

**23rd International Conference on  
Harmonisation within Atmospheric Dispersion Modelling  
for Regulatory Purposes  
15-19 September 2025, Hamburg, Germany**

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**OPERATIONAL AIR QUALITY MONITORING OF MULTIPLE HEATING PLANTS  
IN THE FRAMEWORK OF THE CITY ORCHESTRA PROJECT**

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**Abstract:** City Orchestra is a large project conducted by the Metropolitan Area of Rennes in France. The project is aimed at empowering the data management system of the public authority to be able to improve the usability and diffusion of territorial data. The project is focused on several use cases, including Air Quality. Within the Air Quality use case, one aim is to monitor, in real time, the air quality impact of multiple heating plants located in the urban area and compare their impacts to other contributors to air quality.

The workflow to monitor the air quality in real time and in the vicinity of the heating plant starts from the emission data provided by the managers of the plants and measured at the exhaust of each individual heating boiler. Meteorological data are taken from Meteo France and updated every hour. Simulation are performed each time new emissions data are provided and deployed on Cloud servers to bring elasticity to the system, several plants being monitored. Simulation results are displayed thanks to concentration maps accessible to the users logged into the system and compared to background provided by CAMS service. High resolution local background will be provided in collaboration with Air Breizh, the local Air Quality Monitoring Association, in the next steps of the project. Alert data are extracted on the fly, such as concentration exceeding thresholds, and provided to the users.

After describing the workflow and the various modeling and operational problems encountered during the setup, results are presented and discussed in the framework of operational use by operational supervisors of multiple heating plants.

**Key words:** *real-time monitoring, air quality impact, heating plants, concurrent modeling of multiple units*

## **INTRODUCTION**

City Orchestra is an important project conducted by the Metropolitan Area of Rennes with 16 partners including notably AmpliSIM, the University of Rennes, the Brittany Air Quality Association Airbreizh and Kereval. The project is funded by the *Banque des Territoires* in the Smart and Durable Areas (*Territoires Intelligents and Durables*) framework of the *France 2030* program. The project started in 2024 and should end in 2026.

The aim of the project is to industrialize the data usage by strengthening and upgrading a set of tools and processes, while insuring reliability, continuity and efficiency of the data life cycle. Four critical use cases have been chosen, among which the Air Quality Use Case (AQUC).

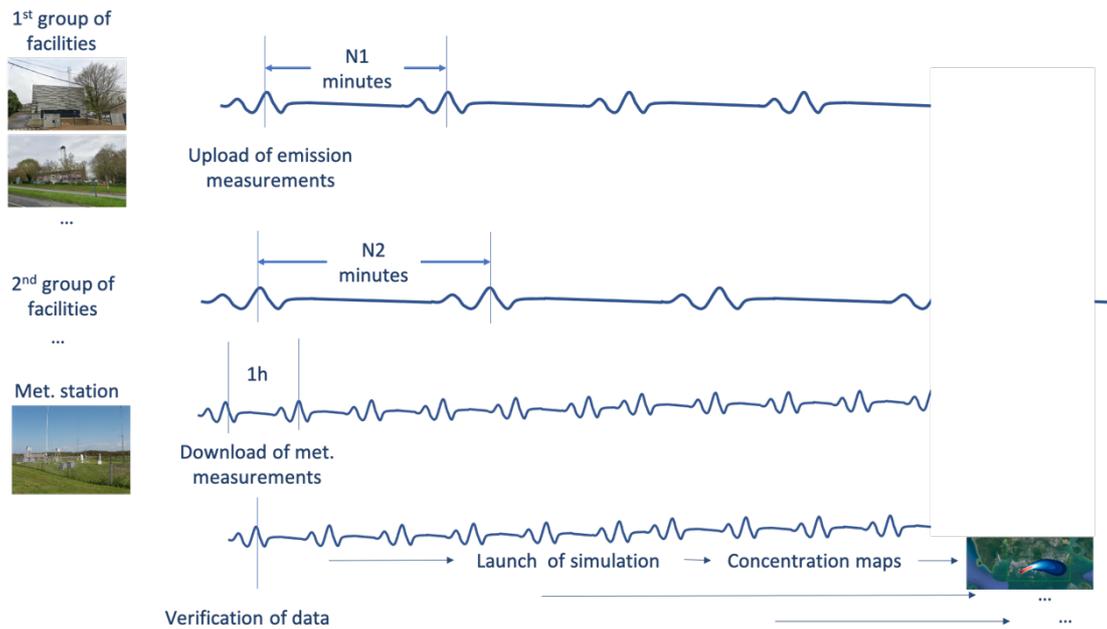
The AQUC is both aimed both to improve air quality knowledge in Rennes Area by modeling the impact in real time – for instance of multiple individual infrastructures, like heating plants – but also to strengthen public policy and operational management of infrastructures.

