Peer review status:

This is a non-peer-reviewed preprint submitted to EarthArXiv.

Bridging ERA5 Reanalysis Data and Regulatory Air Dispersion Modelling: A Transparent Workflow Implemented through the WindRose Toolkit

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Preprint version – DOI: https://doi.org/10.5281/zenodo.18899906.

Abstract

Regulatory atmospheric dispersion models such as AERMOD and CALPUFF are widely adopted for Environmental Impact Assessments involving atmospheric emissions. Despite their scientific maturity and regulatory acceptance, the practical application of these modelling systems outside the North American context is often constrained by the limited availability of suitable meteorological datasets. In many regions, the absence of long-term, spatially representative atmospheric observations represents a significant barrier to the routine implementation of regulatory dispersion modelling workflows.

At the same time, global atmospheric reanalysis datasets such as ERA5 (Hersbach et al., 2020), produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), provide an increasingly reliable and globally accessible source of meteorological information. However, the integration of ERA5 datasets into regulatory dispersion modelling remains technically challenging due to differences between the gridded structure of reanalysis data and the specific input formats required by meteorological preprocessors used in regulatory modelling systems.

This work presents a transparent workflow designed to bridge ERA5 atmospheric reanalysis datasets and regulatory dispersion modelling frameworks. The proposed methodology focuses on the transformation of ERA5 meteorological data into structured time series compatible with regulatory preprocessing systems such as AERMET and CALMET.

The workflow is implemented through a lightweight software toolkit, implemented in the WindRose Studio software environment, which enables the ingestion, inspection and transformation of ERA5 GRIB datasets into meteorological time series suitable for dispersion modelling applications. The proposed approach is illustrated through a real-world application example involving the mechanical-biological treatment facility located in Battipaglia (Southern Italy), demonstrating the full sequence from ERA5 dataset request planning to exploratory statistical characterization of reconstructed wind regimes.

The results highlight the potential of ERA5 reanalysis data as a robust and globally accessible meteorological data source for regulatory dispersion modelling, particularly in regions where observational datasets are sparse or incomplete. By providing a transparent and reproducible pathway from ERA5 datasets to regulatory-ready meteorological inputs, the methodology presented in this work contributes to bridging the gap between modern atmospheric reanalysis products and established regulatory air-quality modelling frameworks.

1. Regulatory air-dispersion modelling and the role of meteorological data

In environmental impact assessment studies addressing the atmospheric environmental component and the associated implications for public health and social well-being, predictive modelling of pollutant dispersion has become an essential analytical tool. Over the last three decades, regulatory practice across much of the world has converged toward the use of numerical atmospheric dispersion models developed and maintained by the United States Environmental Protection Agency (U.S. EPA). These modelling systems-most notably the AERMOD modelling system and the CALPUFF modelling suite-have progressively become the de facto international standard for regulatory air-quality assessments.

The widespread adoption of these modelling systems is primarily the result of their extensive validation history, their transparent formulation, and the continuous scientific development coordinated by the U.S. EPA and associated research institutions. Since the official designation of AERMOD as the preferred regulatory dispersion model in 2005, replacing the earlier ISCST3 model, the modelling system has been widely adopted for regulatory applications worldwide due to its improved representation of atmospheric turbulence, boundary-layer structure, and plume dispersion processes under both simple and complex terrain conditions. (EPA, 2026)

Despite the global diffusion of these modelling systems, an important structural limitation emerges when they are applied outside the North American context in which they were originally developed. In the United States, regulatory dispersion modelling benefits from a long-standing infrastructure of publicly available meteorological and geophysical databases maintained by federal agencies, which provide high-quality inputs for the meteorological preprocessors used by these models. These include surface observations, upper-air soundings, and ancillary datasets describing land use, terrain, and atmospheric boundary-layer characteristics. Such datasets enable automated or semi-automated preparation of meteorological inputs through preprocessors such as AERMET and CALMET (EPA, 2024; Earth Tech, 2000).

In many other regions of the world, however, the availability of comparable meteorological datasets is considerably more limited. The lack of complete and spatially representative atmospheric observations frequently represents the primary practical constraint to the application of advanced dispersion models. As highlighted in several studies, the implementation of high-resolution regulatory dispersion models is often hindered by the absence of sufficiently complete meteorological datasets or by the incompatibility of available data with the input formats required by the modelling systems (Turtos et al., 2010).

This structural asymmetry between the modelling tools and the availability of suitable meteorological data represents one of the most persistent challenges in the practical implementation of regulatory air-quality modelling outside the North American regulatory framework.

2. The meteorological data gap in international applications of EPA models

The importance of meteorological input data in dispersion modelling cannot be overstated. Among the various sources of uncertainty affecting air-dispersion simulations such as emission estimation, model parameterization, and terrain representation, the characterization of atmospheric conditions is often the most influential factor controlling model performance and the resulting concentration fields.

Ideally, meteorological data used in dispersion modelling should originate from on-site measurements or from observational stations located within a short distance from the modelling domain. In practice, however, such datasets are frequently unavailable, incomplete, or lacking the full set of atmospheric parameters required by the modelling preprocessors. In many regions, observational stations do not record all variables required to derive boundary-layer parameters, while in other cases the spatial distribution of stations is too sparse to ensure representativeness for the modelling domain.

