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A MULTI-SCALE APPROACH TO IMPROVING AIR QUALITY MODELLING AND FORECASTING IN TEL AVIV

F. Velay-Lasry[1], M. Nibart[1], I. Makni[1], A. Resovsky[1], I. Levy[2], U. Stein[2] and O. Yossef[2]

[1]SUEZ Air & Climate (formerly Aria Technologies and Arianet), Nanterre, France
[2] Ministry of Environment, Tel-Aviv, Israel

Abstract: In 2003, ARIA Technologies provided to the Israeli Ministry of Environment a complete air quality modelling platform including the installation and configuration of an operational forecast system for air pollution. Since then, this system is under maintenance, its performances are evaluated every year and improvements are regularly brought to the system. The dispersion modelling is mainly based on the CHIMERE Chemical Transport model used with nested domains, 3km being the spatial resolution of the most refined domain.
In 2023, the forecast system has been upgraded to include local scale approaches for Tel Aviv area: PMSS (Parallel Micro SWIFT SPRAY) model has been setup for the densest area and SIRANE model for a larger area.
PMSS is composed by SWIFT model which is diagnostic mass consistent meteorological model considering explicitly the effect of buildings and by SPRAY model which is a lagrangian particles atmospheric dispersion model. They are developed and maintained by ARIA Technologies, ARIANET and CEA. PMSS is here applied on a 9 km x 9 km domain with 5m resolution. SIRANE is a gaussian plume model enhanced a specific algorithm that consider the pollutant transfer into the network of connected street segments. SIRANE is here applied on a 24 km x 24 km domain with 20m resolution. SIRANE is developed by Ecole Centrale de Lyon (ECL).

This downscaling modelling system is compared to observations at the 15 reference Air Quality stations that are available in the area, especially on some recent NOx pollution episodes, NOx being a good tracer of traffic induce pollution that CHIMERE+SIRANE+PMSS should better catch than only CHIMERE.

Key words: *Air Quality, downscaling, CHIMERE, PMSS, SIRANE*

INTRODUCTION

In 2003, ARIA Technologies provided to the Israeli Ministry of Environment a complete air quality modelling platform including the installation and configuration of an operational forecast system for air pollution. Since then, the system has been maintained, its performance assessed annually, and improvements made on a regular basis. The dispersion modelling is mainly based on the CHIMERE chemical transport model used with nested domains, 3km being the spatial resolution of the most refined domain.
In 2023, the forecast system has been upgraded to include local scale modelling for the Tel Aviv area; the SIRANE model is used for simulations over the city and surrounding region while PMSS (Parallel Micro SWIFT SPRAY) is set up over the city's dense central district. The goal is to improve computation of pollutant concentrations for more informed assessments of population exposure in high density road traffic zones.

METHODS

The solution preconised consists in an imbrication of 2 models, SIRANE for the surrounding cities of Tel-Aviv and PMSS for the city centre with the highest density of traffic. The advantage of an hybrid modelling is that it uses the added value of each modelling tool and results benefit from the 3D of PMSS and the fine coverage of SIRANE on the size of an agglomeration.

The name PMSS (Moussafir *et al.*, 2013) derives from Parallel Micro SWIFT SPRAY, parallelized "micro-scale" versions of the SWIFT and SPRAY codes.

The SWIFT code (successor to the MINERVE model) is a simplified weather flow calculation code, in which only the continuity equation is perfectly satisfied, the rest of the flow behavior being controlled by the initial conditions obtained by interpolation, and by the introduction of a corrective term linked to the vertical static stability of the atmosphere. The turbulence calculated by the SWIFT code is purely diagnostic. The micro-scale version of the code, Micro SWIFT, is characterized by the introduction of obstacles, supplied as a collection of straight prisms with a triangular base, and represented inside the code by solid meshes, for which a condition of zero flow to the facets is imposed. Effects of buildings on the flow are added through analytical laws, depending on wind direction and obstacles geometry according to Rockle 1990.

The SPRAY code is a Lagrangian particle dispersion calculation code, in which the concentration distribution of pollutants is represented by the position of a cloud of "particles". The dynamic of this cloud of particles is controlled by mean flow and by turbulence, some quantities of which can be deduced from the outputs of the SWIFT code or parameterized directly in the SPRAY code. The micro-scale version of
the code, Micro SPRAY, is characterized by the introduction of obstacles, directly deduced from the solid meshes provided by Micro SWIFT.

For this study, PMSS is applied on a 9 km x 9 km domain with 5m horizontal resolution.

