22nd International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
10-14 June 2024, Pärnu, Estonia

PROGNOSTIC VS MEASURED MET DATA FOR ODOR DISPERSION MODELLING: A DUAL-SITE CASE STUDY

Francesca Tagliaferri[1], Marzio Invernizzi[1], Anel Hernández-Garcés[2], Selena Sironi[1]

[1]Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano, Milano, Italy
[2]Faculty of Chemical Engineering, Universidad Tecnológica de La Habana José Antonio Echeverría, La Habana, Cuba

Abstract: Olfactory nuisance is a parameter that is increasingly growing in importance within environmental impact assessments. The technical problem of odor exposure assessment is not trivial. Despite this fact, the most widespread technique, at a regulatory level which is prescribed to be used for odor impact assessment, is atmospheric dispersion modelling. Although some criteria for the choice of model type are widely accepted, or at least prescribed, this is not the case for the choice of weather data source. In the present work, a simulation of a real-case odor emission source is considered, and different kinds of meteo datasets have been considered: WRF prognostic data, surface and upper air measured data, and a composition of both of them. The simulation of the wind field has been conducted with the CALMET diagnostic meteo preprocessor considering the mentioned different input data; the odor dispersion simulation has though been conducted with the Gaussian Lagrangian CALPUFF model. Two different geographic areas have been considered: one in a tropical american island and one in a central european site. Odor impact is itself a peak and not an average exposure phenomenon: the regulatory levels are currently expressed as yearly peaks or different levels of yearly percentiles. In the present study, the Italian regulatory guideline has been considered valid for both the geographical sites: so percentiles of 98th order have been considered as representative of odor impact. The outcome of the study is that, despite the choice of the kind of the meteo input dataset, the outcomes of the odor impact assessment arise largely comparable.

Key words: *odor dispersion modelling; meteorological data; WRF data; point source***.**

INTRODUCTION

Odor emissions from industrial facilities stand as a primary source of annoyance for communities residing in the vicinity. While odor annoyance does not directly impact health, it signifies a perceived risk, often resulting in complaints (Aatamila et al., 2011; Zarra et al., 2021).

A common approach to evaluate the odor impact of an industrial plant, widely endorsed in guidelines like those set by CEN (2022), typically follows a standard procedure: first, olfactometry monitoring is conducted at the emission points. Subsequently, dispersion models are employed to generate odor impact maps based on a specified Odor Impact Criteria, which considers a specific averaging time and exxedance percentile (Zarra et al., 2008).

The reliability of dispersion modelling is affected by multiple uncertainties. Firstly, uncertainties come from the model itself and its parameters, including internal settings and dispersion parameterizations (Tagliaferri et al., 2023, 2021). Additionally, various studies discuss the sensitivity of models to different factors like stack temperature and source diameter (Invernizzi et al., 2021). Another crucial uncertainty source is the meteorological data used in simulations (Sørensen, 1998). Meteorological variables like wind speed, direction, stability, temperature, and humidity significantly influence pollutant dispersion. Previous research highlights the impact of meteorological data choice on dispersion predictions for traditional pollutants, yet limited studies address this aspect for odor impact assessment (Finardi et al., 2004; Kumar and Russell, 1996).

Generally, meteorological data can be sourced from meteorological stations (surface + upper air) or prognostic numerical models. Prognostic data implementation is deemed necessary in locations lacking nearby meteorological stations (Mulukutla and Varghese, 2015).

In light of this, the present study compares odor dispersion modelling results by implementing three different meteorological data setups in the Lagrangian puff model CALPUFF: observational data (“OBS”), prognostic meteorological data (“NO-OBS”), and a blend of prognostic and measured data (“HYBRID”). The first approach entails the implementation of surface and upper air data measured from meteorological stations, while in the second case, only WRF 3D prognostic data are adopted. The hybrid simulations incorporate wind fields generated by diagnostic CALMET processor with a combination of prognostic and measured meteorological data.