The consequences of this limitation have been widely documented in the literature. The above cited Authors (Turtos et al., 2010), for instance, presented a methodological framework for implementing the AERMOD modelling system in contexts characterized by incomplete local meteorological information. Their work illustrates how the absence of specific atmospheric parameters-such as turbulence indicators or land-surface characteristics-can significantly complicate the preparation of input datasets required by the meteorological preprocessors.

More recent studies confirm that the uncertainty associated with meteorological data selection remains one of the most critical factors affecting the reliability of dispersion modelling outcomes. Cowan and Barnett (2024) show that dispersion modelling results can vary significantly depending on whether meteorological inputs are derived from direct observations, prognostic meteorological models, or hybrid approaches combining observational and simulated data.

Regulatory authorities in several jurisdictions (MISE – DD n. 309 of 28 June 2023) have explicitly acknowledged this structural limitation. In situations where representative surface observations are unavailable, many regulatory frameworks allow the use of prognostic or diagnostic meteorological modelling systems to generate surrogate datasets for dispersion modelling applications. Such approaches typically involve mesoscale meteorological models-most notably the Weather Research and Forecasting -WRF (MMM-NCAR, 2026) model-which can simulate atmospheric conditions over the modelling domain and provide input data suitable for dispersion models through dedicated preprocessors.

However, as discussed in the already cited article by Cowan and Barnett (2024), the use of mesoscale meteorological models introduces additional layers of complexity in the preparation of meteorological datasets for dispersion modelling applications. Models such as the Weather Research and Forecasting (WRF) system require substantial computational resources, complex configuration procedures, and specialized expertise in atmospheric modelling. In addition, their results may inherit uncertainties associated with model parameterization schemes, spatial resolution choices, and the specification of boundary conditions.

An important aspect highlighted in the same study is that mesoscale simulations frequently rely on global reanalysis datasets as initial and boundary conditions: *"the WRF model was run using ERA5 data obtained from the European Centre for Medium Range Weather Forecasting (ECMWF) using mostly standard settings…"*. This illustrates how high-resolution meteorological fields generated by mesoscale models are often derived from, and constrained by, the underlying large-scale atmospheric datasets.

While mesoscale modelling can provide valuable dynamical downscaling of atmospheric fields, the resulting datasets remain inherently dependent on the quality and structure of the original large-scale inputs. In this context, the direct use of high-quality reanalysis datasets such as ERA5 may represent a transparent and computationally efficient alternative for many regulatory dispersion modelling applications.

Consequently, the practical challenge for air-quality practitioners is not merely the selection of an appropriate dispersion model, but rather the identification of reliable and accessible sources of meteorological data capable of feeding the preprocessing chain required by these models.

3. Global reanalysis datasets as a bridging solution

Within the described context, global atmospheric reanalysis datasets have progressively emerged as one of the most promising solutions for addressing the meteorological data gap in dispersion modelling applications. Among these datasets, the ERA5 global reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) represents one of the most comprehensive and widely used sources of atmospheric data currently available (CDS (a), 2026).

ERA5 provides hourly atmospheric estimates covering the entire globe from 1940 to the present, with a spatial resolution of approximately 0.25° × 0.25°. These datasets are generated through advanced data-assimilation systems that integrate observations from satellites, ground stations, aircraft, and radiosondes with numerical weather prediction models, producing a consistent reconstruction of the global atmospheric state. As a result, ERA5 has become an essential data source for a wide range of scientific and operational applications, including climatology, hydrology, renewable energy assessment, and atmospheric modelling.

The scientific literature increasingly recognizes ERA5 as one of the most reliable global reanalysis products currently available. Comparative studies evaluating ERA5 against other meteorological datasets and in-situ observations show that it provides robust representations of large-scale atmospheric patterns and long-term climate variability, making it particularly suitable for environmental and atmospheric modelling applications. (Mutlu, 2025).

At the same time, ERA5 also constitutes the foundational dataset used to initialize or constrain many mesoscale meteorological models. Numerous modelling studies employing the WRF model rely on ERA5 data as boundary and initial conditions for numerical simulations, demonstrating the central role of this dataset within the broader meteorological modelling ecosystem. (Bayraktar and Mutlu, 2024).

In addition, ERA5 data are widely employed as the large-scale atmospheric input for downscaling frameworks combining mesoscale meteorological models and diagnostic dispersion models such as CALMET. These approaches allow the generation of high-resolution wind fields and atmospheric variables required by dispersion modelling systems, particularly in complex terrain or data-sparse regions. (Wang et al., 2024).

Nevertheless, despite its advantages in terms of global coverage, temporal continuity, and scientific credibility, the direct use of ERA5 datasets within regulatory dispersion modelling workflows is not straightforward. The datasets are distributed in specialized scientific formats, typically NetCDF or GRIB, which require dedicated processing tools and technical expertise for extraction and conversion into formats compatible with regulatory modelling systems. This technical barrier has been recognized in several recent studies focusing on improving accessibility to ERA5 datasets through lightweight software tools designed to simplify data extraction, processing, and visualization. (Jevremović et al. 2025).

