:30 LT. As examples, the pattern and location of the retro-puffs arriving at the three selected receptors at different notification-times during the period 08:00-11:00 LT, are plotted at different time frames, back in time: between 10:00-10:30 LT (Figure 3), 08:00-08:30 (Figure 4) and 06:00 and 06:30 (Figure 5).

The retro-concentration fields generated by the retro-puffs are then combined at all possible emission times, through a process that calculates their geometric average and their arithmetic average, in order to build final maps describing the region where possible sources can be potentially located. Further processing of this information enables associating a related probability density map, indicating the possible locations of the source in the different areas.

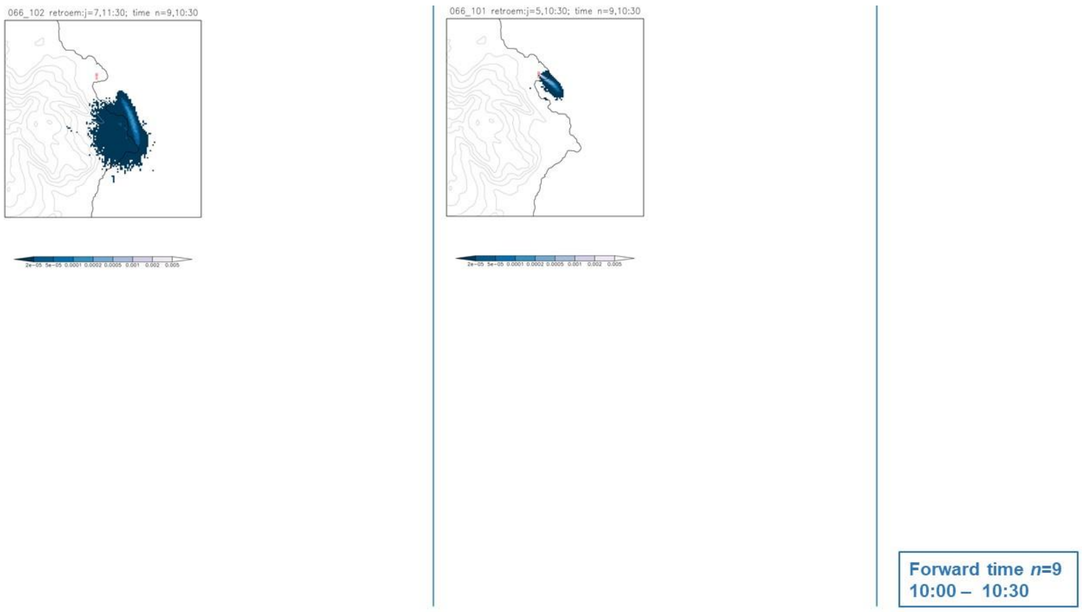

Figure 3. Pattern and location of the retro-puffs simulated by the SMART modelling system in backward mode, through the dispersion model RetroSPRAY, in the timeframe 10:00-10:30.

