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WEB VISUALIZATION OF ATMOSPHERIC DISPERSION MODELLING APPLIED TO VERY LARGE CALCULATIONS

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Abstract: Operational exercises devoted to usage of numerical simulation as tool for decision-making have put forward the necessity to obtain rapidly visualizations of dispersion plumes usable to understand on-site situation. Usually, visualization of numerical models is obtained through the use of dedicated 3D viewers and, in case of very large simulations, of calculation clusters available at the time of the visualization. These 3D viewers usually need knowledge about the software, or dedicated personals able to manipulate the software.

In this paper, we describe a web approach that can provide decision-making teams, either in crisis centre or on the field, with the capability to rapidly make use of numerical simulation results. With this web approach, specific viewing software, associated knowledge or personal, and computational resources dedicated for visualization, are useless.

The web approach relies on tiled pyramidal images extracted from numerical model binaries. This set of images is stored in light databases and served using leaflet web geographical system. Model results can hence be viewed using current web browsers. The approach has been fully parallelized using MPI library and can be performed on the same cluster where the numerical simulations are done.

This approach has been applied to the visualization of very large calculations obtained during EMERGENCIES-Mediterranean (EMED) project. EMED was a capacity demonstration of the feasibility of advanced 3D modelling to support decision-making in an emergency involving noxious atmospheric releases. This project used large mesh sizes, ranging between 1.2 and 12 billions nodes. These sizes of meshes make it impossible to use even parallel 3D viewers to navigate interactively in the results. EMED results were used to evaluate the parallel performances of our web approach. Operational capability is then discussed.

Key words: *web GIS, tiled images, decision-making, emergency response, large numerical simulations, built-up areas.*

INTRODUCTION

Usage of numerical simulation as a tool for decision-making in case of emergency response is an active research field. Experiments are conducted to evaluate the capabilities of models as a support tool for emergency purposes (Leitl et al, 2014). Development of parallel algorithms for air quality modelling (Oldrini et al., 2017) and usage of high performance computers bring new capabilities to support decision-making with numerical simulation of adverse atmospheric releases (Armand et al, 2017, Oldrini et al., 2016). In order to be able to provide rapidly decision makers with information obtained from modelling, specific treatments are to be performed on model output. The problem is even more acute when dealing with parallel calculations over large urban areas.

Traditionally, model outputs are viewed through dedicated software able to load large dataset computed on grids and display 3D time varying field values using 2D slices or iso-surfaces. The authors conducted such post processing experiments using Paraview parallel viewer: visualisations were performed for wind or concentration fields on large built-up domains of more than 1 billion nodes using over 1 000 cores. Such approach can allow for detailed analysis of physical results but is not interactive due to too large time lag: views have hence to be computed in batch mode. These 3d views are also more oriented toward a modelling audience than decision makers.

I order to provide decision makers with the capability to make use rapidly of simulation results, a web approach has been retained. It relied on Web Geographical Information System (Web-GIS) and on pyramidal tiled images. After describing the approach and its parallel implementation, we will illustrate its capabilities on a very large dataset produced by the Emergencies MEDiterranean (EMED) project and then discuss the operational aspects.

WEB APPROACH

Multilevel tiled processing

Fast display of model output under AmpliSIM modelling web service (AMWS) relies on multilevel tiled approach, both for images or data. This approach has been introduced by Google Earth to display Earth pictures. The idea is to provide different data at different zoom level and to slice the data in tiles at each level to only load in memory the part of the data being displayed. The picture on the right hand side describes the multilevel tiled approach for an image.

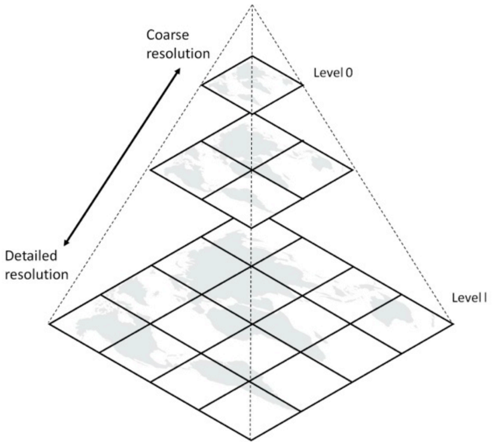

Figure 1: Multilevel tile approach to display a picture

Data or images are then displayed on the user browser using Leaflet library, for its Web-GIS capabilities, and AmpliSIM own javascript to handle the time varying properties. The data are stored in geojson format, while images are stored in an MBtiles database.