The described situation highlights the existence of a conceptual and operational gap between the availability of high-quality global meteorological datasets and their practical integration into regulatory air-dispersion modelling workflows. Bridging this gap requires not only the identification of suitable atmospheric data sources, but also the development of transparent and reproducible workflows capable of transforming reanalysis datasets into meteorological inputs compatible with regulatory dispersion modelling systems.

4. Bridging ERA5 reanalysis data and regulatory dispersion modelling

As outlined in the previous sections, although global atmospheric reanalysis datasets such as ERA5 provide a scientifically robust and readily accessible source of meteorological information, their practical integration into regulatory air-quality modelling workflows is far from straightforward. The regulatory modelling systems most widely used in environmental impact assessments, namely the AERMOD and CALPUFF modelling suites, were originally developed within a data infrastructure primarily based on meteorological observation networks available in North America. Consequently, the meteorological preprocessors associated with these models, such as AERMET and CALMET, expect input data in formats and structures consistent with observational surface and upper-air datasets.

Surface meteorological inputs must typically be supplied in standardized formats such as the SAMSON (Solar and Meteorological Surface Observation Network) format, which was originally developed to facilitate the processing of long-term meteorological observations within regulatory modelling environments. The SAMSON data structure (Lakes Environmental – Web Met; 2026), described in the AERMET and AERMOD technical documentation, provides a structured representation of hourly surface meteorological observations including wind speed, wind direction, temperature, atmospheric pressure, cloud cover, and other variables necessary for the reconstruction of atmospheric boundary-layer parameters.

While such formats are well suited to the ingestion of observational meteorological records, they are not directly compatible with modern atmospheric reanalysis datasets, which are generally distributed in scientific data formats such as GRIB or NetCDF. These formats contain multidimensional geophysical variables organized on spatial grids and pressure levels and require specialized software libraries and technical expertise for their interpretation and processing.

Consequently, the use of ERA5 data in regulatory dispersion modelling requires a transformation process that converts gridded reanalysis datasets into time series of meteorological variables compatible with the input requirements of dispersion model preprocessors. This transformation involves several intermediate steps, including spatial selection of representative grid cells, extraction of relevant meteorological variables, temporal reconstruction of hourly surface parameters, and formatting of the resulting datasets according to the requirements of regulatory modelling systems.

This transformation chain illustrates the practical gap between the availability of high-quality atmospheric datasets and their effective use in regulatory dispersion modelling workflows. In practice, the challenge is not limited to data availability, but rather concerns the methodological process required to translate complex meteorological datasets into regulatory-ready meteorological inputs.

Within this evolving methodological landscape, the development of reproducible workflows capable of translating ERA5 datasets into meteorological inputs compatible with regulatory dispersion models represents an important step toward improving the accessibility of high-quality atmospheric data for environmental modelling applications.

5. The WindRose toolkit and workflow

To address the above-described limitation, the WindRose toolkit was developed as a lightweight software environment designed to facilitate the transformation of ERA5 reanalysis datasets into meteorological time series compatible with regulatory dispersion modelling systems. Rather than proposing a new meteorological model, the toolkit implements a structured workflow that bridges the gap between modern atmospheric reanalysis products and the input requirements of regulatory dispersion models.

Even for practitioners with a solid background in atmospheric dispersion modelling, a certain degree of uncertainty may initially arise when approaching the wide range of options available in the Copernicus ERA5 control panel (CDS (b), 2026), which governs the parameters and the spatial-temporal domain of the dataset to be downloaded.

To guide users toward a reliable and consistent configuration of the ERA5 data request corresponding to the study they intend to perform, WindRose Studio implements a dedicated wizard designed to assist the user in defining the parameters to be requested from the Copernicus ERA5 portal. These include: i) the geographical references; ii) the extraction subregion; iii) the temporal coverage of the request; and iv) the set of meteorological variables most appropriate for the intended analysis.

With specific regard to the definition of the study subregion, the wizard also considers a recent upgrade of the internal ECMWF extraction software, effective from 25 February 2026 (ECMWF, 2026). According to this update, to preserve the integrity of the original values of the meteorological variables, no interpolation is performed during the extraction process. Instead, the operation consists of a simple cropping of the native Copernicus ERA5 grid.

Figure 1 (adapted from the cited source) illustrates the extraction principle currently adopted by the ECMWF software for the selection of georeferenced variables distributed on the standard regular grid. The intersection between the extraction domain and the original grid identifies the grid points represented in black, while the points shown in orange correspond exclusively to those that fall within the requested extraction subregion (orange rectangle).

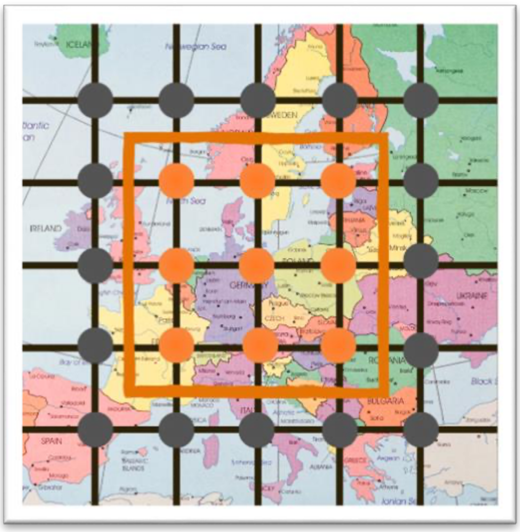

Figure 1. Cropping of grid points extracted by the ECMWF software with respect to the user-defined subarea (orange rectangle). Schematic redrawn representation.

