

 Institute of Atmospheric Pollution Research National Research Council of Italy	<i>Project:</i> APEMAIA Contract n. 2023-39-HH.0	Doc. N.: DEL_002_EN-001 Issue/Rev.:01/01 Date: 25/12/2024 (T0+12) Pages: 12
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Assessment of PM Exposure at intra-urban scale in preparation of MAIA mission (APEMAIA)

WP1101 – Management

DEL002.01 – Management Report

Contract n. 2023-39-HH.0

CUP n. F83D23000210005

ASI CONTRACT N°	2023-39-HH.0		
PROJECT NAME	Assessment of PM Exposure at intra-urban scale in preparation of MAIA mission (APEMAIA)	CONTRACTOR	National Research Council – Institute of Atmospheric Pollution Research
PROJECT MANAGER	Maria Adamo (CNR-IIA)	DATE SUBMITTED	N/A
AUTHOR	M. Adamo, S. Fuina, M. Aquilino,	CONTRACTOR'S REFERENCE	Issue:01 Rev.:01 Date:25/12/24
PROJECT BEGIN DATE	26/09/2023	PROJECT END DATE	25/09/2025

EXECUTIVE SUMMARY



Institute of
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Research
National Research Council of Italy

Project:
APEMAIA

Contract n.
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Doc. N.: DEL_002_EN-001

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Pages: 12

This document is the current **Dissemination and Exploitation Plan (DEP)** designed to comprehensively address all dissemination and exploitation of the results of APEMAIA. It is released at the beginning of activities for WP1104 titled 'Dissemination and Reporting'. The release adheres to the planned schedule: (T0+3M).

**NAME OF ASI PROJECT
MANAGER**

Picchiani Matteo (PM)

Simona Zoffoli (RUP)

STAR CODE

No OF VOLUMES:



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1. AIM OF THE DOCUMENT

The current Management Report, formulated under WP1101 is designed to comprehensively outlines the project’s progress, challenges, and future steps. The project is on track, with significant achievements in data integration, algorithm development, and stakeholder engagement. Recommendations for optimizing resource allocation and addressing minor delays are provided to ensure timely completion.

1.1. Applicable and reference documents

This document incorporates, by dated or undated references, provisions from other documents. These references are cited at appropriate places in the text, and they are listed hereafter. For undated references, the latest edition of the publication referred applies.

In case of conflict between two or more applicable documents, the higher document will prevail.

1.2. Applicable documents

[AD 1] ASI Contract No. 2023-39-HH.0

[AD 2] subcontract CNR-IIA and DIF Prot. CNR-IIA n. 0276290 del 21/09/2023

[AD 3] subcontract CNR-IIA and ARPA Prot. CNR-IIA n. 0273735 del 19/09/2023

[AD 4] APEMAIA DEL004 – User Requirement Document -USD (preliminary version)

[AD 5] APEMAIA DEL006 – Dissemination and Exploitation Plan

[AD 6] APEMAIA DEL001.1 Progress Report (Preliminary Validation Plan included)

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1.3. Acronyms and abbreviations

Table 1-1 provides the acronym list.

Table 1-1: Acronyms and abbreviations

Acronym	Description
APEMAIA	Assessment of PM Exposure at intra-urban scale in preparation of MAIA mission
ARPA Puglia	Apulian Regional Agency for Environmental Protection
ASI	Agenzia Spaziale Italiana
CNR-IIA	Consiglio Nazionale delle Ricerche – Istituto sull’Inquinamento Atmosferico
CTM	Chemical Transport Model
EIRENE RI	Environmental Exposure Assessment Research Infrastructure
GEO	Group on Earth Observations
GPS	Global Positioning System
IGARSS	International Geoscience and Remote Sensing Symposium
NBS	Nature Based Solutions
US	User segment
WebGIS	Web Geographic Information System
WP	Work Package

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2. Achievements to Date

The project emphasizes advanced machine learning models and remote sensing techniques to improve the accuracy and resolution of PM data products.