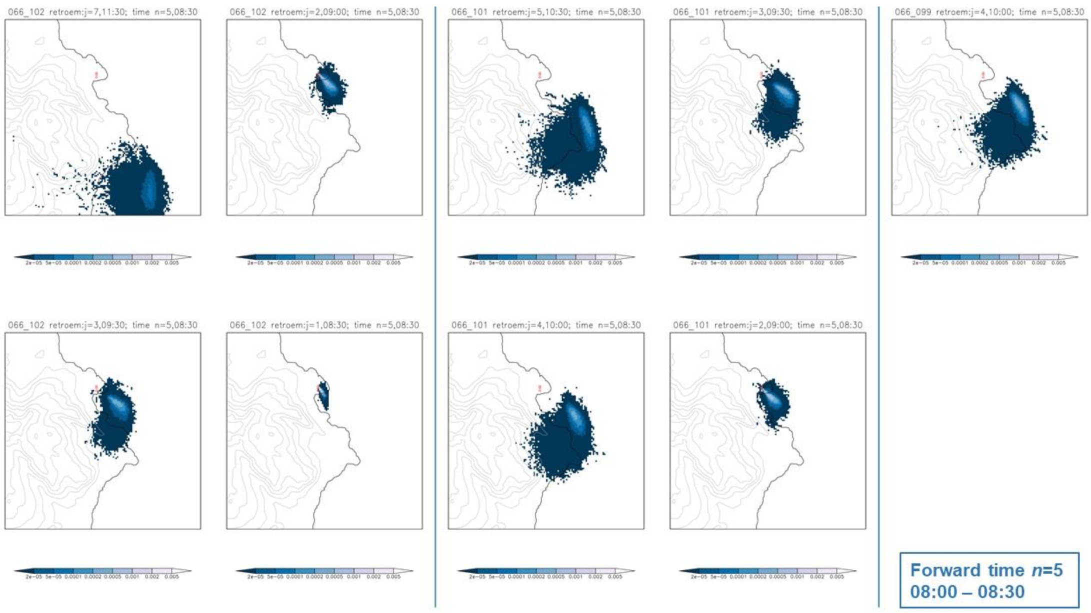

Figure 4. As in Figure 3 but for the timeframe 08:00-08:30

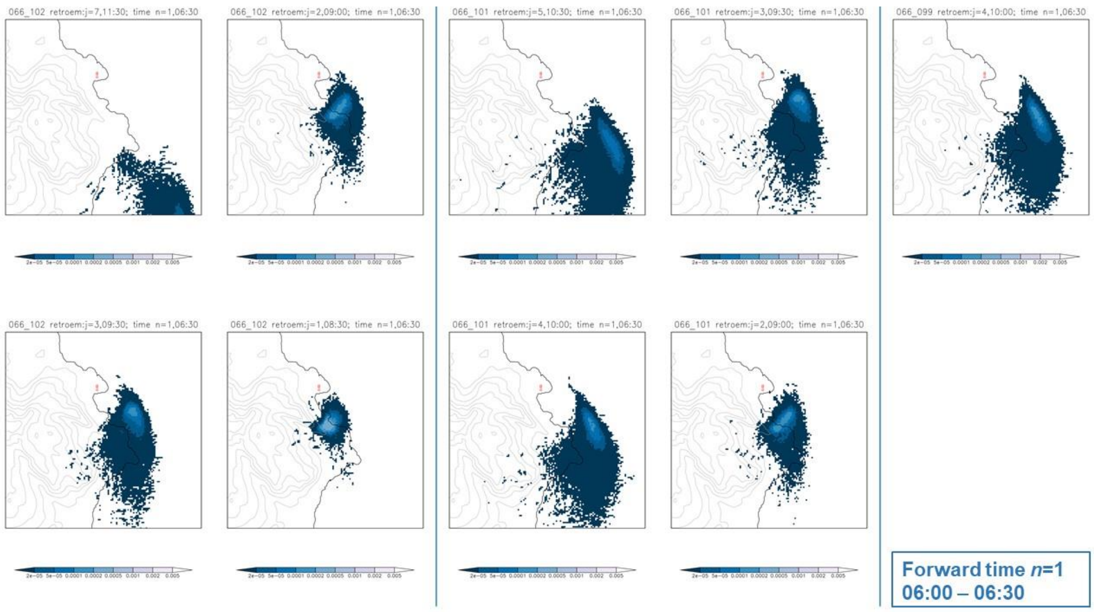

Figure 5. As in Figure 3 but for the timeframe 06:00-06:30

DISCUSSION AND CONCLUSIONS

The newly developed approach implemented to use, after appropriate processing, citizens' warnings from NOSE WEB-APP as input to RetroSPRAY model, demonstrates to be promising and applicable. The methodology has been applied to two rather different case studies, one with a high number of notifications, the other with a lower number of notifications but for which the source was then identified. In both cases, the simulations provided reliable results. In the first case, this has been confirmed by performing test simulations in forward mode, where potential releasing sources have been placed in different locations in the areas identified as more or less possible origin of odour nuisance, and also in the region outside them. It was seen that the sources placed in the 'most probable' areas were in fact affecting the receptor locations during the main hours of the recorded warnings. In the second case, the most problable area identified by the simulations and following output elaboration was in fact hosting the plant that produced the odour nuisance after an accidental release.

The new modules, elaborating the citizens' notifications and the final maps of probability density, are being integrated with the SMART modelling suite and the full package is presently going to be interfaced to NOSE alert system, with the aim of making available an operational system that can respond to a nuisance event in the timeframe of a few hours.

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