Figure 2 below illustrates the roadmap underlying the preliminary workflow referred to as the Wizard implemented in WindRose Studio.

Figure 2. ERA5 data request workflow implemented in WindRose Studio. The Wizard guides the definition of location, extraction subarea aligned with the ERA5 grid, and required meteorological variables, generating a structured request for the Copernicus Climate Data Store (CDS). Source: own elaboration.

For regulatory purposes, the user is guided to download and subsequently provide to WindRose Studio a set of variables including wind components, surface pressure, temperature, and other relevant meteorological parameters. The GRIB data analysis itself begins with the ingestion of ERA5 atmospheric datasets in GRIB format provided by the user and proceeds through the five steps outlined in the roadmap illustrated in Figure 3.

Figure 3. Roadmap of the meteorological preprocessing workflow implemented in WindRose Studio using a user-provided GRIB file. The process includes GRIB message analysis and metadata extraction, reconstruction of the spatial domain, selection of the processing policy (area-averaged projection or point-based), reconstruction of continuous time series, derivation of hourly meteorological variables, and generation of statistical outputs for predictive and regulatory analyses. Source: own elaboration.

Using specialized open-source decoding libraries such as ecCodes (ECMWF (b), 2026), released under the Apache License, these multidimensional datasets can be accessed and interpreted within a computational environment capable of reconstructing time series of meteorological variables for a selected geographical location.

The processing of ERA5 datasets relies on the ecCodes software library, which provides tools for decoding and encoding GRIB and BUFR meteorological messages. The ecCodes ecosystem has historically been developed for Unix-like environments and is therefore natively supported on Linux and macOS platforms.

Although alternative installation procedures exist for other operating systems, the workflow adopted in WindRose Studio follows the native software environment recommended by ECMWF, ensuring full compatibility with the GRIB data structure and with the broader scientific software stack commonly used in atmospheric modelling.

Once the relevant grid cell corresponding to the modelling domain has been identified, the toolkit extracts the atmospheric variables required for the reconstruction of hourly surface meteorological parameters. Attention is given to the extraction of near-surface wind components, which are provided in ERA5 as orthogonal vector components. These components are subsequently transformed into wind speed and wind direction values, allowing the reconstruction of time series suitable for further analysis.

Following the extraction of meteorological variables, the workflow proceeds to the reconstruction of hourly meteorological tables representing the atmospheric conditions at the selected location. These time series can then be exported into standardized formats compatible with regulatory meteorological preprocessors, in particular, the SAMSON format which, as discussed above, is a sound practice for supplying surface data for both the main met preprocessors such as CALMET and AERMET.

In addition to facilitating the conversion of meteorological datasets, the toolkit incorporates visualization and statistical analysis tools that allow the user to evaluate the temporal distribution of atmospheric parameters, including wind speed distributions and directional wind statistics. Such analyses are particularly relevant for the preliminary evaluation of meteorological datasets prior to their use in regulatory modelling applications.

The objective of this methodological framework is not to replace existing meteorological modelling systems, but rather to provide a transparent and reproducible workflow that enables professionals and researchers to integrate globally available reanalysis datasets into established regulatory modelling frameworks. By lowering the technical barriers associated with the processing of ERA5 datasets, such workflows contribute to expanding the practical accessibility of high-quality meteorological data for Environmental Impact Assessments and air-quality modelling studies.

6. Application Example: ERA5 preprocessing for the Battipaglia TMB case study

To illustrate the practical implementation of the proposed workflow, the WindRose toolkit was applied to a real-world environmental assessment scenario involving the mechanical-biological treatment facility (EcoAmbiente Salerno S.p.A.) located in Battipaglia, Southern Italy (Lat: 40.59709; Lon: 15.01748). The site represents a typical regulatory context in which atmospheric dispersion modelling is required in support of environmental permitting procedures.

Even when nearby international meteorological stations exist, as in the case study presented here, where the Italian Air Force meteorological station at Salerno-Pontecagnano Costa d'Amalfi Airport (WMO Code: 16292; ICAO Code: LIRI) is located only a few miles from the facility, practical constraints must still be considered. These include the natural limitations in data availability associated with possible periods of station inactivity, as well as the administrative procedures of the military authority which, for understandable reasons related to the lack of dedicated personnel, cannot always provide the requested datasets within the timeframes required by regulatory procedures, even when the request is made for institutional academic research purposes.

Such practical limitations are consistent with the broader structural data gap already acknowledged in regulatory frameworks governing dispersion modelling applications. As discussed previously, current regulations explicitly allow the use of meteorological inputs derived from prognostic or diagnostic modelling systems when representative surface observations are unavailable.

From this perspective, if one intends to avoid purchasing commercial meteorological datasets derived from predictive modelling systems such as WRF, direct access to the Copernicus ERA5 data source may represent a scientifically sound and attractive alternative.