In the AQUC, multiple modeling, both at local scale around facilities, but also at the metropolitan area scale, are planned. In this paper we will focus on the local modeling of multiple facilities inside and around the city of Rennes.

After describing the workflow of modeling, we will present some typical setups. We will focus then on the workflow and issues regarding emissions and handling of simulation on-the-fly, before presenting some modeling results and discussing the opportunities for operational supervisors of multiple units.

## **WORKFLOW OVERVIEW**

The modeling workflow aims to simulate the dispersion by several facilities in their vicinity every hour using on-site measurements. An overview of the workflow is presented in the Figure 1 here-after.



**Figure 1.** Simulation workflow handling multiple facilities and including various time periods for data availability

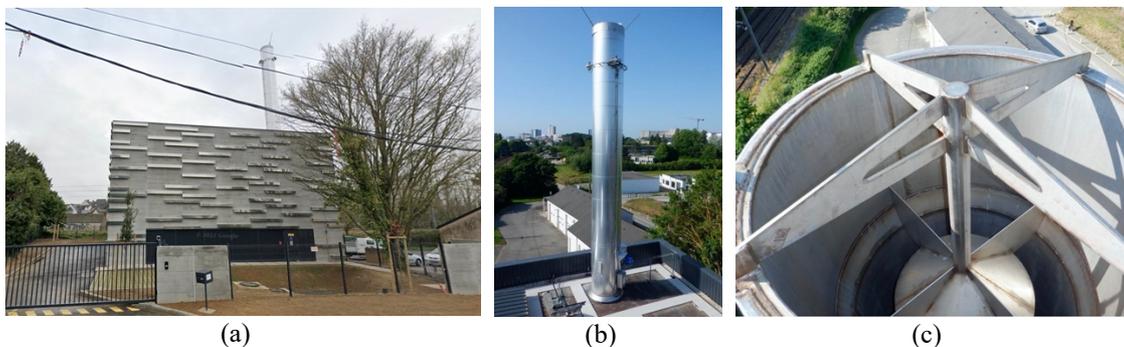
The modeling workflow is separated in several blocks:

- Upload of emission data done by the plant managers, globally for a set of facilities, or individually for each facility, depending on the situation,
- Download of meteorological data performed by the AmpliSIM platform through scheduled API tasks,
- The scheduled verification of available data performed by AmpliSIM and launch of simulations using on-the-fly cloud servers, if emission and meteorological data have both been updated for each facility,
- The consultation of the simulations done by operational managers or civil servants at Rennes, on AmpliSIM web site.

In parallel, simulation results are uploaded on Rennes Data Service using City Orchestra framework through RUDI data sharing portal developed by Metropolitan Area of Rennes (see Web 2023).

### MODELING SETUP

A typical facility is presented in the Figure 2 below. It is a heating plant with several furnaces using various combustibles (gas, renewable, ...).



**Figure 2.** Overview of a typical heating plant – General view (a), chimney (b) and top of the chimney (c)

Since computations are performed using AmpliSIM API by deploying model through containers, any model available in the AmpliSIM platform can be used, as long as it is adapted to the spatial and temporal scales being investigated. Hence a change in model can be performed on the fly. Up to now, the modeling is performed using a Gaussian puff approach, namely the Calmet-Capuff set of models (Scire et al. 2000a and 2000b) that offers a good balance between accuracy at these scales and computing efficiency. But other models such as pure gaussian (see Hanna et al. 1999) or more advanced approaches that takes into account explicitly in 3 dimensions the buildings through Lagrangian particle dispersion such as PMSS (Oldrini et al. 2017 and 2019) or GRAMM/GRAL (Oetl 2015) could be used.

A typical setup is a domain of 10km per 10km with a horizontal grid size of 100m. Emission data are averaged over 15mn periods. Simulation results are computed on an hourly basis. Meteorological data include wind speed and direction, temperature, rain and cloud cover. Emissaries are chimneys which height of is between 20 and 50m and diameter around 1m. Pollutants measured are PM10, NOx, CO and SO2.

### **HANDLING OF EMISSIONS IN REAL TIME**

Emission data are provided by the operator of each plant individually or consolidated in a custom central system by the operator over multiple plants and then uploaded on AmpliSIM platform. Data are uploaded in a batch at an average frequency, for instance every 4 hours, but not on a strictly regular basis.