CALPUFF is recognized by regulatory agencies for environmental impact assessments, permitting, and compliance purposes. Its ability to incorporate complex atmospheric interactions, as turbulence phenomena, local air currents, temperature inversions, makes it a valuable tool for researchers, environmental consultants, and regulatory authorities.

Odor exposure levels are simulated for a point source in a central european site and a tropical american island, characterized both by a flat orography but vastly different from a meteorological point of view, especially in terms of windiness. The simulation domains for both sites are identical, each measuring 6 km x 6 km with a grid resolution of 100 m.

The model outcomes are assessed in accordance to Italian regulations (MinAmbiente, 2023), which specify computing the 98th percentile of annual odor peak concentration values.

This research sheds light on the importance of meteorological data selection in accurately assessing odor impacts.

MATERIALS AND METHODS

Meteorological input data

The meteorological prognostic data adopted for “NO-OBS” and “HYBRID” simulations are three-dimensional hourly data processed by the WRF model with spatial resolutions of 1 km and 3 km, respectively, for the european and the american island domains for one year of simulation period.

The two investigated sites are very different in terms of meteorological conditions: the american island typically experiences a tropical climate characterized by high temperatures and humidity throughout the year, with distinct wet and dry seasons. In contrast, the central european site has a temperate climate with four distinct seasons, including hot summers and cold winters. Additionally, the european site tends to have more variable weather patterns influenced by its continental location, while the tropical island has more consistent temperatures and fewer extreme fluctuations.

For both sites, hourly surface meteorological observations including wind speed, wind direction, atmospheric pressure, air temperature, relative humidity, and cloud cover are recorded by a surface station situated 2 km away from the respective center of the domain, where the emission source is located.

For upper air data, the stations are located approximately 10 km away from the center of the domain in the european case, and more than 200 km away in the case of tropical island, due to the absence of closer suitable meteorological stations.

In this study, the approach outlined in the US-EPA protocol (US-EPA, 2000) is followed to address potential invalid or missing data acquired from measurement stations, by employing an interpolation procedure to substitute missing data.

Emission scenario

After defining the meteorological settings, it is necessary to characterize the emission scenario, identifying the physical, geometrical, and emissive parameters of the source implemented in the model. In particular, the investigated source is represented by an odor emissions abatement system with chemical absorption (scrubber unit), implemented in the model as a point source, positioned centrally within each simulation domain.

For point sources, stack height and diameter, emission temperature, and gas outlet velocity need to be defined. Additionally, in the case of odor dispersion modelling, it is necessary to define the OER (Odor

Emission Rate), which represents the amount of odor emitted per unit time. As for the temporal frequency of emission, it has been considered constant for all hours of the simulated year.

Table 1. Emission scenario for the investigated point source

Parameter		
Odor Emission Rate	2000	ou_E/s
Stack height	9	m
Stack diameter	1.2	m
Emission temperature	40	°C
Gas outlet velocity	5.4	m/s

RESULTS AND DISCUSSION

The Italian regulation in the field of odor (MinAmbiente, 2023) requires calculating the 98th percentile of odor peak concentration values annually. Although the lack of a universally accepted method for defining short-term peak concentration, a suggested constant factor of 2.3 is recommended. This criterion has been adopted in the present study for both simulation domains.

Figure 1. Odor impact maps for the european domain (left) and american island domain (right)

In the central european domain, the contour line corresponding to 5 ou_E/m^3 extends up to approximately 100 meters along the prevailing wind directions (E and W). For 3 ou_E/m^3, the lines stretch from 100 meters to 200 meters. Regarding the distance related to 1 ou_E/m^3, the maximum value reaches approximately 450 meters.
In the american domain, the contour lines for 5 ou_E/m^3, 3 ou_E/m^3, and 1 ou_E/m^3 reach approximately 150 meters, 350 meters, and 600 meters, respectively, along the prevailing wind direction (SW).
The most noteworthy finding from this investigation is that in both domains, the "NO-OBS," "OBS," and "HYBRID" simulations yield largely comparable results in terms of odor impact.