6.1 ERA5 dataset request planning

The first step of the workflow consists in defining the ERA5 dataset request required to retrieve the meteorological variables relevant for dispersion modelling applications. The WindRose interface assists the user in defining the geographical domain, temporal coverage and meteorological variables required for the dataset retrieval from the Copernicus Climate Data Store.

Figure 4 illustrates the ERA5 request planning interface used to prepare the dataset retrieval.

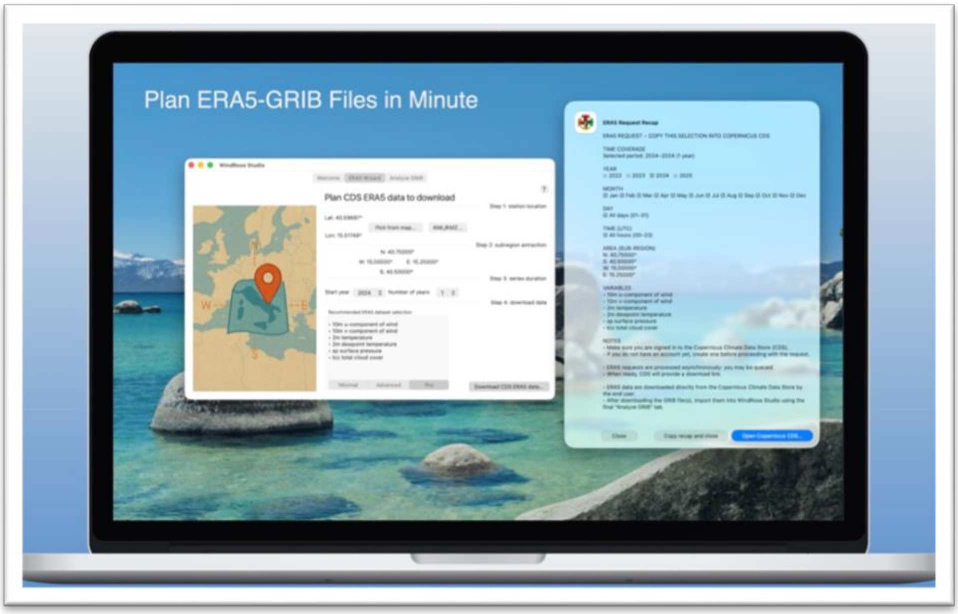

Figure 4. ERA5 request wizard for the TMB Battipaglia case study implemented in WindRose Studio. Source: own elaboration.

The ERA5 dataset used in this example covers a one-year period (i.e.: 2024) and includes the meteorological variables necessary for the reconstruction of hourly surface meteorological conditions, including wind components, temperature, surface pressure and cloud cover.

6.2 GRIB ingestion and dataset validation

Once the ERA5 dataset has been downloaded from the Copernicus Climate Data Store, the GRIB file can be imported into the WindRose environment for inspection and preprocessing.

ERA5 data are distributed as collections of meteorological messages encoded in the GRIB format. Each message corresponds to a specific variable, time step and grid location. Before proceeding with the reconstruction of meteorological time series, it is therefore essential to verify the integrity and completeness of the dataset.

The WindRose toolkit parses the GRIB file and exposes the internal structure of the meteorological messages, allowing the user to inspect the available variables and confirm the temporal continuity of the dataset.

Figure 5 shows the metadata inspection interface used for GRIB validation.

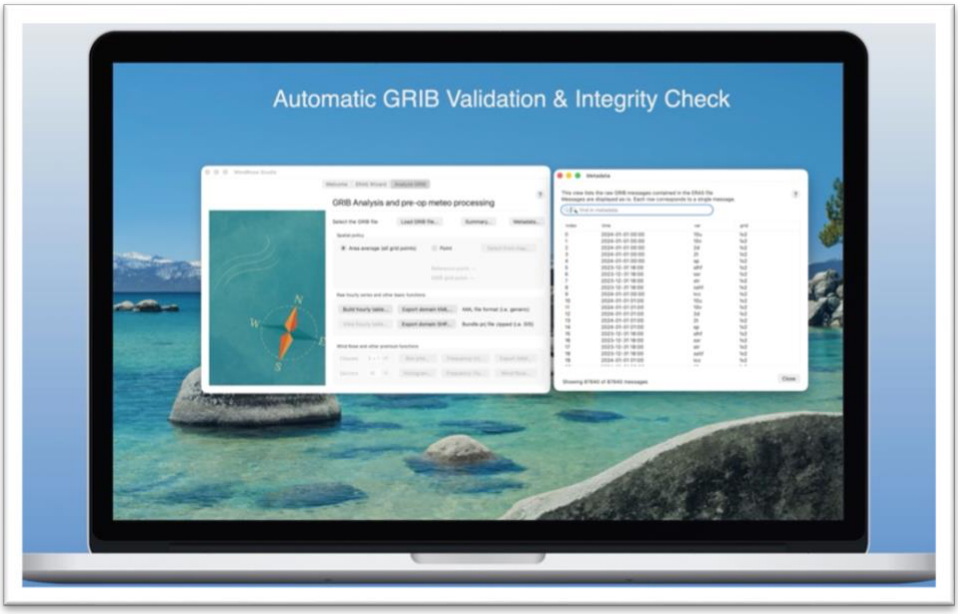

Figure 5. GRIB metadata inspection for the ERA5 dataset (2024) covering the grid cells including the TMB facility in Battipaglia (EcoAmbiente Salerno S.p.A.). Source: own elaboration.6.3 Definition of the modelling reference point

After verifying the integrity of the dataset, the geographical reference point corresponding to the study site must be defined.

