Project: **1234**

Project title: **Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health (AQ-WATCH): High-resolution air quality multi-model forecast system for focus regions in Asia and the Americas**

Principal investigator: **Andrea Orfanoz**

Report period: **2025-11-01 to 2026-10-31**

QUALARIA project

The main objective of QUALARIA was to develop an AI model for producing high-resolution air quality forecasts. This was achieved by providing operational air quality forecasts at a resolution of 30 m in an interactive dashboard (Fig. 1). The model was trained using topography and vegetation data (Feng *et al.*, 2016), local vehicle emissions data produced within the project, population density data (Schiavina *et al.*, 2023), building height data (Pesaresi and Politis, 2026), air quality measurement data from CETESB stations (2015–2024), 120-hour CAMS forecasts (Copernicus Atmosphere Monitoring, 2020), and one year of WRF-Chem simulations for the region, which were also generated in-house.

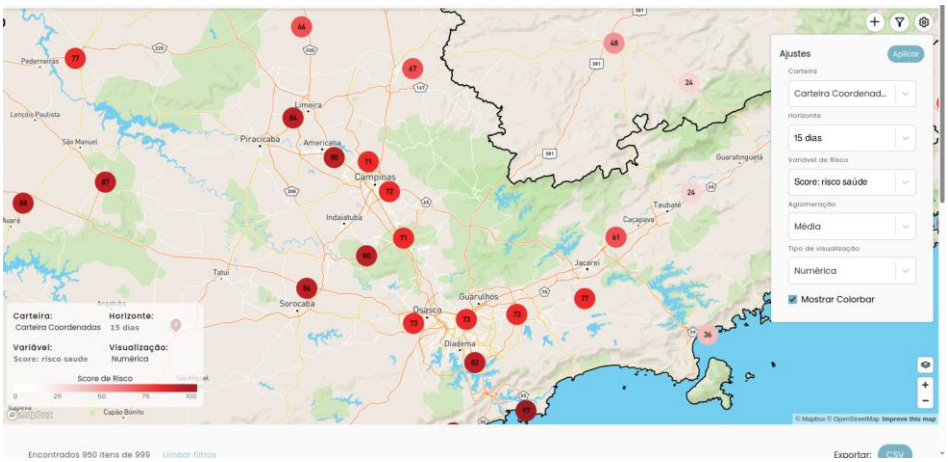



*Figure 1. Dashboard for visualizing forecasts from the developed system. The red dots represent the maximum risk score for human health over the next 4 days.*

The QUALARIA AI system is based on an artificial neural network (ANN) architecture that was specifically designed for this project using the Keras and TensorFlow Python modules (Python Software, 2026a, 2026b). It has convolutional dense connection layers (Huang *et al.*, 2022). To make the convolutional layer's resolution non-linear and increase the complexity of the ANN's learning of the relationship between input and output, we use a combination of ReLU and SELU activation functions. In the temporal dimension, we apply temporal attention mechanisms to dynamically and adaptively assign weights to each time step (Sharma, Sharma and Athaiya, 2020). We use the Adaptive Moment Estimation (Adam) optimization algorithm to adjust the parameters of the weights for each layer and minimize the loss function (Kingma and Ba, 2017).

As part of the still ongoing project, we are developing the implementation of low-cost sensor observations in QUALARIA AI training. One year of observations is required to capture annual variability, and this period ended in September. Another ongoing part of the project involves exploring the extrapolation of the forecast to cover the whole of Brazil.

In parallel, we implemented an independent, automated, bias-corrected air quality forecasting system as a continuation of a previous development in our group (Deroubaix *et al.*, 2026). We performed and presented a comparison analysis with QUALARIA at the iCACGP-IGAC 2026 International Conference. To compare and visualize the models, we developed a near real-time evaluation of the modelled results using local observations (Table 1, Figure 2).

| | **NMB** | | | | **NME** | | | | **R** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Objective | Criterion | **CTM** | **AI** | Objective | Criterion | **CTM** | **AI** | Objective | Criterion | **CTM** | **AI** |
| **$O_3$** | < ±5 % | < ±15 % | **-7.81** | **9.08** | < ±15 % | < ±25 % | **29.31** | **26.68** | > 0.75 | > 0.5 | **0.34** | **0.54** |
| **$PM_{2.5}$** | < ±10 % | < ±30 % | **25.86** | **-2.52** | < ±35 % | < ±50 % | **90.51** | **38.22** | > 0.7 | > 0.4 | **-0.30** | **0.66** |

*Table 1. Performance statistics (Emery et al., 2017) for September 2025, comparing the results of the chemical transport model forecast system (CTM) and the QUALARIA AI system (AI).*

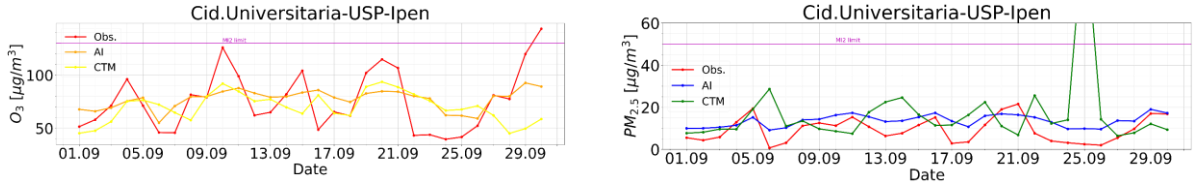



*Figure 2. Time series of ozone (left) and PM2.5 (right) results from the QUALARIA AI system (AI) and the chemical transport model forecast system (CTM) for the monitoring station Cidade Universitaria in São Paulo.*

## FOCAL project

As part of the European Horizon 2020 project FOCAL (Efficient Exploration of Climate Data Locally), the Environmental Modelling Group conducted high-resolution WRF simulations of selected extreme heat events in Lake Constance over ten-day periods. Konstanz is the project's pilot city. The research included improving lake and urban model inputs, evaluating them against observations, and conducting sensitivity and factorial experiments to examine lake conditions, urban characteristics, and their interactions. We also developed model configurations, input datasets and an experimental framework to assess the effects of urban adaptation under different meteorological conditions. Additionally, we are conducting exploratory research to evaluate potential AI-based methodologies for urban model parameterisation, including differentiable urban land surface modelling and parameter estimation approaches, as well as developing and testing a preliminary framework.

Within the same project, the Environmental Modelling Group expanded its involvement by developing a processing framework and an initial vulnerability index, tested in Konstanz. Sixteen gridded census tables from Destatis Zensus 2022 (Statistisches Bundesamt (Destatis), 2024) were harmonized onto a common 100 m reference grid covering Germany and combined with demographic, land surface, and terrain datasets, producing approximately 50 GB of harmonized input data. The initial prototype has since been further developed to provide vulnerability, exposure, and hazard susceptibility layers following the IPCC AR6 risk framework (IPCC, 2023).

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