Data in a batch are to be controlled for quality, in particular to find if the boiler is on and the measurements are significative. Data are not guaranteed to be provided for a time period within a single batch and may spread between multiple batches. Emission data are also sampled to a 15mn time step when provided to the model.

Data, mixed together in a single batch, are updated in parallel in each modeling setup and if large holes are detected, the subsequent batch is waited for before the simulation is launched.

A monitoring of each individual plant is performed to detect the availability of both meteorological and emission data and update time is compared to the last time frame simulated. For each plant setup, once these data are all available, the corresponding simulation is deployed for the additional time period. Each simulation has its own launching process in parallel and is deployed on cloud computers on the fly.

### **HANDLING OF SIMULATIONS ON THE FLY**

In order to launch the simulation in parallel and on the fly, simulations have to rely on elastic computing power provided by computers in the cloud.

The workflow for simulation follows these steps:

- Data required by the modeling, i.e. model files such as topography, landuse, meteorology, emissions and model options, are uploaded on a network drive,
- Computing server is started, the network drive is mounted,
- Computing containers containing the model and the necessary pre and post processing setpssteps in downloaded on the computing server,
- Computation is launched using the container,
- Data are uploaded from the computing server on the AmpliSIM platform,
- Computing server is stopped,
- Network drive data are stored in an archive storage if required.

This workflow uses specific network drives and API, such as the one provided by Qarnot Computing, or Object Store for network drives and Openstack API, for instance for servers provided by OVH.

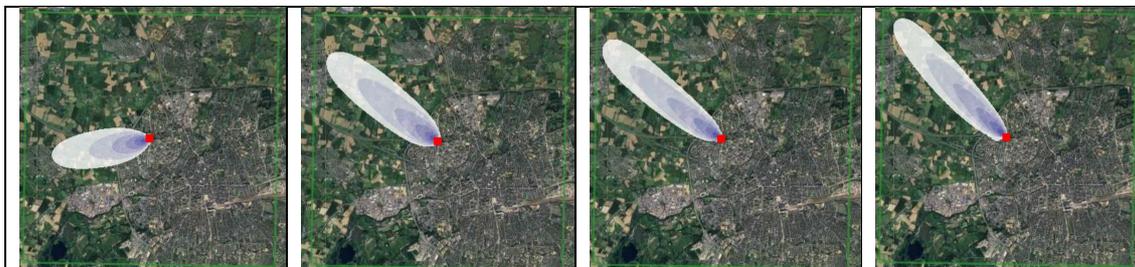
Containers allows to define a control environment with reproductivity properties, particularly important regarding libraries such as MPI for parallel processing of computation, GDAL for geographical handling of data, etc. With the container, the environment is constant regardless of the cloud infrastructure and is defined once and for all.

The use of cloud infrastructure allows for scalability regardless of the number of plants to model.

## RESULTS AND PERFORMANCES

The workflow is operational for more than 6 months without interruption for a first batch of 3 plants simulated every hour, after an initial phase of 3 month for testing, validation and optimization of the process.

An example of some simulation outputs is presented in the Figure 3 below.



**Figure 3.** Example of several time frames of the plume from one heat plant

Results are converted to normalized NetCDF files then into map tiles. These last ones are transferred to AmpliSIM platform and made available to the users of the service. These maps are accessible through:

- Traditional map service and API,
- Maps can be consulted on AmpliSIM platform, and can be shared between various stake holders: private operators of the plant, heat network managers at public authority, ...

Simulation are deployed through cloud computers, containing 8 to 16 cores and the whole process takes less than several minutes, depending on the meteorological condition, and including file transfer, update of the container on the host, etc.

Discussion are now conducted among project partners on the more efficient way to host the data within Metropolitan Area of Rennes data system. For instance, if the data are to be stored as web map data or raw binary data produced by the modeling and stored in NetCDF files, especially regarding the volume to store.

## CONCLUSIONS

A workflow has been designed to simulate the local impact of multiple facilities using emissions in real time and cloud server started on the fly. Emission data are processed to control the quality, adapted to the modeling and split to feed the correct unit. Once all data are updated, each simulation is launched individually on cloud computers. The results are then shared among various stake holders.

The workflow is operational for several heating plants for more than half a year. Other units will be included in the system during the next semester.

The next steps will include the creation of alerts and indicator to supervise the set of plants synthetically and test IA surrogate models.

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