For the Battipaglia TMB, the modelling reference point corresponds to the location of the mechanical-biological treatment facility. The selected point defines the geographical reference for the analysis, while the meteorological variables are retrieved from the nearest ERA5 grid node of the underlying reanalysis grid.

This step is important because, as discussed above, ERA5 data are provided on a regular spatial grid, and the representativeness of the selected grid cell must be evaluated with respect to the modelling domain.

Figure 6 illustrates the interface used to define the modelling reference point.

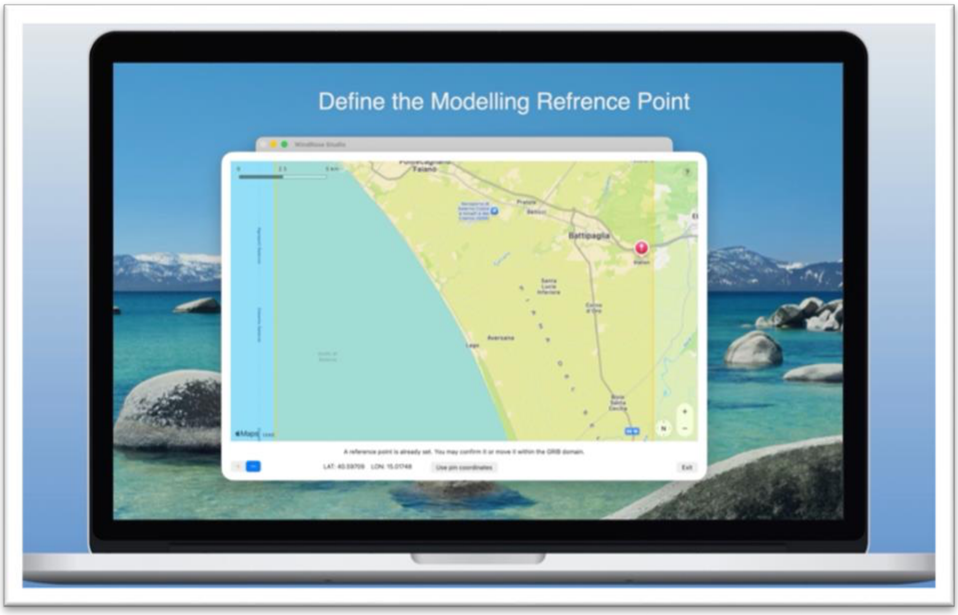

Figure 6. Modelling reference point (red pin labelled "Station", corresponding to the Battipaglia TMB) and the surrounding ERA5 grid cell coverage (yellow domain) reconstructed from the user-provided GRIB file. Source: own elaboration.

Note that, once the spatial policy (i.e., the method used to project the grid data contained in the GRIB file) has been set and confirmed, the user can export the spatial domain either as a KML file (for example, to visualize it in Google Earth) or as an ESRI Shapefile bundle including PRJ, SHX, SHP, and DBF files, allowing the domain to be imported into a Geographic Information System such as QGIS.

6.4 Reconstruction and exploratory analysis of wind statistics

Once the reference location has been defined, the toolkit reconstructs the hourly wind time series by converting the orthogonal ERA5 wind components into wind speed and wind direction values.

The resulting dataset can then be analysed using a set of exploratory statistical diagnostics designed to evaluate the wind regime at the study site.

These analyses include the computation of wind speed distributions, box-plot statistics, and wind class frequency distributions (n and %) in tabular form, all exportable in commonly used file formats. Tables are typically available in TSV and CSV formats, while graphical outputs can be exported as PDF or PNG files.

Such diagnostics provide a preliminary assessment of the wind regime and help identify potential anomalies or inconsistencies in the dataset prior to its use in dispersion modelling applications.