2.1. Data Acquisition

- Successfully integrated multi-source satellite data, including Sentinel-2, Sentinel-3, MODIS (MAIAC and LST products), and other Copernicus services;
- Collected and harmonized ancillary datasets from meteorological models (i.e. ERA5), urban 3D data derived from LiDAR, and national statistical sources (e.g., ISTAT);
- Incorporated environmental and atmospheric data provided by ARPA Puglia, including in-situ air quality measurements (e.g., PM_{2.5}, PM₁₀) and outputs from WRF and FARM meteorological and chemical transport models;
- Established efficient workflows for near-real-time acquisition and preprocessing of Earth Observation and contextual data to support integrated environmental assessments.

2.2. Algorithm Development

1.1.1. Software Infrastructure and Modular Workflow Architecture

As outlined in the PM Modeling Workflow diagram (Figure 1), the APEMAIA project implements a modular software architecture designed to support the ingestion, transformation, and analysis of Earth Observation (EO), climate, and ancillary data.

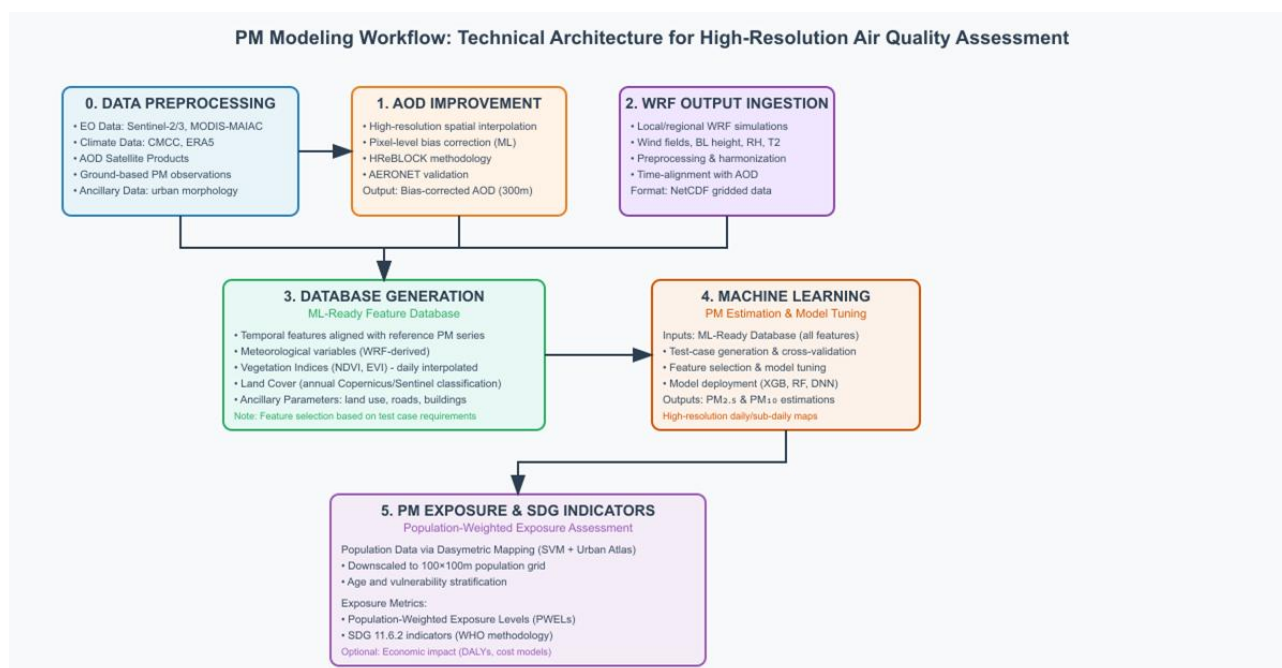


Figure 1 - PM Modeling Workflow – Technical Architecture for High-Resolution Air Quality Assessment.