Multilevel tiled data or images are created during post processing by AmpliSIM Tiling Library (ATL). ATL can handle both single binary type outputs, but also multiple blocks binaries produced by parallel calculations, such as domain decomposition algorithms (see for instance Oldrini et al., 2017). Tiling process of data is independent of the domain decomposition used by the model: tiling process of data uses by defaults tiles of 256x256 points, while domain decomposition blocks used by the numerical model can be of any size.

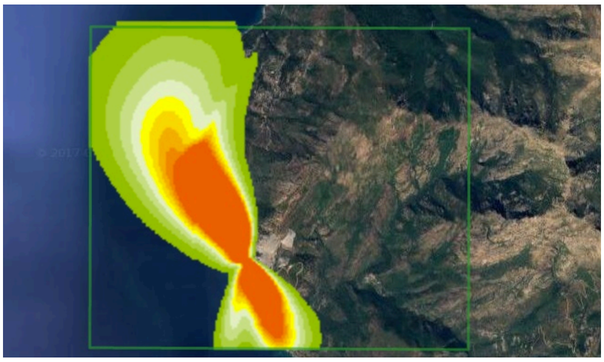

Figure 2: Web display of concentration outputs at zoom level 13

Different data types can be displayed, such as scalar using images, or vectors using either vectors or streamlines. The pictures on the left hand side display a ground concentration field of particles emitted from a facility near the coast The picture below shows the surface wind field pattern through the use of streamlines in the streets of Paris.

Figure 3: Streamline web display of wind field in streets of Paris at zoom level 17

Parallel processing

Parallel processing is using Message Passing Interface (MPI). The parallel algorithm encoded in ATL follows these steps:

- Creation of a virtual tiff using Google Mercator projection and encompassing the whole domain. This applies whether the model is producing a single binary or producing multiple binaries through domain decomposition algorithm,
- Parallel loop on zoom levels,
- For each zoom level, splitting of the virtual tiff in tiles,
- Parallel loop on tiles to distribute each tile data creation on each available core.

Parallelization is very efficient due to reduced communication between cores but is limited by the number of tiles being computed. Hence, if the domain is small and contains only a few tiles at the maximum zoom level, the parallel algorithm is not very efficient. Still the computational cost is small. On the contrary, on very large domains with many tiles, the parallel algorithm is much more efficient.

APPLICATION ON EMED PROJECT

ATL has been tested against very large calculations performed during EMED project. The project EMED (Emergencies MEDiterranean, see Armand et al. 2017) demonstrates the feasibility and interest to perform fine resolution (a few meters) numerical simulations to support decision-making in an emergency involving noxious atmospheric releases. The French Atomic and Alternative Energies Commission (CEA) and AmpliSIM performed EMED on the very large calculation cluster of the Research & Technology Computing Centre of the CEA (CCRT). EMED encompasses three high resolution (3m) domains centred on the cities of Nice, Toulon and Marseille along the Mediterranean Sea coastline. The domain sizes are respectively 20x16, 26x16 and 58x50 km^2. Wind binary outputs need disk sizes of, respectively, 75, 100 and 700Go per time frame.

Post processing using ATL has been realised on the same infrastructure as the numerical simulations. Zoom levels have been extracted from level 10 up to level 16. Levels above 16 are useless since the grid resolution is 3m. To handle a particular time frame of a Marseille, with 100 cores, ATL needed less than

10mn. For Toulon or Nice, using also 100 cores, one time frame needs less than 30s. Examples of wind field intensity displayed using AmpliSIM web service for Nice domain are presented below.

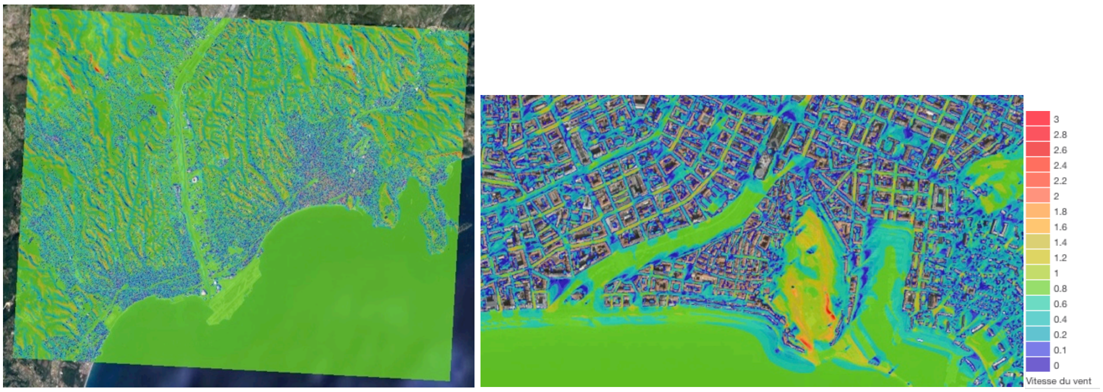

Figure 4: Web visualization using AmpliSIM web portal of ATL post processing of numerical simulation over Nice domain. Wind field intensity near the ground and at 11pm is presented. Picture on the left hand side displays the full domain (20x16km^2) at zoom level 12 while picture on the right hand side displays a close-up view around Nice centre at zoom level 16.