SIRANE (Soulhac *et al.*, 1998) is a gaussian plume model enhanced by a specific algorithm that considers pollutant transfer into a network of connected street segments. It also considers simplified chemical processes for pollutants. SIRANE is here applied on a 24 km x 24 km domain with 20m resolution.

Model outputs are configured for automated daily display online through an integrated web API. Pollutant concentration time series can also be extracted at any point within the model domain and visualized through an interactive display.

The modelling chain is installed on Google Cloud Platform through Docker containers and is currently operational in forecast mode.

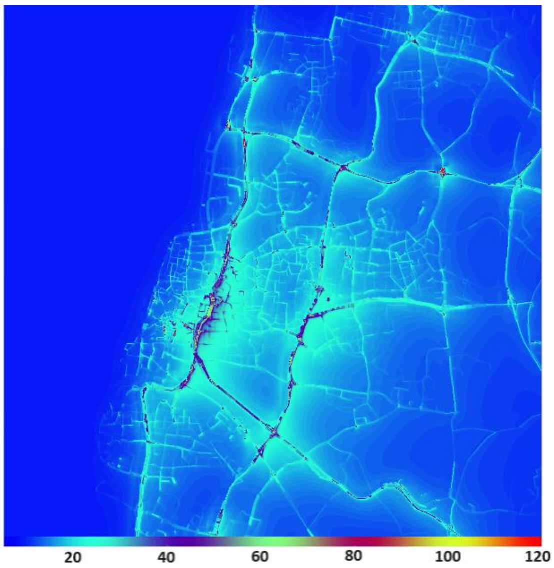

Figure 1. PM2.5 (µg/m³) over Tel Aviv on the morning of 2 March 2023 as simulated by SIRANE.

IMPLEMENTATION

Several modifications were made in order to improve the modelling, and to ensure that the data used as simulation inputs are at scales consistent with the resolutions chosen for the models:

- Adaptation of the road network to the Tel Aviv 3D maquette. Indeed, while superimposing the road network with the maquette buildings, we can notice that some road links intersect buildings. An algorithm has been developed in order to automatically adjust the road links to the building location.
- The width of the emissions lines corresponding to the roads has also been adjusted according to the type of road and number of lanes, as it is a crucial parameter for pollutant dispersion in dense urban area considering the canyon effect.
- In order to avoid double counting of sources between the 2 models SIRANE and PMSS, a distinction has been made between sources covered by both models and by SIRANE only, by taking advantage of sources tagging feature of SIRANE, initially designed for source apportionment .

• the kernel method (Barbero *et al.*, 2021) has been setup for PSRAY to compute concentrations from virtual particles cloud instead of simple box counting method. This methodIt allows reducing CPU calculation times as it allows to use a lower number of particles . This feature is based on the use of statistical technique of kernel density estimation.

RESULTS

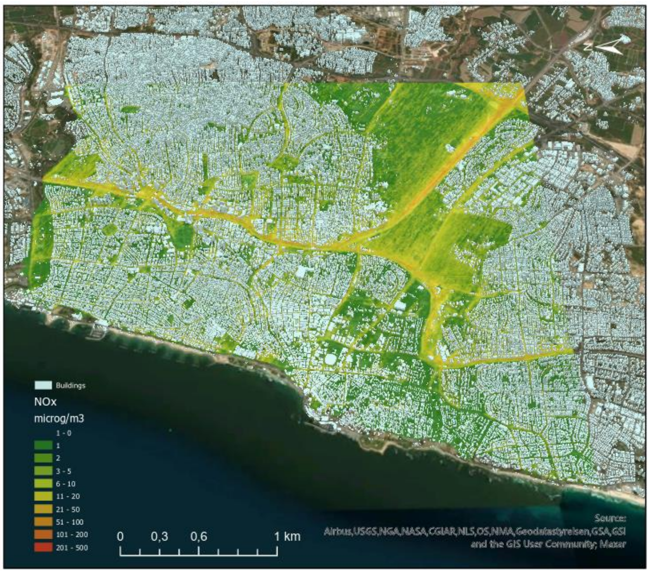

Figure 2. PMSS simulated NO2 (/m3) over central Tel Aviv on 28 February 2023.

In order to assess the modelling chain performances, an analysis over 3 episodes has been conducted. It includes NOx and PM pollution episodes, NOx being a clear tracer of traffic emissions, while for PM, sources of emission are more various including traffic, industries, residential sector and natural dust sources as well.

Model outputs are compared to observations at the 15 reference Air Quality stations that are available in the area. We especially focused on some recent NOx pollution episodes, NOx being a good tracer of traffic-induced pollution. Results show improved simulation of pollution peaks by CHIMERE+SIRANE+PMSS versus standalone CHIMERE runs.