Each module aligns with specific stages of the processing pipeline and is managed independently through bash workflows, and distributed job scheduling systems.

From a management perspective, clear roles and responsibilities were assigned to project partners for each module. Technical specifications, input/output formats, and timelines were shared in advance through collaborative platforms (SharePoint) and reviewed during periodic coordination meetings. Subtasks were tracked via shared task lists, with frequent support to ensure timely implementation.

2.2.1.1 Module 0: Data Preprocessing and Integration

Module 0.0 – Preprocessing & Grid Construction

A standardized 300x300 m spatial grid was created for each Area of Interest (AOI), using projected UTM coordinate systems (EPSG:32633 for Bari/Taranto, EPSG:32632 for Rome). Each grid cell was enriched with geographic centroid data and unique identifiers, serving as a reference for all spatial overlays.

Module 0.1 – Satellite Data Extraction

Automated pipelines download and harmonize AOD and LST products (Sentinel-3 SYNERGY, MODIS-MAIAC and LST). All layers are resampled to a consistent resolution (≥ 500 m) and temporally aligned for integration with other datasets.

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Module 0.2 – Vegetation Indices Extraction

This module is split into two phases:

- **Phase 1 (GEE):** Cloud-masked Sentinel-2 imagery is used to compute MSAVI, NBR, NBR2, NDMI, NDRE, NDVI, NDWI, BSI, EVI, EVI2 and other indices, aggregated to 300 m grids via `ee.Reducer.mean()` and exported as CSV.
- **Phase 2 (Python):** A Gaussian Process Regression (GPR) interpolates daily time series for each vegetation index, filling temporal gaps and aligning with phenological patterns.

Module 0.3 – Ancillary Data and Predictor Variables

Extracts additional spatial features from OpenStreetMap (traffic), EUBUCCO (building density, sky view factor), and other sources. Semi-automated routines ensure consistent naming, formatting, and storage such as:

- Dasymetric method (accessible at <https://plugins.qgis.org/plugins/dasy/>);
- PyQGIS models such as Reclassification and Traffic indicators computation tools.

2.2.1.2 Module 1: AOD Improvement

This module implements advanced spatial interpolation and machine learning-based correction techniques to refine raw AOD products. Main components include:

- HReBLOCK methodology (for harmonizing multi-sensor AOD data;
- Bias correction via machine learning models trained against AERONET stations;
- Generation of 300 m bias-corrected AOD products aligned with atmospheric datasets.