Regarding concentration, calculations were designed to produce concentration fields every minute. This is much more than needed for operational purposes. Due to that very fine time resolution, binary outputs for concentration had sizes rangin from 275Go for Nice up to 670Go for Marseille. These binary outputs contained all time frames for concentration field for the whole exercise, a simulated period of 3h in average. The binaries hence contain roughly 200 time frames.

ATL required, for the whole binaries for Nice, 1h using 20 cores. Each time frame took in average 20s. Pictures of the concentration are displayed below.

Figure 5: Concentration field near ground 2, 5, 15, 55mn and 1h30mn after the release time (from top left to bottom right).

For Marseille domain, the simulation duration is 4h and the binaries contain 240 time frames. ATL took 130mn using 50 cores, which is 30s in average per time frame. Pictures of the concentration produced by ATL, and displayed using AmpliSIM web service, are presented below.

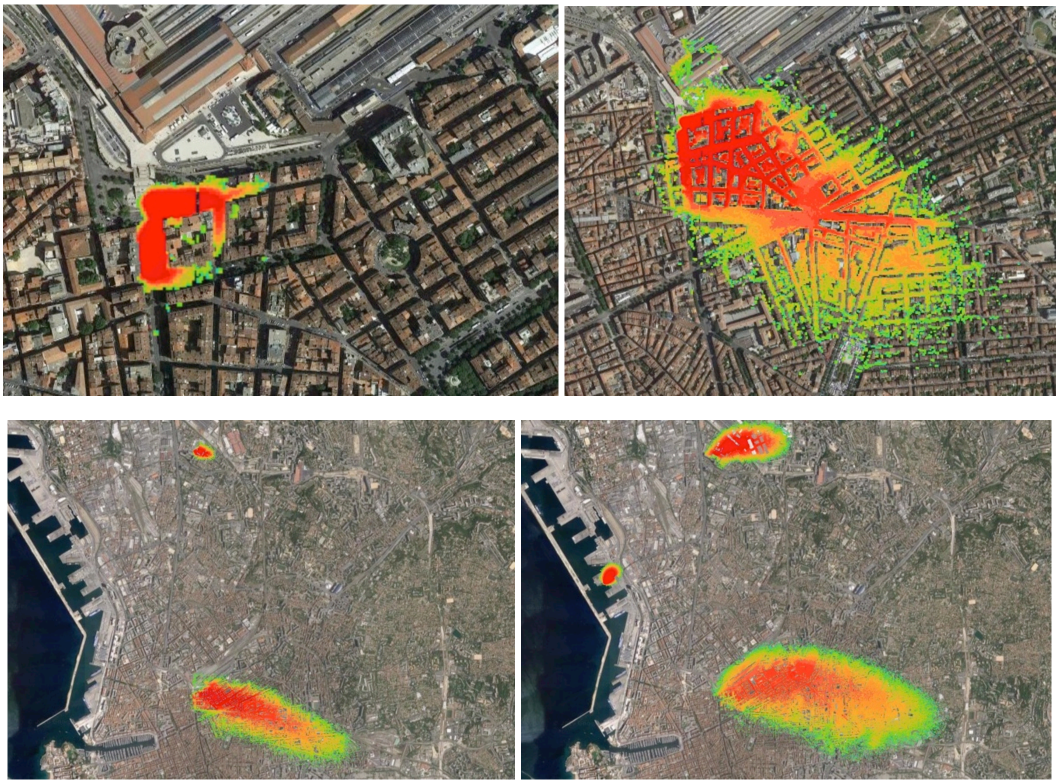

Figure 6: Concentration field near ground 3, 15, 38mn and 1h15mn after the first release time (from top left to bottom right).

CONCLUSION

Web visualization using ATL allowed the project team to access interactive visualization of very large calculations, which was not possible before. Once the post treatment of the calculation by ATL is done, navigation inside the huge amount of results is similar to that from a small test case, due to multilevel tiled approach. Moreover, and thanks to the web nature of the display, modellers can share the model outputs with other users and browse the results concurrently without any particular inconvenience.

ATL processing was only performed once on these calculations and only for display purposes. Hence no benchmarking of ATL performances regarding treatment time has been tried. In particular, the capacity to reduce the treatment duration using more cores was not explored. Future works regarding operational visualization of very large calculations will focus on benchmarking the parallel efficiency and finding the optimal settings for an operational usage.

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