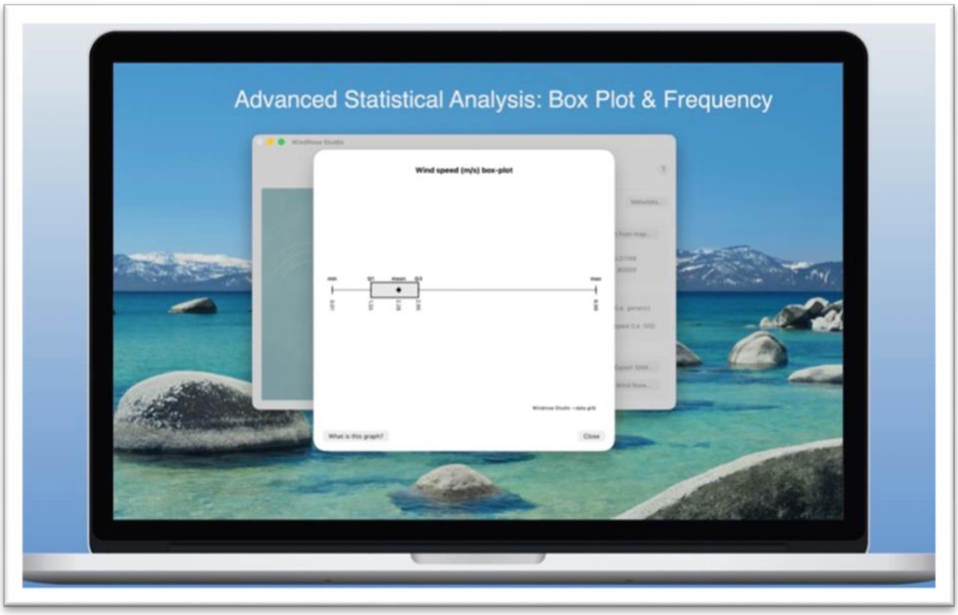

Figure 7. Wind speed box plot for the 2024 wind series derived from the ERA5 dataset and processed by WindRose Studio using the user-provided GRIB file. Source: own elaboration.

Figure 7 shows the classical box-plot representation of wind speed values derived from the ERA5 hourly dataset, including the minimum, maximum, first quartile (Q1), mean, and third quartile (Q3) of the analysed series. Figure 8 illustrates the corresponding wind class frequency distribution.

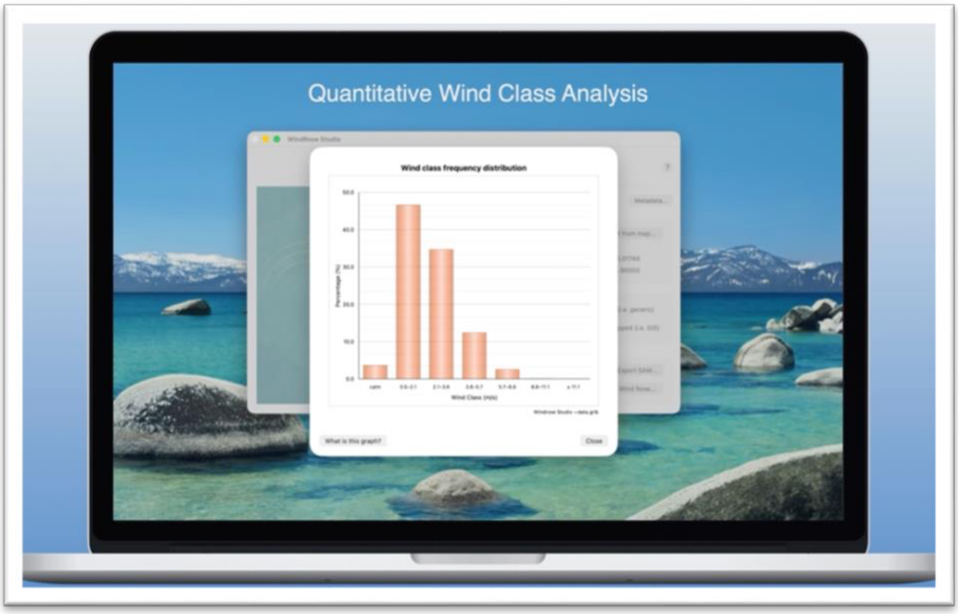

Figure 8. Wind class frequency distribution for the 2024 wind series at the Battipaglia TMB derived from the ERA5 dataset and processed by WindRose Studio using the user-provided GRIB file. Source: own elaboration.

6.5 Wind rose analysis

As a final step, the toolkit generates a wind rose diagram summarizing the directional distribution of wind regimes at the study site.

Wind roses represent one of the most widely used tools in atmospheric dispersion modelling, as they provide a compact visual representation of wind direction frequency and associated wind speed classes.

The wind rose derived from the ERA5 dataset for the Battipaglia case study is shown in the next Figure 9.

Figure 9. Wind rose for the 2024 wind series at the Battipaglia TMB derived from the ERA5 dataset and processed by WindRose Studio using the user-provided GRIB file. Source: own elaboration.

The diagram highlights the dominant wind directions (north-east and south-west) that characterize the entire Sele Plain and offers a first-order representation of the atmospheric transport conditions affecting the study area.

6.6. Samson export and further processing with AERMET

As illustrated above, the primary objective of WindRose Studio is to provide a replicable operational workflow and an accessible technical tool enabling users to obtain reliable meteorological data in situations where Copernicus ERA5 represents the most suitable data source for the study site.

In addition to the statistical analysis and graphical representation of the wind time series, WindRose Studio allows the export of the complete hourly meteorological dataset - at least including the variables 10u ($m\ s^{-1}$), 10v ($m\ s^{-1}$), 2t (K), 2d (K), sp (Pa), and tcc (0–1) - in the SAMSON file format which, as discussed in Section 4, represents a standard input format supported by both the AERMET and CALMET meteorological preprocessors.

The Odour impact assessment carried out for the Battipaglia mechanical-biological treatment facility (TMB), required by the local authorities for the issuance of the Integrated Environmental Permit (IPPC), was performed using the AERMET–AERMOD modelling chain. Within this framework, the SAMSON file generated by WindRose Studio provided the surface meteorological dataset required by the AERMET preprocessing stage.

Figure 10 shows the SAMSON file generated by WindRose Studio as displayed in the AERMET View environment developed by Lakes Environmental.