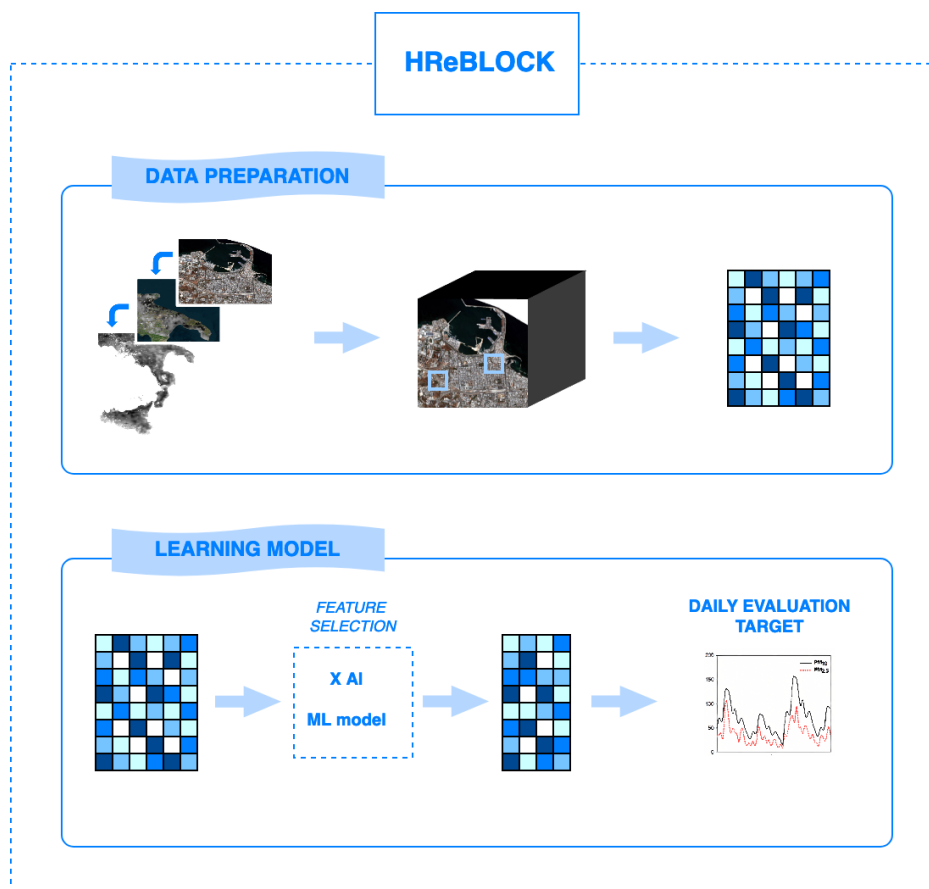


Figure 2 – “HReBLOCK” (High Resolution Environmental Block Processing) for spatial mapping of PM_{2.5}/PM₁₀ concentrations.

Validation activities were coordinated centrally and shared with partners, especially ARPA Puglia. A dedicated protocol was established to assess model performance against ground-based observations [AD 6].

2.2.1.3 Module 2: WRF Output Ingestion

This module integrates WRF simulation outputs into the processing chain:

- Variables: albedo; skin temperature; water vapor mixing ratio; soil temperature at first soil stage; soil moisture at first soil stage; relative humidity; geopotential; atmospheric temperature; atmospheric pressure; terrain height; U wind component; V wind component; W wind component; total solar radiation; net solar radiation; Accumulated Convective Precipitation; Non-Convective Precipitation.
- Harmonized spatial and temporal resolution with AOD layers;
- Export of NetCDF gridded datasets for input into the ML model.

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ARPA Puglia partner handled simulation execution and provide export formatting file on common ReCas shared folder. Guidelines for variable naming and consistency checks were issued as shared documentation.

2.2.1.4 Module 3: Database Building

This module consists in data Harmonization and Integration. All preprocessed layers are merged into a unified ML-ready database through temporal and spatial synchronization procedures.

All layers from Modules 0, 1, and 2 are aggregated into a comprehensive ML-ready database. The database structure includes:

- Temporally aligned features with reference PM data;
- Meteorological and vegetation indicators (daily interpolated);
- Land cover and morphology data;
- Ancillary variables (e.g., roads, building density).

Feature selection is guided by test case requirements and reviewed collaboratively among partners.

2.2.1.5 Module 4: PM Estimation and Machine Learning

This module includes model training, validation, and prediction routines:

- Test-case generation, cross-validation, feature selection;
- Model deployment: XGBoost, Random Forest, Deep Neural Networks;
- Generation of daily and sub-daily PM_{2.5} and PM₁₀ concentration maps.

Model benchmarks and evaluation results will be published on GitHub platform. SHAP-based interpretability tools are used for model diagnostics.

2.2.1.6 Module 5: Exposure Assessment and SDG Indicators

Population exposure is evaluated via dasymetric techniques and SDG-aligned metrics:

- 100x100 m population downscaling (SVM classification building layer + Urban Atlas);
- Stratification by age and vulnerability levels;

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- Calculation of PWELs and SDG 11.6.2 indicators;
- Optional assessment of economic impact e.g., DALYs (Disability Adjusted Life Years).

CNR-IIA led this component. Outputs were validated in internal review meetings with stakeholder feedback.