Results show that the implementation of SIRANE already allows a great improvement of the peak restitutions at Air Quality stations in the urban area of Tel Aviv, . while the additional use ofThe results of PMSS are only allows a light supplementaryslightly better improvement compared to SIRANE, but the improvement is not significative at Air Quality stations for the tested pollution episodes. Here the benefits of PMSS consist more inHowever, the finesse of the spatial representation of gradient concentrations provided by PMSS remains valuable at high resolution 5 m resolution.

For the PM episode, we noticed that neither SIRANE nor PMSS could improve the results for both PM2.5 and NO2 concentrations, indicating that this episode may not be only linked to local traffic emissions over Tel Aviv, but more possibly to a large-scale phenomenon.

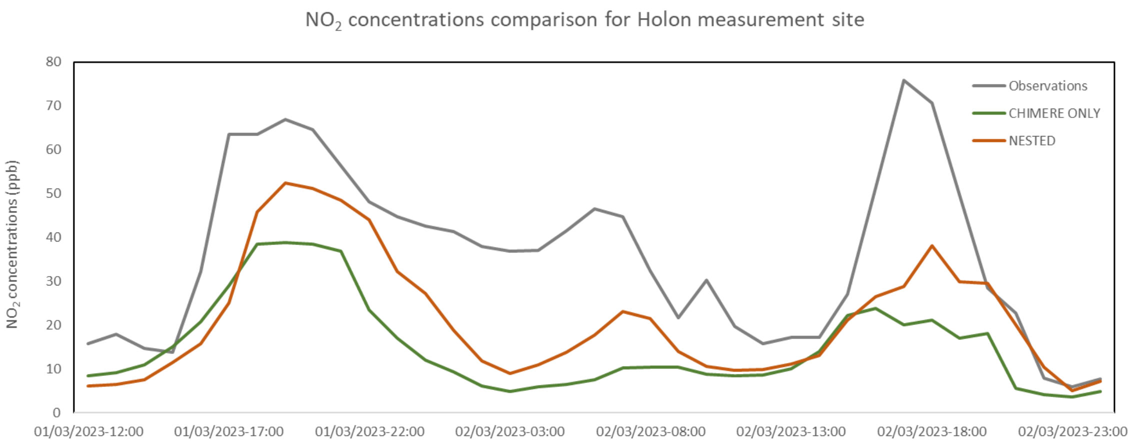

Figure 3. Comparison between measured NO2 and NO2 modeled using 1) CHIMERE and 2) CHIMERE+PMSS+SIRANE at the site of the Holon monitoring station

CONCLUSIONS

In summary, the modelling chain facilitates the generation of high-resolution air pollution forecasts tailored specifically for the Tel Aviv region. Enhancing the resolution enables more accurate capturing of peaks associated with traffic emissions, yet it is not without limitations. This refinement of the model mesh implies the simultaneous improvement in describing various other parameters:

- Improving the resolution of the emission inventory necessitates meticulous attention to input data accuracy. This entails refining emissions per category of emitters such as cars, heavy-duty vehicles, and two-wheelers, while also considering the temporal modulation of emissions and ensuring coherence between road networks and building data. An initiative is already ongoing at the Ministry of Environment in order to improve and update traffic emissions.

- Moreover, optimizing the model configuration involves fine-tuning parameters like canyon width and activating specific chemistry modules.

- Expanding our scope, we aim to comprehensively evaluate meteorological fields by comparing the WRF and SWIFT models within the Tel Aviv domain, and extending this analysis to include the ICON model in collaboration with the Israeli Meteorological Service.

- Furthermore, for particulate matter (PM) episodes, it's imperative to determine whether the episode is localized or more widespread. This entails investigating background concentrations stemming from external emission sources, including the transport of dust particles.

A regular evaluation of the modelling chain on a yearly basis is on-going. It would cover most of the typical episodes in Israel and specifically in Tel Aviv and will allow providing a general assessment of the performances of AIRCITY SIRANE+PMSS modelling suite compared to CHIMERE model. This work will give insights into the main input data and model parametrizations we should focus on and improve.

In addition to improving estimates of pollution exposure in high density areas of Tel Aviv, this work has provided valuable insight as to necessary data upgrades when adding local scale models. For example, automated procedures were developed to facilitate downscaling and account for building geometries in GIS, as well as to model daily traffic patterns. In addition, our downscaling approach meant redefining coupling strategies between the different models, especially to avoid double counting of the sources.

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