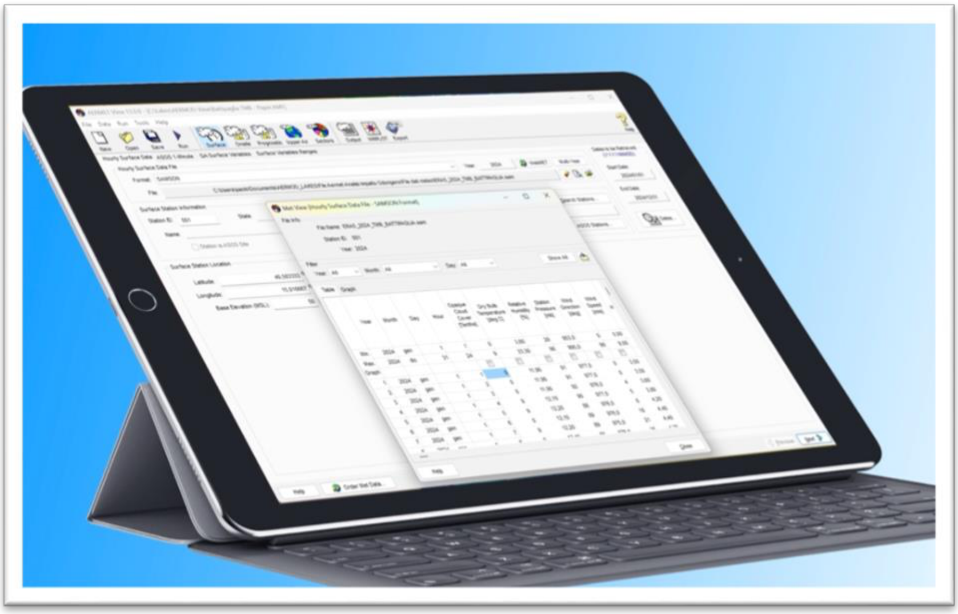

Figure 10. Surface meteorological dataset generated for the Battipaglia TMB case study (EcoAmbiente Salerno S.p.A.) for regulatory purposes within the Integrated Environmental Permit (IPPC) procedure – Odour Impact Assessment. Source: own elaboration.

The interface highlights the correct structure of the meteorological dataset, including the main variables required for atmospheric preprocessing, such as air temperature, atmospheric pressure, relative humidity, and wind speed and direction. The correct interpretation of the file by the visualization software confirms the compatibility of the exported dataset with tools commonly used in atmospheric dispersion modelling workflows.

For confidentiality reasons and in compliance with the non-disclosure agreement with EcoAmbiente Salerno S.p.A., the graphical representation of the Odour Impact Assessment results is intentionally omitted.

7. Conclusions

The widespread adoption of regulatory atmospheric dispersion models such as AERMOD and CALPUFF has established a globally recognized methodological framework for Environmental Impact Assessments involving atmospheric emissions. However, despite the scientific maturity of these modelling systems, their practical implementation outside the North American regulatory environment remains constrained by the limited availability of suitable meteorological datasets.

In many regions of the world, the absence of long-term and spatially representative meteorological observations represents one of the most significant barriers to the routine application of regulatory dispersion modelling. While global atmospheric reanalysis datasets such as ERA5 offer an unprecedented opportunity to overcome this limitation by providing globally consistent meteorological information, the practical integration of such datasets into regulatory modelling workflows remains technically challenging.

This work addressed this gap by proposing a transparent and operational workflow designed to bridge modern atmospheric reanalysis datasets and regulatory dispersion modelling systems. Rather than introducing a new meteorological model, the proposed approach focuses on the methodological process required to transform ERA5 datasets into meteorological inputs compatible with established regulatory modelling frameworks.

The WindRose toolkit implements this workflow through a lightweight software environment that enables the ingestion, inspection, and transformation of ERA5 GRIB datasets into structured meteorological time series suitable for dispersion modelling applications. The application example based on the Battipaglia mechanical-biological treatment facility demonstrates how the workflow can be applied in a regulatory environmental assessment scenario, illustrating the full sequence from ERA5 data request planning to exploratory statistical analysis of reconstructed wind regimes.

The results highlight the potential of ERA5 reanalysis data as a reliable and globally accessible source of meteorological information for dispersion modelling studies, particularly in regions where local meteorological observations are sparse or incomplete. By providing a practical and transparent workflow for the transformation of ERA5 datasets into regulatory-ready meteorological inputs, the proposed methodology contributes to lowering the technical barriers associated with the use of global atmospheric datasets in environmental modelling.

Beyond the specific implementation presented in this work, the broader contribution of the proposed workflow lies in its ability to facilitate the integration of globally available atmospheric datasets into established regulatory modelling frameworks. In this sense, the WindRose toolkit can be viewed as a operational interface between global atmospheric reanalysis datasets with the practical needs of environmental engineers and air-quality practitioners.

Future developments may focus on extending the workflow to additional meteorological variables, integrating automated quality-control procedures, and exploring the coupling of ERA5 datasets with diagnostic meteorological models used in advanced dispersion modelling systems.

By enabling a transparent and replicable pathway from ERA5 reanalysis data to regulatory dispersion modelling inputs, the methodology presented in this work contributes to expanding the accessibility of high-quality meteorological information for Environmental Impact Assessments worldwide.

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