1.1.2. Infrastructure and Execution Framework

All modules are executed on the ReCaS-Bari cloud infrastructure using the HTCondor high-throughput job scheduler. Partners launch processing routines as independent jobs under specific user profiles, with resource allocation and parallelization managed dynamically.

Processing environments are encapsulated in Conda-managed Linux containers, including:

- `gpt_env`: SNAP workflows launched via `gpt` command-line tool;
- `gee_env`: Google Earth Engine scripts using `earthengine-api` and `geemap`;
- `ml_env`: XGBoost, Random Forest, SHAP, and geospatial libraries (`rioxarray`, `netCDF4`, etc.).

Modules are version-controlled and released on [GitHub/APEMAIAproject](https://github.com/APEMAIAproject) under open-source licenses.

2.2.2 Alignment with Work Packages and Task Coordination

This modular architecture directly supports:

- **WP2103** – HR PM Estimation using EO + ML pipelines;
- **WP3102** – Open-source implementation of system modules.

At the management level:

- Partner responsibilities were clearly mapped to software components;
- Interface specifications and operational guidelines were issued centrally;
- Partners were provided with Conda environment templates and testing datasets;
- Technical support was ensured through regular virtual syncs and ticket-based help channels;
- Compliance with deadlines and format standards was monitored through quarterly reviews.

This structured approach ensured full reproducibility, efficient parallel development, and successful integration across modules.

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2.3. Platform Development

The APEMAIA platform development focuses on two main components:

1. WebGIS Platform (WP1102)

Designed for dissemination purposes, the WebGIS platform provides open access to visualizations of PM concentrations, vegetation indices, and exposure indicators. Developed using GeoNode and Dockerized for deployment, the system supports:

- Map and indicator visualization;
- Geo-stories and dashboard integration;
- User-friendly interaction for non-expert audiences.

This component is not designed for data processing or modeling but strictly for the dissemination of final results.

2. GitHub Repository and Containerized Software Modules (WP3102)

The scientific backbone of the project resides in a series of Dockerized modules covering AOD extraction, PM estimation, and machine learning workflows. Each module includes:

- Reproducible Conda environments (e.g., gpt_env, gee_env, ml_env);
- HTCondor-ready job scripts;
- Standardized I/O specifications.

All components are maintained under version control at github.com/APEMAIAproject, ensuring transparent and open access to the entire data processing chain.

2.4. Stakeholder Engagement

The APEMAIA stakeholder strategy targets three main user segments:

- **US1:** Space agencies and scientific communities;
- **US2:** Local and regional authorities and technicians;
- **US3:** Civil society and the general public.

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Engagement activities were designed around real use-case scenarios:

- Conference participation and bilateral technical exchanges with ARPA Puglia;
- Public communication through the WebGIS interface;
- Preparation for the integration of MAIA simulated data to support future EO-based monitoring tools.

The WebGIS platform responds to the need for intuitive access to PM data by non-expert users (US2, US3), while the open-source software stack supports co-development with space agencies and research institutions (US1).

User needs were identified through prior EU projects, interviews with domain experts, and regulatory reviews. Key needs included:

- Higher-resolution PM maps for intra-urban assessments (US2);
- Population-weighted exposure metrics for SDG monitoring (US2, US3);
- Usability of EO data by scientists and institutional end-users (US1).

The system design has remained aligned with these needs through iterative testing, documentation feedback, and a living requirements matrix hosted on SharePoint.

3. Challenges Identified

3.1. Data Coverage

- Limited ground-truth data for validation in specific regions.
- Seasonal variability affecting model performance.
- Ancillary datasets such as urban morphology or building footprint and height often require case-by-case adaptation. For instance, LIDAR coverage is incomplete and inconsistent across AOIs, while the EUBUCCO dataset provides detailed height information only for selected cities like Rome. These discrepancies complicate harmonization across sites and may introduce bias in predictor generation.
- WRF datasets for the Lazio region are managed by third parties and are currently not accessible, limiting the capacity to generate harmonized meteorological layers for that area.

