Bridging the scales in a eulerian air quality model to assess the impact of megacity pollution export at the regional level

1 - Introduction

Investigations of the megacities' impact on the atmospheric environment benefits from a multiscale approach, because megacities have an impact on air quality at all scales.

- At the local scale, the accumulation of primary compounds is responsible for severe respiratory problems and for the alteration of buildings.
- At the regional scale, primary emissions lead to the formation of secondary compounds such as ozone or organic particulate matter which - in addition to their adverse effects on health - have an impact on the climate equilibrium.

Bridging the local and the regional scales in a dynamic fashion would thus improve the characterisation of local pollution export from megacities and their regional impact. The top-down interactions from the global to regional scale or from the regional to the local scale are are well described by state-of-the-art nested models. The interactions from local to regional scale can be represented either by two way nesting in a coupled model or data assimilation; however these last approaches remain relatively costly.

Our study present the development and the results of an alternative multiscale approach using a horizontally stretched grid in the Eulerian CTM CHIMERE.

2 - Stretched grid

The CHIMERE grid being regular in latitude and longitude, it is possible to stretch the resolution over a latitude and a longitude bands. At the intersection of these bands, we obtain a finer grid at a resolution of 0.1°x0.1°. Thus a local zoom can be introduced to simulate a more realistic scenario within a single grid with variable resolution. It allows stretching online the spatial scales from the (0.1°x0.1° of resolution) to the continental area (0.5°x0.5° of resolution) in one simulation.

2.1 - Testing the stretched grid

We introduce an inert tracer at 47°N and 5.5°W. This tracer has a molar mass of 100 g/mol. The total mass emitted is 1000 tons between the beginning and ending simulation (during 120h). The emissions vertical profile has a gaussian shape with height of 1000m and standard deviation of 100m. Its deposition velocity is that of NO₂.

3 - Real case testing: 2003-08-04 to 2003-08-09

In order to validate our stretched method, we compare the results obtained with the CHIMERE model using different configurations of meteorological data versus AIRBASE measurements (http://air-climmate.airbase.eunis.eu/data/bases/airbase) in the BeNeLux region. We obtain the same scores than the nested regular domain in this region.

In order to quantify the regional impact of the BeNeLux region, we introduce a tagged CO tracer from this region. Large differences are found on the outskirts of the hotspot. At the surface, the tracer's concentration using the stretched grid is 12% higher than with the regular continental domain.

4 - Conclusions and insights

An innovative stretched grid has been implemented in the Chimere CTM. It proved to bring a significant improvement of the assessment of the impact of megacities on the larger scale without reducing the performances of the model in the megacity itself:

- The skill of the model in the region where the grid is stretched is similar than the performances with the classical nested approach.
- Estimates based on a 3 weeks case study suggest that megacities export fluxes could be underestimated by a factor 2 with the classical approach.

However, this method also has a major drawback: the local zoom increases the number of cells. For a regular domain at a resolution of 0.5°x0.5° covering Europe, the number of cells is 7 717. A stretched grid covering this same domain with local zoom down to 0.1°x0.1° over a megacity, the number of cells is 17 649. This increase in the number of cells therefore introduces an increase in the computation time.

For the August 2003 case study, the simulation with a stretched grid lasted 3 times longer than the regular approach with a coarse domain and nested fine domain.