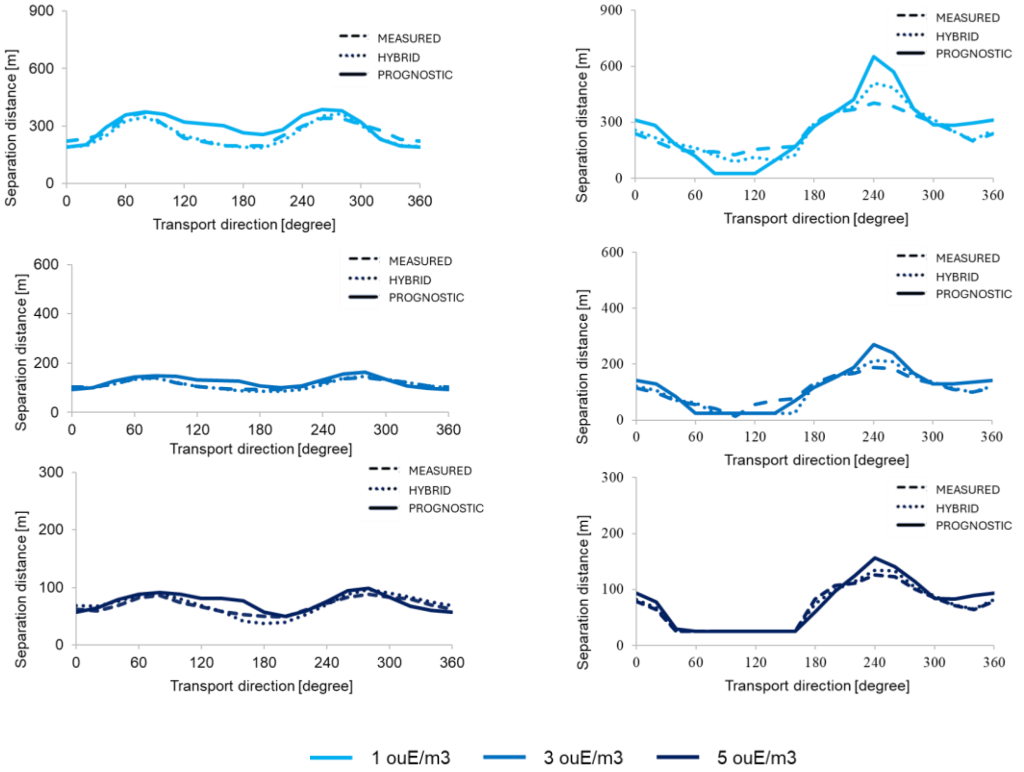

Figure 2. Separation distances for the european domain (left) and american island domain (right)

Figure 2 highlights that, for both the european and american sites, the separation distances obtained under various meteorological conditions show considerable similarity. Specifically, the lines representing different odor concentrations overlap significantly, especially in the southwest direction for the american domain.
For the central european site, separation distances peak at around 100 meters for 5 ou_E/m^3, while for the american site, the maximum separation distance is approximately 150 meters. These distances increase with lower odor concentration thresholds, with values ranging from 100 to 200 meters for 3 ou_E/m^3 in european site and up to 300 meters for american. The greatest separation distances, up to 400 meters for european site and 600 meters for the tropical island, are observed for 1 ou_E/m^3.
Overall, despite variations in meteorological input, the impact of the point source, in both locations, remains consistent, as demonstrated by the largely comparable impact maps and separation distances.
The limited influence associated to various meteorological inputs could be attributed to the buoyancy flux of the plume emitted by the investigated source.The emission temperature of the simulated source (i.e. 40 °C) is generally higher than that of the environment, and such temperature differences may have a significant influence on the spatial distribution of emitted substances, notably affecting their ground concentrations. In other words, it is possible that plume rise predominantly governs the dispersion and dilution of pollutants, leading to a reduced impact of local meteorological conditions.