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3.2. Technical Constraints

- Integration of multi-source data requires additional computational resources.
- Minor delays in the development of the cloud processing pipeline.
- Inconsistencies in ground data due to spatial gaps.
- High computational demand for running RF and XGBoost models on regional datasets.

3.3. Stakeholder Coordination

- Variability in user requirements necessitates iterative platform redesigns

4. Recommendations

4.1. Enhance Ground-Truth Collection

- Plan additional field campaigns to supplement existing datasets.
- Collaborate with local agencies for data sharing.

4.2. Optimize Technical Processes

- Allocate additional resources for cloud infrastructure.
- Streamline the integration of new datasets into the processing pipeline.

4.3. Stakeholder Feedback Loop

- Increase the frequency of feedback sessions with stakeholders.
- Address user interface challenges highlighted during workshops.

5. Financial Overview

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The statement of expenses incurred up to December 11, 2024 — corresponding to the date of the second progress meeting — is provided.

CNR-IIA

Category	Allocated(€)	Spent(€)	Remaining(€)
Labour	62.426,27 € *	40.131,00 €	22.295,27 €
3.1 Raw Materials	10.400,00 €	- €	10.400,00 €
3.6 External major product	15.464,58 €	12.519,00 €	2.945,58 €
3.7 External services	36.416,93 €	- €	36.416,93 €
3.9 Travels	19.226,00 €	6.677,00 €	12.549,00 €
3.10 Miscellaneous	6.066,00 €*	1.335,00 €	4.731,00 €
Total	149.999,78 €	60.662,00 €	89.337,78 €

DIF

Category	Allocated(€)	Spent(€)	Remaining(€)
Labour	55.877,50 €*	- €	55.877,50 €
3.6 External major product	15.300,00 €	- €	15.300,00 €
3.9 Travels	23.271,00 €	- €	23.271,00 €
3.10 Miscellaneous	5.490,00 €*	- €	5.490,00 €
Total	99.938,50 €	- €	99.938,50 €

ARPA

Category	Allocated(€)	Spent(€)	Remaining(€)
Labour	46.720,16 €	22.483,38 €	24.236,78 €
3.6 External major product	3.279,36 €	3.279,36 €	
Total	49.999,52 €	25.762,74 €	24.236,78 €

*amount financed

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General project overview of the amount financed

Category	Allocated(€)	Spent(€)	Remaining(€)
Labour	165.023,93 €	62.614,38 €	102.409,55 €
3.1 Raw Materials	10.400,00 €	- €	10.400,00 €
3.6 External major product	34.043,94 €	15.798,36 €	18.245,58 €
3.7 External services	36.416,93 €	- €	36.416,93 €
3.9 Travels	42.497,00 €	6.677,00 €	35.820,00 €
3.10 Miscellaneous	11.556,00 €	1.335,00 €	10.221,00 €
Total	299.937,80 €	86.424,74 €	213.513,06 €

General project overview of the In-kind Contribution

Category	Allocated(€)	Spent(€)	Remaining(€)
Labour	291.535,04 €	151.724,70 €	139.810,34 €
3.10 Miscellaneous	8.415,00 €	- €	8.415,00 €
Total	299.950,04 €	151.724,70 €	148.225,34 €

- **Budget Utilization:** 29% of financed allocated funds utilized to date, primarily for Labour and external major product. 51% of the planned in-kind contribution has been reported in Labour cost category.
- **Forecasted Costs:** Anticipated within the approved budget.
The budget is expected to be fully spent by the end of the project.

All financial reporting documents were transmitted to ASI by certified email on July 31 2025, and are currently pending official approval.

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6. Conclusions

The APEMAIA project is progressing well, with significant advancements in environmental monitoring capabilities. Addressing current challenges promptly will ensure project objectives are met on schedule. Continued collaboration with stakeholders and optimized resource allocation are key to maximizing project impact.