CONCLUSIONS

This study underscores the critical role of meteorological data selection in accurately assessing odor impacts from industrial facilities. Odor exposure levels are simulated for a point source in two different regions, each characterized by a flat orography but very different meteorological conditions, particularly in terms of windinesss.

Despite variations in meteorological inputs, the simulations using different input meteorological approaches ("NO-OBS," "OBS," and "HYBRID") yield largely comparable results in terms of odor impact in both european and american domains. The consistent impact observed across different meteorological conditions suggests that the buoyancy flux of the emitted plume may play a dominant role in dispersion and dilution, mitigating the influence of local meteorological conditions. These findings emphasize the need for robust methodologies in odor impact assessments to effectively address community concerns and regulatory compliance.

Moving forward, future developments of this study could explore the consideration of different source types, such as those lacking buoyancy flux, or with more complex orographic conditions compared to those observed at the investigated sites.

REFERENCES

Aatamila, M., Verkasalo, P.K., Korhonen, M.J., Suominen, A.L., Hirvonen, M.R., Viluksela, M.K., Nevalainen, A., 2011. Odour annoyance and physical symptoms among residents living near waste treatment centres. Environ. Res. 111, 164–170. https://doi.org/10.1016/j.envres.2010.11.008

CEN, 2022. Stationary source emissions - Determination of odour concentration by dynamic olfactometry and odour.

Finardi, S., Tinarelli, G., Nanni, A., Anfossi, D., Ferrero, E., Trini Castelli, S., 2004. No TitleIn Situ Diagnostic or Nested Prognostic Mereorological Models to Drive Dispersion Simulations in Complex Area: A Comparison in a Real Application, in: Air Pollution Modeling and Its Application XIV. Springer, Boston.

Invernizzi, M., Tagliaferri, F., Sironi, S., Tinarelli, G., Capelli, L., 2021. Simulating Pollutant Dispersion from Accidental Fires with a Focus on Source Characterization. J. Heal. Pollut. 11. https://doi.org/10.5696/2156-9614-11.30.210612

Kumar, N., Russell, A.G., 1996. Comparing prognostic and diagnostic meteorological fields and their impacts on photochemical air quality modeling. Atmos. Environ. 30, 1989–2010. https://doi.org/10.1016/1352-2310(95)00179-4

MinAmbiente, 2023. Decreto Direttoriale 28 giugno 2023, n. 309.

Mulukutla, A.N.V., Varghese, G.K., 2015. Comparison of field monitored and prognostic model generated meteorological parameters for source dispersion modeling. Model. Earth Syst. Environ. 1, 1–12. https://doi.org/10.1007/s40808-015-0051-0

Sørensen, J.H., 1998. Sensitivity of the derma long-range gaussian dispersion model to meteorological input and diffusion parameters. Atmos. Environ. 32, 4195–4206. https://doi.org/10.1016/S1352-2310(98)00178-2

Tagliaferri, F., Invernizzi, M., Capra, F., Sironi, S., 2023. Validation study of WindTrax reverse dispersion model coupled with a sensitivity analysis of model-specific settings. Environ. Res. 222, 115401. https://doi.org/10.1016/j.envres.2023.115401

Tagliaferri, F., Invernizzi, M., Sironi, S., Capelli, L., 2021. Influence of Model Parameters When Simulating Landfill Odour Emission 85, 169–174. https://doi.org/10.3303/CET2185029

US-EPA, 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. Epa-454/R-99-005 171.

Zarra, T., Belgiorno, V., Naddeo, V., 2021. Environmental odour nuisance assessment in urbanized area: Analysis and comparison of different and integrated approaches. Atmosphere (Basel). 12. https://doi.org/10.3390/atmos12060690

Zarra, T., Naddeo, V., Belgiorno, V., Reiser, M., Kranert, M., 2008. Odour monitoring of small wastewater treatment plant located in sensitive environment. Water Sci. Technol. 58, 89–94. https://doi.org/10.2166/wst.2008.330